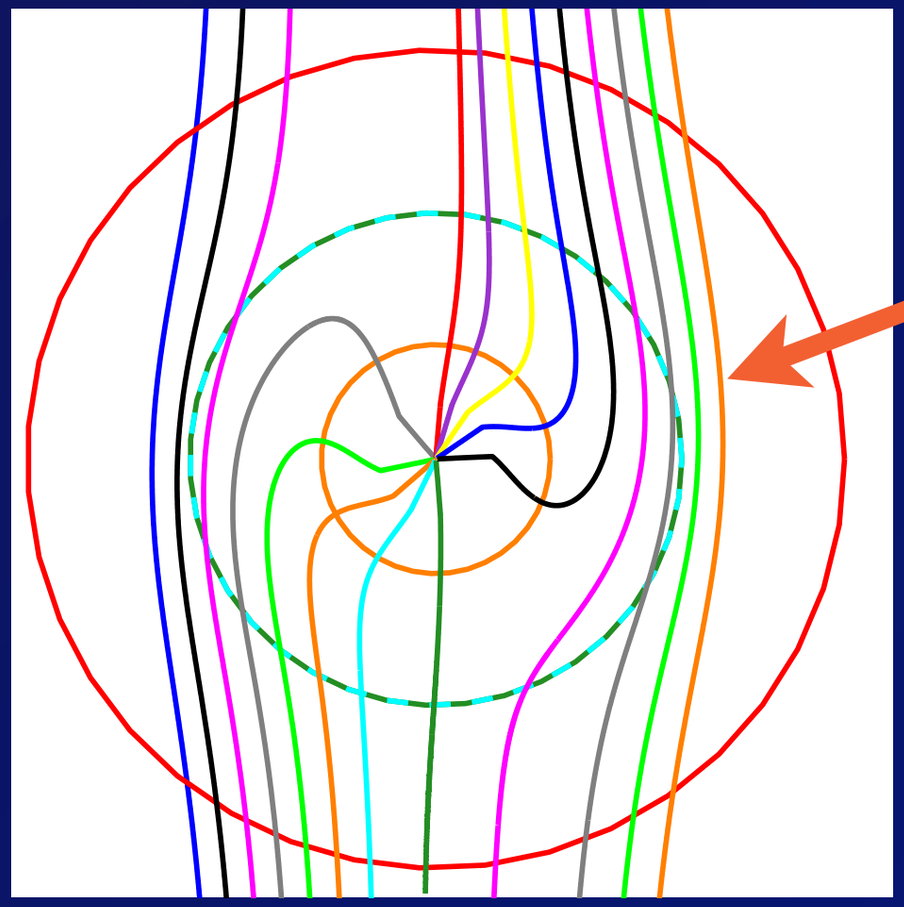
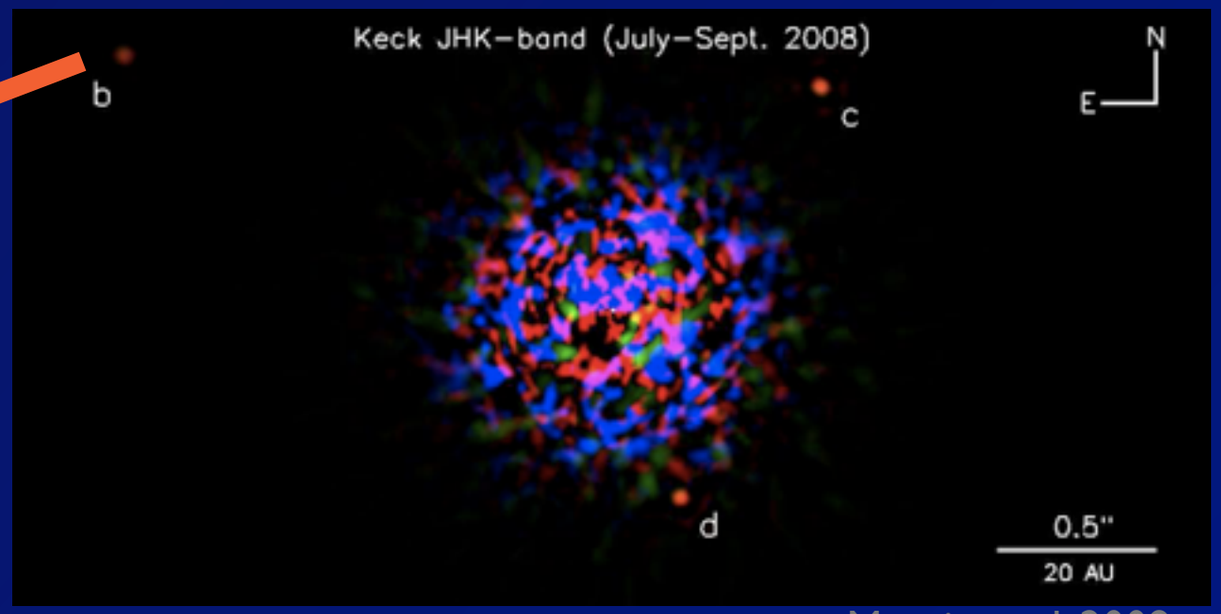
Core Accretion at Wide Separations: The Critical Role of Gas





Marois et al. 2008

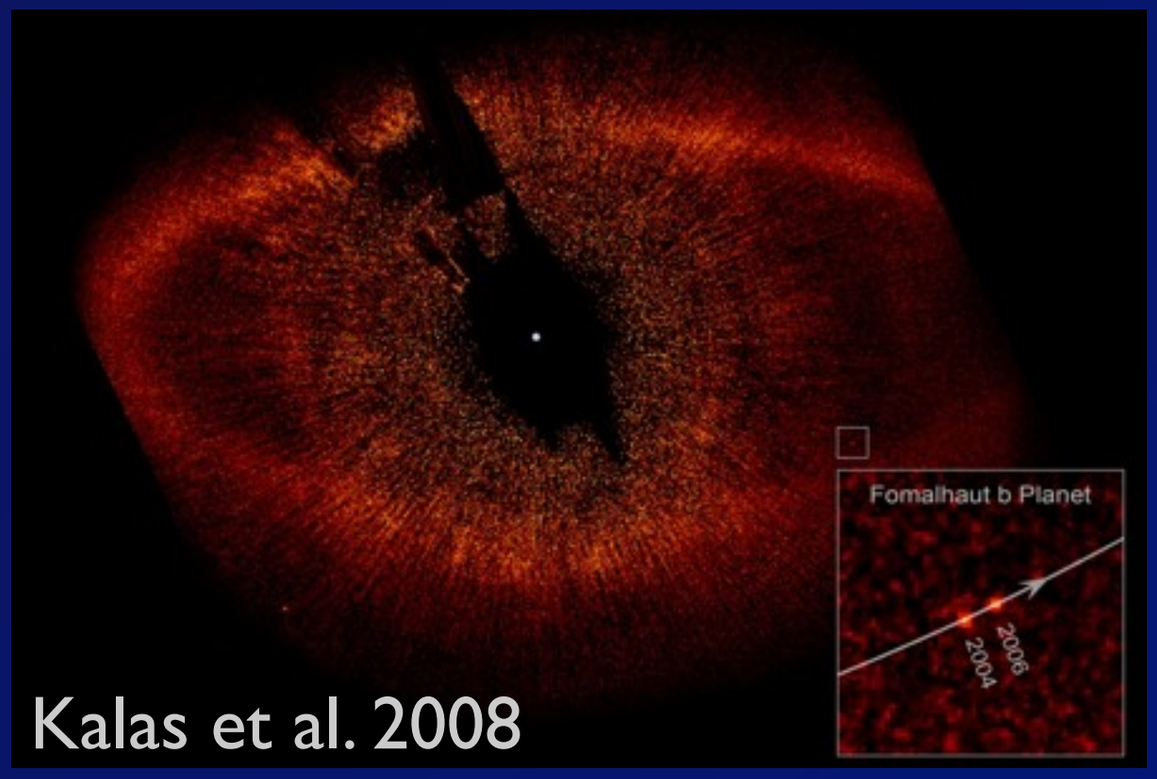
Ruth Murray-Clay

Harvard-Smithsonian Center for Astrophysics

Kaitlin Kratter, Hagai Perets, Andrew Youdin

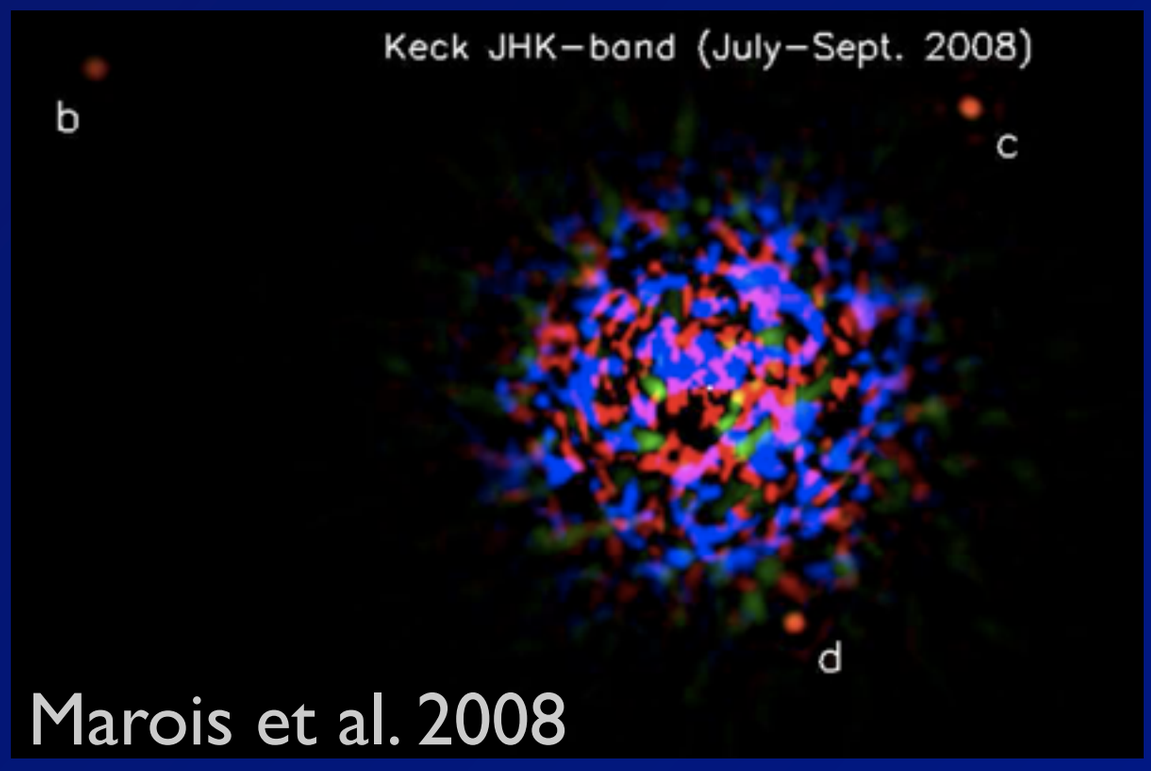
Wide separation gas giants/brown dwarfs/disk fragments exist

Fomalhaut



Kalas et al. 2008

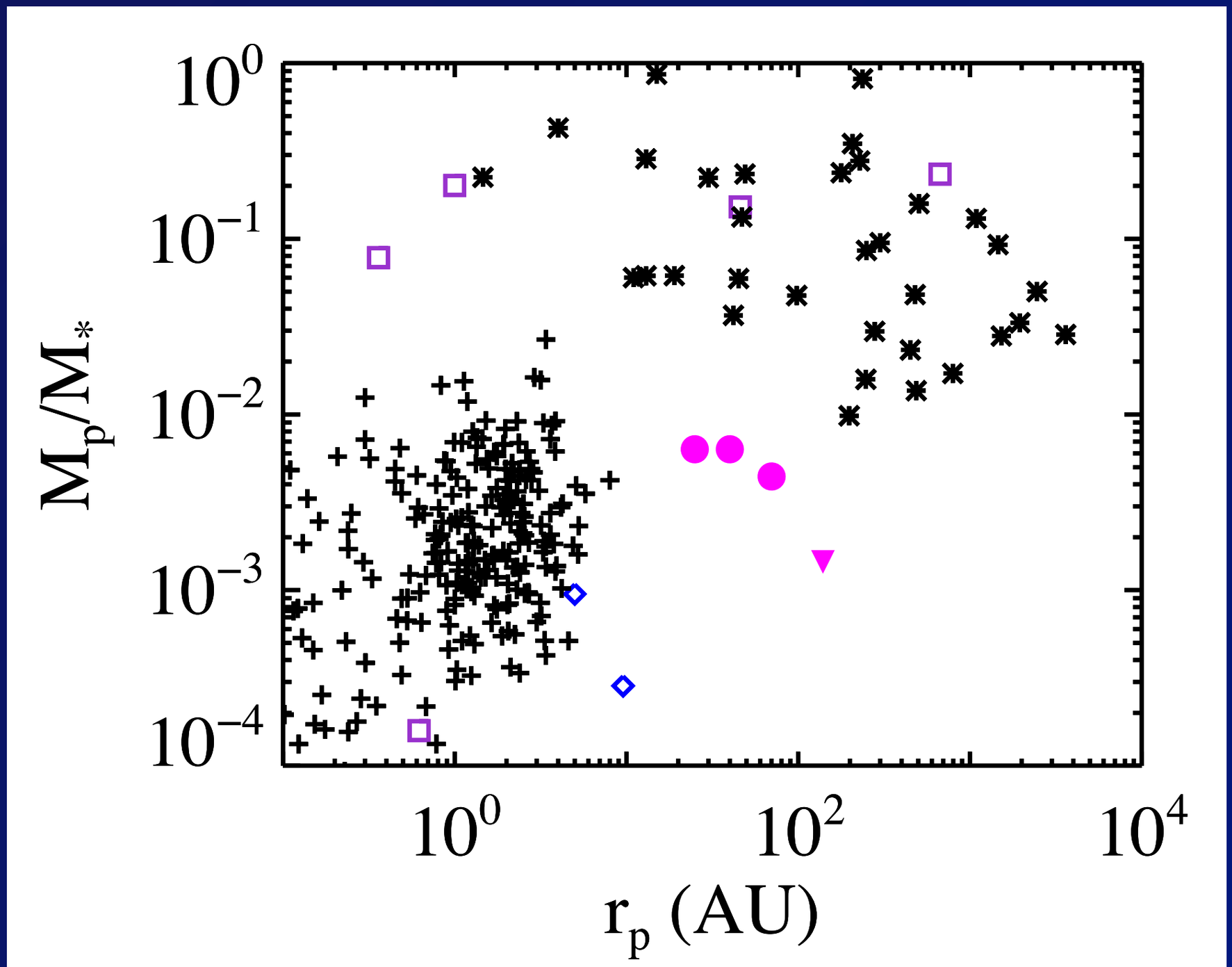
HR 8799

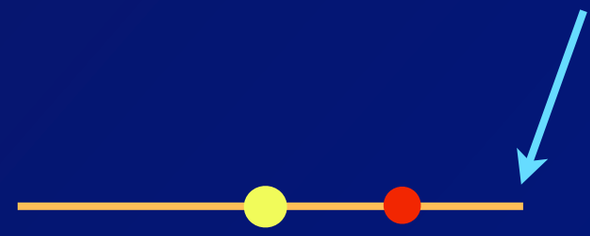


Marois et al. 2008

GI planets can only be failed binary stars

Kratter, Murray-Clay, & Youdin, ApJ (2010)





If this occurs, more brown dwarfs or even M stars should be found at 50–150 AU around A stars.

Data: Zuckerman & Song 2009; exoplanet.eu

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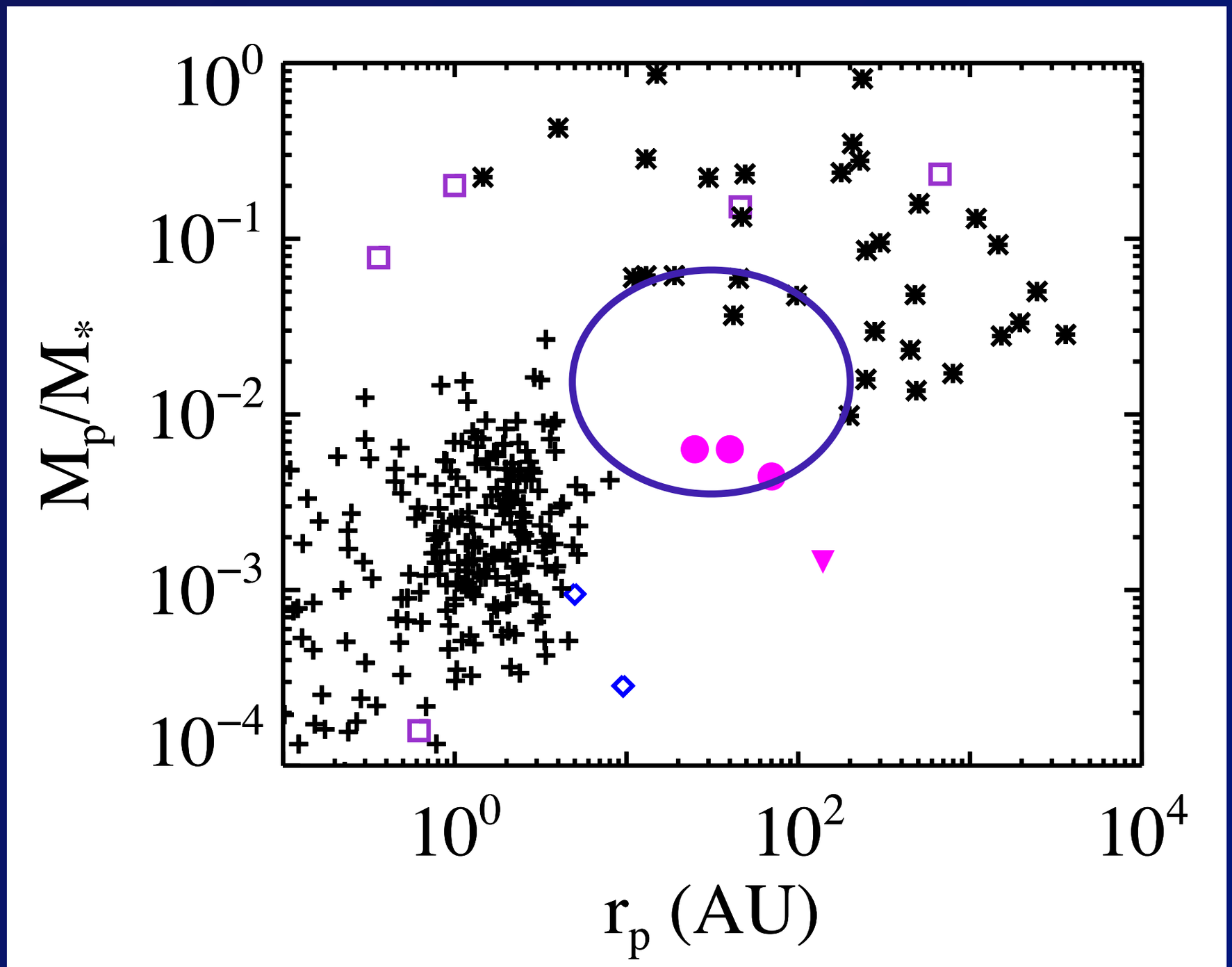

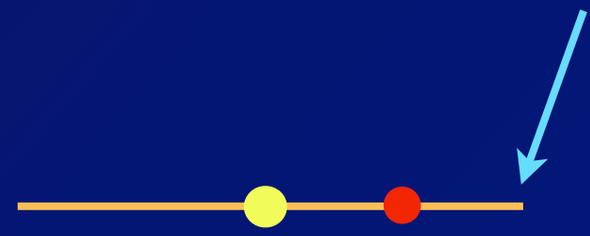

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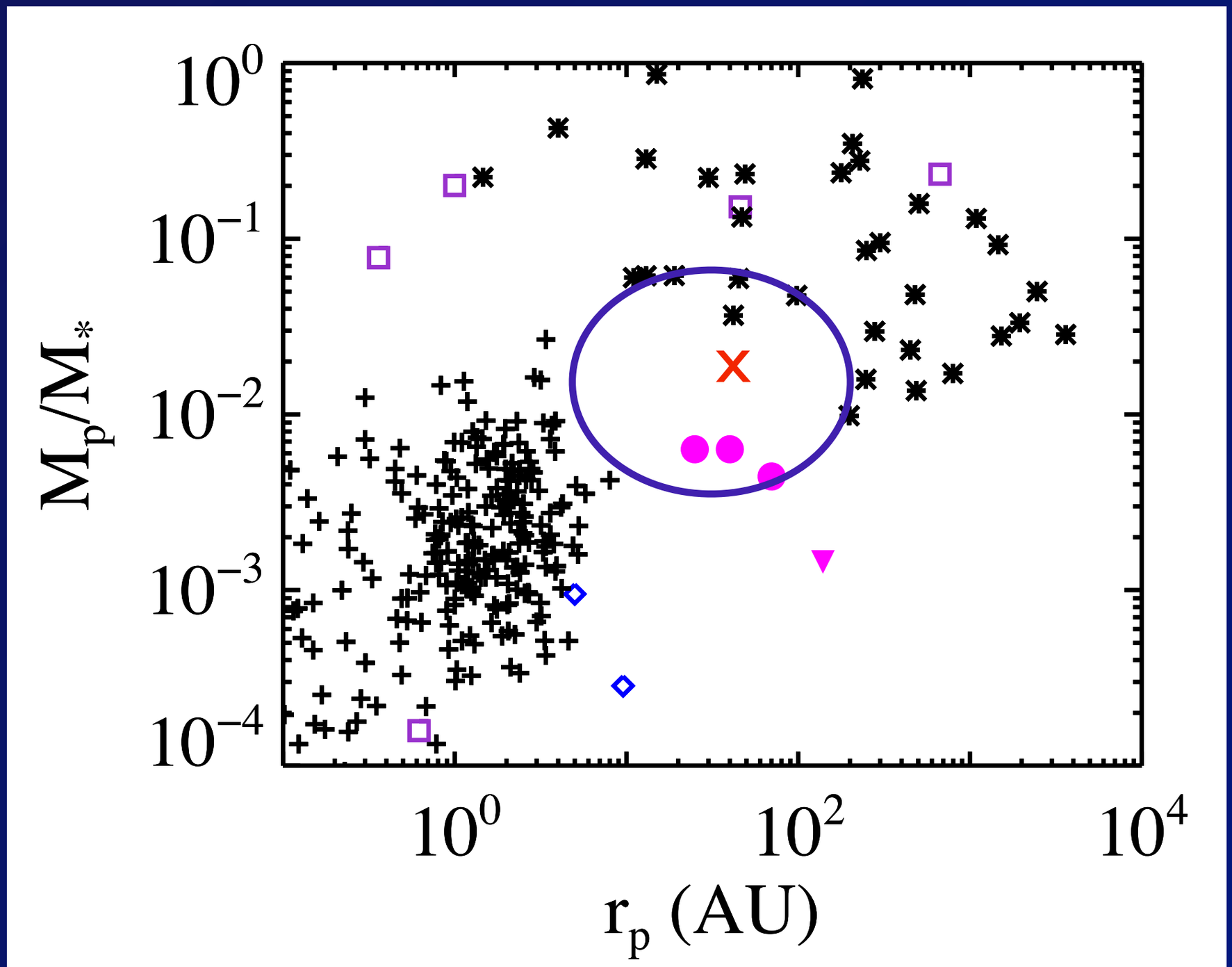

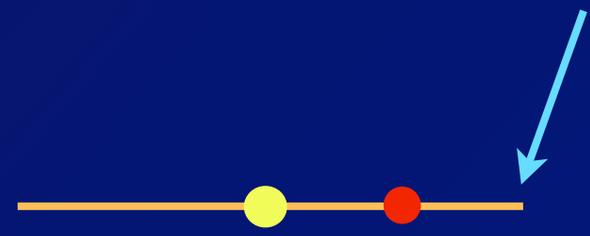

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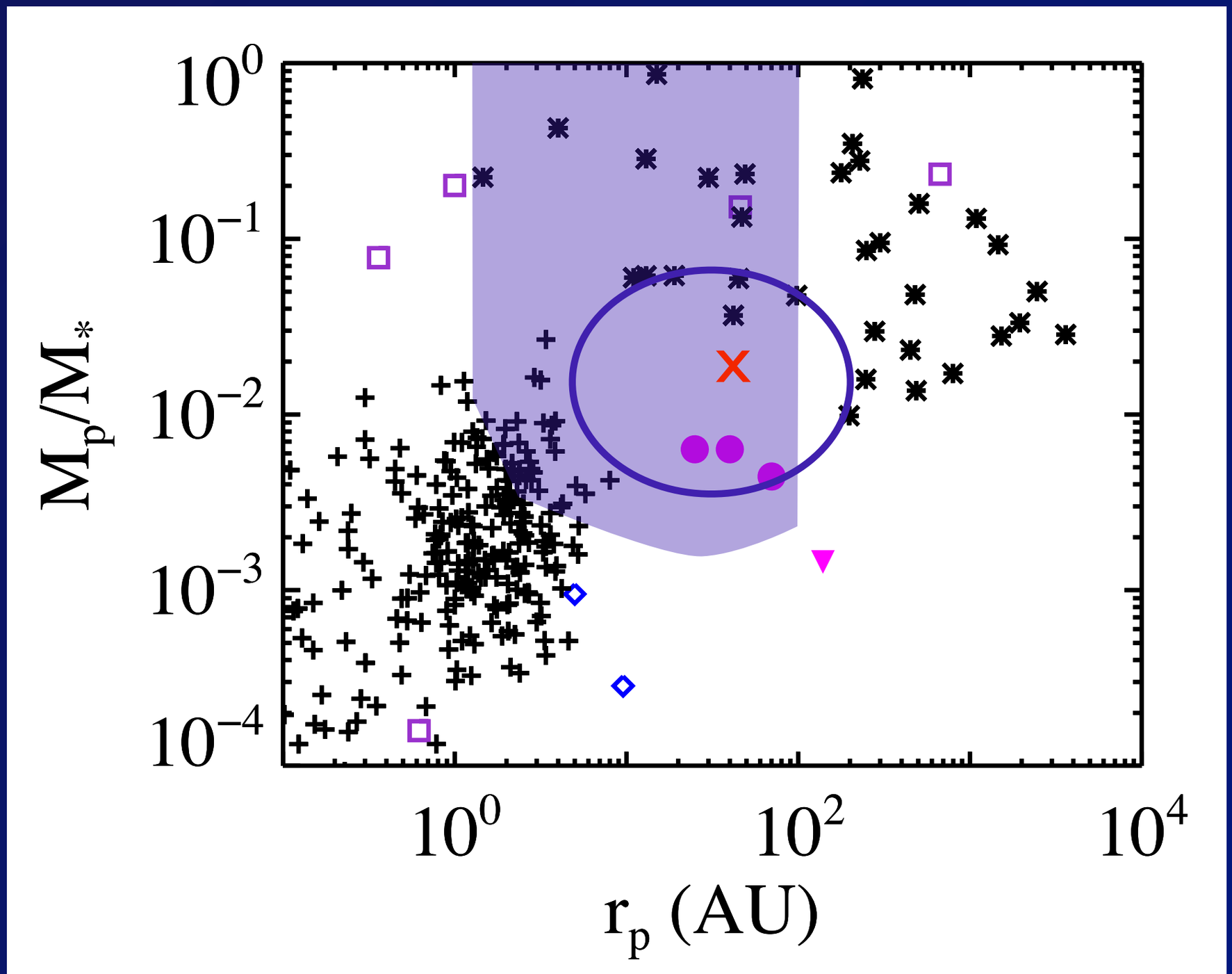

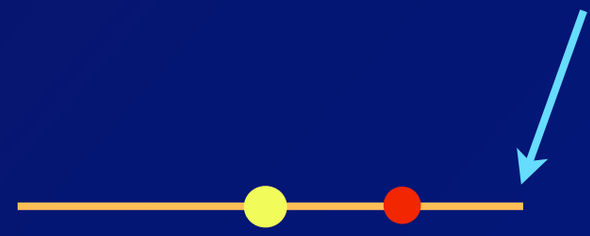

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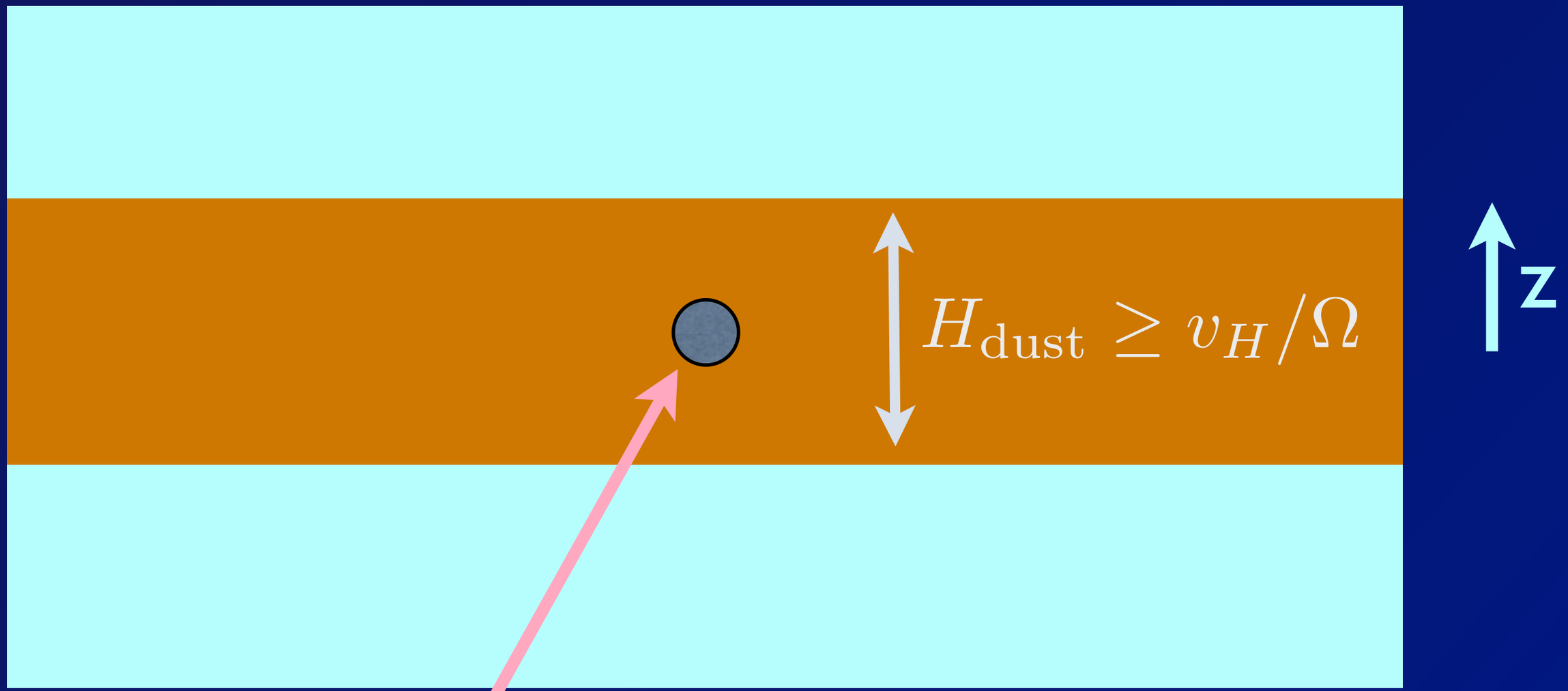
Core Accretion at Large Separations

doesn't work if:



$R_{accrete}$ given by gravitational focusing onto R_{core} given velocity v_H

Gas can help

Rafikov (2004)

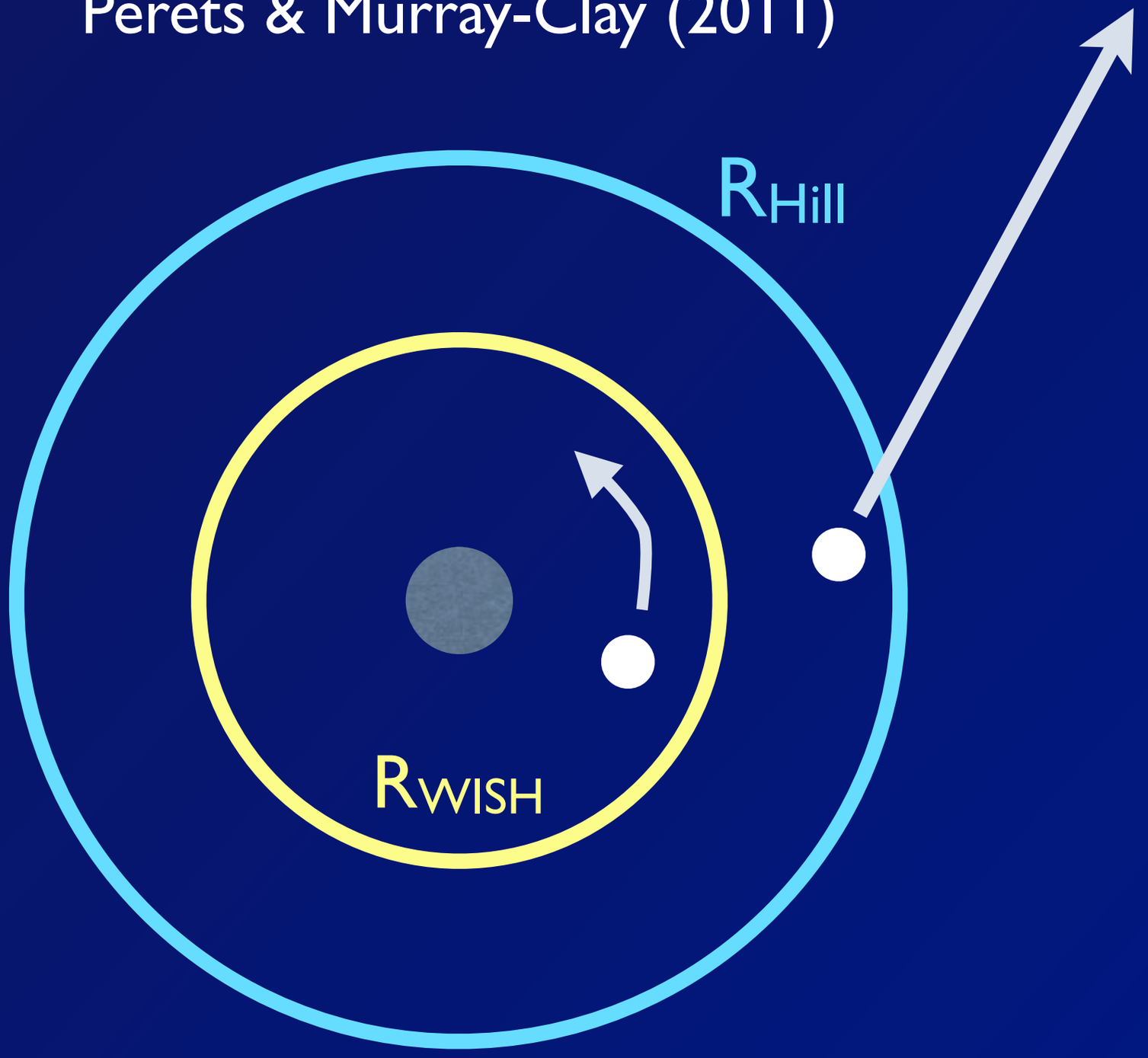
$H_{\rm dust} < v_H/\Omega$

R_{atm}

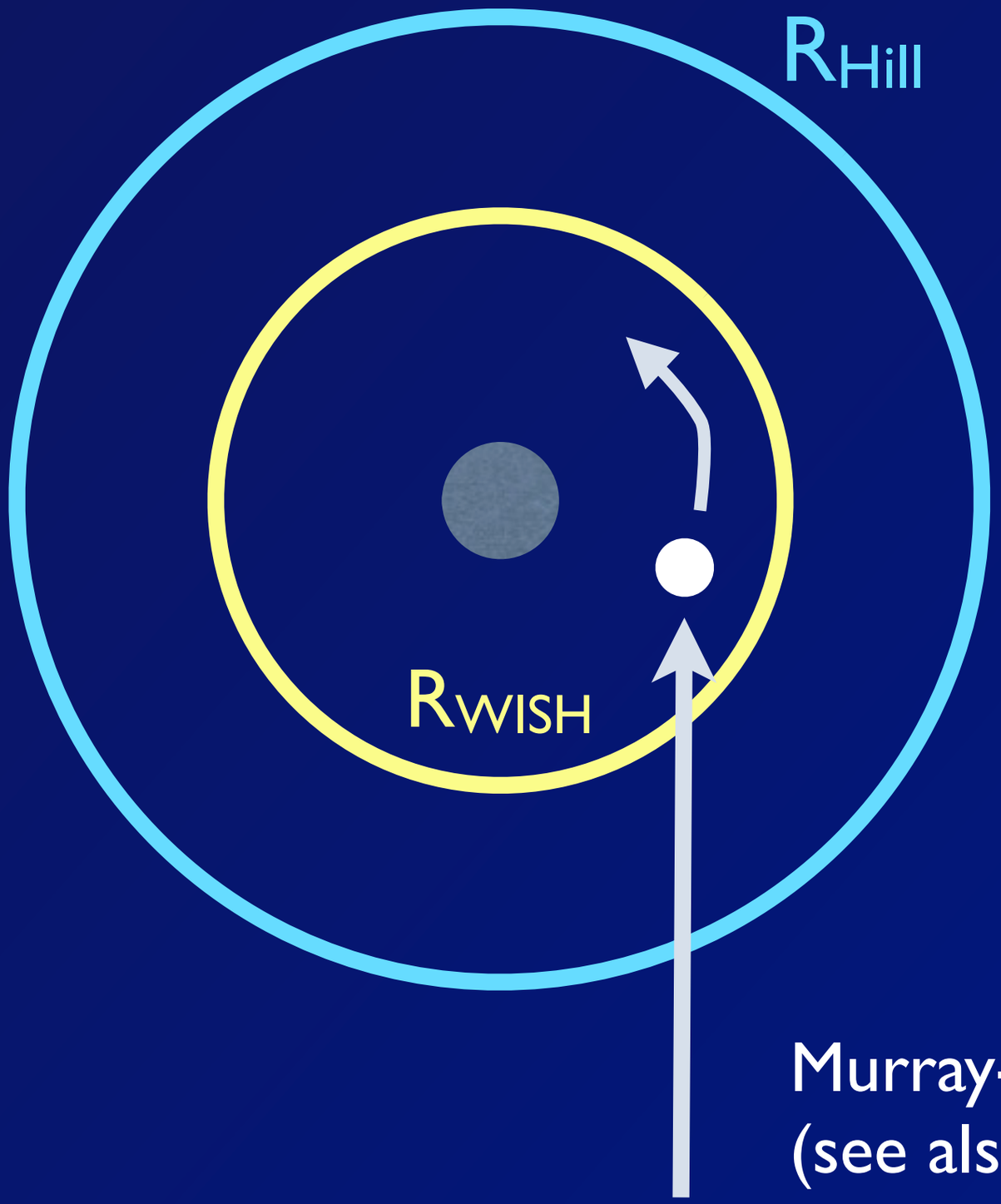
Inaba & Ikoma (2003)

Wind Shearing (WISH)

Perets & Murray-Clay (2011)



"Binary Capture"



dissipation due to interaction with gas

Murray-Clay & Perets (in prep)
(see also Ormel & Klahr 2010)

Decoupling at the Atmosphere

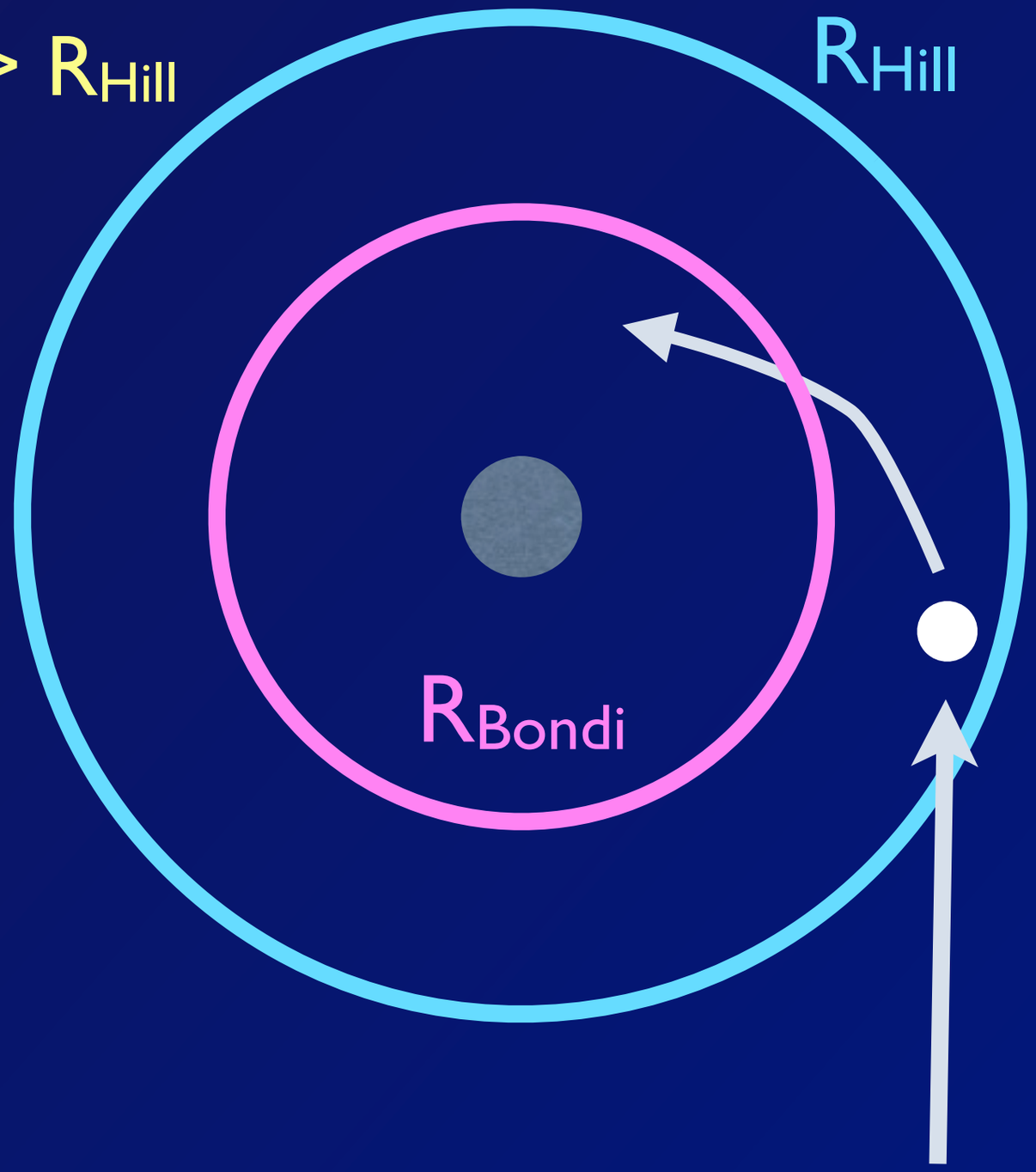
+ gravitational focusing into the atmosphere

capture by the atmosphere only if the small particle can decouple from the exterior gas

Decoupling at the Atmosphere

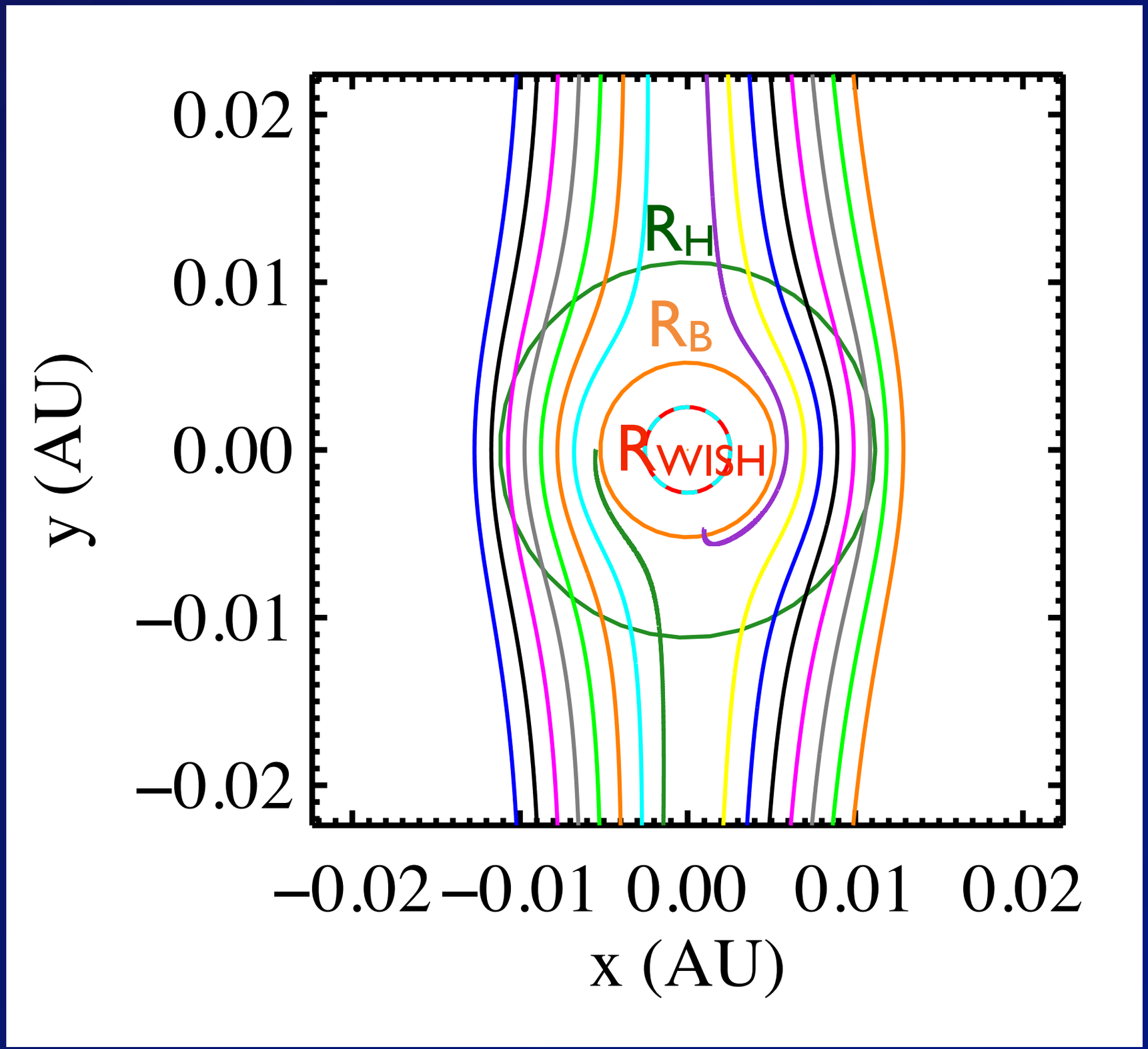
+ gravitational focusing into the atmosphere

$R_{WISH} > R_{Hill}$



Gravitational focusing just needs to get the small body to the atmosphere

We have numerically validated our expressions



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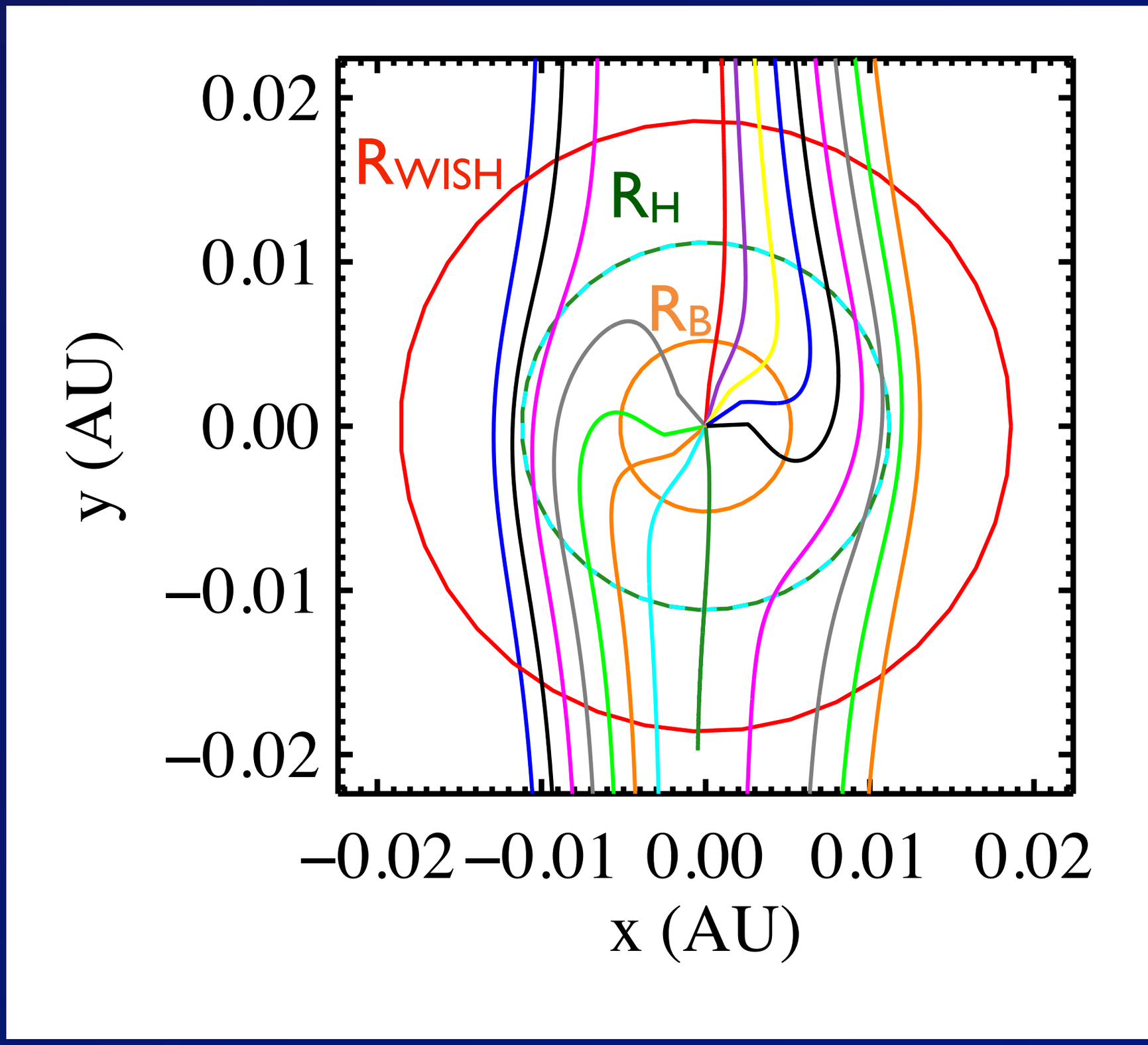
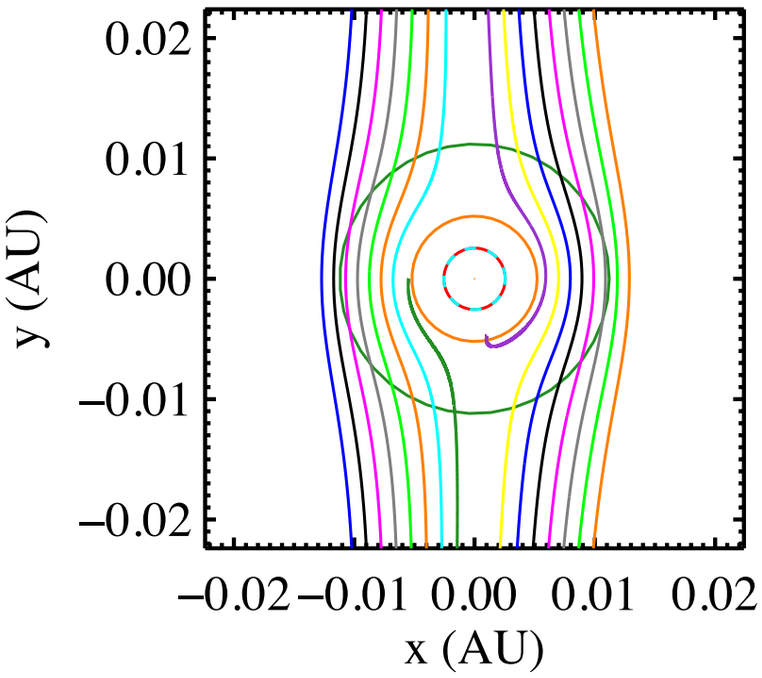
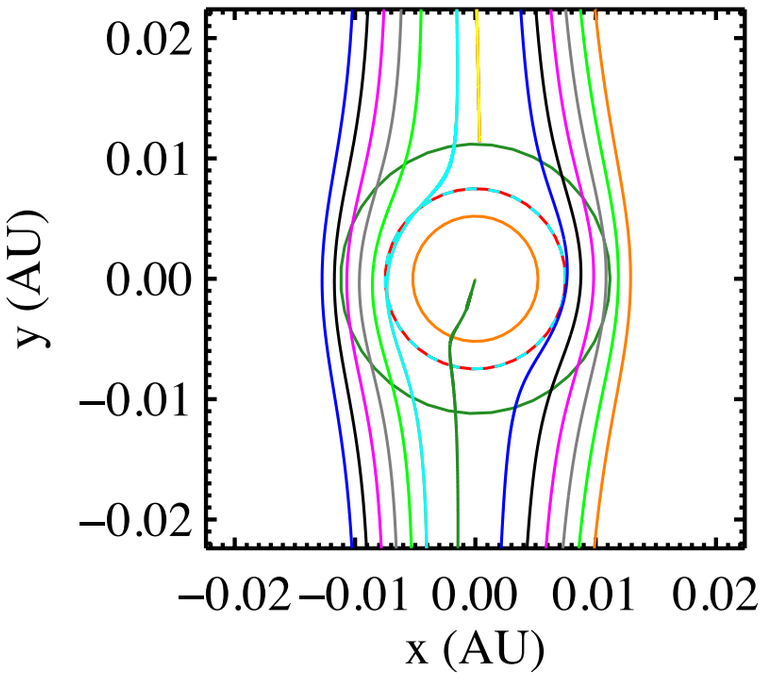
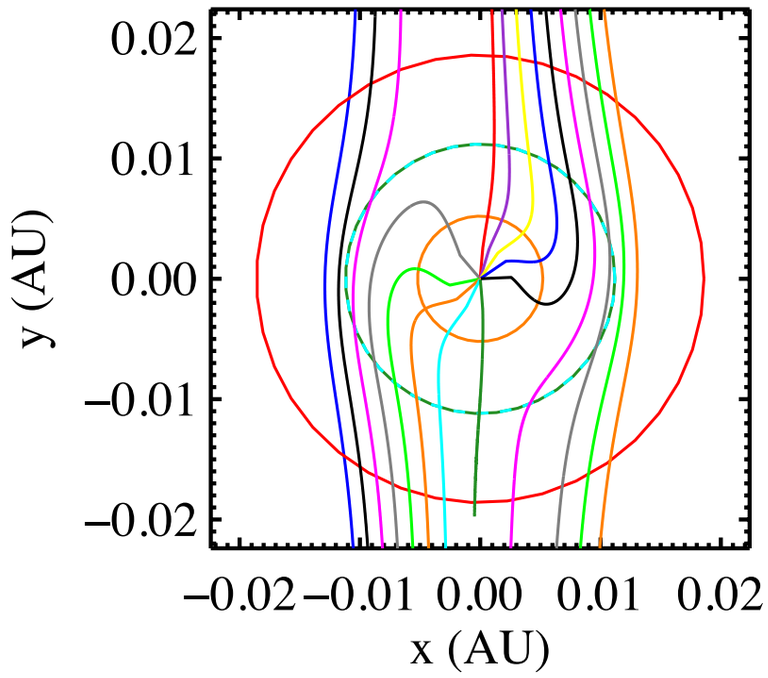


$\alpha = 0$







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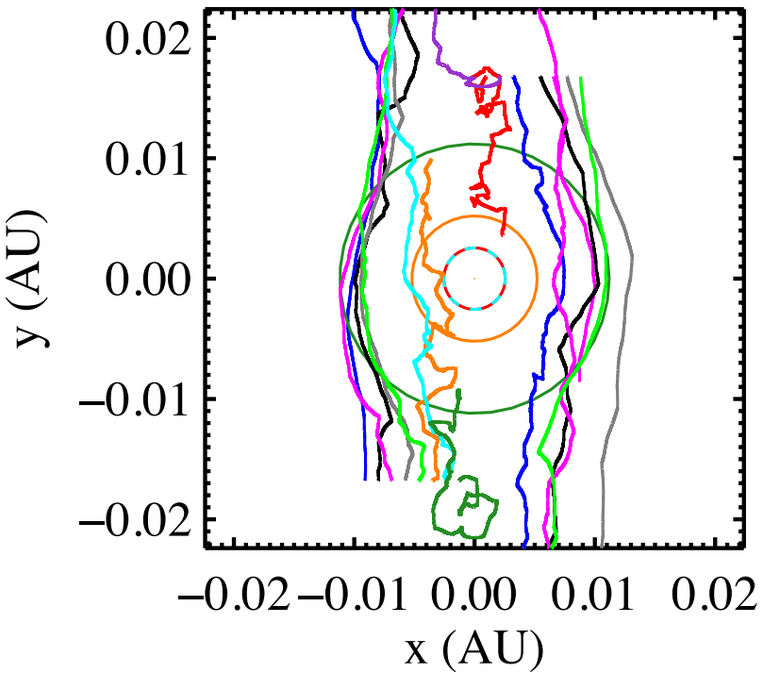

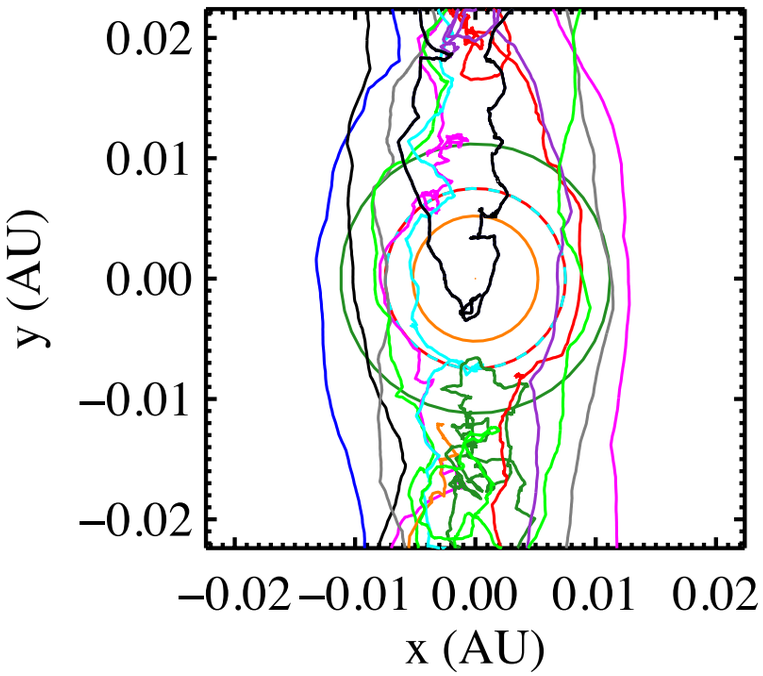

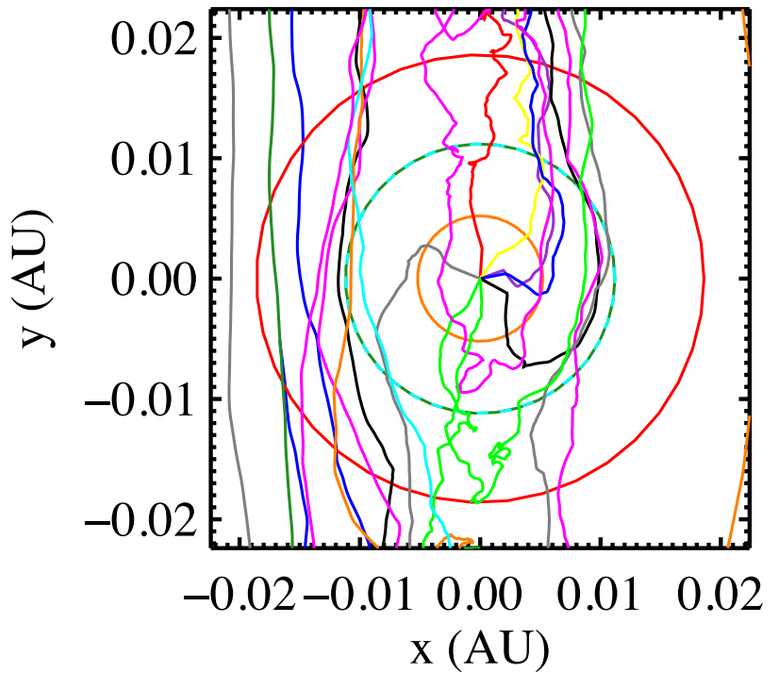

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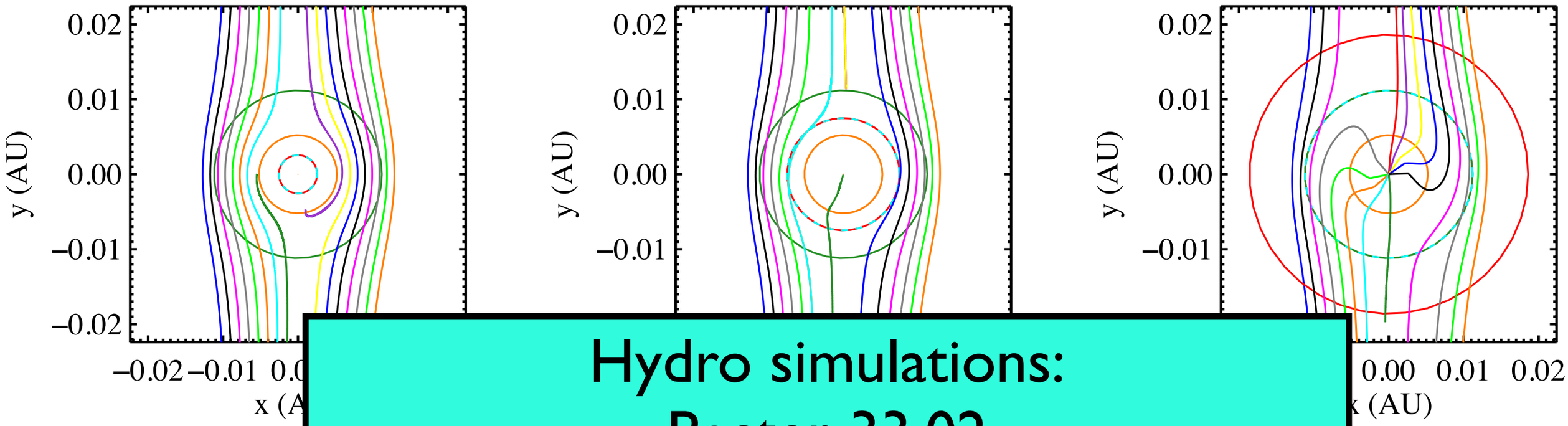
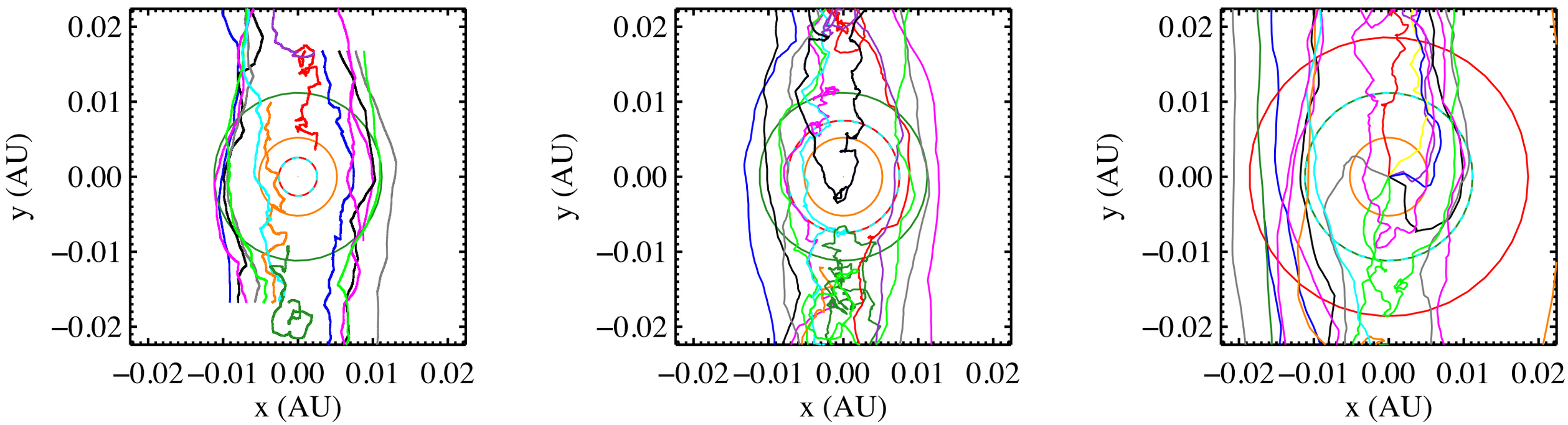
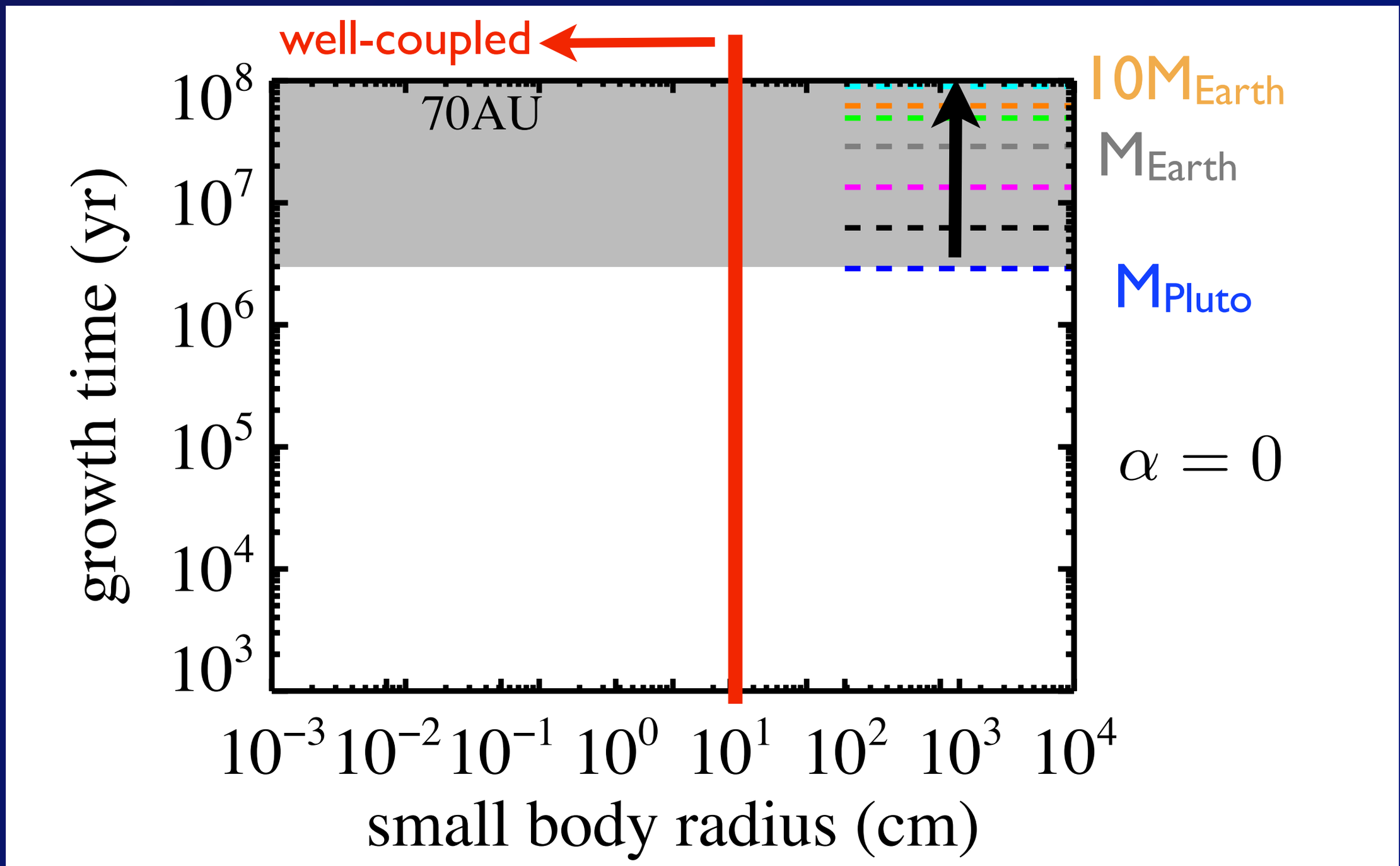


Hydro simulations:
Poster 33.02
Lambrechts & Johansen

$\alpha = 0.01$



Small bodies are accreted quickly, even at wide separations



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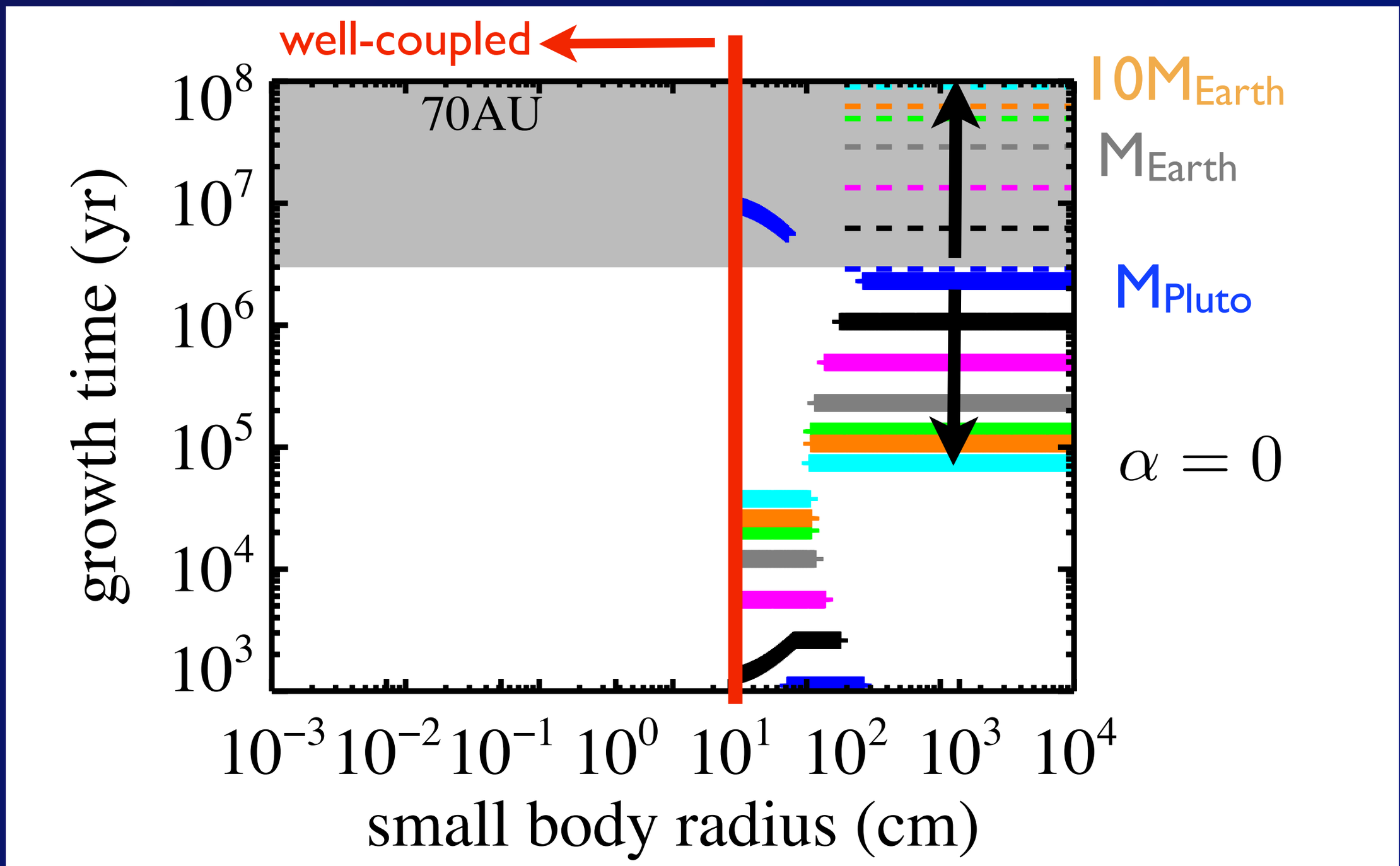

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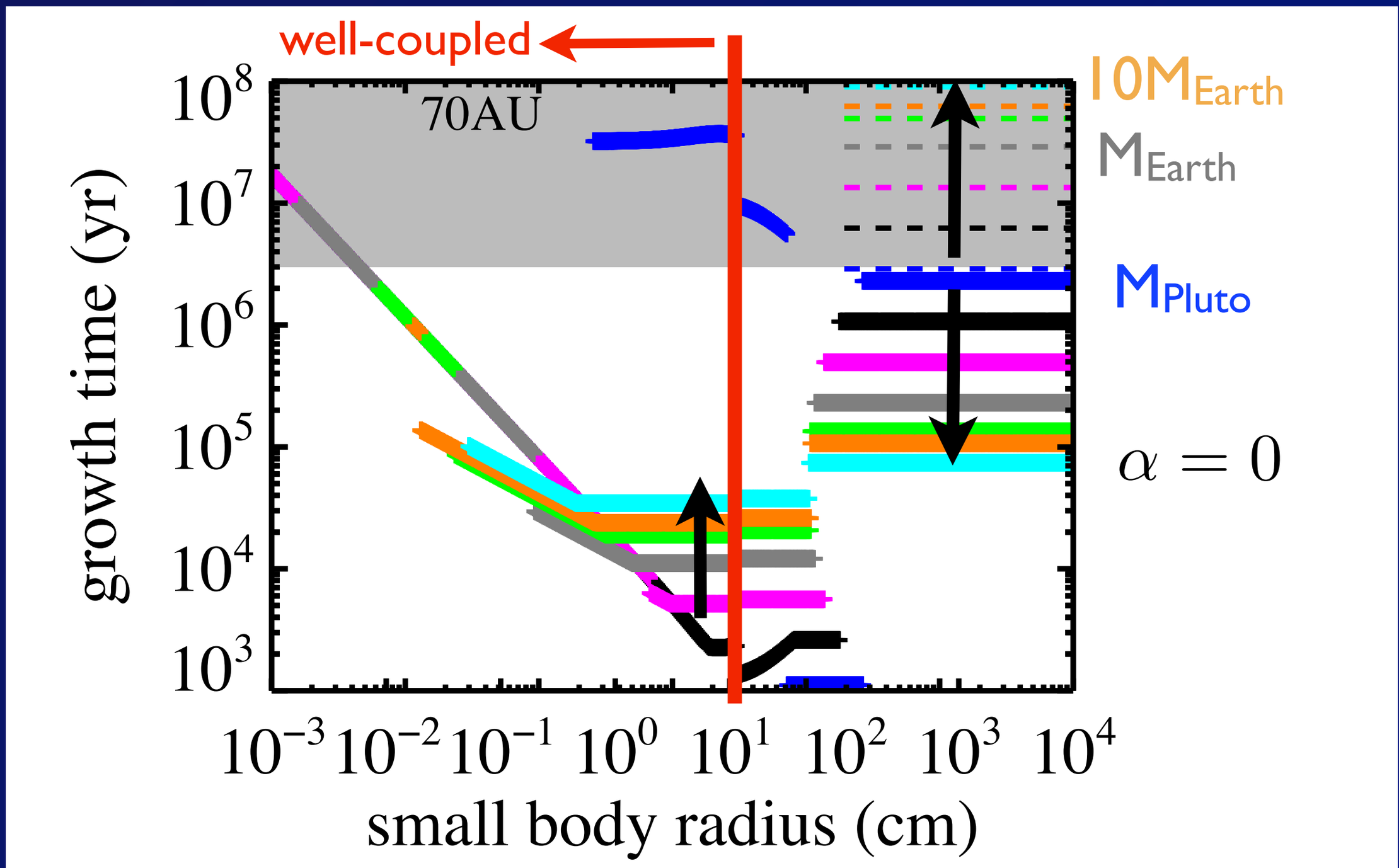

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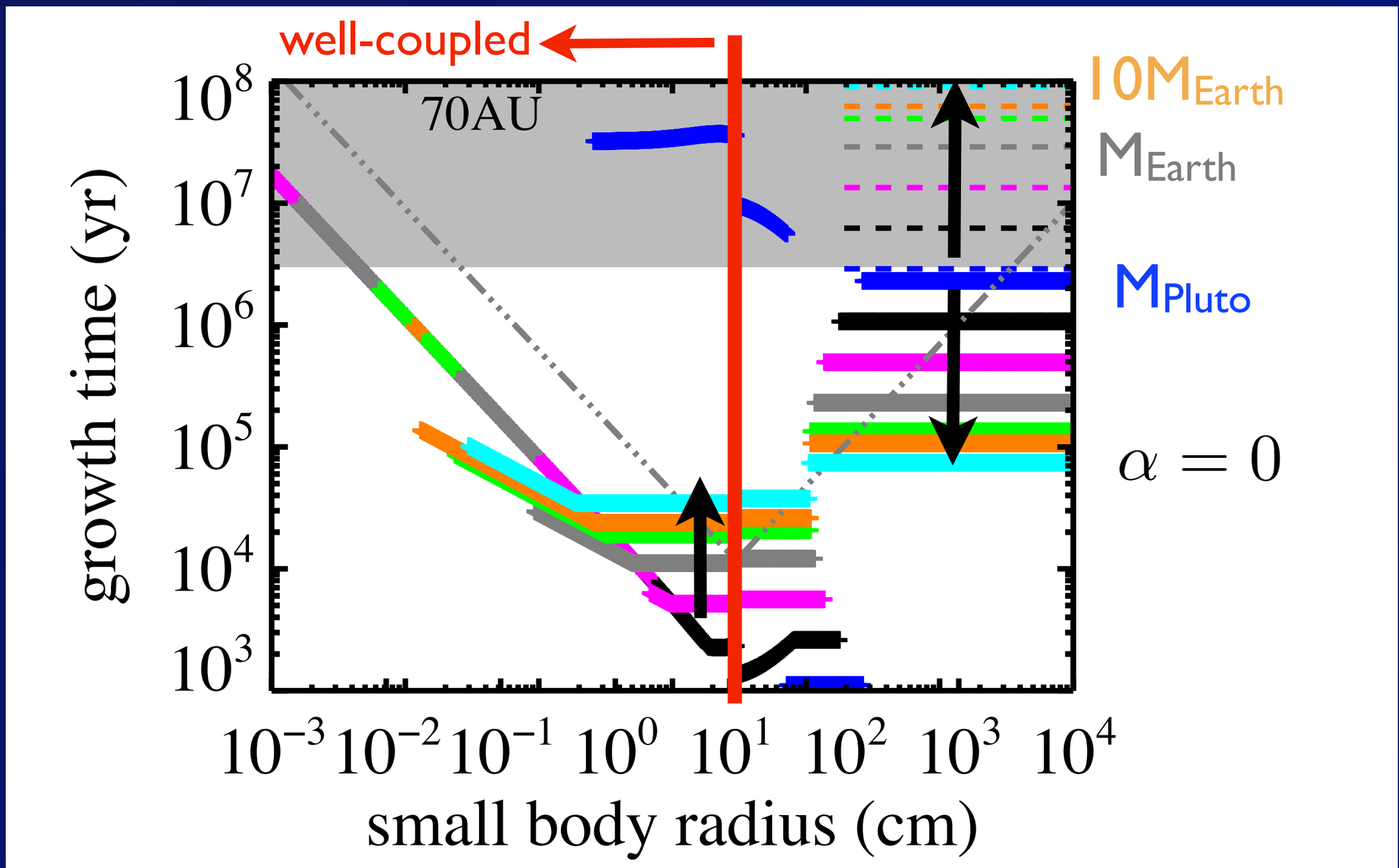

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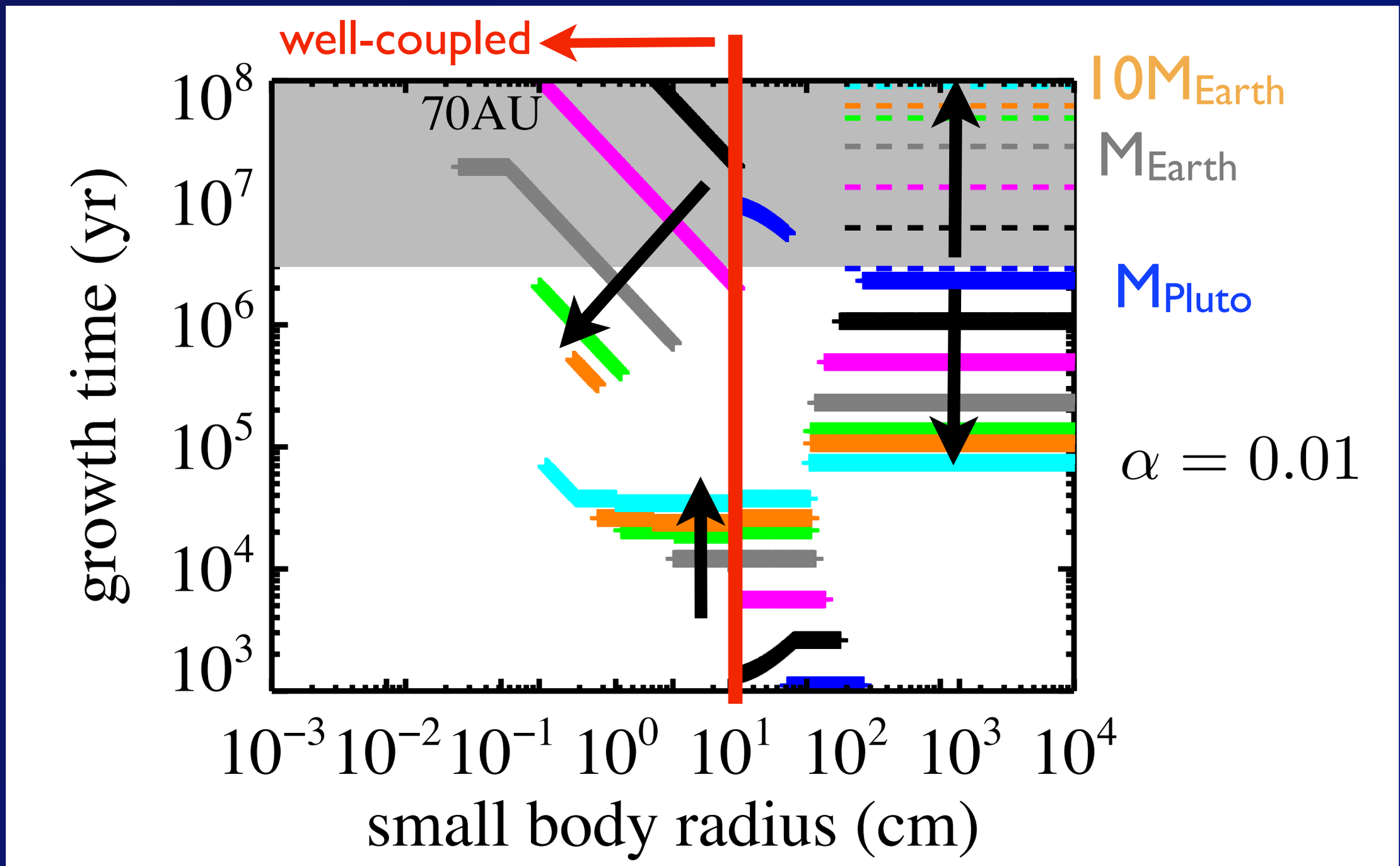
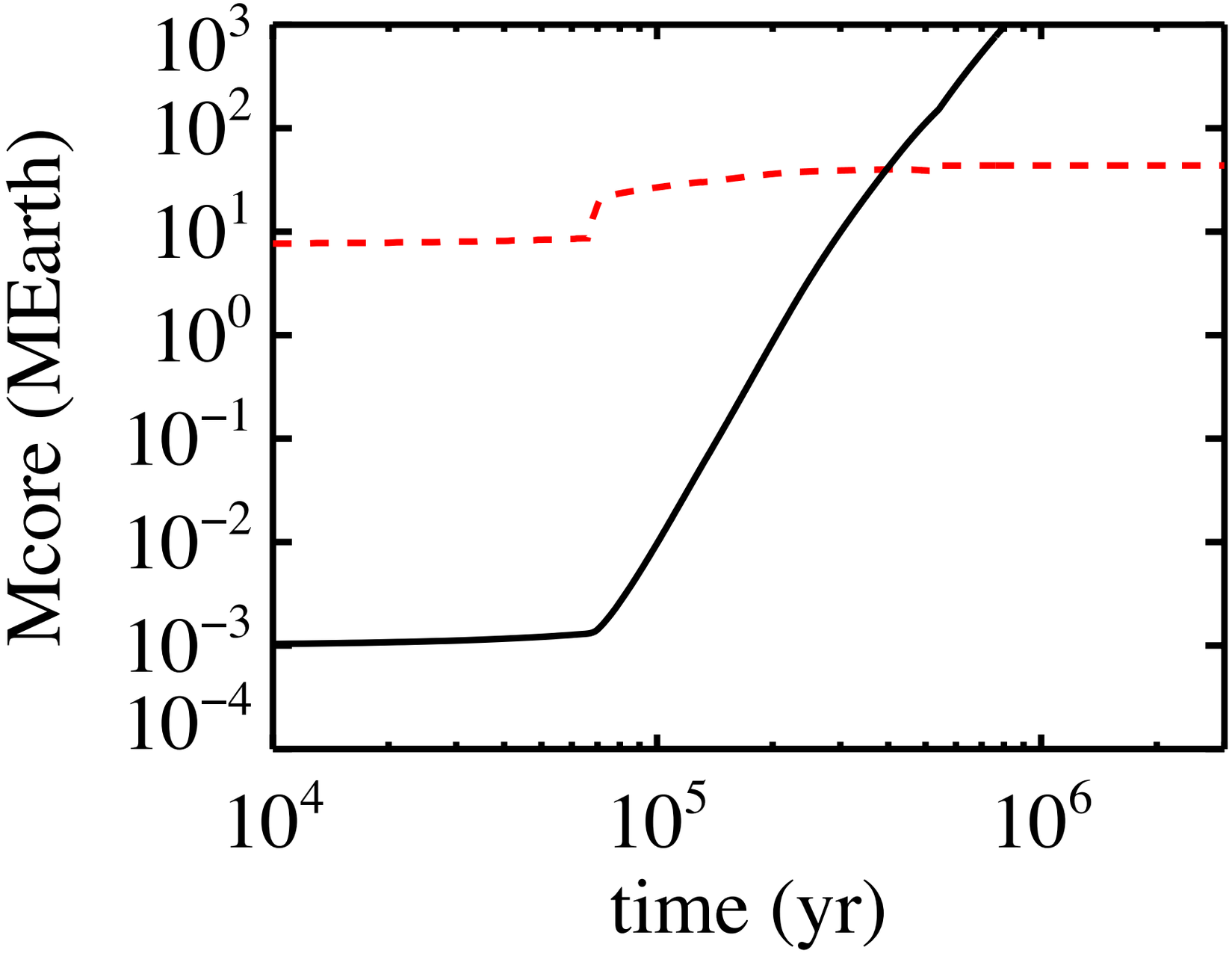


Growth times at 70 AU can be short enough to nucleate an atmosphere



$M_{\rm crit}$ (Rafikov 2006,2010)

$\alpha = 0$

50% of MMSN solids in equal mass per log bin from mm to 10cm

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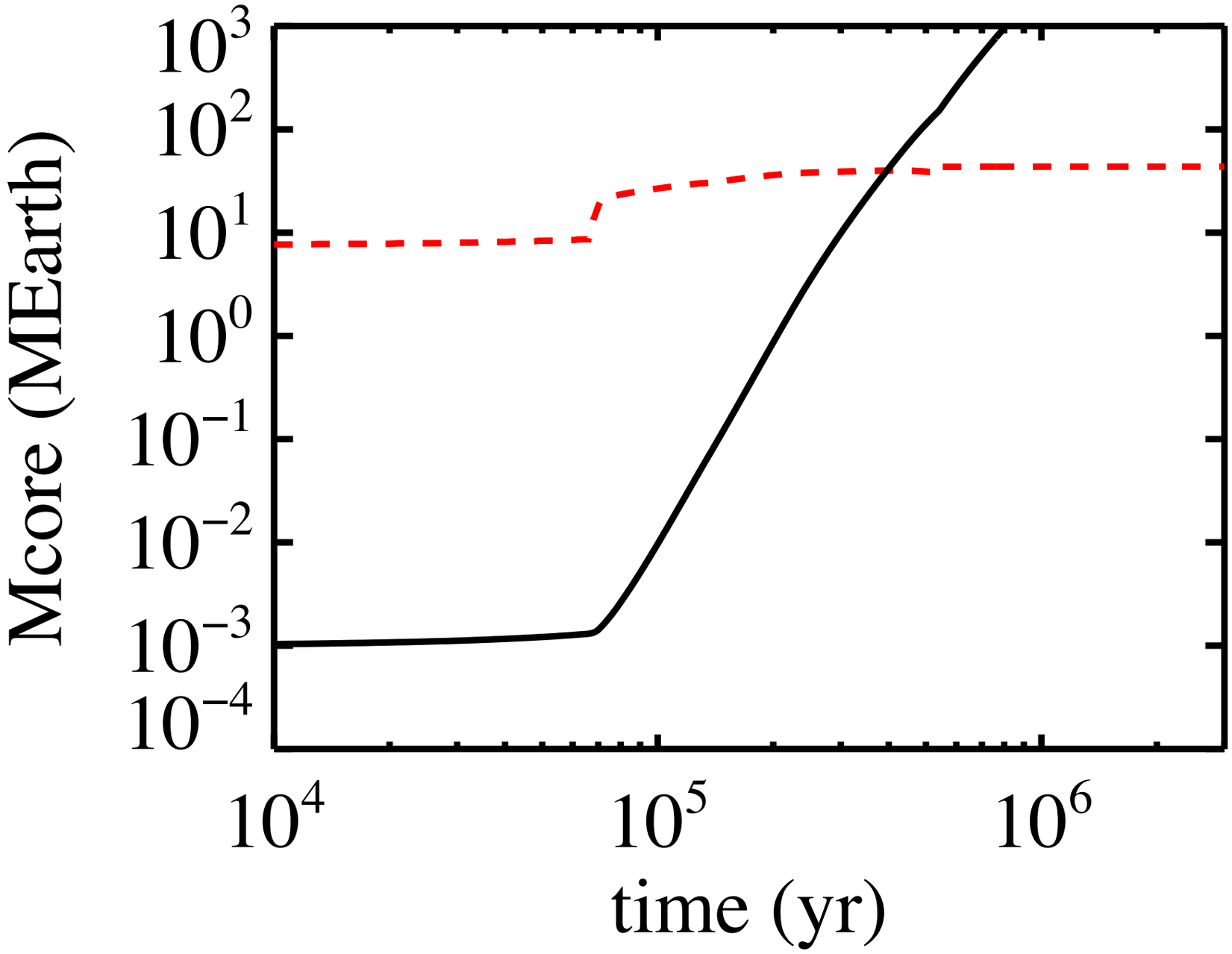

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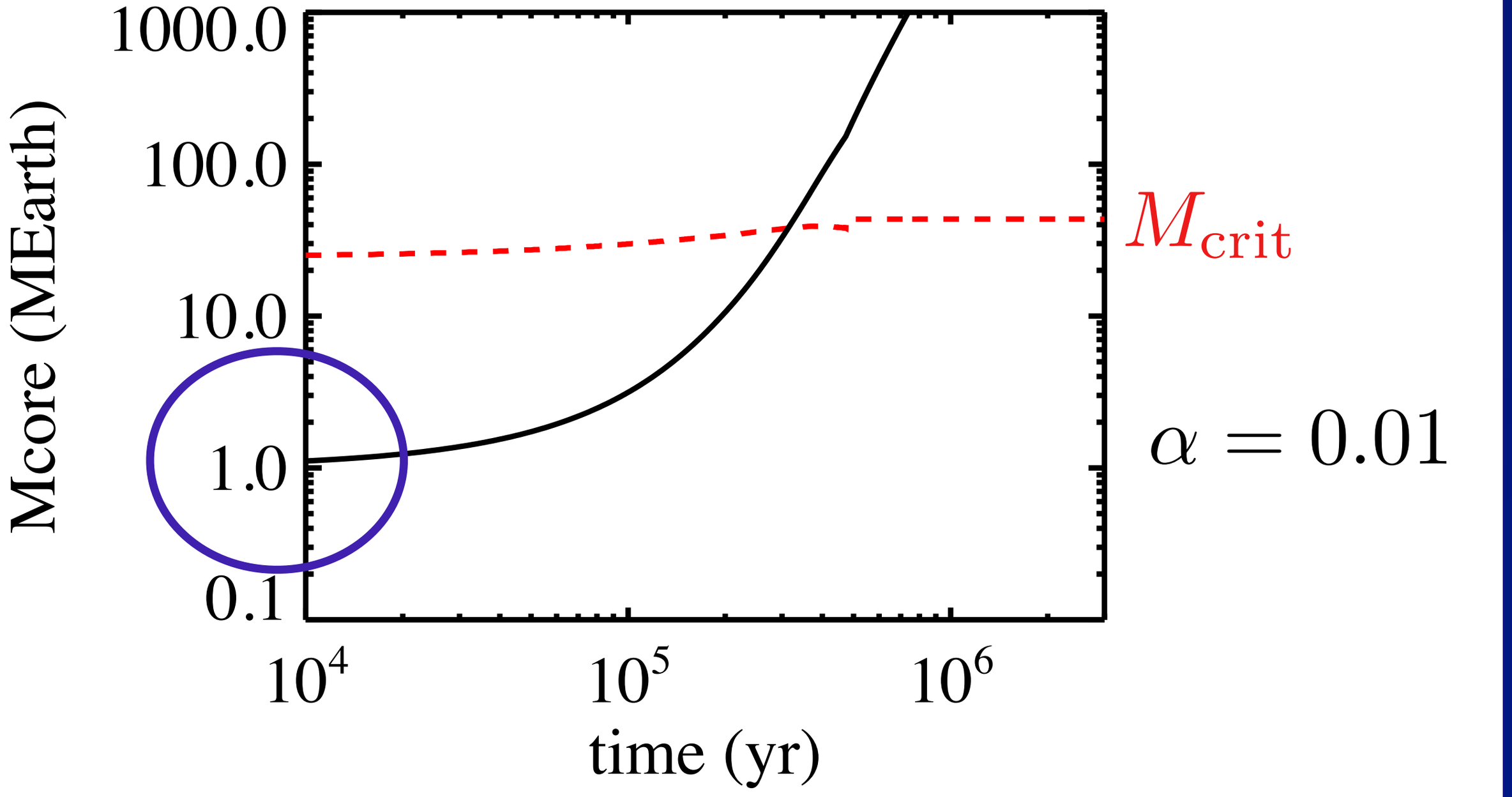

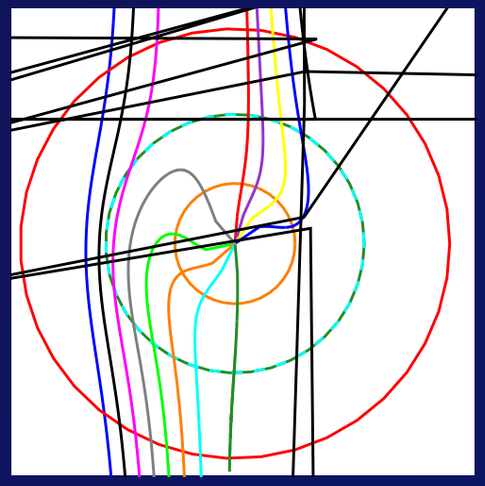

Summary:

Cores can grow quickly in gas, even at wide separations

- Wind shearing (WISH)
- “Binary capture”
- gravitational focusing into the Bondi radius
- decoupling at the planet’s atmosphere