A Method to Identify the Boundary Between Rocky and Gaseous Exoplanets from Tidal Theory and Transit Durations. Rory Barnes (Astronomy Dept., University of Washington, Seattle, WA; NASA Virtual Planetary Laboratory; rory@astro.washington.edu)

The determination of an exoplanet as rocky is critical for the assessment of planetary habitability. Here I show how transit data, interpreted in the context of tidal theory, can reveal the critical radius that separates rocky and gaseous exoplanets. Standard tidal models predict that rocky exoplanets tidally dissipate energy 3—5 orders of magnitude more rapidly than gaseous bodies [1], suggesting the former will tend to be circularized at larger orbital periods than the latter. Well-sampled transits of well-characterized stars can provide the minimum eccentricity of the orbit [2], allowing a probe of this differential circularization.

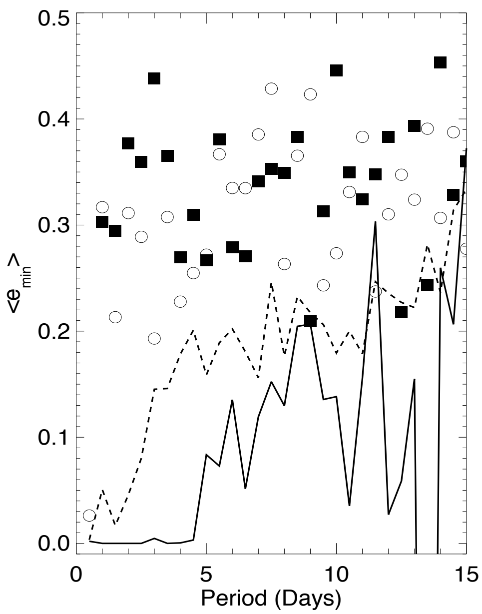

Fig. 1 -- Minimum eccentricities predicted (lines) and observed by *Kepler* (symbols). The boundary between gaseous (dashed line) and rocky planets (solid line) is represented by the different rises from zero at 2 and 5 days, respectively. *Kepler* candidates with radii below 2 Earth-radii are represented by solid squares, larger by open circles. *Kepler* minimum eccentricities derived from [3] are larger than the mean eccentricity of non-tidally-circularized radial-velocity-detected exoplanets.

I performed numerical integrations of tidal evolution of 25,000 star-planet binaries and computed the minimum eccentricities after a randomly chosen age between 2 and 8 Gyr. As a demonstration, I arbitrarily assume the critical radius between rocky and gaseous planets lies at 2 Earth-radii, but allow other physical properties to vary by a factor of 10. After applying the relevant biases, I easily identify the boundary. In Fig. 1, the lines show the predicted average minimum eccentricity, $\langle e_{min} \rangle$, as a function of orbital period. Gaseous planets (dashed line) are all circularized up to ~2 day periods, rocky planets (solid line) up to 5 days.

The signal is not apparent in *Kepler* data (squares and circles in Fig. 1) [3] as impact parameters and stellar radii have not been accurately determined (Fig. 2). Refinement of these parameters could reveal the transitional radius independent of mass measurements by radial velocity, which can be challenging. This research is described in more detail in [4].

In the longer term, space missions such as *TESS* and *PLATO* could detect thousands more close-in exoplanets with better characterized host stars and transits. Thus, this method should ultimately constrain tidal dissipation rates in exoplanets, and, by extension, the boundary between rocky and gaseous worlds.

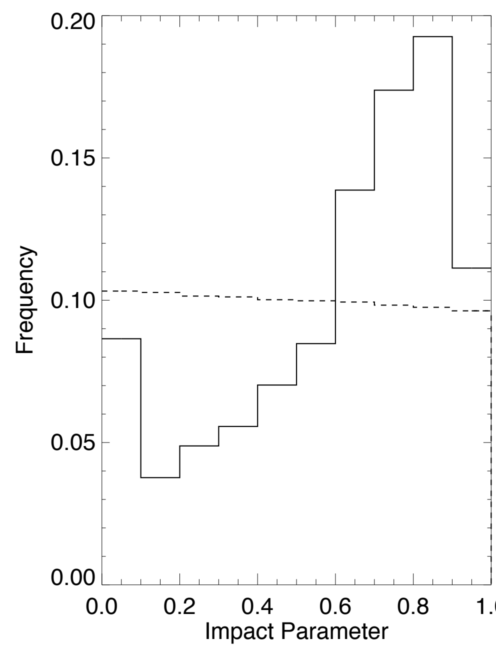

Fig. 2 -- Distributions of impact parameter. The solid histogram is the short-period *Kepler* sample [3], dashed an isotropic distribution of orbits. The *Kepler* data suffer a systematic error that contributes to the large minimum eccentricities seen in Fig. 1.

References

[1] Goldreich, P. & Soter, S. (1966) *Icarus,* 5, 375–389
[2] Barnes, J.W. (2007) *PASP* 119, 986–993
[3] Batalha, N.M. et al. (2013) *ApJS*, 204, 24
[4] Barnes, R. (2015) *Int. J. AsBio*, in press.