International Observing Campaign:
Photometry and Spectroscopy of P Cygni

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The international observing campaign *Photometry and Spectroscopy of P Cyg* is a common project of AAVSO, ASPA and BAV. Launched in November 2008, the project yielded very encouraging results. Markova [1] and Markova et al. [2] suggested an anti-correlation between the variations of the equivalent width EW of the Hα line profile and the variations of the photometric V magnitude of the star P Cyg. The variability of the equivalent width of the Hα line was up to 10Å. In this investigation the time scale of the variability is found to be between 40 and 60 days.

The primary goal of the project is to continue observations to confirm the anti-correlation between the photometric variability and the spectroscopic variations suggested by Markova. In addition further information about the flux of the spectroscopic lines shall be obtained.

The proposed anti-correlation is based on a direct comparison of earlier photometric and spectroscopic observations (Markova, 2001). If the equivalent width of the Hα line decreases, the stellar brightness increases and vice versa (Fig. 1). It is assumed that the variability of the width of the line profiles are more likely caused by variations of the continuum flux and not by variations of the density of the stellar winds. Therefore, the influence of the variability of the continuum flux shall be our primary concern, if the properties of the stellar winds and rate of mass loss are studied.

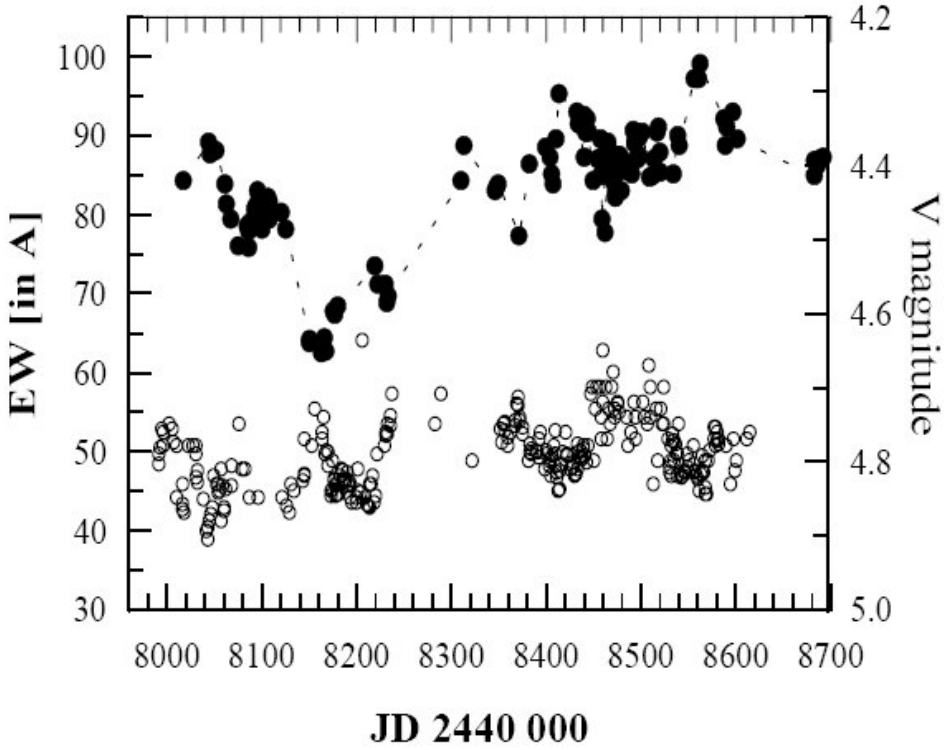

Fig. 1: Plot of the photometric V magnitude versus Hα-equivalent width (from Markova et al. [2]). A anti-correlation is found from the graph.

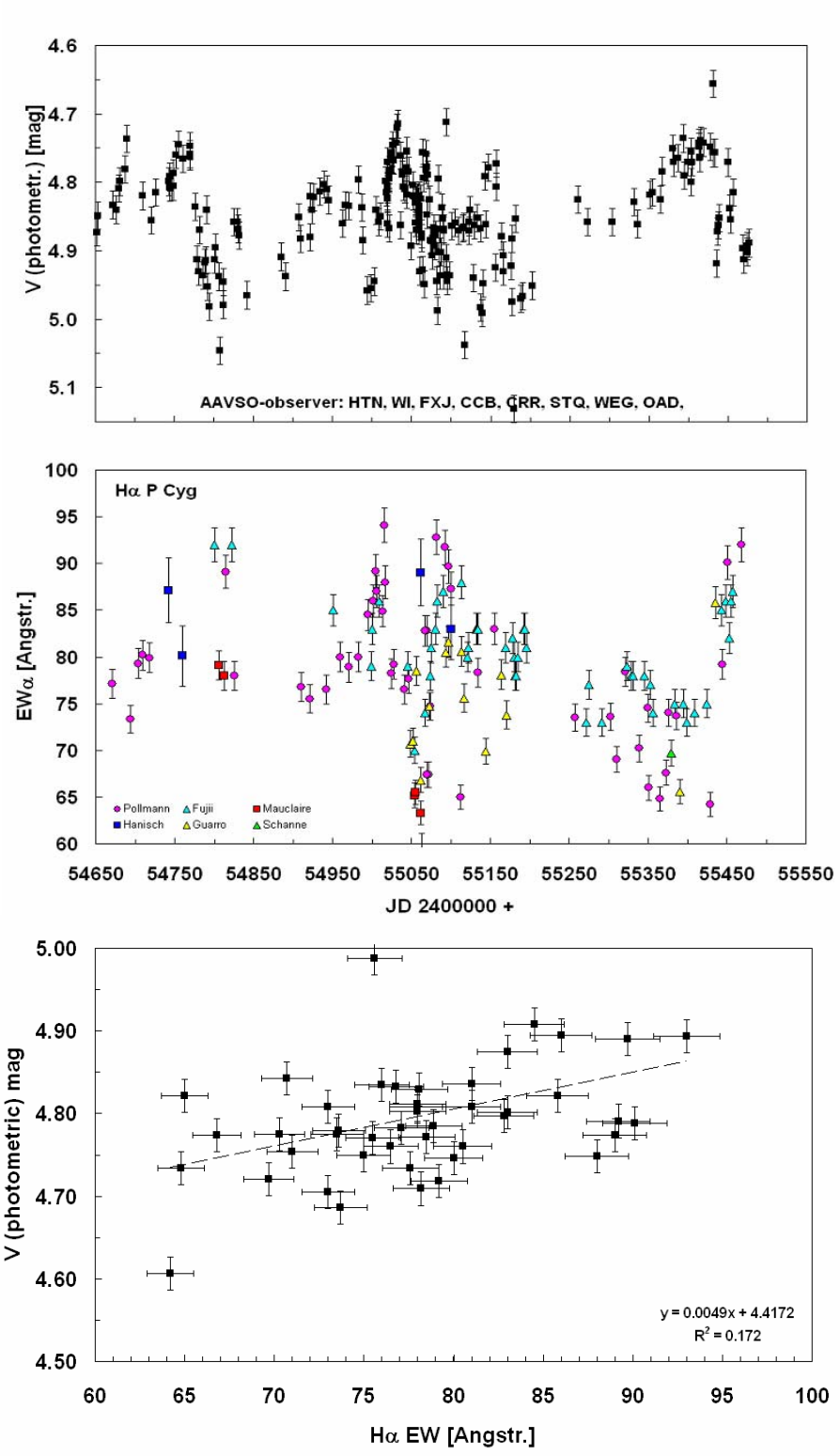

Fig. 2: In analogy to the results in the investigations of Markova et al. (in fig. 1) the comparison of the behaviour of EW and V during our campaign.

So far, our own results (fig. 2) may represents well the anti-correlation results of Markova. Strict anti-correlation is expected if the variation of the continuum flux is independent from spectroscopic variations. If the photometric flux of the spectral line is constant over time an increase of the continuum flux will yield a smaller flux from the evaluation of the equivalent width (EW) found in the line profiles. A simplistic normalization of the continuum is a typical

source of the problem. The lower plot of fig. 2 shows this anti-correlation as V versus Hα EW. The small coefficient of correlation of only 0.17 has at least two causes:
- differences in the continuum fluxes. Strictly applied, the continuum flux at 6563 Å should be used. But here ΔV is a good approximation since the colour indices of P Cygni do not vary greatly.
- further intrinsic components (temperature, density, velocity)

To find out if and how the flux obtained from the spectral line profiles varies the equivalent width measurement is corrected for the effect mentioned in the previous section.

From the definitions of equivalent width $EW = \sum \frac{Fc - F\lambda}{Fc} d\lambda$

and the photometric stellar magnitude $J2/J1 = 10^{-0.4\,(m2-m1)}$ the relation yields

$$F = EW / 10^{(0.4\,Vphot)}$$

In practice, EW is corrected with a simple division by $10^{(0.4*Vphot)}$. It is important to consider the absolute flux of the line because its variations are caused by the effects of mass loss, stellar wind density and changes of the ionization of the chemical elements in the outer gas shell. In the current campaign we have already obtained 46 nearly simultaneous measurements of the equivalent width EW and the photometric flux in the visual (V) spectral range.

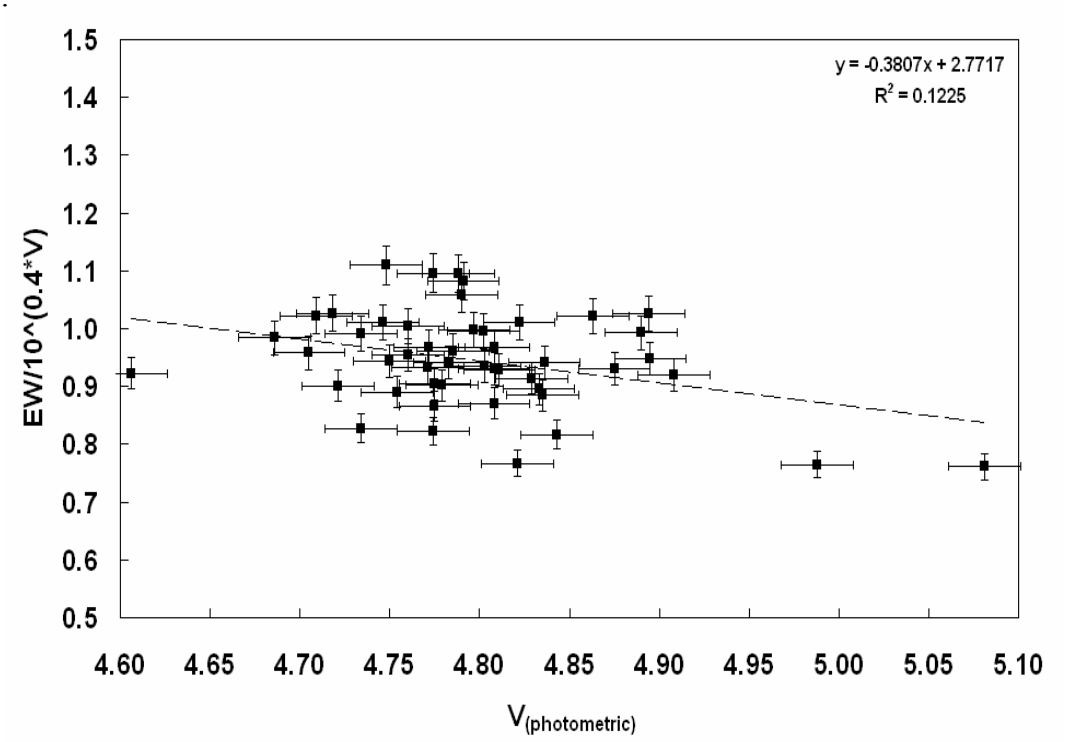

Fig. 3: The relationship between line flux and the V magnitude.
This is uncorrelated in the order of 0.12

Fig. 3 attempts to display if and to what extent the intrinsic line flux (a continuum-corrected EW) depends on Vphot. From a statistical point of view one can say that the low 0.12 correlation coefficient (which should be zero after the continuum correction), with consideration of the measurement uncertainties, suggests the conclusion that the Hα line flux is independent of Vphot.

This would confirm that the uncorrected EW variations with (almost) constant line flux, predominantly results from changes in V, and (if so) the anti-correlation of EW to Vphot shown in Fig.1 and 2.

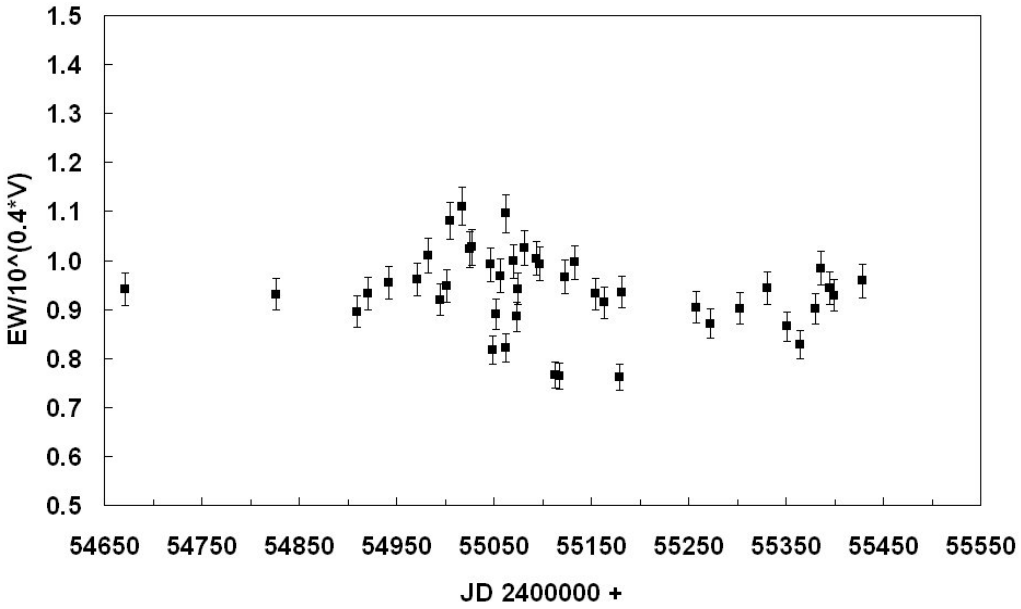

Fig. 4: Intrinsic flux of the Hα line since 2008/11 to 2010/11

The temporal variation of the absolute line flux of Hα is found to be at a nearly constant level with a certain deviation (Fig. 4). This kind of plot will represent changes of the mass loss, stellar wind density and changes of the ionization. The 46 EW and V-measurements of the current campaign are of course, from a statistical point of view, still not sufficient to make firm statements regarding the simultaneous temporal behaviour of V and the intrinsic line flux. In order to achieve this aim further, multiyear, simultaneous spectroscopic and photometric measurements are needed.

[1] Following observers took part at the project:

AAVSO (V_{phot}):
Adrian Ormsby
Robert E. Crumrine
Jim Fox
Kate Hutton
Nick Stoikidis
David Williams
E. G. Williams
Charles L. Calia
Thomas L. Peairs
Jeffery G. Horne

Spectroscopy (Hα-EW)
Mitsugu Fuji (Japan)
Benjamin Mauclaire (France)
Joan Guarro (Spain)
Lothar Schanne (Germany)
Bernd Hanisch (Germany)
Ernst Pollmann (Germany

References:
[1] Markova, N.; P Cygni 2000, 400 Years of Progress; ASP Conference Series, Vol. 233, 2001
[2] Markova, N; Morrison, N; Kolka, I; Markov, H; (2001) A&A 376, 898-906

Acknowledgments:
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Description of figures

Fig. 1: A plot of the photometric V magnitude versus the equivalent width of the Hα according to Markova [2]. A anti-correlation is found from the graph.

Fig. 2: : In analogy to the results in the investigations of Markova et al. (in fig. 1) the comparison of the behavior of EW and V during our campaign.

Fig. 3: Plotted relation between flux of the line and the V magnitude. The relation is found uncorrelated in the order of 0.12

Fig. 4: : Intrinsic flux of the Hα line since 2008/11 to 2010/11