Molecular clouds, star formation, and a black hole

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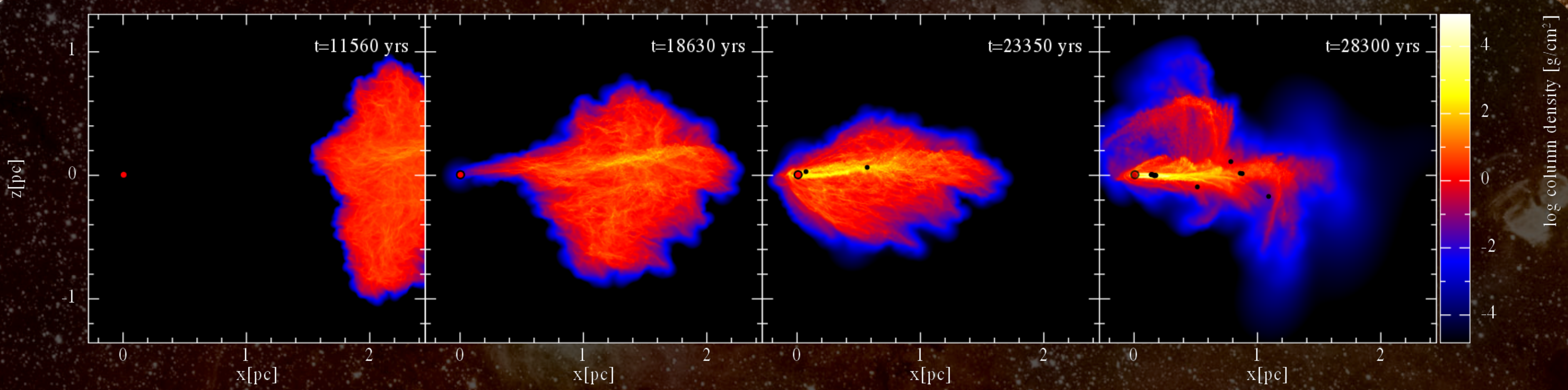
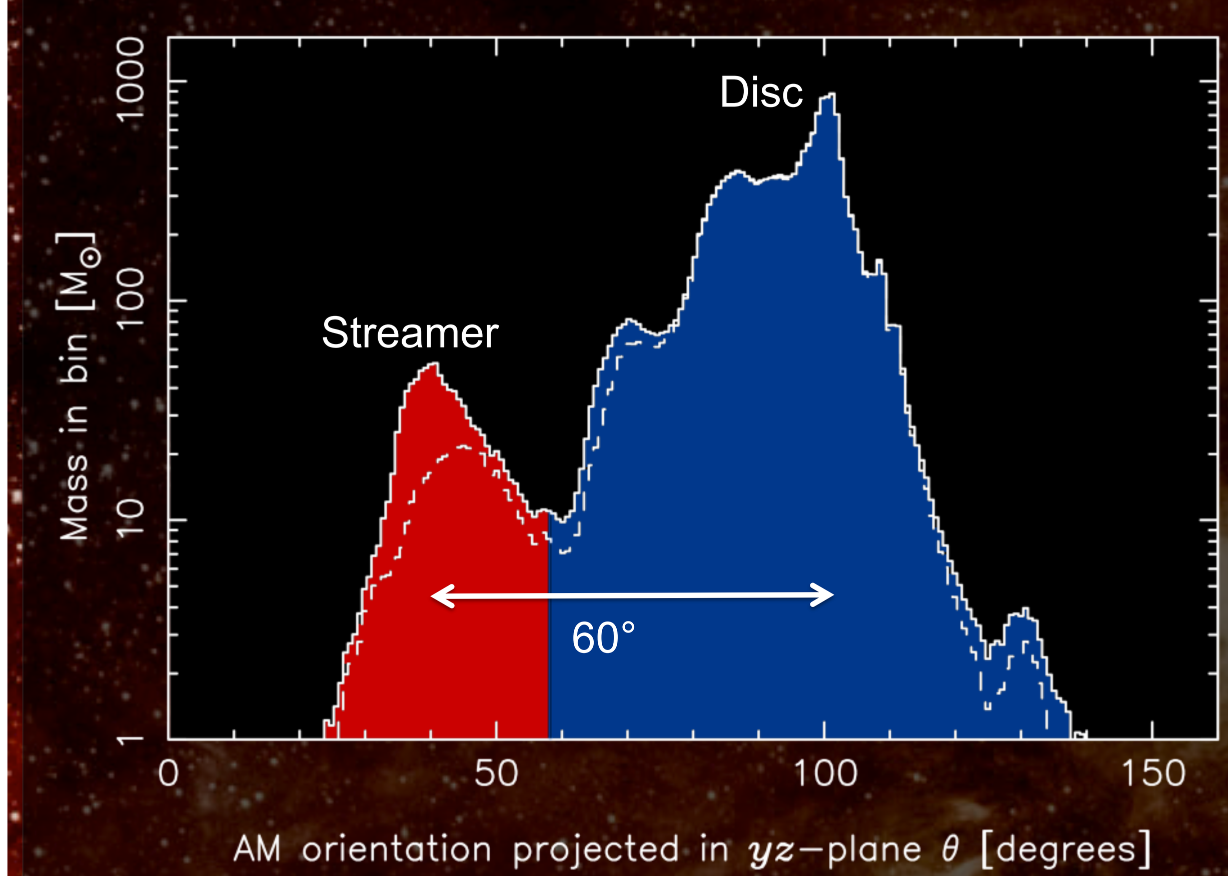
Two misaligned discs or streamers of young (~6 Myr) massive stars orbit the massive black hole in the Galactic Centre, Sagittarius A*, from 0.05 to 0.5 pc (Paumard et al. 2006). A fragmenting disc can provide an *in situ* origin (Bonnell & Rice 2008), but how do two discs come about? Here we show a single prolate cloud can form structures in two distinct orbital planes as the gas cloud tumbles over and under the black hole.

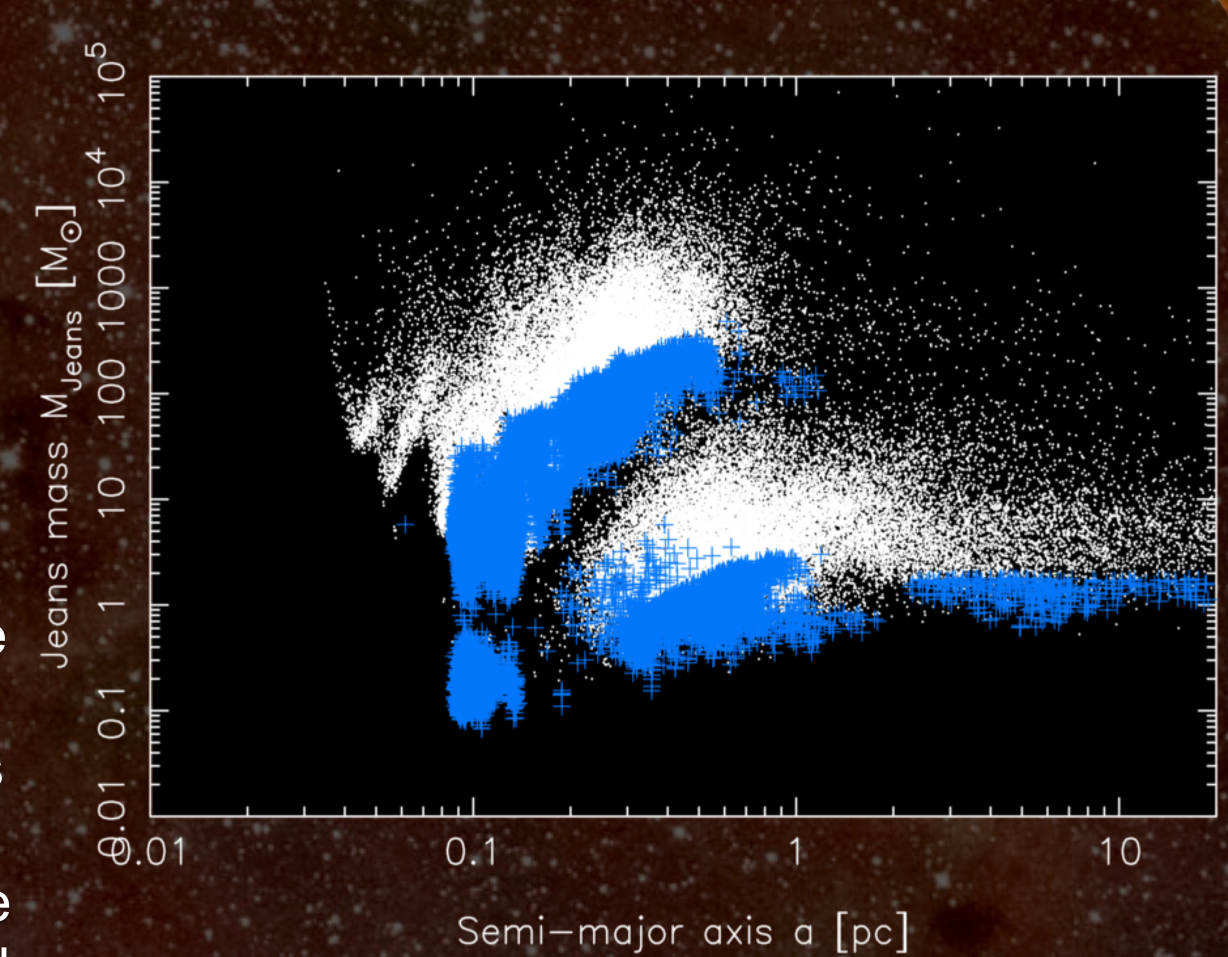


Smoothed particle hydrodynamic (SPH) simulations show the infall of a cloud of $2\times10^4\ M_\odot$ towards a black hole of $4\times10^6\ M_\odot$, represented by the red circle at the origin. A disc has formed in the x-y plane, seen almost edge-on, while a streamer has swept around the black hole at 60° from the disc. Black dots are sink particles, representing stars. By the end, nine sinks had just formed which were bound to the black hole on small orbits with semi-major axes of 0.09 pc and eccentricities of 0.75. They had between two and three solar masses.

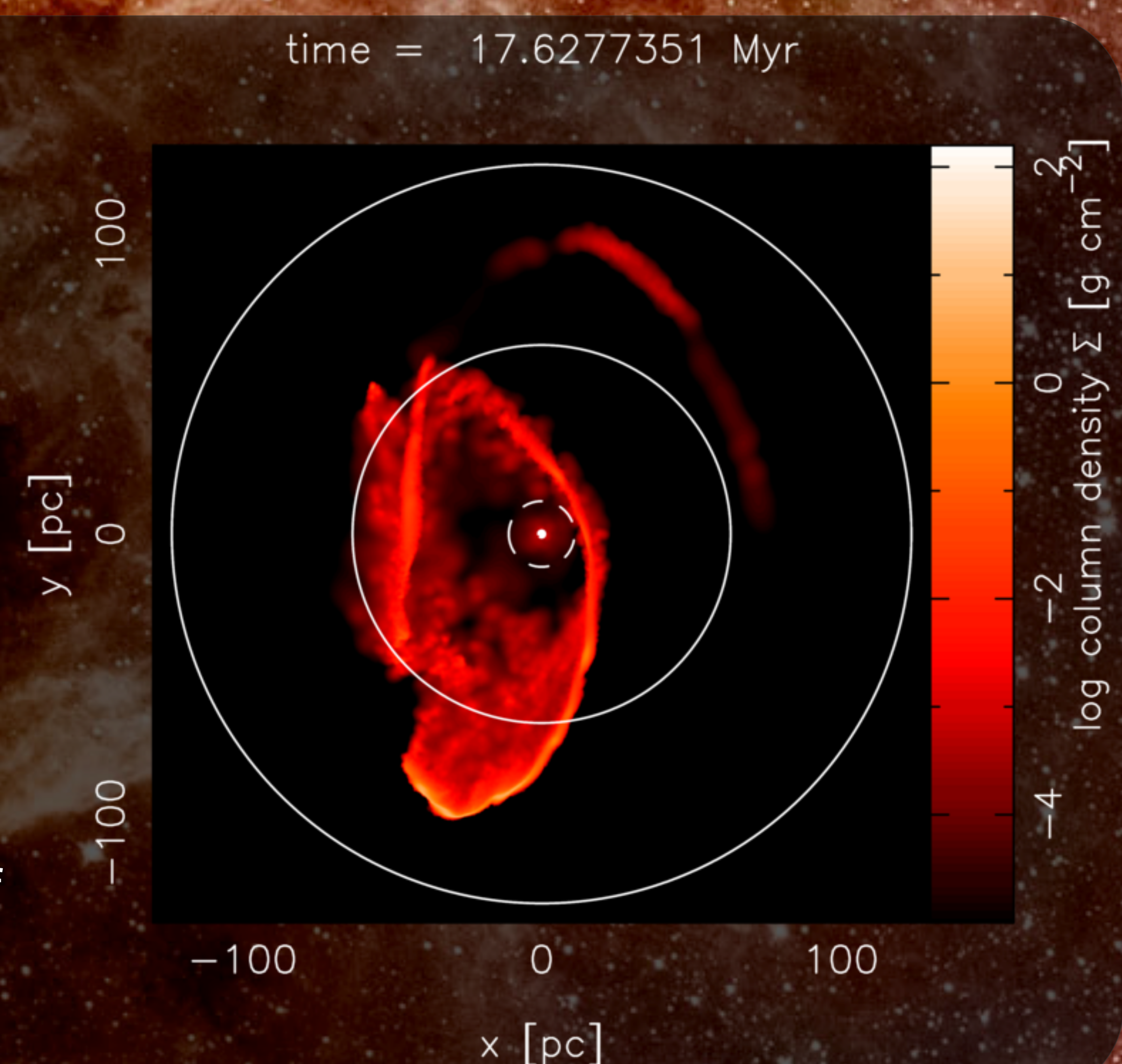


The plot on the left shows gas at the simulation's end at 28300 years binned by the orientation of its angular momentum in the yz-plane, essentially the angle by which its orbital plane is rotated out of the xy-plane. While the solid line represents all gas, the dotted line only shows that which was bound to within one parsec of the black hole.

Fragmenting gas must have a cooling timescale less than three times the dynamical timescale (Gammie 2001). Here we show the Jeans mass and semi-major axis for all the gas which fulfilled this criterion at the simulation's end. The blue crosses mark the gas which also exceeded the local tidal density.



Orbits in the Galactic Centre can be complex. On the right an initially unbound cloud of gas has been tidally sheared. Its non-closing orbit has led to the stream intersecting with itself. Whether tidal forces can also compress the gas to form a bound molecular cloud is a question we aim to answer.
Moving outwards from the black hole the gravitational potential changes from being spherical to axisymmetric (as seen with the contours on the right) to triaxial beyond 200 pc when the Galactic bar dominates. Infall may occur as a result of the complex orbits that arise, either intrinsically or as a result of loss of angular momentum via shocking that occurs at intersections.



Results

We present the simulation shown above and fifteen others in Lucas et al. (2013). We find that the mechanism for streamer formation is viable, but highly dependent on the density structure of the cloud pre-black hole interaction. If it is close to symmetry about the orbital plane, the angular momentum is cancelled out via shocking as gas flows around the black hole. Limited star formation took place before the simulations ended, with more likely to occur. For this simulation, the total mass of star forming gas in the streamer (seen above as the blue crosses at large radii) is only $21\ M_\odot$.

REFERENCES:
Bonnell I.A., & Rice W.K.M., 2008, *Science*, **321**, 1060
Gammie C.F., 2001, *ApJ*, **553**, 174
Lucas W.E. et al., 2013, *MNRAS,* in press
Paumard T., et al., 2006, *ApJ*, **643**, 1011

Infalling cloud plots with SPLASH by Daniel Price (Price D., 2007, *PASA*, **24**, 159)
Image: Hubble/Spitzer composite of the Galactic Centre
Credit: NASA, ESA, Q.D. Wang (University of Massachusetts, Amherst), S. Stolovy (Caltech)

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