# 4. THE POSSIBLE CONNEXION BETWEEN T TAURI STARS AND UV CETI STARS

GUILLERMO HARO
*Tonantzintla and Tacubaya Observatories, México, D.F.*

As is well known, very rapid and non-periodic changes in brightness have been discovered in several late-type dwarf stars in recent years. In the vicinity of the sun, within a radius not exceeding 10 parsecs, nine or ten such objects have been found and named 'flare' stars because of their extraordinarily rapid variations. The prototype of these flare stars is UV Ceti. For the purpose of the present discussion, we shall call these objects 'classical' flare stars.

On the other hand, at the Tonantzintla Observatory twenty objects have been discovered that are associated with the interstellar clouds in Orion [1, 2], Taurus [3], and Monoceros; they show extremely rapid variations in brightness that are similar to those of the classical flare stars. We shall refer to these as 'flash' stars in nebulae, so as to distinguish them, provisionally, from the classical flare stars.

The remarkably similar characteristics of the flash stars in nebulae and the classical flare stars challenge us to decide if it is possible to combine these two groups of rapid variables into one single type. It is evident that this possible amalgamation will not only clarify the obvious relationship of the flash stars in nebulae with the T Tauri type stars but the relationship between the T Tauri stars and the classical flare stars as well.

To clarify the problem let us first inquire whether it is possible to consider the flash stars in nebulae as examples of a more general type of variable star, and, further, let us investigate with care their possible relationship with the classical flare stars.

The criteria that I should like to propose for distinguishing variable stars of the flash type in nebulae comprise four general characteristics and two particular ones. The four general characteristics are:

(1) The exhibition of short-lived and non-periodic outbursts lasting from a few minutes to approximately two hours.

(2) The spectral types range from at least dK6 down to late dM.

(3) With regard to their general shape, the light-curves are 'unique' and are similar in form to the light-curves of novae: the rise to maximum



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is extremely rapid; the decline from maximum may be slower, but it is also rapid. Excepting at the times of the short-lived variations, the star remains near its normal minimum magnitude.

(4) Either the appearance or the enhancement of emission lines may be observed during maximum light.

The two particular characteristics are:

(5) During the outburst, as far as can be learned from very limited observational material, the spectral characteristics are not distinguishable from those of some T Tauri stars; in addition to the bright-line spectrum, a strong emission continuum is present.

(6) The quiescent spectrum shows emission lines.

Characteristics (1) and (3) permit us to distinguish, to a certain extent, a flash star from the common T Tauri type variables, including the T Tauri stars with flare-like spectroscopic characteristics observed by Joy [4]. The four general characteristics are common to all the flash stars known so far, whereas the two particular characteristics (5) and (6) are only observed in some of them.

On the basis of the above criteria, it is now possible to examine the flash stars in nebulae and the classical flare stars together, and point out the similarities and differences to be found not only in the variable stars considered individually within their respective group, but also the two groups compared with each other:

(*a*) All the rapid variable stars of the classical flare type and of the flash type have the four general characteristics in common.

(*b*) Some of the stars of the classical flare group and of the flash group show, in addition to the four general characteristics, the two particular ones. Examples: UV Ceti (classical flare) and the Orion Nebula star No. 8 (flash star) [1].

(*c*) Not all stars of the classical flare group show the particular characteristic (5). Examples are: Proxima Centauri [5] and HD 234677, observed by Popper [6]. Similarly, some stars of the flash group fail to exhibit characteristic (5). Examples are: Orion Nebula No. 11 and Orion H$\alpha$ No. 71 [2, 1]. This fact suggests that each of the two groups of variable stars may be subdivided into rapid variables with and without characteristic (5).

(*d*) Excepting HD 234677 of type dK6, where no direct evidence on the rapidity of the variation has been obtained, all the known classical flare stars have spectral types later than dM3; on the other hand, in the flash stars we find spectral types from dK6 to dM6.

(*e*) All the classical flare stars show emission lines in their spectra at



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minimum; however, not all the flash stars show permanent emission lines at their minima.

It will be noticed from the foregoing exposition that the same general criteria which allow us to distinguish a flash star as such apply equally well to the case of the classical flare stars. Apart from certain differences in the individual characteristics, which are indiscriminately found among the members of both groups (i.e. the presence of the emission continuum: characteristic (5)), there are, nevertheless, as previously pointed out, certain characteristics in some flash stars which have not been observed in the classical flare stars. It would be most important to know how essential these differences can be. They are as follows:

First, although it is true that among the flash stars in nebulae there are spectral types as early as dK6, there are late dM-types as well. For instance, in the Taurus dark clouds, six out of the seven flash variable stars discovered show spectral types later than dM3 and only one has a dMo spectrum [3] (Dr Kuiper has classified this particular star as dK8); the most frequent spectral type of the flash stars in this region is later than dM3. At the same time, in the Orion Nebula the most frequent spectral type for the flash variable stars is between dK6 and dMo. These two examples—of Orion and Taurus—can lead one to believe that it is highly probable that the spectral type frequency of the flash stars may change significantly as a function of the evolutionary state of the stellar aggregate to which they belong.

If in the Taurus region we find out of seven flash stars, six with spectra later than dM3, it is not strange that in the vicinity of the Sun all the classical flare stars known so far show late dM spectral types; this does not necessarily mean that an essential condition for membership in this class of variable stars is to fall within an extremely restricted range of spectral types. The possible inclusion of HD 234677, classified by Popper as dK6, within the group of classical flare stars should eliminate any doubts on this subject.

The second apparent difference refers to the presence of emission lines in the quiescent spectra. Although many of the classical flare stars were discovered without knowing that their spectra were of the dMe type, the data on the most recent discoveries may be seriously affected by observational bias owing to the fact that it has become the fashion to search for variable stars of the classical flare type only among the dMe stars. This may explain why, up to now, no flare stars without emission lines in their normal spectra have been found near the Sun. As regards the flash stars in nebulae, we usually do not find bright lines in their quiescent spectra. If this difference is not the result of an observational selection, I am unable to estimate its importance at this time. (It is to be noted that in the case of the T Tauri type stars, some show permanent emission lines and others do not, but this does not lead us to treat them as two different classes of variables.)

The remarkable similarities in the characteristics of the flash stars and the classical flare stars make it extremely difficult to separate them into two different intrinsic groups and strongly tempt one to consider them as members of a single physical type of variables. However, the obvious implications resulting from such an amalgamation are so far-reaching that great caution should be exercised. Yet an excessive conservatism could lead us to reject or indefinitely postpone the recognition of a phenomenon that may be of great importance in the study of stellar evolution.

Besides the common characteristics that have been listed for the flash stars in nebulae and the classical flare stars, two important observational arguments can be made in favour of the hypothesis that all belong to only one type of variable star:

(1) *The spectrum-rate of variation relation* [3]. If we consider the classical flare stars and the flash stars together, it becomes evident that, on the basis of the observational data now available, there exists in both groups a relation that connects the spectral types to the total duration of the sporadic outbursts: the later the spectral type, the more rapid the variation. It is extremely unlikely that this spectrum-rate of variation relation is the result of a simple and deceiving coincidence, and is not an intrinsic property that reveals, to a certain extent, the operation of the same phenomenon.

(2) *The kinematic properties of the dMe stars.* Jean Delhaye's study [7] of the kinematic properties of the dMe stars in the vicinity of the Sun (out of twelve dMe stars studied by Delhaye, four are classical flare stars) shows there to be a remarkably small velocity dispersion perpendicular to the galactic plane. Therefore, the dMe stars can probably be considered to be young stars, forming a very flat sub-system. Dr Oort, who kindly called my attention to Delhaye's work, suggests the possibility that these dMe stars are associated with interstellar clouds. It is quite plausible that, in the present case, we are observing a fraction of a stellar sub-system having the structural peculiarities of the T-associations as defined by the Soviet astronomers.

The discovery of the flash stars and their peculiar distribution in the Orion Nebula, led us at the Tonantzintla Observatory to believe that these objects belong to the family of the T Tauri stars, and that whenever there exists a T-association there is the possibility of finding, related to it, rapid variable stars of characteristics similar to those of UV Ceti. Our survey of the Taurus dark clouds and our preliminary observations of the nebulous cluster NGC 2264 have strengthened this belief.

All the considerations presented here support—quite forcefully, notwithstanding a reasonable caution—the hypothesis that both the classical flare stars and the flash stars in nebulae belong to the same class of variables and, therefore, have a similar origin and represent parallel evolutionary paths. If this hypothesis is accepted as fundamentally valid, we must recognize that the stars of the UV Ceti type are to be considered as objects related to the T Tauri stars.

It is interesting and perhaps significant to point out again the difference found in the spectral type frequencies of the flare stars (or flash stars) discovered in Orion, Taurus and in the immediate vicinity of the Sun. While in the Orion Nebula the flash stars have late spectral dK types, the majority of known rapid variable stars in Taurus show spectra later than dM3 and only one has a type of dK8 or dM0. Near the Sun, all the known flare stars, with the possible exception of HD 234677, are later than type dM3. These differences lead one to speculate on the possibility that the flare stars belonging to T-associations of various ages disclose, by themselves, the evolutionary stage of the stellar aggregate to which they belong.

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