Circum-nuclear disc mergers

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Introduction

Galaxy mergers can result in:

1) formation and evolution of massive black holes binaries (MBHBs);

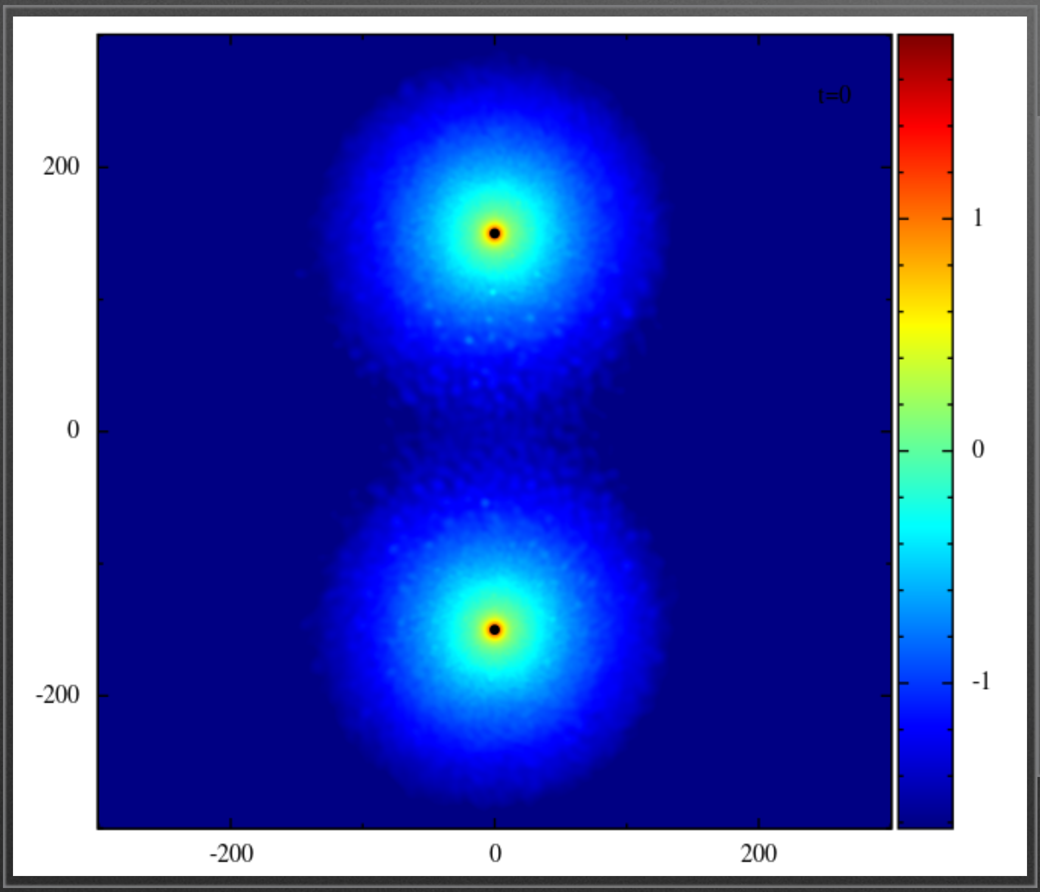
2) the formation of massive black holes via direct collapse of dense gas clouds.

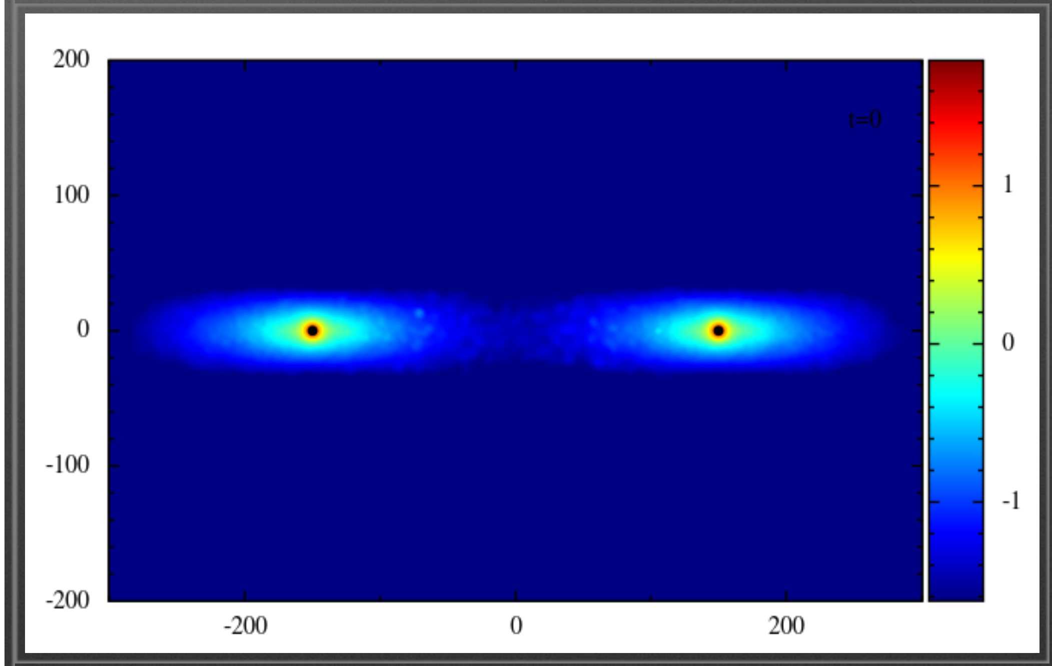
3) the triggering of AGNs

Although the binary formation process is a genuine dynamical problem, stellar and gas components play a pivotal role and need to be self-consistently evolved on the same timescale.

The initial conditions for the merger consist of two equal mass, co-planar co-rotating discs at a distance of 300 pc, placed on an elliptical orbit with eccentricity $e = 0.3$.

The orbital angular momentum is antiparallel to the angular momentum of the disc, in order to maximise the gas shocks and thus the gas infall toward the centre.





Simulation suite

We performed a suite of 8 simulations using the AMR code RAMSES (Teyssier,2002).

AMR codes have a better treatment of gas dynamics wrt SPH codes, and they can increase the hydrodynamical and gravitational resolution when required.

However, because of the grid resolution limit, massive particles suffer spurious orbit perturbations.

In order to better follow the MBH orbits we suitably modified the code.

Our implementation has been described in a recently submitted paper (Lupi et al.)

Simulation suite

In our simulation suite we explored three key parameters:

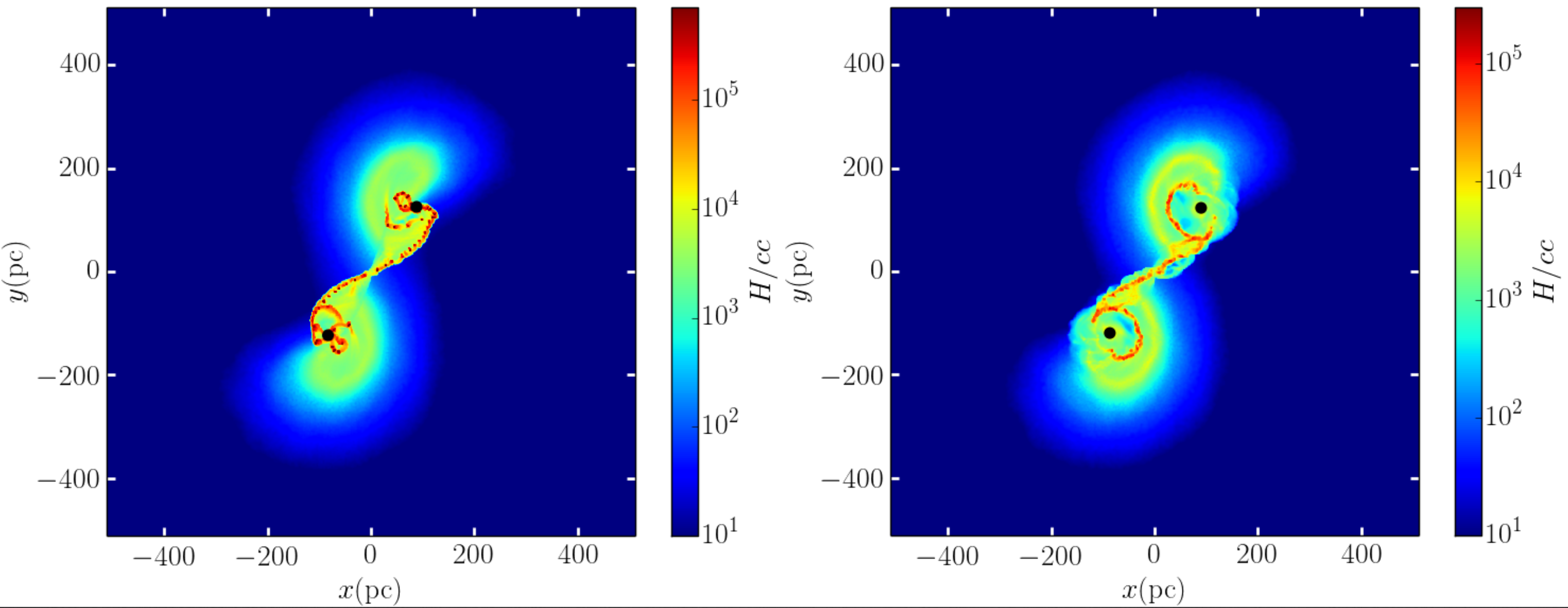
1) threshold density for star formation:

2) lifetime for massive stars before their explosion as supernovae:

3) supernova (SN) feedback model:

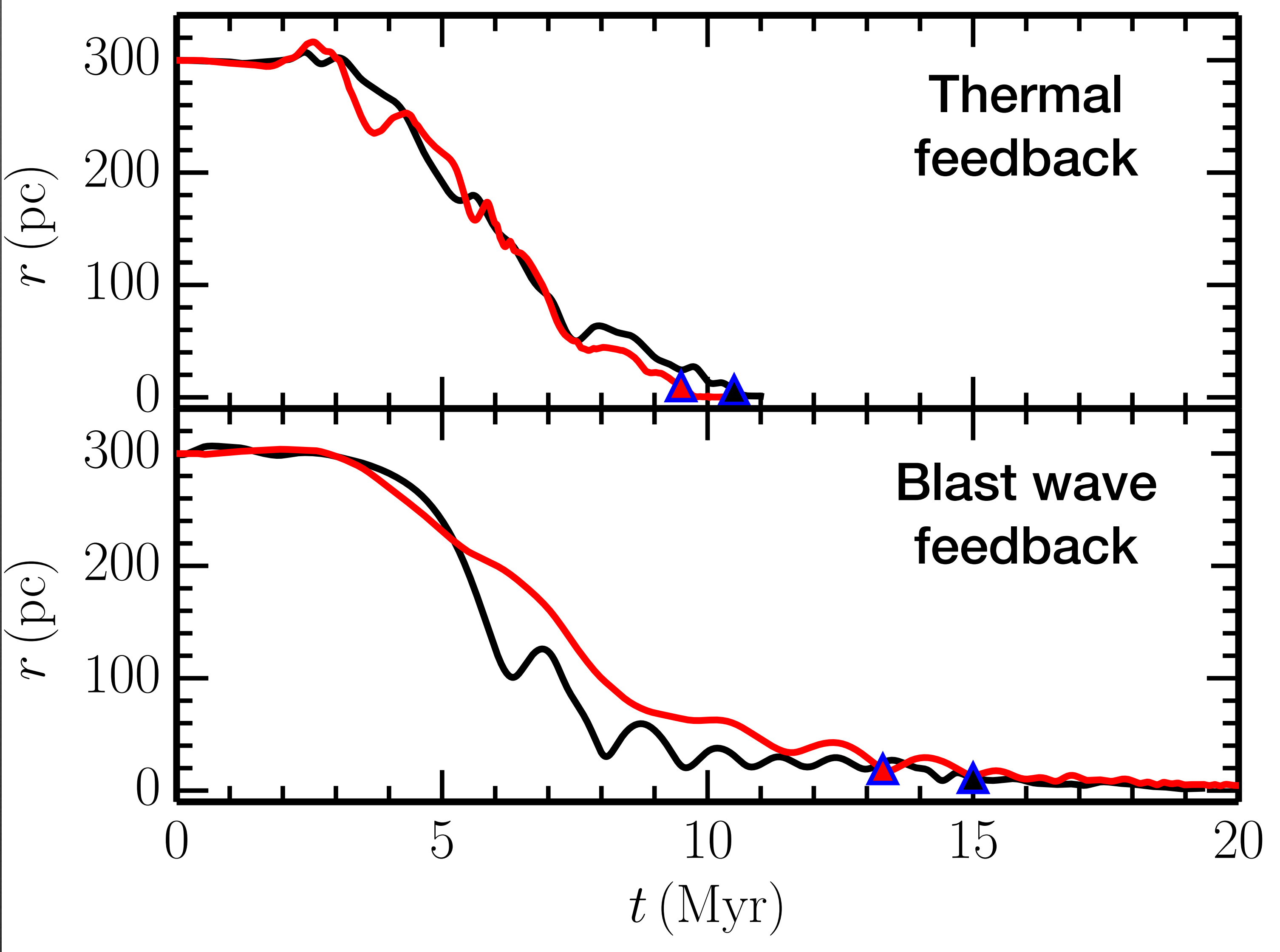
- model a) thermal feedback on the surrounding gas, which immediately starts to cool.
- model b) blast wave like feedback (Teyssier et al. 2013)

Gas disc evolution

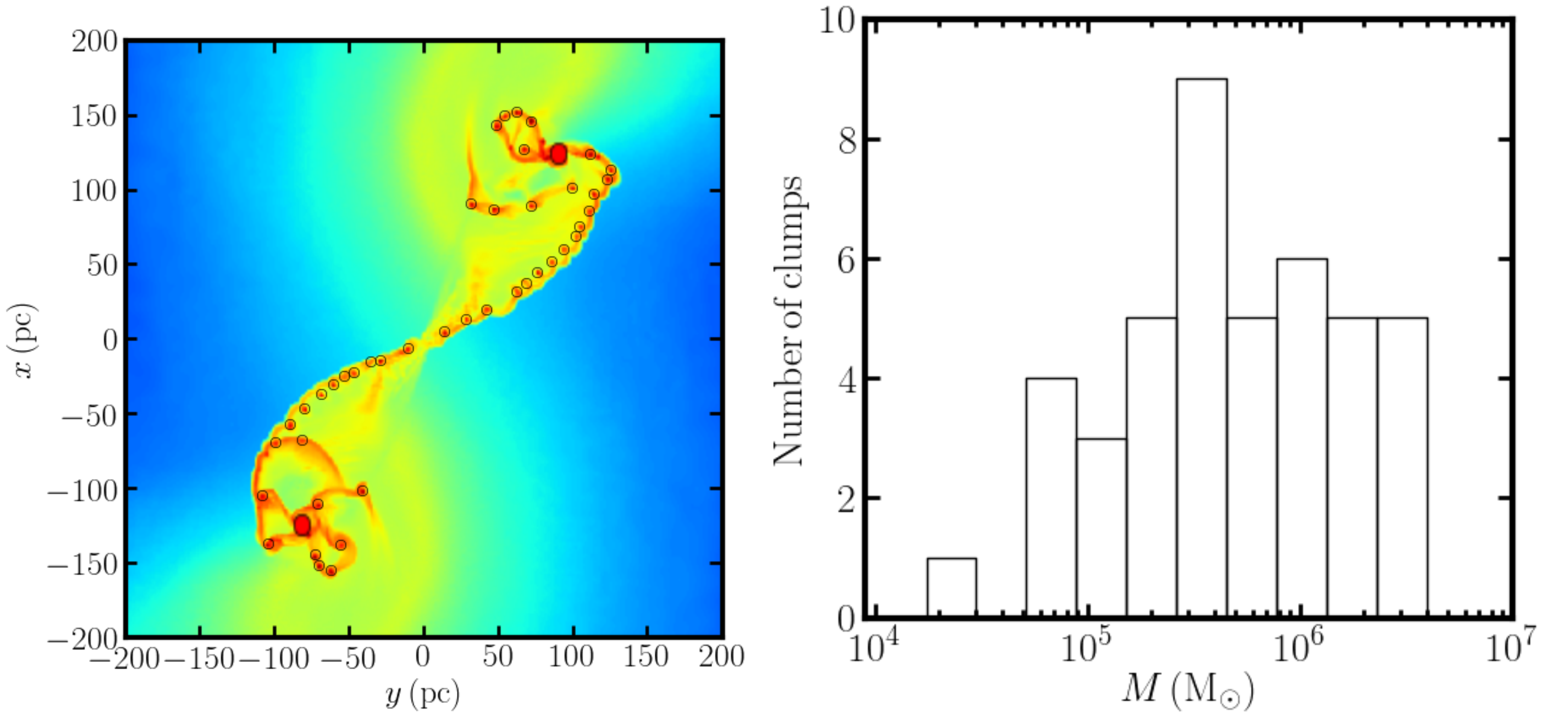


Orbital decay

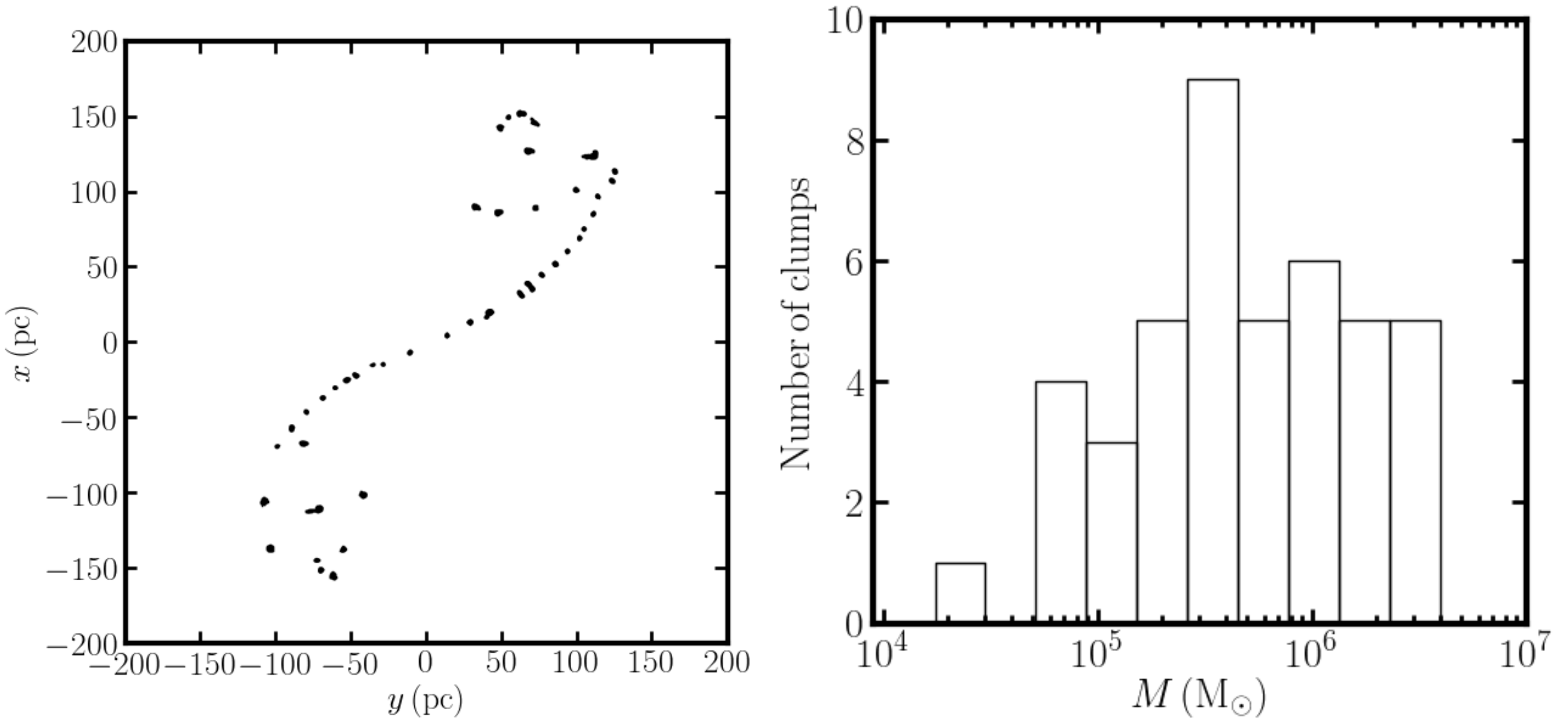
$\tau_{\rm star} = 0\,{\rm Myr}$



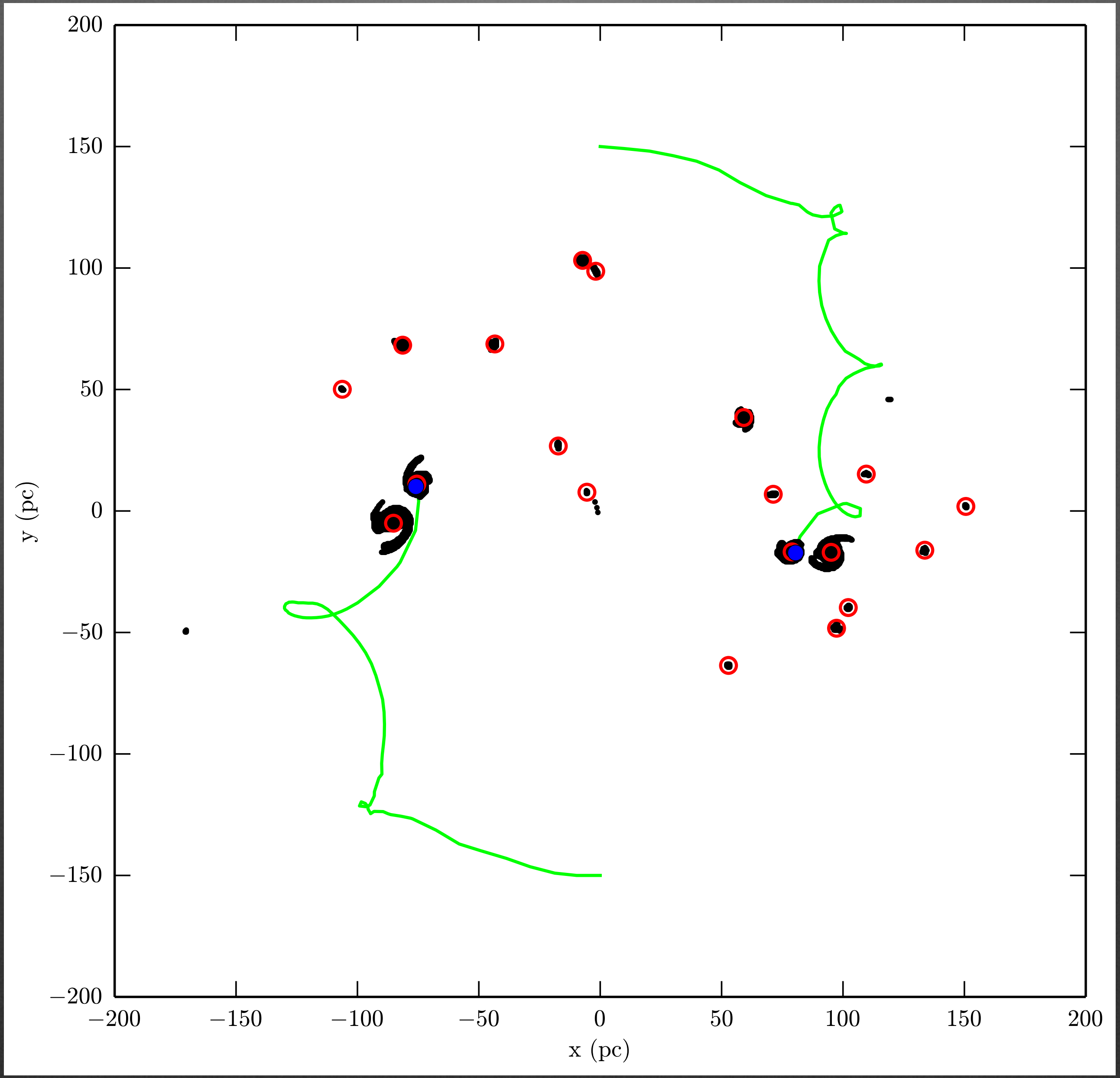
Clump distribution



Clump distribution



Clump - MBH interaction



Conclusions

- The binary pairing occurs on typical timescales of few tens Myr (for MBHs with $M_{\rm BH} = 10^7\,{\rm M}_{\odot}$).
- Star formation and SNe can affect the MBH dynamics, but they do not prevent the binary formation (e.g. by ejecting MBHs after strong interactions with clumps, Fiacconi et al. 2013).

…next

- Add the accretion on MBHs in order to constrain the AGN triggering and the feedback effect on the gas


Thanks for
your attention

Backup slides

Due to the large dynamic range involved, we consider the intermediate phases of gas rich galaxy mergers, on scales between 1 pc and 1 kpc.

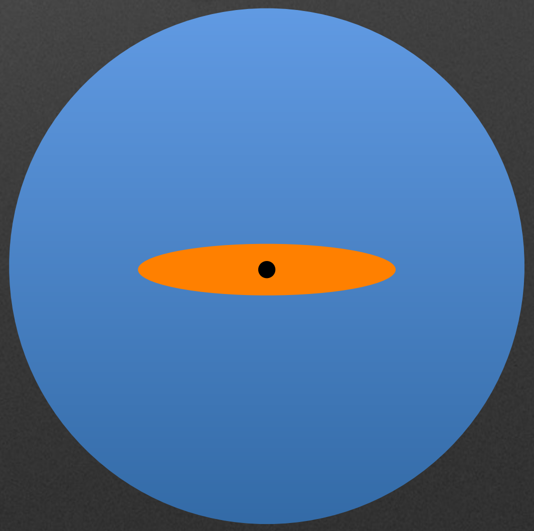
We assume each of the two galaxy nuclei composed by:

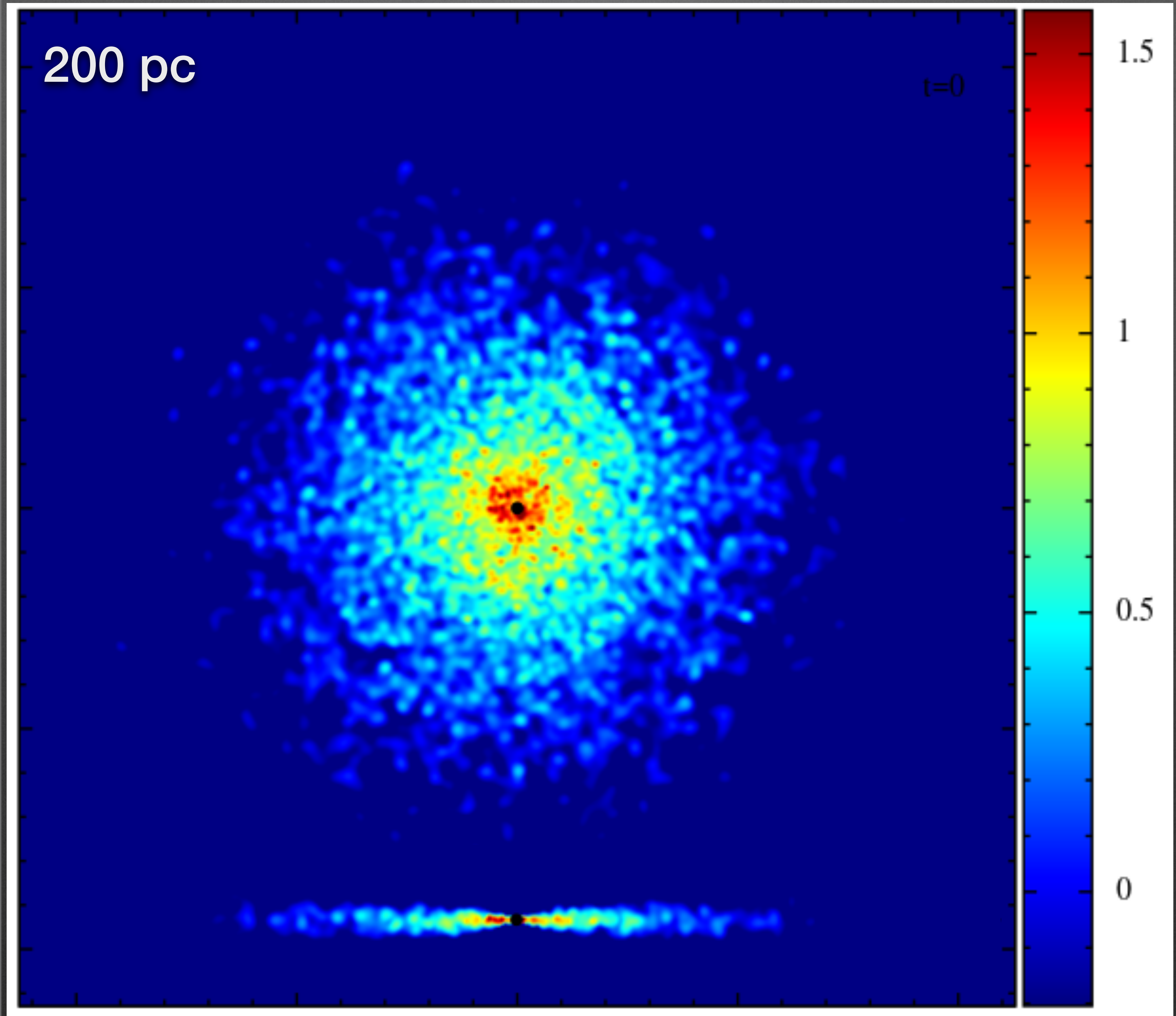
- a stellar nucleus, modeled with a Hernquist spherical profile, with scale radius $R_{\rm bulge} = 100\,{\rm pc}$ and mass $M_{\rm bulge} = 2\times 10^8\,{\rm M_\odot}$;

- a pressure supported gaseous circum-nuclear disc, described by an exponential surface density profile, with $H/R \sim 0.2$, scale radius $R_{\rm disc} = 50\,{\rm pc}$ and mass $M_{\rm disc} = 10^8\,{\rm M_\odot}$;

- a MBH at the centre of the nucleus, with mass $M_{\rm BH} = 10^7\,{\rm M_\odot}$.

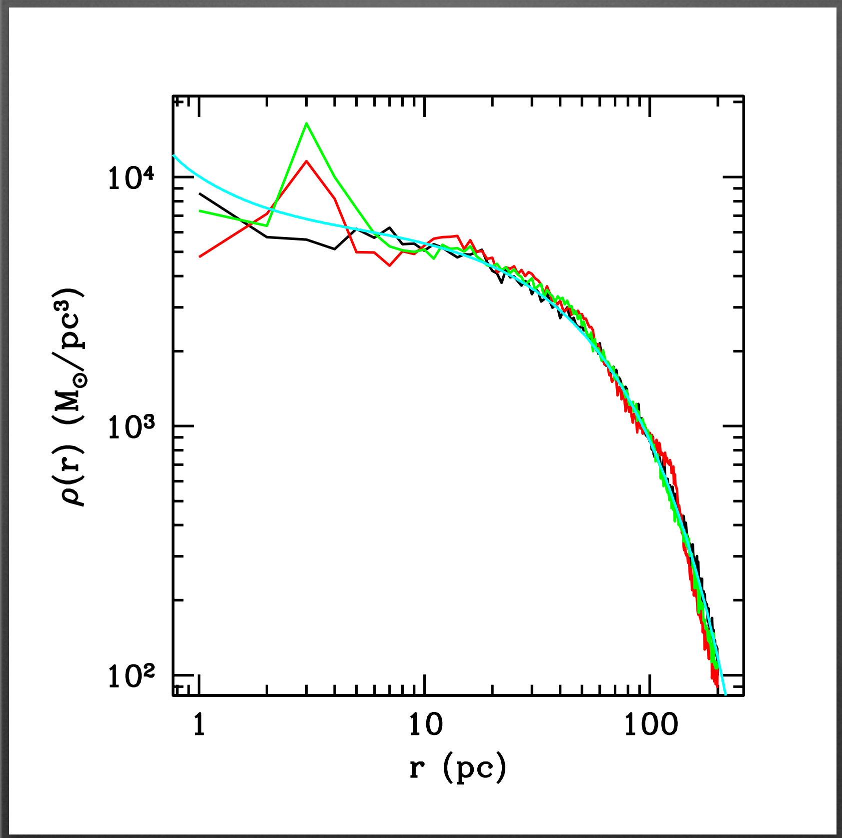
Each disc is initially set in hydrostatic equilibrium and modeled as an ideal gas with polytropic index $\gamma = 5/3$.




200 pc
t=0
1.5
1
0.5
0

Initial conditions

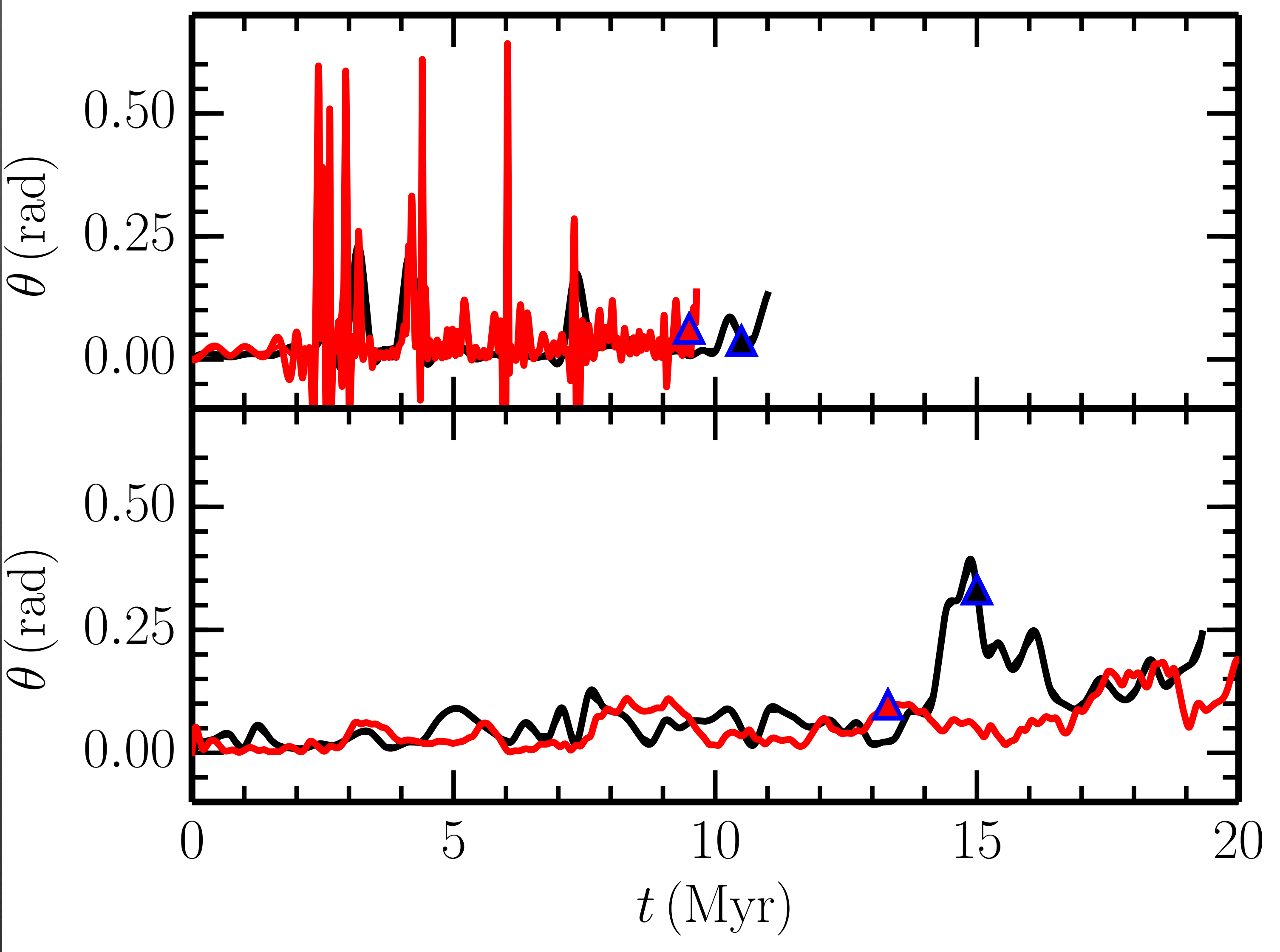
The initial conditions for the considered system have been created with a dedicated code*.



In order to create initial conditions for RAMSES, gas particles have been mapped on a set of grids (8 levels up to a resolution of 0.75 pc) using the code TIPGRID.

* the code is publicly available at my homepage ***http://www.dfm.uninsubria.it/alupi/software.html***

Effect of the density threshold



MBH formation

MBH formation via direct collapse has been pointed out by Mayer et al. (2010), in which authors claim that gas rich mergers can result in very large inflows toward the merger remnant nucleus, forming a very dense and massive gas cloud ($2 \times 10^8\,\mathrm{M_\odot}$ in $2-3\,\mathrm{pc}$).
In these conditions the cloud becomes Jeans unstable and collapses into a MBH.

A preliminar analysis shows quite small inflows in the nuclear region, comparable with 2-3% of the total gas mass, which is stable against collapse. A detailed study is still on going.