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EUV observations of the coronal activity on exoplanet host stars

Hui Tian (田晖)

School of Earth and Space Sciences,
Peking University

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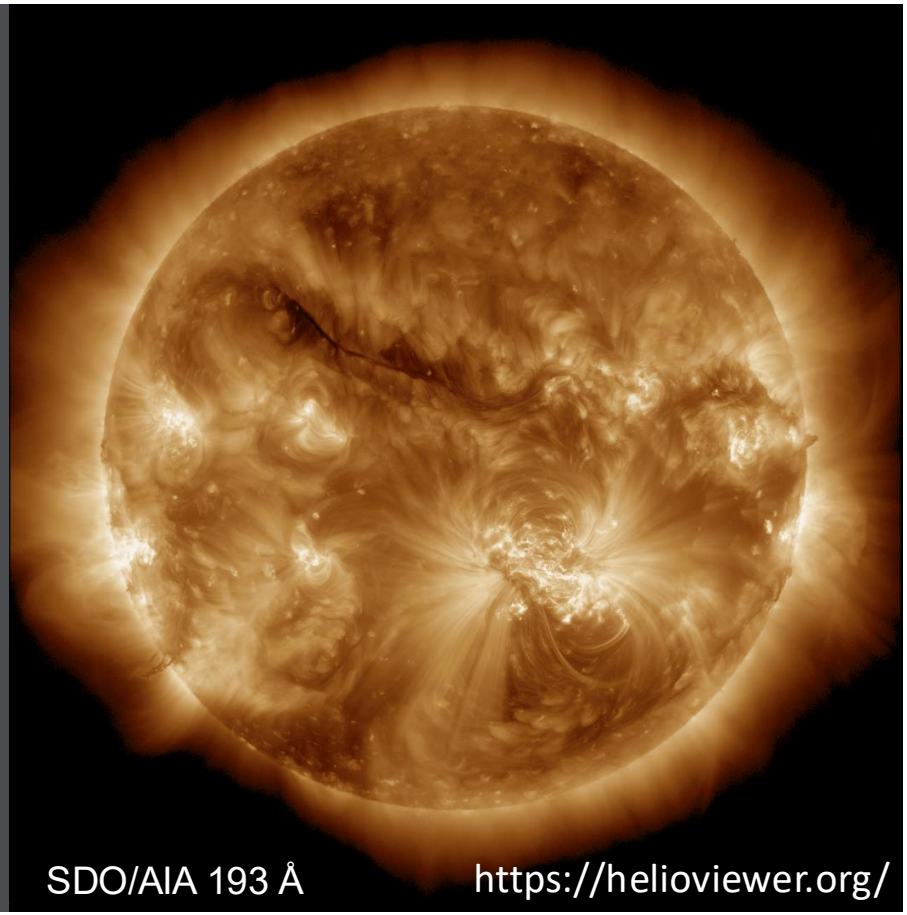
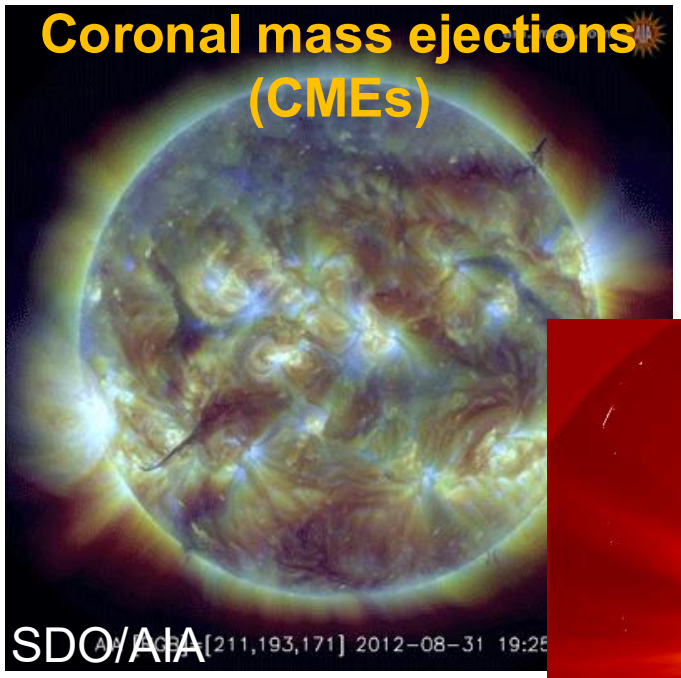
Solar coronal observations

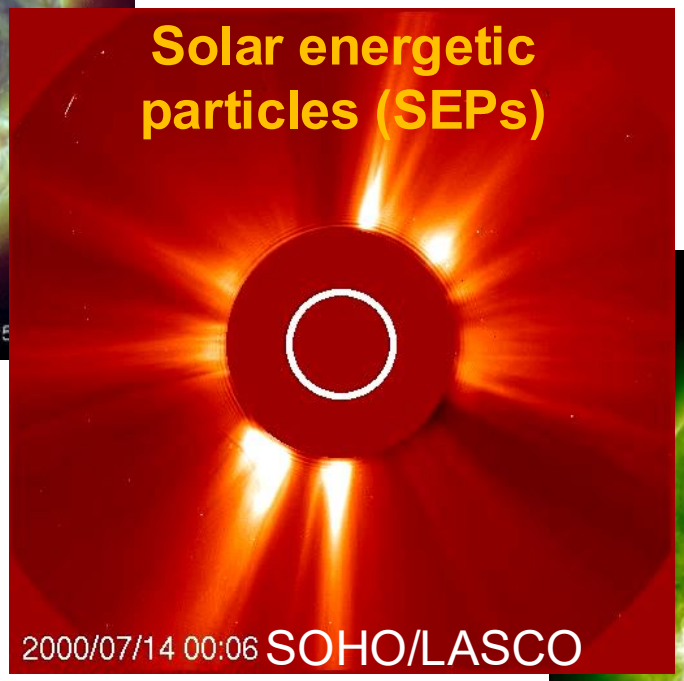
Eclipse/coronagraph obs.: off-limb

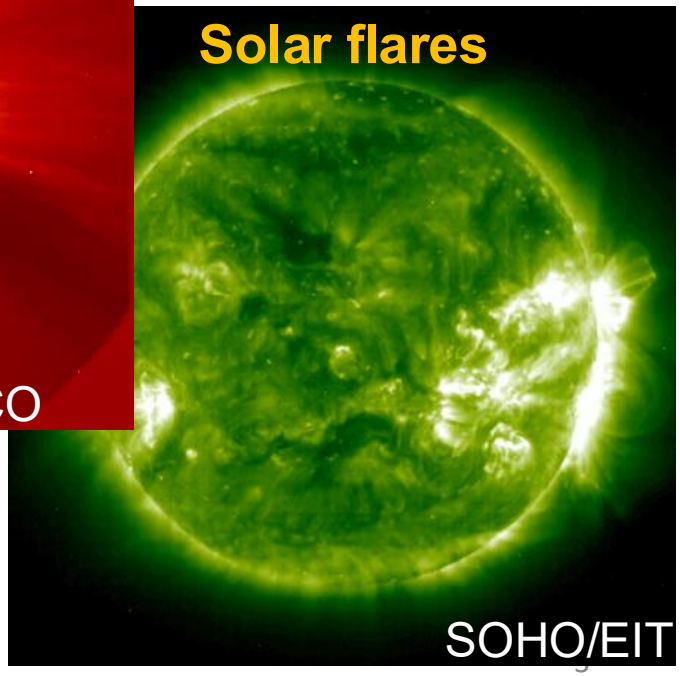
EUV/SXR obs.: ondisk & off-limb



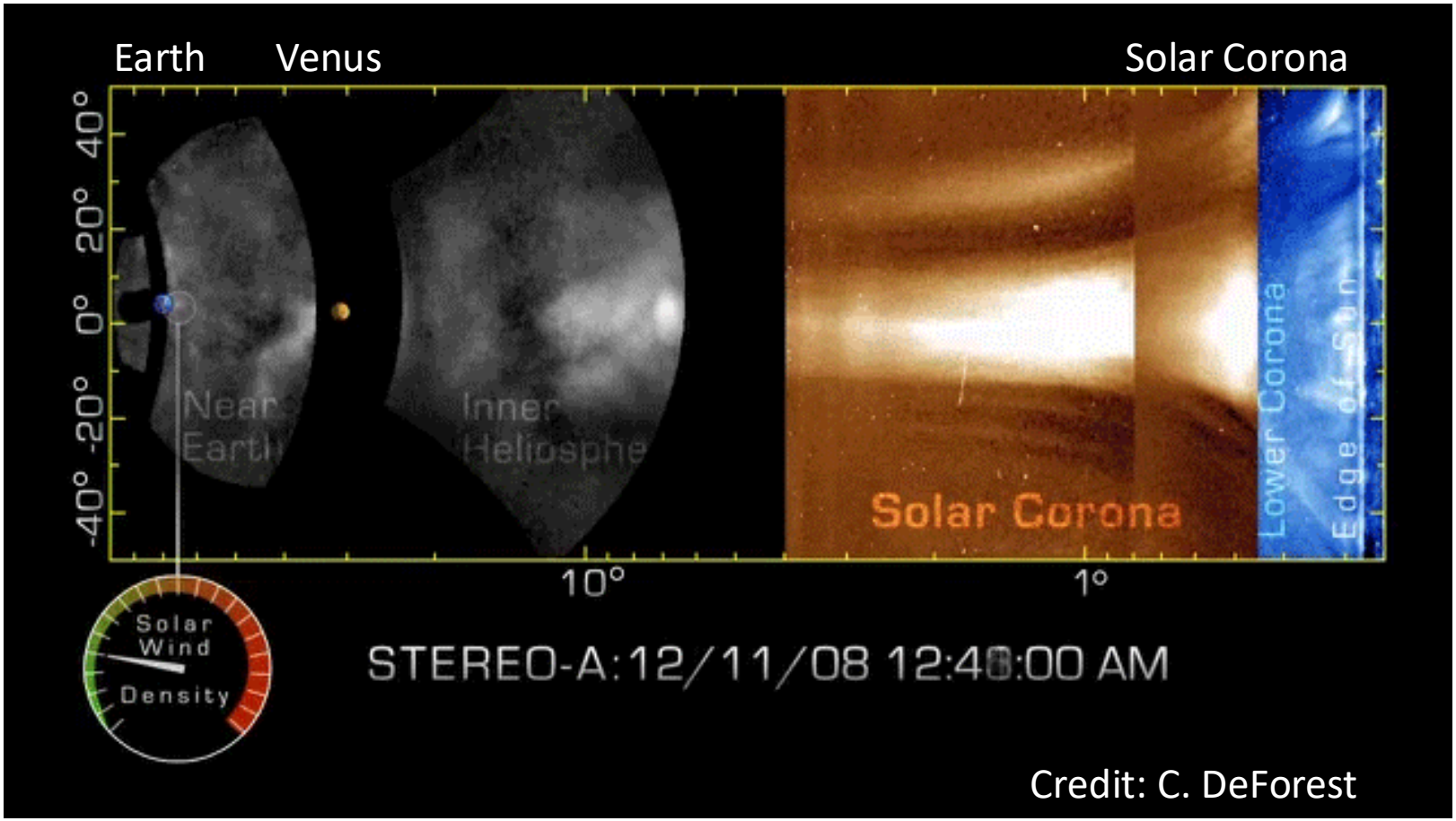
Solar coronal eruptions





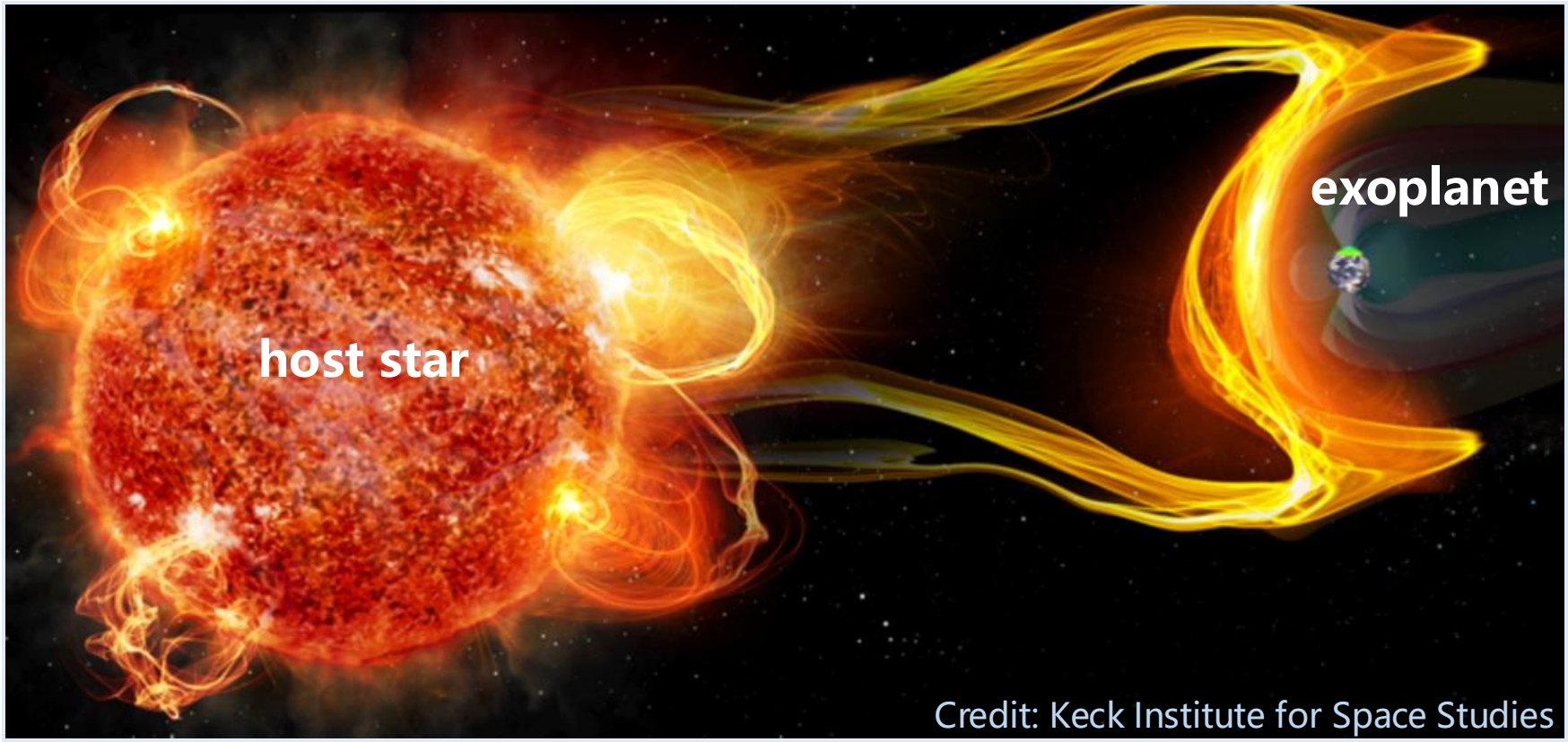


Space weather



Solar coronal eruptions drive disturbances of the solar-terrestrial space environment, affecting the operation of man-made satellites, navigation, communication and electrical systems

Exoplanetary space weather driven by coronal activity of host stars



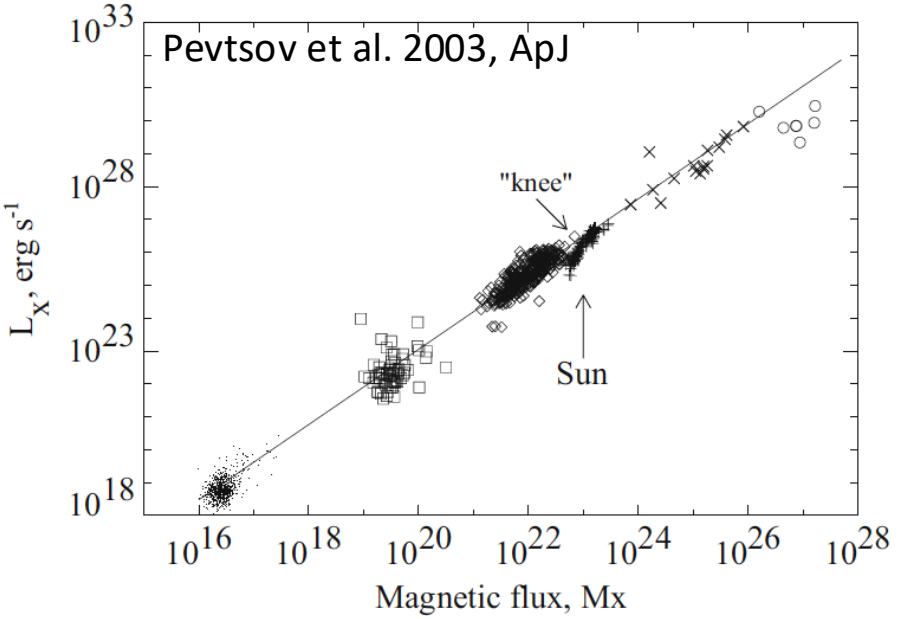
- Similar phenomena also exist in star-exoplanet systems
- Strong UV/X-ray radiation, winds and intense eruptions from stellar coronae could damage biological tissues, change chemical composition and lead to mass loss of exoplanet atmospheres, affecting exoplanet habitability and origin of life (e.g., Airapetian+2016, 2017; Linsky 2019; 田晖+，2022)

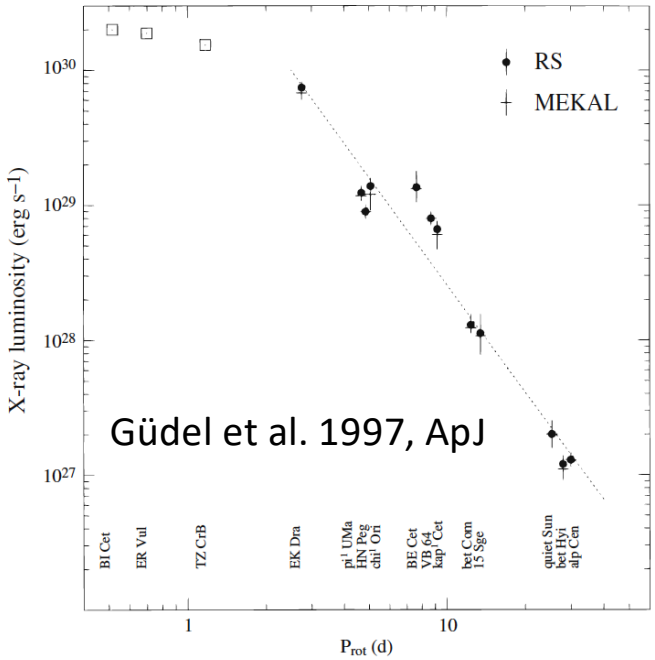
X-ray observations of stellar coronae

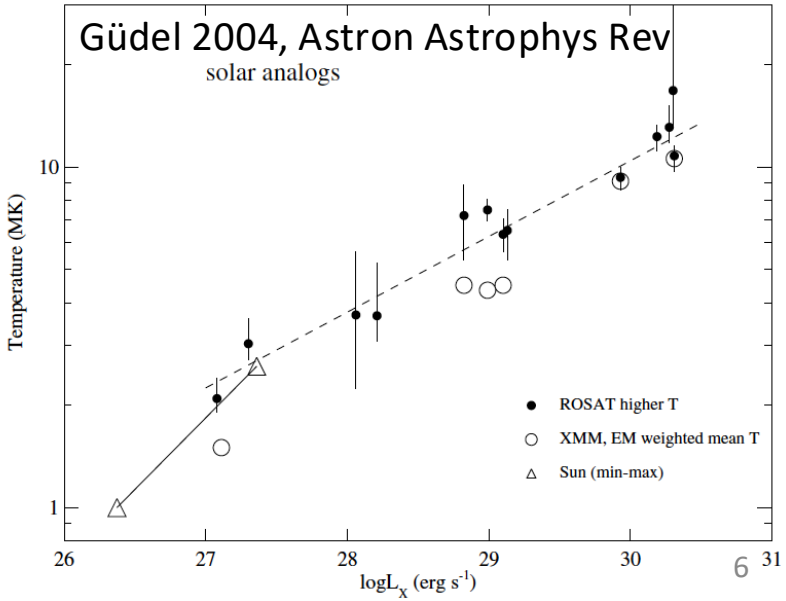
- Chandra, XMM-Newton, et al.
- Faster rotation -> stronger ***B***

-> higher coronal *T* -> higher X-ray luminosity L_x

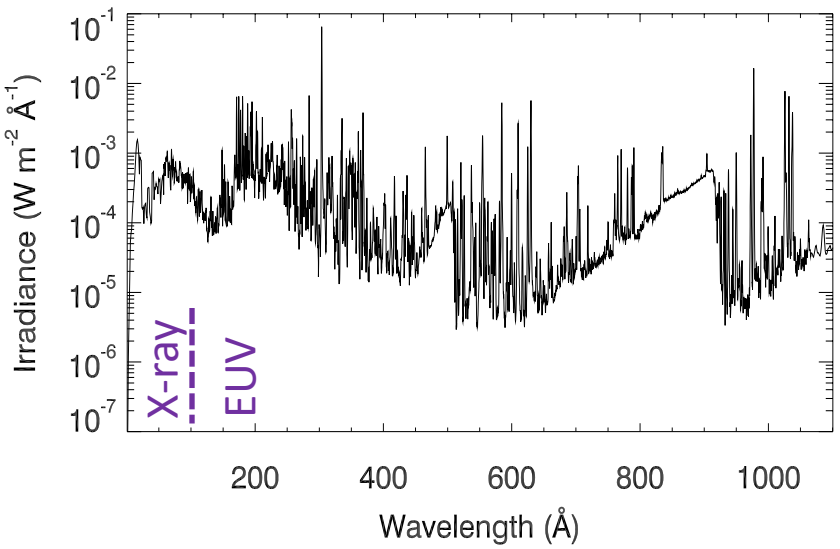
- Good for very hot coronae
- Need long-term continuous obs. with higher-sensitivity telescopes



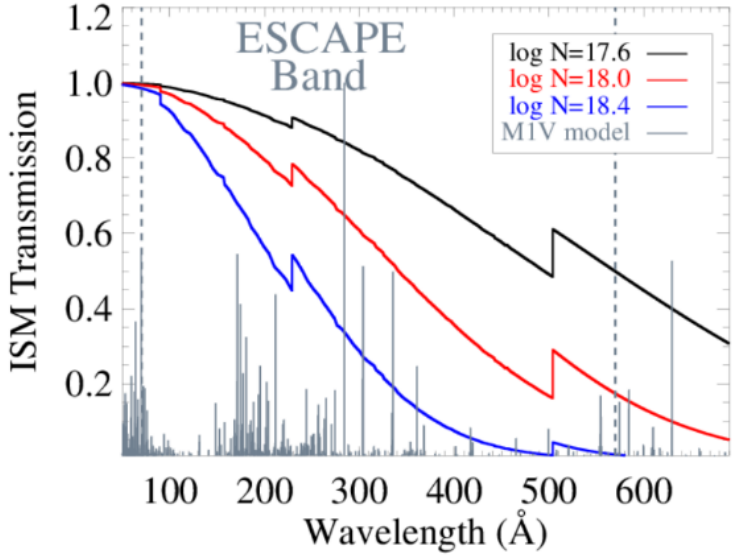




EUV observations of stellar coronae



Quiet-Sun EUV and X-ray spectrum measured by SDO/EVE and TIMED/SEE (田晖等, 2022, 中国科学: 物理学 力学 天文学)

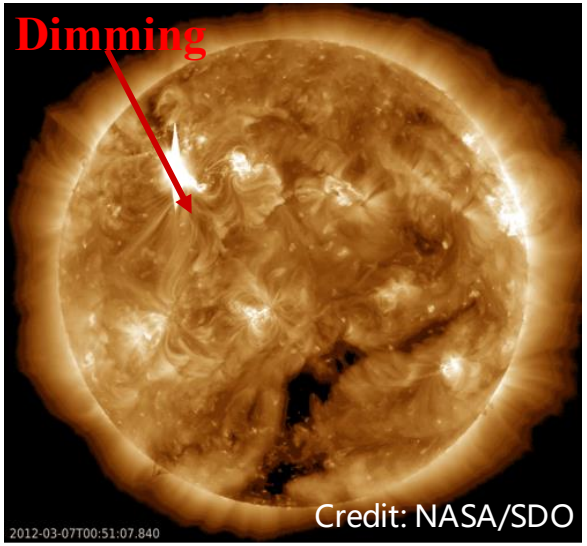


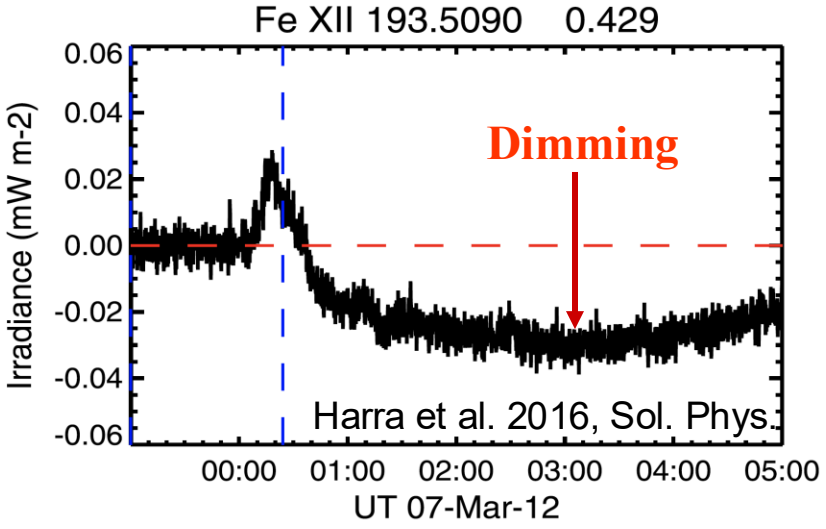
Transmission of the local interstellar medium for H I column densities typical of stars inside 30 pc (France et al. 2019, Proc. SPIE)

- EUV: one of the best wave. bands to observe stellar coronae
- Broad *T* range, primary source of planetary atmospheric heating and ionization

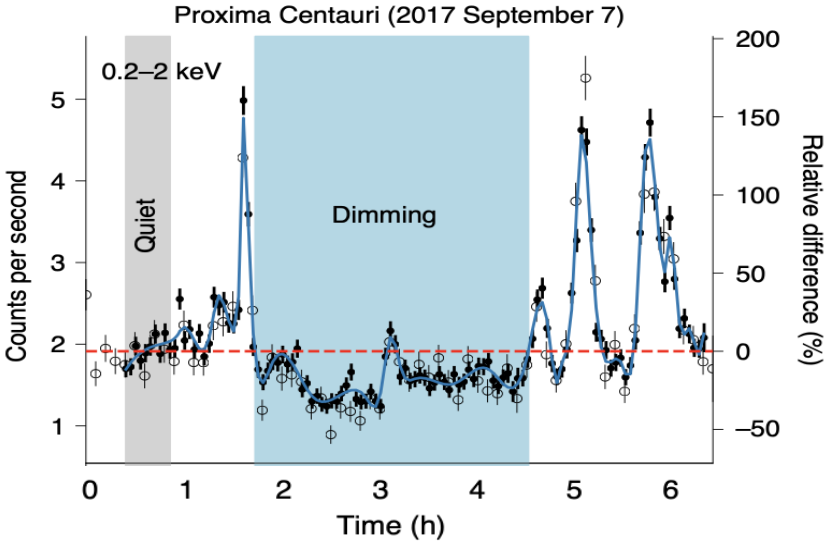
- 100-300 Å: slightly/partially absorbed by interstellar H

Detection of stellar CMEs through coronal dimming



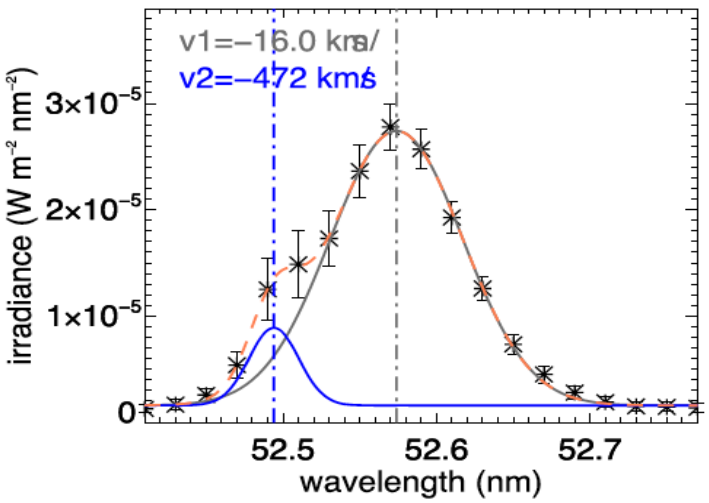


- When CMEs leave the Sun, EUV line emission from the corona often decreases due to density drop (e.g., Tian+2012)
- Seen in Sun-as-a-star EUV spectra (Mason+2014, 2016; Xu+2022)
- Possible stellar coronal dimmings through mainly SXR observations

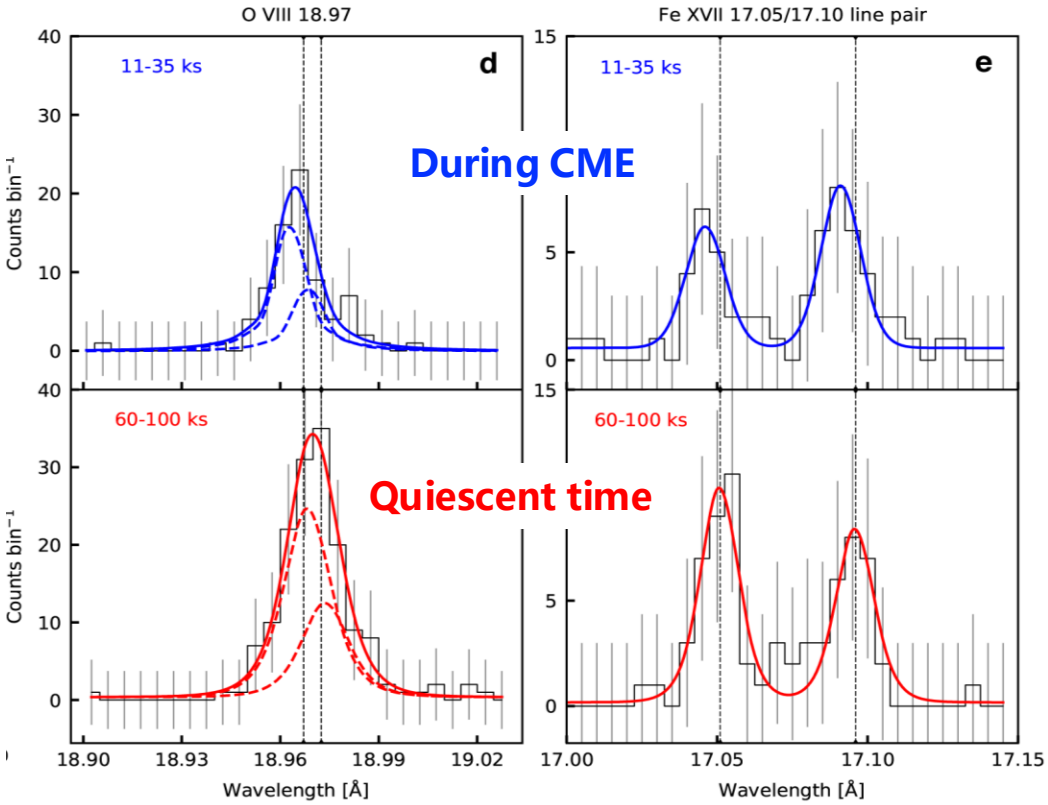


Veronig et al. 2021, Nature Astronomy

Detection of stellar CMEs through Doppler shifts



Xu, Tian, Hou et al. 2022, ApJ



Chen, Tian, Li et al. 2022, ApJ

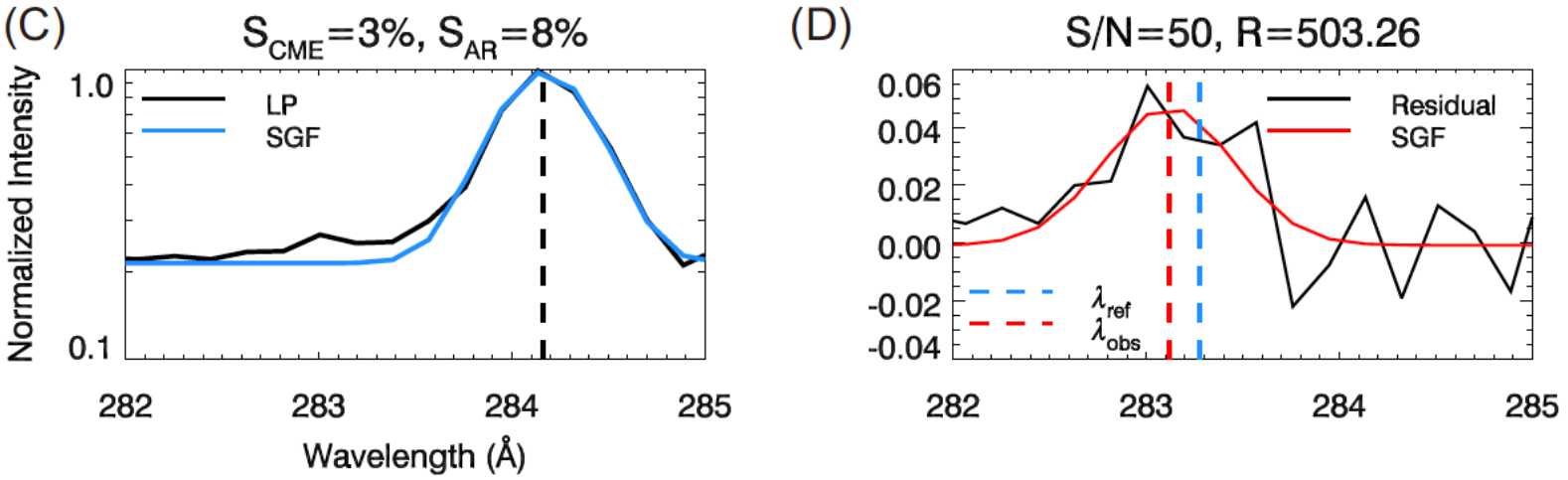
- Blueshifted 2nd comp. caused by CMEs found in full-Sun integrated spectra (Xu+2022, ApJ; Lu+2023, ApJ)

- First detections of blueshifts in SXR lines caused by possible CMEs on a dwarf star (Chen+2022) and a giant star (Argiroffi+2019)

Can we measure stellar CME speeds through EUV spectroscopy?

Yang, Tian, Bai, et al. 2022, ApJS

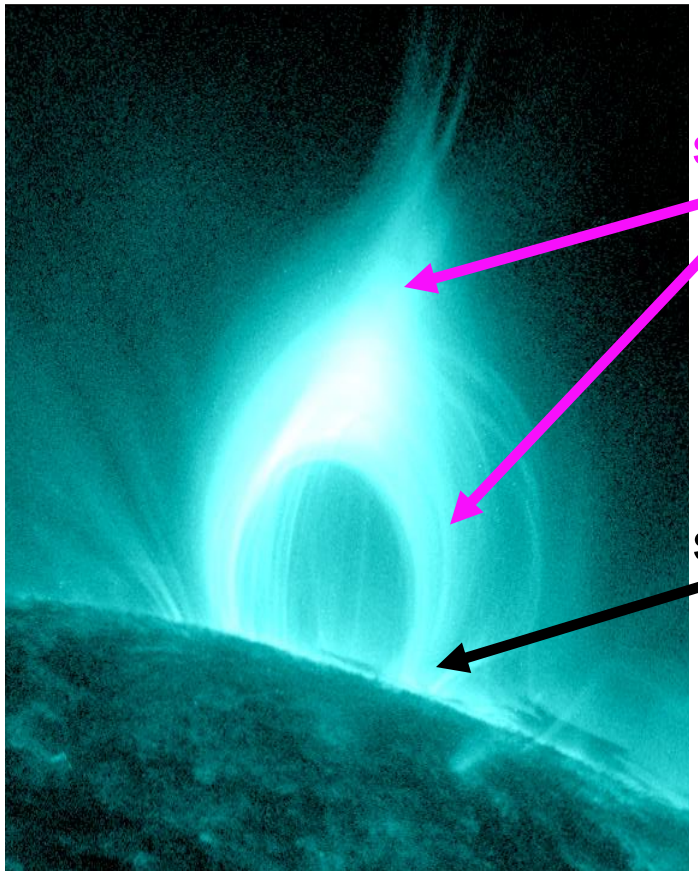
- Typical exposure time: ~1 h
- Instrumental requirements to detect CMEs & measure velocities using Fe IX 171 Å or Fe XV 284 Å: R ≈ 300-400 & S/N ≈ 30-40 (or R ≈ 500 & S/N ≈ 20-30)



Yang, Tian, Zhu, et al. 2024, ApJ
Xu, Tian, Alvarado-Gomez et al. 2025, ApJ

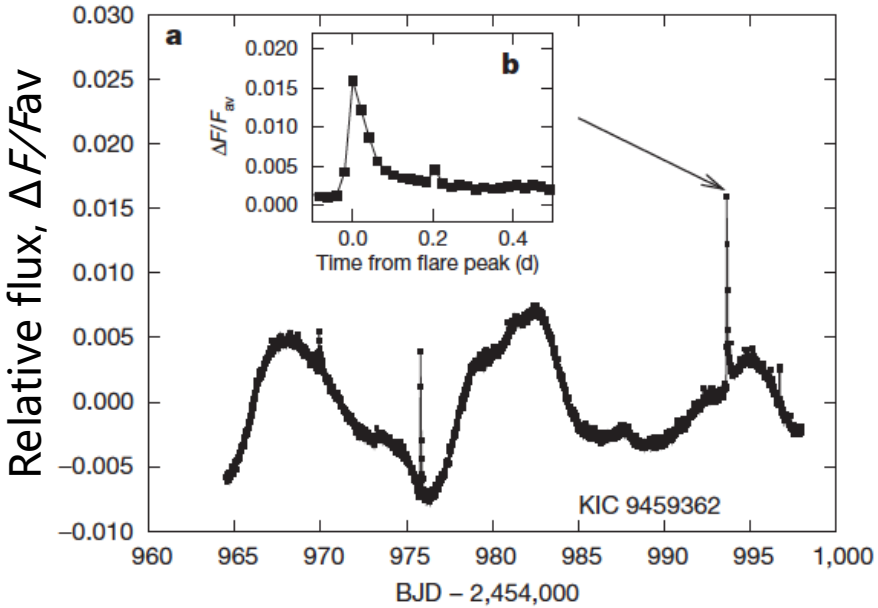
Unveil coronal physical processes in flare regions

Solar flares



Credit: NASA/SDO

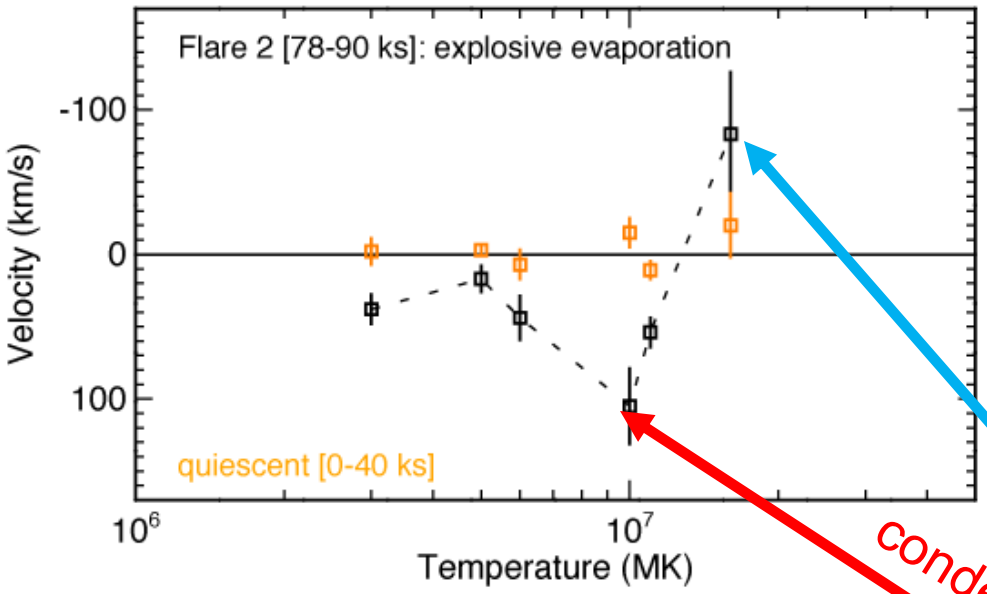
Stellar flares: mainly WL observations



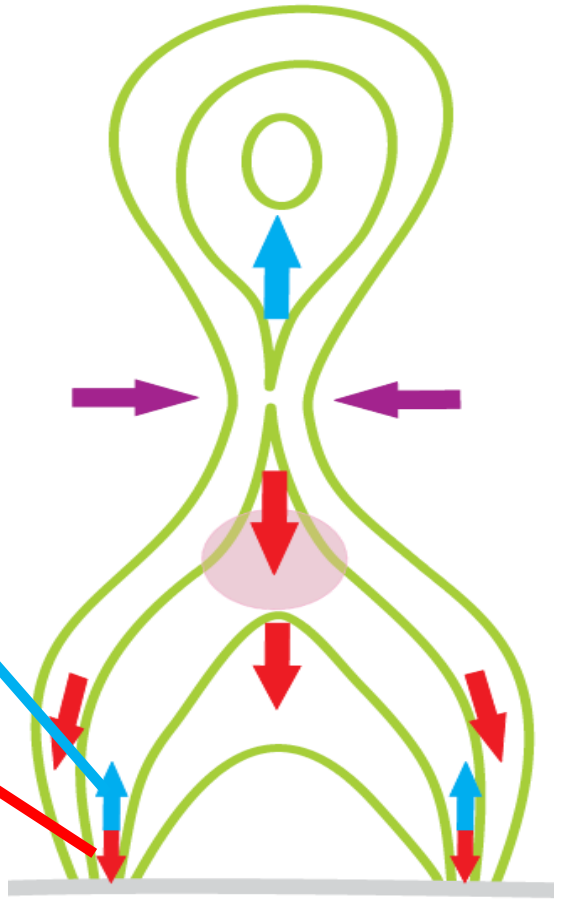
Maehara et al. 2012, Nature

Complete understanding of stellar flares will be achieved through a combination of EUV and WL windows

Unveil coronal physical processes in flare regions



Chen, Tian, Li, et al. 2022, ApJ



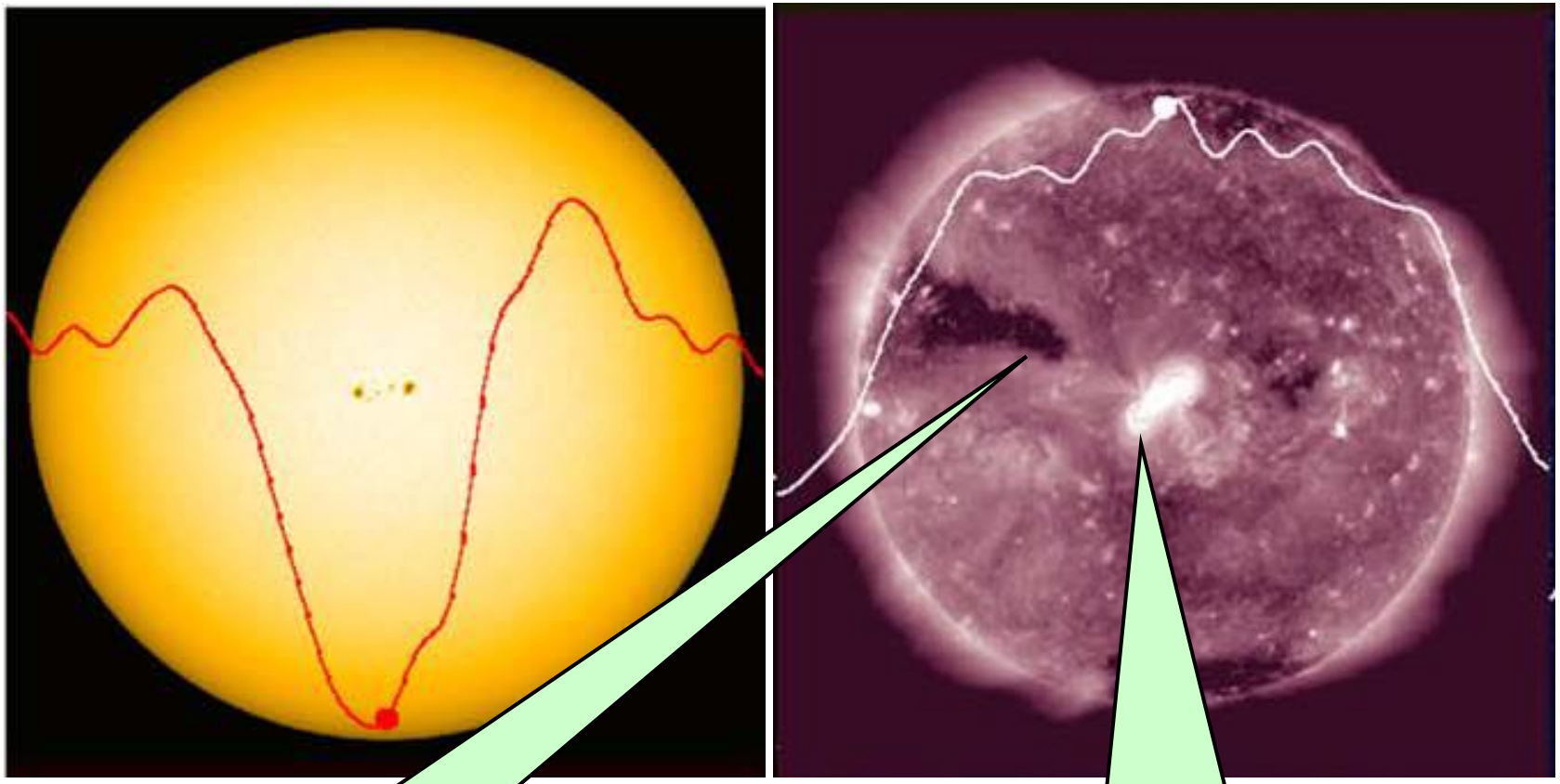
Tian et al. 2014, ApJL

- Flows of flaring plasma rarely observed on other stars
- Chandra observations of EV Lac: detection of hot evaporation flows on other stars

Large-scale coronal structures detectable in EUV

SDO/HMI, WL continuum, Photosphere

SDO/AIA, 211 Å, Corona



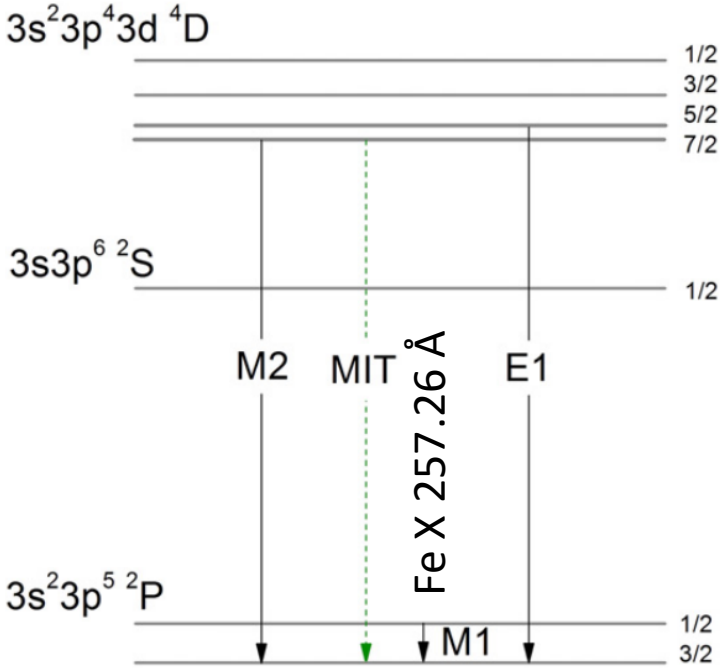
Toriumi et al. 2020, ApJ

Coronal holes (CHs): source regions of stellar winds

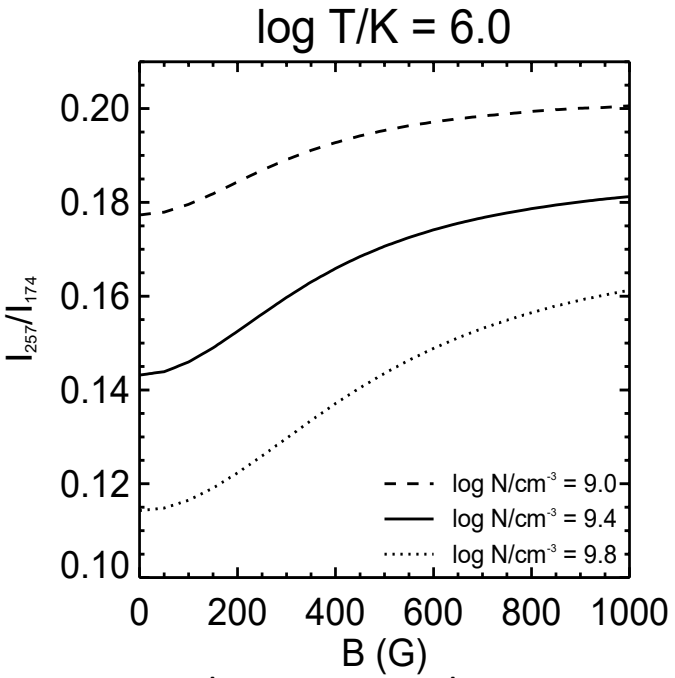
See a reconstruction of ARs on AB Dor (Singh & Pandey 2024)

Active regions (ARs): source regions of coronal eruptions

Measure stellar coronal magnetic field through EUV spectroscopy



Li, Grumer, Yang et al. 2015, ApJ
Li, Yang, Tu et al. 2016, ApJ



Chen, Li, Tian et al. 2021, ApJ; Chen, Liu, Tian et al. 2021, ApJL; Chen, Bai, Tian et al. 2023, MNRAS

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Forward Modeling of Magnetic Field Measurements at the Bases of Stellar Coronae through Extreme-ultraviolet Spectroscopy

Xianyu Liu[1], Hui Tian[1,2,3], Yajie Chen[1], Wenxian Li[3], Meng Jin[4], Xianyong Bai[3,5], and Zihao Yang[1]
[1] School of Earth and Space Sciences, Peking University, Beijing 100871, People's Republic of China; huitian@pku.edu.cn
[2] State Key Laboratory of Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing 100190, People's Republic of China
[3] Key Laboratory of Solar Activity, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, People's Republic of China
[4] SETI Institute, 339 N Bernardo Ave suite 200, Mountain View, CA, 94043, USA
[5] School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China

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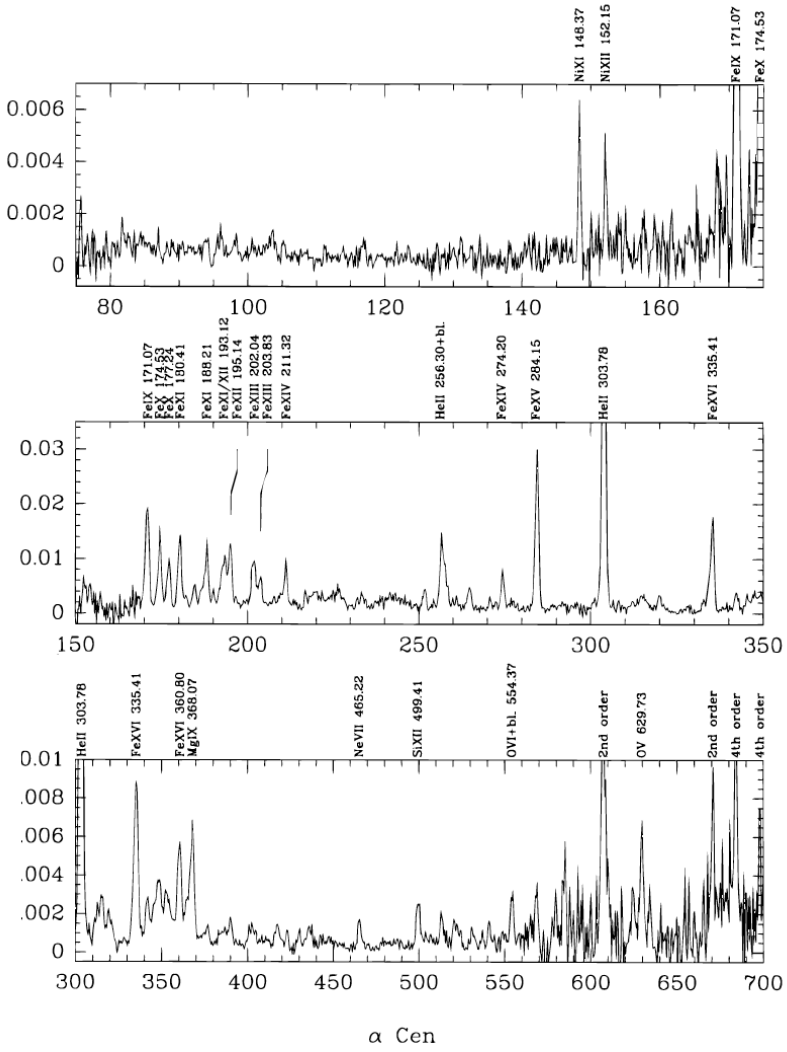
Past EUV observations of main sequence stars

- Extreme Ultraviolet Explorer (EUVE): the only observatory to have made extensive EUV spectroscopic observations of cosmic sources
  - ✓ 1992-2001
  - ✓ Spectra of ~15 cool main sequence stars (short duration)
  - ✓ Low spectral resolution: ~200
  - ✓ Low effective area: ~1 cm^2
- What we need
  - ✓ Effective area: 10-100 cm^2
  - ✓ Long-term & continuous spectroscopic and photometric observations of selected nearby host stars

CESS: Coronal Explorer for our Sun and nearby Stars



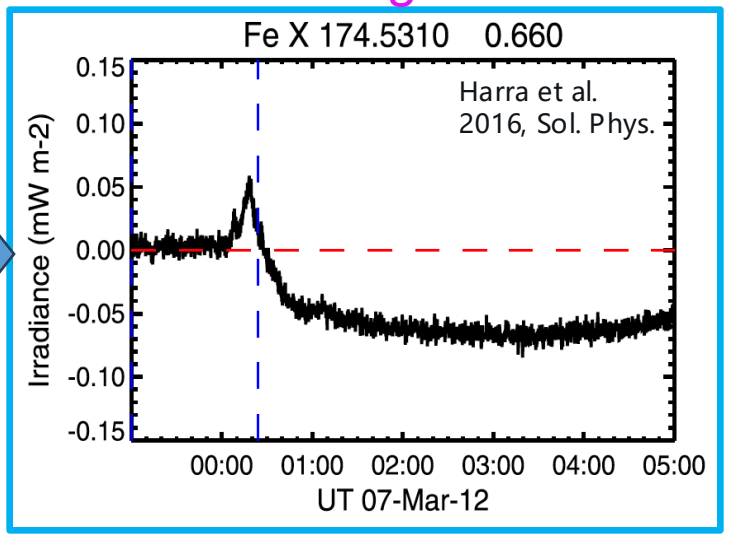
EUVE spectrum of α Cen A+B (Craig et al. 1997, ApJS)

CESS: characterize the coronal activity of host stars and its impact on exoplanet habitability

EUV Photometer

FOV	~ 5° × 5°
resolution	≤40"
wave. band	17.4、28.4、9.4、12.9 nm (*T* = 1、2.5、6 、10 MK)
band width	≤1 nm
cadence	~ 10 min

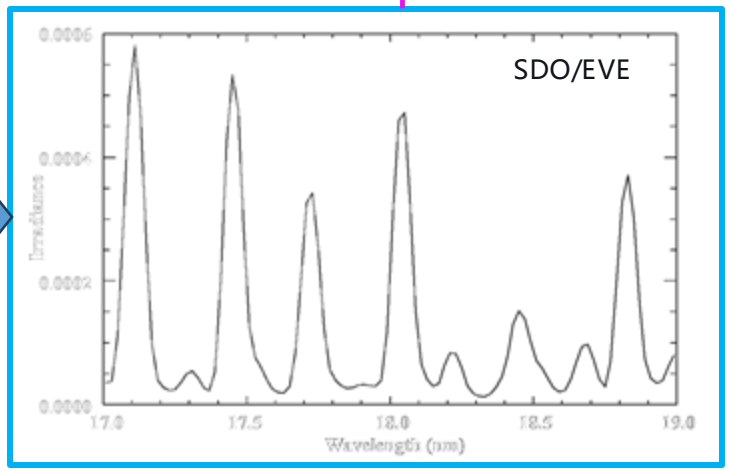
Stellar light curve



EUV Spectrograph

resolution	≤40"
wave. range	9.3-13、17-20.3、25.4-28.5 nm
R	500-2000
cadence	~ 60 min

Stellar spectrum



Summary

- Space weather (EUV/X-ray radiation, wind and eruptions from stellar coronae) also exists beyond the solar system, which could significantly affect the habitability of exoplanets

- Dedicated EUV telescopes for host stars are highly desired to monitor various types of coronal activity and evaluate the impact of space weather on exoplanet habitability

田晖，白先勇，邓元勇等，晚型恒星极紫外和X射线探测的科学目标与初步方案, 中国科学: 物理学 力学 天文学, 2022
田晖，徐昱，陈何超，张佳乐，陆洪鹏等，星冕物质抛射的探测与建模，中国科学：技术科学，2023
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