SOME RESOLUTIONS ON T TAURI STARS

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This symposium is dedicated to the results of studies of flare stars. The necessity of the detailed analysis of observational data on flare stars follows from the very simple fact, that until now the theory has not found for the answer to the question: why the young stars of low luminosity are flaring.

The inability to explain this fundamental property of young stars shows convincingly that theories of stellar structure and stellar evolution which have been proposed until now are in very primitive stage. Therefore in our quest for understanding the flare stars we shall try to find in some empirical way their place in the whole picture of phenomena related to the early stages of stellar evolution. This is the reason why we ask ourselves about the connections between flares and other forms of activity of young stars, on the significance of the presence of flare stars in young stellar groups and clusters and about the correlation between relative frequency of flare stars and the age of the given cluster. In this way many interesting data have been found and one can expect much more findings from the work in the same direction.

Already the first results have shown that proportion of flare stars in young open clusters is much larger than in old open clusters. No flare stars are present in globular clusters. These simple facts show us that the flare stars represent indeed the early stages of stellar evolution, they are relatively young. The observations show also that the flare stars in older open clusters are in the average much fainter (less luminous) than in younger clusters. From this we can conclude that the flare activity in the stars of lower luminosities lasts much longer than in stars of higher luminosities.

Thus these simple and very clear empirical correlations bring us to very important conclusions about the earlier stages of stellar evolution.

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More complicated and more interesting are data on flare stars in T-associations.

The reason for this is the fact that many of flare stars in such associations have been identified with T Tauri stars. It became clear that at some stage of the evolution a young star can show simultaneously both the flare activity and T Tauri activity. In the paper of Dr.Parsamian the correlation between these two forms of activity has been investigated in detail. It was shown that more than 40 percent of T Tauri variables with registered amplitudes of continuous varations $A>1^m$ are at the same time flare stars. This percentage is much higher when we consider T stars which are more active in continuous luminosity variations, reaching 64% in the case of stars having $A>2^m$.

Since in the paper of Parsamian all data refer to photographically observed flares, it is clear that if we take into account also the very small-amplitude flares, almost all T Tauri stars that have cosiderable amplitude of continuous variations will be recognized as flare stars. The inevitable conclusion is that during the evolution of new born stars the T Tauri phase and the flare phase overlap, but the flare phase is usually much longer. And the T Tauri phase almost completely represents the initial part of flare phase.

It is quite possible that the flare activity is more intense during the period when the slow brightness variations are stronger. However this question deserves further study. But the simplest assumption is that the flare activity streches over the whole length of T Tauri life.

But we know that during the T Tauri phase a star shows also other forms of activity which are expressed first of all in the variations of its spectrum.

First of all there are emission lines, that changed not only their intensity, but also their wave length and breadth. The presence of emission lines is an evidence of very extended atmosphere. Their variability suggests us that not only the extent of the chromosphere is changing, but also that the ionisation degree is variable.

Since the T-associations are as a rule embedded in the dark nebulae where we have different streams of gases one can try to assume that these changes of emission lines are caused by influence of such external streams. However the details of these changes speak in favour of internal causes, especially because they are often accompanied with variations of the brightness of the star.

Thus the spectral changes are evidences of very intensive internal underphotospheric processes.

But one of persistent properties of the spectra of majority of T Tauri stars - the presence of an absorption component on short wave length side of $H\alpha$ emission line is a strong evidence of the continous ejection of gaseous matter

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from the atmospheres of these stars. Owing to this phenomenon of the mass outflow from many members of T- associations the total mass of the nebula is increasing and the total mass of stars within it decreases. I would like to emphasize the evolutionary significance of the outflow phenomenon which persists at the earliest stages of the evolution of low mass stars, similar to what happens with many massive stars.

However, according to the spectrophotometric data the mass ejected during such outflow is of the order of $10^{-8}\mathfrak{M}_\odot$ per year. Taking into consideration the existing estimates of the age of T- associations (of the order of 10^7 years) we conclude that the total mass ejected by a star during the existence of an association is of the order of one tenth of solar mass. But the total mass ejected in the nebula by all members of the association is of the almost same order of magnitude as the whole mass of the nebula itself.

In some cases we observe larger descrete formations ejected from T Tauri stars. For example the so called HH objects originate as results of ejection from T Tauri stars, sometimes symmetric ejections. Of course the observations cannot decide definitely whether the main masses of these objects are also ejected from the atmosphere or accelerated by jets from the stars.

However, in both cases the process must be accompanied with very intense loss of mass from outer layers of the T Tauri star and with enrichment of the interstellar medium.

We can assume that within one kiloparsec around us there are about 1.000 T Tauri stars brighter than M=+6. On the other hand in the same volume there are already registered more than 100 HH objects.

Since the age of the observed HH objects is of the order of 10^4 years or less, we can assume that not less than one HH object is formed in that volume of space per each century.

If we suppose that every T Tauri star can form HH objects we come to the conclusion that in the average every T Tauri star can produce one HH object per 10^5 years.

In addition the T Tauri stars can produce also the cometary nebulae. A good example is the variable star PV Cephei. We see that this form of the activity of T Tauri stars is also connected with the ejection of comparatively large mass of material.

But we need to be here more coutious in generalizations since some of the stars generating certain cometary nebulae (for example R Monocerotis) don't correspond exactly to the description of the T Tauri stars.

Finally, the most fascinating kind of the activity of T Tauri stars is their transformation in to Fuors. We can formulate this saying that T Tauri stars are sometimes fuoring. In his recent paper Herbig has shown by means of rough estimates similar to those given above about the

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frequency of formation of HH objects that in the average each T star during every 5 thousand years is transforming itself into a Fuor - a comparatively luminous star.

Regretably enough we don't know the average duration of Fuor-flare. We can state only that FU Orionis - the first discovered Fuor after reaching maximum and then slightly fading, remains bright more than half of century. Other Fuors remain bright during several decades. But if we will not found something extravagant about Fuors we will apparently conclude that their mean lifetime must be not much longer than a century. Otherwise we should have find some stars that have fuored during the last century or even earlier. But of course this is true only when we assume that we can recognize Fuors even during hundreds years after the brightening.

The most interesting thing which we know about Fuors is that the emission line Hα in their spectra has the P Cygni like absorption component. This is an evidence of very intense outflow from the star.

But if we discuss Fuors and the fact that their spectra contain lines of P Cygni structure let us remember that P Cygni itself has sometimes (in the beginning of 17-th century) brightened then slightly faded and after this remains almost constant, thus reminding in some degree the process of fuoring. As I mentioned above the FU Orionis also has somewhat diminished in brightness after the maximum and then remains almost constant in brightness.

Of course I don't suppose that before the brightening the star P Cygni and the similar supergiants in the Galaxy were sometimes low luminosity dwarfs. However it is not excluded that they had some median luminosity. But this is a special question which we must refer to people who study the O-associations and the evolution of early type supergiants.

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MITSKEVICH: Can we say that ejection of matter is the main process for T Tauri stars or is this only the result of accretion?

AMBARTSUMIAN: I believe that the ejection is the main process for T Tau stars because the observations show so. But of course there is a small accretion also. Sometimes we can see it. Never the less, as I believe, the main process is ejection.

RODONO: You have called attention to the important role of mass ejection in stellar evolution, in addition to mass and chemical composition. Now we have indirect and direct evidence of the important role of magnetic fields in active stars and in flares. Can you comment on the role of magnetic fields in the evolutionary scenario you have presented?

BLAAUW: You referred to the occurrence of flare stars in groups of a great variety of ages and concluded that stars of all masses go through a phase of flaring in their youth. I know that as reference groups we have the group around the Trapezium(about 1 million years), the Pleiades (about 100 million years) and the field stars (still older on the average). Do we have any group with age around 10 million years of which we can say that it contains flare stars of that age?

MIRZOYAN: The observations of flare stars are very selective. The observers try to observe mainly the clusters and associations which are not far away. This gives a possibility to observe many flares. Probably this is the reason why in practice we have no observations of flares in groups that you have mentioned.

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