Discovery of peculiar double-mode pulsations and period doubling in KEPLER RRc variables

Discovery of Peculiar Double-Mode Pulsations and Period Doubling in *Kepler* RRc Variables

P. Moskalik, R. Smolec, K. Kolenberg, J. Nemec, A. Kunder, M. Chadid,
G. Kopacki, R. Szabó + WG#13 members

We analyzed the Long Cadence (29.4 min) photometry of four first overtone RR Lyr-type stars (RRc stars) observed by the *Kepler* telescope. Only Q0, Q1 and Q2 datasets were used, spanning 138 days. Analysis including the remaining *Kepler* data will be discussed elsewhere (Moskalik et al. 2012, in preparation).

The frequency analysis was conducted with the standard consecutive prewhitening technique (see e.g. [3]). All four RRc variables turned out to be multiperiodic. Fig. 1 shows the prewhitening sequence for KIC 5520878. After removing the dominant frequency $f_1 = 3.715$ c/d and its harmonics, the Fourier transform of the residuals (middle panel) is dominated by a strong peak at $f_2 = 5.879$ c/d, its harmonic and their combinations with the primary frequency, f_1. The period ratio of the two modes is $P_2/P_1 = 0.6319$. After prewhitening the data with both f_1, f_2 and

P. Moskalik
Copernicus Astronomical Center, Warszawa, Poland, e-mail: pam@camk.edu.pl

R. Smolec
Institut für Astronomie, Universität Wien, Austria

K. Kolenberg
Harvard College Observatory, Cambridge, MA, USA & Instituut voor Sterrenkunde, K.U. Leuven, Belgium

J. Nemec
Department of Physics and Astronomy, Camosun College, Victoria, British Columbia & International Statistics and Research Corporation, Brentwood Bay, British Columbia, Canada

A. Kunder
Cerro Tololo Inter-American Observatory, La Serena, Chile

M. Chadid
Observatoire de la Côte dAzur, Université Nice Sophia-Antipolis, France

G. Kopacki
Astronomical Institute, University of Wrocław, Wrocław, Poland

R. Szabó
Konkoly Observatory, Budapest, Hungary

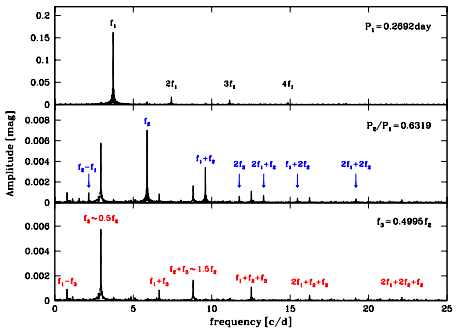

Fig. 1 Prewhitening sequence for KIC 5520878. Upper panel: FT of original data. Middle and bottom panels: FT after consecutive prewhitening steps.

their harmonics and combinations (bottom panel), the strongest remaining signal appears at $f_3 = 2.937$ c/d, *i.e* at $\sim 1/2\,f_2$. Thus, f_3 is not an independent frequency, but a *subharmonic* of f_2. The second subharmonic at $\sim 3/2\,f_2$ is also clearly visible. All the remaining peaks in the Fourier transform (FT) correspond to combination frequencies.

The frequency spectra of the other three *Kepler* RRc stars are very similar. The strongest secondary peak always appears at $f_2/f_1 = 1.58-1.63$ (or $P_2/P_1 = 0.612-0.632$). Also, in each star we detect at least one subharmonic of f_2, either at $\sim 1/2\,f_2$ or at $\sim 3/2\,f_2$. The presence of subharmonics is a characteristic signature of a *period doubling*. After RRab Blazhko stars [9] and BL Her-type stars [5], the RRc variables are the third class of pulsators in which period doubling has recently been found.

Peculiar period ratios of $\sim 0.60-0.63$ are not unique to the RRc stars observed by *Kepler*. They have also been found in 9 other RR Lyr-type variables [2, 4, 7]. Except for the double mode star AQ Leo, all the variables belong to the RRc type. Together with the four *Kepler* stars, they constitute a new class of double-mode RR Lyr-type pulsators.

Secondary modes with the same puzzling period ratios have also been detected in classical Cepheids [3, 6, 8]. Again, they are found only in the overtone pulsators. Both for the Cepheids and for the RR Lyr-type stars, the secondary frequency, f_2, falls *between* the frequencies of the third and the fourth radial overtones [1]. This implies that f_2 must correspond to a *nonradial* mode of oscillation.

References

1. Dziembowski, W., Smolec, R.: AIP Conf. Proc., **1170**, 83–85 (2009)
2. Gruberbauer, M., Kolenberg, K., Rowe, J.F. et al.: MNRAS, **379**, 1498–1506 (2007)
3. Moskalik, P., Kołaczkowski, Z.: MNRAS, **394**, 1649–1666 (2009)
4. Olech, A., Moskalik, P.,: A&A, **494**, L17–L20 (2009)
5. Smolec, R., Soszyński, I., Moskalik, P. et al.: MNRAS (in press), arXiv:1109.5699 (2011)
6. Soszyński, I., Poleski, R., Udalski, A. et al.: AcA, **58**, 163–185 (2008)
7. Soszyński, I., Udalski, A., Szymański, M.K. et al.: AcA, **59**, 1–18 (2009)
8. Soszyński, I., Poleski, R., Udalski, A. et al.: AcA, **60**, 17–39 (2010)
9. Szabó, R., Kolláth, Z., Molnár, L. et al.: MNRAS, **409**, 1244–1252 (2010)