The Dynamical Birth Environment of Planets and Brown Dwarfs

Disc perturbations and accidental accretion

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with kind support
by DFG SPP 1385

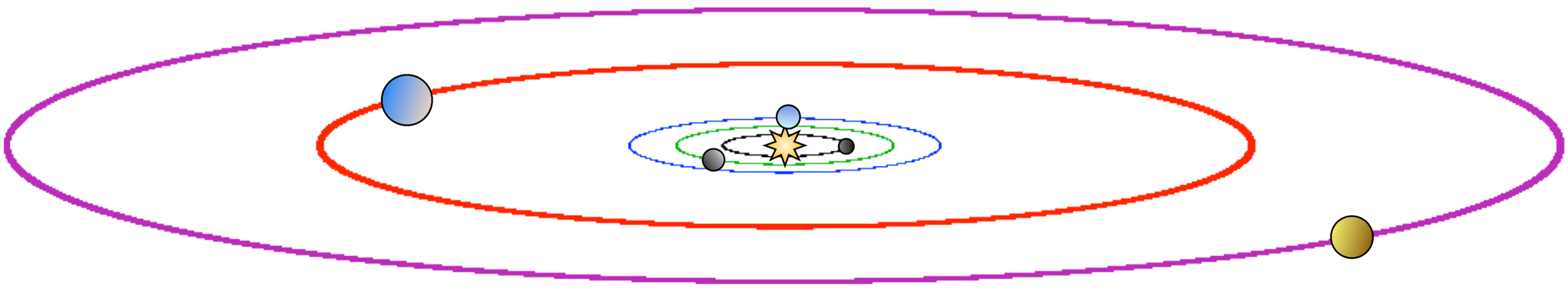
Planet Formation and Evolution 2012-09-04 München

Motivation: Theory

Standard paradigm assumes formation of planetary systems in isolation:

- No influence from other stars (gravity, radiation, stellar winds etc.),
- No (significant) mixing with external material,
- No angular momentum exchange.

But...



...is this really true?

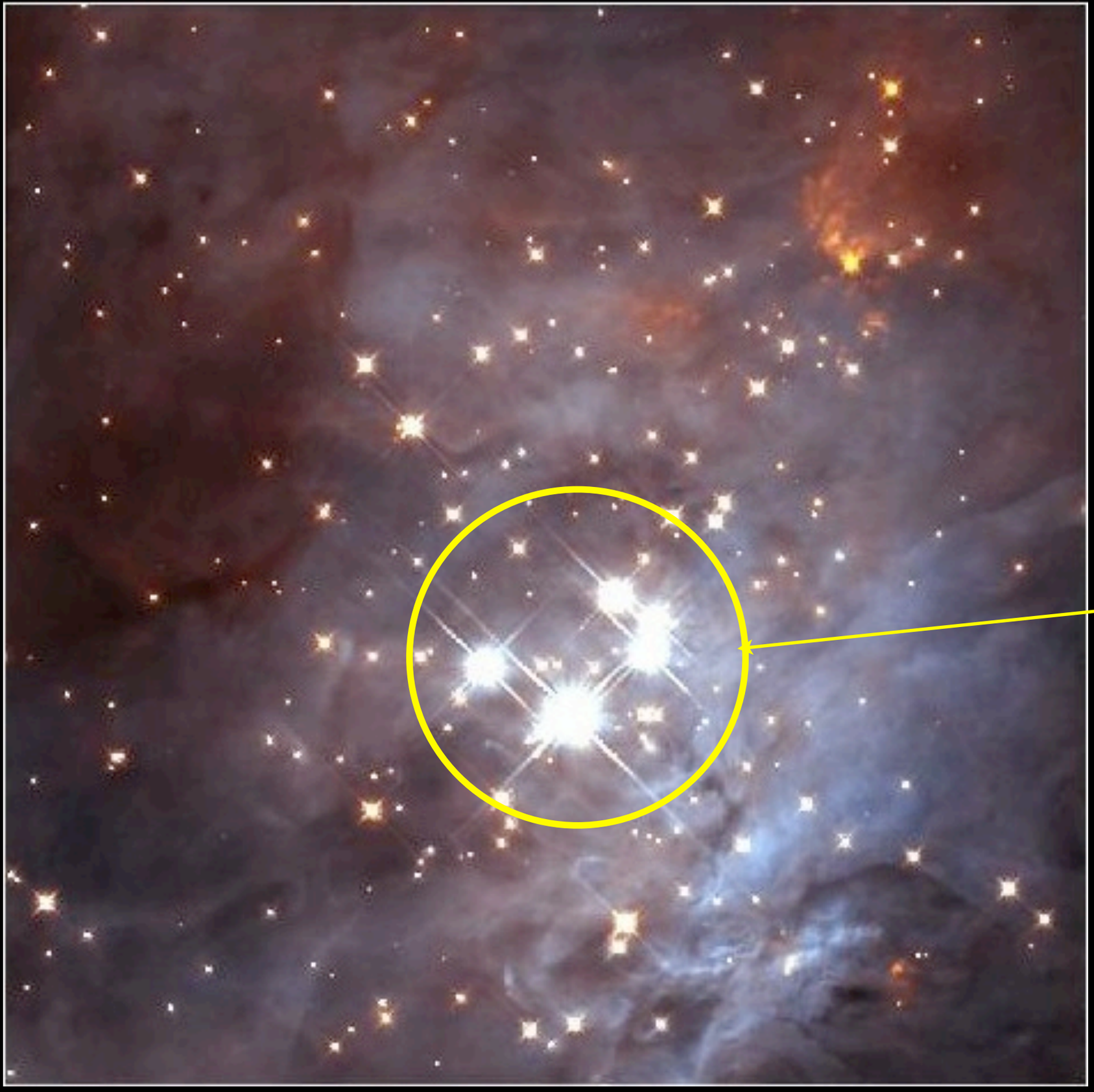
Motivation: Reality

- About 1/4 of all known transiting planets (WASP 2b, 15b, 17b, HAT-P-7b and others) are strongly misaligned wrt. the stellar equatorial plane,
- Truncation and scattered appearance of the Edgeworth-Kuiper Belt
- Substellar population requires pre-processed material to form

⇒ Evidence for mutual perturbations in stellar cradles?

Moreover:

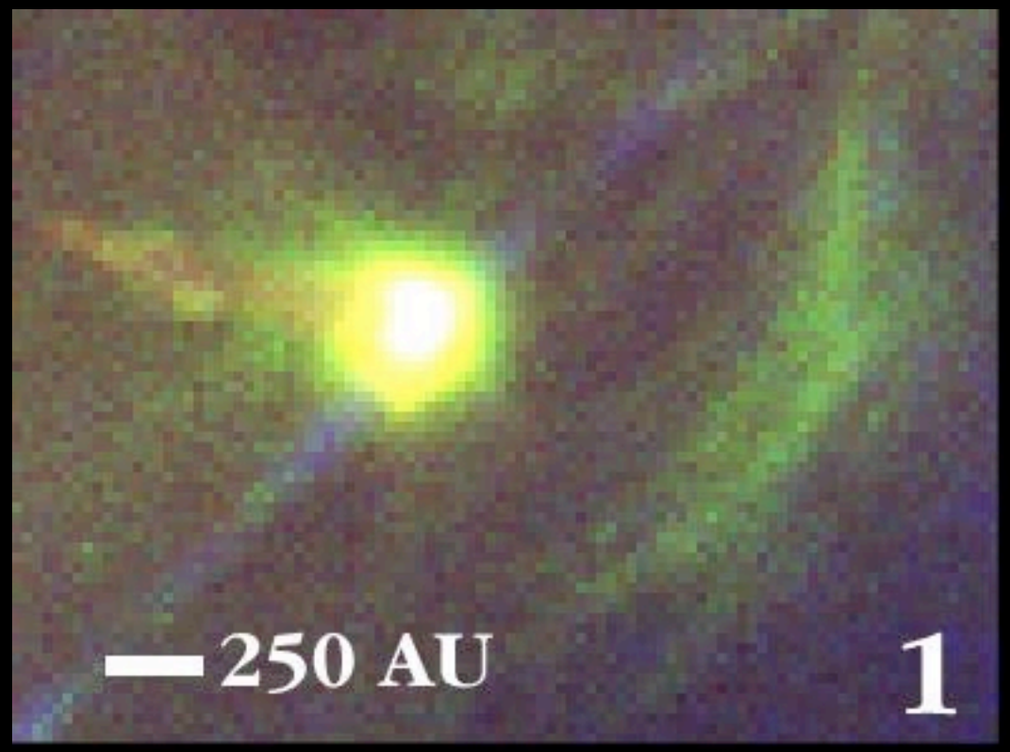
- Stars typically form in dense stellar environments (Marks & Kroupa 2011)
- ⇒ Planet formation not isolated (cf. Pfalzner et al. 2008+)

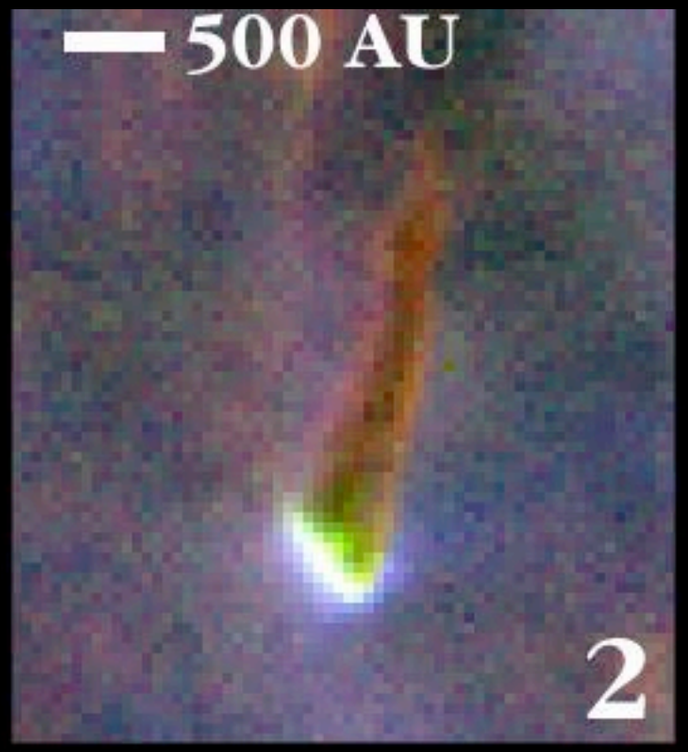


10000 stars / pc^3
(Circle = 0.1 pc diam.)

Trapezium Cluster • Orion Nebula

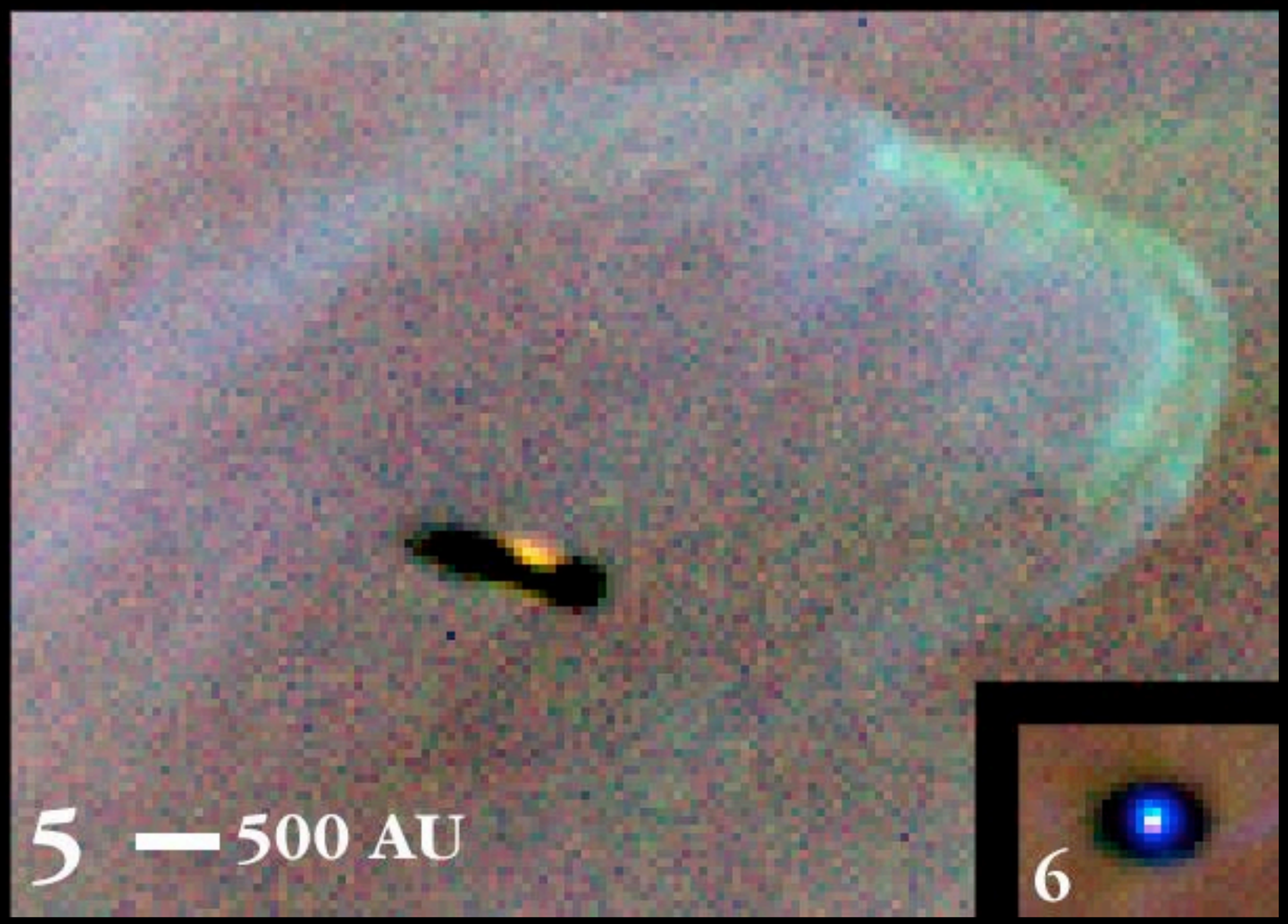
WFPC2 • **Hubble Space Telescope** • NICMOS


250 AU
1

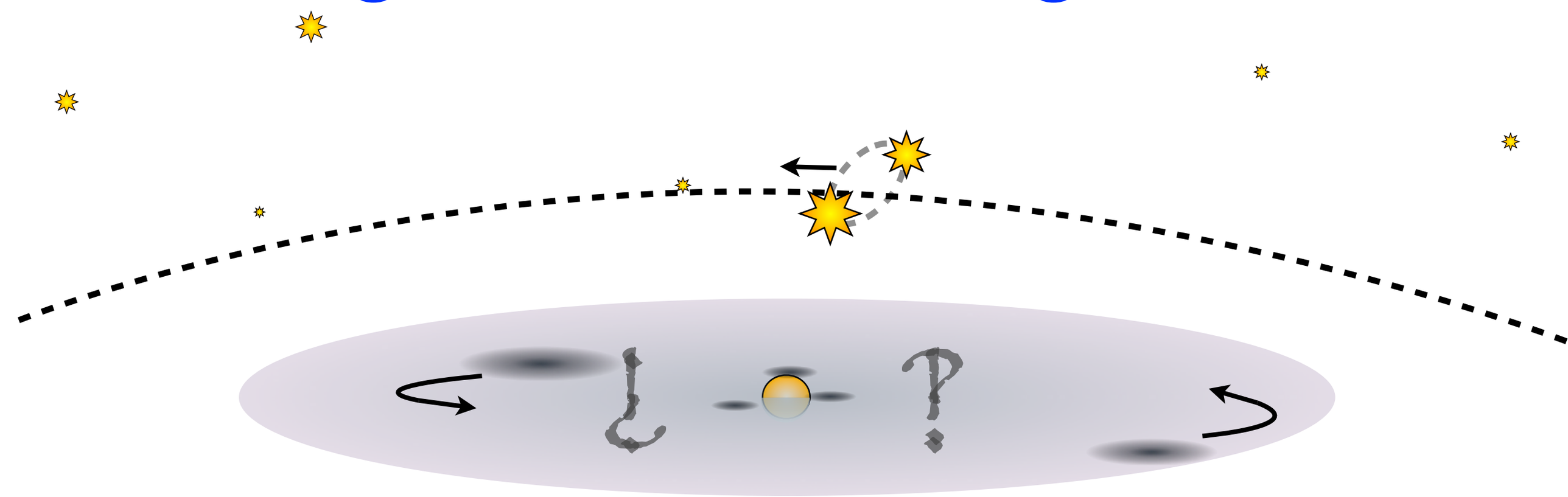

500 AU
2


3
250 AU


250 AU
4


5
500 AU
6

Fragmentation of large discs



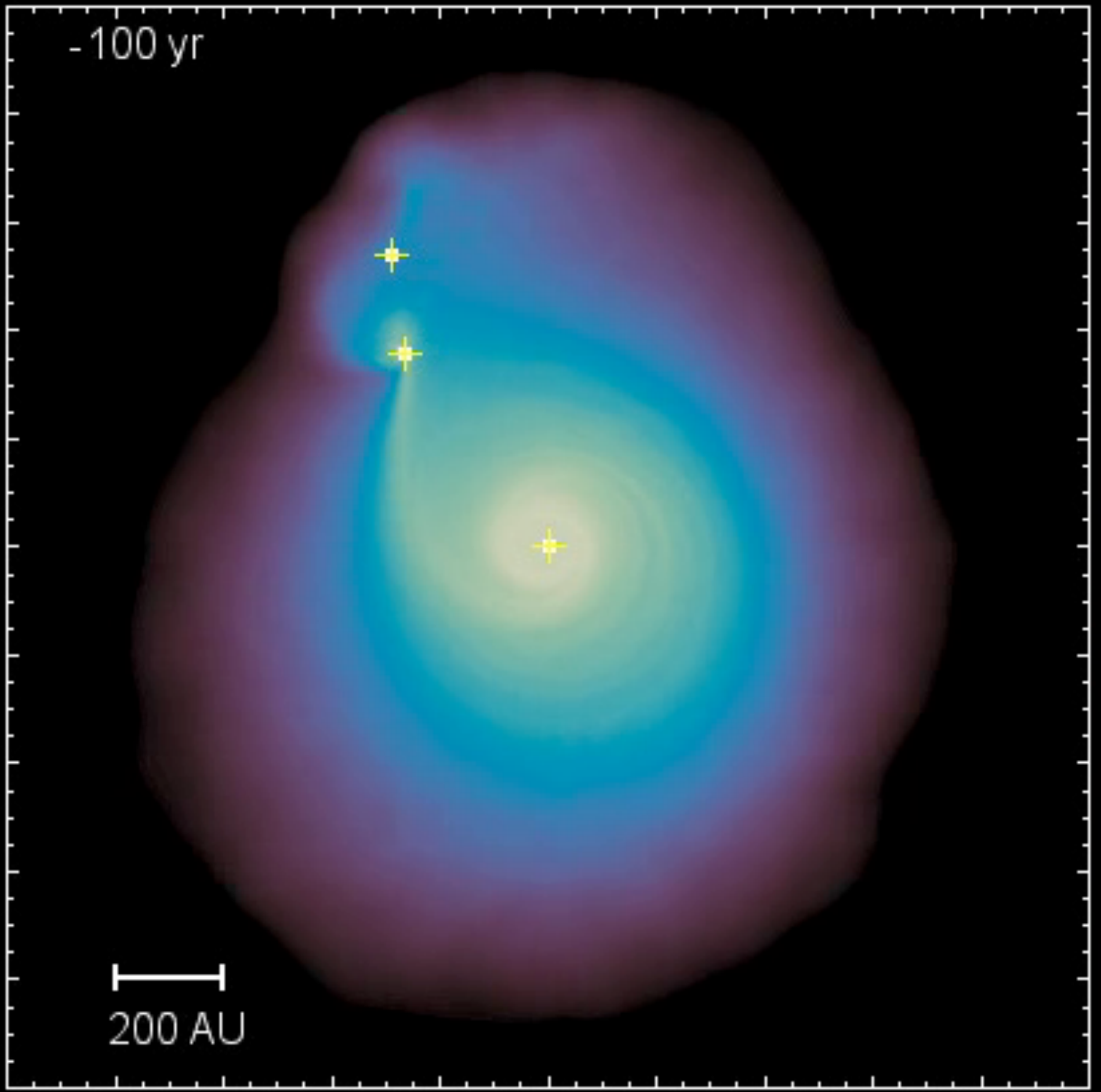
Dense stellar environments:

⇒ perturbations by passing (binary) stars possible!

Disc fragmentation (~~inhibited~~, induced...)?

The Scenario

- System = 0.7 M_{sun} + 0.5 M_{sun} accretion disc
- Perturber mass = 0.5 M_{sun} (binary 0.3+0.2 M_{sun})
- 250,000 SPH particles


-100 yr
200 AU
3
2
1
0
-1
-2
log10 (Σ / g cm-2)

4020 yr

200 AU

3

2

1

0

-1

-2

$\log_{10}(\Sigma$ / g cm^{-2})

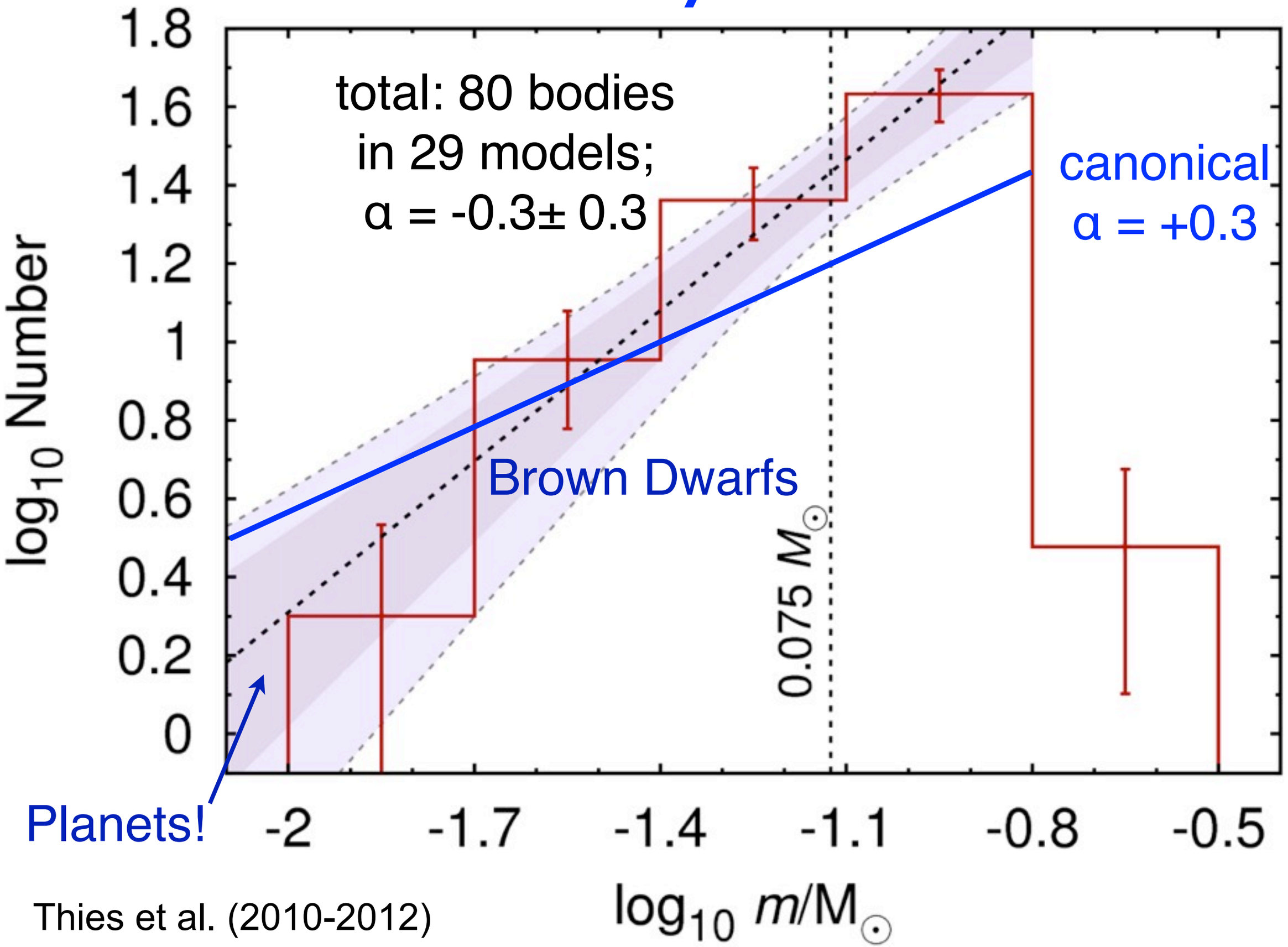
The Scenario

- System = 0.7 M_{sun} + 0.5 M_{sun} accretion disc
- Perturber mass = 0.5 M_{sun} (binary 0.3+0.2 M_{sun})
- 250,000 SPH particles

Results

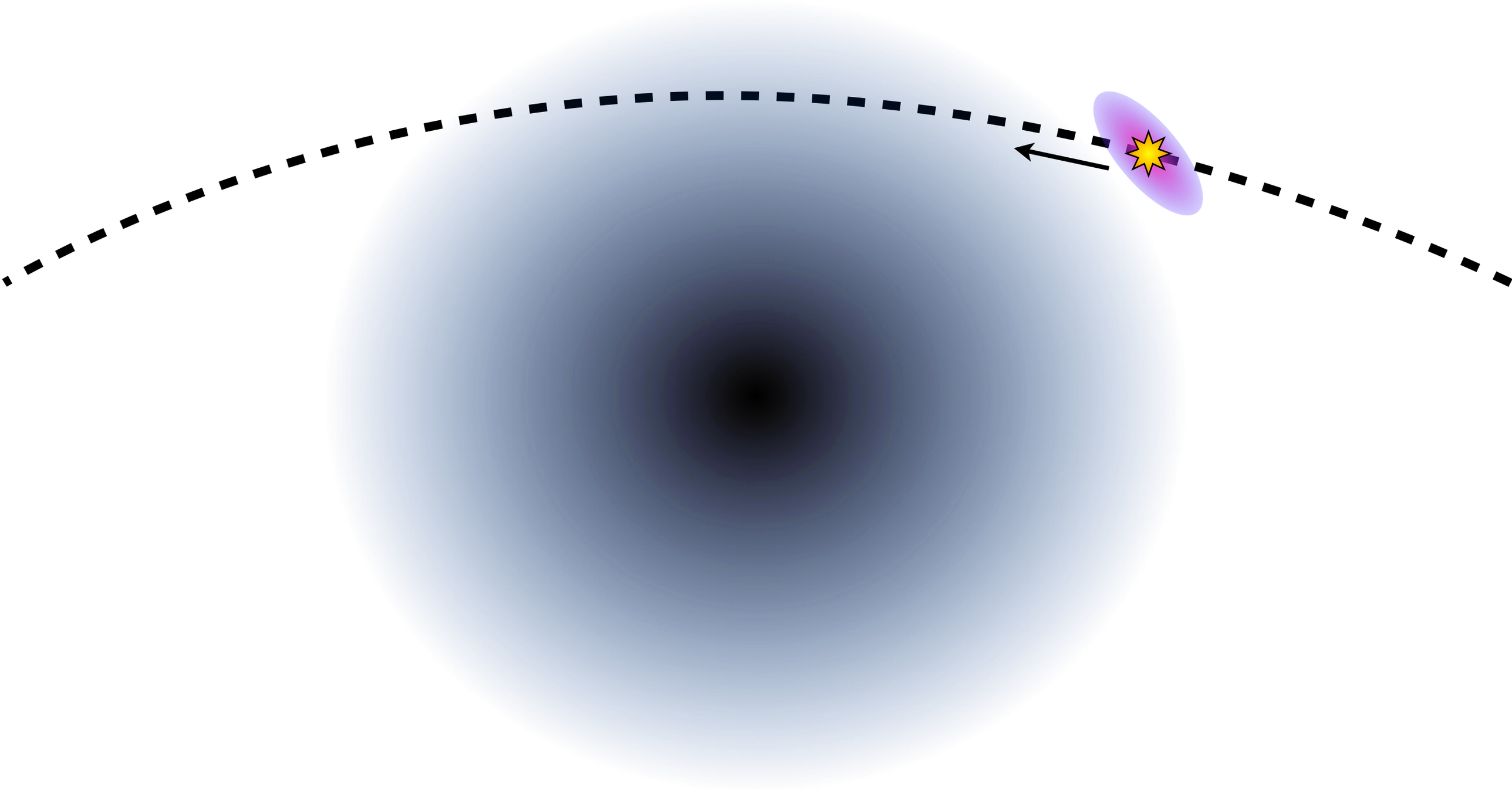
- Induced fragmentation leads to formation of substellar companions
- Wide binaries may get disrupted
- Encountering stars may undergo repeated accretion

Created-body IMF from all



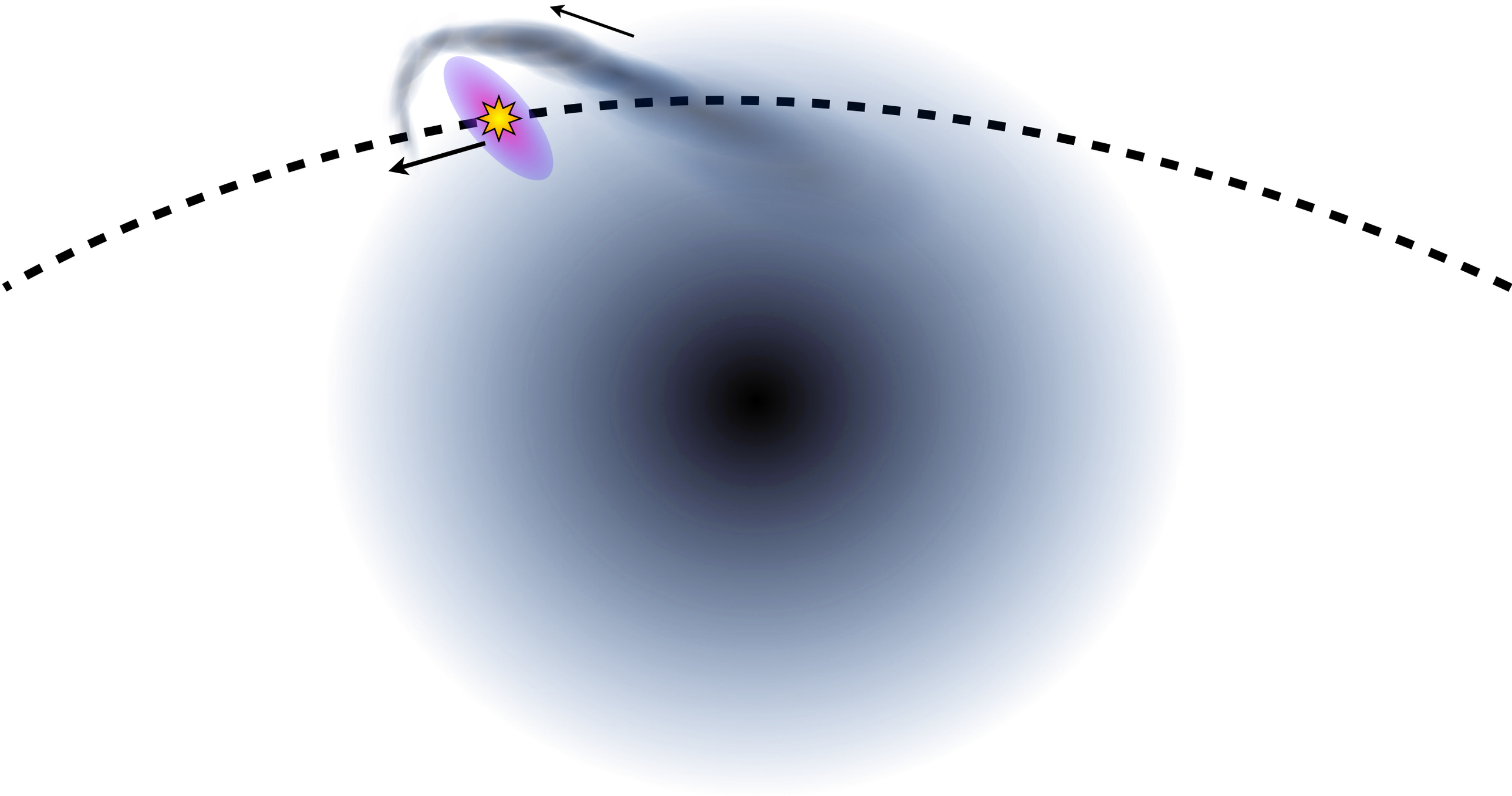
Thies et al. (2010-2012)

Random Accretion



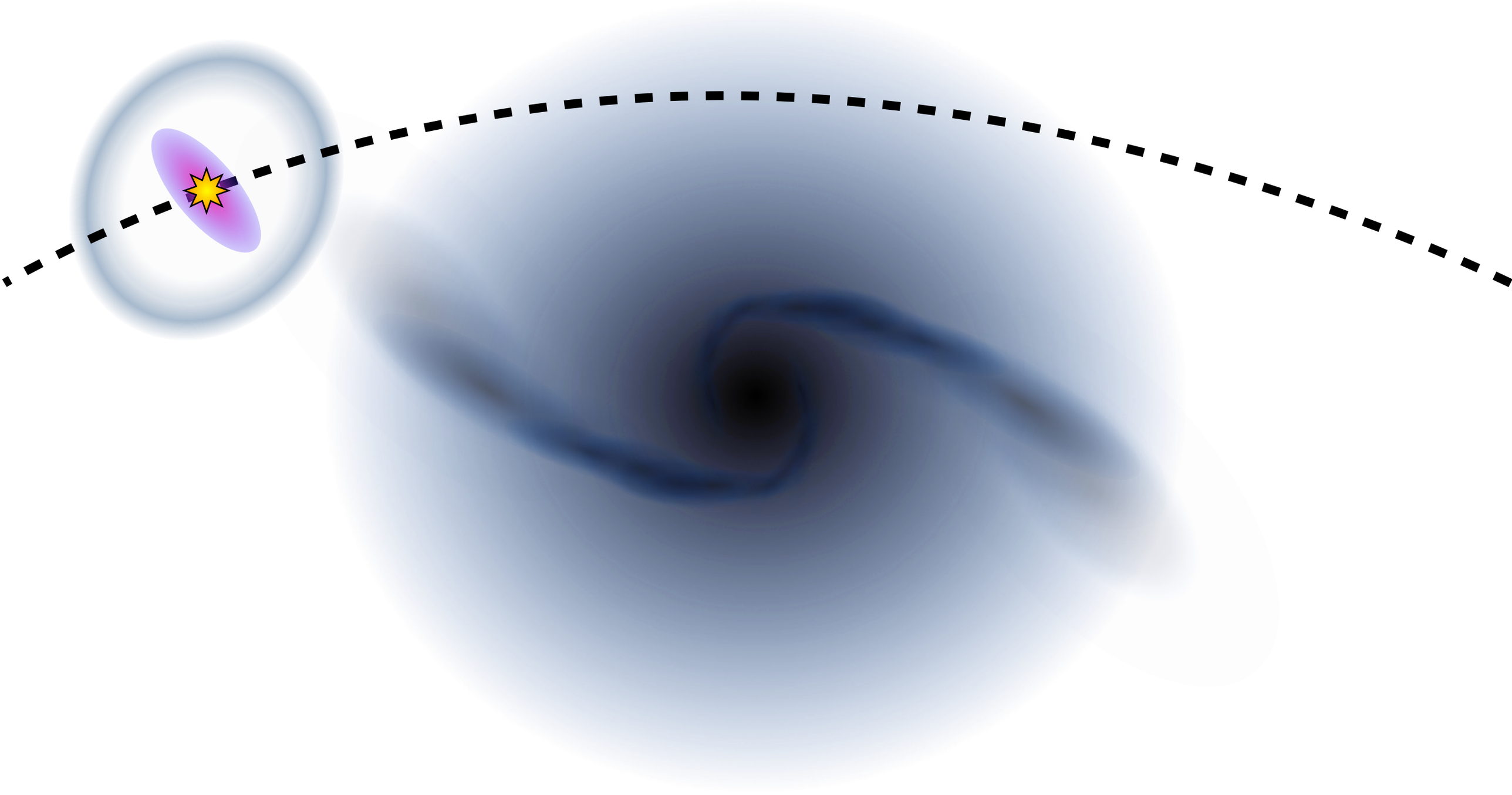
Star with PPD passes a gas cloud

Random Accretion



Accretion of gas from the gas cloud

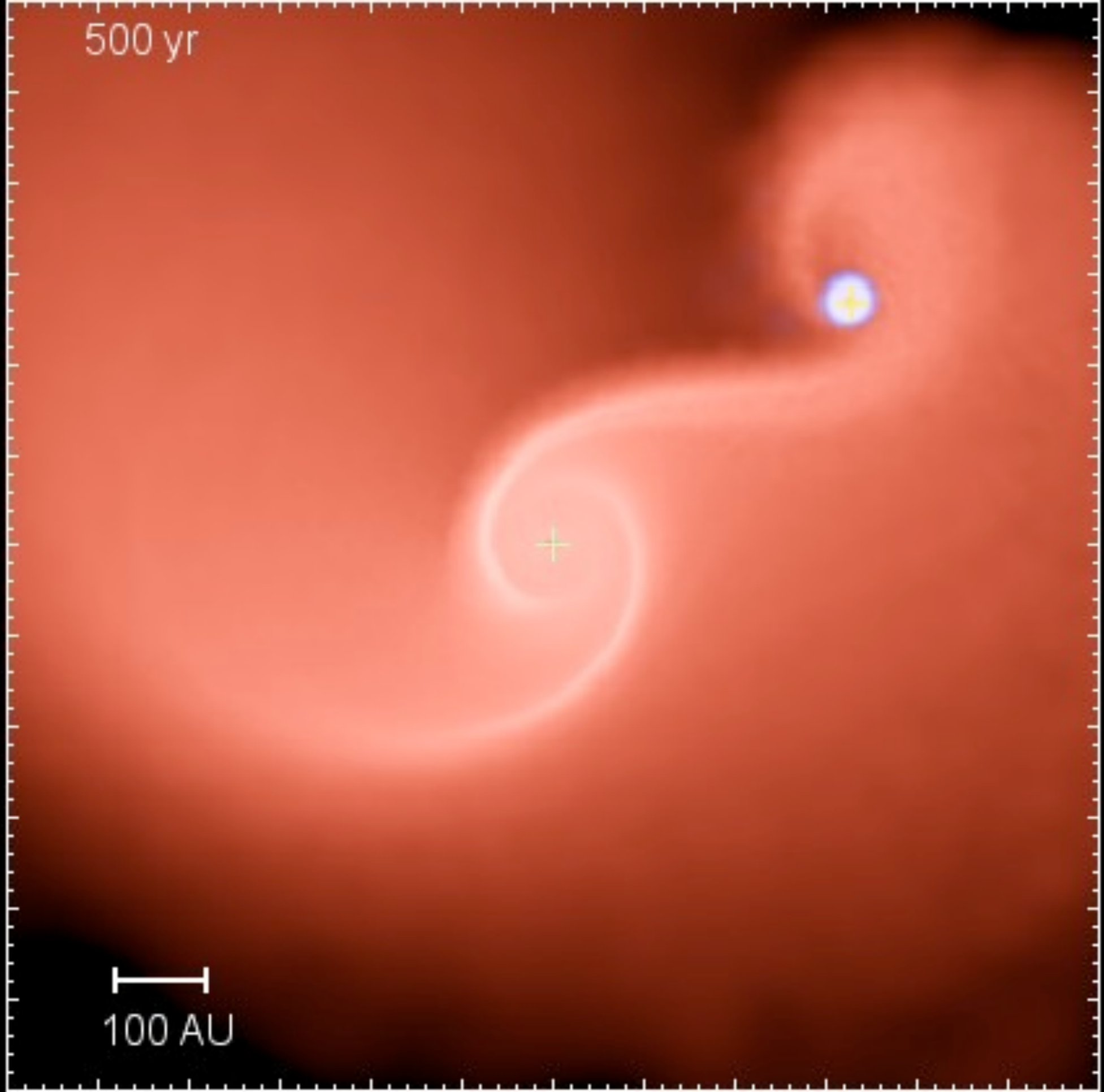
Random Accretion

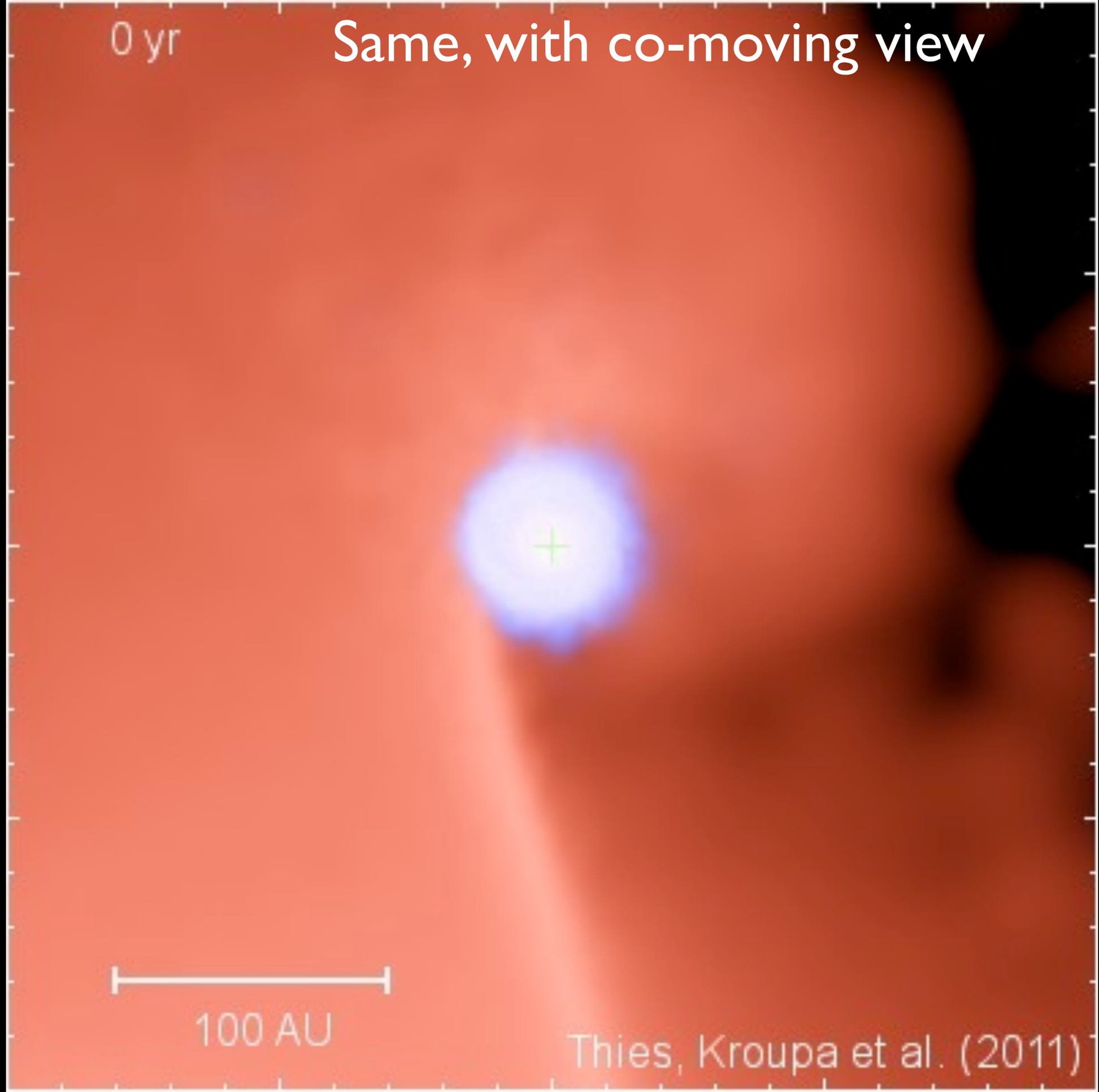


Captured gas, peturbations in the cloud

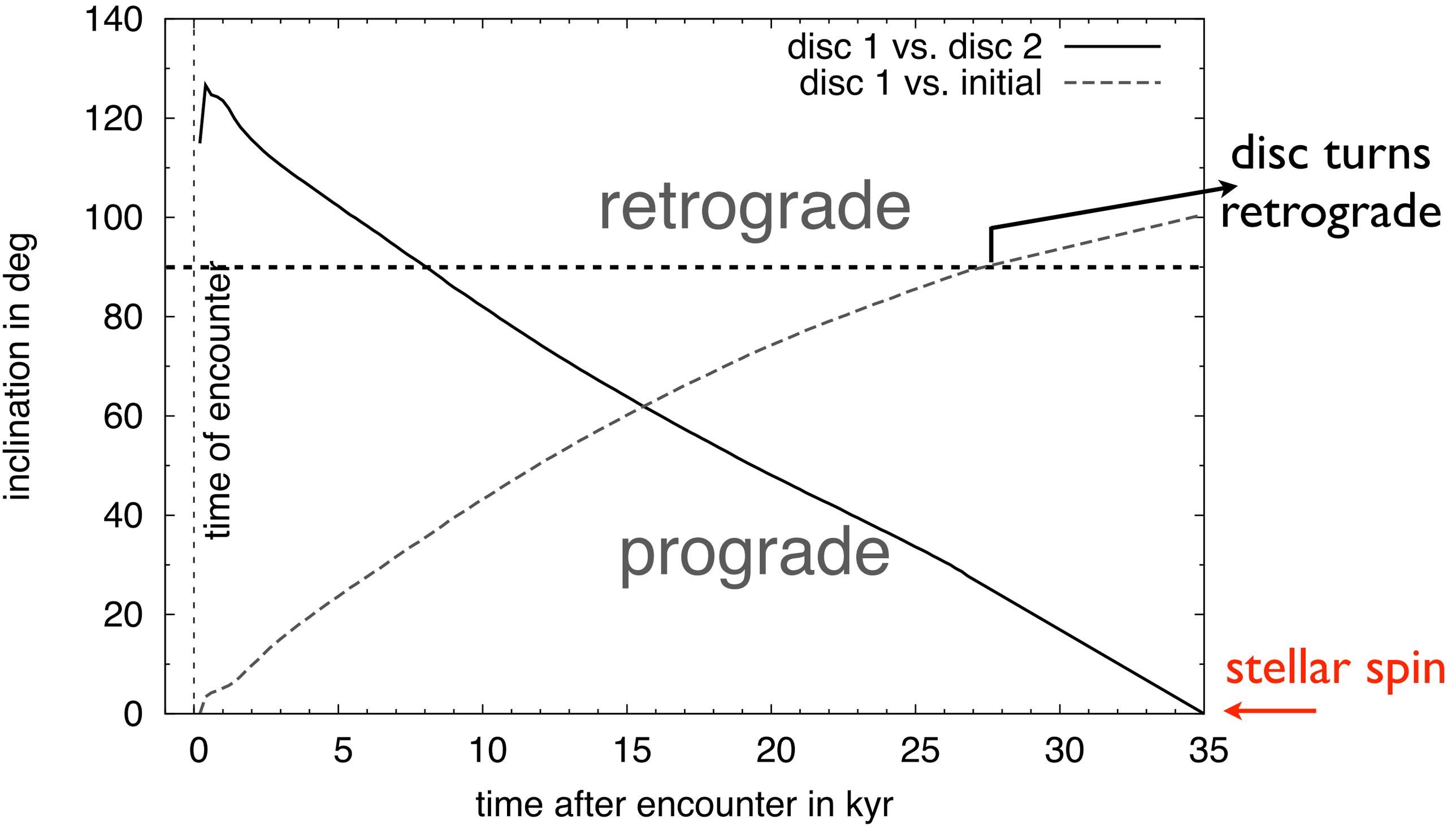
The Scenario

- Star mass = 0.5 to 1.0 M_{sun}
- PPD mass = <0.1 M_{sun}
- Target cloud mass = 0.5 M_{sun} (here: large disc)
- 300,000 SPH particles


500 yr
100 AU


0 yr
Same, with co-moving view
100 AU
Thies, Kroupa et al. (2011)

Disc Orientation vs. Time



Consequences for Stellar Chemistry

- Original and captured circumstellar material may be of different age,
- Chemical composition may be non-uniform within the system
- Stellar models predict lithium depletion upon violent accretion episodes (Baraffe & Chabrier 2010)

Composition inhomogenities and lithium anomalies might be fingerprints of a violent history!

Summary

- Mutual encounter may induce planet+brown dwarf formation,
- BD outcome in agreement with canonical IMF,
- Multi-stage accretion due to encounters with dense gas reservoirs (filaments, accretion envelopes),
- Misaligned planets and lithium depletion may result

Outlook

- Parameter study on PPD perturbation & evolution
- Ongoing increment of BD IMF statistics

To be continued...