Constraining Short, Hard Gamma-Ray Burst Beaming Angles From Gravitational Wave Event Rate Measurements

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Abstract

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This Work

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GRB Beaming Angles From Coalescence Rate Measurements

Assuming that at least some fraction of sGRBs are due to compact binary coalescence, the observed rate of sGRBs may be written,

$$\mathcal{R}_{\text{grb}} = \epsilon \mathcal{R}(1 - \cos\theta), \tag{1}$$

$$p(\theta, \epsilon) = p(\mathcal{R}, \epsilon) \left|\left| \frac{\partial(\mathcal{R}, \epsilon)}{\partial(\theta, \epsilon)} \right|\right|, \tag{2}$$

where the Jacobian matrix is given by,

$$\frac{\partial(\mathcal{R}, \epsilon)}{\partial(\theta, \epsilon)} = \begin{bmatrix} \frac{\partial \mathcal{R}}{\partial \theta} & \frac{\partial \mathcal{R}}{\partial \epsilon} \\ \frac{\partial \epsilon}{\partial \theta} & \frac{\partial \epsilon}{\partial \epsilon} \end{bmatrix}. \tag{3}$$

$$p(\theta) = \int_{\epsilon} p(\theta, \epsilon)\, \mathrm{d}\epsilon, \tag{4}$$

Prior on GRB Efficiency, ϵ

Average Beaming Angle & Rates

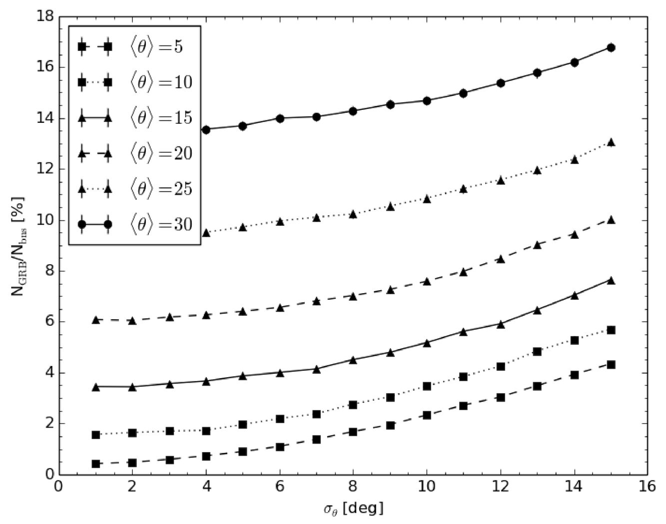

Figure 1: Figure caption

Constraints From The Initial Detector Era

Constructing The Rate Posterior

$$p(\mathcal{R}|C_L(\rho^*), T, \Lambda) \propto p(\mathcal{R}) \left[\frac{1 + \Lambda C_L(\rho^*) T}{1 + \Lambda} \right] e^{-\mathcal{R} C_L(\rho^*) T} \tag{5}$$

Constraints In The Advanced Detector Era

Constructing The Rate Posterior

So let $b = 10^{-2}\,\text{yr}^{-1}$. From there, we can get the detection rate posterior using equations 14.10–14.12 of Gregory. The measured rate r consists of two components, one due to a signal of interest, s, and the other a known background rate, b:

$$r = s + b \begin{cases} s = \text{signal rate} \\ b = \text{background rate} \end{cases} \tag{6}$$

Since the background rate is known,

$$p(s|n, b, I) = p(r|n, b, I), \tag{7}$$

where n is the number of gravitational wave (GW) detections. From eq 14.8 of Gregory, we get to:

$$p(s|n, b, I) = C \frac{T\,[(s+b)T]^n\, e^{-(s+b)T}}{n!}, \tag{8}$$

where,

$$C^{-1} = \frac{e^{-bT}}{n!} \int_0^\infty \mathrm{d}(sT)(s+b)^n T^n e^{-sT} \tag{9}$$

$$= \sum_{i=0}^{n} \frac{(bT)^i e^{-bT}}{i!}. \tag{10}$$

In particular, the detection rate for a given type of binary coalescence in LIGO-Virgo is given by equation 1 in [?],

$$s = \mathcal{R} \times N_G, \tag{11}$$

where $\mathcal{R}$ is the coalescence rate of that type of binary per galaxy and N_G is the number of galaxies accessible with a search for the relevant binary type. N_G is well approximated at large distances by,

$$N_G = \frac{4}{3}\pi \left(\frac{D_{\text{horizon}}}{\text{Mpc}} \right)^3 (2.26)^{-3} (0.0116). \tag{12}$$

The reader is directed to [?] for a discussion of the numerical factors in the equation above.

Finally, we recognise that $\dot{N}$ is the signal rate s in equation **??** so that we arrive at the desired posterior on the binary coalescence rate,

$$p(\mathcal{R}|N_{\text{det}}, I) = p(s|N_{\text{det}}, I) \left| \frac{\mathrm{d}s}{\mathrm{d}\mathcal{R}} \right| \tag{13}$$

$$= N_G . p(s|N_{\text{det}}, I) \tag{14}$$

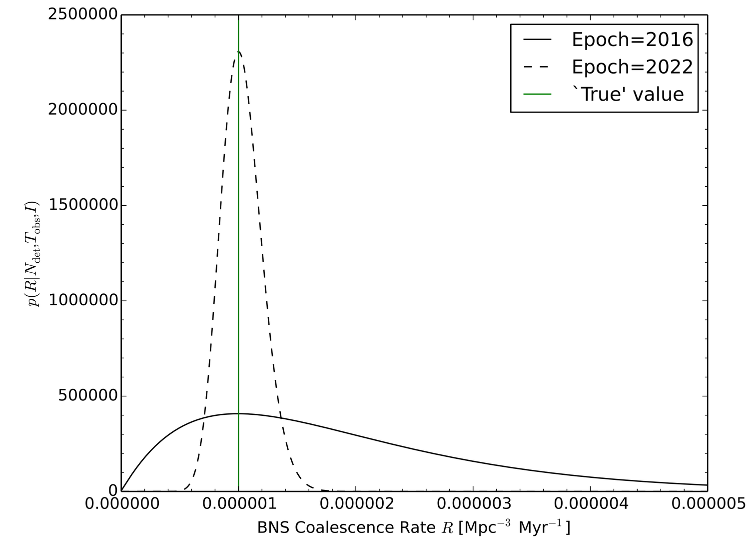

Figure 2: Figure caption

Conclusions

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Acknowledgements

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