Stellar Oscillations and Exo-planets

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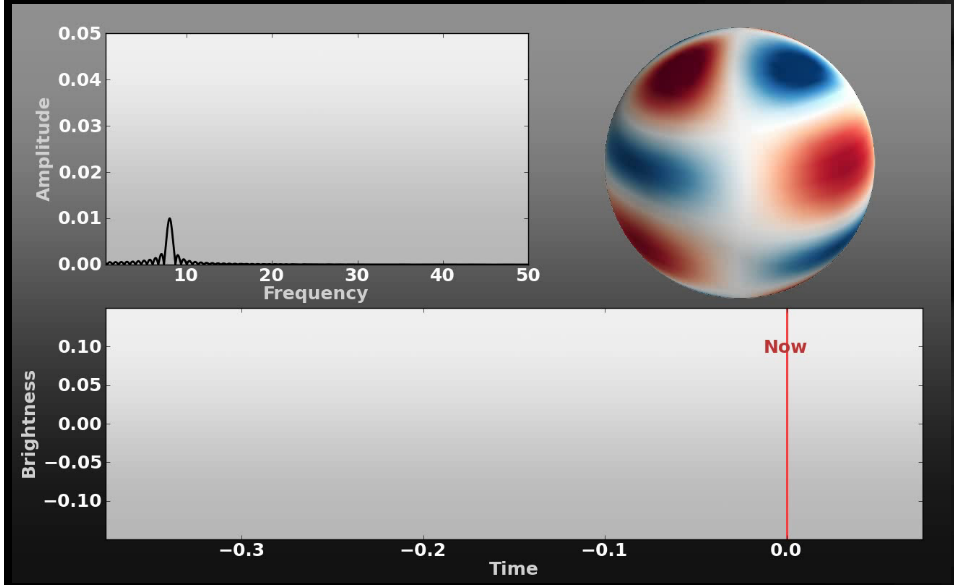
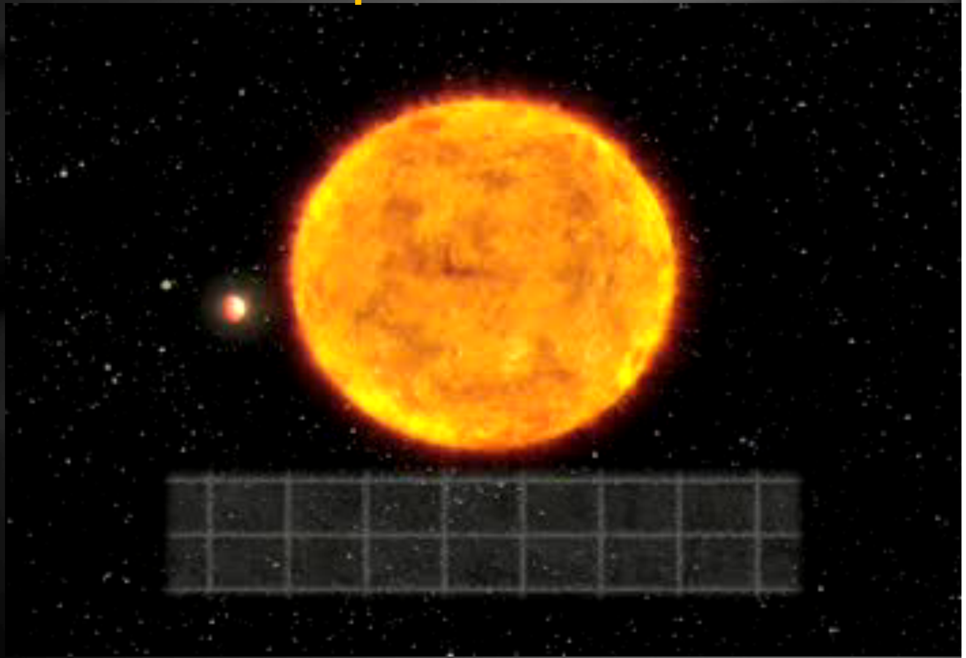
"Asteroseismology is very important for transiting exo-planet surveys."

Pulsating star - Asteroseismology



Exo-planet transit



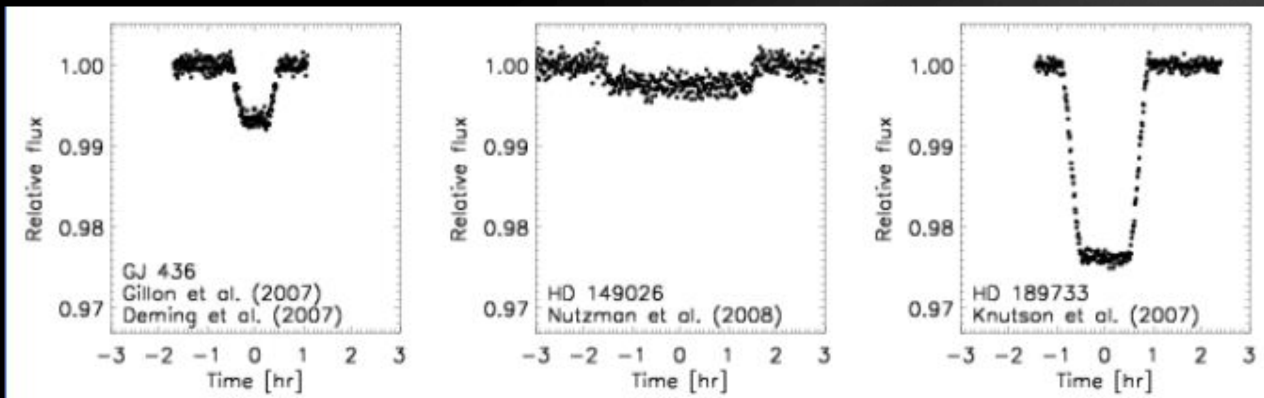
Pieter Degroote, KU Leuven

ESO/L. Calçada

Exo-planet transit surveys

- Observe a part of the sky **continuously** for a "long" time (2y for our system)
- Analyse the light curves; exclude false positives (eclipsing binaries,...)
- Determine the orbital period of planet around star
- Determine relative **Mass** and **Radius** of the **Star** and **Planet.**

➔ The transit technique gives access to the ratio of planet to star radii, so that the planet sizes cannot be determined if the star radii are not perfectly known.

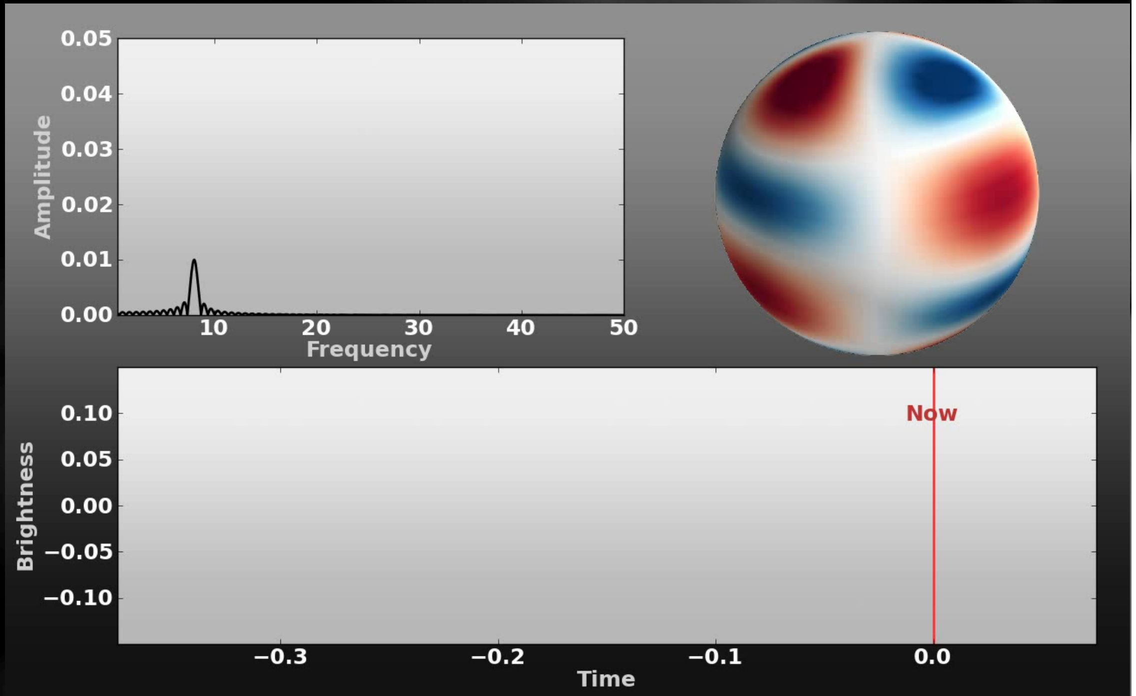


Transit light curves based on Spitzer.
J. N. Winn, arXiv: 0807.4929

Asteroseismology

= study of pulsating stars = study of stellar oscillations

- Observe a pulsating star **continuously** for a "long" time; record light curve
- Perform a **Fourier transform** of the light curve
- Determine the pulsation frequencies
- Match these observations with models



Pieter Degroote, KU Leuven

→ This reveals the internal structure of the star.

Why combine Asteroseismology with Transits?

- With Asteroseismology the Mass and Radius of the star can be determined.
- Together with transit information, the Mass and Radius of the planet can be determined.

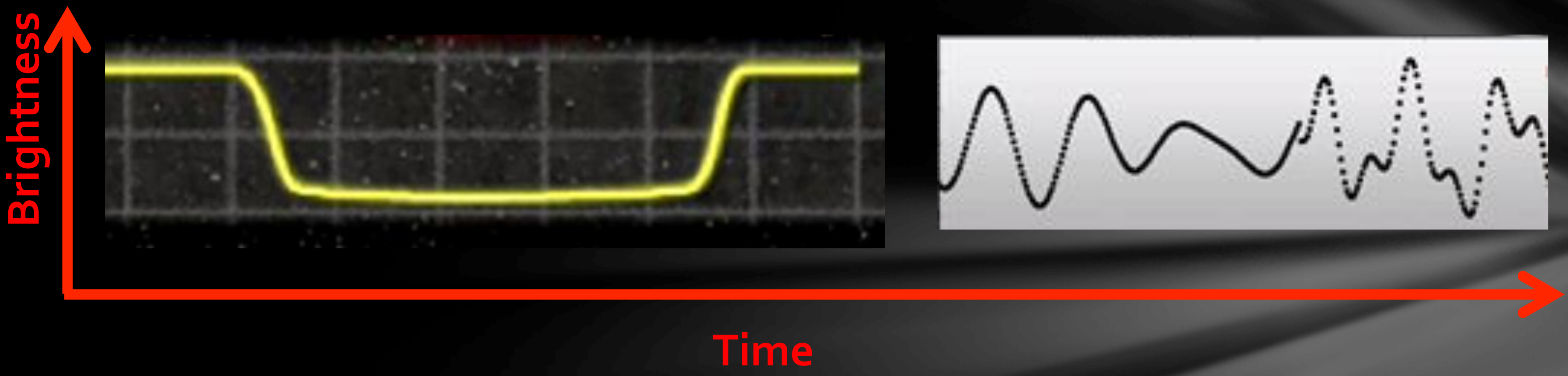
Transit observations alone only lead to relative radii.

- Additionally, the Age of the star and consequently the age of planet can be determined.

This works well for solar-like stars or stars with pronounced outer convection layers (SPBs, b Ceph,..*).

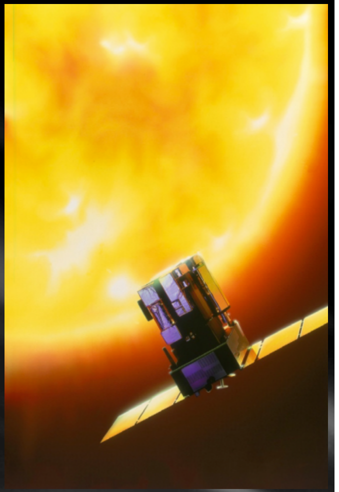
** Note that these are probably too short lived to form planets.*

Combining Transits AND Asteroseismology

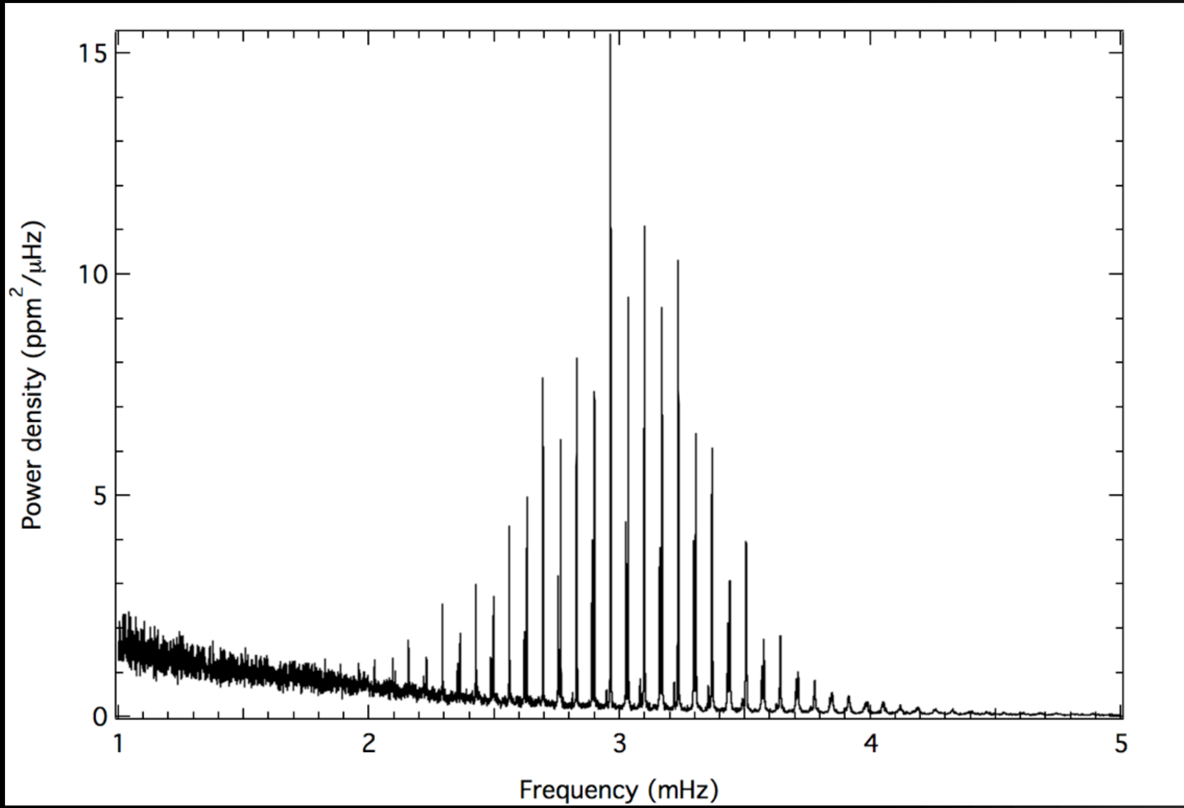


- One data set
- Remove the signal of the transiting planet
- Apply Fourier Transform on the remaining Light Curve
- Perform the frequency analysis
- **Constrain Mass and Radius of the star/planet SIMULTANEOUSLY** with high precision.

The solar example - Helioseismology



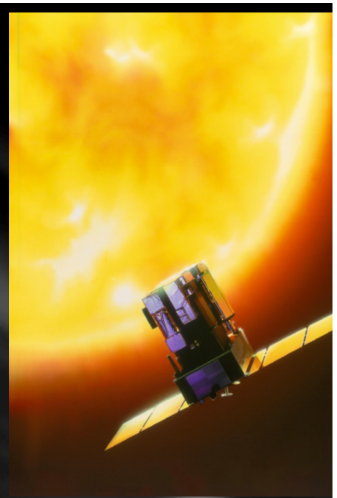
- The Sun exhibits 5-min oscillations with a relatively simple signal – "solar-like oscillations".
- Apply asteroseismological techniques:



zoom

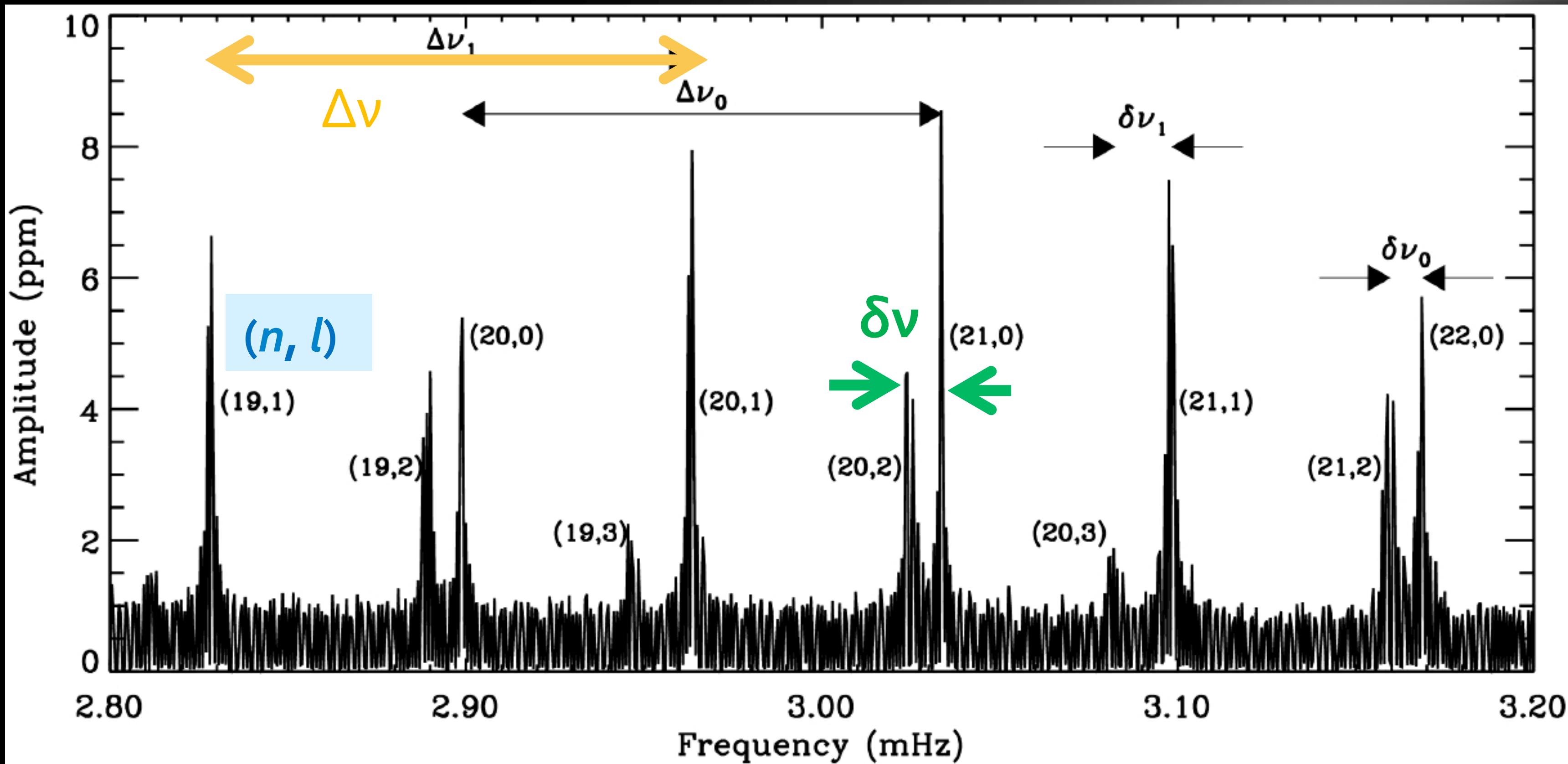
Sun@SOHO/VIRGO

Solar like oscillations - Helioseismology

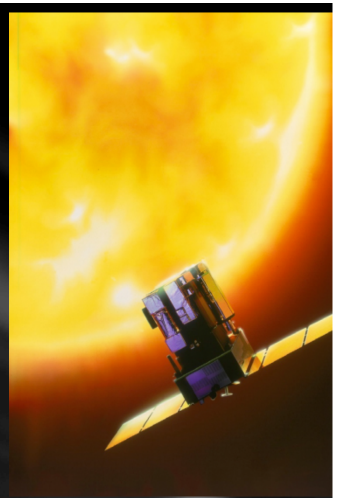


- **Large separation: Δν**
- **Small separation: δν**

"Separation" between pulsation frequencies; n : order l: degree



Solar like oscillations - Helioseismology

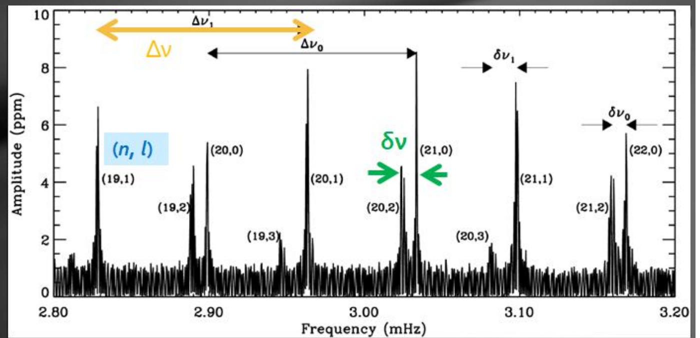


- **Large separation** – mean density:

$$\Delta\nu \simeq \left(2\int_0^R dr/c\right)^{-1} \propto \sqrt{\bar{\rho}}$$ → $\Delta\nu \propto \sqrt{M/R^3}$

- **Small separation** – core (e.g. age):

$$\delta\nu \simeq \Delta\nu \int_0^R \frac{dc}{dr}\frac{dr}{r}$$



➔ Uncertainty in Radius ≤ 2%

➔ Uncertainty in Mass ~10%

➔ Uncertainty in Age ~10%

Solar like oscillations - Helioseismology

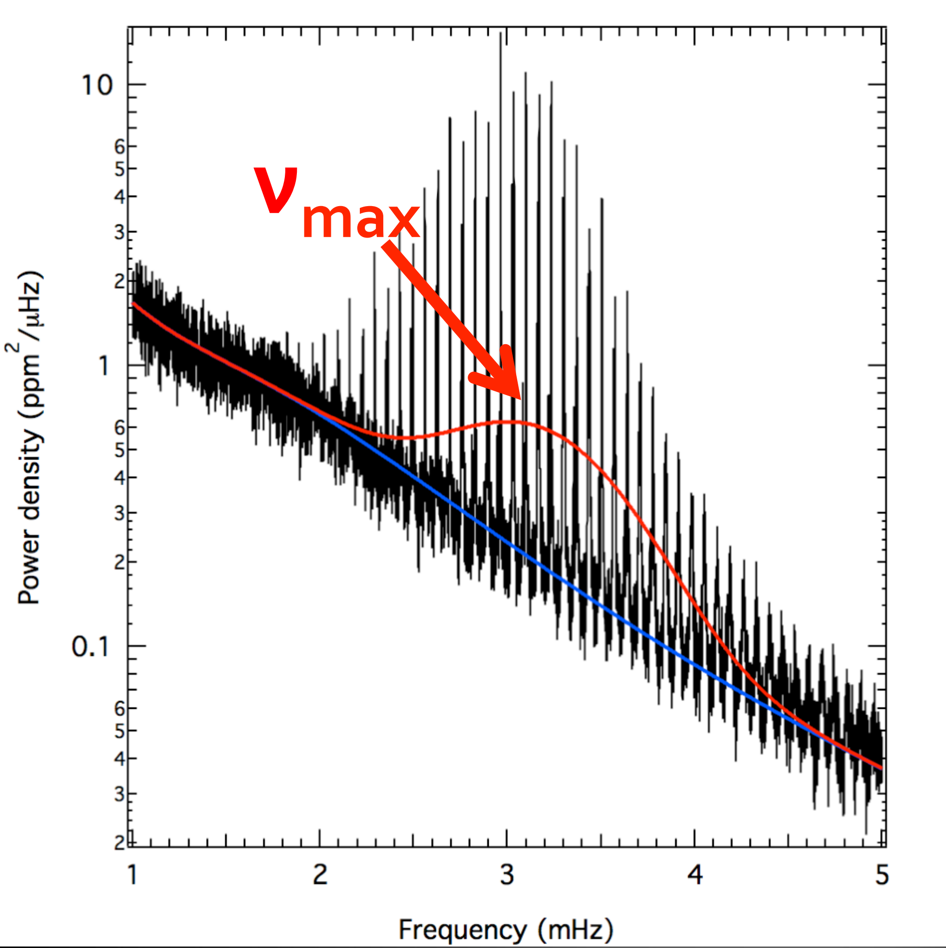
From Brown et al. or Kjeldsen & Bedding:

seismic scaling relation:

$$\nu_{max} \propto g\sqrt{T_{eff}} \propto \frac{M}{R^2\sqrt{T_{eff}}}$$

$$\Delta\nu \propto \sqrt{\rho} \propto \sqrt{\frac{M}{R^3}}$$

ν_{max}, $\Delta\nu$, (T_{eff}) ⇒ R, M, L



Summary

Transit alone

→ relative radii and masses of the star and planet

Combined with Asteroseismology

→ interior structure of parent star

→ density of the star

→ absolute stellar mass and radius → absolute planetary radius and mass

→ accurate age of the planetary system

Questions

Why do we need to find even more exo-planets (>1000)?

- Answer to "how typical is our Solar System?"
- Study the full range of planet masses, down to Earth sized and smaller.
- Need to include intermediate and large orbital distances.

But this has already been done with CoRot!!

- CoRot had two "Eyes", one for transit detection, one for asteroseismology.

But this has already been done with Kepler!!

- The Kepler targets are rather faint and simultaneous asteroseismology can best be done on brighter targets.