# Planet Formation Models Meet Transit Timing Observations

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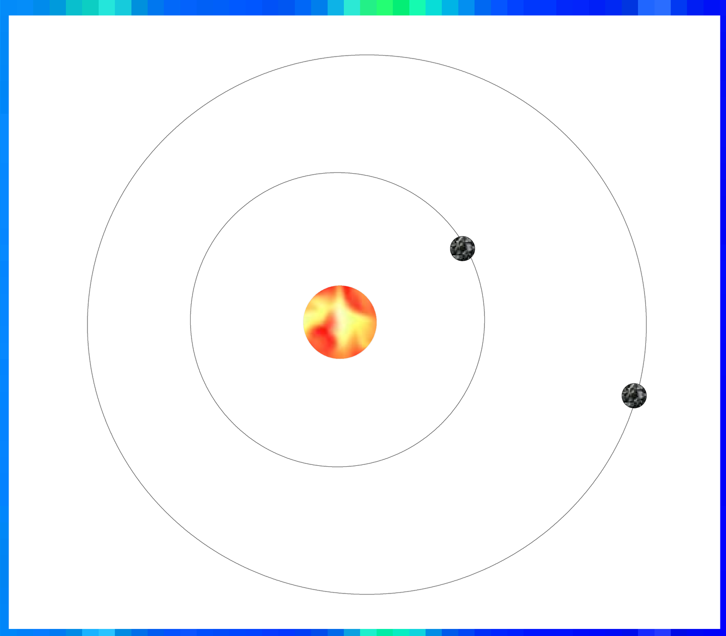
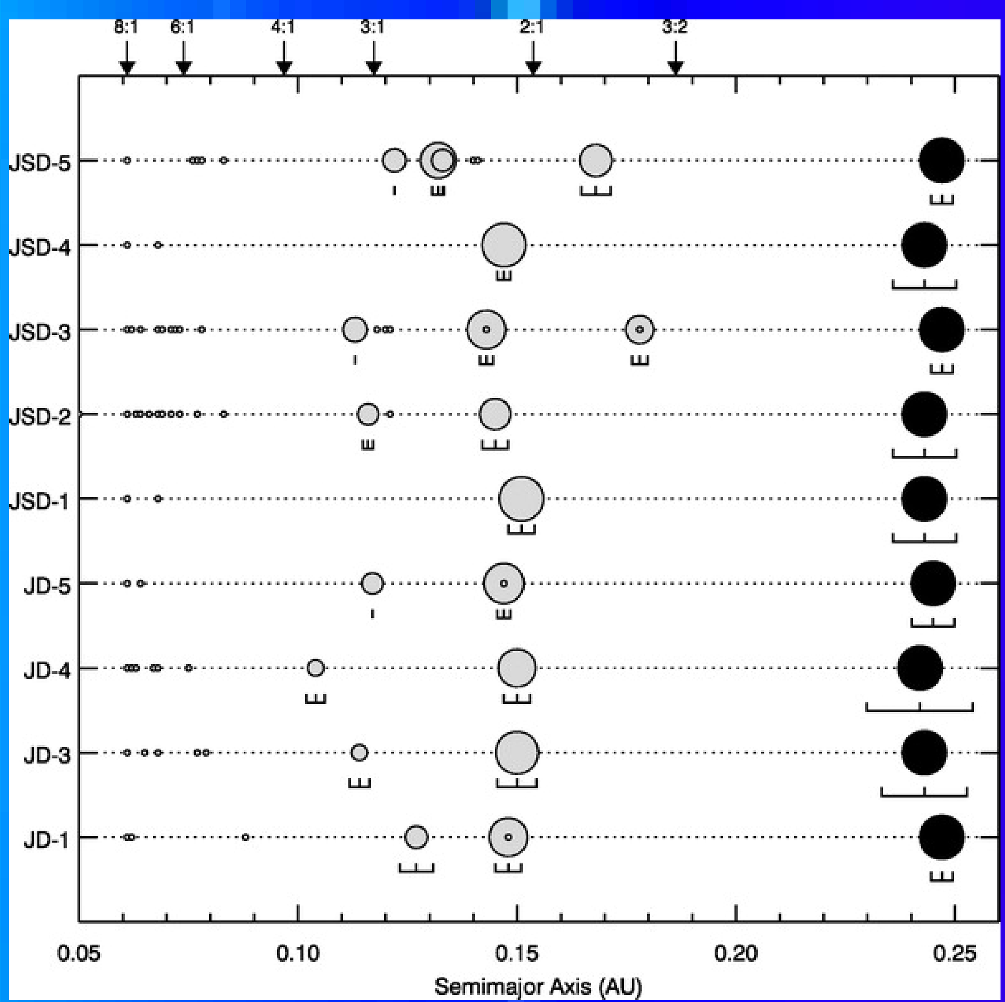
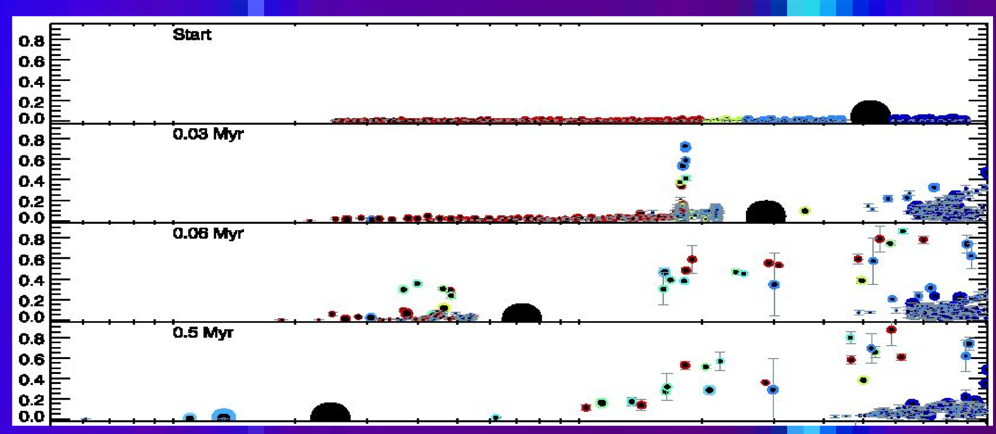
Several planet formation models predict the presence of low-mass companion planets that are shepherded into mean-motion resonance with a gas giant as the giant migrates inward. Such systems, and hence the models that predict them, can be studied by observations of the timing of the transits of the giant. This is because transit timing variations (TTV), that are caused by planet-planet interactions, are largest near mean-motion resonance and have been shown to be sensitive to terrestrial-mass companions. We investigate the TTV signal that arises from several realizations of a core-accretion plus migration model of planet formation. In these systems a giant planet is migrated through a gas disk that is populated with many planetesimals. As the system evolves the planetesimals collide to form planets which are subsequently trapped near mean-motion resonance with the migrating giant. We present the TTV signal that results from these systems and discuss the feasibility of detecting the trapped planets via a TTV study.



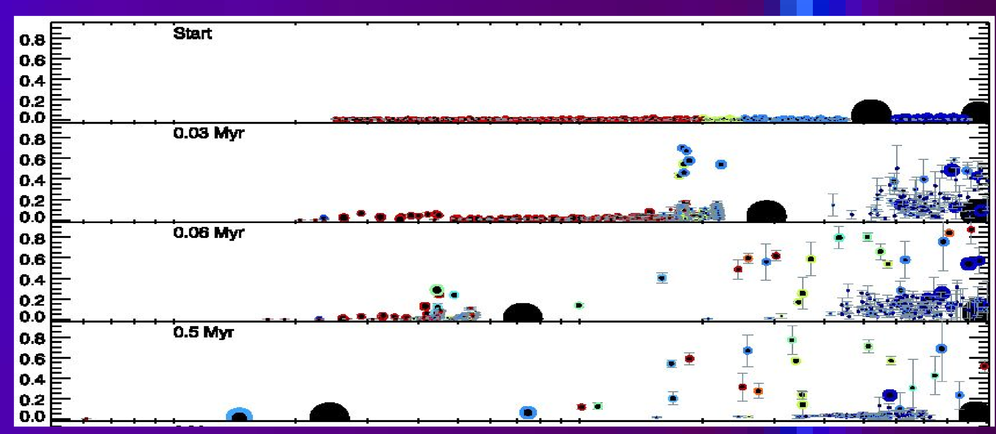
In a system where a planet transits the host star, a secondary planet will perturb the orbit of the transiting planet and cause the time of the transits to vary. These variations, which are very large near mean-motion resonance, can be used to identify the orbit of the secondary planet. This planet detection technique is sensitive enough to detect Earth-mass planets around Sun-like stars.




These are the resulting planetary systems from the given simulations. The JSD simulations include a Saturn-mass secondary gas giant (with gas drag) while the JD simulations have only a Jupiter-mass giant with gas drag. We study the calculated and analyzed the TTV signal that results from these systems.

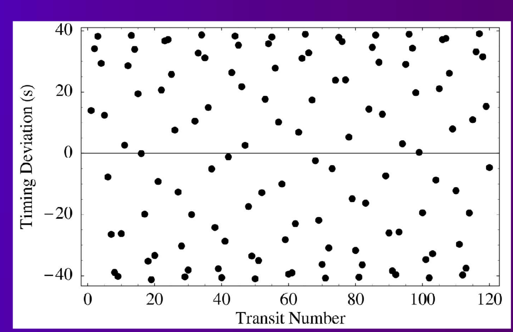



A simulation of planet formation with a single migrating gas giant (above) and with a second, stationary gas giant (below). Small planetesimals are shepherded into mean-motion resonance as the planet migrates inward. These planetesimals later form into Earth-mass planets.

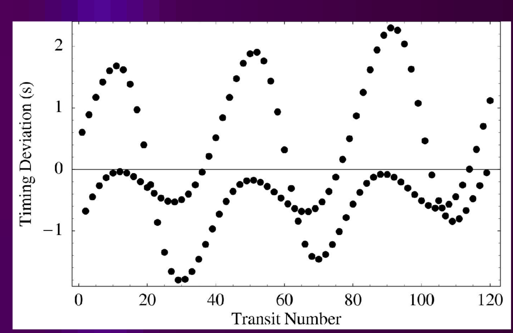



Below are examples of the TTV signal for systems that were correctly identified (right) and that were not correctly identified (left) with our existing software. Planned improvements to this software should improve both the quantity of systems that are identified and the accuracy of the inferred orbital elements.

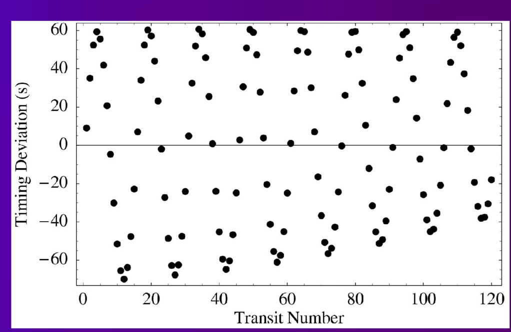
JD3



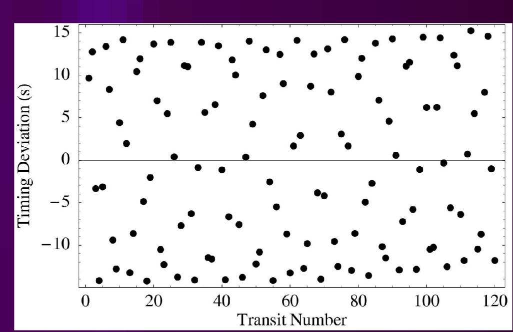

JD5



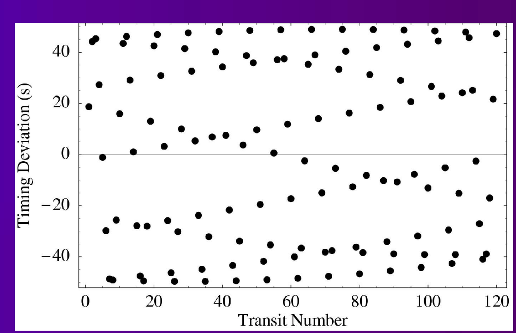

JD4



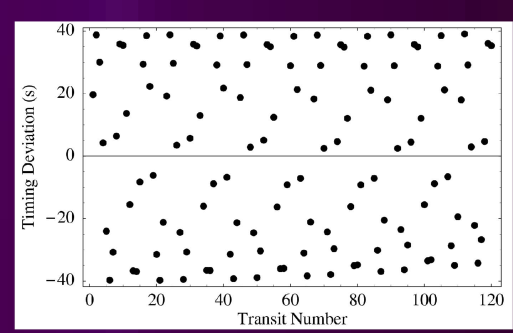

JSD2




JSD1

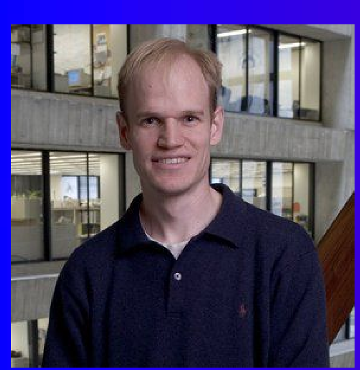



JSD4




Simulations are from Mandell, Raymond, & Sigurdsson (2007)

Background image is the TTV signal vs. period and eccentricity from Agol et al. (2005)



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