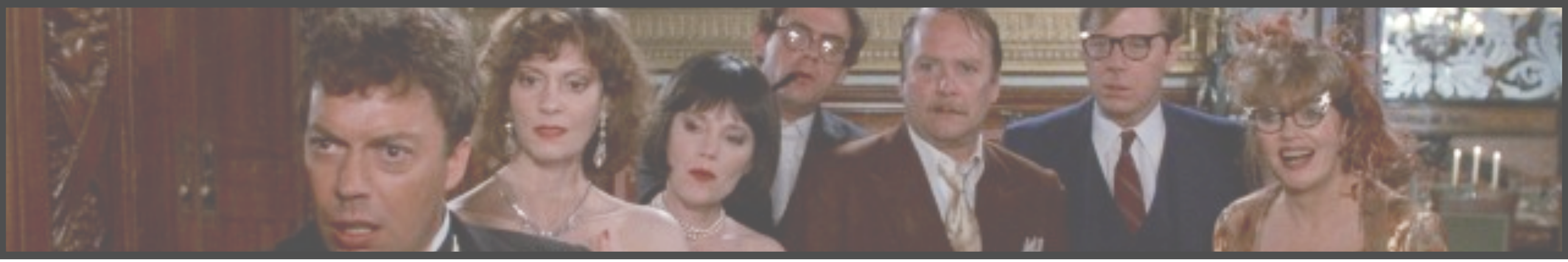
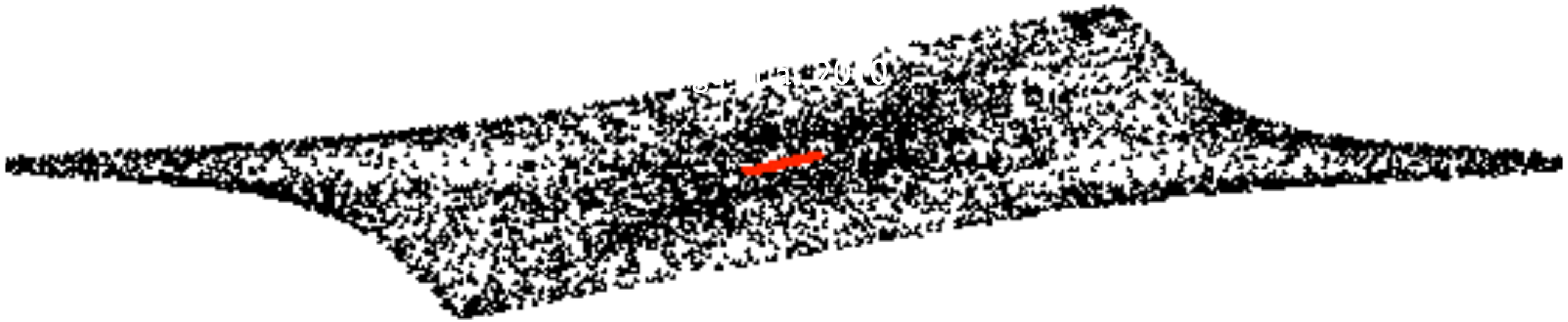


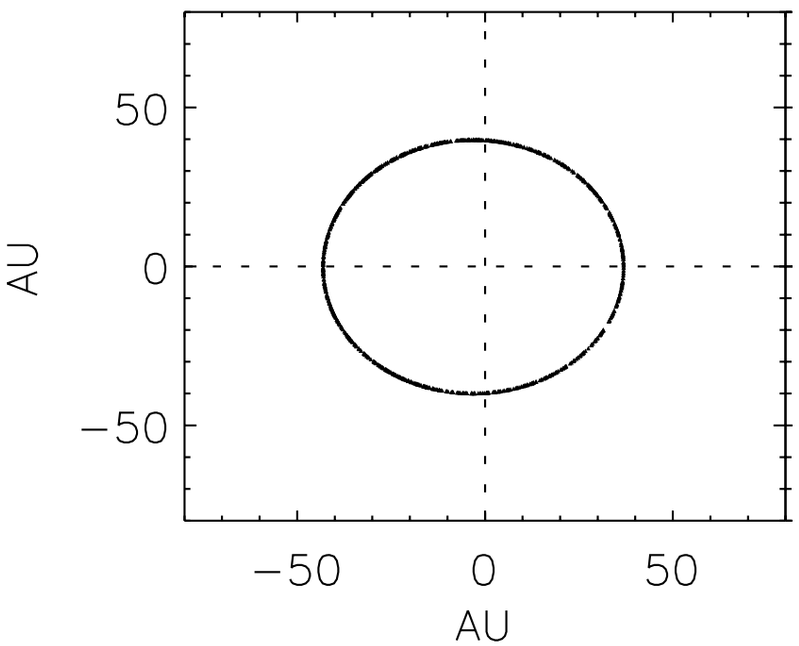


The whodunit of debris disk archaeology

Bekki Dawson (UC Berkeley, Miller Fellow)

Planets sculpt debris disks

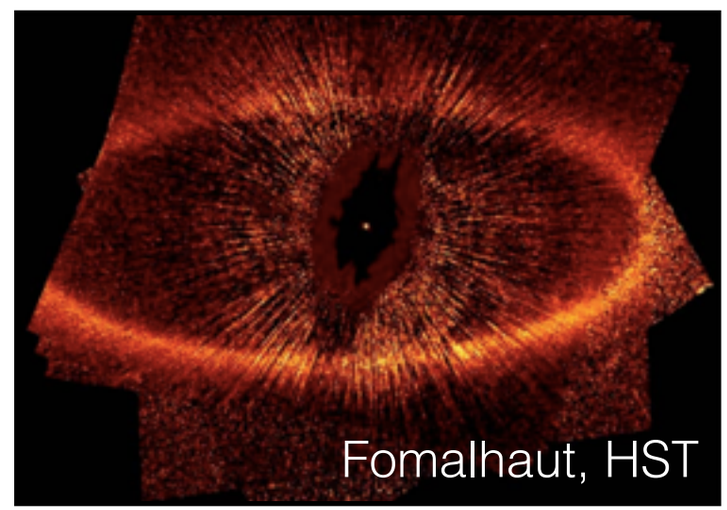
Offsets

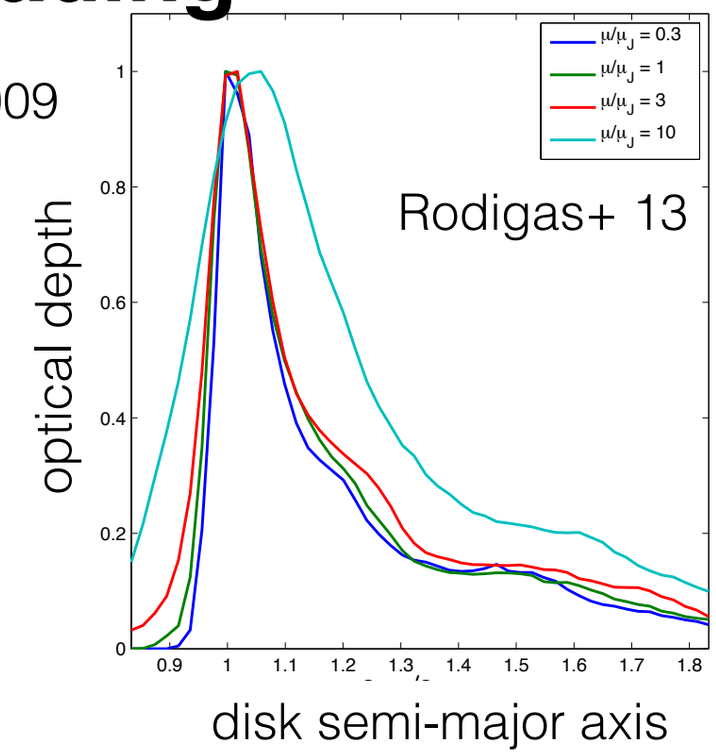


e.g. Wyatt et al. 1999, Kalas et al. 2005

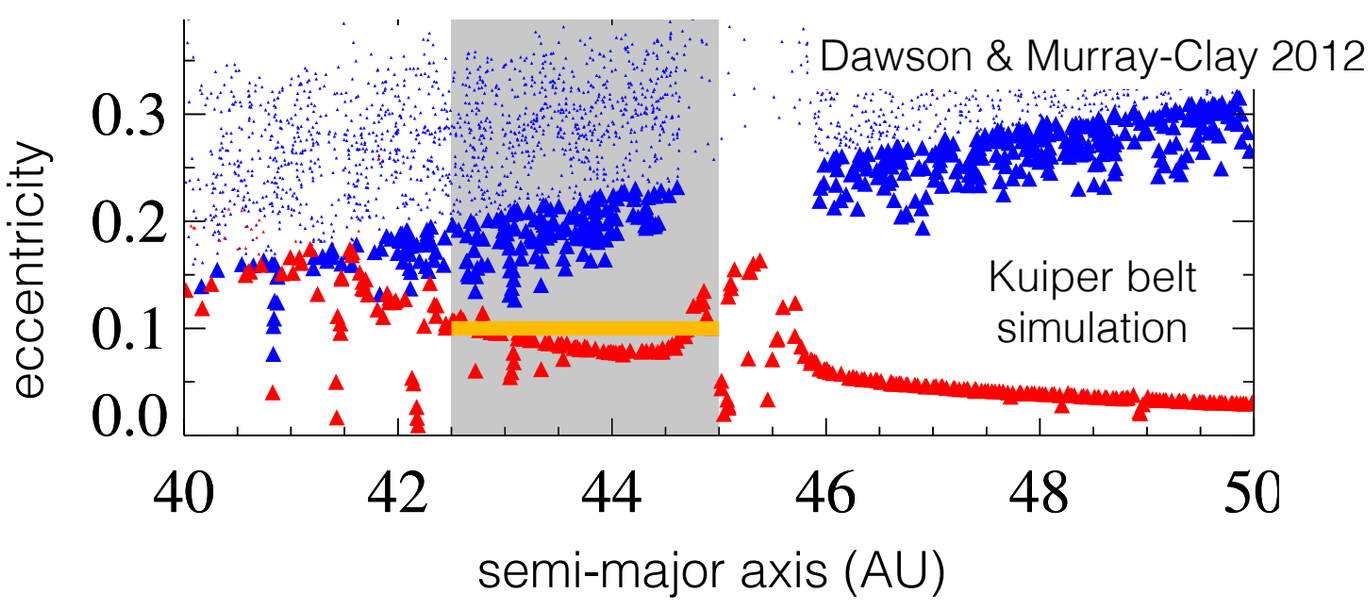
Shepherding, spreading

e.g., Quillen 2006; Chiang et al. 2009

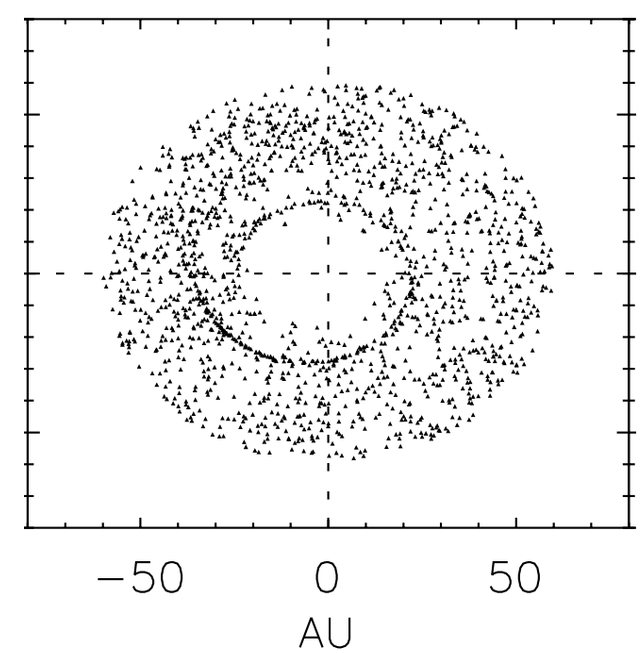




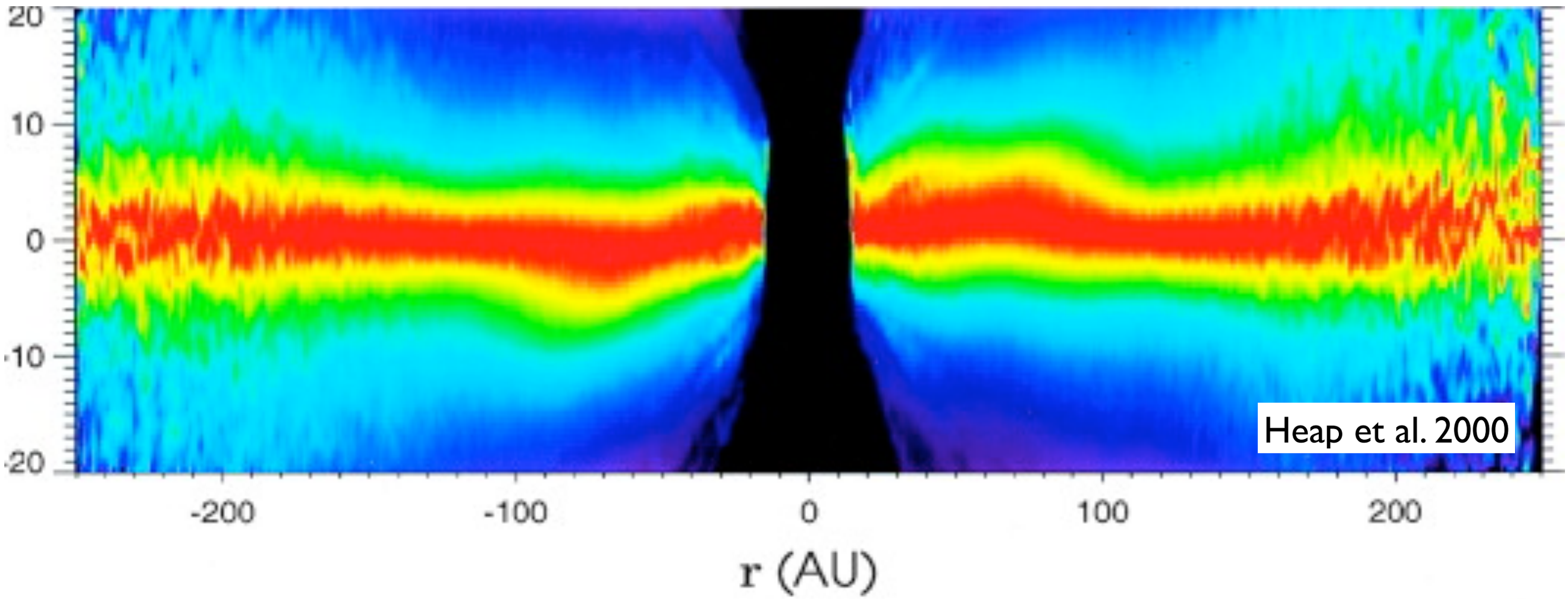
Stirring, mixing



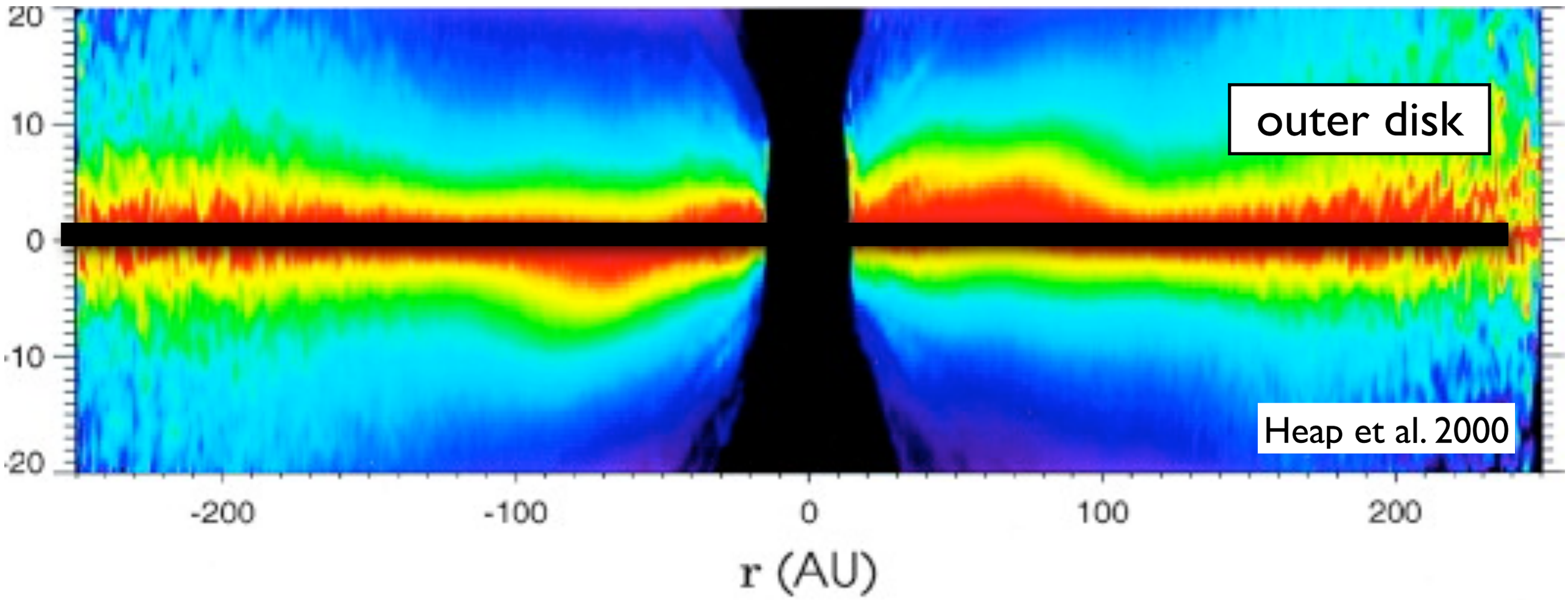
Waves



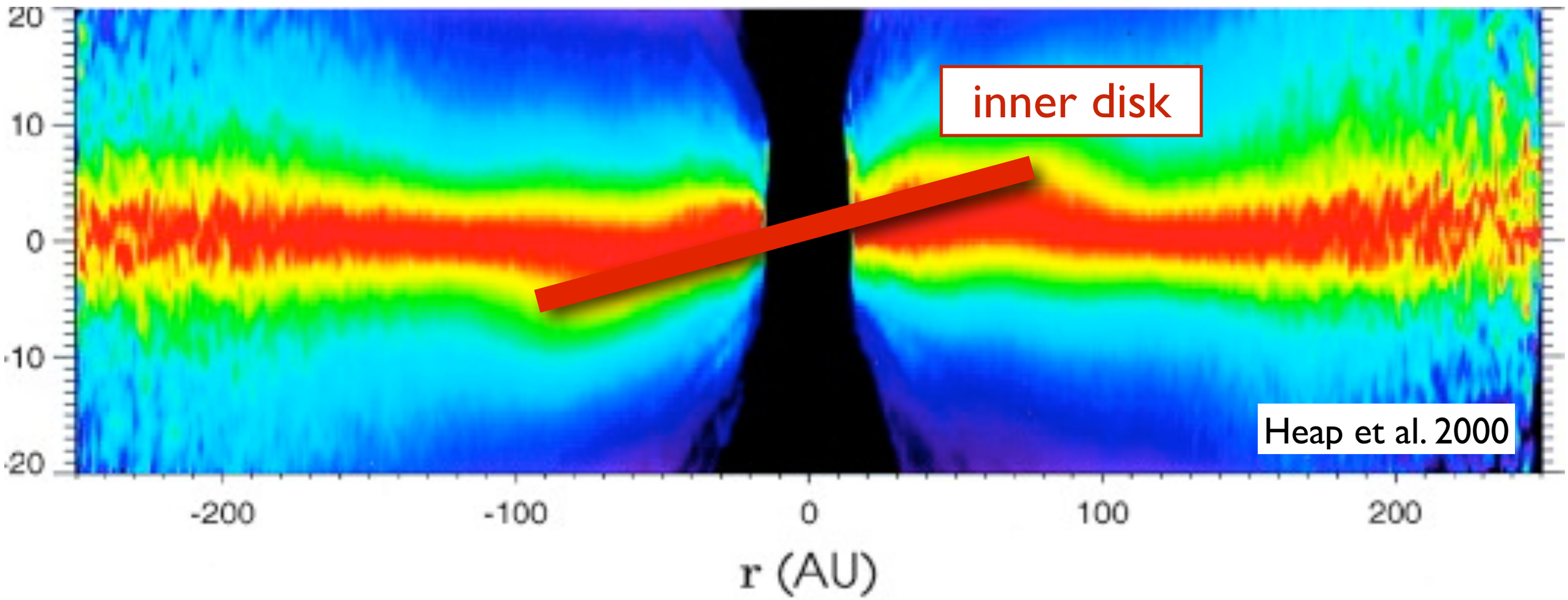
Planets warp debris disks



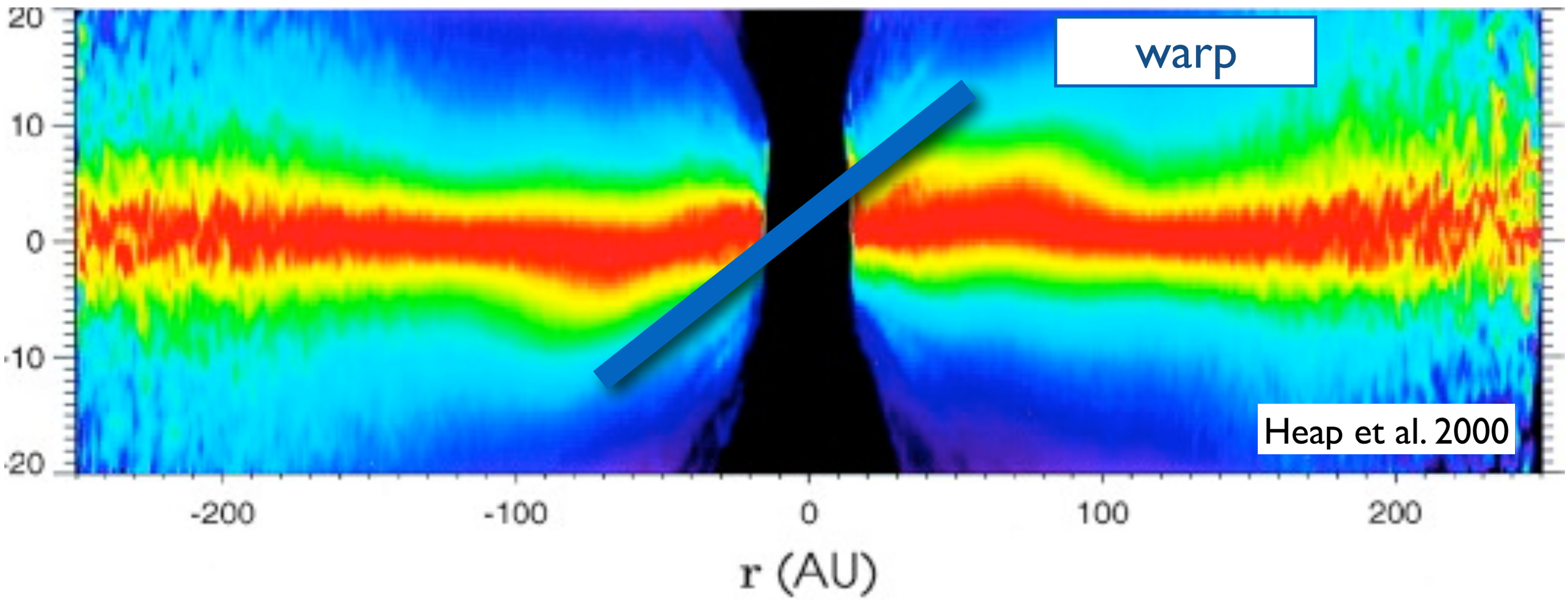
Planets warp debris disks



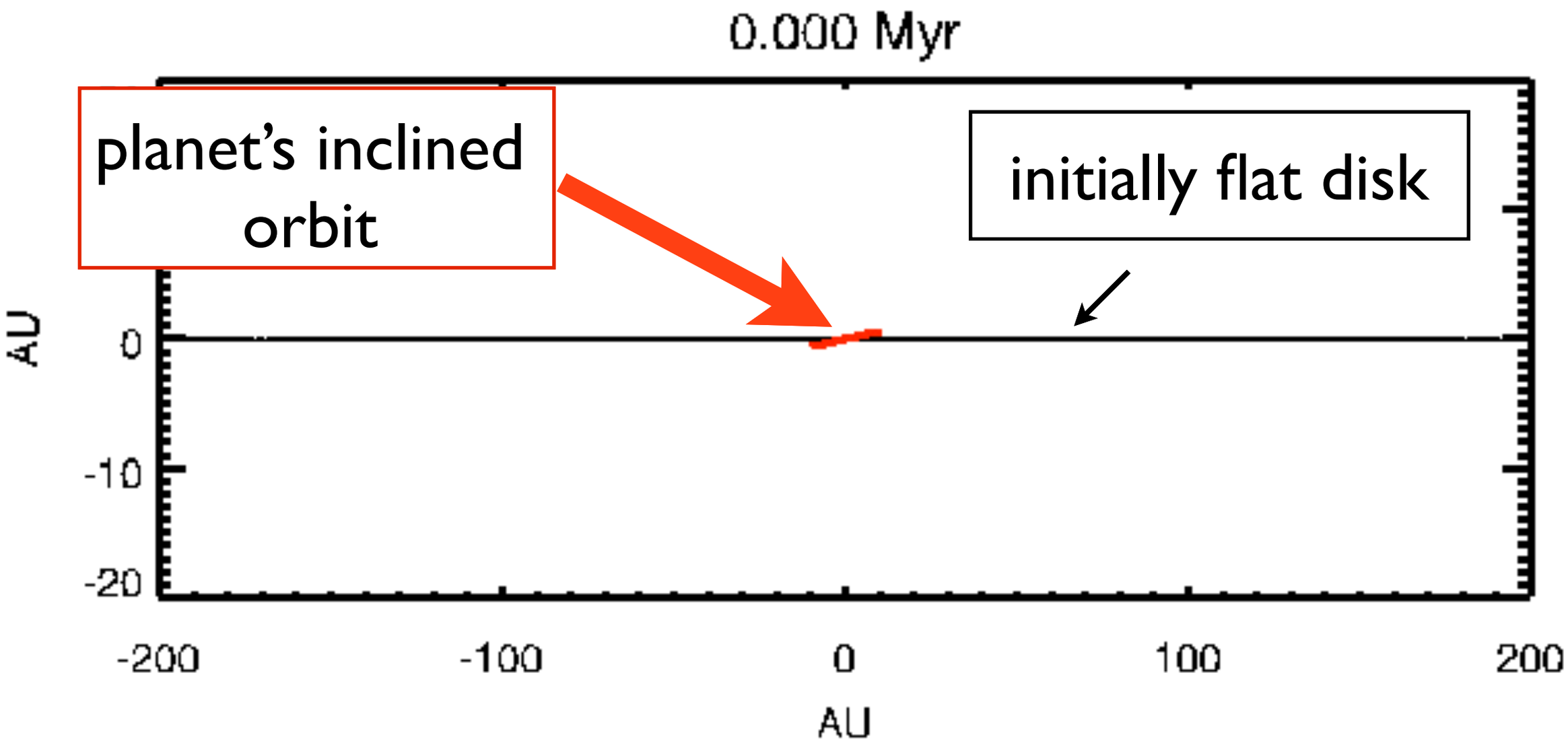
Planets warp debris disks



Planets warp debris disks



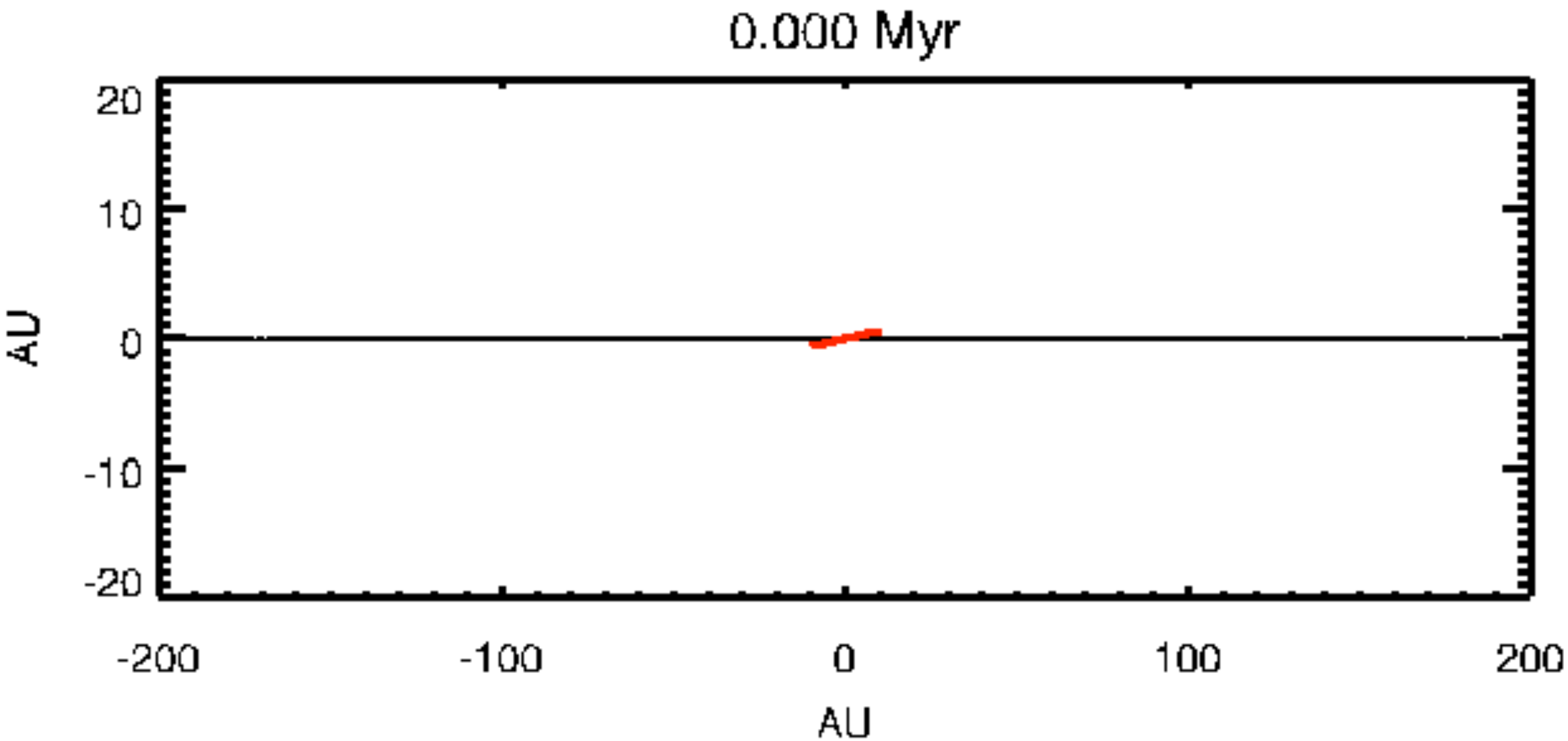
Planets warp debris disks



Dawson, Murray-Clay, & Fabrycky 2011
see also Mouillet+ 1997, Augereau+ 2001

See also poster by Miriam Keppler

Planets warp debris disks



Dawson, Murray-Clay, & Fabrycky 2011

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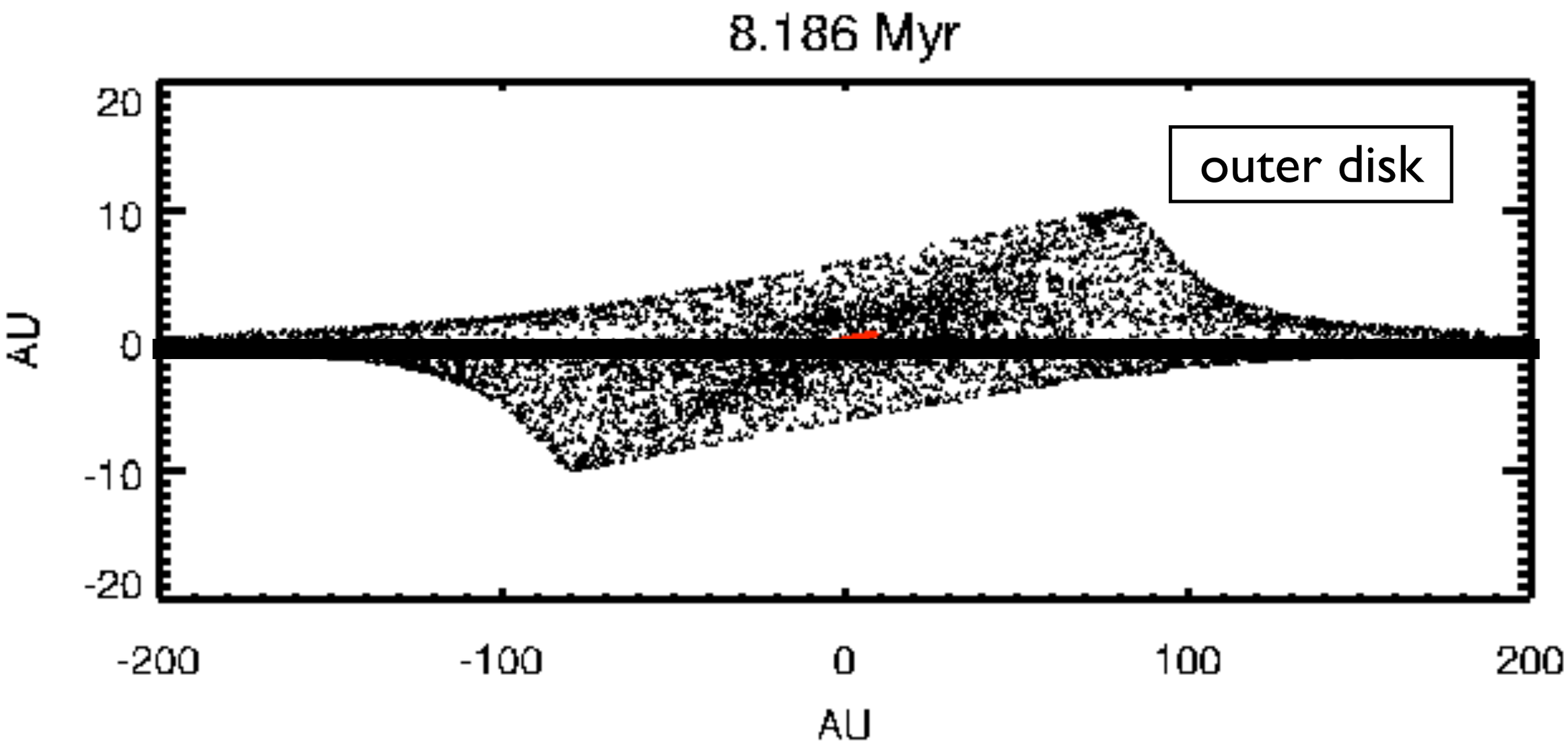
Planets warp debris disks



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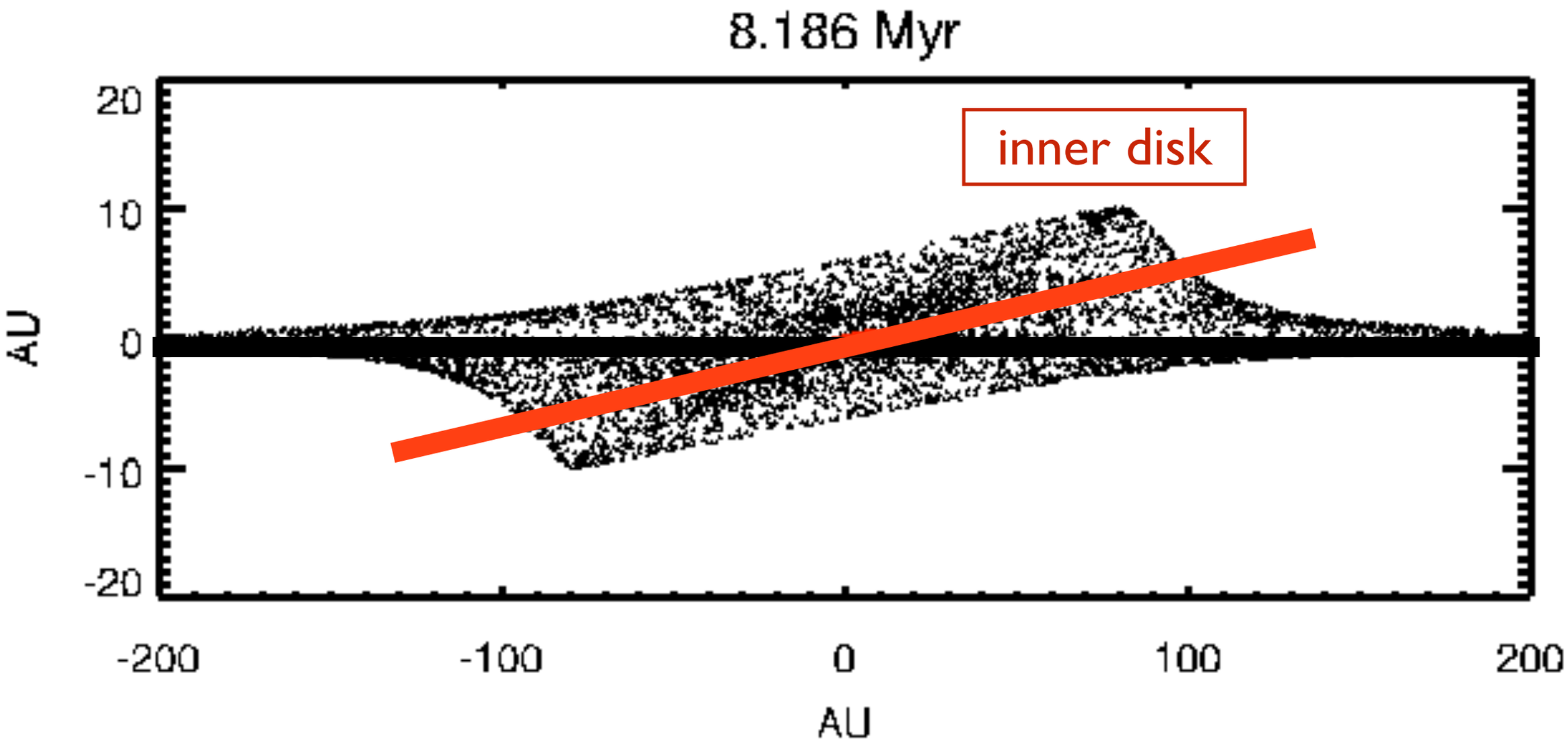
Planets warp debris disks



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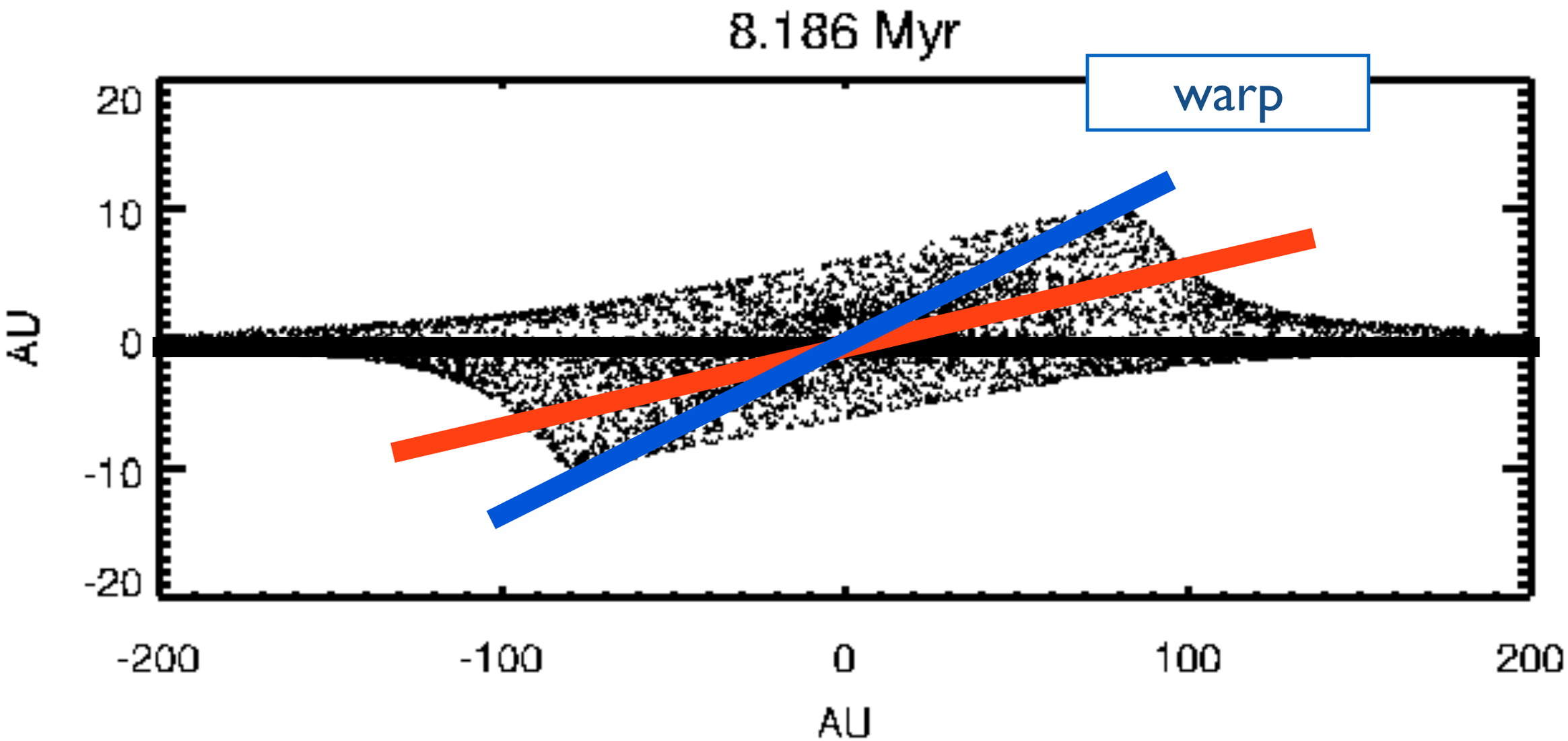
Planets warp debris disks



Dawson, Murray-Clay, & Fabrycky 2011

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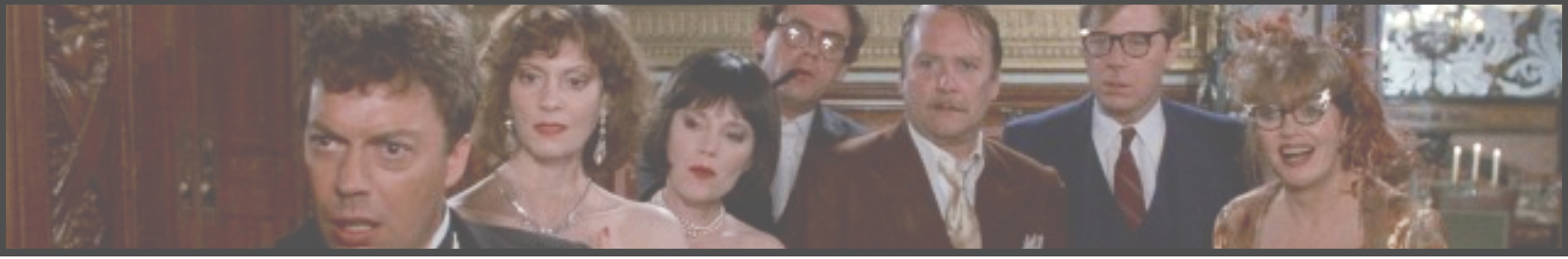
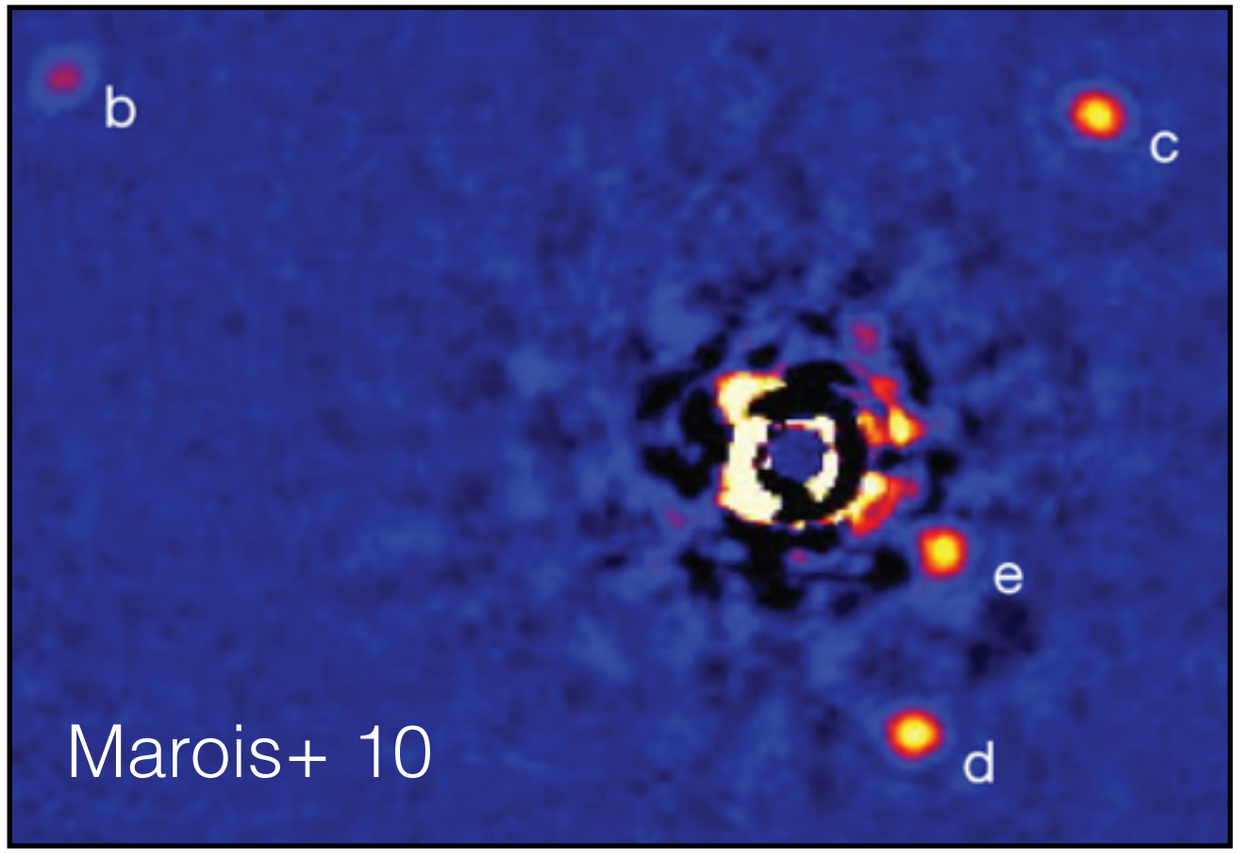
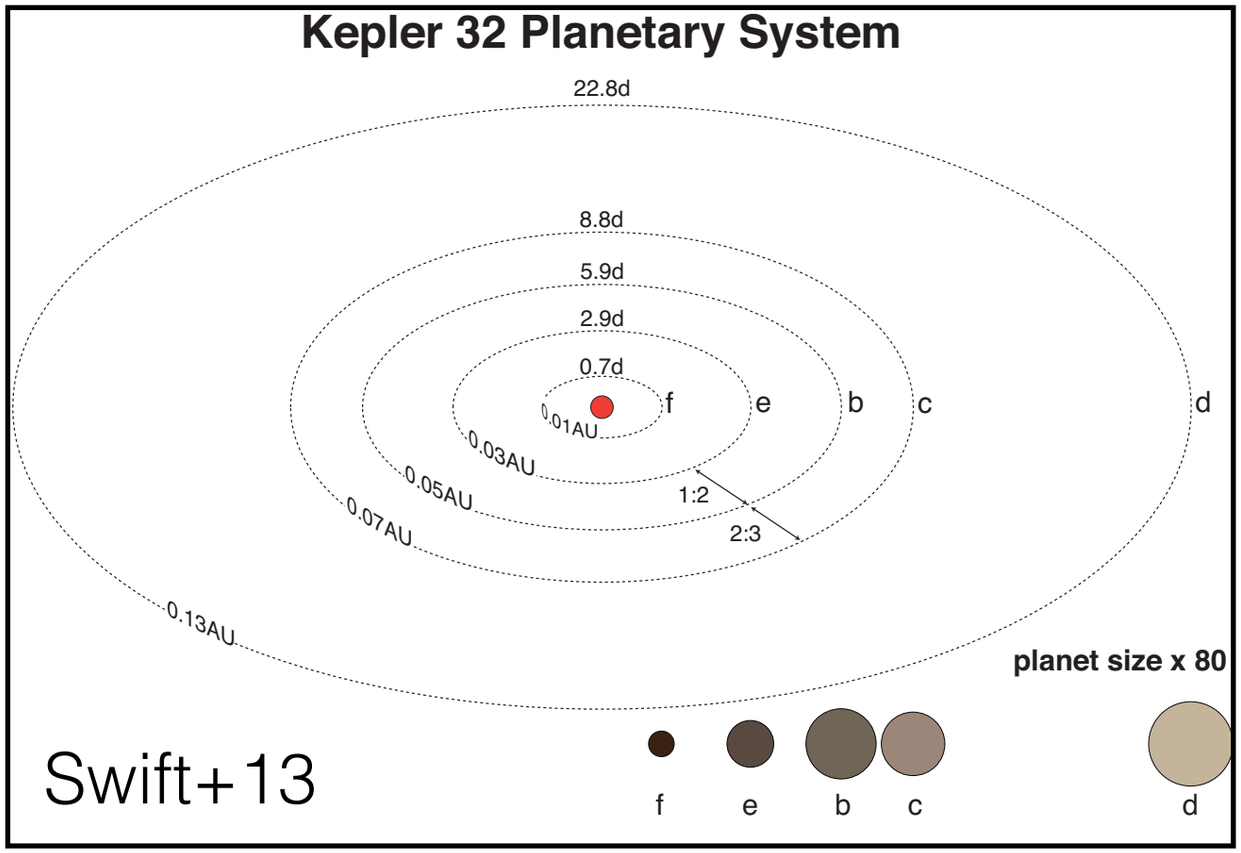


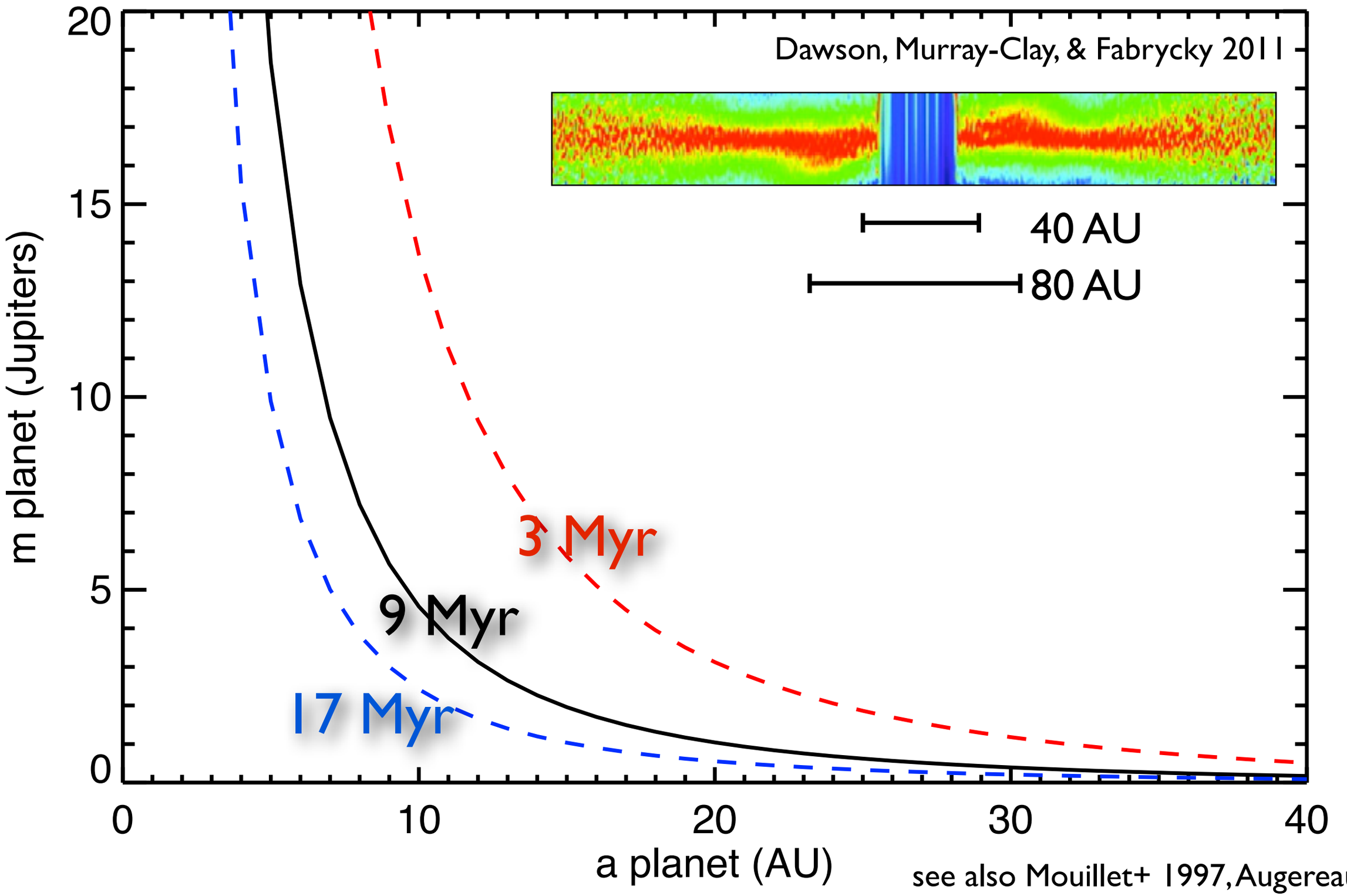
The reality: multi-planet systems





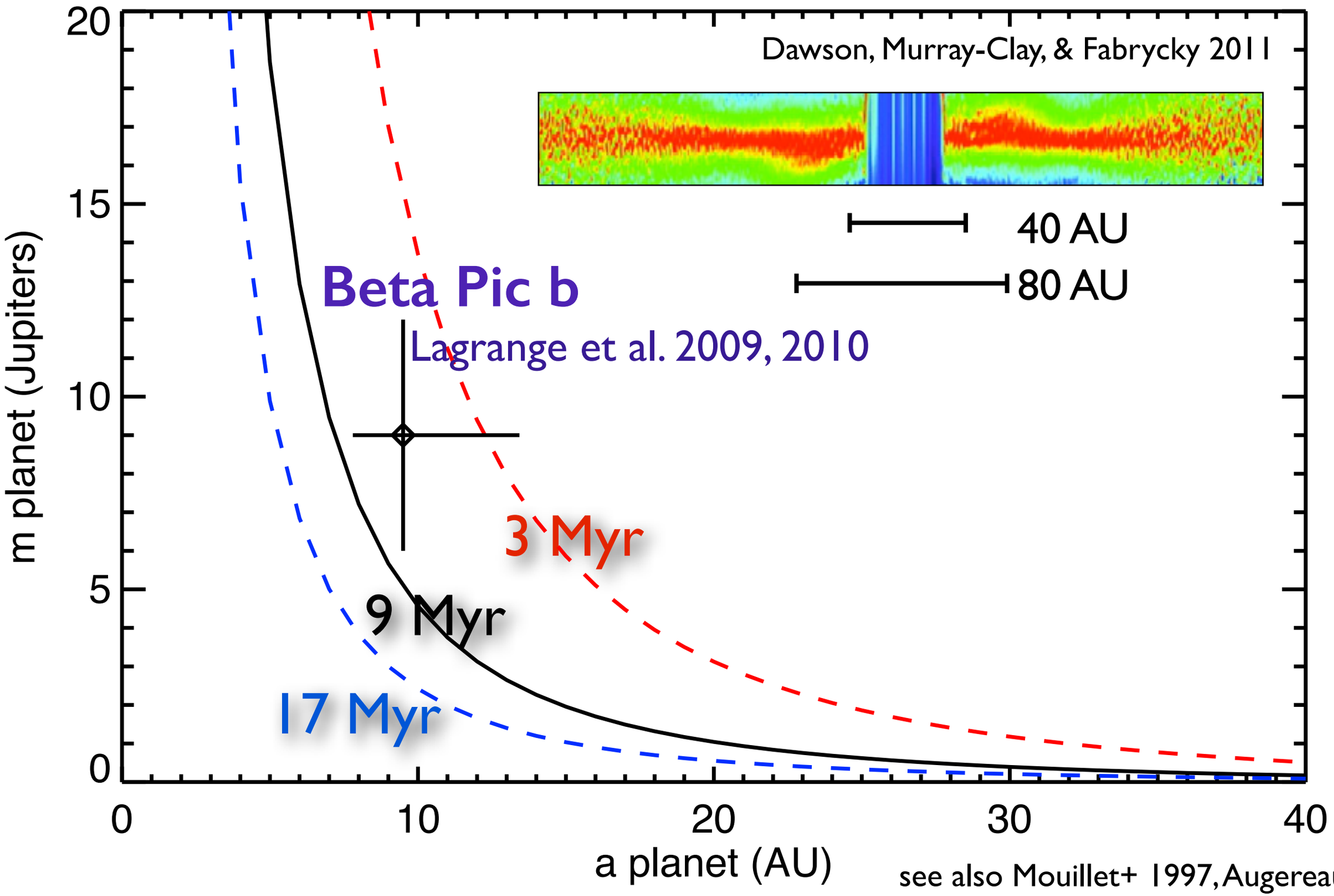
The prime suspect is usually the culprit

Disk sculpting reveals planet's properties



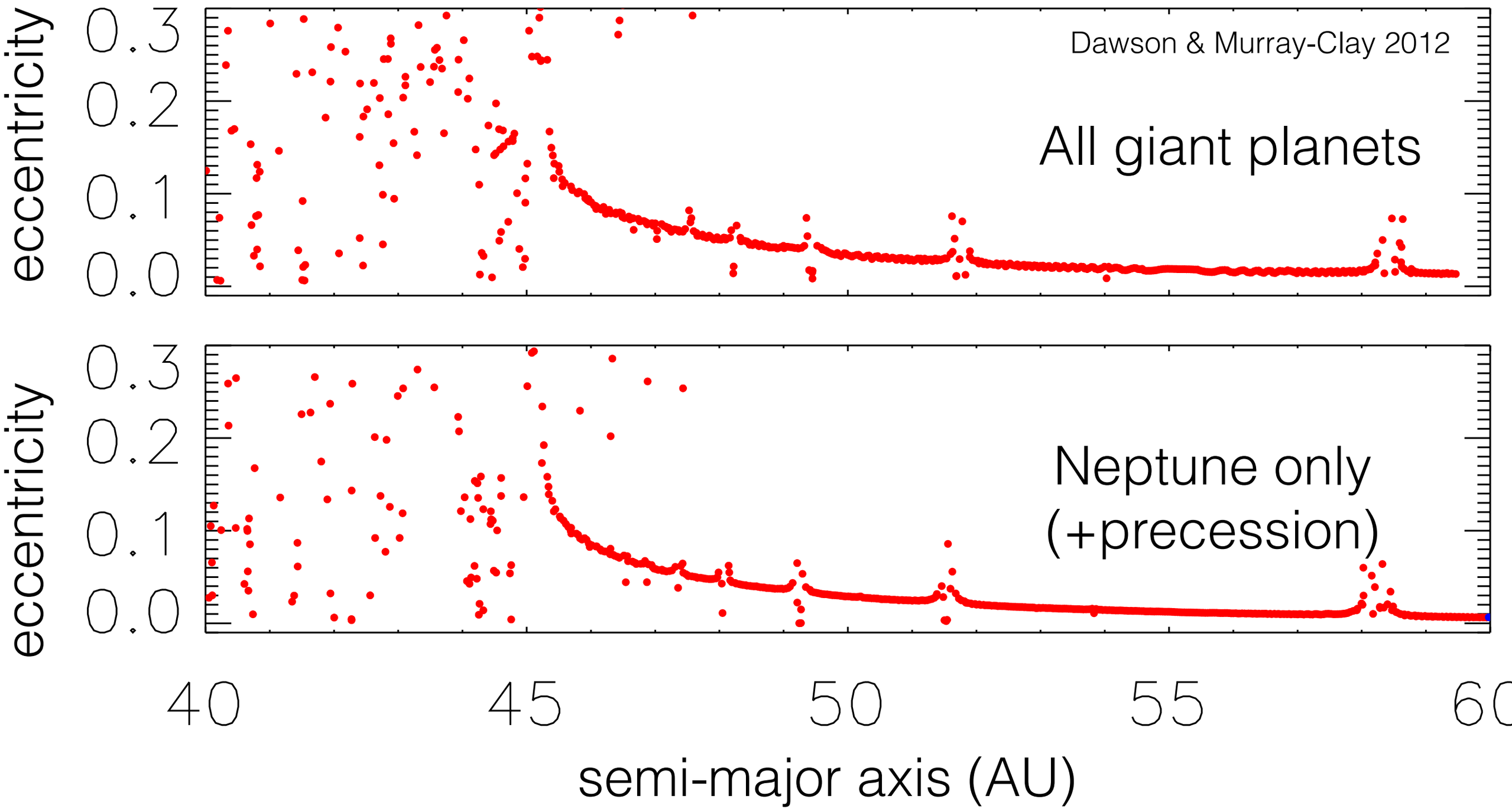
see also Mouillet+ 1997, Augereau+ 2001

Disk sculpting reveals planet's properties

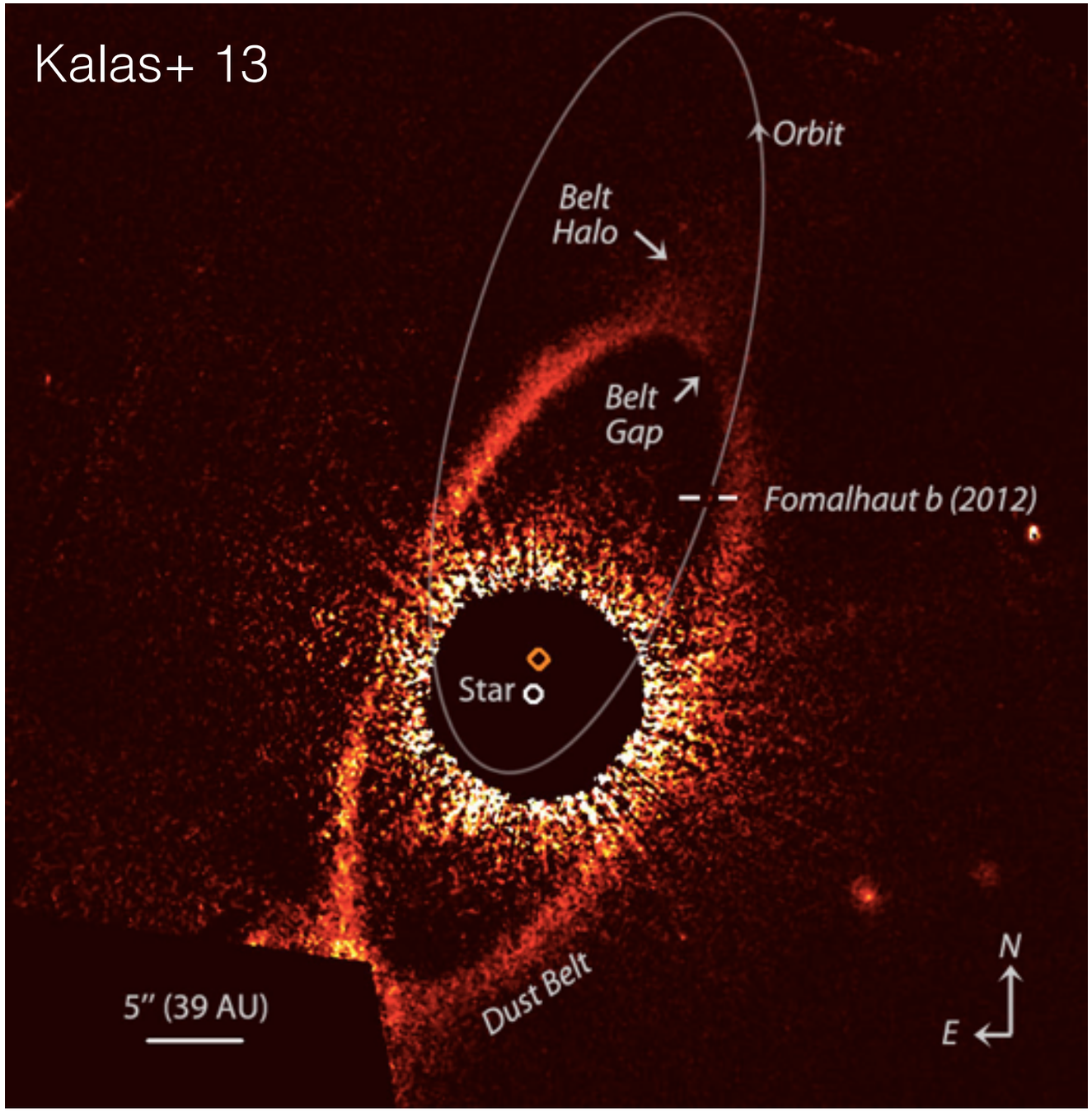


see also Mouillet+ 1997, Augereau+ 2001

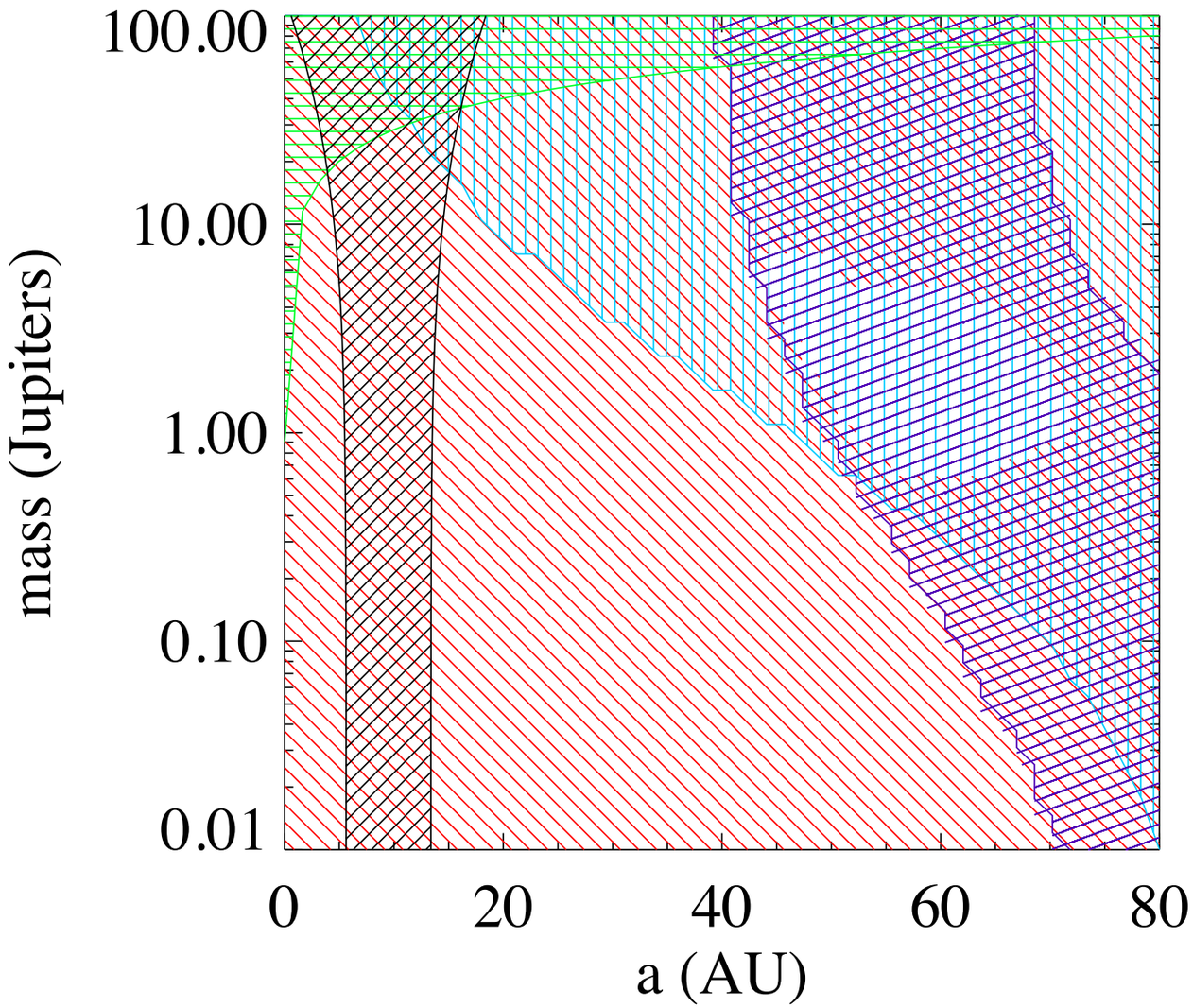
In our solar system, Neptune is the primary sculptor of the Kuiper belt



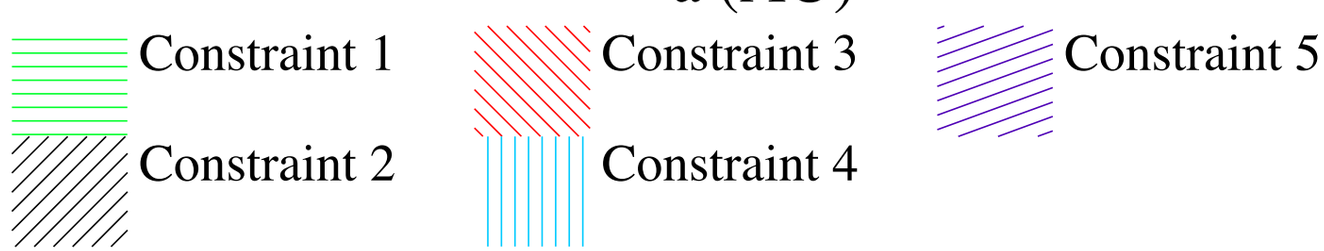
Fomalhaut: directly imaged planet is not the sculptor



Can another planet be responsible for Beta Pic's warp?

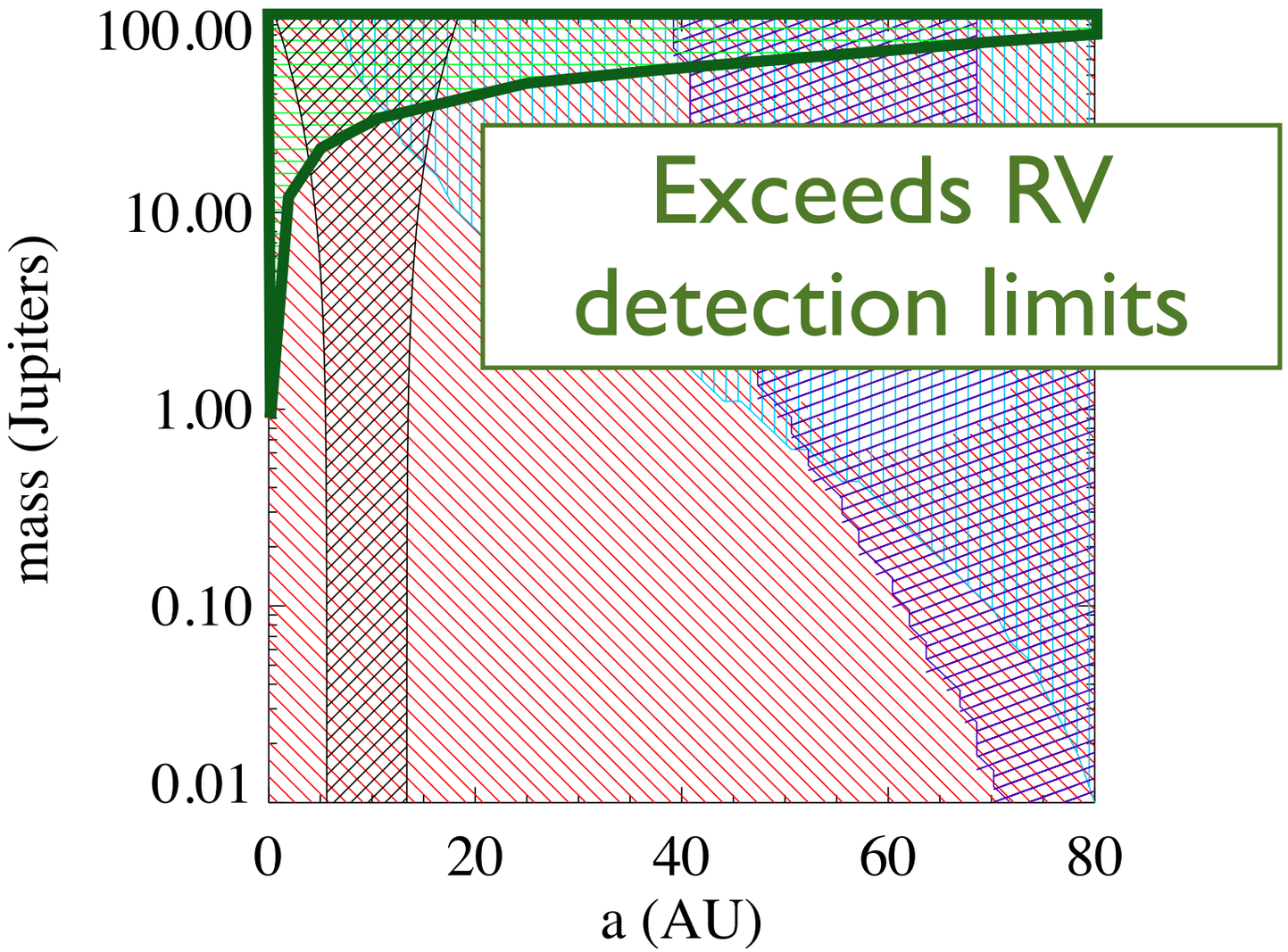


Ruled out by



Dawson, Murray-Clay, & Fabrycky 2011

Can another planet be responsible for Beta Pic's warp?



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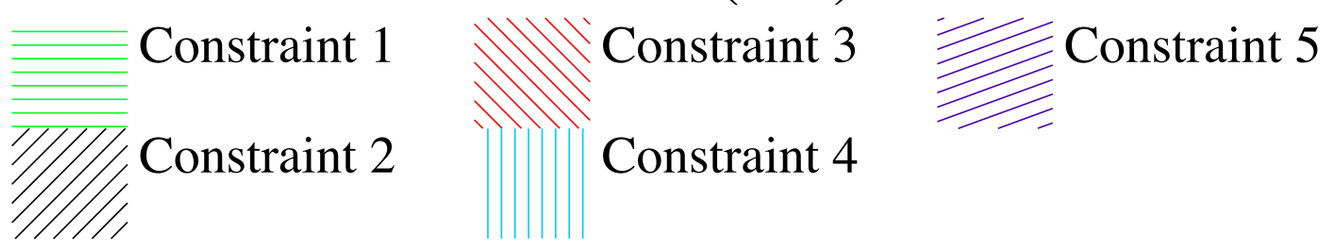

Dawson, Murray-Clay, & Fabrycky 2011

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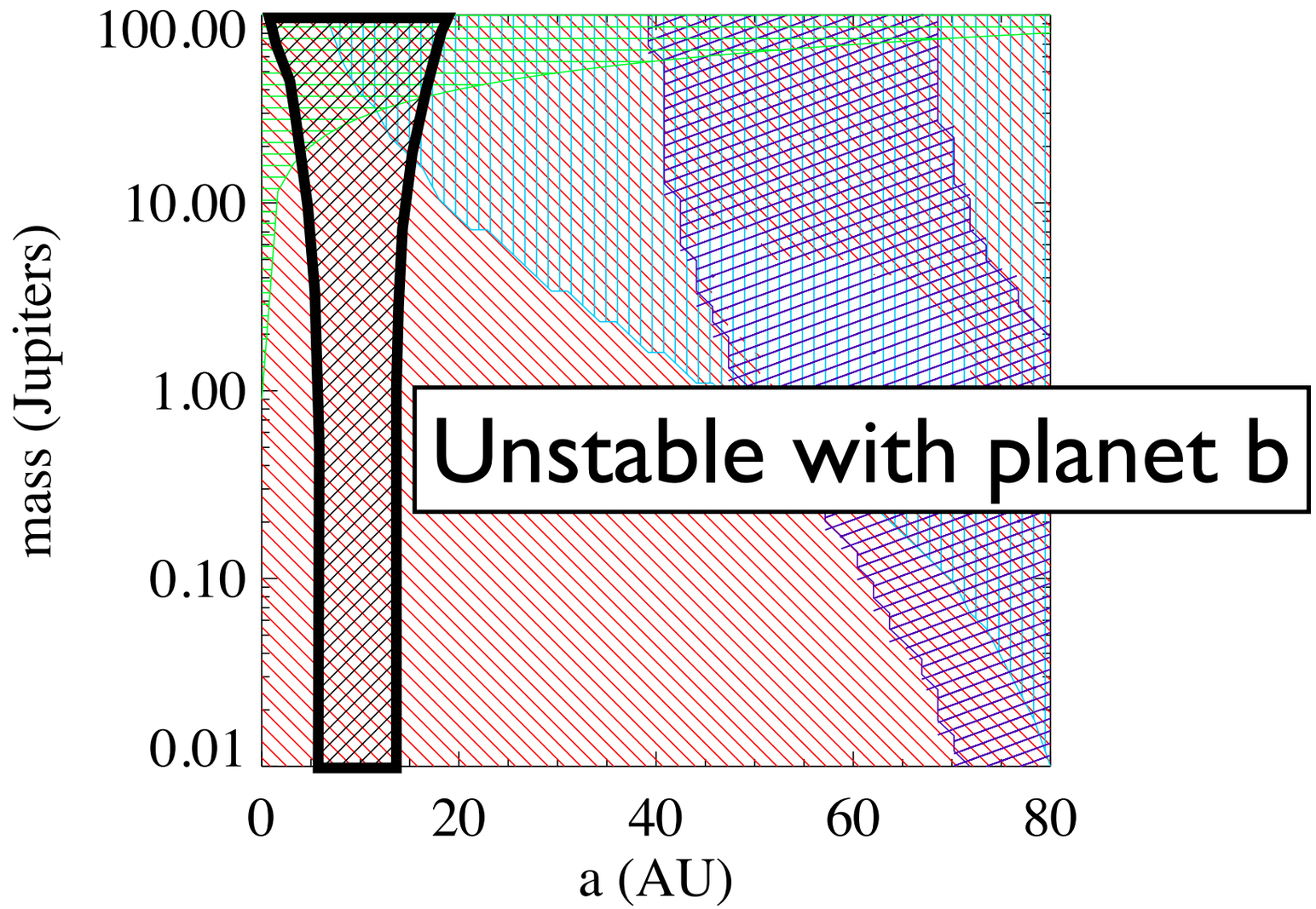

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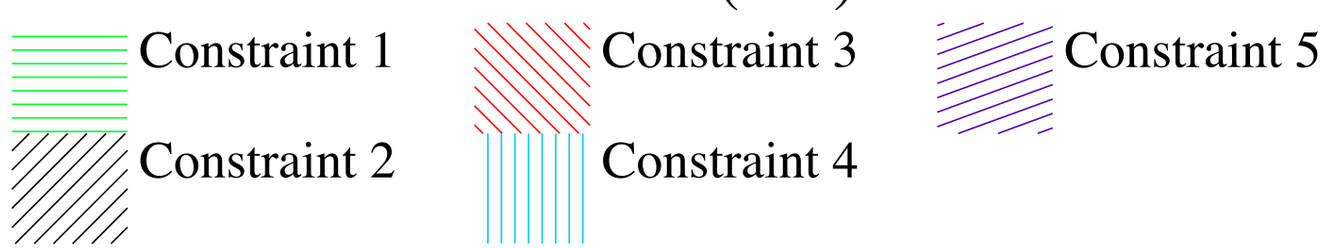

Dawson, Murray-Clay, & Fabrycky 2011

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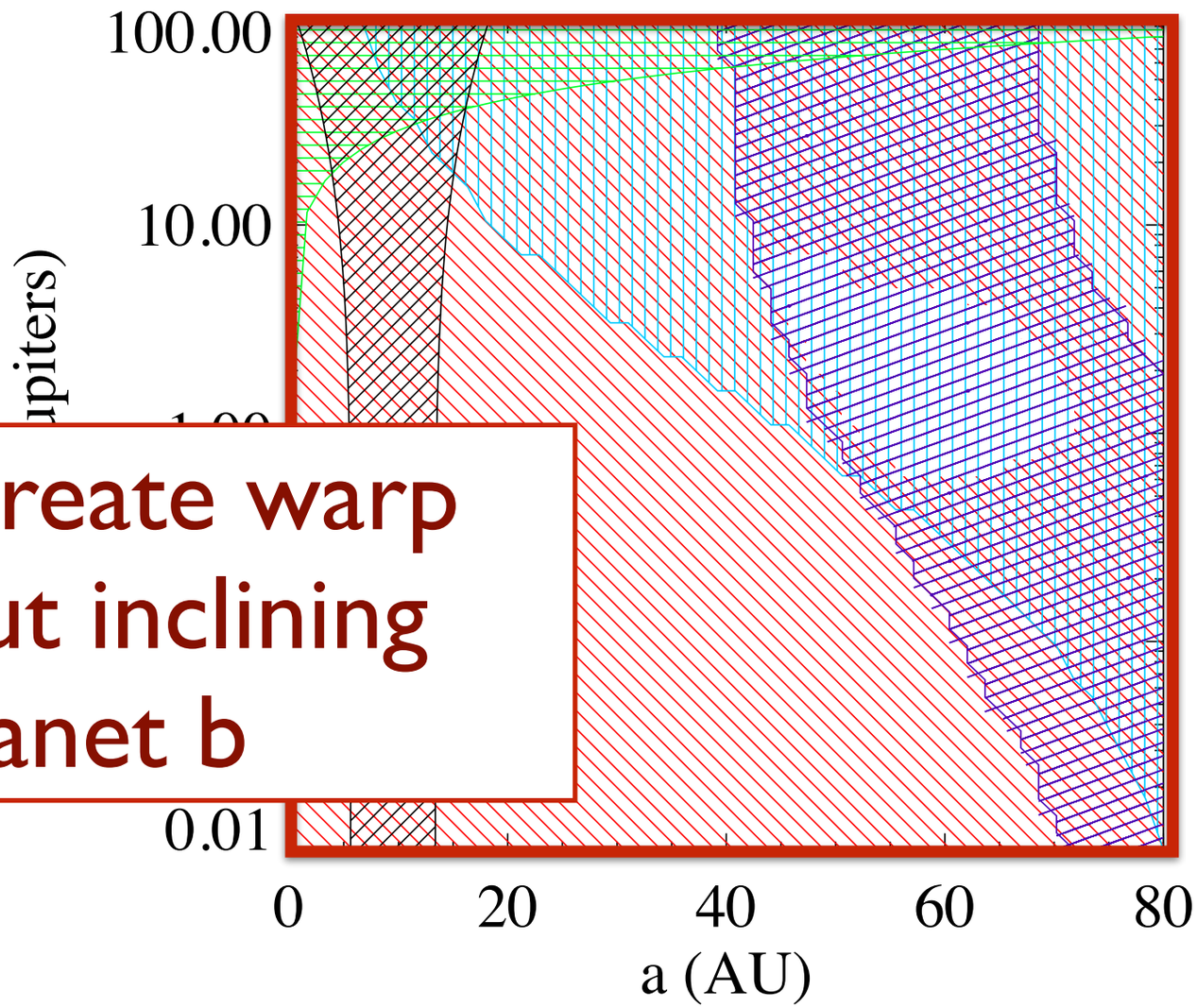
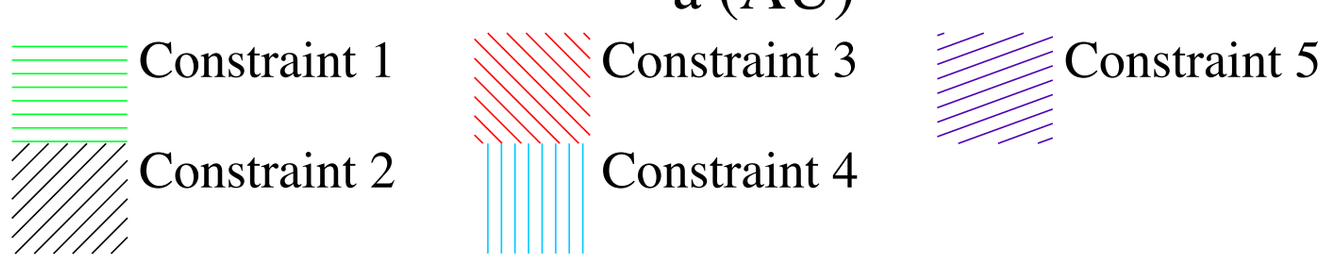


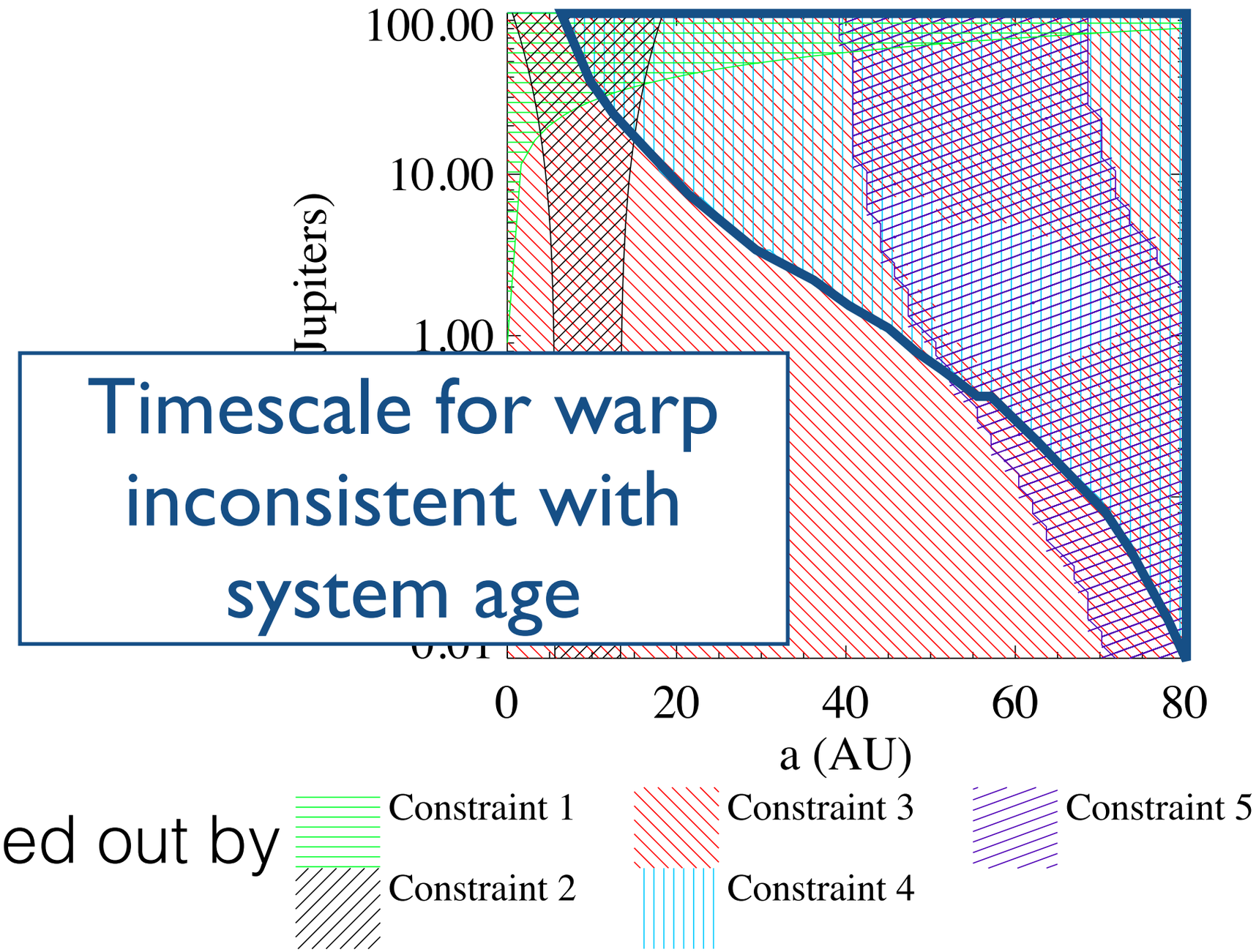
Can't create warp without inclining planet b

Ruled out by



Dawson, Murray-Clay, & Fabrycky 2011

Can another planet be responsible for Beta Pic's warp?



Dawson, Murray-Clay, & Fabrycky 2011

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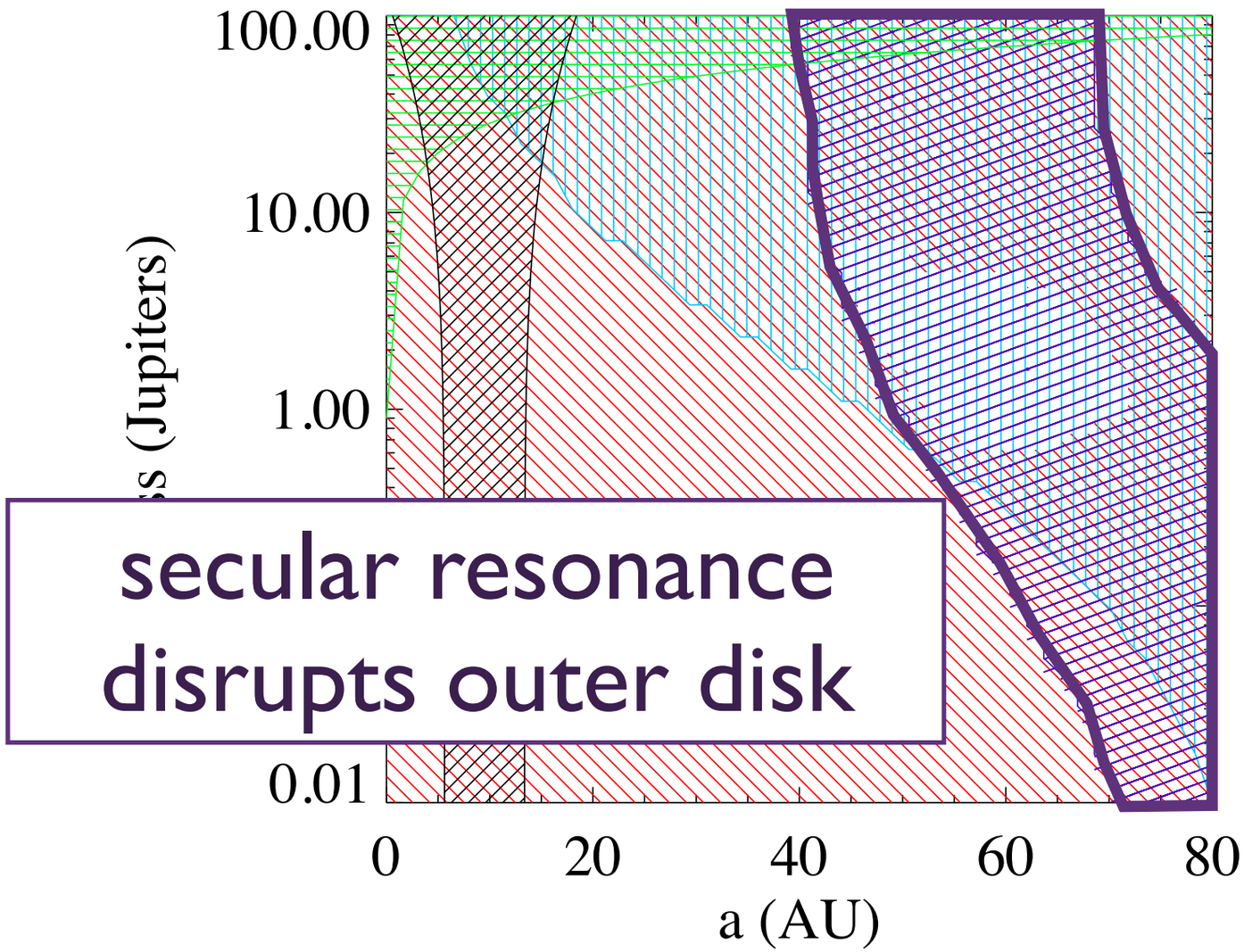
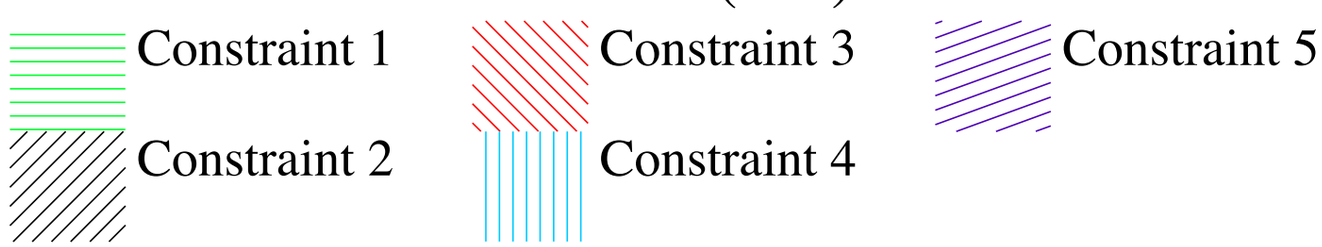


secular resonance disrupts outer disk

Ruled out by



Dawson, Murray-Clay, & Fabrycky 2011

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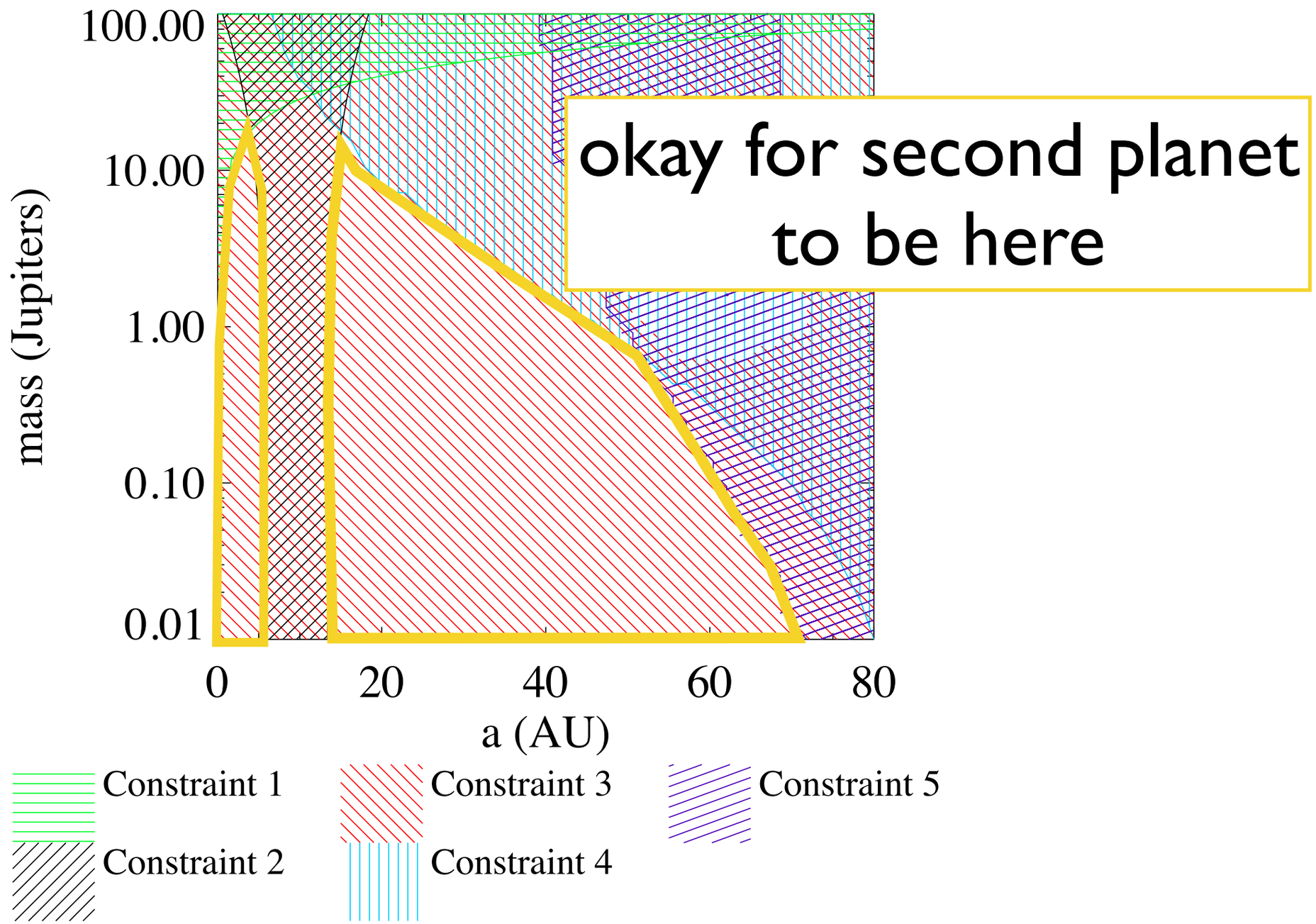
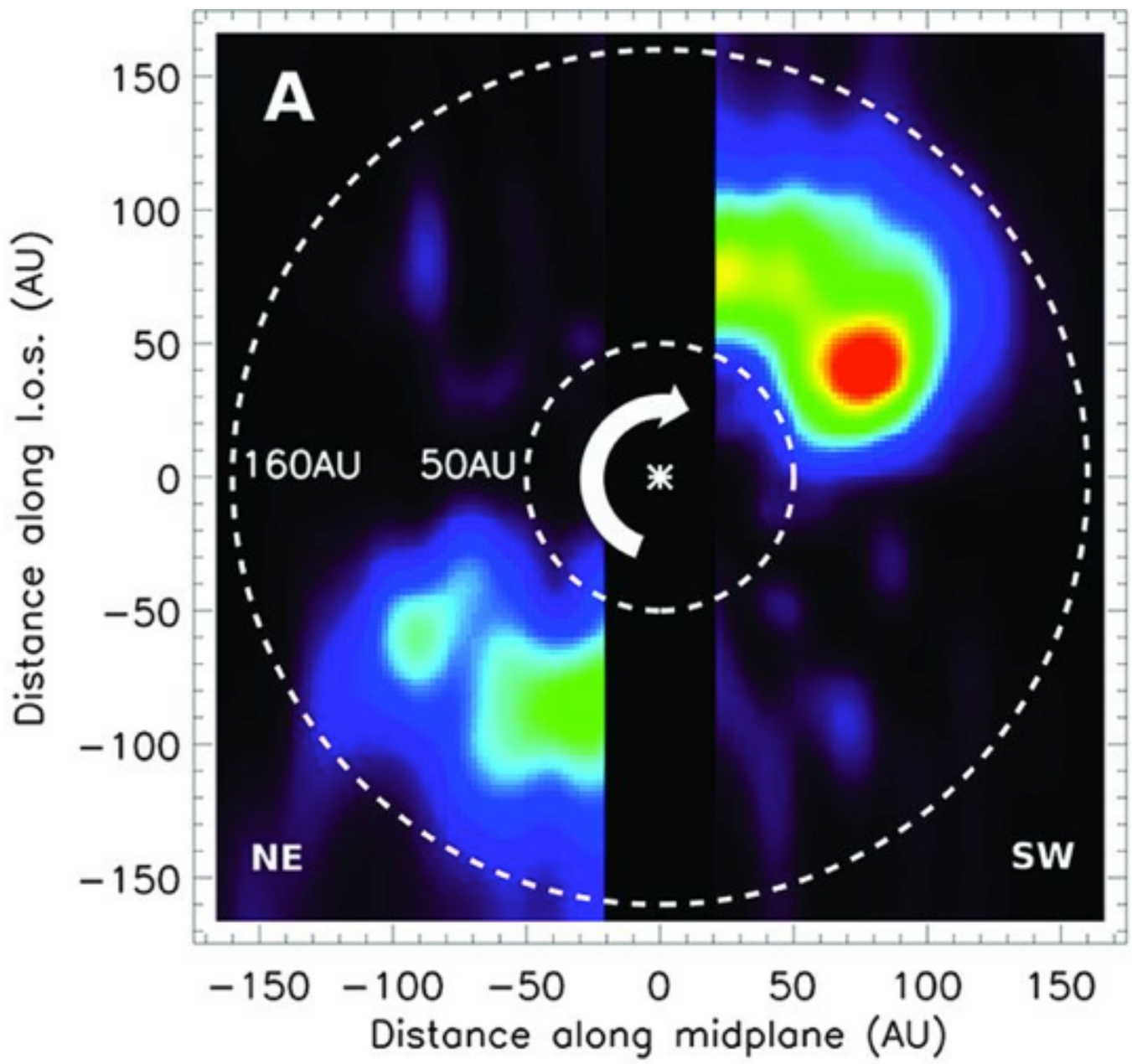


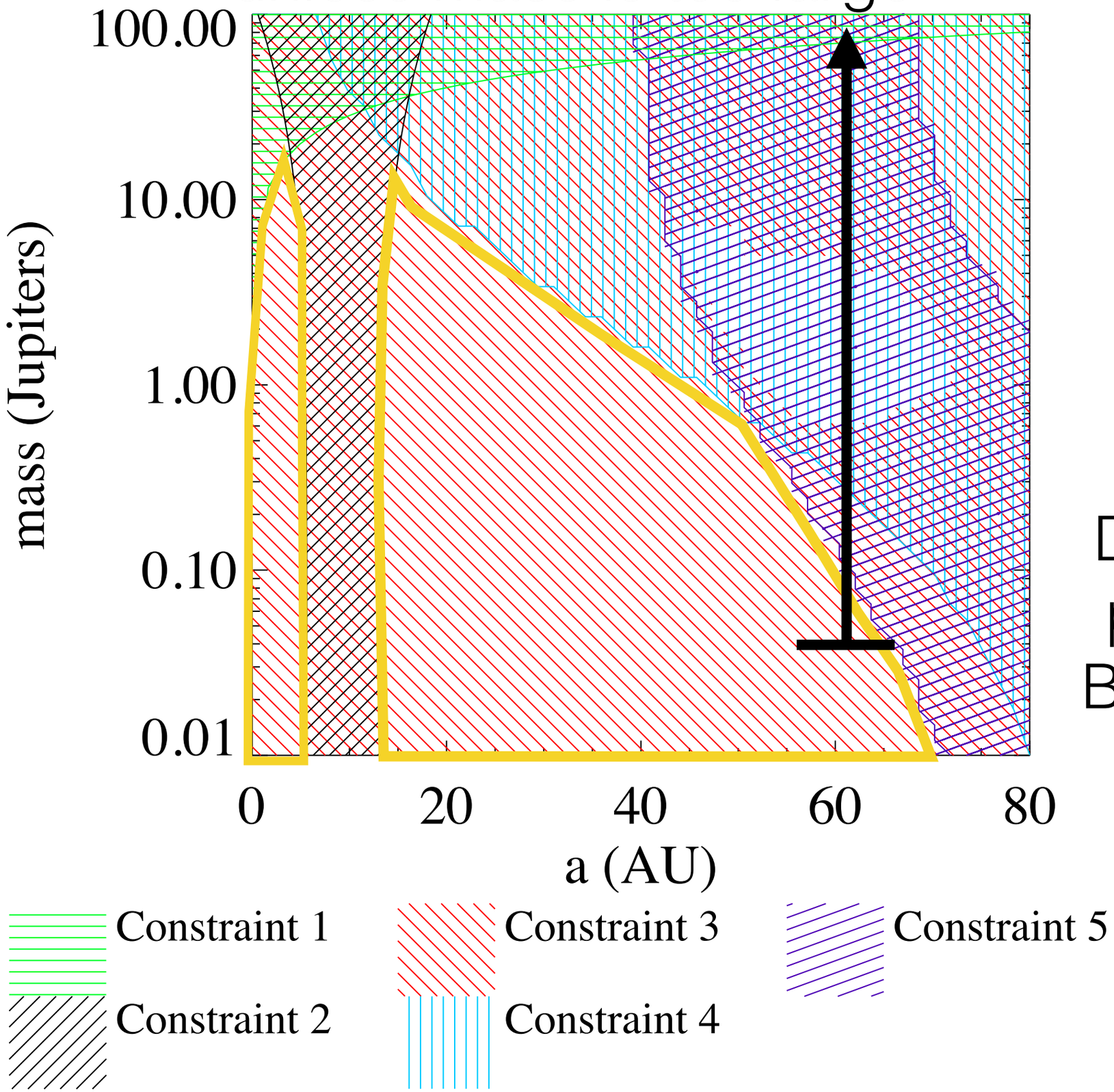
Dawson, Murray-Clay, & Fabrycky 2011

Gas clump raises possibility of third planet in Beta Pic system



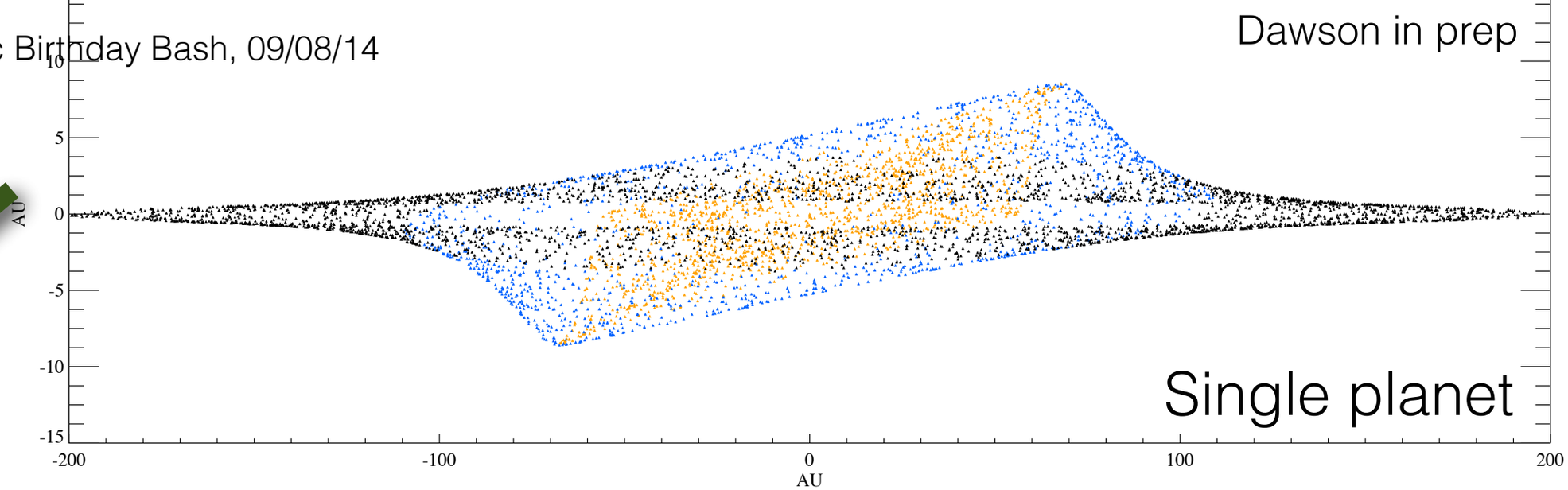
Dent+ 12

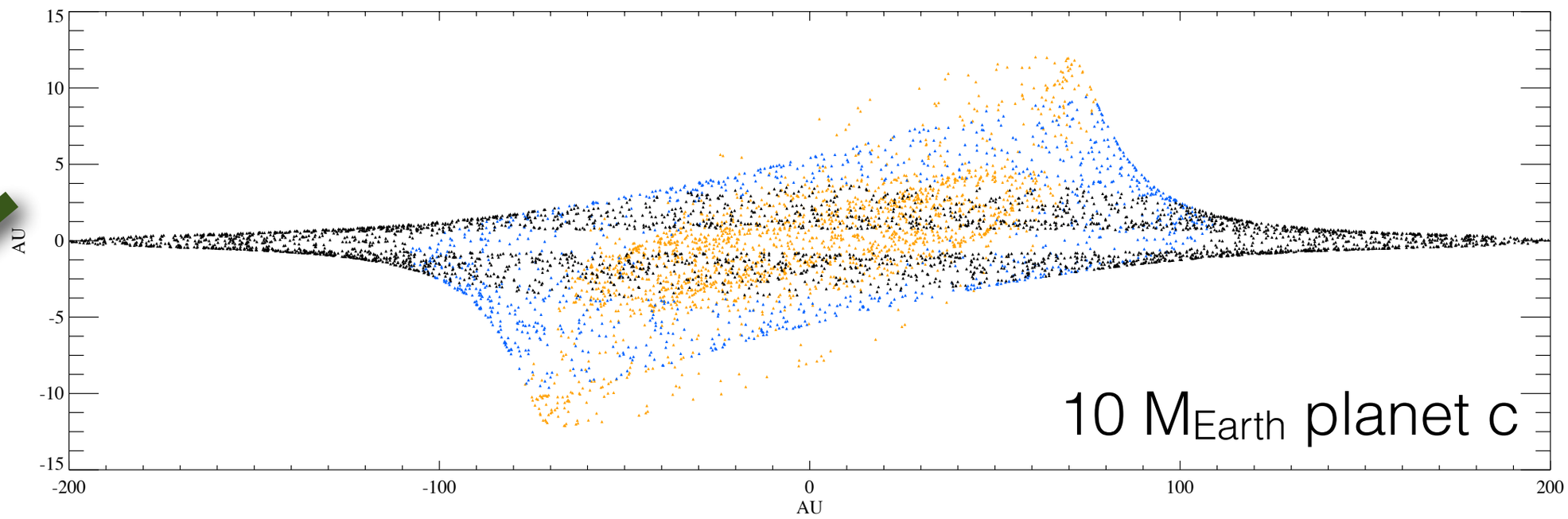
Third planet not inconsistent with warp unless mass is too large

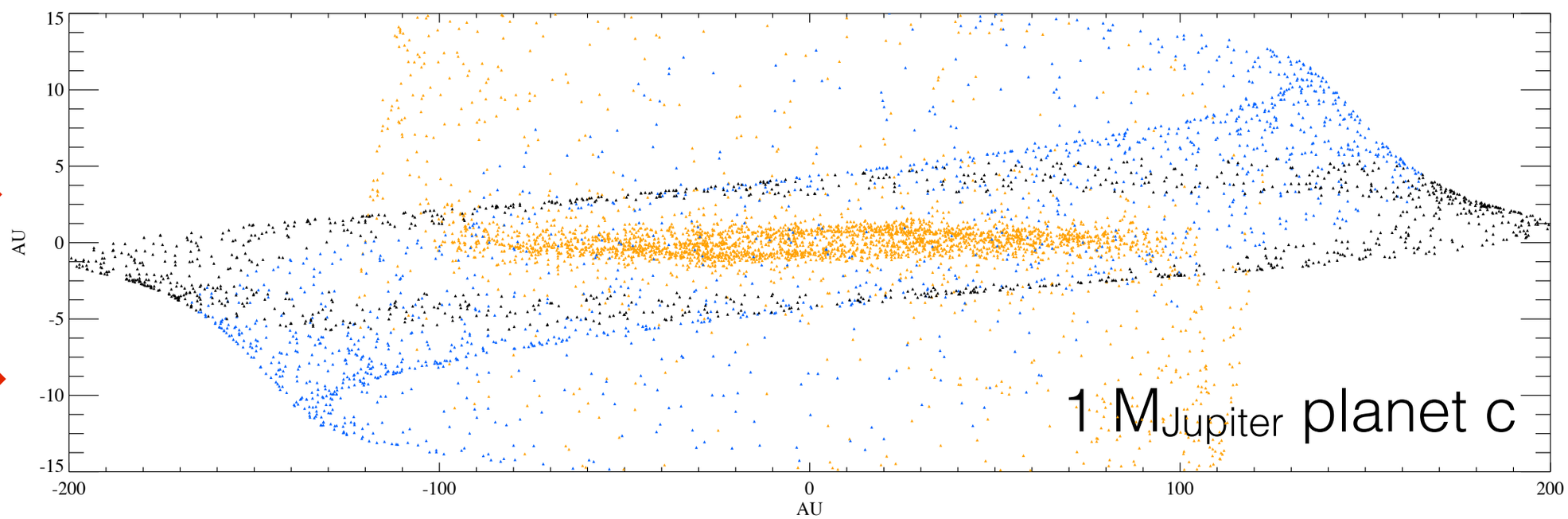


Dent+12: possible Beta Pic c

Dawson in prep

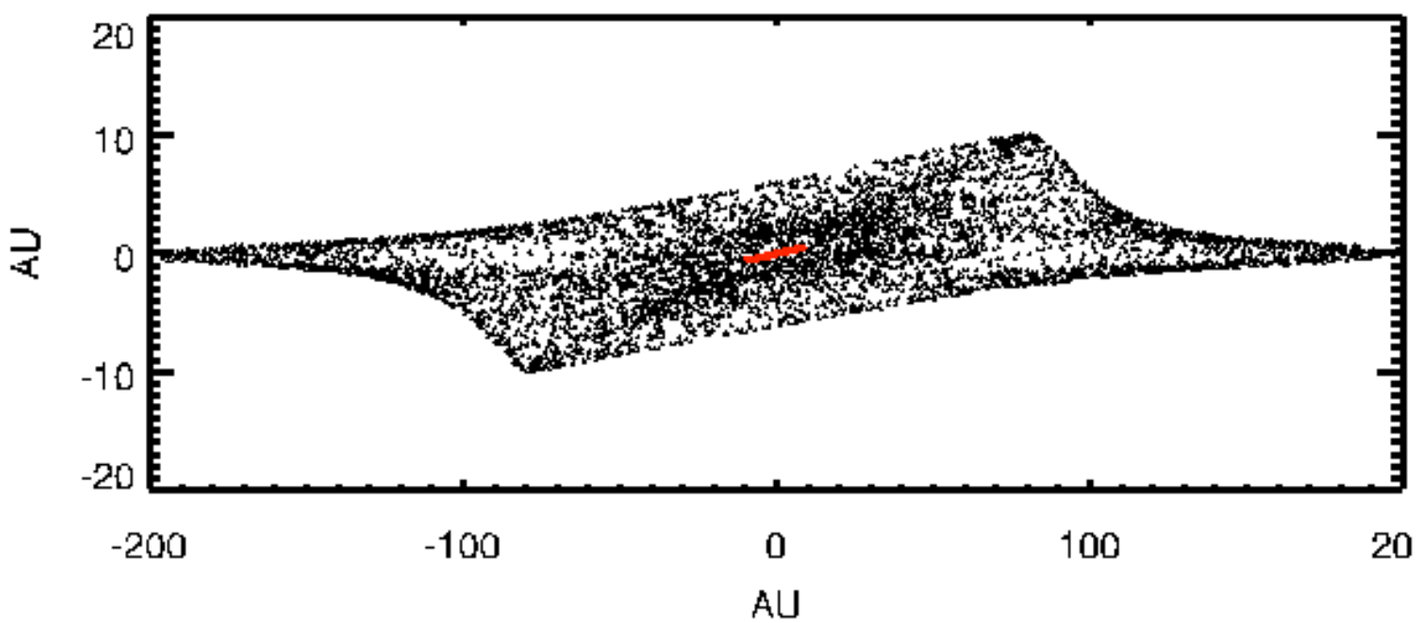






How do undetected planets affect inferences of planetary properties?

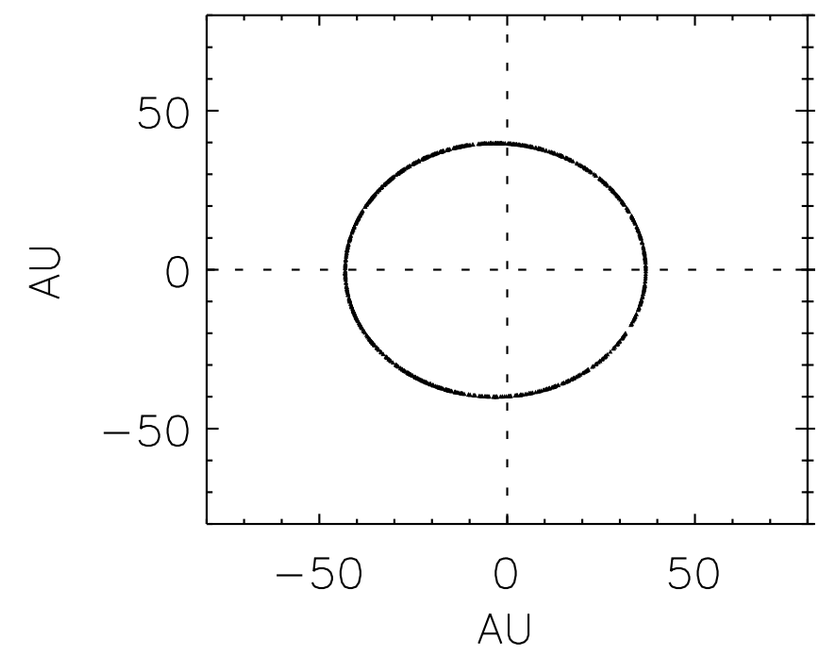
Warp



Position = planet mass + planet semi-major axis + timescale

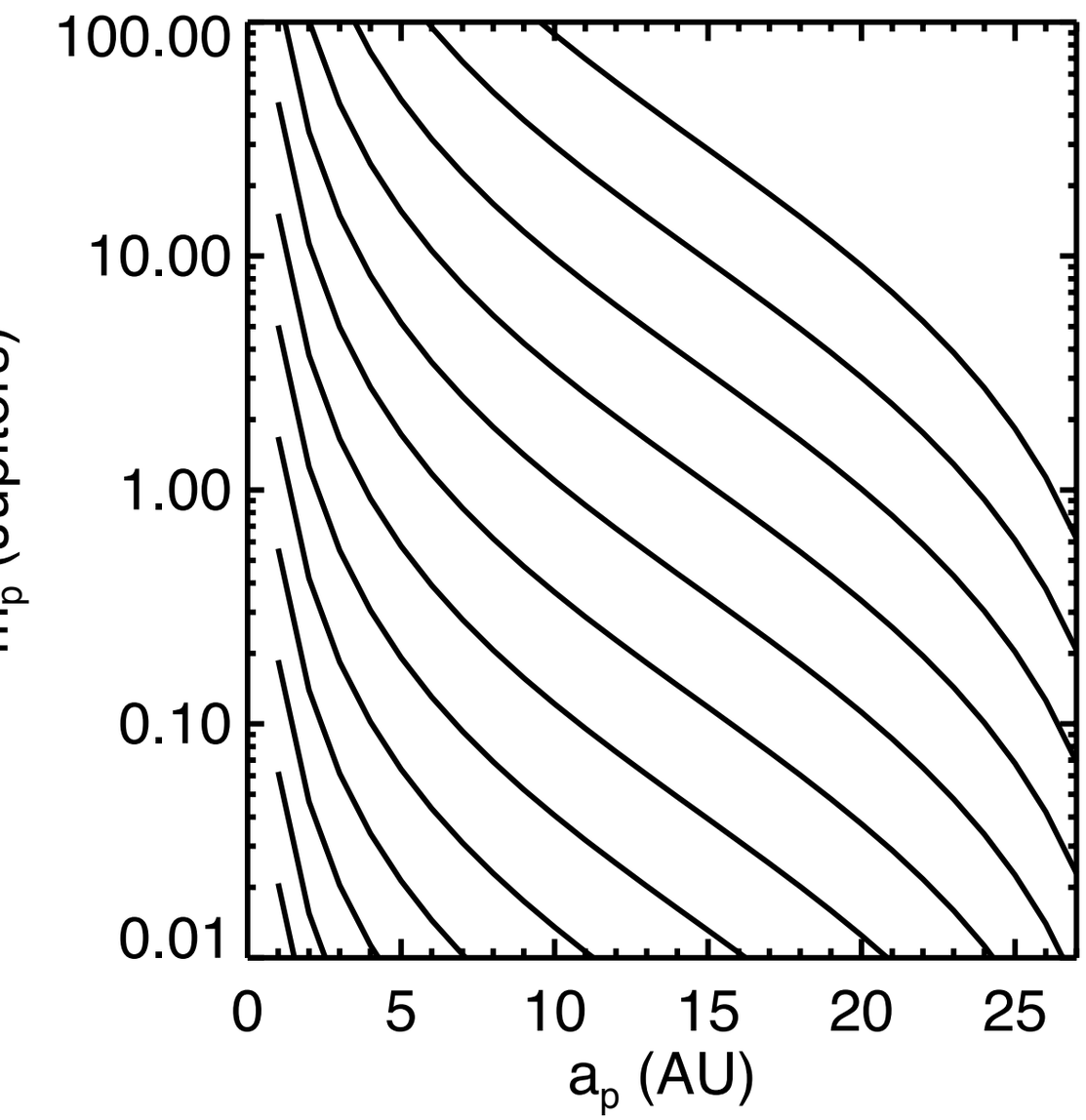
Height = planet's inclination

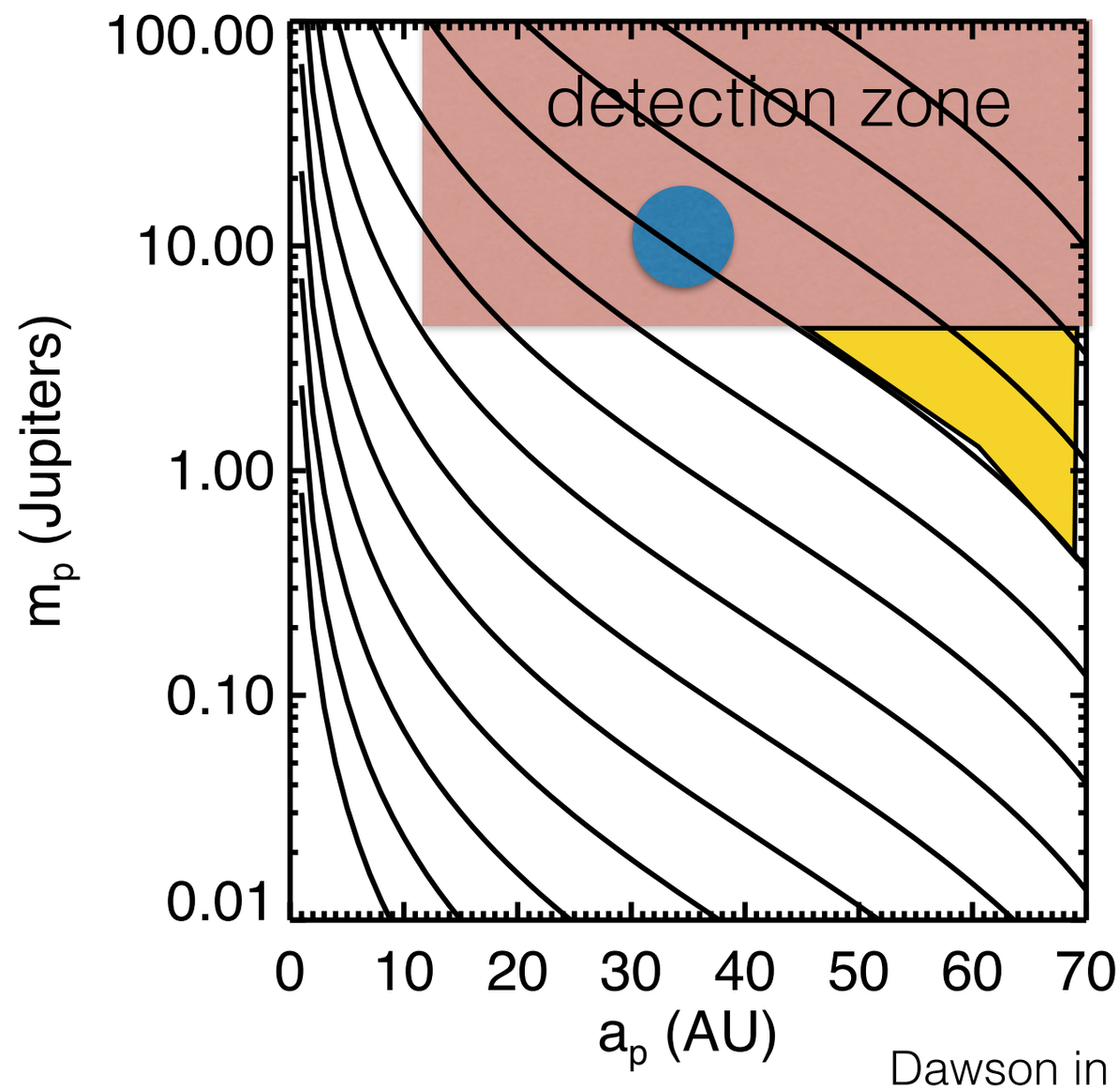
Offset



Eccentricity = planet's eccentricity + semi-major axis

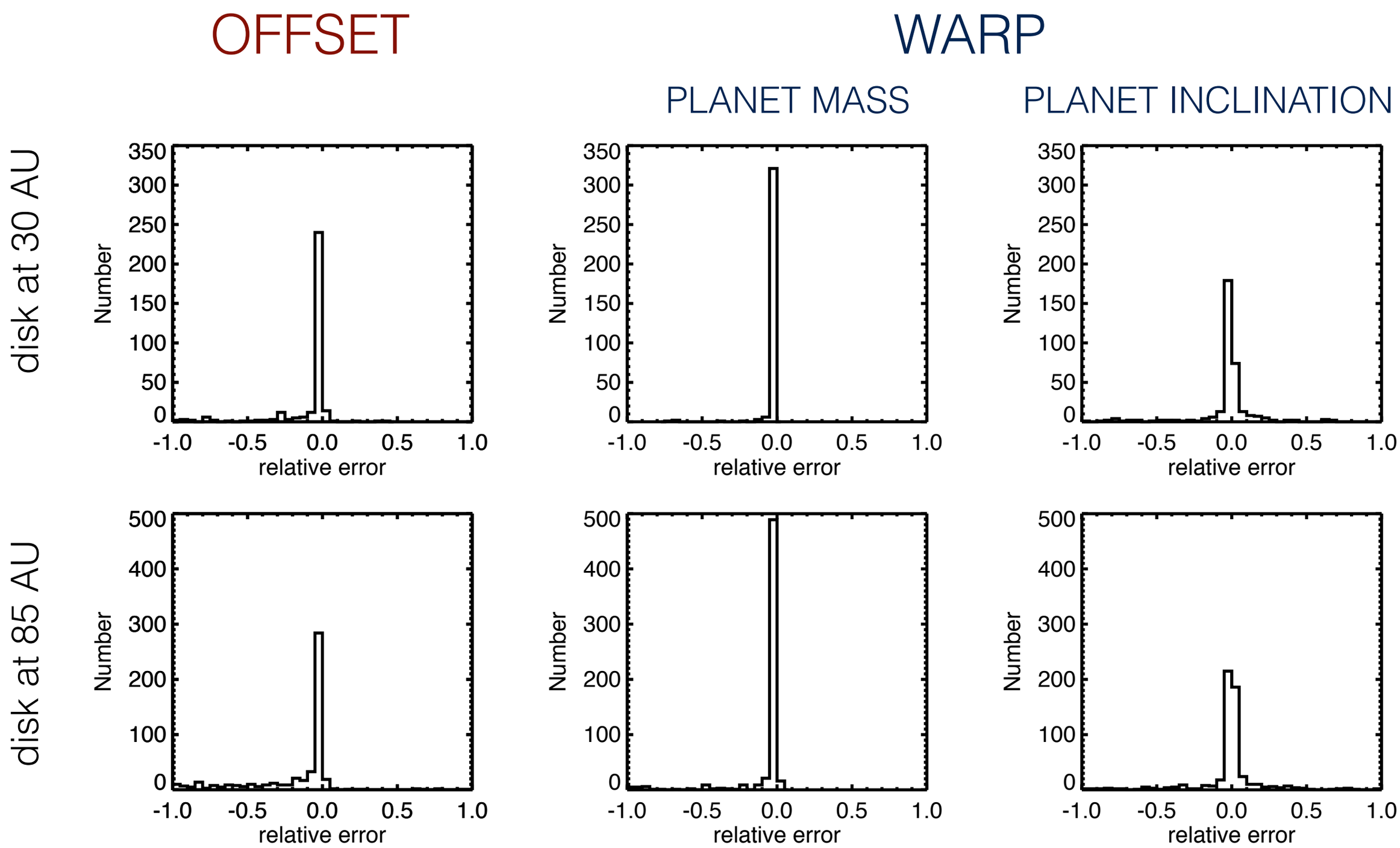
Often one planet dominates the dynamics





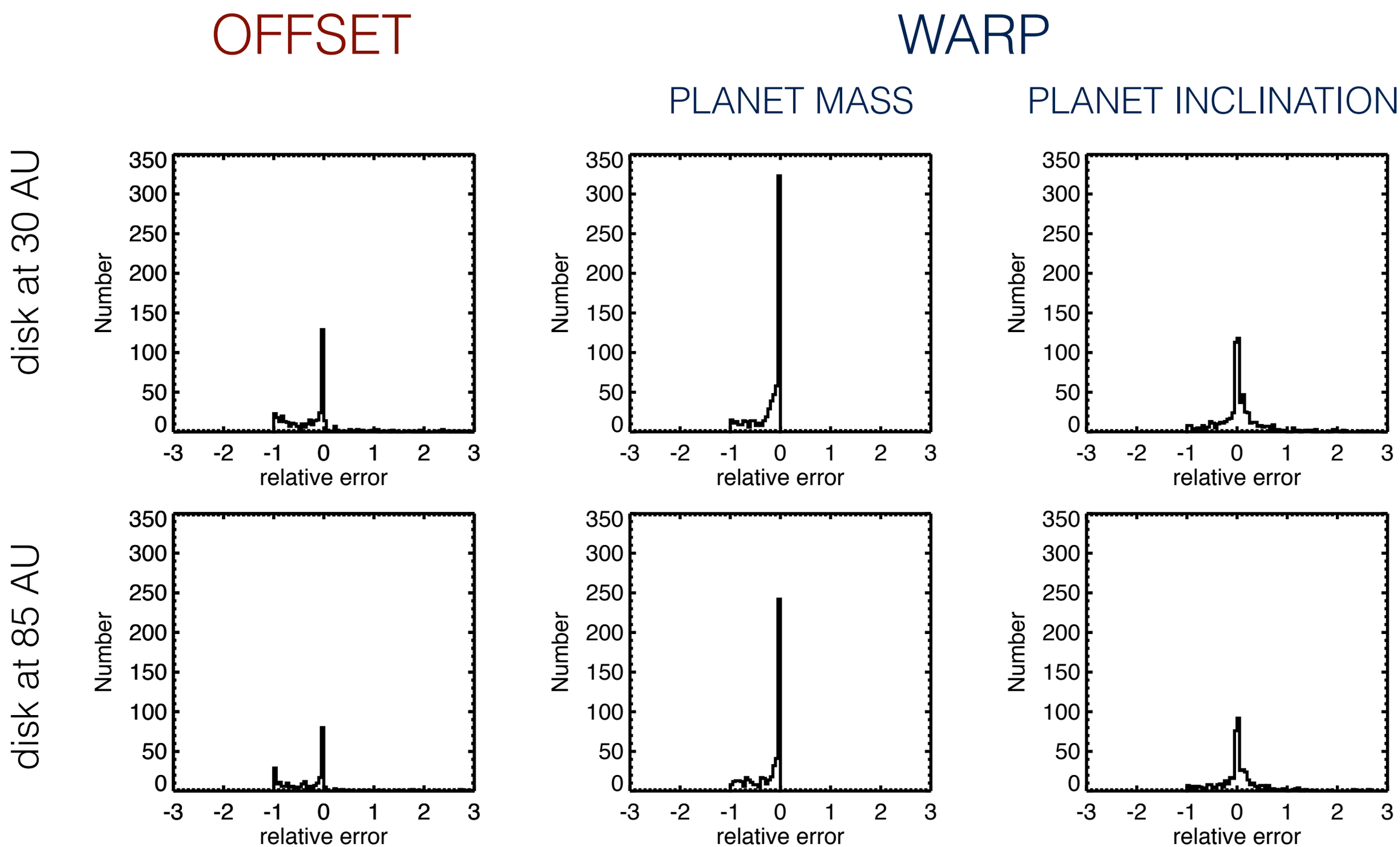
Dawson in prep

Errors in inferred properties from two-planet simulations with one detected planet



Dawson in prep

Errors in inferred properties from two-planet simulations with one detected planet



Dawson in prep

Conclusion: usually the prime suspect is the culprit

- Beta Pic b, not another planet, is responsible for the warp in the Beta Pic debris disk
- Another planet (<~0.5 M_{Jup}) could be responsible for the gas clump without disrupting the warp dynamics
- In multi-planet systems, a single planet generally dominates the sculpting (particularly if that planet is the only one detectable), allowing us to infer its properties without much “contamination”

Acknowledgments: Ruth Murray-Clay, Dan Fabrycky, Tushar Mittal, Paul Kalas, James Graham, Gaspard Duchêne, Mike Fitzgerald, Eugene Chiang