What can transit timing variations tell us about stellar structure?

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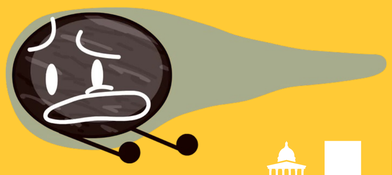
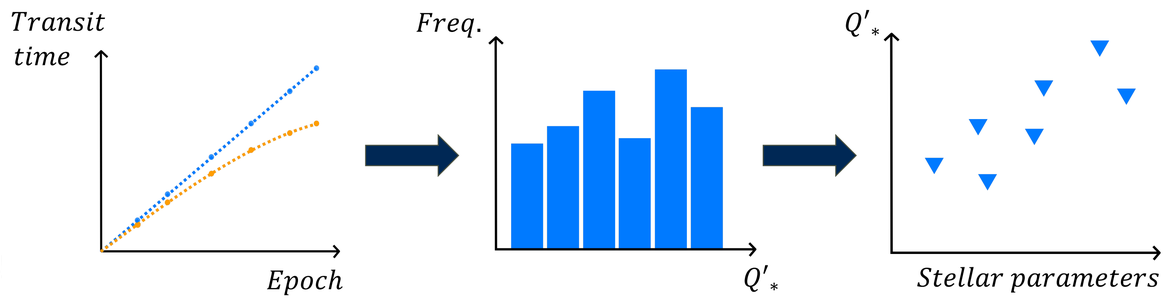
WASP 12a [1]



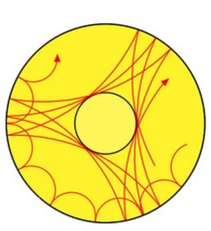
WASP 12b [2]

Summary

- Measuring tidal decay for a large ensemble of stars provides new opportunities for studying stellar structure.
- Initial results suggest a relationship exists between convective envelope mass and the size and lag of a star's tidal bulge.
- Understanding these relationships better could help understand the structure of stars!



1. What tools do we have for understanding stellar structure?



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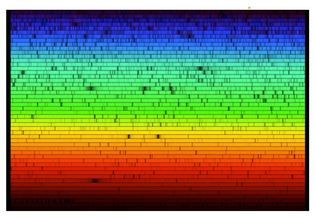
Asteroseismology



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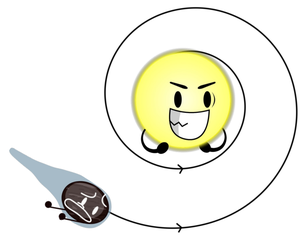
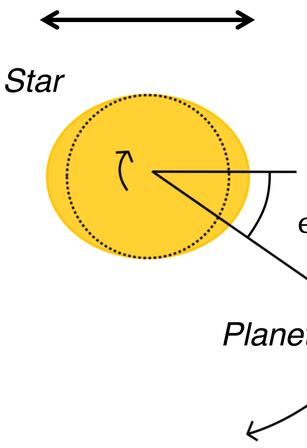
Spectroscopy



Tidal decay?

2. What is tidal decay?



i. Tidal bulge is created by the planet's gravitational potential.

ii. Bulge lags the planet because a viscous fluid cannot change shape instantly.

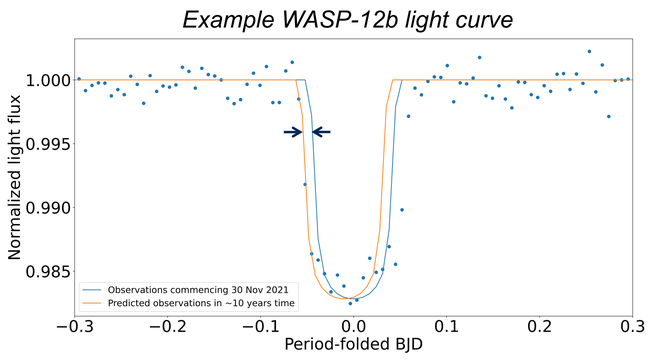
iii. Resulting potential gradient creates a torque that slows the planet down.

Rate of decay of semi-major axis $\dot{a} \propto \frac{1}{Q'_*}$ *Stellar tidal dissipation factor*

Tidal decay is a consequence of **stellar composition and structure**. Decay rates could tell you something about what the star is made of!

3. How can we measure tidal decay?

Example WASP-12b light curve



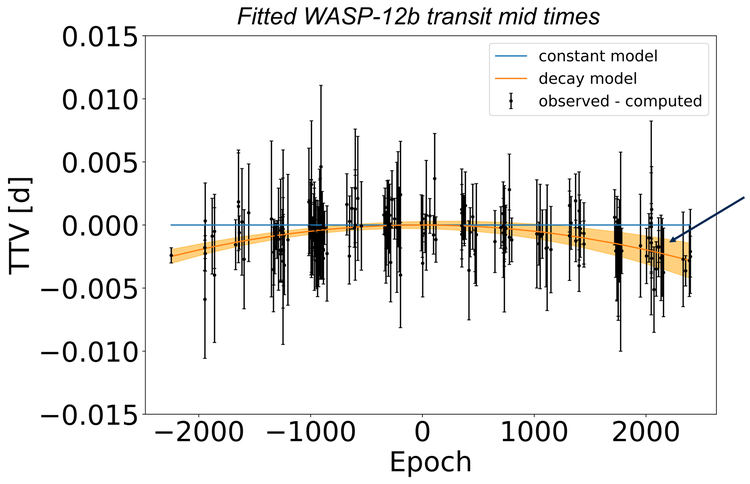
1. Fit light curves to photometry measurements and estimate the transit mid-time.

   Note that the observable change in period is relatively small compared to uncertainty in the mid times: this is a low signal-to-noise problem!

2. Fit a Bayesian multivariate regression model to transit mid times to identify systematically non-zero transit timing variations:

Fitted WASP-12b transit mid times

A curve fits better than a straight line!



3σ posterior model error

4. Can we measure tidal decay for many planets?

Yes, we just need lots of data!

Professional

Kepler — A Search for Terrestrial Planets

MIT TESS

SuperWASP

+

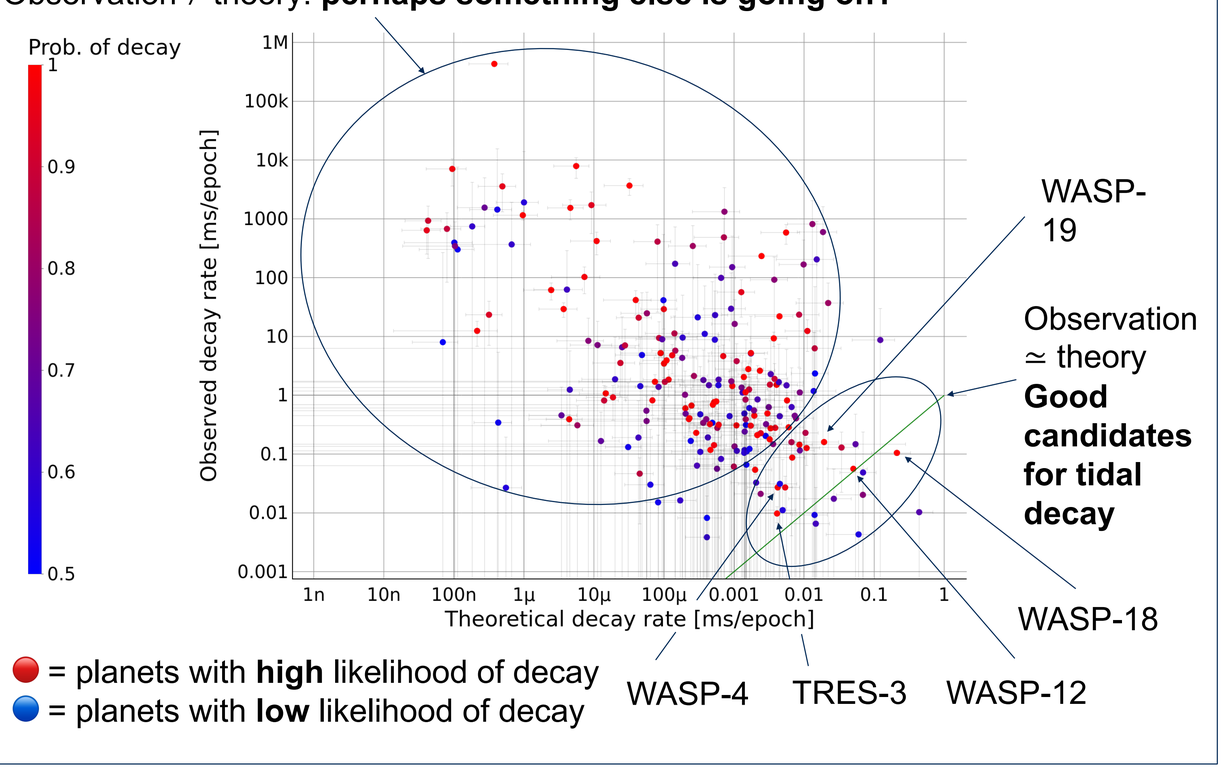
Citizen-science

exoClock

ETD — Exoplanet Transit Database — http://var.astro.cz/ETD

5. Which of these are good candidates for tidal decay?

Observation ≠ theory: **perhaps something else is going on?**



= planets with **high** likelihood of decay

= planets with **low** likelihood of decay

6. How are stellar tidal dissipation factors distributed and what can this tell us about stellar structure?

= 1.75 $M_\odot$ Observed tidal dissipation factors along the main sequence

Lower tidal dissipation factors as we go down the main sequence?

Red dwarfs have convective zones that are an increasingly large proportion of their mass…

Tidal dissipation factor appears to decrease as the mass fraction of the convective envelope grows.

This matches theory that suggests turbulent eddy viscosity in the convective zone is the primary cause of tidal dissipation.

Observed tidal dissipation factor vs mass of convective envelope in FGK main sequence stars

[1] Solar System Comics Rewritten Wiki

[2] Galactic Comics Wiki

[3] Wikipedia

[4] Adam Burrows