

Turning Solar Systems into Extrasolar Planetary Systems

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QUESTIONS:

Why are exoplanets on eccentric orbits?

Why are jupiter-mass exoplanets so close to their stars?

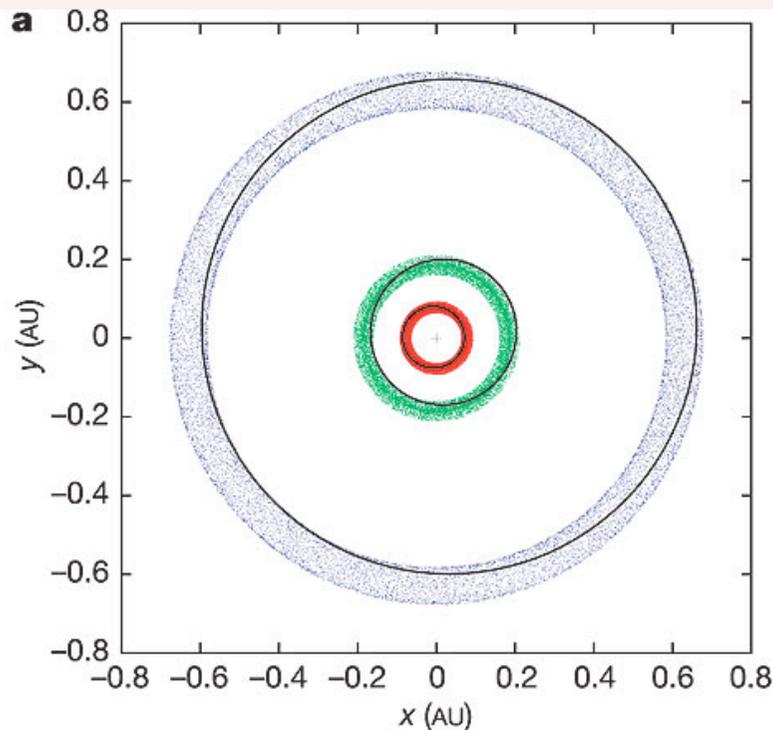
One IDEA:

Planets migrate within disk around star.

An extrasolar planetary system with three Neptune-mass planets

Christophe Lovis¹, Michel Mayor¹, Francesco Pepe¹, Yann Alibert², Willy Benz², François Bouchy^{3,4}, Alexandre C. M. Correia⁵, Jacques Laskar⁶, Christoph Mordasini², Didier Queloz¹, Nuno C. Santos^{1,7,8}, Stéphane Udry¹, Jean-Loup Bertaux⁹ & Jean-Pierre Sivan¹⁰

Over the past two years, the search for low-mass extrasolar planets has led to the detection of seven so-called 'hot Neptunes' or 'super-Earths' around Sun-like stars. These planets have masses 5-20 times larger than the Earth and are mainly found on close-in orbits with periods of 2-15 days. Here we report a system of three Neptune-mass planets with periods of 8.67, 31.6 and 197 days, orbiting the nearby star HD 69830. This star was already known to show an infrared excess possibly caused by an asteroid belt within 1 AU (the Sun-Earth distance). Simulations show that the system is in a dynamically stable configuration. Theoretical calculations favour a mainly rocky composition for both inner planets, while the outer planet probably has a significant gaseous envelope surrounding its rocky/icy core; the outer planet orbits within the habitable zone of this star.



(Lovis et al 2006)

(Alibert et al 2006)

A Different Idea

Solar Systems

Something Happens

Exoplanet Systems



IDEA:

The something is either i) close encounters within young stellar clusters or ii) exchange encounters which leave planetary systems in binaries.

Strong planet-planet interactions within planetary systems may follow.

Singleton:

- 1) a star which has not formed in a binary,
- 2) a star which has not later spent time within a binary system,
- 3) a star which has not suffered close encounters with other stars.

Simulate open cluster evolution

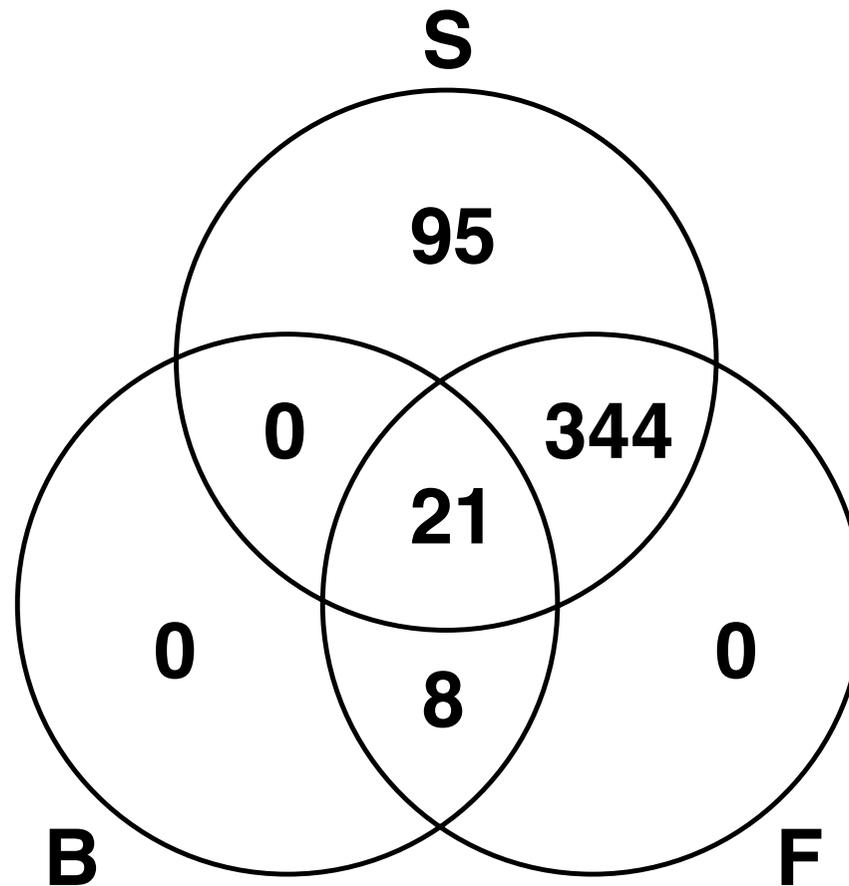
Evolve open clusters considering a range of sizes and masses.

Place some stars in binaries whilst others are initially single.

Trace stellar histories: count the number of stars which exchange into and out of binaries.

(Malmberg et al 2007b)

How common are singletons?



N=700 stars, R=2-4 pc

(Malmberg et al 2007b)

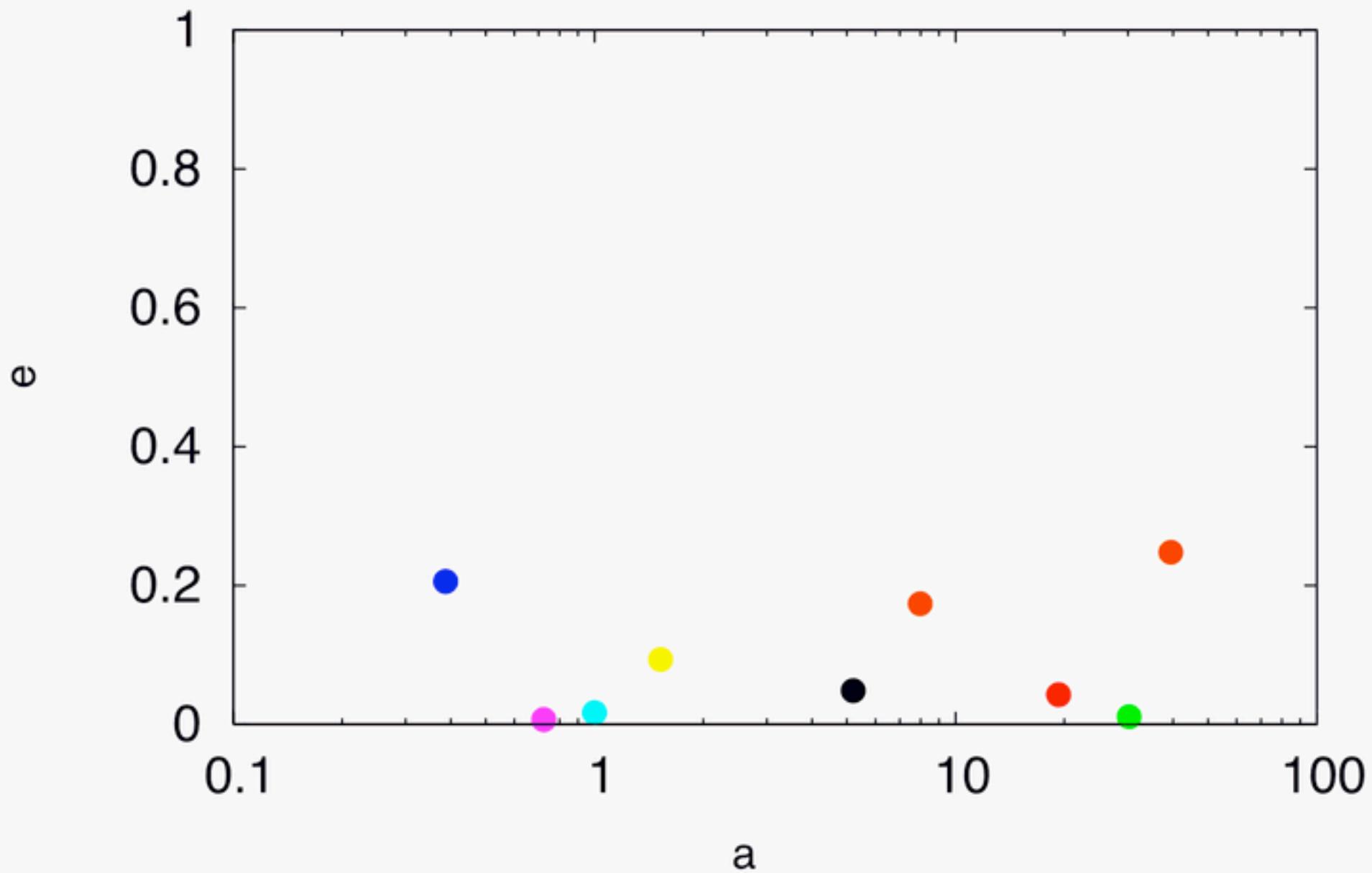
Effects of close encounters

Extremely close fly-by encounters may result in the direct ejection of planets.

Other planets may remain bound but on tighter and more eccentric orbits.

Even very small perturbations can sometimes lead to significant outcomes via planet-planet interactions within planetary systems.

Solar system, Time = 0 years



Effects of being in a binary

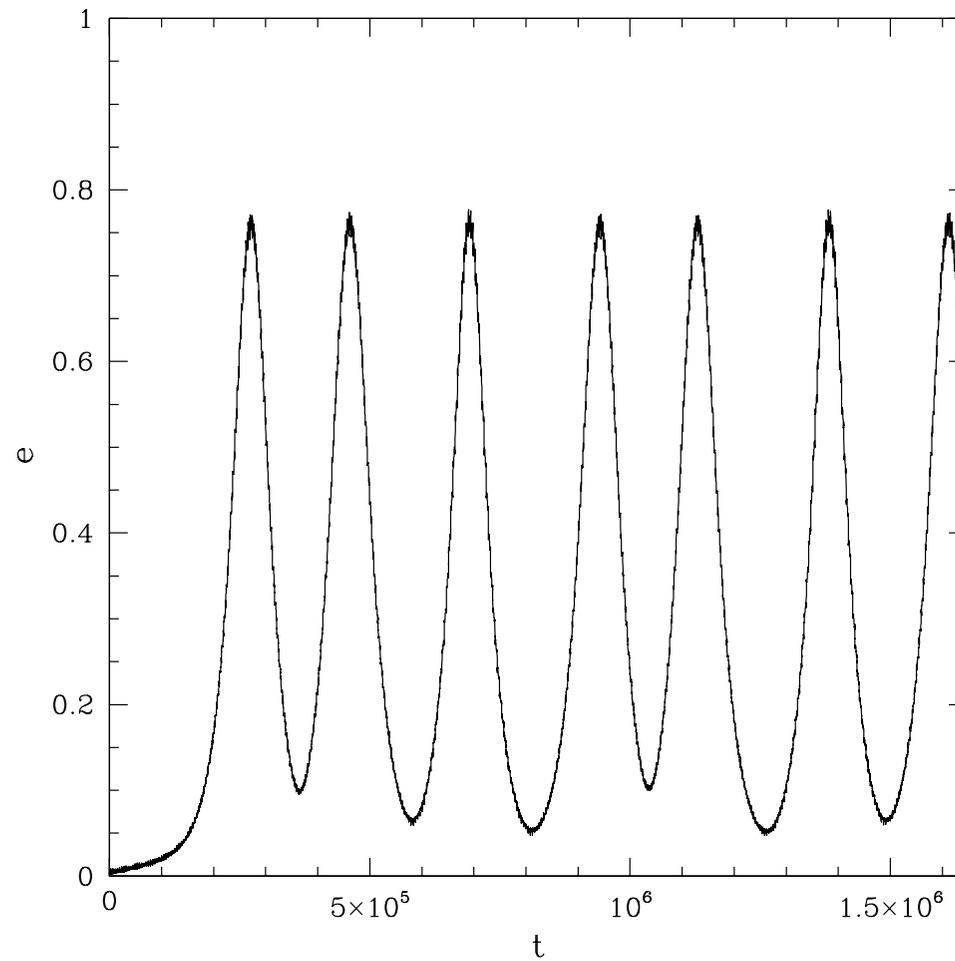
If the planetary system and stellar binary are highly inclined, the Kozai Mechanism will make the planetary orbits highly eccentric.

Strong planet-planet scattering will then occur.

Malmberg & Davies (2009)

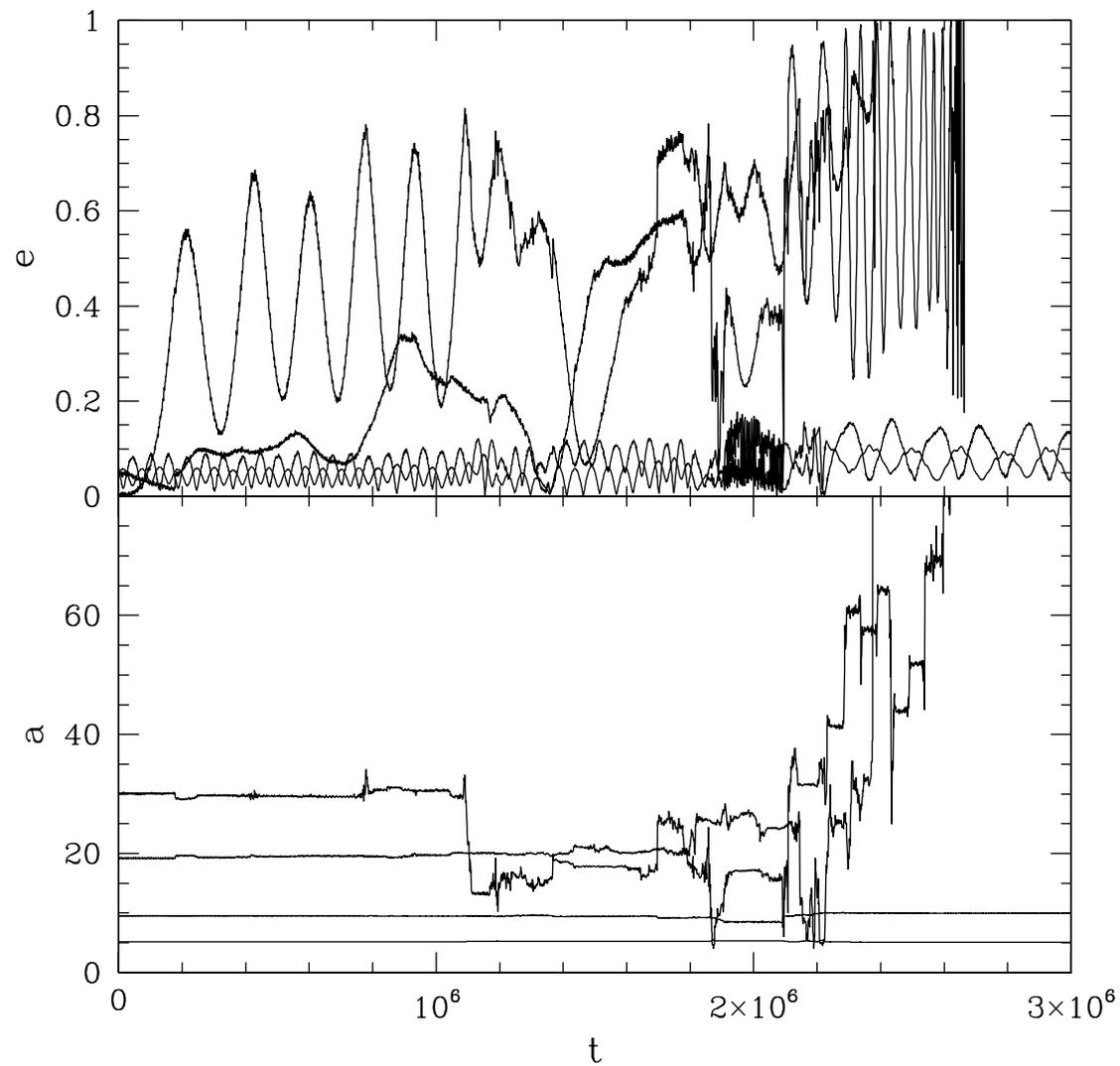
See poster P8.8 Daniel Malmberg

Evolution of a planet within a stellar binary



(Malmberg et al 2007a)

Evolution of our solar system in a binary



(Malmberg et al 2007a)

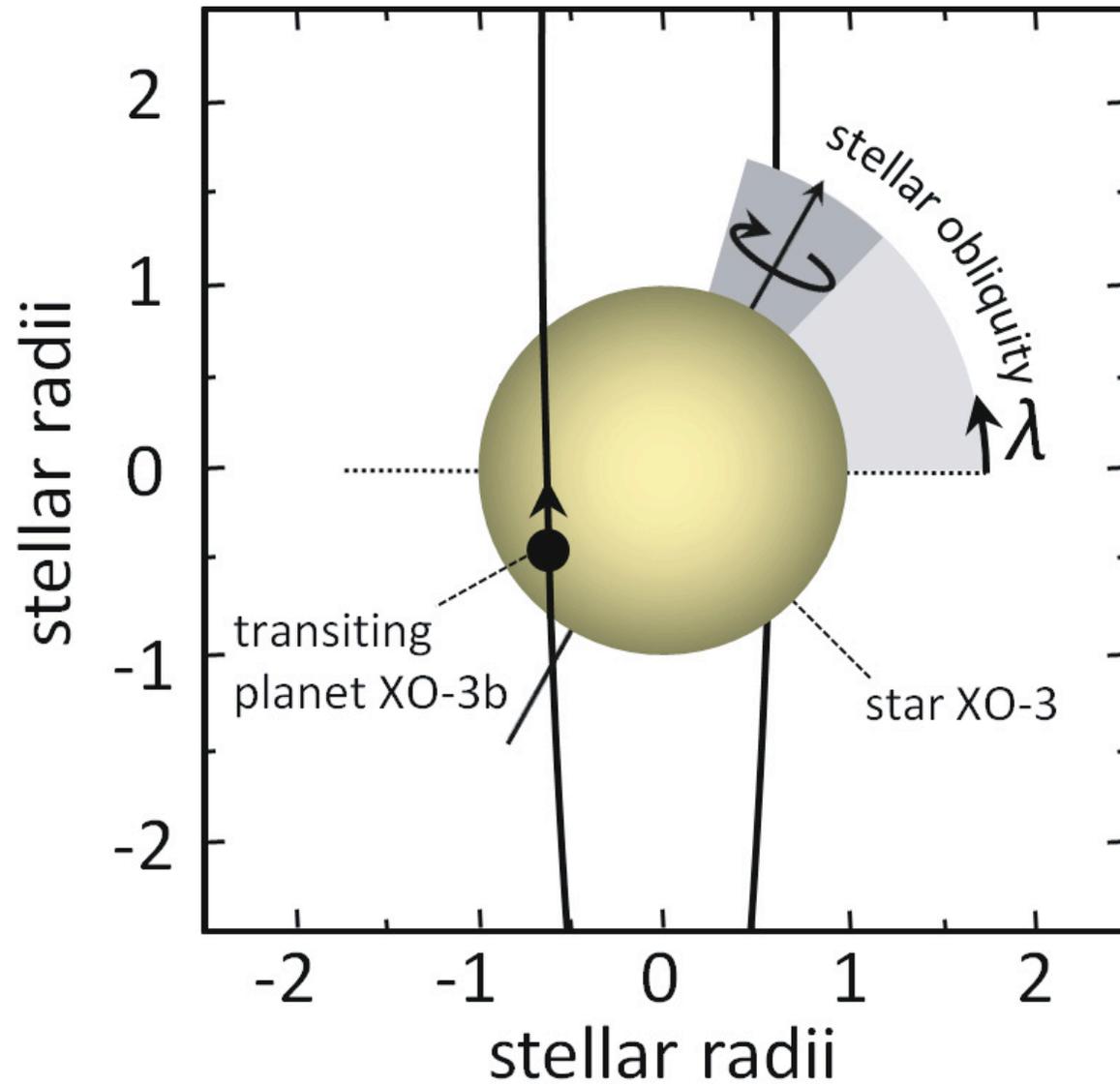
Could the Kozai Mechanism produce hot jupiters?

The idea is that Kozai produces extremely eccentric systems, which could undergo tidal interactions with the star, leaving the planet on a much tighter orbit.

Malmberg et al (2007a)

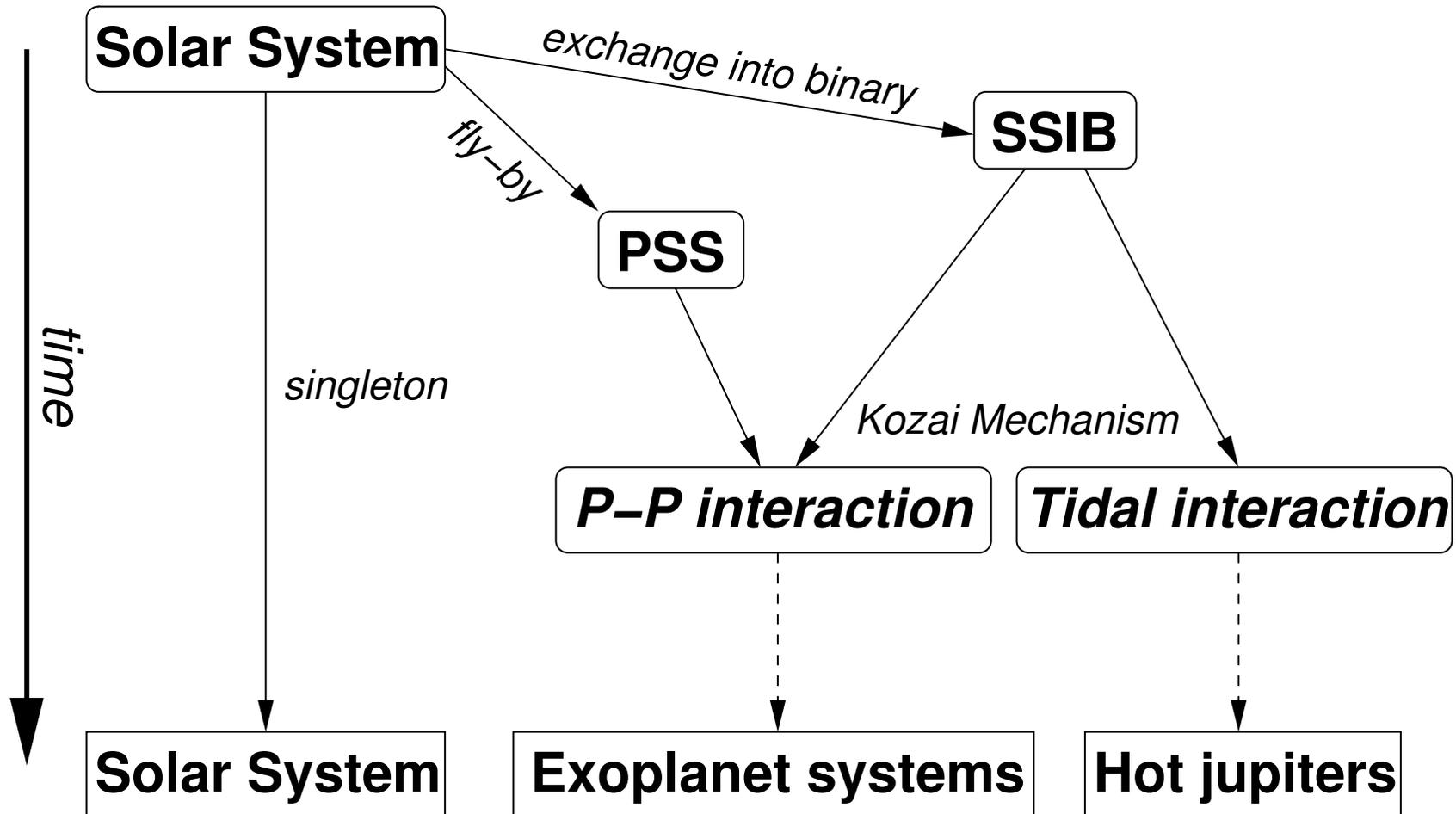
Fabrycky & Tremaine (2007)

Wu, Murray & Ramsahi (2007)



(Hébrard et al 2008)

A planetary flow diagram



Conclusions

Encounters within stellar clusters may damage/destroy planetary systems.

Planetary systems left within binaries may be damaged via eccentricities induced by the Kozai Mechanism.

Singletons are stars which are formed single and are never within binaries or have close encounters.

Is our sun a singleton?

Are extrasolar planets messed-up solar systems?