Mem. S.A.It. Vol. 79, 726

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Modeling M3 RR Lyrae light curves

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Abstract. Nonlinear convective pulsation models of RR Lyrae stars are used to obtain a theoretical fit of the observed light curves for a number of pulsators in the Galactic globular cluster M3, with the purpose of constraining their intrinsic stellar parameters and the cluster distance modulus. The dependence of the fit quality on the input stellar properties is investigated and the self consistency of the adopted theoretical scenario is discussed.

Key words. Stars: evolution – Stars: variables: RR Lyr – Stars: distances

1. Introduction

An important advantage of nonlinear convective pulsation models is the possibility to predict the time variations of the relevant stellar properties, along a pulsation cycle, and in particular to reproduce the observed light and radial velocity curves of true pulsators.

The model fitting of light curves has been successfully applied to both Classical Cepheids and RR Lyrae (Wood, Arnold and Sebo 1997, Bono, Castellani, Marconi 2000, 2002, Keller & Wood 2006).

In this poster we apply the method to seven RR Lyrae (4 RRc and 3 RRab, see Table 1) belonging to the Galactic globular cluster M3 and observed by Corwin & Carney (2001). Specific pulsation models with Z=0.001, Y=0.24 were computed by means of the nonlinear nonlocal time-dependent convective pulsation code adopted by our group (Bono, Castellani, Marconi 2000 and references therein). A detailed discussion of this investigation can be found in Marconi & Degl'Innocenti (2007, hereinafter MD07).

2. Fit of V128 light curve: effects of variations in the input model parameters

Isoperiodic model sequences for the observed period of V128 were built. The resulting bolometric light curves were transformed into the observational bands by means of the static model atmospheres by Castelli, Gratton & Kurucz (1997a). The three panels of Fig.1 show the dependence of the model fitting on variations of effective temperature and luminosity at fixed mass (left), of mass and effective temperature at fixed luminosity (middle) and of mass and luminosity at fixed effective temperature (right).

Similar results are obtained in the B and I bands. This analysis seems to suggest that the key parameter affecting the light curve morphology is the effective temperature. By ac-

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Table 1. Observed properties of the investigated RR Lyrae.

Star	Period	$< V >$	$< B > - < V >$	Type
V128	0.292	15.620	0.216	c
V75	0.314	15.626	0.240	c
V152	0.326	15.496	0.201	c
V126	0.348	15.609	0.265	c
V72	0.456	15.679	0.247	ab
V6	0.514	15.686	0.285	ab
V120	0.640	15.676	0.384	ab

Table 2. Accepted ranges of the physical parameters (mass,luminosity and effective temperature) for variables V128, V126, V72 and V152, together with the corresponding range of apparent visual distance modulus and intensity weighted (B-V) color. For the V152 variable the range in temperature (color) has not been calculated (see MD07).

Variable	Mass [$M_\odot$]	log($L/L_\odot$)	T_{eff} [K]	μ_V [mag]	<B> - <V> [mag]
V128	0.60÷0.71	1.595÷1.670	7050÷7150	14.92÷15.11	0.227÷0.240
V126	0.60÷0.75	1.683÷1.775	7020÷7080	15.12÷15.35	0.235÷0.244
V72	0.60÷0.73	1.643÷1.710	6900÷7000	15.04÷15.22	0.227÷0.237
V152	0.60÷0.69	1.666÷1.711		14.94÷15.04	

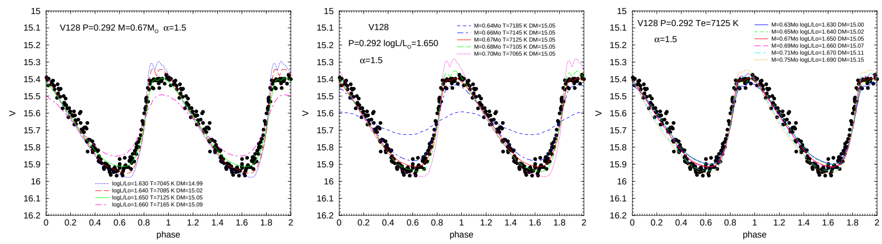

Fig. 1. Predicted light curves constrained to the observed period of V128 for the labeled fixed values of mass (left panel), luminosity (middle panel) and effective temperature (right panel).

cepting only the models reproducing the observed light curve within 0.05 mag at all the pulsation phases, we obtain the ranges for the distance and the stellar parameters reported in Table 2.

3. Model fitting of the other stars

A similar study is performed for the other selected stars. Fig. 2 shows the results at fixed effective temperature for V126, V72 and for the more luminous variable V152 (see Table 1). We selected this star because a further check of the reliability of the estimated cluster distance modulus is to analyze the properties of pulsators with a different luminosity: as these stars are also cluster members, the obtained distance modulus has to be in agreement with the previous results. One of the possible solutions for variables V75 and V6 is shown in MD07. No reasonable fit is obtained for the relatively red, long period RRab V120. However for the very red RR Lyrae, the modeling of the light curve morphology already appeared problematic in previous applications (see e.g

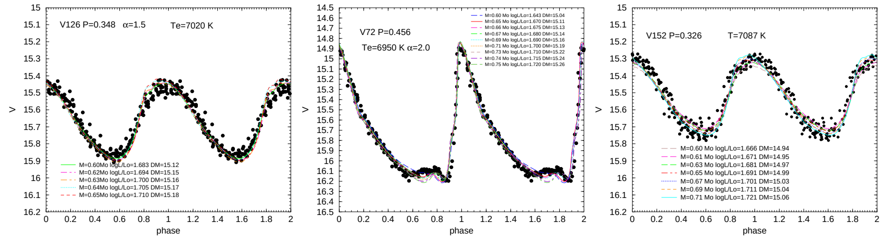

Fig. 2. Dependence of the modeling of V126, V72, V152 light curve on the input parameters when the effective temperature is kept fixed.

Marconi & Clementini 2005); this is probably due to the remaining uncertainties in the treatment of the coupling between pulsation and convection in the hydrodynamical models. The obtained ranges for all the selected stars are reported in Table 2.

4. Conclusions

We have successfully modeled the light curves of six variables (4 RRc and 2 RRab) of the globular cluster M3, covering a significant portion of the instability strip and a variety of periods and light curve morphologies. For V128, V152, V126 and V72 the obtained acceptable ranges of stellar parameters (mass, luminosity and effective temperature) and distance modulus are self-consistent and in agreement with stellar evolutionary predictions. Moreover a general agreement can be found with the physical parameters provided by Cacciari et al. (2005, see MD07 for details) on the basis of a multicolor study. For the other two pulsators (V75 and V6), that show morphological features similar to the previous ones, the obtained stellar parameters and distance moduli are consistent with the already found ranges, confirming the previous estimates. These results represent a cross check for both evolutionary and pulsational theories.

Our final estimate for the distance modulus is μ_V=15.10± 0.1 mag as derived as a mean of the individual determinations, while taking also into account the evolutionary constraints on the pulsator masses (see MD07), one obtains a weighted mean value of 15.05±0.02.

Our obtained distance modulus is consistent, within the uncertainties, with the results from other methods, for example with the determination by Ferraro et al. (1999), obtained from the comparison between the observed and predicted Zero Age Horizontal Branch luminosity, as well as with the results by Marconi et al. 2003, based on additional pulsational methods (see their Table 4). The precision of the technique could be further improved if accurate radial velocity curves will be available together with photometric data covering both the optical and the near-infrared bands.

Acknowledgements. We are grateful to V. Castellani who inspired this work and constantly supported us. We sincerely miss his personality, clearness and enthusiasm in approaching the different issues of stellar astrophysics.

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