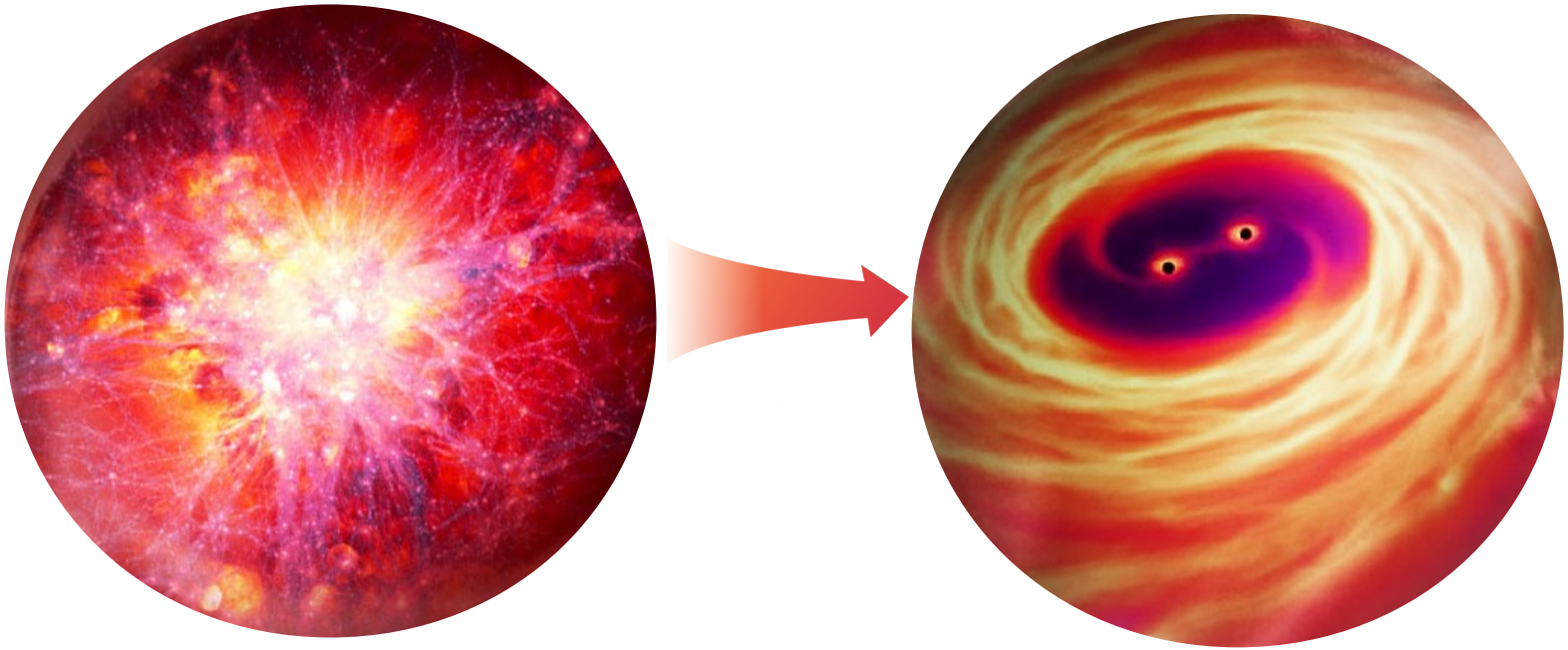
Cosmological simulations of supermassive black hole binaries: spin evolution, coalescence time-scale and merger rate

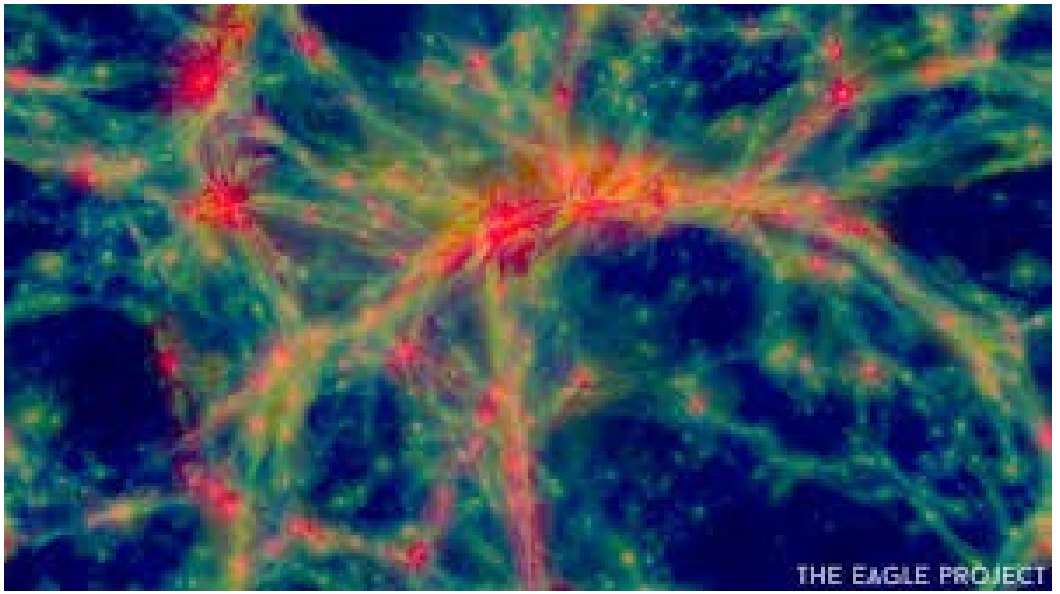


Debora Sijacki

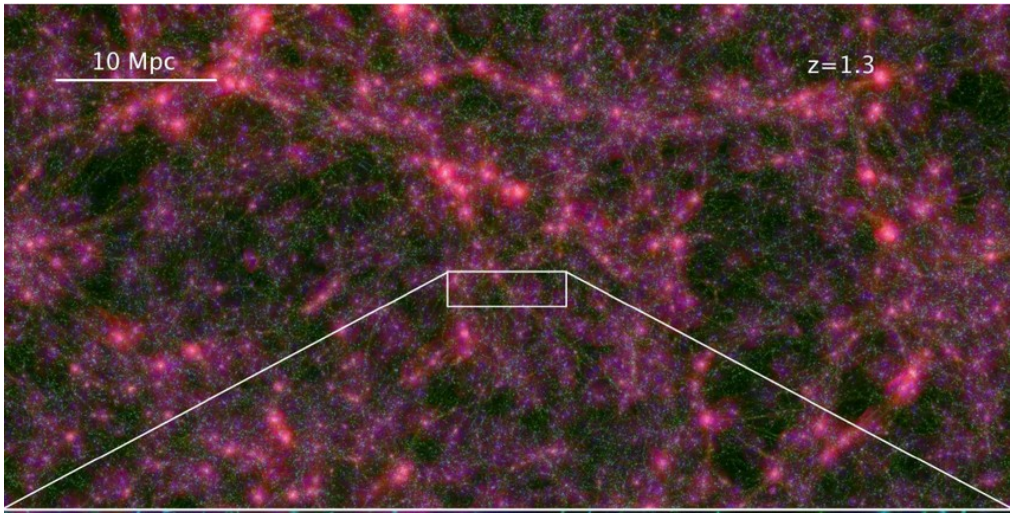
IAP, Paris, December 13, 2018

Current state-of-the-art in cosmological hydro simulations

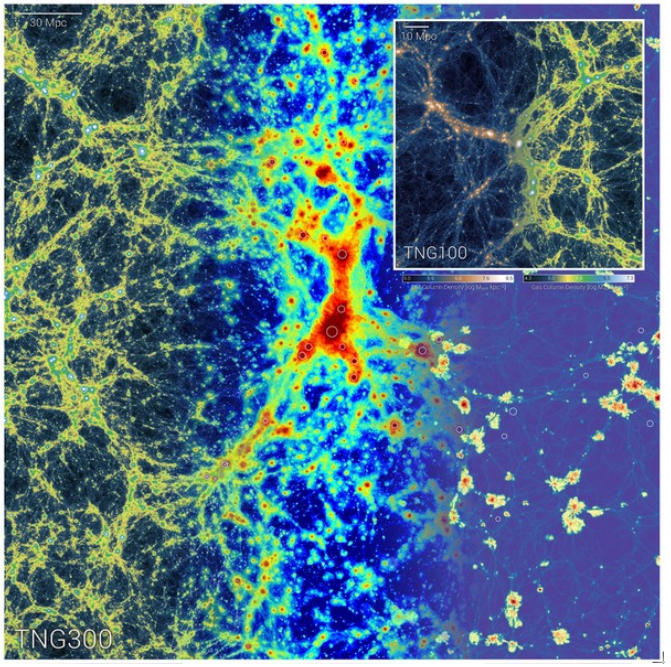
The Eagle Project (Schaye et al. 15)



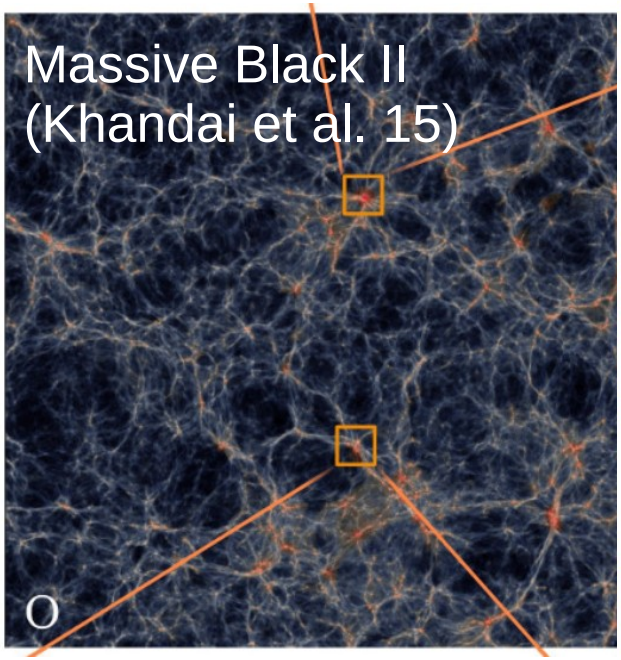
The Horizon AGN project (Dubois et al. 14)



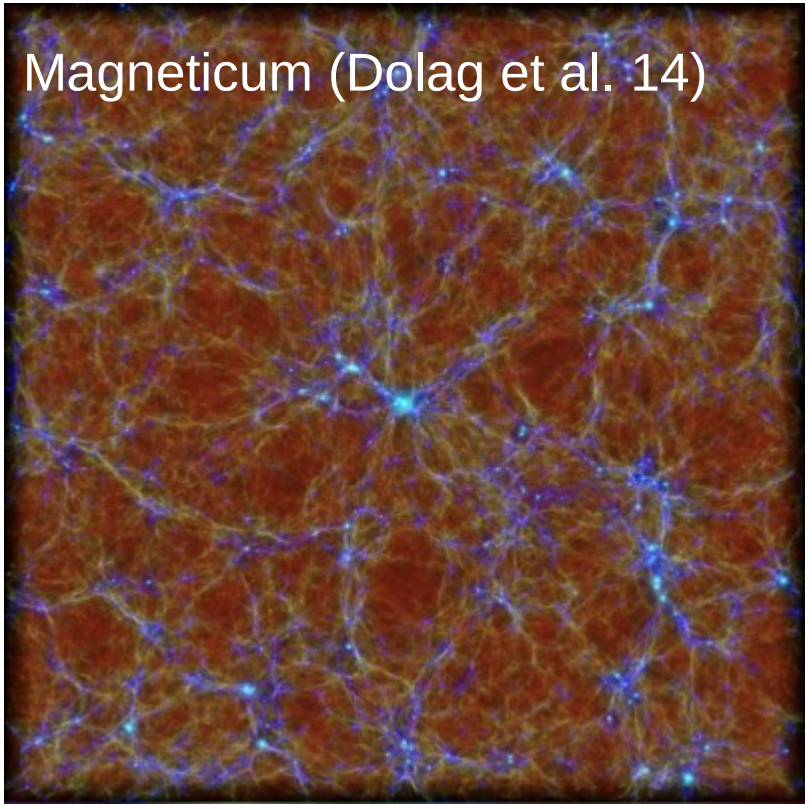
Illustris TNG (Springel et al. 17)



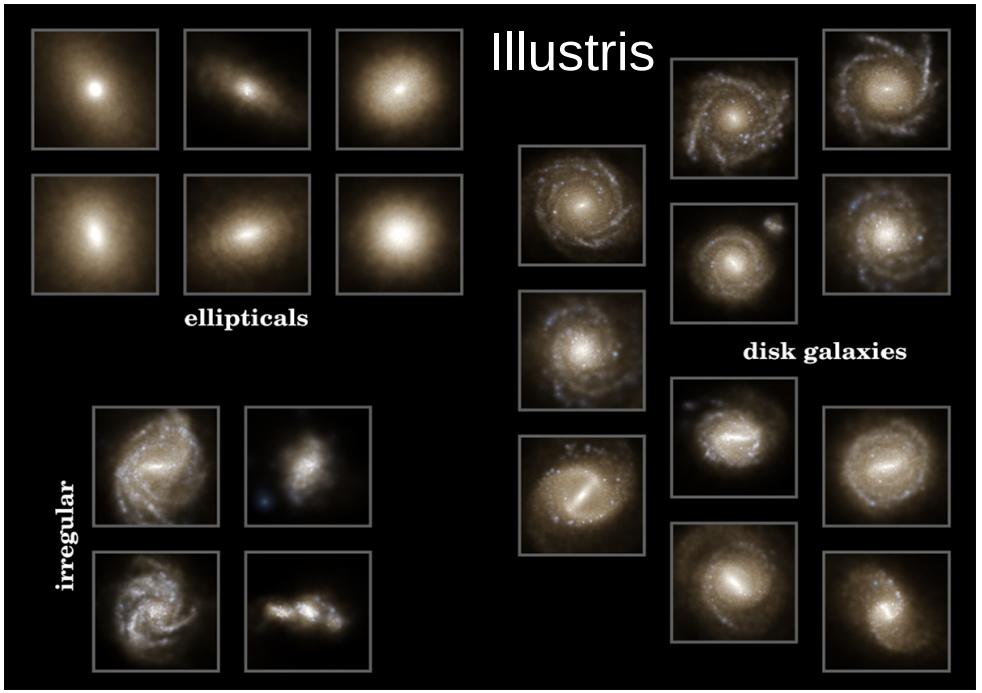
Massive Black II
(Khandai et al. 15)

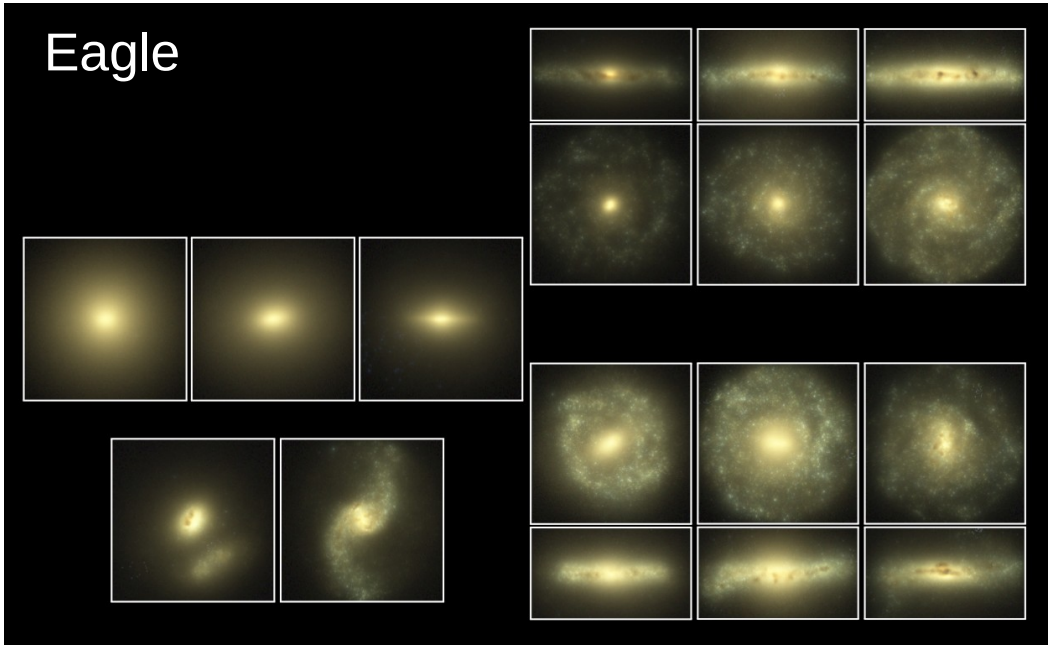


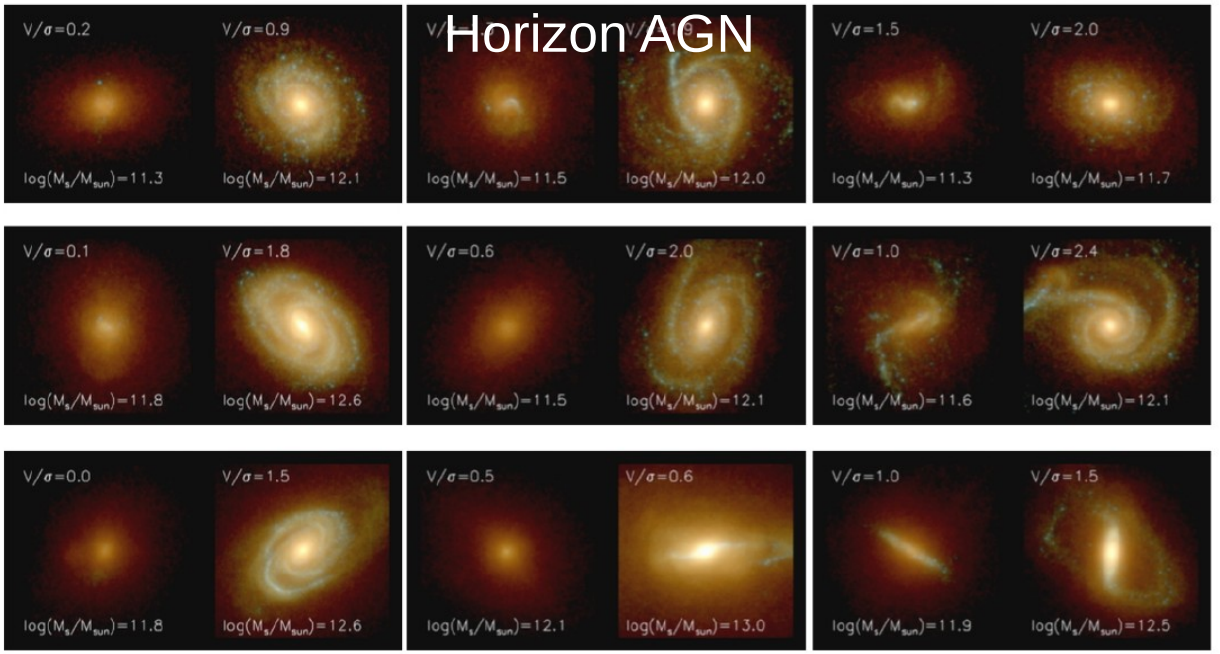
Magneticum (Dolag et al. 14)



SMBH feedback is the key for galaxy morphologies







Caveats

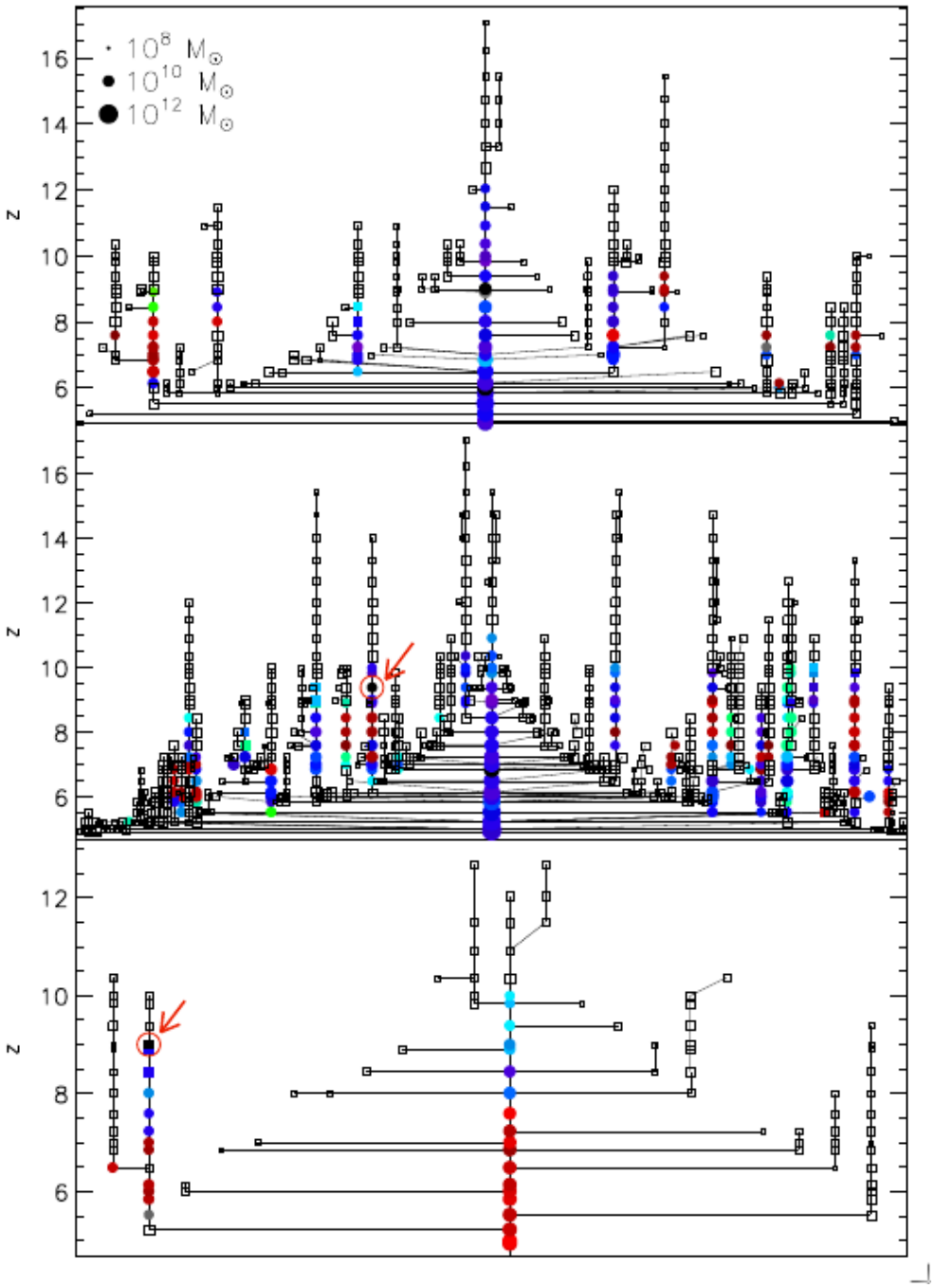
- Majority of these models assume very massive seeds → helps kick start BH growth for z ~6 QSOs

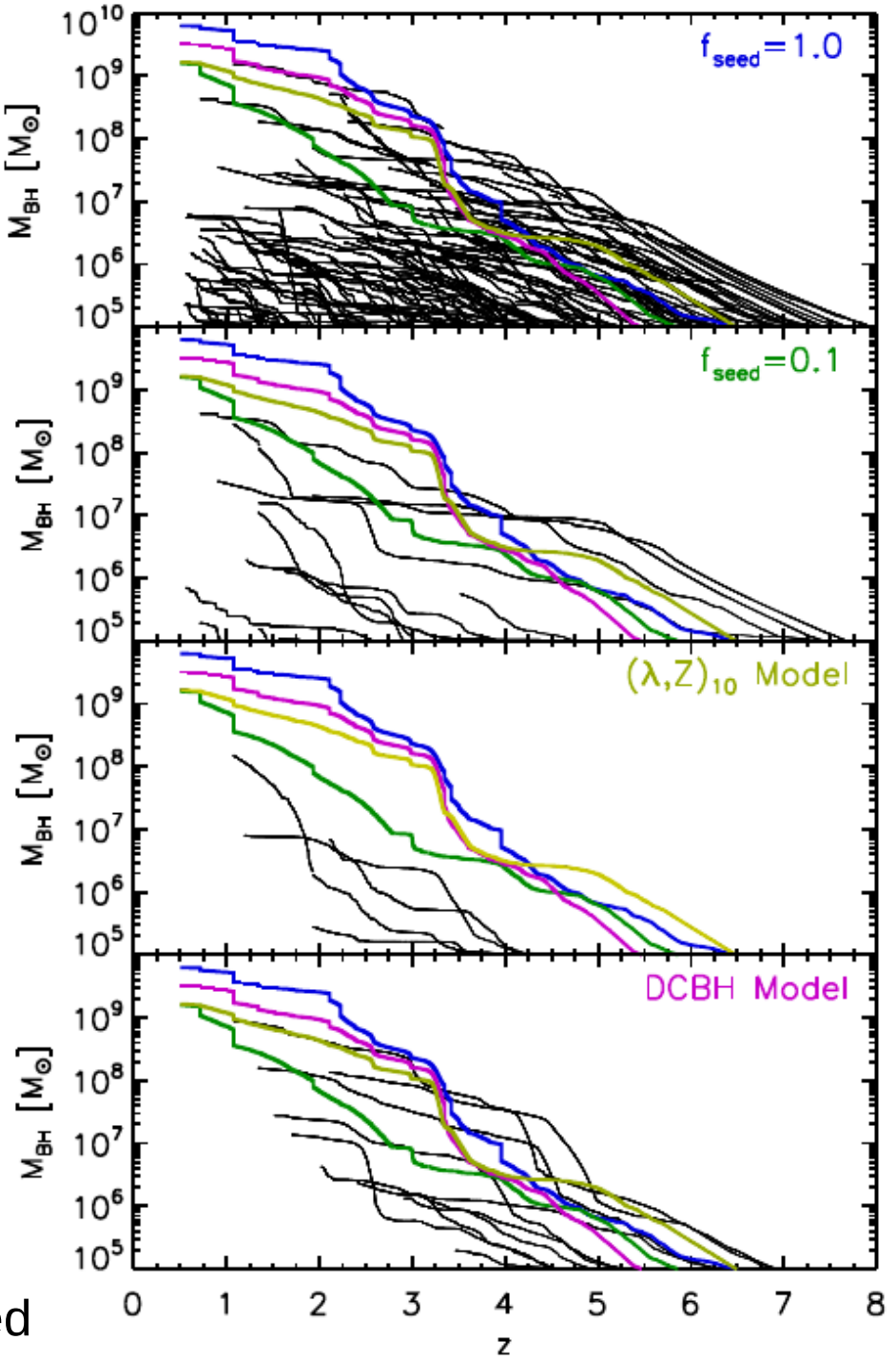
- Majority of these models assumes all massive haloes have SMBHs seeds

- Majority of these models assumes “Bondi-Hoyle”-like accretion → helps kick start BH growth and reach Eddington limit

- Majority of these models neglects various early feedback processes, e.g. radiation from stars, stellar winds, etc. which could stall BH growth

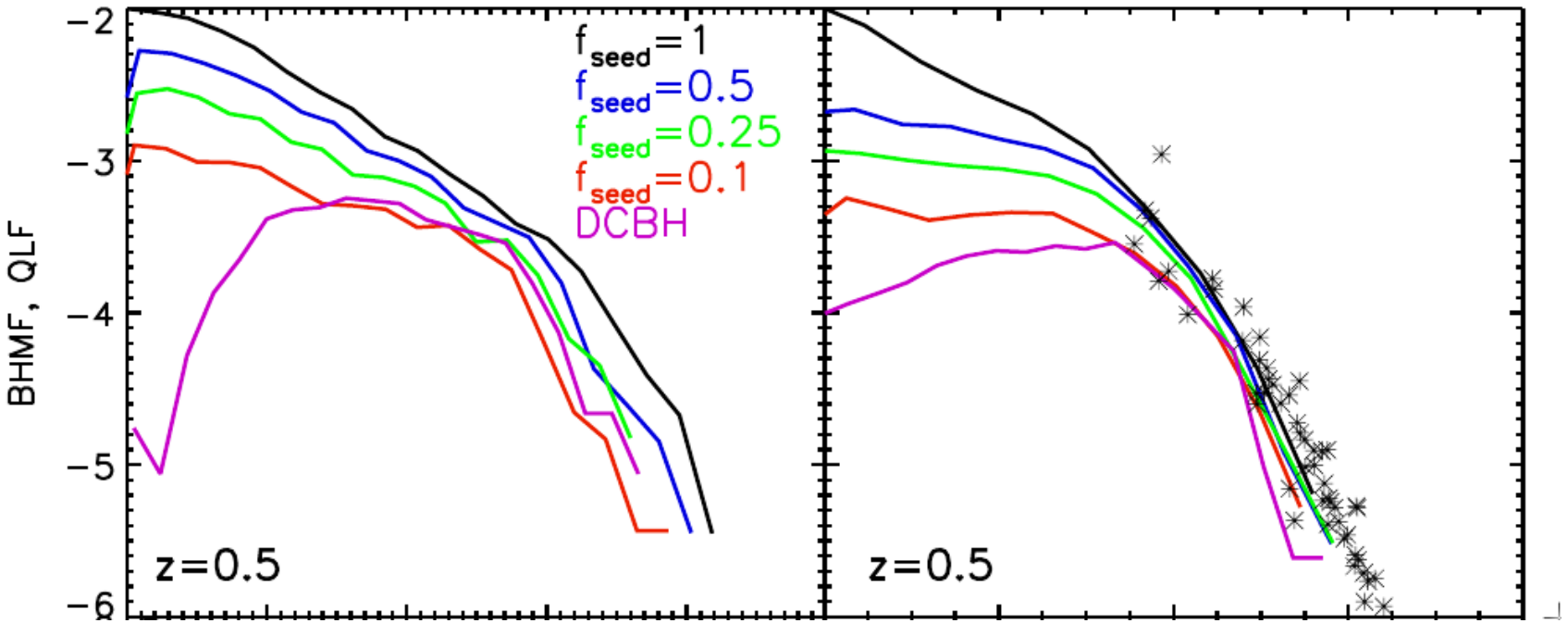
BH seeding in large cosmological simulations



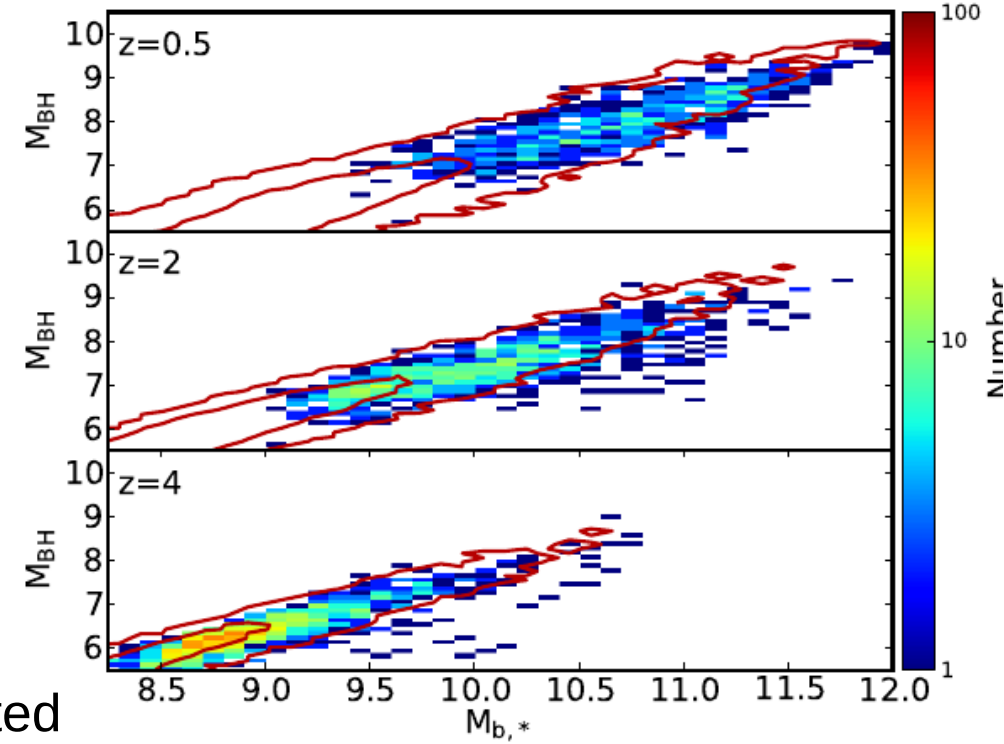


DeGraf & Sijacki, 2019, MNRAS, to be submitted

BH seeding: implications for observational constraints

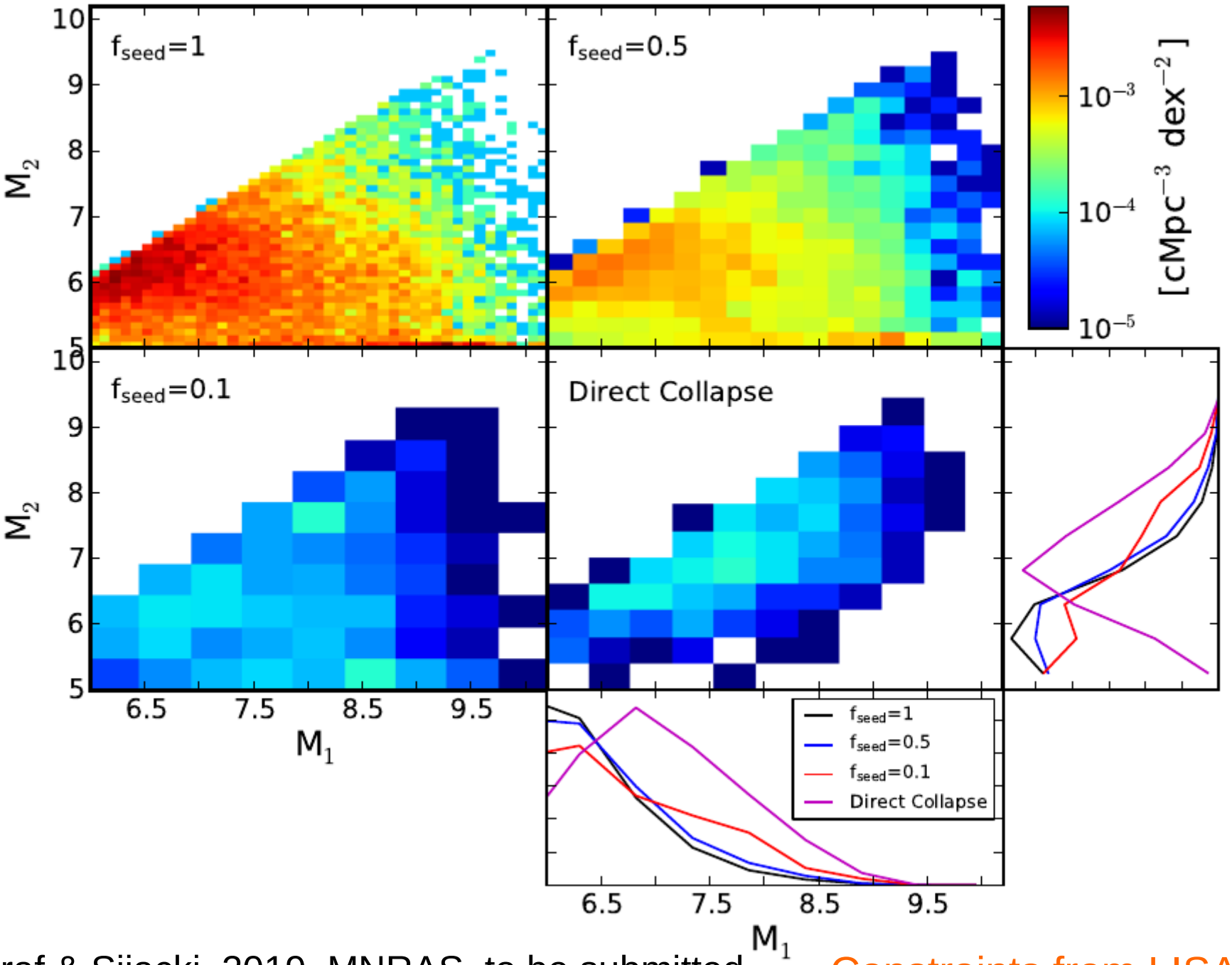


Different seeding models affect BHMF, BHLF and scaling relations especially at the low-mass/faint end



DeGraf & Sijacki, 2019, MNRAS, to be submitted

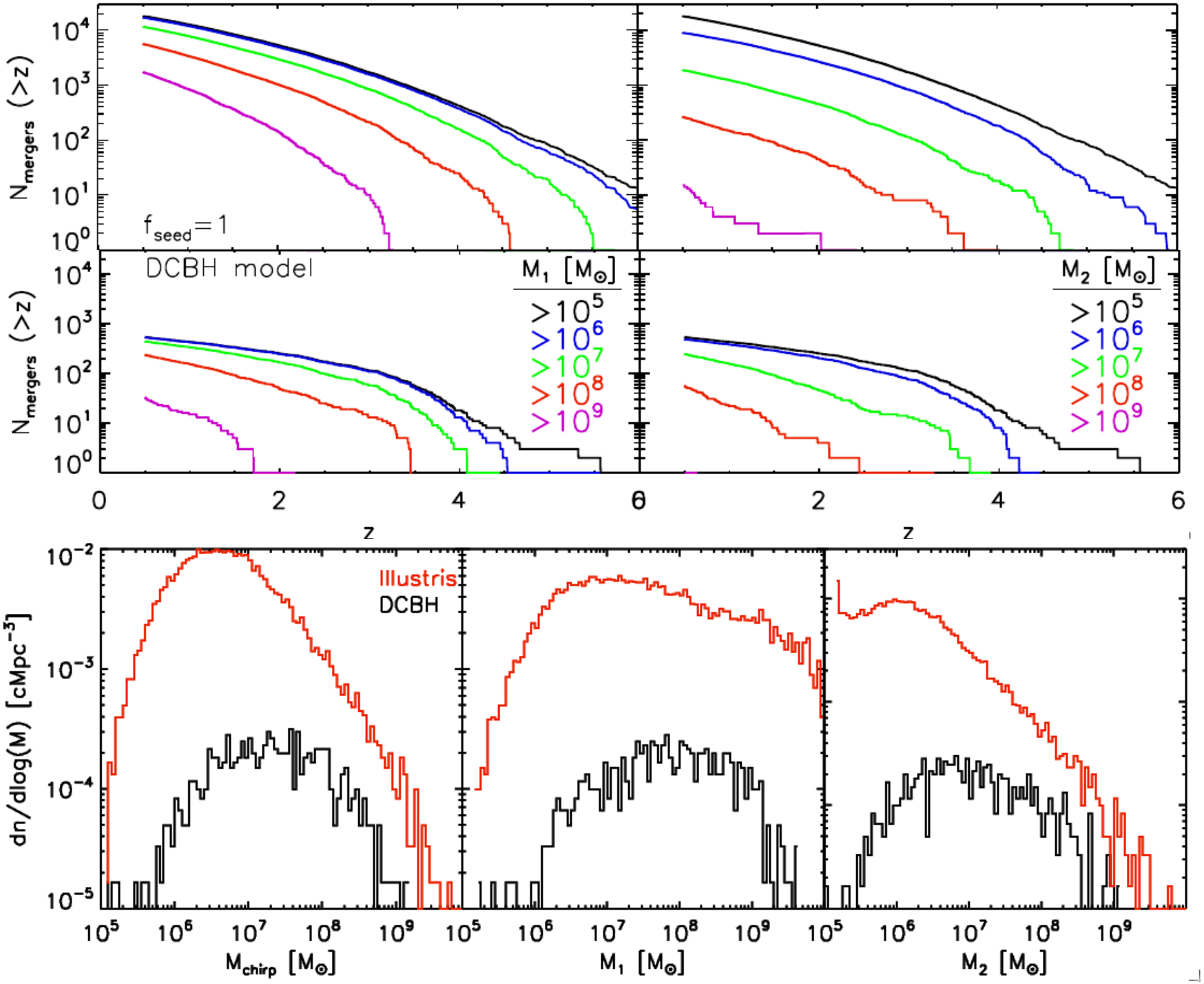
BH seeding: implications for merger rates



DeGraf & Sijacki, 2019, MNRAS, to be submitted

Constraints from LISA & IPTA

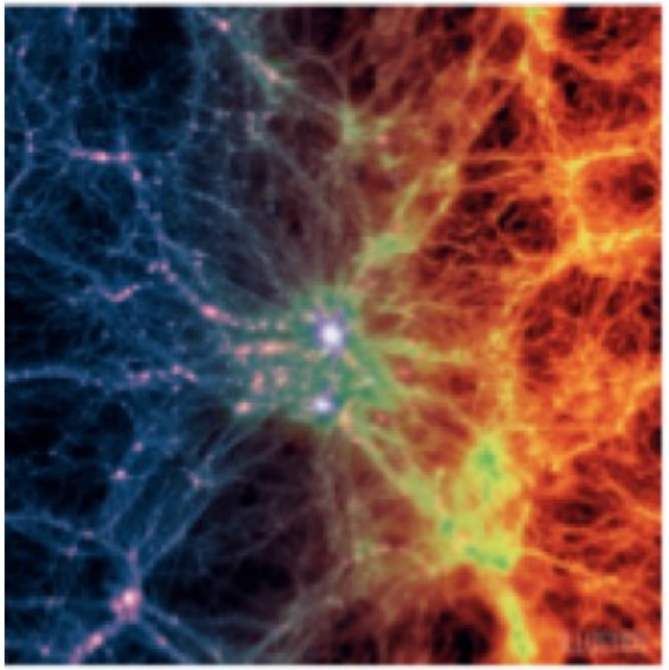
BH seeding: implications for merger rates



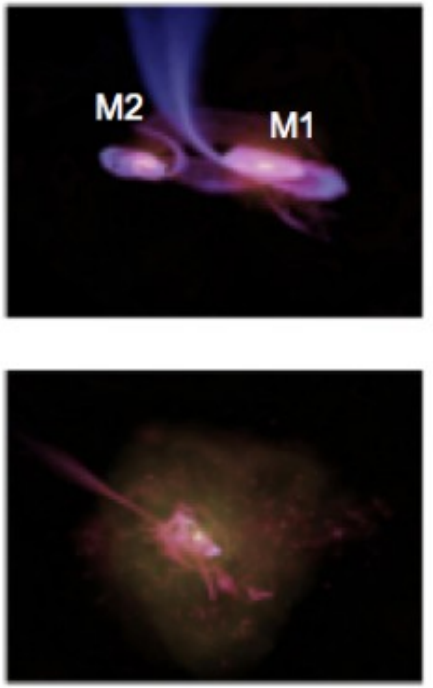
DeGraf & Sijacki, 2019, MNRAS, to be submitted

Multi-messenger astrophysics with SMBH binaries

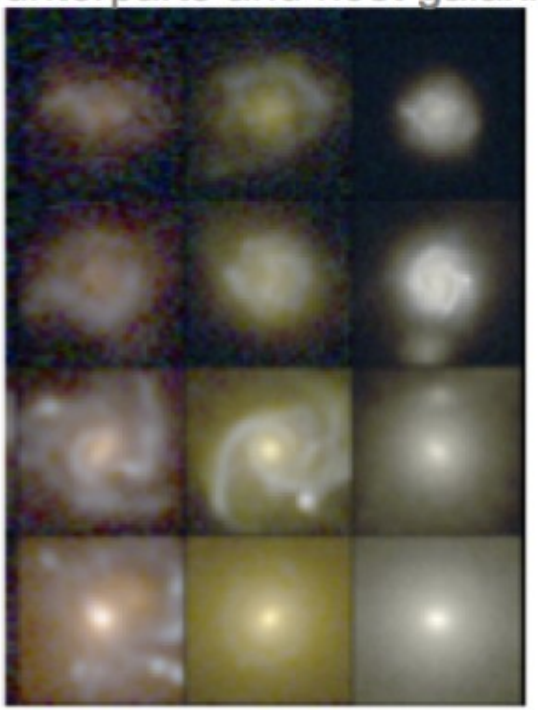
Cosmological Hydrodynamic Simulations



Massive BH Merger rates



Synthetic observations of EM counterparts and host galaxies



Carnegie Mellon University

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

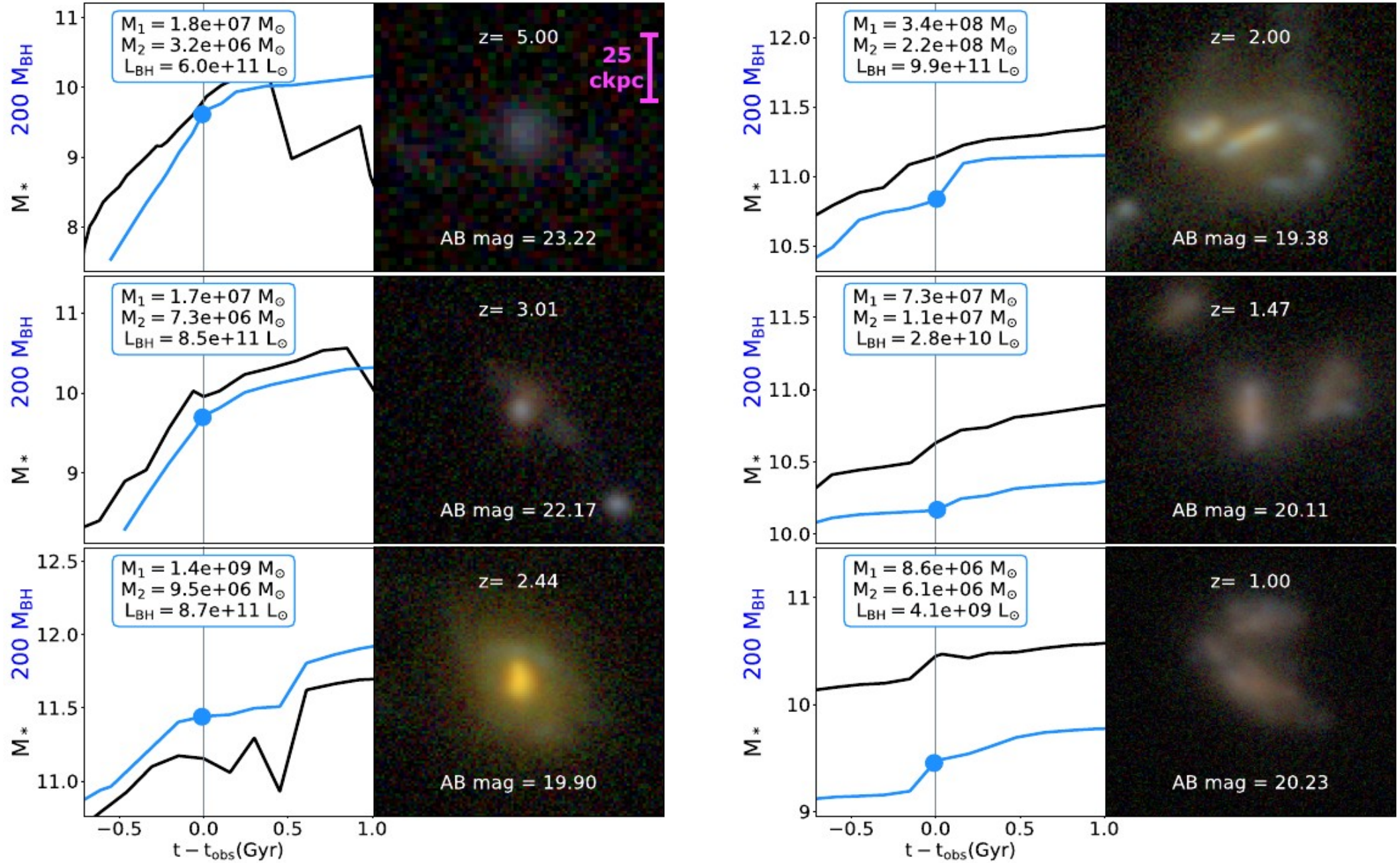
UNIVERSITY OF CAMBRIDGE

Max-Planck-Institut für Astrophysik

VANDERBILT UNIVERSITY

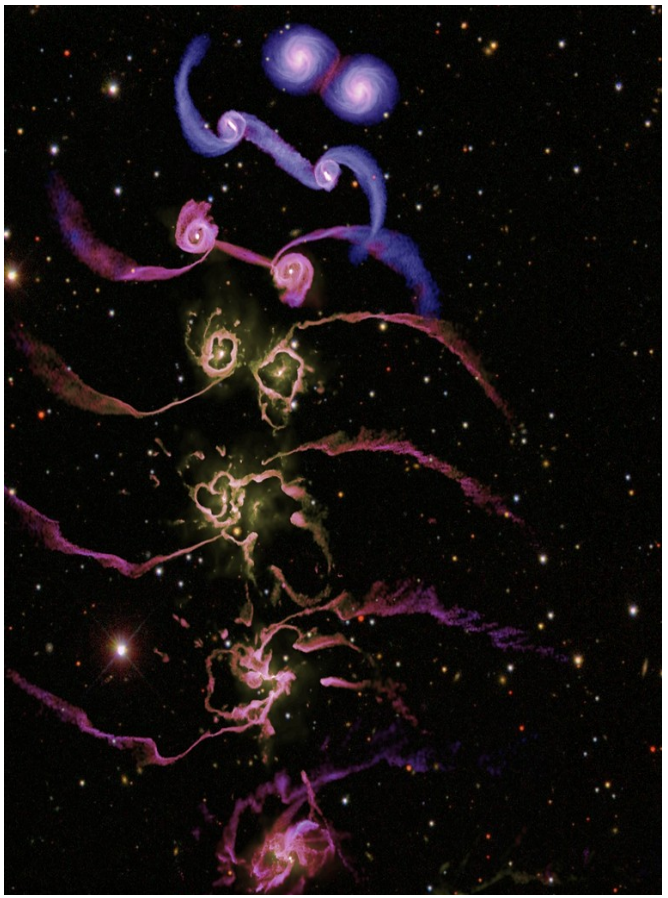
Team members: Tiziana Di Matteo, Gregory Snyder, Colin DeGraf, Debora Sijacki, Volker Springel, Kelly Holly-Bockelmann

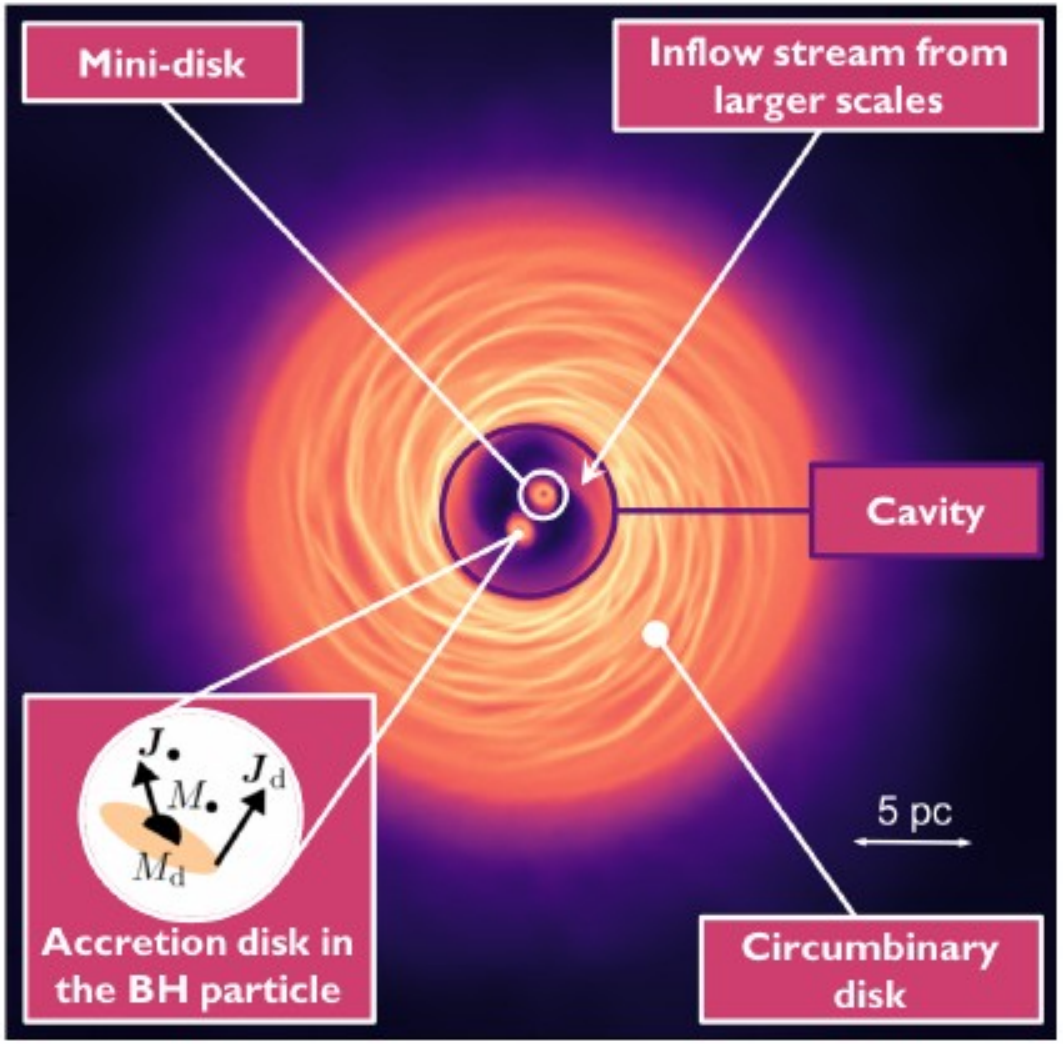
Multi-messenger astrophysics with SMBH binaries



Team members: Tiziana Di Matteo, Gregory Snyder, Colin DeGraf, Debora Sijacki, Volker Springel, Kelly Holly-Bockelmann

Merging supermassive black hole binaries

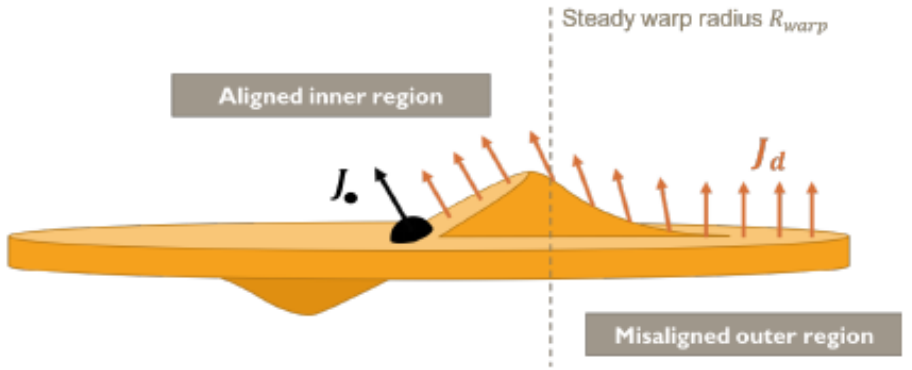




A SIMPLE MODEL FOR BH MASS AND SPIN EVOLUTION ASSUMING THIN, STEADY SS DISK COUPLED TO FULL HYDRO ON LARGER SCALES

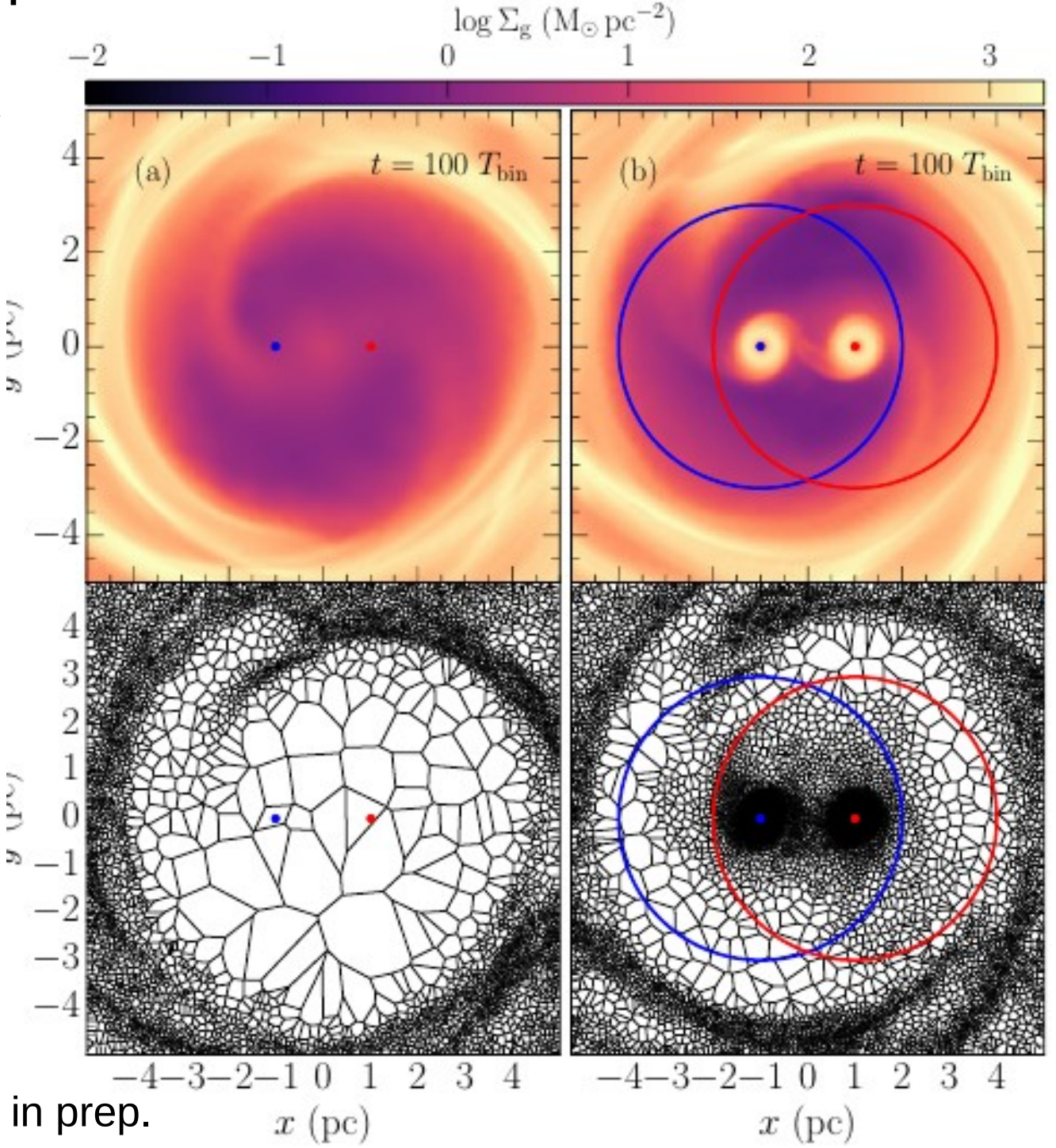
Fiacconi, Sijacki & Pringle, 2018

Fiacconi, Piotrowska & Sijacki in prep.



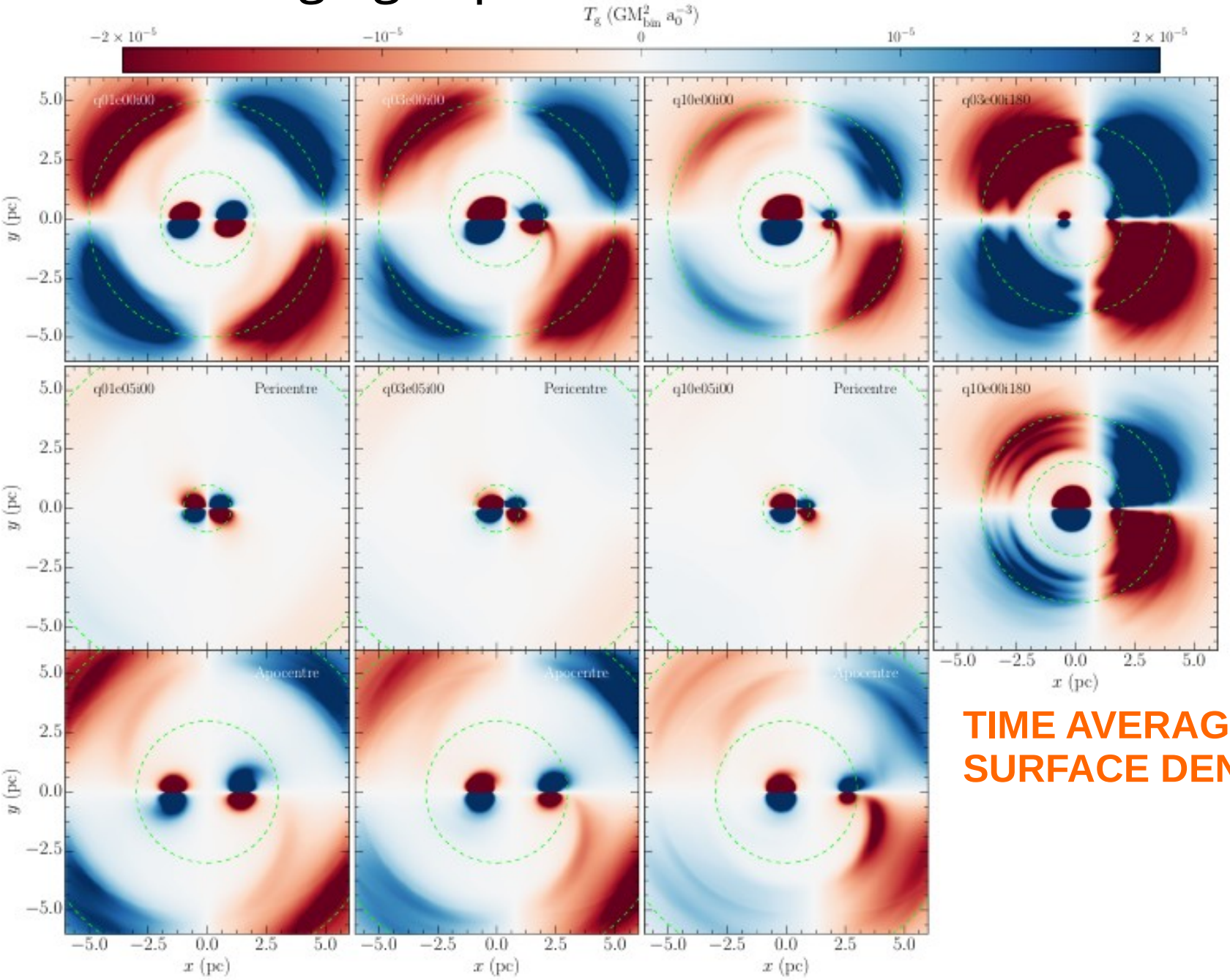
Merging supermassive black hole binaries

MINI DISKS CRUCIAL FOR BINARY DYNAMICS & SPIN EVOLUTION



Fiacconi, Piotrowska & Sijacki in prep.

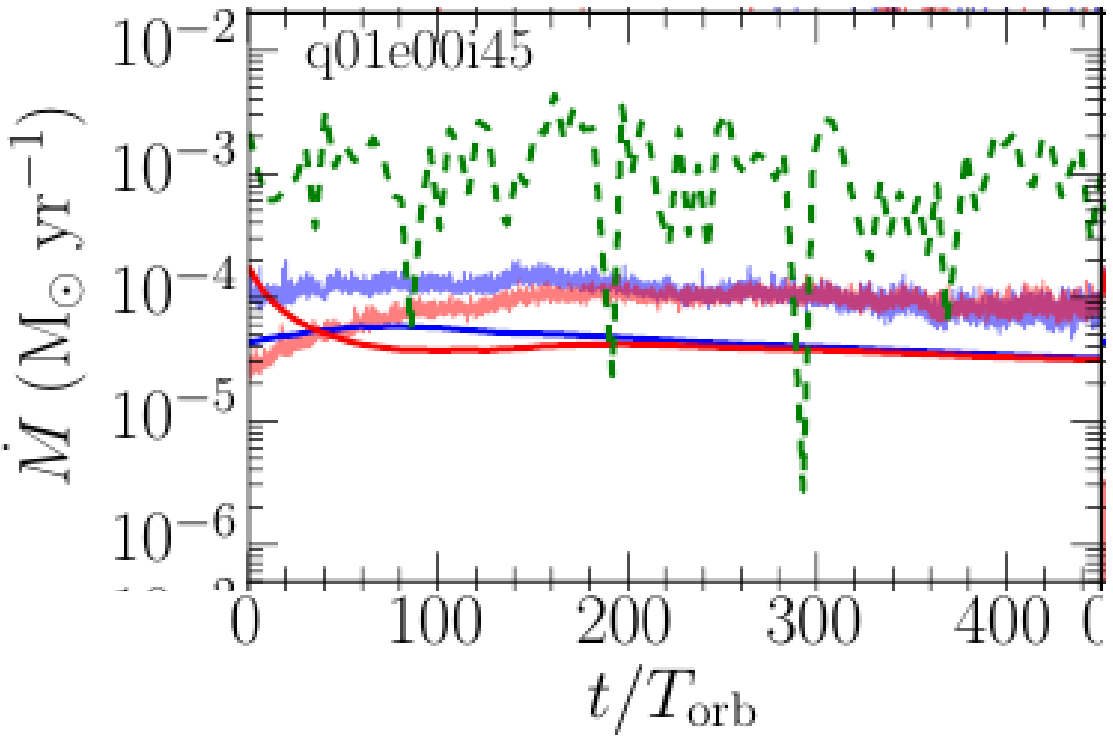
Merging supermassive black hole binaries



TIME AVERAGED TORQUE SURFACE DENSITY MAPS

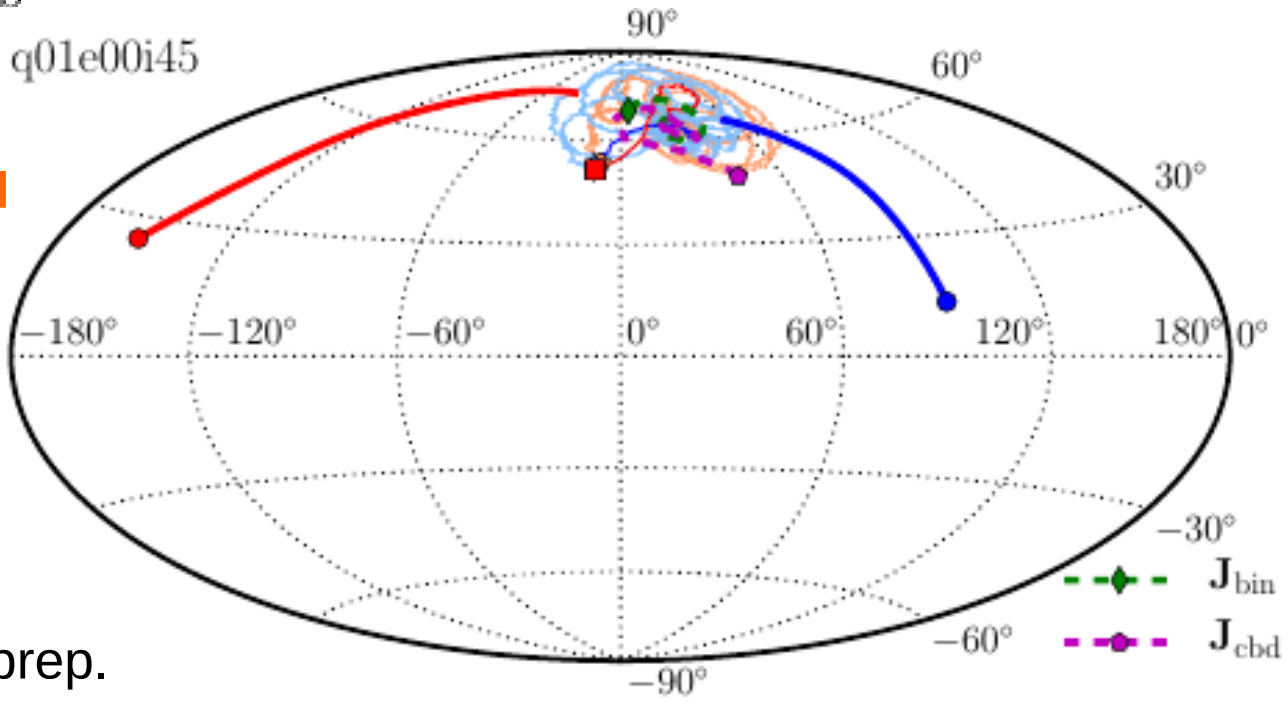
Fiacconi, Piotrowska & Sijacki in prep.

Merging supermassive black hole binaries



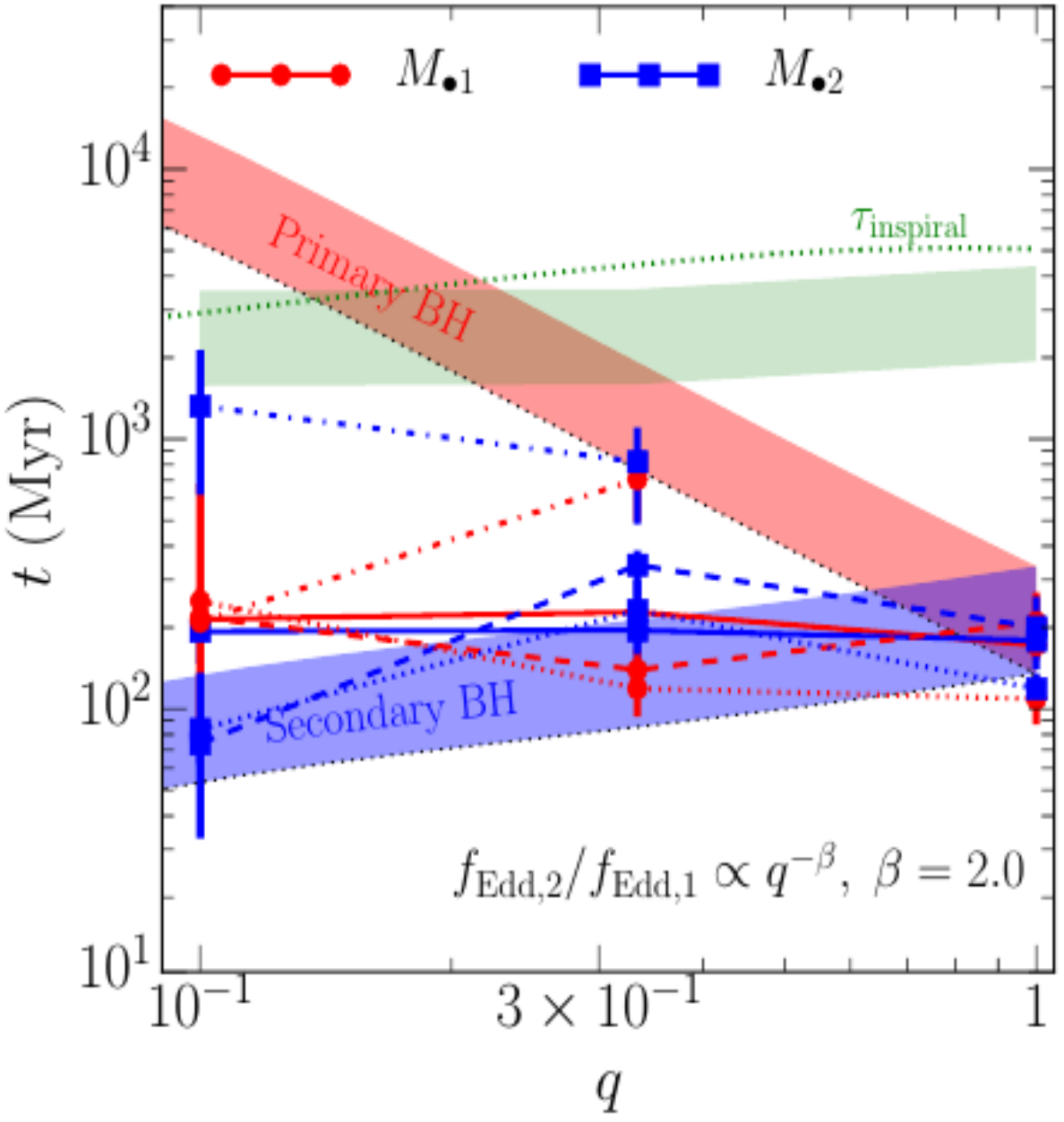
MASS ACCRETION RATES ONTO BLACK HOLES → SPIN MAGNITUDE EVOLUTION

SPIN DIRECTION EVOLUTION



Fiacconi, Piotrowska & Sijacki in prep.

Merging supermassive black hole binaries

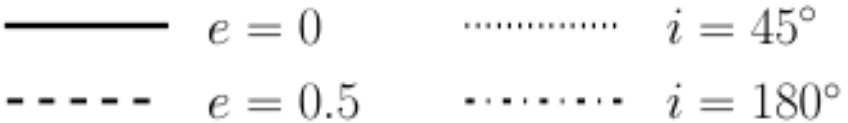


SPIN ALIGNMENT TIMESCALE MUCH SHORTER THAN THE INSPIRAL TIMESCALE

→ LOW RECOIL VELOCITY OF MERGER REMNANT
→ HIGHER BH RETENTION RATE IN GALACTIC NUCLEI

Analytical predictions (Gerosa et al. 2015)

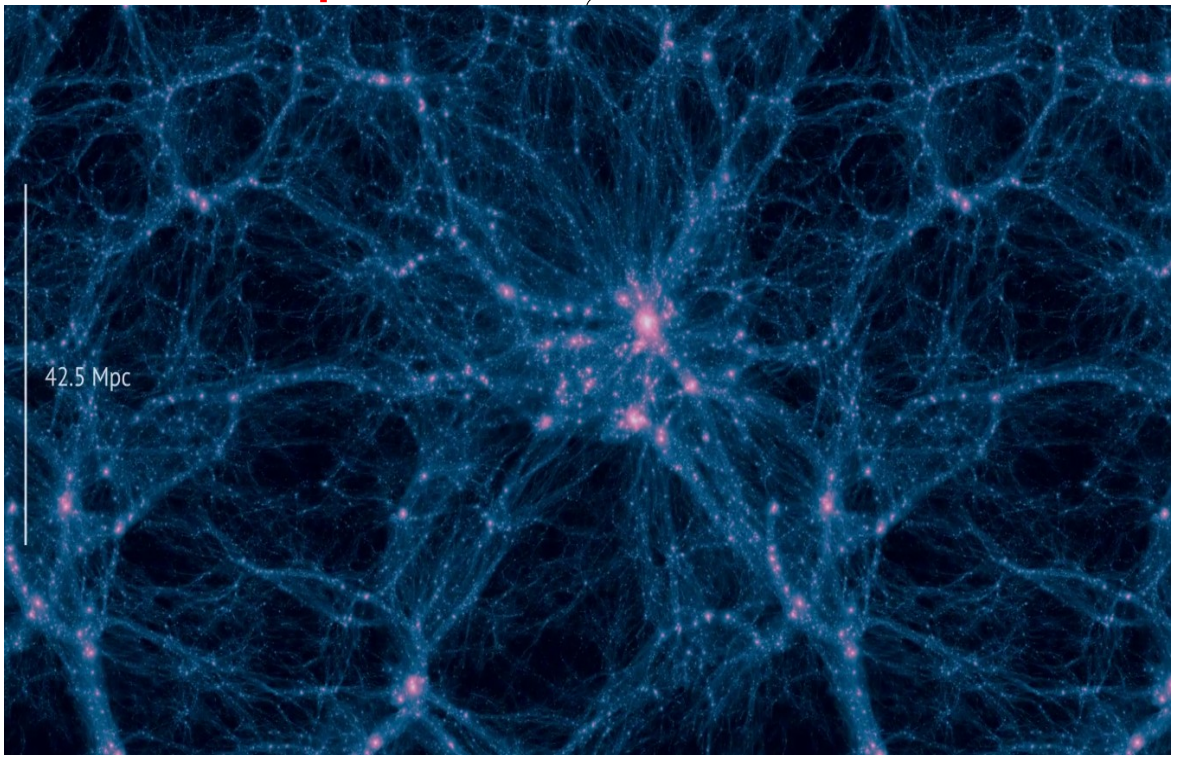
Our simulations



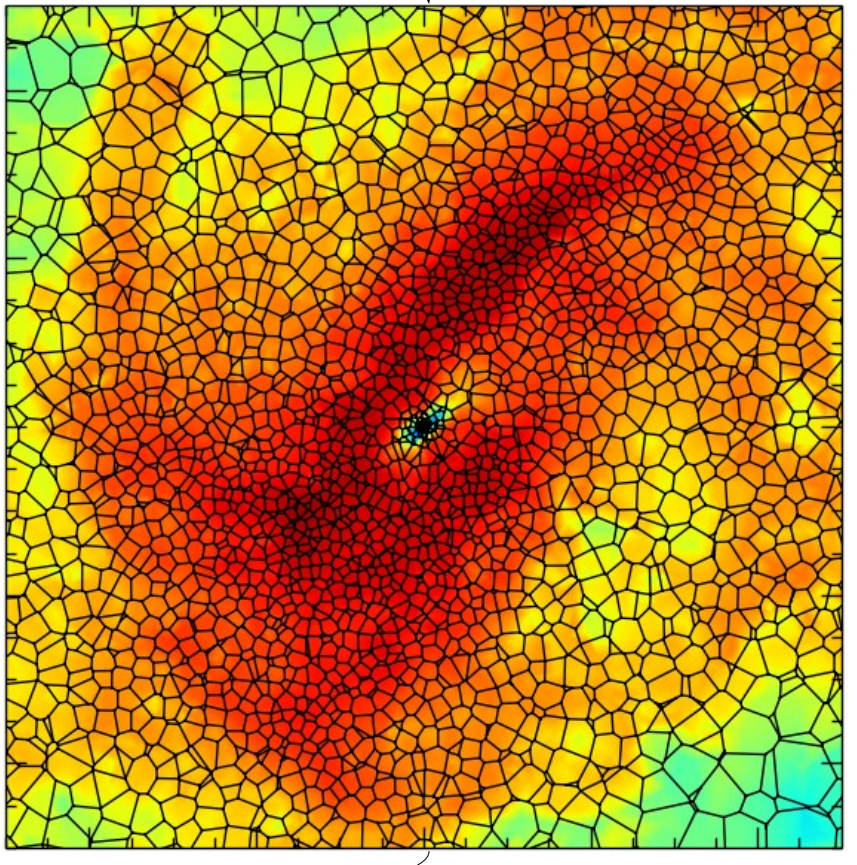
Fiacconi, Piotrowska & Sijacki in prep.

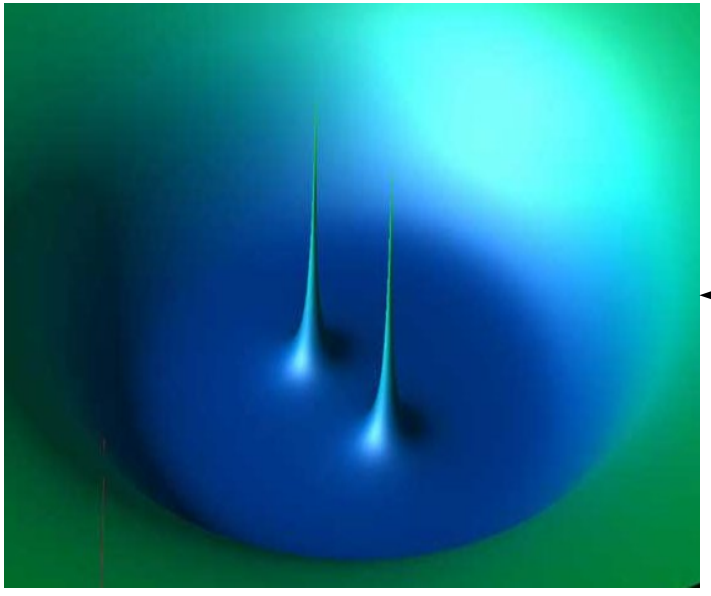
The Future

10^9 pc



10^3 pc





10^{-6} pc

GR simulations