Neglected Orbits in the Sixth Catalog of Orbits of Visual Binary Stars

Wilfried R.A. Knapp
Vienna, Austria
wilfried.knapp@gmail.com

Abstract: The Sixth Catalog of Orbits of Visual Binary Stars lists as of March 2020 around 3,200 orbits, of which 342 were published 20 to 29 years ago and additional 94 even 30 or more years ago. This seems odd because orbital element values of visual binaries are moving targets – a few additional measurements in the observation history lead often to at least minor but significant and in some cases major changes. This report checks the orbits published 30 or more years ago in detail to find an explanation why these orbits remained unchanged for such a long time. Re-calculated orbits are presented for the binaries with an observation history that extends significantly beyond the publication date of the currently listed orbits provided the changed values of the orbit elements offer a better match with the observation history and a better match of the dynamical mass with system mass data from other sources.

1. Introduction

One of the benefits of a given orbit is the prediction of the positions of the components of a binary for any point of time in the future – if the comparison with new measurements results in differences within the error range of the new observations then the orbit fulfills one of the basic quality requirements for orbits. Therefore, it makes sense to give an orbit some time to prove itself – yet it seems a bit curious if this timespan is longer than lets say a decade because a few additional measurements in the observation history may lead to significant revisions of orbital element values if re-calculated. This report offers a closer look at 94 orbits published 30 or more years ago listed in the Sixth Catalog of Orbits of Visual Binary Stars (http://www.astro.gsu.edu/wds/orb6.html, henceforth "6th Orbit Catalog"). These 94 orbits cover 88 different objects because there are a few cases with more than one orbit for the same object.

The 6th Orbit Catalog lists orbits with a grade from 9 to 1 indicating the assumed quality of a given orbit mostly based mainly on the degree of coverage of the assumed orbit period by the observation history:

- 9 for astrometric orbits mostly based on observed photometric variability usually for objects lacking a Washington Double Star catalog (henceforth "WDS catalog") observation history. The introduction to the 6th Orbit Catalog notes "these orbits tend to give rather poor fits to any later resolved measures"
- 5 for indeterminate or premature orbits with elements may be not even approximately correct and with an observation history covering only a small part of the assumed orbit period
- 4 for preliminary orbits usually for objects with an observation history covering only a non-conclusive part of the assumed orbit period and with elements likely to be subject to substantial revisions
- 3 for orbits considered reliable with at least half of the orbit period covered by measurements

- 2 for orbits considered good with nearly full of the orbit period covered by measurements
- 1 for high quality orbits considered definitive usually for objects with an observation history fully covering the orbit period, in some cases even several times.

In reference to van den Bos 1962 any orbit with grade >4 seems to be a candidate for the question "Is this orbit really necessary?"

In a few cases, there is an overlap with the 9th catalogue of spectroscopic binary orbits (Pourbaix et al. 2004, continually updated, hereafter referenced as "SB9 catalog") based on radial velocity variations. The more than 3,000 SB9 orbits come also with a grade indicating the orbit quality, but the grading system is different with values from 0 for 'poor' quality to 5 for orbits considered 'definitive'.

The Fourth Catalog of Interferometric Measurements of Binary Stars (henceforth "Int4 Catalog") includes all published measures of binary and multiple star systems obtained by high-resolution techniques (speckle interferometry, photoelectric occultation timings, etc.). For some objects with a questionable WDS observation history, this catalog is used as source for the subset of most precise measurements but also for failed resolution attempts. Unfortunately, the fourth interferometric catalog is no longer maintained since January 2018. A minor issue with this catalog is the partial mix-up of Besselian and Julian epoch values for the date of the observations.

For objects with an observation history noticeable extended beyond the publishing date of the current entry in the 6th Orbit Catalog I used the set of programs for calculating orbits by the Thiele-Innes method published by Izmailov 2019 (http://izmccd.puldb.ru/vds.htm, hereafter simply "Izmailov program") for a re-calculation of the orbital element values. The position angles of the reported measurements are corrected for precession but no weights are applied in the version of the Izmailov program offered for download. This major weakness is the price to be paid for the ease of use of these programs. Nevertheless, the results are of very good quality as is demonstrated in Appendix D for a random sample of orbits with observation history of sufficient data quality and for observation histories with a large number of measurements it is anyway to expect that measurement errors should compensate each other over time. Additionally, obvious outliers are declared as such directly by the program and thus excluded from the orbit calculation.

Newly calculated orbital element values are presented as follows if the changes to the currently listed ones seem to offer significant new insights:

P	= period in years
a	= semi-major axis in arcseconds
i	= inclination of the plane of the orbit to the plane of the sky in degrees
Node	= position angle of the ascending node (Omega) in degrees
T	= time of periastron passage in fractional years
e	= eccentricity [0,1]
omega	= plane-of-sky longitude of periastron (reckoned from Node) in degrees.

The re-calculated (and in most cases still preliminary) orbit is shown in a plot in comparison with the current 6th Orbit Catalog entry including the observation history and found outliers (with observations and outliers in the plot not corrected for the visually anyway barely noticeable precession effects).

The concept that the closest match (in terms of the usually used least-squares method) with the given observation history is the best criterion to find the "most realistic" orbit is reasonable but it is obvious that there exist usually many possible orbits with similar good fits. This is especially true when the observation history covers less than 180° of the assumed orbit and does not include both ends of the apparent ellipse (Aitken 1918). Therefore, the Izmailov 2019 program for calculating a set of 200 possible orbits was used to get an impression regarding the spread in the orbital element values. The smaller the spread, the better is obviously the quality of the calculated orbit because this reflects that the observation history covers a significant part of the suggested orbit with measurements of good quality. The greater the spread, the less reliable is usually the suggested orbit due to a too small number of measurements of maybe inconsistent measurement quality covering often only a small part of the assumed orbit period. In consequence all orbit element values are given with the error range [-ΔP16/+ΔP84] corresponding with the delta of the given value to the16th and 84th percentiles from the set of 200 possible orbits. This error range covers the usual one sigma spread and reflects the fact that the errors for orbital element values are neither symmetrical nor independent.

Another main benefit of a proposed orbit is the possibility to calculate the dynamical mass (sum of the mass of both components) of a star system provided parallax data is also available. When other reliable sources for the system mass exist then the comparison of the different mass values is also of great interest for assessing the quality of an orbit – a close match suggests good quality of a proposed orbit, a bad match suggests room for improvement either for the orbit or for the other system mass sources. Therefore if Gaia EDR3/DR2 or at least Hipparcos or other parallax data is available for a system then the dynamical mass is calculated as

$$a^3 / [P^2 * \pi^3]$$

(using Kepler's Laws with a for the semi-major axis in arcseconds, P for the period in years and π for the parallax in arcseconds) for the current 6th Orbit Catalog entry and for the newly calculated orbit. The result is compared with the StarHorse median system mass as reference value if available, else other sources considered reliable are used if available. If this comparison suggests issues with the newly calculated orbit then the set of 200 possible orbits is checked for orbits with a dynamical mass close to the reference value – this might then be not the "best fitting" orbit but a more realistic one. If the StarHorse median mass value is given only for a combined DR2 object lacking resolution then the component masses are estimated based on the magnitude delta between the components – such estimations are henceforth referenced as "estimated median system mass". If no StarHorse values are available and no other mass data source (like for example Malkov et al. 2012 or Cvetkovic et al. 2010) is found then an estimation based on the magnitudes of components is calculated henceforth referenced as "absolute magnitudes based estimated system mass" – for details see Appendix B.

However, even in case of missing system mass reference values at all it is of interest to know the dynamical mass of a binary as absurdly large or small numbers indicate most likely a poor orbit quality while reasonable numbers suggest at least some plausibility.

A table with the comparison of the dynamical mass of each listed orbit with the estimated system mass from other sources is given in Appendix C.

Another important aspect when assessing orbits are the residues (deltas between ephemerides and measurements) for position angle Theta and especially angular separation Rho. Interpreting measurement errors as caused by a random process suggests a likelihood of 50% for positive as well as negative deltas, which means measurement results should jump back and forth around the "real" values. If an orbit is assumed to provide "realistic" values then there should no bias in form of overly long stretches of positive or negative deltas contrary to statistical expectations.

2. Results in the sequence of the publishing date of the orbits:

A few new orbits for the listed objects have been included in the 6th Orbit Catalog during the work on this paper – these have been kept in the report with a short reference to the new orbit. Several of the orbits also posed questions how the calculation was done and why this orbit was considered "necessary" requesting to consult the publishing reports – in most of these cases, I succeeded to retrieve the papers but in a few cases I simply failed despite a seemingly clear reference.

2.1. WDS 04149+4825 (STT 73 A) – *Ald1925*

The 6th Orbit Catalog lists this grade 9 orbit published 1925 with a period of 0.778 years and a semi-major axis of 0.0188 arcseconds. There exists no corresponding WDS catalog object, which means that there is no observation history available allowing for an orbit calculation based on measurements of position angle and angular separation. The Int4 Catalog lists 10 observation attempts with failed resolution giving only an upper limit for angular separation.

The WDS catalog lists STT 73 as visual quadruple but the DR2 parallax values suggest that all given components are optical. Tokovinin 2017 lists STT 73 as physical triple system with a "resolved inner orbit" for the A component (referencing Johnson and Neubauer 1946, listed in the SB9 catalog as system 223 with grade 5 for definitive) with a period of ~0.8 years. Tokovinin 2017 gives for this spectroscopic orbit a semi-major axis of 0.009 arcseconds as well as a mass of 10 for the primary ("estimated from spectral type or B-V color index from Allen's table"). No "outer orbit" is given here. Tokovinin 2018 lists STT 73 again as triple system although DR2 parallax and proper motion data meanwhile suggest that STT 73 A and B are most likely not or at least no longer gravitationally bound. Tokovinin 2018 lists STT 73 Aa,Ab with two different orbits – one is again the above mentioned SB9 orbit but this time without the semi-major axis value given in Tokovinin 2017 (as is to expect – spectroscopic orbits offer no direct value for the semi-major axis). The second given orbit is the current STT 73 A Ald1925 entry in the 6th Orbit Catalog.

EDR3 lists STT 73 A as combined object with a parallax of 3.9395 with a large error range without a duplicated_source marker and RUWE 3.4. DR2 lists STT 73 A without a duplicated_source marker and RUWE ~1.28 does not indicate any multiplicity issue. DR2 parallax is 3.4452 (which is quite similar to Hipparcos parallax of 3.62) with a large error range. StarHorse median mass is ~4.60 for the combined DR2 object. Estimating the median system mass with the procedure described in Appendix B gives 7.74 (equal brightness for the missing magnitude of the secondary assumed), which renders the mass estimation from Tokovinin 2017 with 10 for only the primary as most likely wrong. The *Ald1925* orbit gives with the DR2 parallax a dynamical mass of 268.45, which is completely off even considering the large parallax error range and renders this orbit obsolete. The mentioned orbital element values for the 1946 spectroscopic orbit give with the DR2 parallax a dynamical mass of 29.64 – still far away from the StarHorse median mass value. Overall, this looks a bit like a riddle but it seems obvious, that the *Ald1925* orbit is in terms of dynamical mass obsolete – and most likely (despite a grade 5 rating as "definitive") also the SB9 orbit.

2.2. WDS 19098-1948 (B 427) – *Vor1934*

The current 6th Orbit Catalog grade 5 entry with a period of 2.68 years and a semi-major axis of 0.129 arcseconds is from 1934 although a large number of new observations was added to the WDS catalog since then up to 2018. The quality of this orbit seems highly questionable because the match between ephemerides and recent observations is very poor (see the 6th Orbit Catalog plot http://www.astro.gsu.edu/wds/orb6/PNG/wds19098-1948a.png). B 427 is apparently an object very difficult to measure due to its extremely small angular separation. A good part of the listed observations come without a position angle and with an upper limit for the angular separation indicating lack of resolution – this is the case especially for the most recent 24 observations since 2008. Both components are nearly equal bright so some quadrant issues are to expect – however, interestingly not a single quadrant issue marker appears in this observation history. The data quality of the existing observation history seems simply not suited for the calculation of realistic orbital element values. The observation history contains for this reason the note “Voronov orbit rejected from Fourth Orbit Catalog ("probably not double")” – why this orbit is then included in the 6th Orbit Catalog remains unclear.

EDR3 parallax is 9.1471 with a small error range, no duplicated_source marker and RUWE <1. DR2 parallax is 9.1558 and Hipparcos 8.44. EDR3 parallax gives with the above mentioned *Vor1934* orbit values for period and semi-major axis a dynamical mass of ~390. This value seems completely off when compared with the StarHorse median mass of ~1.31 for the combined DR2 object (allowing for a magnitude delta based median system mass estimation of 2.2) which renders this orbit obsolete.

Applying the Izmailov program on the given extended observation history results in a similar bad match with the observation history.

Interestingly Gaia DR2 indicates duplicated_source and RUWE >2.4 suggests to some degree also multiplicity so B 427 might be an optical double but not necessarily a binary.

2.3. WDS 14598-2201 (TOK 47 Aa,Ab) – *Ald1938b*

The 6th Orbit Catalog lists a grade 9 orbit for object “Ci 18,1988” published 1938 with a period of 3.559 years and a semi-major axis of 0.032 arcseconds. The WDS catalog lists for WDS 14598-2201 a triple system TOK 47 AB and Aa,Ab with the note “Ci 18,1988 Alden (1938) orbit rejected from Fourth Orbit Catalog (‘not confirmed by subsequent observations’)”.

This means that TOK 47 Aa,Ab seems to correspond with “Ci 18,1988” – but is listed interestingly without WDS note code “O” for an existing entry in the 6th Orbit Catalog. However, Tokovinin 2018 lists very well the Ald1938 orbit for TOK 47 Aa,Ab and suggests also an orbital period of 626 years for AB but without giving a semi-major axis value. Tokovinin 2018 suggests also masses estimated from absolute magnitudes of 1.20 for Aa, 0.77 for Ab and 0.89 for B.

EDR3 parallax for a combined object is 10.6709 with a small error range, no duplicated_source marker and RUWE ~1.16. DR2 lists for TOK 47 Aa,Ab also a combined object without a duplicated_source marker and RUWE ~1.06 suggests no multiplicity issues. DR2 parallax is 10.5884 (Hipparcos 10.23) with a small error range and StarHorse median mass for the combined DR2 object is ~1. The magnitude for the secondary is missing – assumed equal brightness of the components would give (with the procedure described in Appendix B) estimated masses of 0.84 each.

Dynamical mass for the *Ald1938b* orbit with the EDR3 parallax is 2.15 – this is quite close to the Tokovinin 2018 system mass estimation of 1.97 and near to the median system mass estimation of 1.68 for the combined DR2 object. The observation history for Aa,Ab is with only two full measurements far too short for any orbit re-calculation and the most recent observations are of little help due to non-resolution. The two given measures give residuals by far too large to be considered a good match with the *Ald1938b* orbit within any reasonable error range.

The observation history for TOK 47 AB is with 9 observations also far too short to calculate an orbit with an assumed period >600 years. Assuming identical parallax for A and B and taking the last measured angular separation of 1.1 arcseconds as estimation for the semi-major axis then the minimum period for a circular orbit would be 634 years using the Tokovinin 2018 masses.

2.4. WDS 21415-7723 (BLM 6) – *Ald1939b*

The current 6th Orbit Catalog entry is a grade 5 orbit published 1939 with a period of 2.84 years and a semi-major axis of 0.052 arcseconds. The WDS observation history lists only one valid measurement from 1976, so this is a neglected object.

DR2 provides data for a combined object with duplicated_source marker and RUWE >2.4 suggests also multiplicity. DR2 parallax is 51.5172 (Hipparcos 47.17, no EDR3 parallax) with a relative large error range and StarHorse median mass for the combined DR2 object is ~2.2. Estimating the median system mass with the procedure described in Appendix B gives 3.7 (equal brightness for the missing magnitude of the secondary assumed). The dynamical mass of the *Ald1939b* orbit with the DR2 parallax is 0.13 – completely off compared to the estimated median system mass and rendering this orbit obsolete. The observation history with only one observation is clearly not suited to attempt the re-calculation of a premature orbit. Why the *Ald1939b* orbit is rated as grade 5 and not 9 remains a riddle.

BLM 6 is also listen in the SB9 catalog with a spectroscopic grade 2 (which means poor) orbit with a period of ~2.79 years published 1936.

2.5. WDS 10200+1950 (BAG 32 Ca,Cb) – *Reu1943*

The current 6th Orbit Catalog grade 9 entry with a period of 26.5 years and a semi-major axis of 0.1109 arcseconds is from 1943 based on the observation of astrometric perturbations. First time effectively resolved and measured in 1981 (see Knapp 2020) with a few additional observations added later on to the WDS catalog up to 2012. However, in total only four observations qualify as full measurements because most observations lack position angle and indicate just an upper limit for angular separation due to non-resolution and these four valid measurements are heavily at odds with the corresponding orbit ephemerides.

The observation history quotes the Balega et al. 1984 report with the following note: “Companion has been detected only at 750 nm. The companion is expected to have a very low mass”.

EDR3 parallax for the combined object is 201.4064 with a very small error range, no duplicated_source marker, RUWE is 1.154. DR2 parallax is 201.3683 (no Hipparcos parallax) suggesting for the *Reu1943* orbit a dynamical mass of ~0.0002, which means far less than Jupiter.

The StarHorse median mass for the combined DR2 object is ~0.4 and Cortés-Contreras et al. 2017 suggest a mass of 0.32 for the primary.

Estimating the median system mass with the procedure described in Appendix B gives 0.67 (equal brightness for the missing magnitude of the secondary assumed), which renders the *Reu1943* orbit as clearly obsolete. DR2 indicates no duplicated_source and RUWE ~1.1 indicates no multiplicity. The *Research Consortium On Nearby Stars* list (henceforth RECONS list) records this object as single star object. Together this suggests that BAG 32 Ca,Cb might be bogus but especially the resolution reported by Cortés-Contreras et al. 2017 is an indication that this object is most likely indeed a double.

The observation history is certainly too small to attempt the calculation of a new premature orbit.

BAG 32 Ca,Cb is part of the STF1424 multiple listed in the WDS catalog with two alternative grade 4 orbits for STF1424 with a period of 554 years and a semi-major axis of 3.1 arcseconds published 2014 with a meanwhile extended observation history. DR2 and StarHorse data are not available for STF1424 but the Hipparcos parallax of 25.96 suggests no physical relationship with BAG 32 Ca,Cb.

2.6. WDS 17053+5428 (STF2130 B) – *Str1943*

STF2130 B is listed in the 6th Orbit Catalog with a grade 9 orbit published 1943 with a period of 3.2 years and a semi-major axis of 0.026 arcseconds but lacks a corresponding WDS object. The dynamical mass for the *Str1943* orbit with the DR2 parallax for B of 36.8008 (EDR3 36.7902, Hipparcos 36.45) is tiny 0.03 – seems not very plausible. The StarHorse median mass for the combined DR2 object is ~1.15. Estimating the median system mass with the procedure described in Appendix B gives 1.93 (equal brightness for the missing magnitude of the secondary assumed), which renders this orbit as clearly obsolete.

Tokovinin 2018 lists a spectroscopic orbit for Ba,Bb published 1979 with a period of 6.215 years with the note “needs confirmation” (listed also in the SB9 catalog as system 947 with grade 1 which means poor). DR2 gives for the B component no duplicated_source marker and RUWE ~0.9 suggests no multiplicity issues.

STF2130 AB is a visual binary with a huge observation history listed in the 6th Orbit Catalog with a grade 3 orbit from 2019. DR2 and StarHorse data suggest for STF2130 AB most likely gravitational relationship although StarHorse provides no mass for A but we have the estimated median system mass 1.93 for B. Estimating the median system mass for AB based on magnitude delta gives 3.87. The dynamical mass for STF1230 AB with the Izm2019 orbit and the average DR2 parallax of 36.8 is 2.89 – not a perfect match but at least reasonable close to the estimated system mass.

There is also a C component listed as BU 1088 AC in the WDS catalog according to EDR3/DR2 and StarHorse data also most likely bound by gravitation to AB making this a triple system. DR2 and StarHorse data suggest a minimum period for a circular orbit of 3,645 years close to the value suggested by Tokovinin 2018. This would make this object in total a quadruple system.

2.7. WDS 15073+1827 (A 2385) – *Egg1946*

The current 6th Orbit Catalog grade 4 entry with a period of 8 years and a semi-major axis of 0.1 arcseconds is from 1946 although a large number of new observations was added to the WDS catalog since then up to 2018. A 2385 seems to be a very difficult object to measure, because a good part of the listed observations come without a position angle and most given angular separations are just an upper limit and most of the remaining measurements are marred by quadrant or precision issues. The quality of the *Egg1946* orbit seems highly questionable because the match between ephemerides and corresponding observations is poor; especially the residuals Theta are far beyond any reasonable error range. Applying the Izmailov program on the given extended observation history does not help – similar period but again a poor match with the observation history.

EDR3 parallax for A 2385 is 13.2096 with a small error range with duplicated_source marker and RUWE <1. DR2 parallax is 13.1729 (Hipparcos 13.85) without duplicated_source marker and also RUWE <1. DR2 parallax gives with the *Egg1946* values for period and semi-major axis a dynamical mass of 6.84 – the bad match with the estimated system mass of ~3.2 based on the StarHorse median mass of ~1.9 for the combined DR2 object and magnitude delta renders this orbit obsolete.

The 6th Orbit Catalog plot (http://www.astro.gsu.edu/wds/orb6/PNG/wds15073+1827a.png) shows the extremely bad match with the measurements and supports the conclusion is that the given observation history is of little use to calculate a realistic preliminary orbit.

This observation history looks to me very similar to the observation history for A 3010 meanwhile declared bogus especially as DR2 indicates no duplicated_source for A 2385 and RUWE <1 does not suggest multiplicity. However, EDR3 lists surprisingly very well a duplicated_source marker – new precise measurements would be very valuable for orbit re-calculation.

2.8. WDS 09468+7603 (Ross 434) – *Ald1951*

Ross 434 is listed in the 6th Orbit Catalog with a grade 7 orbit published 1951 with a period of 1.26 years and a semi-major axis of 0.038 arcseconds. No entry for this object in the WDS catalog and thus no observation history. EDR3 parallax is 63.3251 with a small error range, no duplicated_source marker and RUWE is ~1. DR2 lists a combined object without a duplicated_source marker and RUWE ~1.09 suggests good data quality. DR2 parallax is 63.3142 (Hipparcos 61.68) and StarHorse median mass for the combined DR2 object is 0.55. Estimating the median system mass with the procedure described in Appendix B gives 0.92 (equal brightness for the missing magnitude of the secondary assumed). The dynamical mass for the *Ald1951* orbit calculated from the given data is 0.14 – a bad match with the estimated median system mass, which renders this orbit obsolete.

The 6th Orbit Catalog contains the note 'Alden orbit rejected from Fourth Orbit Catalog ("not confirmed by subsequent observations")'.

2.9. WDS 15183+2650 (STF1932 B) – *Mlr1952d*

The 6th Orbit Catalog lists for STF1932 B a grade 9 orbit published 1952 with a period of 50 years and a semi-major axis of 0.055. The WDS catalog lists no corresponding object, which means it lacks an observation history. EDR3 parallax is 27.6125 with a small error range, no duplicated_source marker and RUWE is ~1. DR2 parallax is 27.5280 (Hipparcos 27.79) and StarHorse median mass for the combined DR2 object is ~0.75. Estimating the median system mass with the procedure described in Appendix B gives 1.26 (equal brightness for the secondary with missing magnitude assumed). The dynamical mass for the *Mlr1952d* orbit calculated with the given data is 0.003 – this means three times the Jupiter mass, which makes this an obsolete orbit even without comparison with the estimated median system mass. However, the DR2 duplicated_source marker suggests that STF1932 B might be with some likelihood indeed a multiple. However, EDR3 lists no duplicated_source marker, which leaves room for caveats.

STF1932 A is listed in the WDS catalog as close visual binary with CHR 45 Aa,Ab suggesting together with the assumed multiplicity of STF1932 B a quadruple system. But there is only one successful observation listed from 1984 with several failed resolution attempts up to 2013 making CHR 45 Aa,Ab a somewhat questionable WDS object. Also no entry exists for CHR 45 Aa,Ab in the 6th Orbit Catalog. DR2 lists STF1932 A without duplicated_source marker and a RUWE value of ~1.09 suggests no multiplicity issues. DR2 parallax for A is 27.5889 and StarHorse median mass for the combined DR2 object is ~1.02, so it seems plausible that A might be a single source object. However, EDR3 lists very well a duplicated_source marker.

STF1932 AB is listed in the WDS catalog as visual binary (assumed multiplicity of A and B makes it a potential quadruple) and is listed in the 6th Orbit Catalog with a grade 2 orbit published 2019 with a period of ~197 years and a semi-major axis of 1.22 arcseconds. The dynamical mass for STF1932 AB with the Izm2019 orbit and the average DR2 parallax is 2.22 – this is reasonable close to the estimated median system mass of 2.28 (1.02 for A plus 1.26 for B as given above). Tokovinin 2018 does not list STF1932 AB as multiple system may be due to the fact that CHR 45 Aa,Ab looks a bit like a bogus object but it is unclear why the plausible multiplicity of B was ignored.

2.10. WDS 19190-3317 (I   253) – *B__1954*

The current 6th Orbit Catalog grade 4 entry with a period of 60 years and a semi-major axis of 0.5101 arcseconds is from 1954 although a large number of new observations was added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history gives with a period of ~58.3 years and semi-major axis of 0.471 arcseconds a result very similar to *B__1954* with a reasonable error range.

EDR3/DR2 parallax for I   253 is not available, Hipparcos suggests a parallax of 18.15 giving a dynamical mass of 6.17 for the *B__1954* orbit and 5.14 for the newly calculated orbit – both results do not match well with the system mass of ~2.3 suggested by Cvetkovic et al. 2010.

The set of 200 possible orbits contains several entries with ~2.3 dynamical mass – all of them in the range of ~58 years period and ~0.36 semi-major axis with the best match as follows:

Element	Value	-ΔP16/+ΔP84
P	58.281	-0.725/+0.620
A	0.357	+0.059/+0.193
I	95.177	-4.328/-0.349
Node	139.702	-2.730/+0.980
T	1942.534	-6.559/-1.814
E	0.821	-0.092/+0.012
omega	165.355	-39.744/-12.607

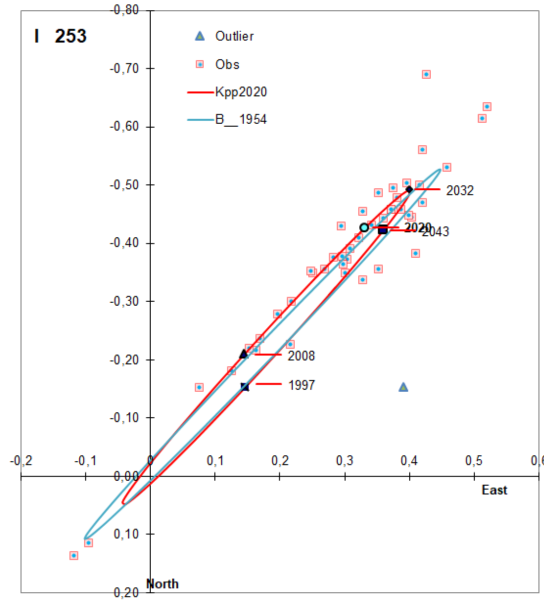


Figure 1. Plot 1: I 253 orbit comparison

This orbit interestingly suggests that the bottom left measurements from 1939.59 and 1940.78 should be flipped. Root mean square error for Rho (angular distance in arcseconds) is 0.0813 for the *B__1954* orbit and 0,0810 for the newly calculated – this is not much of an improvement in terms of residuals but the much better match with the estimated system mass seems more important. The *B__1954* orbit shows also a systematic bias for the most recent six measures.

2.11. WDS 05074+1839 (A 3010) – *Egg1956*

Listed in the 6th Orbit Catalog with a grade 3 orbit published 1956. This object is meanwhile marked in the WDS catalog with note code “X” which means bogus. Extensive notes in the 6th Orbit Catalog describe the up and downs in the observation history for this object. EDR3 parallax is 62.8252, no duplicated_source marker, RUWE <1. DR2 lists this object also without a duplicated_source marker and RUWE ~0.98 does not suggest multiplicity. The DR2 parallax is 62.9467 (Hipparcos 64.79) and the StarHorse median mass for the combined DR2 object is ~1.3 suggesting an estimated median system mass of 2.19 based on magnitude delta. Just out of curiosity, I calculated the dynamical mass for the *Egg1956* orbit and got with the DR2 parallax a value of 16.51 Sun masses – just another hint that this orbit is obsolete.

2.12. WDS 12554+6953 (A 1092) – *Baz1959*

The current 6th Orbit Catalog grade 4 entry with a period of 58 years and a semi-major axis of 0.22 arcseconds is from 1959 although a good number of new observations was added to the WDS catalog since then up to 2004, but was since then neglected. Applying the Izmailov program on the given extended observation history results in orbital element values similar to *Baz1959*:

Element	Value	-ΔP16/+ΔP84
P	55.846	-0.814/+0.950
A	0.225	-0.009/+0.029
i	149.587	-1 .311/+3.863
Node	26.086	-7.313/+53.031
T	1943.200	-1.060/+0.926
e	0.649	-0.034/+0.051
omega	69.602	-3.108/+46.250

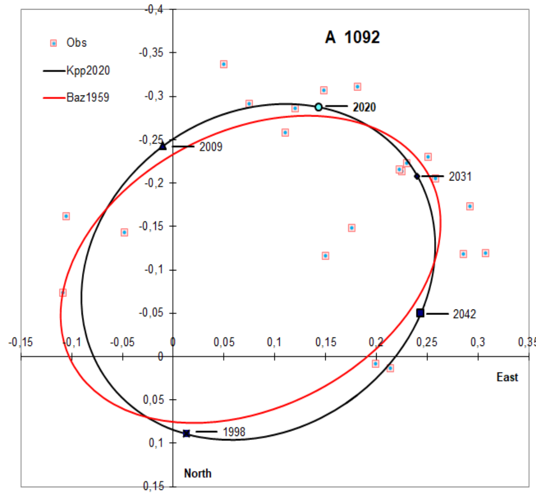


Figure 2. Plot 2: A 1092 orbit comparison

The spread of the orbital element values in the set of 200 possible orbits is reasonable small and residual Rho root mean square error (henceforth RMS) is 0.0389 compared to 0.0461 for the *Baz1959* orbit, which suggests a slightly better quality for the newly calculated orbit.

No EDR3/DR2 parallax available, Hipparcos gives 13.77 suggesting for the *Baz1959* orbit a dynamical mass of 1.21 and for the newly calculated orbit of 1.40. Malkov et al. 2012 list 1.49 photometric and 0.95 spectroscopic system mass and absolute magnitude based system mass estimation is 1.71. Therefore, the dynamical mass value seems for both orbits within a plausible range. However, this WDS object is without observations since 2004 – new measurements would be of great interest.

2.13. WDS 06344+1445 (STF 932) – *Hop1962a*

The current 6th Orbit Catalog grade 5 entry with a period of 2,360 years and a semi-major axis of 3.21 arcseconds is from 1960 although a large number of new observations was added to the WDS catalog since then up to 2017. Even with an observation time span of nearly 200 years it seems very motivated to calculate an orbit with a period over ten times longer especially if the measurements seem to cover a neutral orbit phase. Using the Izmailov program with the extended observation history results in an extremely long period of far over 100,000 years with an absurd large semi-major axis and a very large spread in the orbital element values. This combined with an inclination ~90° suggests indeed a rectilinear solution. The given DR2 data and the StarHorse median mass values of ~1.41/1.26 suggest a likelihood for gravitational relationship of less than 20% with a minimum spatial distance of 149 AU giving a minimum circular orbital period of ~1,300 years. EDR3 data suggests with 60% likelihood better chances for gravitational relationship combined with a shorter minimum circular orbit period of 1,066 years.

EDR3 parallax values are 11.4701 and 11.6016 with a small error range and RUWE is for both components <1.4 indicating good data quality. DR2 average parallax for the STF 932 components is 11.4587 (Hipparcos 12.49) giving with the *Hop1960a* Orbit Catalog data a system mass of 3.95 not too different from the StarHorse median system mass of ~2.67. The set of 200 possible orbits calculated with the Izmailov program includes only one entry coming with a dynamical mass of 2.47 close to the StarHorse median system mass value, which offers in comparison with the *Hop1962a* orbit a slightly better match with the most recent measurements. However, the observation history is far too short for the calculation of a premature orbit with such a long period and the EDR3/DR2 proper motion data for the components seem too different for such a long period orbit suggesting that this might be an optical pair:

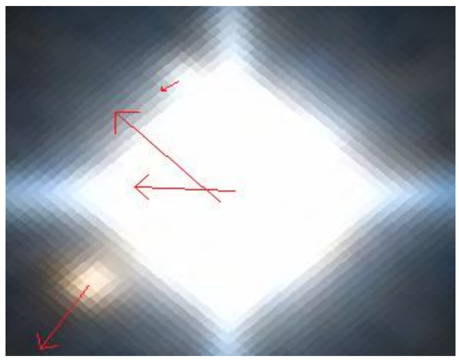


Image 1: Aladin screenshot with STF 932 proper motion vectors

2.14. WDS 11033+3558 (Lal 21185) – *Lip1960*

Listed in the 6th Orbit Catalog with a grade 9 orbit published 1960 with a period of 8 years and a semi-major axis of 0.0336 arcseconds. No WDS catalog entry for this object, which means also lack of an observation history. The RA/Dec J2000 position given in the 6th Orbit Catalog corresponds with no star at this position but the given magnitude suggests the nearby very fast moving flare star HD 95735 which is according to the EDR3 parallax of 392.7529 (Hipparcos 392.64) very close to our Sun (no DR2 data available). Lal 21185 is number 4 on the RECONS list of objects in the solar neighborhood but without any hint for multiplicity. The dynamical mass for the *Lip1960* orbit with the Hipparcos parallax is 0.00001, which clearly renders this orbit obsolete. Simbad indicates an unconfirmed planet. Absolute magnitude based estimation suggests a system mass of ~0.4 assuming a binary with equal bright components or ~0.2 assuming a single star object. The latter seems more realistic. The 6th Orbit Catalog notes state '… orbit rejected from Fourth Orbit Catalog ("not confirmed by subsequent observations")' – so it seems unclear why this orbit is listed in the 6th Orbit Catalog at all.

2.15. WDS 11268+0301 (STF1540) – *Hop1960a*

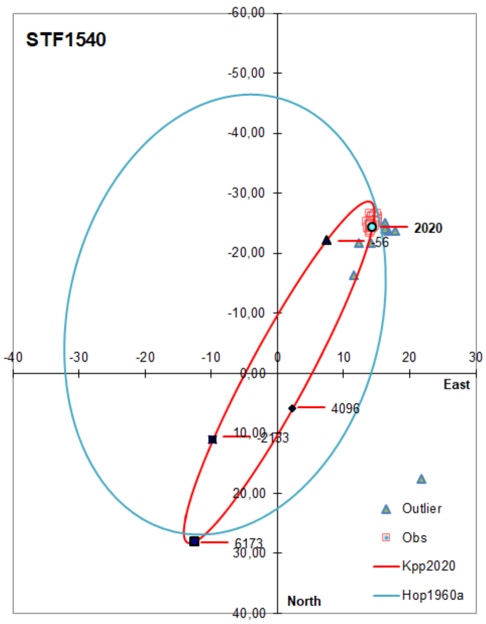
The current 6th Orbit Catalog grade 5 entry with a period of 32,000 years and a semi-major axis of 40.76 arcseconds is from 1960 although a large number of new observations was added to the WDS catalog since then up to 2018. Even with an observation timespan of about 250 years it seems clearly premature to calculate an orbit with such a long period. Using the Izmailov program on the extended observation history gives a somewhat shorter period of ~9,600 years but as expected with a huge spread in the orbital element values.

The close-up of the plot shows clearly that the *Hop1960a* orbit does not correspond well with the observation history. The match is much better with the newly calculated orbital elements but the given pattern of observations could also suggest a rectilinear solution.

EDR3 parallaxes are 55.0090/55.0618 with a small error range, RUWE for both components is ~1 indicating good data quality. DR2 parallaxes are 54.9177/54.9057 (Hipparcos 56.35/55.69). These data are together with the StarHorse median mass values of ~0.94/0.83 very conclusive: The likelihood for overlapping tidal radii is 100% with a minimum spatial distance of 512 AU suggesting a minimum circular orbit period of ~8,800 years. DR2 (but not EDR3) indicates for the secondary a duplicated_source, so this might be a double itself. Common proper motion is another hint, that STF1524 is indeed most likely a physical system. However, the existing observation history is certainly too small to allow for the calculation of reasonable orbital elements and no human time span will be sufficient to change this situation.

Calculating the dynamical mass of the STF1540 system based on the average EDR3 parallax gives 0.4 for the *Hop1960a* orbit and 29.89 for the newly calculated orbit. Both values are extremely bad matches with the StarHorse median system mass value of ~1.77 (this value might be a bit higher if the secondary is indeed a double itself). A lookup in the set of 200 possible orbits for an entry with a dynamical mass as close as possible to the StarHorse system mass value suggests an entry with a dynamical mass of 1.77 with the following orbital element values:

Element	Value	-ΔP16/+ΔP84
P	10381.9	-5282.3/+385107.1
A	31.6	-3.1/+832.1
i	98.3	-7.9/+1.1
Node	154.1	-5.6/+13.4
T	-1831.7	-8787.7/+28707.5
e	0.03	+0.3/+0.9
omega	253.4	-141.5/+31.1



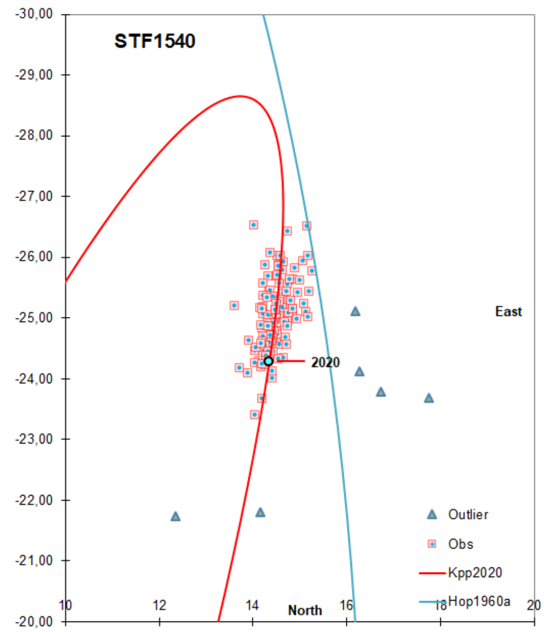


Figure 3. Plot 3: STF1540 orbit comparison with close-up of significant part

It is certainly a valid question if this newly calculated orbit is "really necessary" but in fact, it fits the observation history much better than the current 6th Orbit Catalog entry and offers a dynamical mass that corresponds well with the StarHorse median system mass value. Yet it remains obvious, that the given observation history is far too short to calculate a reasonably realistic if premature orbit for a binary with such a long period.

2.16. WDS 21069+3845 (STF2758 A) – *Dej1960*

The 6th Orbit Catalog lists for STF2758 A a grade 9 orbit published in 1960 with a period of 4.9 years and a semi-major axis of 0.14 without a corresponding object in the WDS catalog. The dynamical mass for the *Dej1960* orbit with the EDR3 parallax of 285.9949 (DR2 285.9459, Hipparcos 286.82) is 0.005 – obviously complete off especially if compared to the estimated median system mass 1.18 based on magnitude delta and the StarHorse median mass for the combined DR2 object of ~0.70, which renders this orbit obsolete.

The WDS catalog lists STF2758 as visual multiple with most components most likely opticals with rectilinear solution. STF2758 AB is also listed in the 6th Orbit Catalog with a grade 4 orbit published 2019 with a period of ~619 years but with a huge error range. No duplicated_source marker in EDR3, but DR2 lists the A component with a duplicated_source marker (supporting the proposition that STF2758 A is a multiple itself) and the B component without, RUWE is ~1 for both components suggesting no multiplicity issues. EDR3 parallax for B is 286.0054 (DR2 286.1457, Hipparcos 285.88) and StarHorse median mass is ~0.60 suggesting together with the corresponding values for A given above most likely gravitational relationship with a minimum period for a circular orbit 872 years. The dynamical mass for the Izm2019 STF2758 AB orbit with the average DR2 parallax is 1.80, which is very close to the estimated median system mass of ~1.78 (1.18 for A and 0.60 for B).

2.17. WDS 21567+6338 (WRH 36) – *Frd1960*

The 6th Orbit Catalog lists a grade 5 orbit published 1960 with a period of 20.34 years and a semi-major axis of 0.0336 arcseconds. WRH 36 (red giant VV Cep) is listed in the WDS catalog with only one observation in 1950, which means a neglected WDS object. This observation history cannot be the base for calculating the *Frd1960* orbit, so it seems unclear why this orbit is rated with grade 5.

Simbad classifies this object as eclipsing binary of Algol type. DR2 lists this object without a duplicated_source marker and StarHorse provides no data for WRH 36. The dynamical mass for the *Frd1960* orbit with the EDR3 parallax of 1.0033 with a large error range (DR2 1.6661 also with a large error range, Hipparcos 1.33) is ~90. This is a bad match with the mass for the primary suggested by Pollmann et al. 2017 between 15 and 20 $M_{\odot}$ even if the secondary is assumed to have similar mass. While the parallax error is large, it is still too small to cover this difference.

VV Cep as a spectroscopic binary is extremely well observed with several orbits from different sources presented by Wright 1977 with one of them from Wright himself – also with a period of 20.34 years (listed in the SB9 catalog as system 1340). Wright 1977 suggests distances between the components in km for periastron and apastron allowing the calculation of a semi-major axis of ~0.0312 arcseconds giving a dynamical mass similar to *Frd1960*. Therefore, the given period seems confirmed but more precise parallax and system mass data would be valuable for assessing the proposed orbits.

2.18. WDS 14565-3438 (I 227) – *Ltg1961b*

The current 6th Orbit Catalog grade 4 entry with a period of 40 years and a semi-major axis of 0.2563 arcseconds is from 1961 although a large number of new observations was added to the WDS catalog since then up to 2016. Although the observation history time span is so far about 120 years only about 60% of the ~42 years orbit period are covered by measurements most likely because the small angular separation during the rest of the orbit makes measurements extremely difficult.

Applying the Izmailov program on the given extended observation history gives with a period of 41.15 years and a semi-major axis of 0.327 arcseconds a result similar to *Ltg1961b*.

No EDR3/DR2 parallax available, Hipparcos suggests 16.38 giving for the *Ltg1961b* orbit a dynamical mass of 2.39 and for the newly calculated orbit of 4.7 – with the former corresponding better with the system mass of ~2.2 suggested by Cvetkovic et al. 2010. The set of 200 possible orbits contains several entries with a system mass in this range – the best match offers a dynamical mass of 2.21 with the following orbital element values:

Element	Value	-ΔP16/+ΔP84
P	41.423	-0,819/+0,264
A	0.255	+0,025/+0,515
i	140.116	-39,356/-12,372
Node	80.799	-23,020/+15,442
T	1956.345	-2,640/+2,032
e	0.884	-0,012/+0,106
omega	160.916	-54,052/+72,932

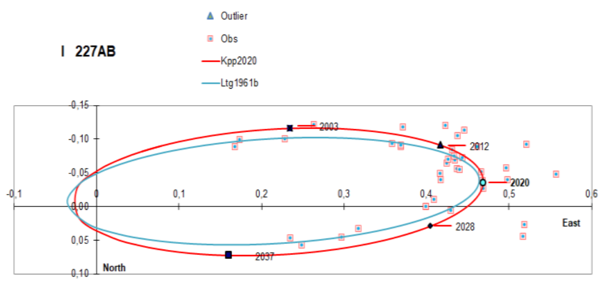


Figure 4. Plot 4: I 227 orbit comparison

Remark: The two first measurements from 1897 are outliers outside the frame of the plot.

The newly calculated orbit offers a better residuals Rho RMS value with 0.0477 compared to 0.0509 for *Ltg1961b* and a better match with the measurements since 1961. More precise parallax and mass data as well as new precise measurements would be valuable for orbit evaluation.

2.19. WDS 17379+1836 (Ci 18,2347) – *Bie1964*

Listed in the 6th Orbit Catalog with a grade 7 orbit published 1964 with a period of 24 years and a semi-major axis of 0.04 arcseconds but without a corresponding WDS object. The J2000 RA/Dec position is slightly off but the corresponding object seems to be the high proper motion star GJ 686/HIP 86287 listed in DR2 without duplicated_source marker and RUWE ~1.1 suggests no multiplicity issues. DR2 parallax is 122.5609 (EDR3 122.5546, Hipparcos 123.67) and StarHorse median mass for the combined DR2 object is ~0.46 suggesting an upper limit for the median system mass of 0.77 in case of equal magnitudes. Missed as questionable object in Knapp 2020.

The dynamical mass for the *Bie1964* orbit with the DR2 parallax is 0.0001, which makes this orbit obsolete.

Interestingly a recent study (Affer et al. 2019) suggests a planet with a mass of ~7 $M_\oplus$ but with a much shorter period.

2.20. WDS 01030+4723 (STT 21) – *Hei1966*

The current 6th Orbit Catalog grade 5 entry with a period of 450 years and a semi-major axis of 0.816 arcseconds is from 1966 (declared as provisional in Heintz 1966) although a large number of new observations was added to the WDS catalog since then up to 2018. The comparison of the *Hei1966* orbit ephemerides with the measurements from the most recent decades shows a systematically increasing delta, so this orbit seems to be not only premature but also clearly obsolete.

STT 21 is resolved in EDR3 with parallax values of 9.2058 and 9.4797 with a small error range and RUWE <1.4. DR2 parallaxes are 9.2182 and 9.1208 also with a reasonably small error range and Hipparcos lists 10.41 for a combined object with a medium large error range. StarHorse provides a median mass for the primary of ~2.1 but none for the secondary. An estimation based on magnitude delta results in ~1.55 for the secondary giving in total a median system mass of ~3.65 with the caveat, that the missing StarHorse data for the secondary puts a question mark on this estimation.

Calculating with the average EDR3 parallax value of 9.34275 gives for *Hei1966* a dynamical mass of 3.32 close to the estimated median system mass but this does not help much because this orbit is rendered obsolete by the bad match with new measurements.

Applying the Izmailov program on the given extended observation history including the additional Gaia measures results in a much better match with the recent measurements with the huge caveat that the dynamical mass for this new premature orbit is >130 $M_{\odot}$, which is obviously absurd. This makes once more clear that a mathematically good match with the observation history alone is not sufficient to get a reasonable orbit solution. In addition, the huge spread in the orbital element values raises doubts about the quality of the observation history; consequently, the Izmailov program declares nearly half of the measurements before 1931 as questionable due to the large residuals – the same measures show by the way similar large residuals with the *Hei1966* orbit. In addition, the set of 200 possible orbits does not offer a single entry with a plausible dynamical mass and the inclination is in all scenarios close to 90° suggesting that a rectilinear solution might be a better option.

Heintz 1966 was aware of erroneous 19th century measurements and remarked “Die Fehler der früheren Messungen bleiben ungeklärt”. Francisco Rica Romero pointed me to the work of Hussey 1901 declaring several of these measurements as a mismatch with nearby double star MAD 1 (private communication). The *Lin2012a* orbit listed for MAD 1 confirms indeed that at least two of these observations (1845.69 and 1879.19) are indeed measurements for MAD 1. I have brought this to the attention of Brian Mason and it should soon be corrected.

Heintz1966 simply eliminated all questionable measurements from his observation history and otherwise worked mainly with averages of measurements from different observers, which compressed the number of measurements from the more than 70 measurements listed in the WDS observation history up to 1964 to just 17. To make things even more confusing, there are differences in the first five measures between Heintz 1966 and the WDS observation history with the WDS data corresponding with the referenced publications and Heintz 1966 not. For example, Aitkens measurement 1904.54 with 1.0° and 0.22” (Aitken 1914) listed as such in the WDS observation history versus 1.2° and 0.10” listed by Heintz 1966. Precession to J2000 is the reason for the difference in position angle but the difference in separation seems to be an error of Heintz.

Gaia EDR3 and StarHorse data suggest <5% likelihood for potential gravitational relationship with a minimum spatial distance of ~140 AU with a potential minimal period of ~875 years possible only if using the error range to full extent – this means a likelihood of >95% that this is an optical pair. The proper motion values are also not similar enough to suggest common proper motion (see table 8 in Knapp and Nanson 2019), which would be to expect for a binary with such a long period – just another hint that this might be an optical pair.

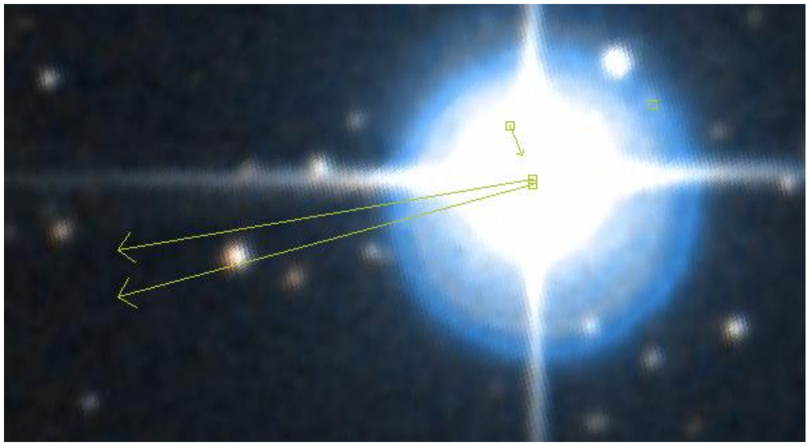


Image 2: Aladin screenshot with STT 21 proper motion vectors

Francisco Rica Romero had a closer look at STT 21 and came to the conclusion that the relative velocity difference is smaller than the escape velocity, which suggests that STT 21 is indeed a physical pair (private communication). He suggested even two new premature orbits to support this opinion, both with a much better match with the observations history compared to *Hei1966* but still with a slight systematic bias compared with the most recent measures.

I tried then to “clean up” the observation history by following Heintz’s approach by eliminating questionable observations up to 1964 and additionally by deleting all measures marked in the WDS observation history as “uncertain/estimated”. Applying the Izmailov programs on this data set resulted in a premature orbit with a period of 498 years and a semi-major axis of 1.02 arcseconds giving a dynamical mass of 5.35 – a bit too high to be a good match with the estimated system mass.

The set of 200 possible orbits contains several entries with a dynamical mass near the estimated median system mass. I selected an entry with a dynamical mass of 3.60, which suggests the following orbital element values:

Element	Value	-ΔP16/+ΔP84
P	702.657	-441.758/-114.736
A	1.129	-0.166/+0.167
i	91.225	-2.424/-1.270
Node	175.069	-0.184/+1.122
T	1905.346	-40.483/-5.467
e	0.831	-0.182/-0.033
omega	189.312	-63.407/-8.095

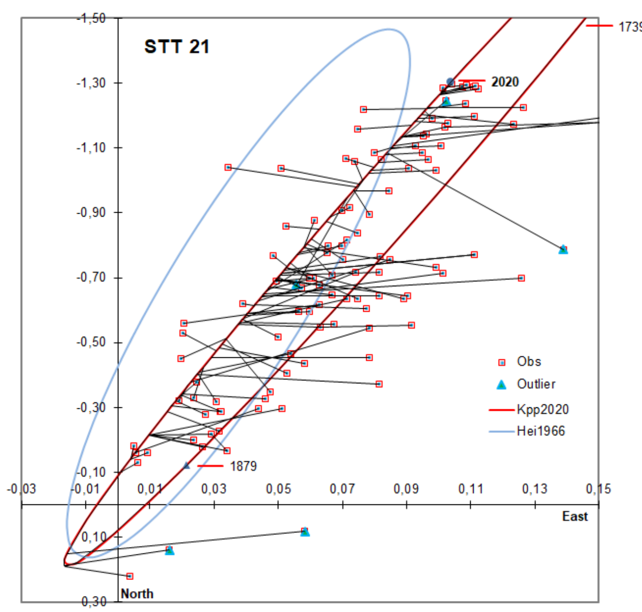
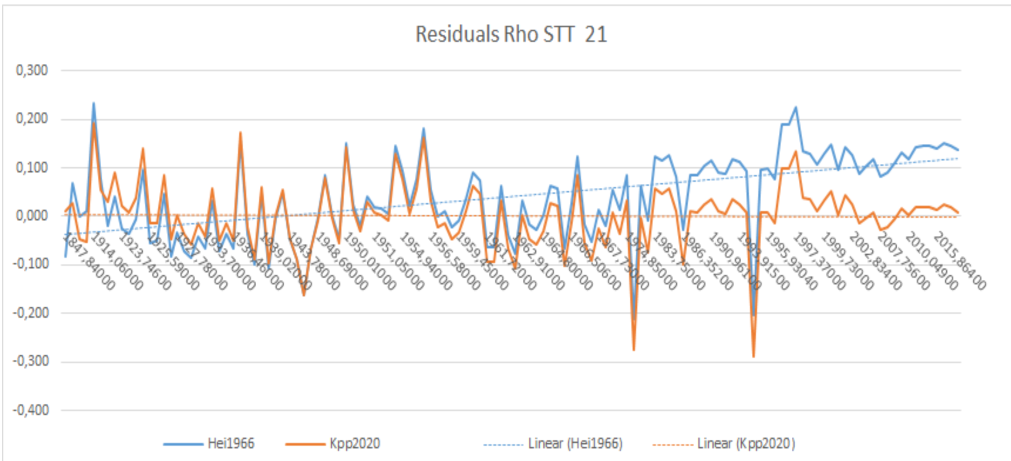


Figure 5. Plot 5.1: STT 21 orbit comparison

Be aware that the plot scaling in the X- and Y-axes is different by 1:10 to allow a better comparison between measurements and orbit. A scaling 1:1 would reduce the orbital ellipses to a nearly straight line (see the 6th Orbit Catalog plot http://www.astro.gsu.edu/wds/orb6/PNG/wds01030+4723a.png) giving the illusion that also the most recent observations are well matched with *Hei1966*, which is certainly not the case.

In terms of residuals, *Hei1966* shows a systematic bias for the measures of the recent decades seen in the plot. The newly calculated orbit offers a significant better match with the most recent observations but a slightly worse one for the bulk of observations in the first half of the 20th century especially in terms of residuals Theta.



Plot 5.2: STT 21 orbit comparison residuals Rho

The linear trend lines show the increasing bias of *Hei1966* while the newly calculated orbit stays around zero even if there is also a slight bias given for the last nine measures.

To check another option, I consulted the Int4 Catalog with a reasonably large number of observations up to 2010. I added the DR1/DR2/EDR3 measurements and decided to run the Izmailov program again with this reduced data set. The resulting premature orbit with a period of 649.5 years and a semi-major axis of 1.1 looked with a dynamical mass of 3.89 promising even with an inclination close to 90°. Then I found out that several of the Int4 measures are not even included in the WDS observation history due to a "poor" or "very poor" rating, so I had to eliminate these. Next, I found out that several of the Int4 measures are listed in the WDS observation history with slightly different results due to corrections from the authors after publication, so I had to consider these corrections. To add to the ambiguity most of these measures are marked in the WDS observation history as "uncertain/estimated" and so it was better to discard them. The number of measures finally remaining was then a bit too small for a useful orbit re-calculation, putting an end to this approach.

The STT 21 observation history is obviously heavily ridden with errors with most of them meanwhile most likely corrected but some caveats remain. The fact that it seems not possible to find an orbit covering both old and new measurements similar well (the former with a tendency to inclination below 90° and the latter above 90°) with a reasonable dynamical mass is a bit annoying and an orbit with inclination close to 90° looks always a bit suspicious.

The question of whether this re-calculated orbit is "really necessary" is easy to answer – most certainly not. However, the *Hei1966* orbit is obviously obsolete and the newly calculated is in terms of residuals Rho overall clearly better. Therefore, this newly calculated orbit is just an example that a better fit with the observation history is not a sufficient criterion for a "really necessary" orbit.

New precise measurements would be very helpful for a better assessment of the so far discussed orbits or support of a rectilinear solution.

The 6th Orbit Catalog contains the note "A may be a spectroscopic binary", which adds complexity by suggesting a potential three body problem, which might contribute to the discussed troubles with the observation history.

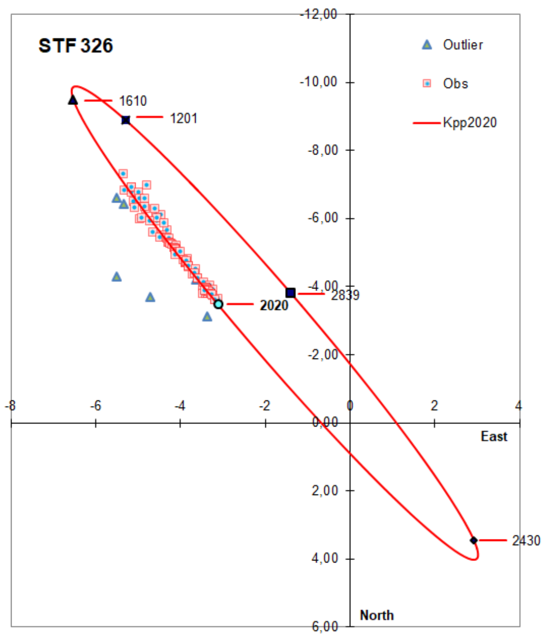
2.21. WDS 02556+2652 (STF 326) – *Hop1967*

This is a quite curious 6th Orbit Catalog grade 7 entry from 1967 given without period and semi-major axis and with an eccentricity of exactly 1. This means a parabolic "orbit" with a non-periodic trajectory where the velocity delta between the two objects corresponds always with the escape velocity. The notes file includes the remark "Data appear equally well fit by rectilinear solution" and the WDS observation history includes such a solution. The Izmailov program provides a proposal for a premature orbit with a period of ~1,200 years and a semi-major axis of 14.65 arcseconds but with a huge spread in the set of 200 possible orbits.

The EDR3 parallax values of 44.4324 and 44.5053 as well as the DR2 parallax values of 44.3676 and 44.3828 (Hipparcos combined object 42.57) are together with the StarHorse median mass values of ~0.88 and 0.75 very conclusive. The likelihood for potential gravitational relationship is 100% with a minimum spatial distance of 108 AU suggesting a minimum circular orbit period of ~880 years. EDR3/DR2 give no duplicated_source indication for both components and RUWE is ~1 suggesting good DR2 data quality. This evidence suggests that a rectilinear solution is unlikely.

Using the average EDR3 parallax of 44.46885 with the newly calculated orbit gives a dynamical mass of ~24.7. This is not only far away from the StarHorse median system mass of ~1.63 but also from the absolute magnitude based estimation of 2.07 – this suggests to have a closer look at the set of 200 possible orbits for a better match in terms of mass. Nearest comes an orbit with a system mass of 1.80 with the following values:

Element	Value	-ΔP16/+ΔP84
P	2047.8	-1169.7/+107.9
A	8.7	+1.2/+20.6
i	84.16	+3.13/+5.08
Node	35.03	-0.73/+0.78
T	2265.19	-639.12/-284.97
e	0.47	-0.06/+0.44
omega	326.74	-247.75/-195.39



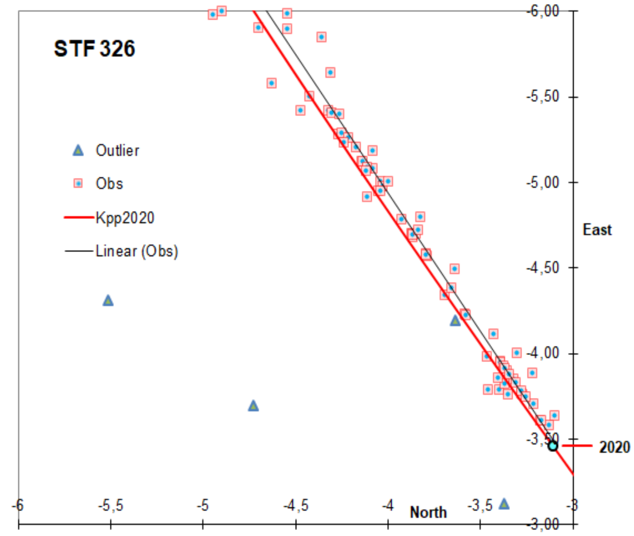


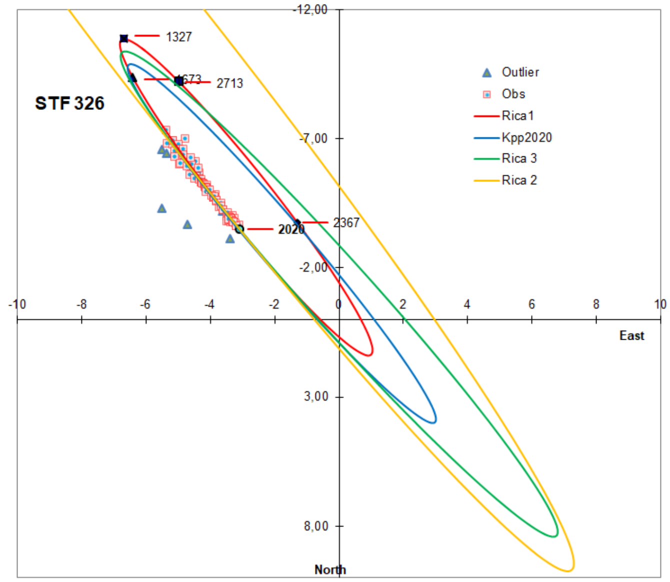
Figure 6. Plot 6.1: STF 326 orbit comparison with dynamical mass of 1.8 with close-up

These premature orbital element values are given with the caveat, that the existing observation history is far too short to calculate a reasonably long period orbit, especially as it does not cover any end of the assumed ellipse. However, that it is possible to calculate a closed orbit for this object with a realistic dynamical mass shows that there is a third option besides a parabolic trajectory and a rectilinear solution (visually plausible with the pattern of the given measurements). Moreover, that the relative velocity is at any point of time ident with the escape velocity (required for a parabolic "orbit") seems unlikely. To add complexity, this object is together with LDS 883 most likely a physical triple: The likelihood for potential gravitational relationship is 100% with a minimum spatial distance of 985 AU from A to C (the distance barycenter AB to C might be somewhat smaller) suggesting a minimum potential circular orbit period of ~22,000 years. The observation history for this object is short and there is no reasonable orbit calculation to expect in the near future. Proper motion values for B and C suggest proper motion but for A/C, however the differences are not large enough to assume just a random encounter. The gravitational effect of C is certainly different for A and B due to the different distances A to C and B to C so there seems no realistic chance for a stable parabolic trajectory.

Wiley and Rica Romero 2015 also concluded that STF 326 is most likely a long period binary and announced the calculation of a premature orbit so far not published. I contacted Francisco Rica Romero by email and he sent me a paper in preparation (Rica Romero 2021) with 3 alternative sets of orbital element values with two of them (Rica 1 and Rica 2) based on the Hauser and Marcy (1999) method using different dynamical parameters. This method has the advantage of working directly with the assumed system mass (Rica Romero 2021 settled on a value of 1.5 $M_{\odot}$) as input parameter. The third orbit (Rica 3) was calculated using the adaptive grid-search algorithm of Hartkopf et al. (1989), as modified by Mason et al. (1999) – this method works without a system mass input but yielded a very reasonable dynamical mass of 1.69 $M_{\odot}$.

Comparison of alternate orbits with dynamical mass near the StarHorse median system mass:

Element	Rica 1	Rica 2	Rica 3
P	1732.755	12797.786	4100.0
A	7.329	27.795	13.531
i	79.67	85.80	85.29
Node	33.63	33.34	215.89
T	2173.604	2314.267	2172.0
e	0.774	0.705	0.525
omega	347.62	300.88	96.47



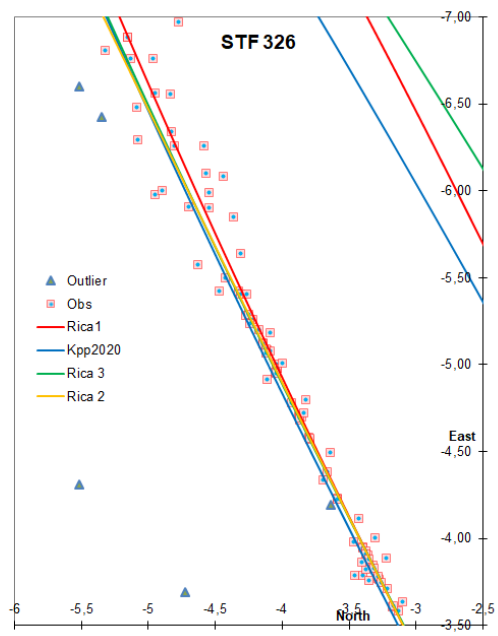


Figure 7. Plot 6.2: STF 326 Rica and Kpp orbit comparison with close up

The close up shows very little differences between the orbits for the time frame covered by observations which demonstrates once more clearly that a multitude of possible orbits exist for a given set of measurements especially when the observation history covers only a small part of the assumed orbit period.

2.22. WDS 05407-0157 (STF 774) – *Hop1967*

The current 6th Orbit Catalog grade 5 entry with a period of 1,508.6 years and a semi-major axis of 2.728 arcseconds is from 1967 although a large number of new observations was added to the WDS catalog since then up to 2017. The comparison with the measurements from the most recent years shows an increasing delta to the orbit ephemerides. Applying the Izmailov program on the given extended observation history results in a period of 4,889 years and a semi-major axis of 7.9 arcseconds offering a much better match with the recent measurements with the caveat that the spread in the set of 200 possible orbits is huge.

EDR3 and DR2 do not offer any information for this object due to the brightness of the primary. The Hipparcos parallax of 4.43 gives an unreasonable huge dynamical mass of >100 for the *Hop1967* orbit and the newly calculated orbit results in an even higher dynamical mass >240 – both values are obviously far off. The currently available data does not allow for reliable conclusions, except that both (the currently listed and the newly calculated) orbits seem obsolete – the former due to the bad match with the recent measurements and the unreasonable large dynamical mass and the latter due to the unreasonable large dynamical mass. The observation history is certainly far too short to allow for the calculation of a reasonable premature orbit.

STF 774 is actually a triple with A being a binary itself (primary O-type supergiant and a B-type secondary) listed in the 6th Orbit Catalog with a grade 2 orbit from 2013 with a period of 7.36 years, a semi-major axis of 0.0359 and a flipped omega value. The comparison with the two meanwhile additionally in the observation history listed valid measurements suggests a quadrant issue while the most recent entries in the observation history come without position angle and with only an upper limit for the angular separation. Apellániz and Barbá 2020 report another new measurement from 2019 so far not included in the observation history. Using the Izmailov program set on the given observation history including these two new measurements with flipped position angle plus the 2019 measurement suggests the following only slightly changed premature orbital elements for NOI 1 Aa,Ab with a remarkable small spread in the set of possible orbits:

Element	Value	-ΔP16/+ΔP84
P	7.3269	-0.006/+0.012
A	0.0359	-0.000/+0.000
i	138.375	-1.079/+0.535
Node	83.250	-1.282/+1.954
T	2003.261	-0.028/+0.023
e	0.342	-0.004/+0.007
omega	23.963	-1.904/+3.040

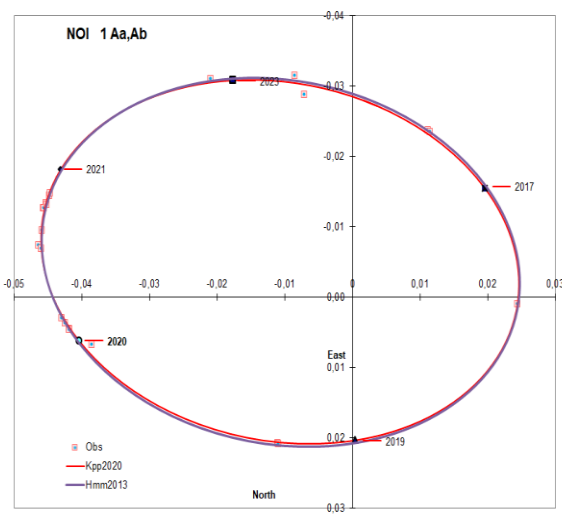
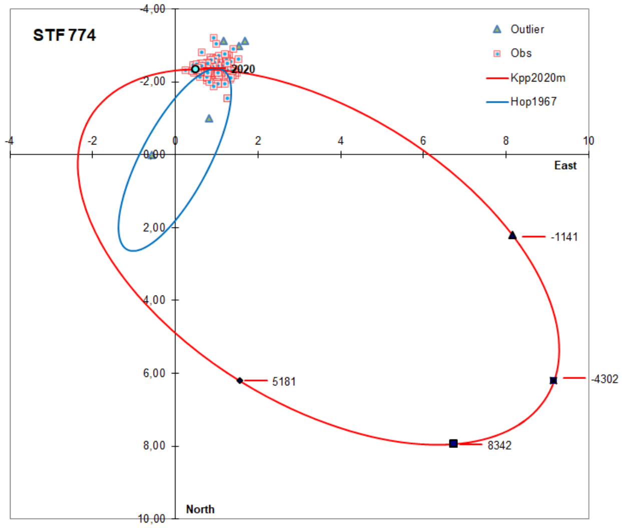


Figure 8. Plot 7.1: NOI 1 Aa,Ab orbit comparison

The dynamical mass for the Hmm2013 as well for the newly calculated orbit is ~10 using the Hipparcos parallax. According to Hummel et al. 2013 the parallax is ~3.4 resulting in a dynamical mass of ~21 for A.

Accepting these values for another look at STF 774 AB suggests based on magnitude delta an estimated system mass ~30 or even larger with some variations discussed in the notes of the 6th Orbit Catalog. There is only one entry in the list of 200 possible orbits with a dynamic mass of 31.57 coming close to this value far outside the 16th percentile with a huge spread showing once again the limits of calculating an orbit based with insufficient data:

Element	Value	-ΔP16/+ΔP84
P	15805	-14615/-12950
A	6.75	-4.0/+3.0
i	40.3	+22.8/+42.8
Node	53.8	-34.1/+88.0
T	2574.6	-949.3/-358.1
e	0.66	-0.02/+0.29
omega	176.3	+78.4/+108.3



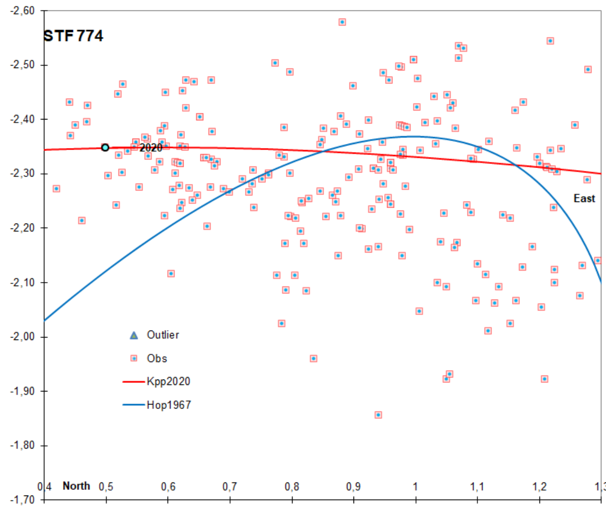


Figure 9. Plot 7.2: STF 774 orbit comparison with dynamical mass 31.57 (with close-up)

This newly calculated orbit is certainly far away from being “really necessary”, yet it offers a significant better match with recent observations and system mass estimations compared with the *Hop1967* orbit.

More precise parallax and mass data would be very helpful for assessing the plausibility of premature orbits.

2.23. WDS 17364+6820 (CHR 62 Aa,Ab) – *Lip1967*

CHR 62 Aa,Ab is listed in the 6th Orbit Catalog with a grade 9 orbit published 1967 with a period of 24.5 years and a semi-major axis of 0.102 arcseconds.

Not resolved in EDR3/DR2, parallax for combined object is 9.6112/9.3797 (Hipparcos 11.26), no duplicated_source marker, RUWE ~6 might be a hint for multiplicity. StarHorse median mass for the combined DR2 object is ~1.54 giving an estimated median system mass of 2.59 with equal magnitude for the secondary assumed. The WDS catalog lists so far only two observations with the last one from 1993 – so this is a neglected WDS object. The dynamical mass for the *Lip1967* orbit with the given DR2 parallax is 2.15 – not ident but reasonable close to the estimated median system mass.

WDS 17364+6820 is listed in the WDS catalog as visual quadruple. DR2 parallaxes for the components are very different suggesting an optical multiple. A faint fourth visual component (DR2 source_id 1637692474737869568) with a parallax value very similar to A was so far despite an obvious elongation in the 2MASS image overlooked. However, the likelihood for potential gravitational relationship seems according to the given parallax of EDR3 9.9365/DR2 9.7613 and StarHorse median mass of 0.45 very small, so this is most likely also an optical companion. However, the proper motion data values are very similar indicating a physical relationship. Curiously, Tokovinin 2018 lists this component erroneously as secondary in the AB pair. The “correct” B component is GJ 687 and is listed in Winters et al. 2019 as M dwarf but without multiplicity data suggesting that this object is a single star with an estimated mass of 0.35 based on absolute magnitude.

Tokovinin 2018 lists an additional orbit for Aa1,Aa2 with a period of only 2.5 days with a reference to Carquillat et al. 1976 (listed in the SB9 catalog as system number 980) with a proposed mass for the primary of 1.47 and 0.45 to 0.9 for the secondary. This suggests that CHR 62 might be a physical triple system but the mentioned SB9 orbit is listed with grade 3 (means medium quality) and the given masses match only moderately convincing with the other sources.

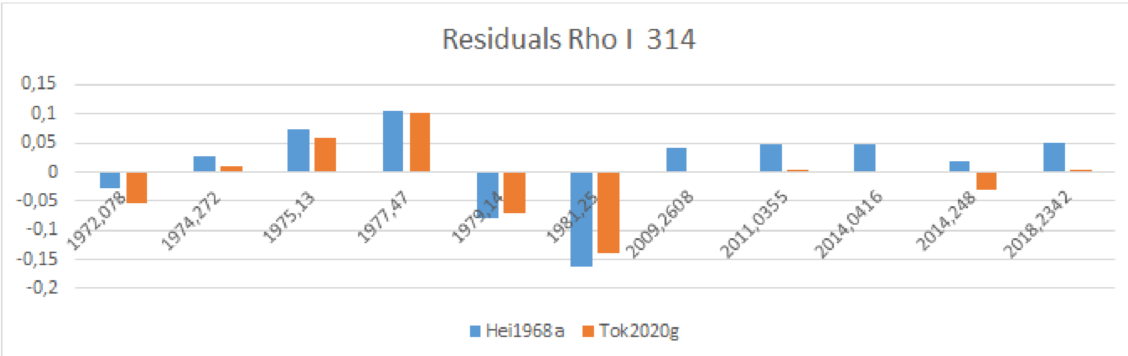
2.24. WDS 08394-3636 (I 314) – *Hei1968a* (*new orbit Tok2020g)*

The current 6th Orbit Catalog grade 4 entry with a period of 66.5 years and a semi-major axis of 0.527 arcseconds is from 1968 although a large number of new observations was added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history results in a similar period of 62.8 years but very different semi-major axis of 2.46 arcseconds giving with the DR2 parallax of 24.1552 (EDR3 24.4093, Hipparcos 26.42) a dynamical mass >200 which is obviously completely off.

StarHorse lists for the combined DR2 object a median mass of ~1.66 suggesting an estimated median system mass based on magnitude delta of 2.68. This value is supported by the absolute magnitude based system mass estimation of 2.42 and the *Hei1968a* orbit comes reasonable close with a dynamical mass of 2.35. The set of 200 possible orbits offers only a few entries with dynamic mass in this range, but the best match with a period of 60.19 years, a semi-major axis of 0.528 arcseconds and a dynamical mass of 2.90 shows a slightly poorer match with the most recent measurements than *Hei1968a*.

In all cases including *Hei1968a*, the bad match with the measurements from 1977, 1979 and 1981 is striking which means that a significant part of the observation history seems questionable. That the observation history time-span covers nearly twice the assumed orbit period should give little room for such ambiguities but there are significant gaps in the observation history from 1913 to 1930 and from 1981 to 2009 with each gap covering the phase with the very small angular separations. The Int4 Catalog offers too few measurements to attempt an orbit calculation based only on high precision observations. Future observations from 2020 to 2040 should solve this riddle because this time-frame covers one end of the assumed ellipse.

During the work on this paper, a new grade 3 orbit Tok2020g has been added to the 6th Orbit Catalog with a period of 65.79 years, a semi-major axis of 0.565 arcseconds and a dynamical mass of 2.98, which seems a bit too high when compared with the system mass estimations given above. This orbit shows compared to Hei1968a a far better match with the most recent measurements.



Plot 8: I 314 orbit comparison delta angular separation

2.25. WDS 00594+0047 (STF 80 A) – *Dom1969*

STF 80 A is listed in the 6th Orbit Catalog with two grade 9 orbits published 1969 with slightly different orbital element values: One with a period 80.92 years and a semi-major axis of 0.278 arcseconds and the second with a period 84.84 years and a 0.276 arcseconds semi-major axis. There exists no corresponding WDS object and also no SB9 catalog entry.

DR2 parallax for STF 80 A is 2.0455 (EDR3 2.0924, Hipparcos 2.25), no duplicated_source marker. RUWE ~1 suggests no multiplicity issues; StarHorse median mass for the combined DR2 object is ~1.19 suggesting an estimated median system mass of 2.0. The dynamical masses for the *Dom1969* orbits are both >300 $M_{\odot}$ – this value is obviously far off and renders both orbits obsolete.

WDS 00594+0047 is listed in the WDS catalog as visual triple. The DR2 parallax values suggest an only tiny likelihood for gravitational relationship between the components, which means STF 80/BU 1354 is most likely an optical multiple.

2.26. WDS 17578+0442 (GJ 699 A) – *Kam1969b/c*

Barnard’s star – the star with the so far known highest proper motion – mentioned as questionable binary star system in the solar neighborhood in Knapp 2020. Not listed in the WDS catalog but three different grade 9 orbits published 1969 are listed in the 6th Orbit Catalog for proposed two companions with an alternate suggestion for one of the components based on extended observations (Van de Kamp 1969). No entry in the SB9 catalog.

DR2 parallax is 547.4506 (Hipparcos 548.31, EDR3 546.9759), there is no duplicated_source marker given and RUWE ~1 suggests no multiplicity issues. StarHorse median mass for the combined DR2 object is ~0.18 suggesting an estimated median system mass of 0.30. The *Kam1969* orbits provide dynamical masses of 0.00000002 and 0.00000006 or 0.00000020 – these very obviously completely off values render these orbits as obsolete.

Yet there are still hints for a potential companion in the range of a very small star or a very large planet suggested by proper motion anomalies reported by Kervella et al. 2019.

2.27. WDS 02460-0457 (BU 83 A) – *Dom1972a*

BU 83 A is listed in the 6th Orbit Catalog with a grade 9 orbit published 1972 with a period of 36 years and a semi-major axis of 0.08 arcseconds "calculated from perturbations seen to rectilinear motion" (quote from the WDS 02460-0457 observation history). Confusingly the WDS catalog suggests with BU 83 Aa,Ab a seemingly corresponding object with so far 6 observations since 2009 but the measurements are too different from the corresponding orbit ephemerides to assume that these are identical objects – so BU 83 A has no corresponding WDS catalog object and is different from BU 83 Aa,Ab.

BU 83 AB is listed in the WDS catalog as visual binary resolved in EDR3 (with Theta 12.847 and Rho 0.97912). Not resolved in DR2 but listed with a duplicated_source marker. The 6th Orbit Catalog lists for BU 83 AB a grade 5 orbit published 2011 with a period of ~716 years and a semi-major axis of 2.38 arcseconds. DR2 parallax is 10.9151 (EDR3 10.6861 for the primary, no value for the secondary. Hipparcos 13.18) and StarHorse median system mass for the combined DR2 object is ~1.43 suggesting based on magnitude delta an estimated mass of 1.37 for BU 83 A.

The dynamical mass for the *Dom1972a* orbit is 0.30 – this value looks far too small, which makes the validity of this orbit questionable. The dynamical mass for the Hrt2011d BU 83 AB orbit is ~20.21, which is obviously completely off when compared with the StarHorse data.

Tokovinin 2018 lists alternate orbits for AB as well as for Aa,Ab with dynamical masses of 7.13 and 2.93 – the former value seems again off and the latter with about twice the StarHorse median mass seems a bit too much on the heavy side to be realistic.

Overall, the properties of this object remain a so-far unsolved riddle.

2.28. WDS 09144+5241 (STF1321) – *Chg1972*

The current 6th Orbit Catalog grade 4 entry with a period of 975 years and a semi-major axis of 17.725 arcseconds is from 1972 although a large number of new observations was added to the WDS catalog since then up to 2018 – since 25 years most of them heavily at odds with the *Chg1972* orbit.

Applying the Izmailov program on the extended observation history results in a period of ~934 years and a semi-major axis of 19.15 arcseconds with a large spread in the values of the orbital elements but offering a much better match with the most recent measurements some years back. This re-calculated orbit was already presented in Knapp 2020 but given without error range reflecting the spread in the set of 200 possible orbits. The size of the given spread reflects the fact that the currently available observation history covers only about a quarter of the assumed orbit period.

EDR3 parallaxes are 157.8879 and 157.8825 with a very small error range and RUWE ~1, DR2 lists data only for STF1321 B with a parallax of 157.8851 (Hipparcos 156.45) with StarHorse giving a median mass of ~0.6. As both components are nearly equal bright it might be save to estimate the median mass for A with ~0.61 – this is then a perfect match with the dynamical mass for the *Chg1972* orbit of 1.25 while the newly calculated orbit suggests 2.05. The set of 200 possible orbits offers several orbits with a dynamical mass in the range of ~1.25 with the best match for the following orbital element values:

Element	Value	-ΔP16/+ΔP84
P	1347.463	-772.669/+72.661
A	20.696	-1.402/+5.722
i	37.227	+2.625/+29.248
Node	33.785	-26.037/+3.642
T	2188.016	-649.252/+28.029
e	9.69E-06	+0.094/+0.789
omega	114.721	+3.692/+168.668

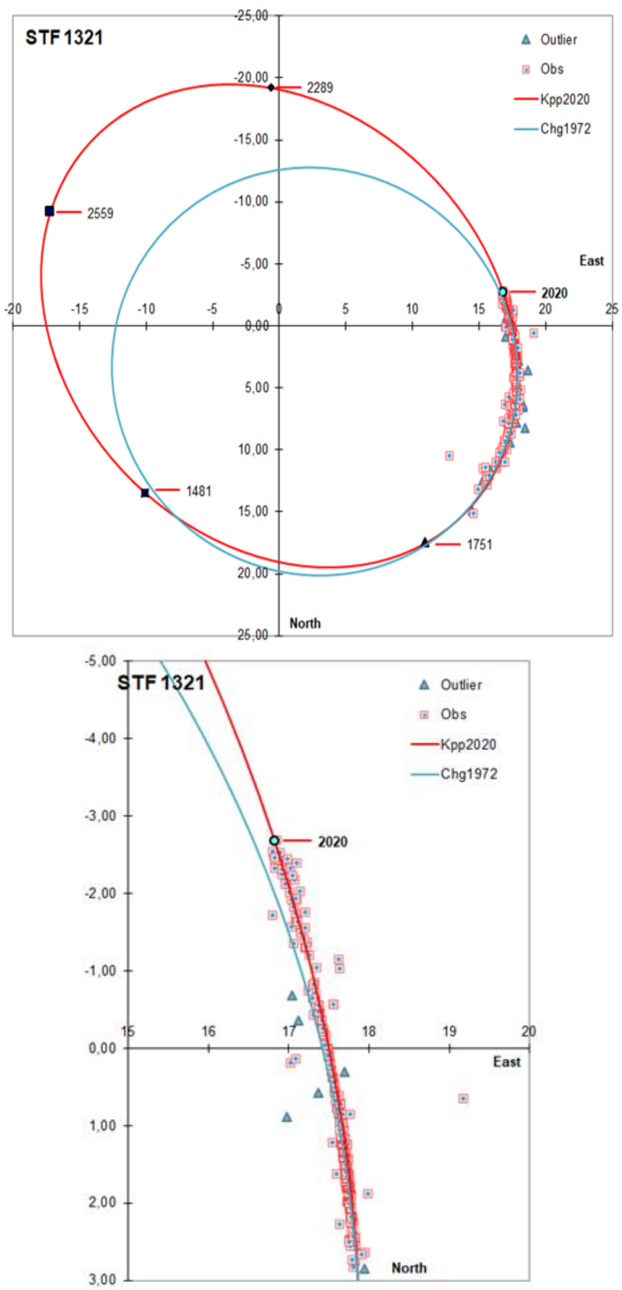
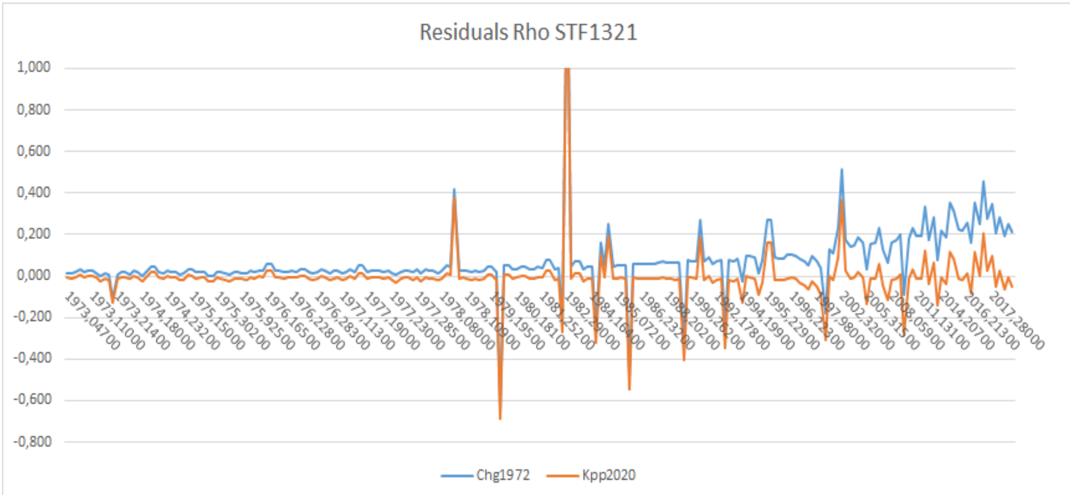


Figure 10. Plot 9.1: STF1321 orbit comparison with dynamical mass ~1.25 with close-up

This newly calculated orbit shows a significant better match with the recent measurements than the *Chg1972* orbit with a systematic bias in the residues Rho since 1973:



Plot 9.2: STF1321 orbit residuals Rho comparison

2.29. WDS 22329+4923 (HU 1320) – *Cou1972c*

The current 6th Orbit Catalog grade 3 entry with a period of 62.6 years and a semi-major axis of 0.21 arcseconds is from 1972 although a large number of new observations was added to the WDS catalog since then up to 2011. Applying the Izmailov program on the extended observation history results in a similar period of ~63.5 years with a semi-major axis of 0.215 arcseconds with a very small error range supporting the validity of this calculation:

Element	Value	-ΔP16/+ΔP84
P	63.471	-0.383/+0.502
A	0.215	-0.004/+0.004
i	30.351	-2.726/+3.506
Node	179.526	-177.356/-3.002
T	1956.085	-0.243/+0.254
e	0.594	-0.013/+0.013
omega	315.369	-187.399/+7.548

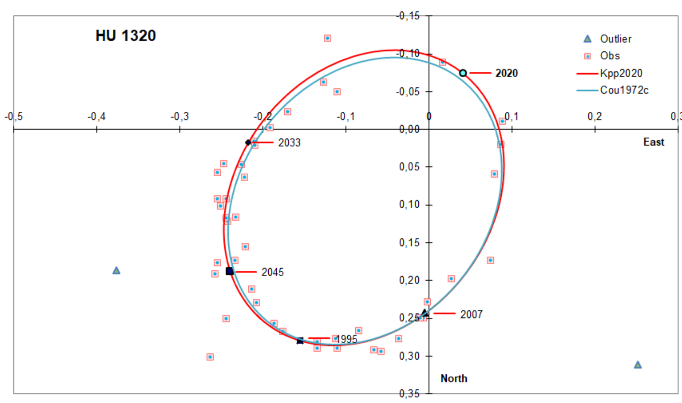


Figure 11. Plot 10: HU 1320 orbit comparison

EDR3 parallax for a combined object is 9.1415 with duplicated_source marker, a large error range and RUWE >30. DR2 parallax is 8.4720 with a large error range (Hipparcos 10.60) and StarHorse median mass for the combined DR2 object is ~1.67 – mass estimation according to Appendix B gives 1.39 for the primary and 1.42 for the slightly brighter secondary. *Cou1972c* as well as the newly calculated orbit give similar dynamical mass values of 3.12 and 3.26 – not this far away from the estimated median system mass of 2.81 but still suggesting a look at the set of 200 possible orbits for a better match. However, only a few entries in this data set come with the EDR3 parallax value close to a dynamical mass of ~2.8 but this is most likely a side effect of the given parallax error because a value of ~9.5 (well within the given error range) would provide a perfect match.

However, the newly calculated orbit does not offer significant better results in terms of residuals Theta and Rho compared to *Cou1972c* so it might not be considered as "really necessary". This result is just proof that the Izmailov programs do a good job when applied to an observation history of good quality.

2.30. WDS 05364+2200 (STF 742) – *Hop1973b*

The current 6th Orbit Catalog grade 5 entry with a period of 2,959 years and a semi-major axis of 5.571 arcseconds is from 1973 although a large number of new observations was added to the WDS catalog since then up to 2019. Applying the Izmailov program on the extended observation history results in a quite different period of more than 22,000 years if with an incredible spread in the values of the orbital elements indicating very questionable orbit quality. The newly calculated orbit shows a somewhat better match of the recent measurements but it seems not very reasonable to try to calculate orbital elements with an observation history covering only a tiny fraction of the assumed orbit period regardless if ~3,000 or 22,000 years. Therefore, neither the current 6th Orbit Catalog entry nor the new calculation can be considered a serious proposition.

EDR3 parallaxes are 12.8846 with a large error range and RUWE ~4.5 and 13.1889 with a small error range and RUWE ~1. DR2 suggests with parallax values of 12.4603 and 13.1274 (Hipparcos 14.83) a minimum spatial distance >200,000 AU giving combined with StarHorse median masses of 1.56 and 1.24 a minimum circular orbit period of >80 million years – this would mean zero likelihood for potential gravitational relationship.

The EDR3 data allow for a somewhat "better" assessment regarding potential gravitational relationship with a minimum distance of ~390 AU and a minimum circular orbit period >3,900 years and a likelihood for gravitational relationship of ~16.6%. Proper motion is similar but not similar enough to call it common proper motion. Altogether a weak evidence for STF 742 being a double star (still?) bound by gravitation.

Dynamical mass for the *Hop1973b* orbit is 9 when using the average EDR3 parallax, which is far away from the StarHorse median system mass of ~2.8 making this orbit obsolete. The newly calculated orbit fares worse with a dynamical mass >78 and no entry in the set of 200 possible orbits comes close to a dynamical mass of ~2.8.

Overall, this looks like an optical pair and the observation pattern potentially suggests a rectilinear solution.

STF 742 A is listed in the SB9 catalog as spectroscopic binary with an orbit of so far undetermined grade published 2001 with a period of ~40.6 days. EDR3 lists STF 742 A without duplicated_source marker but RUWE ~4.5 suggests potential multiplicity issues.

2.31. WDS 12108+3953 (STF1606 A) – *vdW1974*

The 6th Orbit Catalog lists a grade 9 orbit for STF1606 A with a period of 75 years and a semi-major axis of 0.078 arcseconds published 1974 with the note "Preliminary orbit by van der Wiele (1974) calculated to fit perturbations seen to long-period orbit". There is no corresponding object in the WDS catalog. No EDR3/DR2 parallax, Hipparcos parallax is 8.32 with a large error range. Tokovinin 2018 suggests component masses based on absolute magnitudes of 1.66 and 0.96

although the given magnitudes for STF1606 A are not consistent with those given for STF1606 AB, own estimations (see below) come even up to 3.20 system mass. The dynamical mass for the *vdW1974* orbit with the Hipparcos parallax is 0.15 – this looks far too small for such a bright primary, which renders this orbit obsolete regardless of any magnitude values precision issues.

STF1606 AB is listed in the WDS catalog as visual binary and in the 6th Orbit Catalog with a grade 4 orbit *Msn1999* published 1999 with a period of 1,431 years and a semi-major axis of 2.002 arcseconds. Not resolved in DR2, combined object without parallax data but with duplicated_source marker. Tokovinin 2018 suggests a system mass of 4.06, own absolute magnitude based estimation is in a first step with 3.61 a bit smaller. However, the value for component A has to be taken as value for a combined object, which suggests a mass 3.20 for A and a system mass of in total 4.90 for AB.

Dynamical mass for the Msn1999 orbit with the Hipparcos parallax value given above is 6.8 – the delta to the system mass estimations might be caused by an inaccurate Hipparcos parallax. The STF1606 observation history includes meanwhile about 40 new measurements since 1999 but orbit re-calculation with the Izmailov program suggests even a somewhat higher system mass between 7.09 and 7.61 as 16th and 84th percentile in the set of 200 possible orbits. These difficulties might be attributed to the complexity of a three-body problem but more precise parallax and mass data would be of interest anyway.

2.32. WDS 04349+3908 (HU 1082) – *Cou1975c*

The current 6th Orbit Catalog grade 4 entry with a period of 52.19 years and a semi-major axis of 0.355 arcseconds is from 1975 although several new observations were added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history results in a very similar period of ~52.59 years and a semi-major axis of 0.317 arcseconds with a very small error range supporting the validity of this calculation:

Element	Value	-ΔP16/+ΔP84
P	52.587	-0.596/+0.706
A	0.317	-0.004/+0.073
i	18.708	+0.628/+28.029
Node	63.585	-34.814/+49.409
T	1968.606	-0.663/+0.467
e	0.782	-0.016/+0.096
omega	251.505	-47.316/+30.513

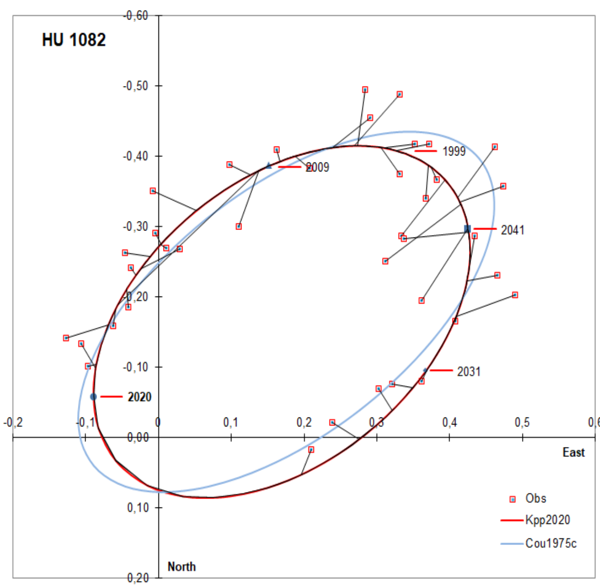


Figure 12. Plot 11: HU 1082 orbit comparison

The newly calculated orbit is in terms of residuals Rho root mean square slightly better than the *Cou1975c* orbit.

There is no EDR3 parallax and no DR2 data available for HU 1082, Hipparcos parallax is 26.82. Estimated system mass based on absolute magnitudes is ~1.2.

The newly calculated orbit gives with the Hipparcos parallax a dynamical mass of 0.60 and the *Cou1975c* orbit results in a dynamical mass of 0.85. Both values seem in absence of reliable parallax and mass data at least reasonable and the spread in the set of 200 possible orbits covers the delta to the estimated system mass very well, but more precise parallax data would be very valuable.

2.33. WDS 04563+5206 (HU 555) – *Hei1976*

The current 6th Orbit Catalog grade 4 entry with a period of 72.1 years and a semi-major axis of 0.21 arcseconds is from 1976 although several new observations were added to the WDS catalog since then up to 2007 – so this object seems to some degree lately neglected. Applying the Izmailov program on the extended observation history results in a very similar period of ~72.8 and semi-major axis of 0.209 arcseconds with a very small error range supporting the validity of this calculation:

Element	Value	-ΔP16/+ΔP84
P	72.817	-0.777/+0.696
A	0.209	-0.006/+0.006
i	52.048	-2.268/+2.692
Node	120.809	-3.164/+3.005
T	1967.425	-0.567/+0.591
e	0.425	-0.018/+0.021
omega	107.912	-2.529/+2.520

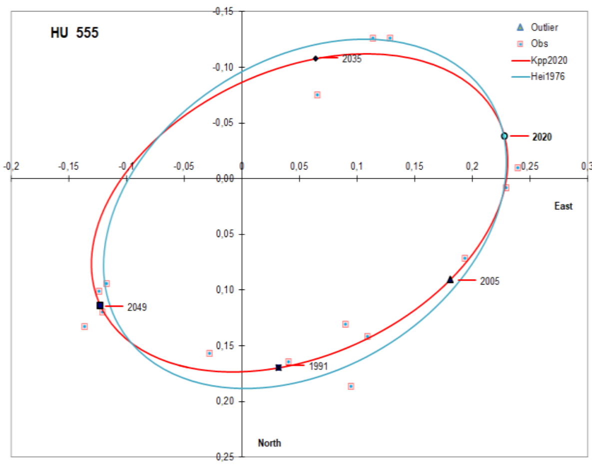


Figure 13. Plot 12: HU 555 orbit comparison

The newly calculated orbit is in terms of residuals Rho RMS slightly better than the *Hei1976* orbit.

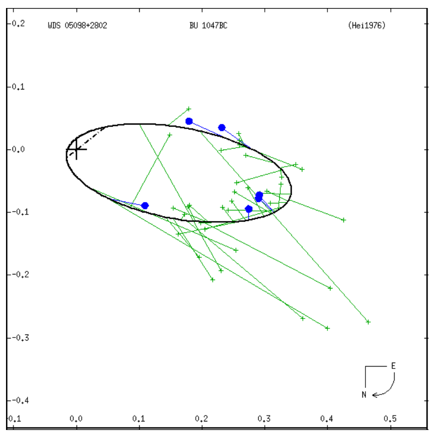
There is no EDR3/DR2 parallax data available for HU 555, also no duplicated_source marker, while Hipparcos parallax is 8.04 with a huge error range. EDR3/DR2 parallax values for the nearby C component suggest (assuming a physical triple system) a slightly larger parallax ~8.9. Estimated masses for the components based on absolute magnitudes with the Hipparcos parallax are 1.41 and 1.31. The Hipparcos parallax gives for the newly calculated orbit a dynamical mass of 3.31 and the *Hei1976* orbit a dynamical mass of 3.43 – both values seem reasonable close to the calculated dynamical masses with the gap easily closed with a slightly larger parallax. More precise parallax and mass data would be valuable for orbit assessment.

2.34. WDS 05098+2802 (BU 1047 BC) – *Hei1976*

WDS 05098+2802 is listed in the WDS catalog as visual pair STF 645 A,BC with the subsystems L 54 Aa,Ab and BU 1047 BC making this object a quadruple.

L 54 Aa,Ab is a neglected WDS object observed only once but listed in the SB9 catalog as system number 1980 with a grade 1 (means poor quality) spectroscopic orbit with a period of 32.52 days. EDR3/DR2 parallax for A is 15.3428/14.9992 with RUWE ~1 and no duplicated_source marker (Hipparcos parallax is 19.01) with StarHorse median system mass for the combined DR2 object of ~1.8 suggesting an estimated system mass of 3.03 (equal brightness of components assumed).

BU 1047 BC is listed in the 6th Orbit Catalog with a grade 4 entry with a period of 32.1 years and a semi-major axis of 0.217 arcseconds published 1976 although several new observations were added to the WDS catalog since then up to 2007 – seems to be a neglected WDS object since. Applying the Izmailov program on the extended observation history results in a first step in extremely different orbital element values obviously completely off. A closer look at the observation history shows a very bad match of several of the given measurements with the currently given orbit (see the 6th Orbit Catalog plot below – the blue dots represent measurements from speckle observations):



Plot 13: 6th Orbit Catalog plot

Heinz 1976 notes “A few observations made in 1903-1908 (Lewis, VB, Farman) are probably spurious” and the very good match with most of the observations between 1976 and 2007 (with the exception of the obvious outlier from 1991.25) confirms his *Hei1976* orbit very well.

After manually eliminating all poor matches as outliers a new run of the Izmailov program more or less confirmed the period of the *Hei1976* with else different orbital element values offering a clearly better match in terms of residuals for the new measurements after 1976.

No EDR3 parallax data, no duplicated_source marker. Also no DR2 and no StarHorse data available for BU 1047 BC, but Tokovinin 2018 suggests component masses of 1.07 and 0.98 estimated based on absolute magnitudes. Hipparcos parallax is 13.53 with a huge error range and if we assume that this is a physical quadruple then a parallax ~15 looks plausible. The Hipparcos parallax suggests for the *Hei1976* orbit a dynamical mass of 4, which seems at least possible, while the newly calculated orbit gives a completely implausible dynamical mass of >60. The set of 200 possible orbits contains several entries in the dynamical mass range of <2 but with a suspicious inclination close to 90° and a less than perfect match with the observation history. The set of 200 possible orbits offers a remarkable cluster of entries with very similar orbital element values and dynamical masses between 2.77 and 4.51. Selecting the entry with the smallest delta

Rho RMS value gives again a dynamical mass of 4 with a slightly better match with the most recent measurements (and especially those from the Int4 Catalog) than *Hei1976*:

Element	Value	-ΔP16/+ΔP84
P	34.173	-1.201/+1.646
A	0.226	+0.078/+0.422
i	137.069	-36.775/-19.613
Node	156.791	-133.498/-3.669
T	1968.017	-2.041/+1.966
e	0.937	+0.015/+0.053
omega	260.637	-162.336/+4.987

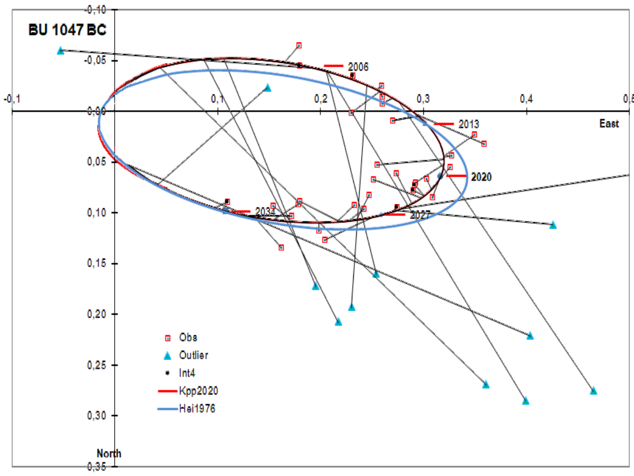


Figure 14. Plot 14: BU 1047 BC orbit comparison

However, this result comes with the caveat, that tampering the input data with the intention to get a desired result contradicts scientific best practice – this is certainly not a "really necessary" orbit although it seems clearly better than the *Hei1976* orbit.

On the other side it seems obvious that the given observation history does not allow for a useful calculation of orbital element values without eliminating suspect measures.

The secondary should currently be according to the listed orbits near apoapsis - new precise measurements should be therefore possible and would be very valuable for orbit re-calculation and assessment.

2.35. WDS 10551+4714 (G 146-72) – *Beh1976/USN1988*

Listed in the 6th Orbit Catalog with a grade 9 orbit published 1976 with a period of 6.7 years and a semi-major axis of 0.03 arcseconds. No WDS catalog object. Not resolved in EDR3/DR2, combined object without duplicated_source marker but RUWE ~17.6/2.9 suggests multiplicity issues. EDR2/DR2 parallax is 33.6003/31.0748 (no Hipparcos parallax) with a large error range and StarHorse median mass for the combined DR2 object is ~0.50 allowing for an estimation of the median system mass of 0.84 assuming equal bright components. Dynamical mass for the *Beh1976* orbit is 0.02 – this value is far off from the estimated median system mass, which renders this orbit obsolete.

There is a second entry for this object in the 6th Orbit Catalog published 1988 with a period of 6.8 years and a semi-major axis of 0.02 arcseconds. Dynamical mass with the DR2 parallax for the *USN1988* orbit is 0.006 – this value is again far off from the median system mass estimate rendering this orbit obsolete too.

2.36. WDS 11056+5448 (A 1591) – *Hei1976*

The current 6th Orbit Catalog grade 4 entry with a period of 105 years and a semi-major axis of 0.205 arcseconds is from 1976 although a few new observations were added to the WDS catalog since then up to 2007 – it looks like a recently neglected WDS object. Applying the Izmailov program on the extended observation history results in a first attempt in about the half orbit period compared with *Hei1976* , which seems odd. The comparison with the 6th Orbit Catalog plot made clear that eight measurements have a quadrant issue without being marked as such in the WDS observation history. After changing the observation history accordingly, the result matches suddenly well with the currently listed orbit from 1976:

Element	Value	-ΔP16/+ΔP84
P	103.381	-1.989/+2.326
A	0.200	-0.008/+0.007
i	145.081	-6.209/+6.174
Node	64.746	-12.466/+11.715
T	1994.662	-1.413/+1.298
e	0.467	-0.021/+0.035
omega	188.563	-15.620/+15.550

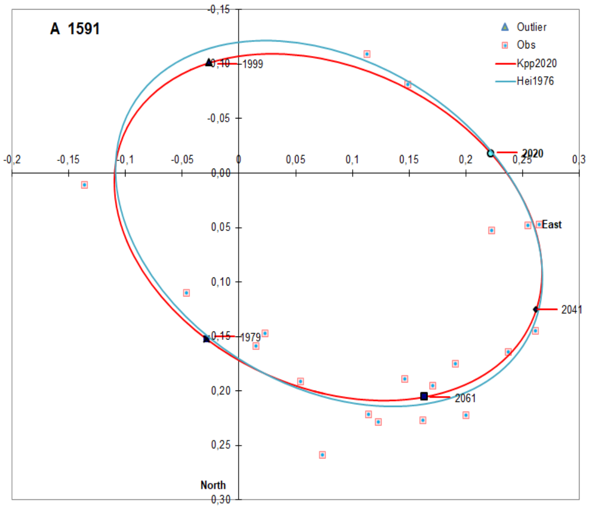


Figure 15. Plot 15: A 1591 orbit comparison

While there is some degree tampering with the observation history to get confirming results, the quadrant issues are in cases with such small angular separation with components of equal brightness simply to be expected.

There is no EDR3/DR2 parallax available for A 1591, Hipparcos parallax is 7.36 suggesting for the newly calculated orbit a dynamical mass of 1.88 and for the *Hei1976* orbit a dynamical mass of 1.96 – both values seem reasonable but lack confirmation. Estimated system mass from absolute magnitudes is 2.67 – not a perfect match but reasonably close.

Delta Rho RMS for both orbits is very similar so the newly calculated orbit does not seem “really necessary” but the delta in the position angle for the three new measurements since 1976 is better with the new orbit.

New precise measurements would be very valuable for orbit re-calculation and assessment.

2.37. WDS 15273+1738 (A 2074) – *Baz1976*

The current 6th Orbit Catalog grade 4 entry with a period of 59 years and a semi-major axis of 0.206 arcseconds is from 1976 although several new observations were added to the WDS catalog since then up to 2011. Applying the Izmailov program on the extended observation history results in orbital element values similar to *Baz1976*.

The small spread in the set of 200 possible orbits suggests a reliable calculation but the visual impression is not very convincing – the match between measurements and ephemerides is less than perfect and the observation history seems overall of low quality (see also the 6th Orbit Catalog plot http://www.astro.gsu.edu/wds/orb6/PNG/wds15273+1738a.png). Although the time span of the observation history covers nearly two full orbit periods, about 40% of the assumed ellipse are not covered by measurements most likely due to resolution issues with angular separations down to smaller than 0.05".

There is no EDR3/DR2 parallax available for A 2074, Hipparcos parallax is 11.02 suggesting with the newly calculated orbit a dynamical mass of 3.66 and the *Baz1976* orbit results in a dynamical mass of 1.88 – both values seem reasonable but lack confirmation by other reliable mass data sources. Estimated system mass from absolute magnitudes is 2.34, which supports the Baz1976 orbit. The set of 200 possible orbits covers the range of dynamical masses around 2.3 very well but the visual impression remains unconvincing.

The Int4 Catalog offers about 20 measurements – a reasonable large base for another attempt – so I decided to give it another try with the following result:

Element	Value	-ΔP16/+ΔP84
P	62.083	+13.173/+287.172
A	0.225	+0.025/+0.437
i	68.400	-16.951/+12.681
Node	100.807	-18.957/+1.903
T	1978.117	-0.233/+31.932
e	0.714	-0.322/+0.168
omega	322.242	-266.854/-4.127

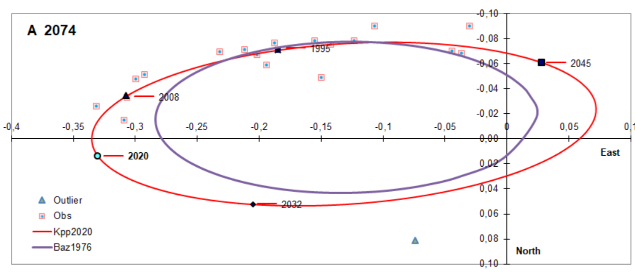
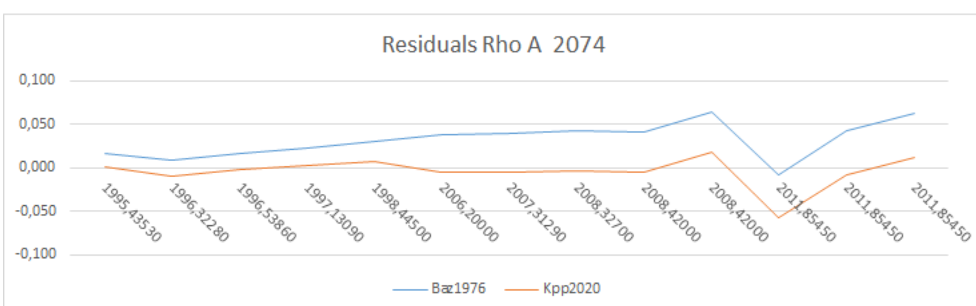


Figure 16. Plot 16: A 2074 orbit comparison with Int4 Catalog measurements

The small number of Int4 observations caused the large spread in the orbital element values. However, this orbit offers a very good match with the full observation history (very similar to *Baz1976* up to 1994, but much better afterwards) and suggests a quadrant issue for the 1977.43 measurement and the 1929.42, 1931.43, 1961.43 and 1990.4404 as well as one of the 2011.8545 measurements as outliers.



Plot 17: Residuals Rho A 2074 orbit after 1994

The dynamical mass of the new orbit is, at 2.23, also very close to the estimated system mass. However, a new precise measurement would be very valuable for orbit re-calculation and assessment.

2.38. WDS 16458-0046 (A 1141) – *Baz1976*

The current 6th Orbit Catalog grade 3 entry with a period of 62 years and a semi-major axis of 0.23 arcseconds is from 1976 although several new observations were added to the WDS catalog since then up to 2018. Slightly confusing is the fact that the listed orbit reverses primary and secondary. A direct comparison of position angles for the given observation history with the corresponding *Baz1976* ephemerides shows additionally a large number of quadrant issues. Applying the Izmailov program on the extended observation history as it is results in a suspect 90° inclination solution indicating troubles with the observation history. After following *Baz1976* for all quadrant issues, the application of the Izmailov program resulted in comparison with *Baz1976* in similar but due to the new measurements with slightly changed orbital element values with a period of 62.07 years and a semi-major axis of 0.22:

Element	Value	-ΔP16/+ΔP84
P	62.069	-0.507/+0.576
A	0.218	-0.005/+0.003
i	101.675	-1.846/+1.376
Node	13.966	-1.037/+1.364
T	1968.853	-14.855/+19.435
e	0.012	-0.012/+0.027
omega	159.606	-84.161/+113.097

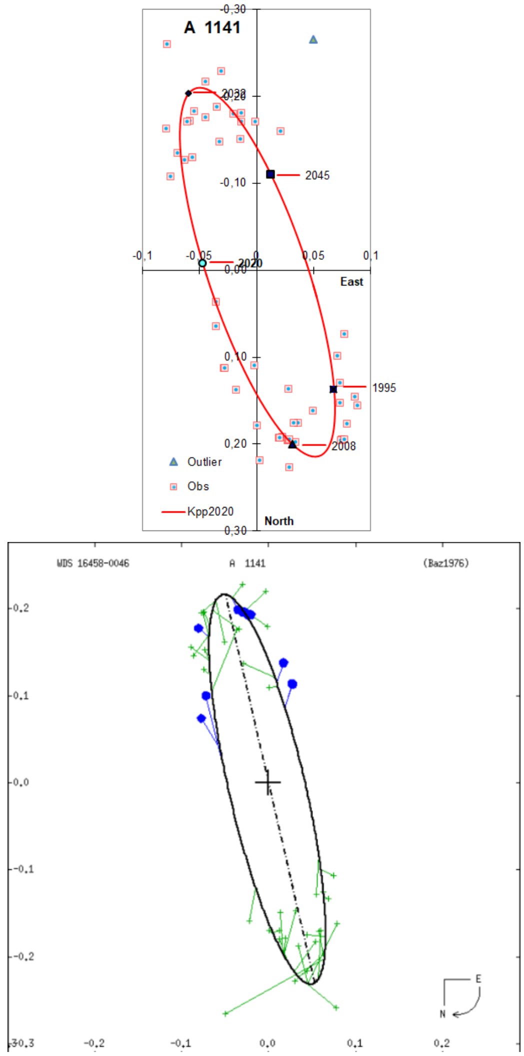


Figure 17. Plot 18: A 1141 orbit – comparison with flipped 6th Orbit Catalog Baz1976 plot

The newly calculated orbit is in terms of residuals Rho RMS slightly better than the Baz1976 orbit but suggests a different quadrant approach for a few measures.

The EDR3/DR2 parallax values for a combined object are with 11.6544/8.4731 (Hipparcos 9.35) different, both with a large error range and StarHorse median mass for the combined DR2 object is ~1.33 suggesting an estimated median system mass of 2.24 (1.13 for the primary and 1.11 for the secondary). Malkov et al. 2012 list a photometric system mass estimation of 2.51 and a spectroscopic system mass estimation of 1.10. The system mass for the newly calculated orbit with the DR2 parallax is 4.42 and for the Baz1976 orbit 5.19 – both results are far off from the estimated median system mass values. The set of 200 possible orbits does not offer an entry below a system mass of 3.65 so this looks bad for the validity of both listed orbits without the possibility to offer a proposition for an orbit with a better matching dynamical mass.

The number of observations in the Int4 Catalog is certainly far too small to attempt an alternative calculation based on these measurements.

To add to the confusion regarding quadrant issues Heintz 1982 published an orbit for A 1141 with a very different quadrant approach with a period of 30.8 years and a semi-major axis of 0.113 arcseconds – but this orbit is for unknown reasons not listed in the 6th Orbit Catalog nor mentioned in the notes of the WDS observation history. Quite interestingly, the dynamical mass of this *Hei1982c* orbit comes with 2.52 based on the DR2 parallax very close to the photometric system mass estimation of Malkov et al. 2012. This issue was brought to the attention of Brian Mason/USNO and should meanwhile be corrected.

The orbit re-calculation based on the Heintz 1982 quadrant approach failed miserably – the set of 200 possible orbits did not include a single entry with a period less than 200 years and most entries list an inclination near 90° raising caveats regarding the *Hei1982c* orbit and the observation history as well.

The EDR3 parallax changes the picture completely: The system mass for the newly calculated orbit with the EDR3 parallax is 1.71 and for the Baz1976 orbit 2.01 – both values are suddenly very realistic given the fact that the StarHorse median mass value is based on DR2 data. The Hei1982 orbit is consequently with a system mass of 0.97 now off.

2.39. WDS 20198+4522 (STT 406) – *Hei1976*

The current 6th Orbit Catalog grade 3 entry with a period of 113.5 years and a semi-major axis of 0.336 arcseconds is from 1976 although several new observations were added to the WDS catalog since then up to 2011. Applying the Izmailov program on the extended observation history results in slightly different but similar orbital elements due to the additional measurements:

Element	Value	-ΔP16/+ΔP84
P	109.271	-1.388/+1.546
A	0.306	-0.006/+0.020
i	137.399	-7.564/+3.336
Node	133.697	-13.467/+13.966
T	1919.368	-1.516/+1.399
e	0.866	-0.028/+0.033
omega	199.123	-18.532/+17.932

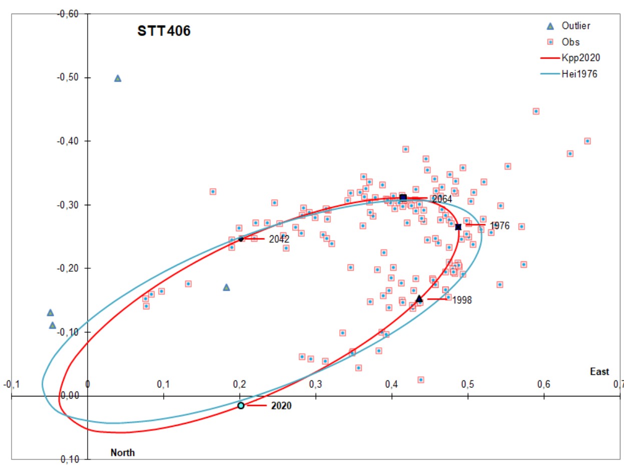


Figure 18. Plot 19: STT 406 orbit comparison

The DR2 parallax is 26.7756 with a huge error range of 1.1855 and Hipparcos parallax is 10.81 with an error range of 0.54 – this is a remarkable difference and RUWE >50 indicates extremely questionable DR2 data quality. No EDR3 parallax given, no duplicated_source marker. StarHorse median mass for the combined DR2 object is ~1.11 suggesting an estimated median system mass of 1.79 (with 1.05 for the primary and 0.74 for the secondary) while Malkov et al. 2012 list a photometric system mass of 2.47 and a spectroscopic system mass of 1.35. The dynamical mass for the newly calculated orbit is 0.13 and for the *Hei1976* orbit 0.15 if calculated with the DR2 parallax – both results are far off from the estimated median mass value suggesting poor quality for the *Hei1976* orbit despite a grade 3 rating as well as for the newly calculated orbit. The set of 200 possible orbits does not include an entry with a dynamical mass close to the estimated median system mass so there is no opportunity to offer a matching orbit proposition.

The situation is completely different with the Hipparcos parallax – dynamical mass for *Hei1976* is 2.35 and for the newly calculated orbit 1.92, both values are close to the estimated median system mass. Just another hint that the DR2 parallax might be off.

A look at the residuals shows that the *Hei1976* orbit is systematically off since 1985 while the newly calculated orbit offers a much better match with the measurements in the recent decades. The newly calculated orbit also suggests that the quadrant issue indicated in the WDS observation history for the 1917.62 measure is questionable.

2.40. WDS 04312+5858 (STI2051 A) – *Str1977*

STI2051 A is listed in the 6th Orbit Catalog as close binary with a grade 9 orbit published 1977 with a period of 23 years and a semi-major axis of 0.07 arcseconds but there is no corresponding Aa,Ab object listed in the WDS catalog. The dynamical mass for the *Str1977* orbit with the DR2 parallax of 180.4215 (EDR3 181.2438, Hipparcos 179.27) for A is 0.0001 – far off from the StarHorse median mass for the combined DR2 object of ~0.35 (suggesting an estimated median system mass of 0.59, equal bright pair assumed), which makes this orbit clearly obsolete. DR2 lists STI2051A A with a duplicated_source marker indicating multiplicity, no duplicated_source marker in EDR3. RUWE ~1.2 suggests good EDR3/DR2 data quality.

STI2051 is listed in the WDS catalog as visual triple with a rectilinear solution for AB suggesting an optical pair but allowing for a long period orbit. EDR3 parallaxes for A/B/C of 181.2438/181.2730/1.1550 (DR2 180.4215/181.2815/1.1658) suggest very well gravitational relationship between A and B but make clear, that C is optical. Estimated median system mass for A is as mentioned above 0.59, but there is no StarHorse data available for B. B is reported as white dwarf with different masses in different papers, most recent with 0.675 by Sahu et al. 2017. Together these data values suggest that STI2051 AB is most likely a physical pair. Knapp 2020 reported for STI2051 AB a premature orbit with a period of ~1,780 years with a semi-major axis of ~32.25 arcseconds if as to expect with a huge spread in the set of 200 possible orbits. The dynamical mass for this orbit with the average DR2 parallax is 1.75, which is not close but at least near to the likely system mass of ~1.27.

2.41. WDS 23487+6453 (STT 507) – *Zul1977b*

The current 6th Orbit Catalog grade 4 entry with a period of ~566 years and a semi-major axis of 0.74 arcseconds was published 1977 with several new observations added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history results in quite different orbital elements due to the additional measurements with the caveat of some noticeable spread:

Element	Value	-ΔP16/+ΔP84
P	368.283	-90.359/+226.998
A	0.560	+0.029/+0.297
i	27.016	+3.984/+27.947
Node	26.139	-14.757/+70.248
T	1802.337	-0.522/+257.951
e	0.453	-0.181/+0.282
omega	100.631	-18.406/+12.952

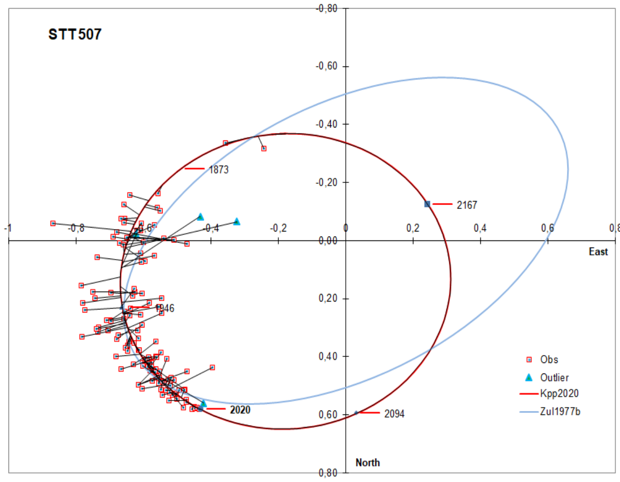


Figure 19. Plot 20: STT 507 orbit comparison

The residuals Theta and Rho RMS values are for the newly calculated orbit overall slightly better than for the *Zul1977b* orbit and the match with the measures of the last decade is significantly better.

EDR3 parallaxes are 5.3787 and 6.0121 with a large error range, RUWE <2 indicates moderate data quality. Hipparcos parallax for the combined object is 5.93. The DR2 parallaxes are 2.2565 and 9.8350 and StarHorse median mass for A is ~7.24, but RUWE ~18 indicates bad DR2 data quality. StarHorse offers no data for B, mass should be much smaller due to the much larger parallax value. Absolute magnitude based system mass estimation is ~5 using the EDR3 parallaxes – this value seems more plausible than the StarHorse median mass for A based on questionable DR2 data. The minimum spatial distance between the components based on EDR3 parallaxes is ~5,000 AU and the likelihood for potential gravitational relationship is despite the large masses close to zero.

Zul1977b gives with the average EDR3 parallax of 5.6954 a dynamical mass of 6.9 and the newly calculated orbit of 7.08 – not identical with the estimated system mass but close enough to be considered plausible.

More reliable parallax and mass data as well as new observations would be very helpful for calculating and assessing STT 507 orbits.

2.42. WDS 03096+0512 (A 2030) – *Sta1978b*

The current 6th Orbit Catalog grade 3 entry with a period of ~54.5 years and a semi-major axis of 0.261 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history results in slightly different but similar orbital elements due to the additional measurements:

Element	Value	-ΔP16/+ΔP84
P	53.621	-0.409/+0.388
A	0.255	-0.007/+0.004
i	150.661	-3.118/+4.077
Node	63.287	-8.530/+10.484
T	1942.857	-0.318/+0.386
e	0.442	-0.016/+0.012
omega	283.908	-7.902/+9.711

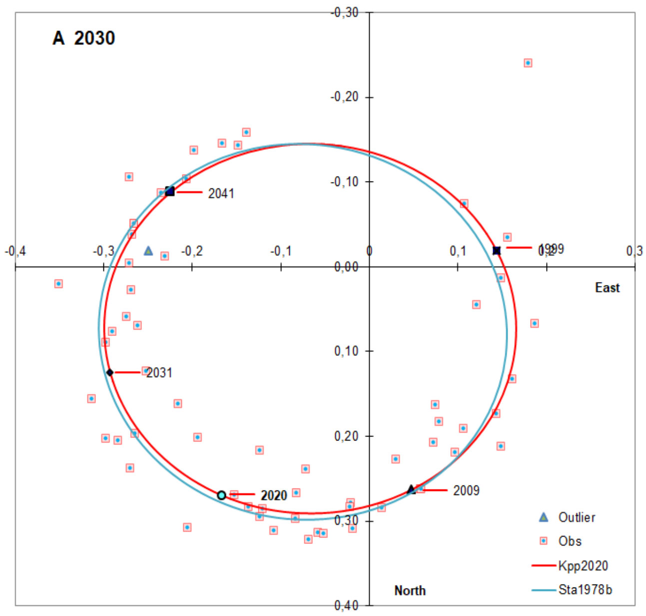
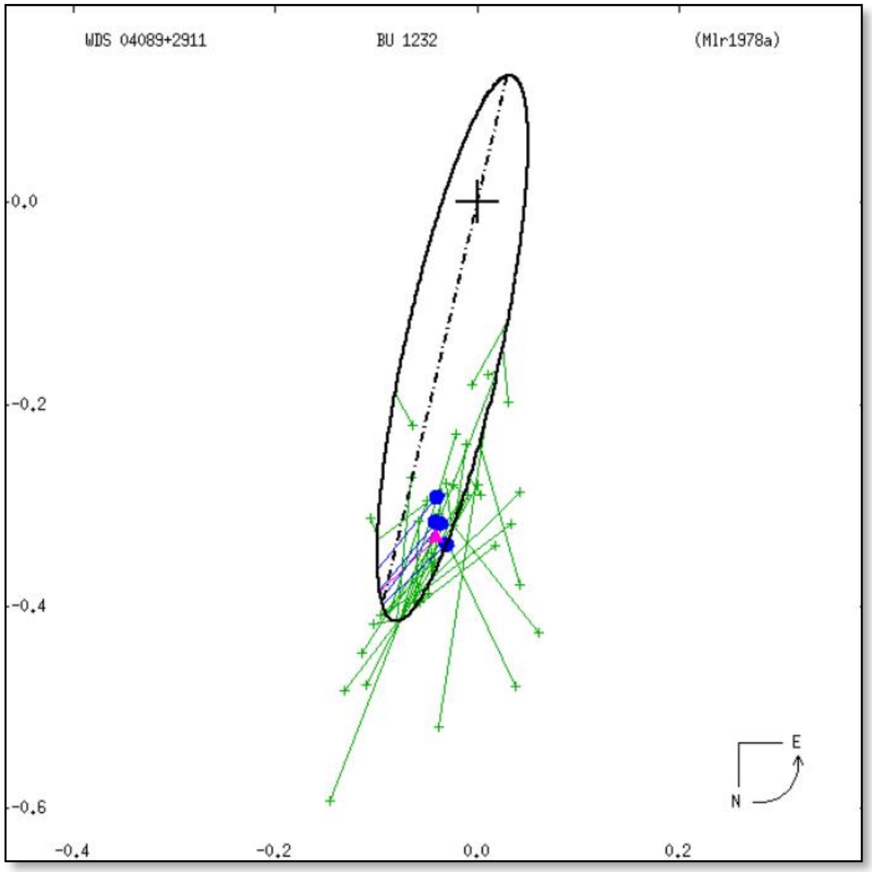


Figure 20. Plot 21: A 2030 orbit comparison

EDR3 lists a combined object for A 2030 without parallax data and without duplicated_source marker. There is not even a combined object available in DR2; Hipparcos parallax is 16.20 suggesting with the newly calculated orbit a system mass of 1.36 and the *Sta1978b* orbit results in a dynamical mass of 1.41. Markov et al. 2012 list a photometric system mass of 2.11 and a spectroscopic system mass of 1.05 – both dynamical mass values are within this range. Absolute magnitude based estimation suggests a system mass of 1.96 – the delta to the calculated dynamical masses could be explained to some degree by the Hipparcos parallax error range. RMS over the Rho residuals is for the newly calculated orbit slightly but not significantly better than for *Sta1978b*. More precise parallax and mass data would be valuable for a better orbit assessment.

WDS 04089+2911 (BU 1232) – *Mlr1978a*

The current 6th Orbit Catalog grade 4 entry with a period of 60 years and a semi-major axis of 0.28 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2011. The WDS history observation contains the note "*Only elements P, T, and a in the Starikova (1980) orbit have been amended from the orbit of Muller*". The 6th Orbit Catalog plot below shows the extraordinary bad match of this orbit with the measurements:



Plot 22: BU 1232 6th Orbit Catalog (blue dots for speckle observations)

Applying the Izmailov program on the extended observation history results with a period of 114 years and a semi-major axis of 0.33 arcseconds in quite different orbital element values but offers also a visually very bad match with the measurements. While this does not look very satisfying, it simply offers a much better match with the observation history in terms of residuals, especially with the few high precision measurements from the Int4 Catalog.

EDR3 parallax is 13.9531 and DR2 parallax is 24.0315 – quite a difference, which leads to doubts about the reliability of the Gaia data; Hipparcos parallax is 12.84. StarHorse median mass for the combined DR2 object is 0.88 suggesting based on magnitude delta an estimated median system mass of 1.46 (but this estimation is based on the obviously questionable DR2 parallax). The EDR3 parallax based absolute magnitude system mass estimation is ~2 and the dynamical mass for the *Mlr1978a* orbit with EDR3 parallax is 2.26, which means a good match. The newly calculated orbit results in a dynamical mass of 1.04, which seems off. The set of 200 possible orbits offers a cluster of entries with a dynamical mass ~2 – but all of them show a systematically bad match with the measurements from 1903 to 1914, which is also the case for *Mlr1978a*. I decided then to simply eliminate these measures and run the Izmailov programs again. The first result was again odd with a dynamical mass of 0.96 but the set of possible orbits listed several promising entries and I selected the most promising of them with a dynamical mass of 1.99:

Element	Value	-ΔP16/+ΔP84
P	57.425	-1.421/+2.787
A	0.260	-0.063/+0.051
i	80.799	-8.617/+2.528
Node	163.592	-2.241/+9.959
T	1991.309	-10.811/-0.221
e	0.836	-0.122/+0.077
omega	47.505	-31.884/+90.698

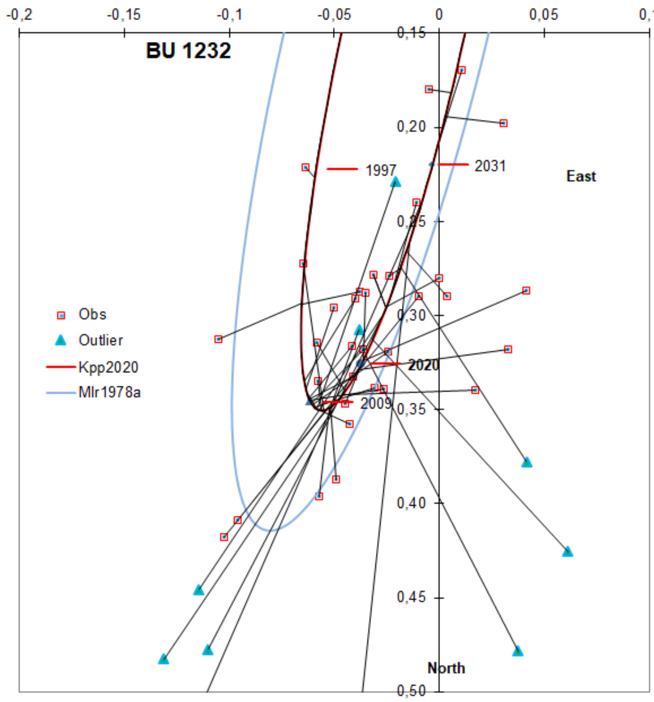


Figure 21. Plot 23: BU 1232 orbit comparison

This newly calculated orbit is in terms of residuals Theta and Rho better than the *Mlr1978a* orbit even if including the assumed outliers. However, this preliminary orbit comes with the caveat that the given observation history poses some questions and requires the intentional elimination of several measures for reasonable results.

I tried to locate the *Mlr1978a* paper to counter-check my assumptions regarding outliers but failed due to a missing A&AS archive back to 1978 and I also could not locate the Starikova paper referenced in the WDS observation history.

2.43. WDS 04170+1941 (HO 328) – *Hei1978a*

The current 6th Orbit Catalog grade 4 entry with a period of 63.3 years and a semi-major axis of 0.358 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history results due to the additional measurements in slightly different but similar orbital elements:

Element	Value	-ΔP16/+ΔP84
P	64.349	-3.427/+1.713
A	0.300	-0.022/+0.392
i	141.171	-39.507/-1.174
Node	80.723	-43.676/+59.872
T	1971.771	-0.852/+3.656
e	0.975	-0.012/+0.015
omega	260.522	-8.441/+23.869

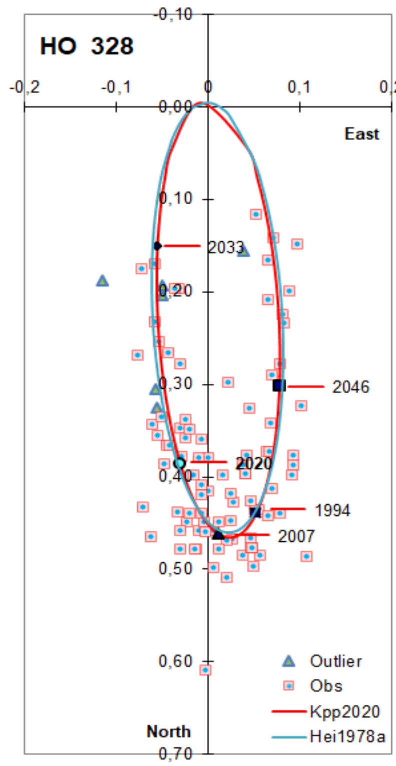


Figure 22. Plot 24: HO 328 orbit comparison with one outlier outside the frame

The newly calculated orbit is in terms of residuals Rho only slightly better than the *Hei1978a* orbit.

EDR3 parallax for a combined object is 12.4073 with a large error range, no duplicated_source marker and RUWE is ~1.7. DR2 offers no parallax value for HO 328, Hipparcos lists 11.83 with an error range covering the EDR3 value. Heintz 1978a reports a system mass of 2.3 corresponding with a dynamical parallax of 17. Markov et al. 2012 list for HO 328 a photometric system mass of 2.74 and a spectroscopic system mass of 1.2. Absolute magnitude based estimation using the EDR3 parallax suggests a system mass of 2.65. The *Hei1978a* orbit suggests with the EDR3 parallax a dynamical mass of 6 and the comparison with the estimated system mass renders this orbit obsolete. The newly calculated orbit gives with the Hipparcos parallax a dynamical mass of 3.44 – a slightly better match. However, the set of 200 possible orbits shows a large spread regarding dynamical mass so the quality of this orbit remains questionable. The set of 200 possible orbits covers the dynamical mass range around 2.7 very good but more precise parallax and system mass data would be of great help for assessing the quality of orbits.

2.44. WDS 09376+1528 (A 2479) – *Hei1978a*

The current 6th Orbit Catalog grade 5 entry with a period of 108 years and a semi-major axis of 0.23 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2008 – so this WDS object was neglected in the last decade. The bad match with the most recent measurements seems to make the quality of the *Hei1978a* orbit questionable. Applying the Izmailov program on the extended observation history results in a very different period of 388 years suggested by the additional measurements since 1978 – but the spread is very large due to the overall small number of observations:

Element	Value	-ΔP16/+ΔP84
P	388.217	-143.909/+92.486
A	0.480	-0.130/+0.078
i	53.555	-5.725/+2.579
Node	40.119	-4.487/+3.718
T	1955.523	-1.136/+0.949
e	0.692	-0.127/+0.042
omega	0.692	+1.367/+357.886

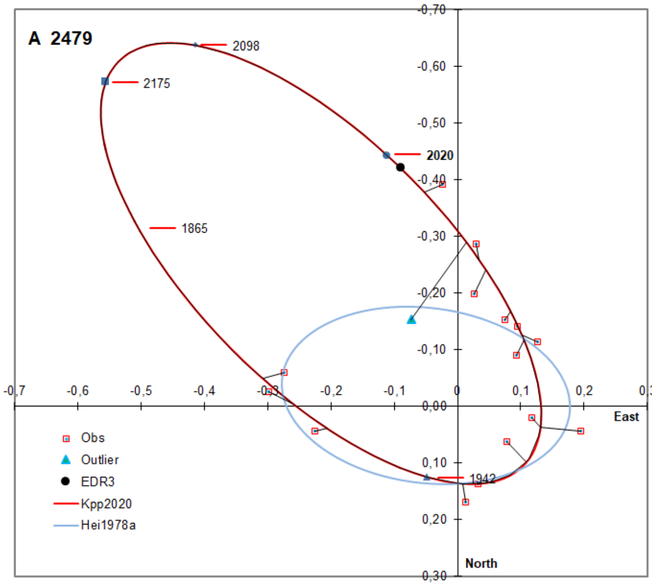


Figure 23. Plot 25: A 2479 orbit comparison

The newly calculated orbit offers a much better match with the observation history in terms of residuals and is supported by the perfect match with the meanwhile available EDR3 2016.0 measurement Theta 192.054° and Rho 0.43111" (not used for orbit re-calculation).

Heintz 1978a reports a system mass of 2.4 with a dynamical parallax of ~8.

EDR3 lists both components of A 2479 with a parallax of 5.7544 for the primary (RUWE 3.7) but none for the secondary. DR2 offers no parallax value for A 2479 as combined object, Hipparcos lists 5.73 with a huge error range. No mass data source found. From absolute magnitudes estimated system mass with the EDR3 parallax is 2.8, the dynamical mass for the Hei1978a is 5.52 and for the newly calculated orbit 3.88. The latter is not a perfect match with the estimated system mass but the set of 200 possible orbits shows a surprisingly small spread regarding dynamical mass suggesting good orbit quality.

Nevertheless, the number of observations seems despite the new EDR3 measure still a bit small for the calculation of a preliminary orbit for A 2479. Additional precise measurements would be of great help for re-calculating and assessing the quality of orbits.

2.45. WDS 14511-3706 (I 529) – *Dom1978*

The current 6th Orbit Catalog grade 5 entry with a period of 2,507 years and a semi-major axis of 2.657 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2009 and there are the additional 2015.5/2016.0 measurements from GAIA DR2/EDR3 so far not included in the observation history. However, the observation history seems a bit too short to allow for the calculation of realistic orbital element values for such a long period – although the given measures cover one end of the assumed ellipse.

Applying the Izmailov program on the extended observation history results surprisingly in a much smaller orbit period of ~832.5 years supported by the recent observations after 1978 with some spread suggesting even shorter orbits:

Element	Value	-ΔP16/+ΔP84
P	832.467	-407.923/-169.030
A	1.422	-0.450/-0.162
i	155.461	-9.691/+1.307
Node	22.127	-3.632/+25.245
T	1944.122	-0.818/+0.269
e	0.854	-0.086/-0.023
omega	200.855	-5.255/+23.145

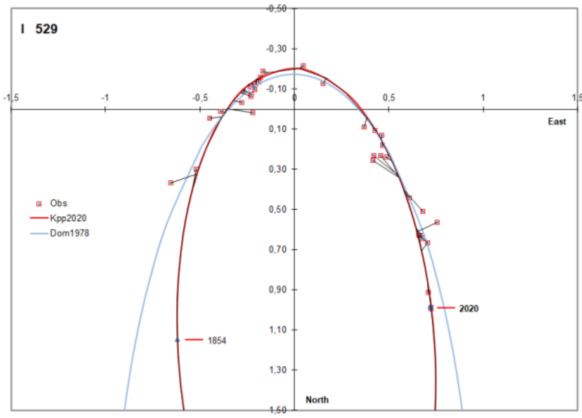


Figure 24. Plot 26: I 529 orbit comparison

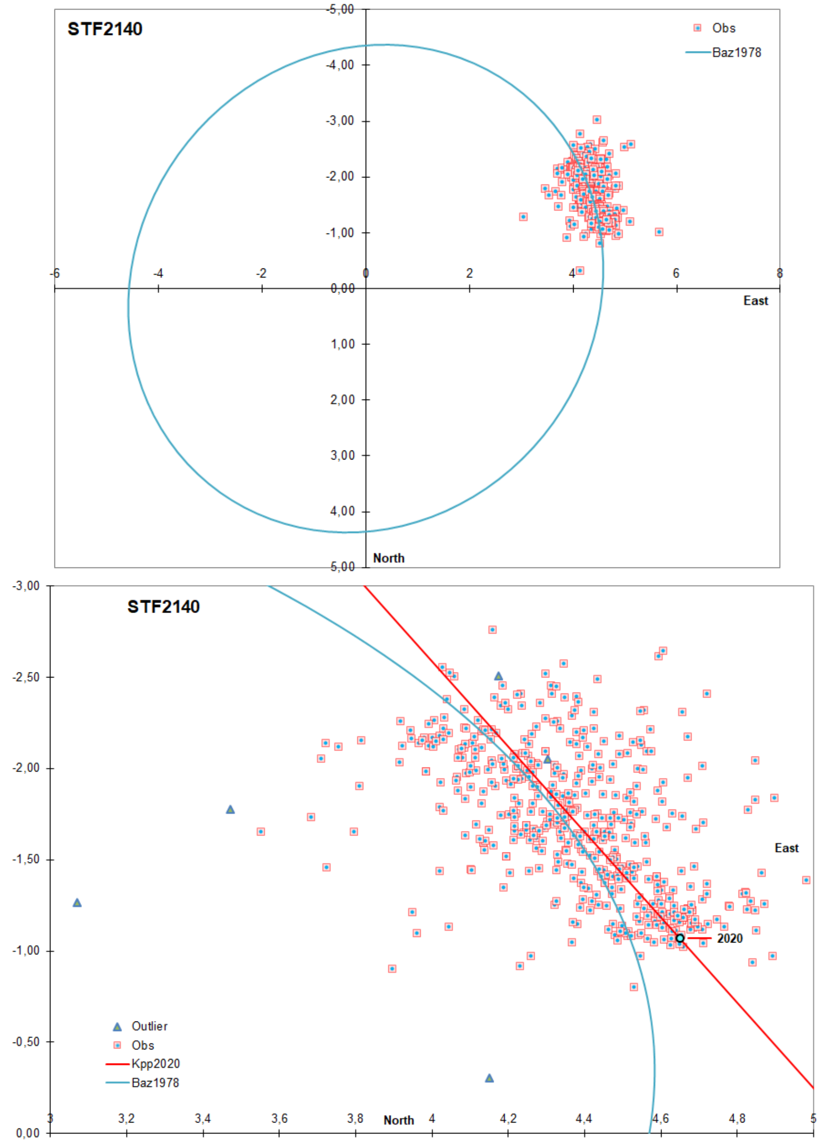
Both orbits are in terms of residuals similar with an advantage for the newly calculated orbit especially for the most recent measures.

EDR3 parallaxes are 13.2781 and 13.2597 with a small error range and RUWE ~1. DR2 lists parallax values of 12.9211 and 13.5385 (Hipparcos combined parallax 12.38) with a large error range, no duplicated_source marker for both components. StarHorse lists no data for these objects, so the DR2 data quality might be a bit questionable. Cvetkovic et al. 2010 suggest a system mass of 1.88, which would give magnitude delta based estimations of 0.98 for the primary and 0.90 for the secondary. Absolute magnitude based system mass estimation with the EDR3 parallaxes is 1.74. The likelihood for gravitational relationship based on the EDR3 data is 100% and the smallest possible spatial distance by simulation is 93 AU, which means a minimum potential circular orbit period of ~680 years close to the period of the newly calculated orbit.

Calculating with average EDR3 parallax gives for the *Dom1978* orbit a dynamical mass of 1.29 and for the newly calculated orbit of 1.79 with a small spread, which supports the good quality of the newly calculated orbit.

2.46. WDS 17146+1423 (STF2140) – *Baz1978*

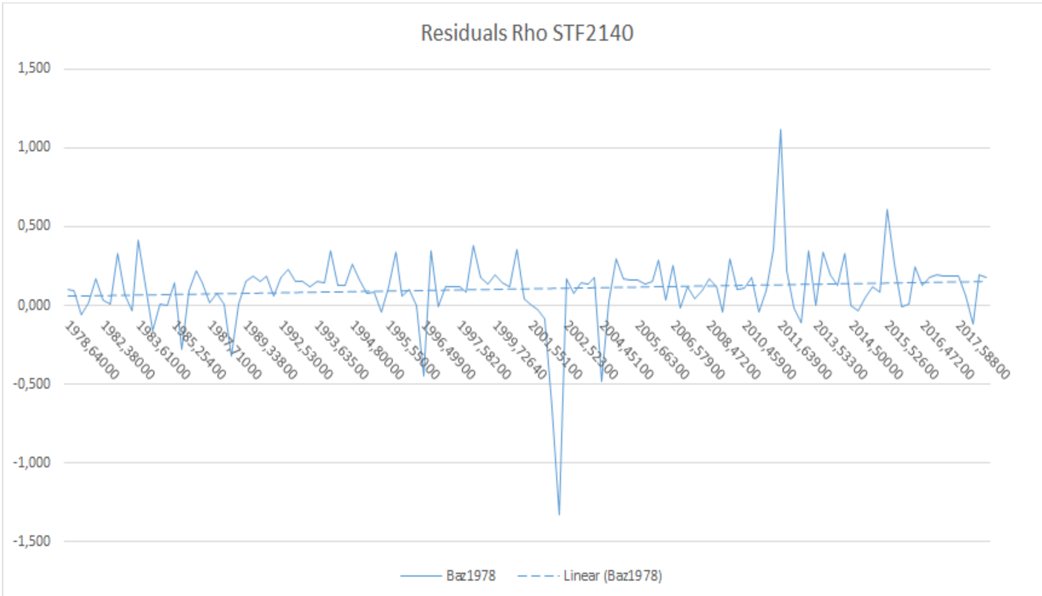
The current 6th Orbit Catalog grade 4 entry with a period of 2,507 years and a semi-major axis of 4.68 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2018. The comparison with the period of the suggested orbit for a tiny fraction of observation time span makes the proposal of a preliminary orbit very questionable and the given observation history shows no systematic development over time. Applying the Izmailov program on the extended observation history results consequently in an absurd long period of ~500,000 years with a huge spread with the given inclination of 90° suggesting a rectilinear solution.



Plot 27.1: STF2140 Baz1978 orbit with close-up comparison with newly calculated orbit

The close-up plot suggests a rectilinear solution which means that STF2140 is most likely an optical pair although the notes in the WDS observation history even speculate about STF2140 being potentially a quintuple. The A component was for some time assumed to be a close binary but CHR 139 Aa,Ab meanwhile was declared to be bogus. B is listed in the SB9 catalog as spectroscopic binary with a grade 4 (means quality close to definitive) orbit with a period of ~51.58 days published 1956.

The brightness of the components caused the lack of EDR3/DR2 data for A but B is listed in DR2 with a parallax of 9.9114, no parallax is given for B in EDR3. No StarHorse data available. Hipparcos combined parallax is 9.07 with a large error range. Using the DR2 parallax value for the dynamical mass calculation of the *Baz1978* orbit results in 8.12. Absolute magnitude based system mass estimation gives a system mass of 7.82 – a very good match, but the residuals Rho show an increasing systematical bias in the last four decades, which makes the Baz1978 orbit questionable.



Plot 27.2: STF2140 orbit Baz1978 residuals since 1978 with a systematic bias increasing over time

The dynamical mass for the newly calculated orbit is absurdly large and the set of 200 possible newly calculated orbits lists only two cases with a dynamical mass in the range ~8 – this orbit is obviously not to be taken seriously.

However, even if the parallax for both components were identical, then the likelihood for a potential gravitational relationship would, even with a such large system mass, be only ~20%. This object seems most likely to be an optical pair with STF2140 B remaining a spectroscopic binary.

2.47. **WDS 17177+1140 (G 139-29)** – *CJW1978/USN1988*

G 139-29 is listed in the 6th Orbit Catalog twice with grade 9 orbits – one published 1978 with a period of 10 years and a semi-major axis of 0.056 arcseconds and a second with a period of 9.5 years and a semi-major axis of 0.056 arcseconds published 1988. No corresponding WDS object. EDR3/DR2 list a combined object without duplicated_source marker but RUWE ~5.7/2.6 suggests multiplicity issues. EDR3/DR2 parallax is 80.8407/80.7994 (no Hipparcos parallax) and StarHorse median mass for the combined DR2 object is ~0.18 giving with an equal bright pair assumed an estimated system mass of 0.30. The dynamical mass for the *CJW1978* orbit is with 0.0033 far off, the same for the *USN1988* orbit with 0.0037 – so both listed orbits seem obsolete due to dynamical mass values in the range of planets.

2.48. **WDS 20012-3835 (HDO 294)** – *Dom1978*

The current 6th Orbit Catalog grade 5 entry with a period of 4,484.5 years and a semi-major axis of 4.916 arcseconds is from 1978 although several new observations were added to the WDS catalog since then up to 2017 and there are additional 2015.5/2016.0 observations from GAIA DR2/EDR3 available. A second orbit published also by Dommanget 1978 with a period of 474.7 years is no longer listed in the 6th Orbit Catalog most likely because the match with the most recent measurements is obviously very bad.

Applying the Izmailov program on the extended observation history results in a short period of ~565 years:

Element	Value	-ΔP16/+ΔP84
P	564.634	-228.694/+86.263
A	1.052	-0.212/+0.120
i	8.747	+10.622/+28.323
Node	39.248	-10.120/+81.930
T	1921.015	-2.955/+0.673
e	0.786	-0.088/+0.021
omega	203.139	-77.967/+6.261

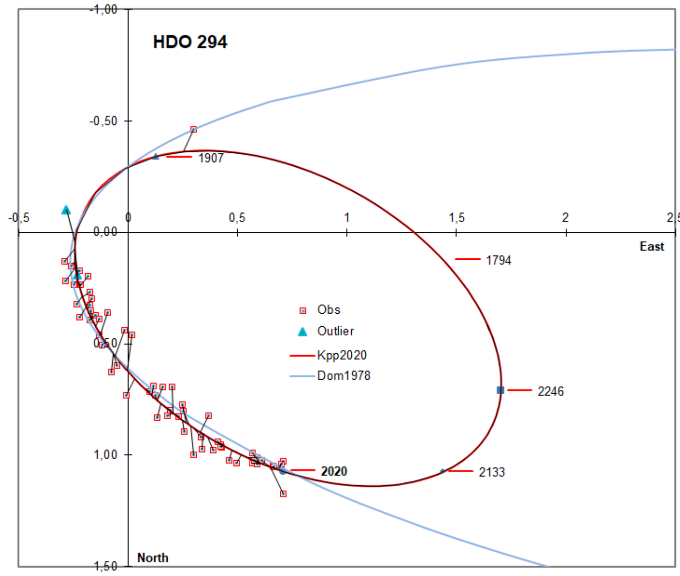


Figure 25. Plot 28: HDO 294 orbit comparison

A look at the residuals shows for the newly calculated orbit a much better match with the observation history. An increasing systematic bias in the last two decades makes the *Dom1978* orbit questionable.

EDR3 parallaxes are 12.0537 and 11.8718 with a small error range and RUWE ~1.2. DR2 parallaxes are 12.2378 and 11.866 (Hipparcos for combined object 14.60) with a large parallax error range and RUWE >1.4 for both components, data quality therefore a bit questionable. EDR3 data suggests a minimum spatial distance between the components of ~104 AU. This gives with the StarHorse median masses of ~1.20/0.78 a minimum potential circular orbit period of ~754 years with a likelihood of ~ 23% for gravitational relationship. Absolute magnitude based system mass estimation with the EDR3 parallaxes is with 2.44 (1.36/1.08) somewhat higher.

With the given data, the *Dom1978* orbit results in a dynamical mass of 3.48 and the newly calculated orbit of 2.14 – quite a good match in between StarHorse median system mass and magnitude based estimated system mass. The set of 200 possible orbits offers little spread in dynamical masses suggesting good orbit quality.

The observation history seems a bit too short for the calculation of a realistic if premature orbit with such a long period. New measurements in the next few years should be very valuable for orbit re-calculation and assessment.

2.49. WDS 08211+4725 (A 1745 Ca,Cb) – *Hei1979b*

The current 6th Orbit Catalog grade 5 entry with a period of 279.5 years and a semi-major axis of 0.479 arcseconds is from 1979 with two new observations added to the WDS catalog since then in 1991 and 1997 – this looks like a neglected WDS object with an overall very small observation history. An additional measurement comes from EDR3 for 2016.0 with Theta 296.306° and Rho 0.64633".

The Izmailov program provides with the extended observation history a period of 294 years and a semi-major axis of 0.686 arcseconds if with some spread:

Element	Value	-ΔP16/+ΔP84
P	527.730	-188.285/+104.606
A	0.686	-0.173/+0.101
i	41.852	-5.958/+5.254
Node	50.351	-8.489/+19.411
T	1930.511	-1.279/+2.114
e	0.833	-0.070/+0.027
omega	99.225	-21.724/+7.549

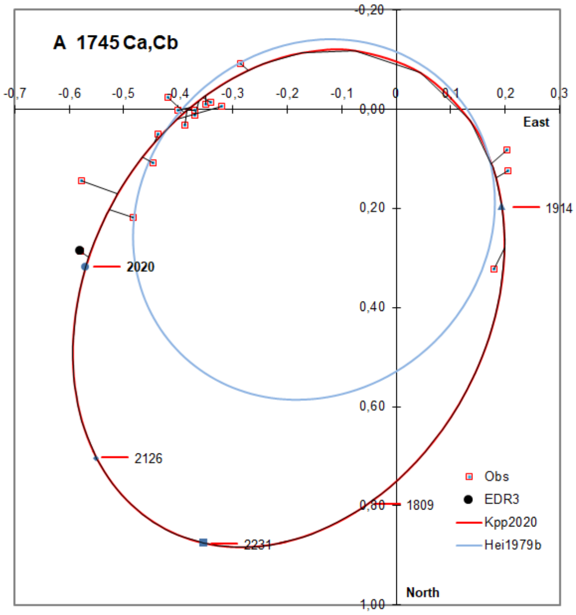


Figure 26. Plot 29: A 1745 Ca,Cb orbit comparison

The residuals for Rho are, for the newly calculated orbit, clearly better than for the *Hei1979b* orbit – but with all due respect to Heintz: The number of measurements is simply too small to calculate a realistic if premature orbit.

EDR3 offers for A 1745 Ca,Cb a parallax only for Ca with a small error range and RUWE ~2, no parallax is given for Cb. DR2 parallax for a combined object is 14.8816 (Hipparcos 14.74) but with an unusual large error range >10%. StarHorse median mass for the combined DR2 object is 0.89 allowing for magnitude delta based mass estimations of 0.81 for the primary and 0.67 for the secondary. Using the EDR3 parallax for absolute magnitude based system mass estimation gives 1.5 (0.82/0.68) quite close to the StarHorse value. The dynamical mass calculated from the orbit *Hei1979b* is 0.85 and for the newly calculated orbit 0.7, which is in both cases a bad match with the estimated system mass. The set of 200 possible orbits shows a small spread regarding dynamical mass with a highest value of ~1.1 still far away from the estimated system mass value – so this object requires additional observations for the calculation of a significantly better premature orbit in terms of dynamical mass.

The observation history contains the note "A,Ca: AB,Ca may be a quadruple system, as the proper motions are in fair agreement", which is supported by the given EDR3 parallax and proper motion data.

2.50. WDS 06003-3102 (HJ 3823 AC) – *Baz1980b*

The current 6th Orbit Catalog grade 5 entry with a period of 390.6 years and a semi-major axis of 3.95 arcseconds is from 1980 although several new observations were added to the WDS catalog since then up to 2015. Additionally comes the EDR3 2016.0 measure with Theta 1.865° and Rho 2.90442". Applying the Izmailov program on the extended observation history results in a similar period of ~394 years but otherwise different orbital element values providing overall a clearly better match with the observation history.

EDR3 parallaxes are 54.0273 and 54.0381 with a small error range, RUWE ~4/12 and no duplicated_source marker. DR2 parallaxes are 53.9661 and 54.8179 (Hipparcos 61.0 with a huge error range) with duplicated_source marker and RUWE ~5/2. StarHorse median masses are 0.79/0.70. There are two additional grade 3 orbits listed in the 6th Orbit Catalog for HU 1399 AB and TOK 9 CE, which suggests that this object is a physical quadruple. This means that the mentioned StarHorse median masses have to be considered given for combined DR2 objects suggesting based on magnitude delta estimated median mass values of 1.33 for the primary and 1.18 for the secondary – these values correspond reasonable well with the mass values listed in Tokovinin 2018.

The *Baz1980b* orbit gives with the average EDR3 parallax a dynamical mass of 2.58 – a perfect match with the estimated median system mass value but a bad match in terms of residuals Theta, with the most recent observations, renders this orbit obsolete. The newly calculated orbit with a dynamical mass >20 is also obviously obsolete – this example demonstrates once more that the best match with the measurement corresponds not necessary with the most realistic orbital element values. The set of 200 possible orbits covers the dynamical system mass ~2.5 range very good with the best matching example as follows:

Element	Value	-ΔP16/+ΔP84
P	1133.042	-700.028/+53.475
A	7.948	-2.079/+6.540
i	103.126	-8.275/+1.156
Node	140.331	-0.781/+4.062
T	1798.702	-21.853/+17.196
e	0.477	-0.055/+0.405
omega	343.521	-70.169/-21.500

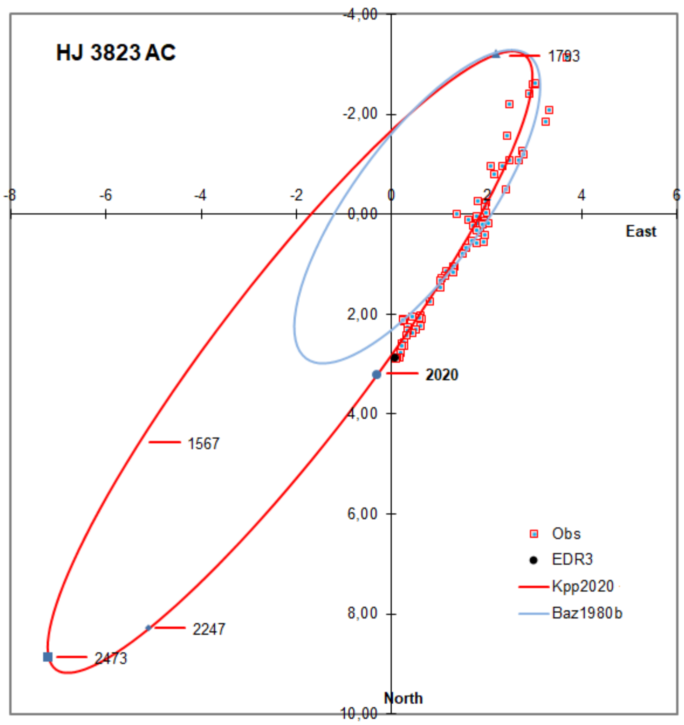


Figure 27. Plot 30: HJ 3823 AC orbit comparison,
Kpp2020 orbital element values selected for system mass ~2.5

This newly calculated orbit fits the observation history much better than the *Baz1980b* orbit as can be seen clearly in the plot. Interestingly, while it shows in terms of residuals Theta a much better agreement with the most recent measurements this is not the case in terms of residuals Rho.

This indicates that there is room for improvement. The observation history given so far seems too small for the calculation of a realistic premature orbit because it does so far not cover one of the ends of the assumed ellipses. This will most likely be the case for the near future. However, new precise measurements would be very valuable for orbit re-calculation.

2.51. WDS 03054+2515 (STF 346) – *Hei1981a*

The current 6th Orbit Catalog grade 3 entry with a period of 227 years and a semi-major axis of 0.47 arcseconds is from 1981 although several new observations were added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history results in a period of ~261 years with what else are very similar orbital elements:

Element	Value	-ΔP16/+ΔP84
P	261.162	-8.944/+9.426
A	0.462	-0.011/+0.011
i	76.692	-0.476/+0.914
Node	93.251	-0.947/+0.719
T	1938.236	-1.119/+0.950
e	0.781	-0.016/+0.014
omega	321.157	-2.654/+2.124

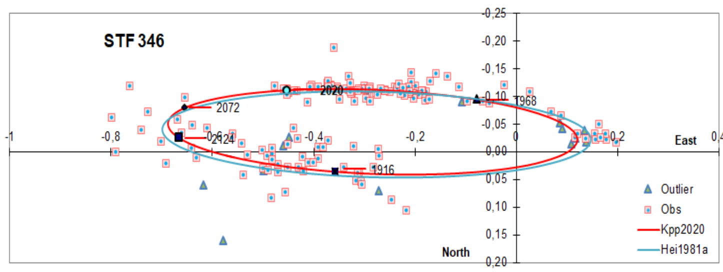


Figure 28. Plot 31: STF 346 AB orbit comparison (one outlier outside the frame)

A look at the residuals shows a systematic bias of the *Hei1981a* orbit in the recent three decades. The newly calculated orbit covers this period much better and offers overall a slightly better residuals Rho RMS value. There is no EDR3/DR2 parallax and no StarHorse data available. Hipparcos parallax is 6.05 with a large error range. Markov et al. 2010 list a photometric system mass of 6.89 as well as a spectroscopic system mass of 3.39 and Cvetkovic et al. 2010 suggest a system mass of 7.18. From absolute magnitudes estimated system mass is 6.32. The dynamical mass for *Hei1981a* with the Hipparcos parallax is 9.1 and for the newly calculated orbit 6.53 – the latter seems for now close enough to the estimated system mass to accept these orbital element values as a reasonably reliable orbit although more precise parallax data would be helpful for orbit assessment.

2.52. WDS 07307+4813 (GIC 75 A and WNO 49 Ba,Bb) – *Hrr1981*

GIC 75 A is listed in the 6th Orbit Catalog with a grade 9 orbit published 1981 with a period of 0.94 years and a semi-major axis of 0.054 arcseconds, but is not listed as Aa,Ab subsystem in the WDS catalog. EDR3/DR2 parallax for A is 88.7231/88.5430 without duplicated_source marker and RUWE <1.4 indicates no multiplicity issues. StarHorse median mass for the combined DR2 object is ~0.20 allowing for magnitude delta based mass estimation of 0.18 for the primary and 0.16 for the secondary. The dynamical mass for the *Hrr1981* orbit with the given parallax is 0.26 – not identical with the estimated median system mass of 0.34 but at least very close.

GIC 75 B is listed in the WDS catalog as subsystem WNO 49 Ba,Bb with a slightly off J2000 position (should be 07 30 47.36 +48 10 27.6). The current 6th Orbit Catalog grade 5 entry with a period of 20.5 years and a semi-major axis of 0.656 was also published 1981. Neither EDR3/DR2 nor HIP parallax data is given for GIC 75 B. Khrutskaya et al. 2010 report for B a parallax of 83.484, Tokovinin 2018 of 80.4, Scholz et al. 2018 of 89.6, Giammichele et al. 2012 of 90.0 and another option might be to simply use a parallax very similar to GIC 75 A assuming a quadruple. No StarHorse mass data available for B, a mass estimation based on magnitude delta compared to A is here of little use because B is a pair of white dwarfs so the system mass for B should be significantly larger than for A.

Tokovinin 2018 suggests for B a system mass of 0.8 and Giammichele et al. 2012 report a mass of 0.51 for the primary and of 0.65 for the secondary (why the heavier star should be the secondary remains unclear). The calculated dynamical mass for the *Hrr1981* orbit for WNO 49 Ba,Bb depends on which of the above listed parallax values is used – using the EDR3 parallax of GIC 75 A results in 0.97 in-between the system masses suggested by Tokovinin 2018 and Giammichele et al. 2012.

The observation history for WNO 49 Ba,Bb up to 1980 consists of 4 measurements with valid position angle and angular separation while several additional measurements cover only the position angle and one gives only the separation. It seems questionable to calculate an orbit with such a weak database because at least 5 data points are needed to define a conic section even if the incomplete measurements could be of use for calculating residuals. Three additional measurements in 2000/2001 add to the complexity of the observation history because non-resolution is reported with an upper limit for the separation <0.23 and <0.34. Finally three measurements from GAIA (the 2015.5 and 2016.0 so far not included in the observation history) were added giving in total 7 complete observations.

The *Hrr1981* orbit matches the observation history up to 1980 including the incomplete measurements well but fails significantly with the GAIA measures and Rho values below 0.23 of 0.34 around 2000 are not covered, which makes this orbit highly questionable.

Applying the Izmailov program on this "extended" observation history results in a period of ~38 years with as expected very different orbital elements. However, the dynamical mass of 0.6 offers a bad match with the mentioned system mass estimations. The set of 200 possible orbits covers despite a small spread the full range of mass values for all mentioned parallax data versions with a large cluster of orbits with a period of ~18.5 years. Using again the EDR3 parallax value the dynamical masses cover in this cluster the range from 0.99 to 1.43 with the best RMS value for an orbit with a dynamical mass of 1.11 and a surprisingly small spread in the orbital element values.

Element	Value	-ΔP16/+ΔP84
P	18.880	-0.098/+0.096
A	0.650	-0.007/+0.067
i	45.410	-7.234/+7.252
Node	164.661	-19.241/+0.246
T	1988.764	-0.274/+11.659
e	0.118	-0.118/+0.297
omega	358.188	-350.090/-74.931

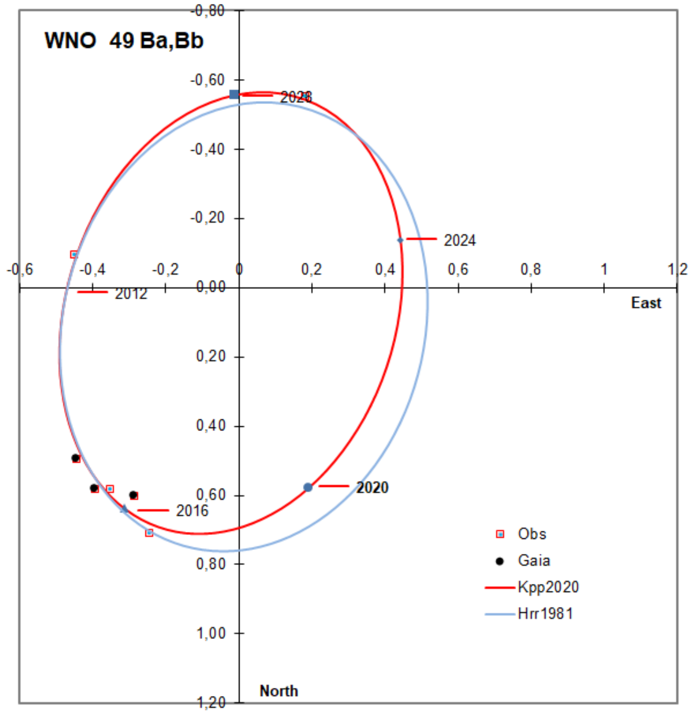


Figure 29. Plot 32: WNO 49 Ba,Bb orbit comparison

This newly calculated orbit offers compared to *Hrr1981* orbit a much better match with the observation history including the Gaia measurements and matches to some degree also with the incomplete measurements very well. However, the small angular separations indicated in the observation history for 2000/2001 are not covered. So either these 2000/2001 measurements are for whatever reason completely off or all so far presented premature orbits are obsolete.

Whether this orbit is "really necessary" is questionable due to the modest data basis, but it is certainly much better than the Hrr1981 orbit especially for the most recent measures.

New measurements in the coming years should settle this issue and precise parallax data would also be helpful for re-calculating and assessing orbits.

GIC 75 AB is listed in the WDS catalog as wide visual pair and as both components are assumed to be binaries themselves this object is either a co-moving double-double or a physical quadruple system. The question if GIC 75 AB is a physical system is with the currently available parallax data undecidable – even if the parallax is assumed ident for A and B then the minimum spatial distance would be ~1,200 AU and the minimum orbit period would still be ~40,000 years (see table in Appendix A). Tokovinin 2018 indicates an orbit period of >32,000 years but gives no other orbital element values. Anyway far too long to get enough measurements for a realistic orbit calculation in a human timespan – the observation history lists so far currently only 12 measurements starting with 1953.

2.53. WDS 10250+2437 (STF1429) – *Zul1981*

The current 6th Orbit Catalog grade 4 entry with a period of ~1,281 years and a semi-major of 2.1 arcseconds is from 1981 although several new observations were added to the WDS catalog since then up to 2017. Applying the Izmailov program on the extended observation history (with the EDR3/DR2 measurements added) results in a period of ~725 years with a large spread because the observation history covers only a small fraction of the assumed orbit period. The residuals show a slightly better match of the newly calculated orbit with the observation history while the systematic mis-match of the *Zul1981* orbit with the most recent observations renders this orbit as obsolete.

EDR3 parallax values are 14.5427/13.5631 with a large error range, no duplicated_source marker and RUWE >1.4. No DR2 parallax available, no StarHorse mass data. Hipparcos parallax is 14.82 with a huge error range. The estimated system mass based on absolute magnitudes using the EDR3 parallaxes is 1.95 and Cvetkovic et al. 2010 reported a system mass of 1.93. Dynamical mass for the Zul1981 orbit with the average EDR3 parallax is 2.05 while the newly calculated orbit is with 27.57 completely off.

The set of 200 possible orbits lists a few entries with a dynamical mass value close to Cvetkovic et al. 2010, the best match comes with a dynamical mass of 1.98 with orbital element values outside the 16th percentile:

Element	Value	-ΔP16/+ΔP84
P	13873.394	-13273.878/-11746.184
A	10.161	-7.772/-2.065
i	104.434	-10.642/-0.450
Node	102.747	-0.247/+16.838
T	1800.091	-81.002/+318.020
e	0.840	-0.424/+0.092
omega	197.950	-118.436/-37.987

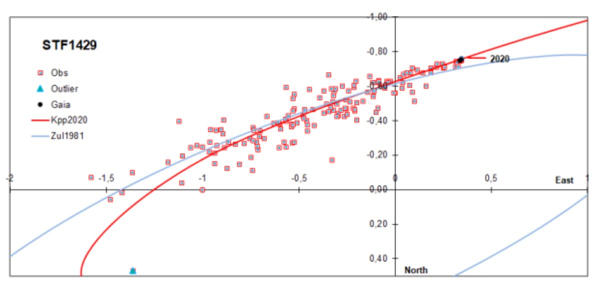


Figure 30. Plot 33: STF1429 orbit comparison

This newly calculated orbit offers a dynamical mass near to the estimated system mass, a slightly better overall delta Rho RMS value than the *Zul1981* orbit and most important – there is no systematic bias in the last two decades compared to *Zul1981*. A few additional measurements would be very useful here although it is not to expect to get measurements for the assumed ends of the orbit ellipses in the near future. For this reason, it is not to expect to be able to calculate reliable preliminary orbital element values within a reasonable time frame.

The bad news is a likelihood of zero for gravitational relationship with the given EDR3 parallax data suggesting that STF1429 is just an optical pair.

2.54. WDS 19358+2316 (A 163) – *Baz1981b* (new orbit *Sca2019d*)

The 6th Orbit Catalog grade 5 entry *Baz1981b* with a period of ~163 years and a semi-major axis of 0.255 arcseconds is from 1981 although several new observations were added to the WDS catalog since then up to 2009. Applying the Izmailov program on the extended observation history results in a period of ~229 years due to the better match with the most recent measurements with a moderate spread and else similar orbital element values with the currently listed orbit:

Element	Value	-ΔP16/+ΔP84
P	228.903	-25.717/+37.042
A	0.279	-0.011/+0.014
i	127.748	-4.483/+3.515
Node	31.659	-2.565/+3.444
T	1977.128	-2.482/+4.260
e	0.307	-0.061/+0.064
omega	296.001	-6.720/+13.793

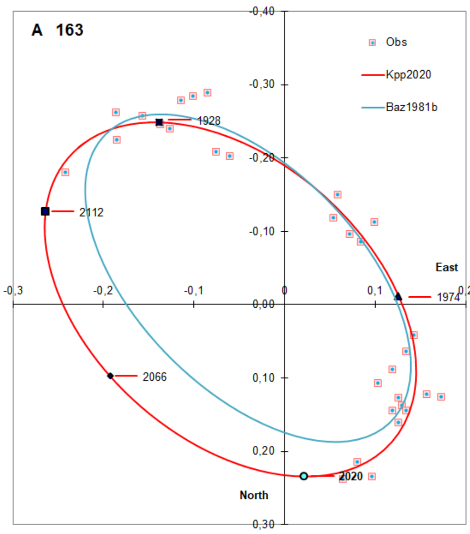


Figure 31. Plot 34: A 163 orbit comparison

The newly calculated orbit offers obviously a clearly better match with the most recent observations.

No DR2 data available for this object, no EDR3 parallax, Hipparcos parallax 5.75 with huge error range. No StarHorse mass data available, no other source found. Estimated system mass from absolute magnitudes using the Hipparcos parallax is 2.55.

Dynamical mass with Hipparcos parallax for the Baz1981b orbit is 3.28 and for the newly calculated orbit 2.17 – both values seem possible with the latter a bit closer to the estimated system mass. More precise parallax, additional measurements and a reliable source for a system mass value for comparison would be very useful.

Note: Meanwhile a new orbit *Sca2019d* is listed in the 6th Orbit Catalog with very similar orbital element values as given above. For whatever reasons – the newly calculated orbit presented here is in terms of RMS residuals Rho with 0.024 to 0.027 slightly better despite the identical observation history.

2.55. WDS 23164+6407 (BU 992) – *Val1981d*

The current 6th Orbit Catalog grade 5 entry with a period of ~517 years and a semi-major axis of 0.43 arcseconds is from 1981 although several new observations were added to the WDS catalog since then up to 2008 – so this is a recently neglected WDS object. The bad match with the most recent measurements renders the *Val1981d* orbit clearly obsolete.

Applying the Izmailov program on the extended observation history results in a very different premature orbit with a period of ~632 years and a noticeable spread but overall much better match with the observation history.

No EDR3/DR2 parallax available, Hipparcos parallax is 3.66 with a huge error range. No StarHorse mass data available, no other mass data source found. From absolute magnitudes estimated system mass is 4.91. The dynamical mass for the *Val1981d* orbit with the Hipparcos parallax is 6.07 and for the newly calculated orbit 10.13 – the latter value seems not very plausible and the former is for an orbit already considered obsolete. More precise parallax data, additional measurements and a reliable source for a mass value for comparison would be very useful to check the reliability of the listed orbits. The spread in the set of 200 possible orbits suggests generous room for improvement with a dynamical mass down to 5.13 if far outside the 16th percentile. This still premature orbit comes with the following orbital element values:

Element	Value	-ΔP16/+ΔP84
P	1314.258	-1039.807/-498.174
A	0.755	-0.337/-0.076
i	122.002	-14.599/-5.613
Node	32.410	-15.044/-4.933
T	1982.979	+17.584/+40.467
e	0.640	-0.205/+0.018
omega	342.149	-329.580/-264.163

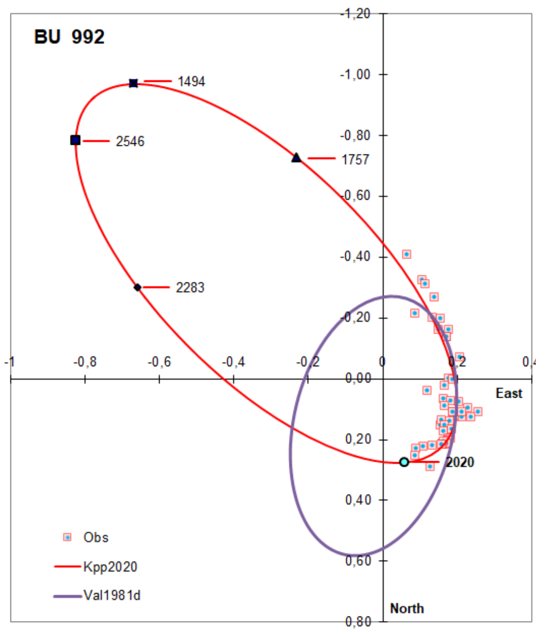


Figure 32. Plot 35: BU 992 orbit comparison

This newly calculated orbit is in terms of residuals clearly better than the *Val1981d* orbit. New measurements over the next few years should cover one end of the assumed orbit ellipse, which would mean a significant enhancement for the reliability of then re-calculated orbits.

2.56. WDS 23375+4426 (STT 500) – *Zul1981*

The current 6th Orbit Catalog grade 4 entry with a period of ~351 years and a semi-major axis of 0.41 arcseconds is from 1981 although several new observations were added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history results in a very different preliminary orbit with a period of ~1.114 years with a huge spread in the orbital element values.

No DR2 data available, no EDR3 parallax, Hipparcos parallax is 4.04. No StarHorse data available, Cvetkovic et al. 2010 list a system mass of ~7.5 and the dynamical mass for the *Zul1981* orbit is with 8.47 close but the dynamical mass of the newly calculated orbit is 11.59. The set of 200 possible orbits contains a few entries with a dynamical mass in the range of ~7.5 with the following one the closest with 7.48:

Element	Value	-ΔP16/+ΔP84
P	458.233	-75.006/+492.059
A	0.470	+0.085/+0.416
i	44.747	+11.408/+20.402
Node	140.690	-15.862/+2.635
T	2175.813	-385.129/-306.061
e	0.277	-0.042/+0.311
omega	29.496	+42.811/+115.650

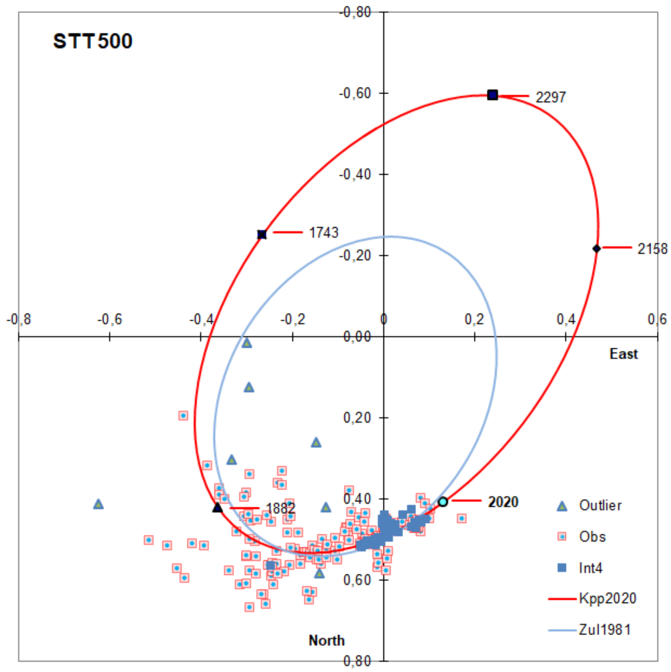


Figure 33. Plot 36: STT 500 orbit comparison

Both orbits are in terms of residuals Rho RMS similar with overall a slight advantage for the newly calculated orbit. The *Zul1981* orbit shows a slight systematical bias in the last decade, which is not the case for the newly calculated orbit. This orbit selection is based on the shaky Hipparcos parallax. More precise parallax data and an additional reliable source for the system mass for comparison would be very valuable for the orbit. There are 55 measurements in the Int4 Catalog but this large number does not help much – the 1923 measurement appears to be an outlier, and the rest of the Int4 measures cover a too small part of the assumed orbital period to be a base for calculating a reasonably preliminary orbit.

2.57. WDS 04064+4325 (A 1710) – *Hei1982c*

The current 6th Orbit Catalog grade 3 entry with a period of 109.5 years and a semi-major axis of 0.396 arcseconds is from 1982 although several new observations were added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history results in a very solid looking preliminary orbit with a similar period of ~112 years with a small spread for all orbital elements:

Element	Value	-ΔP16/+ΔP84
P	112.204	-2.545/+3.163
A	0.398	-0.010/+0.009
i	126.210	-2.473/+2.424
Node	114.016	-1.903/+3.179
T	1948.361	-0.690/+0.734
e	0.717	-0.017/+0.014
omega	326.234	-3.187/+4.664

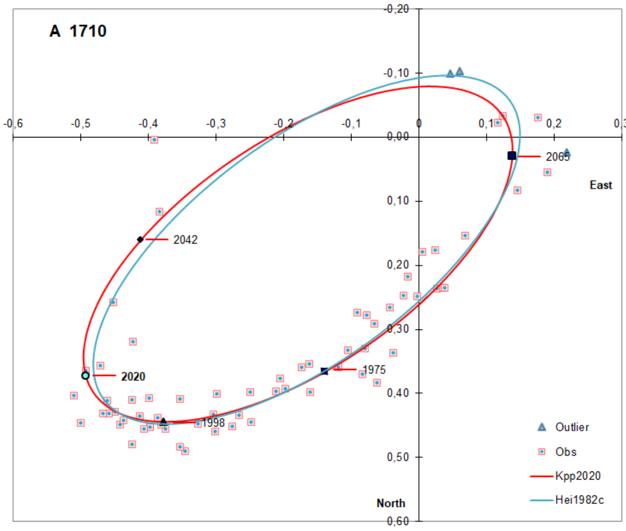


Figure 34. Plot 37: A 1710 orbit comparison

No DR2 and StarHorse data available, not resolved in EDR3, no parallax for combined EDR3 object, Hipparcos parallax is 14.45 with a large error range. Malkov et al. 2012 report a photometric system mass of 2.49 and a spectroscopic system mass of 0.95. The dynamical mass for the *Hei1982c* orbit is 1.72 and for the newly calculated orbit 1.67 – both values are in between the system mass values suggested by Malkov at al. 2012 and look very plausible. Residuals Rho RMS is very similar with a slight advantage for the newly calculated orbit. More precise parallax and system mass data would be valuable for orbit assessment. The time span of the Int4 Catalog measurements is too short to have significant influence on an orbit re-calculation (three of the measurements have slightly different separation values in the WDS observation history with a "P" code, which indicates "measure corrected by author").

2.58. WDS 06517+2503 (A 512) – *Cou1982c*

The current 6th Orbit Catalog grade 5 entry with a period of 187 years and a semi-major axis of 0.21 arcseconds is from 1982 with two new observations added to the WDS catalog since then up to 1991 – so this is a recently neglected WDS object. Applying the Izmailov program on the slightly extended observation history results in a proposed orbit with a very bad match with the given measurements. After a closer look at the observation history and the *Cou1982c* orbit, I got the impression that the 1950 measurement might be an outlier to be eliminated and applied the Izmailov program again – this time with a period of 185.6 years and a semi-major axis of 0.223 arcseconds a reasonably good match with the observations. I could not locate the referenced Couteau paper from 1982 to check if he did the same or if he had other means to get to the orbital element values he reported, Nevertheless, the number of observations seems to me far too small to calculate a realistic if premature orbit.

EDR3 parallax for a combined object is 2.6471 with a large error range, no duplicated_source marker, RUWE >30 indicates data quality issues. DR2 parallax for combined object is 4.052 with a large error range, Hipparcos parallax is 4.01; StarHorse median mass for the combined DR2 object is 1.76 allowing for the magnitude delta based estimation of a median system of 2.95 (mass for the primary of 1.56 and for the secondary of 1.39). The dynamical mass with the DR2 parallax is for the Cou1982c orbit 3.98 and for the newly calculated orbit 4.86 – both values are larger than the estimated median system mass of 2.95 making both orbits a bit questionable. To complicate things EDR3 offers a completely different parallax of 2.6471 for the combined object resulting in unrealistic large dynamical masses >10.

Several entries in the set of 200 possible orbits cover with the DR2 parallax the range of the estimated median system mass with the following orbital element values giving a dynamical mass of 2.93:

Element	Value	-ΔP16/+ΔP84
P	295.710	-143.344/+17.486
A	0.257	-0.042/+0.033
i	23.143	+15.930/+36.953
Node	100.674	+5.599/+38.933
T	1970.534	+0.246/+14.445
e	0.517	-0.200/+0.012
omega	178.004	-16.795/+24.682

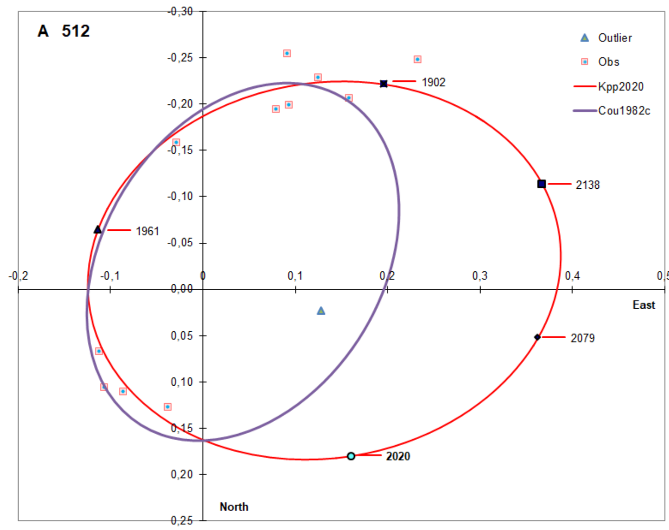


Figure 35. Plot 38: A 512 orbit comparison

The newly calculated orbit offers a better match with the estimated system mass, residuals Rho RMS is similar for both orbits but the Cou1982c orbit shows a systematic bias in the second half of the measurements. Additional measurements for this neglected WDS object would be very useful for a more reliable orbit calculation as so far only 12 observations are certainly not sufficient for such a task. Even a single precise observation in 2020 would be sufficient to eliminate at least one of the listed orbits as obsolete.

2.59. WDS 18058+2127 (STT 341) – *Hei1982b*

STT 341 is a visual multiple listed in the WDS catalog with up to 10 components with most of them most likely optical.

The current 6th Orbit Catalog grade 2 entry for AB with a period of 20.08 years and a semi-major axis of 0.253 arcseconds is according to the 6th Orbit Catalog notes a combined visual-spectroscopic orbit published 1982 although several new observations were added to the WDS catalog since then up to 2018. The huge observation history for STT 341 covers with >250 measurements about 9 times the assumed orbit period, but is at least visually a mess – the XY plot suggests more a swarm of bees than any consistent pattern of data points (see the 6th Orbit Catalog plot http://www.astro.gsu.edu/wds/orb6/PNG/wds18058+2127a.png).

STT 341 AB is also listed in the SB9 catalog (as system 1024) as spectroscopic binary with a grade 3 (means medium quality) orbit published 1979 with an orbit period of ~20.25 years very close to the *Hei1982b* orbit.

To add complexity STT 341 A is additionally listed in the SB9 catalog (as system 1023) as spectroscopic binary of its own with a grade 4 (which means close to definitive) orbit with a period of ~0.88 days also published 1979 making STT 341 a physical triple system.

STT 341 C is also listed in the SB9 catalog (system 1986) as spectroscopic binary of its own with a grade 5 (which means definitive) orbit with a period of ~25.8 days published 1994 making STT 341 potentially a quintuple.

Applying the Izmailov program on the extended observation history for AB results with a period of 19.94 years and a semi-major axis of 0.247 in very similar orbital element values compared to *Hei1982b*, but with an enormous spread in the orbital element values.

DR2 parallax for a combined object is 30.6946 with a large error range and with duplicated_source marker, RUWE >15. Hipparcos parallax is 25.35 with a large error range and EDR3 provides surprisingly no parallax, which can be taken as question mark on the DR2 parallax value. StarHorse median mass for the combined DR2 object is ~1.04 allowing for the magnitude delta based median mass estimation for the primary of 0.98 and for the secondary of 0.71. Malkov et al. 2012 suggests a photometric mass of 2.06 and spectroscopic mass of 2.0. Absolute magnitude based system mass estimation with the DR2 parallax gives 1.72. These values need to be corrected for the fact that A is a binary itself, which suggests for A (based on the StarHorse values) a system median mass of 1.65 giving finally an estimated median system mass for STT 341 AB of 2.36. Tokovinin 2018 lists the following masses for STT 341 components estimated from absolute magnitudes: Aa 1.0, Ab 0.83, B 0.98, Ca 0.71 and Cb 0.7. This would give for AB a system mass of 2.81.

The dynamical mass for the *Hei1982b* orbit with the DR2 parallax is 1.39 and for the newly calculated orbit 1.32 – no good match with the estimated median system mass of 2.36 and even less with the Tokovinin 2018 estimated system mass of 2.81. This suggests that the DR2 parallax might be questionable (also the missing EDR3 parallax makes the DR2 value slightly dubious) because the dynamical masses are with the Hipparcos parallax very well in the discussed estimated system mass range.

Residuals Rho RMS is slightly better for the newly calculated orbit. However, both orbits seem questionable by the very bad match with the two most recent precise measurements. Overall, the observation history does not look very conclusive – less spread would be expected with such an extensive observation history.

The Int4 Catalog offers a list of ~60 measurements of high precision covering the orbit period several times. Two most precise measurements were added to the WDS observation history after the Int4 Catalog was "mothballed". Adding these two measurements to the Int4 Catalog measurements while eliminating these before 1979 (two full orbit periods covered should be enough) brought slightly different orbital element values with a dynamical mass of 1.46 with DR2 parallax and 2.61 with the Hipparcos parallax:

Element	Value	-ΔP16/+ΔP84
P	20.065	-0.139/+346.080
A	0.257	-0.000/+1.958
i	78.173	-0.930/+11.198
Node	91.212	-1.445/+0.839
T	1998.447	-19.475/+0.033
e	0.949	-0.025/+0.016
omega	181.588	-3.769/+106.912

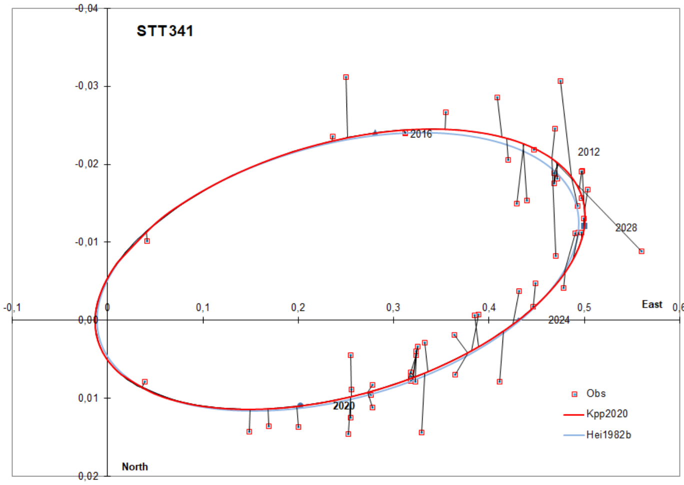
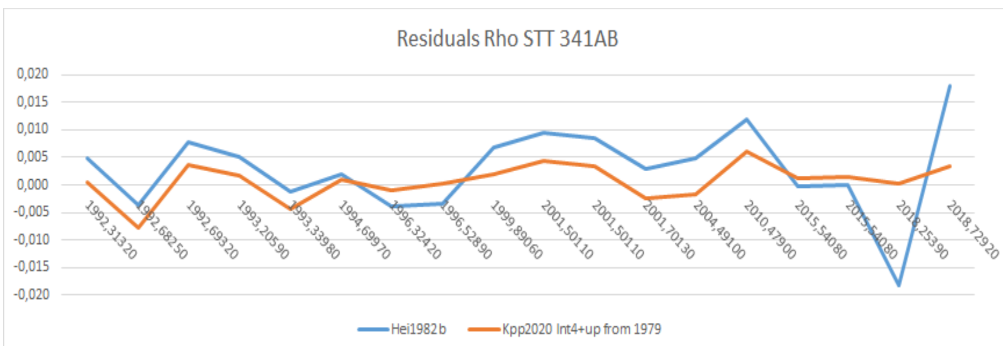


Figure 36. Plot 39: STT 341 orbit comparison (X:Y axis scale 1:10 for better visualization)

This newly calculated orbit offers overall smaller residuals Rho and, above all, covers the last two precise measurements much better than the *Hei1982b* orbit:



Plot 40: STT 341 residuals Rho comparison up from 1992

Finally STT 341 AB,C is listed in the WDS catalog with note code "V" which means potentially physical, yet the DR2 parallax of 24.6453 (EDR3 24.6940) is compared to 30.6946 for A (with the caveat that the DR2 parallax seems somewhat dubious) different enough to suggest that C is most likely an optical component. If AB,C is physical then this would be with an orbit period well over 10,000 years.

DR2 gives no duplicated_source marker for C and RUWE ~1.2 suggests no multiplicity issue. StarHorse median mass is ~0.85 for the combined DR2 object, corresponding well with the estimated component masses given by Tokovinin 2018.

2.60. WDS 02174+6121 (STF 234) – *Sta1983*

The current 6th Orbit Catalog grade 4 entry with a period of ~140 years and a semi-major axis of 0.51 arcseconds is from 1983 although several new observations were added to the WDS catalog since then up to 2012 and there exist GAIA DR2 2015.5 and EDR3 2016.0 measurements so far not included in the observation history. Applying the Izmailov program on the extended observation history results in similar but due to the additional measurements slightly changed orbital element values with a reasonably small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	143.448	-1.634/+1.694
A	0.538	-0.010/+0.009
i	117.855	-1.784/+1.624
Node	65.848	-2.527/+2.464
T	1911.541	-1.557/+1.344
e	0.663	-0.020/+0.026
omega	19.192	-5.700/+5.190

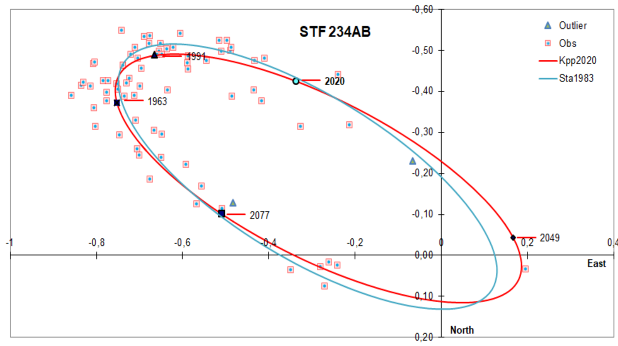


Figure 37. Plot 41: STF 234 orbit comparison

EDR3 parallax for A is 16.5805 (DR2 parallax for A is 25.5 with an unusual large error range) and B is listed in DR2 as well as EDR3 without parallax. Hipparcos parallax for the combined object is 16.91. The StarHorse median mass for A is ~0.85, which suggests estimated ~0.73 for B based on magnitude delta. Cvetkovic et al. 2010 report a system mass of ~1.88 reasonably close to the estimated median system mass value of 1.58. Using the EDR3 parallax results in a dynamical mass of 1.50 for the *Sta1983* orbit and 1.67 for the newly calculated orbit – this looks like a good match for both listed orbits. Residuals Rho root mean square is somewhat better for the newly calculated orbit and *Sta1983* orbit shows a systematic bias for the nine most recent measures.

2.61. WDS 23114-4259 (B 594) – *Nrr1983*

B 594 is listed in the WDS catalog as close binary with 11 observations between 1925 and 1963 and is listed in the 6th Orbit Catalog with a grade 4 orbit published 1983 with a period of 21 years and a semi-major axis of 0.15 arcseconds. B 594 is listed as unresolved in Tokovinin et al. 2014 and meanwhile a declared bogus object with note code "X" in the WDS catalog which means that the listed orbit is also bogus. DR2 parallax is 1.9443 with a large error range, no duplicated_source marker, no StarHorse mass data. EDR3 parallax is 1.6845. The dynamical mass for the Nrr1983 orbit with the given data would be far larger than 1,000 – just another indication that this orbit is obsolete.

2.62. WDS 00462-2214 (RST4155) – *Hei1984a*

The current 6th Orbit Catalog grade 4 entry with a period of 48 years and a semi-major axis of 0.195 arcseconds is from 1984 although several new observations were added to the WDS catalog since then up to 2018. Applying the Izmailov program on the extended observation history results in a period of ~31 years and an obviously very bad match with the observation history. A comparison of the Hei1984a orbit with the observation history made clear that a good part of the measurements is listed with a quadrant issue. The 1991.25 measurement (Hipparcos 1997) with precise magnitudes is the anchor to decide which observations are in need of a quadrant flip, which requires in consequence the overall flip of the currently listed orbit. After correcting these quadrant issues, the result is quite similar to the flipped Hei1984a orbit with minor changes due to the additional observations:

Element	Value	-ΔP16/+ΔP84
P	48.886	-0.662/+0.614
A	0.174	-0.008/+0.010
i	150.921	-9.649/+4.455
Node	15.757	-6.761/+127.680
T	2005.071	-47.734/+0.900
e	0.226	-0.030/+0.034
omega	173.624	-11.655/+127.290

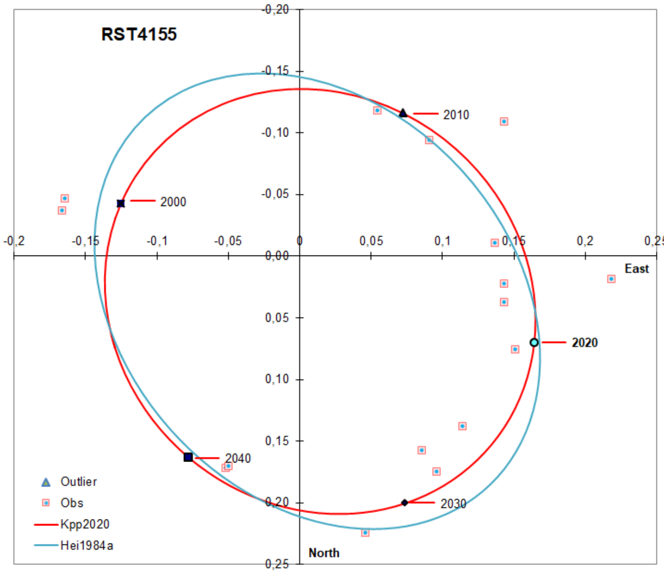
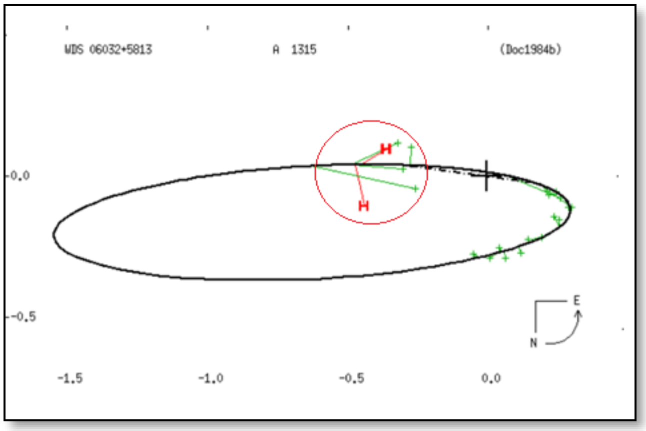


Figure 38. Plot 42: RST4155 orbit comparison (Hei1984a flipped)

The DR2 parallax for the duplicated_source object is 9.2071 with a large error range (no EDR3 parallax, Hipparcos 10.66) and the StarHorse median mass for the combined DR2 object is ~1.16, which allows for a magnitude delta based estimation of the median mass for the primary of 1.01 and of 0.94 for the secondary. Cvetkovic et al. 2010 suggest a system mass of ~1.95 ident with this estimation. The dynamical mass for the Hei1984a orbit with the DR2 parallax is 4.12 and for the newly calculated orbit 2.85 – both values are obviously far off, but the DR2 parallax seems questionable. The dynamical mass values are with the Hipparcos parallax with 2.66 respectively 1.83 reasonable close to the estimated system mass at least for the newly calculated orbit. Residuals Rho root mean square is better for the newly calculated orbit but both orbits show a systematic bias in comparison with the most recent measures.

2.63. WDS 06032+5813 (A 1315) – *Doc1984b (new orbit Doc2020c)*

The current 6th Orbit Catalog grade 5 entry with a period of ~700 years and a semi-major axis of ~2.28 arcseconds is from 1984 although several new observations were added to the WDS catalog since then up to 2016. Using the currently listed orbit on the new measurements since publication suggests a quadrant issue for all these new observations, which seems odd because the magnitudes of the Hipparcos based 1991.25 measurement speak clearly against a quadrant issue. While the 6th Orbit Catalog plot adopts this quadrant proposition automatically the observation history lists all position angles after 1984 without “q” marker – but the match between observations and orbit ephemerides remains poor even after flipping the position angle of the new observations:



Plot 43: A 1315 6th Orbit Catalog plot showing the poor match with the flipped observations after 1984 (red circle)

No DR2 data is available for A 1315, also no StarHorse data. Hipparcos parallax is 6.26 with a huge error range. EDR3 resolves this close pair thus providing an additional observation for 2016.0. No source for reliable mass data found. Estimated system mass based on absolute magnitudes is with the Hipparcos parallax 2.35. The dynamical mass for the *Doc1984c* orbit is 98.16 – obviously not very realistic. There is also a significant bias given for the most recent measures.

I used then the Izmailov program simply with the observation history as given (without correcting any potentially quadrant issues) and got as expected a completely different orbit with a period of ~1,044 years and a semi-major axis of 1.305 arcseconds. The huge spread in the orbital element values due to the not very consistent pattern of the observations after 1984 renders this orbit as clearly premature. The dynamical mass for this newly calculated orbit with the Hipparcos parallax is 8.30 – in comparison with the estimated system mass also not very convincing. The set of 200 possible orbits covers the range of dynamical mass around 2.35 very well – a plausible set of orbital element values is the following with a dynamical mass of 2.20:

Element	Value	-ΔP16/+ΔP84
P	729.035	-272.110/+2946.199
A	0.658	-0.030/+5.438
i	58.627	+3.444/+27.995
Node	158.704	-38.731/+8.279
T	1884.328	-21.812/+162.713
e	0.602	-0.024/+0.365
omega	152.815	-68.134/+2.549

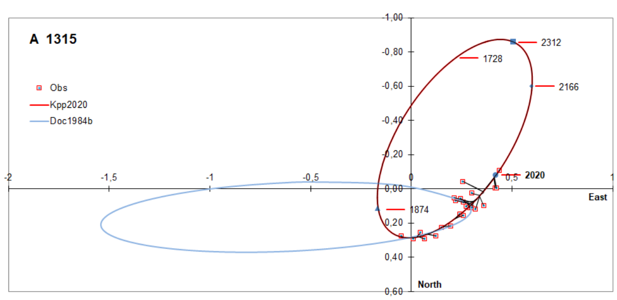


Figure 39. Plot 44: A 1315 orbit comparison

The number of in total 22 measurements so far is certainly too small for the calculation of a realistic if premature orbit for such a long period, more precise measurements as well as more reliable parallax and mass data would be very helpful for re-calculation and evaluation of orbits.

Note: During the work on this paper a new grade 5 orbit Doc2020c has been added to the 6th Orbit Catalog with a period of 600 years, a semi-major axis of 1.135 arcseconds and with the Hipparcos parallax a dynamical mass of 16.56, which seems quite off when compared with the system mass estimations given above. This orbit shows compared to Doc1984b a better match with the measures after 1984 without quadrant flipping but poses a new quadrant issue for the 2016.951 measure. While the match with the flipped 2016.951 measure seems perfect, the Gaia EDR3 magnitudes from the 2016.0 observation do not support this idea. Therefore, I prefer to stick with the newly calculated orbit working well without assuming any quadrant issues at all, which offers also better residuals for Rho than the Doc2020c orbit.

2.64. WDS 15328+1945 (HU 577) – *Cou1984b*

The current 6th Orbit Catalog grade 3 entry with a period of ~112 years and a semi-major axis of 0.285 arcseconds is from 1984 although several new observations were added to the WDS catalog since then up to 2016. Using the currently listed orbit on the observation history suggests a quadrant issue for several measurements. In a first step I applied the Izmailov program on the observation history as given and got a reasonable result but the visual match with the measurements was not fully convincing. Then I flipped the position angle for the measurements in question and got the following updated preliminary orbital element values very close to the Cou1984b calculation with a small error range:

Element	Value	-ΔP16/+ΔP84
P	109.507	-2.265/+1.552
A	0.275	-0.009/+0.004
i	58.982	-1.228/+1.493
Node	41.996	-2.046/+1.632
T	1948.034	-0.557/+0.654
e	0.404	-0.017/+0.017
omega	129.397	-1.971/+2.309

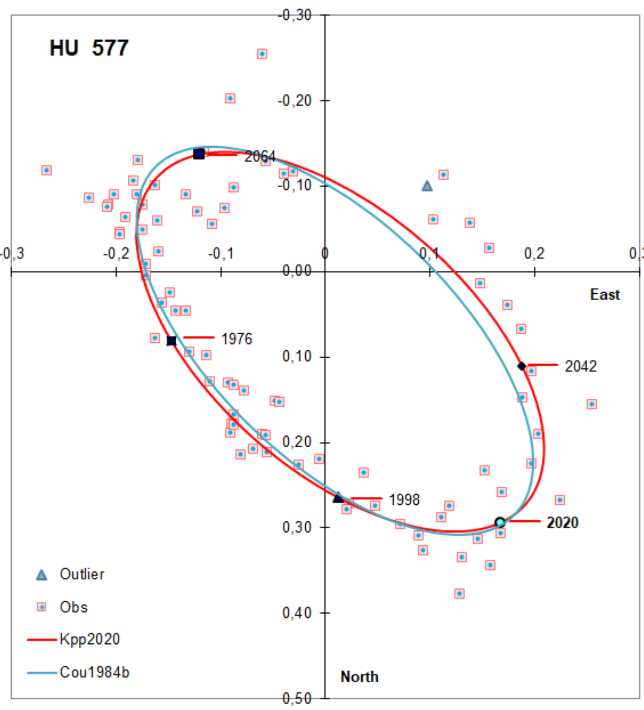


Figure 40. Plot 45: HU 577 orbit comparison with quadrant corrections

No DR2 data available, also no StarHorse data. No EDR3 parallax. Hipparcos parallax is 11.36 and Malkov et al. 2012 list a photometric system mass of 2.40 and a spectroscopic system mass of 1.20. The dynamical mass of the Cou1984b orbit is 1.25 at the lower end but within this frame. The dynamical mass for the newly calculated orbit is 1.36 – not much of a difference. Residuals Rho root mean square is slightly better for the newly calculated orbit but both orbits show a systematical bias for the seven most recent measurements. The number of high precision measurements is too small to make a separate Int4 Catalog based orbit re-calculation. More precise parallax and mass data as well as new precise measurements would be useful for orbit re-calculation and a better orbit evaluation. For the given orbits the dynamical parallax would be about 9.5 for a dynamical mass near the photometric system mass estimation.

2.65. WDS 19216+5223 (BU 1129) – *Baz1984a*

The current 6th Orbit Catalog grade 3 entry with a period of 121.7 years and a semi-major axis of 0.18 arcseconds is from 1984 although several new observations were added to the WDS catalog since then up to 2016. Using the currently listed orbit on the observation history suggests an obvious quadrant issue for a part of the measurements. Applying the Izmailov program on the expanded observation history resulted in a preliminary orbit with a period of ~129.4 years and a reasonable small spread for all orbital elements but the impression remains that the observation history might be at least in terms of quadrant issues not very reliable.

No DR2 and StarHorse data available. No EDR3 parallax. Hipparcos parallax is 4.87 and Malkov et al. 2012 list a photometric system mass of 3.61 and a spectroscopic system mass of 1.89 with the former corresponding well with the dynamical mass of the *Baz1984a* orbit of 3.41. Absolute magnitude based estimation would give a somewhat larger system mass of ~4.7. The newly calculated orbit suggests a dynamical mass of 48.15, which is obviously far off. The set of 200 possible orbits includes a few entries with dynamical mass in the range ~3.15 with orbital element values listed below as best match:

Element	Value	-ΔP16/+ΔP84
P	126.312	-2.573/+8.669
A	0.179	+0.092/+0.305
i	148.656	-40.935/-24.260
Node	133.527	-57.147/-32.438
T	1972.852	-1.921/+1.340
e	0.923	+0.046/+0.067
omega	333.539	-59.525/-46.837

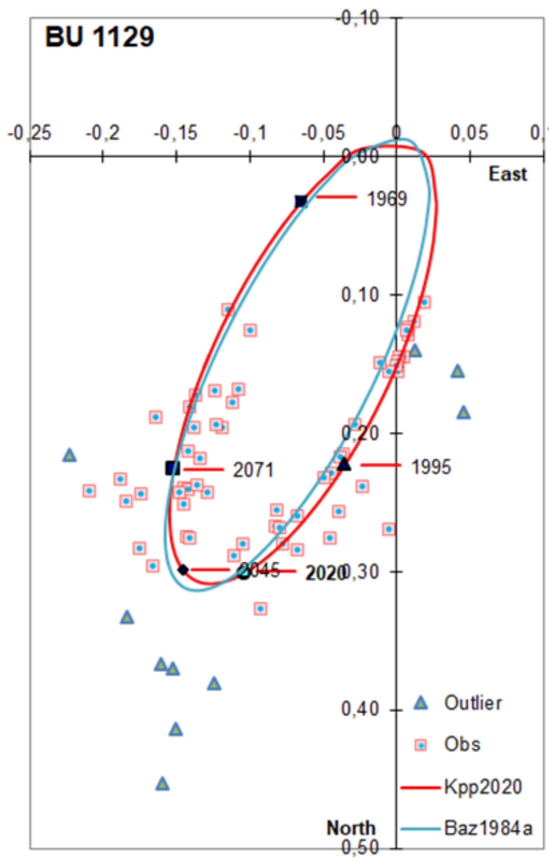


Figure 41. Plot 46: BU 1129 orbit comparison with quadrant corrections

The newly calculated orbit is in terms of residuals Rho RMS slightly better than the *Baz1984a* orbit, but both orbits are not very good matches with the three most recent measurements. There is a reasonably large number of observations listed in the Int4 Catalog but the attempt to get a better result using only these measurements for an orbit calculation led to completely unrealistic orbital element values. More precise parallax and system mass data and new precise measurements would be very helpful for assessing the listed orbits.

2.66. WDS 21510+2911 (A 889) – *Baz1984b*

The current 6th Orbit Catalog grade 3 entry with a period of 20.78 years and a semi-major axis of 0.17 arcseconds is from 1984 although several new observations were added to the WDS catalog since then up to 2007 – looks like a recently neglected WDS object. Applying the Izmailov program on the extended observation history resulted in a very similar if slightly different orbital element values with a very small spread:

Element	Value	-ΔP16/+ΔP84
P	20.682	-0.125/+0.149
A	0.152	-0.005/+0.012
i	33.471	-5.221/+10.809
Node	34.819	-15.073/+36.368
T	1975.358	-21.404/-20.128
e	0.428	-0.048/+0.059
omega	196.943	-48.039/+19.340

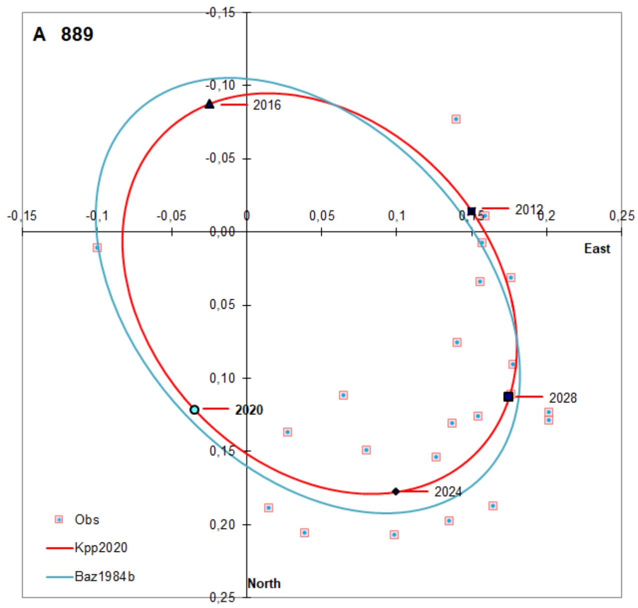


Figure 42. Plot 47: A 889 orbit comparison

DR2 parallax is 17.842 (EDR3 17.7144 and Hipparcos 17.73) without duplicated_source marker and StarHorse median mass for the combined DR2 object is ~0.97 allowing for the magnitude delta based estimation of the median mass for the primary of 0.91 and 0.68 for the secondary. The dynamical mass for the *Baz1984b* orbit is 2.0 and for the newly calculated orbit 1.44 – the latter not a perfect match but at least quite close to the estimated median system mass of 1.58. Residuals root mean square are somewhat better for the newly calculated orbit. New precise measurement would be highly appreciated for orbit re-calculation.

2.67. WDS 04159+3142 (STT 77) – *Sta1985*

The current 6th Orbit Catalog grade 3 entry with a period of ~188 years and a semi-major axis of 0.549 arcseconds is from 1985 although several new observations were added to the WDS catalog since then up to 2015. Applying the Izmailov program on the extended observation history resulted in a very similar if slightly enhanced orbital values supported by a very small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	188.885	-2.838/+2.686
A	0.566	-0.009/+0.007
i	56.969	-0.924/+1.313
Node	75.155	-1.677/+1.794
T	1886.350	-1.527/+1.340
e	0.426	-0.015/+0.016
omega	29.710	-4.315/+4.173

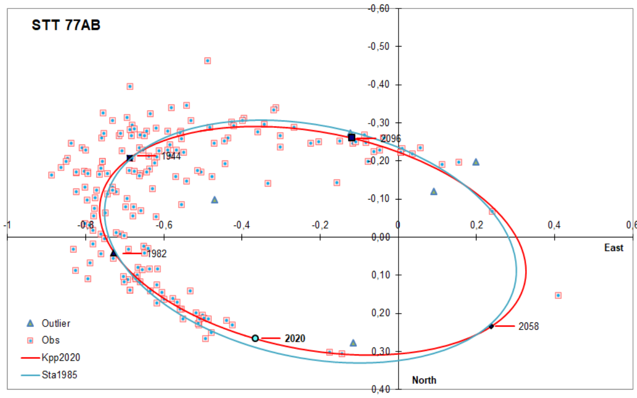


Figure 43. Plot 48: STT 77 orbit comparison

The newly calculated orbit has a small advantage in terms of residuals root mean square. No DR2 and StarHorse data available. EDR3 combined object without parallax. Hipparcos parallax is 9.85 with a huge error range. Malkov et al. 2012 report a photometric system mass of 2.97 and a spectroscopic mass of 1.1. The dynamical mass for the *Sta1985* orbit is 4.9 and for the newly calculated orbit 5.31 – both values seem off and the set of 200 possible orbits does not offer much choice in terms of dynamical mass below 3. Dynamical parallax for a dynamical mass close to an estimated system mass of ~3 would be ~12. The Int4 Catalog lists a reasonably large number of observations but covers only an insignificant part of the assumed orbit period – these precise measurements are for this reason of little help for calculating a more reliable preliminary orbit. More precise measurements as well as more reliable parallax and mass data would be required for the calculation and evaluation of a more reliable orbit.

2.68. WDS 14135+1234 (BU 224) – *Lin1985c*

The current 6th Orbit Catalog grade 4 entry with a period of ~251.6 years and a semi-major axis of 0.6 arcseconds is from 1985 although several new observations were added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history results in a slightly shorter period with else similar orbital element values with a reasonable small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	230.510	-16.938/+14.467
A	0.561	-0.026/+0.022
i	120.299	-1.306/+1.301
Node	81.840	-1.379/+1.153
T	1967.633	-0.576/+0.637
e	0.625	-0.023/+0.017
omega	188.615	-2.132/+1.703

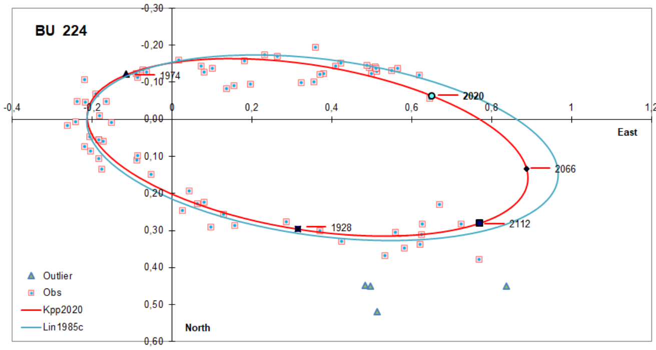


Figure 44. Plot 49: BU 224 orbit comparison

No DR2 and StarHorse data available. EDR3 parallax for A is 10.8153, no parallax for B. Hipparcos parallax is 10.01 with a large error range. No source for mass data found. System mass estimation based on absolute magnitude is (with the EDR3 parallax) 2.26. The dynamical mass for the *Lin1985c* orbit is 2.72 and for the newly calculated orbit 2.65 – both values are close to the estimated system mass. The newly calculated orbit is in terms or residuals Rho root mean square somewhat better than the *Lin1985c* orbit, which shows for the measures from 1994 to 2011 a systematic bias. The EDR3 2016.0 measure is for both orbits not a perfect match, while the 2016.327 measure fits well. The set of 200 possible orbits offers for dynamical masses a spread from 2.13 to 2.99. More precise parallax and mass data as well as new precise measurements would be valuable for orbit re-calculation and evaluation.

2.69. WDS 00048+3810 (BU 862) – *Cou1986b*

The current 6th Orbit Catalog grade 4 entry with a period of 403 years and a semi-major axis of 0.74 arcseconds is from 1986 although several new observations were added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history (including an additional GAIA DR2 measurement) results in a preliminary orbit with a period of ~532 years and orbital element values with a large spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	532.195	-141.594/+75.747
A	0.843	-0.131/+0.075
i	37.199	-0.706/+3.567
Node	34.205	-9.034/+4.365
T	1945.605	-0.723/+0.505
e	0.748	-0.062/+0.020
omega	213.053	-5.281/+9.332

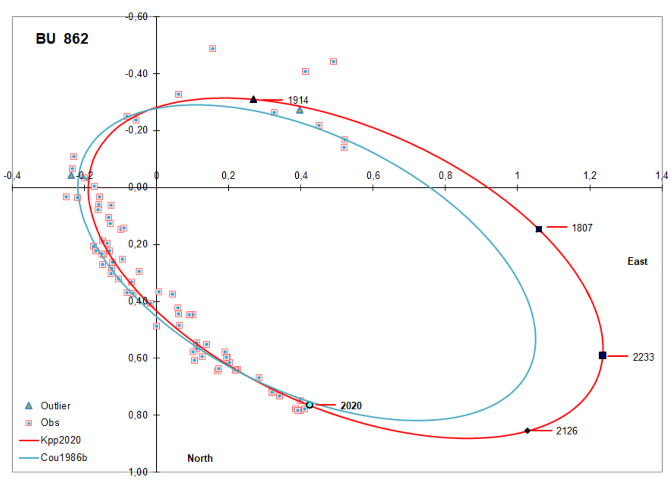


Figure 45. Plot 50: BU 862 orbit comparison

The DR2 parallaxes are 11.2651 und 12.6173 (the latter with a large error range) but no StarHorse mass data is available and I looked in vain for other sources for mass data. EDR3 parallaxes are 10.9449 and 10.9924 with a reasonable small error range. Hipparcos parallax is 10.81 – just another case with Hipparcos more precise than DR2. Absolute magnitude based mass estimation gives ~0.92/0.88 for A/B means a system mass of ~1.8. The dynamical mass using the average EDR3 parallax is 1.91 for the *Cou1986b* orbit and 1.61 for the newly calculated orbit, which means that both orbits dynamical masses are close to the estimated system mass. The newly calculated orbit is a bit better in terms of residuals Rho root mean square but both orbits are interestingly no good matches with the Gaia measures 2015.0/2015.5/2016.0.

The different DR2 parallax and proper motion values suggest only a tiny likelihood for gravitational relationship and the large parallax error range for the secondary causes a huge spread in the possible spatial distance between the components. This picture changes quickly with the EDR3 values with a likelihood of 76% for potential gravitational relationship with a minimum circular orbit period of 544 years. This matches better with the pattern of the measurements indicating a systematic change of position angle and angular separation over time, which suggests very well an orbit.

2.70. WDS 03480+6840 (KUI 13 BC) – *Baz1986a*

The current 6th Orbit Catalog grade 5 entry with a period of 44.21 years and a semi-major axis of 0.44 arcseconds is from 1986 with two new observations added to the WDS catalog since then up to 1991. Both of them are questionable measurements based on Hipparcos 1997 with the second one a revision (Fabricius and Makarov 2000) – this suggests that KUI 13 BC is a very neglected WDS object. Applying the Izmailov program on the observation history extended with the revised Hipparcos measure results in a slightly changed but similar orbit with a small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	42.895	-0.745/+0.719
A	0.585	-0.048/+0.054
i	126.539	-6.811/+5.222
Node	56.609	-9.744/+5.430
T	1983.242	-42.067/+0.566
e	0.575	-0.048/+0.051
omega	45.633	-10.800/+7.859

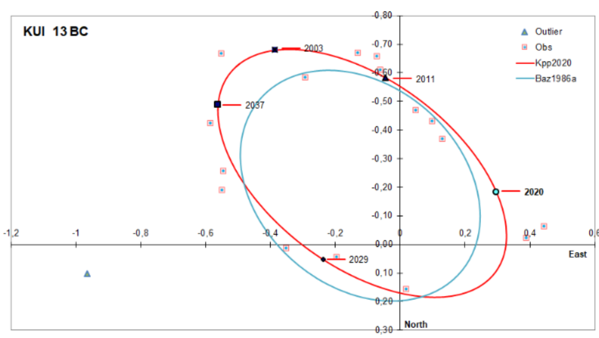


Figure 46. Plot 51: KUI 13 BC orbit comparison

DR2 parallax for the unresolved BC object is 52.3391 (with a large error range) with a duplicated-source marker but no StarHorse mass data is available. EDR3 parallax for the unresolved BC object is 55.9837 with a moderate error range. Hipparcos parallax is 42.45. Absolute magnitudes based on the EDR3 parallax values suggest an estimated system mass of ~0.66. Dynamical mass for the *Baz1986a* orbit is 0.25 and for the newly calculated orbit 0.62 – close to the estimated system mass. Residuals Rho RMS is much better for the newly calculated orbit but worse for Theta. The 1991.25 measure is for both orbits a bad match. New precise measurements would be very valuable for orbit re-calculation.

The WDS catalog lists several other components for this object with rectilinear solutions suggesting all of them but A are optical. The GAIA DR2 data does not offer much support that KUI 13 A,BC might be physical because the difference of the parallax values suggests an only tiny likelihood for gravitational relationship – but as already mentioned BC is not resolved in DR2, the parallax error range is large and StarHorse gives no data for this component. Together this suggests that the DR2 data for BC is not very reliable and that conclusions based on DR2 data seem premature. EDR3 parallax data confirm this impression by allowing for 100% likelihood for gravitational relationship.

Applying the Izmailov program on the observation history of KUI 13 A,BC results in a premature orbit with a period of 1.640 years and a semi-major axis of 26.5 arcseconds with a huge spread in all orbital element values. Closer analysis shows that the data evidence for this premature orbit is weak but the measurements seem indeed to indicate some curvature than a simple rectilinear development over time.

EDR3 parallax values are 55.8254 and 55.9837, StarHorse median mass for A is ~0.58 and system mass estimation for BC based on absolute magnitudes is 0.66 suggesting for A,BC a median system mass of 1.24. The dynamical mass for the calculated premature orbit is with ~40 far off. The set of 200 possible orbits starts with a dynamical mass of 1.87, which is about 50% more than expected. Together this suggests that this orbit is not only premature but also “not really necessary”.

2.71. WDS 04076+3804 (STT 531) – *Hei1986b*

The current 6th Orbit Catalog grade 5 entry with a period of 590 years and a semi-major axis of 3.87 arcseconds is from 1986 although several new observations were added to the WDS catalog since then up to 2018. STT 531 is according to GAIA DR2 data a binary in the solar neighborhood (with a distance of ~21 parsecs) with a minimum spatial distance of 59 AU giving with the StarHorse median masses of ~0.89/0.53 a minimum orbital period of 382 years. EDR3 confirms the DR2 parallax value for A but lists no object for B. Applying the Izmailov program on the extended observation history results in a significant longer period of ~1,247 years if with noticeable spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	1247.026	-806.345/+30.057
A	6.195	-1.015/+1.398
i	100.707	-5.886/+0.190
Node	156.054	-2.240/+2.466
T	1921.726	-171.694/+213.960
e	0.219	-0.047/+0.521
omega	78.316	+3.050/+210.795

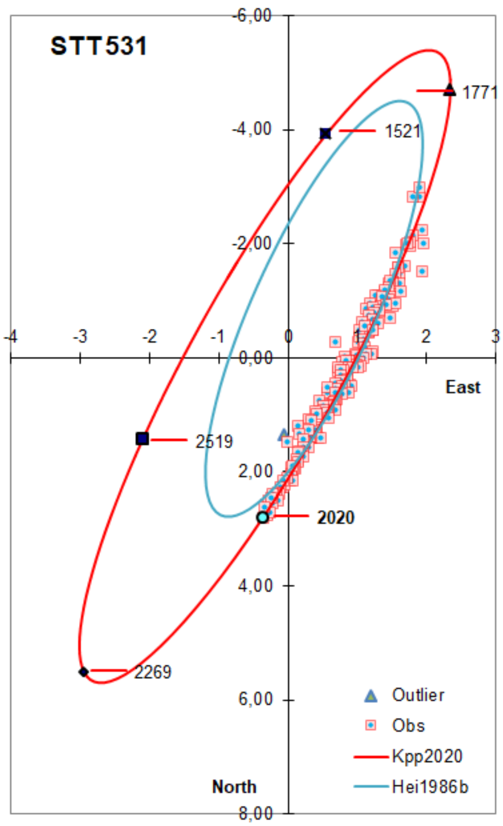
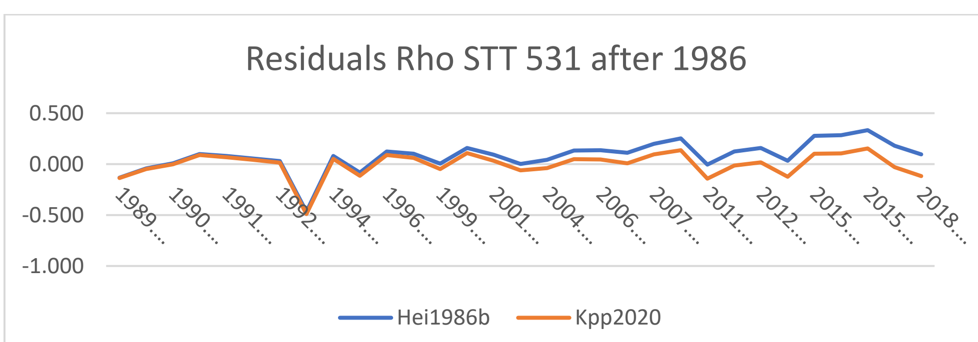


Figure 47. Plot 52: STT 531 orbit comparison

The far better match of the newly calculated orbit with the most recent measurements is visually obvious even without close-up.

DR2 parallaxes are 47.2101 and 47.1305 (Hipparcos 49.06 and EDR3 47.3250 for A) and StarHorse median masses are ~0.89/0.53. The dynamical mass based on the average parallax is for the *Hei1986b* orbit 1.59 and for the newly calculated orbit 1.46 – this is surprisingly close to the StarHorse value and suggests that the newly calculated orbit might be despite the long period and large spread much better than anticipated. *Heintz 1986b* lists a parallax of 48 and a dynamical mass of 1.5 with both values close to the DR2 and StarHorse data but the *Hei1986b* orbit ephemerides for the last 20 measurements are especially for the angular separation systematically too small, which renders this orbit obsolete.



Plot 53: Residuals Rho STT 531 after 1986

Overall the STT 531 observation history is despite the large number of measurements certainly too short for the calculation of a reliable preliminary orbit with such a long period.

2.72. WDS 05384+4301 (A 1563) – *Cou1986b*

The current 6th Orbit Catalog grade 4 entry with a period of 120 years and a semi-major axis of 0.166 arcseconds is from 1986 with only one new observations added to the WDS catalog in the year 1988 – A 1563 is obviously a neglected WDS object. Applying the Izmailov program on the "extended" observation history results in an orbit with a period of 100 years and a semi-major axis of 0.228 arcseconds with a large spread in the set of 200 possible orbits due to the small number of observations.

DR2 parallax is with 0.1789 extremely small with a huge error range of 0.6437 larger than the parallax itself. No duplicated_source marker is given, so DR2 does not support the proposition that A 1563 is a multiple. StarHorse median mass for the combined DR2 object is 3.17 suggesting an estimated median system mass of ~5.3 based on magnitude delta of zero.

No Hipparcos parallax given. EDR3 parallax is 4.4669 with a large error range of ~0.3 with duplicated_source marker and RUWE >13 – overall a confusing situation. Absolute magnitude based system mass estimation using the EDR3 parallax is ~3.4.

Using the EDR3 parallax for the *Cou1986b* orbit gives a dynamical mass of 3.59 close to the estimated system mass. The residuals for Rho as well as Theta are slightly better for the newly calculated orbit but the dynamical mass of 13.34 is obviously off. The set of 200 possible orbits includes several entries with a dynamical mass near the estimated system mass. The best match with still slightly better residuals Rho RMS comes with a dynamical mass of 3.15 with the following orbital element values:

Element	Value	-ΔP16/+ΔP84
P	128.656	-34.643/+38.137
A	0.166	-0.002/+0.268
i	110.373	-16.324/+5.086
Node	103.601	-7.271/-0.068
T	1994.052	-4.051/+2.698
e	0.333	-0.074/+0.587
omega	54.112	-5.503/+34.524

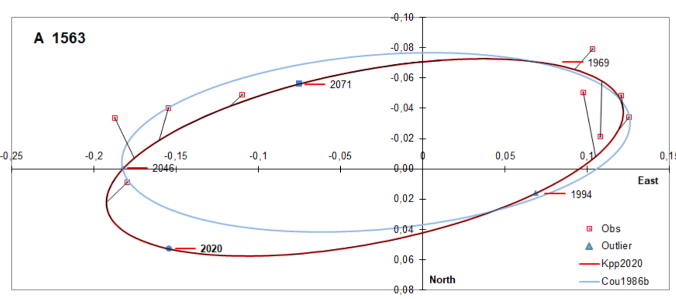


Figure 48. Plot 54: A 1563 orbit comparison

Whether this newly calculated orbit is "really necessary" is questionable but the lack of a significantly extended observation history makes clear, that new precise measurements are needed for orbit re-calculation and orbit assessment. The fact that A 1563 has not been successfully observed for over 30 years potentially suggests even a bogus object but the EDR3 duplicated_source marker supports that A 1563 is indeed a binary.

2.73. WDS 06041+2316 (KUI 23) – *Hei1986b*

The current 6th Orbit Catalog grade 2 entry with a period of 13.35 years and semi-major axis of 0.198 arcseconds is from 1986 with several observations added to the WDS catalog since then up to 2008, which suggests a recently neglected WDS object.

Applying the Izmailov program on the extended observation history results in a very similar orbit with only a tiny spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	13.374	-0.016/+0.017
A	0.198	-0.002/+0.001
i	59.004	-0.616/+0.700
Node	174.910	-0.936/+0.845
T	1982.362	-0.060/+0.064
e	0.363	-0.006/+0.007
omega	199.126	-2.154/+2.002

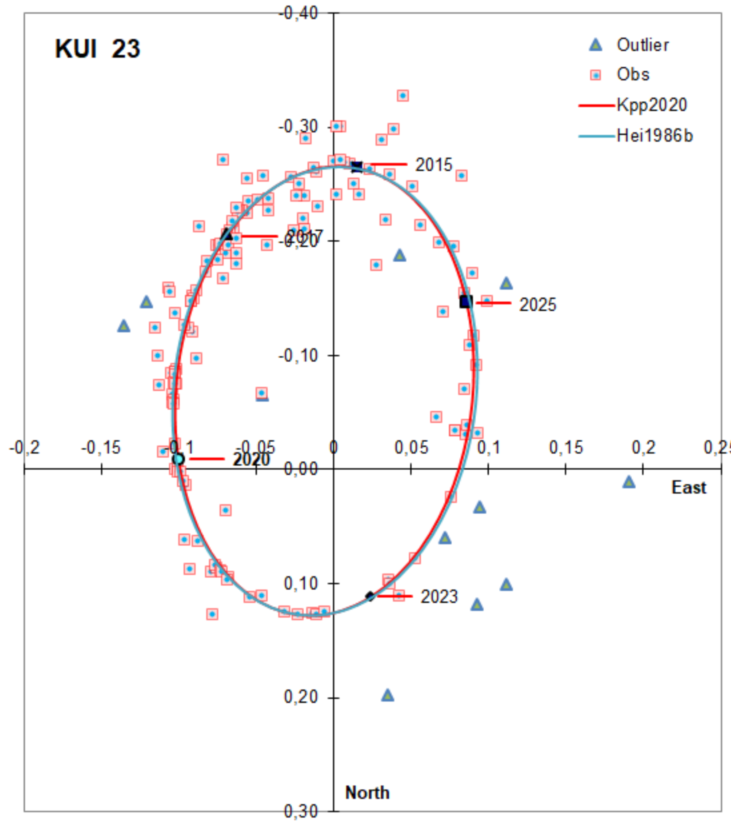


Figure 49. Plot 55: KUI 23 orbit comparison

Not much difference is to see in this plot between the listed orbits. The observation history covers about 70 years, which means about 5 times the assumed orbit period and the measurements seem to be with the exception of a few outliers of good quality.

No DR2 parallax, no duplicated_source marker, no StarHorse mass data, no EDR3 parallax. Hipparcos parallax is 21.03. No other source for mass data found, even Heintz 1986b gives no value. Absolute magnitude based estimation suggests a median system mass of ~4.1. The dynamical mass for both listed orbits parallax is ~4.7 based on the Hipparcos data, which is not a perfect match with the estimated system mass, but close. Both orbits are similar in terms of residuals Theta and Rho with a tiny advantage for the re-calculated orbit and the matches with the most recent measurements are beginning with 2000 nearly perfect. The set of 200 possible orbits offers only a small spread also for the dynamical mass. The given error range for the orbital element values is most likely the greatest advantage for the newly calculated orbit. Still more precise parallax and mass data would be valuable for orbit assessment.

The primary of KUI 23 is listed in the SB9 catalog as system 377 with a grade 4 (means close to definitive) orbit with a period of ~9.6 days published 1976. This means that KUI 23 is a triple system, which leads to a slightly larger system mass estimation for KUI 23 closing the above-mentioned gap between the dynamical and the estimated system masses most likely even more.

2.74. WDS 06455+2922 (A 122) – *Baz1986a (new orbit SCA2020d)*

The current 6th Orbit Catalog grade 4 entry with a period of 100 years and a semi-major axis of 0.328 arcseconds is from 1986 with several observations added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history results in very similar orbital element values with a small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	98.759	-2.030/+2.303
A	0.321	-0.012/+0.010
i	115.275	-2.482/+2.393
Node	38.161	-2.905/+2.036
T	1977.505	-1.007/+0.945
e	0.624	-0.023/+0.024
omega	225.101	-5.304/+3.737

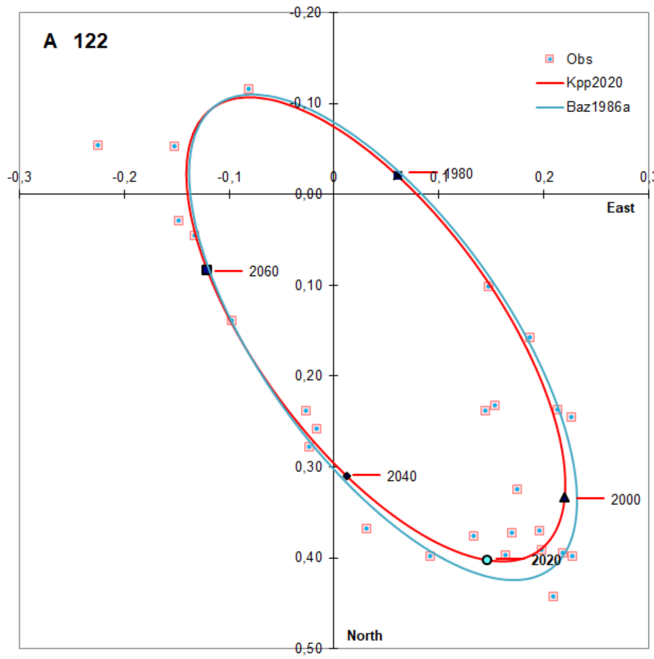


Figure 50. Plot 56: A 122 orbit comparison

No DR2 or EDR3 parallax for this duplicated_source object, no StarHorse mass data. Hipparcos parallax 12.98 with a large error range, no mass data source found. Absolute magnitude based estimation results in a system mass of 2.06. Dynamical mass for the *Baz1986a* orbit with the Hipparcos parallax is 1.61 and for the newly calculated orbit 1.54. Both values look reasonably close to the estimated system mass but more precise parallax and mass data would be necessary to check if the dynamical mass of the listed orbits corresponds well with reliable mass data sources. The newly calculated orbit is in terms of residuals Theta and Rho RMS better than the *Baz1986a* orbit.

Note: Meanwhile a new orbit Sca2020d is listed in the 6th Orbit Catalog with a period of 103.2 years and a semi-major axis of 0.334 arcseconds, which corresponds with a dynamical mass of 1.64. The Sca2020d orbit has a tiny advantage in terms of residuals Theta RMS but the newly calculated orbit is still better in terms of residuals Rho RMS and Sca2020d does not give an error range for the orbital element values.

2.75. WDS 12520-2648 (B 234) – *Hei1986a*

The current 6th Orbit Catalog grade 5 entry with a period of 122 years and a semi-major axis of 0.357 arcseconds is from 1986 with two observations added to the WDS catalog since then up to 2017. Two measurements from 1976.131 and 1979.21 have accordingly to the currently listed orbit flipped position angles – missing magnitudes in these observations make it hard to argue against this.

Applying the Izmailov program on the extended observation history with two mentioned measurements flipped results in very similar orbital element values with a period of 125 years and a semi-major axis of 0.35 arcseconds if with some spread.

No DR2 object, no StarHorse mass data. EDR3 parallax for the combined object is 15.4695 with a reasonable error range but without duplicated_source marker. RUWE ~4.8 indicates some data quality troubles. No Hipparcos parallax.

Heintz 1986a suggests a dynamical mass of 1.7 based on a parallax value of 12 given without reference or explanation. The EDR3 parallax results in a dynamic mass of 0.83 for the *Hei1986a* orbit and of 0.73 for the newly calculated orbit. Absolute magnitude based estimation of system mass using the EDR3 parallax is 1.45, which is a poor match with both dynamical masses. The newly calculated orbit has a slightly better residuals Rho RMS value but this seems irrelevant because the set of 200 possible orbits provides a median mass of 0.78 and ends with a dynamical mass of 1.29 as an outlier – this means the area around 1.45 is not even covered.

However, the observation history seems anyway too small for the calculation of a realistic orbit and the availability of new more precise measurements would be valuable for orbit re-calculation.

2.76. WDS 12579+4948 (HU 641) – *Erc1986c*

The observation history of HU 641 is with so far 8 measurements small with the two last results marked as “uncertain/estimated”. Six additional observations listed in the WDS observation history failed due to non-resolution several of them with an estimated separation <0.1”. The current 6th Orbit Catalog grade 5 entry with a period of ~323 years and a semi-major axis of 0.366 arcseconds is from 1986 with only one observation added to the WDS catalog since then from 2007 – so this is a neglected WDS object. Two measurements from 1974.34 and 1980.3 have accordingly to the currently listed orbit flipped position angles – missing magnitudes in these observations make it hard to argue. The *Erc1986b* orbit ephemerides come never below or even near to the 0.1” separation as suggested by the failed measurements mentioned above.

To calculate orbital element values from such a small number of observations partly of obviously poor quality seems very optimistic to me and the calculated separation for the “new” (if as questionable marked) 2007 observation is a very bad match with the measurement. Applying the Izmailov program on the given observation history with the mentioned two observations flipped results in an only slightly different premature orbit with a period of 310 years and a semi-major axis of 0.336 arcseconds offering a better match with the additional observation. The small number of observations comes with the price of a large spread in the set of 200 possible orbits.

DR2 parallax for the combined object without duplicated_source indication is 0.6701. EDR3 parallax for the combined object is 0.6567 with a very small error range, also without duplicated_source marker and RUWE ~1 indicates good data quality. No Hipparcos parallax.

StarHorse median mass for the combined DR2 object is ~1.35 allowing for a magnitude delta based median system mass estimation of 2.27. This value is quite close to the mass estimation of 2.44 given by Erceg and Olevic 1986 corresponding with a dynamical parallax of ~6. Absolute magnitude based system mass estimation with the EDR3 parallax gives as to expect a much larger value of ~7. Dynamical mass for the *Erc1986b* orbit with the EDR3 parallax is 1,668 and for the newly calculated orbit 1,400 – both values are obviously far off. The dynamical mass data in the set of 200 possible orbits comes despite a large spread in values nowhere near the estimated median system mass values.

The given observation history is simply not a solid basis for calculating a realistic "premature" orbit, so that orbit is not "really necessary" in my opinion. The Erceg and Olevic 1986 paper does not give an explanation why this should be considered otherwise.

2.77. WDS 20205-2749 (RST3255) – *Hei1986a*

The observation history of RST3255 is with so far 9 measurements small. The current 6th Orbit Catalog grade 4 entry with a period of 45.7 years and a semi-major axis of 0.217 arcseconds is from 1986 with only two observations added to the WDS catalog since then up to 2018. To calculate orbital element values from such a small number of observations seems very optimistic to me and the orbit ephemerides for the two "new" observations are a very bad match with the measurements considered most precise. Applying the Izmailov program on the given observation history results with a period of ~53 years in a slightly different orbit with a better match with the additional observations. However, it is clear, that any new measurements will most likely change the calculation significantly even if the spread in the set of 200 possible orbits is despite the small number of observations surprisingly small:

Element	Value	-ΔP16/+ΔP84
P	52.829	-2.697/+3.675
A	0.174	-0.012/+0.023
i	54.658	-6.240/+13.566
Node	92.337	-10.849/+10.923
T	1954.522	-2.059/+14.178
e	0.199	-0.096/+0.149
omega	119.997	-22.246/+18.859

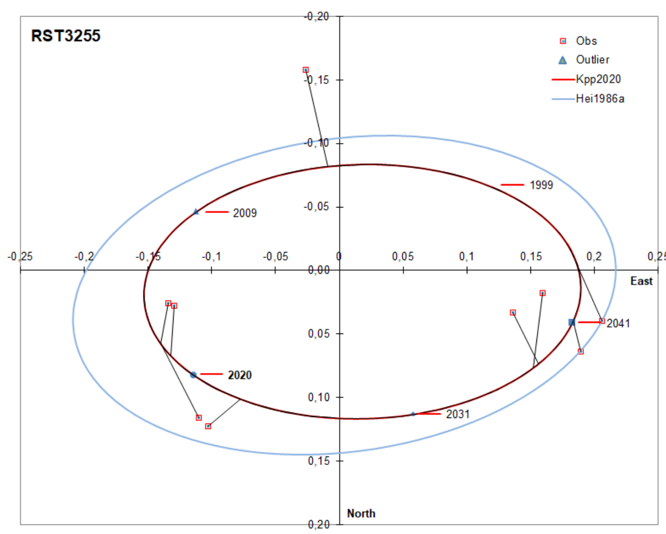


Figure 51. Plot 57: RST3255 orbit comparison

The newly calculated orbit is in terms of residuals (especially Theta but also Rho) a better match with the observation history than the *Hei1986a* orbit.

DR2 parallax for combined object without duplicated_source indication is 5.3729 with a large error range. No EDR3 parallax, no Hipparcos parallax. StarHorse median system mass for the combined DR2 object is ~1.08 allowing for a magnitude delta based estimation of the median system mass of 1.82. RUWE >13 suggests DR2 data quality issues. Absolute magnitude based system mass estimation with the DR2 parallax is 2.3. Heintz 1986a lists for RST3255 a dynamical mass of 1.3 – but this value is based on an obviously wrong parallax of 15. On the other hand, the DR2 parallax does not seem very trustworthy either.

Dynamical mass for the *Hei1986a* orbit with the DR2 parallax is 31.54 and for the newly calculated orbit 12.15 – both values are obviously far off. The dynamical mass data in the set of 200 possible orbits comes despite a large spread in the orbital element values nowhere near the estimated median system mass value. The given observation history is as it seems obviously not suited for the calculation of a preliminary orbit of reasonable quality and the available parallax and mass data seem of questionable quality.

Nearby Gaia DR2 object source_id 6846141933833768192 with a minimum spatial distance of 890 AU might be with a small likelihood part of this system.

2.78. WDS 23328-1645 (VOU 28 BC) – *Hei1986b*

This is a curious WDS object without an A component. The current 6th Orbit Catalog grade 4 entry with a period of 28.2 years and a semi-major axis of 0.59 arcseconds is from 1986 with four observations added to the WDS catalog since then up to 2018. The observation history does not look very solid, one observation is flipped (2001.8497) and another one (1962.68) is an obvious outlier eliminated before applying the Izmailov program on the extended observation history with the following slightly changed result with again a surprisingly small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	27.446	-0.260/+0.222
A	0.750	-0.047/+0.069
i	89.697	-1.469/+1.432
Node	177.938	-3.162/+0.876
T	1999.041	-27.945/-23.038
e	0.264	-0.193/+0.128
omega	286.148	-171.701/+6.874

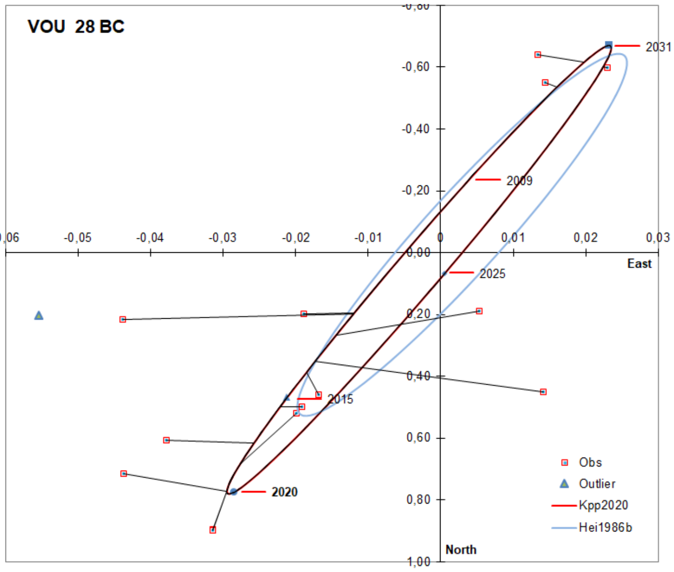


Figure 52. Plot 58: VOU 28 BC orbit comparison

The newly calculated orbit is in terms of residuals much better than the Hei1986b orbit but the visual impression is not very convincing – be aware that the scale in the X-axis is different from the Y-axis by a factor 20, else the orbit would be due to the ~90° inclination reduced to a nearly straight line.

DR2 combined object listed with duplicated_source marker but without parallax data, no StarHorse mass data. Hipparcos parallax is 5.16 with a curious large error range. Resolved in EDR3 with Theta 356.43° and Rho 0.607” for date 2016.0 but without parallax data. No source for mass data found. Absolute magnitude based estimation of the system mass with the Hipparcos parallax is 2.05. Dynamical mass for the *Hei1986b* orbit with the Hipparcos parallax is 1,880 and for the newly calculated orbit 4,094 – both values are clearly far off. Heintz 1986b lists in table 1 a dynamical mass of 1 without giving a parallax but mentions in the text values of either 59 or 63 – the difference to Hipparcos is simply too large to consider these values as realistic.

The given observation history is obviously not suited for the calculation of a realistic preliminary orbit. Additionally more reliable parallax and mass data would be necessary for the evaluation of orbits.

2.79. WDS 01345+3440 (A 1913) – *Baz1987d*

The current 6th Orbit Catalog grade 4 entry with a period of 111.21 years and a semi-major axis of 0.29 arcseconds is from 1987 with several observations added to the WDS catalog since then up to 2009. EDR3 provides an additional measurement for 2016.0 with a position angle of 303.096° and an angular separation of 0.41232”. All new measurements are a bad match with the corresponding orbit ephemerides. The currently listed orbit suggests for about half of the measurements flipped position angles. Applying the Izmailov program on the extended observation history with the mentioned position angles flipped results in a quite different orbit with a period of 253 years and a semi-major axis of 0.53 arcseconds offering a much better match with the additional measurements since 1987.

The visual impression of the orbit plot is not very convincing, but the newly calculated orbit is clearly a far better match with the new measurements after 1987 with overall much smaller residuals than *Baz1987d*.

Missing DR2 object means no DR2 parallax and no StarHorse mass data. Hipparcos parallax is 4.73 with a huge error range. No source for mass data found. Absolute magnitude based estimation of the system mass is 2.45. Using the unreliable Hipparcos parallax gives for the *Baz1987d* orbit a dynamical mass of 18.63 and for the newly calculated orbit of 22.01 – both values are far off. Both orbits show a systematic bias in the most recent seven measurements and the large spread of the newly calculated orbital element values reinforces the impression that both orbits may not be “really necessary”.

More precise parallax and mass data as well as new precise measurements would be very valuable for a better assessment of orbit quality. The quality and size of the observation history do not appear to be suitable for calculating a reasonable premature orbit.

2.80. WDS 15071-0217 (A 689) – *Baz1987d*

The current 6th Orbit Catalog grade 4 entry with a period of 66 years and a semi-major axis of 0.31 arcseconds is from 1987. *Baz1987d* provides a less than perfect match with the six observations added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation history (with the 1937.47 measurement flipped as suggested by *Baz1987d*) results in a similar orbit period of 67.6 years but a very different semi-major axis of 1 arcsecond with a huge spread.

The XY-pattern of the measurements looks like a swarm of bees. The measurement errors in angular separation and position angle are for such small separations unavoidable in relation to the "true" values relatively large with values jumping back and forth around the assumed orbit.

No DR2 object means no DR2 parallax and no StarHorse mass data. Combined EDR3 object parallax is 12.3088 with a large error range, no duplicated_source marker, RUWE >25 indicates data quality issues. Hipparcos combined object parallax 14.45 with a large error range.

No source for mass data found. Absolute magnitude based estimation of system mass with the EDR3 parallax is ~2.5. Using EDR3 parallax gives for the *Baz1987d* orbit a dynamical mass of 3.67 not too far from the estimated system mass. The dynamical mass for the newly calculated orbit is >100 – this value is obviously completely off and makes the newly calculated orbit obsolete. The set of 200 possible orbits covers dynamical mass values down to 0.5 due to the huge spread in the semi-major axis. One entry with very similar orbital element values to *Baz1987d* comes with a dynamical mass of 2.79 closest to the estimated system mass of 2.5 but suggests that also the 1934.54 observation should be flipped, which seems a bit suspect. This newly calculated orbit with a period of ~67 years and a semi-major axis of ~0.29 arcseconds is in terms of residuals slightly better than the *Baz1987d* orbit but both orbits have the mentioned problem with a very bad match with the measurements 1989.3081 and 1993.3479 with Theta differences beyond any plausible measurement error. There might be a problem with the quality of the measurements 1989.3081 and 1993.3479 despite the large apertures of 6 and 4m used even if listed in the Int4 Catalog, but this needs good arguments currently not available to me. This means in my opinion that both orbits are not "really necessary".

Overall, the quality of the observation history seems not very convincing – just minimizing the RMS error value is obviously not sufficient to come close to a realistic if preliminary orbit providing together with reliable parallax data a realistic dynamical mass value. More precise parallax and mass data as well as new precise measurements would be very valuable for orbit re-calculation and a better evaluation of orbit quality.

2.81. WDS 18428+5938 (STF2398) – *Hei1987b*

Already discussed in Knapp 2020 as binary in the solar neighborhood but without orbit re-calculation. The current 6th Orbit Catalog grade 4 entry with a period of 408 years and a semi-major axis of 13.88 arcseconds is from 1987 although many new observations were added to the WDS catalog since then up to 2018. The most recent published orbit (Izmailov 2019) with a period of ~650 years is so far not included in the 6th Orbit Catalog. Applying the Izmailov program on the extended observation history (including the EDR3 measure and an additional own recent measurement date 2019.72526) results in a somewhat longer period of ~728 years with a large but reasonable spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	728.143	-269.708/+119.319
A	19.708	-4.561/+2.073
i	71.310	-3.185/+0.761
Node	143.257	-5.464/+0.910
T	1788.639	-18.550/+30.405
e	0.313	+0.014/+0.198
omega	286.433	-42.466/+15.997

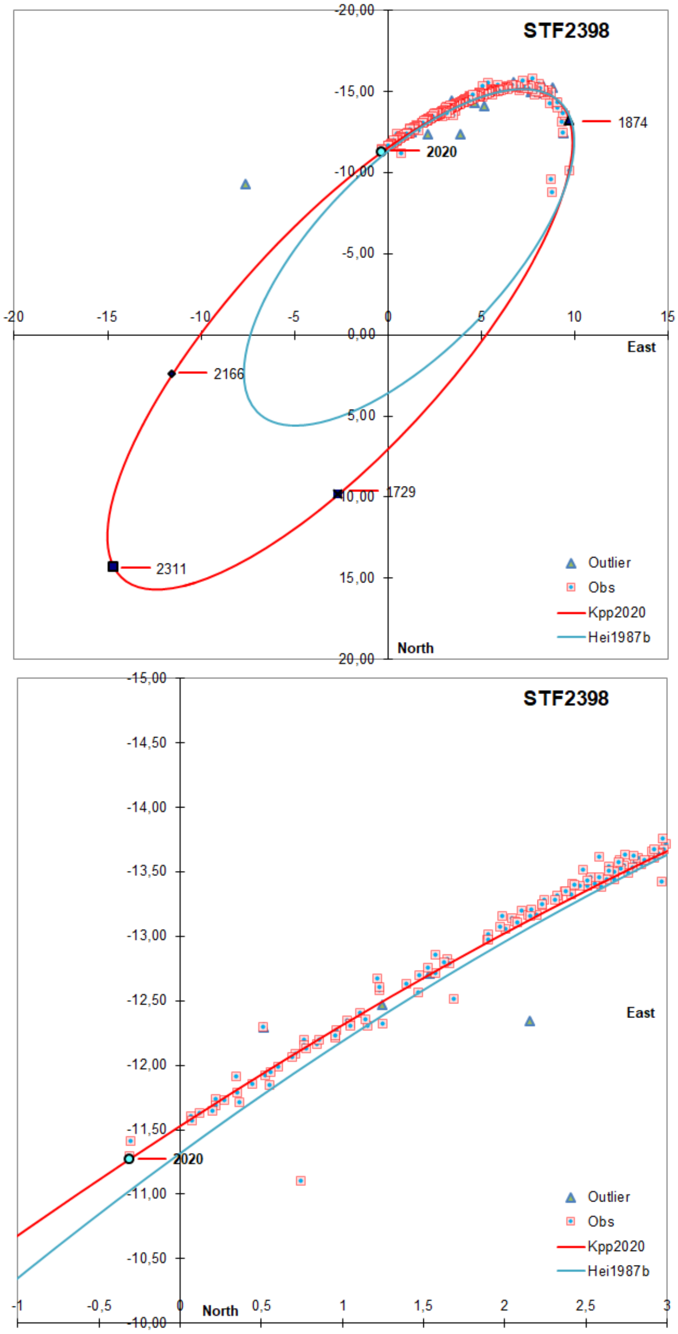
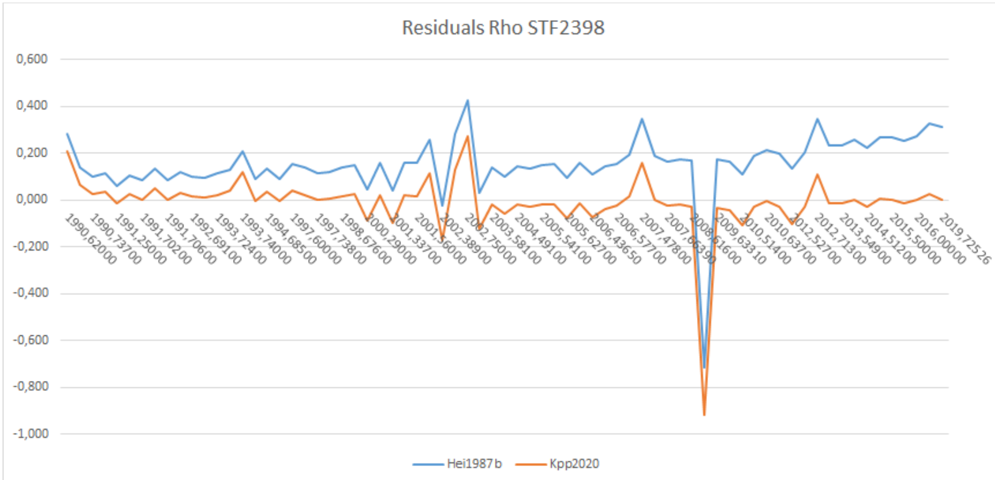


Figure 53. Plot 59: STF2398 orbit comparison with close-up

The close-up plot shows clearly that the newly calculated preliminary orbit is not surprisingly a far better match with the recent measurements than the *Hei1987b* with according to the residuals Rho values a systematical bias in the recent three decades.



Plot 60: STF2398 orbit residuals (with obvious outlier measure in 2009.666)

EDR3 parallaxes are 283.8401 and 283.8378 and DR2 parallax values are 283.9489 and 283.8624. Hipparcos parallaxes are 280.18 and 289.48 with a large error range. StarHorse median mass values are ~0.38/0.30 giving a median system mass of ~0.68. The RECONS list gives masses of 0.35/0.26 (system mass 0.61) and Ward-Duong et al. 2015 give masses of 0.26/0.19 (system mass 0.45). Absolute magnitude based estimations using the EDR3 parallaxes suggest even smaller masses.

Dynamical mass for the *Hei1987b* orbit is with average DR2 parallax 0.71 and for the newly calculated orbit 0.64 – both values offer a reasonable good match with the StarHorse median system mass value of ~0.68 with the caveat regarding *Hei1987b* in terms of residuals. 99% of the entries in the set of 200 newly calculated possible orbits give a dynamical mass in the range between 0.61 and 0.98 so this result looks overall very solid although the observation covers only a small part of the assumed orbit period but includes one end of the ellipse.

The mentioned *Izm2019* orbit offers with a dynamical mass of 0.81 a slightly too high result outside the StarHorse 84th percentile but Theta and Rho residuals are quite similar to the newly calculated orbit.

2.82. WDS 18437+3141 (A 253) – *Baz1987d*

The current 6th Orbit Catalog grade 4 entry with a period of ~98.6 years and a semi-major axis of 0.47 arcseconds is from 1987 with 10 observations added to the WDS catalog since then up to 2016. Applying the Izmailov program on the extended observation (with the GAIA DR2/EDR3 measurements added) resulted in a slightly longer period of ~106 years with else quite similar orbital element values with a small spread in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	105.877	-2.571/+2.738
A	0.480	-0.006/+0.016
i	58.604	-2.654/+3.444
Node	118.171	-5.204/+4.793
T	1943.995	-1.260/+1.378
e	0.803	-0.022/+0.030
omega	192.359	-9.877/+10.653

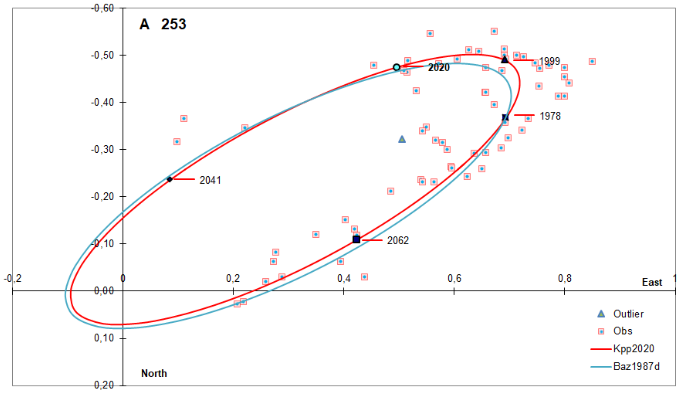
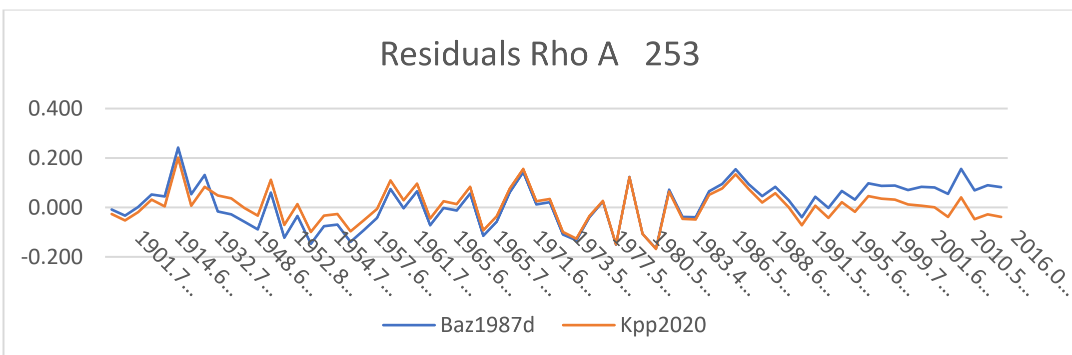


Figure 54. Plot 61: A 253 orbit comparison

The newly calculated orbit is in terms or residuals Rho clearly better than the *Baz1987d* orbit, which shows a significant bias for the most recent measurements.

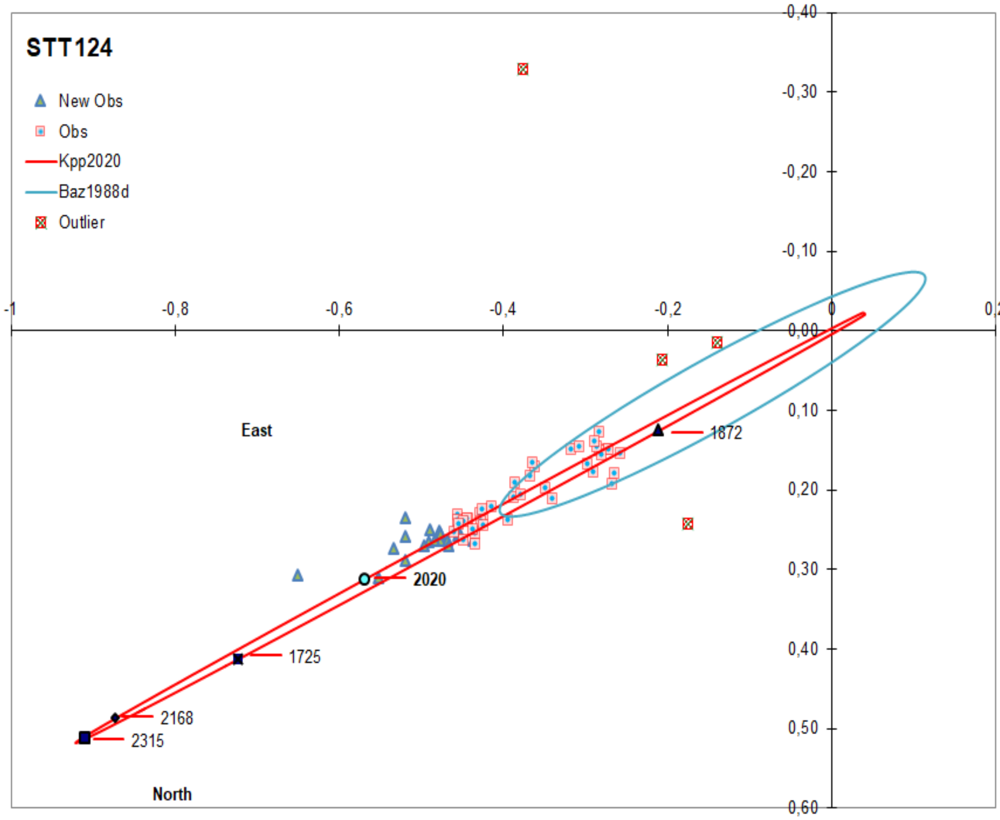


Plot 62: A 253 orbit comparison residuals Rho

Resolved in DR2 but without parallax data, Hipparcos parallax is 21.0. Resolved in EDR3 with parallaxes of 20.5560 and 20.8380 with a reasonable small error range but with RUWE ~6.9/3.7 indicating some data quality issues. No StarHorse mass data available, no other source for mass data found. Absolute magnitude based estimation of the system mass using the EDR3 parallaxes is 1.34. The dynamical mass for the Baz1987d orbit is with the Hipparcos parallax 1.22 and for the newly calculated orbit 1.12. The set of 200 possible orbits covers dynamical mass values up to 1.41 very well with only a few outliers above – more precise mass data would be very valuable for assessing orbits.

2.83. WDS 05589+1248 (STT 124) – *Baz1988d*

The current 6th Orbit Catalog grade 5 entry with a period of 140 years and a semi-major axis of 0.3 arcseconds is from 1988 with many observations added to the WDS catalog since then up to 2018. Comparing the recent measurements with the corresponding ephemerides shows a very bad match. Applying the Izmailov program on the extended resulted in a completely different orbit with a period of ~738 years and a semi-major axis of 0.565 arcseconds. However, the inclination close to 90° poses a question mark on the newly calculated orbit:



Plot 64: STT 124 orbit comparison

The plot shows that recent measurements do not fit at all with the *Baz1988d* orbit suggesting a rectilinear extension of the calculated orbital axis.

EDR3 parallax for a combined object is 4.2749 with a large error range, no duplicated_source marker but RUWE ~8 suggests potentially multiplicity issues. DR2 lists a negative parallax for a combined object without duplicated_source marker, so this is of little help. Surprisingly StarHorse delivers despite the negative parallax mass data for this object with a median value of 1.23 and an 84th percentile value of ~3.11 indicating some spread. This suggests an estimated median system mass of 2.01 and an 84th percentile system mass of 5.08. Absolute magnitude based system mass estimation with the EDR3 parallax gives ~6.8. The dynamical mass for the Baz1988d orbit is with the Hipparcos parallax 17.78, which is another reason to consider the *Baz1988d* orbit as obsolete. The dynamical mass for the newly calculated orbit is 4.29, which seems not so far off. However, the spread in the set of 200 possible orbits is simply too large to accept this result as realistic proposition and all listed entries in the set of 200 possible orbits have an inclination around 90° allowing for a rectilinear solution and suggesting that STT124 might be an optical pair. Therefore, neither the *Baz1988d* nor the newly calculated orbit seem “really necessary.

2.84. WDS 15301-0752 (G 152-31) – *Hrr1988*

G 152-31 is listed in the 6th Orbit Catalog with a grade 9 orbit published 1988 with a period of 5.96 years and a semi-major axis of 0.028 arcseconds. At first glance, there is no WDS object and no WDS observation history.

Combined EDR3 object is listed with a parallax of 26.9868 without a duplicated source marker, same for DR2 with a parallax of 27.0904, but large RUWE values indicate potential multiplicity issues. StarHorse median system mass for the combined DR2 object is 0.40. This allows for the magnitude delta based estimation of the median system mass with 0.67 (assuming an equal bright pair). The dynamical mass for the Hrr1988 orbit with the given data is 0.03 – this value is by a factor 20 quite off making the *Hrr1988* orbit as it seems obsolete.

Second look reveals that this object is the primary of WDS 15301-0750 (GIC 129) which is most likely a wide physical pair (see Appendix A) but the number of so far 7 observations is too small to attempt the calculation of a premature orbit.

To avoid confusion it would be helpful to assign identical WDS IDs for GIC 129 and G 152-31.

2.85. WDS 01512+2439 (HO 311) – *Hrt1989*

The current 6th Orbit Catalog grade 3 entry with a period of 119.3 years and a semi-major axis of 0.298 arcseconds is from 1989 with many observations added to the WDS catalog since then up to 2018. Comparing the corresponding ephemerides with the recent measurements suggests a quadrant issue for the observations from 1983.001 to 1997.8255. However, this includes the 1991.25 Hipparcos measurement with magnitudes given as anchor, which would mean that all other measurements outside 1983.001 to 1997.8255 have a quadrant issue. This said I applied the Izmailov program on the extended observation history with the position angle measurements outside 1983.001 to 1997.8255 corrected and the result confirms the currently listed orbit with small changes of the orbital element values (period 118.65 years and semi-major axis of 0.318 arcseconds) but flipped. This newly calculated orbit corrects the quadrant issue and offers compared with *Hrt1989* else just similar residuals in Theta and Rho over the full observation history. However, the *Hrt1989* orbit shows a systematic bias for the most recent 10 observations making it questionable while the newly calculated orbit is in this regard somewhat better but looks still not fully convincing.

As the number of Int4 Catalog measurements seems large enough to cover a good part of the assumed orbit period I made an alternative calculation using only these most precise Int4 Catalog measurements resulting in a period of 108.375 years and a semi-major axis of 0.276 arcseconds. This newly calculated orbit has over the full observation history a worse residuals Rho RMS value compared to *Hrt1989* but as to expect a much better one for the Int4 Catalog measures and overall a much better one for the measures of the last three decades.

Element	Value	-ΔP16/+ΔP84
P	108.375	-2.080/+2.320
A	0.276	-0.005/+0.005
i	50.732	-1.895/+1.812
Node	26.384	-2.267/+2.015
T	1982.984	-0.199/+0.221
e	0.868	-0.007/+0.006
omega	150.708	-3.179/+2.569

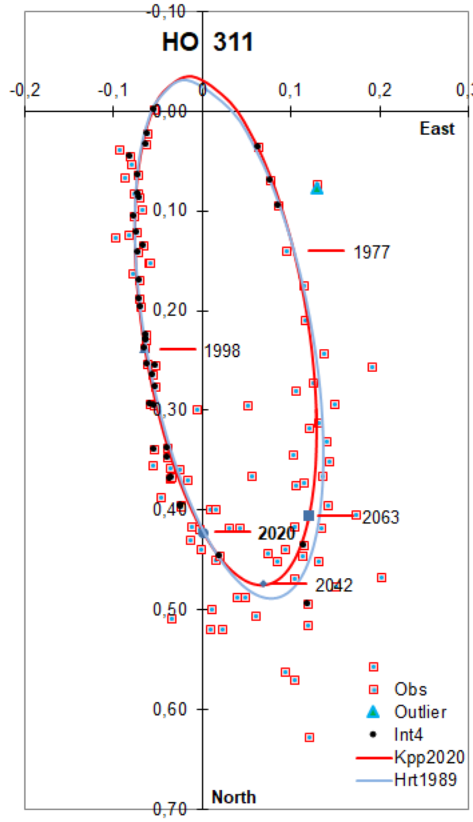


Figure 55. Plot 65: HO 311 orbit comparison with Hrt1989 flipped (one outlier outside the frame)

EDR3 lists HO 311 as combined object without parallax, DR2 offers no object for HO 311, also no StarHorse mass data available. Hipparcos parallax is 7.63 with large error range. Malkov et al. 2012 list a photometry system mass of 3.38 and a spectrometric system mass of 1.40. Absolute magnitude based estimation of system mass is 3.48. Dynamical mass for the *Hrt1989* orbit with the Hipparcos parallax is 4.22. Dynamical mass for the newly calculated orbit is 4.07 – both values seem in comparison with the estimated system mass range too high.

The set of 200 possible orbits include entries with dynamic masses down to 3.15 so it would be easy to select a better match with the estimated system mass but this seems a bit premature as the currently given parallax error range covers fully these differences. More precise parallax and mass data would be very helpful for orbit evaluation.

2.86. WDS 18118+3327 (B 2545) – *Hrt1989*

The current 6th Orbit Catalog grade 3 entry with a period of 23.9 years and a semi-major axis of 0.062 arcseconds is from 1989 with many observations added to the WDS catalog since then up to 2007, so this object is a lately neglected WDS object. Comparing the corresponding ephemerides with the measurements suggests a quadrant issue for most of the observations. This is not such a surprise given an angular separation of ~0.1” and similar brightness of the components (nearly all observations report no magnitudes).

Hartkopf et al. 1989 suggested also a second orbit (henceforth referenced as *Hrt1989-2*) with a period of 58.39 years and a semi-major axis of 0.1155 arcseconds also requiring the flip of most of the measurements. This second orbit was discarded from the 6th Orbit Catalog most likely because of the in comparison with the first orbit much worse match with the most recent observations after 2000.

However, it seems unlikely that more than 50% of such a large number of observations should need a quadrant correction.

The 2007.4248 measure published by Horch et al. 2010 might be used as anchor – no magnitudes are reported here but a clear magnitude difference of 0.31 is given with the statement "Quadrant unambiguous, but inconsistent with previous measures listed in the 4th Interferometric Catalog" without specification which specific measures. Maybe he meant his own measure 2001.5011 (see Horch et al. 2008) with an obviously flipped position angle with a magnitude difference of 0.62 with the note "Quadrant ambiguous, but inconsistent with previous measures in the Fourth Interferometric Catalog". A second anchor might be the Ismailov 1992 report with two measures for 1988 and 1989 with clear magnitude difference without any hint of quadrant ambiguities.

Using the Izmailov program on the observation history as given resulted (in accordance with the anchor measures suggested above) in five outliers (1981.49, 1983.536, 1984.513, 1990.508 and 2001.4998) with a delta in position angle ~180°. Taking this as confirmation for quadrant issues only for these observations, I used then the Izmailov program with these 5 observations flipped and got the following result:

Element	Value	-ΔP16/+ΔP84
P	47.576	-0.918/+0.556
A	0.111	-0.002/+0.001
i	67.799	-0.838/+0.869
Node	60.090	-1.100/+0.451
T	1991.406	-14.367/+2.910
e	0.033	-0.033/+0.011
omega	56.553	-21.569/+240.700

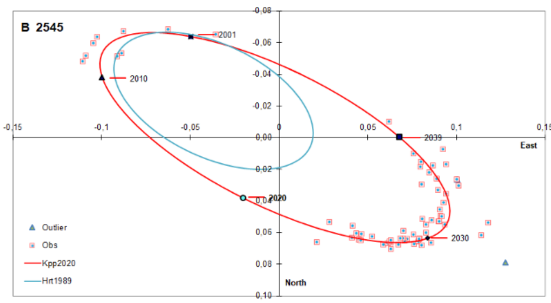


Figure 56. Plot 66: B 2545 orbit comparison

This newly calculated orbit is in terms of period and semi-major axis similar to the mentioned second *Hrt1989* orbit but requests to flip only a few measures, offers a much better match with the most recent observations and is in terms of residuals Rho significantly better than the current *Hrt1989* 6th Orbit Catalog entry.

Out of curiosity, I had a look at the approach of the currently listed orbit, which means flipping more than 80% of the measurements. Using the Izmailov programs with this input resulted in a preliminary orbit with a period of 23.4 years and a semi-major axis of 0.66 arcseconds similar to the currently listed *Hrt1989* orbital element values while offering a slightly better residuals Rho RMS value.

The error range of this solution in the set of 200 possible orbits is slightly smaller than in the version "taking the observation history as far as possible as it is", but the first solution offers in terms of residuals still the better match with the observations. The remark from Hartkopf et al.

1989 "... the situation will probably remain ambiguous for some time ..." seems to be valid until today.

A look at the dynamical mass of the orbits might help to solve this ambiguity. EDR3 parallax for the unresolved object is 3.8525 with a reasonable small error range, no duplicated source marker but RUWE ~2.4 might be a hint for duplicity. Gaia DR2 parallax for the unresolved binary, also without duplicated source marker is 4.6762 but with a more than doubled error range. Hipparcos is with a parallax of 4.21 in between EDR3 and DR2 with an error range covering the EDR3 as well the DR2 value. Cvetkovic et al. 2010 give a system mass between 6.25 to 6.40 and Malkov et al. 2012 give a photometric mass of 7.96 and a spectroscopic mass of 2.0 similar to Gullikson et al. 2016 with 2.4. Absolute magnitude based estimated system mass is with the EDR3 parallax ~6.5. The newly calculated orbits give with the EDR3 parallax similar total masses of 10.66 (for period 47.5 years) and 9.31 M (for period 23.4 years) in comparison to 7.97 and 7.36 for both *Hrt1989* orbits. The StarHorse median mass for the combined DR2 object of 3.02 allows for the magnitude delta based estimation of the median system mass of 5.07 – this would be a good match for the dynamical masses if calculated with the DR2 parallax, but not with EDR3. The question which of the B 2545 orbits and which of the discussed system mass values might be closest to reality remains still ambiguous.

As the number of observations in the Int4 Catalog is reasonably large, an orbit re-calculation based only on the Int4 observations might offer crucial insights. A first run with the observations as given suggested a quadrant issue for only one measurement from 2001.5011, which is obvious. After correcting the position angle of this measurement the result of the orbit re-calculation is with a period of 46.97 years and a semi-major axis of 0.105 arcseconds similar to the result based on the full observation history. The Int4 measures cover both ends of the assumed ellipse so this orbit looks obviously very solid although residuals Rho RMS for the full observation history is slightly worse than for the other discussed orbit variants, yet the match with the most recent measures looks perfect. The dynamical mass for this orbit is with the EDR3 parallax 9.24 with a very small spread in the set of 200 possible orbits of -0.186 to +0.762 from 16^{th} to 84^{th} percentile – certainly not large enough to cover the delta to the estimated system mass. This poses the question if the EDR3 parallax for B 2545 is indeed as precise as proposed, which seems to me a bit questionable.

New precise measurements would be valuable but the expected angular separation for the next decade is most likely too small for resolution with even the largest currently available telescopes.

2.87. WDS 19348+2928 (WRH 32) – *Baz1989b*

The current 6th Orbit Catalog grade 4 entry with a period of 4.56 years and a semi-major axis of 0.03 arcseconds is from 1989 with one observation added to the WDS catalog since then up to 1994. While this looks like a neglected WDS object several recent measurement attempts are listed in the observation history with only an upper limit for the angular separation indicating lack of resolution. The comparison of the orbit ephemerides with the corresponding measurements suggests flipped position angles for about half of the measurements. Bad matches with the 1949/50/51 and the 1985 observations and a very bad match with the last precise observation from 1994.7208 make this approach look like guesswork. Therefore, I tried the Izmailov program on the observation history as given without quadrant flipping but opted for the exclusion of obvious far off measurements as outliers and got the following straightforward looking preliminary orbit with a very small spread of the orbital element values in the set of 200 possible orbits:

Element	Value	-ΔP16/+ΔP84
P	8.622	-0.052/+0.098
A	0.046	-0.002/+0.002
i	100.262	-2.786/+1.922
Node	9.948	-0.844/+3.165
T	1979.259	+0.203/+7.451
e	0.063	-0.063/+0.063
omega	31.182	+4.988/+298.359

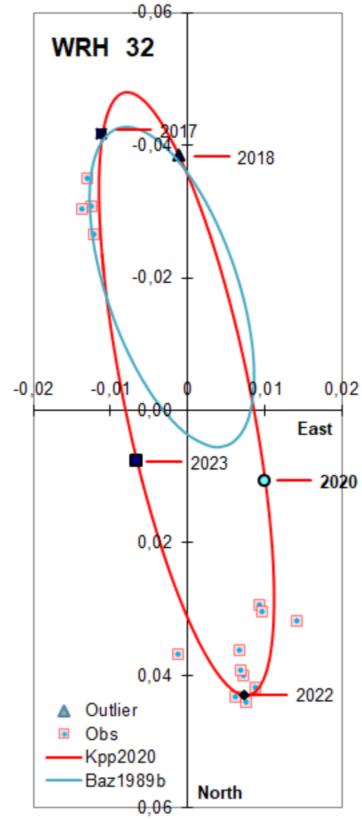


Figure 57. Plot 67: WRH 32 orbit comparison (outliers outside the frame)

EDR3/DR2 parallax for the unresolved binary without duplicated_source marker is 5.3741/5.4904 with a moderate error range, Hipparcos parallax is 5.84. StarHorse median mass for the combined DR2 object is ~1.50 allowing for median system mass estimation based on magnitude of 2.51, no other mass data source found. The dynamical mass for the Baz1989b orbit is with the DR2 parallax 7.85 and for the newly calculated orbit 8.02 – both values are obviously far off from the estimated median system mass. The set of 200 possible orbit does not offer a single entry with a dynamical mass near the estimated median system mass value so the quality of the listed orbits remains a riddle. However, an absolute magnitude based system mass estimation with the EDR3 parallax results in ~6.9 $M_{\square}$, which puts a question mark on the mentioned StarHorse median mass.

WRH 32 is additionally listed in the SB9 catalog as spectroscopic binary system 3652 with an orbit of undetermined grade with a period of ~4.3 years published 1994, which seems to support the period value of the Baz1989b orbit. Then the semi-major axis would have to be far below the given value of 0.03" for a dynamical mass near 2.5, which would make a good match with the given observation history impossible. Or this is just another argument for a much larger system mass as suggested by the absolute magnitude based estimation.

Overall the given observation history seems simply too small for the calculation of a reasonable preliminary orbit and new precise measurements would be very interesting for orbit re-calculation.

3. Discussion

There is a noticeable pattern in the checked neglected orbits published 30 or more years ago as most of these orbits are for objects considered “difficult” for several reasons listed below:

- With few exceptions, all of them are for very close pairs with the unavoidable consequence of a large measurement error range relative to the “true” separation value causing as mathematical consequence an even larger error range for the position angles
- Many pairs are additionally nearly equal in brightness making it difficult to distinguish between primary and secondary. For these reasons, observation histories are often riddled with quadrant issues and full of measurements marked with “q” (for corrected quadrant issues)
- In several cases, this “q” marker is missing although the provided 6th Orbit Catalog plot shows very well flipped quadrants. The cause for this riddle is the fact, that the USNO procedure for creating the plots checks automatically for quadrant issues but does not make corresponding changes in the observation history. In most cases, this is of no relevance for the user of the 6th Orbit Catalog but irritating if the observation histories are used to re-calculate orbits as was the case during the work on this paper. For the objects listed in this paper such quadrant issues in the WDS observation histories were reported directly to USNO and most should meanwhile be corrected
- Gaia EDR3/DR2 is in many cases despite lacking resolution of help because there is often a parallax value for the combined object given, which is of good use for calculating the dynamical mass of the corresponding orbit. However, for nearly 1/3 of the objects there is not even a combined EDR3/DR2 object listed or if then without parallax. In consequence, in such cases there are also no StarHorse mass data available. So Hipparcos parallax data is often used to calculate the dynamical mass for an orbit and for comparison other sources of mass data have to be consulted giving overall a lack of precision unusual in times of Gaia
- In some cases, the parallax data in Gaia EDR3 differs significantly from DR2, far outside the given error range, severely shattering confidence in the alleged precision and reliability of Gaia data
- The comparison between calculated dynamical mass and mass data from other sources renders listed orbits very often questionable making obvious that the calculation of orbits based on the observation history by minimizing the sum of the squares of the residuals might be mathematically sound but does not necessary bring up the orbit best matching the reality.

From the 94 neglected orbits published 30 or more years ago:

- 4 were updated in the 6th Orbit Catalog during the work on this report (from March 2020 to January 2021) with newly calculated orbits but kept in the report for comparison
- 48 (or more than 50%) are considered obsolete either due to the bad match with the most recent measurements or due to obviously unrealistic dynamical masses

- 55 (or about 58%) have an extended observation history used for orbit re-calculation
- 20 (or about 21%) are more or less confirmed by the additional measurements in the extended observation history with only minor changes in the values of the newly calculated orbital elements resulting in slightly better residuals
- 35 (or about 37%) are significantly changed by the additional measurements in the extended observation history with quite different values of the newly calculated orbital elements
- 5 are for most likely bogus objects (two for declared bogus WDS objects and additional 3 found questionable)
- 7 are for objects considered rather optical pairs than physical binaries
- 9 are for neglected WDS objects with only one or two observations each or with the last observation long ago
- 23 are astrometric orbits lacking a corresponding WDS object which means missing an observation history necessary for calculating an orbit
- 17 are based on observation histories considered to be not suited for the calculation of a realistic preliminary orbit due to for example unclear quadrant issues or insufficient precision of measurements
- 19 are based on observation histories simply far too short to allow for the calculation of a realistic preliminary orbit.

The total number of this statistic is larger than 94 due to overlapping categories. The lack of an observation history with sufficient evidence allowing for re-calculating a more realistic orbit seems to be the cause that many of the listed orbits remained untouched for 30 or more years.

As mentioned above a good part of the checked neglected orbits is highly questionable to obviously wrong due to the bad match with the extended observation history or due to an obviously unrealistic dynamical mass. For this reason, it might be a good idea to extend the grade system of the 6th Orbit Catalog with for example “X” for orbits referring to a bogus WDS object (also marked with “X”) and “Q” for orbits obviously questionable beyond being “preliminary” or just “premature”.

Finally, the question from van der Bos 1969 “Is this orbit really necessary?” seems in many cases still up to date 50 years later.

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Acknowledgements:

The following tools and resources have been used for this research:

- Washington Double Star Catalog
- WDS observation histories
- 6th Orbit Catalog: Sixth Catalog of Orbits of Visual Binary Stars (http://www.astro.gsu.edu/wds/orb6/orb6orbits.html, continually updated by Rachel A. Matson, Stephen J. Williams, William I. Hartkopf & Brian D. Mason)
- Int4 Catalog: Fourth Catalog of Interferometric Measurements of Binary Stars (http://www.astro.gsu.edu/wds/int4.html, William I. Hartkopf, Brian D. Mason and Harold A. McAlister, no longer maintained since Jan 2018)
- GAIA EDR3/DR2 catalog
- DSS2 and 2MASS images
- CDS VizieR
- CDS Simbad
- CDS Aladin Sky Atlas v10.0
- VizieR I/349 – StarHorse, Gaia DR2 photo-astrometric distances (Anders+, 2019)
- VizieR I/311 – Hipparcos, the New Reduction (van Leeuwen, 2007)
- VizieR J/A+A/546/A69 – Orbits of visual binaries and dynamical masses (Malkov+, 2012)
- VizieR J/other/Ser/180.71/binaries – Masses of visual binaries (Cvetkovic+, 2010)
- VizieR J/MNRAS/449/2618 – M-dwarfs in Multiples (MinMs) survey. I. (Ward-Duong+, 2015)
- SB9: The ninth catalogue of spectroscopic binary orbits (http://sb9.astro.ulb.ac.be/mainform.cgi, Pourbaix et al. 2004)
- RECONS list: *Research Consortium On Nearby Stars* list with >100 stars and star systems in the solar neighborhood (http://www.recons.org/TOP100.posted.htm)
- Program for calculating orbits by Thiele-Innes method published by Izmailov 2019 (http://izmccd.puldb.ru/vds.htm)

- Program for plotting orbits: Binary Star Calculator (Brian Workman: http://www.saguaroastro.org/wp-content/sac-docs/ObservingDownloads/binaries_6th_Excel97.zip)

Special thanks to

- Brian Mason for providing me with the observation histories for all objects discussed in this report and for his information how quadrant issues are handled when creating plots for the 6th Orbit Catalog. The mentioned missing “q” markers for flipped measurements in several observation histories should meanwhile have been added in most cases
- Andreas Alzner (colleague of Bob Argyle) for making me aware of the van den Bos 1962 paper “Is this orbit really necessary?”
- Francisco Rica Romero for discussing several or the listed objects in detail in private communication
- Reinhold Haefner (Archiv Universitäts-Sternwarte München) for sending me a copy of the Heintz 1966 report

Appendix A

Table of objects discussed in this report with Dr2 and StarHorse data available for assessing the likelihood of potential gravitational relationships:

Object	Comp	Plx1	Plx2	Min_D_AU	M1_50	M2_50	P_M50_min	TR1_AU	TR2_AU	LPGR	Source
BU 862		10.9449	10.9924	80	0.92000	0.88000	540	95 917	93 808	75.89	EDR3
BU 1088	AC	36.7992	36.6703	332	2.30000	0.47679	3 645	151 658	69 050	100.00	DR2
CHR 62	AB	9.3797	9.7613	577	1.19483	1.16876	9 065	109 309	108 109	1.78	DR2
GIC 75	AB	88.5430	88.5430	1 162	0.19938	0.80000	39 836	44 652	89 443	100.00	DR2 for A
GIC 129		27.0904	27.0016	370	0.40059	0.25042	8 875	63 293	50 042	96.97	DR2
HDO 294		12.0537	11.8718	184	1.19582	0.78289	1 780	109 354	88 481	22.74	EDR3
HJ 3823	AC	53.9661	54.8179	52	1.33000	1.18000	241	115 326	108 628	100.00	DR2
I 529		13.2781	13.2597	93	0.91000	0.83000	679	95 394	91 104	100.00	EDR3
KUI 13	A.BC	55.8254	55.9837	303	0.58167	0.66000	4 755	76 267	81 240	100.00	EDR3
LDS 883	AC	44.3676	44.2923	985	1.63192	0.35036	22 070	127 747	59 191	100.00	DR2
STF 80	AB	2.0455	1.7823	15 536	1.19483	1.16876	1 266 498	109 309	108 109	0.14	DR2
STF 326	AB	44.3676	44.3828	108	0.88445	0.74748	883	94 045	86 457	100.00	DR2
STF 742		12.4603	13.1274	229 067	1.56184	1.23934		124 974	111 326	0.00	DR2
STF 742		12.8846	13.1889	348	1.56184	1.23934	3 906	124 974	111 326	16.67	EDR3
STF 932		11.3337	11.5837	149	1.41087	1.25879	1 122	118 780	112 196	18.52	DR2
STF1540		54.9177	54.9057	512	0.94078	0.82819	8 758	96 994	91 005	100.00	DR2
STF1932	AB	27.5889	27.5280	59	1.01880	1.26000	299	100 935	112 250	100.00	DR2
STF2130	AB	36.8008	36.7992	68	1.50000	1.14655	374	107 077	107 238	100.00	DR2
STF2398		283.9489	283.8624	41	0.37965	0.30127	318	61 615	54 888	100.00	DR2
STF2758	AB	285.9459	286.1457	110	1.18000	0.60451	872	108 628	77 750	100.00	DR2
STI2021	AB	180.4215	181.2815	56	0.34966	0.67500	421	59 132	82 158	100.00	DR2
STT 21		9.2058	9.4797	140	2.09140	1.55000	875	144 617	124 499	1.67	EDR3
STT 73	AB	3.4452	4.7689	7 585	4.59877	0.92475		214 447	96 164	0.04	DR2
STT 507		5.3787	6.0121	4 916	2.90000	2.10000		170 760	144 938	0.01	EDR3
STT 531		47.2101	47.1305	59	0.88737	0.53082	382	94 200	72 857	100.00	DR2

Table 2: Calculation Likelihood Gravitational Relationship for neglected orbits with objects resolved in EDR3/DR2

Content description (see also description assessment procedure below):

Object = Object name

Comp = Components

Plx1 = Parallax primary in mas from Gaia DR2

Plx2 = Parallax secondary in mas from Gaia DR2 (red type if estimation)

Min_D_AU = Minimum spatial distance in AU between components

M1_50 = Mass50 value primary from StarHorse catalog (red type if estimation)

M2_50 = Mass50 value secondary from StarHorse catalog (red type if estimation)

P_M50_min = Minimum period for circular orbit with mass50 value (blank for LPGR<0.1)

TR1_AU = Tidal radius according to M1_50

TR2_AU = Tidal radius according to M2_50

LPGR = Likelihood of potential gravitational relationship (WDS note code "T" is suggested for all objects with LPGR >50)

Source = Source parallax data

Description of the LPGR assessment procedure (according to Knapp 2018, extended):

- GAIA EDR3/DR2 data for RA/Dec and Plx are used for a Monte Carlo simulation assuming a normal distribution for these parameters with the given error range as standard deviation. The distance between the components is calculated from the inverted simulated parallax data and the simulated angular separation using the law of cosine $\sqrt{a^2 - 2 * a * b * cos(\gamma) + b^2}$ with a and b = distance vectors for the stars A and B in lightyears calculated as (1000/Plx)*3.261631 and γ = angular separation in degrees calculated as γ = $arccos(sin(DE1) * sin(DE2) + cos(DE1) * cos(DE2) * cos(abs(RA1 - RA2)))$
- The tidal radius of the Sun TR($M_{\odot}$) is considered to correspond with the outer rim of the assumed Oort cloud at a distance of ~100,000 AU as the radius at which the Sun's gravitational force is equivalent to the gravitational force of the stellar neighborhood. For objects with significantly different mass from the Sun this tidal radius TR has to be recalculated for a corresponding gravitational acceleration of $5.87329 * 10^{-13}$ m/s^2. Potential gravitational relationship PGR is assumed to be given with overlapping tidal radii of two stellar objects, which does not necessarily mean that an orbit exists but that at least the movement of both stars through space should be noticeable influenced mutually by gravitational forces
- The likelihood for potential gravitational relationship (LPGR) is the percentage of simulation distance results smaller than the sum of the tidal radii TR1+TR2 out of the simulation sample with a size of 120,000 corresponding with the likelihood that the real distance is smaller than TR1+TR2 with an margin of error of 0.37% at 99% confidence
- The minimum, median and maximum distance is the smallest, median and largest result of the simulation sample

- Ignoring the likely effects of eccentricity the smallest/median/largest distance is used as estimation for the value for the semi-major axis of a potential circular orbit. This allows for the calculation of a minimum/median/maximum orbit period assuming zero inclination using either median mass data from StarHorse (Anders et al. 2019) or if not available mass data from other sources (for example estimation from luminosity$^{\wedge(1/4)}$ for masses between 0.43 and 2 $M_{\odot}$ assuming main sequence stars according to Salaris and Cassisi 2005)

Appendix B

Verification of the concept for assessing the quality of orbits by comparing the calculated orbital dynamical mass with system mass data from other sources:

To check the plausibility of assessing the quality of an orbit by comparing the dynamical mass with system mass data from other sources, especially from the StarHorse catalog I selected all grade 1 orbits from the 6th Orbit Catalog as these orbits can be expected to deliver in most cases realistic dynamical mass values.

The resulting 87 orbits provided the following pattern:

- For all objects the calculation of dynamical masses provides as to expect a reasonable result without obvious outliers
- Only a few binaries are resolved in DR2 with StarHorse masses for both components. The added median StarHorse masses of the components are in all these cases acceptable close to the corresponding dynamical masses supporting the concept, that a system mass based on StarHorse median component masses is of use for assessing the plausibility of given orbital element values by comparing it with the calculated dynamical mass
- In cases with StarHorse mass for only one component the mass for the second component was calculated by using the formula q = $\sqrt[\frac{Vmag2-Vmag1}{10}]{10}$ for the mass ratio q = mass2/mass1 as estimation based on magnitude delta. The resulting system masses for all such objects are close enough to the dynamical masses for the corresponding orbits to be accepted as good approximation even if the magnitudes given the 6th Orbit Catalog might not be very precise
- Most objects are close binaries not resolved in DR2 but in many such cases with parallax and StarHorse median mass value for a combined object. With one exception in all these cases, the StarHorse median mass value is significantly smaller than the corresponding dynamical mass. This allows for the conclusion that the StarHorse median mass for a combined DR2 object is not suited as system mass approximation. Again, the difference in component magnitudes seems to be useful to provide good approximations. For this purpose, the combined magnitude was calculated as $-\log_n({}^1/_{n^{Mag1}} + {}^1/_{n^{Mag2}})$ with n = fifth root of one hundred or ~2.512 and Mag1 for the magnitude of the primary and Mag2 for the magnitude of the secondary. In a few cases with missing magnitudes for the secondary equal brightness was assumed and in one case the given magnitudes in the red band were used as given. Then the mass ratio q for combined magnitude to primary magnitude was calculated using the formula given above to provide a mass estimation for the primary. In the next step, the mass ratio for the object components provides a mass approximation for the secondary. This procedure is based on the assumption that no white dwarfs are

involved and results in most cases in system mass values acceptable as good approximations reasonable close to the corresponding dynamical masses

- For all objects without a corresponding DR2 object with parallax and StarHorse mass data the Hipparcos parallax was used and Malkov 2012 and Cvetkovic 2010 were checked for mass values as range for a plausible system mass. In most such cases the found mass data is close enough to the corresponding dynamical mass to be accepted as good approximation
- Last resort for getting mass reference values is the procedure of estimating mass from estimated luminosity based on estimated absolute magnitude based on given or estimated visual magnitudes following the procedure described for example in Harshaw 2020.

The details of this check are given in table 2 below:

WDS	DD	Mag1	Mag2	Cmag	CPlx	DM	Orbit	SHM	M1	M2	SM	Δ%	Note
02442-2530	FIN 379Aa,Ab	7.50	8.10	7.01	22.4133	2.00	Tok2016b	1.19039	1.06	0.93	1.99	0.45	Malkov et al. 2012 2.20/1.02
08122+1739	STF1196	5.30	6.25	4.92	41.5427	2.45	Izm2019	2.47046	1.37	1.10	2.47	0.87	Mass primary estimated from magnitude delta to secondary. Cvetkovic et al. 2010 2.59/2.44
17080+3556	HU 1176AB	6.10	6.10	5.35	17.9262	3.36	Mut2010b	1.97309	1.66	1.66	3.32	1.32	Malkov et al. 2012 3.33/1.82
00373-2446	BU 395	6.60	6.20	5.63	64.93	1.79	Hrt2010a				1.83	1.93	No Gaia data. HIP Plx. Cvetkovic et al. 2010 1.84/1.82. Malkov et al. 2012 1.92/0.91
15521+1052	BAG 7	9.70	11.16	9.45	47.286	1.26	Doc2019c	0.79807	0.75	0.54	1.29	2.22	No other mass data source found
03082+4057	LAB 2Aa,Ab	2.12	4.60	2.01	36.27	4.93	CIA2012b		3.32	1.73	5.05	2.40	No DR2 Plx. HIP Plx. Mass estimated from absolute magnitude
00321-0511	A 111	9.40	9.40	8.65	20.3336	1.76	Tok2015c	1.71947	1.01	0.70	1.72	2.59	Malkov et al. 2012 1.75/0.85
19121+0254	AST 1	11.29	13.11	11.10	106.2794	0.44	AST2016				0.43	3.04	No StarHorse data. Malkov 2012 0.51/0.35
15232+3017	STF1937AB	5.64	5.95	5.03	55.98	2.11	Mut2010b				2.19	3.71	No DR2 Plx. HIP Plx. Cvetkovic et al. 2010 2.12/2.10. Malkov et al. 2012 2.24/2.14
09006+4147	KUI 37AB	4.18	6.48	4.06	62.23	2.35	Mut2010b				2.27	3.80	No DR2 Plx. HIP Plx. Malkov et al. 2012 2.39/2.14
18092-2211	RST3157	9.58	9.92	8.98	29.0016	1.56	Tok2018e	0.89504	0.78	0.72	1.50	3.95	Malkov et al. 2012 1.48/0.73. Cvetkovic et al. 2010 1.43/1.39
01277+4524	CIA 4Aa,Ab	4.83	*4.90*	4.11	34.9441	2.64	CIA2014a	1.49357	1.27	1.25	2.51	5.13	No other mass

WDS	DD	Mag1	Mag2	Cmag	CPlx	DM	Orbit	SHM	M1	M2	SM	Δ%	Note
													data source found
04136+0743	A 1938	5.70	6.70	5.34	25.2041	2.83	Mut2010b	1.82642	1.68	1.33	3.01	6.16	No StarHorse data. Malkov et al. 2012 2.77/2.55. Cvetkovic et al. 2010 2.67/2.70
13396+1045	BU 612AB	6.35	6.47	5.66	16.67	3.41	Msn1999a				3.21	6.38	No DR2 Plx. HIP Plx. Malkov et al. 2012 3.27/1.40. Cvetkovic et al. 2010 3.24/3.18
17304-0104	STF2173AB	6.06	6.17	5.36	59.6071	2.06	Hei1994a				1.94	6.40	No StarHorse data. Malkov et al. 2012 2.05/0.95. Cvetkovic 1.95/1.93
18211+7244	LAB 5Aa,Ab	3.57	5.70	3.43	124.11	1.71	CIA2010				1.60	6.70	No DR2 data. HIP Plx. Malkov 2012 2.07/1.13
20375+1436	BU 151AB	4.11	5.02	3.72	32.33	3.47	Mut2010e		2.08	1.69	3.77	7.93	No DR2 data. HIP Plx. No StarHorse data, mass estimated from absolute magnitude
13100+1732	STF1728AB	4.85	5.53	4.39	56.1	2.57	Mut2015				2.38	8.02	No DR2 Plx. Cvetkovic Plx. Cvetkovic et al. 2010 2.40/2.35
21446+2539	BU 989AB	4.94	5.04	4.24	29.22	3.89	Mut2008		1.81	1.77	3.57	8.72	No DR2 data. HIP Plx. No StarHorse data, mass estimated from absolute magnitude
09307-4028	COP 1	3.91	5.12	3.60	54.4556	2.83	Msn2017g	2.58228	1.47	1.11	2.58	9.60	Mass secondary estimated from magnitude delta to primary
16044-1122	STF1998AB	5.16	4.87	4.25	35.7765	2.90	Doc2009g		1.55	1.66	3.21	9.71	No StarHorse data, mass estimated from absolute magnitude
18055+0230	STF2272AB	4.22	6.17	4.05	195.2166	1.62	Izm2019	1.83035	1.12	0.71	1.83	11.45	DR2 Plx and StarHorse mass only for secondary. RECONS list 1.62 with 0.7 for sec. Malkov et al. 2012 1.61/1.56, Cvetkovic et al. 2010 1.53/1.51
02171+3413	MKT 5Aa,Ab	4.85	*4.90*	4.12	90.845	1.67	Pbx2000b				1.49	12.34	No StarHorse data, Malkov et al. 2012 1.92/1.05
00572+2325	MKT 2Aa,Ab	4.42	*4.50*	3.71	13.7059	4.31	MkT1993b				3.83	12.81	No StarHorse data, Malkov et al. 2012

WDS	DD	Mag1	Mag2	Cmag	CPlx	DM	Orbit	SHM	M1	M2	SM	Δ%	Note
													5.02/2.63
09123+1500	FIN 347Aa,Ab	7.20	7.20	6.45	49.1493	1.84	Msn2012a	0.96754	0.81	0.81	1.63	13.36	Malkov et al. 2012 1.86/0.91
19311+5835	MCA 56	7.02	8.40	6.75	54.8715	1.76	Kie2018	0.95407	0.90	0.65	1.55	13.47	Malkov et al. 2012 1.63/0.79
21145+1000	STT 535AB	5.19	5.52	4.59	53.5882	2.49	Mut2008	1.71845	1.50	1.39	2.88	13.61	Malkov et al. 2012 2.45/2.33
03492+2403	MKT 12Aa1,2	3.84	5.46	3.62	8.53	5.68	Zwa2004				5.00	13.73	No DR2 Plx. HIP Plx. Malkov et al. 2012 6.68/3.31
18466+3821	HU 1191	8.67	9.42	8.23	28.08	1.47	Doc2009g				1.29	14.27	No DR2 Plx. HIP Plx. Malkov et al. 2012 1.69/0.88
09179+2834	STF3121	7.90	8.00	7.20	57.92	1.39	Sod1999				1.21	14.54	No DR2 Plx. HIP Plx. Malkov et al. 2012 1.57/0.85
23322+0705	HU 298	7.46	7.92	6.91	12.2526	2.98	Hrt2000c	1.54714	1.36	1.23	2.59	15.04	Malkov et al. 2012 2.85/1.13
17121+4540	KUI 79AB	10.02	10.25	9.38	167.29	0.56	Hrt1996a				0.67	15.27	No DR2 data. HIP Plx. Malkov 2012 0.68/0.65. RECONS list 0.72
02095+3459	MKT 4	3.00	*3.10*	2.30	25.71	4.11	MkT1995				3.54	16.12	No DR2 Plx. HIP Plx. Malkov et al. 2012 5.26/1.82
19598-0957	HO 276	6.22	7.83	6.00	46.9328	1.42	Tok2017b	1.06601	1.01	0.70	1.71	17.22	Malkov et al. 2012 2.00/1.10
18384-0312	A 88AB	7.22	7.51	6.60	20.519	2.45	Hrt2013d	1.22890	1.07	1.00	2.06	18.80	Malkov et al. 2012 2.50/1.07
15360+3948	STT 298AB	7.16	8.44	6.87	44.3939	1.79	Izm2019	2.20764	1.27	0.94	2.21	19.11	Mass primary estimated from magnitude delta to secondary
11323+6105	STT 235	5.69	7.55	5.51	34.8382	2.22	Izm2019	1.74625	1.68	1.09	2.77	19.81	Malkov et al. 2012 2.34/1.10. Cvetkovic et al. 2010 2.27/2.21
11480+2013	MKT 7Aa,Ab	4.53	*4.60*	3.81	14.02	3.97	MkT1995				3.32	19.87	No DR2 Plx. HIP Plx. Malkov et al. 2012 4.97/1.66. SB9 system 690
06171+0957	FIN 331Aa,Ab	6.10	6.10	5.35	12.7542	4.58	Hrt1996a	2.25996	1.90	1.90	3.80	20.38	Malkov et al. 2012 3.73/2.09
00022+2705	BU 733	5.83	8.90	5.77	79.0696	1.67	Sod1999	0.93775	0.92	0.46	1.38	21.34	Near Hit, Malkov et al. 2012 1.58 1.56
17190-3459	MLO 4AB	6.37	7.38	6.01	146.29	1.04	Izm2019				1.34	22.15	No DR2 data. HIP Plx. Malkov 2012 1.37/1.40
22409+1433	HO 296AB	6.14	7.22	5.80	29.59	2.12	Mut2010b				1.72	23.54	No DR2 data. HIP Plx. Malkov 2.47/0.97
07518-1354	BU 101	5.61	6.49	5.21	60.59	1.95	Tok2012b				1.56	25.31	No DR2 Plx. HIP Plx. Malkov et al. 2012 2.09/1.02
17542+1108	FIN 381	7.00	7.20	6.34	12.5299	3.89	Doc2013d	1.84532	1.59	1.51	3.10	25.39	Malkov et al. 2012 3.32/1.20. Cvetkovic et al. 2010 3.16
15278+2906	JEF 1	3.68	5.20	3.44	34.8674	1.80	Mut2010b	1.50056	1.42	1.00	2.42	25.47	Malkov et al. 2012 4.09/3.17

WDS	DD	Mag1	Mag2	Cmag	CPlx	DM	Orbit	SHM	M1	M2	SM	Δ%	Note
14492+1013	A 2983	9.36	9.27	8.56	22.59	1.61	Doc2018k				1.27	27.35	No DR2 Plx. HIP Plx. Cvetkovic et al. 2010 1.73/1.69. Malkov et al. 2012 1.74/0.79
14037+0829	BU 1270	8.15	8.78	7.67	12.79	2.36	USN2006b				1.85	27.99	No DR2 Plx. HIP Plx. Malkov et al. 2012 2.49/1.20
11182+3132	STF1523	4.33	4.80	3.79	114.4867	2.92	Izm2019	1.35303	1.19	1.07	2.27	28.81	No other mass data source found
17465+2743	AC 7BC	10.20	10.70	9.67	119.7908	0.83	Pru2014	0.69979	0.62	0.55	1.17	29.05	No other mass data source found
02396-1152	FIN 312	5.22	6.50	4.93	42.4864	2.23	Doc2013d	1.04913	0.98	0.73	1.71	30.17	Malkov et al. 2012 2.39/2.40
05167+4600	ANJ 1Aa,Ab	0.08	0.18	-0.62	76.2	5.01	Trr2015		3.72	3.62	7.35	31.79	No DR2 Plx. HIP Plx. Mass estimated from absolute magnitude
19490+1909	AGC 11AB	5.64	6.04	5.07	12.79	2.23	Mut2010b				3.29	32.26	No DR2 Plx. HIP Plx. Malkov et al. 2012 4.39/2.19
00369+3343	MKT 1Aa,Ab	4.36	*4.40*	3.63	5.939	9.26	MkT1995	4.15351	3.51	3.48	6.99	32.51	Malkov et al. 2012 11.18/4.79
08270-5242	B 1606	6.99	7.85	6.58	17.7221	2.94	Tok2015c	1.33603	1.22	1.00	2.22	32.53	Malkov et al. 2012 2.61/2.27
08538-4731	FIN 316	6.10	6.10	5.35	11.8927	5.45	Tok2015c	2.43660	2.05	2.05	4.10	32.98	Malkov et al. 2012 3.21/1.58
00352-0336	HO 212	5.61	6.90	5.32	47.05	2.83	Msn2005				2.13	33.22	No Plx. HIP Plx. Cvetkovic et al. 2010 2.16/2.09
00284-2020	B 1909	7.23	7.40	6.56	31.06	2.14	Hrt2010a				1.60	33.46	No Plx. HIP Plx. Malkov et al. 2012 2.15/1.05
22280+5742	KR 60AB	9.93	11.41	9.68	249.6797	0.45	Izm2019	0.67407	0.42	0.25	0.67	33.61	Malkov et al. 2012 0.42/0.56
10373-4814	SEE 119	4.13	5.76	3.91	37.26	4.38	Tok2019d		1.93	1.32	3.25	34.66	No DR2 Plx. HIP Plx. Mass estimated from absolute magnitude. Primary is SB9 system 623 with period 10 days
19550+4152	HO 581	8.03	8.72	7.57	20.8663	2.90	XXX2018c	1.27547	1.15	0.98	2.13	36.50	Malkov et al. 2012 2.07/0.88
06573-3530	I 65	6.90	7.31	6.33	23.2	2.53	Doc2009g				1.77	42.44	No DR2 Plx. HIP Plx. Malkov et al. 2012 2.11/1.19
16555-0820	KUI 75AB	9.73	9.81	9.02	161.41	0.98	Sod1999				0.69	43.27	No DR2 data. HIP Plx. Cvetkovic et al. 2010 0.68/0.69. RECONS list 1.02
21158+0515	WRH 35	3.92	*3.95*	3.18	19.4571	3.20	MkT1992b	1.32288	1.12	1.11	2.22	43.64	Malkov et al. 2012 5.08/3.52
16413+3136	STF2084	2.95	5.40	2.84	93.32	2.43	Izm2019				1.69	43.68	No DR2 data. HIP Plx. Malkov et al. 2012 2.12/1.26

WDS	DD	Mag1	Mag2	Cmag	CPlx	DM	Orbit	SHM	M1	M2	SM	Δ%	Note
02278+0426	A 2329	9.45	9.63	8.78	58.33	1.37	Ana2007				0.95	44.51	NoDR2 Plx. HIP Plx. Malkov et al. 2012 1.25/0.65
14323+2641	A 570	6.61	7.08	6.07	12.3717	4.72	Hei1991	1.90926	1.68	1.51	3.20	47.52	Malkov et al. 2012 3.29/1.74. Cvetkovic et al. 2010 3.29/3.24. Absolute magnitude based estimated system mass 3.558
15416+1940	HU 580AB	5.35	5.22	4.53	15.2768	5.42	Mut2010b	2.16964	1.80	1.85	3.65	48.58	Cvetkovic et al. 2010 4.55/4.53
02366+1227	MCA 7	5.68	5.78	4.98	28.8632	1.31	Doc2016d	1.52218	1.29	1.27	2.56	48.63	Malkov et al. 2012 2.95/1.13
08468+0625	SP 1	3.49	5.00	3.25	25.7113	4.29	Hrt1996a	2.87904	1.69	1.19	2.88	49.06	Plx from secondary. Mass primary estimated from magnitude delta to secondary
16035-5747	SEE 258AB	5.20	5.76	4.69	24.2652	3.43	Tok2015c				2.27	51.37	No StarHorse data. Malkov et al. 2012 2.71/1.82
04512+1104	BU 883	7.75	7.50	6.87	18.7775	3.79	Sod1999	1.41957	1.16	1.23	2.38	58.80	Malkov et al. 2012 2.36/2.24
21579-5500	FIN 307	4.80	5.96	4.48	17.8908	6.36	Doc2013d	2.39281	2.22	1.70	3.92	62.02	*) Malkov et al. 2012 3.26/1.58
15245+3723	CHR 181Aa,Ab	4.31	*4.35*	3.58	28.0796	3.12	Izm2019	1.12152	0.95	0.94	1.89	65.28	Cvetkovic et al. 2010 2.12/2.09
02022+3643	A 1813	8.70	8.90	8.04	19.4363	2.75	Hrt2000a	0.95191	0.82	0.78	1.60	71.61	Estimated system mass from absolute magnitudes 1.82
19026-2953	HDO 150AB	3.27	3.48	2.62	36.98	5.24	DRs2012				2.96	77.43	No DR2 Plx. HIP Plx. Malkov et al. 2012 3.45/2.46
04256+1556	FIN 342Aa,Ab	7.74	7.00	6.56	18.9472	4.32	Sod1999	1.35389	1.03	1.22	2.25	91.54	*) Malkov et al. 2012 2.48/1.13
18547+2239	MKT 9Aa,Ab	4.59	4.5	3.79	7.8358	4.74	MkT1995	1.44390	1.20	1.23	2.43	95.20	Malkov et al. 2012 5.64/4.08
23052-0742	A 417AB	6.20	6.34	5.52	15.57	4.62	Hrt1996a				2.33	98.67	No DR2 Plx. HIP Plx. Malkov et al. 2012 2.86/1.79
22430+3013	BLA 11Aa,Ab	4.10	6.90	4.02	13.7236	7.05	MkT1998				3.35	110.41	*) No StarHorse data. Malkov et al. 2012 3.35
20113-0049	MKT 10Aa,Ab	3.23	3.20	2.46	12.8937	6.96	MkT1995	1.85513	1.55	1.57	3.12	122.97	Malkov et al. 2012 9.08/2.88
19091+3436	CHR 84Aa,Ab	6.89	8.96	6.74	20.2306	3.88	CIA2014a				1.71	127.64	No StarHorse data. Malkov et al. 2012 2.39/1.02
01350-2955	DAW 31 AB	7.51	8.94	7.25	38.4341	4.46	Tok2015c	1.13354	1.07	0.77	1.84	142.73	*) Cvetkovics 2010 1.59/1.64 for AB,C
19394+3009	MCA 57	4.90	5.10	4.24	13.5191	5.58	Pbx2000b	1.29096	1.11	1.06	2.17	157.00	Malkov et al. 2012 3.75/1.78
04287+1552	MKT 13Aa,Ab	3.74	4.86	3.41	20.8354	5.04	Lmp2011	1.15762	1.07	0.83	1.90	164.84	Malkov et al. 2012 3.81/2.00

WDS	DD	Mag1	Mag2	Cmag	CPlx	DM	Orbit	SHM	M1	M2	SM	Δ%	Note
15318+4054	A 1634AB	5.80	5.80	5.05	7.8618	5.88	Hor2012a	1.31906	1.11	1.11	2.22	164.87	Malkov et al. 2012 6.07/1.82. Cvetkovics 2010 5.28/5.33
09407-5759	B 780	5.85	6.48	5.37	14.7578	5.12	Tok2015c	1.09330	0.98	0.85	1.82	180.82	Malkov et al. 2012 3.09/2.09
14234+0827	BU 1111BC	7.40	7.70	6.79	9.7572	9.30	Sod1999	1.84664	1.60	1.50	3.10	200.02	Malkov et al. 2012 2.74/2.79. Cvetkovic et al. 2010 2.60. Tokovinin 2017 primary mass 1.33. Large delta to DR2 to HIP Plx

Table 2: Comparison dynamical mass with other system mass data sources for 6th Orbit Catalog grade 1 orbits

Content description:

WDS = WDS ID

DD = WDS Discoverer Designation

Mag1 = Magnitude Primary

Mag2 = Magnitude Secondary

CMag = Combined Magnitude (calculated)

CPlx = Parallax value for combined object (DR2 or HIP, or average if values for both components are given)

DM = Dynamical mass for the given orbit with the given parallax

Orbit = 6th Orbit Catalog Orbit ID

SHM = StarHorse median mass for the combined DR2 object (or sum of median mass values for both components if given)

M1 = Estimated median mass for the Primary calculated from SHM based on magnitude delta

M2 = Estimated median mass for the Secondary calculated from SHM based on magnitude delta

SM = Estimated median system mass (either M1+M2 or sum StarHorse values or average of other system mass data source)

Δ% = Difference between DM and SM in % of SM

Note = Additional information

*) significant better match with EDR3 parallax

With the mentioned caveat that the magnitudes provided by the 6th Orbit Catalog might not be very precise, this procedure provides overall reasonable close dynamical and system mass values for about 80% of the objects. About 20% of the objects have systematically a dynamical mass much larger than the found system mass references – this might be at least in some of these cases a hint that the given orbits might be despite grade 1 in need of improvement or that the used parallax might be questionable. The latter is the case for four of these objects suggested by different EDR3 parallaxes providing a significant better match.

Appendix C

Table with comparison of dynamical mass estimated system mass for all referenced objects

Nr	WDS	Object	Mag1	Mag2	CM	SHM	M1	M2	SM	Av/CPlx	P	A	DM	Δ %	Orbit	Notes
1	04149+4825	STT 73 A	4.18	.	3.43	4.60	3.87	3.87	7.74	3.9395	0.778	0.0188	179.55	2221	Ald1925	2)10)11)12)
2	19098-1948	B 427	7	7.1	6.30	1.31	1.11	1.09	2.20	9.1471	2.680	0.1290	390.525	17629	Vor1934	2)3)
3	14598-2201	Ci 18,1988	8.57	.	7.82	1.00	0.84	0.84	1.68	10.6709	3.559	0.0320	2.129	27	Ald1938b	4)11)12)19)
4	21415-7723	BLM 6	3.73	.	2.98	2.20	1.85	1.85	3.70	51.5172	2.840	0.0520	0.128	-97	Ald1939b	1)2)4)11)12)
5	10200+1950	BAG 32 Ca,Cb	9.64	.	8.89	0.40	0.34	0.34	0.67	201.4064	26.500	0.1109	0.000	-100	Reu1943	1)2)4)11)12)
6	17053+5428	STF2130 B	5	.	4.25	1.15	0.97	0.97	1.93	36.7992	3.200	0.0260	0.034	-98	Str1943	2)10)11)12)
7	15073+1827	A 2385 AB	6.8	6.8	6.05	1.90	1.60	1.60	3.20	13.2096	8.000	0.1000	6.779	112	Egg1946b	2)6)11)
8	09468+7603	Ross 434	10.63	.	9.88	0.55	0.46	0.46	0.92	63.3251	1.260	0.0380	0.136	-85	Ald1951	2)10)11)12)
9	15183+2650	STF1932 B	6.6	.	5.85	0.75	0.63	0.63	1.26	27.6125	50.000	0.0550	0.003	-100	Mlr1952d	2)10)11)12)
10	19190-3317	I 253 AB	8.77	7.25	7.01		0.95	1.35	2.30	18.1500	60.000	0.5101	6.166	168	B__1954	1)7)15)16)
11	05074+1839	A 3010	5.8	5.8	5.05	1.30	1.09	1.09	2.19	62.8252	1.190	0.1800	16.608	660	Egg1956	5)11)
12	12554+6953	A 1092	9.73	9.88	9.05		0.62	0.60	1.22	13.7700	58.000	0.2200	1.212	-1	Baz1959	1)7)15)17)
13	06344+1445	STF 932	8.31	8.54	7.67		1.41	1.26	2.67	11.5359	2360.000	3.2100	3.868	45	Hop1960a	2)3)13)
14	11033+3558	Lal 21185	7.49	.	6.74		0.20	0.20	0.39	392.7529	8.000	0.0336	0.000	-100	Lip1960	1)2)10)12)14)
15	11268+0301	STF1540 AB	6.55	7.5	6.17		0.94	0.83	1.77	55.0354	32000.000	40.7600	0.397	-78	Hop1960a	9)13)
16	21069+3845	STF2758 A	5.2	.	4.45	0.70	0.59	0.59	1.18	285.9949	4.900	0.1400	0.005	-100	Dej1960	2)10)11)12)
17	21567+6338	WRH 36	5.4	.	4.65		17.50	17.50	35.00	1.0033	20.340	0.0336	90.787	159	Frd1960	4)12)20)
18	14565-3438	I 227 AB	8.06	8.39	7.46		1.14	1.06	2.20	16.3800	40.000	0.2563	2.394	9	Ltg1961c	1)7)15)16)
19	17379+1836	Ci 18,2347	9.62	.	8.87	0.46	0.39	0.39	0.77	122.5546	24.000	0.0400	0.000	-100	Bie1964	2)10)11)12)
20	01030+4723	STT 21	6.76	8.07	6.48		2.10	1.55	3.65	9.3428	450.000	0.8160	3.290	-10	Hei1966	2)3)21)
21	02556+2652	STF 326 AB	7.68	10.02	7.56		0.88	0.75	1.63	44.4689					Hop1967	9)13)22)
22	05407-0157	STF 774 AB	1.88	3.7	1.69		21.00	13.81	34.81	4.4300	1508.600	2.7280	102.606	195	Hop1967	9)23)
23	17364+6820	CHR 62 Aa,Ab	9.15	.	8.40	1.54	1.29	1.29	2.59	9.6112	24.500	0.1020	1.991	-23	Lip1967	4)11)12)
24	08394-3636	I 314	6.4	7.9	6.16	1.66	1.57	1.11	2.68	24.4093	66.500	0.5270	2.276	-15	Hei1968a	6)11)
25	00594+0047	STF 80 A	7.65	7.65	6.90	1.19	1.00	1.00	2.00	2.0924	80.920	0.2780	358.169	17796	Dom1969	2)10)11)
25	00594+0047	STF 80 A	7.65	7.65	6.90	1.19	1.00	1.00	2.00	2.0924	84.840	0.2760	318.854	15832	Dom1969	2)10)11)
26	17578+0442	GJ 699A a1	9.54	.	8.79	0.18	0.15	0.15	0.30	546.9759	12.000	0.0074	0.000	-100	Kam1969c	2)10)11)12)
26	17578+0442	GJ 699A a2	9.54	.	8.79	0.18	0.15	0.15	0.30	546.9759	26.000	0.0183	0.000	-100	Kam1969c	2)10)11)12)

Nr	WDS	Object	Mag1	Mag2	CM	SHM	M1	M2	SM	Av/CPlx	P	A	DM	Δ %	Orbit	Notes
26	17578+0442	GJ 699A a	9.54	.	8.79	0.18	0.15	0.15	0.30	546.9759	25.000	0.0275	0.000	-100	Kam1969b	2)10)11)12)
27	02460-0457	BU 83 A	7.53	9.39	7.35	1.37	1.31	0.86	2.17	10.6861	36.000	0.0800	0.324	-85	Dom1972a	1)2)10)24)
28	09144+5241	STF1321 AB	7.79	7.88	7.08		0.61	0.60	1.21	157.8852	975.000	16.7250	1.250	3	Chg1972	1)2)25)
29	22329+4923	HU 1320	8.62	8.51	7.81	1.67	1.39	1.42	2.81	9.1415	62.600	0.2100	3.094	10	Cou1972c	1)6)7)11)
30	05364+2200	STF 742	7.09	7.47	6.51		1.56	1.24	2.80	13.0368	2959.000	5.5710	8.913	218	Hop1973b	2)3)9)13)
31	12108+3953	STF1606 A	6.85	7.35	6.32		1.69	1.51	3.20	8.3200	75.000	0.0780	0.146	-95	vdW1974	2)10)15)26)
32	04349+3908	HU 1082	9.5	10.08	9.00		0.66	0.57	1.23	26.8200	52.190	0.3550	0.851	-31	Cou1975c	1)7)14)15)
33	04563+5206	HU 555 AB	8.83	9.14	8.22		1.41	1.31	2.72	8.0400	72.100	0.2100	3.428	26	Hei1976	1)7)14)15)
34	05098+2802	BU 1047 BC	9.11	9.71	8.62		1.07	0.98	2.05	13.5300	32.100	0.2170	4.004	95	Hei1976	2)6)15)18)
35	10551+4714	G 146-72	12.7	.	11.95	0.50	0.42	0.42	0.84	33.6003	6.700	0.0300	0.016	-98	Beh1976	2)10)11)12)
35	10551+4714	G 146-72	12.7	.	11.95	0.50	0.42	0.42	0.84	31.0748	6.800	0.0200	0.006	-99	USN1988a	1)2)10)11)12)
36	11056+5448	A 1591	8.98	9.52	8.46		1.42	1.25	2.67	7.3600	105.000	0.2050	1.960	-27	Hei1976	7)12)15)
37	15273+1738	A 2074	8.55	9.37	8.13		1.28	1.06	2.34	11.0200	59.000	0.2060	1.877	-20	Baz1976	6)8)12)15)
38	16458-0046	A 1141	9.1	9.2	8.40	1.33	1.13	1.11	2.24	11.6544	62.070	0.2300	1.995	-11	Baz1976	1)2)6)11)
39	20198+4522	STT 406	7.25	8.74	7.00	1.11	1.05	0.74	1.79	26.7756	113.500	0.3360	0.153	-91	Hei1976	1)6)8)11)
40	04312+5858	STI2051 A	11.1	.	10.35	0.35	0.29	0.29	0.59	181.2438	23.000	0.0700	0.000	-100	Str1977	1)2)10)11)12)
41	23487+6453	STT 507 AB	6.76	7.76	6.40		7.24	5.75	12.99	5.6954	565.770	0.7400	6.852	-47	Zul1977b	1)2)3)27)
42	03096+0512	A 2030	8.58	9.2	8.09		0.85	0.73	1.58	16.2000	54.455	0.2610	1.410	-11	Sta1978b	8)15)17)
43	04089+2911	BU 1232	8.8	9.6	8.38	0.88	0.80	0.66	1.46	13.9531	60.000	0.2800	2.245	54	Mlr1978a	2)6)13)
44	04170+1941	HO 328	7.38	9.06	7.17		1.17	0.80	1.97	12.4073	63.300	0.3580	5.995	204	Hei1978a	1)2)8)17)
45	09376+1528	A 2479	9.23	9.87	8.75		1.52	1.31	2.83	5.7544	108.000	0.2300	5.474	93	Hei1978a	1)2)8)9)14)
46	14511-3706	I 529	9.64	10	9.05		0.98	0.90	1.88	13.2689	2507.260	2.6570	1.277	-32	Dom1978	2)8)9)16)
47	17146+1423	STF2140 AB	3.48	5.4	3.31		4.88	2.94	7.82	9.9114	3600.000	4.6800	8.123	4	Baz1978	1)2)3)9)14)28)
48	17177+1140	G 139-29	15.1	.	14.35	0.18	0.15	0.15	0.30	80.8407	10.000	0.0560	0.003	-99	CJW1978	2)10)11)12)
48	17177+1140	G 139-29	15.1	.	14.35	0.18	0.15	0.15	0.30	80.7994	9.500	0.0560	0.004	-99	USN1988a	1)2)10)11)12)
49	20012-3835	HDO 294	8.08	9.11	7.72		1.20	0.78	1.98	11.9628	4484.500	4.9160	3.451	74	Dom1978	8)9)13)
50	08211+4725	A 1745 Ca,Cb	10.33	11.1	9.90	0.89	0.81	0.67	1.48	11.8758	279.500	0.4790	0.840	-43	Hei1979b	8)9)11)
51	06003-3102	HJ 3823 AC	8.9	8.88	8.14		1.33	1.18	2.51	54.0381	390.600	3.9500	2.560	2	Baz1980b	8)9)11)29)
52	03054+2515	STF 346 AB	6.21	6.19	5.45		3.15	3.17	6.32	6.0500	227.000	0.4700	9.099	44	Hei1981a	1)8)14)15)
53	07307+4813	GIC 75 A	15.1	15.6	14.57	0.20	0.18	0.16	0.33	88.7231	0.940	0.0540	0.255	-24	Hrr1981	10)11)
53	07307+4813	WNO 49 Ba,Bb	15.5	15.5	14.75		0.40	0.40	0.80	88.7231	20.500	0.6560	0.962	20	Hrr1981	1)9)18)30)
54	10250+2437	STF1429	9.05	9.34	8.43		1.00	0.93	1.93	14.0529	1280.680	2.1000	2.035	5	Zul1981	1)2)8)9)16)
55	19358+2316	A 163	10.02	9.95	9.23		1.26	1.28	2.55	5.7500	163.100	0.2550	3.279	29	Baz1981b	1)8)14)15)
56	23164+6407	BU 992	8.21	8.29	7.50		2.48	2.43	4.91	3.6600	516.820	0.4300	6.071	24	Val1981d	1)2)14)15)
57	23375+4426	STT 500 AB	6.08	7.38	5.79		4.31	3.19	7.50	4.0400	351.220	0.4100	8.473	13	Zul1981	1)8)15)16)
58	04064+4325	A 1710	8.16	8.27	7.46		1.22	1.19	2.41	14.4500	109.500	0.3960	1.717	-29	Hei1982c	1)7)14)15)
59	06517+2503	A 512	9.57	10.08	9.04	1.76	1.56	1.39	2.94	2.6471	187.000	0.2100	14.278	385	Cou1982c	2)4)8)9)11)
60	18058+2127	STT 341 AB	7.39	8.82	7.13	1.04	0.98	0.71	1.69	30.6946	20.081	0.2530	1.389	-18	Hei1982b	1)2)7)11)
61	02174+6121	STF 234 AB	8.74	9.4	8.27		0.85	0.73	1.58	16.5805	139.868	0.5100	1.488	-6	Sta1983	8)21)

Nr	WDS	Object	Mag1	Mag2	CM	SHM	M1	M2	SM	Av/CPlx	P	A	DM	Δ %	Orbit	Notes
62	23114-4259	B 594	9.1	9.5	8.53		2.69	2.45	5.15	1.6845	21.000	0.1500	1601.114	31009	Nrr1983	5)14)
63	00462-2214	RST4155	9.76	10.03	9.13	1.16	1.00	0.94	1.95	9.2071	48.000	0.1950	4.123	112	Hei1984a	1)6)8)9)11)
64	06032+5813	A 1315	10.18	10.12	9.40		1.17	1.18	2.35	6.2600	700.182	2.2770	98.162	4078	Doc1984b	1)2)6)9)14)15)
65	15328+1945	HU 577	8.91	8.94	8.17		0.90	0.90	1.80	11.3600	112.440	0.2850	1.249	-31	Cou1984b	1)7)15)17)
66	19216+5223	BU 1129	7.69	7.84	7.01		1.40	1.35	2.75	4.8700	121.700	0.1800	3.409	24	Baz1984a	1)6)8)15)17)
67	21510+2911	A 889	9.23	10.48	8.93	0.97	0.91	0.68	1.58	17.7144	20.780	0.1700	2.047	29	Baz1984b	8)11)
68	04159+3142	STT 77 AB	8.04	8.22	7.37		1.04	1.00	2.04	9.8500	187.925	0.5490	4.903	141	Sta1985	1)7)15)17)
69	14135+1234	BU 224	8.94	9.35	8.37		1.23	1.12	2.34	10.8153	251.570	0.6000	2.698	15	Lin1985c	1)8)14)
70	00048+3810	BU 862	10.02	10.18	9.34		0.90	0.82	1.72	10.9687	403.000	0.7400	1.891	10	Cou1986b	8)14)
71	03480+6840	KUI 13 BC	10.66	11.16	10.13		0.32	0.26	0.58	55.9837	44.210	0.4400	0.248	-57	Baz1986a	4)14)
72	04076+3804	STT 531 AB	7.32	9.69	7.20		0.89	0.53	1.42	47.3250	590.000	3.8700	1.571	11	Hei1986b	2)8)9)13)
73	05384+4301	A 1563	9.3	9.3	8.55	3.17	2.67	2.67	5.33	4.4669	120.000	0.1660	3.564	-33	Cou1986b	4)5)9)11)
74	06041+2316	KUI 23 AB	4.77	5.5	4.32		2.26	1.87	4.13	21.0300	13.350	0.1980	4.683	13	Hei1986b	1)8)14)15)
75	06455+2922	A 122	8.89	9.39	8.36		1.09	0.97	2.06	12.9800	100.000	0.3280	1.614	-22	Baz1986a	1)7)14)15)
76	12520-2648	B 234	10.29	10.26	9.52		0.82	0.83	1.65	15.4695	122.000	0.3570	0.826	-50	Hei1986a	1)7)9)14)31)
77	12579+4948	HU 641	10.3	10.3	9.55	1.35	1.14	1.14	2.27	0.6567	323.480	0.3660	1654.426	72768	Erc1986b	2)4)9)11)
78	20205-2749	RST3255	10.6	10.6	9.85	1.08	0.91	0.91	1.82	5.3729	45.700	0.2170	31.544	1637	Hei1986a	1)2)6)11)
79	23328-1645	VOU 28 BC	11.14	11.17	10.40		1.03	1.02	2.05	5.1600	28.200	0.5900	1879.787	91493	Hei1986b	1)2)6)14)15)
80	01345+3440	A 1913 AB	10.46	10.68	9.81		1.26	1.20	2.45	4.7300	111.210	0.2900	18.635	659	Baz1987d	1)2)6)14)15)
81	15071-0217	A 689	8.2	8.7	7.67		0.98	0.81	1.79	12.3088	66.000	0.3100	3.667	105	Baz1987d	1)6)14)
82	18428+5938	STF2398 AB	9.11	9.96	8.70		0.38	0.30	0.68	283.8390	408.000	13.8800	0.702	3	Hei1987b	8)13)
83	18437+3141	A 253	9.71	10.29	9.21		0.71	0.62	1.33	20.6970	98.570	0.4700	1.205	-9	Baz1987d	1)8)14)
84	05589+1248	STT 124	6.11	7.37	5.81	1.23	1.15	0.86	2.01	4.2749	140.000	0.3000	17.633	778	Baz1988d	1)2)3)11)32)
85	15301-0752	G 152-31	14.4	.	13.65	0.40	0.34	0.34	0.67	26.9868	5.960	0.0280	0.031	-95	Hrr1988	2)10)11)12)
86	01512+2439	HO 311	8.22	7.82	7.25		1.66	1.82	3.48	7.6300	119.300	0.2980	4.186	20	Hrt1989	1)7)14)15)
87	18118+3327	B 2545 AB	6.5	6.8	5.89	3.02	2.62	2.45	5.07	3.8525	23.900	0.0620	7.297	44	Hrt1989	6)11)
88	19348+2928	WRH 32	5.9	6.4	5.37	1.50	1.33	1.18	2.51	5.3741	4.560	0.0300	8.366	233	Baz1989b	2)6)11)

Content description:

Nr = Running number of the object in the report (red type for additional orbit)

WDS = WDS catalog ID

Object = Object name with components (AB default)

Mag1 = Visual magnitude of first component from 6th Orbit Catalog

Mag2 = Visual magnitude of the second component from 6th Orbit Catalog

CM = Calculated combined visual magnitude

SHM = StarHorse median mass for combined DR2 object

M1 = Estimated mass first component

M2 = Estimated mass second component

SM = Estimated system mass

Av/CPlx = Average EDR3/DR2 parallax or EDR3/DR2 parallax for combined object or Hipparcos parallax

P = Period in years

A = Semi-Major axis in arcseconds

DM = Dynamical mass

Δ % = Difference between estimated system mass and dynamical mass in percent of estimated mass. Red type for delta >50%

Orbit = Orbit ID from 6th Orbit Catalog

Notes = Reference to notes below

1) EDR3 and/or DR2 parallax missing

2) Orbit considered obsolete

3) Object most likely optical

4) Neglected WDS object

5) Bogus object

6) Observation history seems not suited for calculating a realistic orbit

7) Given orbit seems confirmed by extended observation history

8) Extended observation history suggests changes in orbital values

9) Observation history seems too small for the calculation of a realistic orbit

10) No WDS object

11) StarHorse median mass for combined DR2 object

12) Mag2 assumed to be similar to Mag1

13) StarHorse median mass values for both components

14) Masses estimated from absolute magnitude

15) Hipparcos parallax for combined object

16) System mass suggested by Cvetkovic et al. 2010

17) System mass average from Malkov et al. 2012

18) Mass estimations from Tokovinin 2018

19) Ident with TOK 47 Aa,Ab?

20) Mass for the primary suggested by Pollmann et al. 2017 between 15 and 20

21) StarHorse median mass for the primary

22) Parabolic orbit

23) Hummel et al. 2013 report an estimated mass of ~21 for A

24) System mass for A estimated from combined StarHorse median mass for AB

25) StarHorse median mass for the secondary

26) System mass estimation for A derived from STF1606 AB system mass estimation

27) Very different DR2 parallaxes suggest optical pair. StarHorse median mass for A

28) DR2 parallax only available for B

29) StarHorse median mass values assumed to be for combined DR2 objects

30) Same parallax as GIC 75 A assumed

31) Heintz 1986a suggests a parallax value of 12 given without reference or explanation

32) Negative DR2 parallax value