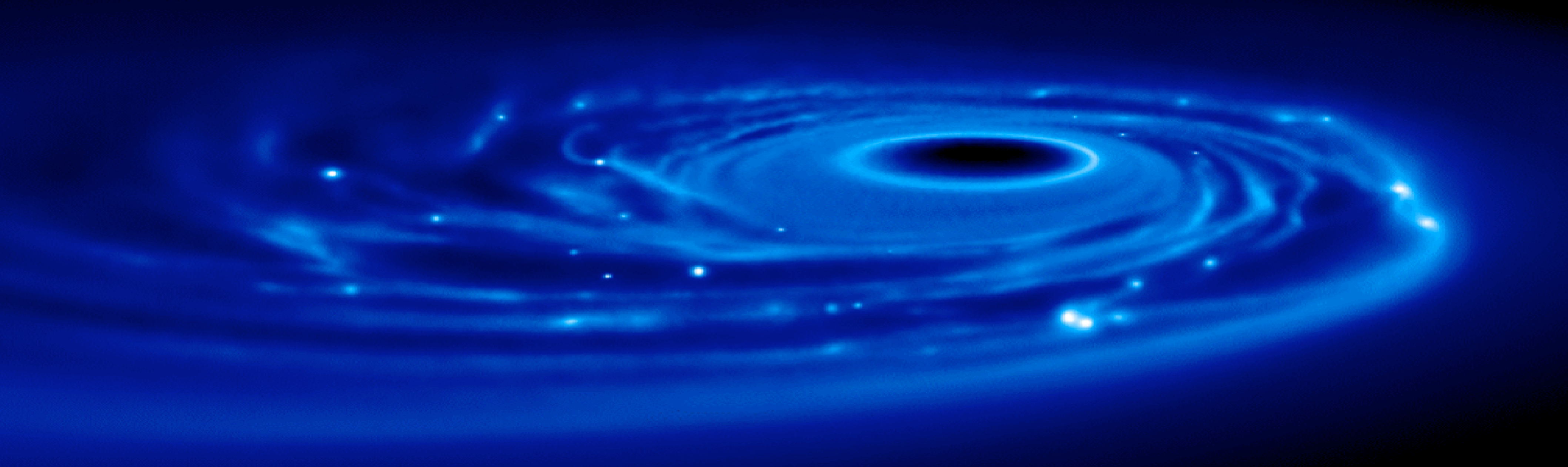
Formation and Dynamics of Nuclear Stellar Discs in the Galactic Centre

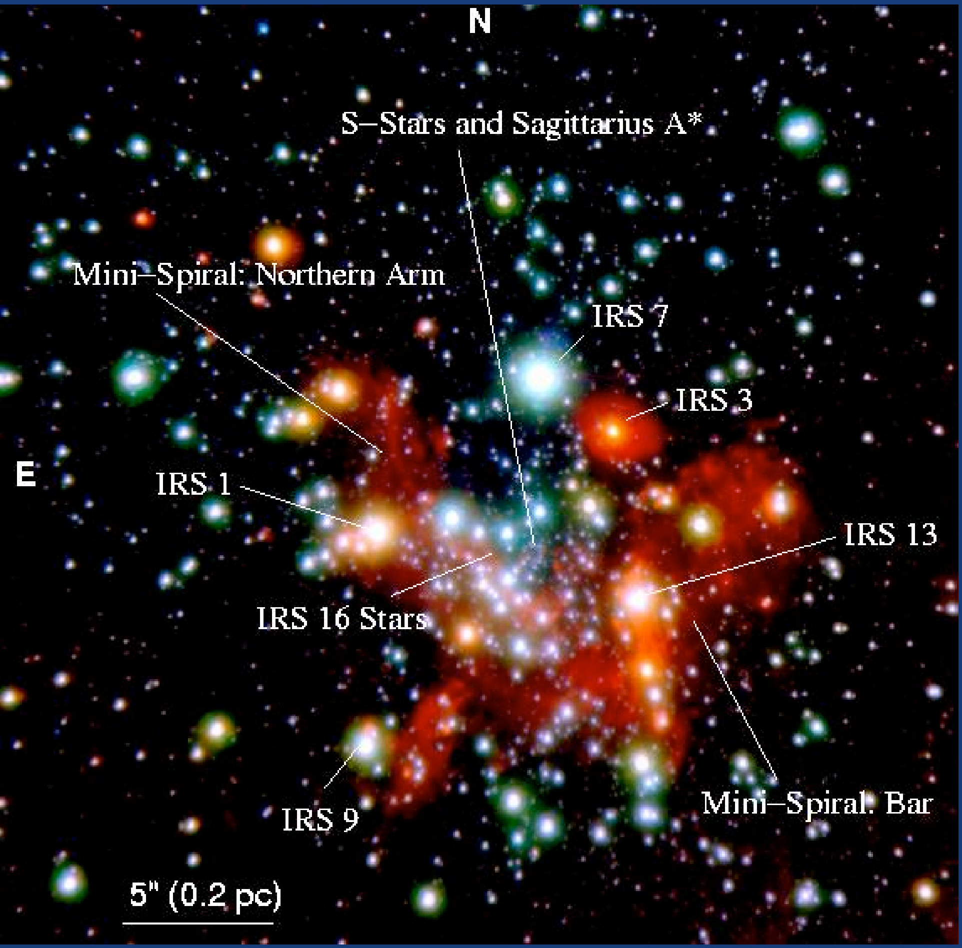


Jorge Cuadra

MPA Garching

S. Nayakshin, P. Armitage, R. Alexander,
V. Springel, M. Begelman, W. Dehnen, R. Genzel

Young Massive Stars in the GC



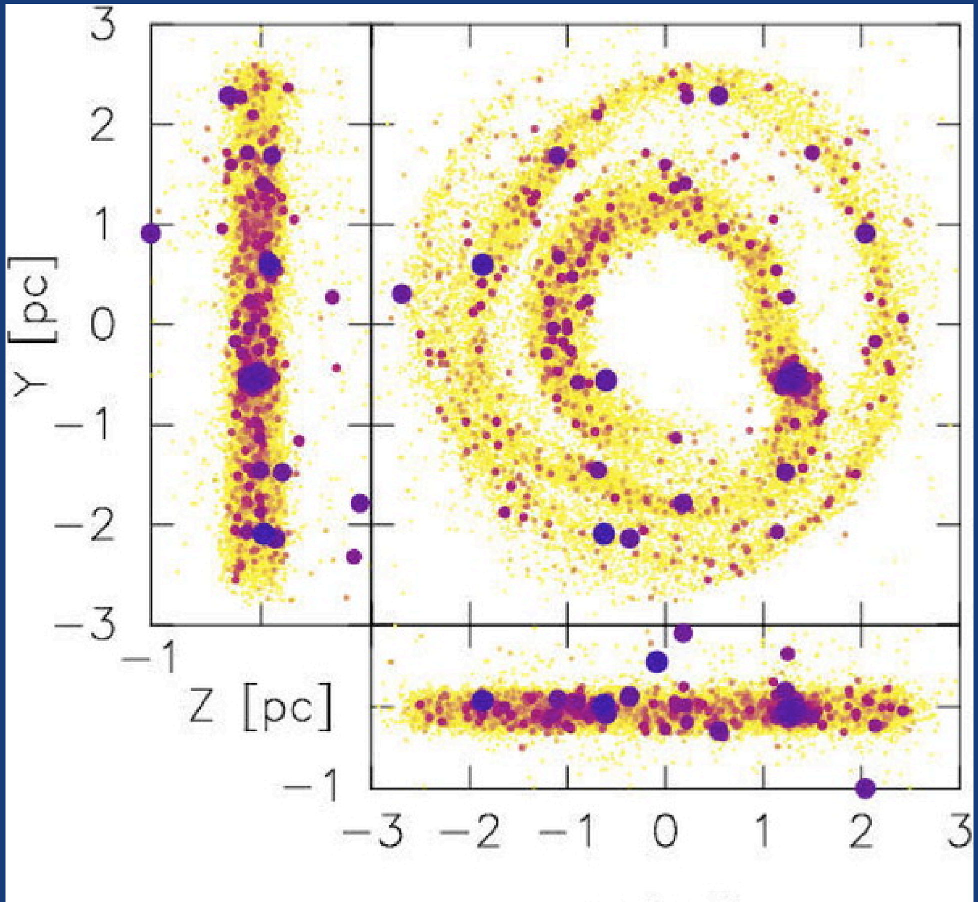
- BH is surrounded by young stars, ~ 5 Myr old.
- What's the origin of the stars?
  - Strong tidal force from the BH requires density ~ 10^8 cm^{-3}, much higher than mol clouds.
- There should be no star formation in inner pc, but we do see young stars at 0.1 pc!

Genzel, Ghez talks

Inspiraling cluster?

Migrated from outer regions? (Gerhard; McMillan & Portegies Zwart; Hansen & Milosavljević; Kim et al; Levin et al; etc)

- Dynamical friction.
- Efficient for compact and massive clusters: $\sim 10^6$ M_{sun}.
- Intermediate mass black hole?
  - Need too massive $\sim 10^4$ M_{sun}.
- No 'tail' observed in NIR or X-rays: hard to reproduce.



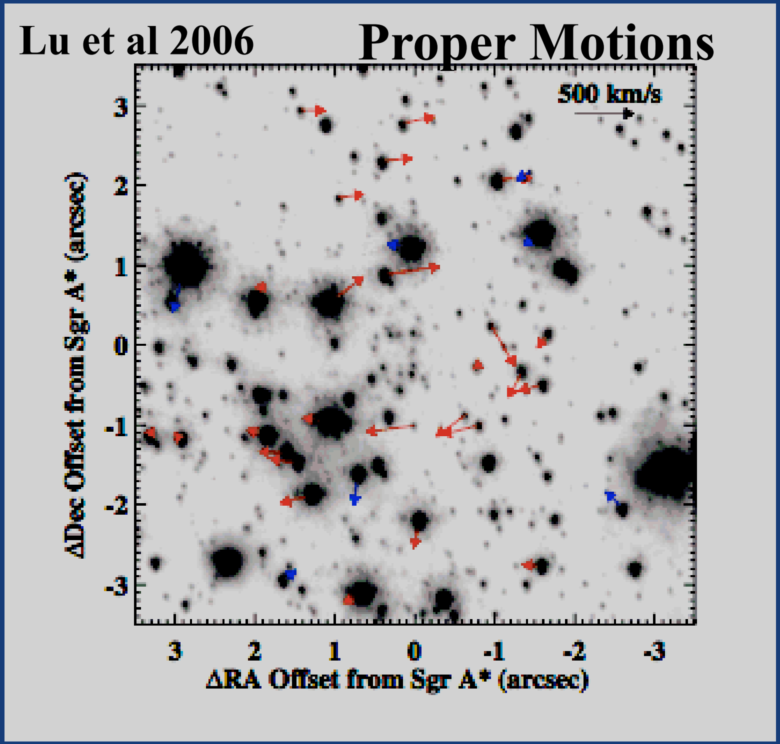
Portegies Zwart et al 2006

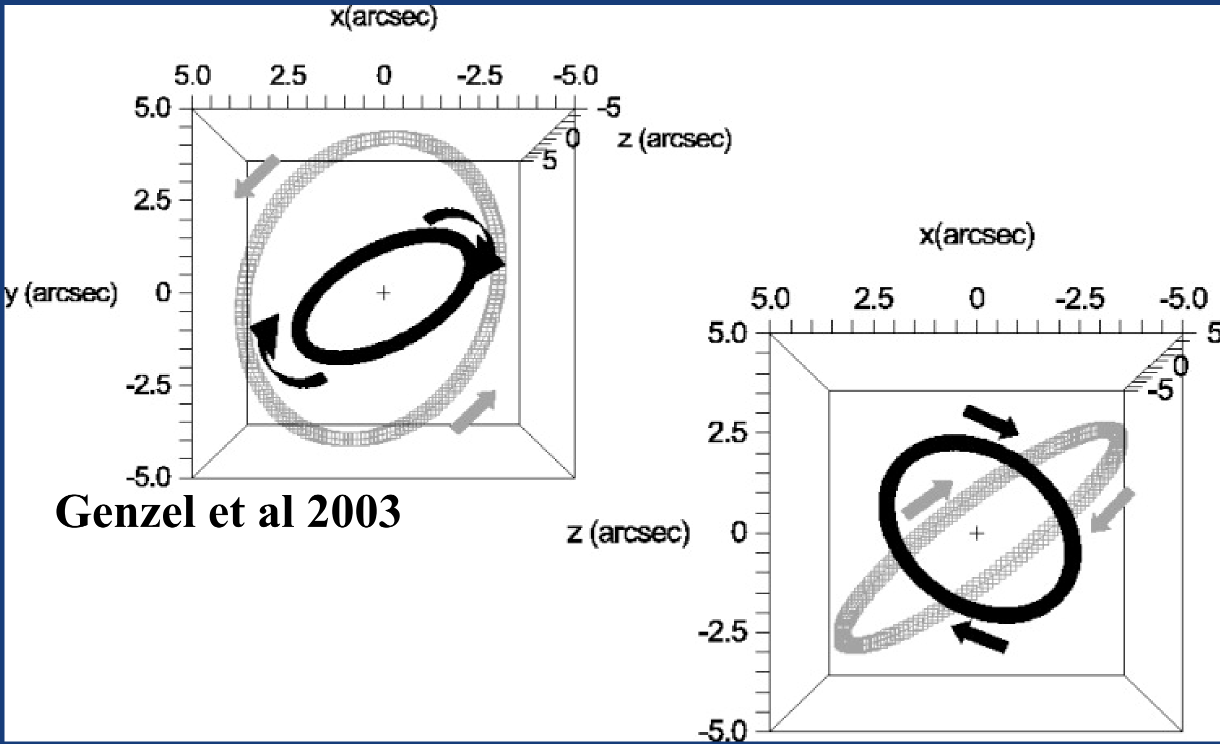
Gualandris talk

Stellar Discs in the Galactic Centre

- *Most* young stars are distributed in one or two discs.
  (Levin & Beloborodov 03; Genzel + 03; Paumard + 06; Lu + 08; Bartko + 09)
- Suggests in situ star formation in discs.

Bartko talk



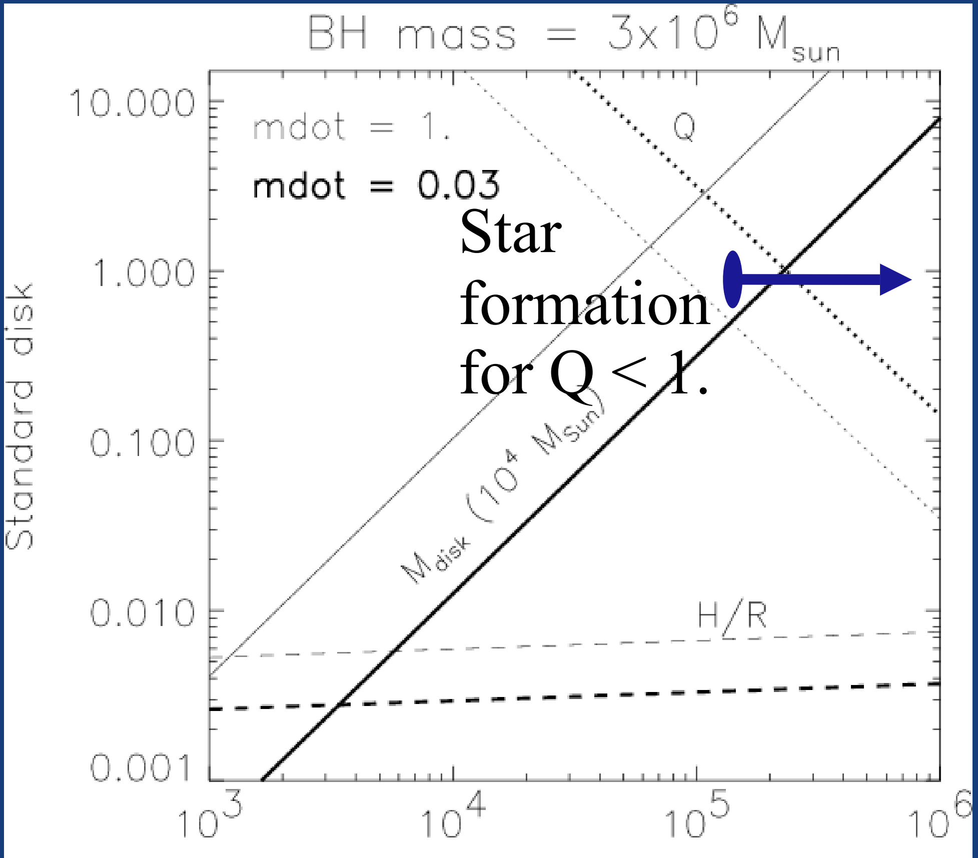


Star Formation in a Disc

- AGN discs become grav unstable at large radius.
  - Toomre $Q = \frac{c_s \Omega}{\pi G \Sigma} \sim \frac{H}{R}\frac{M_{BH}}{M_{disc}} < 1$

(Paczyński; Kolykhalov & Sunyaev; Shlosman & Begelman; Collin & Zahn; Goodman et al; Levin)

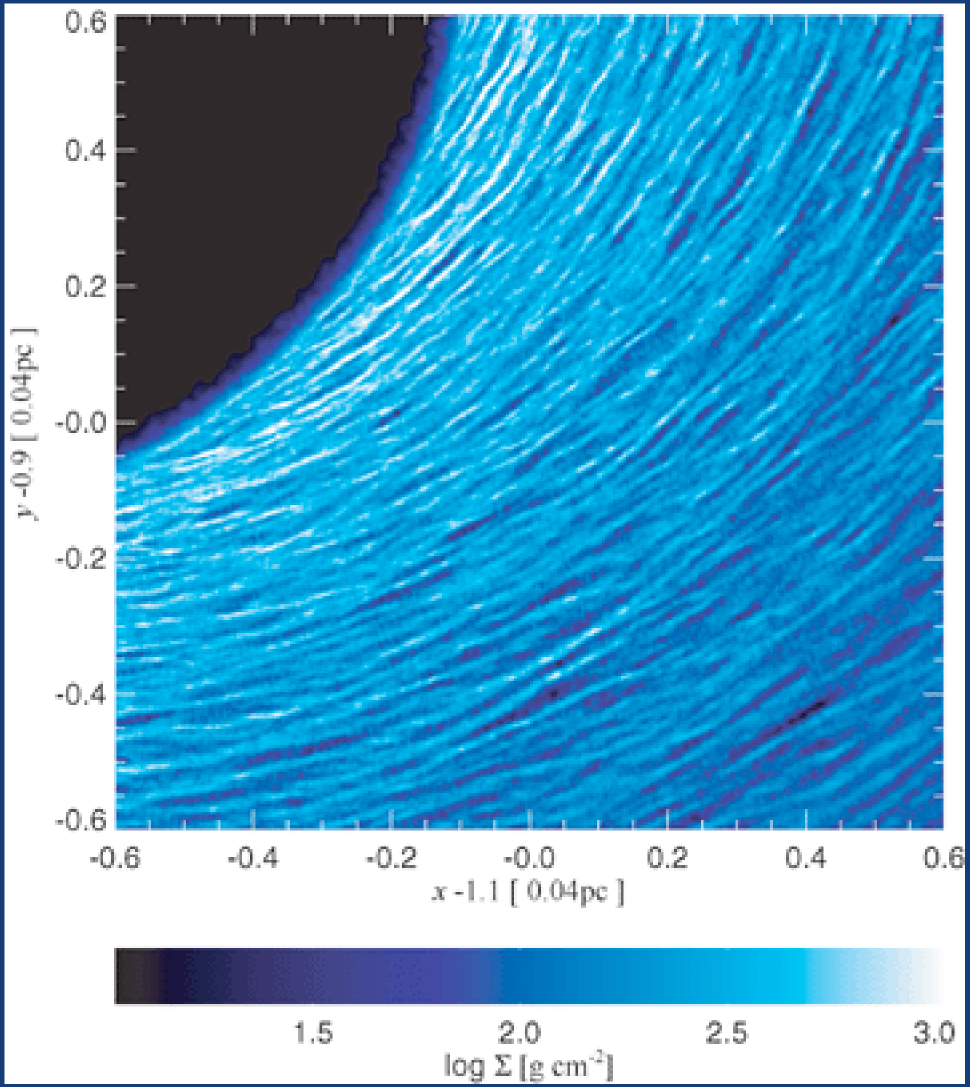
- If cooling is fast enough, clumps should collapse and form stars. (Gammie; Rice et al; etc)
- In the Galactic centre, need $M_{disc} \sim 10^4\ M_{sun}$.



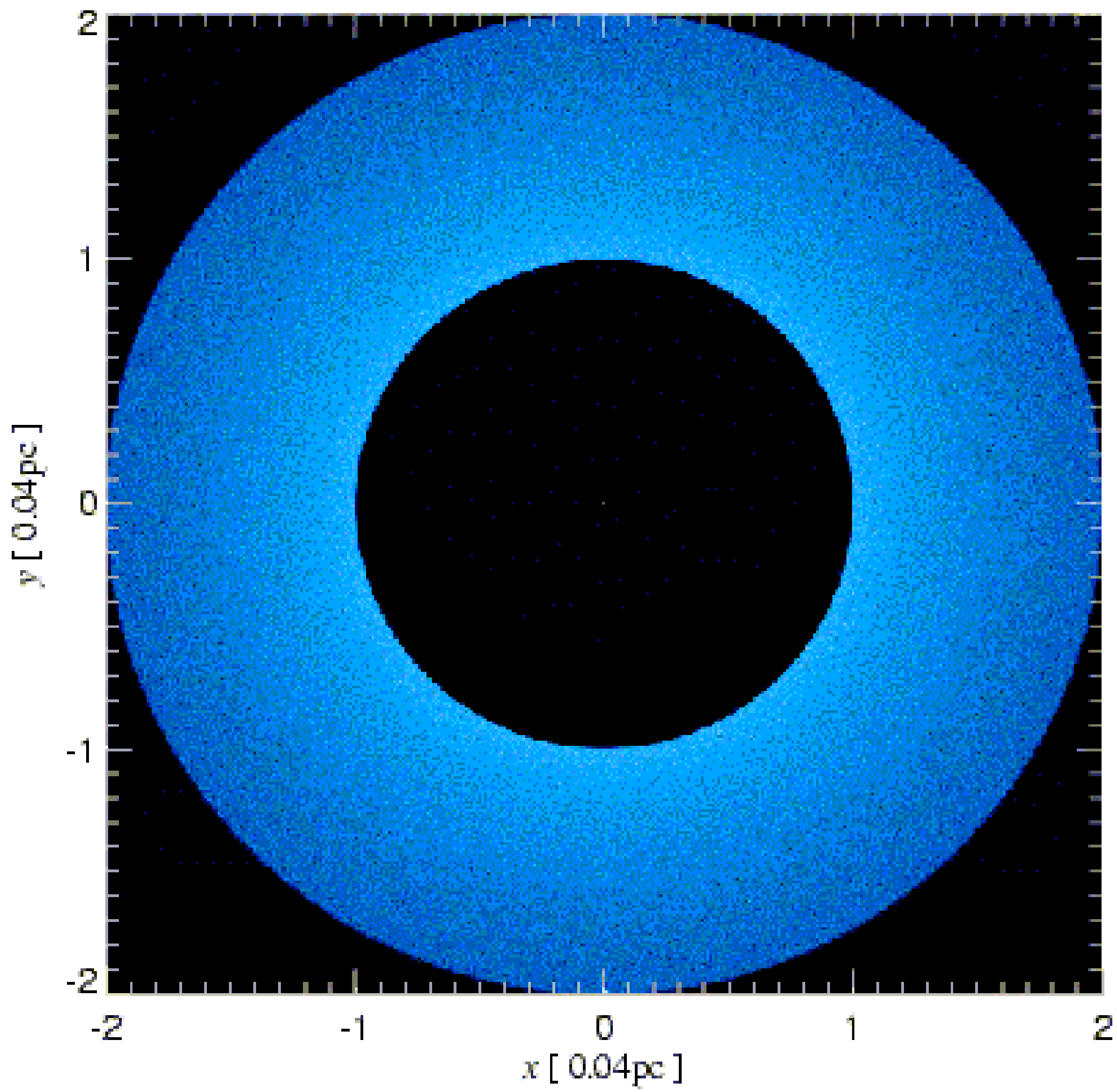
Nayakshin & Cuadra 2005

Numerical Models of Disc Fragmentation

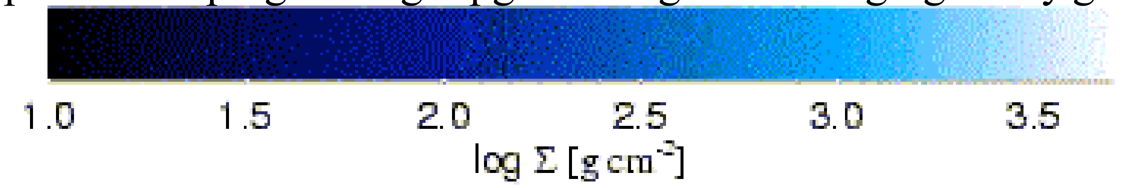
- Disc becomes clumpy due to self-gravity.
- Densest clumps become stars.
- Star formation happens very fast, just few orbital times.
- Gas disc ends up as a stellar disc.

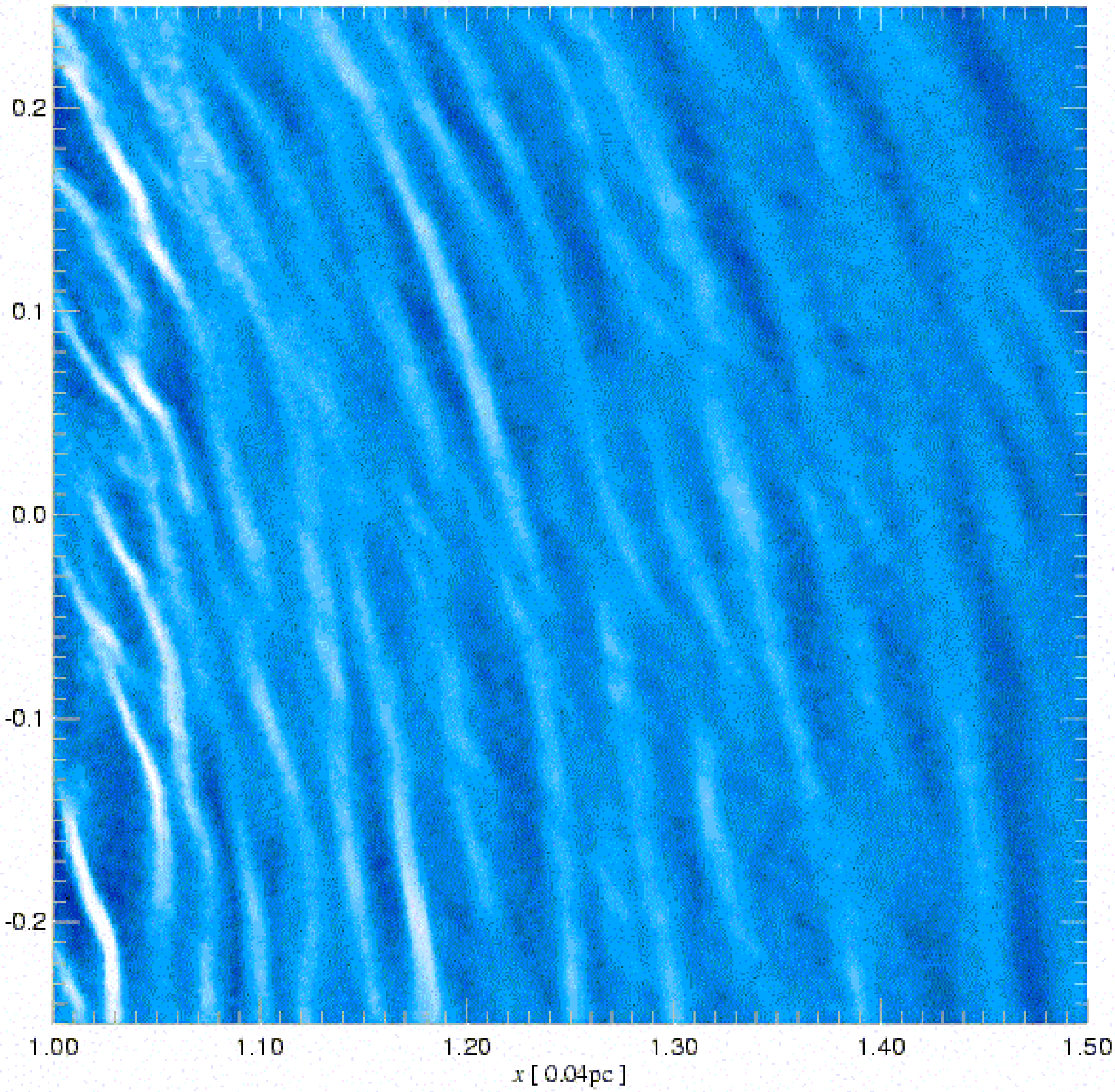


Nayakshin, Cuadra & Springel 2007

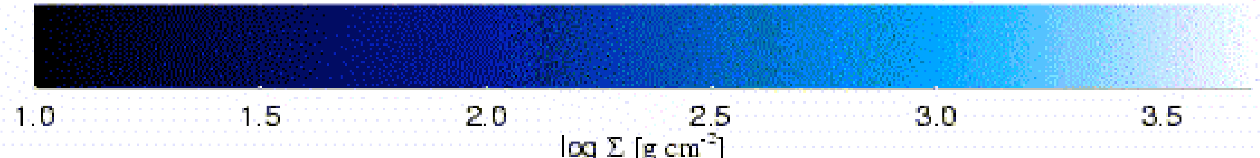


http://www.mpa-garching.mpg.de/~serg/movie.large-gasonly.gif



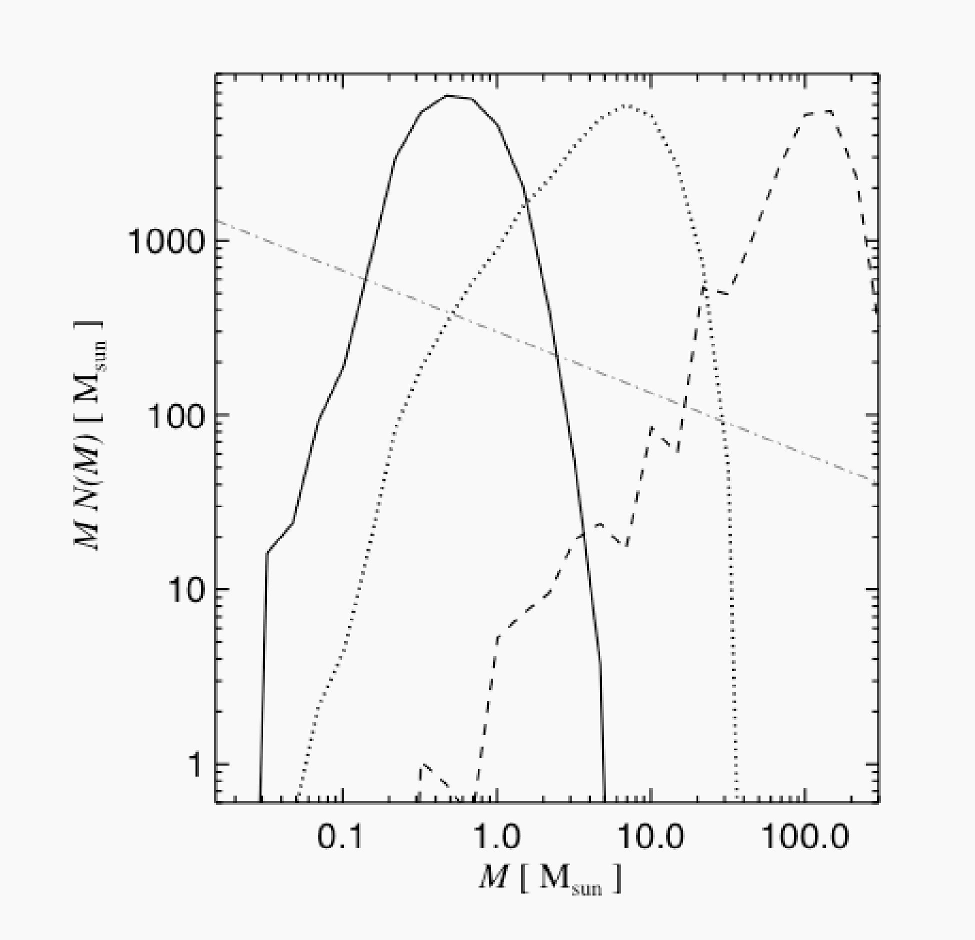


http://www.mpa-garching.mpg.de/~serg/movie.small-patch.gif



Stellar Mass Function

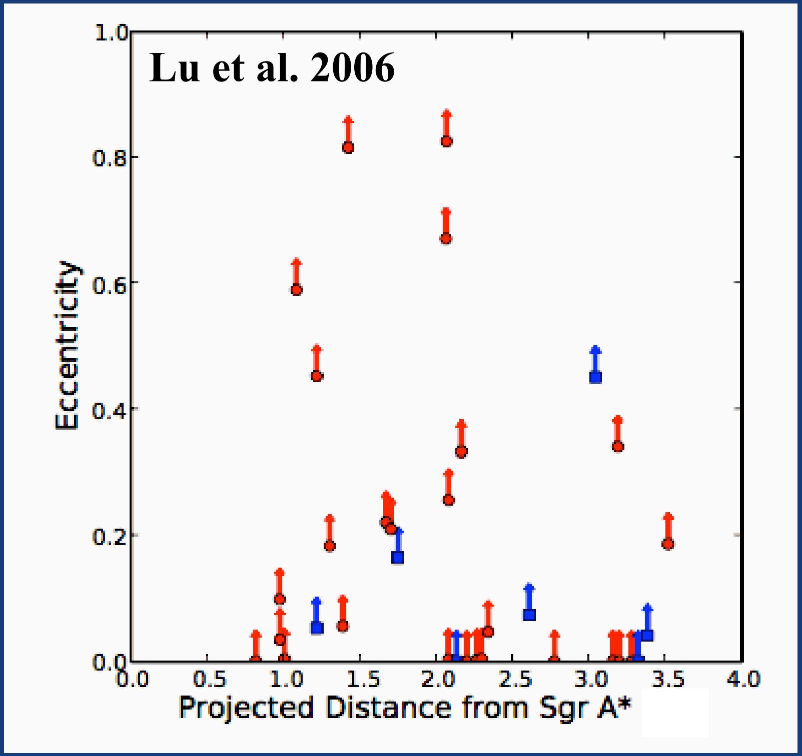
- Longer cooling time -> slower fragmentation -> fewer stars -> top-heavy mass function.
- Models still too simple, need better thermal and radiation physics ...
- What's left for the black hole to accrete?



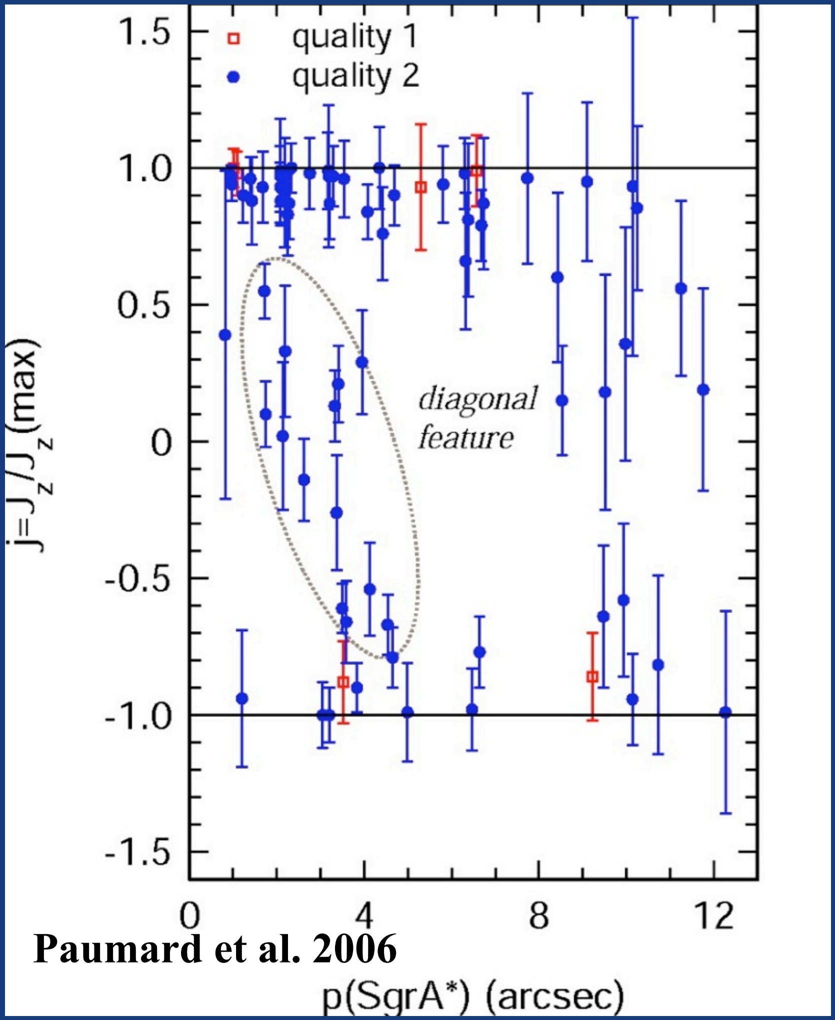
Observed Dynamics in the GC

- We can "easily" explain a disc of stars...
  Is that enough?

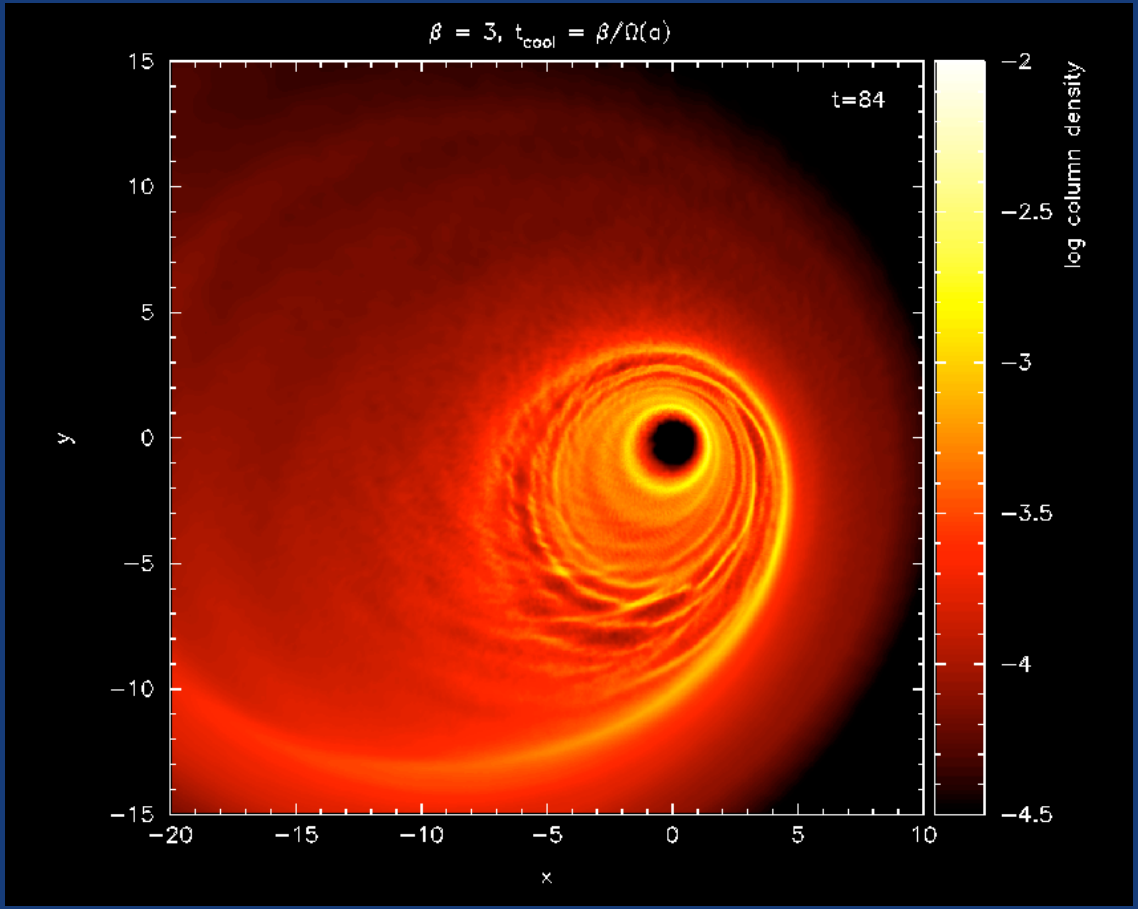
Eccentricities



Inclinations



Fragmentation in Eccentric Discs

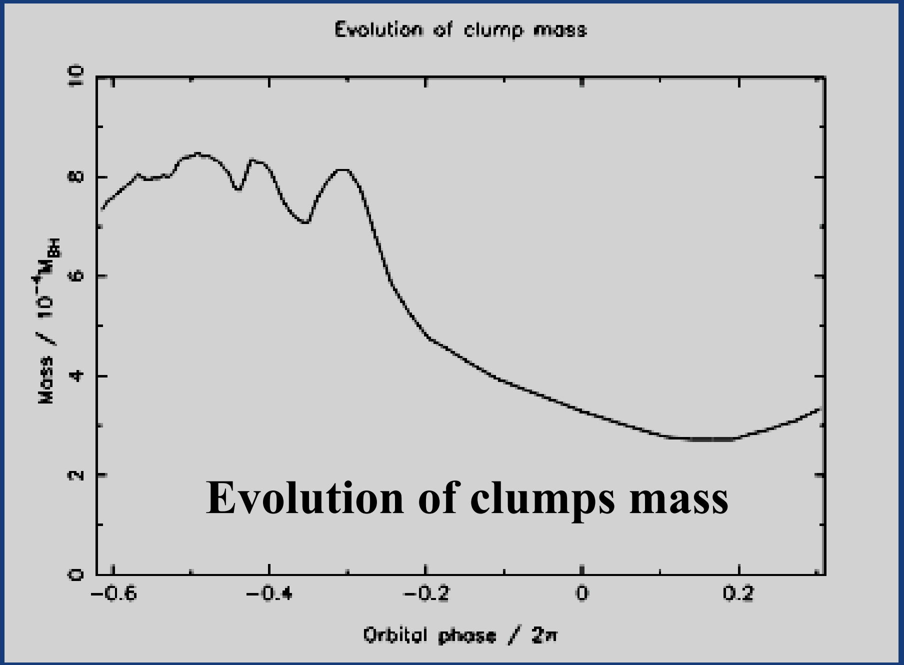


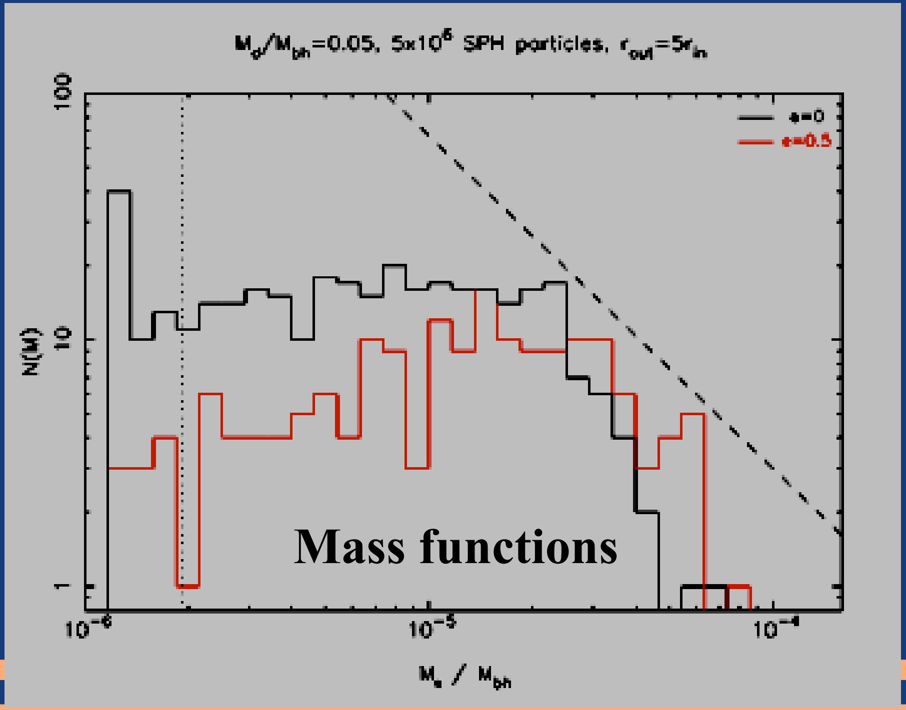
Alexander, Armitage, Cuadra, Begelman, 2008

Eccentricities can be just the result of the initial conditions

Fragmentation in Eccentric Discs

- Masses of clumps are affected by variable shear.
- Weakly-bound clumps don't survive pericentre passage.
- Resulting IMF is somewhat top-heavier.
- Stars retain original gas eccentricity.

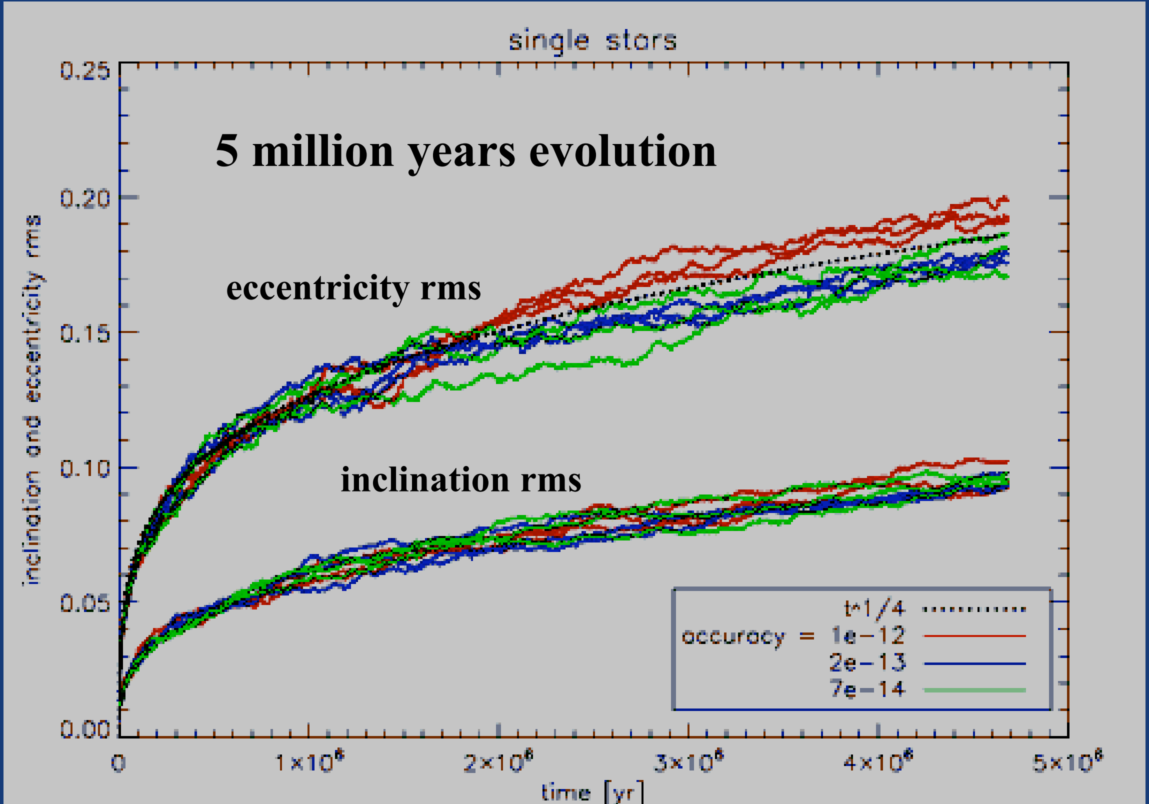




Dynamical evolution of a disc

- N-body scattering increases velocity dispersion.
- Dynamics of stellar disc dominated by central BH
  - dispersion grows slowly, $H/R \sim t^{1/4}$.

There's not enough time to achieve the observed inclinations.



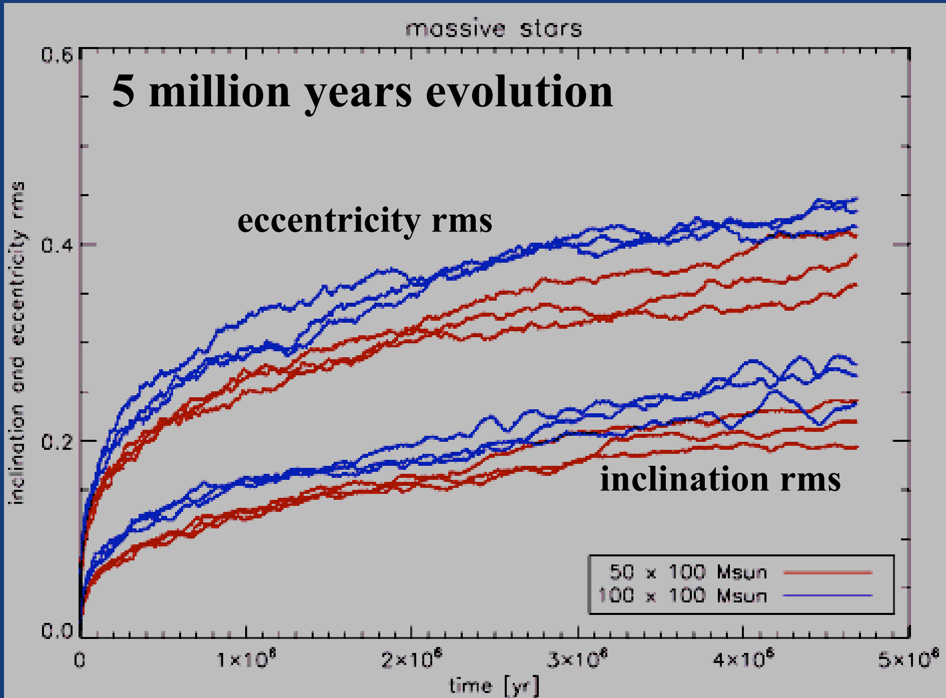
Cuadra, Armitage, Alexander 2008

Evolution of a disc with...

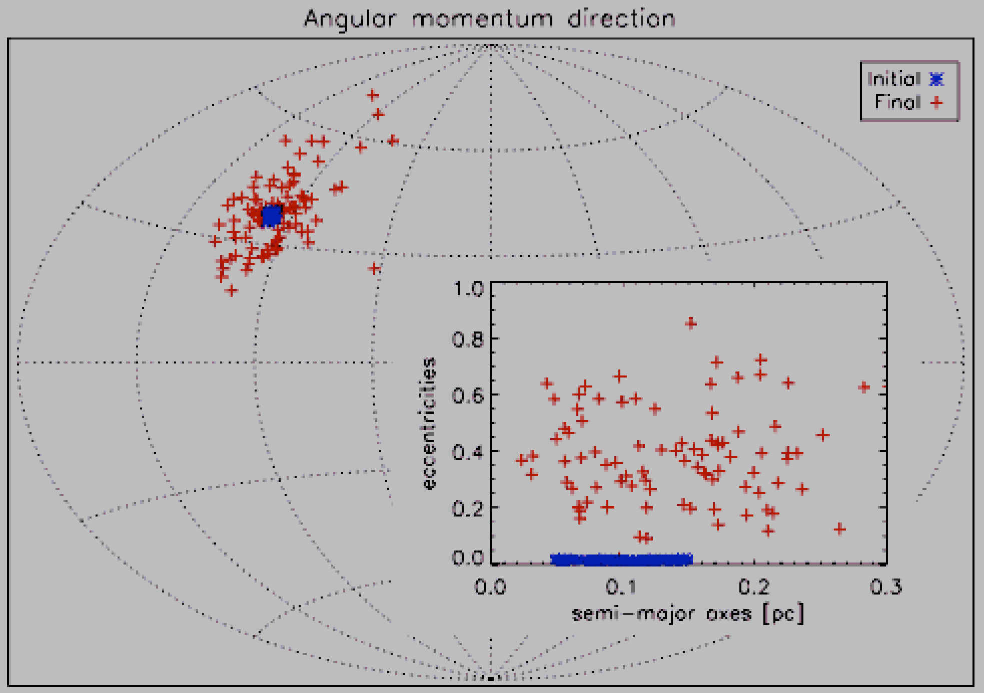
- Top-heavy mass function (as observed)
  - Avoid damping due to low mass stars (Alexander et al '07)
- Binaries
  - Shrinking binaries give energy to the system
- Initial eccentricity
  - More velocity dispersion
- Isotropic population of intermediate-mass black holes
  - Result of core-collapse in clusters (Portegies Zwart et al '06)
- Even more massive stars
  - Already exploded as supernovae

RR: Kocsis talk

Very hard to get large inclinations



Cuadra, Armitage, Alexander 2008



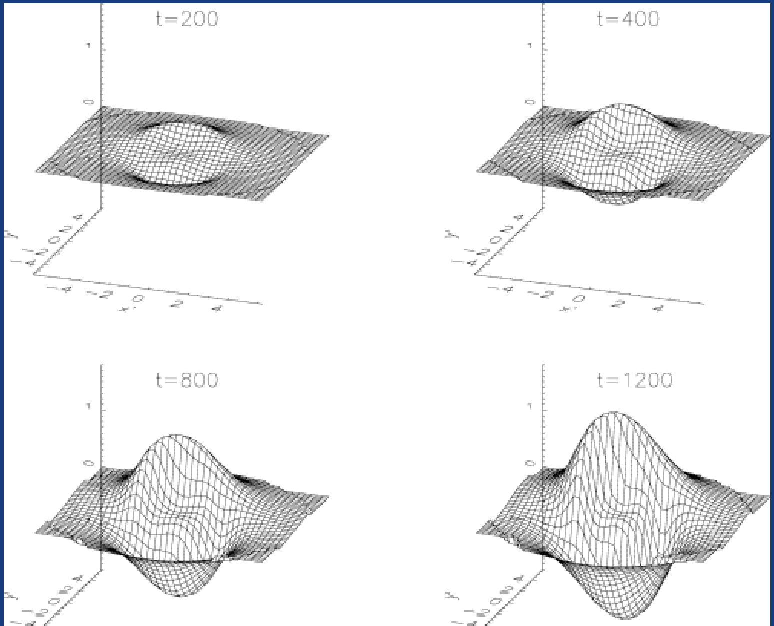
An initially cold disc remains a cold disc.

Need a more complicated origin for the GC stars.

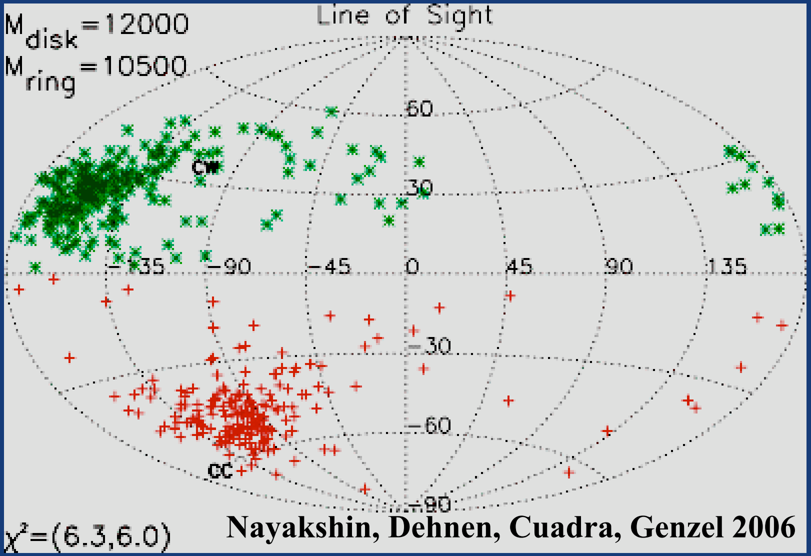
Alternative: two discs?

- Almost coeval formation of two or more discs.

- Two discs can distort each other efficiently, as the non-axisymmetric potential warps them.

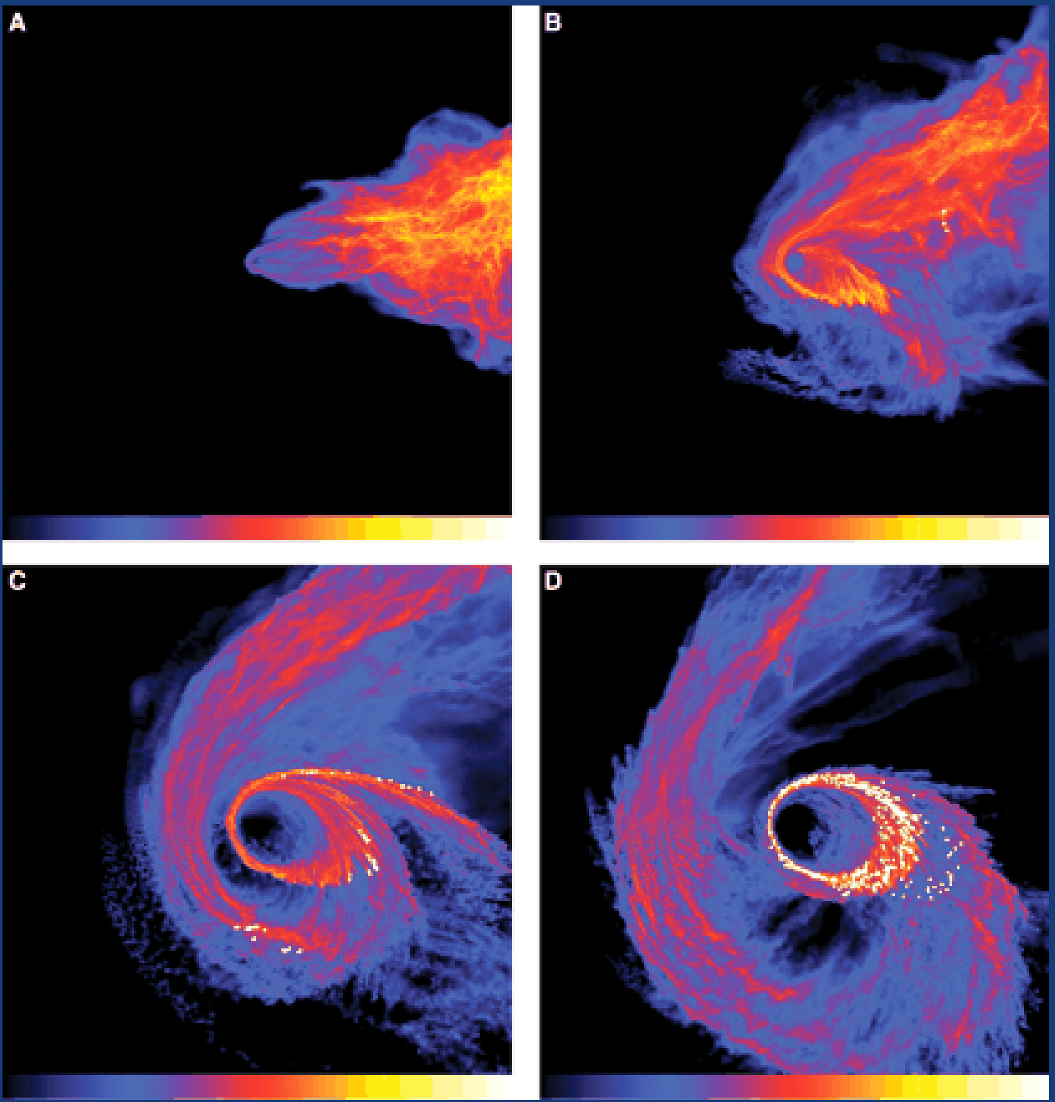


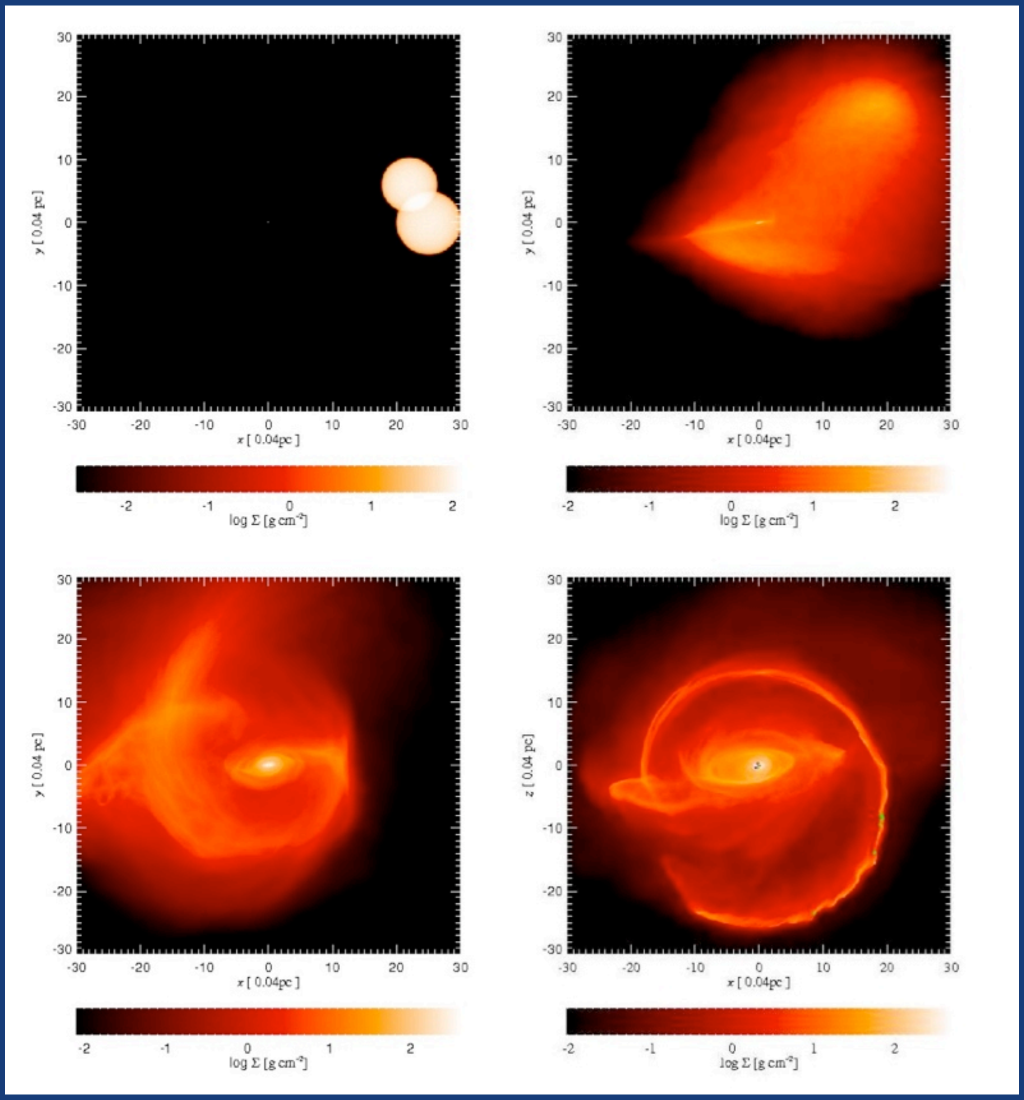
Nayakshin 2005



Nayakshin, Dehnen, Cuadra, Genzel 2006

Where did the gas discs come from?





Infall of a gas cloud?

(Bonnell & Rice)

Morris talk

Collision of two gas clouds?

(Hobbs & Nayakshin)

Conclusions

- Galactic centre stellar discs: first evidence for star formation in a massive AGN-like disc.
- Disc fragmentation roughly consistent with observed dynamics. However, cold disc doesn't fit details.
- N-body scattering increases dispersion, but process is too slow and stars too young.
- Need a more complicated origin, e.g., formation in two discs out of infalling clouds.