The puzzling Maia candidate star α Draconis

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The existence of Maia variables is disputed since 1955. They are claimed to be located between the blue edge of the classical instability strip and the red border of the slowly pulsating B stars, hence in a domain of the HRD where no excitation mechanism for pulsation is yet known. But luminosity variations were discovered in time series of α Draconis, an A0III Maia candidate star, with about 53 minutes period and less than 0.001mag amplitude. Spectroscopic time series indicate radial velocity variations with the same period and about 40 ms^{-1} amplitude. αDra is a single-lined spectroscopic binary with about 51.4 days orbital period and a distance of the components of about 0.46AU. Tidal interaction may therefore be responsible for pulsation. If true, the pulsation amplitude should be modulated with the orbit as is indeed indicated by recent observations.

Introduction

Current knowledge of pulsation theory does not predict pulsating stars between the blue edge of the δScuti instability strip and the red edge of the slowly pulsating B stars (SPB). No opacity anomaly is known like the metal opacity bump for the SPB stars or the HeII bump for the δ Scuti stars which could drive pulsation. However, Struve (1955) introduced a group of variable stars with spectral types between B7V-III and A2V-II and pulsation periods between 2 and 8 hours. He called them Maia stars, but Struve himself later could not confirm pulsation in Maia. The existence still is debated (Percy & Wilson 2000, and references therein). Pulsation of a Maia type star proven beyond doubt would pose a serious problem for theoretical astrophysics. Either a new opacity source has to be identified or a yet unknown pulsation mechanism.

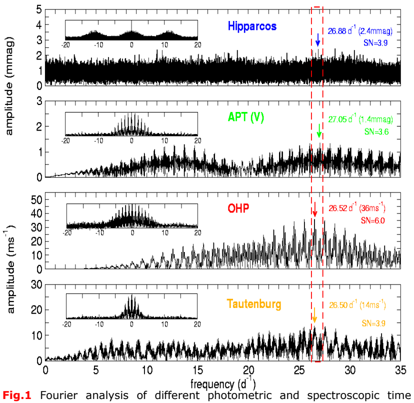

Fig.1 Fourier analysis of different photometric and spectroscopic time series of αDra. The Fourier spectra were derived from following data. From top to bottom: Hipparcos epoch photometry, APT in Johnson V, spectral time series obtained at OHP and at the Thüringer Landessternwarte Tautenburg. The inserted panels show the corresponding spectral windows.

Observations

Indications for variablility in the Maia candidate star αDra observed during a photometric monitoring campaign with the APT$^{(1)}$ in winter 2001 motivated us to investigate this 3.6^V A0III star. In June, 2002, 165 photometric data were obtained with the APT during 17 nights. The Fourier spectrum (Fig.1) shows a peak at about 27d^{-1} (period of about 53min) with an amplitude of about 1.4mmag, but with poor S/N. This frequency was confirmed by Hipparcos photometry with even better S/N.

As is discussed by Kallinger & Weiss (2002), Hipparcos has a good detection capability in the 15 to 35d^{-1} frequency range, whereas frequencies around 11d^{-1} are likely of instrumental origin.

In January, 2003, 140 echelle spectra were obtained during 10 days at the Observatiore de Haute-Provence (OHP) ranging from 3900 to 6800Å with R~35,000. Periodic RV variations with 26.5d^{-1} and an amplitude of about 36 ms^{-1} were detected in the residuals to the orbit using a technique described by Bouchy et al. (2001).

In February, 2004, 17 spectra (centered on CaI 6456.2 and FeII 5362.7) were obtained during one night with the Bulgarian 2.0m RCC Telescope

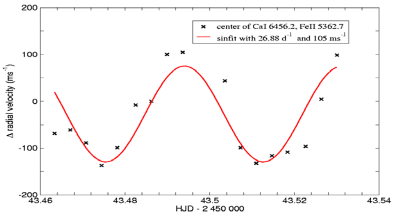

Fig.2 Line center variations (in ms^{-1}) of two spectral lines versus time for a set of 17 spectra obtained during one night at Rozhen. The red line represents the best sinusoidal fit with a frequency of 26.88 d^{-1} resulting in a three times higher amplitude than determined from OHP spectra.

at Rozhen. Periodic RV variations determined from the line center (Fig.2) confirm the photometric frequency, but with a 3 times higher amplitude.

Tidal interaction in the close binary system αDra might excite pulsation with an amplitude depending on the orbital phase. The first evidence encouraged us to organise a spectroscopic campaign with two main goals: The redefinition of the orbital parameters (Lehman & Scholz 1993) and time resolved spectroscopy at different orbit phases. The campaign at the Thüringer Landessternwarte Tautenburg started last summer and is still ongoing. Until now the entire orbit is covered with spectra ranging from 4750 to 7070Å and with R~67,000. Further 1150 time resolved spectra were acquired during 45 nights around apastron. The Fourier spectrum of the RV time series (Fig.1) shows a peak at about 26.5d^{-1} with an amplitude of about 14ms^{-1} which is significantly lower than that determined from OHP spectra.

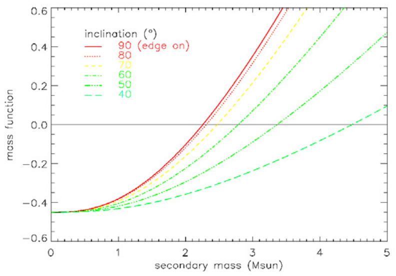

Fig.3 Gradient of the mass function for the αDra binary system for different inclination with a primary mass of 2.8Msol. The secondary mass follows from the zero point of a curve given by the inclination. Assuming a nearly *edge on* system the lowest possible secondary mass is about 2.2Msol.

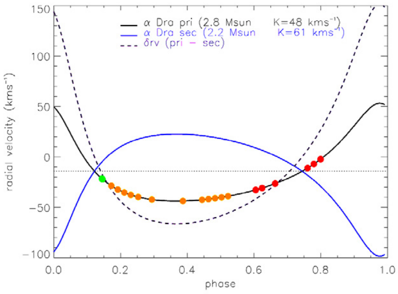

Fig.4 RV curve of both components of the αDra binary systems. (black line: primary; blue line: secondary; dashed line: RV difference) The colored dots indicate orbit phases when spectral time series were obtained. (red: OHP; orange: Tautenburg; green: Rozhen).

Binary System

αDra is a hitherto single-lined spectroscopic binary system.

P	51.439(14)d
K	48.488(80)kms^{-1}
RV$_0$	-14.17(22)kms^{-1}
e	0.4219(16)
T	2452881.736(51)
ω	22.11(29)°

Fundamental parameters (Adelmann et al. 2001) and evolutionary tracks indicate a primary mass of 2.8±0.2Msol (see Fig. 5). The secondary mass has to be sufficiently smaller, otherwise we would detect a secondary spectrum. The lower mass limit is given by the zero point of the mass function

$$\frac{(M_1 \cdot \sin i)^3}{(M_1 + M_2)^2} - \frac{86400}{2\pi} \cdot \frac{K_1}{P} \cdot \sqrt{(1-e^2)} = 0$$

(see Fig.3) which indicates 2.2Msol for an inclination ~90°. Hence both stars lie outside any known instability region. Assuming such a mass for the secondary the semi-major axis of the binary system results to about 0.46AU. The secondary RV curve is given in (Fig.4).

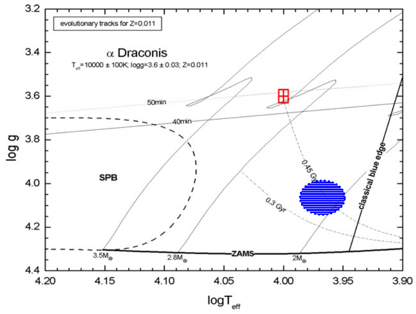

Fig.5 HR-diagram showing the error box (red box) of αDra. The evolutionary tracks correspond to 2, 2.8 and 3.5Msol. The blue ellipse indicates the region where we expect the secondary (based on equal age and our mass estimate). The two lines marked with *40min* and *50min* are lines of equal *frequency of maximum power,* extrapolated from the solar 5min oscillation (Kjeldsen & Bedding 1995).

Conclusions

We have fascinating photometric AND spectroscopic evidence for variability in the Maia candidate star αDra. The observations show different amplitudes at different orbital phases what suggests tidal interaction as the pulsation driving mechanism. Further observations near periastron are required to check the trend of pulsation amplitude with orbit phase.

The secondary's signature is marginally visible in our spectroscopic data what is compatible with simulations based on a high v*sini* of about 100kms^{-1} for the companion.

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