M型矮星YZ CMiのフレアの測光分光同時観測で迫るプラズマ噴出の統計性

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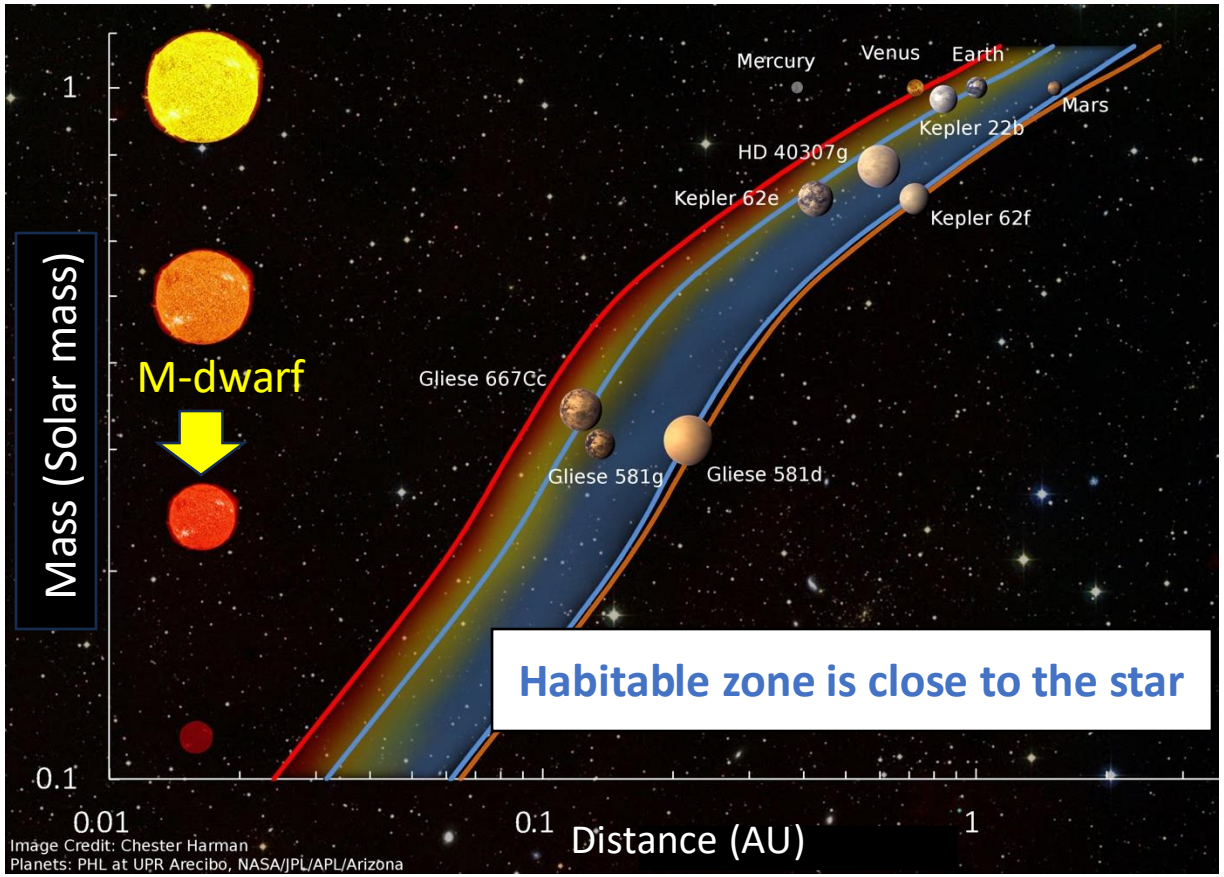
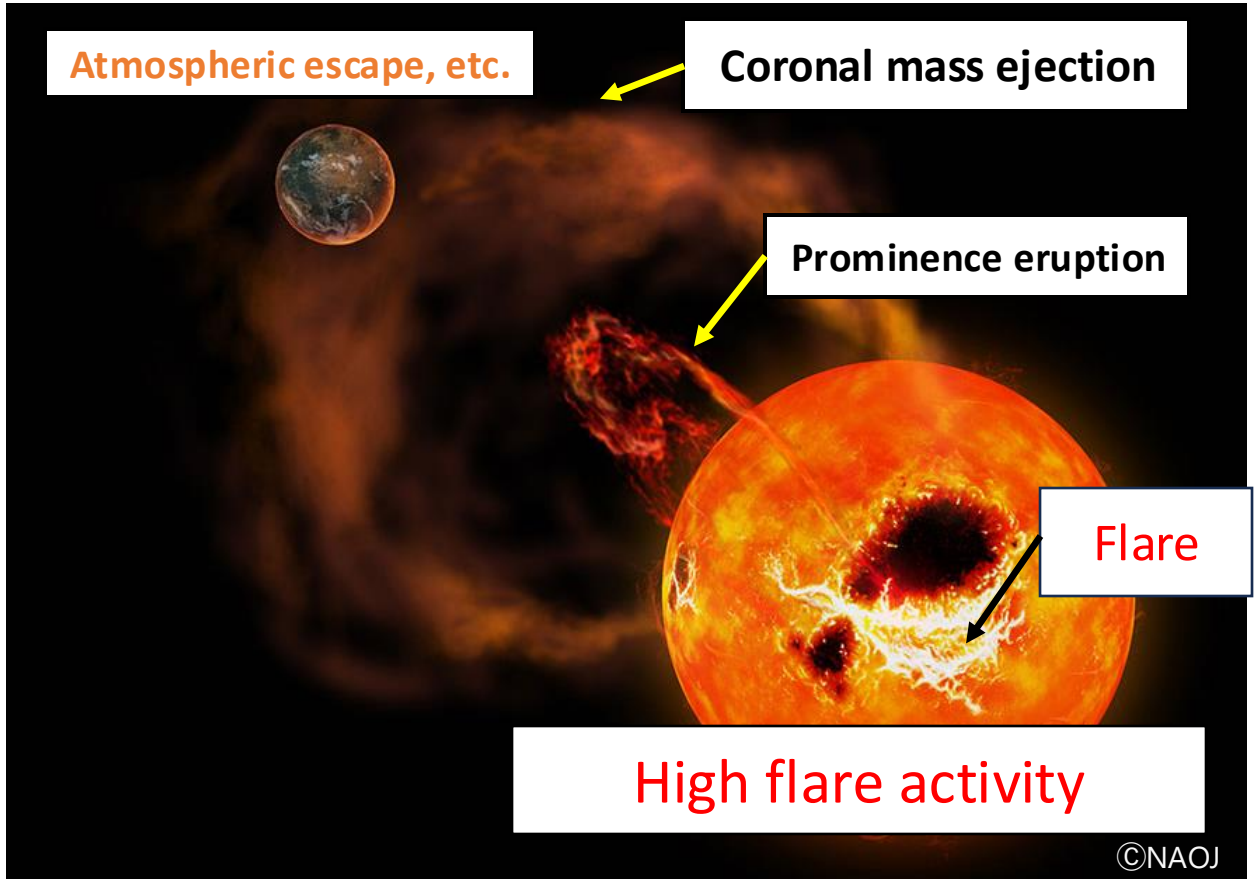
Kajikiya et al., 2025a; Kajikiya et al., 2025b

Background: Habitability of Exoplanets Around M-dwarfs

- M-dwarfs : Main sequence stars with surface temperatures of ~2500-3900K
  - Various M-dwarf systems having habitable planets ･･･Trappist-1 e, f, g, Proxima Centauri b

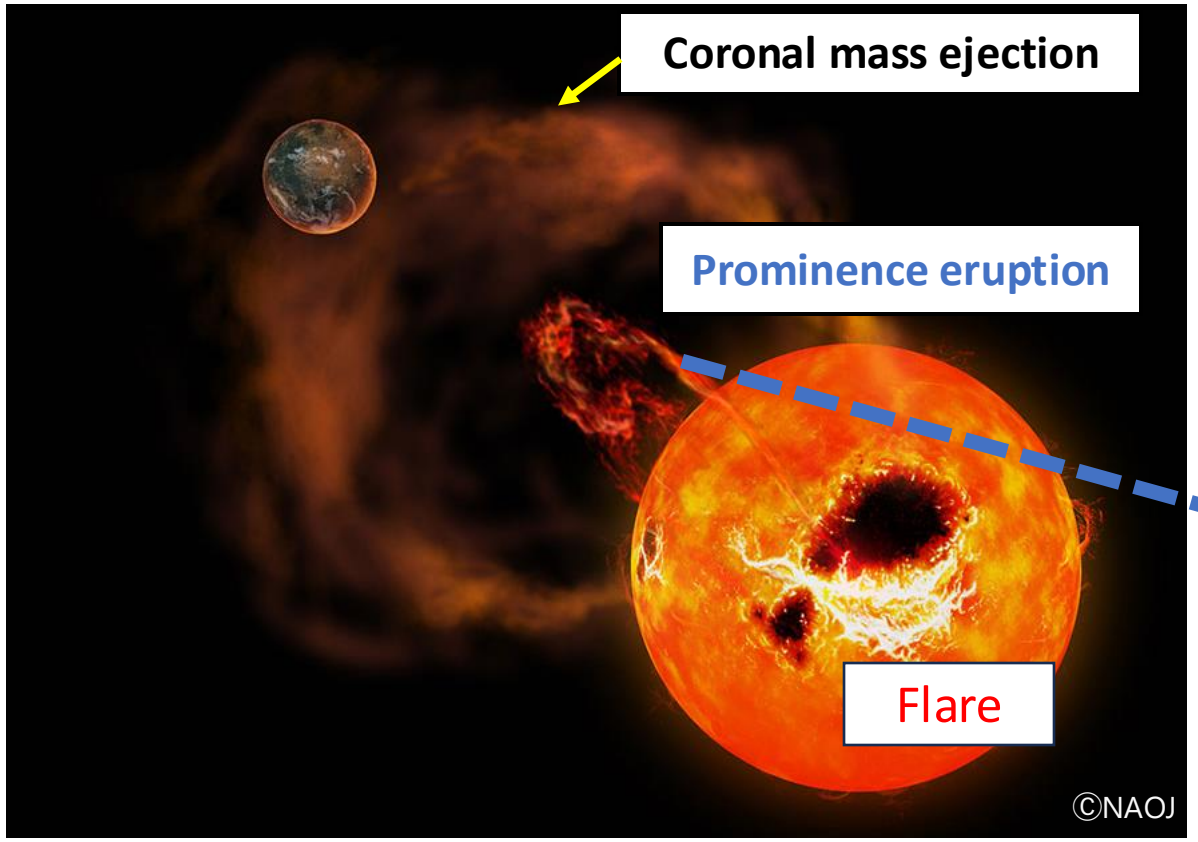




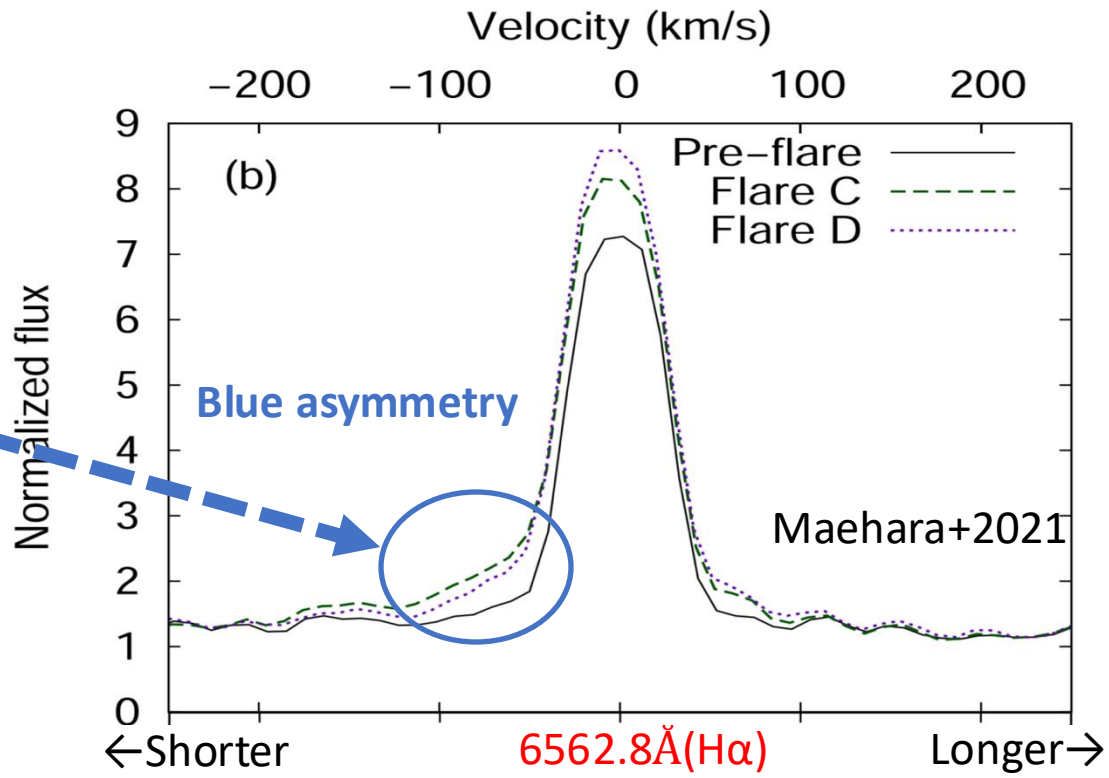
Understanding flare/mass ejection in M-dwarf is important

Motivation(1): Blue/Red Asymmetry in Hα

- A candidate prominence eruption can be observed as a blue asymmetry



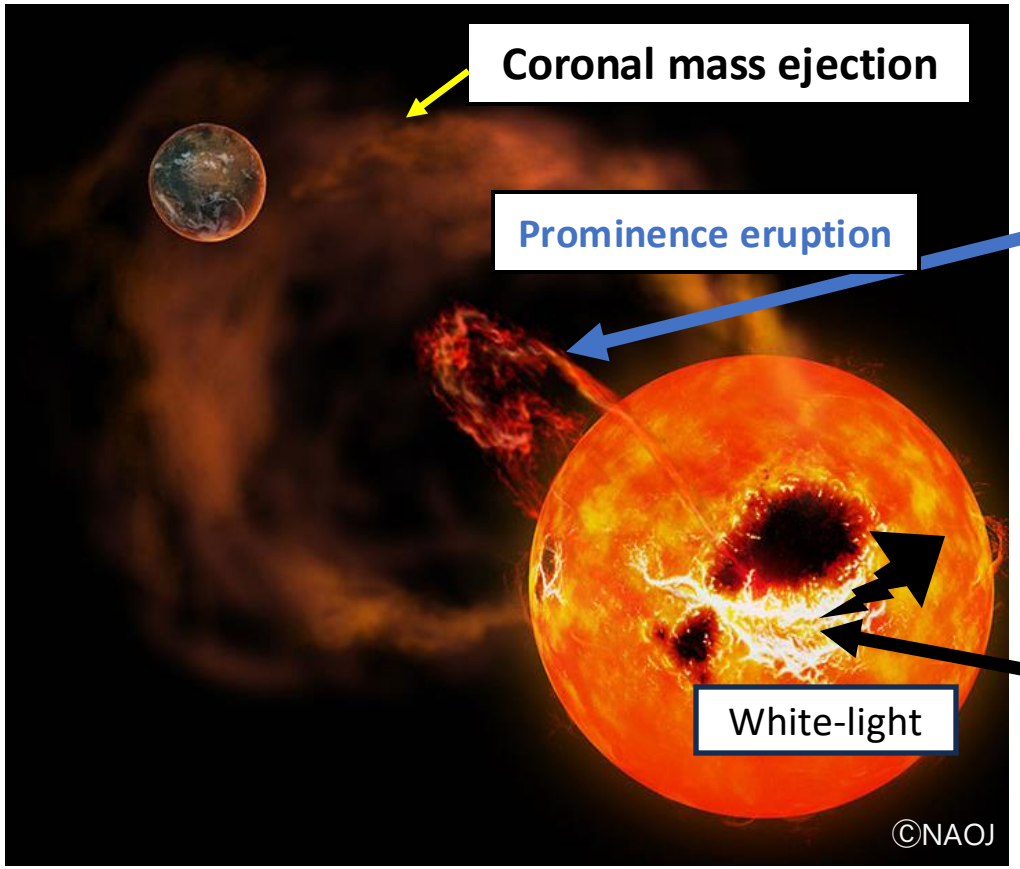
Blue asymmetry in M-dwarf flare

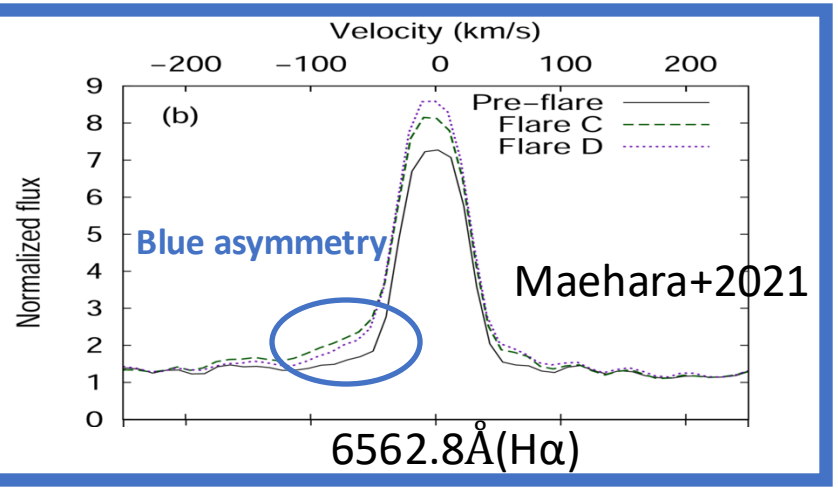


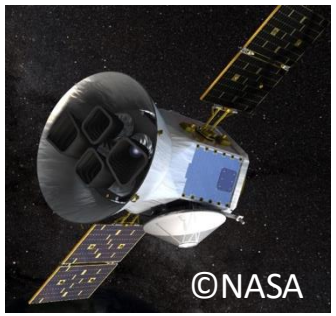
- Many of these asymmetries show velocities of ~100 km/s and durations of >20 minutes, with an association rate of ~20% (e.g., Notsu et al., 2024).
- However, the relation between these asymmetries and flare, spot-properties is unclear.

Motivation(2): Simultaneous Observation with TESS

Simultaneous observations with TESS are crucial for understanding prominence eruptions.







- **White-light flares**
  - **Radiation from footpoints**
- **Bolometric energy**
- Rotational phase
- Starspots

- Simultaneous observations→relationships between **prominence eruptions** and flare, spot-properties.
- **<u>However, such simultaneous observations with TESS are still rare.</u>**

Observation Summary

Target star : Active M-dwarf YZ CMi (M4.5V)

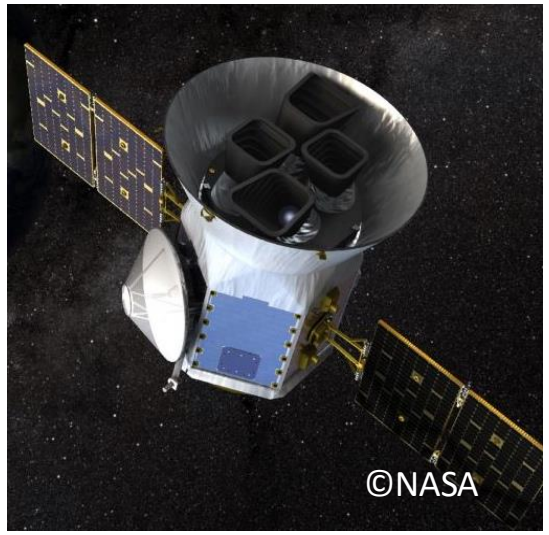
T_{eq} : 3300K, R_{star} : $0.3R_{\odot}$, P_{rot} : 2.8 day

6-7 flares per day → multiple flares can be detected

Photometry

Space) TESS

- 6000～10000Å
- Time cadence :20sec/2min
- January 14, 2021 - February 8, 2021



TESS

Seimei 3.8m

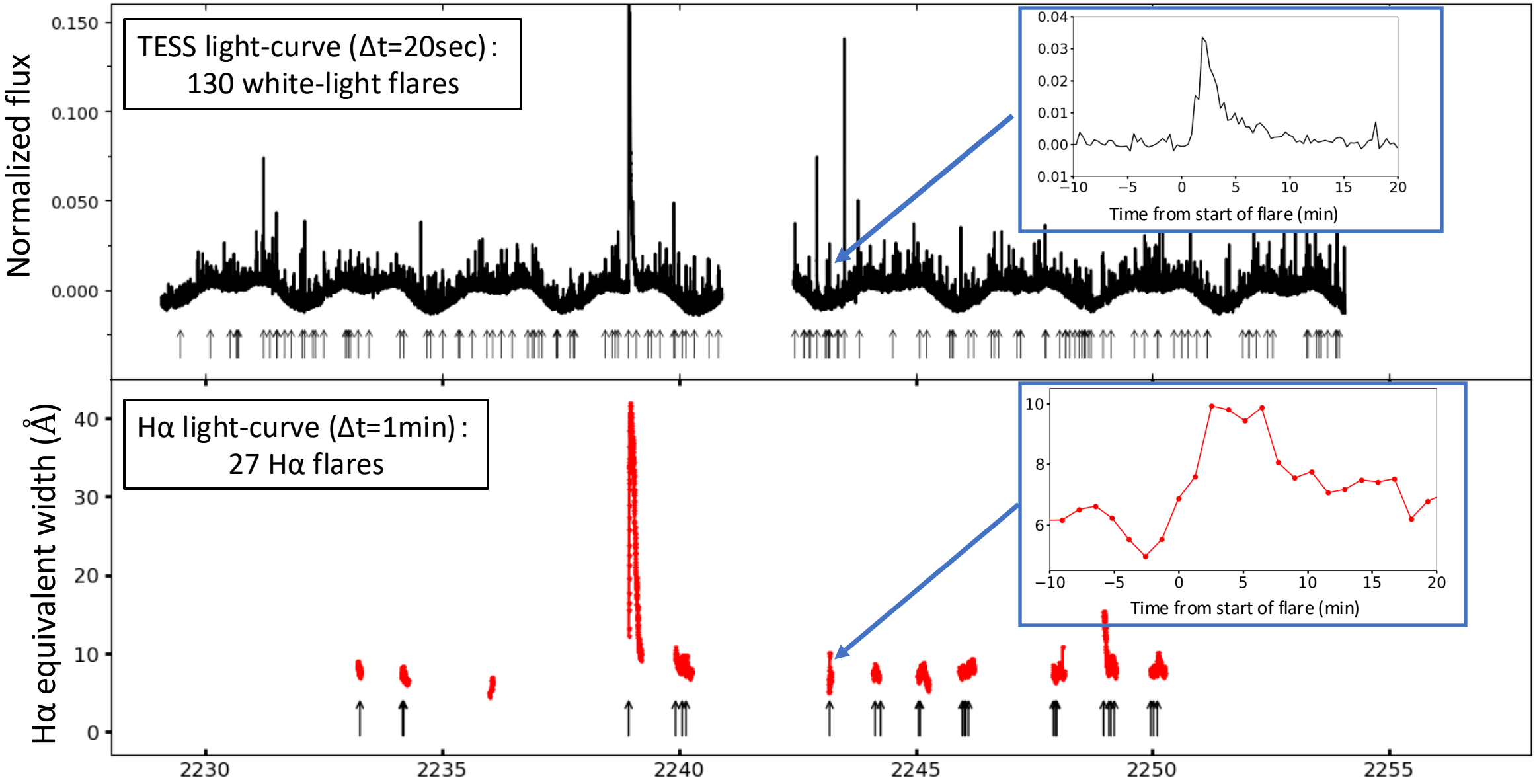
Optical(Hα) spectroscopy (12 nights)

Japan) **Seimei 3.8m (KOOLS-IFU)**

- 5800-8000Å, λ/Δλ~2000
- Time cadence :**~1min**

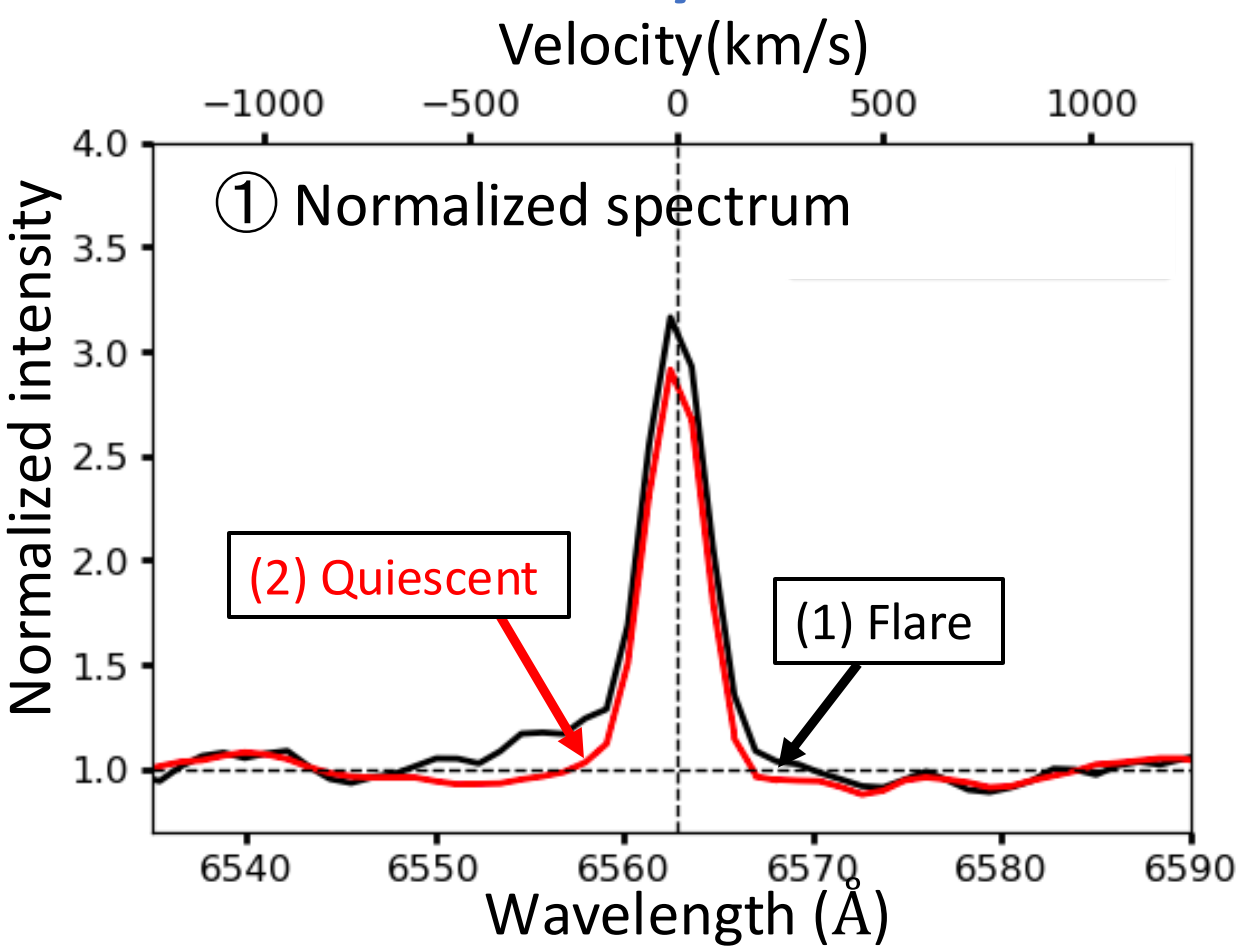
<<Previous study : **~5min** (e.g., Notsu+2024)

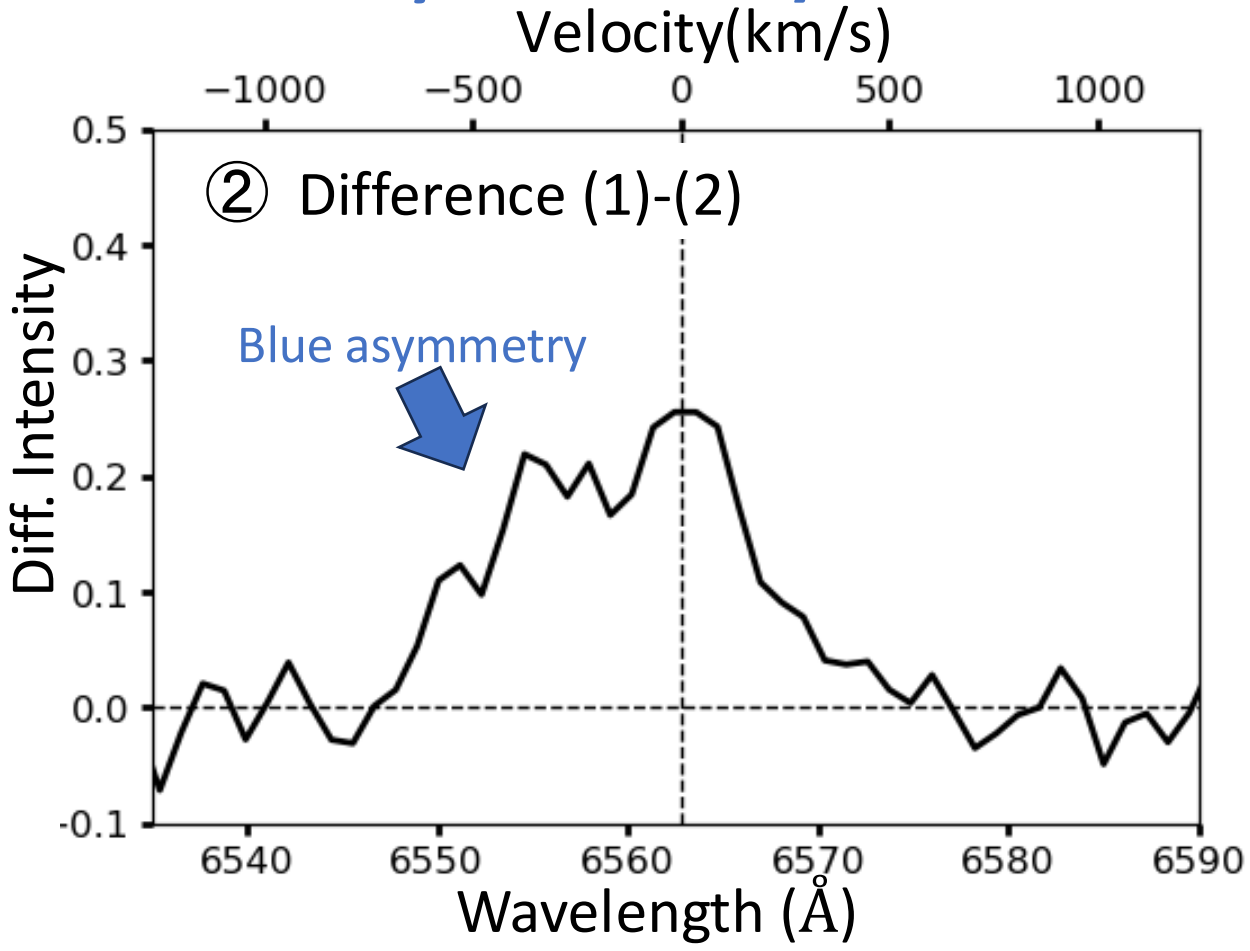
Light-curves and Flare Detection



Kajikiya+2025a

Analysis: Evaluation of Asymmetry

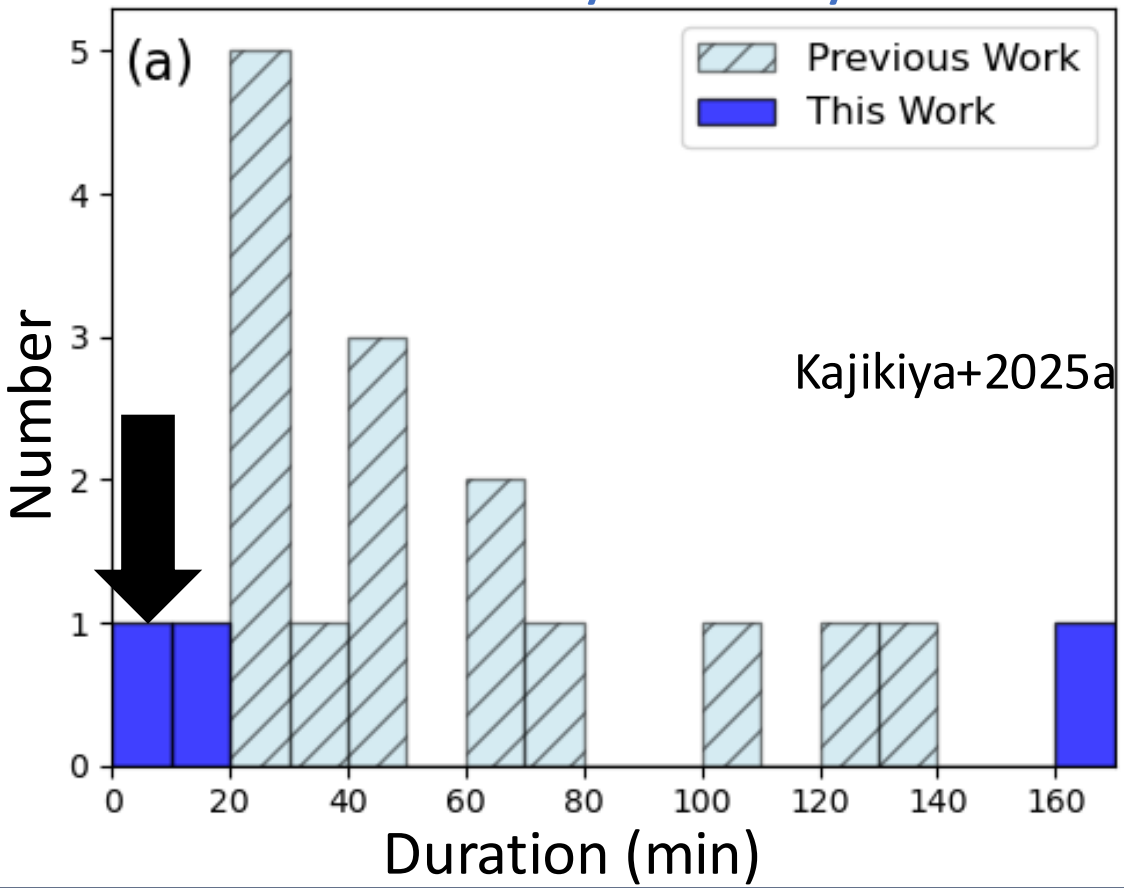




- These differential spectrum enable to evaluate the asymmetry of the line profile.
- Out of the 27 flares, 3 flares show blue asymmetries and 5 flares show red asymmetries in the Hα line profile.

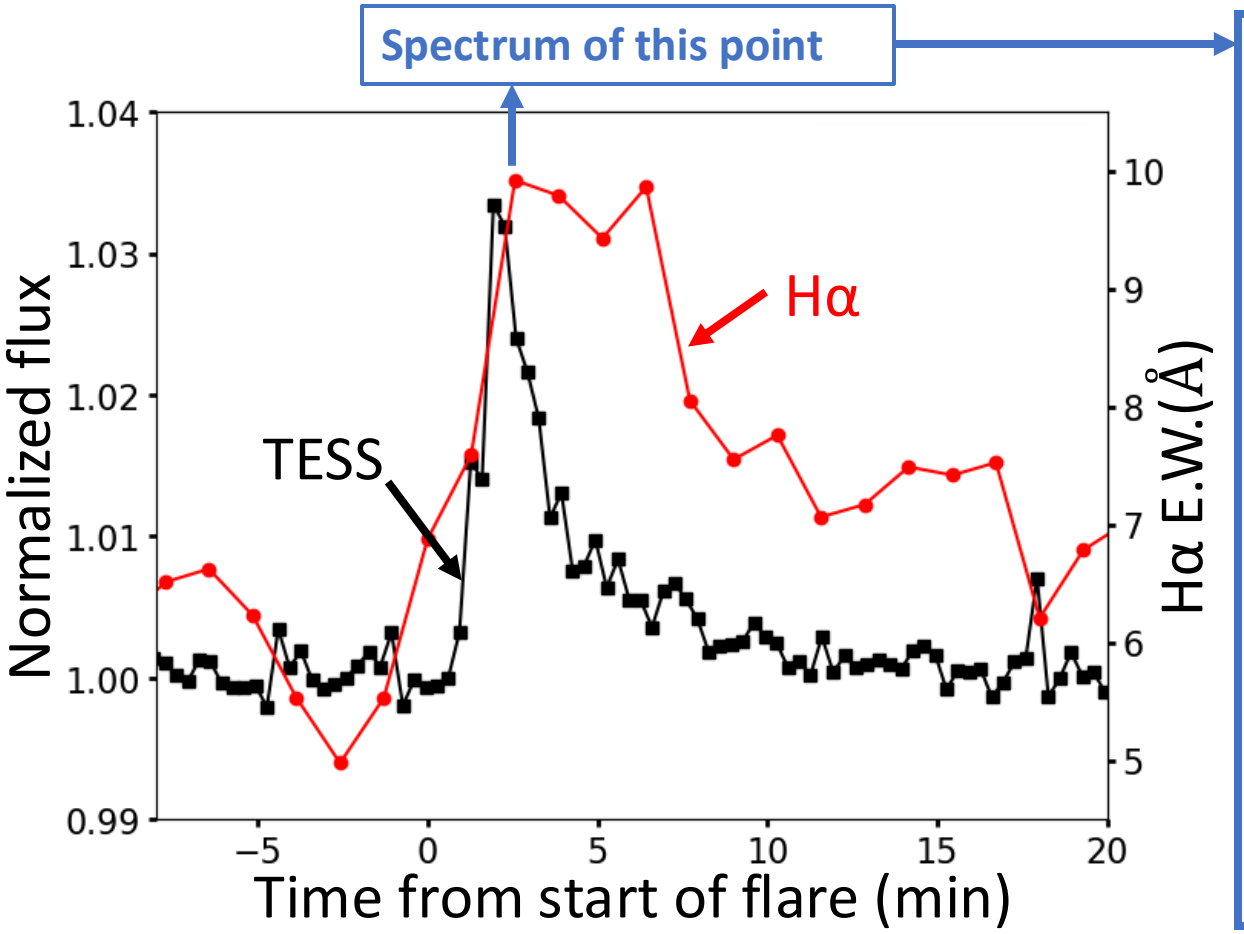
Result(1) : Short-Duration Blue/Red Asymmetries

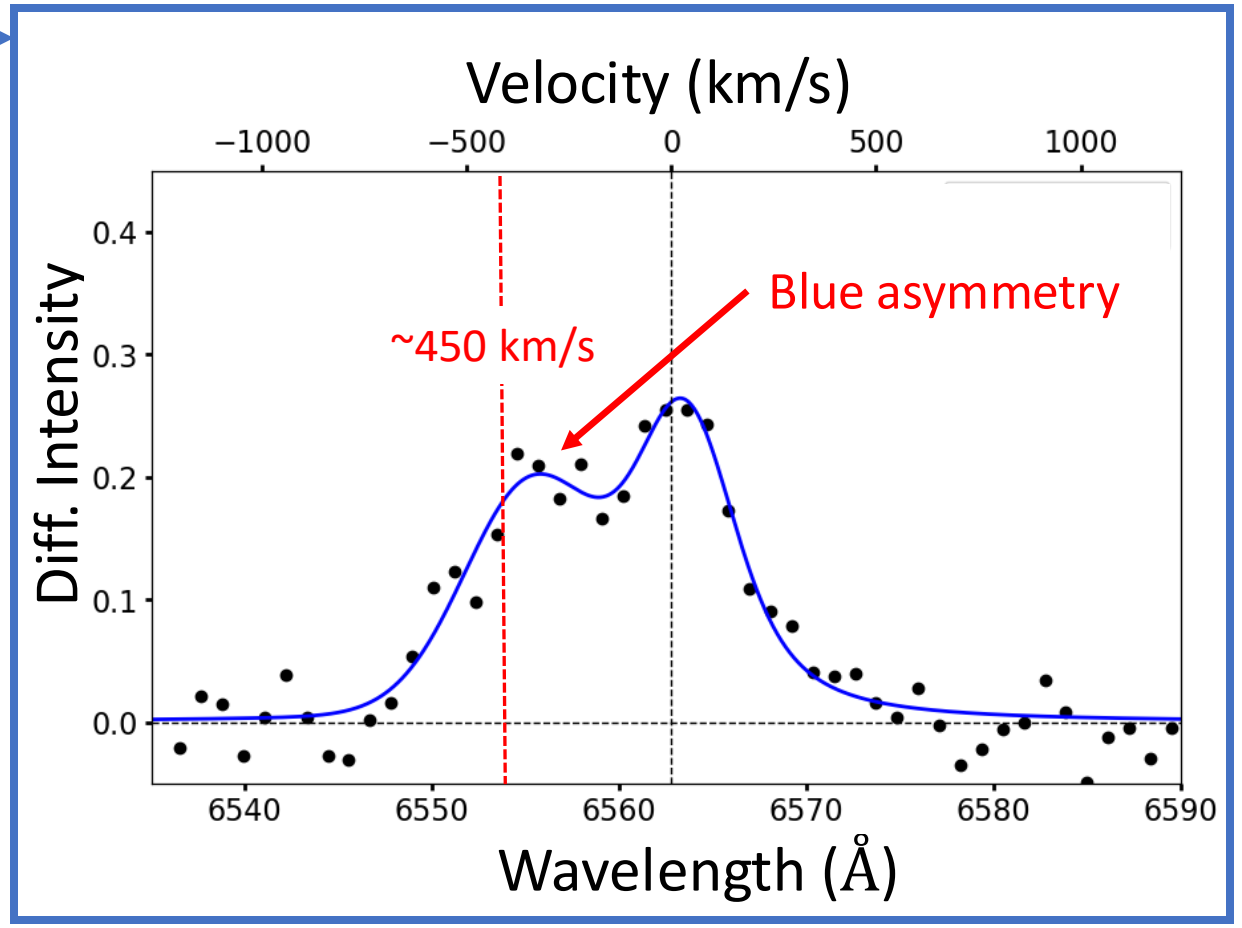
Blue asymmetry



- We discovered short-duration events (<20min) (Kajikiya+2025a).
- Previous studies may not have time-cadence enough for such short events
  (Vida+2018, Honda+2018, Maehara+2021, Notsu+2024)

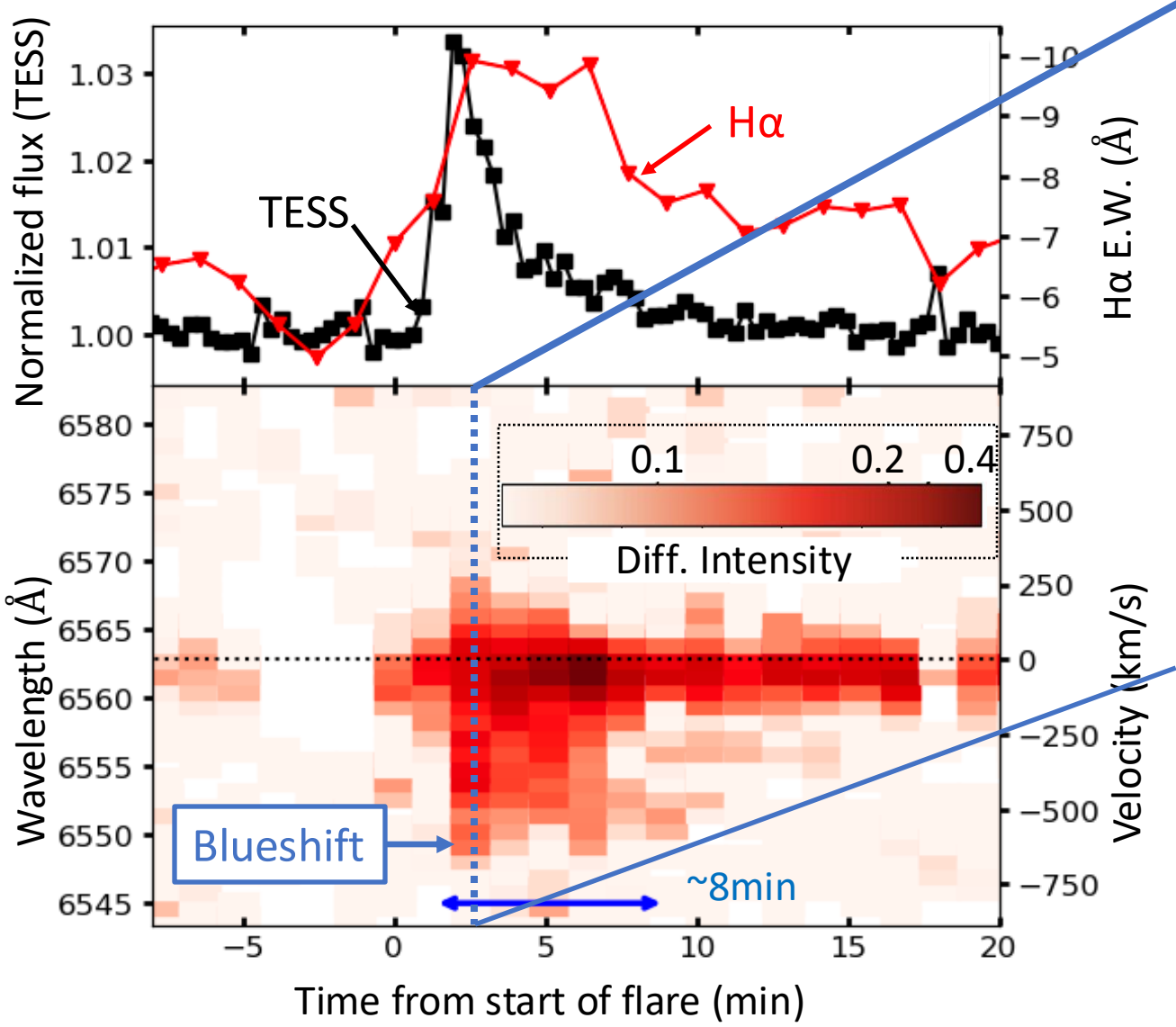
Result(2) : Rapid, Short-Duration Blue Asymmetry

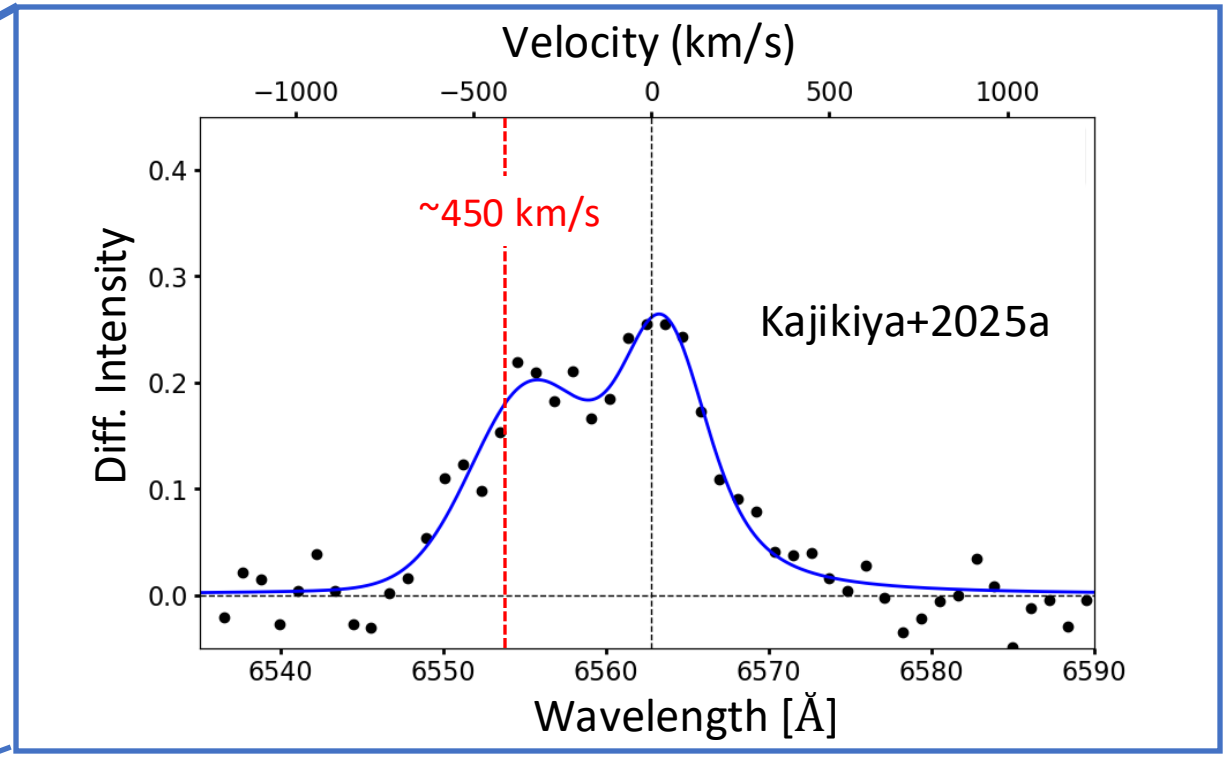




- **Bolometric energy** derived from TESS flux: E_{bol}~ 8×10^{31} erg **(~ the largest solar flares)**
- **V ~ 450 km/s** >> ~100 km/s (e.g., Maehara+2021, Inoue+2024, Notsu+2024)

Result(2) : Rapid, Short-Duration Blue Asymmetry





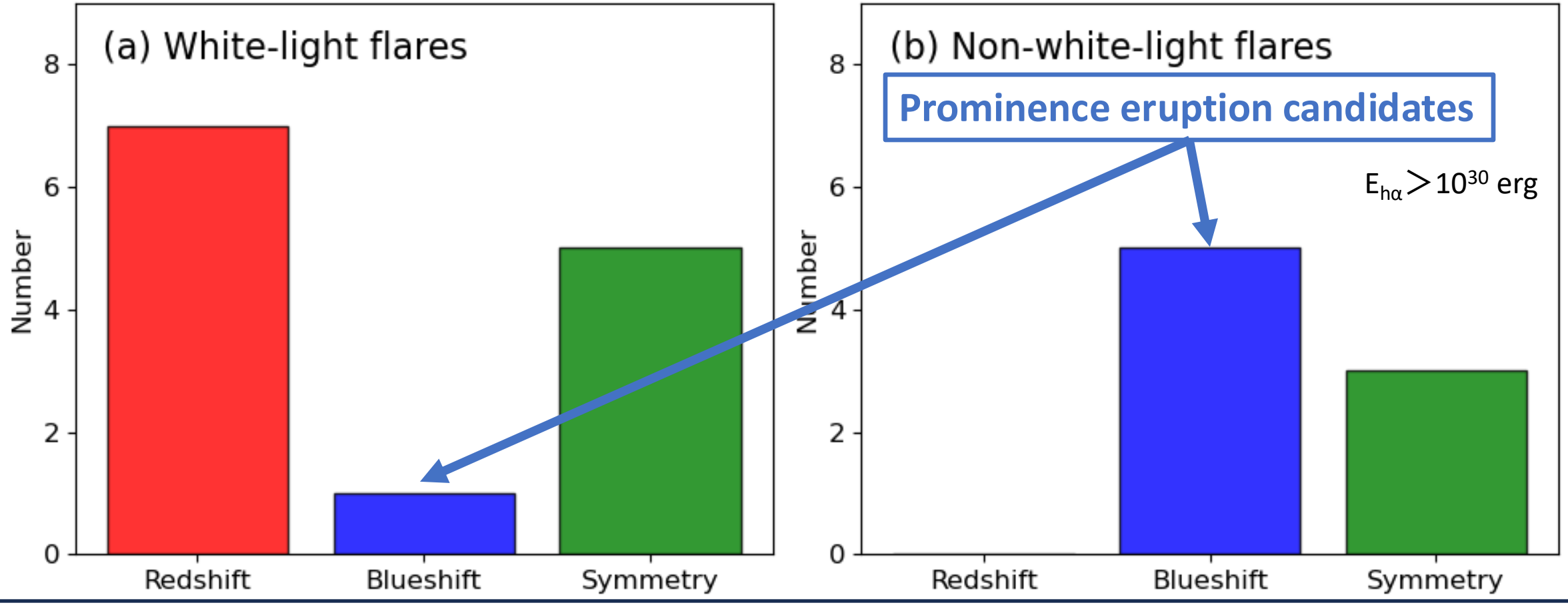
Properties of blue asymmetry

- V~ 450km/s>> ~100km/s (Previous study)
- Duration~8min (record shortest)

→Prominence eruption

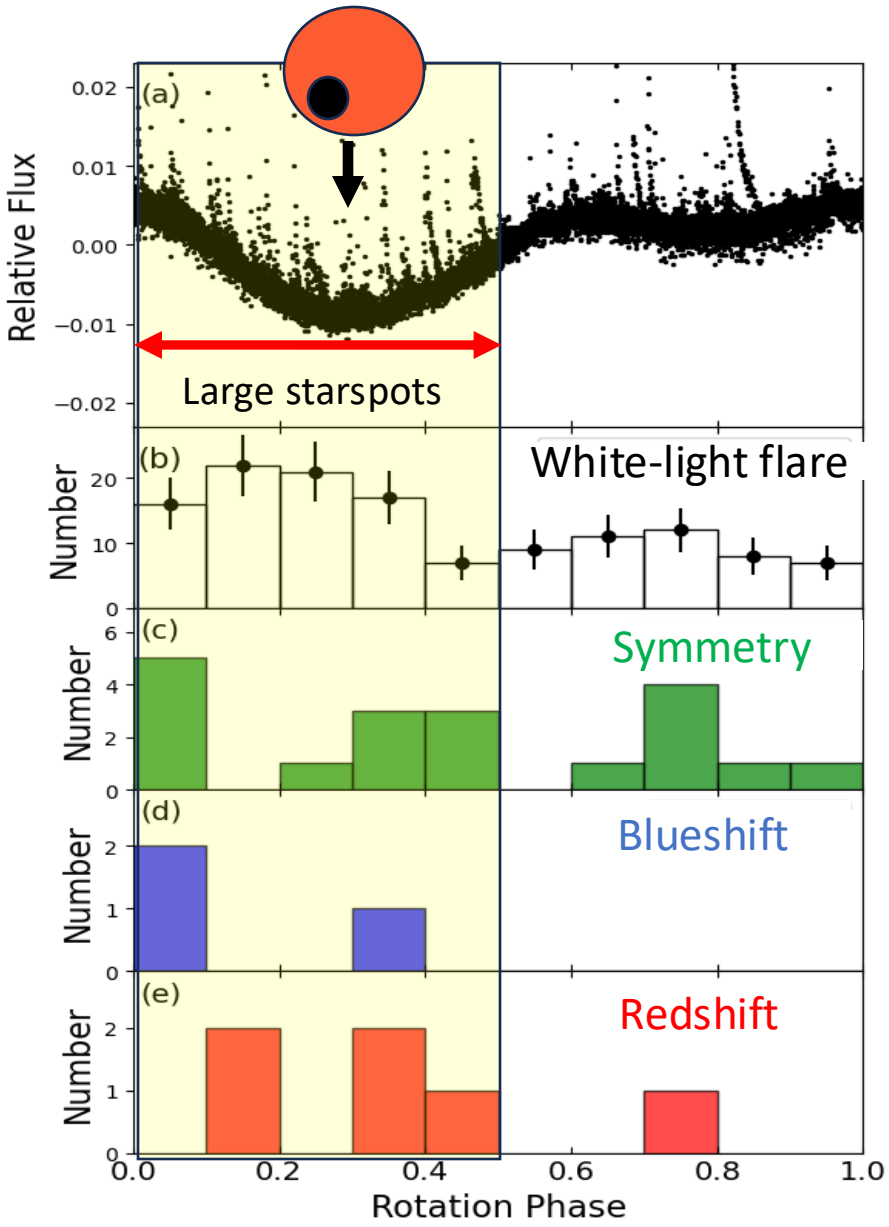
Asymmetry vs White-light Flare

Data including Maehara+2021, Notsu+2024, Kajikiya+2025a



- All 7 red asymmetry events are associated with **white-light flares**.
- 6 out of 5 blue asymmetry events are not associated with **white-light flares**.

Asymmetry vs Rotational Phase



- **White-light flares** occurred more frequently at the phases where **large spots** were observable
  → Statistical significance by chi-squared test

- Most asymmetry events occurred at the phases where **large spots** were observable
  - For blue asymmetry, sample size is limited

Kajikiya+2025 b

Summary

M-dwarf YZ CMi : TESS(WL)+ Seimei(Hα) High time-cadence observations

- ✓ Detected 27 Hα flares:
  - ✓ 3 blue asymmetries, 5 red asymmetries
  - ✓ Rapid, Short-duration(~5 min) blue/red asymmetries
  - ✓ 4 asymmetry events suggest prominence eruptions

Kajikiya et al., 2025a

- ✓ Statistics of blue/red asymmetry:
  - ✓ Red asymmetries show higher association rate of **white-light flares**
  - ✓ Blue asymmetries show lower association rate of **white-light flares**
  - ✓ The frequency of **white-light flares** and the association rate of Hα asymmetries depend on rotational phase (starspots)

Kajikiya et al., 2025b