ABSTRACT

The bright, nearby binary Alpha Centauri provides an excellent laboratory for testing stellar evolution models. The mass, radius, and luminosity of Alpha Centauri A and B are known to better than 1% accuracy thanks to recent interferometric and adaptive-optical observations (Kervella et al., 2017), and p-mode oscillations have been observed in both stars. We present new stellar models which simultaneously fit the classical and seismic observables, with particular emphasis on the convective mixing length parameter α, the adaptivity of which is necessary to fit the models to observations. The oscillation data provide an important constraint on the models: the small frequency separation is sensitive to the composition gradient in the core of the stars, while the large frequency separation constrains the mean density of the stars, providing an independent check on the mass and radius.

SATISFYING OBSERVATIONAL CONSTRAINTS

All models shown were generated using the Dartmouth Stellar Evolution Program (DSEP) code (Dotter et al. 2008), using minima and increase resolution on those α gradients in the core of the stars, while the large frequency separation constrains the mean density of the stars, providing an independent check on the surface abundances. Cen B mass: 0.93 or 0.94 01 to 0 9258) for both stars! This conclusion supports a growing body of evidence suggesting that the use of a solar-calibrated mixing length is insufficient for modeling stars with non-solar chemical compositions (Joyce & Chaboyer, 2017).

FINDING A COMMON AGE

Because αcen A and B are members of the same system, models must satisfy their respective observational constraints at a common age. We run a series of grids, with increasing refinement, over a parameter space consisting of variations in initial metallicity and helium abundances (Z, Y, respectively), mass, and mixing length αMLT. We search for distinct sets of input parameters S: (Z, Y, M, αMLT) for each star which produce a match at any common age. Fits were found at a common age of 3.3 Gyr, as indicated to the left. This age is somewhat lower than what has been reported in previous work (see e.g. 5 to 6 Gyr, Kim 1999).

MODEL GRID AND PARAMETERS

The input parameter spaces S are sampled at the following initial conditions: 
- Cen A mass: 1.1 or 1.11 (M)
- Cen B mass: 0.93 or 0.94 (M)
- [M/H] = 1.3 or 2.0, [α/Fe] = -0.05, Z = 0.01 to 0.046, Y = 0.005, αMLT = 0.025 to 0.045, age = 0.01 From these data, we iteratively isolate local minima and increase resolution on these regions until a match within specified tolerances is found.

NEED FOR ADAPTIVE MIXING LENGTH

We find that, in order to produce any viable solution, we must invoke sub-solar mixing lengths (α = 0.025) for both stars! This conclusion supports a growing body of evidence suggesting that the use of a solar-calibrated mixing length is insufficient for modeling stars with non-solar chemical compositions (Joyce & Chaboyer, 2017).

OBSERVATIONAL PARAMETERS: LITERATURE vs. DSEP

Table 2: Known System Parameters

<table>
<thead>
<tr>
<th>Cen A</th>
<th>Cen B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>1.095 ± 0.004</td>
</tr>
<tr>
<td>Radius</td>
<td>2.1893 ± 0.006</td>
</tr>
<tr>
<td>Luminosity</td>
<td>1.521 ± 0.015</td>
</tr>
<tr>
<td>Z/X</td>
<td>0.039 ± 0.006</td>
</tr>
</tbody>
</table>

Table 3: Frequency Spacing

<table>
<thead>
<tr>
<th>Cen A</th>
<th>Cen B</th>
</tr>
</thead>
<tbody>
<tr>
<td>ν [GHz]</td>
<td>145</td>
</tr>
<tr>
<td>Dν [kHz]</td>
<td>7</td>
</tr>
<tr>
<td>Dν [kHz]</td>
<td>1.45</td>
</tr>
</tbody>
</table>

Data Collection

Observations for α Cen B were collected in 2003 using the UVES spectrograph on the VLT, ESO, Chile, and using the UCLES spectrograph at the Anglo-Australian Telescope. The VLT, 3379 spectra were obtained and the AAT, 1642 were obtained [5]. Observations for α Cen A were likewise collected using UVES and UCLES over the course of 5 nights [1]. The luminosity of the system is inferred via direct observation. The mass is inferred from interferometry, and the radius is inferred from interferometry. The surface abundance Z, is obtained via high resolution spectroscopy.

ABILITY TO FIND A COMMON AGE

Integrating high-resolution evolutionary models from DSEP with the GYRE stellar oscillation code (Townsend & Taller, 2013), we determine the resonant oscillation modes and frequency spacing for models of αcen A and B (as listed in columns 2-5 of Table 1) at the uncovered common age of 3.3 Gyr.


This work is supported by grant AST-1211384 from the National Science Foundation.

REFERENCES