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Target selection of classical pulsating variables for space-based photometry

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Abstract. In a few years the *Kepler* and *TESS* missions will provide ultra-precise photometry for thousands of RR Lyrae and hundreds of Cepheid stars. In the extended *Kepler* mission all targets are proposed in the Guest Observer (GO) Program, while the *TESS* space telescope will work with full frame images and a ∼15-16th mag brightness limit with the possibility of short cadence measurements for a limited number of pre-selected objects. This paper highlights some details of the enormous and important work of the target selection process made by the members of Working Group 7 (WG#7) of the *Kepler* and *TESS* Asteroseismic Science Consortium.

1. *K2* target selection and proposals

The new era of space-based photometry has already begun. The reaction wheel failure of *Kepler* space telescope opened a great possibility to build up a golden sample for many types of variable stars. In the *K2* mission, *Kepler* observes the ecliptic plane and changes field of view in every ∼80 days (Howell et al. 2014). The mission started in March of 2014 with Campaign 0 (C0) and is planned to end in April of 2018 with Campaign 17 (C17). The invitation to the scientific community to propose targets for ultra-precise measurements in the GO Program motivates many astronomers to come forward with new ideas. Working Group 7 (WG#7) is interested in RR Lyrae and Cepheid stars, and it is responsible for the proposals of these objects for each campaign.

WG#7 has submitted altogether 22 proposals, listed in Table 1, at the time of writing this article. According to the initial concept, proposals were separated by variability types and cadence type (30 or 1 min). We dedicated proposals to dwarf galaxies and globular clusters as well. After C1, joint proposals were submitted for two or three fields. We typically submitted four proposals for each of the first four campaigns. Afterwards the calls were made through the 2-step process of the NASA proposal system. Since then we have submitted united proposals for short and long cadence targets for the RR Lyrae and Cepheid stars.

The main goal of the proposals is to obtain all RR Lyrae and Cepheid targets that fall on the *K2* fields. To build up a golden sample it is crucial to calibrate

Table 1. RR Lyrae and Cepheid proposals in the *K2* mission.

Campaign	Proposal Number	PI	Topic
C0	GO0051	Molnár	Long cadence Cepheid targets
	GO0053	Plachy	Short cadence Cepheid targets
	GO0055	Szabó	Long cadence RR Lyrae targets
	GO0124	Kolenberg	Short cadence RR Lyrae targets
C1	GO1018	Plachy	Long cadence RR Lyrae targets
	GO1019	Molnár	RR Lyrae in the dwarf galaxy Leo IV
	GO1021	Molnár	Long cadence Cepheid targets
	GO1067	Kolenberg	Short cadence RR Lyrae targets
C2 & C3	GO2027 & GO3027	Plachy	Short cadence RR Lyrae targets
	GO2039	Molnár	Pulsating variables in M4 and M80
	GO2040 & GO3040	Molnár	Long cadence RR Lyrae targets
	GO2041 & GO3041	Molnár	Type I and II Cepheids
C4 & C5	GO4066 & GO5066	Molnár	Type I and II Cepheids
	GO4069 & GO5069	Szabó	Exploiting RR Lyrae stars
C6 & C7	GO6082 & GO7082	Kolenberg	RR Lyrae stars from different populations
	GO7014	Molnár	Sampling the Cepheid instability strip
C8 & C10	GO3-0039	Szabó	Pulsation dynamics and Galactic structure of RR Lyrae stars
	GO3-0041	Molnár	Extragalactic Cepheids in IC 1613
C9	DDT	Smolec	RR Lyrae stars in the Galactic bulge
	DDT	Plachy	Classical and Type II Cepheids in the Bulge
C11, C12 & C13	GO4-0070	Plachy	Cepheids throughout the Galaxy
	GO4-0111	Molnár	The grand *K2* RR Lyrae survey

the classification and analysis methods. Our scientific justifications focus on the most pressing questions raised recently: the origin of dynamical phenomena, the low amplitude additional modes and the mysterious period ratios. The existence of nonradial modes and the explanation of the Blazhko effect are still open questions. The *K2* mission also provides the opportunity for population and Galactic structure studies as well as statistical analysis of various phenomena. A limited number of targets is observed with 1 minute sampling. We select the most interesting or rare type of targets to propose for short cadence mode (Molnár, Plachy & Szabó 2014).

Our target selection process was first used for the Two-Wheel Concept Engineering Test that led to a detailed analysis of 33 RR Lyrae stars (Molnár et al. 2015). First we collect all known RR Lyrae and Cepheid candidates from the SIMBAD and VSX databases. Several sky surveys provide semi-automated variability catalogues and downloadable light curves as well. We found the Catalina Sky Survey (Drake et al. 2014), Lincoln Near Earth Asteroid Research (Sesar at al. 2013), All Sky Automated Survey (Pojmanski 2002), Northern Sky Variability Survey (Woźniak et al. 2004) extremely useful for the target selection. The next step is to select the stars that fall on silicon. We use the `K2FoV`[1] tool that has been developed by the Kepler GO Office for this purpose. The sky

[1]http://keplerscience.arc.nasa.gov/software.html, https://github.com/KeplerGO/K2fov

surveys overlap, so we have to do the cross-identification of the different catalogues. Because of the relatively high uncertainty in the coordinates of certain objects, we found this step to be more reliable if done manually. The last and the most important step is to check of the folded light curves of the targets. The visual inspection can reveal misclassified objects, erroneous published periods and potential short cadence targets as well.

Table 2. Number of proposed and accepted RR Lyrae and Cepheid targets.

Campaign	RR Lyrae targets			Cepheid targets		
	Proposed	Accepted	Success rate	Proposed	Accepted	Success rate
C0	68	10	**∼15%**	54	13	**∼24%**
C1	136	18	**∼13%**	4	4	**100%**
C2	86	61	**∼71%**	8	8	**100%**
C3	117	82	**∼70%**	1	1	**100%**
C4	86	83	**∼97%**	7	7	**100%**
C5	89	88	**∼99%**	4	4	**100%**
C6	206	206	**100%**	-	-	-
C7	528	528	**100%**	10	9	**90%**
C8	85	85	**100%**	190	190	**100%**
C9	200	N/A	N/A	184	N/A	N/A
C10	224	N/A	N/A	2	N/A	N/A
C11	1629	N/A	N/A	164	N/A	N/A
C12	181	N/A	N/A	6	N/A	N/A
C13	94	N/A	N/A	10	N/A	N/A

Table 2 summarizes the number of targets proposed and accepted in each field so far. The success rate of the proposals is quite high. The reason for the initial low percentages is mostly technical: the lack of `K2FoV` tool in C0 or the 5 degree roll of the field of view in C3. In some cases targets fell near the edge of the CCD and in one case the target is too bright to be measured. We note that the number of RR Lyrae and Cepheid stars measured in *K2* are not identical to the numbers of Table 2. Several additional targets are located in the superstamps of the globular clusters (C2) and the Galactic bulge (C9). Moreover, we predict a significant fraction of misclassified objects among the RRc, RRd and Cepheid candidates, but we also expect new findings among the pre-classified binaries.

2. *TESS* target selection

TESS will observe almost the entire sky and will download full frame images with 30-minute cadence (Ricker et al. 2014). Few hundred thousand targets will be selected for 2-minute sampling. Most of these are exoplanet candidates but 5 percent will be devoted to asteroseismic targets proposed by the *TESS* Asteroseismic Science Consortium. The target selection of these objects need the same careful process that we use in *K2* mission. The major difference will be in the brightness limit that is expected to be ∼12th mag for the short cadence objects reducing the number of the potential targets. In Figure 1 we plotted the continuous viewing zones of *TESS* around the ecliptic poles. 8 (18) RR Lyrae and 3 (35) Cepheid short cadence candidates around the North (South) Ecliptic Poles are marked with black circles and diamonds, respectively.

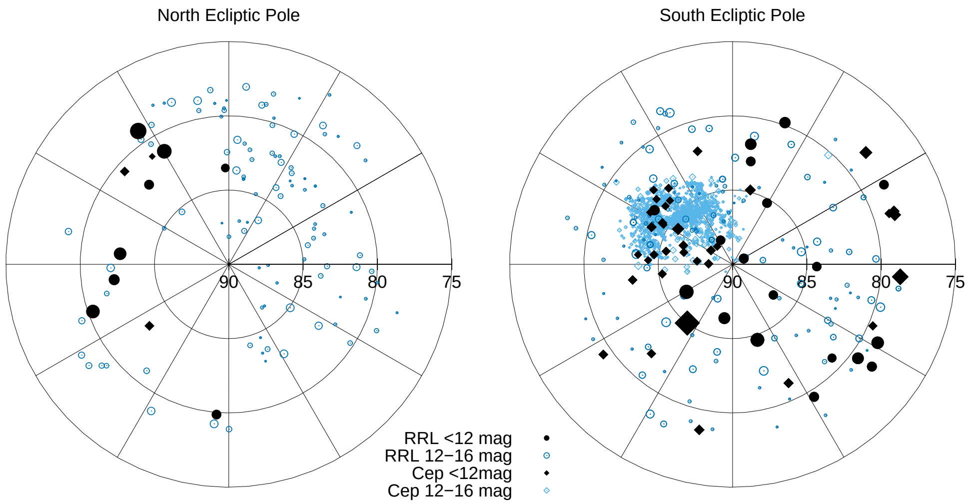

Figure 1. RR Lyrae and Cepheid stars in the *TESS* continuous viewing zone.

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