Differences in Planet Distributions of Iron-Rich and Poor Stars That Change With Eccentricity: Evidence of Whole Planet Pollution of Stars

Stuart F. Taylor
Participation Worldscope/
Global Telescope Science
Job Seeking
Hong Kong, and Sedona, Arizona, USA

Abstract

We present new differences in the distributions of planets of iron-rich and iron-poor stars ([Fe/H] above and below solar respectively) that further show that these are two different populations. We present the new result of an eccentricity dependence of the metallicity-stellar mass correlation found by Murray & Chaboyer (2002, MC02).

There are more giant than medium planets at the shortest period range of roughly one day, even though there are more medium planets. We challenge the conclusion that the shortest period giant planets are present due to unexpectedly weak tidal dissipation in the star. We find that it would only take a small resupply rate of inwardly migrating giant planets to keep this region populated.

Surprising structure in period distributions is dramatically different for systems of high and low stellar [Fe/H]

Figure 1. Period distributions of planets strongly depends on the iron abundance of the stellar host. The difference is greatest when only planets hosted by single stars are considered. We show that after cutting stars with companions, that iron-rich (red) and iron-poor stars (blue filled), where [Fe/H] is greater and not greater than zero respectively, host very different populations of planets. The starkest feature may be the gap separating two sharp peaks of the iron-rich population. Earlier, Dawson & Murray 2013 (hereafter DM13) showed that the "three-day" pileup of giant planets is associated with the metal-rich population.

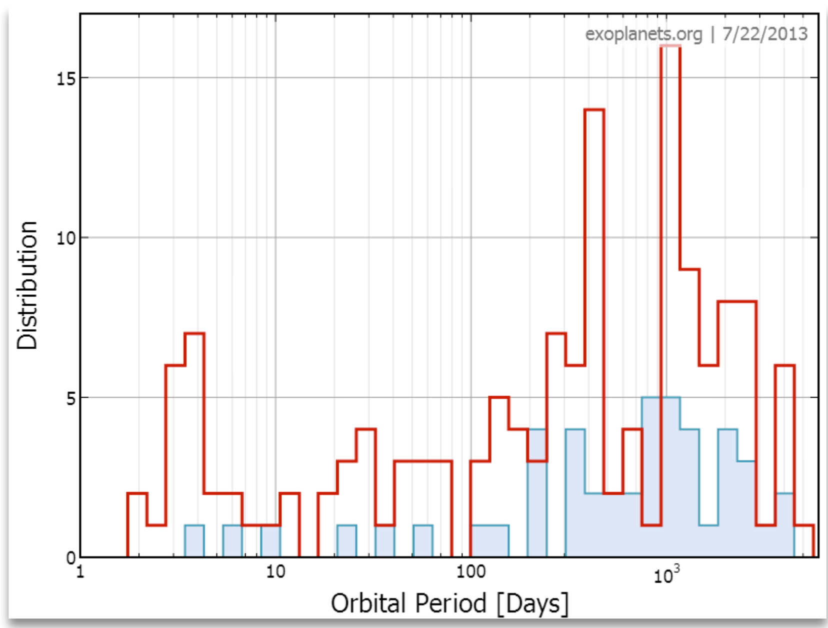
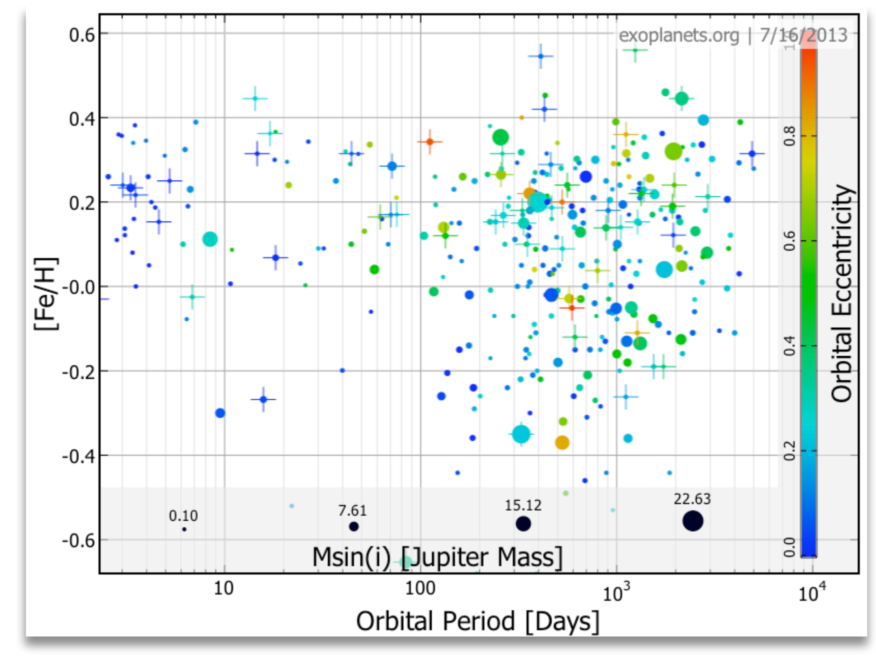


Figure 2. The metallicity-eccentricity correlation is very apparent for periods below 200 days in this plot of stellar [Fe/H] as a function of period. There still is a correlation for longer periods up until the cluster of iron poor systems that peaks somewhere between 500 and 1000 days.



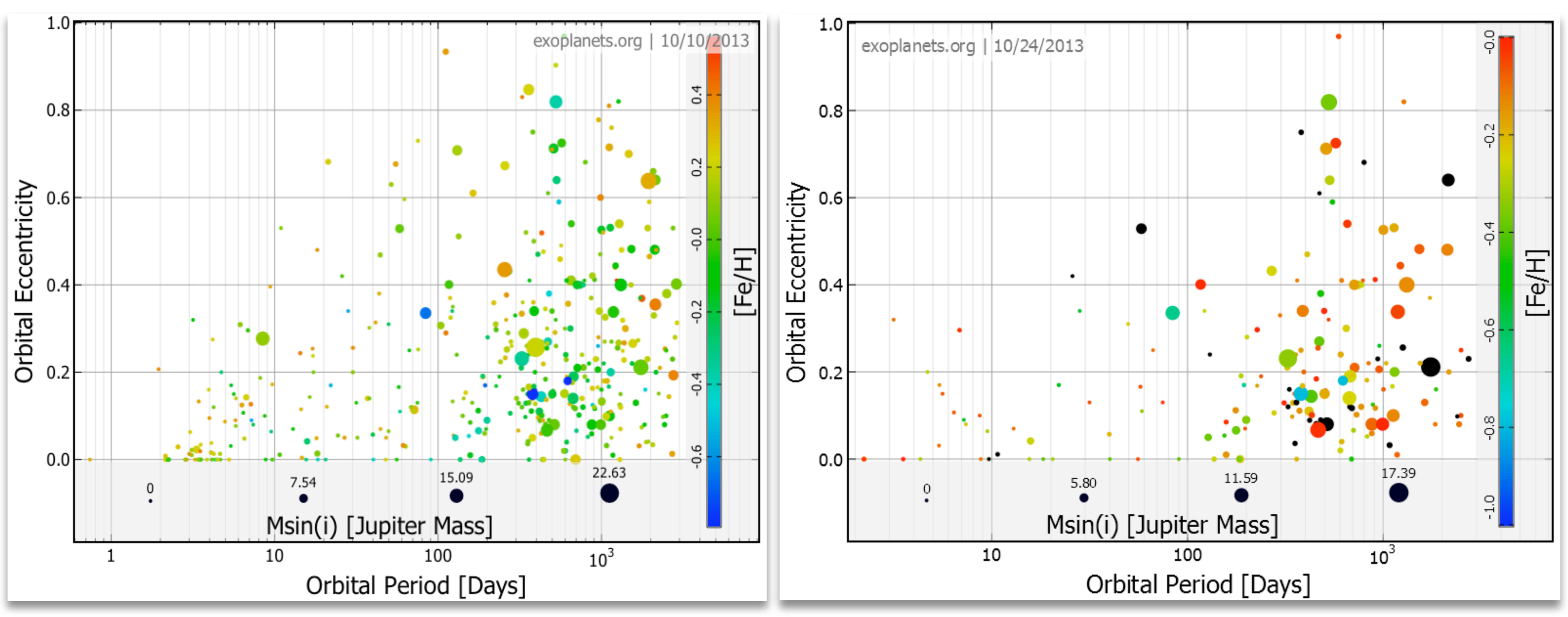
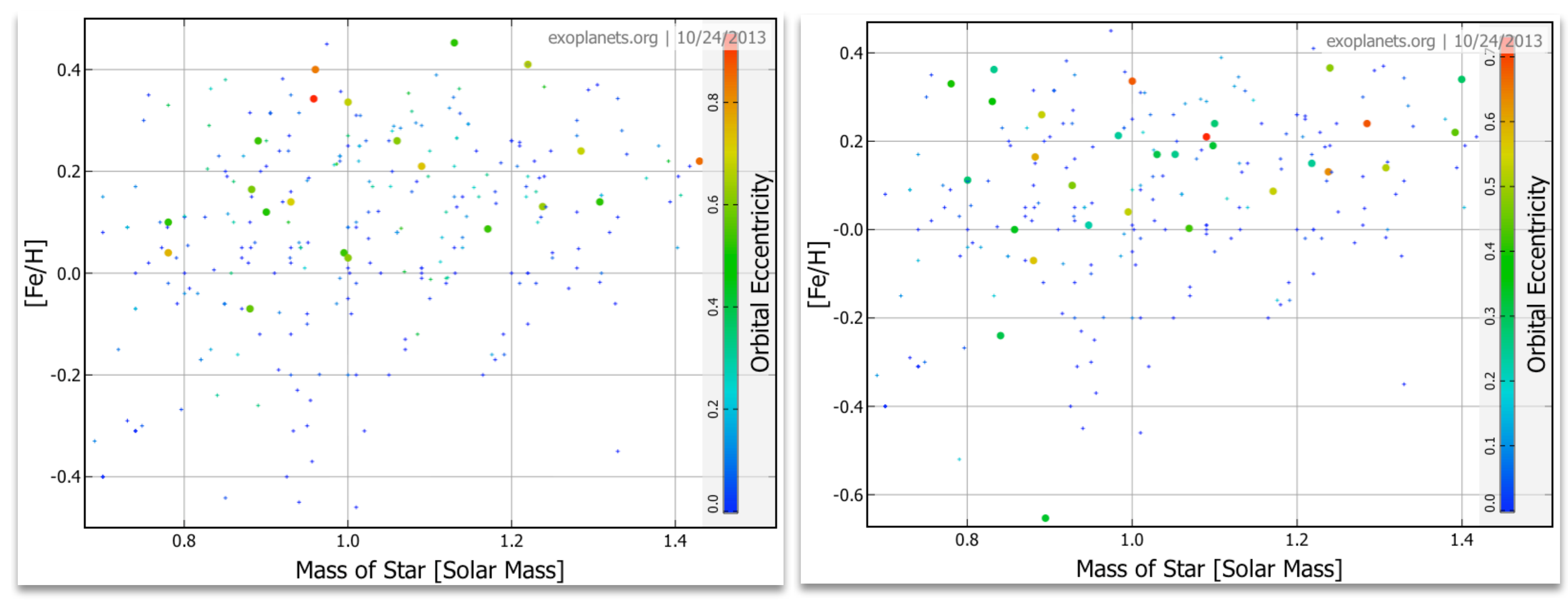


Figure 3. Iron-poor systems (stellar [Fe/H] ≤ 0.0 in color, right, with "near solar systems" having 0.0 < [Fe/H] < 0.05 in black) are a separate population from systems with [Fe/H] ≥ 0.05, with lower eccentricity when compared to all systems (left) for periods below 500d. These plots show systems found by radial velocity. We find in a narrow period range from 500 to 600d the eccentricity of iron-poor systems is rather suddenly distributed similar to iron rich systems, with a possible transition region of systems that have 0.0 < [Fe/H] < 0.05.

Eccentricity-dependent iron abundance correlations with mass of stars



Periods < 500 d, Eccentricity > 0.35 large dots

Periods < 100 d, Eccentricity > 0.2 large dots

Figure 4. Stellar [Fe/H] rises as convective zone mass decreases (Mayor & Chaboyer 2002, hereafter MC02). Two period ranges with two cuts on eccentricity are shown using large dots for systems above [Fe/H] above the cut, and small dots show all systems. New: The minimum cutoff is higher for systems with higher eccentricity. We find an even stronger dependence in the higher eccentricity sample than that found for all stars with planets found previously by MC02.

Giant planet flow versus weaker tidal dissipation in stars for giant planets

Fits to distribution of Kepler candidates compared to migration models

Giant planets: 8 to 32 earth radii, "$R_\oplus$"

Medium planets: 4 to 8 $R_\oplus$

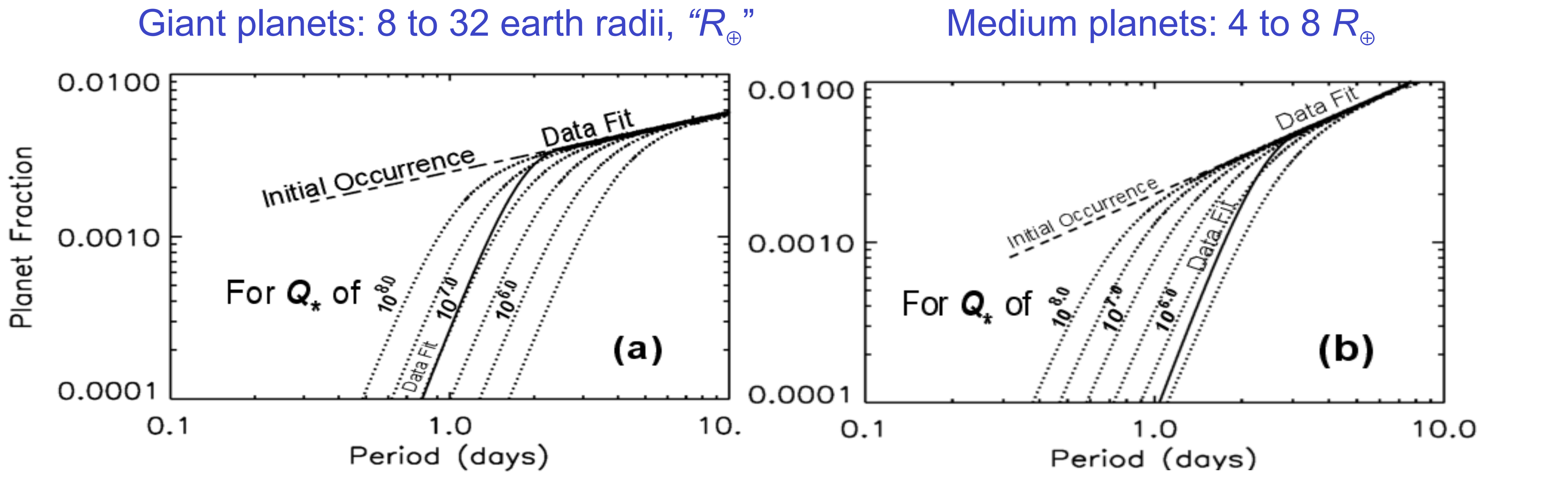


Figure 5. There is an excess of giant planets (a) at the shortest periods that has led many to say that the tidal dissipation in stars is weaker for giant planets than for binary stars. However, this excess is not present for medium planets (b). This can be resolved if the giant planet population is resupplied. The giant and medium planet occurrence functions of Howard et al. (2012, H12) are shown as solid lines. These have been found to have a falloff that has a power index (slope in logarithm space) close to the 13/3 expected from ongoing tidal migration into the star. We show the falloffs that would be expected for a population with ages from 0 to 9 Gyr for a range of "stellar tidal quality" values, "Q_*", which is the inverse of the fraction of the energy dissipated. We show what the occurrence distribution would be, for the weak to stronger dissipation values of from $Q_*=10^{8.0}$ to $Q_*=10^{5.5}$ respectively, in steps of $10^{0.5}$. For medium planets, the distribution of the Kepler candidates corresponds to that produced by tidal friction stronger than Q_* of $10^{7.0}$, but if the shortest period giant planets have been migrating since formation, then Q_* much weaker than $10^{7.0}$ would be required to keep them from merging with the star. This suggests an ongoing infall of a "flow" of planets being scattered inwards.

Rates of future infall show rates of flow required are reasonable

An ongoing infall of less than 10^{-12} giant planets per star per year would give a steady infall rate at more reasonable tidal dissipation values.

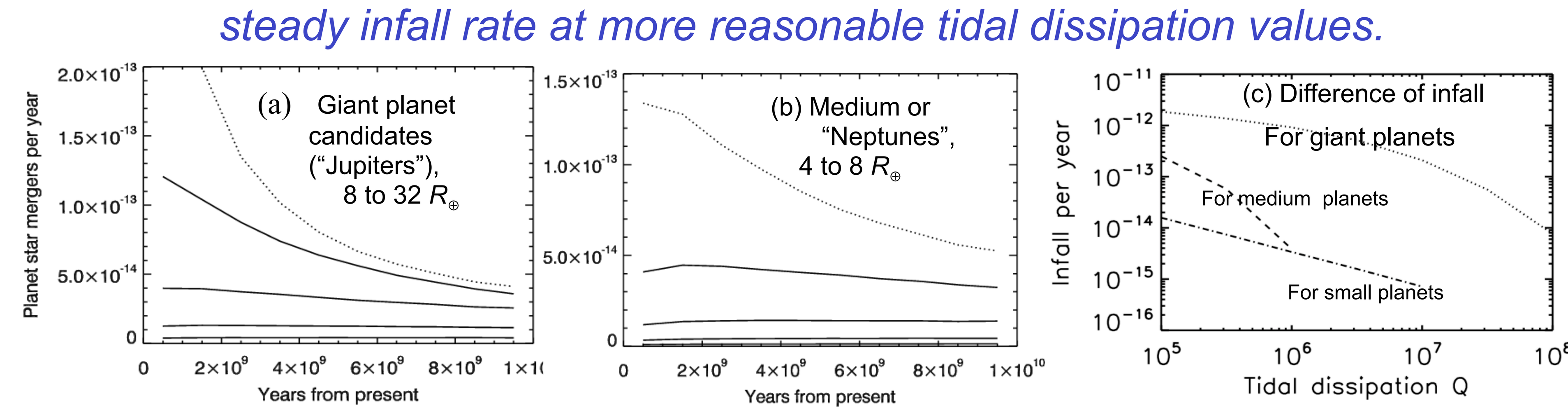


Figure 6. Rate of calculated future planet infall for Kepler giant (a) and medium (b) planet candidates for Q_* values of from $10^{6.0}$ (dotted, top), $10^{7.0}$, $10^{8.0}$, to $10^{9.0}$. The difference of infall from 1 to 10 Gyr in (c) is the amount of flow of planets needed to maintain a flat infall into the star at the 1 Gyr rate. There are enough planets to supply these rates. Current work is emphasizing comparing the numbers of planets with the rates of infall, and how this infall may pollute the star.

Conclusion: Ongoing mergers a major part of planet/star evolution

Planet migration and planet/star mergers an important part of solar systems evolution. It is essential to research how the distributions of planets evolves, and how the stars are affected. Infall occurring at a rate of 10^{-3} per star per gigayear is a rate the planet population can supply We predict that shortening of periods of the closest planets will soon be observed, showing the closet planets are migrating towards merger at a rate indicating a planet flow inward (Hellier 2009; Hamilton 2009; Socrates et al. 2012). Planet/star mergers will be observable by transient searches such as the LSST (Taylor 2010; Metzger et al. 2012).

See Taylor 2013b, in submission, at ar.Xiv:1305.5197

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