Positive AGN feedback on turbulent gas

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Context: AGN feedback

- AGN feedback on galactic ISM can come in four flavours:
  - Radio-mode negative feedback: jets heat the ISM and prevent fragmentation (e.g. McNamara & Nulsen 2007)
  - Radio-mode positive feedback: jets create shockwaves that facilitate fragmentation (e.g. Gaibler et al. 2011)
  - Quasar-mode negative feedback: powerful outflows remove gas from the galaxy, starving it of fuel for star formation (e.g. di Matteo et al. 2005)
  - Quasar-mode positive feedback: powerful outflows compress gas and induce star formation (e.g. Zubovas et al. 2013)
- All four modes probably important at different stages of galactic evolution

Context: AGN feedback

- Typically, low-density gas is expelled, while high-density gas can be compressed and fragment (Nayakshin & Zubovas 2012)
- Both expulsion and compression can happen at the same time in different parts of the galaxy (Zubovas et al. 2013)
- In order to simulate this, we need to resolve the density structure, otherwise even qualitative behaviour remains uncertain

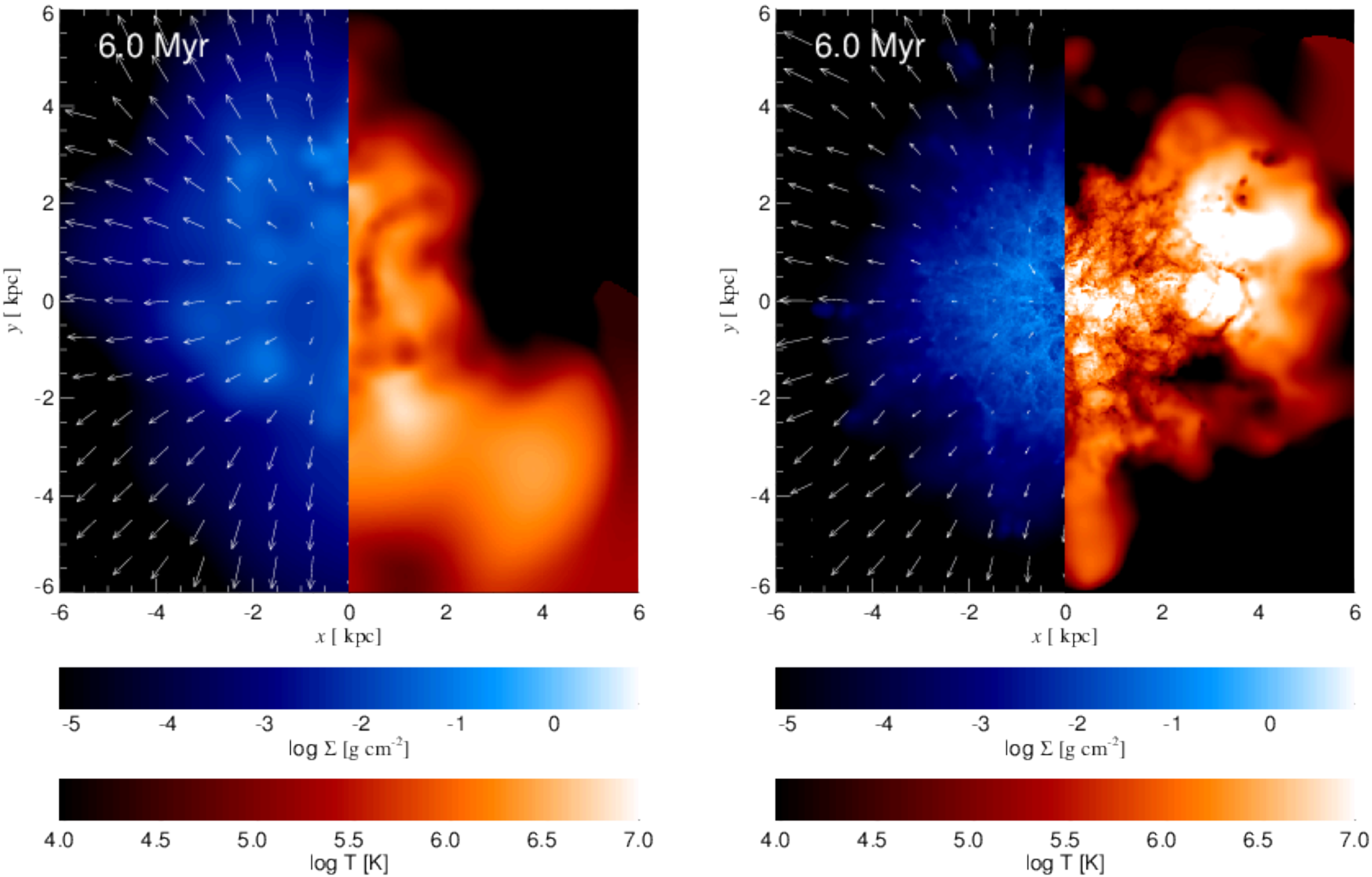
Context: numerical simulations

- Galaxy evolution simulations often probe cosmological scales (~Mpc or larger)
- Linear resolution ~kpc, mass resolution ~10^6 M_{Sun} or worse (e.g. OWLs, Illustris)
- ISM structure hardly (or not at all) resolved, low density contrasts, compression and fragmentation underpredicted
- Our goal: to explore the importance of resolution in galaxy-scale feedback models

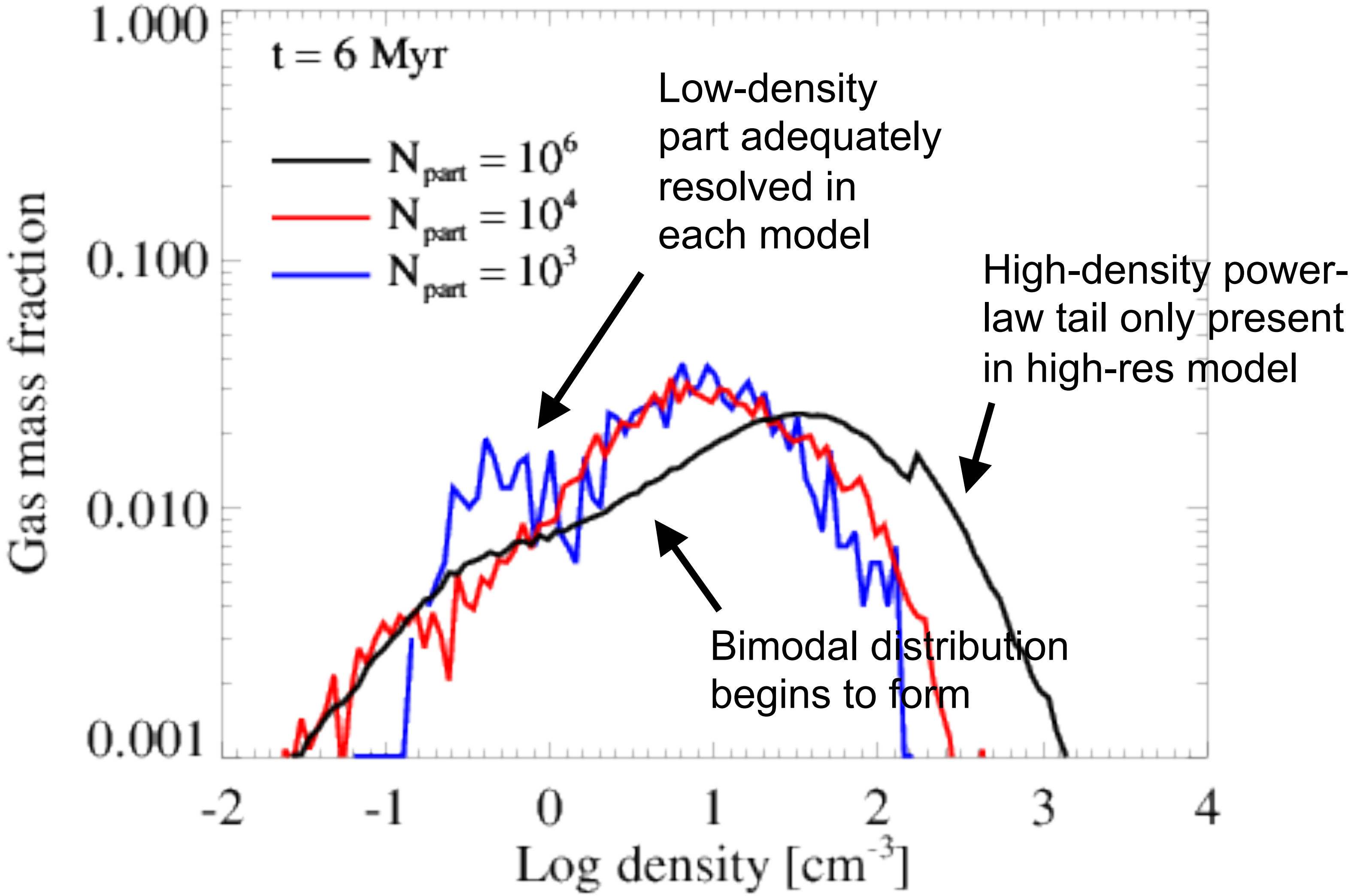
Simulation setup

- Spherical shell surrounding an AGN; idealised initial conditions
- Shell parameters: R_{in} = 200 pc, R_{out} = 2 kpc, M = $5*10^9$ M_{Sun} (f_g = 0.16)
- Turbulent velocity spectrum with σ = 200 km/s, allowed to evolve for 1 Myr
- AGN: M = $2*10^8$ M_{Sun} radiating at $L = L_{Edd}$ for t_q = 1 Myr
- Three resolutions – 10^3, 10^4 and 10^6 particles in the shell
- Test 1: Sink particles form when $n > 10 + 0.02\ (T/10\ K)^3$ cm^{-3}, corresponds to $M_J < 10\ m_{SPH}$ in high-res model
- Test 2: Sink particles form when $M_J < 10\ m_{SPH}$ for each model

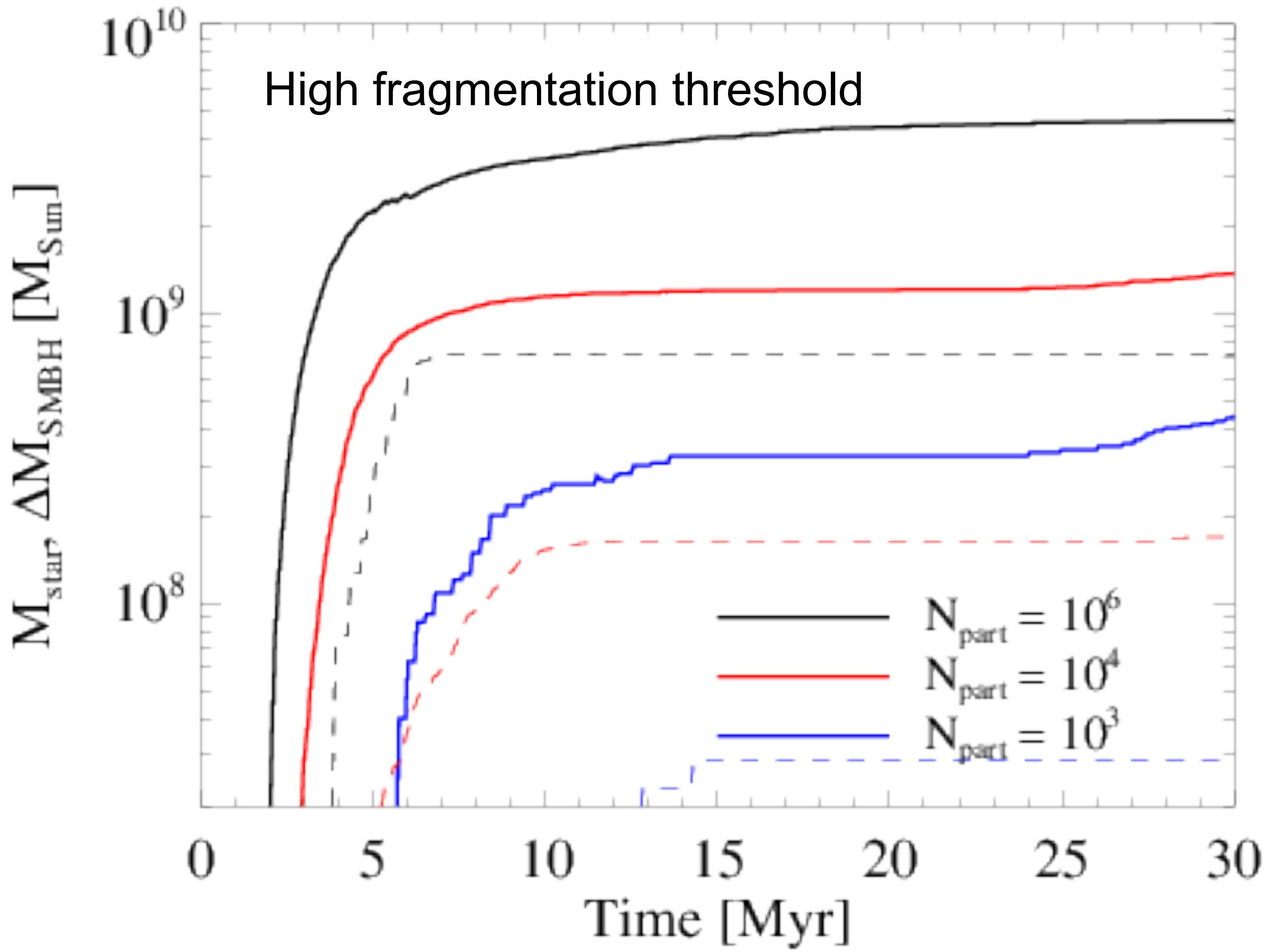
Gas morphology



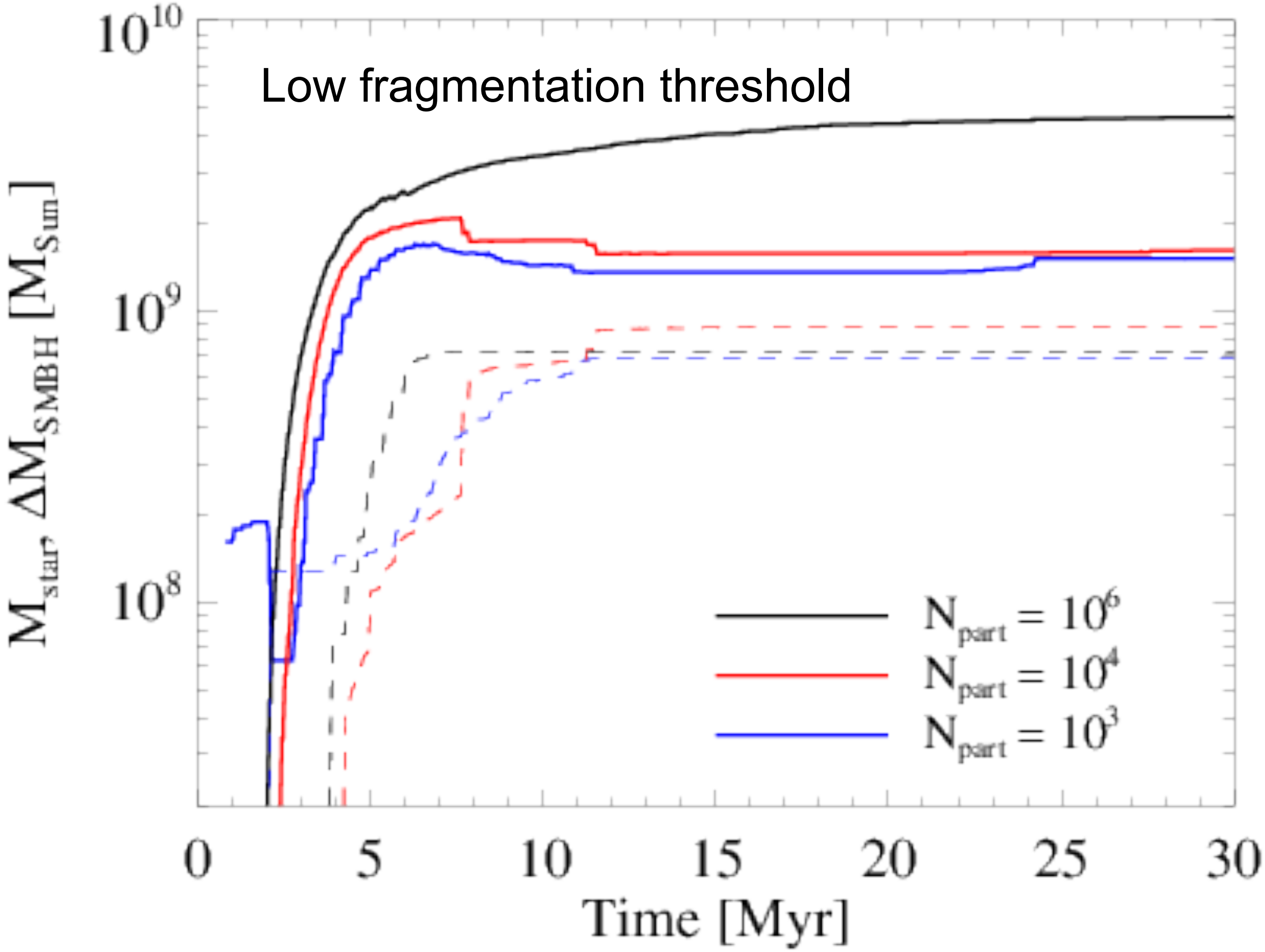
Gas density distribution



Fragmentation and SMBH feeding

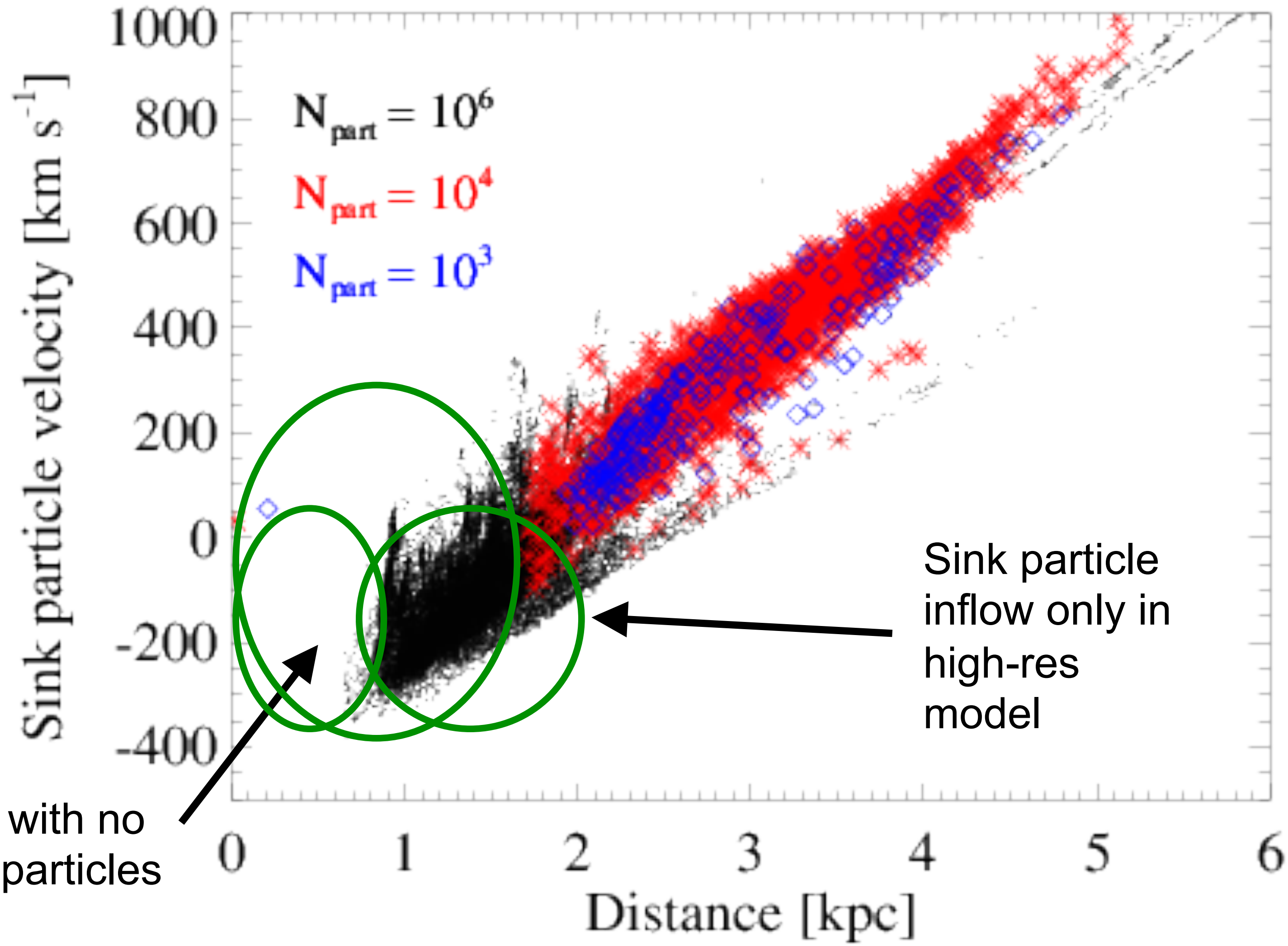


Fragmentation and SMBH feeding



Sink particle dynamics

- t = 6 Myr;
- SF when $M_J < 10\ m_{SPH}$
- Total sink particle mass similar (factor ~3) in all models



Outflow fragmentation - summary

- Low-res simulations:
  - Mostly coherent outflow
  - Sink particles form in rapidly outflowing gas
  - Central void in both gas and sink particle distributions
  - SMBH feeding by stray sink particles
- High-res simulation:
  - Highly uneven gas density distribution
  - Sink particles form both in outflowing and inflowing gas
  - Lack of central void
  - SMBH feeding by gas flows

Summary

- Positive AGN feedback can cause starbursts comparable in magnitude to those observed in AGN
- Low (cosmological) resolution numerical simulations do not produce self-gravitating gas clumps and hence underpredict the SFR
- As a result, AGN feedback in such simulations is more negative than in higher-resolution simulations or in reality
- Convergence of numerical simulations not achieved yet ($6*10^7$ particle simulation ongoing!)
- Effects of AGN feedback in galactic evolution simulations must be considered with extreme caution