Beyond perturbative non-Gaussianity for primordial black holes

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- Common to write $\zeta = \zeta(\zeta_G)$
- Typically treated perturbatively (f_{NL}, g_{NL}, ...)
- Not sufficient for non-G in the far tail
- Need to find a non-perturbative method

Beyond perturbativity

- Classical USR transformation

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- Doesn't include full effects
- Want general $P(\zeta_G) \to P(\zeta)$
- Can do in general with CDF transformation:

$$F[\zeta(r), r] = F_G[\zeta_G(r), r]$$

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$$C = C_l - \frac{3}{8}C_l^2, \quad C_l = -\frac{4}{3}r\zeta'$$

- Need to get $P(C_l)$ to determine PBH properties

Compaction probability

- Bivariate Gaussian $P(X, Y)$

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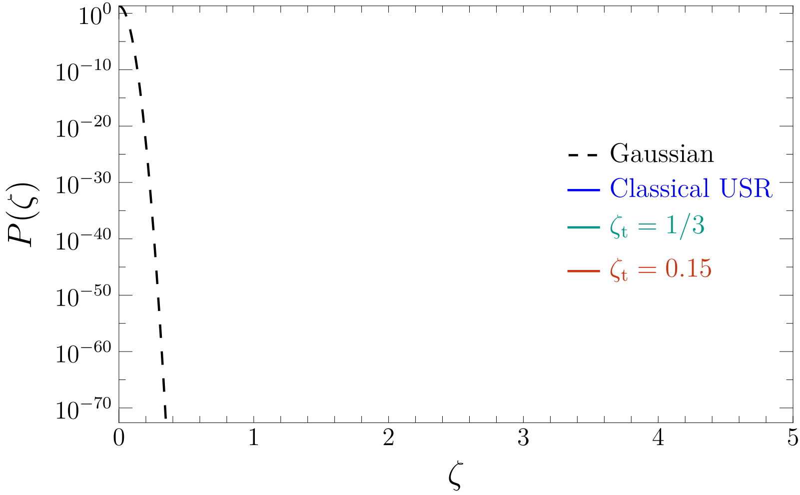
- Compaction probability

$$P(C_l) = \int \mathrm{d}\zeta_G \, \frac{3}{4|\mathcal{J}_1(\zeta_G)|} P\left[-\frac{1}{\mathcal{J}_1(\zeta_G)}\left(\frac{3}{4}C_l + 2\Sigma_{XY}\mathcal{J}_2(\zeta_G)\right), \zeta_G\right]$$

$$\mathcal{J}_1(\zeta_G) = \frac{\mathrm{d}\zeta}{\mathrm{d}\zeta_G}, \quad \mathcal{J}_2(\zeta_G) = \frac{\mathrm{d}\zeta}{\mathrm{d}\Sigma_{YY}}$$

Tail vs transition



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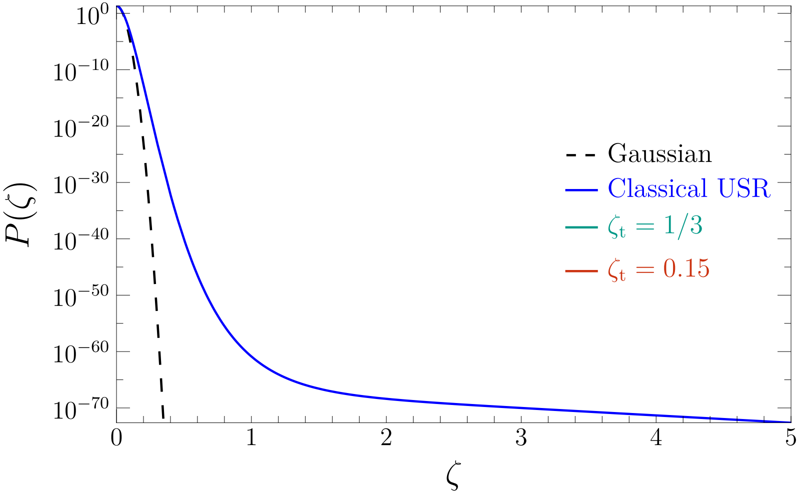

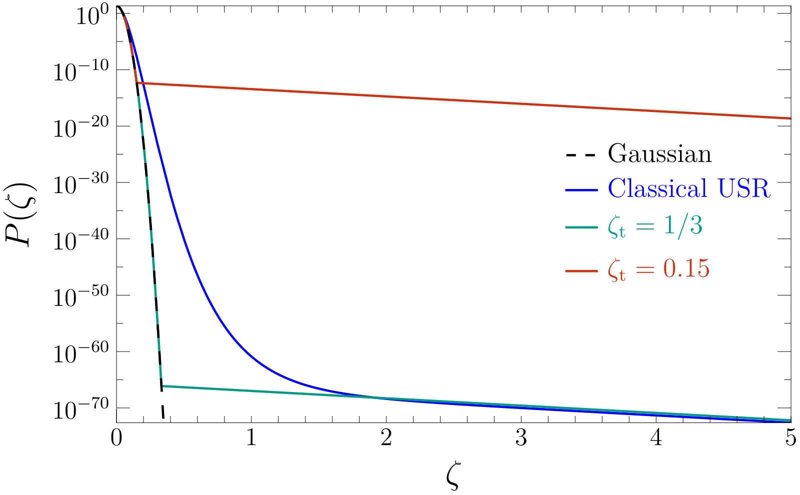

10^{0}
10^{-10}
10^{-20}
10^{-30}
10^{-40}
10^{-50}
10^{-60}
10^{-70}
$P(\zeta)$
0
1
2
3
4
5
ζ
Gaussian
Classical USR
$\zeta_{\rm t} = 1/3$
$\zeta_{\rm t} = 0.15$

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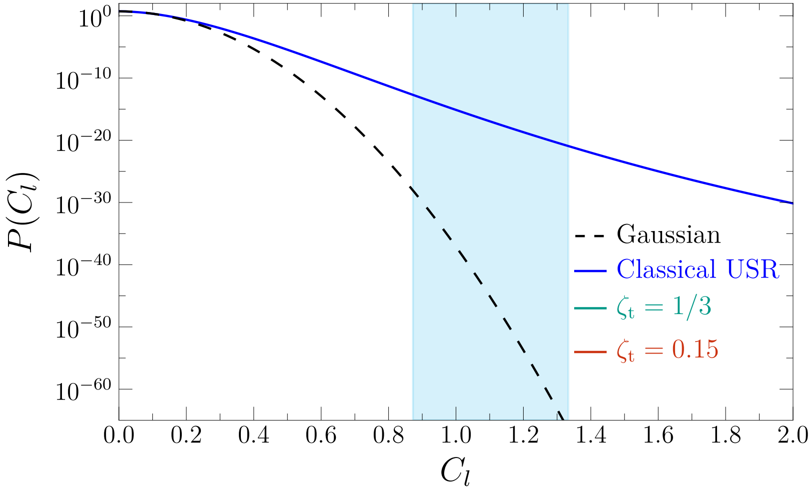

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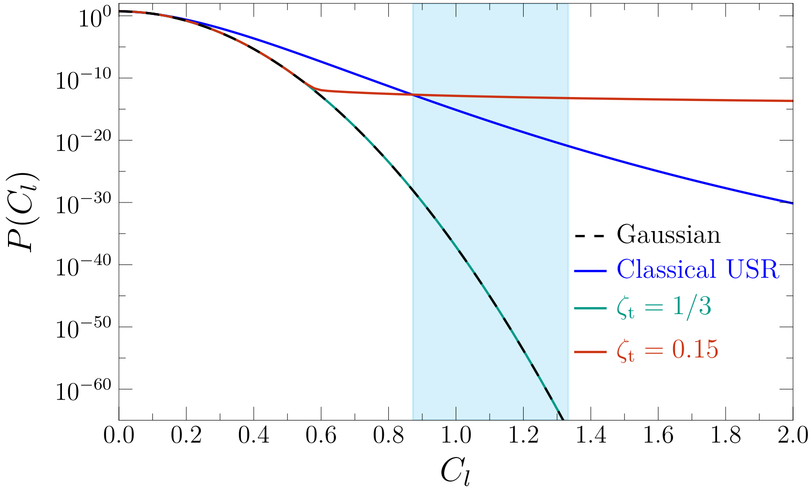

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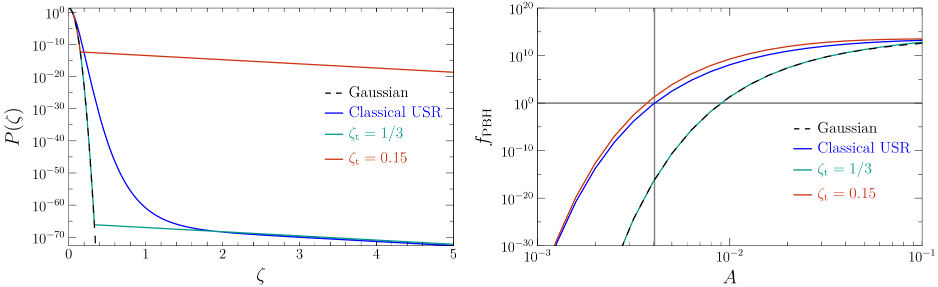
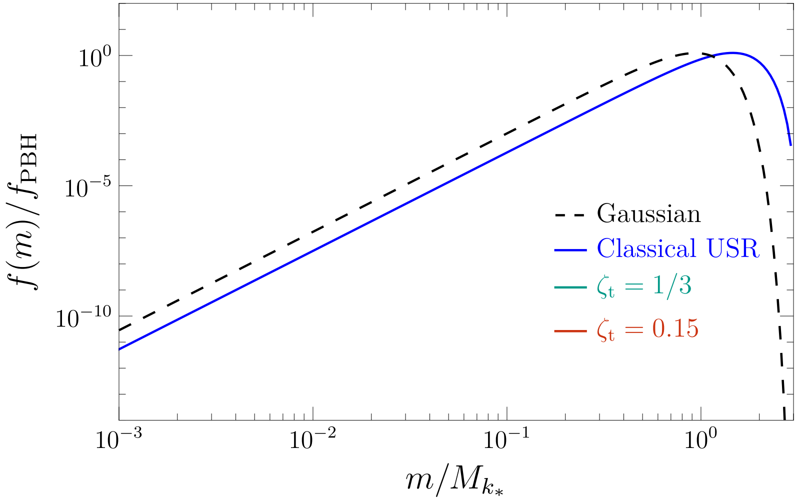


PBH mass distribution



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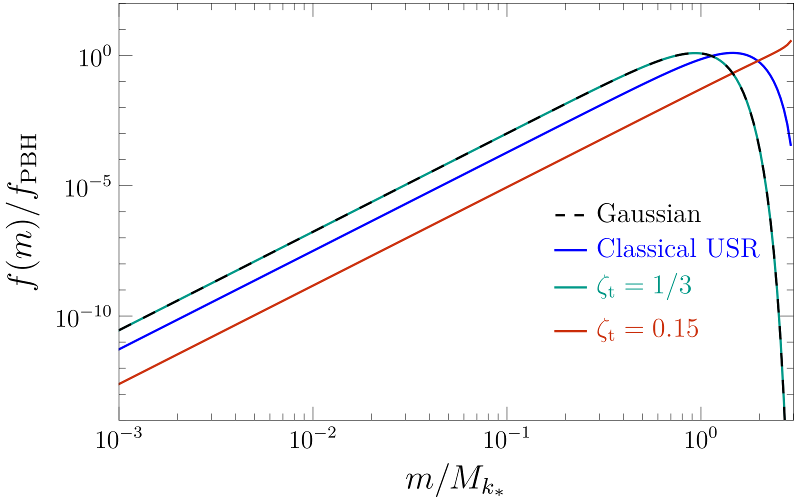

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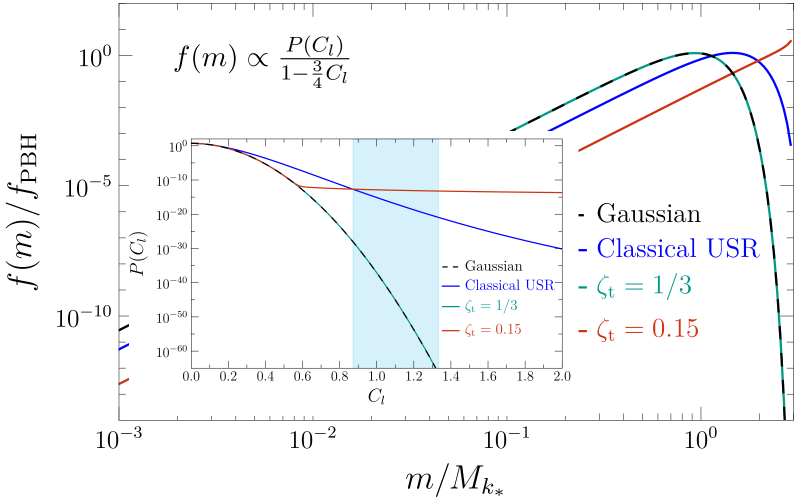
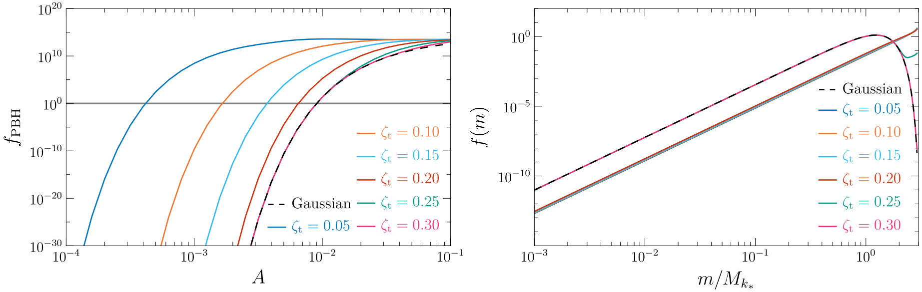
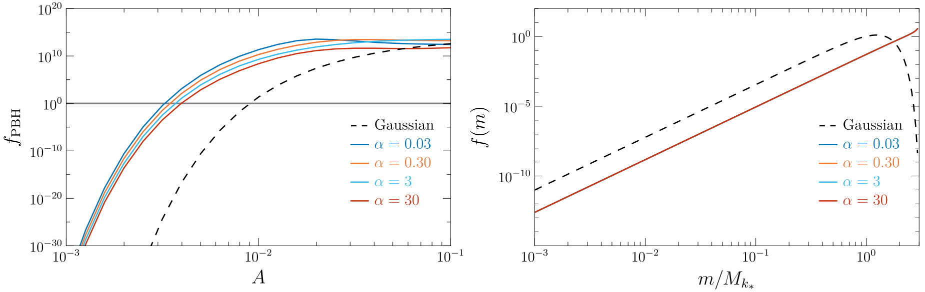


Transition point ζ_t



Exponential slope α



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- Perturbative treatment may miss deviations from Gaussianity in the far tail
- Non-perturbative treatment can be used for any $P(\zeta)$
- Transition between Gaussian and non-Gaussian behaviour is more important than the far tail
- Shallow tail in $P(\zeta)$ highlights divergence in mass distribution

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