

# A Search for Longer-Period Exoplanets with TESS and CHEOPS

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**Collaborators:** Hugh Osborn,  
Solène Ulmer-Moll, Davide Gandolfi

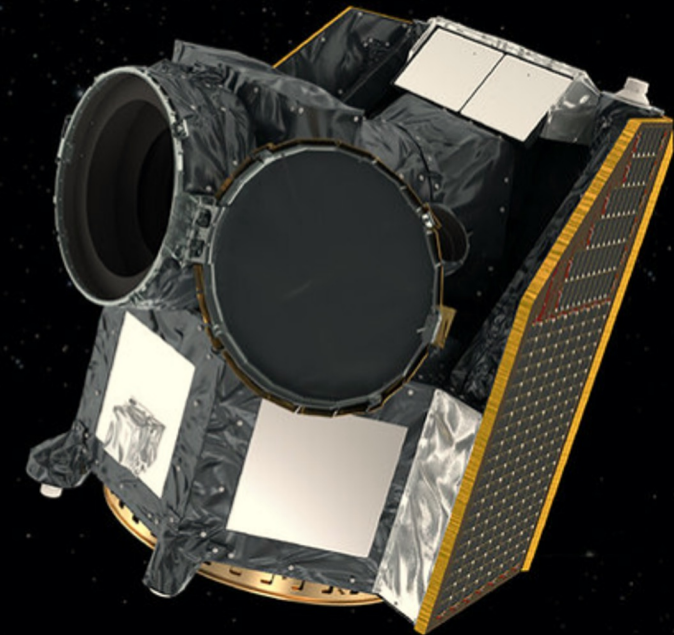




Image: NASA's Goddard Space Flight Center

# TESS

- All-sky survey to discover new exoplanets
- Large pixels (21 arcseconds)
- High precision
- 2, 10 or 30 minute cadence

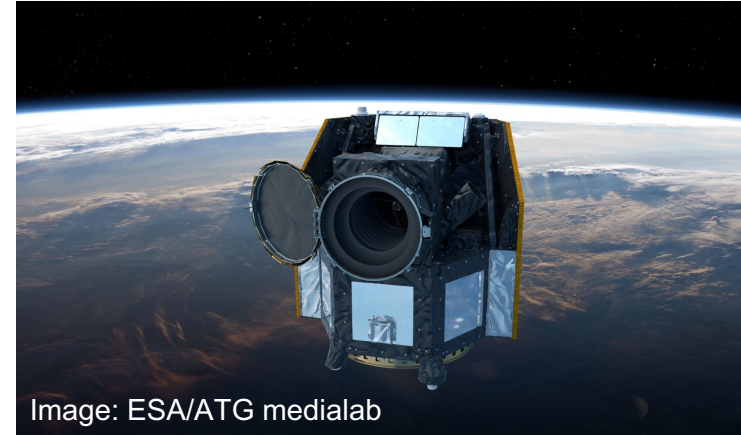
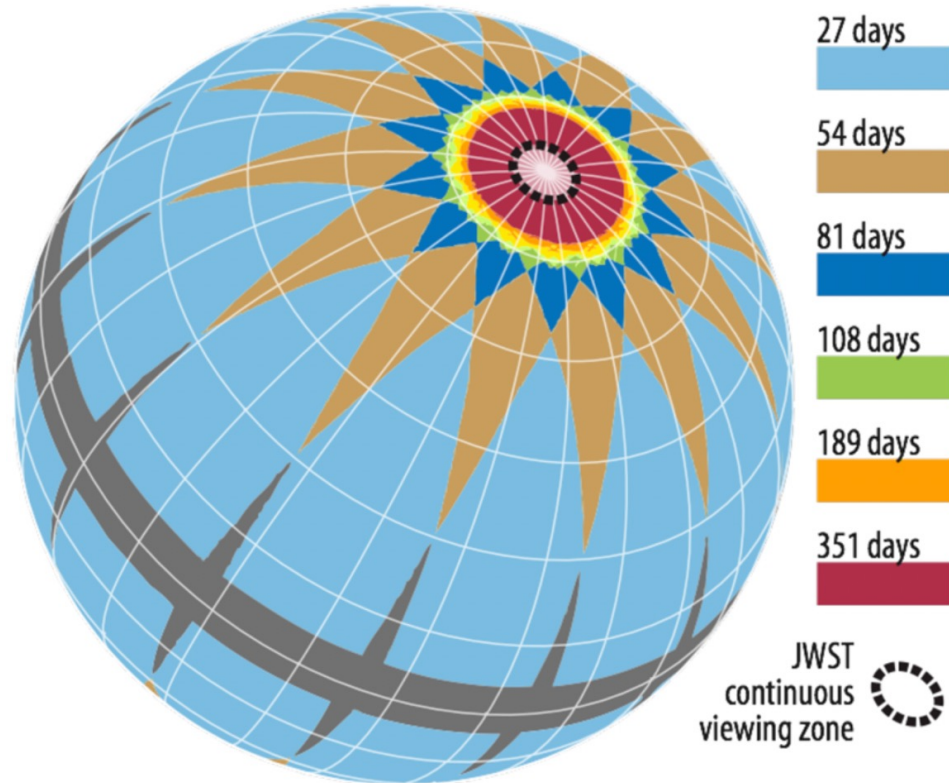


Image: ESA/ATG medialab

# CHEOPS

- Targeted follow-up of known exoplanets
- Small pixels (1 arcsecond)
- Ultra-high precision
- 1 - 60 second cadence

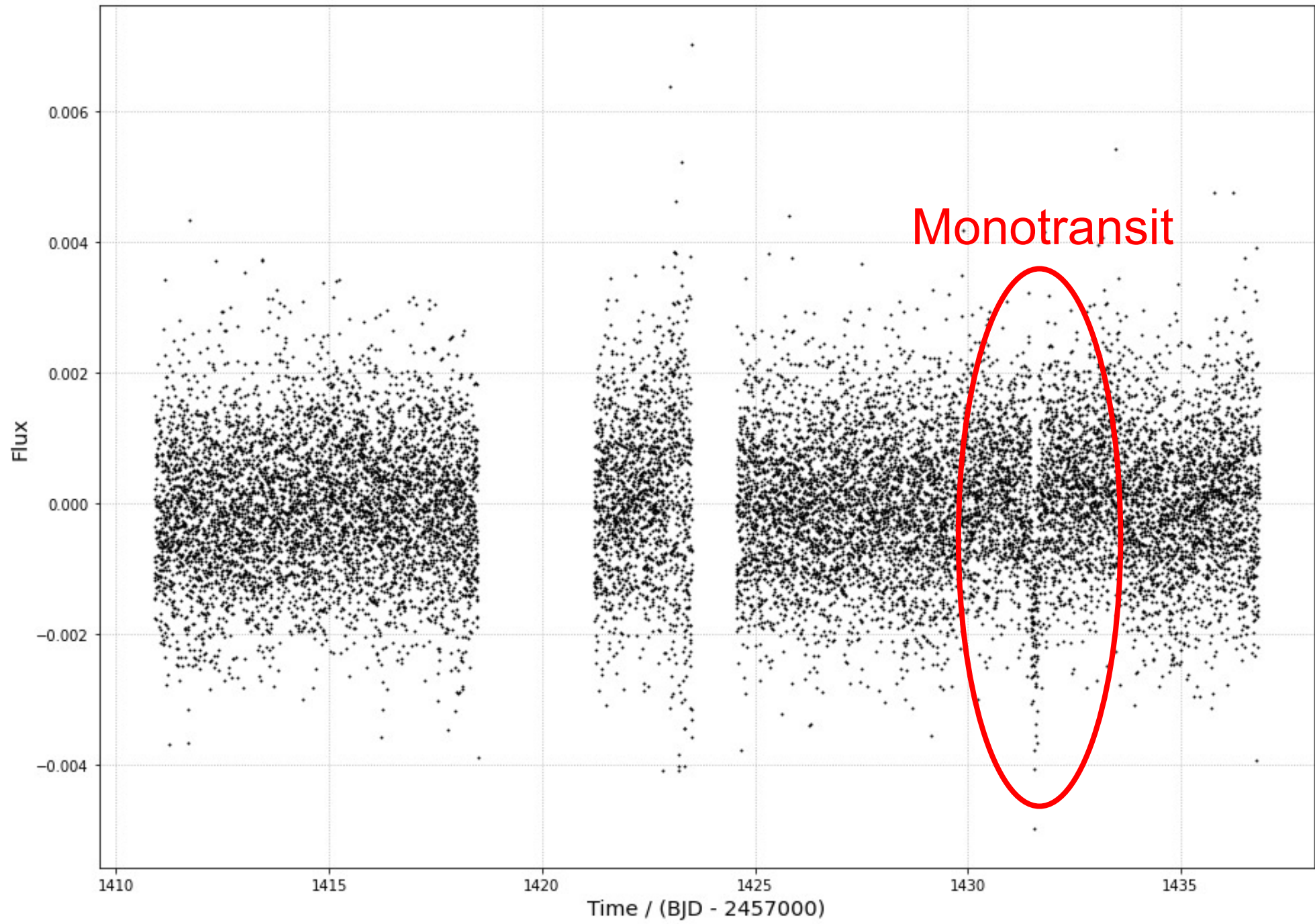
# TESS Observing Strategy



TESS observed the majority of the sky for 27 days during its primary mission.

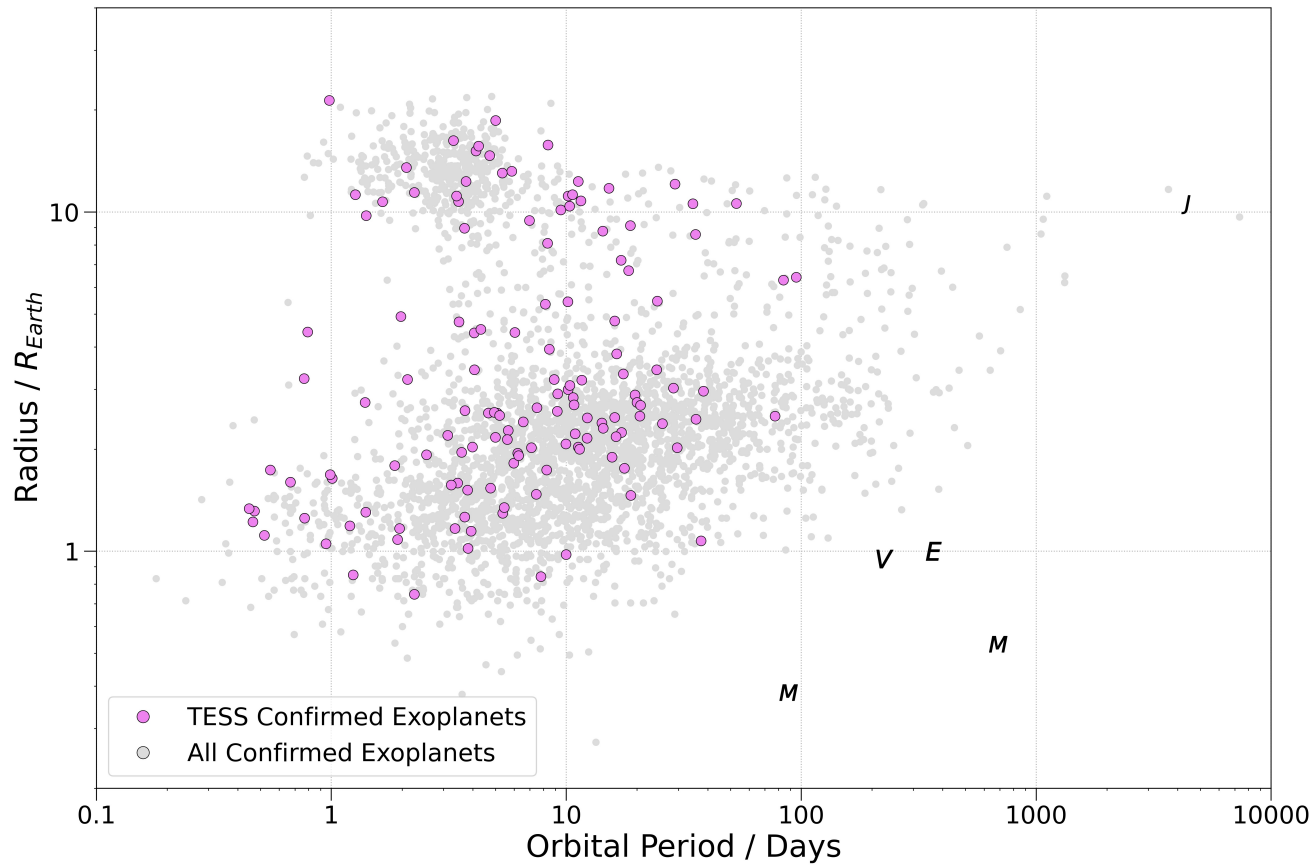
**Lots of single transit detections = monotransits**

[Ricker+15]



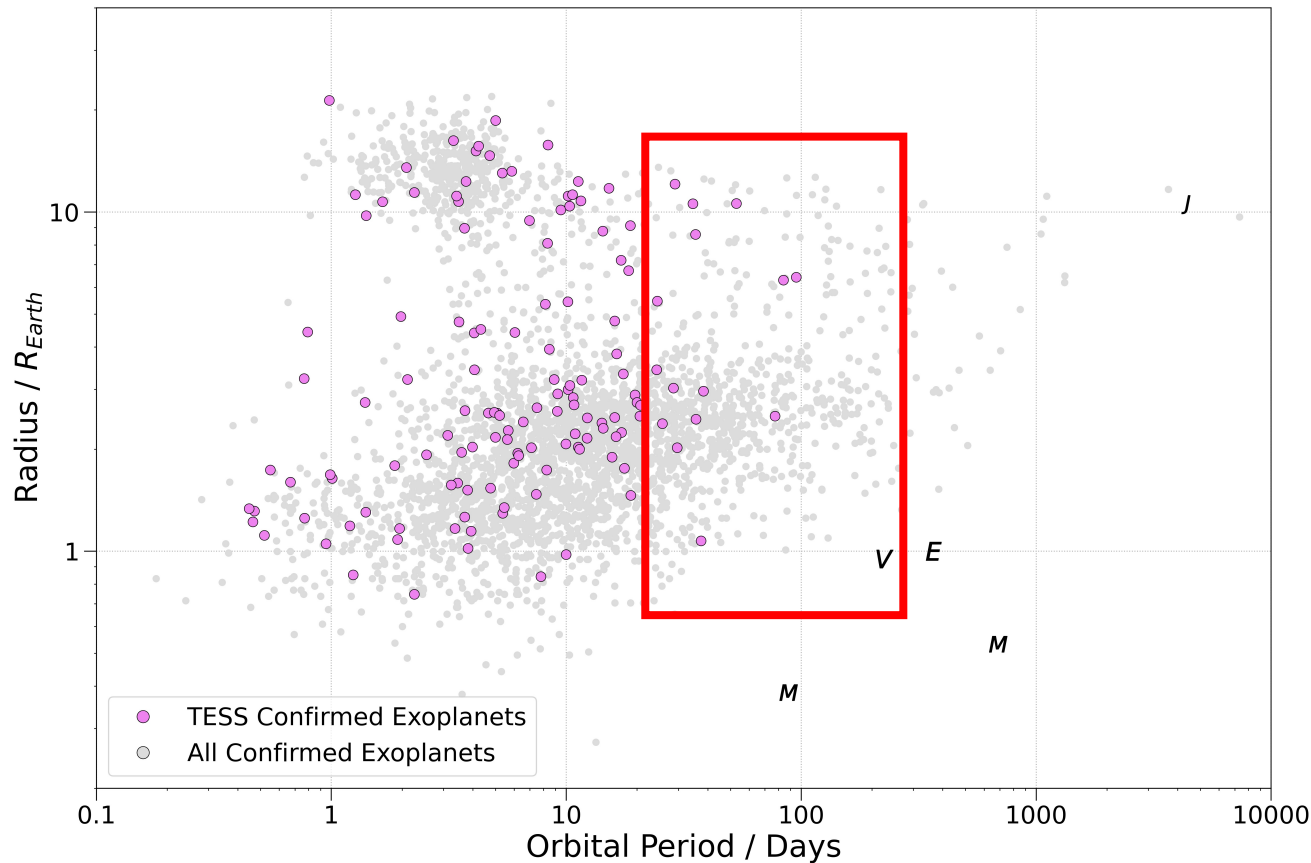
# Confirmed Exoplanet Population

Biased towards short-period planets.



[Data from NASA  
Exoplanet Archive]

# Confirmed Exoplanet Population

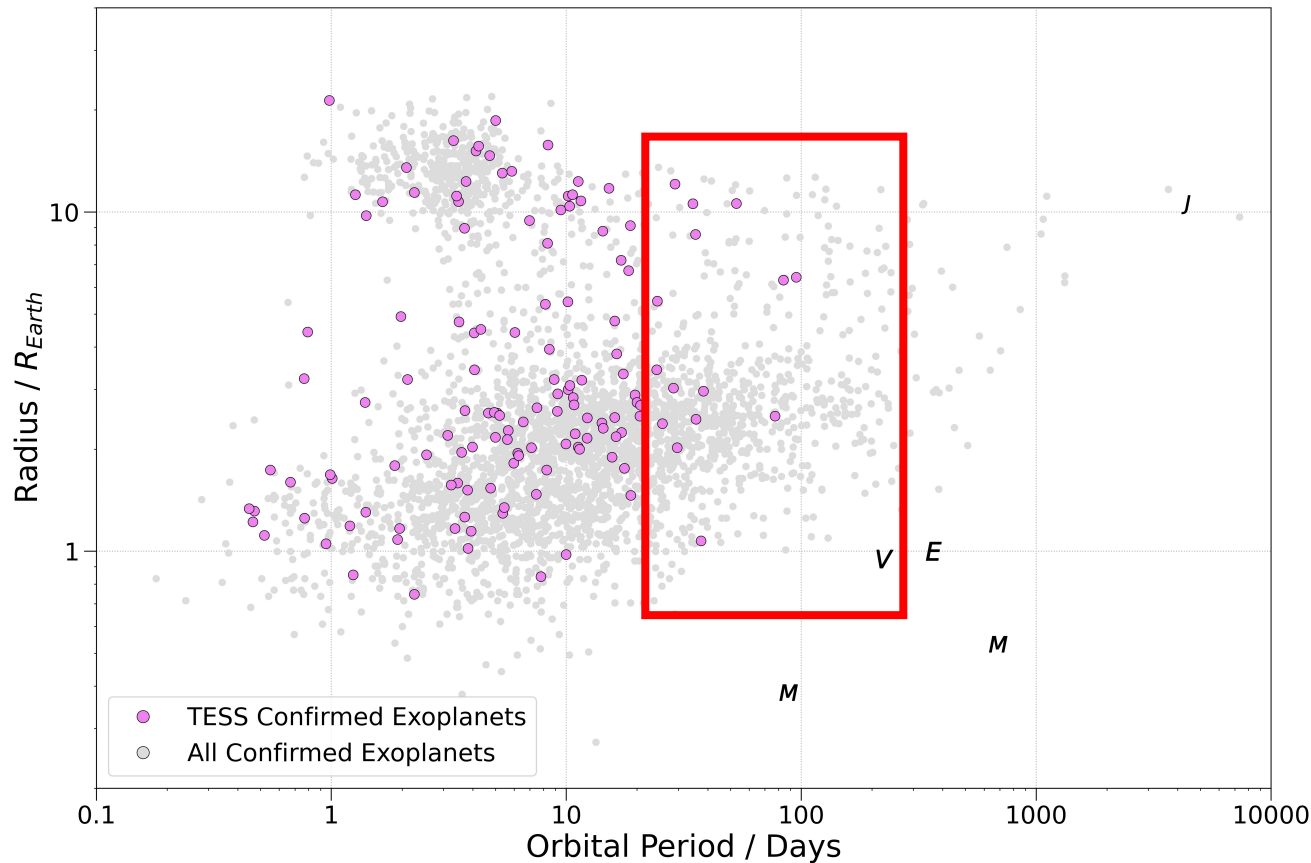


Biased towards short-period planets.

Monotransits  $\rightarrow$  longer-period exoplanet discoveries...

[Data from NASA Exoplanet Archive]

# Confirmed Exoplanet Population



Biased towards short-period planets.

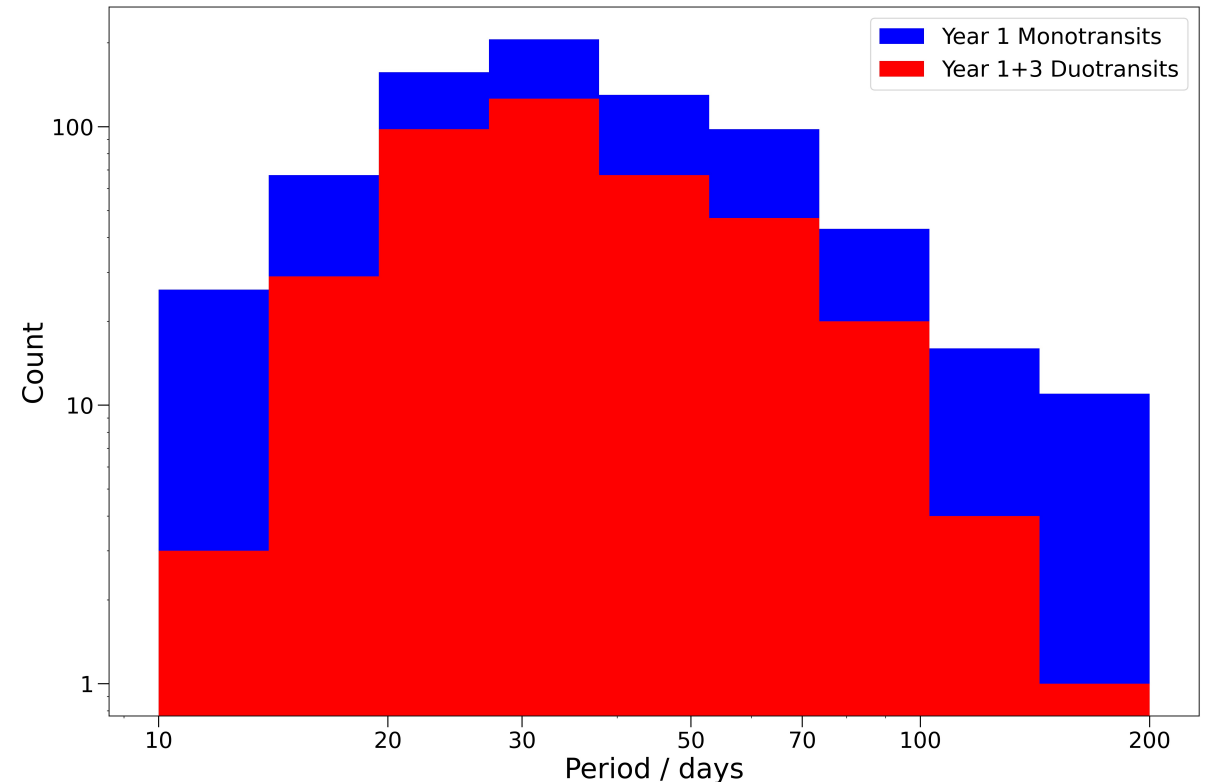
Monotransits  $\rightarrow$  longer-period exoplanet discoveries... at high observational cost.

[Data from NASA Exoplanet Archive]

# TESS Duotransits

- TESS is reobserving the sky.
- Simulations predict 52% of primary mission monotransits will be observed to transit a second time [Cooke+21].

**Two transits with a two year gap = duotransit**



[Data from Cooke+21]

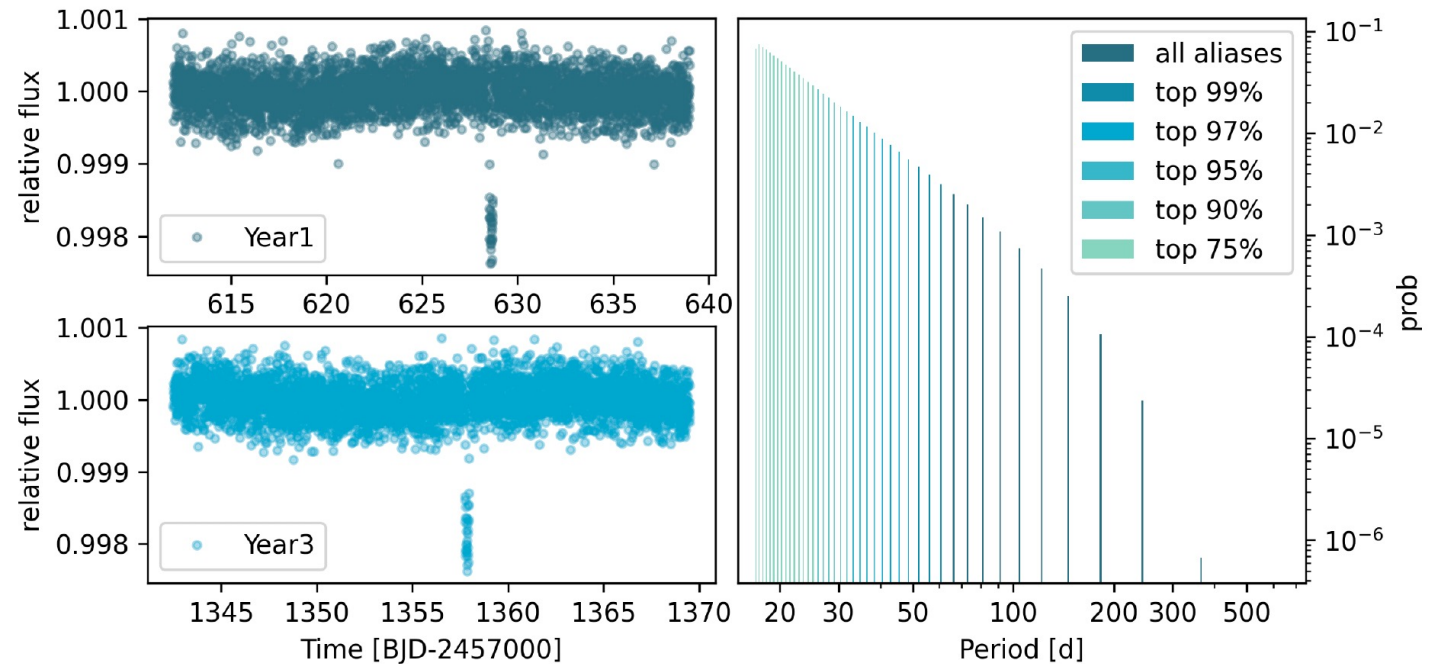


# Duotransit Follow-Up

- Discrete set of allowed period aliases,  $P_n$

$$P_n = \frac{T_{diff}}{n}$$

- Target each alias until another transit of object is detected.



[Thanks to H.Osborn]

# CHEOPS Duotransit GTO Program

**Goal:** use high-precision CHEOPS satellite for targeted follow-up of TESS duotransits.

- Complementary to ground-based efforts  $\Rightarrow$  select targets which are shallow and/or long duration.

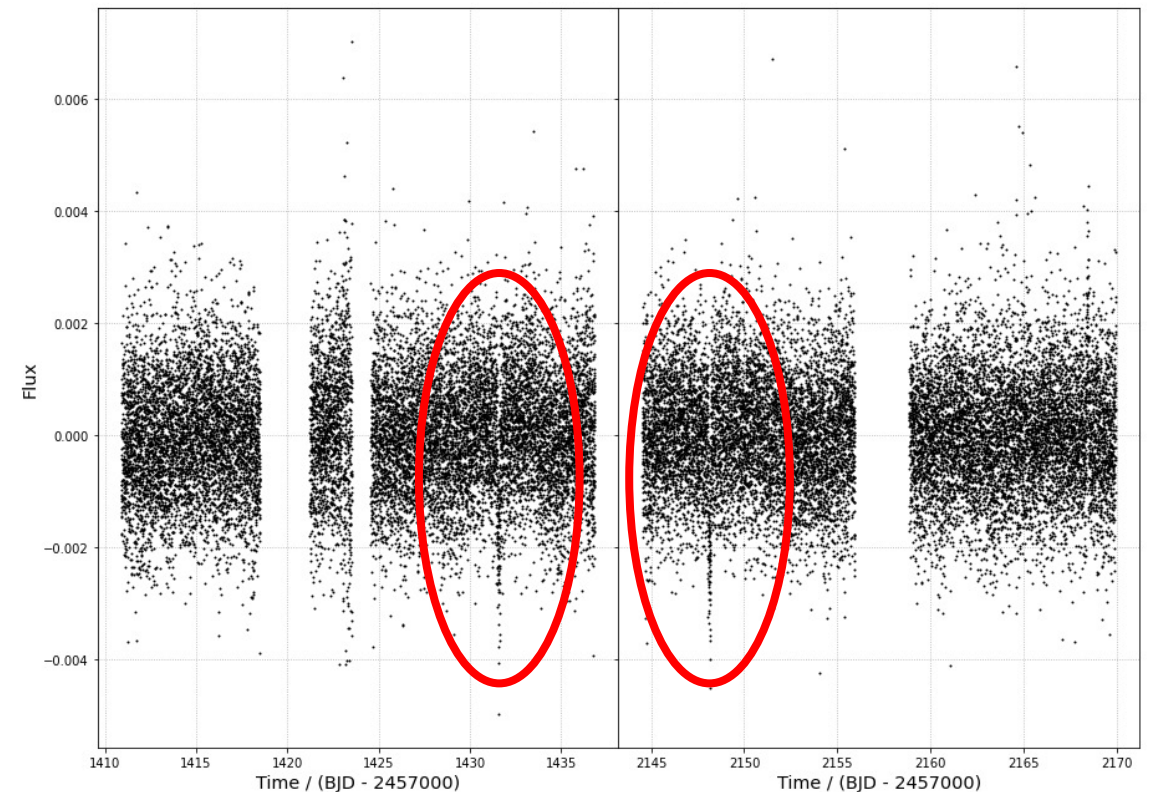
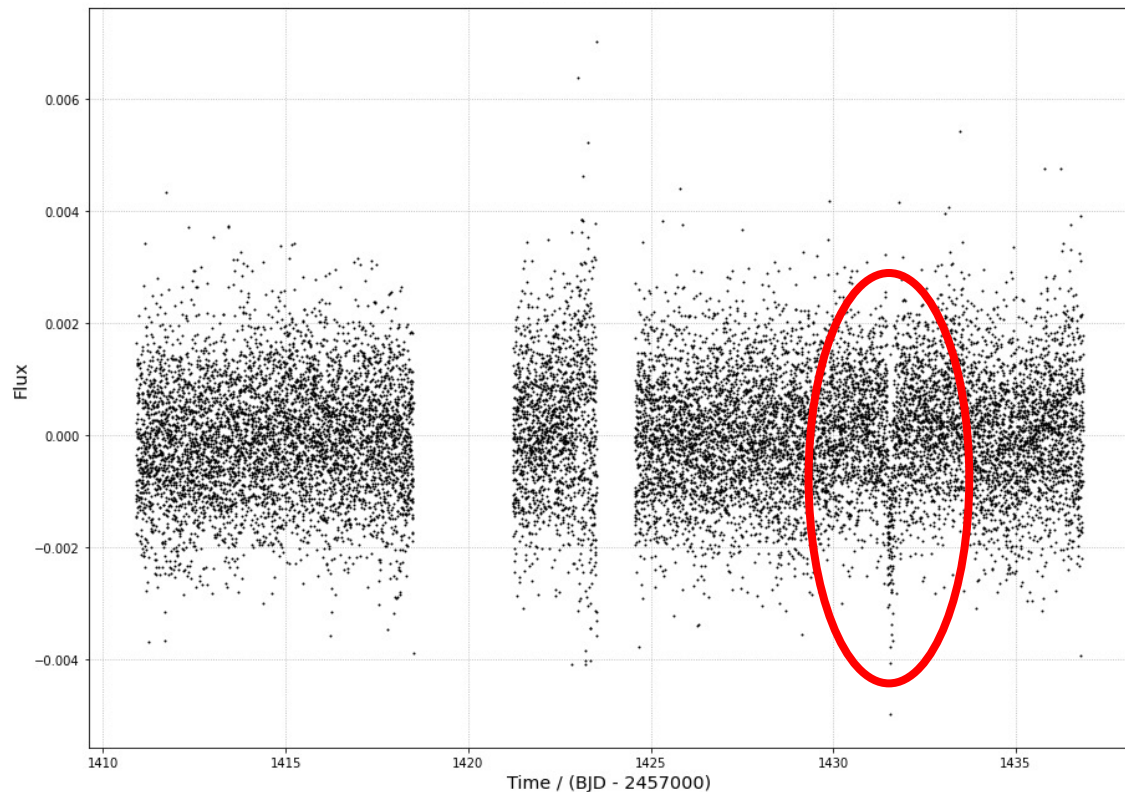
e.g. TOI 2076 [Osborn+submitted]

# Finding Duotransits

Monotransit



Duotransit



# Duotransit Pipeline

# Stellar Sample

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232,764 stars observed at 2 minute cadence in TESS primary mission – assess for suitability of CHEOPS follow-up and planet search:

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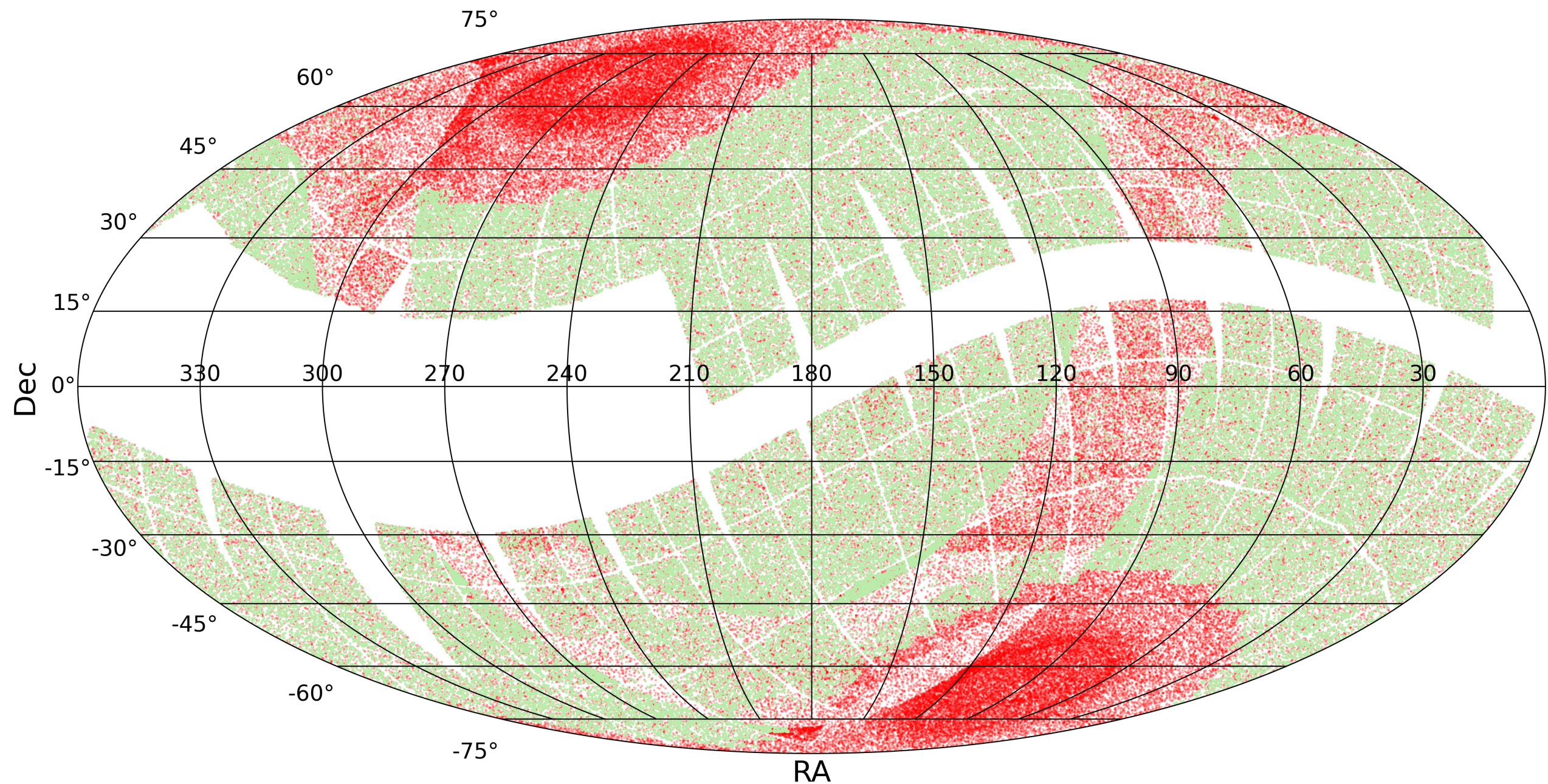
1. Good CHEOPS visibility
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3. Dwarf stars with radius  $\leq 2 R_{\text{Sun}}$

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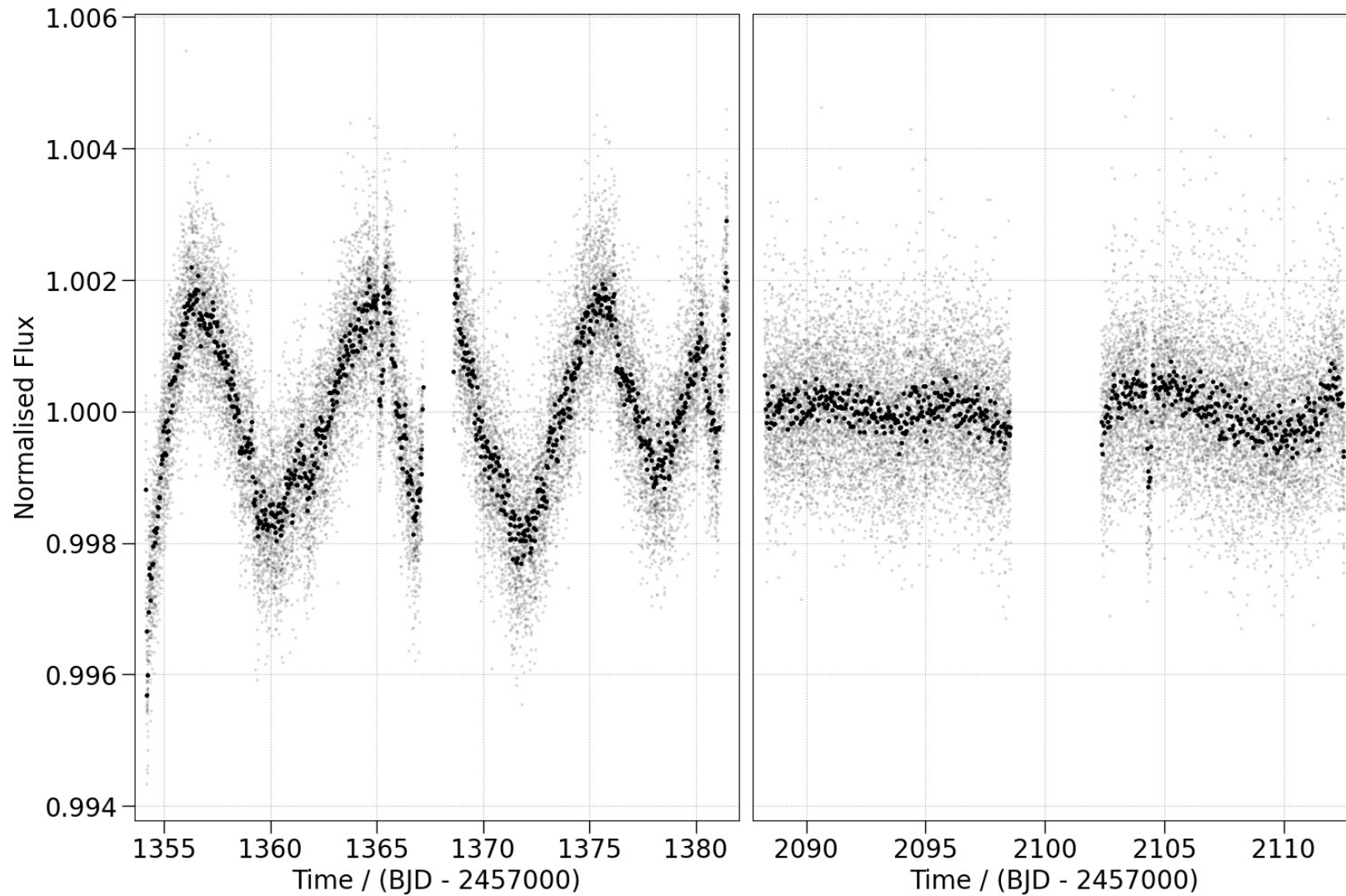
232,764 stars observed at 2 minute cadence in TESS primary mission – assess for suitability of CHEOPS follow-up and planet search:

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⇒ 84,288 stars suitable for duotransit search

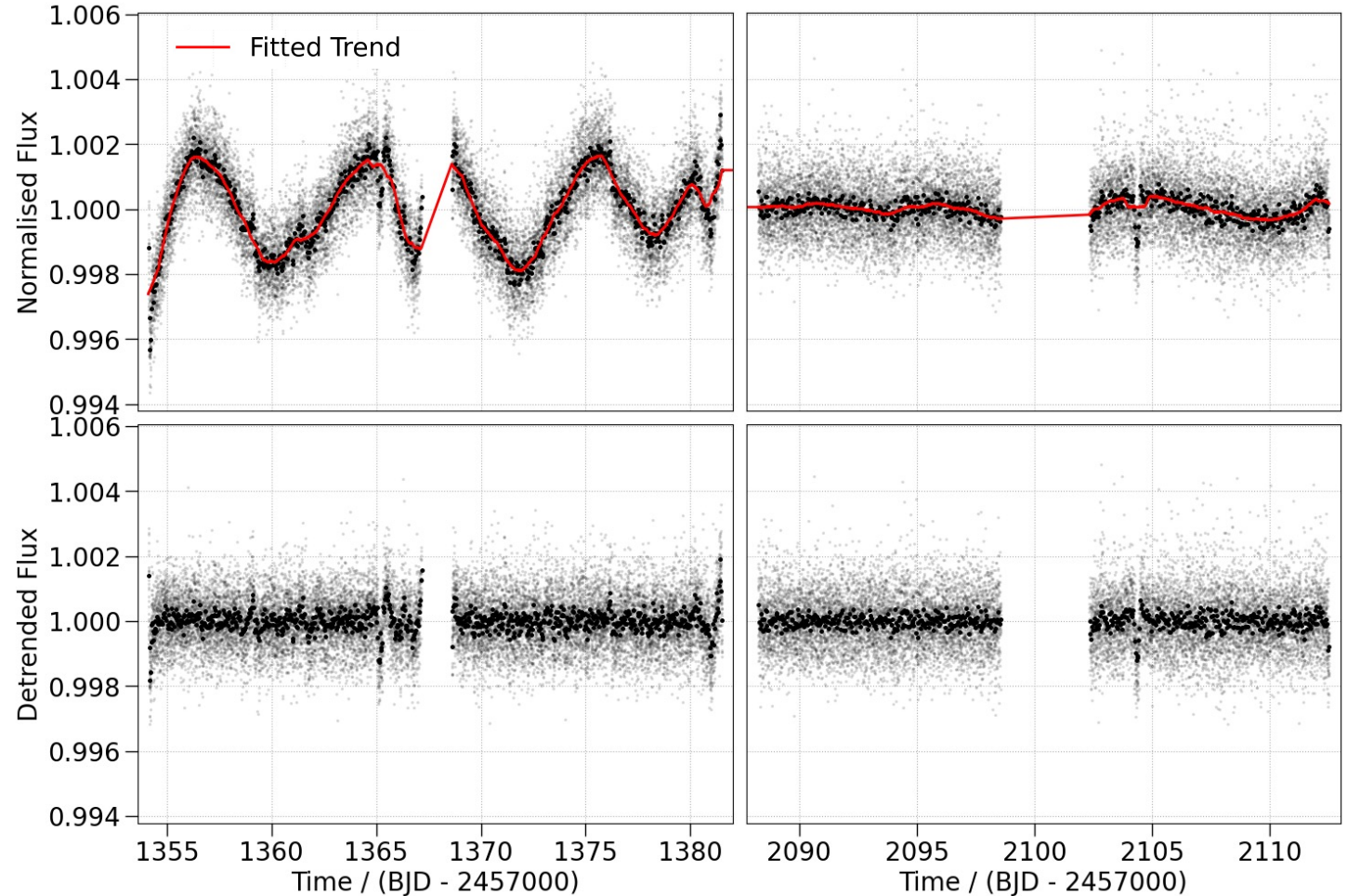


# Duotransit Pipeline



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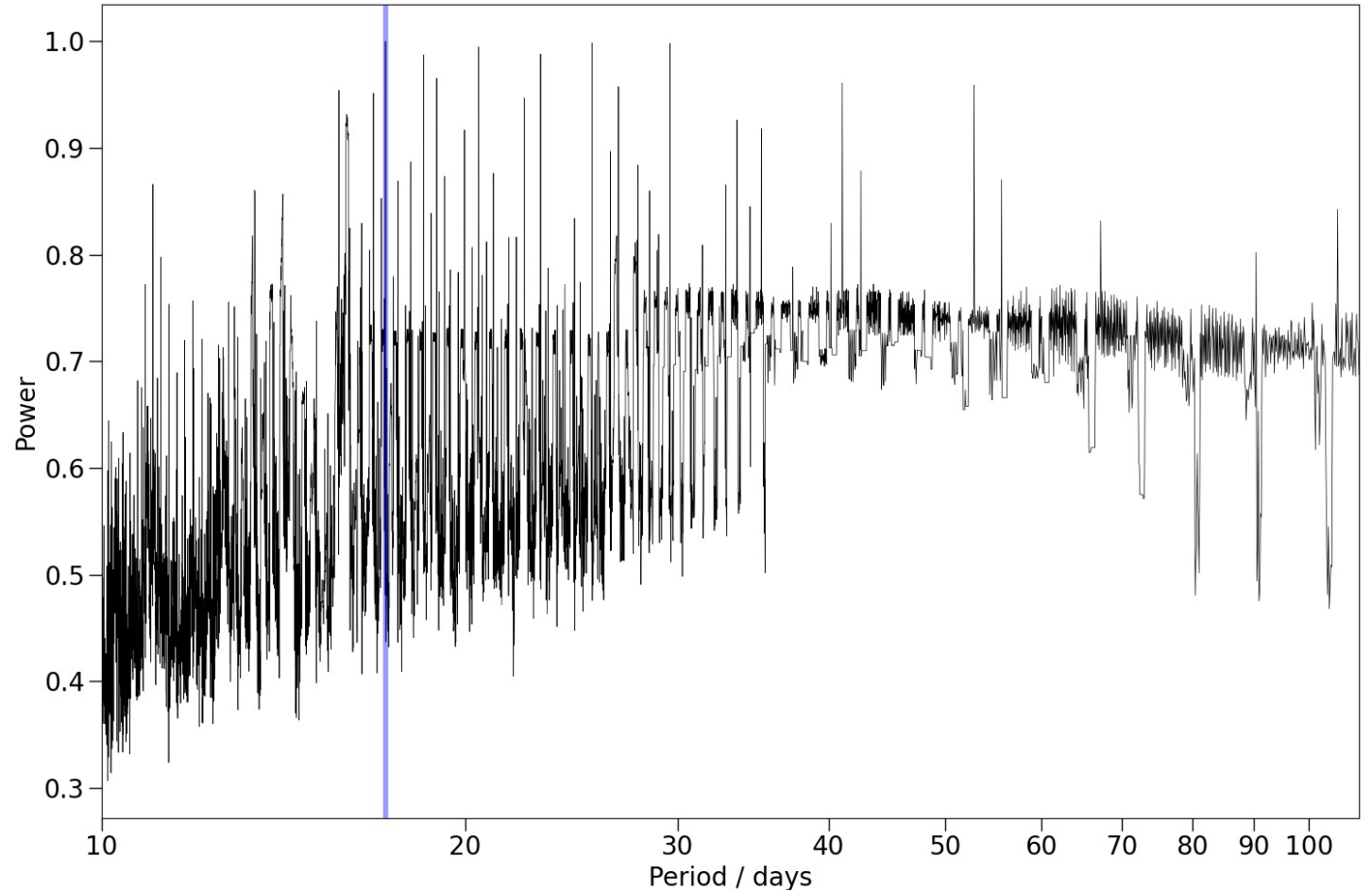
1. Detrend lightcurve (LC) using a mean sliding window



# Duotransit Pipeline

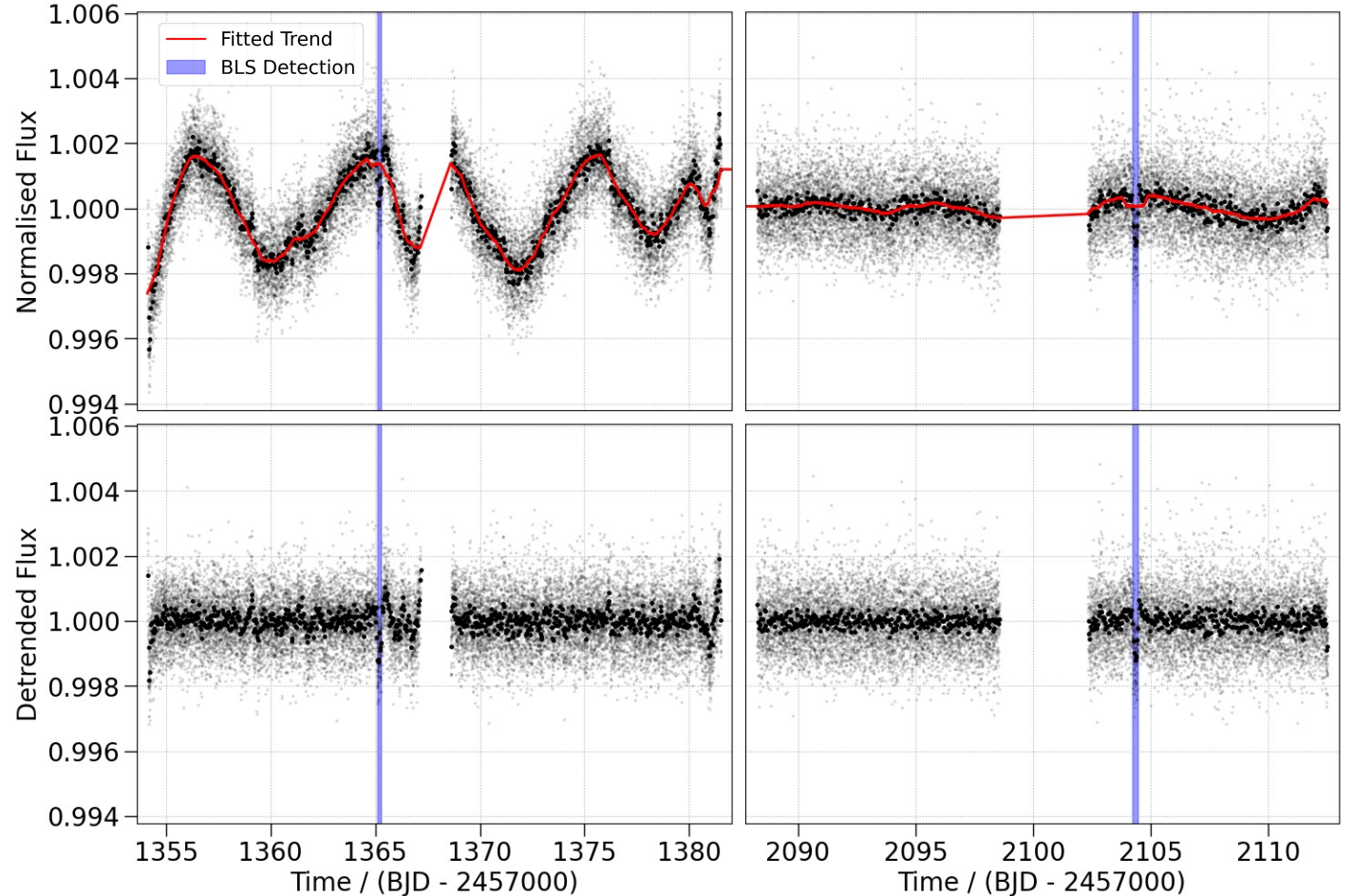
2. Transit search –  
box least squares  
(BLS) algorithm

**Remember:** a  
duotransit does not  
have a unique period,  
you get a series of  
peaks at period  
aliases!



# Duotransit Pipeline

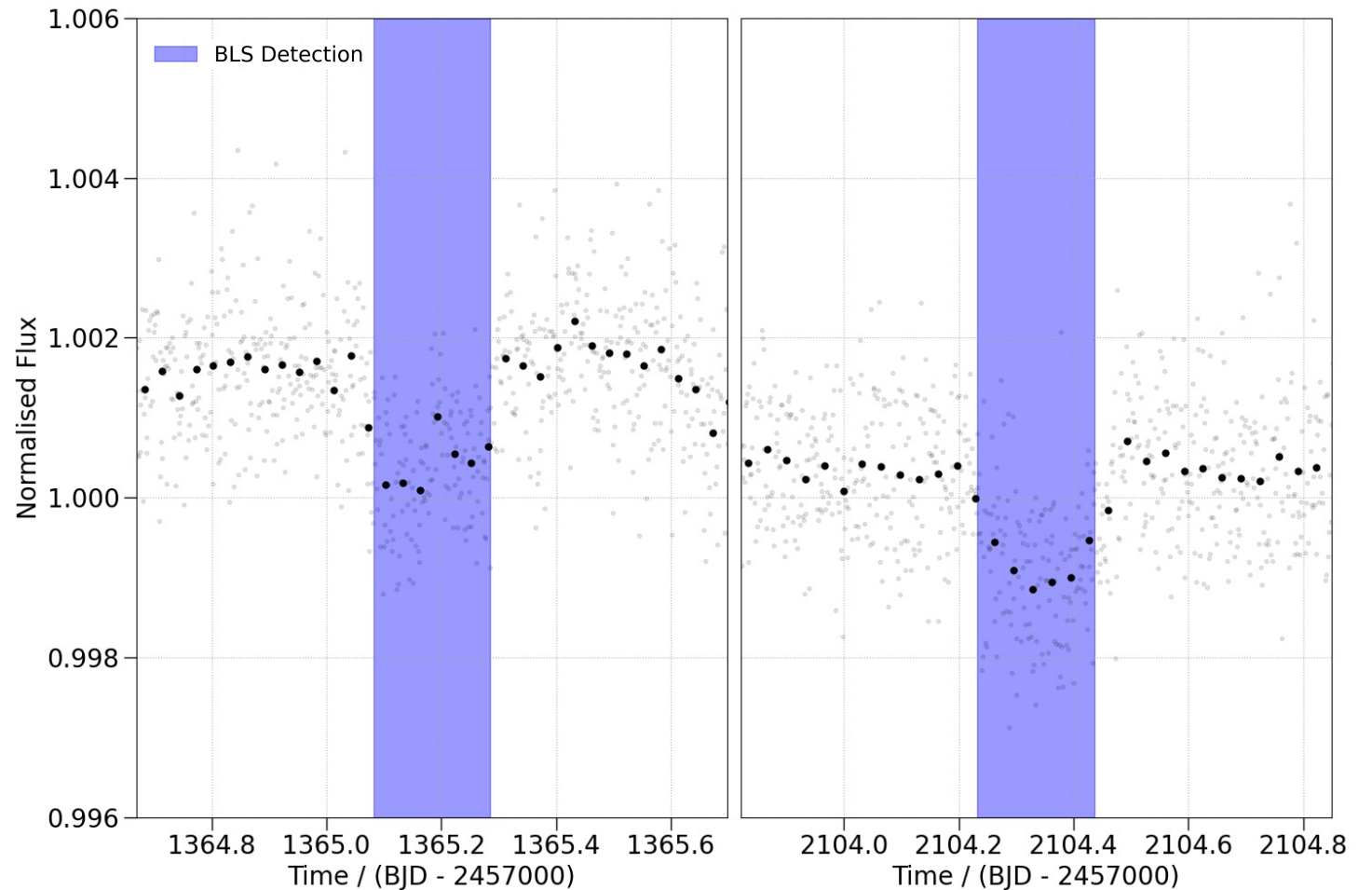
## 2. Transit search – box least squares (BLS) algorithm



# Duotransit Pipeline

## 3. Manual inspection of duotransit candidates:

- Examine two transits
- TOI catalog
- Modelling





# Duotransit Pipeline

> 50% of 2 minute primary mission targets are NOT observed at 2 minute cadence in the extended mission.

⇒ Incorporate TESS-SPOC 10 minute LCs.

## TESS Light Curves From Full Frame Images ("TESS-SPOC")

Primary Investigator: Douglas A. Caldwell

HLSP Authors: Douglas A. Caldwell, Jon M. Jenkins, Eric B. Ting, Peter Tenenbaum, Joseph D. Twicken, Jeffrey C. Smith, Christina Hedges, Michael M. Fausnaugh, Christopher J. Burke, Bill Wohler

Released: 2020-11-12

Updated: 2020-11-12

Primary Reference(s): [Caldwell et al. 2020](#) 

DOI: [10.17909/t9-wpz1-8s54](https://doi.org/10.17909/t9-wpz1-8s54) 

Citations: [See ADS Statistics](#) 

[Read Me](#) 

# Predicted Results

# Simulated Duotransits

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## **41 duotransits:**

- in the southern ecliptic hemisphere.
- around stars in the same parameter space as my stellar sample.
- detectable with signal-to-noise  $\geq 7.3$ .

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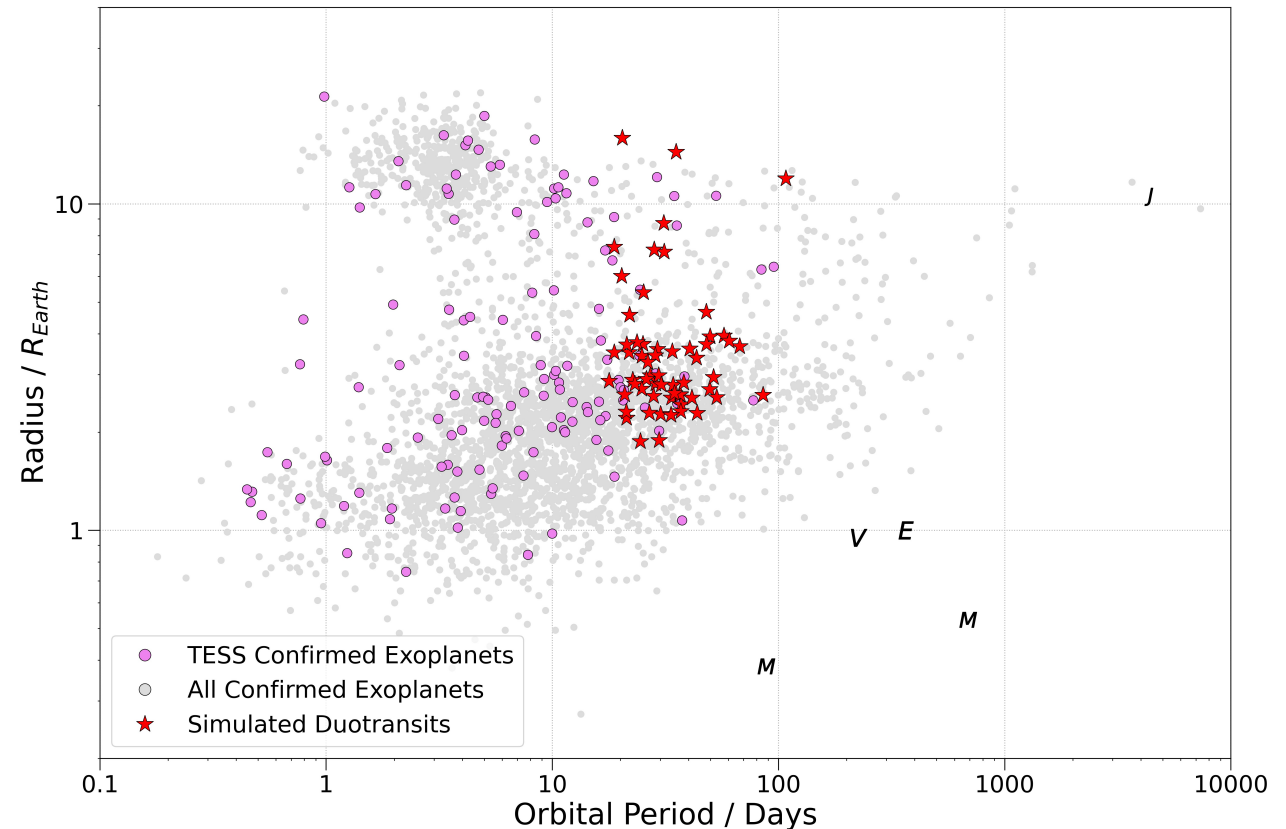
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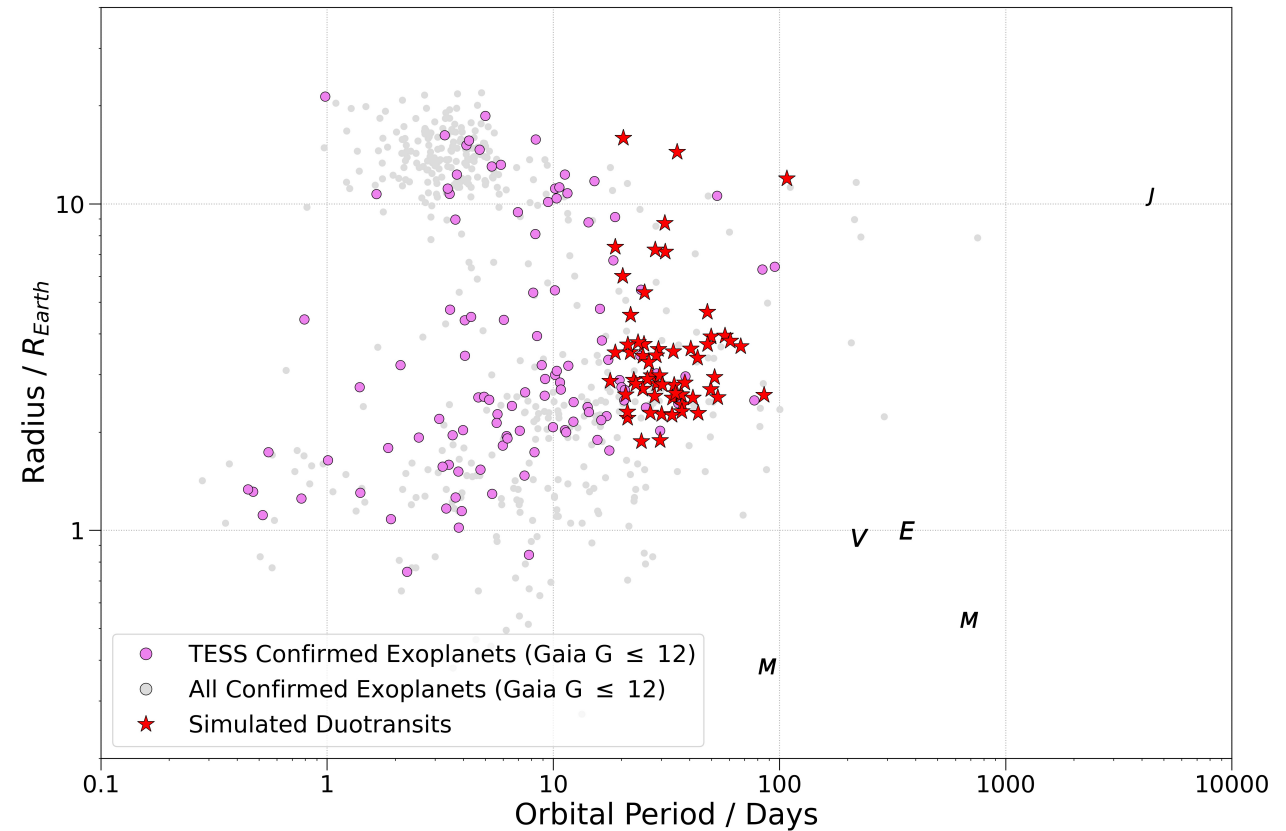


[Data from Cooke+21 and NASA Exoplanet Archive]

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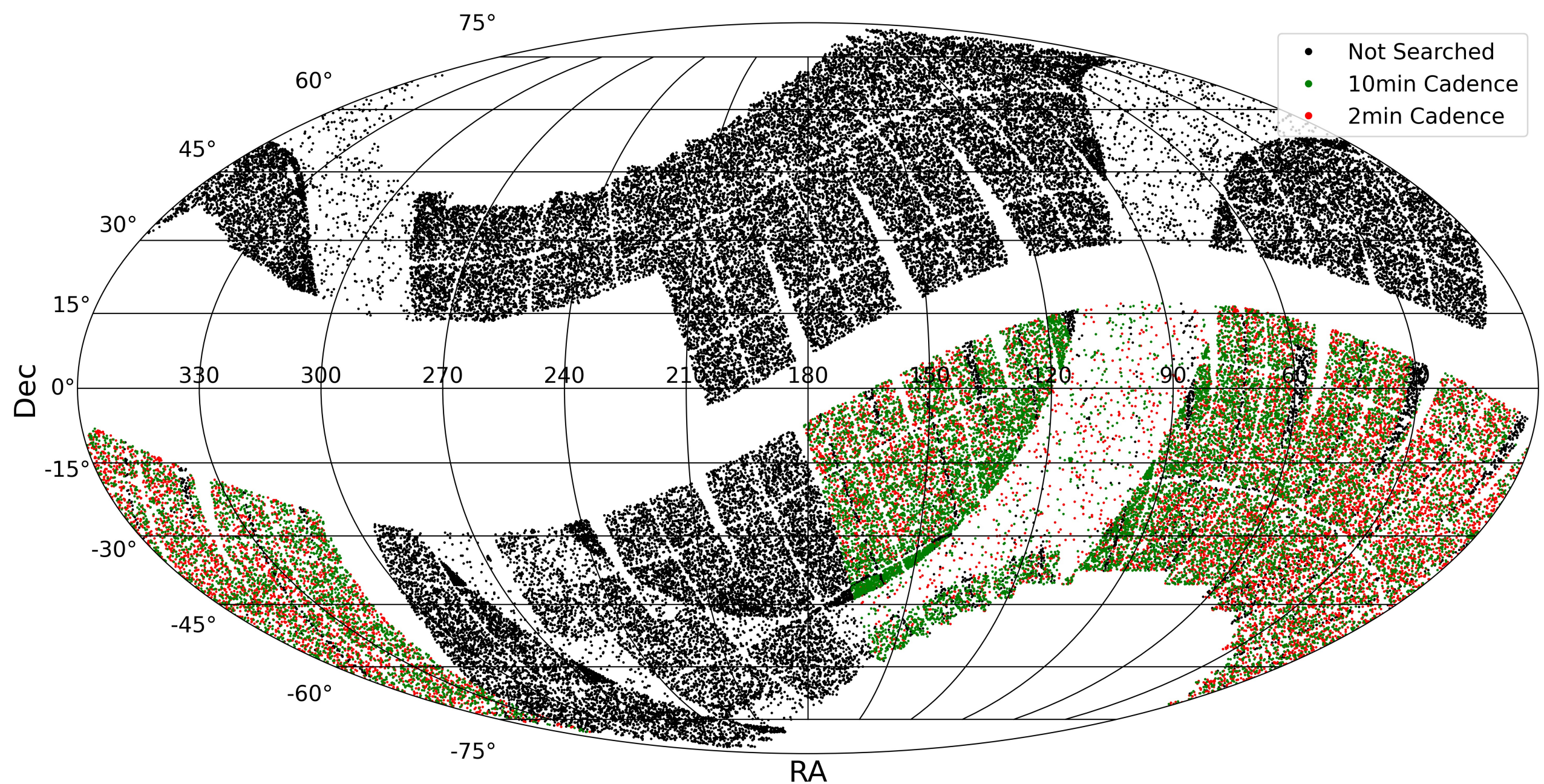


# Duotransit Yield Predictions

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Expect to find ~ 65 duotransits in the southern ecliptic hemisphere with my pipeline.

# Results



28,808 stars searched for duotransits.

# Results

2,814 / 28,808 stars ( $\sim 10\%$ ) return a duotransit candidate.

**What did the visual inspection reveal?**

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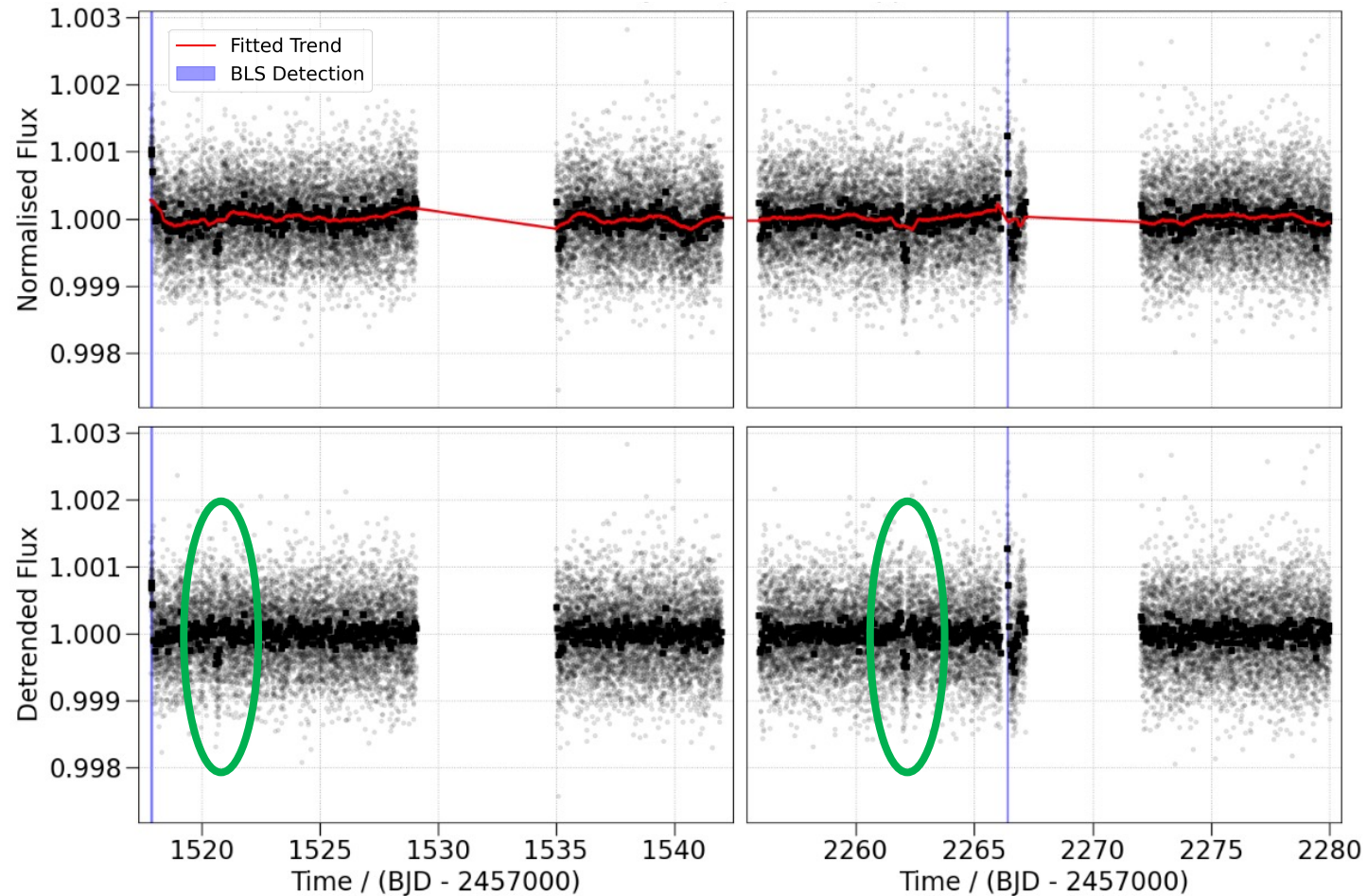
- False positives, including eclipsing binaries and monotransits
- 13 genuine detections - 3 new duotransits and 10 duotransits from the existing sample

**BUT...** I expected to recover 15 duotransits from the existing sample.



# Results: missing duotransits?

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# Results: reality vs simulation

Sample Size: 28,808 stars

## **Reality:**

18 duotransits

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44 detectable duotransits

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## **Reality:**

18 duotransits

## **Simulation Prediction:**

44 detectable duotransits → makes the assumption that all stars are reobserved at 2 minute cadence.

# Results: reality vs simulation

Sample Size: ~~28,808~~ 13,132 stars

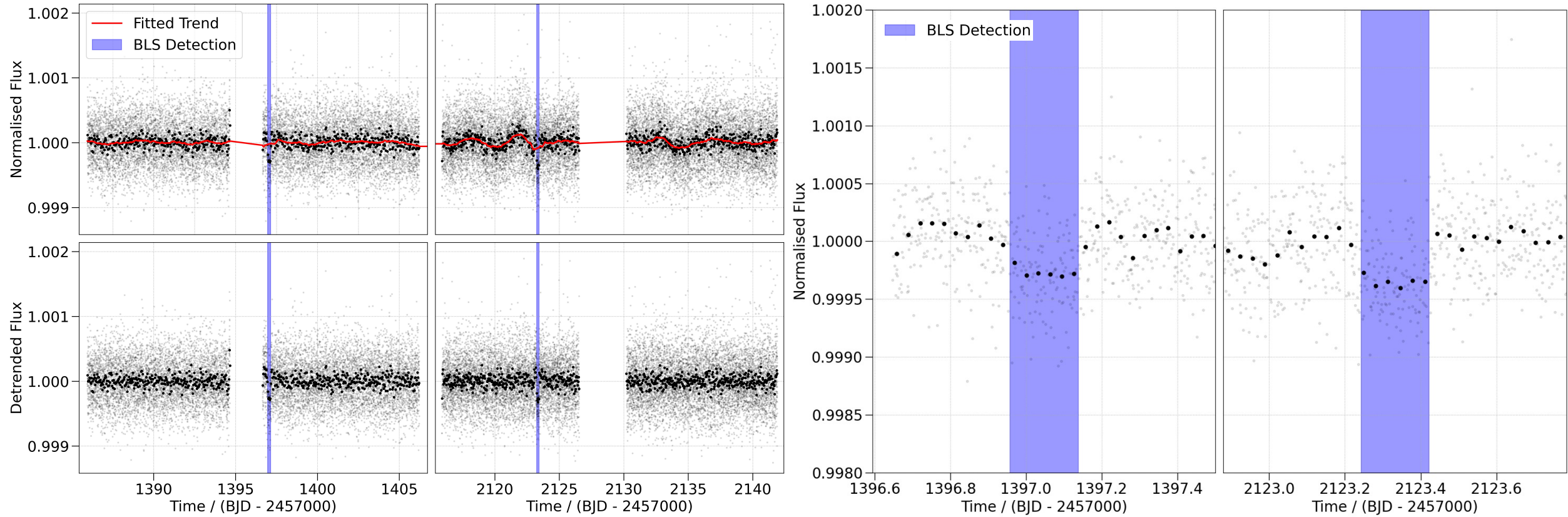
## **Reality:**

~~18~~ 16 duotransits

## **Simulation Prediction:**

~~44~~ 20 detectable duotransits

# Results: new duotransit!



# Conclusions

- Duotransits offer the exciting opportunity to discover long-period transiting exoplanets.
- A pipeline has been developed to find duotransits in TESS data.
- The pipeline has revealed at least 3 new duotransits.
- The most interesting duotransits are being followed-up with CHEOPS in order to determine their periods and confirm their planetary nature.

Thank you! Any questions?