AN OBSERVATIONAL APPROACH TO STELLAR EVOLUTION (FLARE STARS AND RELATED OBJECTS)

GUILLERMO HARO

Instituto Nacional de Astrofísica, Óptica y Electrónica, Tonantzintla, México

(read by L. Rosino)

Abstract. Flare stars in the solar neighborhood and in associations belong to the same class of objects but might represent different evolutionary stages. In this report, fundamental contributions, based on observations by various groups, on flare stars ranging from extremely young ones to dMe flare stars are summarized.

About two decades ago we suggested for the first time that the flare stars in the vicinity of the Sun and the flare or flash stars in associations belong to the same physical class of variables and might have a similar origin, and that they might represent different evolutionary stages of their common predecessors, namely, the T-Tauri or T-Tauri-like stars. The obvious implications of this suggestion were so far reaching that several important objections arose and still persist, at least as the expression of a natural scientific skepticism.

This contribution, which tries to collect some of the fundamental observations of the last 20 yr on flare stars and related objects, aims to present a clearer observational picture of how some stars can evolve from their original advanced typical T-Tauri antecessors passing through different evolutional stages. These stages can comprise not only the possible pre-T Tauri stage represented by the so called Herbig-Haro objects as well as the well known flare stars in associations of different ages up to the UV Ceti stars in the solar vicinity but also the amazing evolutionary process typified by FU Orionis and V 1057 Cygni.

It seems that in the great majority of the T-Tauri stars the time required for the diminishing or disappearance of the typical T-Tauri characteristics depends on the mass of the original object or on the observed spectral type: the earlier the spectral type, the more rapid the disappeance. Therefore, if we look for weakened T-Tauri features in stellar aggregates of different ages but in which the typical and advanced T-Tauri stars have already disappeared, we will find that the older the aggregate, the later the spectral type in which we can detect the last T-Tauri relics.

To substantiate the above statements, we summarize the available observational data in different stellar groups that range from extremely young ones, such as those in Orion and NGC 2264, up to the dMe flare stars in the solar neighborhood. Special emphasis is given to the flare stars in the Pleiades region because they represent a 'middle-age' stellar system and we have a significant number of different kinds of observational results.

Some of the main conclusions reached through observational data are the following:

(a) In very young stellar aggregates, such as Orion and NGC 2264, apart from the

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presence of a large number of typical T-Tauri stars, the brightest known flare stars are of late G or K0 types. In some instances typical T-Tauri stars behave as flare stars.

(b) In the Pleiades field (16 square degrees) we found flare stars that are members of the cluster and flare stars that belong to the Hyades or to the vicinity of the Sun as well as background flare stars. The earliest spectral type of a flare star member is K3 with Ca II emission lines. From spectroscopic observations and proper motion data, there is no doubt that the flare phenomenon in the Pleiades star members and the incidence of flare-ups in a given star are strongly correlated with the presence of emission lines that are reminiscent of T-Tauri emission spectra. In general, the richer the remanent bright line spectrum, the more propitious the stellar condition for production of flare-ups.

(c) In some older stellar groups, such as Coma, Praesepe, Hyades and in the vicinity of the Sun, the brightest flare stars show progressively later 'normal' spectral types than in the Pleiades group.

(d) Contrary to what some theoreticians predict, we demonstrate: first, that the flare stage cannot be and is not a predecessor of the T-Tauri stage and, second, that the closer the flare stars are to the main-sequence, the greater the outburst incidence.

(e) The younger the association, the greater the possibility of finding the so-called 'slow' flare stars. The older the stellar groups, the smaller the dispersion of flare stars above and below the main-sequence.

(f) Although some years ago we reported a correlation between the duration of stellar flares and the spectral type of the star, now, with a considerably larger number of observations, we cannot maintain such a straightforward statement.

(g) Some typical extreme T-Tauri stars can evolve through a much slower and more permanent flare-up that seems to affect the whole structure of the star involved. Such is the case of FU Ori and V 1057 Cygni. Very probably some of the early type stars associated with nebulosity and having the FU Ori peculiarities are of a similar origin.

(h) If the above is true, we cannot avoid assuming that a large range in masses, from less than a solar mass to many solar masses exists among the original T-Tauri stars.