Multimessenger Signatures of Intermediate Mass Black Holes

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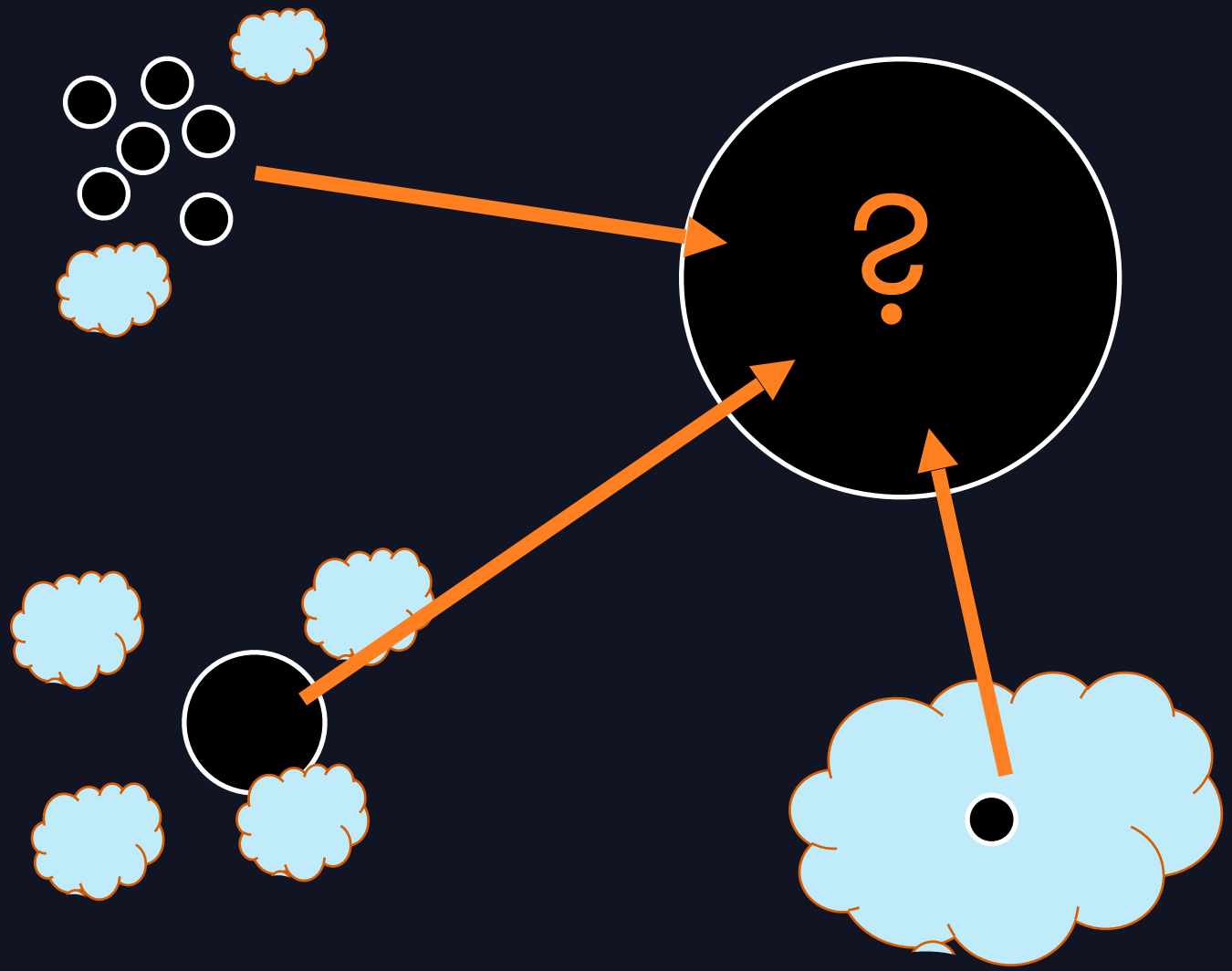
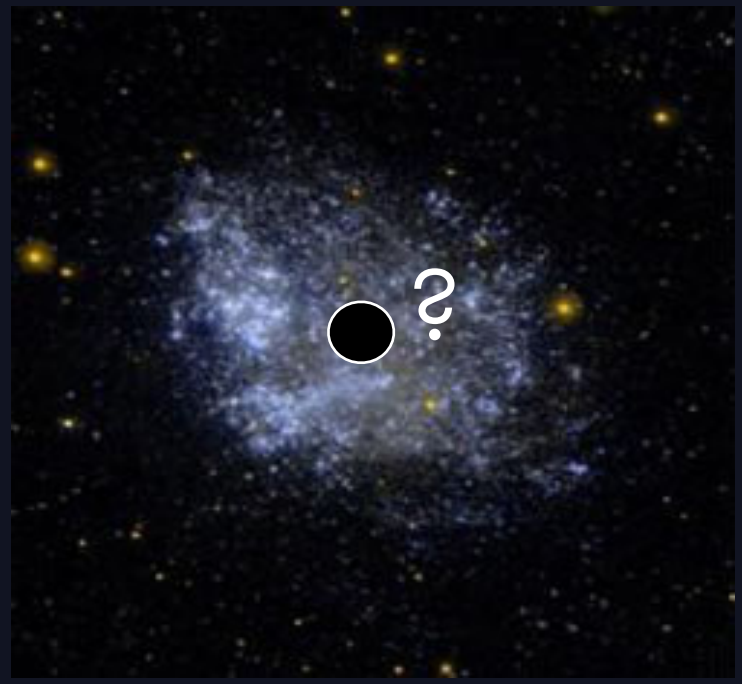
How do you build a SMBH?

Problem: SMBHs have erased their seed history



IMBHs in dwarf galaxies

- How do they get there? And when?
- Are they the seeds to SMBHs in massive galaxies?

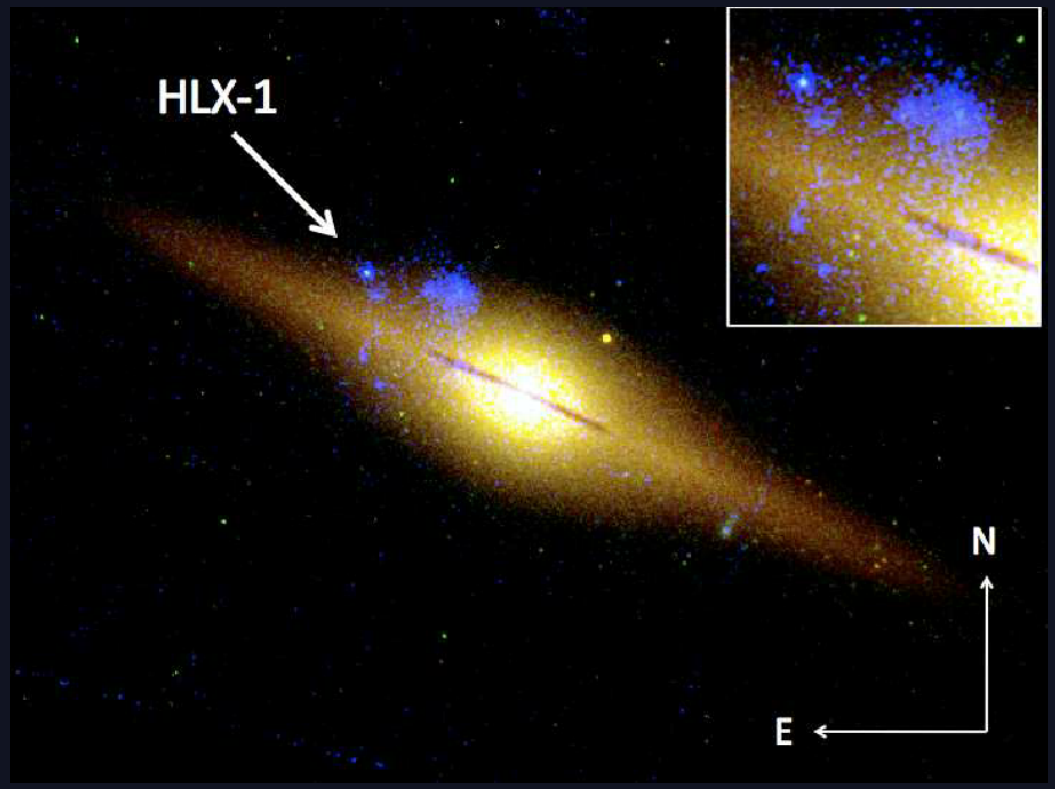


Two places to look:

Dwarf Galaxy AGN

RGG 118, Baldassare+ 17

Off-nuclear / halo sources



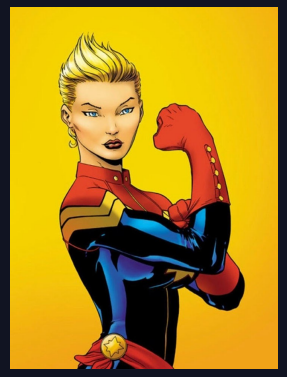
HLX-1, Mapelli+ 13

Tool: Cosmological Simulations

- code: ChaNGa
- Four zoom-in dwarf volumes
  "Marvel-ous Dwarfs"
- Four zoom-in MW-like simulations, including copious dwarf satellites
  "DC Justice League"

Elektra

Captain Marvel



Rogue

Storm

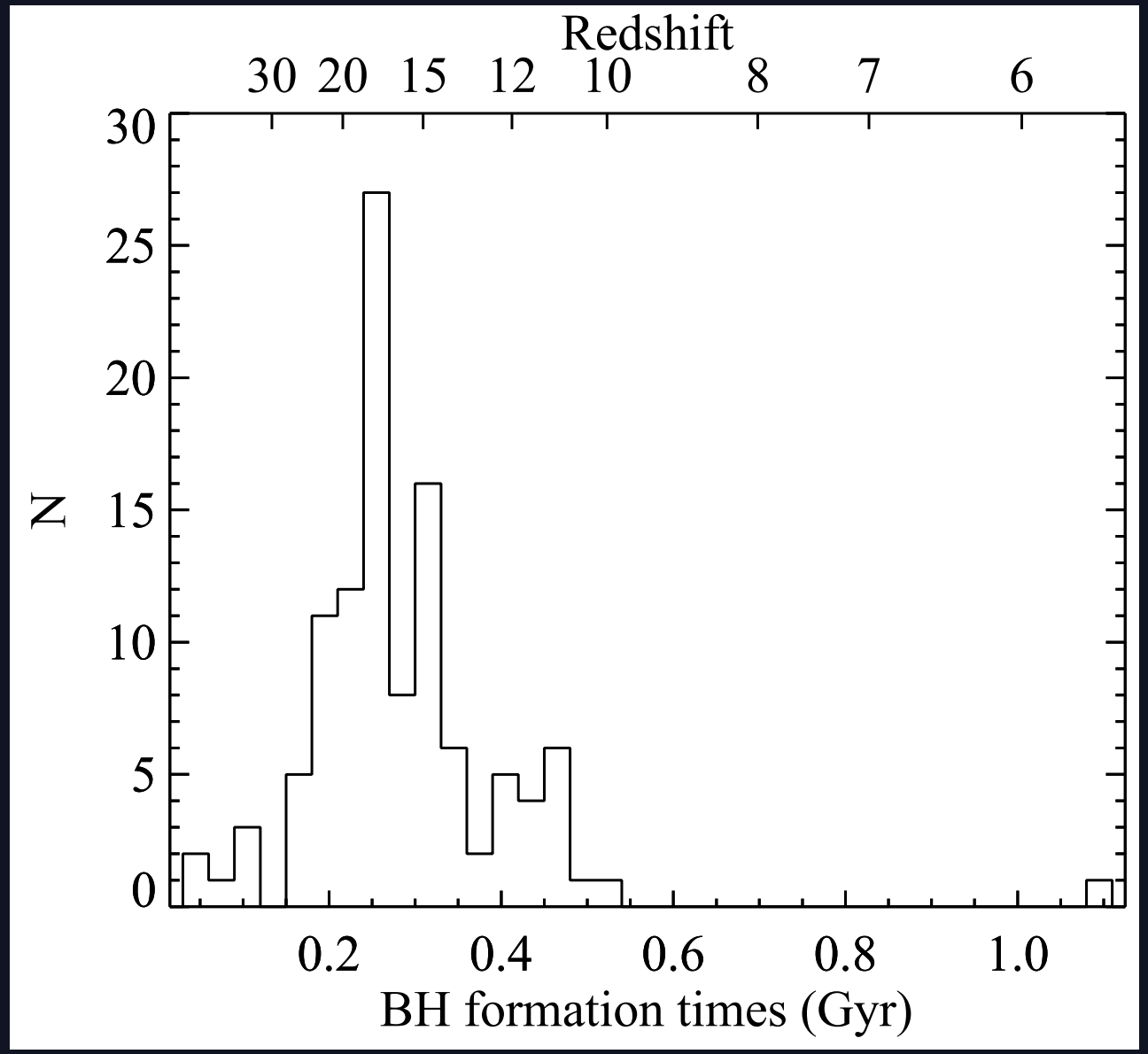
Sandra

Ruth

Sonia

Elena

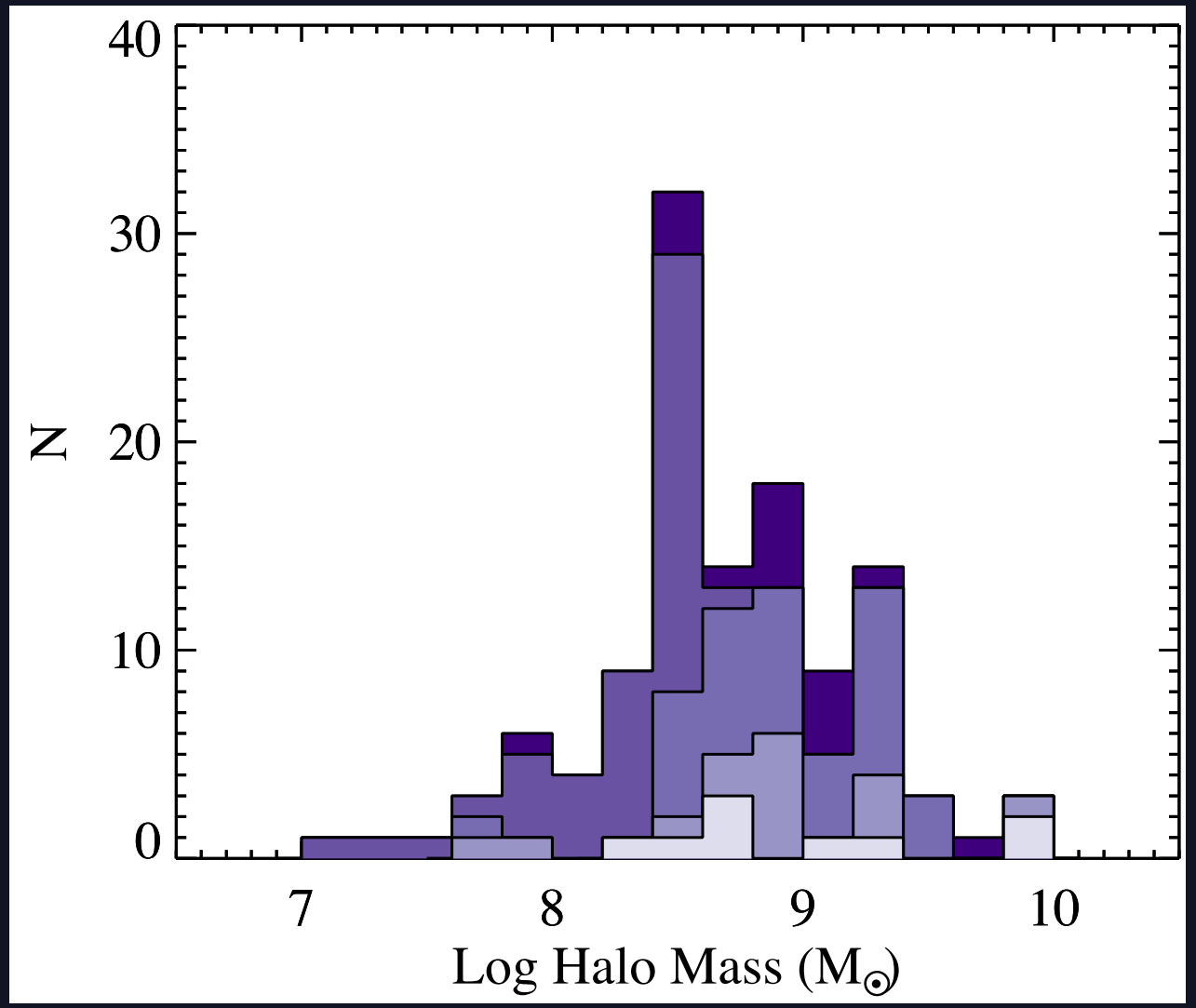
Seed BH Formation History



Peak of seed formation is z ~ 10 - 20

Bellovary+19

Halo mass at time of BH formation



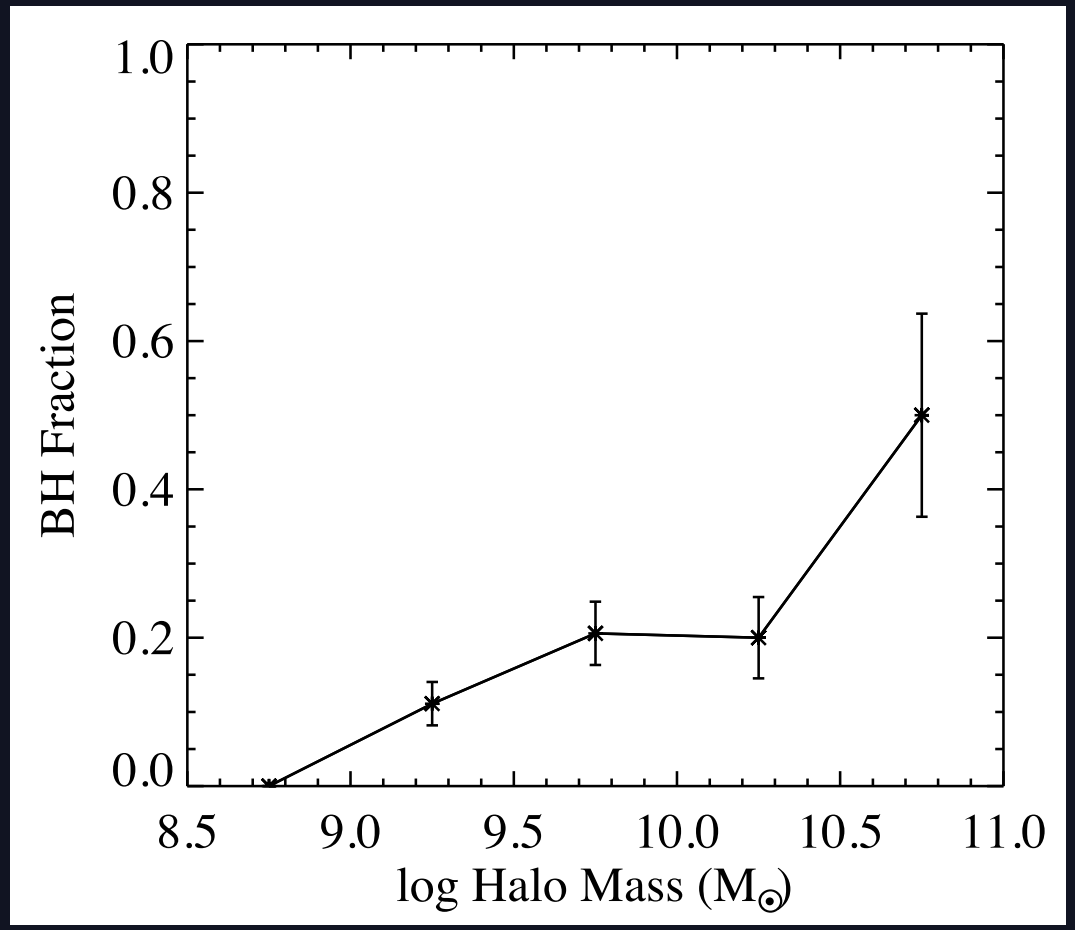
BHs form in halos with total mass of $10^{8\text{-}9}$ $M_\odot$

These are small!

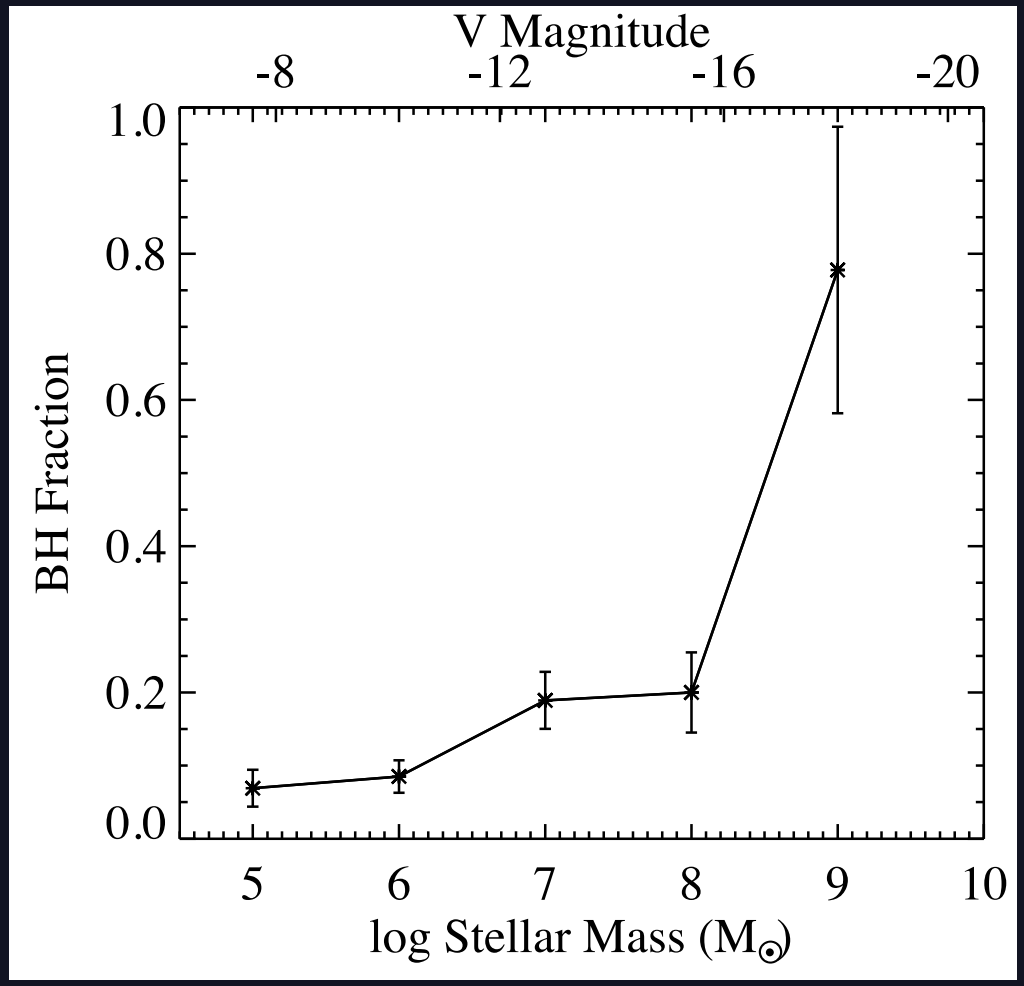
Bellovary+ 19

Occupation Fraction at z = 0

Total (halo) Mass



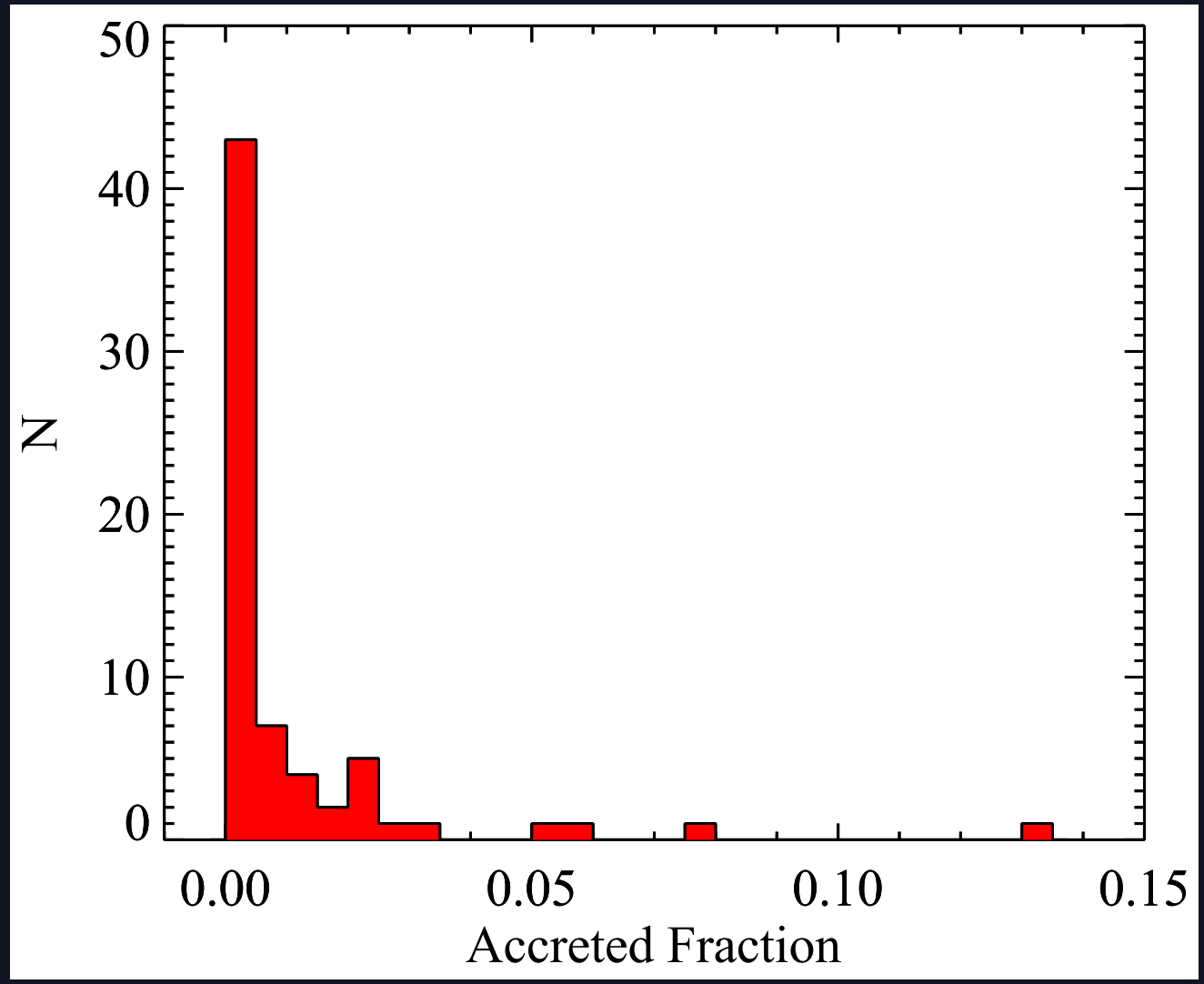
Stellar Mass



Bellovary+ 19

Dwarf BHs do not accrete much

- Fraction of accreted gas mass / total mass
- Dwarf galaxies hosting MBHs give clues to original seed BH masses



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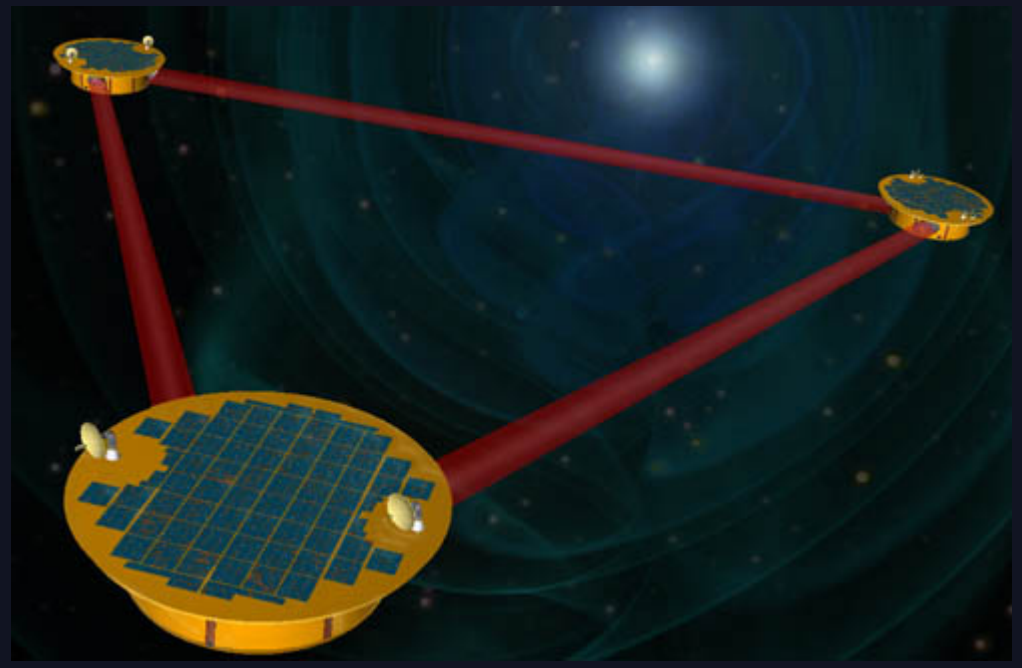
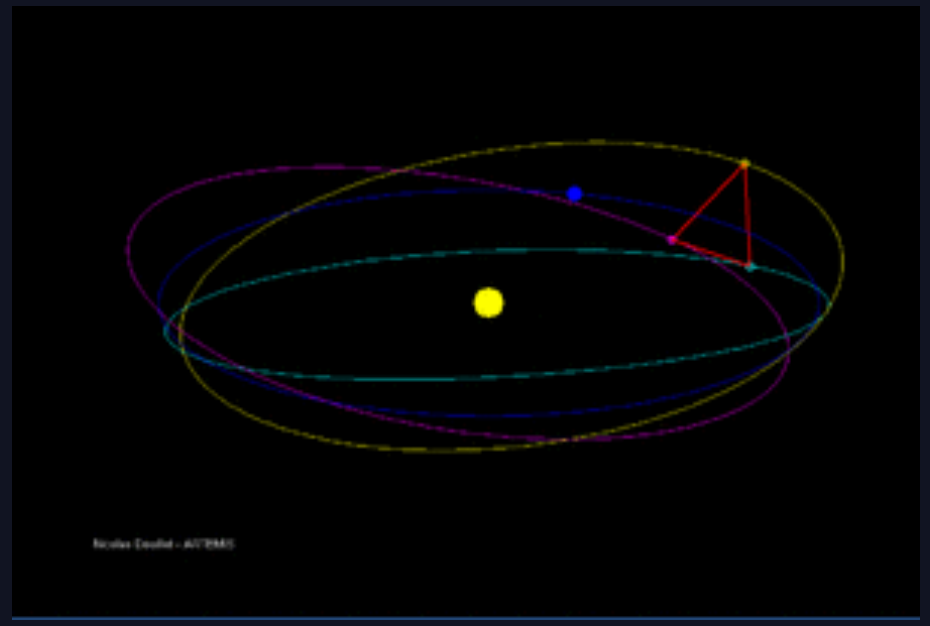
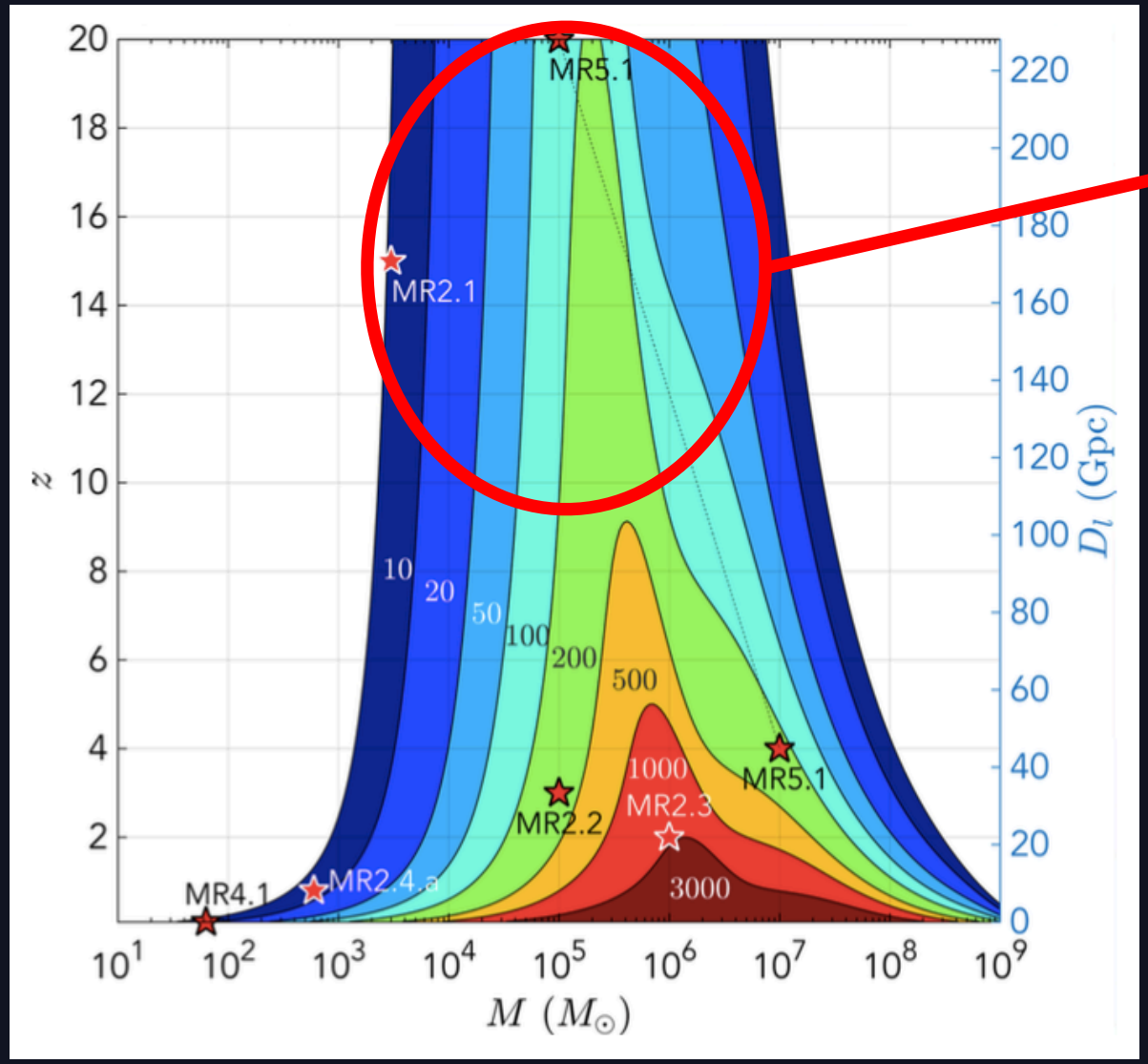
IMBHs merge! Gravitational Waves!

LISA! The Laser Interferometer Space Antenna



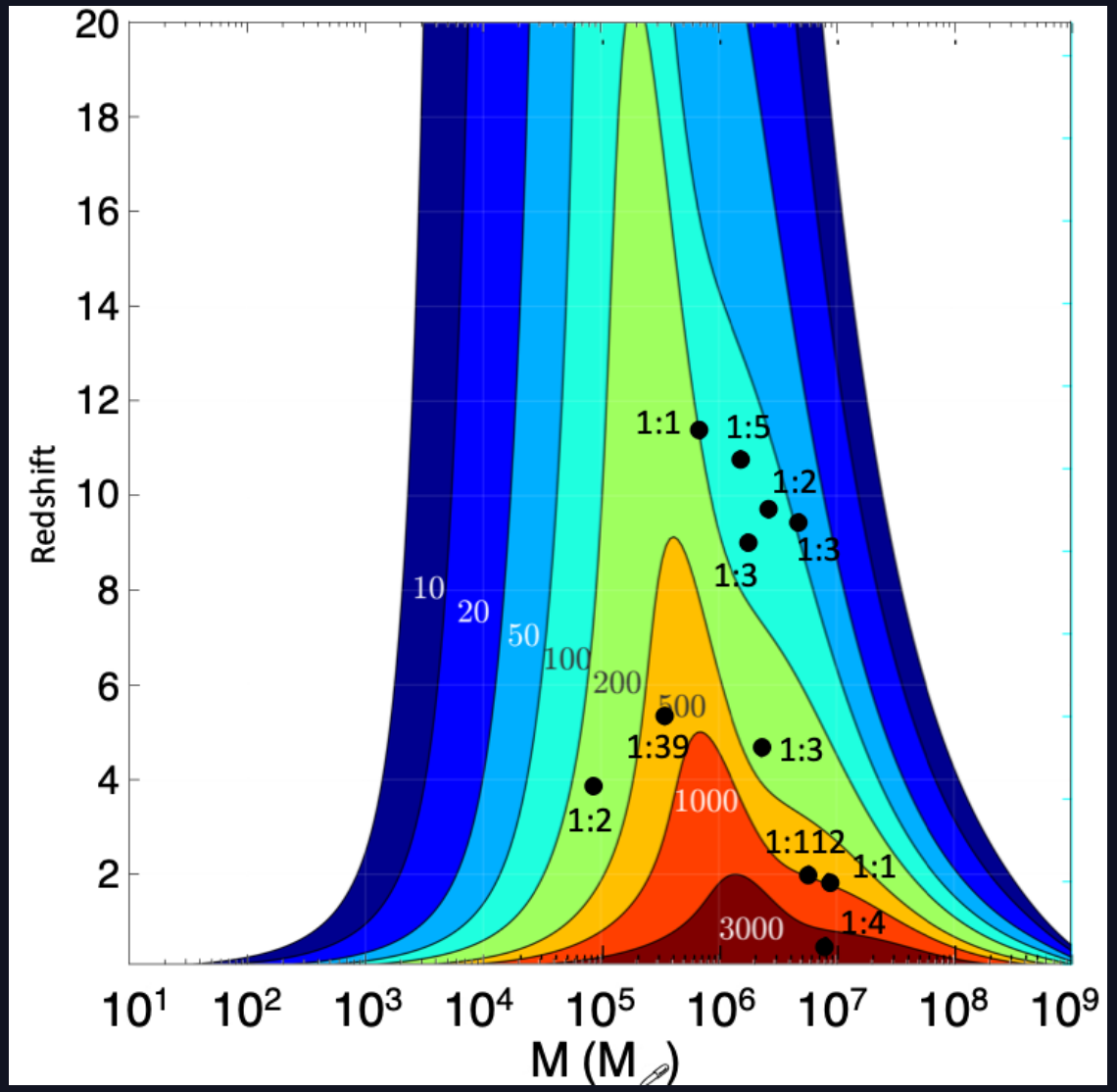


What will LISA find?



Intermediate Mass Black Hole mergers at $10 < z < 20$

BH mergers in dwarf galaxies



0 > z > 12

(mostly)
0.2 > q > 1

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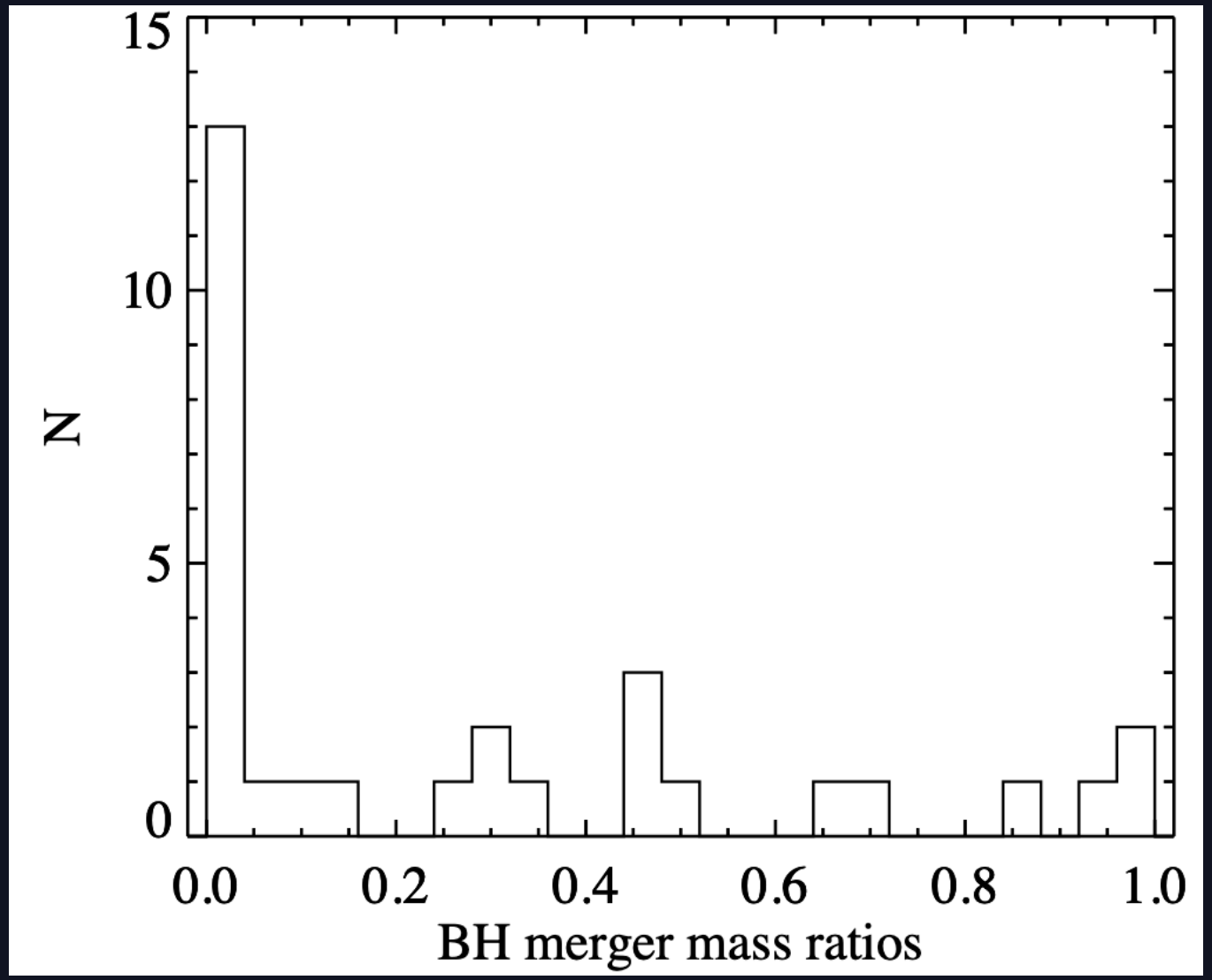
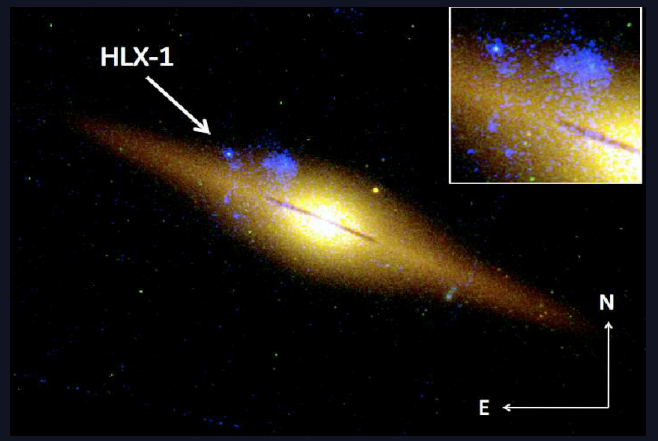
Merging BHs including massive galaxies



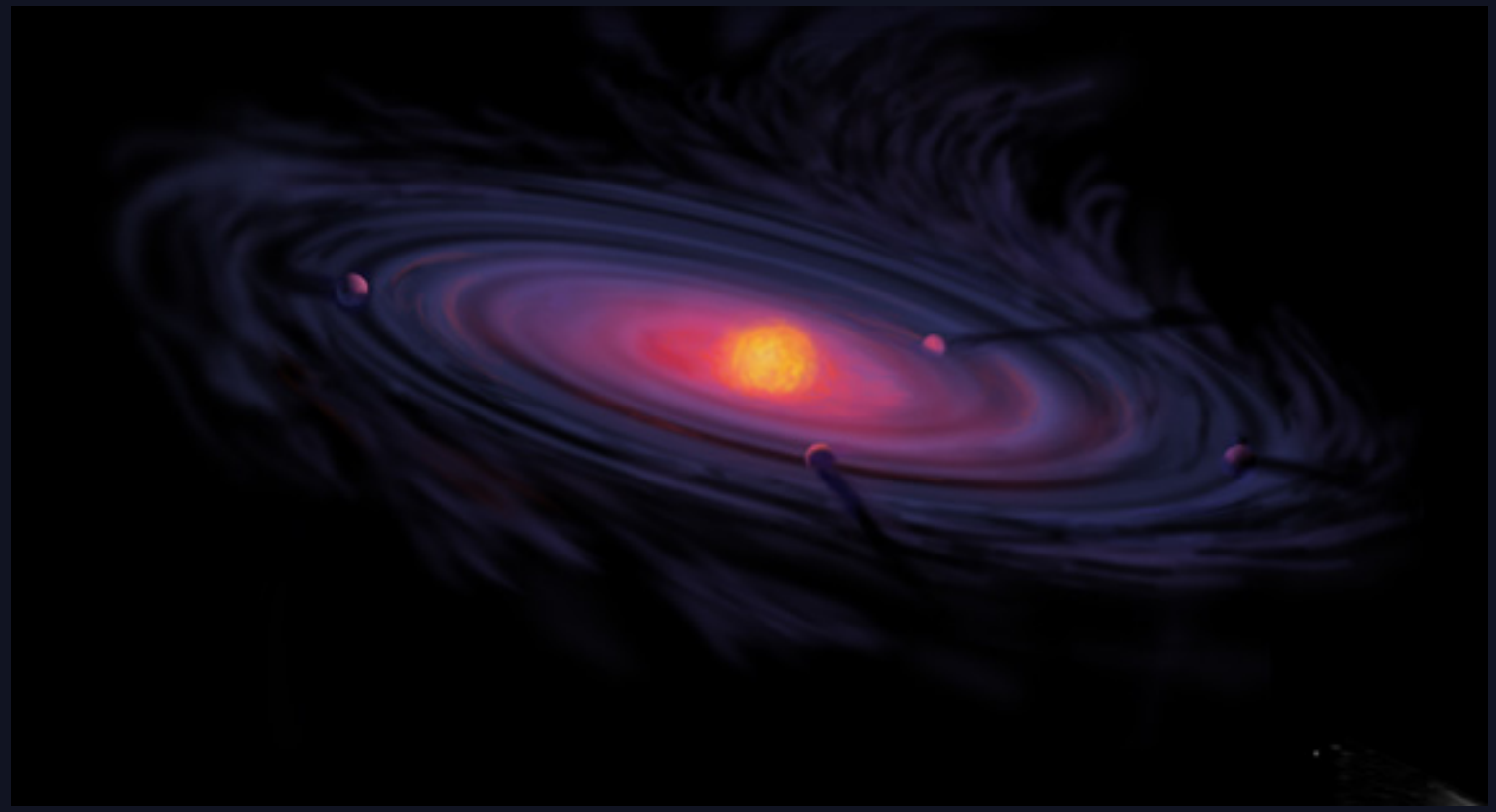
Very few mass ratios are 1:1!

Most are ~ 1:50



AND NOW FOR SOMETHING COMPLETELY DIFFERENT

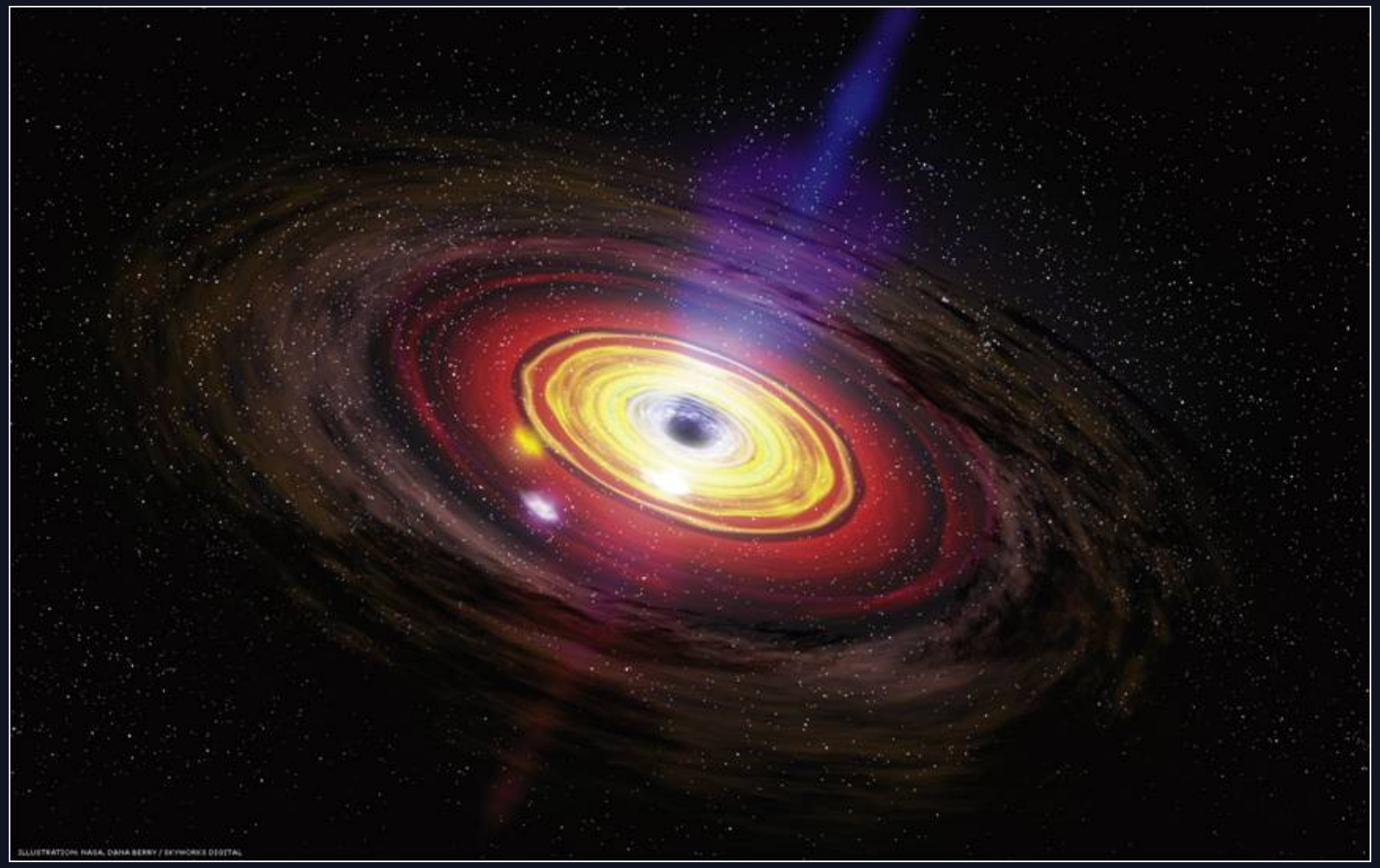
Diversion: Let's talk about planets



- Protoplanets migrate in the disk, depending on how they are torqued
- There are "sweet spots" where the torques balance

MIGRATION TRAPS

Back to black holes, and migration traps



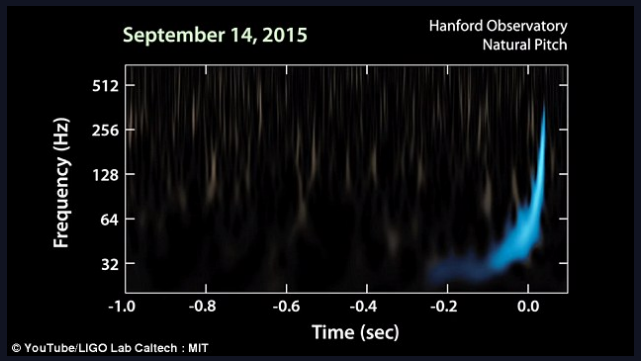
- Protoplanets → stellar mass black holes
- Protoplanetary disk → SMBH accretion disk
- Black holes can migrate too!

→ MIGRATION TRAPS

Result → lots of black hole mergers, making bigger and bigger black holes?!

McKernan+ 12, 18, Bellovary+ 16

Gravitational Wave Implications



- LIGO: Provides explanation for large masses
- LISA: runaway growth in disk creates an IMBH (10^2-10^3 $M_\odot$), if merge with SMBH we get an EMRI/IMRI (McKernan+ 12)
- EM Counterparts… the AGN wins 😔 but target searches on AGN instead of galaxies for improved efficiency!) 😀

See Saavik Ford's talk on Wednesday in the MMA-SAG session

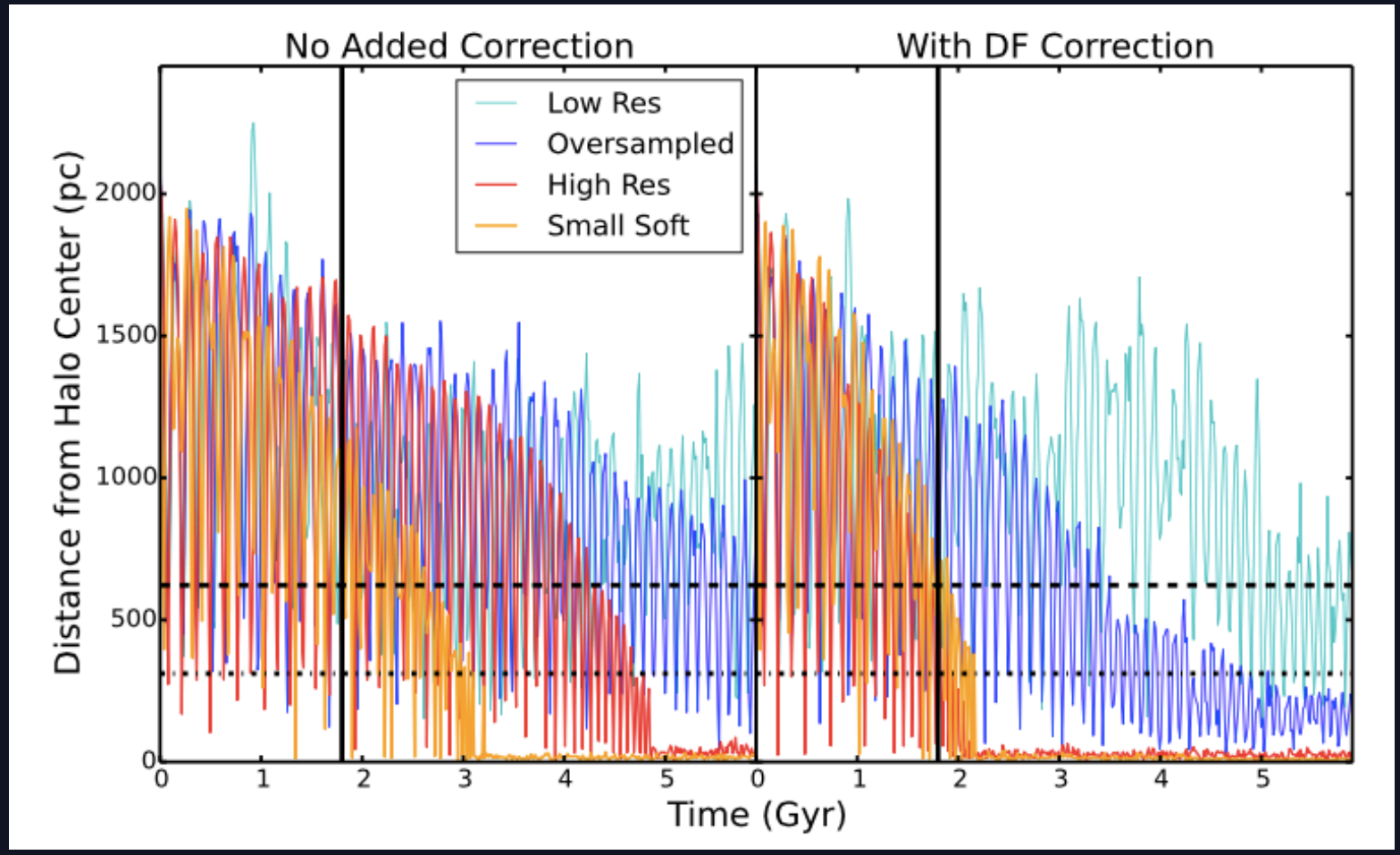
Conclusions

- Dwarf and wandering SMBHs can give us clues to the original seed mass
- Few SMBH mergers in low mass galaxies environments are 1:1
- AGN disks can also be places to seek IMBHs

Extra slides

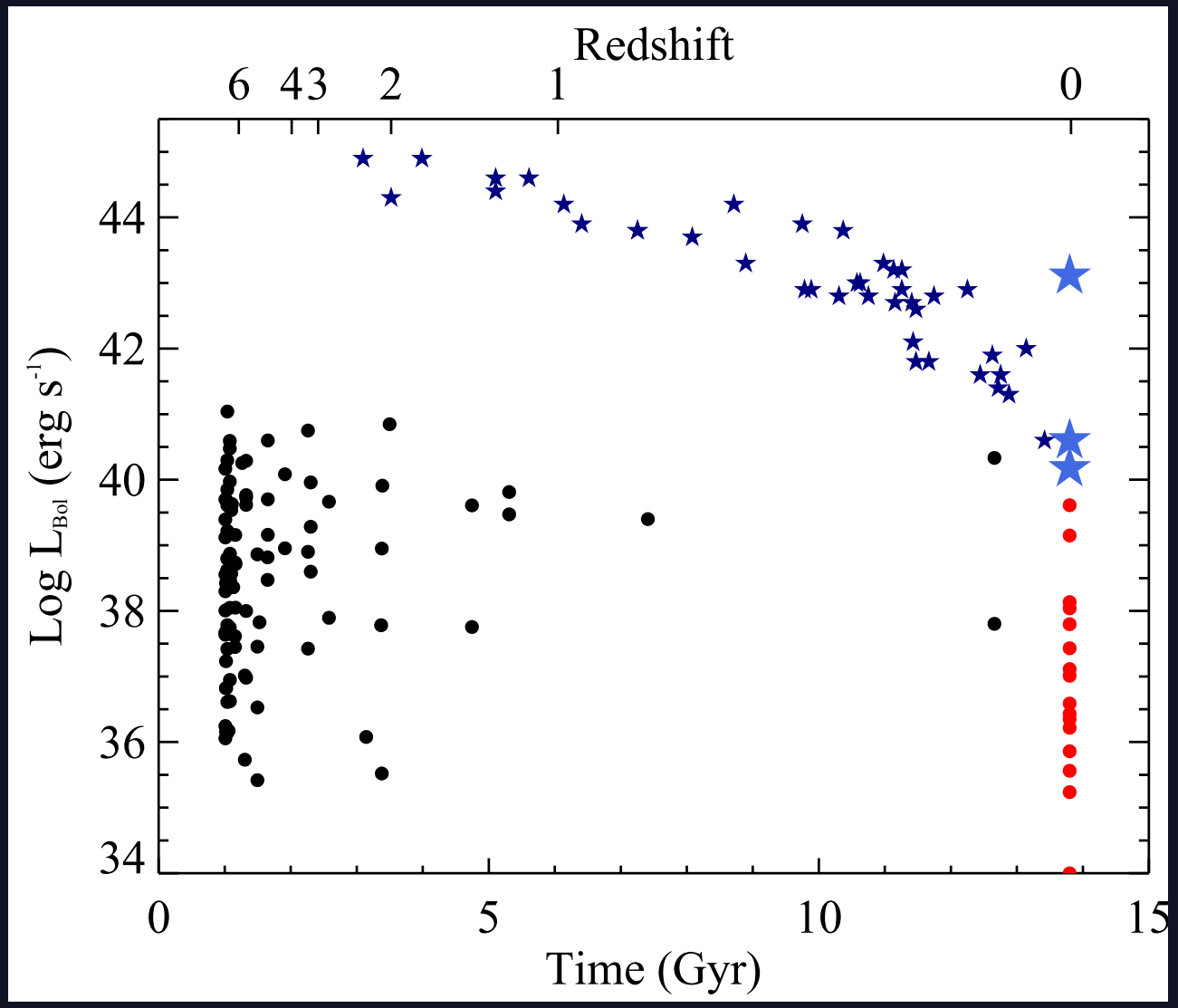
BHs in Simulations

- Form at mass of 50,000 $M_\odot$ from dense, collapsing, low-metallicity, low-H_2 gas
- Dynamical friction (Tremmel+ 15)
- Accretion: modified Bondi-Hoyle
- Feedback: thermal (Tremmel+ 17)



Tremmel+ 15

Low Luminosities



arXiv:1806.00471

Simulated Galaxies

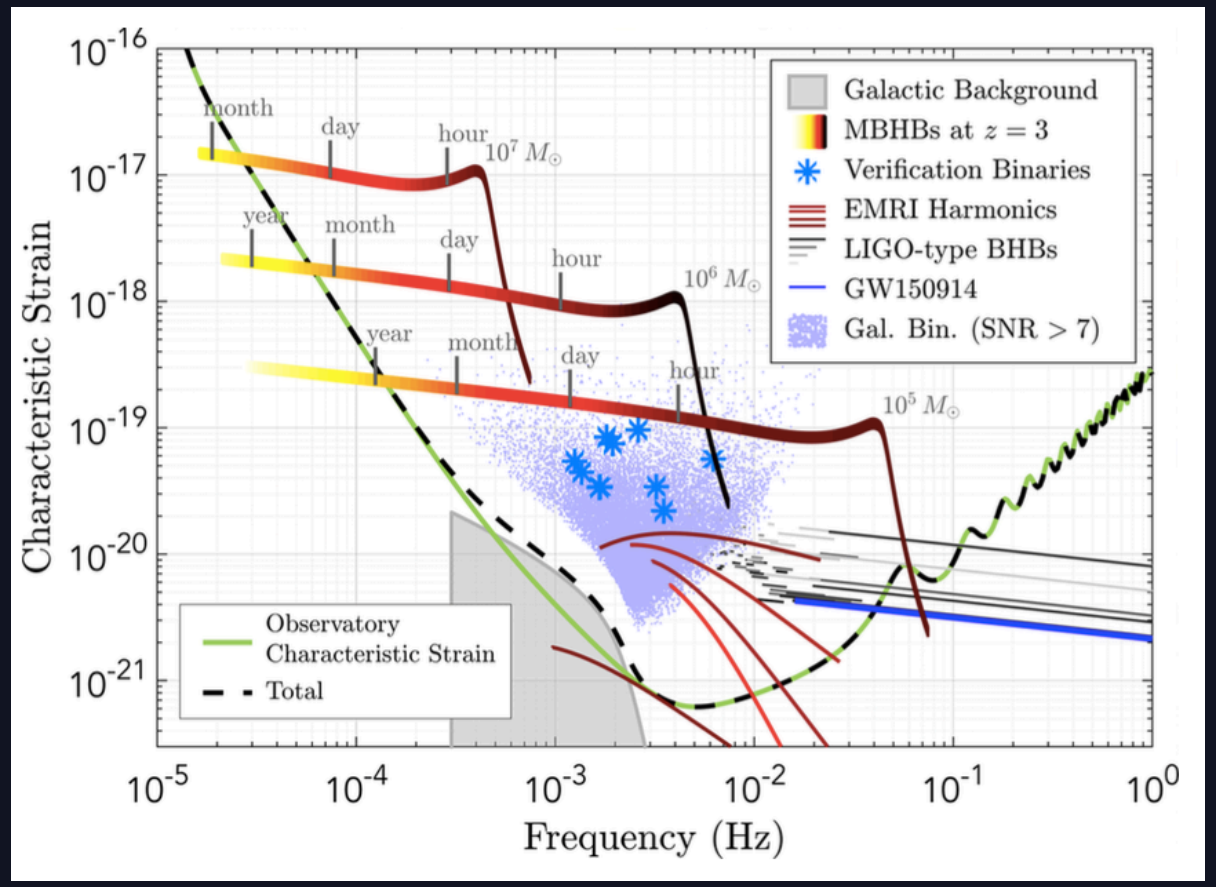
- Maximum Luminosity reached
- z=0 luminosities

Observed Galaxies

- Local Dwarf AGN
- High z IMBH candidates (Mezcua +18)

Bellovary+19

Intermediate BH merger signatures



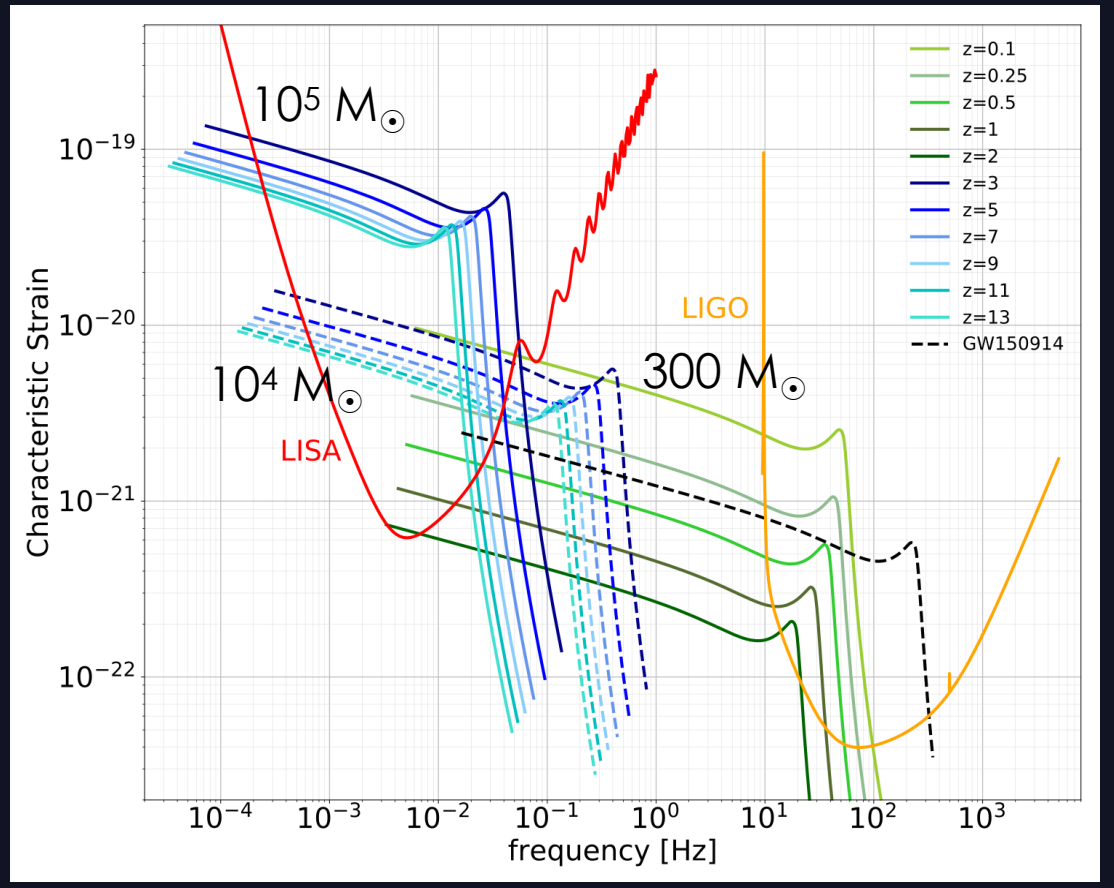


Figure courtesy Monica Colpi