NEW ASPECTS OF LONG-PERIOD VARIABLE STARS FROM HIPPARCOS: FIRST RESULTS

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ABSTRACT

The Long Period Variable stars are a mixing of several types of evolved red stars which are traditionnally distinguished only according to the amplitude and the regularity of the light curves. They can be oxygen or carbon rich or have an excess of s-elements. The thicknesses of their envelopes are strongly different.

The accuracy and the number of the Hipparcos data allows us to refine the distinction between the different types of LPVs in terms of stellar populations and to calibrate their absolute visual magnitudes. This provides new information on their evolutionary links and implications for the stellar and circumstellar physics.

Key words: variable stars; carbon stars; S stars; luminosity calibration.

1. INTRODUCTION

Although the Long-Period Variable stars (hereafter LPVs) posed specific problems to be observed by Hipparcos because of the large amplitude of their photometric variations, nearly 900 such stars have been finally measured during the mission. They are oxygen (O) or carbon-rich (C) variables or stars (S) of spectral type S. Their empirical classification into variability types – miras (M), semi-regular a (SRa) and b (SRb), semi-regular c (SRc) and irregular (L) – do not strictly correspond to different physical properties. They occupy a key stage of the stellar evolution, participate in the enrichment of the interstellar medium in heavy elements, and are peculiarly good tracers of Galactic history.

Hipparcos provides not only astrometric but also photometric data. The results obtained from photometric data will not be given in detail in this paper: they allow the detection of rapid variations which will be reported elsewhere (de Laverny et al. 1997). We will focus on results from astrometric data, which are related to Galactic populations and luminosity calibrations.

2. CALIBRATION

The calibrations were done using the LM method (Luri et al. 1996) that:

- allows to consider the sample as composed by several group not fixed *a priori*;
- produces unbiased estimates of mean velocities and axes of the velocity ellipsoid of each group and at the same time of their mean scale height;
- calibrates the luminosity of each group;
- gives the individual probabilities of belonging to each group;
- estimates the most probable distance of each star and thus provides estimations of the individual absolute magnitudes.

The input data are the parallaxes, proper motions, radial velocities and apparent magnitudes. The main part of this presentation is based on the use of mean V magnitudes at maximum light taken from Mennessier et al. (1997a) or AAVSO (Mattei et al. 1997). The other cases are clearly indicated.

The sample was composed of 882 LPVs treated altogether. The statistical test on calibrations done by assuming different number of groups in the sample indicates 6 groups as the most significant partition.

3. PERIOD-LUMINOSITY RELATIONS

We first looked at period-luminosity relations, which play an important role in the determination of the cosmic distance scale (see, e.g., Feast et al. 1989). In V no clear relation appears for any of the variability types. This is not a surprising result: indeed the V

magnitude of such stars reflects the properties of the stellar medium, but also of the circumstellar medium and so is not the best wavelength for studying a problem related with the pulsation of the stars.

In order to obtain a more meaningful result, a similar calibration of oxygen-rich miras using K magnitudes was performed. This calibration shows period-luminosity relations (Alvarez et al. 1997a) that depend on metallicity. Their slope and locations agree the distance modulus of the Large Magellanic Cloud deduced by van Leeuwen et al. 1997. More details can be found in Alvarez et al. (1997b).

4. GALACTIC POPULATIONS

Table 1 gives the estimated values of the more meaningful parameters of each one of the 6 groups found in the sample. These values can be interpreted as corresponding respectively to the bright disk population (BD), the disk population (D), old disk population (OD), thick or extended disk population (TD and ED). The number of stars in ED is too small to be sure of its real nature and to be taken into account in the interpretations.

Table 1. Estimated characteristics of the 6 groups in the sample: M_V is the mean absolute V magnitude, Z_0 the scale height in pc, V_0 and $sig(V)$ the mean velocity in the V direction and the corresponding axes of the velocity ellipsoid in km/s. N is the number of stars assigned to each group.

Group	BD	D	OD1	OD2	TD	ED
M_V	-3.6	-1.0	-1.1	-0.2	-1.2	-2.8
Z_0	104	126	217	249	409	1227
$sig(V)$	9	9	22	23	65	72
V_0	-11	-6	-35	-21	- 84	-235
N	66	240	85	438	58	5

The possibility, offered by the LM method, of separating either groups with the same kinematics but with different luminosities (OD1 and OD2) or groups with a similar luminosity but with different kinematics (D and TD) appears clearly in this result.

5. THE GROUPS AND THE VARIABILITY TYPES

The calibrations were made with all LPVs together, not taking into account their variability or/and spectral types. Let us look now at the distribution of the stars between the determined groups according to their types and thus let us analyse the contengency table of the kinematical groups and of the variability and spectral types.

The most reliable parameter for such an analysis is the index of attraction-repulsion because it takes into account both of the compared distributions. If this index is larger than 1, the group and the type are attractive, if it is smaller, they are repulsive. 1 indicates independancy. Table 2 gives these indices.

Table 2. Indices of attraction-repulsion between kinematical groups and variability and spectral types

Group	BD	D	OD1	OD2	TD
L.O	1.6	1.2	0.7	0.9	0.7
L.S	4.5	2.5			
L.C	2.3	2.4	0.2	0.3	
SRc.O	7.9	1.0	0.4	0.2	
SRb.C	1.9	2.0	0.9	0.4	0.5
SRa.C		2.8	0.8	0.3	
M.C		1.9		0.9	0.6
SRb.S		1.5		0.4	3.1
M.S	1.2	1.7	0.9	0.7	
SRb.O	0.2	0.6	0.9	1.3	1.1
SRa.O		0.4	2.3	1.1	2.6
M.O	0.1	0.3	1.5	1.3	1.5

It can be seen that, with the increase of their mean age (i.e. from BD to TD) the groups become more attractive from irregular variables to miras and from carbon-rich to oxygen-rich stars. In other words, for a given spectral type, the most initially massive stars become preferentially L-irregular variables and miras seem to correspond to initially less massive stars. Semi-regular variables occupy the intermediate place.

6. FROM OXYGEN TO CARBON-RICH LPVS

Let us examine in more detail the ratio of the number of carbon to oxygen-rich miras and semi-regulars a and b according to the kinematical groups. These ratios are given in Table 3. We confirm the well-known result: in the mean the ratio of carbon to oxygen-rich LPVs is around 0.2–0.3. But we find a strong difference according to the groups: the relative number of carbon stars strongly increases with increasing initial mass from less than 0.1 to 0.7 or more. This can be due to more efficient dredge-ups for more massive stars but also to the influence of the metallicity on the evolution along the Asymptotic Giants Branch (AGB) (Busso et al. 1995).

Table 3. Ratio C/O of the number of carbon to oxygen-rich LPVs according to the kinematical groups.

Group	BD	D	OD1	OD2	TD	all
all	0.4	0.7	0.1	0.1	0.05	0.2
M		0.7		0.1	0.05	0.13
SRa		1.4	0.14	0.15		0.3
M+SRa		1.0	0.03	0.1		0.16
SRb	2.0	0.8	0.25	0.1	0.1	0.25

7. S STARS

LPVs of S spectral type have an excess of s-elements. Such stars can be intrinsic S stars i.e. processing s-

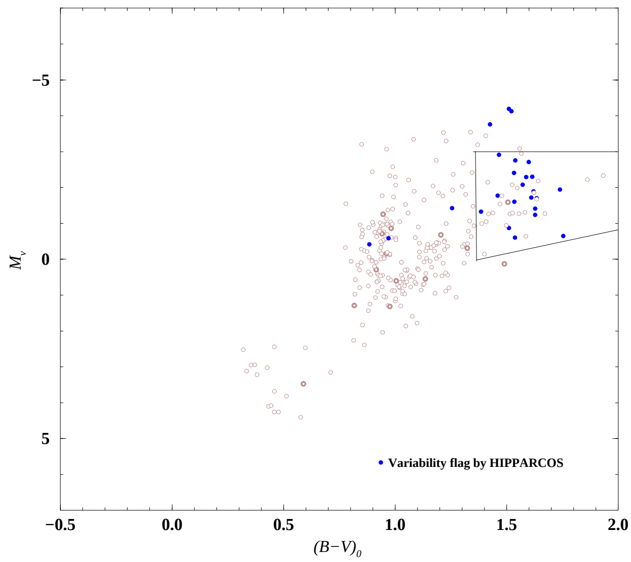

Figure 1. Distribution of Ba stars in the $[M_v, (B-V)_0]$ plane from Hipparcos data. Circles indicate Ba stars with a variability flag. Lines show the location of LPVs of S spectral type.

elements, or extrinsic S stars i.e. enriched by a mass transfer phenomenon from an evolved companion as is the case for Barium stars. Independently of the calibration of LPVs, we also performed a calibration of Barium stars (Mennessier et al. 1997b Luri et al. 1997). Some Ba stars are discovered as new photometric variables by Hipparcos.

We have shown that nearly all of these variable Ba stars are located at the upper right end of the giant branch, very close to the AGB. We deduce that they could be 'false' Ba stars, i.e. not enriched in s-elements by an already evolved companion but 'true' AGB stars processing such elements. Figure 1 indicates these stars among all the sample of Ba stars and at the same time the location of LPVs of spectral type S from the present calibration, in the $[M_v, (B_T - V_T)_0]$ plane. The coincidence of both locations enhances the suspicion about the special status of these stars among the Ba stars. It also proves the reliability of the LM method of calibration.

We find one S LPV brighter ($M_v = -4.6$) and younger (only this one belongs to the group BD) than the others. If we look at the results shown by van Eck et al. (1997), this S LPV could be Tc-rich.

8. CONCLUSION

This is only a brief view of the results that can be obtained about LPVs from Hipparcos data in spite of the difficulty of observing these faint and particularly red stars.

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