VARIABLE K-TYPE STARS IN THE PLEIADES
(based on observations obtained at the European Southern Observatory, La Silla, Chile, and Lick Observatory, USA)

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Photometric observations in the VBLUW system (Lub, 1979) have been performed during 1980 and 1981 of 19 late G and early K-type members of the Pleiades Cluster, in order to study their variability. All stars showed variations with amplitudes of 0.02 to 0.20 magn. in V. For 12 stars lightcurves were obtained which show periods that range from 0.24 to 1.22 days. The light curves are semi-regular and resemble those of BY Dra stars, although the periods are shorter.

Figure 1 shows three differently shaped lightcurves. The absolute magnitudes in V range from 7.0 to 7.2. The first lightcurve has a 'v' shape, the other two show 'u' and 'n' shapes respectively. The 'v' shape has been observed most often. Comparisons between 1980 and 1981 observations show that the lightcurves can change from one type to the other at constant period. (See Van Leeuwen and Alphenaar, 1982).

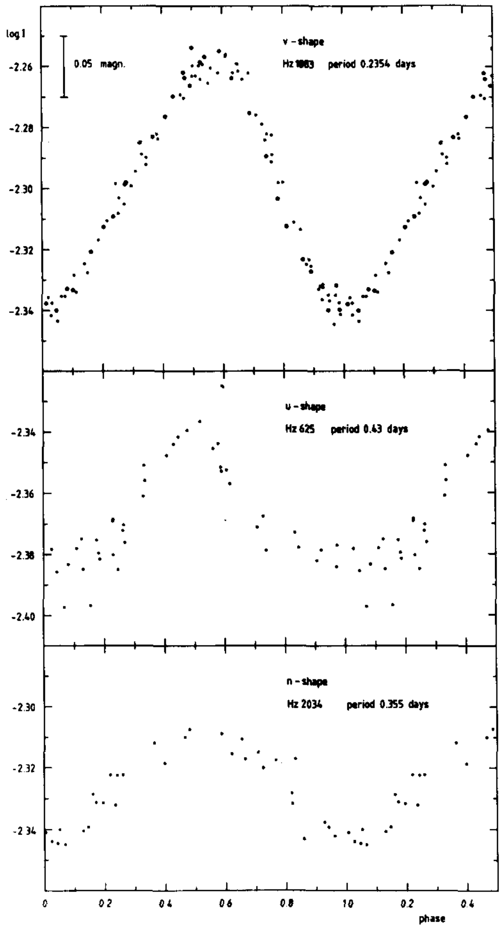

Figure 1.
Lightcurves for three of the Pleiades K stars. These observations are obtained in 1981 except for the dots of Hz 1883, which are 1980 observations.

P. B. Byrne and M. Rodonò (eds.), Activity in Red-Dwarf Stars, 189–193.

Figure 2 shows the relation between amplitudes and periods that was found for the variables. The symbols indicate the shapes of their lightcurves. This relation strongly indicates a dynamical background for the variations. There is no indication that a similar relation holds for other BY Dra stars, probably due to their spread in masses and ages. The stars shown in Fig 2 are all of the same age and mass.

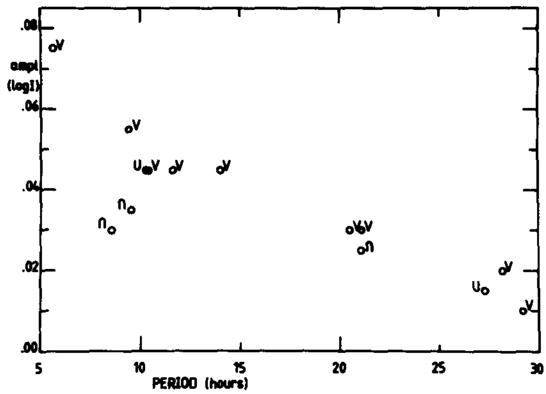

Figure 2. The period-amplitude relation for Pleiades K-stars.

In 1980 and 1981 Dr M F Walker of Lick Observatory carried out spectroscopic observations for two of the variables. He found single stars of spectral type K3Ve. They show very fast rotation: Vsini values of 150 and 75 km sec^{-1} were found for stars with photometric periods of 0.24 and 0.42 days respectively. Such rotational velocities are two orders of magnitude higher than usually observed for K-stars, and bring the rotational periods close to the photometric ones. If they are related, which is generally assumed for BY Dra stars, the variations are due to rotational modulation. The relation of Fig 2 is in that case a relation between amplitude and rotational velocity. Variations in (V-B), the temperature index, have been observed which are proportional to those in V. The temperature variations are probably sufficient to explain most or all of the brightness variations. In the case of rotational modulation this implies a temperature gradient over the stellar surface, of which the amplitude is increased with increasing rotational velocity.

The observed variations decrease in amplitude rapidly for stars brighter than absolute magnitude 6.5 in V. The same happens with their flare activity and the fast rotation (Mayor, priv. comm.). The age of the Pleiades, 10^8 years (Golay and Mauron, 1982), strongly indicates that these changes in the behaviour of early K stars are due to the last stage in their evolution towards the main sequence.

The amount of angular momentum contained in the Pleiades K-stars is, in case one assumes the photometric and rotational periods to be related, comparable with that contained in the solar system. In relation to their masses, they follow a trend set by O, B and A main sequence stars. This relation is shown in Fig 3, which was presented first by McNally (1965). It probably indicates the initial distribution of angular momentum in star formation. There exists a second relation, set by F, G and K main sequence stars, which shows much lower amounts of angular momentum for these stars. It has been explained as a stability relation, beyond which the stars are not able to keep their initial angular momentum. The Pleiades K stars arrive, according to this explanation, near to the main sequence with most of their initial angular momentum. They are not stable, and loose most of their angular momentum on a relatively short time-scale. Their photometric variations as well as their flare activity may have much to do with this process.

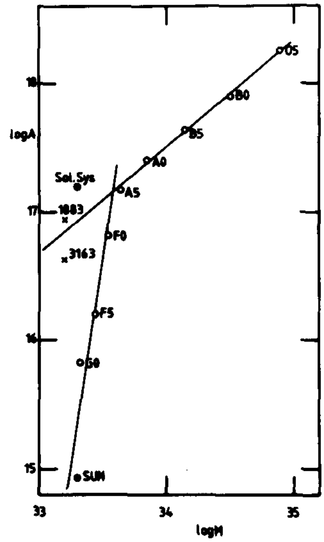

Figure 3.
The relation between the logarithm of the angular momentum per unit mass (A) and the logarithm of the mass (M) for main sequence stars, the solar system, the Sun, and two of the Pleiades K stars (1883 and 3163).

Acknowledgements

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References

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Van Leeuwen, F. and Alphenaar, P. 1982: ESO Messenger 28, 15.

DISCUSSION

Rodonò: I notice that you said the light curve was AU Mic-type. I would like to advise you that AU Mic had a v-shaped light curve 5 years ago and since then it has become successively double-peaked and flat and back to sinusoidal. If you say AU Mic-type for a changing light curve I would agree with you. Looking at your light curves (in Fig.1) I would expect that the v-shapes occur when the amplitude is a maximum and the u-type curve occurs at smaller amplitudes.

van Leeuwen: No, in fact the u- and v-shape light curves have similar amplitudes.

Rodonò: What I mean is that I would expect that, sooner or later those stars with v-type curves will change to u- or n-types with smaller amplitudes as we observe on nearby dwarf stars.

van Leeuwen: We have no indication that this is so and, as I have said, the amplitudes of the three kinds of light curves are similar. The changes from n-type to v-type have been observed in both directions.

Rodonò: Yes, but this is over one year, is it not?

van Leeuwen: We have observed 5 light curves over a one year interval and 7 light curves at one epoch only.

Rodonò: This is not enough. You should wait longer.

Rucinski: I would like you to say whether you believe that these are spots or not.

van Leeuwen: No, I do not believe that they are spots. There are many reasons for this belief. One concerns the stability of at least one of the light curves we have observed. It is stable to within 1% over a year or 1500 cycles. There are problems with the relation between amplitude and period. It is also a problem that all of the stars which we have observed to date are variable. I would accept spots if someone can convince me that spots can be always concentrated on one side of the star. Otherwise one would not expect always to see a single large minimum and maximum which stay exactly the same shape.

Rodonò: It was not my intention to prove that these light curves were due to spots. Spots can however reproduce almost any kind of light curve. So it is wrong to quote the kind of lightcurve as evidence against a spot interpretation. I would also like to question the statement that the lightcurve has been stable over a one-year period. We have very beautiful examples of light curves which stayed unchanged for years e.g. BY Dra. Subsequently these began to change their lightcurves. So it is quite possible to reproduce your lightcurves with spots.

van Leeuwen: You have observations as accurate as these?

Rodonò: Yes, I believe so.

Basri: These stars seem very interesting. Are you aware of any X-ray observations or other activity indicators? They would provide an interesting test of the activity-rotation correlations.

van Leeuwen: Since we know of these stars for only 1½ years there are no X-ray observations that I know about.

Basri: It is possible that the Einstein satellite may have observed some of them as part of their survey.

van Leeuwen: It is possible but I don't know of any.

Worden: We had a similar programme to your one at Cloudcraft Observatory New Mexico. We looked at the Pleiades, Hyades and the Malmquist field F, G and K stars. Our results showed, for the Pleiades and Hyades that about 30% were variable. There was a fairly large increase in variability in the K stars. However we did not look for periods, having only

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observations about a week apart. So assuming that we were seeing the same thing, it is interesting that it continues in the Hyades which are much older.

Hartmann: From Ca II modulation on such stars one can see the same longitudes active for some years at a time. So I think that your expectation that there cannot be active longitudes persisting over one year is not borne out by either experience with RSCVn or BY Dra stars or Ca II variable stars.

Walter: I would like to add to that that even in the case of the Sun one can see active longitudes for very long periods of time, not perhaps for 1500 rotations but perhaps for a year or two at a time.

van Leeuwen: But it is not a case of the stability of a single lightcurve or even of two or three lightcurves but rather of our entire sample. I agree that part of the observations can be explained with spot models. I think you get into problems to explain why all the stars are variable, why and how a relation exists between the amplitudes and periods and why there is so little scatter on that relation. Anything that is interposed between the rotation and its amplitude such as a magnetic field rise to spots would, I believe, give rise to a spread in the relation.

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