Abstract. We carried out intensive spectroscopic observations of two WZ Sge-type dwarf novae, GW Lib, and V455 And during their superoutbursts in 2007, at 6 observatories. The observations covered the whole of both superoutbursts from the very maximum to the fading tail. We found evidence of the winds having a speed of \(\sim 1000 \text{ km s}^{-1}\) which blew in GW Lib during the rising phase. The evolution of the hydrogen, helium, and carbon lines suggests flaring of the accretion disk and emergence of the temperature inversion layer on the disk.

1. Introduction

Dwarf novae are a class of cataclysmic variable stars, which show outbursts by the disk instabilities, and SU UMa-type dwarf novae are a subclass giving rise to two types of outburst: normal outbursts and superoutbursts (for a review Osaki 1996). There is a small group of SU UMa stars, being called WZ Sge-type dwarf novae. Their peculiar feature is summarized as: the large outburst amplitude over 6 mag, the long recurrence cycle of the superoutburst (several years or more), and no (or few) normal outburst. In addition, they show curious behavior in many points, such as “early” superhumps, a variety of rebrighten-
ing light curves after the main superoutburst, long fading tail, and so on (see Uemura et al. 2008, and references therein).

The driving mechanisms working in WZ Sge stars are still in debate (see Nogami 2007), while the basic properties of normal SU UMa-type dwarf novae are generally explained by the thermal-tidal disk instability theory. For further investigation, we have prepared for coordinated spectroscopic observations during forthcoming superoutbursts, following a success of intensive spectroscopy during the 2001 superoutburst in WZ Sge itself (Baba et al. 2002; Nogami & Iijima 2004).

Under this circumstances, superoutbursts of two WZ Sge-type dwarf novae, GW Lib, and V455 And (=HS2331+3905) were discovered in the very early phase in 2007 by eager contributors to VSNET (about VSNET, see Kato et al. 2004). We succeeded in soon starting coordinated spectroscopic campaigns before or around the maximum in both stars, and here review the preliminary results and implications. The details will be published in our forthcoming papers.

2. GW Librae

GW Lib was discovered during an outburst at 9 mag as a novalike object in 1983 (Maza & Gonzalez 1983), and is the first cataclysmic variable where white dwarf pulsations with periods of hundreds-thousands of seconds were found (Woudt & Warner 2002; van Zyl et al. 2004). Thorstensen et al. (2002) measured its orbital period to be 0.05332(2) d, and estimated the inclination to be \( \sim 11 \) deg.

After dormancy of 23 years since the discovery, an outburst was caught at 13.8 mag at 2007 April 12.494 (UT) (R. Stubbings, vsnet-alert 9279). Our spectroscopic observations started at April 12.66 (UT).

The light curve of the superoutburst cut on the way of the long fading tail, and the observation date are displayed in figure 1a. Figure 1b exhibits the representative spectra, normalized to a unity continuum value, before the maximum, at the maximum, and in the plateau phase. All the spectra had a very blue continuum before the normalization, as is often seen in dwarf novae in outburst.

Before the maximum, the spectrum had only Balmer absorption lines. The central wavelength of the Balmer lines are blue-shifted by \( \sim 1,000 \) km s\(^{-1}\), and the full width at the half maximum is about 3,000 km s\(^{-1}\). Taking into account that GW Lib is a nearly pole-on system, these results indicate that optically thick winds blew just after the onset of the outburst.

By the maximum, H\( \alpha \) turned to be a singly-peaked narrow emission line (FWZI < 1000 km s\(^{-1}\)). There also appeared emission lines of highly excited species, He II 4686, C III/N III, and possibly C IV/N IV around 5800 Å, and a hint of absorption lines of Na I D. These lines became weaker during the plateau phase. These imply that a temperature inversion layer emerged on the accretion disk after switching off the winds, and this layer gradually faded away. Short-term variabilities in the line profile were not detected in our time-resolved low-resolution spectra.
Spectroscopy of GW Lib, and V455 And in Superoutburst

We can clearly see only Balmer emission lines in the spectra in the fading tail. They mimic those in quiescence, but the equivalent widths are much smaller.

3. V455 Andromedae

V455 And was originally found as a CV candidate in the Hamburg Quasar Survey (Hagen et al. 1995). Thorough observations by Araujo-Betancor et al. (2005) revealed its orbital period of 81.08 min by using eclipses, 5-6 min variabilities resulting from the WD pulsations, 1.12 min coherent oscillations attributable to the WD spins. They also detected radial velocity modulations of Balmer and helium lines with a period of ~3.5 h. Based on this report, this star has attracted an attention as a candidate of WZ Sge stars.

First outburst of this star was detected in the very early phase at 2007 September 4.775 (UT) (H. Maehara, vsnet-alert 9530). We then started spectroscopy from September 5.38 (UT).

The superoutburst light curve and the time when we obtained spectra are shown in figure 2. The light curve is cut on the way of the fading tail for a visual purpose, but we obtained several spectra during the period not shown in figure 2. The details of the photometric observations are reported by Maehara et al. (2008).

The spectral line evolution is exhibited by the representative spectra in figure 3. The top spectrum in figure 3a was taken just at the maximum. There exist strong emission lines of the Balmer series and He II. We can also see the Bowen blend C III/N III, and C IV/N IV, and He I in emission. Note that all these emission lines have singly peaked shape, while the spectrum in
Figure 2. Whole light curve of the 2007 superoutburst in V455 And generated with the data reported to VSNET. The down arrows indicate the date when the spectra were obtained. We took several more spectra during the long fading tail which is not displayed in this figure.

Figure 3. Long-term spectral evolution indicated by representative spectra. HJD 2454349 is around the maximum. HJD 2454355, 2454362, and 254364 are in the plateau phase. HJD 2454378, and 2454424 are in the fading tail. The singly-peaked strong Balmer and He II lines at the maximum became weaker, as the superoutburst proceeded. During the fading tail, the doubly peaked Balmer and He I emission lines grew again, as V455 And approached its quiescence state.

quiescence possesses doubly peaked emission lines (Araujo-Betancor et al. 2005). As time passed, these emission lines became weaker during the plateau phase, and doubly peaked shapes emerged. These line-profile variabilities imply the following scenario: 1) the accretion disk flared up by the outburst maximum,
and the singly peaked shape we observed is formed by significant contributions of the temperature inversion layer on the disk edge, and 2) the flaring disk gradually settled down during the plateau phase, and the inner part of the accretion disk got observable, which resulted in the doubly peaked emission lines.

During the long fading tail (HJD 2454378, and 2454424), the line spectra are very similar to that in quiescence. The equivalent width of the Balmer and He I emission lines, however, grew up, as the the system gradually faded.

4. Disk Evolution

We here summarize the plausible disk evolution during the superoutburst in WZ Sge stars which are suggested by the intensive spectroscopic observations of the nearly pole-on system, GW Lib, and the nearly edge-on system, V455 And during the 2007 superoutbursts.

The winds with a speed of 1,000 km s\(^{-1}\) blow just after the onset of the superoutburst, and they drop by the maximum. At the same time, the disk flares up, and the temperature inversion layer is formed on the accretion disk. This flaring disk, and this layer gradually settle down during the plateau phase. After the rapid decline from the plateau phase, the emissivity at the continuum gradually returns to the value in quiescence, as that in the Balmer and He I lines do it more gradually.

More detailed analyses and quantitative discussion will be published in our forthcoming papers.

Acknowledgments. The authors are grateful to the observers for reporting their precious data to VSNET. This work is partly supported by a grant-in-aid from the Ministry of Education, Culture, Sports, Science, and Technology (No. 17204012, 17740105).

References

Araujo-Betancor, S., et al. 2005, å, 430, 629
Baba, H., et al. 2002, PASJ, 54, L7
Hagen, H.-J, et al. 1995, A&AS, 111, 195
Kato, T., et al. 2004, PASJ, 56, S1
Maehara, H. et al. 2008, in this volume
Maza, J., & Gonzalez, L.E. 1983, IAU Circ., 3854
Nogami, D. 2007, in Proceedings of the 7th Pacific Rim Conference on Stellar Astrophysics, ASP Conf. Ser. Vol. 362, eds. Y. W. Kang et al. (San Francisco: ASP), 195
Nogami, D., & Iijima, T. 2004, PASJ, 56, S163
Osaki, Y. 1996, PASP, 108, 39
Thorstensen, J.R., et al. 2002, PASP, 114, 1108
Uemura, M., et al. 2008, PASJ, 60, 227
van Zyl, L., et al. 2004, MNRAS, 350, 307
Woudt, P.A. & Warber, B. 2002, Ap&SS, 282, 433