

Luminous Red Novae Phenomenon

The International Conference

“Stars: from collapse to collapse”

October 3-7, 2016, SAO RAS

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ILOT (Intermediate Luminosity Optical Transients)

V838 Mon and its light echo (HST)



Red novae are stars turning into cool supergiants during their outbursts. They belong to new class of variable stars demonstrating powerful outbursts - Intermediate Luminosity Optical Transient (ILOT), which have absolute magnitudes in the maximum of their outbursts between those of classical novae and supernovae.

Known and suspected red novae:

V1006/1007 M31 = RedVar = McDonald 88 No.1 (1988).

Max $V=15.^m5$, $B-V=1.^m89\pm0.^m24$, $M_V=-9.^m1$ Sp. M0 Ie

V4332 Sgr (1994) Max $V=8.^m5$, $B-V=1.^m95$, Sp. K3-4 I-III

V838 Mon (2002) Max $V=6.^m8$, $B-V=1.^m05$, $M_V=-9.^m8$, Sp. K0 I

V1309 Sco (2008) Max $V=7.^m9$, $B-V=1.^m3$, Sp. K2 Ie

V1148 Sgr (1943) Max 8^m , Mayall (1949), Sp. K (TiO, Ca I)

CK Vul (N Vul 1670) ($Vis \sim 2.^m7$)

NGC 4490-OT (2011) Max $R \sim 15.^m79$, $M_R=-14.^m2$ Sp. F-G I

M31N 2015-01a ($R=15.^m2$, $V=15.^m5$, $B-V=0.^m6$, $M_V=-10.^m13$ Sp F0 I- F5 I)

LRN 2015 / M101 ($R=16.^m2$, $B-V \sim 0.^m2 \pm 1.^m6$, $M_V=-11.^m65$ Sp K0 I – K5 I)

OGLE-2002-BLG-360 ($I_c=11.^m3$, $V-I \sim 5.^m3$)

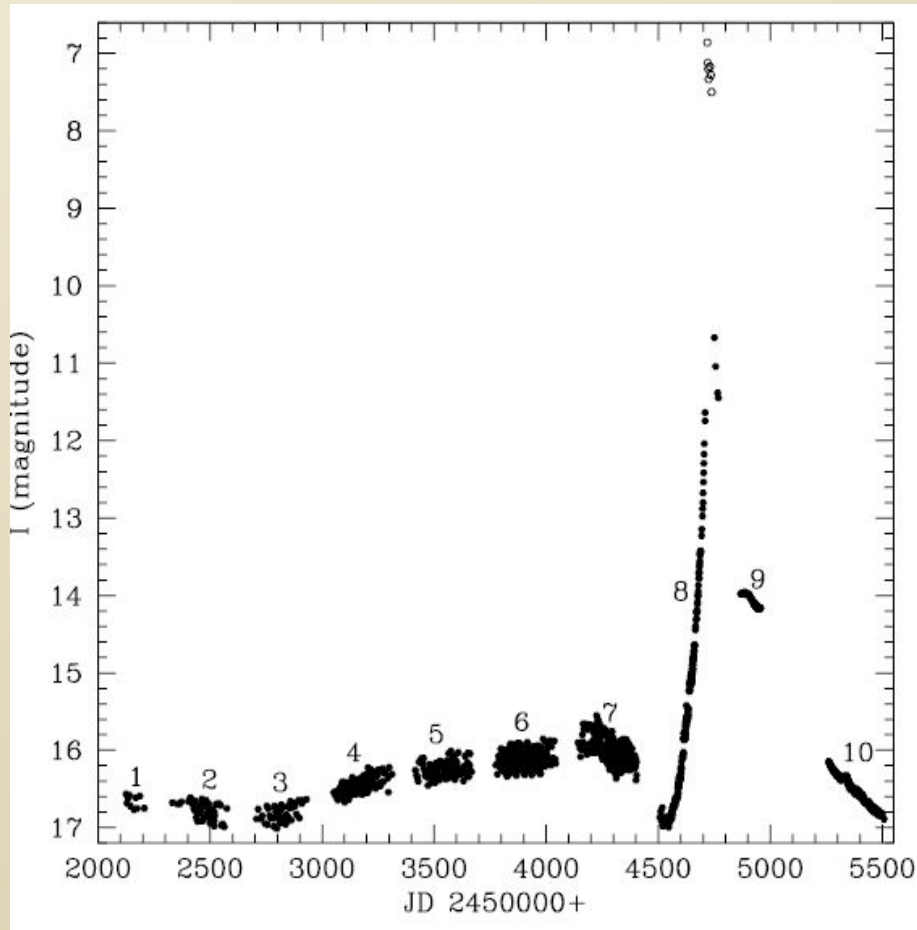
+ 4 extragalactic novae

Total : ~14 objects

V838 Mon
ZEISS-1000, 2003.12.30

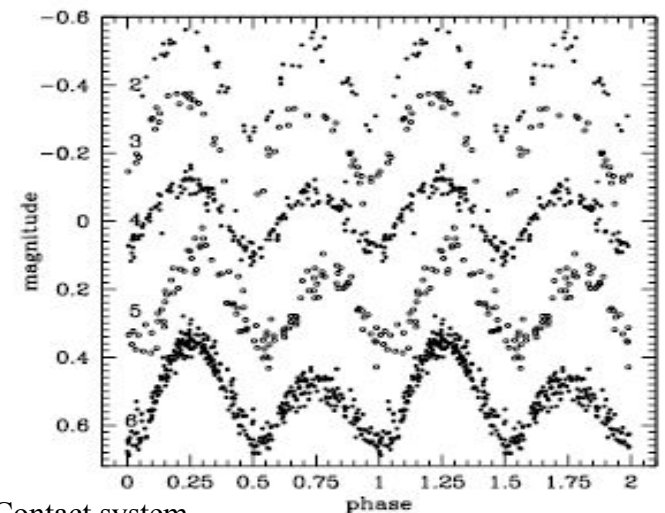


V1309 Sco – first observations of components merging of contact binary

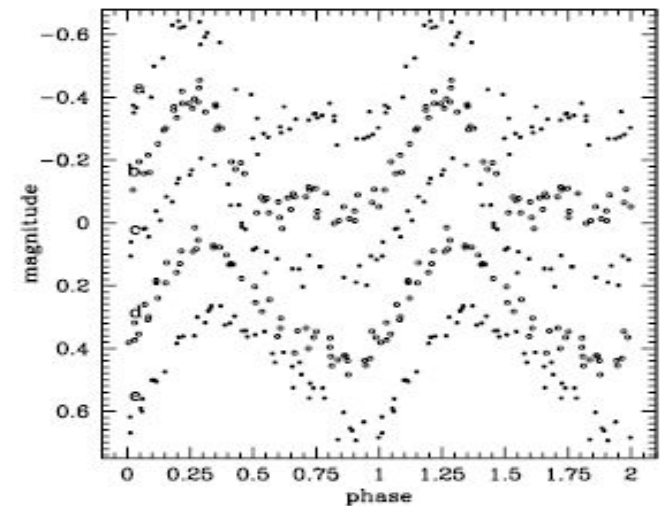


V1309 Scorpii: “Death of a Binary and Birth of a new star” (Tylenda et al., 2010, OGLE).

Spectra in the outburst K2 – M7 (Mason et al. AsAp 516, A108, 2010)



Contact system

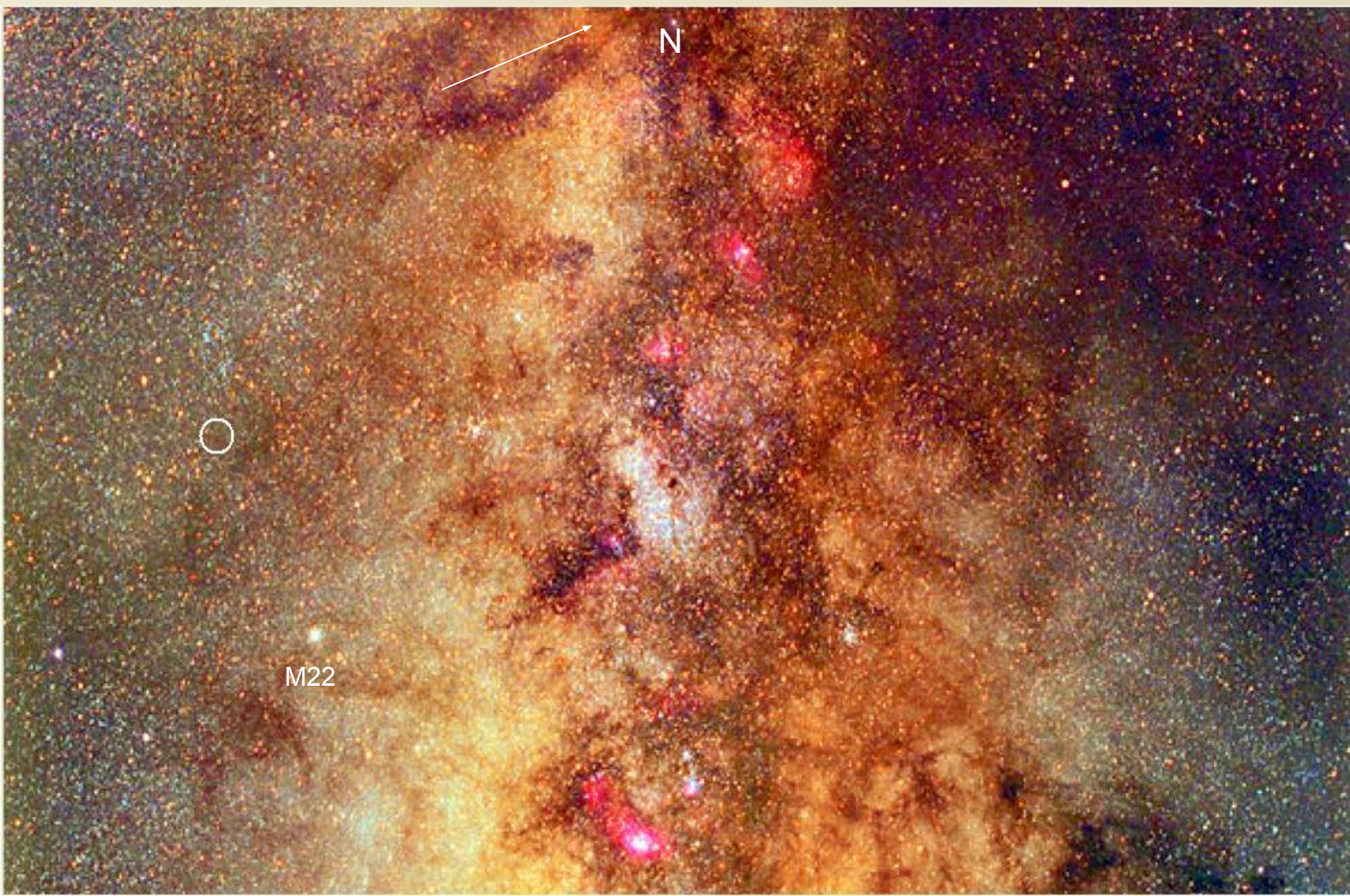


System with a common envelope

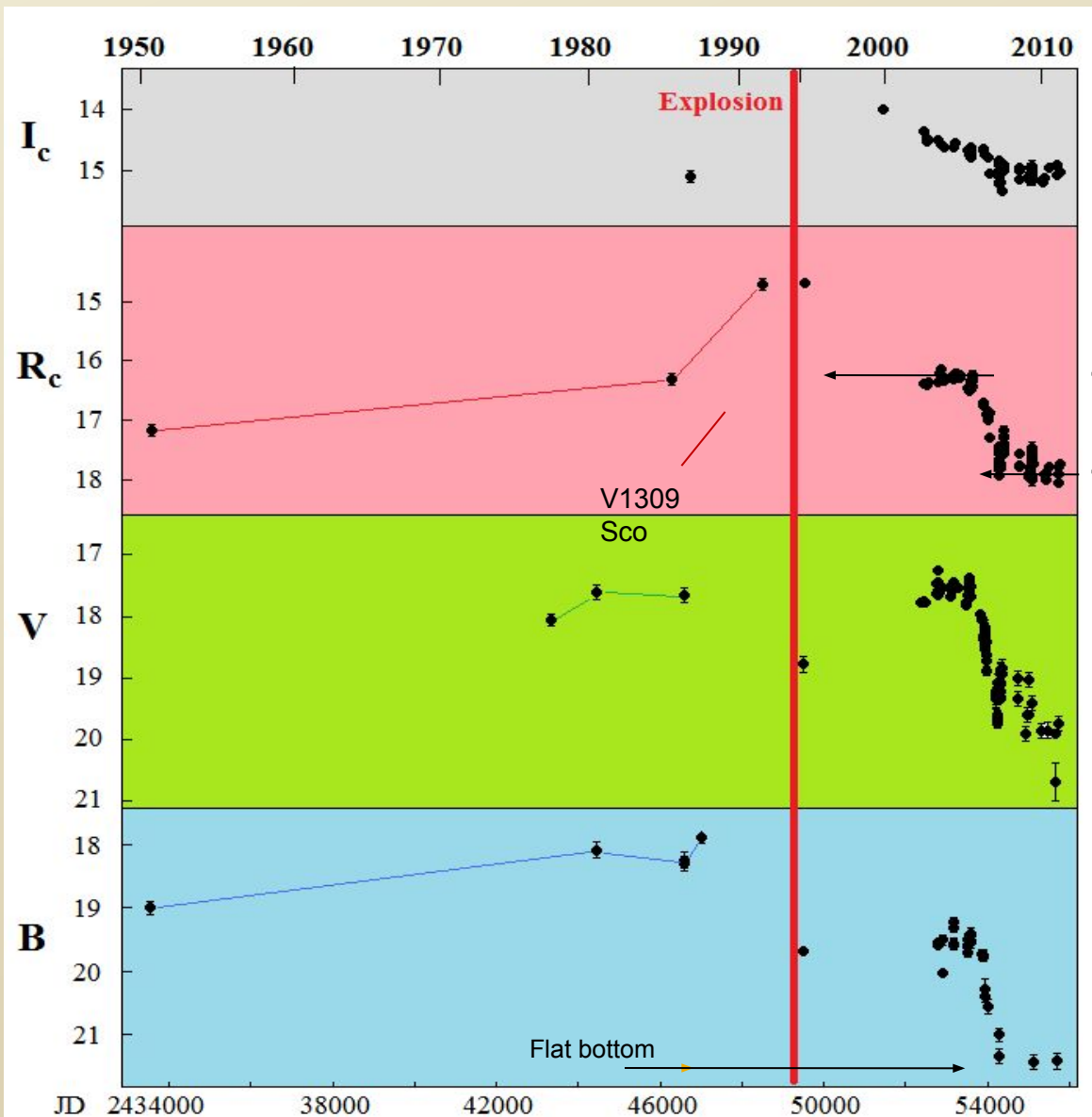
Orbital light curves according OGLE data. The period was reduced in the range of 1.44 – 1.42 day.

V4332 Sgr: location

$b = -9^{\circ}.4$, far from the Galactic plane, low extinction, $E(B-V) = 0^m.32$. Halo or old-disc object.



V4332 Sgr: photometric history



Progenitor:

$V = 17^m.63$, $B - V = 0^m.56 \pm 0^m.08$, $(B - V)_0 = 0^m.24 \pm 0.08$
(1980 July, 1986 June).

Brightness raising before the outburst by $2^m.5$ R (like in V1309 Sco, by $1^m.0$ I)

Outburst:

Amplitude $\sim 9^m$

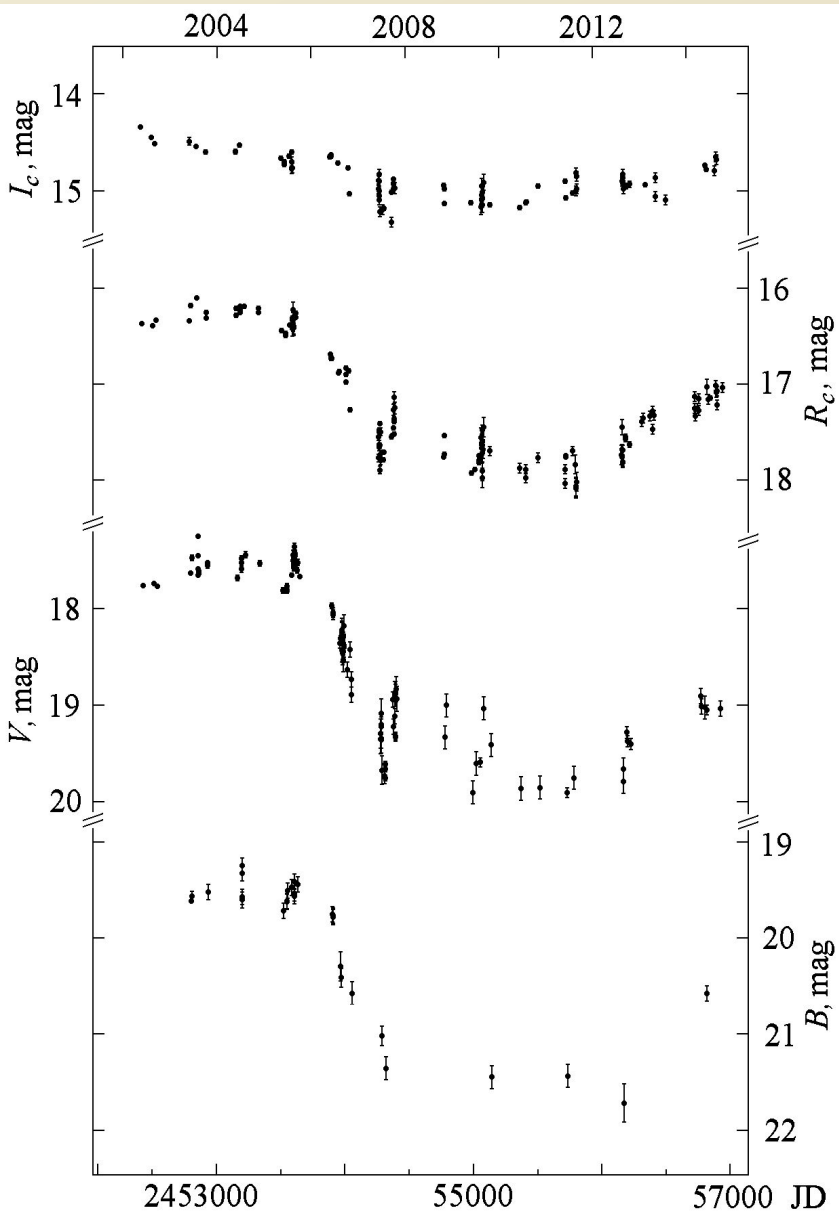
Spectrum: K3-4 III-I

Remnant:

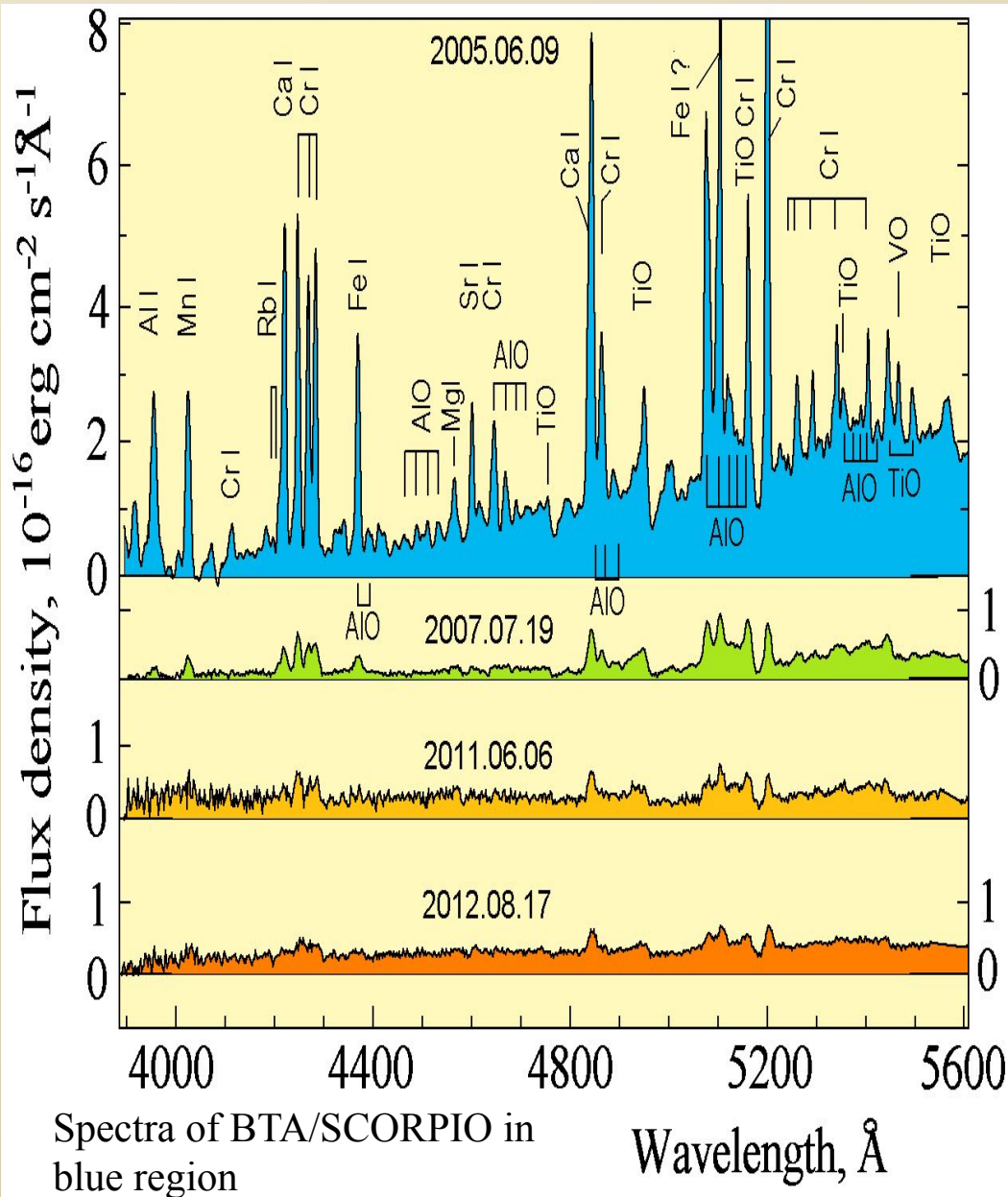
$V = 17^m.55$, $B - V = 1^m.80 \pm 0^m.1$, $(B - V)_0 = 1^m.48$.

Sudden decay by $2^m.5$ V band between 2005 October and 2008 October. The decay accompanied with light oscillations with the amplitude up to $0^m.6$.

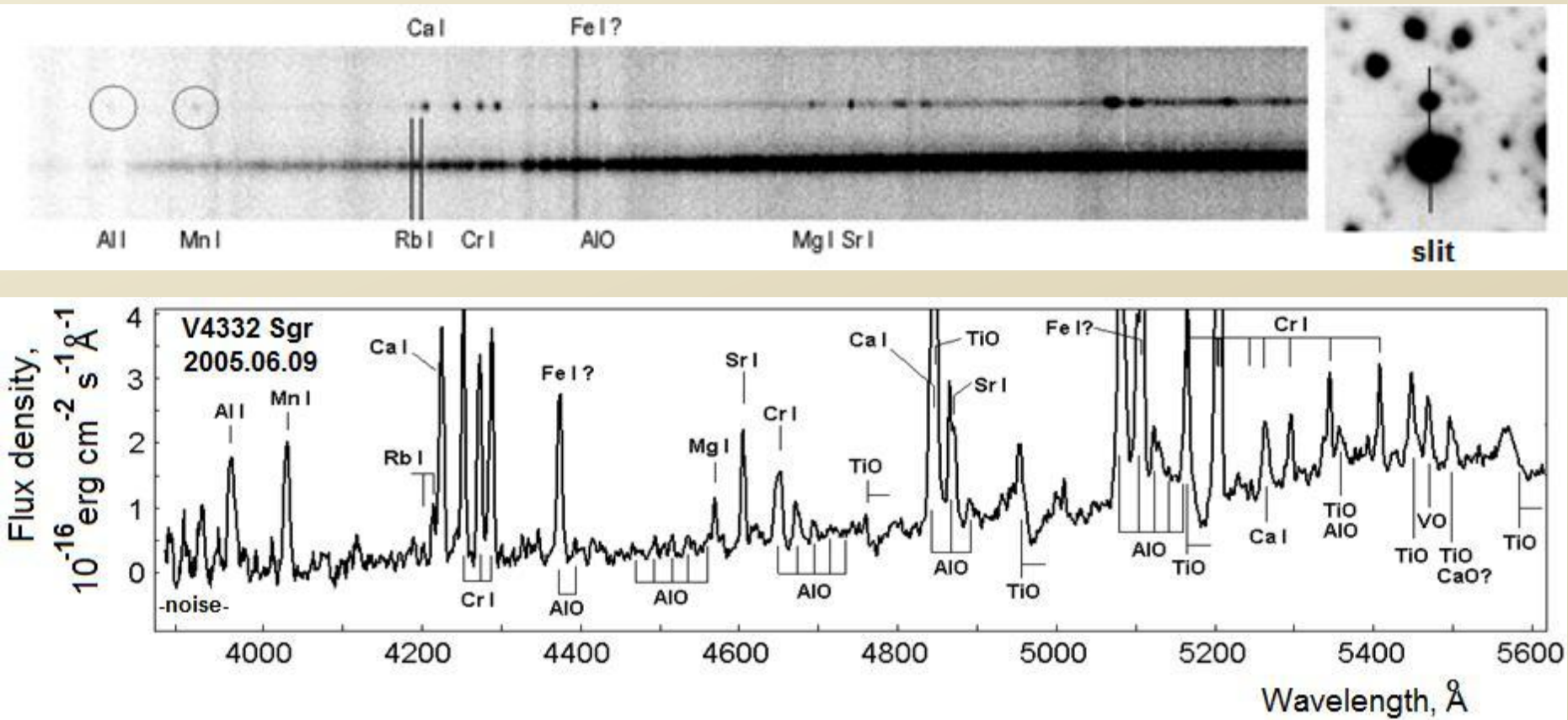
V4332 Sgr (N Sgr 1994): photometry and spectroscopy after the outburst



Light curves in four filters

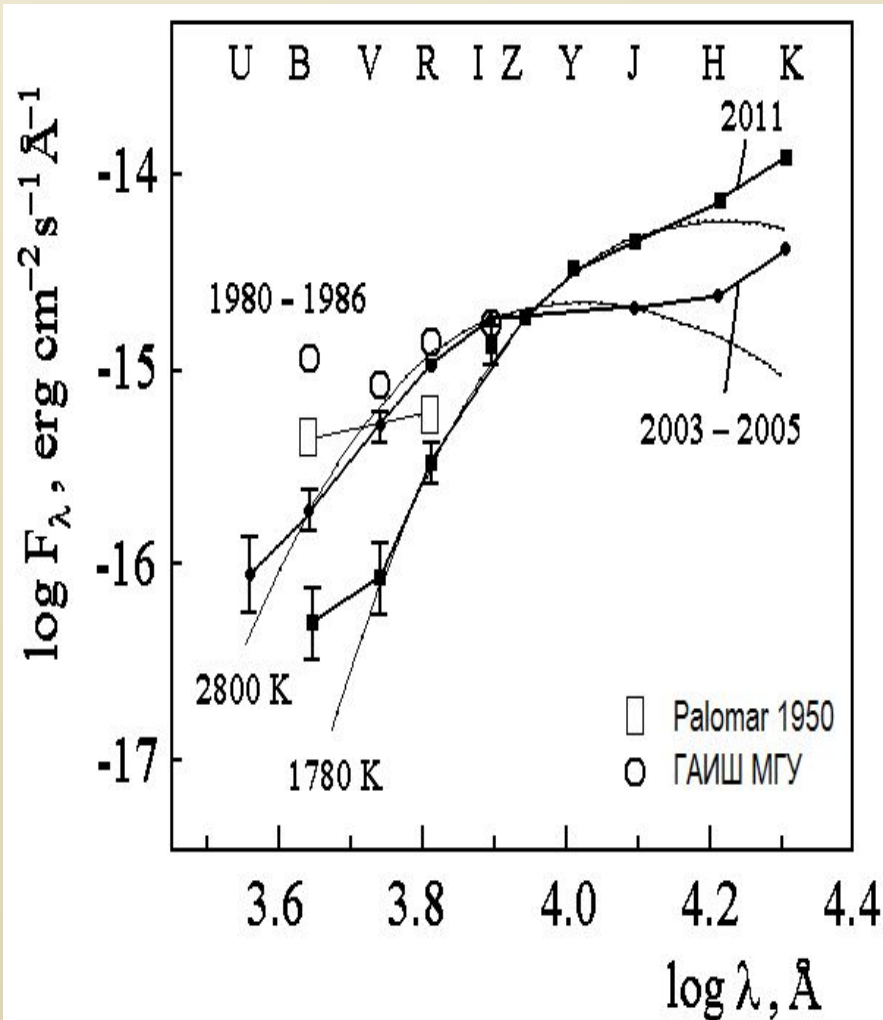


V4332 Sgr: spectra after the outburst

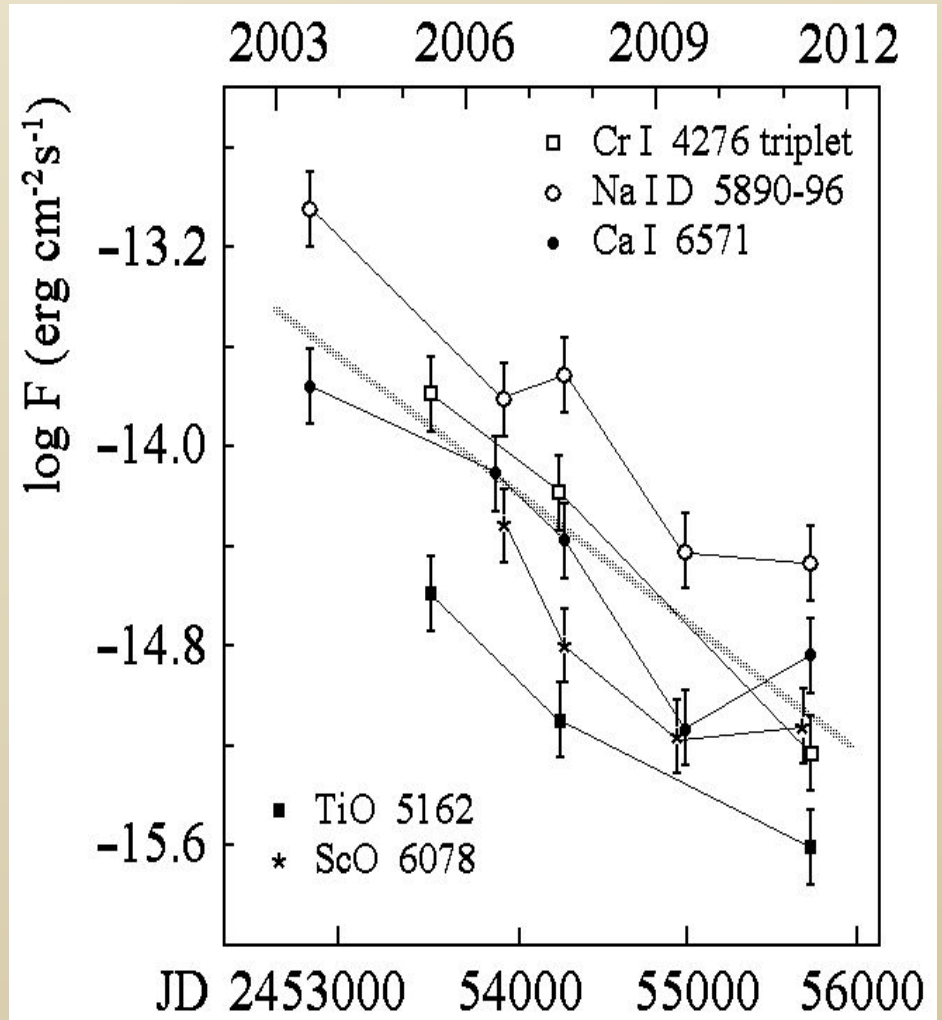


Al I, Ca I, Sr I resonance lines; Mn I, Cr I triplets; weak emission lines of Rb I; AIO and TiO molecular emissions, a lot of Cr I emissions. There is Mg I 4571Å intercombination line, which is known to be formed in a very extended and rarefied gas cloud. This gas cloud is undoubtedly the explosion remnant of the 1994 outburst. The emission line spectrum belongs to cool optically thin nebula with the temperature of 1100K. It is imposed on the red continuum (with TiO absorption bands) of a cool star with the spectral type of M7. **Cool optically thin gas with the temperature between 1000 and 1350 K (Kimeswenger, 2006).**

V4332 Sgr: Spectral energy distribution of progenitor and remnant of the outburst



IR observations by Banerjee et al. (2003)
and Varicatt et al. (2012)

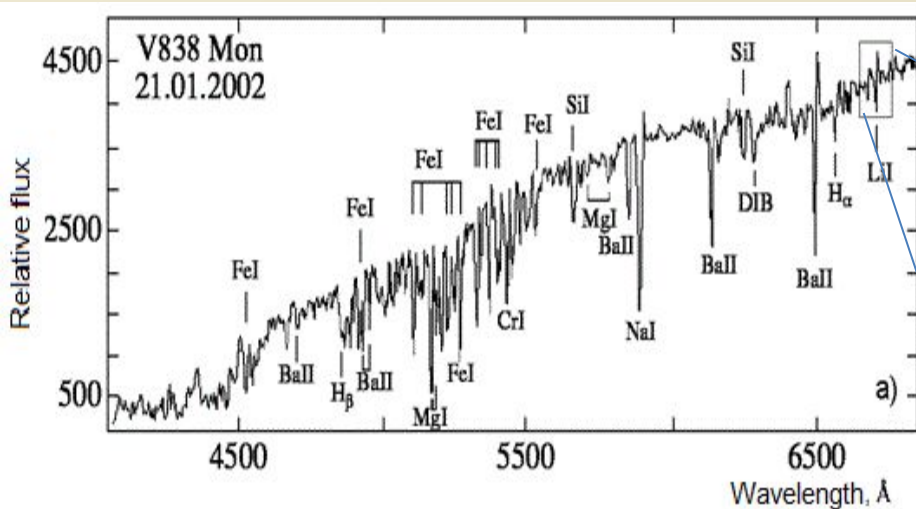


Evolution of emission spectrum

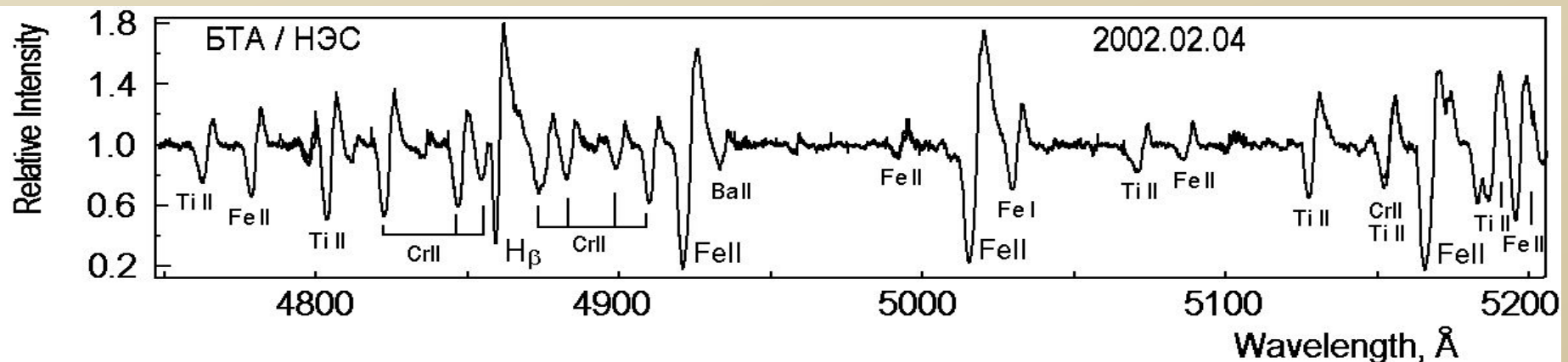
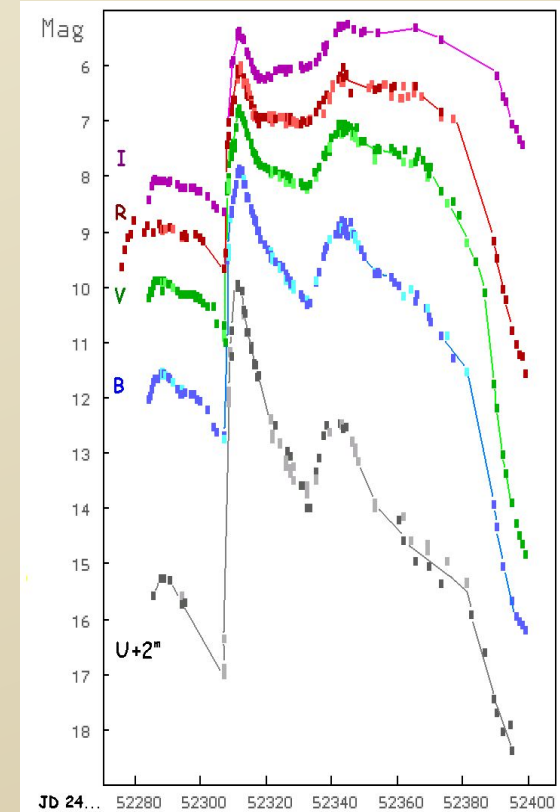
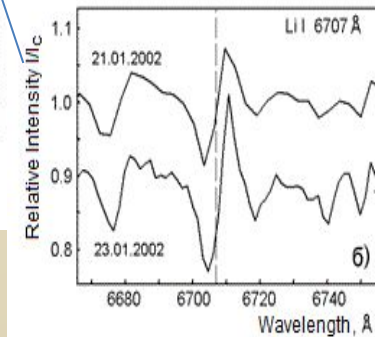
On average line intensities decreased by 30 times



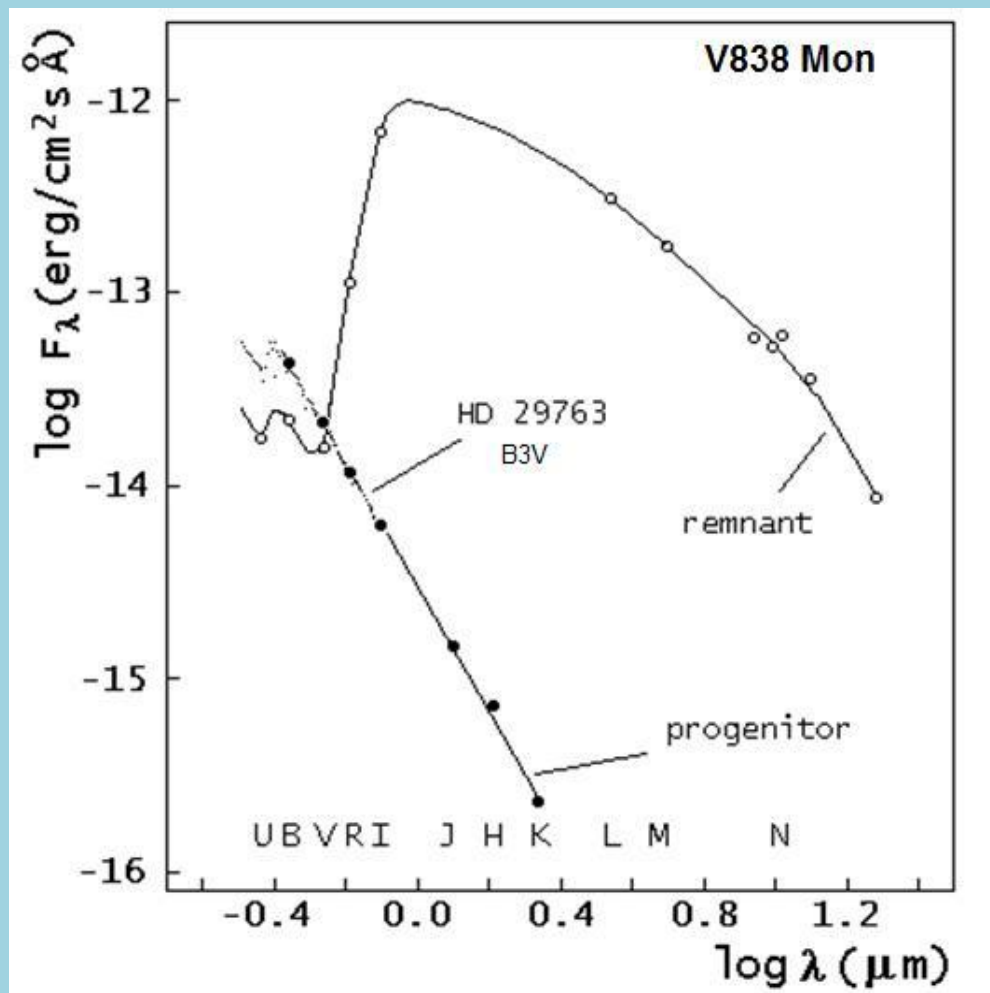
V838 Mon in the outburst



Spectrum K0 I



The comparison of the spectral energy distributions of the progenitor and the remnant with the energy distribution of B3V star.



Reddening $E(B-V)=0.77$ was taken into account

Progenitor is definitely a blue star with $(B-V)_0 = -0.17$. It did not show considerable variability over 66 years (from 1928 to 1994).

After the outburst, the energy distribution is two-component, containing the B3 component and a IR component, L-type supergiant.

Before outburst: B3V + B3V

After outburst: B3V + sg(L-M)

The exploded B3V star was brighter than its blue companion before the outburst by a factor of 1.36 ± 0.03 and their colors were indistinguishable within photometric uncertainties.

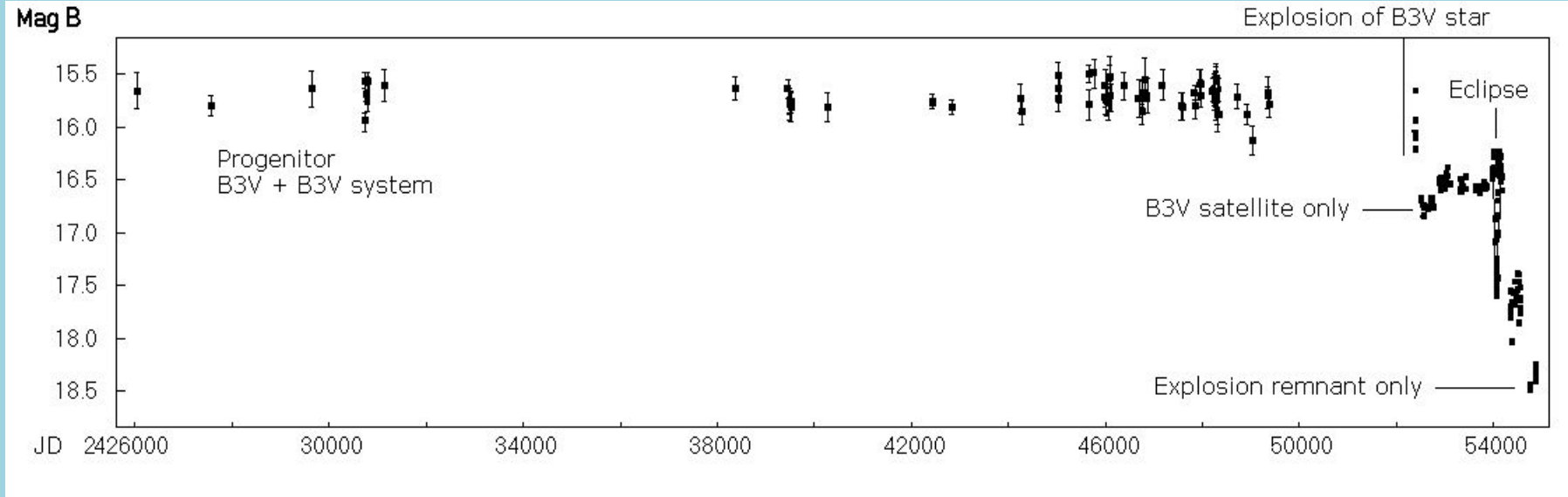
We showed that, before the outburst, the star which later exploded had the same spectrum as its companion and mimicked its blue companion .

Summary brightness: 15.27 V, 15.87 B B-V=0.60

B3V component: 16.21 V, 16.79 B B-V=0.58

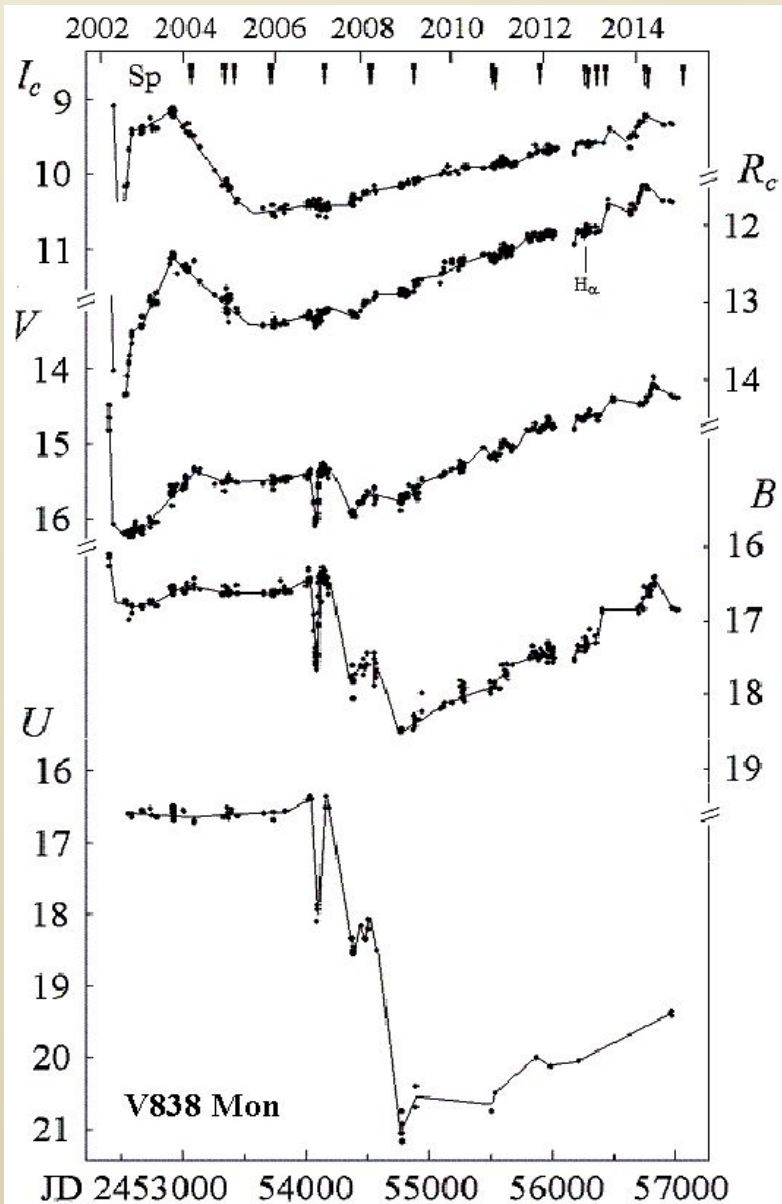
B3V exploded: 15.86 V, 16.48 B B-V=0.62

The photometric history of V838 Mon

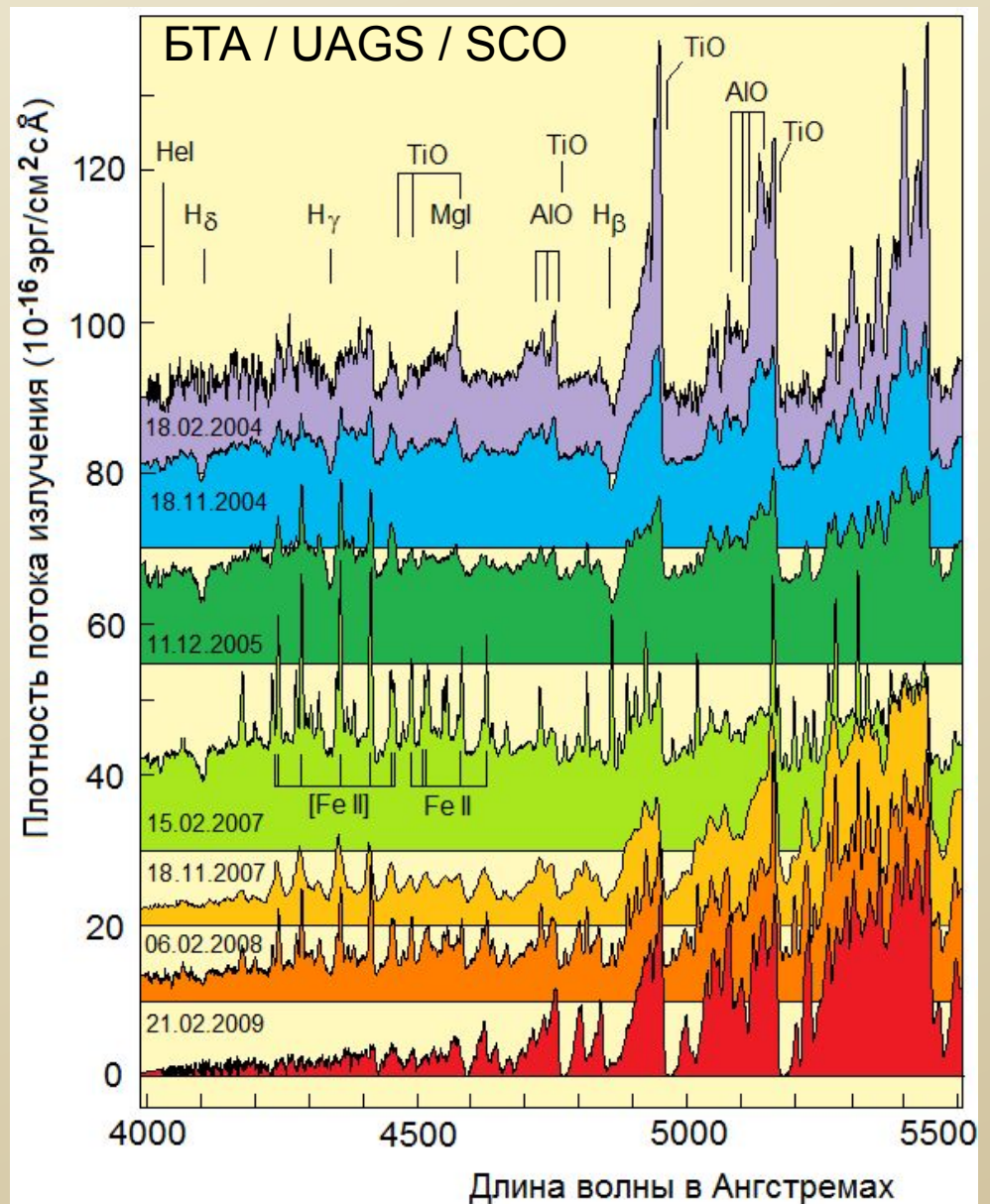


During 66 years the system's brightness was constant. After the outburst, we see photometric indications of a close approach and a collision of two components: first, brightening due to appearance of emission-line spectrum, then, an eclipse of B star observed for 70 days.

V838 Mon: photometry and spectroscopy



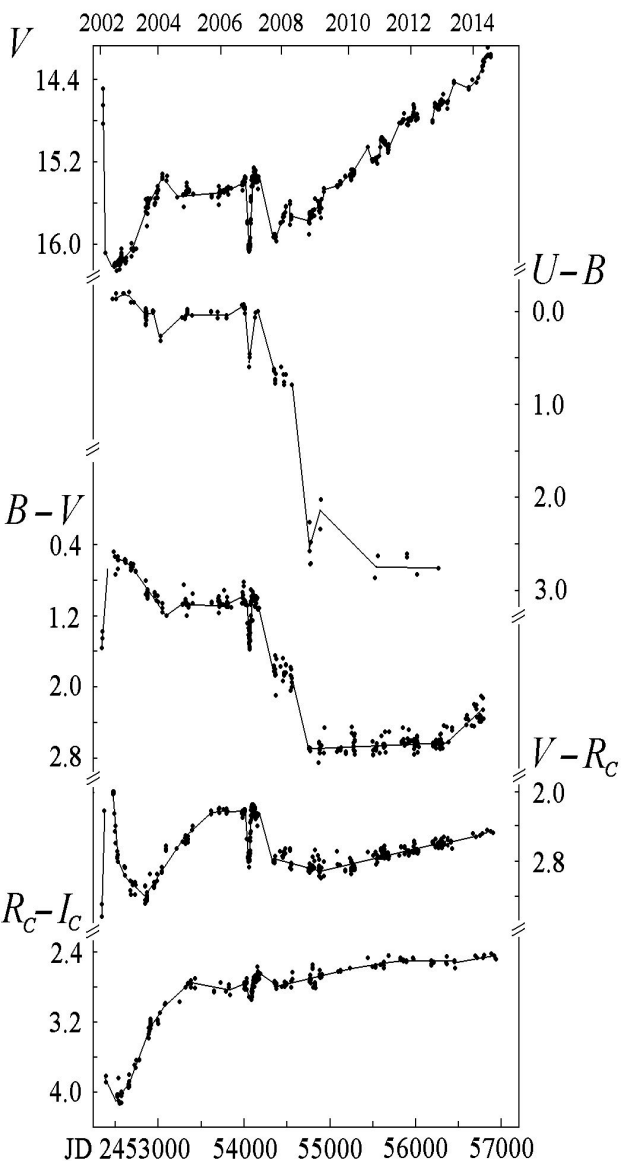
Light curves



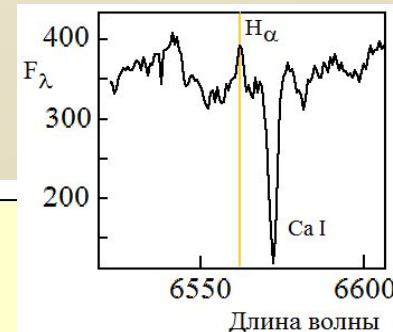
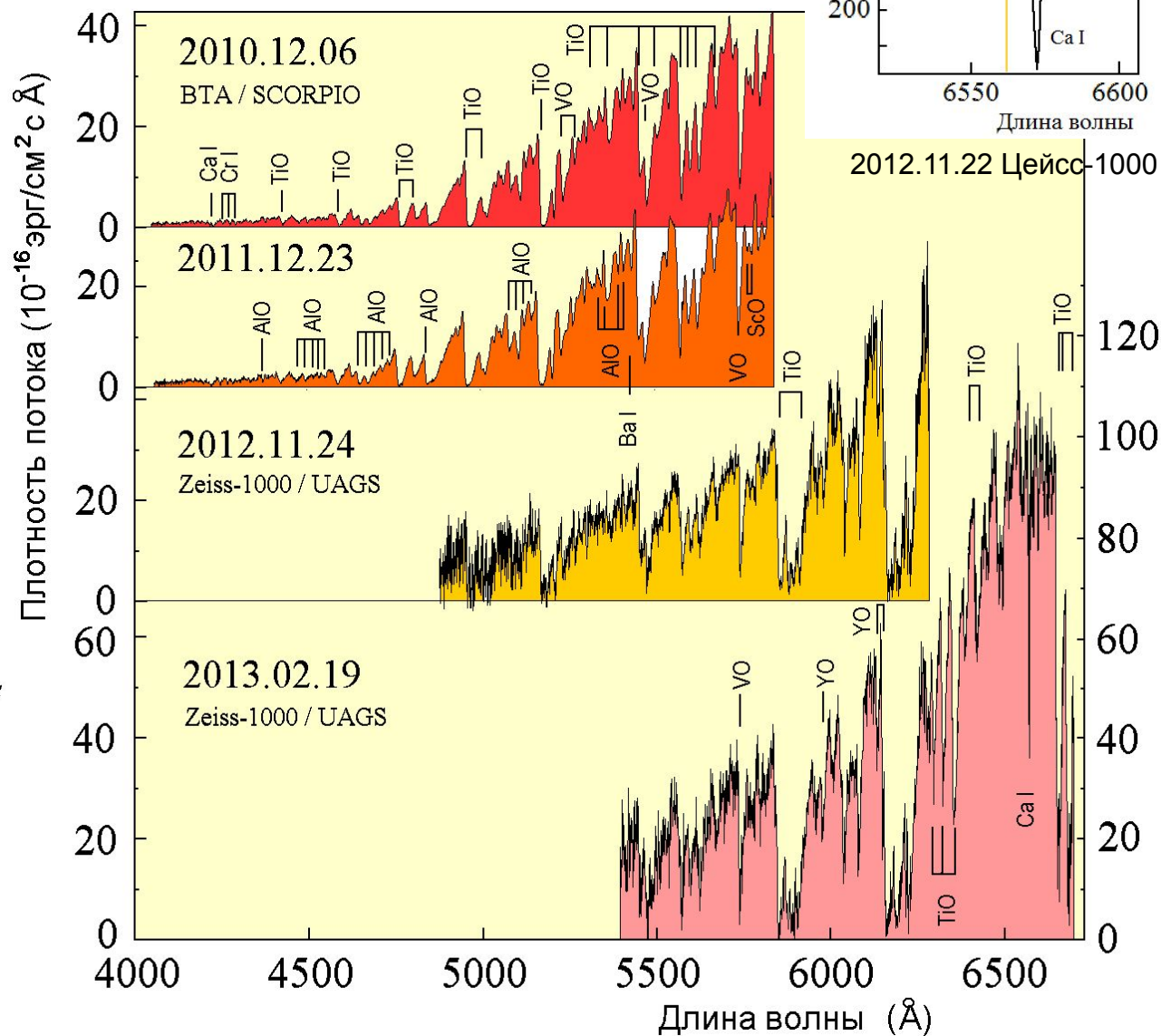
Spectra in 2004 – 2009

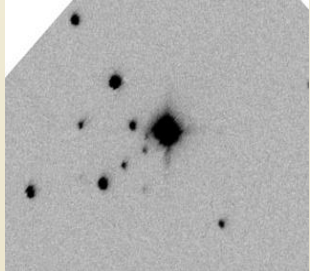
V838 Mon: photometry and spectroscopy

Changes of color indices

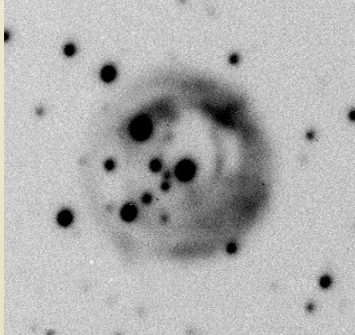


Spectra in 2010 – 2013

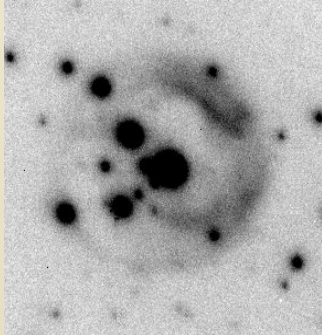




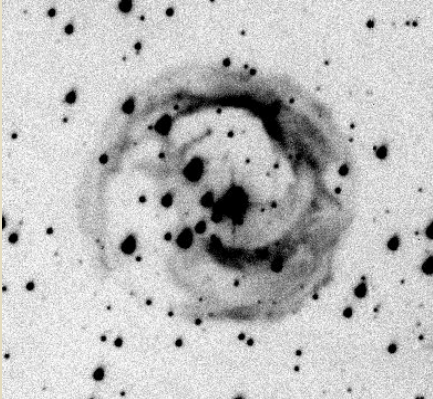
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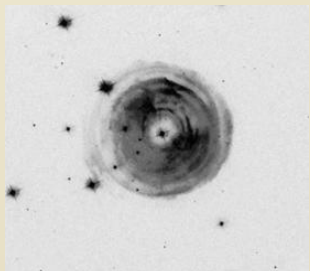
2002.10.10



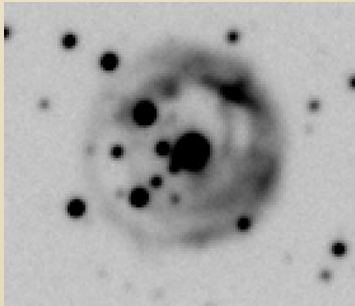
2003.03.28-31 SUM



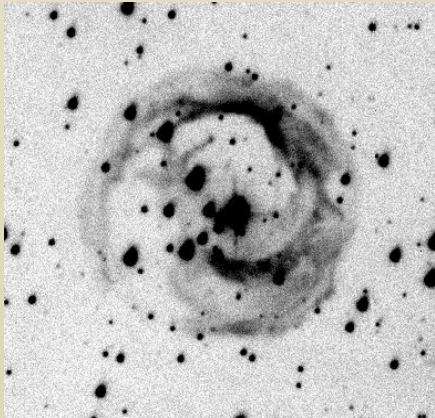
2003.12.22



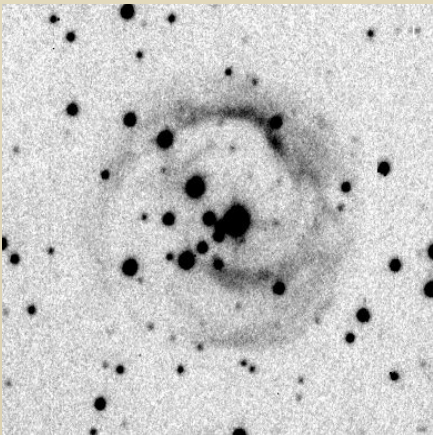
2002.04.30 HST



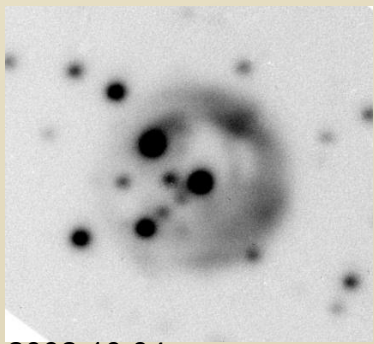
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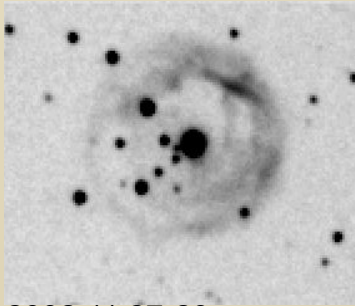
2003.10.01



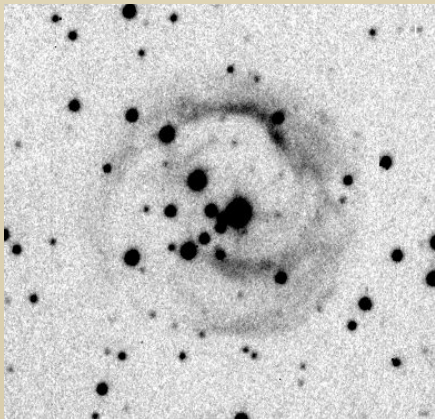
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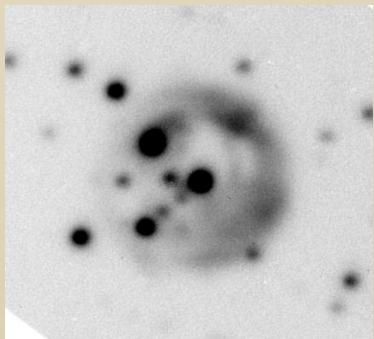
2002.10.04



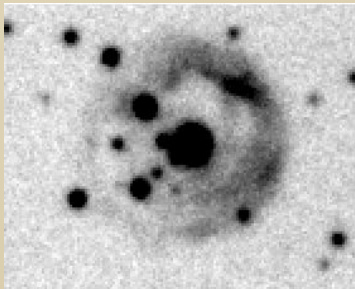
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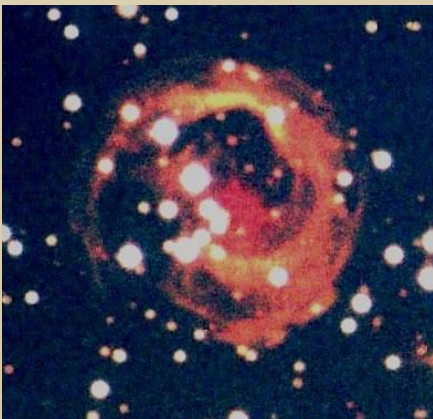
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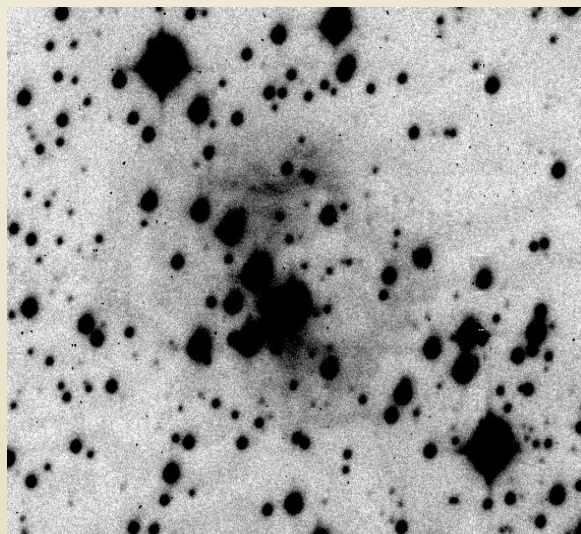
2002.10.08



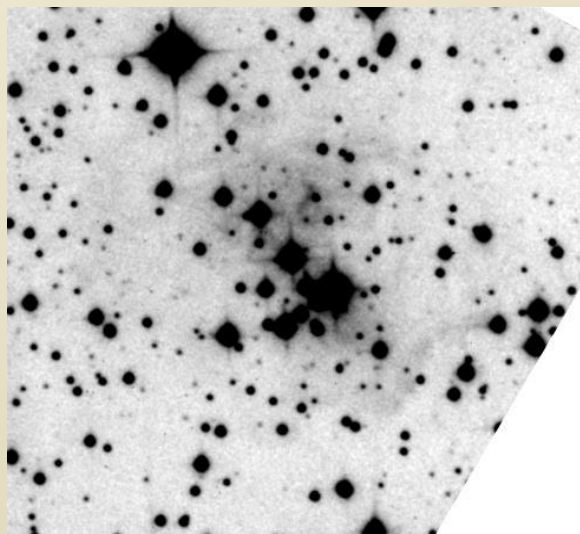
2002.12.07-09 SUM



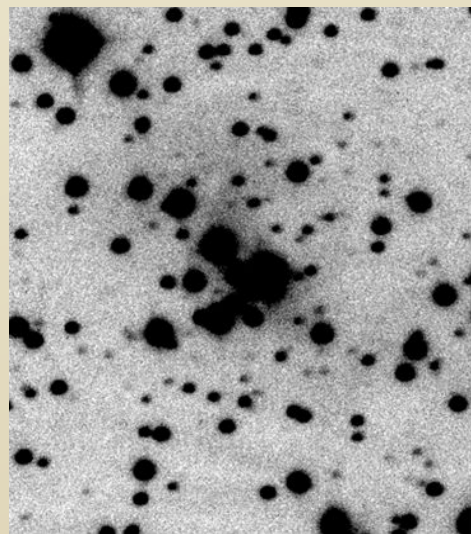
2003.12.30



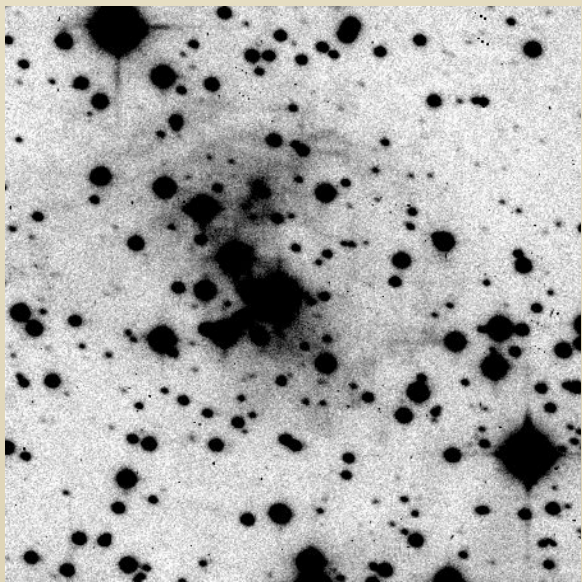
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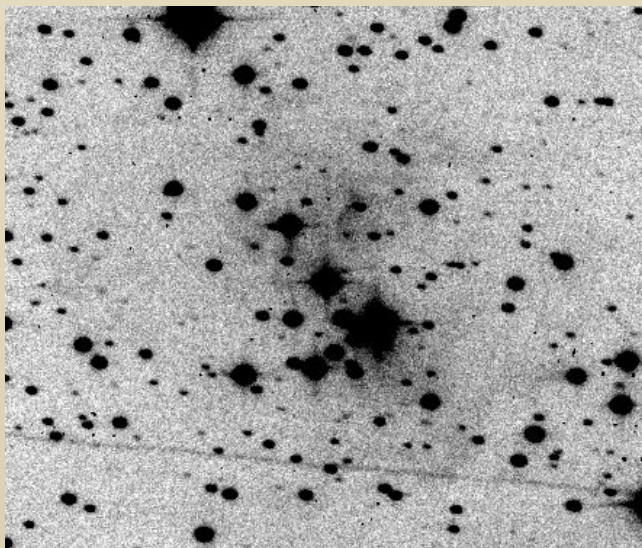
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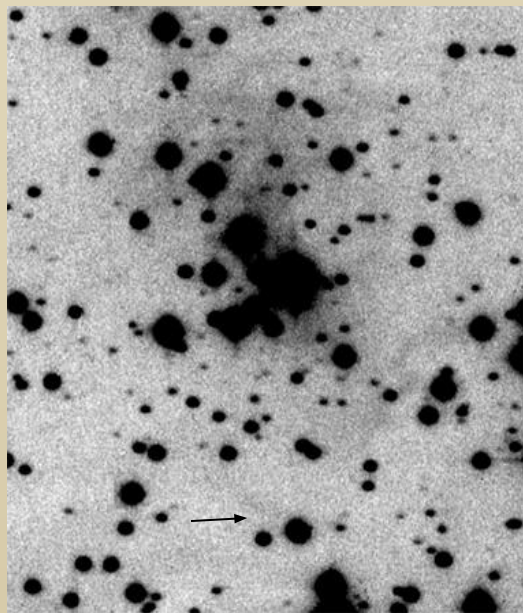
2008.01.02



2006.10.26



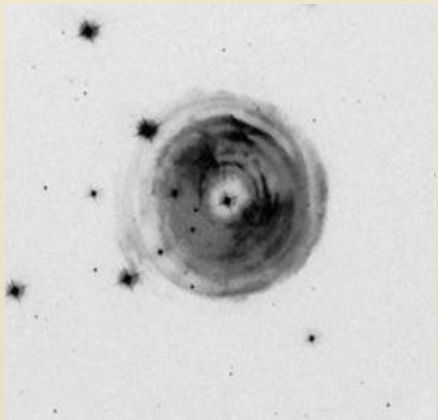
2007.03.21



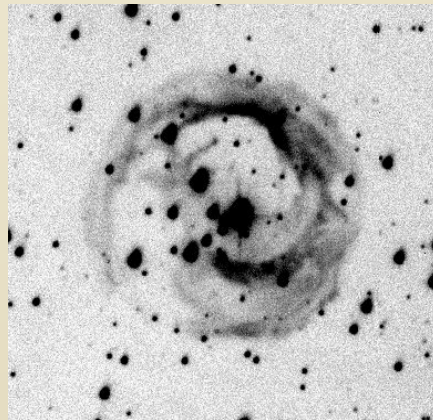
2008.01.12

Cirrus

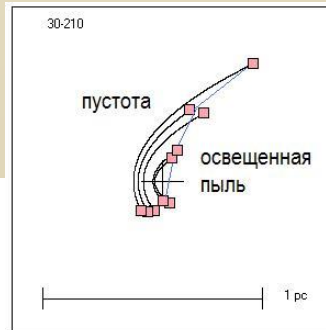
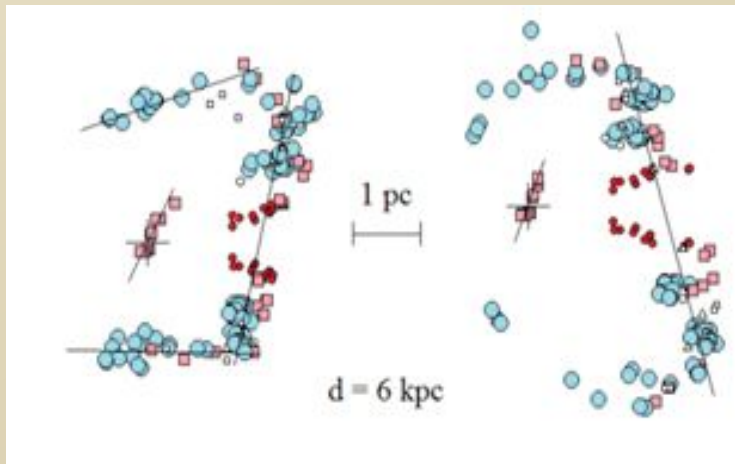
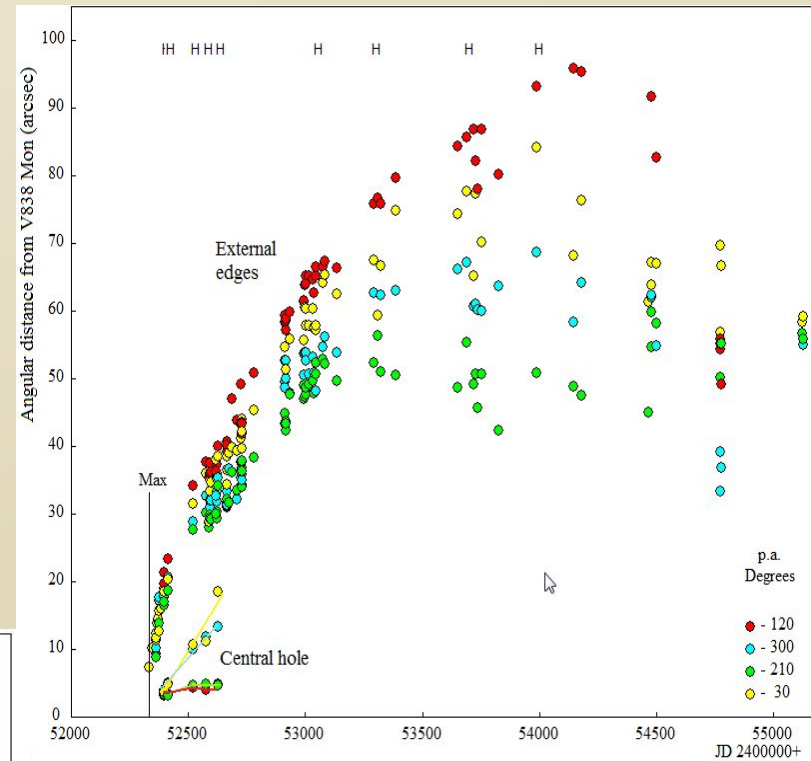
V838 Mon: light echo



2002.04.30 HST



2003.12.22 Zeiss-1000



■ HST
● SAO+SAI
◆ USNO FS
 superluminal part

85
 120-300
 1 pc

Form2

52312.0

JD₀

RUN

6000

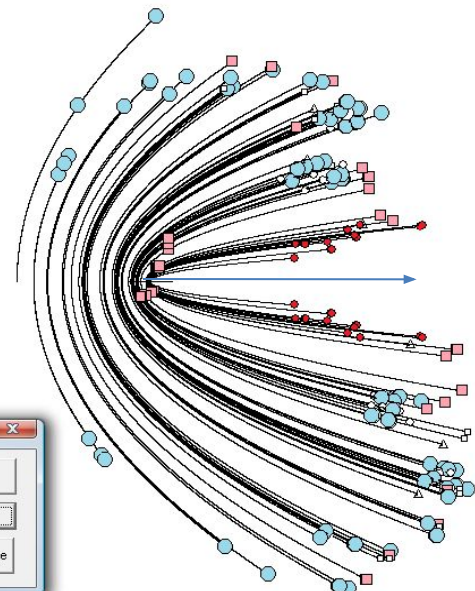
Distance

BF

100

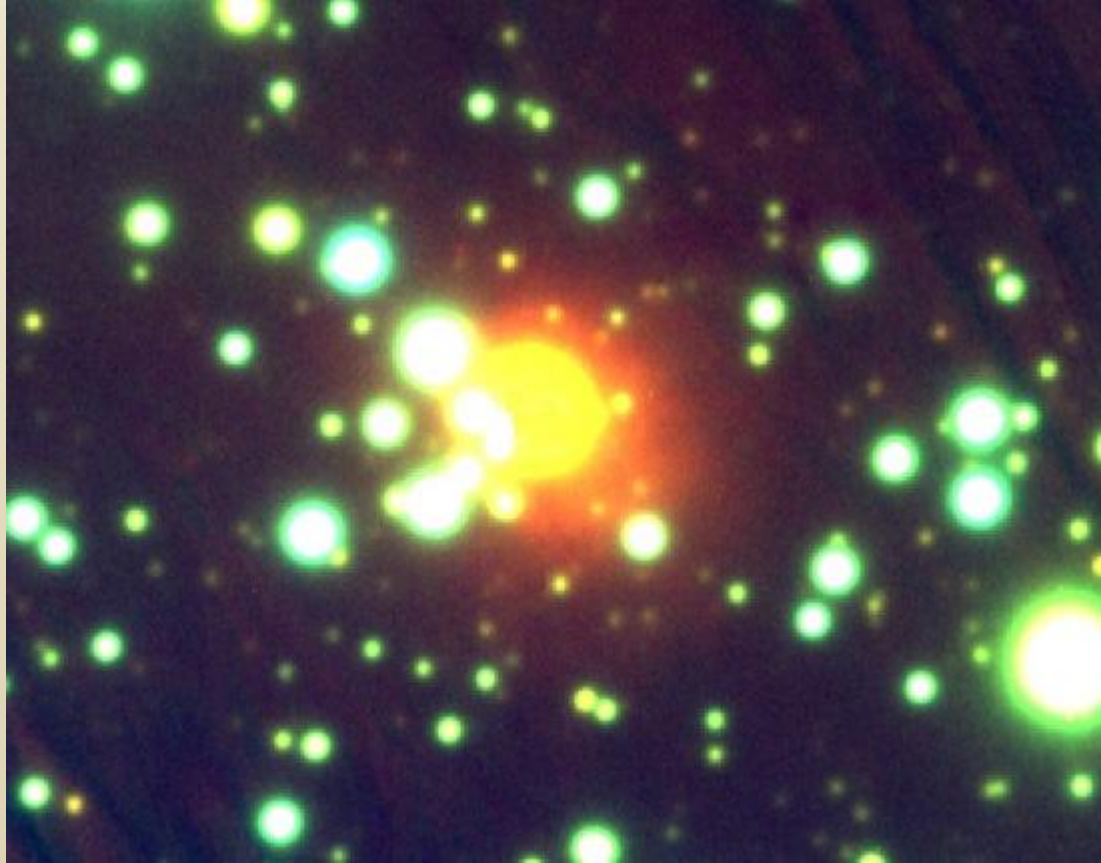
Scale

Trace

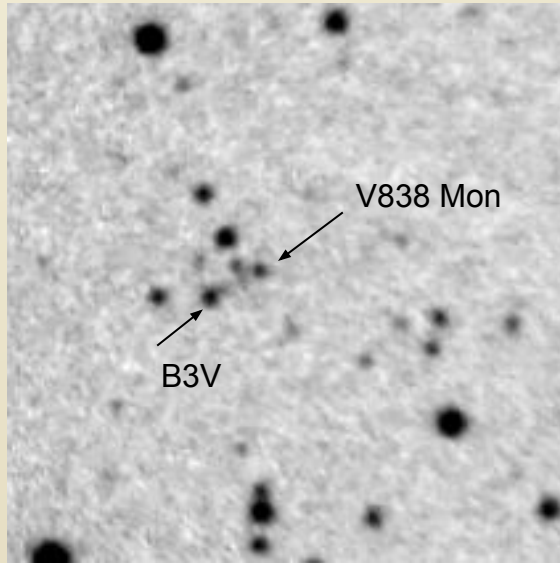


Section of dust nebula in two directions

2015. Light echo of V838 Mon continues in the infrared range. (the image in the I band picked out by red color)

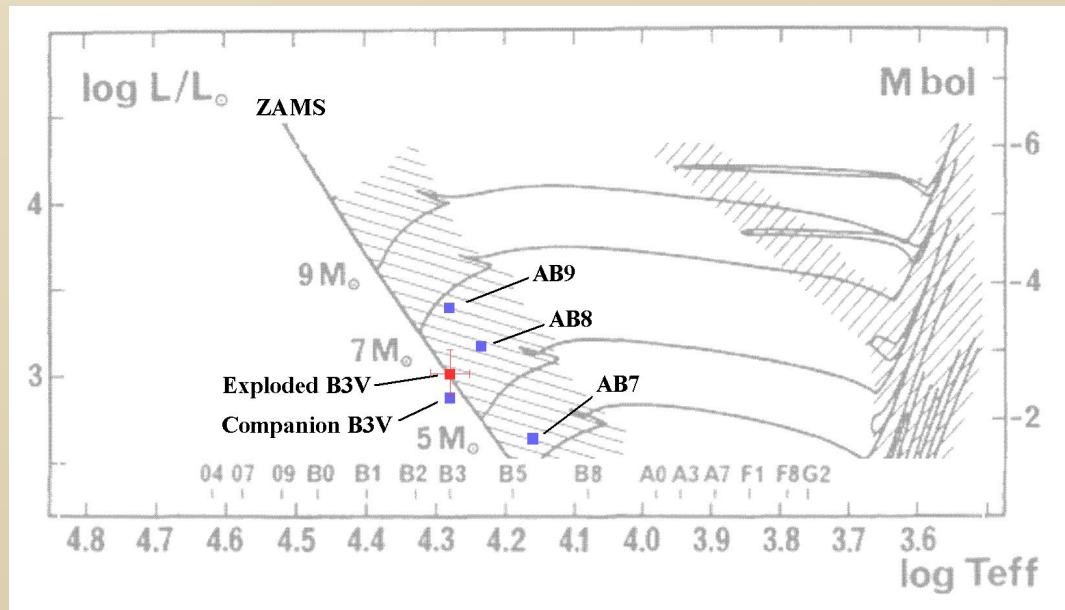
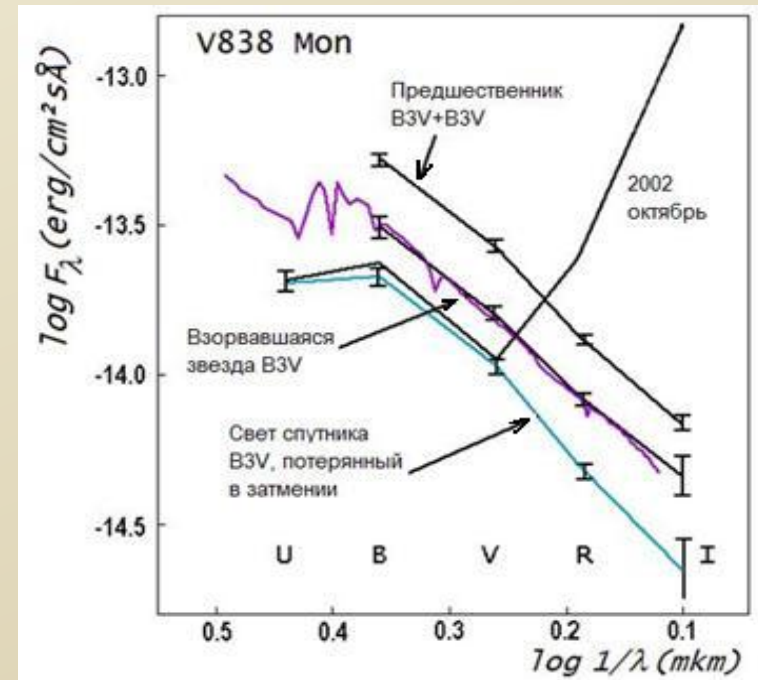


V838 Mon: progenitor and environment



1977.09.21 A3T-5 V

Spectral energy distributions of components



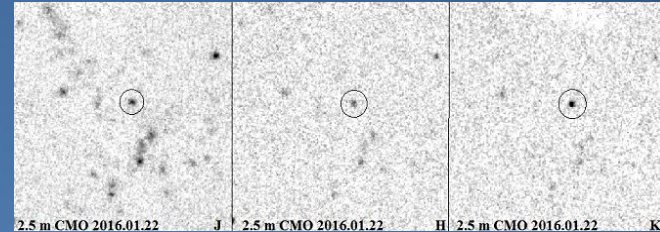
Tracks: Schaller et al. 1992

PSN J14021678+5426205 – светимая красная новая в галактике M101, вторая в 2015 г.: слияние компонентов массивной двойной системы

Барсукова Е.А., Валеев А.Ф., Спиридонова О.И. (САО РАН), Горанский В.П., Возякова О.В., Черясов Д.В., Сафонов Б.С., Шатский Н.И. (ГАИШ МГУ)

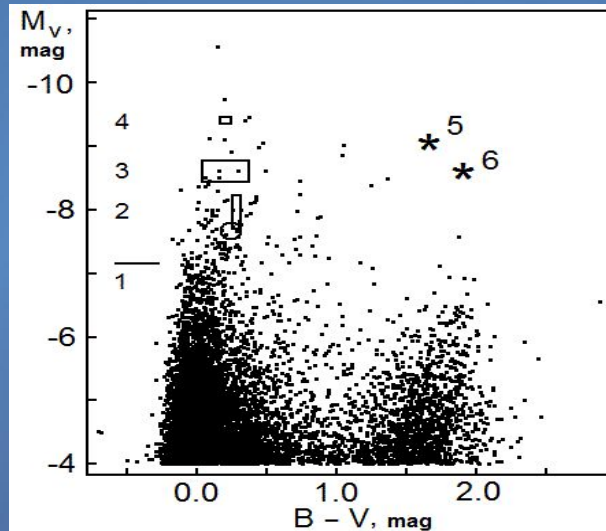
Красный транзиент промежуточной светимости (ILRT). Откр. К.Д. Винтдевара (Румыния). Объект молодого населения, ассоциируется со спиральной ветвью галактики. $M_V = -12.2$ mag в пике вспышки.

Опубликовано: ATeI # 7206, 8599, 8848; *Астрофизический бюллетень* т.71, с.88, 2016.
Работа по ILRT поддержана грантом РФФИ 14-02-00759.

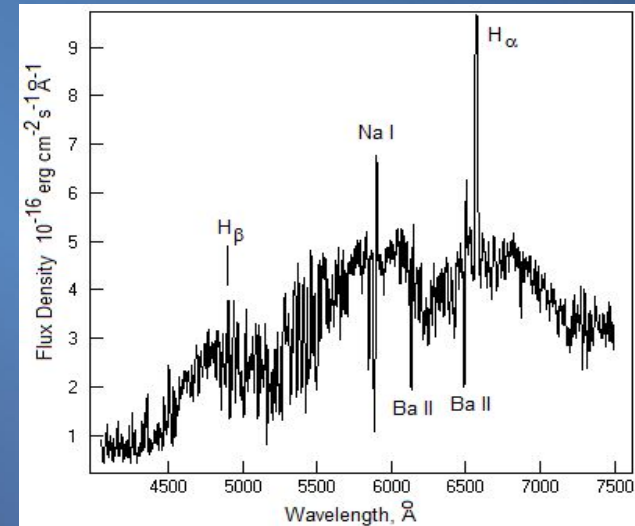


Наблюдения в ИК диапазоне (JHK) остатка – L-сверхгиганта на 2.5 м телескопе КГО ГАИШ.

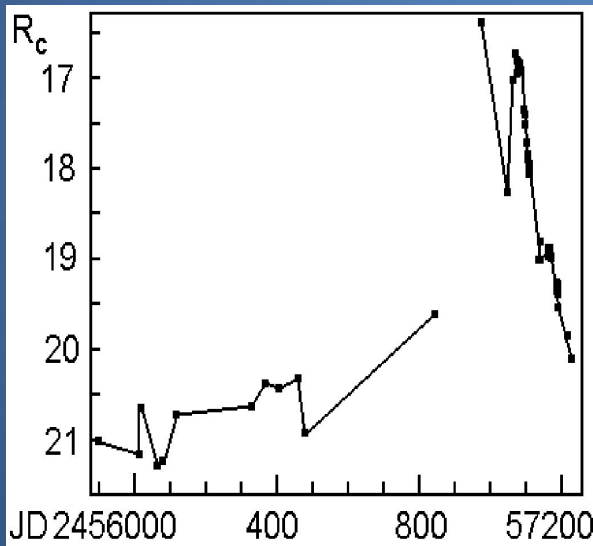
Фото БТА / SCORPIO



Положение предшественника (1-4) и остатка (5,6) красной новой в M101 на диаграмме цвет-светимость. Кругок – сливающаяся система H-альфа19 в галактике M33.



Спектр получен 24 февраля 2015 года на БТА / SCORPIO. Классифицирован по абсорбционным линиям как K0-K5 I. Поглощение в линиях усилено в 4-8 раз по сравнению с нормальными сверхгигантами.



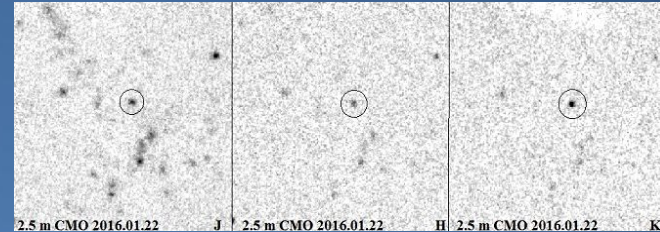
Кривая блеска красной новой 2015 г. в M101 в полосе R.

PSN J14021678+5426205 – светимая красная новая в галактике M101, вторая в 2015 г.: слияние компонентов массивной двойной системы

Барсукова Е.А., Валеев А.Ф., Спиридонова О.И. (САО РАН), Горанский В.П., Возякова О.В., Черясов Д.В., Сафонов Б.С., Шатский Н.И. (ГАИШ МГУ)

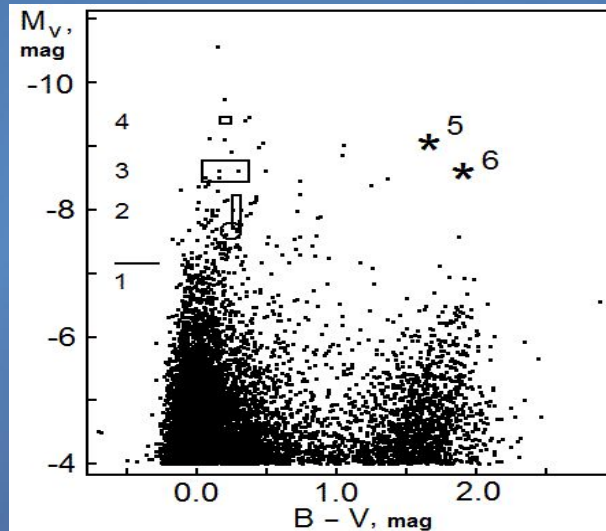
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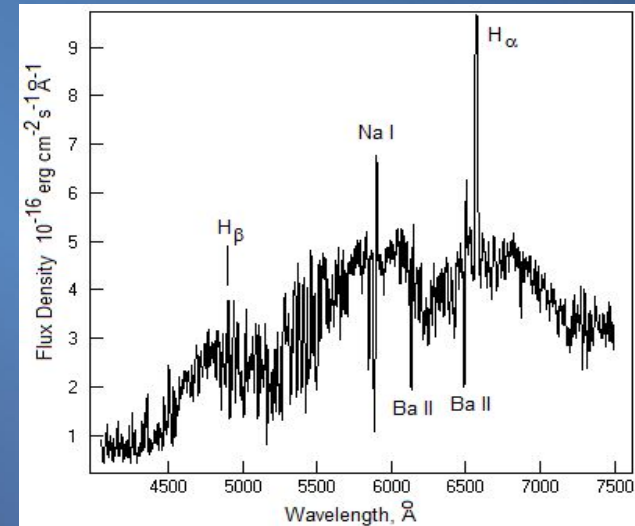


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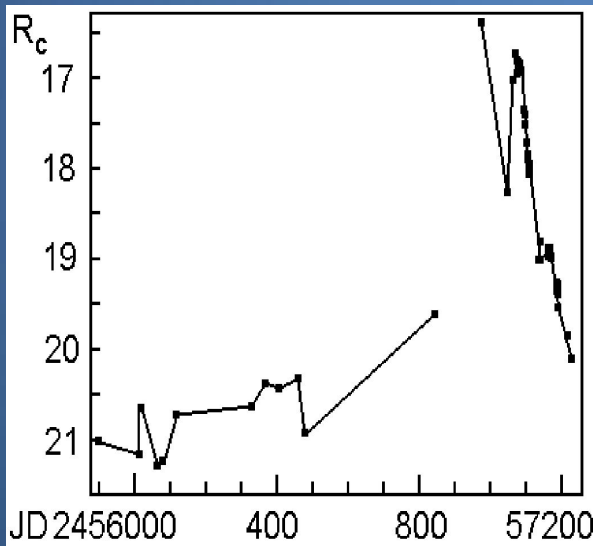
Фото БТА / SCORPIO



Положение предшественника (1-4) и остатка (5,6) красной новой в M101 на диаграмме цвет-светимость. Кругок – сливающаяся система H-альфа19 в галактике M33.



Спектр получен 24 февраля 2015 года на БТА / SCORPIO. Классифицирован по абсорбционным линиям как K0-K5 I. Поглощение в линиях усилено в 4-8 раз по сравнению с нормальными сверхгигантами.

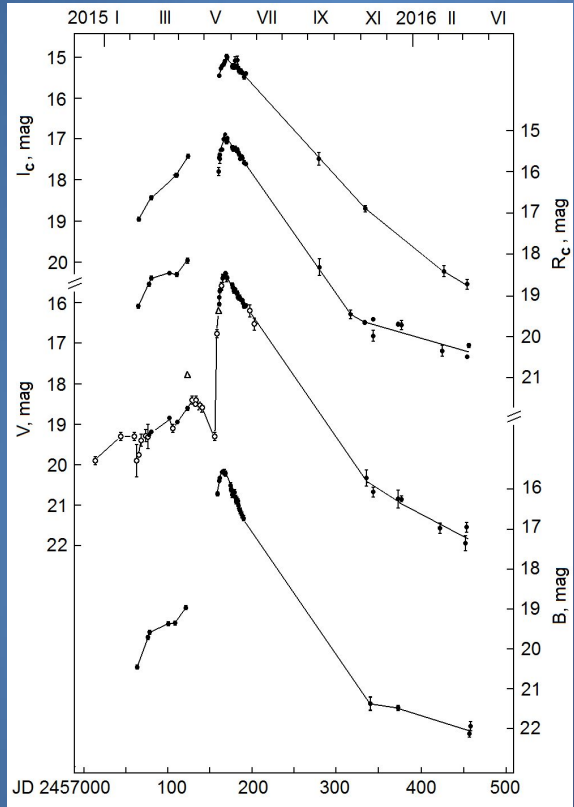


Кривая блеска красной новой 2015 г. в M101 в полосе R.

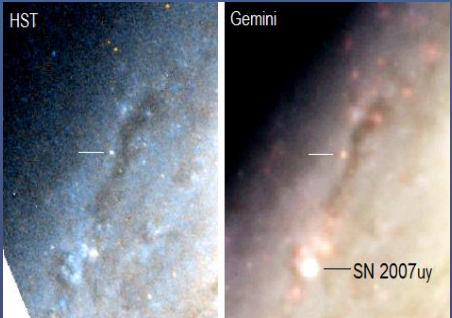
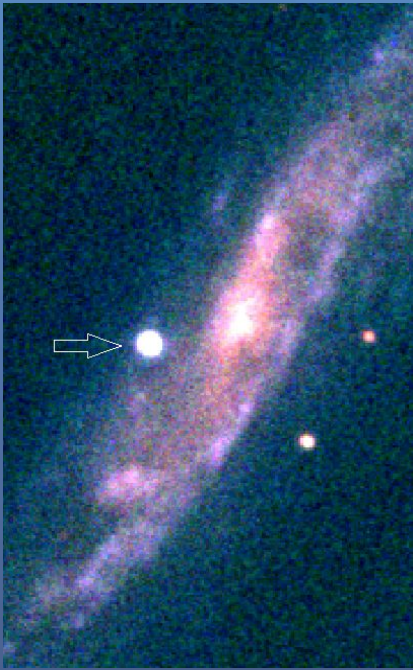
PSN J09096496+3307204 в галактике NGC 2770: взрыв массивной звезды LBV, который привел к коллапсу ее ядра и вспышке Сверхновой

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Объект открыт в Catalina Real-Time Transient Survey & Stan Howerton 2015.02.07. Идентифицирован как импостор SN в работе Elias-Rosa et al, ATel #7042. В пике вспышки SN $M_v = -18.1$ mag.



Кривые блеска в полосах BVRI (снизу – вверх).



Предшественник на снимках КО «Хаббл» и телескопа «Джемини» – звезда типа LBV.

Фото БТА / SCORPIO в фазе Сверхновой

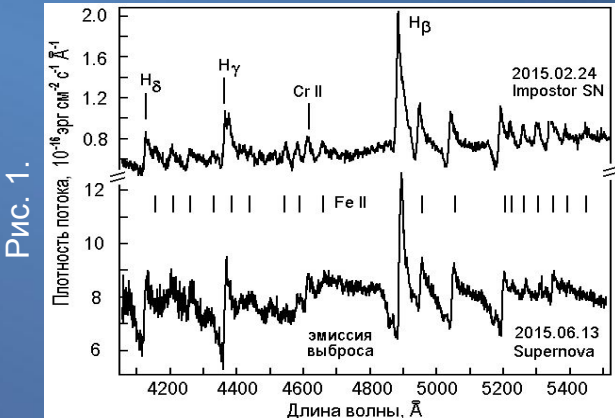


Рис. 1.

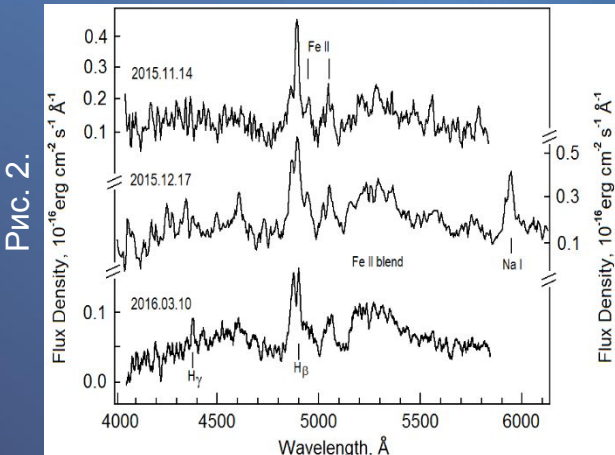


Рис. 2.

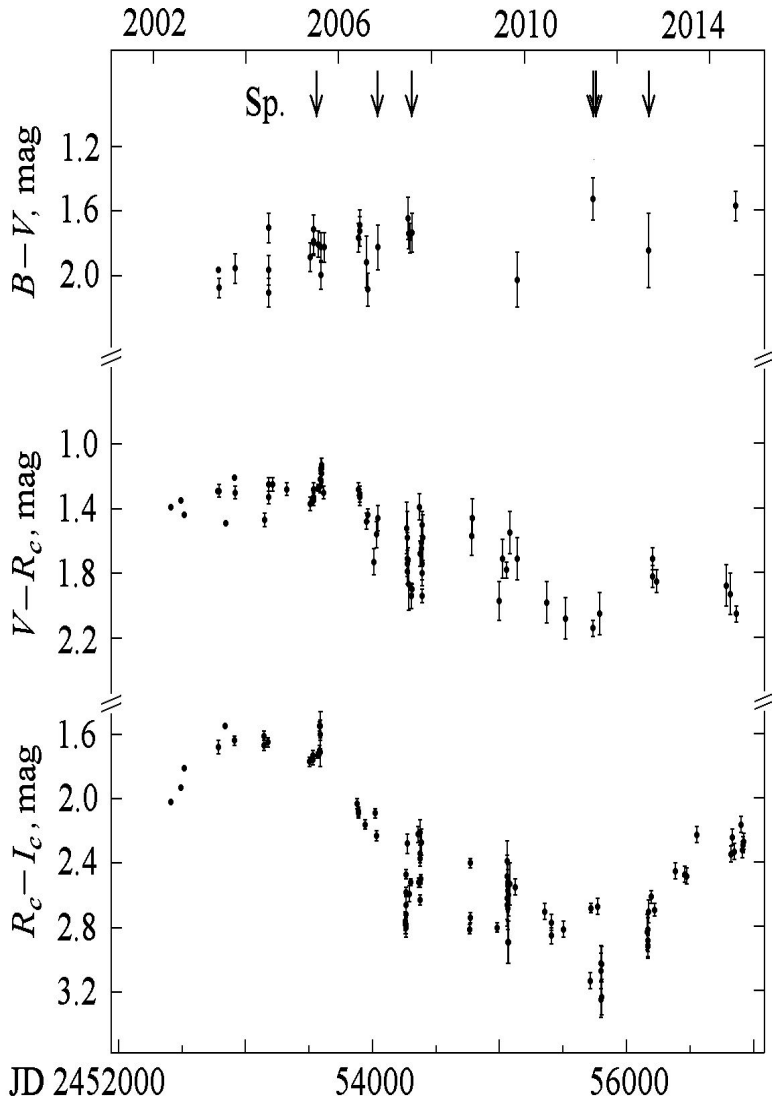
Рис. 1. Фрагменты спектров в фазе импостора (вверху) и в максимуме блеска SN (внизу). Скорость выброса в H β 18000 км/с. Появились вторые компоненты в абсорбционных линиях.

Рис. 2. Спектры на спаде блеска SN.

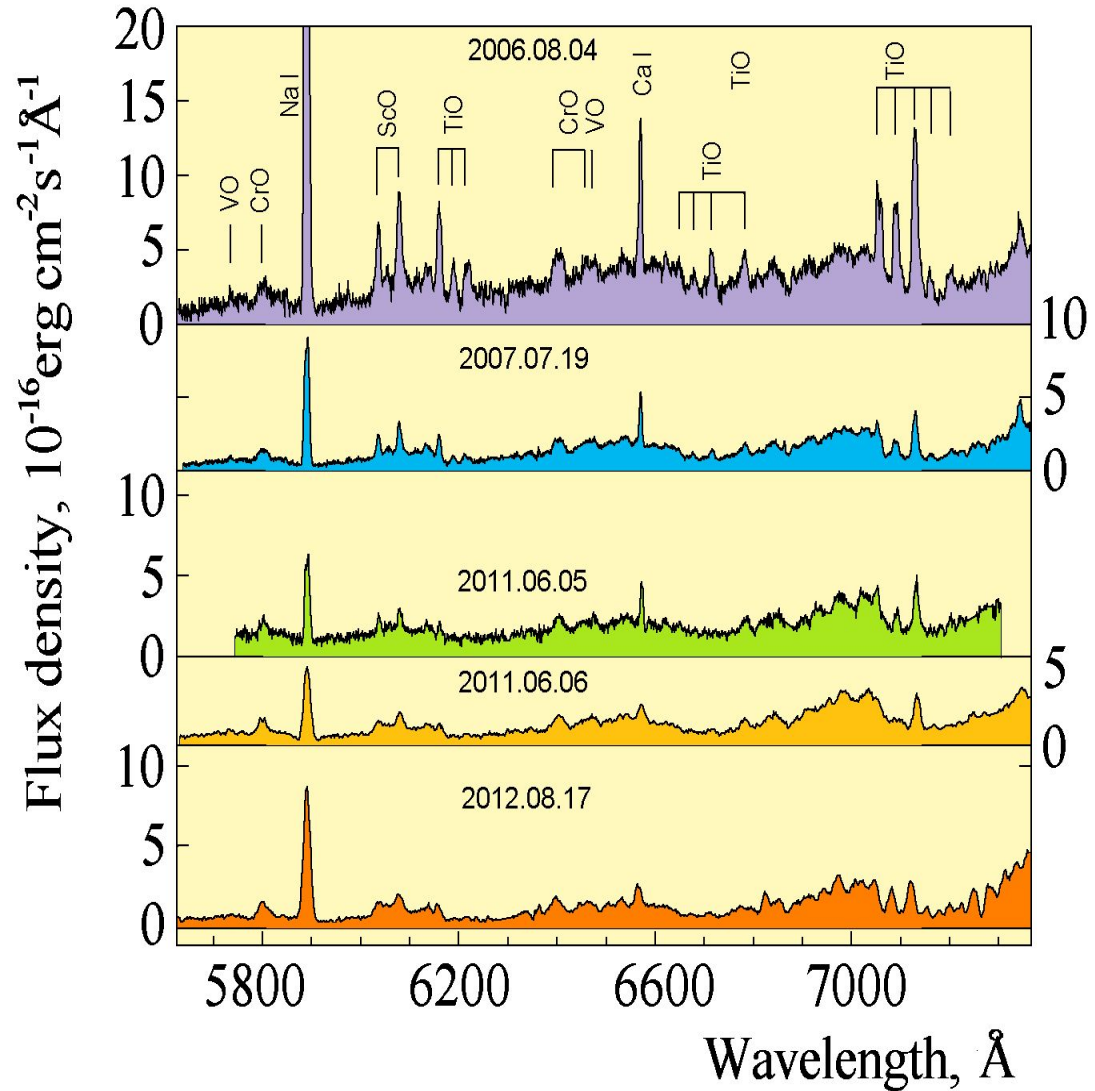
Благодарю за внимание



V4332 Sgr (N Sgr 1994): photometry and spectroscopy after the outburst



Changes of color indices



Spectra of BTA/ SCORPIO in the red range

V4332 Sgr: location in the Galaxy

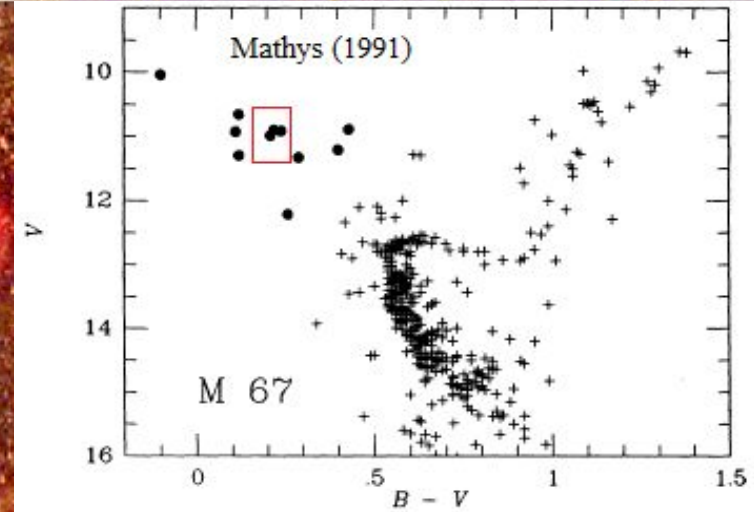


Fig. 1. Colour-magnitude diagram of M 67. The 11 blue stragglers studied in this paper are represented by filled circles