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A new outburst of the yellow hypergiant star ρ Cas

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Yellow hypergiants are massive stars that have passed through the red-supergiant phase and evolve back bluewards in the Hertzsprung-Russell diagram (HRD). It has been suggested that these stars may be evolving toward the B[e] supergiant phase (Davies et al. 2007). Such a possible evolutionary link should be investigated.

The yellow hypergiant ρ Cas is famous for its historical and recent outbursts, during which the star develops TiO bands in a cool, optically thick wind with a very brief but high mass-loss rate. Each outburst is accompanied by a drop in the light curve of more than one magnitude. At least three such outbursts were recorded for ρ Cas: 1945–1947, 1985–1986, and 2000–2001.

In 2010 we started to monitor spectroscopically several yellow hypergiants using the Ondřejov 2m telescope. The aim of this campaign is to track and study their mass ejection phases. One of the objects we monitor is ρ Cas. Our spectroscopic data show that during 2013, another outburst occurred, which is obvious from the development of TiO bands. Also many atmospheric lines characteristic for a later spectral type appear. Moreover, the photometric light curve displays a drop by about 0.6 mag during the same period. While this recent outburst was probably less violent, the decrease of the time interval between the outbursts might indicate that ρ Cas is preparing for its passage through the Yellow Void region towards the hot side of the HRD.

Spectra were obtained during 2010 – 2015 using the Coudé spectrograph attached to the 2-m telescope at Ondřejov Observatory, Czech Republic in three wavelength regions:

- ▷ H α: 6250–6760 Å, $R \simeq 13\,000$
- ▷ [Ca II]: 6990–7500 Å, $R \simeq 15\,000$
- ▷ IR: 8470–8980 Å, $R \simeq 18\,000$

We show our observation dates at the bottom of Fig. 3, along with three points from SAO, Russia, provided by Klochkova et al. (2014) which overlap with the time-span of our observations.

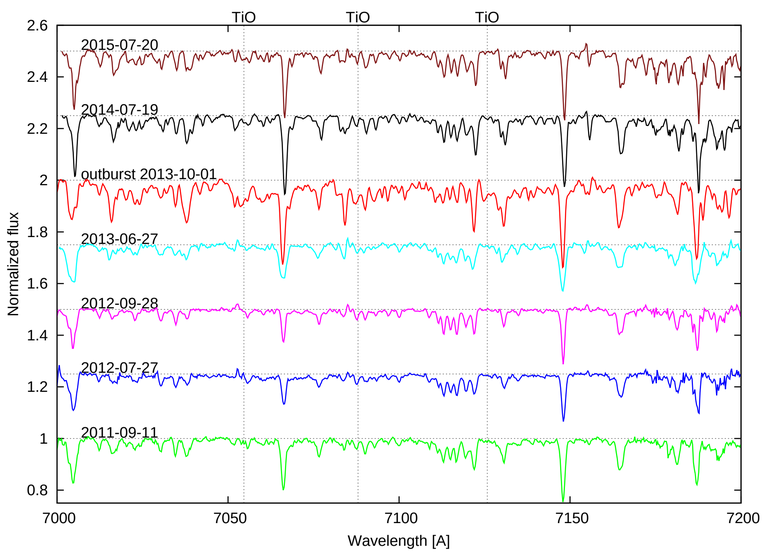


Figure 1. Near-IR TiO bands are observed in October 2013.

OUTBURST 2013:

- ▷ Appearance of TiO bands in October 2013 (Fig. 1)
- ▷ Drastic changes in line profiles (Fig. 2)
- ▷ Drop of the visual magnitude (Fig. 3).

All three diagnostics of the outburst indicate a decrease of the stellar temperature. Similar behaviour was observed during the millennium outburst of ρ Cas in 2000 – 2001 (Lobel et al. 2003).

We estimated the temperature of ρ Cas using the ratio of line depths Fe I λ6431 / Fe II λ6433, calibrated by high resolution spectra (Elodie and UVES POP) of 19 late A to early K supergiants with precise $T_{\rm eff}$ from the literature (Kovtyukh 2007). The estimated error is $\pm$100 K.

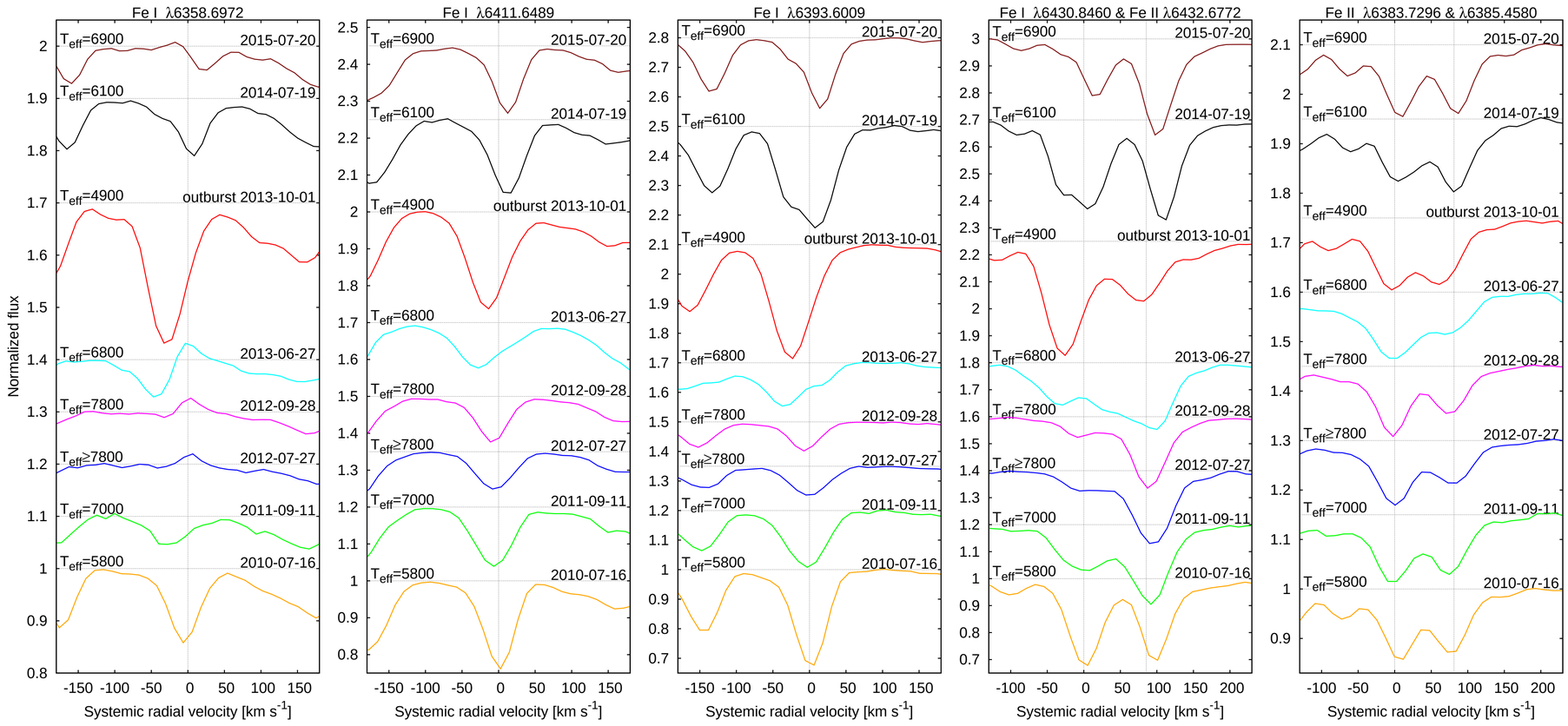
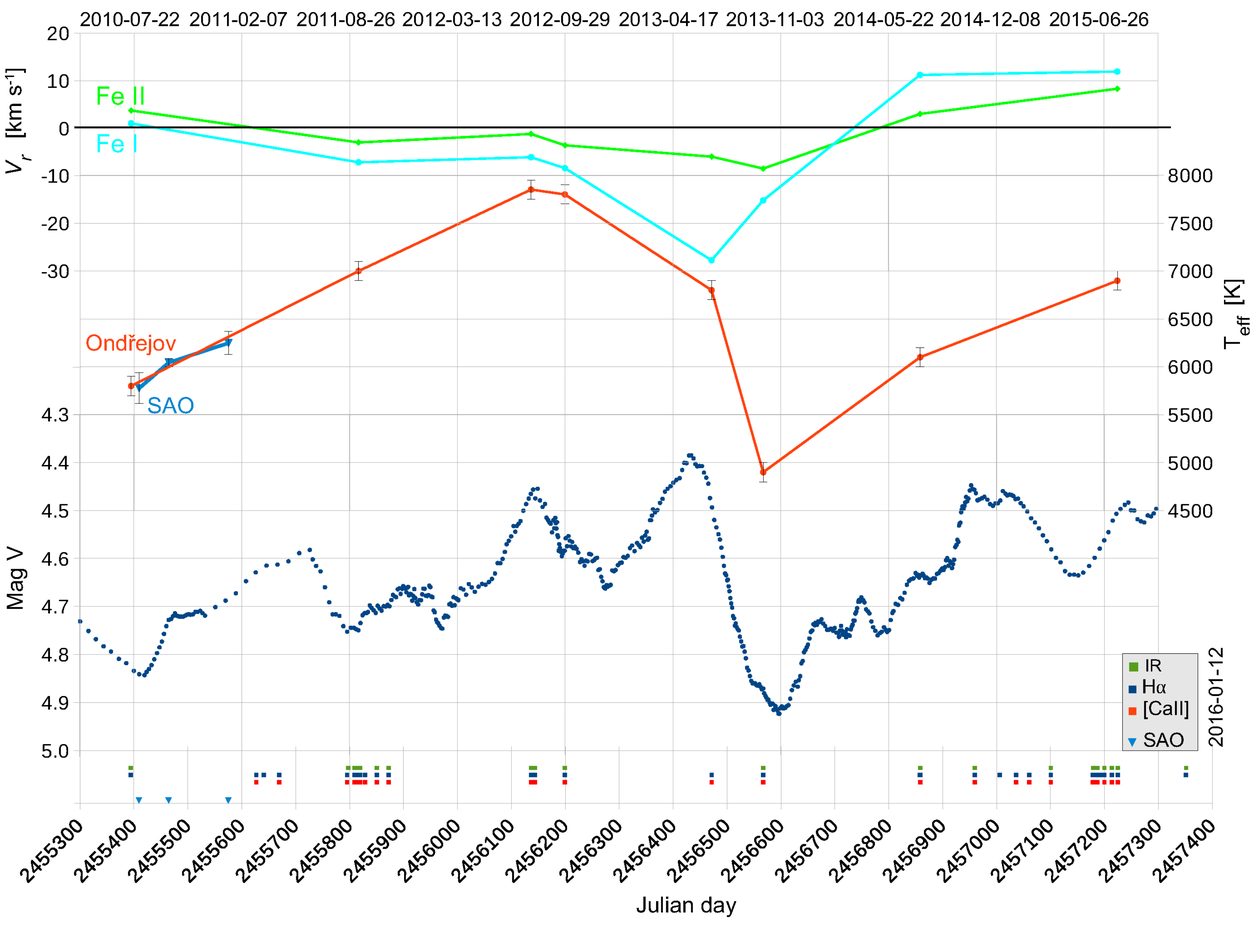


Figure 2. Profiles of Fe I and Fe II lines in years 2010 – 2015. Systemic velocity of –47 km s^{-1} was adapted.

Note the drastic change of line profiles just before the outburst in June 2013 and strong blue shift of spectral lines during outburst in October 2013.

Fe I λ6359 line (Panel 1) appears in *emission* during the hottest stages in 2012 and develops a *P-Cygni profile* with a broad blue wing before the outburst indicating the onset of a strong stellar wind.

An emission component at V_r=0 can also be noted in Fe I λ6394 (Panel 3) in June 2013. This line shows *a split after the outburst* indicating the development of an expanding shell. Similar split was observed in several low-excitation lines.



Variations of effective temperature values $T_{\rm eff}$ follow the general trend of the light curve: hotter during bright phases and cooler during the outburst. Our temperature estimates agree with results by Klochkova et al. (2014) during the time overlap of our observations in 2010–2011 (blue line in Fig.3).

Radial velocity variability displayed by lines of different elements in various ionization stages indicates the vertical velocity structure within the outer atmosphere.

From the radial velocity measurements of Fe I & Fe II lines it follows:

- ▷ The amplitude in Fe I is larger than in Fe II;
- ▷ The outer layers where Fe I lines form, are much more affected by the outburst activity;
- ▷ We observe the same shift of Fe I radial velocity curve with respect to the light curve as reported by Lobel et al. (2003);
- ▷ Fe II radial velocity curve follows the light curve and effective temperature curve.

Figure 3. V-brightness curve of ρ Cas (blue dots) is compared with effective temperature values (red line) and with radial velocities of Fe I λ6412 (light blue line) and Fe II λ6443 (green line). Data for the light curve were obtained from the AAVSO International Database and BAAVSS database contributed by W. Vollmann (AAVSO) and D. Loughney (BAAVSS). Spectral observation dates are marked below the light curve.

References:

Davies B., Oudmaijer R. D.; Sahu K. C., 2007, ApJ 671,2059 ★ Klochkova V. G., Panchuk V. E., Tavolzhanskaya N. S., Usenko I. A., 2014, Astron. Rep. 58, 101 ★ Kovtyukh V. V., 2007, MNRAS 378, 617 ★ Lobel A. et al., 2003, ApJ 583, 923