APO3.5m spectroscopic monitoring observations of a M-dwarf superflare star YZCMi with TESS and ARCSAT0.5m photometric and NICER soft X-ray observations

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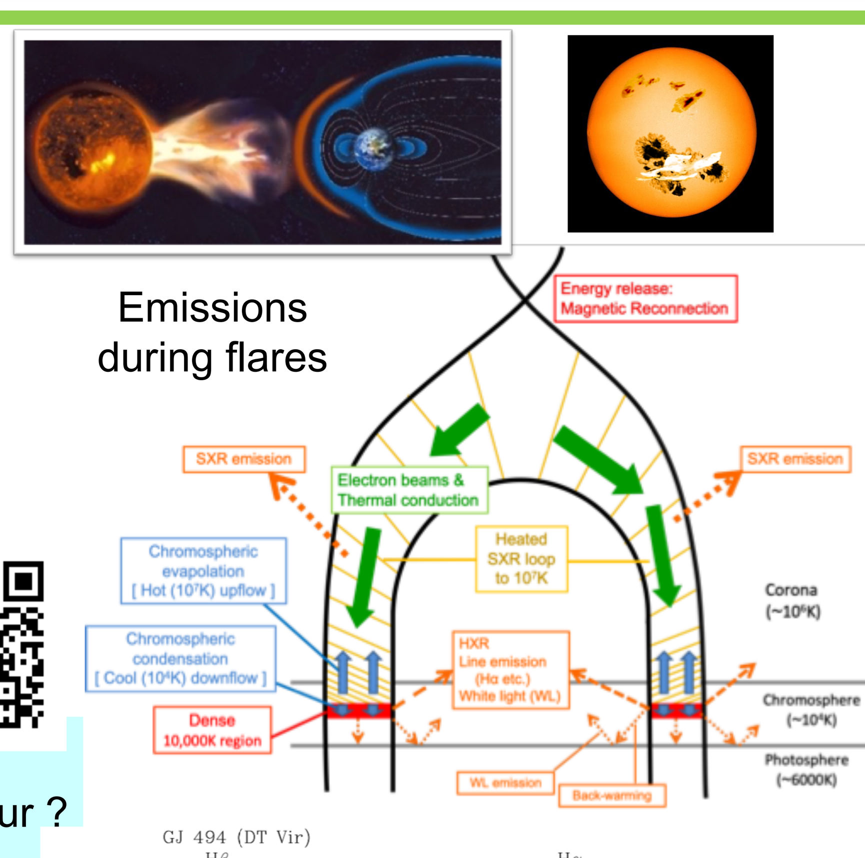
1. Introduction

<Superflares>

Very large flares 10-10⁴ times more energetic than the biggest solar flares (~10³²erg).

Statistical studies of Kepler data (Maehara+12, Notsu+19)

- Flare energy and frequency depends on rotation period and age.
- Even old Sun-like slowly-rotating stars can have superflares. cf. Press Release at AAS234 →

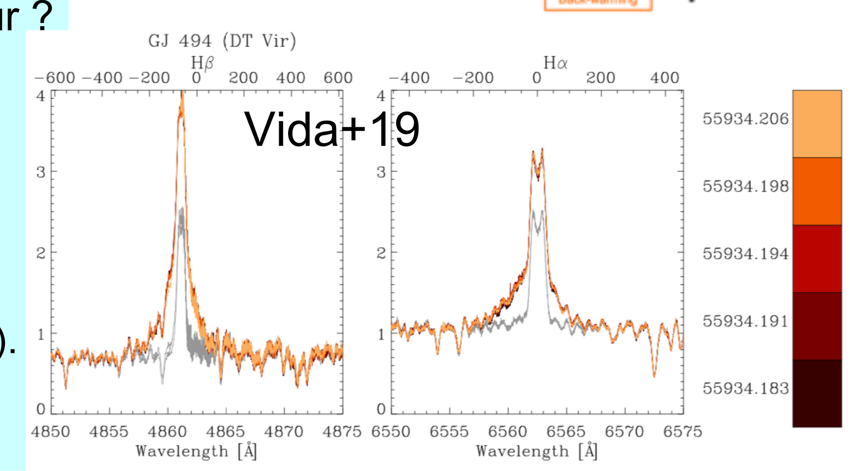


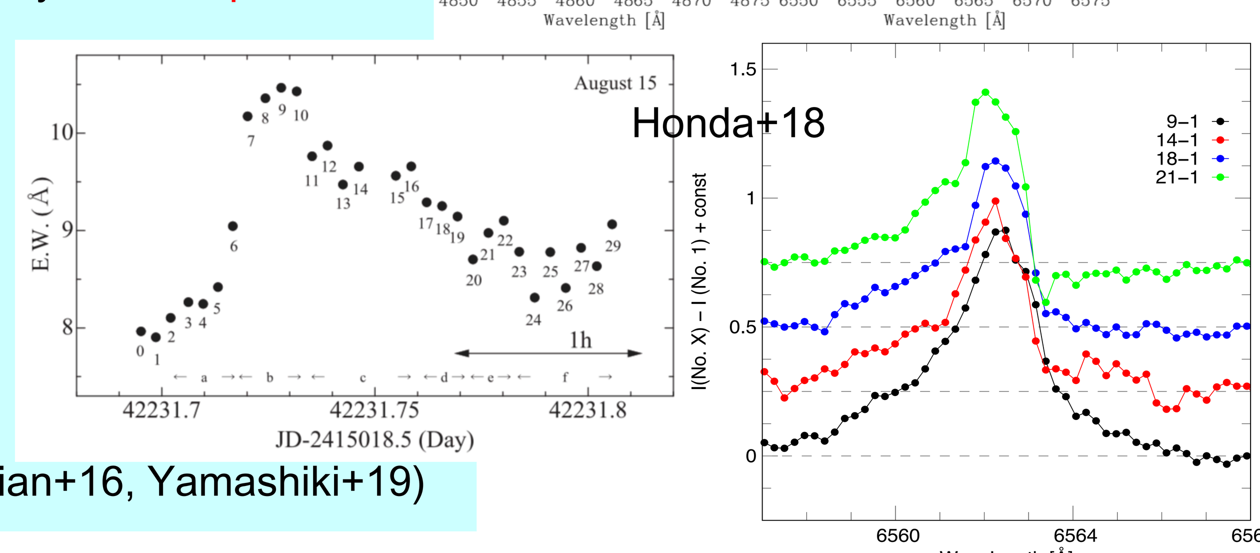
<Remaining problems>

○ How superflare energy release and emission occur ? Similar to solar flares ?

○ Can coronal mass ejections (stellar CMEs) be detected ?

- "Blue shifts" candidates caused by prominence eruptions (Vida+16&19, Moschou+19).
- "Blue assymetries" caused by chromospheric dynamics (Honda+18).
  (⇄ "Red asymetries" are usually observed with solar flares.)





○ CME shocks cause high-energy particles
→ Effects on (exo)planetary atmosphere
(e.g., Segura+10, Airapetian+16, Yamashiki+19)

More detailed multi-wavelength observations are strongly needed !!

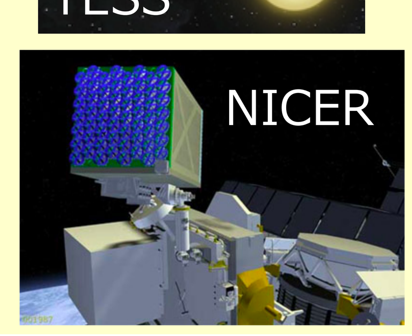
2. Targets and Observations

Targets: YZCMi (M4.5V, V=11.2mag)
Single M-dwarf flare star (e.g., Kowalski+13)

Observations: 2019UTJan-26, Jan 27, & Jan 28

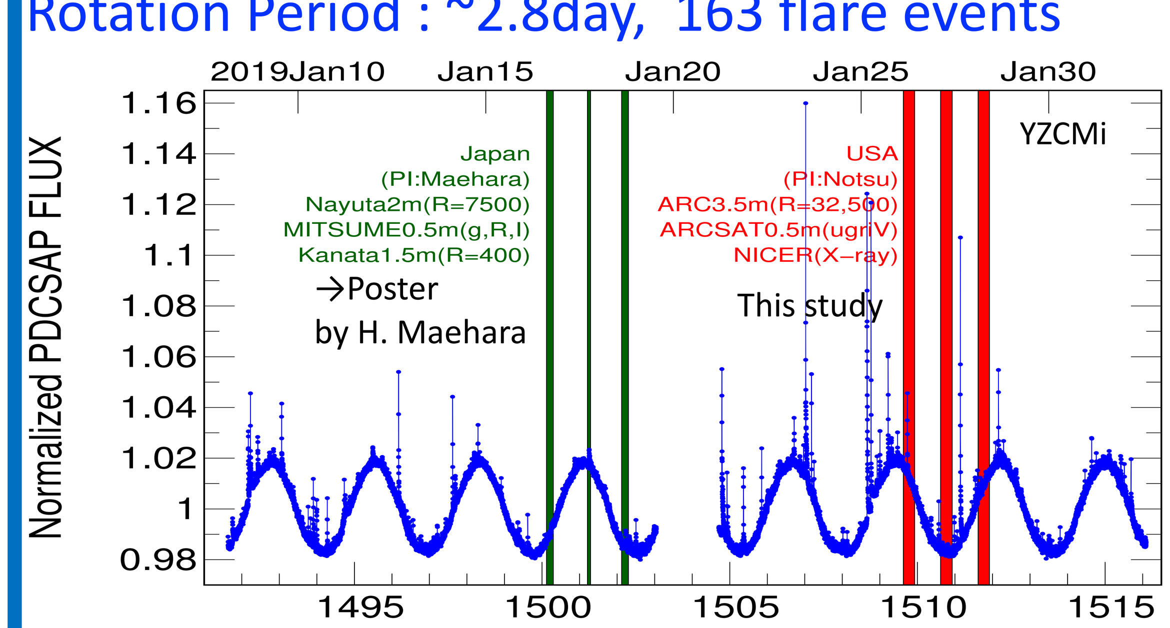
- **Apache Point Observatory (APO) ARC 3.5m telescope**
  high dispersion spectroscopy
  R=λ/Δλ~32500, λ : 3600-10000Å
- **APO ARCSAT 0.5m telescope**
  multi-color photometry (u,g,r,i,V)
- **TESS** : single broad band high-precision photometry (6000-10000Å)
  Cycle1 Sector 7 (2019 Jan07 - Feb04)
- **NICER** (Neutron Star Interior Composition Explorer)
  soft X-ray spectroscopy (0.3-10keV) on ISS

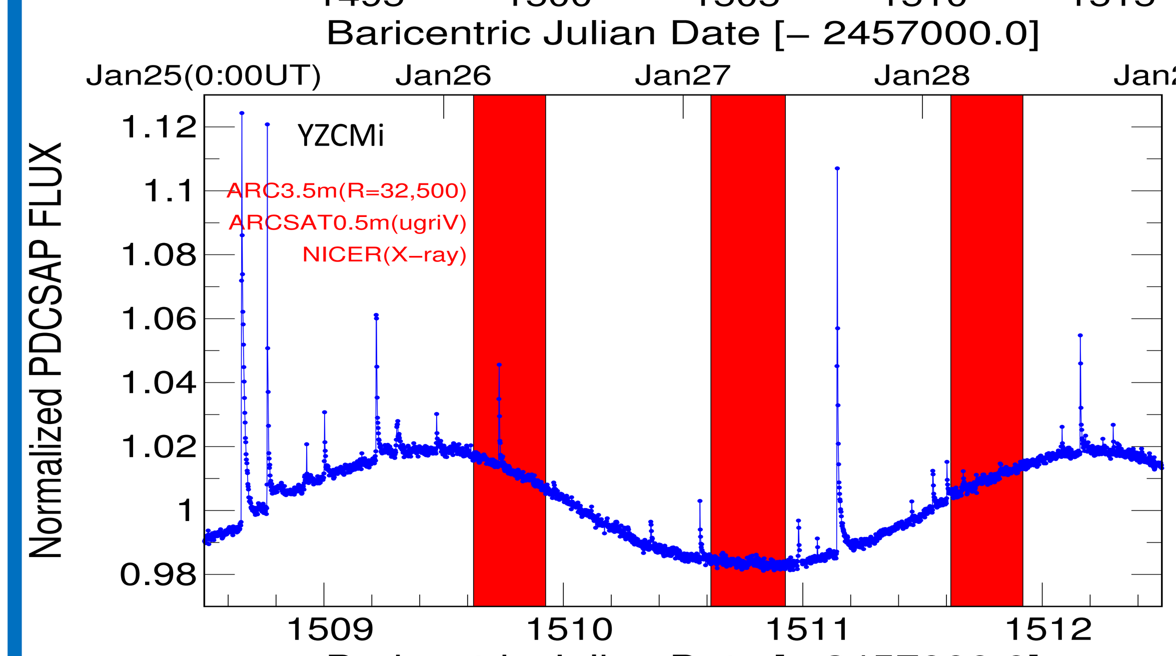
Apache Point Observatory (3.5m & 0.5m)



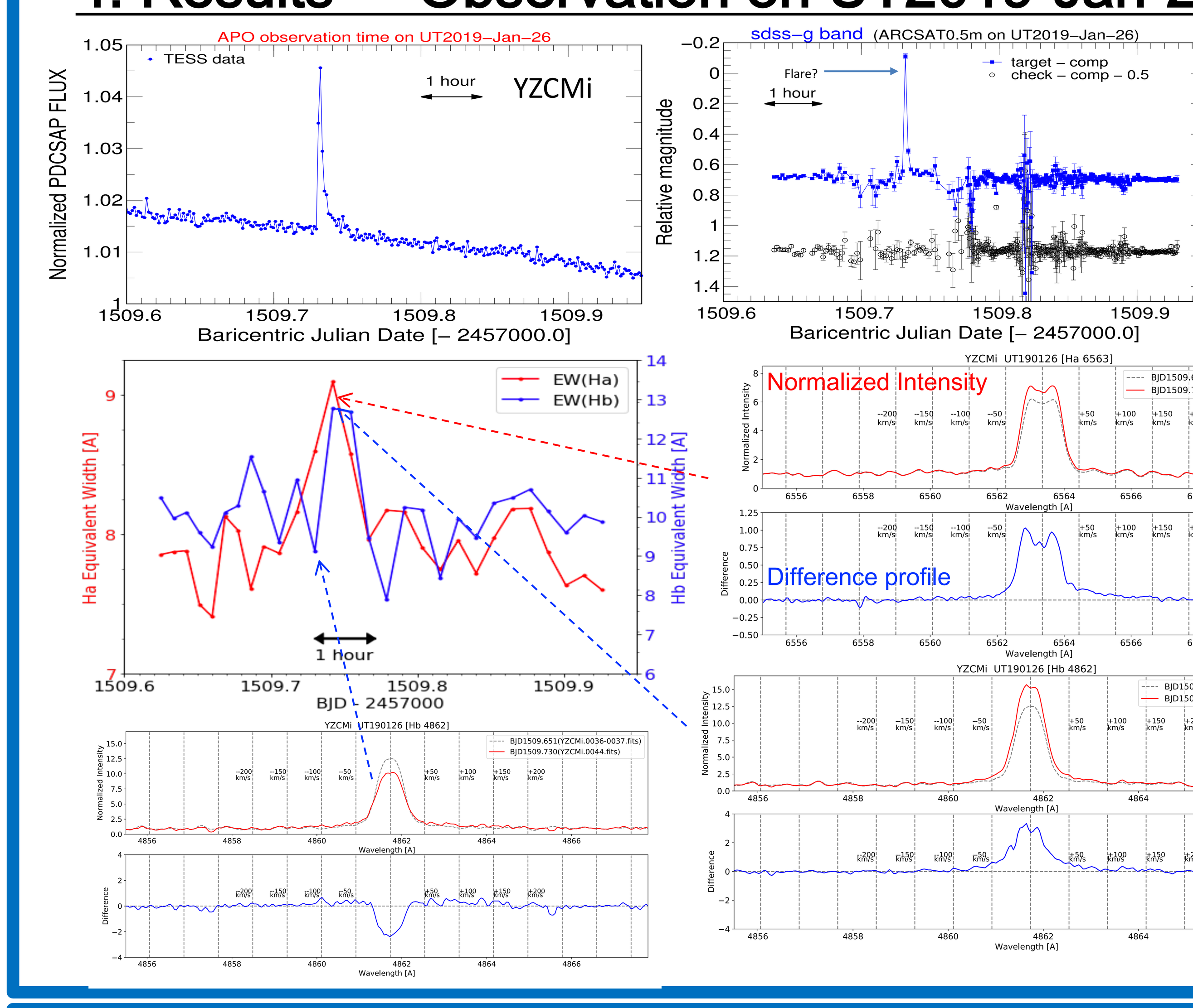
3. Results - TESS light curve

Rotation Period : ~2.8day, 163 flare events





4. Results - Observation on UT2019-Jan-26

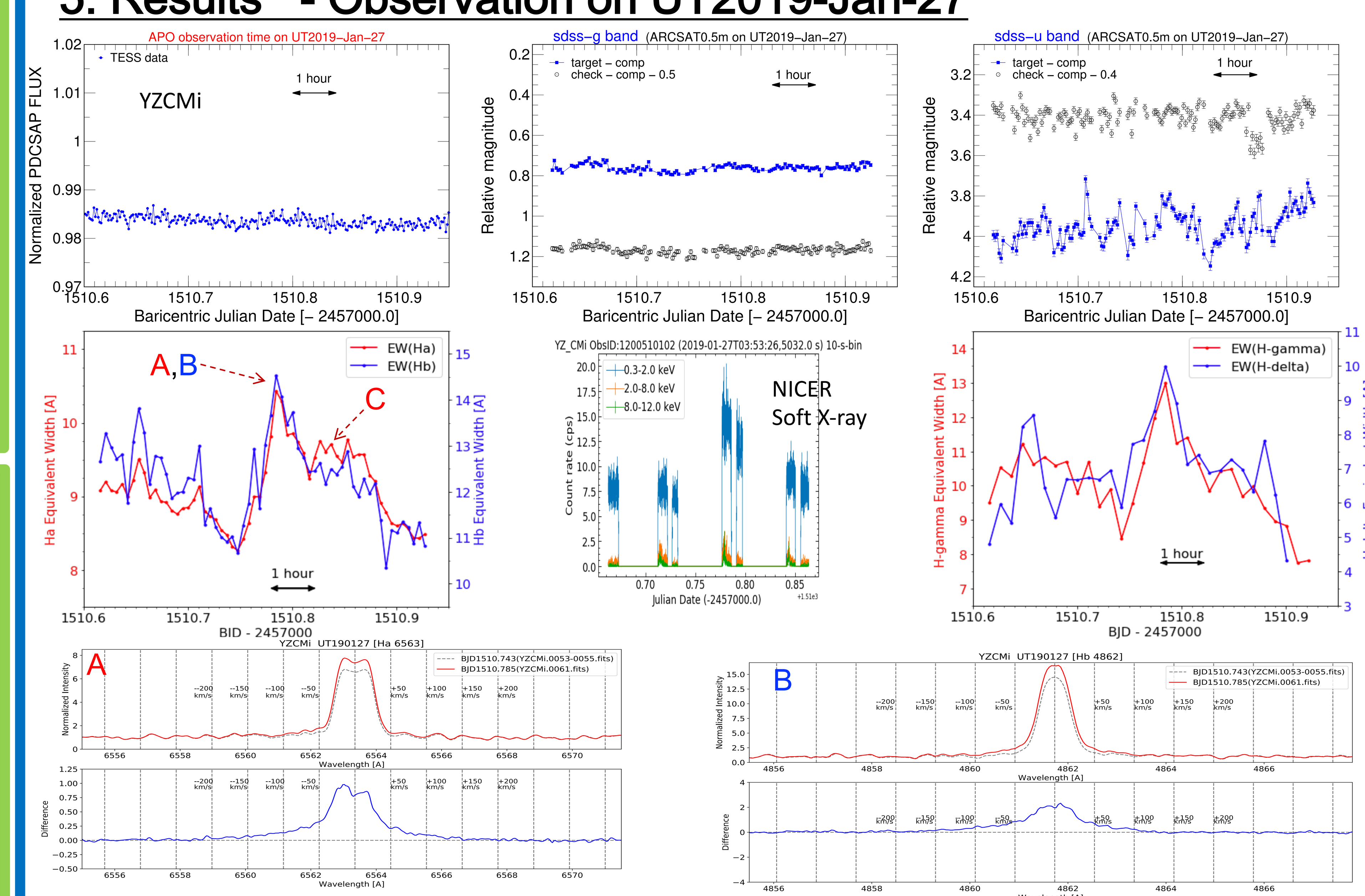


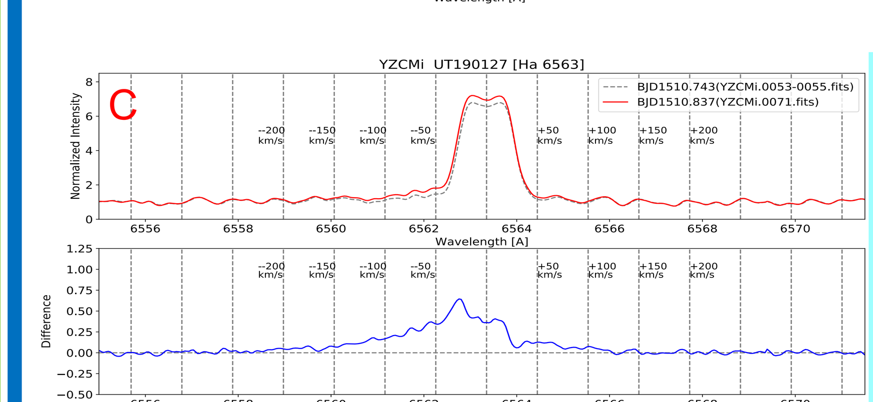
One flare with continuum enhancements.
- g-band: ~0.8mag
  TESS: ~4%
- duration ~ 15-20min

No clear line wing shifts (or slight red shifts ??)

Other chromoshpheric lines (e.g., Hδ, Hγ, Ca K, Ca II 8542, He D3 5876, Na D lines) also show similar time evolutions.

5. Results - Observation on UT2019-Jan-27

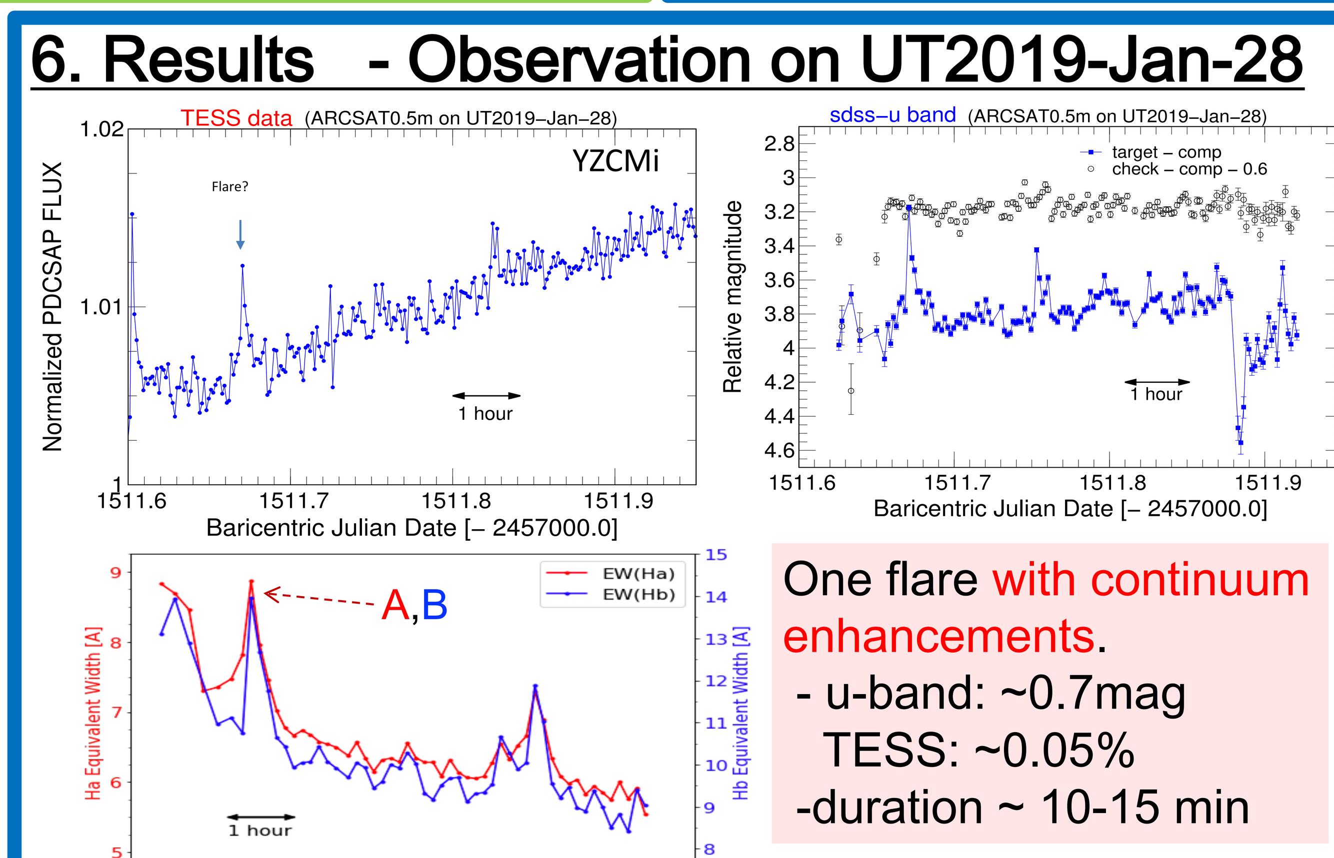


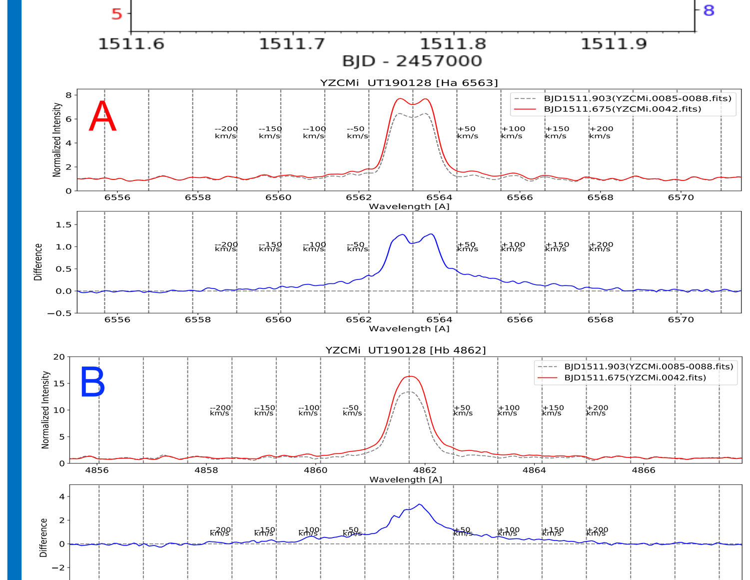


One flare without continuum enhancements.
Only chromospheric and coronal emissions.
("Non-white light flare" like many solar flares ??)

Hα: Slight blue shifts (especially decay phase).
Other lines (e.g., Ca K, Ca II 8542, He D3 5876, Na D lines) also show similar time evolutions.

6. Results - Observation on UT2019-Jan-28





One flare with continuum enhancements.
- u-band: ~0.7mag
  TESS: ~0.05%
- duration ~ 10-15 min

No clear line wing shifts (or slight red wing enhancements ??)

Other chromoshpheric lines (e.g., Hδ, Hγ, Ca K, Ca II 8542, He D3 5876, Na D lines) also show similar time evolutions.

7. Summary

From 3-night campaign observations of YZCMi, we detected small flares with two different properties.
- "Non-white-light" flares with chromospheric and coronal emissions (and possible slight blue shifts).
- Small "white-light" flares.

[Ongoing discussions]

Comparisons of line profiles with radiative hydrodynamic simulation results (using RADYN code: e.g., Allred+06, Kowalski+17).

[Next observational studies]

- Observations of more flare stars
  → detecting larger flares with optical emissions.
- Campaign observations in TESS Cycle 2 (and later)
  M-dwarf flare star EV Lac in 2019Sep. (Sector 16)
- Proxima Centauri : TESS&NICER simultaneous observations (just finished observations!!)