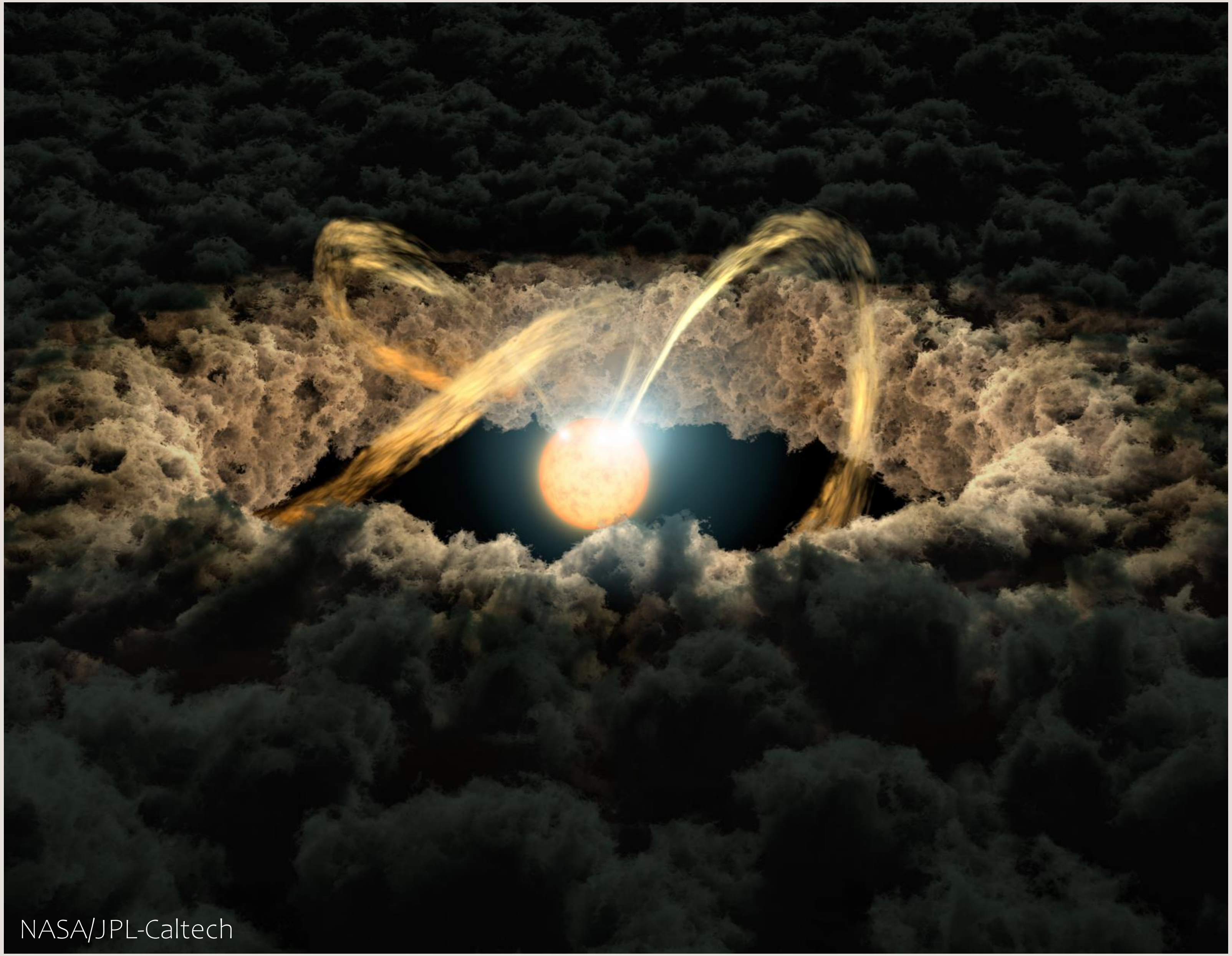
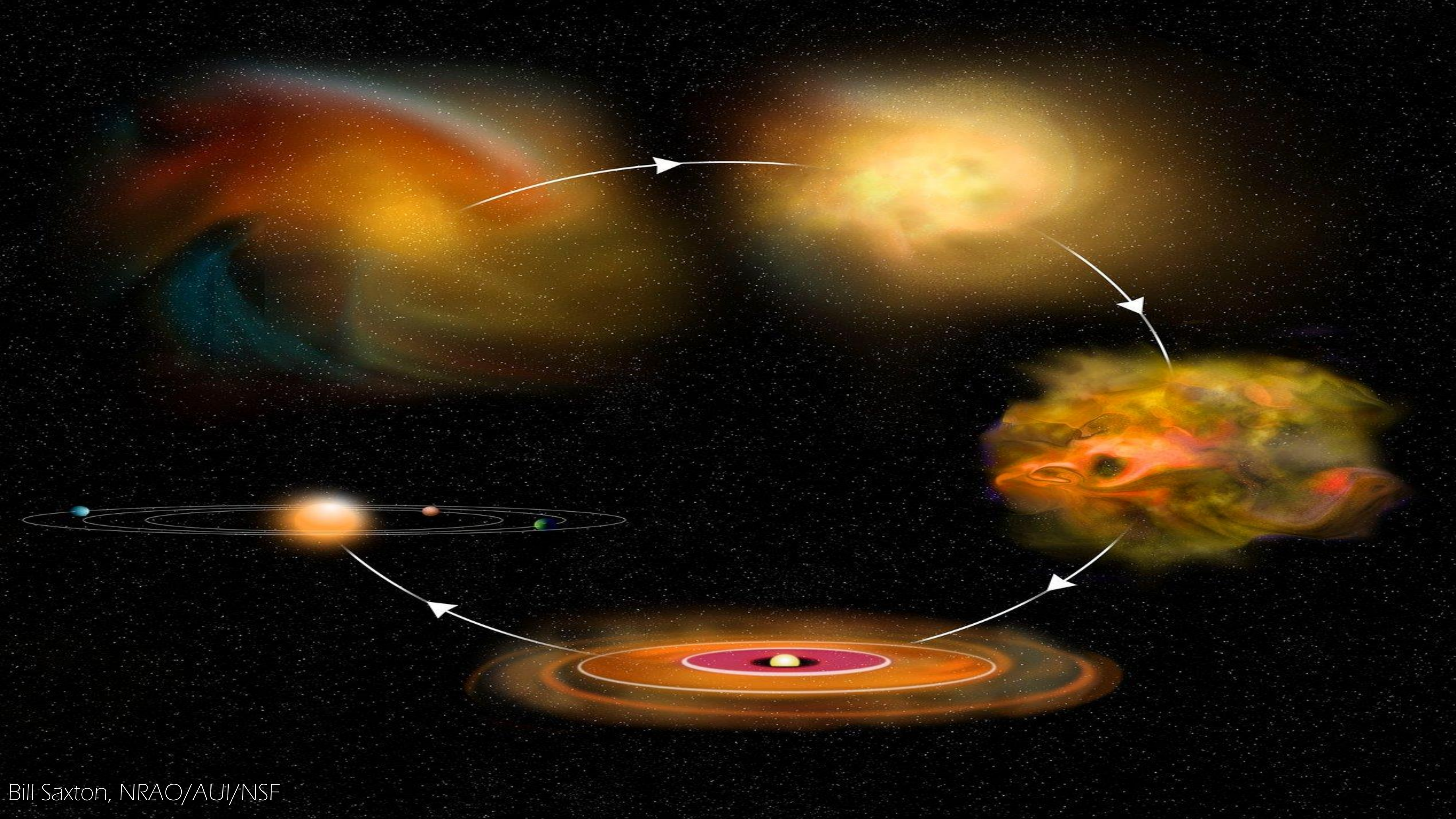


EVAPORATION BEFORE DISRUPTION: COMPARING TIMESCALES FOR JOVIAN PLANETS IN STAR-FORMING REGIONS

Emma C. Daffern-Powell and Richard J. Parker

Presented by Heidi Chávez



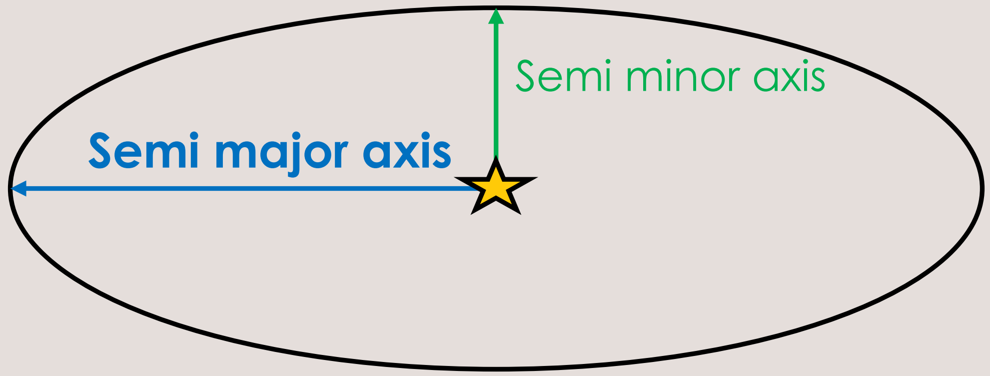
Bill Saxton, NRAO/AUI/NSF

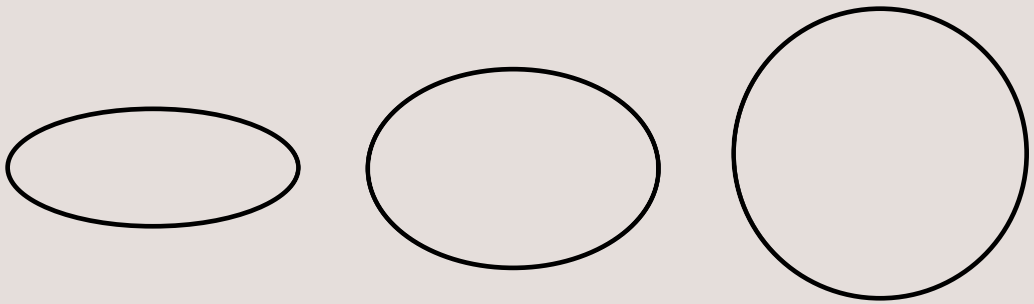
DISRUPTION

Most stars form in groups where the density (other stars, leftover gas and dust) ranges from 10 – 10^3 M_{sol} pc^{-3}

Starting at modest densities (>100M_{sol} pc^{-3}) protoplanet orbits can be disrupted by outside forces

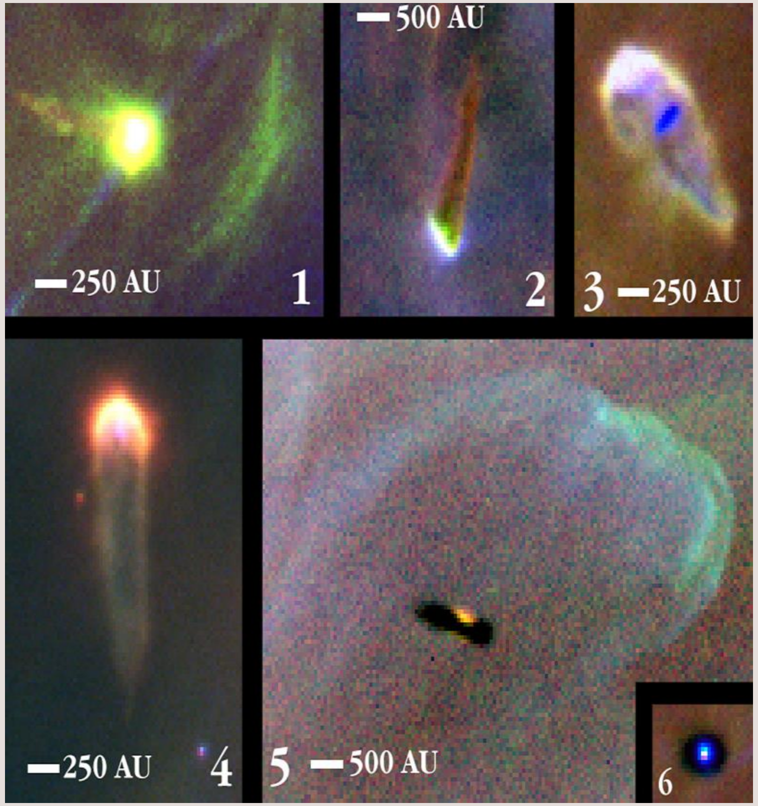
- Free floating
- Altered: still orbits its parent star, but eccentricity (e) has changed by more than 0.1 or semimajor axis (a) changed by more than 10%
- Captured: free floating for at least 0.01 Myr before being (re)captured
- Stolen: directly exchanged between two stars without ever being free floating





e = 0.9 e = 0

EVAPORATION



Photoevaporating planetary disks in Orion Nebula
NASA, C.R. O'Dell and S.K. Wong

Photoevaporation: loss of gas due to ionizing photons

Massive stars (>5 M_{sol}) emit far and extreme ultraviolet radiation that can photoevaporate the gas in a protoplanetary disk.

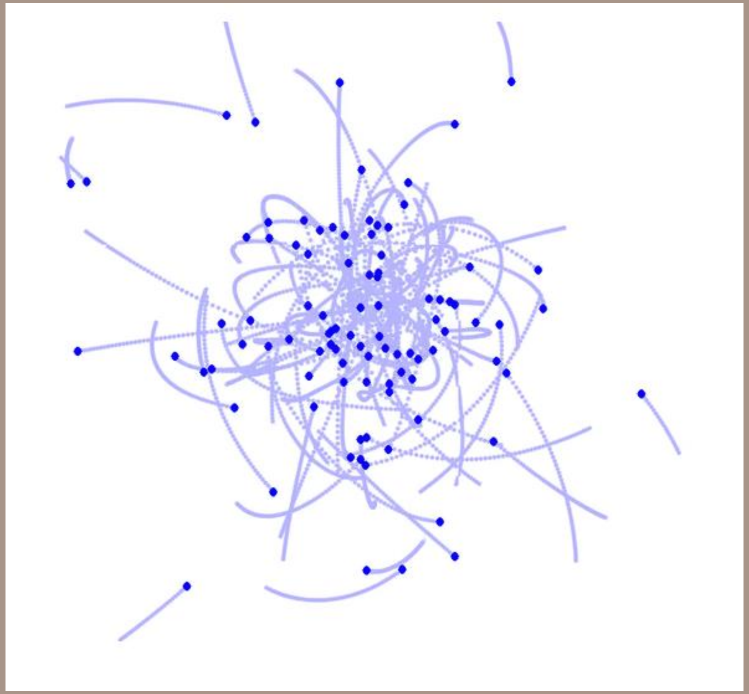
- Far ultraviolet (FUV; ~122-200 nm)
- Extreme ultraviolet (EUV; ~10-121 nm)

Dust in the disk is mostly unaffected by photoevaporation. However, it can greatly impact the amount of material to form gas giants such as Jupiter (which is mostly H and He)

How does timescale for orbital disruption compare with that for photoevaporation?

Run 2 analyses: allow planetary systems to evolve independent of disks, then determine how much evaporation would have taken place during that time

DYNAMICAL DISRUPTIONS



$$\mathbf{a}_i = G \sum_{j \neq i} m_j \frac{\mathbf{r}_j - \mathbf{r}_i}{|\mathbf{r}_j - \mathbf{r}_i|^3}$$

Phillip Mocz

N-body simulations model the interactions of particles (atoms, stars, etc) over time

20 simulations: 10 at a high density (10^4 M_{sol} pc^{-3}) and 10 at moderate density (10^2 M_{sol} pc^{-3})

Constraints:

- N = 1000 ; 20000 stars total
- Stellar mass range 0.1-50 M_{sol} (about 5-20 stars are above 5 M_{sol})
- **½ of stars under 3 M_{sol} are assigned a 1 M_{jup} Jovian planet with semimajor axis = 5 AU and eccentricity = 0**
- No brown dwarfs, no stellar binaries, assume the planets could form quickly

HIGH DENSITY (10^4 M_{SOL} PC^{-3})

Majority of disruption happen within **0.1 Myr.**

4257 out of 10000 planets disrupted **(~43%)**

- 2253 altered
- 171 captured
- 220 stolen
- 1613 free floating

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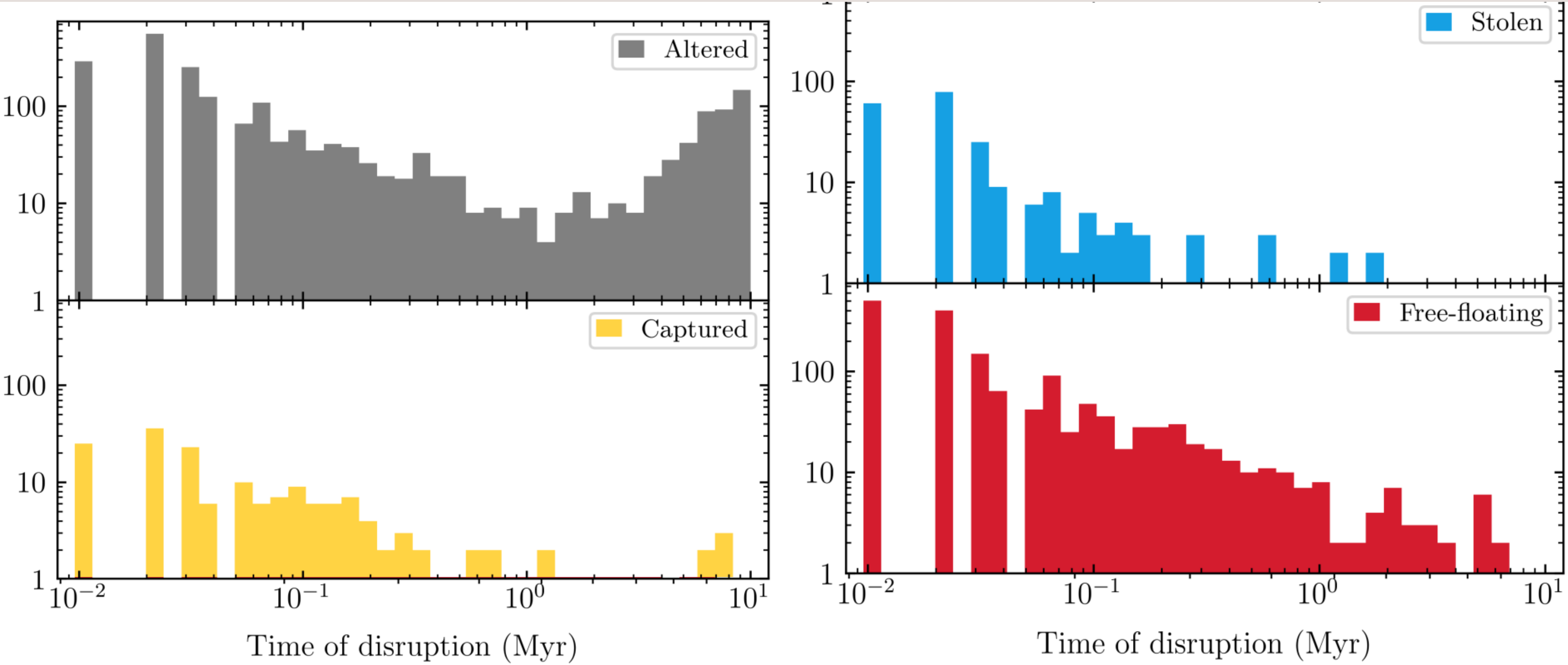
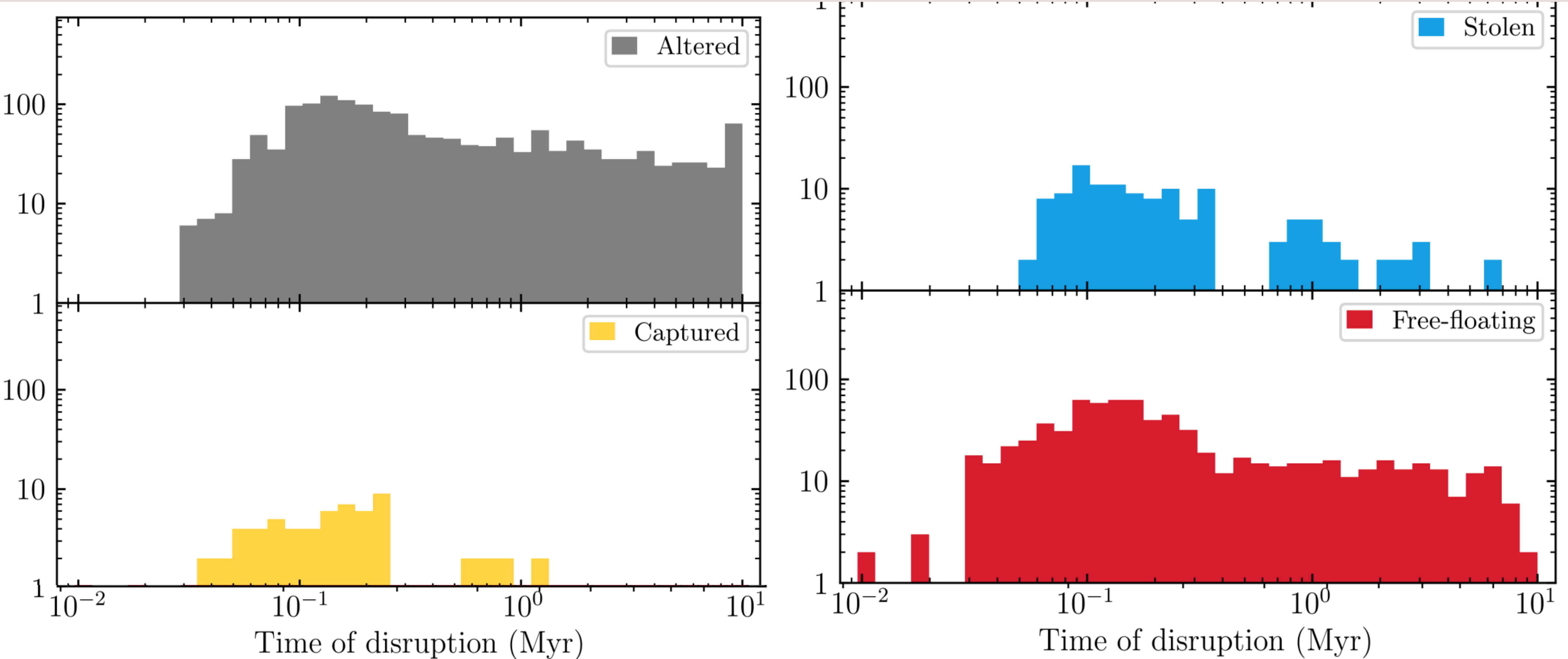


MODERATE DENSITY ($10^2\ M_{SOL}\ PC^{-3}$)

Majority of disruption takes place over a longer time scale (within **1 Myr**)

2515 out of 10000 planets disrupted (~**25%**)

Daffern-Powell / Parker



PHOTOEVAPORATION AND DISK EVOLUTION

Each planet hosting star is given a **disk mass of $0.1M_{star}$ and disk radius of 50AU.**

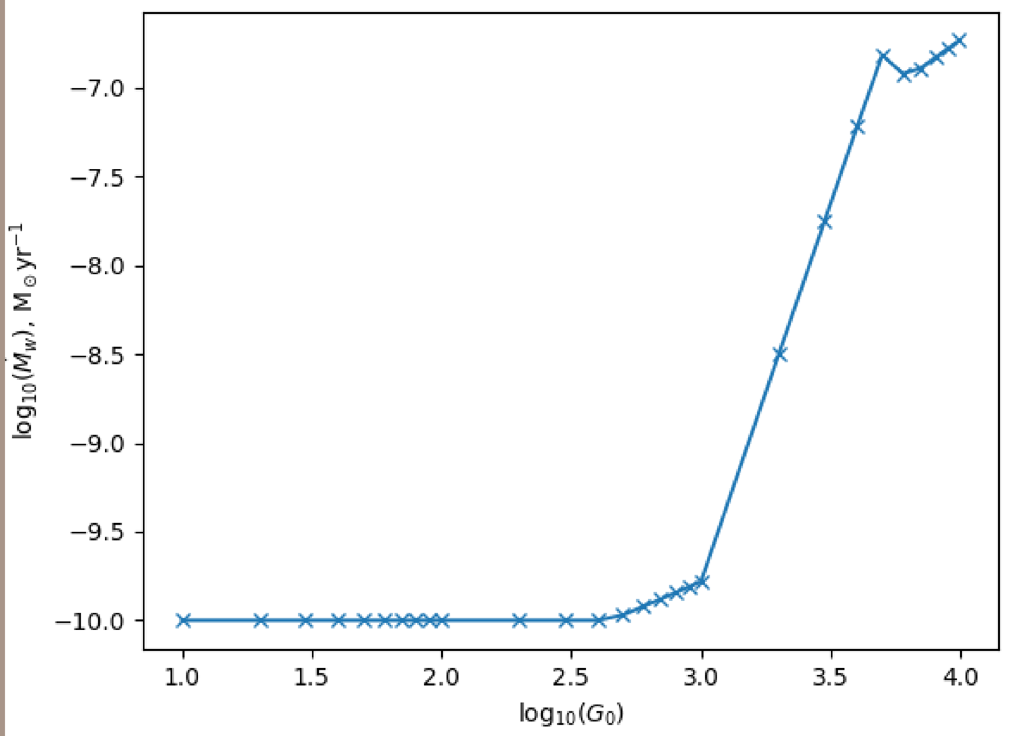
Calculate the FUV and EUV fluxes coming from stars more massive than $5M_{sol}$. Convert mass loss due to radiation through FRIED (Far-ultraviolet Radiation Induced Evaporation of Discs) grid. Sum up mass loss over amount of time it takes for orbit disruption

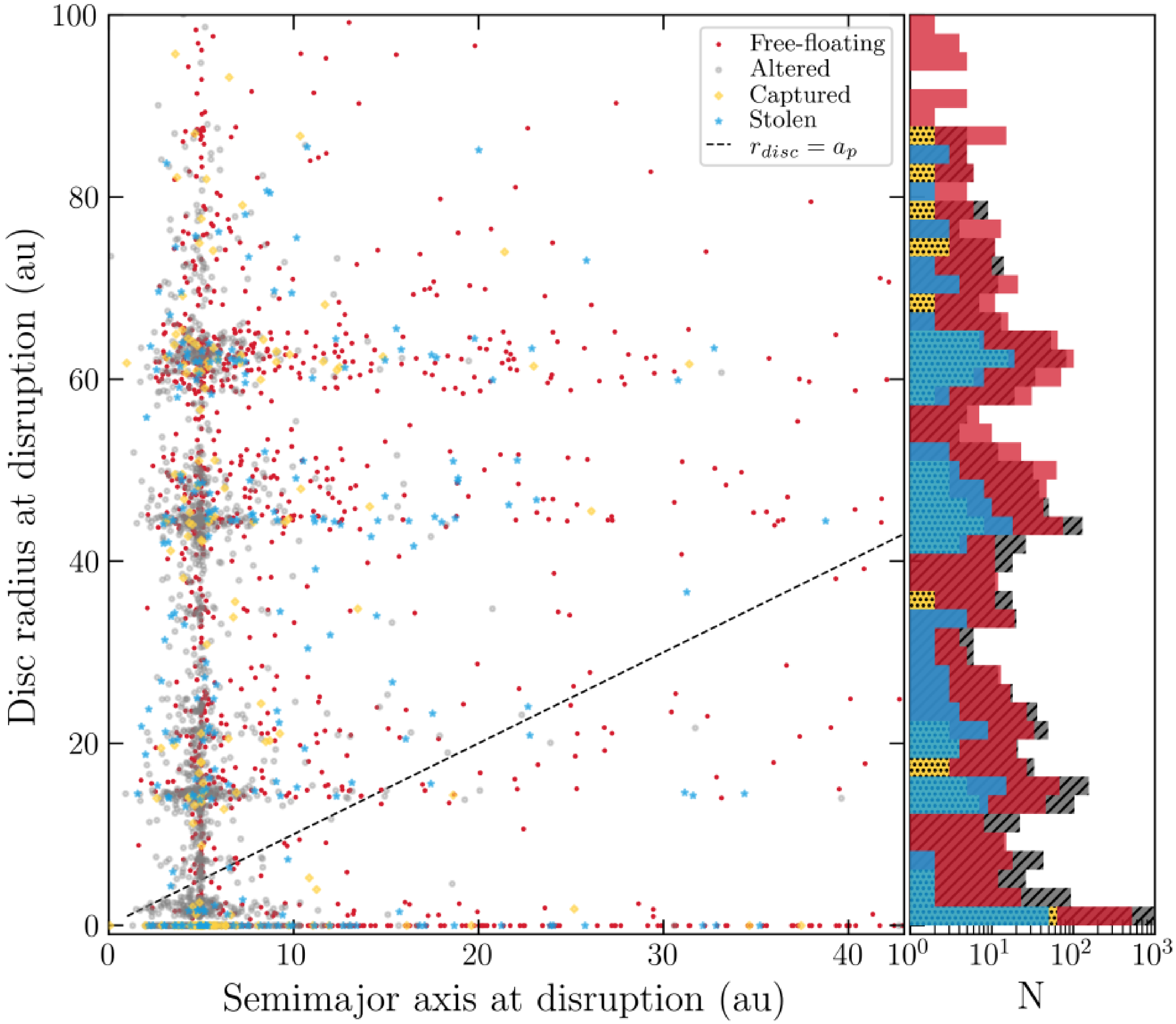
Since dust is mostly unaffected by photoevaporation, *any change in mass is likely to be a loss of gas*. If density of disk remains constant, then loss of mass results in disk radius decreasing

$$F_{\rm FUV} = \frac{L_{\rm FUV}}{4\pi d^2},$$

$$\dot{M}_{\rm EUV} \simeq 8 \times 10^{-12} r_{\rm disc}^{3/2} \sqrt{\frac{\Phi_i}{d^2}}\ {\rm M_\odot\,yr^{-1}}.$$

Daffern-Powell / Parker





HIGH DENSITY (10^4 M_{sol} pc^{-3})

DISC RADIUS VS SEMIMAJOR AXIS

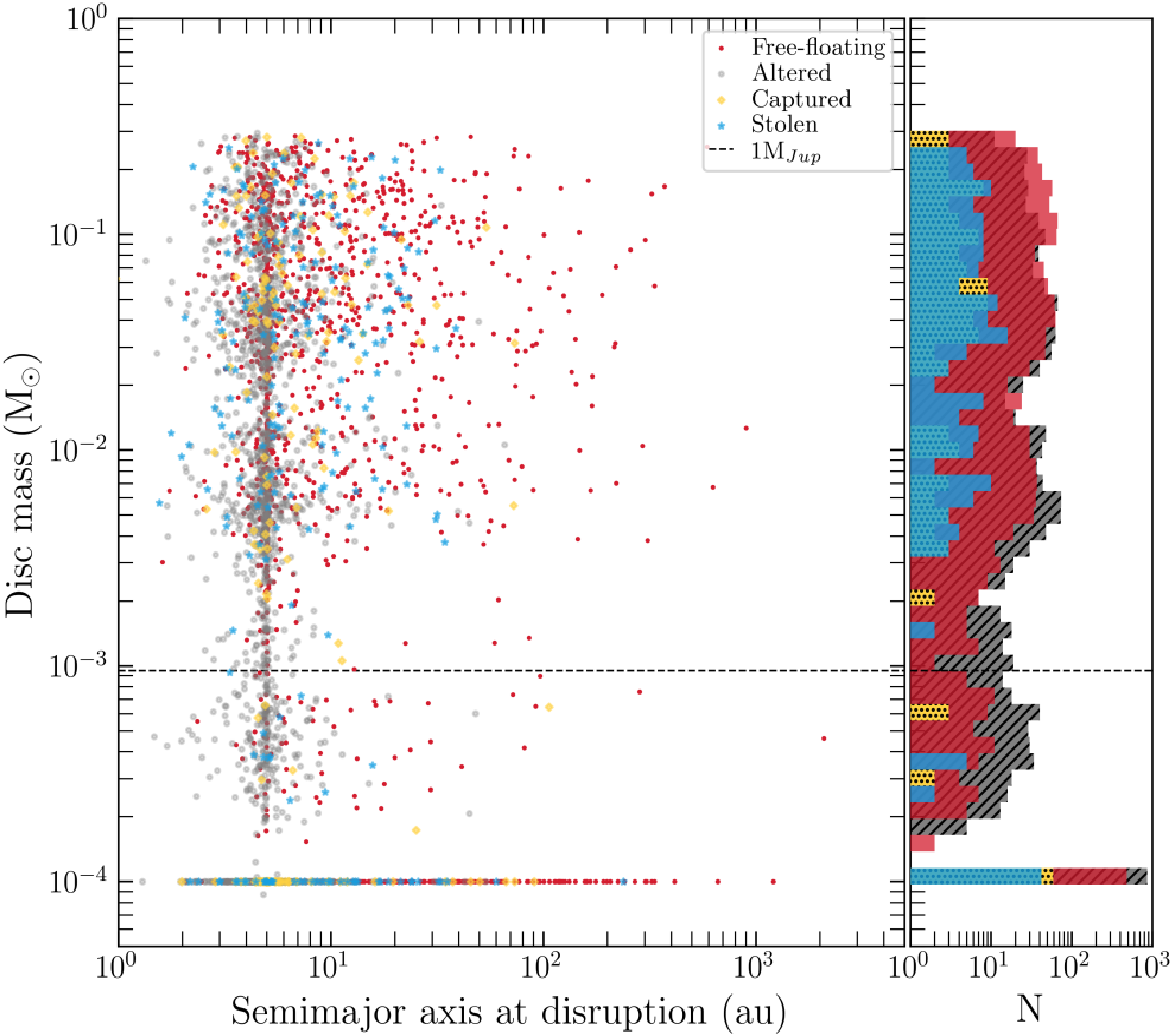
at time of disruption

Of 4257 disrupted planets, 1871 (~44%) have a planetary semimajor axis greater than disk radius at time of disruption

1441 (~34%) have a radius of 0 AU

$a_{planet} > r_{disk}$ means the gas in the disk has already evaporated before the planet experienced a significant disruption

Daffern-Powell / Parker



HIGH DENSITY (10^4 M_{sol} pc^{-3})

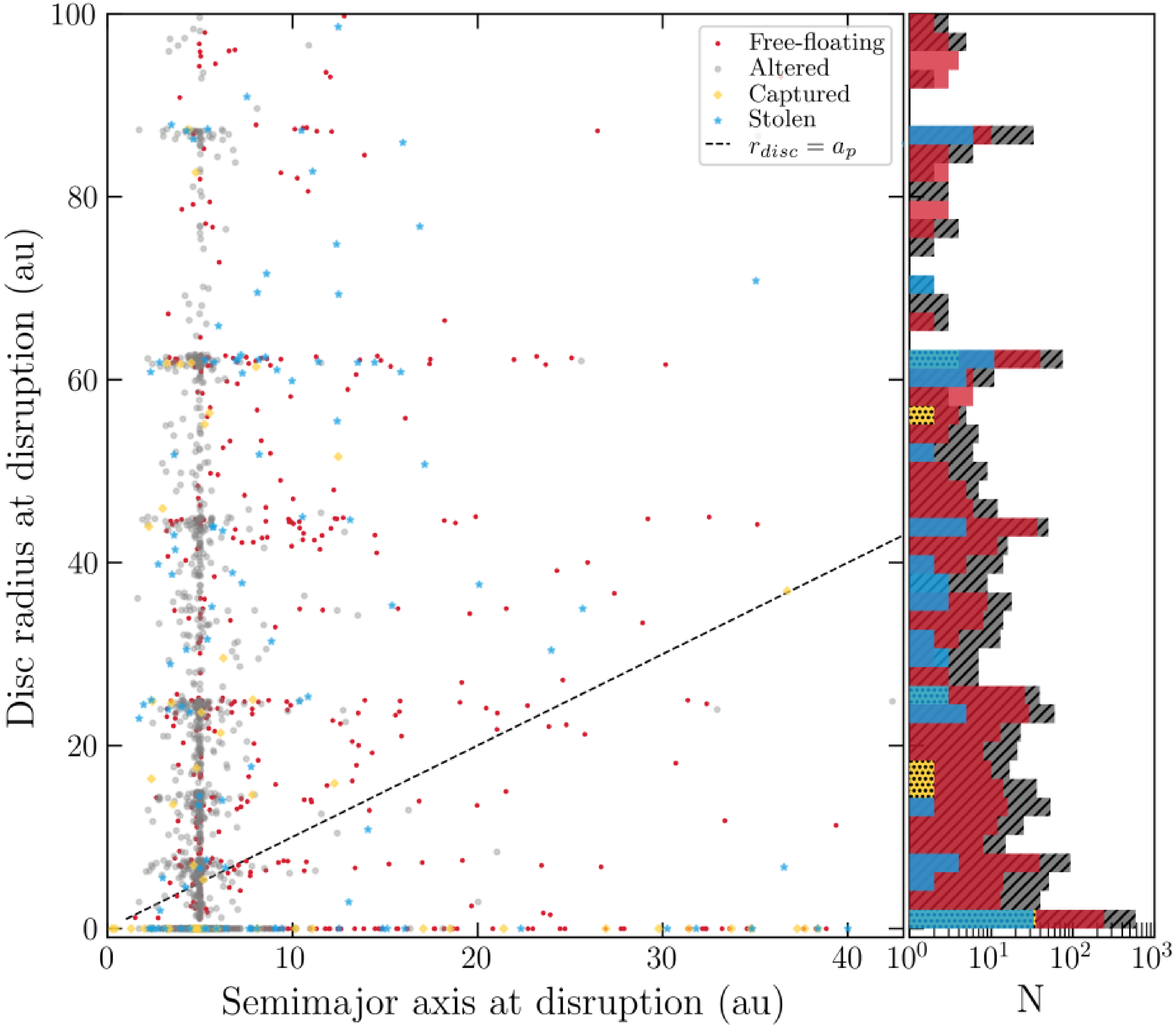
DISK MASS VS SEMIMAJOR AXIS
at time of disruption

More than half of disks lose all gas due to evaporation
(disks with 0 mass are assigned a value of 10^{-4} so they can be shown on logarithmic scale)

Of those that still have a disk, most still have at least $1M_{Jup}$ worth of material (dashed line at 10^{-3})

If disruption happens quickly (within 0.1 Myr) then evaporation happens quickly too—would gas giants even have formed?

Daffern-Powell / Parker



MODERATE DENSITY

(10^2 M_{SOL} PC^{-3})

DISK RADIUS VS PLANET SEMI MAJOR AXIS

at time of disruption

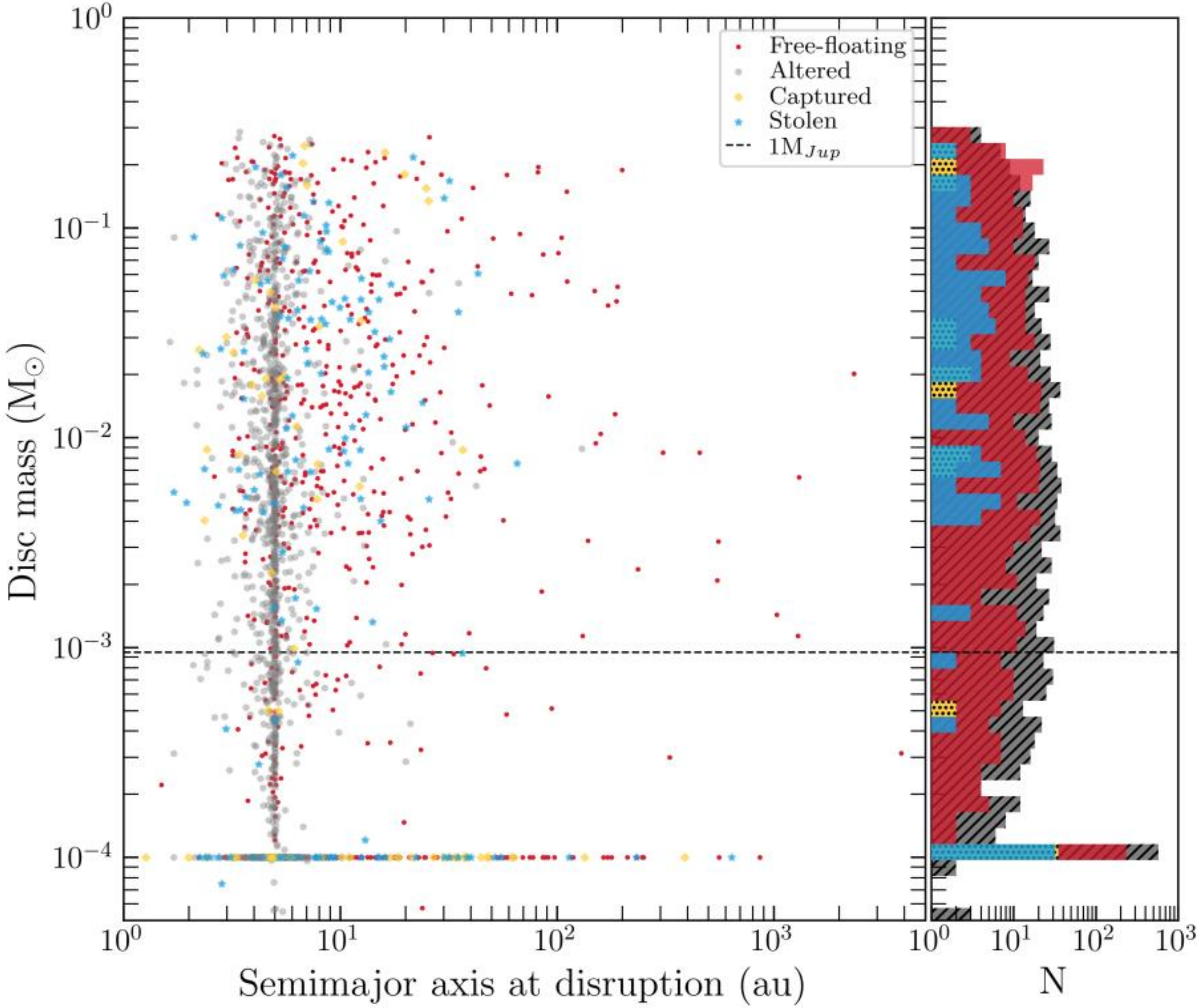
Of 2515 disrupted planets, 1043 (~41%) have a semimajor axis greater than radius at time of disruption

> similar to 44% of planets in high density conditions

883 (~35%) have a radius of 0

> similar to 34% of planets in the high density conditions

Daffern-Powell / Parker



MODERATE DENSITY

(10^2 M_{SOL} PC^{-3})

DISK MASS VS SEMIMAJOR AXIS
at time of disruption

"*Whilst there are fewer disruptive events in these lower density simulations, and fewer discs affected by photoevaporation, photoevaporation still dominates over disruption and occurs at even lower stellar densities than the regimes we model here*"

– the authors

Daffern-Powell / Parker

CONCLUSIONS

Evaporation before disruption!

- For more than half of systems with a Jovian planet, external radiation had already destroyed all the gas in the planetary disk by the time the planet's orbit was disrupted

- Higher stellar mass densities can hasten both disruption and evaporation, and increase amount of disruption but not proportion of evaporation

- 44% of the disrupted planetary systems had disk radii smaller than planet semimajor axis, or lost all gas in disk, before the planets' orbits are disrupted
  - This implies that the planets that do get disrupted in dense star forming regions are probably super Earths or mini Neptunes, since there wouldn't have been enough gas to form a Jupiter sized planet in the first place