## The Multiple Star: Eta Orionis.

An article by Andrew James (Australia)

**η Orionis**/ 28 Ori/ HIP 25281 (RA 05h 24.5'; Dec. -02$^{O}$ 24") is one of my favourite double stars, which W.R.Dawes discovered in 1848. This pair is easy to find, as it lies on the lip of the "saucepan" opposite to Orion's sword. Catalogued as "DA5", this 3.8 and 4.8 pair is just visible under high power (and good seeing) in a 10.5cm., though it is easy in a 20cm. I saw the colours as bluish/bluish on 30th Dec. 1979, and bluish/ bluish-grey on the 7th Feb 1983. This is easy reflected in the B1V+B2-3e spectral type. Since the first measures 151 years ago, the separation has increased from 1.0" to 1.7"arc sec, while the position angle has decreased by some 10$^{O}$ (87$^{O}$ to 79$^{O}$.)

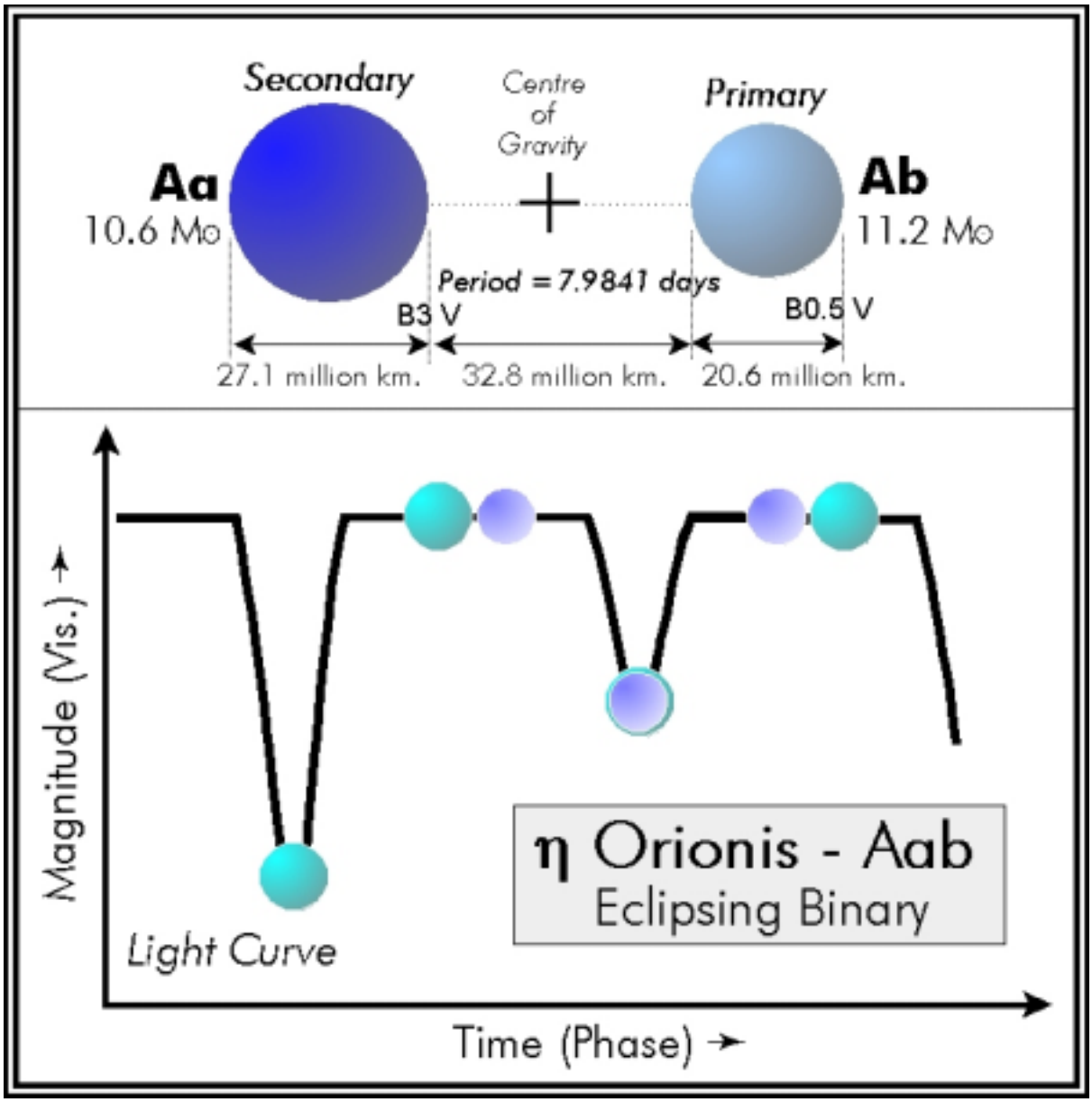


**Figure #1**

A description of Eta Orionis appears in Burnham's Celestial Handbook (Vol.2 pg1306) - but it is so out of data, that most of the information is now irrelevant.

Four stars, possibly five, are associated with this system, making a good “classical” archetypal example of a hierarchical multiple. Eta Orionis stands out from others multiples, because each component makes a visual binary, a spectroscopic binary and an eclipsing binary. All the stars and have very similar spectral classes, between B1 and B3, and masses between 10 and 1.3 solar masses.

Some eighty multiple systems are known to contain eclipsing binaries, but only a handful has this type of hierarchical configuration. With multiples, the property of the “hierarchy” is based on the orbital arrangements of the individual gravitational “pairs”. First theorised by Evans in 1968, these arrangements can be likened to a child’s mobile, where each of the varying masses throughout the entire system can be balanced. Each level of an existing pair is measured downwards, so the widest binary is Level 1, a second sub-binary is Level 2, etc.

Figure #1 “Mobile Diagram of Eta Orionis” shows the configuration of Eta Orionis - so this system is classed as a Level 3 multiple. To paint a mental picture of the separation within each levels; if the eclipsing binary on Level 3 was 1cm. apart, then the spectroscopic component on Level 2 would orbit 42cm. from the combined masses. Moving up to the visual pair on Level 1, the three sub-components would be separated by about 1.0 metres.

In the telescopic AB pair, using the meagre data available, the period of the AB pair is about 1470 years. [Chambliss (PASP, 184, 663-677 (1992)) gives a larger 2300 years.] A rough computation, using the combined masses of the trio “A” component, finds 23.05 solar mass, with the inaccurate 'B' mass of 9 solar masses, computed by the magnitude difference. Photometric observations show a magnitude variation between 3.14 and 3.35, which is mainly caused by the fluctuating light of the eclipsing binary. According to this data, the AB system has a separation axis of 1.65"arc sec, suggesting that the pair is near it greatest true separation - its apastron. Calculations suggest a mean separation of about 410AU or 61.5 billion km. ($6.5 \times 10^{-3}$ lty.) Hipparcos has produced a high quality parallax for both these stars of 0.00362"±0.00088"arc sec, giving the distance of c.276±54pc. or 890±165lty. This value is give further credence from the derived dynamical parallax of 0.004" discovered in 1952.

Unlike most systems, the “A” is again a single line spectroscopic binary with an estimated period of 9.22 years. In 1981, speckle interferometry first resolved these stars, finding a separation varying between c.0.16" and 0.05"arc sec. From the orbital data, deduced by McAlister (1976), the total mass subdivides into 21.8 solar masses for “Ab” and a minimum mass of 1.25 solar masses for the “Ac' component. This apparent orbit is highly elliptical, with a mean orbital velocity of 19.5km.sec$^{-1}$. Speckle interferometry observations in Nov. 1985 revealed the true orientation of the orbits, so unlike most spectroscopic binaries, the orbital data is deemed fairly accurate. Mean separation of this binary pair is 1.88 billion kilometres, but due to the eccentricity of the orbit, this may vary between 2.7 and 1.0 billion kilometres - the size of Uranus' orbit down too just a tad larger of Jupiter's one. Another level down shows the “A” component splitting again into another eclipsing/spectroscopic binary, listed as “Aab”.

Details of the comparatively minuscular orbit were first obtained by Adams and Stanford in 1903, but later revised by the same team in 1928. Magnitude variations of the eclipsing binary during the primary eclipse is 3.31 and 3.60. From the orbital elements, the period is 7 days 23h 44.5m (7.989268 days) (11th Jan 1902), though later data suggest the period is 7 minutes less (7.9841days). Using the orbital data from the “*8th Catalogue of Spectroscopic Binaries*.” (A.H.Batten et.al. (1989)), the component's masses are 11.2 and 10.6 , respectfully. Throughout the near circular orbit, the true separation is about 0.218 AU or 32.7±2 million kilometres, though earlier values gave a separation of 28 million kilometres or 49.07 Solar Radii. Both stars move with an orbital velocity of 34.6km.sec$^{-1}$.

Later observations place the upper limit of the combined mass ( M ) of 24.89 , giving upper individual masses of 12.76 and 12.13 . Kaukarkin in 1974 was first to state that this is a detached Beta Lyrae type eclipsing binary.

Compared to the bright eclipsing binary Delta Orionis, both stars are intermediately massive and luminous. In Solar terms, the diameters of the two stars is 15.68 and 20.52. Both throughout the orbit range between 20.6 and 27.1 million kilometres, while the measured relative solar luminosities are 6853L and 5826 L (Roche Lobes are filled to 42% and 52%, respectfully.) Temperatures are 18870K and 15860K, reflected by the given B0.5VEA+B3V spectral types. The stellar sizes and light curve is shown in Figure #2.

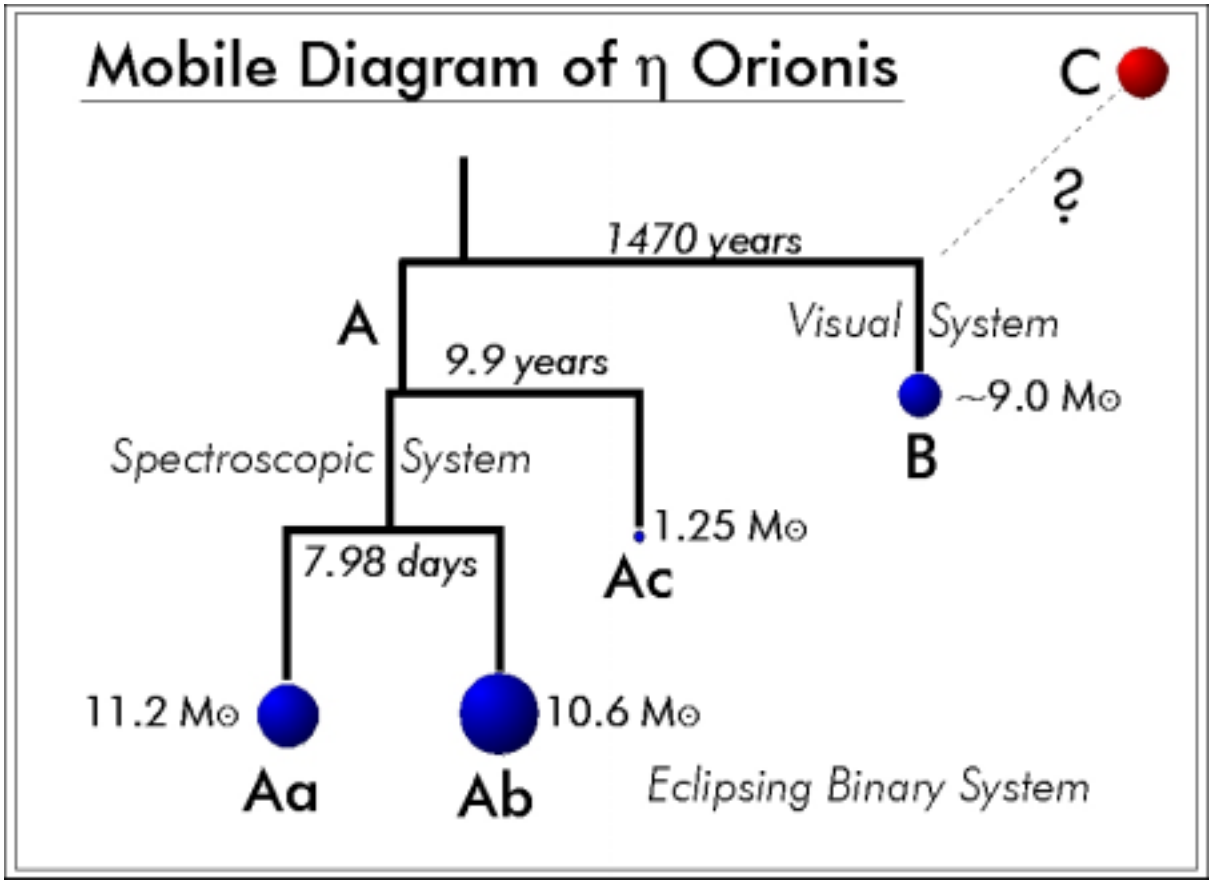


**Figure #2**

Glancing at the properties of this system, you might notice that the most massive star happens to be the smallest, seemingly 'thumbing its nose' in complete defiance of modern stellar evolution theory. The rule of "Algol's Paradox" seems to apply here, suggesting that some mass transfer has occurred in the past between the eclipsing binary's components - but additional observations now say this is yet to happen. If this is so, then how these stars now appear in this form is a bit of a mystery! The secondary ("Ab" ) of the eclipsing binary also shows evidence of being a Beta Cephei variable of an uncertain period, which was found by examining the eclipsing binary's secondary light curve. (Beta Centauri and Beta Orionis are other examples of a Beta Cepheid, brighter in fact than its namesake!) Waelkens and Lampens (1988) suspect that this data is in error, and that the more distant Eta Ori B is the star producing the slight variations.

A remote fifth component star, component "C" was first suspected by the double star Guru, Robert Aitken in the 1928. Known as BD-02135C, this 9.4 magnitude star lays 115"arc sec northeast of Eta Ori "AB" at position angle $49^{O}$. (At position RA 05h34m34.4s -02d 22' 34") (I thought the brightness of this star to be about a magnitude fainter than this.) Little is known about this star because of its proximity to the brighter pair. It can easily be seen in a 7.5cm., but if you want to see it on a star atlas, it doesn't appear on any of them, including Uranometria 2000.0, the Millennium Star Atlas, or even Megastar 4.0. Both the modern Hipparcos and Tycho catalogues don't list it, nor does it appear in the PPM Catalogue. Looking at the near nonexistent proper motion data of this star, it is likely just a optical foreground or background star. Proper motions studies by the mid- to late 21st century may shed some light on the actual association.

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Reference:
"MSC - A Catalogue of Physical Multiple Stars" by A.A.Tokovinin. (A&A Suppl.Ser.,**124**,75T (1997))