Uniting MEarth and TESS

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MEarth-South
Cerro Tololo, Chile

MEarth-North
Mt Hopkins, AZ
MEarth Targets in Sectors 1-12
MEarth & TESS

• MEarth data modeling
• MEarth planets in Sectors 1-12
• MEarth contribution to TESS discoveries
• TESS vetting of MEarth targets of interest
MEarth finds terrestrial planets in real time
Discovery of LHS 1140 c on 14 Aug 2016

Ment et al 2019
We also use an Advanced BLS Search
Advanced BLS Vetting with 15 parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit midpoint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit duration</td>
<td>28.98 min</td>
<td>GREAT</td>
</tr>
<tr>
<td>Transit depth</td>
<td>4.2 mmag</td>
<td>OK</td>
</tr>
<tr>
<td>Reduced $\Delta \chi^2$</td>
<td>2.67</td>
<td>DUBIOUS</td>
</tr>
<tr>
<td>Reduced $\Delta \chi^2$ (in-transit)</td>
<td>2.91</td>
<td>GREAT</td>
</tr>
<tr>
<td>Max. night contribution</td>
<td>14.2%</td>
<td>OK</td>
</tr>
<tr>
<td># of in-transit data (exp)</td>
<td>158 (152)</td>
<td>GREAT</td>
</tr>
<tr>
<td># of in-transit nights (sig:insig)</td>
<td>101 (17:34)</td>
<td>OK</td>
</tr>
<tr>
<td>Depth IC odd-oven</td>
<td>6.3%</td>
<td>GREAT</td>
</tr>
<tr>
<td>Depth IC meridian flips</td>
<td>-2.7%</td>
<td>GREAT</td>
</tr>
<tr>
<td>Depth IC trigger nights</td>
<td>-9.4%</td>
<td>GREAT</td>
</tr>
<tr>
<td>Depth IC half-phase</td>
<td>-116%</td>
<td>OK</td>
</tr>
<tr>
<td>Depth IC noise</td>
<td>5.2%</td>
<td>OK</td>
</tr>
<tr>
<td>Ingress/egress baseline IC</td>
<td>6.3%</td>
<td>GREAT</td>
</tr>
<tr>
<td>Frac. $\Delta \chi^2$ of quadratic fit</td>
<td>1.165</td>
<td>OK</td>
</tr>
</tbody>
</table>

The vettig results for M-580.R6.2 with P = 0.462932 and $\Delta \chi^2 = 353.16$ is OK with a total $\Delta \chi^2 = 276.47$.
Advanced BLS Noise Spectrum

Original BLS spectrum
Advanced BLS

Noise Spectrum

Original BLS spectrum

Residual BLS spectrum after subtracting “noise”
Shortlist of MEarth planet candidates
Shortlist of MEarth planet candidates
MEarth & TESS

- MEarth data modeling has produced a series of new planets and potential candidates
- MEarth planets in Sectors 1-12
- MEarth contribution to TESS discoveries
- TESS vetting of MEarth targets of interest
MEarth data modeling has produced a series of new planets and potential candidates

MEarth planets in Sectors 1-12

MEarth contribution to TESS discoveries

TESS vetting of MEarth targets of interest
LHS 1140

M4.5 V type
15.0 pc away

LHS 1140 b

P = 24.73696 days
7.0 ± 0.9 M_{Earth}
1.73 ± 0.03 R_{Earth}
within HZ

LHS 1140 c

P = 3.77797 days
1.8 ± 0.4 M_{Earth}
1.28 ± 0.02 R_{Earth}
T ~ 440 K
LHS 1140 b

- **LHS 1140**
  - M4.5 V type
  - 15.0 pc away

- **P = 24.73696 days**
- **7.0 ± 0.9 M_{\text{Earth}}**
- **1.73 ± 0.03 R_{\text{Earth}}**

within HZ

Source: SPOC

LHS 1140 c

- **P = 3.77797 days**
- **1.8 ± 0.4 M_{\text{Earth}}**
- **1.28 ± 0.02 R_{\text{Earth}}**

- **T ~ 440 K**

Source: SPOC
GJ 1132 b

TESS (SPOC)
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Rotational modulation of LHS 3844

Binned observations from MEarth-South

Vanderspek et al 2019
LP 791-18 b

Orbital period: $0.9480050 \pm 0.0000058$ days

$R_p/R^* = 0.0604 \pm 0.0028$

Crossfield et al 2019
(submitted)
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All 3 MEarth planets in Sectors 1-12 have been observed and confirmed by TESS.

MEarth has helped validate and further characterize several TESS discoveries (including LHS 3844 b and LP 791-18 b) and rule out a spurious TOI (226.01).

TESS vetting of MEarth targets of interest.
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TESS vetting of MEarth targets of interest
<table>
<thead>
<tr>
<th>P</th>
<th>Δm</th>
<th>$K_t^{*\text{diff}}$</th>
<th>$K_{\text{mag}}^{*\text{diff}}$</th>
<th>$K_{\text{mag}}^{*\text{ref}}$</th>
<th>$\Delta X^2$</th>
<th>$X^2$</th>
<th>$X^2_m$</th>
<th>N</th>
<th>$N_{\text{exp}}$</th>
<th>$t_{\text{night}}$</th>
<th>$\Delta X^2 - \Delta X_{\text{ref}}$</th>
<th>$X_{\text{mag}} / X_{\text{ref}}$</th>
<th>$t_{\text{night}}$ (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6491</td>
<td>0.003853</td>
<td>7.5%</td>
<td>15.4%</td>
<td>-122.7%</td>
<td>90.5</td>
<td>2.04</td>
<td>1.43</td>
<td>44 (43)</td>
<td>35 (13.3)</td>
<td>0.2561</td>
<td>18.46</td>
<td>10.5%</td>
<td>-7.3%</td>
</tr>
<tr>
<td>OK</td>
<td>GREAT</td>
<td>OK</td>
<td>OK</td>
<td>DUBIOUS</td>
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<td>0.04466</td>
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<td>-154.8%</td>
<td>68.04</td>
<td>1.66</td>
<td>1.71</td>
<td>55 (25)</td>
<td>12 (1.3)</td>
<td>0.4954</td>
<td>49.57</td>
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<td>2.15</td>
<td>69 (67)</td>
<td>38 (7.13)</td>
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<td>26.82</td>
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<tr>
<td>P</td>
<td>Δm</td>
<td>KΔC (e, r)</td>
<td>KΔC (g, r)</td>
<td>ΔKΔC</td>
<td>ΔX</td>
<td>ΔX (m)</td>
<td>N</td>
<td>t (night)</td>
<td>Δm (night)</td>
<td>ΔXΔC (e, r)</td>
<td>ΔXΔC (g, r)</td>
<td>ΔXΔC (m)</td>
<td>Δχ² (teff)</td>
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Shortlist of MEarth planet candidates

LHS 1140 b

LHS 1140 c
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• MEarth has helped validate and further characterize several TESS discoveries (including LHS 3844 b and LP 791-18 b) and rule out a spurious TOI (226.01)

• TESS has ruled out a dozen of MEarth candidates, and will provide definitive answers for many more in the remaining sectors