Darmstadt Lecture 16 – S190426c – A Black Hole-Neutron Star Merger?

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July 19, 2019

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S190426c: The First Black Hole-Neutron Star Merger?

Information from LVC indicates a marginal case, with 14% chance of being 'terrestrial'.

Assuming it is cosmic, GCN circular 24411 stated: $p_{\rm BHNS} = 0.60$, $p_{\rm gap} = 0.25$, $p_{\rm BNS} = 0.15$, $p_{\rm BBH} < 0.01$, $p_{\rm HasNS} > 0.99$ and $p_{\rm rem} = 0.72$.

LVC defines NS if $M \le 3M_\odot$, BH if $M \ge 5M_\odot$ and gap if either mass satisfies $3M_\odot < M < 5M_\odot$.

LVC will not release the chirp mass $\mathcal{M}$ (even though it is known precisely), the mass ratio $q = M_1/M_2 > 1$ (known much less precisely), or the spin parameter χ if one component is a BH (also poorly known).

But it is possible to recover $\mathcal{M}, M_1, M_2$ and χ in cases where $p_{\rm BHNS}, p_{\rm gap}$, p_{BNS} and $p_{\rm rem}$ are nonzero.

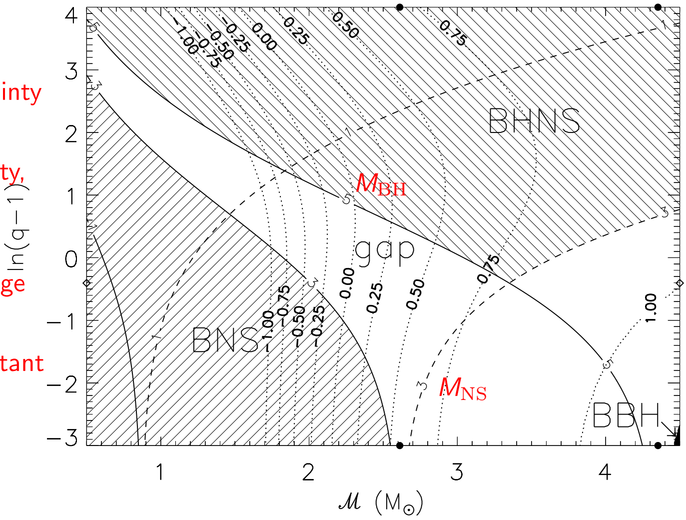
Suitable Variables

$\mathcal{M}$ has small uncertainty $\sigma_{\mathcal{M}}$.

q has large uncertainty, but $q \in [1, \infty]$.

$\bar{q} = \ln(q-1)$ has $\bar{q} \in [-\infty, \infty]$ and large uncertainty σ_q.

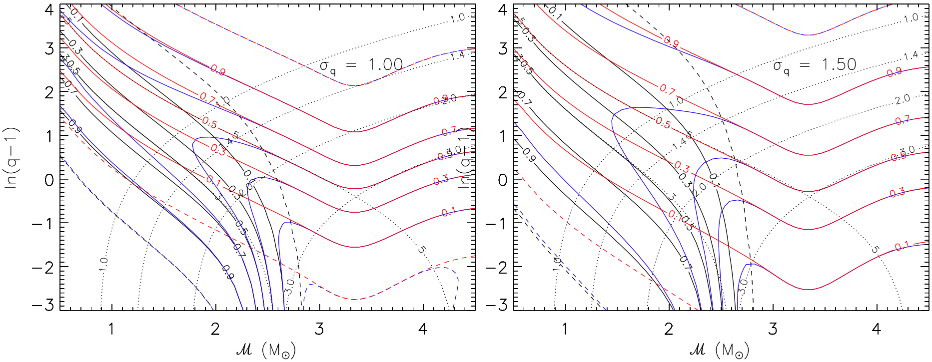
σ_q is the most important parameter.



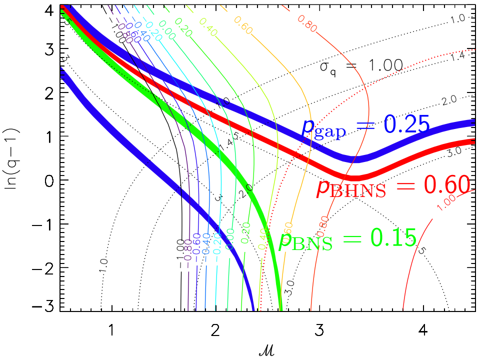
Probabilities

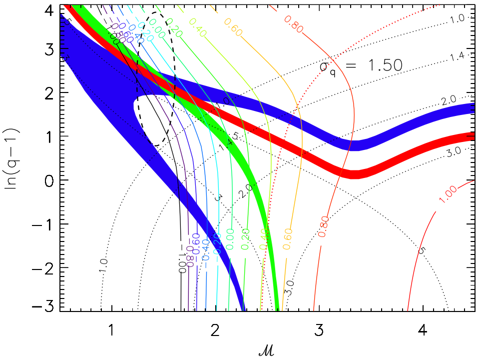
Assume

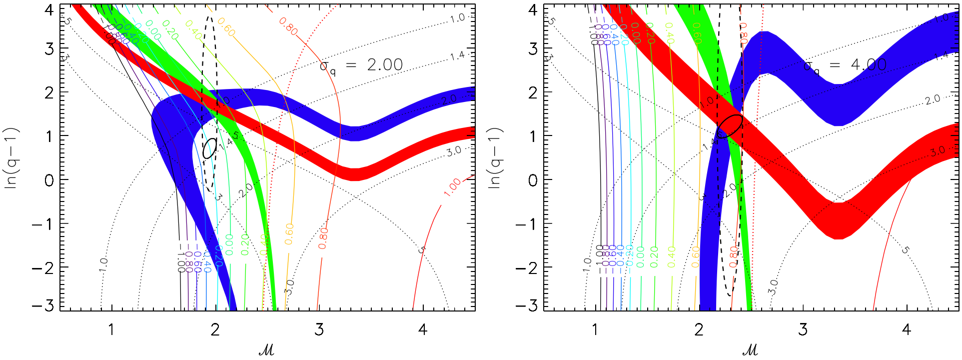
$$\frac{d^2p}{d\mathcal{M}d\bar{q}} = \frac{1}{2\pi\sqrt{\sigma_\mathcal{M}\sigma_q}}\exp\left[-\frac{(\mathcal{M}-\mathcal{M}_0)^2}{2\sigma_\mathcal{M}^2}-\frac{(\bar{q}-\bar{q}_0)^2}{2\sigma_q^2}\right].$$



Results For Various σ_q Values







σq = 2.00
σq = 4.00
ln(q−1)
M

Spin

LVC uses model of Foucart et al. (2012, 2018) to determine mass M_d remaining outside the remnant more than a few ms after a BHNS merger:

$$M_d/M^b_{\rm NS} \simeq \alpha' \eta^{-1/3}(1-2\beta) - \hat{R}_{\rm ISCO}\beta\beta'\eta^{-1} + \gamma',$$

$\beta = \dfrac{GM_{\rm NS}}{R_{\rm NS}c^2}$, $\eta = \dfrac{q}{(1+q)^2}$ and $\hat{R}_{\rm ISCO} = \dfrac{R_{\rm ISCO}c^2}{GM_{\rm BH}}$.

$\alpha' \simeq 0.406$, $\beta' \simeq 0.139$ and $\gamma' = 0.255$.

For the Kerr metric

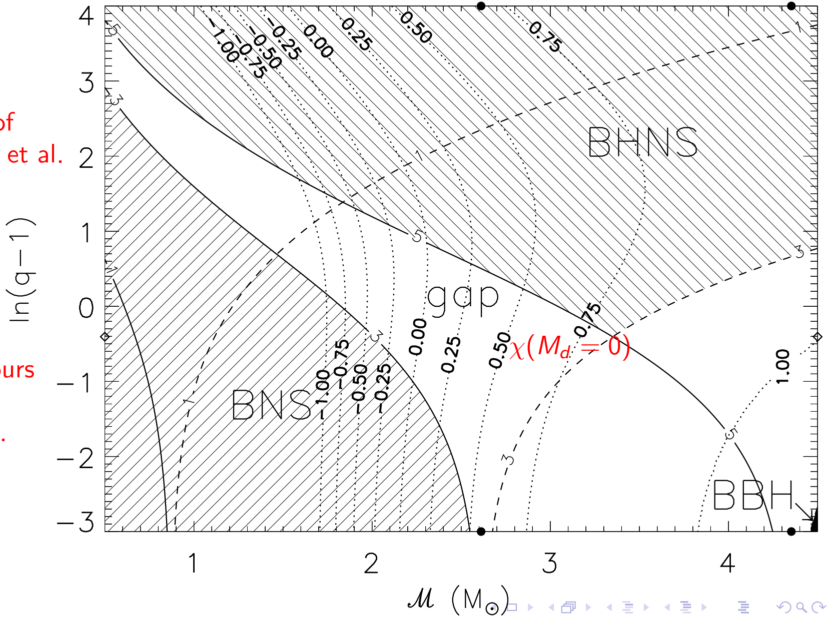
$$\chi = \sqrt{\hat{R}_{\rm ISCO}}\left(4/3 - \sqrt{\hat{R}_{\rm ISCO}/3 - 2/9}\right).$$

$M_d = 0$ implies

$$\hat{R}_{\rm ISCO} = (\beta'\beta)^{-1}(\alpha'\eta^{2/3}(1-2\beta) + \gamma'\eta).$$

χ is found from $p_d = \int\int_{M_d \geq 0} \dfrac{d^2p}{d\mathcal{M}d\bar{q}} d\mathcal{M}d\bar{q}$.

Spin Contours



Model of Foucart et al. (2018)

χ contours where $M_d = 0$.

Convergence Occurs For Large σ_q