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Use of CCDs in Schmidt Telescopes for the Investigation of Hα Emission of Flare Stars

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Abstract. The use of Schmidt telescopes in their traditional mode for the detection of stellar flares and for the UV and PG photometry of these stars proved to be very productive. The fast optical system and reliable sensitivity of modern photographic emulsions resulted in a photometric time-resolution of several minutes even in the case of distant objects. One of the most important characteristics of flare stars may be the tendency for coexistence with more massive and more luminous member stars of young stellar aggregates (mainly open clusters). Although the vast majority of flare stars discovered seem to belong to clusters, a great many of them are neighbours of our sun. These can be investigated in depth because a sufficient number of their photons can be collected and recorded in narrow photometric bands or even in spectra of good resolution. The direct comparison of solar vicinity flare stars with flare-active members of distant clusters has been almost impossible. However recent developments in silicon-based photon-detecting technology offer the advantage of incredibly high detector quantum efficiency (DQE) in many spectral regions where photographic materials never reached an acceptable level. Hα emission is one of the most characteristic features of flare stars, and the wavelength of Hα photons fits extremely well with the peak of the spectral sensitivity curves of silicon photon detectors. CCD chips placed in the focal surface of Schmidt telescopes seem to be very promising for the future investigation of Hα emission of flare stars.

1. Introduction

Photographic and photoelectric UBV photometry of solar vicinity and cluster member flare stars have yielded a large amount of data about the apparent brightness and colour of these objects. In many cases it was possible to determine the absolute brightness of nearby stars (Tsvetkov et al. 1994) and the position of these objects on the Hertzsprung-Russell (HR) diagram could be marked. As a good example Fig. 4 of the paper by Golub (1983) can be mentioned. Similar studies were done in the Pleiades field where more than five hundred flare stars have been discovered (Haro et al. 1982; Szecsenyi-Nagy 1990a). Although no precise distances for the individual stars are known the fact that they belong to the cluster M45 allows the common treatment of all photometric data. It means that their apparent brightnesses may be compared directly and can be plotted against the spectral types of the stars. This kind of a HR diagram for the flare

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stars of the Eta Tauri fields shows that points representing late-type flare stars are not arranged along the schematic line of the cluster's main sequence but tend to scatter across a wide brightness range. The apparent visual brightness of stars of the same spectral subclass may often differ by 4 magnitudes and this fact can not be explained by measuring errors. On the contrary it reflects true intrinsic brightness differences of active red dwarf stars of the same decimal subclass. In order to better understand these objects and the flare phenomenon a new physical parameter (which characterizes this strange behaviour of the late-type flare stars) should be identified and introduced as a more powerful classification parameter.

2. Line Emission in the Spectra of Flare Stars

The majority of the late-type flare stars are emission line objects. dKe and early dMe stars show distinctive CaII (H and K) emission while all emission line M dwarfs produce characteristic Balmer lines. The spread in their M_V values against spectral types becomes fairly detectable in the case of the most abundant subclasses (M2–M5). The dominant emitter being HI the energy emitted in the Balmer lines exceeds that emitted in the spectral lines of CaII (Linsky 1983). Unfortunately hydrogen lines too fade away at and after dM6 but *Hα line emission seems to be a good choice as the new parameter* for the majority of flare stars. Simple statistics for the very limited sample of solar neighbourhood flare stars shows that more than 90 % of these objects are M dwarfs. Of these two thirds belong to the spectral subclasses dM3, dM4 and dM5 and only 4 % are dM6 stars or later. It has been demonstrated too that amongst these stars at least 60 % and very likely 80 % are emission line objects (Szécsényi-Nagy 1990b).

3. Photographic or CCD-Photometry ?

Astronomical observations have been based on photographic techniques for decades. Consequently almost all astronomers are supposed to be more or less familiar with astrophotography and it is not necessary here to give a detailed description of its drawbacks. It is evident that the spectral sensitivity and the quantum efficiency of photographic emulsions is far from being ideal for the detection of Hα emission from faint stars. Furthermore, the well known problems of photometric calibrations also urge the user to look for a more sophisticated photon detector which has very wide and linear dynamic range. Until recently, the high resolution of emulsions and the large surface of astrophotographic plates, combined with the wide field and fast optical system of Schmidt cameras, made wide field photography superior to imaging with electronic devices. However, the latest results of research and development in the photonics industry have offered competitive devices: large area CCDs with several million pixels (see e.g. Szécsényi-Nagy 1994 and references therein). We can now postulate almost certainly that large area CCDs or similar semi-conductor based photon detectors (which may be used or read out many times of course) will replace the traditional photographic plates in the future.

4. CCD-Photometry of the Hα Emission and its Spectral Vicinity

The goal of the study is to characterize the Hα emissivity of flare stars relative to their continuous emission. In order to establish an effective procedure only two new photometric passbands were defined. One of them was set to involve as many Hα photons as possible while rejecting the majority of photons arriving in the neighbouring spectral regions. The other one was intended to check the mean level of the object's continuous radiation in the red region of the spectrum. The idea of the measurements is to collect enough photons to reach a preselected S/N value and then determine the apparent intensity of the light in both spectral bands. Having received the intensity values, they are to be compared and their ratio is to characterize the Hα emissivity of the active flare star.

The Half Band Width (HBW) of the narrower filter was 2.6 nm (i.e. its width at double the theoretically determined minimum width) and its central transmission exceeds 52 %. The other band was defined by a medium band Hα filter. Its central wavelength is 656.5 nm and differs only slightly from that of the narrow band filter (656.6 nm). The HBW of the medium-band filter is 11.4 nm while its total transmittance is 4.35 times as large as that of the narrow one (Szécsényi-Nagy 1990c). Preliminary test measurements were carried out at the Observatory of the Stockholm University with a Photometrics CCD camera and the above filter system mounted on the 40″ reflector's f/5 focus. By careful choice of the program fields, an average of 2–3 flare stars per field was attainable in the Pleiades region. Long exposures and the stability and extremely low noise level of the device resulted in an RMS error less than 1 % for some of the brighter objects, while for the faintest but measurable ones, the error slightly exceeded the 2 % level.

5. Preliminary Results

Insufficient observing time and abruptly changeable weather prevented us from collecting enough photometric data for a really detailed and serious study of the Hα emissivity of flare stars but the results are promising and allow some preliminary conclusions.

The apparent brightnesses of 17 flare stars of the Eta Tauri fields were determined in two red photometric bands, namely the narrow Hα and the medium Hα (mH) band. The values received for each star were compared and the intensity ratio: R(n/m) = I(nH)/I(mH) was computed. As there was no way to receive any kind of absolute calibration during the run these relative Hα emissivity parameters of the stars had to be analyzed. Nevertheless, the investigation resulted in various R(n/m) values which may be classified into three groups. Relative emissivity values for 7 objects seemed to be similar and were spread in a narrow band around R(n/m) (the average which was chosen as an arbitrary reference level). Stars emitting more powerfully in Hα (large squares) were less numerous in this sample. Only 4 stars produced significantly (practically by a factor of 2) higher R(n/m) values while 6 were definitely fainter (small squares) than the reference mean. Members of these three groups can easily be distinguished on the colour-magnitude diagram shown as Fig. 1. However the squares representing the observed dMe stars are not ordered into perfect branches and

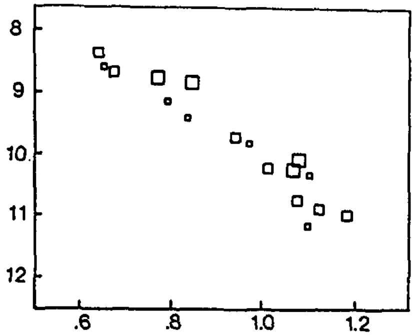

Figure 1. M_V versus $R - I$ colour plot for 17 flare stars of the Eta Tauri fields computed according to a value: $m - M = 5.5$ (Larger symbols represent stars with higher relative Hα emission.)

it seems highly probable that *for flare stars of the same colour the stronger Hα emitters tend to be absolutely brighter in the visual range.*

For the importance of this relation in the explanation of the energy budget of atmospheres of dMe stars this kind of investigation has to be repeated for the Pleiades region amidst better weather conditions, and carried out for other sky fields rich in flare-active dMe stars

6. Conclusions

The method developed to measure and characterize the Hα emissivity of flare stars is suitable. The LN-cooled CCD-camera is sensitive enough at this very low light level and is a highly useful tool for photometric measurements especially in the red–orange spectral range. The two filters defining the system seem to work better than those suggested by Herbst & Layden (1987). Theirs have bandwidths of 3 and 15 nm respectively being a bit too large. Nevertheless to be able to adapt this method for use in faster telescopes (e.g. Schmidt cameras), larger area filters and more scrupulous experimentation are necessary.

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