FORMATION OF SUPERMASSIVE BLACK HOLE SEEDS

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Supermassive Black Holes :

-M_{BH}~10^6-10^9 M_{sun};

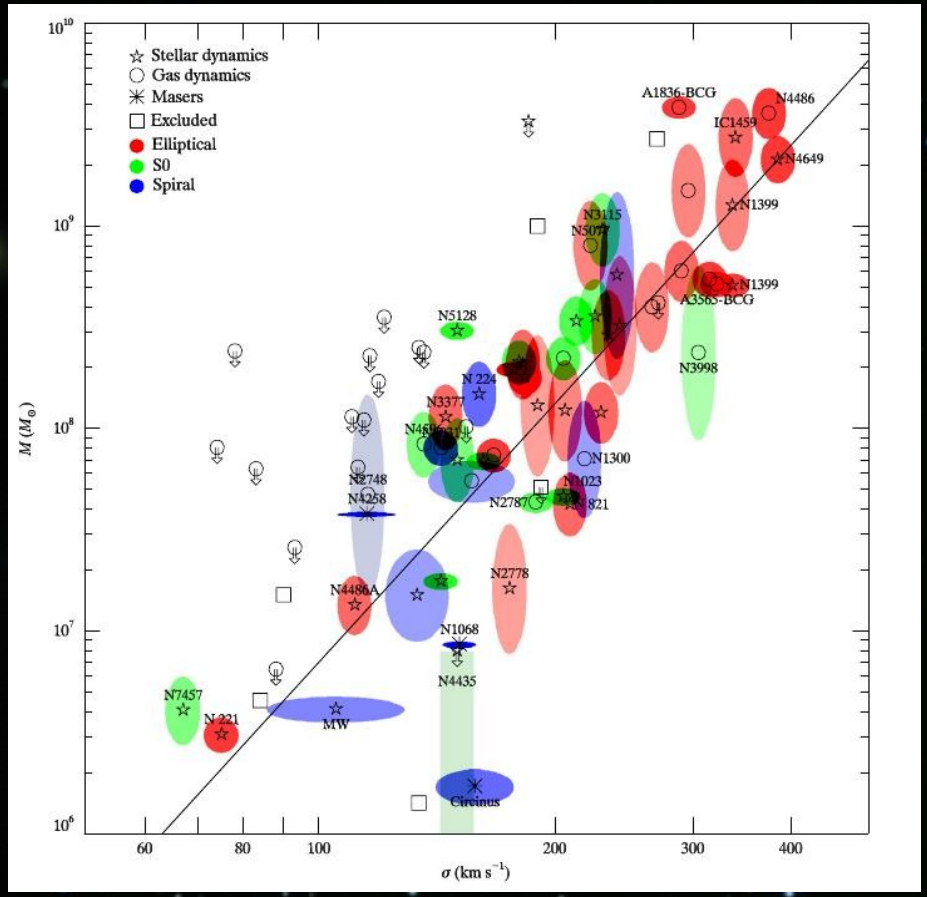
-Common objects in massive galaxies;

-Co-evolution with their hosts;

-Growth by accretion --> relict of the AGN population we see at higher redshift.

-High mass SMBHs detected up to z~6

--> early formation and growth!

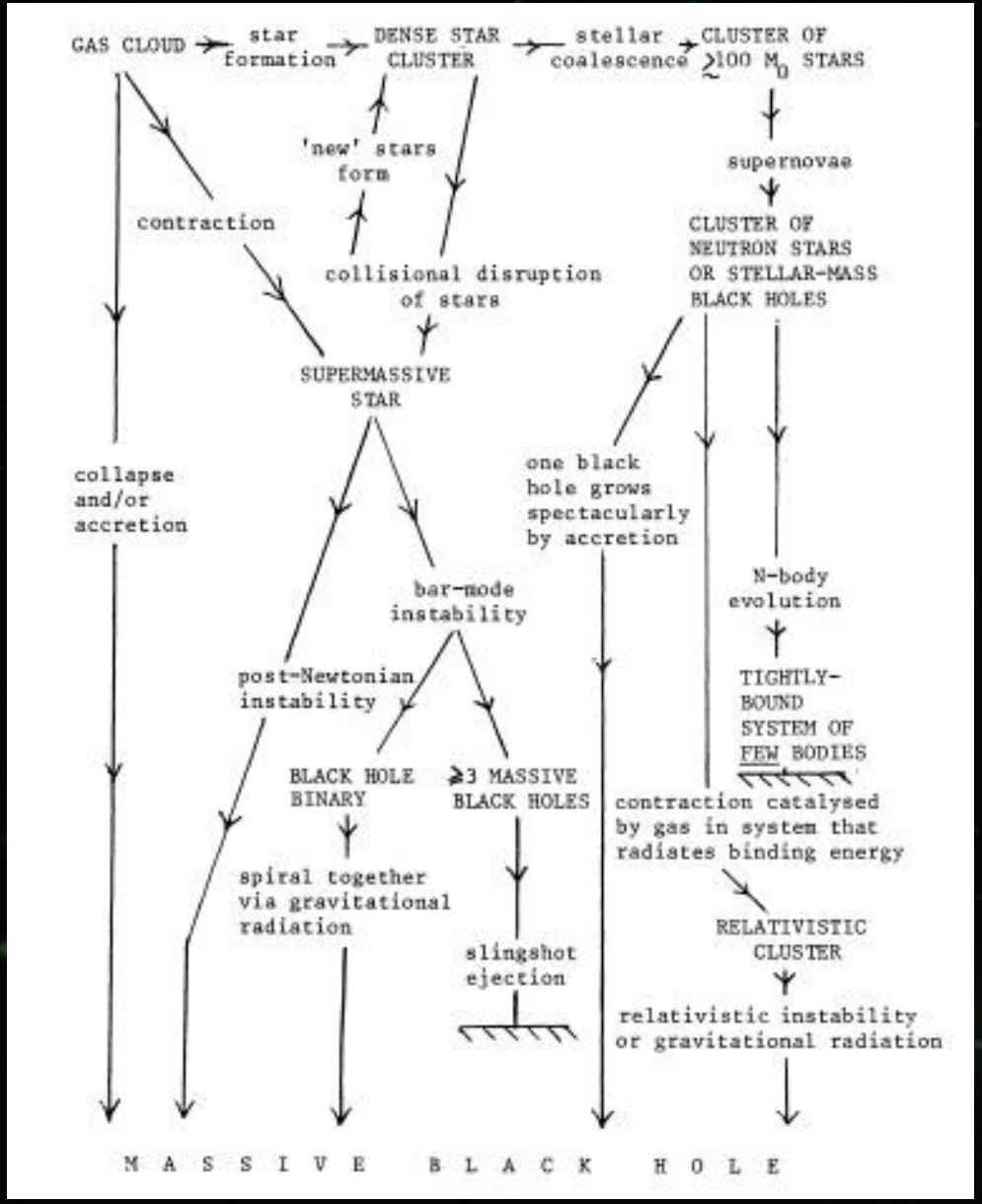


SMBH seed formation:

-PopIII remnants <-- metal free

-Collapse of a super-massive object <-- metal free

-Dynamics in compact clusters <-- $Z>Z_{crit}$



Rees (1984)

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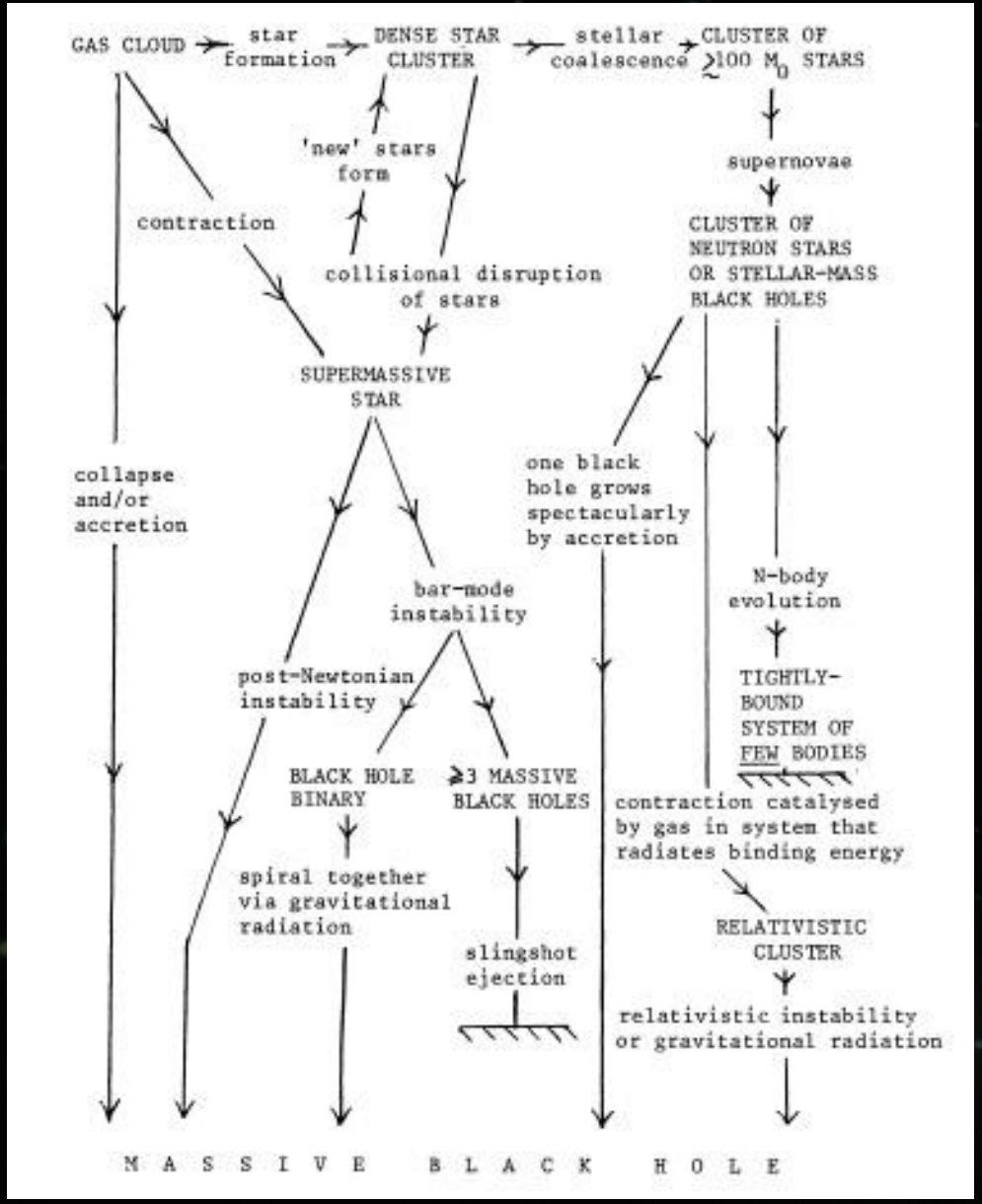


Rees (1984)

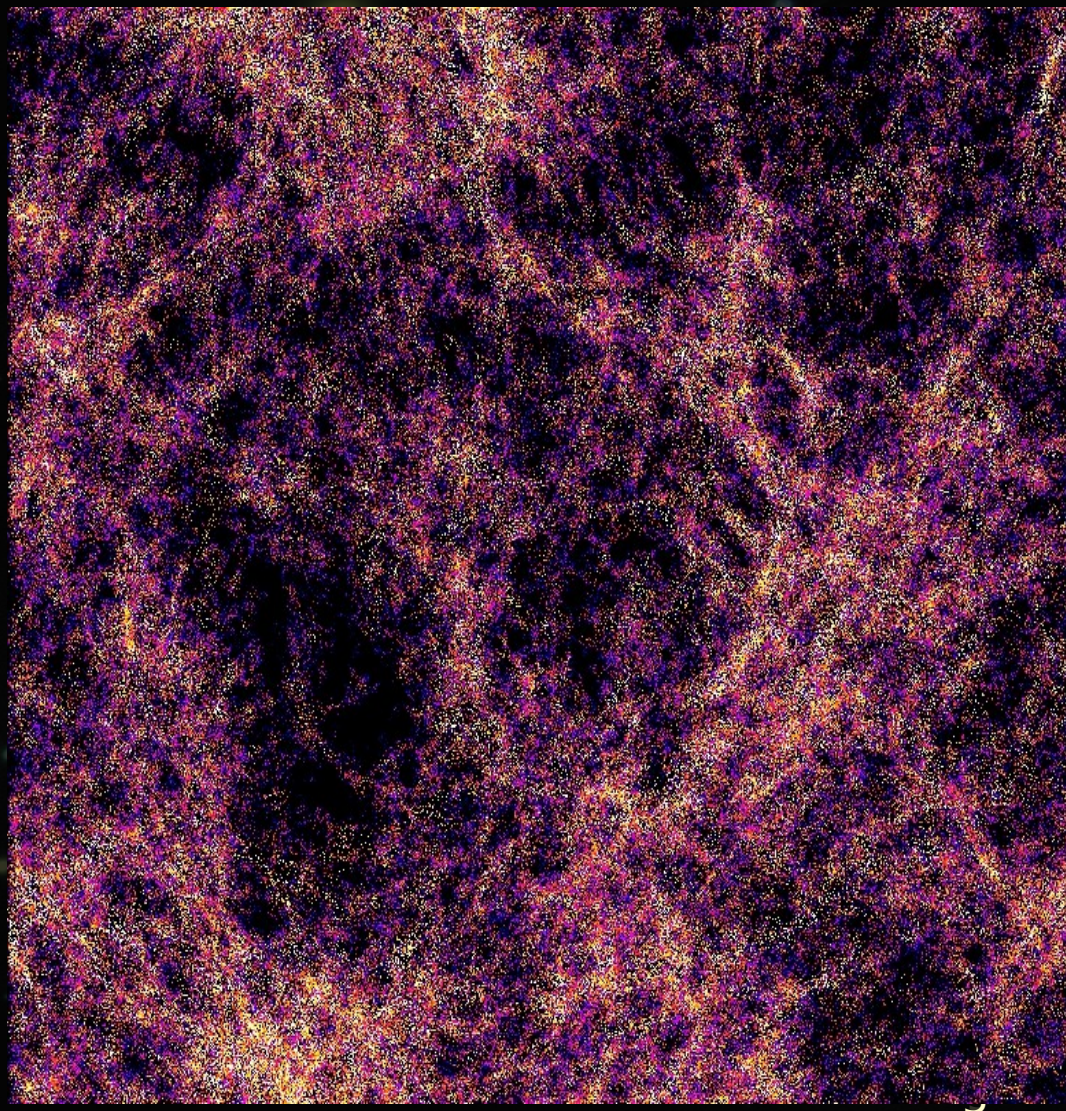
Seed formation during galaxy assembly:

Different mechanisms are efficient in halos with different characteristics: how do they compete in forming the entire BH seed population?

Following merger tree histories of halos!

-PINOCCHIO code --> dark matter halos.
(Monaco et al. 2002a,b)

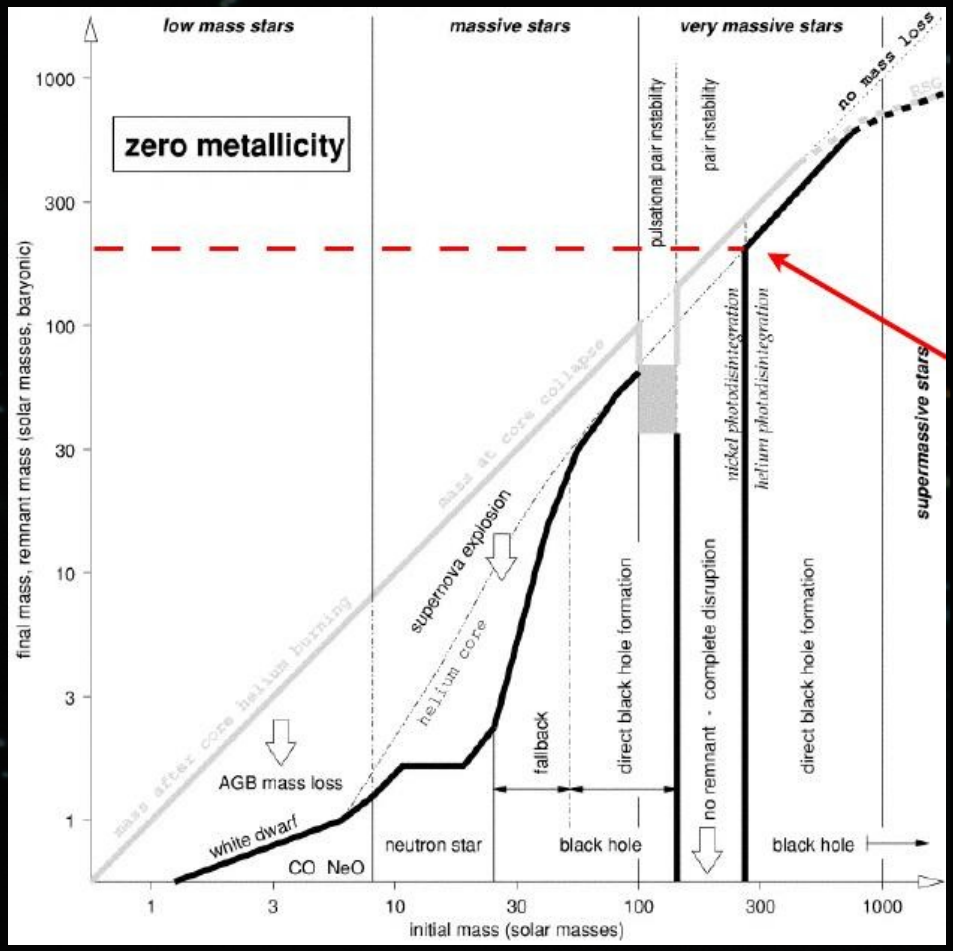
-Semi-analytical code --> baryons:
1) PopIII in metal free halos;
2) PopII/I in enriched halos.



PopIII stars:

Metal free gas: cooling via H2; single high mass star per halo
(but see Clark et al. 2008, 2010; Stacy et al. 2010, Turk et al. 2009).

Feedback effects on surrounding structures:
-radiative (during lifetime): LW flux;
-chemical (after death): metal pollution;
-formation of BHs.



Heger & Woosley (2002)

$Z > Z_{crit}$: inflow versus fragmentation

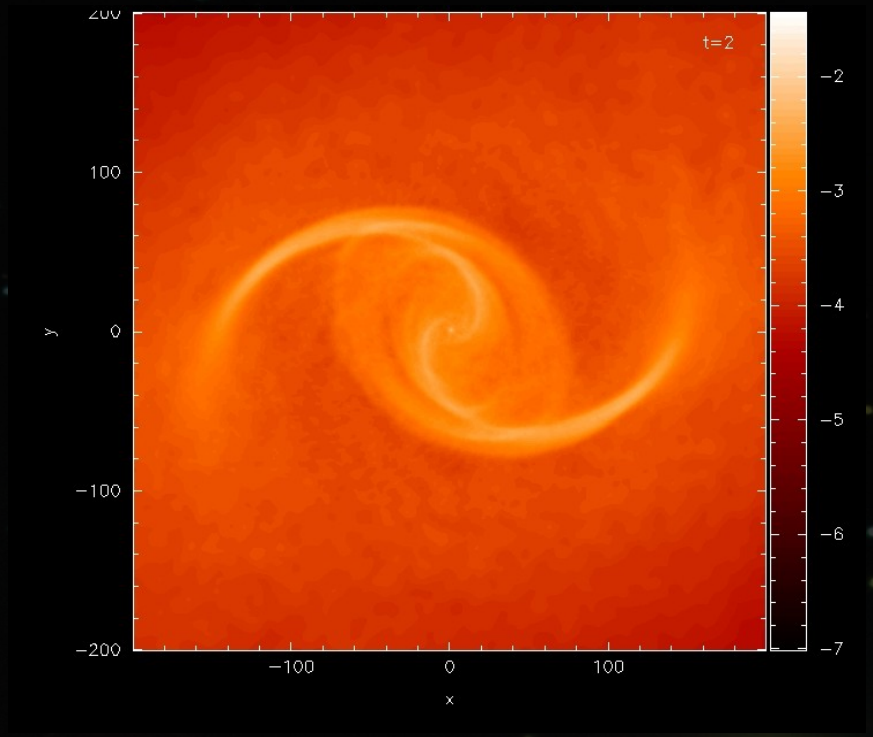
High redshift halo virialises.

Baryons cool down forming a disc.

Unstable disc:

$$Q = \frac{c_s \kappa}{\pi G \Sigma} < Q_c$$

$$\dot{M}_{\rm grav} = \frac{2\eta c_s^3}{G}\left[\left(\frac{Q_c}{Q}\right)^2 - 1\right]$$



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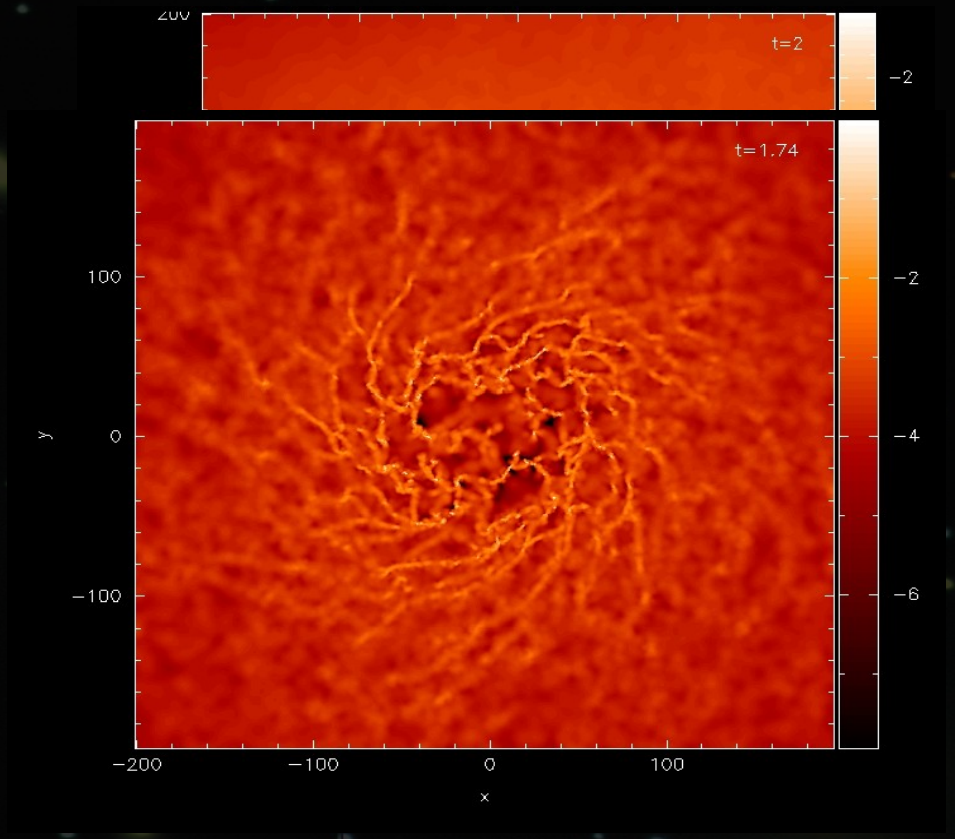
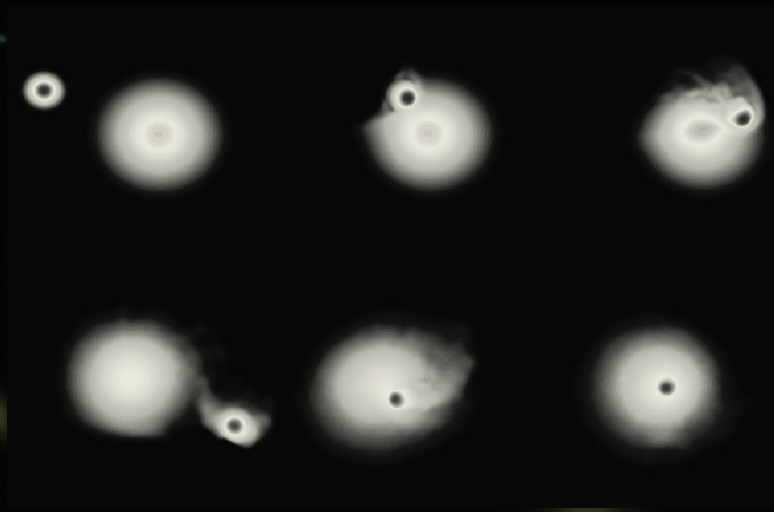
$$\dot{M}_{\rm inf} = \dot{M}_{\rm grav} - \dot{M}_{*,\rm d}$$



Stellar dynamics in dense stellar clusters:

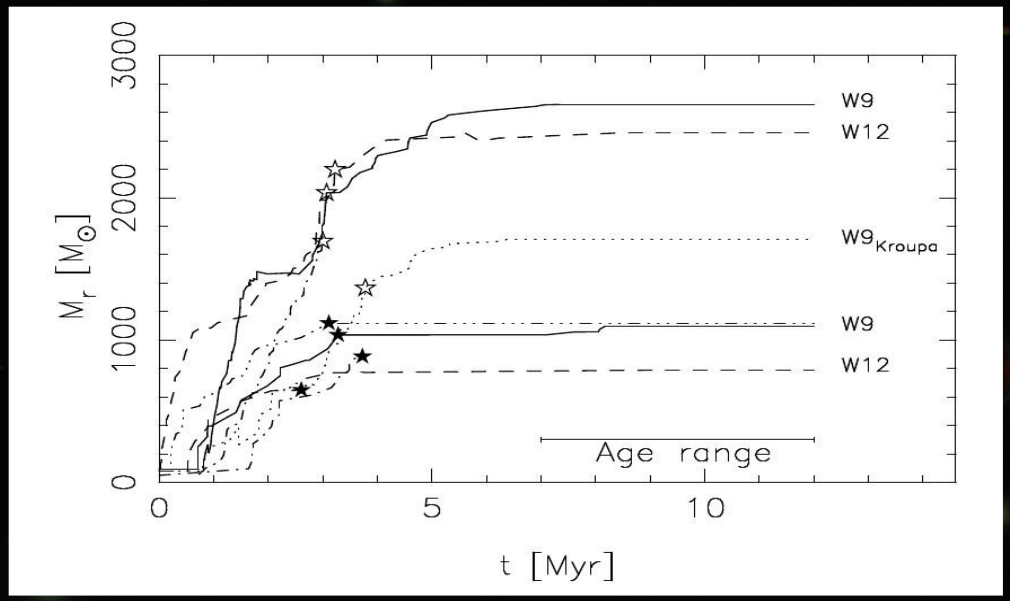
Fast mass segregation and core collapse: core of massive stars!

$$t_{cc} \simeq 3\mathrm{Myr}\left(\frac{R_\mathrm{h}}{1\mathrm{pc}}\right)^{3/2}\left(\frac{M_{cl}}{5\times10^5\,M_\odot}\right)^{1/2}$$



Runaway collisions between massive stars: formation of a very massive star!

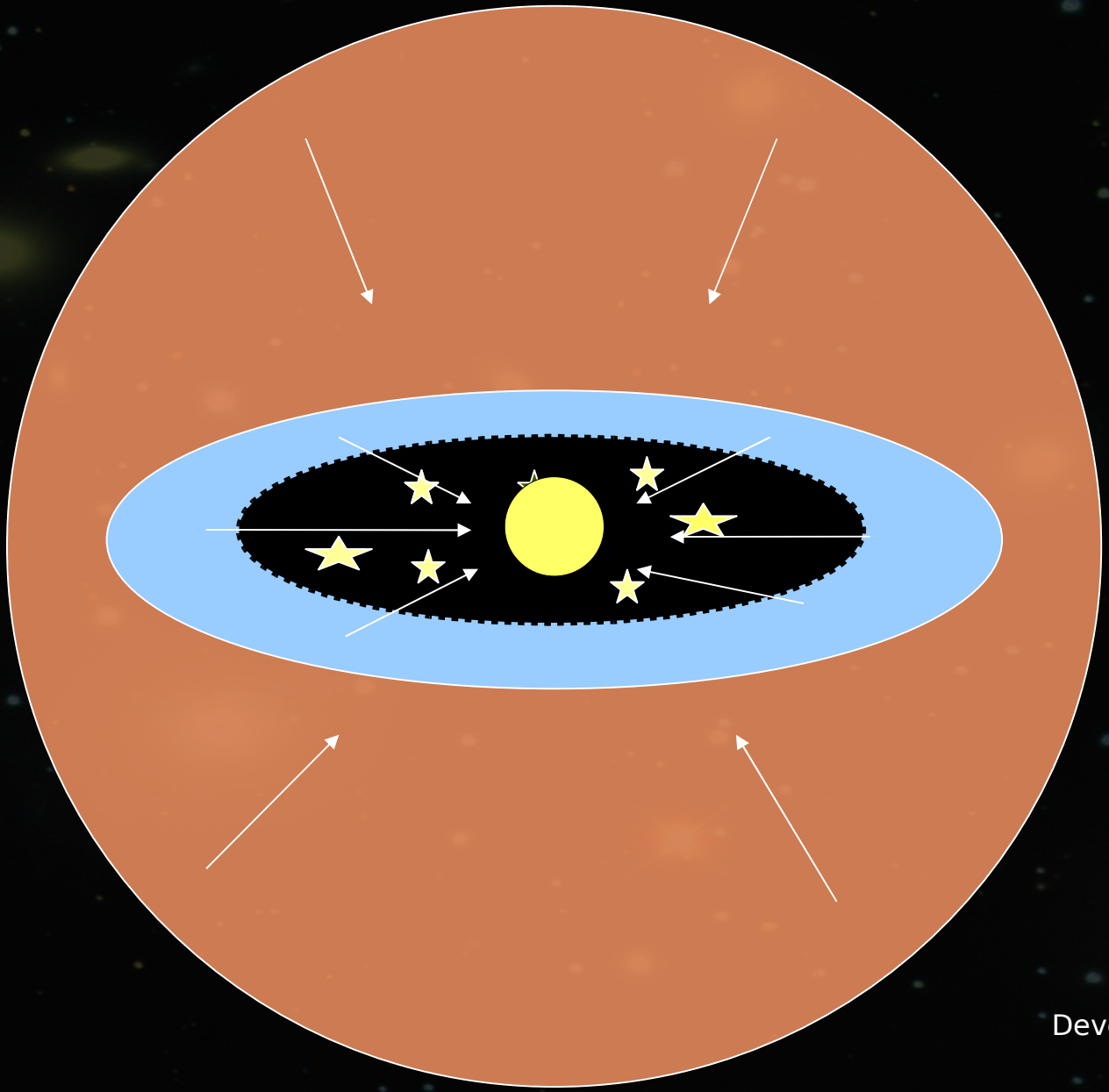
Portegies Zwart & McMillan (2000)
Freitag et al. 2002a,b, Gurkan et al. (2001)



Formation of a massive black hole without strong mass loss *(low Z!)*:

$$M_{BH} = m_* + 4\times10^{-3} M_{cl} f_c \ln\lambda_C \ln\left(\frac{t_{MS}}{t_{cc}}\right)$$

Structure of the system:

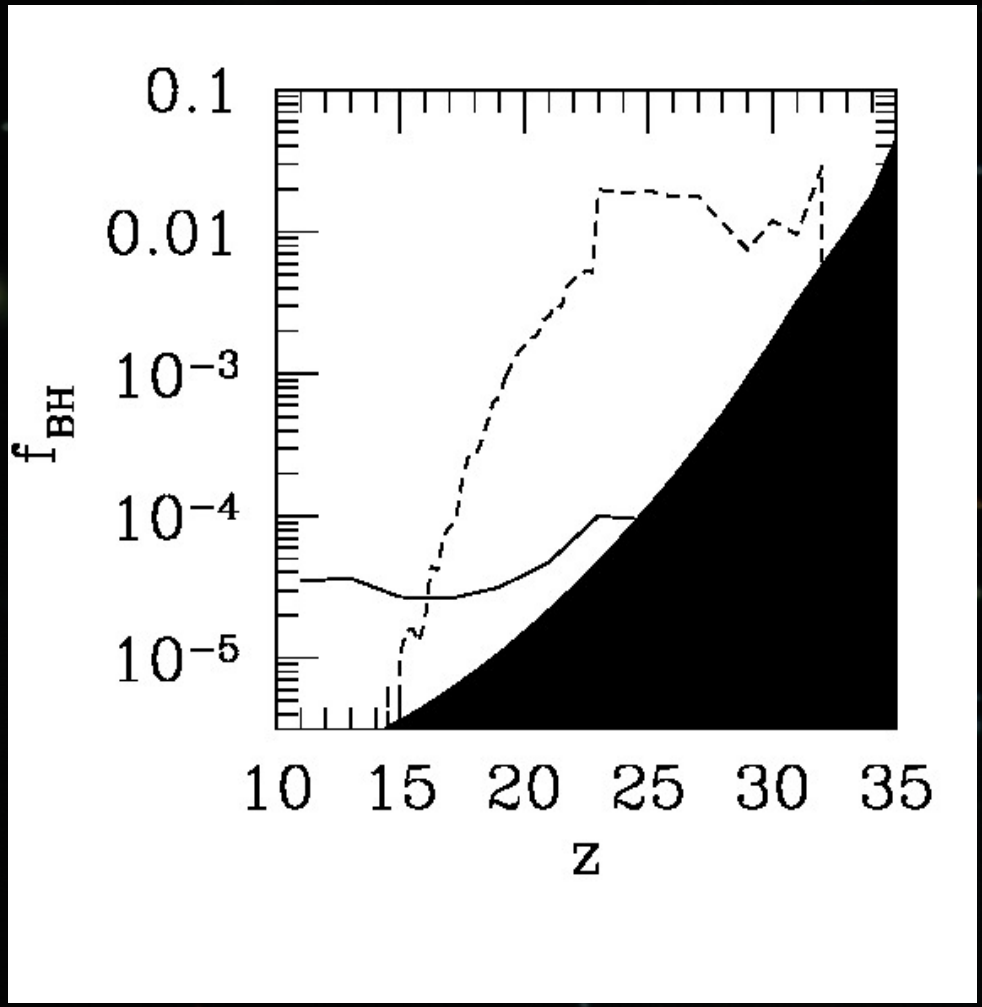


Devecchi et al. 2010

SMBH seeds during galaxy assembly:

Nearly constant f_{BH} .

Stellar dynamics channel overcomes PopIII channel after z=15.



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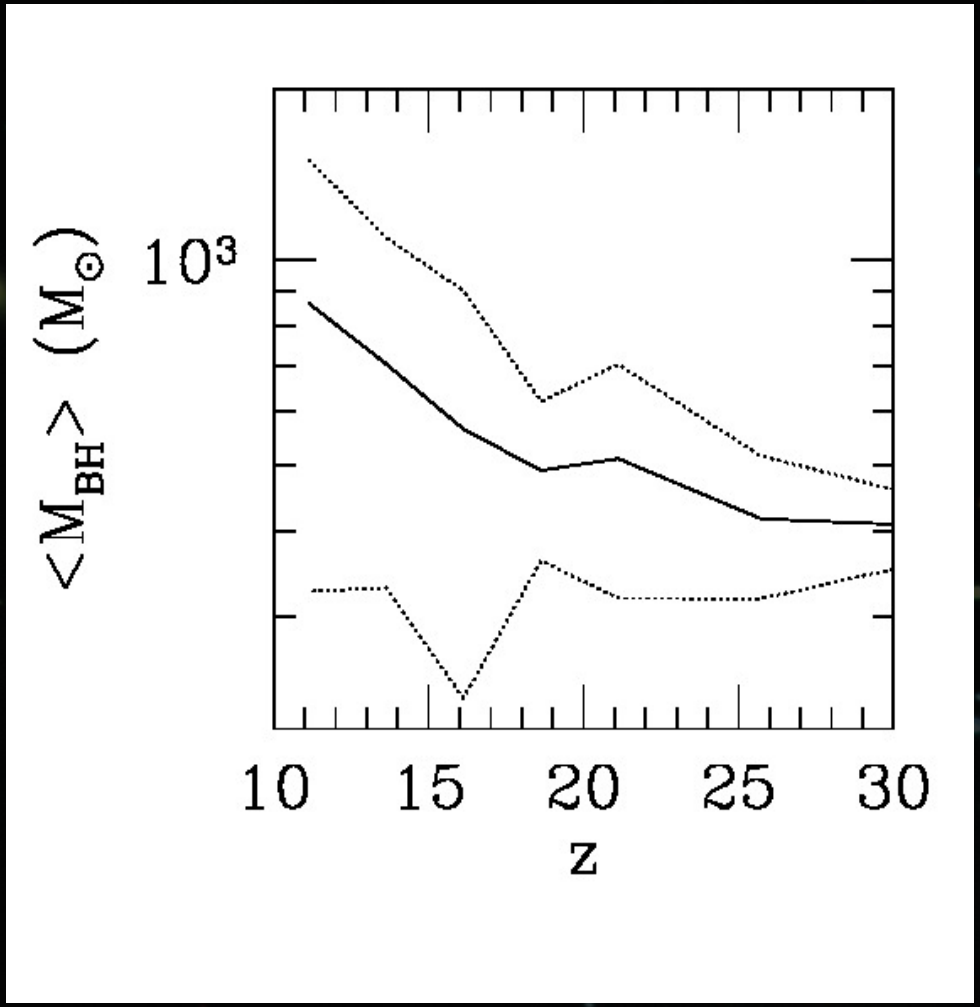
Large dispersion M_{BH}.

Mean value slightly increases with decreasing z.



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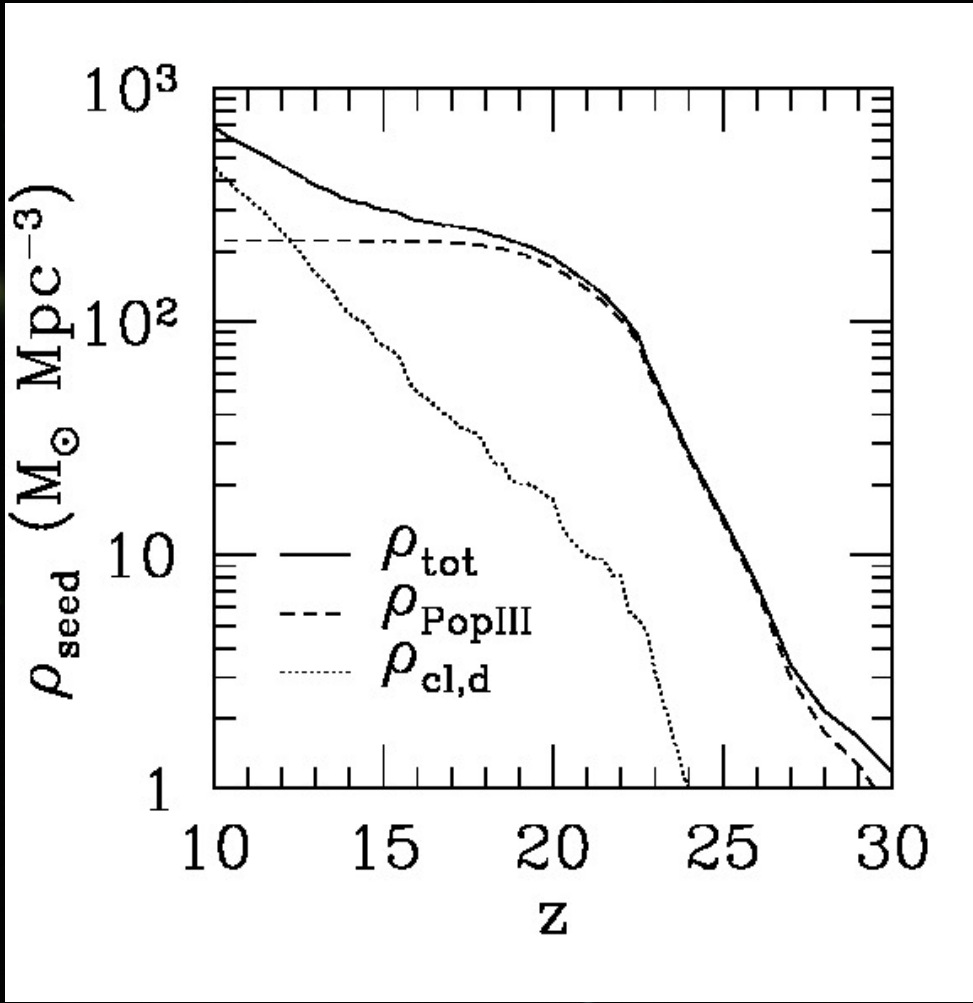
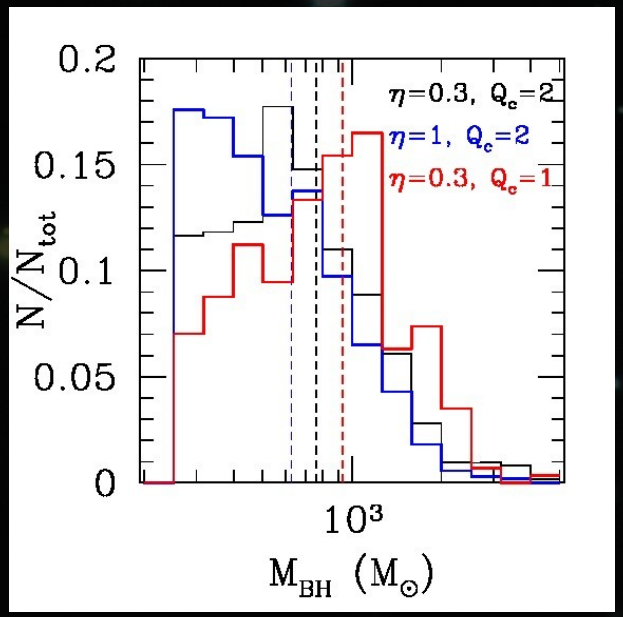
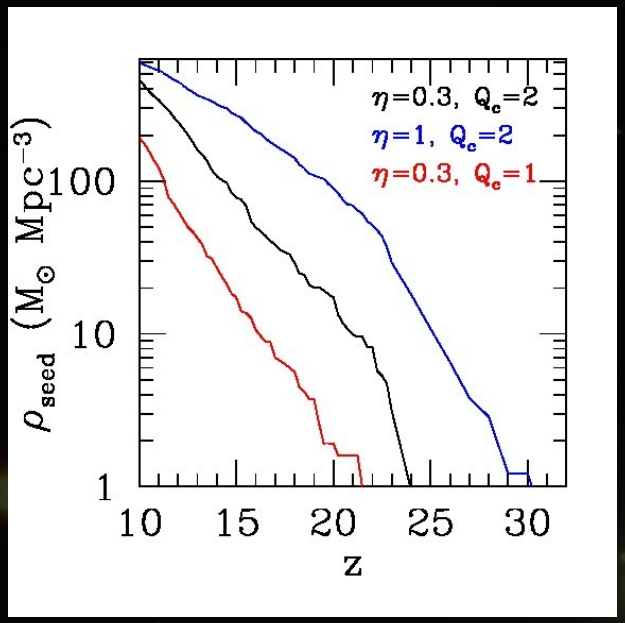
$\rho_{BH,sd}$ reaches the PopIII channel around z~10-15.



Changing inflow parameters:

Mean masses are not strongly affected by the inflow physics.
Number of BHs that form changes more consistently.



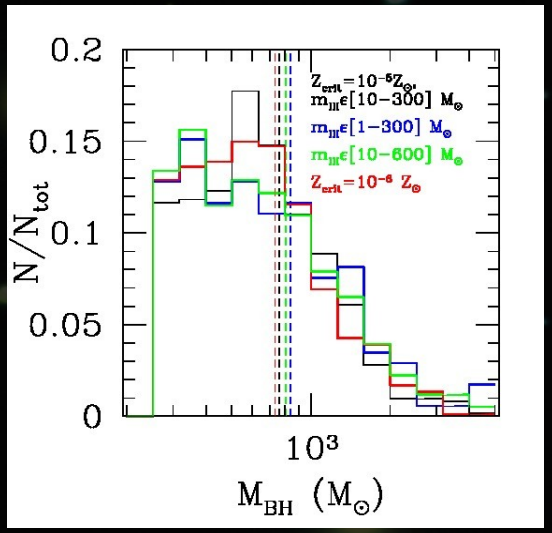


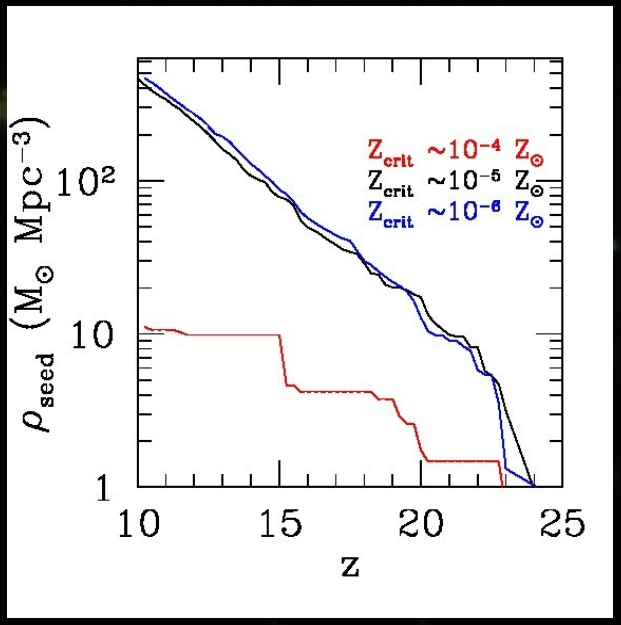
Devecchi et al. (in preparation)

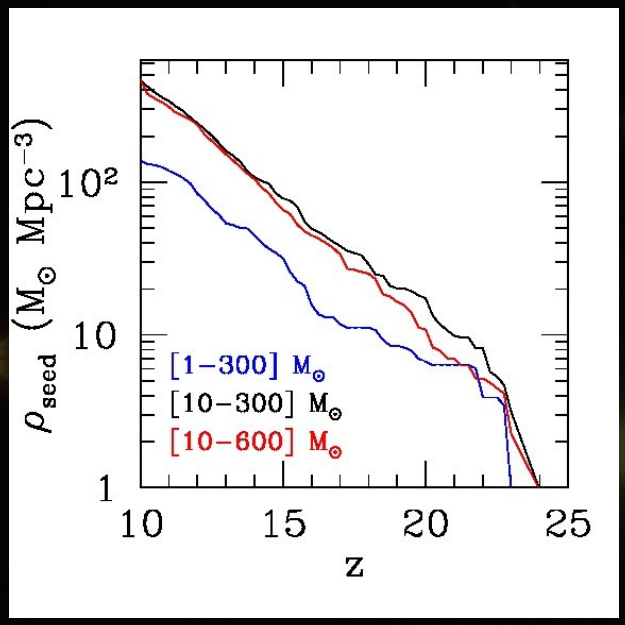
Changing SF parameters:

Masses are not affected by changes in the PopIII IMF or Z_{crit}.

Number of BH formed is mildly lowered if lower mass stars are allowed. Stronger reductions for high Z_{crit}.







Summary and conclusions:

2 paths considered: PopIII + dynamically unstable clusters;

Mildly enriched, gravitationally unstable disks can lead to the formation of compact NC seeds;

Runaway collisions in NCs allow the formation of BHs from z~20 up to (at least) z~10.

M_{BH}~300-1000 Msun, regardless the prescriptions describing baryon physics *but* N_{BH} is (strongly) dependent on Z_{crit}, Q_c and η.

Work in progress:

Constrain the efficiency of runaway collisions at low Z;

Add direct formation channel.

Future work:

Include the effect of SN feedback on surrounding halos;

Growing the seeds: how do BHs and NCs share the gas reservoir?