The Radius Anomaly of Transiting Hot Jupiters Explained?

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ABSTRACT

The radius anomaly displayed by many transiting hot Jupiters has motivated the development of new models that try to account for this bizarre property. These theoretical approaches include a wide variety of physical processes. Here we examine the scenario where hot Jupiters form in excretion disks that result from the merging of two main sequence stars. We find that this scenario may have some pros but also has some cons in explaining the properties of hot Jupiters.

Background

-Over 100 transiting planets are known, most of which have masses in the range 0.3 to 10 Jupiter masses, and are located within 01 AU of their host stars (Figure 1).

-Gas giant planets close to their stars are generally called Hot Jupiters because their surface temperatures are much higher than that of Jupiter.

-A large spread of planetary radii is observed in trasniting hot Jupiters (Figure 2)

- Many hot Jupiters have radii well in excess the equlibrium radius for the age inferred from the host star, this has been termed the `radius anomaly' of hot Jupiters (Leconte et al. 2009, A&A, 506, 385).

- A hot Jupiter needs a thermal energy excess of the order of its gravitational binding energy in order to inflate it by as much as 50\%.

- A plausible mechanism to transport the stellar flux to the planet interior where it is needed for significant inflation needs to invoked. We argue that such a mechanism is not required if inflated hot Jupiters come from binary mergers.

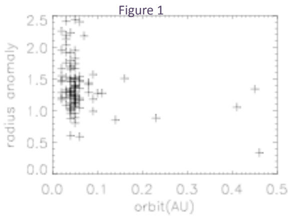

Figure 1: Radius excess of hot Jupiters with respect to their Semi-major axis for over 100 Known trasniting hot Jupiters.

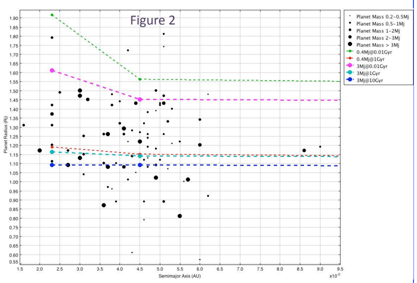

Figure 2: A zoom on the previous figure with different symbols for different planet masses, and showing models of Irradiated planets by Baraffe et al. 2003, A&A, 402, 701.

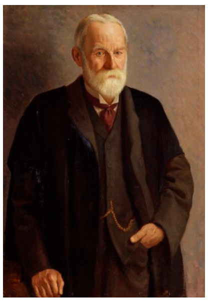

Figure 3: Sir George H. Darwin in 1912 by Mark Gentler.

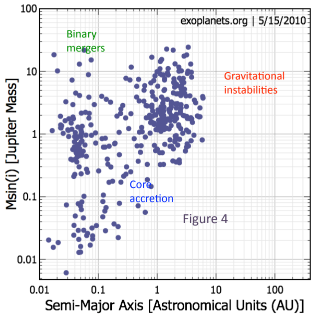

Figure 4: The diversity of exoplanets suggests that there are several pathways to forming them. Here it is proposed that hot Jupiters may form as a result of binary mergers.

Results

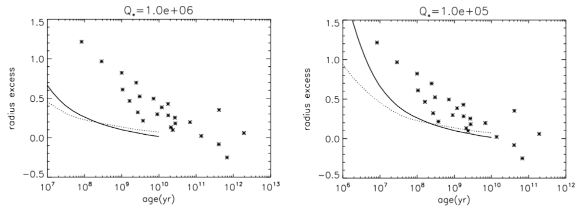

Figure 5 : Evidence that the radius excess is related to the planet's age, independent of the uncertainty in the dissipation parameter Q. Cooling curves of irradiated planets from Baraffe et al. (2003) are shown, Since spiral-in time measures age only in an average sense, we have binned the data.

- We find a strong correlation between the radius excess and the spiral in time of hot Jupiters due to G. Darwin´s instability.

- The correlation shown in Figure 5, can be explained if inflated hot Jupiters are young, of order of 100 Myr old. Their large sizes are not an anomaly but an indication that they are found at an early stage in their cooling evolution.

- The host stars are typically a few Gyr old, as judged from kinematics and evolutionary status (Lee et al. 2011, ApJ, 728, 32). Hot Jupiters could be younger than their host star if they formed in an excretion disk after a binary merger (Tutukov 1991, Astron. Zh., 68, 837). The cooling age of the planet would be an indicator of the time elapsed after the merger.

-Binary progenitors must be some 30 times more abundant than inflated hot Jupiters, and should be easily identifiable. The frequency of transiting planets found by CoRoT around G-type main-sequence stars is around 1 per 2000 stars, so the recognizably inflated fraction of 1/3 has an abundance of about $1.6\,10^{-4}$ per G star. Their progenitors must then have an abundance of $\sim 5\,10^{-3}f$. An obvious candidate population is contact binaries (W~UMa stars), but the direct merger of lower mass binaries that have not gone through an extended W~UMa-type contact phase is likely.

-A merger scenario agrees the peculiar distribution of orbital distances of transiting planets. The concentration near 0.05 AU, with a rapid decline at larger distances, indicates an origin close to the host star.

- An issue with the merger scenario is that some inflated Jupiter host stars seem to be rotating quite slowly. A very efficient angular momentum mechanism would be required.

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