Fuelling the Galactic Center via infall from the Central Molecular Zone

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SUPA

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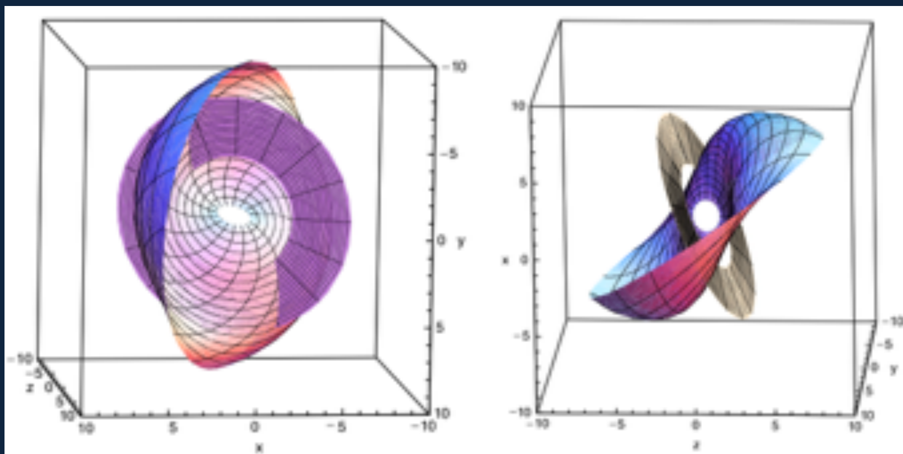
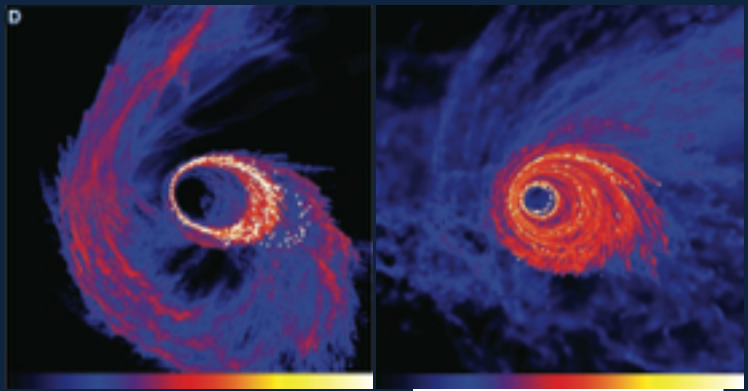
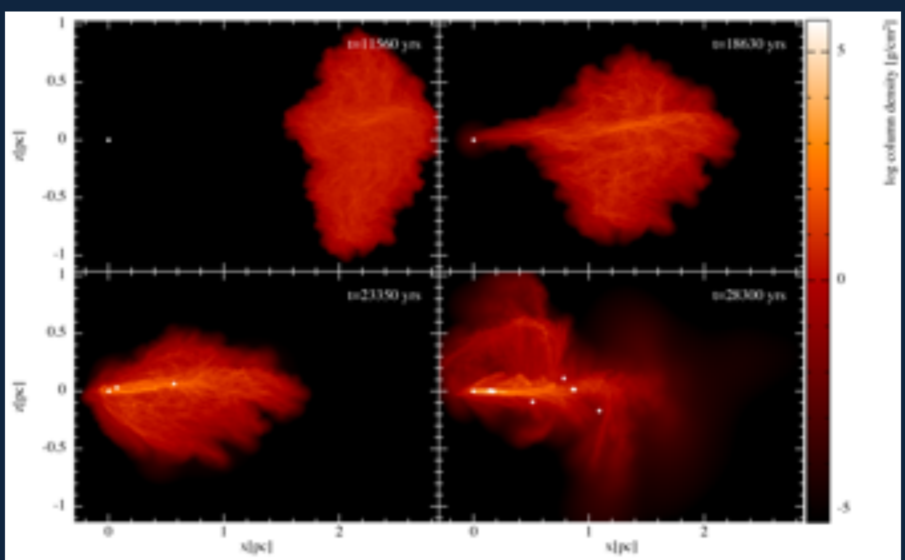
Star Formation around Sgr A*



Bartko et al. 2009



Bonnell & Rice 2008



Lucas et al. 2013

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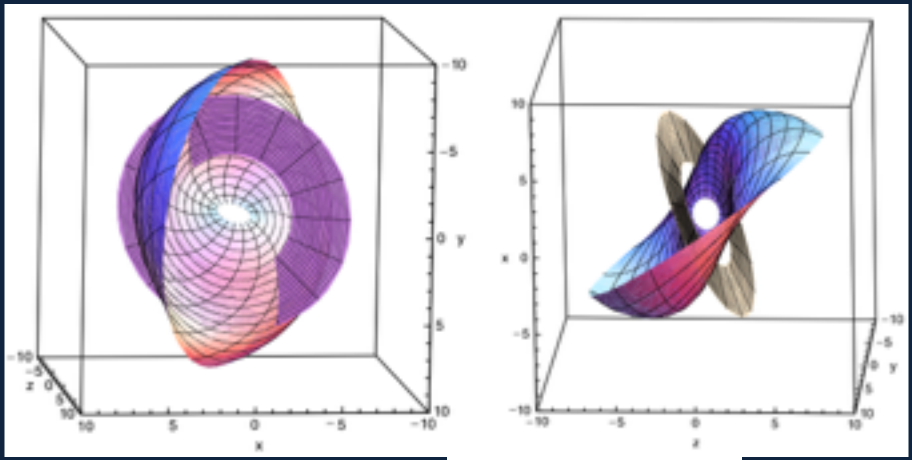

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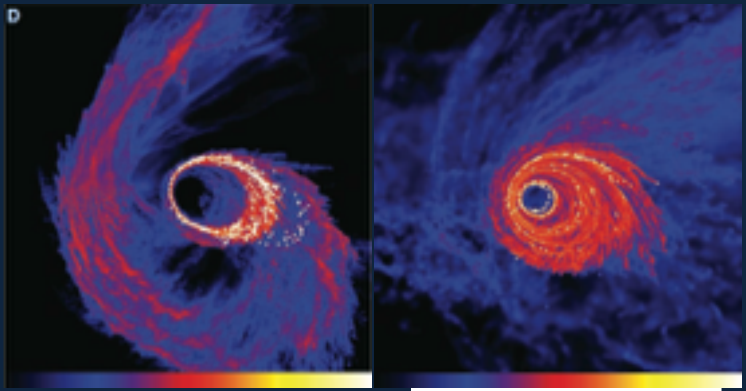

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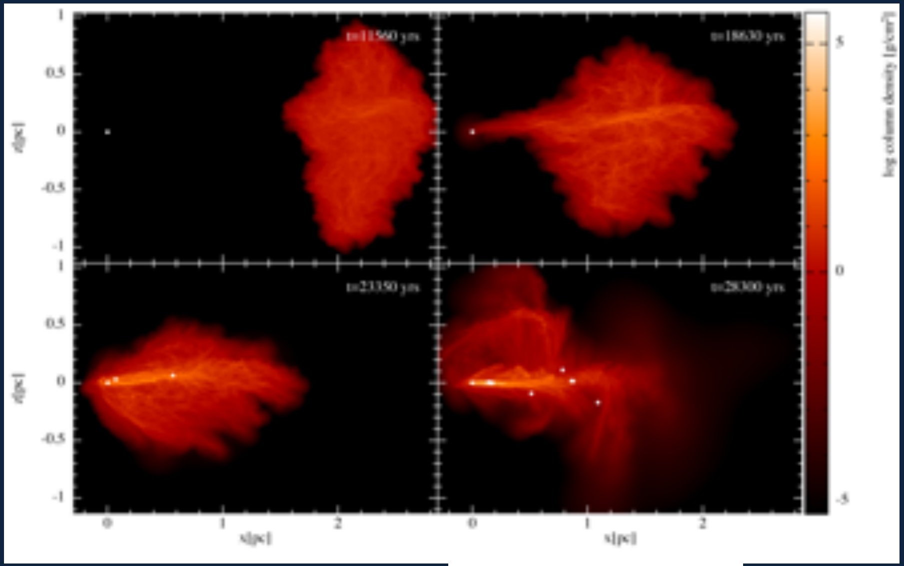
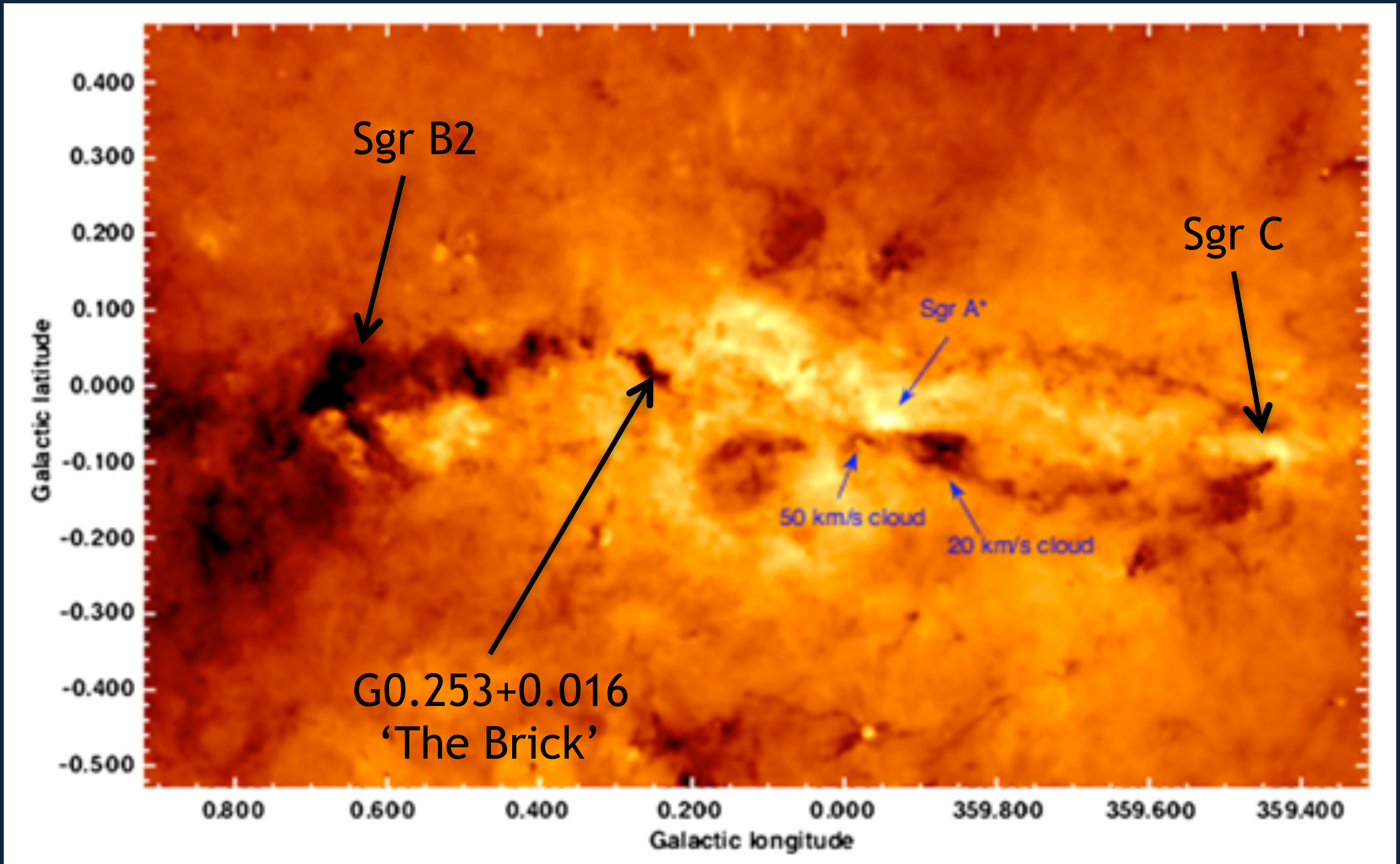


Lucas et al. 2013

If formation of a star forming disk does result from an infalling cloud's tidal destruction, then we need a source of infalling material.

A likely source – the Central Molecular Zone

Twisted ring-like structure containing 3–7 x 10^7 $M_\odot$ of molecular gas.



Molinari et al., 2011

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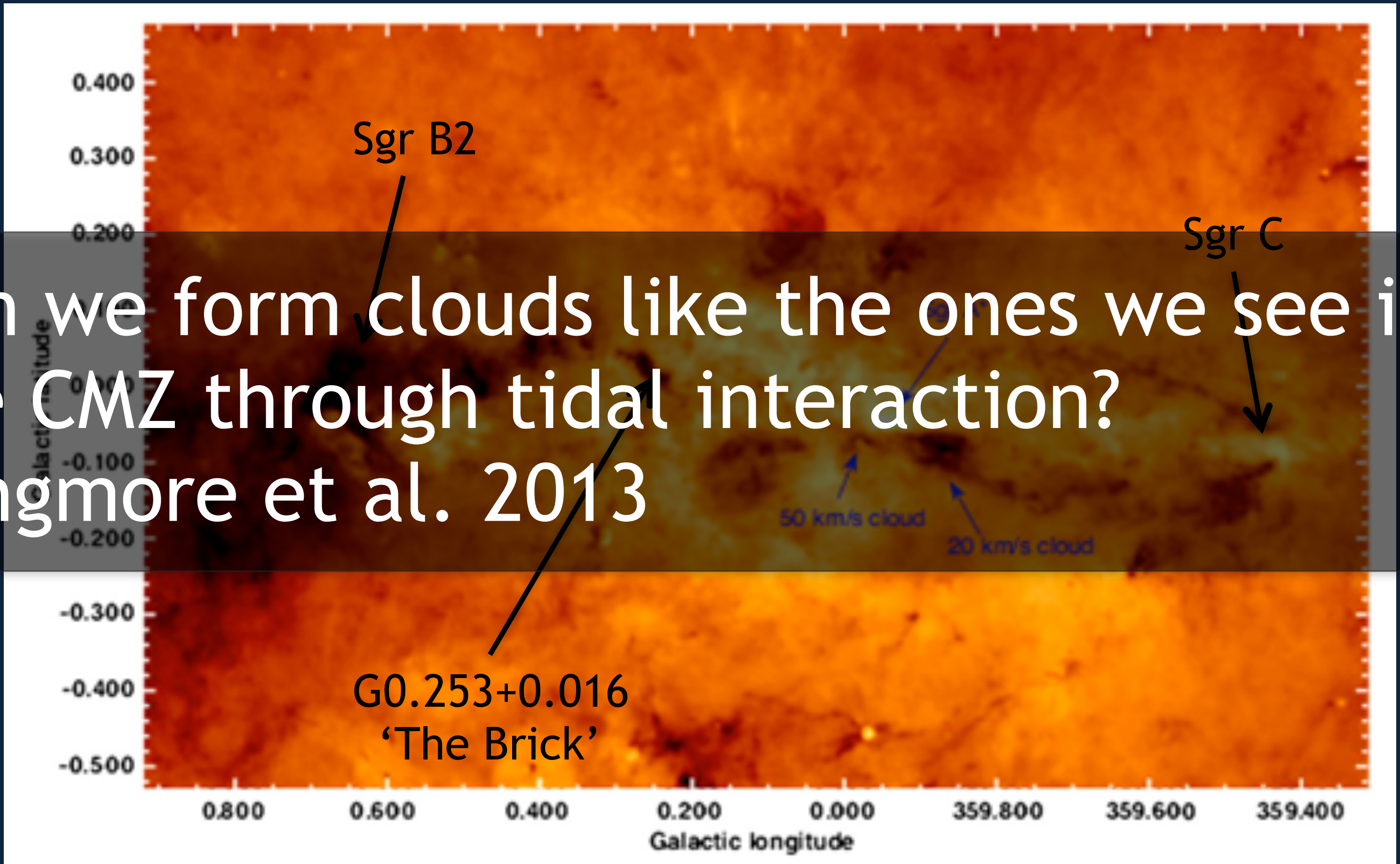


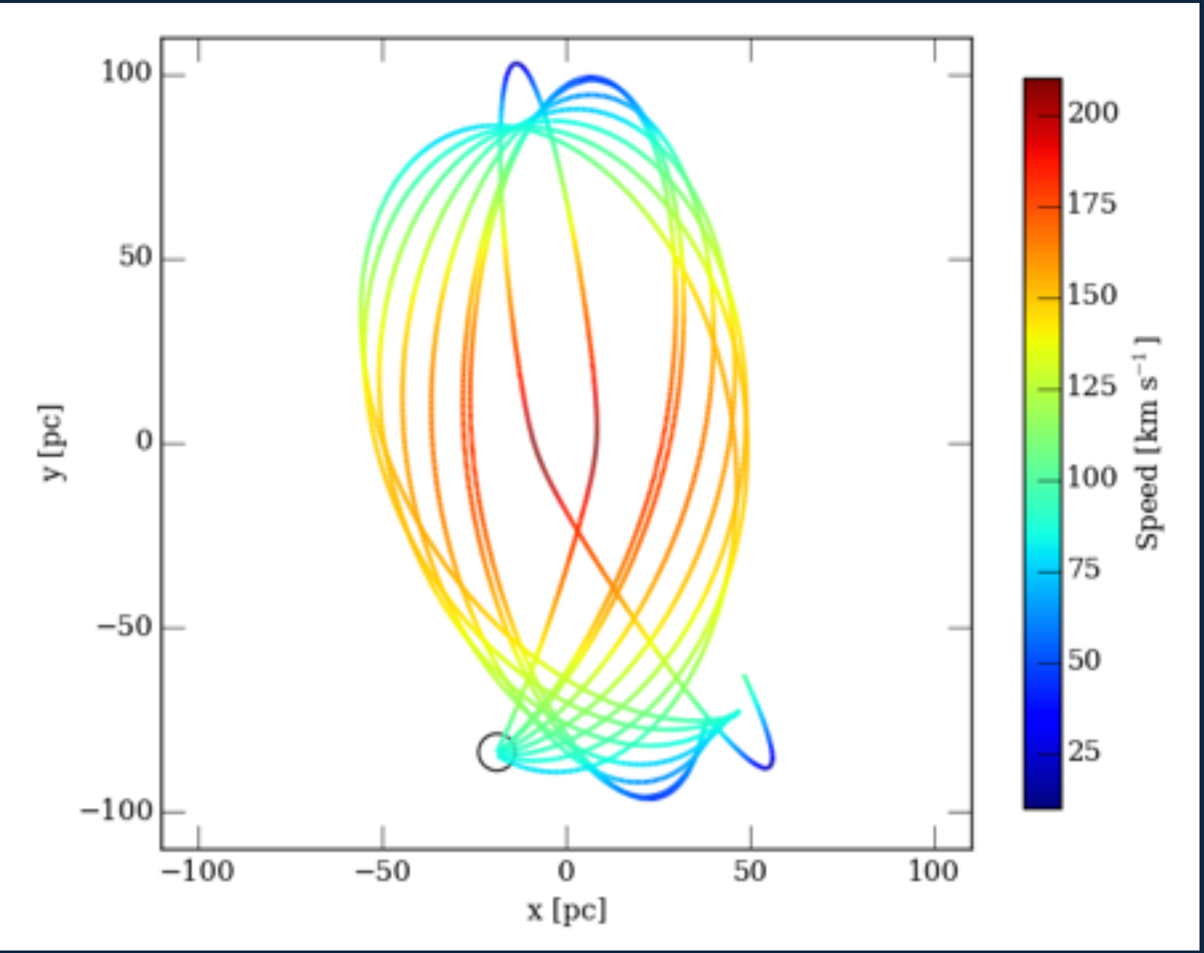
Molinari et al., 2011

Can we form clouds like the ones we see in the CMZ through tidal interaction? Longmore et al. 2013

Simulation setup

Initial clouds in sphNG (Bate, Bonnell & Price 1995)

- Mass 1×10^{6} $M_{\odot}$
- Radius 16.9 pc
- Number density of 2×10^{3} cm^{-3}
- Initial temperature 300K.
- RMS turbulence 30 km s^{-1}
- Koyama & Inutsuka 2002 cooling.



Place test particles at 90 km s^{-1} in the GC potential (Stolte et al. 2008).

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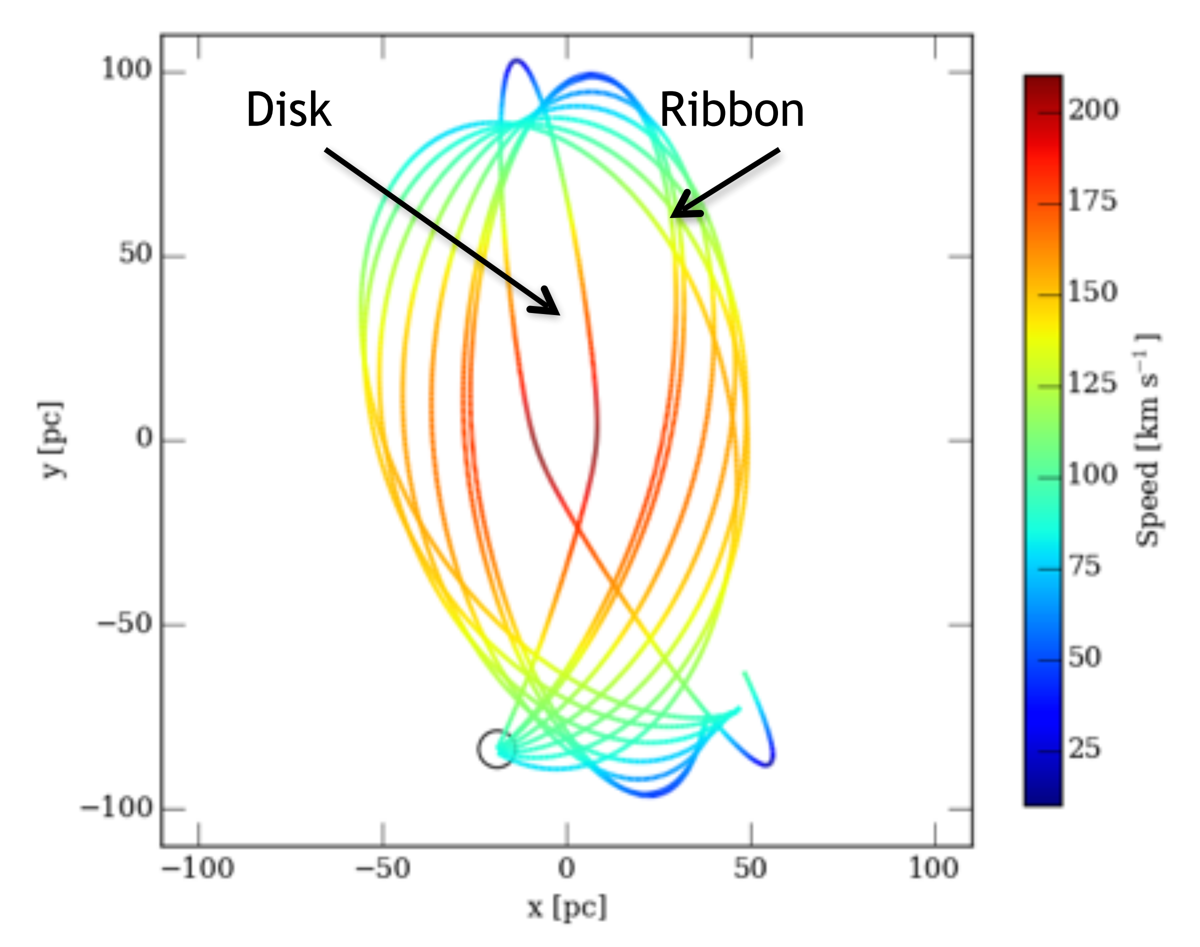

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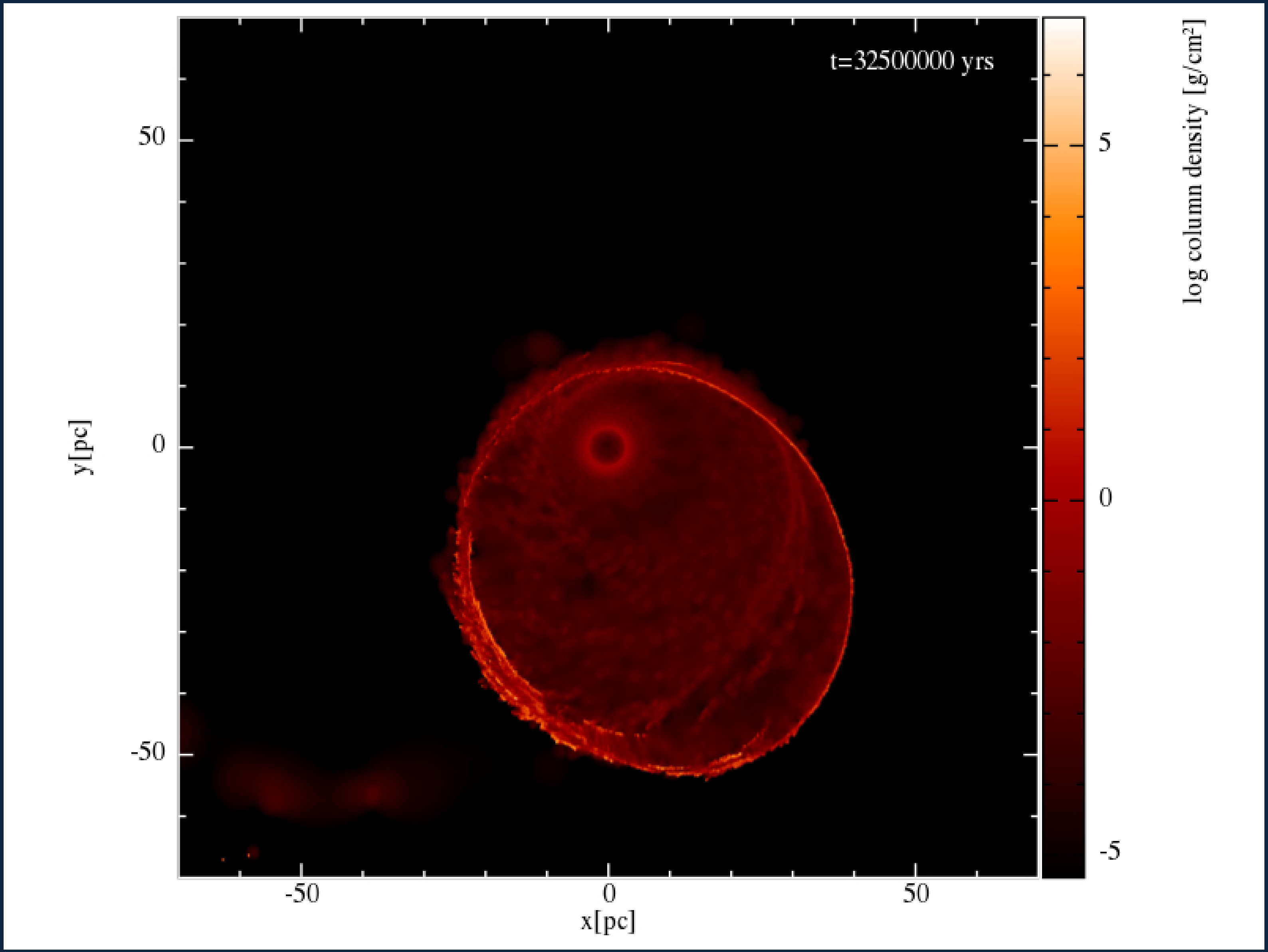
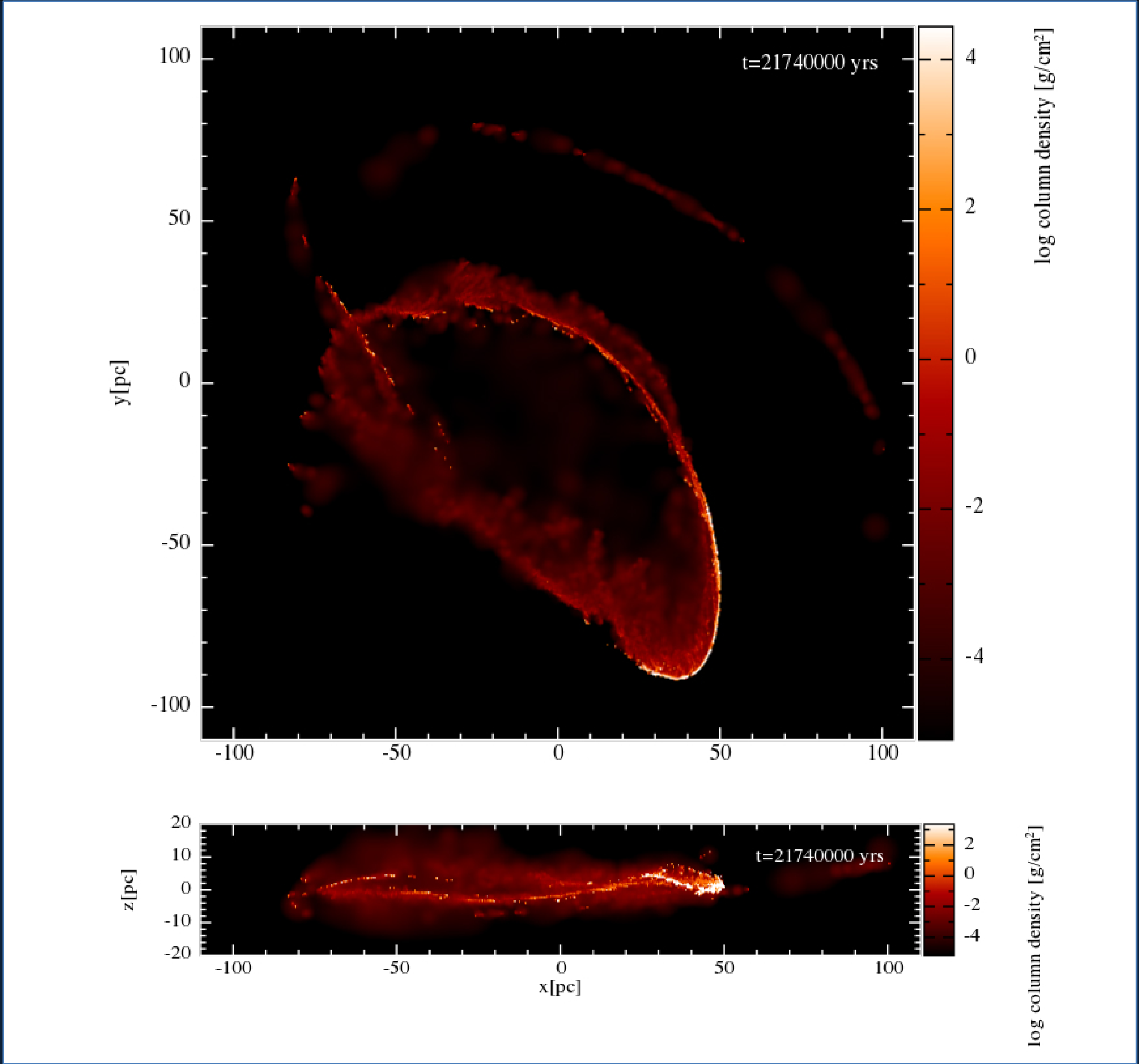
Cloud simulations I – Disk

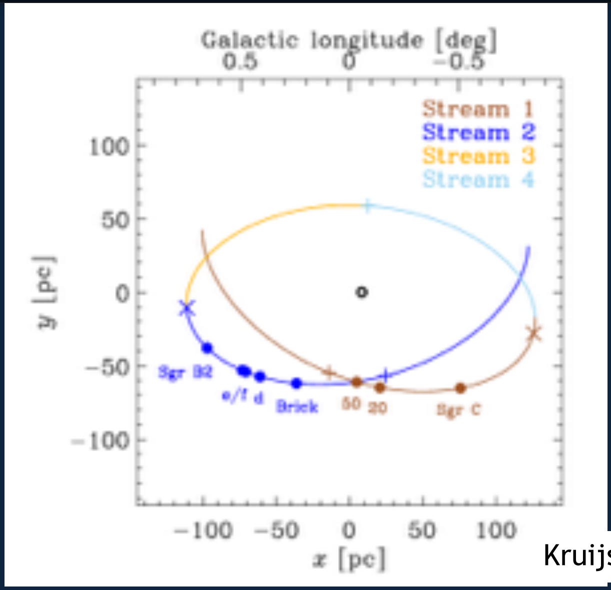


Cloud simulations II - Ribbon

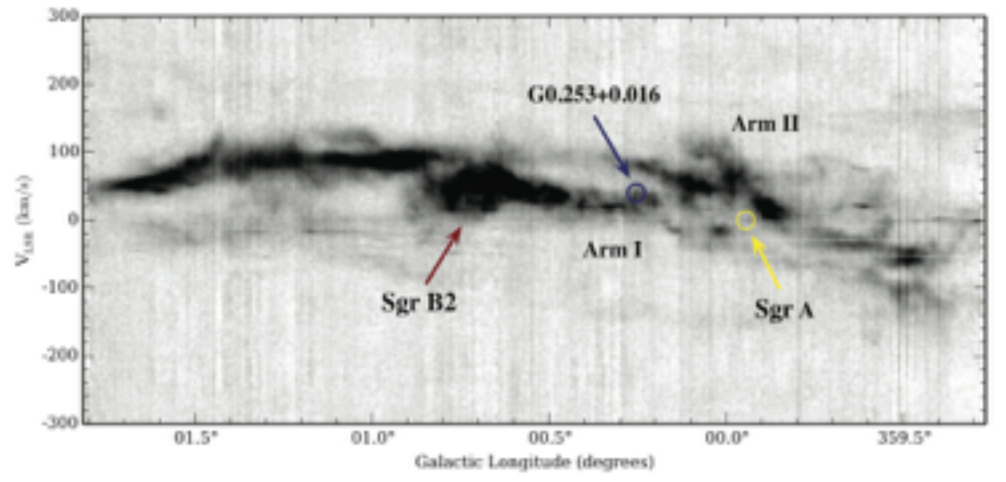


Comparison to observations

- Traces similar extents to the Molinari et al. 2011 ring
- Off-centre position of the BH
- Self-intersection, similar to suggestion of Johnston et al. 2014 and Kruijssen et al. 2015



Kruijssen et al., 2015



Johnston et al., 2014

- Gas densities can become very high – 10^7 or more cm^{-3}.
- These simulations unable to resolve within clouds.

x_2 orbits - Simulating an entire gas disc

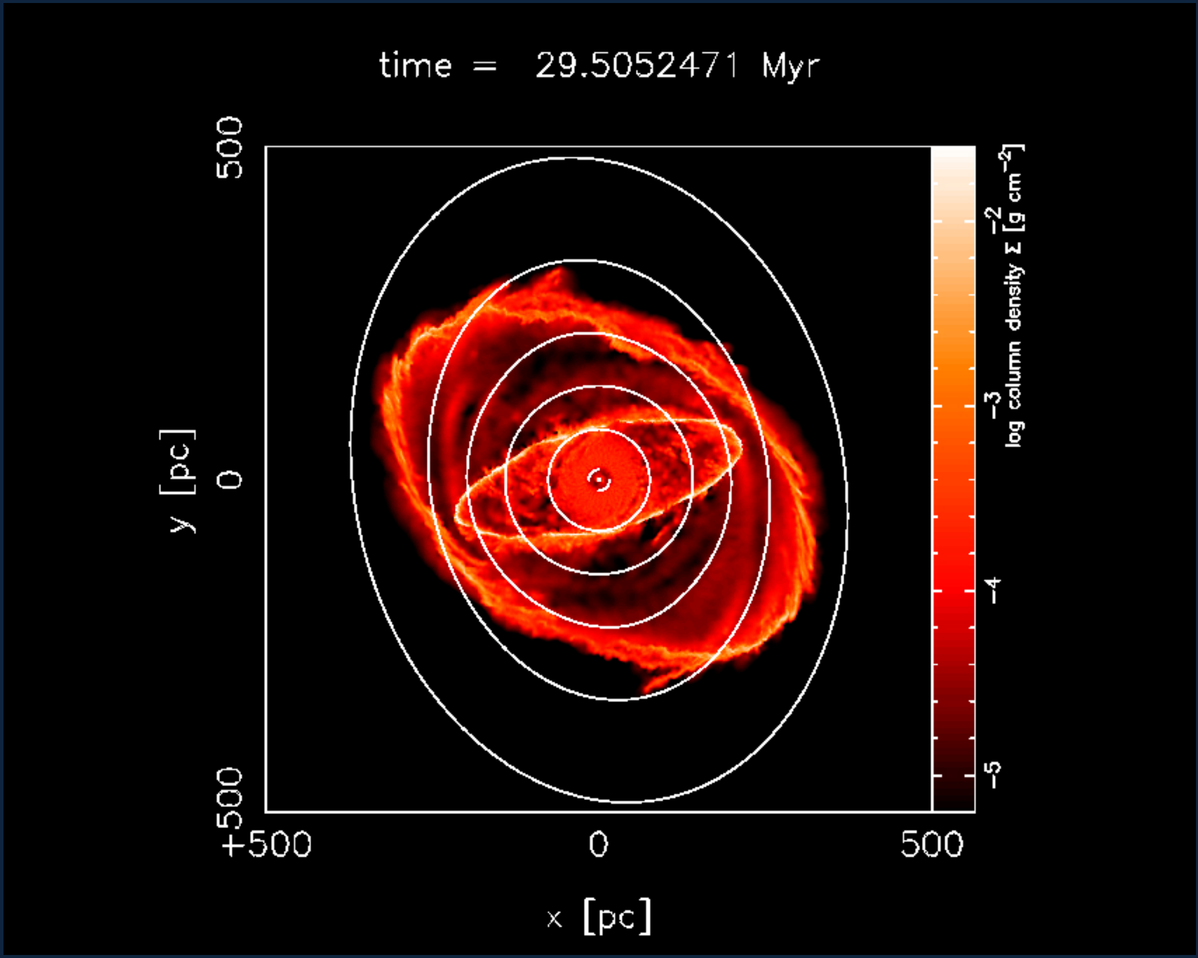
Start with an axisymmetric potential and slowly introduce the triaxial scaling factors to the log potential – end potential of Stolte et al. 2008.

248,000 particles

Disk extends to 400 pc and is 10 pc thick. 10pc hole at center.

Uniform density at 2 cm^{-3}, total gas mass is 5 x 10^5 $M_\odot$.

Initial temperature of 10^4 K + cooling (Koyama & Inutsuka 2002)



The Jacobi integral

Simple approximation to n body to keep things easy. From the Hamiltonian in the rotating frame (e.g. Binney & Tremaine):

$$E_{\mathrm{J}} = \frac{1}{2}|\mathbf{v}|^2 + \Phi - \frac{1}{2}|\boldsymbol{\Omega}_{\mathrm{b}} \times \mathbf{x}|^2$$

which is an integral of motion (a conserved quantity).
But, with axis of rotation in z, i.e.:

$$\boldsymbol{\Omega}_{\mathrm{b}} = \Omega_{\mathrm{b}} \hat{\mathbf{e}}_z$$

this simply becomes

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Nothing hard!

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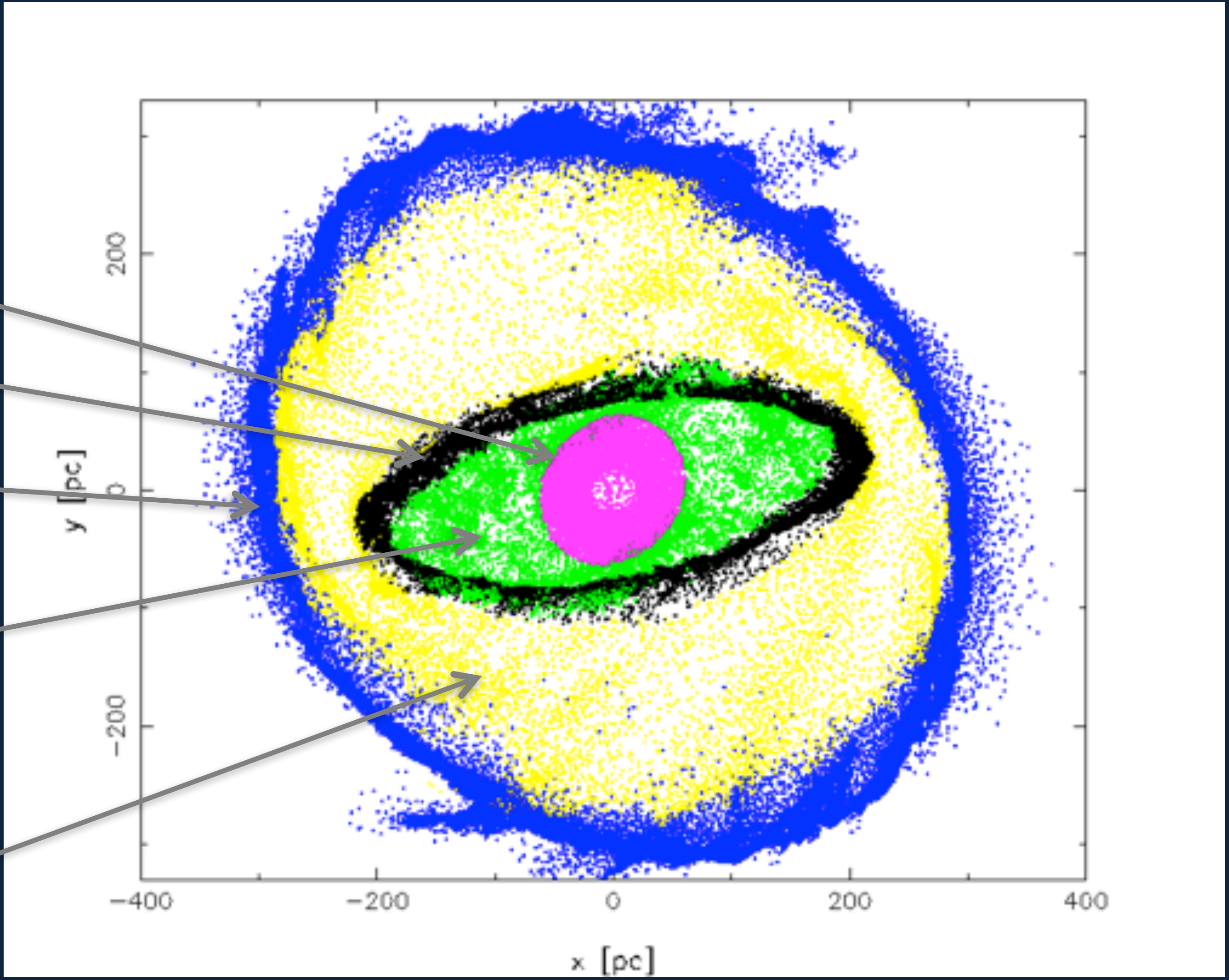
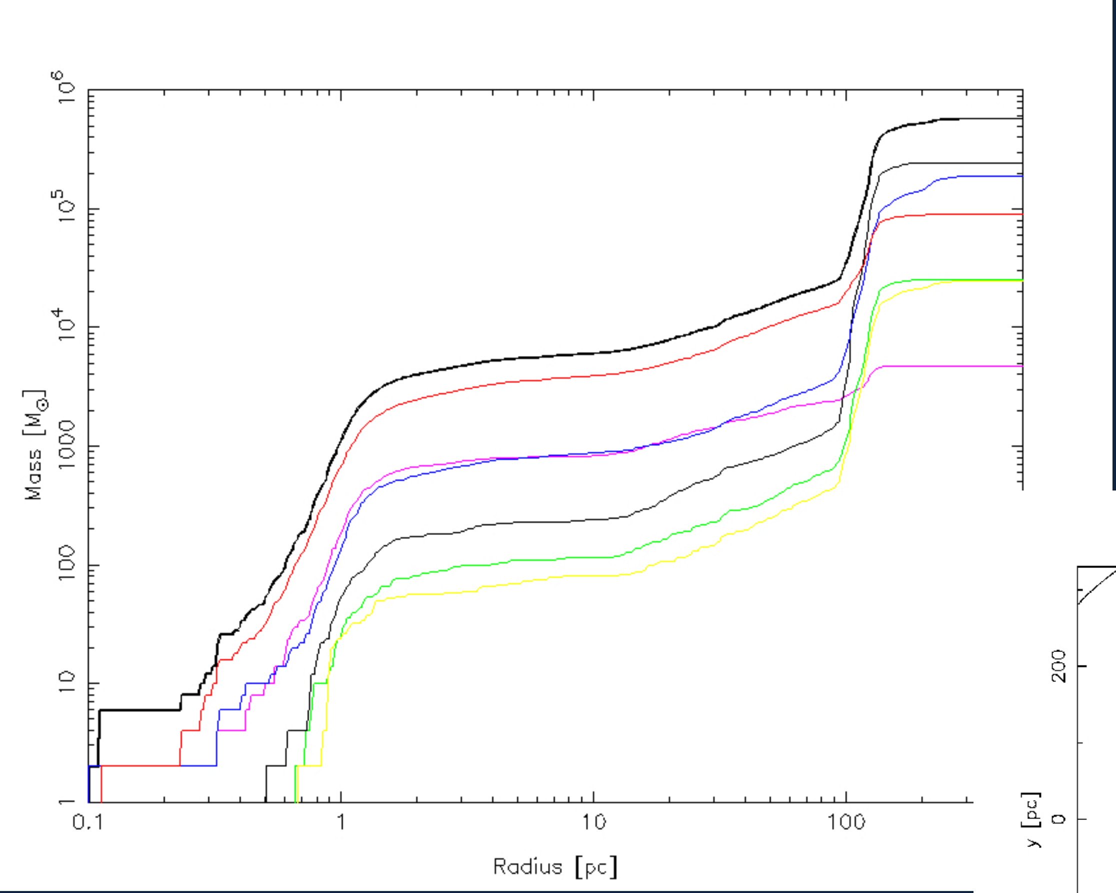
Identifying structures with E_J

Bracket by E_J to label:

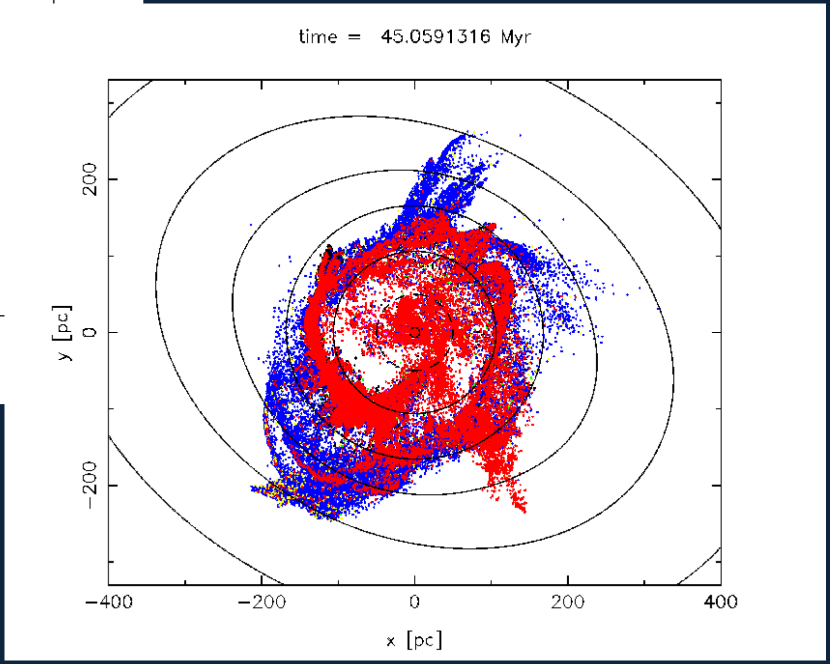
- Disk
- Inner ring
- Outer ring
- Disc to inner ring diffuse gas
- Inner to outer ring diffuse gas



Snooker/billiard/take-your-pick ball impact

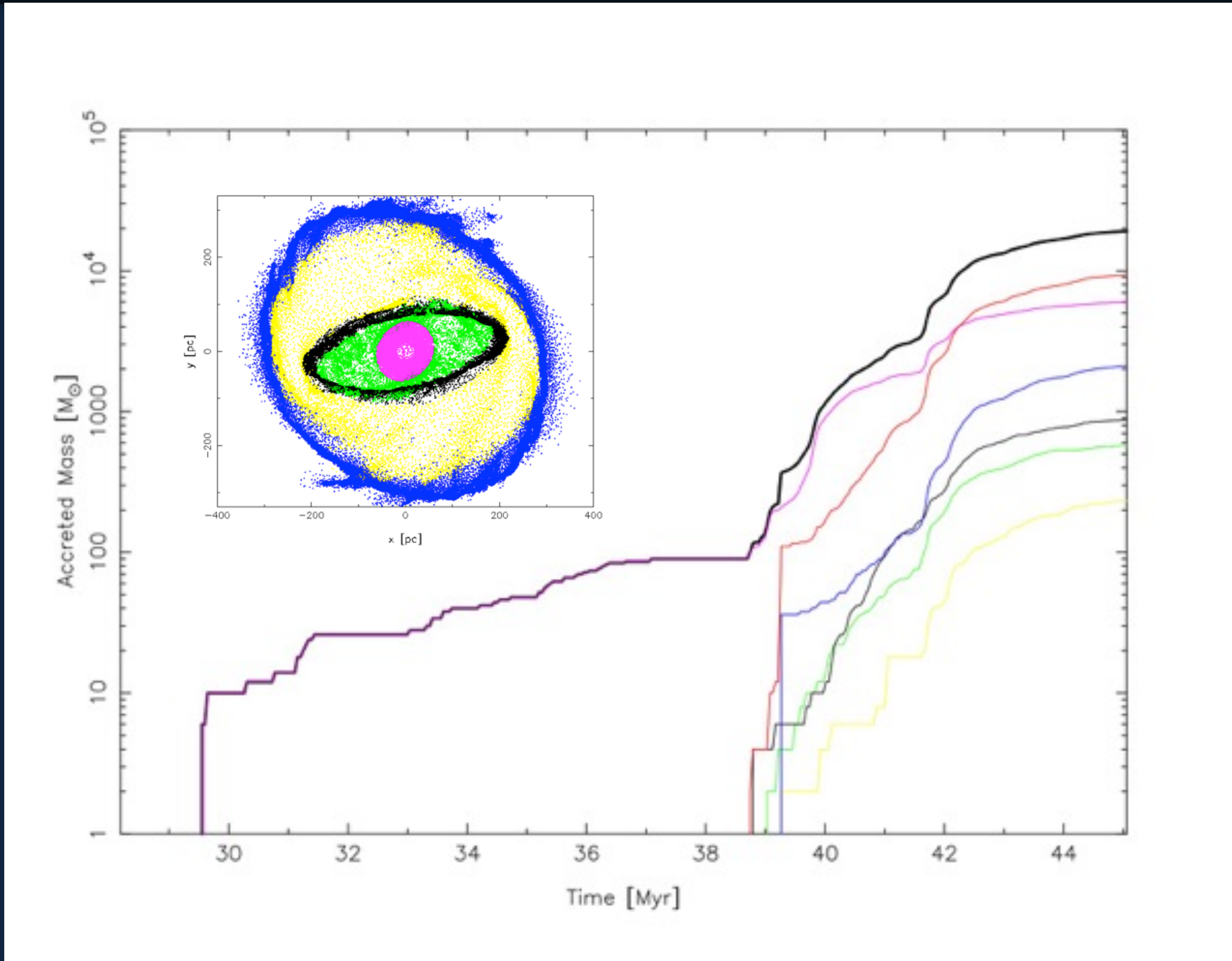


- Cumulative mass with radius.
- Lines match particle colours.
- Thick black line at top is total mass.



- Significant gas infall only at later times after multiple passes.

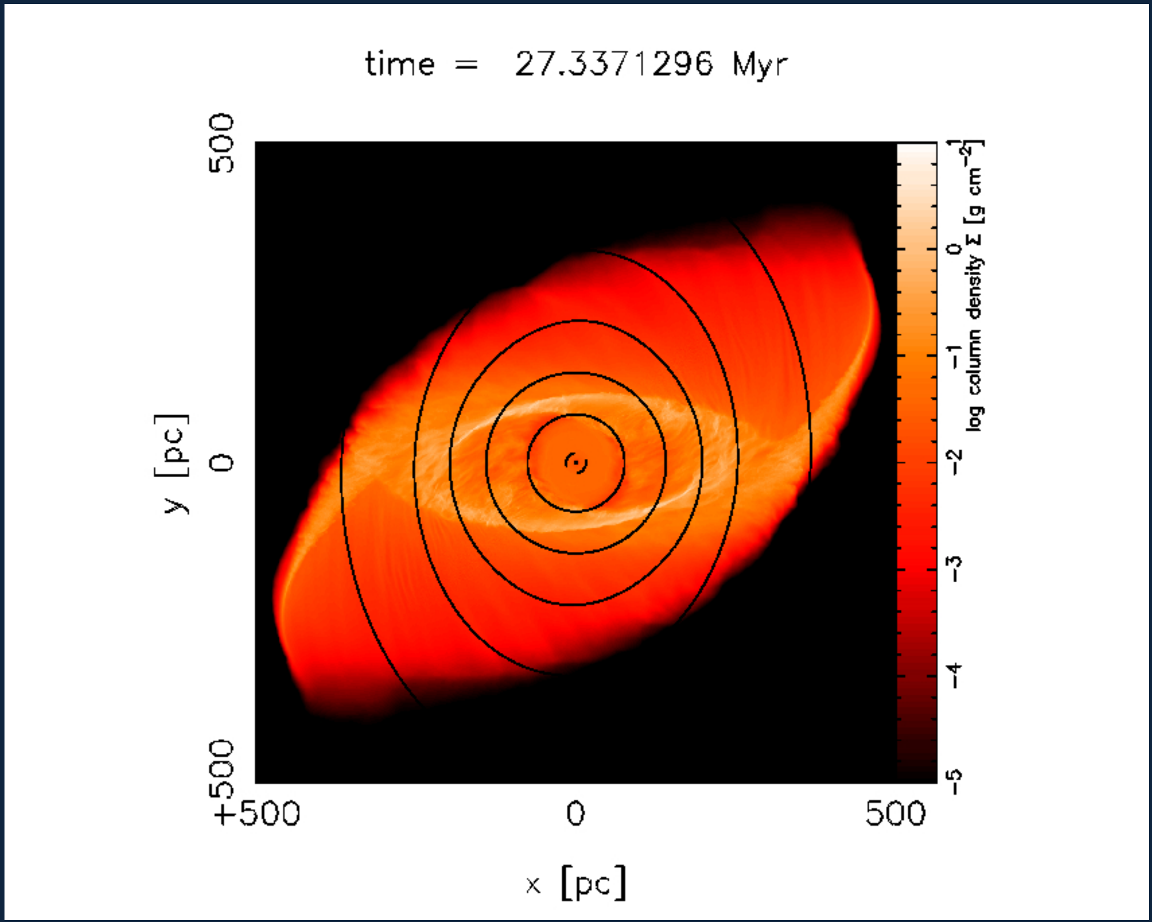
Direct accretion to BH sink particle

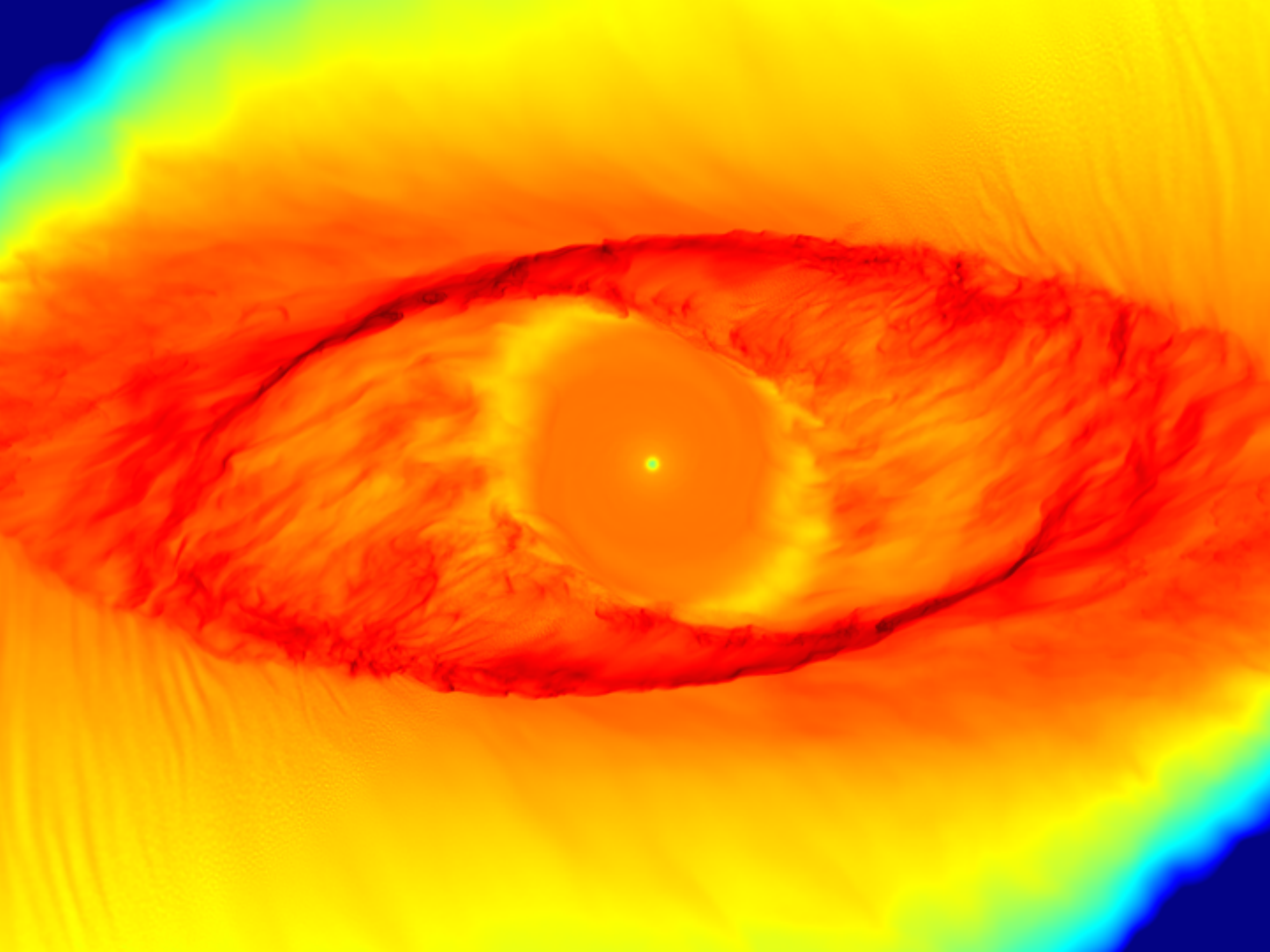


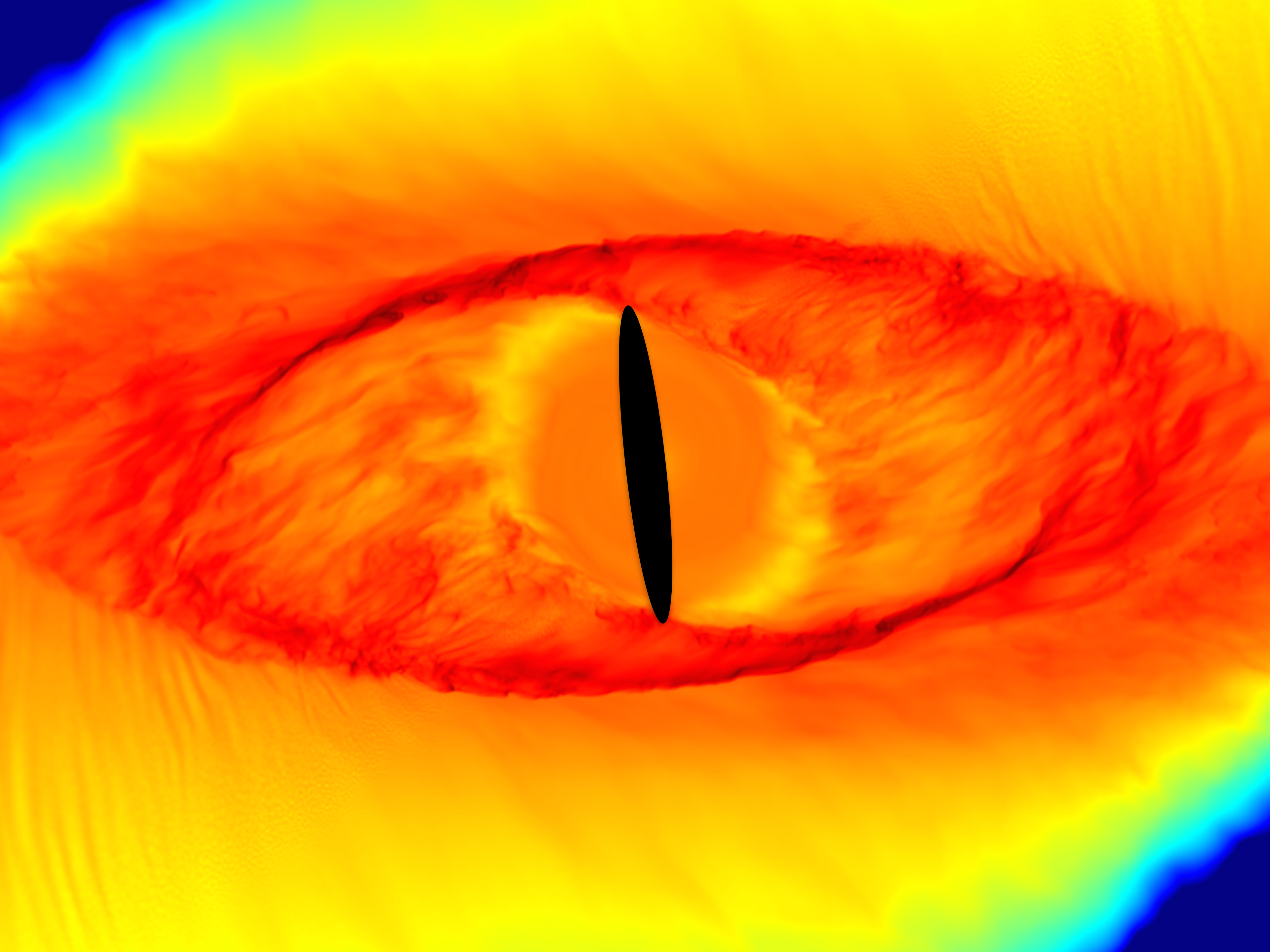
High resolution, high mass simulation

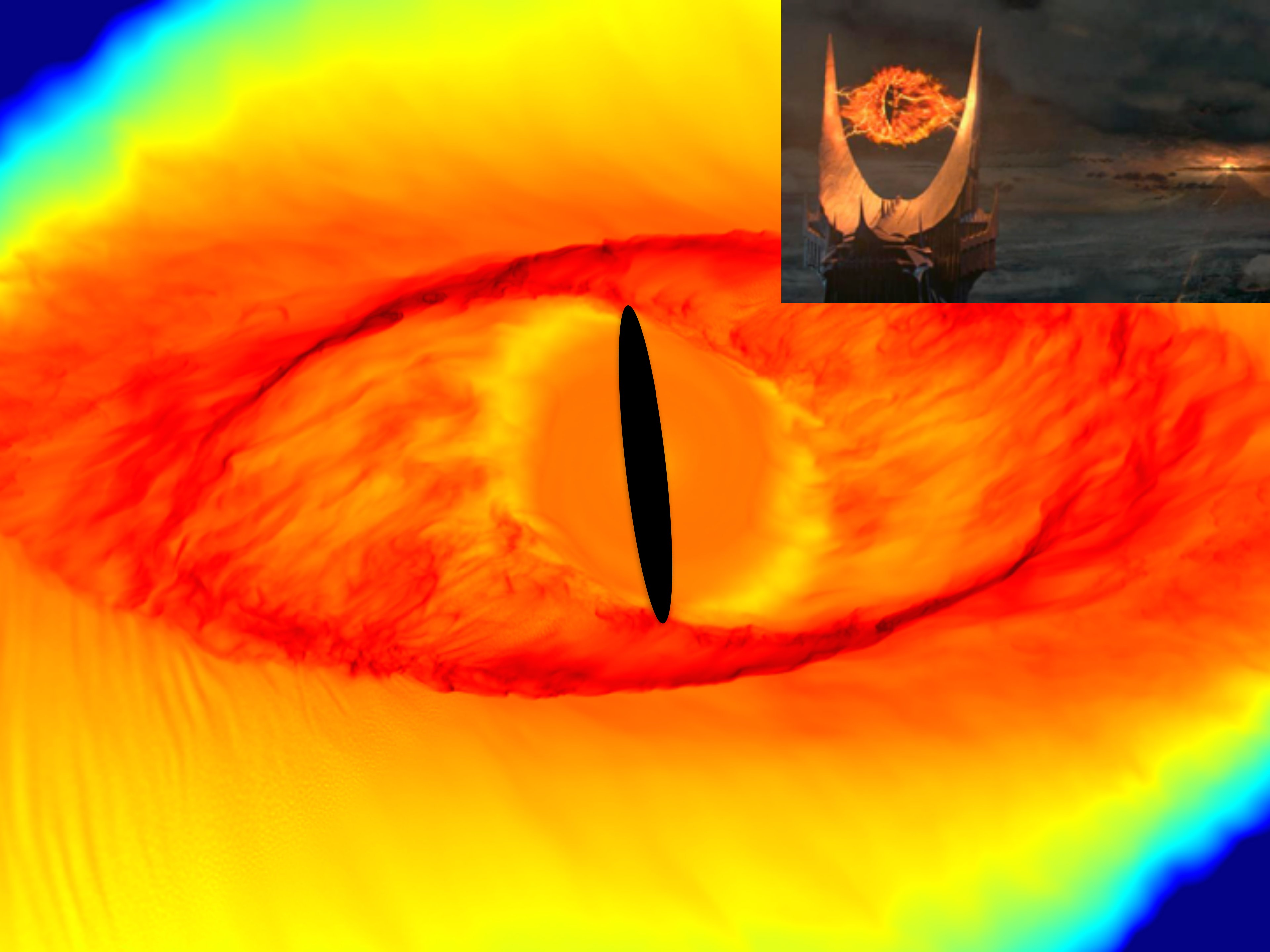
Reworking with:

- 50 million particles representing 10^8 $M_\odot$ of gas.
- 1 sink particle (BH)
- Slightly slower transition to bar from axisymmetric
- Running in OpenMP/MPI hybrid over 256/512 cores on DiRAC ‘complexity’

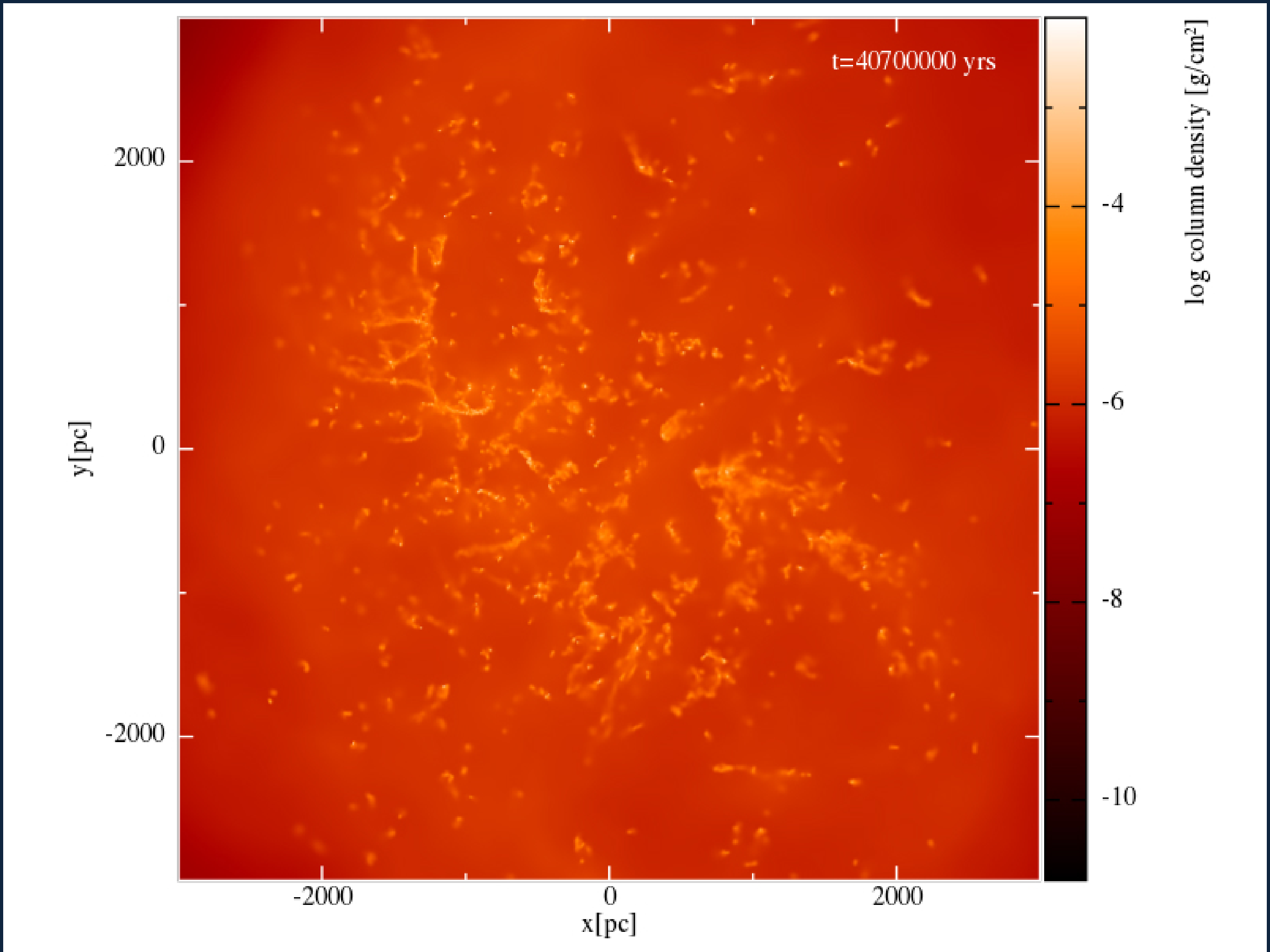








A bit extra: supernova feedback!?



Take home points:

- Tidal disruption of a single large cloud -> gas ribbon, likely containing multiple clouds along its length.
- Potential + turbulence causes the ribbon to resemble the features of the observed ring.
- Easy to form an x_2 type ring. Low level of accretion from inner gas disc (10^{-5} $M_\odot$ yr^{-1}).
- Disrupting the system increases accretion in the chaotic aftermath (10^{-3} $M_\odot$ yr^{-1}).
- SF / AGN? – but we again require input from further out into the Galaxy, and are not accounting for feedback.