THE NATURE OF THE DOUBLE STAR M40

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Abstract. WNC 4 is listed as a double star in the literature dating back to 1869. Charles Messier catalogued this object as M40 in his famous list. Using new TYCHO-2 and other data, the minimum distance to the pair is found to be 170 ± 70 pc. The new parallax and proper motion data failed to support any assumption that the two stars in the pair are gravitationally connected. The observed position angle changes of the pair can be explained by the TYCHO-2 proper motions of two optically aligned stars instead of real orbital motion. If the components were gravitationally connected, the data suggest a minimum separation of 5,000 AU, and a minimum period of 232,000 years, which is highly improbable for a true binary star system.

Résumé. Depuis 1869, WNC 4 est classée dans la littérature comme étant une étoile double. Charles Messier a nommé cet objet M40 dans sa célèbre liste. A l'aide de nouvelles données parvenant de TYCHO-2 et d'autres sources, la distance minimale de la paire est établie à 170 ± 70 pc. Les nouvelles données au sujet du parallax et du mouvement propre de ces deux objets n'ont pas réussi à appuyer l'hypothèse qu'ils ont un lien gravitationnel commun. Les changements de l'angle de la position observée peuvent s'expliquer par les mouvements propres observés par TYCHO-2 de deux étoiles alignées optiquement, plutôt que de par leur mouvement propre réel. Si ces objets sont bien liés par la gravitation, les données suggèrent une séparation minimale de 5 000 UA, et une période minimale de rotation de 232 000 ans, ce qui est très improbable pour un véritable système d'étoiles binaires.

1. Introduction

WNC 4 (Winnecke 4, WDS 12222 +5805, SAO 28353 and 28355, TYC 3840:1031 and 3840:0564), is a faint double star originally found by Charles Messier in 1764. He catalogued it as M40 in his famous list (RA = $12^h\ 22^m\ 12^s$, Dec = +58° 4′ 59″, J2000). Since no known nebula exists at this location, historians have suggested that Messier made a mistake in this entry. The galaxy, NGC 4290, m = 12.7 is 9 arcminutes west of M40, but was probably too faint to be seen by Messier in his 90-mm telescope. WNC 4 consists of two stars with visual magnitudes 9.7 and 10.1. Only a few measurements of position angle and separation of the pair appear in the literature and in the NASA Astronomical Data Center database, with the most recent one from the HIPPARCOS/TYCHO astrometry mission. The present investigation combines data from the TYCHO-2 Catalog and other scarce sources to determine if WNC 4 is a real binary system that is gravitationally connected or a chance optical alignment of two stars.

2. Measurements and Reductions

Winnecke (1869) published the position angle and separation of the pair as 88.0° and 49.2″ for the epoch 1863. In 1991, TYCHO positions from the HIPPARCOS/TYCHO astrometry mission showed only a small change in position angle and separation to 77.0° and 52.8″. Only a few other measurements of the pair exist from the archives of the *Washington Double Star Catalog* (Worley & Douglass 1996).

With a scarcity of observations for this slow moving pair, an additional photograph was selected to compute position angle and separation. A photograph taken in 1966 by Kreimer (Mallas & Kreimer 1978) was reduced using the image scanning method described by Nugent (1998). This resulted in a separation of 51.7″ and a position angle of 80.6°. Existing position angle, p and separation, ρ data for WNC 4 are given in Table I.

Table I
Data for WNC 4

Date	Separation ρ(″)	Position Angle p(°)	Source
1863	49.20	88.0	Winnecke 1869
1903	49.60	84.6	WDS[1]
1912	50.40	83.0	WDS
1912	49.50	83.2	WDS
1913	49.72	83.1	WDS
1916	50.34	84.3	WDS
1918	50.14	83.2	WDS
1930	50.43	82.3	WDS
1947	51.10	81.2	WDS
1958	51.27	80.4	WDS
1966	51.70	80.6	Kreimer[2]
1983	52.10	78.3	WDS
1991	52.80	77.0	Derived from TYCHO-2 Catalog

3. Discussion

No trigonometric parallax data were available for the pair prior to the HIPPARCOS/TYCHO astrometry mission. The HIPPARCOS-TYCHO Catalog gives a parallax π = 6.4 ± 17.9 mas for the primary and a negative parallax for the secondary. With this information the distance to the primary (brighter) component is computed as 150 pc, but with the error nearly 300% larger than the parallax, this distance is meaningless. However, this parallax and error give an estimate for the minimum distance to the primary. Based upon the spectral types of the primary and secondary, K0III and G0V from Skiff (2001), the absolute visual magnitudes are M_v = +0.88 and +4.0, and masses are

[1] Washington Double Star Catalog Data
[2] Derived using published photograph from Mallas & Kreimer (1978).

1.1$M_\odot$ and 1.2$M_\odot$ respectively (Lang 1992). With the relatively high galactic latitude of the system, b = +58.6°, the absorption correction is +0.014 (Schlegal, Finkbeiner & Davis 1998), giving a negligible effect on the absolute magnitudes.

Using the method of spectroscopic parallaxes, distances of 590 ± 230 pc and 170 ± 70 pc are computed for the primary and secondary. The uncertainty in this method is due to observational errors in estimating true B–V magnitudes and the scatter in the H-R diagram magnitudes (±1.0m). If we assume the distance to WNC 4 is at least 100 pc, the observed separation of 50″ yields a physical separation of at least 5,000 AU. Since the 50″ measurement is a projected separation, the 5,000 AU distance represents a minimum distance between the primary and secondary components. There are no known binaries with this large physical separation in the literature. Assuming Keplerian orbits, the period P (in years) is related to the separation of the pair a, (in units of AU) from:

$$P^2 = [4\pi^2 / G(M_1 + M_2)]\, a^3$$

Using 5,000 AU for a, $M_1 + M_2 = 4.6 \times 10^{33}$ gm, G the gravitational constant, the period comes to 232,000 years. (At 150 pc distance, a = 7,500 AU, P = 427,000 yrs). This result alone, independent of observed orbital motion, clearly shows the implausibility of the pair being a real binary star system.

Additional evidence to discount the physical association of the pair comes from the change in position angle. The observed change in position angle is only 11° in 128 years. While this position angle change is not uncommon in close (< 2″) binary pairs, it is unheard of with large separations in the 50″ range. If we again assume circular Keplerian orbits, independent of any projection effects, and extrapolate this motion to 360° (a complete orbit) this corresponds to a period of some 4,400 years, a very high value. Even with this period, the physical separation computes to over 355 AU. While this separation is not unrealistic for a binary, the distance to the system with a 50″ observed separation would be 7.1 pc. If the apparent orbit were projected in such a way so that the actual separation was 500 AU, the distance to the system would be 10 pc. Obviously, these distances are gravely inconsistent from the observed TYCHO mission parallaxes.

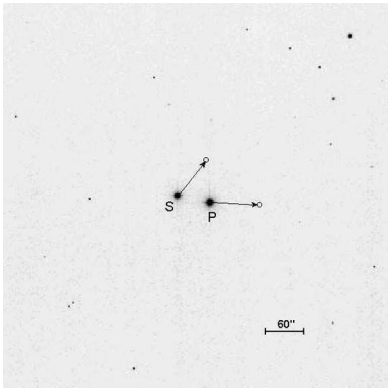

Fig. 1 — TYCHO-2 proper motion components of the primary, P and secondary, S. Proper motion errors are 2 mas, given by error circles by the arrow heads. Field of view: 10′ × 10′. North is at the top, East is to the right. Kitt Peak National Observatory 0.9-metre CCD image of WNC 4 at f/13.5, February 1996, Copyright NOAO/AURA/NSF.

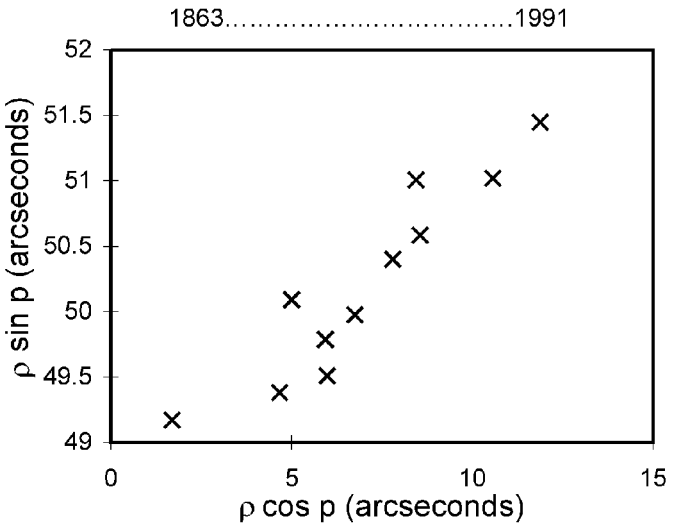

Fig. 2 — p and ρ converted to rectangular coordinates as a function of time from Winnecke's first measurement in 1863 to TYCHO-2 position for 1991. The uncertainties in the plotted data are smaller than the data point characters themselves.

The TYCHO-2 proper motion data are graphically shown as Figure 1. For a true binary system, the motion of the pair's barycenter should remain constant across the sky. The proper motions of WNC 4 show the two stars moving in discordant directions 55° from one another. Earlier proper motion data from the Smithsonian Astrophysical Observatory (SAO) (SAO staff 1966) and the Catalogue of Positions and Proper Motions (PPM) (Roeser & Bastian 1988) catalogs also show different motions for the components of WNC 4. The TYCHO-2 proper motions support these earlier results. Figure 2 illustrates the change in position angle and separation of the pair over time resulting in a linear relationship. This would be expected for two stars that are passing each other in the sky.

4. Conclusion

For a true visual binary star system, parallax, proper motion and observed orbital data should be in agreement within the observational errors. For WNC 4, the new TYCHO and TYCHO-2 data do not add any support for any real physical association of the pair. The highly accurate HIPPARCOS/TYCHO parallaxes have given astronomers some surprises, but such is not the case for WNC 4. The apparent orbital motion of the pair can be explained by the proper motion of two optically aligned stars, indicating no gravitational connection. TYCHO and spectroscopic parallax data verify the distance to the fainter star is at least 150 pc and to the brighter star 570 pc. At 150 pc distance, the calculated physical separation is 7,500 AU which is unrealistic for a binary.

The addition of radial velocity data for the WNC 4 stars will not likely change the case presented here for the non-physical association of the pair. No such radial velocity data exists currently, thus future

work in this area can add to our knowledge of WNC 4.

It is concluded that WNC 4, more commonly known as M40, is thus an optically aligned pair of stars, and not gravitationally connected.

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