APPENDIX
to the article "The orbits of visual binary and multiple stars obtained by the Apparent Motion Parameters method during the last 40 years". Comments and graphics. Part II

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January 2023

Description

This Appendix presents comments and graphs for each star. The comments contain the brief story of studies and justification of this result. For all graphs, the designations are as follows: observations from the WDS catalog version of 2016 (Mason et al., 2016)— green circles (among them the observations of F. W. Struve — red triangles), Pulkovo photographic observations (Kiselev et al., 2014; Izmailov et al., 2016) — red crosses, Pulkovo CCD observations (Izmailov et al., 2010; Izmailov, Roshchina, 2016; Izmailov et al., 2020) — magenta stars, Hipparcos (Mason et al., 2016) and Gaia DR2 (Gaia Collaboration et al., 2018) observations — yellow diamonds, the lines denote the orbits ephemeris in comparison with observations, the orange straight line indicates the direction of movement according to Gaia DR2 data at the instant 2015.5.

For the orbits from the Table 3, the following dependencies are given: $\rho(t)$, $\theta(t)$ and $y(x)$. The graph in to the picture plane $y(x)$ is sometimes represented in two forms: a fragment of an arc covering by observations and a complete orbit during the entire period. Then one can see how small the observed arc is. If the relative radial velocity is known, but there are two solutions, then the solid line corresponds to $+\beta$, the dashed line corresponds to $-\beta$. If the radial velocity modulus is chosen according to the agreement with all positional observations, then we get four solutions (2 pairs of orbits) and the sign of β is depended from the sign of radial velocity. In the sky plane the ephemeris of each orbits pair coincide.

The families of satisfactory orbits are given in Table 4. The range of ephemeris in dependence on β is limited by the red and blue lines. The orbit having a minimum period ($\beta = 0°$) is indicated by a solid black line, the rest orbits are denoted by solid ($+\beta$) and dashed ($-\beta$) lines.

In addition, the dependence of the semi-major axis on the eccentricity is presented graphically. The top line bounds the area, below which the influence of the gravitational field of the Galaxy is insignificant. For visual triple stars (ADS 48, ADS 7034 and ADS 10288) the bottom line bounds the area, above which the triple system is stable (for description see Kiyaeva, Romanenko (2020)).

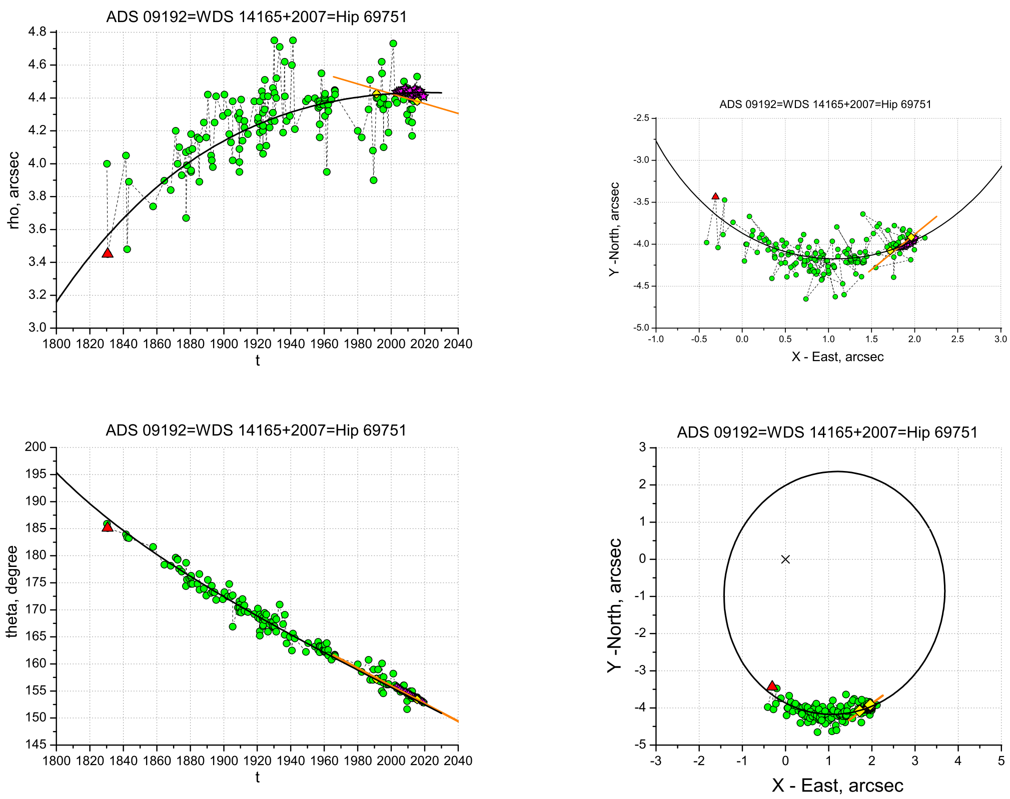


Figure 1: ADS 09192

1 WDS 14165+2007=ADS 9192=Hip 69751

In the article (Kiyaeva et al., 2017), we obtained the orbit according to AMPs calculated from all observations of 1830–2014 at the mean epoch 1927.0. All parameters were obtained, including the radius of curvature. We used parallax from Hipparcos catalog (van Leeuwen, 2007). The radial velocities in 2016 were observed with the telescope RTT-150 purposefully to obtain an AMP-orbit. The error of the radial velocity observations was very large for component A (0.9 km/s), so the relative radial velocity, as well as the component mass sum, were specified by the best agreement with CCD observations. The independently obtained value of the mass sum 2.0 $M\odot$ coincides with the estimate of 2.08 $M\odot$ from the work (Tokovinin, Kiyaeva, 2016).

The new orbit passes well through all observations and no improvement is required. However, the motion of Gaia DR2 contradicts the orbit. This allows you to count, that the component A has a satellite, and explains the big mistake in observations of radial velocity.

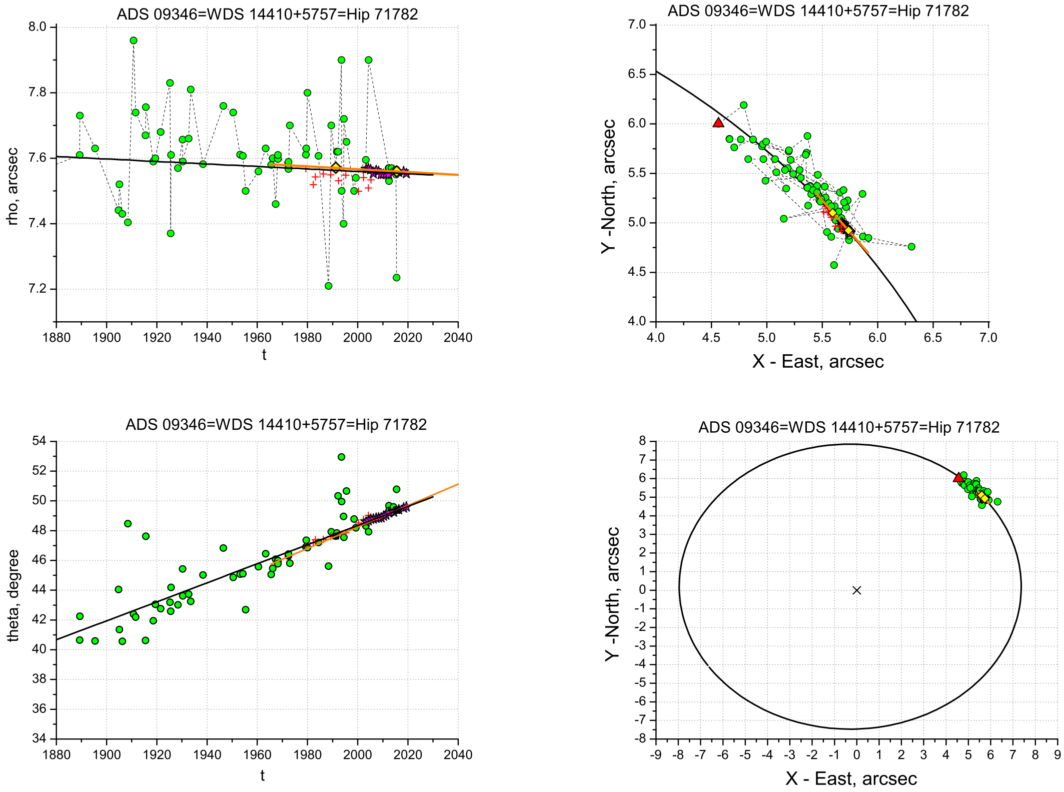


Figure 2: ADS 09346

2 WDS 14410+5757=ADS 9346=Hip 71782

The first AMP-orbit (Kiyaeva et al., 2010) was obtained on the basis of the Pulkovo photographic observations and specially performed radial velocity observations using RVM (Tokovinin, 1987), installed on the 1-m telescope of the Simeiz Observatory of the Research Institute of CrAO. It was noted that the orbit orientation is close to the picture plane and there is a significant excess of mass in the system.

The new AMP-orbit (Kiyaeva et al., 2021), obtained from the 2003–2019 CCD observations and the Gaia DR2 parallax, is consistent with the previous result. The suspicion of low-mass satellites arose due to the analysis of long-term positional, spectroscopic and photometric observations. The motion of Gaia DR2 does not contradict the orbit and observation of Hipparcos.

The best solution corresponds to a total mass of $4M_{\odot}$, but we give an orbit with an expected mass of $2.4M_{\odot}$, taking into account the low-mass satellite of the A component, since the satellite of the B component has not yet been confirmed (details are in the work Kiyaeva et al. (2021)). Since $\beta \approx 0^{\circ}$ and $\Delta V_r \approx 0$ km/s, the orbit's plane is oriented near the picture plane, and therefore the values of Ω and of ω are formally determined with large errors.

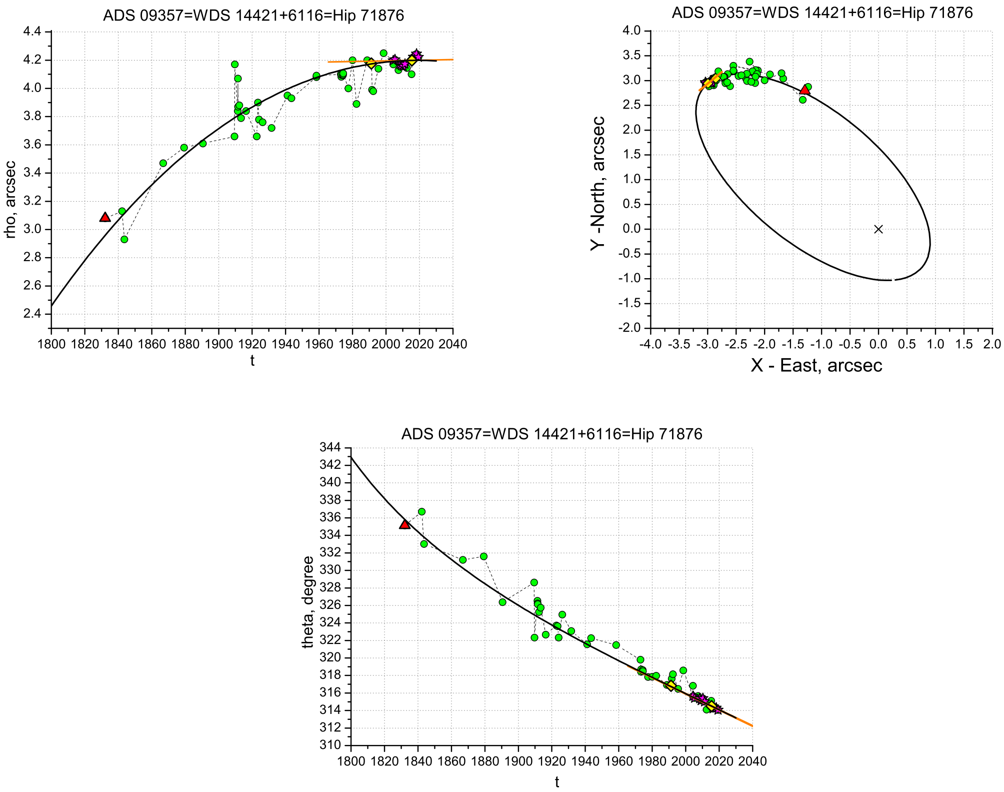


Figure 3: ADS 09357

3 WDS 14421+6116=ADS 9357=Hip 71876

Component A is a variable of type δ Sct, and according to the MSC catalog (Tokovinin, 2018) may have a low-mass satellite. The orbit (Kiyaeva, Romanenko, 2020) is first obtained from the Gaia DR2 data and is good consistent with the whole series. The found mass of the system 2.4 $M\odot$ slightly exceeds the expected 2.2 $M\odot$ according to MSC. Taking into account the possible satellite, the excess is insignificant.

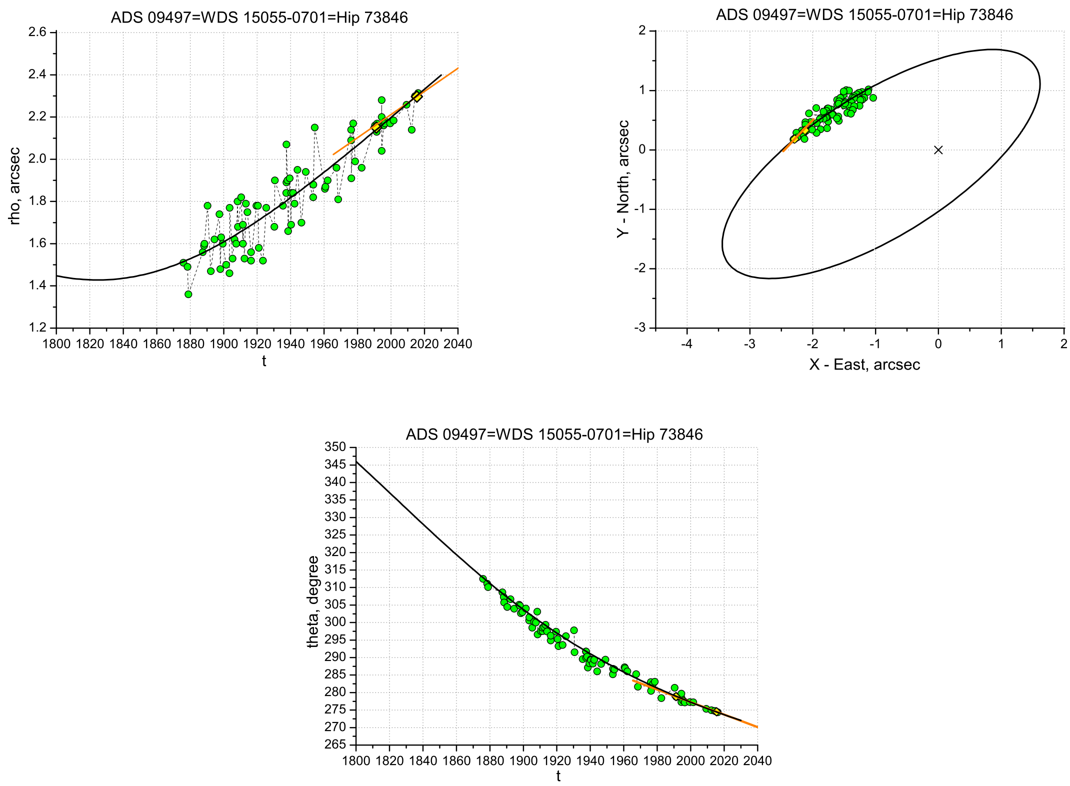


Figure 4: ADS 09497

4 WDS 15055-0701=ADS 9497=Hip 73846

In (Kiyaeva et al., 2017) 2 orbits were obtained with two sets of AMPs: at the instant 1950.0 (over the whole series 1873–2014) and at the instant 2005.5 (based on 5 high-precision observations from WDS — Hipparcos, SOAR, USNO (1999)). Both orbits coincide within the error limits and agree well with all observations. We have used the Hipparcos parallax and the sum of masses 2.0 $M\odot$ from the article (Tokovinin, Kiyaeva, 2016). The relative radial velocity has been chosen. Comparing ephemeris with observations in different moments made it possible to unambiguously determine the negative sign of the angle β. The Gaia DR2 motion slightly diverges in ρ.

Gaia DR2 has all the data for both components. The chosen value $|\Delta V_r| = 0.8$ km/s at 2005.5 agreed with the observed $\Delta V_r = +0.4 \pm 0.4$ km/s. Parallaxes on space observations differ significantly: 21.0 ± 1.1 mas for Hipparcos (van Leeuwen, 2007) and 18.9588 ± 0.0827 mas for Gaia DR2. With Hipparcos parallax $M_{A+B} = 2.0 M_{\odot}$, with parallax Gaia DR2 $M_{A+B} = 2.7 M_{\odot}$. An estimation of total mass by effective temperature of Gaia DR2 is $2.3 M_{\odot}$. It was not possible to obtain a satisfactory orbit based on the Gaia DR2 data. Therefore, it can be concluded that the divergence in the Gaia DR2 motion with the rest observations is no accident, and there may be a satellite in the system that distorts AMPs at the moment of 2015.5.

In this article, we include an orbit with AMPs at the instant 2005.5, with parallax and radial velocity from Gaia DR2, and with an expected mass of $2.3 M_{\odot}$. The orbit is uniquely obtained, since the sign of the angle β and radial velocity is known. Within error limits, its elements are consistent with the previous orbits.

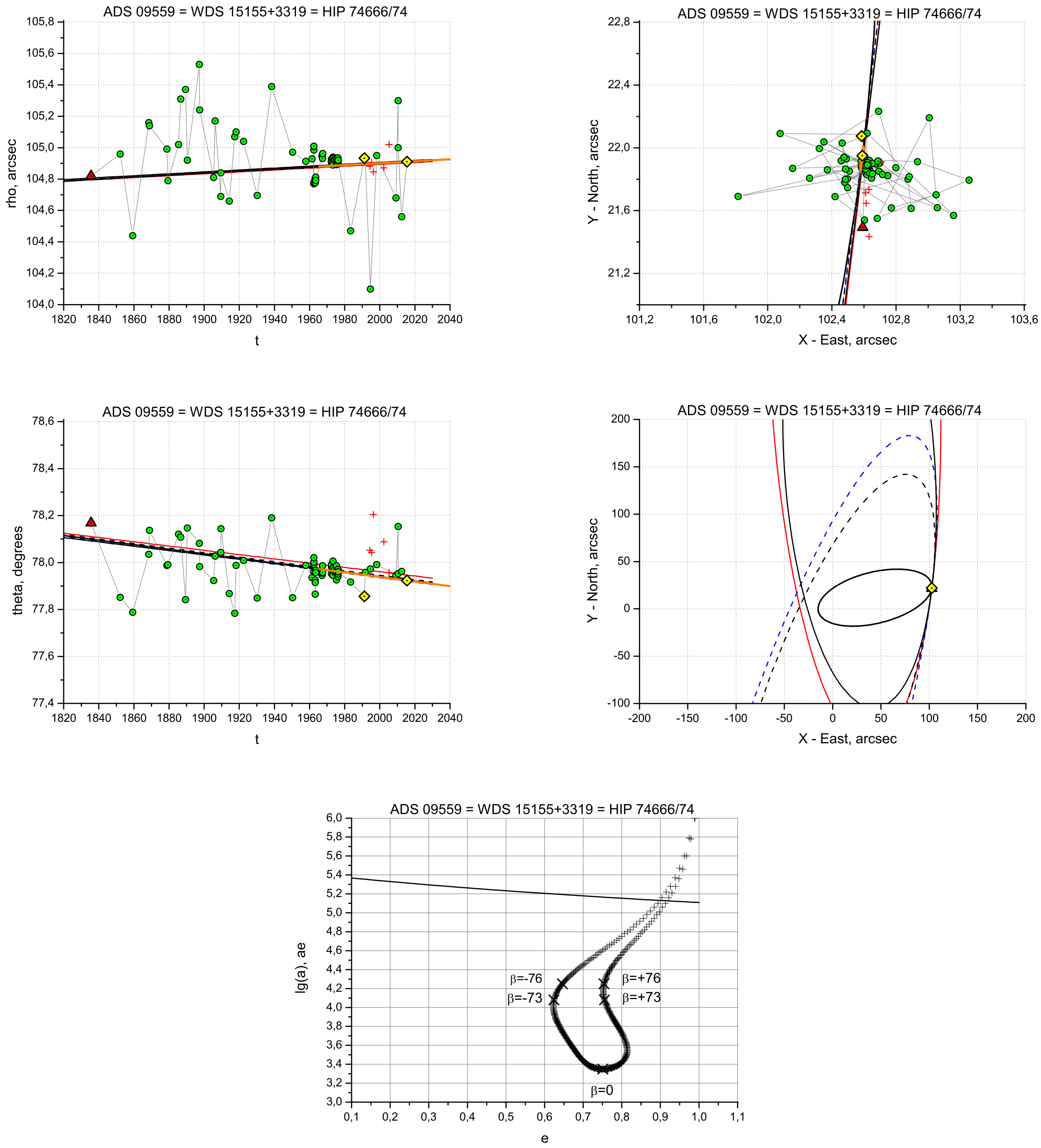


Figure 5: ADS 09559

5 WDS 15155+3319 = ADS 9559 = Hip 74666/74 (delta Boo)

Bright component of this wide pair (with a separation of $\sim 105''$) is one of the few giants in the Pulkovo program. The spectral types of the pair are G8III and G0V. We estimate the component mass sum as $3.7M_{\odot}$ in accordance with the "mass – luminosity" relation (see Allen (1999)). Family of orbits was obtained by AMP-method (Kisselev et al., 2009) with this estimate and with the radial velocities from the article (Tokovinin, Smekhov, 2002).

In the present work, we used the same radial velocities (they are constant) and the mass estimate, as well as the GAIA DR2 data (positions, proper motions, and parallaxes). And we determined a new family of AMP-orbits which is in good agree with observations and coincide on the entire 1835–2015 segment. The minimal period $P_{min} \sim 55000$ years.

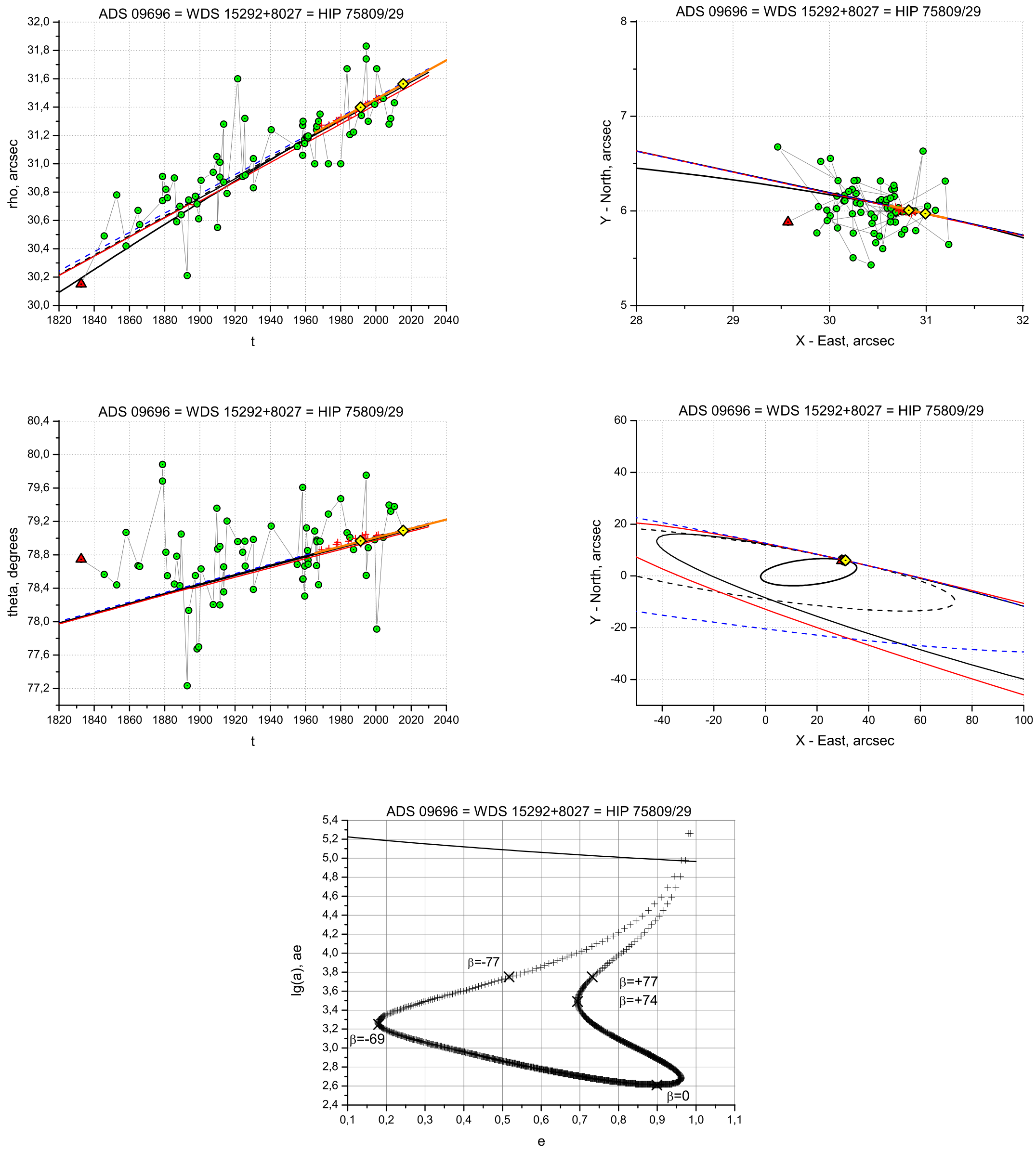
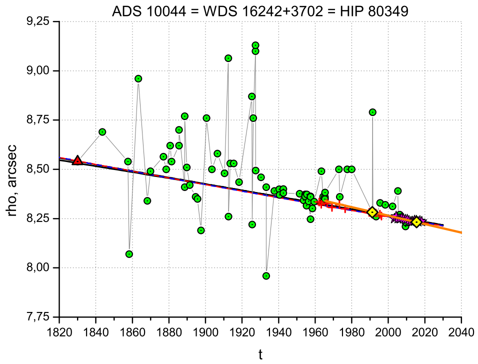


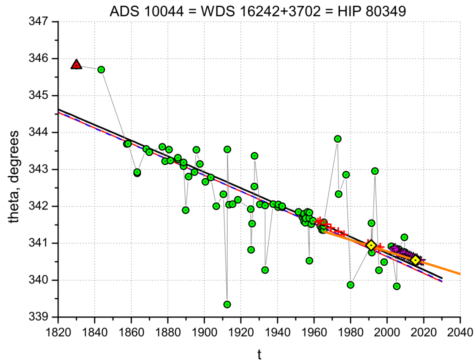
Figure 6: ADS 09696

6 WDS 15292+8027 = ADS 9696 = Hip 75809/29

Previously, two orbital solutions were obtained by the AMP method (Grosheva, 2006b) using radial velocities from the article (Tokovinin, Smekhov, 2002).

In accordance with the updated spectral classification of components (it not subgiants, but dwarfs G1.5V and G9V), their sum of masses is not $3.6M_{\odot}$, but $1.84M_{\odot}$. There are no data of spectral binarity. Therefore, in this work, we have determined a new family of AMP-orbits according to only the data from Gaia DR2 (positions, proper motions, parallaxes, effective temperature and radial velocities of the components). The orbits are in good agreement with observations and coincide on the entire 1832–2015 segment. Minimum period $P_{min} = 6153$ years.





7 WDS 16242+3702 = ADS 10044 = Hip 80349

It is known that component A is a spectroscopic binary with $P_A \sim 21.6$ days (Tokovinin, 1999). Previously, a family of orbits was determined by the AMP-method using the basis of Pulkovo photographic observations (Kiselev et al., 2000), radial velocities, and mass estimates from the Tokovinin article. The Pulkovo dense series of CCD observations shows perturbations in ρ with a period of about 8 years, it is necessary to continue this series. The direction of motion according to the Gaia DR2 data does not agree with the θ observations, which also is a reflection of the presence of a satellite in this system. Radial velocities of the required accuracy are missing in the Gaia DR2 data.

Here, we give a family of AMP-orbits using the Gaia DR2 parallax, the same AMPs from the 2000 article, radial velocities from (Tokovinin, 1999) and the component mass sum according to the new version of the MSC catalog (Tokovinin, 2018). $P_{min} \sim 11000$ years. The ephemerides of all orbits of the family practically coincide over the entire segment covered by observations (1830-–2018). For other graphs, see next page.

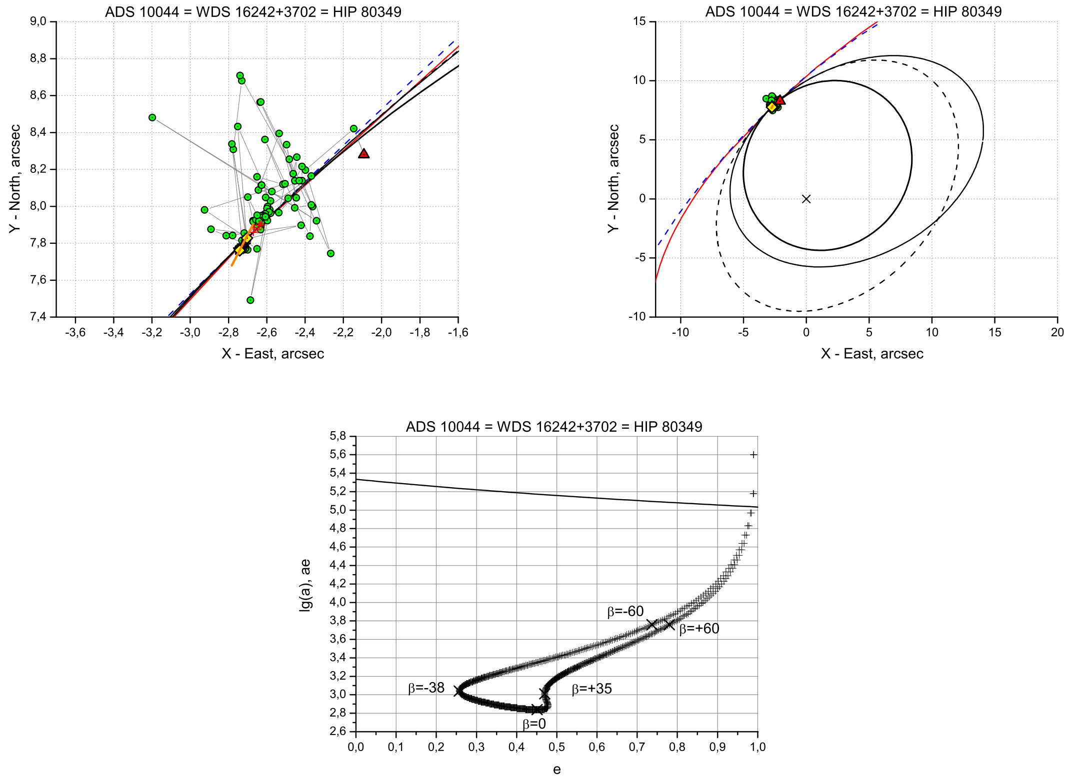


Figure 7: ADS 10044

See previous page for explanations.

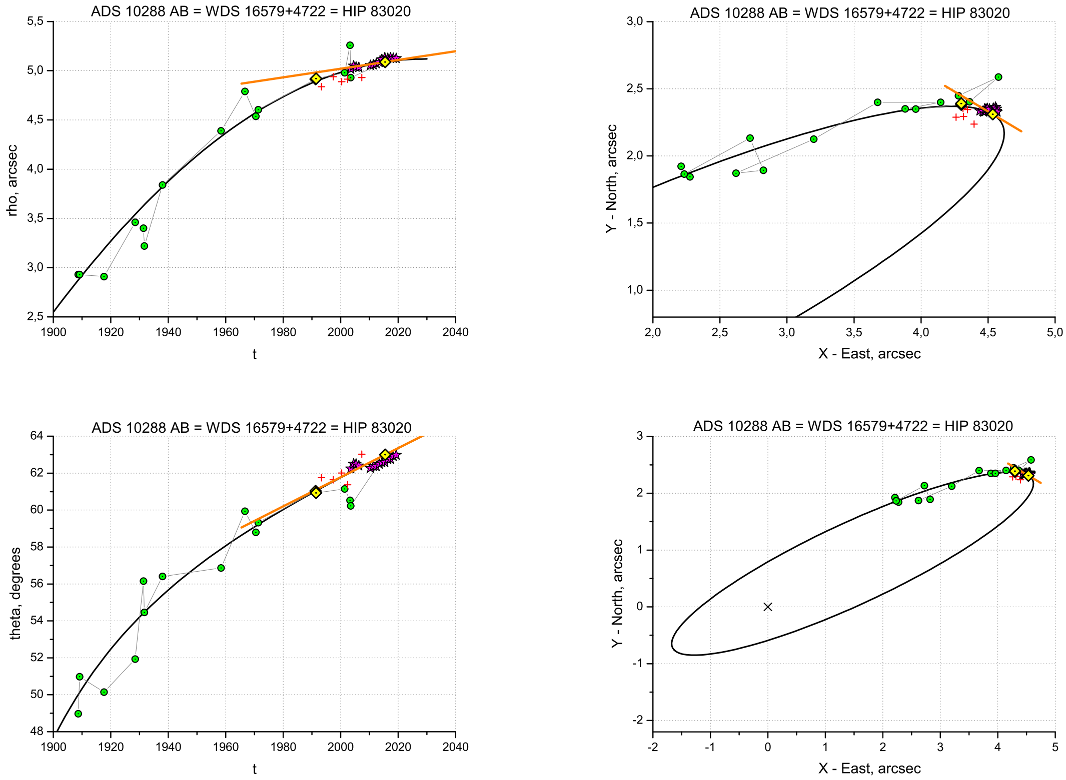


Figure 8: ADS 10288 AB

8 WDS 16579+4722 = ADS 10288 AB = Hip 83020

This triple system consists of two bright and almost identical components A and C ($m_V \sim 8^m$) with a separation of $\sim 110''$ and the weak B component ($m_V \sim 11^m$) at a distance of $\sim 4''$ from component A. This configuration led to the fact that the weak component did not have not only observations of radial velocities, but also the final spectral classification.

Previously, we obtained both the radial velocities of the components and the AMP-orbits of inner and outer pairs (Kiselev et al., 2009a). We have now redetermined these orbits from the Gaia DR2 data using the components mass estimate according to the new version of MSC (Tokovinin, 2018). The direction of motion in the inner pair of AB according to the Gaia DR2 data is tangential to the observations and the ephemeris is in good agreement with them. Two solutions are obtained, but after taking them into account to determine the outer pair AB–C orbit (see next page), it became clear that the best agreement corresponds to only the inner orbit with $\beta = +10^0$.

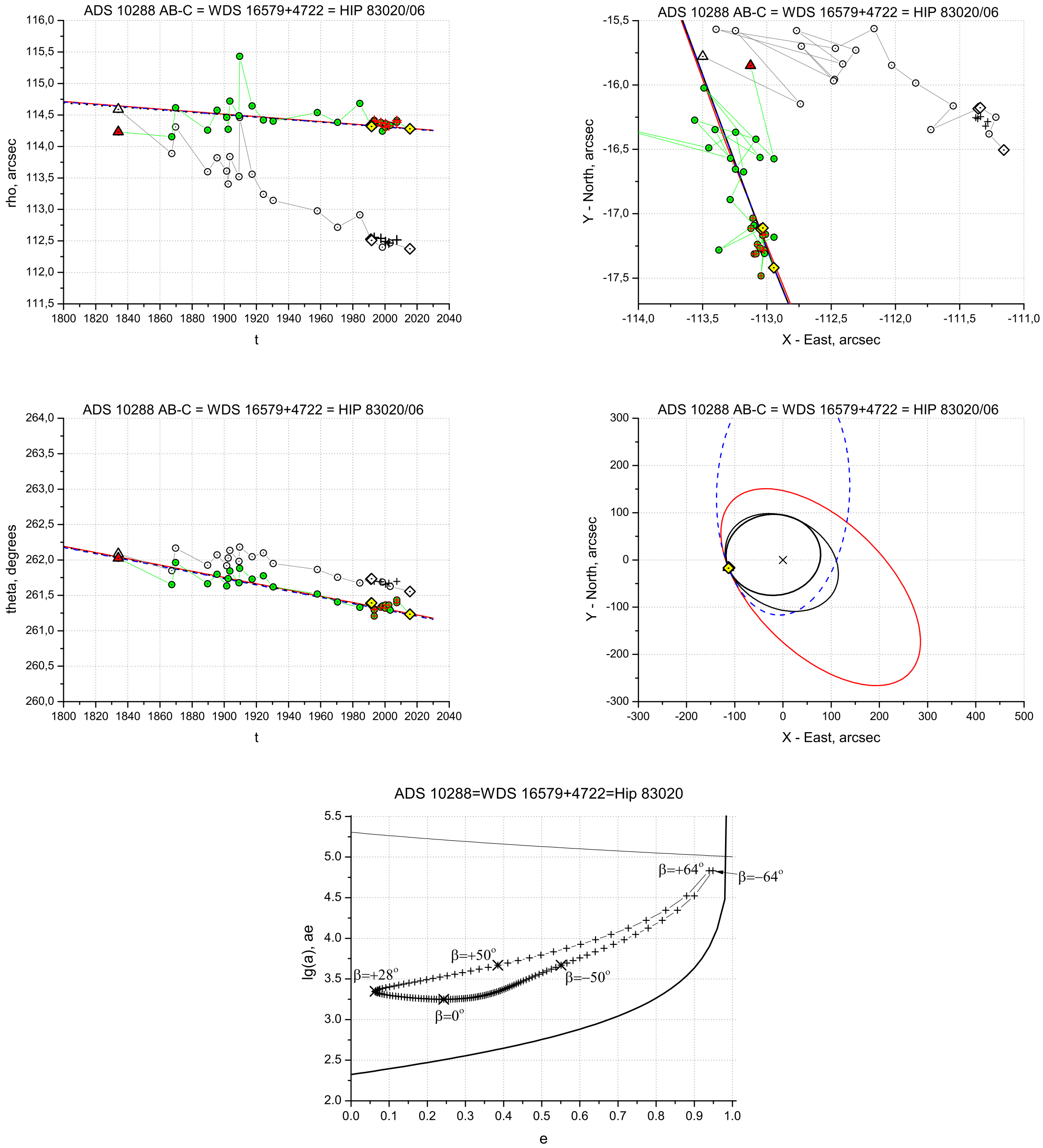


Figure 9: ADS 10288 AB-C

9 WDS 16579+4722 = ADS 10288 AB-C = Hip 83020/06

This triple system consists of two bright and almost identical components A and C ($m_V \sim 8^m$) with a separation of $\sim 110''$ and the weak B component ($m_V \sim 11^m$) at a distance of $\sim 4''$ from component A. Previously, we were obtained both the radial velocities of the components and the AMP-orbits of the inner and outer pairs (Kiselev et al., 2009a).

We have now re-determined these orbits from the the Gaia DR2 data using the components mass estimate according to the new version of MSC (Tokovinin, 2018). For a wide AB-C pair, we obtained a family of orbits with $Pmin = 52000yr$, coinciding over the entire segment (1834–2015). On the graphs, observations of the outer pair of AC without taking into account the inner subsystem are marked with open circles, after taking into account the AB orbit — with green circles. See the previous page for other explanations.

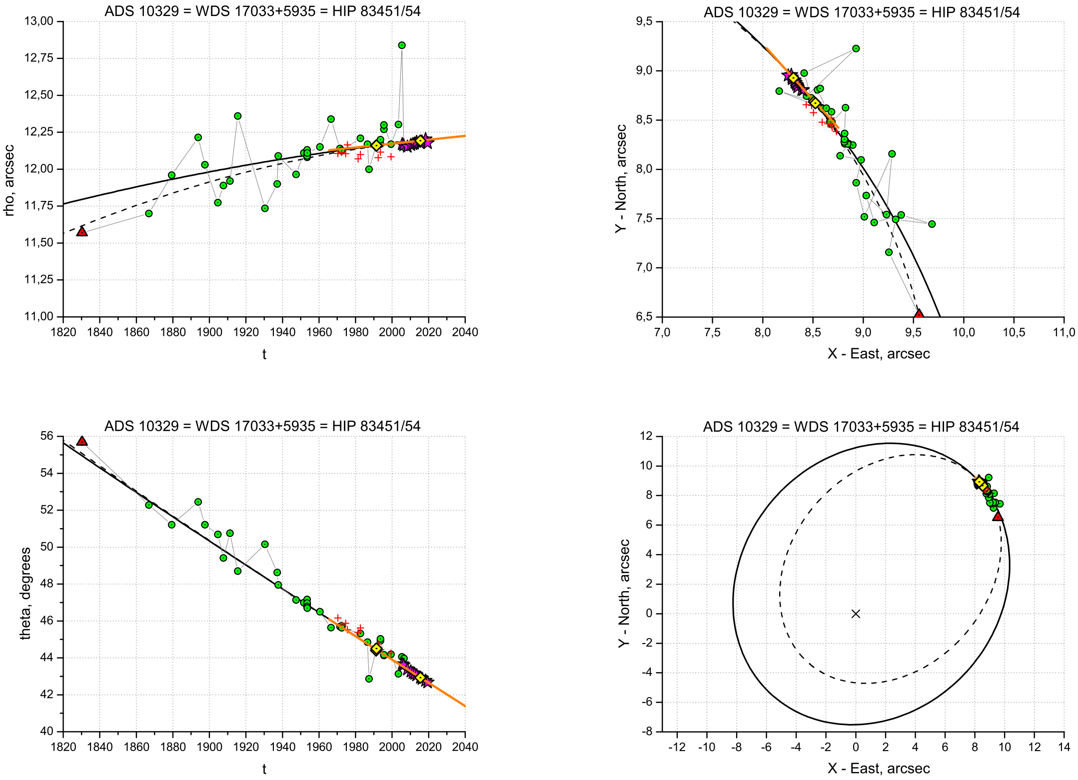


Figure 10: ADS 10329

10 WDS 17033+5935 = ADS 10329 = Hip 83451/54

Previously, an orbit was obtained by the AMP method, and a mass excess of $\sim 3M_{\odot}$ was revealed (Kisselev et al., 2009). The radial velocities from the article (Tokovinin, Smekhov, 2002) and the Hipparcos parallax (ESA SP-1200, 1997) were used. The direction of motion according to the Gaia DR2 data does not contradict observations.

In this paper, we present a new result obtained only from the Gaia DR2 data, including radial velocities and estimate of the components mass sum according to the effective temperature corresponding to the normal value ($1.4M_{\odot}$). A mass excess of not less than $0.6M_{\odot}$ is possible if the observation by W.Struve (1830) is not erroneous (dotted line on the graph).

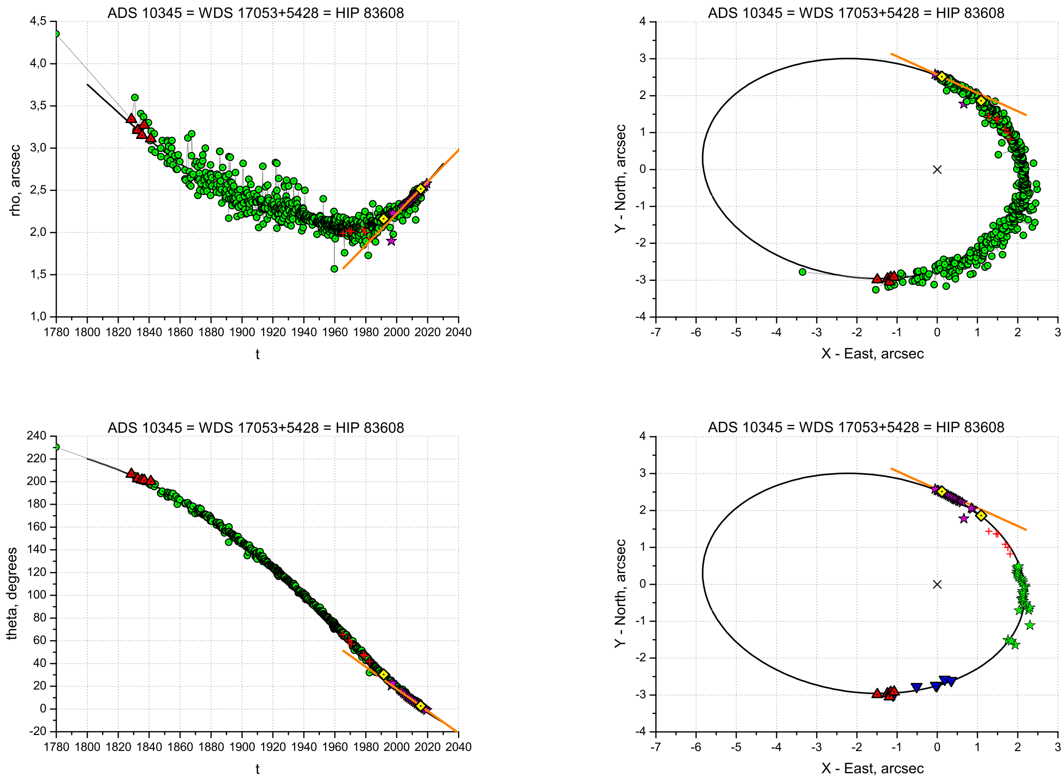


Figure 11: ADS 10345

11 WDS 17053+5428 = ADS 10345 = Hip 83608 (mu Dra)

This bright, close pair (with a separation of $\sim 2''$) is at the limit of the possibility of photographic observations. The orbit presented here was obtained in the article (Kiselev et al., 2000) using a differential version of the AMP method. This orbit almost coincides with the orbit (Heintz, 1981) and describes all observations just as well as the orbit (Prieur et al., 2012). The component mass sum for all three of the above orbits corresponds to their spectral classes F7V and F7V. In 2000, the relative radial velocity was chosen in such a way that the resulting AMP orbit passes through the earliest observations of the 19th century beginning. The Hipparcos parallax (ESA SP-1200, 1997) was used.

The direction of motion according to the Gaia DR2 data is tangential and does not contradict observations, nor ephemeris. It is known from the MSC catalog (Tokovinin, 2018) that the component B is a supposed spectroscopic binary with a period of ~ 3.2 years. However, this did not show up in our study. The last graph shows only Pulkovo and some other series, as well as observations by W.Struve.

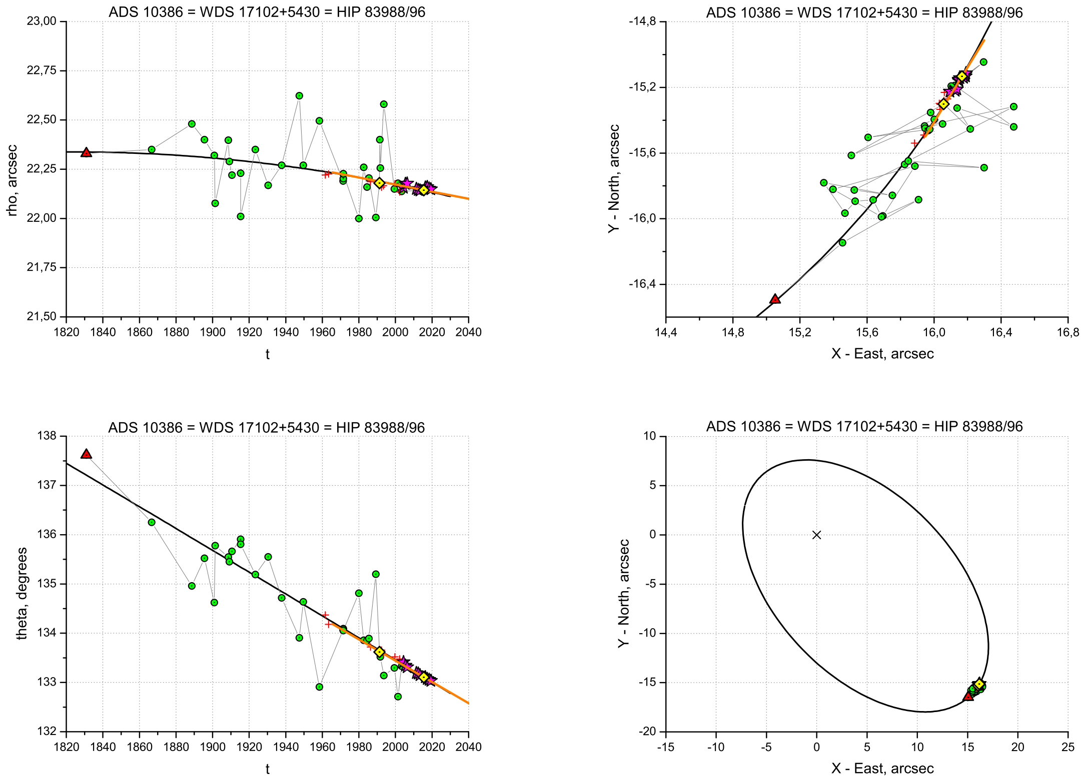
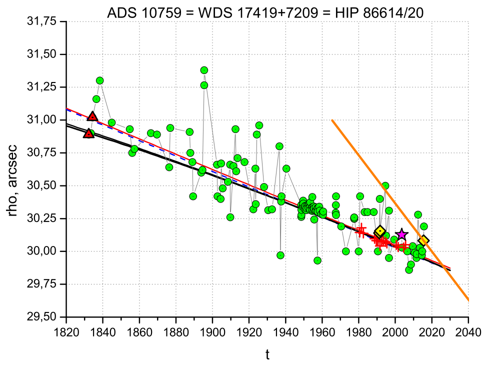


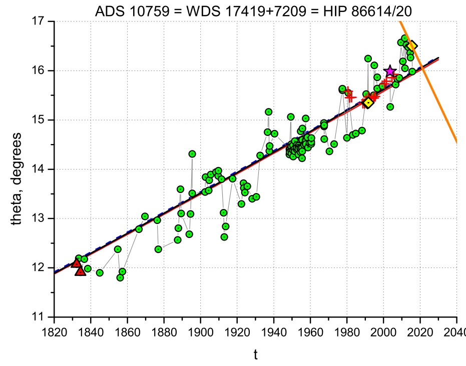
Figure 12: ADS 10386

12 WDS 17102+5430 = ADS 10386 = Hip 83988/96

Previously, a family of orbits was obtained using the AMP method (Romanenko, Kiselev, 2014). The radial velocities from the article (Tokovinin, 1994) and the Hipparcos parallax (van Leeuwen, 2007) were used. In our article (Romanenko, Izmailov, 2021), we improved this result using the parallax from Gaia DR2, the same radial velocities of Tokovinin, and the modified algorithm of the AMP method. The coincidence of AMP orbits obtained from three different bases led to obtaining a single-valued orbit and the sum of the component masses of $1.7M_{\odot}$, which is somewhat higher than follows from the “mass-luminosity” dependence.

In this work, we present the orbit from the article (Romanenko, Izmailov, 2021) obtained from the combined series of Pulkovo photographic and CCD observations (the PCCD basis). The direction of motion according to the Gaia DR2 data does not contradict either observations or ephemeris.





13 WDS 17419+7209 = ADS 10759 = Hip 86614/20 (psi Dra)

Earlier, we detected a disturbance with a period of 40 years and amplitude $0.3''$ in the relative motion of the AB pair; the minimum mass of a possible satellite is $0.4 M_\odot$. An orbit was obtained (Kisselev et al., 2009) by AMP method using the basis of Pulkovo photographic observations combined with the WDS data. The radial velocities from the paper (Tokovinin, Smekhov, 2002), the Hipparcos parallax (ESA SP-1200, 1997), and the estimation of the component masses with taking into account this satellite ($3.4 M_\odot$) were also used. The period is ~ 10000 years.

Subsequently, binarity of component A with a period of 18.2 years and an exoplanet around component B (see catalog MSC — Tokovinin (2018)) were discovered. The direction of motion according to the Gaia DR2 data is under angle to the observations both in ρ and in θ, which is a reflection of the presence of satellites in this system. The radial velocities of the required accuracy are not available in the Gaia DR2 data.

Here we give a new family of AMP orbits using the Gaia DR2 parallax, the same parameters of apparent motion from our 2009 article, the radial velocities from the article (Tokovinin, Smekhov, 2002) and $\Sigma M = 3.34 M_\odot$ according to the new version of the MSC catalog. $P_{min} \sim 11000$ years. The ephemeris of all orbits of the family practically coincide with each other over the entire segment covered by observations (1832–2015) and correspond to them.

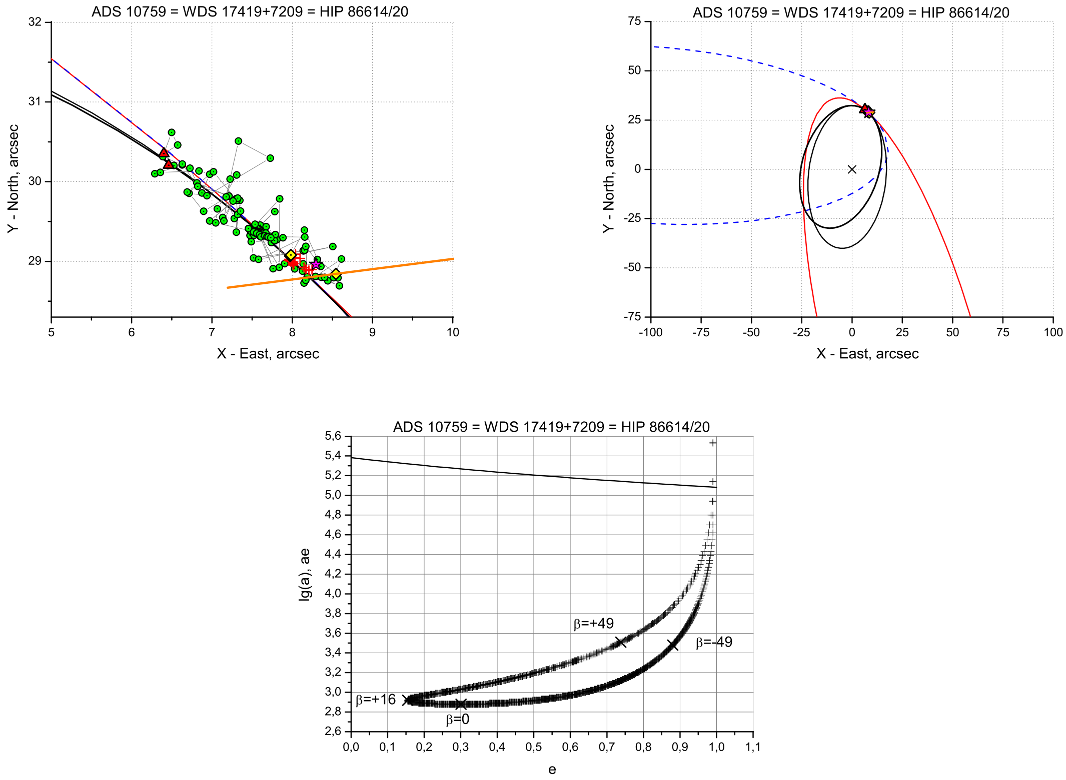


Figure 13: ADS 10759

For explanations of the graphs, see the previous page.

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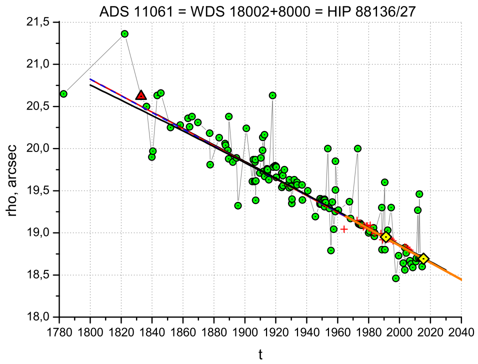
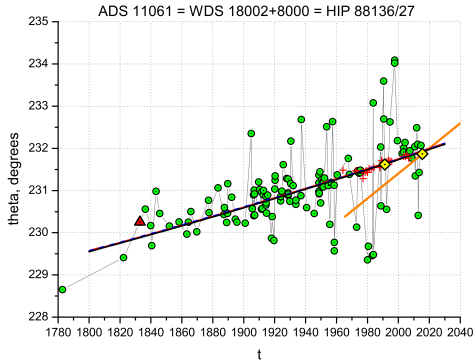




14 WDS 18001+8000 = ADS 11061 = Hip 88136/27

Both components are spectroscopic binaries (Tokovinin et al., 2003). A family of AMP orbits of the visual pair AB was determined (Afanasyeva, Grosheva, 2012) by the Pulkovo series of photographic observations taking into account the influence of these inner subsystems. Also, a periodic perturbation was revealed with a probability of 95% and a period of 10.7 years.

Here we give a new family of AMP orbits using the Gaia DR2 parallax, the same apparent motion parameters and the same radial velocities from the 2012 paper, but the components mass sum according to the new version of MSC (Tokovinin, 2018). $P_{min} \sim 10000$ years. The ephemeris of all orbits of the family practically coincide with each other over the entire segment covered by observations (1780–2015). The direction of motion according to Gaia DR2 is at an angle to observations in θ, which is a reflection of the presence of satellites in this system.

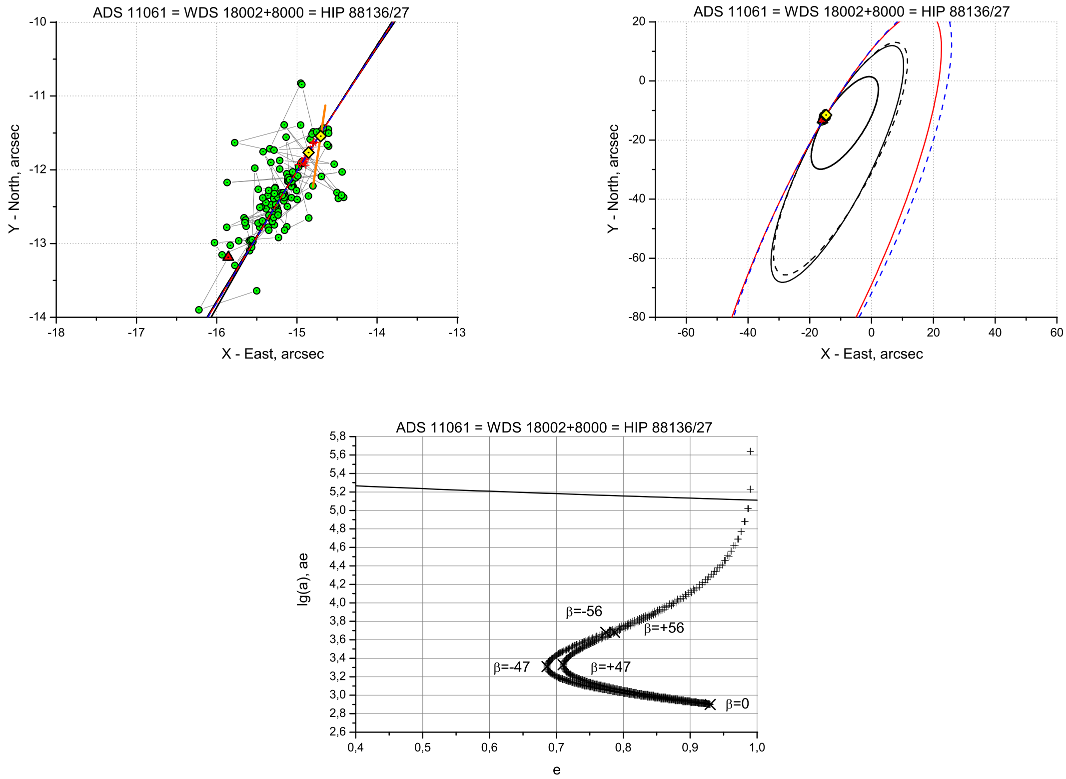


Figure 14: ADS 11061

For explanations of the graphs, see the previous page.

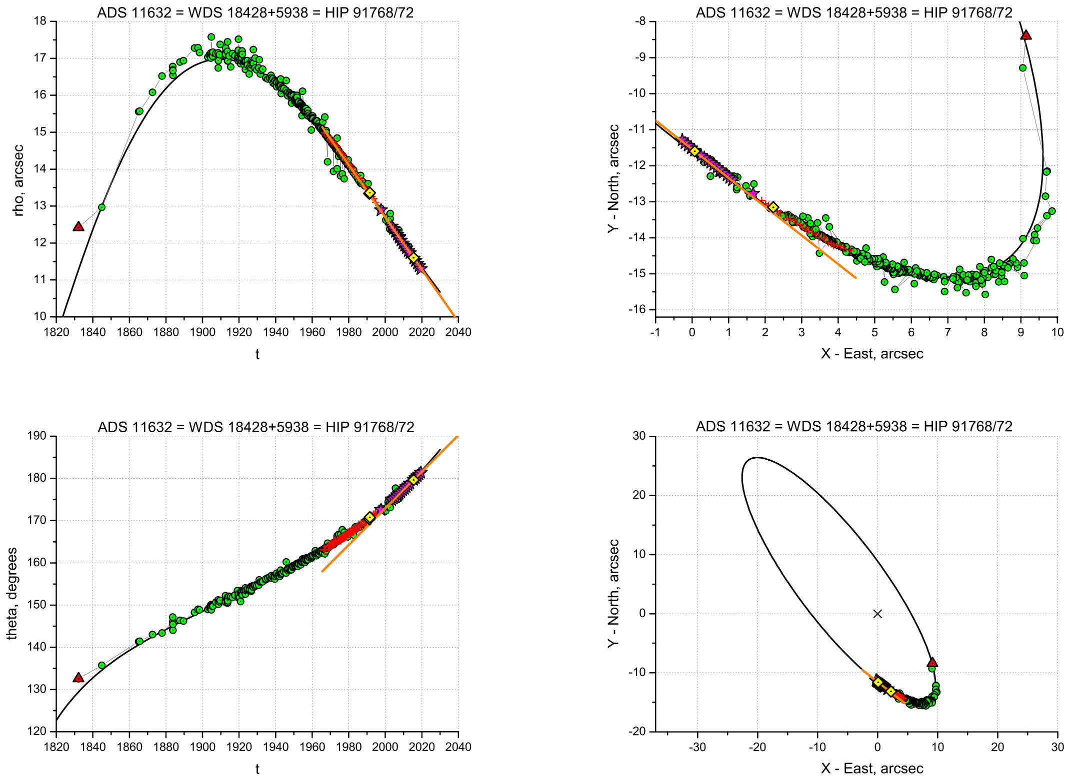
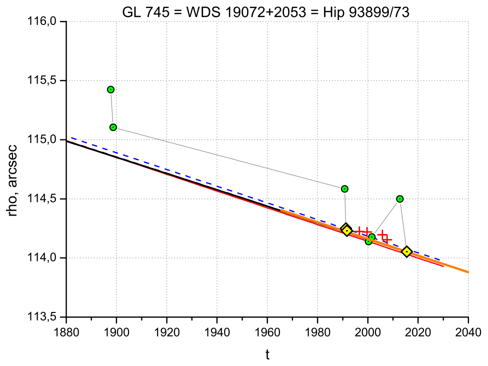


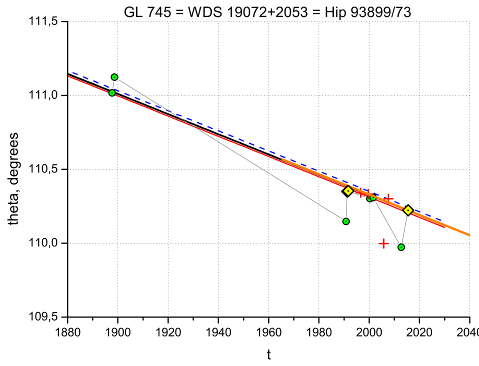
Figure 15: ADS 11632

15 WDS 18428+5938 = ADS 11632 = Hip 91768/72

This nearby star was suspected to have invisible companions with orbital periods of 10.7, 5.0, and 5.5 years (Kamper, 1966; Baize, 1976; Hershey, 1982). The study of the Pulkovo series of observations in 1961–1997 showed presence of two periodic signals with periods of 16.4 and 4.5 years and with amplitudes of about $0.020''$ in the residuals calculated from the distance between the components. It may indicate the presence of two satellites with a lower mass limit of $0.008M_\odot$ (Shakht, 1984) and $0.012M_\odot$ (Shakht et al., 1999). These periods did not appear in the position angle.

The AMP orbit is presented for pair AB (Kiselev et al., 2009b) with a period of 1100 years. The parallax and the components mass sum of $0.68M_\odot$ according to (Baize, 1976) are used. The direction of motion according to the Gaia DR2 data is tangential to the observations and does not contradict either them or the ephemeris. The radial velocities of the visible components are absent in the Gaia DR2 data.





16 WDS 19072+2053 = Hip 93899/73 = GL 745

This close to the Sun wide pair is included in all catalogs of stars with large proper motions. It consists of twin stars having magnitudes and color indices that are the same to within hundredths of a stellar magnitude. Since the components are weak ($m_V \sim 11^m$) and $\rho \sim 114''$, the studied binary star is difficult to observe — it is lost among the field stars of the same brightness. Therefore, there is a discrepancy in the identification of components in the WDS and Gliese catalogs (Mason et al., 2016; Gliese, 1969). We have adopted the designations according to the last one.

Previously, a family of AMP orbits was obtained (Kiyaeva et al., 2012) using the Hipparcos parallax (van Leeuwen, 2007) and radial velocities from the article (Marcy, Benitz, 1989). The components mass sum was estimated as $0.8M_\odot$ according to the M2V spectra. Here, we give a new family of AMP orbits using the Gaia DR2 data and the same mass estimate of the components. $P_{min} \sim 42000$ years. The ephemeris of all orbits of the family practically coincides on the whole segment covered by observations (1897–2015).

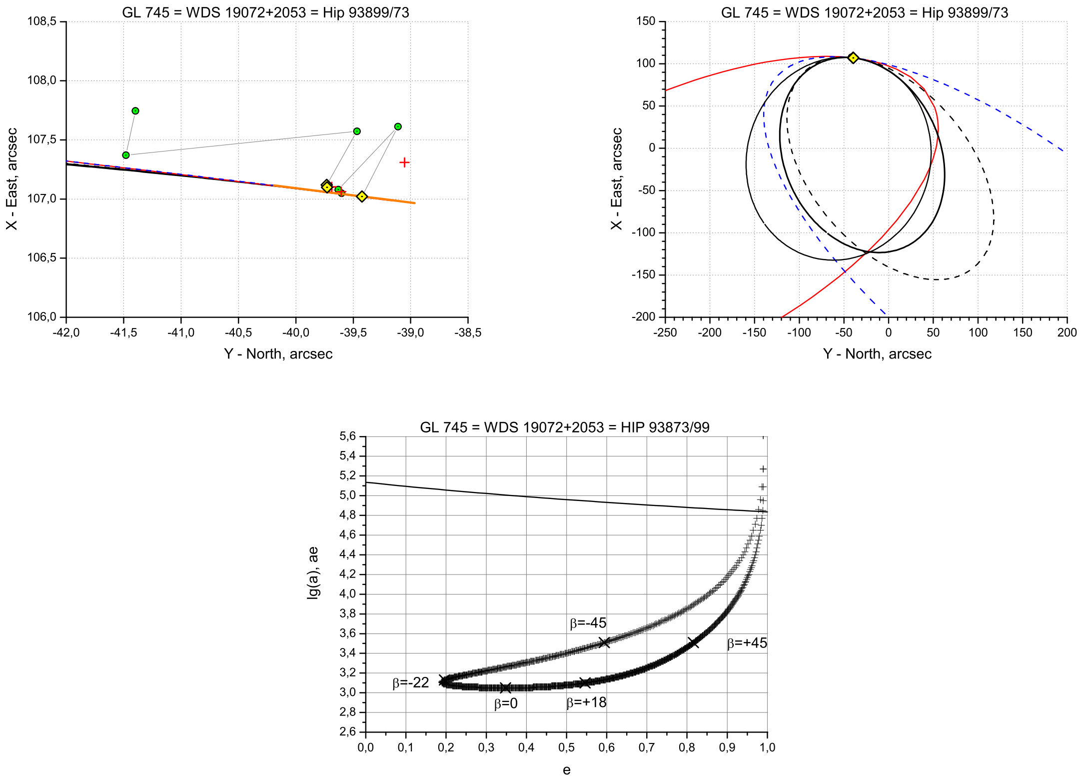


Figure 16: GL 745

For explanations of the graphs, see the previous page.

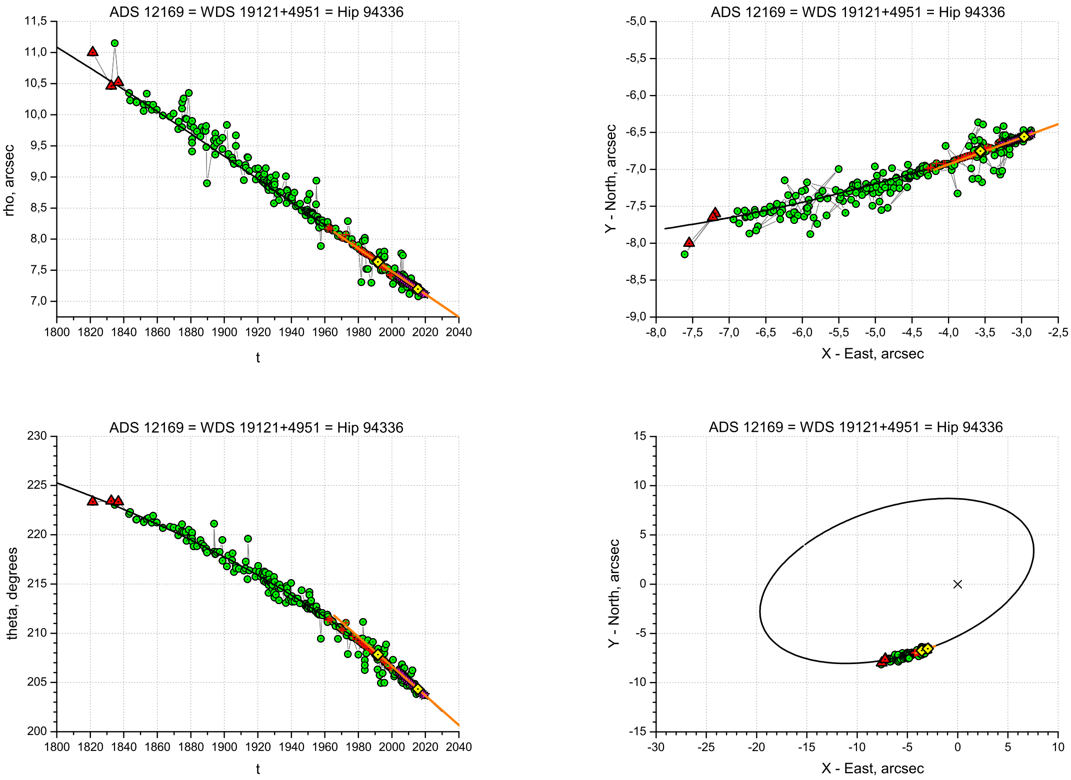
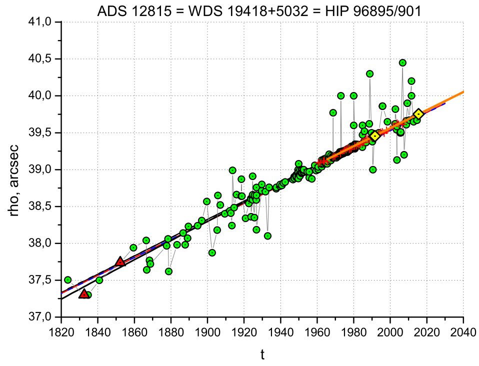


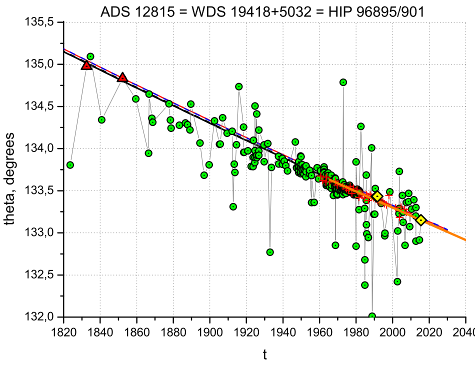
Figure 17: ADS 12169

17 WDS 19121+4951 = ADS 12169 = Hip 94336

Previously, a family of orbits was obtained by the AMP method (Kiselev, Romanenko, 1996). The radial velocities from the article (Tokovinin, 1994) and the parallax from the work (van Altena et al., 1991) were used. In our article (Romanenko, Izmailov, 2021), we improved this result using the Gaia DR2 parallaxes, the same radial velocities, and the modified algorithm of the AMP method. The coincidence of the AMP orbits obtained from three different bases led to obtaining single-valued orbit and the components mass sum of $2.25M_{\odot}$, which coincides with the value corresponding to the "mass-luminosity" dependence within the error limits.

In this work, we present the orbit from the 2021 article, obtained from the combined series of Pulkovo photographic and CCD observations (the PCCD basis). The direction of motion according to Gaia DR2 does not contradict either observations or ephemeris. The orbit with period of 3100 years (Hale, 1994) also describes the observed arc well, but corresponds to a mass sum of $3.5M_{\odot}$ (excess).





18 WDS 19418+5032 = ADS 12815 = Hip 96895/901 (16 Cyg)

Cochran et al. (1997) discovered a planet-like satellite with a period 2.2 years near the component B. Pulkovo observations allow the existence of this satellite, if its orbit has an inclination to the picture plane greater than 70^o. The family of orbits for the visual pair AB was obtained by the AMP method (Kiselev, Romanenko, 2011). The basis was the combined series of homogeneous photographic observations of three observatories — Dearborn, Washington (USNO) and Pulkovo. The Hipparcos parallax (van Leeuwen, 2007) and the radial velocities obtained at the Lick Observatory (Hauser, Marcy, 1999) were used. The direction of motion from the Gaia DR2 data is consistent with all observations.

Here, we give a new family of AMP orbits using the Gaia data and the components mass sum of $2.53M_{\odot}$ according to the new version of MSC (Tokovinin, 2018) taking into account the mass of the stellar companion of the A component. $P_{min} \sim 12000$ years. The ephemeris of all orbits of the family coincide with each other by the entire segment covered by observations (1823–2015).

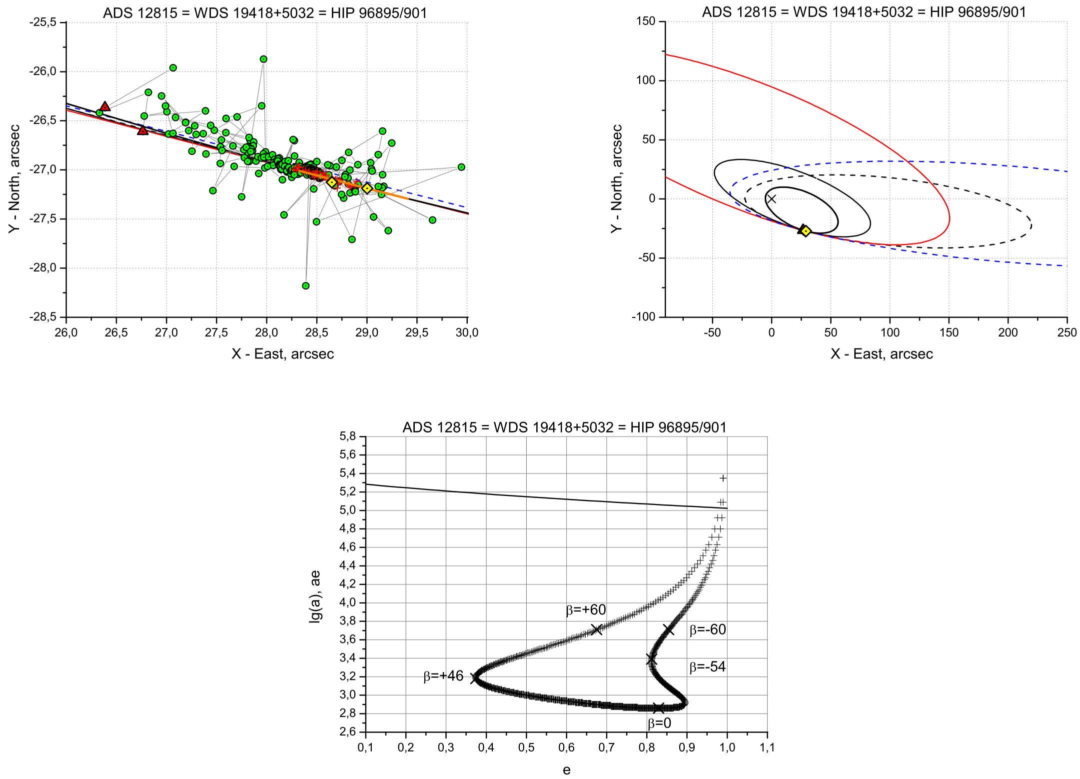


Figure 18: ADS 12815

See previous page for explanations.

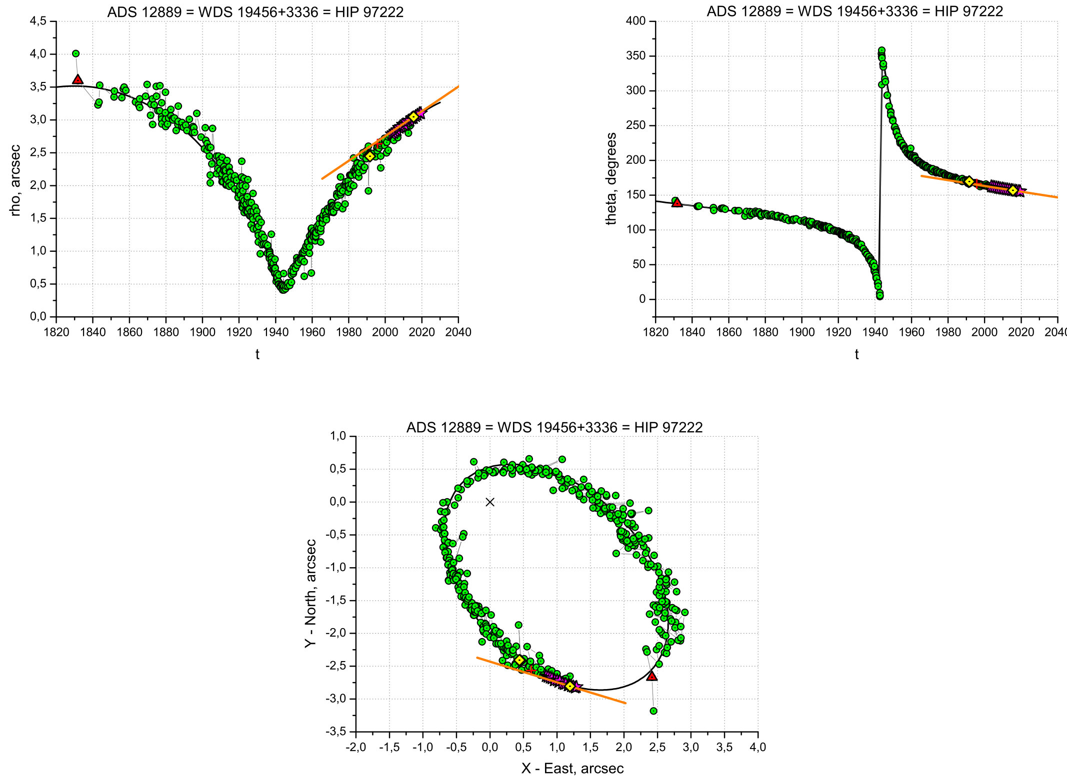


Figure 19: ADS 12889

19 WDS 19456+3336 = ADS 12889 = Hip 97222 (17 Cyg FG)

An identification of this star is presented according to the CCDM catalog, which corresponds to its coordinates and number in the Aitken catalog (Aitken, Doolittle, 1932). In the WDS catalog, this star is identified as 19464+3344 FG.

A single-valued AMP orbit of this close pair with a period of 238 years was calculated by Romanenko (2017) based on the series of Pulkovo CCD observations. The Hipparcos parallax (van Leeuwen, 2007), the radial velocities from the article (Tokovinin, Smekhov, 2002), and the estimates of the components mass according to the MSC catalog were used. The orbit consistent well with the other authors ones. The direction of motion according to Gaia DR2 is tangential to the observations and does not contradict either them or the ephemeris. There are no radial velocities of the components in the Gaia DR2 data.

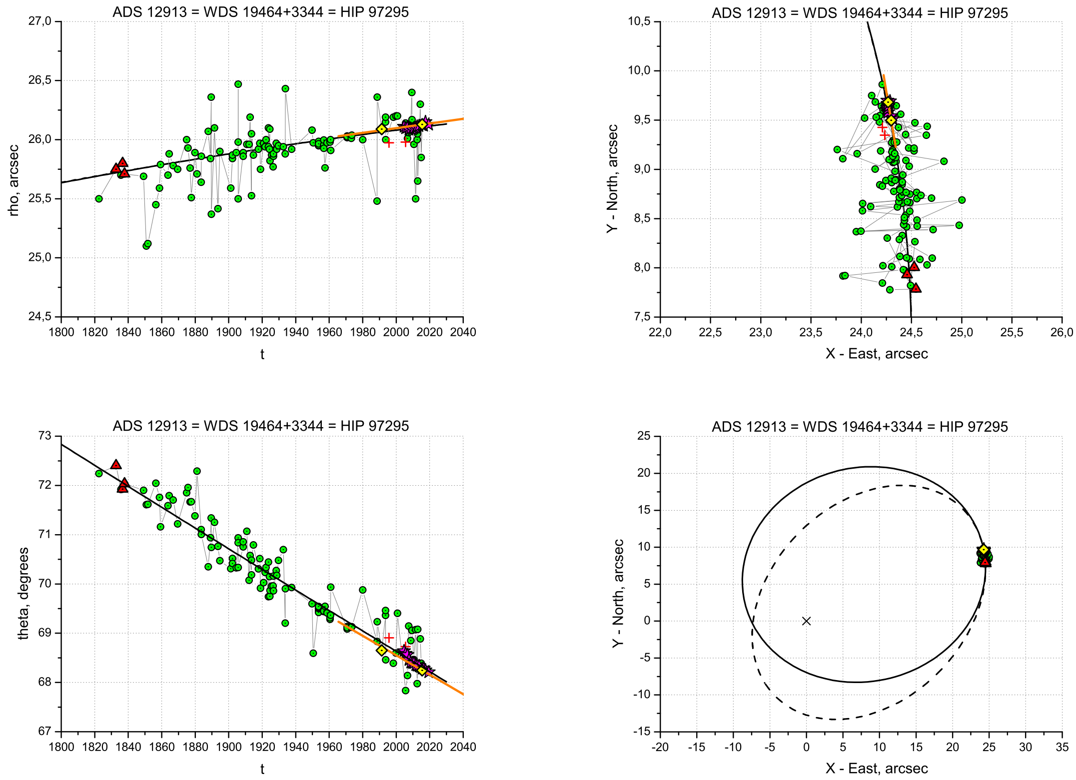


Figure 20: ADS 12913

20 WDS 19464+3344 = ADS 12913 = Hip 97295 (17 Cyg AB)

This star system was studied by us as a quadruple one, with components A, B, F and G (Romanenko, 2017). Two most probable AMP orbits of 17 Cyg AB with period of 6200 years were obtained using basis of the Pulkovo CCD observations combined with observations by W.Struve. The Hipparcos parallax (van Leeuwen, 2007), the radial velocities from the catalog of Tokovinin (1990) and the components mass estimates according to MSC were used. The direction of motion according to the Gaia DR2 data does not correspond accurately enough to the global observations of the position angle.

An unambiguous orbit of the FG pair with a period of 238 years was obtained wich well consistent with the orbits of other authors. A family of possible orbits of the outer AB-FG pair, close to parabolic, with periods of 3.7 million years or more was also obtained. The Monte Carlo method was used to calculate the probability of a stable gravitational connection of the outer pair equal to 47%. The similarity of proper motions and radial velocities of all components may indicate that they belonging to one stellar stream. According to the catalog (Gliese, Jahreiss, 1991), a list of possible candidates for membership of this stream was compiled (Romanenko, 2017).

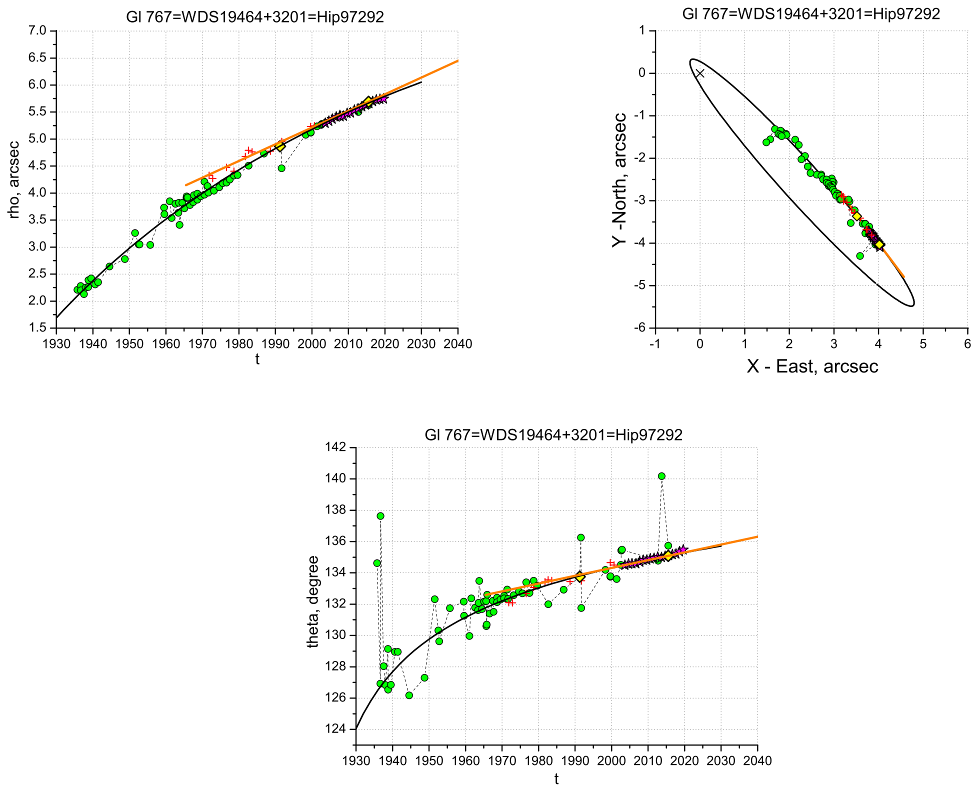


Figure 21: Gliese 767

21 WDS 19464+3201=Hip 97292=GL 767

This fast-moving star was discovered by Van de Camp only in 1935. The first orbit was published in (Kiyaeva, Gorynya, 2015). AMPs at the instant 2008.0 were obtained from the Pulkovo CCD-observations in 2003–2013. The radial velocities observations had been performing on RVM from 1999 to 2014, the value of $\Delta Vr = 0.0 \pm 0.5$ km/s was received. We used parallax from Hipparcos catalogue (74 ± 2 mas, van Leeuwen (2007)). A total system mass $0.9 M_{\odot}$ was adopted according to spectral classes. With the parallax Gaia DR2 (71.75 ± 0.06 mas), the mass of the system is $1.0 M_{\odot}$, which corresponds to the effective temperatures of the stars, published in Gaia DR2.

In Gaia DR2, there is a radial velocity of only one component A. Observations of radial velocity on RVM indicated variability in component B. In Pulkovo CCD observations, tangential oscillation is also noticeable, however, the direction of motion according to Gaia DR2 does not contradict the resulting orbit, so the presence of the satellite is not confirmed.

A systematic discrepancy (38 mas) between Gaia DR2 and CCD observations, was found in ρ. This explains the large inconsistency of the Gaia DR2 observation with respect to the orbit ephemeris (26 mas). The previously obtained orbit (Kiyaeva, Gorynya, 2015) does not require improvement.

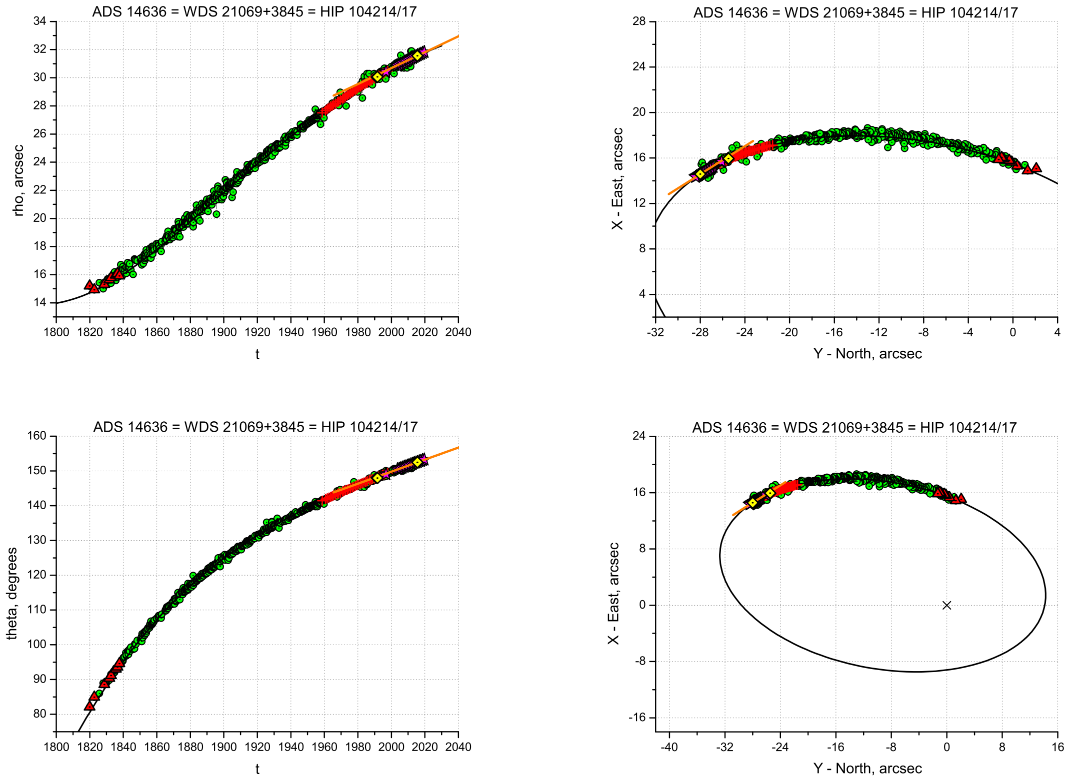


Figure 22: ADS 14636

22 WDS 21069+3845 = ADS 14636 = Hip 104214/17 (61 Cyg)

This star is interesting as an object with possible planet-like companions (Strand, 1943; Deutch, 1978). The physical properties of this pair are also of interest, as both components are variable flare stars. Orbital elements of 61 Cyg obtained from photographic observations are given in the works (Josties, 1983; Gorshanov et al., 2006).

In the article (Izmailov et al., 2021), the orbit of 61 Cyg was constructed based on all its observations made at the Pulkovo Observatory with several instruments from 1819 to 2019. A method was used which based on the calculation of Thiele–Innes constants and generating of a large number of random sets of three orbital elements (see, Izmailov (2019), for the algorithm). The period was obtained $P = 704.858 \pm 40.221$ years and $\Sigma M = 1.286 \pm 0.107 M_{\odot}$.

Here we give the AMP orbit (Shakht et al., 2017) derived from a series of Pulkovo photographic observations with a 26-inch refractor in 1958–2006. The Hipparcos parallax (van Leeuwen, 2007) and the radial velocities obtained with 6-m LTA telescope (Romanenko, Chentsov, 1994) are used. For the best convergence with observation, we have determined an orbit with a period of 664 years and a sum of the component masses of $1.4 M_{\odot}$, which somewhat exceeds the estimates from astrophysical observations ($1.3 M_{\odot}$). The direction of motion along Gaia DR2 data does not contradict either observations or ephemeris.

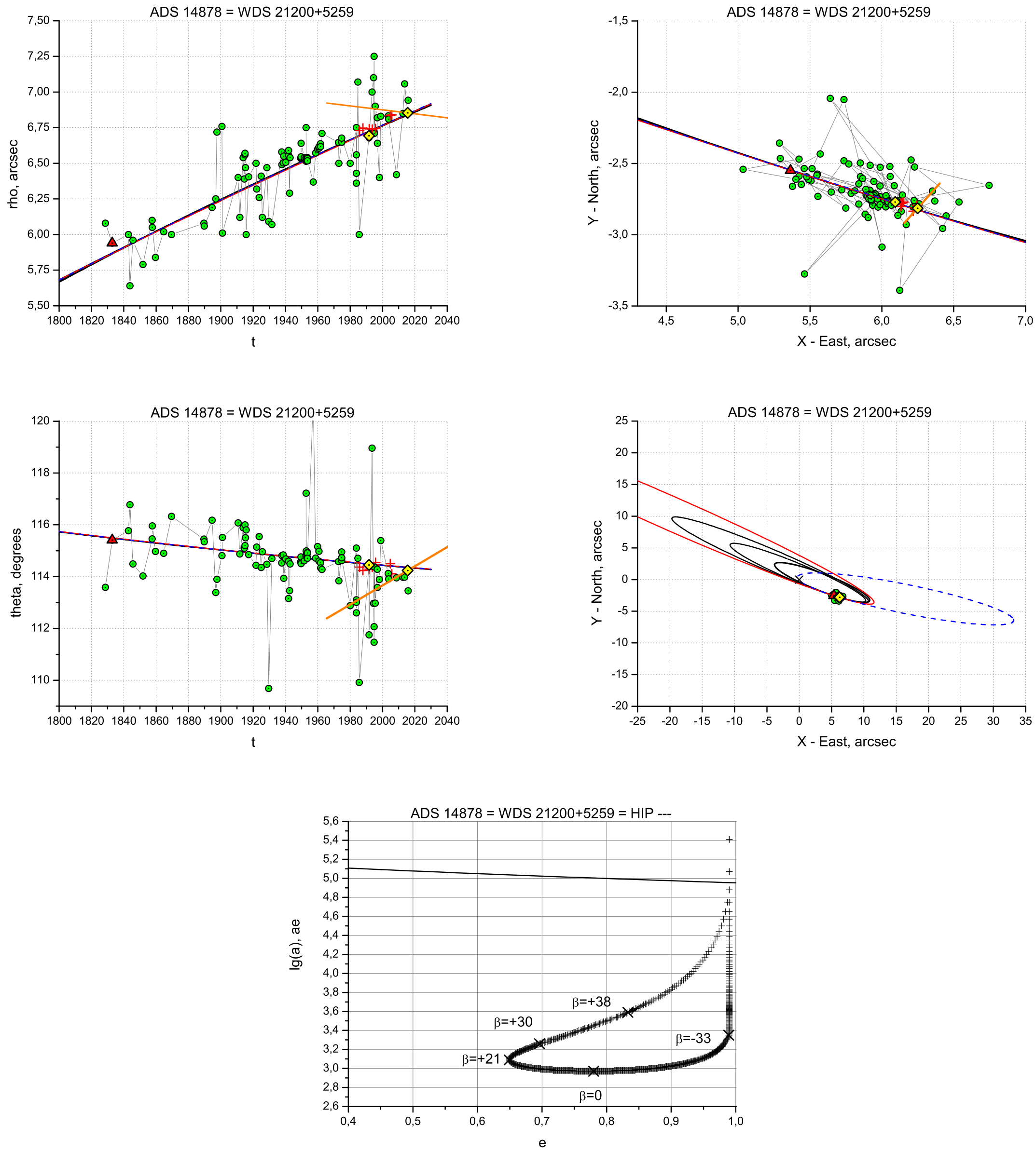


Figure 23: ADS 14878

23 WDS 21200+5259 = ADS 14878

A study using the AMP method showed that if the parallax is $0.006''$, then an elliptical orbit is possible only if the total mass of the system is at least $25M_\odot$ (Kisselev et al., 2009). Component C is optical according to proper motions from the WDS catalog (Mason et al., 2016). The direction of motion in the AB pair according to Gaia DR2 data goes under an angle to all-world observations. In this paper, we present a family of AMP orbits (Romanenko, 2018) obtained from the combined series of observations 1828–2005 using radial velocities from the article (Tokovinin, Smekhov, 2002). At the Gaia DR2 parallax (12.11 ± 0.06 mas), the components mass sum is $3.5M_\odot$ (an excess remains).

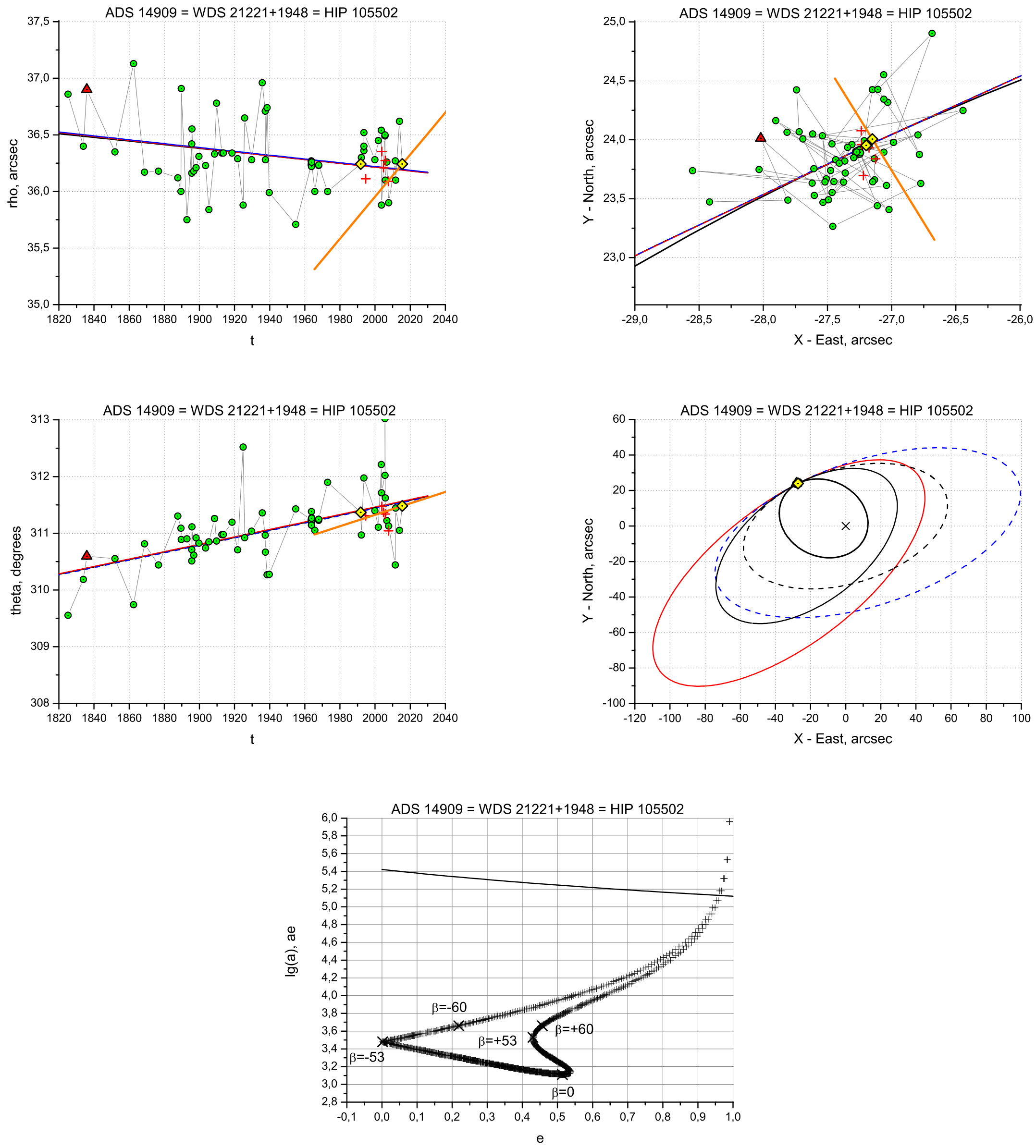


Figure 24: ADS 14909

24 WDS 21221+1948 = ADS 14909 = Hip 105502 (1 Peg)

In this wide pair, the A component is bright ($\sim 4^m$), and the B component is a well-known spectroscopic binary (Griffin, 1987). Previously, with the radial velocities from this article, we calculated the family of orbits of the pair AB (Romanenko, Kiselev, 2014) by the AMP method. The direction of motion in this pair according to the Gaia DR2 data is at an angle to all-world observations.

In this paper, we present a new family of AMP orbits obtained from the same basis of the combined series of observations. The same radial velocities, the Gaia DR2 parallax, and the components mass sum according to the new version of the MSC catalog (Tokovinin, 2018) are used. $P_{min} \sim 23000$ years. The ephemeris of all orbits of the family coincide with each other over the entire segment covered by observations (1825–2015).

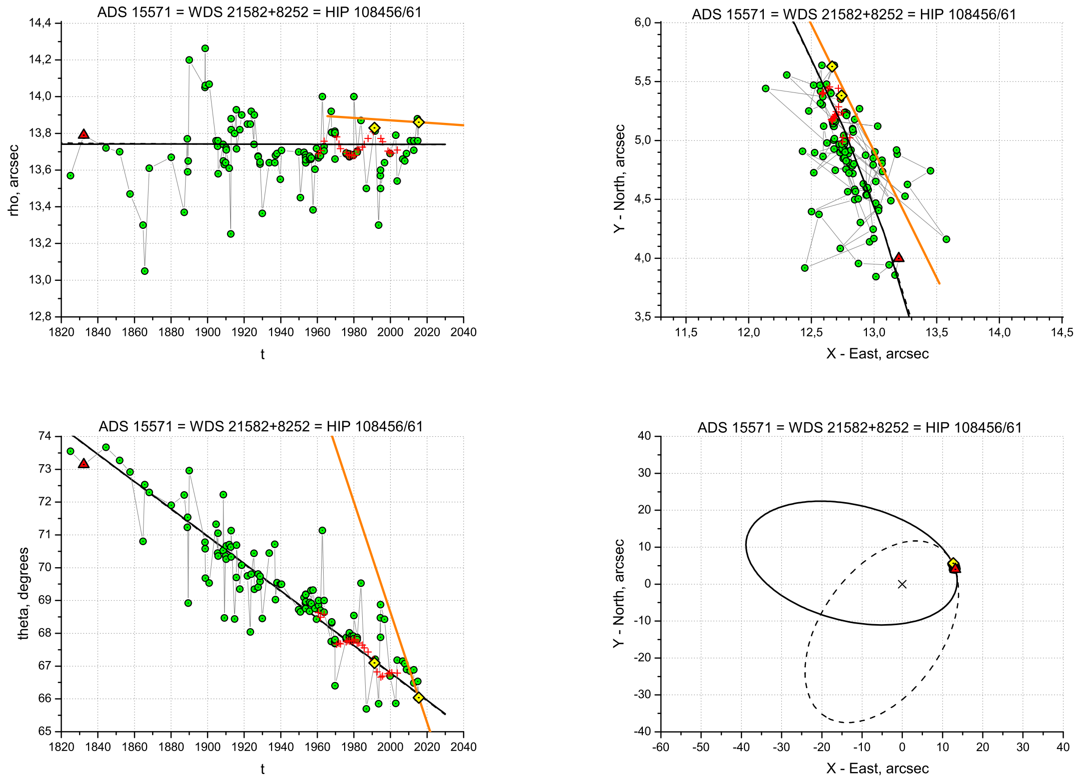


Figure 25: ADS 15571

25 WDS 21582+8252 = ADS 15571 = Hip 108456/61

The B component is known a spectroscopic binary with $P_B \sim 1.15$ days (Sanford, 1927).

Previously, two orbital solutions with a period of 19000 years were obtained by the AMP method (Grosheva, 2006a) using the Hipparcos parallax (ESA SP-1200, 1997) and a fitted relative radial velocity. Based on photographic observations with a 26-inch refractor in 1960–2003, an invisible companion with a period of 23 years and a minimum mass of $0.6M_\odot$ was also discovered (Grosheva, 2006a).

A "wave" is clearly seen in the observations both in ρ and in θ. The ephemeris of both orbits coincide with each other over the entire segment covered by observations (1825–2015). With the Gaia DR2 parallax and the components mass sum according to the new version of MSC (Tokovinin, 2018), the orbit period is 17000 years. The direction of motion according to the Gaia DR2 data is parallel to the "wave" in ρ and at an angle to all observations in θ, which is a reflection of the presence of satellites in this system.

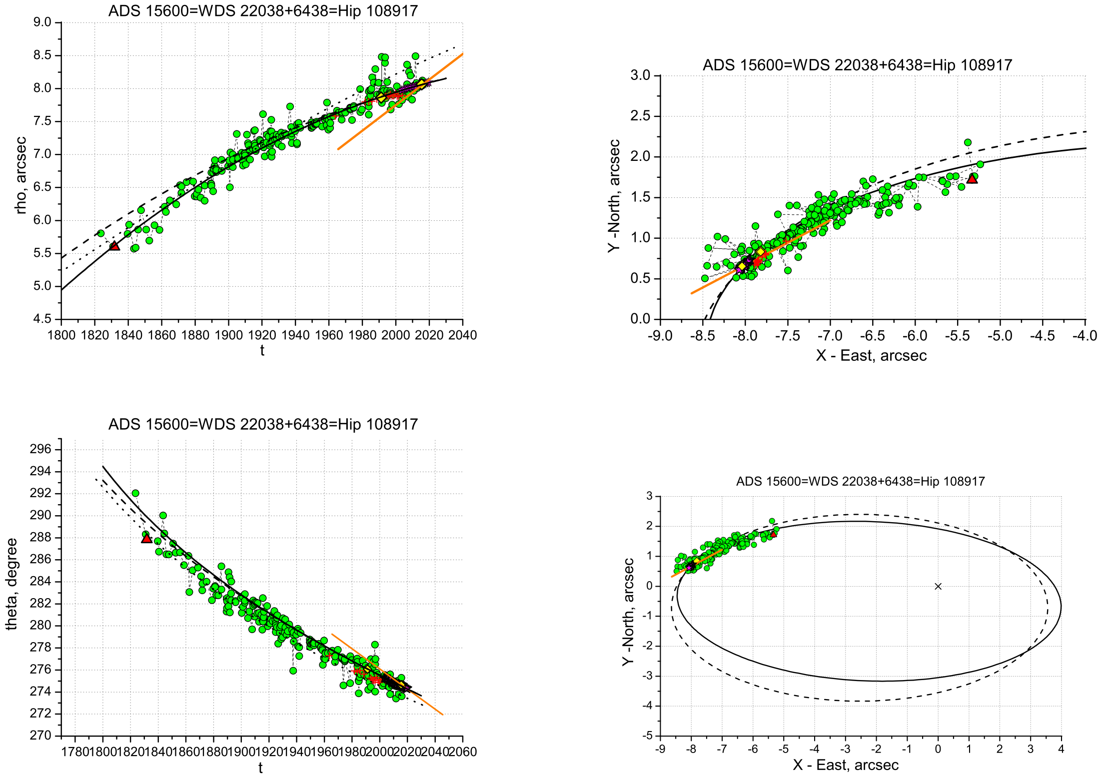


Figure 26: ADS 15600

26 WDS 22038+6438=ADS 15600 Aa-B=Hip 108917

The first orbit of the outer pair (Zeller, 1965) does not satisfy modern observations in ρ (the dotted in the graphs).

The AMP-orbit presented here was obtained on the basis of the Pulkovo CCD- observations in 2003–2019. The astrometric orbit of the inner pair Aab by McAlister, with a period 2.24 years was taken into account, see MSC (Tokovinin, 2018). The influence of a satellite with such period is manifested in CCD observations, and the orbit of the photocenter is consistent with the McAlister orbit. The Gaia DR2 parallax is used, but the radial velocities of both components are absent. The mass of the system and the relative radial velocity were chosen according to a convergence with the rest observations.

The best solution (the solid line on graphs) corresponds to the mass of $3.6M_{\odot}$, which is overestimated compared to the expected of $2.62M_{\odot}$ according to the MSC catalog (the dashed line on graphs). We give here orbits with two mass values. Since the angle is $\beta = 0°$, and the sign of radial velocity is unknown, for each mass value we get 2 solutions that differ only in orientation in the galactic coordinate system. Perhaps the satellite is not one.

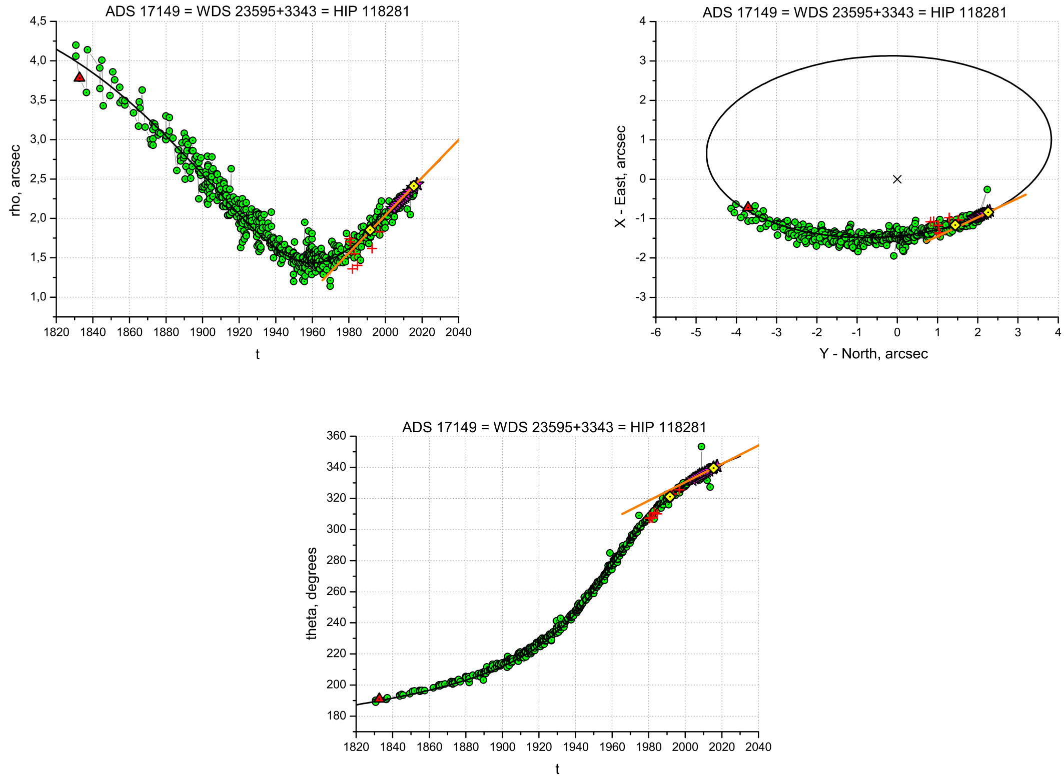


Figure 27: ADS 17149

27 WDS 23595+3343 = ADS 17149 = Hip 118281

This is a close pair with a separation of $\sim 2''$ at the limit of the possibility of photographic observations. The direction of motion according to Gaia DR2 is tangential to an impressive number of observations (more than 600) and does not contradict them. The radial velocities of the components are absent in the Gaia DR2 data, but there are two observations for each in the article of Tokovinin, Smekhov (2002).

In the present work, we used these values as a first approximation, as well as the apparent motion parameters and parallax from the Gaia DR2 data. At the best convergence with observations and taking into account the orbital motion, the relative radial velocity of 3.0 km/s at the time of 2015.5 was obtained. An unambiguous AMP orbit was determined with a period of 1032 year and the components mass sum of $2.4M_\odot$ which corresponding to the "mass-luminosity" dependence.

The orbit with a period of 717 years (Hartkopf, Mason, 2011) also describes all observations well, but it corresponds to the mass sum of $2.7M_\odot$. We do not have any signs confirming this excess.

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