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Analysis of γ Doradus and δ Scuti stars observed by *Kepler*

Paul A. Bradley[1], Joyce A. Guzik[2], Lillian F. Miles[1], Jason Jackiewicz[3], Katrien Uytterhoeven[4], and Karen Kinemuchi[5]

[1]Los Alamos National Laboratory
XCP-6, MS F699, Los Alamos, NM 87545, USA
email: pbradley@lanl.gov, lfmiles@lanl.gov

[2]Los Alamos National Laboratory
XTD-NTA, MS T086, Los Alamos, NM 87545, USA
email: joy@lanl.gov

[3]Dept. of Astronomy, New Mexico State University
P.O. Box 30001, MSC 4500, Las Cruces, NM 88003, USA
email: jasonj@nmsu.edu

[4]Instituto de Astrofisica de Canarias (IAC)
E-38200, La Laguna, Tenerife, Spain
email: katrien@iac.es

[5]Apache Point Observatory,
P.O. Box 59, 2001 Apache Point Road, Sunspot, NM 88349, USA
email: kinemuchi@apo.nmsu.edu

Abstract. The *Kepler* spacecraft observed over 2000 faint stars that were part of our Guest Observer proposals. The stars were selected from the *Kepler* Input Catalog (KIC) to be in or near the γ Doradus or δ Scuti instability strips (8300 K $> T_{\rm eff} >$ 6200 K and $3.6 < \log g < 4.7$). The *Kepler* magnitude was < 16 and the contamination factor was $< 10^{-2}$. The goal was to extend the search for "hybrid" δ Sct-γ Dor pulsators to fainter magnitudes. By inspecting the light curves and Fourier transforms, we find 42 δ Sct candidate stars, 299 γ Dor candidates, and 36 "hybrid" candidate stars showing both types of variations.

Keywords. techniques: photometric, stars: variables: δ Scuti, stars: variables: γ Doradus

1. Motivation, analysis and results

The *Kepler* spacecraft launched on 6 March, 2009 has revolutionized stellar pulsation studies with its ability to gather nearly continuous (duty cycle $> 90\%$) data with micromagnitude precision. To better understand the statistics of δ Sct and γ Dor stars, we obtained Guest Observer (GO) data for multiple quarters. The first data set comes from Quarter 2 (Q2) and the last set we analyze in this paper is Q15. Almost all of the data are long cadence, with a few short-cadence data sets. Except for several of the 14 Cycle 1 Q2 – Q4 targets, these stars were chosen to have 8300 K $> T_{\rm eff} >$ 6200 K, $3.6 < \log g < 4.7$, and *Kepler* magnitude between 14.0 and 15.8. Recent *Kepler* observations show that the γ Dor and δ Sct stars have much overlap in the Hertzsprung-Russell and $\log g$ vs. $T_{\rm eff}$ diagrams (Grigahcène *et al.* 2010, Uytterhoeven *et al.* 2011).

In this paper, we take a "quick look" at the data to search for stars worthy of more detailed analysis. We use either MATLAB scripts written by J. Jackiewicz, or the "TOPCAT" (Taylor 2011) program to extract time series of the raw and corrected fluxes in ASCII format. We then removed outlying data points, divided the light curve by the mean value and wrote output that could be read by our Fourier Transform (FT)

Table 1. Fraction of γ Dor, δ Sct, and hybrid stars from different studies.

Star type	Grigahcène *et al.*	Uytterhoeven *et al.*	This work
γ Dor	116 (55%)	100 (21%)	299 (79%)
δ Sct	67 (27%)	203 (43%)	42 (11%)
hybrid	51 (23%)	172 (36%)	36 (10%)

program (Tukey 1967). All of these steps were carried out in an automated manner via Python scripts. Stars with asteroseismic potential will be subjected to more rigorous analysis at a later date.

So far, we have analyzed data from 2251 stars for Quarters 2 through 15. 1021 of these stars show a signal consistent with random noise. There are 1230 that show variability in their light curves ($>$ 20 ppm amplitude, with a range between 50 and 5000 ppm). Of these, 785 have longer period ($>$ 3 d) variations and most of these stars probably have starspots rotating in and out of view. A number of stars show variations consistent with being a short period Cepheid or something similar. We found 67 eclipsing or ellipsoidal binary systems with periods ranging from several hours to about 20 days. The remaining 377 variable stars consist of 42 δ Sct candidate stars, 299 γ Dor candidates, and 36 "hybrid" candidate stars showing both δ Sct and γ Dor variations.

We compare our observational results to those of Grigahcène *et al.* (2010) and Uytterhoeven *et al.* (2011) in Table 1. Our data set shows mostly γ Dor stars, which is consistent with the findings of Grigahcène *et al.* (2010) but not of Uytterhoeven *et al.* (2011). One reason for the difference is that the *Kepler* Asteroseismic Science Consortium (KASC) sample studied by Grigahcène *et al.*, and the even larger KASC sample analyzed by Uytterhoeven *et al.* included nearly all of the brighter (*Kepler* mag $<$ 14) stars in the *Kepler* field, as well as many previously known or suspected δ Sct stars; the KASC target stars also included more short-cadence observations able to identify high-frequency δ Sct stars. In contrast, our Guest Observer selection targeted stars in the *Kepler* input catalog with no prior observations, that were generally fainter and cooler, and so it is not surprising that a larger percentage of γ Dor variables were discovered. In future work, we plan to determine the relative fractions of γ Dor, δ Sct, and hybrid stars as a function of magnitude to see how the relative noise level affects the detection limits. We also plan to compare the H-R diagram location of the different types of variable stars relative to the boundaries of ground-based instability strips. The other readily apparent conclusions from these data are that *Kepler* can detect pulsations in 15th magnitude stars, and it can find δ Sct and hybrid stars even using only long-cadence data.

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