ÉVOLUTION DE LA PÉRIODE DES RR, MISE À JOUR 11.2007
III. Period variations in field RRc stars derived from the GEOS database

1. Introduction

Lors de la réunion du GEOS qui a eu lieu à Carona du 30 avril au 1er mai 2007, nous avions projeté d'étudier l'évolution de la période des RRc comme nous l'avions fait pour les RRab. Un tel projet avait été rédigé en anglais au milieu de 2007, mais il n'avait pas été publié, la priorité ayant été accordée à la finalisation de notre article pour les A&A (Le Borgne et al., 2007). Nous l'avons maintenant complété avec les nouveaux maxima disponibles, tout en conservant l'usage de l'anglais.

RR Lyrae variables are low-mass stars in a core helium burning phase; they fill the part of the HR diagram where the horizontal branch intersects the classical instability strip. The RRc variables have periods from 0.2 to 0.5 d and amplitudes not greater than 0.8 mag. V with nearly symmetric, sometimes sinusoidal light curves. They are pulsating in the first-overtone mode and are, on an average, a little bluer than the RRab Lyrae stars.

The crossing of the instability strip of the RRab variables can take place in both directions; as a consequence, the periods could be either increasing if the stars evolve from blue to red or decreasing if they evolve from red to blue. It is perhaps also the case of the RRc stars. Moreover, it is known that the RRc Lyrae stars are showing a much more complex and irregular behaviour than the RRab and their observed rate of period variation is still an unknown quantity despite its importance as a test for the stellar evolution theory.

In the present paper, we used the GEOS RR Lyr database (Le Borgne et al., 2006 – 2007) to study the period variations of the best observed RR Lyrae stars belonging to the RRc sub-class.

2. Data analysis

We extracted, from the GEOS database, the RRc stars for which the times of maximum brightness span more than 40 yr. Such stars are less numerous than the RRab stars for several reasons: there are less RRc than RRab, the amplitude of their light variation is generally smaller and the more sinusoidal shape of their light curve makes the determination of the times of maxima more difficult giving low accuracies. As a consequence, we found only 21 RRc Lyrae stars with enough times of maxima spanning 40 yr or more and without to much long gap making the evaluation of the cycle value to be assigned to old maxima uncertain.

The period of ten of the stars remained constant since they were observed, the period of seven other stars was irregular, whereas two RRc showed a period with a constant rate of increase and two RRc showed a period with a constant rate of decrease. The different groups of stars are analysed in more details hereafter.

2.1. Stars with constant period

Table 1: Refined linear elements for stars showing a constant period

Star	N_{max}	Time (yr)	Epoch	Period (d)	s.d. (d)	Spect. (GCVS)	Metal. (Fe/H)	Ampl. (mag)	Rising (% p)
NU And	33	41	38651.5340	0.31353491	0.0282			0.5 (p)	
V1070 Aql	21	64	28045.3704	0.36641771	0.0194				
AE Boo	42	65	30388.2001	0.31489332	0.0318	F2	79	0.44 (V)	45
ST CVn	43	93	40390.6488	0.32905655	0.0294	A1	- 129	0.56 (V)	43
YZ Cap	20	63	43729.7387	0.27345691	0.0202				
U Com	24	78	24961.4507	0.29273844	0.0131	A9	- 22	0.47 (V)	35
LS Her	22	69	28004.9464	0.23080773	0.0214	A5		0.33 (V)	40
V458 Her	47	71	27719.2530	0.35997946	0.0290			0.6 (V)	31
TV Lyn	64	85	40950.9302	0.24065140	0.0175	A6		0.42 (V)	42
DH Peg	134	56	44463.5784	0.25551068	0.0211	A5-F0.5	- 70	0.67 (V)	39

Notes : metallicity is from Fernley et al., (1998) ; sp., ampl. and rising time are from GCVS 85
s.d. = standard deviation

We note that those 10 RRc Lyrae stars have relatively short period (<0.37 d) with very different metallicity. None of them is catalogued with a Blazhko effect in the GCVS 85. However, ST CVn is reported as a multiperiodic star (Fitch et al., 1966). Fernley et al. (1998) wrote that LS Her has a too short period to be an RRc and he did not study it. V1070 Aql is noted RR in GCVS but period and light curve indicate an RRc.

2.2. Stars with irregular period

Table 2: Linear "mean" elements for stars showing irregular period

Star	Max	Time (yr)	Epoch	Period (d)	s.d. (d)	Sp. (GC)	Metal. (Fe/H)	Ampl. (mag)	Rising (% p)	Bl. effect
VW CVn	40	105	19486.2709	0.42498597	0.0485			0.46 (V)	46	B:
RZ Cep	385	117	42635.5323	0.30866533	0.1578	A0-F2	9	0.64 (V)	32	B
HY Com	33	96	44056.3776	0.44861105	0.0781			0.48 (V)		
RV CrB	261	100	42925.8668	0.33162931	0.4209	A9	- 125	0.56 (V)	36	B:
VZ Dra	289	45	43361.3890	0.32102744	0.0199	A		0.8 (p)		B:
T Sex	40	81	41384.3584	0.32470452	0.1018	F4		0.51 (V)	42	
SX UMa	112	107	45109.3880	0.30712539	0.1366	A4-F5	- 154	0.63 (V)	38	

VW CVn : mean $(B-V)_J$ = 0.27 mag deredded (J. Vandenbroere et al., 2002)

We note that the 7 RRc Lyrae stars with irregular period have period >0.3 d, on an average longer than the period of the RRc with constant period. The presence of a Blazhko effect has been reported for RZ Cep and is probable for three of the other irregular RRc whereas short variations have been mentioned for HY Com (Oja, 1996). Worse: "The acuteness and rise times of VZ Dra is appropriate to RRc stars but the light curves appear to be more like those of RRab stars. We have classified it tentatively as RRab star but suggest it is an interesting object for further study." (Schmidt et al., 1995). In fact, nearly all those stars have to be observed and study more intensively.

2.3. Stars with a linearly variable period

The O-C of four RRc stars are showing a parabolic pattern when linear elements are used (see fig. 1). This pattern is originated by a regular period variation. TV Boo and RU Psc have a period with a constant rate of increase whereas the period of EG Del and SS Psc are decreasing at a constant rate.

Table 3: Parabolic elements for RRc stars showing a linearly increasing or decreasing period

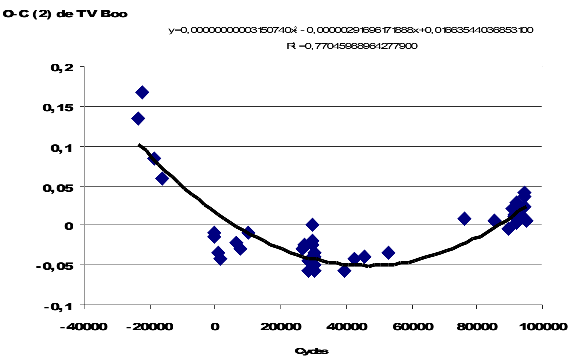
Star	N_m	Time (yr)	Epoch	Period (d)	Quad t (10^{-10})	R^2	dP/dt 10^{-10} j/j	Sp. (GC)	Metal Fe/H	Rising (% p)
TV Boo	54	101	24609.5419	0.31255971	+0.315	0.7705	+2.02	A7-F2	–38	35
RU Psc	100	82	40143.3236	0.39033852	+1.326	0.2982	+6.80	A9.5	–131	48
EG Del	24	74	32580.4555	0.3248470	–0.702	0.7948	–4.32			30
SS Psc	79	95	19130.3435	0.28779199	–0.099	0.2099	–0.76	A7-F2		44

Ampl. (mag) : TV Boo 0.59 V ; RU Psc 0.47 V var ; EG Del 0.5 p ; SS Psc 0.48 V
Blazhko effect : TV Boo and SS Psc
Metallicity : from Fernley et al. (1998).

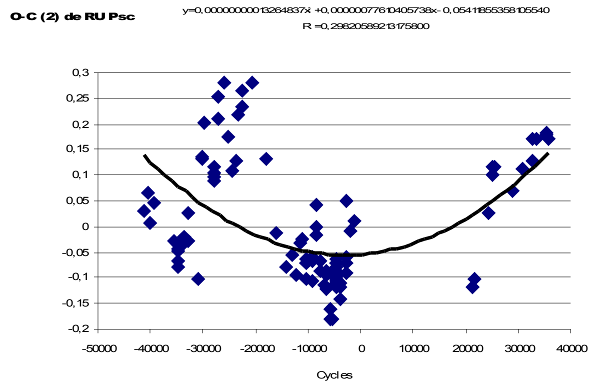
Of course, the correlation coefficients for the parabolic elements of RU Psc and SS Psc are too low, partly owing to the faint accuracy of the observations and the rounded shape of the maxima, but also because RU Psc has light curves with changing shapes and because the rate of decrease of SS Psc is very faint with the presence of a Blazhko effect. However, the rates of change of the four RRc are very similar to those of the RRab Lyrae stars with constant period increase or decrease.

Fig. 1 : O-C values for the three RRc stars with period showing a constant rate of variation

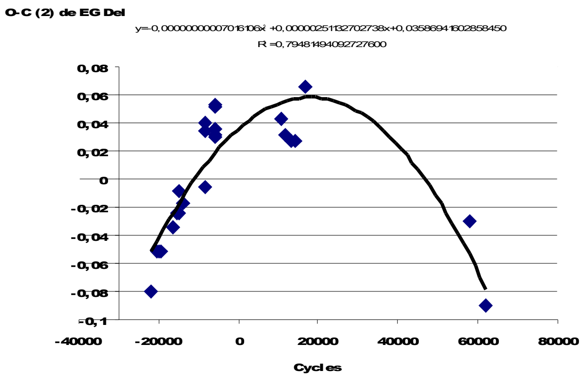
TV Boo



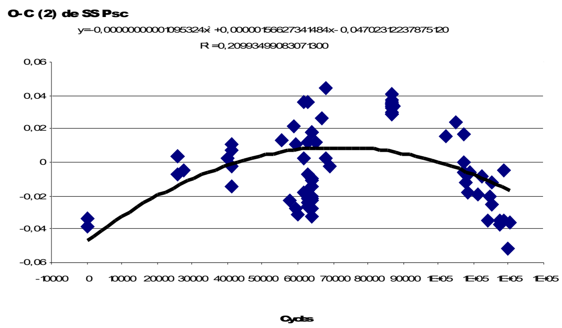
RU Psc



EG Del



SS Psc



3. Discussion

In the literature, we found that the period along the blue edge for first-overtone pulsation is a function of mass, luminosity and helium content, with a marginal dependence on Z (the amount of metals) (Caputo et al., 1998). Generally, there are two or three times less RRc Lyrae stars than RRab. The RRc have shorter periods, but they are following the same ratio period / magnitude and period / colour index. RRc and RRab are distinct groups but without real discontinuity (Nemec et al., 1994). Generally, the first-overtone does not descend under a certain luminosity where we obtain only pulsators in fundamental mode. In the region of the instability strip where both the fundamental and first-overtone present a stable limit cycle, first-overtone attain vanishing amplitudes close to the high-temperature edge (FOBE), whereas fundamental pulsators are close to the low temperature edge (TRE) (Nemec et al., 1994).

Thanks to the maxima gathered in the GEOS database, we have been able to study the period evolution of 21 RRc Lyrae stars during at least 40 years. The number of irregular periods is proportionally around twice what we found for the RRab Lyrae stars (Vandenbroere, 2008) and that corresponds to what was yet known. If we have found a fainter percentage of RRc than of RRab with constant rates of change, it is probably because it is more difficult to obtain accurate times of maxima on RRc shaped light curves.

Of the 21 RRc studied here, six are noted in the GCVS with a, sometimes, probable Blazhko effect and two other ones have changing shapes of their light curves : RU Psc (Szeidl, 1975) and ST CVn (Peniche et al., 1989). Only ST CVn belongs to the group of RRc with constant period.

4. Conclusions

The evolution of the period of the RRc Lyrae stars does not seem to be very different than this of the RRab, except that it is more often irregular. It seems also that the longer the period, the more often it is irregular. The RRc stars are unfortunately too seldom and badly observed. However, they are less numerous and nowadays it is no more so much difficult to obtain quality photometry. The knowledge of what is going during the RRc phase of the live of some stars is interesting and important to obtain a comprehensive track of all their evolution. Some disparities of evolution of RRc with regard to the RRab would help to understand the two groups of variable stars.

5. Bibliography

- Caputo F. et al., 1998, MNRAS 293, 364
- Fernley J. et al., 1998, A&A, 330, 515
- Fitch W.S. et al., 1966, Comm. Lunar Planet Lab., 71, 5
- Kholopov P.N. et al., 1985, General Catalogue of Variable Stars
- Le Borgne J.F. et al., 2007, A&A, 476, n° 1
- Le Borgne J.F. et al., 2006 – 2007, the GEOS RR Lyrae stars database, http://dbrr.ast-mip.fr
- Nemec J.M. et al., 1994, A.J., vol 108, n° 1, 222
- Oja T., 1996, IBVS 4276
- Peniche R. et al., 1989, A&A, 209, 56
- Schmidt E.G. et al, 1995, the A.J., vol 109, n° 3, 1239
- Szeidl, 1975, IAU Colloquium 29, Multiple Periodic Variable Stars, ed. E. Fitch, Dordrecht, p. 133
- Vandenbroere J. et al., 2002, GEOS Circular RR 18

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