Parameters of log-normal spectrum of PBH

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- Primordial Black Holes (PBHs) were formed at the very early epoch of universe.
- One of the most viable candidates of Dark Matter.

\[ \sim (10^{-7} - 1)M_\odot \]
Number density of PBHs ([Dolgov & Silk 1993]) -

\[ \frac{dN}{dM} = \mu^2 \exp \left[ -\gamma \ln^2 \left( \frac{M}{M_m} \right) \right] \]

Why Log-Normal? Because based on strong a theory which explains the formation of PBHs.
The value of $M_m$, at which the distribution reaches attains its peak value.

\[
\frac{\text{Total mass density of PBHs}}{\text{The dark matter density}} = f.
\]

The number density of large galaxies is equal to the number density of the heavy black holes with masses exceeding some boundary value, $M_b$. 

\[\mu, \gamma, M_m\]
Choosing $M_m$

- BH formed by evolution of star -
  
  Very massive star → Super red giant → Black Hole

- Search for X-ray binary system in our galaxy - Why the number of BHs in the narrow mass range $(7.8 \pm 1.2) M_\odot$?

  *(arXiv:1011.1459)*: Mass spectrum has two peaks - one peak is below the lower limit of the BH masses mentioned above. Lower mass BHs are presumably produced by the usual mechanism of stellar collapse. We expect the galactic black holes follow Log-Normal distribution.

- Matter accretion is expected to increase the mass of galactic black holes. Thus we have chosen $M_m/M_\odot = 6, 7$ and $8$. 

Mass density of PBHs

\[
\rho_{PBH} = \mu^2 \int_0^{M_{\text{max}}} dM M \exp \left[ -\gamma \ln^2 \left( \frac{M}{M_m} \right) \right] = f \star \rho_{DM}
\]  

Maximum possible value of PBHs
\[M_{\text{max}} = (10^3 - 10^5) M_\odot\]. As the peak is at \(8 M_\odot\), we can take the maximum limit of integration to \(M_{\text{max}} \to \infty\).

Different experiment predicted \(f < 0.1\); but median for \(M_m \geq 20M_\odot\). As value of \(M_m\) considered is relatively lower, it is assumed \(f = 1\).
SMBHs

- Each large galaxy possesses a supermassive black hole (SMBH). Moreover, SMBHs are also observed in some small galaxies and even in practically empty space. How were they formed?

- Galaxy before SMBH or SMBH before galaxy?

- **Number density of supermassive primordial black holes = number density of galaxy.**

  \[ N_b = \mu^2 \int_{M_b}^{M_{max}} dM \exp \left[ -\gamma \ln^2 \left( \frac{M}{M_m} \right) \right] = N_{gal} \]  

  (2)

- We have chosen \( N_{gal} \) in the interval \((0.1 - 0.001)Mpc^{-3}\) and sampling values for \( M_b = [10^3, 10^4, 10^5]M_\odot \).
Conclusion: MACHO

- PBHs are the most viable candidate for Massive Astrophysical Compact Halo Object.

- Although, different MACHO experiments are not in agreement on the contribution of MACHO to DM energy density, the calculated mass density of MACHO is several order less than the measured value.

- Wait! Are we not considering the inhomogeneous and isotropic distribution of PBHs due to formation of clumped structure?