Exoplanets Orbiting Asteroseismic TESS Stars

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Asteroseismology to the Rescue
A Definitive Catalogue of Exoplanets Orbiting Asteroseismic Stars with *Kepler*, *K2*, & *Tess*  

Huber+ 2013  
Lundkvist+ 2016
Lundkvist+ 2016
Hot Super-Earth Desert

Period (days)

$R_p (R_{\oplus})$

Non-seismic hosts
Known Kepler seismic hosts
A Definitive Catalogue of Exoplanets Orbiting Asteroseismic Stars with *Kepler*, *K2*, & *Tess*  

Van Eylen+ 2018  
**Hot Super-Earth Desert**  

Lundkvist+ 2016  

**Photoevaporation Valley**
Takeaway: We need more systems for which we can do asteroseismology!

Van Eylen+ 2018
Photoevaporation Valley

Lundkvist+ 2016
Hot Super-Earth Desert
Kepler
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- Non-seismic hosts
- Known Kepler seismic hosts
- New Kepler seismic hosts
KOI 4: *Kepler’s First Planet*

![Graph showing power density vs frequency with marked frequencies and peaks]

Chontos+ 2019a
KOI 4: *Kepler’s* First Planet

**Chontos+ 2019a**

- **a) Primary**
  - Transit depth vs. time from mid-transit (hours).
  - Data points and model fit showing a clear transit signal.

- **b) Secondary**
  - Transit depth vs. time from mid-transit (hours).
  - Data points and model fit showing a smaller transit signal.

- **c)** Fractional change in flux (ppm) over phase (days).
  - Data points and model fit showing stability.

- **d)** Velocity vs. phase (days).
  - Data points and model fit showing orbital motion.

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Despite being the 1st candidate planet discovered by the @NASAKepler telescope, Kepler-1658b had a rocky road to confirmation. 10 years later, scientists have now confirmed that it is, in fact, a planet. It whips around its star every 3.85 days. Info: go.nasa.gov/2TvTbKh
K2
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- K2-93
- K2-99
- K2-196
- K2-236
- + some interesting candidates
TESS
For planets orbiting TESS asteroseismic giants
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TOI 197
TOI 197: First TESS Seismic Host

Huber, Chaplin, Chontos+ 2019
TOI 197: First TESS Seismic Host

A HOT SATURN ORBITING AN OSCILLATING LATE SUBGIANT DISCOVERED BY TESS

Daniel Huber,1 William J. Chaplin,2,3 Ashley Chontos,1,4 Hans Kjeldsen,3,5 Jorgen Christensen-Dalsgaard,3 Timothy R. Bedding,8,3 Warrick Ball,2,3 Rafael BrahM,7,8,9 Nestor Espinoza,10 Thomas Henning,10 AndréS Jordán,8,9 Paula Sarkis,10 Emil Knudstrup,3 Simon Albrecht,3 Frank Grundahl,3,5 Mads Fredslund Anderson,3 PerE L. Pallé,11,12 Ian Crossfield,13 Benjamin Fulton,14 Andrew W. Howard,15 Howard T. Isaacson,16 Lauren M. Weiss,1 Rasmus Handberg,3 Nikkel M. Lund,3 Aldo M. Serenelli,17,18 Jakob RosTrsted Mosumgaard,3 Amalie Stokholm,3 Allyson Bieryla,19 Lars A. Buchhave,20 David W. Latham,19 Samuel N. Quinn,19 Eric Gaidos,21 Teruyuki Hirano,22,21 George R. Ricker,13 Roland K. Vanderspek,13 Sara Seager,13,23,24 Jon M. Jenkins,25 Joshua N. Winn,26 H. M. Antia,27 Thierry Appourchaux,28 Sarbani Basu,29 Keaton J. Bell,30,3 Orthman Benomar,31 Alfio Bonanno,32 Derek L. Buzasi,33 Tiago L. Campante,34,35 Z. Çelik Orhan,36 Enrique Orozco,32 Margarida S. Cunha,34 Guy R. Davies,2,3 Sebastien Deheuvels,37 Samuel K. Grundblatt,1 Amir Hasanzadeh,38 Maria Pia Di Mauro,39 Rafael A. García,40,41 Patrick Gaulme,30,3 Léo Girardi,42 Joyce A. Guzik,53 Marc Hon,44 Chen Jiang,45 Thomas Kallinger,46 Steven D. Kawaler,47 James S. Kuszlewicz,30,3 Yveline Lebreton,48,49 Tanda Li,6,3 Miles Lucas,47 Mia S. Lundkvist,5,3,50 Andrew W. Mann,51 Stéphane Mathis,49,41 Savita Mathur,11,12 Anwesh Mazumdar,52 Travis S. Metcalfe,53,54 Andrea Miglio,2,3 Mario J. P. F. Monteiro,34,35 Benoit Mosser,48 Anthony Noll,37 Benard Nsamoa,34,35 Jia Mian Joel Ong,29 S. Örtel,36 Filipe Pereira,34,35 Pritesh Ranadive,52 Clara Régulo,11,12 Thaïse S. Rodrigues,42 Ian W. Roxburgh,55 Victor Silva Aguirre,3 Barry Smalley,56 Mathew Schofield,2,3 Sérgio G. Sousa,34 Keivan G. Stassun,35,57 Dennis Stello,34,6,3 Jamie Tayar,1,59 Timothy R. White,60 Kuldeep Verma,3 Mathieu Vrard,34 M. Yildiz,36 David Baker,61 Michæl Bazot,31 Charles Beichmann,62 Christoph Bergmann,63 Lisa Bugnet,49,41 Bryson Cale,64 Roberto Carlino,65 Scott M. Cartwright,66 Jessie L. Christiansen,66 David R. Ciardi,62 Orlagh Creevey,67 Jason A. Dittmann,69 Jose Dias Do Nascimento Jr.,19,68 Vincent Van Eylen,69 Gabor Füersz,13 Jonathan Gagné,69 Peter Gao,16 Kosmas Gazelas,70 Frank Giddens,71 Oliver J. Hall,2,3 Saskia Hekker,30,3 Michael J. Ireland,60 Natasha Latoupe,64 Danny Lebrun,64 Alan M. Levine,13 William Matzko,64 Eva Natsinsky,61 Emma Page,61 Peter Plavchan,64 Masoud Mansouri-Samani,65 Sean McCauliff,72 Susan E. Mullally,73 Brendan Orenstein,60 Aylin Garcia Soto,23 Martin Paegert,19 Jennifer L. Van Saders,1 Chloë Schnaible,61 David R. Soderblom,73 Róbert Szabó,74,75 Angelle Tanner,76 C. G. Tinney,63 Johanna Teske,69,77,59 Alexandra Thomas,2,3 Regner Trampedach,3,5 Duncan Wright,78 Thomas T. Yuan,61 and Farzaneh Zohrabi70

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TOI 197: First TESS Seismic Host

Huber, Chaplin, Chontos+ 2019

\[ \log g = 3.584 \pm 0.010 \text{ cgs} \]
\[ R_* = 2.943 \pm 0.064 \text{ R}_\odot \]
\[ M_* = 1.212 \pm 0.074 \text{ M}_\odot \]
\[ t = 4.9 \pm 1.1 \text{ Gyr} \]
TOI 197: First TESS Seismic Host
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\[ \sigma_{\rho_p}/\rho_p = 14.8\% \]
TOI 197: First TESS Seismic Host

\[ \frac{\sigma_{P_p}}{\rho_p} < 50\% \]

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TOI 197: First TESS Seismic Host

Typical asteroseismic systems we expect to find with TESS

\[
\frac{\sigma_{p_p}}{\rho_p} < 50\%
\]

\[
\frac{\sigma_{p_p}}{\rho_p} = 14.8\%
\]
TOI 197: First TESS Seismic Host

Typical asteroseismic systems we expect to find with TESS

Sub-Saturn to Saturn/Jupiter Transition

\[ \sigma_{\rho_p}/\rho_p < 50\% \]
77 known asteroseismic hosts (114 known planets)
+ = 26 new asteroseismic hosts (34 new planets)
+ = many more to come!
Extra Slides
Kepler Planet Radius Uncertainties
Kepler Planet Radius Uncertainties

![Graph showing PDF (%) against \( \sigma_{R_p}/R_p \)]
Kepler Planet Radius Uncertainties

The diagram shows the distribution of planet radius uncertainties as a function of $\sigma_{R_p}/R_p$. The different lines represent data from Kepler/K2, CKS, and Gaia, with distinct colors for each dataset. The x-axis represents the ratio of the planet's radius uncertainty to its observed radius, while the y-axis represents the probability density function (PDF) in percentage.
Kepler Planet Radius Uncertainties
Kepler Planet Radius Uncertainties

We need more accurate and precise planet radii and ages to discern theories of planet formation and migration!
K2-93: A Benchmark K2 System

Lund, Knudstrup, Silva Aguirre, Basu, Chontos+ 2019 (submitted)
K2-93: A Benchmark K2 System

Lund, Knudstrup, Silva Aguirre, Basu, Chontos+ 2019 (submitted)
K2-93: A Benchmark K2 System

Age = 2.07 ± 0.32 Gyr

Lund, Knudstrup, Silva Aguirre, Basu, Chontos+ 2019 (submitted)
TOI 257: New TESS Seismic Host

\( \nu_{\text{max}} \sim 900 \ \mu\text{Hz} \ (3346) \)

\( R_\star \sim 2 \ R_\odot \)

\( R_p \sim 8 \ R_E \)
TOI 257: New TESS Seismic Host

![Graph showing power density vs frequency for different filter settings. The graph displays two plots: one for power density in $(ppm^2/\mu Hz)$ on a logarithmic scale, and another with the same scale in $ppm^2/\mu Hz$. The plots compare power density with and without filters at 1.0 $\mu$Hz and 2.5 $\mu$Hz. Additional data points indicate ACF and $\Delta \nu$.](image)
Solar-like Oscillators

![Graph showing white noise vs TESS magnitude with observed, definite detection, and possible detection markers.]
Solar-like Oscillators

![Graph showing white noise and detection fraction vs. TESS magnitude.

On the y-axis:
- White noise in a log scale ranging from $10^1$ to $10^5$.

On the x-axis:
- TESS magnitude ranging from 4 to 10.

Legend:
- Observed data points (gray).
- Definite detection (red).
- Possible detection (blue).

Below the graph:
- Detection fraction with $P_{det \_vary} > 0.99$.