THE CLASSIFICATION OF RED SUPERGIANT VARIABLES

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Abstract

The *GCVS* classification of red supergiant variables is discussed and it is suggested that a more significant division can be made between those variables of small amplitude, such as μ Cephei, and those of large amplitude, such as S Persei.

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Among the cooler stars, supergiants may be defined as those which have an absolute visual magnitude brighter than -3. Some estimates (Strohmeier 1972) suggest that, of the approximately 1800 irregular and semiregular variables with later spectral types that are listed in the *General Catalog of Variable Stars* (1969), as many as 30% may be supergiants. It is somewhat paradoxical, therefore, to find that the *GCVS* explicitly recognizes only 48 red supergiant variables. This misleading total arises because spectroscopic, photoelectric, or extensive photographic observations are generally required to distinguish supergiant stars from the more numerous but fainter giants. Since these studies are frequently unavailable it is likely that the *GCVS* lists many supergiants not yet recognized as such.

The *GCVS* places the 48 red supergiant variables into catagories depending upon the degree of regularity evident in their light fluctuations. Into class *Lc* go those supergiants with seemingly irregular light variations, while class *SRc* contains those which exhibit semiregular brightness variations. No known red supergiant variable shows light oscillations of a completely regular nature, and it is possible that all are variable to some extent.

Deciding whether a supergiant belongs to class *Lc* or class *SRc* can be a difficult task. The time interval between successive maxima is long (from a few hundred to as many as a few thousand days) and the amplitudes are usually small (<$1^{m}_{.}5$), so that classification can be attempted only after extensive observation. It is not unknown for a variable to be first classed an irregular and later shifted to the semiregular class as additional observations reveal some hitherto unsuspected periodicity. Even after long study, unanimity in classification can be hard to achieve. For example, μ Cephei has been watched for more than a century, yet debate continues over whether its light curve can be attributed to purely random processes (Ashbrook *et al*. 1954; Sharpless *et al*. 1965).

To be useful a classification scheme should carry as much significance as possible, differentiating groups on the basis of some fundamental property. Thus it is a little unsettling to discover that classification ambiguities can arise even for stars which have been among the best observed. Possibly even more disturbing, however, is the fact that, other than regularity of the light variations, no differences have been established which serve to distinguish the *Lc* from the *SRc* variables. To within the accuracy of the observations both groups lie in the same portion of the HR diagram. This raises the question of whether or not all red supergiant variables belong to a single, essentially homogeneous group.

The answer to this question is probably "no," but the usual classification into *Lc* and *SRc* stars is ill-suited for demonstrating the greatest inhomogeneities. A distinction between red supergiant variables of small and of large amplitude may be more useful for this purpose. This is illustrated in Figures 1 and 2.

Figure 1 presents the light curves of two well studied red supergiant variables of small amplitude. Both display light fluctuations of amplitude $0^{m}_{.}5$ - $1^{m}_{.}0$, the characteristics of which show little change with time. (VV Cep is also an eclipsing binary, but the illustrated portion of the light curve is wholly outside eclipse). From GCVS data on four typical small amplitude red supergiant variables (μ Cep, α Her, α Ori, and α Sco) we find a mean maximum amplitude of $1^m.1$ with a dispersion among the four of $0^m.3$.

Contrast Figure 1 with Figure 2, which displays portions of the light curves of three red supergiant variables of large amplitude. From the complete published light curves (Smith 1974, Dinerstein 1973, Robinson 1970) we find a mean maximum amplitude of $4^m.2$ (visual) with a dispersion of $1^m.1$ among the three. Note that the amplitude of these three variables changes greatly with time, exhibiting a growth and decay on a time scale of several thousand days.

The light curves strongly suggest that the variables in Figure 2 have something in common which distinguishes them from the variables in Figure 1. However, the GCVS classification system places S Per with the SRc's, VY CMa with the Lc's, and VX Sgr erroneously with the SRb (giant) variables. While it is likely that these three stars could reasonably be classified SRc, this still would not adequately recognize their common characteristics. A classification system based on amplitude would, on the other hand, naturally group the three together.

We should consider whether this division into large and small amplitude variables is supported by observations of other stellar properties. The evidence on this point is suggestive though not conclusive. The three prototype large amplitude variables all have long semiregular periods, in excess of 500 days. In addition, Humphreys (1974) has found the three share certain spectral peculiarities. In particular, they have unusual energy distributions in the infrared and a weakening of the absorption lines in the visual portion of the spectrum. The three are also very strong OH and H_2O emission sources. The extent to which these properties distinguish between large and small amplitude variables remains to be clarified.

The division of red supergiant variables into two groups with greatly differing amplitudes does not seem to be restricted to the Galaxy. Evans (1971) has found that perhaps 15% of the M supergiants in the Small Magellanic Cloud (SMC) vary by 3 or 4 magnitudes in V. It is difficult to fix a similar percentage for the Galaxy, though the fact that all of the naked eye M supergiants belong to the small amplitude group indicates that the variables of lesser amplitude predominate here as well. However, Evans' estimate that only 1-2% of the galactic M supergiants show a large amplitude may be an underestimate. He suggested only S Per and Y Lyn as possible galactic large amplitude variables, whereas VX Sgr, VY CMa, and maybe S Aur also belong in that group. It must be remembered, too, that even large amplitude variables have extended spells during which their light changes little so that they might be mistaken for small amplitude variables. It is not impossible that large amplitude red supergiant variables are as frequent in the Galaxy as they are in the SMC.

If we acknowledge that the large and the small amplitude variables are distinct, can we say anything about why they are distinct? Unfortunately, there are no theoretical and few observational guides for us to follow in answering this question. The best we can do is to raise possibilities deserving examination. Both small and large amplitude red supergiants have been found to occur in h and χ Persei (S Per is a member of this cluster). We might therefore suppose that during its lifetime as a red supergiant a massive star passes through phases both of large and of small amplitude variability, the former having the briefer duration to account for the paucity of large amplitude variables. Evans (1971) has suggested that S Per may lie close to the tip of the red supergiant branch in the HR diagram since it is redder in (R-I) than the smaller amplitude supergiants in h and χ Persei. However, S Per has a large infrared excess which may arise from a circumstellar shell of dust and gas and this complicates the (R-I) index.

We conclude that it is not known why different supergiants exhibit different brands of variability. Nor is it certain whether the large and the small amplitude variables form completely distinct groups, or whether there exist some variables of moderate amplitude which bridge the gap between the extremes. Additional observations, and of equal importance, theoretical studies are required before the reasons for this dichotomy can be understood.

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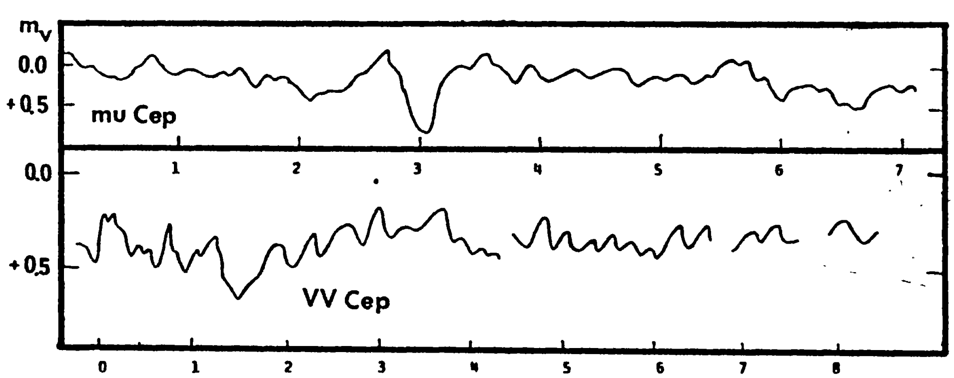

Figure 1. Portions of the visual light curves of two red supergiant variables of small amplitude. The ordinate is in magnitudes, the abscissae are in thousands of days from an arbitrary zero point. Note that the scales for the two variables are not the same. The curve for μ Cephei is from Hassenstein (1938), while that of VV Cephei is after Fredrick (1960).

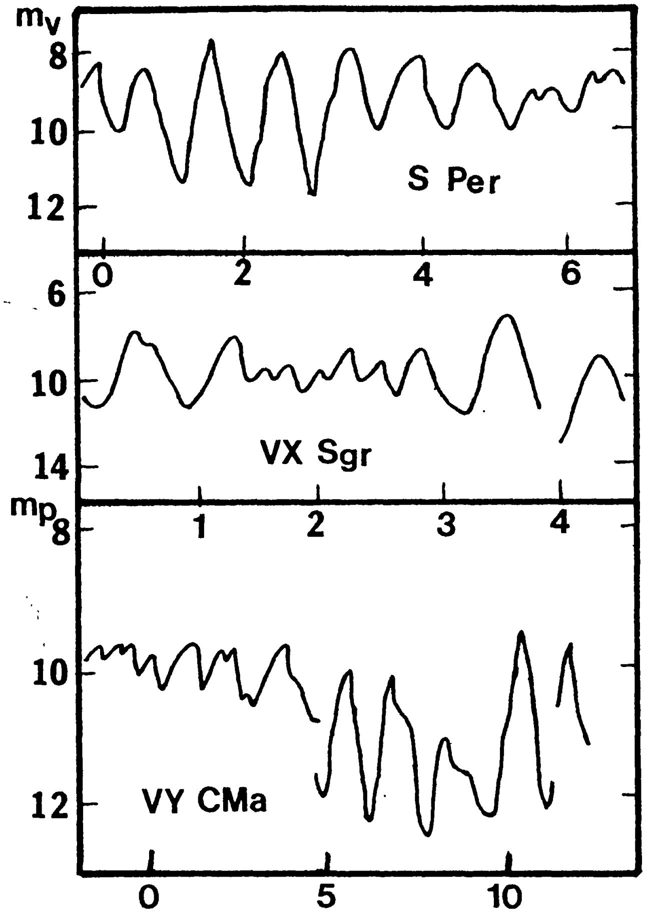

Figure 2. Portions of the light curves of three red supergiant variables of large amplitude. The ordinates for S Persei and VX Sagittarii are in units of visual magnitude, while for VY Canis Majoris photographic magnitudes are given. The abscissae are thousands of days from an arbitrary zero point. The visual light curves are based upon AAVSO observations while the photographic curve was determined by Robinson (1970) from Harvard plates.