A New Visual Binary System in Orion

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Abstract: Presented in this paper is a brand new visual binary system in Orion that is not in the current WDS catalog, the components of which show orbital motion. From three sets of historical measurements, V, J and K-band photometry, and a calibrated distance of the system based on common proper motions, a provisional orbit is determined that appears to fit the observations remarkably well.

The system was first identified in June 2013 on image plates taken during the Palomar Observatory Sky Surveys (POSS) and then assessed against various methods adopted by the author in recent papers in order to determine binarity. The components bear no formal designations in major catalogs, being of obscure brightness of approximate V mags 11.8 and 13.0 [1]. The pair resides in the northern part of Constellation Orion, at 2000.0 ICRS: 05 30 01.66, +12 07 26.5.

Individual FITS images were obtained from each of three POSS surveys for epochs 1954-11-03, 1989-11-30 and 1997-11-07, as shown in Figures 1 (a), (b) through (c) below. From these images, three pairs of positional measures (θ^{o} , ρ'') were found, as shown in Table 1.

Table 1 – Historical astrometry

Epoch:	θ	ρ
1954.841	$45^{o}.2$	11″.23
1989.914	$46^{o}.3$	11″.58
1997.851	$47^{o}.9$	11″.95

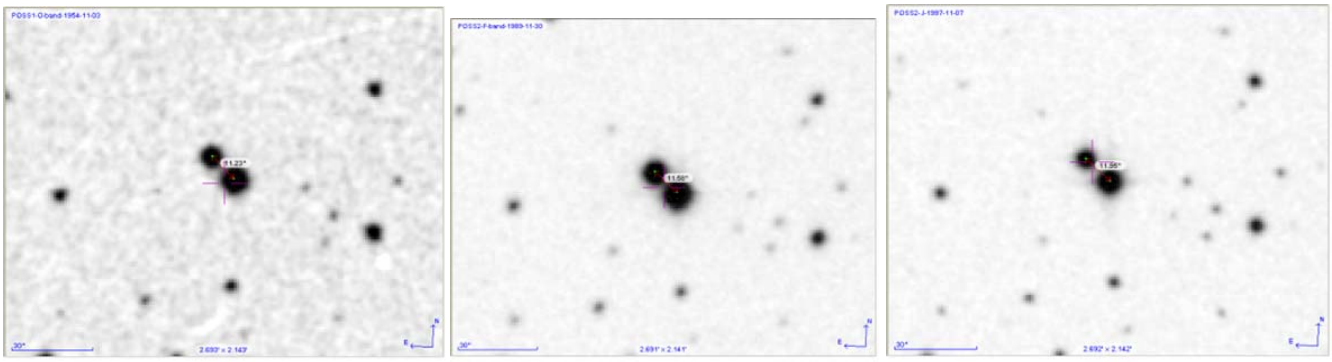

Figure 1 (a), (b), (c) – Images from POSS I & POSS II surveys.

A New Visual Binary System in Orion

Table 2: Proper motion of the components

	μ_α	μ_δ
A-component	+54.8 mas/yr	-72.3 mas/yr
B-component	+56.2 mas/yr	-69.8 mas/yr

Table 3: J and K band photometry and Color Indices

	J	K	Color Index (J - K)
A-component	+9.653	+8.924	+0.73
B-component	+10.253	+9.406	+0.85

Derivation of Astrophysical Properties

From the UCAC4 Catalog [2], we find the two stars share similar proper motions in both RA and Dec as shown in Table 2.

The system, as a whole, therefore has a total proper motion of: { $[(54.8)^2 + (-72.3)^2]^{½} + [(56.2)^2 + (-69.8)^2]^{½}$ } / 2 = 90.2 milliarcseconds per year. This suggests a distance in the region of something like 100 light-years, which may be taken as a reasonable baseline assumption for determining astrophysical properties.

From the 2MASS Catalog [3], we find J and K-band magnitudes for the two components shown in Table 3.

As illustrated in previous papers [4], these 2MASS color indices (J – K) would categorize the components of this system into a pair of red dwarves of fractional solar masses each, of likely spectral types of ~M0V and ~M2V, respectively. From a combination of their distance moduli, observed apparent visual brightnesses, and the colors determined from 2MASS J and K magnitudes as shown above, we can infer estimates for masses of the two stars in the region of approximately 0.6 and 0.4 solar masses, respectively. By way of comparisons to stellar yardsticks that have been better studied, the secondary red dwarf component of the 61 Cygni binary system (61 Cygni B) and the singular red dwarf Lalande 21185 are stars of comparable mass and luminosity to the components of this Orion binary, which are located much nearer to us in the Solar neighborhood, and they are of equivalent masses of about 0.6 and 0.4 solar masses, respectively. If both 61 Cygni B and Lalande 21185 were projected out to a distance of some 100 to 150 light-years and placed next to each other, they would broadly be expected to shine at similar brightnesses as the two component stars of this Orion binary. We can therefore approximate a total system mass for this Orion binary at circa 1.0 solar mass overall.

Projection of the Apparent Orbit

Since the pair is proven to be moving across the sky in tandem, with common proper motions, the resultant changes in (θ^o , ρ") can only be properly attributed to orbital motion.

From the stated positional measures at each of the three epochs of t_1=1954.841, t_2=1989.914 and t_3=1997.851 stated in Table 1, a preliminary outline of the apparent orbit may be projected as in Figure 2.

From the diagram, it can be seen that the semi-major axis of the apparent orbit, a, is certain to lie close to the ρ" values and it may be taken as a = 10" as an approximation for the purposes of a preliminary orbit. At a projected distance of this binary of circa 100 light-years, the linear value of the length of the semi-major axis of the orbit ellipse would be: Tan 10" x 63240 x 100, which comes to ~306 Astronomical Units. Since we have already made a baseline deduction as to the sum of the masses of the two stars in this system, we are then in a position to obtain a provisional estimate of the orbital period, P, from the expression:

$$P = \frac{4\pi a^{3/2}}{\sqrt{GM}}$$

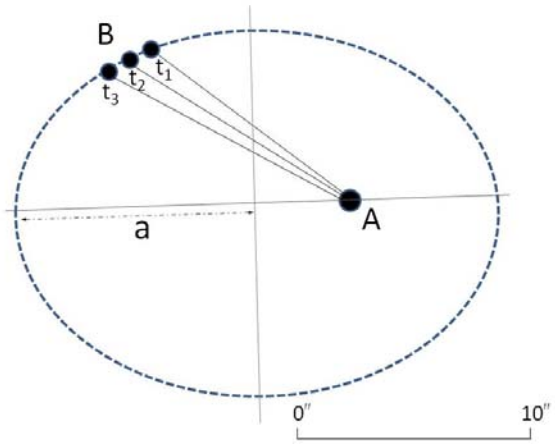

Figure 2 – Projection of the apparent orbit ellipse

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Substituting a = 306 AUs and a value for the gravitational constant, G, of 158.0, yields an orbital period of revolution, P, of 5,351 years. We have thus determined two out of the seven orbital elements required to completely specify the apparent orbit of this binary system in the sky. We do not have values for the orbital eccentricity, e, nor do we have any value for the angular inclination, i, to the line of sight. However, if we assume a circular orbit (e = 0) projected at 90^o to the line of sight (i = 90^o), the full orbit circumference of the apparent projected orbit would be 2 x π x 10" = 62".8. Thus in the 43 -year interval between the first POSS survey (t1) and the last POSS survey (t3), we expect the B-component to have travelled by: (43/5351) x 62".8 = 0".50 along the length of its orbit about the primary. This is in close agreement with the observed difference of the separations: $\rho_3 - \rho_1$ = 11".95 – 11".23 = 0".72. Similarly, the projected change in the position angle, θ, between t_1 and t_3 ought to be: (43/5351) x 360^o = 2^o.9. This again is in close agreement with the actual observed changes in θ: $\theta_3 - \theta_1 = 47^o.9 - 45^o.2 = 2^o.7$.

Conclusions

The apparent orbit, determined from just three pairs of measures in the limited timescale of this study in relation to the five-millennia long orbital period, is a reasonably good fit to the observations of this system at the current time. Further observations will help to refine the apparent orbit, lead to a better approximation of the masses of the system and enable a full determination of the true orbit in 3D space.

References

1. The Guide Star Catalog version 2.3.2 (STScI, 2006)

2. UCAC4 Catalog (Zacharias, et al., 2012)

3. The Two Micron All-Sky Catalog of Point Sources (Cutri, et al., 2003)

4. Ahad, A. 2012, "A New Common Proper Motion Star in Cetus", *JDSO*, **8**, 332-334.