Spectroscopy of pulsating stars at Poznan Spectroscopic Telescope – data reduction and radial velocity measurements

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Introduction

We present the results of radial velocity measurements for pulsating stars obtained with Poznan Spectroscopic Telescope (PST) operating at Borowiec Observing Station near Poznan. Observations on PST are run since August 2007. During the 10 months observational period we counted about 700 h of observation, collecting about 1100 stellar spectra. Results of radial velocity measurements done with PST so far show a stability at a level of 100 m/s.

The telescope was built as a small telescope producing high resolution spectra. It is a binary telescope, currently operating a single 40 cm mirror of a newtonian focus. For summer 2008 an upgrade to two 50 cm mirrors is scheduled. Since autumn 2008 both mirrors will be working, acquiring parallel spectra.

Binary telescope was designed to fit a fibre-fed echelle spectrograph of a medium resolution of 35000. The spectrograph optical construction is based on a modified MUSICOS design with a rotating carousel removed and only one fixed prism being used. The spectral range covers 64 echelle rows with wavelength from 4500 Å to 9200 Å.

The PST observing program includes pulsating stars like δ Sct, β Cep, δ Cep and SPB as well as spectroscopic binary stars and, with its limiting magnitude increased soon, extrasolar planetary systems.

Observations and data reduction

The exposure times at PST varies from 150^{s} for the brightest stars to 1800^{s} for stars of 11^{m}, our limiting magnitude. Wavelength calibration is based on the mean of two Th-Ar spectra obtained before and after each object exposure. We have identified 1400 thorium and argon emission lines.

Tungsten lamp spectra are obtained for flat field correction at the end of each night. They are is used to solve the problem of strong fringes appearing in the red part of the spectra.

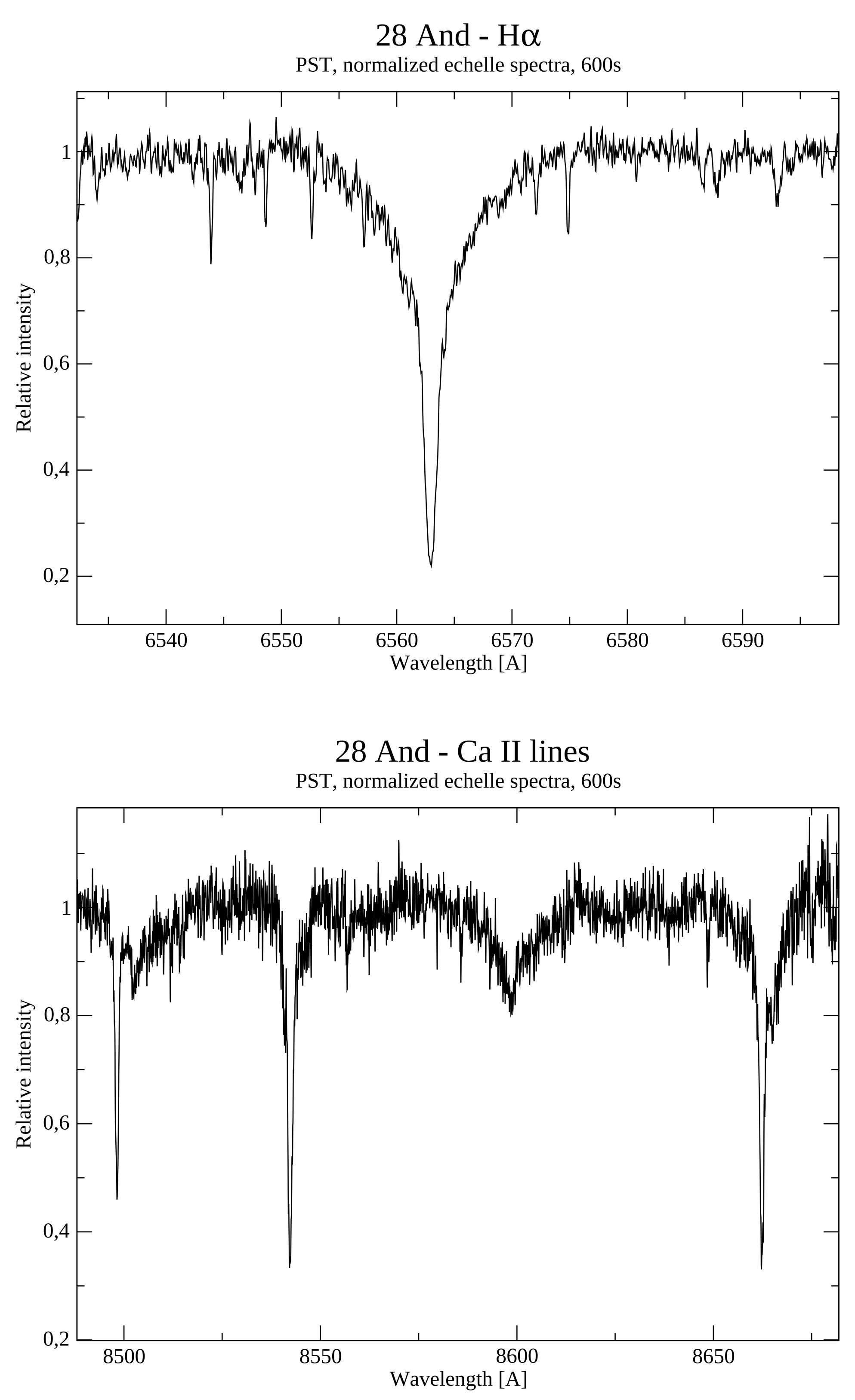

Fig. 1 Examples of extracted echelle spectra from PST. Top: a strong absorption line H α; bottom: the infrared Ca II triplet with the fringing effect removed thanks to the flat field correction

The data reduction is performed with the Image Reduction and Analysis Facility (IRAF) package. From our spectrum 64 echelle rows are extracted. Either well exposed stellar spectrum or the Tungsten lamp spectrum (in case of faint stars) can be used as a reference for tracing. The spectrum consisting of separated rows is divided by a normalized flat spectrum to remove the fringe patterns. This process is aimed at recovering several important lines in the red part of the spectra, like the Ca II triplet (see Fig. 1).

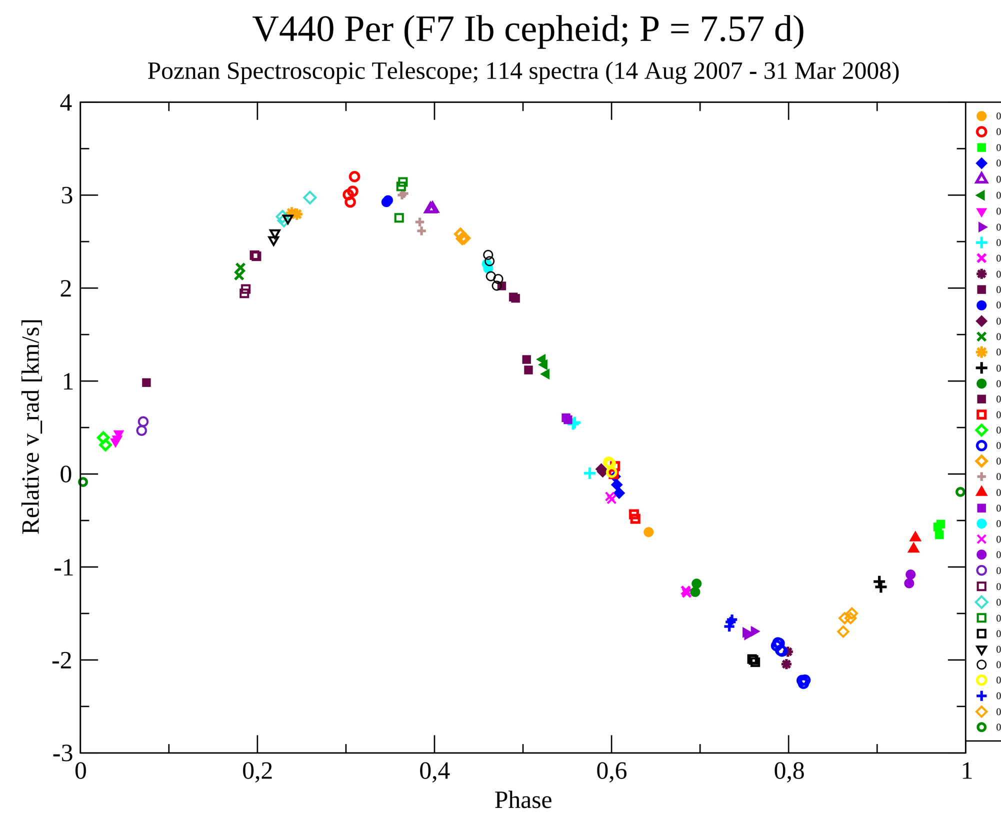

Fig. 2 V440 Per is an example of a classical cepheid researched at PST

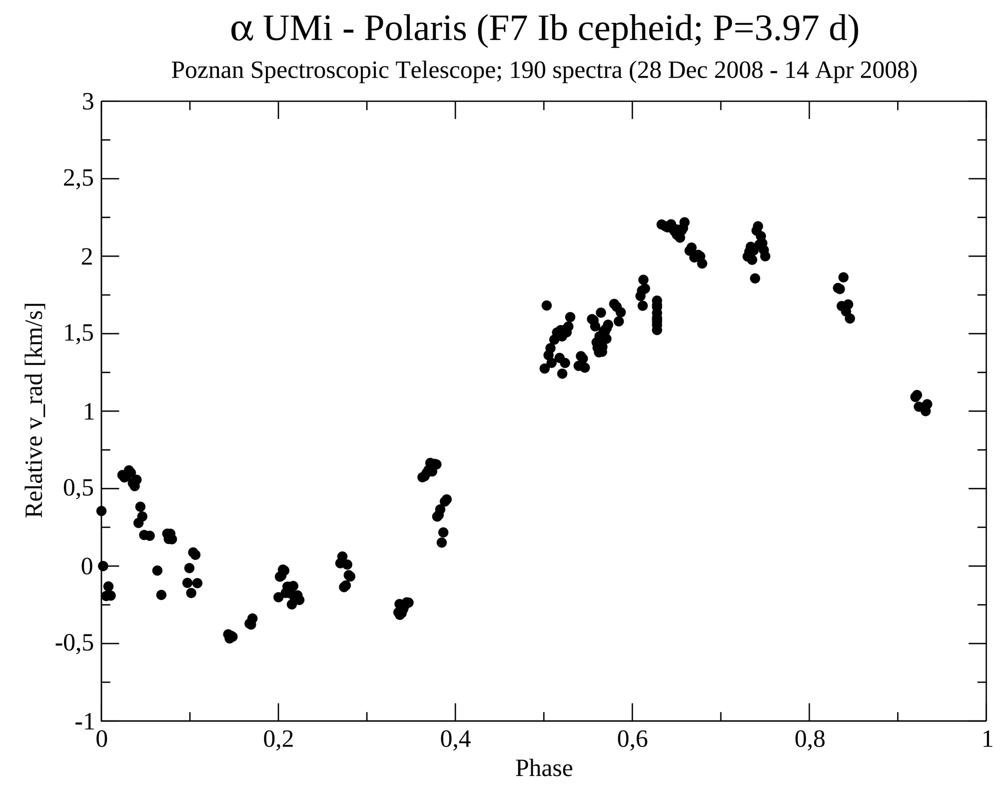

Fig. 3 Polaris was observed at PST for 460 hours in 58 nights. The observational period covers about 27 pulsational cycles of the star

The continuum normalisation is applied before the wavelength calibration. The latter is based on the Th-Ar spectra but possible use of telluric lines is also investigated. Spectra of the separate echelle rows, obtained this way, are then combined into a single spectrum, which is used in further analysis.

Radial velocity measurements are performed at separate rows or at combined spectrum. The stellar spectra are cross-correlated with a template, which could be either the spectrum of the same star or one of the radial velocity standards.

Results

We present two examples of stars from the Cepheid instability strip studied with PST. Results for V440 Per are presented in Fig. 2. The object is a bright F7 Ib star of visual magnitude $6\overset{\mathrm{m}}{.}3$. For V440 Per we have acquired over a 110 spectra exposed for 600^{s} to 900^{s}. Current measurements result in detection of a low amplitude, about 90 m/s, second harmonic of pulsation. The star is scheduled for further observations to confirm the result.

The brightest and the nearest classical Cepheid observed is Polaris. For α UMi we achieved a signal-to-noise ratio $S/N = 30-70$. The pulsational period detected from PST radial velocity measurements is $P = 3\overset{\mathrm{d}}{.}97792 \pm 0\overset{\mathrm{d}}{.}0015$. It is consistent with the latest estimations by Lee et al. (2008), which obtained a value of $3\overset{\mathrm{d}}{.}97208 \pm 0\overset{\mathrm{d}}{.}00013$. The phased radial velocity curve is presented in Fig. 3.

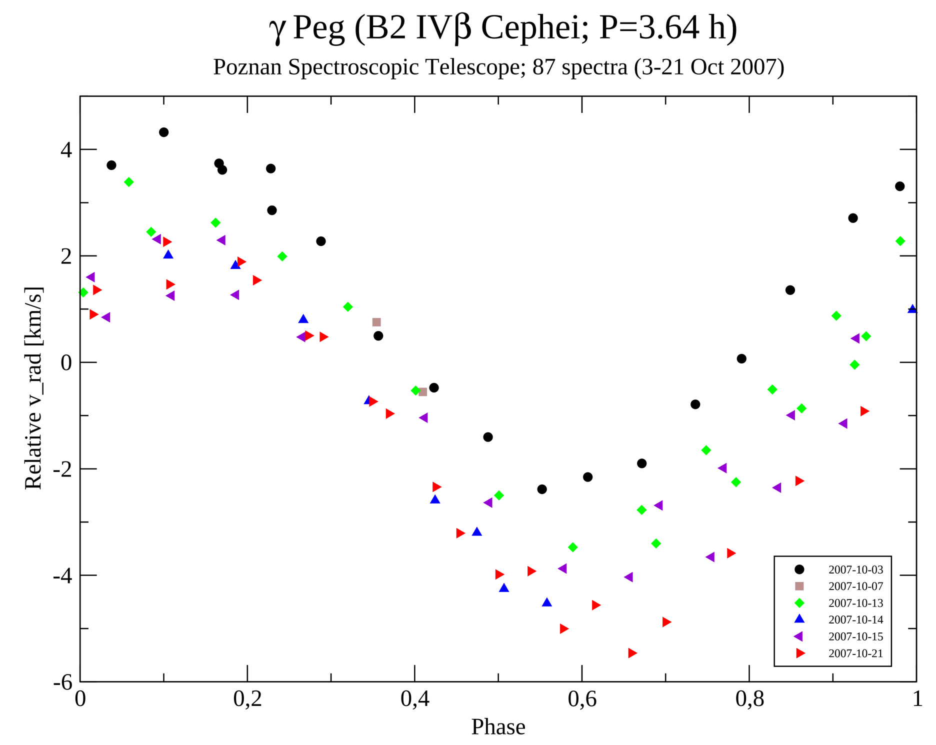

Fig. 4 Radial velocity curve for γ Peg phased with the frequency of 6.59140 ± 0.00151 [cycles/day]

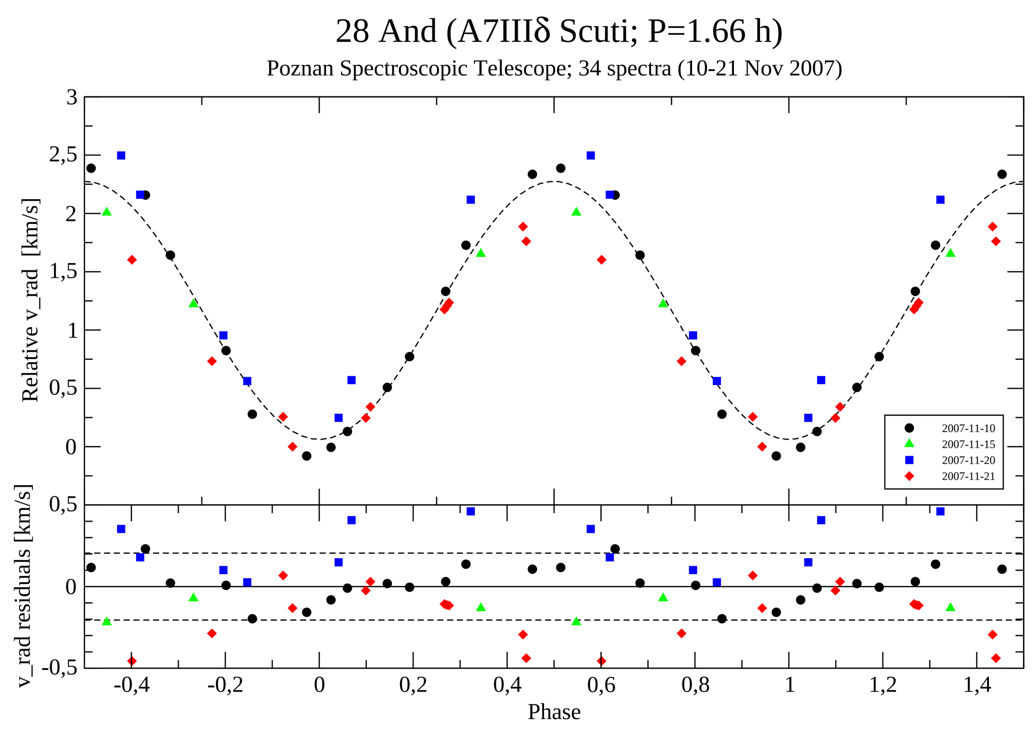

Fig. 5 Observations of 28 And were a good test of PSTs capability of observing short period stars. 600^{s} exposure covers about 10% of pulsational period for this star. Residuals show goodness of a single sine fitting

Radial velocity curve for γ Peg is shown in Fig. 4. The star is a bright B2IV β Cephei type pulsator. Our results reveal a period of $3\overset{\mathrm{h}}{.}4$ and an amplitude of variations about 3.5 km/s. The curves from different nights are shifted with respect to each other which is due to stars binarity and possible beats connected with a long term SPB pulsations.

The results presented in Fig. 5, were obtained for a star belonging to δ Sct family. 28 And is an A7III star. The obtained frequency of 14.427 ± 0.004 cycle/day, corresponds to earlier photometric estimations of 14.429 cycle/day by Rodriguez. The presented radial velocity curve has a RMS scatter of a single sine fitting at a level of 200 m/s.

The radial velocity curves obtained for featured stars show the quality of observations done with PST. Despite the small aperture PST is eligible of resolving low amplitude and short period radial velocity variations, sufficient enough for research of pulasating stars.

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Acknowledgements This work was supported by the MNiI/MNiSW grant No. 1 P03D 025 29. The authors acknowledge the use of the NOAA IRAF package and Period04 by P. Lenz during reduction of the data.