Galaxy Merger and Hungry Black Hole: Suppression of Black Hole Activity due to Galaxy Merger

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Contents

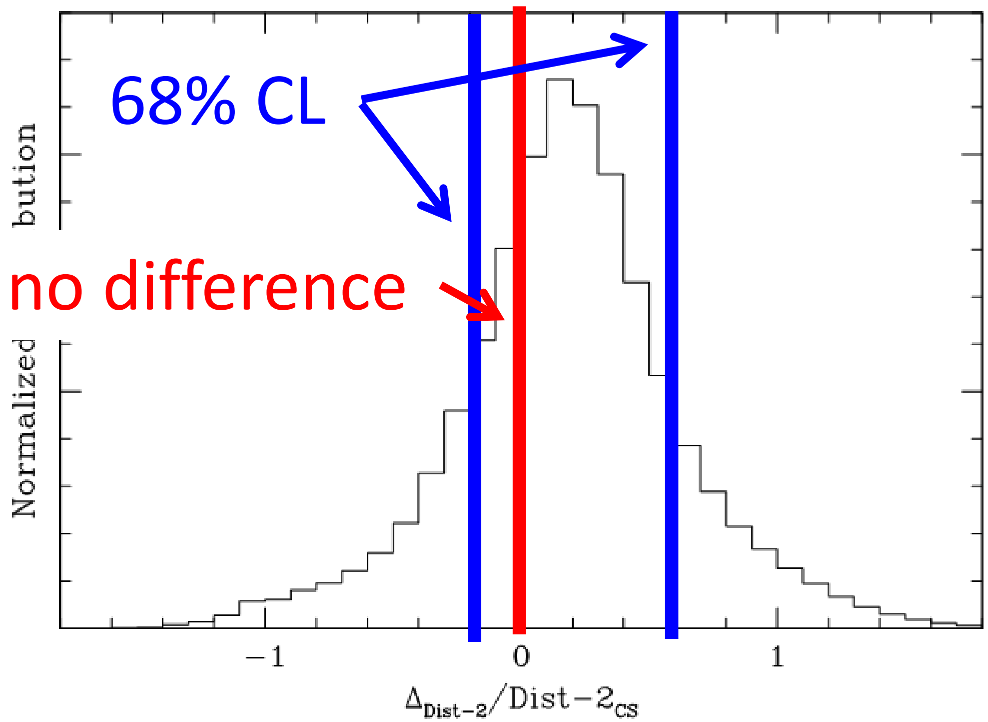
Black Hole Activity and Galactic Merger (1/2: theoretical hypothesis)

- SuperMassive Black Holes (SMBHs) become bright as Active Galactic Nuclei (AGN)
  - by releasing gravitational energy of accreting gas
  - need sufficient amount of accreting gas
- Does enough gas accrete to the central SMBH ?
  - angular momentum barrier prevents the accretion
  - galaxy collisions enhance angular momentum transfer
  - galaxy collisions ignite the AGN activity (Sanders et al. 1988; Hopkins & Quataert 2010 etc.)

Black Hole Activity and Galactic Merger (2/2: observational results)

- probability distribution of the difference of highly distorted galaxies (signature of merger) between the AGN and control sample
- no significant difference between AGN hosts and inactive galaxies
- galactic mergers also suppress AGN activity??

Cisternas et al. 2011



Our model (suppression mechanism)

- Do galaxy collisions suppress AGN activity ?
  - If mass fueling source of the BH is swept away, then the AGN activity must be turn off.
  - This process has never been considered.
  - We investigate the possibility of this scenario.

Do galaxy collisions suppress AGN activity?

- If it is possible, then what is the condition ?
- We assume AGN torus as fueling source to the SMBH.
  - we investigate influence on the AGN torus due to a galactic collision using one dimensional analytic model and three dimensional hydrodynamic simulations.
- Andromeda galaxy (M31) has a central SMBH (M_{BH}= 1.4 × 10^8 $M_\odot$: Bender et al. 2005), but its activity is very low ($L_{0.3\text{-}0.7\,keV} < 10^{-10}\,L_{Edd}$; Li et al. 2009).
  - Origin of the low activity is still an open question.

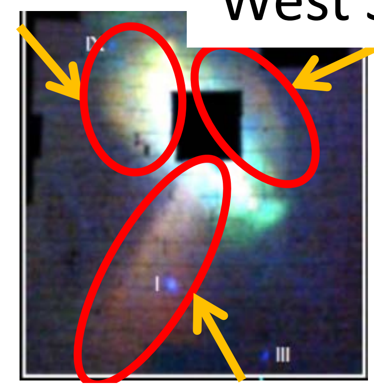
Merger remnants in the M31 halo

- Observed structures (stream, shells: Ibata et al. 2001; McConnachie et al. 2009) are the merger remnant of a tidally-disrupted dwarf galaxy about 1 Gyr ago (Fardal et al. 2007; Mori & Rich 2008; YM, Mori, Rich in prep.).
- Results of *N*-body simulations
  - The infalling satellite can blanket most of the central region of M31.
    - it passed 1kpc from center of M31.
    - its size is greater than 1kpc.
  - Time scale of the stripping < 2 Myr.
    - infalling satellite passed the region for 1.1 Myr.

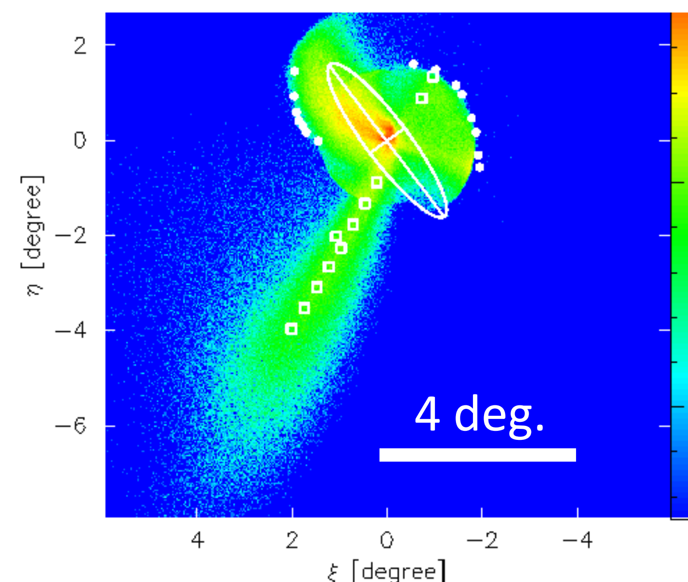
McConnachie et al. 2009

East Shell

West Shell



Andromeda Stellar Stream



Model of torus, infalling satellite

- Torus component (Krolik & Begelman 1988; Mor et al. 2009 etc.)
  - Steady, axisymmetric polytrope gas under a spherical gravitational potential (Okada et al. 1989 etc.)
  - maximum value of the aspect ratio is unity

$$R_0 = 9\,\mathrm{pc} \qquad R_{\mathrm{out}} = 50\,\mathrm{pc}$$

$$M_{\mathrm{torus}}/M_{\mathrm{BH}} = 1,\ 0.1,\ 10^{-2},\ 10^{-3}$$

- Gas component of the infalling dwarf galaxy

(Mateo 1998; Conselice et al. 2003)

$$f_{\mathrm{gas}} = 1,\ 0.1,\ 10^{-2},\ 10^{-3} \qquad u = 850\,\mathrm{km\,s^{-1}} \qquad T = 10^4\,\mathrm{K}$$

- Important parameter

$$x \equiv f_{\mathrm{gas}} \times \left(\frac{M_{\mathrm{torus}}}{M_{\mathrm{BH}}}\right)^{-1}$$

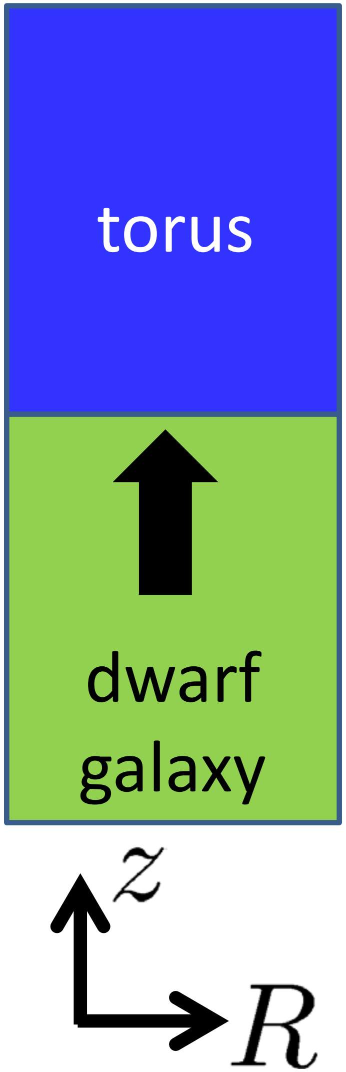
← corresponds to gas density ratio between the satellite and torus

1-dim. Analytic Estimation

- estimation using only hydrodynamics
  - solving time evolution of torus gas along the shock direction after the collision with dwarf galaxy as a function of *R*
  - i.e. shocktube problems along the velocity vector of the infalling satellite
- condition for stripping
  - effect of momentum transfer

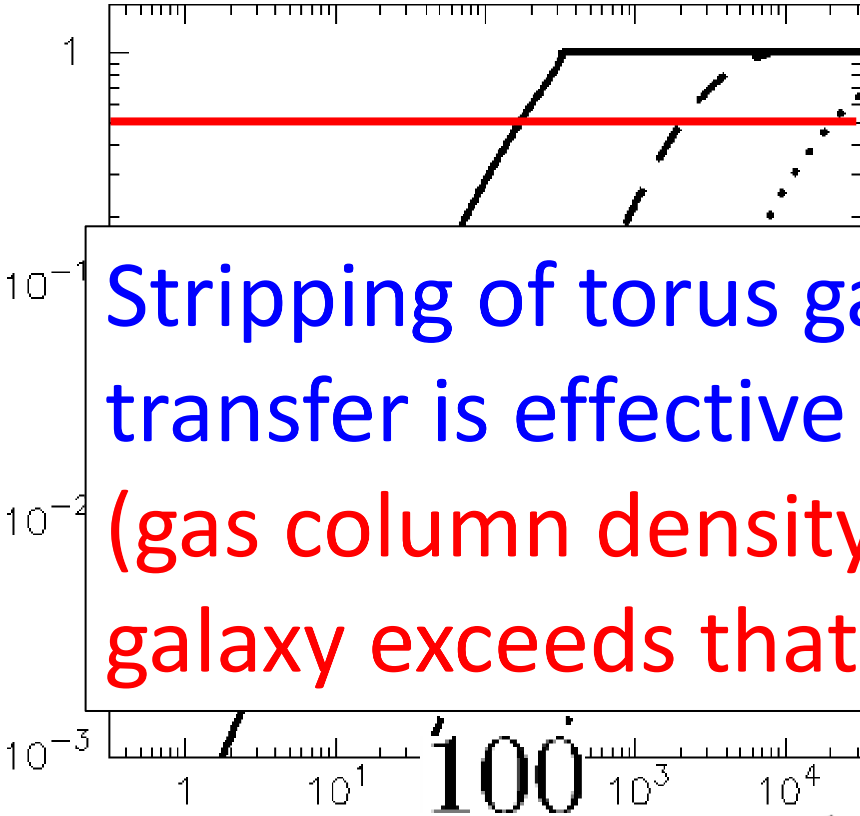
$$V_{\rm both}(R) \geq \sqrt{2\left[\Phi_{\rm M31}(r_{\rm esc}) - \Phi_{\rm M31}(R,\, z=0)\right]}, \quad V_{\rm both} = \frac{\Sigma_{\rm t} v_{\rm t,\, after} + \Sigma_{\rm d} v_{\rm d}}{\Sigma_{\rm t} + \Sigma_{\rm d}}$$

  - is the most important one compared to other physical processes (next slide)



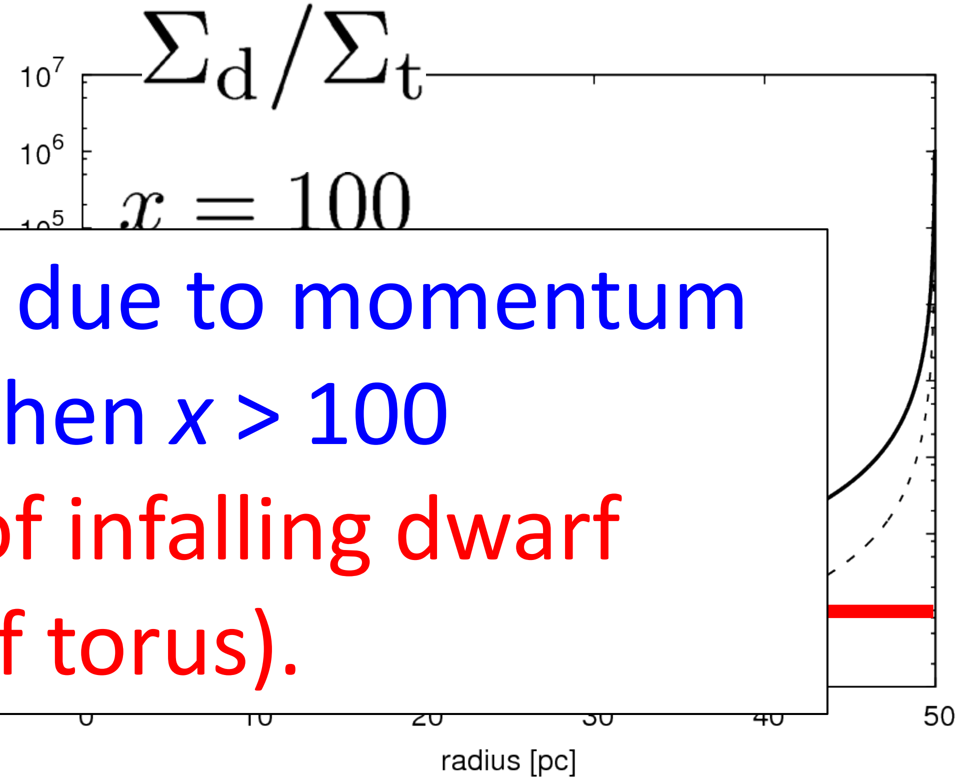
Result of Analytic Estimation

Mass stripping rate vs. x



$$x \equiv f_{\rm gas} \times \left(\frac{M_{\rm torus}}{M_{\rm BH}}\right)^{-1}$$

Column density ratio profile



Stripping of torus gas due to momentum transfer is effective when *x* > 100

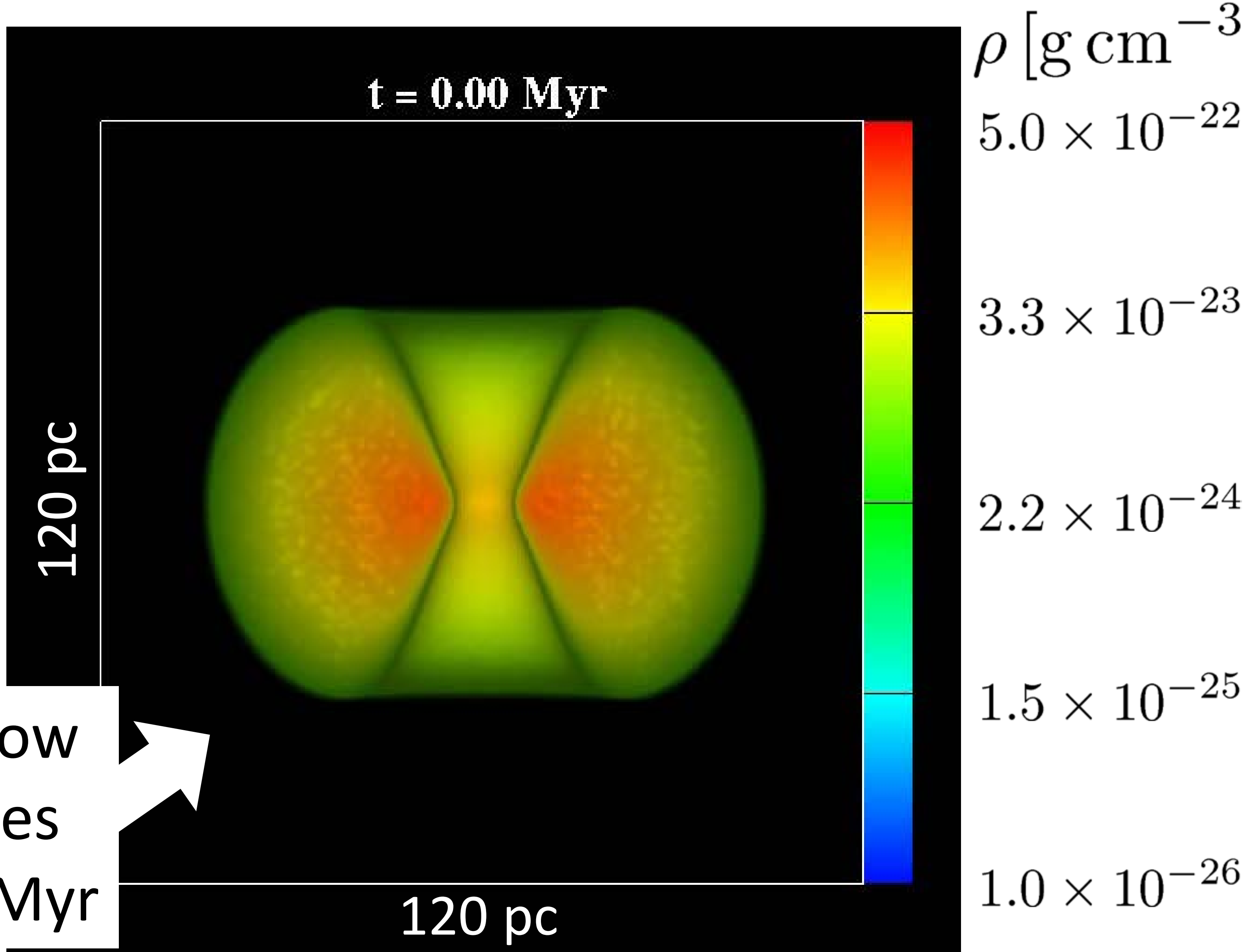
(gas column density of infalling dwarf galaxy exceeds that of torus).

3-dim. Hydrodynamic Simulations

- Local simulations for the central part of the M31
  - uniform grid
  - HLLC, PLM(MUSCL)
  - gravity: external potential
  - addiabatic calculation
  - inflowing boundary condition (as gas of the infalling satellite)
  - T2K, FIRST (U. of Tsukuba)

- 12 runs (256^3 grids) for parameter survey
- a run (1024^3 grids) for convergence check
- a run (512^3 grids) for twice bigger torus size (i.e., 8 times lower density torus model)

Case 1: torus gas is stripped (x=100)

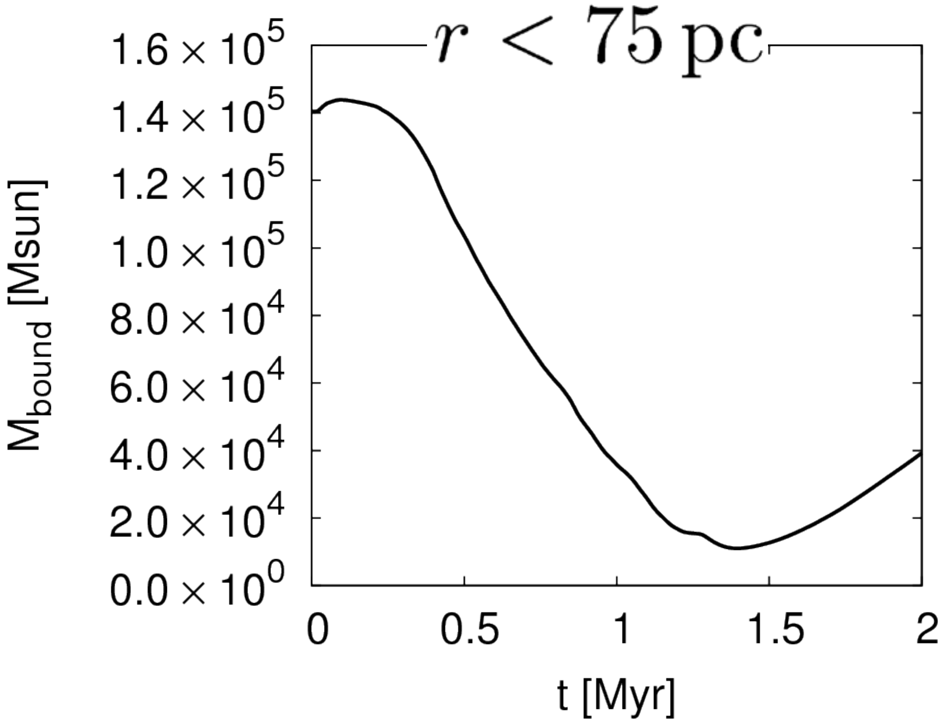


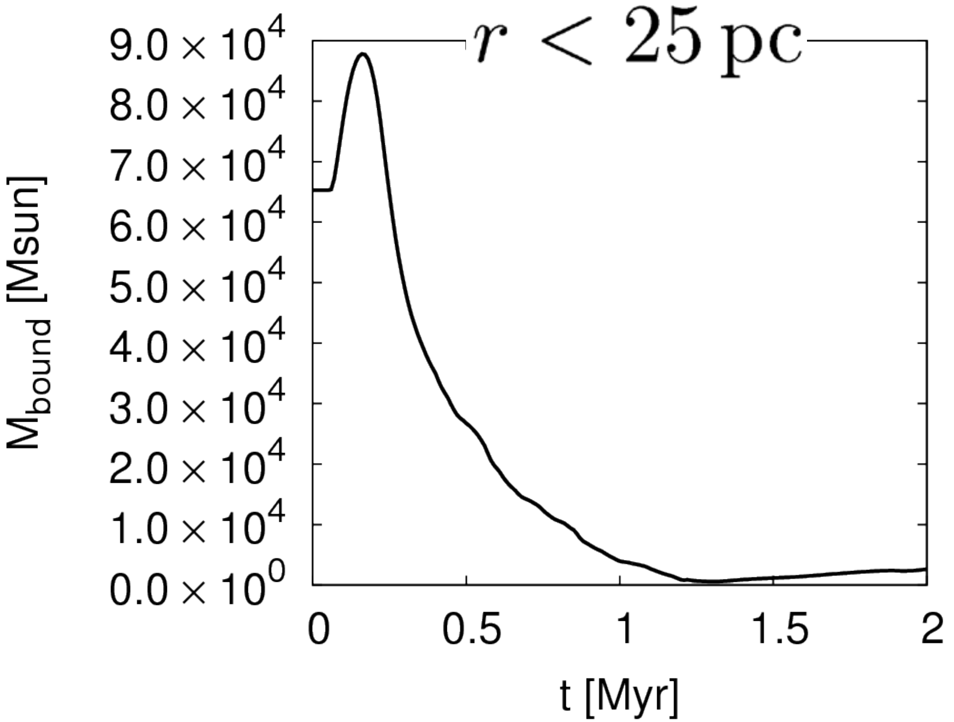
Gas inflow continues for 1.1 Myr

Case 1: torus gas is stripped (*x*=100)

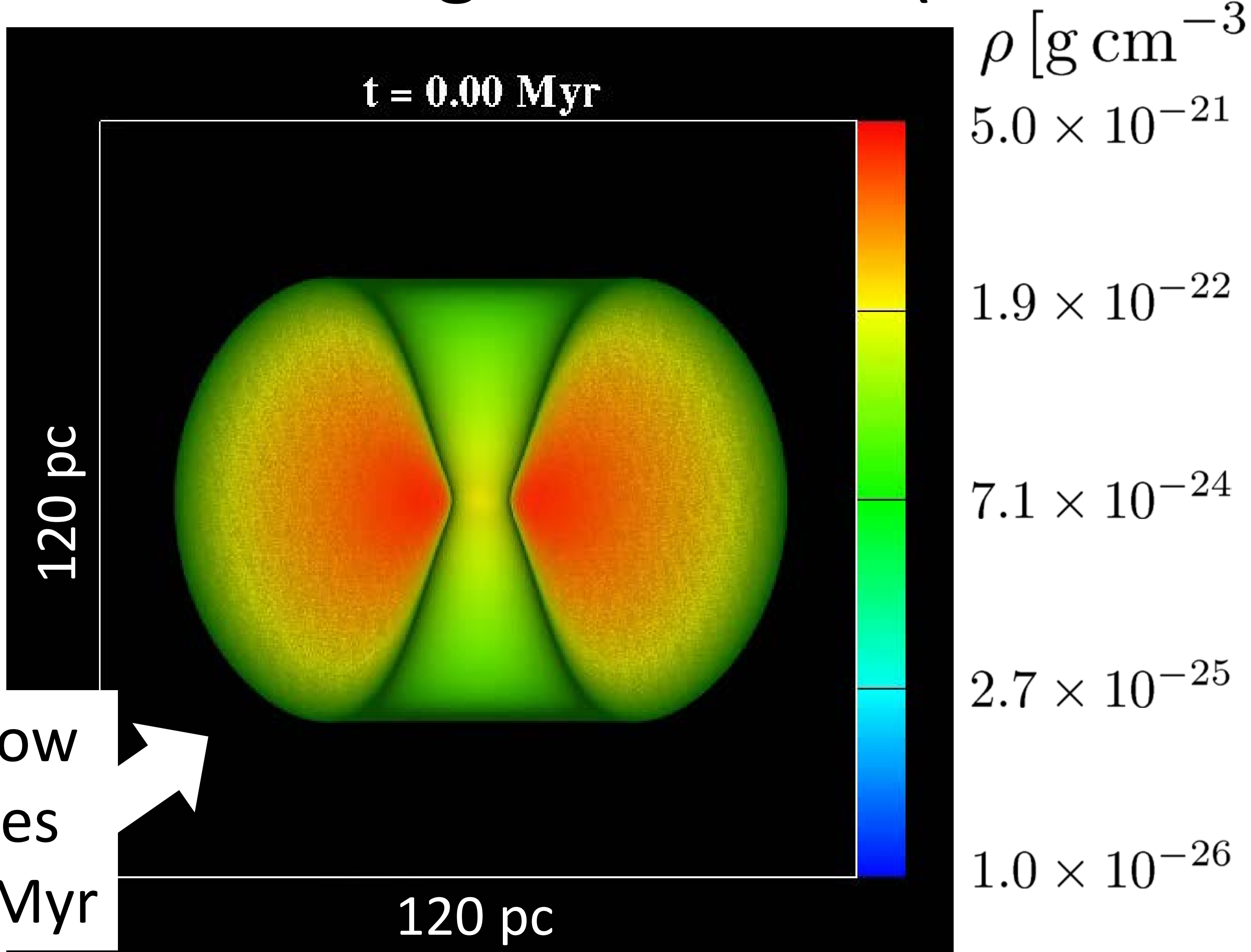
- Escape fraction: M_{strip}/M_{torus} is 0.922

$$\frac{1}{2}\boldsymbol{v}^2 + \frac{1}{\gamma - 1}\frac{p}{\rho} + \Phi_{\mathrm{M31}}(r) \geq \Phi_{\mathrm{M31}}(r_{\mathrm{esc}} = 10\,\mathrm{kpc})$$





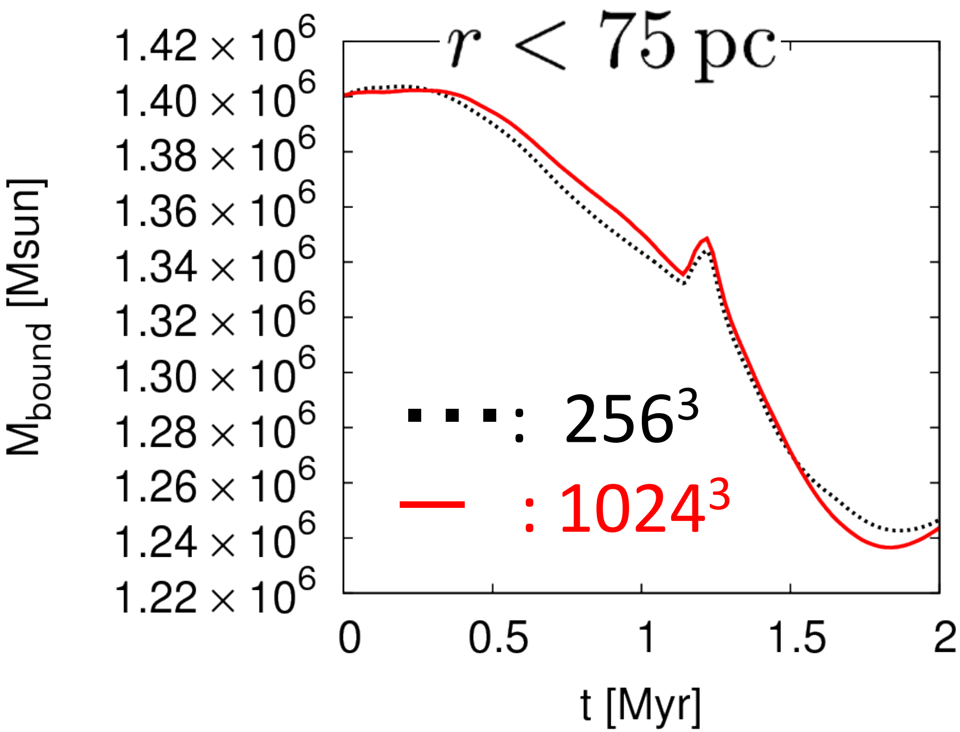
Case 2: torus gas survives (*x*=10)

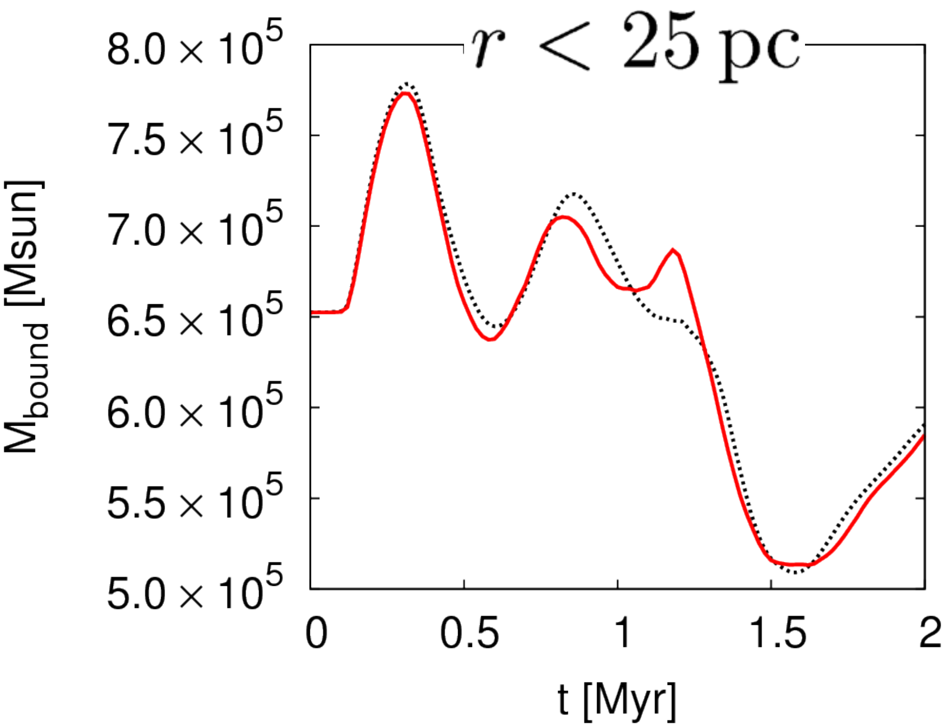


Gas inflow continues for 1.1 Myr

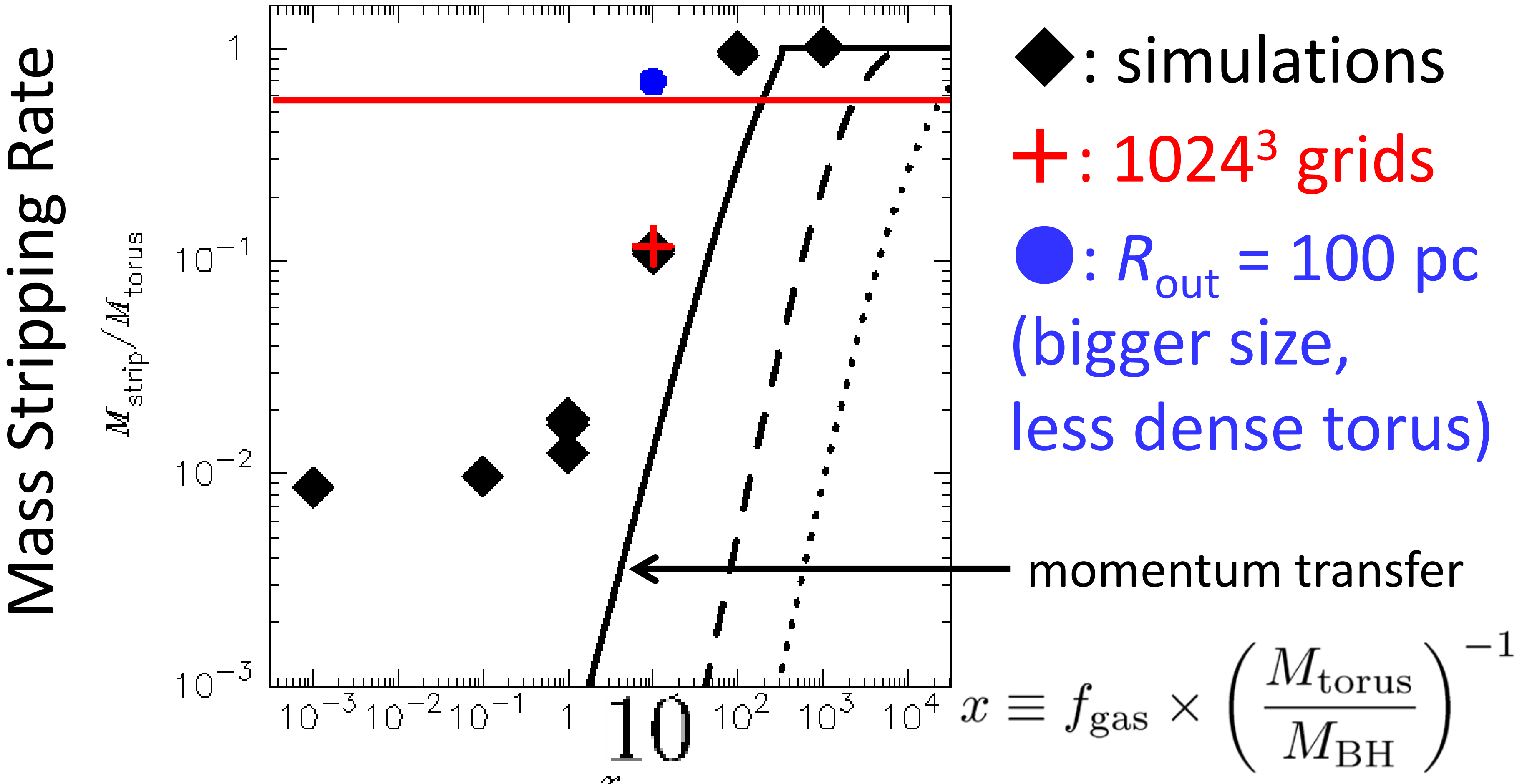
Case 2: torus gas survives (*x*=10)

- Escape fraction: M_{strip}/M_{torus} = 0.113
  - M_{strip}/M_{torus} = 0.117 for the high resolution model (simulation of 1024^3 grids)





Results of Parameter Study



$$x \equiv f_{\rm gas} \times \left(\frac{M_{\rm torus}}{M_{\rm BH}} \right)^{-1}$$

less ← amount of dwarf gas → much

much ← amount of torus-shaped gas → less

Summary

- Question: Do galactic mergers suppress BH activity?
- We investigate whether or not torus-shaped gas surrounding an SMBH is stripped due to a galactic merger using 1-D analysis and 3-D simulations.
  - momentum transfer is the most effective process
  - column density ratio between gas of an infalling galaxy and torus-shaped gas is the most fundamental quantity
- Answer: Suppression of BH activity due to galactic collision occur when the gas column density of an infalling satellite exceeds that of AGN torus.