Progenitors and remnants of red novae V838 Mon and V4332 Sgr

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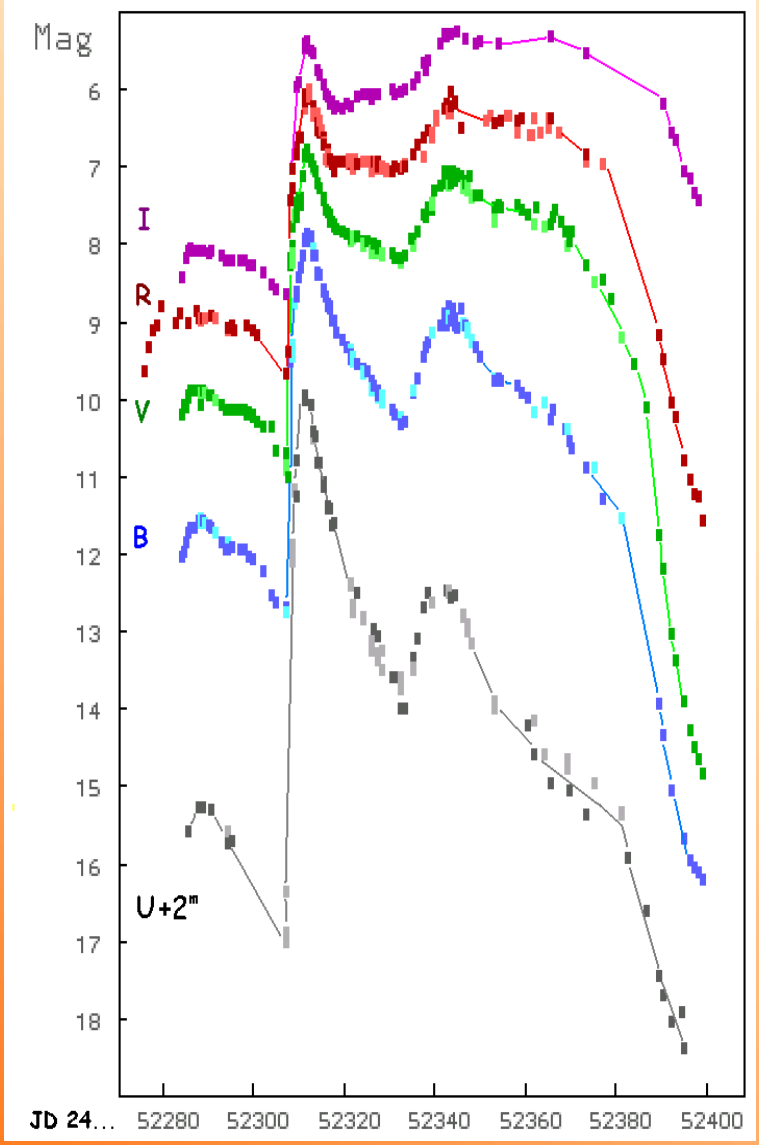
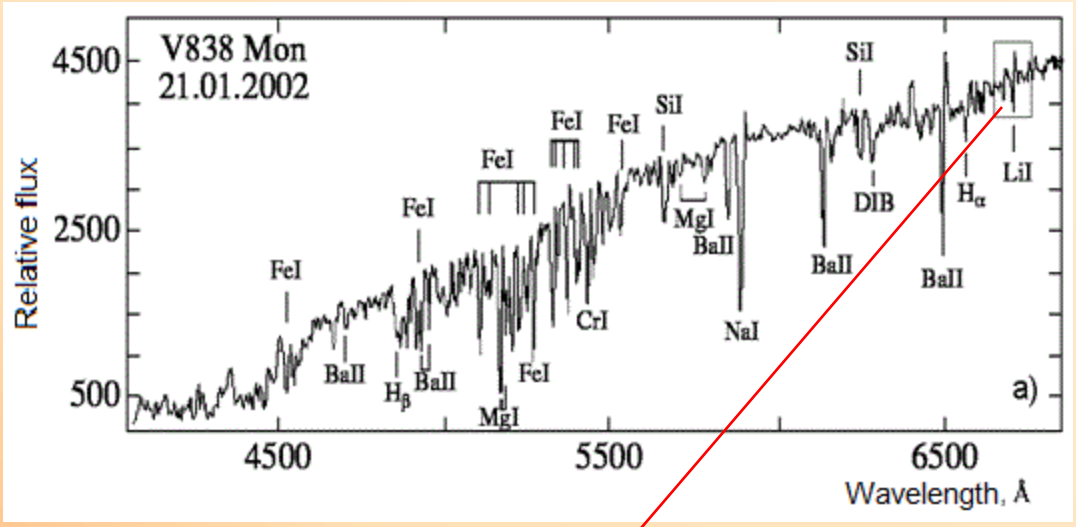
The light curve of V838 Mon in the outburst from January to May 2002.

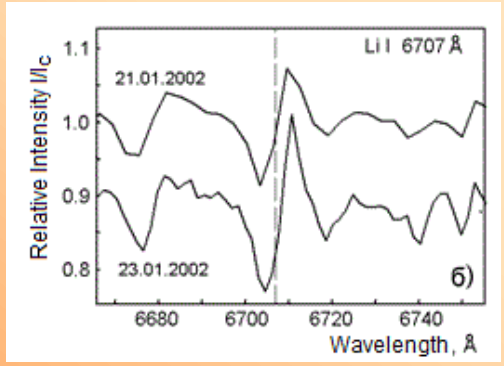


The light curve shows several peaks in maximum.

We explain these peaks as shock waves coming out to the surface.

The spectrum of V838 Mon in the outburst corresponds to type K0I

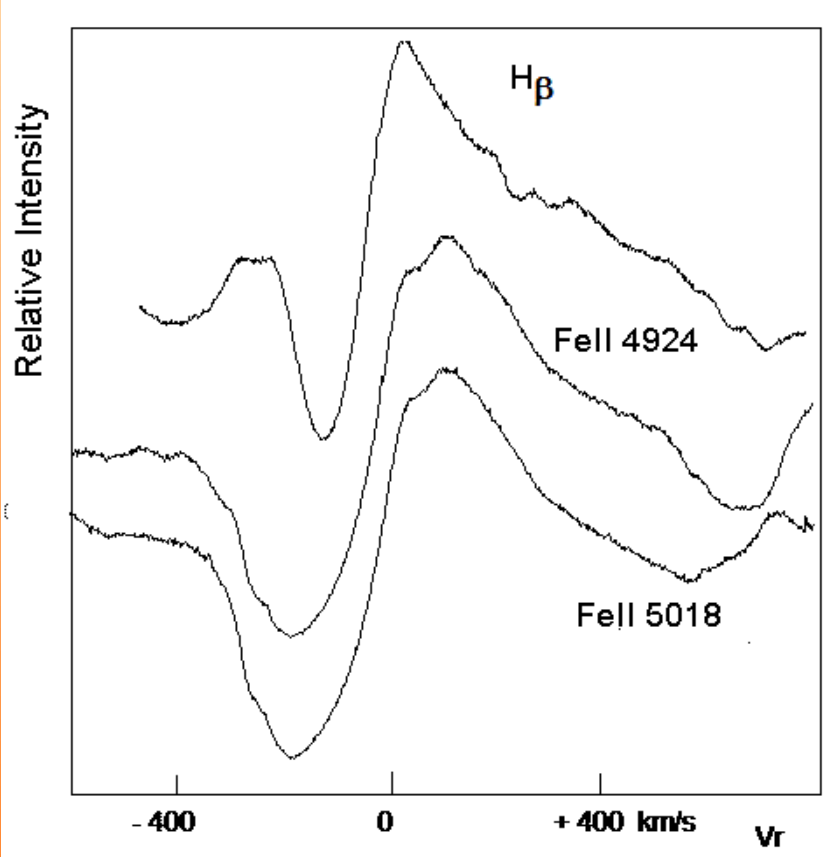




Li I 6707 Å line

Spectral analysis showed that the star's chemical composition is close to solar one or even it corresponds to the composition on ZAMS. The remnant of the outburst relates to oxygen branch of cold stars. I.e., the exploded star was an unevolved star . (Barsukova et al., AIP Conf. Proc. 637,303, 2002; Kipper et al., A&A 416, 1107, 2004)

P Cyg profiles in V838 Mon spectrum with high resolution in a peak of the outburst are an evidence of a radial-symmetric outflow.

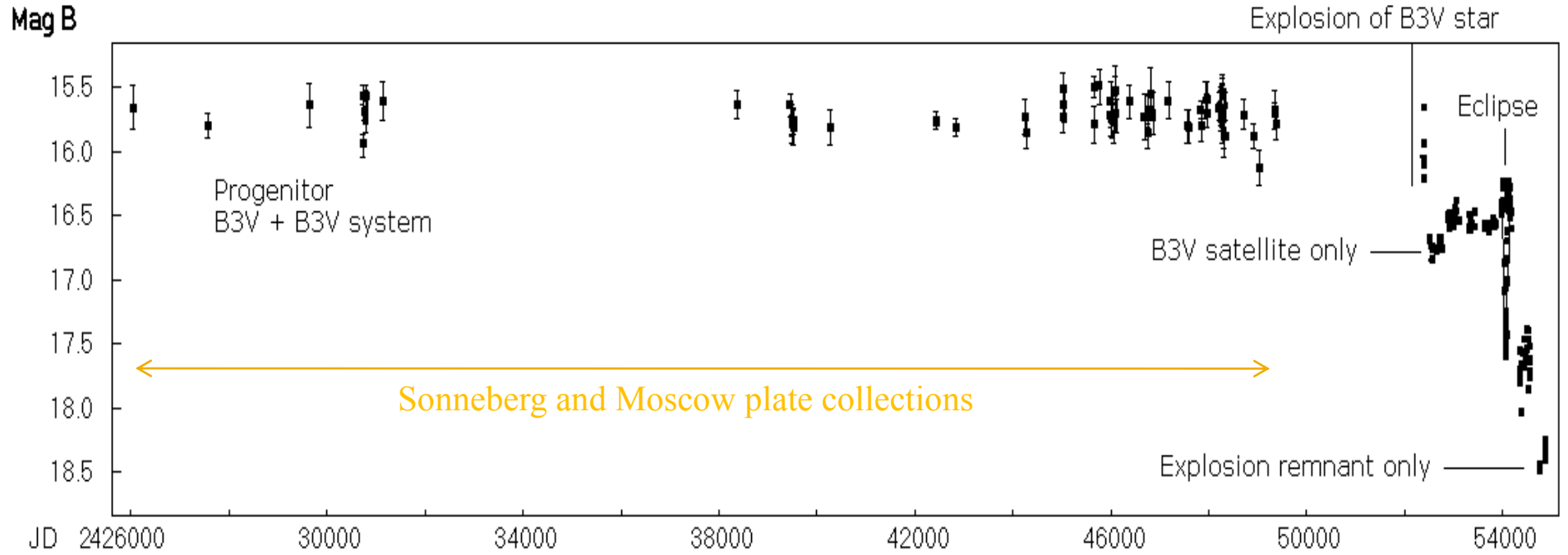


The Russian 6-m BTA / NES spectrum, resolution 1km/s

(Kipper et al., A&A 416, 1107, 2004)

Such profiles are hardly possible in case of stars' collision

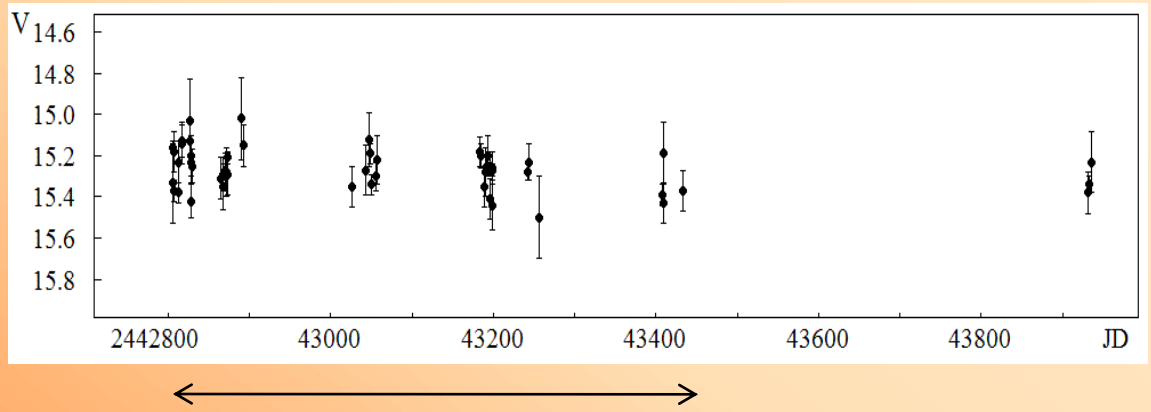
The photometric history of V838 Mon



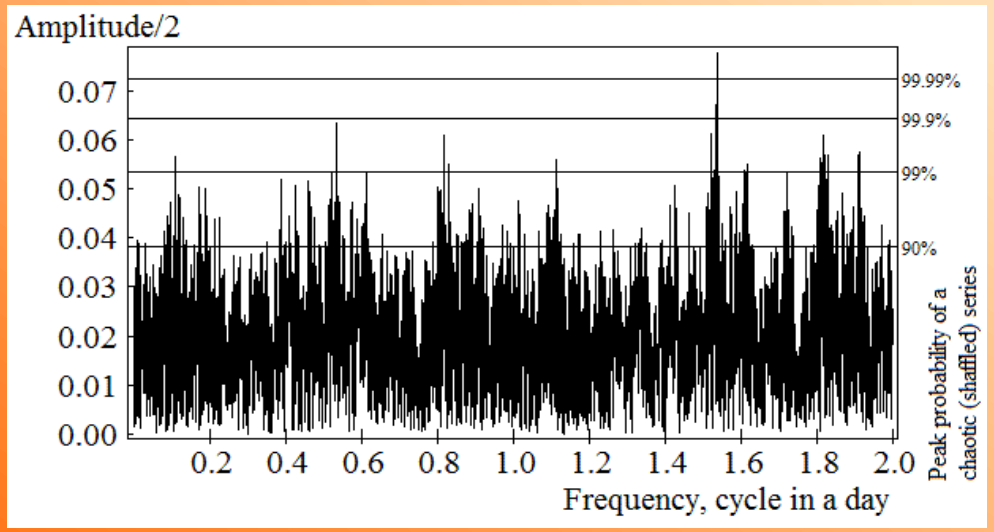
From 1930 to 1994 a brightness of the progenitor was constant.
After the outburst in Autumn 2002 only the B3V companion was visible in the B filter.
Then in this band a radiation of the cool component appeared.
Later on December 2006 the emission line spectrum strengthened and the B companion disappeared for 70 days.
Next season 2007/2008 the B star became weaker and its radiation partly leaked out through cloudy structure of the remnant.
In October 2008 the B star vanished completely. This was an engulf.

Examination of progenitor ‘s V magnitude series for periodicity

It is known that the light contribution of exploded star in a binary was 57.6 per cent.

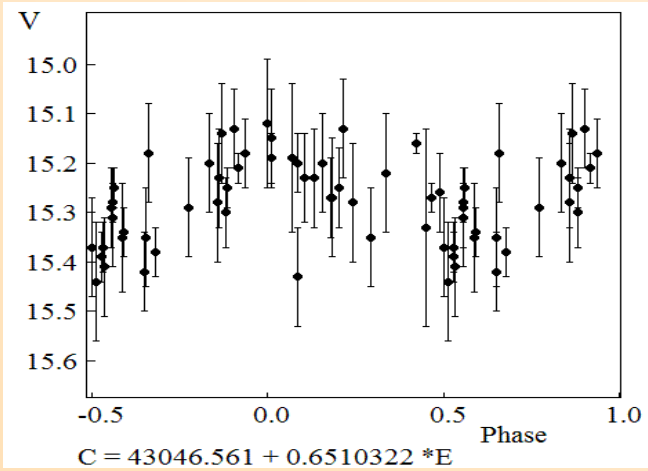


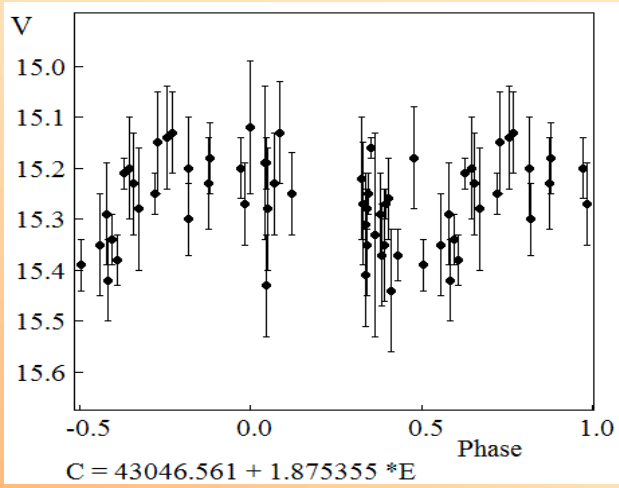
Only this dense 640-day portion was used for calculations



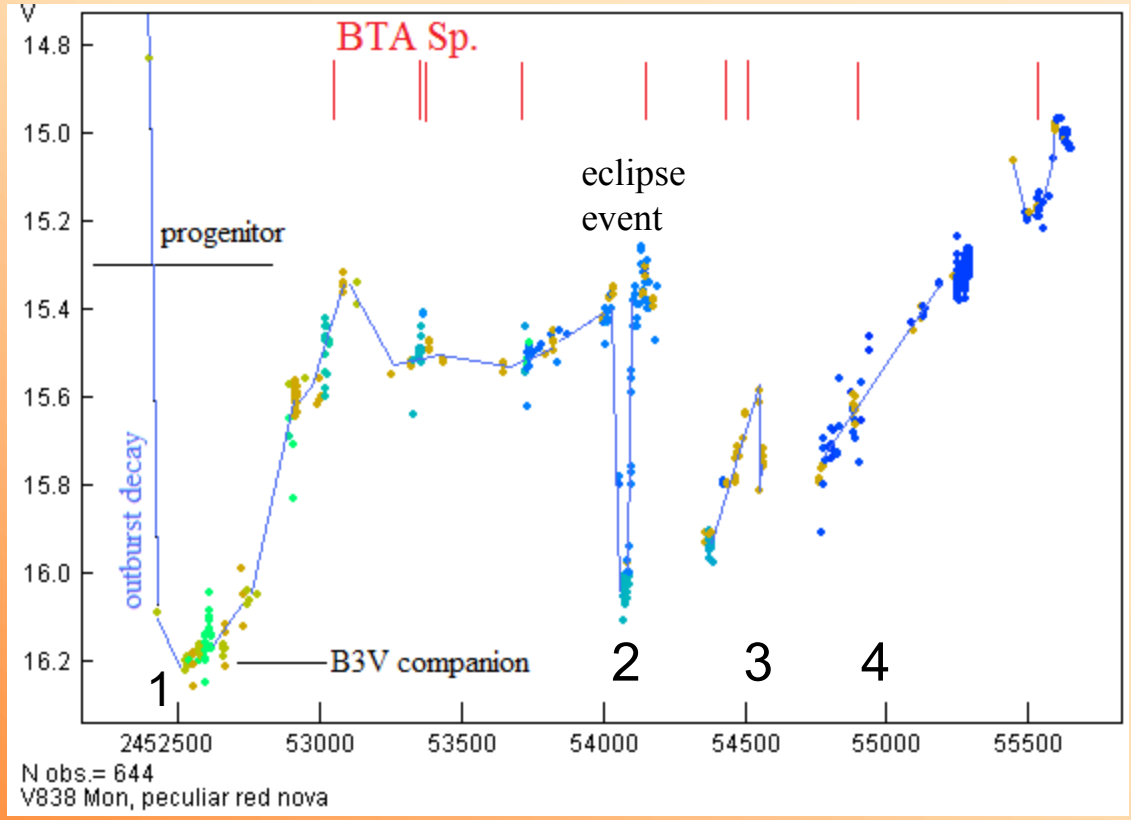
Diming amplitude spectrum. Peak probabilities are compared with those of a chaotic series.

These two best periods are not significant



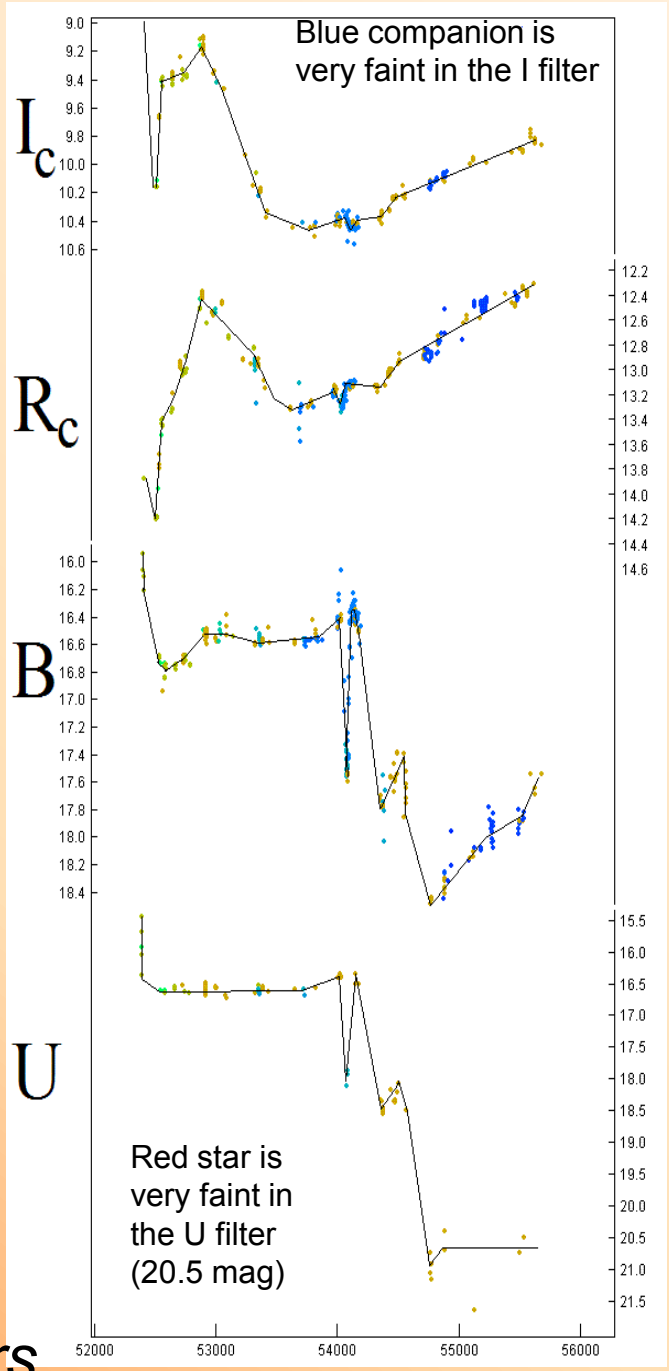


The brightness evolution after outburst



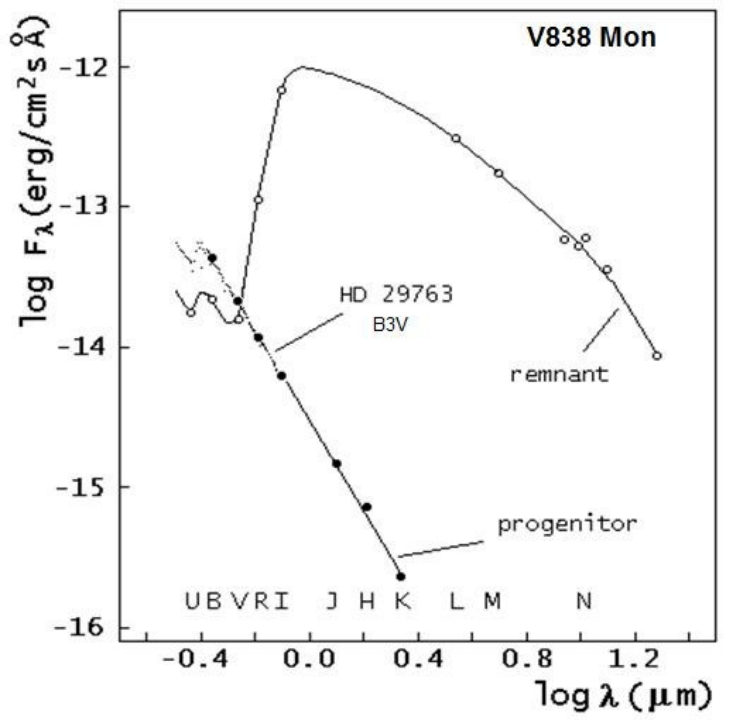
V band curve

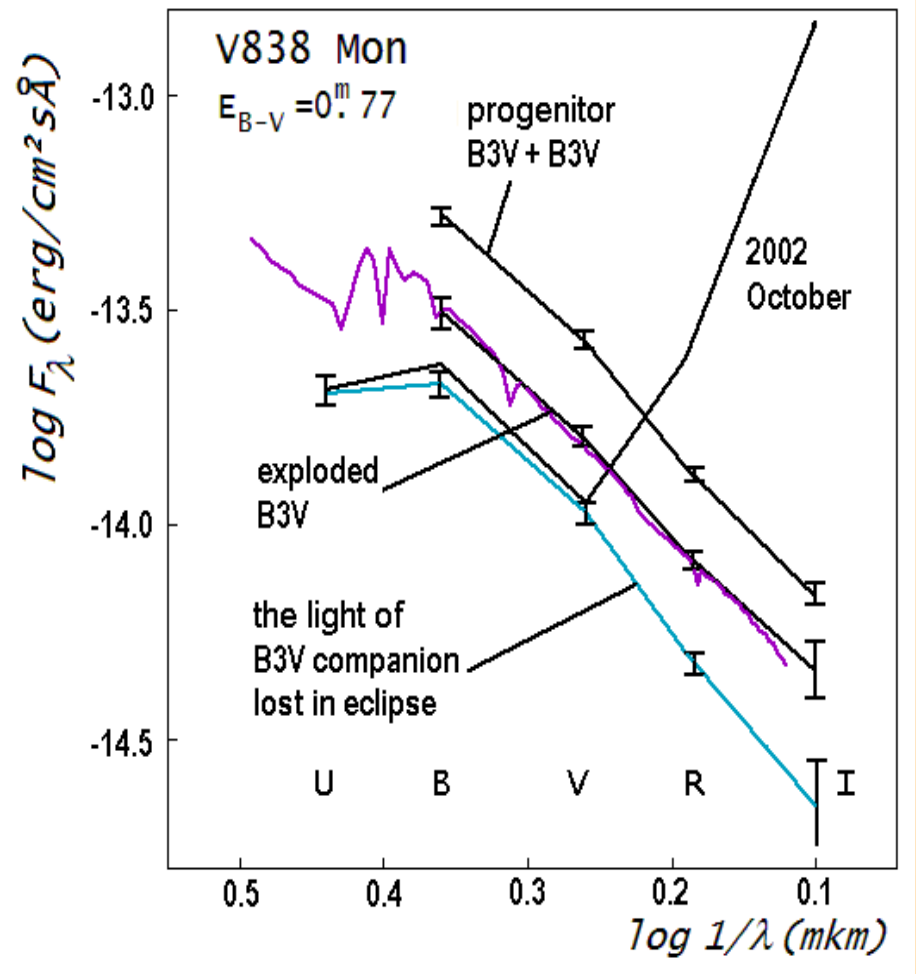
We think that the eclipse event was a result of forming a transient accretion disk around the B3V component. We could not see the hot star through the plane of the disk but we observe the ionized gas radiation in all directions around B star.



Light curves in other filters

Spectral energy distribution of the progenitor and the remnant

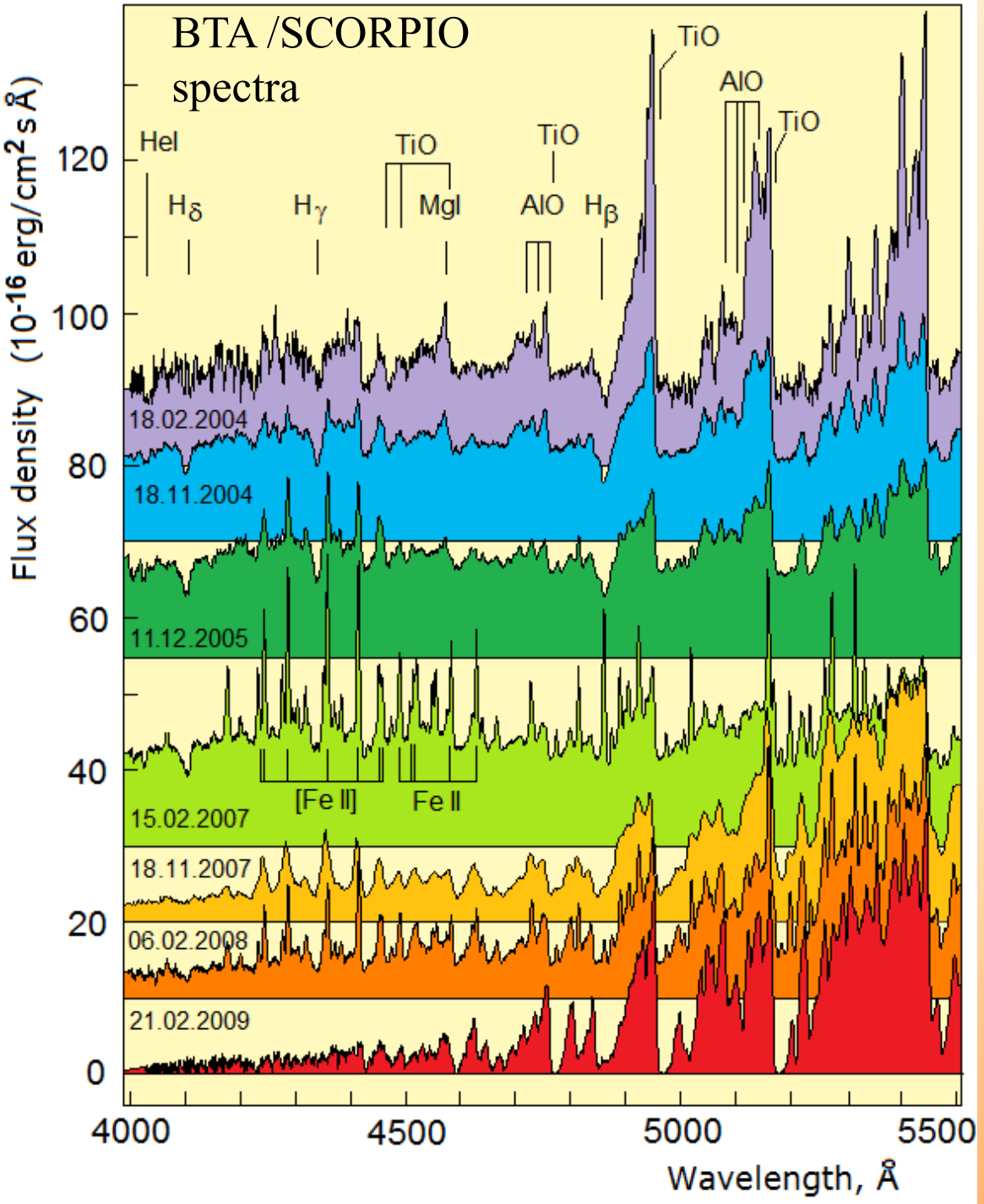




Summary brightness:	15.27 V,	15.87 B	B-V=0.60
B3V component:	16.21 V,	16.79 B	B-V=0.58
B3V exploded:	15.86 V,	16.48 B	B-V=0.62

The brightness level of the system fell in B and V filters. This means that the radiation of an exploded star disappeared from these filters. From the difference of light we calculated magnitudes and colors of the exploded star and its companion given in the above Table. Their colors are undistinguishable.

Energy distribution of the exploded star from B to I bands was calculated by subtracting the light lost in the eclipse from the light of progenitor. This distribution coincides with that of a B3V example star (violet line).



Spectral evolution of two-component spectra of V838 Mon after the outburst

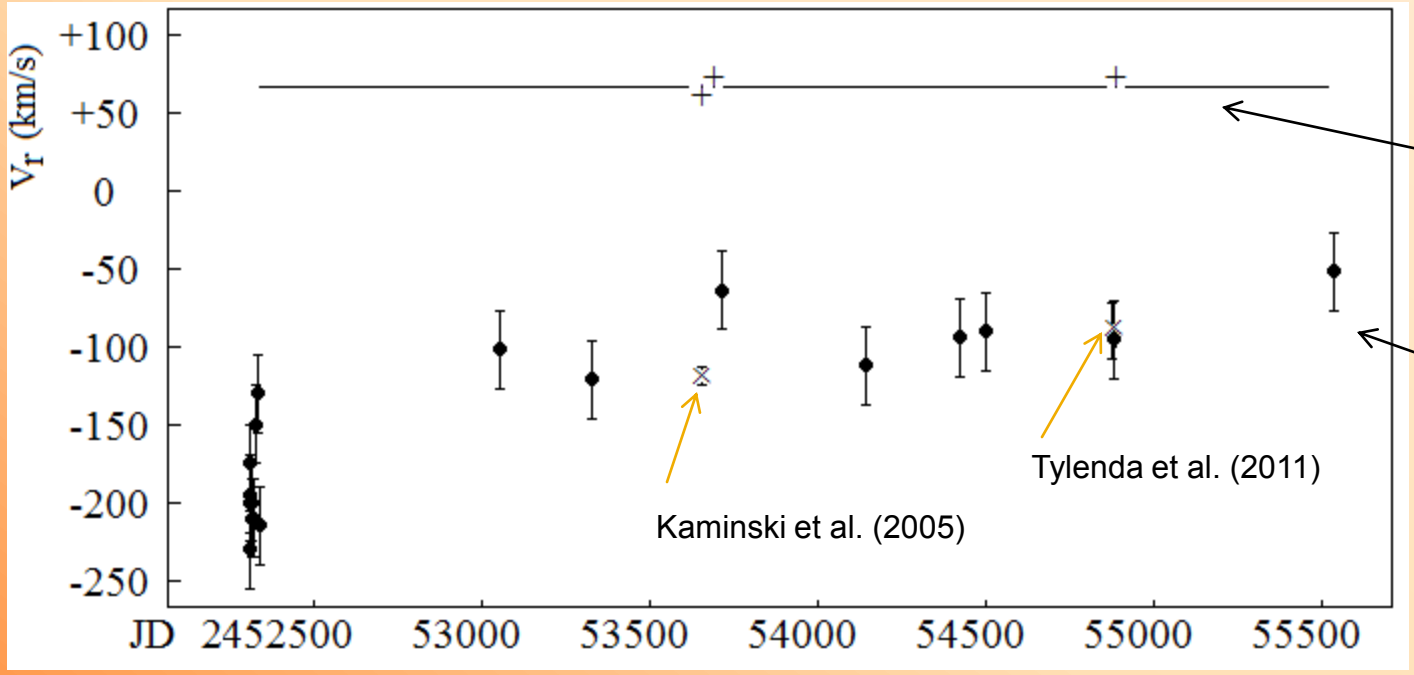
2004-2005: the B3V absorption lines are visible well, [FeII] emission of low-density gas rises with time. Very likely this has happened due to approach the companion with the explosion remnant.

15.02.2007: After the eclipse of the hot companion, the perittted-line emission spectrum of a dense gas became strong.

2007-2008: The light of the plunged companion is visible partly, the emission spectrum decreases.

2009-2010: the B3V companion disappered totally. The emission-line spectrum have disappeared too.

V838 Mon: expansion of the remnant



Heliocentric radial velocity measured using SiO maser radiation

Heliocentric radial velocity of upper leyers' expansion using the head of TiO absorp tion band $\alpha(1,0)$ at 4954.6 A

Absorption component of H_α line P Cyg type profile

Deceleration of expansion is visible

The question remains whether the start of the expansion coincides with the start of the outburst.

Discussion

Evidence of an early age of V838 Mon

Chemical composition in the outburst (not evolved star of zero age main sequence).
The remnant belongs to the oxigen branch of cool stars (TiO, VO, AlO in the spectrum).
Li is present.
Both components have reduced luminosity relative normal B type stars.
V838 Mon belongs to a star cluster of B type stars.
This cluster associates with a gas and dust nebula (illuminated by a light echo).

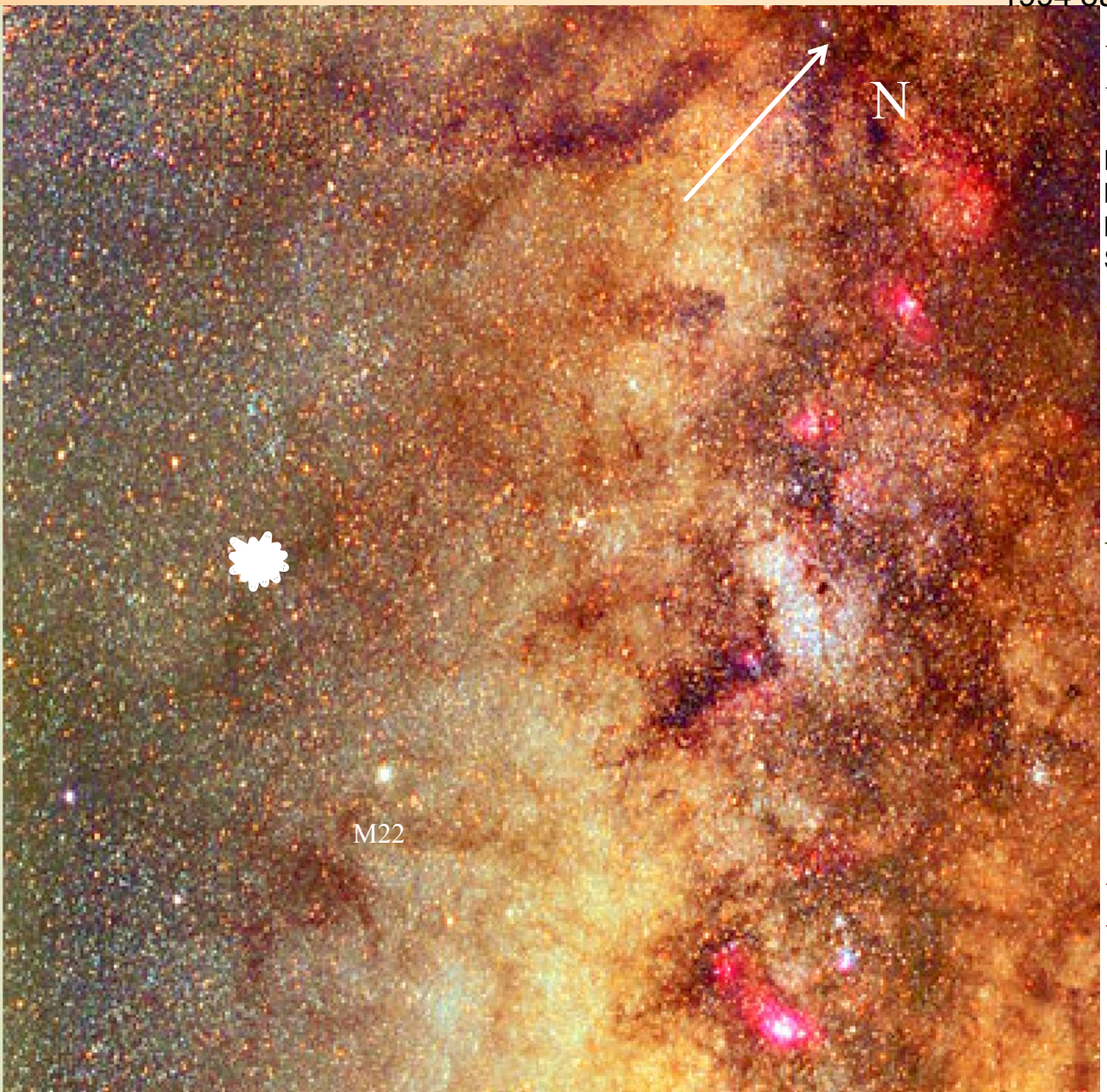
Hypotheses on the nature of explosion:

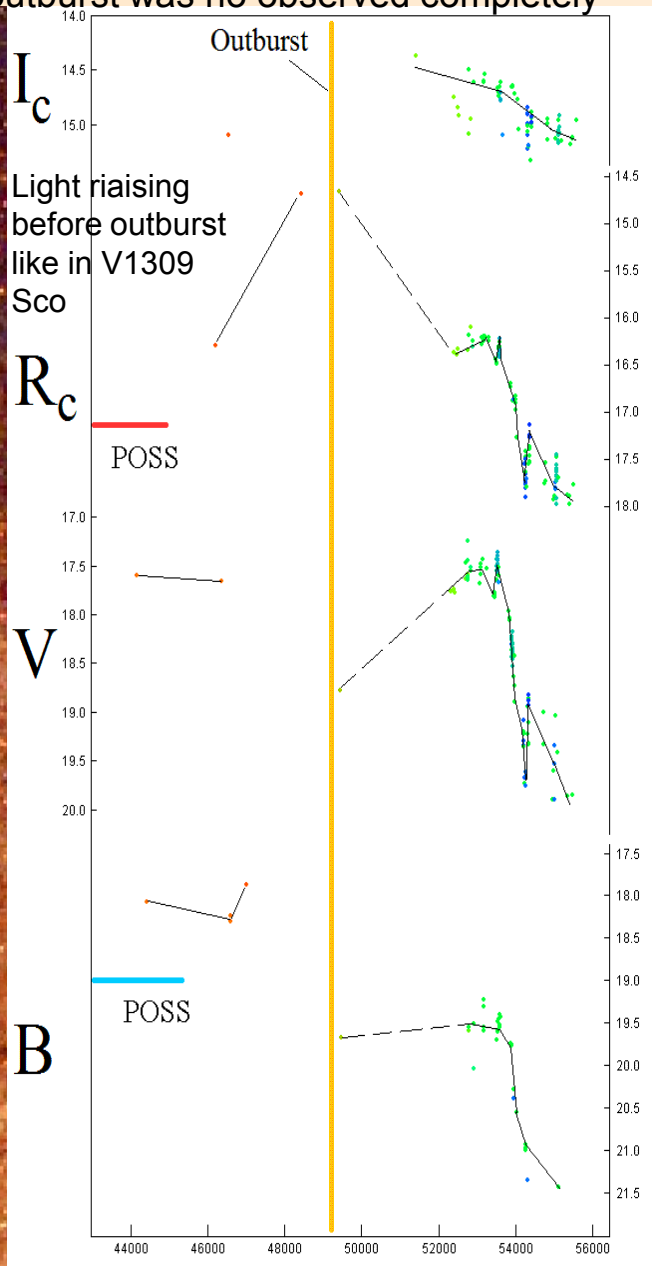
Flash on a «cool» degenerated white dwarf in a binary system, classical nova without nebular stage, helium flash in AGB stage, **stellar collision or merging in a multiple system**, Thorne-Zhitkov event (merging with a neutron star), **hydrogen explosion in the star center at the end of the gravitational contraction stage (or due to merging of initial stellar nuclei),** engulf of planets, a peculiar type II-p supernova.

Remark: in terms of merging hypothesis, the progenitor of V838 Mon should be a triple system.

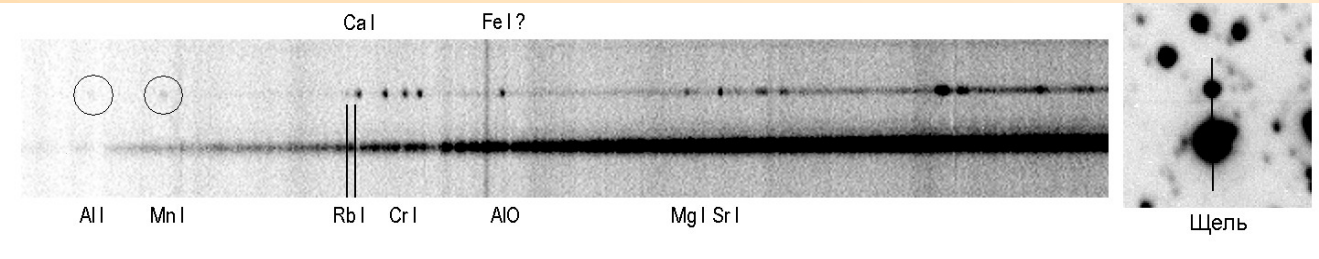
V4332 Sgr: location and photometric history

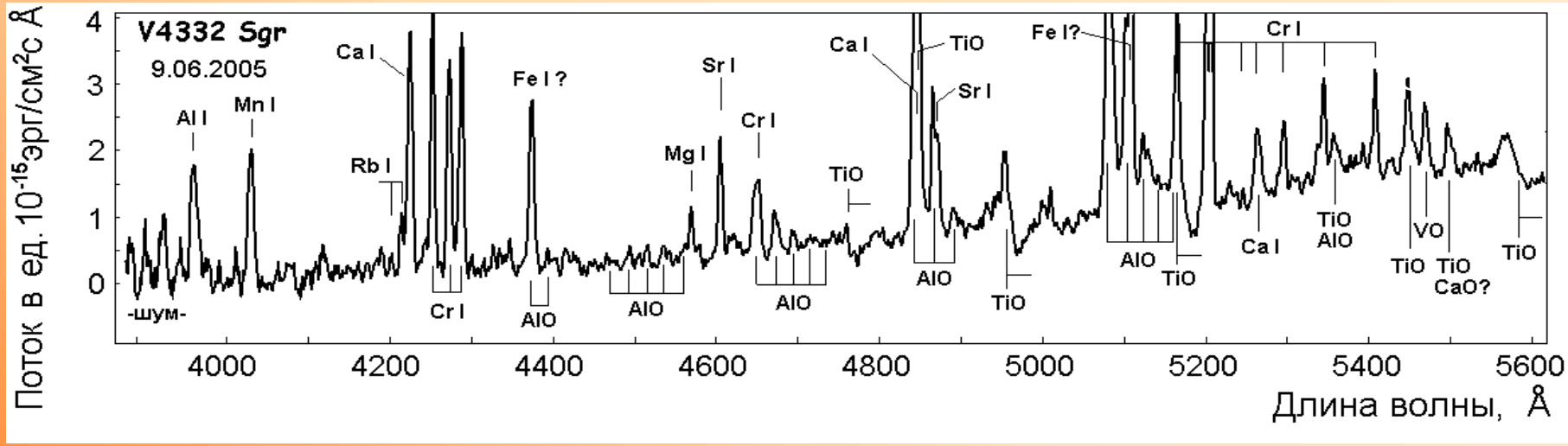
1994 outburst was no observed completely





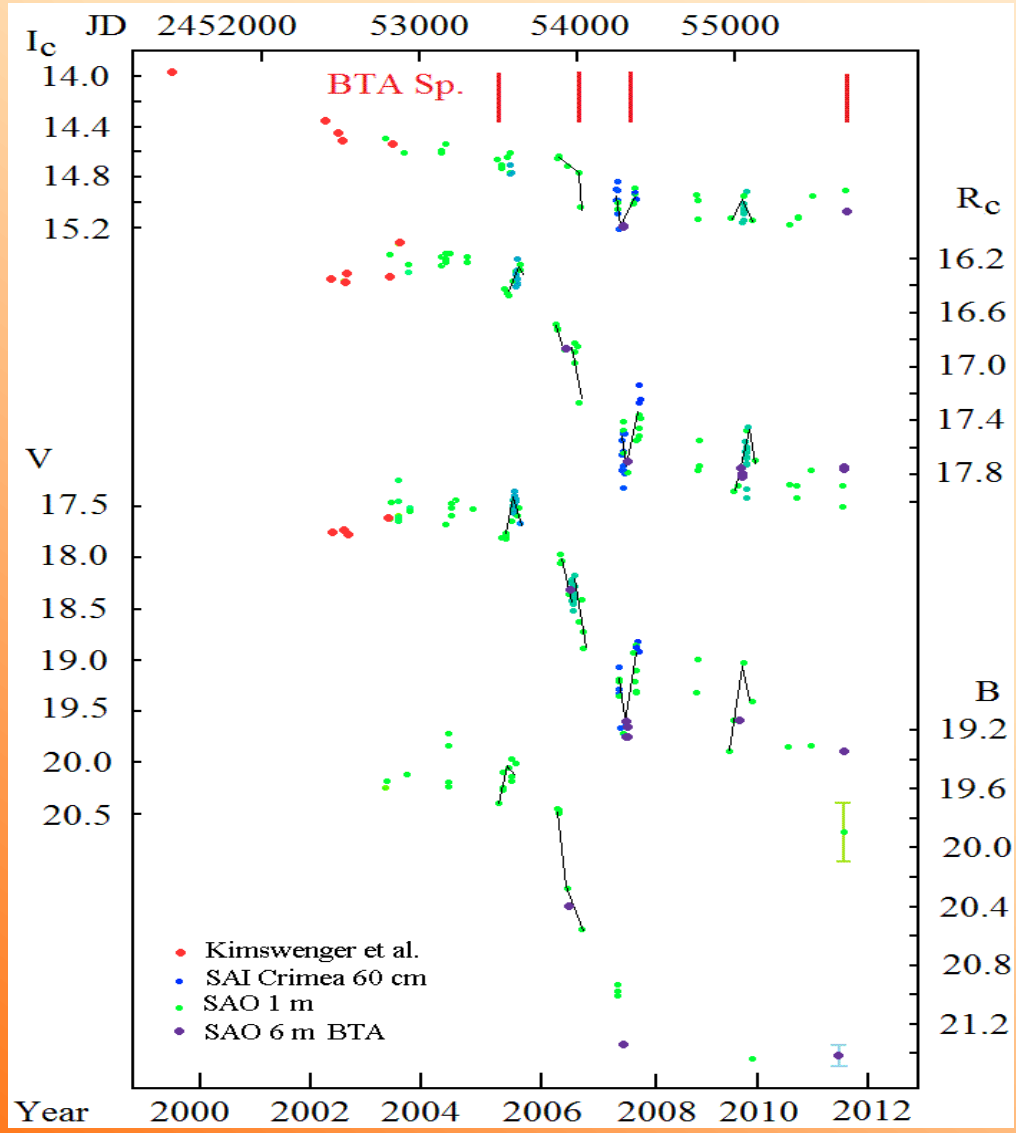
Spectra of V4332 Sgr after the outburst

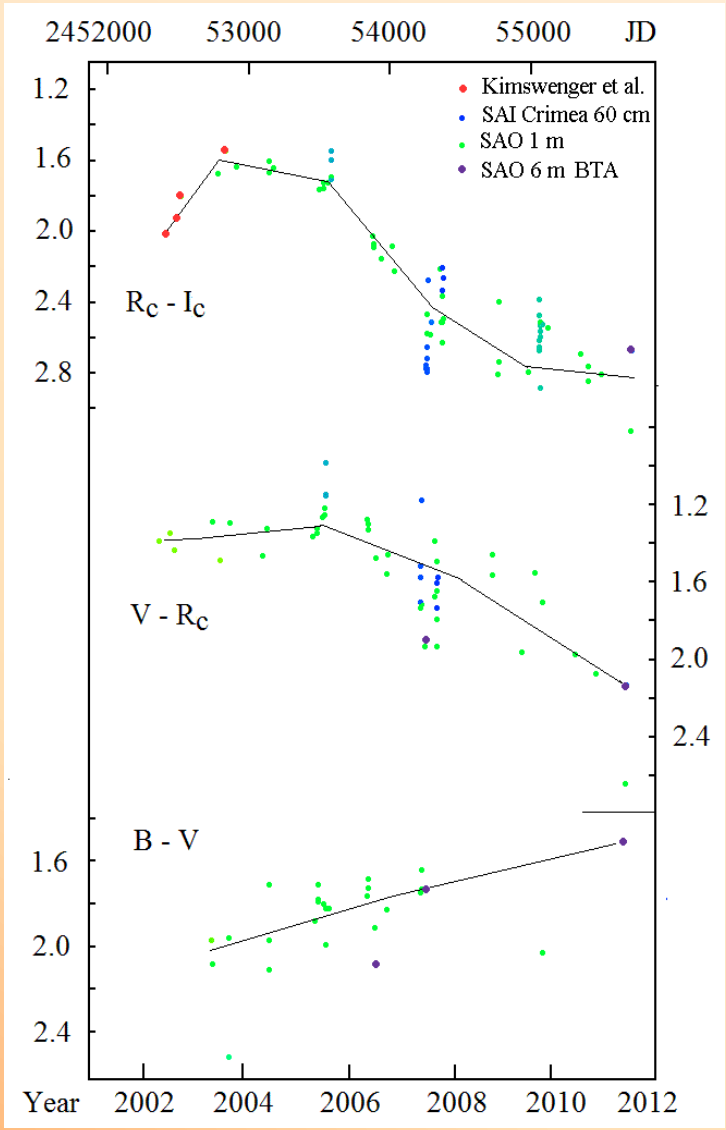




Al I, Ca I, Sr I resonance lines; Mn I, Cr I triplets; Mg I 4571Å intercombination line; weak emission lines of Rb I; AlO and TiO molecular emissions, a lot of Cr I emissions. Emission line spectrum belongs to rerified nebula with the temperature of T=1100K. Emission spectrum superimposed on the red continuum (with TiO absorption bands) of a cool star with spectral type M7.

Photometric evolution of V4332 Sgr remnant

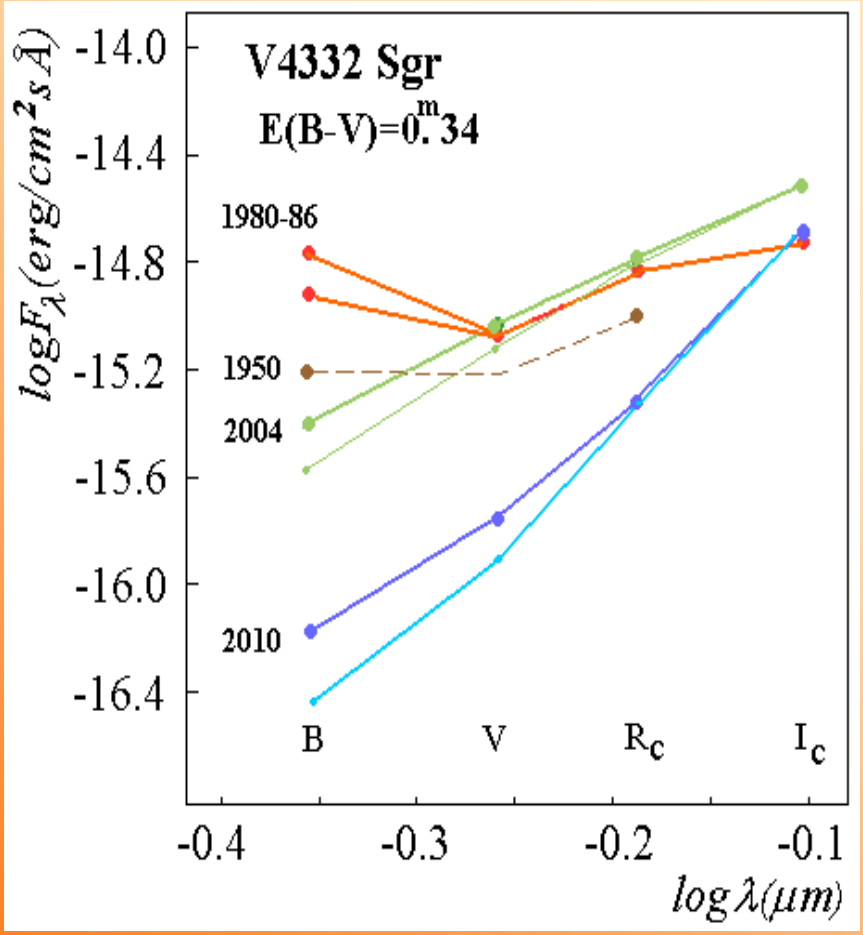




BVRI light curves from bottom to top

Color curves

Spectral energy distributions of V4332Sgr



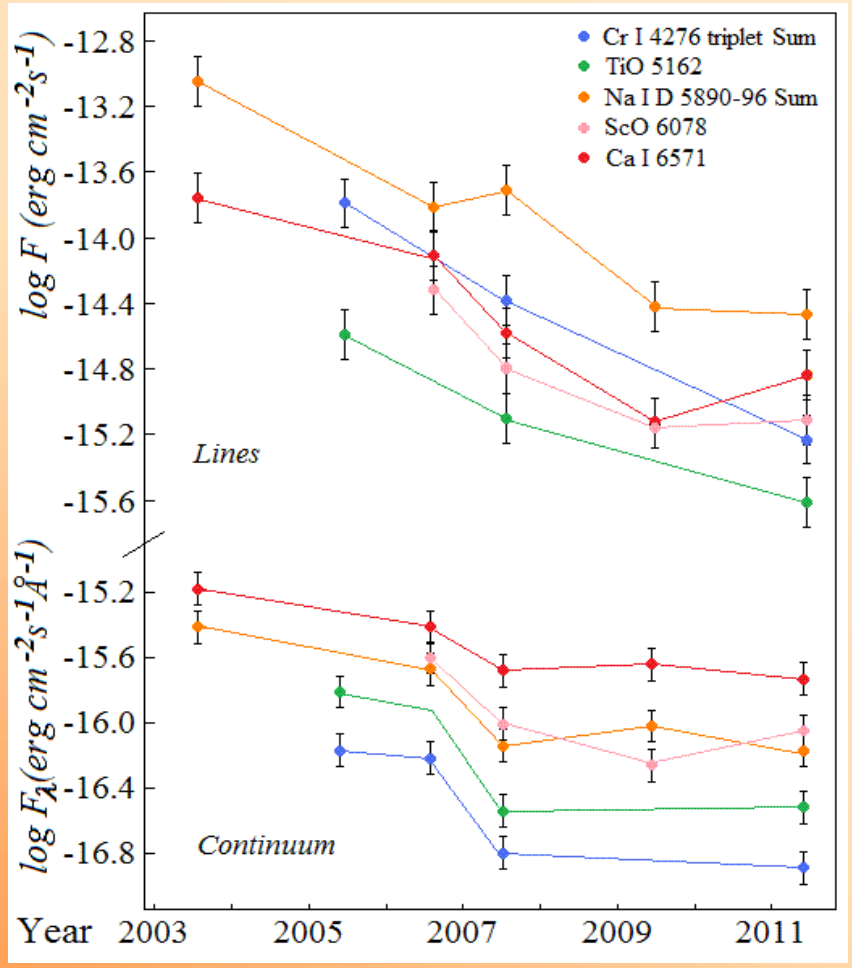
Lighter lines are obtained with consideration of the emission cotribution

Again archival images helped to reconstruct SED before the outburst. The SED is two-component. It contained red and blue components.

The contribution of the red one to the modern spectrum remained nearly unchanged. The B star disappeared.

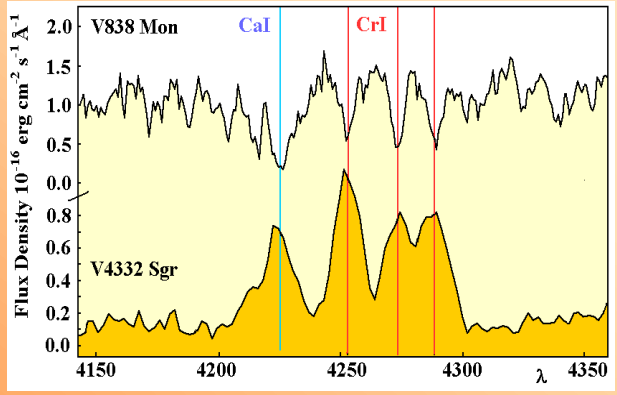
The essential weakening of the M7 type star happened between 2004 and 2010.

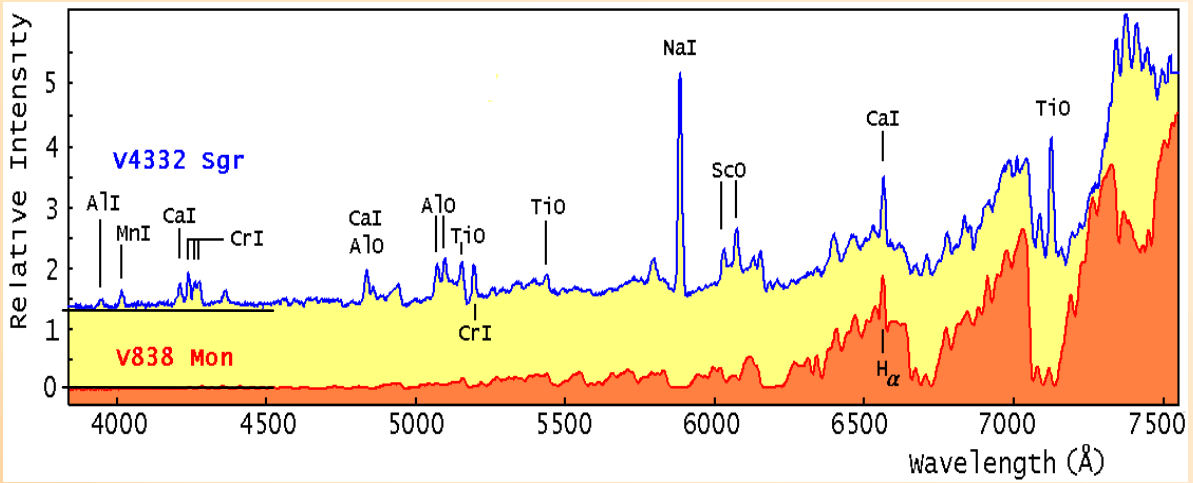
Fluxes of atomic and molecular emission lines depending on time



Flux densities of underlying continuum are shown in the bottom. Note that emission lines of the nebula fall in a more rapid rate than the stellar continuum. This fact contradicts hypothesis by Kaminsky et al. (2010) that a circumstellar disk obscures the main object.

Spectrum of V4332 Sgr is in comparison with V838 Mon spectrum (2007)





CaI and CrI resonance lines are seen in the blue range in V838 Mon (in absorption) and V4332 Sgr (in emission).

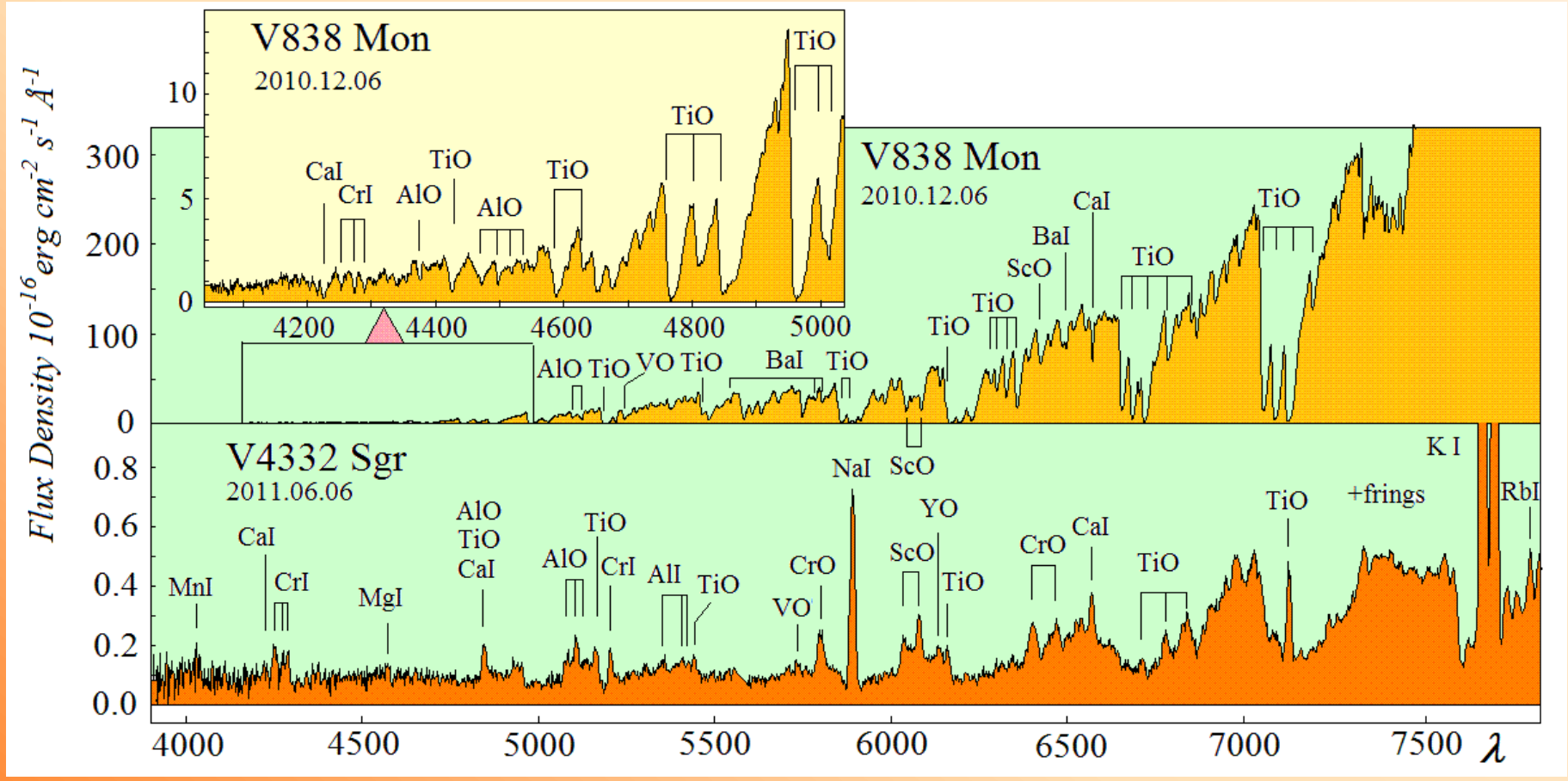
This means that V4332 Sgr remnant is already in the optically thin phase, but V838 Mon remnant is still in the optically thick phase.

Spectra of V4332 Sgr (top) and V838 Mon (bottom) in 2007. In this year, the spectral classes of cool stellar components became equal.

The cool companion of V838 Mon is the remnant of 2002 explosion. But the cool stellar M7 type component of V4332 Sgr is not the remnant of 1994 explosion, because it was visible before the explosion. Probably the cool remnant was not survived in V4332 Sgr because this system was not so wide as V838 Mon.

B + B → M + B → M + gas neb

Comparison of modern spectra of V838 Mon and V4332 Sgr

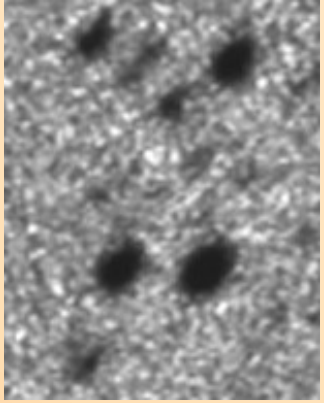


On the basis of the study carried out we have come to the following conclusion: **these two cases V838 Mon and V4332 Sgr are binary systems that contained a blue hot star. Possibly the explosion of namely this hot companion resulted in the outburst**.

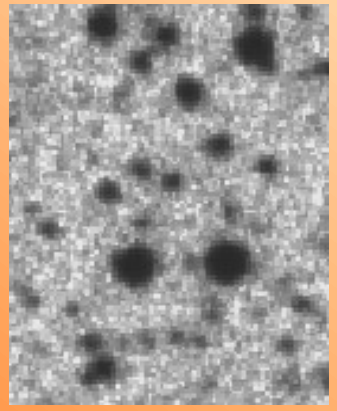

Thank you

AZT-5 Telescope archive

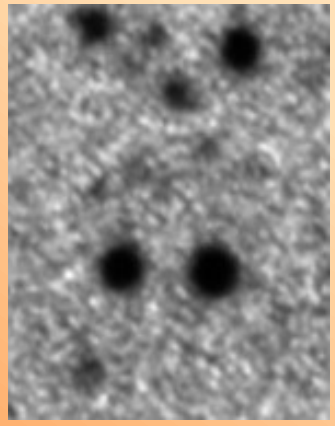
B



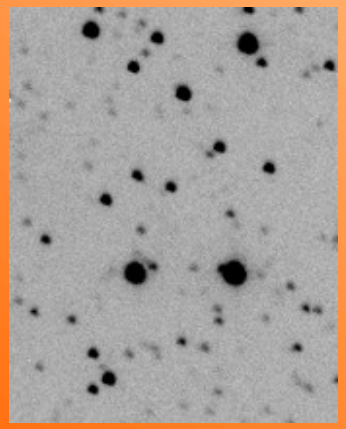
1980. 07. 14



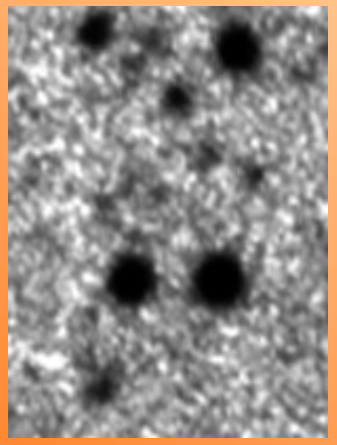
POSS O 1950



1986. 06. 07

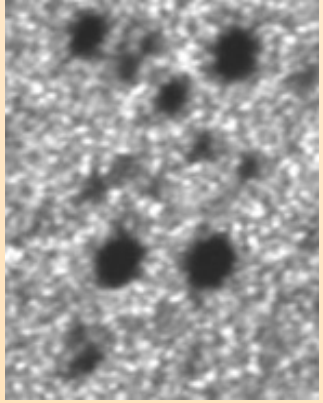


CCD B: 2005.06. 08

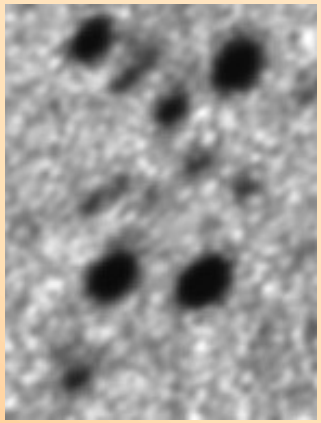


1986.06. 15

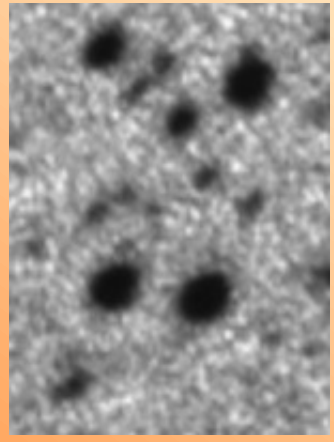
V



1977. 06.17



1980. 07.15



1986. 06. 08

When measured, fragments of a frame distorted by a brighter star were substitute for fragments of a blank sky from the same frame.