Accretion and collisions in nuclear star clusters

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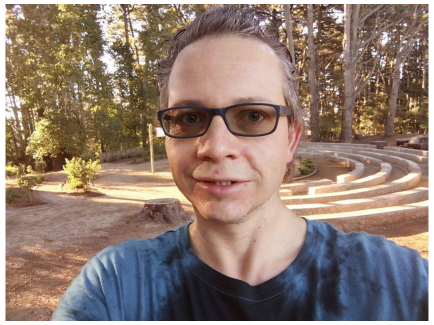
Volkswagen Trilateral Project
Dynamical Mechanisms of Accretion in Galactic Nuclei
Joint Meeting with China-Kazakhstan collaboration

Group members



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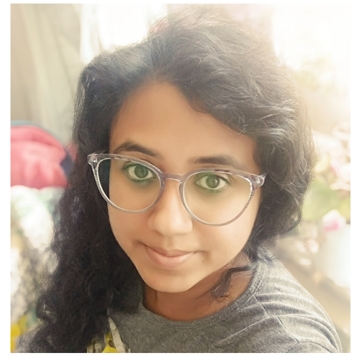

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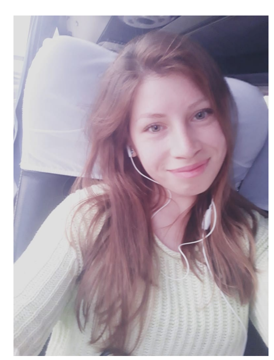

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Basic considerations and starting point

- In the early Universe, protostellar clusters are usually embedded in gas. Also nuclear star clusters can be exposed to gas, for instance during galaxy mergers.

- Both the protostars and the gas follow a Plummer distribution with the same Plummer radius.

- Protostellar radii are enhanced in the presence of accretion.

- We explore various prescriptions for the accretion of the protostars.

- In the following, we model protocluster embedded in a static gas potential with AMUSE.

Black hole formation via accretion and collisions

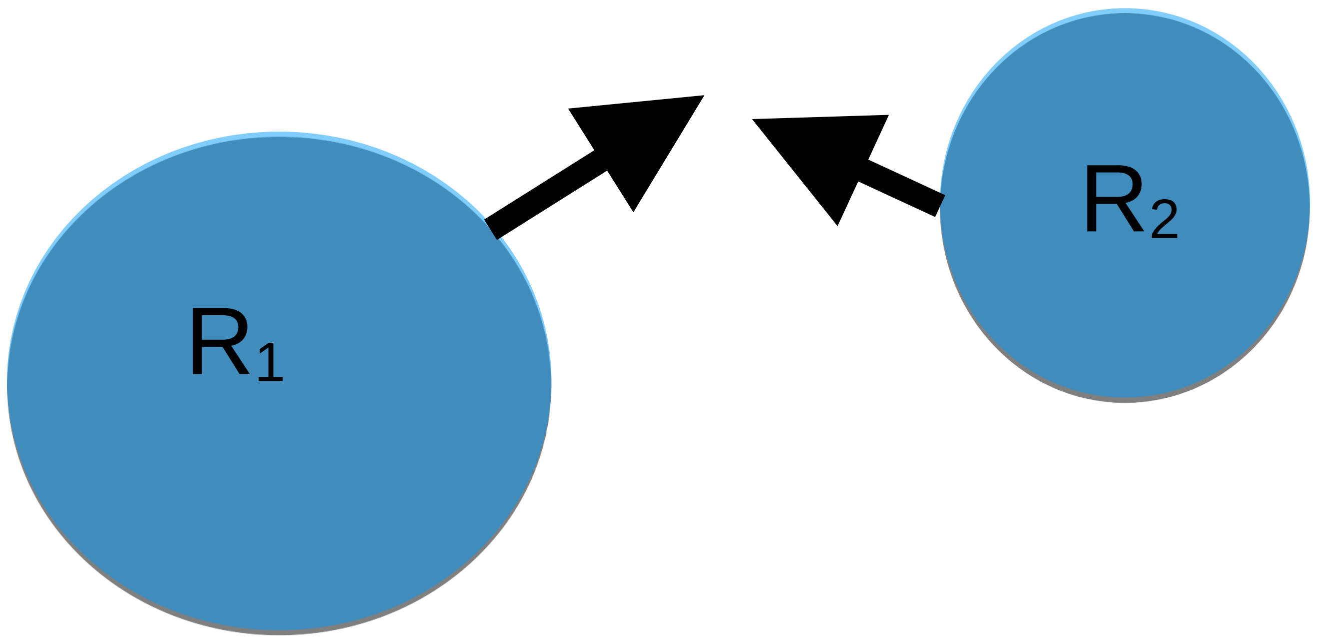
Model	Gas reservoir	Position-dependent accretion model	Time-dependent accretion model
1	Infinite	No	No
2	Infinite	Yes	No
3	Finite	No	No
4	Finite	Yes	No
5	Finite	No	Yes
6	Finite	Yes	Yes

- infinite gas reservoir: constantly replenished

- position-dependent accretion: proportional to gas density (following Plummer profile)

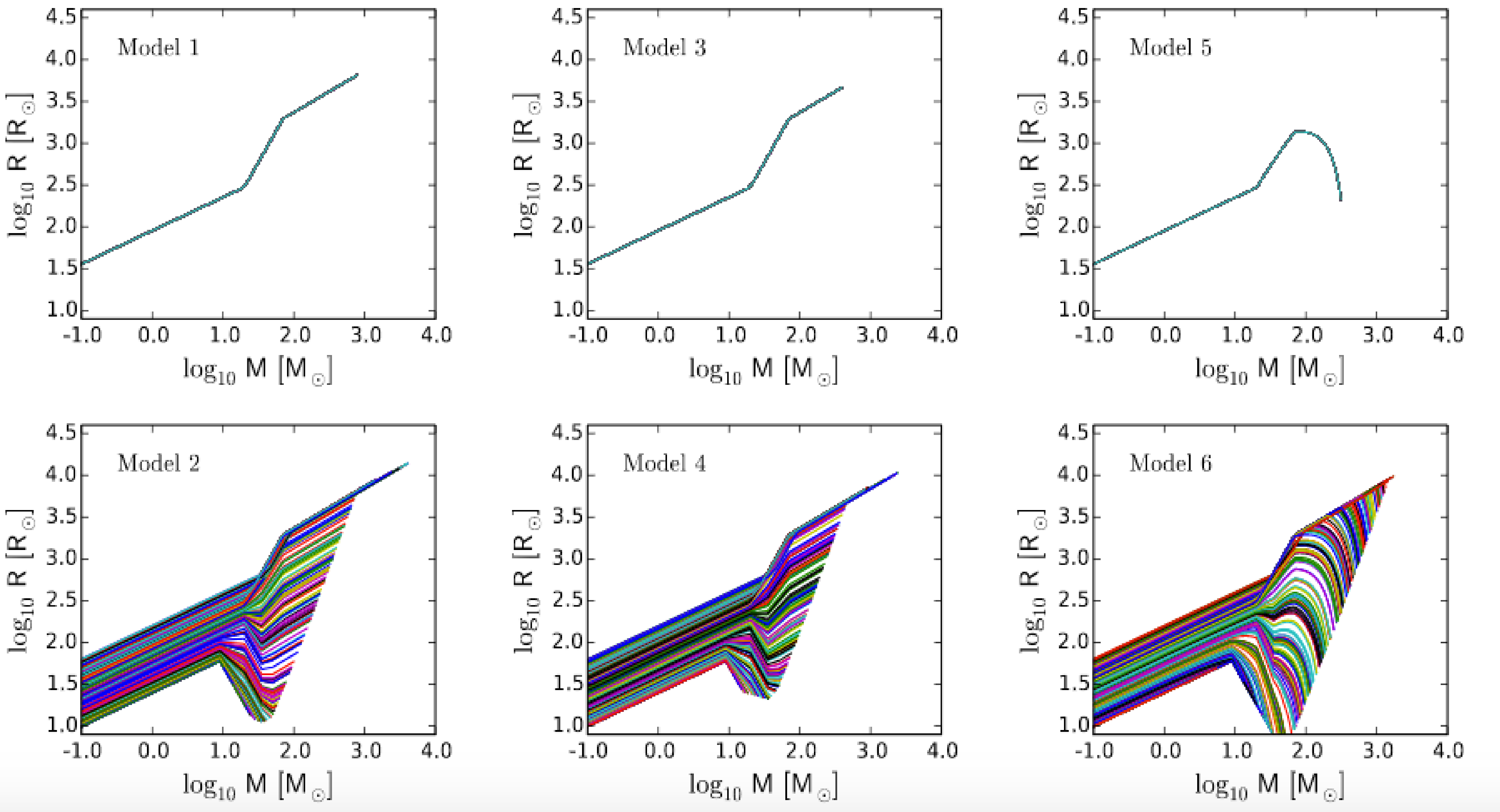
- time-dependent accretion: accretion rate decreasing for decreasing gas reservoir

Treatment of stellar mergers



Two stars merge when their radii overlap.
We will initially assume mass and momentum conservation.

Testing mass-radius relation



Boekholt, Schleicher, Fellhauer et al. (2018)

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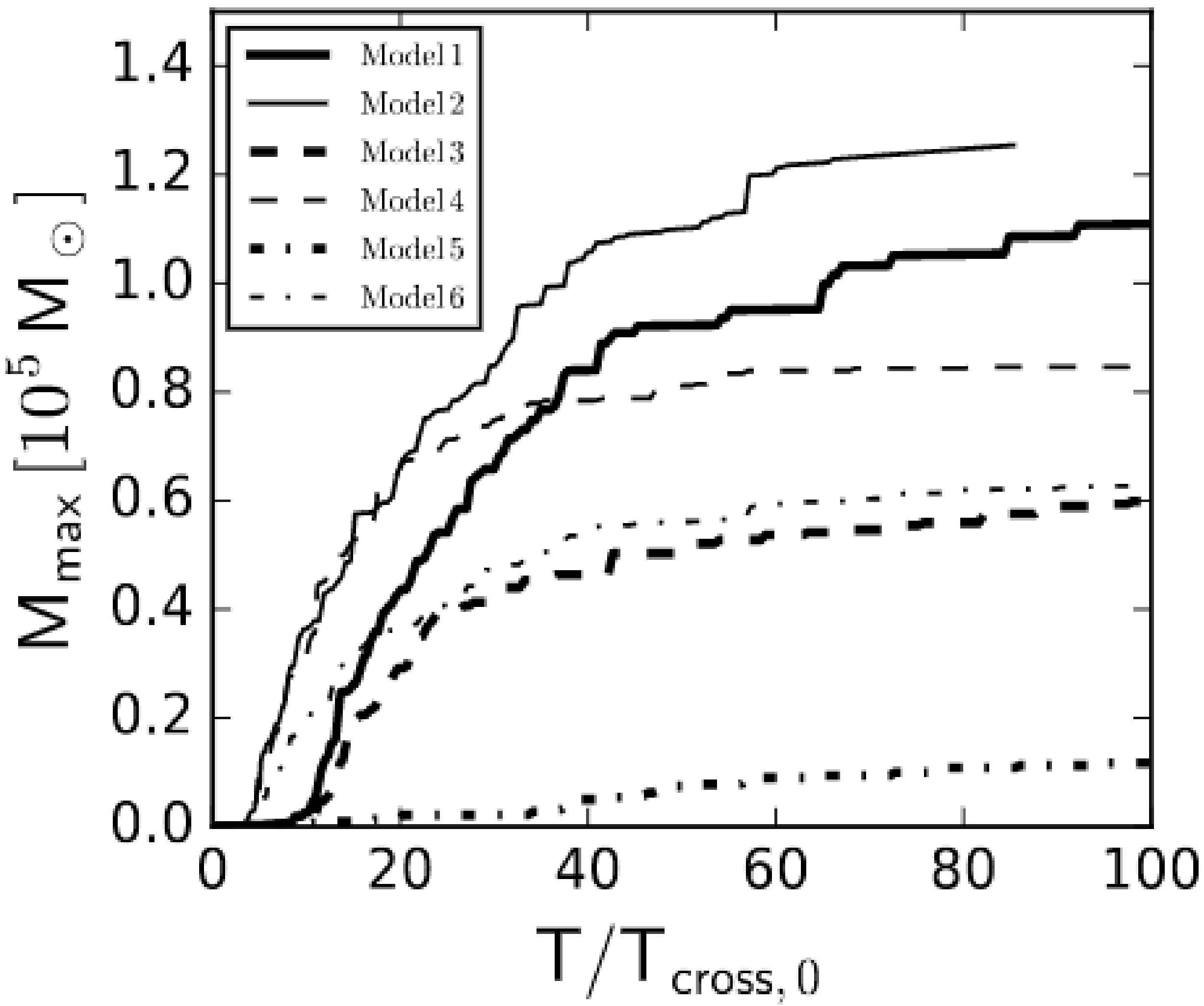
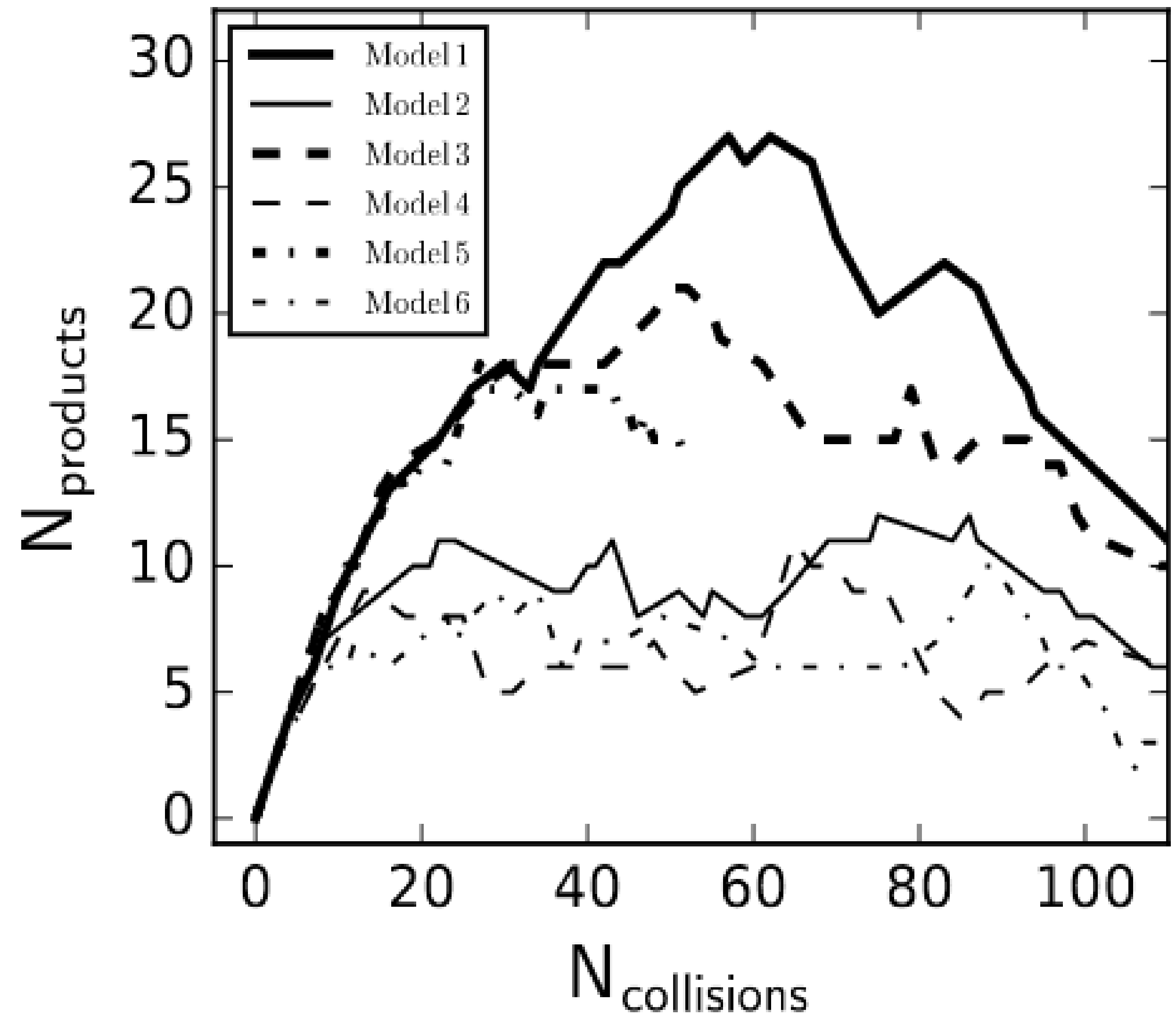
Evolution in our reference model

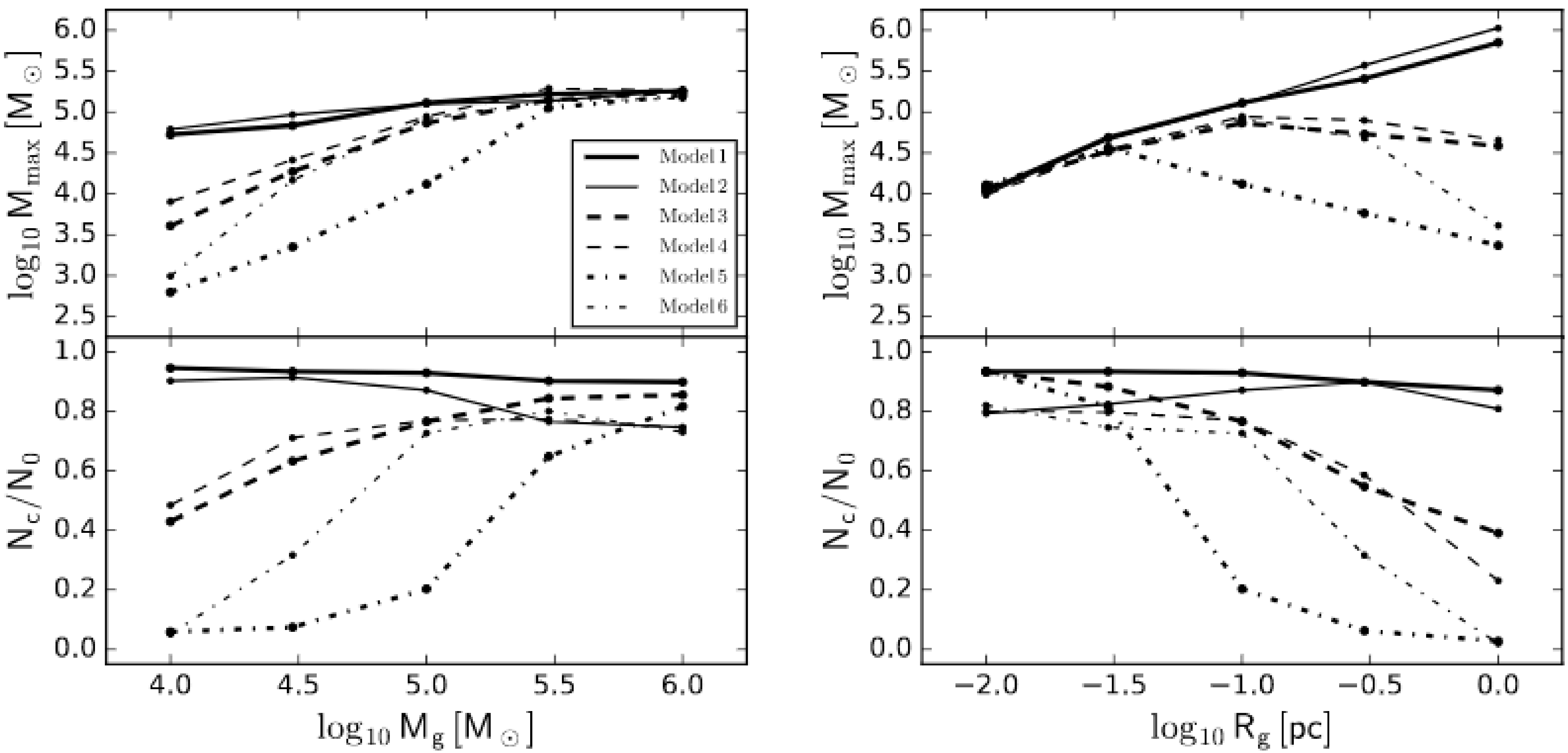




Plummer radius 0.1 pc, initial gas mass 10^5 solar, protostellar accretion rate 0.03 M_{sol}/year

Boekholt, Schleicher, Fellhauer et al. (2018)

Weak dependence on gas mass and Plummer radius



Boekholt, Schleicher, Fellhauer et al. (2018)

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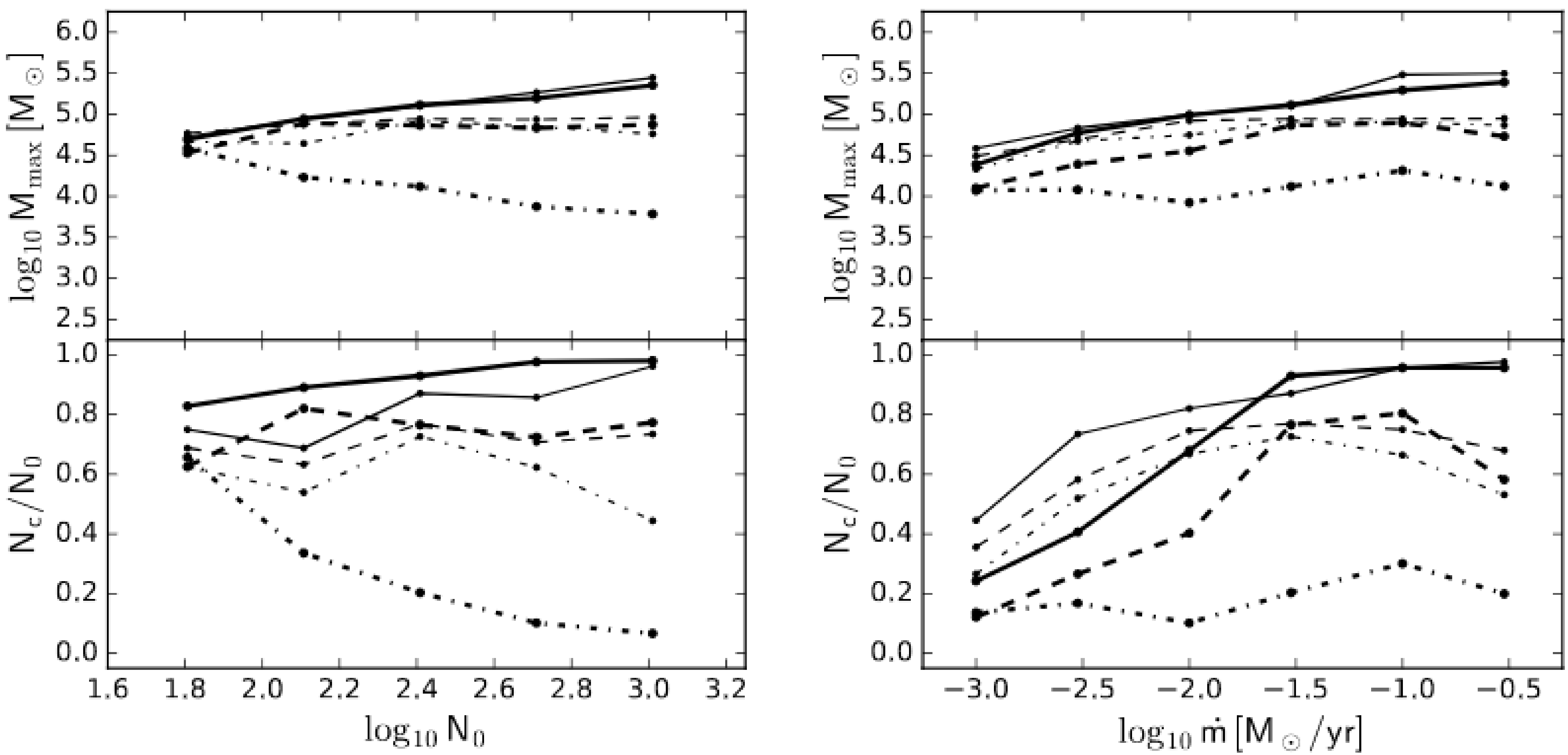
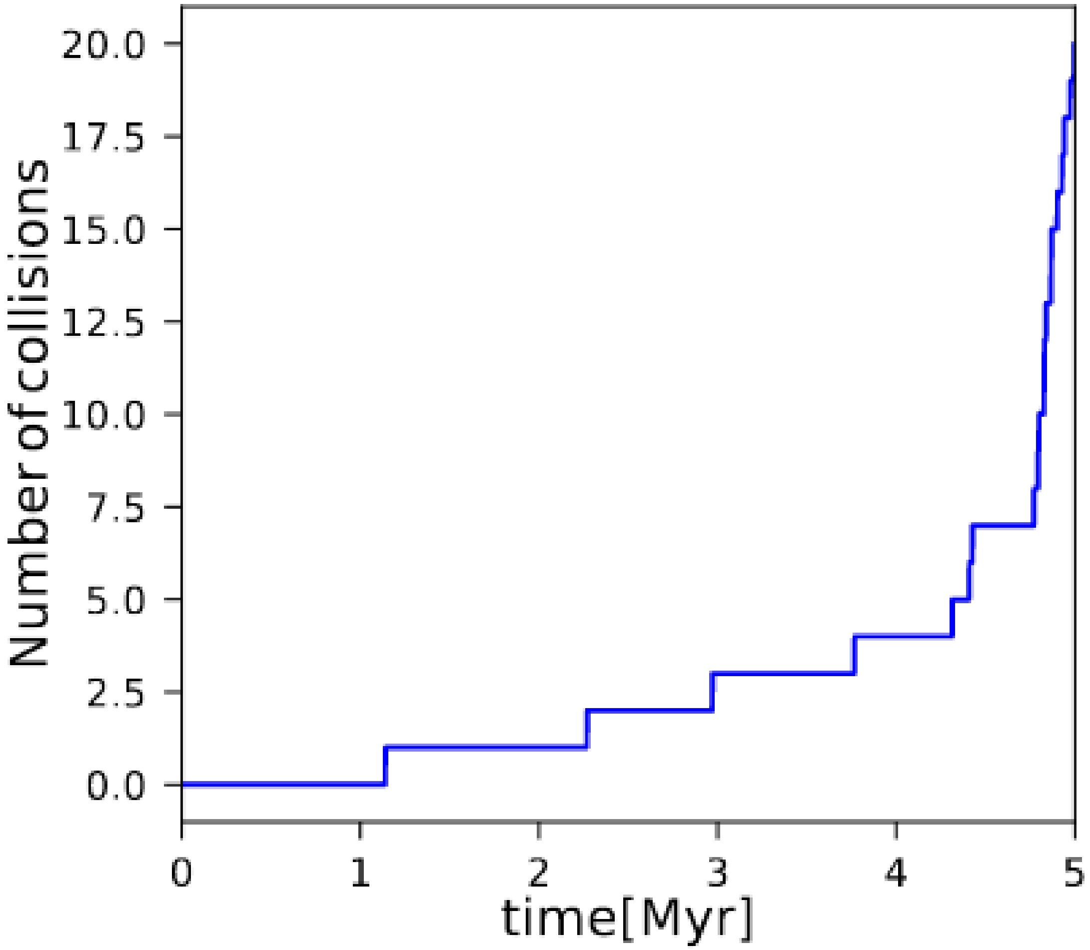
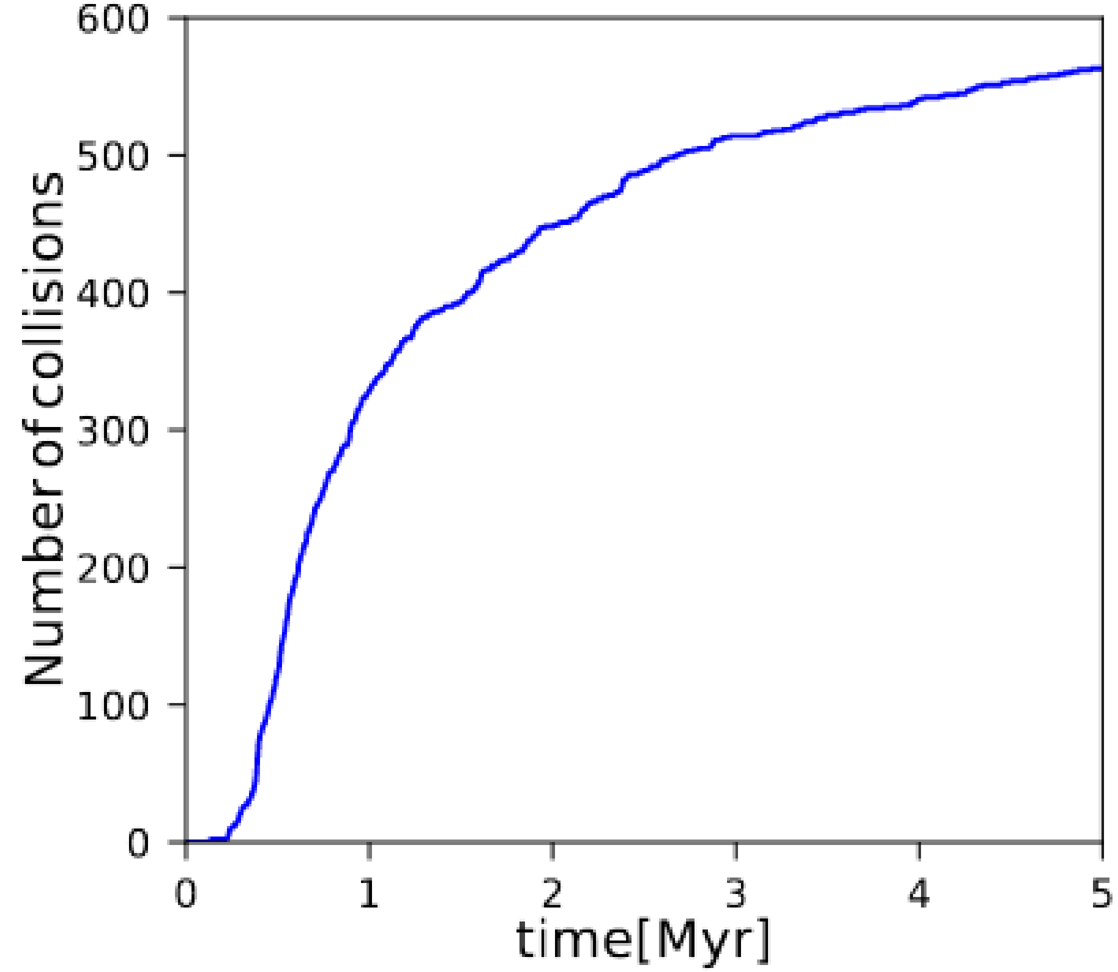
Weak dependence on number of stars and accretion rate



Boekholt, Schleicher, Fellhauer et al. (2018)

Accretion enhances number of collisions!

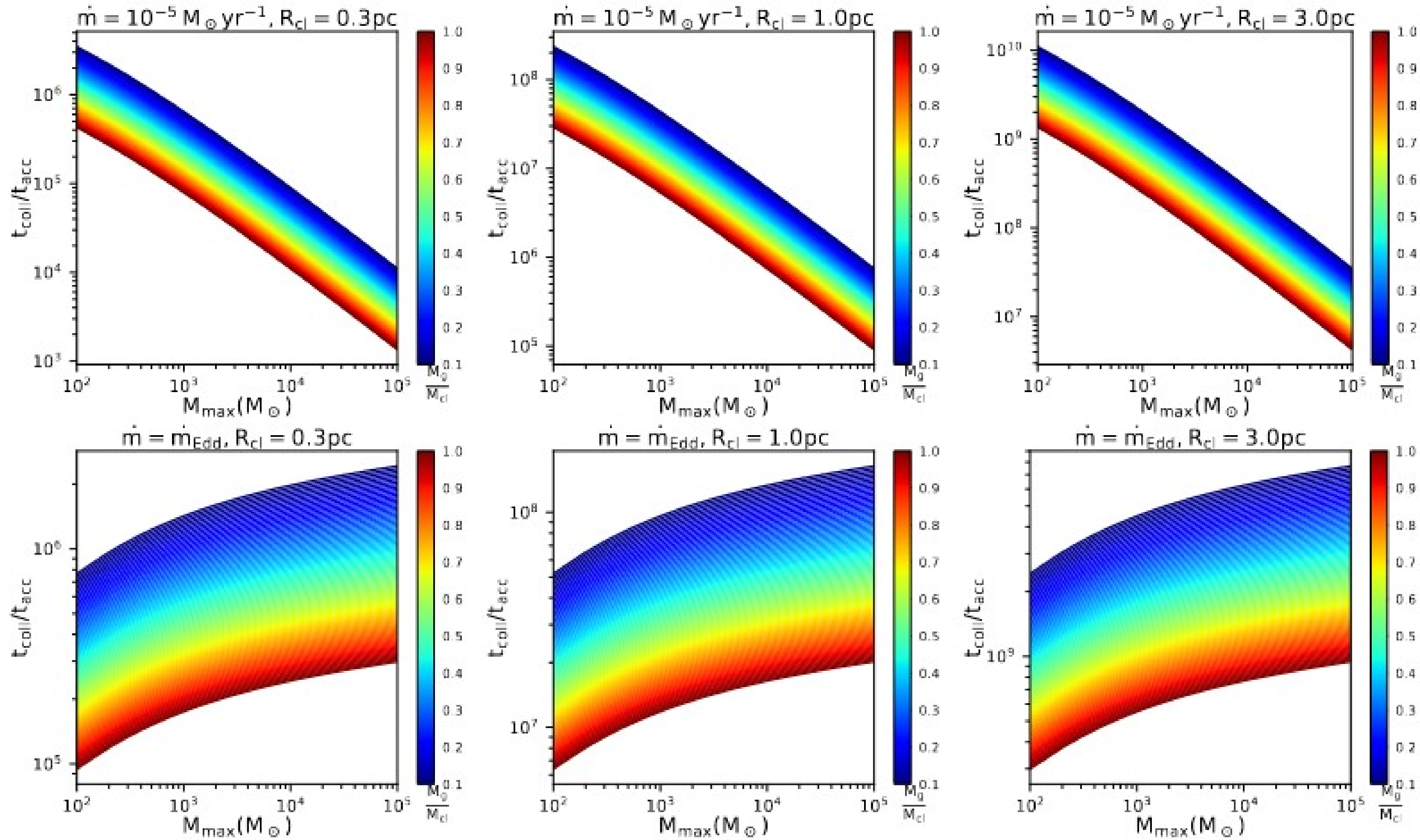




Left: Accretion rate of 10^{-6} M_{sol}/year. Right: Accretion rate of 10^{-4} M_{sol}/year. Otherwise same parameters!

Das, Schleicher et al. (2021a)

Comparison of accretion and collision timescale for most massive object



Collision timescale from Leigh et al. 2017 assuming mean free-path approximation. Considerably overestimates collision timescale. Accretion changes stellar masses and momentum, enhancing collisions! Das, Schleicher et al. 2021a

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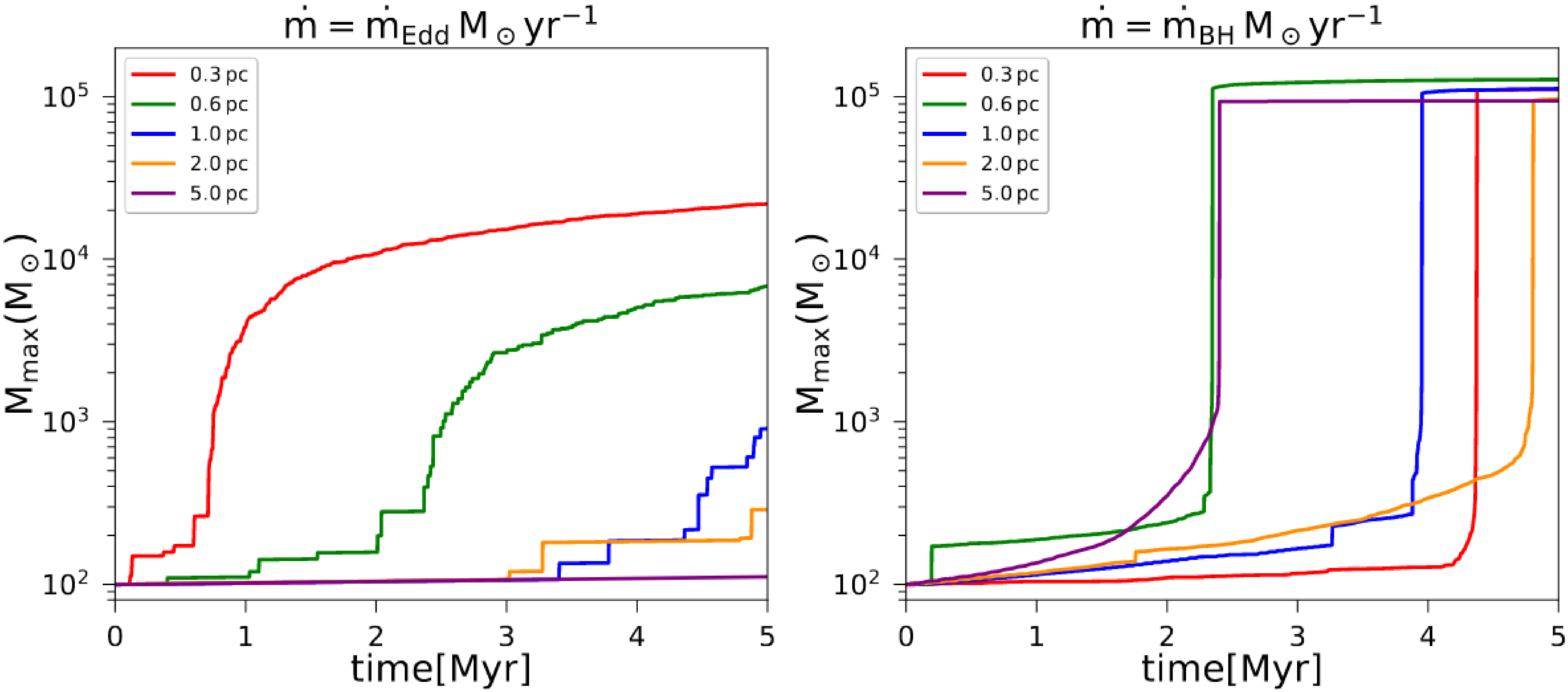
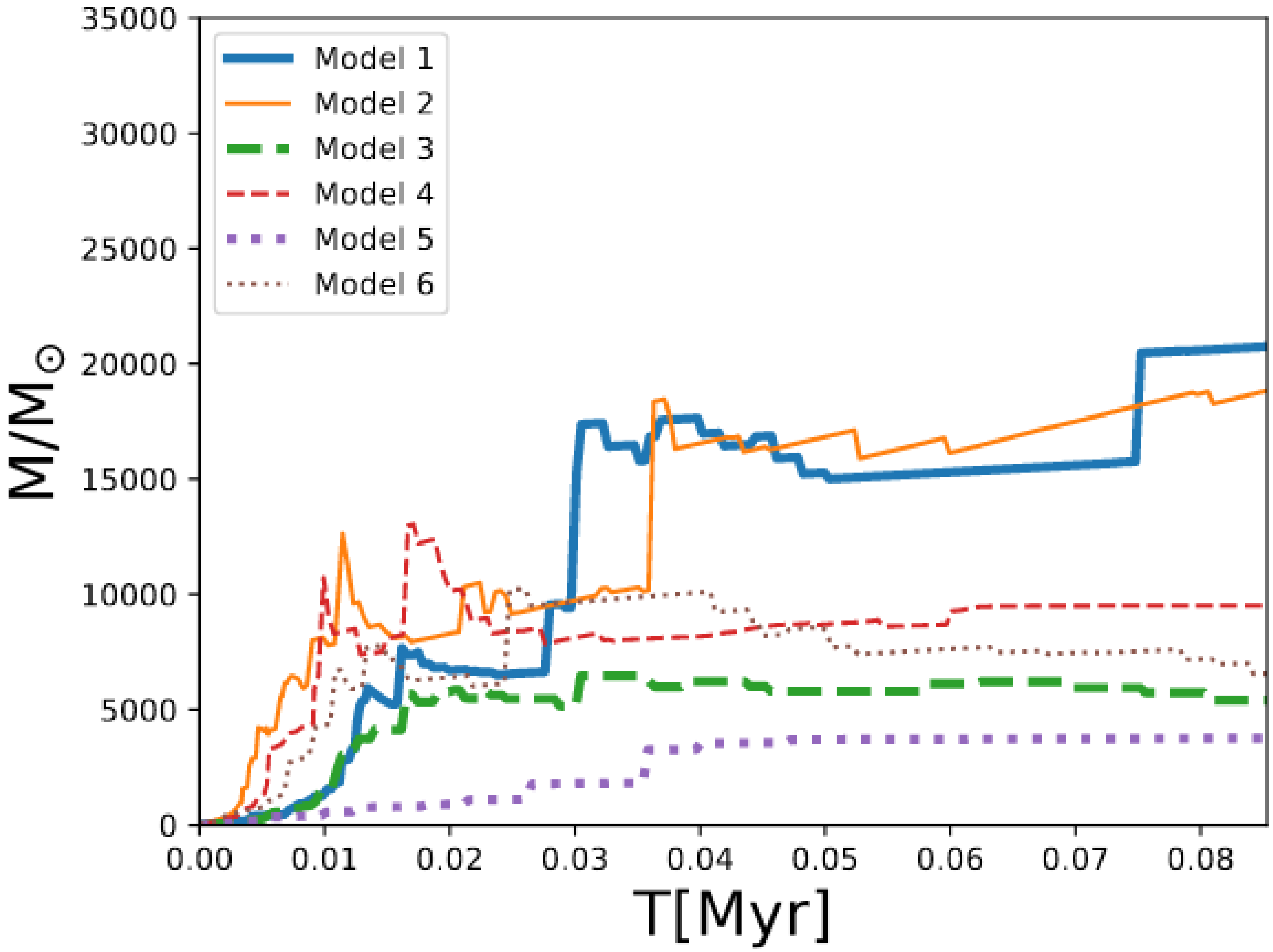
Impact of different accretion recipes



The accretion reciple can strongly influence the growth of the most massive object. Das, Schleicher et al. 2021a.

Impact of mass loss during collisions



Assumption: 90% of mass retained during collisions.
Alister, Schleicher et al. 2020

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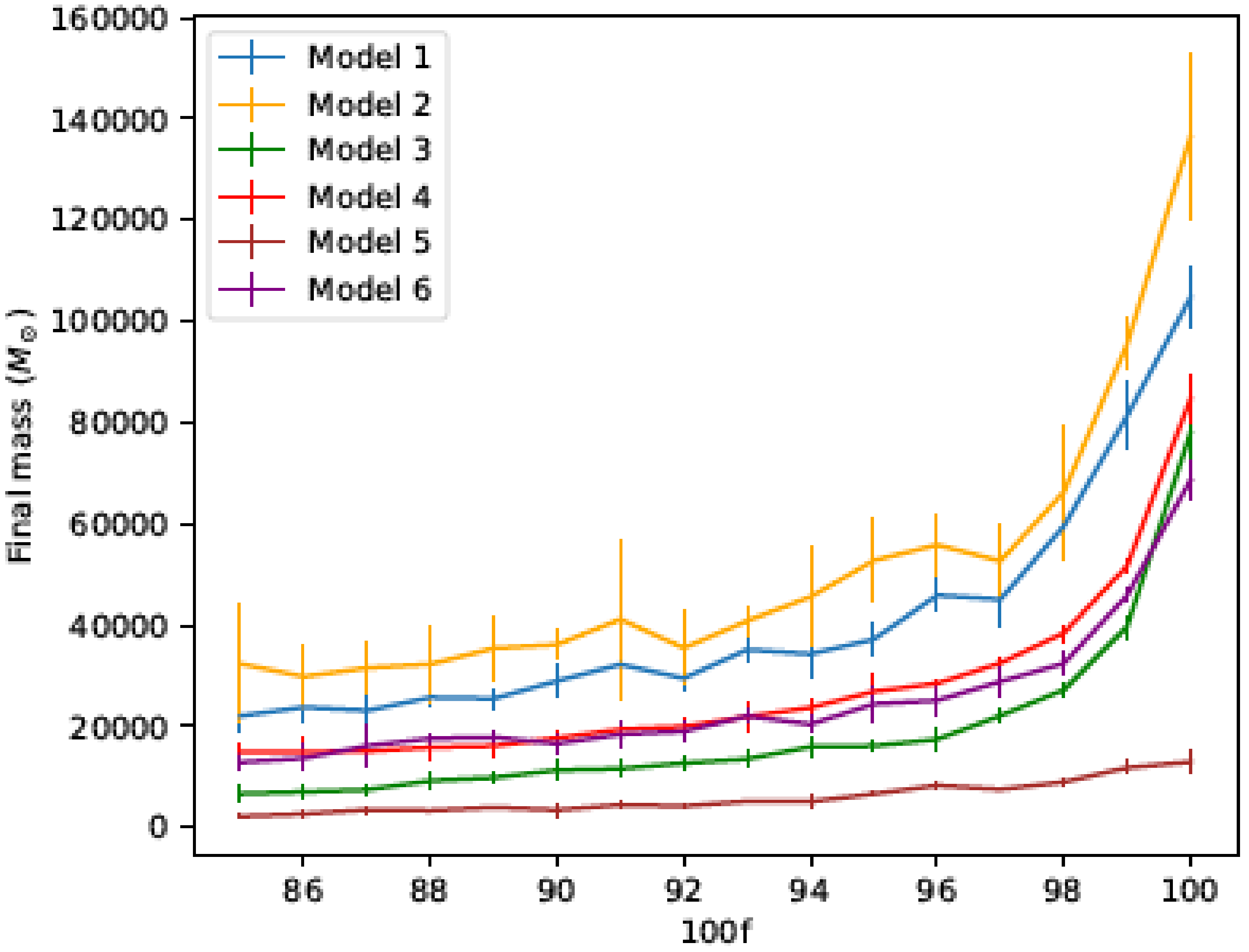
Impact of mass loss during collisions

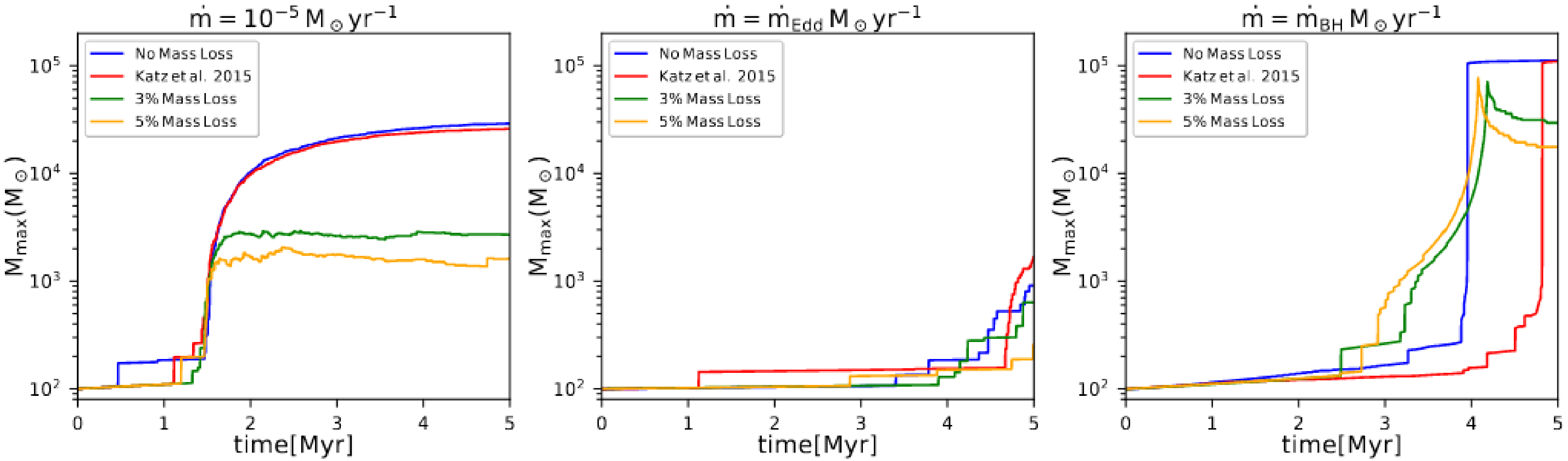


f: fraction of retained mass during collision

Even small mass loss fractions can change final mass by an order of magnitude! Alister, Schleicher et al. 2020.

Relation of mass loss and accretion

constant Eddington Bondi



The stronger the accretion rate depends on the most massive object, the weaker the effect of mass loss. Das, Schleicher et al. 2021a.

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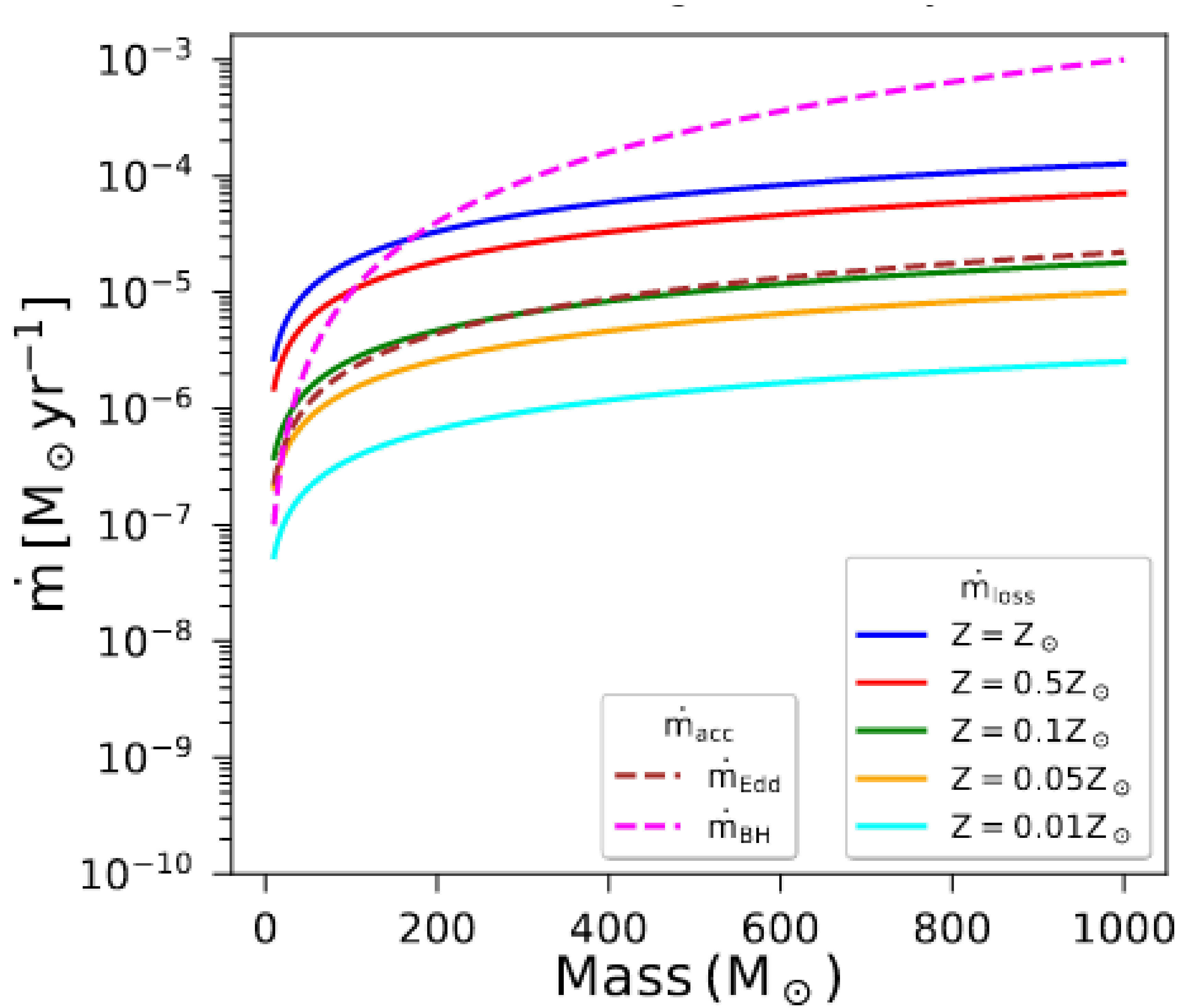
Mass loss through winds as a limiting factor at high metallicity



Wind model by Vink et al. (2001)

Das, Schleicher et al. (2021b)

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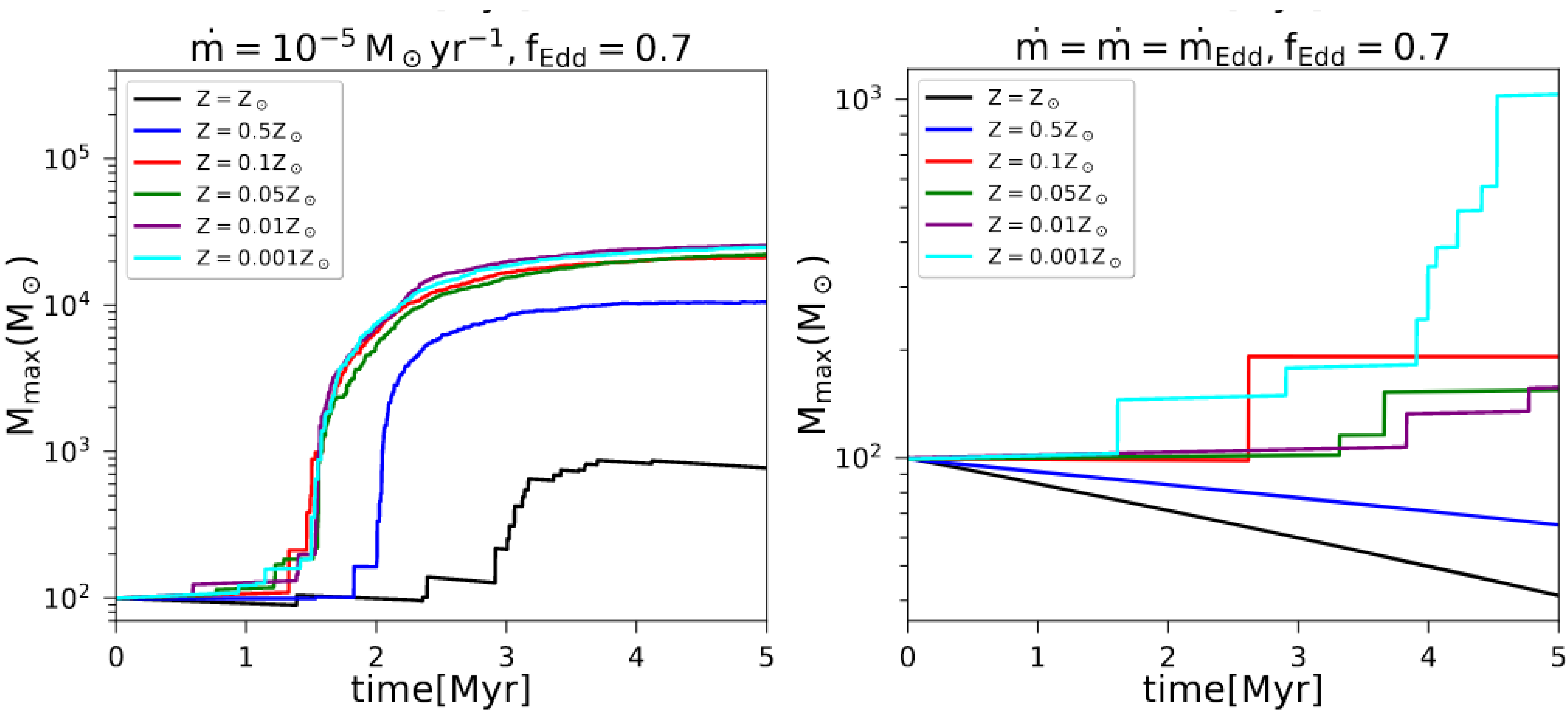
Impact of wind mass loss in dynamical models



Das, Schleicher et al. (2021b)

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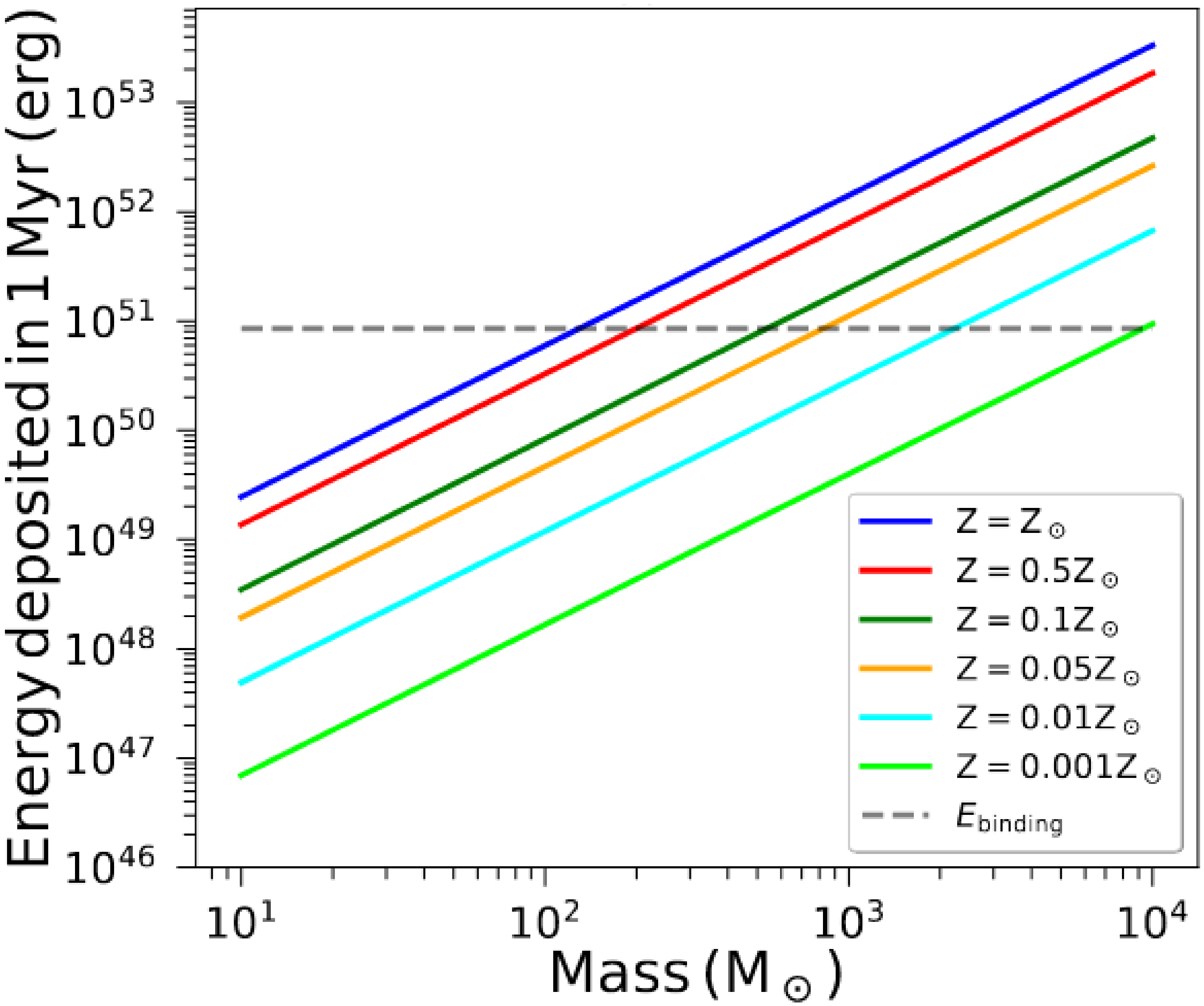
Impact of energy deposition into the gas as additional limiting factor



Wind model by Vink et al. (2001)

Das, Schleicher et al. (2021b)

Summary and conclusions

- We consider black hole formation scenarios based on the interaction of collisions and accretion.

- These scenarios can potentially produce massive objects of up to $\sim 10^5$ solar masses.

- Mass loss during collisions does not seem to inhibit the process, but strongly influences the final masses.

- Feedback through winds is a strong limiting factor, likely restricting the scenarios to low metallicity.