The Origin of Exozodiacal Dust?

Amy Bonsor
IPAG, Grenoble

Collaborators: Jean-Charles Augereau, Philippe Thèbault, Hervé Beust, Jérémy Lébreton, Virginie Faramaz, Steve Ertel

What is an Exozodi?

The Solar System's zodiacal dust

Gote Flodqvist, Nambia

Thanks to Steve Ertel for his brilliant introduction to this topic!

Emission from warm dust, close to a main-sequence star

We detect emission over and above that expected for the stellar photosphere, either with Spitzer in the near-infrared or interferometry

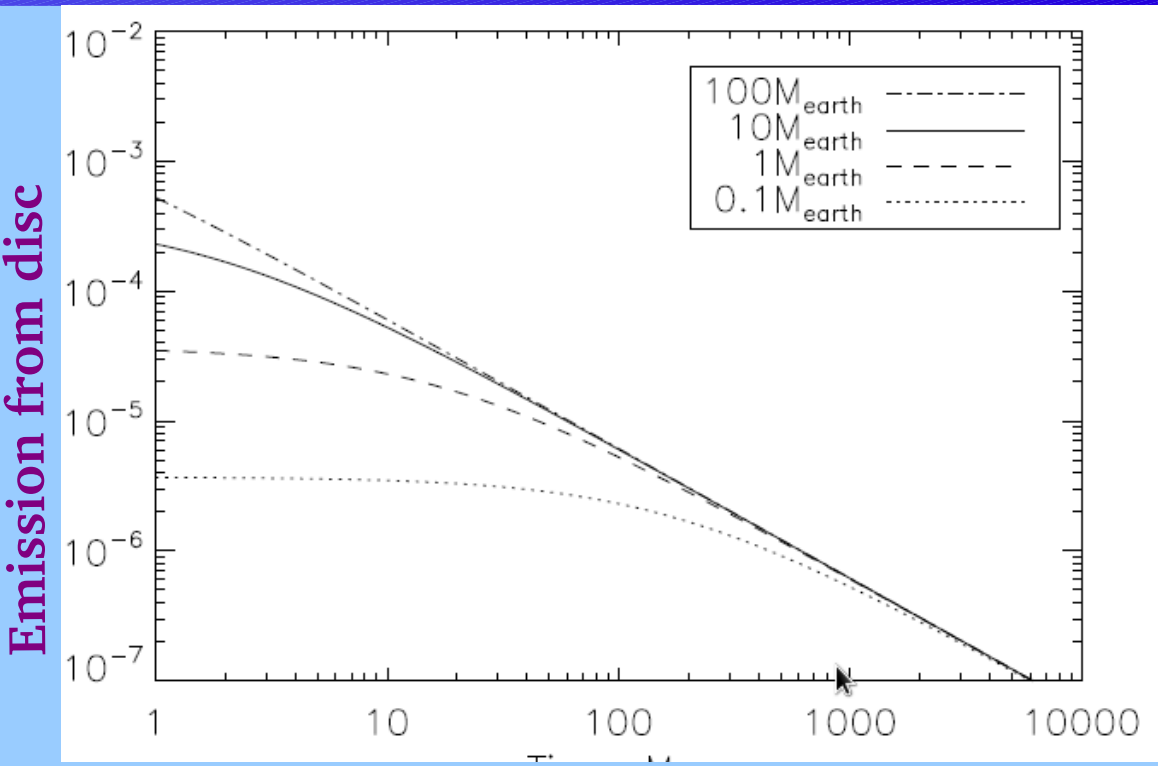
The dust, like the Solar System's zodiacal dust is found within ~3AU of the star

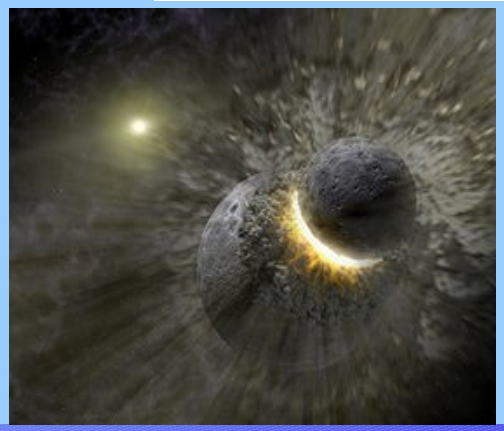
Why is the origin of Exozodi a mystery?

Small dust has a short lifetime, so if we observe it, it must have been replenished recently

Debris discs are thought to be collisional systems in which large parent bodies are ground down into the observed small dust

Total mass of the disc decreases with age- the disc gets fainter!



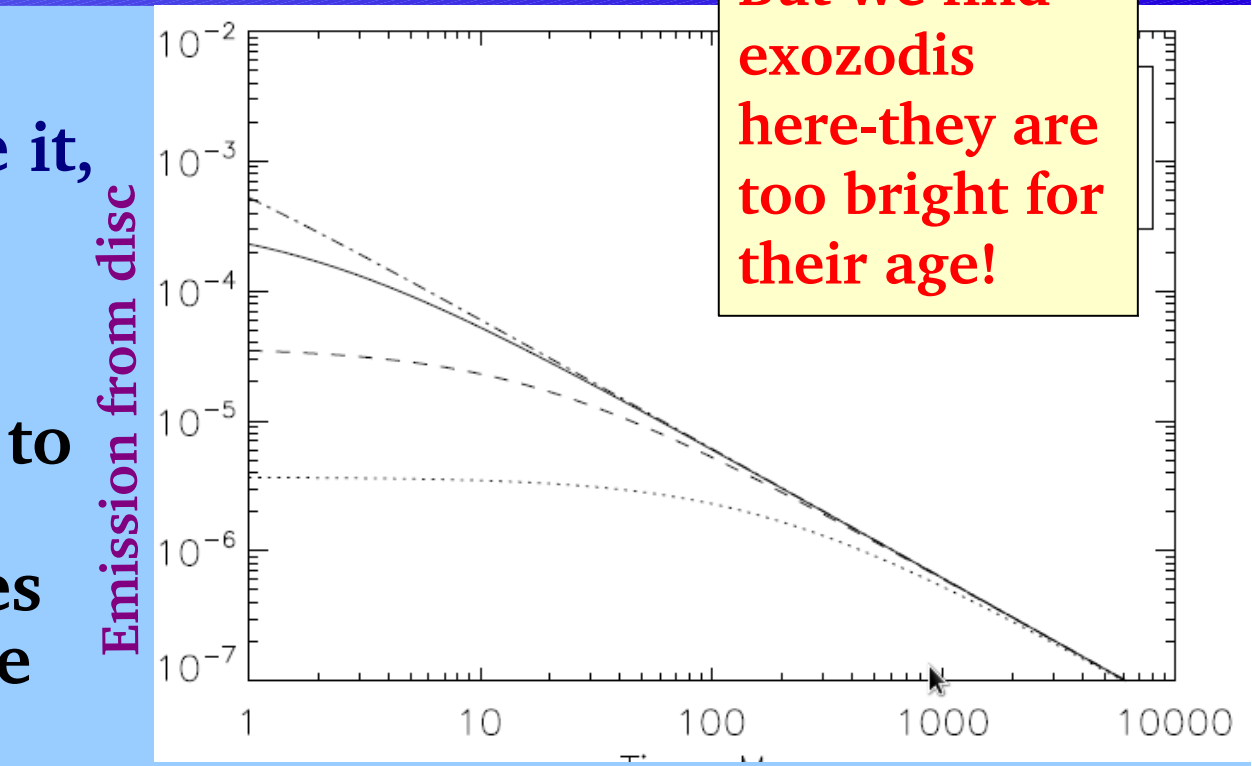


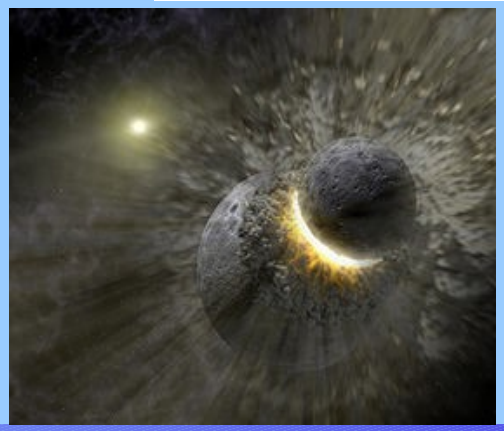
Why is the origin of Exozodi a mystery?

Small dust has a short lifetime, so if we observe it, it must have been replenished recently

Debris discs are thought to be collisional systems in which large parent bodies are ground down into the observed small dust

Total mass of the disc decreases with age- the disc gets fainter!

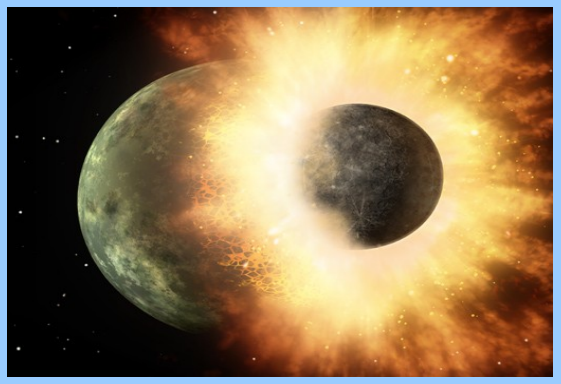




So, how do we explain the high levels of dust observed in these systems?

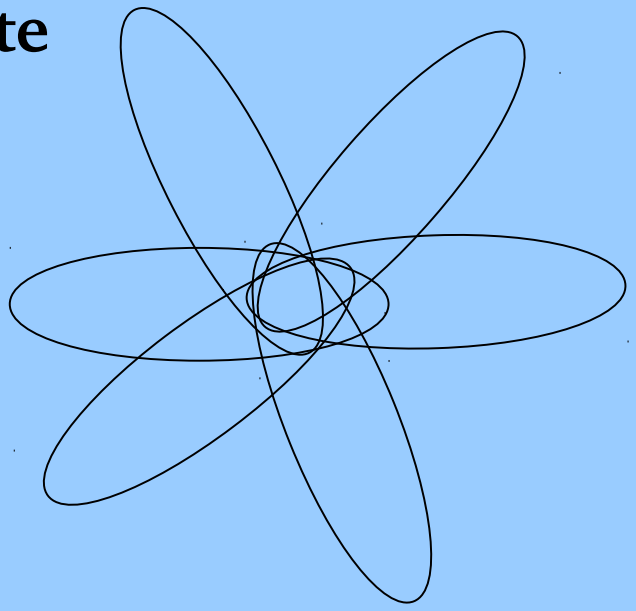
Maybe it has a recent origin – e.g. a collision between two large bodies

e.g. Lisse et al 2009



Maybe it was scattered in from an outer planetary system? In a steady-state manner or post a dynamical instability?

A population of two bodies on highly eccentric orbits Wyatt et al 2010

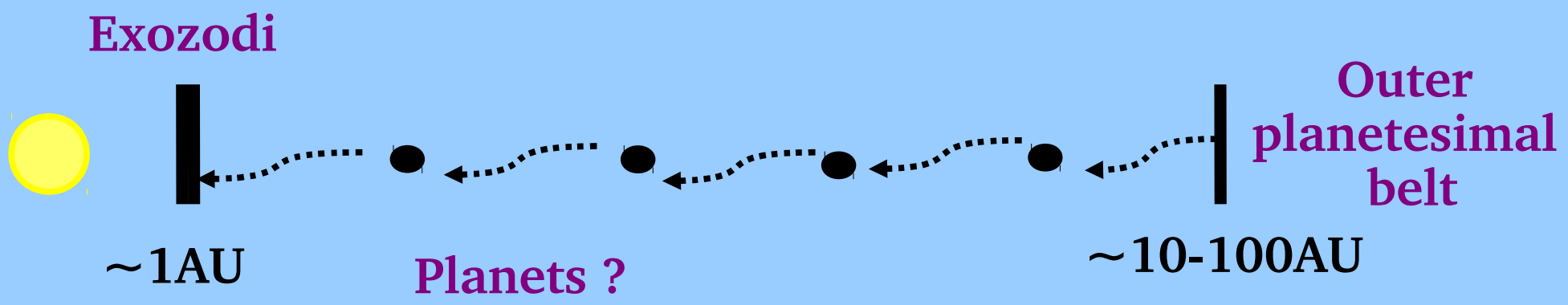


Maybe it spiralled inwards under Poynting-Robertson drag (radiative forces)

e.g. Epsilon Eridani Reidemeister et al, 2010

Can a stable chain of planets scatter in sufficient material from an outer belt?

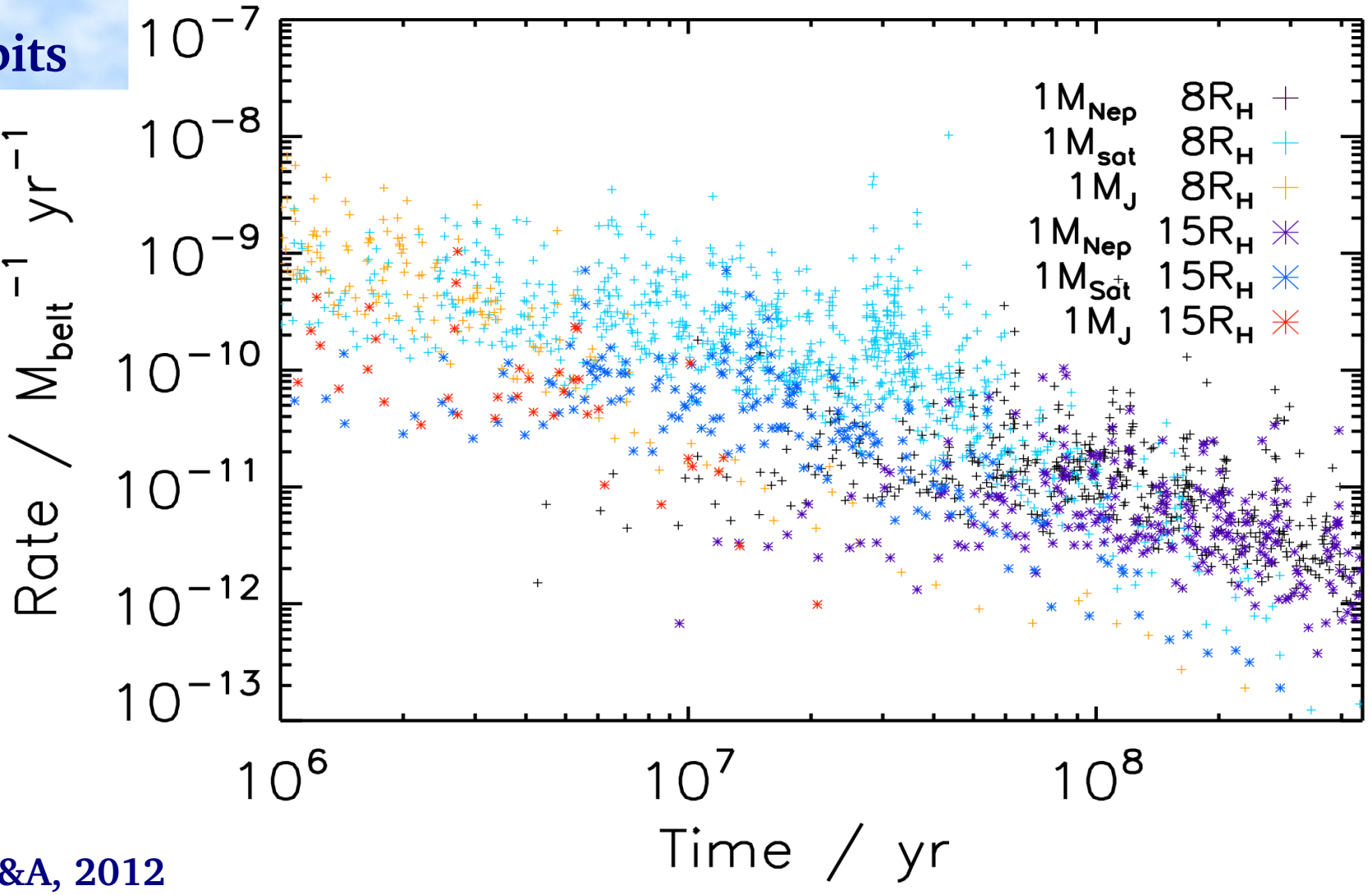
In a similar manner the Kuiper belt and JFCs are thought to be the origin of 90% of the Solar System's zodiacal cloud Nesvorny et al 2010



Use N-body simulations to determine how much material can be scattered inwards for a sample of representative planetary systems Bonsor et al 2012

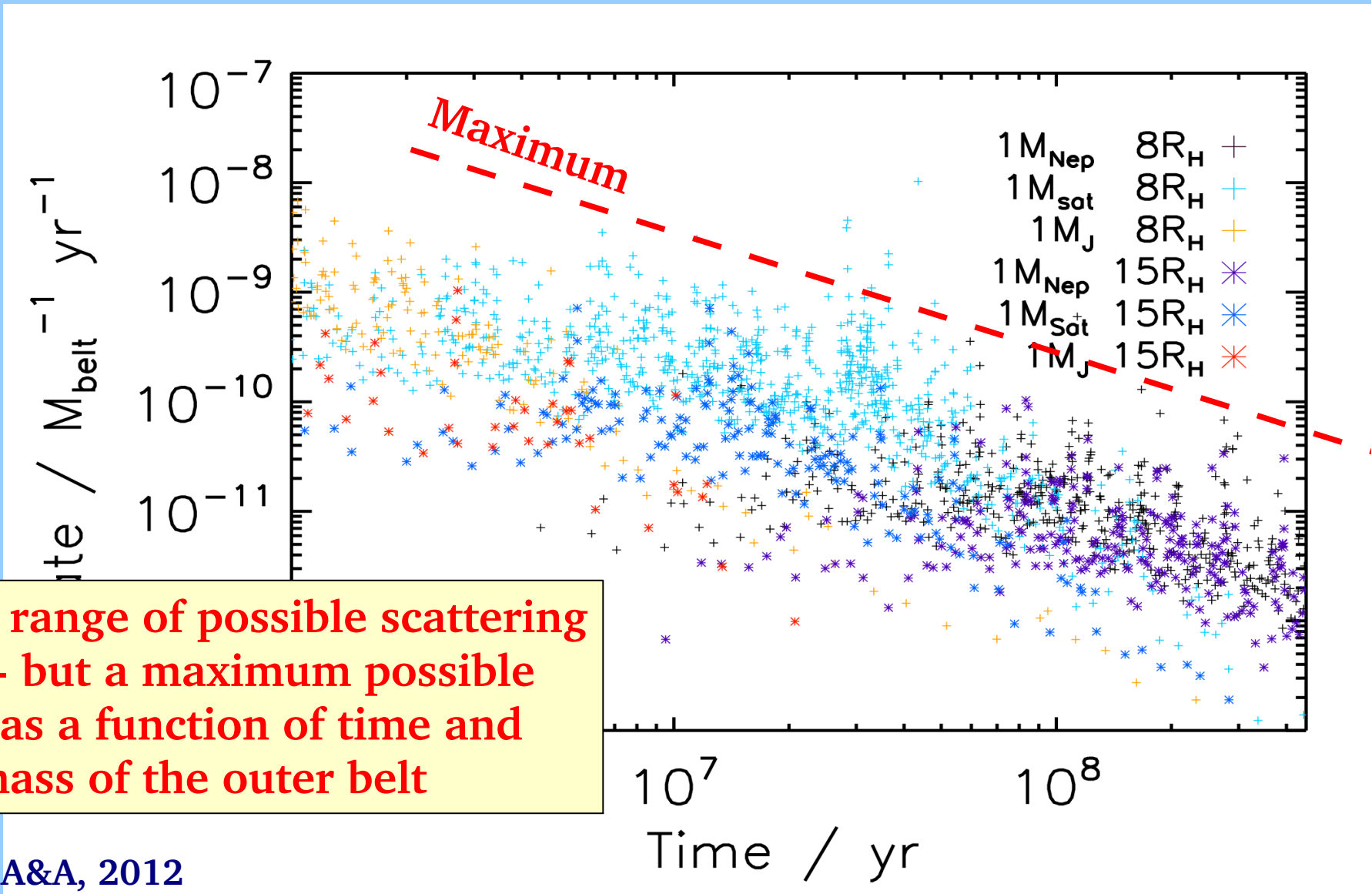
Tightly packed chains of low mass planets most efficient at scattering material inwards, at late times

Chains of equal mass planets on circular, coplanar orbits



Bonsor et al, A&A, 2012

Tightly packed chains of low mass planets most efficient at scattering material inwards, at late times



Wide range of possible scattering rates- but a maximum possible rate, as a function of time and the mass of the outer belt

Bonsor et al, A&A, 2012

The example of VEGA

Exozodi: ~1AU

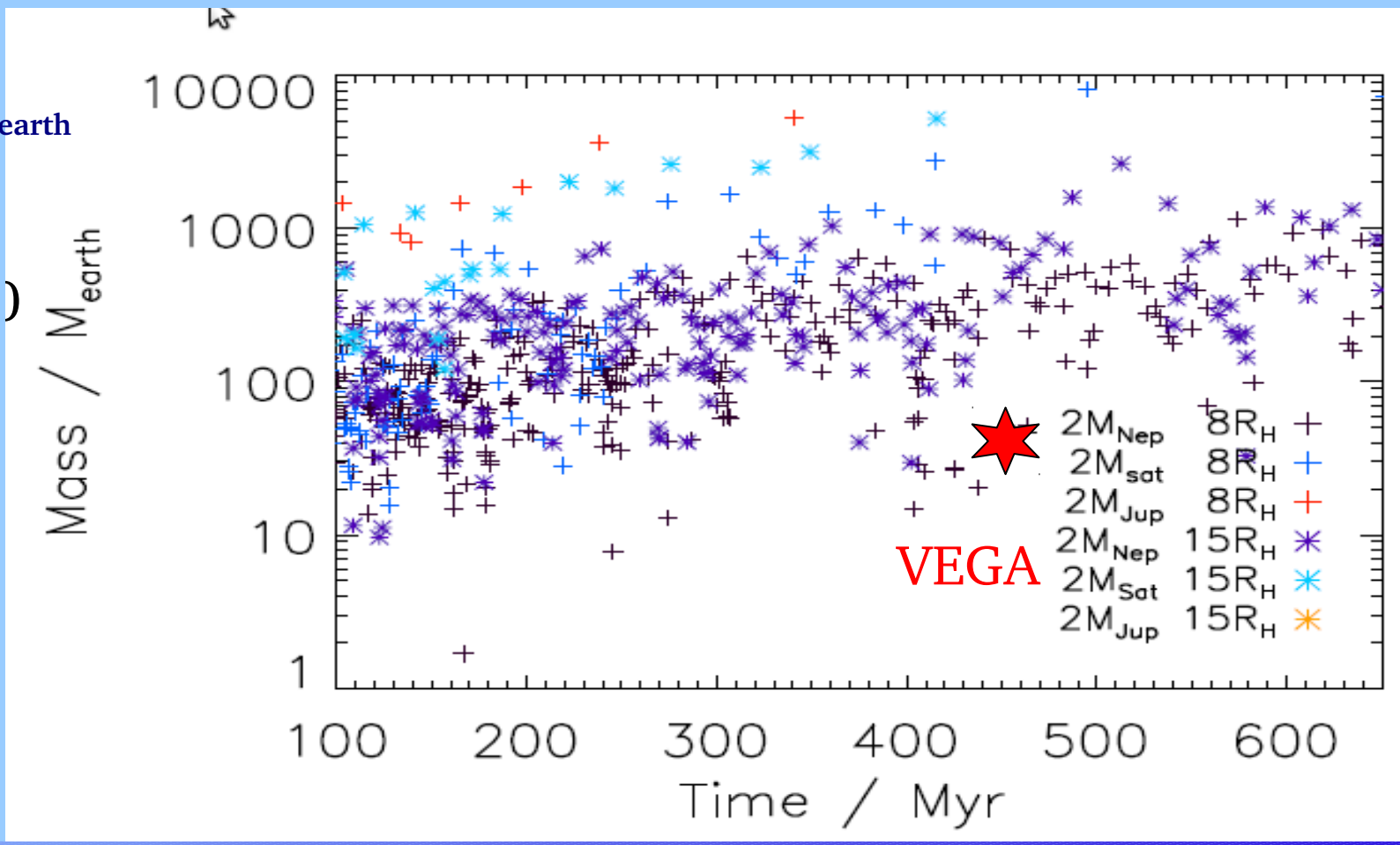
Outer belt: 62-130AU

What mass is required in the outer belt to retain the dust at its currently observed levels, as a function of time?

Dust mass: $10^{-9}M_{earth}$

Lifetime ~ 1year

Defrère et al (2011)



The example of VEGA

Exozodi: ~1AU

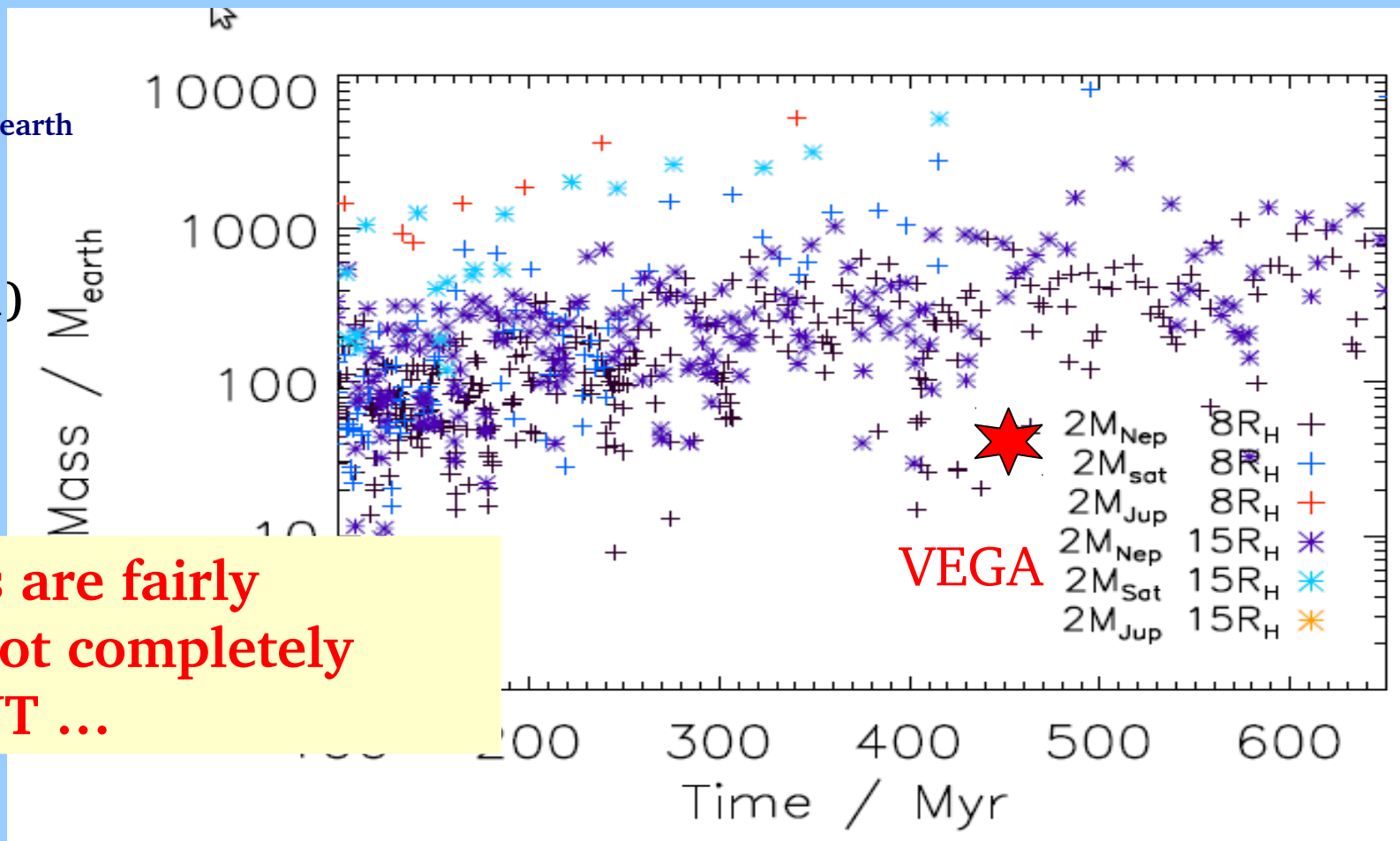
Outer belt: 62-130AU

What mass is required in the outer belt to retain the dust at its currently observed levels, as a function of time?

Dust mass: $10^{-9} M_{earth}$

Lifetime ~ 1year

Defrère et al (2011)

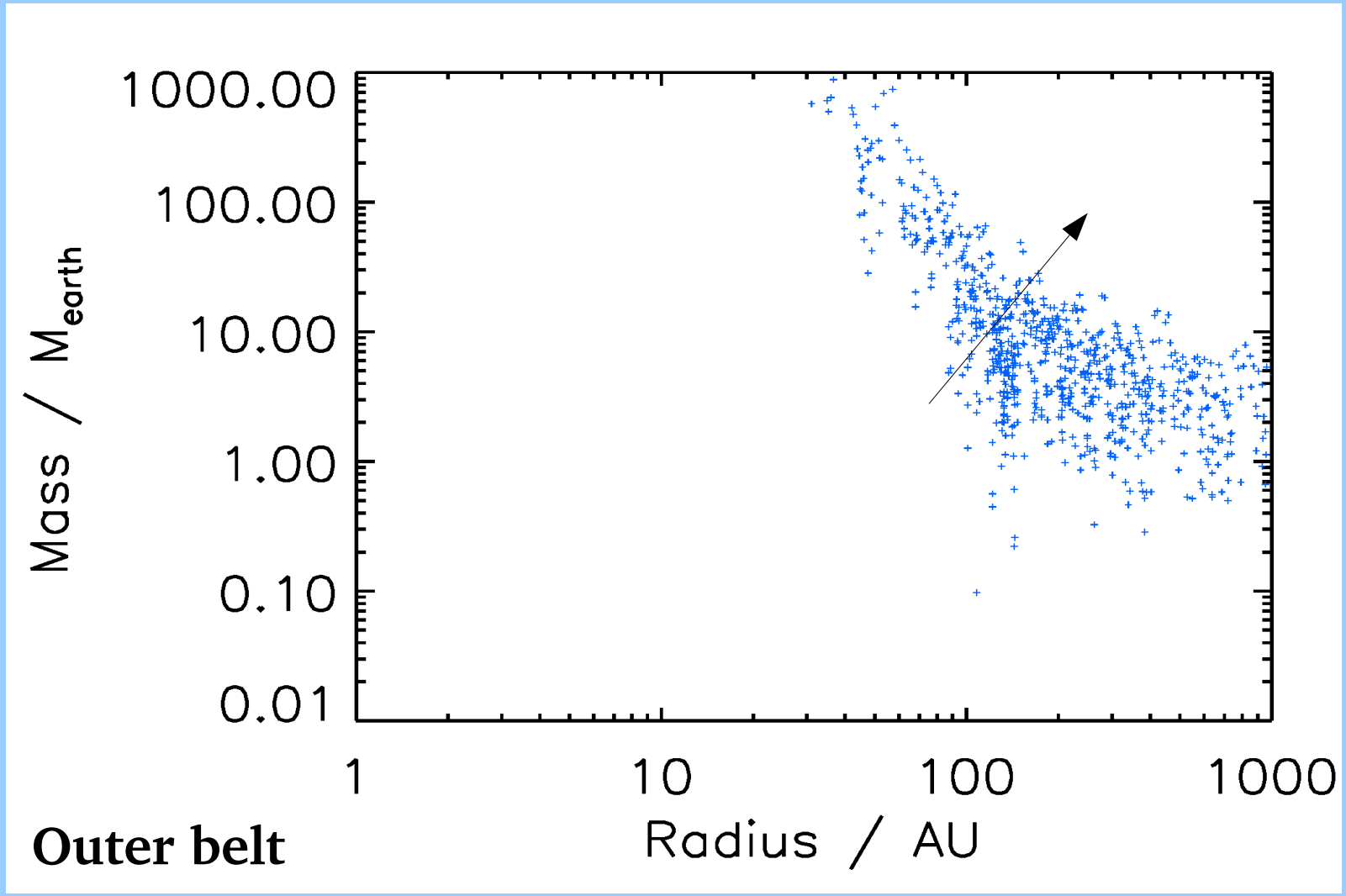


These numbers are fairly uncertain, so not completely ruled out.... BUT ...

What about other systems?

Only high mass, large radii belts are capable of scattering at sufficiently high rates

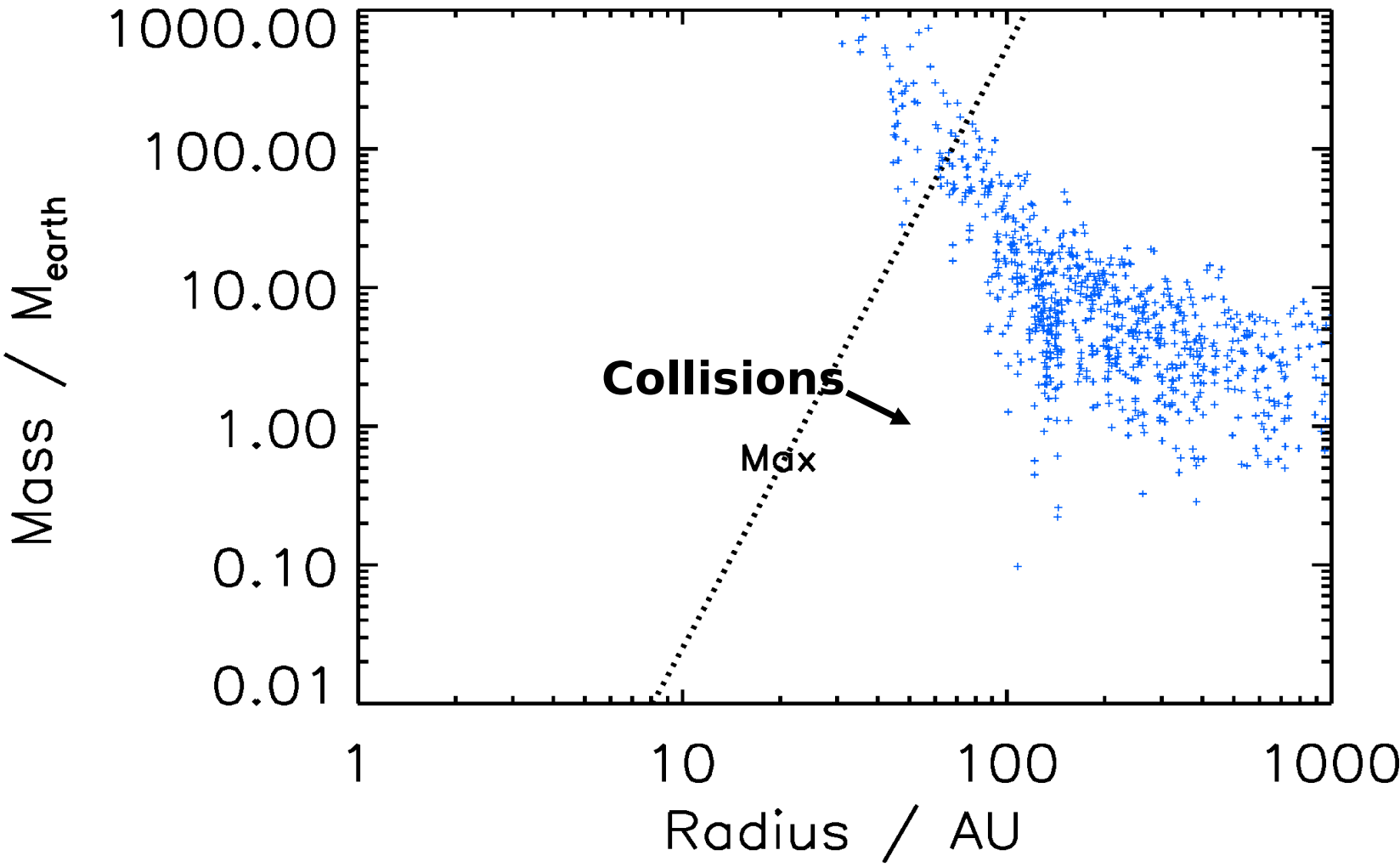
This takes the maximum scattering rates, assumes a solar mass star and a typical required replenishment rate for an exozodi of $10^{-9} M_{earth}$ yr^{-1} after 100Myr



What about other systems?

Only outer belts that sufficiently low in mass that they survive against collisions can supply the scattering process...

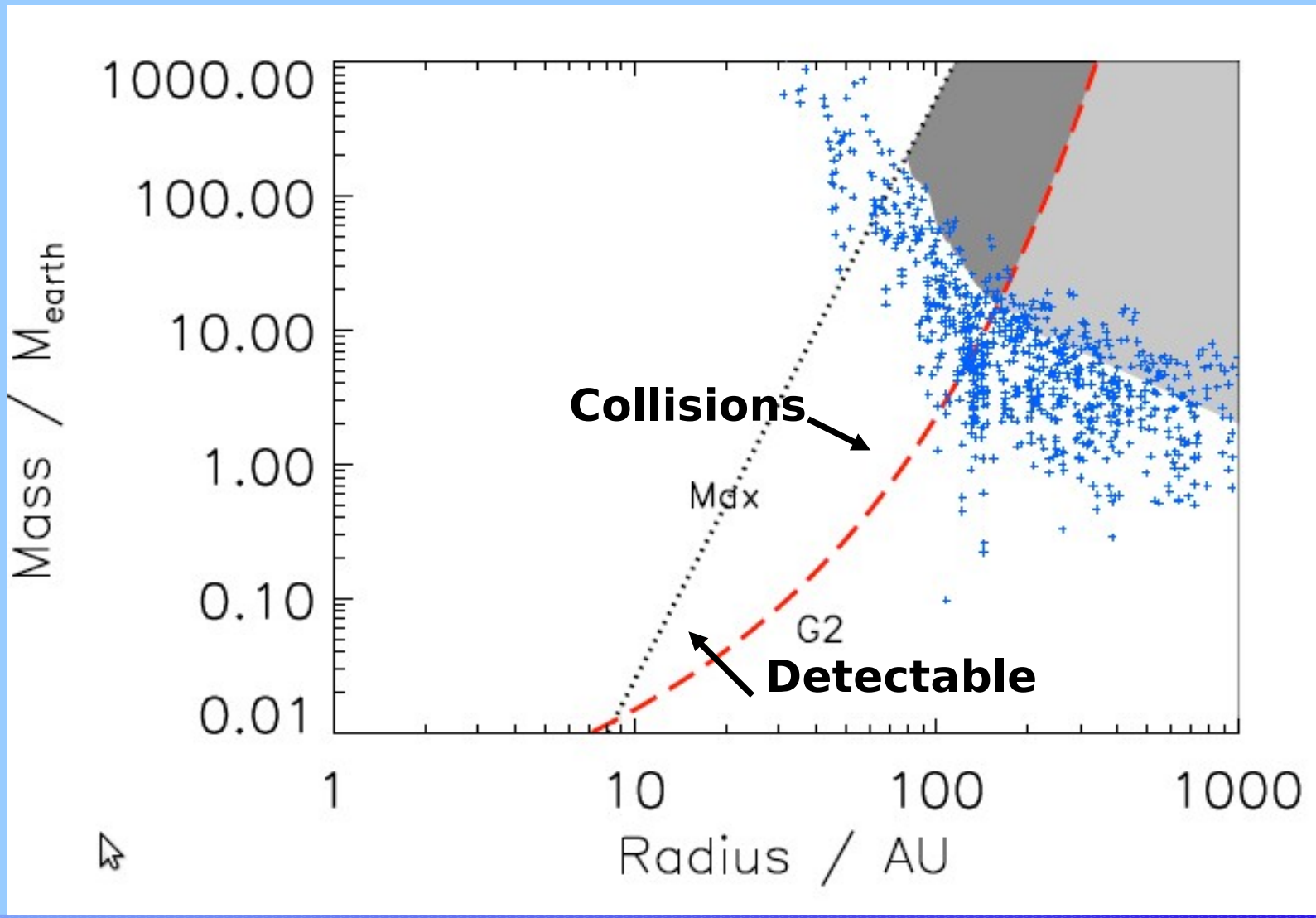
This takes the maximum scattering rates, assumes a solar mass star and a typical required replenishment rate for an exozodi of $10^{-9} M_{earth}$ yr^{-1}



What about other systems?

Can we detect the outer belt?

With Spitzer at 24um, G2 solar type star

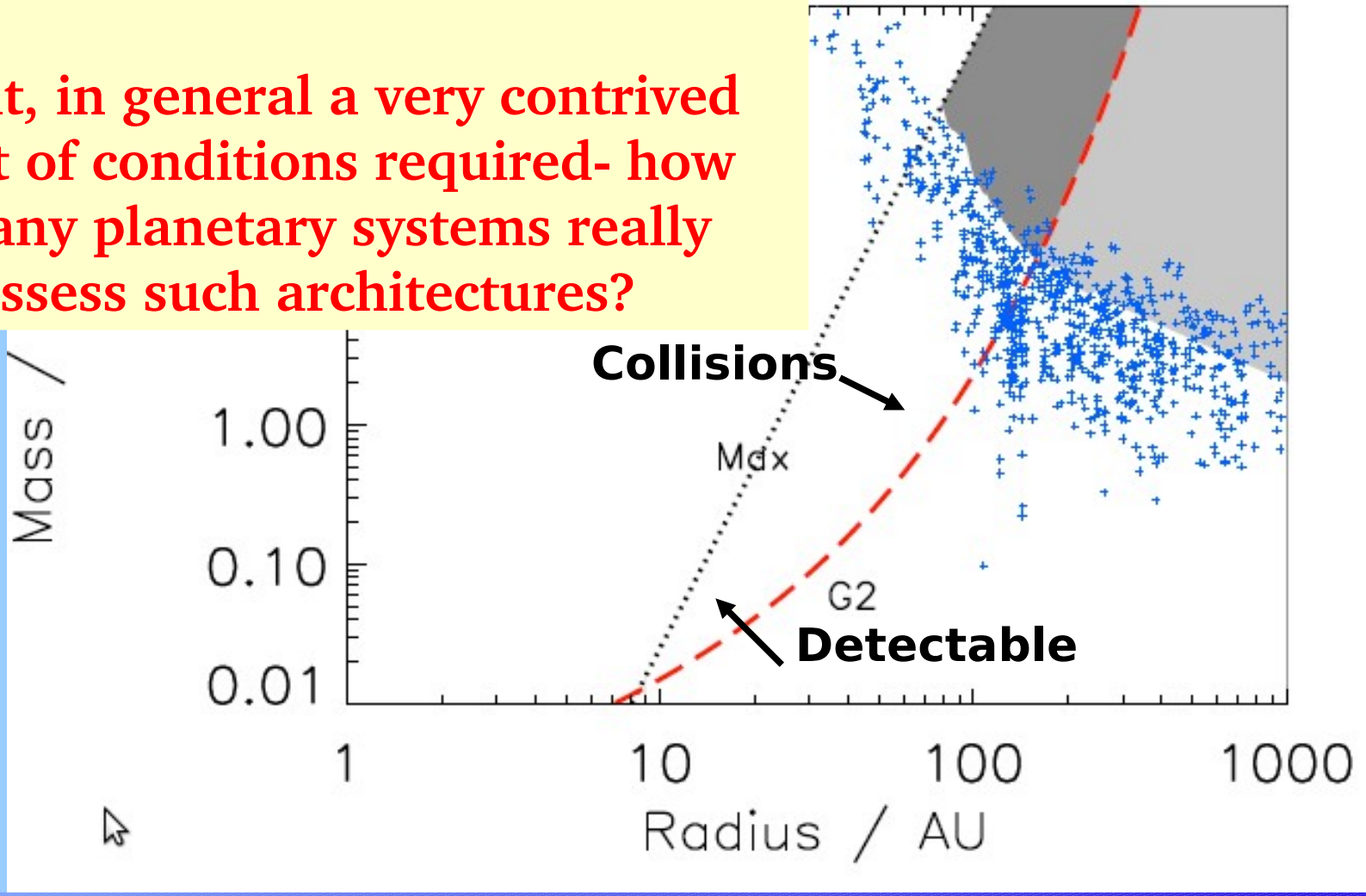


What about other systems?

Only high … sufficiently … cattering at

Some systems with undetected outer belts could scatter sufficient material

But, in general a very contrived set of conditions required- how many planetary systems really possess such architectures?



Conclusions: how do we explain exozodiacal dust?

Many observations of exozodi with high levels of warm dust, over and above those expected for normal collisional evolution

Can we explain these systems if material was scattered inwards from an outer planetesimal belt, by planets on circular, coplanar orbits?

Only for very contrived architectures, or if we have overestimated the mass of dust in the exozodi, or underestimated its lifetime.

FURTHER POSSIBILITIES: could a dynamical instabilities explain the exozodiacal dust?

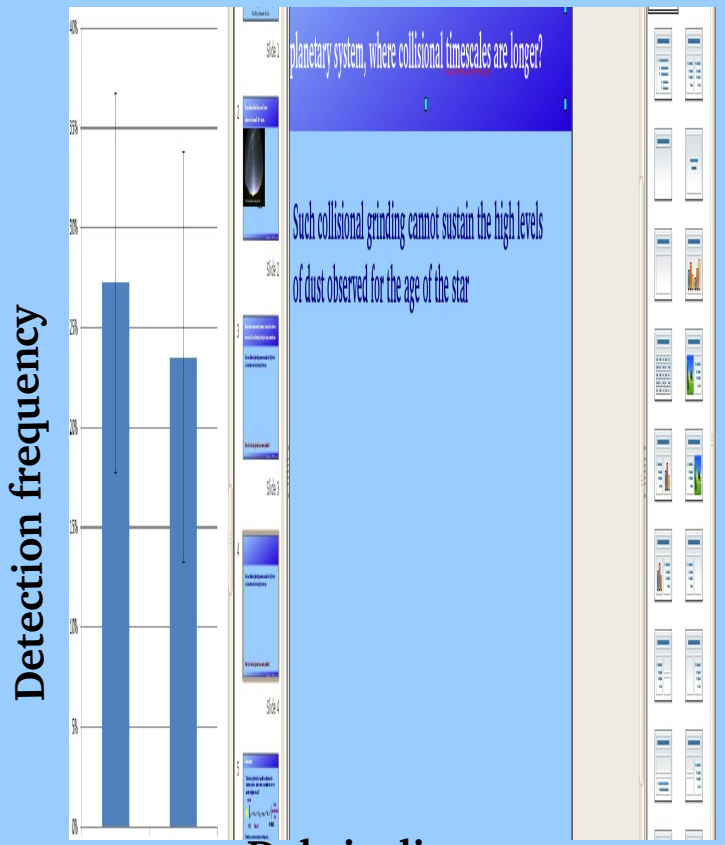
Watch this space!

Maybe the material originated further out in the planetary system, where collisional timescales are longer?

Some of the detected exozodis also have cold, outer debris discs

Maybe the dust could originate from these?

But, what about the large fraction of the sample that don't have outer belts?



Maybe the material originated further out in the planetary system, where collisional timescales are longer?

Some of the detected exozodis also have cold, outer debris discs

Maybe the dust could originate from these?

But, what about the large fraction of the sample that don't have outer belts?

WATCH THIS SPACE!