Effects of the HeII ionization zones on oscillation frequencies
Applications to Kepler and CoRoT stars

Z. ÇELIK ORHAN, C. KAYHAN and M. YILDIZ*
*mutlu.yildiz@ege.edu.tr

Department of Astronomy and Space Sciences, Science Faculty, Ege University, 35100, Bornova, Izmir, Turkey

ABSTRACT. Solar-like oscillation frequencies of 93 target stars of Kepler and CoRoT are analyzed. In the present study, we present results for two of them. Recently, two new reference frequencies \( \nu_{\text{ref1}} \) and \( \nu_{\text{ref2}} \) are found in the spacing of solar-like oscillation frequencies of stellar interior models. In order to fit model frequencies to observational frequencies, we change model mass and hydrogen abundance. We also try to obtain similar patterns around \( \nu_{\text{min1}} \) and \( \nu_{\text{min2}} \) for model and observational frequencies.

INTRODUCTION. There are several paper about finding fundamental parameters of solar-like stars with asteroseismology in the literature. In this work, we analyze two Kepler target stars, namely, KIC 11244118 and KIC 8524425. The models of these stars are constructed with using the MESA evolution code (Paxton et al. 2011; 2013). For asteroseismic investigation, we use method which is explained in detail in Yildiz et al. (2014a, 2015). There are several minima in their \( \Delta \nu \) versus \( \nu \) graph. We check if observational and theoretical results are in agreement in such a graph.

Properties of the MESA code
In this study, these models are constructed by using Modules for Experiments in Stellar Astrophysics (MESA) evolution code (Paxton et al. 2011; 2013). Nuclear reaction rates are taken from Angulo et al. (1999) and Caughlan & Fowler (1988). Convection is treated with standard mixing-length theory (Böhm-Vitense 1958). MESA offers the opacity tables of Iiglesias & Rogers (1993, 1996) and includes their OPAL opacity tables with fixed metal distributions as the default option. We selected simple photosphere for atmospheric boundary condition. We do not use microscopic diffusion in the models. The model frequencies are computed using ADIPLS (Christensen-Dalsgaard 2008).

Figure 1. \( \Delta \nu \) versus \( \nu \) graph for model (MESA and AMP) and observational frequencies of KIC 8524425.

KIC 8524425 (Sub-giant Star)
KIC 8524425 (TYC 3142-1229-1) is an active star and visual magnitude is 9. MESA model frequencies are in better agreement with observational frequencies than AMP model frequencies. However, we see only part of \( \nu_{\text{min1}} \) for observational frequencies. We plot model and observational frequencies in Fig. 2. MESA model frequencies are very similar to the observed patterns in Fig. 3. Small separation between the oscillation frequencies (observation, MESA and AMP) and observational frequencies of KIC 11244118 is plotted in Fig. 4.

CONCLUSION. In the present study, we analyse two Kepler target stars (KIC 8524425 and KIC 11244118). We construct interior models for these stars with using the MESA evolution code. We compare our best model results with AMP models. Fundamental parameters and seismic properties of KIC 8524425 and KIC 11244118 are in agreement with observed values. For KIC 8524425 and KIC 11244118, patterns of model frequencies are very similar to the observed patterns in \( \Delta \nu \) versus \( \nu \) graphs (see in Fig. 1 and 3). Also, we have matched small separations of frequencies for KIC 8524425 and KIC 11244118 (see Fig. 2 and 4). Input parameters of MESA models (M, Z, \( \xi \)) are different from AMP, but model ages are found very similar for KIC 8524425. The model ages for KIC 11244118, however, are significantly different, approximately 2.7 Gyr. This discrepancy may arise from extremely low hydrogen abundance of the AMP model.

Table 1. Observation properties of KIC 8524425 and KIC 11244118.

<table>
<thead>
<tr>
<th>KIC</th>
<th>( \nu_{\text{p}} ) (Hz)</th>
<th>( \log g )</th>
<th>( \log L )</th>
<th>( \Delta \nu ) (Hz)</th>
<th>( \nu_{\text{min1}} ) (Hz)</th>
<th>( \nu_{\text{min2}} ) (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8524425</td>
<td>55794</td>
<td>5.50</td>
<td>4.50</td>
<td>0.10</td>
<td>640</td>
<td>365</td>
</tr>
<tr>
<td>11244118</td>
<td>5770</td>
<td>5.65</td>
<td>4.00</td>
<td>0.15</td>
<td>640</td>
<td>365</td>
</tr>
</tbody>
</table>

REFERENCES

Caughlan G. R., Fowler W. A., 1988, At. Data Nucl. Data Tables, 40, 283
KIC 11244118
KIC 11244118 was observed short cadence (58.85 s, Gilliland et al. 2010) by Kepler. Observational atmospheric parameters are taken from Bruntt et al. (2012) and listed in Table 1.

Models are constructed by using MESA. We change model mass and hydrogen abundance to fit model frequencies to observational frequencies. MESA model are in agreement with atmospheric and seismic observational parameters. In Table 2, MESA and AMP model (taken from Metcalfe et al. 2014) results are listed. \( \Delta \nu \) versus \( \nu \) graph for model (MESA and AMP) and observational frequencies of KIC 11244118 is plotted in Fig. 3. Small separation between the oscillation frequencies (observation, MESA and AMP models) with respect to \( r \) for KIC 11244118 is plotted in Fig 4.

Table 2. Fundamental parameters of KIC 8524425 and KIC 11244118 are constructed by using models. Also, some models are listed.

<table>
<thead>
<tr>
<th>KIC</th>
<th>( \nu_{\text{p}} ) (Hz)</th>
<th>( \log g )</th>
<th>( \log L )</th>
<th>( \Delta \nu ) (Hz)</th>
<th>( \nu_{\text{min1}} ) (Hz)</th>
<th>( \nu_{\text{min2}} ) (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8524425</td>
<td>55794</td>
<td>5.50</td>
<td>4.50</td>
<td>0.10</td>
<td>640</td>
<td>365</td>
</tr>
<tr>
<td>11244118</td>
<td>5770</td>
<td>5.65</td>
<td>4.00</td>
<td>0.15</td>
<td>640</td>
<td>365</td>
</tr>
</tbody>
</table>

Figure 3. \( \Delta \nu \) versus \( \nu \) graph for model (MESA and AMP) and observational frequencies of KIC 11244118.

Figure 4. Small separation between the oscillation frequencies with respect to \( r \) for KIC 11244118.

Figure 5. Small separation between the oscillation frequencies with respect to \( r \) for KIC 11244118.

ACKNOWLEDGEMENTS
This work is supported by The Scientific and Technological Research Council of Turkey (TUBITAK 112T989).