Evolution of Massive Black Hole Pairs in Clumpy Environments

From Circumnuclear Disks to Major Mergers

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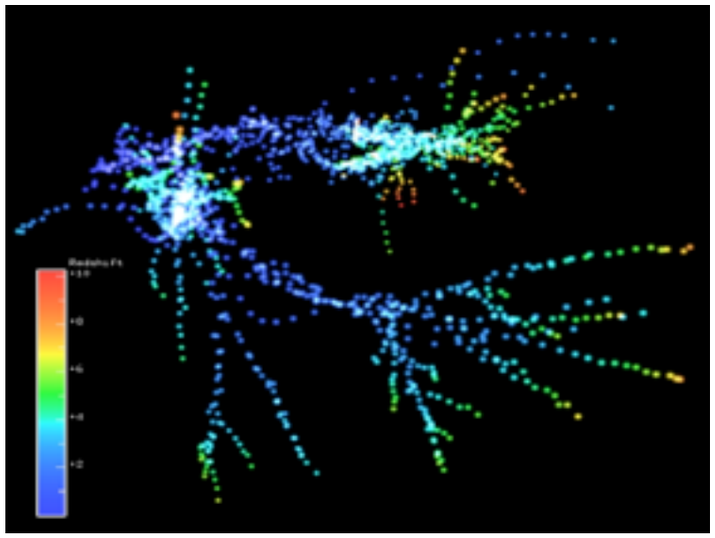
MBHs: Birth, Growth and Impact
Santa Barbara, Aug 5-9 2013

Outline

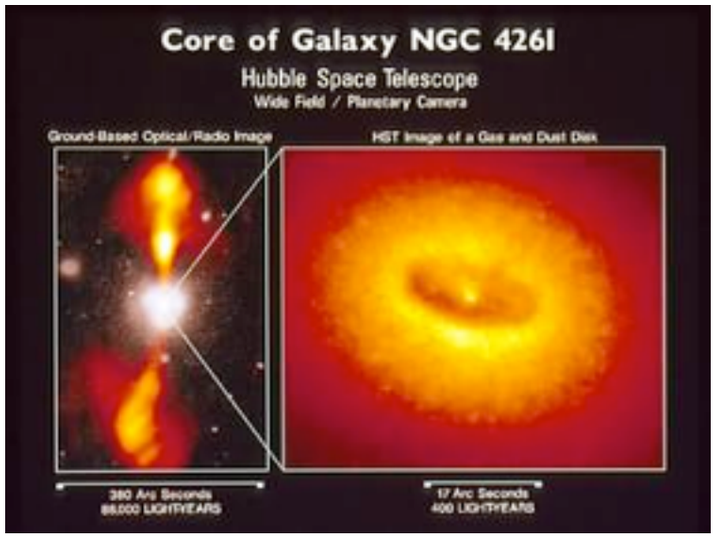
- ***Introduction***
- ***Circumnuclear Disk: Idealized Simulations***
- ***Major Merger Simulations: Preliminary Results***
- ***Conclusions***

Introduction

Dual Black Holes in the Universe



Assembly History of Galaxies

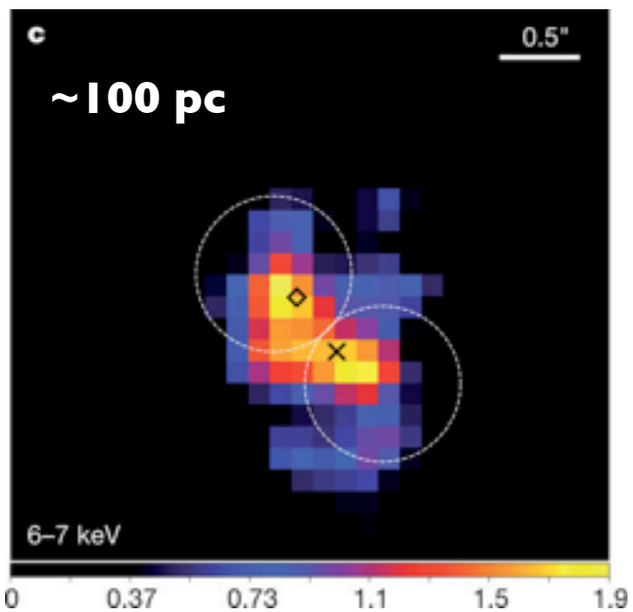


SMBH at the Center of Galaxies

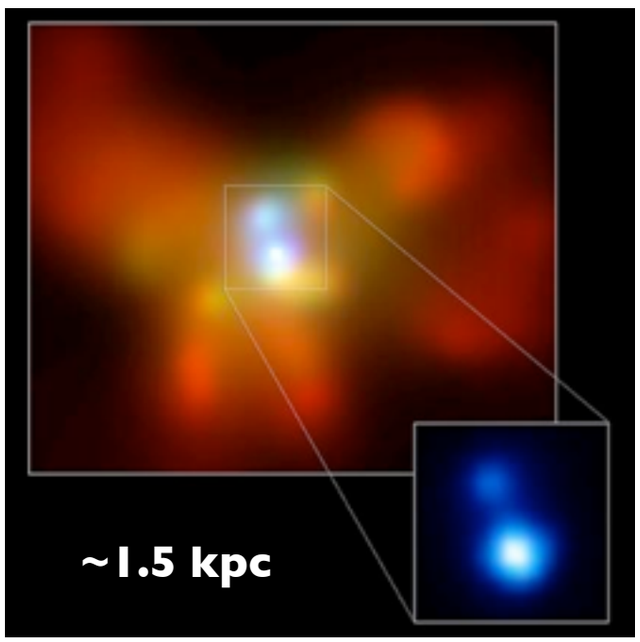
Dual Massive Black Holes

Separations between ≲10 pc and >10 kpc

Begelmann et al. (1980)



NGC 3393, Fabbiano et al. (2011)

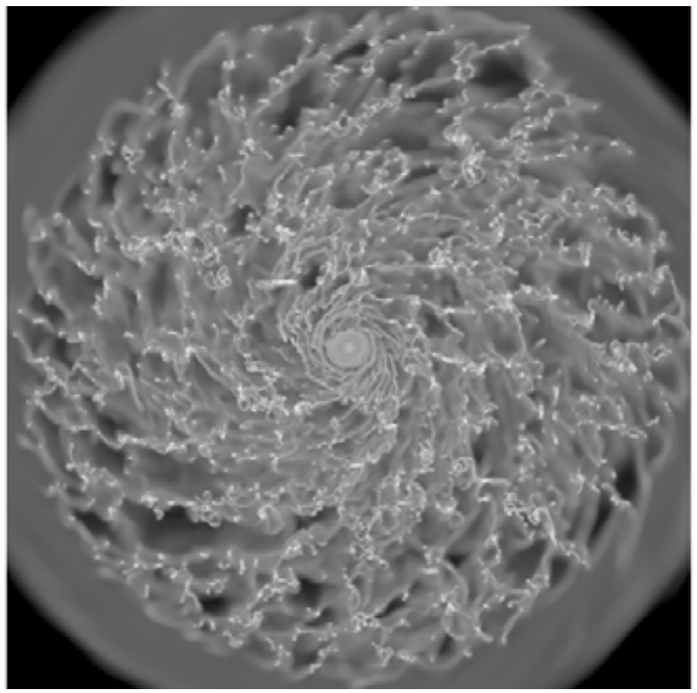


NGC 6240, Komossa et al. (2003)

Introduction

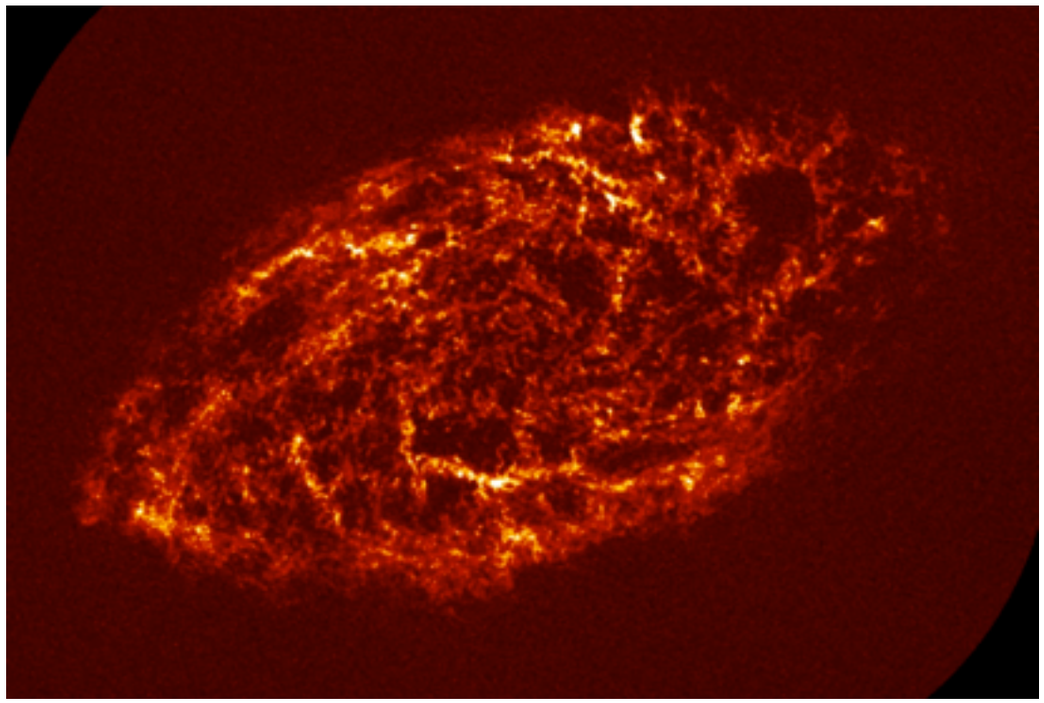
Clumpy Environments

Tasker & Tan (2009)



Theory

M33, HI map, VLA, NRAO



Observations

(Giant) Molecular Clouds (~10^4-10^6 $M_\odot$, ~5-100 pc)
Seeded by Gravitational Instability

Clumpy ISM at Different Scales
Influence on Dual BHs' Dynamics?

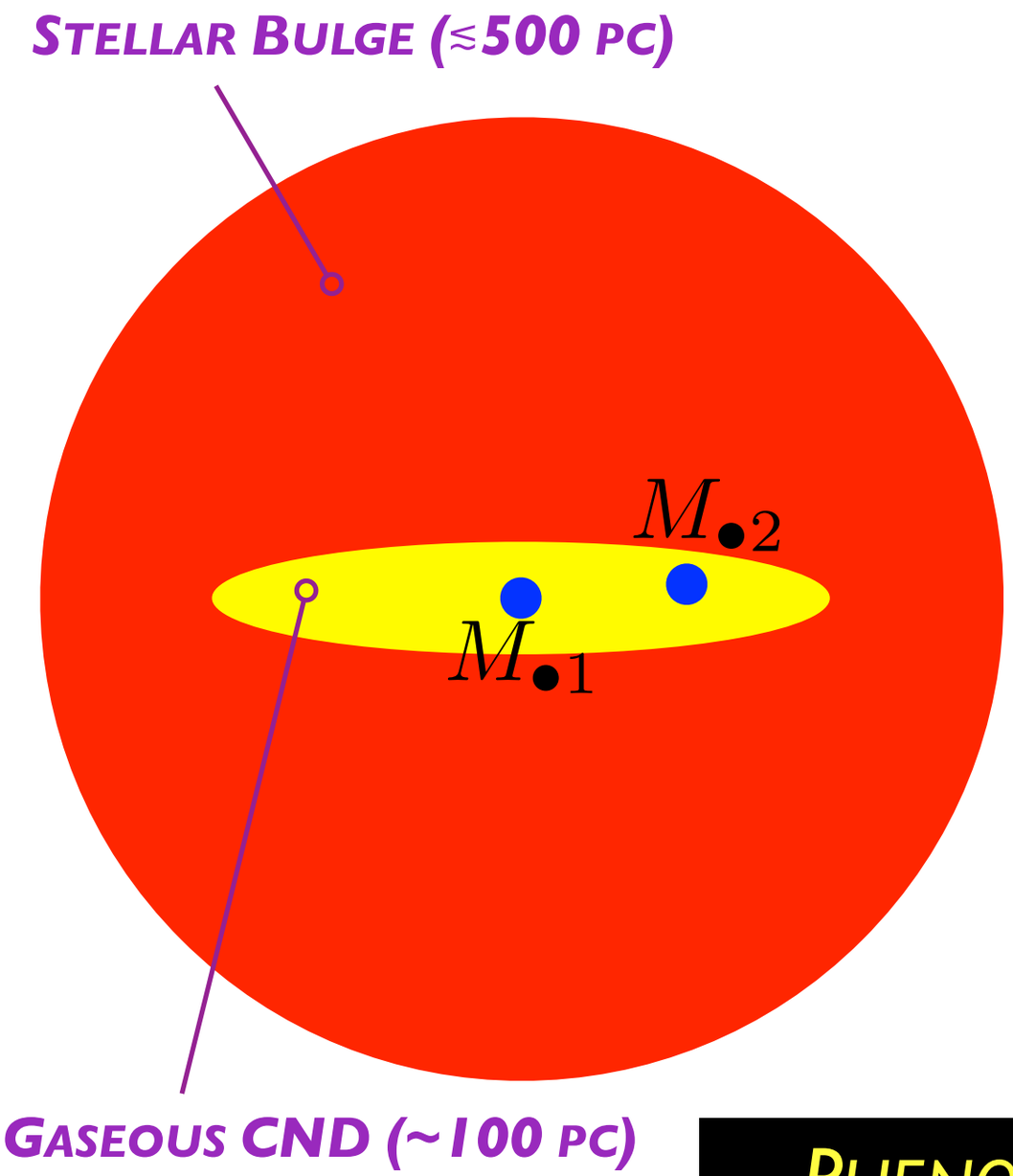
MBH Pairs & CNDs: Simulations

Simulation Set-Up

Fiacconi, Mayer, Roškar & Colpi, ApJ submitted

- *SPH Simulation with GADGET2*
- *Plummer stellar spheroid*
- *Self-Gravitating Mestel gaseous disk*

$$M_\star / M_{\rm d} = 5$$



List of performed simulations and of their parameters.

Label	$M_{\rm d}$ [$M_\odot$]	q[a]	f	e_0[b]	$t_{\rm cool}$ [Myr]
q005f02LM	10^8	0.05	0.2	0.2	1.0
q005f1LM	10^8	0.05	1.0	0.7	1.0
q02f025LM	10^8	0.2	0.25	0.25	1.0
q02f2LM	10^8	0.2	2.0	0.9	1.0
q01f02HM	5×10^8	0.1	0.2	0.2	0.5
q01f2HM	5×10^8	0.1	2.0	0.9	0.5
q02f02HM	5×10^8	0.2	0.2	0.2	0.5
q02f2HM	5×10^8	0.2	2.0	0.9	0.5

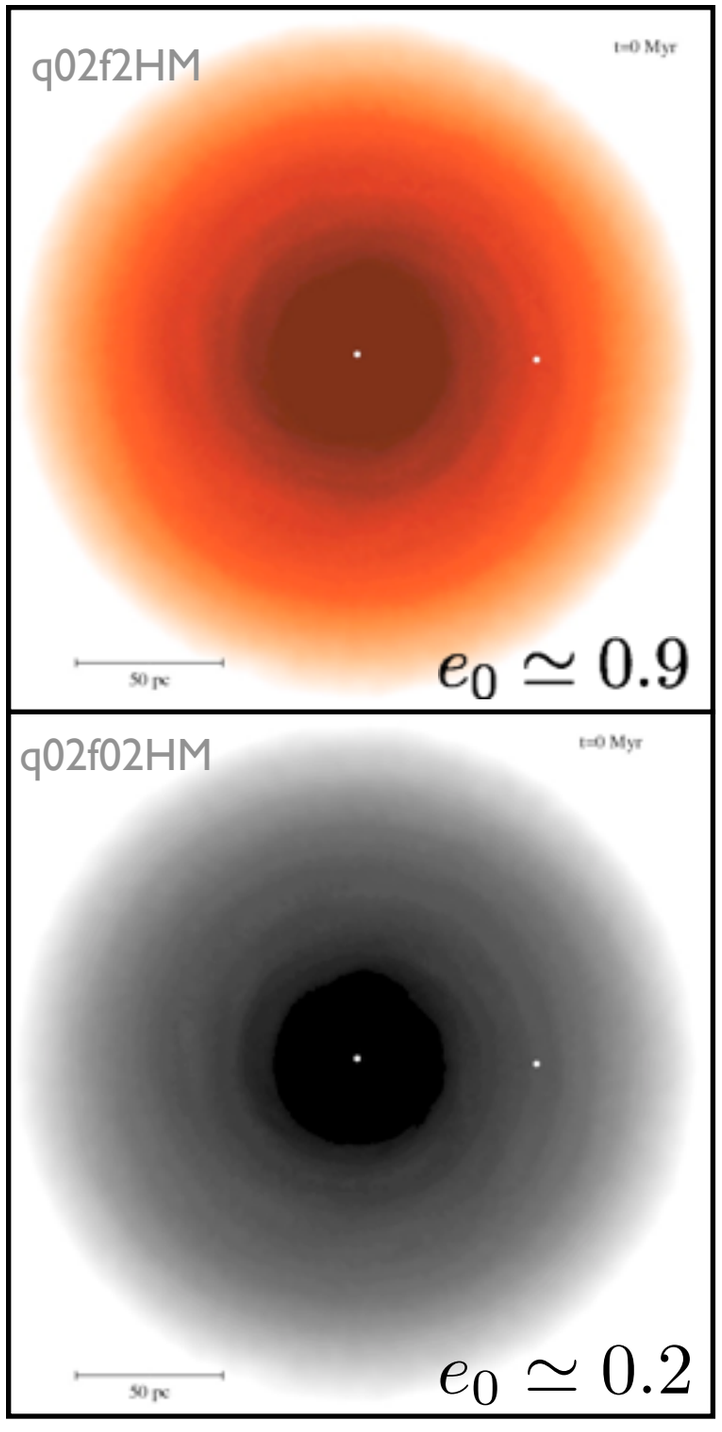
[a] $q = M_{\bullet 2}/M_{\bullet 1}$, $M_{\bullet 1} = 10^7$ $M_\odot$.
[b] $e_0 \sim \sqrt{1 - 1/(1+f^2)}$.

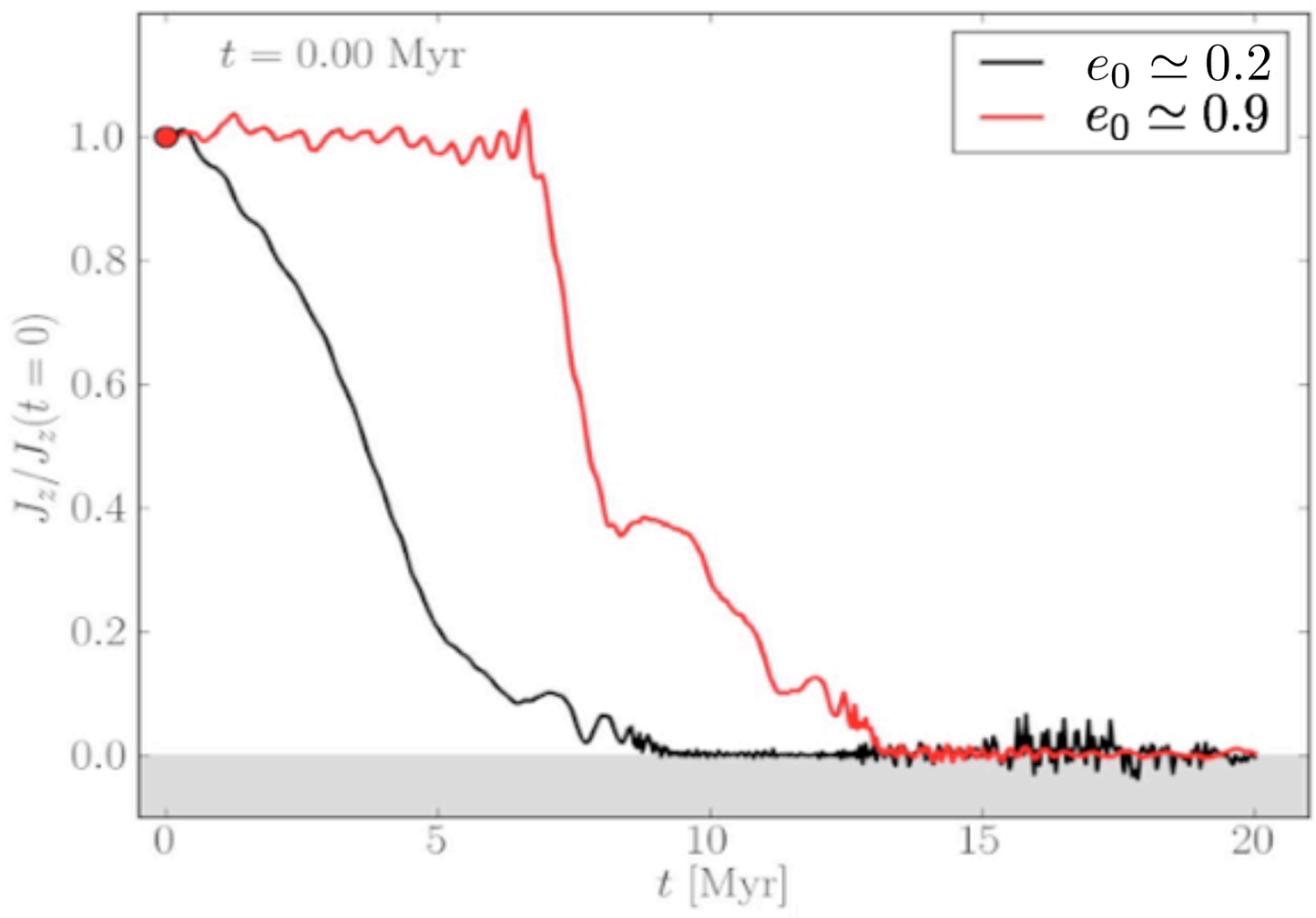
Phenomenological Cooling for Clumpy ISM

$$\Lambda_{\rm cool} = -\frac{u}{t_{\rm cool}}$$

MBH Pairs in Smooth CNDs

Reference Case: Overview





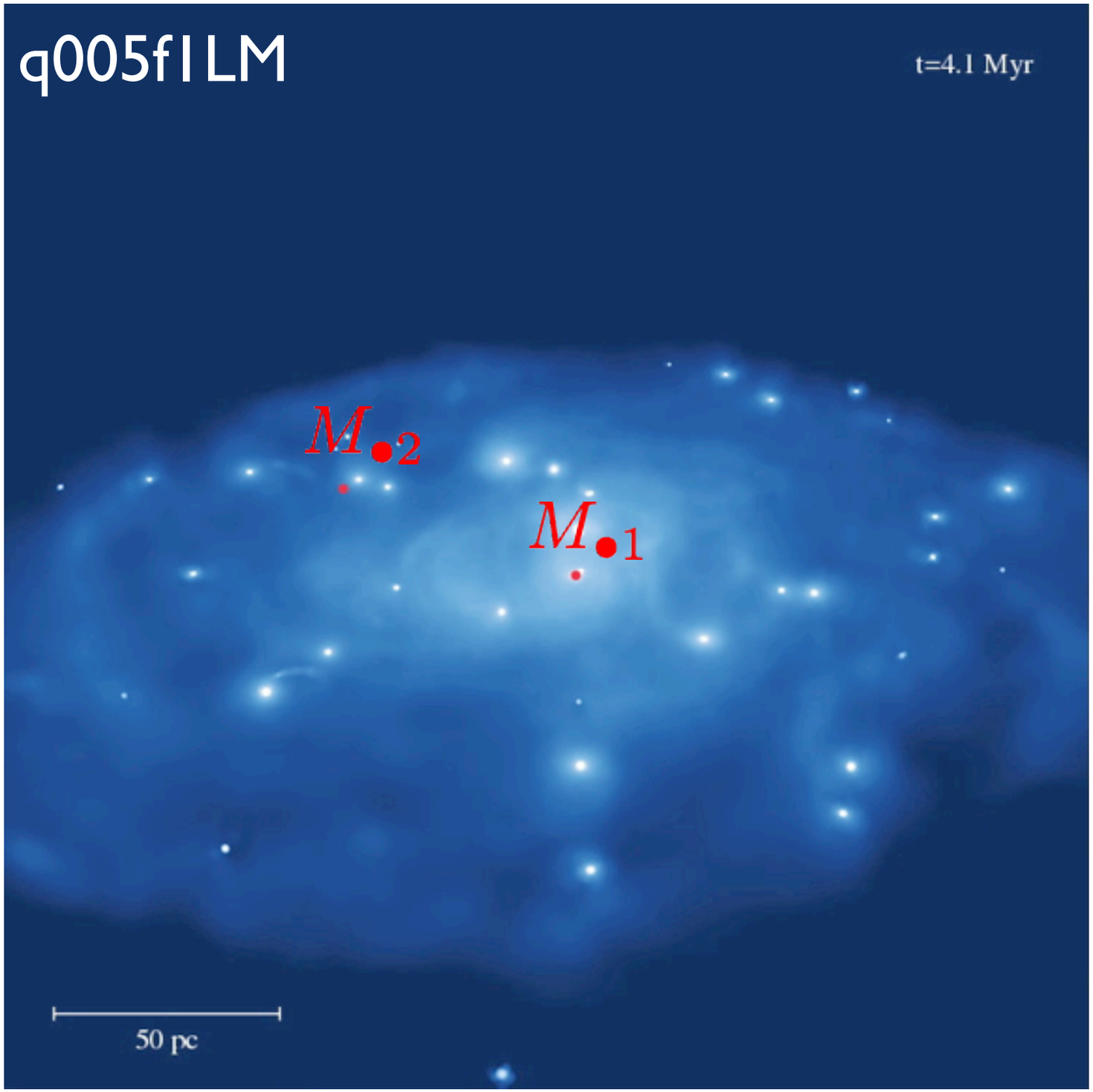
Orbit Circularization & Fast Decay ~10 Myr

Dotti et al. (2006,2007)

DF et al., submitted to ApJ

MBH Pairs in Clumpy CNDs

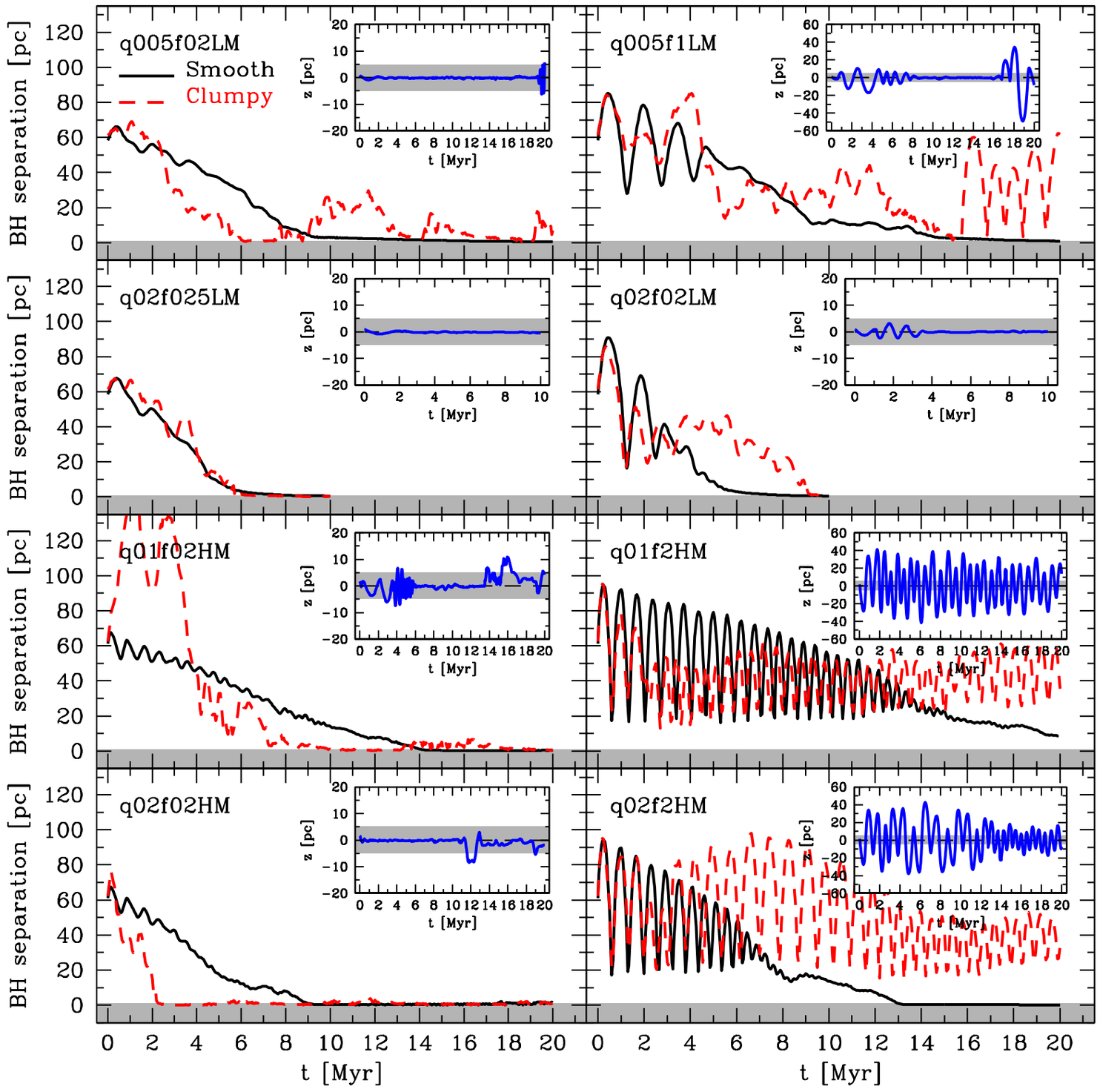
Dynamics in Clumpy ISM: Results



DF et al., submitted to ApJ

MBH Pairs in Clumpy CNDs

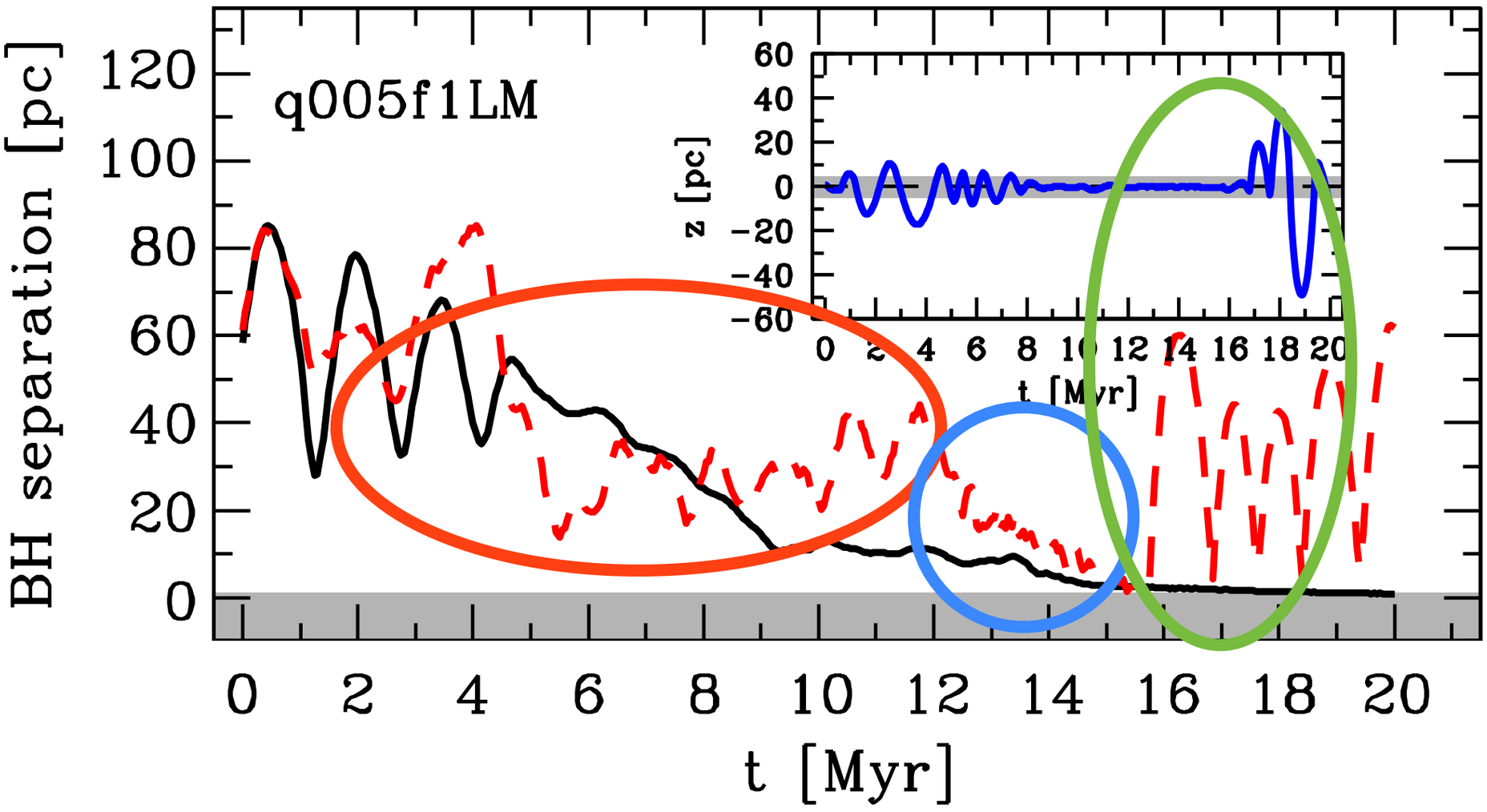
Dynamics in Clumpy ISM: Results



DF et al., submitted to ApJ

MBH Pairs in Clumpy CNDs

Dynamics in Clumpy ISM: Results



BH Scattering from Clumps & Spiral Arms

BH-Clump Binary & 3-Body scattering

BH Ejection from Disk Plane

$$1 \lesssim \tau_{\rm decay}/{\rm Myr} \lesssim 50$$

$$\xi = \frac{M_\bullet}{M_{\rm cl}} \lesssim 1$$

BH-Clump Binary | Clump Scattering | BH Ejection

DF et al., submitted to ApJ

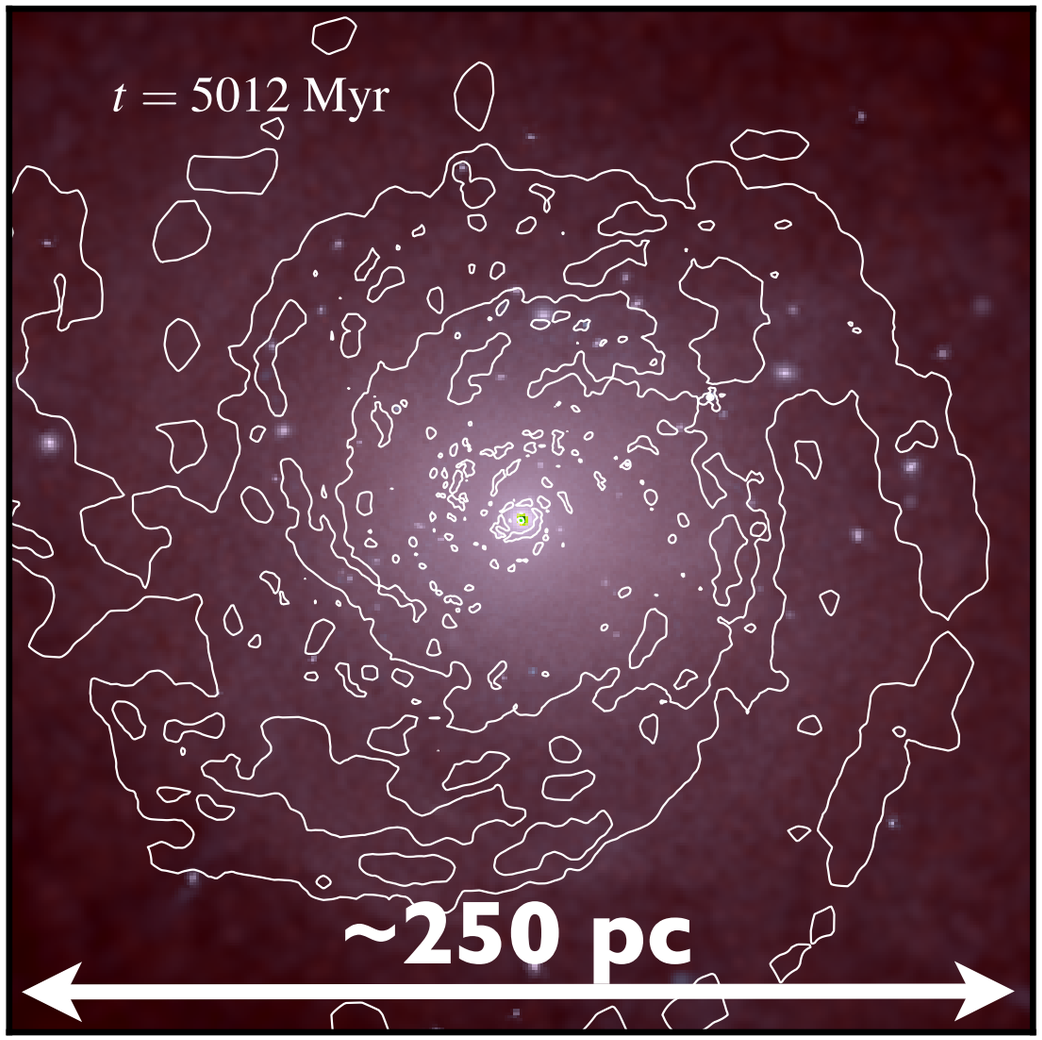
MBH Pairs in Major Mergers

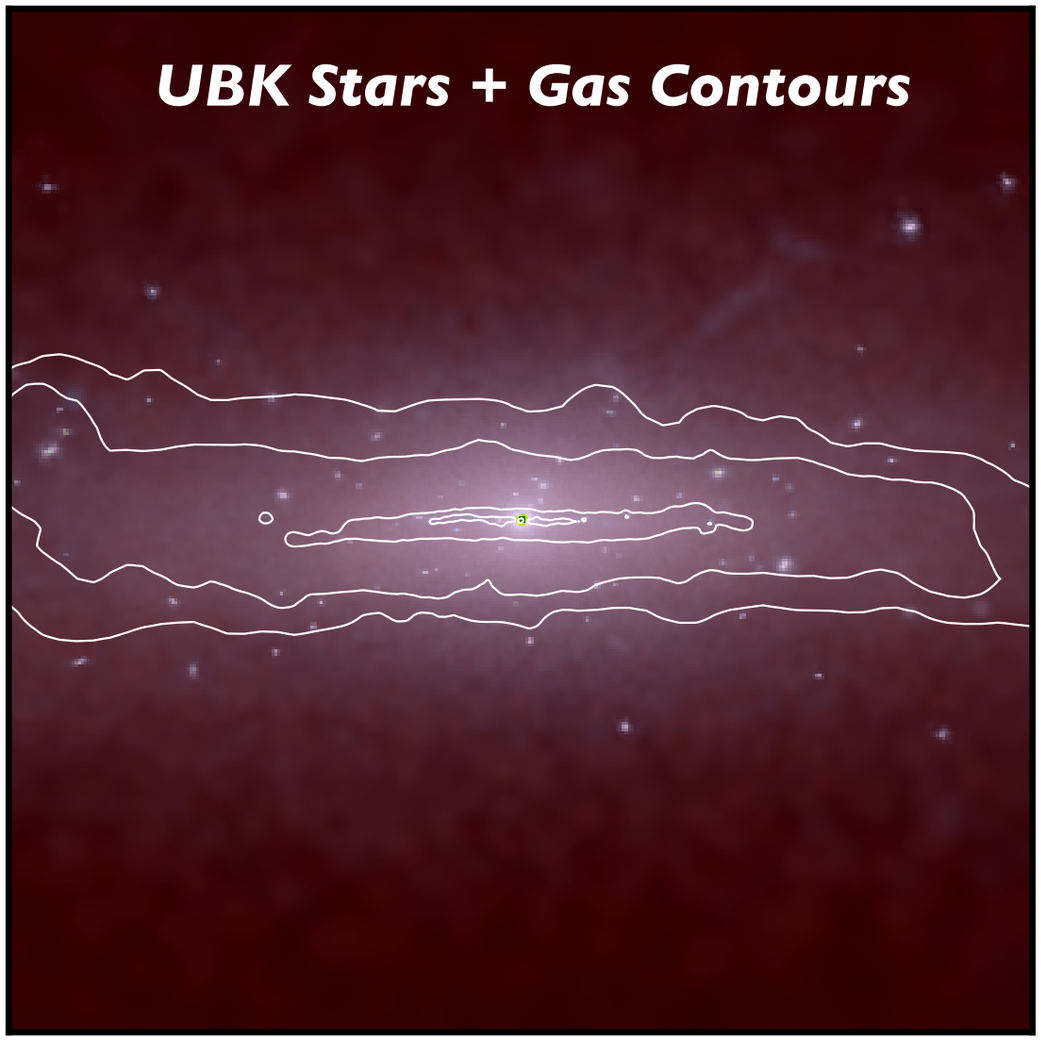
Preliminary Results

Roškar, Fiacconi, et al., in preparation

Second Step

1:1 Major Merger of gas-Rich Galaxies with Multi-Phase ISM

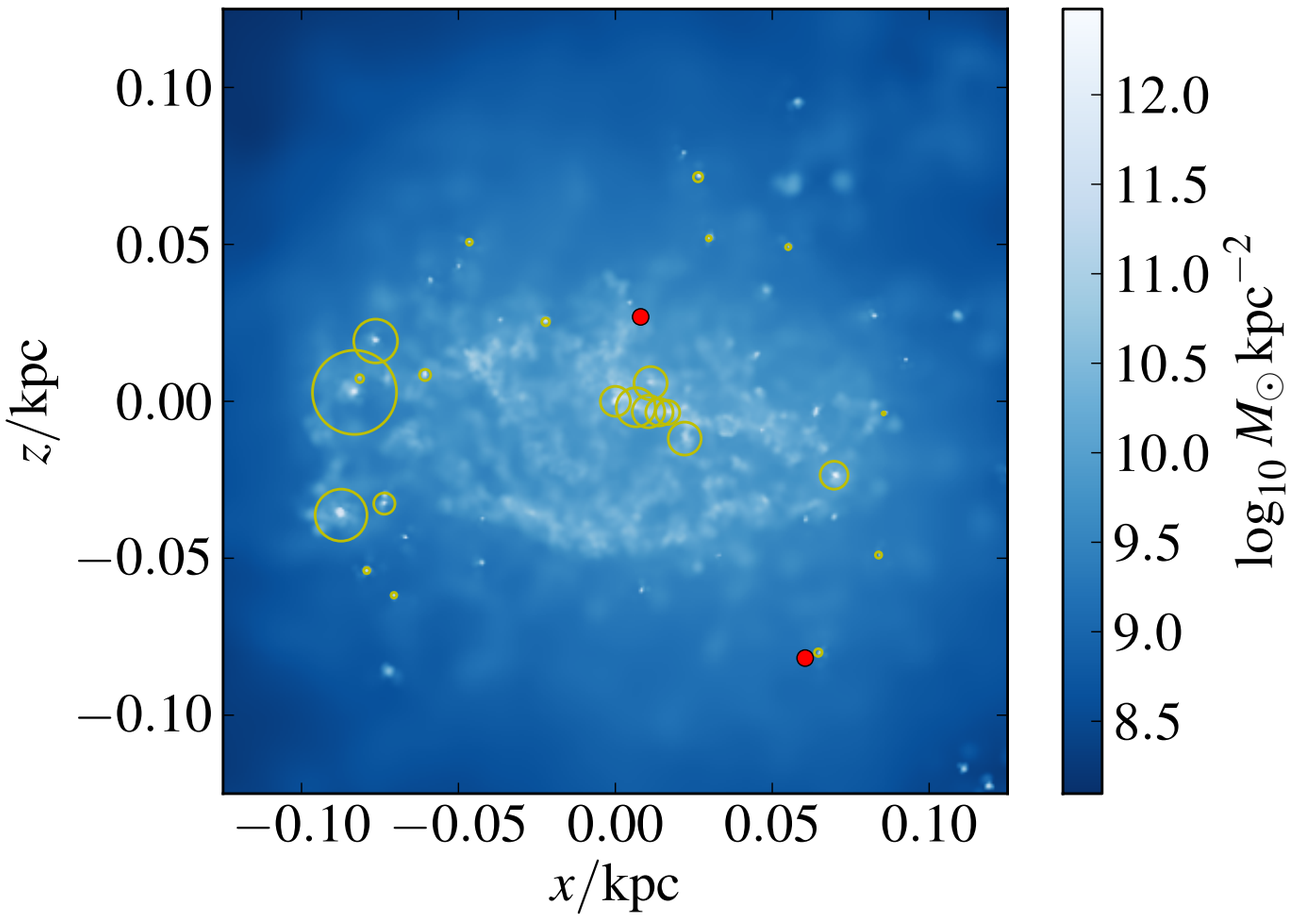




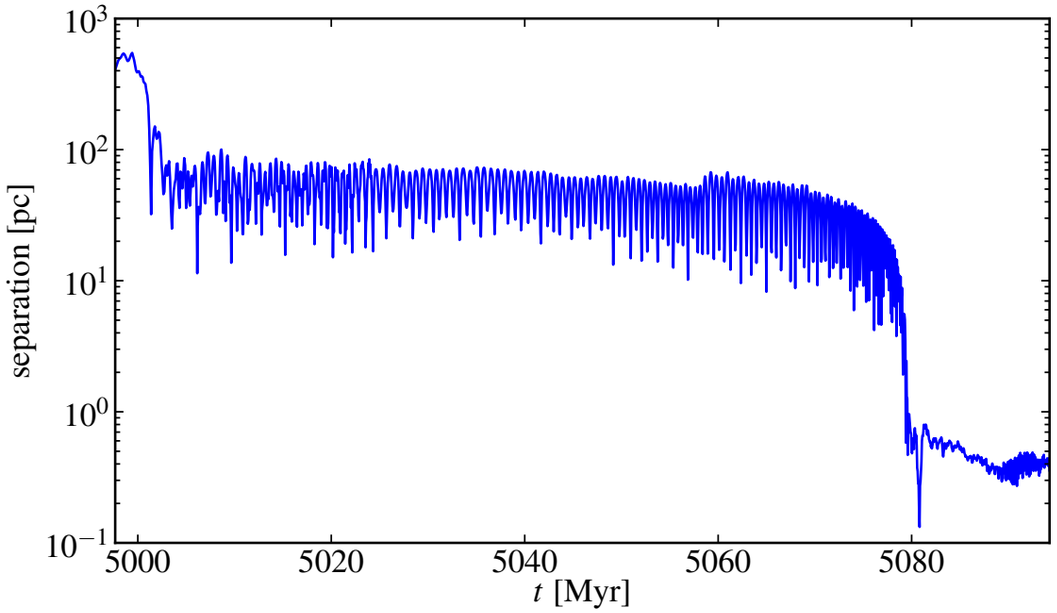
Initial Set-Up as in Mayer et al. (2007)

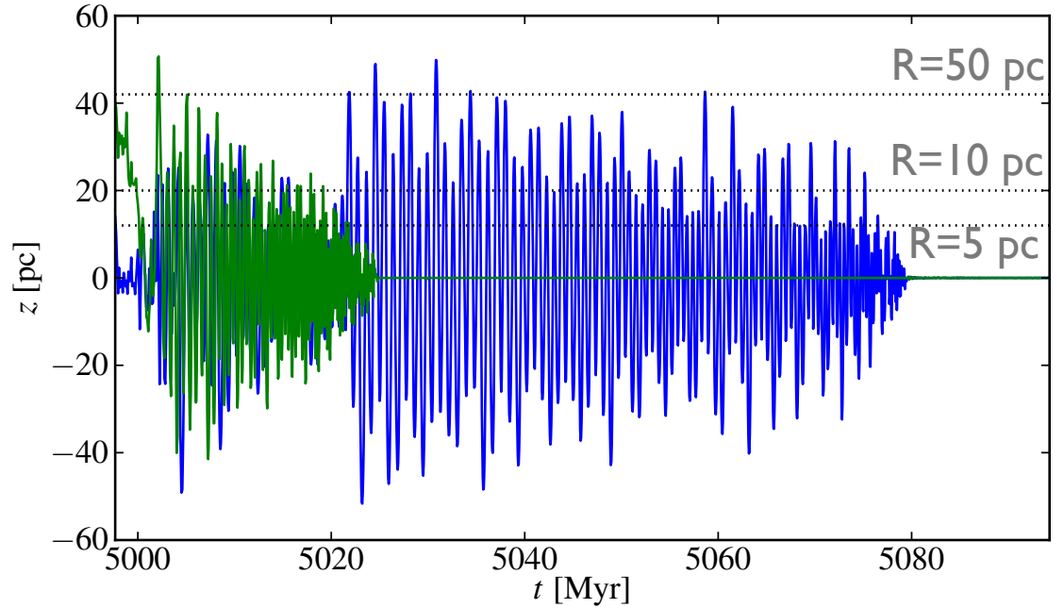
MBH Pairs in Major Mergers

Preliminary Results



BH Ejection & Temporary Stall





$$\tau_{\rm decay} \sim 100\ {\rm Myr}$$

$$\tau_{\rm Mayer+07} \sim 5\ {\rm Myr}$$

Roškar, DF, et al., in preparation

Conclusions

Is the ISM Relevant for MBH Orbital Decay?

- *Massive **BH pairs** in **Gaseous Environments**: Path to **Binary Formation***
- *However, **ISM Matters!** Inhomogeneities lead to **BH Scattering** and **Ejection** from Disc-Like Configurations*
- ***Stochastic** Orbital **Decay**: Wider Range of **Timescales**, a Factor ≲**10 Longer/Shorter!***