Asteroseismology of Exoplanet Host Stars from the *Kepler* /K2 missions

Mia Sloth Lundkvist

Stellar Astrophysics Centre, Aarhus University, Denmark
Asteroseismology and exoplanets

Kepler → astero

\(\bar{\rho}_*, R_*\)

\(M_*, \log g, \text{age, } i\)
Asteroseismology and exoplanets

Kepler

\[ \bar{\rho}_*, R_* \]
\[ M_*, \log g, \]
\[ \text{age, } i \]
\[ P, \left( \frac{R}{R_*} \right) \]

Borucki et al. (2009)
Asteroseismology and exoplanets

Kepler

\( \bar{\rho}_*, R_* \)

\( M_*, \log g, \) age, \( i \)

\( T_{\text{eff}} \) \( \rightarrow \) \( R \) and more

\( P, \left( \frac{R}{R_*} \right) \)

Borucki et al. (2009)
Asteroseismology

Lundkvist et al. (2018)

Asteroseismology of Exoplanet Host Stars
Asteroseismology

Jørgen Christensen-Dalsgaard

Lundkvist et al. (2018)
Asteroseismology

\[ \nu_{\text{max}} \propto \frac{g}{\sqrt{T_{\text{eff}}}} \]

\[ \Delta \nu \propto \sqrt{\bar{\rho}} \]
Seismic host stars

![Graph showing surface gravity vs. effective temperature for pre-Kepler/K2 and post-Kepler/K2 stars.](image)

- **Seismic host stars**
- **Graph** showing surface gravity vs. effective temperature for pre-Kepler/K2 and post-Kepler/K2 stars.

Asteroseismology of Exoplanet Host Stars
Seismic host stars, including KOI-4

![Plot showing surface gravity vs. effective temperature for pre-Kepler/K2 and post-Kepler/K2 stars.](image)
Kepler/K2 confirmed planets with seismic hosts
Kepler/K2 confirmed planets
Planetary radius uncertainty

![Graph showing the probability density of relative radius uncertainty for Kepler/K2 data.](image)
Planetary radius uncertainty

![Graph showing probability density vs. relative radius uncertainty for Kepler/K2 and CKS methods.]
Planetary radius uncertainty

![Graph showing probability density of relative radius uncertainty for different methods: Kepler/K2, CKS, and Gaia DR2.](image)

- Kepler/K2
- CKS
- Gaia DR2
Planetary radius uncertainty

![Graph showing probability density distribution of relative radius uncertainty for different methods: Kepler/K2, CKS, Gaia DR2, Seismic.](image)
Individual systems

Kepler-444

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-444

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-444

Tiago Campante/Peter Devine

Adapted from Campante et al. (2015)

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-10b

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-10b

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-10

NASA/Kepler Mission/Dana Berry

Fogtmann-Schulz et al. (2014)

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-10

Silva Aguirre et al. (2015)

NASA/Kepler Mission/Dana Berry

Fogtmann-Schulz et al. (2014)

Asteroseismology of Exoplanet Host Stars
Individual systems

Kepler-10

Silva Aguirre et al. (2015)

NASA/Kepler Mission/Dana Berry

Fogtmann-Schulz et al. (2014)

Asteroseismology of Exoplanet Host Stars
Obliquity of exoplanet systems
Ensemble studies

Obliquity of exoplanet systems

Asteroseismology of Exoplanet Host Stars
Obliquity of exoplanet systems

Obliquity: \( \cos \psi = \sin i_p \cos \lambda \sin i_* + \cos i_p \cos i_* \)

- \( i_p \): angle between line-of-sight and normal to orbital plane of exoplanet.
- \( i_* \): stellar inclination angle wrt. line-of-sight.
- \( \lambda \): sky-projected obliquity.

Lund et al. (2014)
Obliquity of exoplanet systems, stellar inclination

Credit: Andrea Miglio
Ensemble studies

Constraints on the obliquity

Credit: Simon Albrecht, updated from Albrecht et al. (2013)
Eccentricities
Ensemble studies

Eccentricities

Asteroseismology of Exoplanet Host Stars
Ensemble studies

Eccentricities

\[
\frac{\bar{\rho}_*}{\bar{\rho}_{*, tr}} = \frac{(1 - e^2)^{3/2}}{(1 + e \sin \omega)^3}
\]

Systems with single transiting planet

Systems with multiple transiting planets

Van Eylen and Albrecht (2015) and Van Eylen et al. (2019)
Ensemble studies

Evaporation

Asteroseismology of Exoplanet Host Stars
Ensemble studies

Evaporation desert

Asteroseismology of Exoplanet Host Stars
Ensemble studies

Evaporation desert

![Graph showing the relationship between period (days) and radius (Earth radii) for exoplanet host stars. The graph includes data from Kepler, K2, and Seismic sources.](image)
Ensemble studies

Evaporation valley

![Graph showing the relationship between period and radius for exoplanet host stars. The graph includes data from Kepler, K2, and Seismic observations, with different markers for each dataset.](image)
Ensemble studies

Evaporation valley

Asteroseismology of Exoplanet Host Stars
Ensemble studies

Evaporation valley

Asteroseismology of Exoplanet Host Stars
Kepler and K2 have resulted in the detection of solar-like oscillations in close to 90 exoplanet host stars. The planets orbiting these stars have very well-known planetary parameters.

Exploiting the sample of “seismic” planets have, for instance, led to results concerning obliquities, eccentricities and evaporation.

Thank you Kepler.