High Energy Diversity

of Nearby Rocky Exoplanet Host Stars

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Stellar Effect (XUV) on Exoplanet

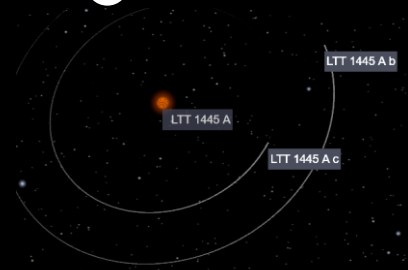
- Planetary atmospheric evolution is linked to XUV
  (e.g Watson+1981, Lammer+2003, Baraffe+2004, Erkaev+2007, Poppenhaeger+ 2020)
- Flares impact on exoplanet conditions
  (e.g. Güdel+ 2002, Segura+2010)
- Stellar XUV radiation catalyzes prebiotic chemistry
  (e.g. Ranjan& Sasselov2016)
- X-rays trace magnetic structure (magnetosphere)
  (e.g. Branduardi-Raymont 2018, Guo+2021)

Benchmark Systems

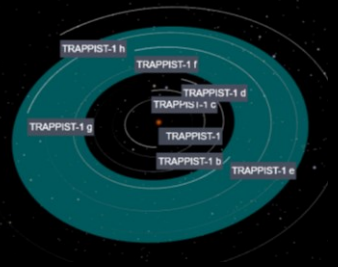
< 8 Jmag | < 25 pc | Rocky Planets | RV & Transit

Astudillo-Defru+ 2020

LTT 1445A
6.8 pc

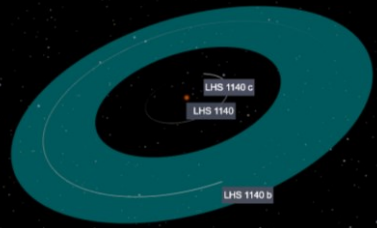


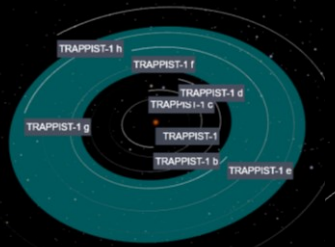
10.6 pc
L 98-59



Trappist 1
12.47 pc

12.47 pc
LHS 1140





Trappist 1

12.47 pc

LHS 3844

15 pc

12.47 pc

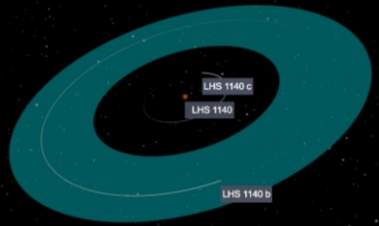
LHS 1140

13 pc

GJ 1132

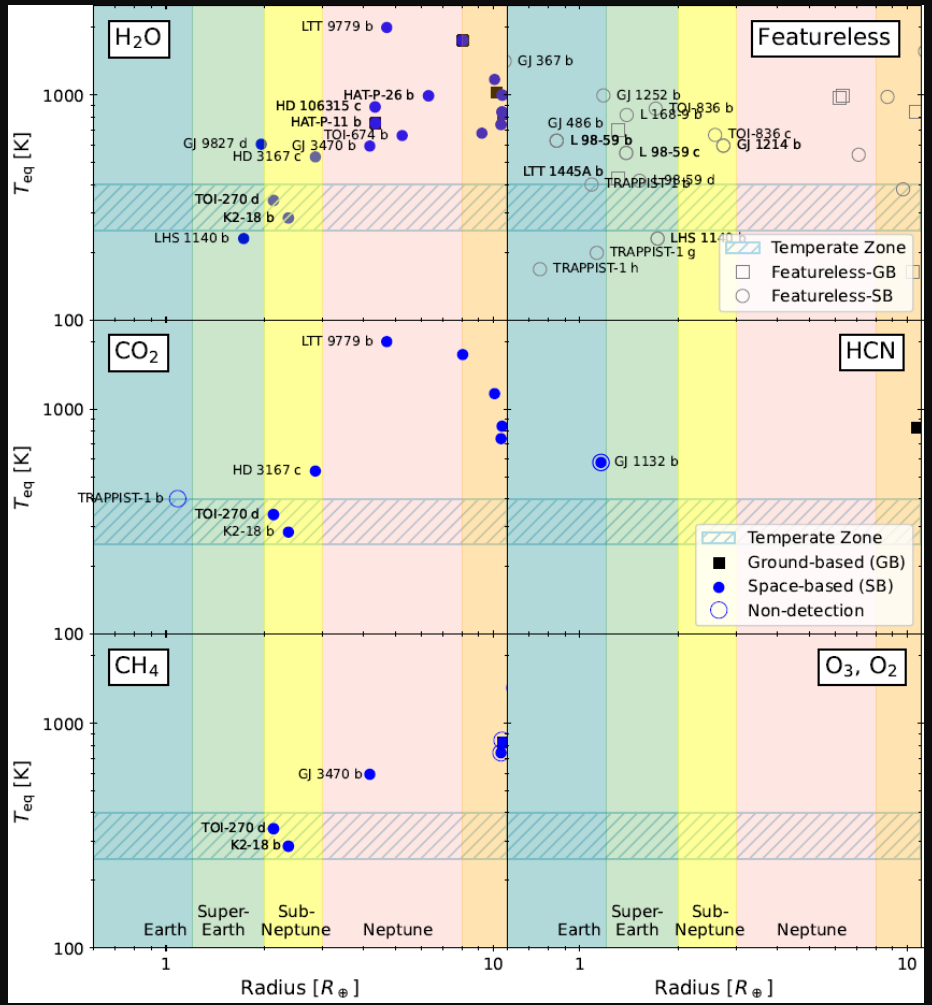
25 pc

L 168-9



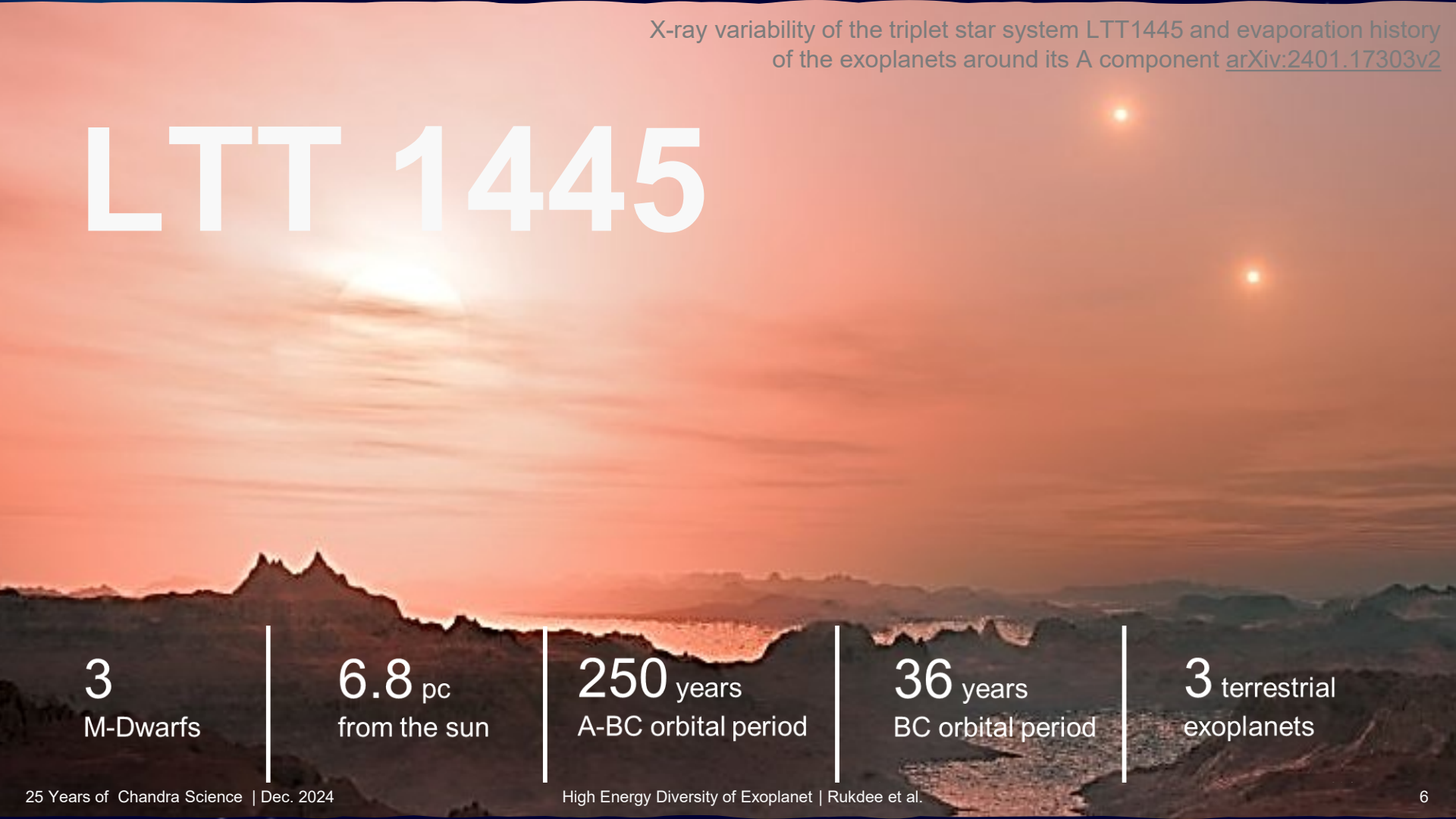
Detection of Molecules in Exoplanet Atmospheres

- **Possible causes of featureless**
  - Cloud and Haze
  - Instrument limit/sensitivity
  - Stellar Effect



X-ray variability of the triplet star system LTT1445 and evaporation history of the exoplanets around its A component arXiv:2401.17303v2

LTT 1445



3 M-Dwarfs

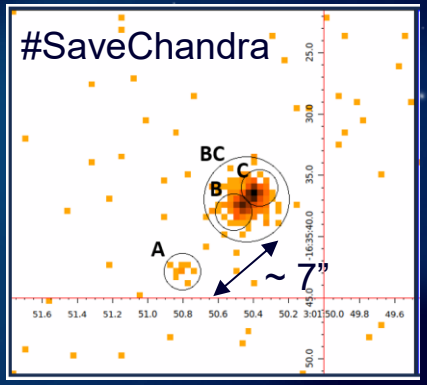
6.8 pc from the sun

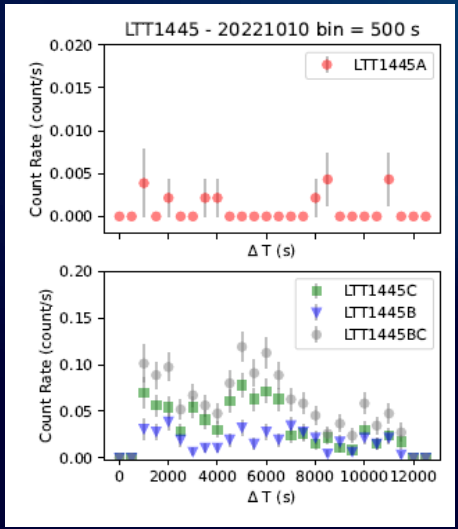
250 years A-BC orbital period

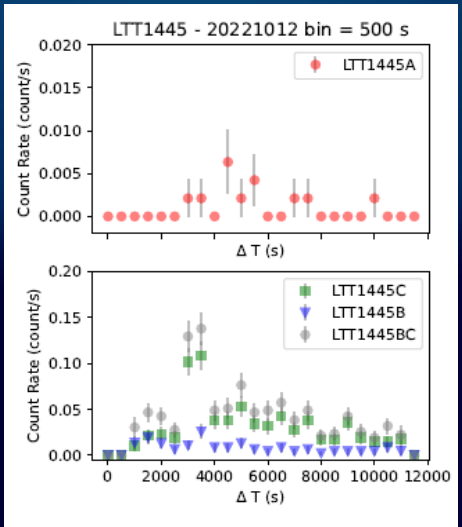
36 years BC orbital period

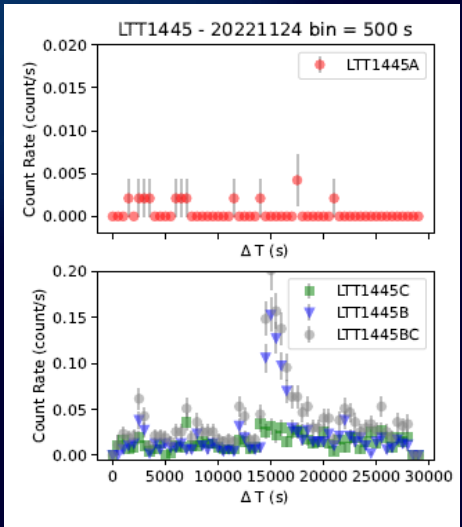
3 terrestrial exoplanets

Observations









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Fun fact: Bayesian framework nested sampling, is also commonly used in exoplanet searches (Nelson+ 2020) and atmosphere radiative transfer modeling (Mollière+ 2019)

BXA-plasma

BXA connects the X-ray spectral analysis environments Xspec/Sherpa to the nested sampling algorithm 'UltraNest'

- **Bayesian Parameter Estimation**
- **Model comparison**

BXA-plasma connects BXA with plasma models e.g. APEC, VAPEC

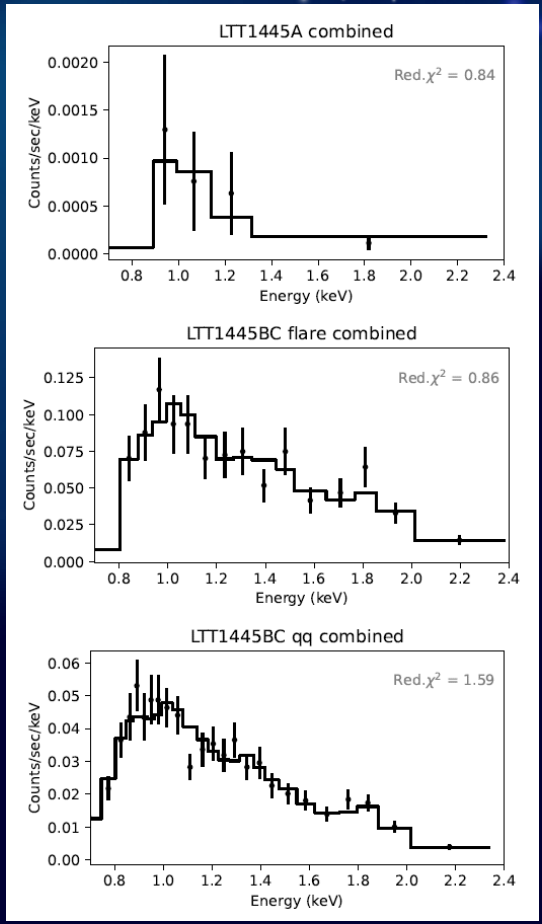
https://github.com/SurangkhanaRukdee/BXA-Plasma

Buchner+ 2014
Rukdee+ 2024

BXA model comparison

- Compare APEC and VAPEC on the flare dataset
- Fit abundances, temperature, normalization, sigma
- Disclaimer: low counts data

Model	ln(Z)	C-stat
APEC	-114.8±0.47	214.14
VAPEC	-115.3±0.46	212.87



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Plasma Temperature

Robrade & Schmitt 2005

- Study 4 active M-stars: M3.5 – M4.5
- Temperature Grid: the 3 –T and the 6 -T model lead to fully consistent results on abundance

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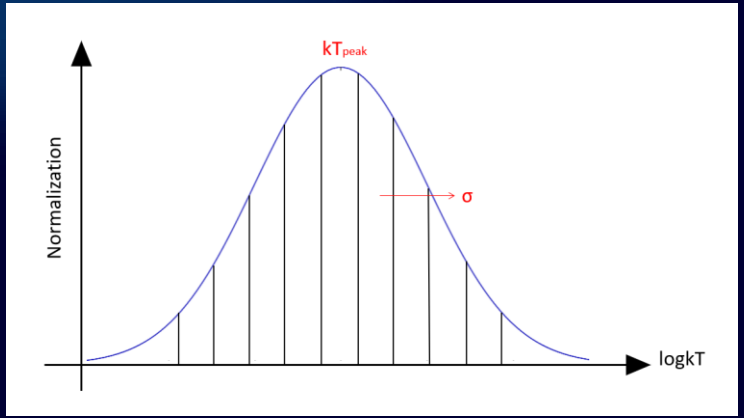
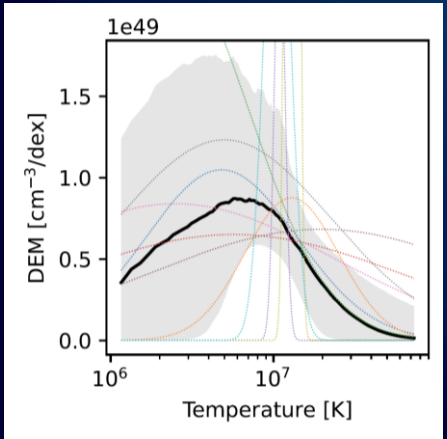
- Temperature Distribution
- Capture the behavior of the plasma temp. better than a single point (kT1 or kT2)
- Approximated by summing many single temperature component > increase sampling

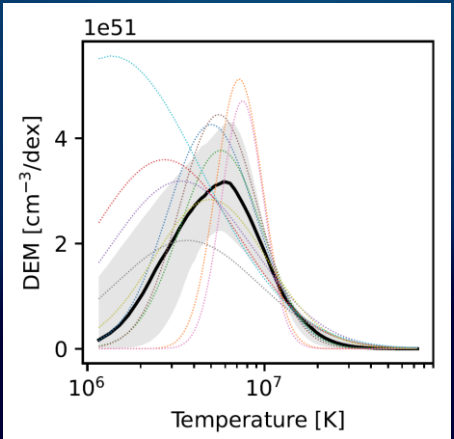


Temperature ~~grid~~ distributions

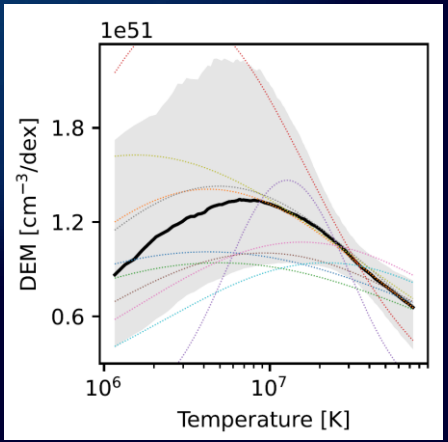
Quiescence



Quasi-Quiescence



Flare



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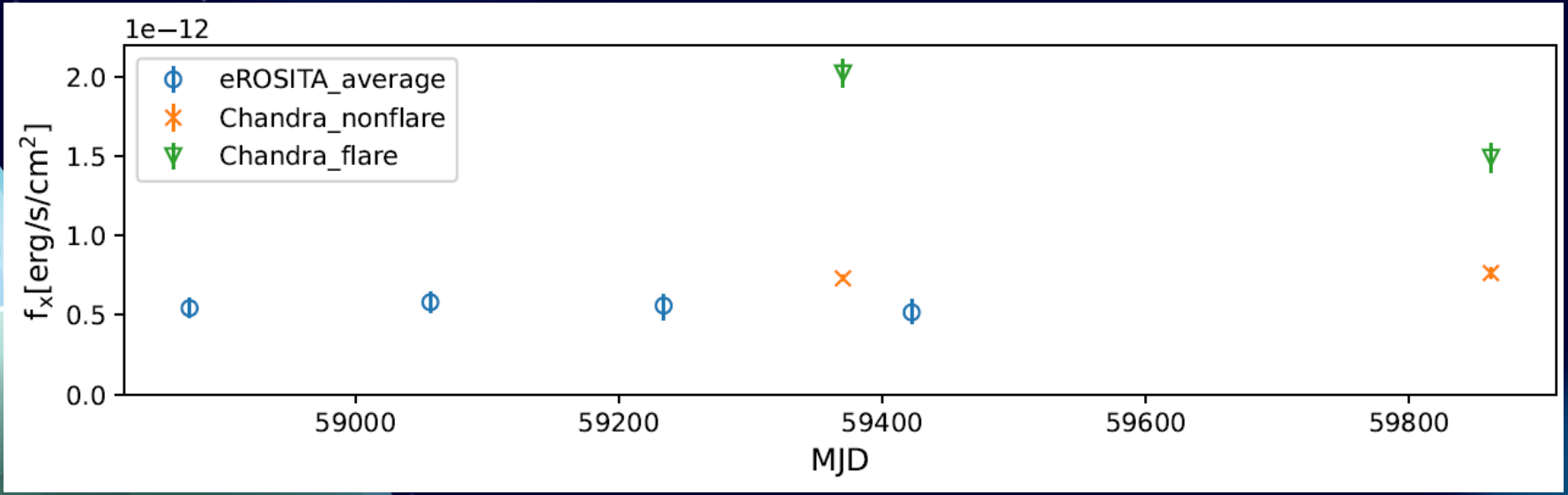
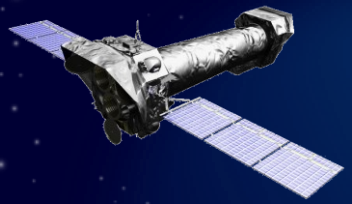
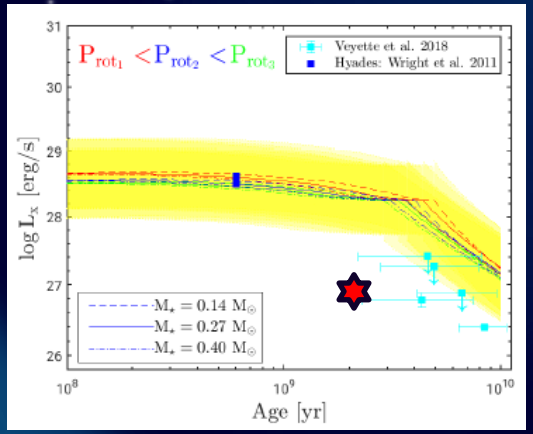
Long-term Monitoring on BC



Caveat: as of 2020, Chandra is most sensitive from 0.9-7 keV, while eROSITA has most sensitive energy range from 0.3-2.3 keV

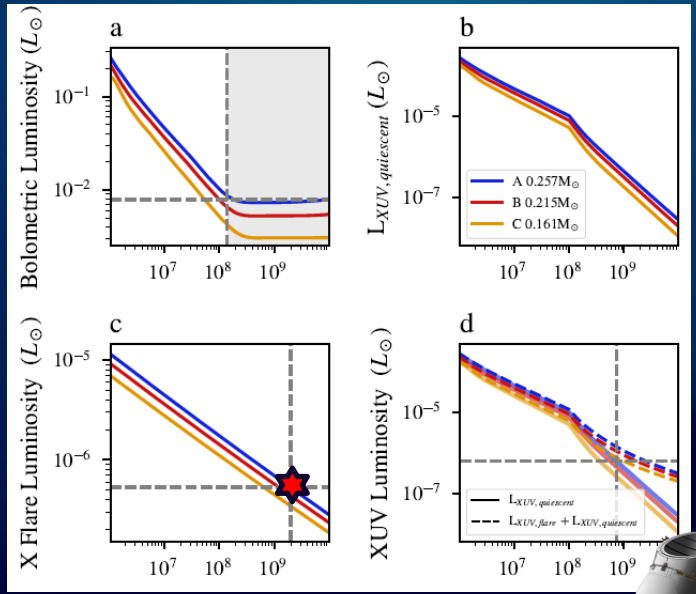
Age of the Star



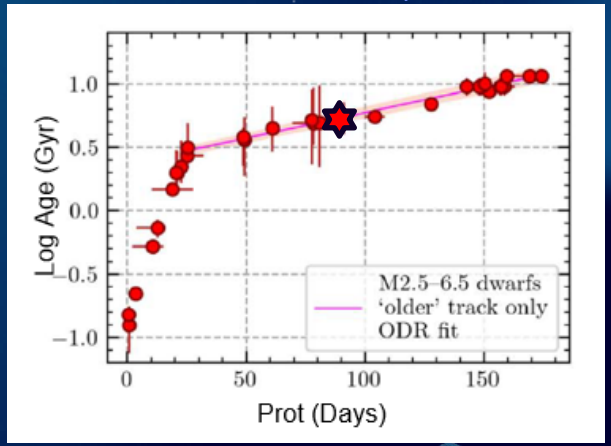


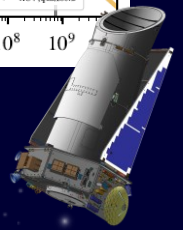
Magaudda+ 2020

Rukdee+ 2024



Engle+ 2023





Water loss & Oxygen Build-up

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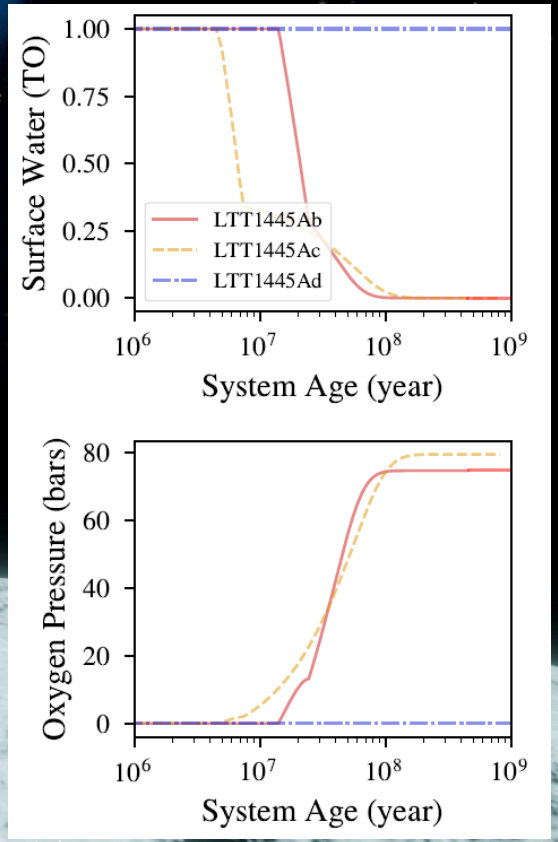
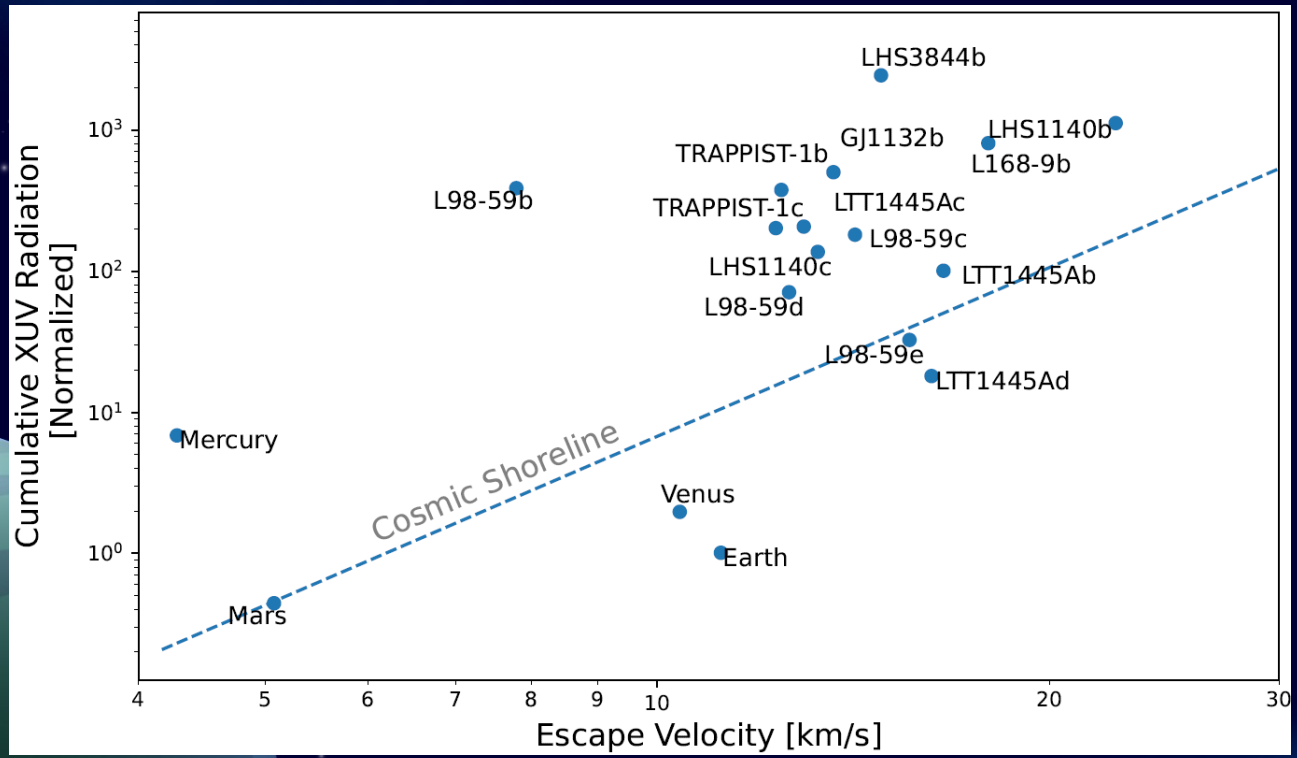
- A's age estimated ~2 Gyr
- Surface water of 1.0 Terrestrial Ocean

Models:
Barnes+2020
Baraffe+2015
Bolmont+2017
Davenport+2016,19
Do Amaral+2022



Cosmic Shoreline (Preliminary)



Rukdee+ 2025 in prep.

Zahnle+2017

Mansfield+2024

Summary

It is crucial to characterize stellar XUV radiation together with an assessment of exoplanet atmospheres.

We use BXA to connect the X-ray spectral analysis environments Xspec/Sherpa to the nested sampling algorithm UltraNest' and the plasma model with temperature distribution (BXA-plasma) for

- systematically analyzing a large data set
- comparing multiple models
- analyzing low counts data with realistic models

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