Enhanced Coagulation in Tidally Perturbed Disks

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Planet Formation and Evolution – Tübingen 2009

Outline

- Motivation
  - Problems
  - Possible solutions
  - Planet formation in star clusters
- Methods
  - The DRAGON code
  - Disk models
- Results
- Summary

Principles and Problems of Planet formation

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- Collapse of star-forming core to star + protoplanetary disk around it,
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- Dust coagulates to grains & boulders,
- Accretion of surrounding material (dust & gas) by gravity.
- Grain growth stage up to 1 metre poorly understood ("metre barrier")
- Long planet formation times >100 Myr at >10 AU (Uranus & Neptune!)
- Disk lifetime usually only about 5 Myr
- Direct gravitational instability (GI) improbable below <100 AU

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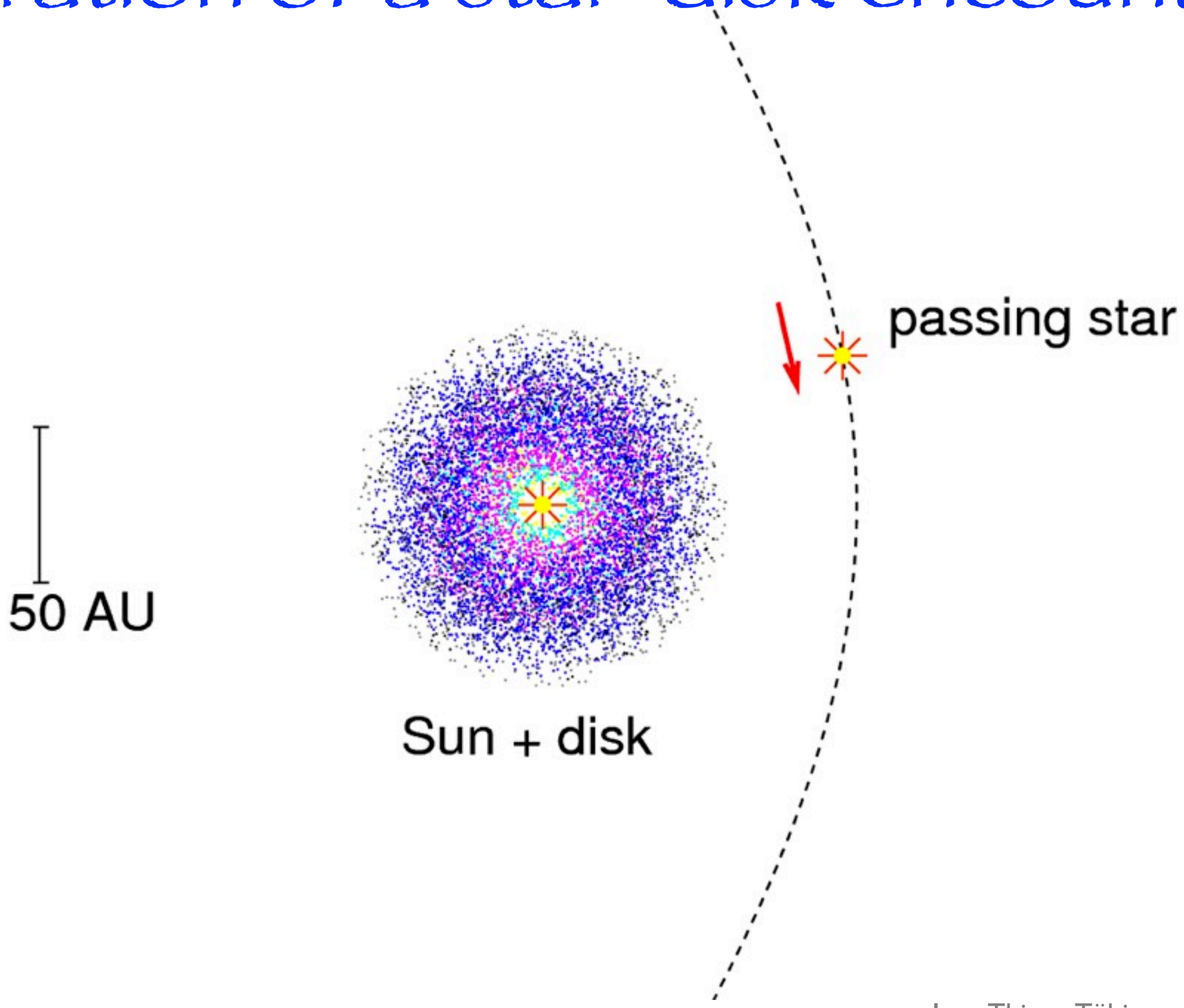
- Vortices form in contracting gas due to conservation of angular momentum.
- Trapped dust coagulates rapidly to >1m-sized boulders.

Illustration of a star-disk encounter



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The stellar environment of Planet formation

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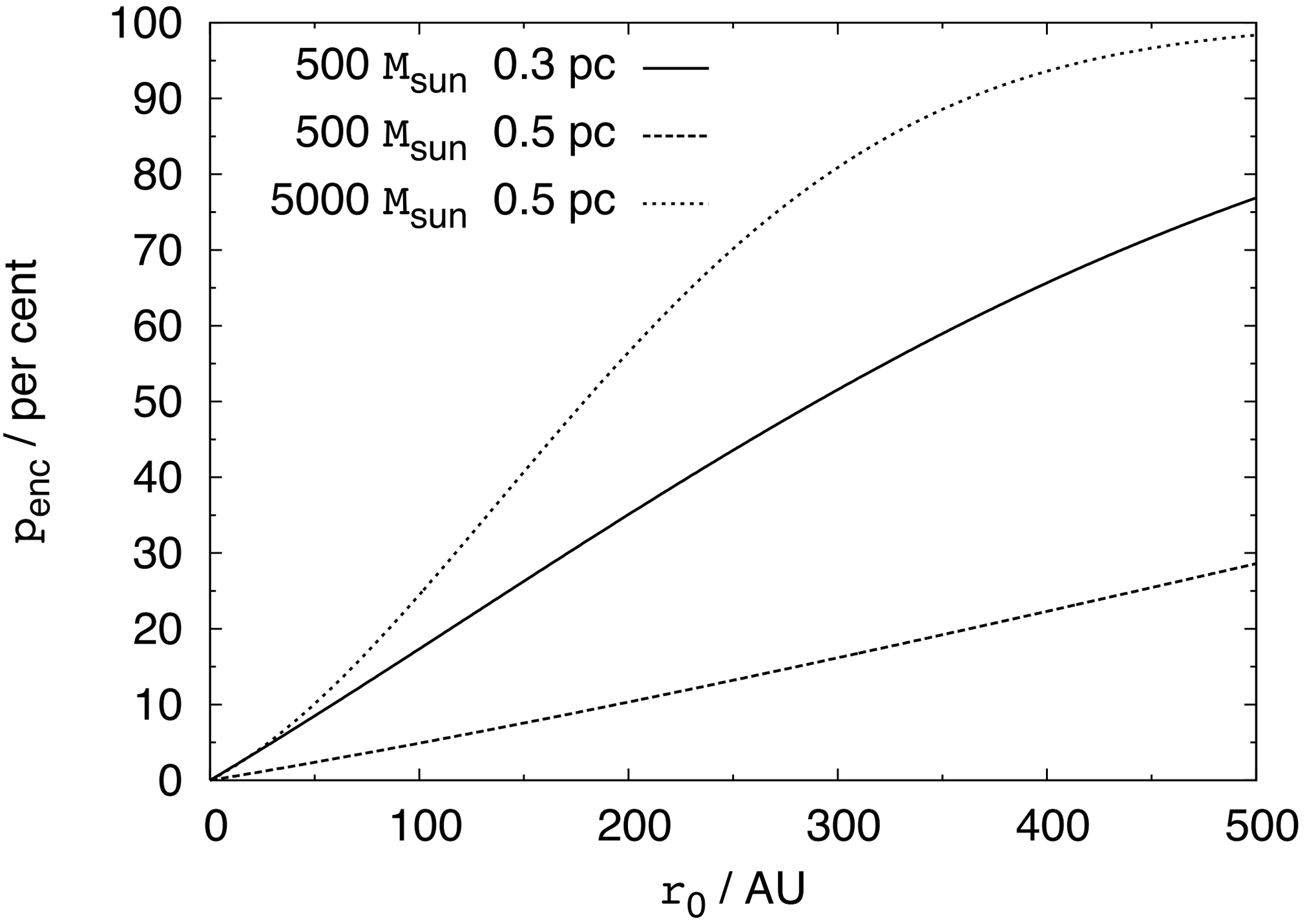
Realistic planet formation models must include star-star encounter effects!

Encounter probability



(Thies, Kroupa & Theis 2005)

Smoothed Particle Hydrodynamics

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SPH Features:

- Simple implementation and data evaluation
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The DRAGON Code

- Based upon the Cardiff group code, rewritten and improved by Simon Goodwin (Sheffield)
- DRAGON is a well-tested SPH code and used for star formation as well as for disk dynamics
- New routines for radiative cooling by Whitworth et al. 2007ff available

Disk models

- Radial profile from Stamatellos & Whitworth (2008)

$$\Sigma(R) = \Sigma_0 \left(\frac{R}{\mathrm{AU}} \right)^{-q_\Sigma}$$

$$T(R) = \left[T_0^2 \left(\frac{R}{\mathrm{AU}} \right)^{-2q_T} + T_\infty^2 \right]^{1/2}$$

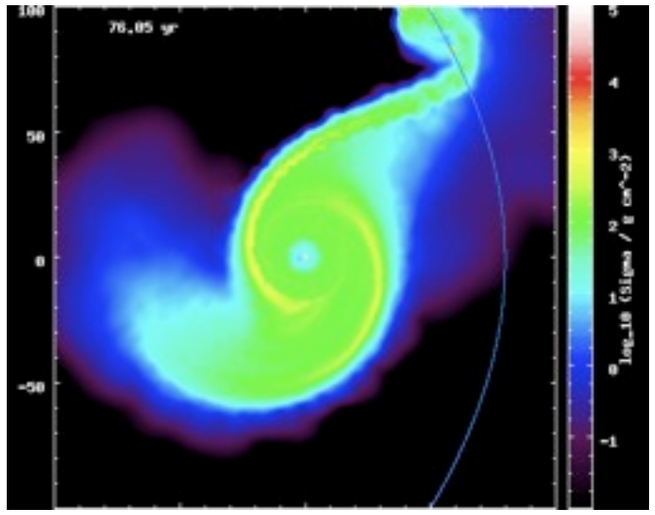
- Simple T(R) equation of state (EOS) for first runs to test the general effects of tidal perturbations (and to save CPU time...)
- Whitworth et al. 2007ff EOS for long-term runs

Disk and Encounter Params

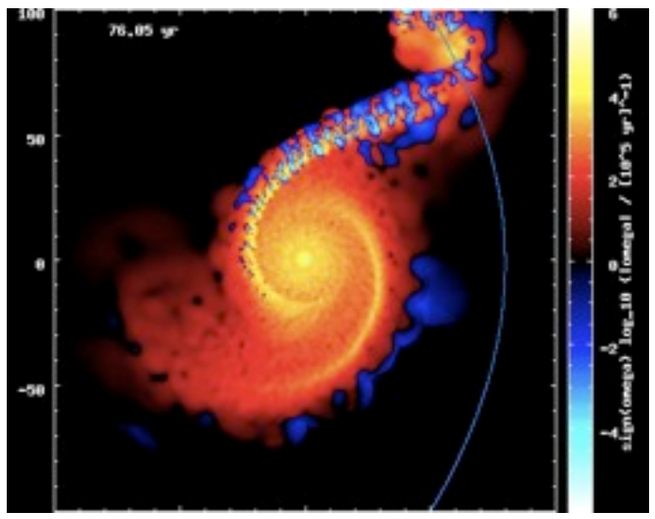
Disk mass	0.09 M_{sun}
Disk radius	10–50 AU
Σ_0 (at 1 AU)	600 g/cm^2
T_0 (at 1 AU)	1200 K
T_∞ (background)	10 K
Perturber mass	0.3 M_{sun}
Periastron	80 AU
Eccentricity	1.1
Inclination	10°

Sample Sequences

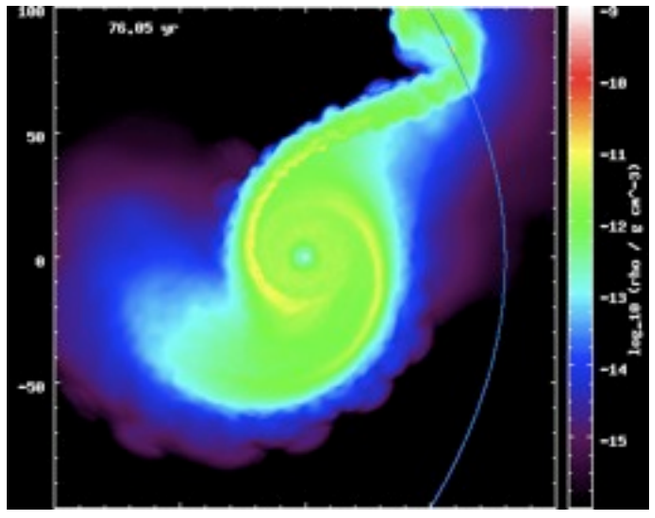
Surface density (g /cm^2)



Local rotation (revs / 10^5 yr)



Average density (g / cm^3)



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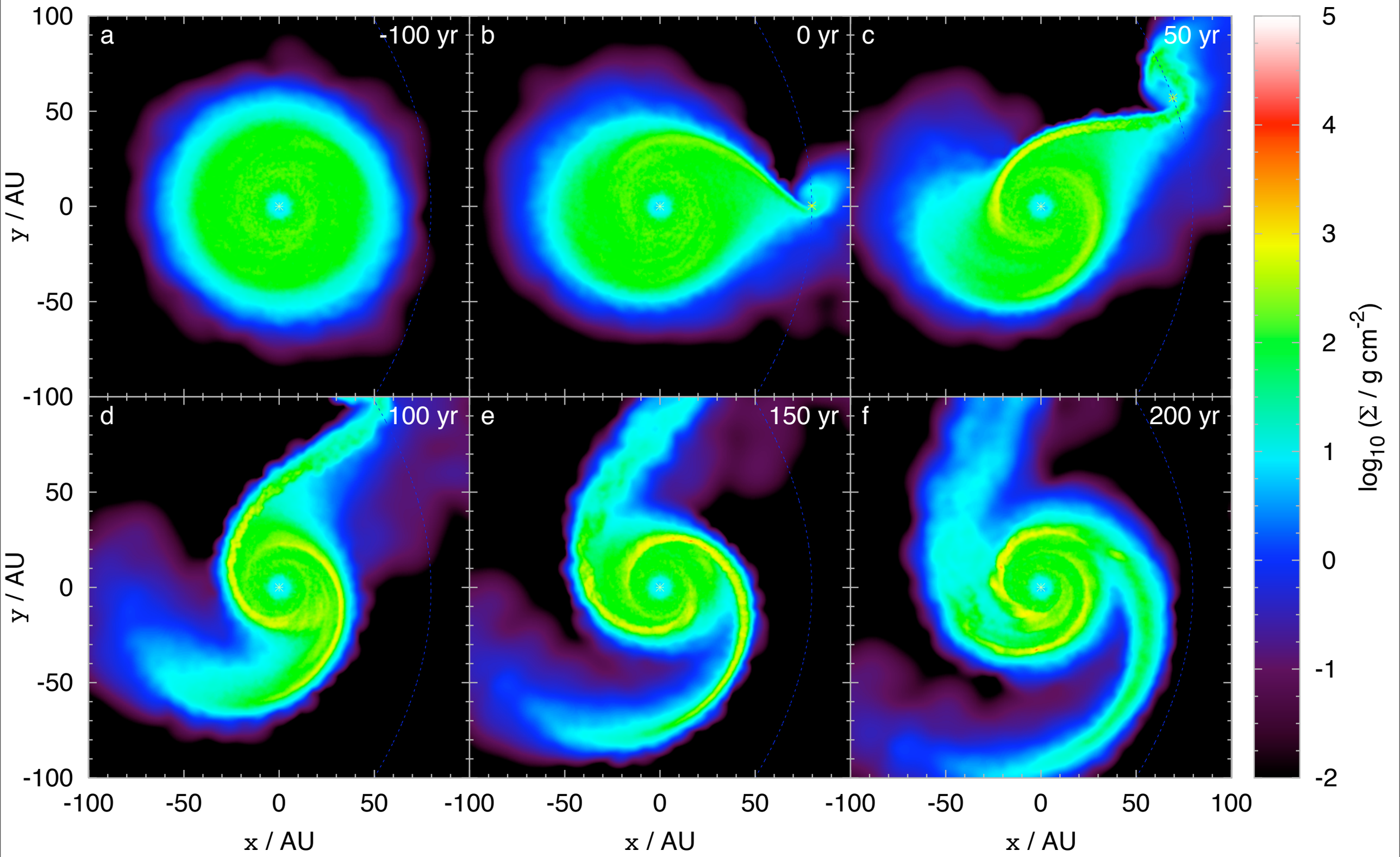

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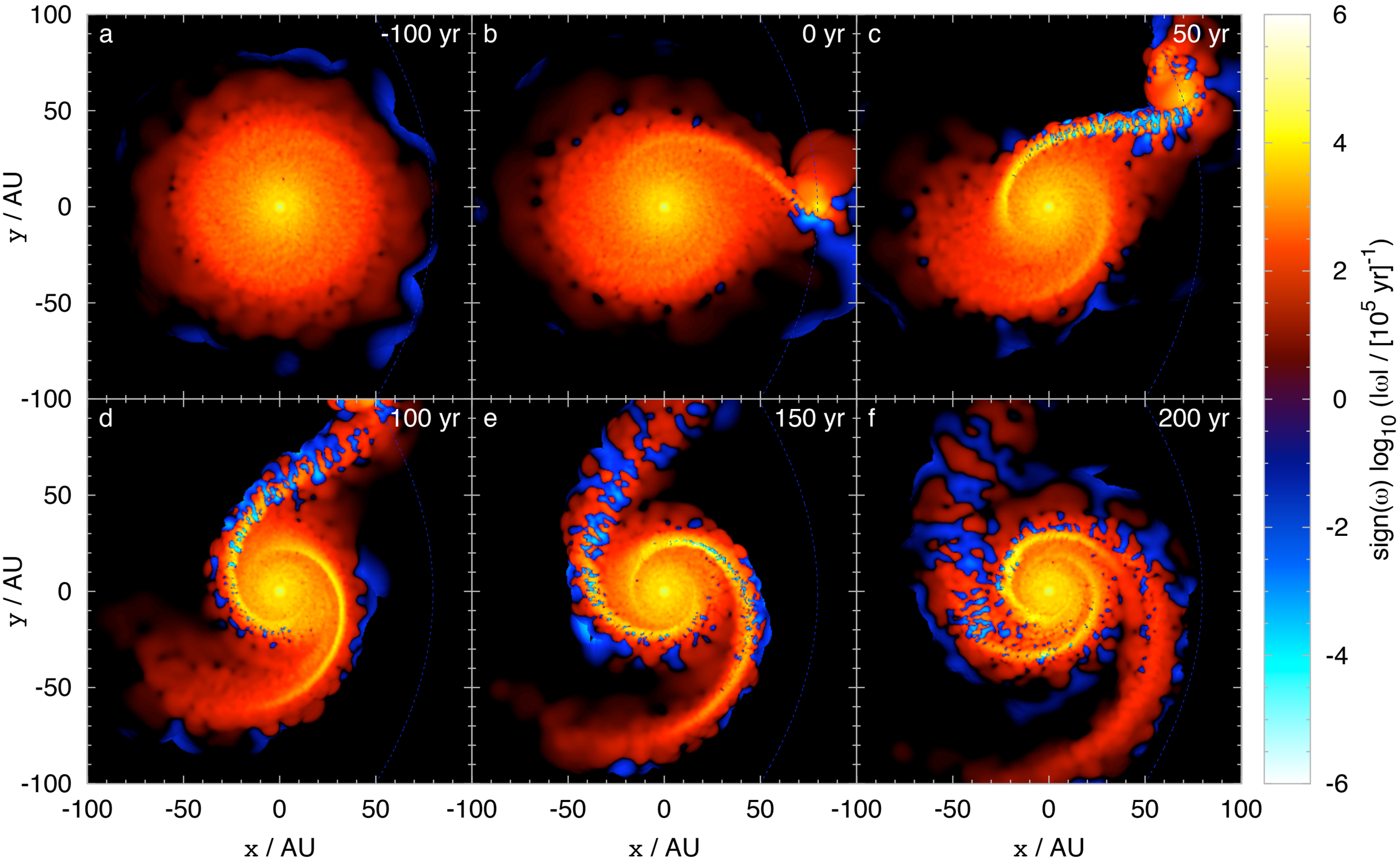

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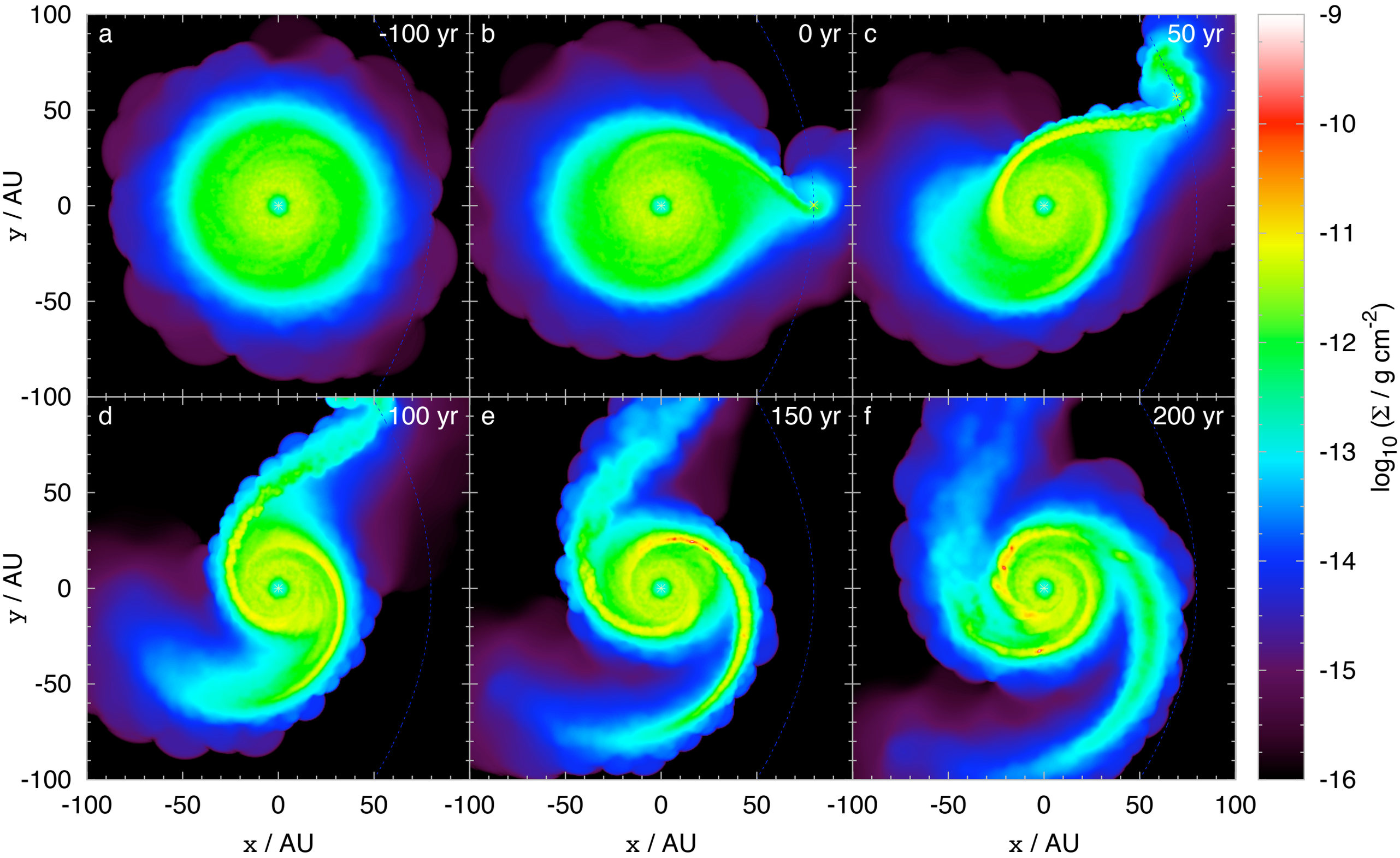

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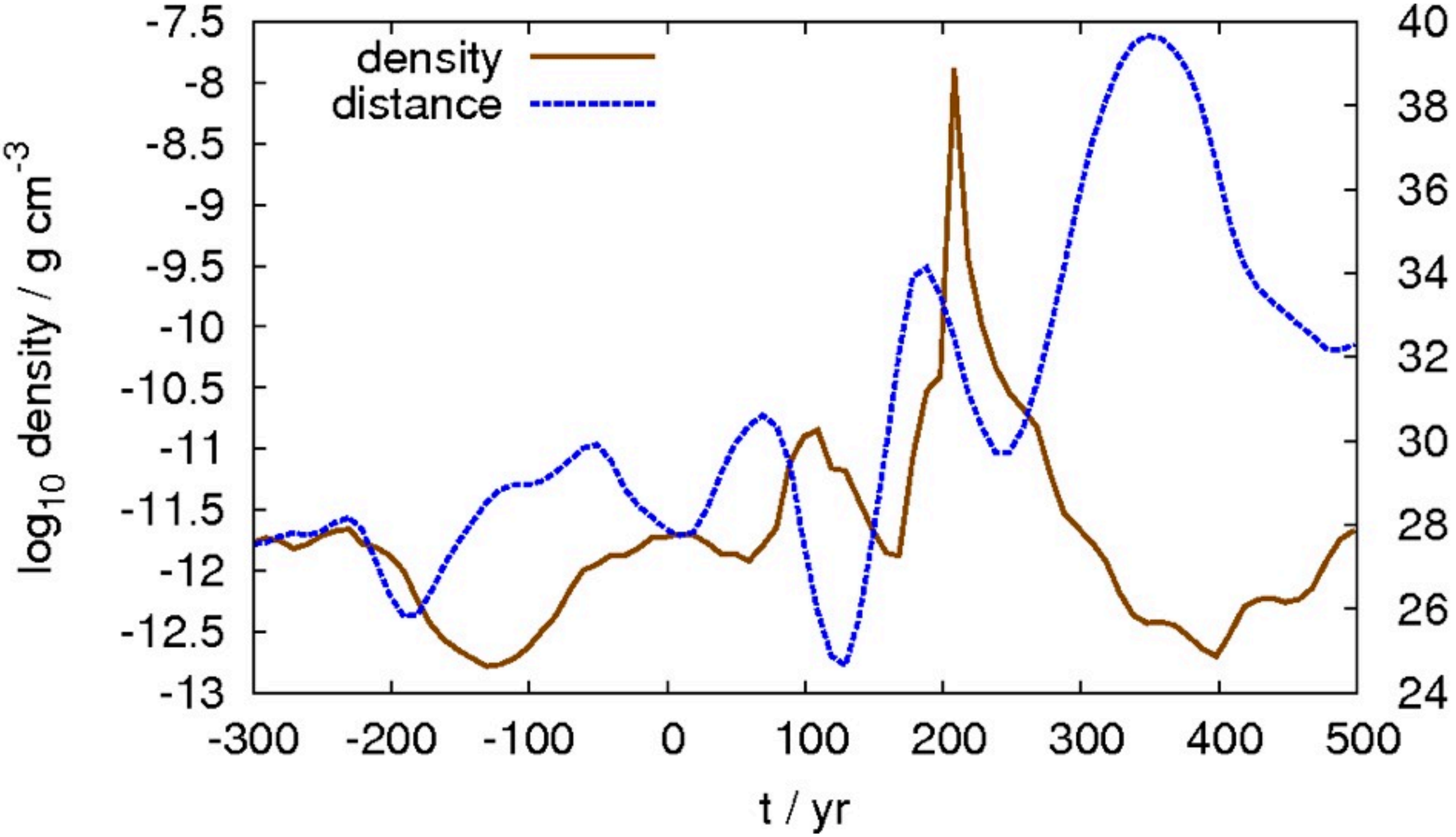
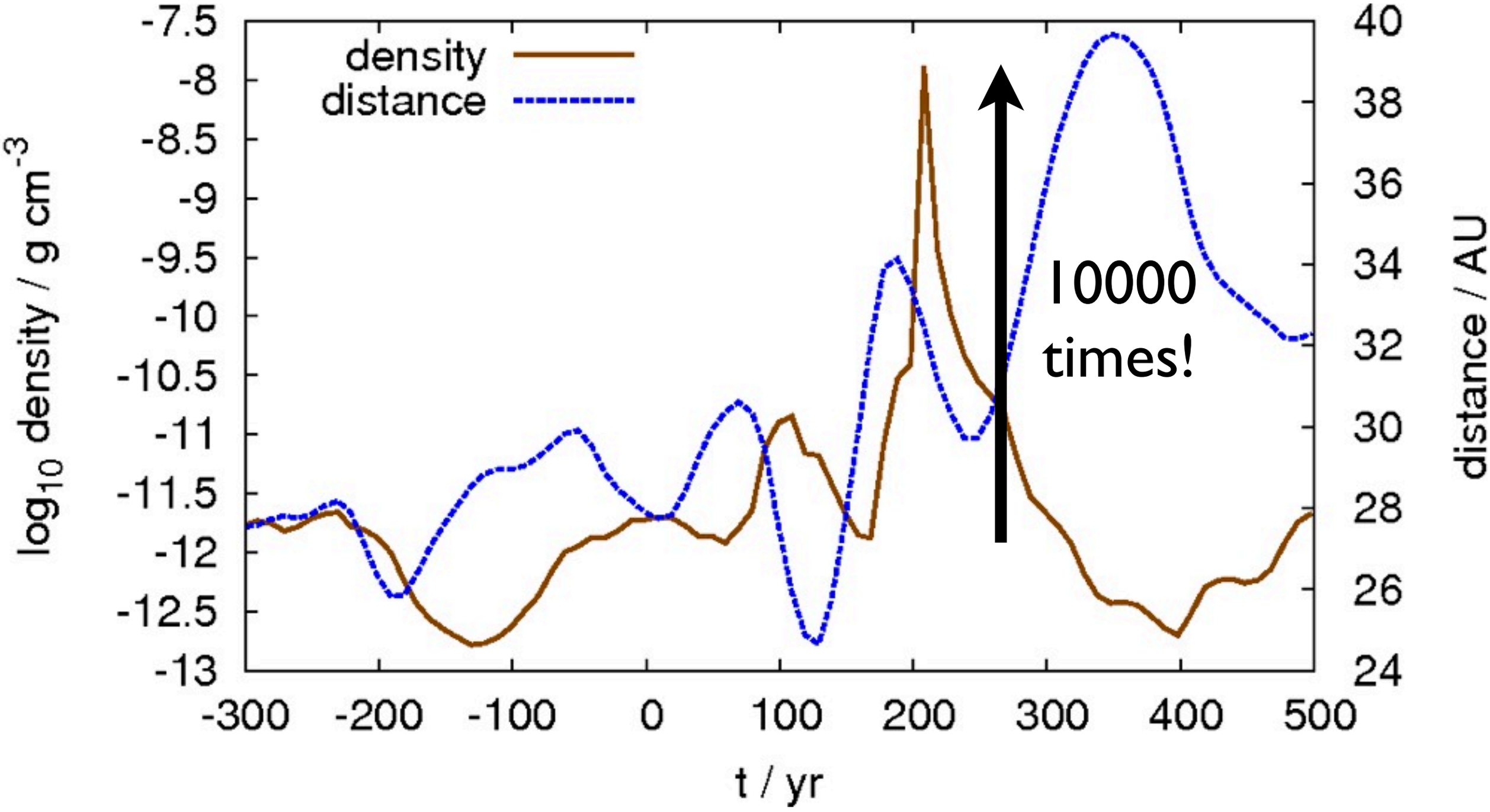


Density and solar distance of another SPH particle. This time there is only a brief rise by 4 dex while the average distance increases slightly.



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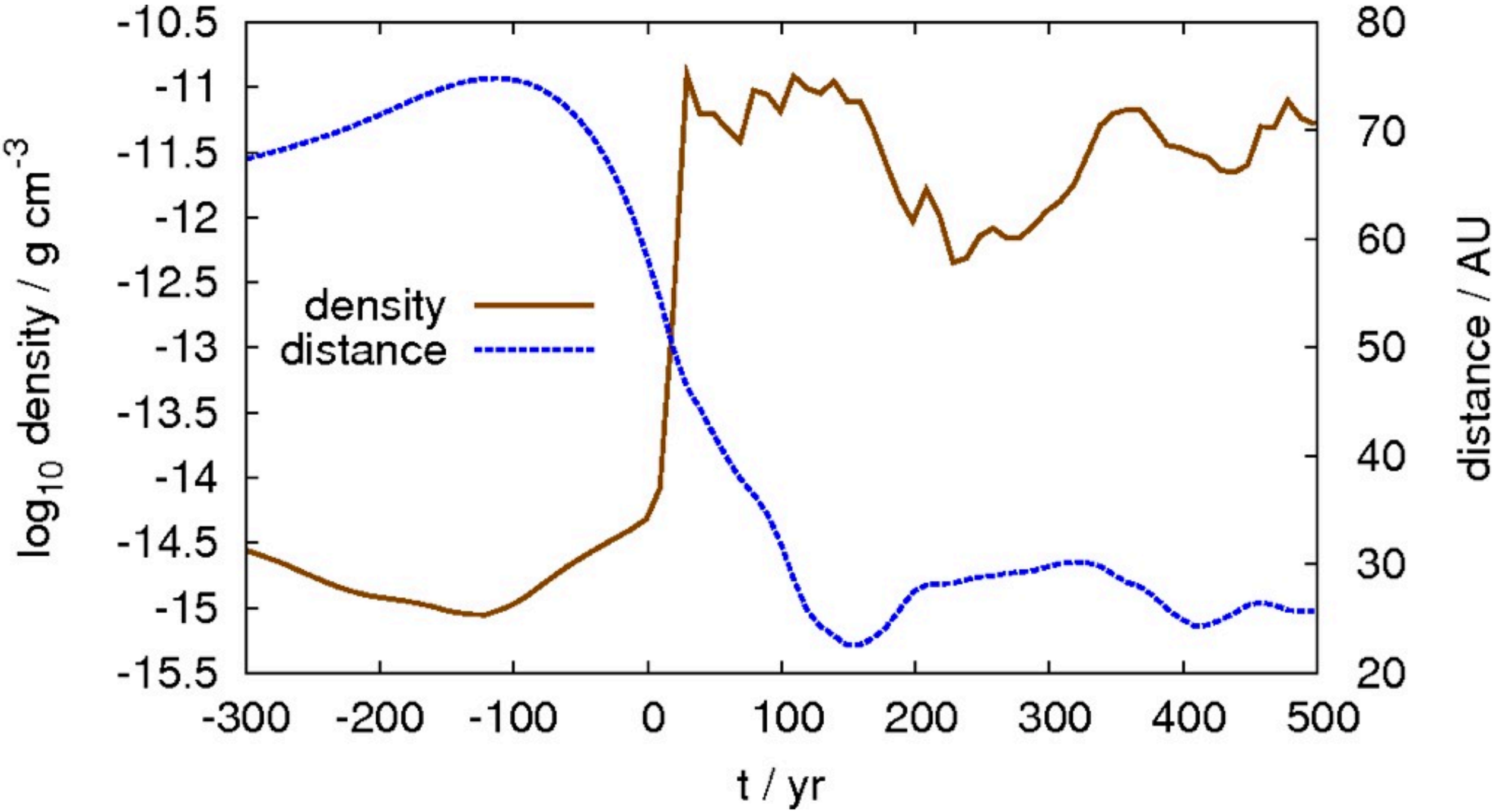

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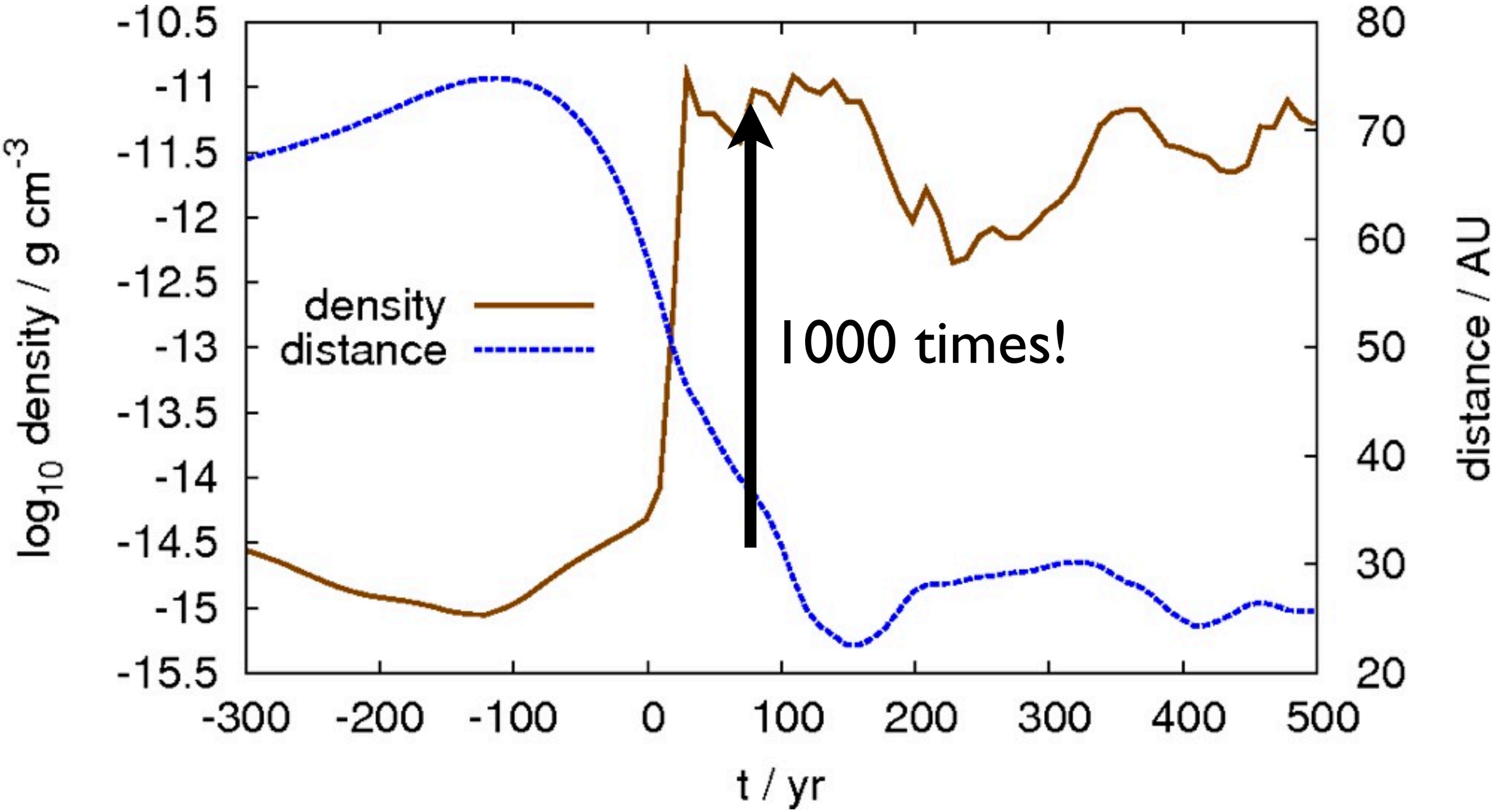

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