# X-ray Study of Classical Novae : V458 Vul and V2491 Cyg

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Abstract

We conducted target of opportunity X-ray observations of the classical novae V458 Vulpeculae and V2491 Cygni using the Suzaku satellite. 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. V458 Vulpeculae shows lots of emission lines with a ∼1 keV plasma temperature, while V2491 Cygni shows an emission line from Fe with a ∼3 keV plasma temperature and a hard X-ray component. We report the results of these observations in this proceedings.

Key words: workshop: proceedings — stars: novae — X-rays: stars

## 1. 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) aboard the Suzaku satellite can obtain spectra of moderately bright novae with high signal-to-noise ratio and medium energy resolution in a reasonable telescope time. Here, we report the results of Suzaku observations of two recent novae — V458 Vulpeculae (Tsujimoto et al. 2008) and V2491 Cygni (Takei et al. 2008) — using the XIS, exposing for ∼20 ks each in the director's discretionary time.

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## 2. V458 Vulpeculae

V458 Vulpeculae was discovered on 2007 August 8 (Nakano et al. 2007; Samus 2007). Optical observations have been conducted since then. Swift failed to detect the initial X-rays, but reported its first detection on day 70 (Drake et al. 2007) and continued its monitoring. We conducted a ∼20 ks target of opportunity (ToO) observation with Suzaku on day 88. The background-subtracted spectrum was shown in figure 1. We identified emission lines from N, Ne, Mg, Si, S, and Ar. We fitted the spectrum using an isothermal optically-thin plasma model (APEC; Smith et al. 2001) with an interstellar extinction (wabs; Morrison & McCammon 1983). In addition, an absorbed power-law model (dotted lines in figure 1, $N_H = 8.9\times10^{21}$ cm$^{-2}$, $\Gamma = 2.2$) was added to account for the contribution by a nearby source. The best-fit parameters are shown in table 1.

## 3. V2491 Cygni

V2491 Cygni was discovered on 2008 April 10 (Nakano et al. 2008; Samus 2008). The optical light curve has an unusual behavior, showing a clear rebrightening followed by a sudden fading around day 15. Two ∼20 ks observations were performed with the Suzaku on days 9 and 29, just before and after the rebrightening. The second data are being processed now and not presented in this proceedings. In the first data, an emission line from Fe and a hard X-ray component was found in the spectrum

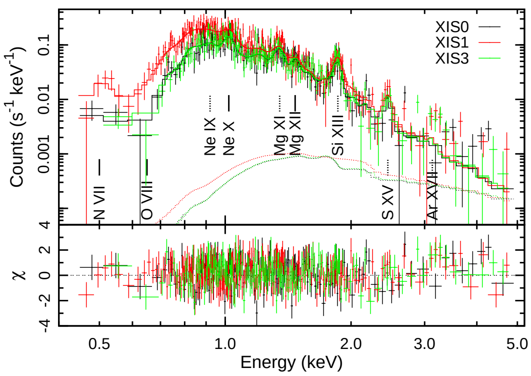


Fig. 1. XIS background-subtracted spectrum.

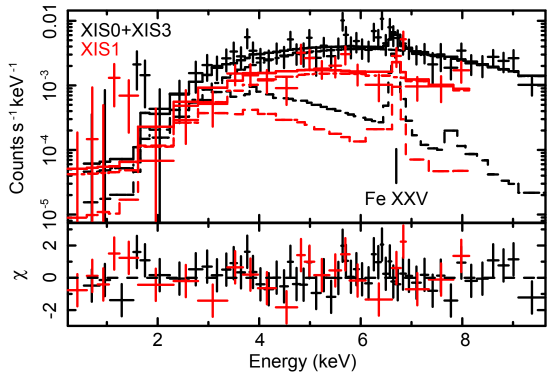


Fig. 2. XIS background-subtracted spectrum.

Table 1. Best-fits spectral parameters of V458 Vulpeculae.

| Param. | Unit | Value |
|---|---|---|
| $N_{\rm H}^{*}$ | (cm$^{-2}$) ....... | 3.1 (1.8–4.9)$\times 10^{21}$ |
| $k_{\rm B}T^{*}$ | (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) |
| $F_{\rm X}^{*\dagger}$ | (erg s$^{-1}$ cm$^{-2}$) | 1.1 (0.4–1.7)$\times 10^{-12}$ |
| $\chi^2$/d.o.f. | ............... | 394.3/440 |

* The 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.

(figure 2). We fitted the spectrum using an optically-thin plasma (APEC; Smith et al. 2001) and a power-law model with an interstellar extinction (wabs; Morrison & McCammon 1983). The best-fit parameters are shown in table 2.

Table 2. Best-fits spectral parameters of V2491 Cygni.

| Param. | Unit | Value |
|---|---|---|
| $N_{\rm H}^{*}$ | (cm$^{-2}$) ....... | 8.1 (4.3–20.1)$\times 10^{22}$ |
| $k_{\rm B}T^{*}$ | (keV) ......... | 3.1 (1.4–10.7) |
| $Z^{*}$ | (solar) ........ | 3.0 (0.2–5.0) |
| $F_{\rm X}^{*\dagger}$(APEC) | (erg s$^{-1}$ cm$^{-2}$) | 1.0 (0.1–26.4)$\times 10^{-13}$ |
| $\Gamma$ | ............... | $-0.4$ ($-1.7$–$+0.1$) |
| $F_{\rm X}^{*\dagger}$(Power) | (erg s$^{-1}$ cm$^{-2}$) | 9.2 (0.5–18.9)$\times 10^{-13}$ |
| $\chi^2$/d.o.f. | ............... | 64.5/72 |

* The uncertainties are indicated by the 90% confidence range.
† The X-ray flux in the 2.0–10.0 keV band.

## 4. Summary

We conducted Suzaku ToO observations of the classical novae V458 Vulpeculae and V2491 Cygni. 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 Vulpeculae shows lots of emission lines with a ∼1 keV plasma temperature. The possible overabundance of N against other metals indicates that the plasma has an ejecta origin. V2491 Cygni 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 Cygni 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. The MAXI is very useful for searching and monitoring of novae. We expect further progress of evolutionary studies of novae with Suzaku-MAXI collaboration.

## References

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