Bulletin of the AAS • Vol. 54, Issue 6

Polarimetric asteroseismology: its application to β Cru and other β Cep type stars

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Published on: Jun 29, 2022

URL: https://baas.aas.org/pub/2022n6i204p13

Asteroseismology has revolutionized our knowledge of low- and intermediate-mass stars across their entire evolution – determining fundamental parameters like mass, radius and age, and inferring interior rotation. High-mass stars in the range 8–25 solar masses, the progenitors of supernovae and black holes, are also asteroseismically active and are known as β Cep stars. Their pulsation modes are of low radial order and lack recognizable frequency patterns, making mode assignment difficult. Identification of the mode degree, l, and azimuthal order, m, is a prerequisite for asteroseismic inferences of the stellar interior. Here we report the detection of polarization variations due to nonradial modes in the bright B0.5 III type star β Cru (HD 111123). In so doing we confirm 40-year-old predictions of pulsation-induced polarization variability and its utility in mode identification. We combine polarimetry with space-based photometry and archival spectroscopy to identify the dominant nonradial mode in polarimetry, f_2, as l = 3, m = –3 (in the m-convention of Dziembowski 1977), and determine the stellar axis position angle as 25 (or 205) ± 8°. The rotation axis inclination to the line-of-sight was derived as ~46° from combined polarimetry and spectroscopy, facilitating identification of additional modes and allowing for asteroseismic modelling. The modelling reveals a star of 14.5 ± 0.5 solar masses, about half way through its core hydrogen burning, with a convective core ~28% of its total mass – making β Cru the most massive star with an asteroseismic age. Once the interior structures of several β Cep stars in various phases of their evolution are determined, main-sequence stellar evolution calculations can be calibrated and more accurately extrapolated to the supernova stage, which can in turn constrain the spectral and chemical evolution theories of galaxies. Our approach is applicable to other β Cep type stars with similar pulsation amplitudes, of which there are at least a dozen brighter than fifth magnitude. We also present preliminary data on a few of these.