Suzaku ToO Studies of Classical Novae V458 Vul and V2491 Cyg

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Introduction

Classical novae are a class of cataclysmic variables. Sudden outburst occurs by nuclear fusion of hydrogen on the white dwarf surface. In a typical classical nova, the visual magnitude increases by ~10 magnitudes within a few days. X-rays are emitted at various stages in the post-burst evolution via different mechanisms. Hard X-rays are emitted in an early phase, originating presumably from a shock in the expanding ejecta. Soft X-rays emerge in a later phase, arising from the photospheric emission of the white dwarf. The mass and chemical composition of the ejecta, the transition process, and the white dwarf mass can be estimated with X-ray spectroscopy, but almost all previous novae (except for a few bright enough for grating spectroscopy) were studied with insufficient statistics and spectral resolution. The X-ray Imaging Spectrometer (XIS) onboard Suzaku can obtain spectra of moderately bright novae with high signal-to-noise ratio and resolution in a reasonable telescope time. Here, we report the results of Suzaku ToO observations of two recent novae --- V458 Vul[1] and V2491 Cyg[2] --- using the XIS, exposing for ~20 ks each in the director's discretionary time.

V458 Vul

V458 Vul was discovered on 2007 August 8[3,4]. Optical observations have been conducted since then (Fig. 1). Swift failed to detect the initial X-rays, but reported its first detection on day 70[6] and continued its monitoring (Fig. 1). We conducted a ~20 ks ToO observation with Suzaku on day 88.

Figure 2 shows the background-subtracted spectrum. We identified emission lines from N, Ne, Mg, Si, S, and Ar. We fitted the spectrum using an isothermal optically-thin plasma model (APEC[7]) with an interstellar extinction (wabs[8]). In addition, an absorbed power-law model (dotted lines in Fig. 2, NH = 8.9x10^{21} cm^{-2}, Γ = 2.2) was added to account for the contribution by a nearby source. The best-fit parameters are shown in Table 1.

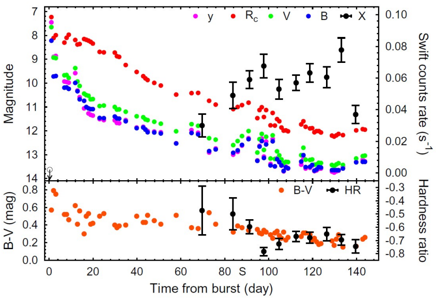

Fig.1. Optical and X-ray light curves respectively by Kazuhiro Nakajima[5] and the Swift XRT. The Suzaku observation is indicated with "S".

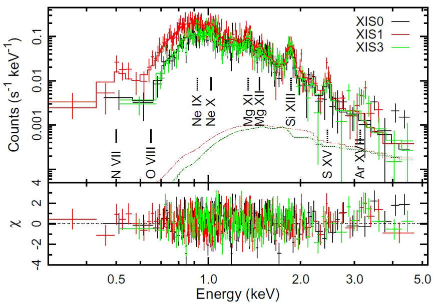

Fig.2. XIS background-subtracted spectrum.

Table 1. Best-fit parameters.

Param.	Unit	Value
$N_{\rm H}{}^*$	(10^{21} cm^{-2}) ..	3.1 (1.8–4.9)
$k_{\rm B}T^*$	(keV)	0.64 (0.57–0.71)
$Z_{\rm N}{}^*$	(solar)	4.2 (0.0–)
$Z_{\rm O}{}^*$	(solar)	0.0 (0.0–2.3)
$Z_{\rm Ne}{}^*$	(solar)	0.6 (0.3–2.3)
$Z_{\rm Mg}{}^*$	(solar)	0.5 (0.2–0.7)
$Z_{\rm Si}{}^*$	(solar)	0.6 (0.3–1.8)
$Z_{\rm S}{}^*$	(solar)	0.8 (0.1–2.5)
$Z_{\rm Fe}{}^*$	(solar)	0.2 (0.1–0.5)
$Z_{\rm Ni}{}^*$	(solar)	0.2 (0.1–0.5)
$F_{\rm X}{}^{*§}$	(erg s^{-1} cm^{-2})	1.1 (0.4–1.7) $\times 10^{-12}$
χ^2/d.o.f.	....	394.3/440

* The statistical uncertainties are indicated by the 90% confidence range. The upper limit for $Z_{\rm N}$ is unconstrained.
§ The X-ray flux in the 0.45–5.0 keV band.

V2491 Cyg

V2491 Cyg was discovered on 2008 April 10[9,10]. The optical light curve has an unusual behavior (Fig. 3), showing a clear rebrightening followed by a sudden fading around day 15. Two ~20 ks observations were performed with Suzaku on days 9 and 29, just before and after the rebrightening. The second data are being processed now and not presented in this poster.

In the first data, an emission line, a hard component, and a hint of a soft excess was found in the spectrum (Fig. 4). We fitted the spectrum using an optically-thin plasma (APEC[7]) and a power-law model with an interstellar extinction (wabs[8]). The best-fit plasma temperature is ~3 keV.

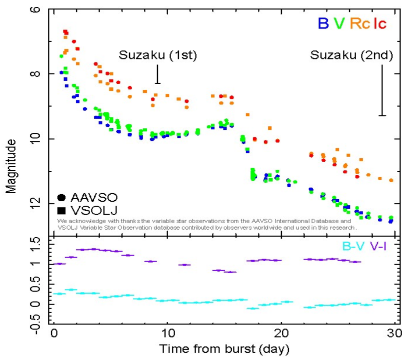

Fig.3. Optical light curves by the American Association of Variable Star Observers (AAVSO) International Database (circle) and the Variable Star Observers League in Japan (VSOLJ) Observation Database (square). The B-V and V-I colors are shown in the lower panel.

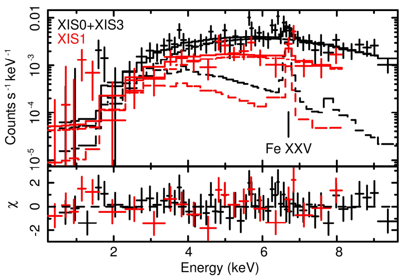

Fig.4. XIS background-subtracted spectrum.

Table 2. Best-fit parameters

Components	Par.	Unit	Value*
Absorption	$N_{\rm H}$	(cm^{-2})	$8.1^{+12.0}_{-3.8} \times 10^{22}$
APEC	$k_{\rm B}T$	(keV)	$3.1^{+7.6}_{-1.7}$
	Abundance	(solar)	$3.0^{+2.0}_{-2.8}$
	$F_{\rm X}{}^{\dagger}$	(erg s^{-1} cm^{-2})	$1.0^{+25.4}_{-0.9} \times 10^{-13}$
Power-law	Index		$-0.4^{+0.5}_{-1.3}$
	$F_{\rm X}{}^{\dagger}$	(erg s^{-1} cm^{-2})	$9.2^{+9.7}_{-8.7} \times 10^{-13}$
χ^2/d.o.f. ($\chi^2_{\rm red}$)			64.5/72 (0.90)

* The uncertainties indicate the 90% confidence ranges.
† The energy flux are estimated in the 2.0–10.0 keV band.

Summary

We conducted Suzaku ToO observations of the classical novae V458 Vul and V2491 Cyg. With a short exposure of ~20 ks each, we obtained well-exposed spectra, enriching unique data sets of the shock X-ray emission from classical novae. The two spectra are strikingly different. V458 Vul shows lots of emission lines with a 0.64 keV plasma temperature. The possible overabundance of N against other metals indicates that the plasma has an ejecta origin. V2491 Cyg is much harder. In addition to the ~3 keV thermal component, a power-law component is necessary to explain the spectrum extending beyond 10 keV, which is indicative of a particle acceleration. In a quick-look data of the second V2491 Cyg observation, the spectrum is entirely different from the two presented here.

These entirely different spectra and multiple spectral components may represent different stages of the shock evolution, but their relation is unclear. Obtaining well-exposed X-ray spectra of various novae at various epochs is vital for a better understanding. We demonstrated that Suzaku XIS data are capable of doing this. We will continue our Suzaku ToO studies in collaboration with Swift. We expect several sources per year can be a good target for Suzaku ToO.

References

[1] Tsujimoto, M., et al. 2008 in prep, [2] Takei, D., et al. 2008 in prep, [3] Nakano, S., Kadota, K., Waagen, E., Swierczynski, S., Komorous, M., King, R., & Bortle, J. 2007, IAU Circ., 8861, 2, [4] Samus, N. N. 2007, IAU Circ., 8863, 2, [5] Nakajima, H., 2007, VSOLJ Observation Database (private comm.) [6] Drake, J. J., et al. 2007, The Astronomer's Telegram, 1246, 1, [7] Smith, R. K., Brickhouse, N. S., Liedahl, D. A., & Raymond, J. C. 2001, ApJ, 556, L91, [8] Morrison, R., & McCammon, D. 1983, ApJ, 270, 119, [9] Nakano, S., et al. 2008, IAU Circ., 8934, 1, [10] Samus, N. N. 2008, IAU Circ., 8934, 2