A spectral study of the active giant OP And in the period 1979 - 2010

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Abstract. We present a study of the activity indicators of the single giant star OP And. Spectral data obtained with the Coudé spectrograph of the 2m telescope of Rozhen National Astronomical Observatory in Bulgaria and from Narval at the 2-m Telescope Bernard Lyot (TBL), Pic du Midi Observatory, France, as well as data from the literature are used in order to study the long-term behaviour of H_α, CaII H&K, and CaII IR triplet lines. The star has periods with variable activity. The intensity of the CaII H&K emission lines and the partially filled-in by emission H_α absorption core vary in time. OP And was on the higher activity level up to 1996, but for 2008 and 2010 it had a lower activity stage. This fact supports the idea that the mass outflow in OP And is controlled by the magnetic field.
Key words: Stars: activity - Stars:individual:OP And -Line: profiles

Introduction

OP And (HD 9746, HR 454) is a variable, ($V \sim 6.21$ to 6.47 mag, Samus et al. 2011) giant star of spectral class K1 III and $(B-V)$ color of 1.21 mag, (de Medeiros & Mayor 1999). Its brightness shows photometric changes with variable amplitude of about 0.1 mag, variable period and light curve shape changes in different observational seasons, (Strassmeier & Hall 1988) due to different cool spot configurations.

The star is of intermediate mass and its estimation, based on different evolutionary models and Hipparcos data, vary in the interval $1.5\mathcal{M}_\odot$– $1.9\mathcal{M}_\odot$, (Konstantinova-Antova et al. 2005, Charbonnel & Balachandran 2000). The star has lithium abundance $logN(Li)$=3.75$\pm$0.16 (Balachandran et al. 2000). This means that OP And is one of the giants with the highest lithium abundance and it is placed in the region of the red-giant bump on the HR diagram (Charbonnel & Balachandran 2000).

The radial velocity measurements led to the conclusion that the star is apparently single. CORAVEL spectrometry data (de Medeiros & Mayor 1999) give radial velocity RV of -42.7 ± 0.3 km s^{-1}and rotational velocity $Vsini$ of 8.7 ± 1.0 km s^{-1}. Similar RV values are reported earlier by Abt & Biggs (1972) and Fekel, Moffett & Henry (1986). 2008 and 2010 measurements from Narval spectrometer also provide a constant RV of -42.33 ± 0.07 km s^{-1}. The constancy of the RV measurements support the idea that the star is single.

Optical spectra of the star are remarkable with a strong chromospheric emission lines, pointing to an active chromosphere. Emission in the CaII H&K lines was first discovered by Bidelman (1983). H_α line of the star has a complex structure. It consists of partly filled-in absorption core and variable emission features in the line wings. Coronal and transition region lines also present in the OP And spectra.

Flare activity of the star is also observed. Konstantinova-Antova & Antov (2000) reported for photometric and spectral flares with different duration. They observed a photometric flare in December 1993 with duration > 1 h and amplitude in U colour of 0.24 mag and flares in the H_α and $CaI\lambda6572.78$ lines on 18-22.08.1996, 2.2.1996 and 8-9.06.1996 (Konstantinova-Antova, 2001). OP And is also active in X-rays and was observed with ROSAT (Voges at al. 1999) with 0.64 source count-rate.

1 Observations and data processing

For our study we have used OP And spectral observations and measurements by Fekel, Moffett, & Henry (1986), Strassmeier at al. (1990), Konstantinova-Antova (2001), Demsey et al. (1992), Smith & Shetrone (2000) and high resolution spectral observations obtained with the Narval spectropolarimeter at TBL, Pic du Midi Observatory, France.

The earliest spectral observations in H_α were obtained by Fekel, Moffett, & Henry (1986) with the 2.1 m telescope of McDonald Observatory with a spectral resolution of 0.42 Å in 1979. Strassmeier et al. (1990) used the same telescope with the same spectral resolution, for observations in H_α in 1983 and Kitt Peak National Observatory 0.9 m telescope with coudé spectrograph and resolution of 0.24 Å for observations in CaII H&K lines in 1987. In 1998 the 2.1 m telescope of McDonald Observatory with Cassegrain echelle spectrograph and resolution of 40000 was used by Smith & Shetrone (2000) for CaII H&K line observations. CaII IR triplet lines at $\lambda\lambda8498, 8542, 8662$ Å was observed by Demsey et al. (1993) with 1.0 m telescope of Ritter Observatory, Toledo, Ohio and fiber-fed echelle spectrograph with resolution 0.39 Å and 1.2 Å in 1989 and 1990.

Spectra in H_α line were obtained with the coudé spectrograph of the 2m-RCC telescope of Rozhen NAO, (Konstantinova-Antova at al. 1995; 2005), with a spectral resolution of 0.2 Å in the period 1993 - 1996.

The most recent spectral data of OP And were obtained with the Narval spectropolarimeter at the 2m TBL at Pic du Midi Observatory, France, in 2008 and 2010. Narval is a fiber-fed echelle spectrometer and covers the spectral region from about 3700 to 10400 Å, in 40 orders aligned in the CCD frame by 2 cross-disperser prisms. We used it in spectropolarimetric mode with a spectral resolution of 65000. The basic spectra extraction and reduction was performed by the fully automatic software package Libre ESpRIT (Donati et al. 1997), installed at TBL. For the present research we used the unpolarized spectral data. Analysis of the spectropolarimetric data is in progress and is the subject of another paper.

OP And activity has been studied by monitoring of the spectral lines H_α, CaII H&K and CaII infrared triplet at ($\lambda\lambda8498, 8542, 8662$ Å). Measurements of the relative intensity regarding the continuum (R_c) was performed for H_α and CaII IR triplet lines. For CaII H&K lines we measured the relative intensity of the emission core, $I/I(3950)$, regarding the intensity at 3950 Å. R_c

was calculated as a mean value at the minimum for central absorptions and at the maximum for emission wings. These numbers are instrument dependant (mainly because of different spectral resolutions) and would deserve some normalization to enable comparison. However, the changes in activity level are so strong, that we considered that a comparison of raw measurements was meaningful.

2 H_α line behaviour in the period 1979 - 2010

H_α line of OP And has a complex, composite profile with significant variations. It consists of partially filled-in absorption core and blue and red-shifted emission features in the wings. The relative intensity variations of the H_α absorption core are presented in Fig.1. Available observations show that a relatively high intensity is measured up to 1996, and a relatively lower intensity is measured in 2008 and 2010. The blue-shifted emission component, (Fig.2), in general follows the changes in the absorption core, with stronger component up to 1996, and weaker in 2008 and 2010, when much lower amplitude of variations is observed.

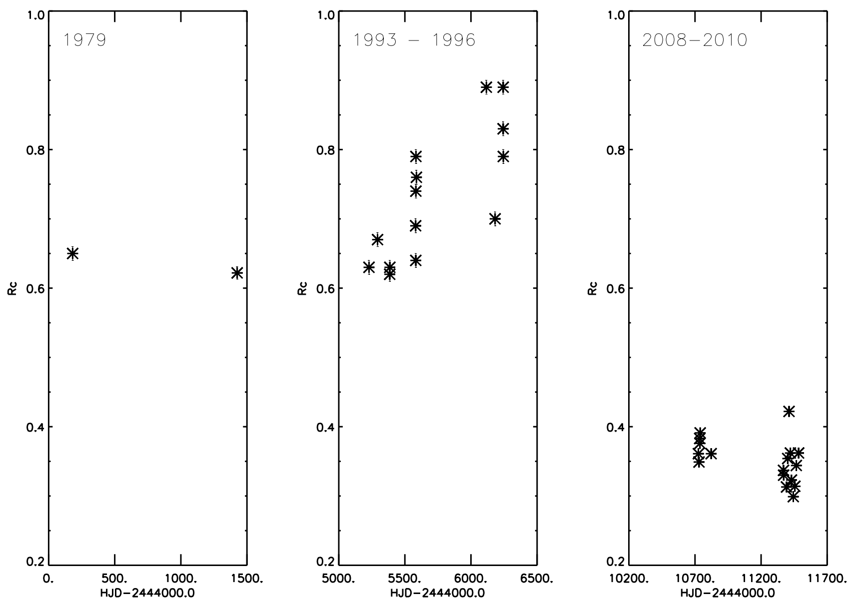

Fig. 1. H_α absorption core variability in the period 1979 - 2010

H_α relative intensity in 2008 and 2010 shows moderate (compared to the long-term H_α variability) changes. We observed a flare event on 2 August 2010 (HJD=24455411.8) with rising of the core filling relative intensity and an opposite behaviour of the blue and the red emission wings. During this event, with duration of about one day, the amplitude of the variation of the blue-shifted emission component is greater than, tht of the red-shifted component.

Typical spectral profiles of the H_α line in 1979 from Fekel, Moffett, & Henry (1986), in the period 1993 – 1996 from Konstantinova-Antova et al. (1995, 2005), in 2008 and 2010 from Narval data are with asymmetric and variable shape. Typical spectra for these periods are presented in Fig. 3 and Fig.4. Up to 1996 significantly filled-in due to emission H_α absorption core and strong blue-shifted emission component are observed. H_α line profile in 1996, presented on the right panel of Fig.**??** is taken during a strong flare event and it is distinguished with emission enhancement in the line wings and stronger in blue-shifted component. In 1996 maximum of the line intensity is detected with relative core intensity of 0.89 and blue-shifted emission relative intensity of 1.15. Observations in 2008 and 2010 show that the line has relatively low intensity, the absorption core is less filled-in and the blue-shifted emission peak is less intensive, close to and even under the continuum level. On some spectra red-shifted emission enhancement is observed.

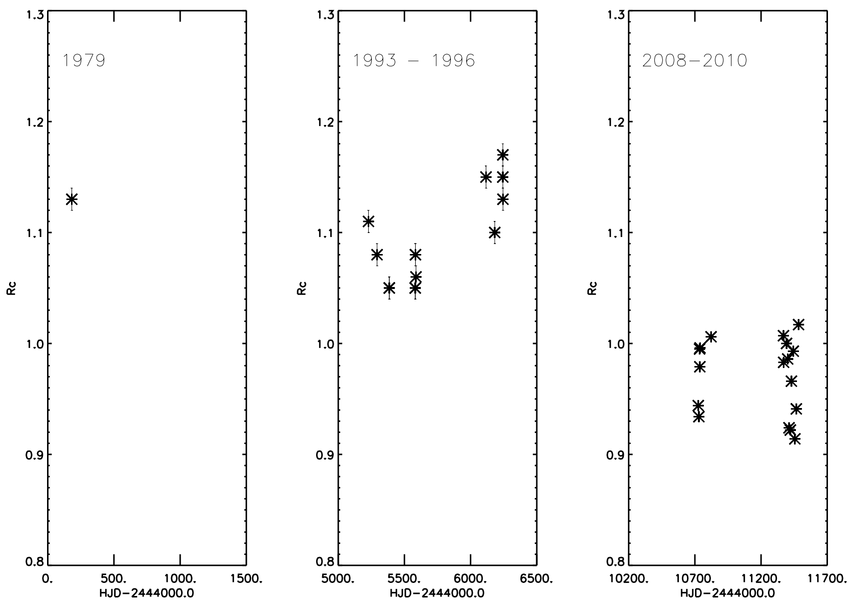

Fig. 2. H_α blue-shifted emission variability in the period 1979 - 2010

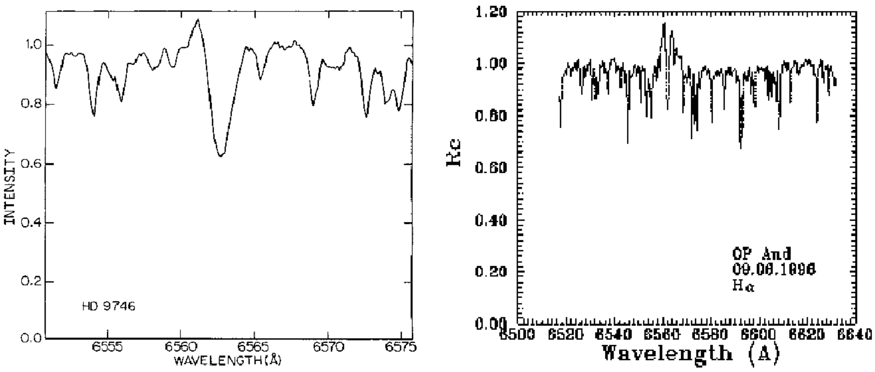

Fig. 3. H_α line profile in 1979 from Fekel, Moffett, & Henry 1986 (left panel) and in 1996 during a flare, Konstantinova-Antova et al. 2005 (right panel).

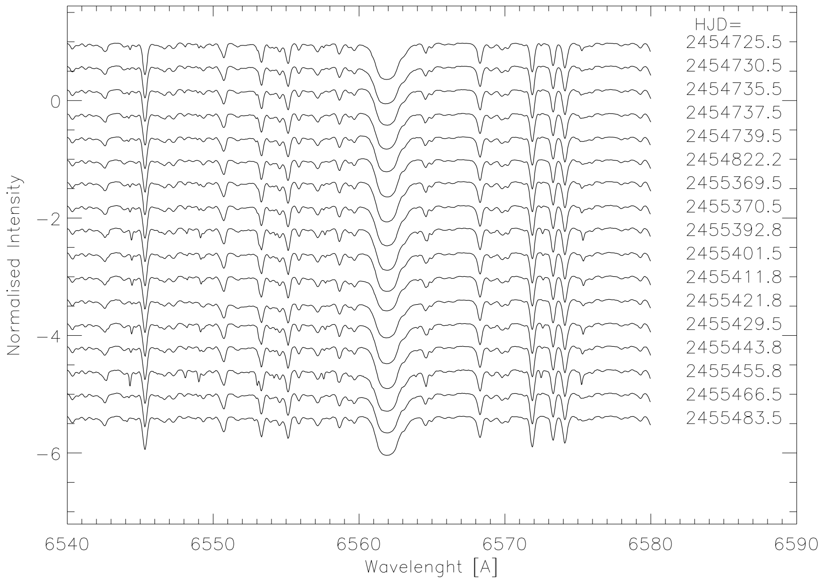

Fig. 4. H_α line profiles in 2008 and 2010 from Narval at TBL, France. Spectra are shifted vertically for display purposes.

3 CaII lines behaviour in the period 1983 - 2010

CaII H&K lines of OP And have a typical profile for the chromospherically active stars, with complex structure and broad emission component. Both, H and K lines have similar intensity changes and profile structure, thus we represent only the measurements of the CaII K line. In the time interval 1983 - 2010 significant variations of relative intensities and profile structure are observed (Fig. 5).

In 1983 and 1997 OP And is observed with relatively high chromospheric emission of CaII H&K lines with a maximum in 1997. Observations before 1997 show evidences for asymmetric emission profile, stronger at the blue part. On the latest Narval spectra line is clearly resolved with a double-peak structure. However this might be an observational effect, due to the different instruments and resolution. Data obtained in 1983 reported by Strassmeier et al. (1990) show broad emission with equivalent width of 2 Å and 11 Å for K and H respectively, (Fig.6 left panel). Data taken in 1997 at Rozhen observatory, (Fig.6, right panel), show that CaII H&K lines have similar profile, but with emission even stronger.

In 2008 and 2010 we observed relatively low chromospheric emission and double-peak structure of the emission core with separated V and R emission peaks. Such double peaked emission profile is for a first time observed for OP And because of the higher spectral resolution of Narval. In 2008 and 2010 both, V and R components have a similar behaviour, generally with stronger V component and $V/R > 1$. This ratio, according to Smith & Shetrone (2000) is an indication for variable vertical motions in the chromosphere, with the downward component being the strongest. CaII H&K line profiles are presented in Fig.7. Variations in the overall emission intensity, line profile and V and R components are clearly seen. The flare event observed in 2010 in H_α line is also detected in CaII H&K lines. During the flare the V/R ratio decreases down to 1.00 ± 0.01.

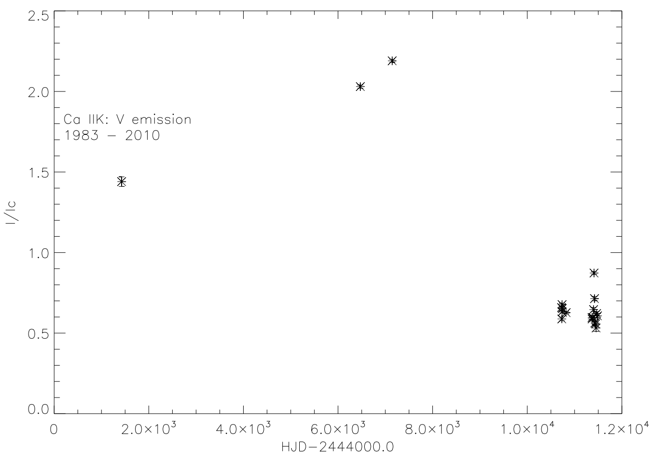

Fig. 5. CaII K line relative intensity changes in the period 1983 - 2010

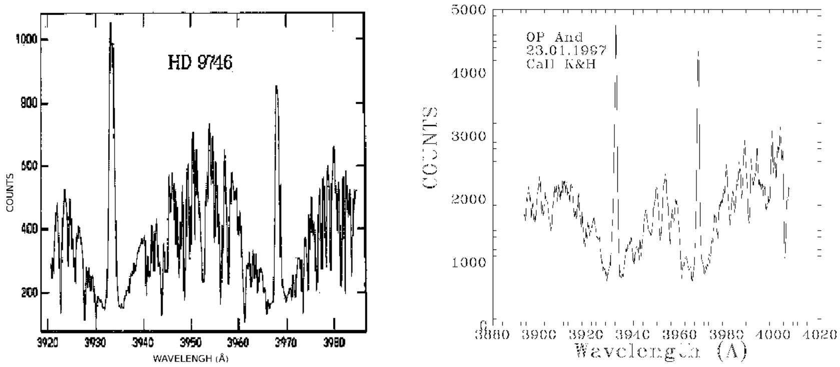

Fig. 6. Ca II H&K line profile in 1983 from Strassmeier et al. (1990) (left panel) and in 1997 from Konstantinova-Antova et al. (2005) (right panel)

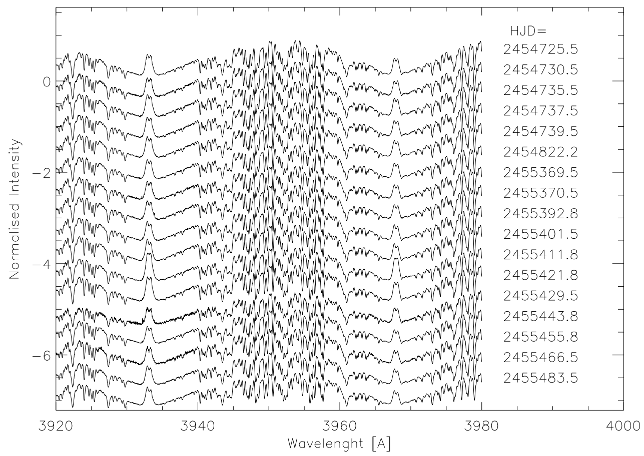

Fig. 7. Ca II H&K line profiles in 2008 and 2010 from Narval at TBL, France

Fig.8 and Fig.9 represent respectively measurements and observations of the CaII IR triplet line at λ8542 Å in the period 1989 - 2010 and line profiles, obtained in 2008 and 2010 with Narval. Early observations in 1989 are taken from Demsey et al. (1993). Our observations show slightly filled-in variable and asymmetric line profile. This CaII IR triplet line is also affected by the flare event observed in 2010, but with a lower amplitude of variation than in H_{α}. Interesting variations in the CaII IR triplet at λ8542 Å were observed by Demsey et al. (1993) with a very shallow line profile in the interval 10-23 January 1989 and moderate filled-in line profile on 10 December 1990.

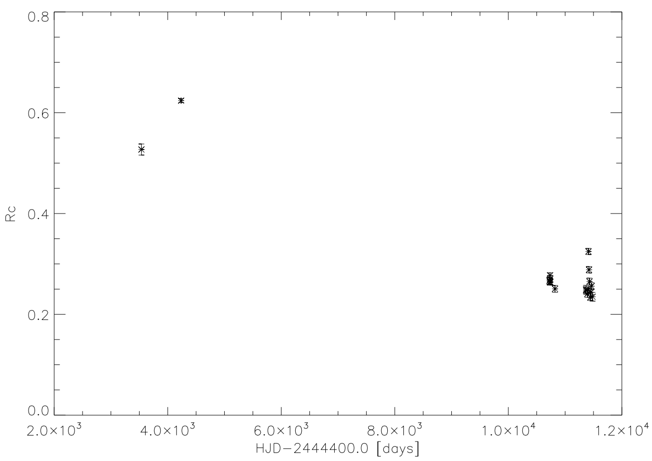

Fig. 8. CaII IR triplet line (λ8542 Å) absorbtion core relative intensity in the period 1989 - 2010

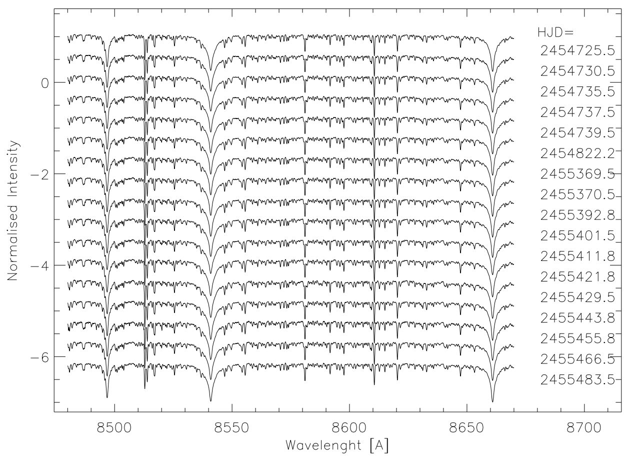

Fig. 9. CaII IR triplet line (λ8542 Å) profiles in 2008 and 2010 from Narval at TBL, France. Spectra are shifted vertically for display purposes.

Conclusions

High resolution spectroscopic data for OP And, collected in the period 1979 - 2010, indicate that the star has a variable activity level. Although scarce data for all the examined lines, obtained up to 1996, show that the star is observed in relatively high activity level. In 2008 and 2010 OP And is observed in a relatively low activity level, with similar behaviour for all the monitored lines. Available data do not allow us to study in details the type of variability through activity indicators of OP And, but further observations may indicate to a possible long-term activity cycle. More regular observations are required to enable us to study activity stages of the star and eventually provide the period of the cycle. Some evidences for a long-term variability of this star are reported in Strassmeier & Hall (1988) and Konstantinova-Antova et al. (1995).

Observed H_α line profile with filled-in core and with variable blue-emission component, according to Konstantinova-Antova et al. (1995), gives evidence for an expanding optically thick chromosphere. Observed stages of OP And with high and low activity levels correlate with the variable chromospheric outflows. Thus we may conclude that the chromospheric outflows and eventual mass-loss are in a close dependence with activity level and it is likely to be controlled by the magnetic field.

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