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THE BEGINNING OF THE STORY

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RESUMEN

Se describe la evolución de los conceptos relacionados con la pérdida de masa de las estrellas hasta llegar a la consideración de la colisión de vientos estelares.

ABSTRACT

The evolution of our concepts in regard to the loss of mass from stars, stellar winds and wind collision is briefly presented.

Key words: **BINARIES: CLOSE — STARS: MASS LOSS**

1. AUTHOR'S GRATEFULNESS

May I start this talk by thanking all of you for coming to this Workshop, to Virpi Niemelä for having thought about it, and for having organized it and to all those who have contributed in the successful organization, including the young students who are carrying out their assigned task so earnestly and so enthusiastically. I feel really grateful to everyone for all this!

If you permit me, I would like to point out that connected with the Workshop that has gathered us today here at La Plata, there has been a **very good and very nice idea** —at least, from my point of view— that came out of Virpi Niemelä's restless and fruitful mind, who had the beautiful initiative of organizing the present meeting to celebrate my most recent birthday, and for which I feel very happy, most honored and quite moved. At the same time somebody —and that was me— had **a very bad, wrong idea** of asking her what she expected me to do at this meeting. And she readily answered **why do you not talk about when the stellar winds were not called stellar winds?** And because of such a bad idea, this mistake of mine, I am now here trying to fill in the first item of the program.

Virpi thought that because of my age I could give you a first-hand account of the very beginning of the tale that ended in the colliding wind story. But I can assure you that the story began much earlier than the day of my birth and I had to rely on the records available in the library to prepare this talk.

2. FIRST EVIDENCES FOR MASS LOSS FROM STARS

In the early days we used to speak about **mass loss**, not of **stellar winds**. Of course, earliest in the game, stars were supposed to be well-behaved, but this was long before photography showed that the nova/supernova phenomena involve loss of matter from a stellar object, and spectroscopy had disclosed the existence, in the spectrum of a number of stars, of what we now call a P Cygni-type profile. And when observations were bringing up the idea of matter being lost by stars, at least from some types of stars, theoretical considerations began to bring about the idea that stars at some stage or stages in their lives must lose mass. So, even if observations would not have shown us the existence of stellar winds, theory would have convinced us that they ought to exist.

The first nova phenomenon —actually we were dealing with a supernova event— for which there is a record of having been visually detected, corresponds to the year 1054, but what the event really implied or meant became understandable when the dark lines that appeared in the spectrum of Nova Persei 1901, the first

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bright nova of the present century, indicated velocities of approach in excess of 1000 km s^{-1}, and an expanding nebulosity around the object was independently discovered in 1916, by W.H. Steavenson and by E.E. Barnard (cf., Struve & Zebergs 1962a).

Another important element on the same question is connected to the star, in the constellation of Cygnus, that underwent a nova phenomenon in the year 1600. It corresponds to the object that we now know as P Cygni = HD 193237 = HR 7763 = 34 Cyg and is shining as a 5th magnitude object since 1715. On August 8, 1600 (cf., Underhill 1966) the object reached the 3rd magnitude, and then displayed varying brightness, being of 6th magnitude in 1620, then becoming fainter and again becoming as bright as of 6th magnitude in 1654, of 5th magnitude in 1655 and, then, of 3.5 mag, the same year, remaining that bright up to 1659.

The line profiles which are characteristics of P Cyg were first detected with a visual spectrograph by W.W. Campbell, a fact that was reported in 1894, and were also noted on the Harvard objective prism spectrograms. The interpretation that is accepted for the P Cyg profiles is the one that was first put forward by C.S. Beals in 1929 (see Beals 1929, 1955), when he undertook an investigation of the Wolf-Rayet stars. Such an interpretation traced the origin of the profile to atoms being continuously ejected radially from the star at the velocity suggested by the profile's shortward absorption.

3. FIRST LISTS OF OBJECTS THAT UNDERGO MASS LOSS

Beals' interpretation of the P Cygni-type profiles permitted to add one more group of stars to those that would be showing evidence of mass loss, namely, the Wolf-Rayet stars, because in their spectra one finds P Cyg-type profiles. So, at the end of the decade of the 1920's we were having the novae and the supernovae, the stars called of the P Cygni type, i.e., with spectra displaying P Cyg-type lines, the Wolf-Rayets, and, of course, the central stars of planetary nebulae, as objects for which the observational evidence was for mass having been or being ejected from. The derived velocities, were in general, smaller than the velocities of escape, and, as a consequence, it was not certain that matter ejected meant actually matter shed into the interstellar medium. Only after the finding of dilution lines like He I 3888 Å in Wolf-Rayet stars or the high temperature resonance lines in the UV, it was clear that the largest velocities of "expansion" suggested by the spectra were indeed larger than the velocities of escape.

In Greenstein's volume on *Stellar Atmospheres*, Deutsch (1960) mentions other objects that were believed to undergo the phenomenon of mass loss, namely, some A-type supergiants, the Be stars, and the so-called shell stars, a name assigned to B stars that ocassionally "*develop a series of strong and sharp absorption lines*" (cf., Struve 1951), the prototype being Pleione = 28 Tauri. An additional group of objects, namely, the "young stars now undergoing contraction" (cf., Struve & Zebergs 1962b), was later added to the list.

4. LATE TYPE OBJECTS

Two additional discoveries that provided additional observational information towards completing our picture of mass loss in stars, resulted from observations carried at the Mount Wilson Observatory and refer to two visual binaries with M supergiant components. In 1937, O.C. Wilson and R.F. Sanford (Wilson & Sanford 1937) found emission of forbidden Fe II in the spectrum of the B companion, a 6th magnitude star, 3″ away from the first magnitude M supergiant α Scorpii (Antares). The [Fe II] nebulosity's diameter was estimated in something of the order of five seconds of arc, and the interesting fact was that the [Fe II] lines were double on the west side of the B star, yielding velocities of +3 and of −4.5 km s^{-1}, respectively, and single on the east side of B star, the corresponding velocity being +3 km s^{-1}. Twenty three years later Deutsch found also lines of Si II in emission, the velocities of which agree with the velocity of the B star. No emission lines of forbidden Fe II were found near the M star.

The second finding is related to α Herculis, an M5 supergiant that has a G0 giant companion, about 4″.7 apart, the latter being also a single-lined spectroscopic binary. In 1956, Deutsch (1956) discovered that the spectra of the two members of the pair displayed relatively narrow absorption lines of Ca I, particularly at 4227 Å, and other lines of constant velocity, a fact that was interpreted as indicating that α Her has "*an enormous chromosphere extending from the M5 supergiant to a distance at least as great as that of the companion, at some 700 AU, or possibly even greater*".

5. INTERACTING BINARIES

The attempts to understand peculiar close binaries like β Lyrae by Struve, Kuiper, Greenstein, etc., in the decades of the 1930's and 1940's, made it clear that in these objects their peculiar spectral and/or photometric behavior arises in the phenomenon of mass ejection or mass loss from one, or perhaps even from both, of the components of the system, and from the existence of circumstellar and expanding circumbinary envelopes. In the decade of the 1950's the Algol binaries provided a good case for the phenomena of mass transfer and mass loss in interacting binaries, an appropriate name that was proposed by Paczyński and by Plavec, in 1967, for close binaries where strong interaction between the components, besides the gravitational one, is present.

6. THE SUN

Let us now go to the case of the Sun. Towards the beginning of the decade of the 1930's it was clear that the aurorae and some geomagnetic effects should result from the bombardment of energetic particles coming from the Sun in episodes related to flare activity (Chapman & Ferraro 1931, 1940), but it was Biermann (1951) the first who, in 1951, advanced the idea of *continuous particle emission or corpuscular radiation* from the Sun, in trying to explain the comet tails that are directed against the Sun. The idea attracted the mind of non-solar astronomers and people like Su-Shu Huang invoked a stellar similar phenomenon in several papers. Finally, it was Parker (1958) who "*pointed out that solar gravity cannot retain the coronal gas at so high a temperature*" and developed "*a theoretical model indicating a flow with low velocities near the Sun, rising to very large supersonic values at large distances*; he called this transonic flow the **solar wind**. Its detection dates only from the early 1960's, with instruments onboard spacecrafts.

7. INFORMATION FROM SPACE OBSERVATIONS

As soon as we entered the space age, astronomical instrumentation onboard rockets and, then, onboard the *Copernicus* orbiting observatory, gave us first access to spectral regions in the UV where one finds resonance lines of abundant light elements arising from ground states, that provided evidence for the existence of high velocity outflows in O and B supergiants, the outflow velocities, of the order of $1 - 2 \times 10^3$ km s^{-1}, being much larger than the escape velocities, and similar or even larger than the ones suggested by the diluted lines found, for instance, on the "photographic" spectra of Wolf-Rayet stars.

In September, 1968, a Colloquium was held in Trieste, Italy, on the subject of *Mass Loss from Stars*, and all papers presented talked about mass loss, even those that dealt with satellite UV work; nobody then used the expression *stellar wind*, and I was interested in finding out who was the first to use the expression in correspondence to the case of the Sun. I did not want to waste too much time because it was mere curiosity. It would seem as though Pikel'ner (1968), in a review paper published in 1968, was the first or perhaps one of the first ones who talked about the stellar wind when stating that "*a... possible explanation of the formation of the interstellar field is that it was swept out of the stars by the stellar wind*". On the other hand, Mihalas (1969), in 1969, about one year after Pikel'ner's paper, referring to "*the expansion velocities of the order of a few thousand kilometers per second, well above the escape velocity of the star*" that were derived from the resonance lines in the UV, said "*We thus have compelling evidence for a stellar wind (a term used advisedly) leading to mass-loss at a rate estimated between* 10^{-7} *and* 10^{-5} $M_{\odot}$ yr^{-1} *(although these estimates are based on very primitive analyses and are uncertain to an order of magnitude)*".

8. COLLIDING WINDS COME IN

Now, what about the question of colliding winds?

When I was in Garching, in 1981, spending a couple of months at the Max-Planck-Institut-für-Astrophysik, I was trying to deal with some *IUE* spectra of the Wolf-Rayet binary γ^2 Velorum, and was wondering what one would expect to find or to "see" on those spectra as the result of the collision of the winds from the two components of such a system: the two winds ought to be strong and, therefore, their collision should produce some observable effects. I posed the problem to Professor Kippenhahn, the Director of the Institute, who thought that the problem was interesting indeed and that he would think about it. After some time, when I was eagerly expecting to receive an answer to my question, I received instead from Professor Kippenhahn, a reprint of a paper by R.Q. Huang and A. Wiegert (1982), from the Hamburg Observatory, that had just been published in *Astronomy and Astrophysics*. The paper aimed at explaining, as a result of a wind collision effect, the observational fact I have already mentioned to you in regard to the forbidden lines of Fe II in Antares.

I think that the first attempt to try to explain spectral variations in close binaries in terms of wind collision effects is due to Sara Heap (1982), of Goddard, who considered the then available *IUE* material of Plaskett's star, HD 47129, but the number of observations at her disposal was not very large. That was a very important attempt that opened up the field.

Afterwards, there appeared a few other papers that dealt with ζ Aurigae, with β Lyr and so on, and I would just like to end the list of the earliest papers on the subject by mentioning the articles by George Wallerstein, Lee Anne Willson, together with other people (Wallerstein et al. 1984; Willson et al. 1984), who tried to explain, as an effect of wind collision, the forbidden lines present in the spectra of the eruptive symbiotic objects V1016 Cygni and HM Sagittae.

A steadily increasing number of papers have been published later on by different research workers, some of whom are here with us today, on the observable effects of colliding winds in early type and Wolf-Rayet binaries. Anything I would say about those papers would take us beyond the "beginning of the story". In consequence, let me stop here with this introduction and let us use our time more profitably by listening about the new findings and results that you have in store for us.

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