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A SHORT HISTORY AND OTHER STORIES OF BINARY STARS

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RESUMEN

Se presenta una corta historia de estrellas binarias desde los primeros descubrimientos. Se discuten ejemplos actualmente conocidos de sistemas con componentes de temperatura y masas mas altas.

ABSTRACT

A short history of binary stars from the first discoveries is presented. Examples of currently known binary systems with components of highest temperature and mass are discussed.

Key Words: **STARS: BINARIES — STARS: EARLY TYPE**

1. A SHORT HISTORY

Soon after the construction of the first telescopes, also the first *visual binary star* was discovered. This was Mizar (ζ U Ma) discovered by the Italian astronomer J. B. Riccioli $\sim$ 1650 (when Isaac Newton was 7 years old). During the 70 years following the discovery of the first visual binary star, only a few more were resolved, namely:

- in 1656, three components of θ Ori by Huygens
- in 1664, γ Ari by Hooke
- in 1685, α Cru by Farther Fontenay
- in 1689, α Cen by Farther Richaud
- in 1718, γ Vir by Bradley & Pound
- in 1719, Castor by Bradley & Pound

These discoveries were considered as mere curiosities of accidental line of sight coincidences. Until Isaac Newton grew older and began publishing theories.

The first catalogue of binary stars, containing 80 systems, was published in 1781 by C. Mayer, who speculated that "these stars could be small suns revolving around larger suns" (as predicted by I. Newton).

However, in the opinion of the owner of the then largest telescope in the world, Wilhelm Herschel, evidence was completely lacking for this speculation, since nobody had ever observed such motions of "small suns revolving round larger ones". He decided to examine "every star in the heavens".

It seems that W. Herschel in principle did not believe that binary stars may be physical systems. He wanted to observe binary stars to determine differential parallaxes in order to find the distances to the stars. W. Herchel's astronomical passion, and obsession, was to discover with his largest telescope of the world the structure of the Universe, a passion still driving much of the astronomical research with the currently largest telescopes of the world today.

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W. Herschel presented his first catalogue of 269 binary stars in 1782. Two years later, he presented a second catalogue with 434 additional binary stars. He continued observing with the skillfull aid of his sister Caroline.

In 1797 W. Herschel published a revision of all his work with binary stars, revealing that changes had taken place in the relative positions of the components observed during many years. He admitted that the observed changes could not be due to differential parallaxes.

In 1803 W. Herschel published a demonstration, based on his measurements of binary stars, that some systems should be physical systems of mutual attraction. This is probably the first observational evidence of the universality of Newton's law of gravitational attraccion. And it is quite remarkable how the tiny motions of the components in visual binary systems could be observed with an alt-azimuth mounted huge telescope without a driving mechanism.

Wilhelm Herschel's son, John, continued his farther's work after 1816. John Herschel first worked in cooperation with his friend, James South, who having married a rich woman, could dedicate his time to astronomy in his private observatory. Together, John Herschel and James South produced a catalogue of 380 binary stars.

With the coming in Europe of new telescope technologies incorporating equatorial mountings and driving mechanisms, John Herschel decided to observe the largely unknown southern sky. In 1833 he packed 3 of his father's telescopes and sailed to South Africa. He dedicated the next four years in observing the whole southern sky, measuring clusters, nebulae and over 2100 binary stars. In 1838 he returned to England and never opened his telescope again.

The first equatorial telescope with a driving clock used in observations of binary stars was the Fraunhofer refractor acquired by Wilhelm Struve for Tartu Observatory. Struve was very enthusiastic about his new telescope, and four days after receiving the telescope in 1824, he had already mounted it and begun his observations. Struve said that the telescope was so easy to use that he could examine 400 stars per hour! In fact he observed 120000 stars in 129 nights.

W. Struve's aim was to examine binary stars as physical systems. He set to work with systematic efficiency. First he made a catalogue, published in 1827 as *Catalogus Novus*, then he measured the relative positions of the components, and published the results in 1837 as *Mensurae Micrometricae.* Finally he published the mean positions of the stars in 1852 as *Positiones Mediae.*

In 1839 Wilhelm Struve was invited to build the new Russian Imperial Observatory at Pulkovo, where he acquired the then largest refractor of the world, a telescope with equatorial mounting and a lens of 15 inches of aperture. The study of binary systems with this instrument was performed by Wilhelm's son, Otto Struve.

At the end of 1800 and beginning of 1900, the astronomers worldwide were competing with each other in who had discovered more binary stars. Much in the same manner as today the competing involves who has discovered the galaxy with the largest redshift.

Catalogues of the orbital elements of visual binaries can now be found at the website:

`http://aries.usno.navy.mil/ad_home/wds/wds.htlm`

When the components of a binary star are very close, they cannot be observed as visual binaries. These binaries can be detected as *spectroscopic binaries* from the periodic movements of their spectral lines; or if their orbital plane is sufficiently close to the visual, as *eclipsing binaries* from the periodic light variations when one component hides the other.

The first spectroscopic binary system was discovered by E. C. Pickering in August, 1889, and remarkably it was one of the components of the first visual binary, namely Mizar.

The first eclipsing binary, Algol, had been discovered by Goodericke in 1782. In November, 1889, H. C. Vogel found that Algol was also a spectroscopic binary.

The first catalogue of spectroscopic binaries was published only 15 years after the discovery of the first such system, and it contained already 140 stars.

A catalogue of orbital elements of spectroscopic binaries is presently mantained by astronomers at the Dominion Astrophysical Observatory, Victoria, Canada (cf. Batten et al. 1989).

2. OTHER STORIES OF BINARY STARS

The binary stars, both visual and spectroscopic, are our fundamental source of informacion about the stellar masses. In particular those spectroscopic binaries which also are eclipsing systems, are the principal source of mass estimates to be compared with numerical models of stellar evolution.

One of the most important results of the many years spent by so many astronomers securing observations of binary systems, is the *Empirical Stellar Mass-Luminosity Relation.* However, we should keep in mind that despite of two hundred years of observations, this relation is only known for stars up to about 25 $M_\odot$ in our own Galaxy (e.g., Andersen 1991), and extrapolated to higher masses, and to other galaxies. When you read about dozens of stars more massive than 100 $M_\odot$ in e.g., the Magellanic Clouds, this means that there are dozens of stars which have luminosities as high as those predicted by some stellar evolutionary models for stars more massive than 100 $M_\odot$. Their high luminosity could be as well due to multiplicity, as often happens. Different mass-luminosity relations may operate in the domain of high-mass stars, and in environs of different metallicities.

What do we know about the masses of highest temperature early type stars?

2.1. *HD 93205*

In our Galaxy the spectroscopic binary system which harbours the component of earliest spectral type is HD 93205, discovered and classified as O3V+O8V by Conti & Walborn (1976). This binary belongs to the very young open cluster Tr 16 in the Car OB1 association, and has an elliptical orbit with a period of 6 days. Unfortunately, light variations have not been found for this binary, thus the inclination of the orbit remains undetermined.

A new orbit of HD 93205 based on high resolution digital spectra obtained at Complejo Astronómico El Leoncito (CASLEO[2]), in San Juan, Argentina, has been recently determined (cf. Morrell & Niemela 1998; Corti et al. 1999). A somewhat different mass ratio than in previous studies is found for the components, and assuming that the O8V star has a normal mass of 25 $M_\odot$, results in a mass of 60 $M_\odot$ for the O3V component. Such value is less than predicted by the stellar evolutionary models for stars as hot as spectral type O3, but would be compatible with the main sequence models for stars just one spectral class later. This is within the uncertainties of spectral classification for components of double lined spectroscopic binaries.

2.2. *HD 92740*

The spectroscopic binary with the most massive component known today, is HD 92740, a neighbour of HD 93205 in the Car OB1 assotiation. HD 92740 is a double lined spectroscopic binary with WN7 + OB type spectrum and a period of about 80 days, the WN7 component being the more massive one (cf. Niemela 1979). A new orbital study recently published by Rauw et al. (1996), finds a mass of 72 $M_\odot$ for the WN type component. The emission line spectrum of HD 92740 includes strong H lines, and may indicate that the WN component was born near the stellar high-mass limit.

It is interesting to note, that the most luminous stars observed in the core of 30 Dor nebula in our neighbour galaxy, the Large Magellanic Cloud (LMC), have spectra similar to that of HD 92740. The luminosities of these stars, when compared with the stellar evolutionary models, correspond to stars more massive than 100 $M_\odot$ (Massey & Hunter 1998).

2.3. *Binaries in the Magellanic Clouds*

The first O type spectroscopic binary discovered in the LMC, was Sk-67^o105 (Niemela & Morrell 1986). This system, classified as O4f+O6V, has a period of 3.3 days. Therefore, strong interaction effects on the binary components are expected, thus Sk-67^o105 probably is unreliable for comparison with evolutionary models of single stars.

[2]operated under agreement between CONICET, SeCyT, and the Universities of La Plata, Córdoba and San Juan, Argentina.

The microlensing searches in the Magellanic Clouds have detected large amounts of eclipsing binaries. The coming into operation of larger telescopes in the southern hemisphere in the near future, e.g., Gemini, will hopefully allow the determination of spectroscopic orbits for these eclipsing binaries, and finally find an empirical Mass-Luminosity relation for our nearest neighbour galaxies.

But much work is ahead.

2.4. *..and the culprits are ...*

The evolution of binary stars is more complex than that of single stars. When a component of a binary system begins to evolve, complicated interactions between the components take place. In addition, at the massive end of the early type stars, their powerful stellar winds whirl around and collide with the neighbours. Therefore, whenever a star has been observed to behave oddly, it is suspect of belonging to a binary system. Among other things, binary stars are blamed for

- explosive manners (e.g., Novae)
- polluting the space with X-rays
- producing eruptions (e.g., η Car, HD 5980)
- pouring non thermal radiation by their colliding winds (cf. Niemela et al. 1998)
- showing strange atmospheres (Am stars)
- etc.

And when the observations disagree with models
...it must be a binary...

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