Asteroseismology

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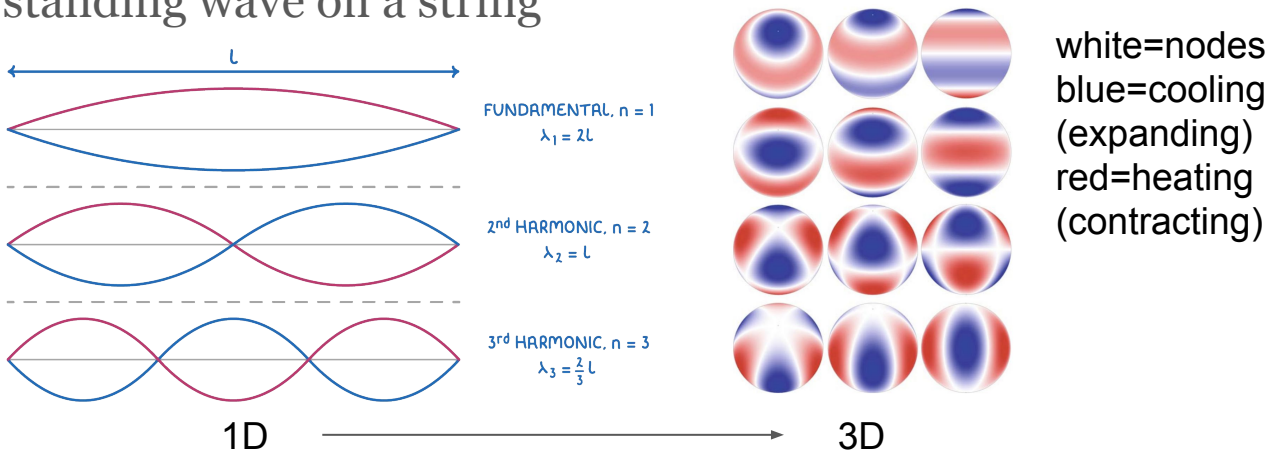
What is Asteroseismology

- Seismology: earthquakes and seismic waves that move through and around the Earth
- Asteroseismology: study of oscillations in stars
  - “Music of the stars”
- Caused by trapped sound wave or gravity wave inside stars
- Similar to standing wave on a string



Uses and Missions

- One of the few ways to see inside a star
- Can calculate star's mass and radius
  - Important for finding exoplanets
- Track composition of stars which tells you age
- Missions
  - Kepler, TESS, CoRoT
  - Global Oscillation Network Group (GONG): groundbased, studies asteroseismology of the sun
  - ESA mission PLATO (PLAnetary Transits and Oscillations of stars): upcoming mission will monitor variations in stars' brightness to characterize host stars of exoplanets

What Cause Oscillations

- Kappa Mechanism
  - H and He blocks radiation
  - This causing gas to heat up and pressure to increase which makes the star expand
  - H and He ionize which decreases opacity so more radiation flows through
  - Gas cools down again and star contracts
- Stochastic Driving
  - Caused by acoustic noise from turbulent motion in convection zone
  - Similar to ringing bell

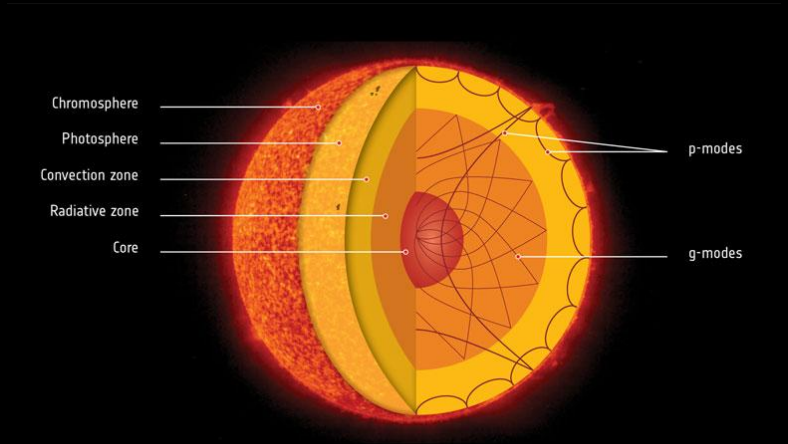
Modes

P-modes (pressure/acoustic modes)

- pressure is restoring force
- usually in outer part of stars
- equally spaced frequency

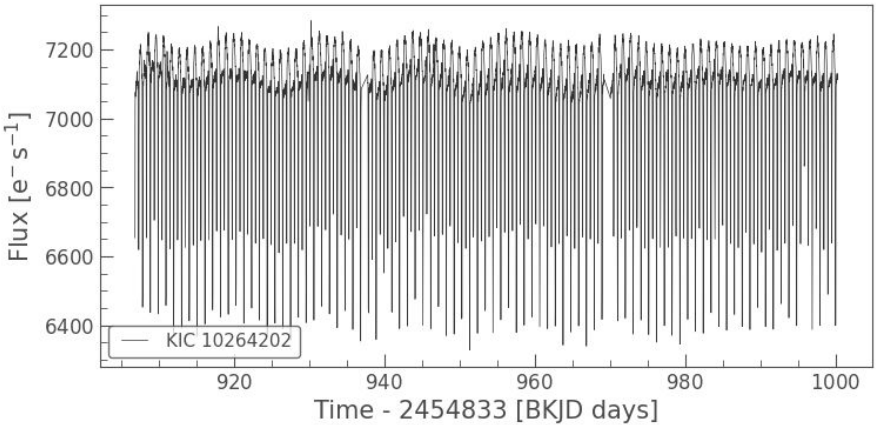
G-modes (gravity modes)

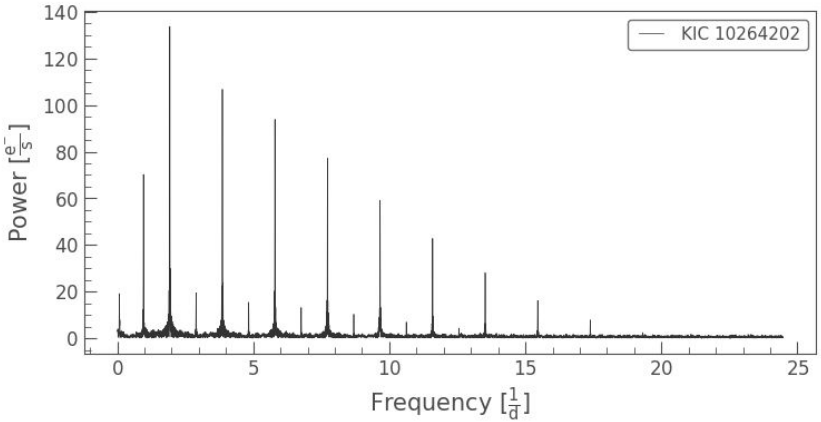
- buoyancy/gravity is restoring force
- usually in deep interior
- equally spaced periods



Fourier Transforms

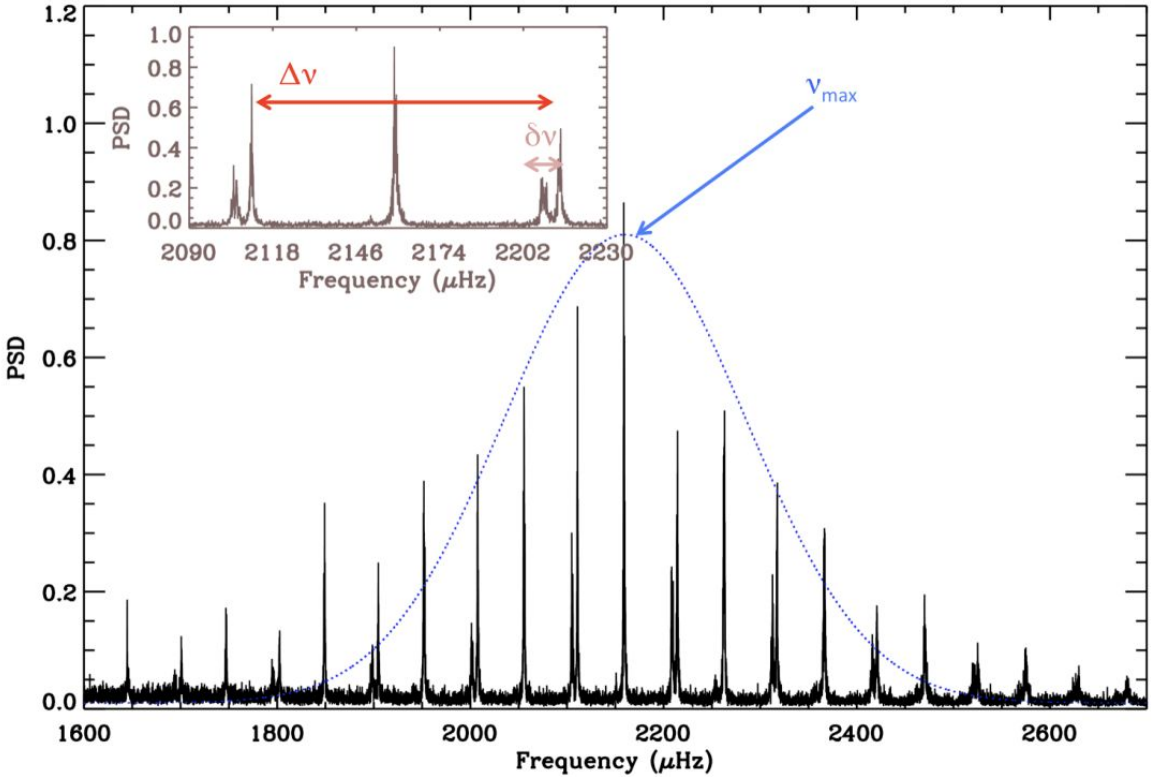
- Decomposes a signal like brightness over time into the individual frequencies (or sine and cosine waves) that make it up





Light Curve → Fourier transform → Power Spectra

Finding Mass and Radius



$\Delta\nu$: large frequency separation

ν_{max}: frequency of maximum oscillation power

$$\frac{R}{R_\odot} = \left(\frac{\nu_{\max}}{\nu_{\rm ref}}\right)\left(\frac{\Delta\nu}{\Delta\nu_{\rm ref}}\right)^{-2}\left(\frac{T_{\rm eff}}{T_\odot}\right)^{1/2},$$

$$\frac{M}{M_\odot} = \left(\frac{\nu_{\max}}{\nu_{\rm ref}}\right)^{3}\left(\frac{\Delta\nu}{\Delta\nu_{\rm ref}}\right)^{-4}\left(\frac{T_{\rm eff}}{T_\odot}\right)^{3/2},$$

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