The Origin of Exozodiacal Dust?

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What is an Exozodi?

The Solar System's zodiacal dust

Gote Flodqvist, Nambia

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

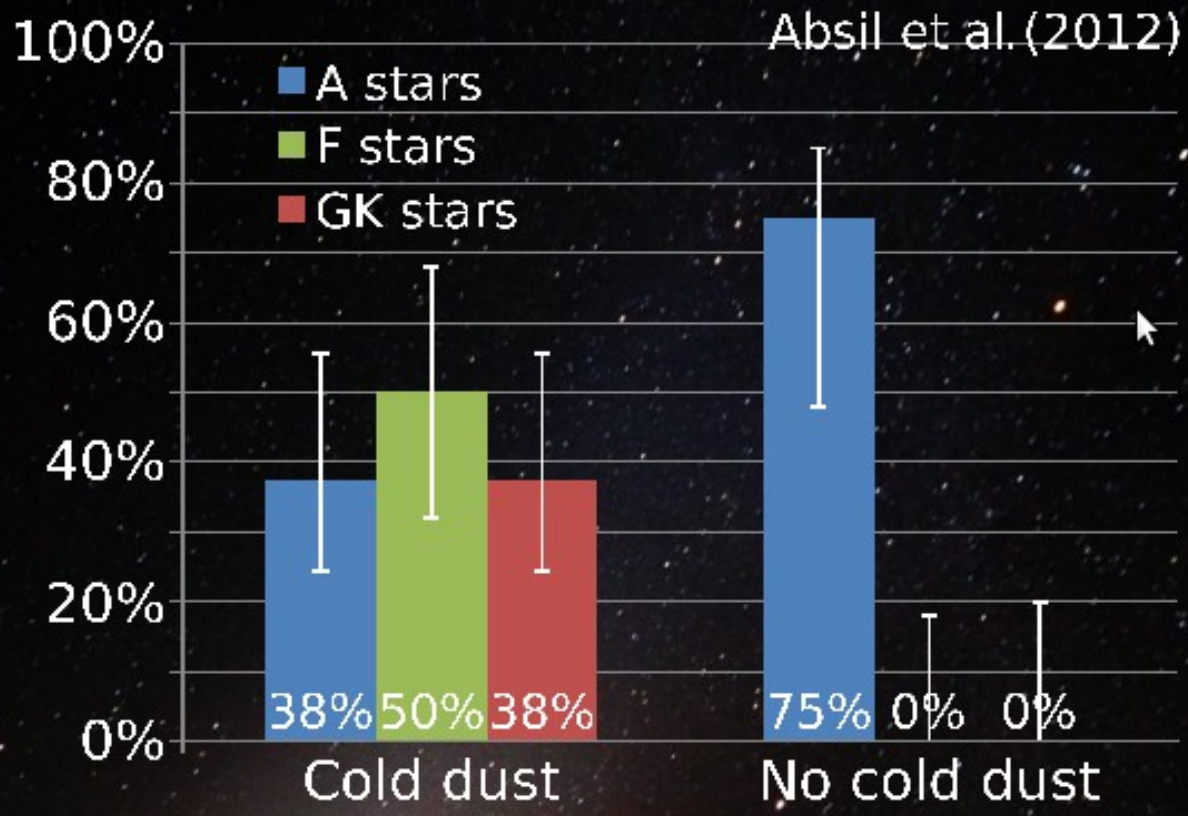
The dust, like the Solar System's zodiacal dust is found within ~3AU of the star

The EXOZODI Project: A statistical survey for exozodiacal dust with near-infrared interferometry

Jean-Charles Augereau, Philippe Thébault, Olivier Absil, Jean-Baptiste Le Bouquin, Denis Defrère and the EXOZODI team

- **First statistical survey for exozodiacal dust**
- **Northern (CHARA/FLUOR) and southern hemisphere (VLTI/PIONIER)**
- **~ 100 stars (K < 5) with debris disks, same number of stars without (known) cold dust, unbiased sample**
- **Observation, statistics + detailed modeling & theoretical investigation**
- **Development of next-generation debris disk modelling tools**
- **Direct contribution to instrument development (e.g. PIONIER)**

First results:
Statistics so far from the CHARA/FLUOR survey



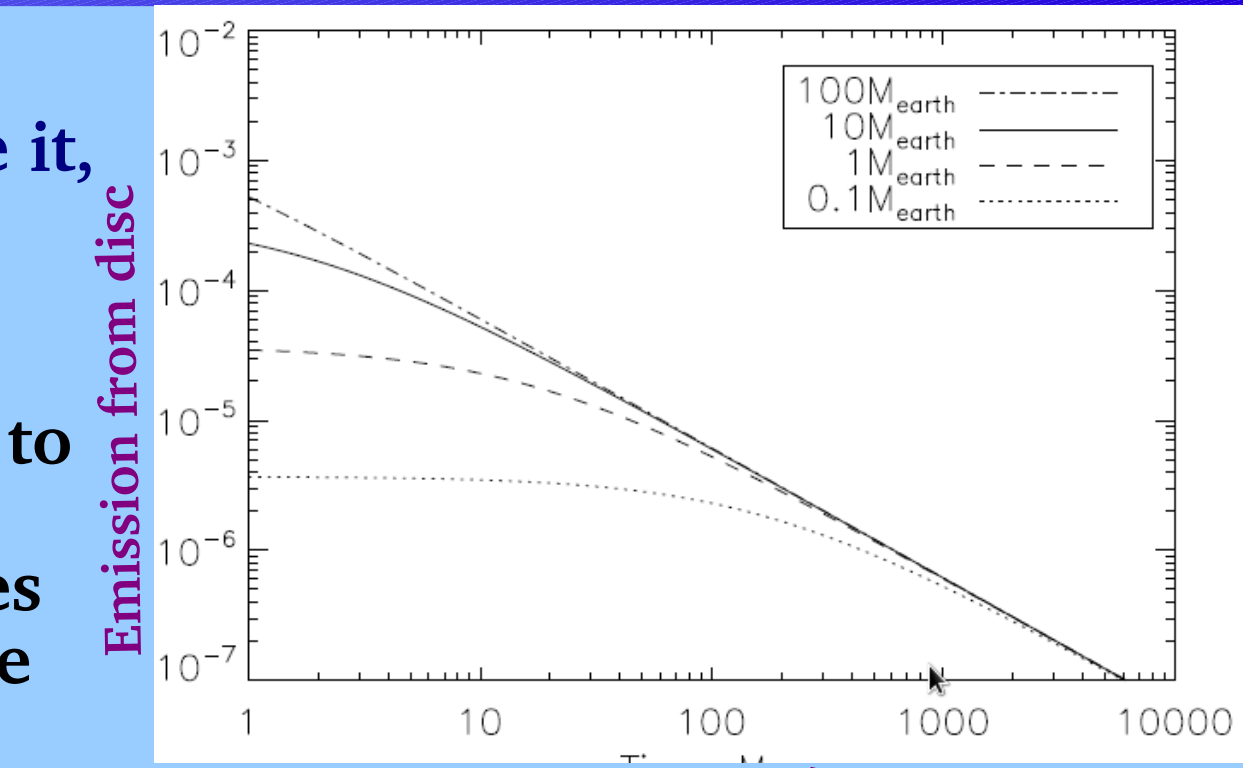
- So far 12 detections out of 41 stars (29^{+8}_{-6} %)
- Cold & hot dust correlated for late type stars, for early type stars not
- **Note low statistical significance so far!**

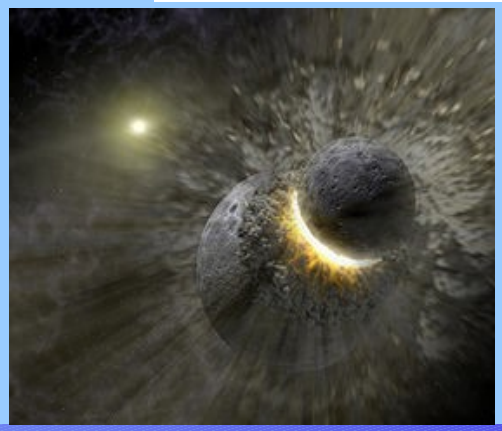
Why is the origin of Exozodi a mystery?

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!





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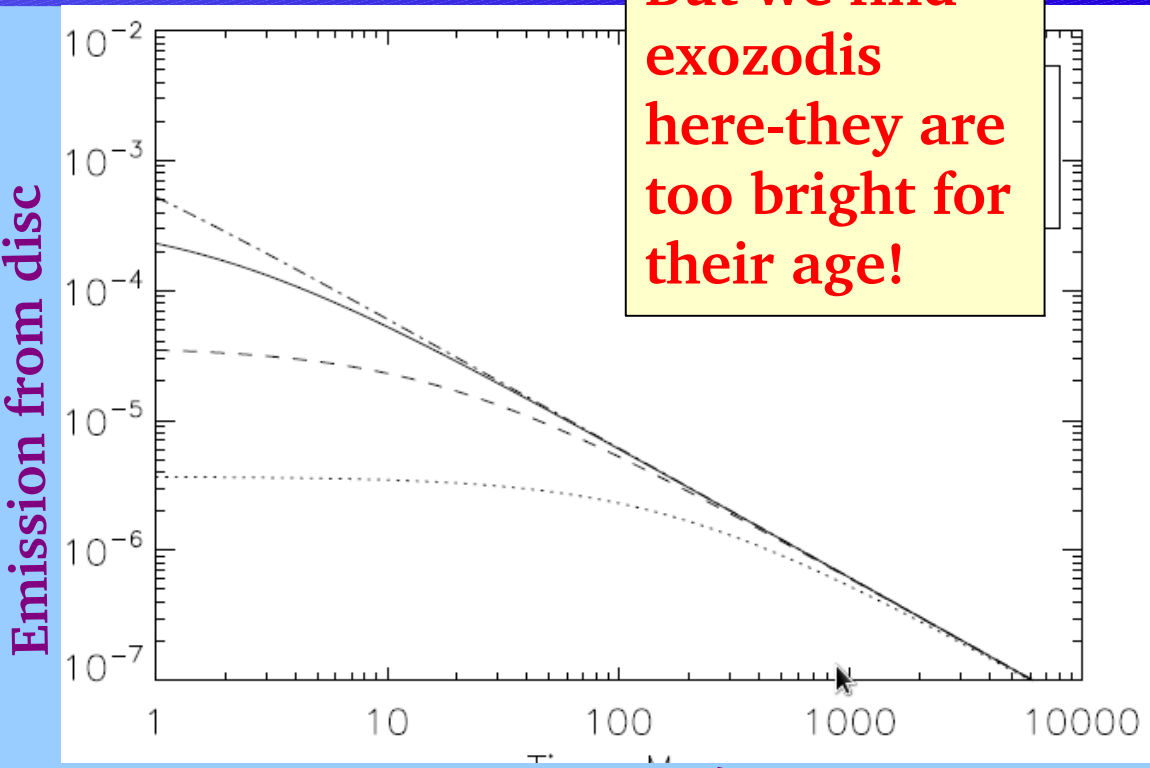
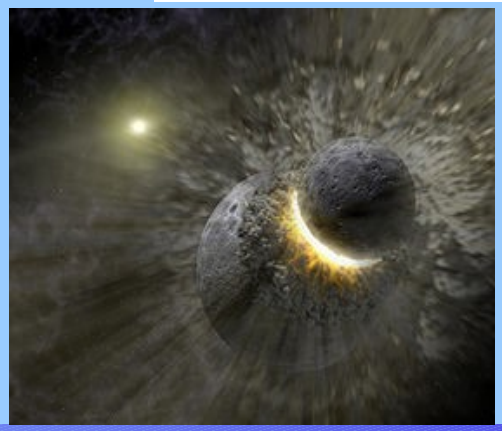
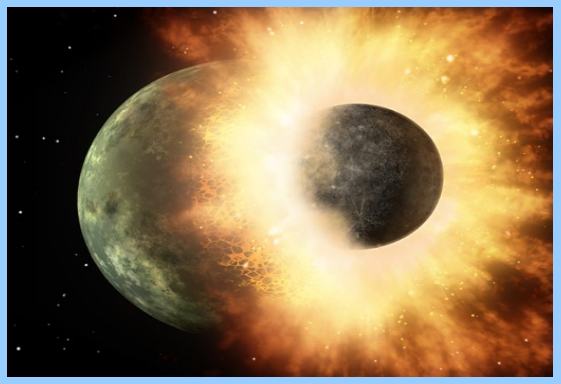




So, how do we explain the high levels of dust observed in these systems?

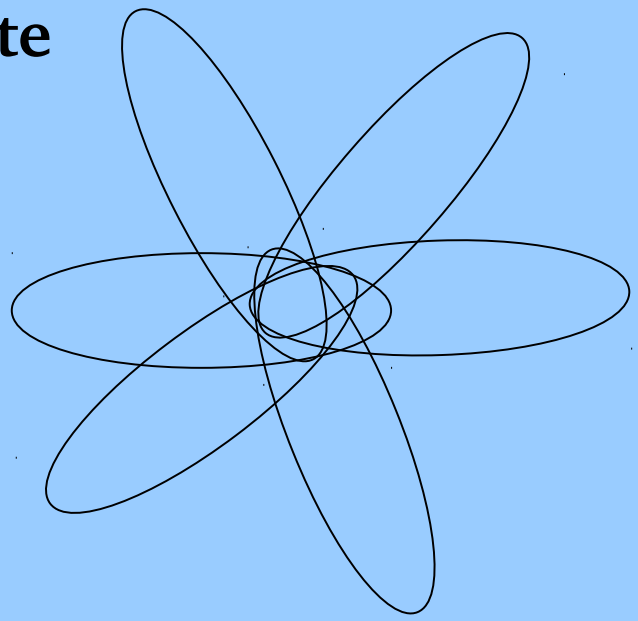
Maybe it has a recent origin – e.g. a collision between two large bodies

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

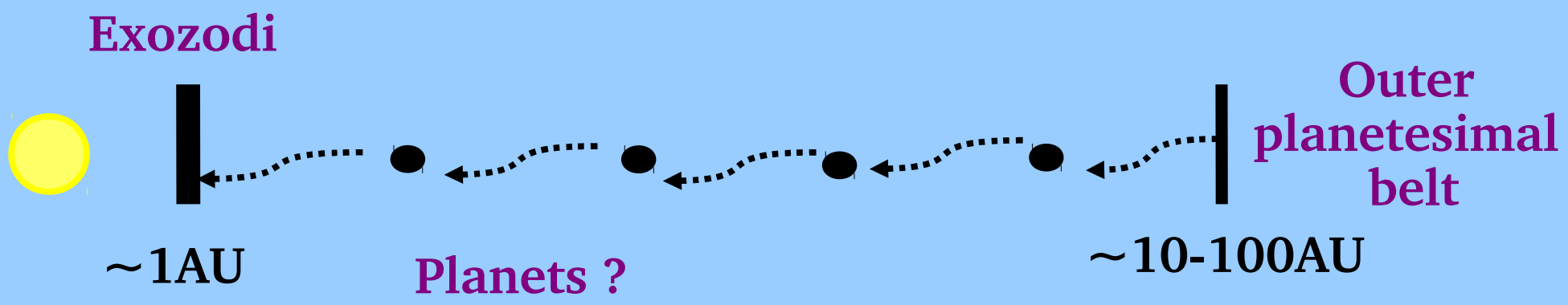


Maybe it spiralled inwards under Poynting-Robertson drag (radiative forces)

e.g. Epsilon Eridani Reidemeister et al, 2010

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

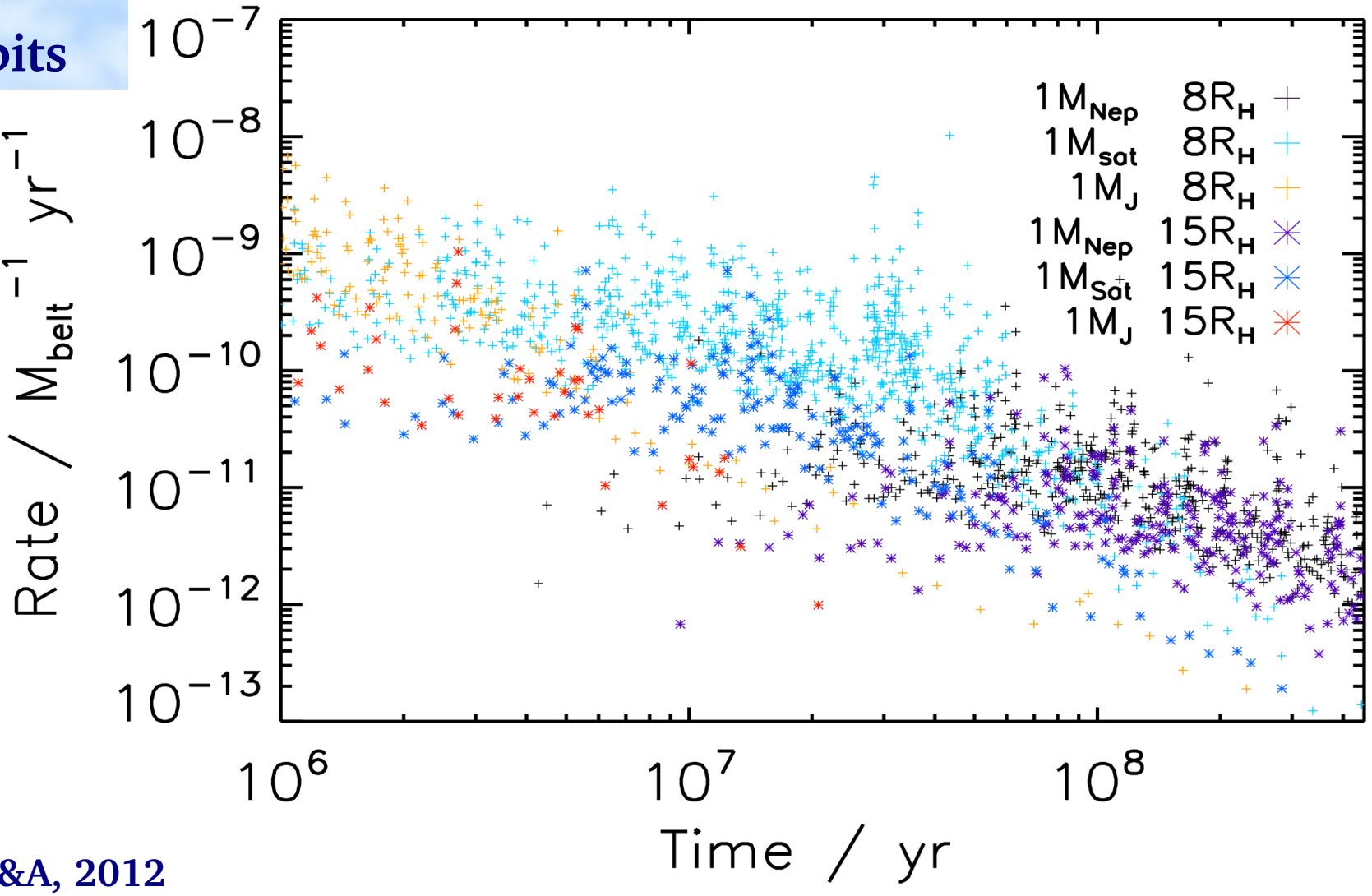
In a similar manner the Kuiper belt and JFCs are thought to be the origin of 90% of the Solar System's zodiacal cloud Nesvorny et al 2010



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

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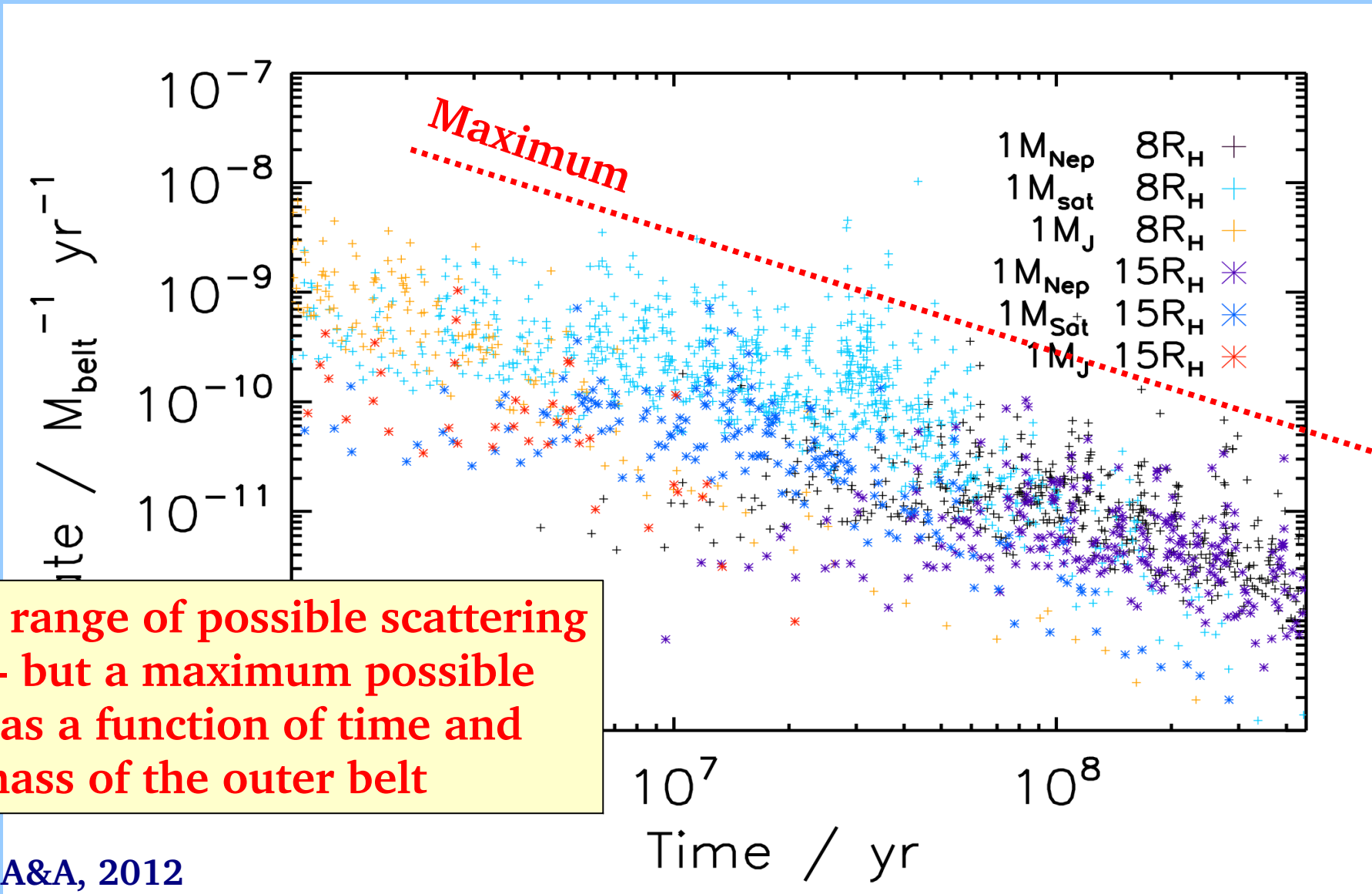


Wide range of possible scattering rates- but a maximum possible rate, as a function of time and the mass of the outer belt

Bonsor et al, A&A, 2012

The example of VEGA

Exozodi: ~1AU

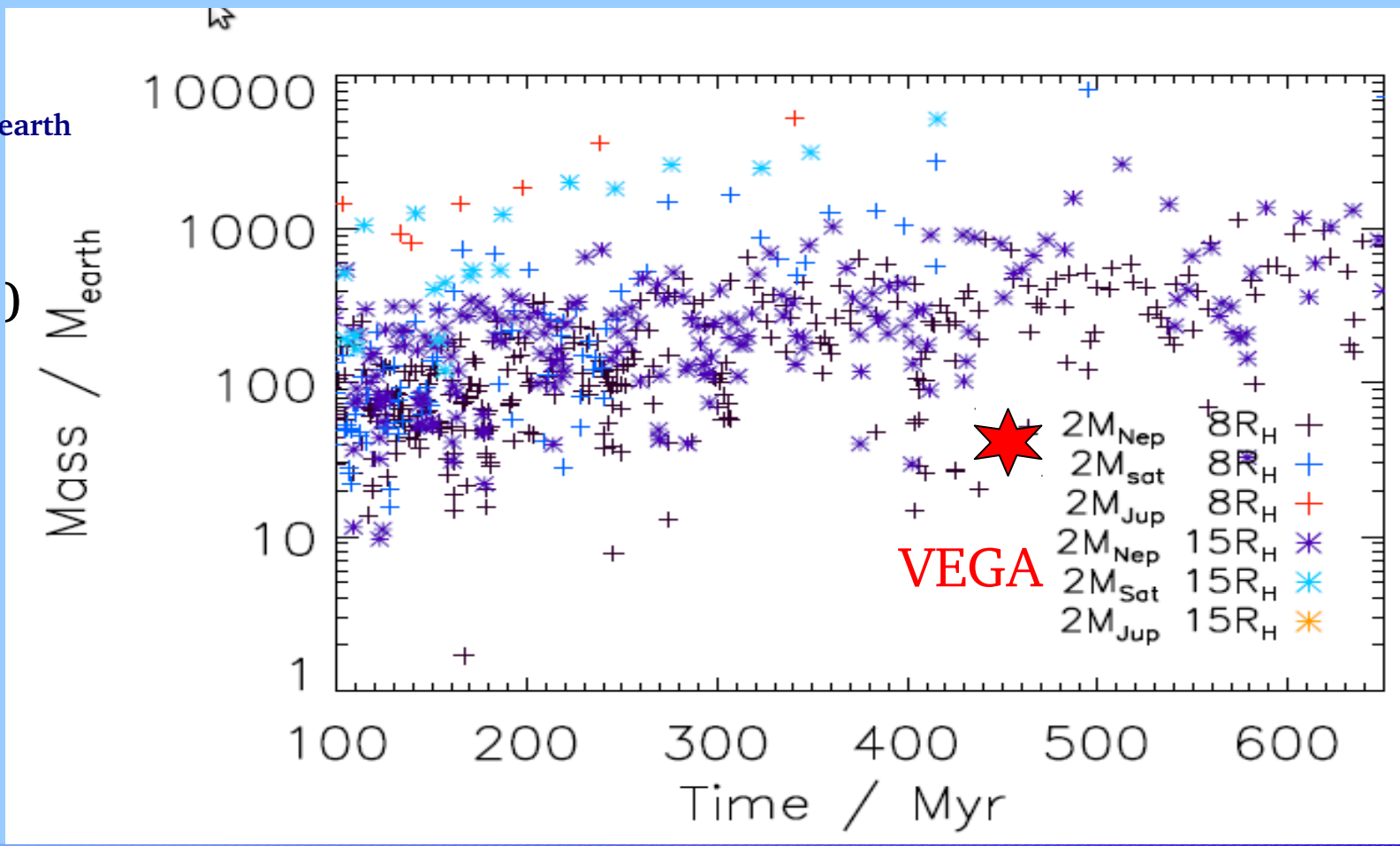
Outer belt: 62-130AU

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)



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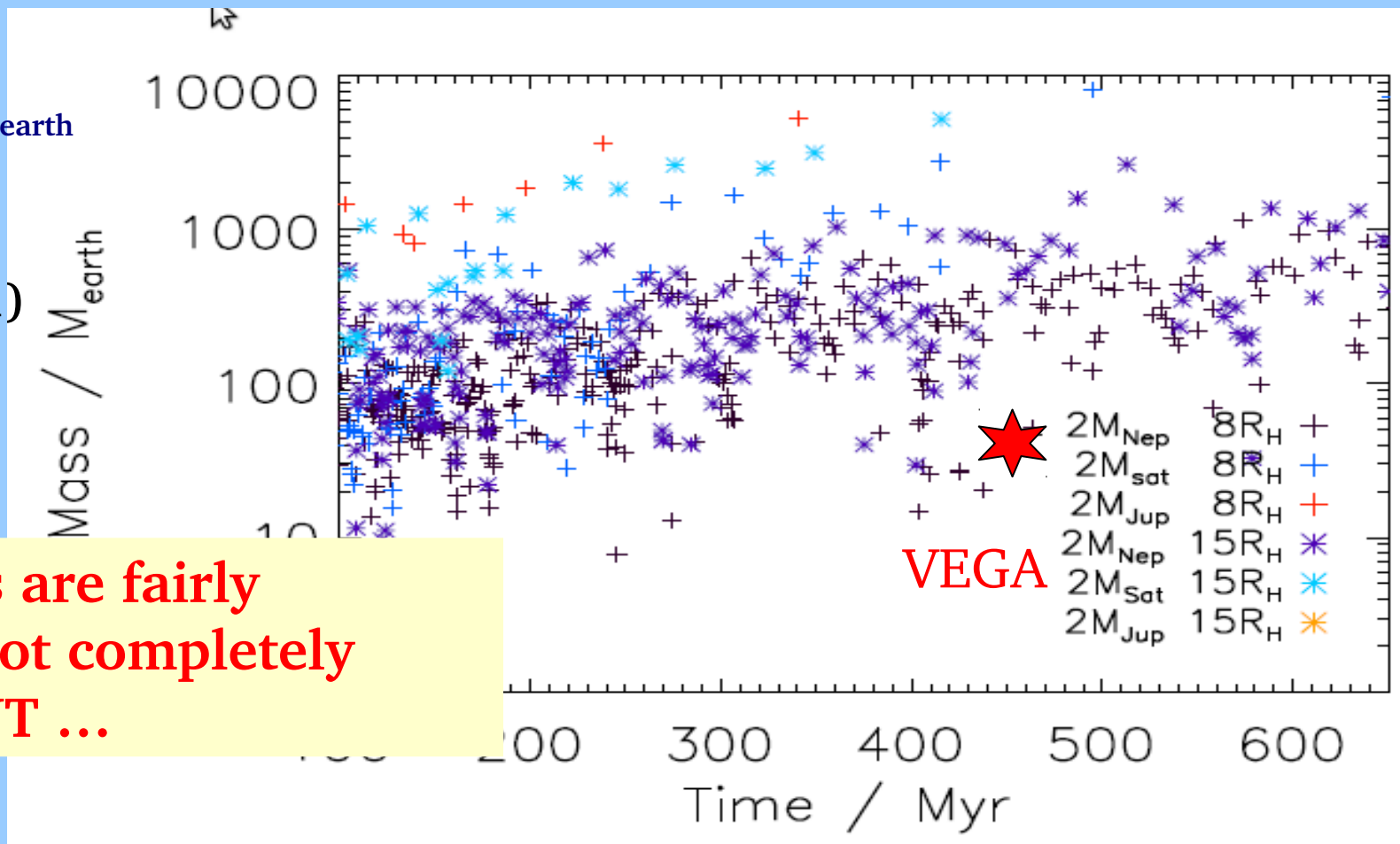
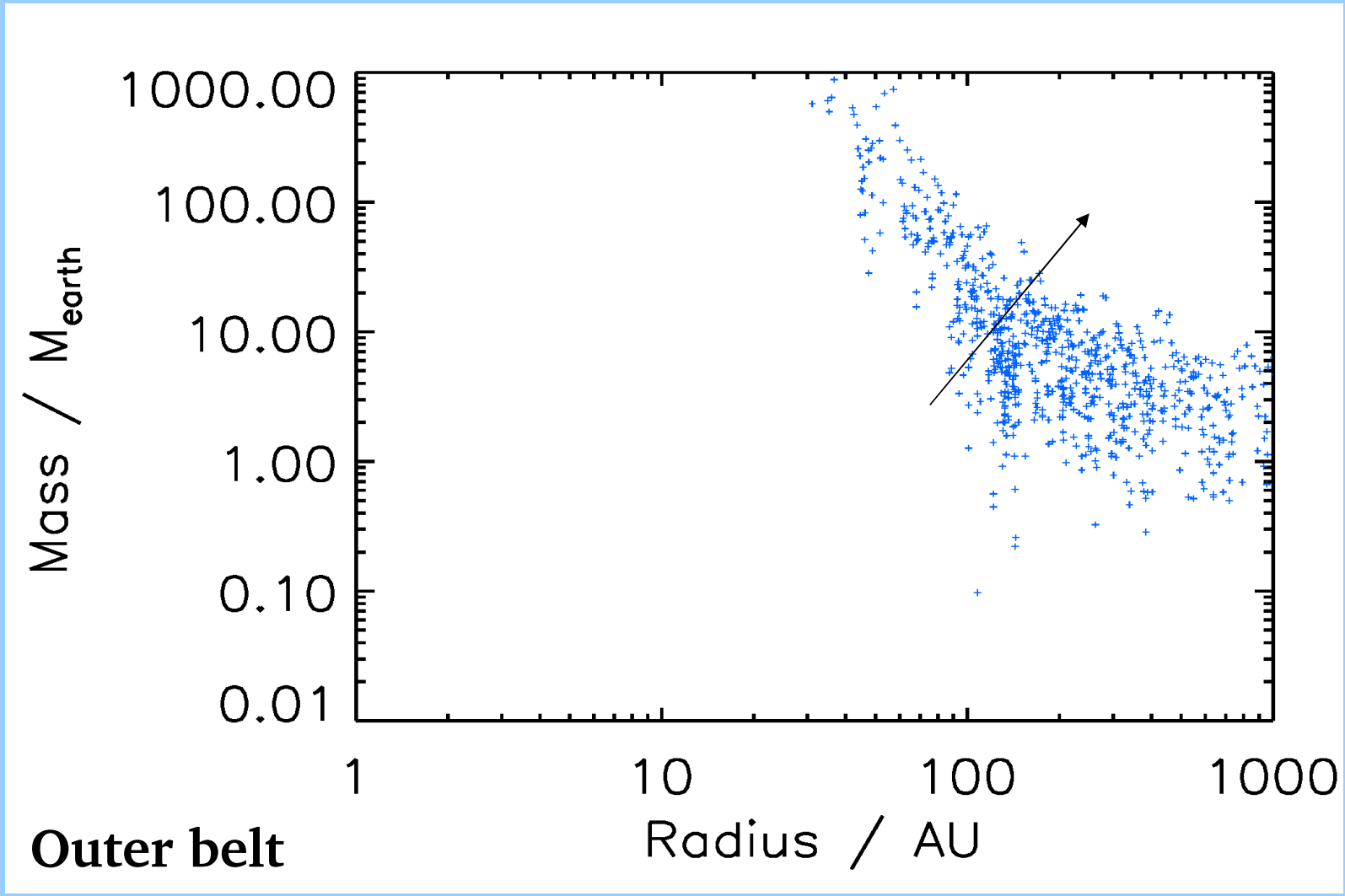


These numbers are fairly uncertain, so not completely ruled out.... BUT ...

What about other systems?

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

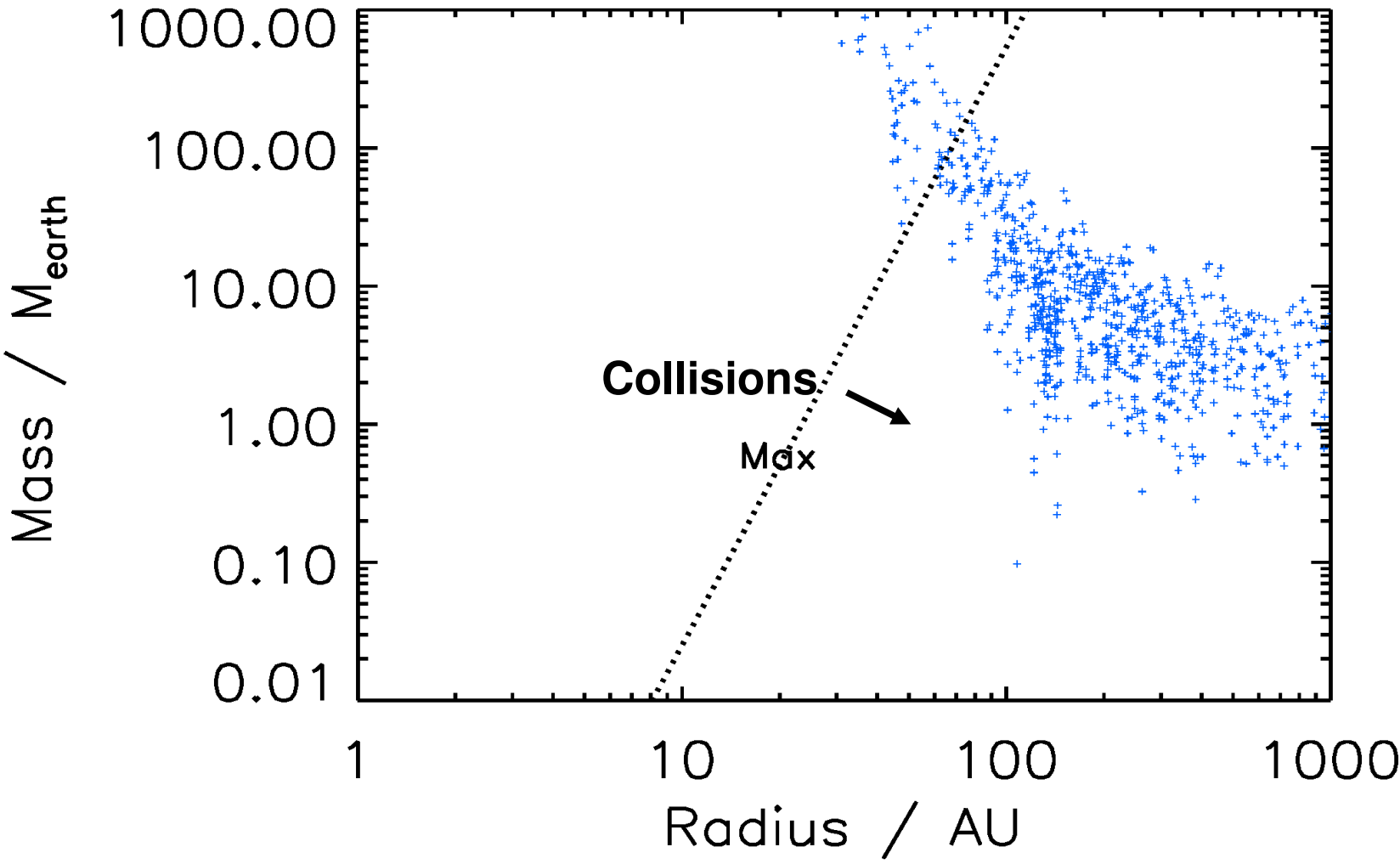
This takes the maximum scattering rates, assumes a solar mass star and a typical required replenishment rate for an exozodi of $10^{-9} M_{earth}$ yr^{-1} after 100Myr



What about other systems?

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

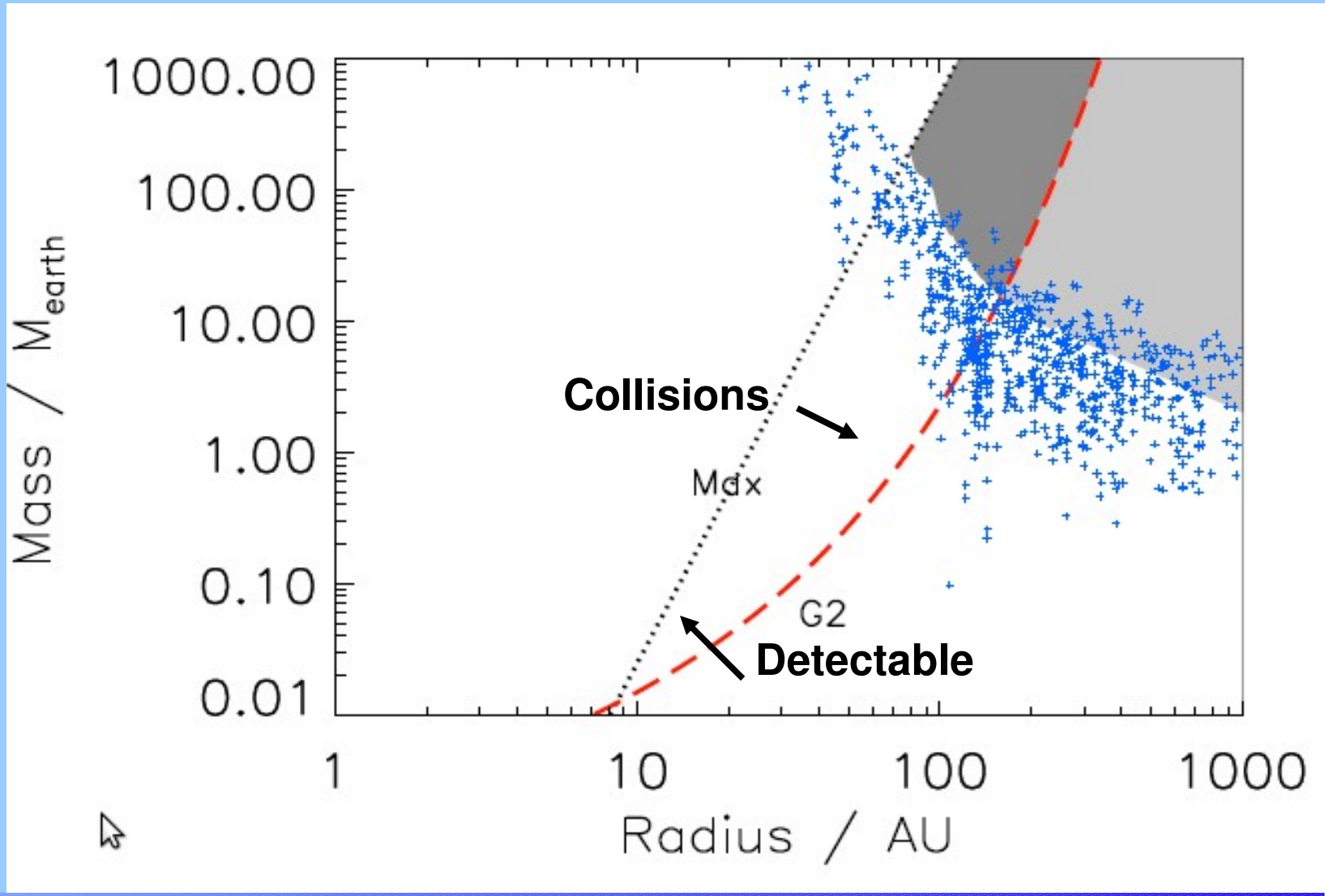
This takes the maximum scattering rates, assumes a solar mass star and a typical required replenishment rate for an exozodi of $10^{-9} M_{earth}$ yr^{-1}



What about other systems?

Can we detect the outer belt?

With Spitzer at 24um, G2 solar type star

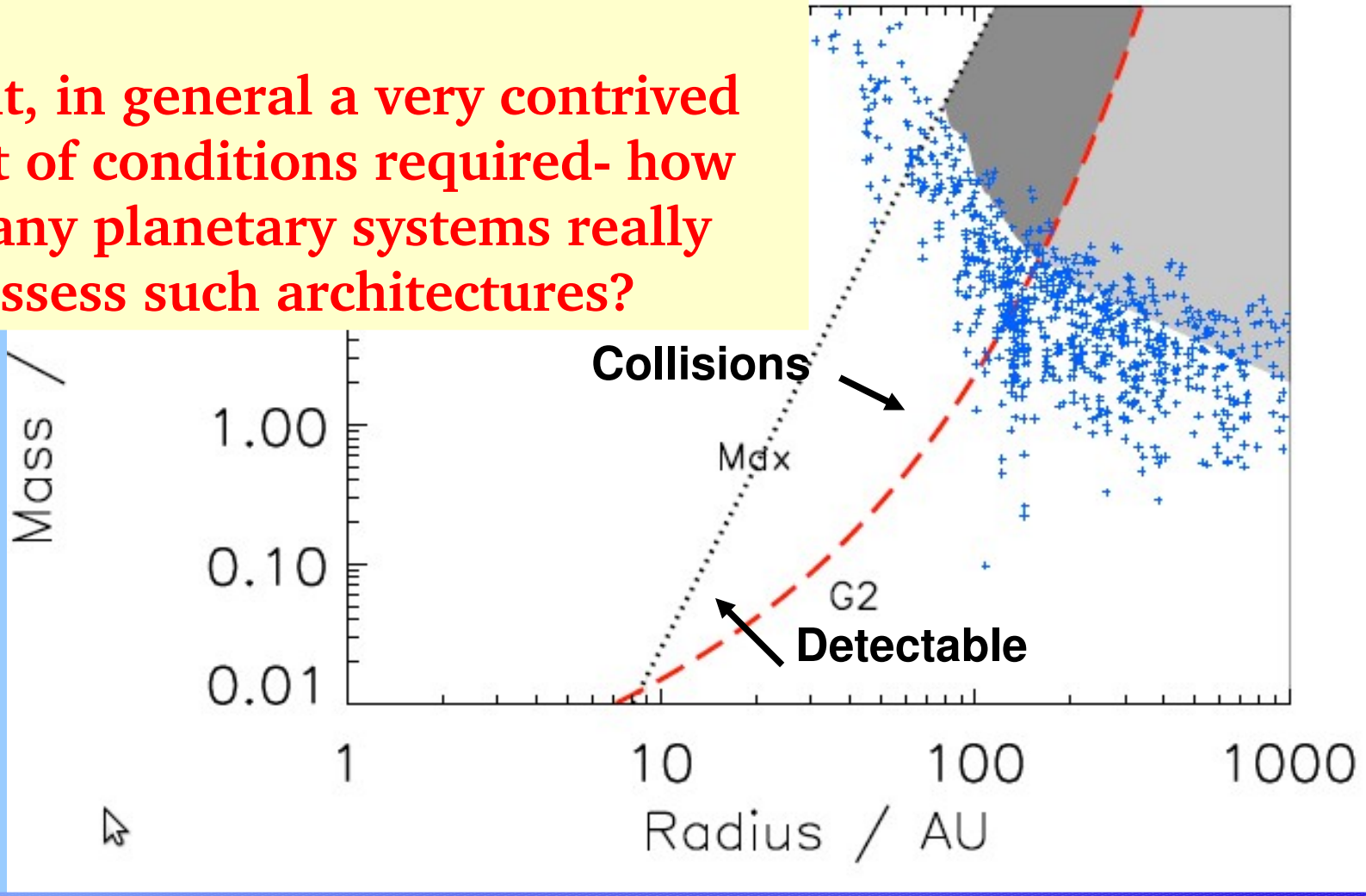


What about other systems?

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 the high levels of exozodiacal dust observed?

CHARA/FLUOR and PIONEER surveys should produce better statistics in the near future

Bonsor et al (2012), A&A - 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.

We need to investigate FURTHER POSSIBILITIES e.g. dynamical instabilities, comet sublimation, etc