# 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 I

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## 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 $\beta$ 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 $\beta$ 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)).

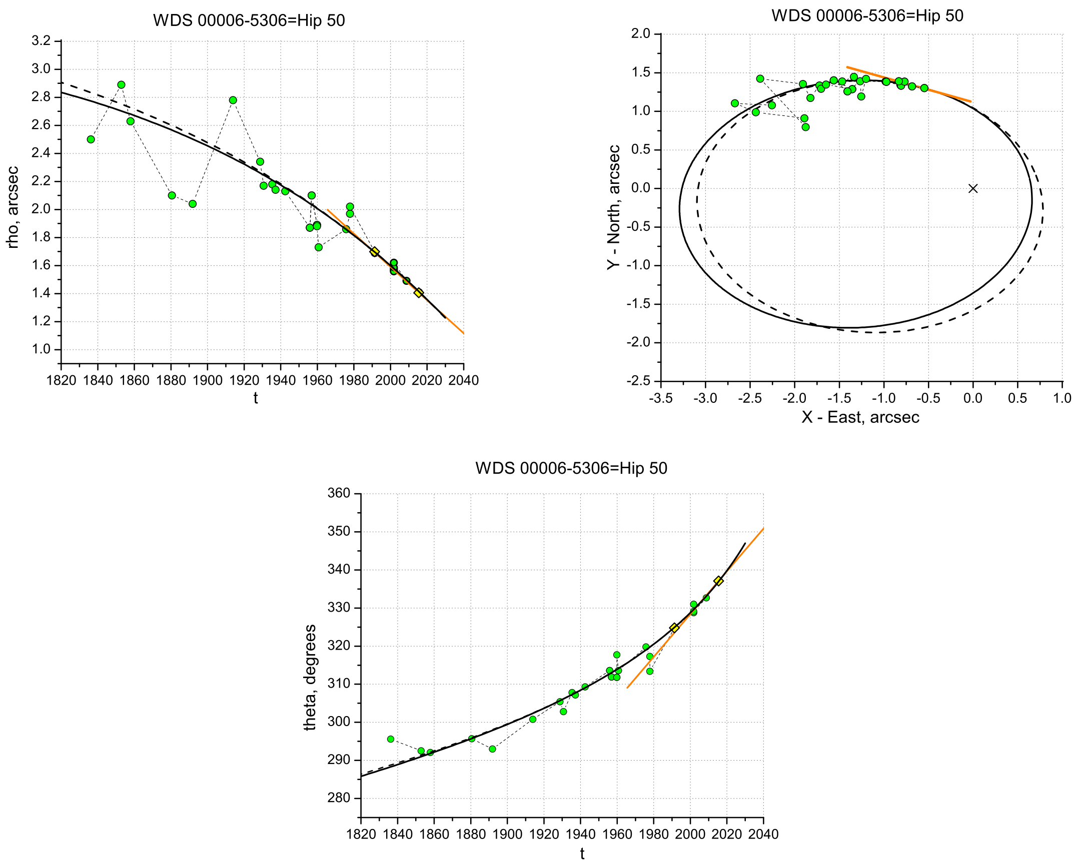



**Figure 1:** Hip 00050

# 1 WDS 00006-5306=Hip 50

The AMP-orbits were determined firstly in the work (Kiyaeva et al., 2017). The AMPs were obtained on the basis of 1991–2015 observations from WDS. We used the parallax from Hipparcos (van Leeuwen, 2007), estimations of masses from (Tokovinin, Kiyaeva, 2016). The relative radial velocity was chosen according to agreement with entire series of observations. In the catalogue Gaia DR2, there is radial velocity for one component only. Two pairs of orbits with $\beta = \pm 5°$ were determined. According to Gaia DR2 data the relative motion at the instant 2015.5 fits observations and ephemerides. The orbit obtained in the article (Kiyaeva et al., 2017) does not require improvement.

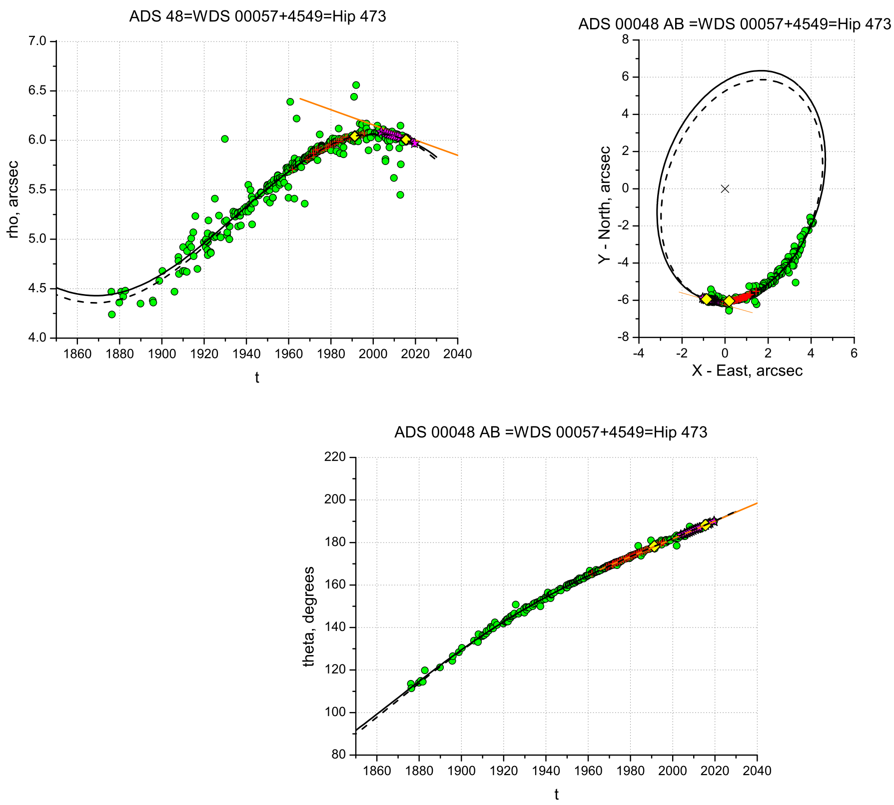



**Figure 2:** ADS 00048 AB

# 2 WDS 00057+4549= ADS 48 AB=Hip 473

The AMP-orbit of the inner pair ADS 48 AB had been obtained on the basis of Pulkovo photographic observations (AMPs at the instant 1980.0, on graphs — dashed line), it was presented in the article (Kiyaeva et al., 2001). Also the AMP- orbit was presented in the article (Kiyaeva et al., 2020). The last was calculated on the basis of the Gaia DR2 positions and proper motions after taking into account the systematic correction between space and ground observations $\Delta\rho = 0.03''$ (AMPs at the instant 2015.5, on graphs — solid line). In this work, we include both orbits which are in agreement each other, and also they fit orbit published in the work (Izmailov, 2019). It confirms good quality of AMP method and photographic observations. The discrepancy indicates the actual accuracy of the orbital elements.

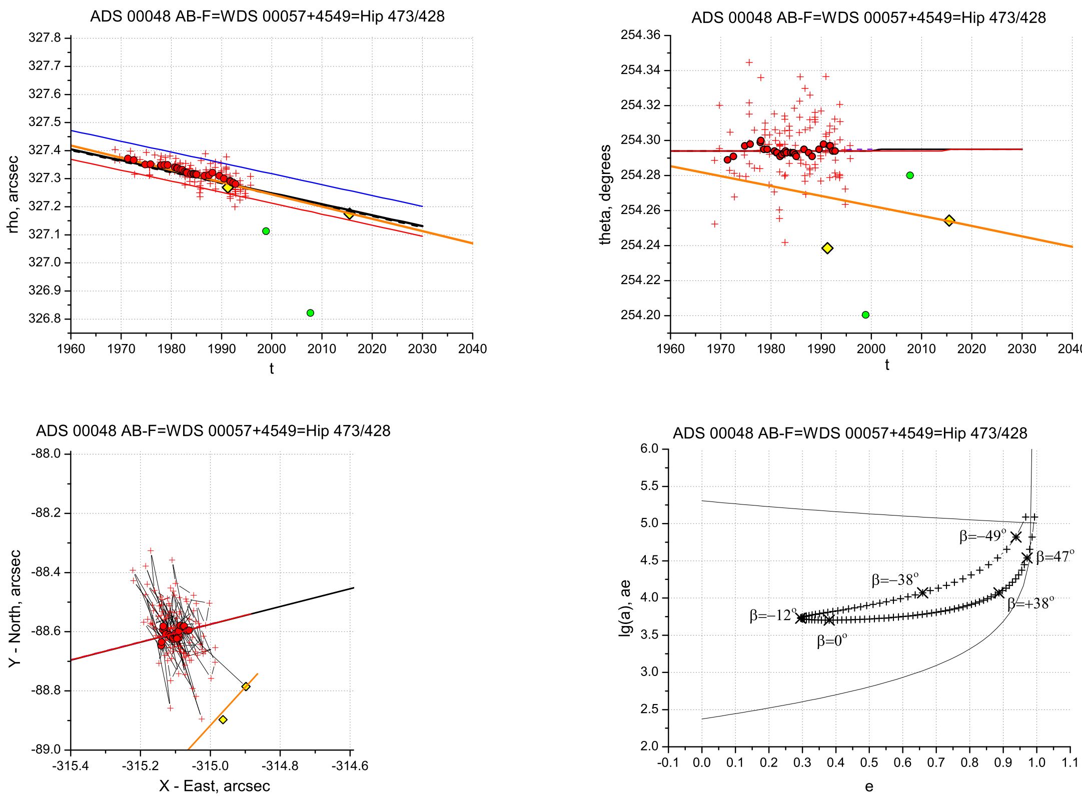



**Figure 3:** ADS 00048 AB-F

## 3 WDS 00057+4549= ADS 48 AB-F=Hip 473/428

The outer pair ADS 48 AB-F is the most wide binary star included in the Pulkovo program of investigations ($\rho = 327''$). We had measured the long-term series of homogeneous photographic observations in 1968–1995 (117 photographic plates, (Kiyaeva et al., 2001)) using an automatic measuring device "Fantazia". After accounting for the internal subsystem, normal places in sliding window of 5 years were calculated (red circles on the graphs). This set was the basis for this work. The family of orbits was obtained with parallax and radial velocities of Gaia DR2; masses are taken from the article (Neves et al., 2013). All orbits of the family are oriented perpendicular to the picture plane. Movement along the positional angle in photographic observations does not appear due to its small value ($\dot{\theta} = -0.0000 \pm 0.0001°/\text{g}$), but it manifested in Gaia DR2 motion ($\dot{\theta} = -0.00056 \pm 0.00001°/\text{g}$). It explains the discrepancy in the $\theta(t)$ graph. Perturbation with a period of 11 years in the movement of the outer pair with an amplitude of about 30 mas, manifests itself not only in the dependencies $\rho(t)$ and $\theta(t)$, but also in the dependence of $y(x)$. Causes of perturbation and stability of the triple system are in detail analysed in (Kiyaeva et al., 2020).

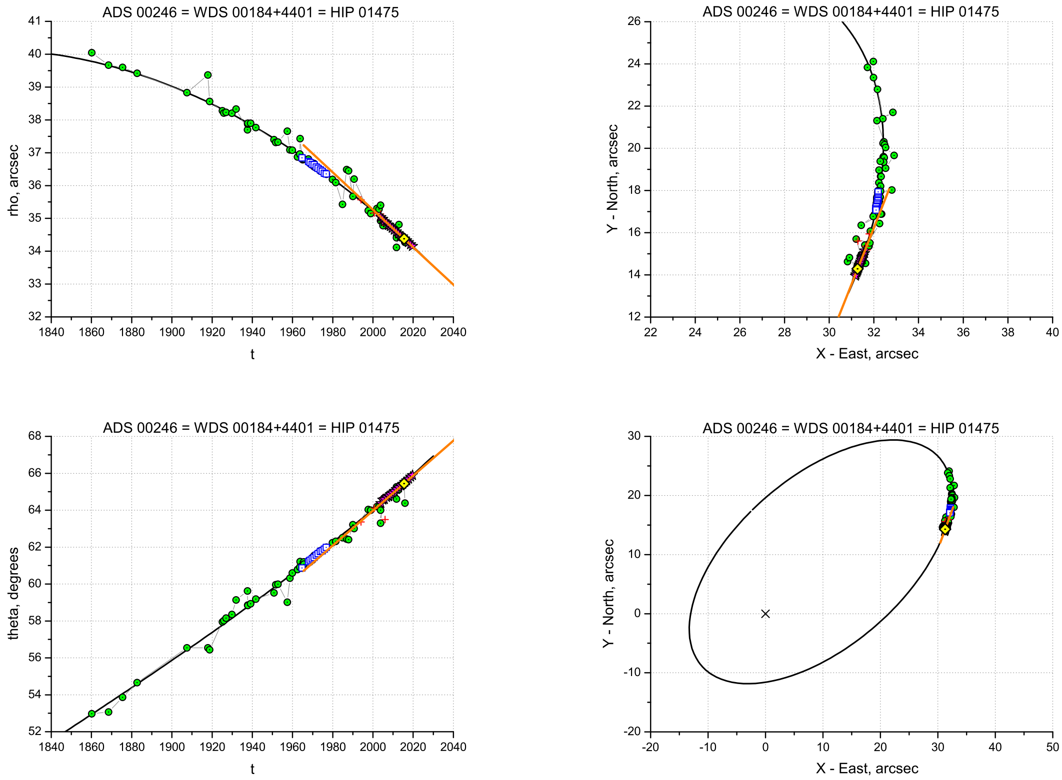



**Figure 4:** ADS 00246

# 4 WDS 00184+4401 = ADS 246 = Hip 1475

An orbit (Romanenko, Kiselev, 2014) with a period two times smaller than that of a circular orbit (Lippincott, 1972) was previously determined using the AMP- method. The Lippincott orbit describes modern observations worse than this AMP-orbit. We used radial velocities from the article (Marcy, Benitz, 1989). In our article (Romanenko, Izmailov, 2021), we improved the 2014 orbit using the Gaia DR2 parallaxes, the same radial velocities, and a modified algorithm of the AMP-method. The latter consists in the fact that the coincidence of the AMP-orbits obtained on to three different bases leads to a single-valued orbit. The component masses sum corresponding to it coincides within the error with the value corresponding to the mass–luminosity dependence.

In this paper, we present the 2021 orbit obtained on to a combined series of photographic observations of the US Naval Observatory and of the Pulkovo CCD observations (USNO+CCD basis) with $a \sim 100$ AU. The direction of motion according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris. The radial velocity of the B component is absent from the Gaia DR2 data. Component C is optical according to proper motions from the WDS catalog (Mason et al., 2016) and to work (Kiyaeva et al., 2008).

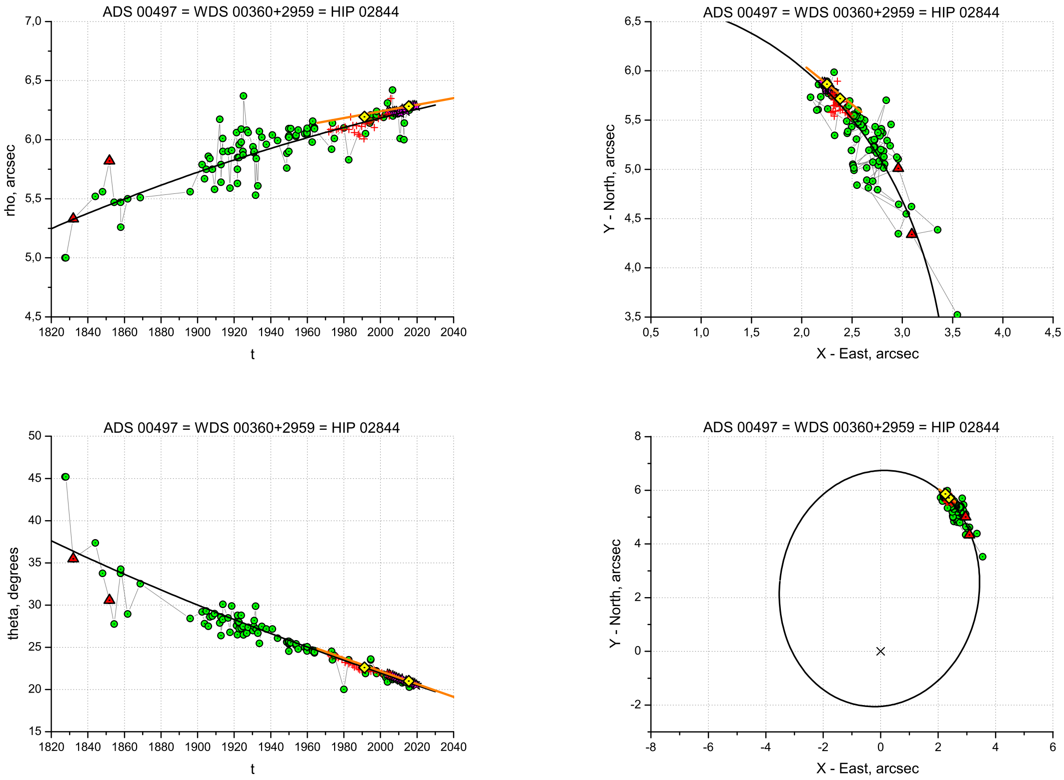



**Figure 5:** ADS 00497

## 5 WDS 00360+2959 = ADS 497 = Hip 2844

Component A is a spectroscopic binary (Tokovinin, 1999). The radial velocities from this article as well as the Pulkovo series of photographic observations and the Hipparcos parallax (ESA SP-1200, 1997) were used. The AB pair orbit by the AMP-method was determined, and a mass excess of $\sim 1M_{\odot}$ was revealed (Kisselev et al., 2009). Component C is optical according to proper motions from the WDS catalog (Mason et al., 2016) and to the work (Kiyaeva et al., 2008).

The direction of motion in the AB pair according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris. However, attempts to determine the AMP-orbits from these data do not lead to satisfactory results. The radial velocity of the A component is absent from the Gaia DR2 data. In this article, we present the 2009 AMP-orbit. At the Gaia DR2 parallax, it corresponds to the component mass sum $3.57M_{\odot}$ (the excess remains).

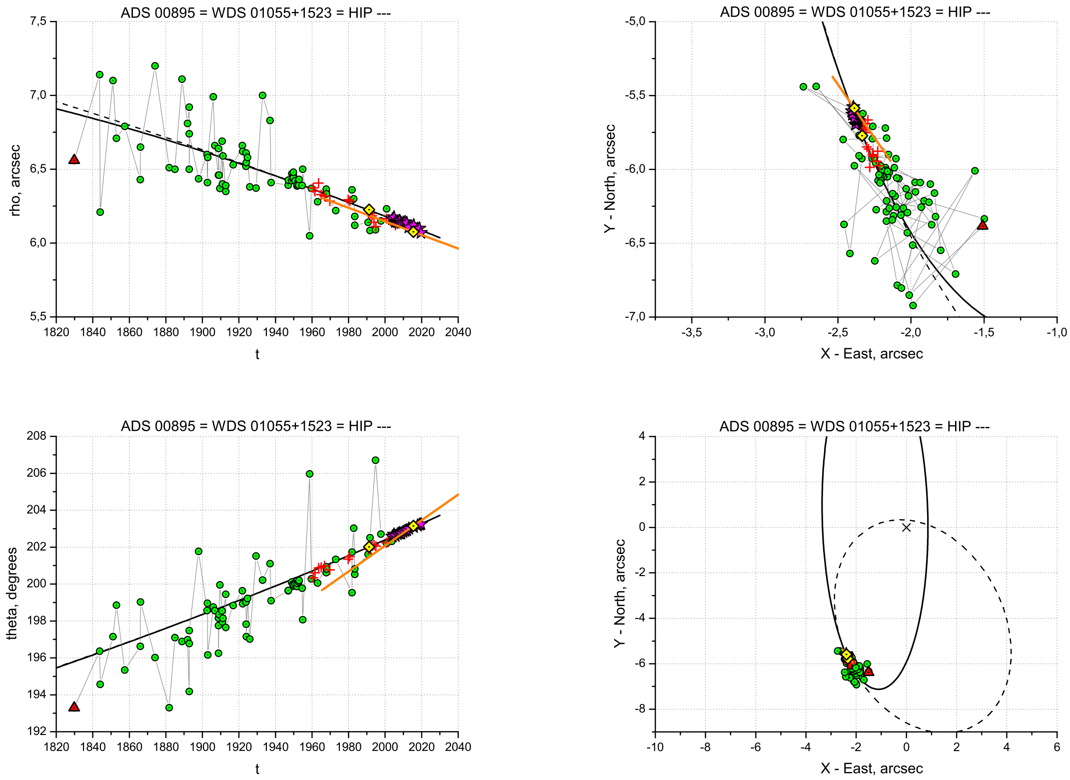



**Figure 6:** ADS 00895

## 6 WDS 01055+1523 = ADS 895 = Hip 5110

This close pair of K dwarfs has been observed at Pulkovo since 1960 and had no radial velocities. The analysis showed that the direction of motion according to Gaia DR2 data is at an angle to observations. An invisible satellite interferes with the calculation of the orbit, the presence of which manifests itself in large errors in determining both the parallax and the radial velocity of the B component.

In this paper, we present the first orbits of the AB pair, obtained by us from a series of Pulkovo CCD observations of 2004–2019. According to the effective temperature and to the spectral classes, the components mass sum is equal to $1.4M_{\odot}$. We also used the parallaxes and radial velocities of the components from the Gaia DR2 data (the latter — for lack of more reliable ones). The determined two preliminary AMP-orbits are with a period of 3471 years, which are correspond to $\beta = +60°$ and $-60°$, are in good agreement with observations and coincide between himself on the entire segment (1829-2019). The largest contribution to the errors of the orbital elements is made by large radial velocity errors according to the Gaia DR2 data.

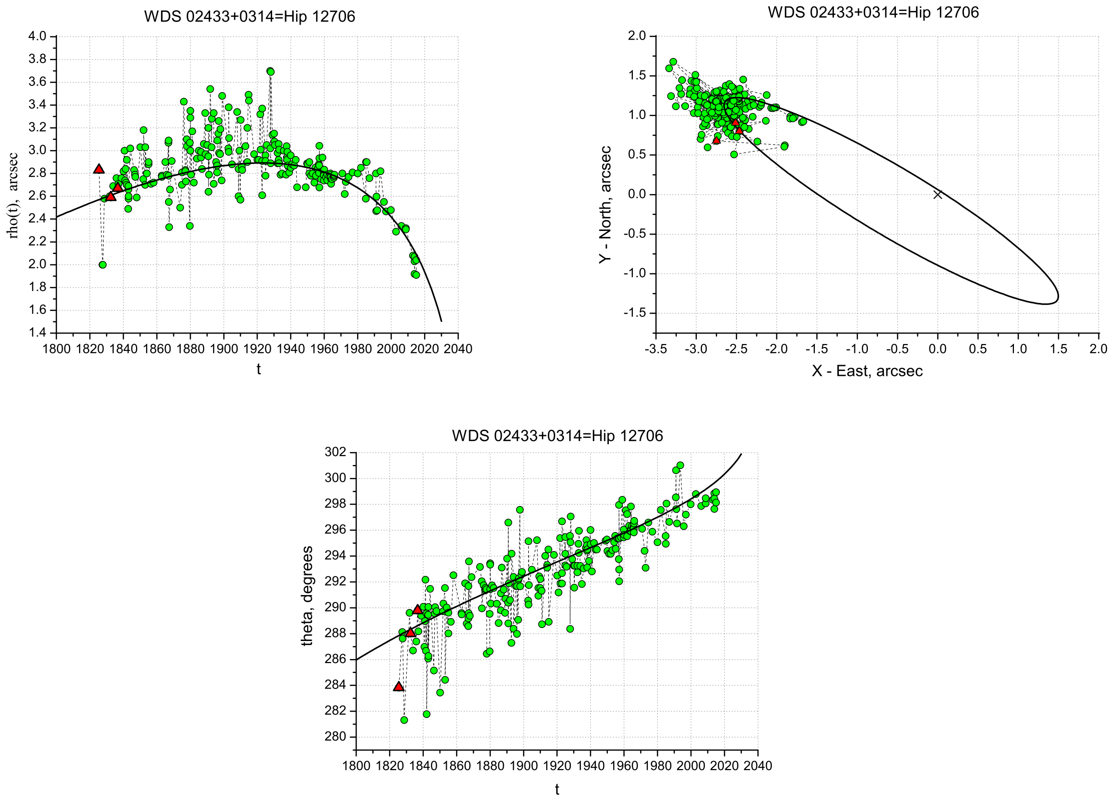



**Figure 7:** Hip 12706

## 7 WDS 02433+0314=Hip 12706

According to (Kervella et al., 2019), component A may have a low-mass satellite. In the Gaia DR2 catalogue only this component was observed. It is the bright star ($m_G = 3.4^m$) with a great proper motion: $\mu_x = -151$ mas/yr and $\mu_y = -147$ mas/yr. Parallax of Gaia DR2 ($43.6 \pm 0.8$ mas) is different from Hipparcos one ($41.0 \pm 0.6$ mas, van Leeuwen (2007)). Hipparcos parallax has a less uncertainty.

AMPs at the instant 1987.0 were determined according to heterogeneous WDS observations of 1959–2014. We have used Hipparcos parallax, sum of masses ($3.0 M_\odot$) from the work (Tokovinin, Kiyaeva, 2016). The radial velocity was chosen according to the agreement with all positional observations. It was necessary to correct the AMP-orbit with helping of the Tokovinin's program ORBITX (Tokovinin, 1992). According to this improved orbit, the total mass of the system is close to the expected one ($2.8 M_\odot$) with the Hipparcos parallax, but it has a less value ($2.3 M_\odot$) with the Gaia DR2 parallax. This orbit determined for the first time.

The eccentricity of the orbit is 0.88, and there is an accelerated orbital motion now. Thus, in the near future, further refinement of the orbit is possible.

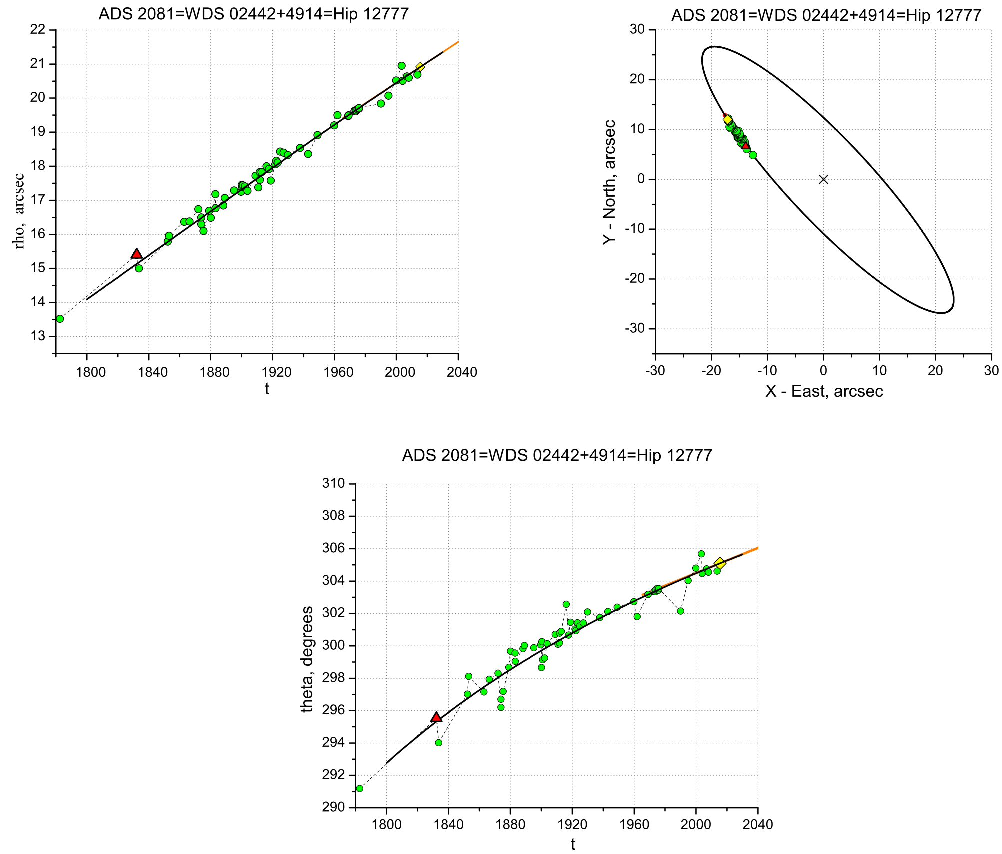
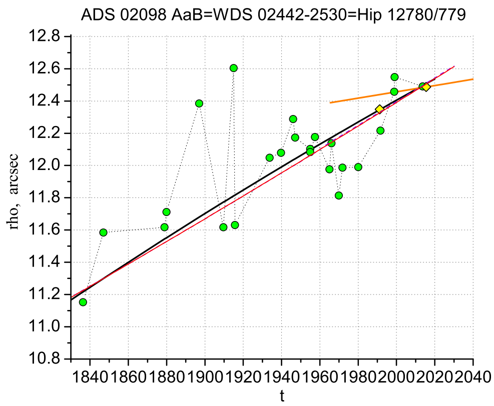
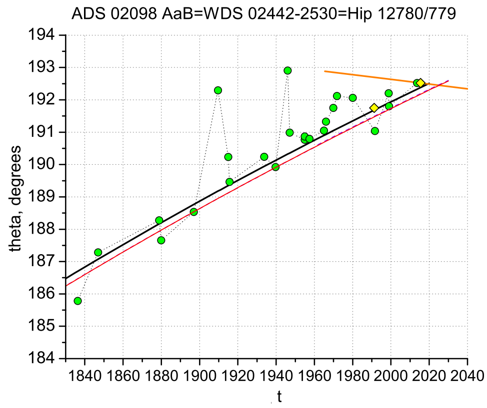



**Figure 8:** ADS 02081

# 8 WDS 02442+4914= ADS 2081=Hip 12777

The first orbit was published in the article (Kiyaeva et al., 2017). Then there was no a homogeneous reliable series of observations for the production of apparent motion parameters. Orbit recalculated with AMPs and parallax from Gaia DR2. The found mass $1.8M\odot$ is consistent with the previously accepted $1.7M\odot$. In Gaia DR2there is a radial velocity of only component A. We used $\Delta Vr = +1.3$ km/s as defined in the work (Nidever et al., 2002) and confirmed in the catalog (Soubiran et al., 2018). The new orbit, determined from the Gaia DR2 data, travels better through the entire series of observations, and we can estimate of the mass of the system independently.




# 9 WDS 02442-2530=ADS 2098=Hip12780/779

The family of orbits obtained in (Kiyaeva et al., 2017) does not require improvement. We have used Hipparcos parallax, sum of masses ($3.2M_\odot$) and the radial velocity $+0.17 \pm 0.08$ km/s accoring to the work (Tokovinin, 2016), where the orbits of inner subsystems were determined. Visual orbit of inner pair Aab with a period of 6.7 years was taken into account, spectroscopic orbit of internal pair Bab having a period of 27 days, was not taken into account. AMPs were obtained throughout the row of WDS for the instant 1930.0. The motion of Gaia DR2 at the instant 2015.5 contradicts the entire series of observations in both coordinates, which is explained by the presence of satellites.

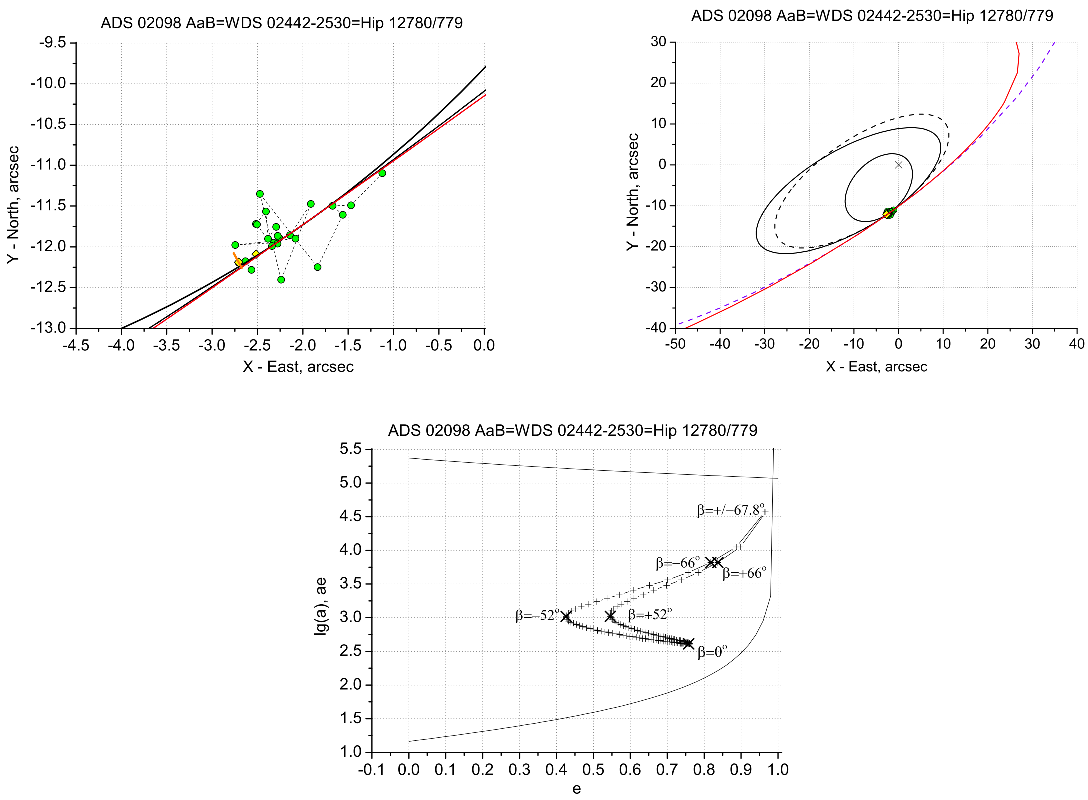



**Figure 9:** ADS 02098

For explanations of the graphs, see the previous page.

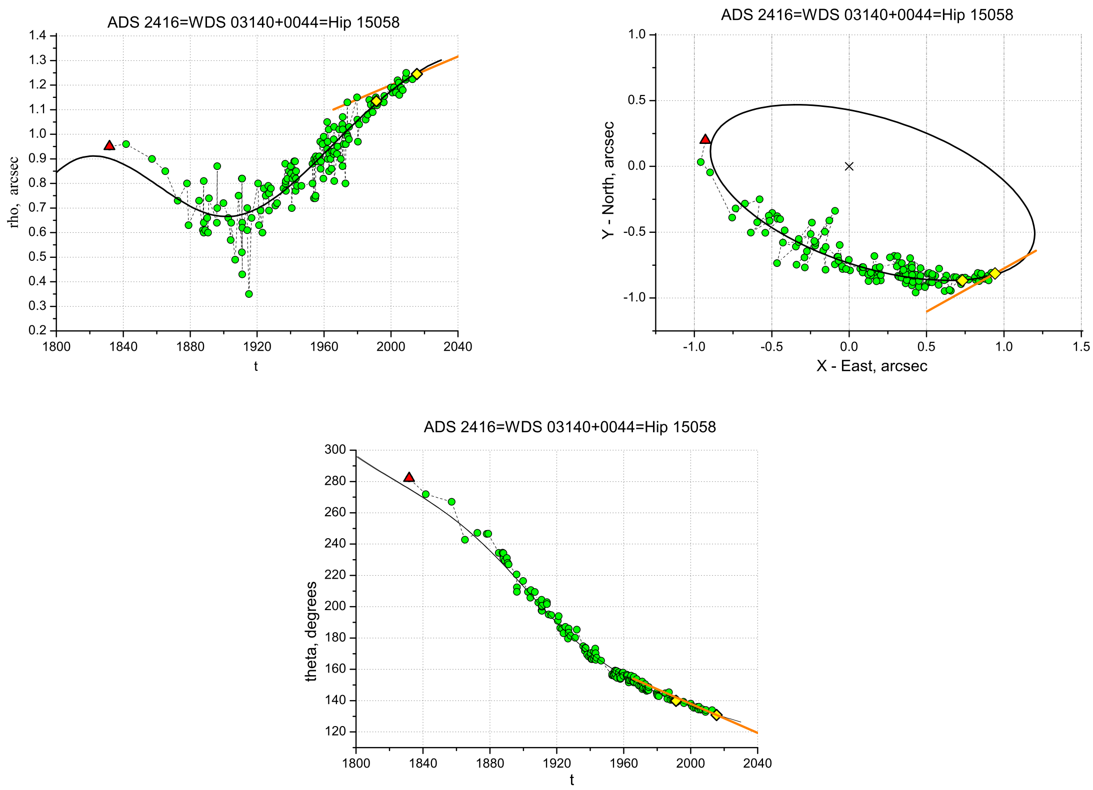



**Figure 10:** ADS 02416

## 10 WDS 03140+0044=ADS 2416=Hip 15058

Only modern observations of 1989–2012 of WDS were used to determine AMPs for the epoch 2000.5, among which mostly USNO speckle interferometric observations. We used the parallax from Hipparcos catalog (van Leeuwen, 2007), the masses — from the article (Tokovinin, Kiyaeva, 2016), the radial velocity was chosen. Our orbit aligns well with all observations and, unlike published by (Riddle et al., 2015), does not contradict the parallax data and the masses of stars corresponding to spectral class F8. The orbital ephemeris agree well with the observations, but a move Gaia DR2 contradicts observations along $\rho(t)$. Perhaps there is a satellite.

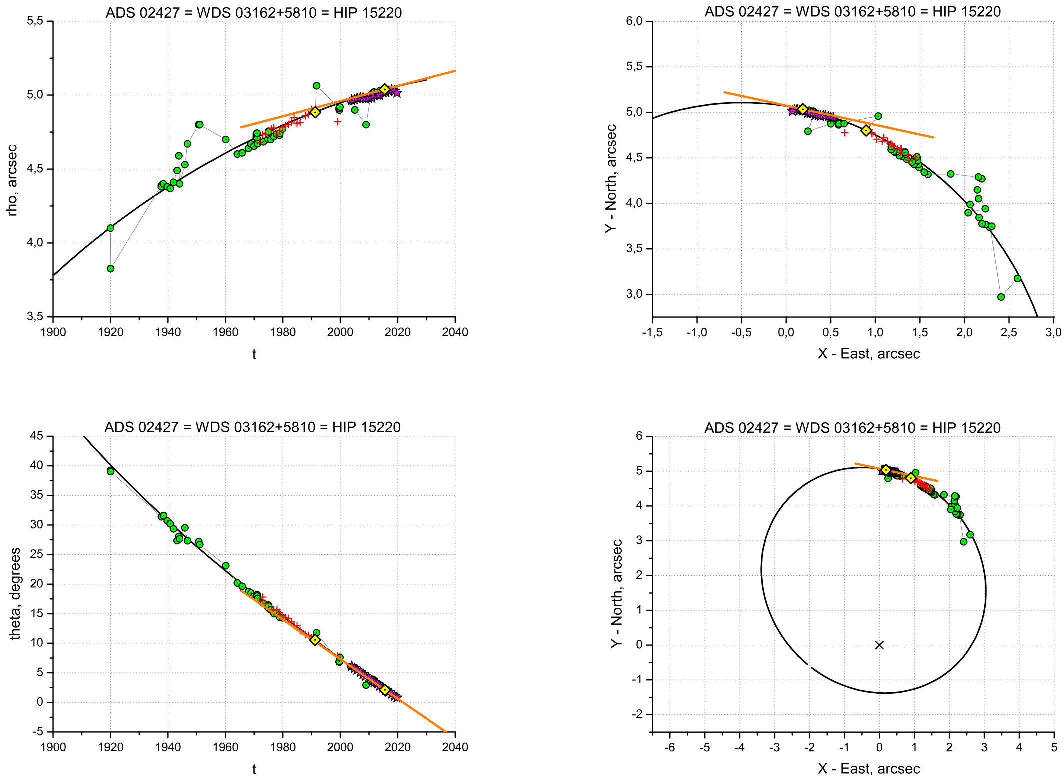



**Figure 11:** ADS 02427

## 11 WDS 03162+5810 = ADS 2427 = Hip 15220

According to the spectral types (both M2V components), the sum of the masses is $0.80 M_{\odot}$. Previously, with such masses and with the radial velocities by (Tokovinin, 1994) we determined two orbits by the AMP-method (Kisselev et al., 2009). According to the Gaia DR2 data, the relative radial velocity error is twice as large as that according to Tokovinin's article. Therefore, in this work, we used the latter, and the parallax and AMP we used according to the Gaia DR2 data. We obtained an unambiguous orbit with a period of 439 years, which is in good agreement with all observations. The direction of motion according to the Gaia DR2 data is tangential to the observations and does not contradict them.

The orbit indicated in the WDS catalog (Zirm, 2008) with a period of 780 years also agrees well with all observations, but with the parallax of Gaia DR2 corresponds to the mass sum of $0.53 M_{\odot}$. Is it possible?

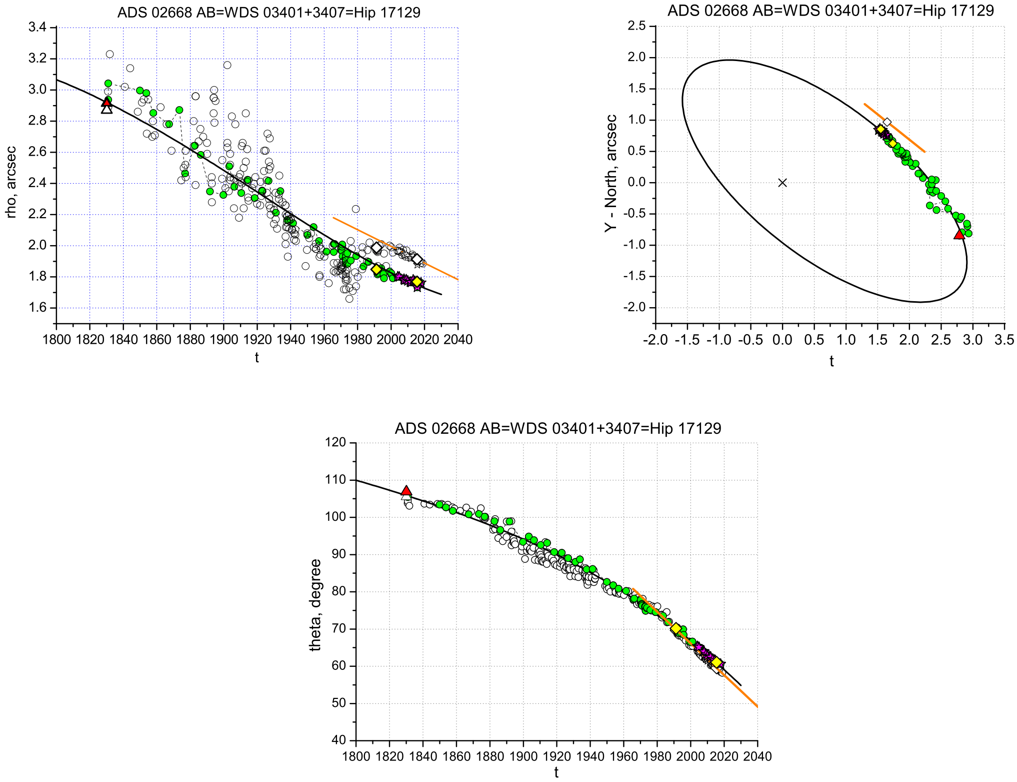



**Figure 12:** ADS 02668

## 12 WDS 03401+3407=ADS 2668=Hip 17129

There is a large series of 214 observations, mostly micrometric (open circles on the graphs) in WDS catalogue. This series is converted by following: average positions are calculated in the window for 3 years (77 observations, green circles on the graphs).

There is a long-periodic satellite with a period of P=106 years (Genet et al., 2015), however the motion of Gaia DR2 at the instant of 2015.5 does not contradict observations. In the article (Kiyaeva, Izmailov, 2018) the AMP-orbit was calculated based on CCD observations on a 26" refractor after taking into account the influence of the satellite. The parallax was taken from the Hipparcos catalogue (van Leeuwen, 2007), the masses — from the article (Tokovinin, Kiyaeva, 2016), the radial velocity was chosen accordantly with the converted set of observations after taking into account of the inner orbit.

This work uses the same data (Kiyaeva, Izmailov, 2018) with the parallax replacement onto the more accurate one from the Gaia DR2 catalog ($21.80 \pm 0.08$ mas).

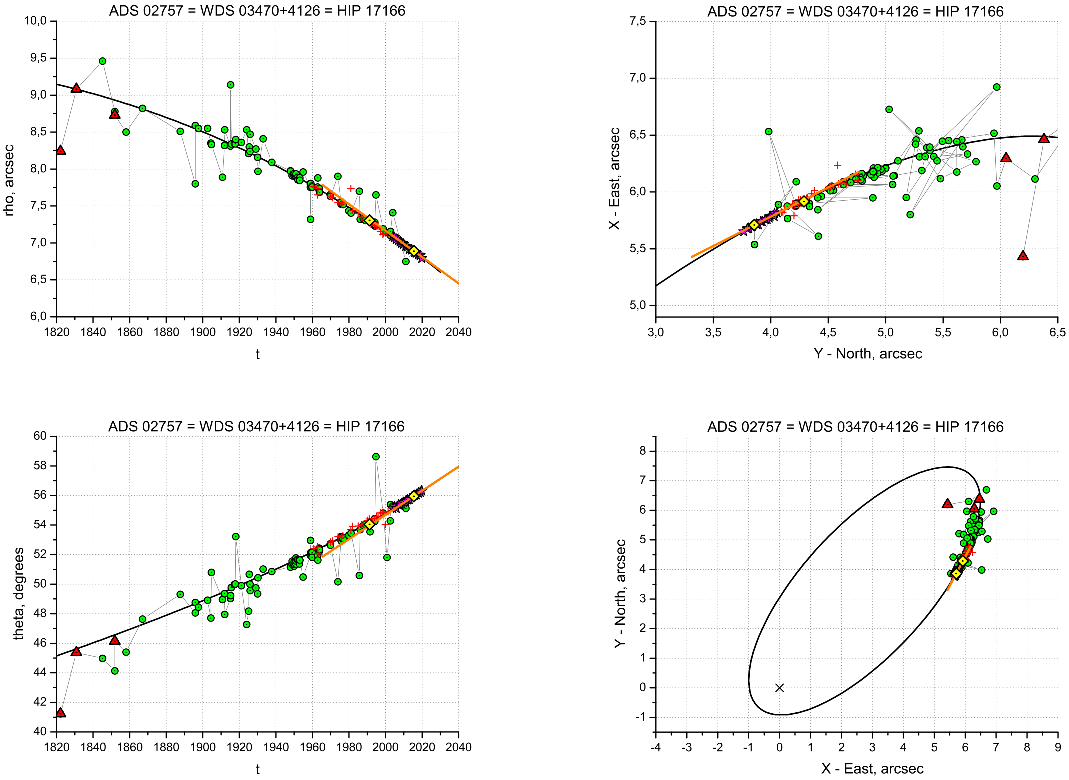



**Figure 13:** ADS 02757

## 13 WDS 03470+4126 = ADS 2757 = Hip 17666

Component B is a known spectroscopic binary star (Tokovinin et al., 1994). Previously, using the radial velocities from this article, two orbits we determined by the AMP-method (Kiselev et al., 2000). In our article (Romanenko, Izmailov, 2021), we improved these orbits using the Gaia DR2 parallaxes, the same radial velocities, and a modified algorithm of the AMP- method. The coincidence of the AMP-orbits obtained from three different bases led to a single-valued orbit and to the component mass sum, coinciding within the error with the value corresponding to the "mass–luminosity" dependence.

In this paper, we present the orbit from the 2021 article obtained from a number of Pulkovo CCD observations (CCD basis). The direction of motion according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris. The radial velocity of component B in the Gaia DR2 data has an error of 1.91 km/s and is not applicable. Component C is optical according to proper motions from the WDS catalog (Mason et al., 2016) and to work (Kiyaeva et al., 2008).

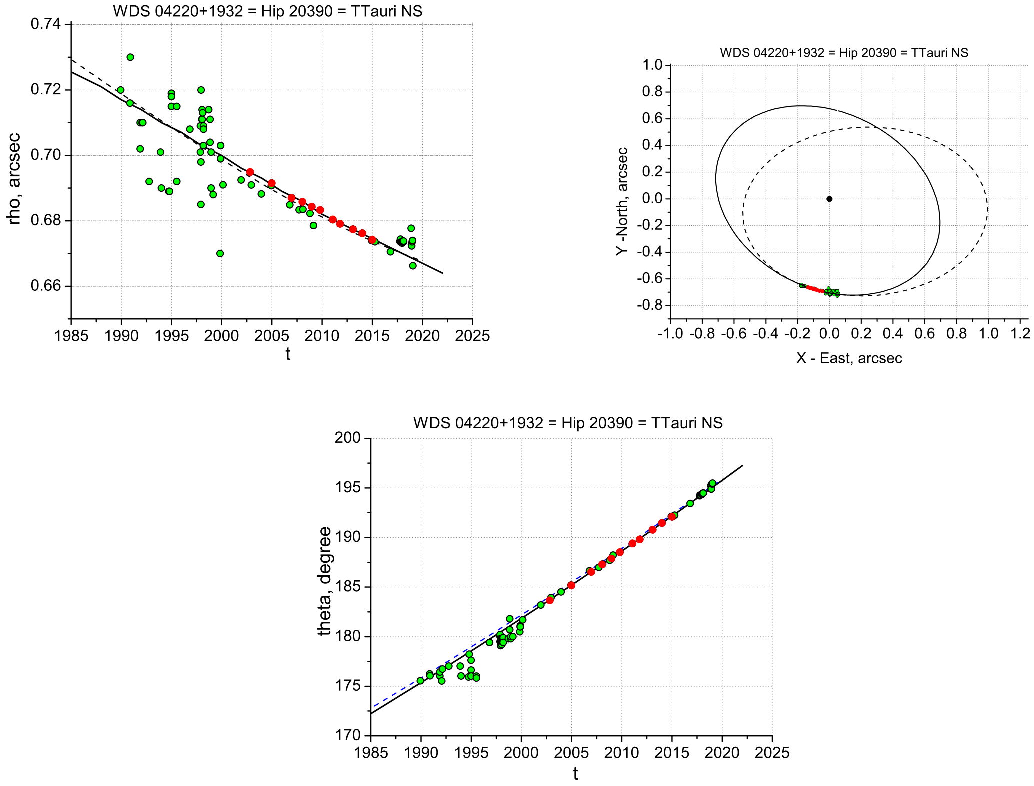



**Figure 14:** TTauri NS

## 14 WDS 04220+1932=Hip20390 (T Tauri NS)

A reliable orbit of the inner pair SaSb (P=27 years) was obtained on the basis of all observations with the telescope Keck I (Schaefer et al., 2020). If to use the Gaia Dr2 parallax ($6.929 \pm 0.058 mas$), the sum of masses is $M_{(Sa+Sb)} = 2.48 M_{\odot}$.

AMP-orbits of outer NS pair, corresponding to $\beta = \pm 32^{\circ}$ were obtained by us in this work on the basis of homogeneous observations on the Keck I telescope for 2002–2014 and one observation VLT (2014.9), which fits this series ($T_0 = 2009.0$, red circles on the graphs). They were published in works (Schaefer et al., 2014; Köhler et al., 2016) and were corrected by us according to the orbit of the inner SaSb pair. There was used the parallax of Gaia DR2, the radial velocity was chosen.

Since the observations of all three components are made on the same telescope, it is possible to estimate the masses of these stars independently. According to our estimate, the masses of the components depend on the entire mass of the inner pair and take the following values: $M_N = 1.1 * M_{(Sa+Sb)} = 2.7 \pm 0.4\ M_{\odot}$, $M_{Sa} = 0.84 * M_{(Sa+Sb)} = 2.08 \pm 0.05\ M_{\odot}$, $M_{Sb} = 0.16 * M_{(Sa+Sb)} = 0.40 \pm 0.05\ M_{\odot}$, then $M_{(S+N)} = 5.2 M_{\odot}$. Details see in the article (Kiyaeva, Zhuchkov, 2017).

One of the two AMP-orbits has a very small eccentricity ($e = 0.05 \pm 0.10$). With the Gaia DR2 parallax, we got the corresponding to a circular orbit the value of $M_{(S+N)} = 4.8 M_{\odot}$. Consent of two independents estimates for the values of the mass of the whole system, allows us to accept $M_{(S+N)} = 5.0 M_{\odot}$. The corresponding orbit is presented in this work.

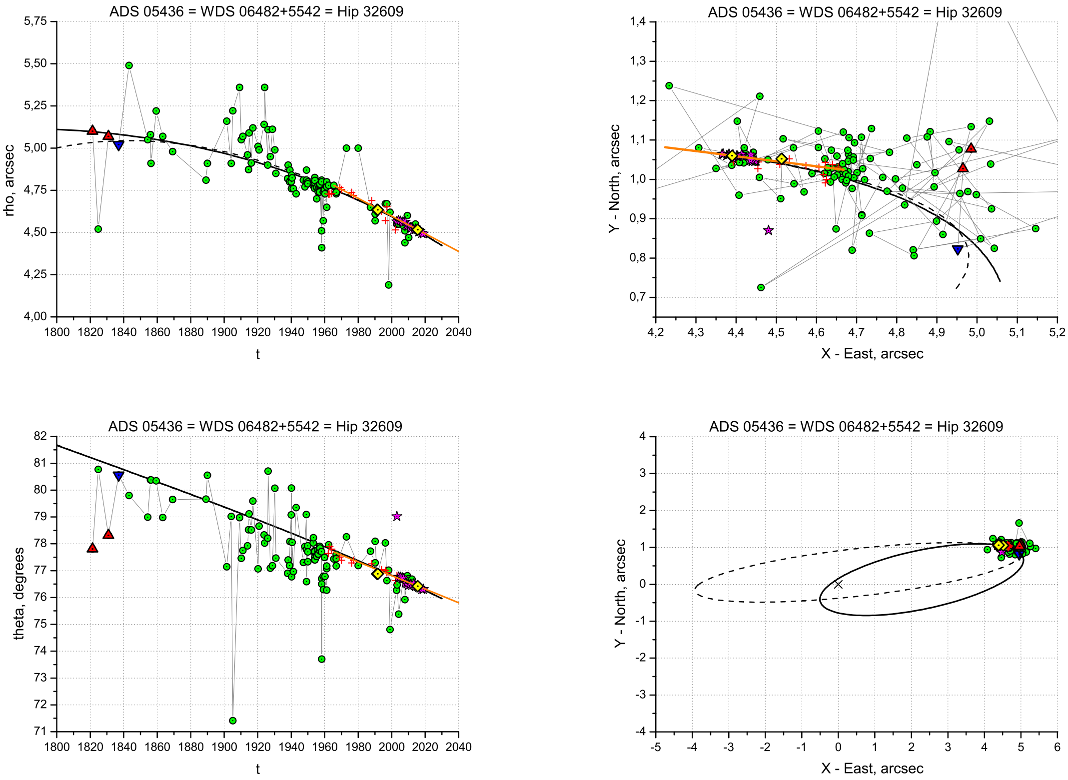



**Figure 15:** ADS 05436

## 15 WDS 06482+5542 = ADS 5436 = Hip 32609

It should be noted the confusion in the designation of the components of this pair, since the brightnesses are almost the same and reach $6.3^m$. It is known from the article (Tokovinin, 1999) that the B component is a spectroscopic binary ($P = 4.25856d$). This designation of the component corresponds to the ADS catalog (Aitken, Doolittle, 1932). In the WDS catalog of the 2016 version (Mason et al., 2016) there is a note on this duality, but the components themselves are relabeled. We adhere to the WDS notation.

In the Gaia DR2 catalog, namely the radial velocity of component A has an error of 3.48 km/s. This means that the radial velocity obtained by Gaia is instantaneous and cannot be used. We used the data from Tokovinin's article and the algorithm described in our work (Romanenko, Izmailov, 2021). The coincidence of the orbits obtained from three different bases led to two asymmetric solutions. They correspond to $\beta = +38°$ and $-45°$ and the expected sum of the component masses (taking into account the spectral satellite). They coincide with each other over the entire 1830–2019 segment, covered by observations.

Here we present the orbits obtained this year on the basis of the Pulkovo CCD series. The direction of motion according to the Gaia DR2 data is in good agreement with the observations. The Struve's observations deviate from the observation band by $3°$ in $\theta$. In a previous article (Kisselev et al., 2009), a family of AMP orbits was given using the same radial velocities (Tokovinin, Smekhov, 2002; Tokovinin, 1999).

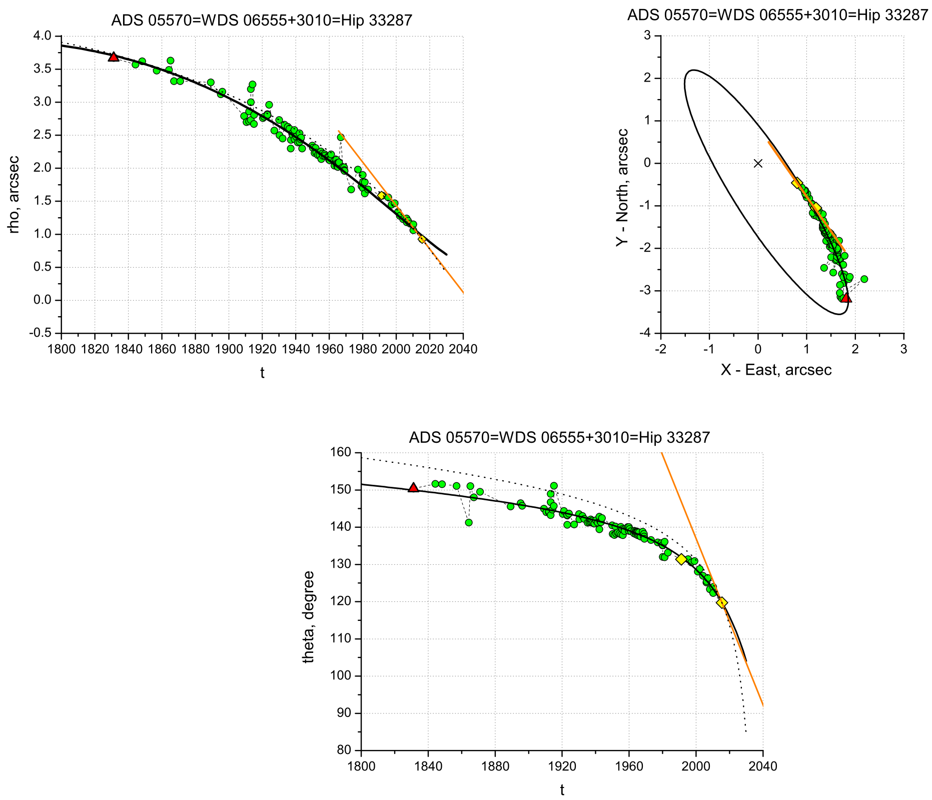



**Figure 16:** ADS 05570

## 16 WDS 06555+3010=ADS 5570=Hip 33287

The AMPs were obtain according to heterogenous observations 1937–2010 of WDS at the instant 1974.0 (Kiyaeva et al., 2017). We have used CCD and specle interferometric observations and also photographic observations obtained with long-focus telescopes. Parallax was taken from the Hipparcos catalogue (26.0 $\pm$ 2 mas, van Leeuwen (2007)), masses ($1.8 M_{\odot}$) — from the article (Tokovinin, Kiyaeva, 2016), the relative radial velocity was chosen. The orientation ($\Omega$ and $\omega$) of the resulting AMP-orbit was corrected by the program ORBITX (Tokovinin, 1992), the mass and other elements of the orbit did not change.

The motion according to Gaia DR2 slightly diverges from observations, but the attempt to obtain an orbit based on the AMPs and parallax of Gaia DR2 is unsuccessful — strong discrepancy in positional angle. In the graph, this orbit is indicated by dashed line. There are no radial velocities of both components in Gaia DR2.

The refinding of the presented here orbit, published in (Kiyaeva et al., 2017), is currently premature. With the parallax from Gaia DR2 (23.8 $\pm$ 0.4 mas) the sum of the component mass is significantly higher than expected ($2.3 M_{\odot}$). We suspect the presence of a satellite.

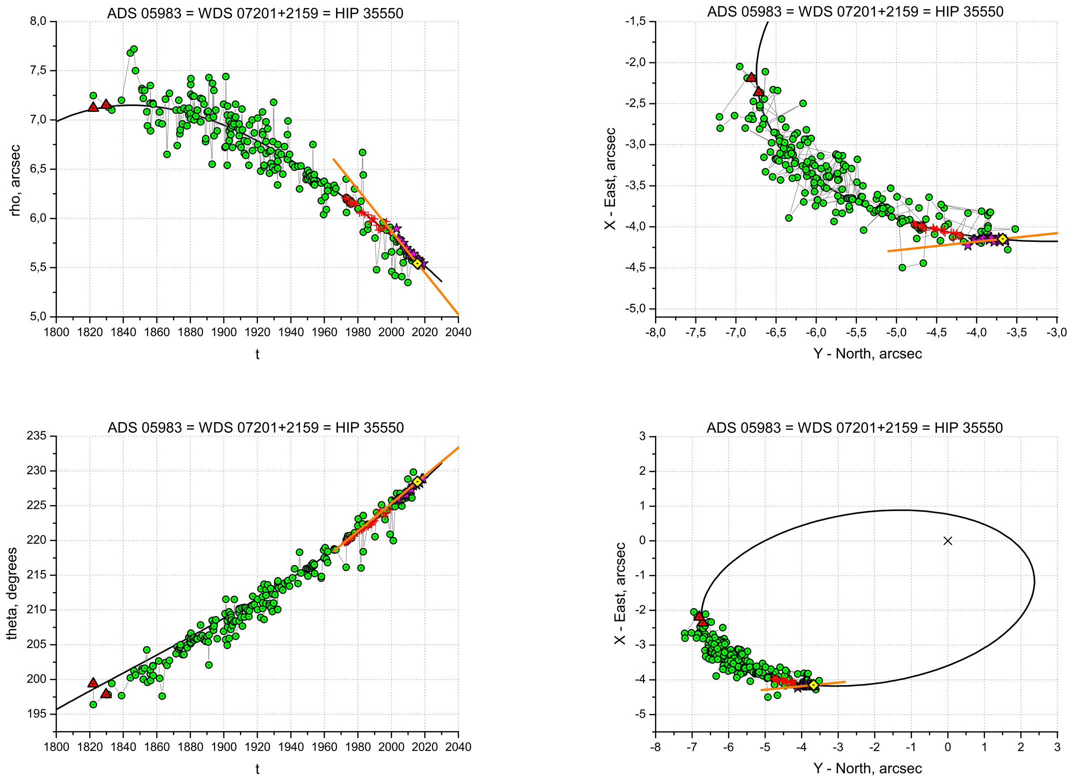



**Figure 17:** ADS 05983

## 17 WDS 07201+2159 = ADS 5983 = Hip 35550 (delta Gem)

This bright star ($3.55^m$) was suspected to have a massive companion $6 - -10 M_\odot$ (Zeldovich, Guseynov, 1966; Trimble, Thorne, 1969). Our photographic observations did not show deviations in the distances between the visible components corresponding to the influence of a massive satellite. However, a period of $5.6 - -6.1$ years with an amplitude of $0.020 \pm 0.006''$ was revealed, which can be explained by the presence of a dark companion with a lower mass limit of $0.2 M_\odot$ (Shakht, 2000). The orbits of the photocenter and of the outer visual pair AB were determined (Shakht et al., 2007). The latter (period of 622 years) was obtained with a parallax of $0.061''$ (Wooley et al., 1970) and a component mass sum of $2.5 M_\odot$.

According to the Gaia DR2 data, the parallax of component A has a large error and differs from that of component B. Therefore, here we give this orbit with a weighted average parallax ($0.0540''$). Then $\Sigma M = 3.6 M_\odot$. This sum corresponds to the spectral types of the components (F2IV and K3V) and takes into account as the presence of a spectral companion discovered by H. Abt from radial velocities (Abt, 1965) ($\Sigma M = (1.59 + 1.09) + 0.74 = 3.4 M_\odot$, see MSC, Tokovinin (2018)), as well as the aforementioned satellite (Shakht, 2000). This orbit is in good agreement with all observations. The direction of motion according to the Gaia DR2 data is at a small angle along $\rho$. There are no radial velocities in the Gaia DR2 data; in (Shakht et al., 2007) and here, the data from *the Catalog of radial velocities of stars* (Wilson, 1953) are used. The orbit (Hopmann, 1960) with a period of 1200 years corresponds to the component mass sum $1.5 M_\odot$, which is inconsistent with their spectral types.

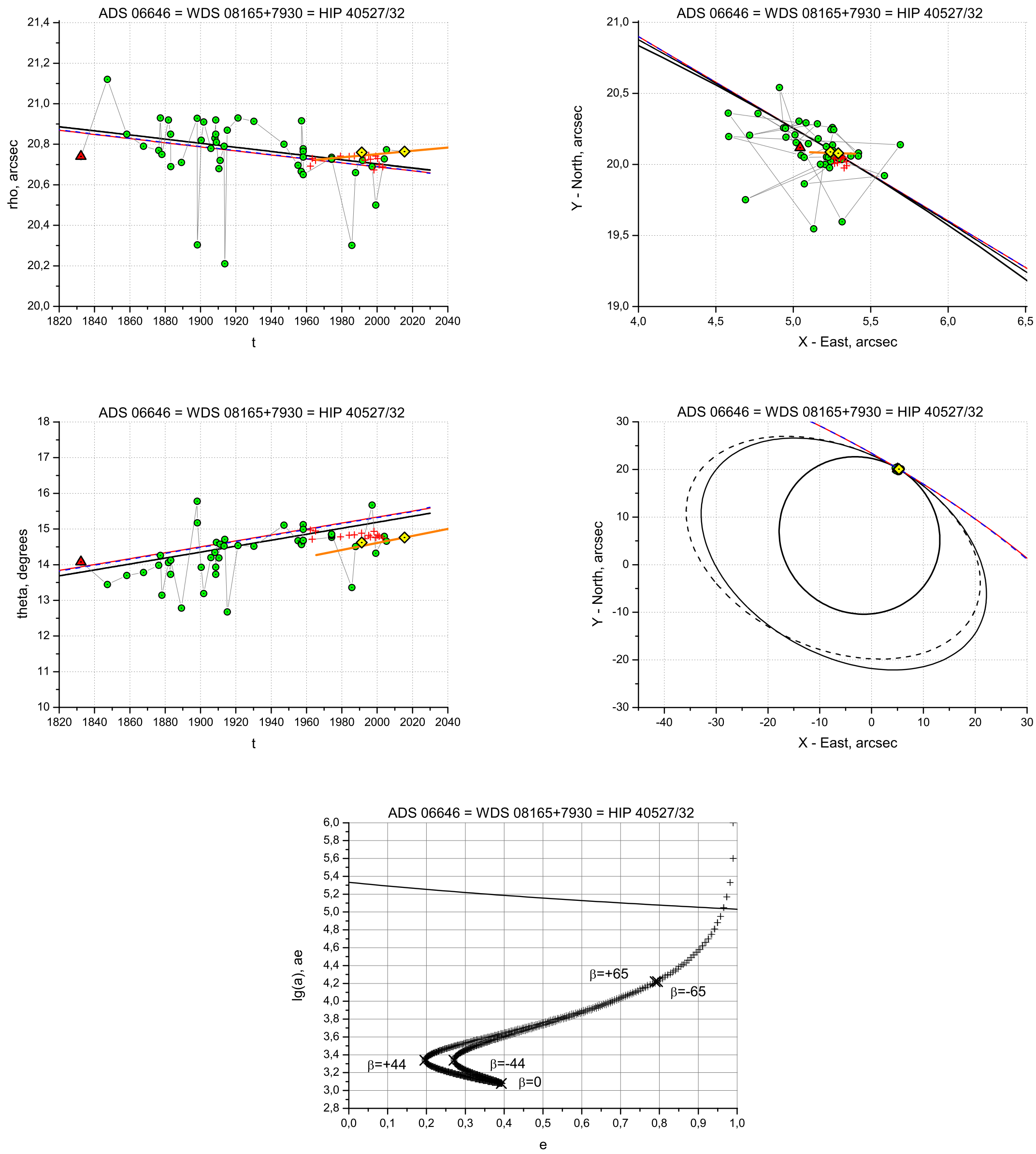



**Figure 18:** ADS 06646

## 18 WDS 08165+7930 = ADS 6646 = Hip 40527/32

In this system, the C component is optical according to the study (Grosheva, 1997), and the A component is spectroscopic binary (Tokovinin, 1997). Using the radial velocities of Tokovinin for AB, a family of AMP-orbits was obtained (Kisselev et al., 2009). Here we give a family of AMP-orbits with the same data, except for the Gaia DR2 parallax and the component mass sum according to the new version of MSC (Tokovinin, 2018). The minimum period $P_{min} \sim 25500$ years was obtained.

The ephemeris of all orbits of the family practically coincide with each other over the entire 1832–2015 segment, covered by observations. The direction of motion according to the Gaia DR2 data is in poor agreement with observations, which is a reflection of the presence of a satellite in this triple system.

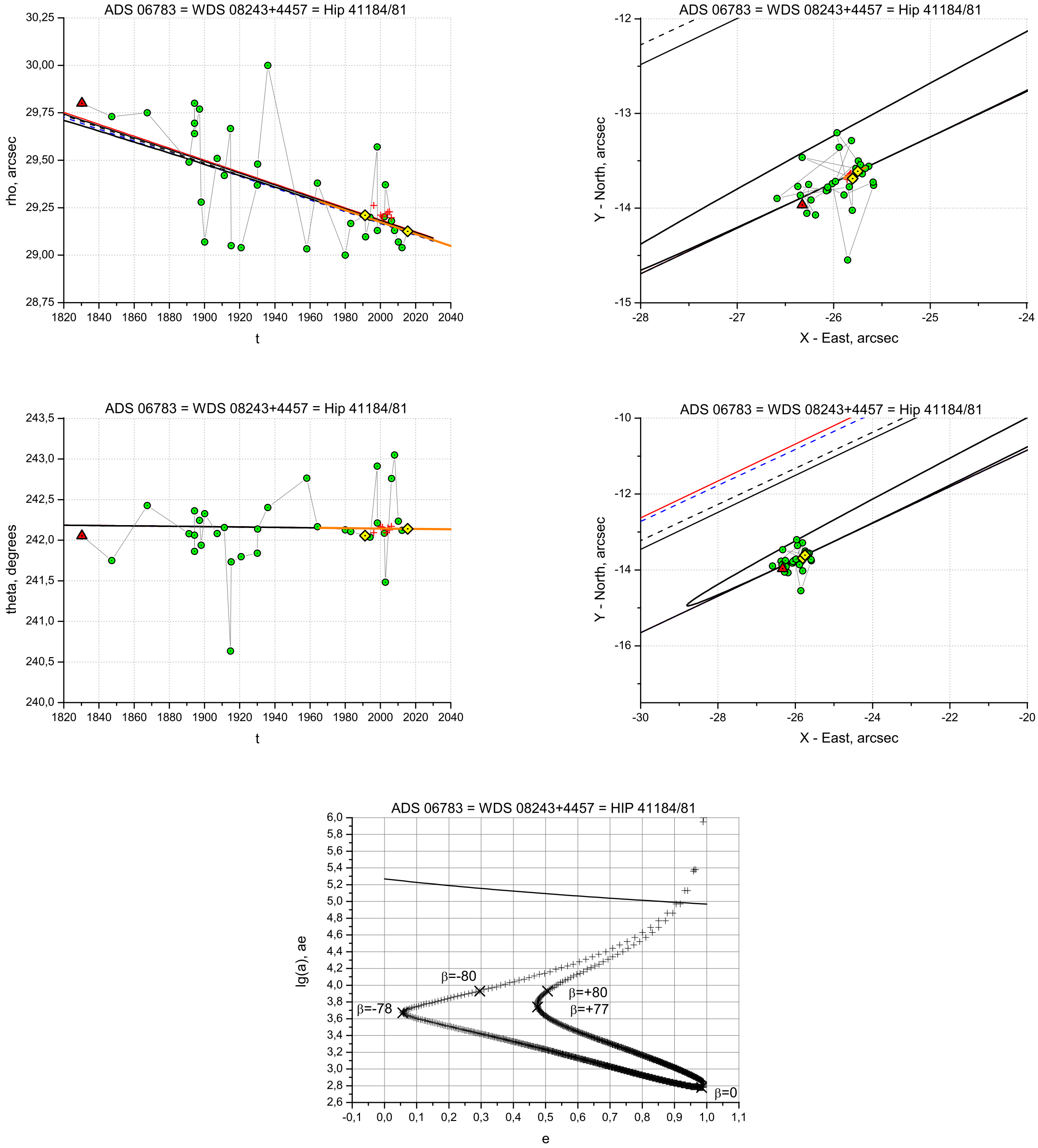



**Figure 19:** ADS 06783

## 19 WDS 08243+4457 = ADS 6783 = Hip 41184/81

A family of AMP-orbits was previously obtained (Kisselev et al., 2009) with using radial velocities (Tokovinin, Smekhov, 2002). In this work, we took data only on Gaia DR2 (positions, proper motions, parallaxes, effective temperatures, and radial velocities of the components) and determined a new family of AMP-orbits, that are in good agreement with 1830–2015 observations and coincide over the entire segment. The minimum period $P_{min} \sim 11000$ years, the inclination of all orbits of the family $i \sim 90°$.

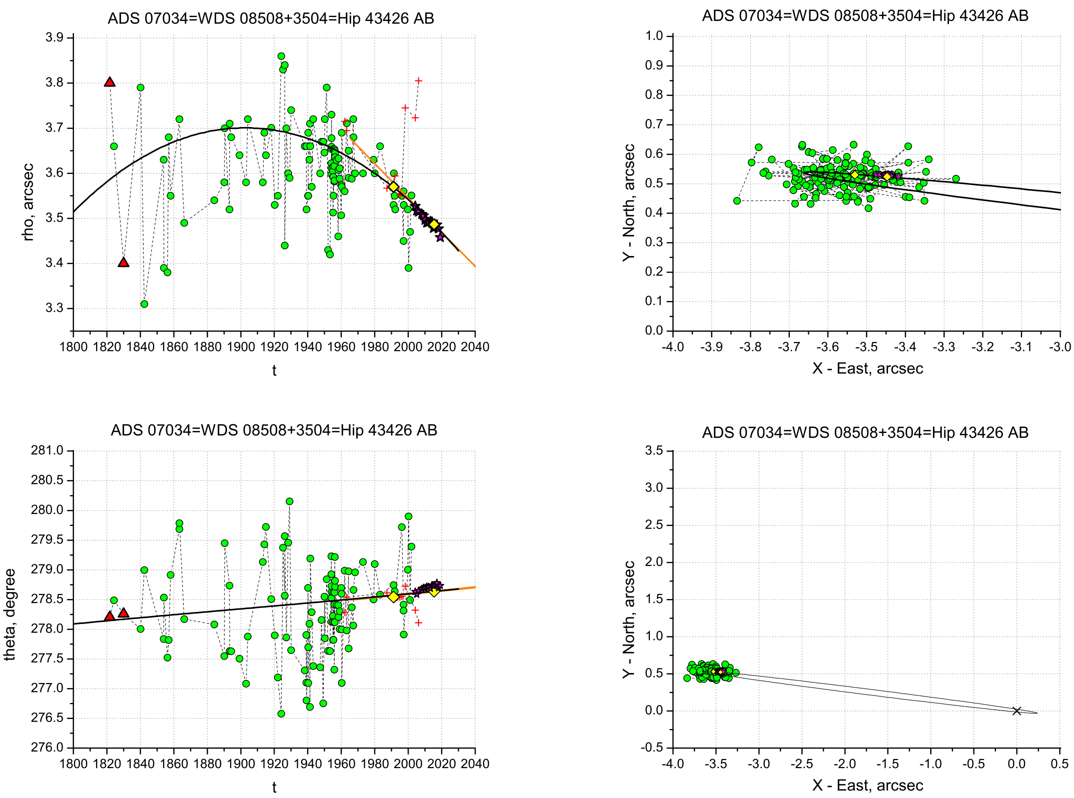
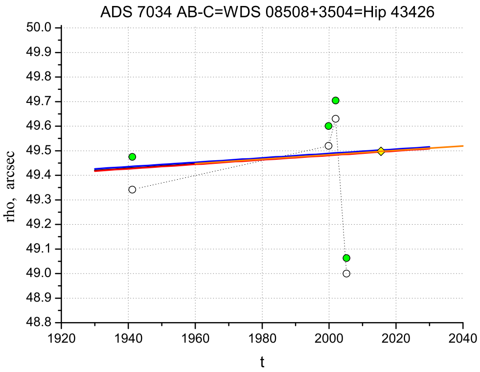


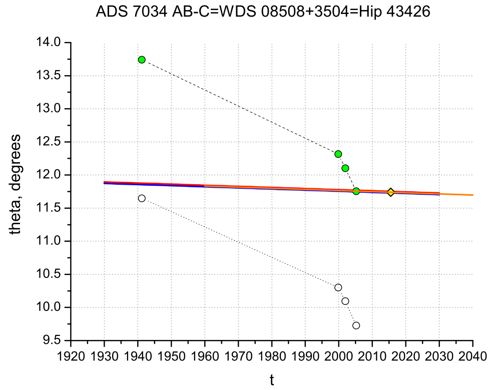

**Figure 20:** ADS 07034 AB

## 20 WDS 08508+3504=ADS 7034 AB=Hip 43426

The single-valued orbit of the inner pair AB and the family of orbits of the outer pair AB-C were obtained from the Gaia DR2 data, including the parallax and the radial velocities of all three components (Kiyaeva, Romanenko, 2020). The masses were estimated by the effective temperature.

To refine the orbit of the inner pair, smoothed observations were used. For this purpose AMPs were obtained on the basis from the WDS observations over the each 40-year interval as well as from homogeneous series of the Pulkovo observations at the instants 1990.0 (photos) and 2006 (CCD).




## 21 WDS 08508+3504=ADS 7034 AB-C=Hip 43426

The family of orbits of the outer pair ADS 7034 AB-C (Kiyaeva, Romanenko, 2020) is also obtained from the Gaia DR2 data. In the WDS catalogue, there are only 5 untrusted observations of the remote component C, so they cannot be used to refine the outer orbit of AB-C. On the graphs, the initial observations of WDS are indicated by open circles, ones after taking into account the orbit of inner subsystem AB by green circles.

The family of orbits of the outer pair includes solutions that diverge from Gaia DR2 by no more than 10 mas. For continued graphs, see also the next page.

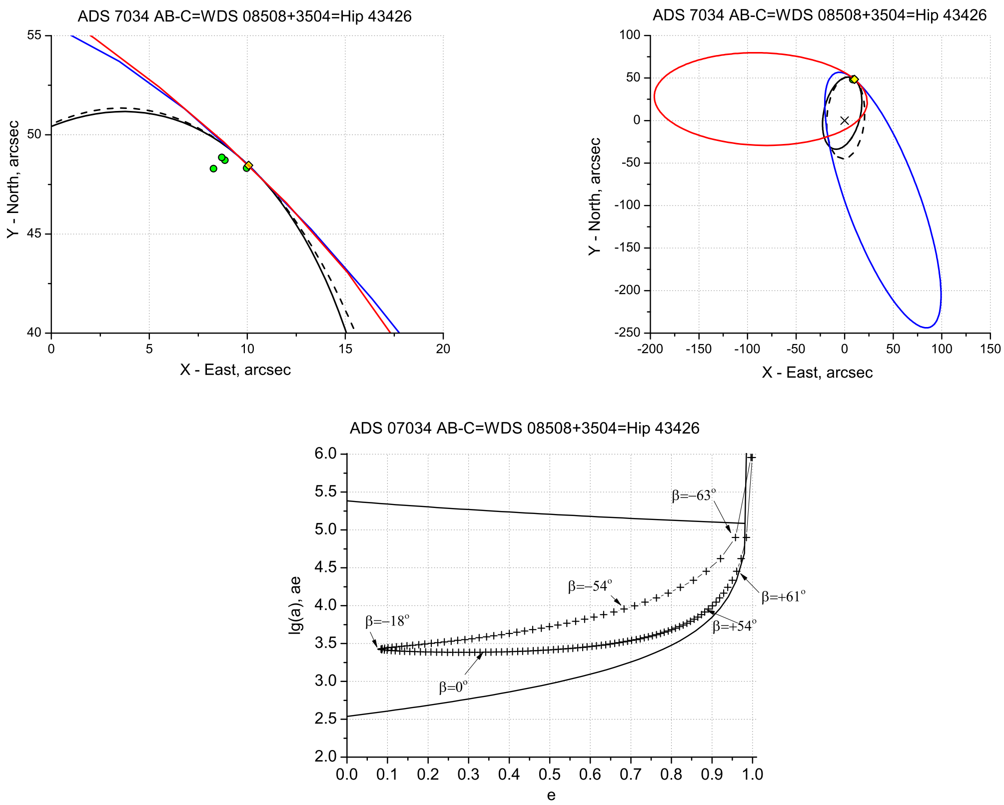



**Figure 21:** ADS 07034 AB-C

For an explanation of the graphs, see the previous page.

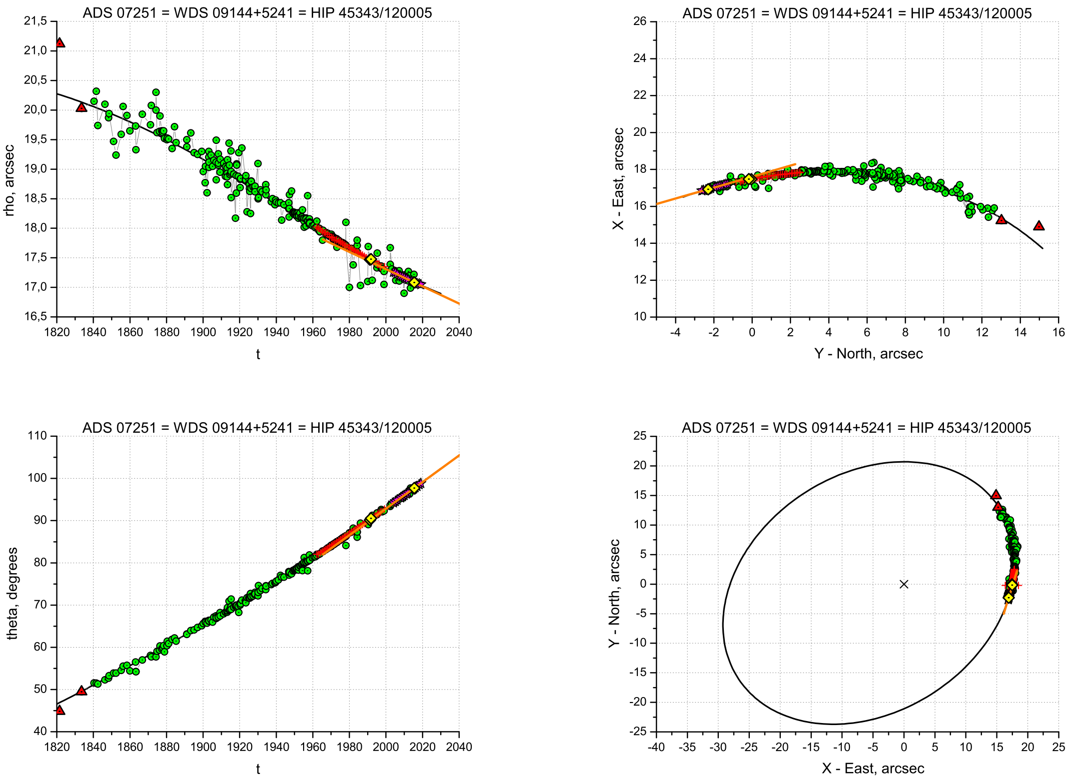



**Figure 22:** ADS 07251

## 22 WDS 09144+5241 = ADS 7251 = Hip 45343/120005

Previously, the orbital elements were determined by the AMP-method and the masses of the components were estimated (Shakht et al., 2010).

In this paper, the orbit of this star is given (Shakht et al., 2020), wich calculated from the combined series of Pulkovo photographic and CCD observations. It were taking into account the component mass sum $1.10 M_{\odot}$ according to the 2010 article, and the parallax from (Gaia Collaboration et al., 2018). The radial velocities were taken from the article (Nidever et al., 2002). The direction of motion according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris. The orbit (Chang, 1972) with a period of 975 years does not agree with modern observations.

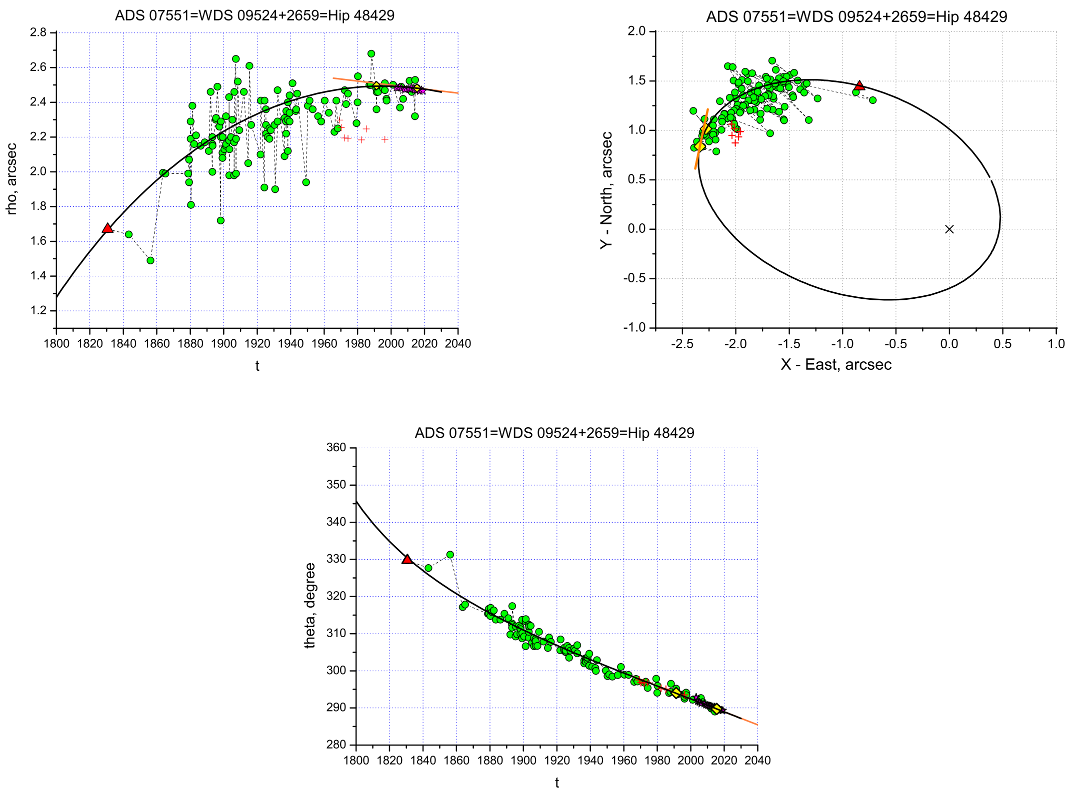



**Figure 23:** ADS 07551

## 23 WDS 09524+2659=ADS 7551=Hip 48429

The previous orbit of this star was obtained according to AMPs at the average moment of 1939.0 (Kiyaeva et al., 2017), but it did not satisfy the CCD observations and of the radial velocitys obtained specifically for calculating the AMP-orbit. Therefore, an assumption about an invisible satellite was made.

Gaia DR2 observations are well consistent with our CCD observations, but they are more accurate. A new orbit was obtained from the Gaia DR2 data, including parallax and radial velocities. The expected mass of $1.8M_{\odot}$ from the article (Tokovinin, Kiyaeva, 2016) was accepted. Orbit satisfies all observations well. We have no basis at this time suspect an additional satellite.

The pair is close ($\rho = 2.4''$) and this explains the systematic deviation photographic observations on a 26-inch refractor from the general series.

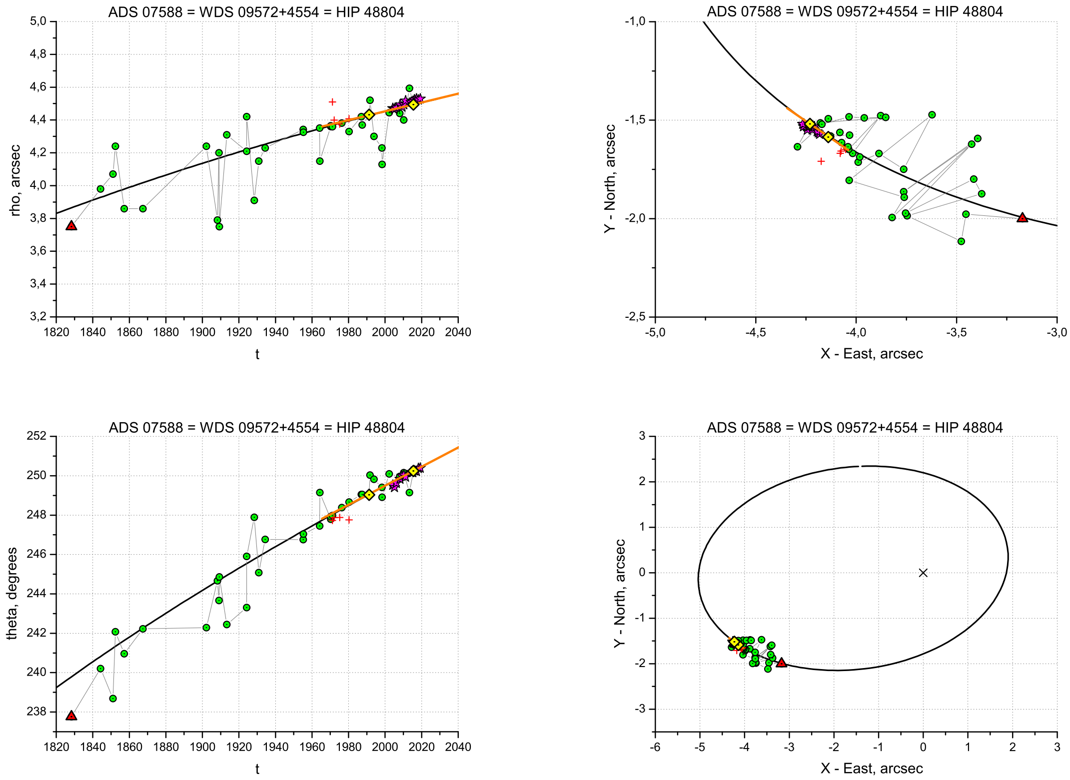



**Figure 24:** ADS 07588

## 24 WDS 09572+4554 = ADS 7588 = Hip 48804

The direction of motion according to the Gaia DR2 data (Gaia Collaboration et al., 2018) does not contradict the observations. In this paper, we present the first orbit of this pair, obtained by us in the article (Kiyaeva, Romanenko, 2020) only from the Gaia DR2 data (positions, proper motions, parallaxes, effective temperature and radial velocities of the components). The orbit is in good agreement with observations over the entire 1828–2019 segment.

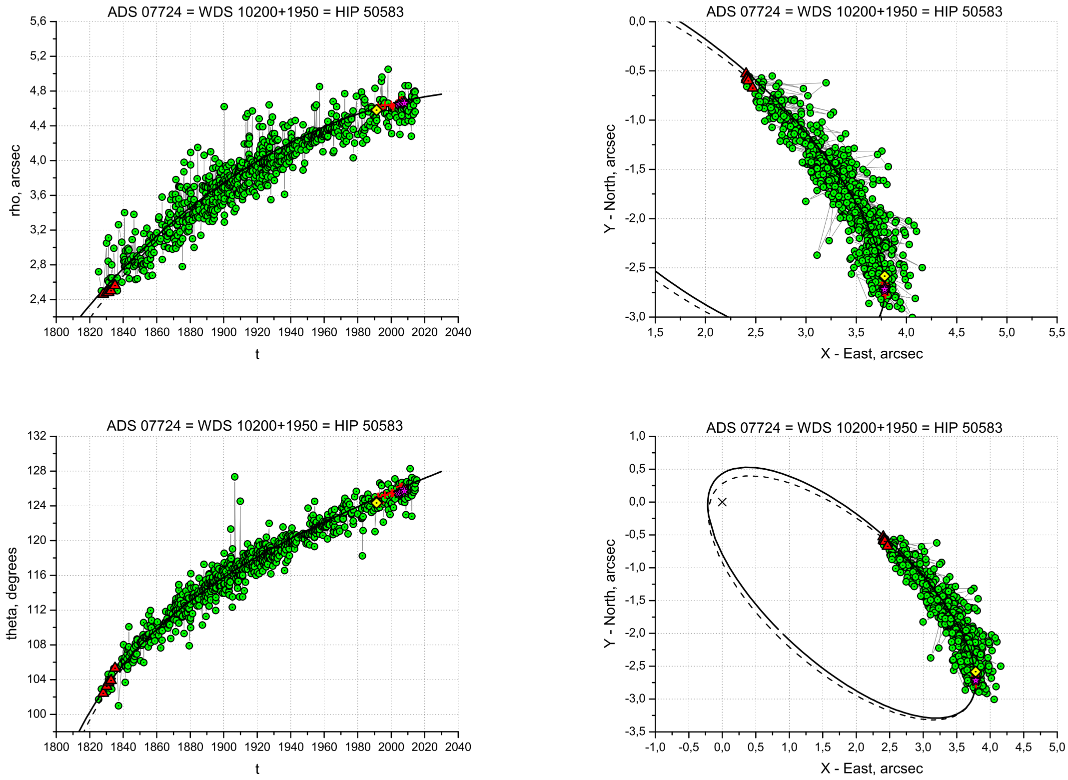



**Figure 25:** ADS 07724

## 25 WDS 10200+1950 = ADS 7724 = Hip 50583 (gamma Leo)

In our paper (Romanenko, Kiselev, 2014), two variants of the orbit ($\beta = +38°$ and $\beta = -38°$) with a period of 553 years, corresponding to the sum of the component masses $5.5M_{\odot}$ according to the "mass–luminosity" relation, were obtained using the AMP-method. The radial velocities from the article (Tokovinin, Smekhov, 2002) and the Hipparcos parallax (van Leeuwen, 2007) we used. The orbit (Mason et al., 2006) with a similar period (510 years) corresponds to a mass of $16.66M_{\odot}$, but we did not find any data in favor of the mass exceeding the normal one.

There are no data on this star in the Gaia DR2 catalog, because the components are too bright (2nd and 3rd magnitude) and the pair is too close ($\rho \sim 5''$). Therefore, in this paper, we present both orbits of 2014, the ephemeris of which coincides over the entire observed segment and is in good agreement with all observations, including 26 later ones for 2010–2015 and our CCDs.

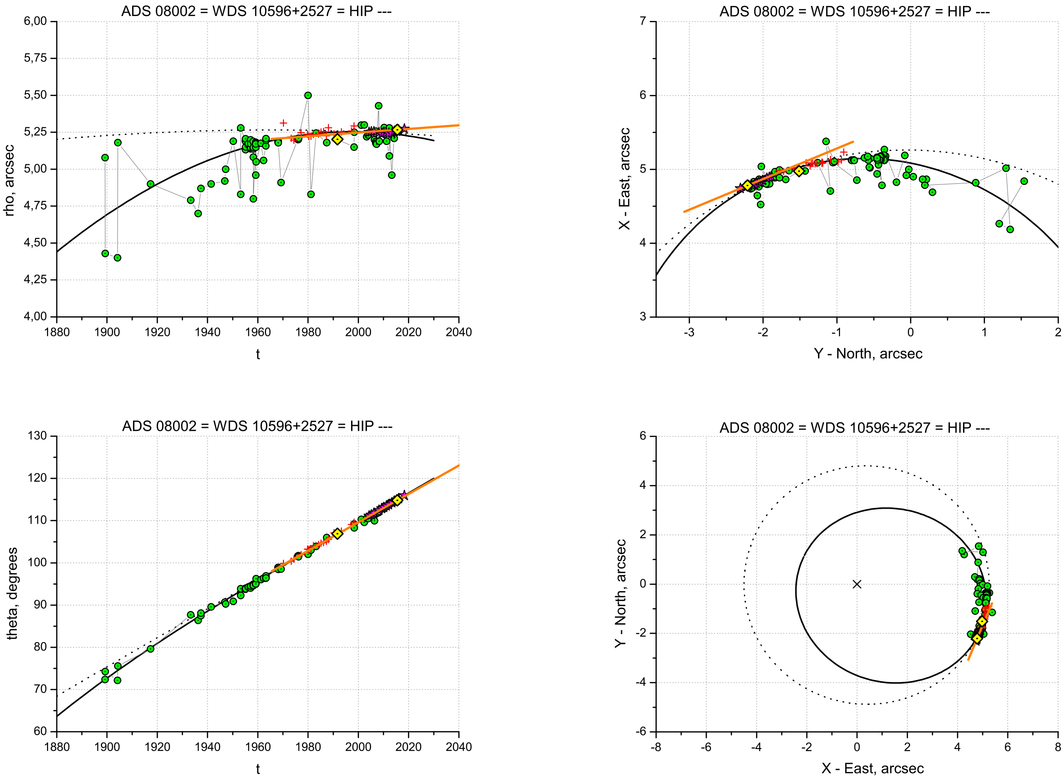



**Figure 26:** ADS 08002

## 26 WDS 10596+2527 = ADS 8002

Based on observations with our telescope, the trigonometric parallax was obtained, and two orbits were calculated by the AMP-method (Kiselev et al., 2000) using the radial velocities from (Tokovinin, 1994). In the Gaia DR2 data (Gaia Collaboration et al., 2018), the radial velocity for component B is absent.

Here we present a new result from (Romanenko, 2018). It is a single-valued orbit obtained from the basis of the combined series of Pulkovo photographic and CCD observations. The same radial velocities from the Tokovinin's work and the Gaia DR2 parallax we used. The minimum possible sum of the component masses was determined, equal to $2.07M_{\odot}$, exceeding the normal value ($1.4M_{\odot}$). The ephemeris of the AMP-orbit corresponding to the latter (dotted line on the graph) does not agree with the observations. The direction of motion according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris corresponding to $\Sigma M = 2.07M_{\odot}$.

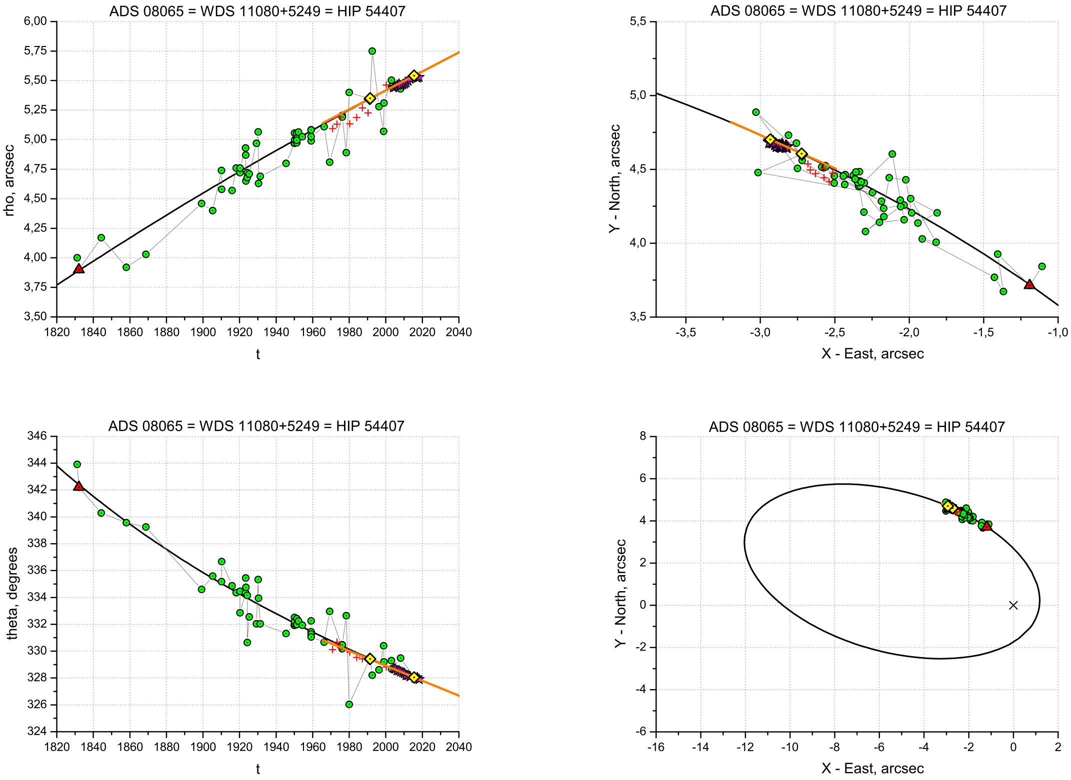



**Figure 27:** ADS 08065

## 27 WDS 11080+5249 = ADS 8065 = Hip 54407

The radial velocities of the components and two AMP-orbits were previously obtained (Kiselev et al., 2012) with the Hipparcos parallax (van Leeuwen, 2007) and with the components mass sum of $2.0M_\odot$ according to the mass–luminosity relation.

In this paper, we present an unambiguous orbit of this pair, which is obtained this year. Only the Gaia DR2 data (positions, proper motions, parallaxes, effective temperatures, and radial velocities of the components) is used. The orbit is in good agreement with observations throughout plot (1831–2018).

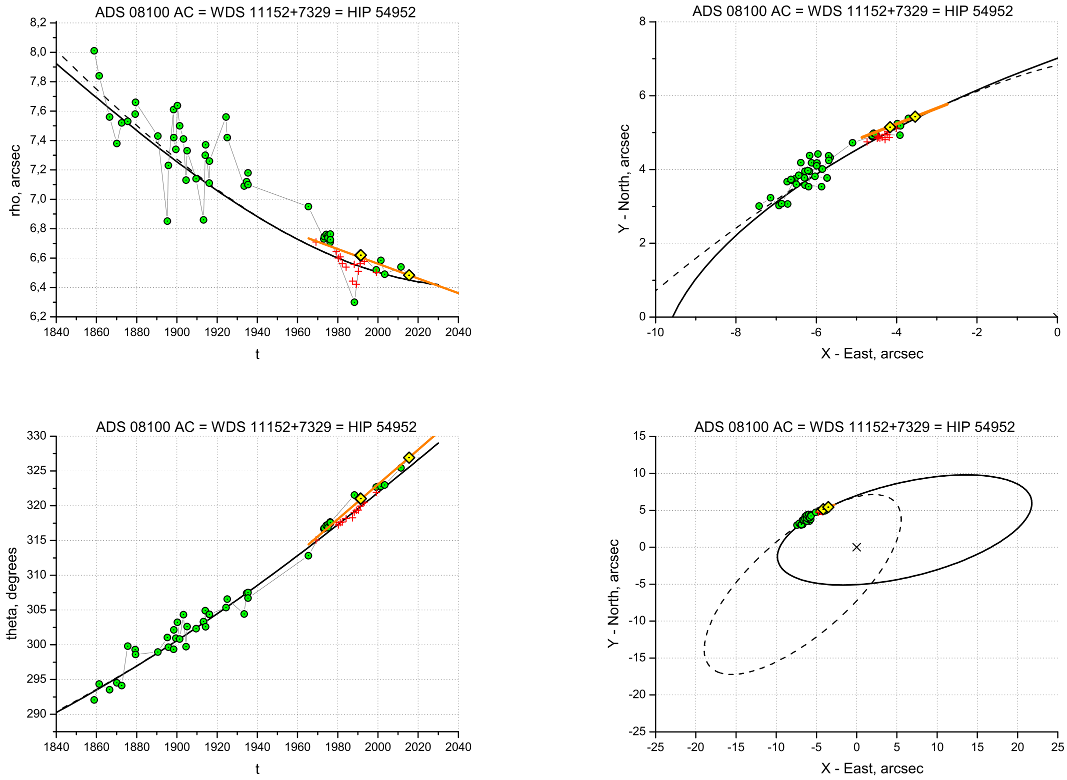



**Figure 28:** ADS 08100 AC

## 28 WDS 11152+7329 = ADS 8100 AC = Hip 54952/76

Component B is optical from the radial velocities (Tokovinin, 1994) and from the WDS proper motions (Mason et al., 2016). The two orbits of the AC pair presented here (Grosheva (2006), period 3800 years) with the Hipparcos parallax (ESA SP-1200, 1997) and the component mass sum $1.0M_{\odot}$ have been obtained by the AMP-method. The direction of motion according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris. However there is a systematic difference with the Pulkovo photographic observations, in which perturbations with a period of 14 years were found (Grosheva, 2006). There are no radial velocities in the Gaia DR2 data; a fitted value was used in the 2006 paper.

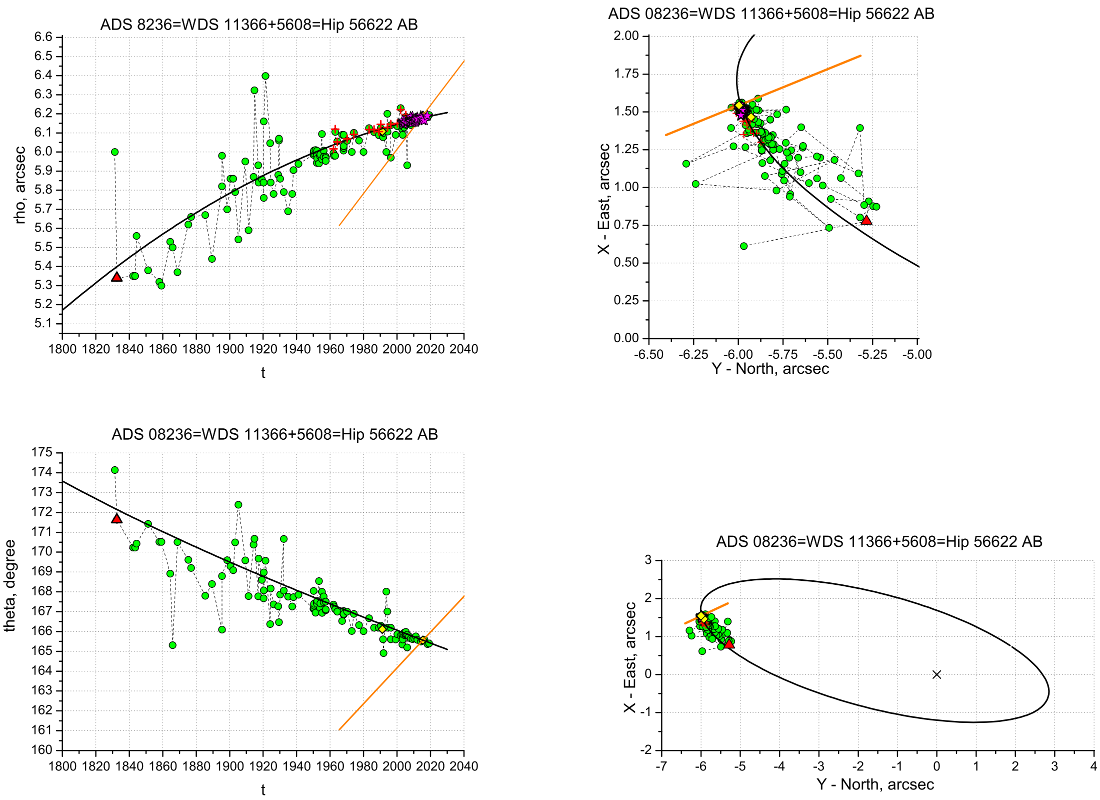



**Figure 29:** ADS 08236

## 29 WDS 11366+5608=ADS 8236 A-Bb=Hip 56622

There is a satellite of the component B with a period of 4.6 years (Tokovinin, 1999), which is the reason discrepancies in Gaia DR2 motion at the instant 2015.5. Using the elements of the spectroscopic orbit (P, T and e), according to the deviations of Pulkovo CCD observations 2003–2018, the orbit of the photocenter was determined. After its accounting, AMP-orbit (Kiyaeva, Izmailov, 2018) was obtained from CCD observations. We used radial velocities from the article (Tokovinin, 1999), parallax from the Hipparcos catalog (van Leeuwen, 2007), and component masses from the MSC (Tokovinin, 2018).

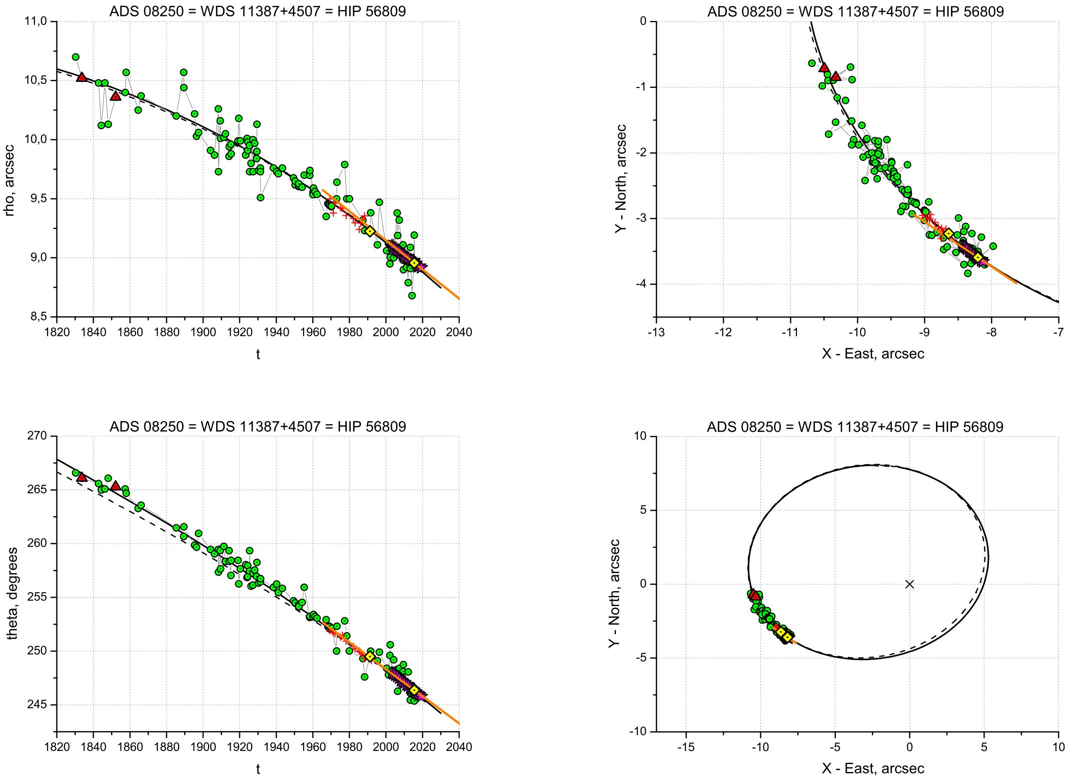



**Figure 30:** ADS 08250

## 30 WDS 11387+4507 = ADS 8250 = Hip 56809

Component B is a well-known spectroscopic binary (Duquennoy, Mayor, 1991). Previously, we determined two orbits for the AB pair (Kiselev et al., 2009) by the AMP-method. The radial velocity for component B in the Gaia DR2 data has an error of more than 3 km/s and is not applicable.

In this paper, we present the result (Romanenko, 2018) obtained from the basis of the combined series of Pulkovo photographic and CCD observations. The same radial velocities of 1991 and only Gaia DR2 parallax are used. The component mass sum was determined to be $2.5M_\odot$, which exceeds the expected value for the spectral classes, taking into account the mass of the spectral satellite ($2.2M_\odot$).

The direction of motion according to the Gaia DR2 data is tangential and does not contradict either the observations or the ephemeris. The AMP-orbit obtained by us using the Gaia DR2 basis and the same radial velocities (Duquennoy, Mayor, 1991) practically coincides with the one presented above. The Gaia DR2 orbit corresponds to the mass sum of $2.3M_\odot$, but is in worse agreement with the observations of position angle (dashed line in the graphs). The orbit of Hale (1994) describes the observed arc well and corresponds to a mass sum of $3.3M_\odot$ (an excess remains).

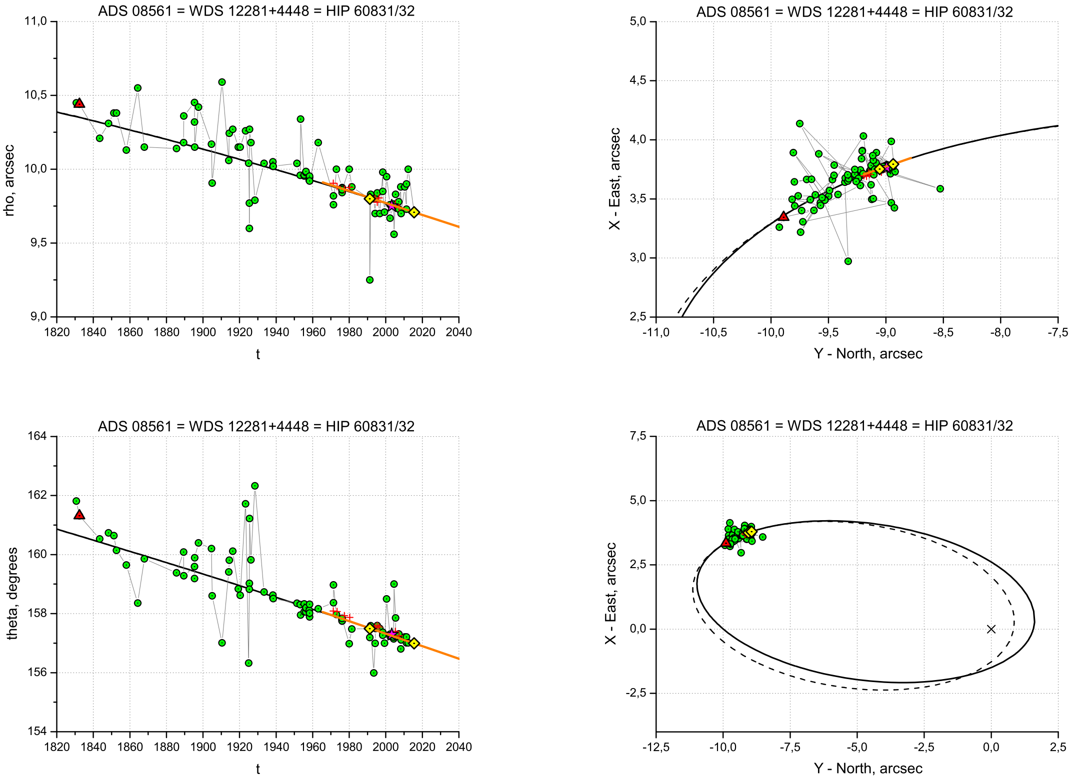



**Figure 31:** ADS 08561

## 31 WDS 12281+4448 = ADS 8561 = Hip 60831/32

The direction of motion according to the Gaia DR2 data does not contradict the observations of this star. In this paper, we present the first two orbits of this pair, obtained by us in the article (Kiyaeva, Romanenko, 2020) only from the Gaia DR2 data (positions, proper motions, parallaxes, effective temperature, and radial velocities of the components). Both ephemeris coincide over the entire segment (1830–2015) and are in good agreement with observations.

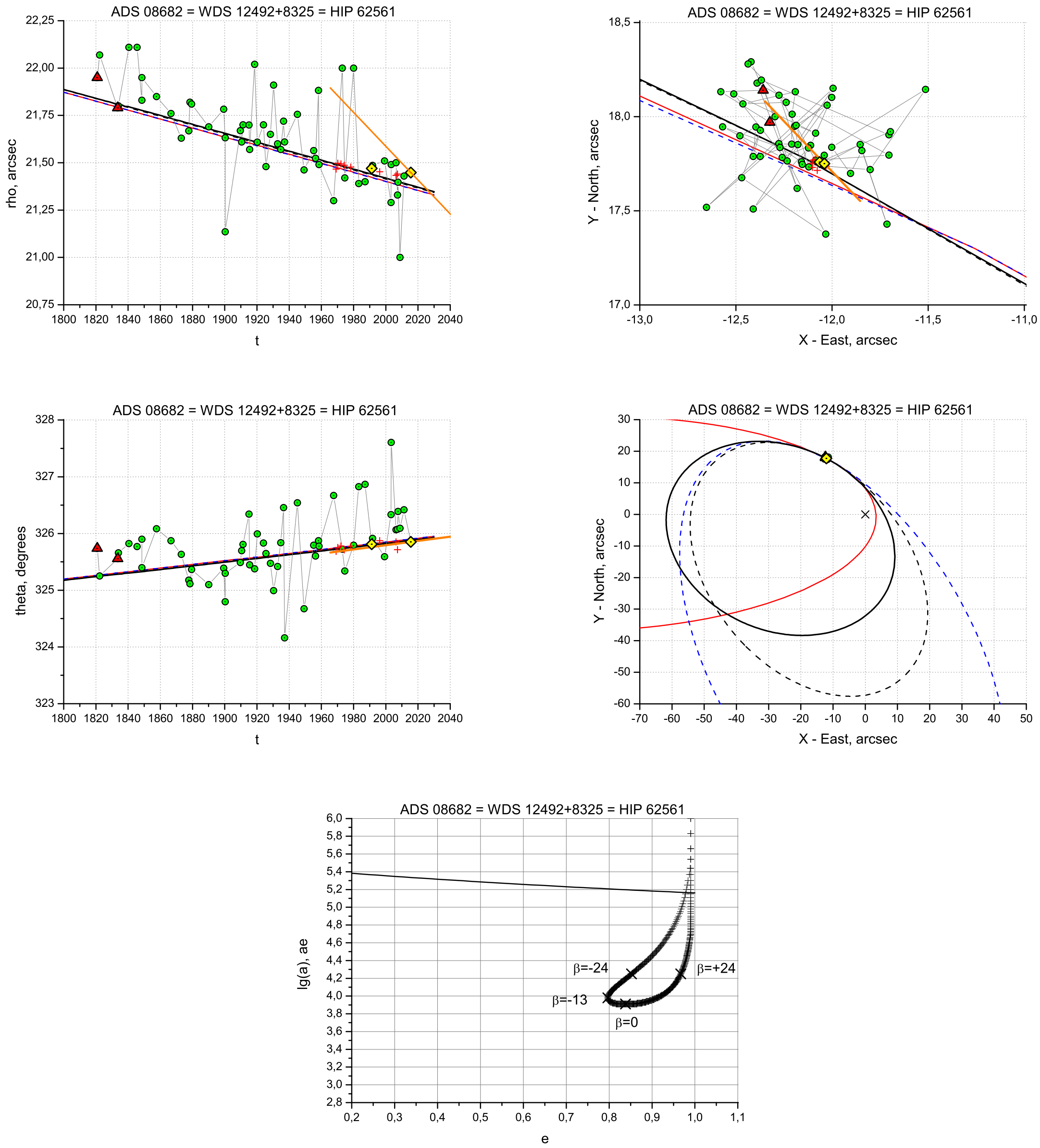



**Figure 32:** ADS 08682

## 32 WDS 12492+8325 = ADS 8682 = Hip 62561

In the article (Grosheva, 2006), a family of orbits was determined using the AMP-method. Here we give a family of AMP-orbits using the Gaia DR2 parallax, the same parameters of apparent motion and radial velocities from the 2006 article and the component mass sum according to the new version of the MSC catalog (Tokovinin, 2018). The minimum period is $P_{min} \sim 250000$ years. The ephemeris of all orbits of the family practically coincide with each other over the entire segment covered by observations (1820–2015).

The direction of motion according to the Gaia DR2 data is in poor agreement with the $\rho$ observations, which reflects the presence of a companion in this system (component B is known a spectroscopic binary with a period of $\sim 3.28$ days, Plaskett (1926)).

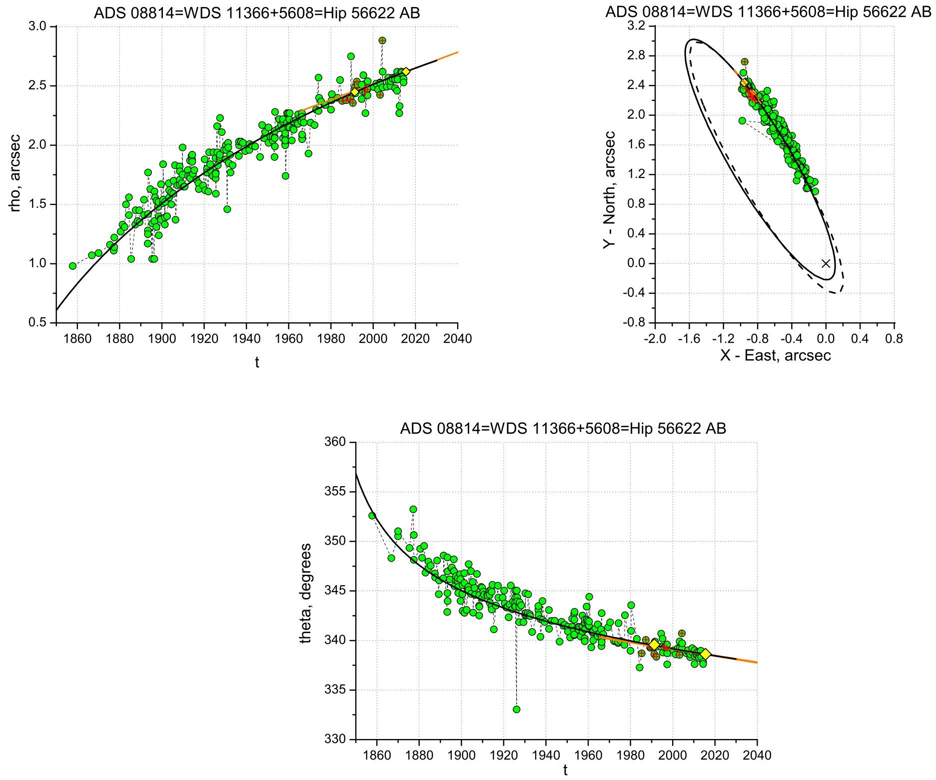



**Figure 33:** ADS 08814

## 33 WDS 13120+3205=ADS 8814=Hip 64405

The first orbit (Kiselev et al., 2012) was obtained from AMPs at the instant 1925.0 and was improved by ORBITX program (Tokovinin, 1992). Its ephemeris of the relative motion for the instant 2015.5 is somewhat different from Gaia DR2 motion. Radial velocities were published in the same 2012 work for the middle epoch of 2006.0. According to these observations, the question of a possible satellite for component A was considered.

There are no radial velocities in Gaia DR2. There are also no our CCD observations. In this work, two solutions ($\beta = \pm 7°$) based on AMPs and parallax Gaia DR2 were obtained, mass was used according to (Girardi et al., 2000) and radial velocity from the work (Kiselev et al., 2012). The new orbits are in good agreement with all observations. At this time, we have no reason to suspect an additional satellite that could affect the result.

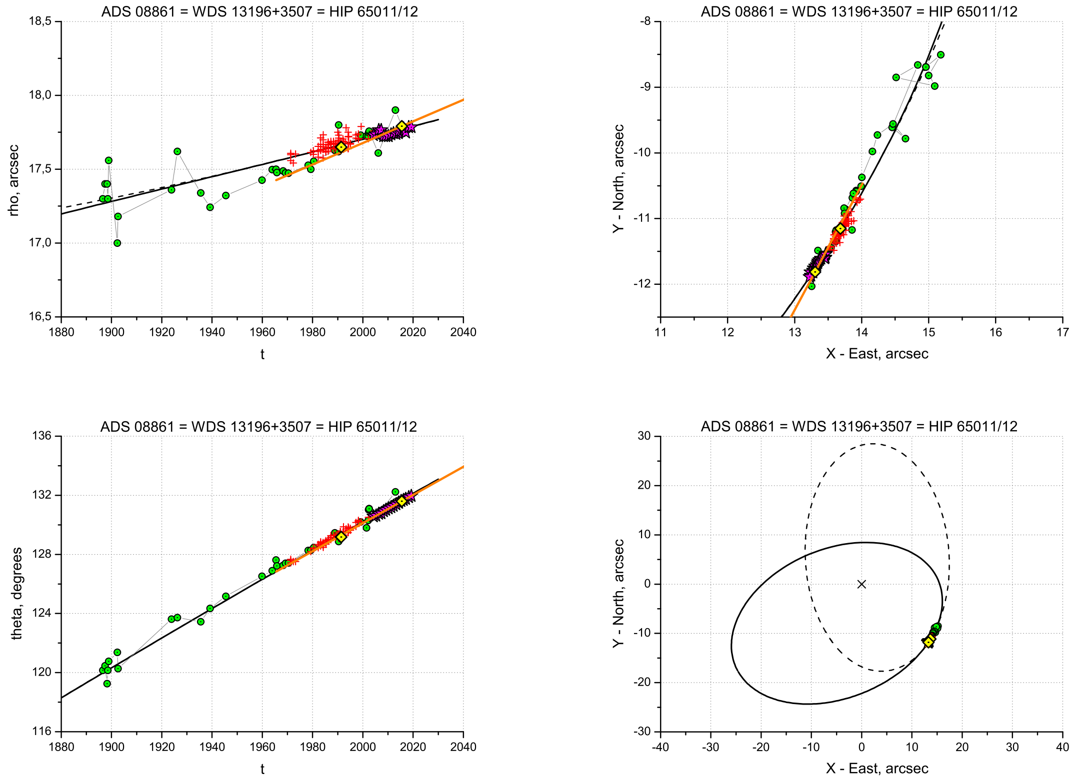



**Figure 34:** ADS 08861

## 34 WDS 13196+3507 = ADS 8861 = Hip 65011

The bright A component is a well-known spectroscopic binary (Tokovinin, 1997). Due to the insufficient brightness of component B, the relative radial velocity could not be determined. In 2000, the $\Delta V_r$ value was fitted so that the resulting AMP-orbit would pass through the earliest observations of the beginning of the 20th century. Two versions of the orbit were obtained (Kiselev et al., 2000) with the component mass sum $2.0M_\odot$, which exceeds the Tokovinin's estimate in the MSC catalog by $0.7M_\odot$. Hipparcos parallax (ESA SP-1200, 1997) we used too. Both ephemerides practically coincide with each other over the entire segment covered by observations (1896–2019) and correspond to them.

The direction of motion according to the Gaia DR2 data is at a small angle to the $\rho$ observations, which is a reflection of the presence of a satellite in this system. It is necessary to continue a dense series of CCD observations, since the presence of perturbations is possible. There are no radial velocities in the Gaia DR2 data.

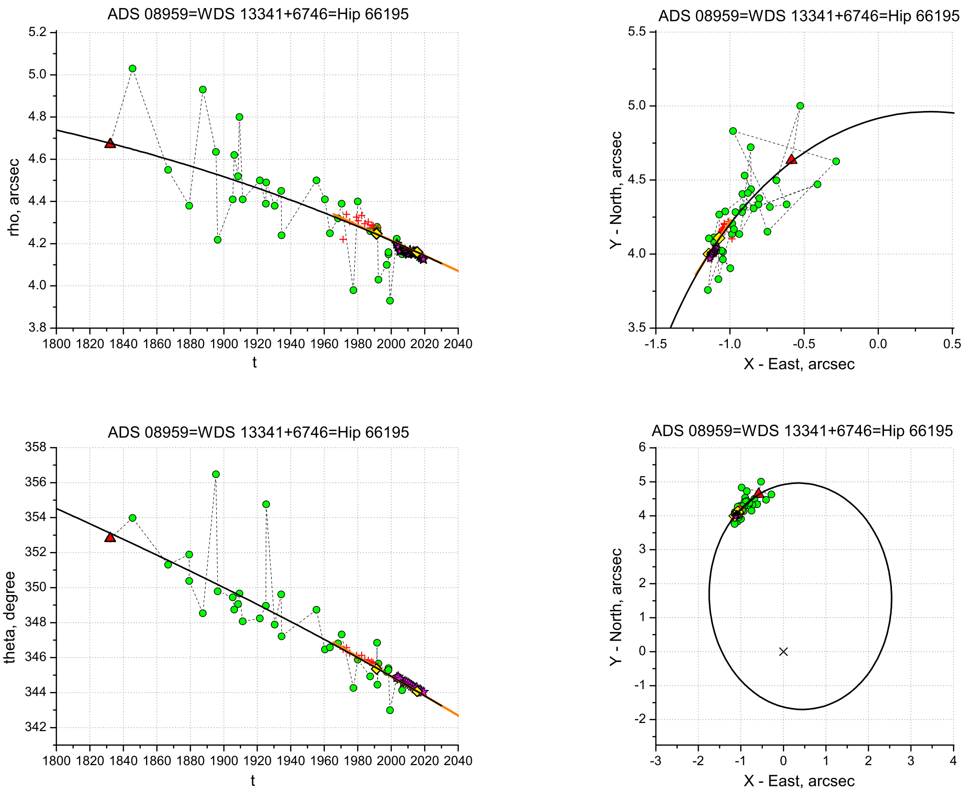



**Figure 35:** ADS 08959

## 35 WDS 13341+6746=ADS 8959=Hip 66195

Previously, we calculated two AMP-orbits (Kiyaeva et al., 2017) obtained from a combined series of Pulkovo photographic and CCD observations for the instant 2000.0 . We used the parallax from the Hipparcos catalogue ($14.4 \pm 1.1$ mas, van Leeuwen (2007)).

The Gaia DR2 parallax ($13.27 \pm 0.04$ mas) is much more accurate. In addition, Gaia DR2 has the radial velocities of both stars. The only new orbit is obtained on the basis of the Gaia DR2 data at the instant 2015.5. This orbit is well consistent with the whole series of observations. Besides, by agreement with observations, the mass of the system is confidently determined. It does not contradict astrophysical data ($2.5 \pm 0.1$ $M_{\odot}$).

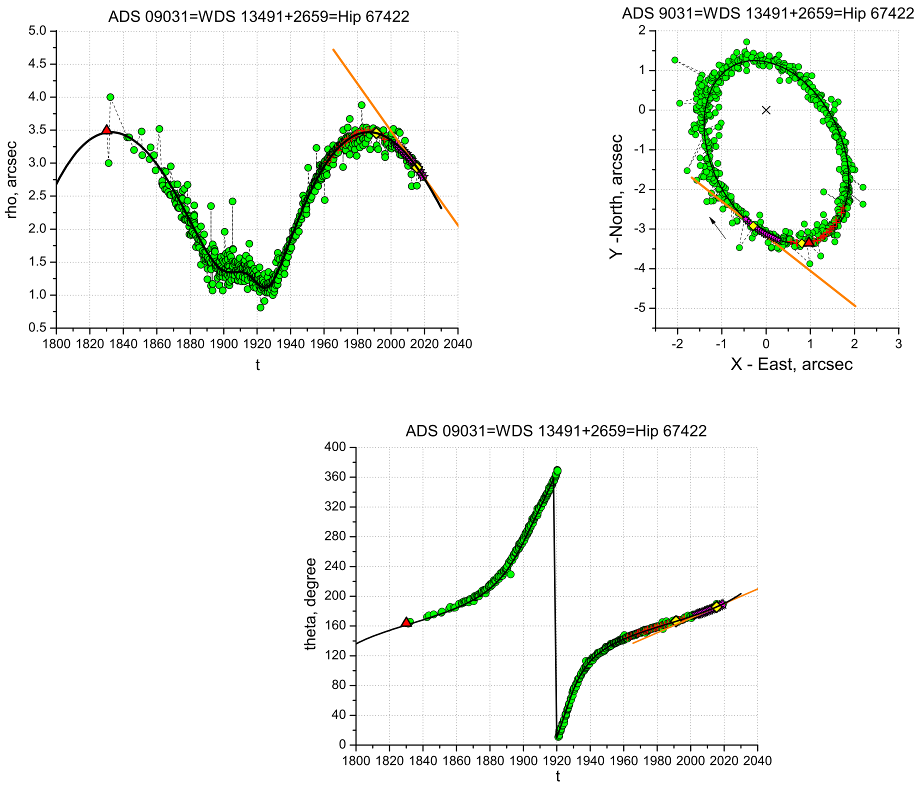



**Figure 36:** ADS 09031

# 36 WDS 13491+2659=ADS 9031=Hip 67422

The orbital period of this star is approximately 155 years, currently observations cover a complete revolution. Its orbit was determined by repeatedly (see, for example, Strand (1955),Izmailov (2019)).

This work includes an orbit obtained on the basis of positions, proper motions and parallax from the Gaia DR2 catalogue. There are no radial velocities of the components in the Gaia DR2 catalogue. The relative radial velocity and the sum of masses were selected by agreement with all observations. Remarkably, that the orbit, calculated from the data at one point in time, perfectly consistent with observations spanning the entire orbital period.

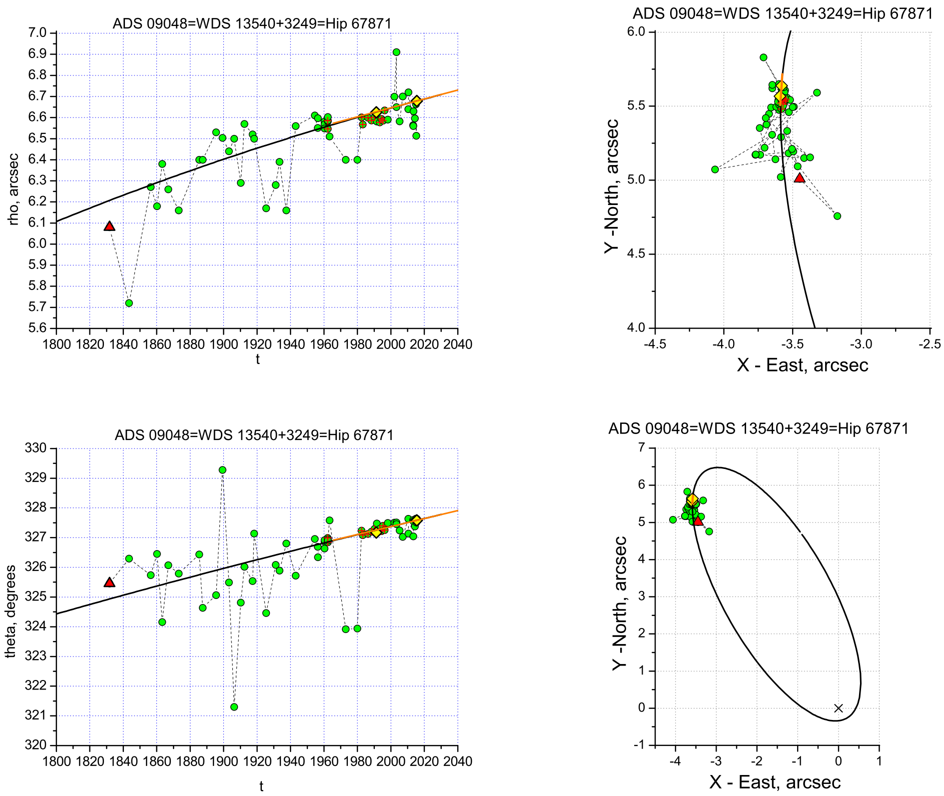



**Figure 37:** ADS 09048

## 37 WDS 13540+3249=ADS 9048=Hip 67871

A systematic difference was found between Gaia DR2 and Pulkovo photographic observations: $\Delta\rho = +0.028''$. There are no our CCD observations. This orbit is derived from Gaia DR2 data. To choose the correct solution, the observations up to 1960, the Hipparcos observation and the calculated AMPs over the series of homogeneous photographic observations at the instant 1990.0 after correction, are used.

Formally, the best solution corresponds to the total mass of 3.1 $M_{\odot}$, but the advantage is insignificant, so we give a solution with an expected mass of 2.25 $M_{\odot}$. The direction of motion according to Gaia DR2 does not contradict the observations. Details are in the article (Kiyaeva, Romanenko, 2020).

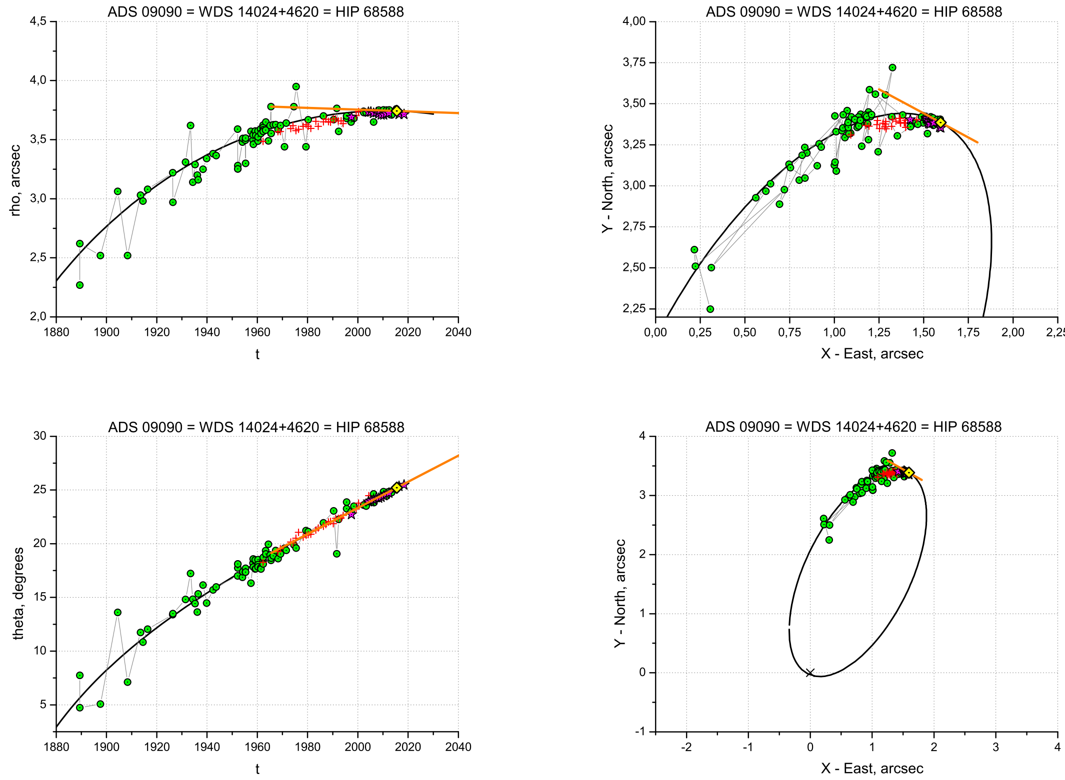



**Figure 38:** ADS 09090

## 38 WDS 14024+4620 = ADS 9090 = Hip 68588

This is a weak, close pair with a separation of $\sim 3.5''$ at the limit of the possibility of photographic observations. Previously, two AMP-orbits with a large eccentricity of $\approx 0.98$ were obtained (Kiselev et al., 2000). The trigonometric parallax from the catalog (van Altena et al., 1991) and the radial velocities of Tokovinin (private communication) were used. The direction of motion according to the Gaia DR2 data is tangential and does not contradict the observations, but there is no the radial velocity of component B.

In this paper, we present the unambiguous orbit of this pair, which we obtained this year from the Gaia DR2 data (positions, proper motions, parallaxes, and effective temperature) and with the relative radial velocity from the paper (Tokovinin, Smekhov, 2002) corrected for the orbital motion. The period of 342 years and the component mass sum $1.2M_{\odot}$ are determined. The orbit (Seymour et al., 2002) with a period of 455 years corresponds to the component mass sum $0.11M_{\odot}$, which is inconsistent with the mass–luminosity dependence.

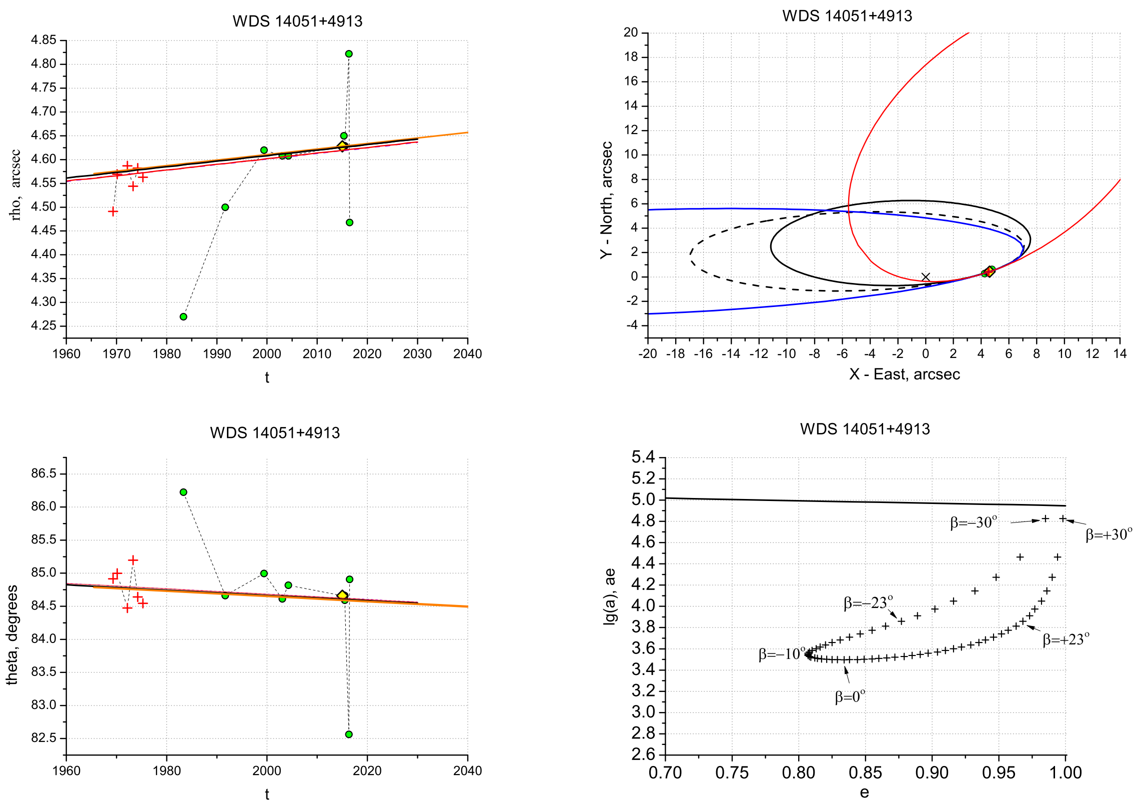



**Figure 39:** WDS 14131+4913

# 39 WDS 14051+4913

This is the most distant star we have studied in this work. The pair is interesting in that it was very little observed, but the relative motion obtained from Gaia DR2 is well consistent with photographic observations on a Pulkovo 26-inch refractor. According to Gaia DR2 (AMPs, parallax, relative radial velocity), a family of orbits was obtained. The masses of the components were estimated from the effective temperature. All orbits of the family have an eccentricity greater than 0.8. Details are in the article (Kiyaeva, Romanenko, 2020).

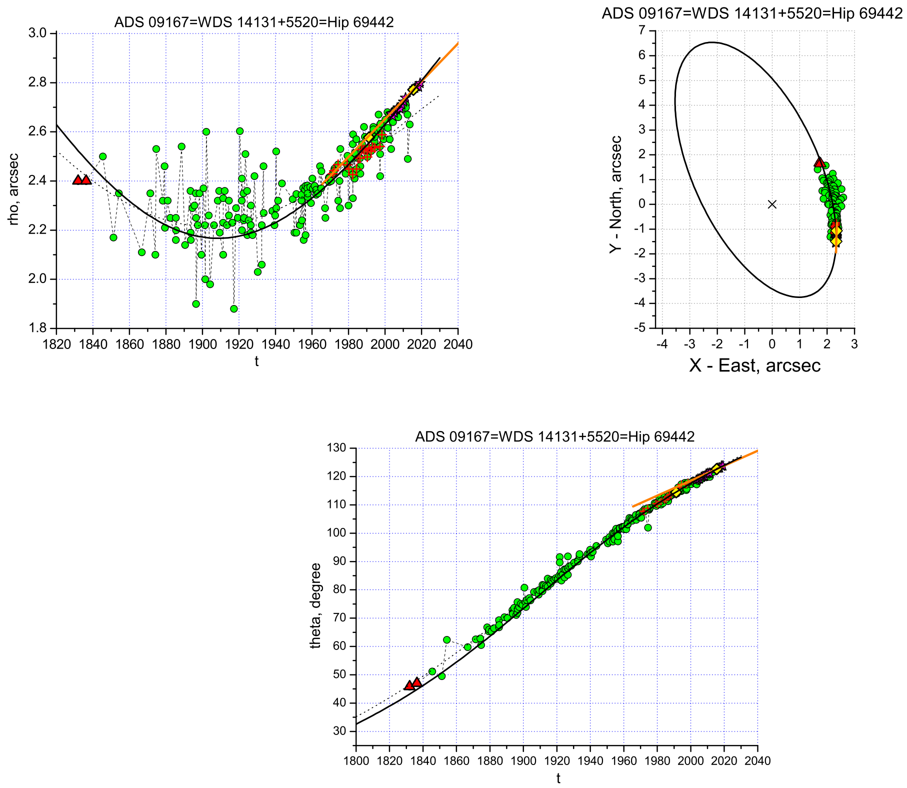



**Figure 40:** ADS 09167

# 40 WDS 14131+5520=ADS 9167=Hip 69442

The motion in the triple system was investigated on the basis of photographic and spectroscopic observations in the article (Kiyaeva et al., 1998). The jnner and outer orbits were obtained. The inner spectroscopic orbit of the component A with a period of 2.87 years was determined from the radial velocity observations. The outer orbit was obtained from AMPs at the instant 1984.0 and it needed to be clarified, as it significantly diverges from the last observations in $\rho$ (it is indicated by a dotted line on the graph). Despite the fact that component A has a satellite that did not manifest itself in photographic but does manifest itself in CCD observations, its effect on the 16-year interval is insignificant.

An attempt was made to determine the astrometric orbit of inner pair according to deviations relative to outer orbit, but it does not agree with a more accurate spectroscopic one (different longitudes of the periaster from the node). Therefore, the AMP-orbit of the external pair was determined based on CCD observations without taking into account the satellite. The Gaia DR2 parallax was used, but the mass and radial velocity were according to (Kiyaeva et al., 1998). The ephemeris of the relative radial velocity of the new orbit at the instant 1984.0 is within the error corresponds to the observed one.

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