Precise Stellar Radial Velocities
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How could Precise Stellar Radial Velocities Help to Understand Field and Cluster Member Flare Stars?

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Abstract. Until recently the problem of collecting high resolution spectra of flare stars has been intractable since the techniques available have not been sensitive enough to reach these extremely faint objects. Although many of the nearest stars (and practically all of the nearby variable stars) belong to this class, even the ones nearest to our sun are fainter than magnitude 8 or 10. In determining the radial velocity of nearby flare stars astronomers accepted the available accuracy of ~ 1 km/s. This may be adequate for the classification of the objects into age classes (according their kinematic properties).

The other considerable group of flare stars is taken traditionally as a natural by-product of star formation processes which go on in clusters and associations. Until recently there has not been any serious attack against the widely popular hypothesis that all but a few of the flare stars discovered in the fields of stellar aggregates (their number exceeds that of the solar neighborhood flare stars) are physical members of the systems. The discovery (Szécsényi-Nagy et al. 1997, 1998) that hundreds of flare stars found in the field of M45 may not be cluster members may change the situation. Most flare stars observed there are very faint and consequently they were missing from previously published lists of Pleiades members. For one third of the objects only reliable membership probabilities have been determined, and many of them are listed as probable non-members (Haro, Chavira, & Gonzalez 1982). However, a recently published photographic proper motion survey of the Pleiades' field (Souchay & Schilbach 1995) provided reliable membership probability values for many stars of extremely low luminosity too. Based on that about 85% of the well-documented flare stars can be – and have been – identified. Our results (Szécsényi-Nagy et al. 1997) undoubtedly prove that a substantial fraction ($\sim 40\%$) of the so called Pleiades flare stars are (more or less) definitely non-members. Since all of these new cluster membership probability calculations have been based on stellar proper motion values, in order to be able to reach a final decision, we badly need some other independent data set for the very same stars. It is to be shown that precise stellar radial velocities, an unexploited – because almost unknown – parameter for flare stars, could solve the problem by supporting or disproving these faint objects' cluster membership. Consequently the flare stars of these two kinds (which are accidentally mixed on the photographic plates) could be classified into different age groups and their evolutionary stages and tracks could be investigated more deeply.

Our intention is to persuade astronomers involved in stellar radial velocity business that developing and using a method of high precision stellar radial-velocity measurement for late dK/dM stars is not a waste of time but a really feasible job and that we can and will contribute to the success of it by identifying the best tartgets, taking part in the necessary observations and evaluating the data.

1. Flare Stars in Stellar Aggregates

Since these variables are cool and tiny with very low energy output (their absolute visual magnitudes are between +8 and +15) they were not discovered until the middle of the century. Their spectra may contain emission lines, and in most of the cases they can be classified as dM0e – dM7e type stars. Haro & Morgan (1953) discovered that flare stars seem to cluster in certain parts of the sky. Objects similar to UV Ceti were identified in the field of the Orion nebula. Since the Orion association, to which the majority of these variable stars presumably belong, was born quite recently, the red dwarfs discovered there must be very young too. Researchers have discovered flare stars in many other groups of stars and galactic clusters. Some of the best known examples are NGC 2264, NGC 7000, Coma Berenices, Hyades, Pleiades, and Praesepe. These cover a substantial age range.

2. Our Recent Results

Many years of scientific cooperation in this particular field have proved to be really fruitful. Well over one thousand flare stars have been identified in the fields of stellar aggregates. However, this fact does not necessarily mean that these objects are physical members of the groupings. Here we have to point out to readers that in most cases it is extremely difficult to decide whether the object in question is a member of the group or not. That is why I emphasized that flare stars were observed in the area of the Pleiades, and did not say in the cluster itself. This famous open cluster is probably the most photographed region in the sky. But until now, not more than 35% of the flare stars discovered in its field have had membership probabilities determined (Hertzsprung 1947; Haro et al. 1982). These were not in contradiction with the assumption that the majority of the flare stars found there are cluster members (Parsamian 1986: 80% – 96% of the catalogued objects; Szécsényi-Nagy 1986: at least 50% of the discovered and latent flare stars). In fact photographic patrol observations performed in two control fields of the same galactic environment provided quite a few field flare stars (Parsamian 1986), endorsing the hypothesis of the cluster membership of these objects, a conclusion to be confirmed. That is what we have tried. Based on recent, high-precision proper motions of every star, a schematic map of the region showing all objects with determined proper motion components has been generated (Schilbach et al. 1995). The identification charts of flare stars, published by their discoverers or by Haro et al. (1982), have then been compared to the highest-resolution images of the relevant subfields, and the membership of each object seen on the latter images has been evaluated. The outcome of that work is most interesting. According to the newly-derived proper motions of the objects, hardly more than 50% of all of the reported flare stars proved to be Pleiades cluster members (for a more detailed discussion see Szécsényi-Nagy et al. 1997). A plot showing the two-dimensional apparent distribution of the rejected stars demonstrates, too, that the non-member flare stars do not have any obvious concentration in the field, which is wide enough to give a hint on the spatial structure of the cluster and to outline its extent.

3. Questions to be Answered

How can we explain the unexpectedly high field flare star density around the Pleiades (and maybe around the Orion Nebula too – although we can only suppose the build up of a similar enigma there) when in all of the control fields the probability of discovering galactic background flare stars is only 1/10 or 1/20 of the value found in the region of M45?

Where in space are the non-member flare stars, in the foreground or in the background? (The answer is of course both, but for a more reliable modeling of the star distribution we have to know which ones are in the foreground and which are behind the cluster.) As to the number of foreground flare stars, a straightforward statistical estimation gave 10% of the non-members, while the rest (90%) are expected to populate the background (where these faint objects are unfortunately not accessible by direct parallax measurements).

Are the cluster member flare stars coeval with each other and with the more massive members? And what about the non members?

Is the non member (or field) flare star subsystem of the same origin or have its stars arrived from very different space volumes, possibly with a considerable contribution from the young open cluster's lowest-mass stars, that may have evaporated from the corona of the Pleiades?

To answer the above problems more precise data on the kinematics of the flare stars of different origin are needed. Having precise radial velocity values we would be definitely nearer to the solutions. In astronomically young and loose star systems like the Pleiades and the Orion aggregate, member stars free-fall on parallel lines. Their radial velocity dispersion may not exceed about 1 km/s, and as it is written: "the combination of radial velocity and proper motion data provides an almost unambiguous membership criterion for objects participating in the same overall space motion" (Perryman et al. 1998 and references therein). Consequently it is a fairly acceptable strategy to collect as many radial velocity data on these stars as possible, and with the highest precision. In fact the Coravel radial velocity measuring device was employed to determine the radial velocities of F5 – K0 stars, and provided convincing results (Rosvick, Mermilliod, & Mayor 1992) in the field of the Pleiades. It was found that cluster stars move with the same radial velocity (5.85 km/s) while field stars may have very different velocities, from -42 to $+50$ km/s. The velocity dispersion depends of course on the sample of stars taken into account, but it is definitely inferior to 0.7 km/s. The Coravel radial velocities proved very useful for cluster membership determination in an impressively wide field (Rosvick et al. 1992). Its diameter ($d > 9°$) is practically equal to the diameter of the cluster

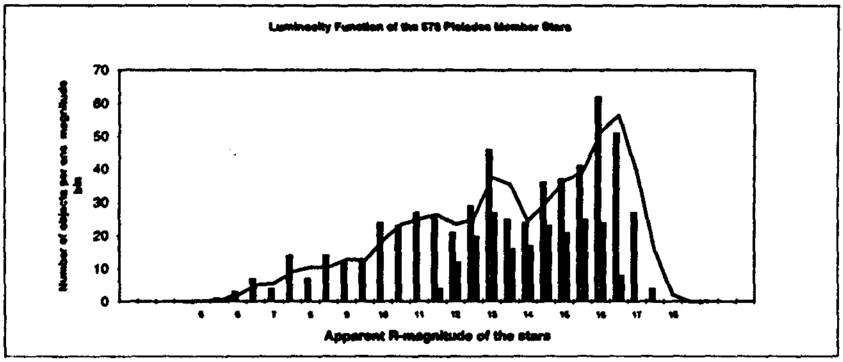

Figure 1. Apparent R-magnitude distribution of the Pleiades member stars. The subset of columns shows the contribution of cluster member flare stars.

field that was checked for cluster members a decade earlier (van Leeuwen 1983). Since many of the flare stars discovered are too far from the cluster's projected center, even the proper motion studies will have to be extended in the future in order to obtain the missing data for the suggested combination with precise stellar radial velocities. Fig. 1 gives the most basic information for the potential observers on the apparent brightness distribution of the flare stars in question.

The author is convinced that all results are expected to contribute considerably to the understanding of the behavior and evolutionary processes of flare stars and probably all red dwarfs, and of their role in building up stellar aggregates.

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