The Nature of the Symbiotic Recurrent Nova V407 Cygni

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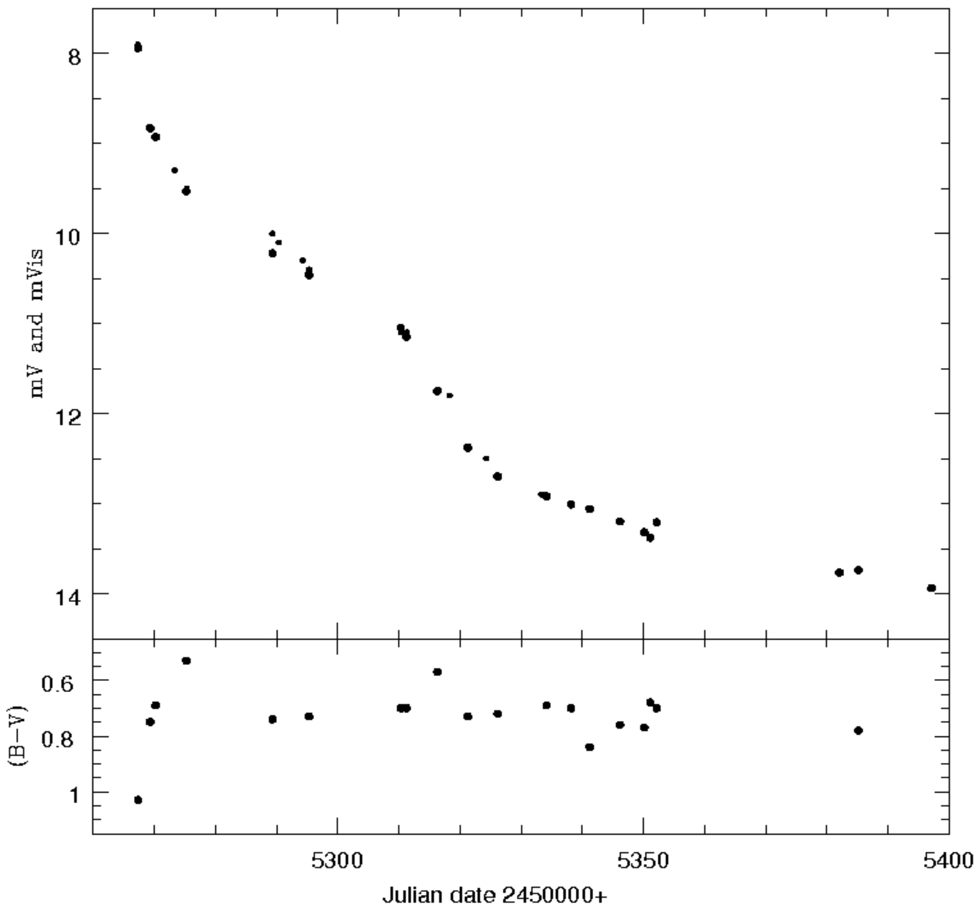
V407 Cyg: A symbiotic star consists of a hot component and a Mira variable.

A semi-periodical light variation of about 750 days (Meinunger 1966; Munari et al. 1990; Kolotilov et al. 2003) in the quiescent stage.

This object performed a large amplitude outburst, similar to those of classical fast novae, in March 2010.

A member of a subclass of recurrent novae with a red giant secondary: RS Oph, T CrB, V745 Sco, and V3890 Sgr.



mV(max)=7.26 ± 0.1 mag at March 10.81 UT. The time for 2 mag decline was t2=6.5 ± 0.5 day and (B-V)=0.58 ± 0.05 at t2. Mv=-8.85±0.2 mag (Della Valle & Livio 1995).

$(B\text{-}V)_0$ = -0.02±0.04 at t2 (van den Bergh & Younger 1987).

E(B-V)=0.60 ± 0.05. The distance is 7.1±0.6 kpc.

Fig. 1 Light curve and (B-V) color by VSNET.

This distance is roughly three times larger than those in previous works: e.g. 2.7 kpc by Munari et al.(1990) or 1.9 kpc by Kolotilov et al. (1998). 750 days: the period of pulsation.

Only Hδ was prominent emission line on the absorption spectrum of M type star (Herbig 1960). Such a characteristic spectral feature of Mira variables appears in the pre-maximum phase of light variation, but the spectrum was obtained on 1952 October 10: JD2434296.

116 days after light maximum of Meinunger (1960) and Munari et al. (1990).

Light minimum of Kolotilov et al. (2003).

750 days is unlikely the period of the pulsation of the secondary Mira variable.

The period 750 days is likely related the orbital motion of the binary system, and the variation of the Mira variable may be embedded in it.

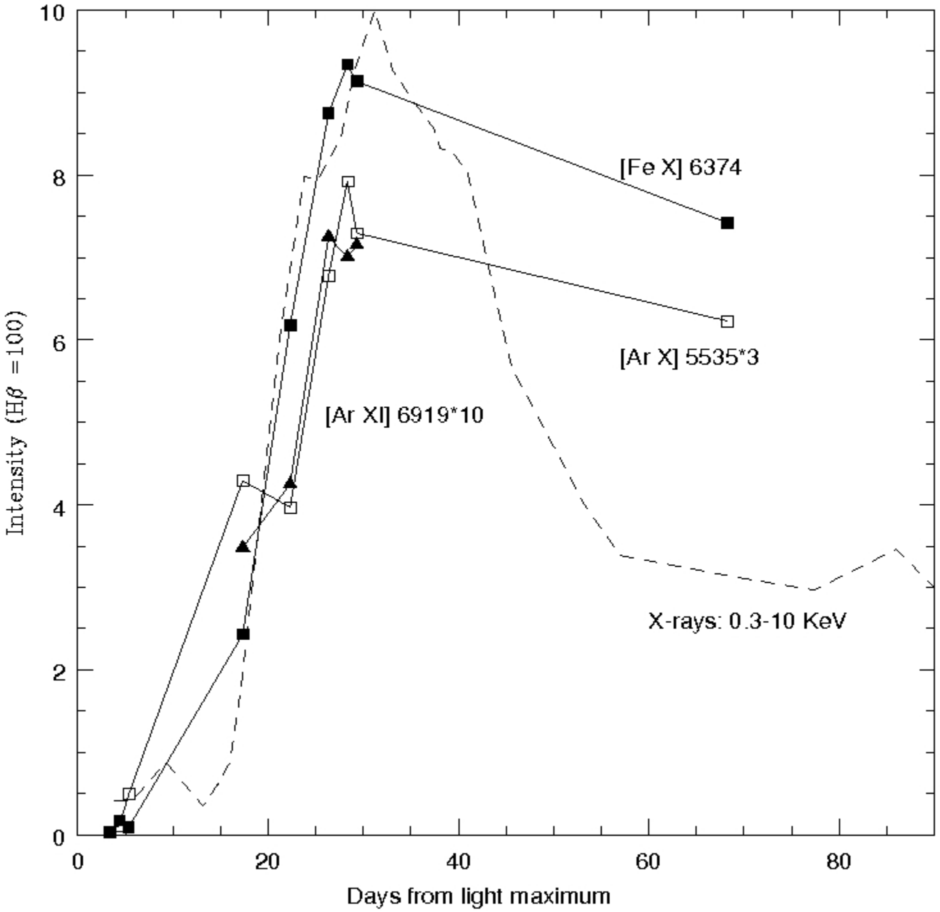
Reanalysis of historical photometric data is needed.

Spectroscopic observations

Spectroscopic observations were carried out at Asiago Astrophysical Observatory from 2010 March 14 (day 3) to May 18 (day 73).

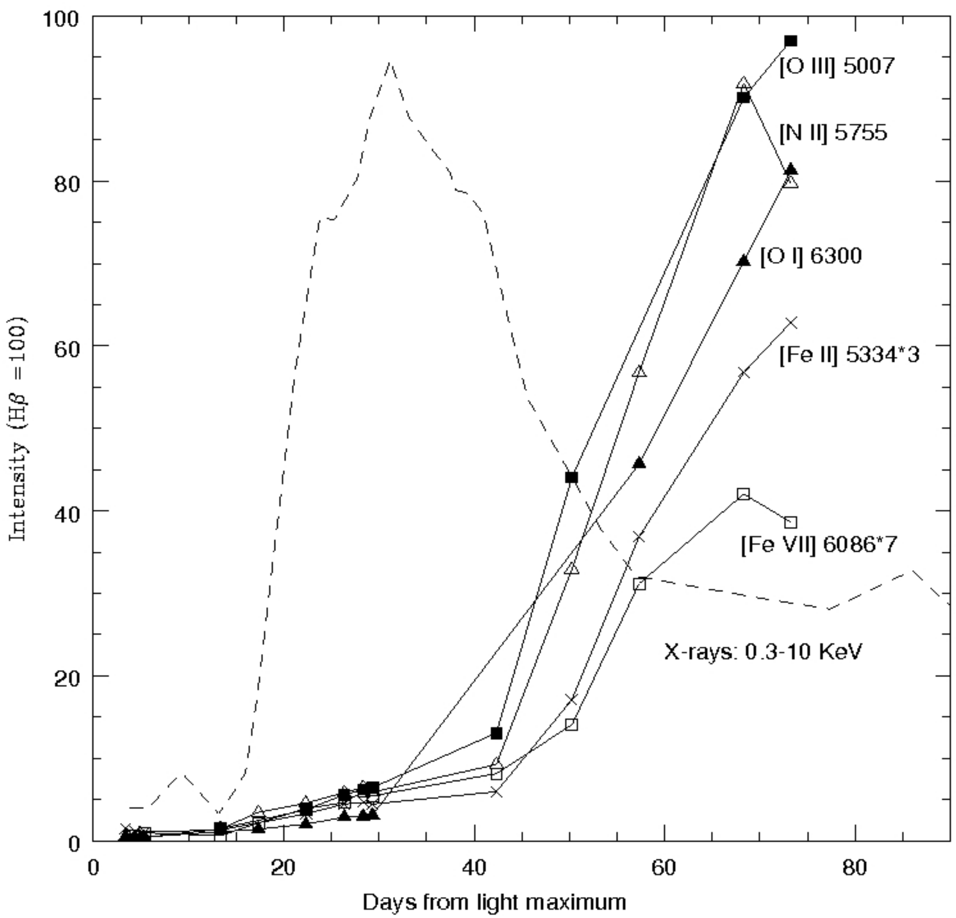
Boller & Chivens grating spectrograph mounted on the 122cm telescope at for medium resolution spectra.

Echelle spectrograph mounted on the 182cm telescope for high resolution spectra.



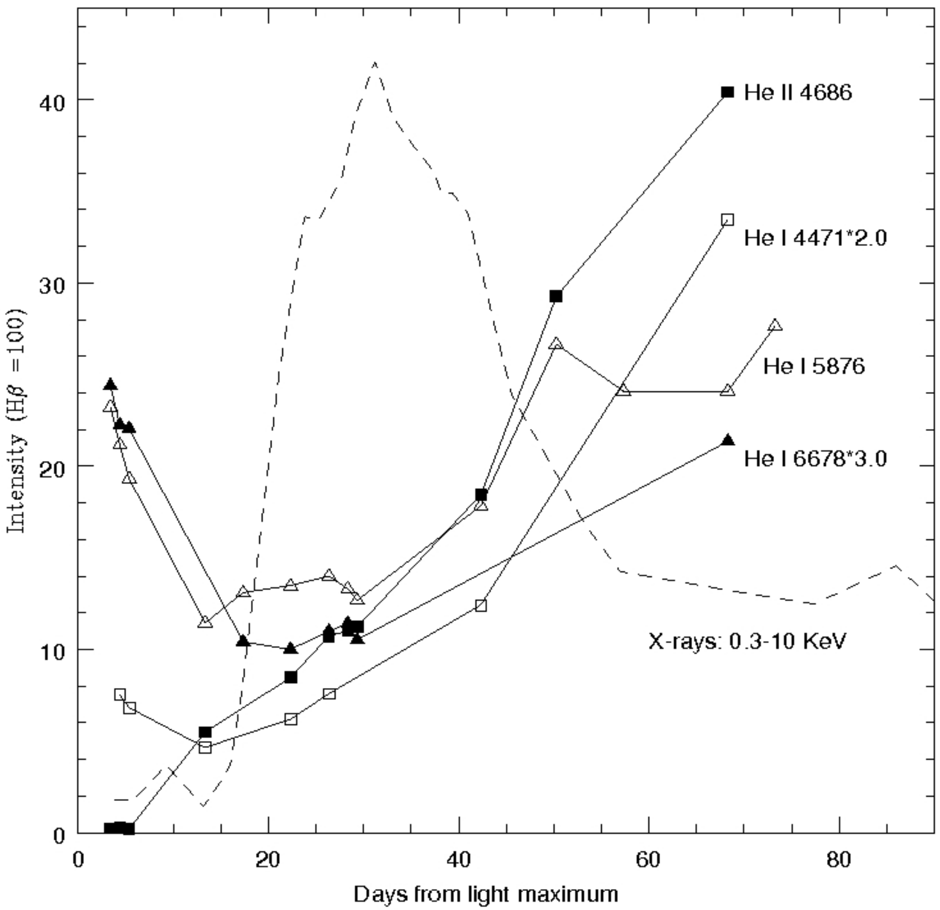
The coronal emission lines [Fe X] 6374, [Ar X] 5535, and [Ar XI] 6919 were detected.
The coronal emission lines and the Soft X-rays (Nelson et al. 2012) strengthened rapidly on day 20 of the outburst.

Fig. 2: Intensities of the coronal emission lines.
The broken line exhibits the Soft X-ray flux.



Forbidden lines rapidly strengthened about on day 50, which coincided with the fading of Soft X-rays. The fading of Soft X-rays was probably related to the decreasing of the electron density, namely the decreasing of the emission measure of the nebulosity.

Fig. 3: Intensities of selected forbidden lines.



If the Soft X-rays had been the thermal emission of the hot component, its flux should have been related to the intensity ratio He II 4686/ Hβ, but such a phenomenon was not observed.

The variations in intensity of He I emission lines in the first two weeks of the outburst coincided with that of γ-ray flux (Abdo et al. 2010). ? ? ?

Fig. 4: Intensities of He I and He II lines relative to Hβ. The broken line exhibits the Soft X-ray flux.

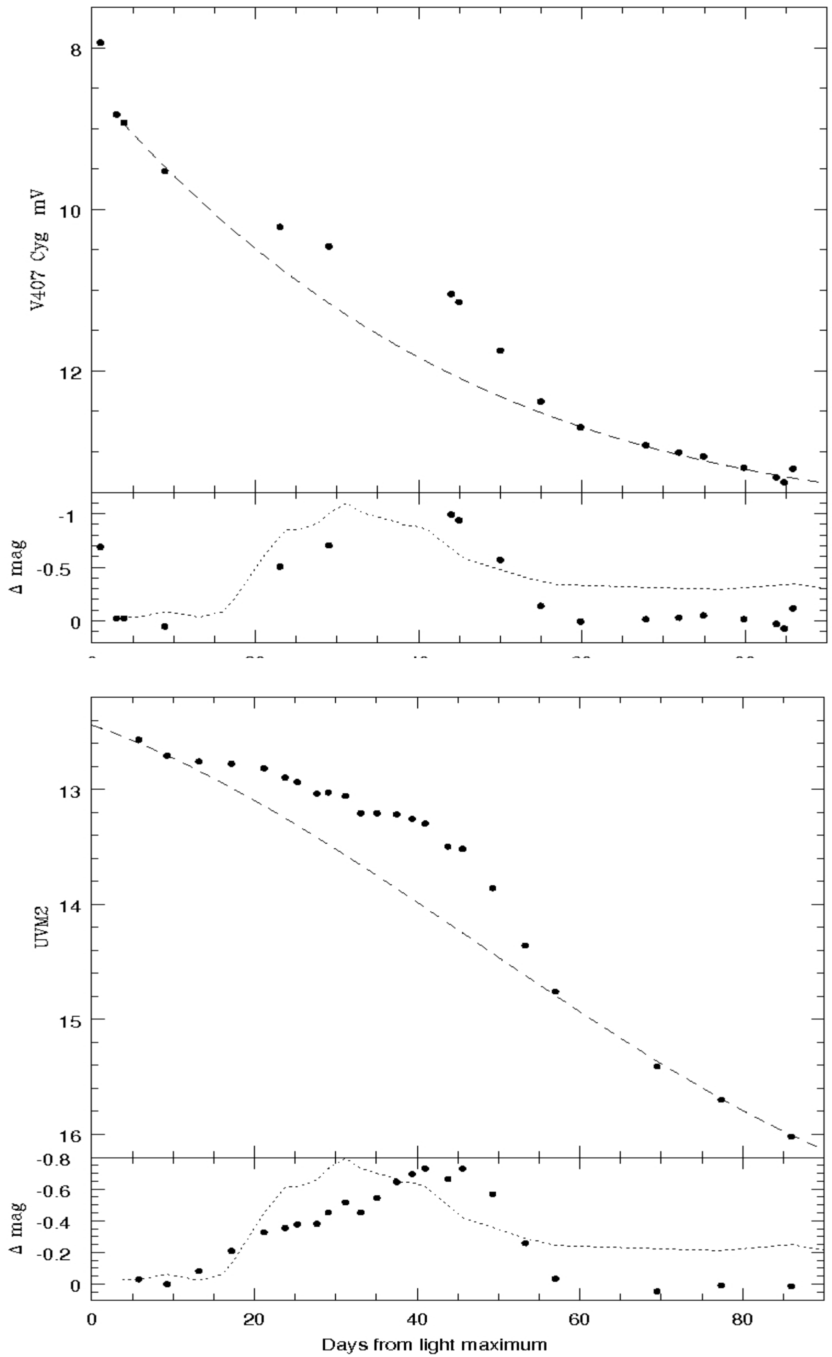


Fig. 5 Excess of optical and UV continuum radiation.

Additional ionized gas was formed by the collisional ionization on day 20 and later, which made the free-free emission intense.

The top of the ejecta reached the outer boundary of the circumstellar envelope on day 50, when no more ionized gas was formed, because the collision ceased. The emission measure of the nebulosity decreased rapidly by the free expansion.

Nelson et al. (2012) proposed that the Soft X-rays were emitted in the interaction between the ejecta and the circumstellar envelope, but they assumed a very long orbital period for the binary system: 43 years. Thus, the ejecta collide the circumstellar envelope from the outside. In such a condition, however, the sudden decreasing of the electron density will not occur, because a part of the ejecta can expand freely from the beginning.

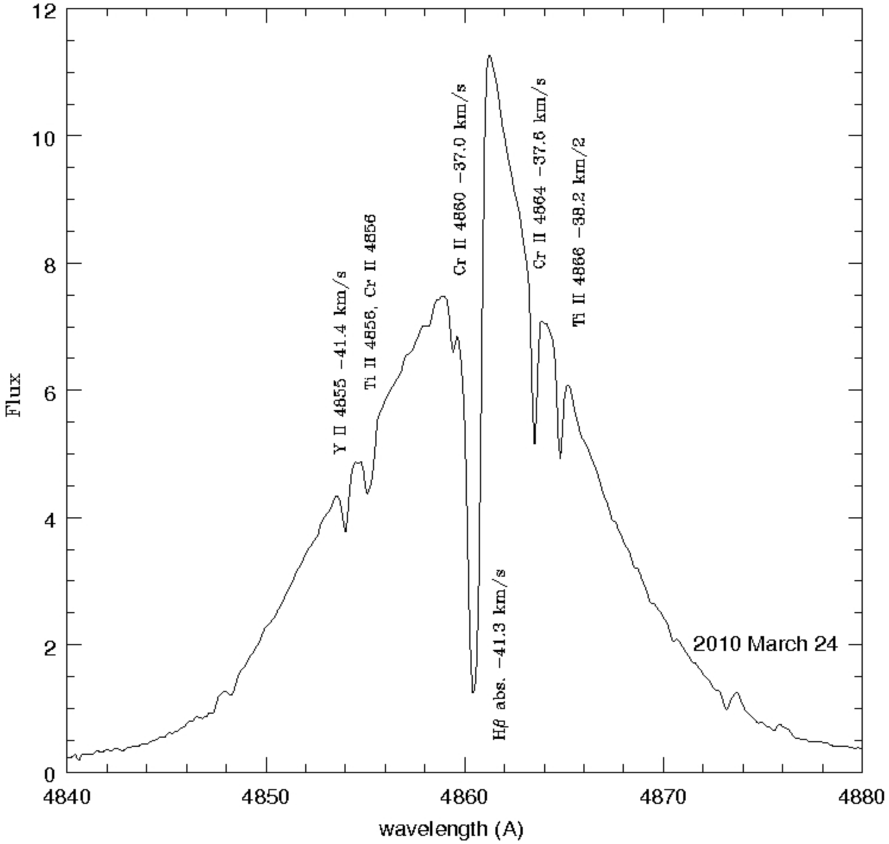


Fig. 6: Hβ emission component and narrow absorption lines.

The radial velocities of the narrow absorption lines agree with that of SiO maser emission line of the circumstellar envelope (Deguchi et al. 2011).
This spectral feature suggests that the emitting region of H I lines, the ejecta, was surrounded by the circumstellar envelope.

A more probable model is: the ejecta started to expand within the circumstellar envelope, and its expansion was restricted by the collision with it until the top of the ejecta reached the outer boundary.

If the period of 750 days is related the orbital motion, the dimension of the binary system is about 2 AU and this model is possible.

Distance to V407 Cyg is 7.1±0.6 kpc.

The light variation with the period of about 750 days is unlikely due to the pulsation of the secondary Mira variable, but is more probably related to the orbital motion of the binary system.

The Soft X-rays and the coronal emission lines were emitted in the interaction between the ejecta and the circumstellar envelope.

The bends on the light curves on day 50 were related to the fading of the free-free emission of the nebulosity.

The variations in intensity of He I emission lines coincided with that of γ-ray flux in the first two weeks.

Fig. 7 Intensities of selected emission lines of RS Oph on the outburst in 2006

(Iijima, T. A&Ap, 505, 287, 2009)