

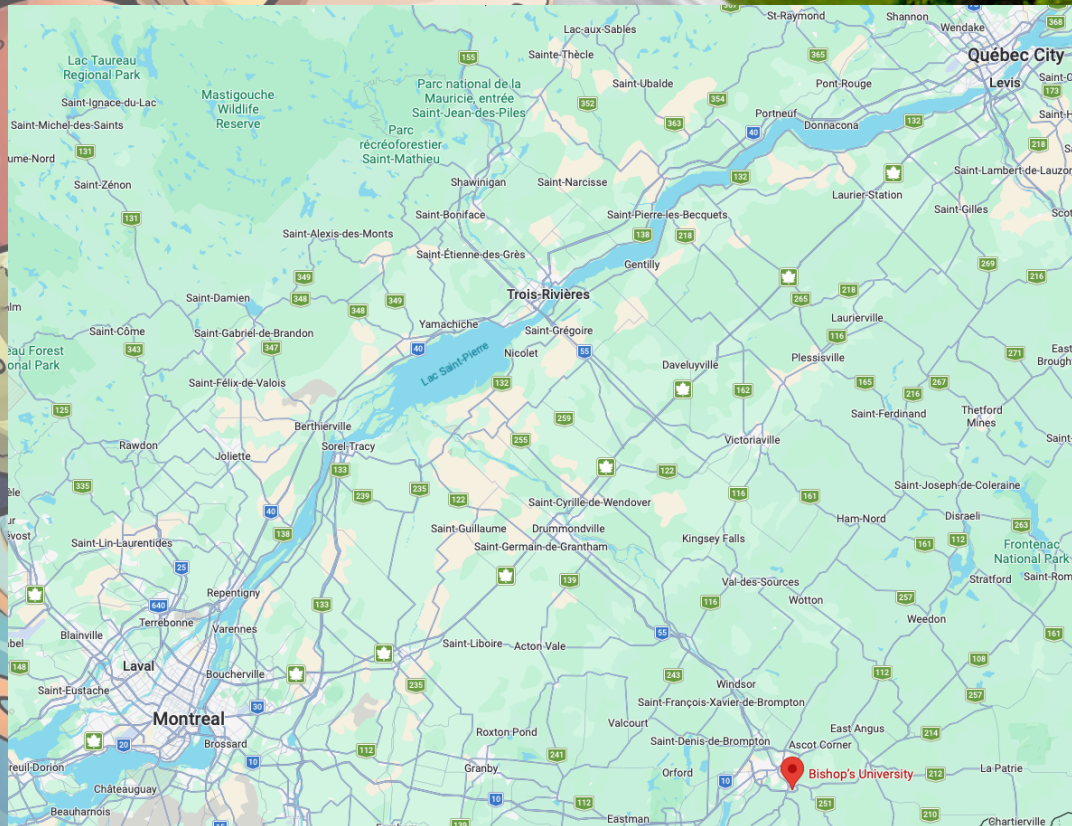


Challenges with Roman Transits

2026 Sagan Workshop

Jason Rowe, Bishop's University, July 22nd, 2026

Bishop's University



Bishop's University is located in Sherbrooke, Quebec on the traditional and unceded territory of the Abenaki people.

Exoplanet Team at Bishop's

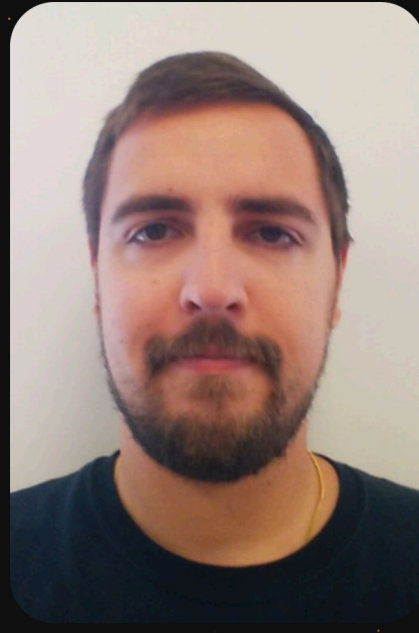
Team BU



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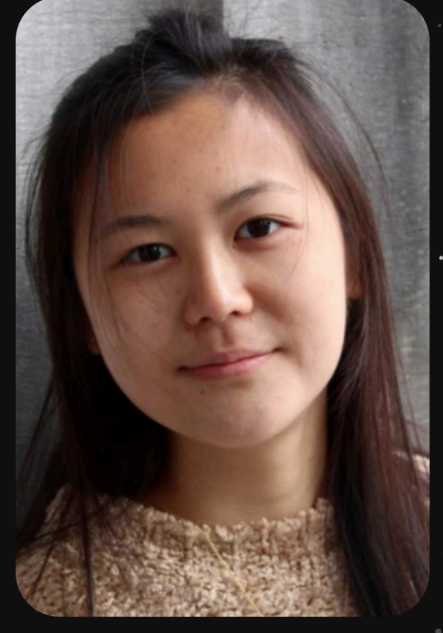
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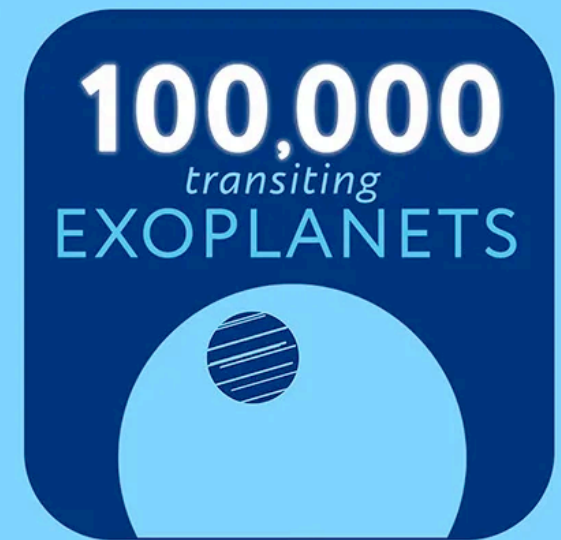


Trottier Institute
for Research
on Exoplanets



R.OMAN

CAPTURING THE BIG PICTURE: *What Roman Will Reveal*



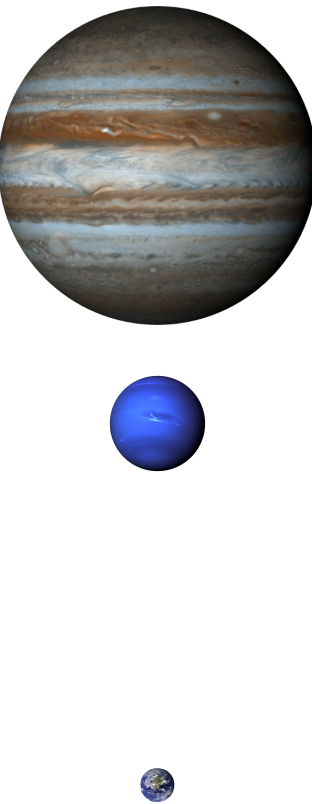
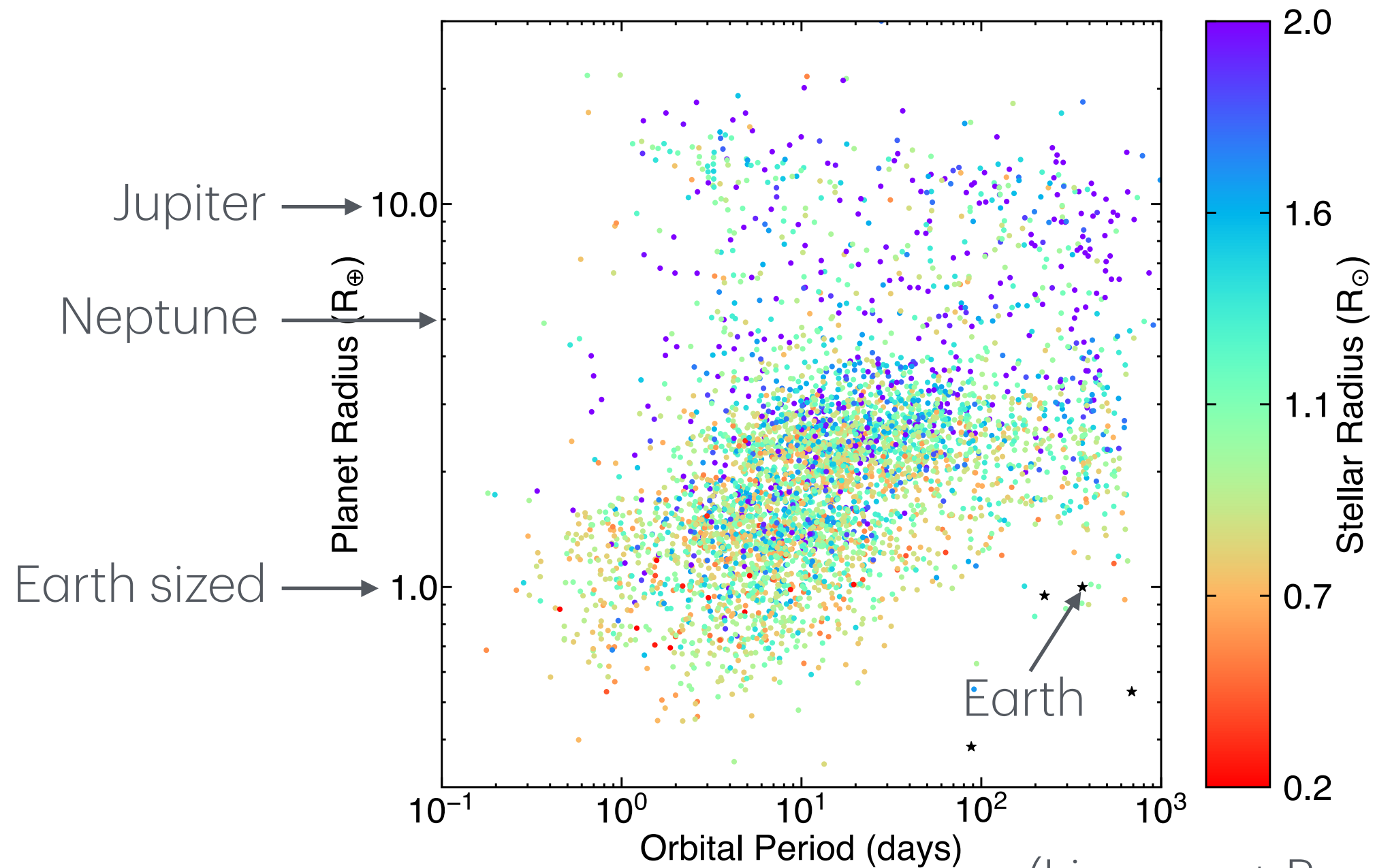
Talk Overview

Too many ideas, not enough time....

- Transit depth
 - Apparent vs theory
 - dilution
- Signal to Noise
 - Various definitions SES, MES, SNR
 - Impact of red-noise
 - $MES > 7.1$
- Data Pre-conditioning
 - Stellar and instrumental noise
- Data volume
 - Computational burden
- Eclipsing binaries
 - Foreground
 - Background
- Multi-planet systems
- Candidates/ validation/ confirmation
 - False-alarm vs false-positive
- Recovery curves
 - Injection / recovery
- Community Software
 - BLS_cuda + pytfits (*transitfit5*)

Planet Properties

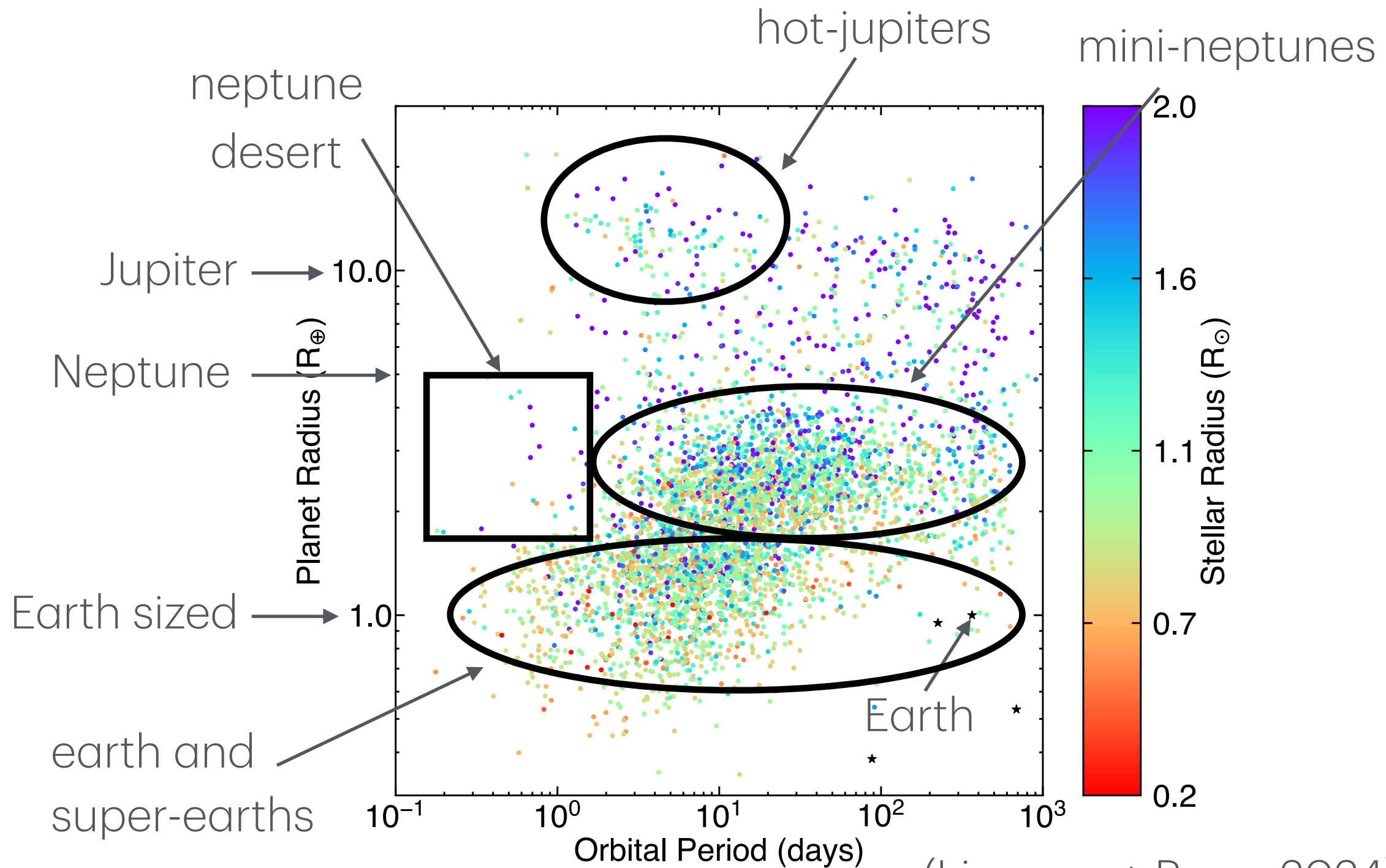
Some scales for reference



(Lissauer + Rowe 2024)

Planet Properties

Some scales for reference

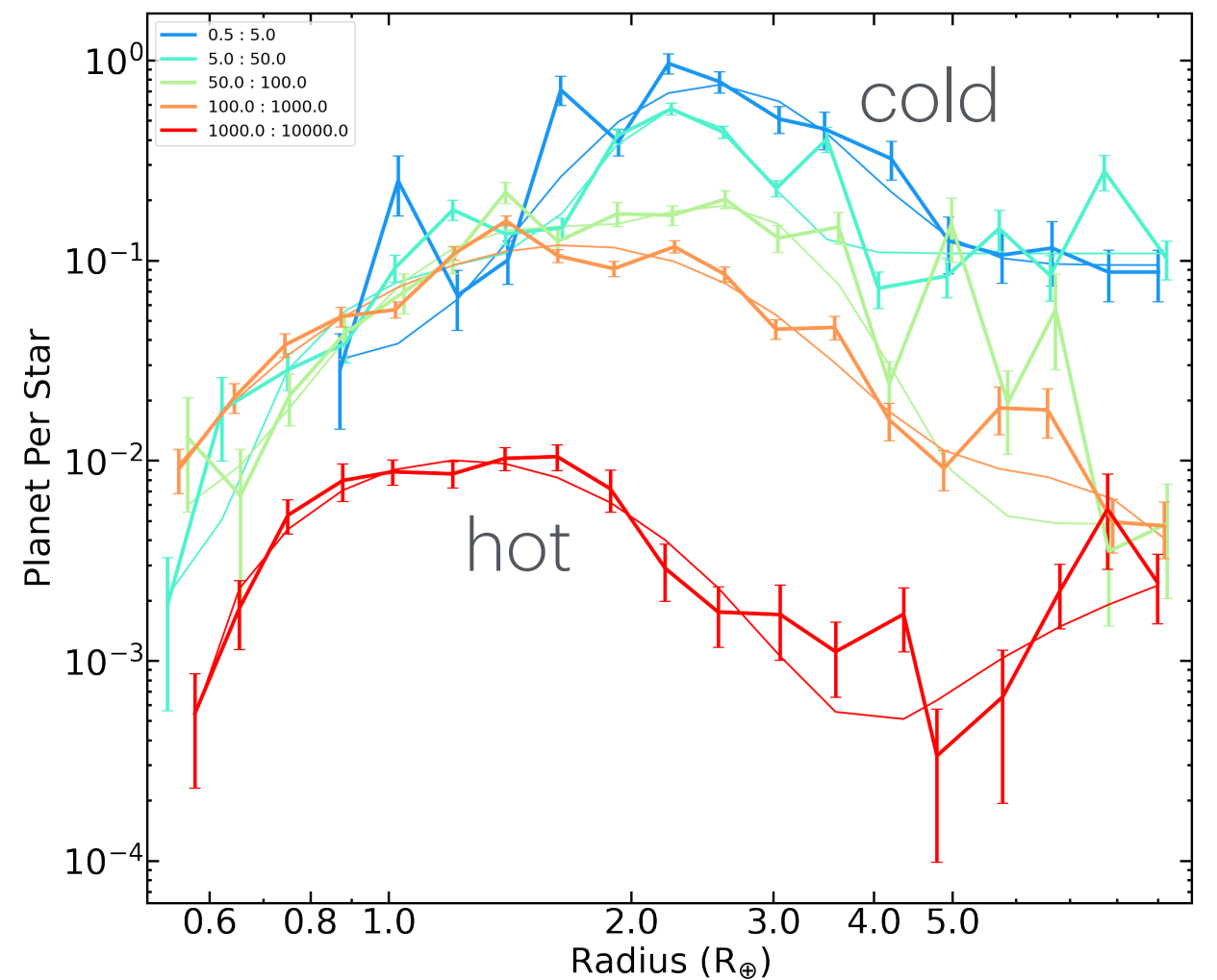
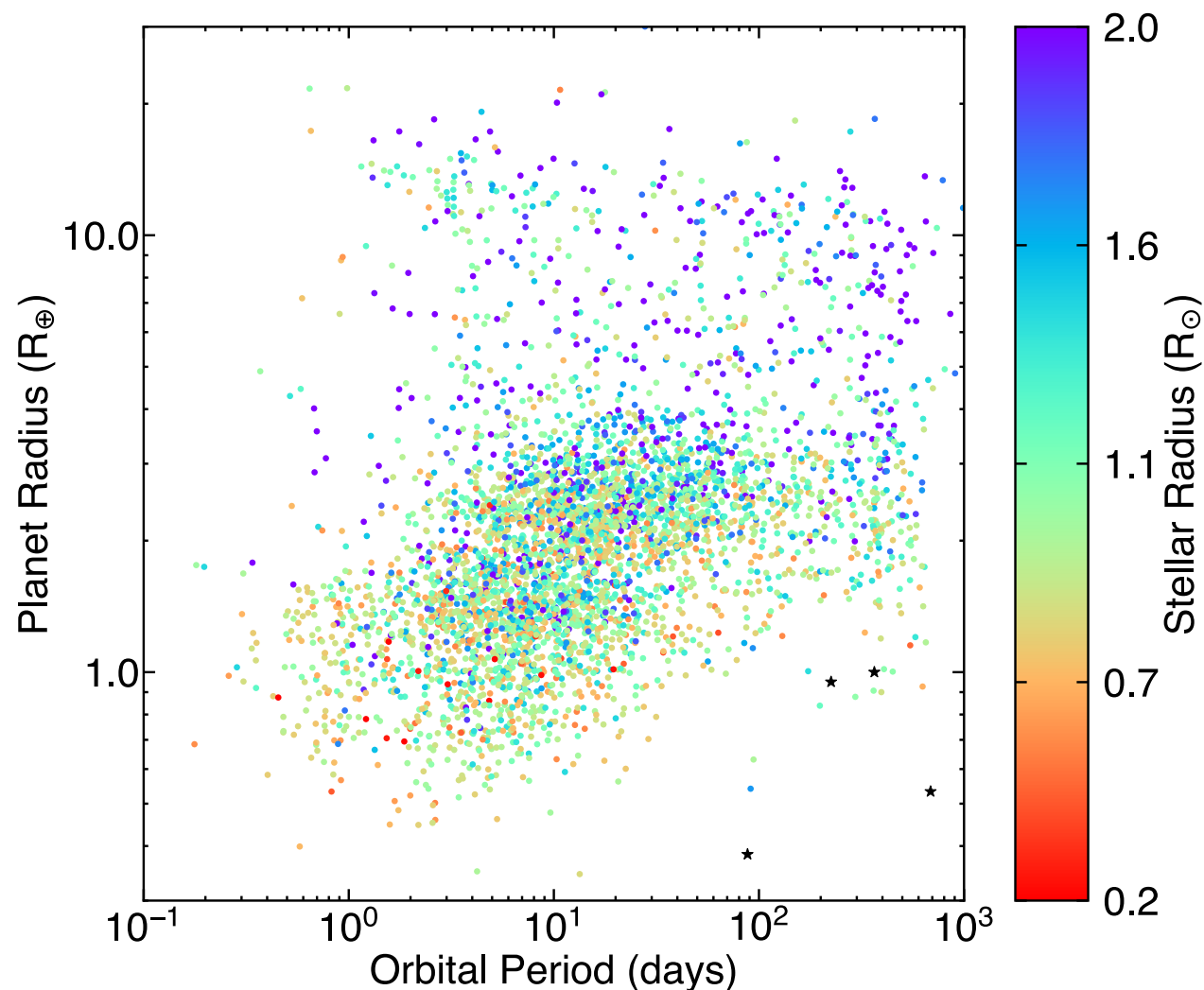


(Lissauer + Rowe 2024)

Demographics

From observations to occurrence rates

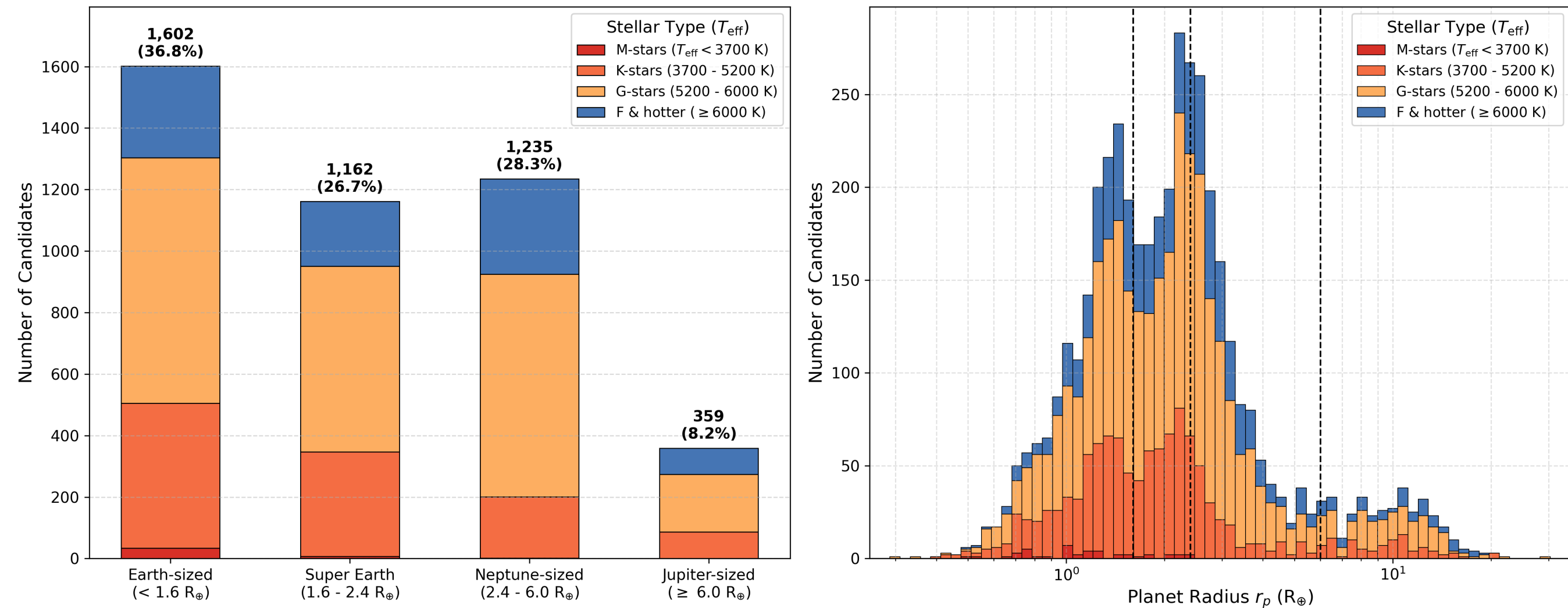
incompleteness + reliability
geometry + stellar sample



(Lissauer + Rowe 2024)

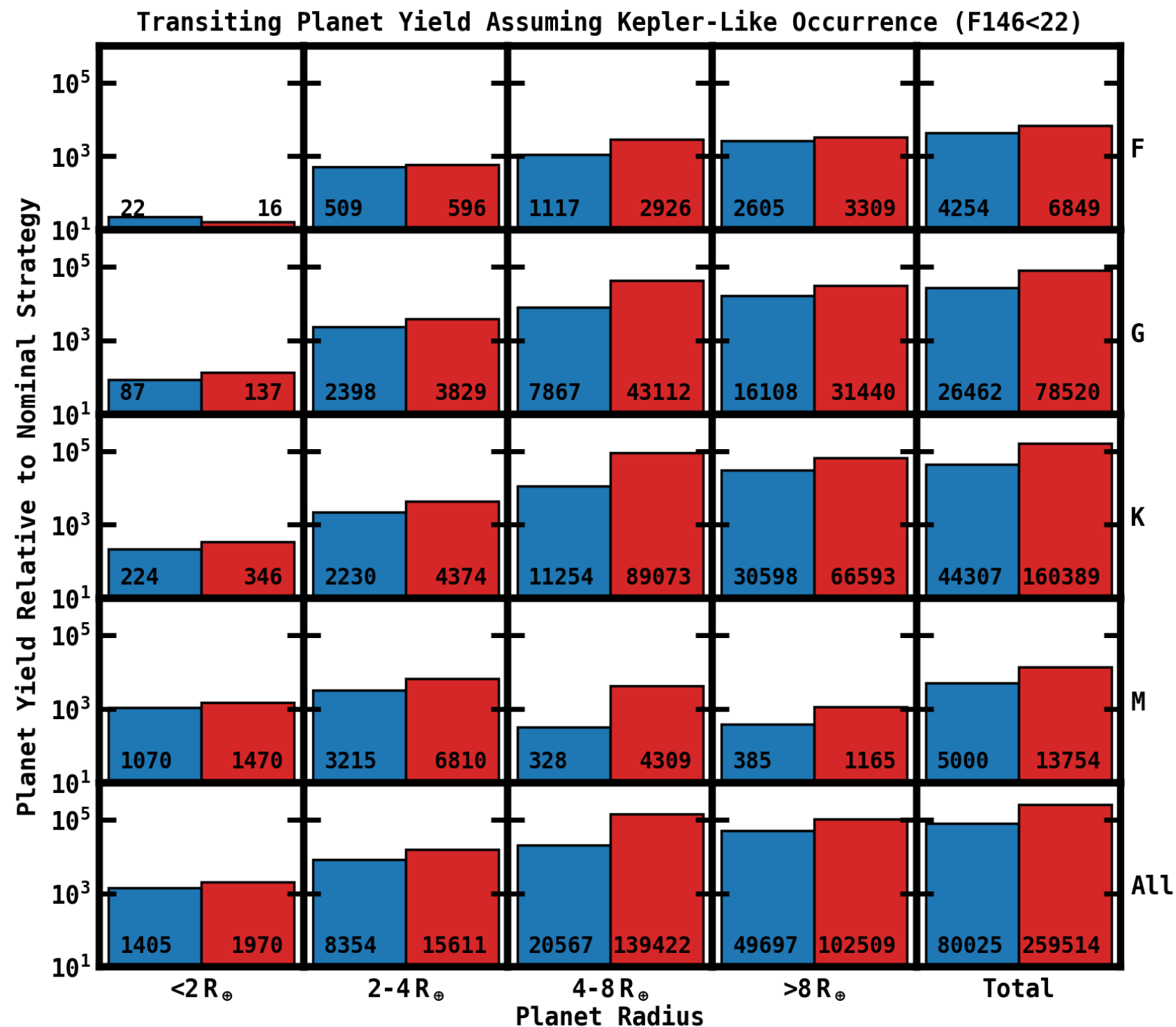
Kepler Discoveries

Raw number of planet candidates



(Lissauer + Rowe 2024)

Transiting Exoplanet Yields for Roman



See next talk for the deets!

Exoplanet Pipeline

GPU/CPU optimized code based on Kepler heritage

https://github.com/jasonfrowe/bls_cuda

- Part of the Roman Transit Search Infrastructure (RTSI)
- Searching over 100 million light curves
- Developed highly optimized CPU and GPU tools to search and classify multi-colour photometry
- Digital Research Alliance Canada (DRAC)
- Support from the Canadian Space Agency ROSS program
- 100% open source



📖 README 📄 GPL-3.0 license

pytf5

An implementation of TransitFit5 and BLS in Python (1

This package provides tools for transit search and fitting, including Box-Least-Squares (BLS) algorithms optimized for both CPU and GPU (via CUDA).

Installation

Prerequisites

- Python 3.8+

Installing from Source

It is recommended to install this package in "editable" mode inside a virtual environment to allow you to modify the source code without needing to reinstall.

1. Clone the repository:

```
git clone https://github.com/jasonfrowe/bls_cuda.git
cd bls_cuda
```

2. Install via pip:

```
pip install -e .
```

Digital Research Alliance of Canada

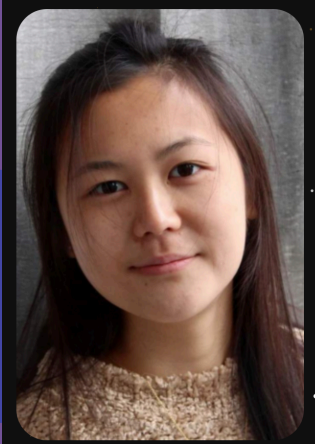


Alexis Roy

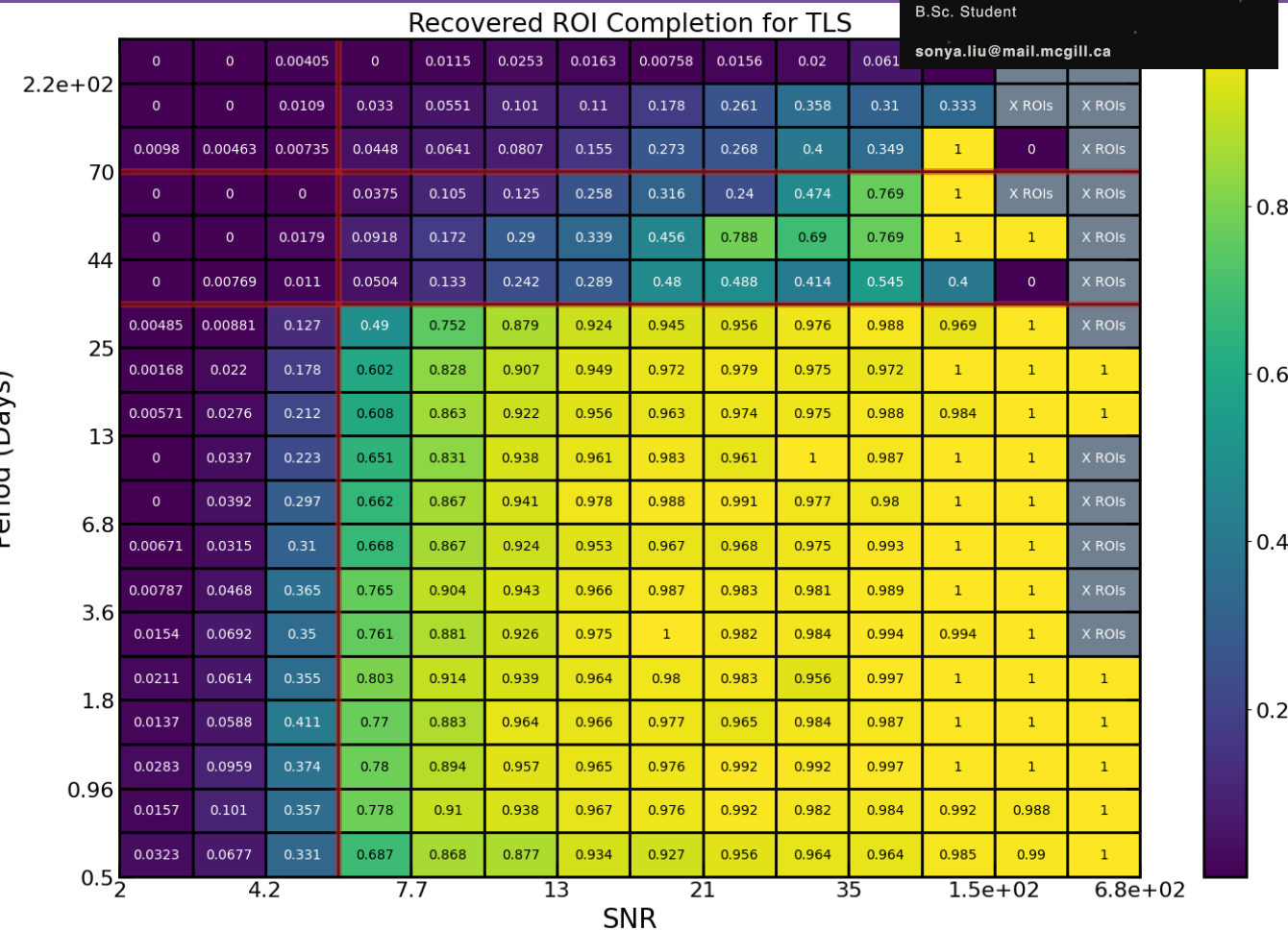
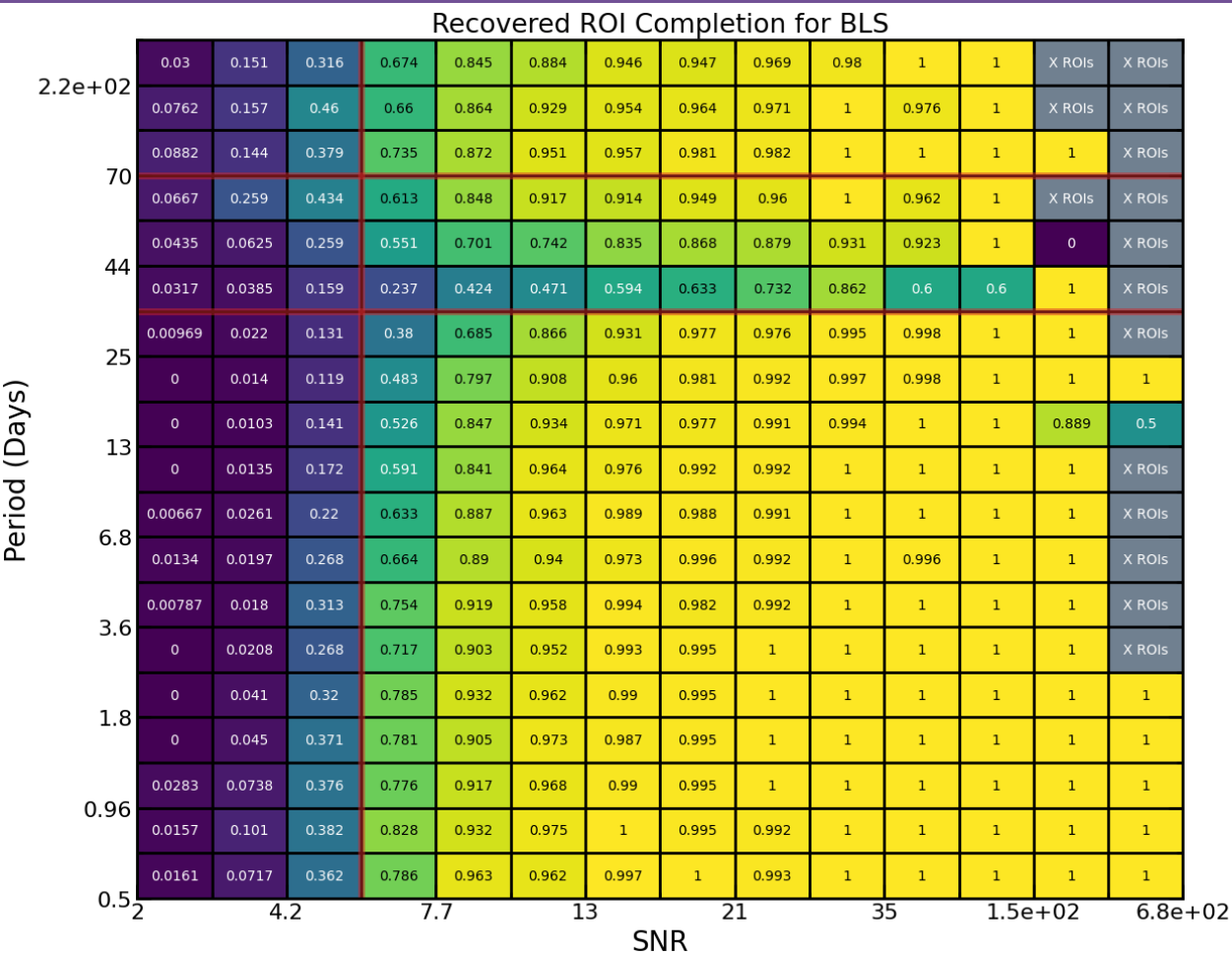
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Recovery Completion (Period versus SNR)



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13 for < 35 days
3 between 35 -70 days
3 bins for > 70 days

Period Bins

SNR Bins

3 for $2 < \text{SNR} < 6$
7 between 6 and 35
4 bins for $\text{SNR} > 35$

Multiple-Event Statistic (MES)

[See: Jenkins 2002]

- MES > 7.1 is commonly stated as a cut-off for detecting a transiting exoplanet.

- **Why 7.1?**

- The Kepler pipeline monitored roughly 150,000 target stars. For each star, it searches through thousands of trial orbital periods, epochs, and transit durations (ranging from 1 to 15 hours).
- This grid of trial ephemerides and durations results in on the order of **1x10¹²** independent statistical tests across the mission.
- To keep the total expected number of false alarms below 1, the single-test false alarm probability must be the inverse of the number of tests (roughly **1x10¹²**).
- **The 7.1 σ Limit:** Assuming the noise is well-behaved and follows a **standard normal distribution**, the right-tail probability of a 7.1 σ event is:

$$P(Z > 7.1) = \frac{1}{2} \text{erfc} \left(\frac{7.1}{\sqrt{2}} \right) \approx 6.2 \times 10^{-13}$$

- When you multiply that single-test probability (**6.2 × 10⁻¹³**) by the roughly **1.5 × 10¹²** independent tests performed across the Kepler target list, the expected number of false positive TCEs due strictly to white noise works out to **~ 0.9** (or **≤ 1**).

SNR threshold

Why even have a MES / SNR cut-off?

- A CPU bounded BLS search with multiple pass throughs takes about 15-seconds to run for a single season Roman light curve
- We are searching 10^8 stars
 - ~ 50 years on a single machine.
 - We will use 1000+ nodes on DRAC to process and search the data on the time-scale of a 1-month
- We will also use GPU nodes to speed this up.
- The search will produce 10^9 events to classify.
 - We will likely impose a SNR threshold to ensure we are not dominated by False-alarms for dispositioning of exoplanet candidates
 - **Machine Learning will be likely necessary**

	TLS	BLS
Time (Days)	42.587084	24.799318
Mean (s)	28.668786	15.221439
Median (s)	28.581646	15.207770
Range (s)	127.940007	31.238844
# Runs	128346	140766
# Runs/RIC	2.401684	2.634094
# Pulses Runs		65658
Mean Pulse (s)		15.083037
# Periodic Runs		75108
Mean Periodic (s)		15.342428

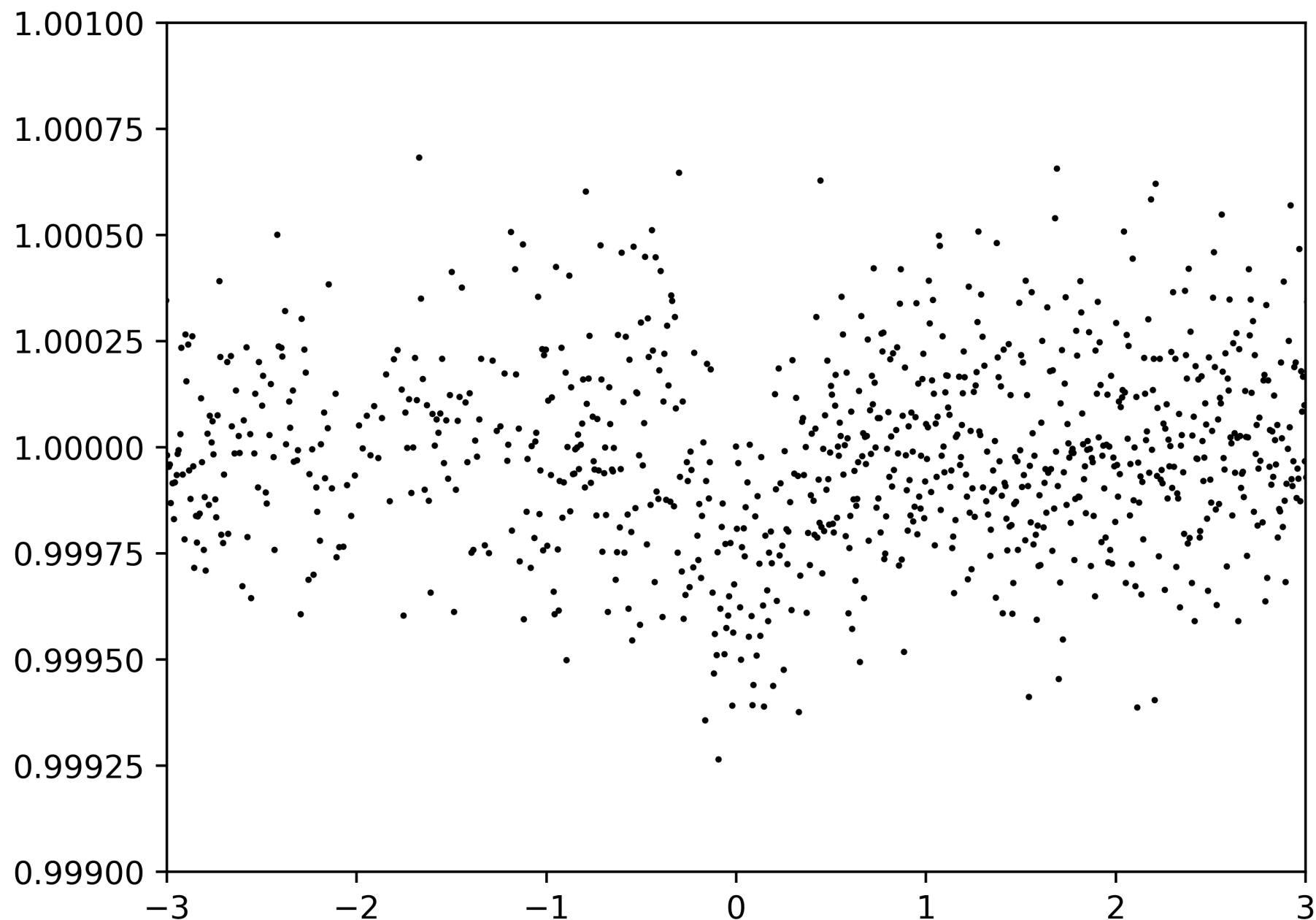
False-alarms vs False-positives

We need to start separating TCEs as FP, FA and PCs

- A Transit Search returns Transit Threshold Events (TCEs)
 - Kepler lumped FA and FP together as FPs.
- A false-positive is something that creates a transit-like event in the photometry that is astrophysical in nature (e.g., an eclipsing binary)
- A false-alarm is something that creates a transit-like event in the data due to noise. Can be instrumental or astrophysical. (Cosmic rays, stellar activity, pointing jitter, etc.).
- As SNR drops the number of false-alarms **exponentially** increases
- False-positives will behave in a manner similar, but identical to exoplanet signals

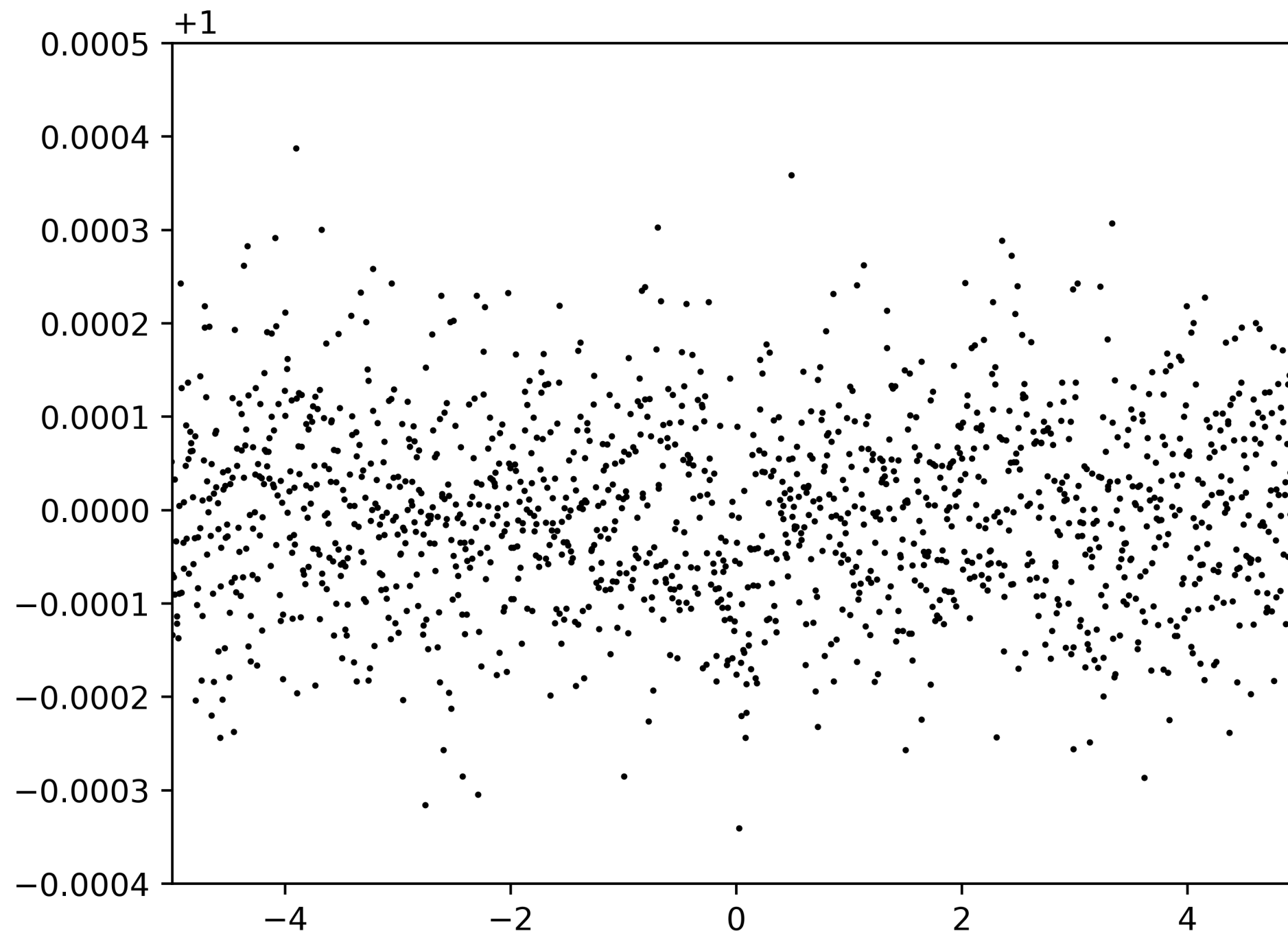
Can you spot the transit?

Examples of eta Earth candidates from NASA's Kepler mission



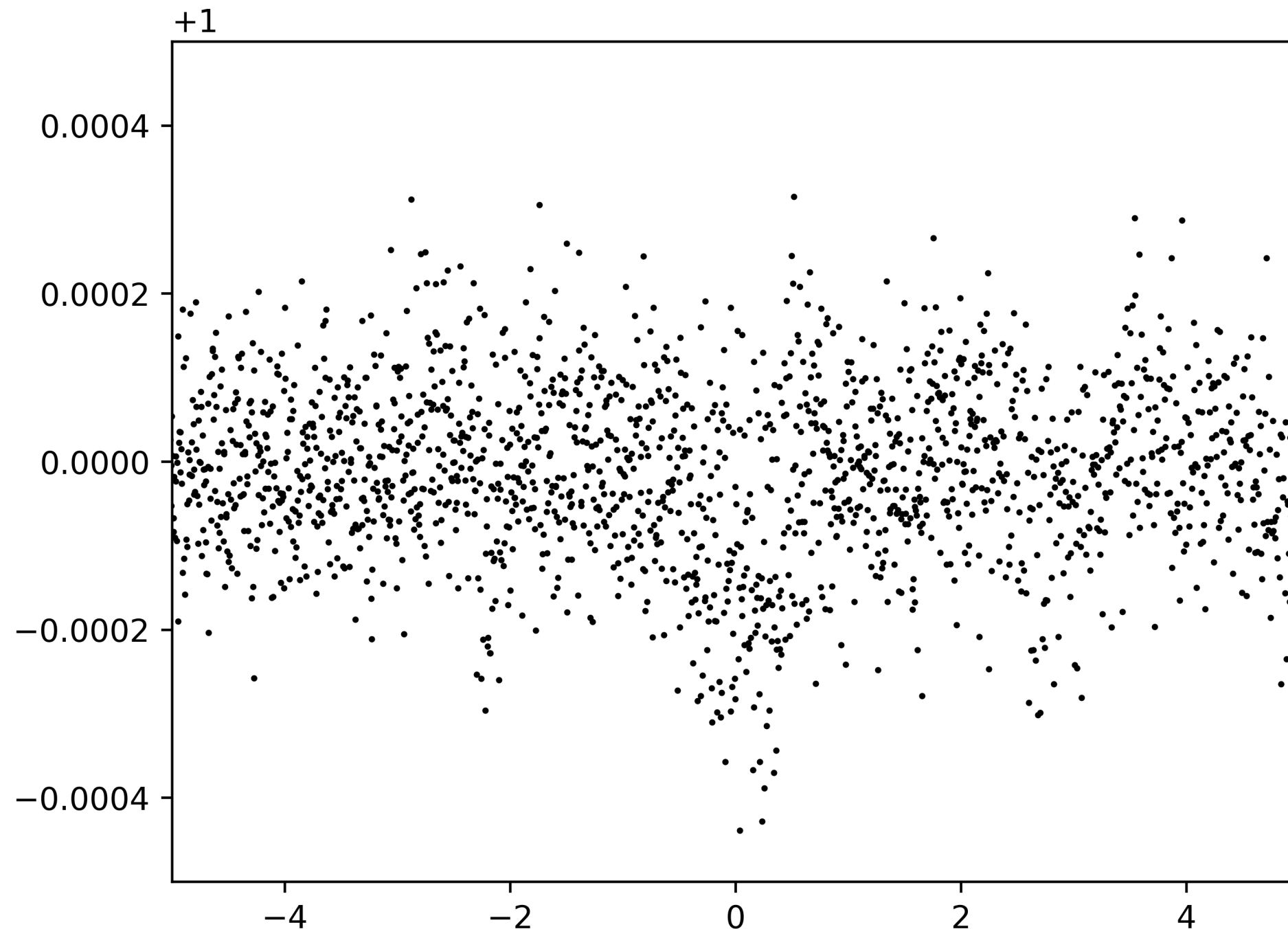
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Examples of Earth candidates from NASA's Kepler mission



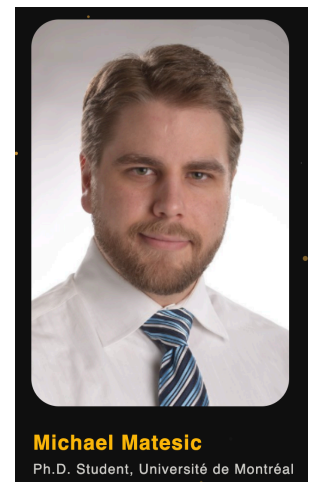
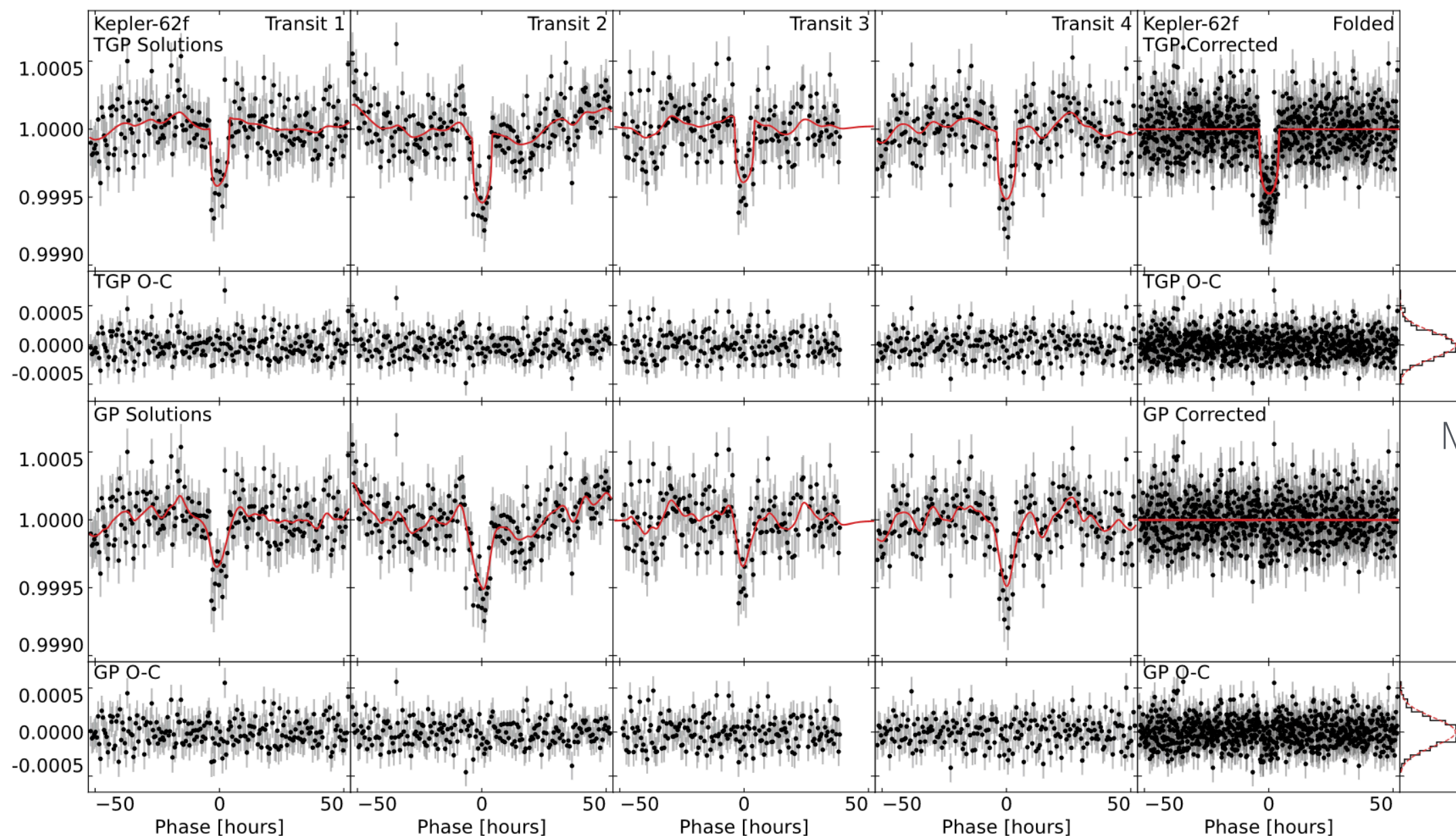
Can you spot the transit?

Examples of Earth candidates from NASA's Kepler mission



GP + Transit modelling

Kepler-62f — clean, clear detection. ($P \sim 267$ days, $1.5 R_{\oplus}$, $0.5 S_{\oplus}$, $T_{\text{eff}} \sim 5000K$)

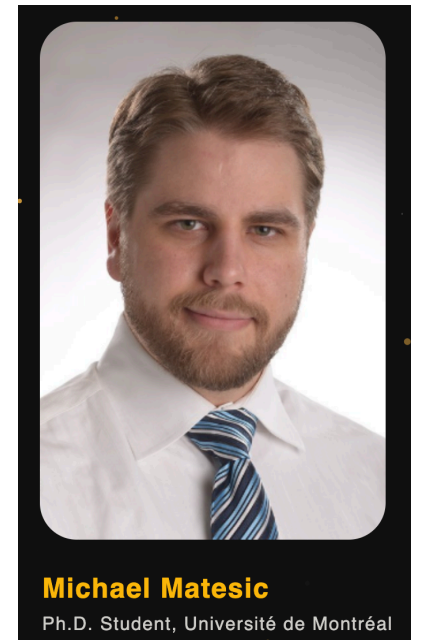
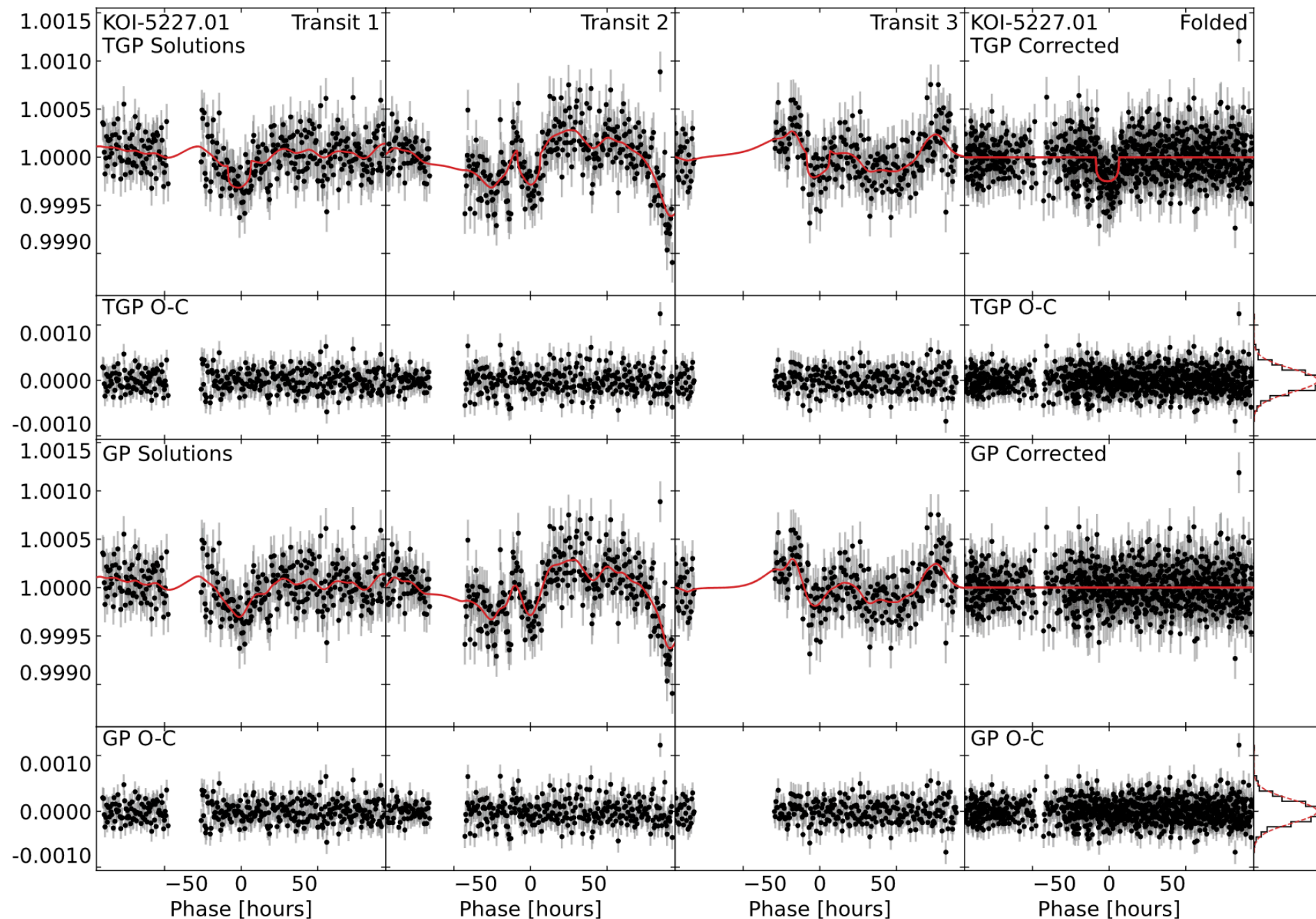


Matesic et al. 2024

GP Modelling of candidates is computationally expensive

GP + Transit modelling

KOI-5227.01 $P \sim 371$ days $1.3 R_{\oplus}$ $0.7 S_{\oplus}$ $T_{\text{eff}} \sim 5500K$



Matesic et al. 2024

GP Modelling of candidates is computationally expensive

Recovery Curve

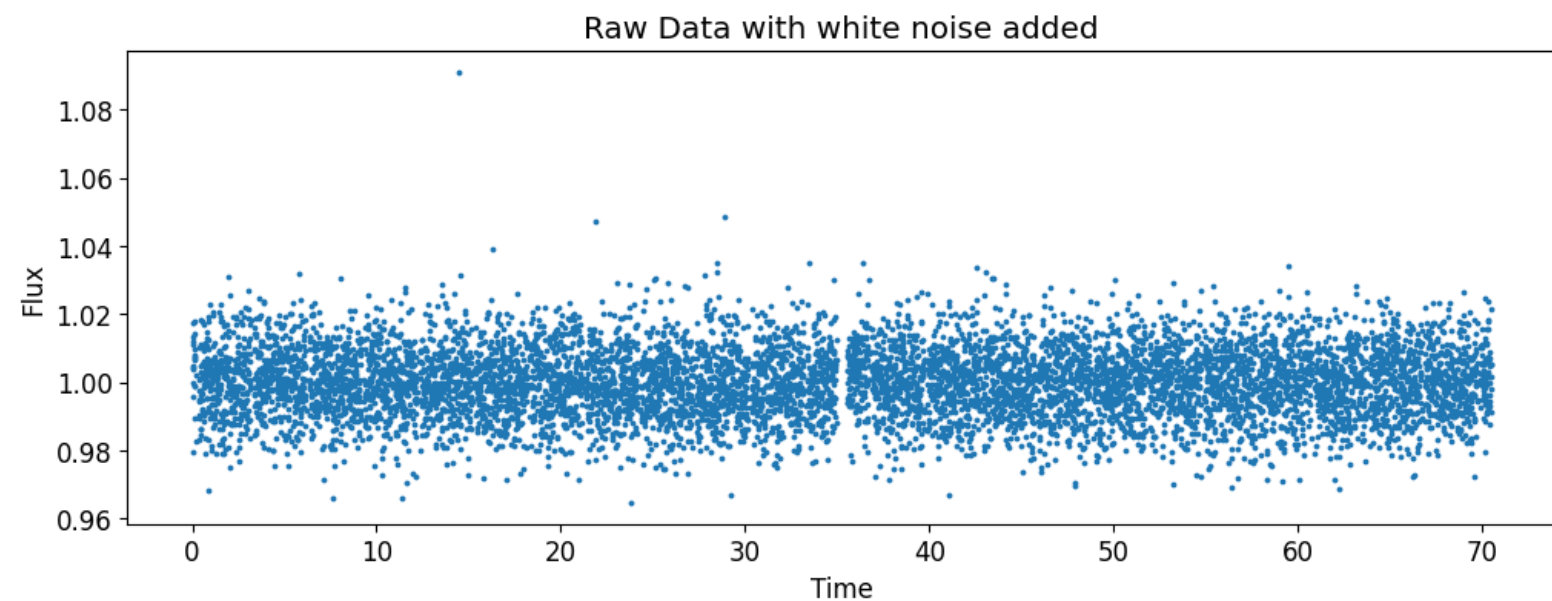
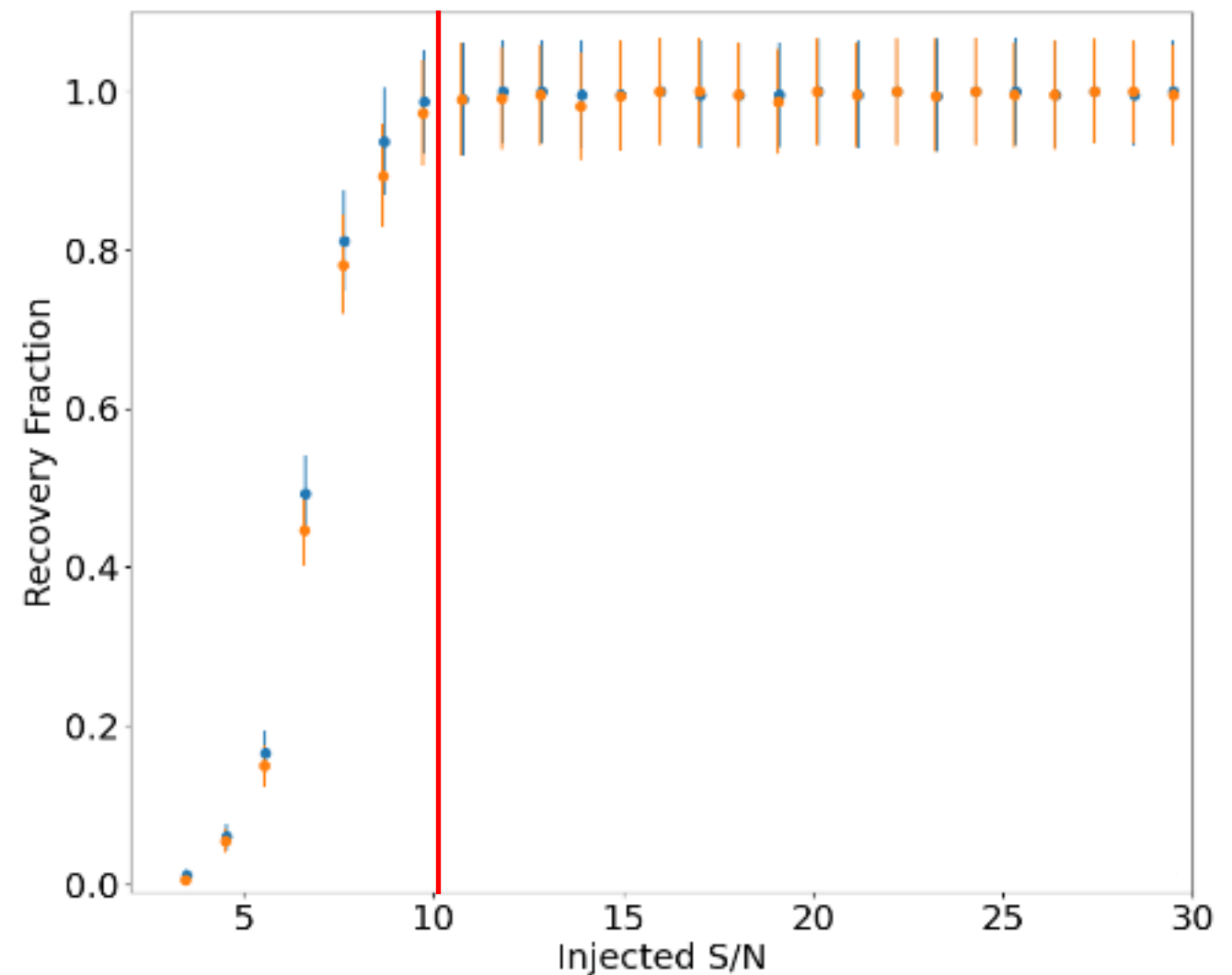
- See : Christiansen et al. 2016

Injection tests

- Recovery tests for a light-curve primary dominated by white-noise



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Recovery Curve

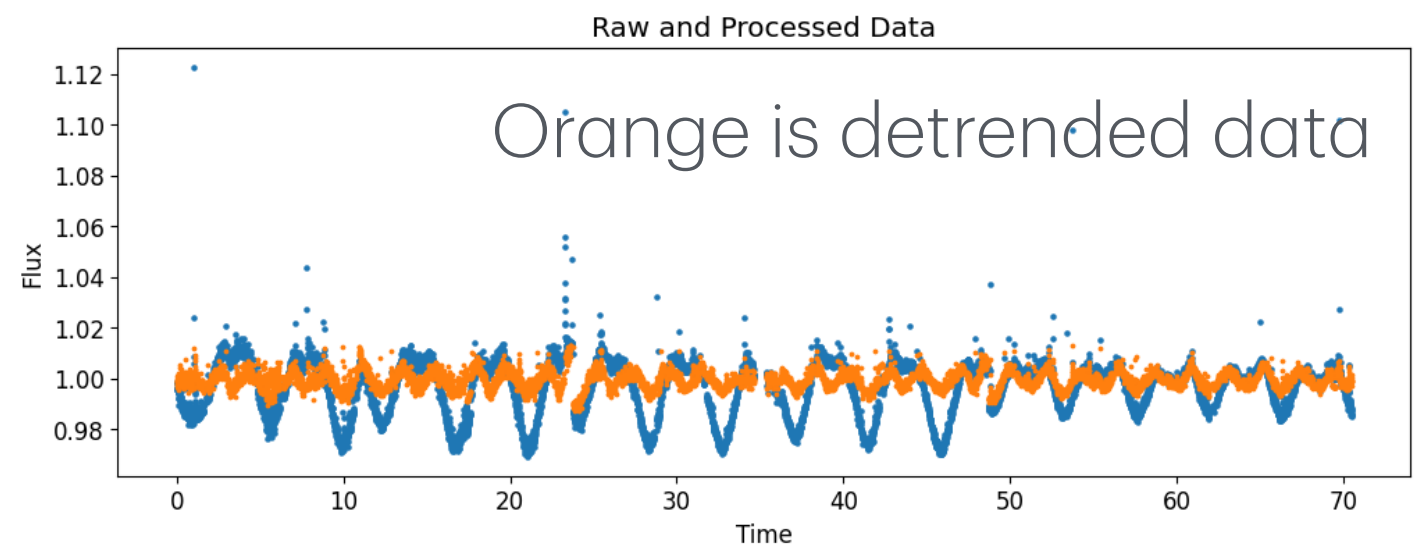
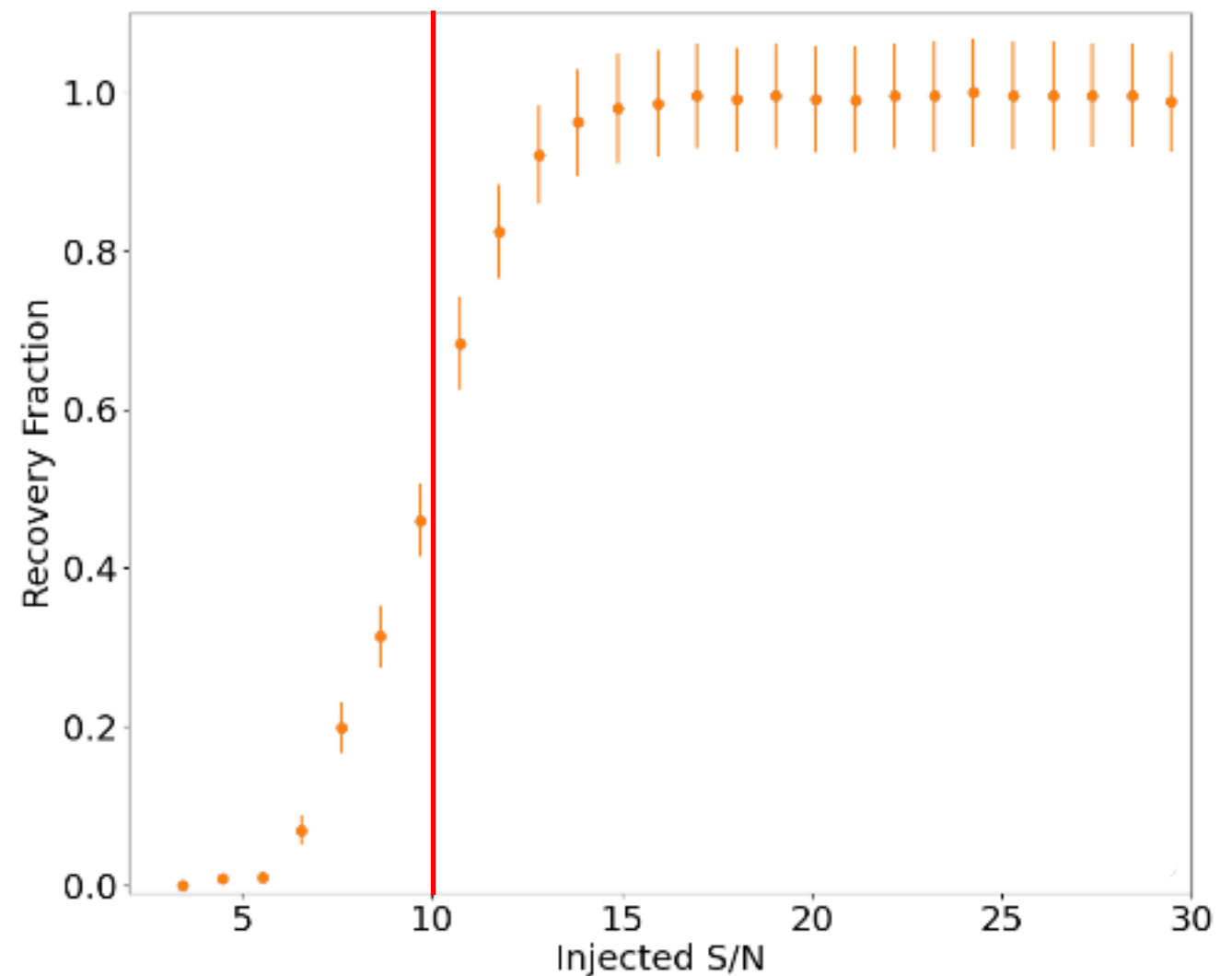
- See : Christiansen et al. 2016

Injection tests

- Recovery tests for a light-curve primary dominated by red-noise
- There are bespoke processes that can be applied, but we need a bulk-process



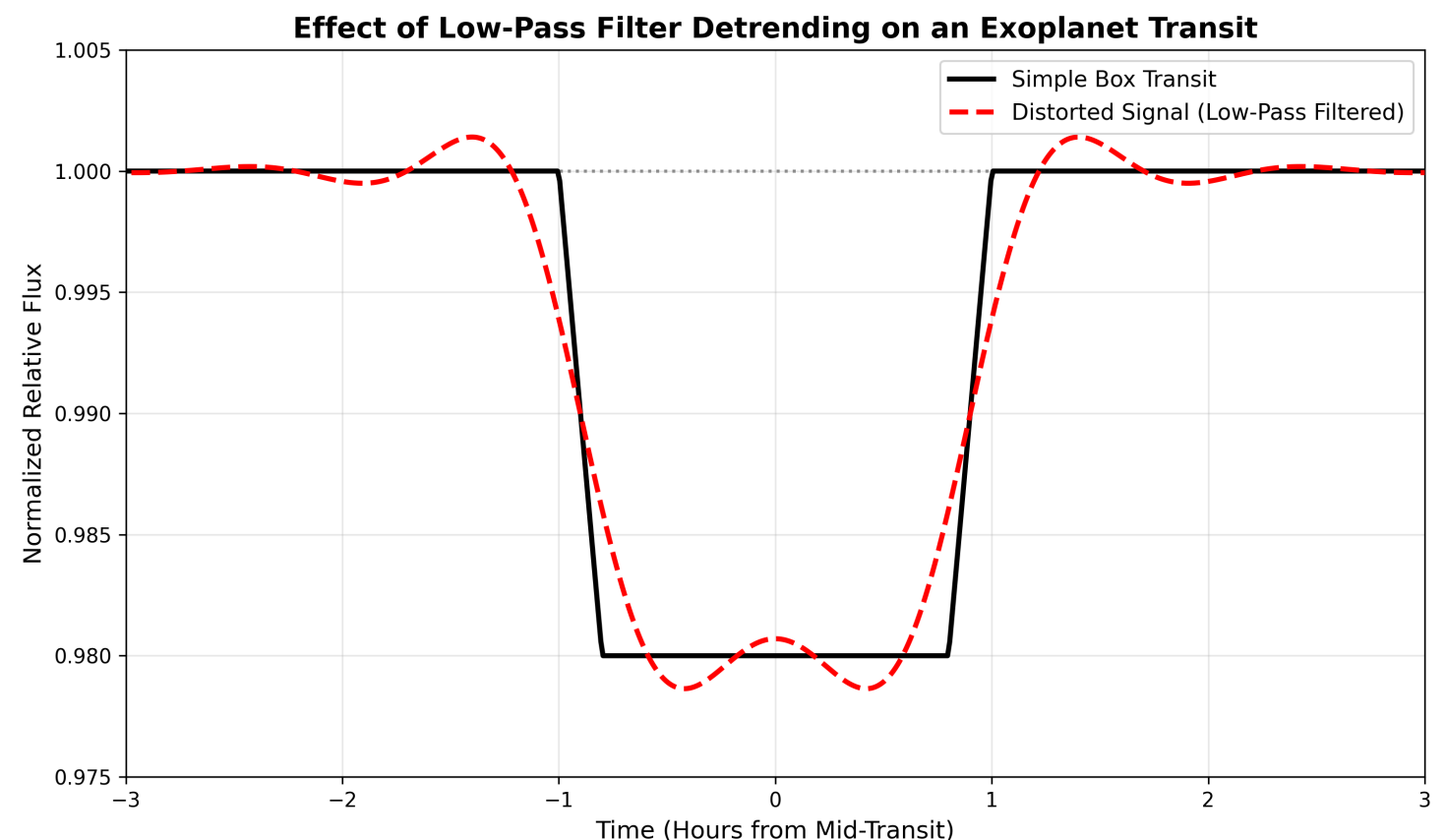
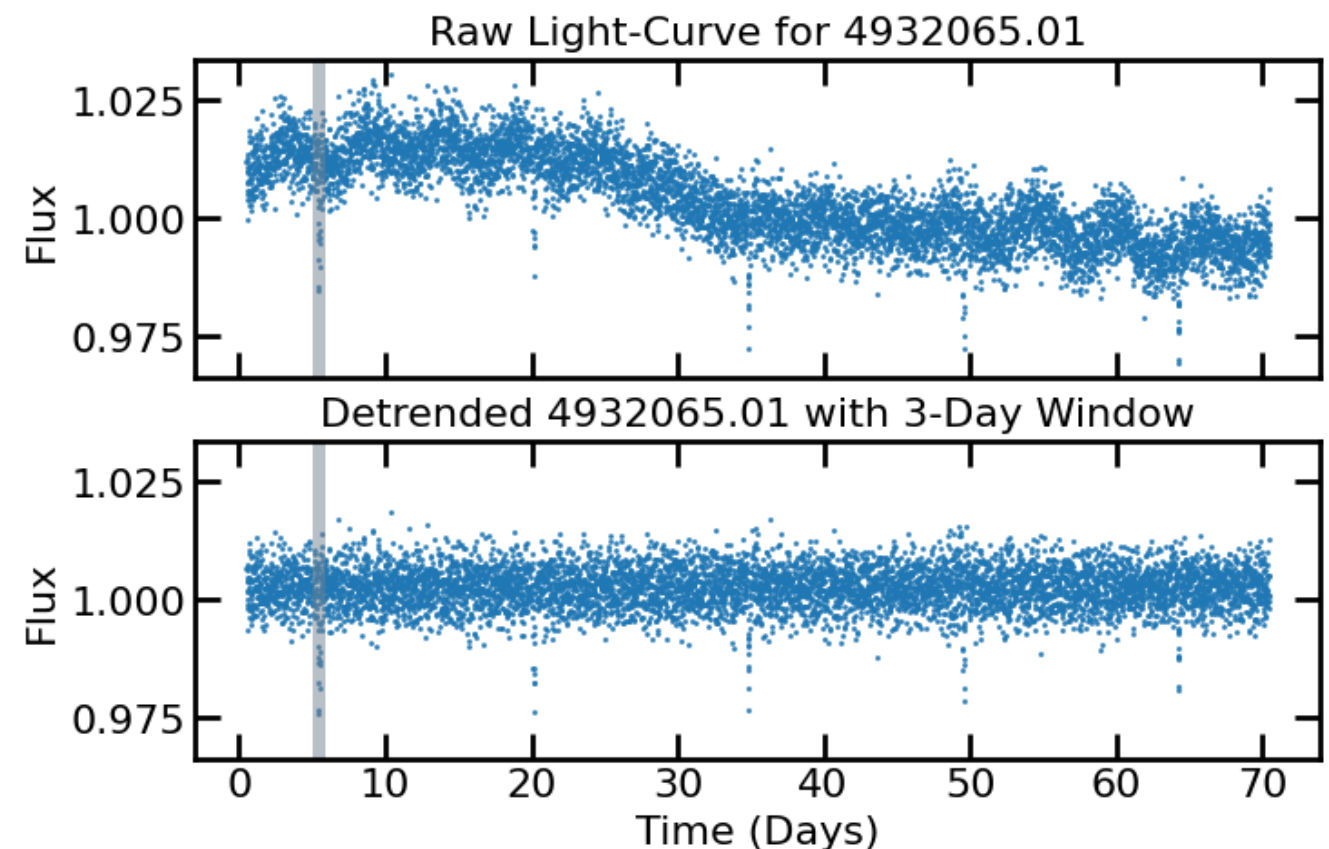
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Data Preconditioning

A necessary evil...

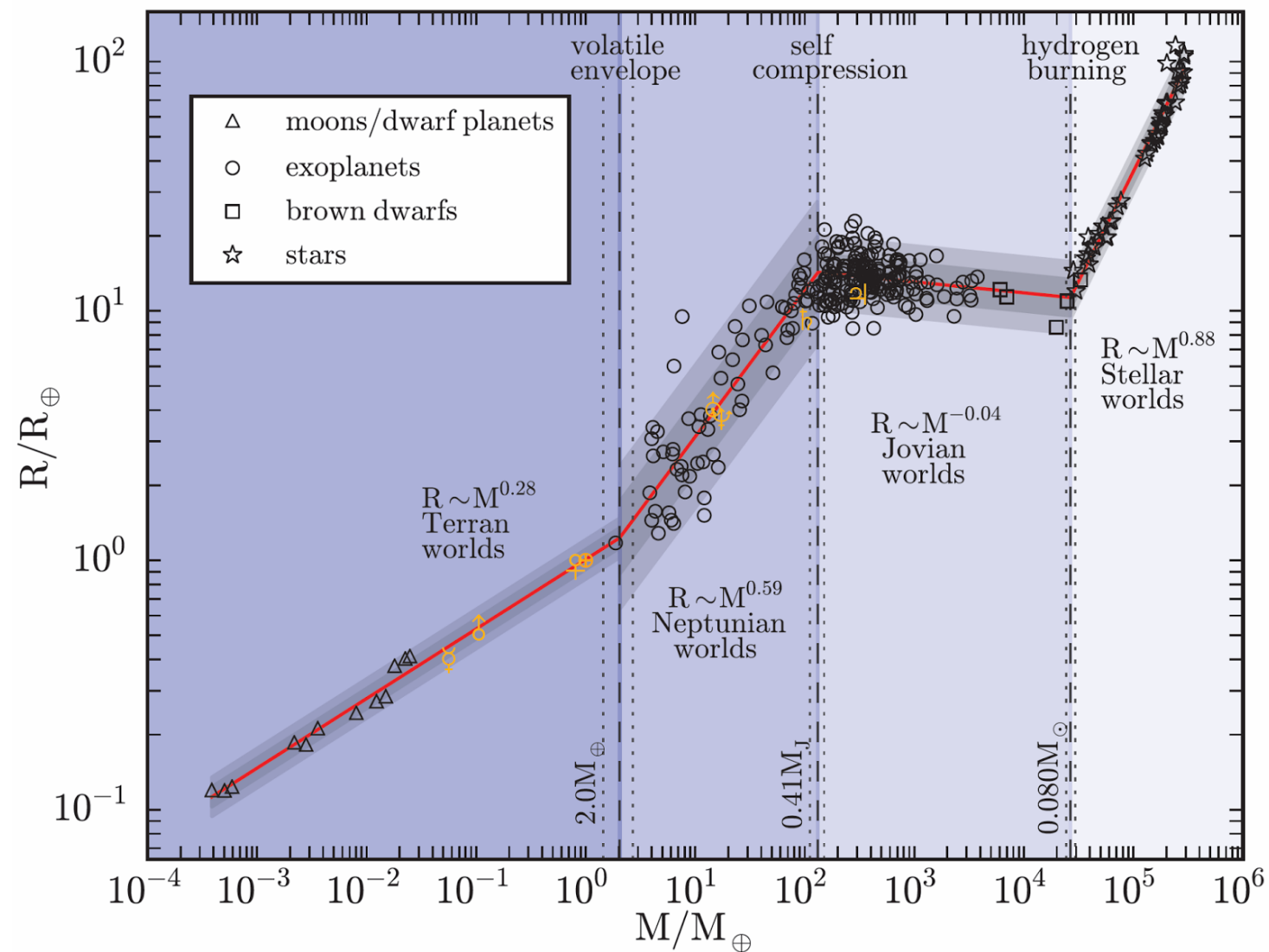
- Most transit searches require *flattened* data products.
- Achieved through application of a filter
- Filters **will** distort a transit potentially resulting a loss of signal seen by a transit search routine



Dispositions

False alarms / False positives / Planet Candidates / Planets

- Datasets have infinite false alarms
- A finite set of false-positives
- A transit event (commonly called a TCE or threshold crossing event)
 - Planet candidates
 - Confusion for larger radius planets (electron degeneracy)
 - Confusion at low SNR regimes
- Most planets have a radius less than $4 R_{\oplus}$
- Recovery/reliability drops as SNR goes below 10

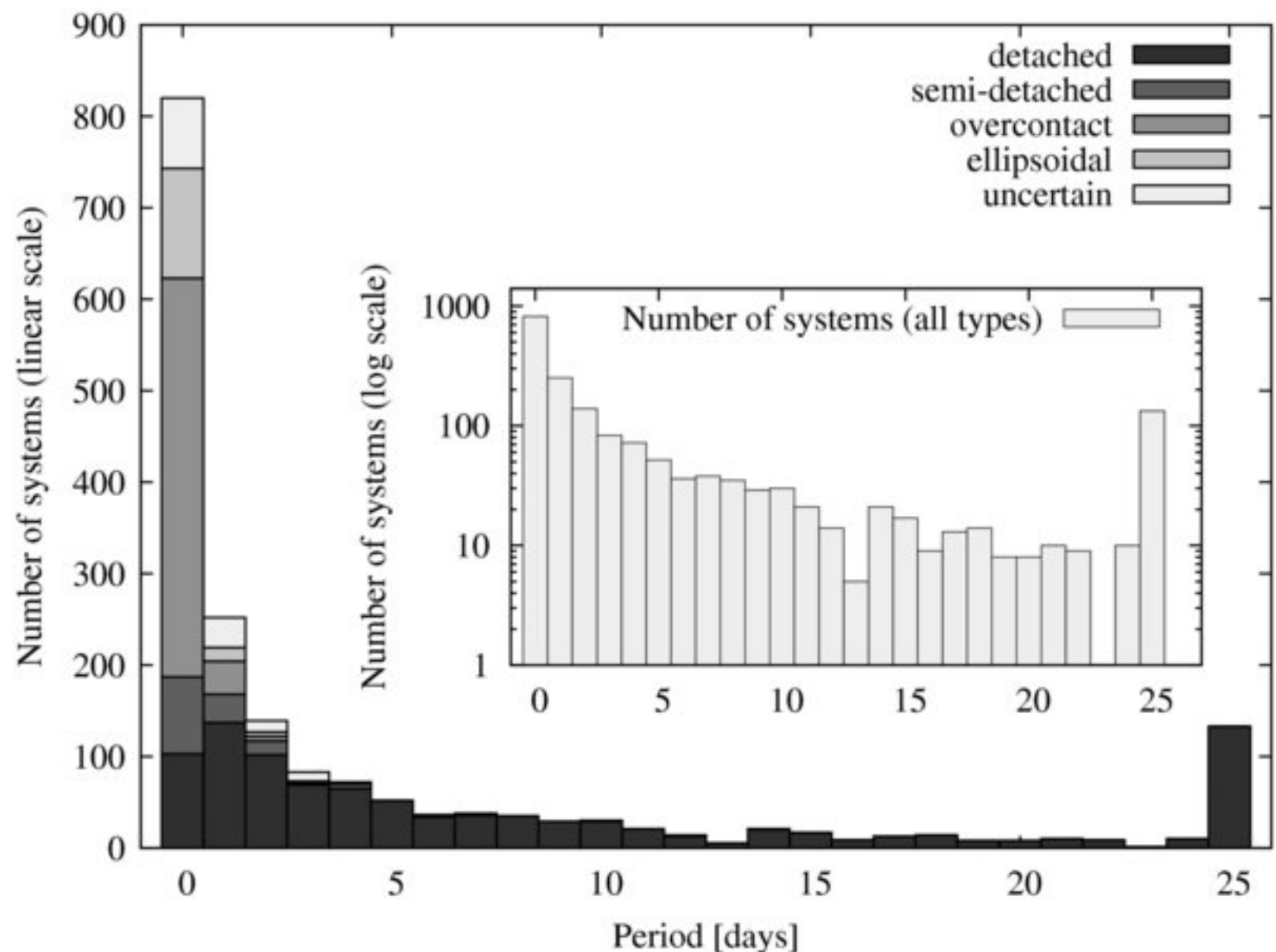


Chen & Kipping (2016)

Eclipsing Binaries

Problematic for low SNR

- The rate of EBs increases quickly towards short periods.
- Was problematic for Kepler, primarily driven by 30-minute cadence/integration time
- Roman has better integration times, reducing smearing
- Much larger Roman sample means blends are more likely



<1% of GBTDS fields

0.003%

30''

7.5' = 1 detector

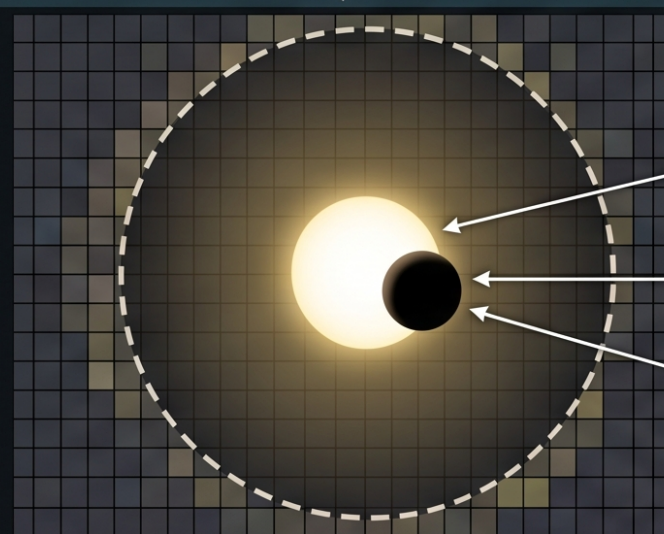
Dilution

Why it matters

- Transit Models for Roman should include dilution as a modelled parameter with prior.
- Our group will attempt to do this.

HOW EXTRA LIGHT IN THE PHOTOMETRIC APERTURE CAUSES TRANSIT DEPTH DILUTION

CASE 1: IDEAL (TARGET STAR ONLY)

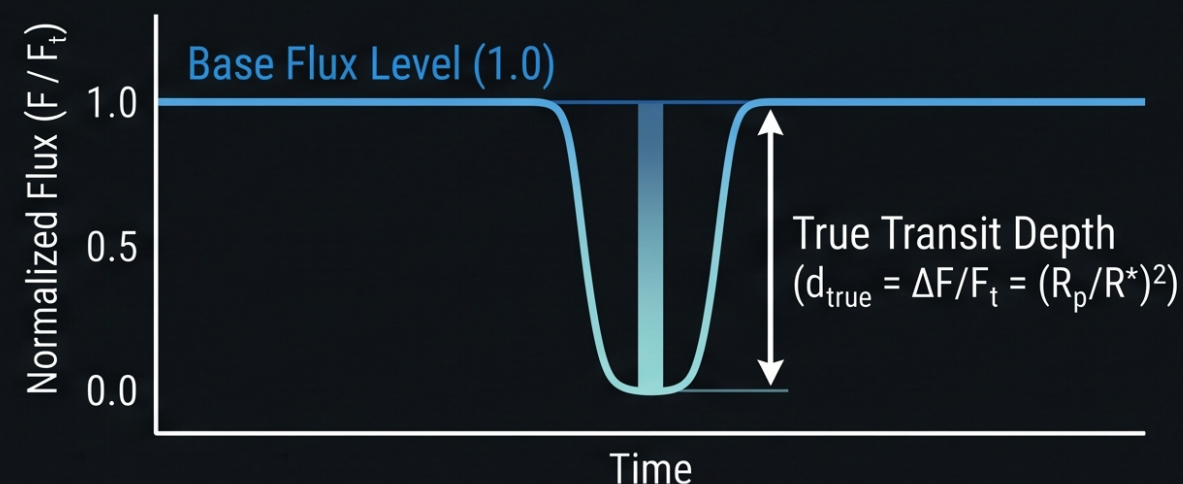


True Geometric Transit Depth

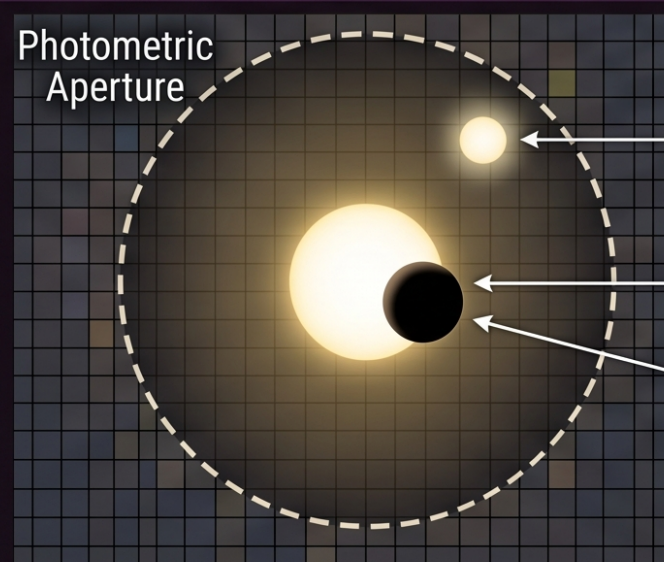
Target Star (F_t)

Planet (R_p)

Flux Blocked during Transit
($\Delta F = F_t * (R_p/R^*)^2$)



CASE 2: REAL (TARGET STAR + CONTAMINATING LIGHT)



Observed (Diluted) Transit Depth

Contaminating Light Source (F_c)
(e.g., a background star)

Total Flux = $F_t + F_c$

Planet blocks ΔF from F_t ,
NOT from F_c

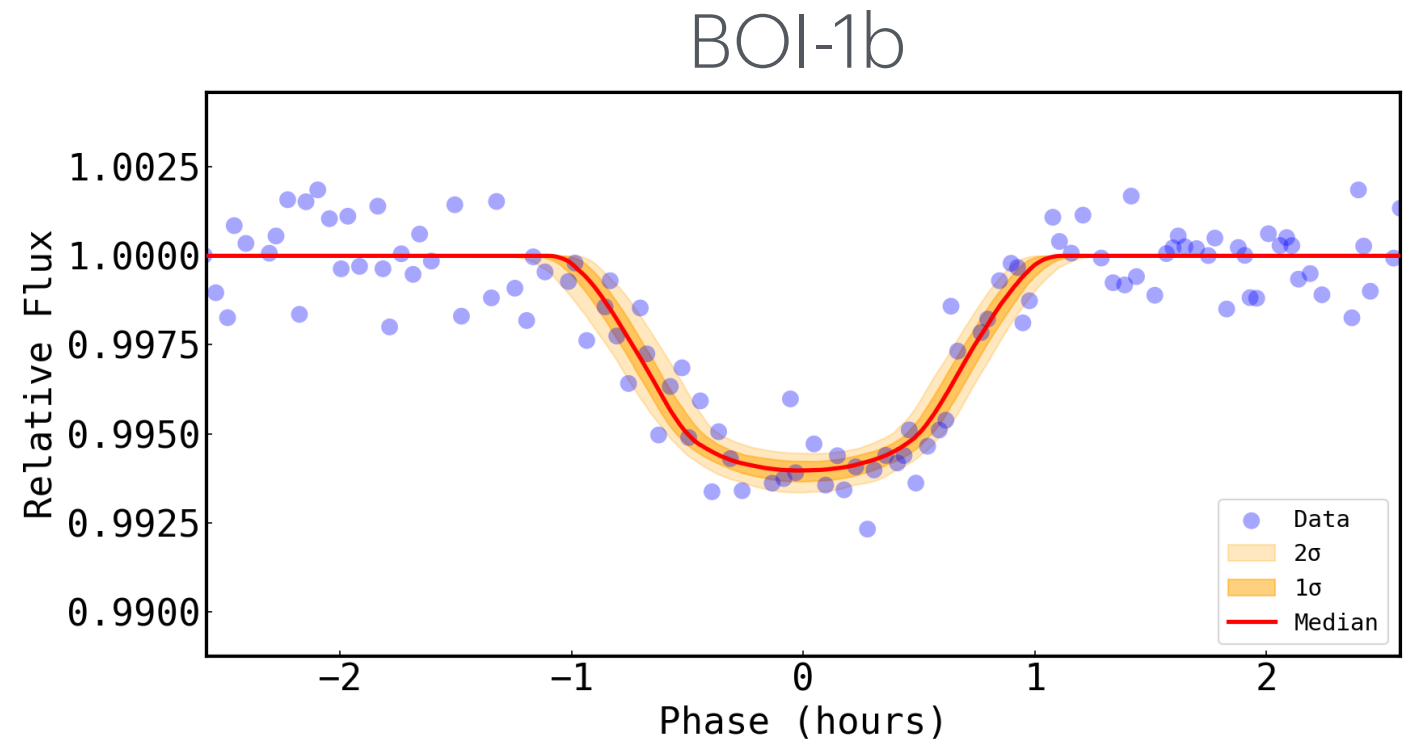


Key takeaway: Extra light in the aperture, not blocked by the planet, reduces the relative size of the transit dip

Exoplanet Transit modelling

Likely the product you want for your research.

- After dispositioning we will model every Roman Object of Interest (ROIs?)
- This is also computationally expensive
- 10^5 candidates with full posteriors, will be an end-game product
- Maximum likelihood models available quickly



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Julie Moquin

Summary and Thoughts

We can do this!

- Roman presents a great opportunity to expand our knowledge of transiting exoplanets
- Roman has some challenges
 - Dilution
 - We should include this in our models as a distribution
 - Red noise
 - Will be hard to understand until we have real data
 - Computational burden
 - GPUs and Memory are expensive!!
 - Ensuring a statistically valid sample for demographics

