On the Dynamical Tidal Response of Kerr Black Holes

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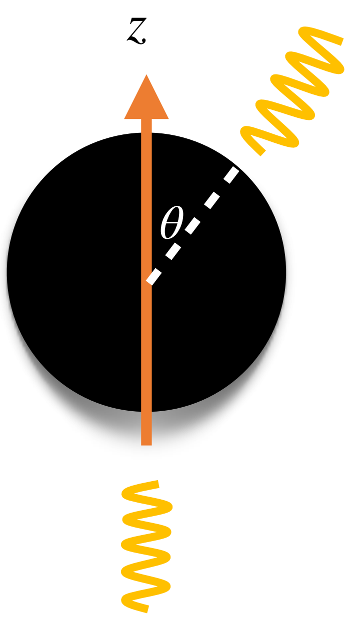
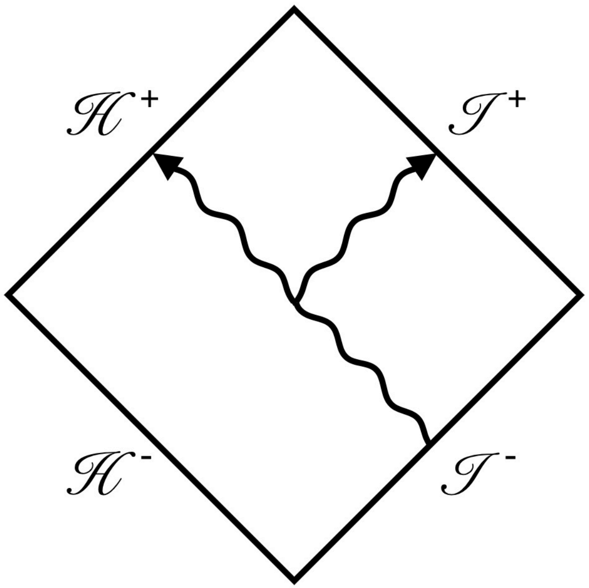


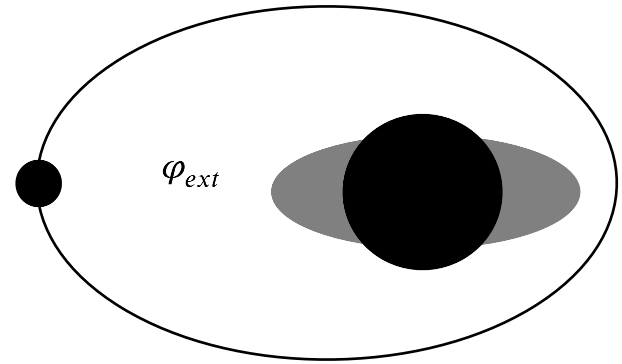


Based on 2209.14324, 2307.10391, ++ to appear with M. Ivanov and M. S. V Saketh

Tidal Deformation and Dissipation

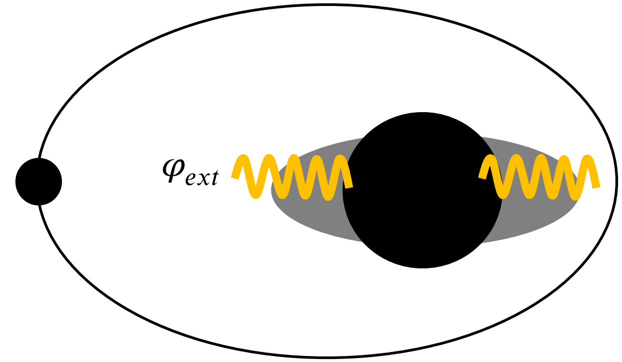
$$S_{\text{tidal}} = \int d\tau Q^E_{ij} \cdot E^{ij} + \int d\tau Q^B_{ij} \cdot B^{ij}$$

Tidal Deformation:



* Love number: time-reversal even part of $\langle QQ \rangle_{\text{ret}}$

Tidal Dissipation (Heating):



* Dissipation number: time-reversal odd part of $\langle QQ \rangle_{\text{ret}}$

Love/Dissipation Numbers of Compact Objects

$$Q^E_{ij} = -M(GM)^4\left[(\lambda^E)_{ijkl}E^{kl} - (GM)(\lambda^E_\omega)_{ijkl}\frac{d}{d\tau}E^{kl}\right]$$

SO(3) rep:

$$(\lambda^{E/B})^{ij}_{kl} = \Lambda^{E/B}_{\hat{s}0}\delta^{\langle i}_{\langle k}\delta^{j\rangle}_{l\rangle} + H^{E/B}_{\hat{s}1}\chi\hat{S}^{\langle i}{}_{\langle k}\delta^{j\rangle}_{l\rangle} + \Lambda^{E/B}_{\hat{s}2}\chi^2\hat{s}^{\langle i}\hat{s}_{\langle k}\delta^{j\rangle}_{l\rangle} + H^{E/B}_{\hat{s}3}\chi^3\hat{s}^{\langle i}\hat{s}_{\langle k}\hat{S}^{j\rangle}{}_{l\rangle} + \Lambda^{E/B}_{\hat{s}4}\chi^4\hat{s}^{\langle i}\hat{s}_{\langle k}\hat{s}^{j\rangle}\hat{s}_{l\rangle}$$

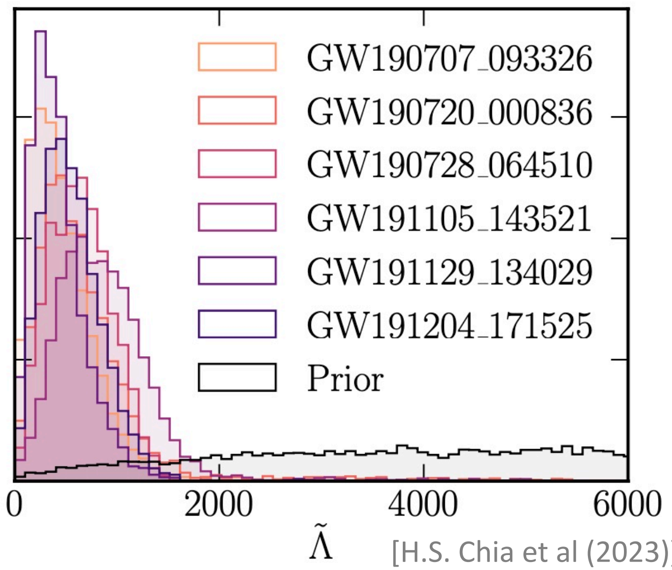
Love 5PN — Dissipation 2.5PN — Love — Dissipation 3.5PN — Love

$$(\lambda^{E/B}_\omega)^{ij}_{kl} = H^{E/B}_{\hat{s}0,\omega}\delta^{\langle i}_{\langle k}\delta^{j\rangle}_{l\rangle} + \Lambda^{E/B}_{\hat{s}1,\omega}\chi\hat{S}^{\langle i}{}_{\langle k}\delta^{j\rangle}_{l\rangle} + H^{E/B}_{\hat{s}2,\omega}\chi^2\hat{s}^{\langle i}\hat{s}_{\langle k}\delta^{j\rangle}_{l\rangle} + \Lambda^{E/B}_{\hat{s}3,\omega}\chi^3\hat{s}^{\langle i}\hat{s}_{\langle k}\hat{S}^{j\rangle}{}_{l\rangle} + H^{E/B}_{\hat{s}4,\omega}\chi^4\hat{s}^{\langle i}\hat{s}_{\langle k}\hat{s}^{j\rangle}\hat{s}_{l\rangle}$$

Dissipation 4PN — Love — Dissipation — Love — Dissipation

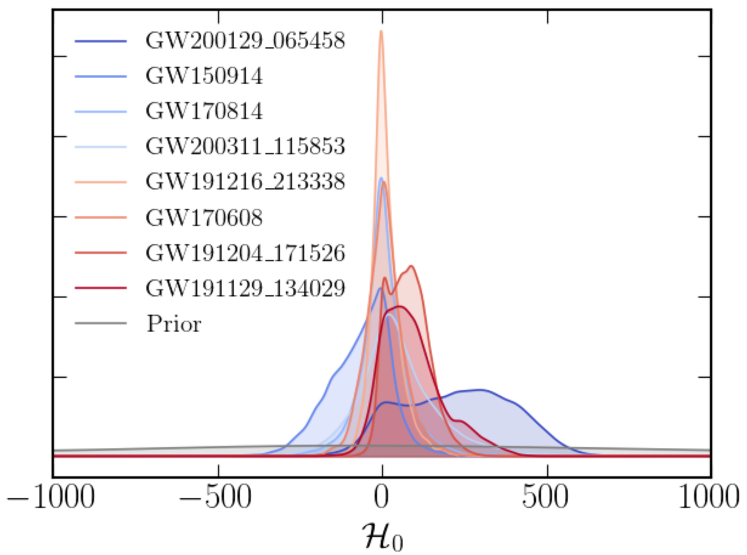
BHs:

mass-weighted Love number



[H.S. Chia et al (2023)]

mass-weighted spin-independent dissipation

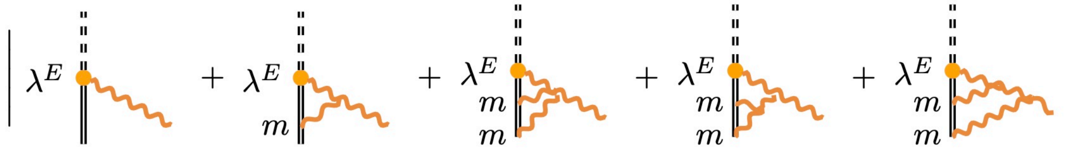


[**Zhou**, Chia, Ivanov, Zaldarriaga et al, in prep]

RG Running of Dynamical Tides

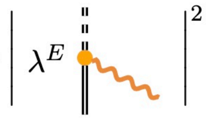
Tidal Dissipation:

$p(1+\mathrm{BH}\to 0+\mathrm{BH}') =$



$+\,|\mathrm{magnetic}|^2$

$=$



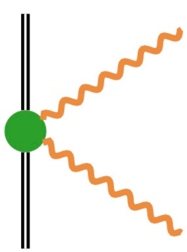
$$\Big|^2 \times \left(1+\pi r_s|\omega| - \frac{107(r_s\omega)^2}{210}\left[\frac{1}{(d-4)_{\mathrm{UV}}}+\gamma_E+\log\left(\frac{\omega^2}{\pi\mu^2}\right)\right]+\frac{(r_s\omega)^2}{4}\left[\frac{4\pi^2}{3}+\frac{634913}{44100}\right]\right)$$

[Saketh, **Zhou**, Ivanov (2023)]

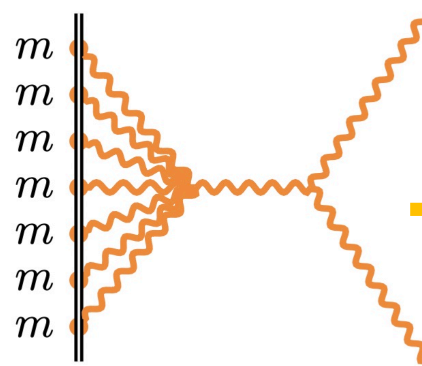
* BH absorption probably has logarithmic dependence at 2-loop order (G^2)

Tidal Deformation:

$\Lambda^{E/B}_{\omega^2}$



$$= -\frac{1}{225}(r_s\omega)^7\log(2r_s\mu) + \mathrm{const}$$



UV?

* BH "dynamical" Love numbers have RG running behavior, which corresponds to the UV divergence at 6-loop order.