

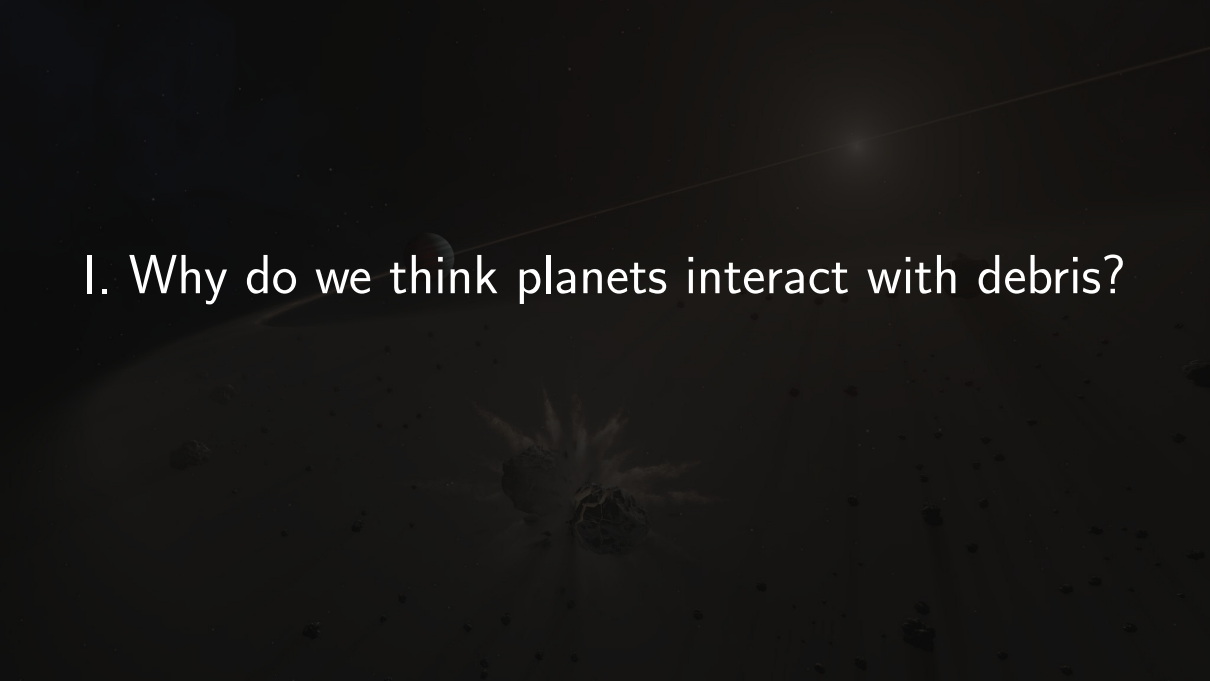
Planet-debris interactions

Tim Pearce



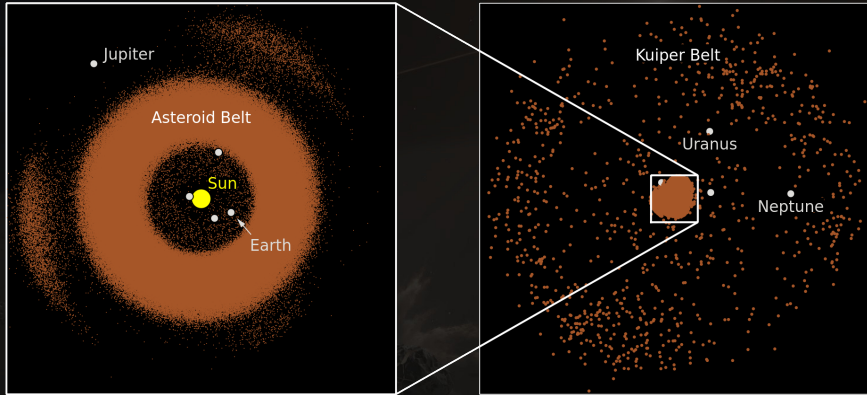
Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Image: NASA/JPL-Caltech



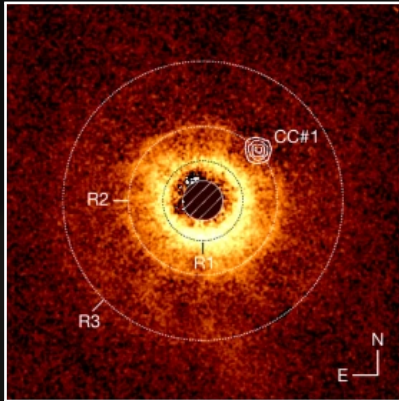
I. Why do we think planets interact with debris?

Solar System



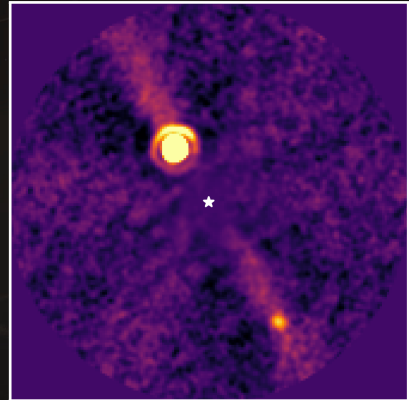
We see it around others stars too!

TWA 7



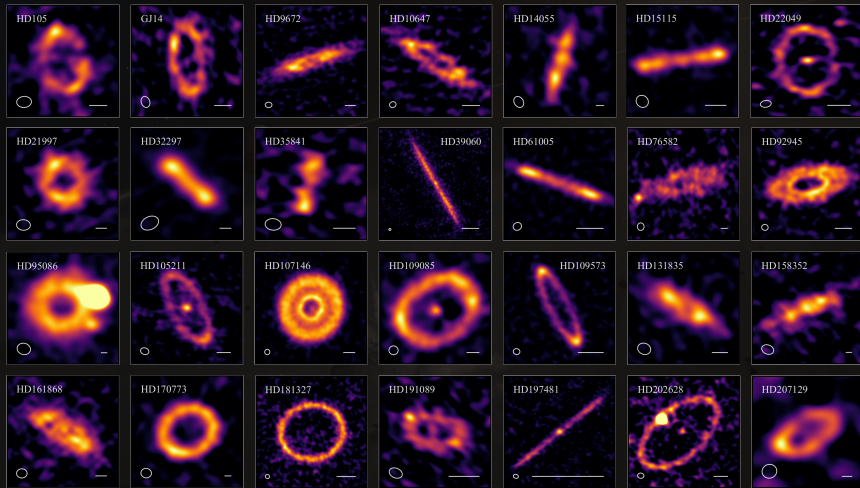
Lagrange et al. 2025

β Pic



Sutcliffe et al. 2026; Gibbs et al. 2026

Extrasolar debris discs



Stirring

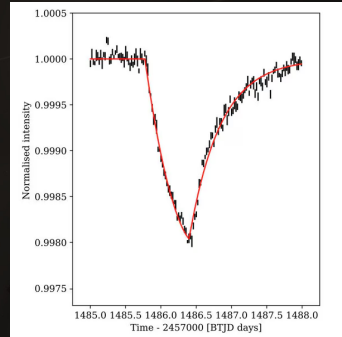


NASA/JPL-Caltech. Stirring: Mustill & Wyatt 2009; Muñoz-Gutiérrez, Marshall & Peimbert 2023; Costa, Pearce & Krivov 2024; Sefilian 2024; Marshall et al. 2025...

Exocomets



ESO, Calçada

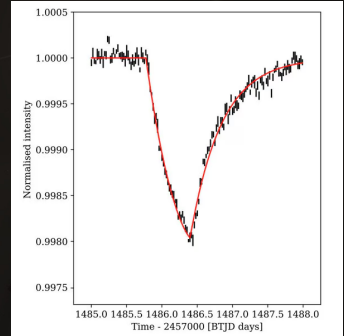


Zieba et al. 2019

Exocomets

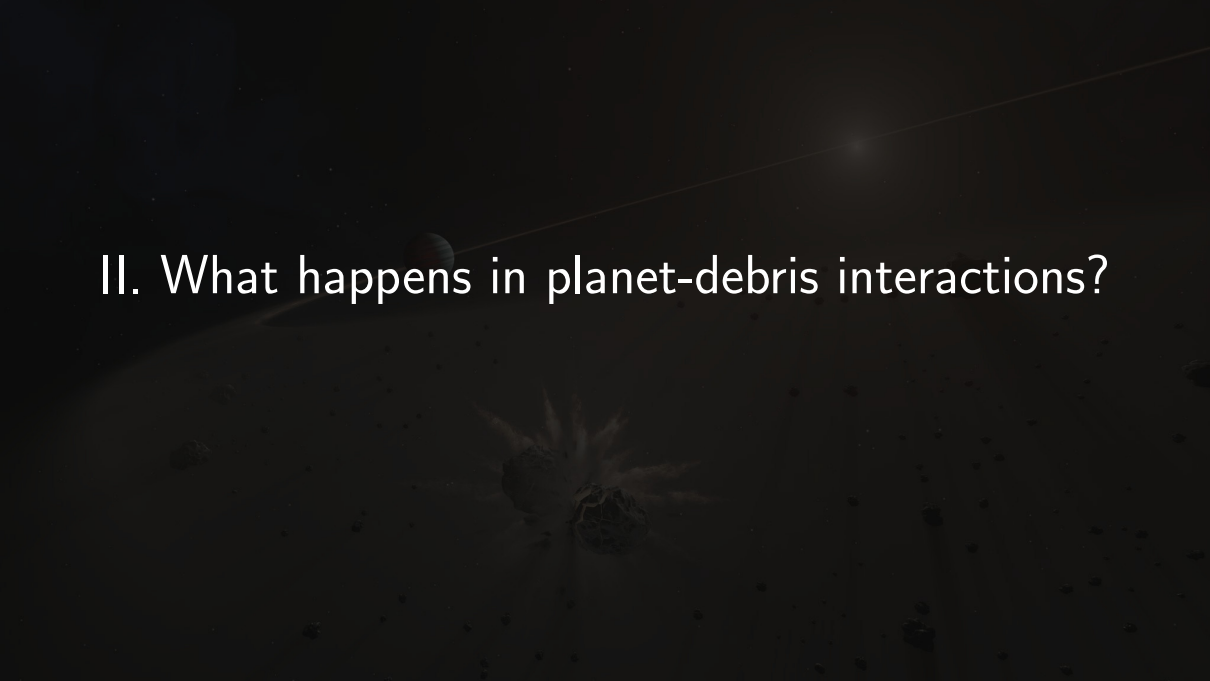


ESO, Calçada



Zieba et al. 2019



The background is a dark, deep space scene. A bright, glowing star is visible in the upper right quadrant. A thin, curved line, possibly a planet's horizon or a ring, stretches across the middle of the frame. In the lower center, there is a large, complex, star-like structure that appears to be a debris field or a collision site, with many smaller, irregular shapes radiating from it. The overall tone is dark and mysterious.

II. What happens in planet-debris interactions?

What happens in planet-debris interactions?

Carve gaps



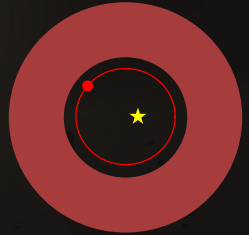
Warp belts



Pass bodies inward



Make belts eccentric



Sculpt disc edges



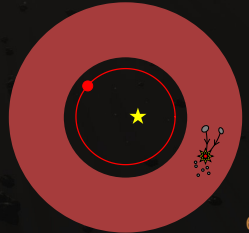
Drive spirals



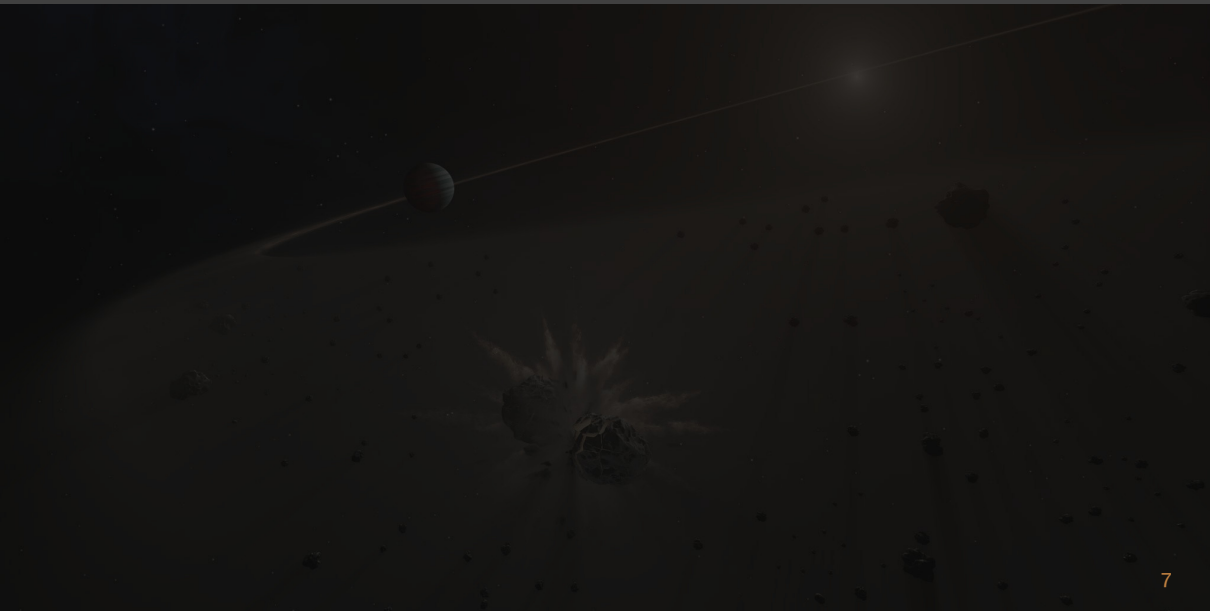
Make clumps



Stir debris



1. Planets can sculpt disc edges



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1. Planets can sculpt disc edges

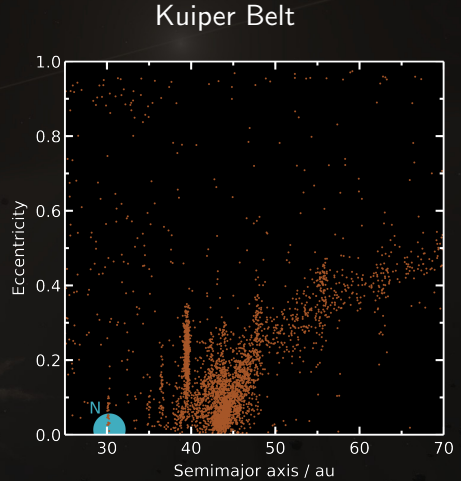


1. Planets can sculpt disc edges



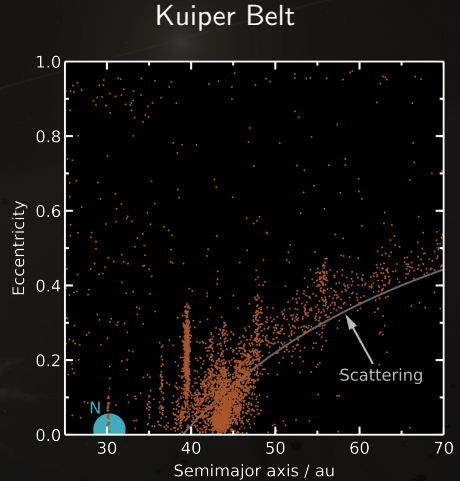
E.g. Wisdom 1980; Duncan, Quinn & Tremaine 1989; Gladman 1993; Malhotra 1998; Morrison & Malhotra 2015; Pearce & Wyatt 2014; Lazzoni et al. 2018...

1. Planets can sculpt disc edges



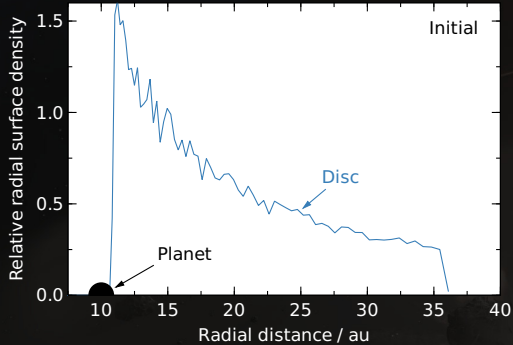
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1. Planets can sculpt disc edges



E.g. Wisdom 1980; Duncan, Quinn & Tremaine 1989; Gladman 1993; Malhotra 1998; Morrison & Malhotra 2015; Pearce & Wyatt 2014; Lazzoni et al. 2018... Ephemerides: JPL

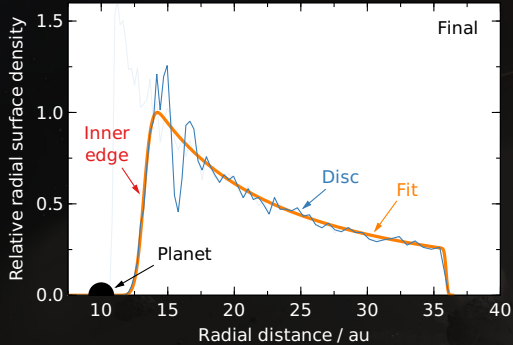
1. Planets can sculpt disc edges



Pearce et al. 2024

E.g. Quillen 2006; Chiang et al. 2009; Mustill & Wyatt 2012; Thebault, Kral & Ertel 2012; Rodigas, Malhotra & Hinz 2014; Nesvold & Kuchner 2015; Imaz Blanco et al. 2023; Pearce et al. 2024...

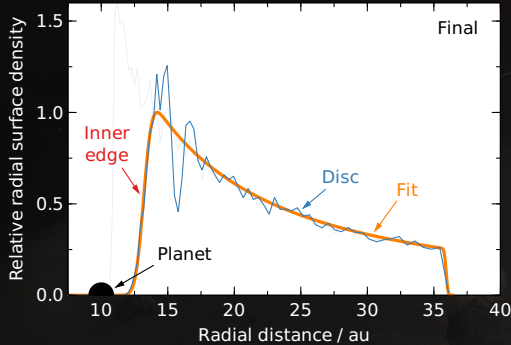
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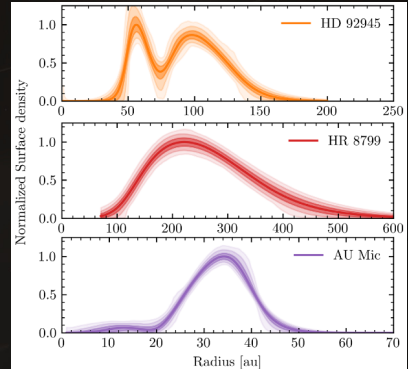
Pearce et al. 2024

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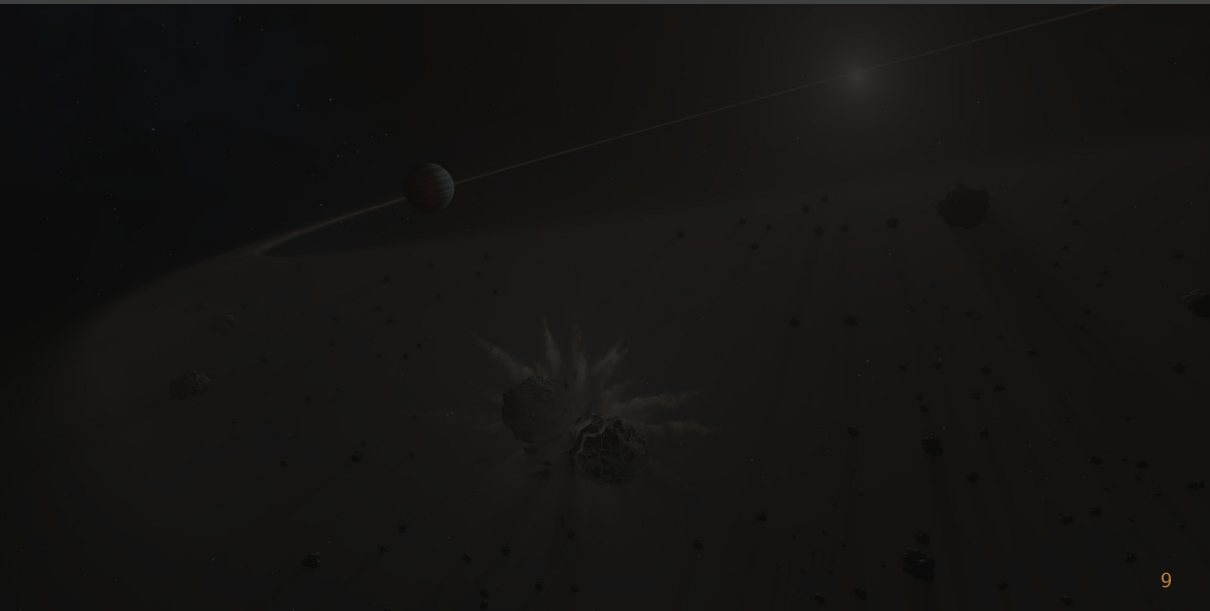
Pearce et al. 2024



Marino 2021

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2. Planets can make discs **eccentric**



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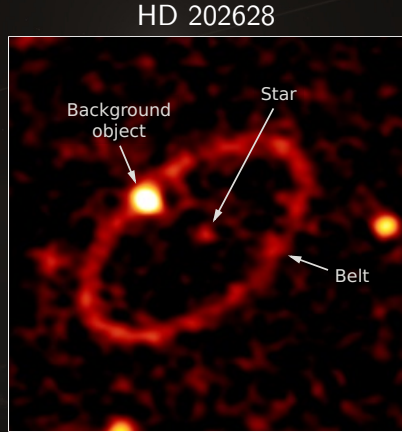


2. Planets can make discs **eccentric**



E.g. Quillen 2006; Chiang et al. 2009; Beust et al. 2014; Faramaz et al. 2014; Tamayo 2014; Pearce & Wyatt 2014; Kennedy 2020; Lynch & Lovell 2022; Lovell & Lynch 2023; Stuber et al. 2023; Lithwick et al. 2026...

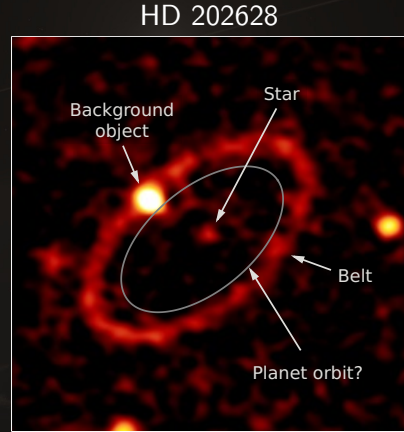
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Faramaz et al. 2019

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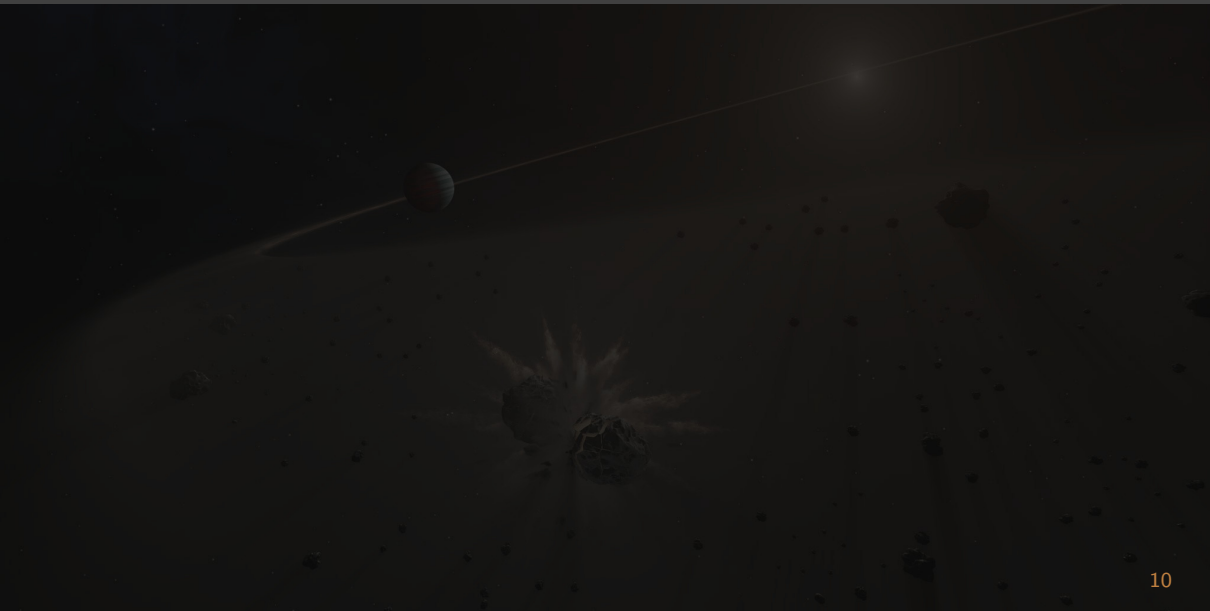
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Faramaz et al. 2019

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3. Planets can warp discs



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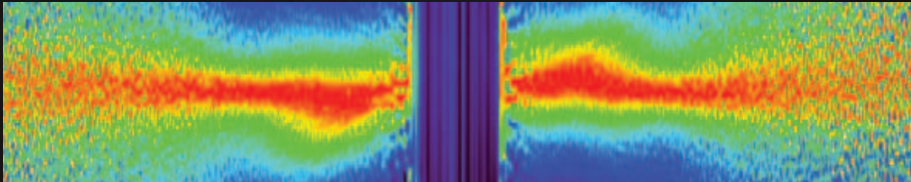


E.g. Dawson, Murray-Clay & Fabrycky 2011; Pearce & Wyatt 2014; Nesvold & Kuchner 2015; Smallwood 2023; Sefilian et al. 2025...

3. Planets can **warp** discs



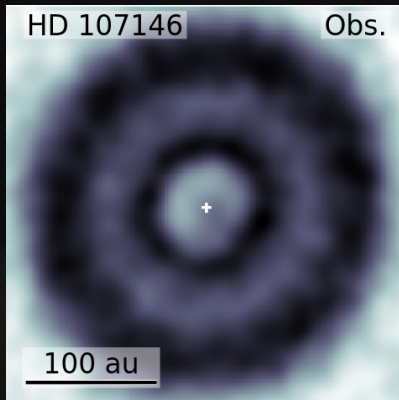
β Pic



Golimowski et al. 2006

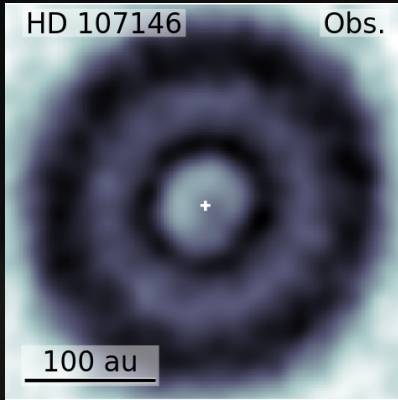
E.g. Dawson, Murray-Clay & Fabrycky 2011; Pearce & Wyatt 2014; Nesvold & Kuchner 2015; Smallwood 2023; Sefilian et al. 2025...

4. Planets can **carve gaps**



Marino et al. 2018

4. Planets can carve gaps

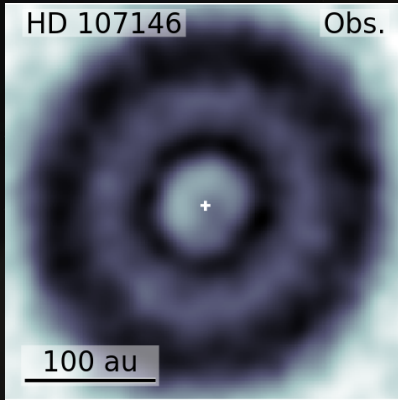


Marino et al. 2018

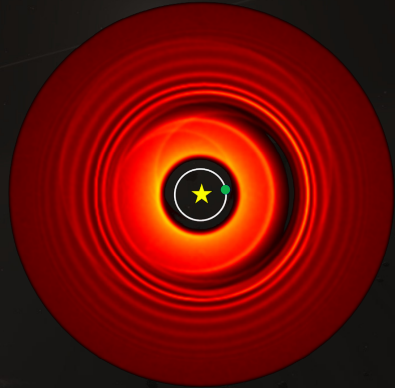


E.g. Faber & Quillen 2007; Kirsh et al. 2009; Su et al. 2013; Pearce & Wyatt 2015; Shannon et al. 2016; Lazzoni et al. 2018; Sefilian, Rafikov & Wyatt 2021; Friebe, Pearce & Löhne 2022, Friebe & Sefilian in prep....

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Marino et al. 2018

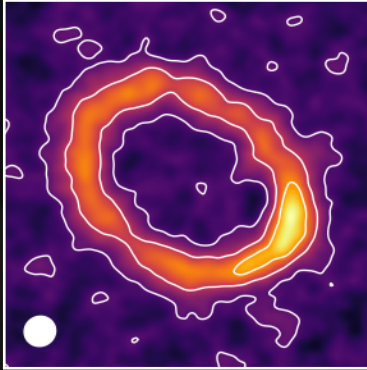


Sefilian, Rafikov & Wyatt 2021

E.g. Faber & Quillen 2007; Kirsh et al. 2009; Su et al. 2013; Pearce & Wyatt 2015; Shannon et al. 2016; Lazzoni et al. 2018; Sefilian, Rafikov & Wyatt 2021; Friebe, Pearce & Löhne 2022, Friebe & Sefilian in prep....

5. Planets can create resonant clumps and rings

HD 121617



Marino et al. 2026

Fomalhaut



Gáspár et al. 2023

See also Wyatt 2003, 2006; Krivov et al. 2007; Reche et al. 2008; Tabeshian & Wiegert 2016, 2017; Booth et al. 2023; Sommer, Wyatt & Han 2025; Weber et al. 2026...

What happens in planet-debris interactions?

Carve gaps



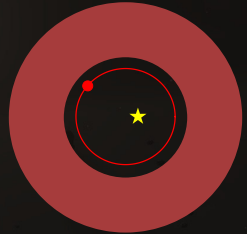
Warp belts



Pass bodies inward



Make belts eccentric



Sculpt disc edges



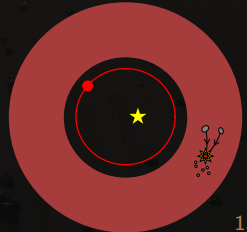
Drive spirals



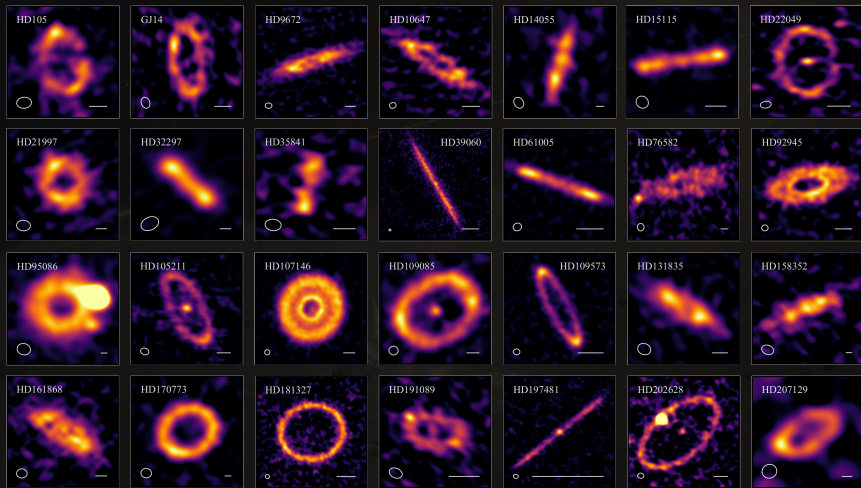
Make clumps



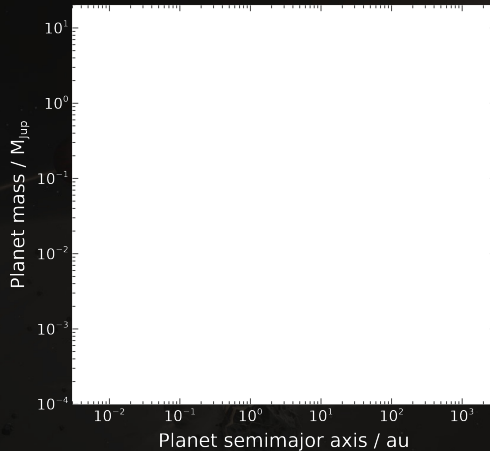
Stir debris



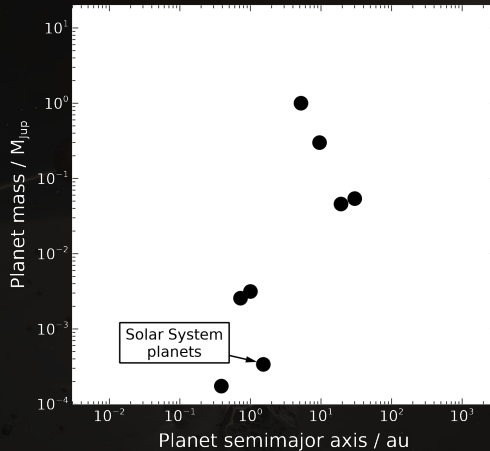
Planets inferred from debris discs



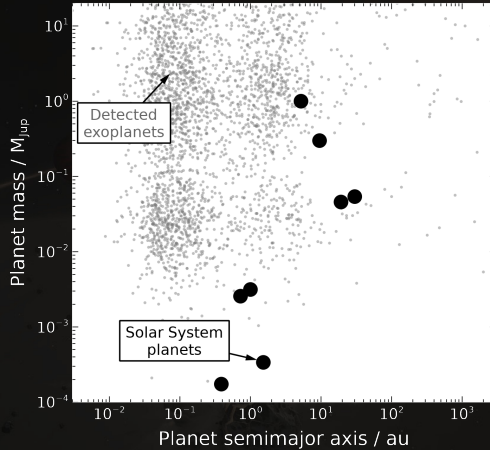
Planets inferred from debris discs



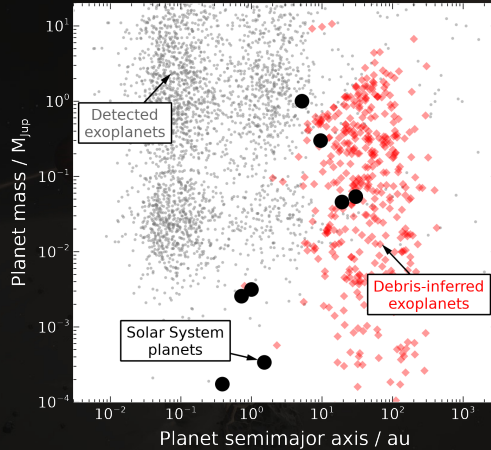
Planets inferred from debris discs



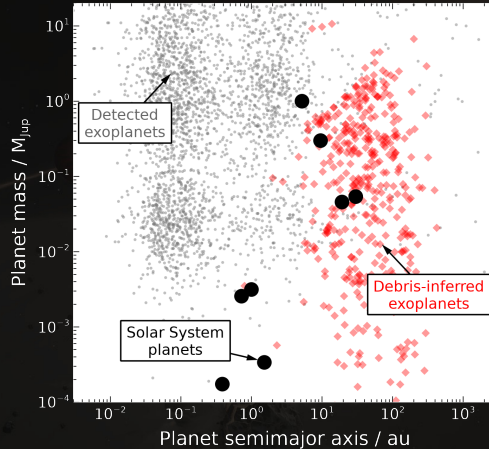
Planets inferred from debris discs



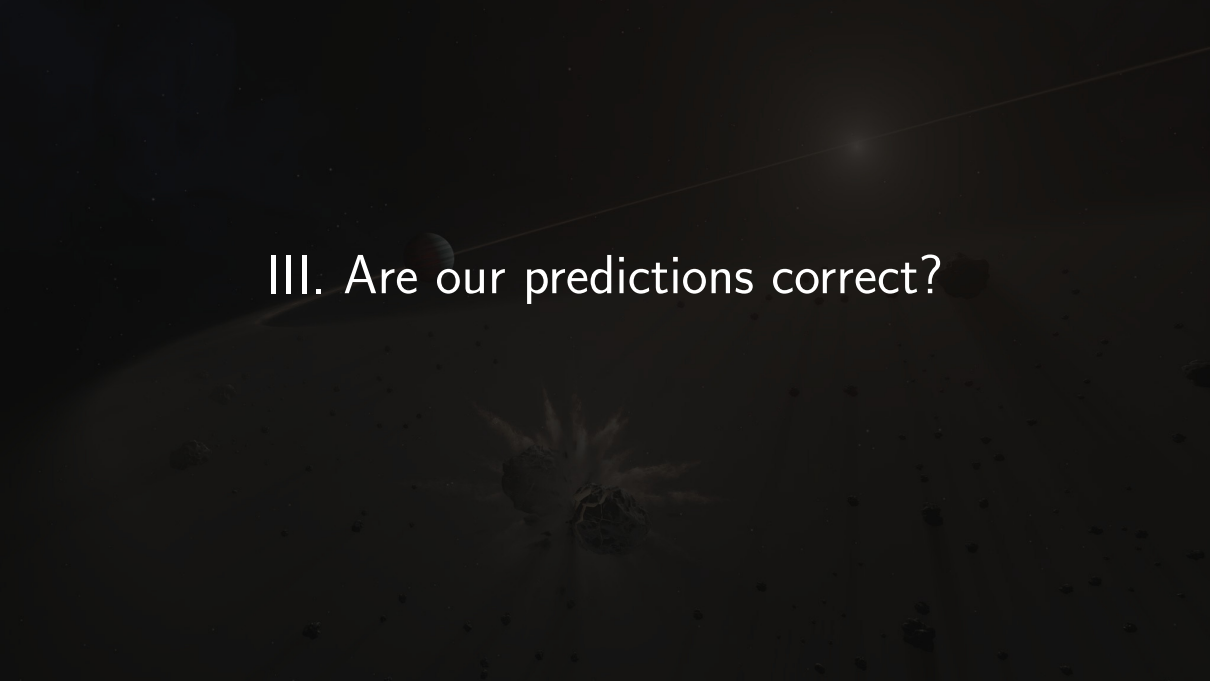
Planets inferred from debris discs



Planets inferred from debris discs



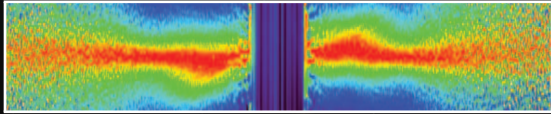
⇒ Typical prediction: Neptunes to Jupiters

The background of the slide is a dark, deep space scene. In the upper right, a bright star or distant galaxy core glows with a soft, out-of-focus light. A thin, faint ringed planet, similar to Saturn, is visible in the upper left quadrant. The foreground is filled with numerous small, dark, irregular shapes representing asteroids or dust particles, scattered across the dark void. The overall tone is mysterious and scientific.

III. Are our predictions correct?

Sometimes, yes!

β Pic

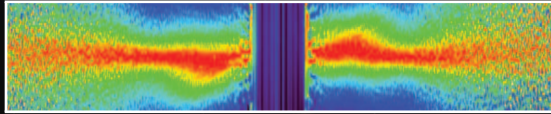


Golimowski et al. 2006

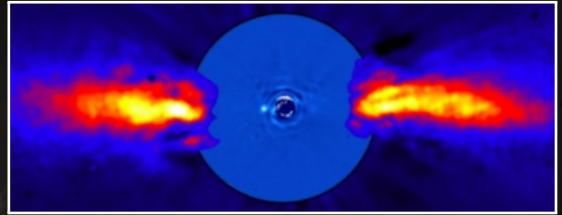


Sometimes, yes!

β Pic



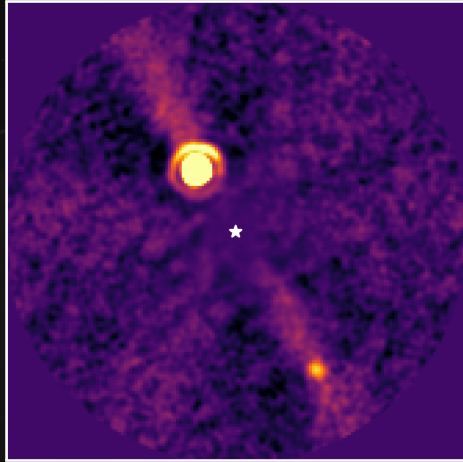
Golimowski et al. 2006



ESO / A.-M. Lagrange et al.

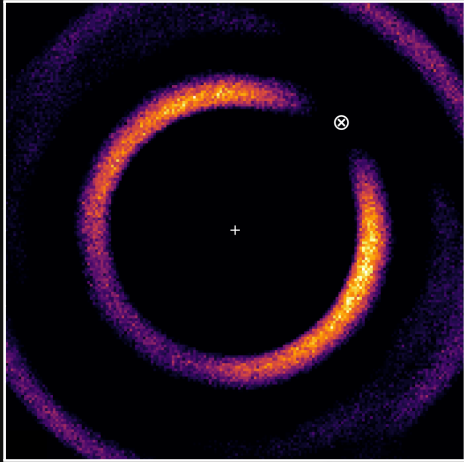
Sometimes, yes!

β Pic



Sometimes, yes!

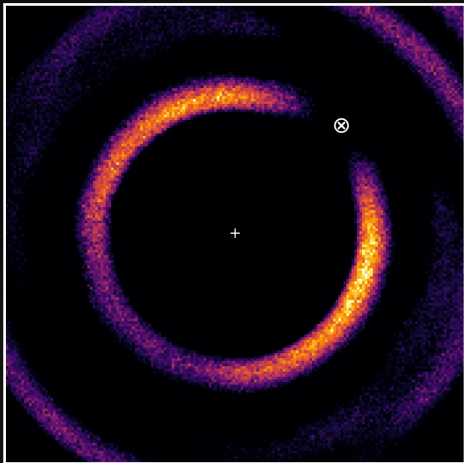
TWA 7



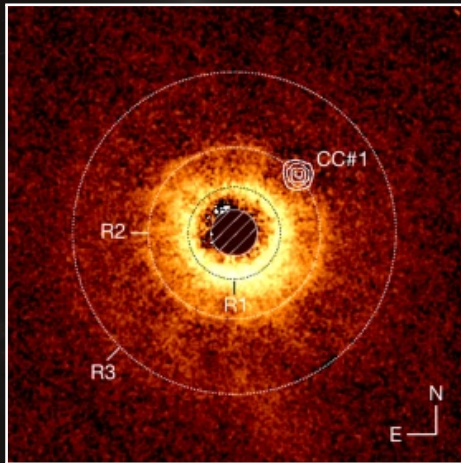
Ren et al. 2021

Sometimes, yes!

TWA 7

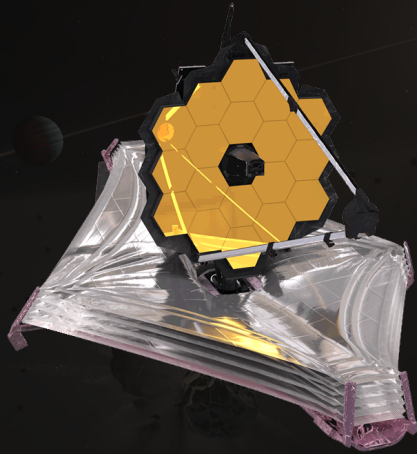


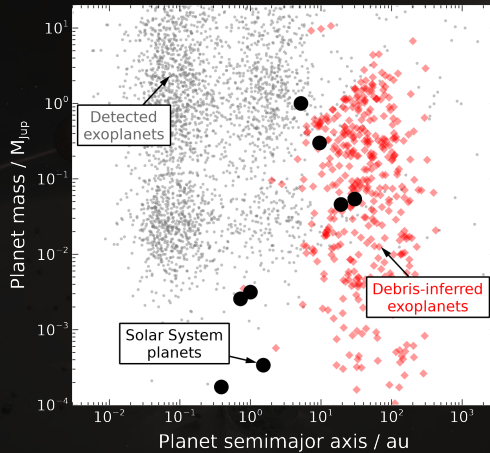
Ren et al. 2021

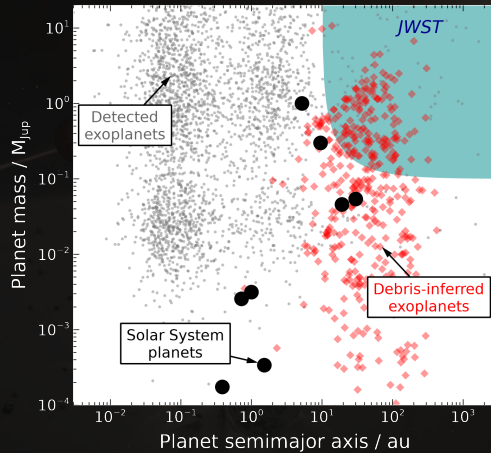


Lagrange et al. 2025

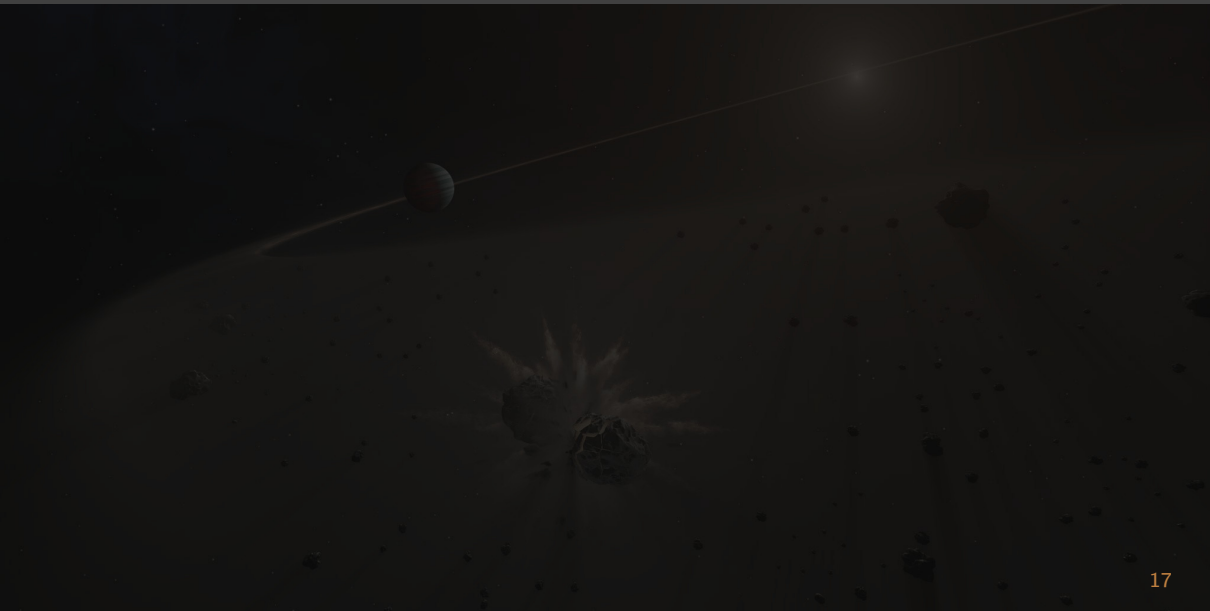
JWST





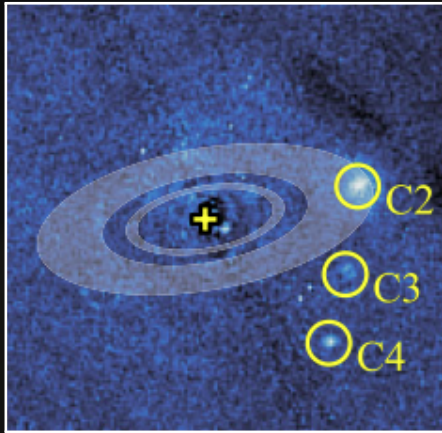


Lots of non-detections :(



Lots of non-detections :(

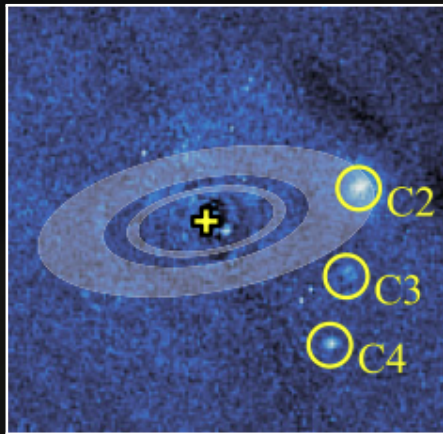
HD 92945



Bendahan-West et al. 2026

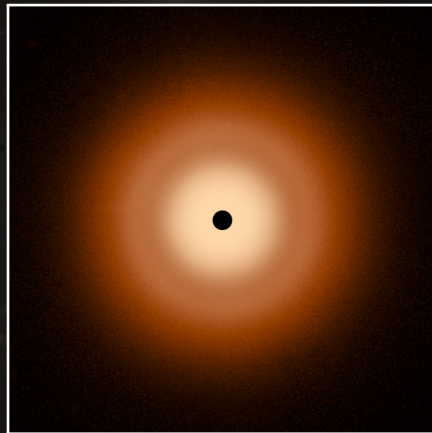
Lots of non-detections :(

HD 92945

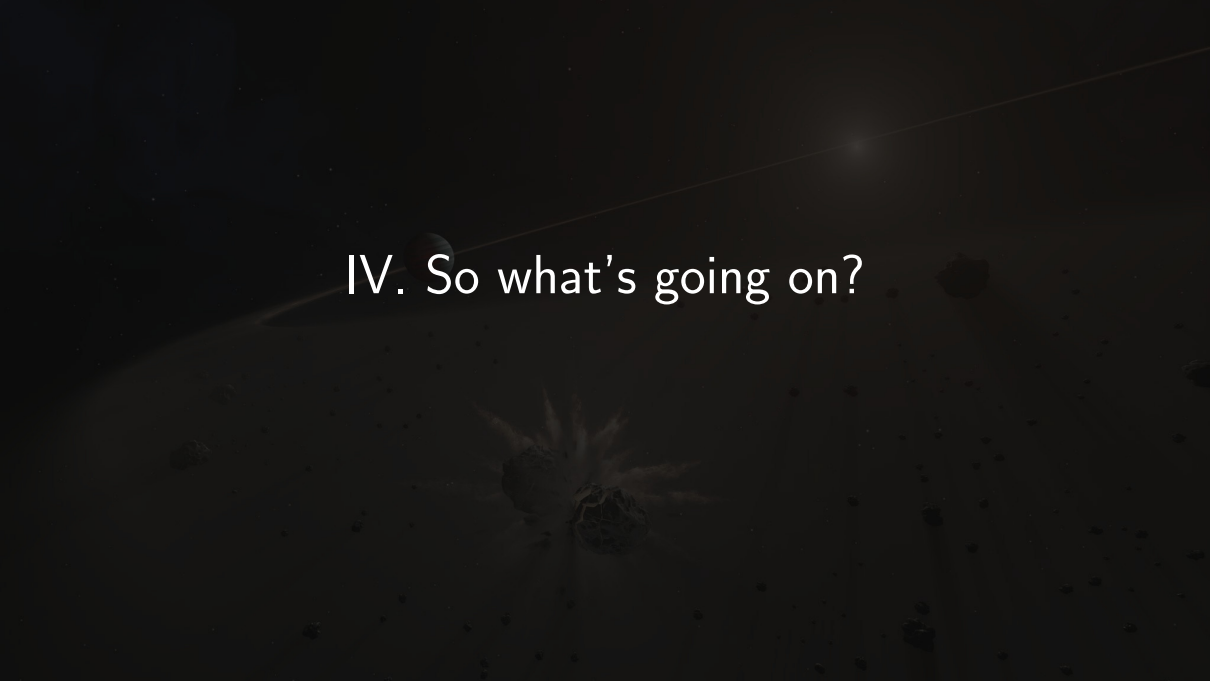


Bendahan-West et al. 2026

Vega

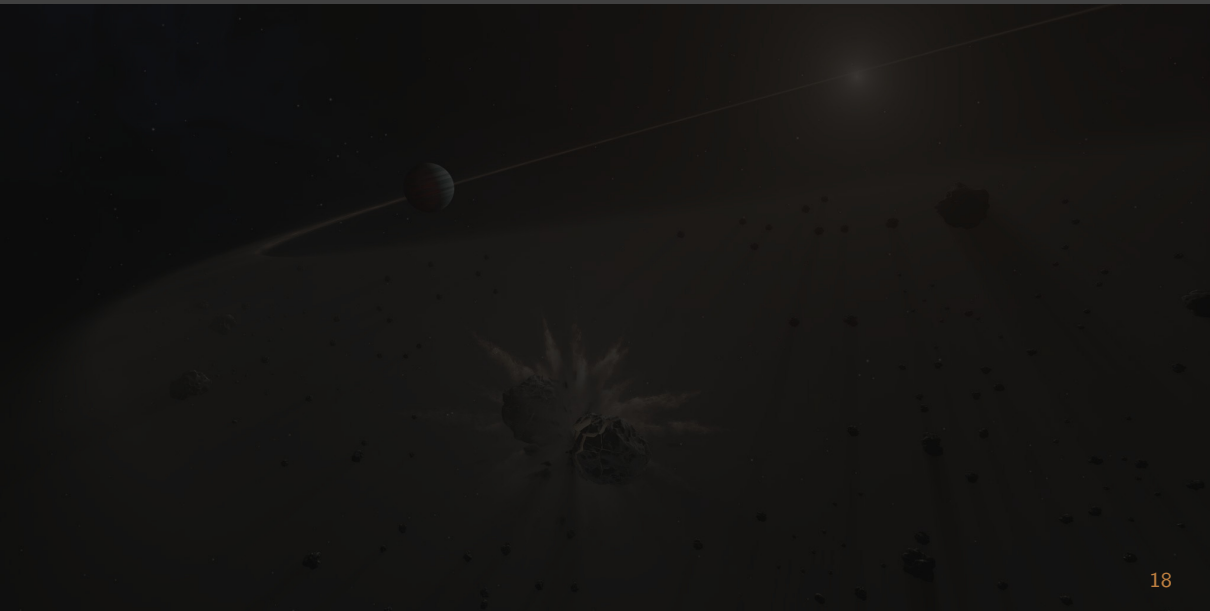


Su et al. 2024

The background is a dark, textured space. A bright, glowing light source is positioned in the upper right quadrant, casting a soft, diffused light. A thin, curved orange line, resembling a comet's tail or a celestial boundary, stretches from the left side towards the light source. In the lower center, there is a faint, star-like object with a central bright spot and several radiating, wispy lines. The overall atmosphere is mysterious and cosmic.

IV. So what's going on?

Where are the *JWST* debris-disc planets?



Where are the *JWST* debris-disc planets?

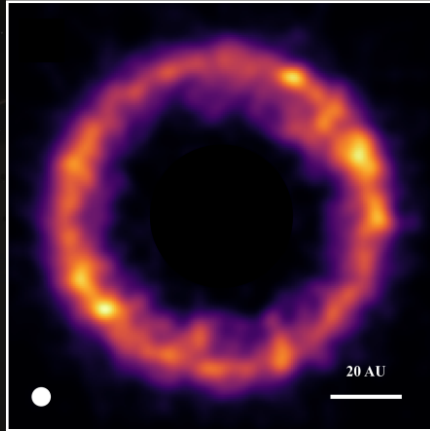
Some possibilities:

1. Our models don't work?



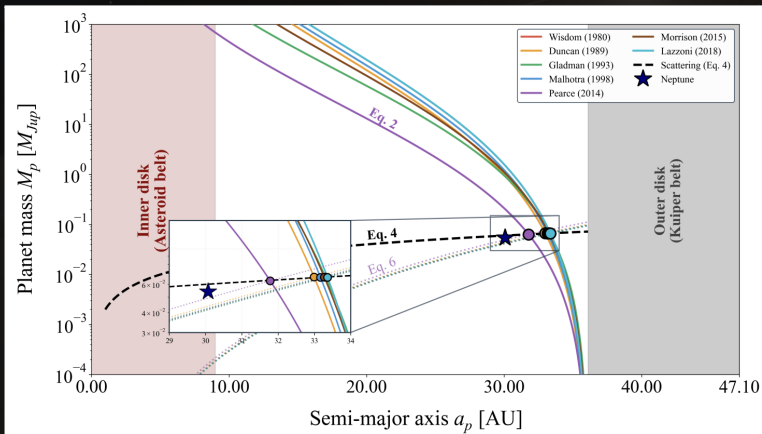
Our models don't work?

Simulated Kuiper Belt



Our models don't work?

Simulated Kuiper Belt



Where are the *JWST* debris-disc planets?

Some possibilities:

1. Our models don't work?



Where are the *JWST* debris-disc planets?

Some possibilities:

1. Our models don't work?
2. More than one planet?

More than one planet?



E.g. Faber & Quillen 2007; Su et al. 2013; Shannon et al. 2016; Lazzoni et al. 2018

More than one planet?



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Where are the *JWST* debris-disc planets?

Some possibilities:

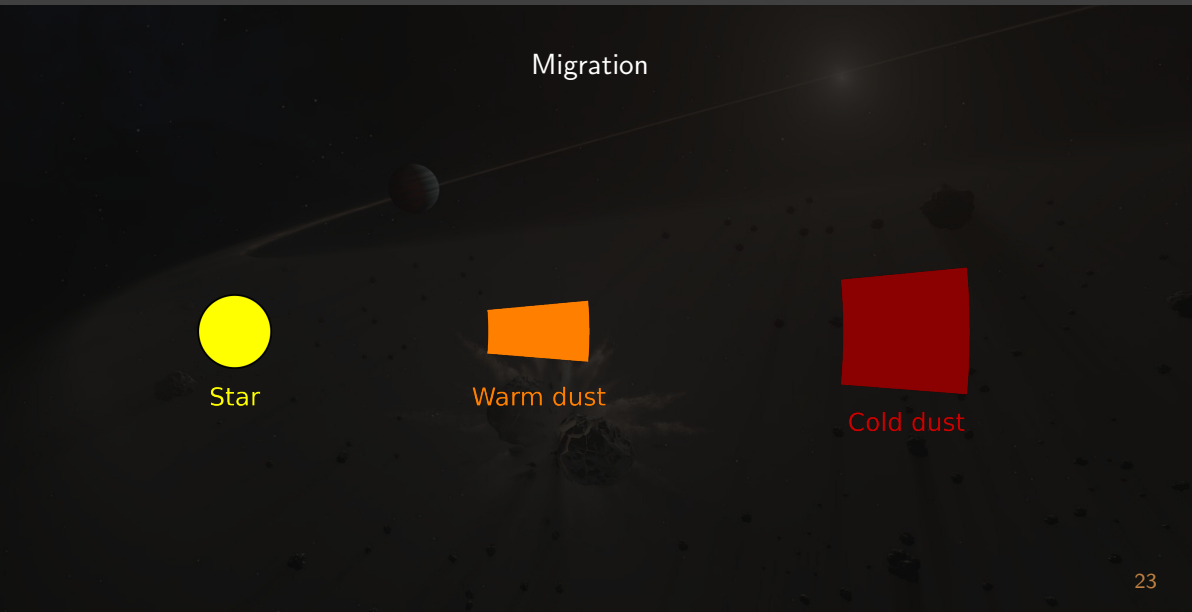
1. Our models don't work?
2. More than one planet?
3. More-complicated interactions?

More-complicated interactions?

Migration



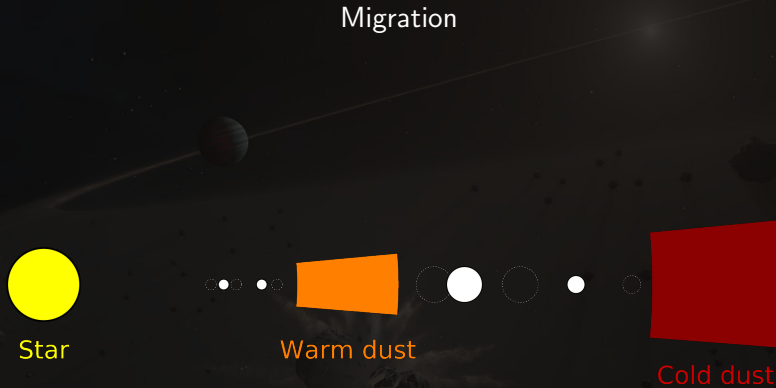
More-complicated interactions?



More-complicated interactions?

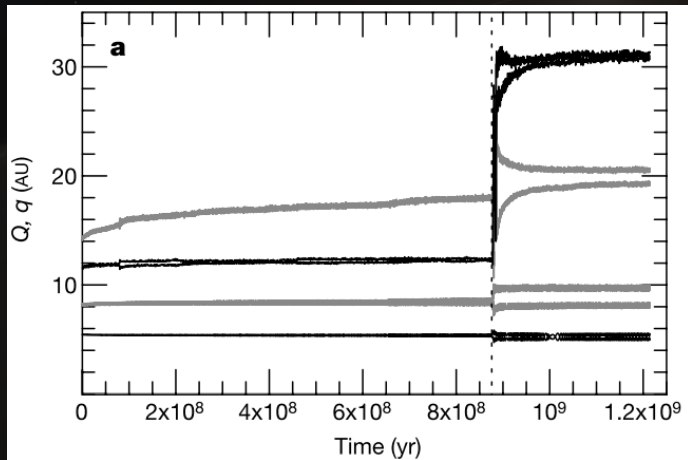


More-complicated interactions?



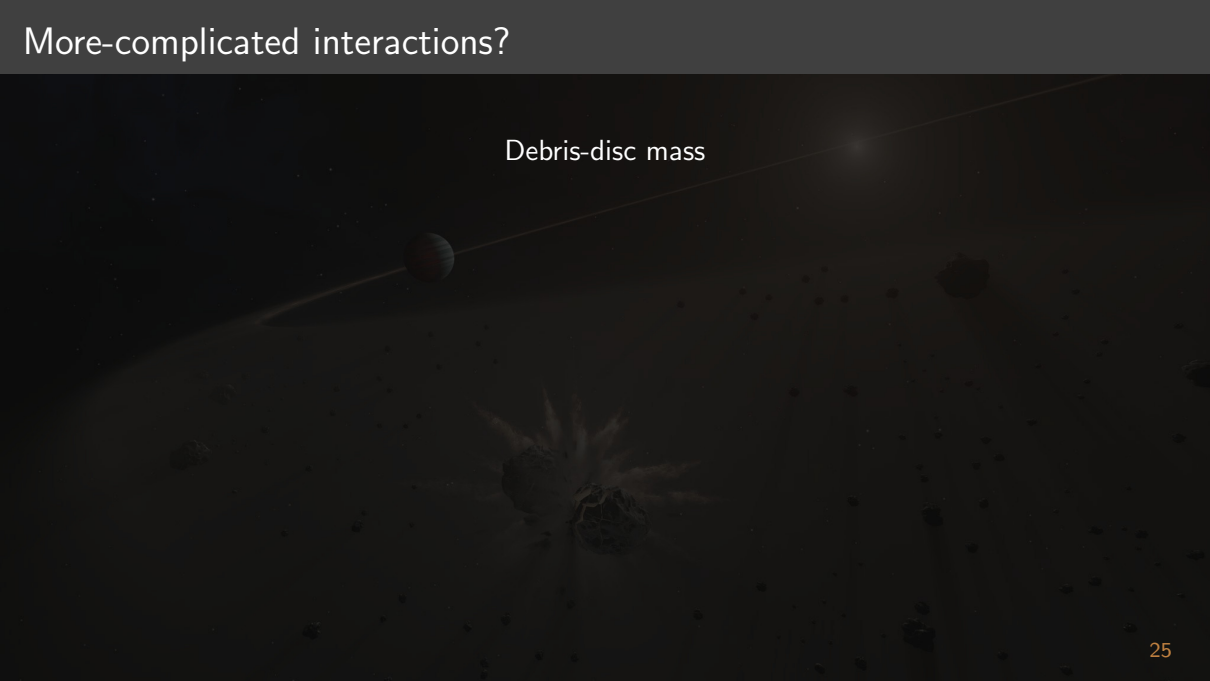
More-complicated interactions?

Migration



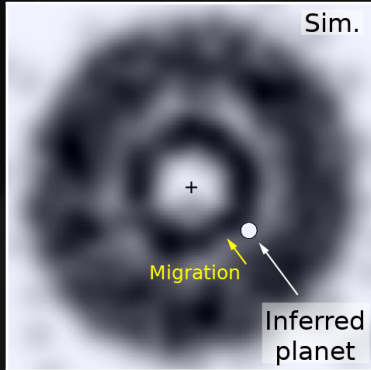
More-complicated interactions?

Debris-disc mass



More-complicated interactions?

Debris-disc mass

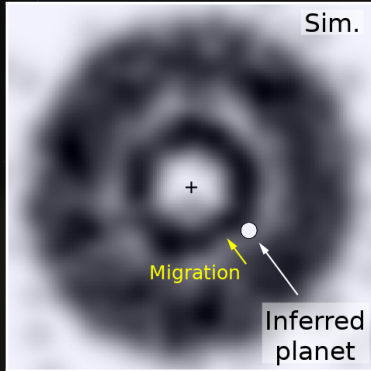


Friebe, Pearce & Löhne 2022

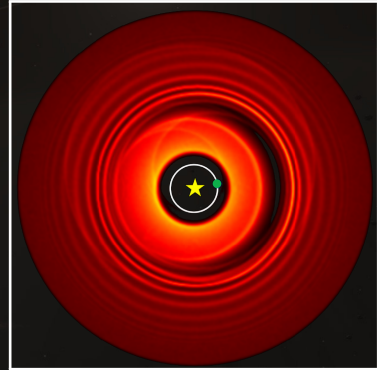
E.g. Gomes et al. 2005; Kirsh et al. 2009; Bonsor et al. 2014; Pearce & Wyatt 2015; Yelverton et al. 2019; Poblete et al. 2023; Sefilian, Rafikov & Wyatt 2023; Lithwick et al. 2026; Rafikov, Akansoy & Sefilian 2026...

More-complicated interactions?

Debris-disc mass



Friebe, Pearce & Löhne 2022



Sefilian, Rafikov & Wyatt 2021

E.g. Gomes et al. 2005; Kirsh et al. 2009; Bonsor et al. 2014; Pearce & Wyatt 2015; Yelverton et al. 2019; Poblete et al. 2023; Sefilian, Rafikov & Wyatt 2023; Lithwick et al. 2026; Rafikov, Akansoy & Sefilian 2026...

Where are the *JWST* debris-disc planets?

Some possibilities:

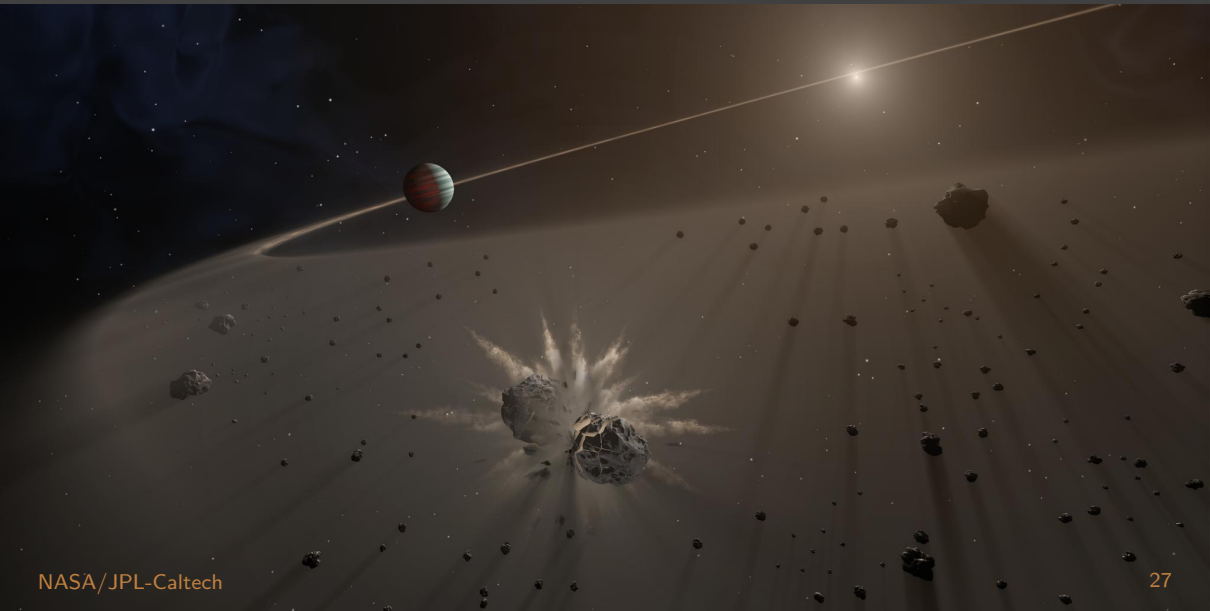
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Some possibilities:

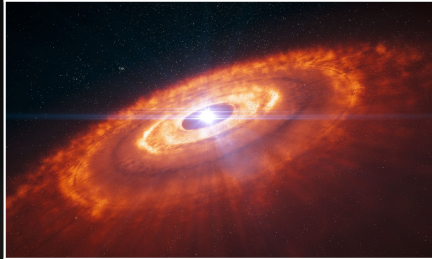
1. Our models don't work?
2. More than one planet?
3. More-complicated interactions?
4. We can't ignore the protoplanetary disc?

We can't ignore the protoplanetary disc?



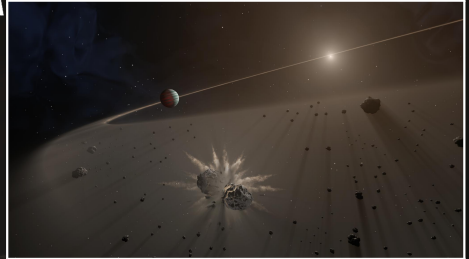
We can't ignore the protoplanetary disc?

Protoplanetary disc



ESO/L. Calçada

Debris disc



NASA/JPL-Caltech

E.g. Michel, van der Marel & Matthews 2021; Miller et al. 2021; Najita, Kenyon & Bromley 2022; Poblete, Pearce & Charalambous 2025; Poblete et al. 2026, Johnston et al. in prep.

Where are the *JWST* debris-disc planets?

Some possibilities:

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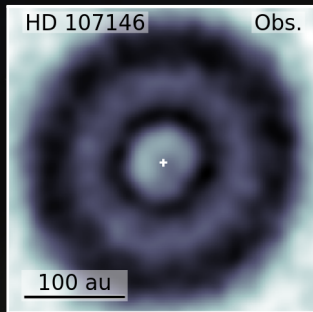
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5. Debris features aren't always linked to planets?

Debris features aren't always linked to planets?

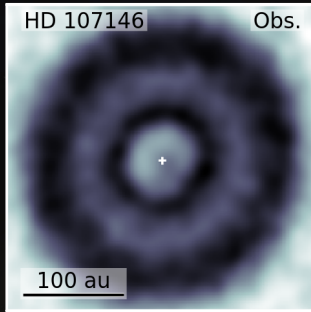
Debris-disc observation



Marino et al. 2018

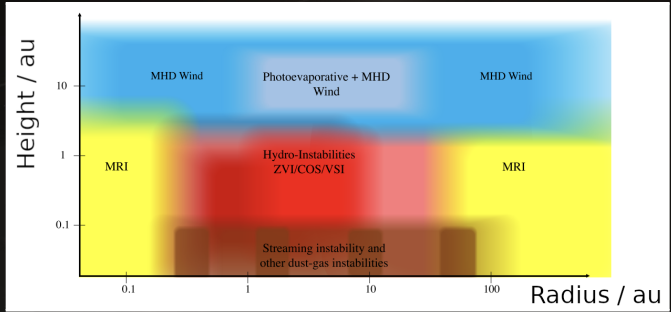
Debris features aren't always linked to planets?

Debris-disc observation



Marino et al. 2018

Protoplanetary-disc theory



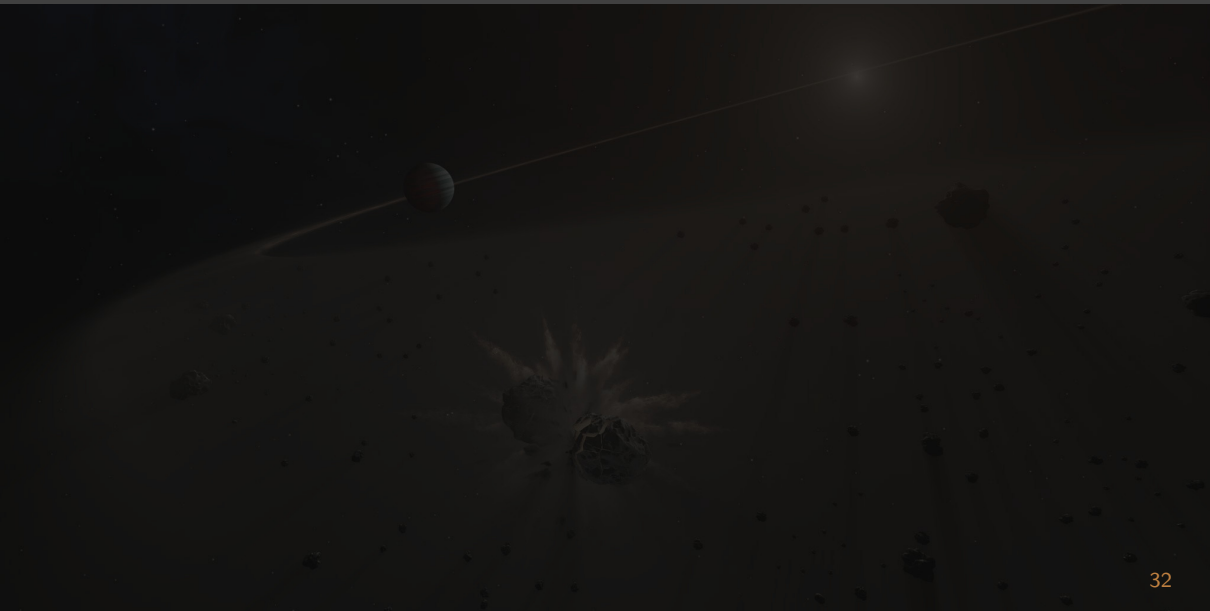
Lesur et al. 2023

Where are the *JWST* debris-disc planets?

Some possibilities:

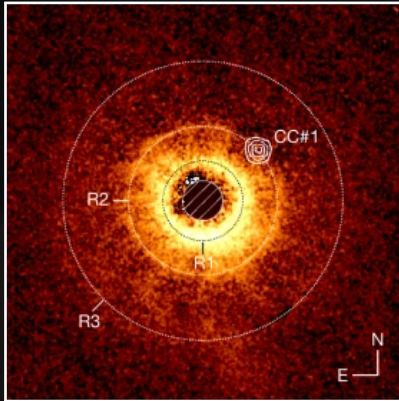
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Conclusions



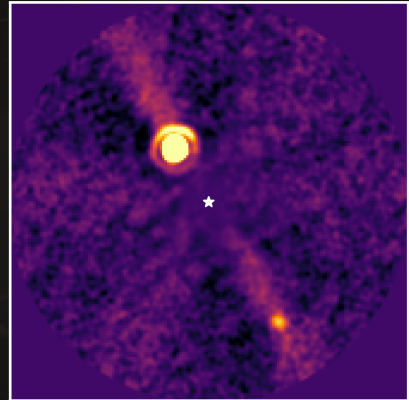
Conclusions

TWA 7



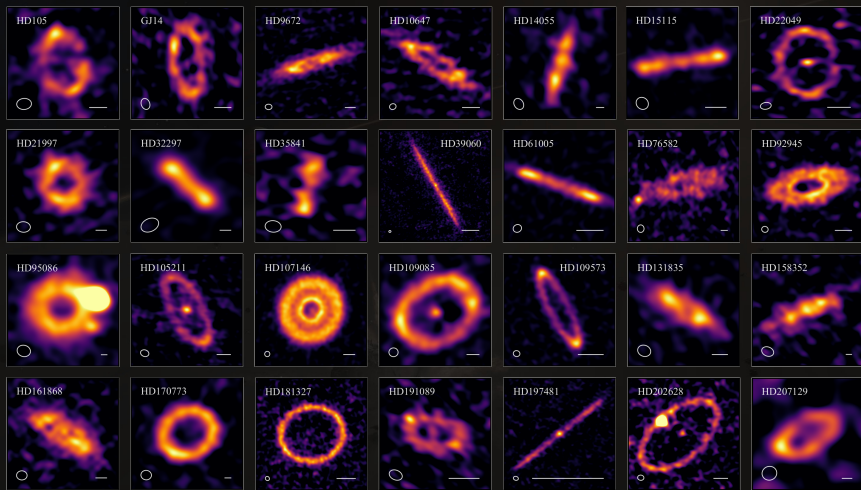
Lagrange et al. 2025

β Pic



Sutcliffe et al. 2026; Gibbs et al. 2026

Conclusions



Conclusions

Carve gaps



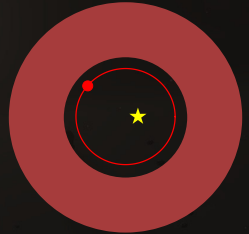
Warp belts



Pass bodies inward



Make belts eccentric



Sculpt disc edges



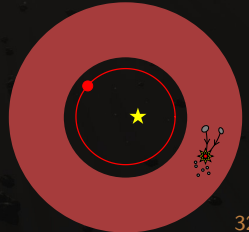
Drive spirals



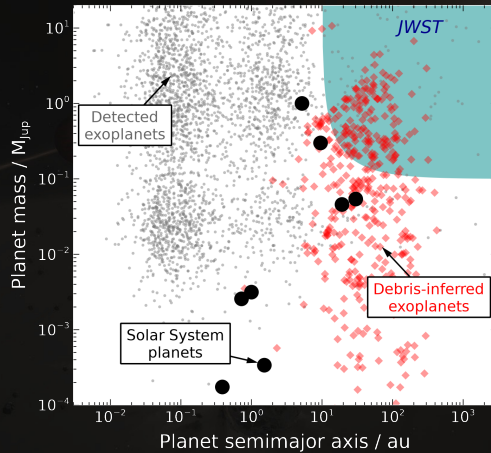
Make clumps



Stir debris



Conclusions



Conclusions

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Conclusions

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Questions?

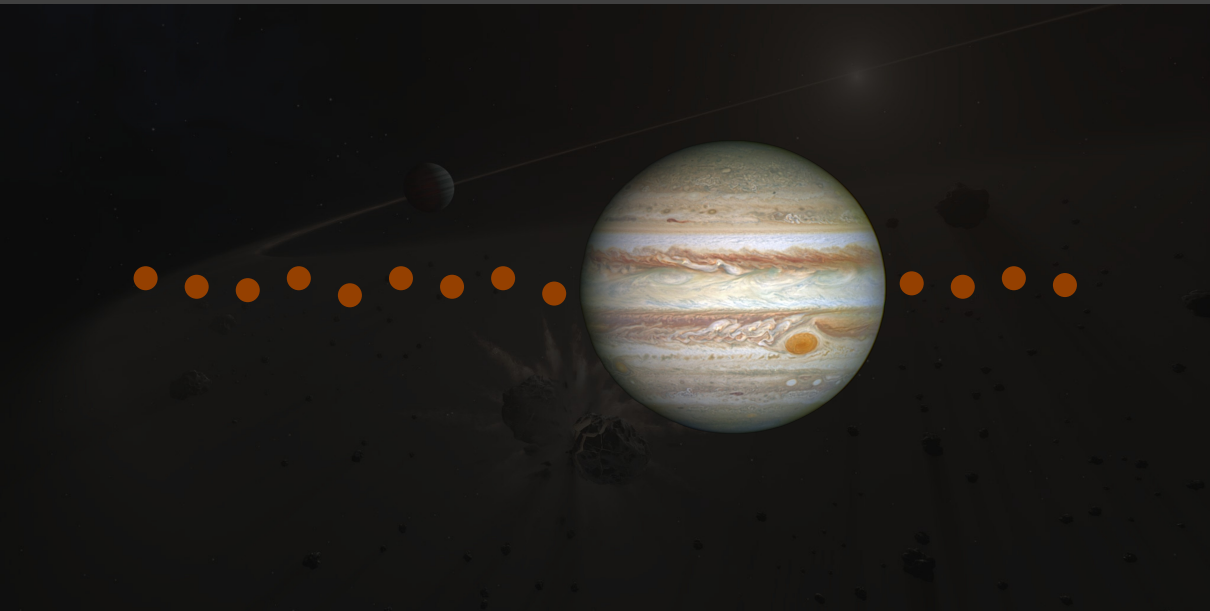
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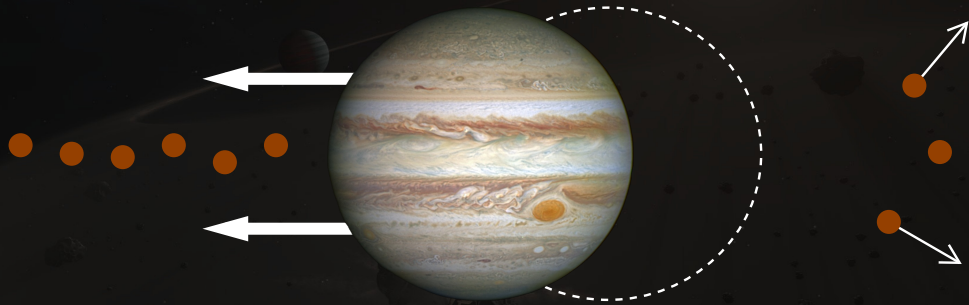


Extra slides

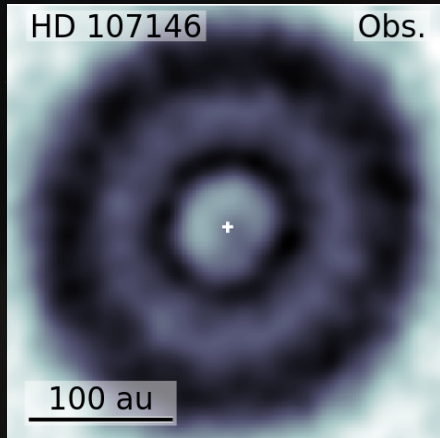
5. Debris can make planets migrate



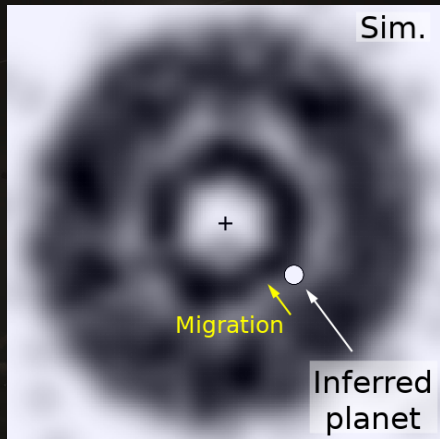
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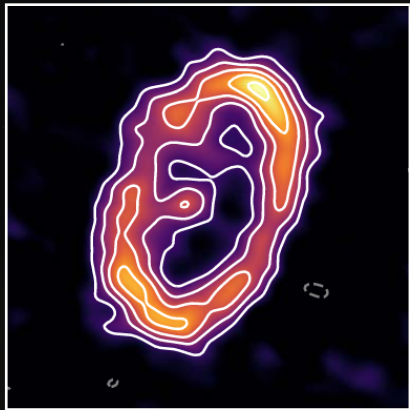
Marino et al. 2018



Friebe, Pearce & Löhne 2022

Lots of non-detections :(

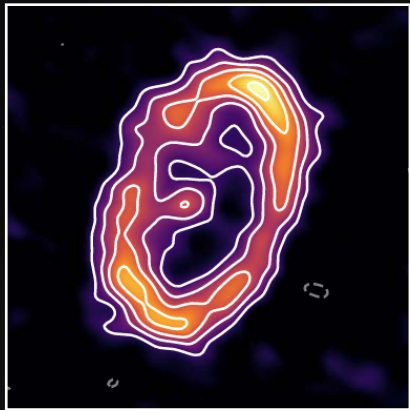
HD 53143



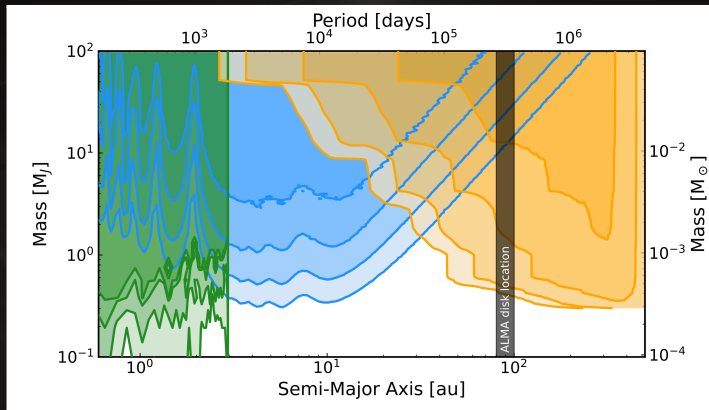
MacGregor et al. 2022

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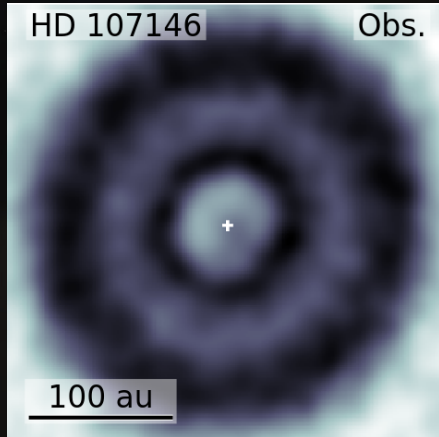
MacGregor et al. 2022



Matthews et al. in prep.

More-complicated interactions?

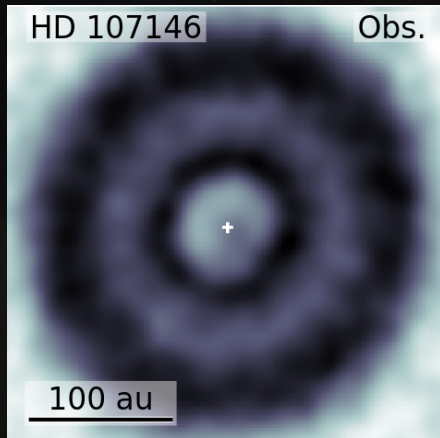
Migration



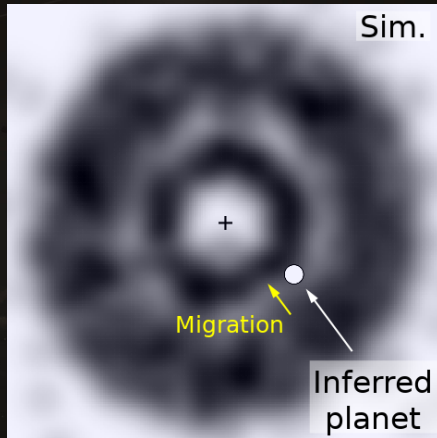
Marino et al. 2018

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Migration



Marino et al. 2018



Friebe, Pearce & Löhne 2022