Lab Notebook

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THE INTERNAL STRUCTURAL ADJUSTMENT DUE TO TIDAL HEATING OF SHORT-PERIOD INFLATED GIANT PLANETS

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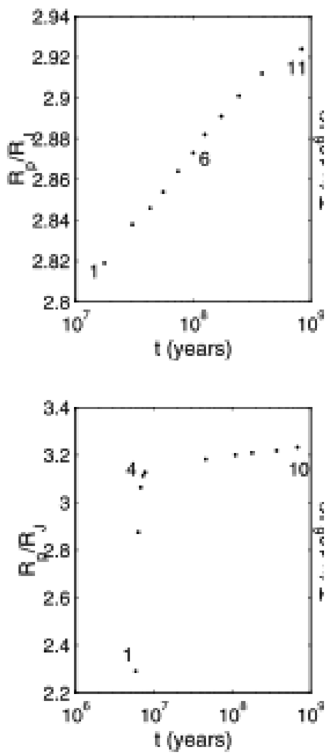

Fig. 6.—Evolution of R_p, the temperature profile, and the density profile for models 11 (*top*) and 12 (*bottom*) in Table 1. While we only show the data after the planet has reached a quasi-thermal equilibrium in model 11, in model 12 the planet is not in the quasi-thermal equilibrium until data point 4 (*bottom left panel*). The three solid curves from right to left in each of the temperature and density plots for model 11 (model 12) correspond to the three different stages marked by 1, 6, and 11 (1, 4, and 10), respectively, in the R_p-vs.-t plot. The vertical dashed lines in the temperature and density plots mark the location of the maximal heating of the Gaussian heating profile for model 11 ($m_0/M_p = 0.9$) and model 12 ($m_0/M_p = 0.7$). The temperature and density profiles for the uniform heating per unit mass represented by model 9 (*dot-dashed curve*) and for the surface heating denoted by model 10 (*dotted curve*) are also plotted for comparison.

From Figure 6 in the Gu, Lin & Bodenheimer paper, we see that it takes ~10^7 yrs for the planet to inflate due to the tidal energy input. This is roughly what my own simulations show, as well. (See Figure 2).

The difference b/w the simulations in their paper and mine is that theirs center their gaussian energy inputs farther out (in mass) in the planet than mine do. Also, their simulations include stellar irradiation in the overall planets' structure and energy budget.

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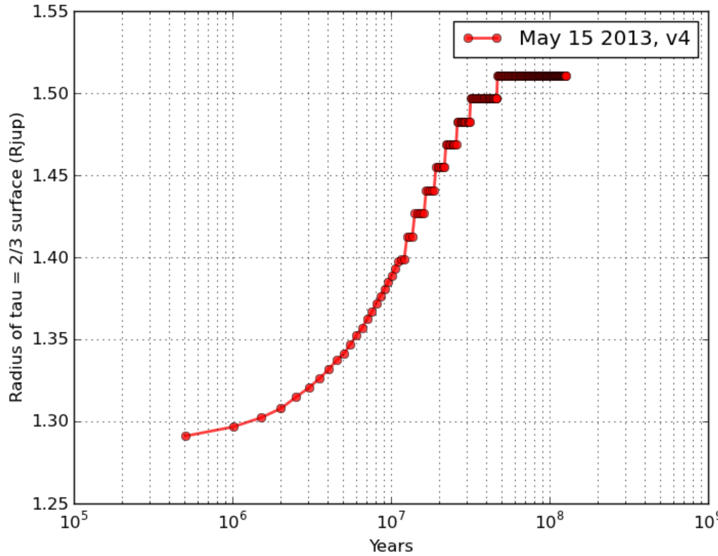

Figure 2:

Simulation of a 1Mjup, starting age = 3e7 yrs, efac = 10, gaussian energy input profile (centered at 0), with a time-indep. amplitude, set equal to the time averaged value of the sinusoidal (in time) energy input for all timesteps.

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INFLATING AND DEFLATING HOT JUPITERS: COUPLED TIDAL AND THERMAL EVOLUTION OF KNOWN TRANSITING PLANETS

N. Miller[1], J. J. Fortney[1], and B. Jackson[2]

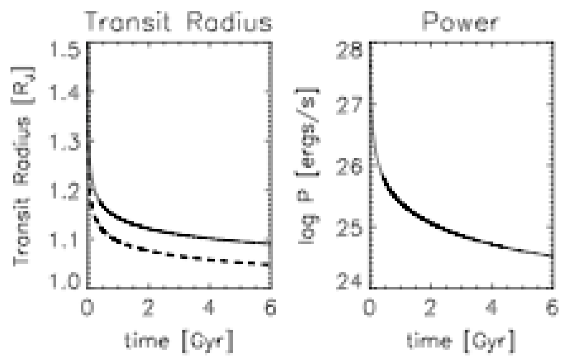

Figure 1. Radius and intrinsic planet luminosity evolution for a 1 M_J planet at 0.05 AU around a 1 $M_\odot$ star without any tidal effects. In the left panel, the dashed line is the radius at 1 kbar, near the convective/radiative boundary at gigayear ages. The solid line is the radius where the atmosphere reaches 1 mbar—approximately the radius that would be observed in transit.

Lab Notebook

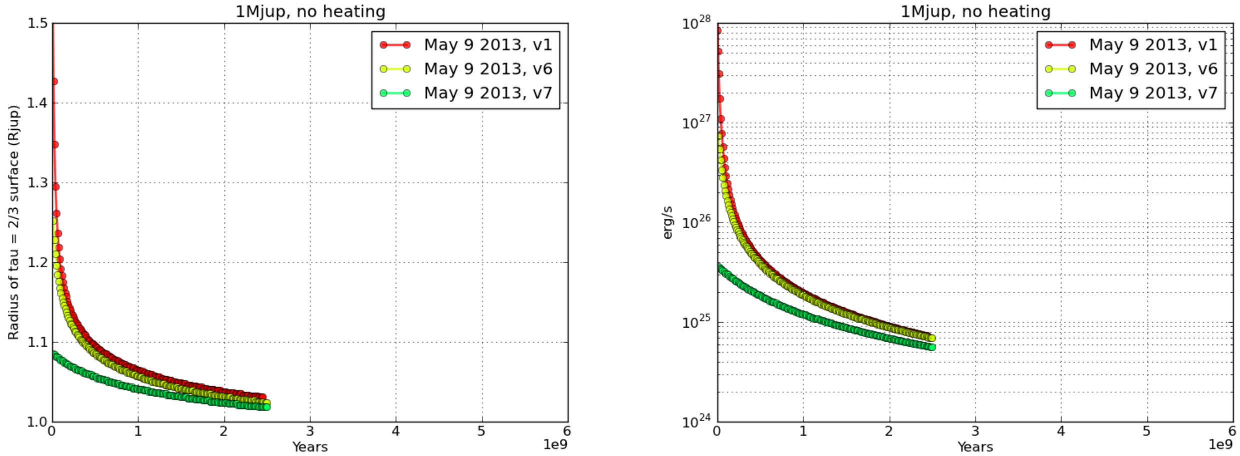

Figure 3:

Results from my runs for a 1Mjup planet with no tidal heating inputs, for comparison with Figure 1 from the Miller, Fortney & Jackson paper above.

My evolution curves have lower L and R values at 2Gyrs than theirs do. This may be because their simulations include the effects of stellar irradiation on the planet, while mine do not.

What are the timescales for inflation/deflation from these two papers (or from any others)?

From the Miller & Fortney paper,

For a given radius, assumed core size and average incident flux of the planet, $\dot{R}_p \propto -L_{\rm net}$. Therefore, if we calculate $\dot{R_{NH}}$, the radius contraction rate when there is no internal heat source, we can use the following relationship to calculate $\dot{R}_p$ when there is an assumed P_t tidal heating (or an input power of another source).

$$\frac{\dot{R}}{\dot{R_{NH}}} = \frac{L - P_t}{L}. \qquad (6)$$

Kozai cycle timescale:

$$T_{\rm Kozai} = 2\pi \frac{\sqrt{GM}}{Gm_2} \frac{a_2^3}{a^{3/2}} \left(1 - e_2^2\right)^{3/2} = \frac{M}{m_2} \frac{P_2^2}{P} \left(1 - e_2^2\right)^{3/2}$$

"where a indicates semimajor axis, P is orbital period, e is eccentricity and m is mass; variables with subscript "2" refer to the outer (perturber) orbit and variables lacking subscripts refer to the inner (satellite) orbit; M is the mass of the primary. The period of oscillation of all three variables (e, i,) is the same, but depends on how "far" the orbit is from the fixed-point orbit, becoming very long for the separatrix orbit that separates librating (Kozai) orbits from oscillating orbits."

Lab Notebook

(from Wikipedia, but cites Merritt, David (2013). Dynamics and Evolution of Galactic Nuclei. Princeton, NJ: Princeton University Press. p. 575.)