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Time-resolved spectral analysis of the pulsating helium star V652 Her

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Abstract. We present a summary of a new time-dependent spectroscopic analysis of the pulsating helium star V652 Her. The instantaneous properties of the star (effective temperature, surface gravity, radial displacement, etc.) are evaluated throughout the pulsation cycle. The data are used to establish measurements of the mean stellar radius and mass more accurately than hitherto. The first direct evidence of a supersonic shock at minimum radius is also obtained.

1. Introduction

V652 Her is an early-type extreme helium star which pulsates with a period of 0.108 days. Its surface composition and location in the HR diagram have posed a considerable challenge to the theory of stellar evolution. However, its regular pulsation, a decreasing pulsation period and unusual surface composition have allowed stringent tests of various evolution models. The most successful model (Saio & Jeffery 2000) involves the merger of two helium white dwarfs which, after expanding to become a yellow giant, contracts towards the helium main sequence (where sdB stars are found). The most poorly determined property of V652 Her is its mass, a consequence of the difficulty of measuring surface gravity. The most crucial measurement, however, is that of radius, which may be measured using Baade's method. This poster presented a summary of a detailed analysis of new observations presented by Jeffery et al. (2001) aimed at refining the radius and mass measurements of V652 Her.

A series of 59 moderate-resolution high signal-to-noise spectra of the pulsating helium star V652 Her covering 1.06 pulsation cycles were obtained with the William Herschel Telescope in 1998 July. These have been supplemented by archival ultraviolet (IUE) and visual spectrophotometry (Kilkenny & Lynas-Gray 1982) and used to make a time-dependent study of the properties of V652 Her throughout the pulsation cycle. Archival high-resolution ultraviolet spectroscopy (IUE) and new infrared spectroscopy (UKIRT) have also been introduced.

2. Analysis

Analysis of the new data features the following: new software for the automatic measurement of effective temperature, surface gravity and projected rotation velocities from moderate-resolution spectra, the most precise radial velocity curve for V652 Her measured so far, self-consistent high-precision measurements of effective temperature and surface gravity around the pulsation cycle, a demonstration of excessive line-broadening at minimum radius and evidence for a pulsation-driven shock front, a new method for the direct measurement of the radius of a pulsating star using radial velocity and surface gravity measurements alone, new software for the automatic measurement of chemical abundances and microturbulent velocity, updated chemical abundances for V652 Her compared with previous work (Jeffery et al. 1999), a reanalysis of the total flux variations (cf. Lynas-Gray et al. 1984) in good agreement with previous work, an independent verification of the interstellar reddening using Lyman α from IUE high-resolution spectra and spectrum synthesis, the first infrared spectrum of an extreme helium star, showing He I λ10830 Å to be unexpectedly weak and hydrogen Paschen lines to be unexpectedly strong relative to other He I lines, and revised measurements of the stellar mass and radius from a number of different diagnostics (surface gravity, visual magnitude, bolometric flux).

3. The mass of V652 Her

Masses measured without reference to the ultraviolet fluxes turn out to be unphysically low ($\sim 0.25\mathrm{M}_\odot$). The best estimate for the dimensions of V652 Her averaged over the pulsation cycle is given by: $\langle T_{\rm eff}\rangle = 22\,930 \pm 10$K $\langle \log g\rangle = 3.46 \pm 0.05$ (ionization equilibrium), $\langle T_{\rm eff}\rangle = 20\,950 \pm 70$K (total flux method), $\langle R\rangle = 2.31 \pm 0.02\mathrm{R}_\odot$, $\langle L\rangle = 919 \pm 14\mathrm{L}_\odot$, $M = 0.59 \pm 0.18\mathrm{M}_\odot$ and $d = 1.70 \pm 0.02$kpc.

Two significant problems were encountered. The line-blanketed hydrogen-deficient model atmospheres used yield effective temperatures from the optical spectrum (ionization equilibrium) and visual and UV photometry (bolometric flux) that are inconsistent. Secondly, the IUE spectra are poorly distributed in phase and have low signal-to-noise. These problems may introduce systematic errors of up to $0.1\mathrm{M}_\odot$. New models and new ultraviolet observations are required.

References

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