The time behavior of the visual brightness Vmag in the context of the Hα equivalent width EW of delta Sco

by Ernst Pollmann, 2017-07-05

The spectroscopic long-term monitoring of the Hα equivalent width (EW), mainly by members of the ARAS and two of the VdS spectroscopy group, as well as the visual brightness Vmag (various sources) since more than 17 years (since June 2000) offers the possibility of investigating both values in the context of possible correlations. Fig. 1 shows the time behavior of the visual brightness Vmag in the upper plot, and the Hα-EW in the lower plot.

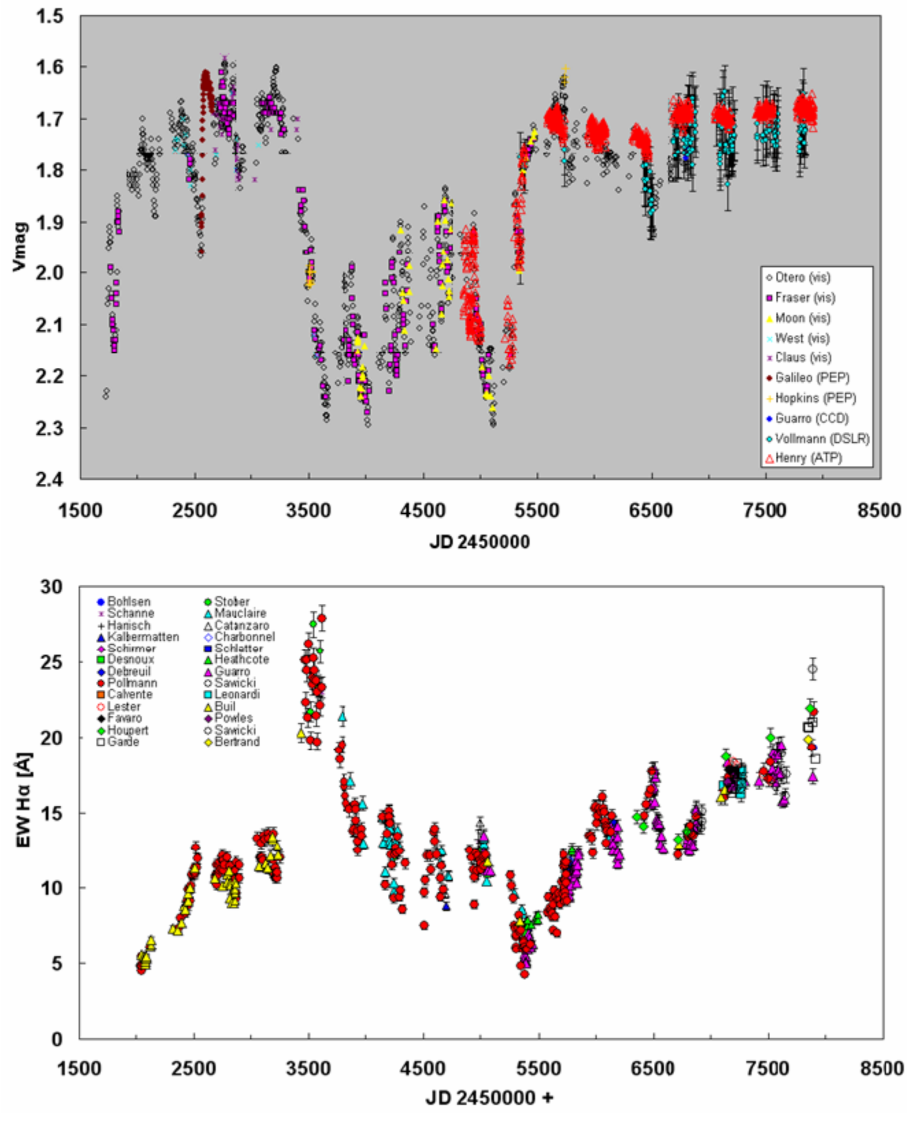

Fig. 1: Long-term monitoring of the visual brightness Vmag (above) and Hα equivalent width EW (bottom) of δ Sco

How can the time behavior of the V-brightness and the EW in Fig. 1 be understood? The optical continuum (free-free transitions > Vmag) generated in the circumstellar gas of the disk should generally correlate with the Hα line flux (free-bound transitions > recombination), because they both are dependent on the number of ionized hydrogen atoms in the circumstellar gas. Deviations from this general correlation can be due to the effects of the optical depth and the geometry of the circumstellar material (matter ejected by the star in the observation line).

Moreover, further effects can also lead to deviations from this general correlation, and are investigated using radiation transfer models. Such studies are carried out, for example, by A. Carciofi and his colleagues (University of Sao Paulo).

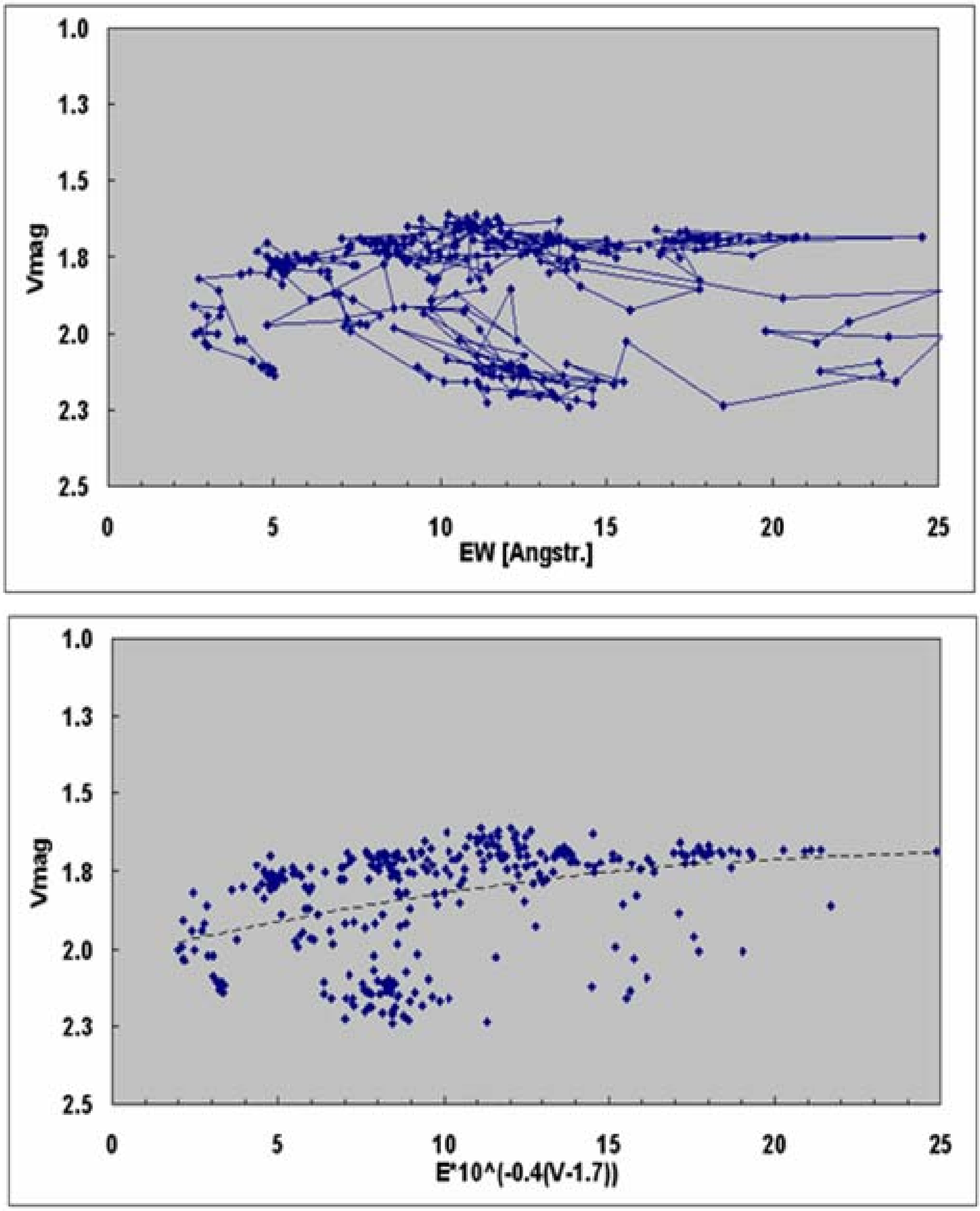

Fig.2: above: Vmag versus Hα-EW; bottom: Vmag versus Hα-flux

The two diagrams in Fig. 2 show the attempt to correlate the V-brightness with temporally exactly congruent Hα EW data (top) and Hα line flux data (bottom). How are these two diagrams to be understood?

When new material is introduced into the disk by the Be star, it begins to rotate around the star, and remove itself from the star by viscous energy transfer. At the same time the disk density at all distances from the star and the continuum optical depth becomes larger. When the mass loss increases, it first affects the spectral lines, which become stronger. The disk size and the Hα emission intensity increase.

The optically thick, inner disk regions begin - caused by the inclination of 38°- to cover more and more the photosphere of the Be star (in extreme cases up to half). After some time as the ejected matter penetrates deeper in the disk (further away from the stellar surface), the star fades.

If the matter ejection from the star moves away or stops, the disk turns into a ring (Rivinius et al. 2001, A&A, 379, 257). When a disk becomes a ring, the Balmer lines become narrower, because the most rapidly rotating matter from the inner parts of the disk does not exist, and the coverage of the Be star becomes smaller and the V brightness of the continuum increases.

The diagrams in Fig. 2 indicate that the variations in the visual brightness are most likely due to variations in the circumstellar matter of the disk, which in turn are attributable to a variable mass loss rate. Such a correlation was very well documented in observations from July to October 2000 in Fig. 3.

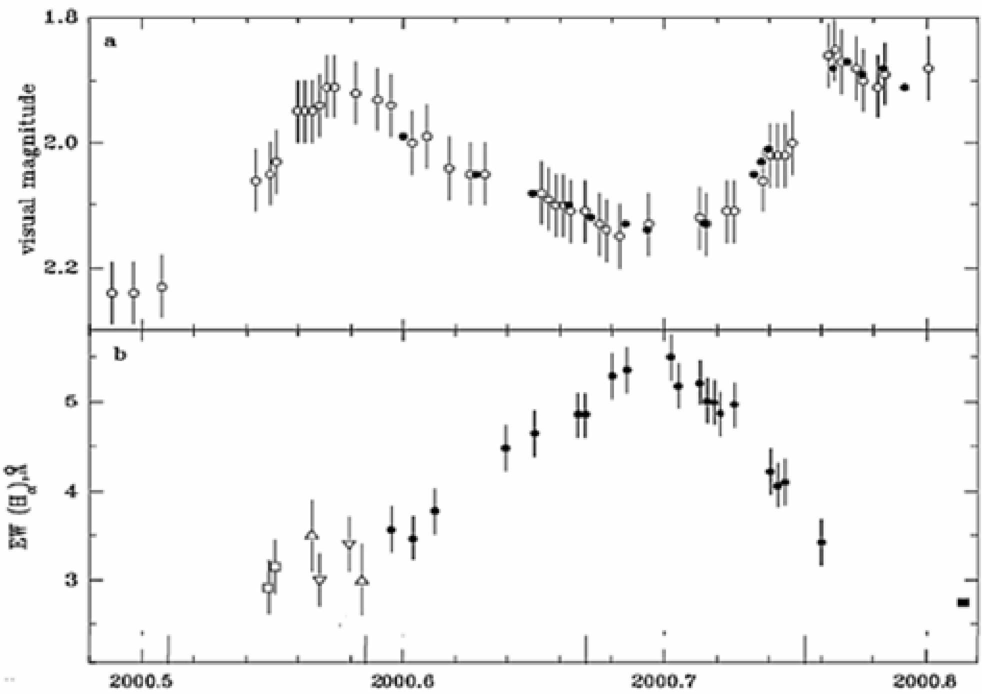

Fig. 3: Relationship between Vmag and Hα EW
in July - October 2000 (taken from A&A 377, 485-495)

When the matter is spread out beyond the projection of the circumstellar onto the star's disk, the optical depth drops and the star becomes brighter. Subsequent outbursts, occurring close to one another in time, could also produce a cumulative effect on the brightness.

Thus, the overall behavior of the star's brightness is determined by two major effects:

- the increasing amount of circumstellar matter in the disk adds additional radiation,
- while the varying circumstellar optical depth is responsible for the brightness variations.

This comparison and an almost constant maximum brightness of δ Sco in 2001–2002 and from 2014 to now (see Fig. 1, above) suggest that there will be no further significant brightening of the star due to additional circumstellar matter, although the line emission may become stronger, as it is currently observable.