Synergy between asteroseismology and exoplanet observations

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Overview

1. Current key synergies
   - Precise characterization of host stars
   - Dynamical architectures of planetary systems

2. Future synergies
   - Giant planets orbiting evolved stars
   - Densities of sub-Neptunes

3. TESS asteroseismology of exoplanet-host stars
   - Overview of TESS
   - Asteroseismic yield of exoplanet-host stars
A revolution in cool-star asteroseismology

- Solar-like oscillations excited by turbulent convection
- Cool-star asteroseismology with *Kepler*:
  - Several hundred solar-type stars
  - Over 10,000 red giants
- $>100$ KOIs with detected solar-like oscillations

Motivation

- Transit observations only provide estimate of planet-to-star radius ratio \( R_p \propto R_* \)
- RVs + transits used to estimate planetary masses \( M_p \propto M_*^{2/3} \)
- From TTVs in multi-planet systems one instead has \( M_p \propto M_* \)
- Stellar ages used to assess dynamical stability and relative chronology
Fundamental properties of KOIs

- 33 KOIs with high S/N in the oscillations
- Oscillation frequencies matched to grids of evolutionary models
- 1.2% precision in $R$, 3.3% in $M$ and 14% in age
- Precision commensurate with that expected from *PLATO* asteroseismology

Metal-poor, Sun-like star from Galactic thick disk
Hosts five sub-Earth-size planets
All planets orbit in less than 10 days
Precise age of $11.2 \pm 1.0$ Gyr from asteroseismology

Detection of a ‘hot-super-Earth desert’

Lundkvist et al. (2016, Nature Commun., 7, 11201)
Revisiting the retired A star controversy

- RV surveys point to increasing occurrence of giant planets with stellar mass
- Surveys rely on retired A stars for sample of intermediate-mass stars
- Validity of relation subject to mass accuracy for evolved stars
- Figure shows asteroseismic constraints (from K2) on stellar models of HD 212771

Obliquities

- Stellar inclination from rotationally split modes
- Independent of planet size
- Multi-transiting systems: tests of primordial star-disk alignment hypothesis
- Impact on hot-Jupiter formation theories

Huber et al. (2013, Science, 342, 331)
Eccentricities

- Asterodensity profiling:
  \[
  \frac{\rho_*}{\rho_{\text{transit}}} = \frac{(1-e^2)^{3/2}}{(1+e \sin \omega)^3}
  \]

- Transits used to constrain eccentricity without RVs (given independent \( \rho_* \))

Current key synergies

**TESS**
- Asteroseismology of exoplanet-host stars
- Giant planets orbiting evolved stars
- Densities of sub-Neptunes

**Future synergies**
- **TESS**, **PLATO**, and **WFIRST** to continue asteroseismic revolution
- Dedicated ground-based support (e.g., SONG)
- Number of solar-like oscillators will ascend to a few million
- >90% will be evolved stars
- **PLATO** will contribute the most detections for solar-type stars (80,000)

Figure courtesy of Dan Huber
*(PLATO red-giant yield not included!)*
Insight into occurrence and structure of giant planets

- *Kepler/K2* discovery of several giant planets around oscillating low-luminosity RGB stars
- *TESS* will allow conducting populational study
- Key unsolved questions:
  - Role of incident flux on hot-Jupiter inflation
  - Giant-planet occurrence as function of stellar mass and evolution
  - Correlation between stellar metallicity and giant-planet occurrence

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Probing transition from rocky to gaseous

- Composition models sensitively dependent on radius
- *PLATO* asteroseismology provides unique opportunity to precisely study composition diversity
- *Gaia* parallaxes alone will not reach comparable precision
- Kepler-10, Kepler-36 and Kepler-454 (see figure) have radius and mass from asteroseismology

Gettel et al. (2016, ApJ, 816, 95) (only masses measured to better than 20%)
An all-sky survey for transiting planets

- Stars observed for at least 27 days
- 2-min cadence (∼2 × 10^5 pre-selected FGKM dwarfs)
- 30-min cadence (full-frame images or FFIs)

https://tess.gsfc.nasa.gov
There are three separate contributions to this yield:

- *TESS* target hosts (2-min cadence)
- *TESS* FFI hosts (30-min cadence)
- Previously known hosts (transiting or not)
Asteroseismic yield of *TESS* target hosts


\[(\Delta t = 2 \text{ min}; \sigma_{\text{sys}} = 0 \text{ ppm hr}^{1/2})\]

Asteroseismic yield of \textit{TESS} FFI hosts


\[ (\Delta t = 30 \text{ min}; \sigma_{\text{sys}} = 0 \text{ ppm hr}^{1/2}) \]

Asteroseismic yield of known hosts and link to CHEOPS

\[ \Delta t = 2 \text{ min}; \sigma_{\text{sys}} = 0 \text{ ppm hr}^{1/2} \]

Current key synergies
Future synergies

TESS asteroseismology of exoplanet-host stars

Book release

Asteroseismology and Exoplanets: Listening to the Stars and Searching for New Worlds
IVth Azores International Advanced School in Space Sciences

Editors: Campante, Tiago, Santos, Nuno, Monteiro, Mario (Eds.)

Compiles the contributions from 18 invited lecturers who are widely recognized as leaders in their respective fields of research

https://arxiv.org/abs/1709.00645