TESS Update

Michelle Kunimoto
TESS Postdoctoral Associate,
MIT Kavli Institute

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NASA.gov
Mission Highlights

- TESS achieved the main goal of its Primary Mission: to detect 50 planets smaller than Neptune and measure their masses
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- ~1 publication pertaining to TESS per day.

[Link to TESS publications](https://heasarc.gsfc.nasa.gov/docs/tess/publications.html)
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- TESS Science Conference II (August 2021): 900 registered participants!
5000+ TESS Objects of Interest!

5164 TOIs
4371 TOIs (false positives removed)
- 1313 TOIs with $R_p < 4 R\oplus$
- 161 Confirmed Planets
5000+ TESS Objects of Interest!

Stay tuned...

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Exoplanet Highlights

- 125 planets and planet candidates in multi-planet systems
- Exotic exoplanets
  - circumbinary planets
  - hot Jupiters with companions
  - planets in the Neptune desert
  - planets around young stars
Exoplanet Highlights

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- Prime Mission TESS Objects of Interest Catalog released (Guerrero et al. 2021)
## Other Astrophysics

### Solar System Objects
*Thousands in 3.5 years*
- occultation events
- comets
- asteroids
- trans-neptunian objects
- SDOs/Centaurs

### Explosive & Variable Extragalactic Sources
*Thousands in 3.5 years*
- supernovae
- AGNs
- blazars
- quasars
- tidal-disruption events
- gamma-ray bursts
- kilonovae
- hypernovae

### Variable Stars
*Millions in 3.5 years*
- asteroseismology
- brown dwarfs
- eclipsing binaries
- flare stars
- cepheids
- emission line stars
- RR Lyrae stars
- T Tauri stars
- neutron stars
- white dwarfs
- WD oscillations
- young stellar objects
Proposal for Extended Mission 2

- Three years: Sectors 56 - 96
- FFI cadence improved from 600s to 200s
- calibrated FFIs available as soon as 4-5 days after downlink
- revisit the North/South, finish the Ecliptic
What can we expect from EM2?
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1. How many planets should be detectable?

2. How many planets will be in the Habitable Zone?

3. How many planets will be promising follow-up targets?

4. How well do these predictions reflect the actual TESS exoplanet yield?

See: simulations from Sullivan et al. (2015), Bouma et al. (2017), Barclay et al. (2018), etc
~ 9.4 million AFGKM stars in the Candidate Target List (CTL) v8
**AFGK stars:** Kunimoto & Matthews (2020)

**M stars:** Dressing & Charbonneau (2015)

**Simulate planets around each star**
Check with stars are observed by TESS
Predict which planets will be detectable in TESS lightcurves
Assess the final list of simulated TESS detections
1. How many planets should be detectable?

Primary Mission:

4721 ± 330 planets
1. How many planets should be detectable?

Extended Mission 1:

3703 ± 217 planets

(8424 ± 518 planets in total)
1. How many planets should be detectable?

---

Extended Mission 2:

4100 ± 205 planets

(12524 ± 676 planets in total)
1. How many planets should be detectable?

The small planet ($R_p < 4 \, R_\oplus$) yield could double in EM2.
1. How many planets should be detectable?

Typical planets will have progressively longer periods
How many planets should be detectable?

G dwarf stars are the most common TESS planet hosts.
2. How many planets will be in the Habitable Zone?

Sectors 1 - 45 (Rp < 2 R⊕):

<table>
<thead>
<tr>
<th></th>
<th>Optimistic Habitable Zone</th>
<th>Conservative Habitable Zone</th>
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<tr>
<td>Prediction</td>
<td>6 ± 2</td>
<td>3 ± 1</td>
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<tr>
<td>Actual</td>
<td>5 TOIs</td>
<td>2 TOIs</td>
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★ = Rp < 2 R⊕
2. How many planets will be in the Habitable Zone?

- **Optimistic Habitable Zone**
  - $R_p < 2 \, R_\oplus$: $18 \pm 5$
  - All planets: $198 \pm 24$

- **Conservative Habitable Zone**
  - $R_p < 2 \, R_\oplus$: $9 \pm 3$
  - All planets: $97 \pm 14$
3. How many will be promising follow-up targets?

Radial Velocity (RV) Observations
(Rp < 4 R⊕):

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<th>K &gt; 3 m/s V &lt; 11 mag</th>
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<td>Years 1 - 2</td>
<td>117 ± 17</td>
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### Atmospheric Characterization (using Transmission Spectroscopy Metric (TSM) from Kempton et al. 2018):

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<th>Mission Duration</th>
<th>Rp &lt; 1.5 R⊕ TSM &gt; 10</th>
<th>1.5 &lt; Rp &lt; 10 R⊕ TSM &gt; 90</th>
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<td>Years 1 - 2</td>
<td>21 ± 6</td>
<td>366 ± 35</td>
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<td>41 ± 9</td>
<td>529 ± 48</td>
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<td>Years 1 - 7</td>
<td>58 ± 11</td>
<td>632 ± 55</td>
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4. How well do the predictions reflect actual yields?
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Important notes:

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Important notes:

- I'm only comparing to TOIs orbiting CTLv8 AFGKM stars within simulated range (Rp \(<\) 16 R\(_{\odot}\))
- I'm only comparing to Primary Mission TOIs (Guerrero et al. 2021)
- the TOI identification process is not complete or straightforward to simulate
  - Assume simulated 2min detections reflect NASA's SPOC pipeline
  - Assume simulated FFI detections with T < 10.5 mag reflect the Quick Look Pipeline (QLP)
4. How well do the predictions reflect actual yields?

Predictions for the TESS Primary Mission TOI yield:

1259 ± 58 planets

Actual TESS TOIs (Guerrero et al. 2021):

1227 TOIs
4. How well do the predictions reflect actual yields?

Predictions for the TESS Primary Mission TOI yield:

$1259 \pm 58$ planets

Recall my predictions for the full Primary Mission yield:

$4721 \pm 330$ planets
TESS Faint Star Search

1617 new TOIs from the Primary Mission

412 new TOIs from Extended Mission 1 (ongoing)
Takeaways

1. **More than 12000 planets should be detectable** by the end of EM2

2. New planets will be smaller, with longer orbital periods, orbiting fainter stars

3. The $R_p < 4 \, R_\oplus$ yield should double between EM1 and EM2

4. Thousands more TESS planets can be detected **even with the data at hand**
Supplemental Slides
## Comparisons to previous works

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The graph shows the detection probability as a function of the signal-to-noise ratio. The curves represent different numbers of transits: 37 transits (blue), 10 transits (orange), 5 transits (green), and 2 transits (red). As the signal-to-noise ratio increases, the detection probability increases as well, approaching a maximum value of 1.0.
Simulation results using Fressin et al. (2013) occurrence rates, S/N > 7