A Photometric Survey for Rapidly-Pulsating Hot Subdwarf Stars with SKYNET

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Background

Hot subdwarf B (sdb) stars were once red giant branch stars that had their outer layers stripped off due to interactions with a binary companion (Heber 2009). They have around half the mass of the sun and will fuse helium in their cores for approximately 100 Myr on the extreme horizontal branch.

Out of the thousands of known sdb stars, only about 100 are known pulsators. There are three main types of pulsators: (i) sdbV\textsubscript{a} stars, which show rapid p–mode pulsations, (ii) sdbV\textsubscript{b} stars, which show slow g–mode oscillations, and (iii) the hybrid sdbV\textsubscript{b} stars, which exhibit both types of pulsations.

Our survey focused on finding new rapid pulsators, which have periods from 1–10 minutes and amplitudes <10%. These pulsations are useful because they reveal information about the composition, mass, size, and density of hot subdwarf stars. Similar to white dwarfs, studying these stars helps to shed light on how physics works at temperatures and pressures we cannot easily recreate in laboratories on Earth.

Survey Description

We used SKYNET, a network of robotic telescopes located around the world (Reichart et al. 2005), to conduct our survey. Within SKYNET, we chose to use the 0.4–m PROMPT telescopes located on Cerro Tololo in Chile. PROMPT, like all SKYNET telescopes, can be controlled remotely via a simple web interface (see Figure 1).

Targets for our survey were selected primarily from the Online Subdwarf Database (Østensen, 2006); those in the Southern-hemisphere and brighter than V=15.5 were given top priority. For each target, we observed 2–4 hours of continuous time–series photometry with 30 s integration times and a 83% duty cycle. We used our own aperture photometry program in IDL to extract light curves and Period04 to compute discrete Fourier Transforms of the light curves to look for periodic signals.

Survey Stats

- Targets observed: 288
- Telescopes used: 4
- Frames taken: ~120,000
- Data size: ~480 GB
- Total integration time: 988 hr

Quick Summary:

- Targets not observed to vary: 281
- Variables found: 7

Overview of Variables Found:

- New sdb pulsators: 3
- Already known pulsators: 3
- New eclipsing sdb binaries: 1

<table>
<thead>
<tr>
<th>Survey Name</th>
<th>Sample Size</th>
<th>Variables Found</th>
<th>Yield (%)</th>
<th>Selection Criteria?</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>1200</td>
<td>20</td>
<td>1.7</td>
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<tr>
<td>Billeres</td>
<td>74</td>
<td>4</td>
<td>5.4</td>
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<tr>
<td>Dreizler</td>
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<td>1</td>
<td>8.3</td>
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<tr>
<td>Østensen</td>
<td>309</td>
<td>24</td>
<td>7.8</td>
<td>Yes (Tm)</td>
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<tr>
<td>This work</td>
<td>288</td>
<td>7</td>
<td>2.4</td>
<td>None</td>
</tr>
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</table>

TABLE 1 Summary of other photometric sdbV surveys.

Results & New Variables

<table>
<thead>
<tr>
<th>CS 1246</th>
<th>EC 10246-2707</th>
<th>HE 0341-2449</th>
</tr>
</thead>
<tbody>
<tr>
<td>A new sdbV, star</td>
<td>A new eclipsing HW Vir binary</td>
<td>A new sdbV, star</td>
</tr>
<tr>
<td>(Barlow et al. 2010)</td>
<td>(Barlow et al. 2013)</td>
<td>(Barlow &amp; Vultaggio, in prep)</td>
</tr>
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</table>

Figure 1: SKYNET web interface (skynet.unc.edu)

References

Kilkenny, D., et al., 2010, Information Bulletin on Variable Stars, 5927, 1
Østensen, R. H., 2006, Baltic Astronomy, 15, 85

FIGURE 1 SKYNET web interface (skynet.unc.edu)

FIGURE 2 Targets observed in our survey (red circles) plotted over all hot subdwarfs in the Online Subdwarf Database (black points). The celestial poles and equator are marked in blue for reference.

FIGURE 3 (Top) Maximum amplitude detected in the FT of each target’s light curve plotted against the mean noise level. Dotted and dashed lines represent the 3- and 4-sigma levels, respectively. Variables and pulsators found in the survey are plotted as red stars. (Bottom) Histogram of the mean noise levels of all survey observations.

FIGURE 4 (Top) Light curve of CS 1246, a new pulsating hot subdwarf discovered during the survey. (Bottom) Fourier transform of the light curve, which shows one strong signal at a period of 371.7 s.

FIGURE 5 (Top) Light curves of EC 10246-2707, a new eclipsing sdb + M dwarf discovered during the survey. (Bottom) Residual light curves after subtracting the best model fits from the MORO code.

FIGURE 6 (Top) Discovery light curve of HE 0341-2449, a new pulsating hot subdwarf. (Bottom) Fourier transform of the light curve, which shows a single oscillation at a period near 150 s.

Acknowledgements

We acknowledge the support of the National Science Foundation, under award AST-0707381 (BNB). We are grateful to SKYNET team members Dan Reichart, Aaron LaCluyze, Josh Haslup, and Kevin Iversen for their generous support and ample observing time over the years. Lastly, we also recognize Bart Dunlap and Chris Clemens for their unwavering support and useful insight.