Primordial black holes and how to (not over-) produce them

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NEHOP 2023, Naples

The rise of the PBH





Where are we with observational constraints? Overview





What do we need in order to produce them?



All or nothing



Current constraints on primordial power spectrum



Current constraints on primordial power spectrum



Feature needs to fit in between small-scale constraints on the power spectrum



Non-Gaussianity and accretion can help a little but won't survive next-generation constraints





General shape of the power spectrum has a steepest growth limit



Or can we go steeper...



Tasinato 2021

Future constraints will rule out almost PBHs entirely (if they formed from large over densities in early universe)





Is there a fine-tuning problem?



Cole et al. 2023 See e.g. Hertzberg & Yamada 20⁻



Is there a fine-tuning problem?



Multi-field inflation

$$\frac{-1}{60} \frac{1}{80} N$$

$$\frac{-1}{60} \Delta \chi^{2} \sim 0.4 - - \Delta \chi^{2} \sim 0.7$$

$$- \Delta \chi^{2} \sim 1.6$$

Qin et al. 2023 See also e.g. Fumagalli et al. 2023, Palma et al. 2020

Conclusions

- PBHs are still viable (even as all DM on asteroid range) from an observational standpoint
- However, they are hard to produce in a generic way and we need to consider both parts of the pipeline at the same time
- This is so that we respect both direct and indirect constraints
- Given how much information they would provide, worth checking every part of still-viable parameter space

Potentials

- Mishra et al.
- Germani et al.
- Hertzberg et al.
- Cicoli et al.

 $U(\phi$

$$V_{
m inf} = V_0 \left(C_{
m i} \right)$$

$$V(\phi) = V_0 \frac{\phi^2}{M^2 + \phi^2} \left[1 - A \exp\left(-\frac{1}{2} \frac{(\phi - \phi_0)^2}{\sigma^2}\right) \right]$$

$$V(\phi) = \frac{\lambda}{12} \phi^2 v^2 \frac{6 - 4a\frac{\phi}{v} + 3\frac{\phi^2}{v^2}}{\left(1 + b\frac{\phi^2}{v^2}\right)^2} ,$$

$$\phi) = U_0 \left[1 + c_1 \frac{\phi}{\Lambda} + \frac{c_2}{2} \frac{\phi^2}{\Lambda^2} + \frac{c_3}{3!} \frac{\phi^3}{\Lambda^3} + \frac{c_4}{4!} \frac{\phi^4}{\Lambda^4} + \frac{c_5}{5!} \frac{\phi^5}{\Lambda^5} \right]$$

 $C_1 + C_2 e^{-\frac{4}{\sqrt{3}}\hat{\phi}} + C_3 e^{-\frac{2}{\sqrt{3}}\hat{\phi}} - e^{-\frac{1}{\sqrt{3}}\hat{\phi}} + C_4 e^{\frac{2}{\sqrt{3}}\hat{\phi}} + C_5 e^{\frac{1}{\sqrt{3}}\hat{\phi}}\right)$

Open questions about production

- Single-field vs. multifield inflation?
- Effect of non-gaussianity
- Quantum diffusion
- Totally different production mechan topological defects

• Totally different production mechanism? E.g. collapse of cosmic strings or

The rise of the PBH

Where are we with observational constraints?

Cole, PhD thesis 2020

