Simultaneous photometry and spectroscopy of an active M-dwarf YZ Canis Minoris with TESS and OISTER

Hiroyuk Maehara[1] (Hiroyuki.maehara@nao.ac.jp), S. Honda[2], Y. Notsu[3], S. Notsu[4], K. Namekata[5], K. Ikuta[5], D. Nogami[5], K. Shibata[5], M. Yamanaka[5], N. Kato[2], T. Ohshima[2], K. Murata[6], K. Iida[6], M. Oeda[6], K. Takagi[7], M. Sasada[7], H. Akitaya[7], and OISTER collaboration (1. National Astronomical Observatory of Japan, NINS, 2. University of Hyogo, 3. University of Colorado, 4. Leiden Observatory, 5. Kyoto University, 6. Tokyo Institute of Technology, 7. Hiroshima University)

1. Introduction

1.1. Stellar flares and their impact on exoplanet

- Rapid releases of magnetic energy in the solar/stellar atmosphere caused by the magnetic reconnection
  - electromagnetic radiations at all wavelength
  - prominence eruptions and coronal mass ejections (CMEs)
    - Stellar CMEs are thought to affect the exoplanet's atmosphere
      e.g. Airapetian et al. (2016), Yamashiki et al. (2019)
- Plasma ejections associated with stellar flares are not well studied
  - only a few events were detected
    - prominence eruptions: enhancement of blue-shifted components in chromospheric lines (Opt.): e.g. Vida et al. (2016, 2019)
    - CMEs: blue-shifted coronal emission lines (X-ray): e.g. Argiroffi et al. (2019)

➡ More Time-resolved/simultaneous observations are strongly needed.

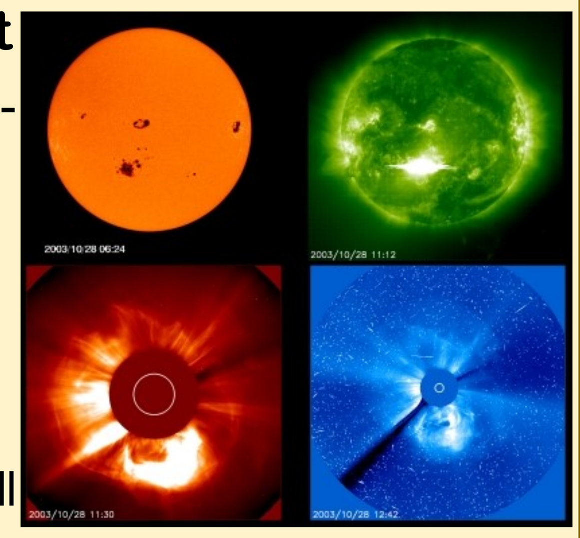

Fig.1 Solar flares and CME
(http://sci.esa.int/ho/47811-soho-catches-bright-solar-flare-and-cme/)

1.2 OISTER

- Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) is the first Japan's nation-wide cooperation project by universities on the optical-infrared observational astronomy.
- The aims of OISTER collaboration:
  - Quick/long-term follow-up observations of transent objects
    - GRBs, SNe, EM counterparts of GW and neutrino sources
  - Coordinated (simultaneous) multi-band/-mode observations
    - Multi-band: optical and NIR (from U–band to Ks-band)
    - Multi-mode: photometry, spectroscopy and polarimetry

Fig.2 OISTER Telescope network

➡ OISTER network is a powerful tool for studying stellar flares.

2. TESS-OISTER observations of YZ CMi

- TESS: 2019-01-07 — 2019-02-01 (Sector 7)
  - Total observation time: 22.7 days
- OISTER: 2019-01-16 — 2019-01-18

Telescope and obs. mode	Wavelength, resolution, etc.	Time-cadence
MITSuME 50-cm (multi-color photometry)	g', Rc, Ic	12-sec
KANATA 1.5-m (low-resolution spectroscopy)	4000-9000Å ; λ/Δλ=400	1-min
NAYUTA 2-m (medium-resolution spectroscopy)	6350-6800Å ; λ/Δλ=8000	5-min

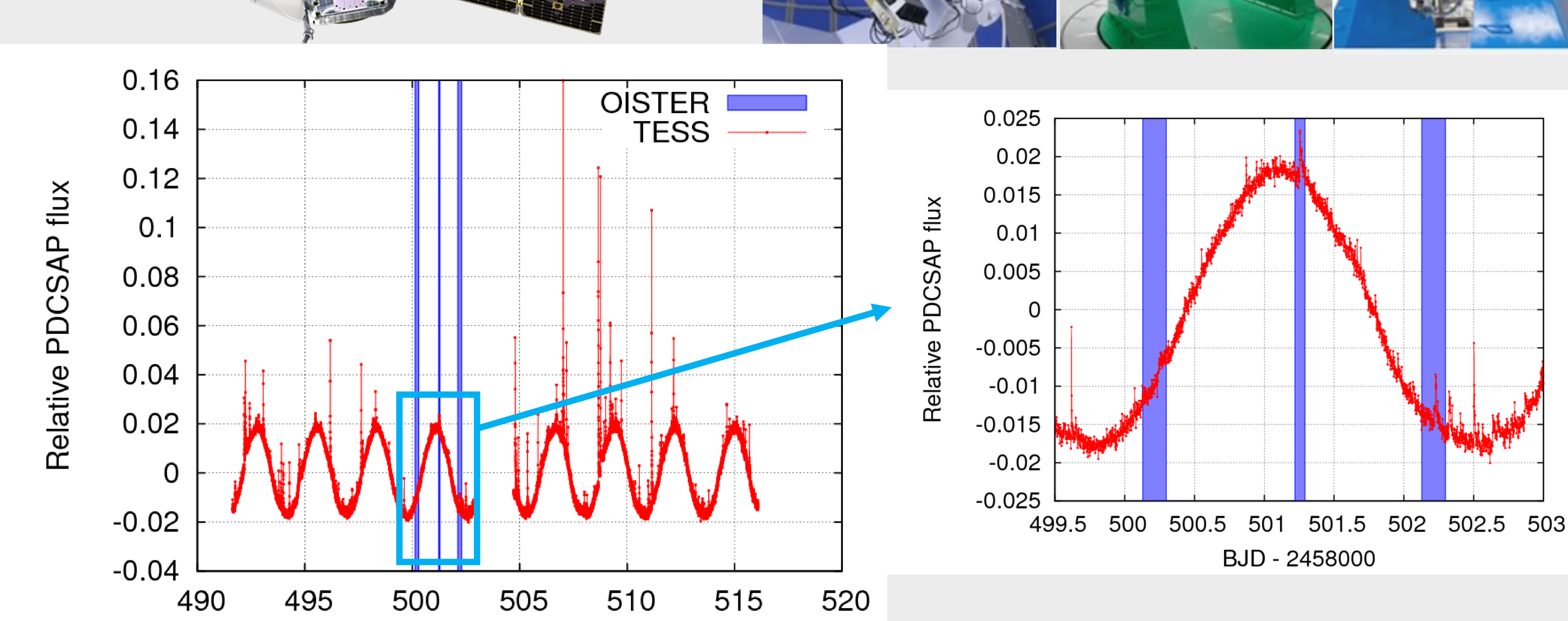

Fig. 3 TESS ight curve of YZ CMi

3. Results

3.1. Flares detected by TESS

- We found 194 flare candidates from the TESS light curve (fig.).
- Flare frequency: power-law distribution ($dN/dE \propto E^{-1.7}$)
- Flare duration vs. flare energy: 10-times longer than that of G-dwarfs

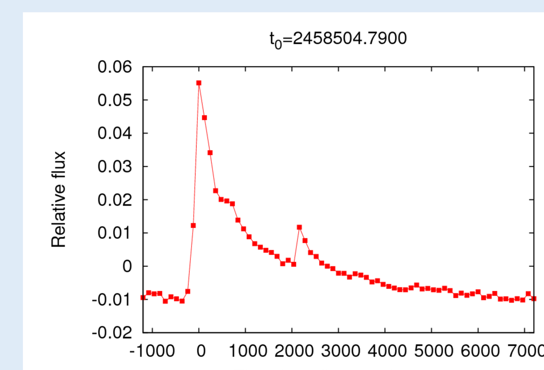

Fig. 4 Light curve of the flare on YZ CMi.

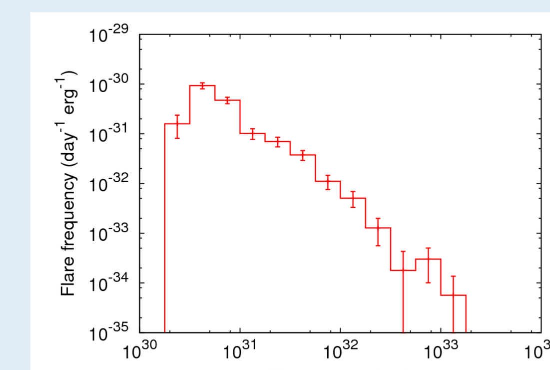

Fig. 5 Flare frequency (dN/dE) as a function of flare energy.

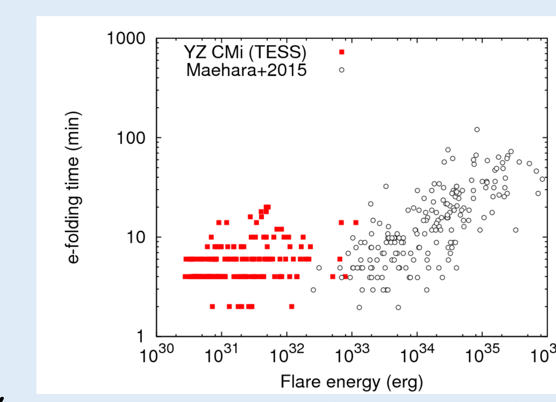

Fig. 6 Flare duration (e-folding time) as a function of flare energy

3.2. Flares observed with OISTER and TESS

- We detected two different types of Hα flares on Jan. 18.
  - **Flare A**: slow rise and slow decay; no white-light flare
    - Hα line profile: blue-asymmetry (-40km/s)
  - **Flare B**: rapid-rise and exponential decay; typical white-light flare
    - Hβ/Hα: rapid enhancement associated with the white-light flare
    - Hα line profile: No red-/blue-asymmetry

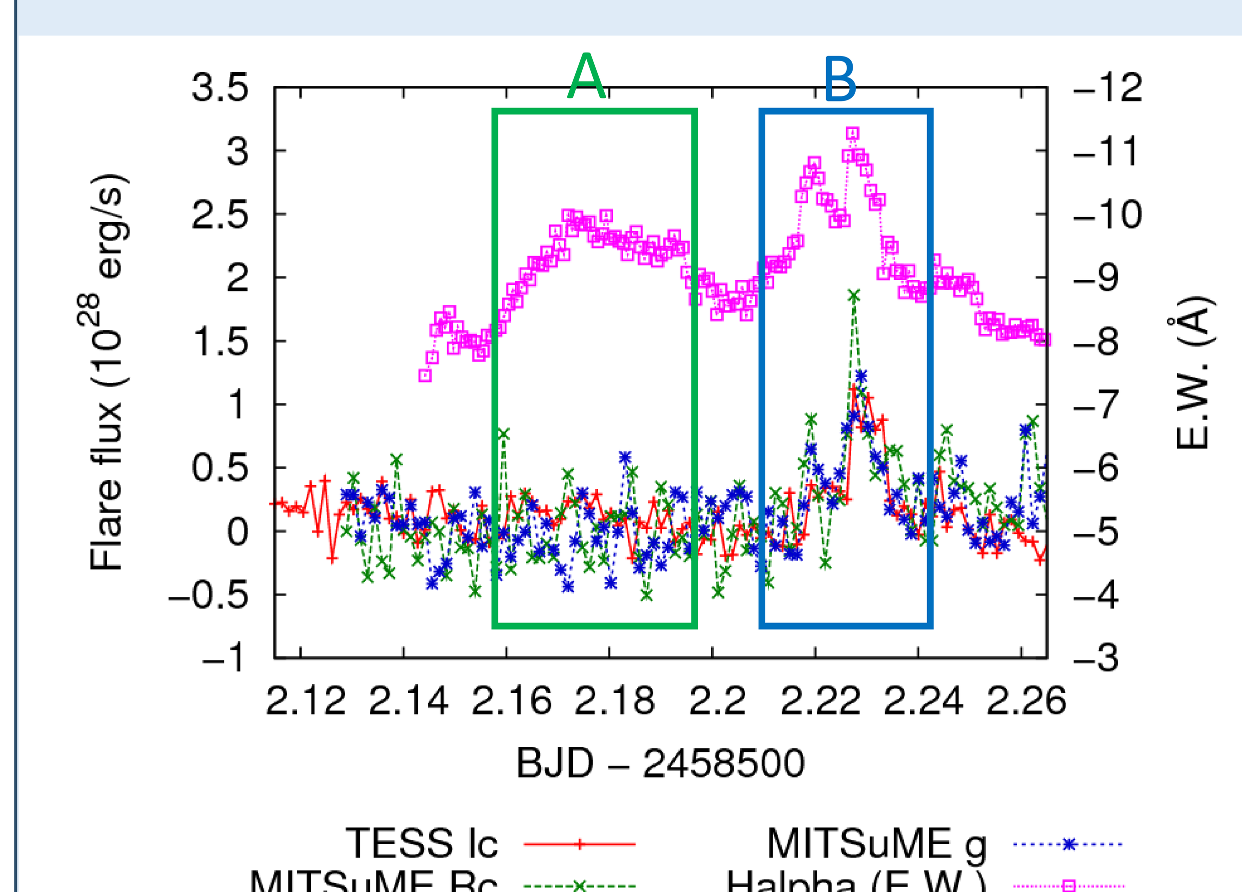

Fig. 7 Time-variation of continuum flux and equivalent width of Hα line during the OISTER observation on Jan. 18.

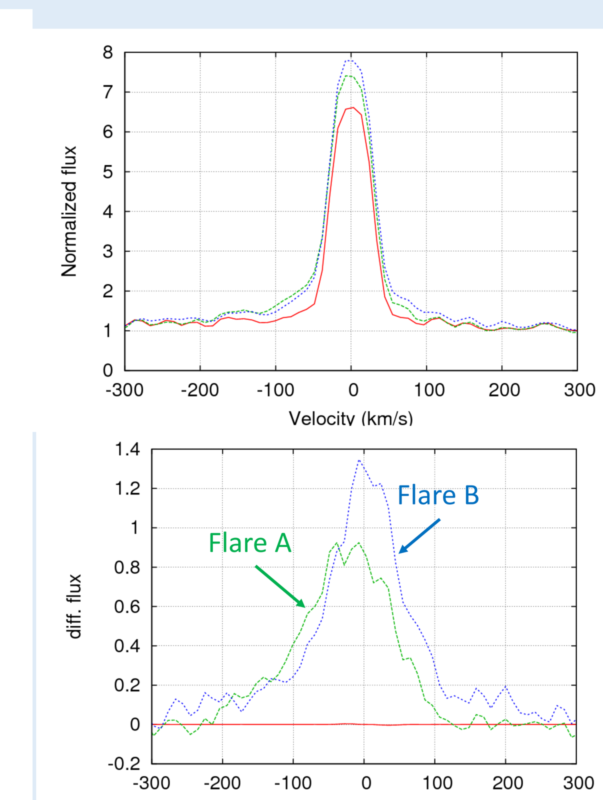

Fig. 8 Hα line profile at the peak times of flare "A" (green) and flare B (blue).

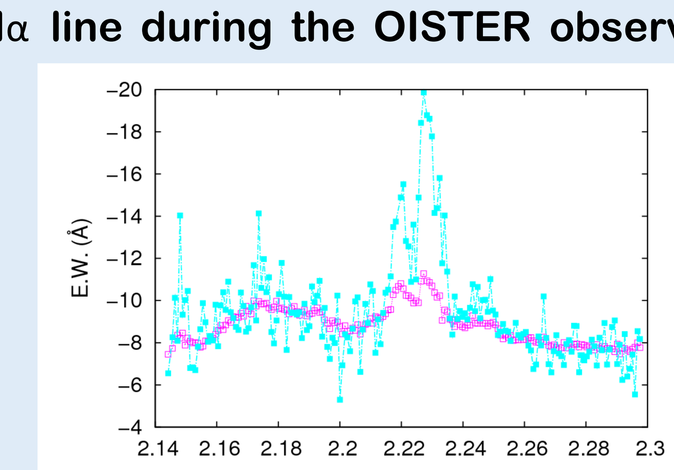

Fig. 9 Time-variation of equivalent width of Hα and that of Hβ.

4. Summary

- We found two types of Hα flares from TESS/OISTER observations on January 2019.
  - **Slow-rise/decay; no white-light flare; blue-asymmetry**
  - **Rapid-rise/exponential decay; typical white-light flare; no red-/blue-asymmetry**
- Future work
  - Next OISTER campaign observation of an active flare star EV Lac is scheduled from September 12 to October 4. → TESS: Cycle 2 Sector 16