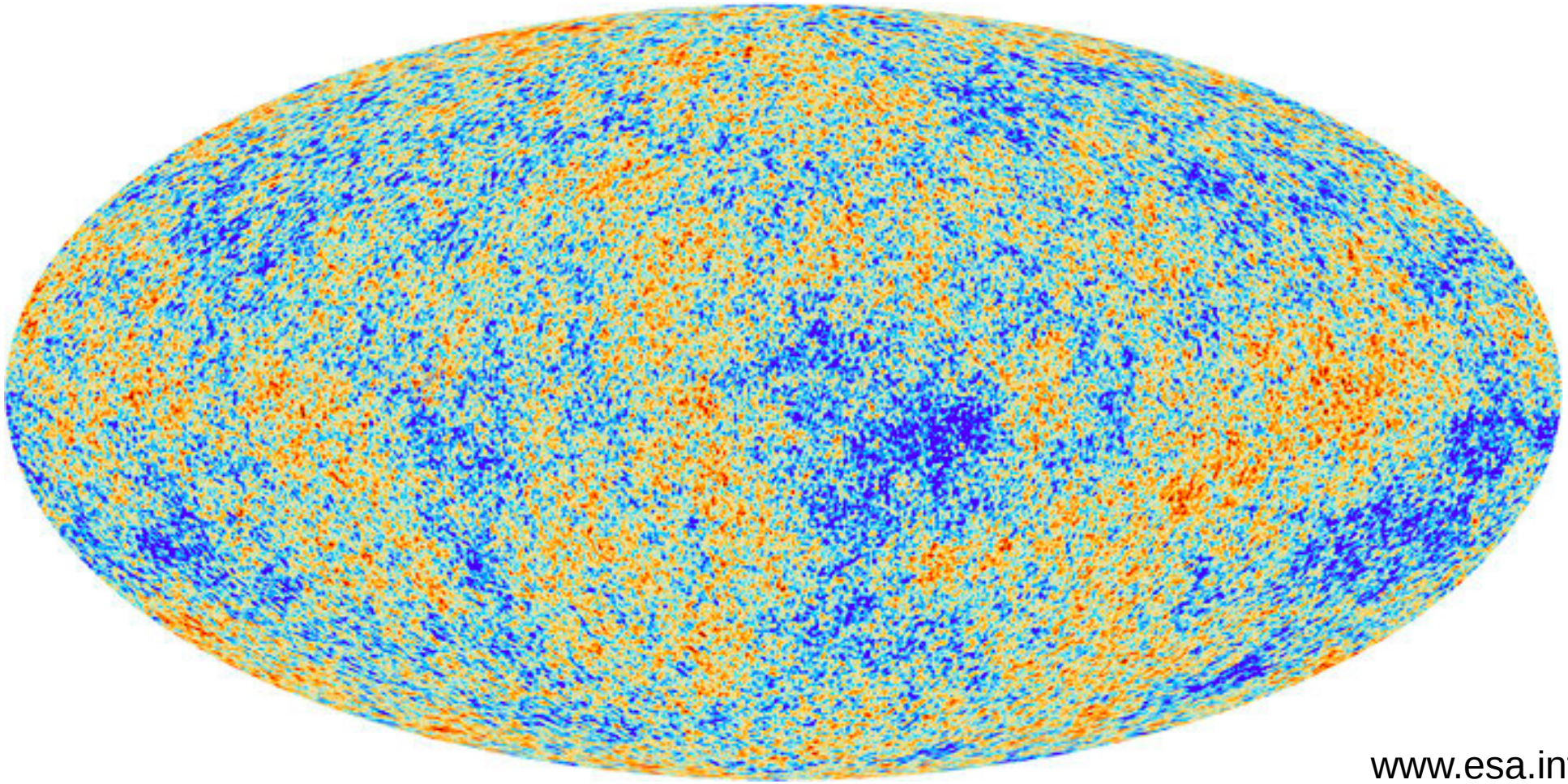
Planck Constraint on Relic Primordial Black Holes

Steven J. Clark
Texas A&M University

Based on: Clark, Dutta, Gao, Strigari, and Watson; arXiv: 1612.07738 (Phys. D95 (2017), 083006)



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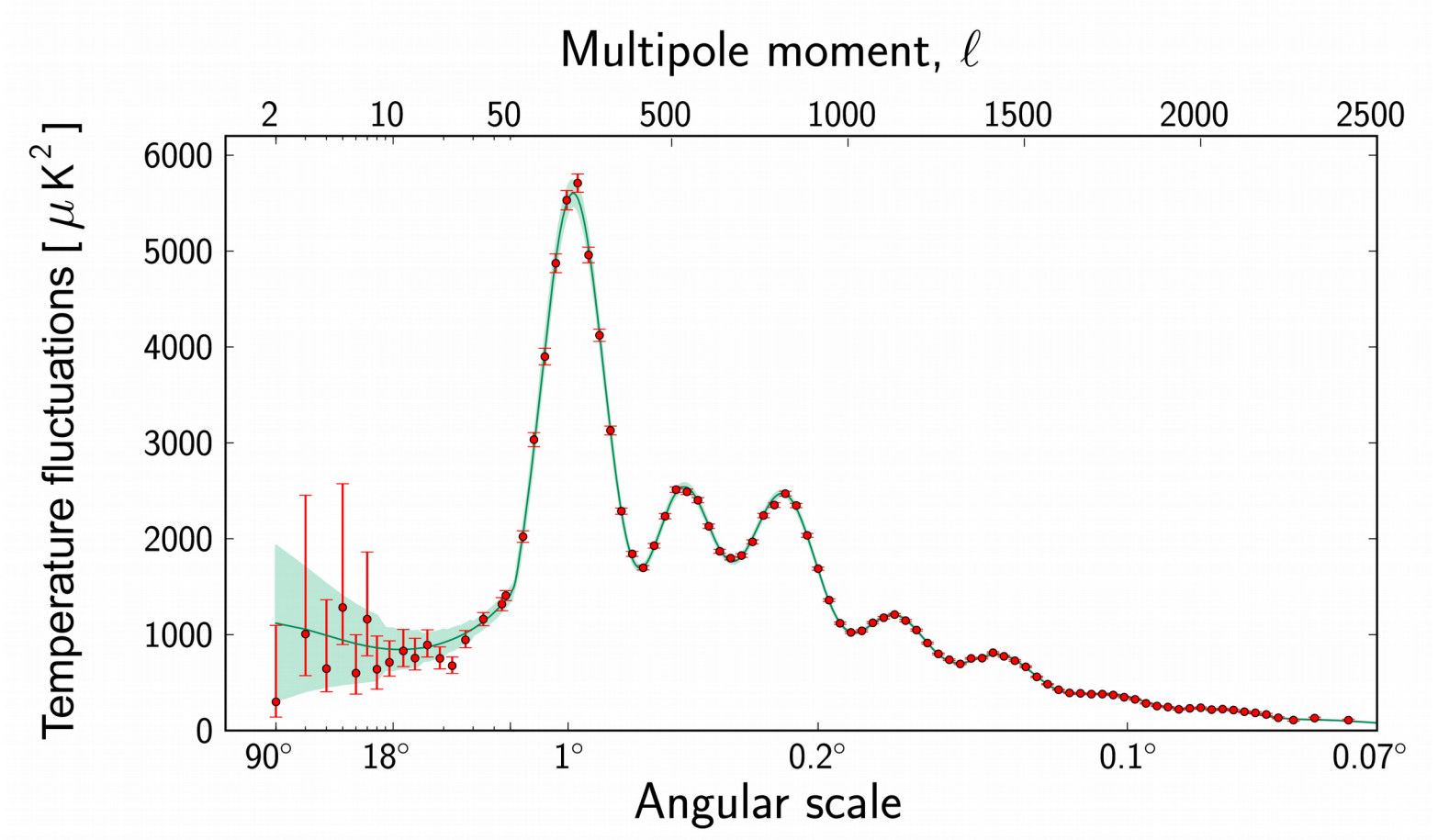

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Primordial Black Holes (PBHs)

- LIGO measurements of black holes

  Abbott, et al, [LIGO Scientific and Virgo Collaborations]; arXiv:1602.03837

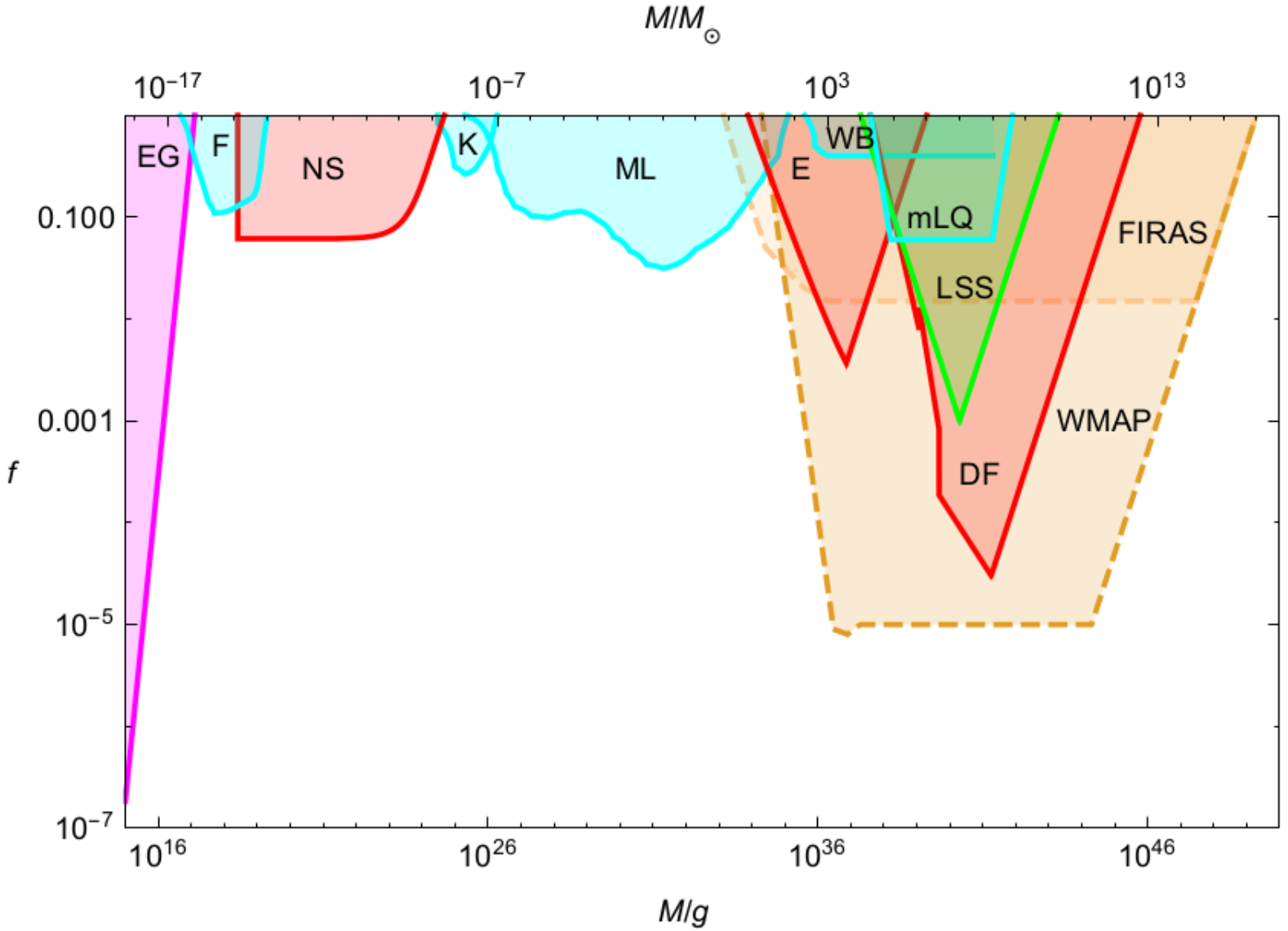
- Formed in the early Universe

  Hawking; Mon. Not. Roy. Astron. Soc. 152, 75 (1971)

- Possible Dark Matter Candidate

  Carr, Kohri, Sendouda, and Yokoyama; arXiv:0912.5297

PBH Constraints



Carr, Kühnel, and Sandstad: arXiv:1607.06077

Intergalactic Medium Interactions

- Ionization Fraction

$$\frac{dx_e}{dz} = \left(\frac{dx_e}{dz}\right)_{\text{orig}} - \frac{1}{(1+z)H(z)}(I_{Xi}(z) + I_{X\alpha}(z))$$

- Medium Temperature

$$\frac{dT_{\text{IGM}}}{dz} = \left(\frac{dT_{\text{IGM}}}{dz}\right)_{\text{orig}} - \frac{2}{3k_B(1+z)H(z)}\frac{K_h}{1+f_{\text{He}}+x_e}$$

Liu, Slatyer, and Zavala; arXiv:1604.02457
Belotsky and Kirillov; arXiv:1409.8601
Slatyer; arXiv:1211.0283

Intergalactic Medium Interactions

- Hydrogen Ionization

$$I_{Xi}(z) \;=\; f_i(E,z)\frac{dE/dVdt}{n_H(z)E_i}$$

- Lyman-Alpha Excitations

$$I_{X\alpha}(z) \;=\; f_\alpha(E,z)(1-C)\frac{dE/dVdt}{n_H(z)E_\alpha}$$

- Medium Heating

$$K_h(z) \;=\; f_h(E,z)\frac{dE/dVdt}{n_H(z)}$$

Liu, Slatyer, and Zavala; arXiv:1604.02457
Belotsky and Kirillov; arXiv:1409.8601
Slatyer; arXiv:1211.0283

Hawking Radiation Energy Injection

$$\frac{dE}{dV\,dt} = \dot{M}_{\rm BH} c^2 n_{\rm BH}$$

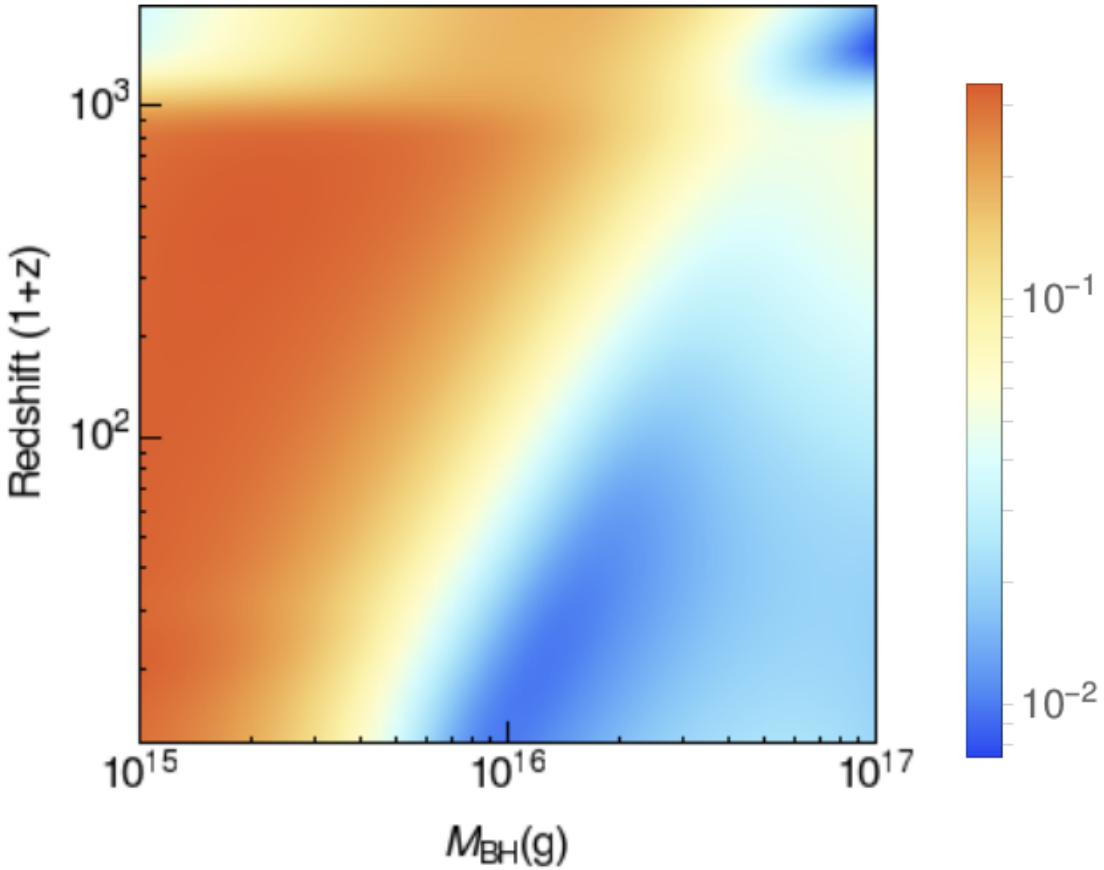
$$= \frac{\dot{M}_{\rm BH}}{M_{\rm BH}} \rho_c c^2 \Omega_{\rm BH,0} (1+z)^3$$

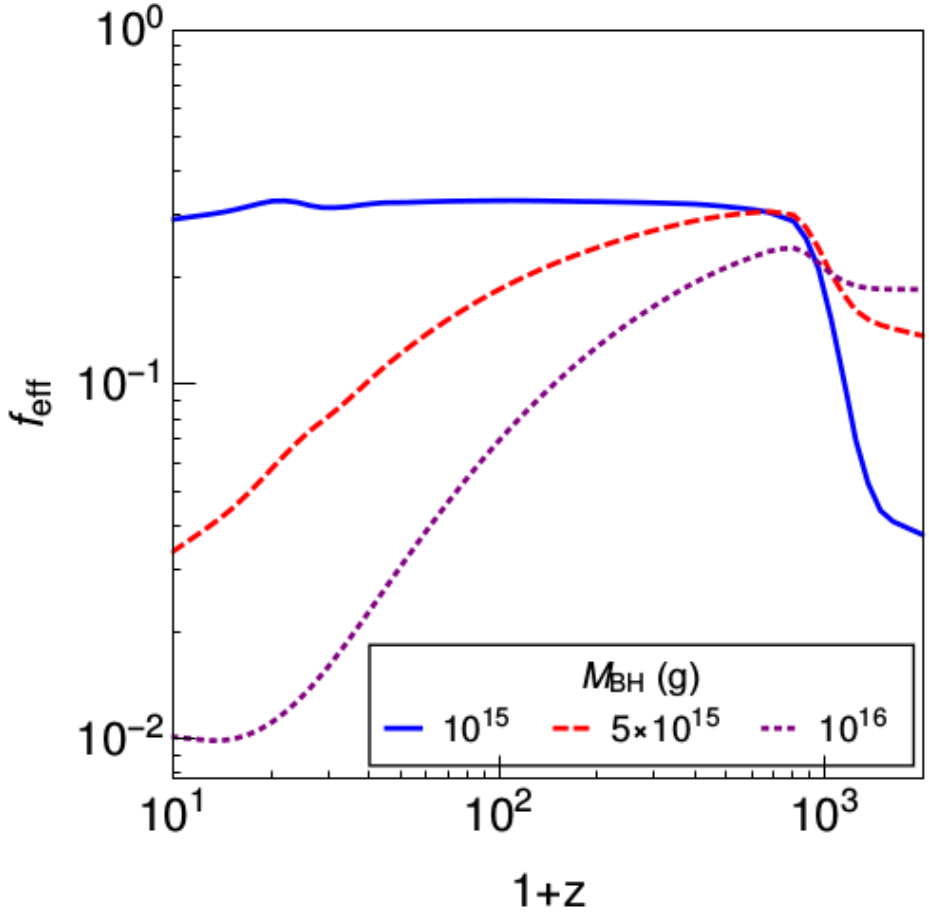
$$\dot{M}_{\rm BH} = -5.34 \times 10^{25} F(M_{\rm BH}) M_{\rm BH}^{-2}\,{\rm g}^3\,{\rm s}^{-1}$$

Carr, Kohri, Sendouda, and Yokoyama; arXiv:0912.5297

Effective Efficiency

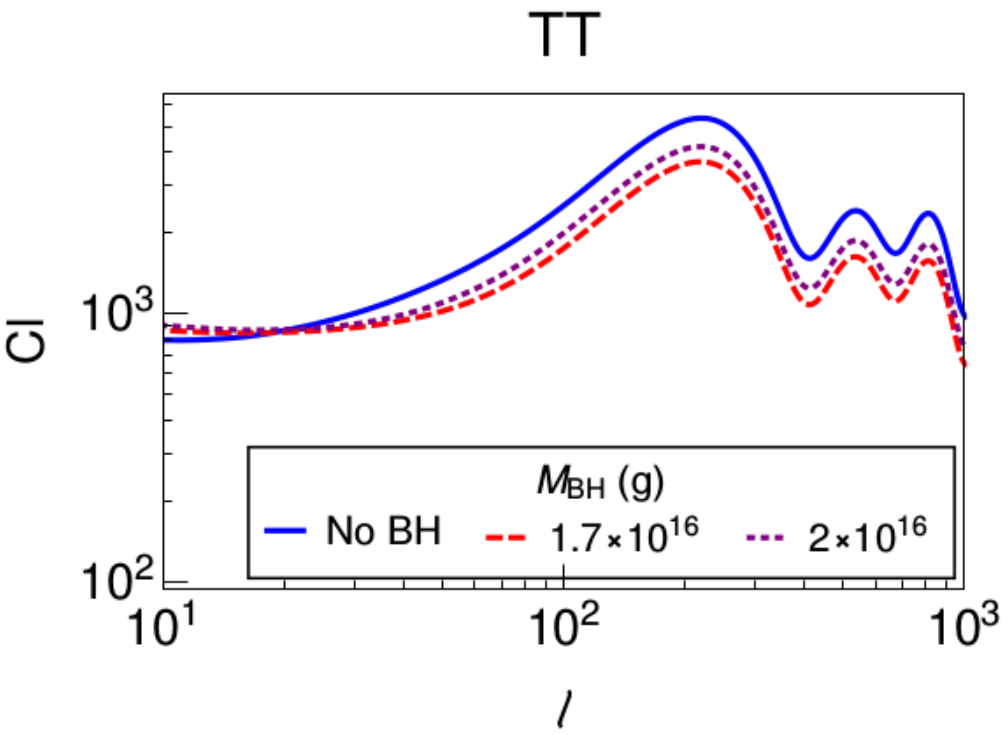
$$f_{c,\mathrm{BH}}(M_{\mathrm{BH}},z)=\frac{\sum_i \int_0^\infty g_i f_i f_{c,i}(E,z)\left(\frac{dN}{dEdt}(E)\right)_i dE}{\sum_i \int_0^\infty g_i f_i \left(\frac{dN}{dEdt}(E)\right)_i dE}$$

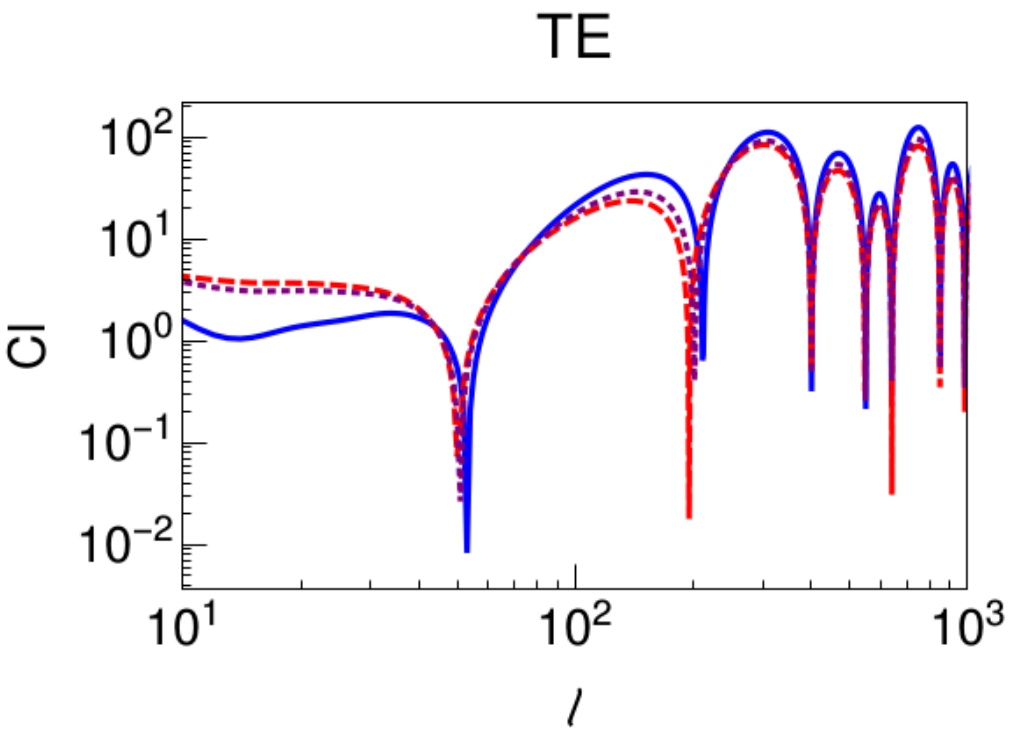




Clark, Dutta, Gao, Strigari, and Watson; arXiv: 1612.07738

CMB Anisotropies





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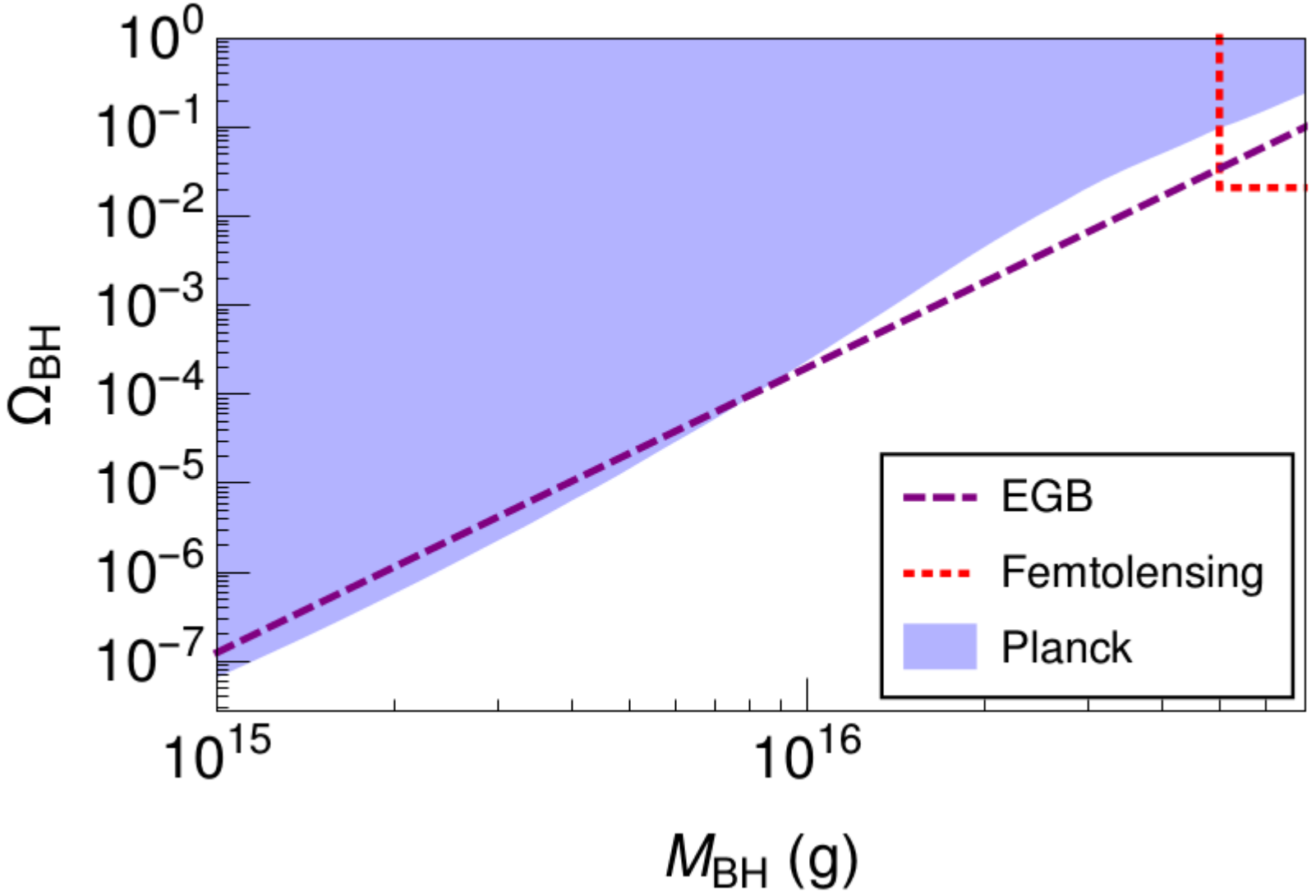
PBH Density Constraints



Clark, Dutta, Gao, Strigari, and Watson; arXiv: 1612.07738

Thank You