Virtual Research Presentation Conference

Exoplanetary Science Initiative Postdoc

Principal Investigator: Virginie Faramaz (3262) - Administrative PI: Karl Stapelfeldt (3260)
Supervisors: Karl Stapelfeldt (3260) & Geoff Bryden (3262)
Summer Intern: Adrian Hernandez (Calstate LA)
Program: Strategic Initiative

Jet Propulsion Laboratory
California Institute of Technology

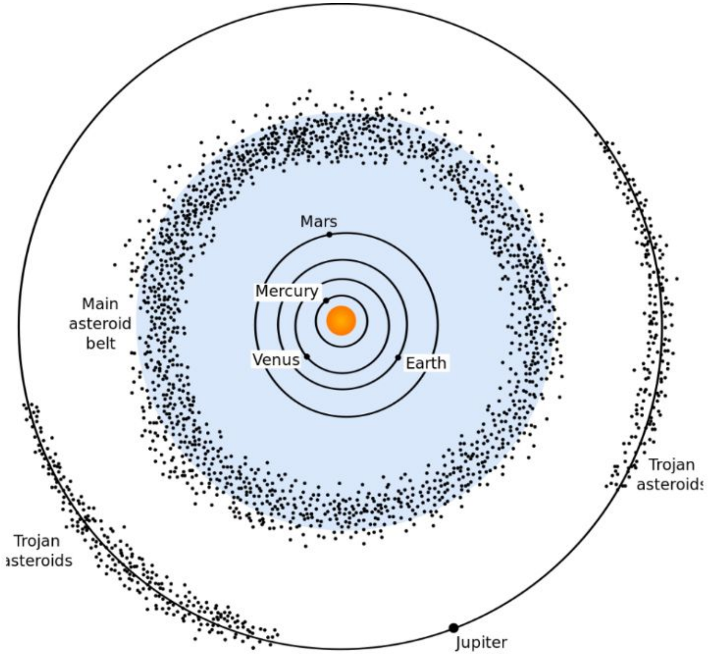
Assigned Presentation RPC-029

On the Formation of Exozodis in Old Systems

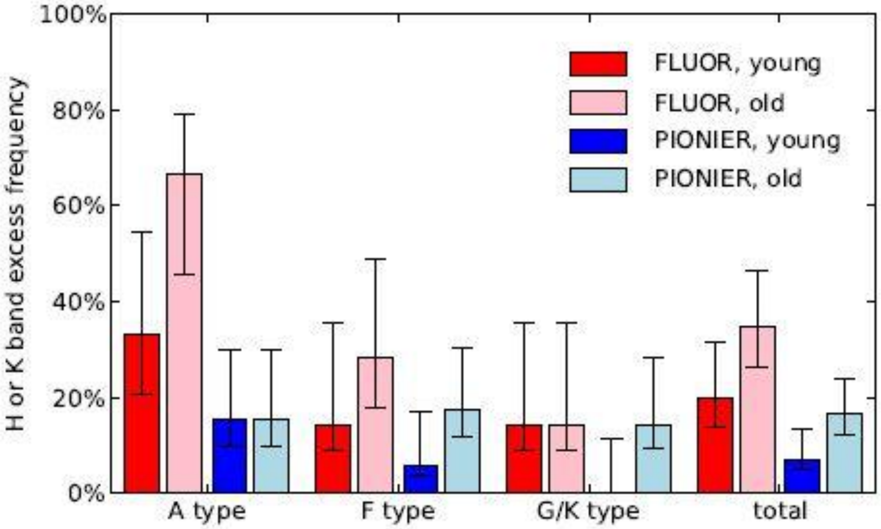
Exozodis are analogues to the Solar System Zodiacal cloud, a collection of dust grains orbiting inner to the Asteroid Belt and down to the dust sublimation radius.

Exozodiacal dust is short-lived relative to the age of the exoplanetary systems in which it is observed, and impossible to produce in-situ via collisions among parent bodies.
It implies an external replenishment mechanism from a distant reservoir, such as the evaporation of comets detached from parent belts analogous to the Kuiper and Asteroid belts, and interactions between those and distant planets.

Therefore, the interest in studying exozodis is twofold: 1) we need to assess how frequent they are and the typical levels of dust so as to determine whether they will mask Earth analogues in the Habitable Zone to future instruments, and 2) they can be related to the overall architecture of the planetary system, and in particular, to distant reservoirs and planets.



Problem Description



As the reservoir belts are themselves not replenished over time, the trend for more frequent exozodi detection in old (>100 Myr) than young systems is thus very surprising

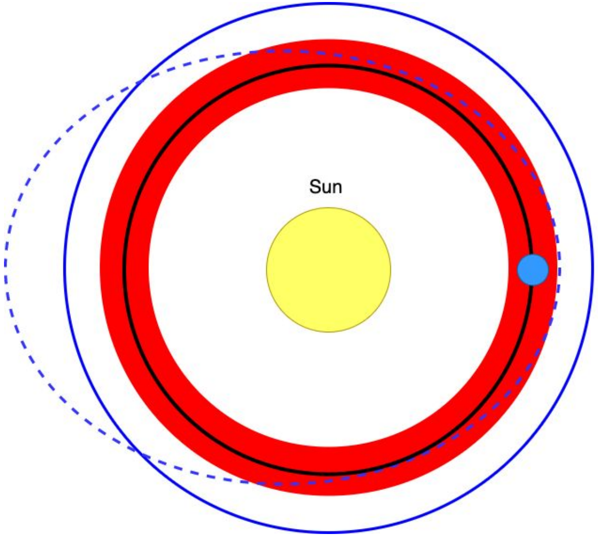
(data from CHARA/FLUOR survey by Absil+2013 and VLT PIONIER survey by Ertel+2014; figure from Ertel+2014)

Several scenarios studied:

- ***scattering of bodies from a reservoir by a chain of planets***
  - *Advantage*: sustains exozodis replenishment on large timescales.
  \- *Inconvenient*: requires massive reservoirs and contrived architectures
  (Bonsor+2012,Bonsor+2014)
- ***Late-Heavy Bombardment-like event***
  \- *Advantage:* exozodis can be produced late in the life of a system.
  \- *Inconvenient:* occurrence rate 1%
  (Bonsor+2013)

Faramaz+2017:
Inner mean-motion resonances (MMRs) with an eccentric planet combines both advantages

Extending the Study to Outer Mean Motion Resonances



The planetesimal (blue orbit) stars on a quasi circular orbit. Because it is in MMR with an 0.1 eccentric planet (black orbit), i.e., it achieves n orbits when the planet achieves p (with n and p integers), the shape of its orbit will “pulse” and regularly become eccentric enough so that it crosses the chaotic zone of the planet (red annulus), where it could be scattered, potentially on a cometary-like orbit.

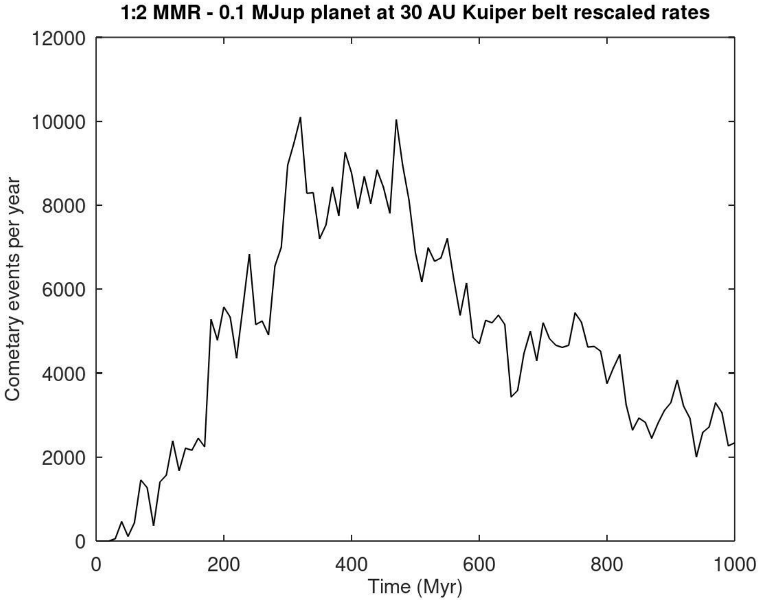
We used a combination of analytical and numerical tools.

Analytically, we can predict, thanks to celestial mechanics, whether the orbit of the planetesimal will cross the chaotic zone of the planet.

However, we cannot predict whether the planetesimal will actually encounter the planet when its orbit is in that configuration, nor whether it will be scattered on a cometary-like orbit, nor the timescales involved and the total number of bodies that can be expected to be on cometary orbits.

To answer these questions, we use numerical N-body simulations, where we study planets of eccentricity 0.1 and different masses and semimajor axes, and how a set of 5,000 test particles in MMR with these planets behave.

Results



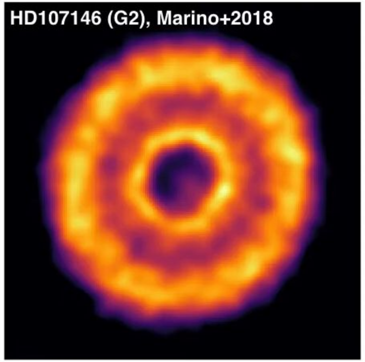
We show that continuous production of active comets over Gyr timescales producing dust levels comparable to detected exozodis can also be sustained, and from reservoirs as mature and little massive as the Kuiper Belt.

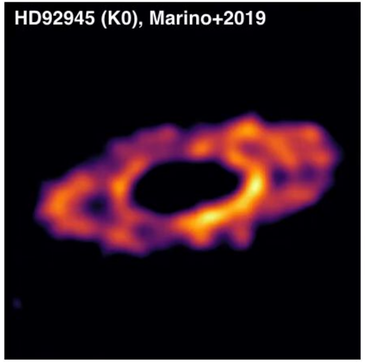
We also investigated how an additional Jupiter mass planet could shield the Habitable Zone from such massive inputs. We have found that it can reduce them of at least two orders of magnitude.

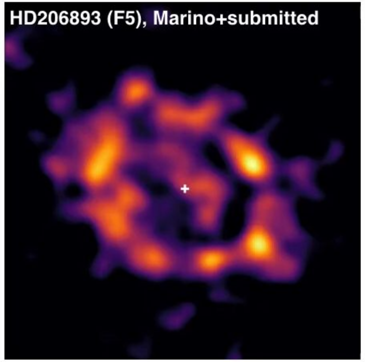
If you want to know more about this, do not hesitate to get in touch:
virginie.c.faramaz@jpl.nasa.gov
(until 11/05/2020, use
virginie.faramaz@gmail.com after 11/05)

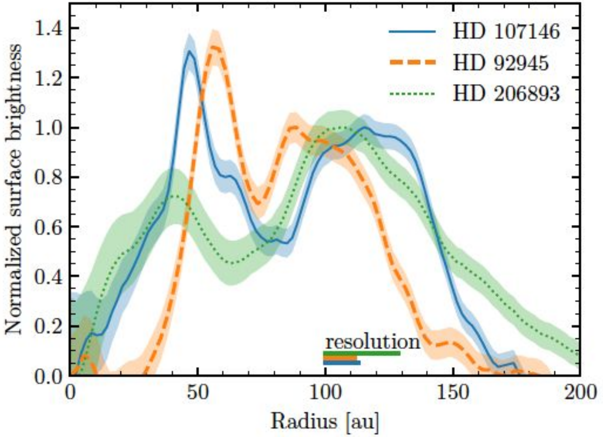
You can also reach my supervisors at JPL:
karl.r.stapelfeldt@jpl.nasa.gov and
geoffrey.bryden@jpl.nasa.gov

THANK YOU FOR YOUR ATTENTION (AND BONUS)









We characterize these distant planets acting on reservoirs via their imprint on those reservoirs, that can be seen with ALMA.

During my 3 years of ESI postdoc, I have co-authored 3 publications (Marino+2018, 2019, 2020), which revealed belts with gaps, and set constraints on the unseen planets shaping those gaps..

Publications and References

Absil, O., Defrère, D., Coudé du Foresto, V., et al. 2013, A&A, 555, A104
Bonsor, A., Augereau, J.-C., & Thébault, P. 2012, A&A, 548, A104
Bonsor, A., Raymond, S. N., & Augereau, J.-C. 2013, MNRAS, 433, 2938
Bonsor, A., Raymond, S. N., Augereau, J.-C., & Ormel, C. W. 2014, MNRAS, 441, 2380
Ertel, S., Absil, O., Defrère, D., et al. 2014, A&A, 570, A128
Faramaz V., Ertel, S., Booth, M., Cuadra, J., Simmonds, C., 2017, MNRAS, 465, 2352
Marino, S., Carpenter, J., Wyatt, M. C., et al. 2018, MNRAS, 479, 5423
Marino, S., Yelverton, B., Booth, M., et al. 2019, MNRAS, 484, 1257
Marino, S., Zurlo, A., Faramaz, V., et al. 2020, MNRAS, 498, 1319