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The Slow Nova V1280 Sco: A Short Review

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Abstract

We summarize the results of the extremely slow nova V1280 Sco and discuss the approach using discrete multiple blue-shifted absorption lines, such as metastable He I* and Na I D, detected in our high-resolution spectra.

Keywords: cataclysmic variables - classical novae - optical - spectroscopy - photometry - individual: V1280 Sco.

1 Introduction

A nova occurs in a binary system consisting of a white dwarf (WD) and a normal star. The correlation between the WD mass and the decline rate of the light curve is widely accepted (e.g. Hachisu and Kato 2006), and the nova which occurs on low mass WD tends to decline in brightness at a slow rate and shows slow ionization evolution of its ejecta. A slow nova provides us a good opportunity to perform detailed observation over a long duration. In this review, we summarize the results of the extremely slow nova V1280 Sco and discuss the approach using discrete multiple blue-shifted absorption lines, such as metastable He I* and Na I D, detected in our high-resolution spectra.

2 Summary of V1280 Sco

2.1 Initial observations

V1280 Sco was independently discovered by two Japanese amateur astronomers (Y. Nakamura and Y. Sakurai) at the position of R.A. = $16^{\mathrm{h}}57^{\mathrm{m}}41^{\mathrm{s}}.0$, Decl. = $-32°20'\ 36''.4$ (equinox 2000.0) on 2007 February 4 at ninth visual magnitude (Yamaoka et al. 2007). It was identified as a classical nova by Naito and Narusawa (2007) from a low resolution spectrum obtained on February 5.87 (one day after the discovery). It reached the maximum brightness of $V = 3.78$ mag on February 16, which was 11.3 days after its discovery (Munari et al. 2007). The amplitude (A), the magnitude difference between pre-outburst and maximum brightness, is 15 mag or larger because Das et al. (2008) noted that no star was visible down to B and R magnitudes of 20.3 and 19.3, respectively, at the position on pre-discovery plates. The notable point is that V1280 Sco showed a remarkable formation of dust in its very early phase (Das et al. 2007). This dust formation was directly detected using ESO's Very Large Telescope Interferometer (VLTI) by Chesneau et al. (2008) and this result was published as the ESO press release (ESO0822: http://www.eso.org/public/news/eso0822/).

2.2 Infrared observation

Das et al. (2007) observed the nova in the NIR region on 2007 March 4.95, and found that the continuum in the 1.08-2.35 μm region had risen sharply, indicating dust formation in the nova ejecta. Das et al. (2008) suggested that the dust was in clumps from NIR studies of V1280 Sco. Puetter et al. (2007) reported spectroscopic observations in the visual-NIR regions carried out in 2007 May, and found that the nova was in a very low-excitation state showing strong C I lines and no discernible He I emission.

2.3 High spatial resolution observation

High spatial resolution monitoring of the dust formation event was performed using the VLTI during the first four months following the discovery, indicating that the dusty shell expanded regularly (Chesneau et al. 2008). Chesneau et al. (2012) revealed the presence of a dusty hourglass-shaped bipolar nebula around V1280 Sco based on mid-infrared imaging observations taken in 2010 and 2011 using the VLT spectrometer and imager for the mid-infrared (VISIR).

2.4 High quality photometric observation

Hounsell et al. (2010) published the data set of V1280 Sco observed by the Solar Mass Ejection Imager (SMEI) on board the *Coriolis* satellite. Thanks to high quality and high time resolution, they revealed that there had been three major but short episodes of brightening near maximum light (before 2007 February 20), which had not been detected by any ground-based telescopes.

2.5 Distance and WD mass

Parameters (distance and WD mass) of V1280 published in the literature are controversial (see Table 1). Hounsell et al. (2010) estimated the distance to be 630 $\pm$ 100 pc by measuring the condensation time of dust grains, assuming that the condensation temperature of the dust was 1200 K and the ejection velocity was about 600 km s^{-1}. They also noted that WD mass of 0.6 $M_\odot$ is likely to be an upper limit. On the other hand, Chesneau et al. (2008) derived the distance of 1.6 $\pm$ 0.4 kpc from direct observations of the size of the expanding shell with velocity of $\sim$500 km s^{-1}. The discrepancy between these two estimations of distance is over a factor of two, which could result from the complexity in the physical conditions (temperature and velocity) of the dust shell.

Das et al. (2008) estimated the distance to be 1.25 kpc using the maximum magnitude versus rate of decline (MMRD) relation, and inferred that the higher mass end (1-1.25 $M_\odot$) may be supported when the amplitude A and the expansion velocity values observed inV1280 Sco were taken into account.

3 Our Results

In this section, our results of V1280 Sco are summarized. Especially we focus on multiple absorption lines detected in high-resolution spectra (see Sadakane et al. 2010, Naito et al. 2012, Naito et al. 2013 for details).

Photometric and spectroscopic observations have been conducted from February 2007 to July 2013 over

Table 1: Parameters of V1280 Sco in the literatures

Distance [kpc]	WD mass [$M_\odot$]	Reference
0.63 $\pm$ 0.10	$<$ 0.6	Hounsell et al. 2010
1.6 $\pm$ 0.4	—	Chesneau et al. 2008
1.25	1.0-1.25	Das et al. 2008
1.1 $\pm$ 0.5	$< \sim$0.6	Naito et al. 2012

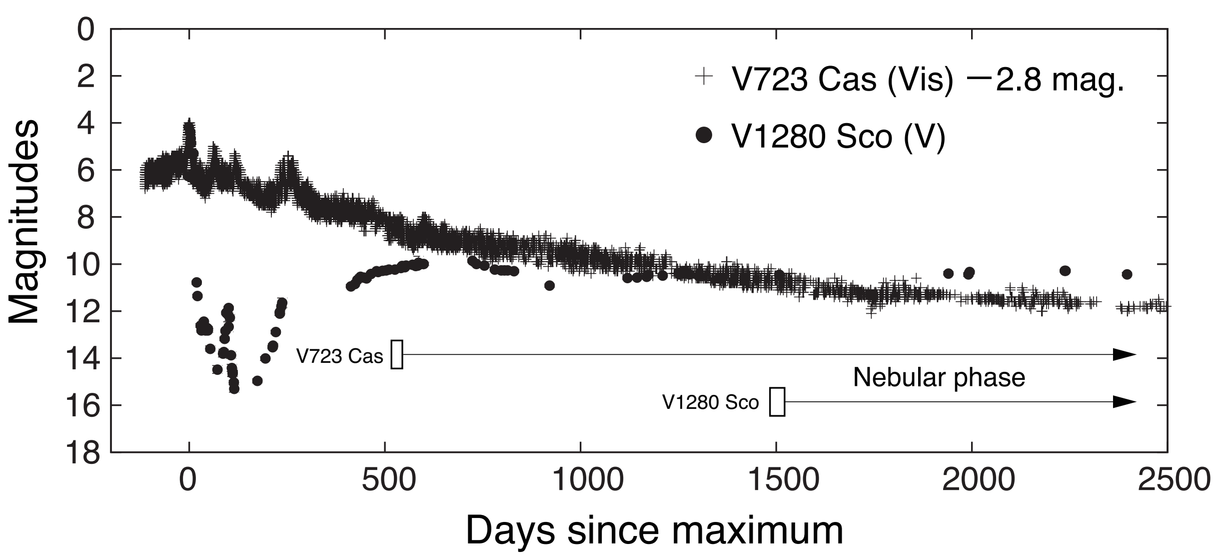

Figure 1: Comparison of light curve and nebular phase between slow novae V1280 Sco and V723 Cas. Light curve of V723 Cas is collected from AAVSO database (http://www.aavso.org) and is shifted by −2.8 mag. V723 Cas entered the nebular phase about 18 months after maximum (Iijima 2006), while V1280 Sco took about 50 months (about three times longer than V723 Cas) to enter the nebular phase (Naito et al. 2012).

six years. Photometry in B, V, R_c, I_c, and y band was carried out with a 0.51-m reflector at Osaka Kyoiku University. Low-resolution spectroscopy ($R\sim1000$) was carried out mainly with 2.0-m NAYUTA telescope at Nishi-Harima Astronomical Observatory and high-resolution spectroscopy ($R\sim60000$) was carried out with 8.2-m Subaru telescope.

According to Iijima 2006, V723 Cas had been the slowest nova, spending a long time to enter the nebular phase. To compare the evolution between V1280 Sco and V723 Cas, the light curves and the nebular phases of them are shown in Figure 1. V723 Cas declines in brightness at very slow rate gradually, while V1280 Sco keeps its brightness (V$\sim$10) for 2000 days. V723 Cas entered the nebular phase, defined by the appearance of both [O III] 4959 and 5007, about 18 months after maximum (Iijima 2006), while V1280 Sco took about 50 months (about three times longer than V723 Cas) to enter the nebular phase (Naito et al. 2012). Considering that V723 Cas had the longest transitional time to enter the nebular phase, we conclude that V1280 Sco is going through the slowest spectral evolution among known classical novae. Hachisu and Kato (2004) estimated the mass of V723 Cas to be 0.59 $M_\odot$ by fitting their theoretical light curve. Our results suggest that the mass of a WD in V1280 Sco system might be 0.6 $M_\odot$ or lower by comparing evolution rates between V1280 Sco and V723 Cas.

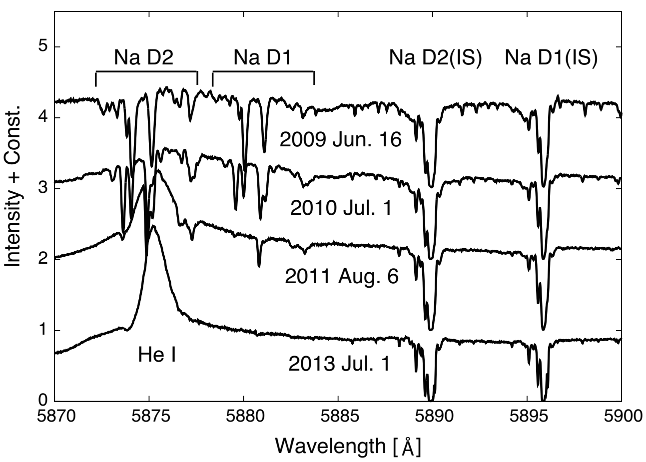

Figure 2: Multiple high velocity absorption lines associated with Na I D1 and D2.

We found discrete multiple blue-shifted Na I D lines, ranging from -650 to -900 km s^{-1}, on high-resolution spectra (Figure 2). Some components weakened significantly from 2009 to 2011 and almost all lines disappeared in 2013. Similar absorption lines associated with Ca II H and K and metastable He I* 3188 and 3889 are shown on our spectra. Metastable He I* 3889 absorption lines were detected for the first time in 2011 (four years after the maximum light) and have been shown until 2013 (Figure 3). This is the first detection of He I* absorption lines in the ejected (circumstellar) gas around novae (Naito et al. 2013). We suggest that the complex evolutions of multiple absorption lines are due to combined changes in physical conditions, such as the density, recombination and ionization rate. Survival time of these absorption lines in V1280 Sco is an order of years, which is much longer than those observed among fast novae (an order of weeks or months; Williams and Mason 2010). This can be related to the fact that the ionization evolution of V1280 Sco is very slow. The behavior associated with He I* in 2011 can be understood that the number of ultraviolet photons had increased significantly to produce singly-ionized helium as the central photosphere shrinks to become hotter, and the disappearance of Na I D lines - low excitation lines - in 2013 can be caused by an additional increase in the number of ultraviolet photons.

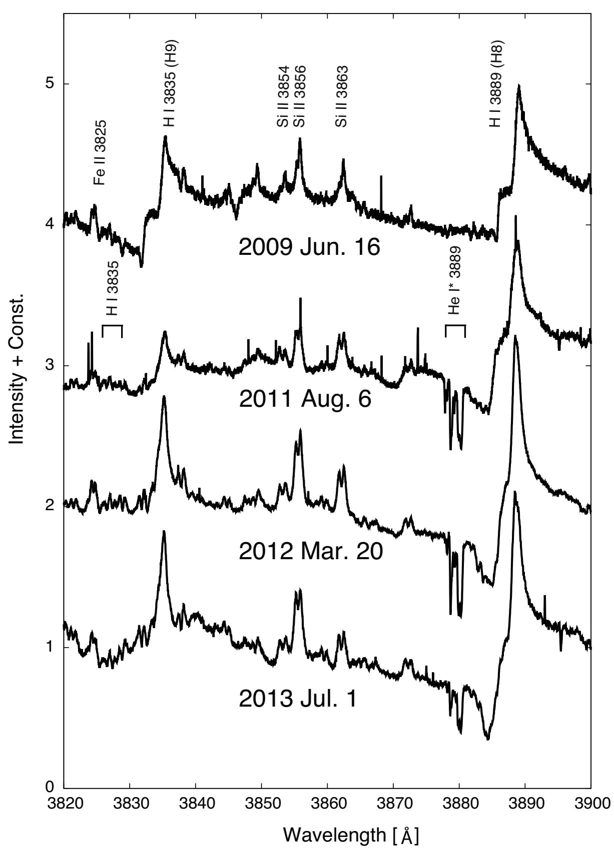

Figure 3: Multiple high velocity absorption lines associated with He I* 3889.

4 Discussion and Conclusions

As described in the previous section, metastable He I* absorption lines could survive longer than low excitation lines, such as Na I D and Ca II H and K. This means that metastable He I* absorption lines are more likely to be detected than low excitation lines in the late phase. Moreover metastable He I* lines are often used to derive physical parameters of nebulosity because the processes of transition are well understood. These characteristics of metastable He I* lines have advantage in measuring helium composition and the mass of the ejected material, and in studying nova shell structures. Using metastable He I* lines in V1280 Sco, we show that the ejected shell consists of numerous clumpy gas which cover a significant part of the continuum emitting radiation region as Figure 4 (Naito et al. 2013). We postulate that this approach is very useful to research nova shell.

We reveal that V1280 Sco is the extremely slow nova and is available for high-resolution spectroscopic observation for long periods. We attempt to obtain new results of V1280 Sco by follow-up observations.

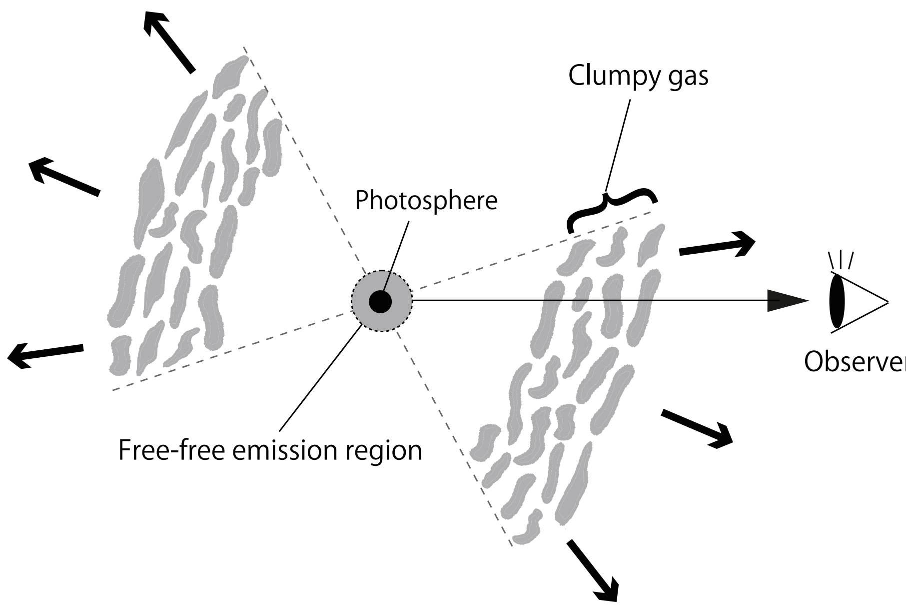

Figure 4: Schematic of ejected shell producing absorption lines of metastable He I* (see Naito et al. 2013 for details).

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DISCUSSION

ALESSANDRO EDEROCLITE: How long after the explosion do you see the emergence of the He I* lines?

HIROYUKI NAITO: Our latest spectrum taken in July 2013, shows the emergence of the He I* lines which indicates that these lines have appeared until at least 6.5 years after maximum.