

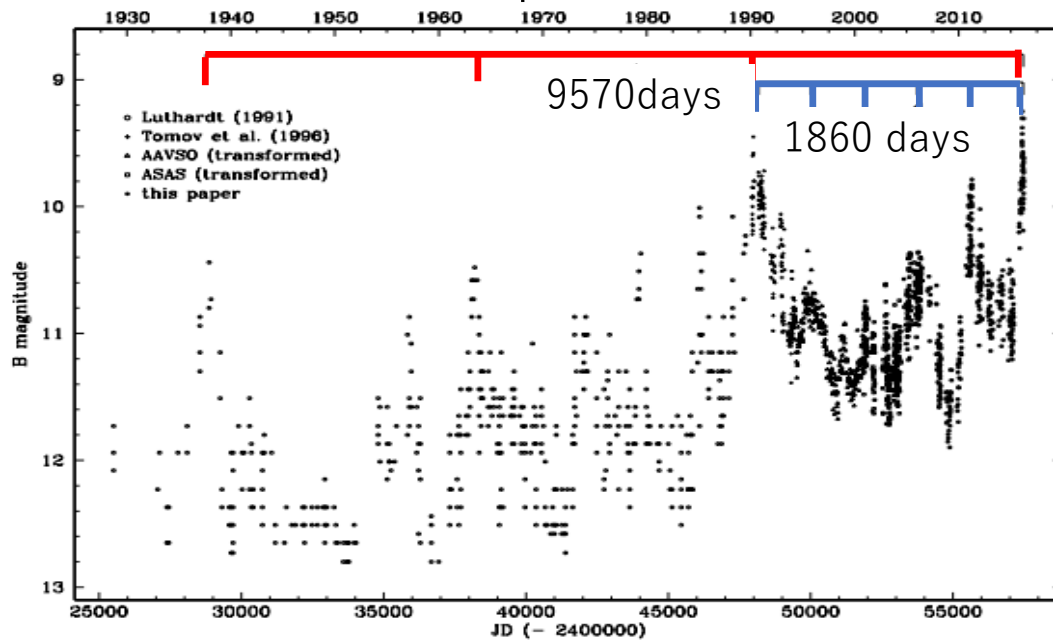
# Spectroscopic observations of MWC560

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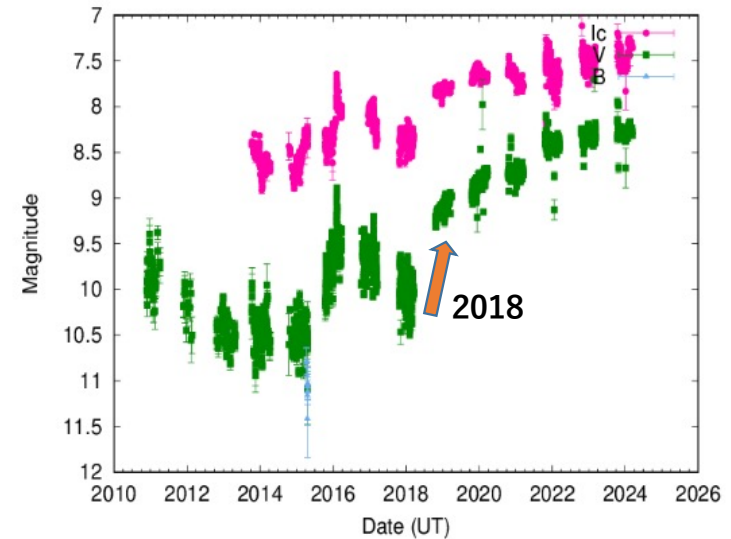
Symbiotic stars, Prague, - June 2024

# MWC560

- Symbiotic star with jet
- WD+M5 III
- An outflow of up to  $-6000$  km/s was observed (Tomov 1990).



1928 – 2016 Light curves (Munari et al. 2016)



2010 – 2024 Light curves (KWS)

- **Irregular brightening in 2018** (Goranskij et al., 2018)
- Three years after the brightening, many emission lines changed to absorption lines. (Goranskij et al. 2021)

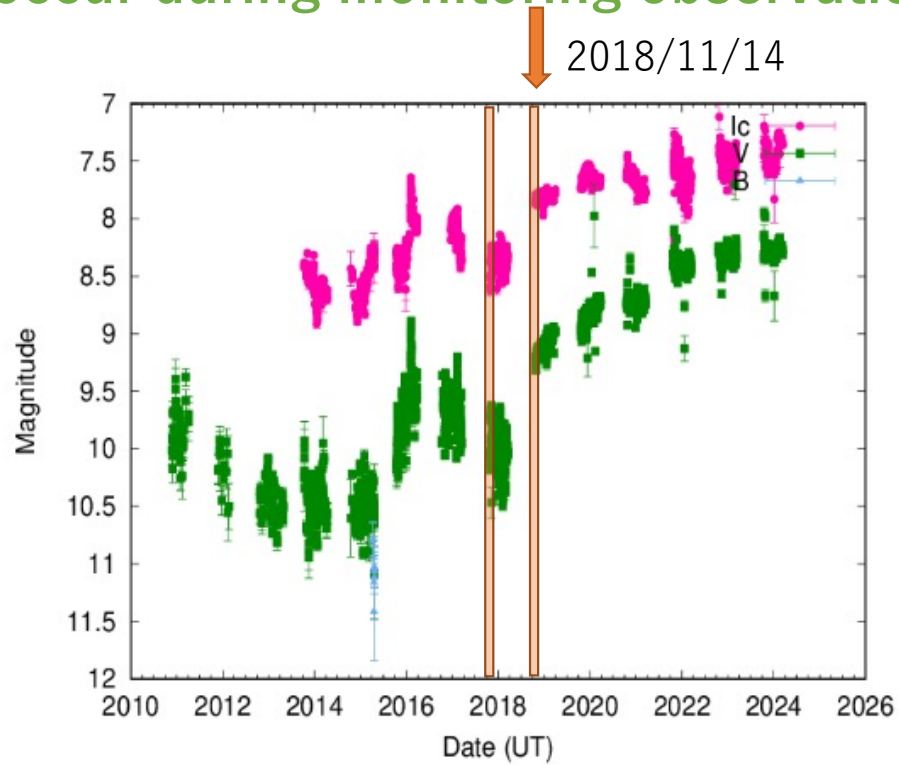
# Observations

Site	Telescope / Resolutions	Numbers of observations
Okayama University of Science Observatory (OUSO)	Celestron11 (28cm Telescope) / $R \approx 400$ (DSS-7)	<b>83 nights</b> from Mar. 26, <b>2016</b> to Jan. 21, <b>2020</b> .
Okayama Astrophysical Observatory (OAO) <small>(*OAO ended its project at NAOJ in 2018, and is now operated by a group led by the Tokyo University of Science.)</small>	188cm Telescope / $R \approx 65000$ (HIDES-F)	<b>61 nights</b> from Dec. 25, <b>2018</b> to Apr. 12, <b>2022</b> .
Bisei Astronomical Observatory (BAO)	101cm Telescope / $R \approx 1500$ (300 lines / mm) • $R \approx 3100$ (600 lines / mm)	- <b>10 nights</b> from Dec. 27, <b>2019</b> to Mar. 13, <b>2024</b> .(Low) - <b>2 nights</b> from Jan. 6, <b>2024</b> to Mar. 13, <b>2024</b> .(Mid)



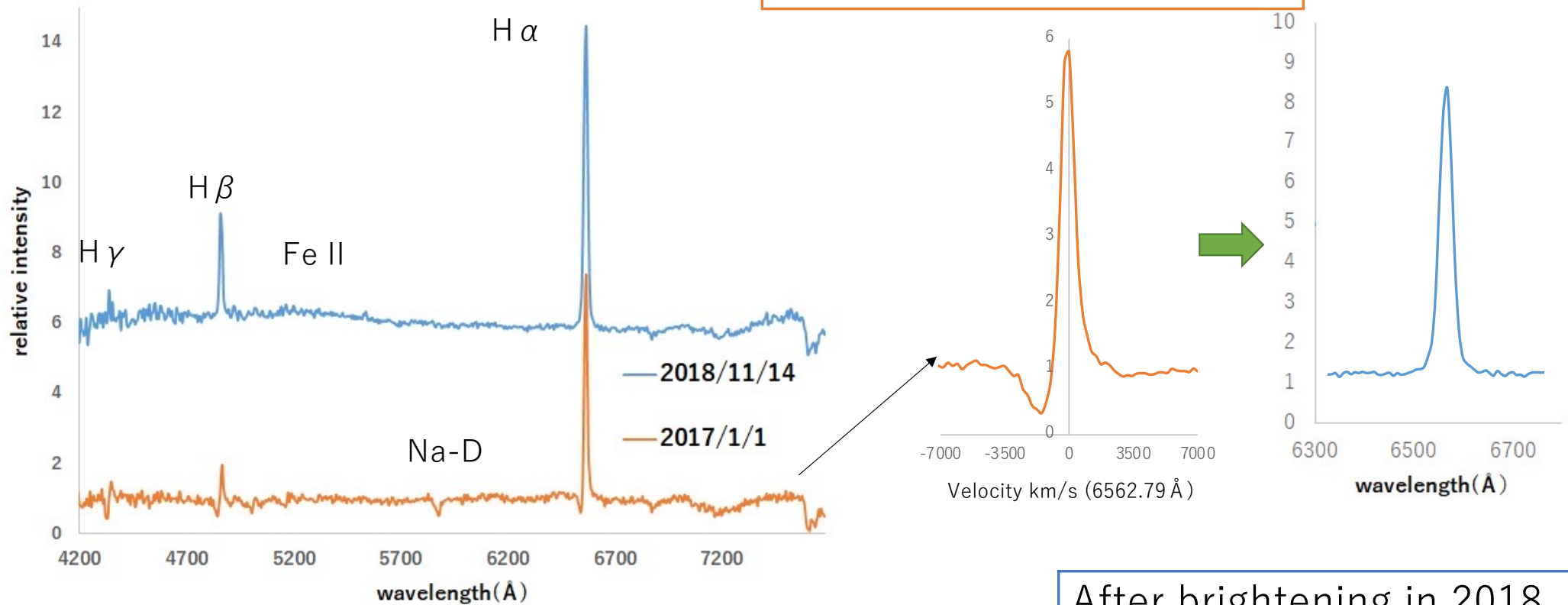
# Observations at OUSO

Changes occur during monitoring observation.



# High-velocity absorption lines were disappeared.

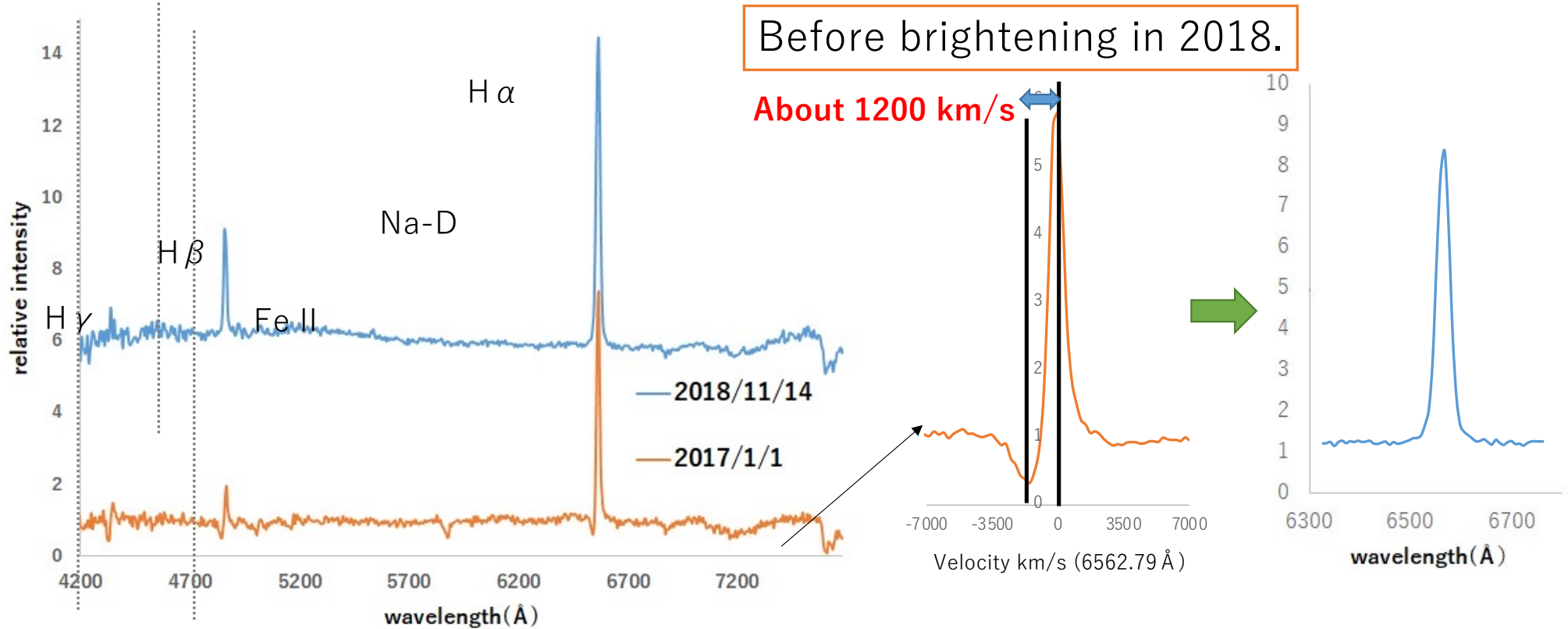
Before 2018 brightening.



Spectra on 2017/1/1 + 2018/11/14

After brightening in 2018.

# High-velocity absorption lines were disappeared.



Before brightening in 2018.

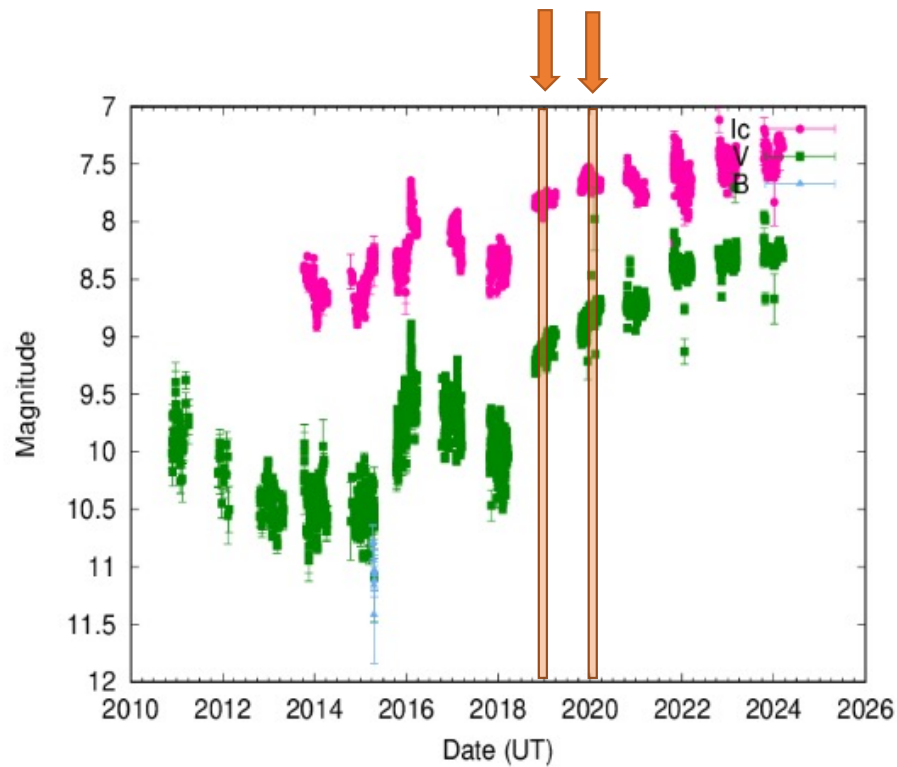
About 1200 km/s

After brightening in 2018.

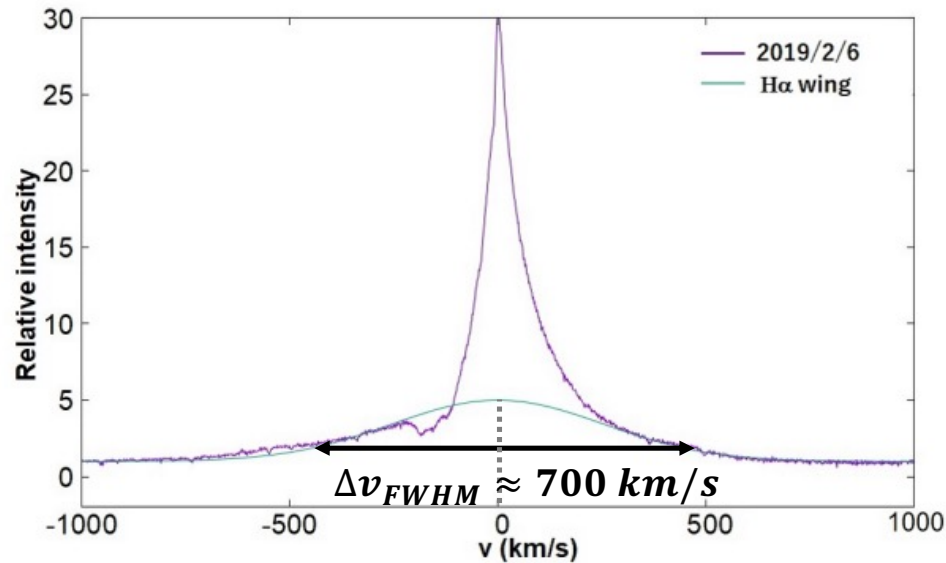
Spectrum on 2017/1/1 + 2018/11/14

# Observations at OAO

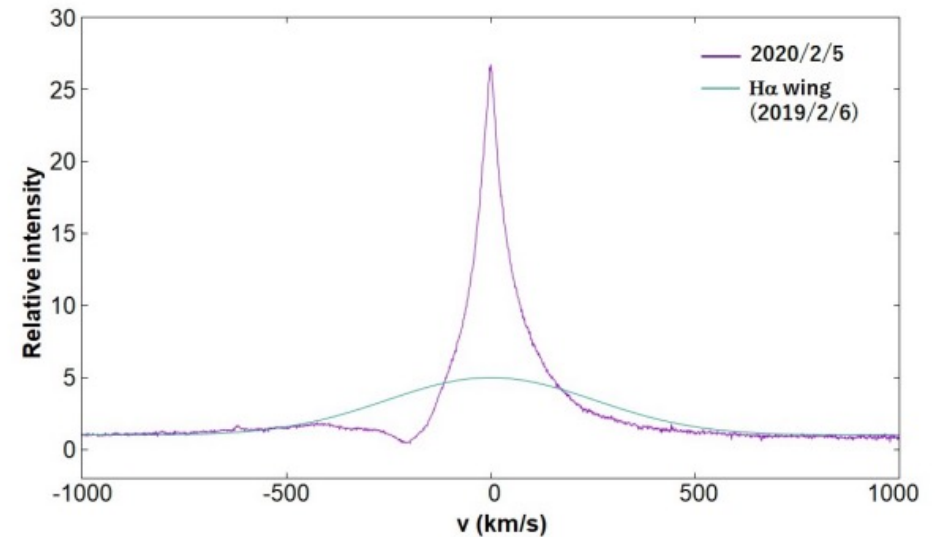
When the spectra changed, we started high-resolution spectral observations.



## Low-velocity absorption lines were detected!



**Fig. 4.** An enlarged view of the H $\alpha$  emission line on 2019 February 6 obtained by high dispersion spectroscopy (purple line). The horizontal axis is velocity. The vertical axis is relative intensity. The green line is the Gaussian fitting of the H $\alpha$  line, the new outflow component (wing) identified since 2018 November, with a velocity of about  $v_{FWHM} \approx 700 \text{ km s}^{-1}$ .

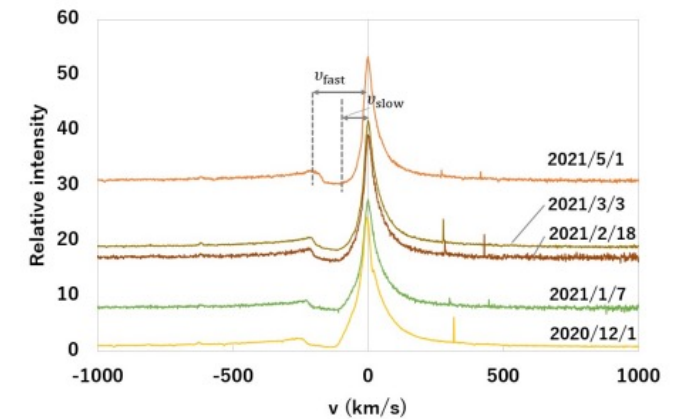
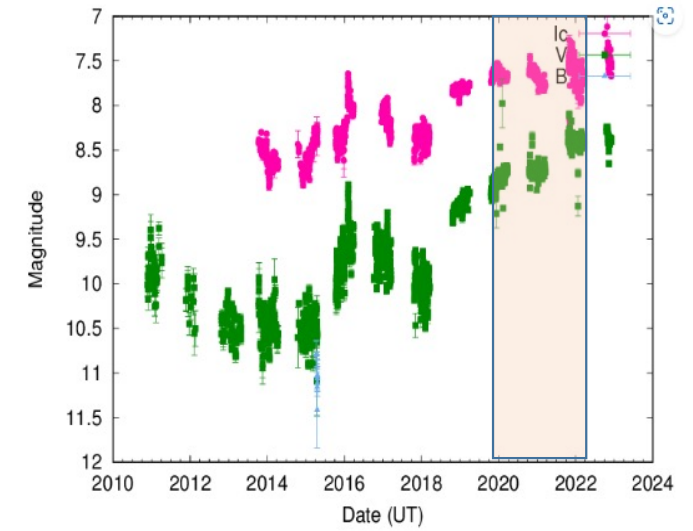
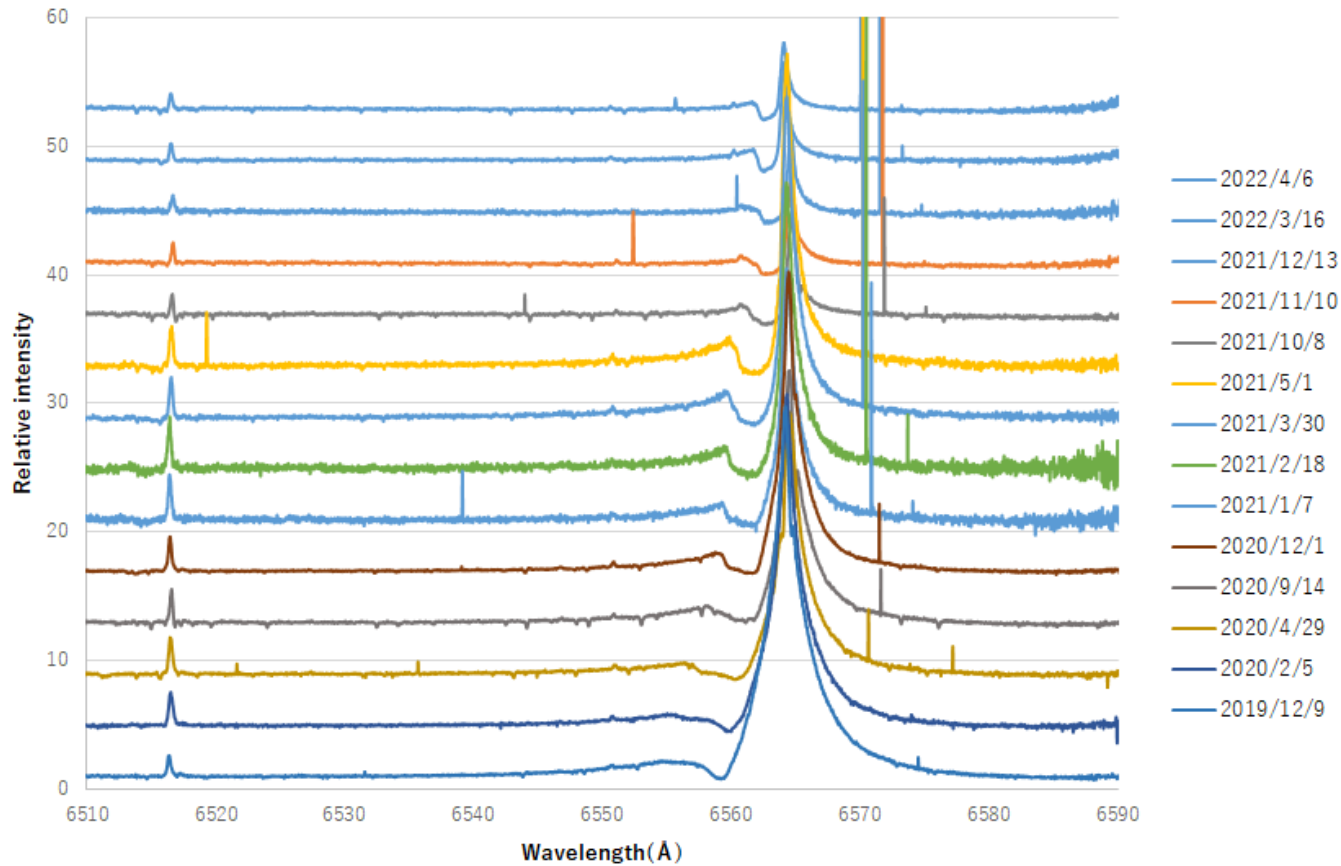


**Fig. 6.** Same as Fig. 4 but for the spectrum on 2020 February 5. The green line is the Gaussian fitting of the H $\alpha$  line on 2019 February 6 same as Fig. 4.

**Weak high-velocity components were detected in 2019 and disappeared in 2020.**



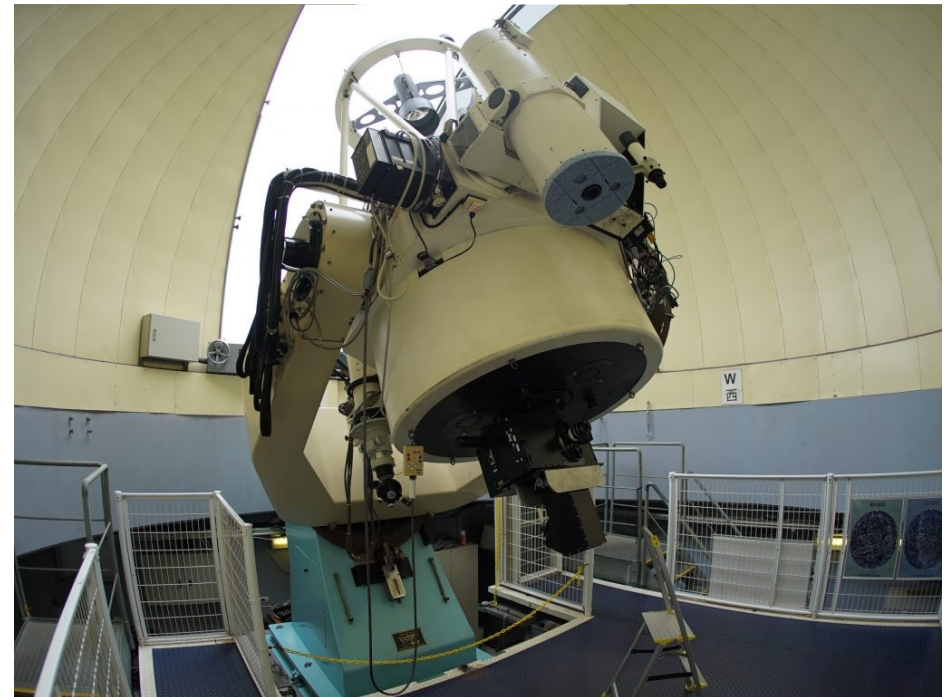
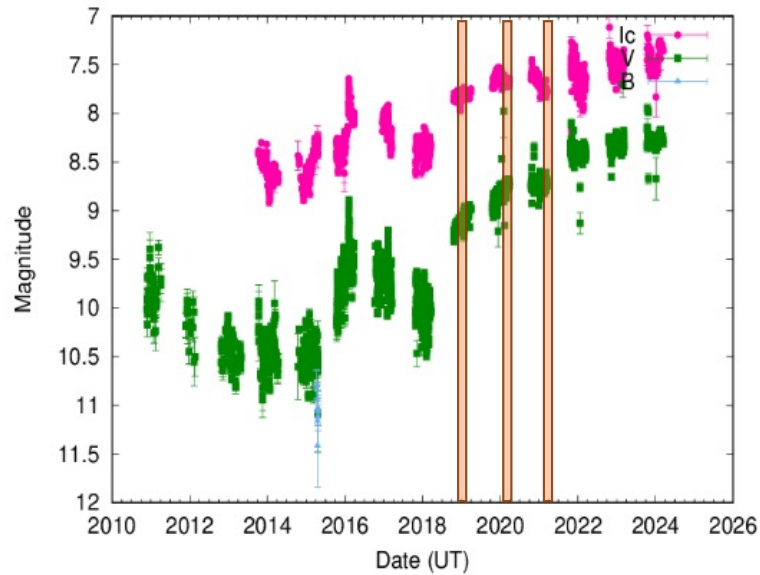
# Evolution of OAO spectra : H $\alpha$



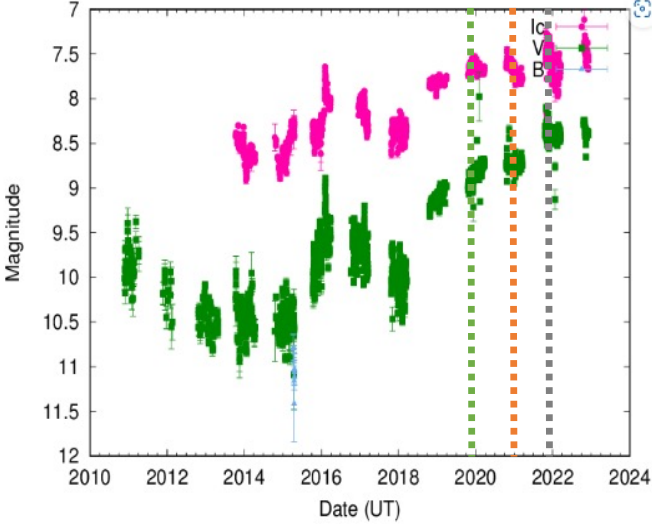
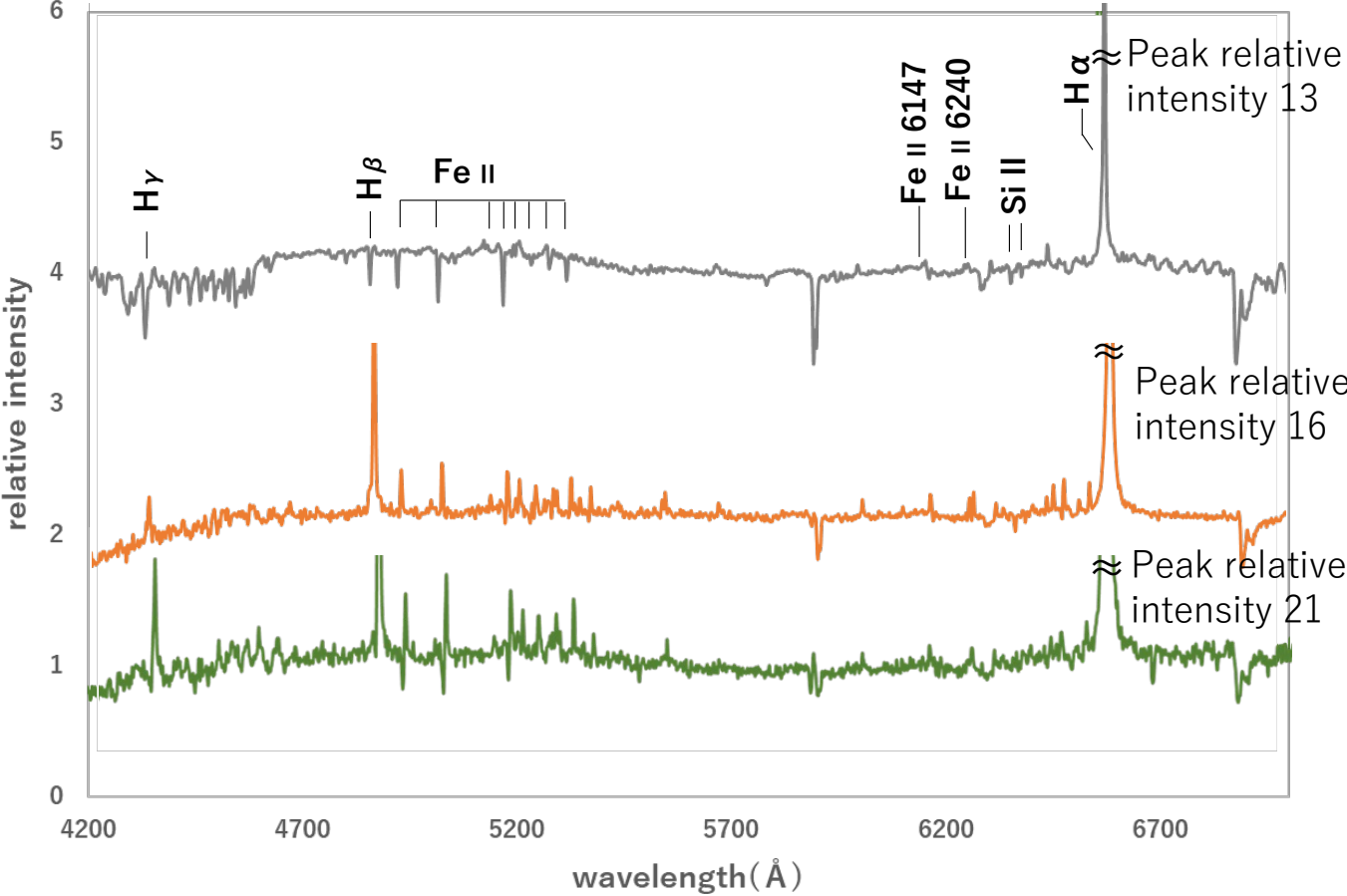
**Fig. 7.** Part of the spectrum from 2020 December 1 to 2021 May 1, when the wing is no longer visible. The spectra were offset according to the number of days elapsed. Bat-pixels are seen between 300 km s<sup>-1</sup> and 500 km s<sup>-1</sup>. The determine for fast and slow outflow velocities shown for the spectrum of 2021 May 1 are described in the discussion.

# Observations at BAO

Many spectral lines changed during monitoring observations at the Bisei Astronomical Observatory.



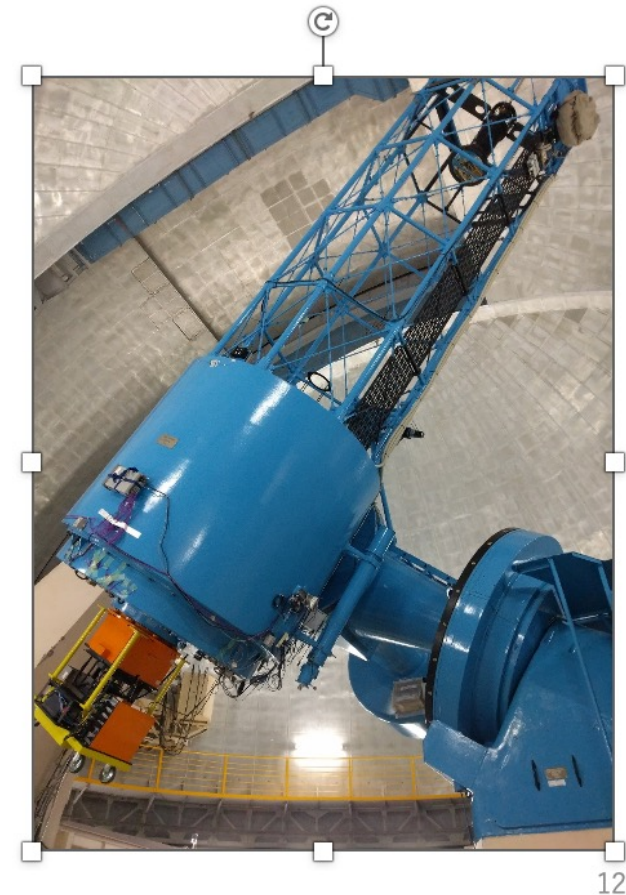
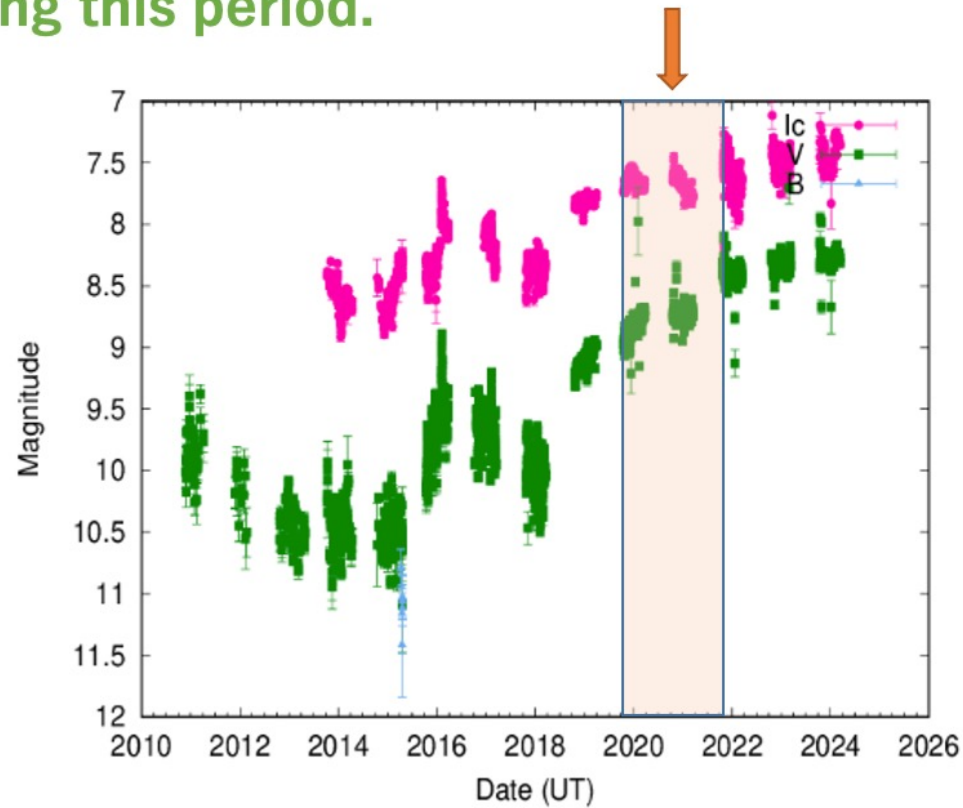
# The emission lines changed to the absorption lines.



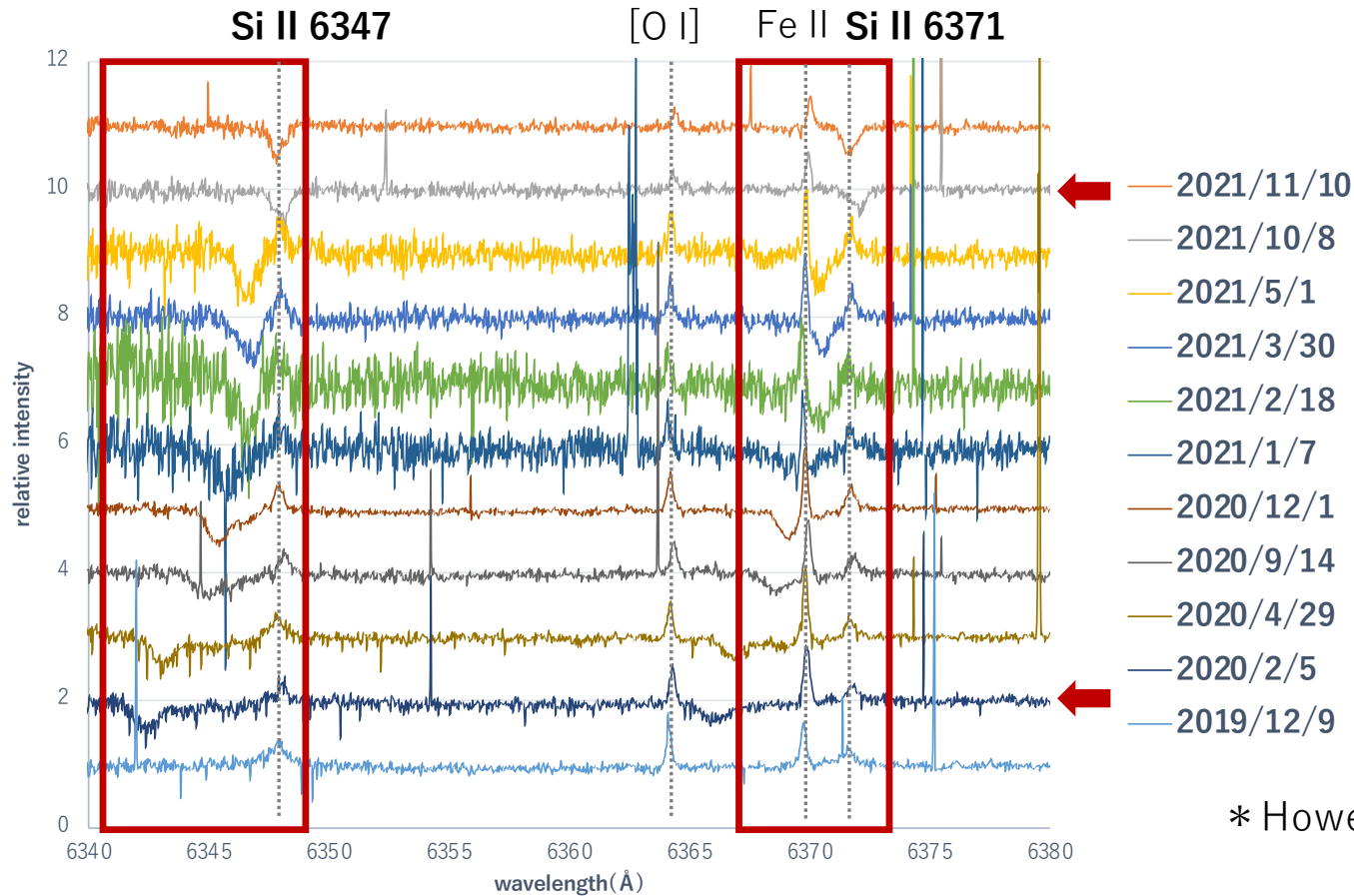
2021/12/10(outburst+about 3 years)  
 2020/12/12(outburst+about 2 years)  
 2019/12/27(outburst+about 1 years)

# Observations at OAO

Changes were observed in other lines during this period.



# Evolution of OAO spectra : Si II (6347, 6371 Å)



Absorption components start to be seen on Feb. 5, 2020.



Complete disappearance of the emission line component on Oct. 8, 2021.

\* However, due to the nearby He II, so it may be blended.

## Discussion 1. Outflow velocity

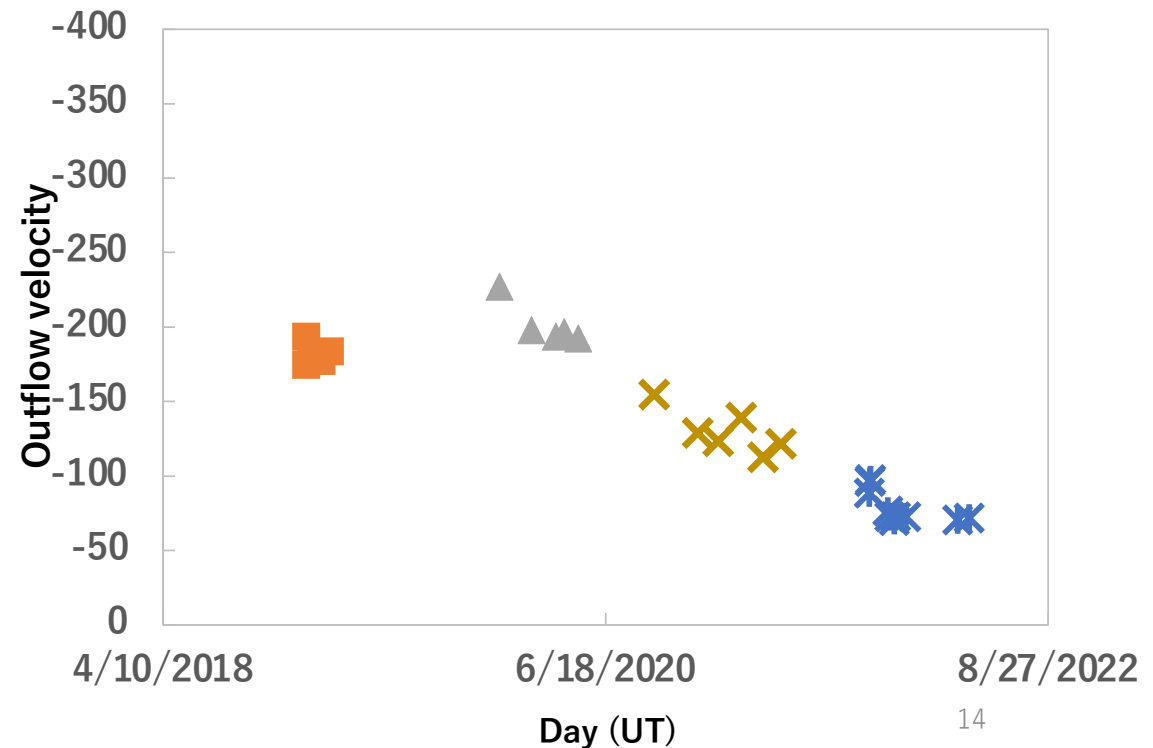
- Change of outflow velocity.
  - The velocity difference between the peaks of the absorption line and the emission line is defined as the outflow velocity.

Its speed slows down during the brightening period.

- Deceleration at about 30m/s per day
- Until 2021, the absorption line region was apart from WD with approximately 1.4 au.
- It reached about 3.9 au.

$$(M_{WD} = 0.9M_{\odot}) \quad \downarrow$$

Would the white dwarf's gravity slow the expansion of the shell?



## Conclusion

### (1) The evolution of the H $\alpha$ line

- The wing component of the H  $\alpha$  was shown during the brightening, and the **wing disappeared on Feb. 5, 2020.**
- Outflow velocity was decelerated, and appeared to be constant after Dec. 13, 2021.

### (2) The evolution of Si II (6371, 6347 Å) lines

- Si II were emission line until Dec. 9, 2019.
- **Absorption lines started to appear on the blue side on Feb. 5, 2020.**
- The line will be fully absorbed on Oct. 8, 2021.

- The process of pseudo-light sphere formation due to the outburst should have been observed.