Wide Pairs in the Sixth Catalog of Orbits of Visual Binary Stars – II

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

Abstract: New measurements for seven wide pairs from the Sixth Catalog of Orbits of Visual Binaries give reason to assess the accuracy of the existing orbits. In most cases, the result is the suggestion of a new orbit or, in some cases, of an alternative rectilinear solution

1. Method

Identical with the first report Knapp 2022 “Wide Pairs in the Sixth Catalog of Orbits of Visual Binary Stars”. Remote telescopes equipped with V-filter were used to take images for own astrometric and photometric measurements in the visual band. Parallax values in the text are in *mas* and mass values in *Sun masses.*

2. Results

2.1. WDS 11214-2027 STN 22

The 6th Orbit Catalog lists for STN 22 a grade 5 orbit *Izm2019* with a period of 1,028 years and a semi-major axis of 6.53 arcseconds. Own recent measurement (Table 1) corresponds with the *Izm2019* ephemerides within the given large error range caused by overlapping star disks in the used images.

Hipparcos parallax for the combined object is 75.97. Gaia DR1 lists both components without parallax. DR2 lists parallaxes of 76.4165/76.3549. StarHorse median masses are 0.65/0.50, which is close to the mass estimation based on spectral classes K4/5 listed in the WDS catalog. Monte Carlo simulation with these data (see Appendix) suggests 100% likelihood for gravitational relationship with a minimum spatial distance of 50 AU and a minimum period of ~330 years for an assumed circular orbit. EDR3 lists parallaxes of 72.8638 and 76.1918 – a surprising different value for the primary compared with DR2 far outside the given error range. However, the likelihood for gravitational relationship remains intact, but the minimum orbit period is now in the range of millions of years.

The dynamical mass for *Izm2019* is with DR2 parallaxes 0.59, which seems in comparison with the StarHorse median mass values not very convincing but is close to the photometric mass estimation of 0.63 based on the currently given WDS magnitudes. Own visual magnitude measures are very consistent significantly brighter and give an absolute magnitude based mass estimation of 0.75. Alonso-Floriano et al. 2015 suggest spectral classes of M2.5 to K7 for the variable primary and K7 for the secondary, indicating an estimated system mass between 0.7 and 0.9.

Overall, this somewhat confusing data situation regarding system mass suggests that the *Izm2019* dynamical mass might be too small to be realistic.

Using the Izmailov 2019 programs with the rather short observation history extended with Gaia (Table 2) and own measures results in a set of possible orbits with a median mass of 1.05 but with a frequency peak around 0.75. The best match with the Gaia measures offers a solution with a period of 1,139.5 years and a semi-major axis of 7.5 arcseconds (Table 3) resulting with the DR2 parallaxes in a dynamical mass of 0.72. The close-up plot (Figure 1) gives the impression that the Gaia measures suggest a steeper path than the presented orbit, which does not match well with the rest of the observation history. New precise measurements should solve this riddle.
There is clearly a curvature to notice in the plot of the existing measures and the alternatively calculated rectilinear elements offer a bad match especially with the most recent measurements, which supports strongly the binary character of STN 22.

2.2. WDS 11550-5606 HLD 114

The 6th Orbit Catalog lists a grade 5 orbit *Izm2019* for HLD 114 with a period of 972 years and a semi-major axis of 6.55 arcseconds. Own recent measurement (Table 1) corresponds with the *Izm2019* ephemerides within the given error range.

Hipparcos parallax for the combined object is 33.11. DR1 lists a parallax of 32.71 for the primary, but gives no parallax for the secondary. DR2 gives parallaxes of 31.9236 and 32.1791. StarHorse median mass for the primary is 0.926, no value is given for the secondary; estimation based on magnitude difference suggests 0.83. Photometric mass estimation using own new visual magnitude measurements suggests a system mass ~2 close to the spectral class G4/5 based mass estimation of ~1.85. Simulation based on these data suggests 100% likelihood for gravitational relationship with a minimum spatial distance of 140 AU and a minimum period of 1,250 years for an assumed circular orbit. EDR3 lists parallaxes of 31.7940 and 32.2320.

The dynamical mass for *Izm2019* is with DR2 parallaxes ~9, which makes this orbit clearly obsolete.

Using the Izmailov 2019 programs on the observation history extended with Gaia (Table 2) and own measures results in a set of possible orbits with several entries with a dynamical mass between 1.7 to 2.0. After eliminating all such entries with a period smaller than 1,250 years the best match with the Gaia measures offers a solution with a period of 1,881 years and a semi-major axis of 6.04 arcseconds resulting with the DR2 parallaxes in a dynamical mass of 1.9 (Table 3).
This newly calculated orbit offers a realistic dynamical mass value and better residuals than the *Izm2019* orbit as well as a better match with the Gaia measures (Figure 2).

Alternatively calculated rectilinear elements offer much larger residuals and a bad match with most measurements, which supports the binary character of HLD 114.

2.3. WDS 15155+3319 STFA 27

This object is listed in the 6th Orbit Catalog with two alternative orbits *Kis2009*, both with a period of 76,000 years and a semi-major axis of 78 arcseconds, but with different inclination and eccentricity. Kisselev at al. 2009 state that the presented orbital element values are given with the caveat to be estimated.

Own recent measurement (Table 1) is within the given error range corresponding with the first *Kis2009* orbit but a closer look at the plot shows no connection between measurements and orbit with exception of the most recent measures. Beyond that, the residuals show an obvious bias. The orbit plot in Figure 3 indicates clearly that the *Kis2009* orbits are far off and suggests that the measurements might very well support also a rectilinear solution.

Hipparcos parallaxes for STFA 27 are 26.78/27.05. DR1 lists no objects for STFA 27. DR2 gives parallaxes of 26.7797/27.0648. StarHorse median masses are 1.23/0.92. EDR3 lists parallaxes of 27.0746 and 27.1573. Photometric mass estimation using WDS Catalog magnitudes (own measures confirm these values) suggests a somewhat higher system mass ~3.6. WDS Catalog notes indicate that STFA 27A might be a binary itself. Kervella at al. 2019 suggest a companion in the range of a brown dwarf based on proper motion anomaly, which however, would be without significant influence on the brightness of this object. Significant lower is the spectral class G8/G0 based mass estimation of ~1.9. The dynamical mass for the *Kis2009* orbits is with the EDR3 parallaxes ~4.1 (Kisselev at al. 2009 report a dynamical mass of 3.7 based on Hipparcos parallax values, but this calculation is not comprehensible) – not completely unrealistic but most likely a bit too high. However, Kisselev et al. 2009 explain this by assuming the primary being a spectroscopic binary itself referring to Tokovinin and Smekhov 2002. This would result in a significantly higher system mass – but this report also indicates for both components of STFA 27 constant radial velocity, which means no hint regarding spectroscopic binary.

Simulation based on DR2 and StarHorse data suggests ~85% likelihood for gravitational relationship with a minimum spatial distance of 3,850 AU and a minimum period >165,000 years for an assumed circular orbit. Simulation with EDR3 parallax values gives 100% % likelihood for gravitational relationship, but minimum spatial distance and minimum period for an assumed circular orbit remain similar. Proper motion of the components is similar enough to assume common proper motion as to expect from a wide physical pair.

Using the Izmailov 2019 programs on the observation history extended with Gaia (Table 2) and own measures results in a set of possible orbits with a huge spread including several entries with a dynamical mass around 2. The best match with the Gaia measures offers the orbit with a period of ~433,737 years and a semi-major axis of ~198 arcseconds giving with the EDR3 parallax values a dynamical mass of ~2.1.

The plots in Figure 3 give a sobering impression – the overall plot suggests a good agreement with the measurements; however, the close-up shows that the newly calculated orbit is despite clearly better residuals visually also heavily at odds with the WDS observation history. The alternatively calculated rectilinear solution is in terms of residuals better than the so far presented orbits but again – the close-up plot shows again an extremely bad match with the measurements.

A closer look at the observation history shows an interesting pattern: There is, with one outlier, a stretch of nearly identical measurement results between 1961 and 1976, made with the 66cm USNO refractor in Washington, DC. Before and after we find unsystematic jumps in the measures most likely due to the larger measurements error range caused for example by observation equipment and procedures and this might explain the confusing pattern of the residuals. The brightness of the primary might also have an influence on the precision of measurements. The angular separation seems to have changed from 78.5 to 78 arcseconds during the recorded observation period covering about 250 years and the position angle remained unchanged at ~105°.

Overall, the period of a potential STFA 27 orbit is simply far too long to calculate reasonable orbital element values from the given observation history. A rectilinear solution might be an interesting alternative due to the better residuals, but the given Gaia data supports heavily the binary character of this object.

2.4. WDS 16147+3352 STF2032

The 6th Orbit Catalog lists the grade 4 orbit *Izm2019* for STF2032 with a period of 656.7 years and a semi-major axis of 5 arcseconds. Own recent measurement (Table 1) corresponds within the given error range well with the ephemerides of this orbit.

The WDS Catalog lists several additional components for STF2032. Most of them are optical with rectilinear elements already calculated. Gaia data suggest that component E is despite the huge angular separation of more than 600 arcseconds physical. However, the long period of most likely ~1 million years makes it impossible to calculate a realistic premature orbit with the given observation history. To add complexity, STF2032 E is listed in the 6th Orbit Catalog as binary itself with two alternative orbits: grade 9 astrometric orbit *Hei1990d* and grade 5 *Tok2019e*.

Hipparcos combined parallax for STF2032 AB is 47.44. Gaia DR1 parallax for A is 44.03, no value given for B. DR2 parallax values are 44.1346/44.1475 and StarHorse median mass value for B is 1.2, no value given or A. EDR3 parallax values are 44.0575/44.1340. Estimated median mass for component A based on magnitude delta would be 1.47; however, the primary is listed in the SB9 Catalog as spectroscopic binary system 894, which means in consequence a correspondingly higher system mass for A of ~2.1 in case of equal brightness of the components. Tokovinin 2018 lists for A a mass of 2.23 and for B of 1.81 – the latter value is given without source and seems a bit too high. The 6th Orbit Catalog includes for Aa,Ab also an orbit *Rag2009* based on radial velocity data plus long-baseline interferometry from CHARA Array with a corresponding dynamical mass. This suggests an overall system mass of ~3.3.
Simulation with these values results in 100% likelihood for gravitational relationship with a minimum spatial distance of 163 AU and a minimum period for an assumed circular orbit of 1,155 years.
The dynamical mass for the *Izm2019* orbit is with the EDR3 parallax values 3.35 – a nearly perfect match with the estimated system mass. However, the in comparison with the assumed circular orbit too short period gives reason to have closer look.

Using the Izmailov program with the given observation history plus Gaia (Table 2) and own measurements gives as result an orbit with a period of 1,317 years, a semi-major axis of 7.8 arcseconds and a dynamical mass of 3.23 (Table 3). The *Izm2019* orbit and the newly calculated orbit are nearly identical regarding residuals for the measurements since the year 1900 despite the very different orbital element values (Figure 4, first close-up) but the new orbit comes with a more realistic orbit period.

Most interestingly, the Izmailov program declares a good part of the measurements of the 19th century as outliers with the consequence that the match of this orbit with these measures is inferior to the *Izm2019* orbit leading to larger overall residuals. However, the residuals for the 19th century measurements are also for the *Izm2019* orbit not convincing, so there is obviously an issue with the precision of these measurements (Figure 4, second close-up). In fact, most of these measurements are based on observations with telescopes of modest aperture size – while this offers no issue for visual resolution it might very well be a problem for the accuracy of measurements.

2.5. WDS 16256-2327 H 2 19/ BU 1115

H 2 19 is embedded in the Rho Ophiuchi cloud complex, a nebula of gas and dust with a large number of young stars. This object is listed in the WDS Catalog with in total 6 components and the AB pair is listed in the 6th Orbit Catalog with a grade 5 orbit *Izm2019* with a period of 4,193 years and a semi-major axis of 6.6 arcseconds, both values come with a huge error range. Own recent measurement (Table 1) corresponds with the ephemerides within the given error range even if not very precise due to overlapping saturated star disks. A shorter exposure time would be helpful for resolution but at the price of an insufficient number of stars bright enough for plate solving.

Hipparcos lists a combined parallax of 9.03. Gaia DR1 gives no data for this object. DR2 lists parallaxes of 7.13 for A and 6.83 for B; EDR3 of 7.26 and 5.48. The spread in these values indicate some difficulties in measuring precise parallax values for this object. EDR3 parallax values indicate by simulation zero likelihood for a gravitational relationship between A and B. The DR2 parallax values suggest less than 10% likelihood for gravitational relationship. DR2 and EDR3 proper motion values for A and B show differences by far too large for common proper motion, which would be expected for a physical pair with such a long period.

StarHorse median masses are 1.34 and 1.79 giving a system mass of 3.13. Spectral types are given with B2 for both components, which means a system mass of ~20.0. Photometric mass estimations with the DR2 parallaxes are 3.9 and 3.3 suggesting a system mass of 7.2. This means a range for the possible system mass from ~3 to ~20.
The dynamical mass for the *Izm2019* orbit is with the DR2 parallax values ~48 far outside of this range, which means that this orbit is clearly obsolete.

Using the Izmailov programs on the given WDS Catalog observation history extended with the EDR3 (Table 2) and own recent measurements results in a suggested orbit with an even worse dynamical mass. Finally, the set of 200 possible orbits includes only two entries with a dynamical mass of ~20 but none below, the best fitting one with a period of 28,619 years and a semi-major axis of 17.7 arcseconds (Table 3). This is a very weak support for the mass estimation derived from the spectral type but by far above the photometric mass estimation as well as the StarHorse median mass value.

Overall this suggests serious doubts that H 2 19 AB is a physical pair supported by the fact that the observation history does not show the slightest hint of a curvature and that all calculated orbits are close to a straight line through the observation history time frame. A look at possible rectilinear solutions seems therefore appropriate and the result (Table 4) is not surprising in terms of RMS over the residuals Rho and Theta at least equivalent to the best-fitting orbits (see plot Figure 5.1).

As to expect, there are many stars in this cloud with very similar parallax and proper motion values (Grasser et al. 2021) allowing for possible gravitational relationship but there is little evidence for the existence of "true" binaries – may be with the exception of the DE pair not resolved in EDR3 but marked as duplicated_source object.

The WDS Catalog lists the DE components with different discoverer code "BU 1115" and the 6th Orbit Catalog lists for these components a *Nov2007b* grade 5 orbit with a period of 675.5 years and a semi-major axis of 1.01 arcseconds. The *Nov2007b* ephemerides suggest for 2016 an angular separation below the EDR3 threshold; in consequence, we have no Gaia data for this pair but only for the combined object with quite different values in DR2 and EDR3, both sources with a large error range.
The EDR3 parallax is with 8.0932 close to the Hipparcos parallax of 8.01 and considered more realistic than the 10.8982 from DR2. The dynamical mass for the *Nov2007b* orbit is 4.26 with the EDR3 parallax. The (combined?) spectral type B5 gives as starting point a mass estimation >5. StarHorse median mass for the combined object is 1.78 suggesting a median system mass of 2.86 (with component masses of 1.69 and 1.17 based on magnitude difference). Photometric mass estimation is 3.8 in between the values discussed so far.
The WDS observation history includes meanwhile two additional measures from Tokovinin et al. 2018/2019 considered very precise. These measures are slightly at odds with *Nov2007b* and suggest potentially a shorter period orbit.

Using the Izmailov programs on the WDS observation history plus the new measurements suggests in a first run a result very similar to *Nov2007b* with a period of 624 years, a semi-major axis of 0.97 arcseconds and a dynamical mass of 4.46. The match with the mentioned recent measures is slightly better than with *Nov2007b* but far from perfect. The number of entries in the set of 200 possible orbits with a dynamical mass in the discussed range is huge but a few stand out by the perfect match with the two last measures. Finally I selected a solution with a period of 336 years, a semi-major axis of 0.645 arcseconds and a dynamical mass of 4.49 (Table 3 and Figure 5.2) as most promising result.

2.6. WDS 16579+4722 A 1874/STFA 32

WDS 16579+4722 is a physical triple of BY Dra type variables discovered in two steps – components AC 1823 by F. Struve and component B 1908 by Aitken. The 6th Orbit Catalog lists six alternative grade 5 orbits *Kis2009b* for A 1874 AB with a period between 311 and 390 years and a semi-major axis between 2.79 and 3.34 arcseconds and five alternative orbits *Kis2009b* for STFA 32 AC with a period between 47,000 and 88,000 years and a semi-major axis of 89.1 and 133.7 arcseconds. Own recent measurements (Table 1) for AB and AC correspond within the given error range at least with one of the Kis2009b orbit ephemerides for 2021.

The Hipparcos parallaxes for A and C are 54.63 and 56.18 – both values with a moderate error range. Gaia DR1 parallaxes for A and C are 55.96 and 55.69, no value for C. Gaia DR2 parallaxes for A, B and C are 55.71, 55.78 and 55.72 with a small error range. StarHorse median star masses for A, B and C are 0.77, 0.50 and 0.75. Gaia EDR3 parallaxes for A, B and C are 55.75, 55.77 and 55.72 with a small error range. Spectral types K0 for A, M1.5 for B and K3 for C suggest star masses of 0.76, 0.41 and 0.67. Photometric mass estimation for A, B and C gives 0.66, 0.28 and 0.64, with caveats due to the variable property. Overall, a system mass between 1.0 to 1.3 for AB and 1.6 to 2.0 for ABC seems realistic.

Simulation with the EDR3 and StarHorse data for AB suggests 100% likelihood for gravitational relationship with a minimum spatial distance of 91 AU and a minimum period for an assumed circular orbit of 778 years. Simulation with DR2 data gives nearly identical results. Proper motion data suggest common proper motion with small differences due to a potential orbit. EDR3 radial velocity values are also very similar.
Simulation with Gaia data for AB as inner system with C as third component suggests also 100% likelihood for gravitational relationship but with a spatial distance >2,000 AU and a minimum period for an assumed circular orbit >64,000 years.

Using the Izmailov programs with the WDS observation history for A1874 AB plus the new measurements since publication of *Kis2009b* plus EDR3 (Table 2) and own recent measures results in a first step in a proposed orbit with a period of 1,038 years, a semi-major axis of 6.4 arcseconds and a dynamical mass of 1.4. While the overall residuals are better than for the best matching sixth *Kis2009b* version, the match with the Gaia measures remains unsatisfying. A look at the set of 200 possible orbits in the dynamical mass range 1.0 to 1.3 brought a best fitting orbit with a period of 841 years, a semi-major axis of 5.45 arcseconds and a dynamical mass of 1.29 (Table 3). The full plot in Figure 6.1 does not show much difference in the match with the observations between *Kis2009b* and the newly calculated orbit, but the close-up reveals that the match with the measurements after 2009 is much better with the newly calculated orbit.

Using the Izmailov programs with the WDS observation history for STFA 32 AC and new measurements since publication of *Kis2009b* plus EDR3 (Table 2) and my own recent measures results in a first step in a proposed orbit with a completely unrealistic huge dynamical mass. The set of 200 possible orbits does not include a single entry with a dynamical mass <6.
To some degree, this might be a side effect of a triple system with the center of mass for the inner system not ident with the position of A. However, a closer look at the observation history gives the impression of no systematic change of Rho and Theta over the observation time frame of about 200 years (with the first measurement in 1823 obviously an outlier). This suggests a potential rectilinear solution (Table 4) despite the fact that Gaia data clearly supports gravitational relationship, but this does not necessarily mean an orbit. The comparison with the best fitting *Kis2009b3* orbit (Figure 6.2) shows clearly the much better match of the rectilinear solution with the most recent measurements.

2.7. WDS 17153-2636 SHJ 243

SHJ 243 is a physical triple (system in the solar neighborhood discussed in Knapp 2020) listed in the WDS Catalog with two additional optical components D and E. Separation and position angle for the optical components are due to the huge difference in proper motion quickly changing. The 6th Orbit Catalog lists a grade *4 Irw1996* orbit for SHJ 243AB with a period of 471 years and a semi-major axis of 13 arcseconds. Own recent measurement for SHJ 243 AB (Table 1) corresponds with the 2021 ephemerides within the given error range. There is no orbit listed for AC, because the number of AC measurements is simply too small for the calculation of a realistic orbit.

Hipparcos lists for AB a combined parallax of 168.54 and for C of 167.49. Gaia DR1 provides no parallax values for SHJ 243 ABC and DR2 gives for AB parallaxes of 167.82/167.78 and for C of 168.07 while EDR3 offers parallax values of 168.00/168.13/167.96.
StarHorse median masses are 0.79/0.79/0.70 corresponding very well with the RECONS list values of 0.85/0.85/0.71. Spectral types K5/K1/K5 suggest masses of 0.58/0.72/0.58, but there is no good explanation, why the primary should have less mass than the secondary. Photometric mass estimations are 0.72/0.72/0.53. This give a range of 1.3 to 1.7 for the inner system AB and for the total system mass ABC from 1.9 to 2.4.

The *Irw1996* orbit gives with the EDR3 parallaxes a system mass of 2.09, which seems a bit too high. Izmailov 2019 suggested orbits (one with and one without measurement weights) with a dynamical mass <0.2, which is clearly obsolete – may be this is the reason why they are not included in the 6th Orbit Catalog. The dynamical mass for the orbit suggested in Knapp 2020 is even smaller, which demonstrates that the presentation of orbital elements without prior check of the dynamical mass is not very useful.

Simulation with EDR3 plus StarHorse data suggests 100% likelihood for a gravitational relationship for AB with a minimum spatial distance of 30 AU with a minimum period of 132 years for an assumed circular orbit. Simulation for AB/C gives despite the huge angular separation also 100% likelihood for gravitational relationship with a minimum spatial distance >4,300 AU and a minimum period >190,000 years for an assumed circular orbit.

The WDS observation history starts 1777 with about 280 measurements up to now with several of them clearly outliers. The initial result with the Izmailov programs using the WDS observation history extended with EDR3 and own measurements was as to expect nearly identical with Knapp 2020, which is obsolete due to the far too small dynamical mass. The set of 200 possible orbits contains only a few entries with a dynamical mass between 1.3 and 1.7. One of these with a period of 622 years and a semi-major axis of 13.81 arcseconds (Table 3) offers a dynamical mass of 1.43, slightly better overall residuals than *Irw1996* and especially a very good match with the Gaia measures (Figure 7).

3. Side results

3.1. WDS 09245+0621 STF1348

This object is so far (per June 2021) not listed in the 6th Orbit Catalog; however, three different orbits are suggested by Greaves et al. 2021. Therefore, I decided to have a closer look at this object, even if I cannot contribute own measures (the angular separation of ~2 arcseconds is too close for resolution with the equipment I use currently for imaging).

STF1348 is the main component of an assumed at least quintuple system (Greaves et al. 2021) with a long observation history starting in 1831. Hipparcos parallax is 14.05 with a large error range; DR1 parallax for the primary is 16.19. DR2 parallaxes are 16.14 and 16.20 with a small error range. StarHorse median masses are 1.47 and 1.25 giving a system mass of 2.72 – quite close to the system mass of 2.88 estimated based on absolute magnitudes. EDR3 parallaxes are 16.21 and 16.17 with a small error range. Simulation with these data results in a minimum spatial distance of 120 AU and a minimum period of ~800 years for an assumed circular orbit suggesting 100% likelihood for gravitational relationship. The three orbits presented by Greaves et al. 2021 come with very different periods of 4,734, 8,613 and 568 years, which indicates the large spread of possible orbits for this pair. The first one (henceforth Rica1) seems the most realistic one with a dynamical mass of 2.57 and a very good match with the Gaia measures. The second orbit offers a bad match with the Gaia measures and the third one comes with an unrealistic large dynamical mass of 5.51.

Eliminating observation history outliers causing spikes in Rho or Theta, adding the missing EDR3 measure (Table 2) and using then the Izmailov programs resulted in several entries in the set of 200 possible orbits with a dynamical mass around 2.8. The solution with a period of 723 years and a semi-major axis of 1.8 arcseconds (Table 3) offers a very good match with the Gaia measures. The fact that STF1348 has the distant binary system NSN 594 as companion is a plausible reason why the AB orbit is not a perfect ellipse, so that even measurements without errors would yield some residuals.

The first close-up plot (Figure 8) gives the impression that Rica1 is in terms of Gaia measure residuals the clearly better orbit even if the differences are only in the dimension of hundredths arcseconds. However, the second close-up shows that Rica1 has a small but obvious time lag making the match with Gaia comparable. The newly calculated orbit has overall the advantage of slightly better residuals and a more realistic dynamical mass at the price of a period <800 years, which is potentially a bit too fast.

3.2. WDS 01499+8053 STT 34

The 6th Orbit Catalog lists for STT 34 currently the grade 3 *Hrt2008* orbit with a period of ~196 years and a semi-major axis of ~0.7 arcseconds. Alzner 2021 reports a new measurement for this object offering a very bad match with this orbit and suggests three newly calculated alternative orbits. Therefore, I decided to have a closer look at this object, even if I cannot contribute own measures (the angular separation of ~0.5 arcseconds is far too close for resolution with the equipment I use for imaging).

Hipparcos parallax for the combined object is 5.03 with a large error range of 0.68. Gaia provides no parallax data so far; therefore, also no StarHorse data is available.
From a statistical point of view there are about 13,000 matches of Hipparcos objects with Gaia EDR3 objects with a Hipparcos parallax between 4.4 and 5.6 and less than 1% show a positive difference in the parallax value greater than three times the given error value and less than 3,5% twice the error value. This means a likelihood of 99% that a realistic parallax should be smaller than *5.03+3*0.68=7.1* – with the caveat that Gaia seems to have some troubles with this object as DR1, DR2 do not even list a combined object, and EDR3 gives a combined object without duplicated_source marker.
Malkov et al. 2012 report a dynamical mass for the older *Hei1997* orbit of 14.28 offering a bad match with the photometric mass estimation of 4.72 and a spectroscopic mass of 2.24. As the spectral class A0V is either only for the primary or for the combined object, the latter value should most likely be doubled.

The observation history for this object starts 1843 with so far 56 measurements, the first 16 of them showing quadrant ambiguities due to the similar visual magnitude. Several of these observations seem questionable due to the small (and most likely for resolution unsuited) aperture used with one of them (1925.63) a clear outlier. Alzner 2021 takes the approach to locate all measures up to 1931 in the second quadrant, which means quadrant correction for all but three measures, which follows the lead of Heintz 1997. The best fitting of the three Alzner orbits is *Alz2021 B* with a period of 176.6 years and a semi-major axis of 0.35 arcseconds, which gives with the Hipparcos parallax a dynamical mass of ~8.4, while the two other orbits give a dynamical mass >12.
Hrt2008 takes regarding quadrants the opposite approach, but the dynamical mass for the *Hrt2008* orbit with the Hipparcos parallax is >70 Sun masses, which makes this orbit clearly obsolete. Overall, none of the orbits discussed so far seems to be a realistic solution.

The observation history (with the Alzner 2021 approach regarding quadrants) brings with the Izmailov programs a very consistent result: The set of 200 possible orbits with a median period of 163 years and a median semi-major axis of 0.39 arcseconds suggests a median dynamical mass of 17.6, which is obviously far too high. But this leads to the speculation that the Hipparcos parallax might be too small beyond the given error range – for example, a parallax of 7.15 gives for the *Alz2021 B* orbit a dynamical mass of ~3.65 corresponding with the photometric system mass with this parallax value. Interestingly Heintz 1997 reported a dynamical parallax of 8.0 for a photometric system mass of 3.55.

However, manipulating the estimated parallax value in order to obtain a desired result for the dynamical mass seems questionable anyway, and the mixture of quadrant problems with measurement quality problems raises additional doubts about the reliability of such results.

Just as experiment I therefore decided to simply eliminate all measures before 1931 as outliers and have a look at the remaining solid observation history with the Izmailov programs with the target to find a solution with a dynamical mass corresponding with the photometric system mass as close as possible to the Hipparcos parallax.
One of the calculated possible orbits offers with a period of 194 years, a semi-major axis of 0.32 arcseconds a dynamical mass of 4.2 (Table 3) with a parallax value of 5.9, which means within 1.3 times the Hipparcos error value. This orbit seems also to confirm the Alzner approach regarding quadrants for the measures up to 1931. Residuals are only slightly worse compared to *Alz2021 B* even over the full observation history including the eliminated measures up to 1931 (Figure 9, second close-up with the *Alz2021 B* residuals up to 1931).

The question remains, if this orbit is "really necessary" – in relation to the currently given data as it seems rather not, but in comparison with the orbits published so far most certainly yes. Most important, a more precise parallax value would be highly appreciated as well as additional new precise measurements.

3.3. WDS 02270+3117 HO 216

There is a grade 5 *Izm2019* entry given in the 6th Orbit Catalog for this pair with a period of 1,041 years and a semi-major axis of 2.5 arcseconds and the WDS Catalog lists spectral type F6 for the primary. The question, which spectral type the secondary might then be motivated me to have a closer look at this pair, although the current separation of ~1.4 arcseconds is too close for own measurements with the equipment available for me.

Hipparcos parallax for the combined object is 12.67. Gaia DR1 lists a combined object without parallax and DR2 lists parallaxes of 12.029 and 11.837. Simulation with Gaia EDR3 parallaxes of 12.02 and 11.94, angular separation of 1.41 arcseconds and StarHorse median masses of 1.55 and 0.87 suggests a likelihood for gravitational relationship of ~95% with a minimum spatial distance of 118 AU and a minimum period of 827 years for an assumed circular orbit.
Photometric mass estimations are 1.42 and 1.0 close to the StarHorse values. Together this suggests that a system mass of ~2.4 seems realistic. The average EDR3 parallax gives with the period and semi-major axis values of the grade 5 orbit *Izm2019* a dynamical mass of 8.15, which seems far too high and makes this orbit obsolete.

The WDS observation history covers about 135 years with a surprising small number of measurements and Gaia DR2 and EDR3 measures (Table 2) not included. Several of the older measures result in spikes in between the measurements before and after indicating some quality issues but overall a systematic curvature is evident. Using the Izmailov programs with the observation history as given including the Gaia data yields a good number of possible orbits with a dynamical mass ~2.4 but none of these offers a reasonable good match with the Gaia measures. After exanimating the observation history closer, I decided to eliminate the mentioned spikes by averaging several of the measures made within a short time period and applied the Izmailov programs again. The resulting set of possible orbits included again a good number of orbits with a dynamical mass ~2.4. One of them with a period of 885 years and a semi-major axis of 1.49 arcseconds (Table 2) offers a very good match with the Gaia measures with else identical residuals to the currently listed *Izm2019* orbit, but with a realistic dynamical mass. The orbit plot (Figure 10) shows that the newly calculated orbit is in the time frame of the given measurements quite ident with *Izm2019* with only a slight modification in the curvature but stands out significantly in the coming decades.

Coming back to the mentioned spectral type issue: F6 for the primary, which means most likely for the combined object, corresponds with a mass of 1.22, which is in the middle of the assumed system mass of ~2.4 with assumed component masses of ~1.4 and ~1.0. Using the relationship spectral type to mass gives crude spectral type estimations of ~F2 for the primary and ~G5 for the secondary.

4. Discussion

It is difficult to compete with small terrestrial telescopes against satellite-based measurements for accuracy. Therefore, own measurements rarely give a serious reason to question published orbits since the error range of the measurements usually covers the orbit ephemerides. However, own measurements give anyway reason to have a closer look at published orbits to check especially for reasonable dynamical mass and for a satisfactory match with Gaia data (often not fully covered by the WDS observation history). Unrealistic dynamical masses and bad matches with the Gaia measures are common properties of premature orbits, which makes them obsolete and gives reason to attempt the calculation of still premature but at least realistic orbit variants or in some cases rectilinear solutions.

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

- VizieR B/wds – The Washington Visual Double Star Catalog (Mason+ 2001-2020), 2001AJ....122.3466M
- WDS observation histories. Special thanks to Brian Mason for providing me with the observation histories for all objects discussed in this report
- 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)
- Second Catalog of Rectilinear Elements (http://www.astro.gsu.edu/wds/lin2.html, William I. Hartkopf & Brian D. Mason, U.S. Naval Observatory, Washington, DC, last update: Sep 15 2020)
- VizieR I/337, I/345, I/350 – Gaia DR1, DR2, EDR3 catalogues (Gaia Collaboration, 2016, 2018 and 2020), 2016A&A...595A...1G, 2018A&A...616A...1G, 2020yCat.1350....0G
- VizieR I/329 – URAT1 Catalog (Zacharias+ 2015), 2015AJ....150..101Z
- VizieR I/322A – CAC4 Catalogue (Zacharias+, 2012), 2012yCat.1322....0Z

- VizieR I/349 – StarHorse, Gaia DR2 photo-astrometric distances (Anders+, 2019), 2019A&A...628A..94A
- VizieR I/311 – Hipparcos, the New Reduction (van Leeuwen, 2007), 2007A&A...474..653V
- VizieR J/A+A/546/A69 – Orbits of visual binaries and dynamical masses (Malkov+, 2012), 2012A&A...546A..69M
- VizieR J/other/Ser/180.71/binaries – Masses of visual binaries (Cvetkovic+, 2010), 2010SerAJ.180...71C
- VizieR B/sb9 – SB9: The ninth catalogue of spectroscopic binary orbits (Pourbaix+ 2004-2014), 2004A&A...424..727P, (http://sb9.astro.ulb.ac.be/mainform.cgi)
- 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)
- CDS VizieR
- CDS Simbad
- CDS Aladin Sky Atlas v11.0
- DSS2 and 2MASS images
- AAVSO VPhot
- Astrometrica v4.10.0.427
- AstroPlanner v2.2
- MaxIm DL6 v6.08
- iTelescope
    - iT24: 610mm CDK with 3962mm focal length. Resolution 0.625 arcsec/pixel. V-filter. Located in Auberry, California. Elevation 1405m
    - iT32: 430mm CDK with 2912mm focal length. Resolution 0.64 arcsec/pixel. V-filter. Located in Siding Spring, Australia. Elevation 1122m

References:

- Alonso-Floriano, F. J.; Morales, J. C.; Caballero, J. A.; Montes, D.; Klutsch, A.; Mundt, R.; Cortés-Contreras, M.; Ribas, I.; Reiners, A.; Amado, P. J.; Quirrenbach, A.; Jeffers, S. V. – 2015, CARMENES input catalogue of M dwarfs. I. Low-resolution spectroscopy with CAFOS, Astronomy & Astrophysics, Volume 577, A128, 19 pp.
- Alzner, Andreas – 2021, Micrometric measures of double stars 2020.10 to 2020.90, Double Star Section Circular No 29, The Webb Deep-Sky Society
- W. H. van den Bos – 1962, Is This Orbit Really Necessary?, Publications of the Astronomical Society of the Pacific, Vol. 74, No. 439, p.297
- Natalie Grasser, Sebastian Ratzenböck, João Alves, Josefa Großschedl, Stefan Meingast, Catherine Zucker, Alvaro Hacar, Charles Lada, Alyssa Goodman, Marco Lombardi John C. Forbes, Immanuel M. Bomze and Torsten Möller – 2021, The ρ Ophiuchi region revisited with Gaia EDR3 - Two young populations, new members, and old impostors. A&A, 652 A2
- Greaves, John, Rica Romero, Francisco Manuel and Otero, Sebastian – 2021, Σ1348AB, LDS 3888C and NSN 594 are a physical double-double with one of these stars also eclipsing, Journal of Double Star Observations Volume 17 pp 137 – 140

- Heintz, W.D. – 1997, Orbits of 40 Visual Binaries, The Astrophysical Journal Supplement Series, Volume 111, Issue 1, pp. 335-338
- A. A. Kisselev, L. G. Romanenko and O. A. Kalinichenko – 2009, A Dynamical Study of 12 Wide Visual Binaries, Astronomy Reports, 2009, Vol. 53, No. 2, pp. 126–135
- Knapp, Wilfried R. A. – 2020, Star Systems in the Solar Neighborhood up to 10 Parsecs Distance, Journal of Double Star Observations, Volume 16, Number 3, pages 296-408
- Knapp, Wilfried R. A. – 2021, Neglected Orbits in the 6th Catalog of Orbits, Journal of Double Star Observations, Volume 17, Number 4, pages 229-288
- Knapp, Wilfried R. A. – 2022, Wide Pairs in the Sixth Catalog of Orbits of Visual Binary Stars, Journal of Double Star Observations, in publishing pipeline
- Malkov, Oleg, Tamazian, V., Docobo, J., Chulkov, Dmitry – 2012, Dynamical masses of a selected sample of orbital binaries, Astronomy and Astrophysics, volume 546A, 69
- A. A. Tokovinin1 and M. G. Smekhov – 2002, Statistics of spectroscopic sub-systems in visual multiple stars, A&A 382, 118-123
- Tokovinin, Andrei – 2018, The Updated Multiple Star Catalog, The Astrophysical Journal Supplement Series, Volume 235, Number 1

Table 1: Averaged Measurements 2021

WDS_ID	Comp	Date	PA	e_PA	Sep	e_Sep	M1	e_M1	M2	e_M2	WL	FW	Ap	N	Ref	Me	DE
11214-2027		2021.30346	356.216	1.525	3.64916	0.09741	8.447	0.093	10.449	0.107	550	89	0.4	4	KPP2022a	C	7
11550-5606		2021.30237	168.622	1.785	3.81931	0.11888	6.897	0.089	7.352	0.090	550	89	0.4	5	KPP2022a	C	7
15151+3318	AB	2021.45987	336.376	0.263	27.49113	0.12596	12.765	0.090	11.172	0.079	550	89	0.6	7	KPP2022a	C	7
15151+3318	AC	2021.45987	70.099	0.194	37.14107	0.12596	12.765	0.090	12.928	0.092	550	89	0.6	7	KPP2022a	C	7
15151+3318	BC	2021.45987	105.274	0.152	47.61952	0.12596	11.172	0.079	12.928	0.092	550	89	0.6	7	KPP2022a	C	7
15155+3319		2021.48906	77.733	0.080	104.97771	0.14694	3.358	0.085	7.747	0.078	550	89	0.6	9	KPP2022a	C	7
16147+3352	AB	2021.44038	239.516	0.959	7.21570	0.12110	5.651	0.087	6.542	0.087	550	89	0.6	7	KPP2022a	C	7
16147+3352	AC	2021.44038	91.175	0.248	27.73770	0.12018	5.651	0.087	13.377	0.097	550	89	0.6	7	KPP2022a	C	7
16147+3352	AD	2021.44038	82.005	0.072	95.32042	0.12018	5.651	0.087	10.642	0.088	550	89	0.6	7	KPP2022a	C	7
16147+3352	AE	2021.44038	241.102	0.011	635.06791	0.12018	5.651	0.087	12.272	0.091	550	89	0.6	7	KPP2022a	C	7
16147+3352	BD	2021.44038	80.510	0.067	102.03839	0.12018	6.542	0.089	10.642	0.088	550	89	0.6	7	KPP2022a	C	7
16256-2327	AB	2021.44860	334.883	5.268	3.01510	0.27803	5.011	0.081	5.253	0.083	550	89	0.6	1	KPP2022a	C	7
16256-2327	AC	2021.44860	359.911	0.105	151.09018	0.27803	5.011	0.081	6.978	0.080	550	89	0.6	1	KPP2022a	C	7
16256-2327	AD	2021.44860	252.556	0.102	156.14147	0.27803	5.011	0.081	6.443	0.080	550	89	0.6	1	KPP2022a	C	7
16579+4722	AB	2021.43777	63.946	1.192	4.97928	0.10354	7.803	0.075	11.251	0.086	550	89	0.6	6	KPP2022a	C	7
16579+4722	AC	2021.43777	261.520	0.053	112.37699	0.10354	7.797	0.076	7.906	0.076	550	89	0.6	6	KPP2022a	C	7
17153-2636	AB	2021.44040	137.938	2.406	5.08478	0.21368	4.685	0.096	4.704	0.096	550	89	0.4	2	KPP2022a	C	7
17153-2636	AC	2021.44040	74.148	0.017	732.51912	0.21368	4.685	0.096	5.861	0.095	550	89	0.4	2	KPP2022a	C	7
17153-2636	AD	2021.44040	342.189	0.041	295.52351	0.21368	4.685	0.096	7.257	0.095	550	89	0.4	2	KPP2022a	C	7

17153-2636	AE	2021.44040	342.066	0.232	52.63792	0.21368	4.685	0.096	12.532	0.110	550	89	0.4	2	KPP2022a	C	7
17153-2636	BD	2021.44040	341.763	0.041	300.20875	0.21368	4.704	0.096	7.257	0.095	550	89	0.4	2	KPP2022a	C	7

Content description:

WDS_ID	001-010	a10	WDS Designator
Comp	012-016	a5	left justified component designator. If AB this is blank
Date	018-027	f10.5	Observation date, in years
PA	030-036	f7.3	position angle, in degrees
e_PA	038-043	f6.3	published formal theta error, in degrees
Sep	046-054	f9.5	separation, in arcseconds
e_Sep	057-063	f7.5	separation error, in same units as rho
M1	066-071	f6.3	primary magnitude, in mag
e_M1	073-077	f5.3	primary magnitude error, in mag
M2	080-085	f6.3	secondary magnitude, in mag
e_M2	087-091	f5.3	secondary magnitude error, in mag
WL	093-096	a4	filter effective wavelength in nm
FW	097-100	a4	filter FWHM in nm
Ap	103-107	f5.1	telescope aperture, in meters
N	110-111	i2	number of nights averaged into mean measure
Ref	113-120	a8	reference code
Me	122-123	a2	technique code, for example, Gaia = Hg
DE	127-127	a1	data entry note. Now, this is "7".

Table 2: Gaia measures (so far not included in the WDS observation history, but used for orbit re-calculation)

WDS_ID	Comp	Date	PA	e_PA	Sep	e_Sep	M1	e_M1	M2	e_M2	WL	FWHM	Ap	N	Ref	Me	DE
09245+0621		2016.0	314.343	0.002	1.94971	0.00005	7.369	0.003	7.394	0.003	640	455	1.0	1	KPP2022a	Hg	7
11214-2027		2015.0	353.855	0.006	3.86133	0.00038	8.026	.	10.006	.	673	440	1.0	1	KPP2022a	Hg	7
11214-2027		2016.0	354.430	0.005	3.81136	0.00034	8.125	0.003	10.181	0.003	640	455	1.0	1	KPP2022a	Hg	7
11550-5606		2016.0	349.044	0.001	3.86325	0.00004	7.557	0.003	7.074	0.003	640	455	1.0	1	KPP2022a	Hg	7
15155+3319		2015.5	77.923	0.000	104.90753	0.00042	3.053	0.004	7.665	0.000	673	440	1.0	1	KPP2022a	Hg	7
15155+3319		2016.0	77.922	0.000	104.90713	0.00012	3.211	0.003	7.678	0.003	640	455	1.0	1	KPP2022a	Hg	7
16147+3352		2016.0	238.527	0.000	7.23114	0.00006	5.431	0.003	6.438	0.003	640	455	1.0	1	KPP2022a	Hg	7
16256-2327		2016.0	334.894	0.004	2.99978	0.00023	4.912	0.003	5.566	0.003	640	455	1.0	1	KPP2022a	Hg	7
16579+4722	AB	2016.0	63.037	0.000	5.09094	0.00003	7.521	0.003	10.419	0.003	640	455	1.0	1	KPP2022a	Hg	7
16579+4722	AC	2016.0	261.552	0.000	112.37755	0.00003	7.521	0.003	7.622	0.003	640	455	1.0	1	KPP2022a	Hg	7
17153-2636	AB	2016.0	140.761	0.002	5.07208	0.00015	4.831	0.003	4.829	0.003	640	455	1.0	1	KPP2022a	Hg	7

Content description identical to table 1

Gaia magnitudes G-band. WL and FWHM according to existing DR1/DR2 entries in the WDS observation history

EDR3 WL and FWHM according to Gaia Early Data Release 3 Documentation, 5.4.1 Calibration, Author(s): G. Busso, P. Montegriffo https://gea.esac.esa.int/archive/documentation/GEDR3/Data_processing/chap_cu5pho/cu5pho_sec_photProc/cu5pho_ssec_photCal.html

Table 3: Newly calculated orbits

WDS_ID	D		P	A	i	Node	T	e	omega	mass
09245+0621	STF1348		722.975	1.835	105.659	153.467	1784.425	0.793	65.144	2.808
		ΔP16	-156.310	-0.058	-6.686	-6.221	-3.230	-0.142	-2.056	-0.570
		ΔP84	+848.512	+2.114	+0.440	+7.918	+25.103	+0.140	+30.450	+6.498
11214-2027	STN 22		1139.465	7.475	46.742	177.722	2068.344	0.645	253.501	0.728
		ΔP16	-699.868	-2.795	-7.077	-160.614	-21.752	-0.190	-183.060	-0.104
		ΔP84	-0.069	+3.075	+21.598	-30.566	+30.603	+0.273	+12.337	+5.970
11550-5606	HLD 114		1880.790	6.044	111.944	171.762	1894.506	0.475	302.147	1.911
		ΔP16	-1468.782	-3.264	-4.779	-27.459	-126.319	-0.274	-193.739	-0.219
		ΔP84	-934.341	-1.678	+14.371	-4.052	+180.516	+0.294	-56.641	+3.423
15155+3319	STFA 27		433736.596	198.058	65.319	8.507	-197281.706	0.208	270.971	2.088
		ΔP16	-425621.356	-103.678	+19.561	+48.729	+35476.538	+0.148	-164.681	+0.179
		ΔP84	+100349.173	+257.048	+25.663	+72.211	+345579.077	+0.724	-1.415	+1428.926
16147+3352	STF2032		1317.365	7.832	50.145	37.475	1824.368	0.666	79.000	3.255
		ΔP16	-850.266	-3.309	-22.716	+2.259	-7.015	-0.014	-55.928	-0.085
		ΔP84	-351.021	-0.718	+0.426	+70.588	+3.769	+0.140	+248.035	+2.495
16256-2327	H 2 19		28618.884	17.736	127.887	65.576	2420.016	0.774	144.248	20.214
		ΔP16	-26497.202	-9.841	-37.641	-33.389	-2075.499	-0.248	+85.574	+112.610
		ΔP84	+213153.915	+570.425	-16.995	+19.937	+3859.836	+0.173	+146.634	+10234.831
16256-2327	BU 1115 DE		335.991	0.645	144.316	160.392	2013.172	0.590	292.883	4.526
		ΔP16	-69.841	-0.083	-13.065	-127.936	-5.570	-0.000	-101.645	-0.784
		ΔP84	+282.679	+0.333	+6.329	+2.793	+3.443	+0.143	-8.455	+1.167
16579+4722	A 1874 AB		851.449	5.450	78.963	61.726	1868.385	0.212	281.068	1.298
		ΔP16	-456.709	-1.821	-4.581	-0.302	-39.174	+0.043	-195.955	-0.282
		ΔP84	+305.340	+3.110	+5.446	+6.388	+263.321	+0.591	-8.752	+3.193
16579+4722	STFA 32 AC		851.449	5.450	78.963	61.726	1868.385	0.212	281.068	1.298
		ΔP16	-456.709	-1.821	-4.581	-0.302	-39.174	+0.043	-195.955	-0.282
		ΔP84	+305.340	+3.110	+5.446	+6.388	+263.321	+0.591	-8.752	+3.193
17153-2636	SHJ 243 AB		622.053	13.808	100.099	107.852	2106.946	0.889	82.917	1.445
		ΔP16	-72.388	-6.735	+1.179	-8.695	-6.797	-0.660	-41.474	-1.388
		ΔP84	+777.399	-0.404	+24.672	+3.985	+105.598	-0.012	+7.568	-0.269
09245+0621	STF1348		722.975	1.835	105.659	153.467	1784.425	0.793	65.144	2.808
		ΔP16	-154.038	-0.076	-6.380	-5.317	-5.164	-0.121	-2.397	-0.485
		ΔP84	+701.135	+1.720	+0.213	+8.140	+23.880	+0.136	+28.614	+7.377
01499+8053	STT 34		194.032	0.319	18.413	143.220	1936.353	0.764	332.730	4.214
		ΔP16	-21.035	+0.037	+26.936	-64.002	-15.482	-0.381	-296.029	+0.430
		ΔP84	+365.664	+0.416	+50.270	-31.250	+11.169	+0.004	-35.839	+5.481
02270+3117	HO 216		884.938	1.490	52.957	146.229	1820.073	0.632	89.099	2.472
		ΔP16	-387.785	-0.226	-1.462	-47.067	-4.184	-0.090	-5.239	-0.318
		ΔP84	+564.436	+2.579	+24.295	+0.959	+40.846	+0.328	+19.779	+58.553

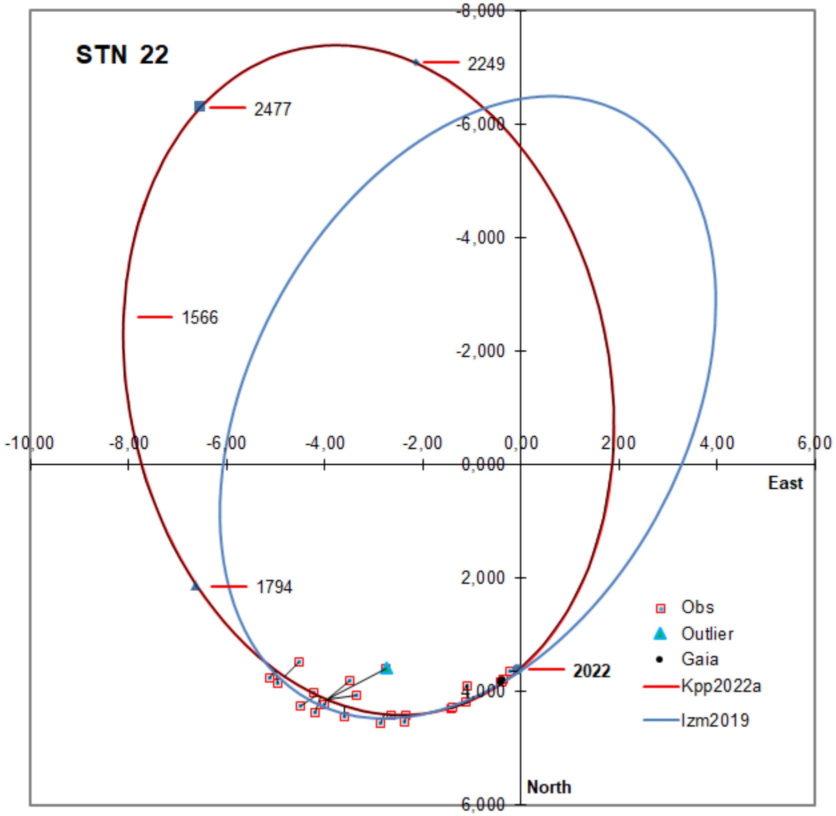
Content description:
WDS_ID WDS Designation
D Discoverer ID
P Period in years
A Semi-major axis in arcseconds
i Inclination of the plane of the orbit to the plane of the sky in degrees
Node Position angle of the ascending node (Omega) in degrees
T Time of periastron passage in fractional years
e Eccentricity [0,1]
omega Plane-of-sky longitude of periastron (reckoned from Node) in degrees
mass Dynamical mass
ΔP16 Delta of the given value to the 16th percentile from the set of 200 possible orbits
ΔP84 Delta of the given value to the 84th percentile from the set of 200 possible orbits

Table 4: Newly calculated rectilinear elements

WDS_ID			X0	XA	Y0	YA	T0	Rho0	Theta0
16256-2327	H 2 19	AB	3,158923	-0,005154	-0,698647	-0,007062	1942,189	3,235	347,529
		+/-	0,020544	0,000420	0,027054	0,000554		0,179	5,111
16579+4722	STFA 32	AC	-15,355228	-0,020475	-112,073837	0,015163	1950,801	113,121	262,198
		+/-	0,121242	0,002185	0,080875	0,001457		0,383	2,097

Content description:
WDS_ID WDS Designator
X0, XA Regression result for the X-axis
Y0, YA Regression result for the Y-axis
T0 Mean date of all measures
Rho0 Rho for T0
Theta0 Theta for T0
+/- X0, XA, Y0 and YA: Standard deviation from regression analysis
+/- Rho0 and Theta0: Observation history residuals root mean square for Rho and Theta

Figures



STN 22
2249
2477
1566
1794
2022
-8,000
-6,000
-4,000
-2,000
0,000
2,000
4,000
6,000
-10,00
-8,00
-6,00
-4,00
-2,00
0,00
2,00
4,00
6,00
East
North
Obs
Outlier
Gaia
Kpp2022a
Izm2019

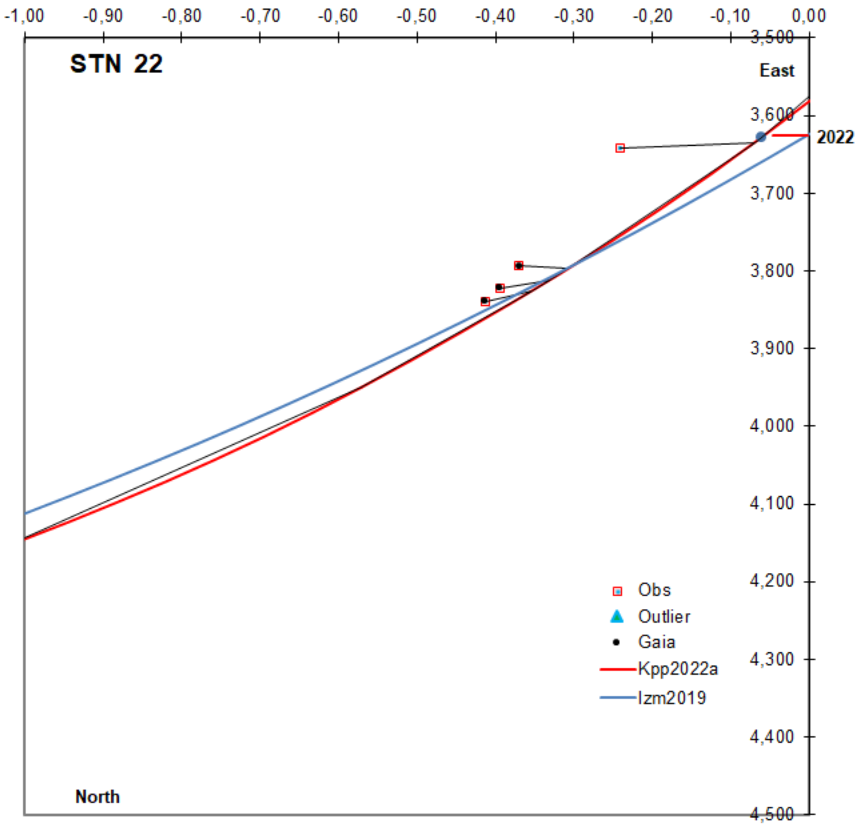
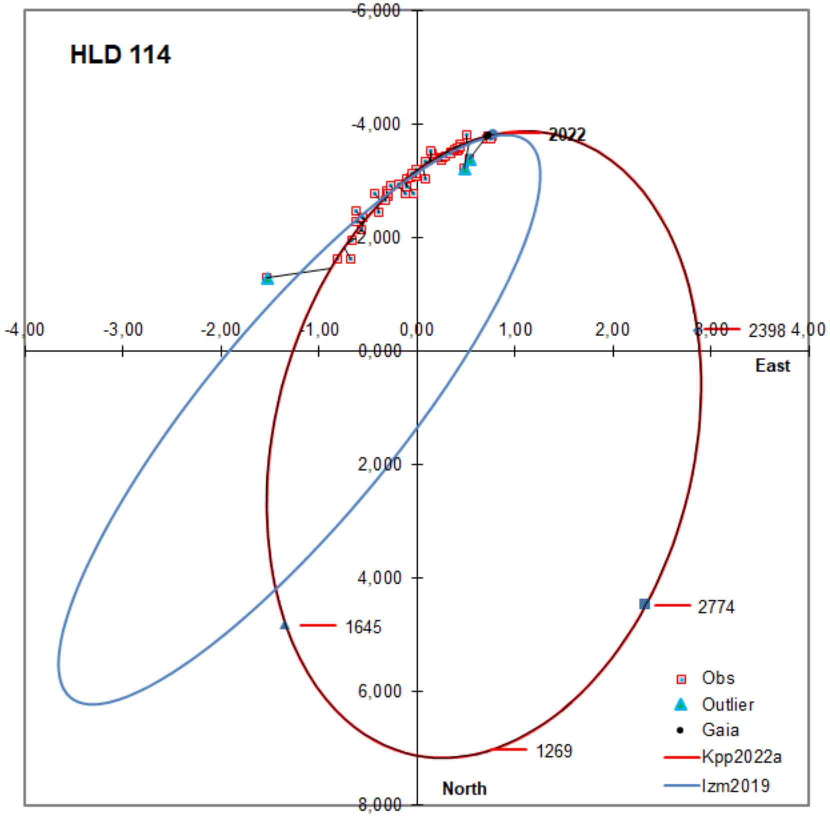


Figure 1:STN 22 orbit comparison with close-up


HLD 114
-6,000
-4,000
-2,000
0,000
2,000
4,000
6,000
8,000
-4,00
-3,00
-2,00
-1,00
0,00
1,00
2,00
3,00
4,00
2022
2398
East
1645
2774
1269
North
Obs
Outlier
Gaia
Kpp2022a
Izm2019

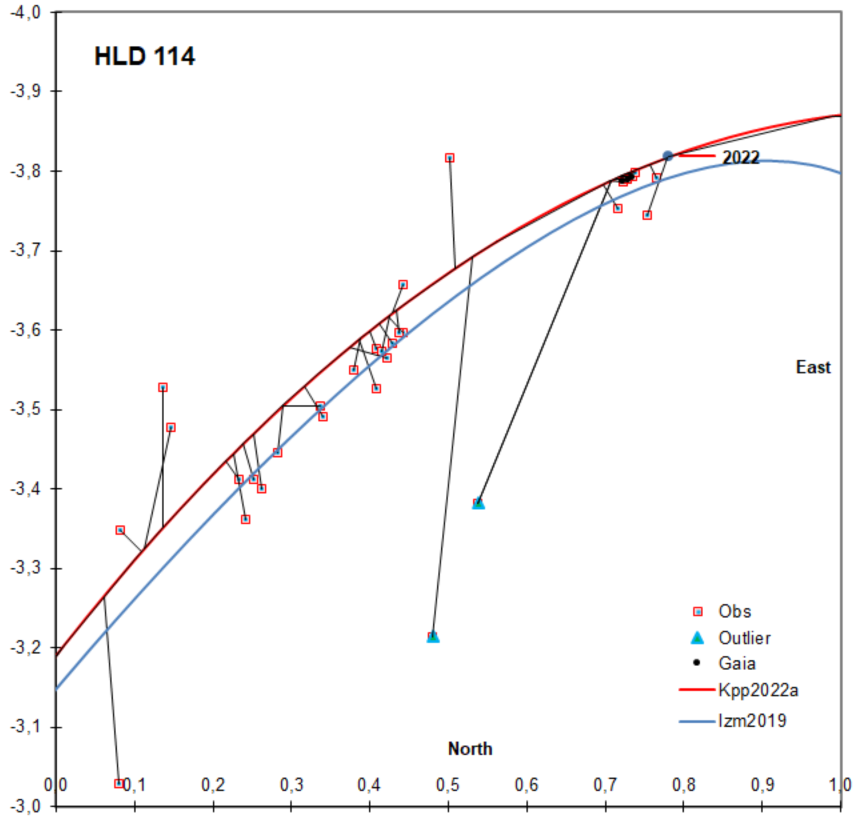


Figure 2: HLD 114 orbit comparison with close-up

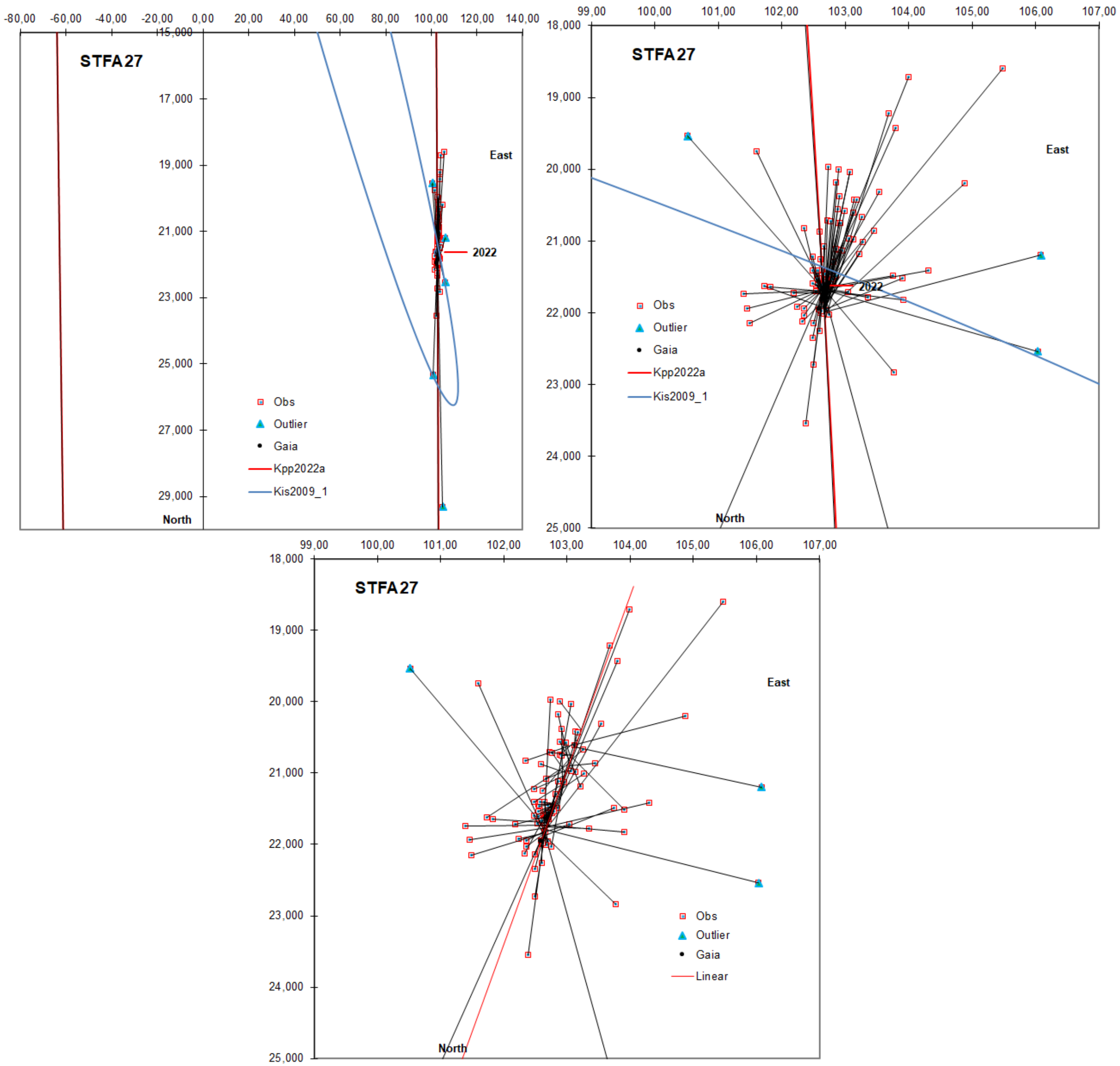


Figure 3: STFA 27 orbit comparison with close-up for orbit and rectilinear solution

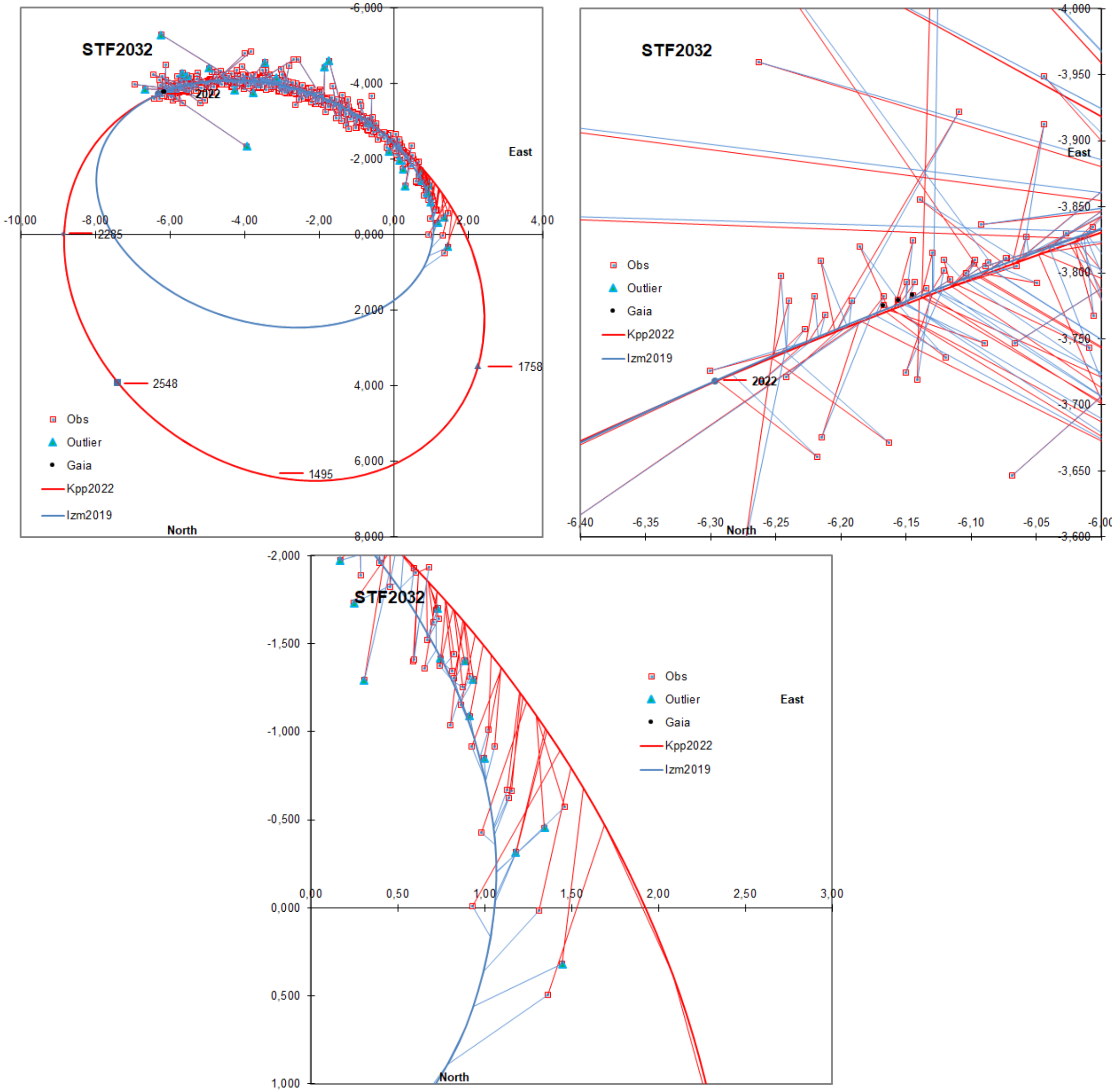
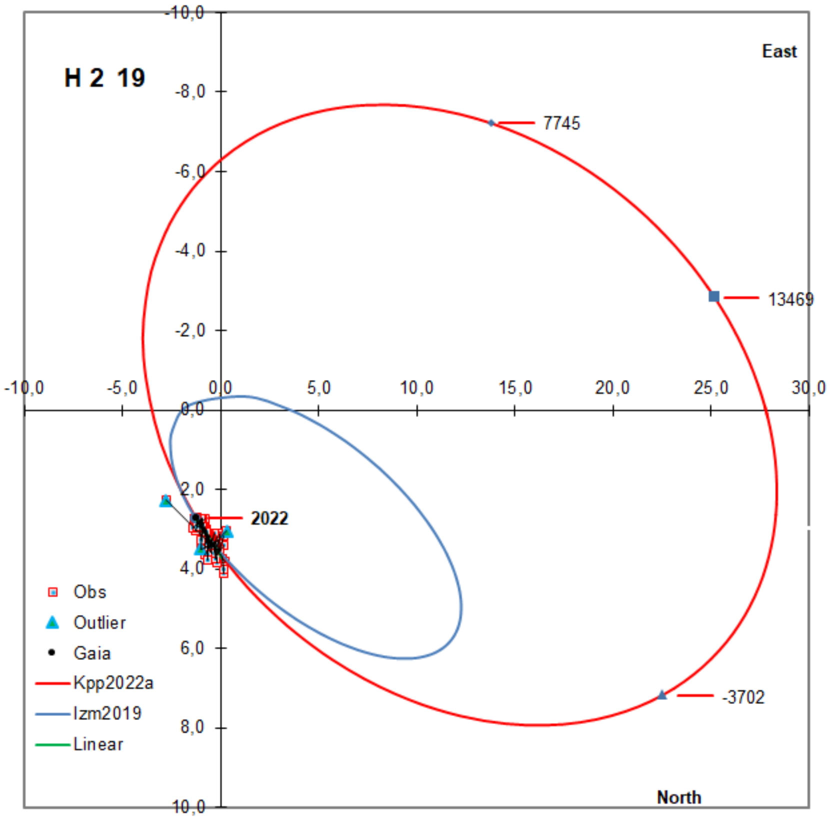


Figure 4: STF2032 orbit comparison with two close-ups


H 2 19
East
North
7745
13469
-3702
2022
Obs
Outlier
Gaia
Kpp2022a
Izm2019
Linear
-10,0
-8,0
-6,0
-4,0
-2,0
0,0
2,0
4,0
6,0
8,0
10,0
-5,0
5,0
15,0
20,0
25,0
30,0

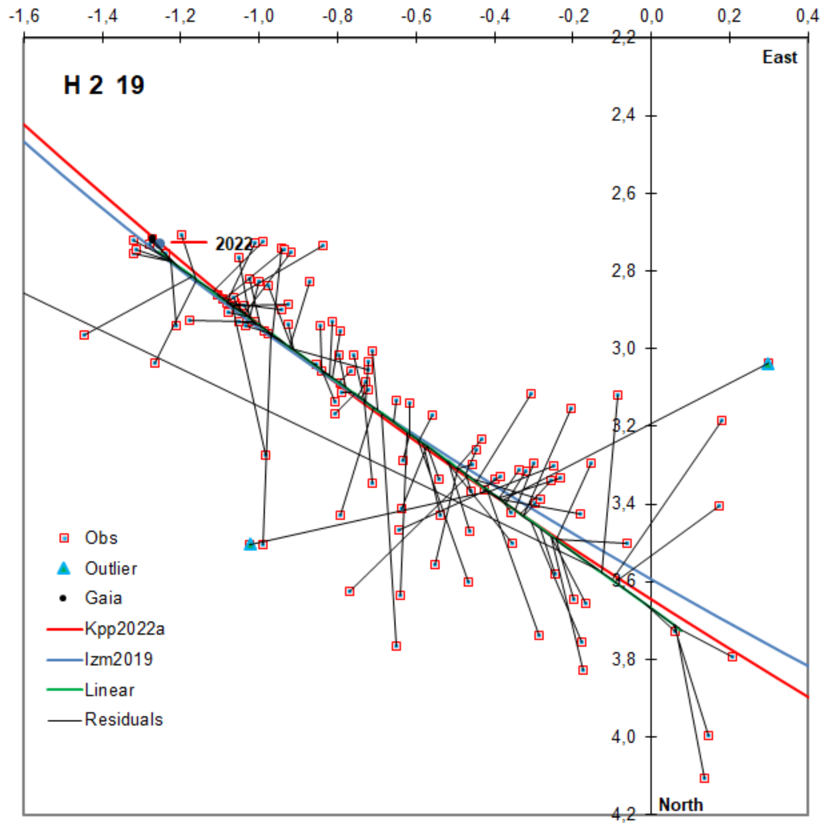
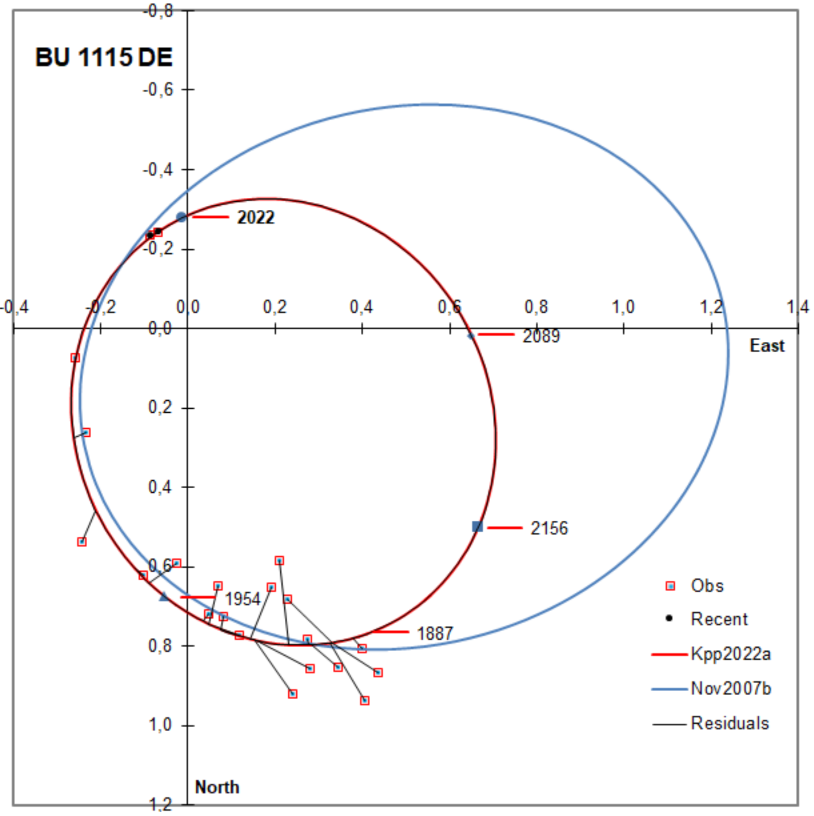


Figure 5.1: H 2 19 orbit comparison with close-up (residuals for rectilinear solution)


BU 1115 DE
-0,8
-0,6
-0,4
-0,2
0,0
0,2
0,4
0,6
0,8
1,0
1,2
-0,4
-0,2
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
2022
2089
East
2156
1954
1887
North
Obs
Recent
Kpp2022a
Nov2007b
Residuals

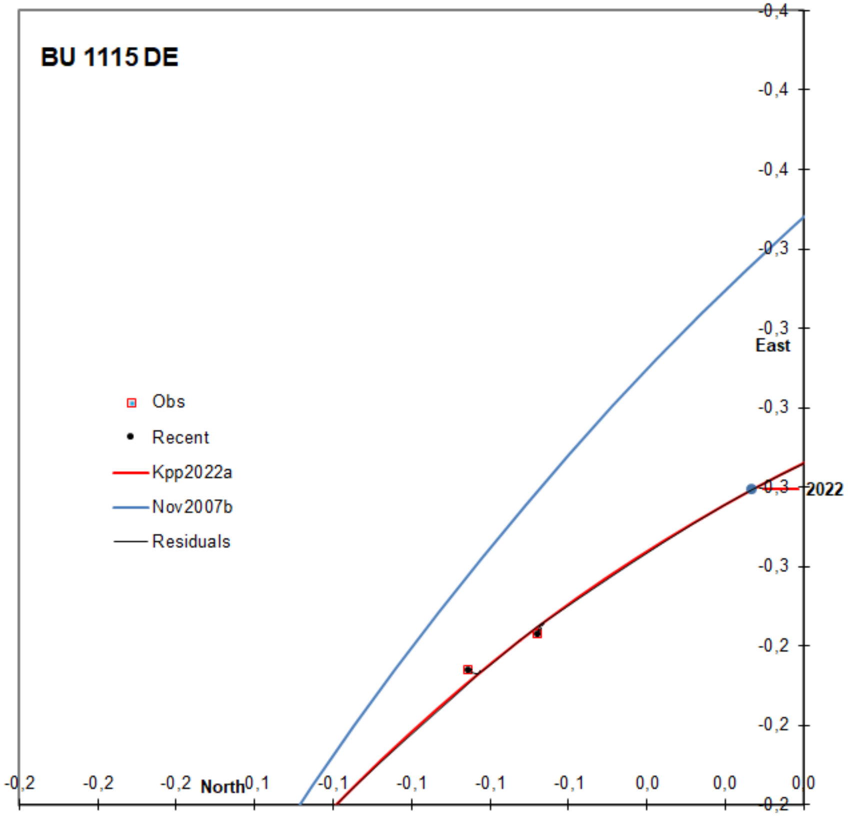
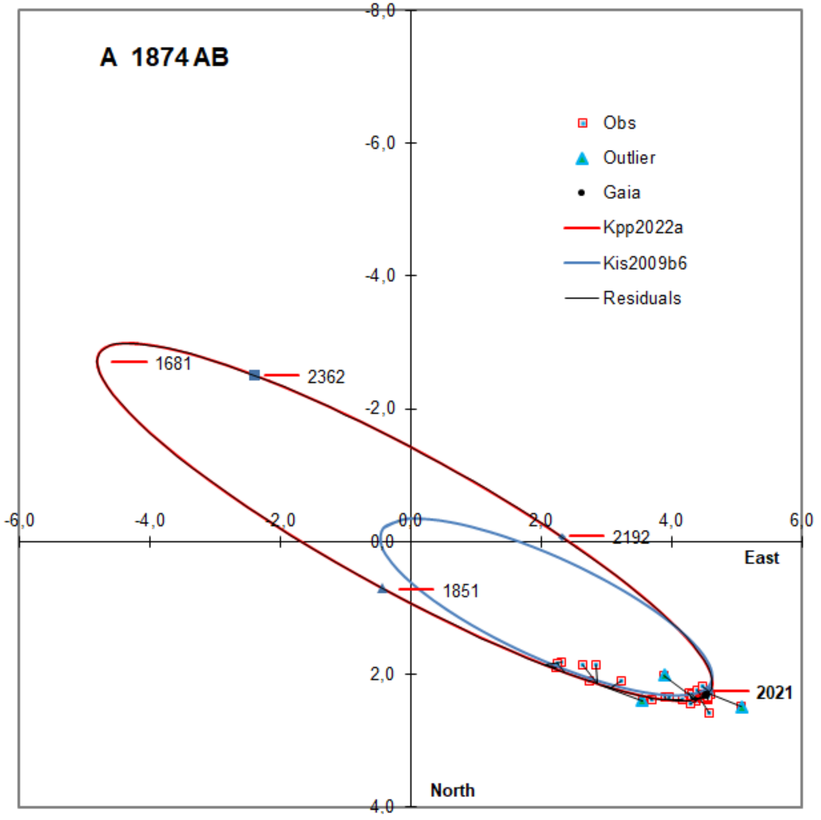


Figure 5.2: BU 1115 DE orbit comparison with close-up


A 1874 AB
Obs
Outlier
Gaia
Kpp2022a
Kis2009b6
Residuals
1681
2362
2192
1851
2021
East
North
-8,0
-6,0
-4,0
-2,0
0,0
2,0
4,0
-6,0
-4,0
-2,0
0,0
2,0
4,0
6,0

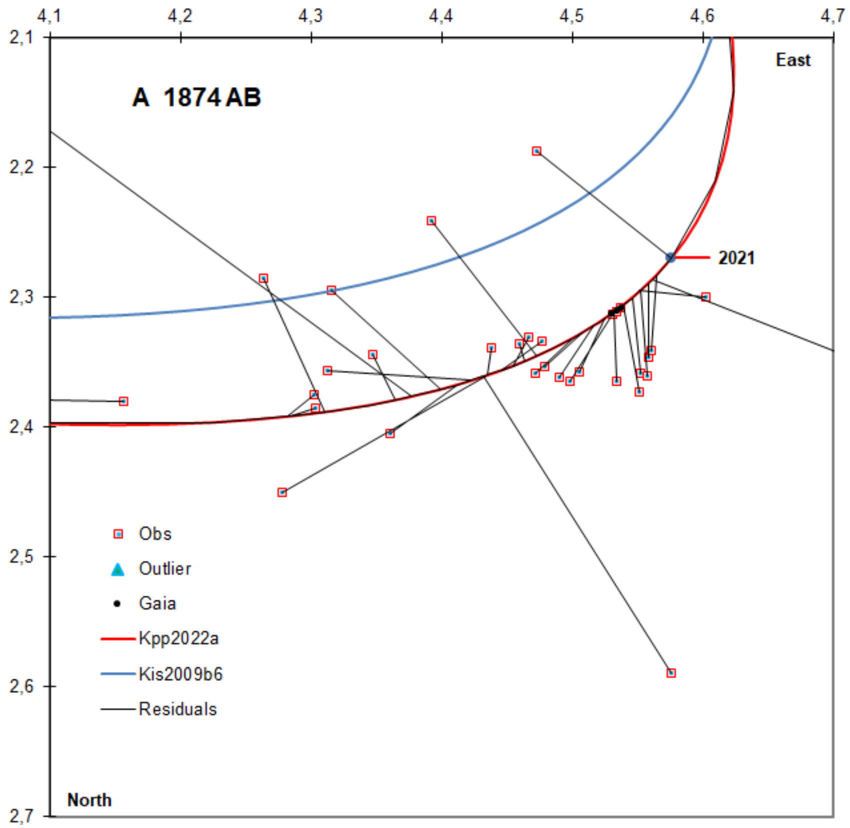
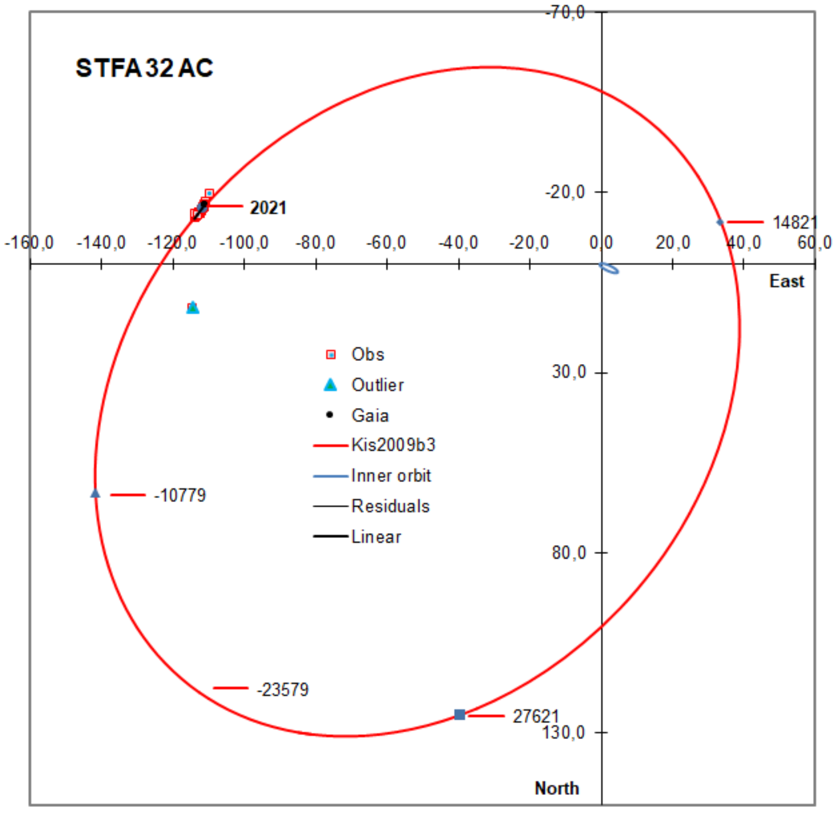


Figure 6.1: A 1874 AB orbit comparison with close-up


STFA 32 AC
2021
14821
-10779
-23579
27621
Obs
Outlier
Gaia
Kis2009b3
Inner orbit
Residuals
Linear
-160,0
-140,0
-120,0
-100,0
-80,0
-60,0
-40,0
-20,0
0,0
20,0
40,0
60,0
-70,0
-20,0
30,0
80,0
130,0
East
North

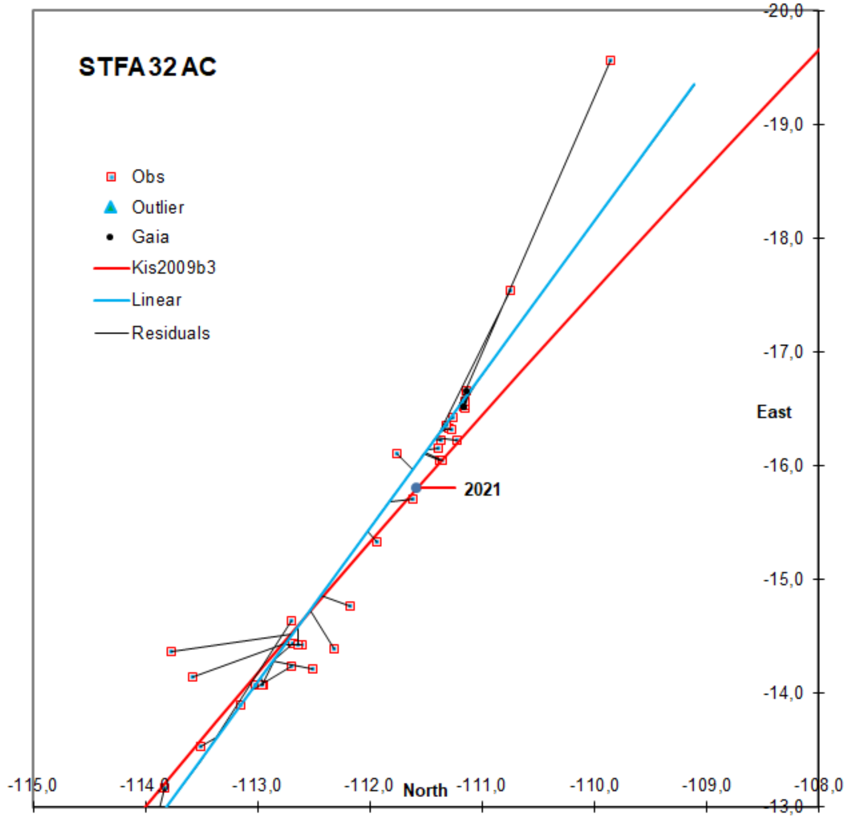
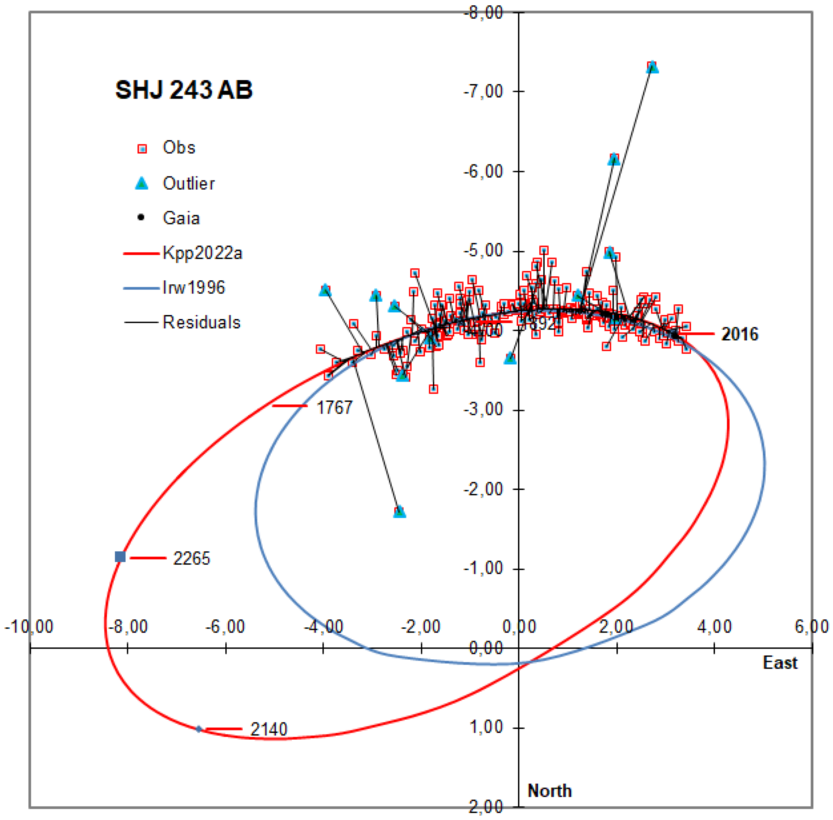


Figure 6.2: STFA 32 AC orbit comparison with close-up (residuals for rectilinear solution)



SHJ 243 AB
Obs
Outlier
Gaia
Kpp2022a
Irw1996
Residuals
2016
1767
2265
2140
East
North

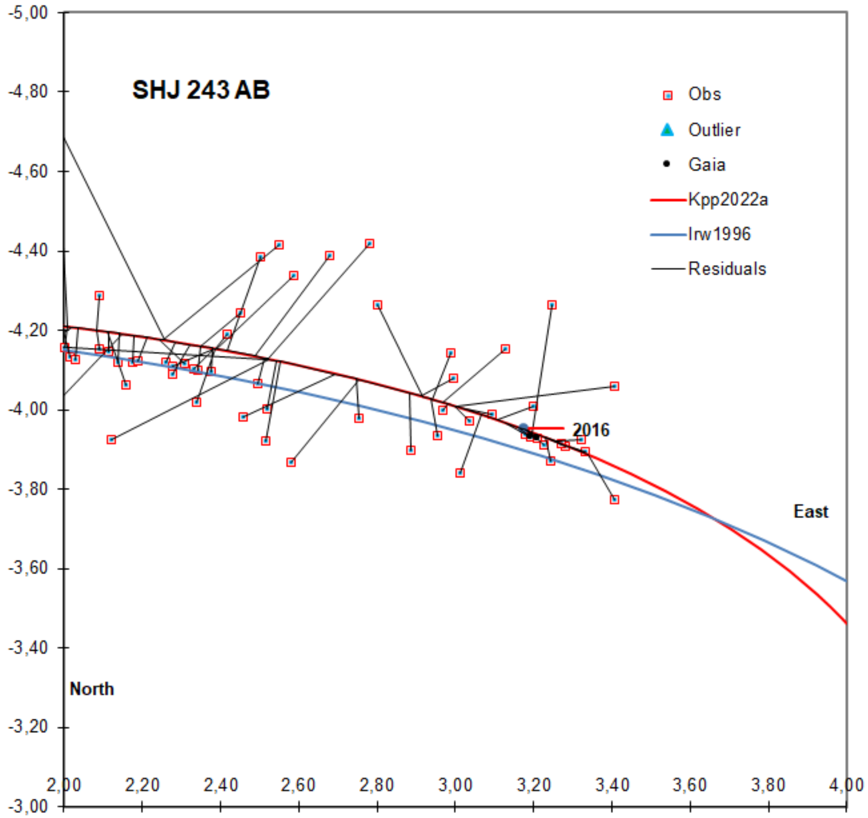


Figure 7: SHJ 243 AB orbit comparison with close-up

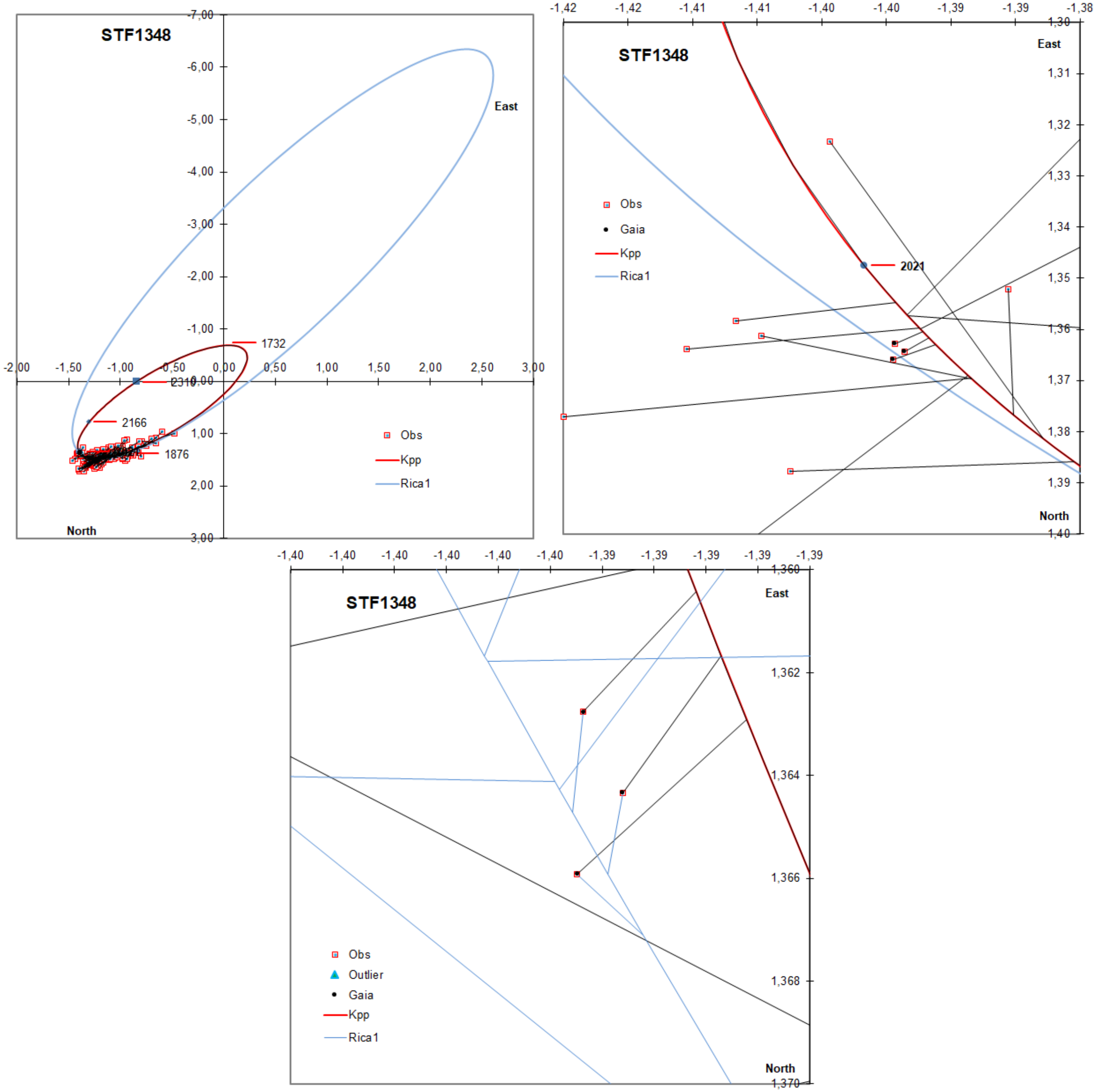


Figure 8:STF1348 orbit comparison with two close-ups

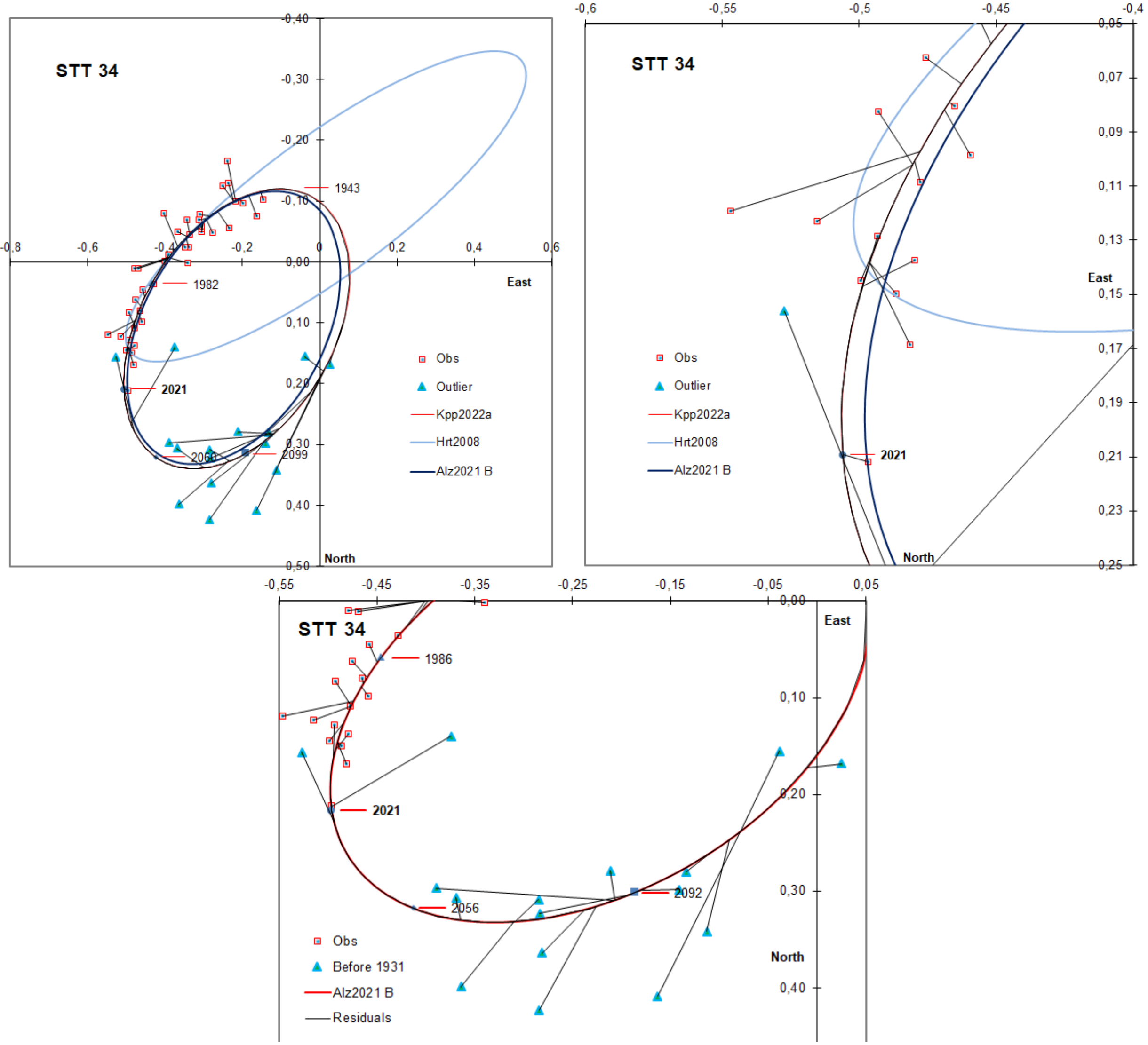


Figure 9: STT 34 orbit comparison with two close-ups

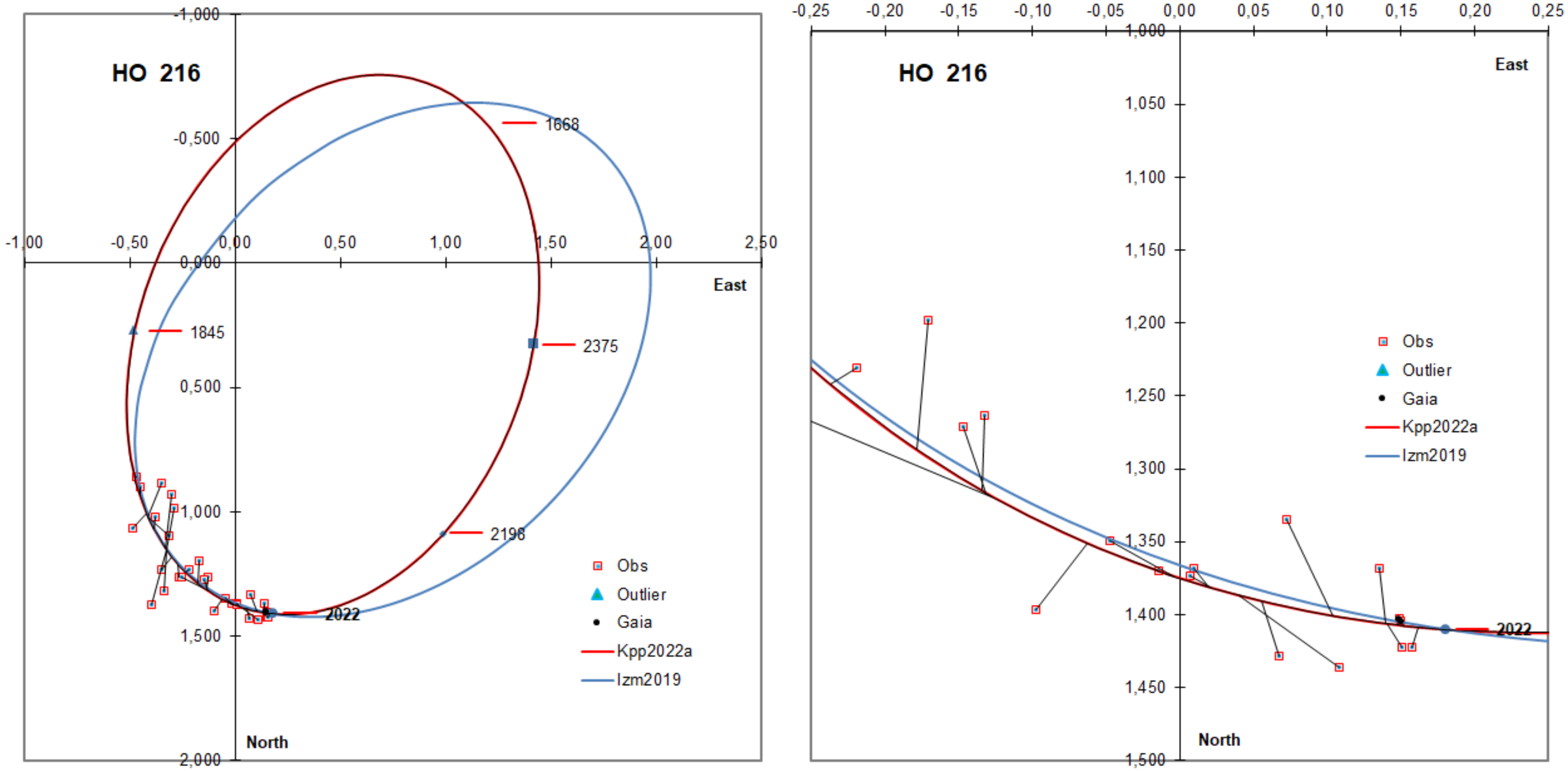


Figure 10: HO 216 orbit comparison with close-up

Appendix

Description Monte Carlo simulation for potential gravitational relationship assessment

- GAIA 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 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 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 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 orbit period assuming zero inclination using either median mass data from StarHorse catalog (Anders et al. 2019) or from photometric/spectroscopic estimation