Double-Pulsator 'Hidden' Binaries: New Targets for Studying Classical and Solar-like Oscillations

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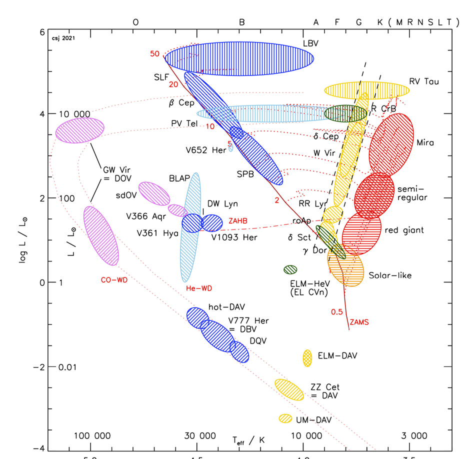
The power of combining asteroseismology and orbital dynamics

Space-based missions revolutionized asteroseismology

Unprecedented photometric precisions and frequency resolution led to an explosion in the number of known pulsators across the H-R diagram

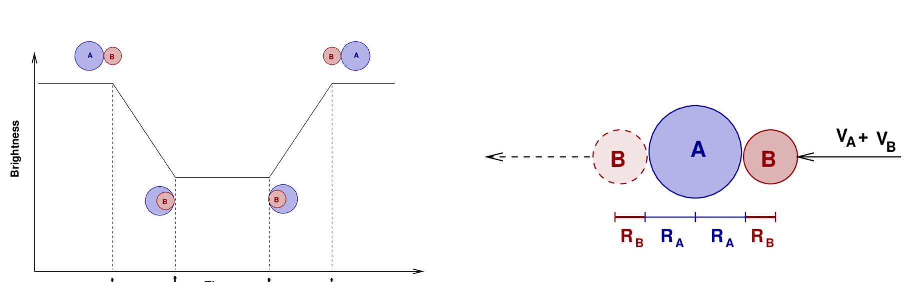
- Internal rotation profiles for thousands of stars for the first time
- Mass/radius for thousands of stars informing galactic archeology
- Observational constraints on convective core overshoot and mixing, updates to pulsation excitation mechanisms and pulsator classification, numerous other advancements!



Credit: Kurtz (2022)

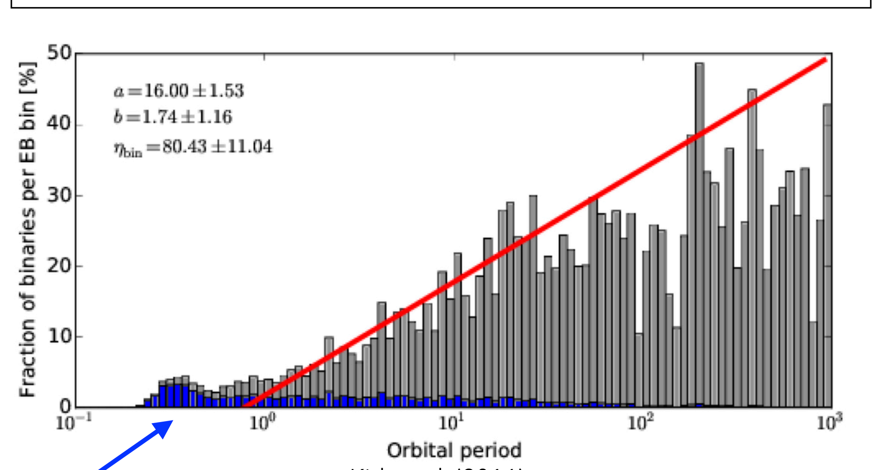
Binary star systems as testbeds for refining stellar models

- Constraints of equal age and initial composition
- Kepler's 3rd law allows for derivation of precise stellar and orbital parameters
- Studying pulsators in binaries has led to calibration of asteroseismic scaling relations and comparison of observed versus predicted pulsation modes



Michael Richmond

The Kepler sample of pulsating binaries



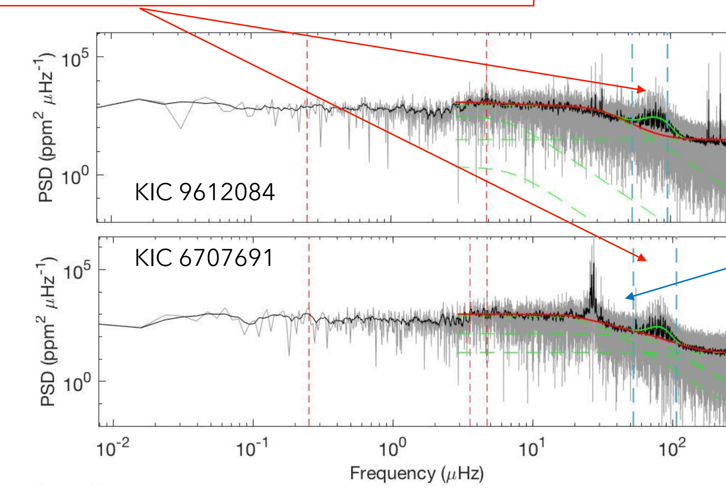
Kirk et al. (2016)

- Kepler sample is limited in number and biased towards less evolved stars with shorter orbital periods
- Spectroscopic observations in combination with Kepler/TESS data can increase the sample of pulsing binaries (illustrated by Beck et al. (2022))

Searching for 'Hidden' Binaries in the *Kepler* Archive

Identifying 'Hidden' Pulsating Binary Targets

Solar-like oscillations = surface turbulent convection
Characterized by acoustic mode bump of regularly spaced modes



21 Kepler red giants displaying signatures of solar-like and classical oscillations

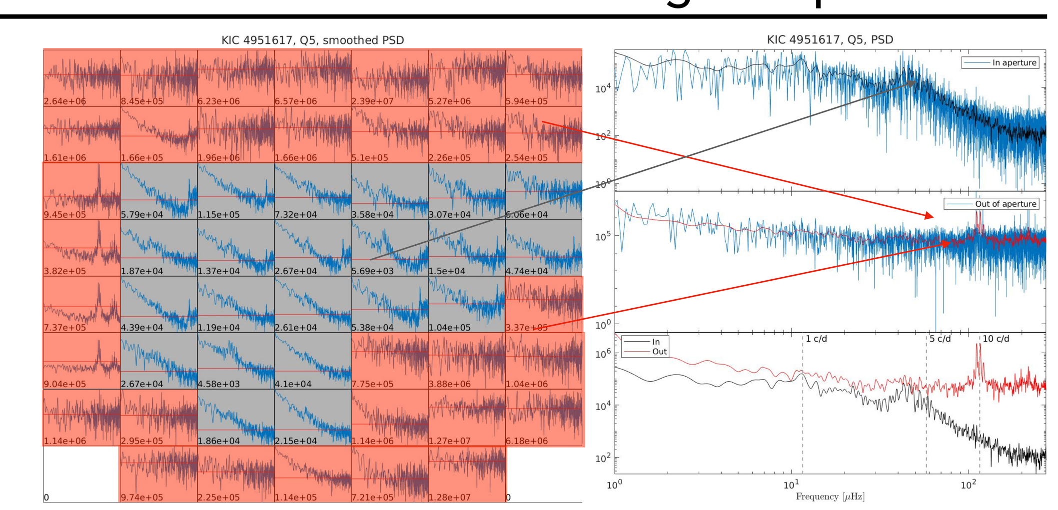
Classical oscillations = heat engine driven by opacity changes
δ Scuti / γ Doradus are A/F type classical pulsators
Potentially 100s of excited modes, higher amplitude

Eliminating false positives

Power spectra are FT of stitched light curve

Objects can fall in/out of aperture leading to blended signal

Inspect single quarter of data by pixel to check if one set of oscillations falls outside of aperture



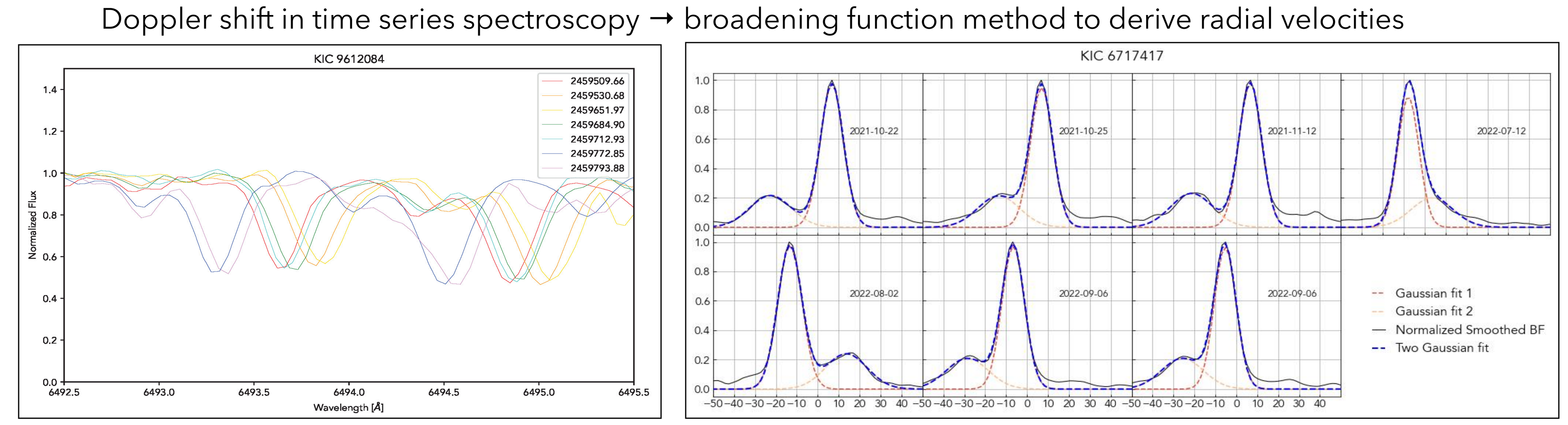
Discovering pulsating binaries through spectroscopic observations

Apache Point Observatory

Apache Point Observatory 3.5-meter telescope

ARC Echelle Spectrograph (ARCES) = high resolution, visible spectrograph

Doppler shift in time series spectroscopy → broadening function method to derive radial velocities

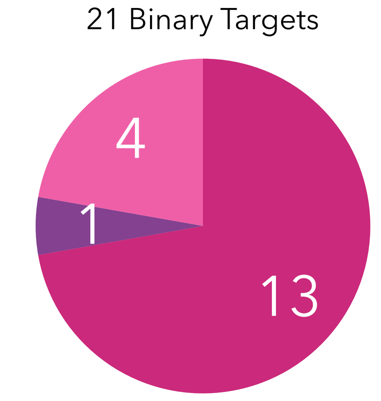


Current Results

4 targets likely blends, single stars, or require more observations

13 targets classified as spectroscopic binary

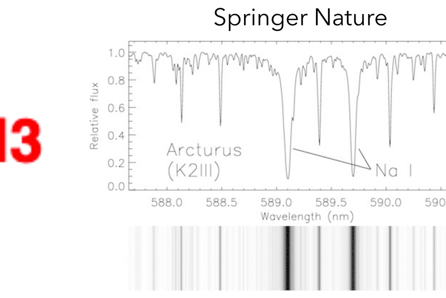
1 target classified as double-lined spectroscopic binary



Dynamical modeling to constrain stellar parameters and other future work

Next Steps:

fd3



- Spectral disentangling and spectral line analysis
- Asteroseismic analysis of solar-like oscillations

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

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

- Dynamical modeling of binary star system to constrain stella orbital parameters
- Stellar evolution/oscillation modeling of binary components

PHOEBE

MESA

GYRE

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