Precession of the Disk in Pleione

Study of the Hα Line Profile

Introduction

Pleione (28 Tau, HD 23862) is a B8Vpe star (Hoffleit & Jaschek 1982) and a member of the Pleiades cluster. It is known to exhibit prominent long-term spectroscopic variations with a period of approx. 35 yr. A comprehensive summary of observations of Pleione is given at Hirata (1995) and Hirata et al. (2000). The observation and study of the Hα emission line and its profile of this binary system reveals at least five types of variabilities:

1. the equivalent width (EW)
2. the red and blue line wings
3. the so-called V/R ratio
4. the radial velocity (RV)
5. the central absorption depth (CA)

Fig. 1 shows the variation of the Hα line profile at some typical epochs:

1974: the early shell phase
1981: the shell maximum phase
1999: the Be phase with maximum emission
2004: the Be phase

One can readily see that the profiles changed from the edge-on type (shell-line profile) to the surface-on type (wine-bottle type), implying that the disk inclination angle changed remarkably.

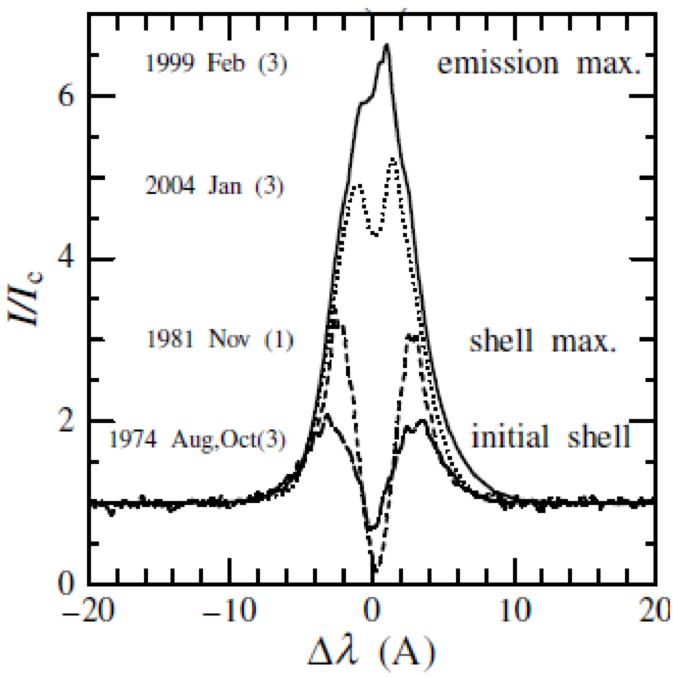

Fig. 1: Variation of the Hα line profile at some typical epochs
(taken from R. Hirata ASP Conference Series, Vol. 361, 2007)

The forming of a new disk and its observation of the Hα EW and the line wings between November 2005 and May 2007 have been impressively documented by Katahira et al. (2006), Tanaka et al. (2007) and Lliev (2000). Within the time span January 2012 to February 2015 the ARAS spectroscopy community (http://www.astrosurf.com/aras/) was successful in documenting four periastron passages of the star in order to investigate the change in radial velocity (RV) along with the V/R ratio of the Hα double peak profile (Pollmann, 2015). Our results were very well in agreement with that of Katahira et al. (1996) and Nemravova et al. (2010).

But the question regarding point 5 is, how can we understand the causes of the variability of the Hα CA?

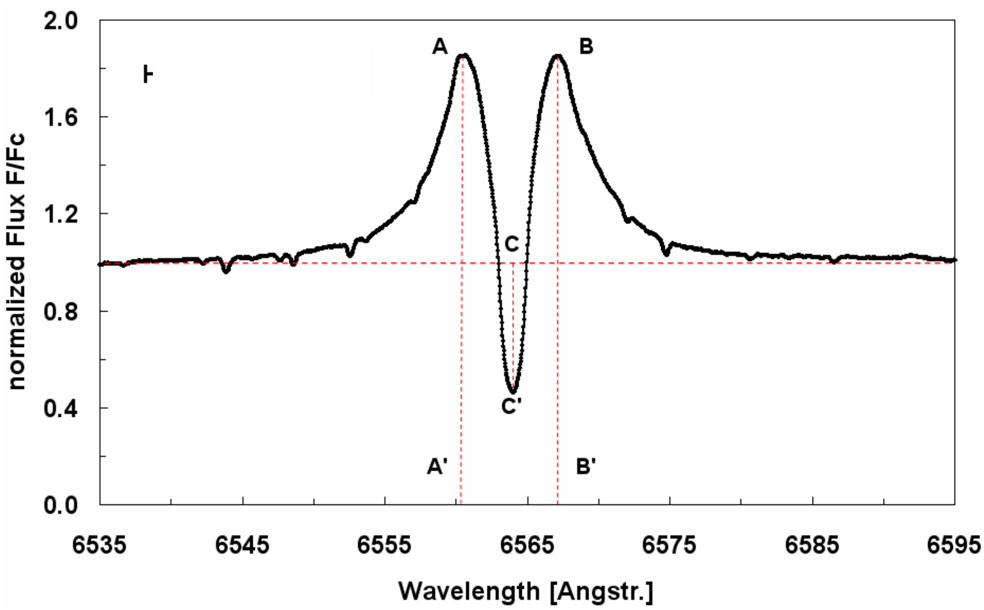

Fig.3: Measured quantities illustrated on a Hα line profile: (AA') and (BB') emission peaks, depth of the central absorption (CC'). The horizontal line marks the normalized continuum.

The depth of the Hα CA is defined as the difference between the local continuum level (equal to unity) and the minimum value at the line minimum intensity (Fig. 3). While the Hα emission line samples the disk as a whole, the region probed by the shell lines (CA) is restricted to the line of sight. The diagnostics they provide should not be neglected, as their properties (absorption depth) reflect the structure and dynamics of the disk in the observer's direction.

In the literature it is assumed (Schaefer et al. 2010) that the CA is caused by a different angle of the disk plane related to the observer´s line of sight, as a consequence of the disk precession around the primary star. Since 28 Tau is a binary, any tilt of the disk will be modulated by the tidal force of the companion. This can manifest itself as nodding.

Observation and Results

For the investigation presented here, 226 representative spectra of the time span October 2004 (JD 2453300) until now were taken from the BeSS database. The Hα spectra were obtained with 0.2m to 0.4m telescopes with a long-slit (in most cases) and echelle spectrographs with resolutions of R = 10000-20000. All spectra included the 6400−6700 Å region, with a S/N of ~100 for the continuum near 6600 Å. The spectra have been reduced with standard professional procedures (instrumental response, normalisation, wavelength calibration) using the program VSpec and the spectral classification software package MK32. Fig. 4 shows the CA time behavior from October 2004 until now.

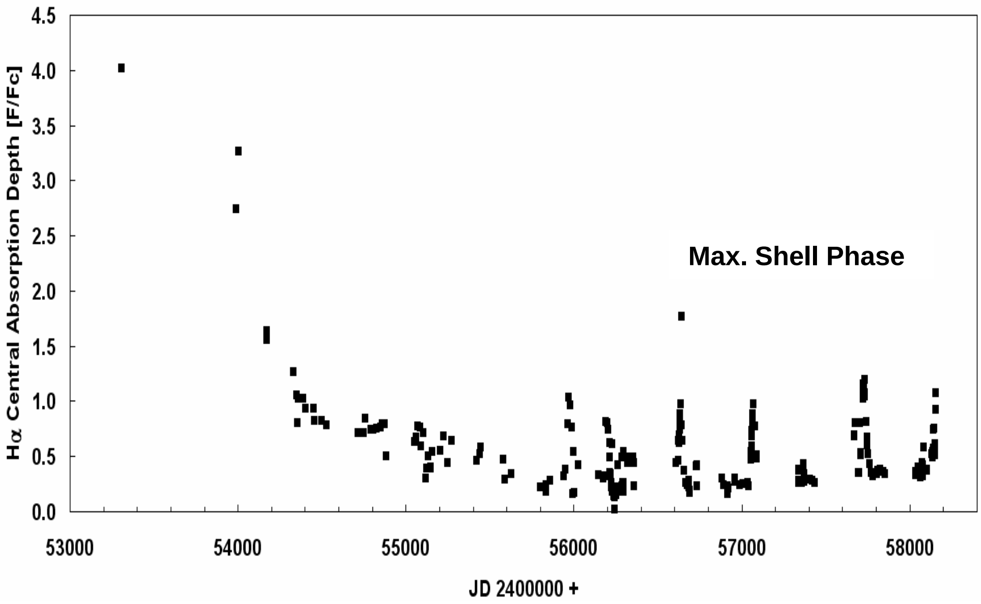

Fig. 4: Central Absorption Depth of the Hα Emission in 28 Tau
since October 2004 JD 2453300 (Hα emission maximum)
Amateur spectra of the BeSS Database

The time span from October 2004 (approx. JD 2453300) until August 2011 (JD 2455800) was dominated by the behavior after the formation of a new disk and the corresponding decrease of the EW and the CA. One notable fact, however, can be seen in Fig. 4: a to-date observable, periodic variability since JD 2455800, which however in the time before, until at least October 2004, was not visible. So, we can define that time section, corresponding to the definition of Hirata (2007) in Fig. 1, as max. shell phase.

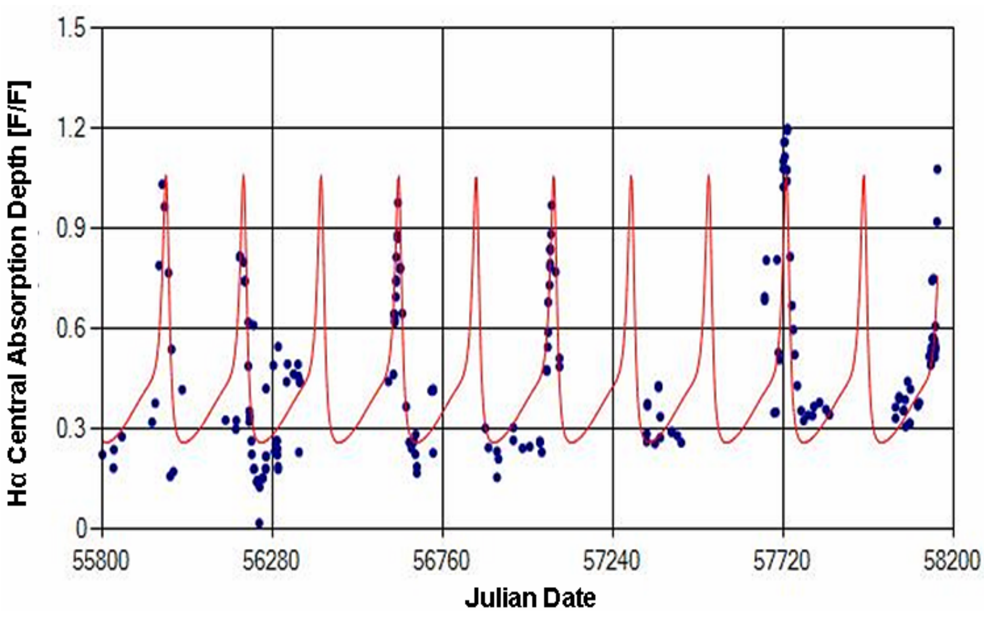

Fig. 5: Central Absorption Depth of the Hα Emission in 28 Tau
Max. Shell Phase since approx. JD 2455900 until now

Fig. 5 clarified the CA variability during the max. shell phase since approx. JD 2455900 until now, which is of course followed by a period analysis. This is done and shown in Figs. 6 & 7.

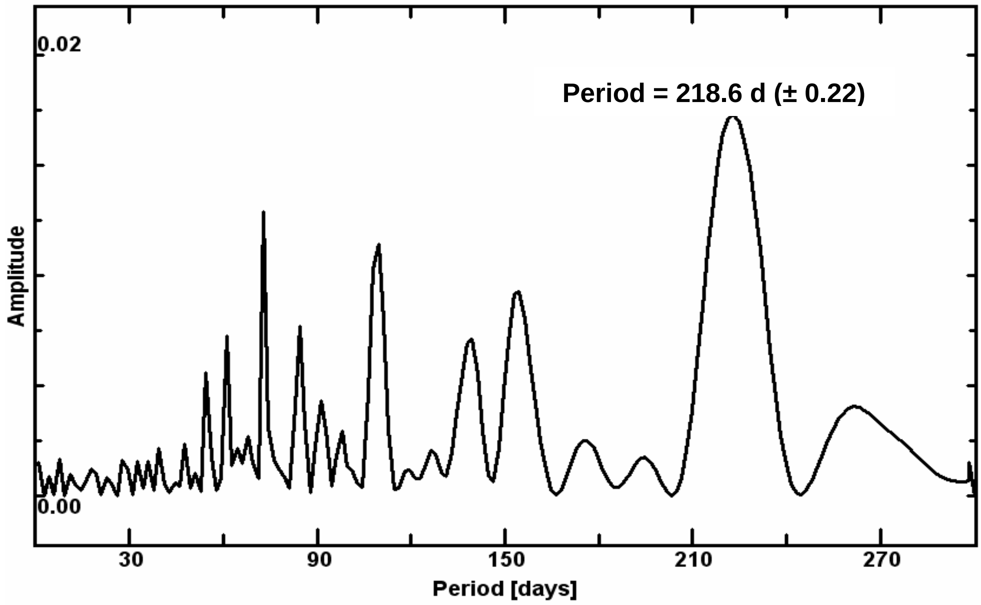

Fig. 6: Periodogram of the CA time series data in Fig. 5

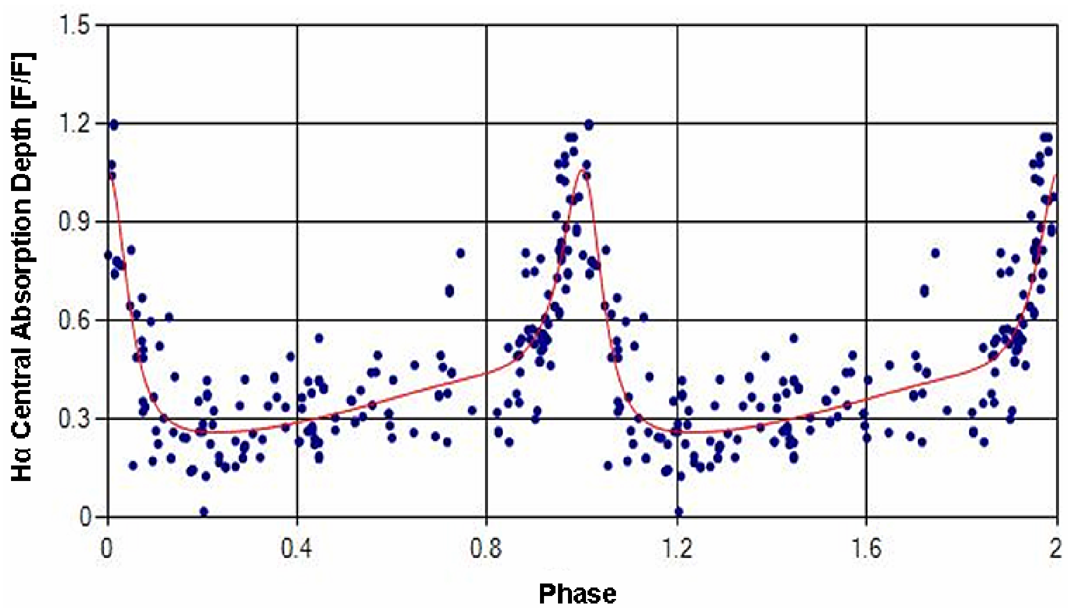

Fig. 7: Phase diagram of the found period of 218 days in Fig. 6

The period analysis of the CA time series data in Fig. 5 was performed with the use of the program AVE (Barbera 1998), and produced the Scargle periodogram with the discriminant factor plotted in Fig. 6 and the phase diagram in Fig.7. This period of 218 days is exactly in agreement with the period of the V/R ratio and the radial velocity found by Pollmann (2015).

This CA variabililty as a result of the disk precession has never before been observed during the max. shell phase in the years around 1980, or during the initial shell phase around August/October 1974. It is known that the precession of the disk depends on its size (radius) and its mass due to gravitational effects (Katz et al. 1982, Larwood et al. 1996, Lubow & Ogilvie 2001).

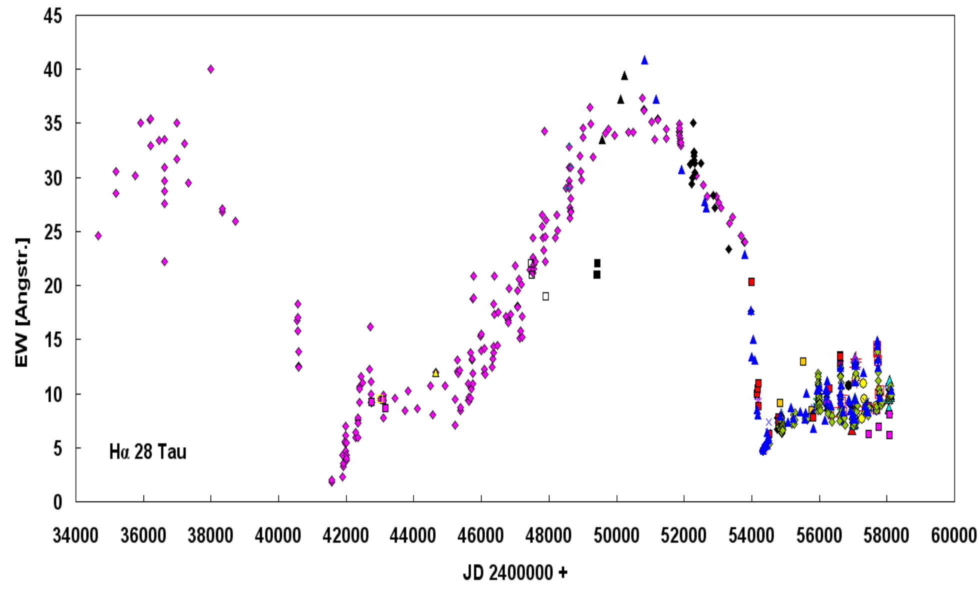

Fig. 8: Long-term monitoring of the Hα EW in 28 Tau since October 1953
by the following observers:

Against this background it is interesting to locate the time section of the periodic CA variability of Fig. 5 in the long-term monitoring of the Hα EW in Fig. 8. It is noticeable that this time section coincides with the minimum of the EW, i.e. with the minimum of volume and/or size of the disk. It will therefore be very exciting to see how a growing disc will impact the precession period of 218 days in the next few years.

That´s why it is planned to continue this project as collaboration with professional experts. The more ARAS observers are willing to take part in this project in the future, the larger the database we will have in order to find out a possible link between the disk size (and / or volume) and the period of the central absorption depth CA and hence also the V/R period as this variability reflects directly the nodding oscillation as a result of the precession of the disk, as it have been found at the Be star zeta Tau (Pollmann, 2017).

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