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The enigmatic wind of 55 Cygni*

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Abstract. The early B-type supergiant 55 Cyg exhibits variations in its P-Cygni line profiles (mainly in H_α and H_β) related to the presence of a strong variable stellar wind. To study this variability we have started a spectroscopic observing campaign at the Observatory of Ondřejov (Czech Republic). In this work we show a sample of Hα line profiles which were modeled using the FASTWIND code. We discuss the derived wind parameters and the possible mechanisms driving this variable wind.

Resumen. La estrella supergigante 55 Cyg, de tipo espectral B, presenta variaciones en los perfiles P-Cygni de sus líneas espectrales (principalmente en H_α y H_β), relacionadas con la presencia de un intenso viento estelar variable. Para estudiar estas variaciones, hemos iniciado una campaña de observaciones espectroscópicas en el Observatorio de Ondřejov (República Checa). En este trabajo presentamos una muestra de los perfiles de líneas que fueron modelados utilizando el código FASTWIND. Discutimos los parámetros obtenidos para el viento y los posibles mecanismos responsables que impulsarían a un viento variable.

1. Background

The post-main sequence evolution of massive stars is one of the major unsolved problems in massive star research. The complete understanding of this problem requires the knowledge of the mass-loss process. It is well–known that O and B supergiants (O-BSGs) lose huge amounts of mass via their strong stellar winds (see Castor et al. 1975). The line radiation-driven wind hydrodynamics for OSGs can be approximated by a classic β velocity law with β around 0.8,

* Based on observations taken with the Perek 2m-telescope at Ondřejov Observatory, Czech Republic

while the winds of the BSGs agree better with a β power in the range $1-3$ (Crowther et al. 2006; Markova & Puls 2008). On the other hand, BSGs' winds are highly variable producing large photometric and spectroscopic variations on short time scales, from hours to tens or even hundreds of days (Waelkens et al. 1998). Therefore, various mechanisms were proposed in the last years for explaining these observations and the most convincing hypothesis seems to be the presence of wind instabilities and/or non-radial pulsations. Periodic variations and periods for a large group of B stars are explained by different gravitational modes of oscillation (Balona & Dziembowski 1999; Saio et al. 2006).

To probe a possible link between wind variability and pulsations we carried out a spectroscopic observing campaign of the variable star 55 Cyg.

2. Observations and reduction

Spectra of 55 Cyg were collected using a Coudé spectrograph attached to the Perek 2-m telescope at Ondřejov Observatory, Czech Republic, with a grating of 830.77 lines/mm and a SITe 2030x800 CCD. A total of 339 spectra were taken in the H_α region over 59 nights between August 2009 and August 2013. The spectral coverage was 6270–6730 Å with a resolution of R $\sim$ 13 000.

The data were reduced using IRAF (Image Reduction and Analysis Facility[1]) tasks, such as bias subtraction, flat-field normalization, and wavelength calibration. To perform telluric corrections, a telluric standard star was observed each night. The final spectra were corrected for heliocentric velocity.

3. Results

We fitted H_α and HeI line profiles for 33 observations of 55 Cyg using the FASTWIND code (Puls et al. 2005). Due to their strong variability (see Fig. 1), the stellar and wind parameter values were quite different from night to night.

We found that the wind parameters vary between:

- The mass loss rate, which indicates the mass lost per year in solar masses: $0.14 \times 10^{-6}\ M_\odot\ yr^{-1} \leq \dot{M} \leq 0.43 \times 10^{-6}\ M_\odot\ yr^{-1}$
- The velocity of the wind at great distances of the star (terminal velocity): $250\ km\,s^{-1} \leq V_\infty \leq 700\ km\,s^{-1}$
- The microturbulence velocity: $10\ km\,s^{-1} \leq V_{\rm micro} \leq 69\ km\,s^{-1}$
- The proyected rotational velocity: $40\ km\,s^{-1} \leq V\,sin(i) \leq 105\ km\,s^{-1}$
- The β parameter of the velocity field aproximation: $1.8 \leq \beta \leq 2.2$
- Surface gravity: $2.1 \leq \log g \leq 2.6$
- Effective temperature: $18\,600\ K \leq T_{\rm eff} \leq 19\,000\ K$

Based on the derived stellar parameters we obtained the star's luminosity and computed a synthetic lightcurve for the years 2009 and 2013 (see Fig. 2).

[1] IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy (AURA) under cooperative agreement with the National Science Foundation.

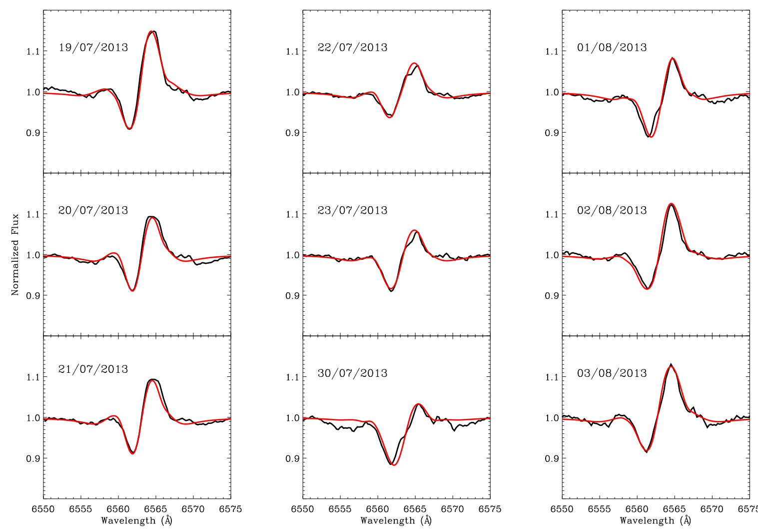

Figure 1. Night to night variations in the H_α line. Model fittings (red line) are overplotted to the observations (black line).

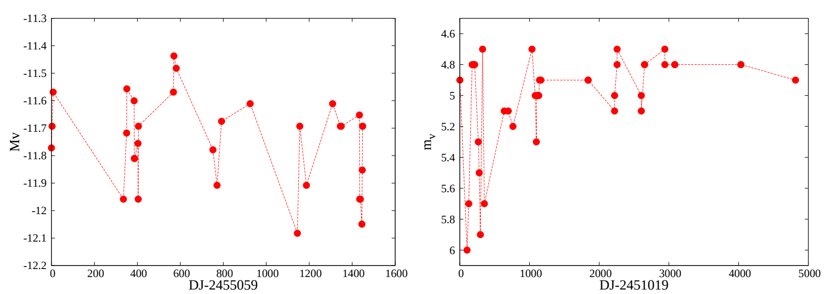

Figure 2. Left: Theoretical lightcurve (M_v) obtained from H_α line profile fittings to observations taken between 2009 and 2013. M_v varies by ~ 0.8 mag and shows irregular variations. Right: Observed lightcurve, from 1998 to 2011 showing irregular light variations (Henden 2013, observations are from the AAVSO International Database, http://www.aavso.org).

4. Discussion

The observed lightcurve of 55 Cyg was taken from the American Association of Variable Star Observers (AAVSO, Henden 2013). It reveals that the star has shown irregular light variations with an amplitude up to 0.8 magnitudes (Fig. 2). Both, observed lightcurve behaviour and its amplitude of variation resemble our theoretical curve. We are still not able to find a period from these variations of the H_α profile, but it seems to vary between 15 to 20 days. On the other hand, Kraus et al. (2014) found that the HeI, $\lambda 6678$Å photospheric line presents a 1.09 day period, which could be superimposed by another longer period. This could imply that the coupling of multiperiodic pulsation modes is responsible for mass ejection episodes. However, in the log($T_{\rm eff}$) vs log(g) diagram, our theoretical parameters of 55 Cyg (Fig. 3) do not agree with the results from Pamyatnykh (1999) and Saio et al. (2006), this suggests that gravitational modes should not be responsible for the observed variations.

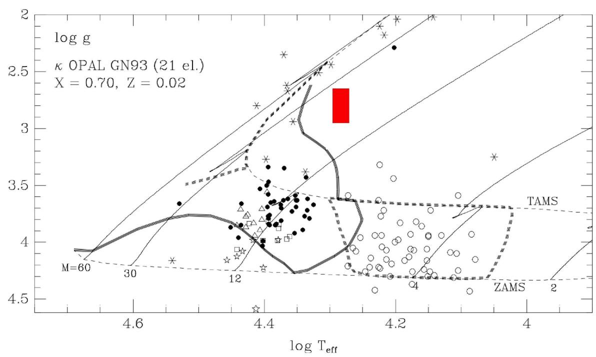

Figure 3. $\log(T_{\rm eff})$ vs $\log(g)$ diagram obtained from Pamyatnykh (1999). Asterisks represent the α Cygni variables, empty circles are slow pulsating B stars (SPBs) and the rest are β Cepheid stars. The red rectangle covers the region for all the resulting parameters obtained from 55 Cyg H_α line profile fittings.

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