PERIODIC PERTURBATIONS OF RELATIVE MOTION IN MULTIPLE SYSTEM ADS 15571

E.A. Grosheva
Pulkovo Observatory, St.Petersburg, Russia.
e-mail: star-fox@yandex.ru

For the multiple system ADS 15571, it was calculated a preliminary orbit of visible secondary component (around primary) and periodic perturbations of its relative motion were investigated. ADS 15571 has been observed in the Pulkovo with 26″-refractor since 1960, it was observed for the first time in 1832 by Struve. Treatment of astronegatives was made with scanner UMAX (resolution 1200 dpi, transparency adapter). The accuracy of annual average relative positions amounts to 0″,0048 in angular separation ρ and 0°,018 in positional angle θ.

As known, the secondary component of visual double star ADS 15571 is spectroscopic binary with period of 1.1522 days (Sanford,1927). Study of more then 40-yrs set of photographic observations with 26″-refractor shows that system has more one component with period of 23 years. I obtained astrometric orbit of photocenter on base of apparent motion ellipse and concluded that detected periodic perturbations of relative motion caused by existence of low magnitude companion. Its minimum mass was estimated at 0.62 of Solar mass.

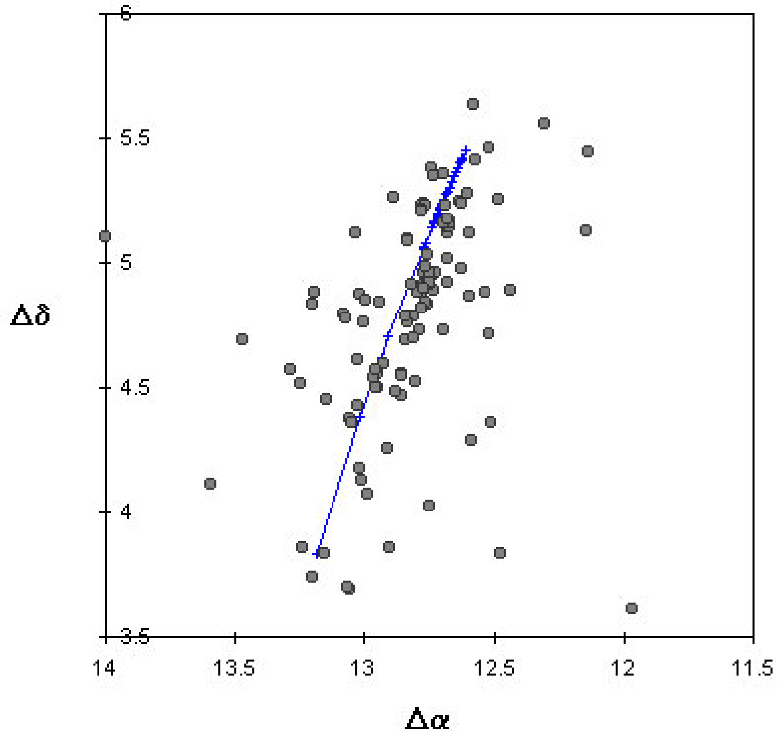
I. Observations.

Wide visual double star **ADS 15571** (separation **$\rho \approx 13''.7$**) consists of two visual componets: A of F6V–type and RS CVn–type spectroscopic binary B. System is also observing as X-ray source (Makarov, V., 2003). Orbital solution for B (Sanford, R. F., 1927) gave period as 1.1522 days and minimal masses of spectral components as 0.65 and 0.61 $M_\odot$. General information for visual components is shown in Table 1.

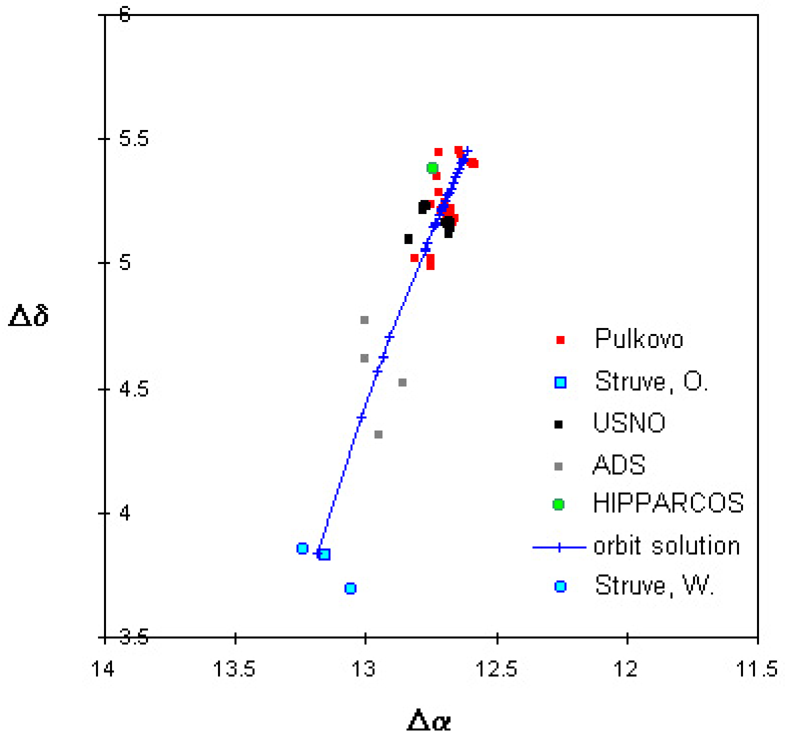
Table 1. General information.

$\alpha_{J2000.0}$ $\delta_{J2000.0}$	ρ	m_A m_B	Sp_A Sp_B	μ_{xA} μ_{xB}	μ_{yA} μ_{yB}	π_A $\pm\varepsilon$	V_{rA} V_{rB}	M_A M_B
$21^h\ 58.2^m$ $+82°\ 52'$	13.7″	6.98 7.43	F6IV-V F5	-129.14 -132.18	-74.42 -40.28	25.38 ±1.92	-22.2 ± 2 -17.5 ± 0.9	1,2 1,26

ADS 15571 is being observed with 26″-refractor of Pulkovo Observatory since 1960. More then 110 plates were obtained during 43 years of observations. Results of plates measuring were used for deriving of 25 annual average positions. The mean accuracy is 0.0048 arcsec in separation and 0.018 degress in positional angle. Plate measuring results can be found in Pulkovo Observatory Data Base (http://www.puldb.ru). Pictures 1A and 1B illustrate set of component B positions relative to A and the periodic perturbations in relative positions can be seen.



Pic. 1 A. Relative positions from WDS catalogue and our orbital ephemerides were derived from Pulkovo observations [in arcsec].



Pic. 1 B. Pulkovo's set of observations, orbital ephemerides and positions from different sources [in arcsec].

II. Orbital solution for wide pair AB.

First observarion of pair AB were obtained by Struve (Aitken, R.G., 1932). Arc of apparent relative motion is 7° since 1832. This arc is too short for orbit determination with classic methods and we applied Apparent Motion Parameters Method for short arc (Kiselev, A.A., 1996). The method determines orbit of visual double star using position vectors and velocity vector of component B relative to component A obtained for mean epoch of observation T_0. These vectors are calculated on base of precise set of relative positions, trigonomenric parallax and relative radial velocity. Apparent motion parameters are derived from Struve's position (1832) and Pulkovo set observations and shown in Table 2. Radial velocities were taken from (Wilson, R.E., 1953). Mass estimation for component A was made correspondingly to mass estimations for stars of this spectral type (Parenago, P., 1954, Belikov, A., 1995).

Table 2. Apparent motion parameters.

mean epoch, yr	T_0	1967,93
separation, arcsec	ρ_0	13,739
positional angle, deg	θ_0	68,119
curvature radius of apparent trajectory, arcsec	ρ_c	13,9
relative motion, mas/yr	μ	10
positional angle of relative motion, deg	ψ	338,23
mass of system, $M_\odot$	M	3.1 *
relative radial velocity, km/s	V_r	1,8 **

* mass of unseen component is added

** value, adopted for preliminary orbit determination. Relative velocity by Wilson catalogue data is 4.7 km/sec, it does not satisfy to orbital motion with estimated mass of system.

Table 2 contents values were calculated by formulae:

apparent motion $\mu'' = \sqrt{\left(\frac{d\rho}{dt}\right)^2 + \frac{\rho^2}{(57.3)^2}\left(\frac{d\theta}{dt}\right)^2}$

positional angle of relative motion $\psi^\circ = \theta \pm 90^o \mp \arcsin\frac{d\rho/dt}{\mu}$

curvature radius of apparent trajectory $\rho_c = \dfrac{T_k - T_n}{\psi_k - \psi_n}\mu$

values $T_0, \rho_0, \theta_0, \dfrac{d\rho}{dt}, \dfrac{d\theta}{dt}$ were derived from set of relative positions (ρ, θ, t).

The key formula of Apparent Motion Parameters Method lets calculate space separation between A and B using value of curvature radius:

$$\mathrm{r}^3 = \pm \mathrm{k}^2 \frac{\rho\rho_c}{\mu^2}\sin(\psi - \theta) \quad [AU^3] \text{ where } k^2 = 4\pi^2(M_A + M_B) \quad [AU^3 / yr^2]$$

Space velocity value is obtained with the following formula:

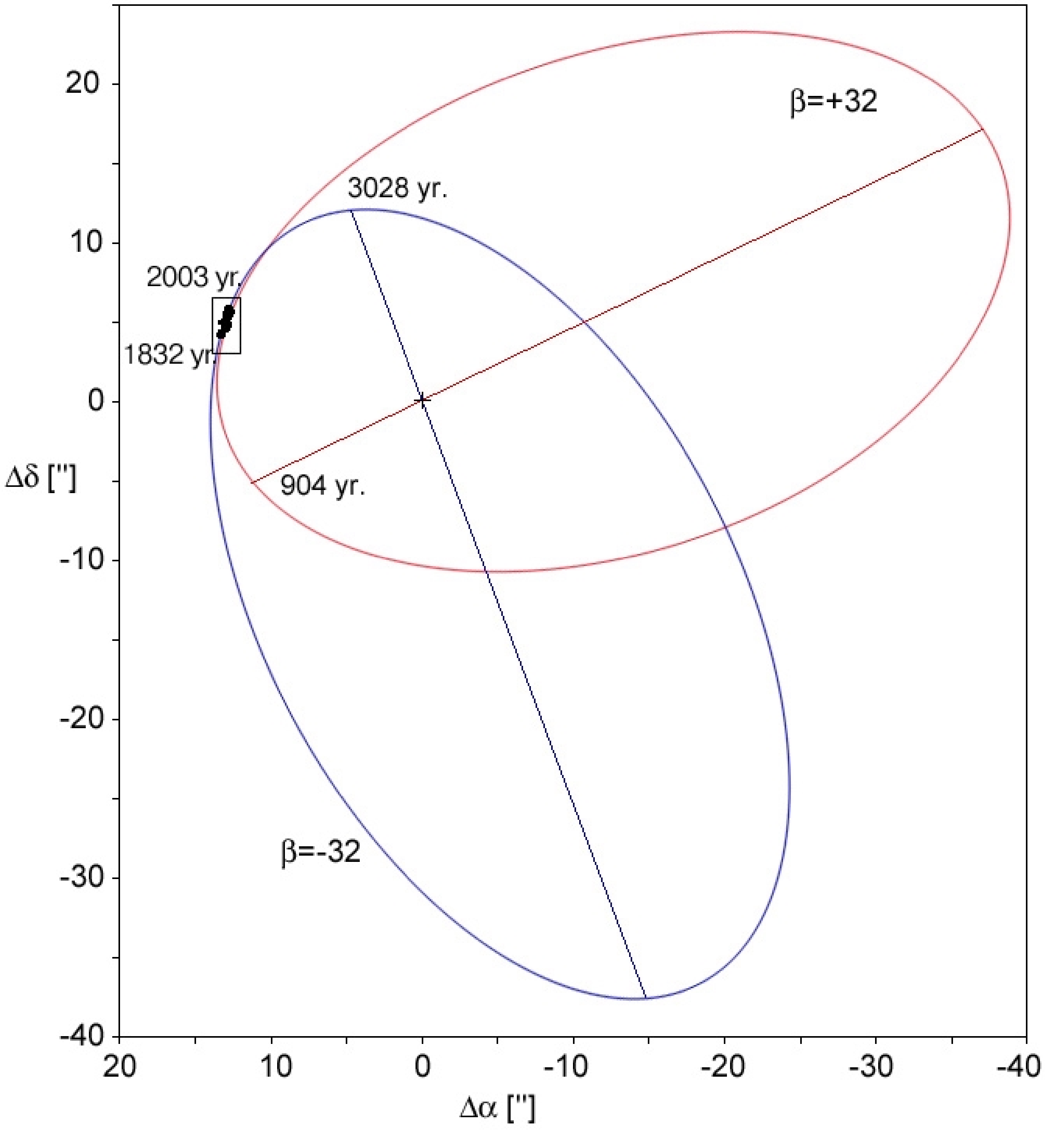
$$v^2 = \left(\frac{\mu}{\pi_{tr}}\right)^2 + \left(\frac{v_r}{4.74}\right)^2 \quad [AU^2 / yr^2]$$

It is necessary to note that Apparent Motion Parameters Method determine two variants of orbit solution due to ambiguity of angle β calculation. Angle β is an angle between positional vector r and its projection on plane: $\beta = \pm \arccos\left(\dfrac{\rho}{r\pi_t}\right)$

Picture 2 shows apparent ellipses for these two variants of orbit. Observation arc is too small that even observation of 1832 does not allow selecting one of these orbits. But these orbital solitions can be used in calculating of the ephemerides. Those are required to exclude orbital motion in wide pair to analyse perturbation in relative motion. Both β>0 and β<0 orbit parameters are shown in Table 3. It is necessary to note that both orbit variants are in good agreement with observations.

Table 3. Orbital solutions for wide pair AB of ADS 15571.

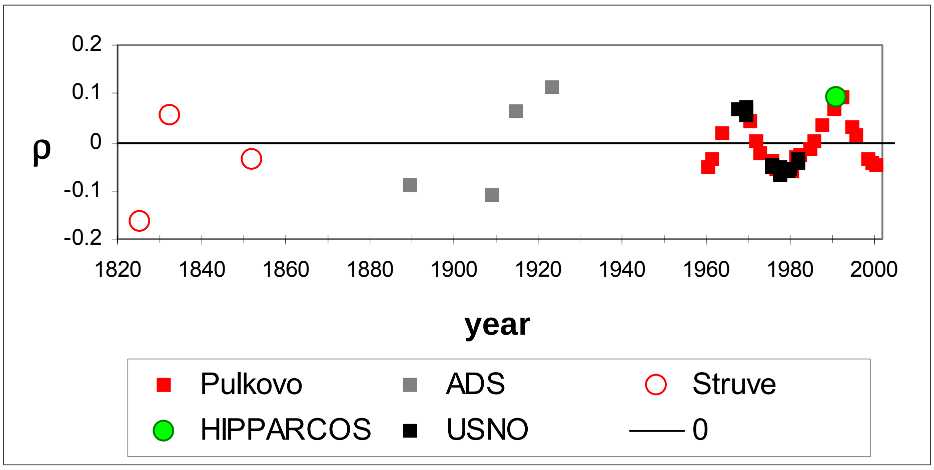
	β=-31,7	β=31,7
semiaxis major a	1081,8 a.e.	1081,8 a.e.
period P	19240 лет	19240 лет
excentricity e	0,5286	0,5299
longitude of periastron ω	20°,56	339°,12
inclination *i*	48°,90	48°,84
longitude of ascending node θ_Ω	35°,47	100°,84
periastron passing Tp	3029	904

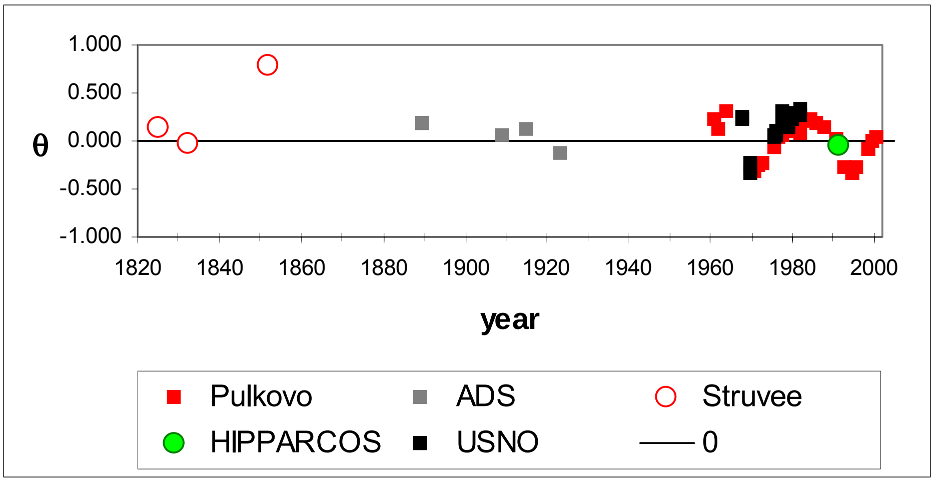


Pic. 2. Variants of orbit solution for wide pair AB. It is shown the projections of semiaxises major, the moments of periastron passing and arc observed from 1832 to 2003 yrs.

III. Periodic perturbation analysis.

Picture 3 illustrates the differences of observations with 26″-refractor of Pulkovo Observatory and calculated orbital ephemerides (O-C). Also it is shown observations from WDS catalogue: observations from USNO Naval Observatory, one position from HIPPARCOS, positions by Struve.





Pic. 3. Differences «Observed - Calculated». Also it is shown differences the orbital ephemerides with some observations from WDS catalogue: observations from USNO Naval Observatory, one position from HIPPARCOS, 3 positions by Struve. [Separation in arcsec, positional angle in degrees]

After excluding of barycenter orbital motion we got apparent ellipse of protocenter motion. As turned out, photocenter motion follows Keplerian laws and we obtain period, minimal mass of unseen component, semiaxis major of apparent ellipse and parameters of orbit orientation. Period was determined using software realizing algorithm of spectral analysis

CLEAN, that was developed at Astrometry Laboratory of St.Petersburg University on base of (D.H. Roberts et al 1989). Orbital solution for photocenter was obtained by Direct Geometrical Method (Kiselev A.A., 1996) using apparent ellipse and found position of barycenter. The criterion for baricenter position is a mimimum of sectorial velocity variance.

Van de Kamp (1981) considered process of unseen companiom mass estimation in details. Orbital components masses sum is a function of period and semiaxis major:

$$\frac{a^3}{P^2} = M_A + M_B$$

If mass of unseen component is M_B and only the period and semiaxis major of photocenter orbit α, is known, the relationship is the following:

$$\frac{\alpha^3}{P^2} = (B-\beta)^3 (M_A + M_B) \,,$$

where $B = \frac{M_B}{M_A + M_B}$ and β – parameter in case of interacting images.

It is supposed that images are not ineracting. Then mimimal mass of unseen companion is calculated from the following equation:

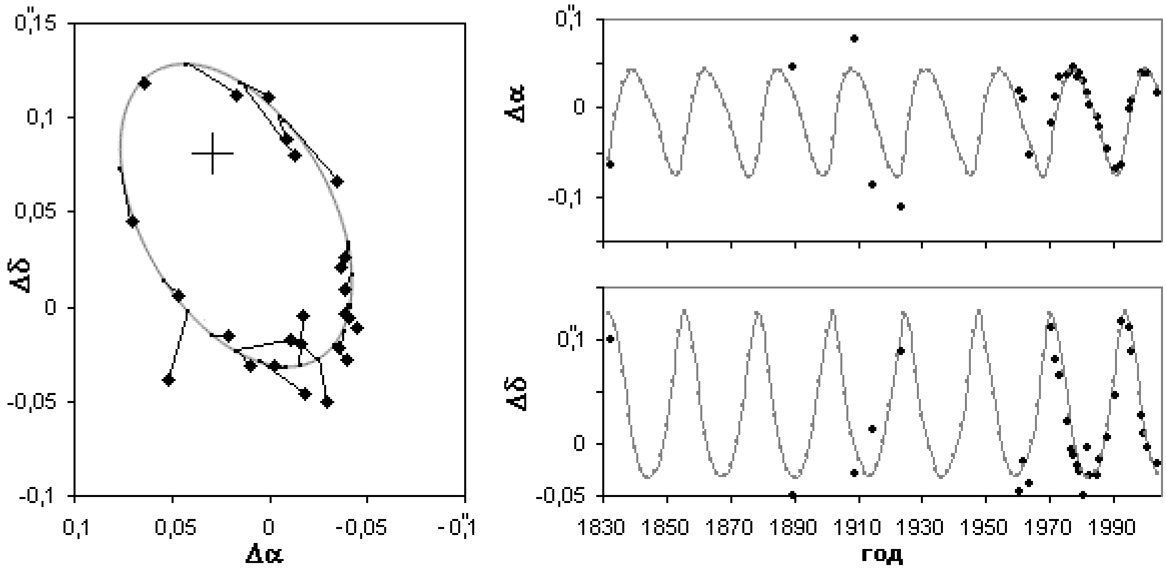
$$M_B = \frac{\alpha}{P^{2/3}} (M_A + M_B)^{2/3}$$

Dark companion mass estimation and orbital solution for photocenter motion are shown in Table 4.

Table 4. Orbital solution of photocenter and estimation of unseen companion mass.

semiaxis major a	0″,087 ± 0″,011
period P	23 years
excentricity e	0,4 ± 0,2
longitude of periastron ω	16° ± 22°
inclination *i*	52° ± 11°
longitude of ascending node θ_Ω	31° ± 7°
periastron passing Tp	1993,5 ± 0,8
minimal mass of unseen component	0,6 ± 0,1 $M_\odot$

To estimate a minimal mass of component we adopted value for M_A as 1,2 $M_\odot$. **Pic. 4** shows comparison of observed positions and ephemerides.



Pic. 4 ADS 15571. Photocenter orbit. Comparison of orbital ephemerides and observation.

IV. Conclusion

Only the extremely long time of observations with 26″-refractor in Pulkovo Observatory allowed to make a discovery of periodic perturbation in relative motion of ADS 15571 components. Uniform high precision set of relative positions was used to determine wide visual pair preliminary orbit and to analyse recognized periodis perturbation. Mimimal mass of unseen component is estimated as 0,6 $M_{\odot}$.

We supposed that the found unseen component relates to A, but ROSAT position of bright X-ray source is closer to component B (2″ mismatch against 16″) (Makarov V., 2003). Relation this X-ray source to visual double star ADS 15571 is still doubtful, although probably it may be a RS CVn–type spectroscopic binary B. The discovery of the unseen companion force make us look at this problem with new point of view. So we may venture to suppose that discovered perturbations caused by unseen X-ray source and related to component B. We are going to take a special astrometric investigation to solve question which visual component is “the owner” of dark satellite with mass of 0,6 $M_{\odot}$ at least.

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