SSS Phase of Classical Novae

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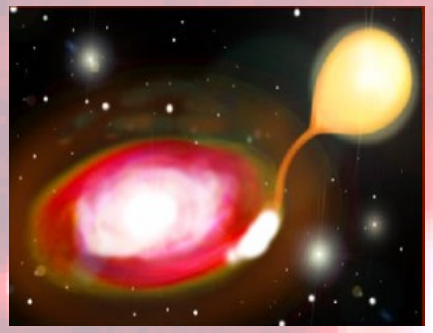


For scientific researches competition of SAO RAN , 2013

Section: Astrophysical Researches

What is SSS?

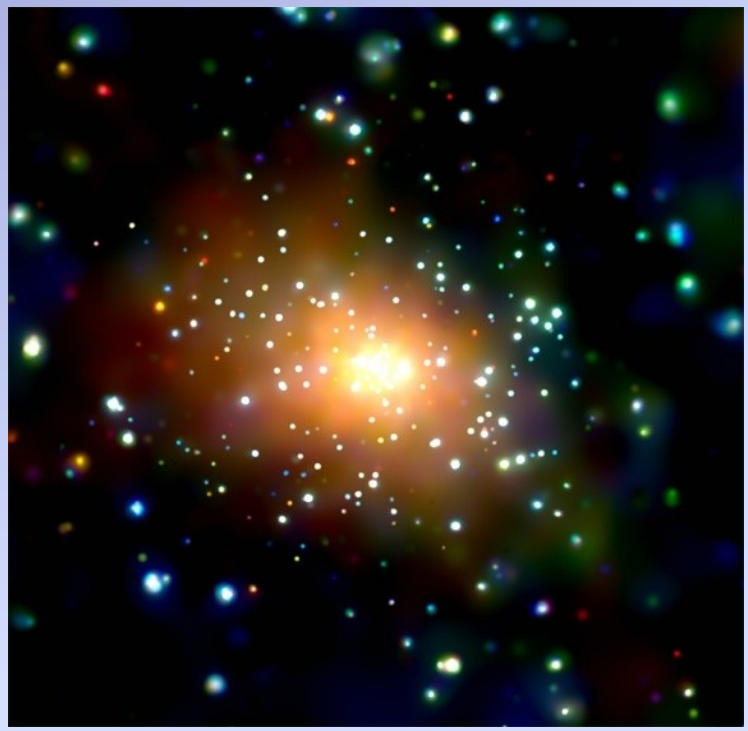
SSS is SuperSoft [X-ray] Source.

They have maximum radiation in the range of 15–100 eV, commonly 30 – 40 eV, luminosity Lx = 10^{36}–10^{38} erg/s.

Examples: CAL 83 and CAL 87 in LMC.

The nature: steady hydrogen burning at the surface of white dwarf in the cataclysmic binary (Kahabka, van den Heuvel, 1997). Probably, the burning is due to the strong magnetic field, and it is about the magnetic pole (debatable).

Approximately, 1/3 of classical novae pass the stage of steady burning on the surface of a white dwarf after the nova outburst.



X-ray image of the centrum of M31 galaxy (Chandra).

The basic content of soft X-ray sources are the remnants of classical novae in the SSS phase.

SSS as an uncovered natural thermonuclear reactor

Thermonuclear runaway of hydrogen on the surface of a white dwarf is a cause of the classical nova outburst.

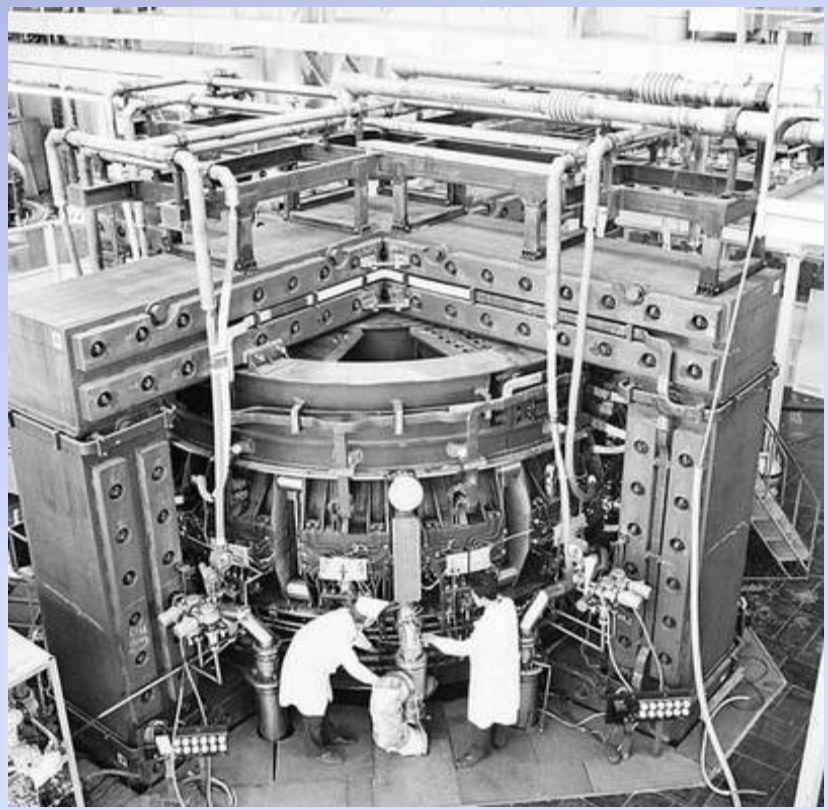
Uncovered thermonuclear burning on the surface continues sometimes after the dispersion of the expanding envelope.

In some novae, burning continues in the steady regime during several dozens of years. Probably, steady SSS are the remnants of ancient classical novae.

The fuel is hydrogen. Perhaps part of impurities CNO as catalysts.

Temperatures are 300–600 thousands K.

Mechanism? Maybe compression and plasma confinement in a magnetic trap in a magnetic pole of a white dwarf .



Thermonuclear reactor tokamak of Kurchatov Institute

Fuel: deuterium + tritium.
Working temperature: 10 millon K.
Mechanism: toroidal magnetic system for plasma confinement.

Observations of classical novae passing SSS phase.

Zeiss-1000 of SAO RAS

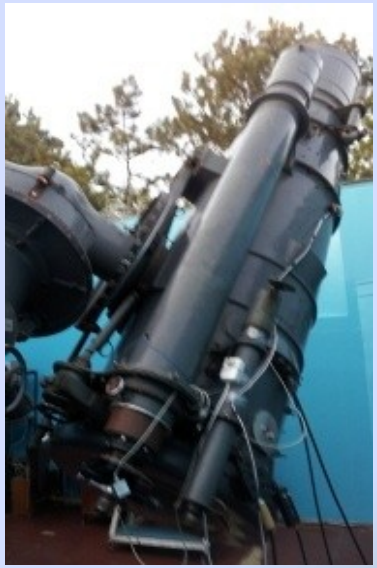
Spectroscopy:
BTA/UAGS and BTA/SCORPIO, classical novae were reserve objects in different observational programs.

Zeiss-1000 / UAGS

6-m telescope BTA

Multicolor photometry using CCD and UBV(RI)$_C$-photometer Zeiss-1000

Multicolor photometry using CCD and UBVR$_C$(RI)$_J$ –photometers, and **monitoring** with the time resolution of 2 min with 60-cm Zeiss telescope and 50-cm Maksutov AZT-5 telescope of SAI Crimean Station.

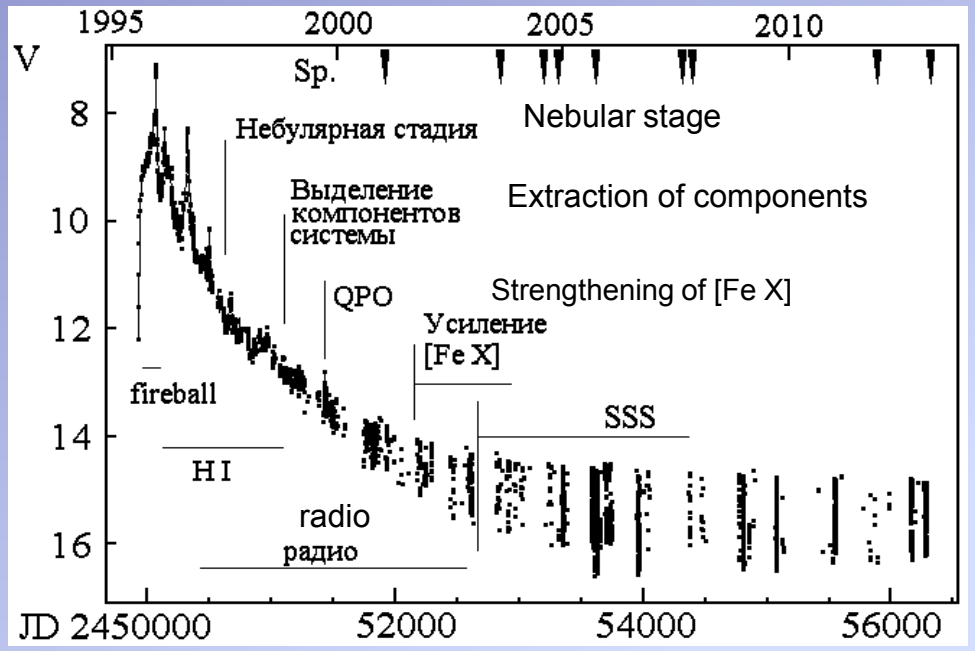


AZT-5

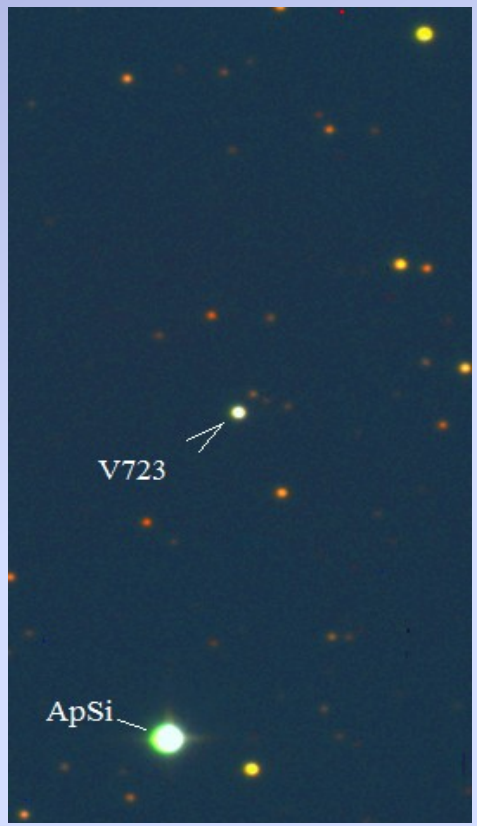
SAI Zeiss-600

V723 Cas (1995). Photometry.

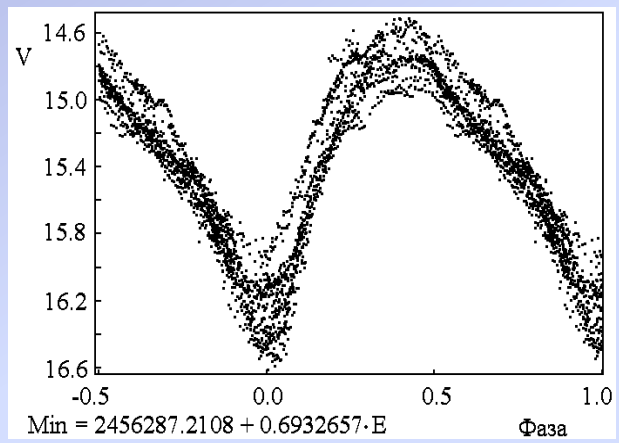
Spectral class FeII, P = $0^d.69327$. The star is observes in the SSS phase during 10 years till now.

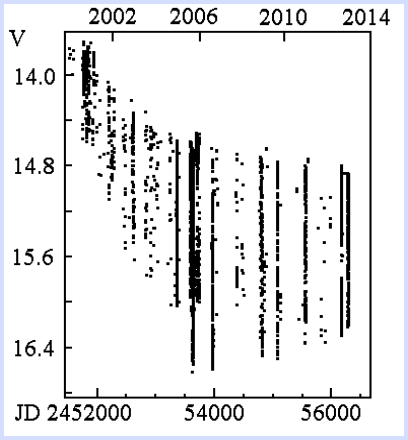


Light curve (based on SAO and SAI data)

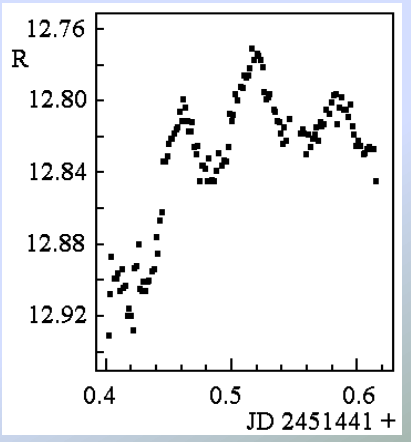


Zeiss-1000, 2012





Phase light curve (2005-2012) and its amplitude evolution



QPO

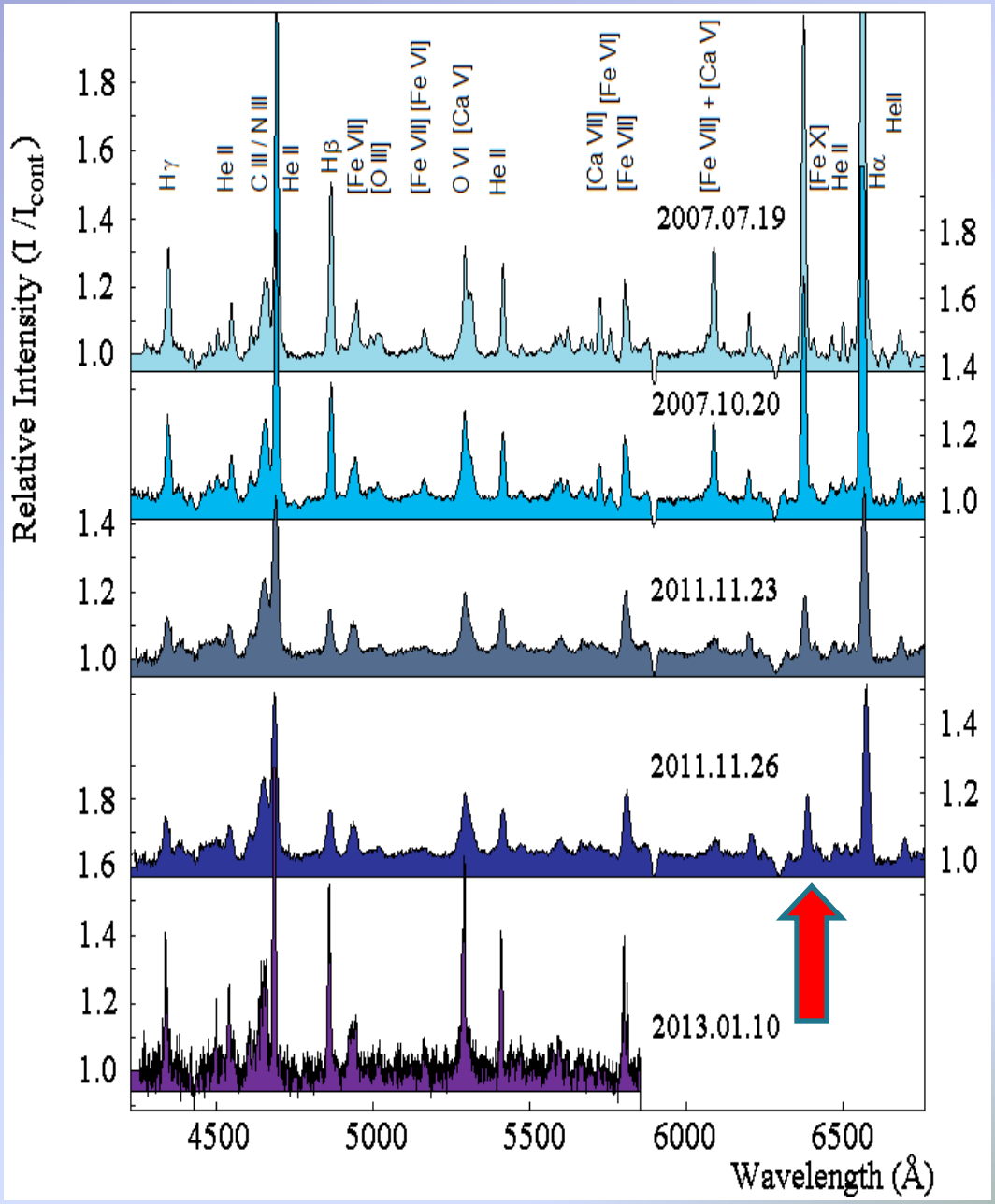
V723 Cas Spectroscopy

The coronal lines of [Fe VII], [Fe X], [Ca VI], emissions of O VI и He II 4686 Å appeared and strengthened in the SSS phase.

Line [Fe X] is the third intense after Hα and He II 4686 Å (red arrow).

Temperatures determined by us using the relation of He II and Hβ line fluxes were coincident with X-ray data.

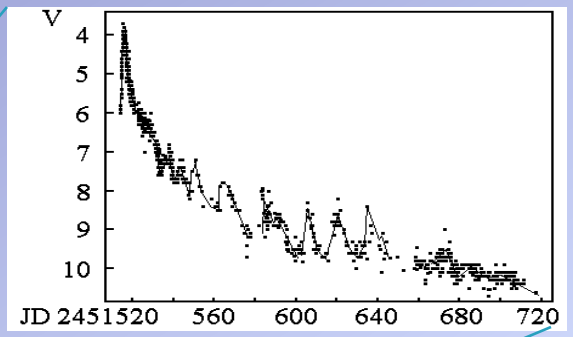
We observed growth of SSS temperature from 195000 to 340000 K for three years .

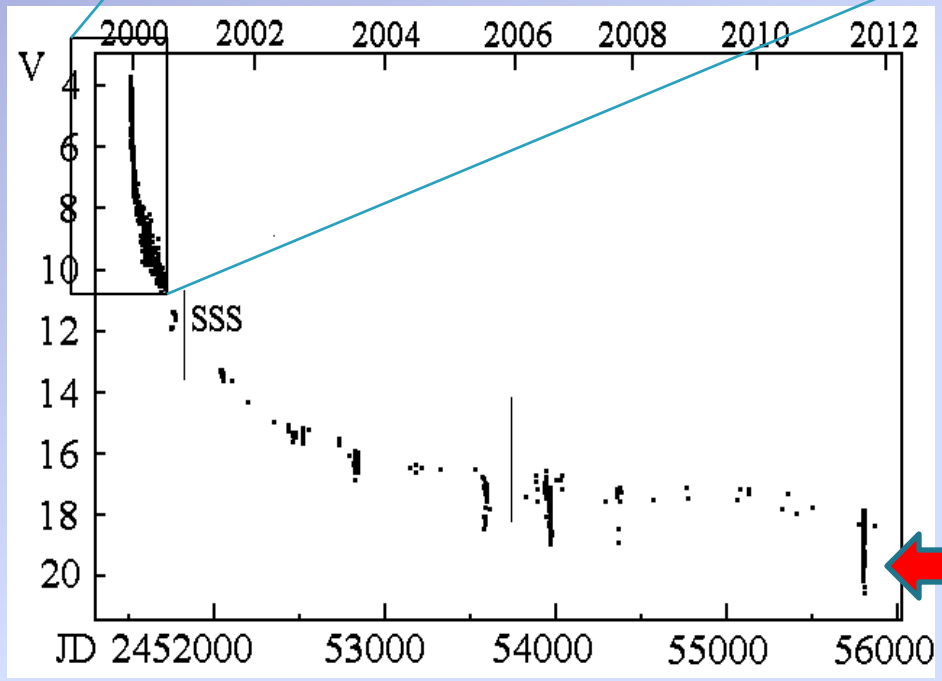


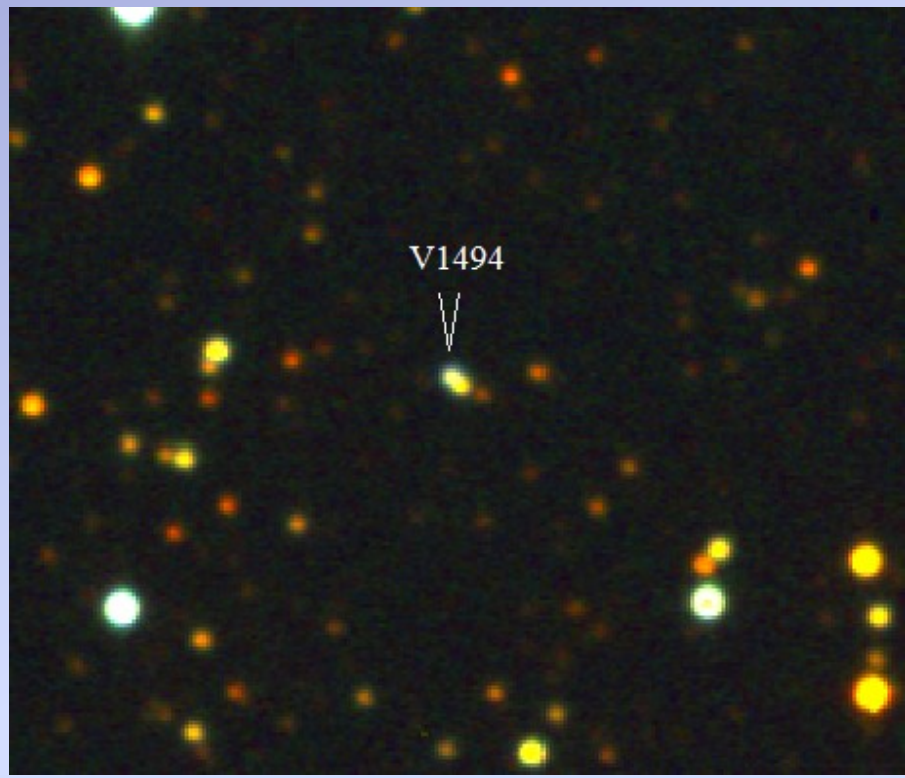
The last spectra of BTA/SCORPIO (normalized)

V1494 Aql (1999 No.2)

Spectral class Fe II, eclipsing system,
$P_{orb} = 0^d.1346141$







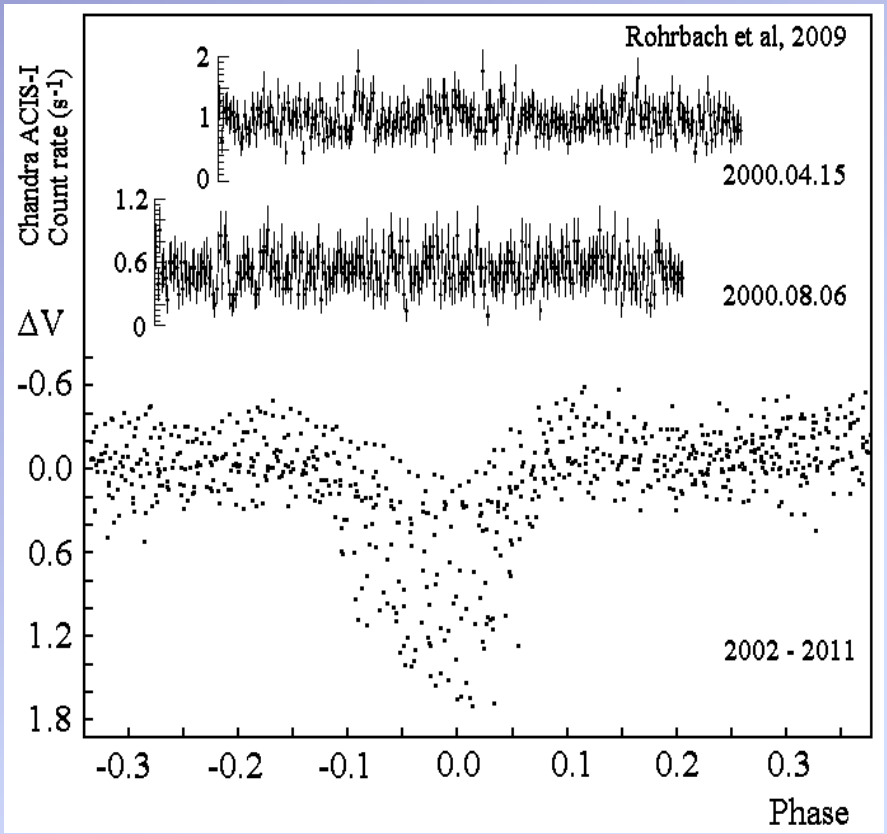
Цейсс-1000 САО РАН, 2012 год

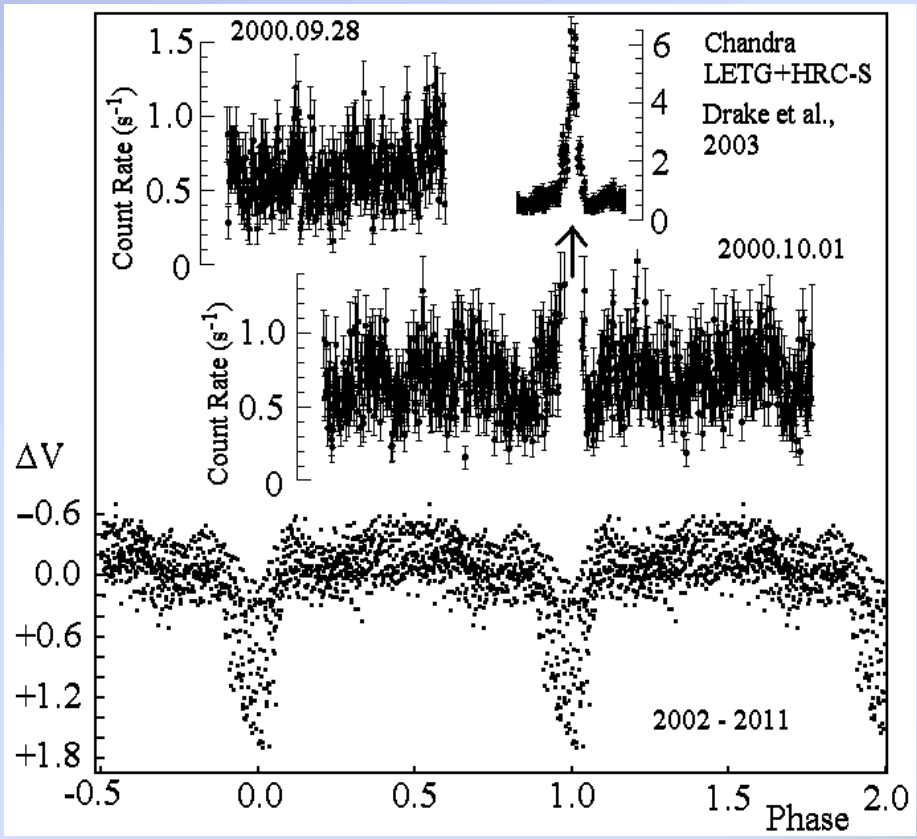
Recurrent flaring at the light decay is an evidence of the strong magnetic field of the white dwarf. The magnetic field of the white dwarf is responsible of the accumulation of mass in the accretion disk and its repeating falling on the white dwarf surface.

The light curve of the outburst. Eclipses are visible (red arrow).

V1494 Aql
Comparison of optical observations with the Chandra X-ray data

We improved the orbital elements: Min I = 2455803.4005 + 0^d.1346161 E



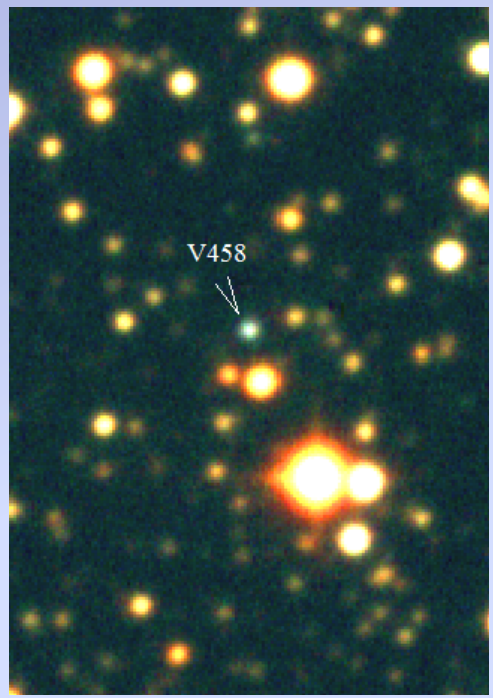


Eclipses are absent in the soft X-rays.

The only X-ray flash came in eclipse. These observations raise doubts on the hypothesis (Kahabka and van den Heuvel, 1997) that the soft X-ray source is located on the surface of a white dwarf.

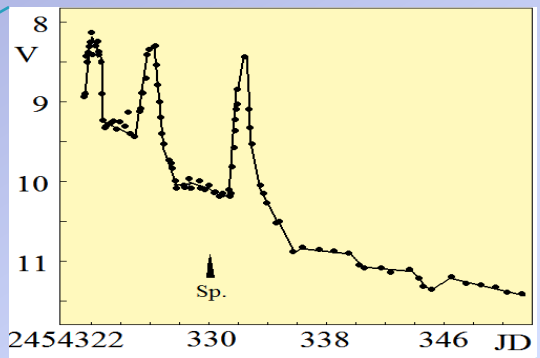
V458 Vul (2007)

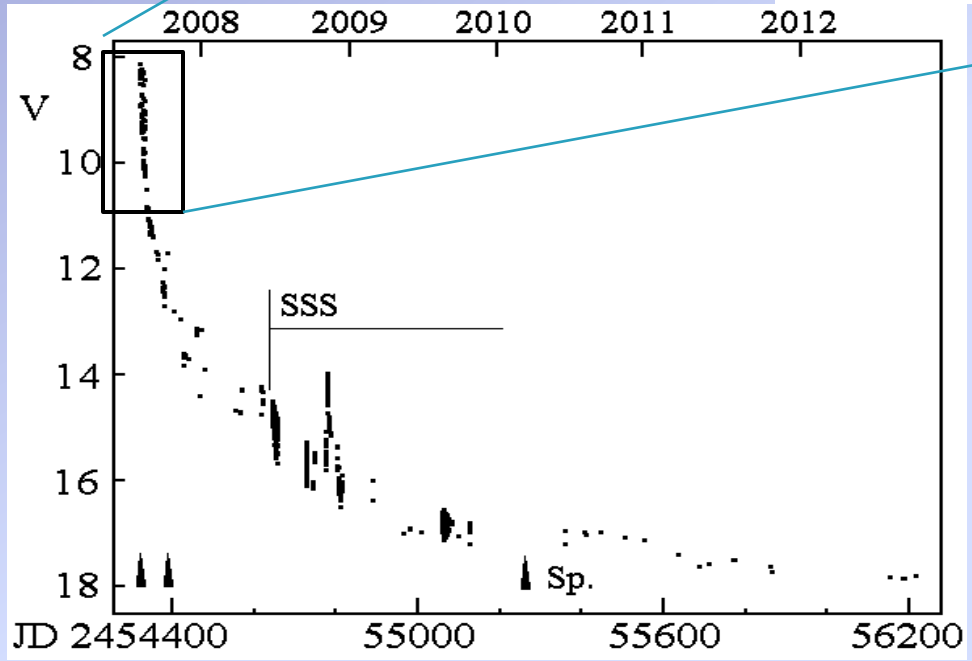
Unique nova changing spectral class from Fe II to He/N. Hybrid nova. $P_{orb} = 0^d.06812255$ (Rodrigues-Gil et al., 2010) is found using Doppler shift of the HeII 4686 Å line. In the center of a planetary nebula.



Zeiss-1000, 2012

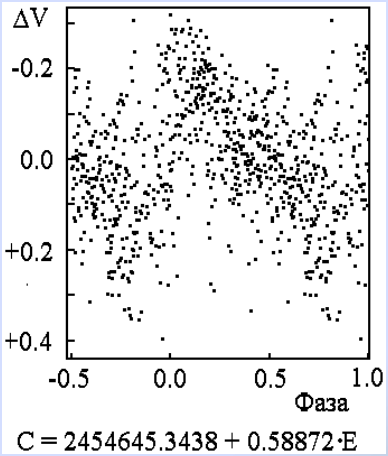
Photometry



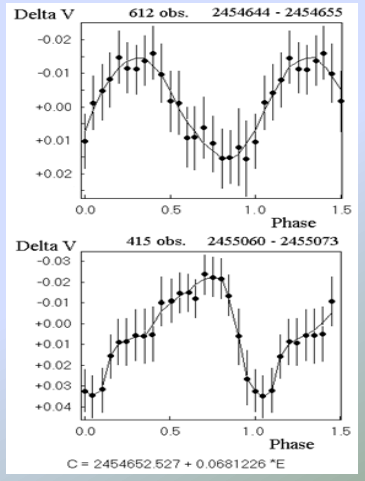


The outburst light curve

Periodic variability in the SSS phase



Orbital variability

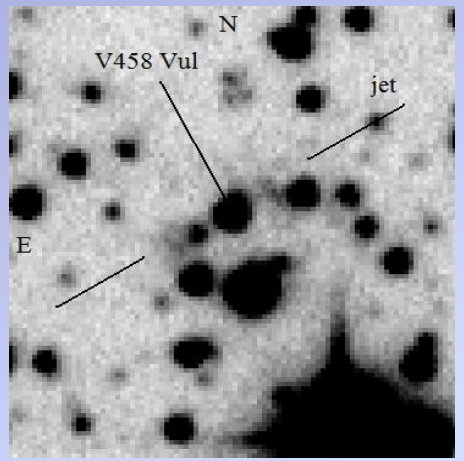


V458 Vul

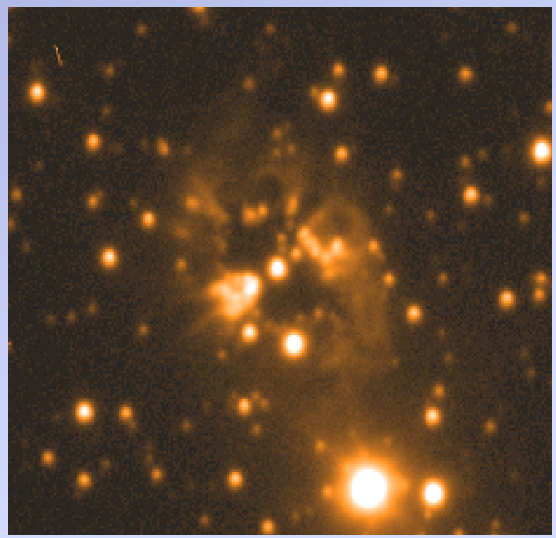
Planetary nebula, polar jets and light echo

The outburst of a nova in the center of planetary nebula is an unique phenomenon.

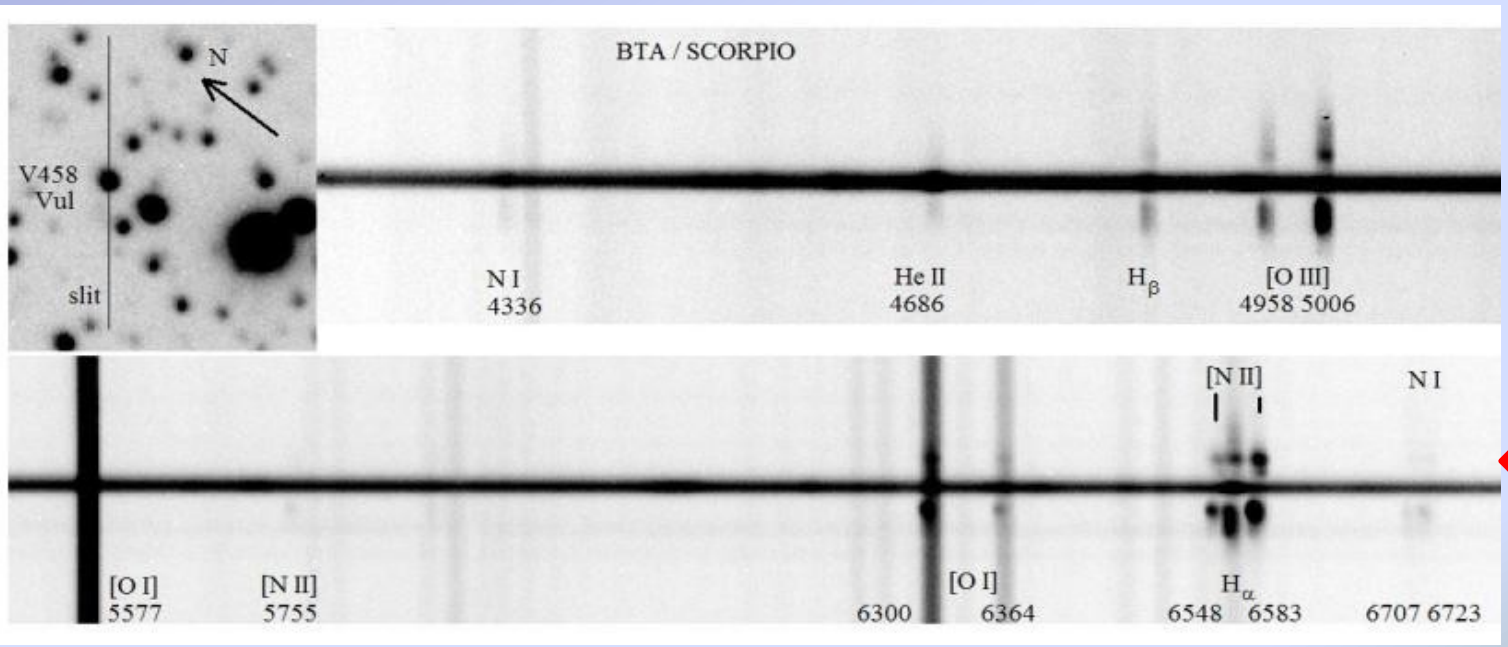
Nebula was formed as a result of ejection of the shell with the secondary component of the system and its entry into the evolutionary stage of the post-AGB.



Zeiss-1000, 2010



IPHAS Hα survey



Velocity of jet motion is70 km/s

Light echo

V458 Vul. Spectroscopy.

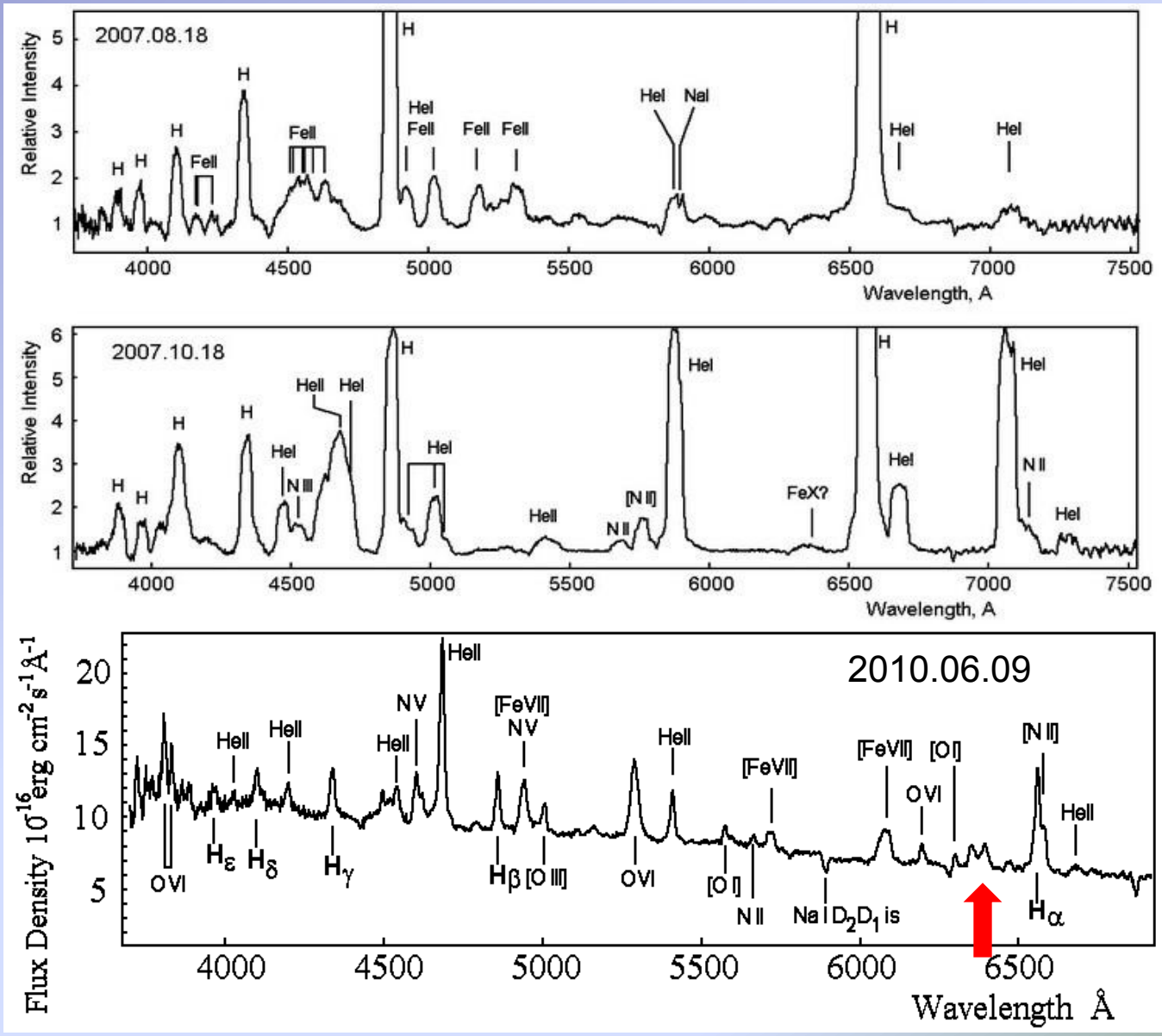
Spectral class change is seen in the spectra of Zeiss-1000

Here FeII lines predominate.

FeII lines disappeared, and He I with N lines appeared or strengthened.

Hybrid nova spectrum in SSS phase. There are [FeVII] lines, and additional [N II], N V, [O III], O VI lines.

Strange double-peak structure in [FeX] (red arrow)



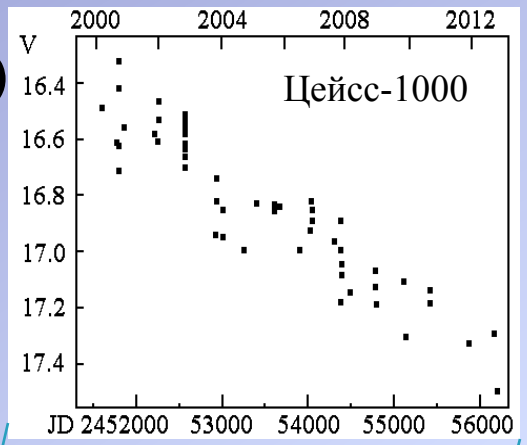
Based on flux ratio Hβ /He II, T = 500000 K.

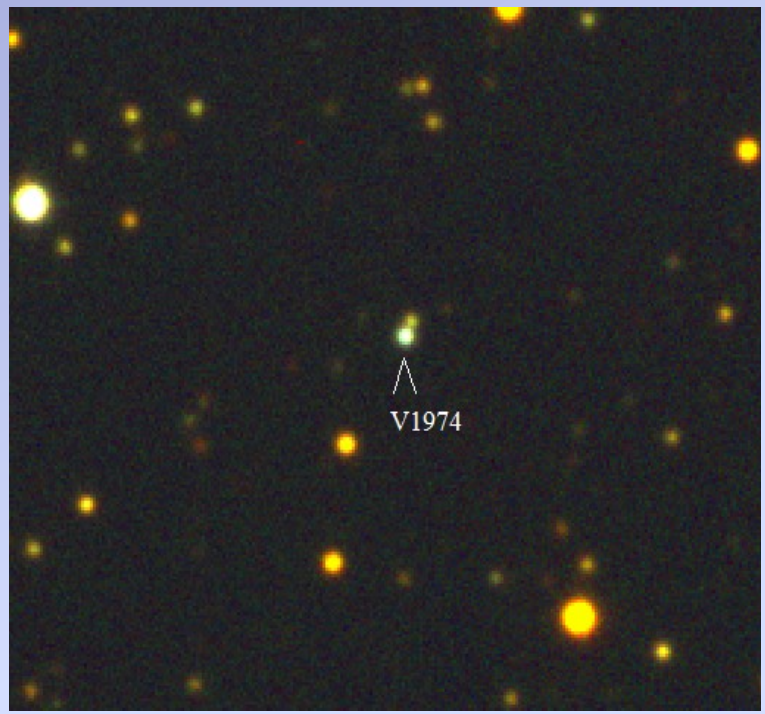
V1974 Cyg (1992)

O-Ne-Mg class nova. It was the first nova with SSS phase discovered.

$P2 = 0^d.08126$ (orb)

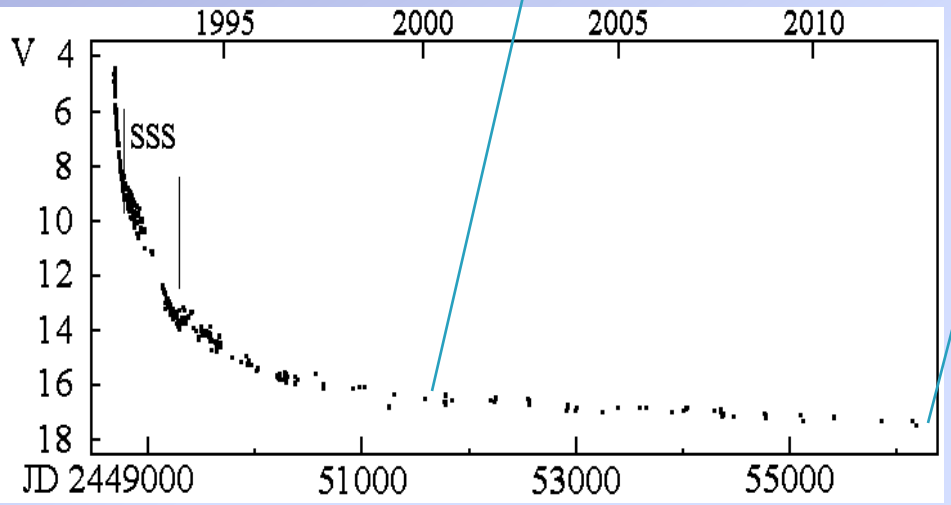
$P1 = 0^d.08521$ (sh)



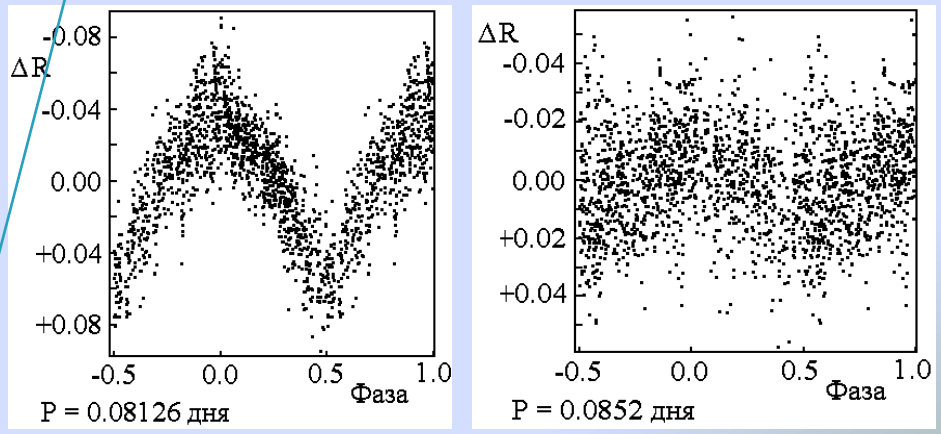


Zeiss-1000, 2012

Photometry



The outburst light curve

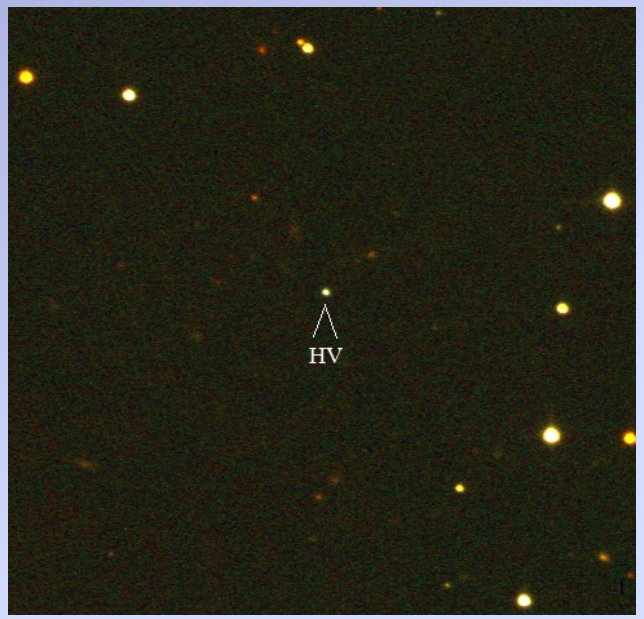


Periodic components in the SSS phase. The period given in the right figure is observed in the residuals of the mean light curve (left).

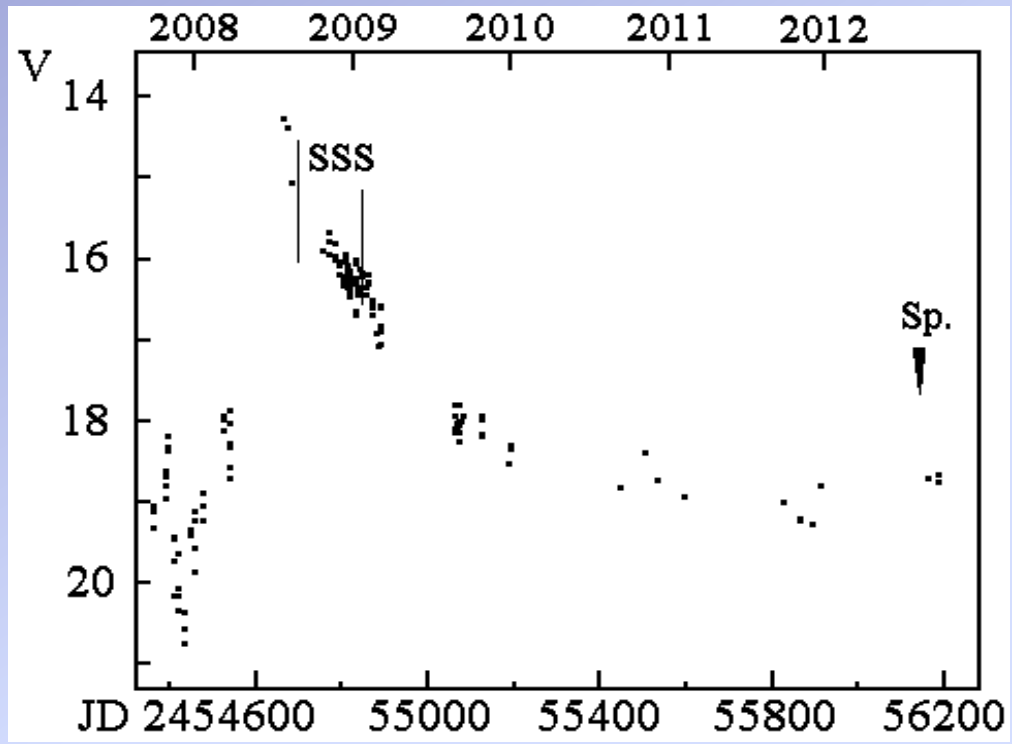
HV Cet (2008)

CSS 081007:030559+054715

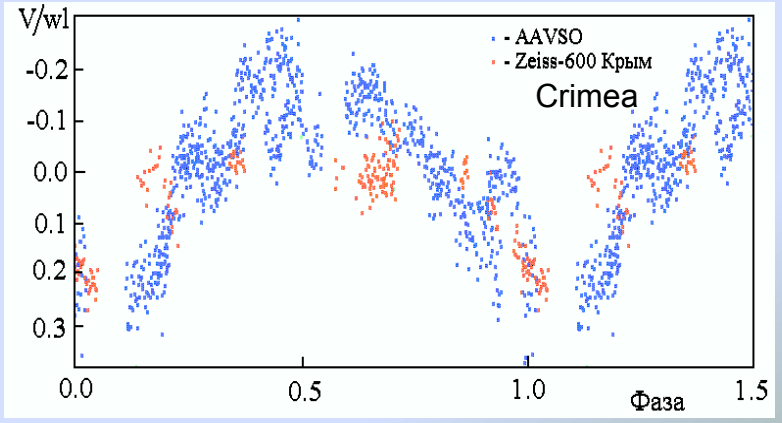
Fast neon nova. Has an unusual location in the Galaxy: l = 172°.6, b = – 43°.7, in the direction to anticenter and at the high Galactic latitude. Population II object. There is a clear orbital period in X-rays, P_{orb} = $1^d.7718$.



Zeiss-1000, 2012. Distant galaxies are visible around HV Cet.

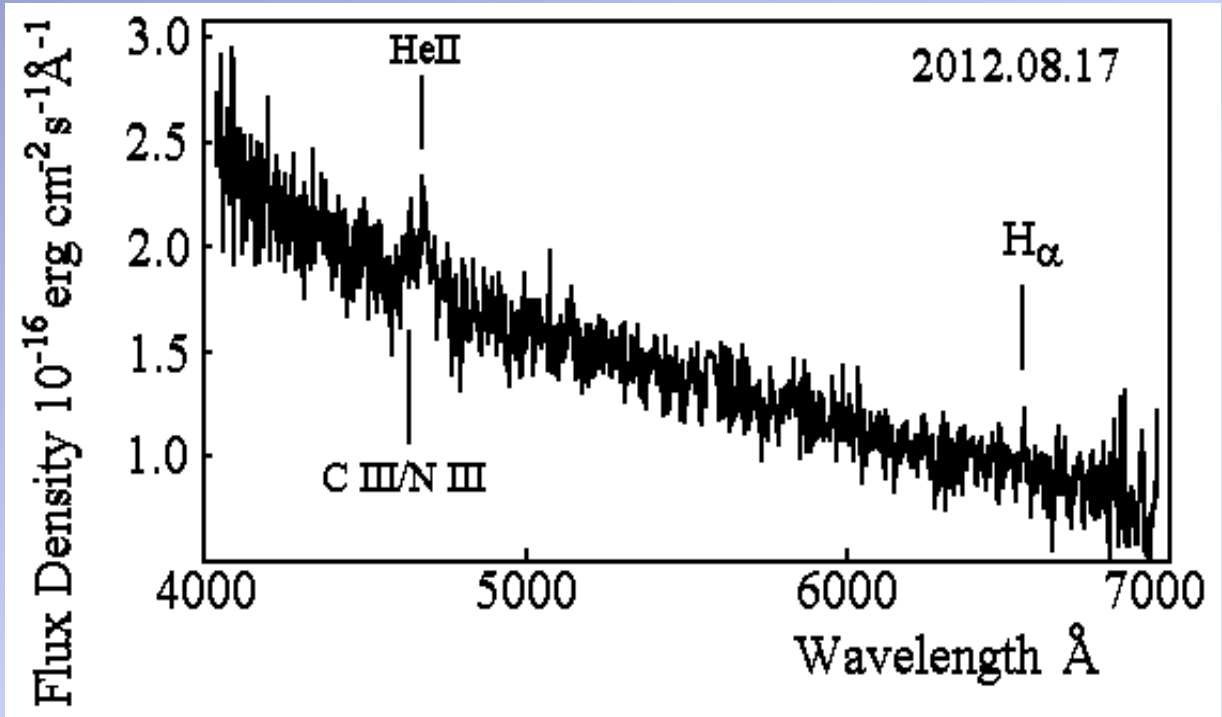


The outburst light curve. Maximum was missed due to vicinity to Sun.



Our observations plotted versus phase of orbital period (red points)

HV Cet
Spectroscopy

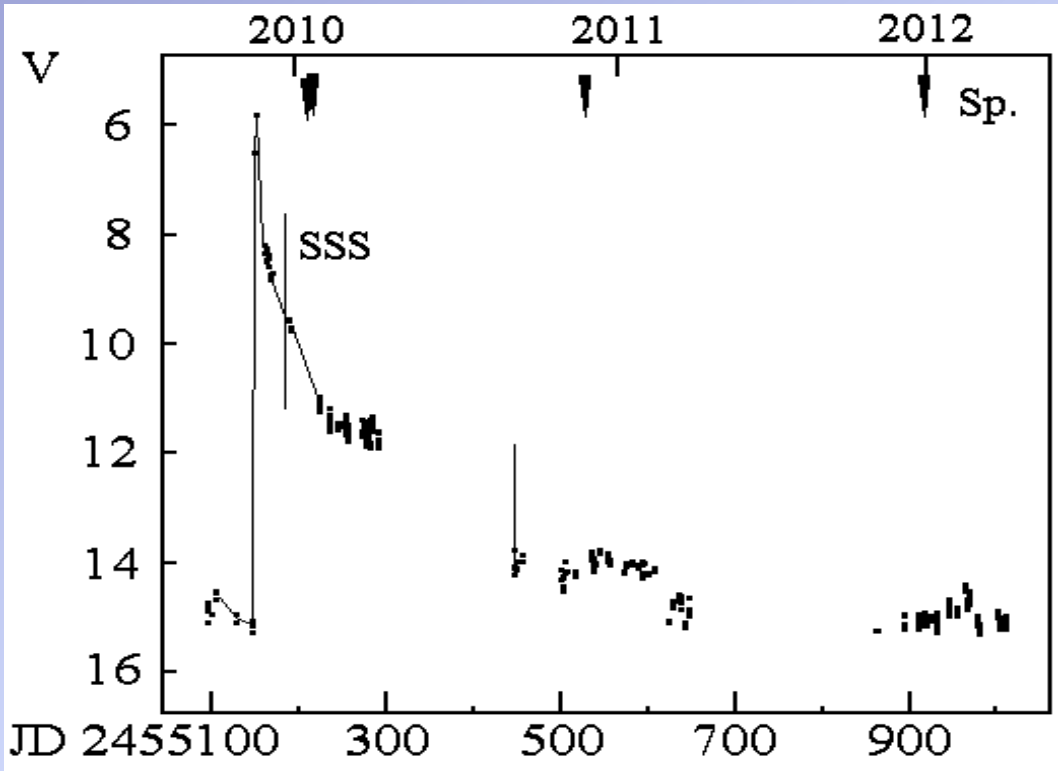


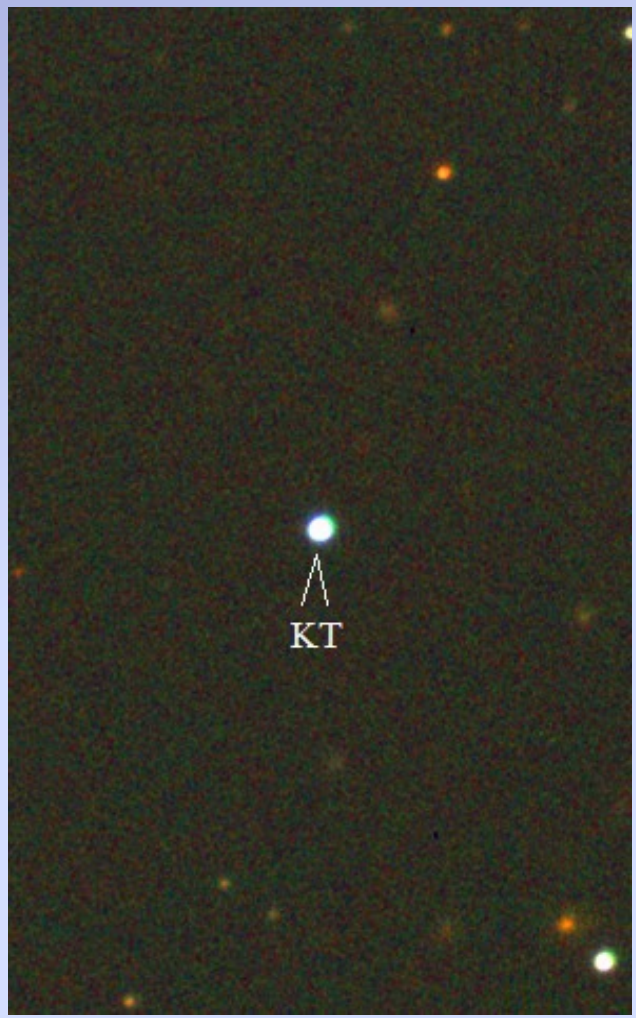
The БТА / SCORPIO spectrum taken when its brightness fell at the pre-outburst light level. In this low S/N spectrum the HeII 4686 Å is visible with the shift of -180 km/s, along with weaker emissions of Hα and Bowen CIII/NIII blend. Evidently, the expanding envelope has dispersed, and only the accretion disk emits light.

KT Eri (2009)

Fast nova of He/N class. It appeared also at the high Galactic latitude, at the anticenter direction (l = 208°, b = –32°) and has distance of 4 kpc.

Population II object.





Zeiss-1000, 2012. In this field, the distant galaxies are seen, too.

The outburst light curve. For 2 years, the star has reached pre-outburst light level. We haven't determined any period. Based on Harvard plates, it may be equal to 737^{d} (Jurdana-Sepic et al., 2011). RS Oph type recurrent nova?

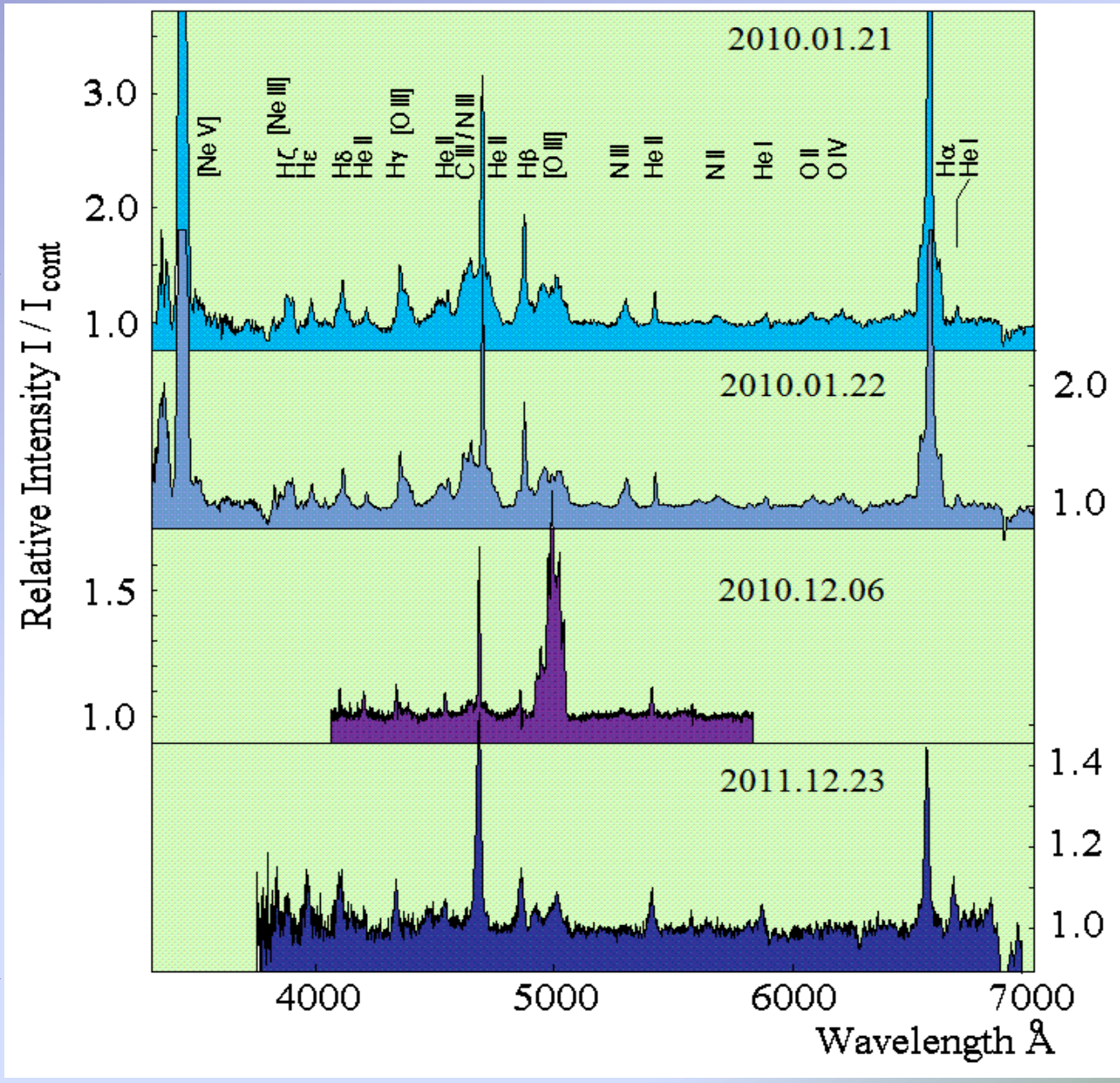
KT Eri (2009)

Spectroscopy

In the KT Eri spectrum, H and He II lines were narrow with FWHM = 600 km/s, but had a wide pedestals with FWHM 2700 km/s.

This is a rare case where the spectrum of the outburst even near the maximum brightness demonstrates lines of the accretion disk at the same time with the lines of the expanding shell.

We determined T = 440000 K for the SSS.

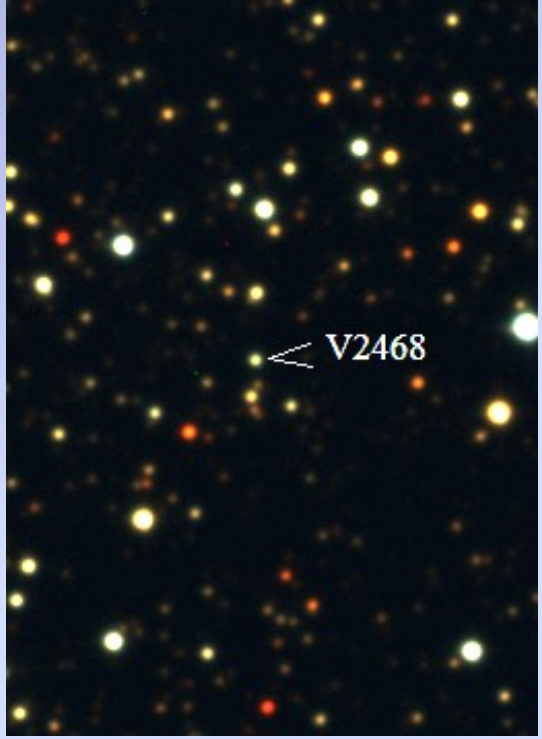


BTA//SCORPIO spectra

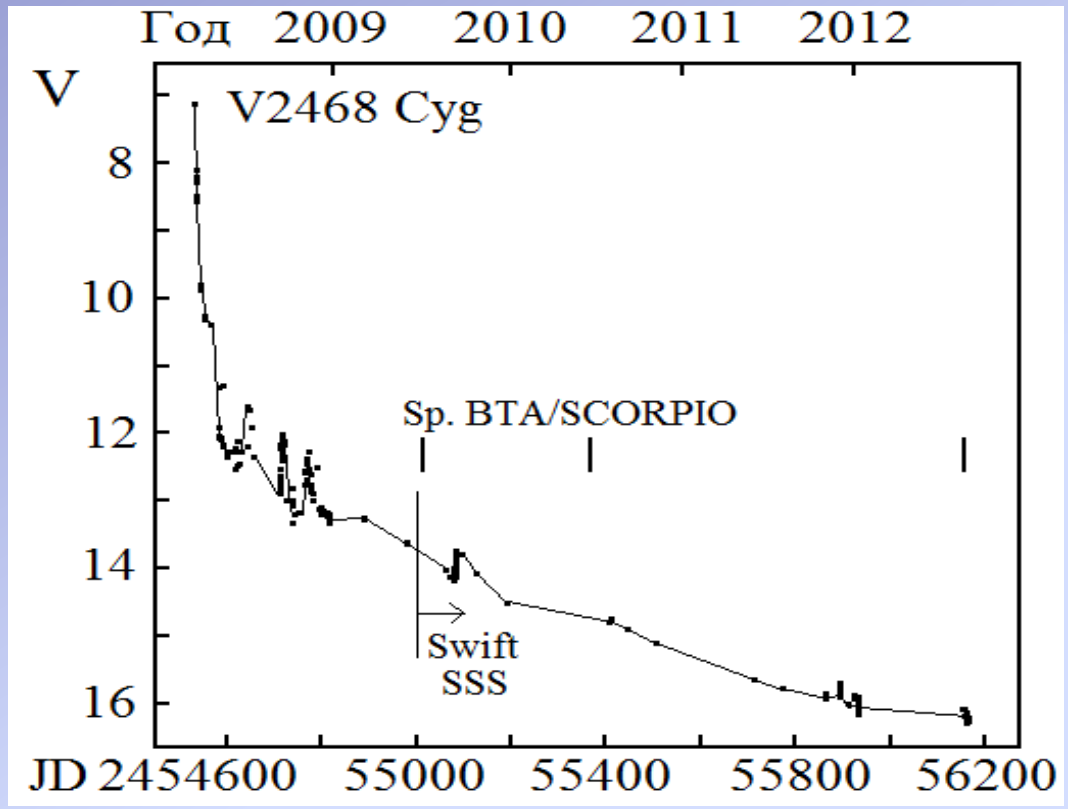
V2468 Cyg (2008)

FeII class nova.

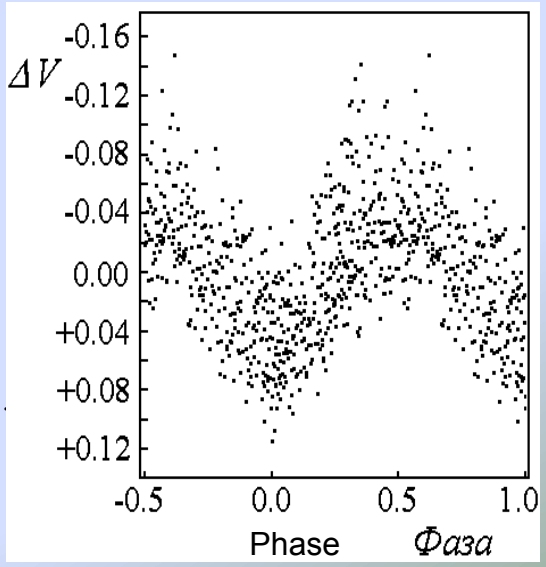
The light modulation period $0^d.145243$ is found by us using the photometry carried in Crimea.



Zeiss-1000, 2012

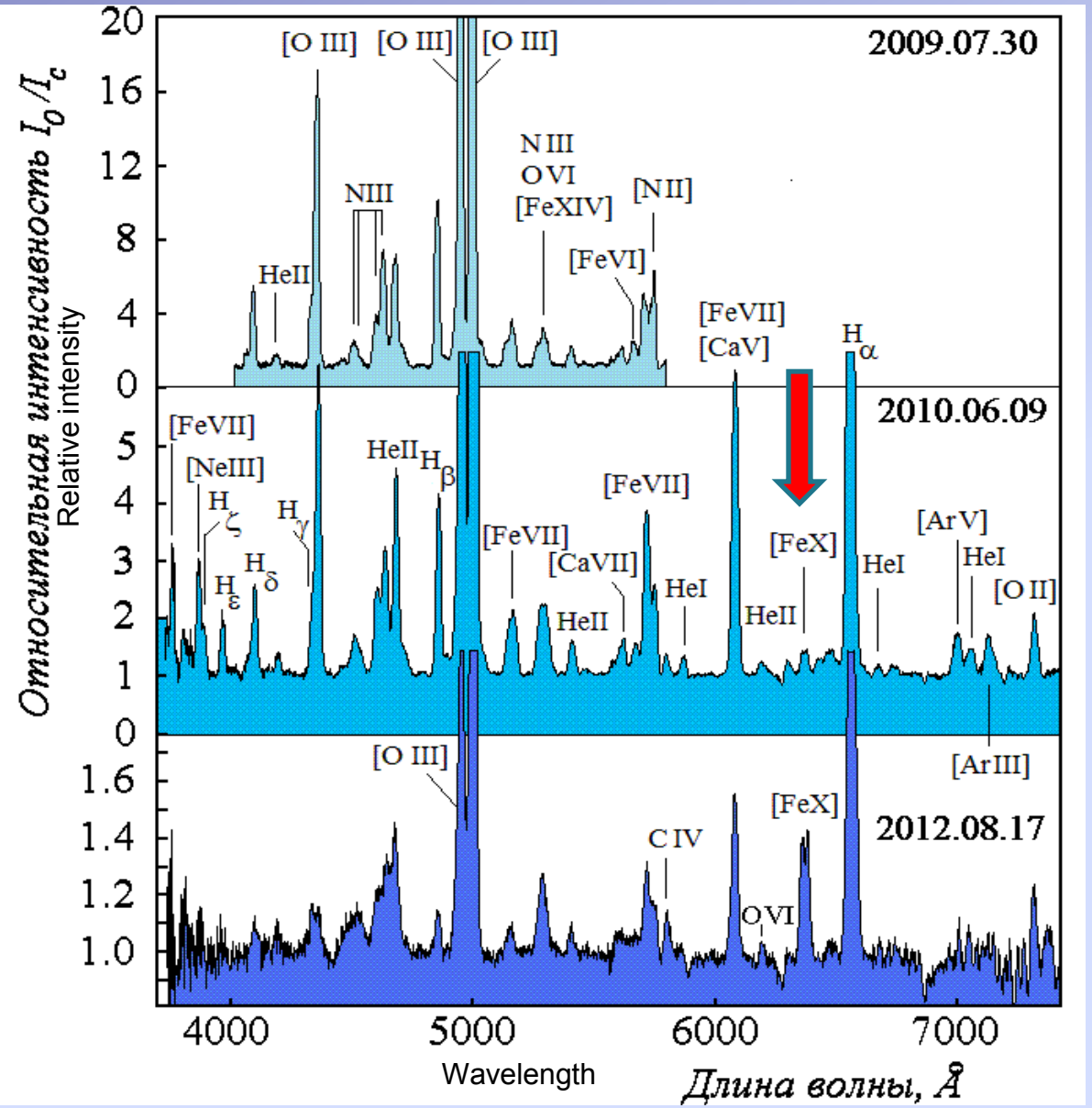


The light curve of V2468 Cyg. The SSS phase continues for 3 years.



Phase-folded light curve taken with the 60 cm Zeiss telescope at the SAI Crimean Station.

V2468 Cyg
Spectroscopy with BTA/SCORPIO

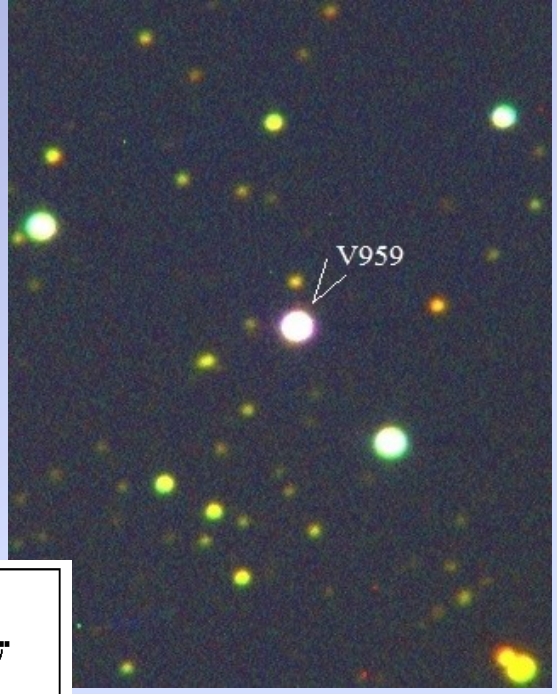


Emission line spectra of high degree ionization species are presented indicating a high temperature ionization source. Coronal [FeVI], [FeVII], [FeX], [FeXIV], [CaV], [CaVII] are visible. Red arrow shows [FeX] line, its equivalent width increased by1.4 times. In optical range, CNO-cycle element lines are well presented.

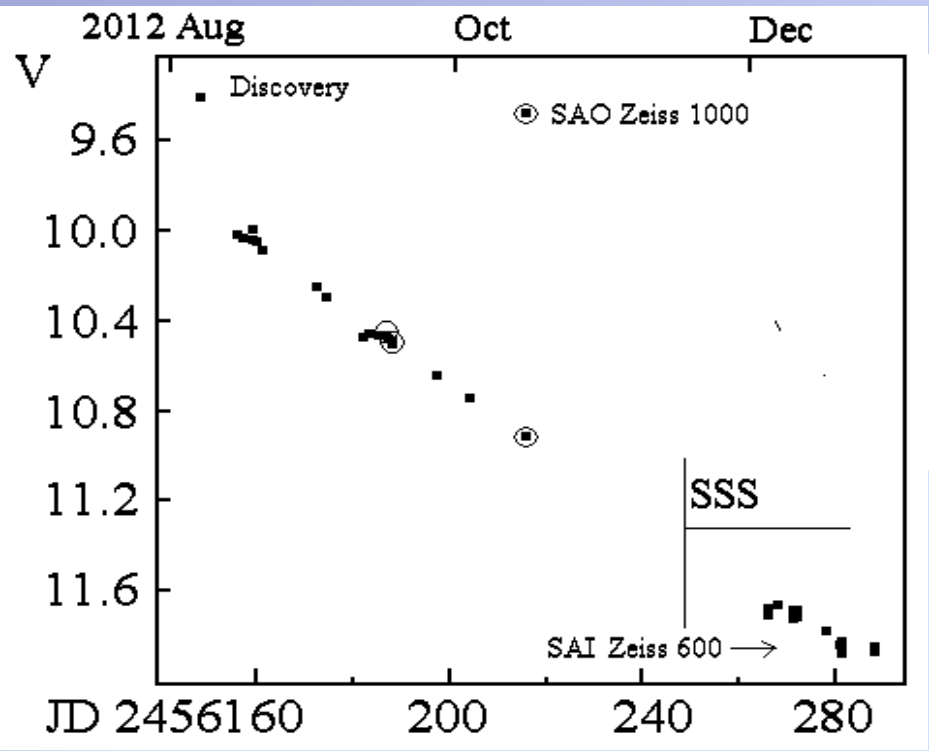
Source temperature measured using the flux ratio of the emission lines Hβ to HeII 4686Å increased from 210000 to 380000 K.

V959 Mon (2012) Photometry.
Fermi J0639+0548

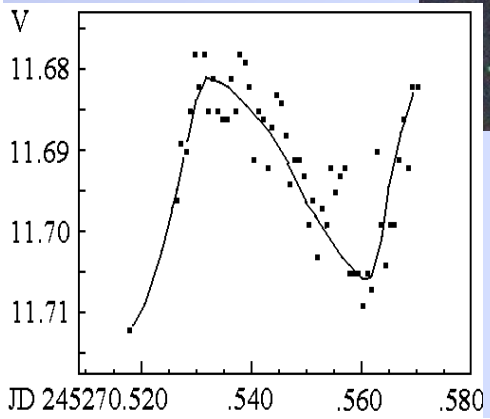
He/N class nova with the orbital period of $0^d.2957$ (Osborne et al., 2013) very bright in γ rays. It was discovered by Fermi space observatory working in hard X-ray and γ-ray energy ranges. SSS was detected onboard of Swift on 2012 November 18.



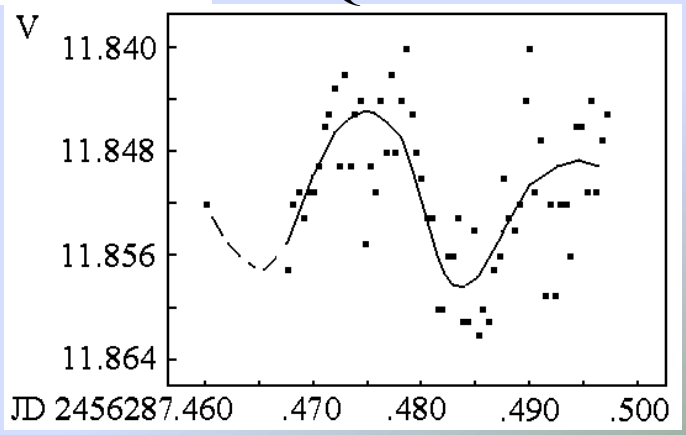
Zeiss-600 of SAI Crimean Station, 2012



QPO examples

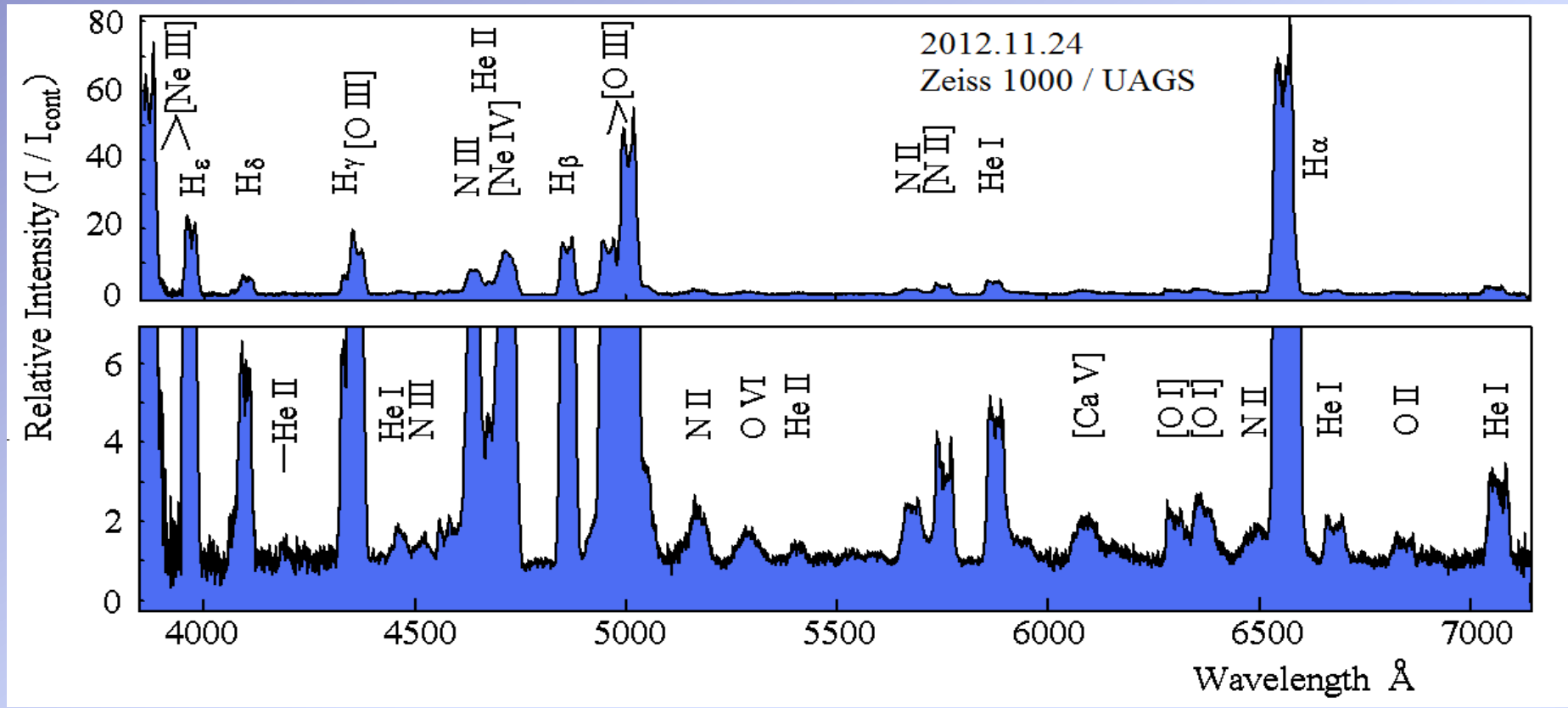


QPO



The outburst light curve of V959 Mon. Outburst maximum was missed as the star was located in the Sun direction. No flares at the decay were visible.

V959 Mon
Spectroscopy



The spectrum of V959 Mon (Цейсс-1000 / UAGS) taken 6 days after entry into SSS phase. With the low ratio Hβ / He II and absence of [Fe X], the temperature is not high. SSS is not confirmed. FWHM of H and He I lines is 2200 km/s, FWZI 3700 км/с. γ-radiation is explained by the interaction of erupted envelope with the dust envelope of the secondary companion (Bannergee et al., 2013).

Thank you for your attention