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AN OBSERVATIONAL APPROACH TO STELLAR EVOLUTION

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As a natural consequence of the XVII century Newton's physical ideas, some fundamental assumptions emerge regarding the formation of stars out of interstellar dense clouds. Helmholtz and Kelvin postulated more than a century ago the formation of stellar objects through a gravitational contraction mechanism. Of course and as far as I know, the Angloamerican astrophysicist H. N. Russell was the first to describe qualitatively the early stages of star formation. He wrote in 1913: "Such [a contracting star], when it began to shine, would be red of low surface brightness, but of very low density and great surface, so that its total line emission would be large. As it contracted it would grow smaller, hotter, whiter and increased in surface brightness so that its light-emission would not change much". Then he described the initial stage of a star as a sphere of very rarefied gas and larger diameter, with central temperature of a few thousand degrees contracting very rapidly, drawing upon its gravitational energy. A star of great initial mass, according to Russell, would evolve crossing the [M_{bol} vs. spectral class] diagram near its top and joining the main sequence at class O, B or A. The ones with smaller masses might arrive at F, G, K or M types.

The present theoretical investigations of the contracted process follows, at a more or less sophisticated way, Russel's main ideas. I do not intend to follow the modern arguments of the supposed contraction formation process; but I just want to indicate that, to my knowledge, there are not convincing observational tests for this kind of a theoretical approach to star formation. Probably it will be of interest to quote again a paragraph written by Sir Arthur Stanley Eddington (in Background to Modern Science p. p. 128 and 142, Cambridge University Press, 1938): "... *To return to historical order... the next big sensation in stellar astronomy was the Giant and Dwarf Theory put forward by Hertzsprung and Russell, which came into prominence about 1913. In 1900 we were supposed to understand thoroughly the course*

of stellar evolution... But whereas in most branches our knowledge has greatly advanced, our knowledge of stellar evolution seems to have diminished, until now it is repre-sented approximately by the symbol 0...".

For many years and in relation to the photometric studies of very young clusters, great emphasis was given to the stars lying above the normal (V vs. $B-V$) main sequence. This was and perhaps still is considered as a very strong observational support of the gravitational contraction theory for the formation of stars. The colour-magnitude diagrams of Walker and Johnson published for the NGC 2264 and Orion aggregates clearly show that starting at given point in the diagrams of these two stellar aggregates [the star members — mainly T-Tauri and T-Tauri like objects — lie high above the main sequence up to the visual magnitude approximately 15.

However, there is no doubt that the Johnson and Walker results were seriously affected by observational selection in the sense that the faint cluster members were not included.

From the very beginning of my search in Orion and NGC 2264 I noticed the existence of T-Tauri stars with abnormally strong blue and ultraviolet colours, and that introduced my first doubts about the Walker and Johnson results. Of course, before my findings there were indications that at least in some T-Tauri stars the strength of the continuous emission increases towards shorter wave lengths when the normal energy distribution of the underlying stellar spectrum is used as reference. Later on, during my stay at the Mt. Palomar Observatory as a visiting research fellow, I had the opportunity of obtaining several 48″ Schmidt camera plates in which I made two or three different exposures in two or three different colours either in the V and U bands or in the three UBV bands, reaching stars of the 19.5 visual magnitude. On these particular plates I confirmed my preliminary results, finding a large number of T-Tauri like stars, many of them with H_α emission in the Tonantzintla spectral plates. In general, it seems that the occurrence of an ultraviolet excess in the H_α emission stars is better correlated with the presence of strong emission lines in the photographic region and with the strength of the bright H and K lines of CaII. Up to the faintest limit of the Palomar multiple exposure plates there is an increasing number of ultraviolet T-Tauri stars. A very striking example of these faint ultraviolet stars in the Orion Nebula, among others, is the Brun star No. 276 from which Walker derives visual magnitude = 18.04 and $U-B=-0.99$. We classify this particular object as of early spectral K type and even after correction for interstellar absorption it lies about 2.5 magnitudes below the normal main sequence.

It seems very plausible that there exists among the T-Tauri objects a "natural" sequence in which we can order the stars according to the relative strength of their ultraviolet excesses: from the very strong and more or less steady ultraviolet cases passing through the ones in which the ultraviolet emission undergoes frequent or perhaps continual changes up to the stars such as the great majority of the flare objects in which the ultraviolet emission appears only during the occasional outburst.

Within the risk of being repetitive, I want to state that observationally it seems quite well established that the T-Tauri stars as well as some other stellar or semi-stellar objects considered as very young are always found associated with dark and bright nebulae and this fact, among other arguments, has apparently led to two fundamental contradictory suppositions.

First, the "nebular" star must represent an early stage of nebular contraction process by which the stars in general are supposed to have been formed.

For several reasons I avoided this conclusion. I dare to say that among my reasons for this there is an epistemological one, which I will try to support, at least partially, on the basis of some observations and considerations.

Second, the T-Tauri stars and many of the stellar objects embedded in nebular material must be extremely young and the observations of their peculiarities point to the reasonable fact that they do not exist in stellar groups or aggregates older than few times 10^6 years and consequently we do not find them in clusters or associations older than very few times 10^7 years. A very beautiful example of the latter can be represented by the Pleiades group. In this second hypothesis the stars are not formed by gravitational contraction but by a process of fragmentation or explosion of very dense stellar or pre—stellar nuclei. The main leader of this second heterodoxal supposition is Academician Victor Ambartsumian.

As I said before, there are no sound observational tests for the gravitational contraction star formation process, although the great majority of astronomers postulate it. Paradoxically enough most of the astrophysicists who maintain this gravitational contraction theory support and believe in the highly mythological supposition that the whole Universe started through the Big Bang Bomb of a primitive super dense "atom" suggested by the Belgium priest and scientist George Lemaitre.

Apparently at the very beginning the Lemaitre primitive atom has a quasi—symmetrical structure and composition. Being the matter slightly greater than the anti—matter, a few microseconds after the supposed

explosion the temperature went lower and the antimatter was annihilated, so in this way the expanding Universe and our present metagalaxy are composed only of common matter. This particular conception is analysed by Professor Hannes Alfvén and wittily criticized.

How can we explain, Alfvén said, the tremendous cosmic explosion in the nuclei of galaxies which merely due to Ambartsumian's studies are supposed to be by large greater than the most spectacular explosion of a supernovae. With the discovery of the quasi—stellar objects (QSO) Alfvén says a still more gigantic rellease of energy was found. Does this represent the upper limit? Obviously not, Alfvén states. In this latter case a release of nuclear energy is not sufficient as it is possibly behind the case of supernovae. According to Alfvén and others the only reasonable energy source for this supergiant explosion in galaxies seems to be matter-antimatter annihilation, although this point of view implies a rather drastic revision of present physical theories.

Going back to the problem of the formation of stars, although the present orthodoxal physics cannot explain the dense pre-stellar matter postulated by Ambartsumian as the original starting point of star evolution, what we in fact observe everywhere is explosions, ejection of matter, steady mass loss as in the extraordinary case of SS 433 star system (Vl 343 Aql.) with twin Doppler shift with a range of 80 000 km/s which has been observed. Perhaps we can add cold outflows and enigmatic jets around young stellar objects.

According to Charles Lada it is now generally accepted that during the earliest stages of evolution most, if not all stars, undergo a phase of very energetic mass ejection frequently characterized by the occurrence of massive bipolar outflows of cold molecular gas. A notable manifestation included the rapid moving of the so-called Herbig- Haro objects, high velocity maser sources, shock-excited molecular hydrogen emission regions and optical visible jets with fantastic quasi-relative velocities. However, Lada said, despite the vast body of intriguing and valuable observational data that has been accumulated in an intense effort during the last few years, our understanding of the outflow phenomena is still in its infancy.

It would be very long just to enumerate all the very striking known observational cases of well established nebular matter ejection or explosions, starting let us say with the Nova, cometary and planetary Nebulae cases, passing through the supernova remnants up to the colossal explosions in the QSO. In our galactic vicinity we observe practically always explosions and expansions and not one single case of apparent and not doubtful contraction. From the very massive OB associations, the P-Cygni type stars up to the T-Tauri objects, the flare stars and the amazing FU

Orionis type stars (called FUORS by Ambartsumian) we are confronting expansions and explosions. The very massive Trapezium systems, which in a way can reflect the process of formation of stars itself are, according to the classical works of Parenago and Ambartsumian, in expansion. The expansion age of the Trapezium in Orion determined by Parenago has a value of 10 000 years. Later, Strand comparing the Wilhelm Struve observations with modern photographic observation of the Trapezium in Orion, derived the expansion age of 14 000 years with a mean error of 3000 years. The Orion Nebula itself, according to Kahn and Menon (1961) and then to Vandervoort (1964) based on gas-dynamical considerations indicates an expansion age of 10 000 to 20 000 years. It is proper to point out the very important work by Ambartsumian, in which he maintains that the OB and T associations have positive energies. In other words, they are in expansion.

Based on the existing hypothesis and speculations about star formation and considering the new observational data, which includes of course radio and the astronomical satellite information, it seems more and more apparent that it is quite difficult to maintain the gravitational contraction theory of star formation.

Just to put an end to this rather compact and incomplete talk, I would like to recall an informal conversation with one of our students in Mèxico after he obtained, about 20 years ago, his Doctoral Degree in one of the most prominent universities of the United States of Anglo America:

I asked him why he maintained and believed in the gravitational contraction process for the formation of stars. He quickly answered me: because I have been educated under such direction. I just told him about an anecdcte regarding Galileo when he discovered the moving Jupiter satellites and in a hurry went to visit a prominent mathematician who was at the same time his protector and a distinguished Roman Cardinal. Galileo said: excellency I can now prove that Aristotele is wrong. Please come and see through my small telescope. The old (83 years) Cardinal answered: Galileo, I am quite old and all my beliefs and intellectual life are erected under Aristotelian basis. Please let me die in peace.

I really hope that the majority of us do not want to die, intellectually, in peace.

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