Debris Disks in STIPs

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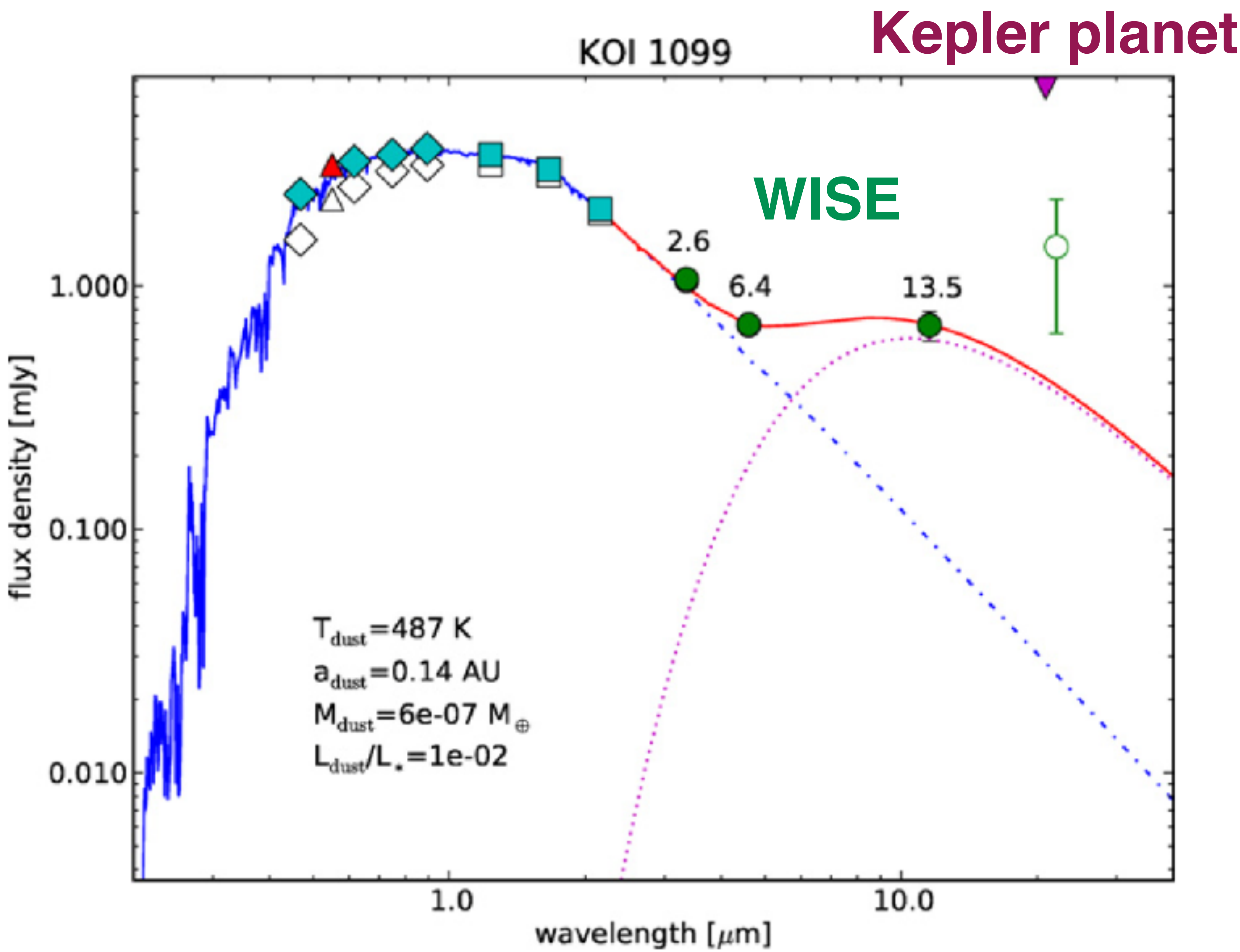
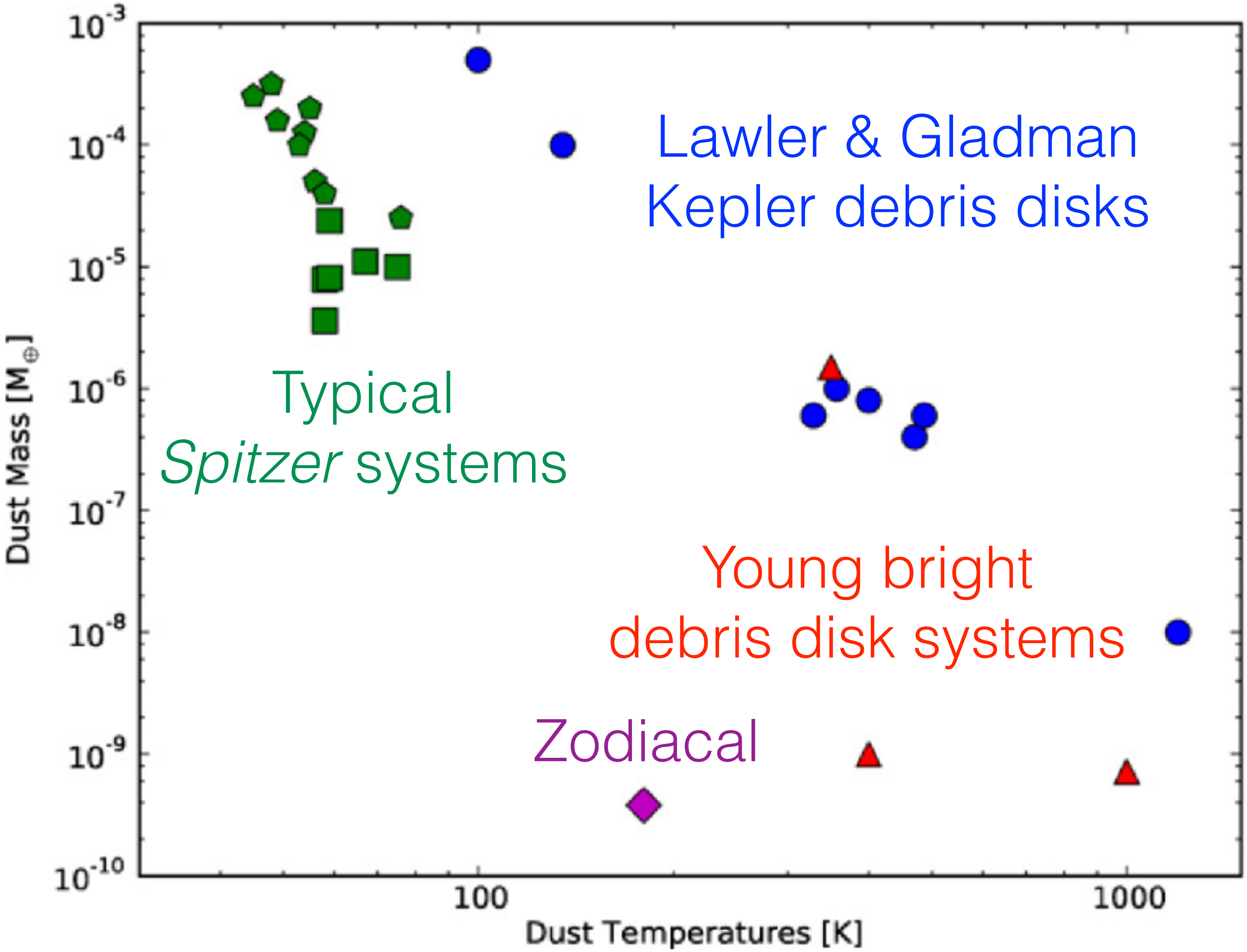
Debris Disks in Kepler systems: observations

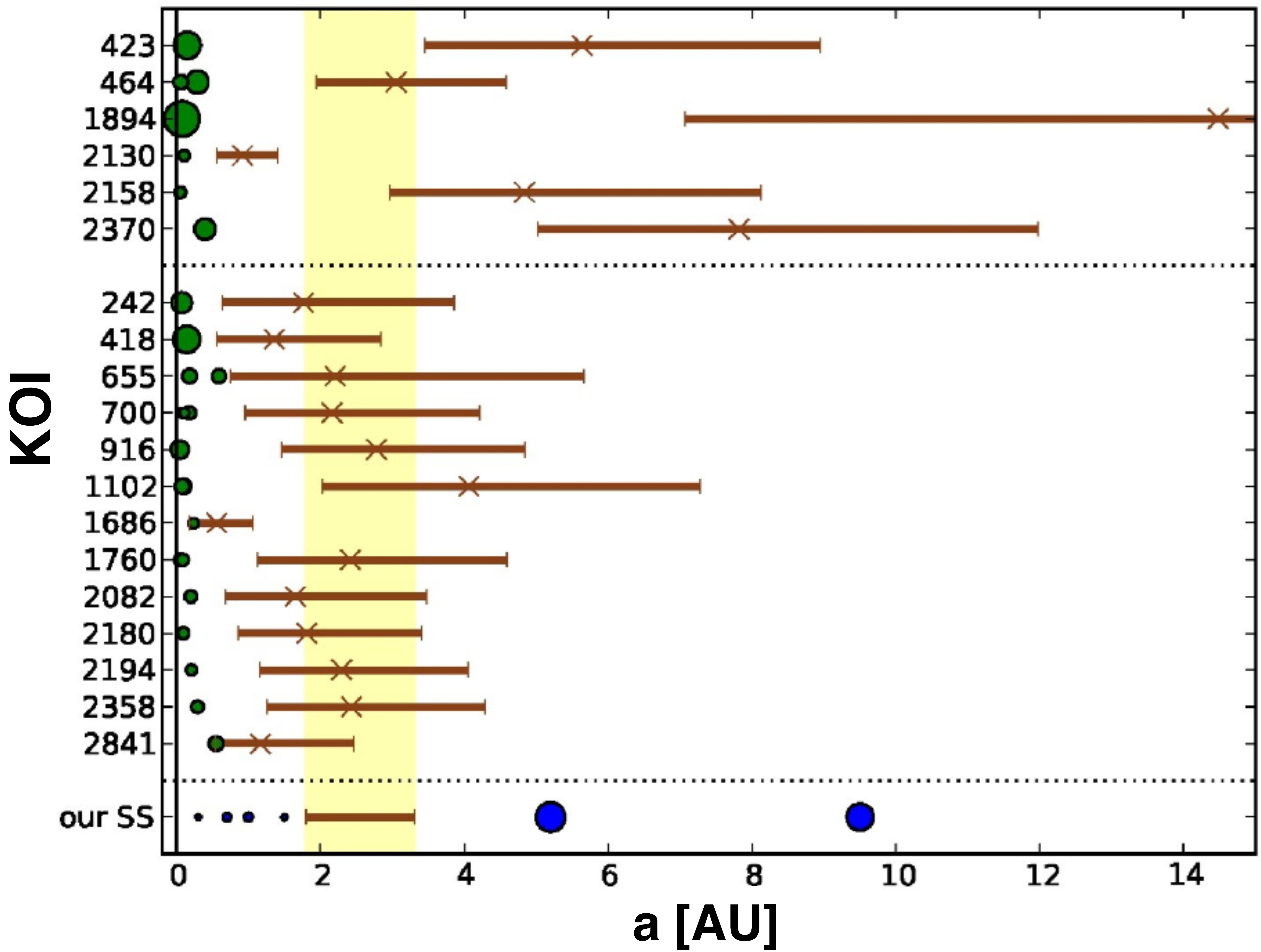


Lawler & Gladman (2012)

Debris Disks in STIPS: observations

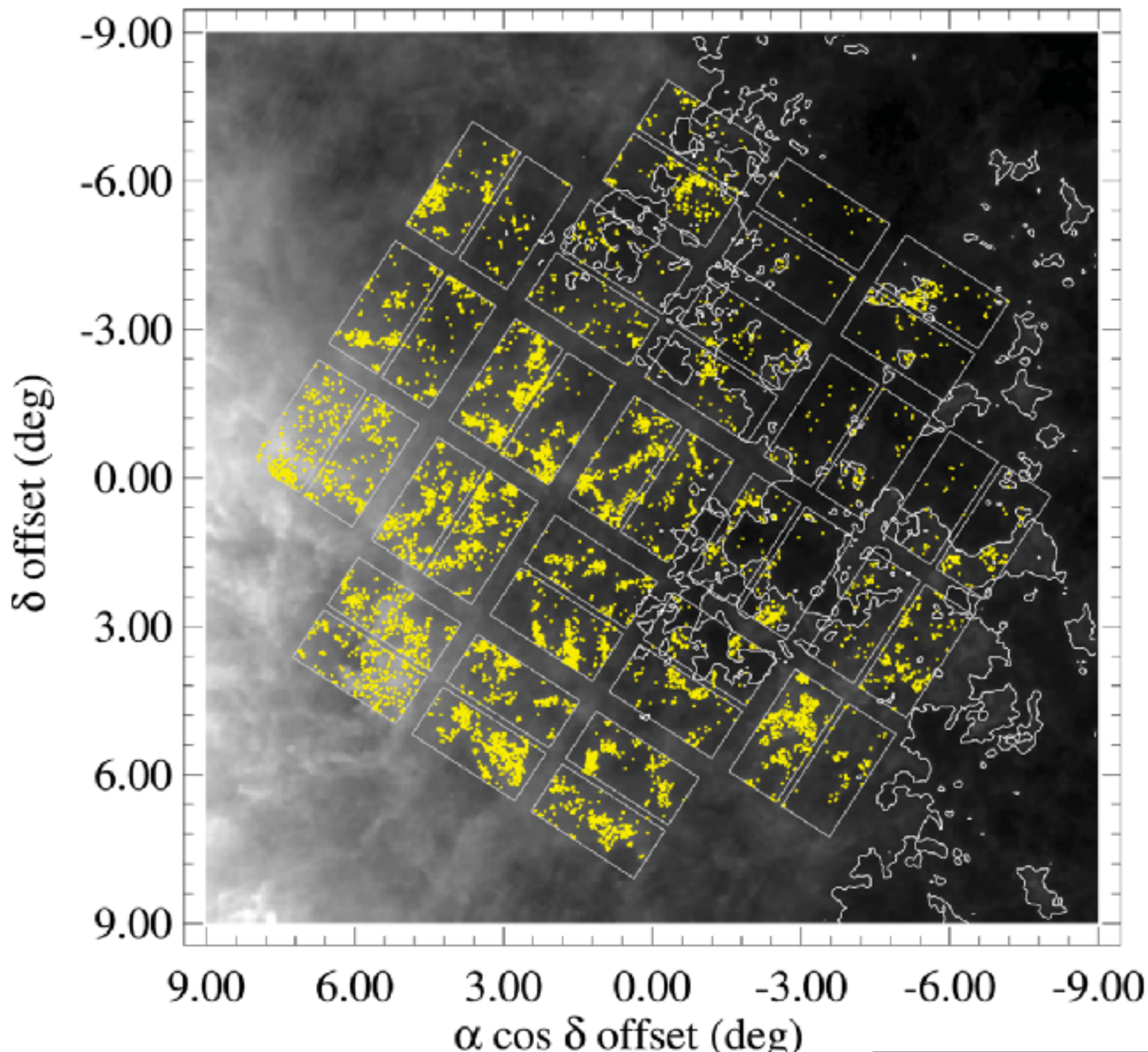


Lawler & Gladman (2012)



Lawler & Gladman (2012)

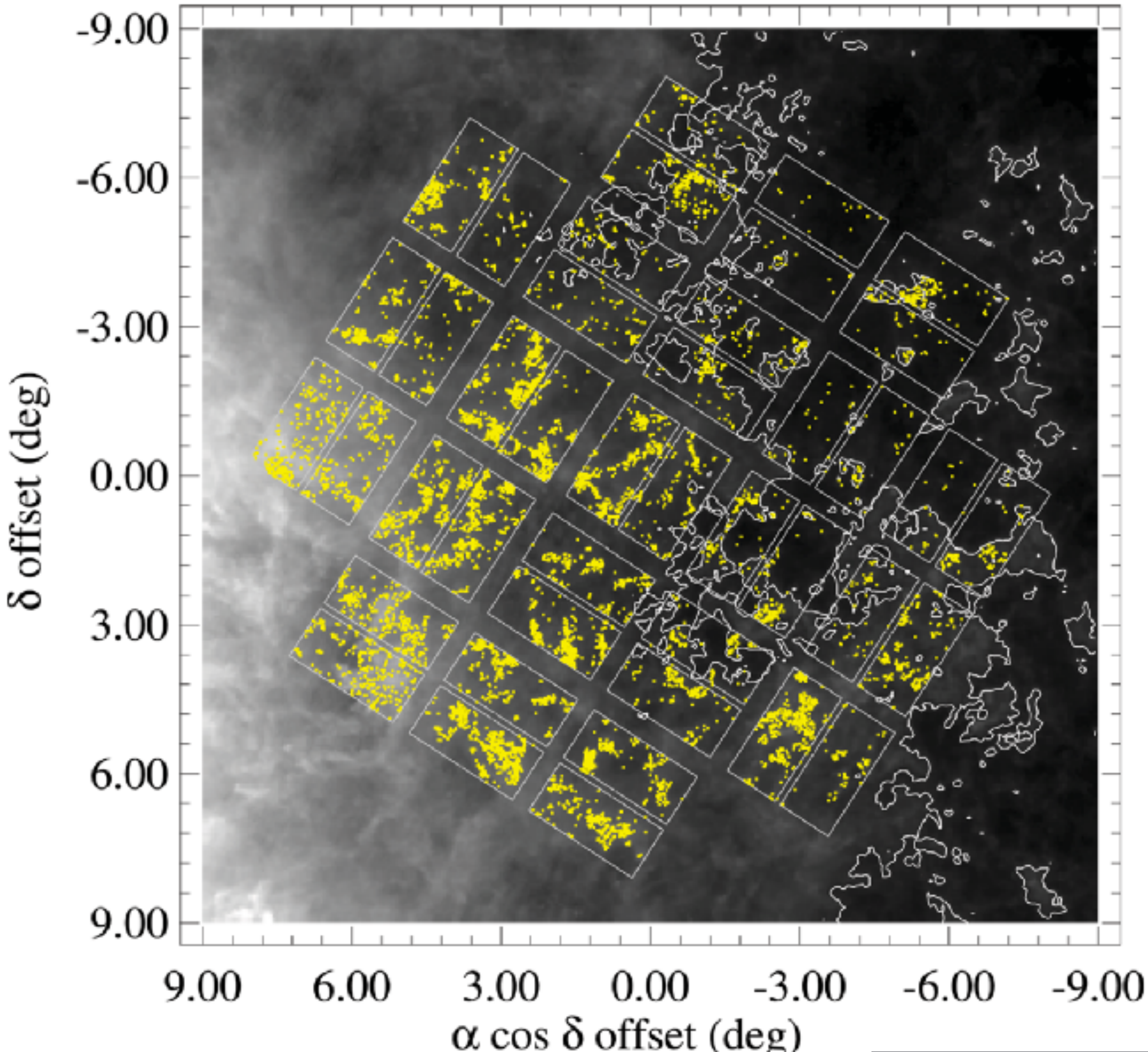
Kepler systems are too far away. Stupid Galaxy.



Kennedy & Wyatt (2012)

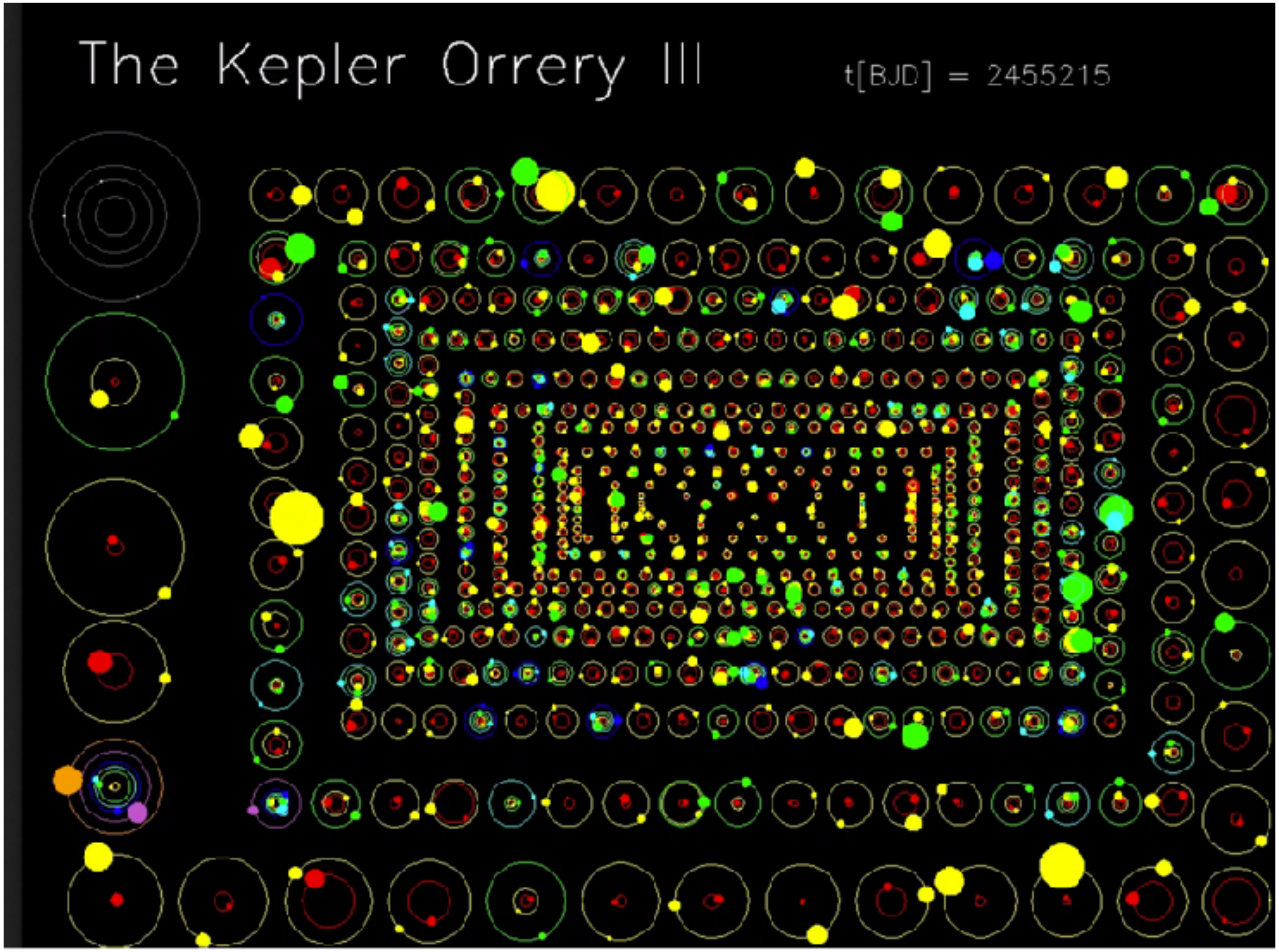
Know thy star (background), Know thy planet(esimals)

[or that you can't observe them…grr]



Kennedy & Wyatt (2012)

STIPs



D. Fabrycky

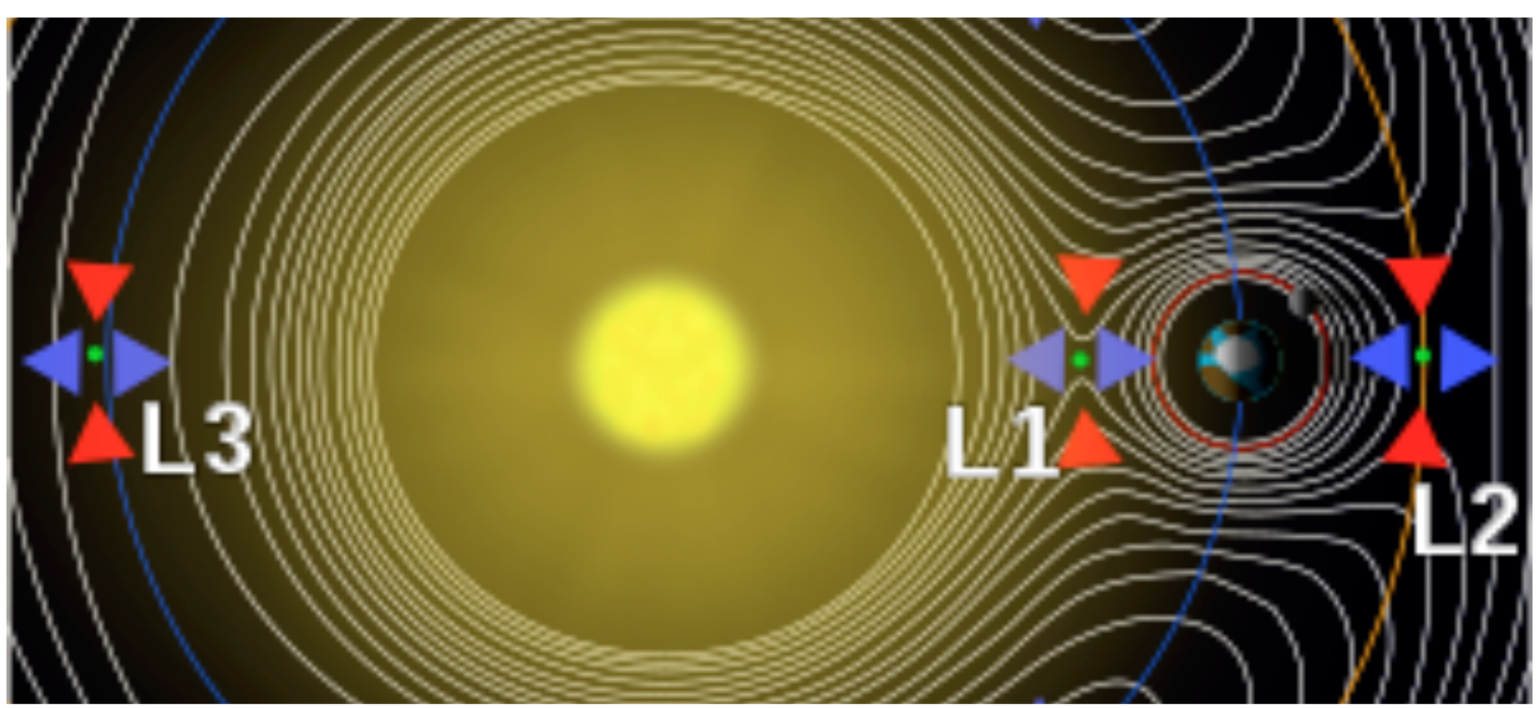
So much rocky material
But what is in outer parts of systems?

Defining “packedness” (yes that’s totally a word)

$$\Delta = \frac{a_2 - a_1}{R_{H1,2}}$$

e.g.
Gladman 1993
Chambers+ 1996

$$R_{H1,2} = \left(\frac{M_1 + M_2}{3M_*}\right)^{1/3} \frac{a_1 + a_2}{2}$$



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$$R_{H1,2} = \left(\frac{M_1 + M_2}{3M_*} \right)^{1/3} \frac{a_1 + a_2}{2}$$

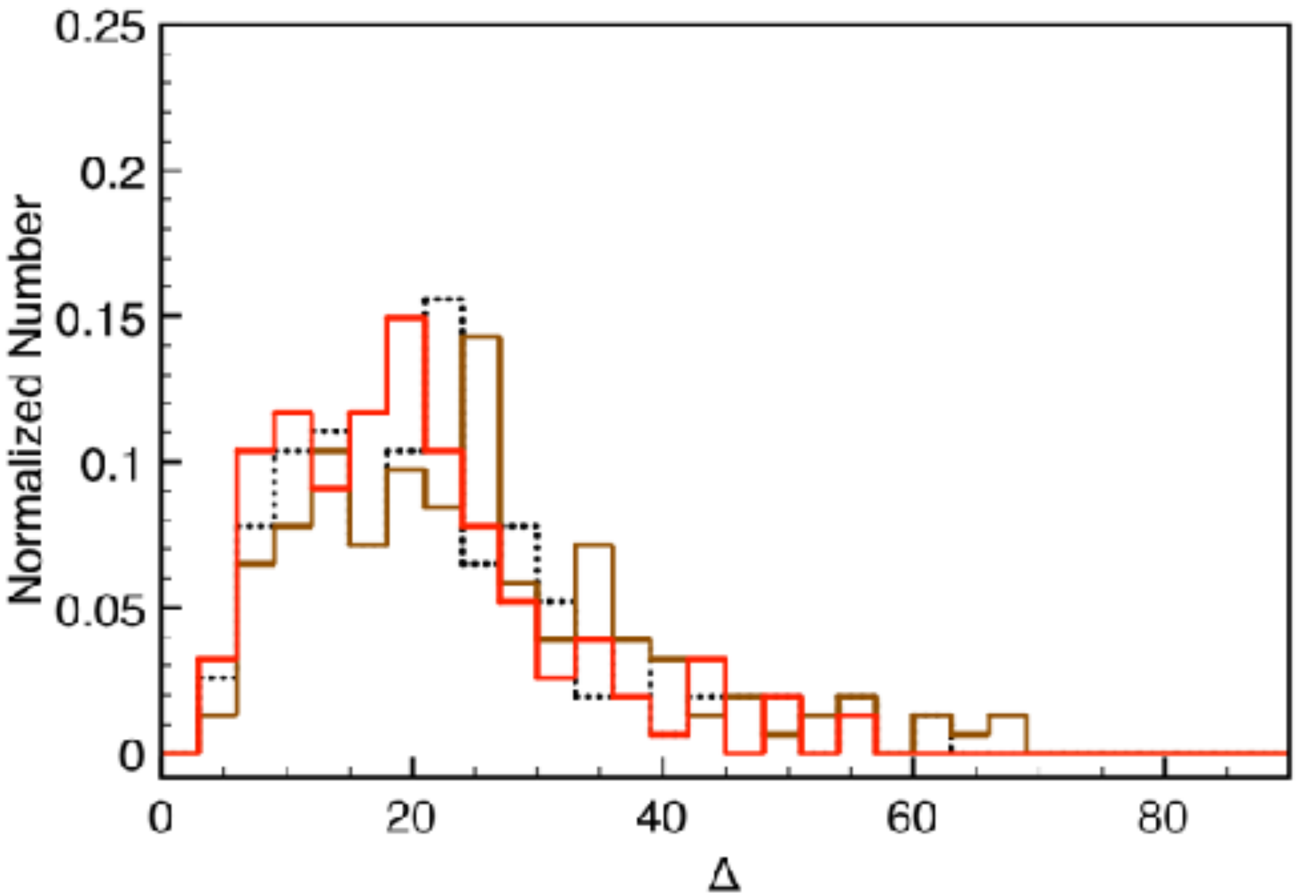
$$\Delta > 3.46$$

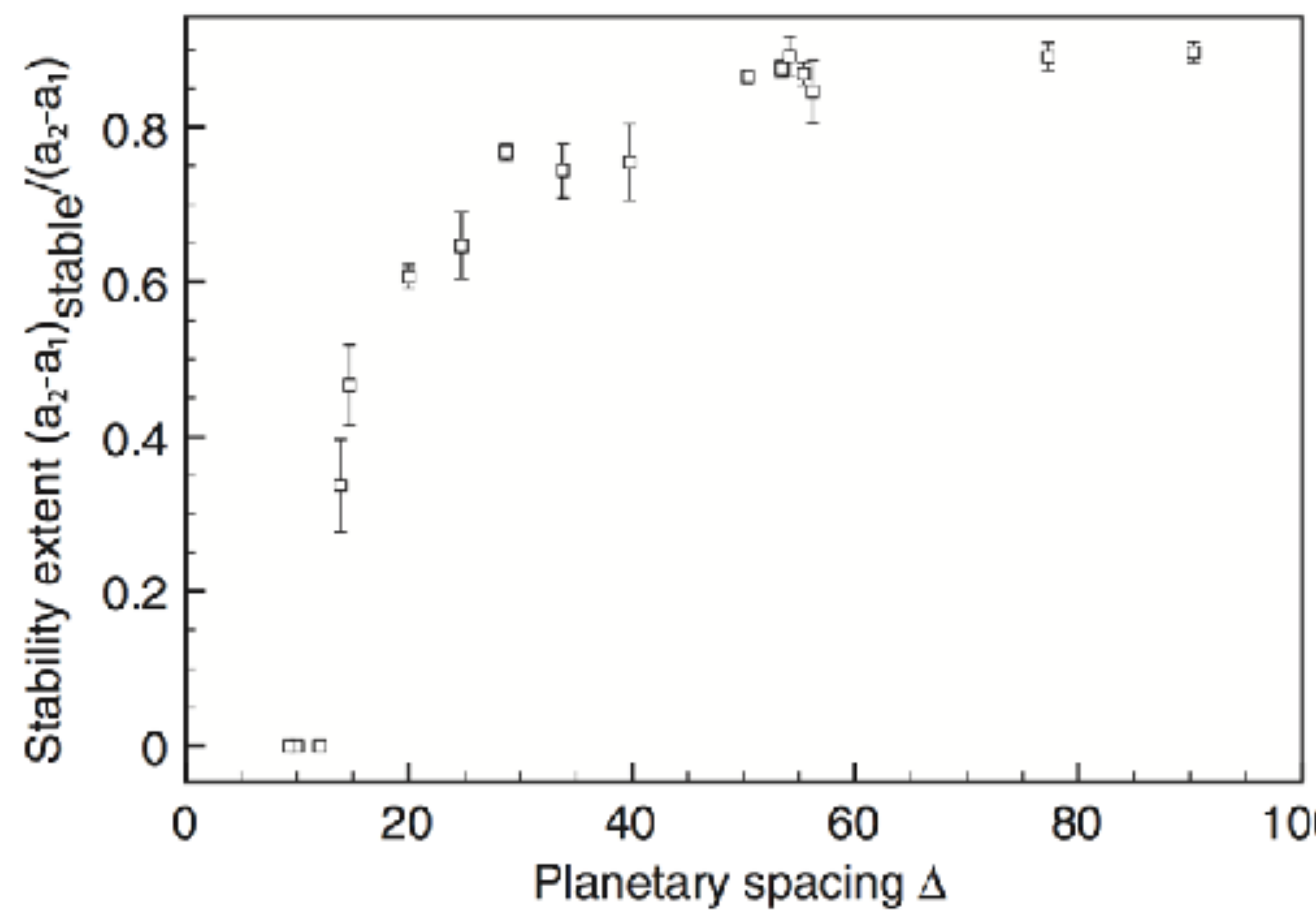
For a non-resonant 2-planet system to be stable

Gladman 1993

No analytic solution for >2 planet systems

How packed are STIPs?





“Tightly packed”

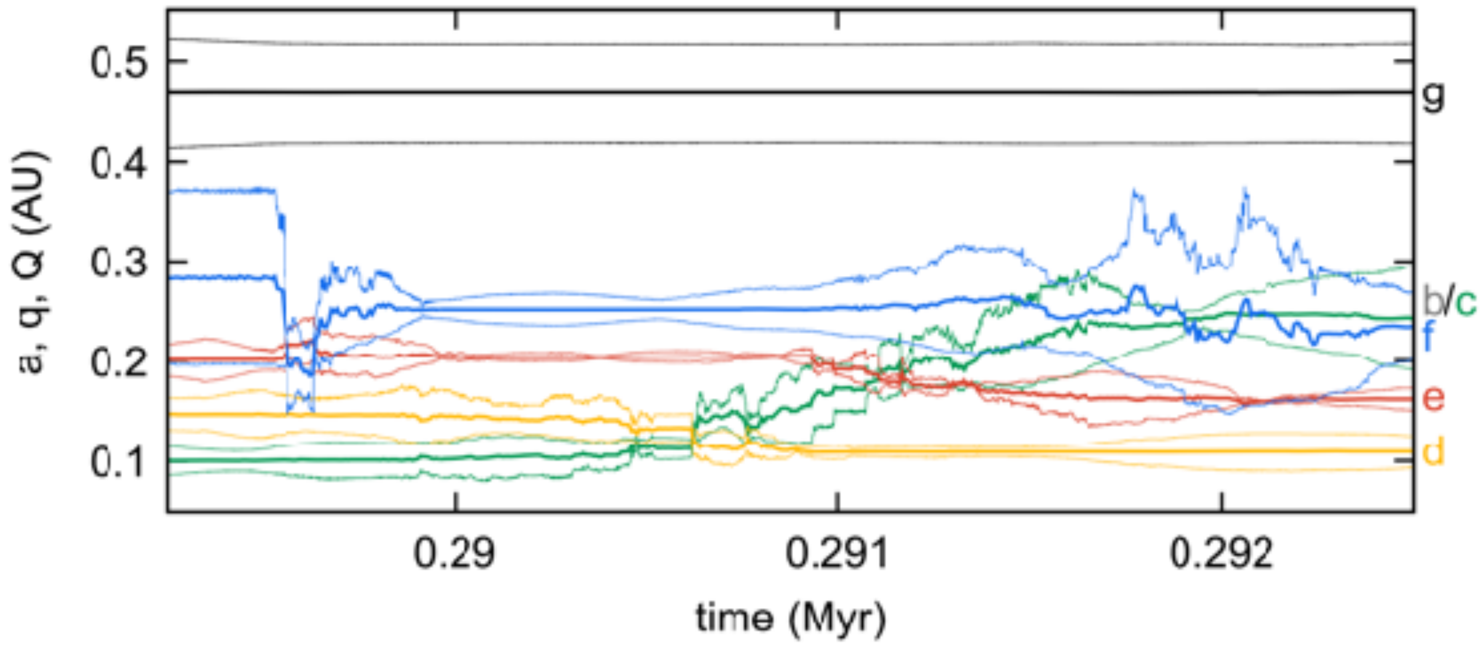
1/3 of 2 and 3 planet Kepler systems

1/2 of 4 planet Kepler systems

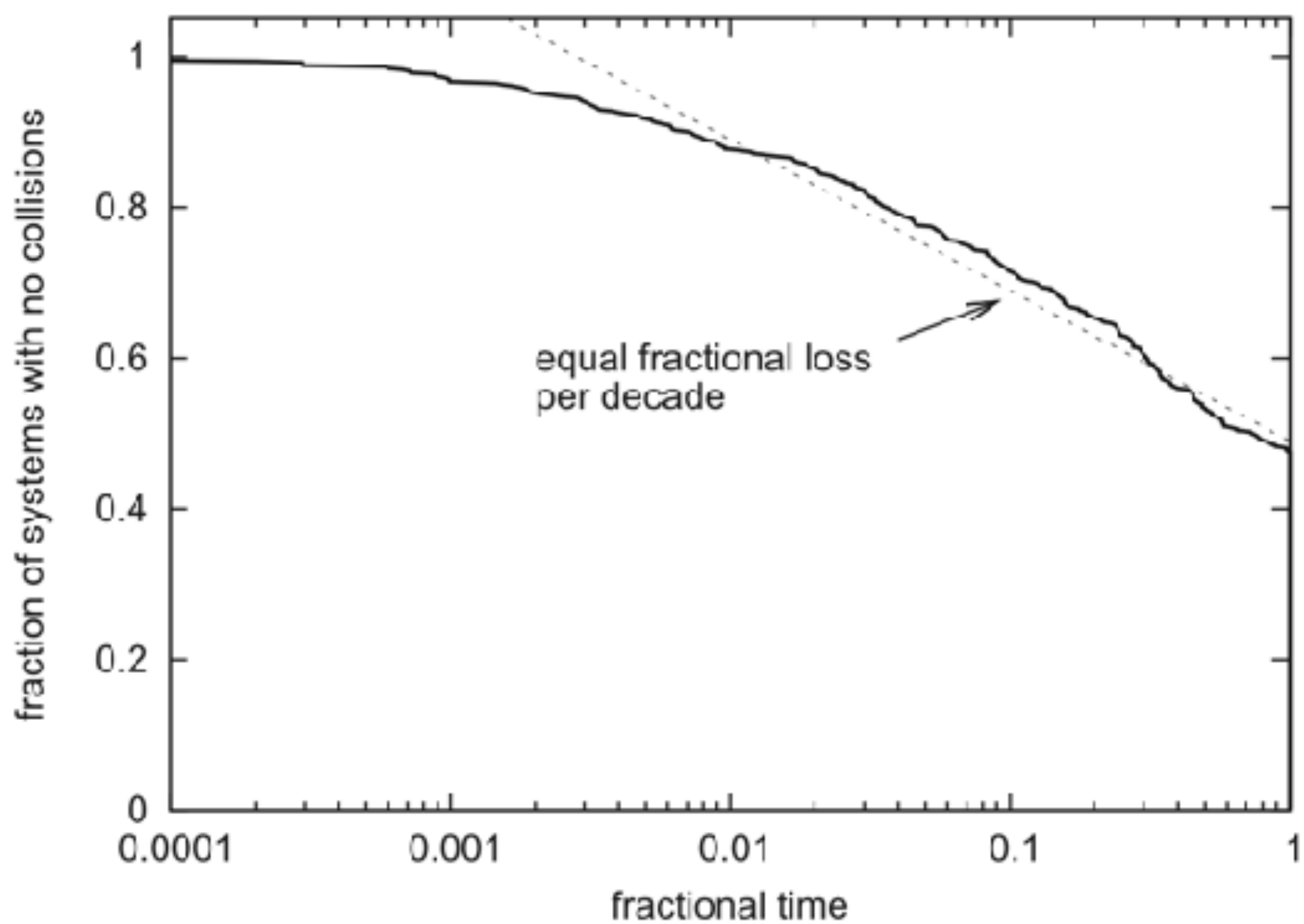
Fang & Margot (2012, 2013)

STIPs are metastable

Kepler 11 analogue

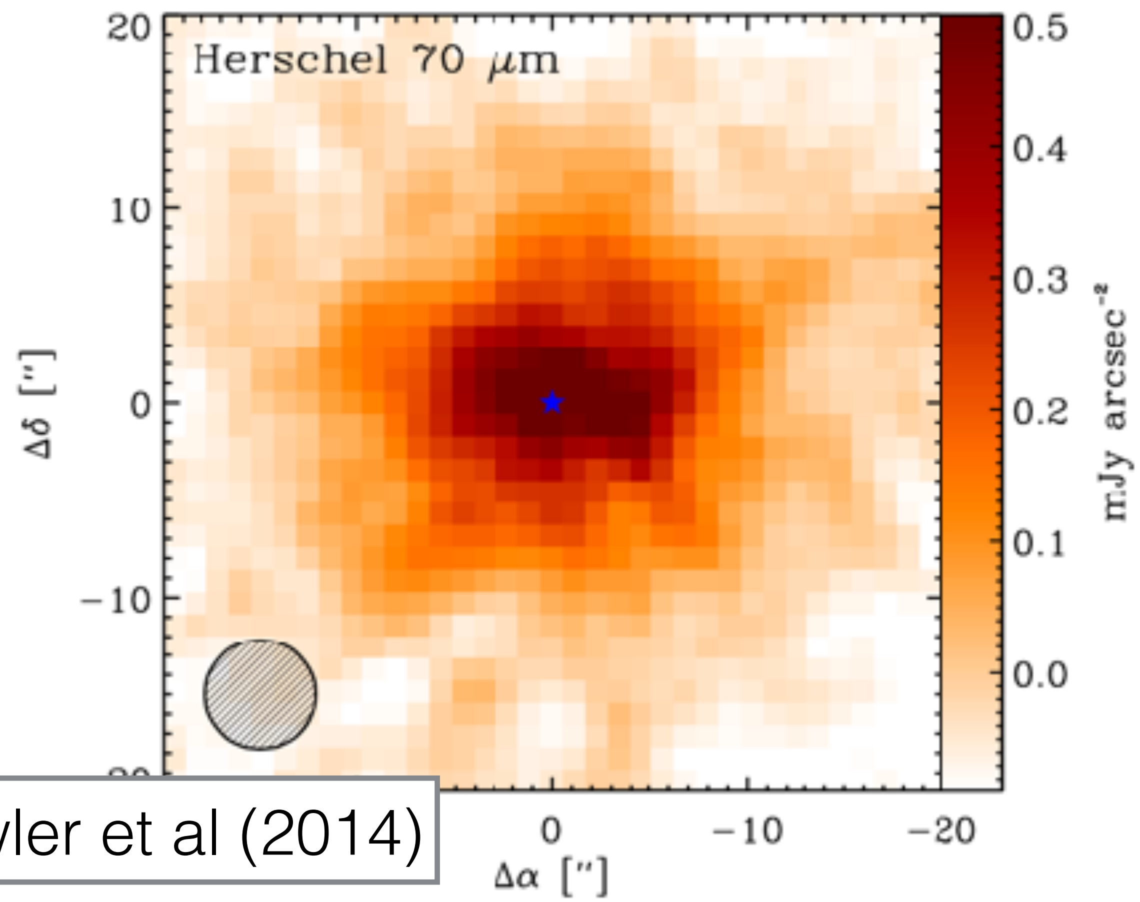


Volk & Gladman (2015)

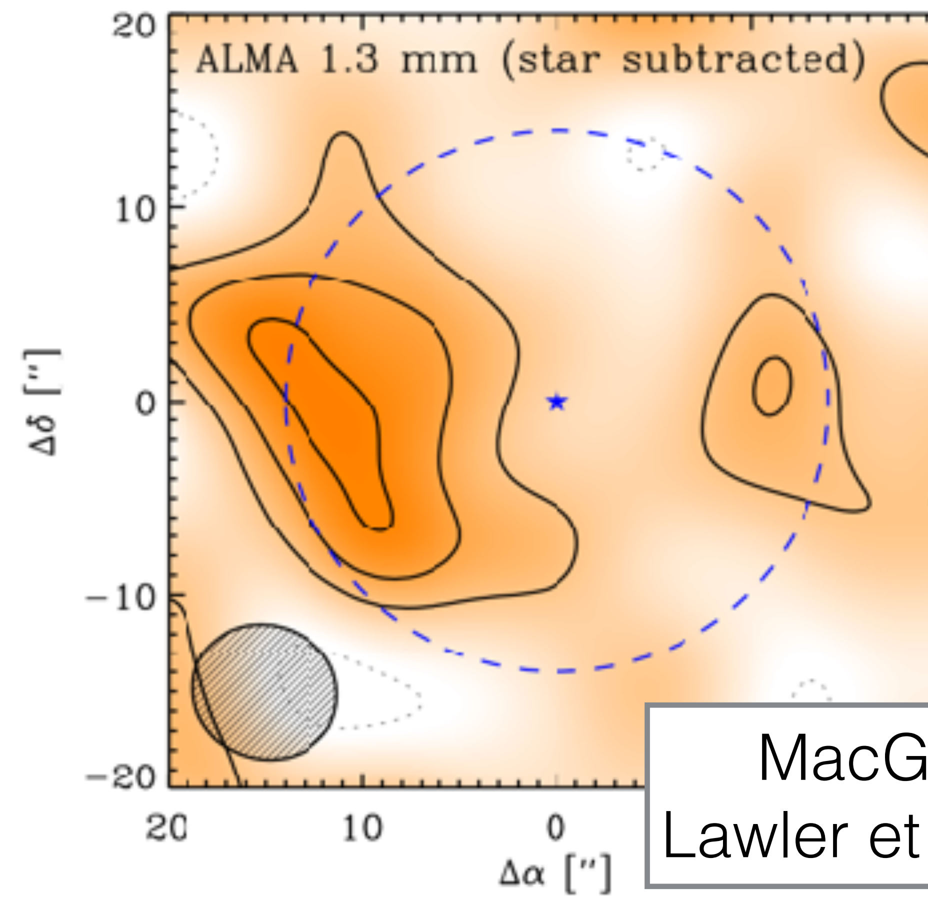


(same result in Wu & Pu 2015, Hwang+ 2017)

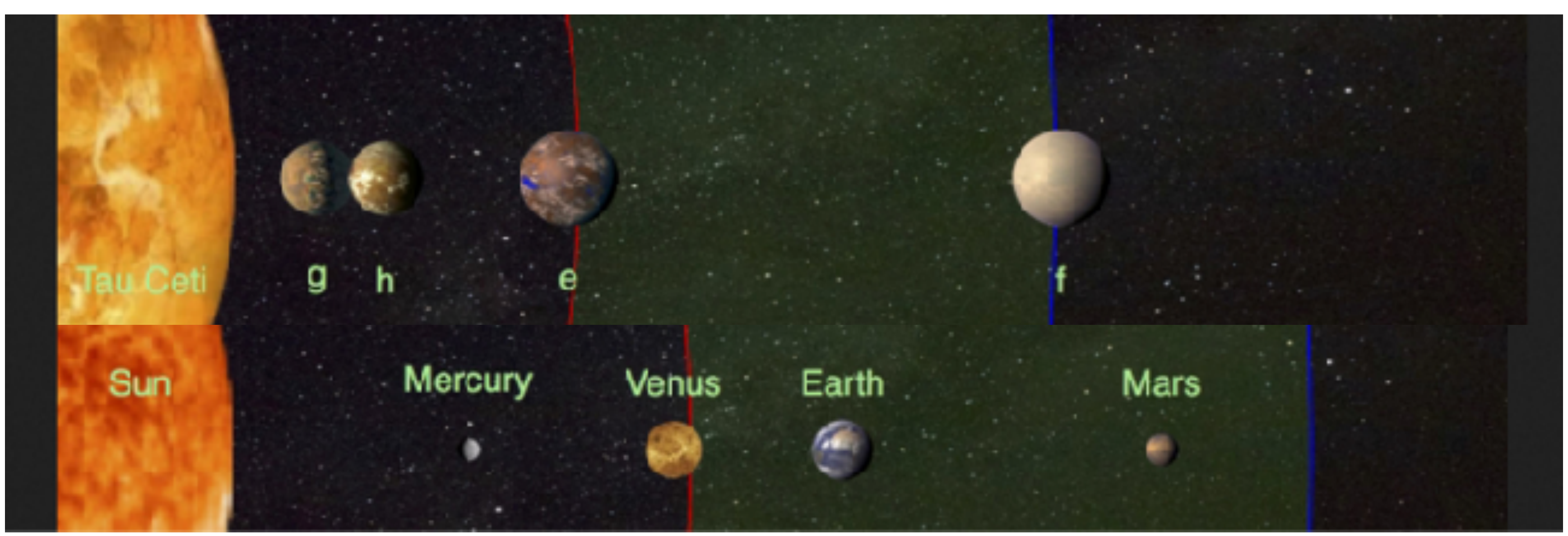
tau Ceti: a STIP with a debris disk



Lawler et al (2014)



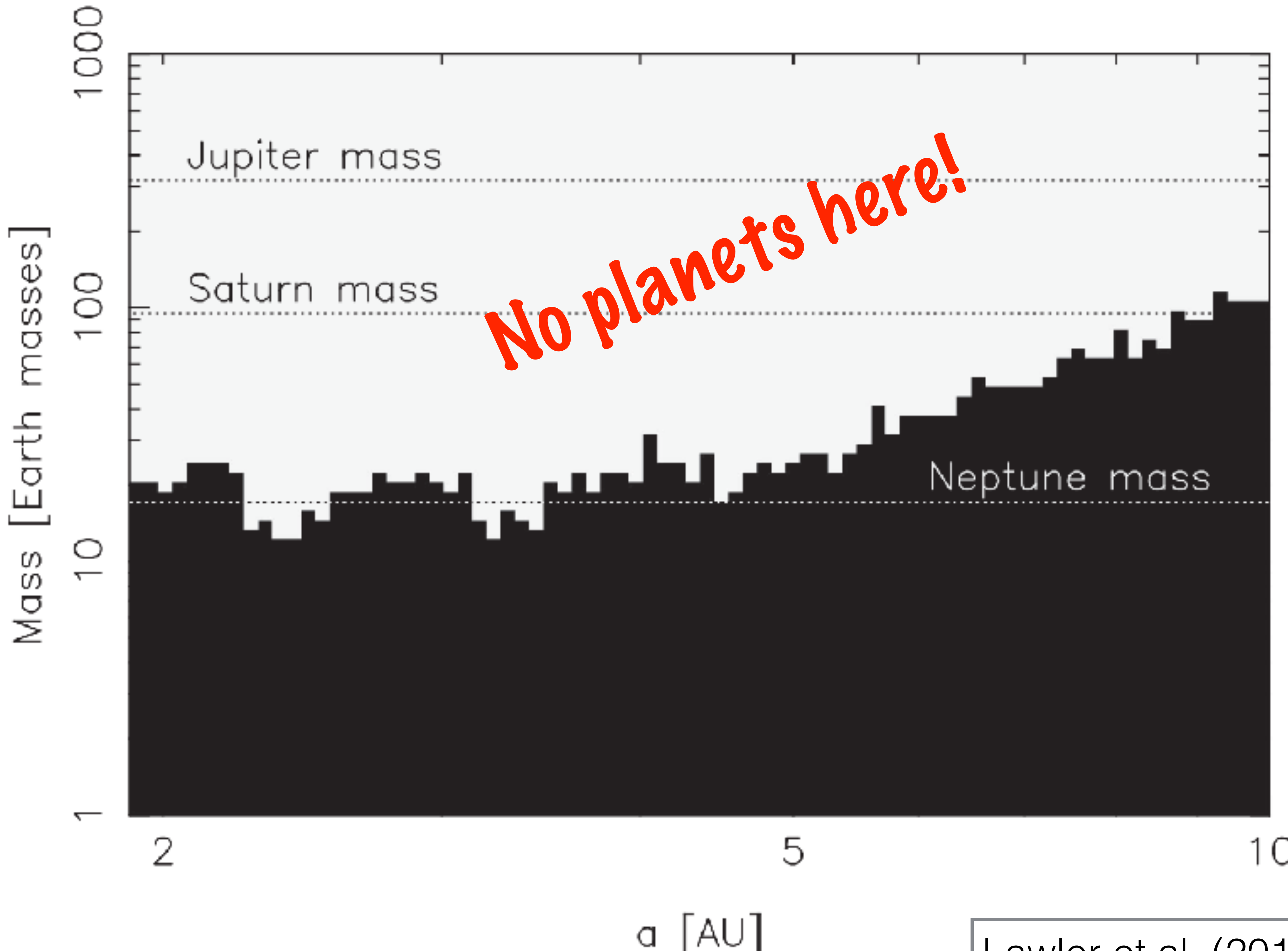
MacGregor, Lawler et al (2016)



STIP confirmed

Feng et al. (2017)

tau Ceti: a nearby STIP with a debris disk?



Lawler et al. (2014)

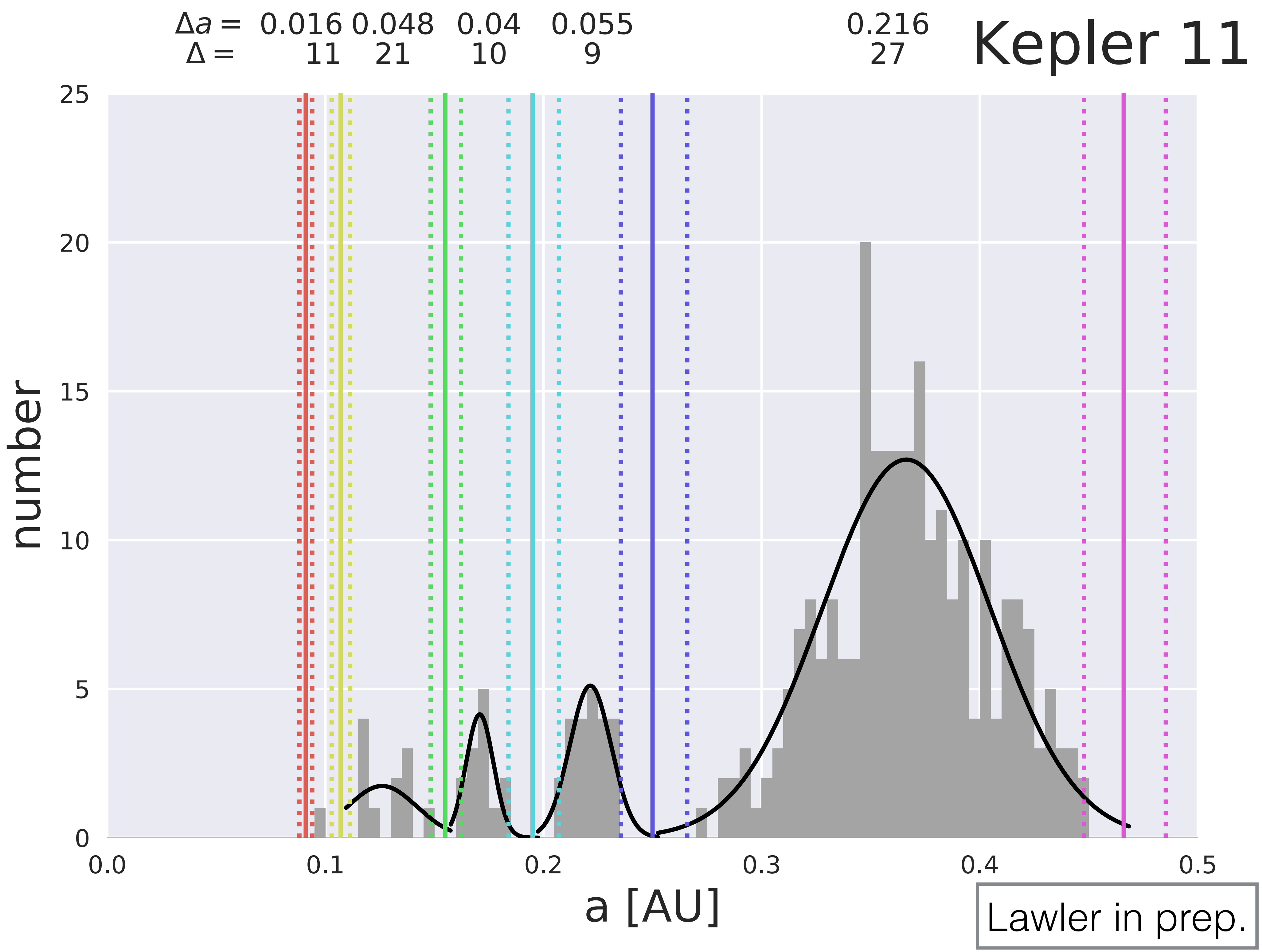
SIMULATION ZONE WARNING!

Everything I will talk about now is completely made up

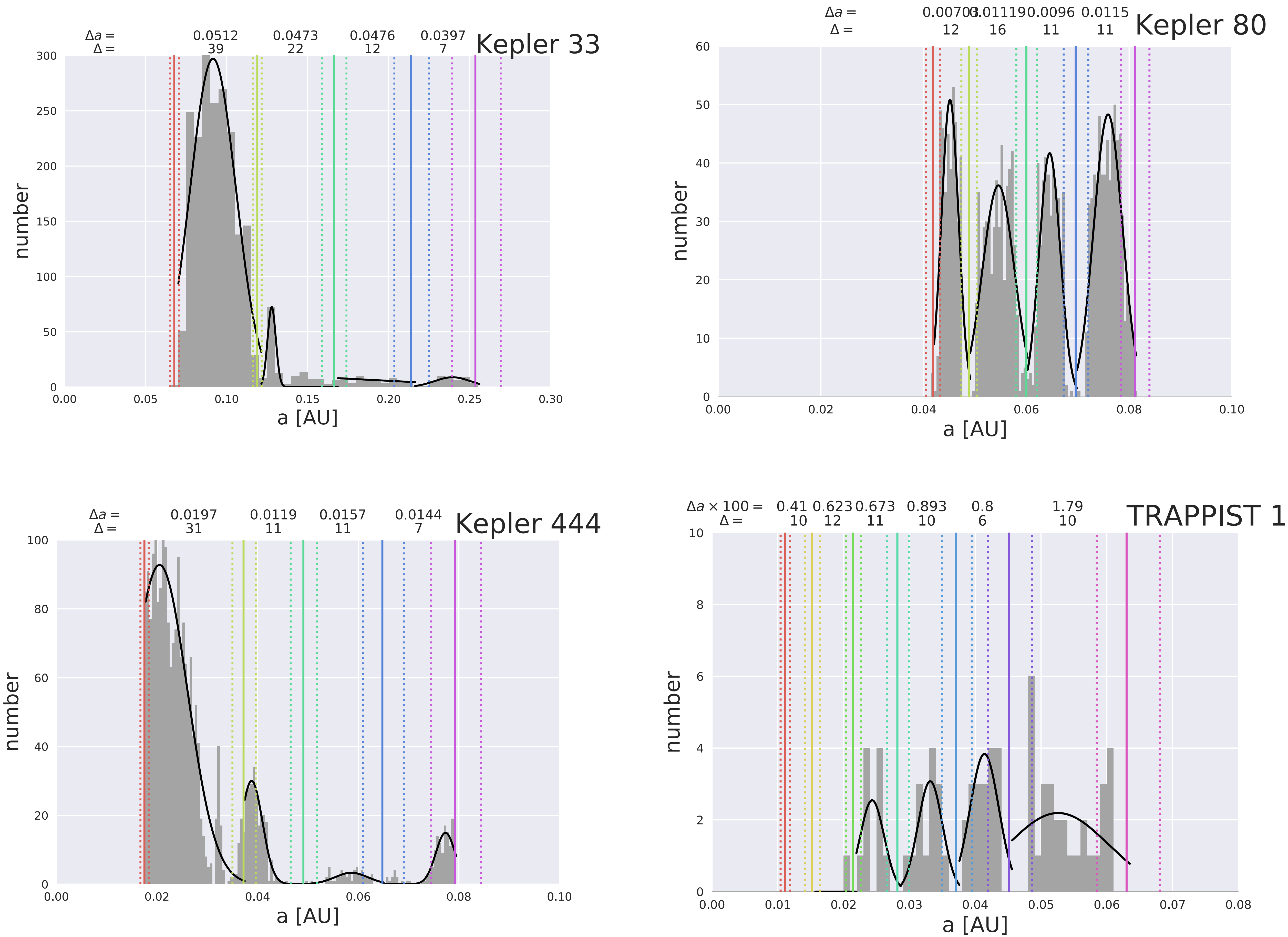
SIMULATION ZONE WARNING!

Everything I will talk about now is completely made up

I’ll build my own debris disks!

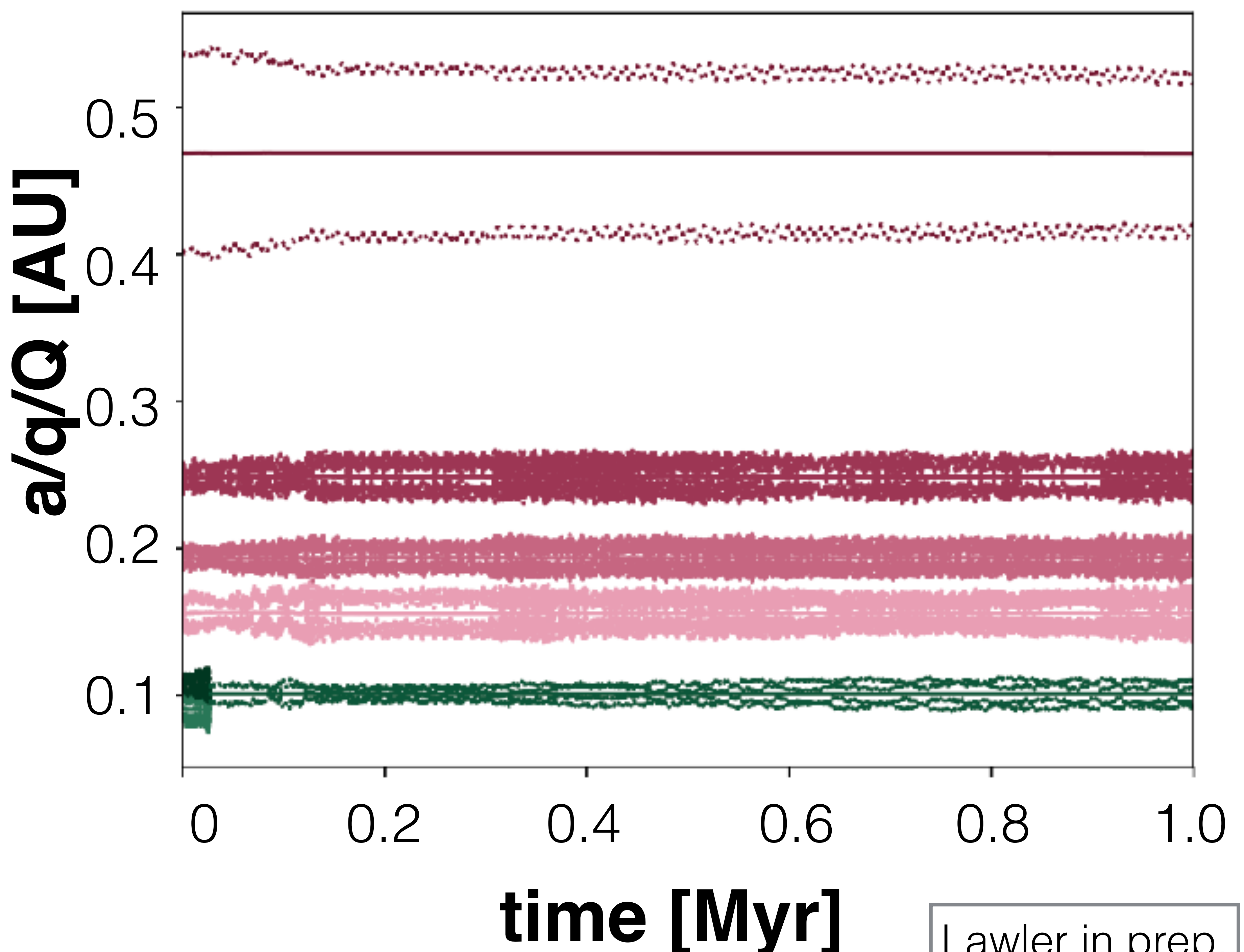


Stable planetesimals after 1 Myr integration

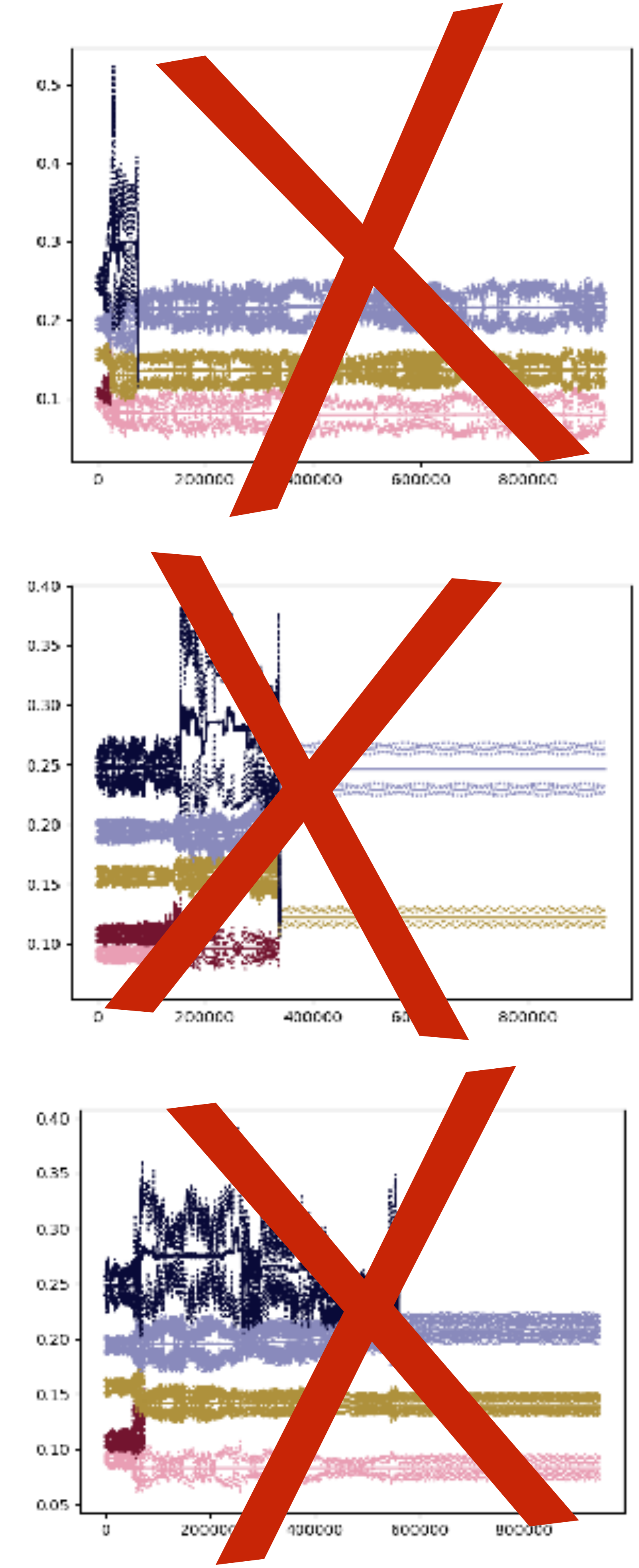


Lawler in prep.

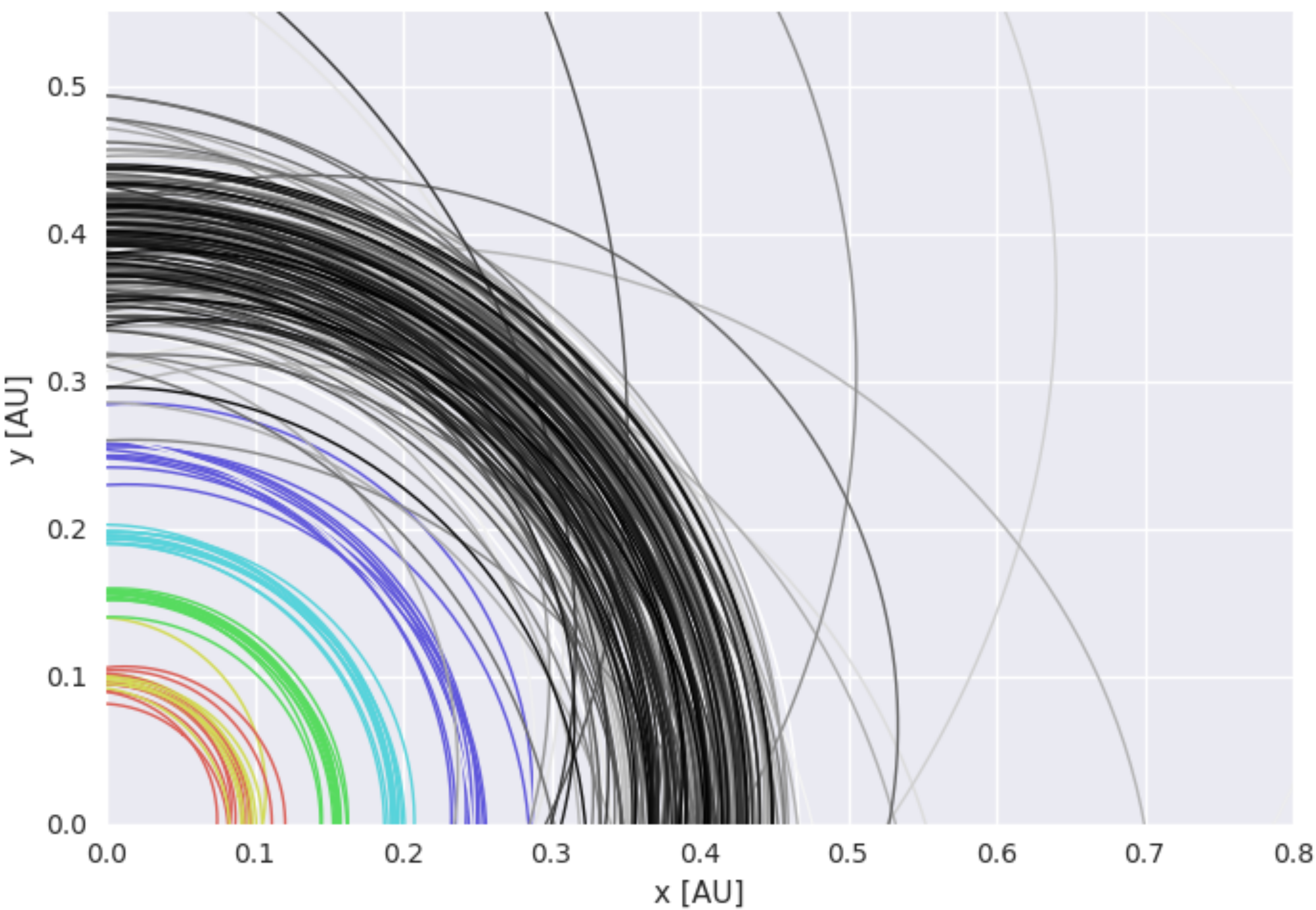
Kepler 11 analogue



Lawler in prep.

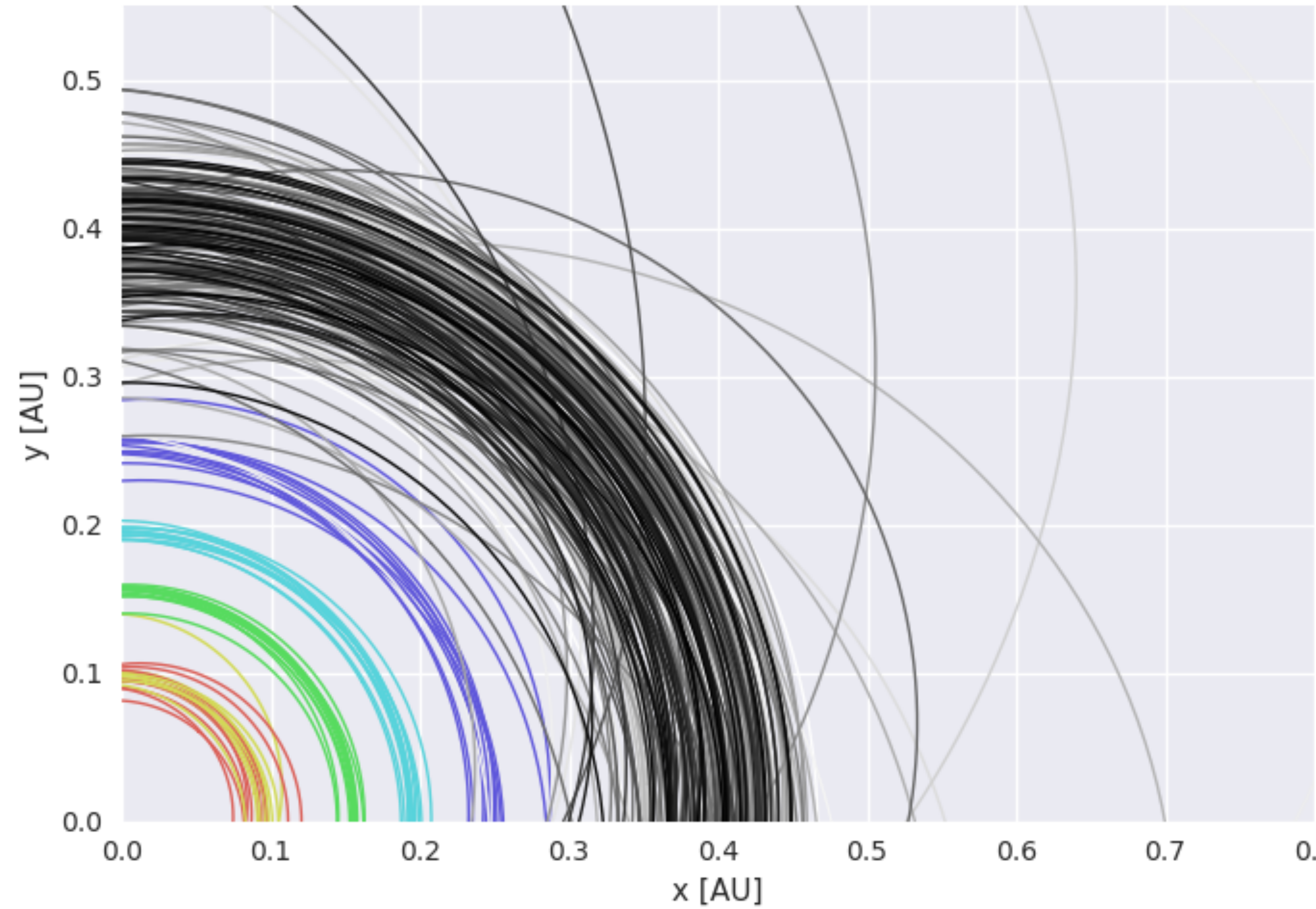


After 1 Myr of integration…



Lawler in prep.

After 1 Myr
of integration…



No planetesimals left between planets having delta < 20

Most planetesimals impact the planets

Small fraction “ejected” (>2 AU)

Survivors stay dynamically cool, <e>~0.1, <i>~2 deg

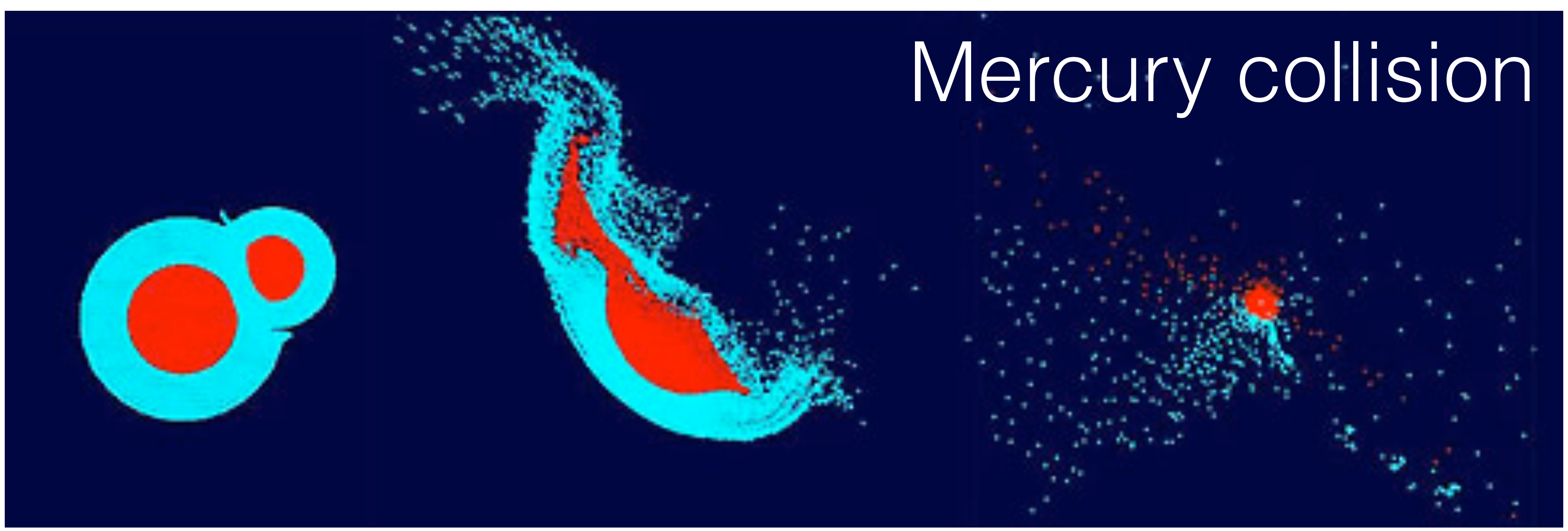
Lawler in prep.

Which dominates, planetary ejecta or debris disk?

Most ejecta from catastrophic Mercury collision swept up by Mercury within few Myr (~10^7 orbits) (Gladman & Coffey 2009)

(Only ~1% makes it to Earth)

Scale to STIP: 10^7 orbits is < 1 Myr



Horner/Astronomy magazine

Debris disk timescale?

Collisional timescale:

$$t_{\rm coll} \sim 0.3\,{\rm yr}\left(\frac{e}{0.1}\right)\left(\frac{\rho}{3\ {\rm g\ cm^{-3}}}\right)\left(\frac{10^{-6}M_\oplus}{M_{\rm grain}}\right) \times \left(\frac{r_{\rm grain}}{10\ \mu{\rm m}}\right)\left(\frac{a}{0.25\ {\rm AU}}\right)^{3.5},$$

Lawler & Gladman (2012)

PR drag timescale:

$$t_{\rm PR} = 200\,{\rm yr}\left(\frac{r_{\rm grain}}{10\ \mu{\rm m}}\right)\left(\frac{a}{1\ {\rm AU}}\right)^{2}$$

Burns et al. (1979)

Collisional timescale: ~10 kyr for cm-size grains

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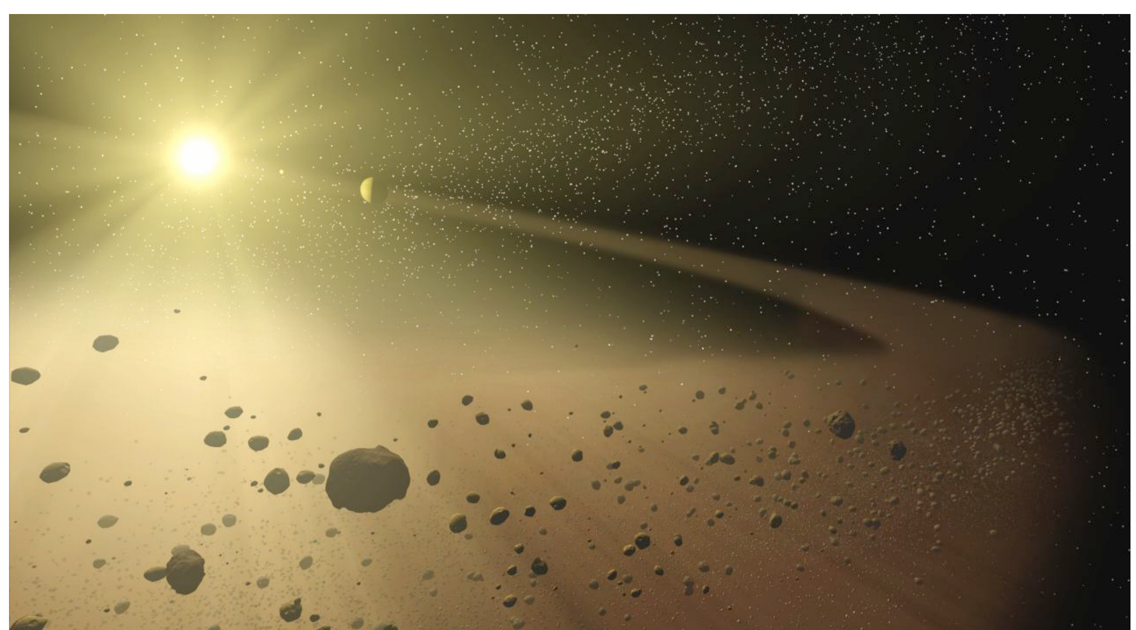
Burns et al. (1979)

What about other warm disks?

- Warm dust (~few AU) is relatively rare around Sun-like stars
  - ~2% with *Spitzer* (Lawler et al. 2009)
  - ~1% with *WISE* (Patel et al. 2014, 2017)
- Hot dust (<1 AU) is much more common
  (Defrere+ 2011, Mennesson+ 2014, Kirchschlager+ 2017)
  - 30-40% with NIR interferometry!
  - Veeery small dust masses, hard to explain origin…

STIPs *can* have debris disks!
(…I'm pretty sure)

- Finish simulations: more systems, more delta values
- How to observe? Need to find closer STIPs!
  - Only tau Ceti so far
- Debris disk/planet correlation?
- Disks in STIPs could support or challenge migration



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