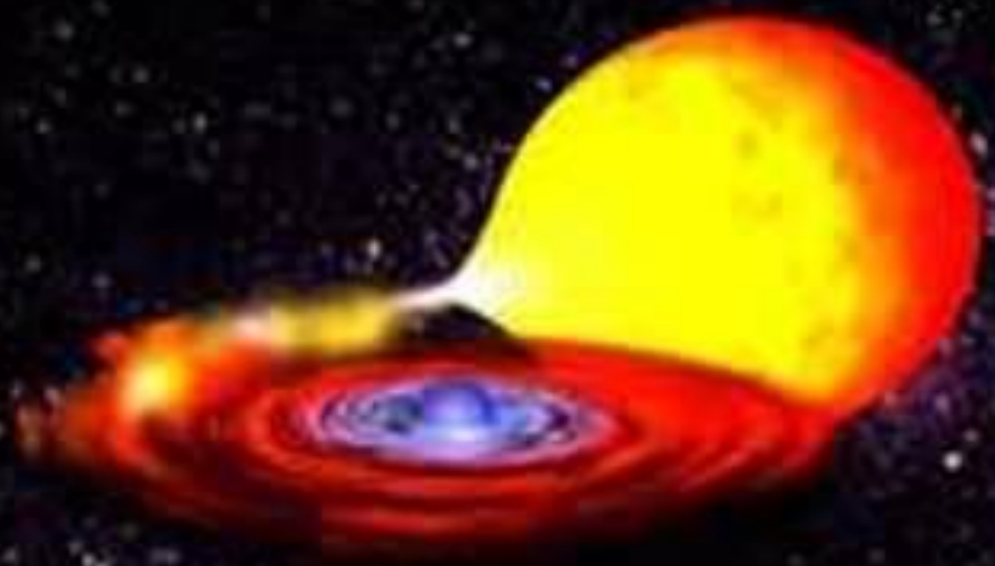
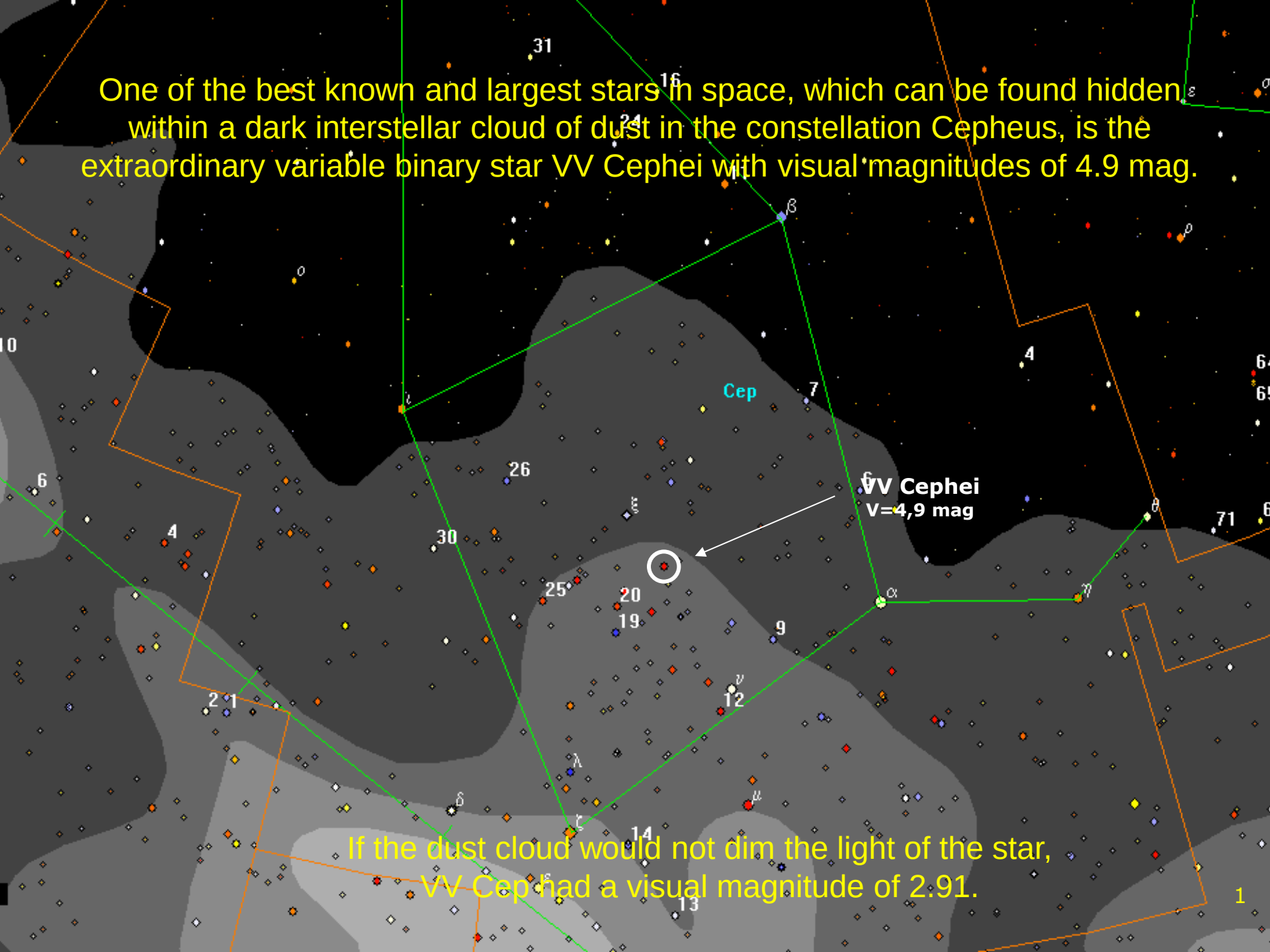
The Binary System VV Cephei
Eclipse Campaign 2017/2019

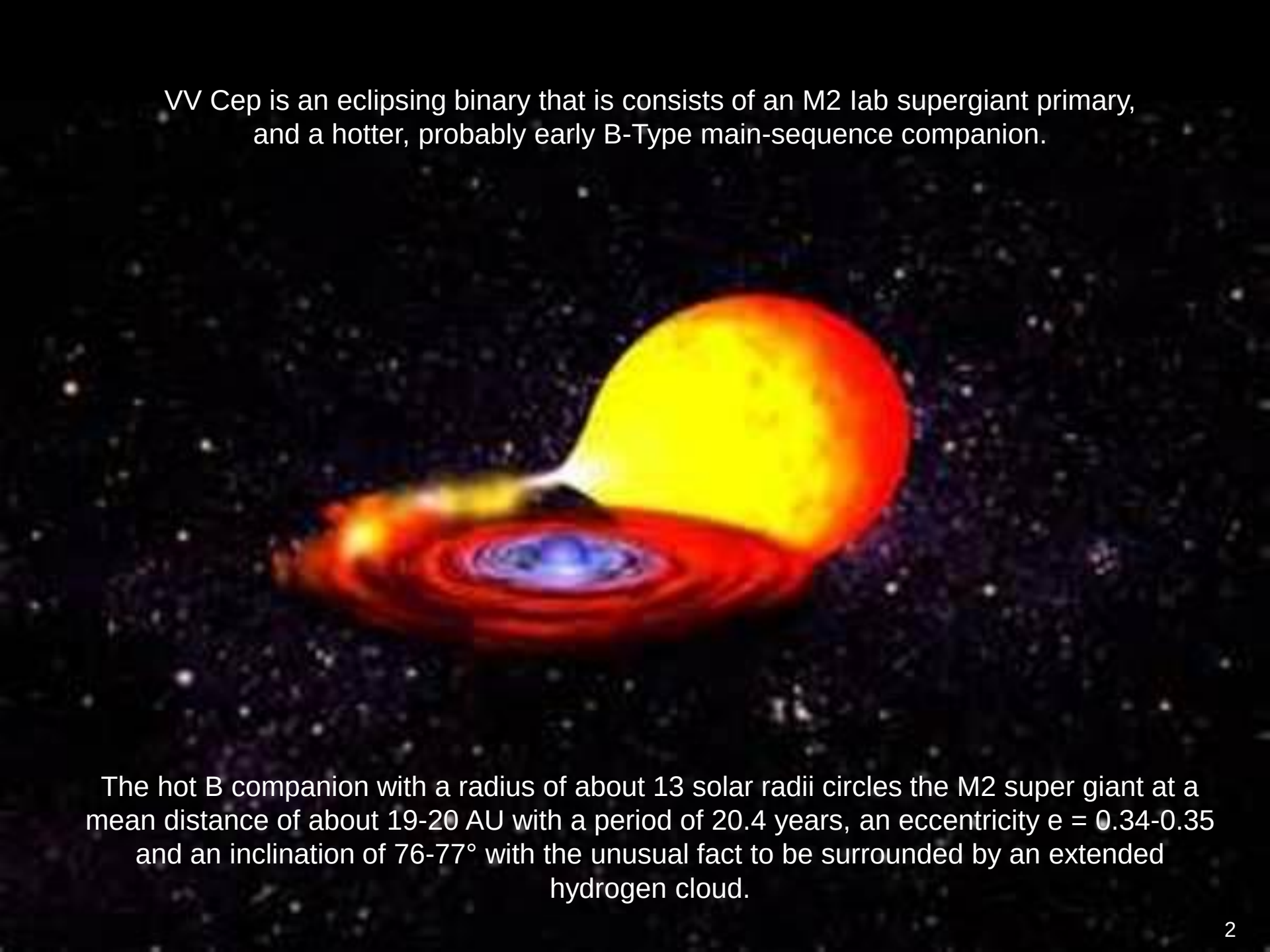


BAV-Meeting Hartha 2017

Ernst Pollmann
International Working Group
Active Spectroscopy in Astronomy
http://astrospectroscopy.de

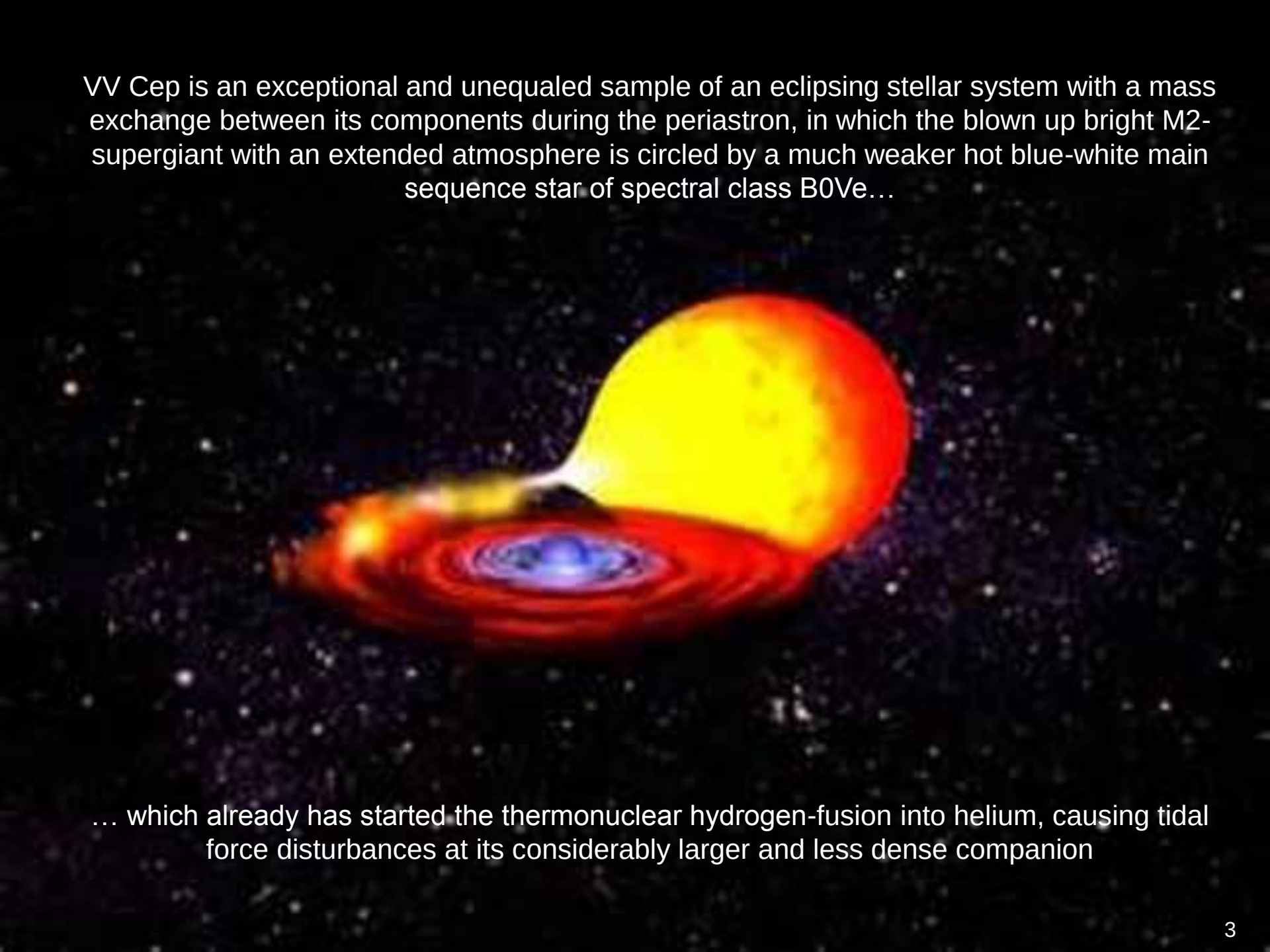

One of the best known and largest stars in space, which can be found hidden within a dark interstellar cloud of dust in the constellation Cepheus, is the extraordinary variable binary star VV Cephei with visual magnitudes of 4.9 mag.
Cep
VV Cephei
V=4,9 mag
If the dust cloud would not dim the light of the star,
VV Cep had a visual magnitude of 2.91.

VV Cep is an eclipsing binary that is consists of an M2 Iab supergiant primary, and a hotter, probably early B-Type main-sequence companion.



The hot B companion with a radius of about 13 solar radii circles the M2 super giant at a mean distance of about 19-20 AU with a period of 20.4 years, an eccentricity e = 0.34-0.35 and an inclination of 76-77° with the unusual fact to be surrounded by an extended hydrogen cloud.

VV Cep is an exceptional and unequaled sample of an eclipsing stellar system with a mass exchange between its components during the periastron, in which the blown up bright M2-supergiant with an extended atmosphere is circled by a much weaker hot blue-white main sequence star of spectral class B0Ve…

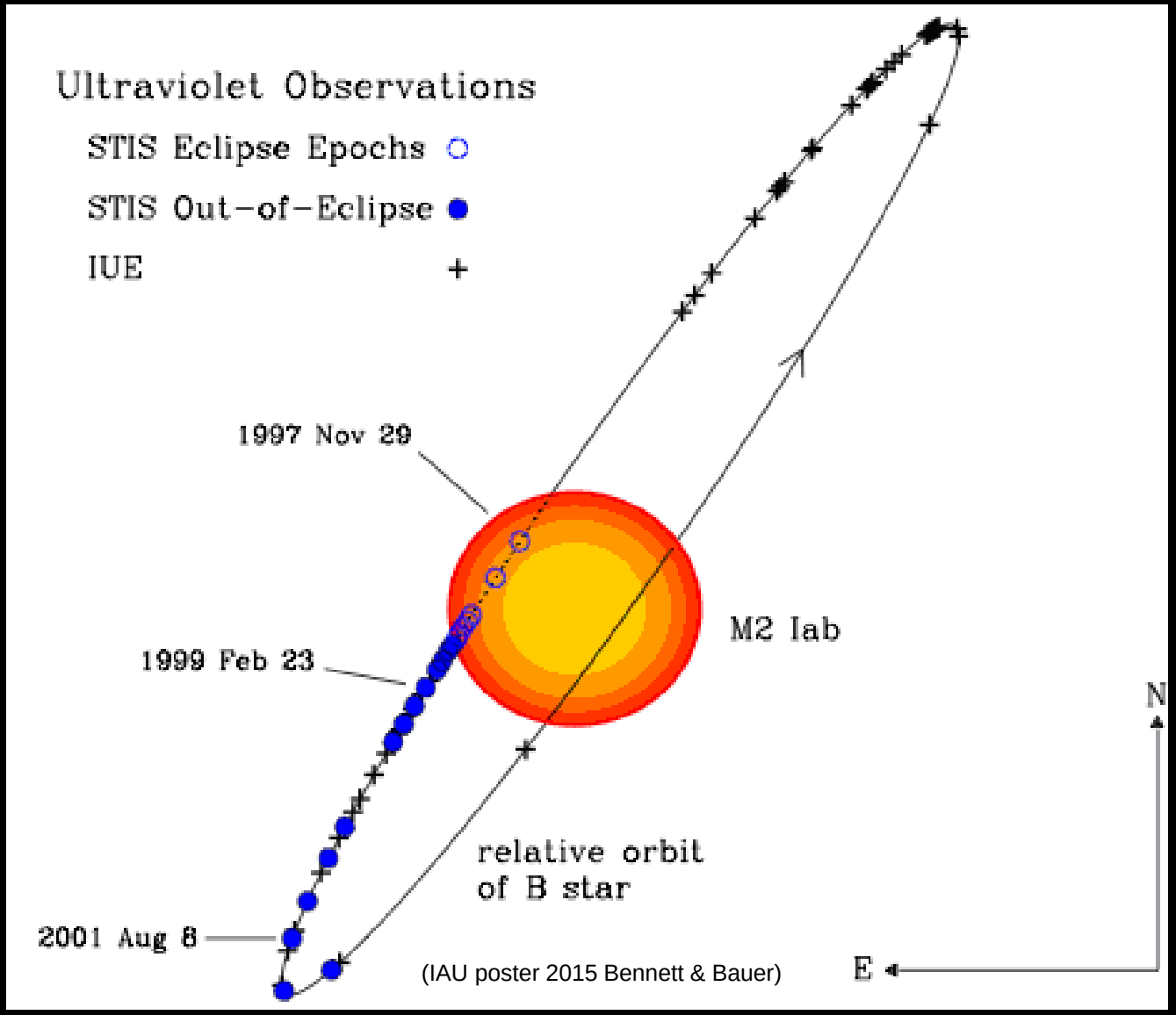


… which already has started the thermonuclear hydrogen-fusion into helium, causing tidal force disturbances at its considerably larger and less dense companion

The dimension of the disk around the B star was determined by Peery (1965) to be less than 1/18 of the diameter of the M stars photosphere and is according Hutchings & Wright (1971) not spherically symmetrical but rather in the direction of the stars equator more dense as in the case of a normal Be star. This seems to be quite logical in view of the remarkable stream of gas in this system.

The orbit of VV Cephei as seen on the sky

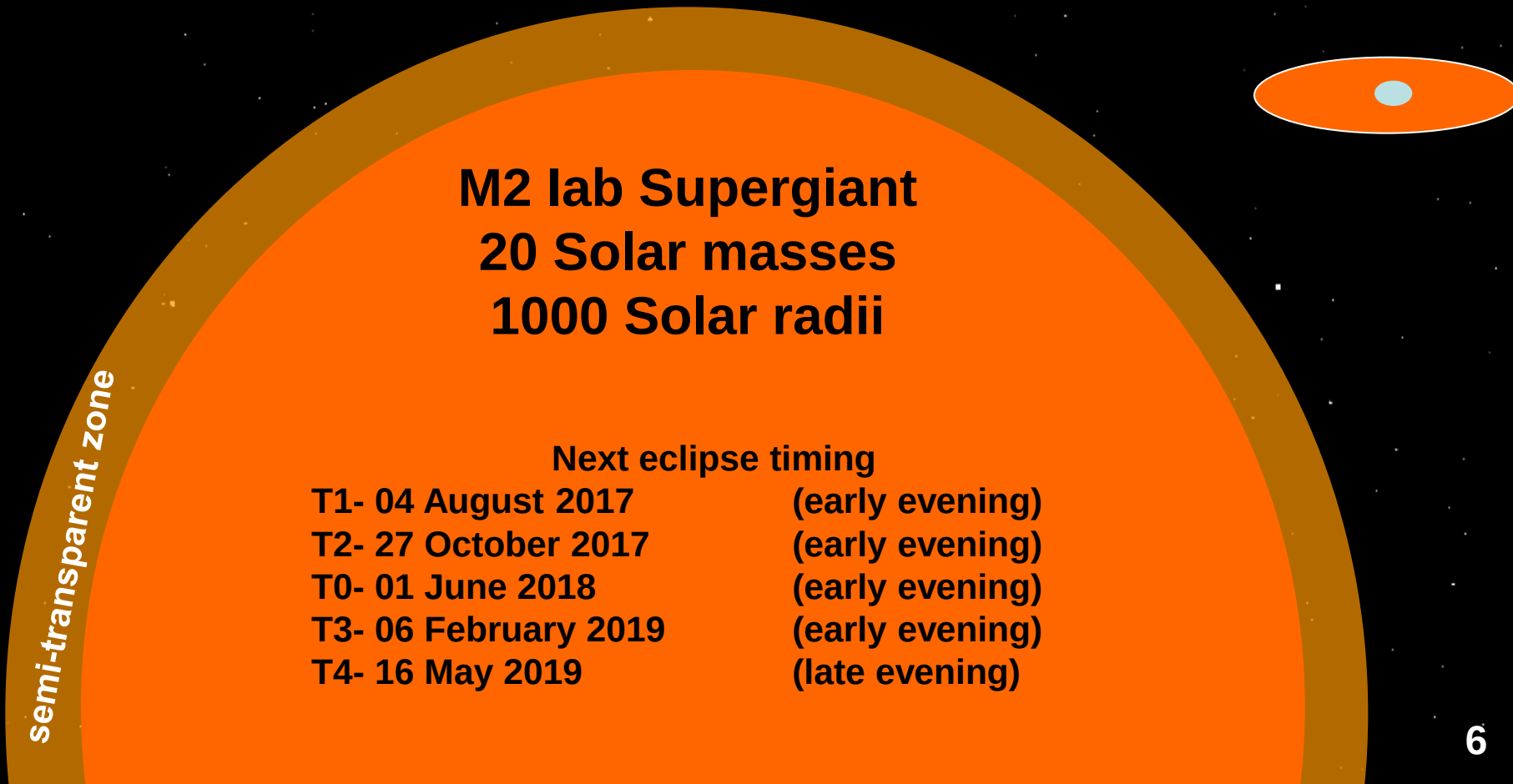
The positions of the companion at the times of the 21 STIS observations are marked



(IAU poster 2015 Bennett & Bauer)

Both, the M super giant and the B star, are offering excellent opportunities to observe and study their outer shells or atmospheres during as well as outside the eclipses.

The Primary Eclipse occurs when the smaller and hotter blue B Star + Gas disk passes behind the larger and cooler red M Star



M2 Iab Supergiant
20 Solar masses
1000 Solar radii

Next eclipse timing

T1- 04 August 2017	**(early evening)**
T2- 27 October 2017	**(early evening)**
T0- 01 June 2018	**(early evening)**
T3- 06 February 2019	**(early evening)**
T4- 16 May 2019	**(late evening)**

In 2015 a Photometric and Spectroscopic campaign has been organized by Jeff Hopkins, Phil Bennett and me to observe the next eclipse, which begins in August of 2017 and will last about 650 days.

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Photometric Campaign Goals

Photometric time series (UBVIJK) photometry is requested. As much data as possible should be obtained starting as soon as possible.

It is useful to have a long baseline of photometry out-of-eclipse, as well as during the eclipse itself.

The "u" (Stromgren or SDSS filter, not Johnson "U") band, would be *extremely* useful because it provides a direct measure of accretion luminosity around the hot star.

Photometric Data (1976/78 & 1997/99)

VV Cephei:	HR8383, HD208816, HIP108317
RA (2000)	21h 56m 39.1s
Dec (2000)	+63d 37m 32.01s
Epoch:	JD 2435931.4
Period:	7430.5 days
Ingress/Egress:	128/171 days
Totality:	450-475 days

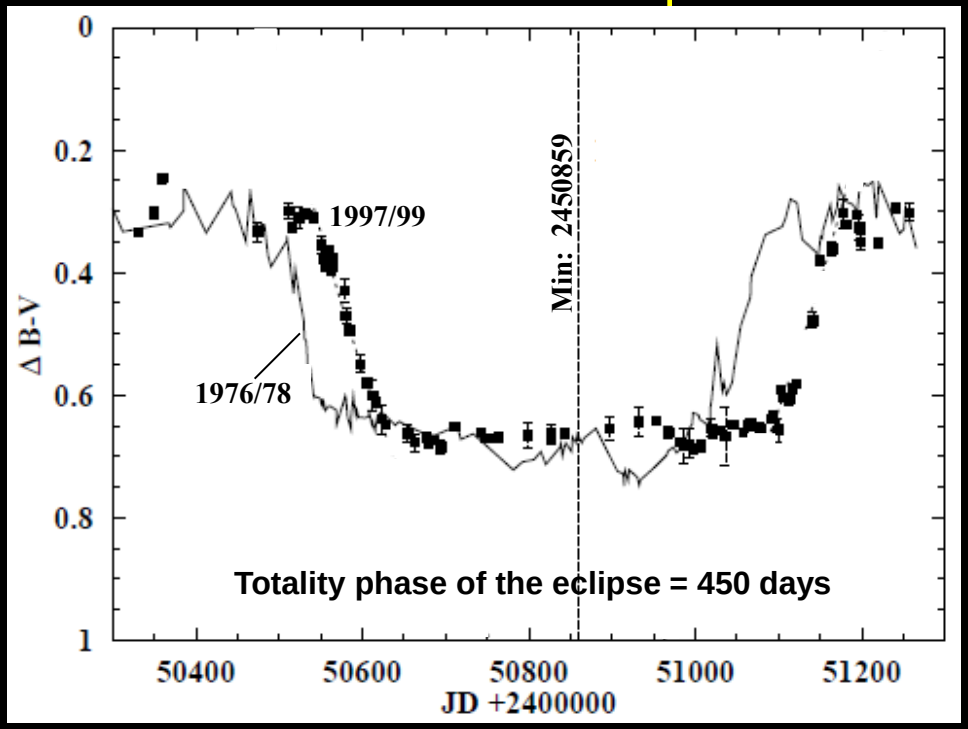
Out-of-eclipse Magnitudes:

U= 7.07 B=6.68 V=4.91 R= 3.2 I= 1.86

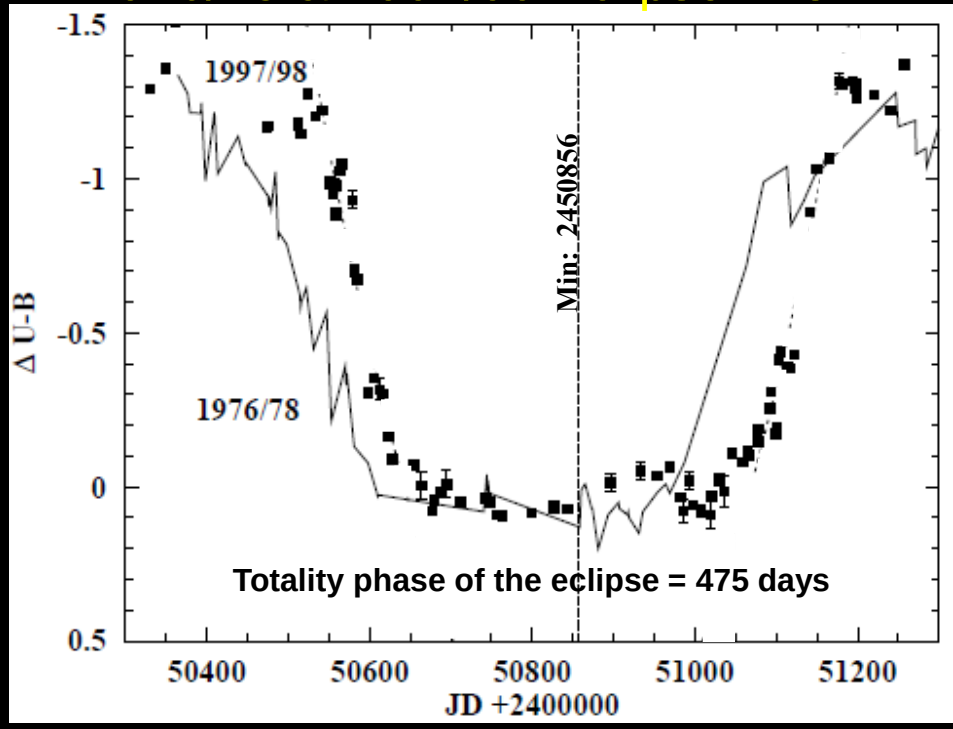
Comparison Star:	20 Cephei, HR8426
RA (2000)	22h 05m 00.4s
Dec (2000)	+62d 47m 09s
Magnitudes	U= 8.46 B= 6.68 V= 5.27 R= ? I= ?

Check Star:	19 Cephei, HR8428
RA (2000)	22h 05m 08.8s
Dec (2000)	+62d 16m 48s
Magnitudes	U= 4.33 B=5.17 V= 5.11 R= ? I= 0.03

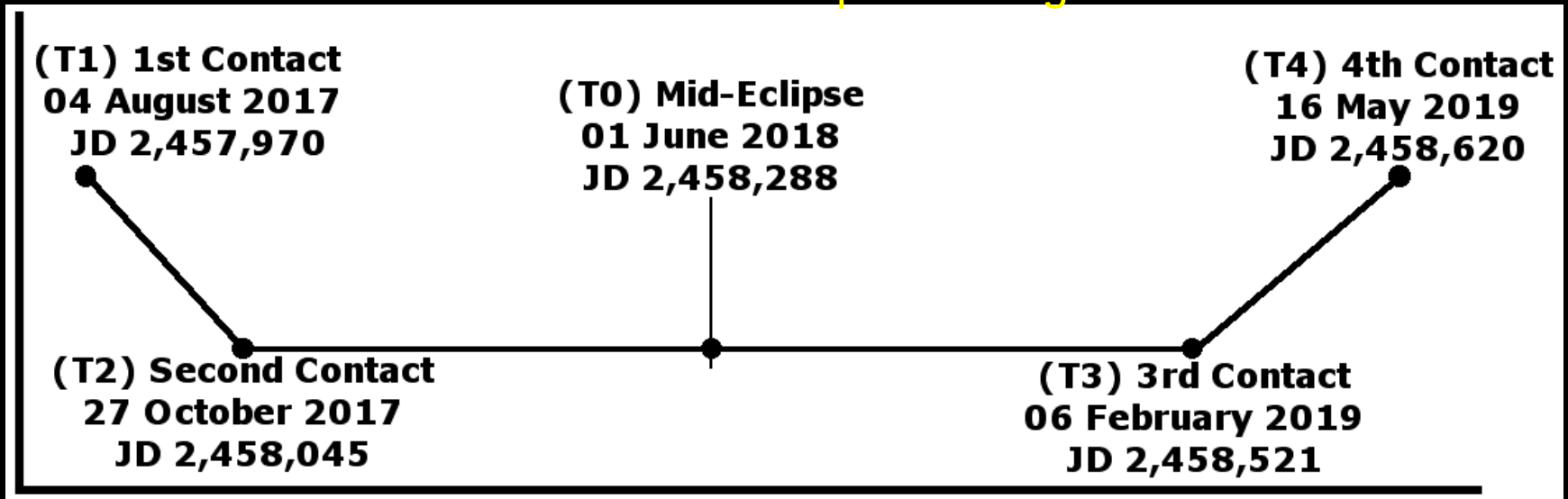
1976/78 & 1997/99 Eclipse in B-V



1976/78 & 1997/99 Eclipse in U-B

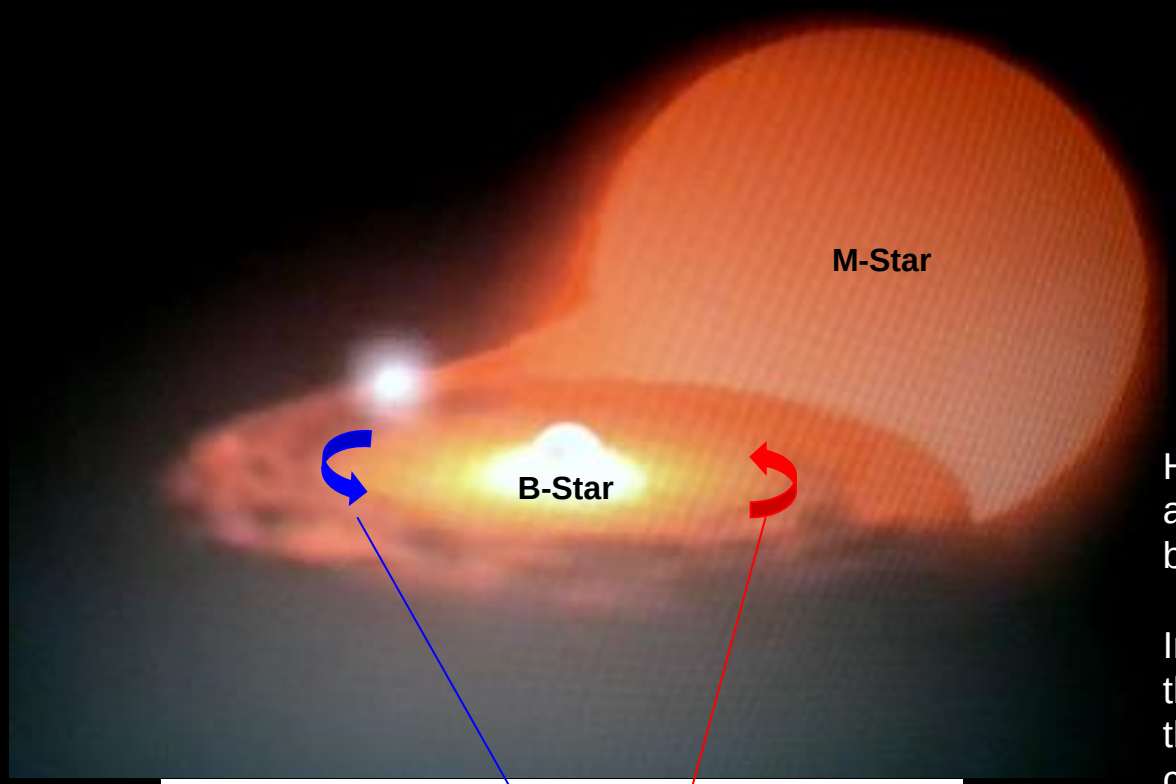


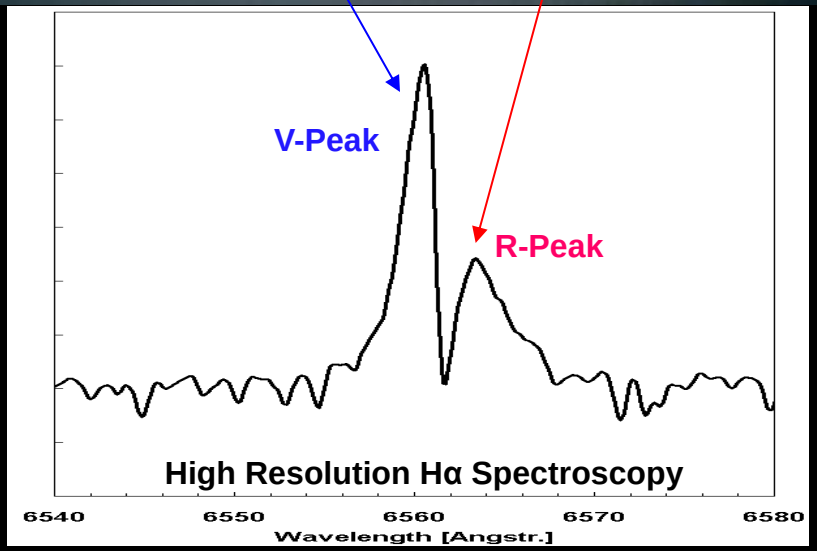
2017-2019 Eclipse Timing



Spectroscopical observations provides beside the photometrical data, additionally information of the duration and the mid-term of the eclipse.

They allows us, to observe the
disk-like rotating shell of the hot companion in the same direction as the orbital movement.

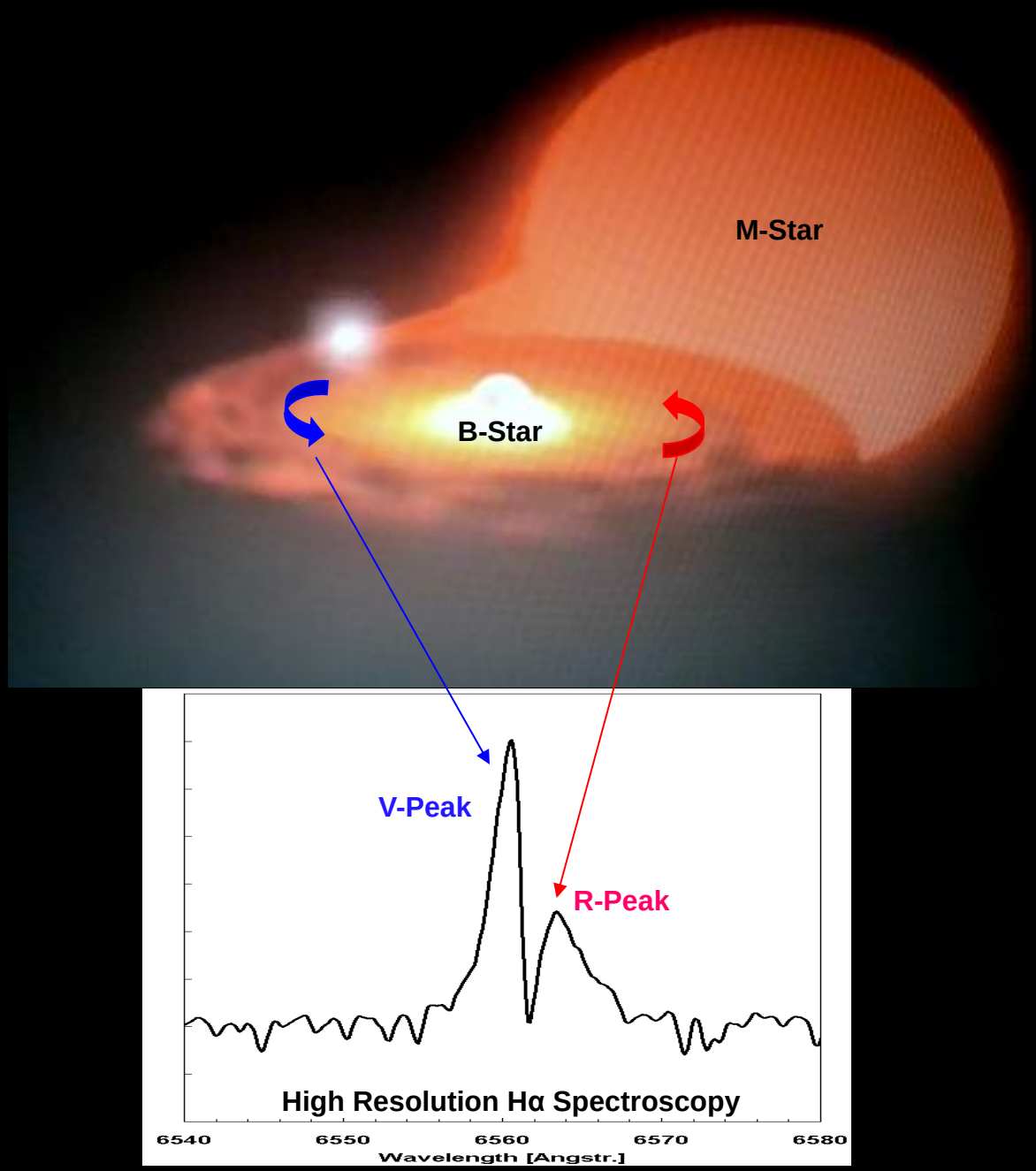




Hα in the spectrum of VV Cep normally is a double-peaked emission line with a blue- (V) and red- (R) shifted component

In the beginning of the eclipse, the side of the disk which is moving towards us and therefore emitting the blue-shifted (V) component of the emission lines is eclipsed first.

During the totality both emission components should be suppressed, while in the egress phase the blue-emitting side of the disk emerges first from behind of the supergiant star.



The V and R components into which the emission line of the VV Cep spectrum is split can be linked to the radiation of the gas disk around the B star.

Due to its counter clockwise rotation around the central star, in relation to the line of sight of the observer, it results in a blueshift by moving towards the observer (V-component) and a redshift by moving away (R-component) from the observer.

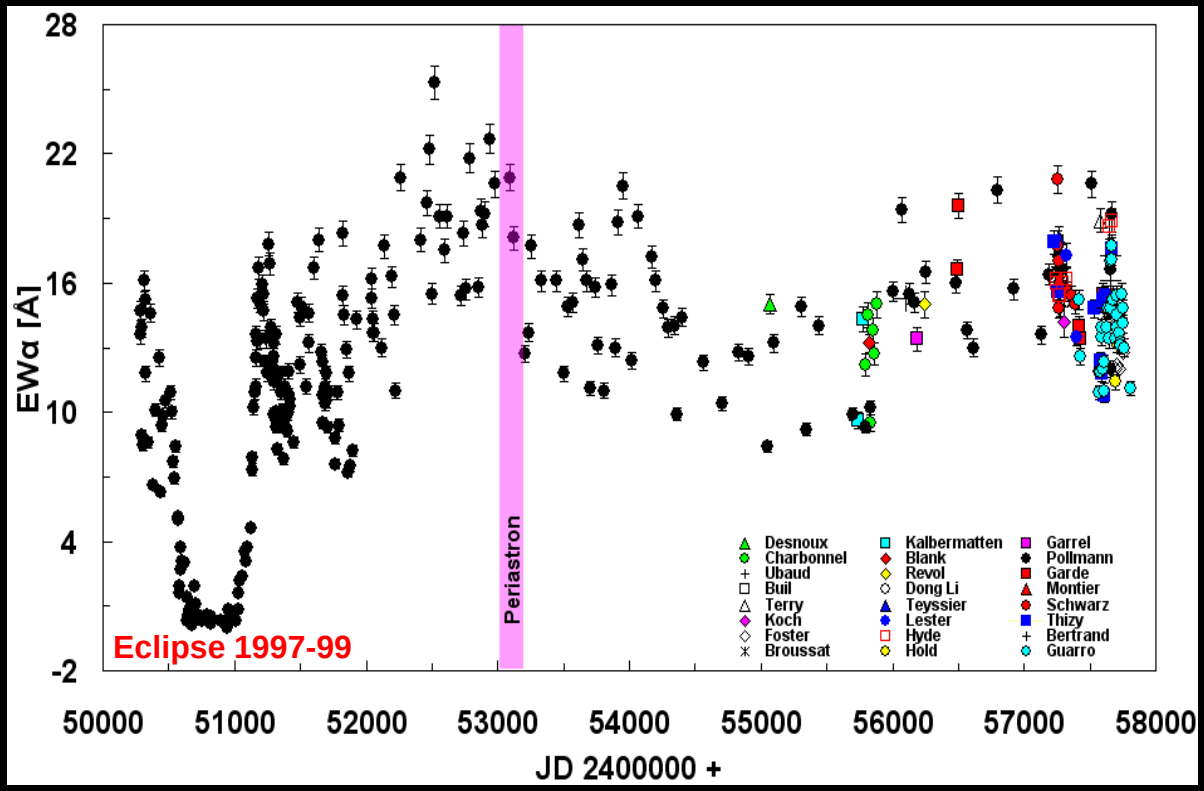
Long-term monitorings of the intensity variations of the V and R emission peaks (that so-called V/R ratio) delivers important information about the peak strength as measure for the mass and/or density of the gas in the disk, expressed as equivalent width EW of the emission, and the direction of movement of the corresponding gas region within the disk.

Spectroscopic Campaign High Resolution Goals

LHires III spectrograph (or similar) with a 2400 L/mm grating is suggested for the high-resolution spectroscopic work to study the disk properties:

- Hα equivalent width (EW)
- Hα line profile dynamic (V/R ratio)

Monitoring Hα-EW since 1996



The Hα emission is the only indication of the presence of the disk.

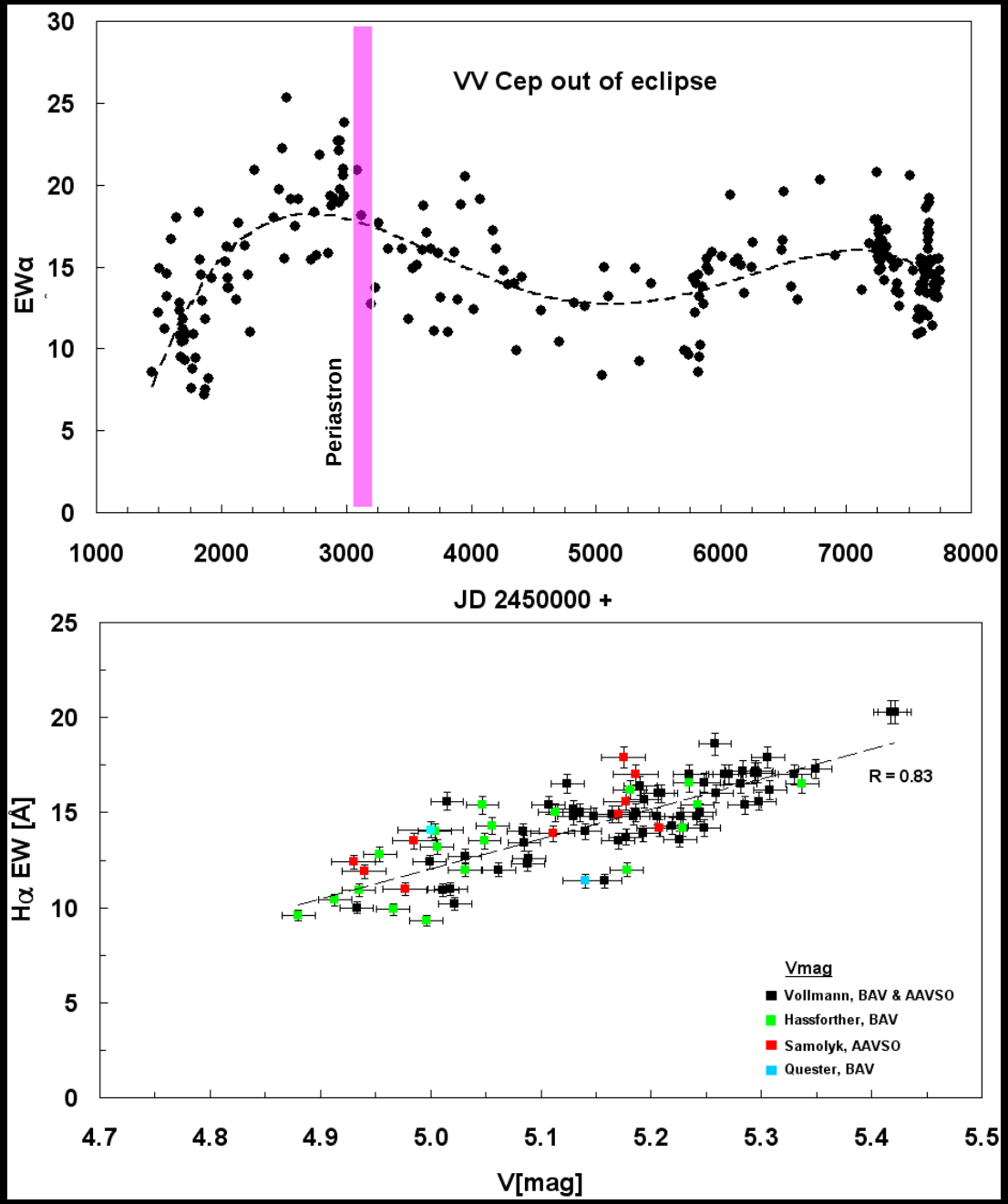
This Figure shows monitoring of the Hα-EW since July 1996 until today.

The eclipse of the emitting Be star disk by the M supergiant started in March 1997 (JD 2450511) and ended 673 days later.

The period from the beginning of the disk coverage (contact 1) up to coverage end (contact 2) lasted 128 days, from first appearance of the disk (contact 3) up to the complete visibility (contact 4) 171 days.

The full eclipse period was 373 d. The entire event required about 1000 days.

EW Fluctuation outside eclipse



The Hα emission is variable on short and longer timescales.

The slow variability appears

• to correlate with the orbital separation of the two stars, with larger emission flux seen when the companion is near periastron

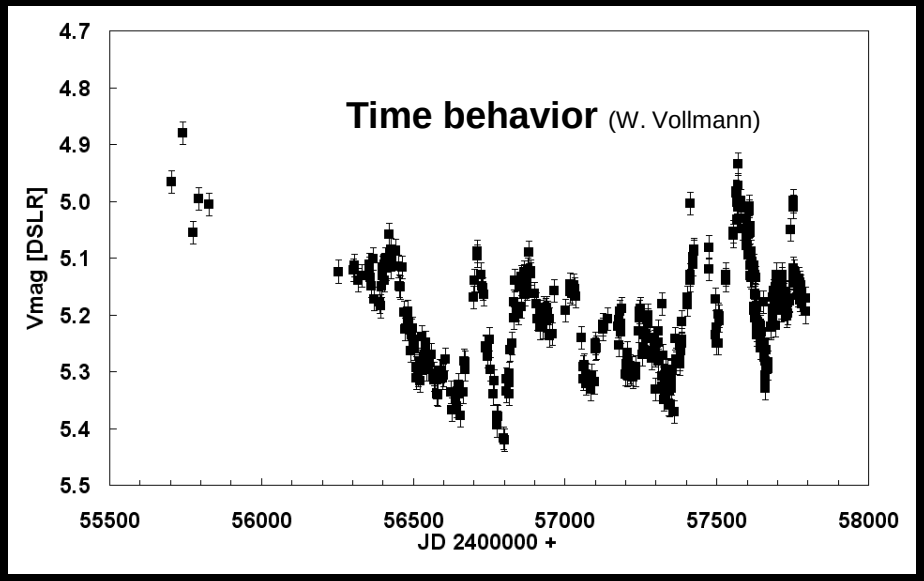
The short timescales is due

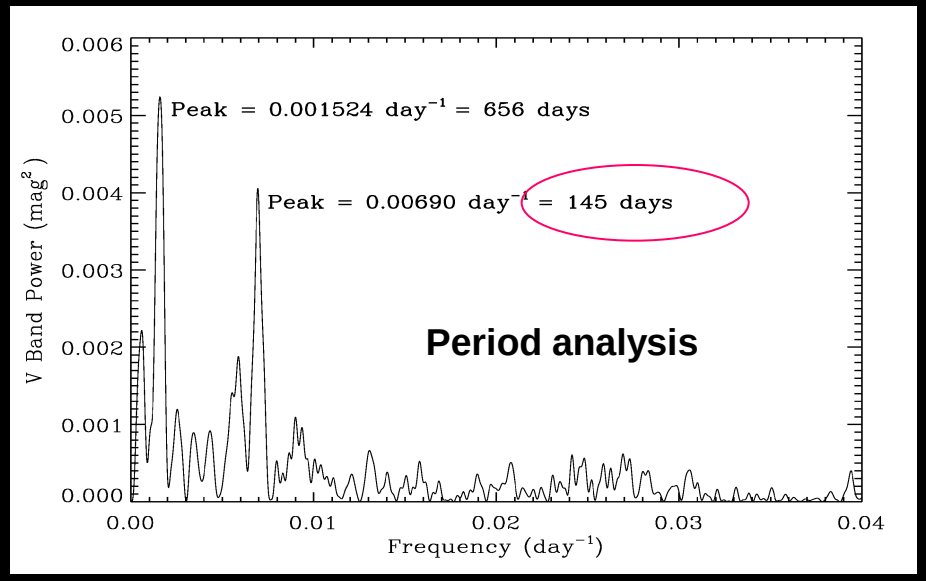
• to irregular variable mass accretion from the M supergiant to the accretion disk as described by Wright (1977) and Stencel et al. (1993)

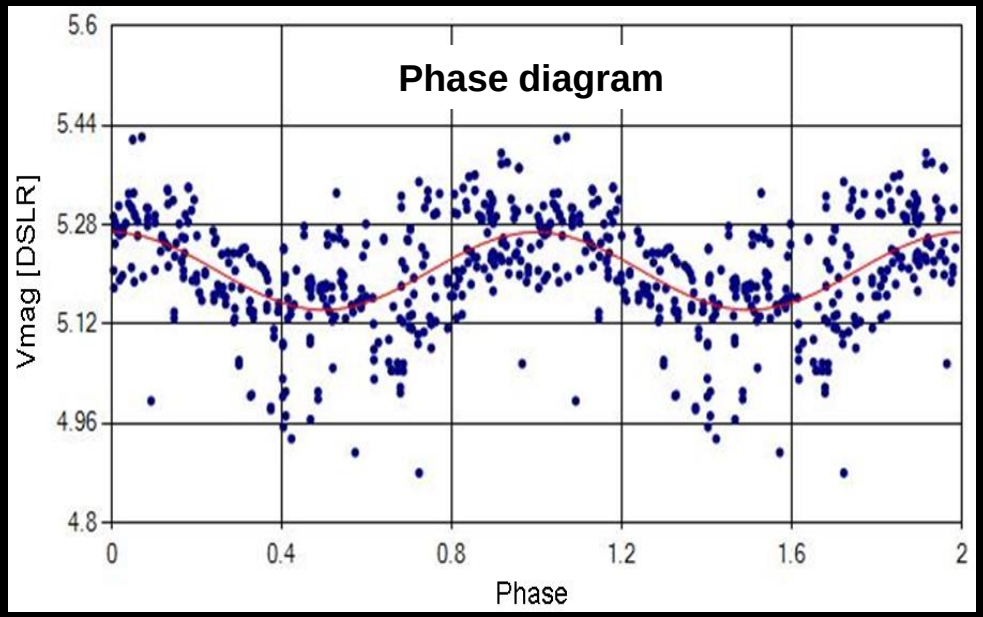
• and by the photometric variability Vmag of the continuum under the Hα emission.

• the weaker the Vmag, the higher the EW and vice versa

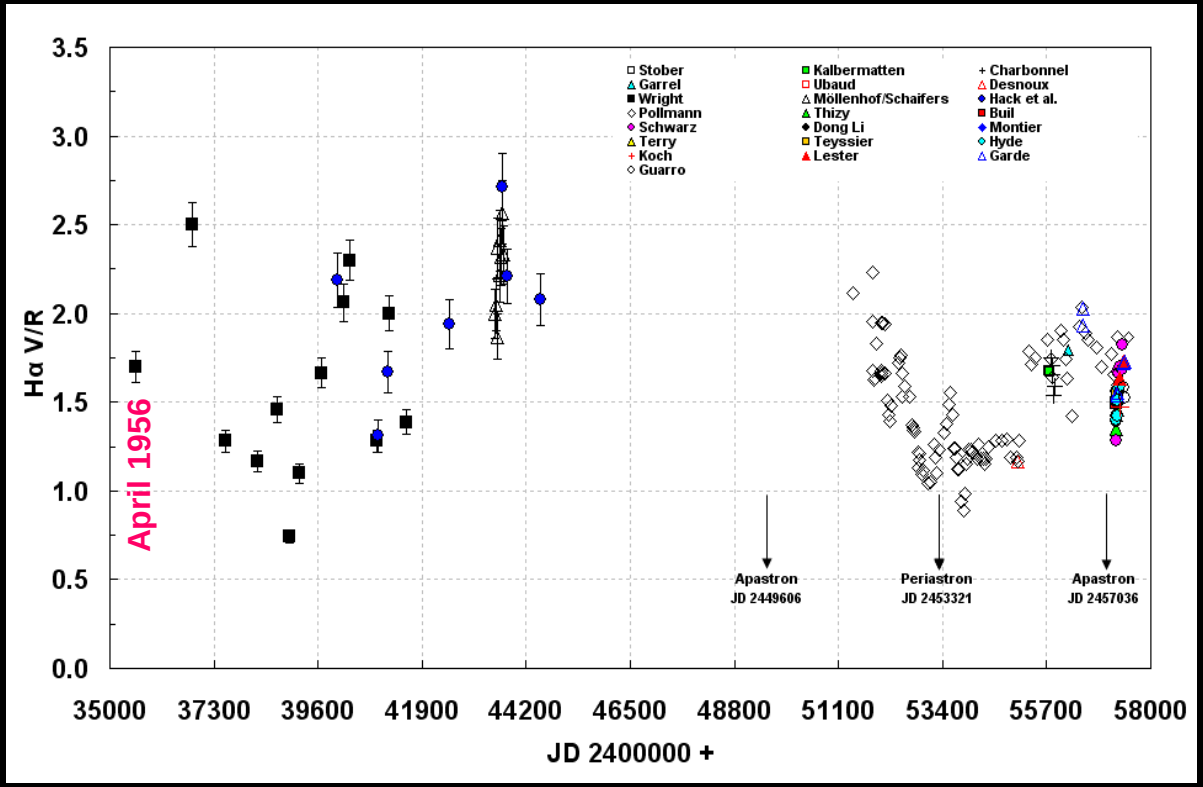
Vmag periodic variability







Monitoring Hα-V/R since 1956



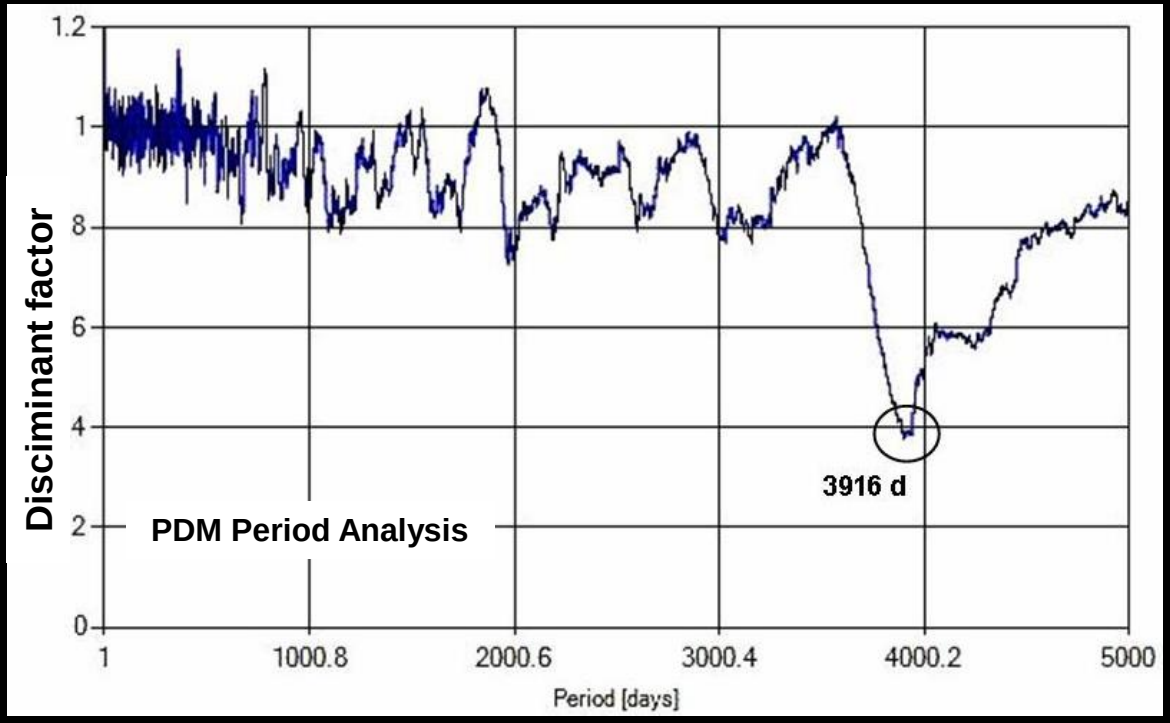
The long term monitoring of the variations in intensity of both components (so called V/R relation) results in important information about:

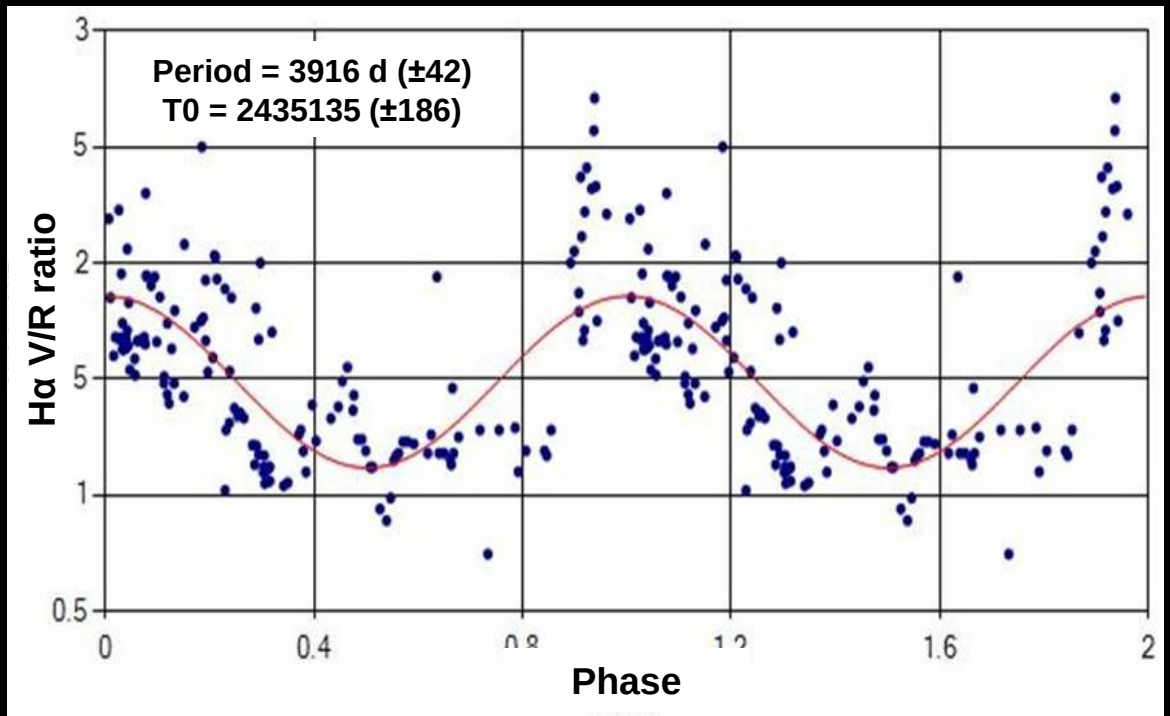
- Emission peak intensity as a measure of the mass or density of the gas in its shell expressed in equivalent width EW of the emission,

- The direction of motion of the gas shell's region.

Since November 2000 (JD 2451413) the V/R ratio have been observed with good density of observations. It became evident how dramatically the V/R relation is changing.

The data confirm clearly the time evolution of the V/R relation. The V/R variation asks for a more detailed evaluation about its cyclic behavior.





Periodic Variability of the Hα V/R ratio

The upper Figure shows a PDM period analysis of the entire V/R data set in with a dominant period of 3916 d.

In the lower Figure the phase diagram of the 3916 d period is shown.

It seems to be the half of the orbital period, approximately 7450 d.

A possible explanation for that behavior might be a tidal effect of the M supergiant on the B star disk during each periastron.

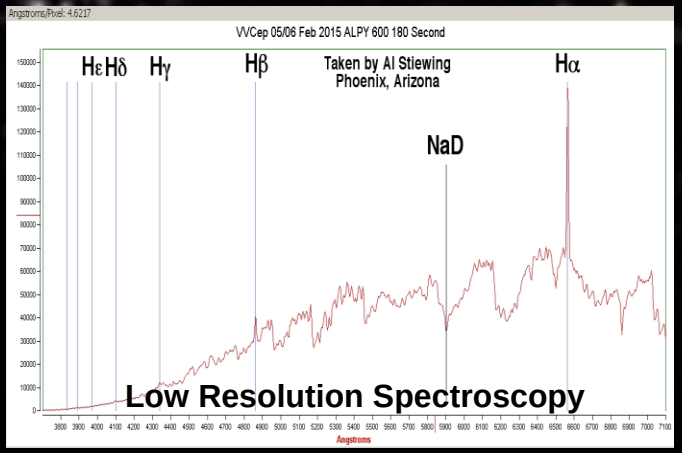
Spectroscopic Campaign Low Resolution Goals

Atmosphere of the M Star

Low-resolution spectroscopy will not be able to provide sufficient resolution to measure EW, V/R or RV.

However, it does have the advantages of showing a complete visible spectrum window and with a short exposure.

This means it is also *very* useful for spectrophotometry: monitoring the overall behavior of the spectrum over time. The ALPY 600 (R=600) is ideal for this.



Low Resolution Spectroscopy

Other Campaign Goals

Interferometry
CHARA interferometric observations (at hydrogen alpha) to better constrain the orbit.

Radio Astronomy
ALMA observations. ALMA, using the full 15-km baseline at sub-mm wavelengths, has an angular resolution of about 6 mas, which will suffice to resolve VV Cephei.

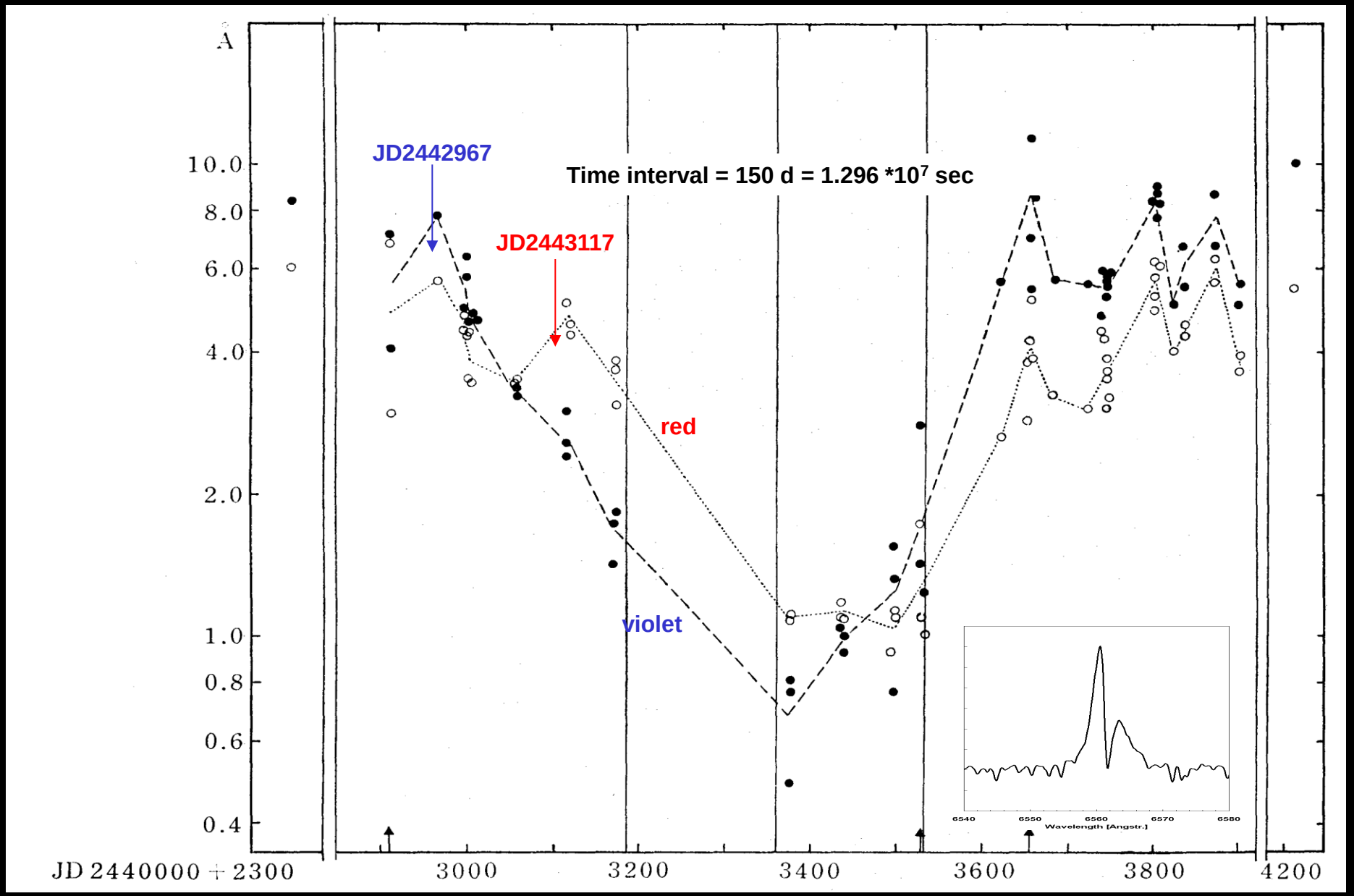
HST Observations
Finally, it is worth proposing a modest HST program using the STIS spectrograph at the longest wavelengths (2800-3150 Å).

VV Cephei Eclipse
Campaign Web Site

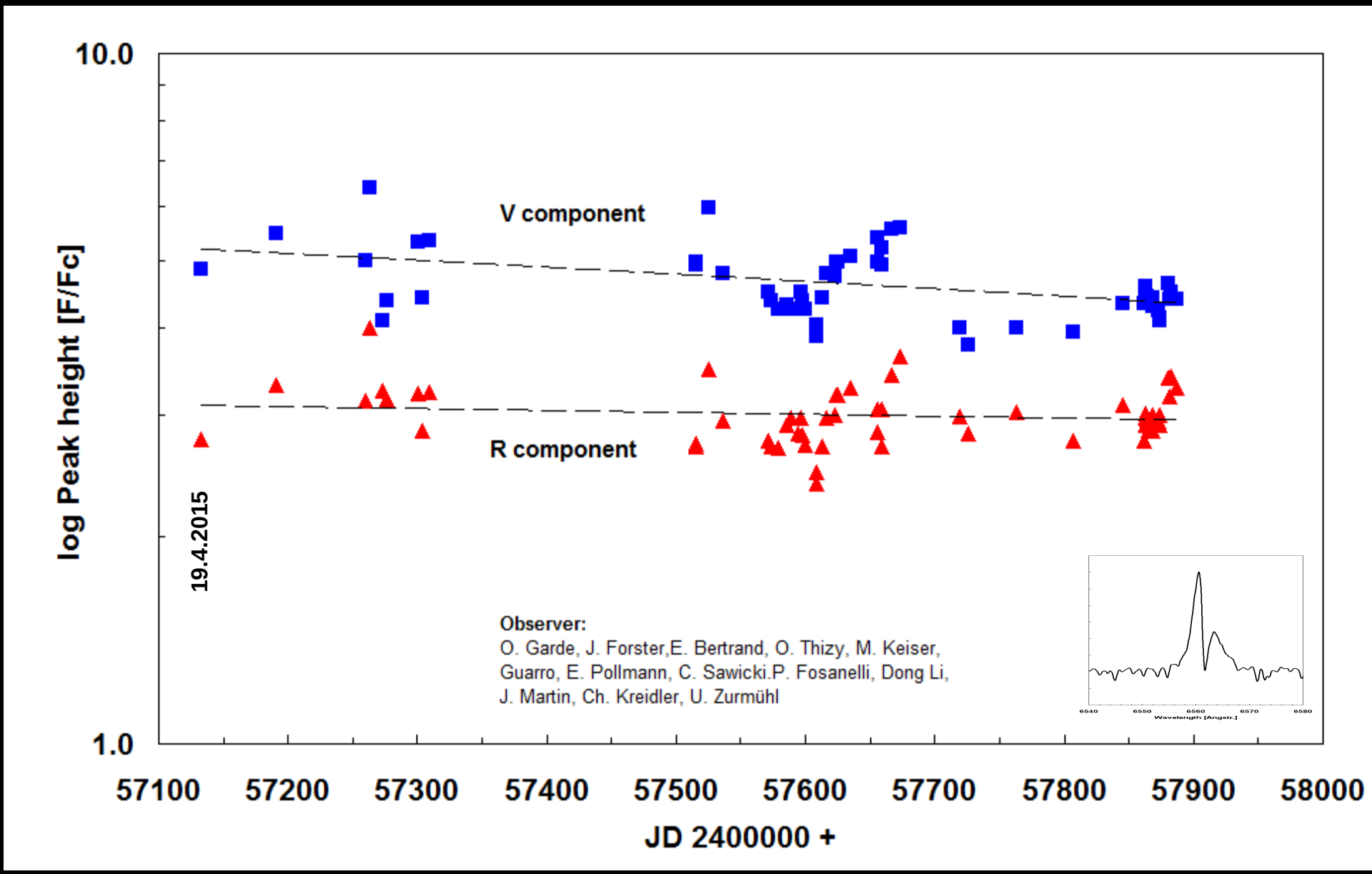
A Campaign web site has been created at:

http://www.ap.smu.ca/~pbennett/vvcep/campaign2017.html

Anyone interested in the Campaign is encouraged to periodically visit the web site for the latest information on the Campaign.



Kawabata et al. 1971



ARAS-Spectroscopy-Group

…ready for observation?