VV Cephei campaign
Periodic precession of B stars rotational axis after periastron 2025

by Manfred Schwarz & Ernst Pollmann

VV Cephei is a binary star consisting of an M-type supergiant star and a B-type companion on an orbit of 20.36 years. A lot of amateur and professional astronomers as well did contribute particularly during the eclipse 2017-2019 with high professional spectra of the Hα region.

Ernst Pollmann collected all the spectra and performed a new wavelength calibration with typical metal lines of the M-star (according to K. O. Wright) to archive a correct and common base for evaluation of the Hα profile. That procedure leads to discover a new unknown periodic behaviour of R/V and EW(R), EW(V) of 43 days. Together with Philip Bennett (University of Halifax), they found a plausible explanation for that periodicity. You will find further details later.

A brief history of research on VV Cephei

1934 Dean B. McLaughlin published a paper about the variability of the VV Cephei spectrum. He studied the absorptions in the emission lines and the R/V ratios for several years, especially during the period of eclipse. He thus contributed significantly to the understanding of the composition and mass transfer between the two components.
[https://ui.adsabs.harvard.edu/abs/1934ApJ....79..380M/abstract]

1971 J. B. Hutchings and K. O. Wrigth published a paper with measurements during the eclipse of 1956-58. Wrigth measured the radial velocity within the system on metal lines of the M-component against the central-absorption of the Hα-emission. The emission comes from the accretion disk around the B-component. In that paper they describe a lot of mechanical data of the system.
[https://ui.adsabs.harvard.edu/abs/1971MNRAS.155..203H/abstract]

1977: Wrigth published again new measurements. Included is also the table of Hα near M-type calibration lines:

LINES IN THE M-TYPE SPECTRUM USED TO DETERMINE THE RADIAL VELOCITY OF THE B-TYPE STAR AND THE COMPONENTS OF Hα

Wavelength Å	Atom	Wavelength Å	Atom
6531.440	V I	6572.840	Ca I, Cr I
32.891	Ni I	74.238	Fe I
37.921	Cr I	81.220	Fe I
46.260	Fe I, Ti I	86.330	Ni I, Mn I
51.680	Fe I	93.878	Fe I
54.226	Ti I	99.112	Ti I
56.066	Ti I		

[https://ui.adsabs.harvard.edu/abs/1977JRASC..71..152W/abstract]

1979: R. Faraggiana & P. L. Selvelli took spectra in the UV region and calculated the surface temperature if the B-component with 10000K.
[https://ui.adsabs.harvard.edu/abs/1979A%26A....76L..18F/abstract]

1980: Shusaku Kawabata, Keiichi Saijo, Hideo Sato and Mamoru Saito monitored the Hα profile during the eclipse 1976-78. The found out that the envelope around the B-star should have a radius of ~500R⊙ and a rotating velocity of 85kms-1 in the same direction as that of the orbital motion of the B-star.
[https://ui.adsabs.harvard.edu/abs/1981PASJ...33..177K/abstract]

1981: C. Moellenhoff & K. Schaifers calculated the shape of the envelop around the B-star

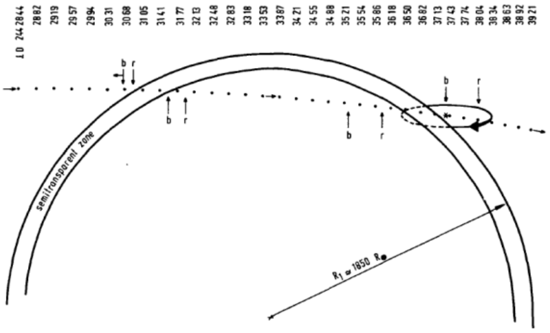


Fig. 5. The primary star of VV Cep and the companion's orbit as they appear projected against the sky. The orbit is indicated by dots, the corresponding Julian Dates are on top. The contact times for H_β blue (*b*) and H_β red (*r*) are indicated. The equator of the rotating emission envelope is drawn at the position of the fourth contact for H_β blue

[https://ui.adsabs.harvard.edu/abs/1981A%26A....94..333M/abstract]

1981: Keiichi Saito calculated the shape of the envelop around the B-star

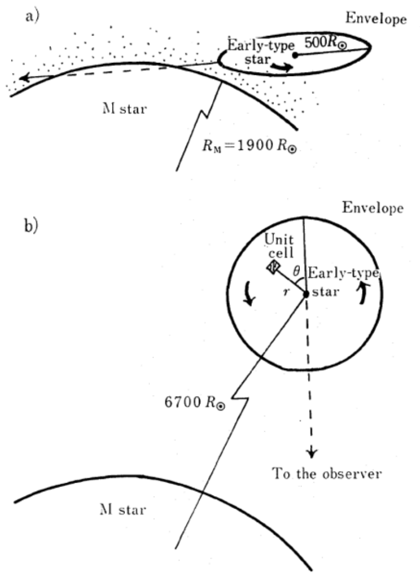


Fig. 3. Geometry of the emitting disk: a) the view along the line of sight, b) the view perpendicular to the orbital plane. The position in the envelope is described by the polar coordinates (r, θ), where the origin is at the early-type star's center. The effective radius of the envelope is $500 R_\odot$ and the radius of the M star is $1900 R_\odot$. The distance between the centers of the two stars is about $6700 R_\odot$ during the eclipse.

[https://ui.adsabs.harvard.edu/abs/1981PASJ...33..351S/abstract]

1989: M. Hack, S. Engin & N. Yilmaz measured the system in the UV region and found out, that the best fit of the companion would be an A0 II type.
[https://ui.adsabs.harvard.edu/abs/1989A%26A...225..143H/abstract]

1991: W. H. Bauer, R. E. Stencel & D. H. Neff analysed the mass transfer from the M star to the B component. They realized that the upper atmosphere of the M star is highly clumped.
[https://ui.adsabs.harvard.edu/abs/1991A%26AS...90..175B/abstract]

1992: M. Hack, S. Engin, N. Yilmaz, G. Sedmak, L. Rusconi & C. Boehm confirmed in their study the late B or early A type of the companion and showed the orbit in pole-side-view:

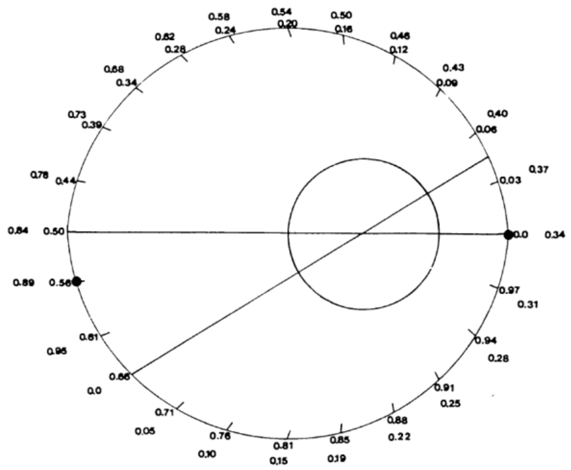


FIGURE 2. The orbit of the companion, according to Wright (1977). The phases counted from mid-eclipse and from epoch of passage at the periastron are given.

[https://ui.adsabs.harvard.edu/abs/1992A%26AS...95..589H/abstract]

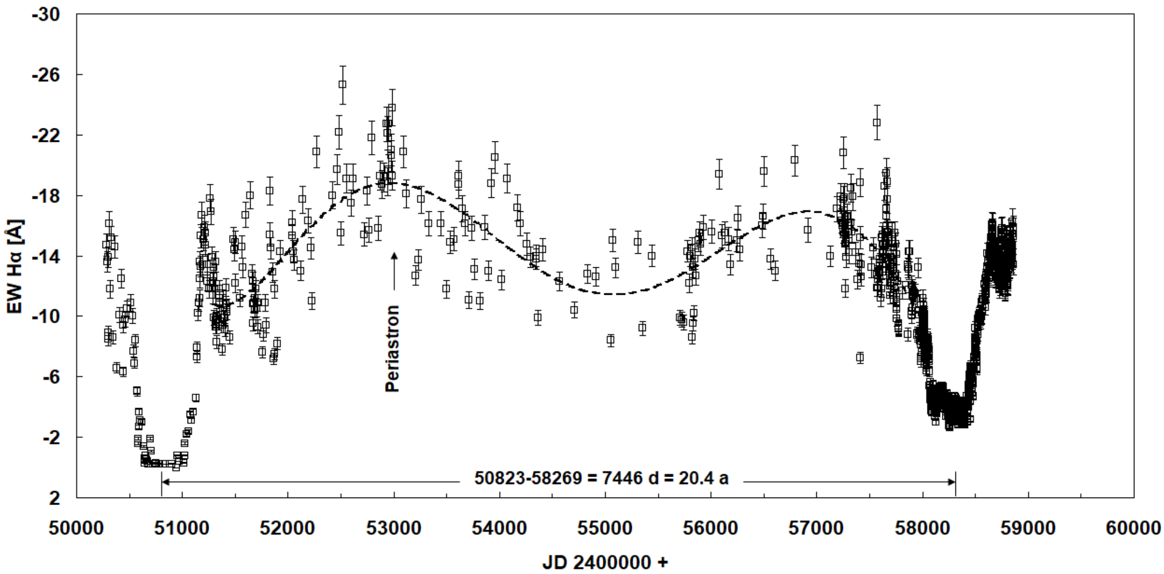
1993: Robert E. Stencel, Daniel E. Potter & Wendy H. Bauer published a paper of UV spectra analyses with the result of high massive mass transfer from the M-supergiant to the hot companion. [https://ui.adsabs.harvard.edu/abs/1993PASP..105...45S/abstract]

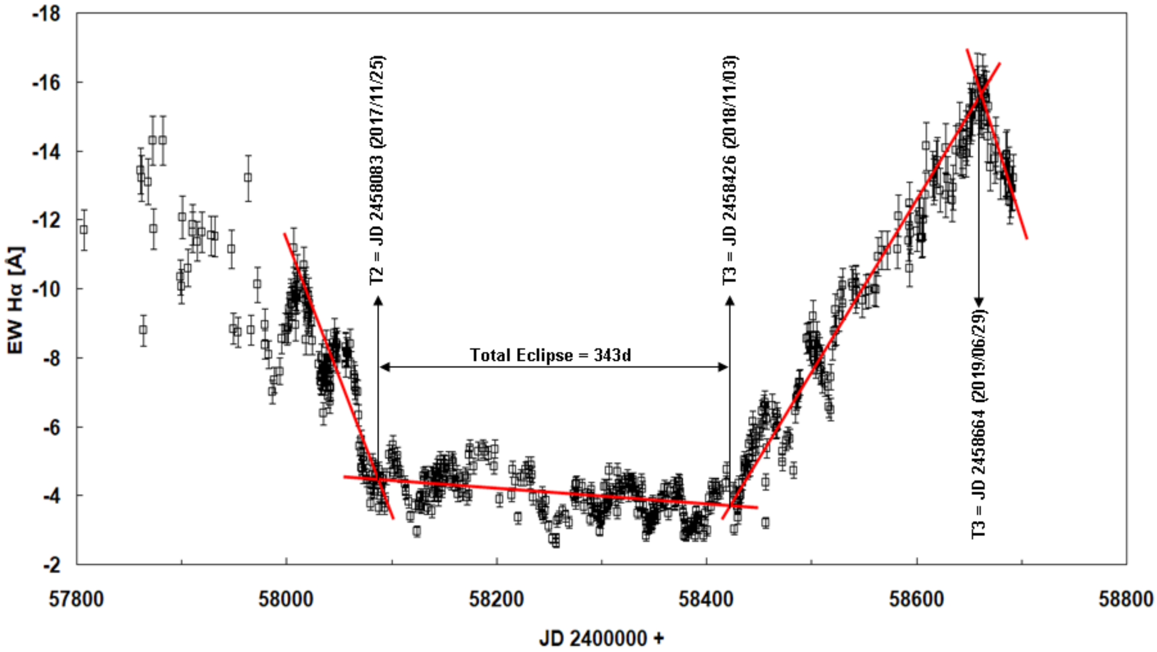
1997: Shusaku Kawabata & Mamoru Saito determined spectra in the region of 0.35 up to 0.45µm. In the focus were forbitten lines Fe II, Ni II and Cu II. They calculated a mass-loss rate from ~ $10^{-6} M_\odot\ yr^{-1}$ with a velocity of ~20km s^{-1}.
[https://ui.adsabs.harvard.edu/abs/1997PASJ...49..101K/abstract]

2023: Ernst Pollmann & Philip Bennett described the results of the high-cadence spectroscopic monitoring of about 3 years during the eclipse of 2017-19.
[https://ui.adsabs.harvard.edu/abs/2023BAVMS..13...12P/abstract]

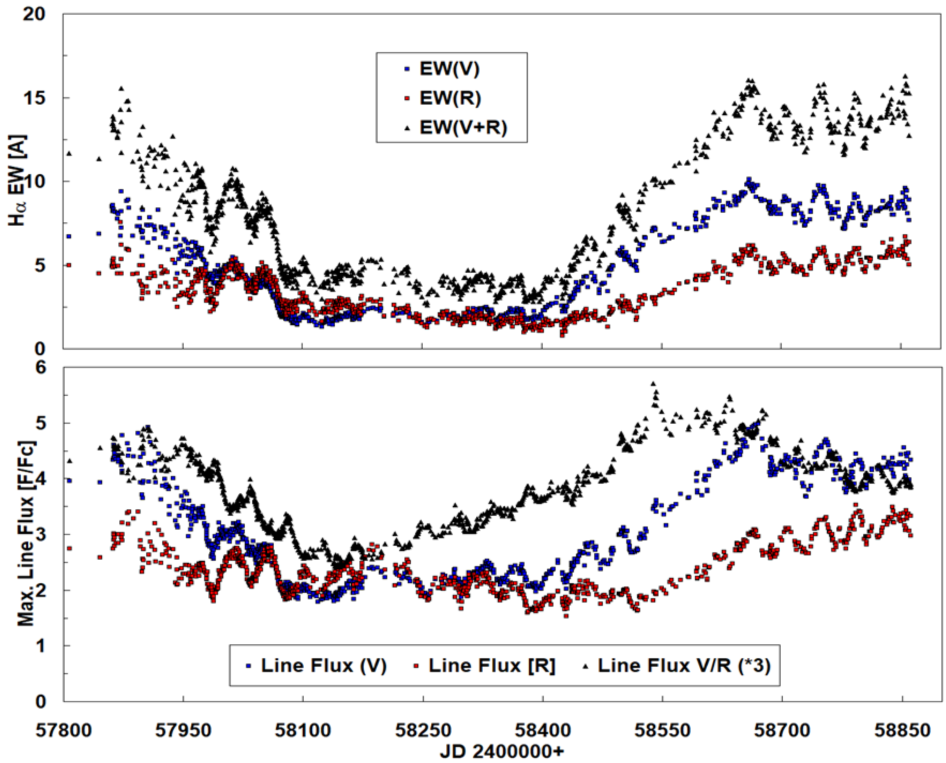
Results of the campaign 2016 – 2020

Ernst Pollmann used spectra from 1996 until 2020 and analysed different Hα parameter: EW, R/V, flux of R & V

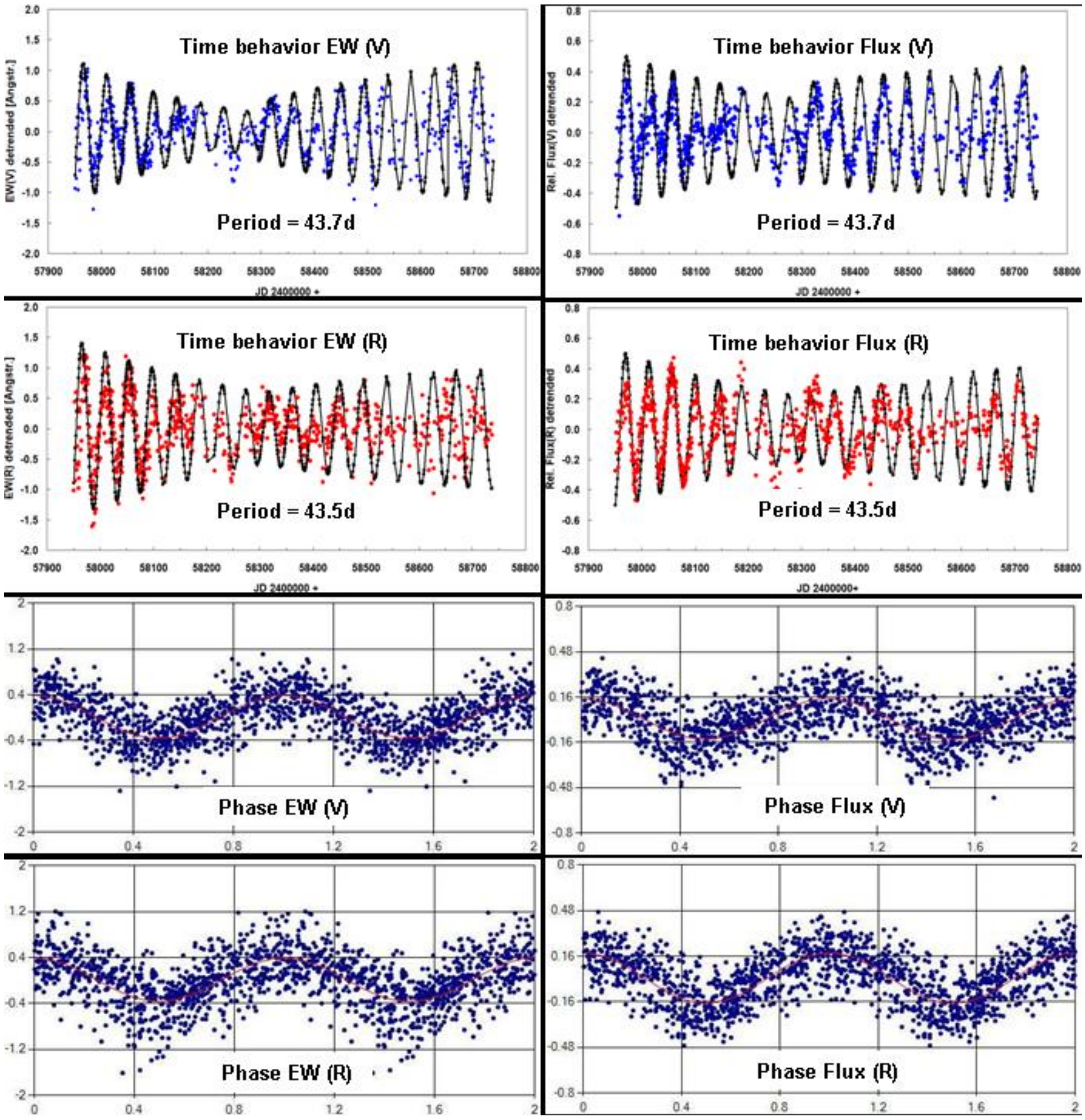




The high-cadence measurement in the years 2017 to 2019 showed a unknown periodicity of 43-days of different Hα parameters. The plausible explanation of that phenomenon is a precession of the accretion disk of the B-component.

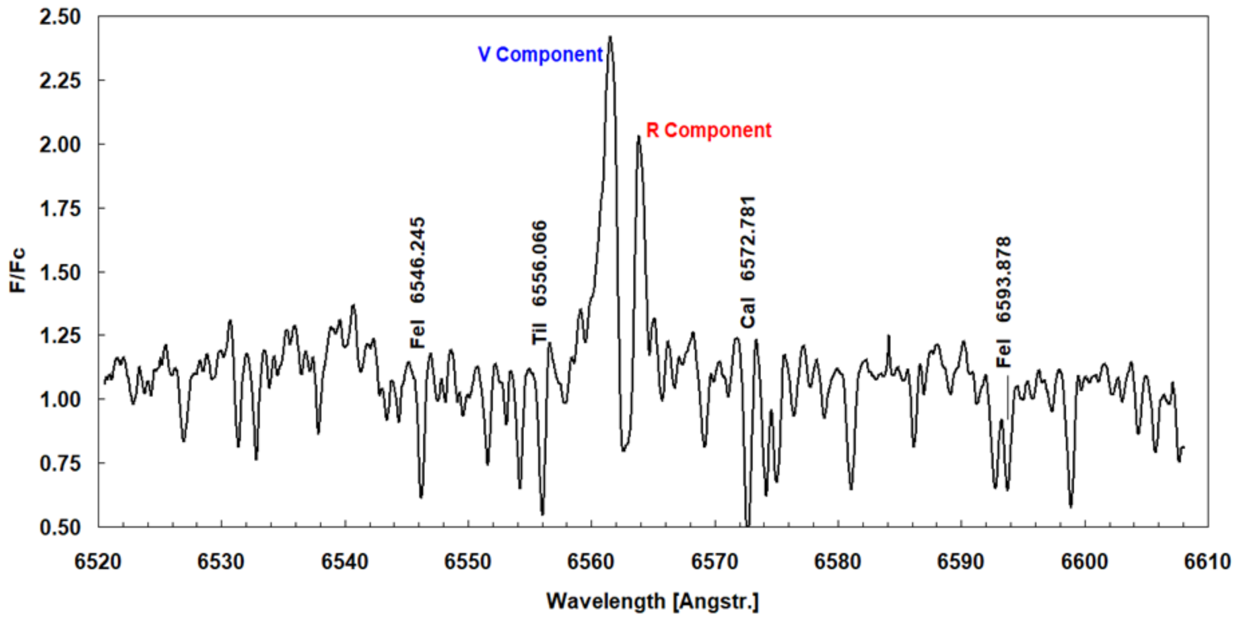


Periodic variability of EW (upper) and peak line flux (lower). Both periods are ~ 43 days.

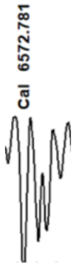


Periodic variability of EW (left) and peak line flux (right). Both periods are ~ 43 days.

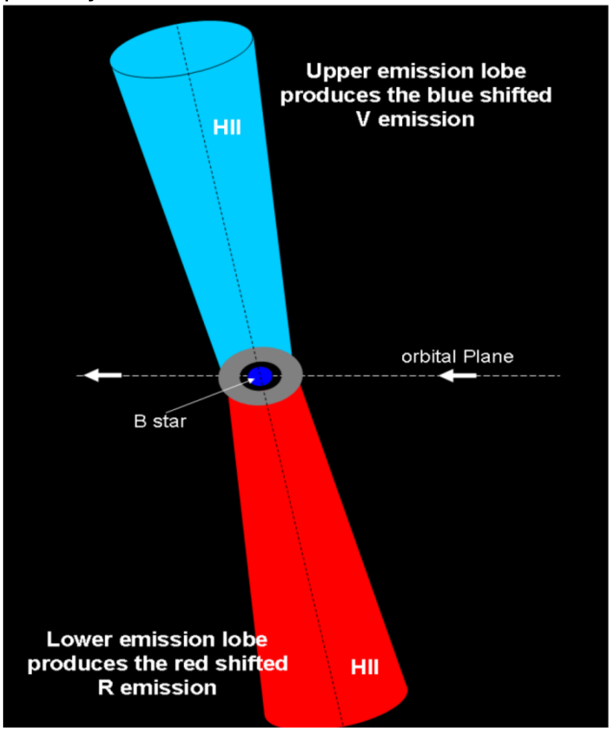
To eliminate the system velocity, the wavelength calibration has been performed with the metal lines of the M-star:



One of the quality criteria to accept a spectrum was the separation of the double-peak right of the Ca I line:



As before described, the 43 days period is produced by the precession of the rotational axis of the B star. This variability was also measured during the eclipses, where the disk was completely behind the M-star. Therefore, Philip Bennett proposed a model of two Hα emission lobes developing primary in the accretion disk.



The upper lobe is large enough to extend beyond the cover of the M star. For detailed information please read the BAV-Magazine Spectroscopy 2023/13.

The Campaign
"VV Cephei, periodic precession of B stars rotational axis after periastron 2025"

Thanks to the previous campaigns and the great efforts of amateur astronomers, VV Cephei is one of the best observed stars in the northern hemisphere. The large amount of data allows new insights into the system that are not covered by professional astronomers previously.

Another high-cadence observation would now be necessary as the B component approaches the periastron.
Ernst Pollmann predicts a disturbance of the 43-day period by mass exchange from the M supergiant to the B component during the coming orbital phase started in 2025. It would be interesting to see whether this long-term process will change the 43 day precession period of the B stars rotational axis. All of this can only be determined through long-term observation of this system.

Desired Observing Parameter:

R >= 9000
Minimum wavelength range: 6540 – 6580

Heliocentric Correction: not necessary, because of post-calibration with the metal lines of the M star.
Cadence of observation: each single spectra is valuably, one or more spectra per week would be great.
Please let me know, that you are interested in this campaign. Send an email to ms@astrophoto.at. I will send you a link to a Dropbox folder where you can upload your 1D-FITs files in your personal folder. I will also look periodically into the data base of AAVSO and BAA.

If you upload files into my Dropbox, please name the file in following order:
Date_object_surname_foreame.fit, e.g., 20240824_vvCep_Schwarz_Manfred.fit

Due to the current health condition of my friend Ernst Pollmann, I have decided to work with him in coordinating this project. This means that please keep in touch primarily with me. Ernst is still involved in data analysis, but not on the front line.

Cheers,
Manfred Schwarz

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