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STATISTICAL ANALYSIS OF INFRARED COLOR-INDICES OF VARIABLE LATE TYPE STARS

Observations of infrared radiation for a large sample of cool stars have been carried out among others by Gillett, Merrill and Stein (1971). These authors have made four-color infrared photometry at 3.5, 4.9, 8.4, and 11 μm over the period 1969 October - 1970 June at Kitt Peak Observatory for 59 stars of spectral type M, 31 carbon stars and 7 stars of spectral type S.

I have used these observations for the discussion of the changes of [11] - [8.4] and [8.4] - [3.5] color indices with the physical properties of M and carbon variable stars such as the visual light amplitude and the light period. This work has been motivated by several earlier observations which have indicated the existence of the changes of intrinsic stellar polarization with the light phase (Dyck 1968) and occurrence of infrared excesses mainly for variable stars (Gehrz and Woolf 1970, 1971). There are also some theoretical considerations of the possibility of the grain formation in the circumstellar envelopes of cool variable stars (Fix 1969, 1970, Donn et al. 1968).

The relations of the infrared color indices [8.4] - [3.5] and [11] - [8.4] to the visual amplitudes of light variations (Kukarkin et al. 1969) are shown in Figs.1 and 2 for M type stars and carbon stars respectively. In these figures and the following ones the long-period variables (LPV) are shown as crosses. The semiregular and irregular variables (SR, Lb) are considered as one stellar group and are signed in different ways according to the luminosity classes in the case of M type stars only (see Fig.1). In Figs.1 and 2 the semiregular-irregular and long-period variable stars seem to form two separate sequences. The infrared color indices increase with the visual light amplitudes for the two sequences of variable stars of M type stars as well as for carbon stars. The largest infrared excesses among M type stars generally occur for stars that have the highest luminosity classified as supergiants. However, visual amplitudes of light variations are strongly affected by differential molecular absorptions. Now, there is no way to eliminate these effects for carbon stars, but we were able to correct visual amplitudes of M type stars for a TiO differential absorption according to data given by Smak (1964). The corrections are contained between $0\overset{m}{.}3$ and $3\overset{m}{.}3$. The [8.4]-[3.5] and [11] - [8.4] color indices are shown against the corrected visual amplitude $(\Delta m_V)_C$ in Fig.3. It seems that there is a separation of semiregular-irregular and long-period variable stars for [11] - [8.4] color index. The [8.4] - [3.5] color indices increase with the corrected visual amplitude, although there is a large scatter. It would be necessary to investigate the changes of the infrared color indices with the infrared light variations, e.g. at 1.04μm. These amplitudes are not affected by the molecular absorptions and they measure the changes of the photospheric temperatures and radii of cool stars. Unfortunately, the infrared amplitudes of light variations are known only for a small number of long-period variables, mainly of spectral type M (Lockwood and Wing, 1971). I have investigated the changes of infrared color indices with infrared light amplitudes at 1.04μm for long-period variables and have obtained a continuous increase of these color indices with infrared light amplitudes.

Finally, I have discussed the behaviour of [8.4] - [3.5] and [11] - [8.4] color indices with the light period for M type stars (Fig.4) and carbon stars (Fig.5). The inspection of these figures shows that there is probably a continuous increase of [8.4] - [3.5] color indices with the ligth period for M type stars as well as for carbon stars. If the [8.4] - [3.5] color indices measure the infrared emission from circumstellar grains, then their increase with the light period and with visual light amplitude may be explained by the rise of luminosities and the drop of the temperatures. The temperature decrease and the luminosity increase are connected with the larger mass loss and the larger infrared emission from grains formed around cool stars.

However, it seems that two separate relations occur between [11] - [8.4] color index and light period (Fig.4) for semiregular-irregular and long-period variables of spectral type M (except three semiregular supergiants). This behaviour of [11] -[8.4] color indices can be explained, if we assume after Gehrz and Woolf (1971) that the circumstellar silicate envelopes of long-period variables are optically thick. In shells of large optical depth, self absorption of thermal radiation at 11μm and circumstellar emission at 8.4μm ought to diminish the [11] - [8.4] color indices.

The changes of the [11] - [8.4] color indices with light period are quite different for carbon stars (Fig.5). There is probably a maximum of these color indices for semiregular carbon stars at P=250 days. It is difficult to explain such a behaviour because of the lack of period-luminosity relation for carbon stars. However, if one supposes, that luminosities of carbon stars increase with light periods, what is the case for M type stars, then may be, the influence of molecular absorption, which is the most important for the latest spectral subclasses, can affect the color indices in such a way.

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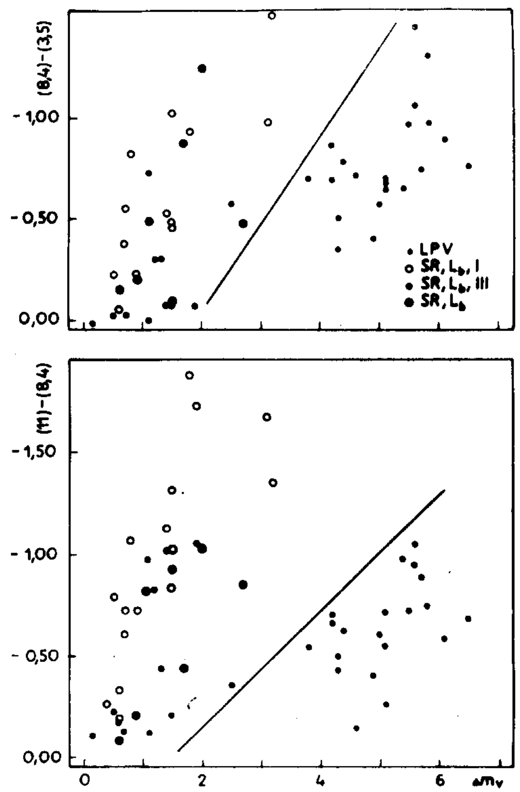

Fig.1. Relation between infrared color indices and visual light amplitudes for variable stars of spectral type M.

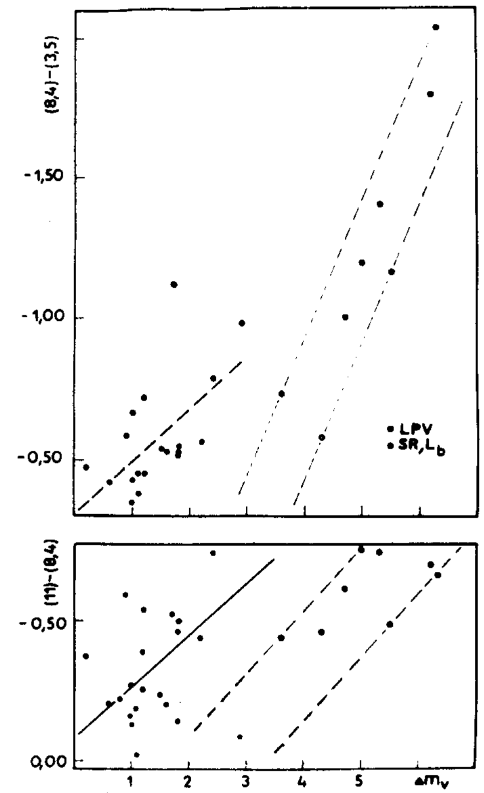

Fig.2. Same as Fig.1. for carbon stars.

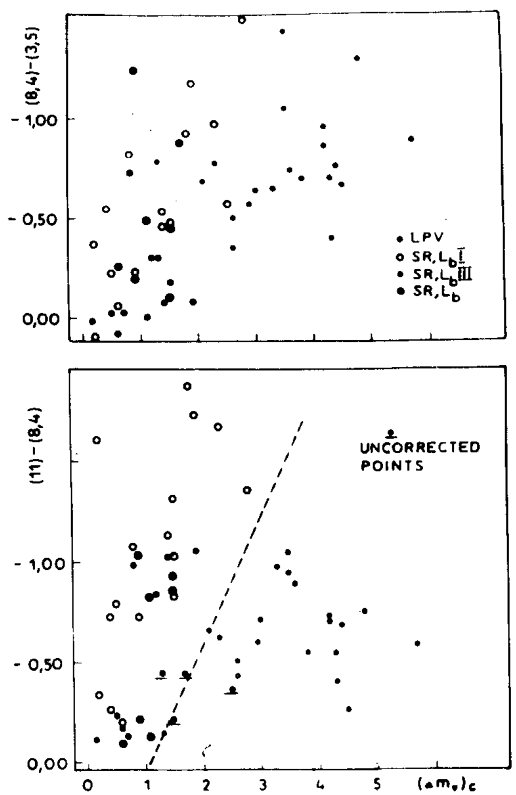

Fig.3. Plots of infrared color indices against the corrected visual light amplitudes for M type stars.

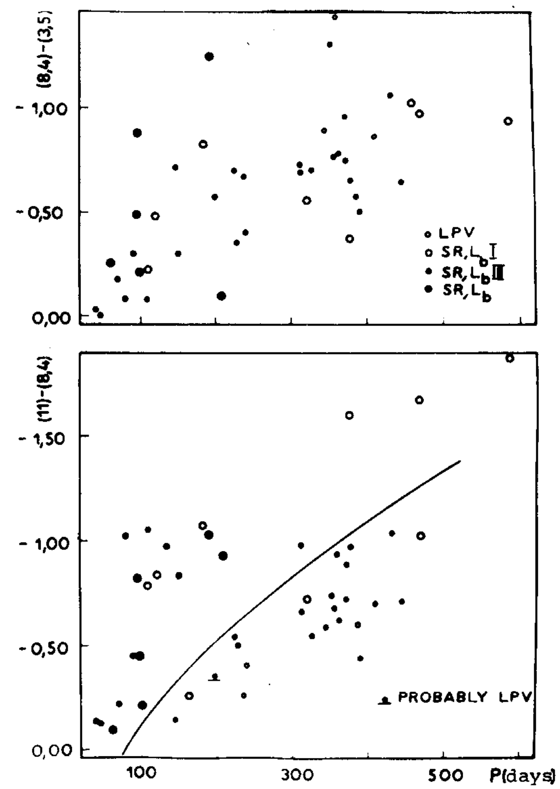

Fig.4. Relation between infrared color indices and light periods for variable stars of spectral type M.

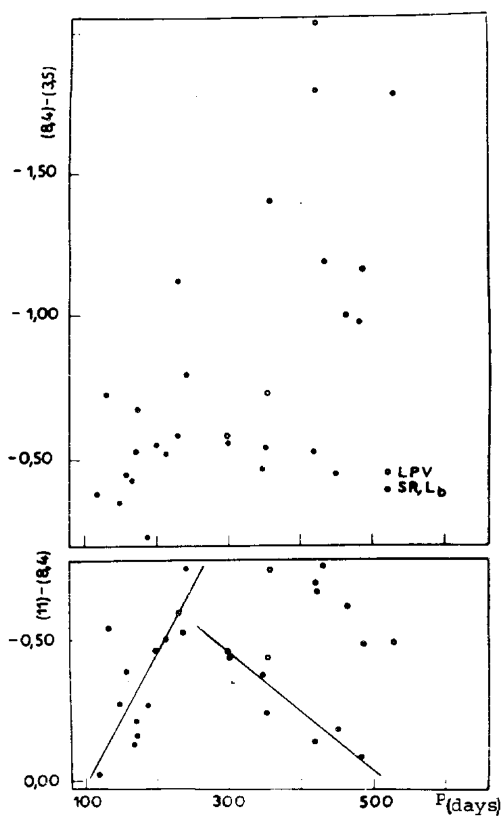

Fig.5. Same as Fig.4. for carbon stars.