Planets and Debris disks

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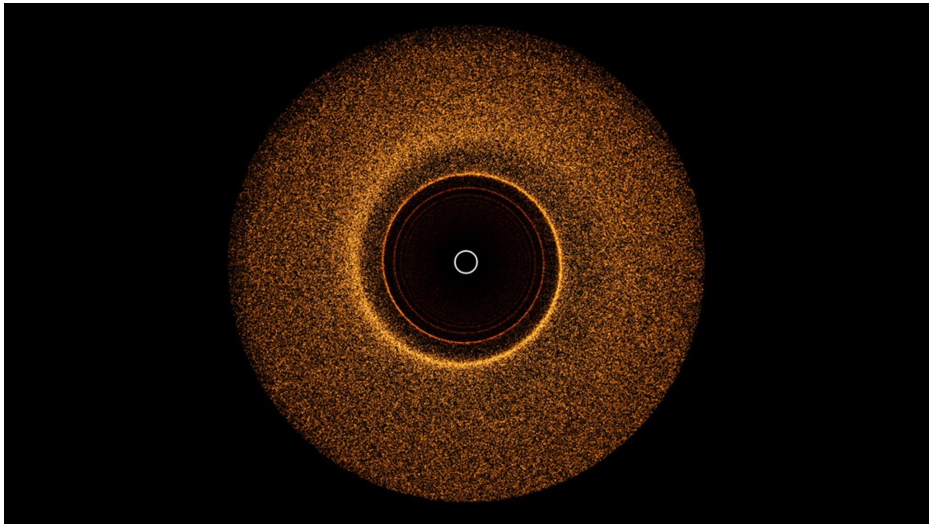
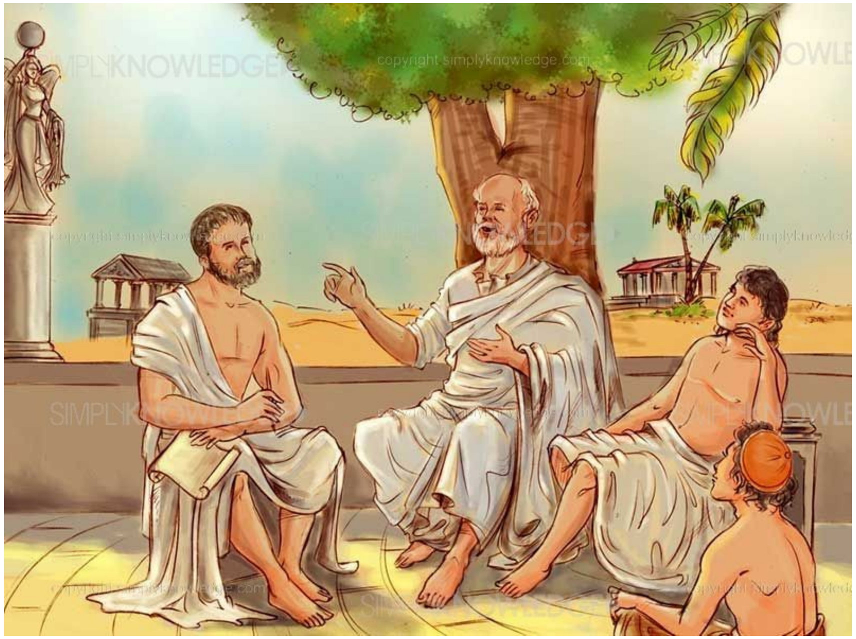


What can PLATO tell us about this complex coexistence?



Some facts about debris disks

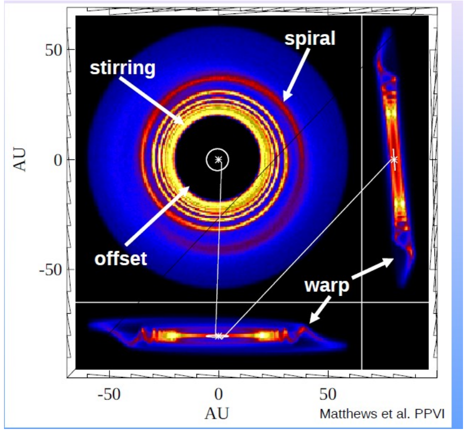
About 20% of solar type stars host debris disks (Eiroa et al. 2013 with DUNES-Herschel).

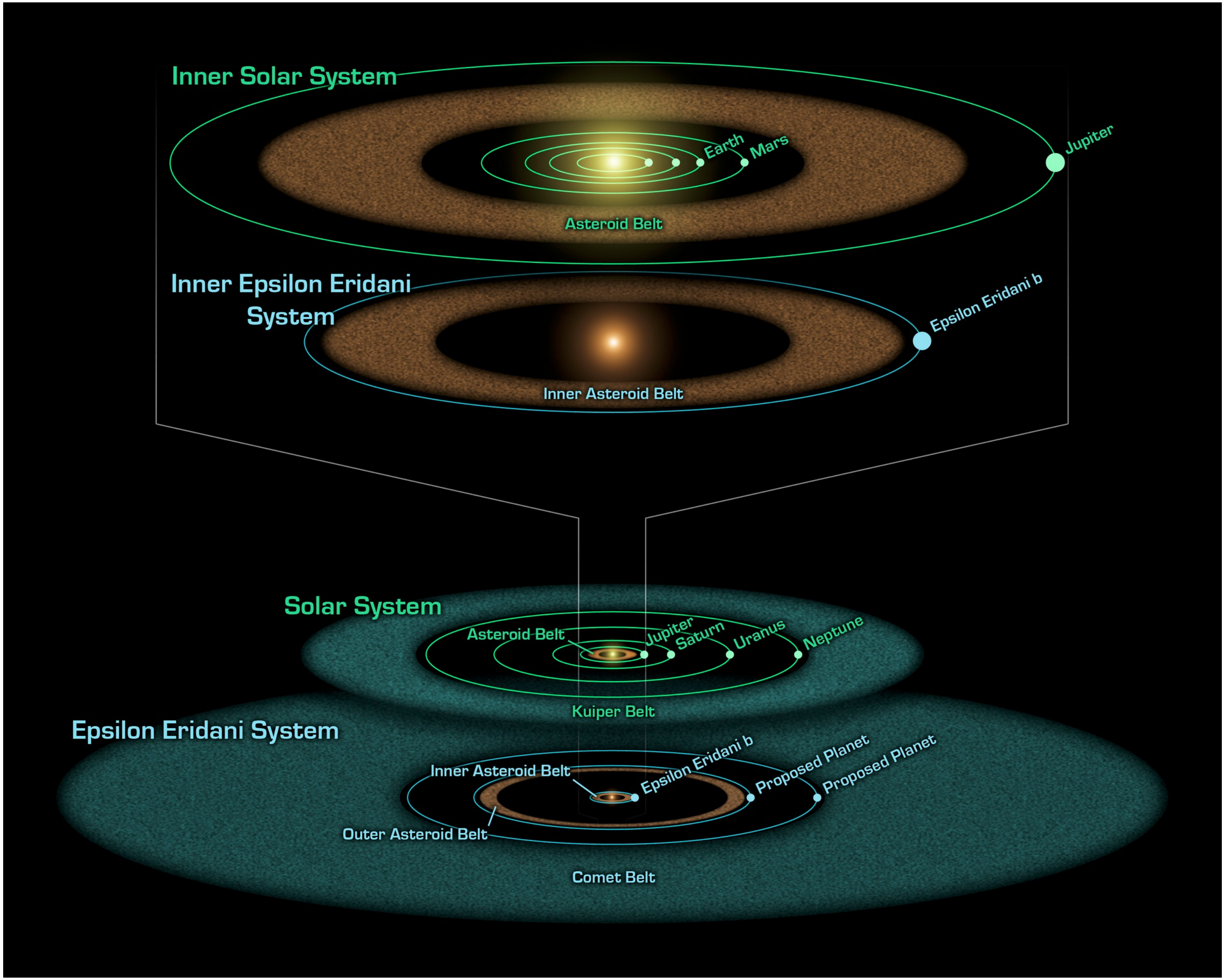
They are signature in most cases of planetesimal belts leftover of planet formation.

Many systems harbour cold and warm components possibly related to inner (asteroidal) and outer (Kuiper Belt like) planetesimal belts. Possible ambiguity in interpretation and radial distance location.

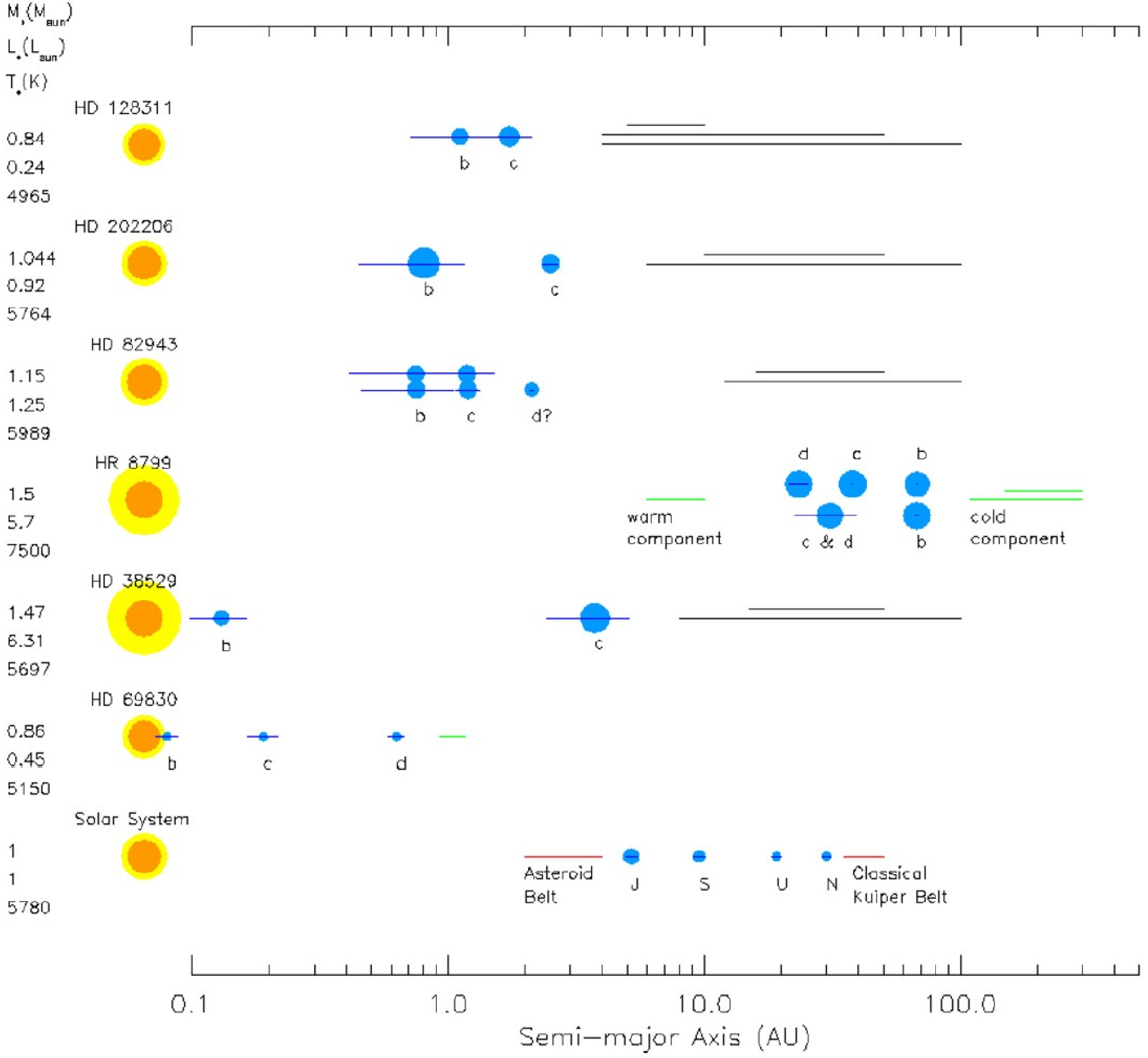
Relavant possible *correlations* of debris disks with:

- **Stellar age.** Some mild decline with age but small number statistics (Wyatt 2008)
- **Metallicity or spectral type.** Too poor statistics
- **Presence of exoplanets.** Some correlation but weak (in particular with small planets). Correlation with external planets discovered by direct imaging. Formation of spirals and warping if the disk is directly imaged.





Epsilon Eridani: Planetesimal belts: 1 or 2 in between 1-20 AU and another one beyond 64 AU. Need of a one or more planets inside the outer belt (40 AU?) to explain the dust-free zone (debated planet at 3.5 AU) (Su et al. 2017)

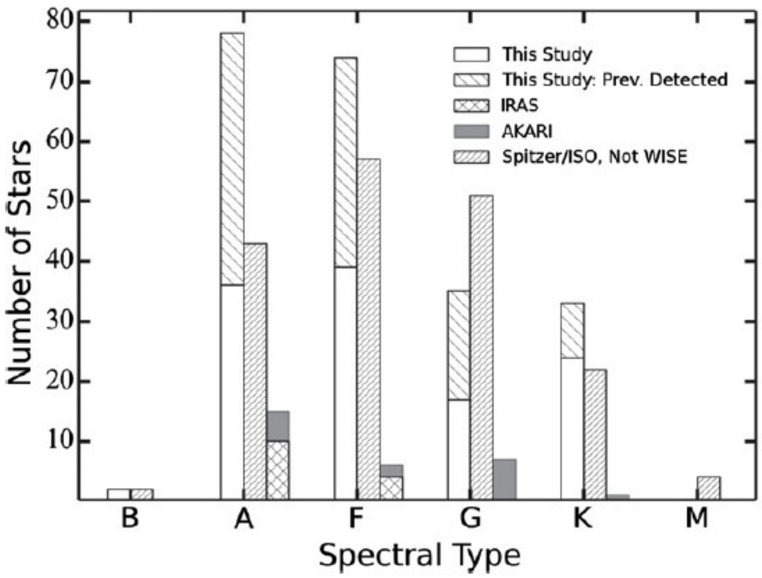


Moro-Martin et al. (2010)

Warm dust typical location: 0-10/20 au

Possible origins

- Mutual collisions (or giant impacts if the star is young) in a local planetesimal belt



Patel et al. (2014): stars within 75 pc

- Outgassing of comets similar to JFC comets: it requires a complex dynamical configuration similar to the solar system

- PR-drag inward migration of dust from an outer belt. It can be halted by planets ot it may possibly stop at the present snow line where the ices sublimate changing the PR-drag inward drift.

Nb: The last two mehcanims require an outer belt while some systems have only a warm component (Ballering et al. 2013).

5 good reasons to choose stars with infrared excess as PLATO targets.

- **Increase the discovery rate of terrestrial planets with PLATO since terrestrial planets should preferentially form in stars with debris disks**

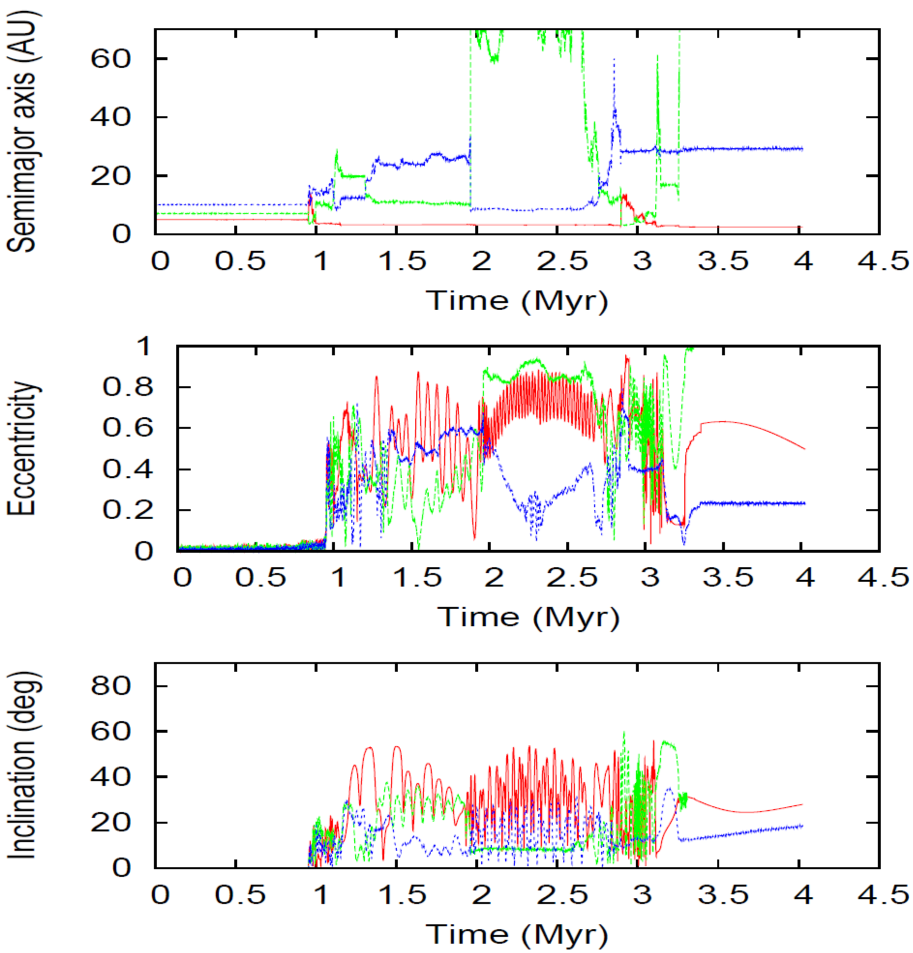
- **Investigate under which conditions the coexistance of planets and debris disks is possible clear the relation between planetesimal and planet formation. At present no convincing evindence of such correlation between warms belts and close planets. Direct imaging searches have found that systems with *far* exoplanets often have debris disks, i.e., β Pic, HR 8799, and HD 95086 (Rameau et al. 2016). Need to improve statistics for *close* planets.**

- **Derive constraints on the architecture of planetary systems (presence of double belts, localization of the edges of the belts respect to planet orbits etc.)**

- **Test theories of post-formation dynamical evolution:**
  a) Chaotic evolution with P-P scattering of giant planets and survival of debris disks
  b) Planet migration by planetesimal scattering

- **Test the correlation between debris disk brightness & stellar age (PLATO will give good age estimates). Old stars: collisional erosion of the planetesimal belts. Young stars: giant impacts during the final formation of terrestrial planets?**

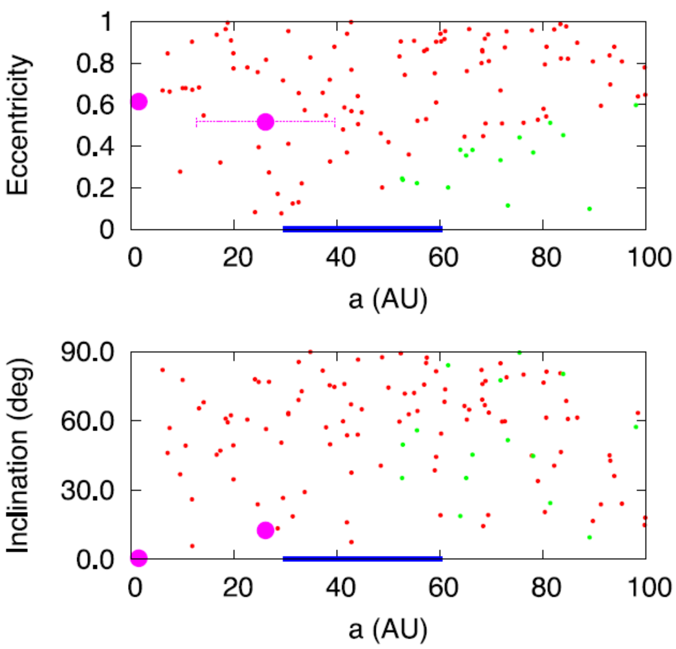
We DO NOT expect cohabitation of disks and planets in presence of giant planets in eccentric orbits.

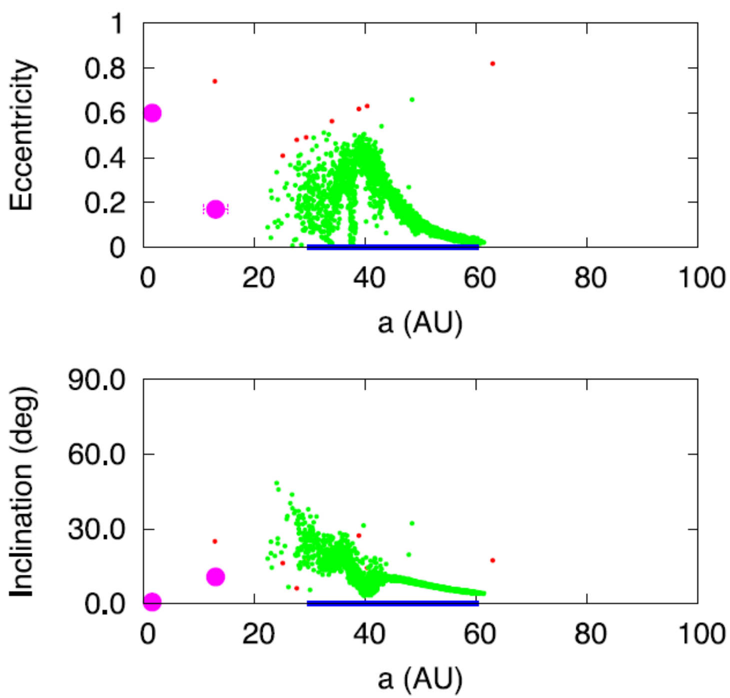


No debris disk may indicate a period of dynamical instability. Planet-planet scattering in a newly born planetary system may destroy any leftover planetesimal belt.

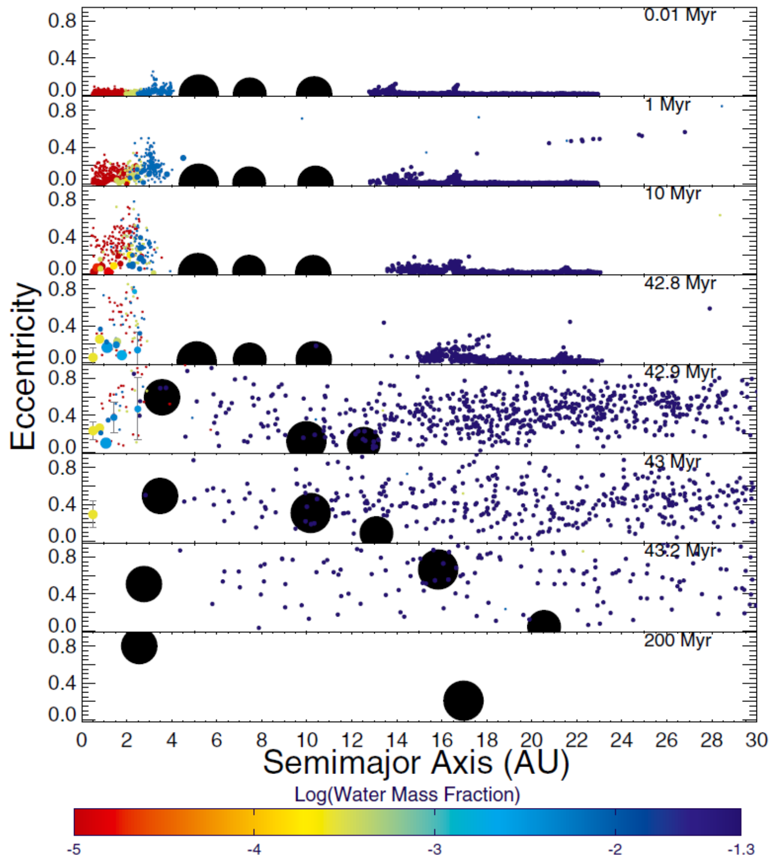
$$\Delta_c \sim 2\sqrt{3}R_H$$

Planets roaming around on high eccentric orbits scatter all leftover planetesimals at different degrees depending on the P-P scattering dynamics.



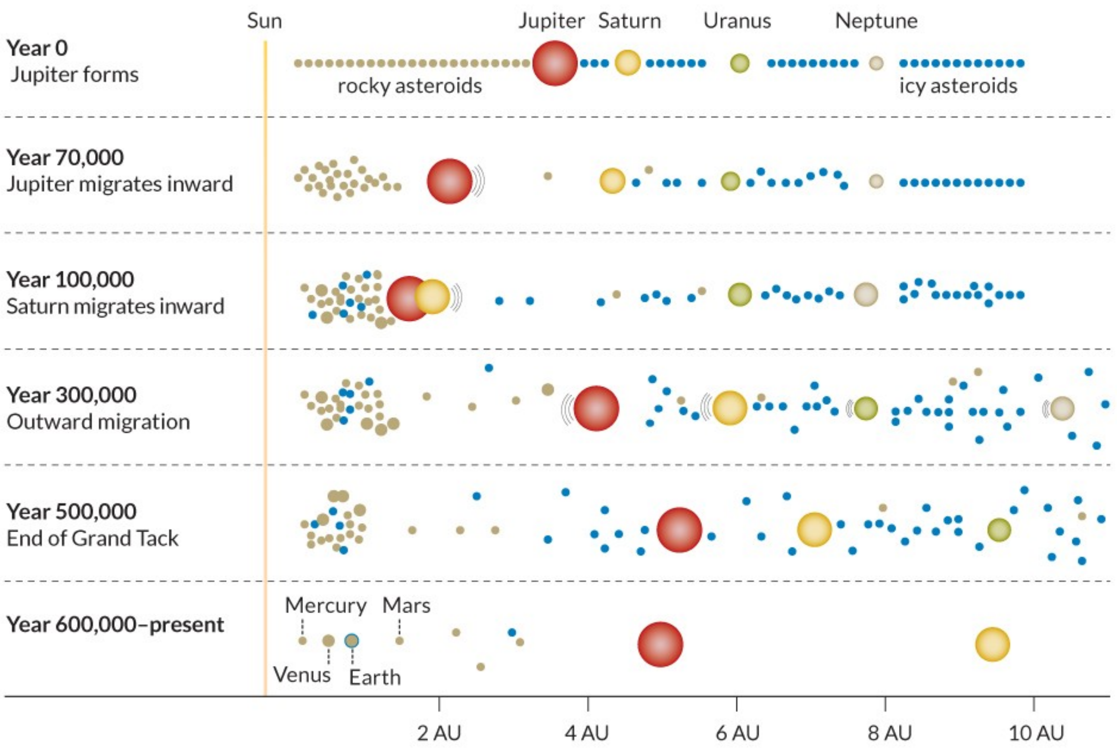


Two extremes: on the left the chaotic phase is long and the planetesimals are almost all scattered away. On the right, the chaotic phase is short and the belt is collisionally 'activated' but not dispersed (Marzari, 2014).



Similar results by Reymond et al. (2012)

Various different dynamical paths ...



Other possible less perturbing evolution can be envisaged like the Grand Tack (Walsh et al. 2011)

We DO expect cohabitation of disks and planets in presence of terrestrial planets! Magic words: *formation & survivial*

a) Planetesimal formation and accumulation is at the origin of both debris disks and rocky planets.

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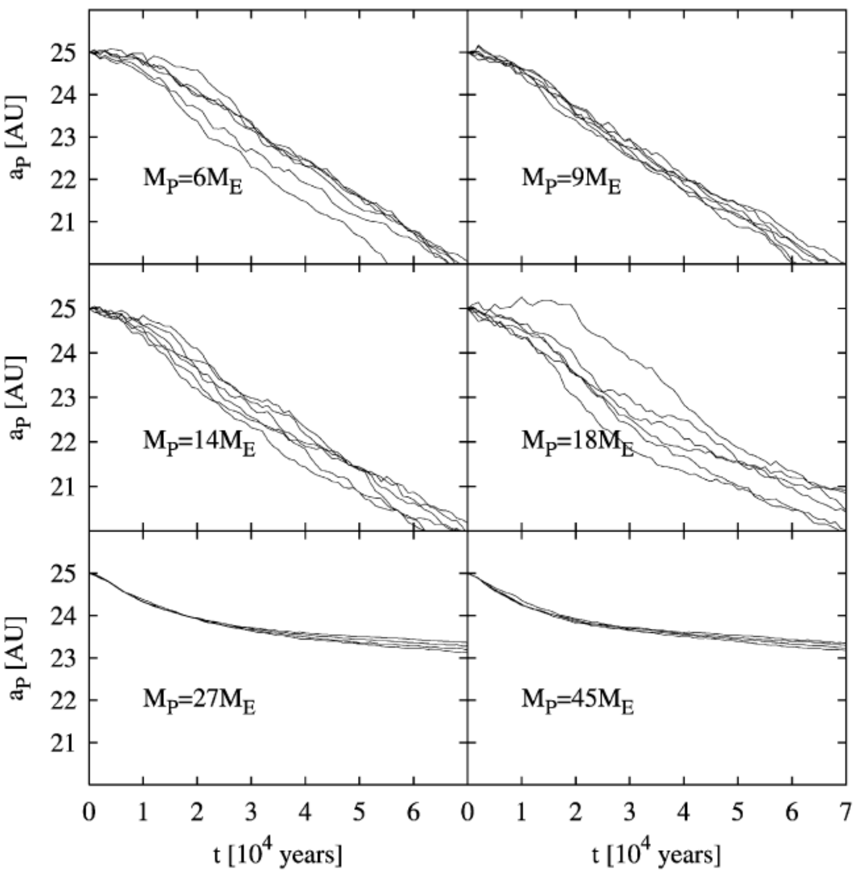
b) *Dynamically calm conditions favor the formation of massive terrestrial planet systems and simultaneous survival of debris disks.* Ad example, Wyatt et al. (2012) find that the RV-discovered systems with only Saturn-mass planets have a higher-than-expected debris disk fraction, 4 out of 6 (67%) compared to 4 of 11 (36%) in the full sample of stars with RV planets. The correlation between higher disk fraction and lower-mass planets suggests that the formation mechanism for Saturn-only systems results in large, stable debris disks which can produce dust for a long time (small number statistics). This can be extended to Super-Earth or Earth like planets (Raymond et al 2011, 2012).

Interesting dynamicsl mechanisms acting in presence of both planets and disks: 1) migration by planetesimal scattering

Kirsh et al. (2009) Planetary migration due to planetesimal scattering (revisiting old idea of Murray et al. (1998) for smaller planets.

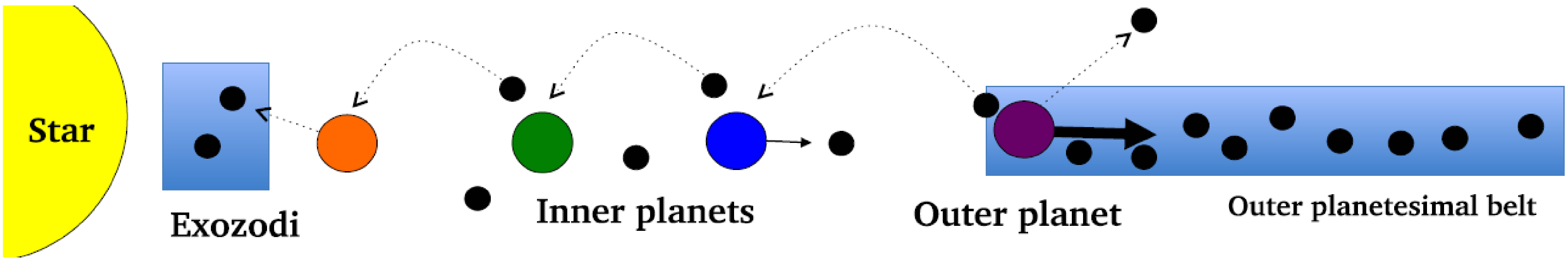
$$\frac{da}{dt} = 4\frac{M_D}{M_S}\frac{d_p}{T_p}$$

At 1 AU the timescale scales to abut 6 x 10^7 yr



Statisical implications? Stars with debris disks should have planets closer to the star on average due to migration.

2) Complex configurations of planets and dusty belts due to mutual interactions. **Bonsor et al. (2014) explains the excess of warm dust observed in some systems (not explicable by a collisionally active inner belt) with some kind of late heavy bombarment where planetesimals from a putative outer belt are injected into an inner belt causing an higher than normal collisional activity and the presence of exozodi (high density warm dust).**



Even in this case a calm dynamical evolution is required so that the planets are on low eccentricity orbits.

In CONCLUSION, in the selection of PLATO targets it is important to devote a significant effort to include stars with known infrared excess. This would:

- **Enhance the probability of finding terrestrial planets**
- **Test statistically theories about the coexistance of giant planets and debris disks and its dependence on their eccentricity**
- **Increase the probability of finding solar system analogs.**
- **Better outline the radial extent of dusty belts (planets shape the planetesimal belts) and eliminate possible ambiguities in the interpretation of SEDs**
- **Test theories of planet migration in general and by planetesimal scattering in particular and late heavy bombardement analogs**
- **Estimate debris disk collisional erosion.**
- **Possibility of proving the coexistence of outer planets, possibly formed by disk instability (and discovered by direct imaging), with inner planets formed by core accretion (whose presence is suggested by debris disks).**