The very first IMBHs from PopIII stars: Relation with bright $z \approx 6$ quasars

Abstract
We discuss the link between dark matter halos hosting the first PopIII stars formed at redshift $z > 40$ and the rare, massive, halos that are generally considered to host bright $z \approx 6$ quasars. We show that within the typical volume occupied by one bright high-$z$ quasar, the remnants of the first few thousand PopIII stars form do not end up in the most massive halos, but rather in a large variety of environments. We implement a simple feedback model for the growth of the seeds planted by these very first PopIII stars and obtain $\approx 6$ BH mass function consistent with the observed QSO luminosity function.

Spatial distribution of the very first IMBHs

• The very first IMBHs ($M_{BH} \approx 10^{6} M_{\odot}$) formed in the universe are considered to be the remnants of PopIII stars within 10 Myr. Dark matter halos.

• When a relatively small cosmic volume is considered ($\approx 10^{6} M_{\odot}$), these first IMBHs tend to be created at $z \approx 25$ in regions of space that will later form massive halos at $z < 6$.

• Within a large cosmic volume the very first IMBHs from PopIII stars are formed from extremely rare density peaks ($\approx 7 \times 10^{7} M_{\odot}$). These IMBHs are formed earlier at $z > 30$.

• Such rare peaks tend to be spread around the whole simulation box, as density perturbations on large scales have typical amplitudes smaller than the ones of the most compact objects.

• Therefore the remnants of the first IMBHs in the universe live at $z \approx 6$ in a variety of environments.

• The evolution of the halo mass at $z \approx 6$ is consistent with the SDSS QSO luminosity function.

Conclusions
We investigate the link between the very first IMBHs from PopIII stars and the most massive halos at $z \approx 6$ with the aim to establish the relationship between the BH seeds and the super-massive black holes that power the emission of bright $z \approx 6$ quasars.

• We show that almost no correlation is present between the global properties of the first few thousand IMBHs and the most massive halos at $z < 6$ when the simulation box has a total comoving volume larger than $10^{6} M_{\odot}$.

• Therefore if the bright QSO at high redshift are residing in the most massive halos, then they are not linked to the very first BH seeds created in the universe.

• The first several hundreds IMBHs seeds formed at $z > 40$ in our Gadget box can easily grow by Eddington accretion up to $10^{10} M_{\odot}$, by $z < 6$. Quenching of the accretion efficiency must therefore be present to avoid overproduction of supermassive black hole at lower redshift.

• One way to obtain a picture consistent with observational limits on the QSO luminosity function is to limit the accretion up to a fraction $\approx 5 \times 10^{-3}$ of the total baryon mass of the halo when the black hole is living.

Growth of SMBHs from PopIII seeds

Assuming Eddington accretion with radiative efficiency $\eta$, the BH mass at time $t$ is:

$$M_{BH} = M_{BH,0} \exp(1 - t_{Edd}/t_{Edd})$$

with:

$$t_{Edd} = \frac{M_{BH}}{\dot{M}_{Edd}} \sim \frac{M_{BH}}{c^2} \frac{\epsilon}{1 - \epsilon} \frac{10^{51}}{10^{48}}$$

If $\eta < 0.1$, the typical e-folding time $t_{Edd}$ is $5 \times 10^{-5} M_{\odot}$, so by $M_{BH} \approx 10^{6} M_{\odot}$ the BH accretes a large fraction of its mass and grows to $10^{5} M_{\odot}$.

Bibliography