MSCA

Marie Skłodowska-Curie Actions

Stellar BBH mergers in AGN environment

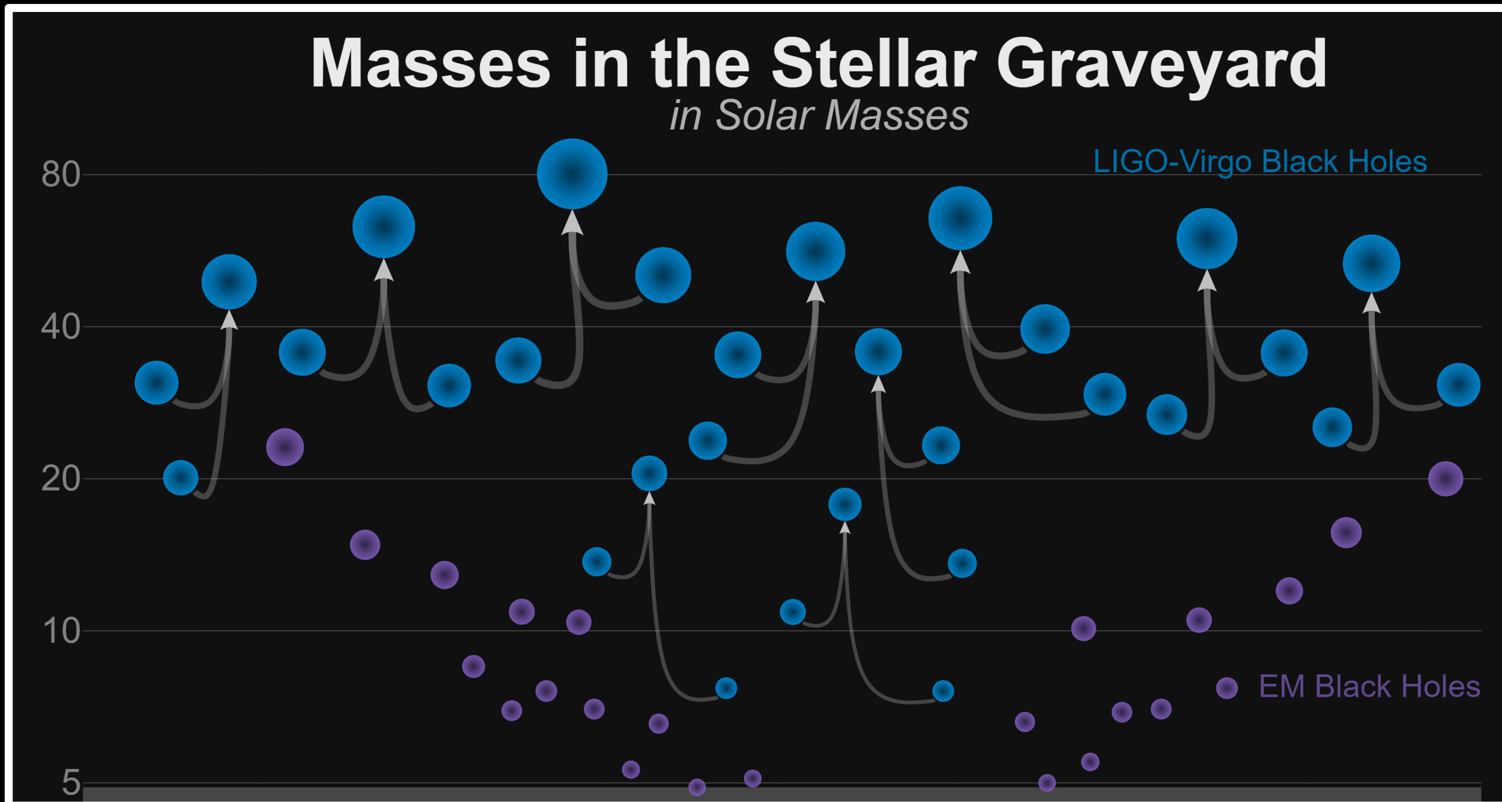
Journal Club - Nov 26, 2019

Gwen de Wasseige

Disclaimer

- Many articles treating the topic, only 4 discussed today
- Many unknown, many ignored effects
- Promising future:
  more detailed simulations
  + higher statistics in GW data
- Discussion about BBH, but similar conclusion for neutron star
- Try to focus on observables
- Not an expert…

Motivation



- More massive BBHs than inferred from EM observations in our galaxy
- Isolated binary evolution could explain the LVC BBH rate, but an additional mechanism would help
- AGN and their disk represent a promising site for dynamical BBH encounter/merger

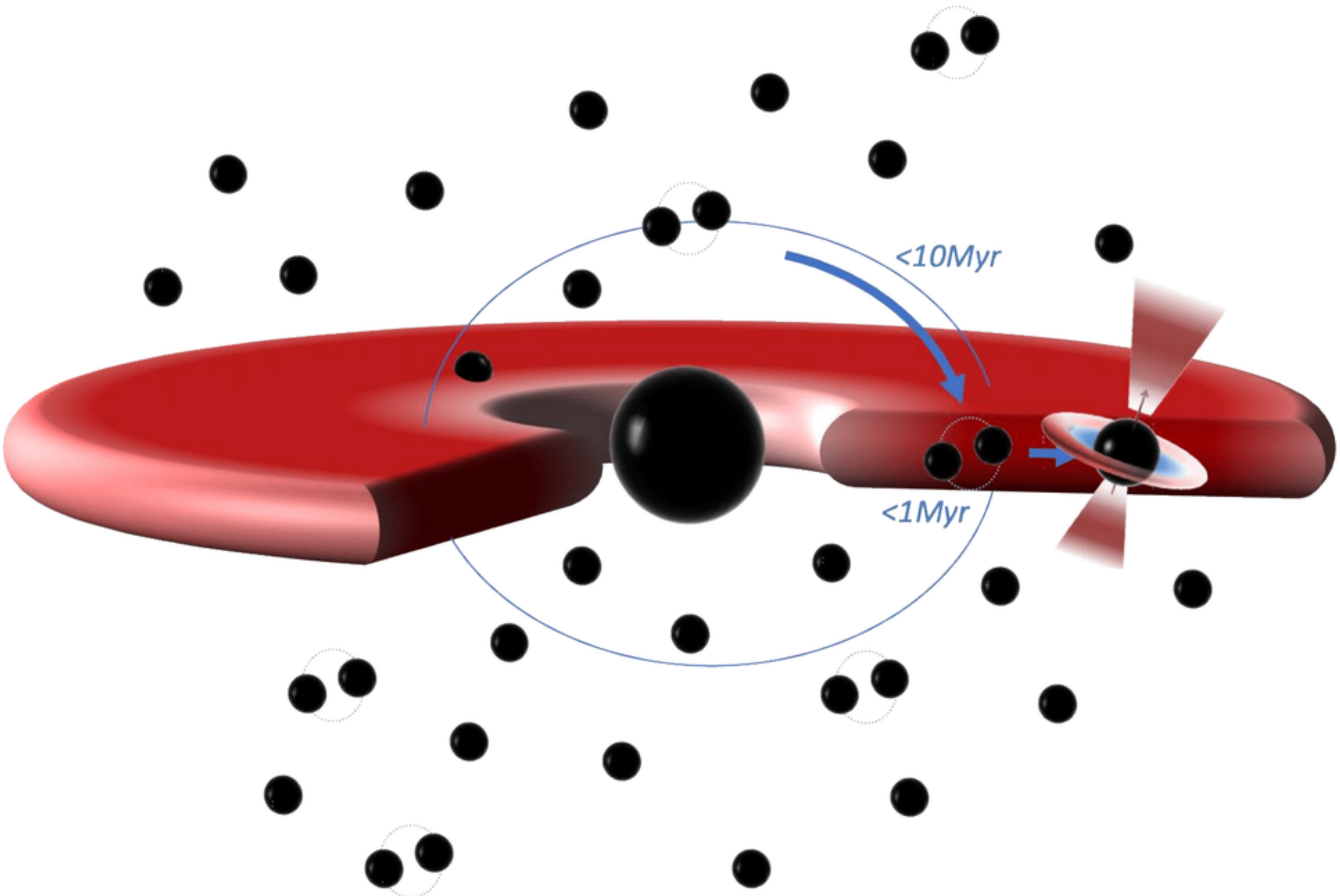
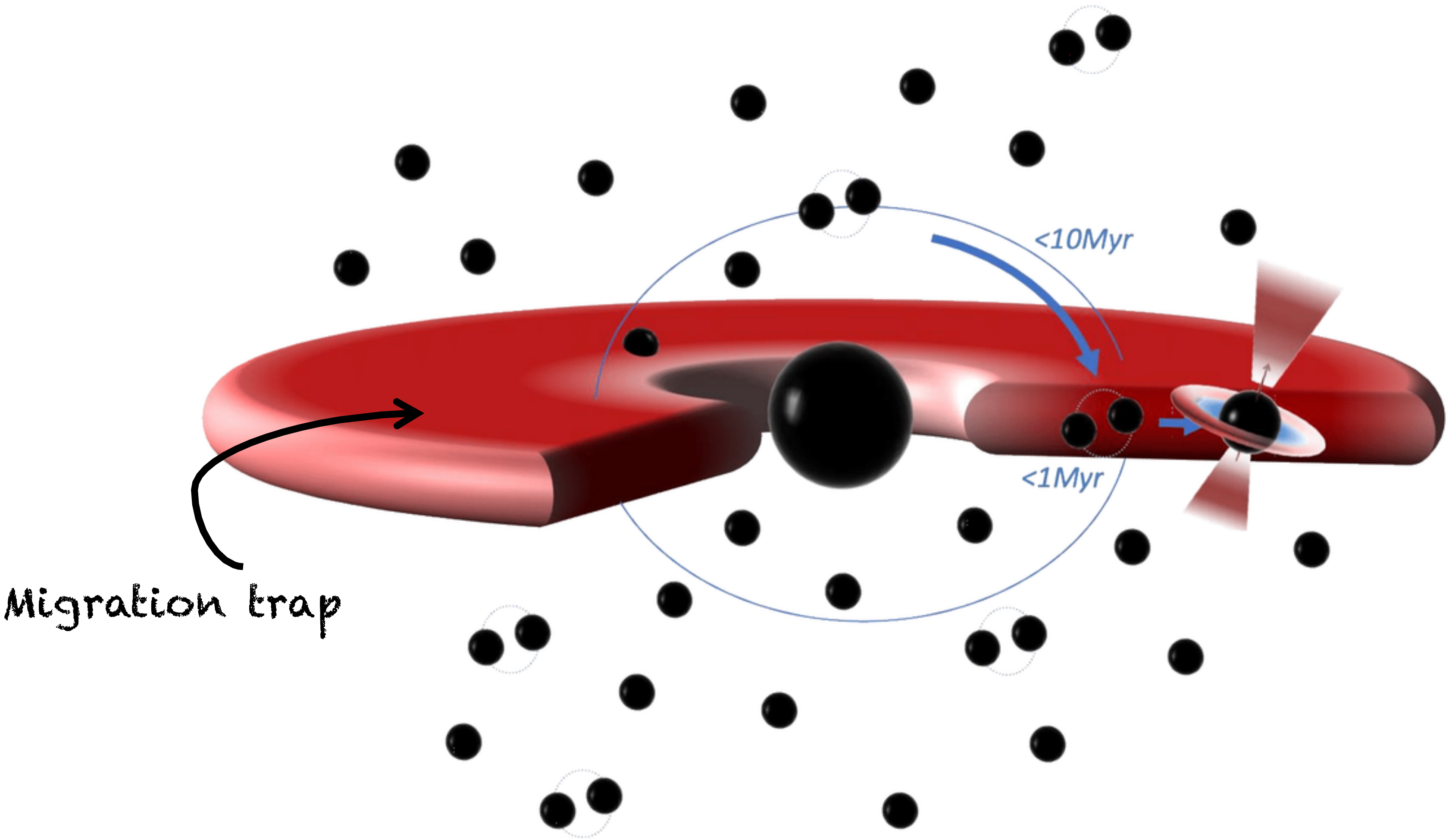


Image from Bartos *et al.*, Astrophys.J. 835 (2017) 165

A. BHs ground down to the disk due to gas damping
B. BHs migrate through the disk due to angular momentum exchange with the disk
C. BHs have higher chance to form a binary in migration traps



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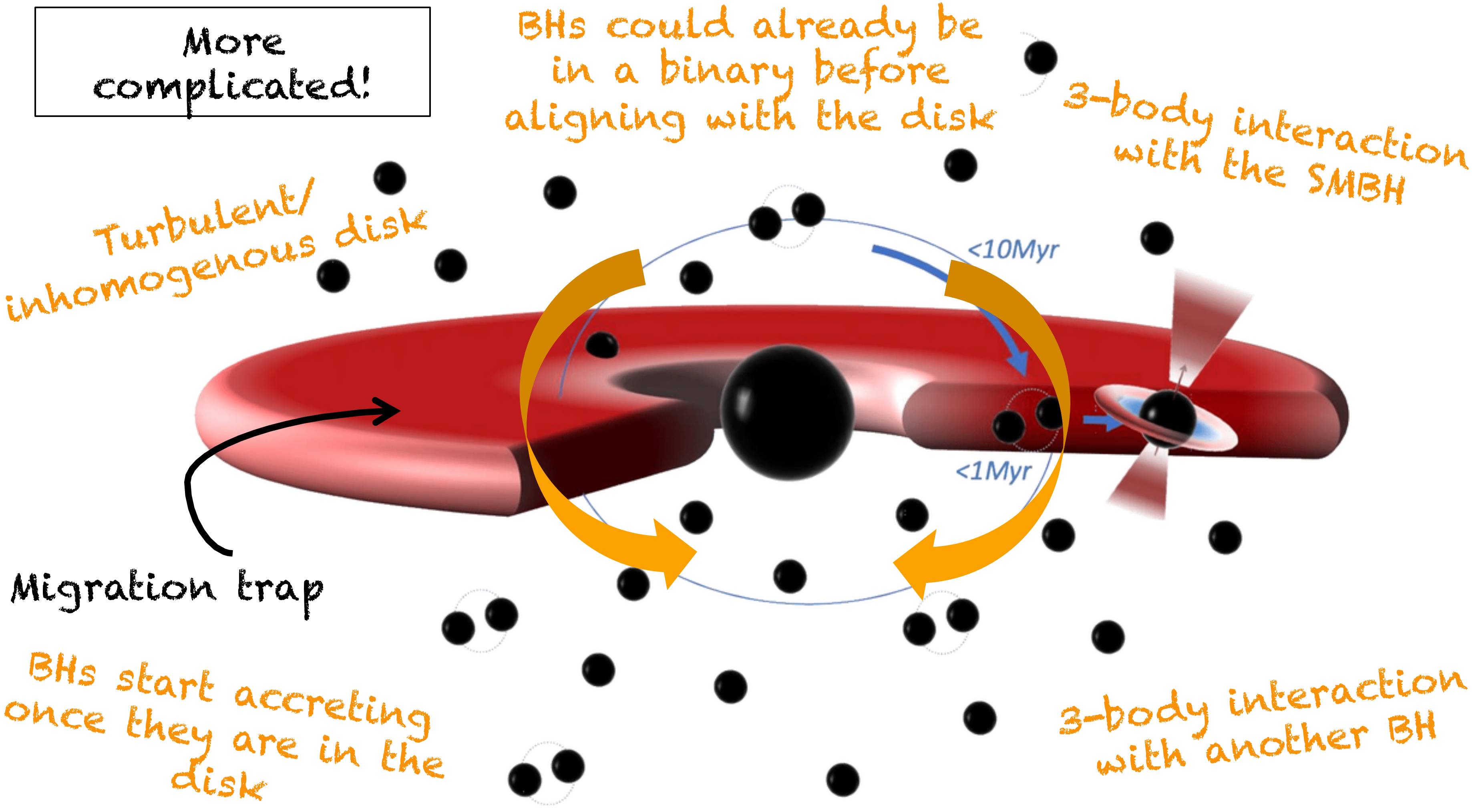

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For reference

1 - *On stellar-mass black hole mergers in AGN disks detectable with LIGO*, B. McKernan et al. (https://arxiv.org/abs/1702.07818)

2 - *Orbital Migration of Interacting Stellar Mass Black Holes in Disks around Supermassive Black Holes*, A. Secunda et al. (https://arxiv.org/abs/1807.02859)

3 - *AGN Disks Harden the Mass Distribution of Stellar-mass Binary Black Hole Mergers*, Y. Yang et al. (https://arxiv.org/abs/1903.01405)

4 - *Black Hole Mergers Induced by Tidal Encounters with a Galactic Centre Black Hole*, Joseph John Fernández, Shiho Kobayashi (https://arxiv.org/abs/1805.09593)

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(Shows qualitative behavior of objects near the migration trap)

3 - *AGN Disks Harden the Mass Distribution of Stellar-mass Binary Black Hole Mergers*, Y. Yang et al. (https://arxiv.org/abs/1903.01405)

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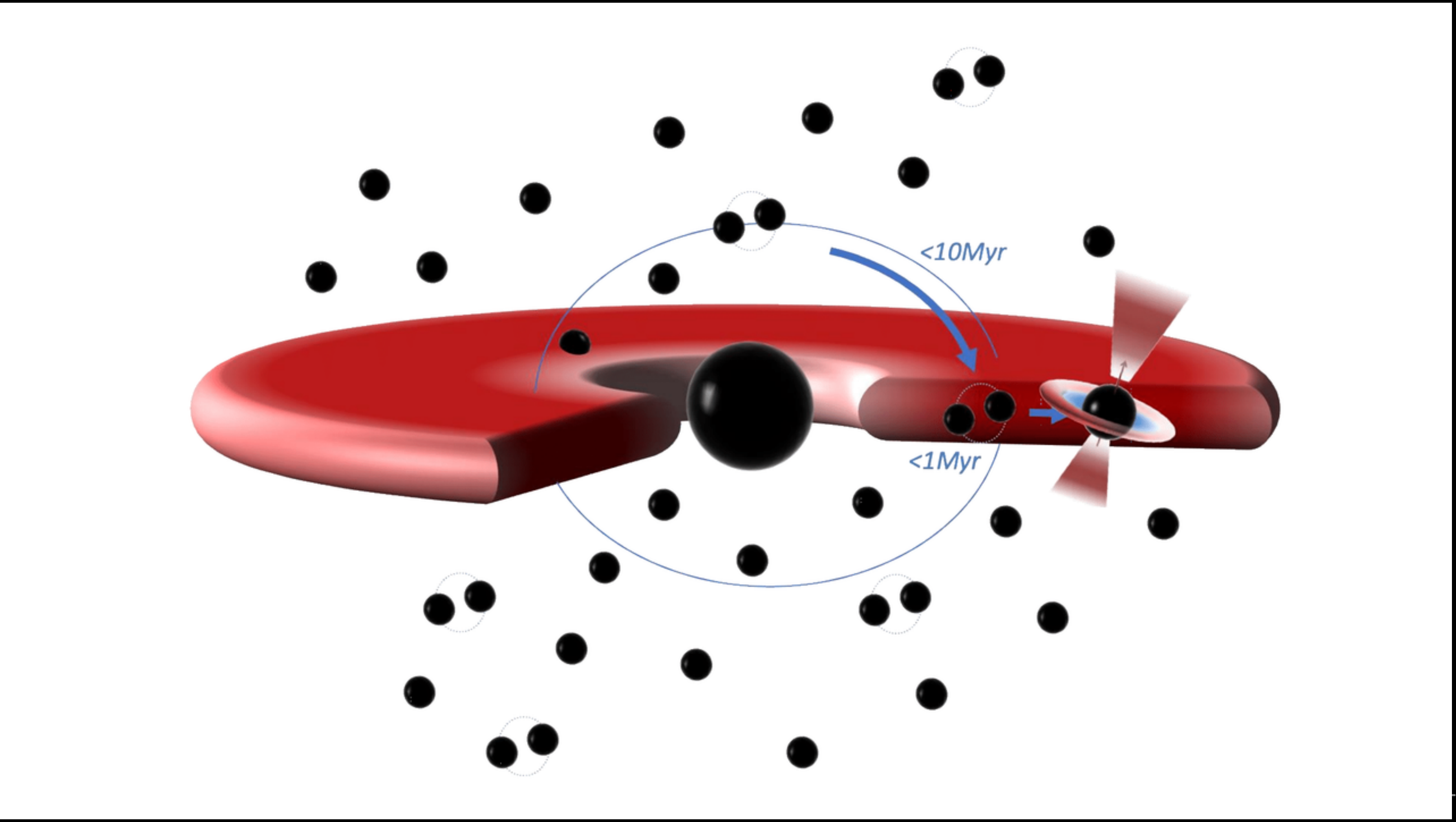
Assumptions

	BH accreting?	Multiple mergers?	Retrograde-Prograde?	3-body interaction	Interaction with the SMBH
1	No/yes	Yes	Yes	No	No
2	No	Yes	No	Yes	No
3	No	No	Not considered	No	No
4	No	No	Yes	No	Yes

Rate of BBH mergers

$$R = N_{GN}\, f_{AGN}\, N_{BH}\, f_d\, f_b\, \varepsilon \;/\; \tau_{AGN}$$



Rate of BBH mergers

	Rate ($Gpc^{-3}yr^{-1}$)	
1	$10^{-4} - 10^{4}$	
2	72 (UL)	
3	4	
4	0.6	

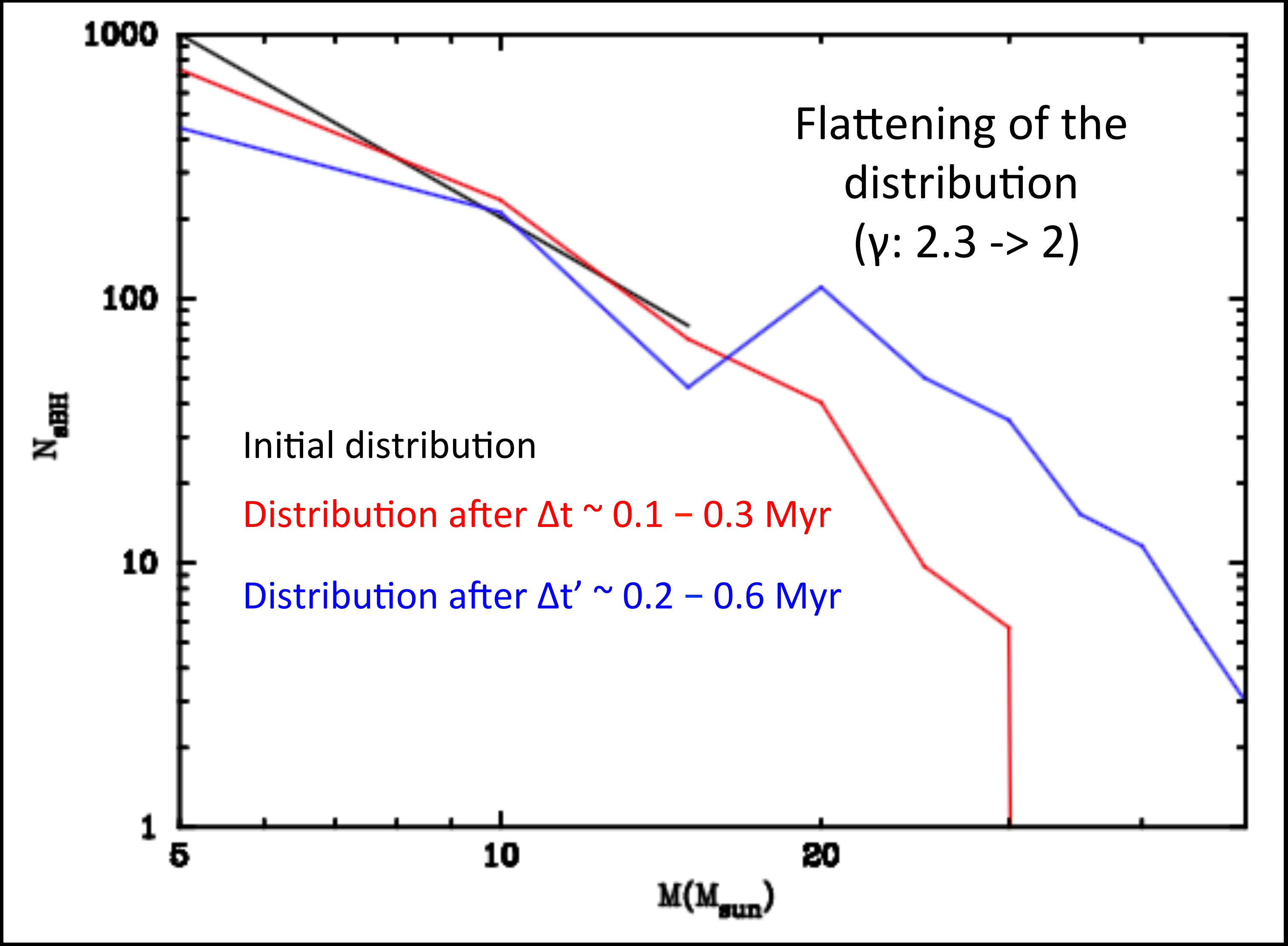
Rate of BBH mergers

	Rate ($Gpc^{-3}yr^{-1}$)	
1	10^{-4} – 10^{4}	already constrained
2	72 (UL)	70% of LVC max rate
3	4	4% of LVC max rate
4	0.6	negligible contribution
LVC	9.7–101	

- Can be translated in constraints on AGN disk model!
- LVC could probe this population

Mass distribution

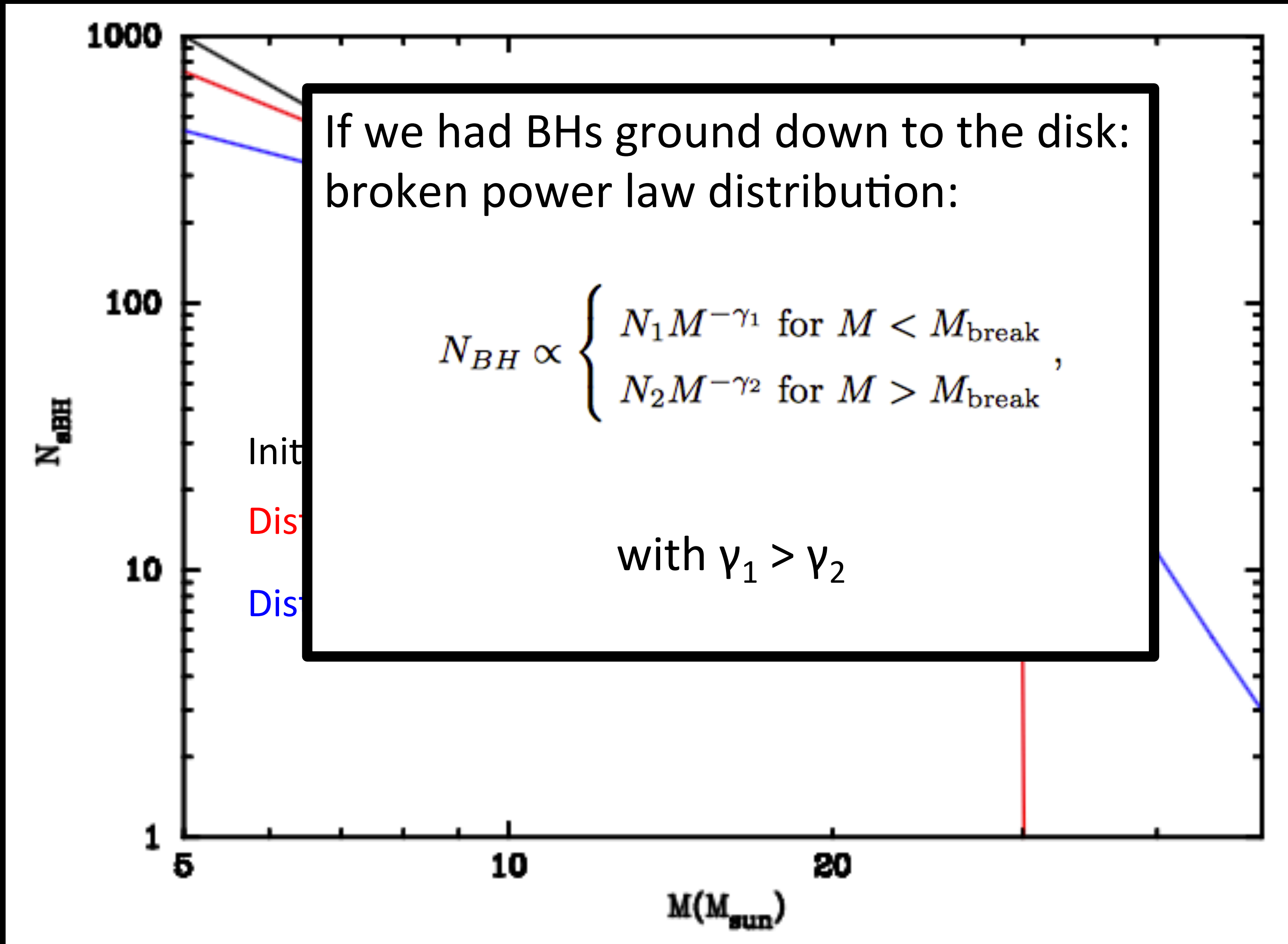
①



no accretion / no binaries in initial distribution / no BH added / BH embedded in the disk

Mass distribution

①



If we had BHs ground down to the disk: broken power law distribution:

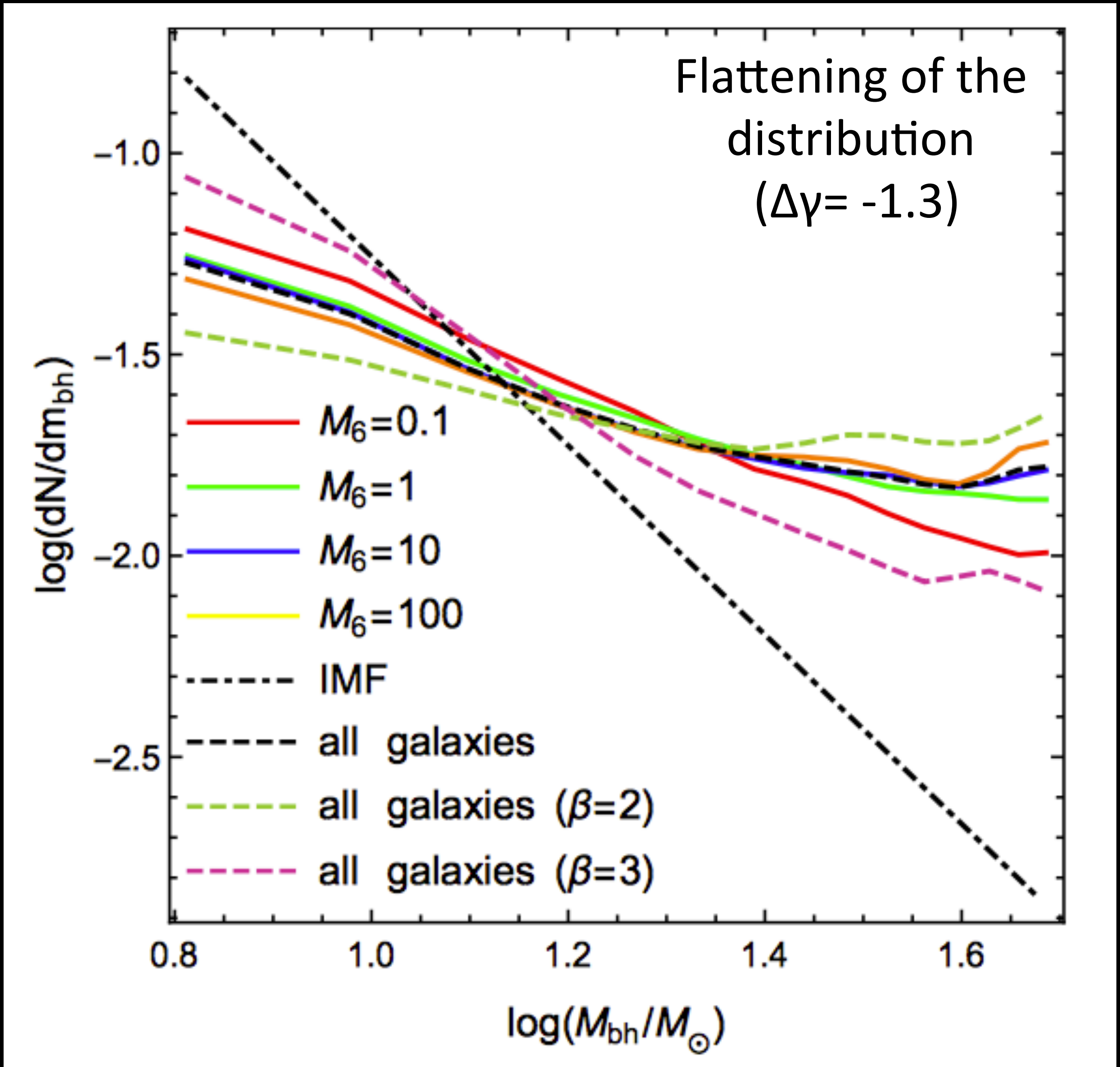
$$N_{BH} \propto \begin{cases} N_1 M^{-\gamma_1} \text{ for } M < M_{\rm break} \\ N_2 M^{-\gamma_2} \text{ for } M > M_{\rm break} \end{cases},$$

with $\gamma_1 > \gamma_2$

no accretion / no binaries in initial distribution / BH embedded in the disk + added BH

Mass distribution

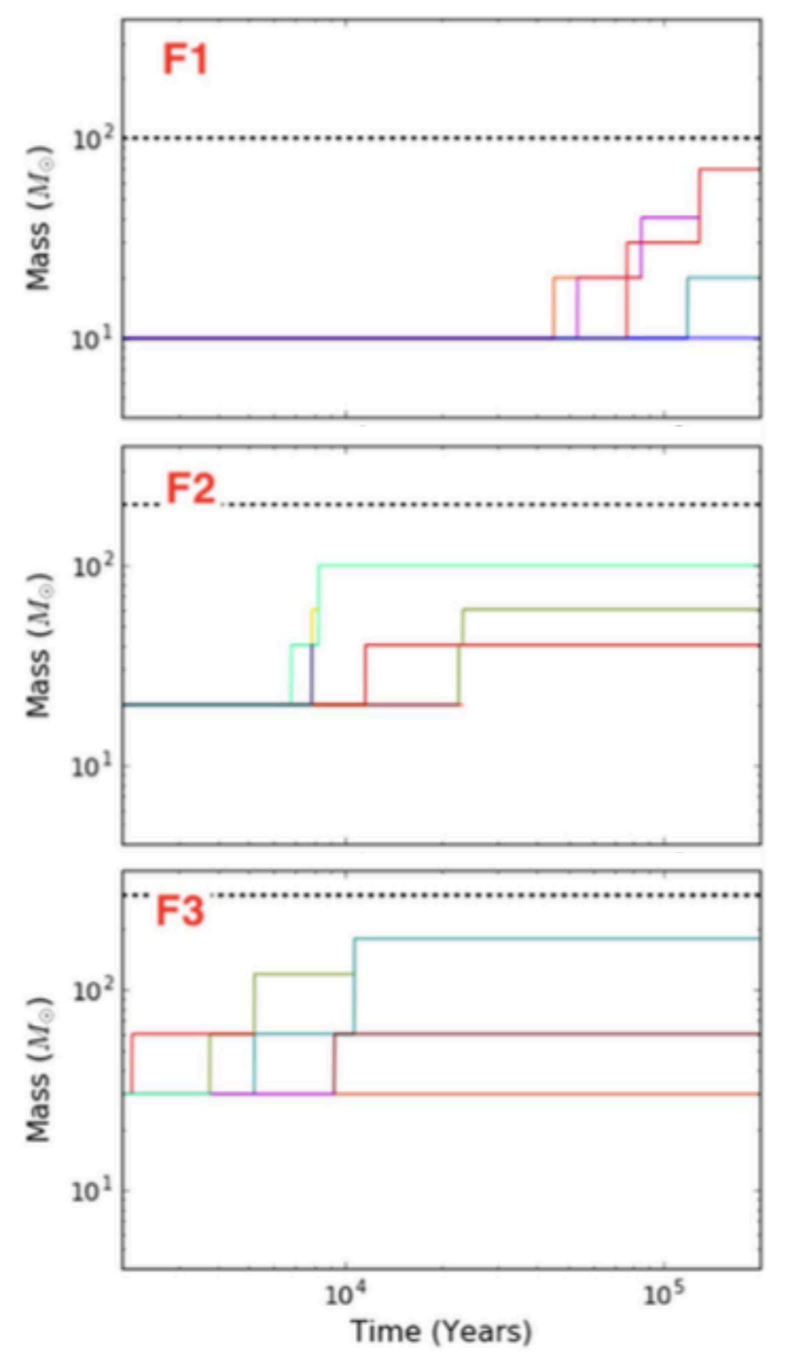
③



no accretion / no binaries in initial distribution / BHs ground down to the disk

Mass distribution

②



10 BHs with 10$M_\odot$ each

Uniform mass distribution

10 BHs with 20$M_\odot$ each

10 BHs with 30$M_\odot$ each

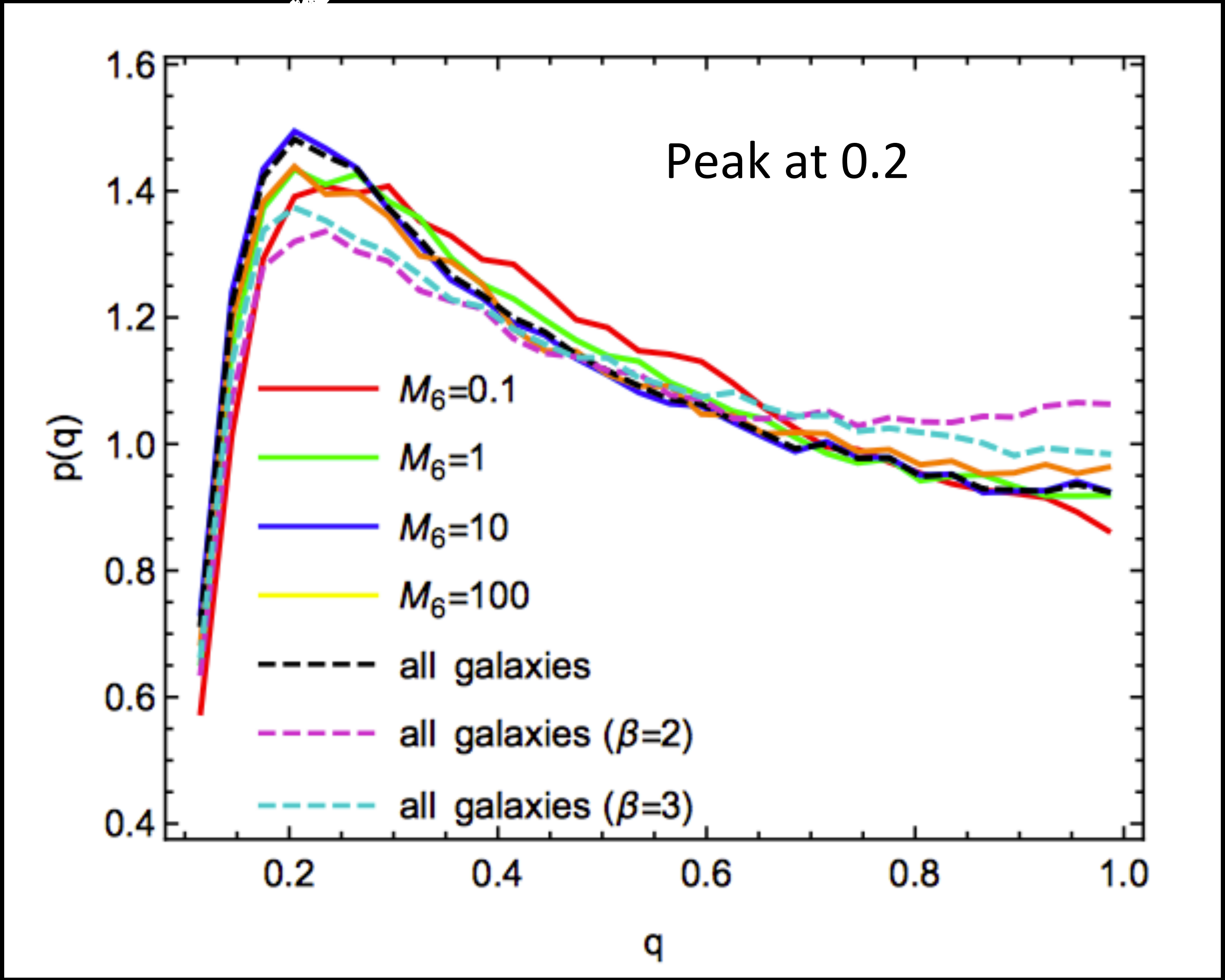
(See paper for more realistic mass distribution)

no accretion / no binaries in initial distribution

Binary mass ratio

③

$q = M_1 / M_2$
with $M_1 \leq M_2$



- Peak at q = 0.2 -> low compare to q from isolated binaries
- q is independent of initial distribution
- BUT not random pairing as heavier BHs are closer to the SMBH, so shift to higher q

Spin

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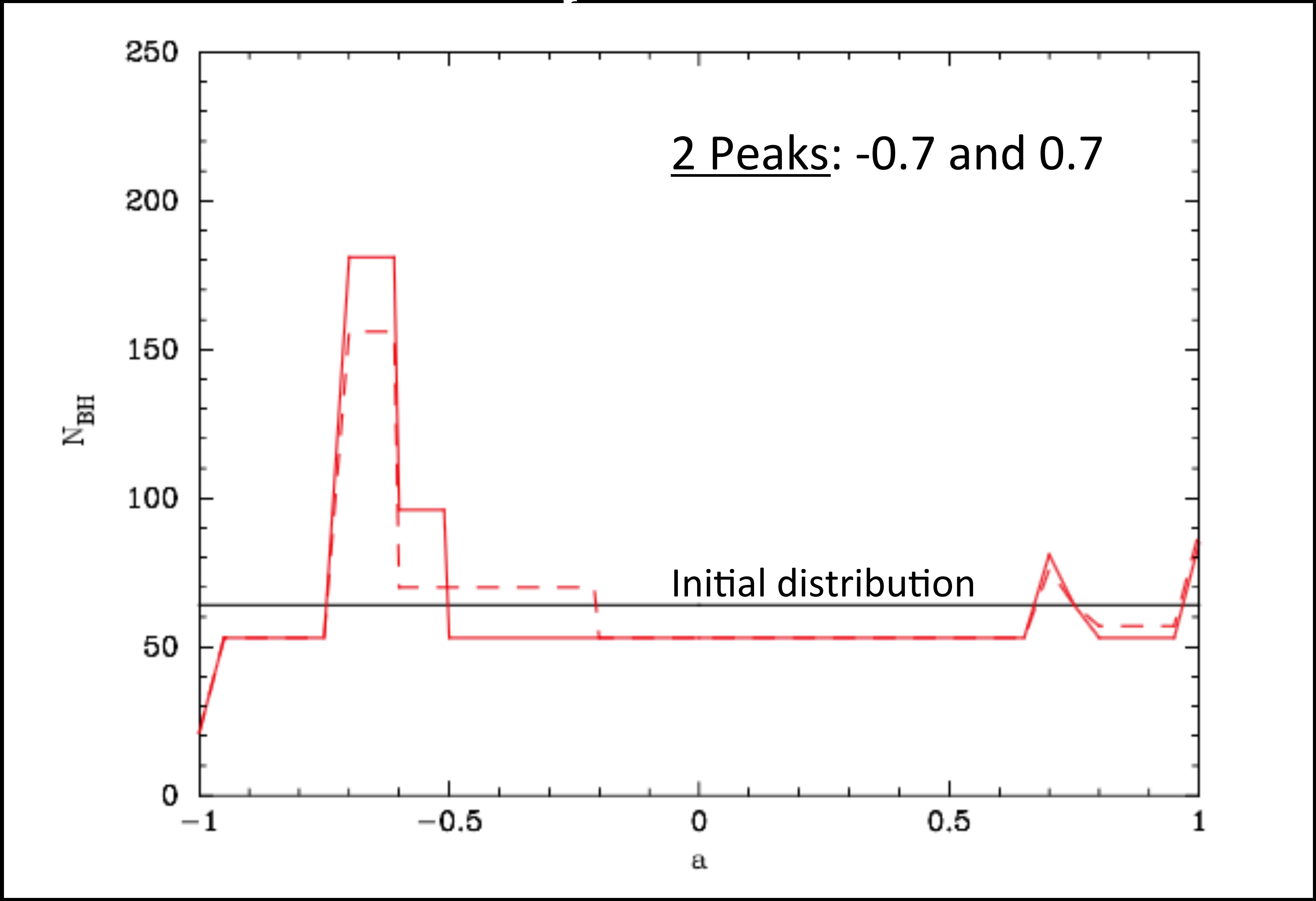

- Comparison at Eddington accretion rate / Super-Eddington accretion rate
- Faster merger rate for retrograde binaries
- Smearing due to gas accretion

More info from the papers

3 – Merger rate (almost) insensitive to the AGN accretion rate

3 – Alignment rate continuously increases with SMBH mass

Conclusion

- Migration through AGN disk = potential efficient mechanism to quickly create a population of hard compact binaries

- Hardening of the mass distribution and heavier BHs merger faster, so channel might already contribute to LVC observations

How can we probe this population?

- With GW:
  - Population maybe already part of LVC. Hints:
    - Spin distribution with aligned/anti-aligned spin binaries
    - Population of overweight BHs
  - IMBH − SMBH in a migration trap around SMBH should be detectable with LISA

- With EM:
  - Features in the optical, UV, X-ray spectral signatures due to IMBHs moving in migration traps or cavities.
  - Correlation between SGRBs and AGN disk
  - Focus on low-luminosity / low-accreting AGNs ([3] says Seyfert galaxies)

- With Neutrinos: let's discuss!