

FAST LINE PROFILE VARIATIONS FOR γ Cas TYPE STARS: CASE π AqrA.F. Kholtygin¹, M.A. Burlak², Yu.V. Milanova¹, A.V. Dementyev¹, and O.A. Tsiopa³¹*Saint-Petersburg University**E-mail: afkholtygin@gmail.com*²*Sternberg Astronomical Institute, Moscow University*³*Main (Pulkovo) Astronomical observatory*

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Abstract. Fast spectral variations of γ Cas type stars π Aqr (a γ Cas analogue star) are analysed. Regular line profile variations (LPVs) at the short-time scale with periods from 4 to 136 minutes are detected.

Introduction

The γ Cas type stars is a special subclass of Be stars [1]. These stars possess by the hard and strong thermal X-ray emission [1, 2] with high plasma temperature up to 20-30 keV. Their X-ray luminosities $L_X > 10^{31}$ erg cm⁻²s⁻¹ and are intermediate between those of normal massive stars and those of X-ray binaries and are characterized by short- and long-term variations in the [2–10] keV energy range [2].

The origin of these peculiar X-ray emission remains badly known with two leading scenarios: accretion on to a compact object [3] or star-disc interactions [1]. To shed light on the nature of these enigmatic objects, we started a program of searching for their fast spectral variations [4, 5]. In the present paper our recent observations of the B1III-IVe γ Cas type stars π Aqr made at the 1.25-m telescope in the Crimean station of Sternberg Astronomical Institute by Moscow State University are analysed.

Observations and data reduction

The Be star π Aqr (HD 212571) is the fast rotating ($V \sin i = 215 \pm 4$ km s⁻¹) massive ($M = 10.7 \pm 0.7 M_\odot$) binary stellar system [6, 7]. The orbital period of the binary system is 84.1 days and the mass of the component ($2 - 3 M_\odot$) corresponds to the main sequence A-F stars [8].

Our observations of π Aqr were made with the 1.25-m telescope on the night of October 10/11, 2021. All spectra were obtained with an exposure time 5 s and time resolution 8 s including SSD reading-out time. Totally 1250 spectra in the range $\lambda\lambda 4420 - 6860$ Å with a spectral resolution ~ 1000 are obtained. The full duration of observation is ~ 165 min.

The data reduction was made using the code CCDops¹. One-dimensional spectra were obtained by summing the counts within a 40-pixel (79'') aperture, at a mean FWHM of 26

¹<http://company7.com/library/sbig/sbwhtmls/ccdopsv5.html>

pixels, with the subtraction of the sky background from a region of 60–120 pixels from the centre of the stellar spectrum. The wavelength calibration was made with a Ne-Ar lamp.

The spectra are normalized to the continuum. The normalization procedure is described by Kholtygin et al. [9]. The normalized spectra averaged over all 1250 spectra is given Fig. 1.

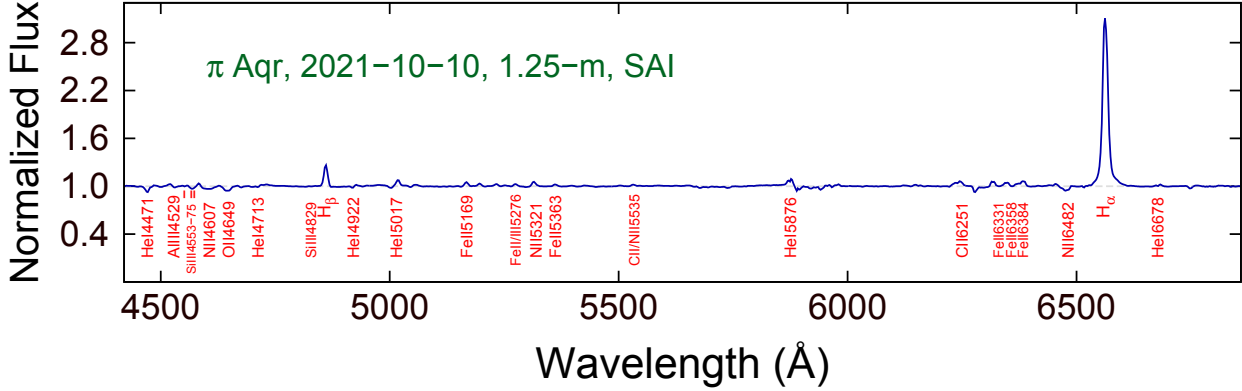


Figure 1: Averaged over all obtained spectra the mean spectrum of π Aqr

Fast LPVs

Analysing the difference profiles we will use the Doppler shifts V from the laboratory wavelength λ_0 of the line instead of the wavelength λ , where

$$V = c \cdot \left(\frac{\lambda - \lambda_0}{\lambda_0} \right),$$

and c is the speed of light. The difference line profile

$$d(V, t) = F(V, t) - \bar{F}(V). \quad (1)$$

where N is the total number of the analysed spectra, $F(V, t)$ is the continuum normalized line flux for the spectrum obtained at time t , and $\bar{F}(V)$ is the mean normalized line flux at the velocity V . Dynamical spectra $d(V, t)$ for H and HeI lines are given in Fig. 2. One can see the similarity of LPVs for H_β , HeI 5107, and H_α lines. Fast variations at the minute time scale may be seen.

Regular components of LPVs

For looking for the periodic components of the line profile variations in the spectrum of π Aqr the CLEAN method of Fourier analysis [10] for difference profiles $d(V, t)$ of HeI and H lines are used. The errors of the regular component frequency and the errors of the corresponding periods in the Fourier spectrum are calculated using the expression $\Delta\nu \leq 1/T$ [11], where $T = 165.4$ minutes is the total duration of observations.

The detected periods together with their errors are given in Table 1. Given short-time LPVs are firstly detected in spectra of π Aqr was not known before but they are similar to those calculated by us for γ Cas [4].

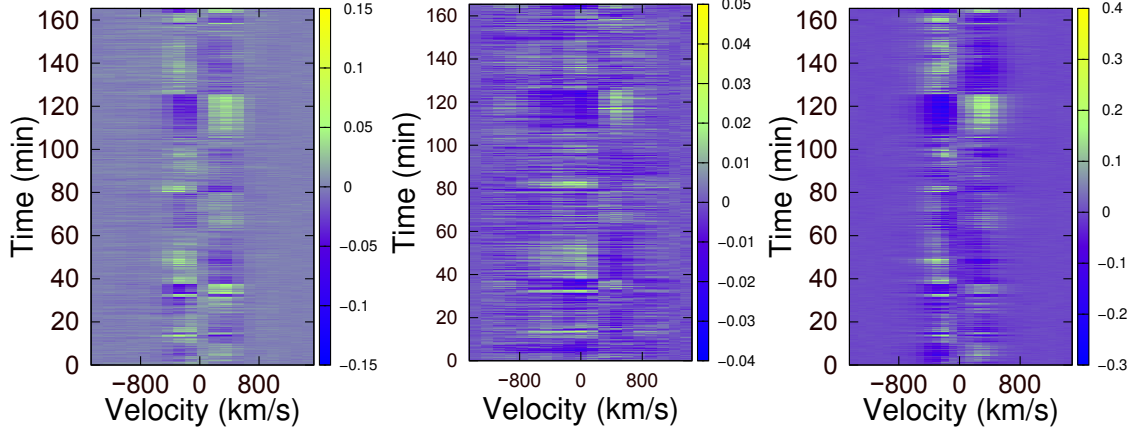


Figure 2: Dynamical spectra of lines H_β (left panel), HeI 5017 (middle panel), and H_α (right panel)

Table 1: Periods of regular LPV's components

No.	1	2	3	4	5
P, min	4.02 ± 0.10	23.08 ± 3.22	27.78 ± 4.67	42.86 ± 11.11	62.51 ± 23.63
No.	6	6	8	9	10
P, min	75.01 ± 34.02	88.25 ± 47.09	107.15 ± 69.43	115.39 ± 80.52	136.39 ± 112.49

The period $P_9 = 115.39 \pm 80.52$ of LPVs is close to period $P_{\text{opt}} = 113$ min detected from an analysis of spectral observations and to period $P_{\text{phot}} = 122$ min from the photometric observations of π Aqr [2].

The similar short time scale periods we detected in the X-ray light curve of the γ Cas type star HD 110432 and in the optical spectra of the γ Cas type star HD 45995 from 30 to 150 min [12]. Resuming we can conclude that the minute time scale optical and photometric variations can be typical for the γ Cas type stars.

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БЫСТРАЯ ПЕРЕМЕННОСТЬ ПРОФИЛЕЙ ЛИНИЙ В СПЕКТРАХ
ЗВЕЗД ТИПА γ Cas: СЛУЧАЙ π Aqr

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Резюме. Проанализирована быстрая спектральная переменность профилей линий в спектре π Aqr. Обнаружены регулярные вариации профилей с периодами от 4 до 136 минут.