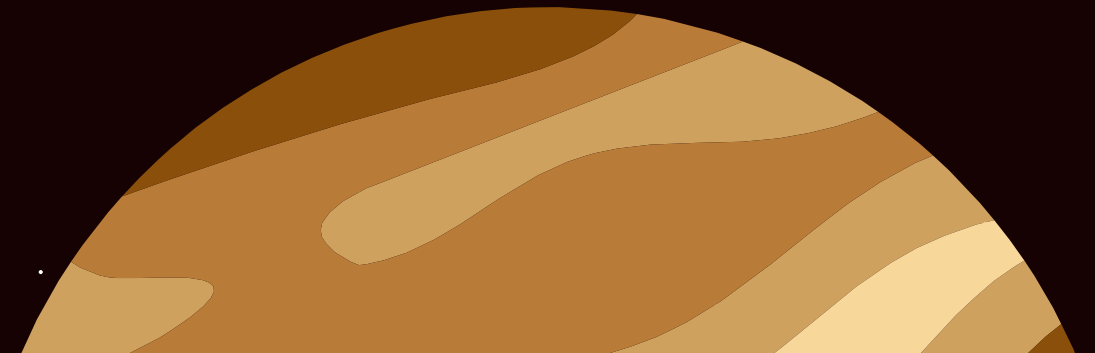
Bridging Observations

X-ray Calibration of Faint Stellar Hosts Across eROSITA, Chandra, and XMM-Newton

S. Rukdee

M. Güdel, S. Boro Saikia, K. Poppenhäger,
J. Buchner, V. Burwitz, J. Seidel, G. Roccetti



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

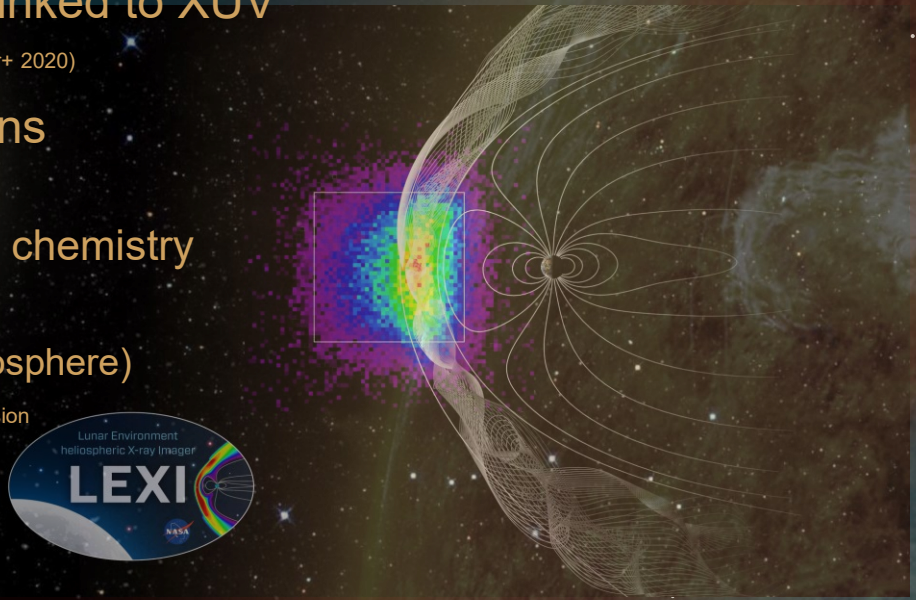
  (e.g. Güdel+ 2002, Segura+2010)

- Stellar XUV radiation catalyzes prebiotic chemistry

  (e.g. Ranjan& Sasselov2016)

- X-rays trace magnetic structure (magnetosphere)

  (e.g. Branduardi-Raymont 2018, Guo+2021,Waish 2024) > check out LEXI mission



Re-cap

High Energy Environment
of Rocky Exoplanets

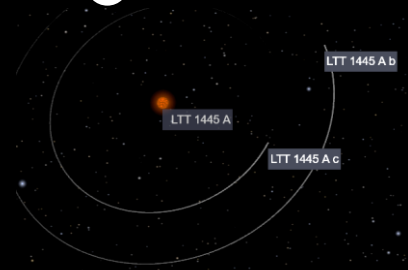
Benchmark Systems

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

Astudillo-Defru+ 2020

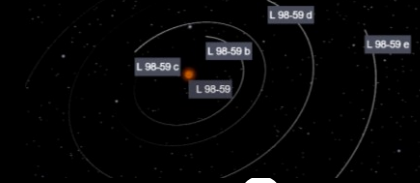
LTT 1445A

6.8 pc



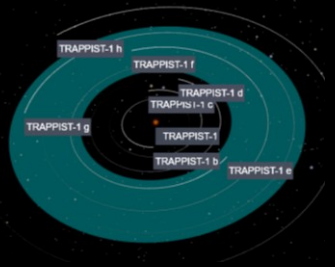
L 98-59

10.6 pc



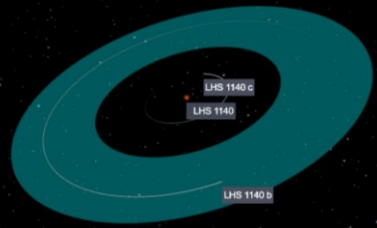
Trappist 1

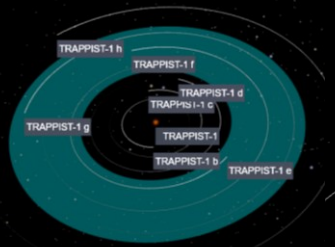
12.47 pc



LHS 1140

12.47 pc



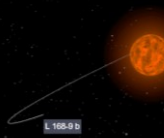


Trappist 1

12.47 pc

LHS 3844

15 pc



12.47 pc

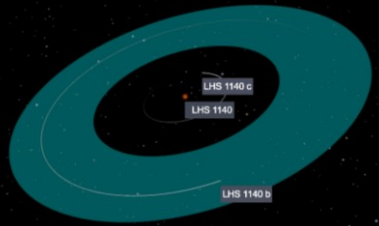
LHS 1140

13 pc

GJ 1132

25 pc

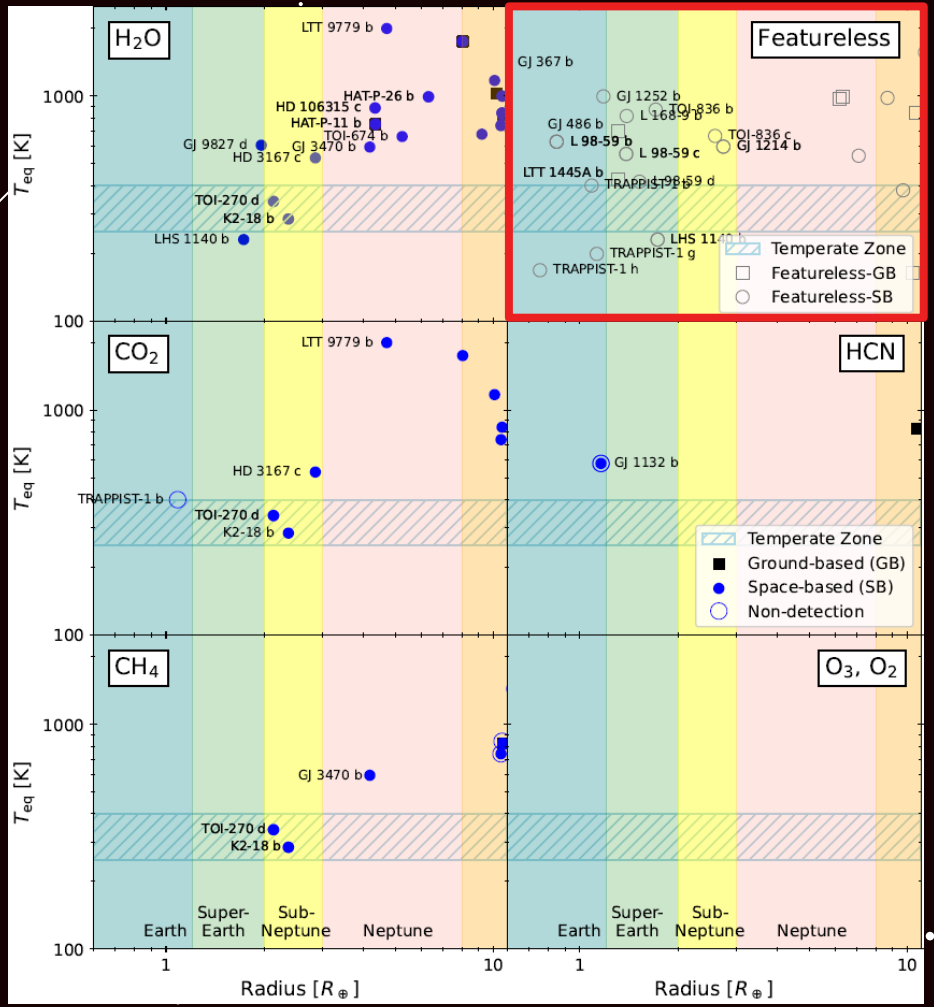
L 168-9



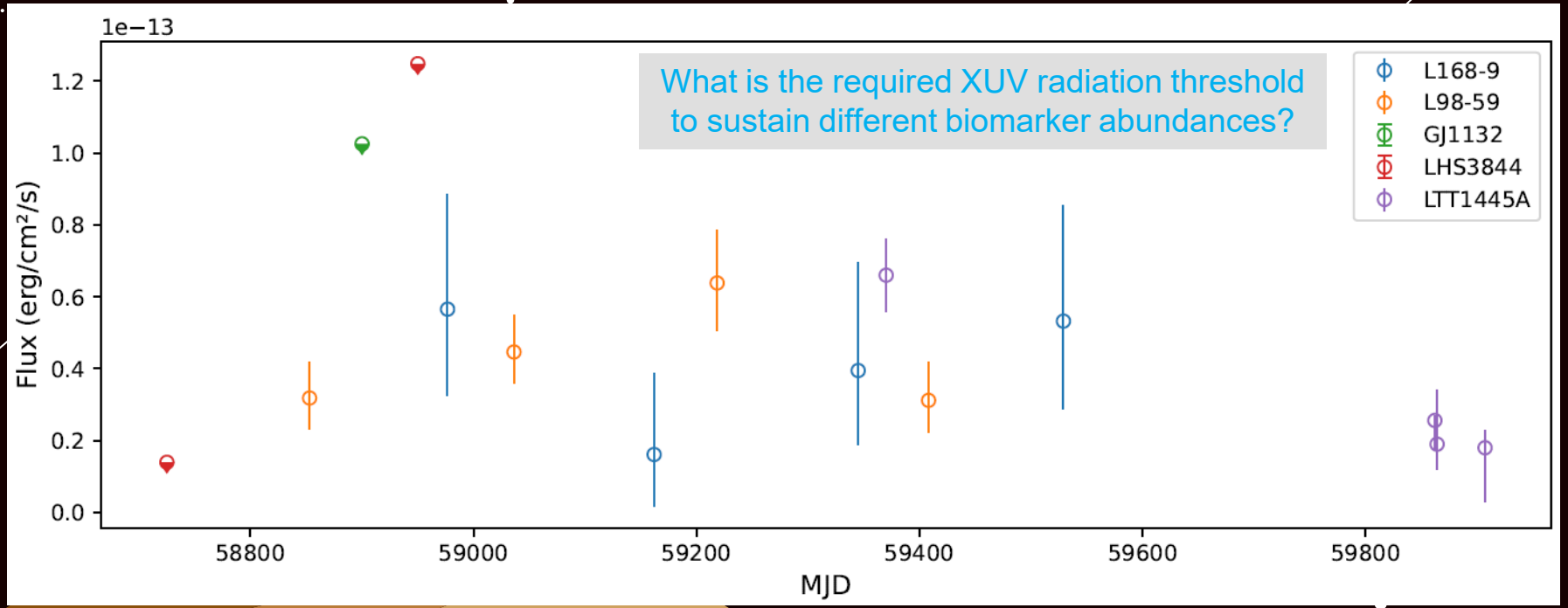
Detection of Molecules in Exoplanet Atmospheres

Why featureless?

- Cloud and Haze
- Instrument limit/sensitivity
- Stellar Effect

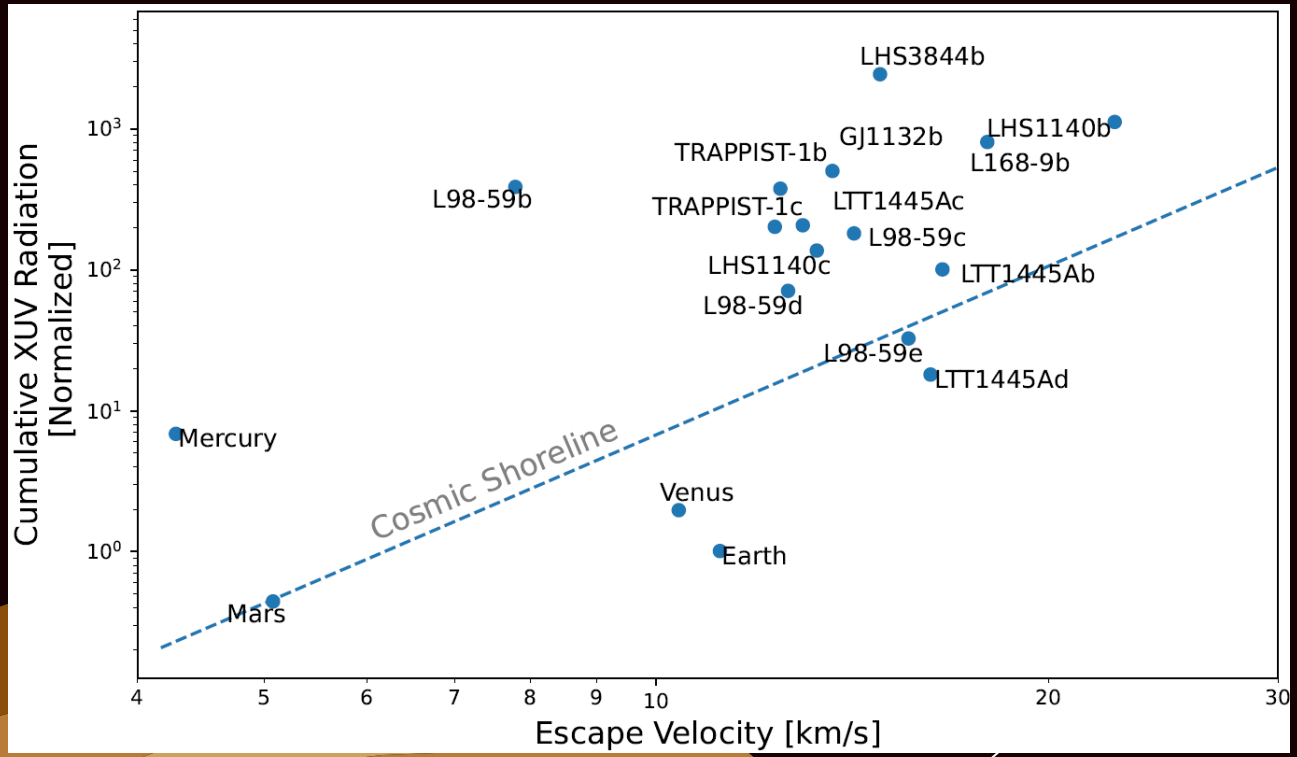


Long-term Monitoring (Swift, eROSITA-DE, Chandra)



Rukdee 2025a in prep.

Cosmic Shoreline (Preliminary)



Rukdee+ 2025a in prep.

Zahnle+2017 Model

Mansfield+2024

K2-18b

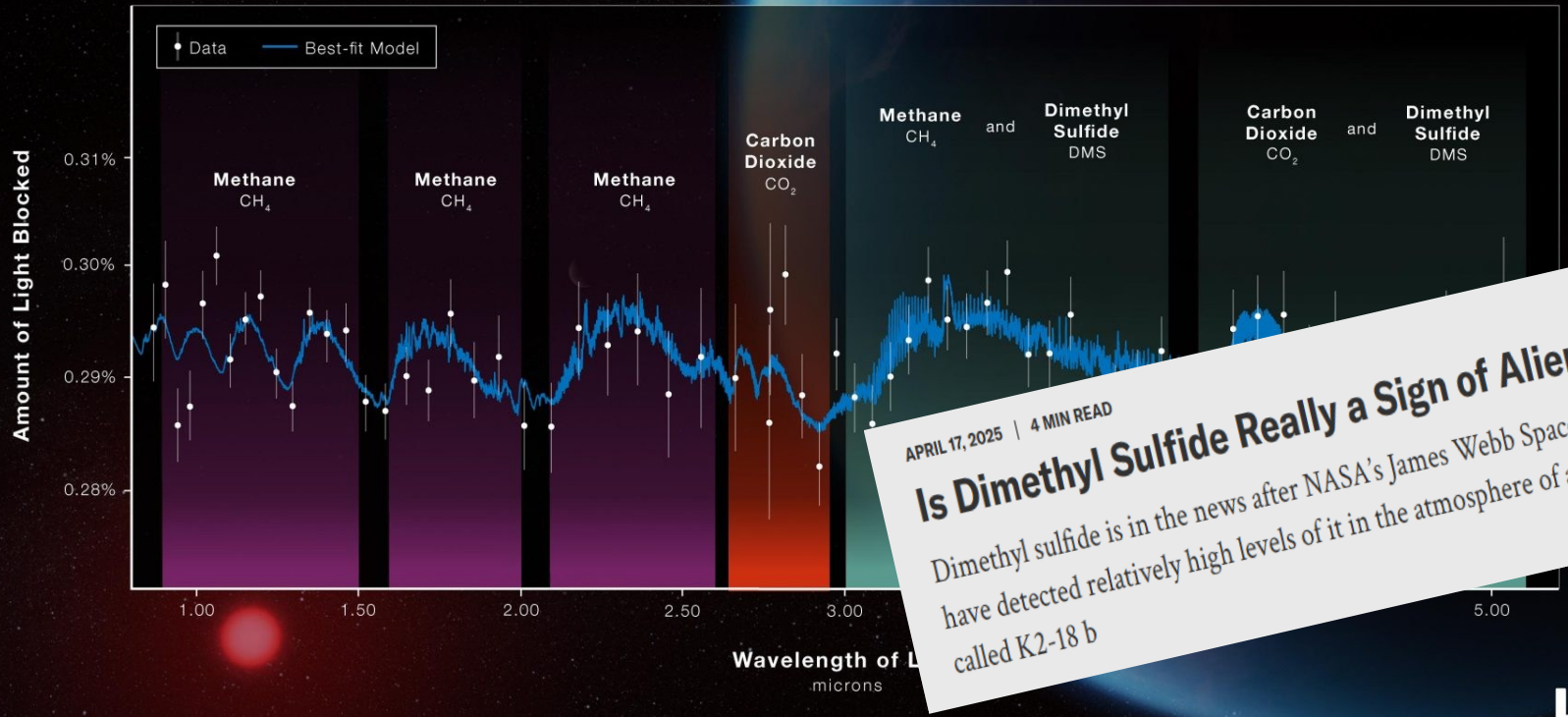
Super-Earth around M star

EXOPLANET K2-18 b

ATMOSPHERE COMPOSITION

Madhusudhan+ 2023, 2025

NIRISS and NIRSpec (G395H)



APRIL 17, 2025 | 4 MIN READ

Is Dimethyl Sulfide Really a Sign of Alien Life?

Dimethyl sulfide is in the news after NASA's James Webb Space Telescope may have detected relatively high levels of it in the atmosphere of an exoplanet called K2-18 b

WEBB SPACE TELESCOPE

K2-18

Super Earths around M star

3457 K
Stellar Temp.

284 K
Planet b Temp.

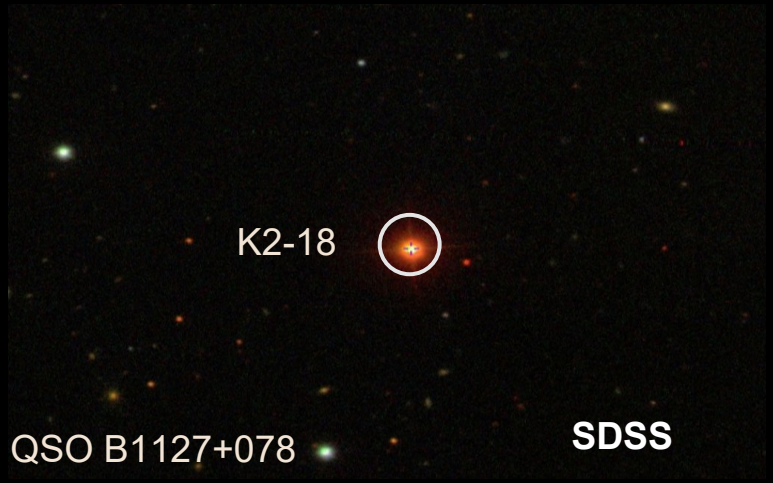
38 pc
from the sun

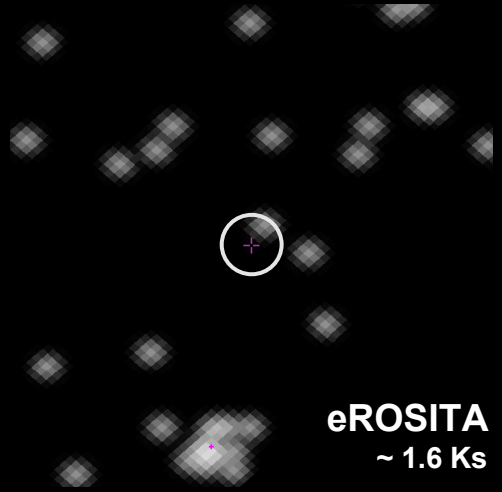
0.14 AU
Semi Major Axis
Planet b

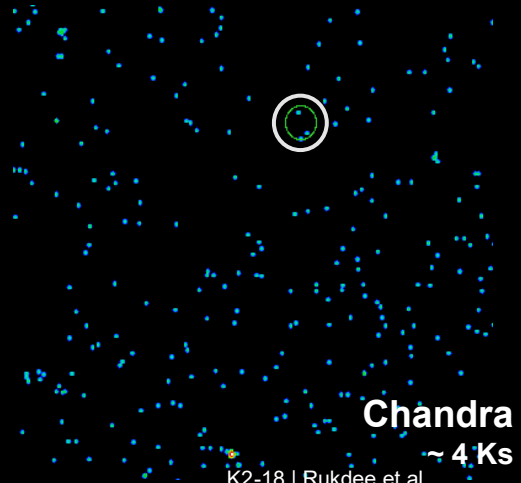
2
exoplanets

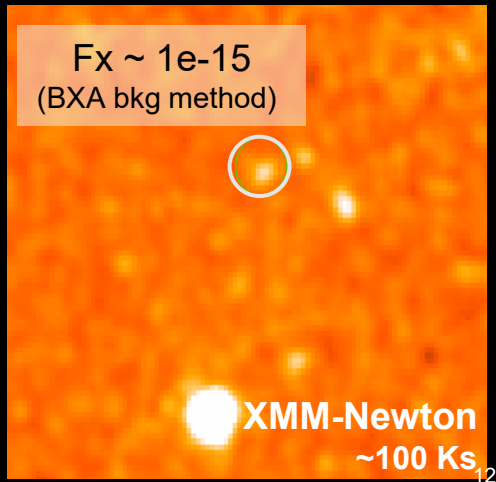
K2-18 Observations

Rukdee 2025b in prep.









PCA-based background models

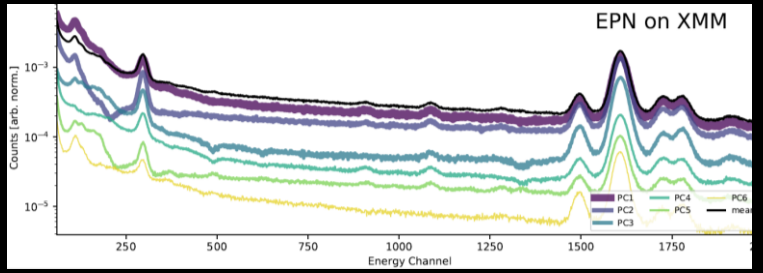
Machine Learning Approach:
- Simmonds et al. (2018) applied PCA to build empirical background models.

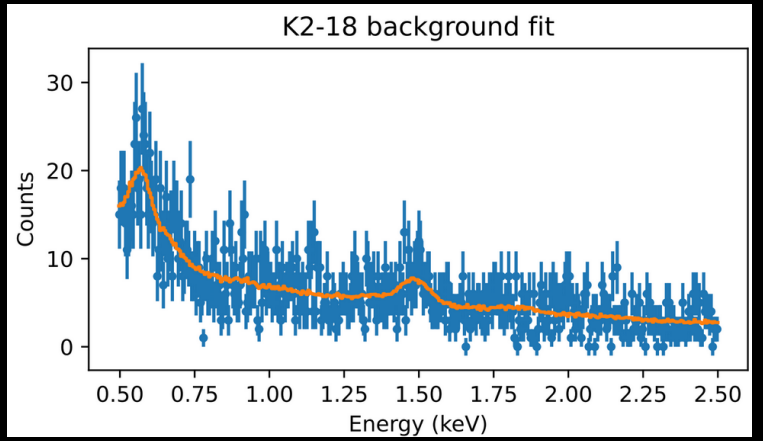
Enhanced Low-Count Analysis:
- Models leverage bin correlations and instrument behavior to extract more from low-count data.

PCA Modeling:
- Trained in $\log_{10}(\text{counts} + 1)$ space, PCA operates on detector channels without using response files.

Adaptive Model Refinement:
- Gaussian lines are added at residual peaks, with complexity guided by the AIC

Simmonds+ 2018





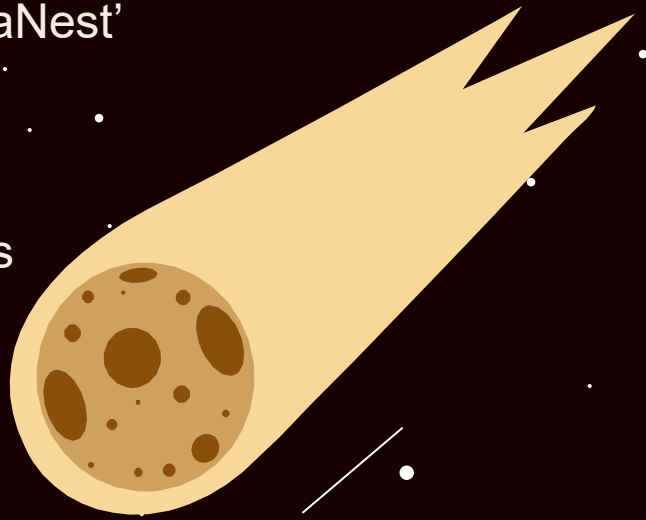
BXA-plasma

Buchner+ 2014
Rukdee+ 2024

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 multi-plasma models e.g. APEC



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

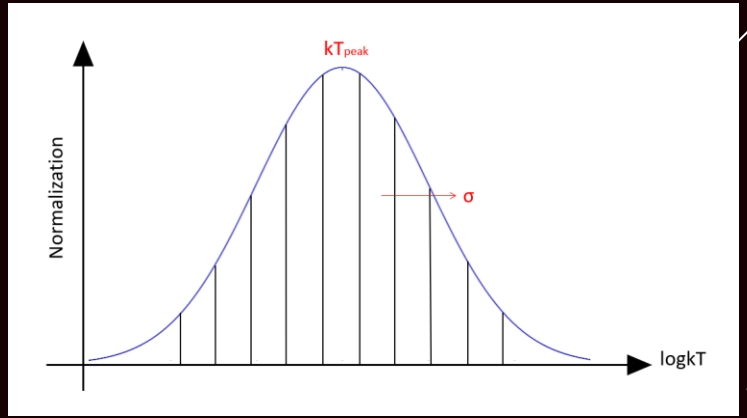
Plasma Temperature

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

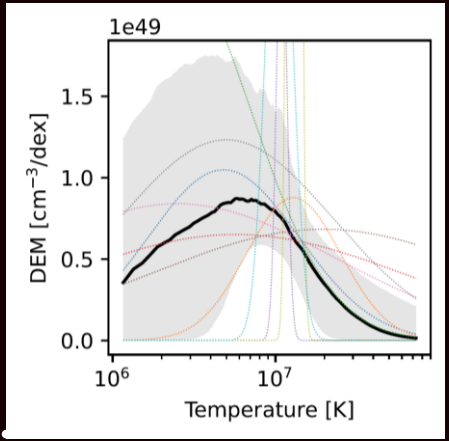
Rukdee+ 2024

- Log-Gaussian 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

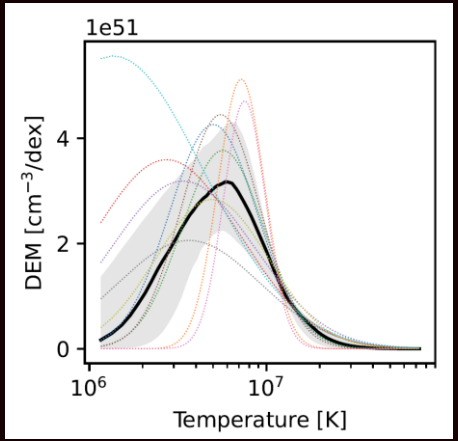


TEMPERATURE GRID DISTRIBUTIONS

Quiescence

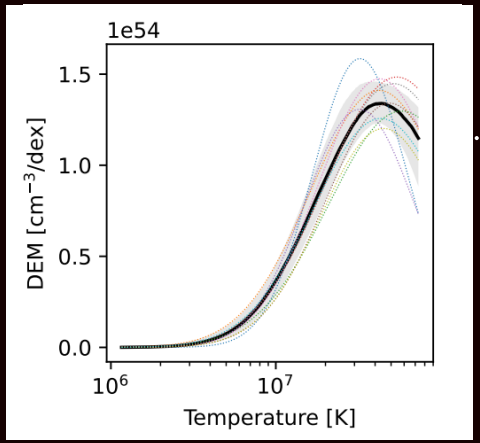


Quasi-Quiescence



Flare

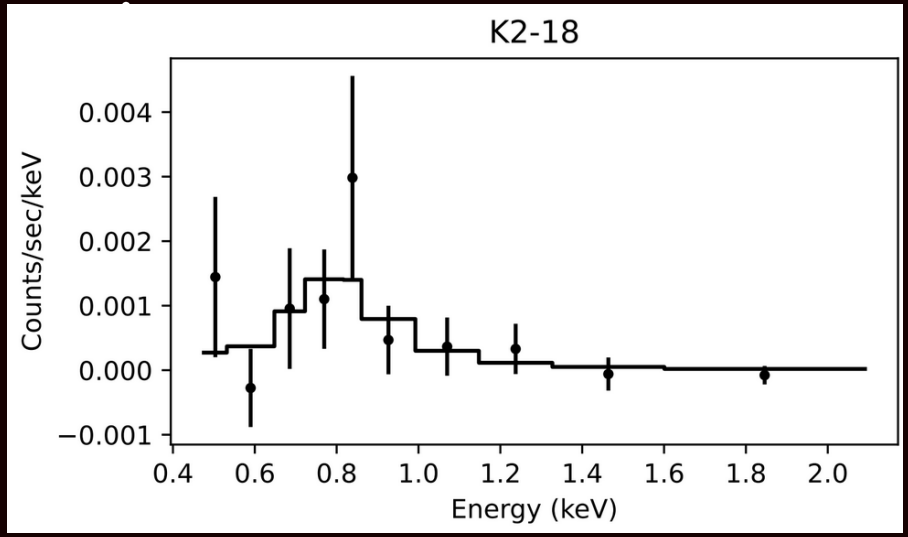
Gaia DR3 3918904293185534080

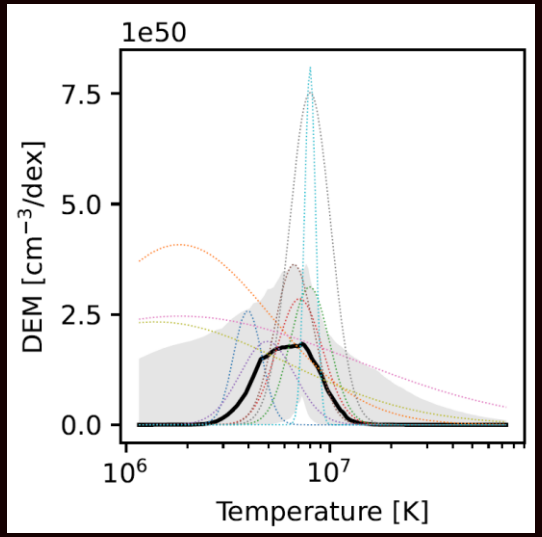


Rukdee+ 2024 - LTT1445 system

SPECTRAL FITTING

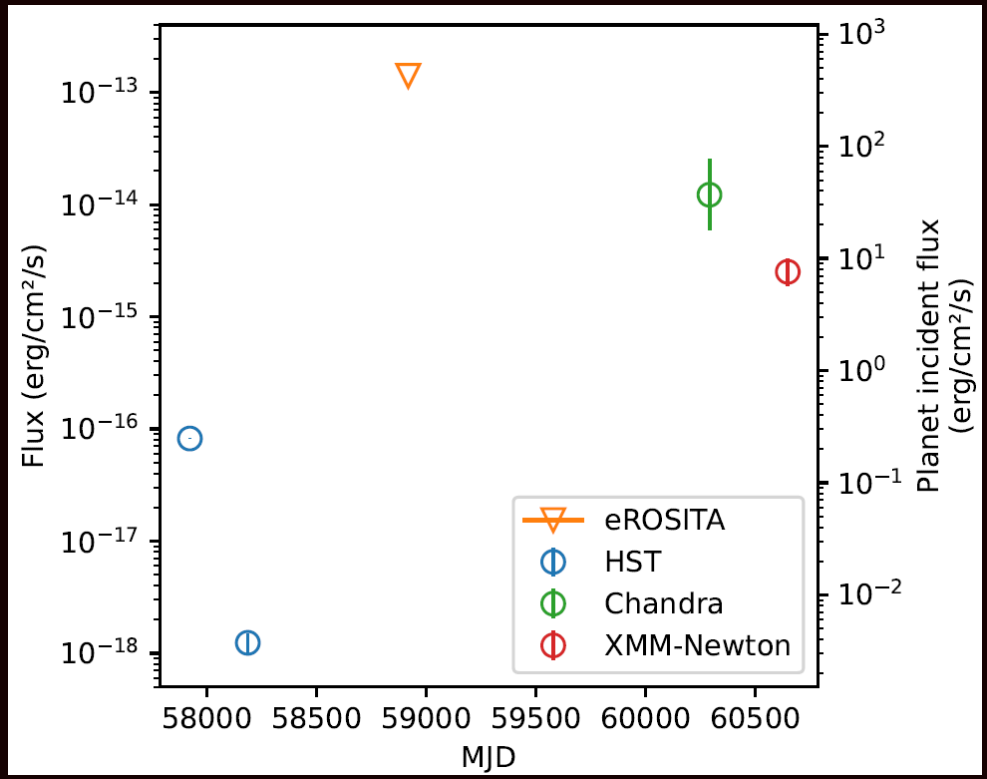
Rukdee 2025b in prep.





High Energy Flux

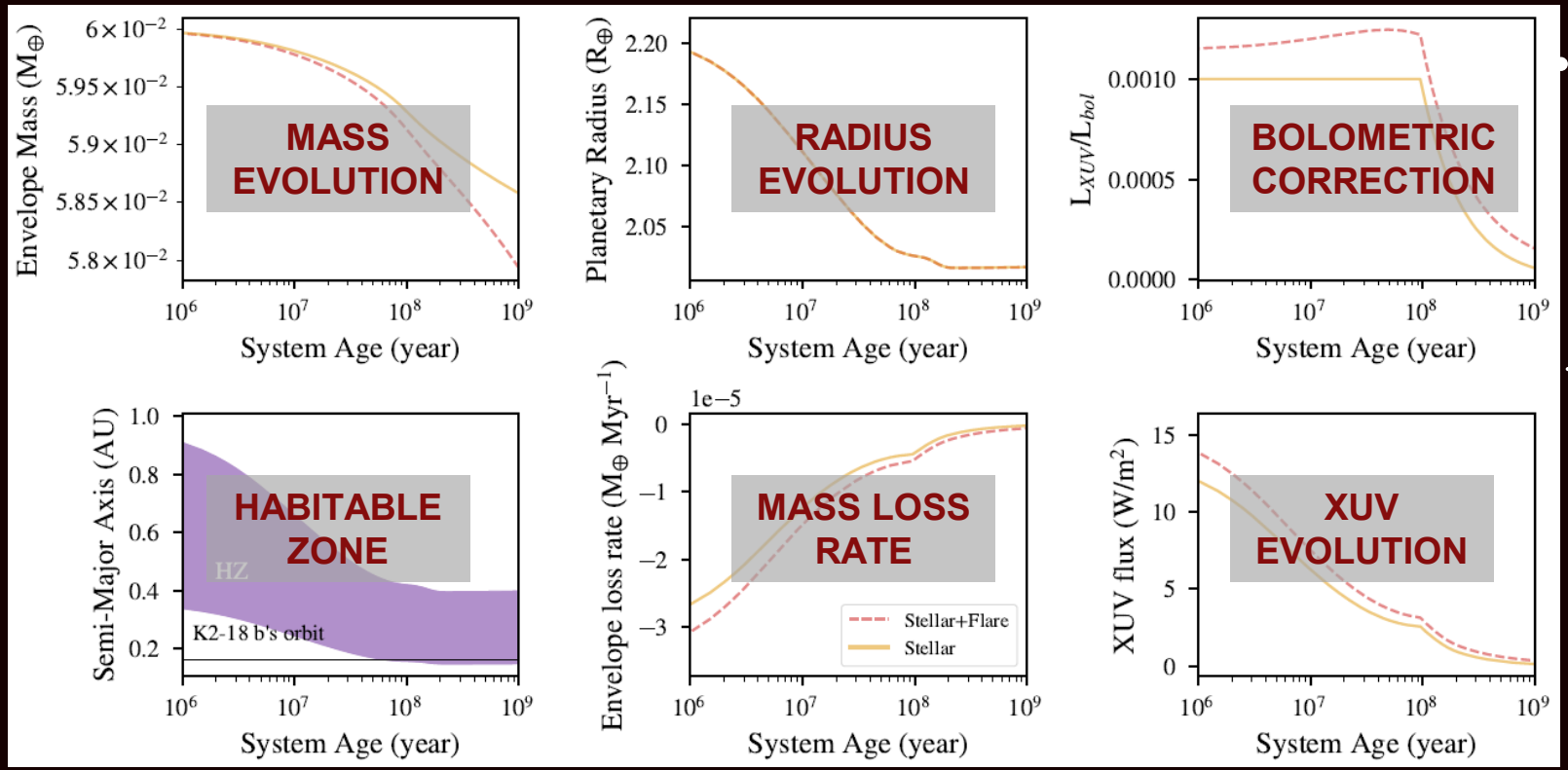
Rukdee 2025b in prep.



INTERPRETATION

Rukdee 2025b in prep.

Barnes+2020 VPLanet Model



What do we learn?

PRECISE X-RAY FLUX CONSTRAINTS PROVIDE

- Understanding of planetary atmospheres
- Refine habitability criteria
- Improving exoplanet evolution models.

We are undergoing the joint XMM-VLT pilot program for small planets around FGK stars

NEWATHENA will play a crucial role in studying star-planet interactions and chemical abundances in both stellar and planetary atmospheres.

Thank you IACHEC for your calibration work and enabling science!