Suzaku Observations of the Classical Nova V2491 Cygni

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ABSTRACT

We report the discovery of super-hard X-ray emission from classical novae V2491 Cygni with a ToO observation of Suzaku (Takei et al. 2009, ApJL, submitted). V2491 Cygni was discovered in April 2008 (Nakano et al. 2008). Initial Swift observations showed a hard spectrum (Kuulkers et al. 2008). The nova is peculiar for its pre-nova X-ray activity (Ibarra et al. 2009) and a secondary peak in the optical light curve, which infers a magnetic nature of the white dwarf (Hachisu & Kato 2009). We conducted ToO observations 9 and 29 days after the outburst with Suzaku. As a result, super-hard continuum emission extending up to 70 keV was detected on day 9, but it was not present on day 29. This is the highest energy at which X-rays have been detected from a classical nova. The spectrum is well fitted by a flat (photon index of 0.1) power-law model, but not by a thermal bremsstrahlung model with a reasonable temperature. The power-law emission indicates the presence of an accelerated population of electrons with a non-thermal energy distribution. The extremely flat photon index is too hard for standard diffusive shock acceleration, suggesting that other mechanisms might take place.

1. INTRODUCTION

The classical nova V2491 Cygni was discovered on 2008 April 10.728 UT [1,2]. The evolution of the nova was extremely fast (Figure 1), declining at a rate of $t_2 \sim 4.6$ day [3,4]. The nova is peculiar for its pre-nova X-ray activity [5] and a secondary peak in the optical light curve, which infers a magnetic nature of the white dwarf [6].

The onset of the nova triggered an X-ray monitoring campaign using the Swift X-ray satellite [7,8,9]. No emission was found on day 1, but X-rays emerged clearly on day 5 with hard continuum emission [7]. These X-ray features are quite rare in classical nova explosions, yet are important for understanding their high-energy behavior.

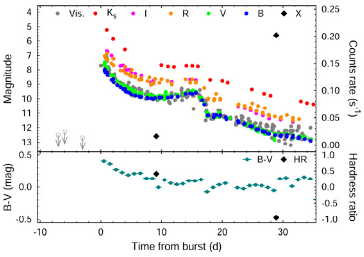

Fig.1. Development of multiple wavelength brightness (upper panel) and color (lower panel). A Suzaku X-ray count rate (0.2-12.0 keV) and a hardness ratio (H-S/H+S; S=0.2-5.0 keV, H=5.0-12 keV) are shown with black symbols. The optical photometry data are taken by the American Association of Variable Star Observers (AAVSO), the Variable Star Observers League in Japan (VSOLJ), and other ground-based observations [1,3,4,10,11,12,13]. The infrared photometry data are taken by the Kanata TRISPEC team (private communication with A. Arai).

2. OBSERVATIONS

We conducted ToO observations of V2491 Cyg 9 and 29 days after the outburst with the Suzaku X-ray satellite (Table 1). Suzaku has two instruments in operation: The X-ray CCDs (XIS) sensitive at 0.2-12 keV and the non-imaging hard X-ray detector (HXD) above 10 keV.

V2491 Cyg was clearly detected as a very hard source at the center of the X-ray CCD image on day 9 (Figure 2). The detailed results of the observations are presented in Takei et al. (2009).

Table 1
Suzaku Observation Log

Observation		First	Second
Sequence number		903001010	903001020
Start time	(UT)	2008-04-19 15:21	2008-05-09 08:39
End time	(UT)	2008-04-20 02:00	2008-05-09 21:30
t_b [a]	(d)	9.13	28.90
Δt_{XIS} [b]	(ks)	21	25
Δt_{PIN} [c]	(ks)	18	19

[a]Elapsed days in the middle of the observation from the discovery of V2491 Cyg (54566.73 d in MJD).
[b]XIS exposure time averaged over the three operating CCDs.
[c]Net exposure time of the PIN.

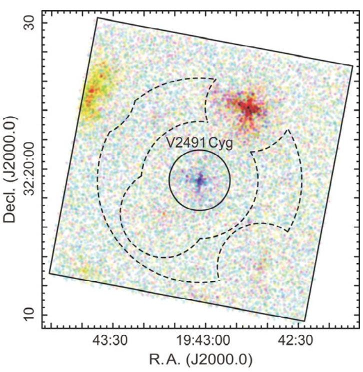

Fig.2. X-ray CCD image on day 9 coded with yellow (0.2–2.0 keV), magenta (2.0–5.0 keV), and cyan (7.0–12.0 keV). The source and background photons are accumulated respectively from the solid and dashed regions in order to avoid contamination from other sources in the view.

3. SPECTRAL ANALYSIS

On day 9, the X-ray spectrum is characterized by an extremely hard flat continuum extending up to 70 keV and the Fe XXV Kα line (Figure 3). This is the highest energy at which X-rays have been detected from a classical nova. The spectrum is well fitted by a combination of a thermal plasma and a power-law emission (Table 2). The super-hard continuum emission cannot be explained by a thermal bremsstrahlung model with a reasonable temperature. On day 29, the spectrum became much softer, and the hard continuum emission disappeared (Figure 4).

Table 2
Best-fit Parameters on day 9

Comp.	Par.	Unit	Value[a]
Absorption	N_H	(cm^{-2})	$1.4^{+0.9}_{-0.4}\times10^{23}$
Power-law	Γ		$0.1^{+0.2}_{-0.2}$
	$F_X^{(pl)\,b}$	(ergs s^{-1} cm^{-2})	$4.8^{+0.7}_{-1.3}\times10^{-11}$
	$L_X^{(pl)\,b,c}$	(ergs s^{-1})	$6.4^{+0.9}_{-1.7}\times10^{35}$
Thermal	k_BT	(keV)	$2.9^{+4.3}_{-2.6}$
	$F_X^{(th)\,b}$	(ergs s^{-1} cm^{-2})	$1.4^{+12}_{-1.1}\times10^{-13}$
	$L_X^{(th)\,b,c}$	(ergs s^{-1})	$1.9^{+16}_{-1.4}\times10^{33}$
χ^2/d.o.f.			22.8/35

[a]The statistical uncertainties indicate the 90% confidence ranges.
[b]The values are derived in the 1.0–12.0 keV and 15–70 keV bands respectively for the thermal and the power-law components.
[c]A distance of 10.5 kpc is assumed.

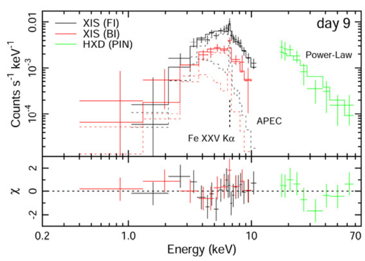

Fig.3. Background-subtracted spectra (cross) and the best-fit model on day 9. The best-fit models are shown by the solid (total) and dashed (each component) histograms.

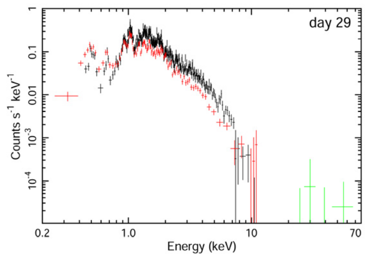

Fig.4. Background-subtracted spectra (cross) on day 29.

4. DISCUSSION

We have found super-hard X-ray emission extending up to 70 keV from V2491 Cyg on day 9. Super-hard X-ray emission was studied in two other classical novae to date; V382 Vel by the BeppoSAX satellite [14], and RS Oph by the RXTE and the Swift satellite [15,16]. Similarly to V2491 Cyg, these observations were conducted a short time after the outburst (days 3 and 15 for RS Oph and V382 Vel, respectively). However, neither of the two other cases shows clear evidence of non-thermal signature of the emission.

In V2491 Cyg, the power-law emission indicates the presence of an accelerated population of electrons with a non-thermal energy distribution. Non-thermal particles in classical nova explosions are suggested in some radio observations and theoretical studies of RS Oph [17,18]. Our result is the first to claim a non-thermal signature from classical nova explosions in the X-ray band. The extremely flat photon index of 0.1 is too hard for standard diffusive shock acceleration, suggesting that other mechanisms such as acceleration by multiple shocks or magnetic reconnections might take place.

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