

2105.04559



# Detecting new forces in the gravitational wave background

Benjamin V. Lehmann [blehmann@ucsc.edu]

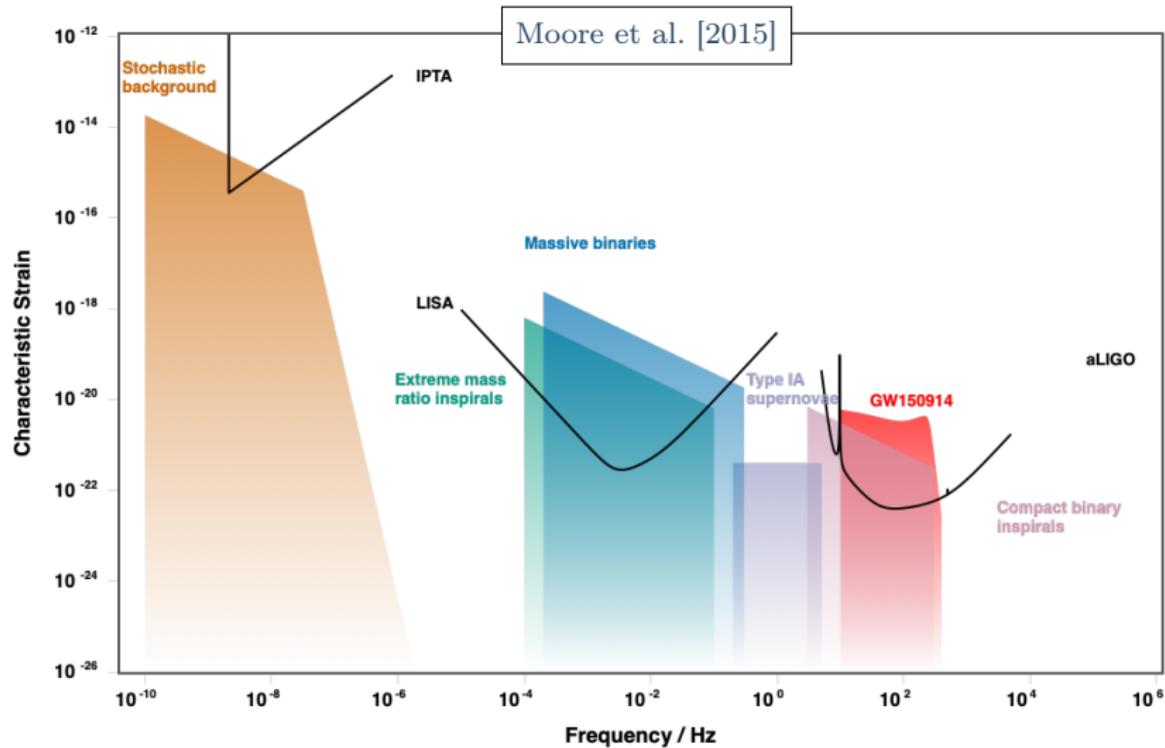
+Jeff A. Dror, Hiren H. Patel, & Stefano Profumo

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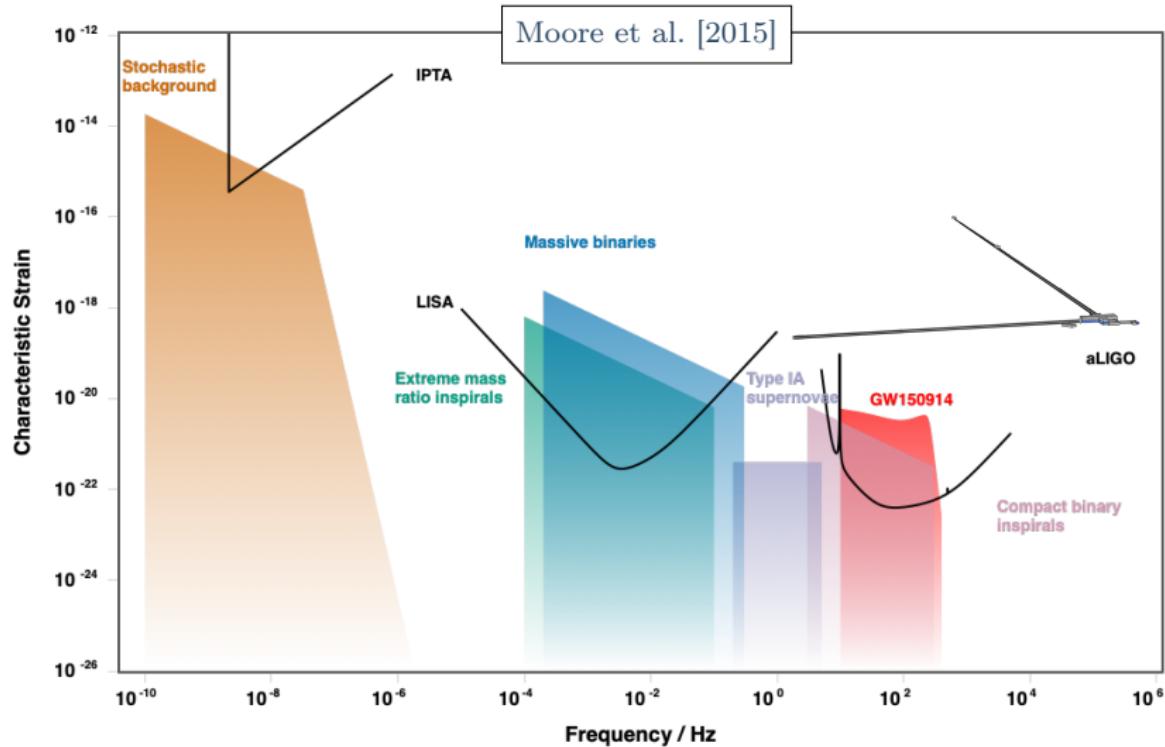


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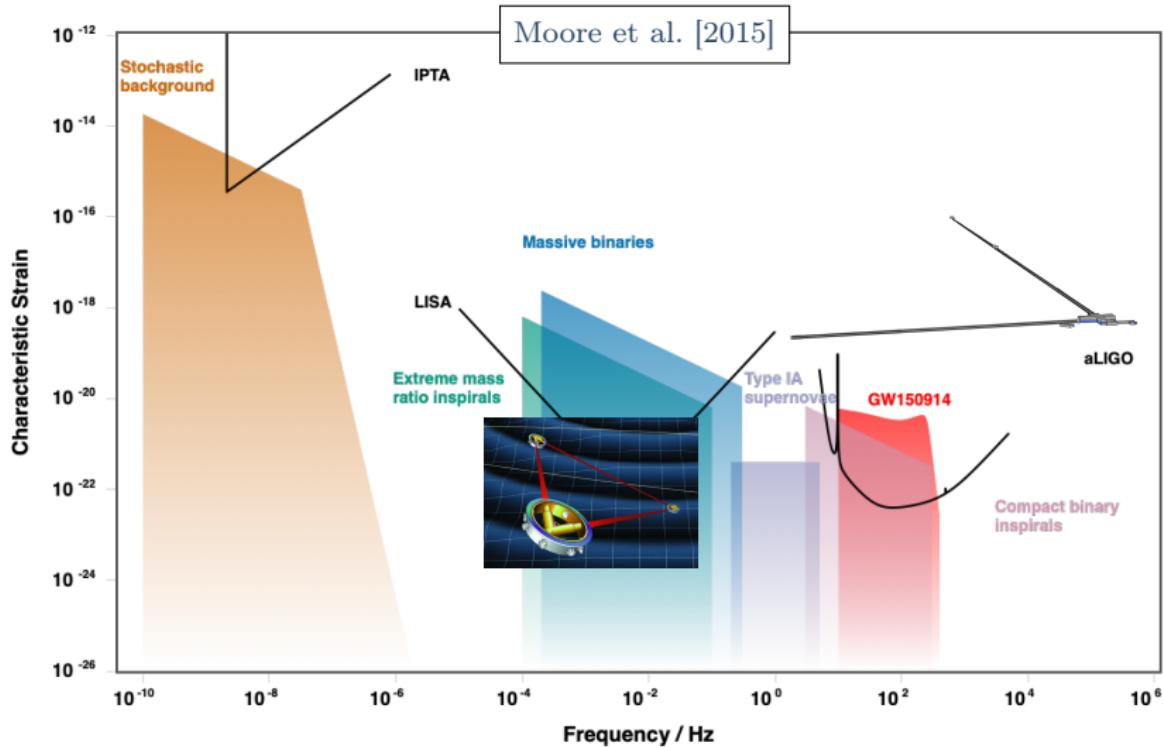
# The era of gravitational waves



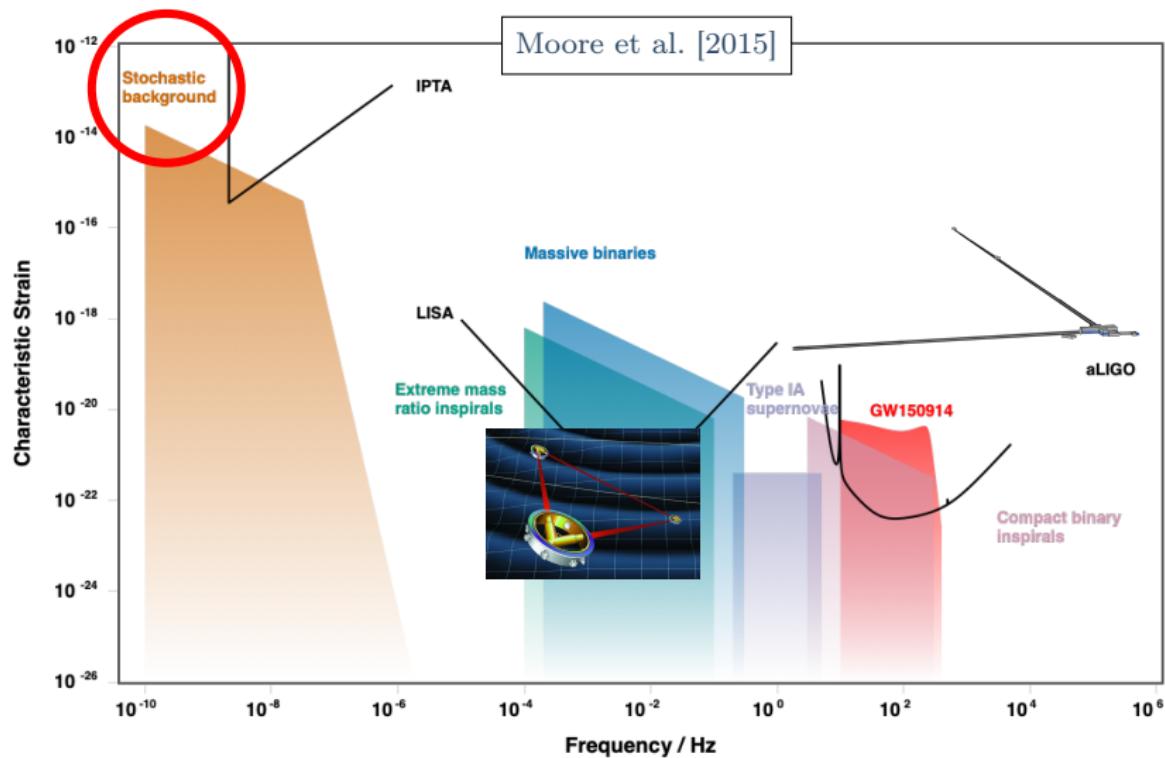
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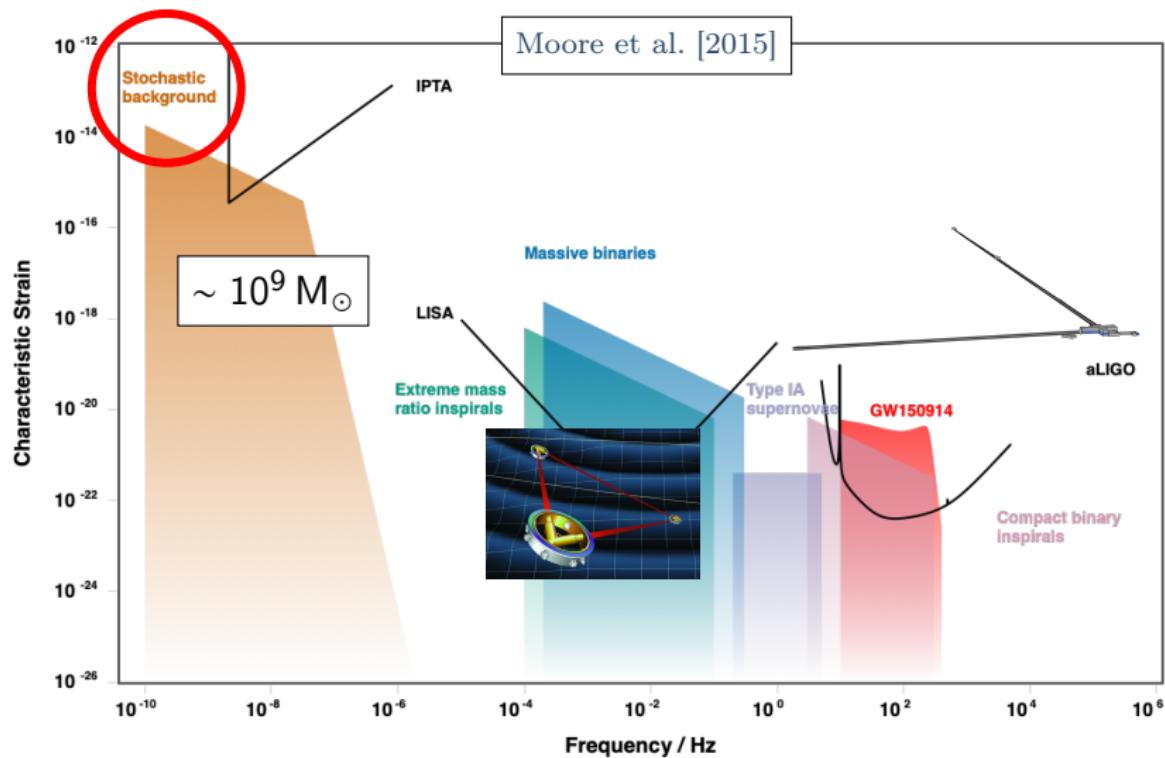
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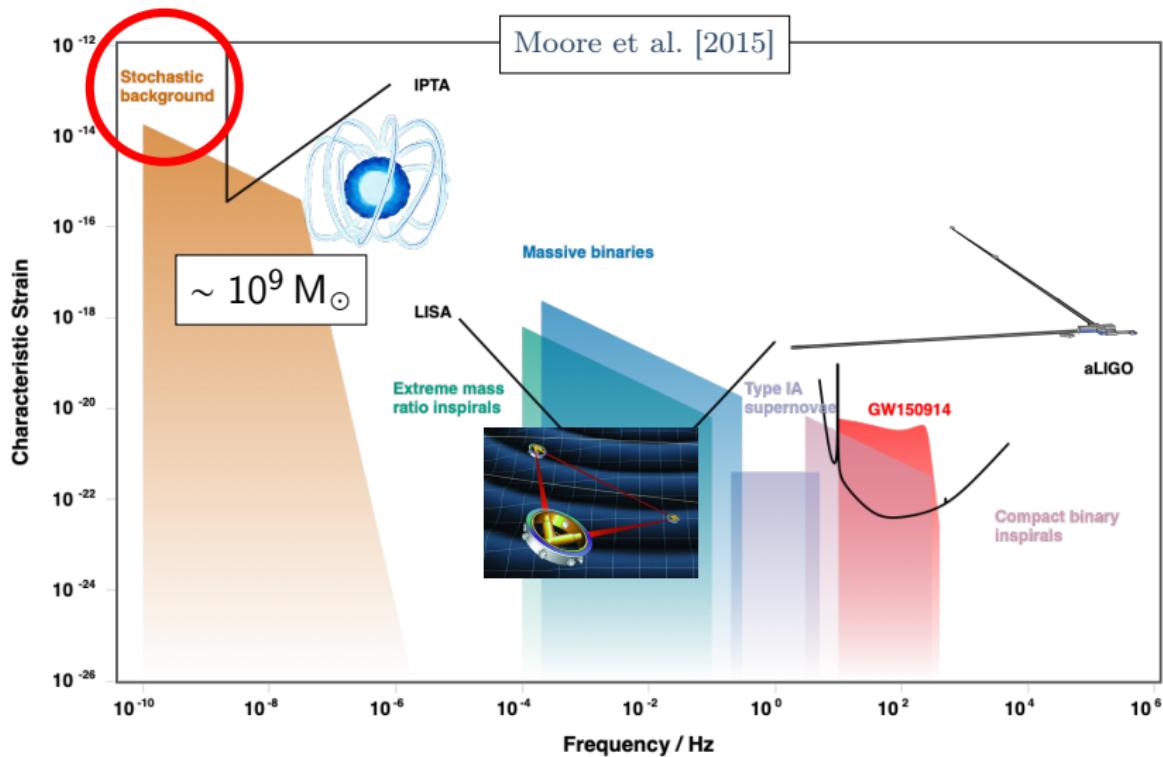
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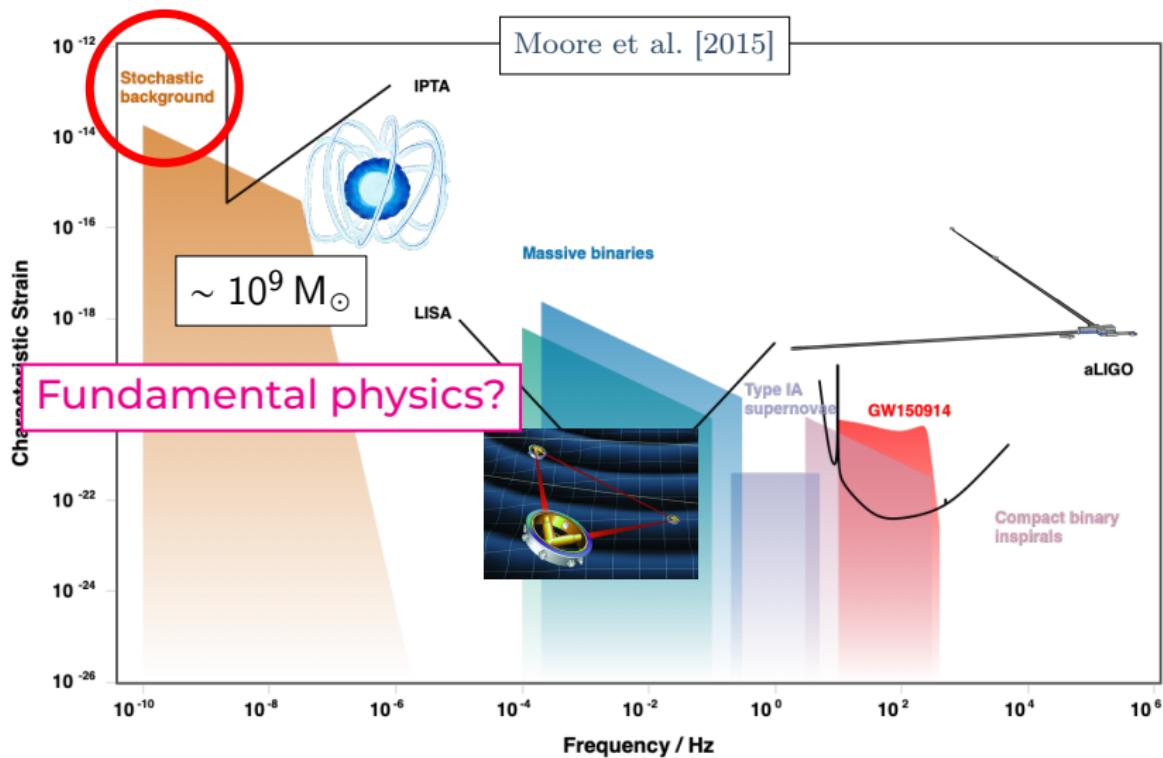
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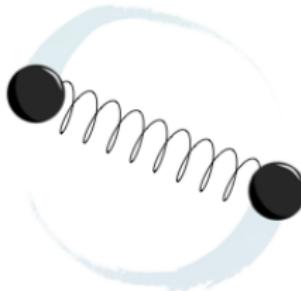
# This talk in one slide

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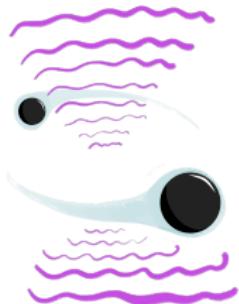
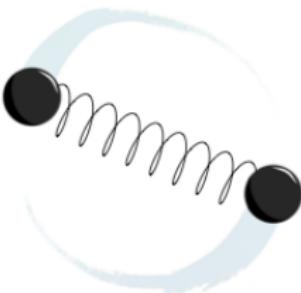
**1. SMBH GW background is a guaranteed discovery**

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2. Long range forces can *detectably* modify spectrum

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1. SMBH GW background is a guaranteed discovery
2. Long range forces can *detectably* modify spectrum
3. SMBH GWs potentially probe many BSM scenarios

# The stochastic GW background



1



2



3



4

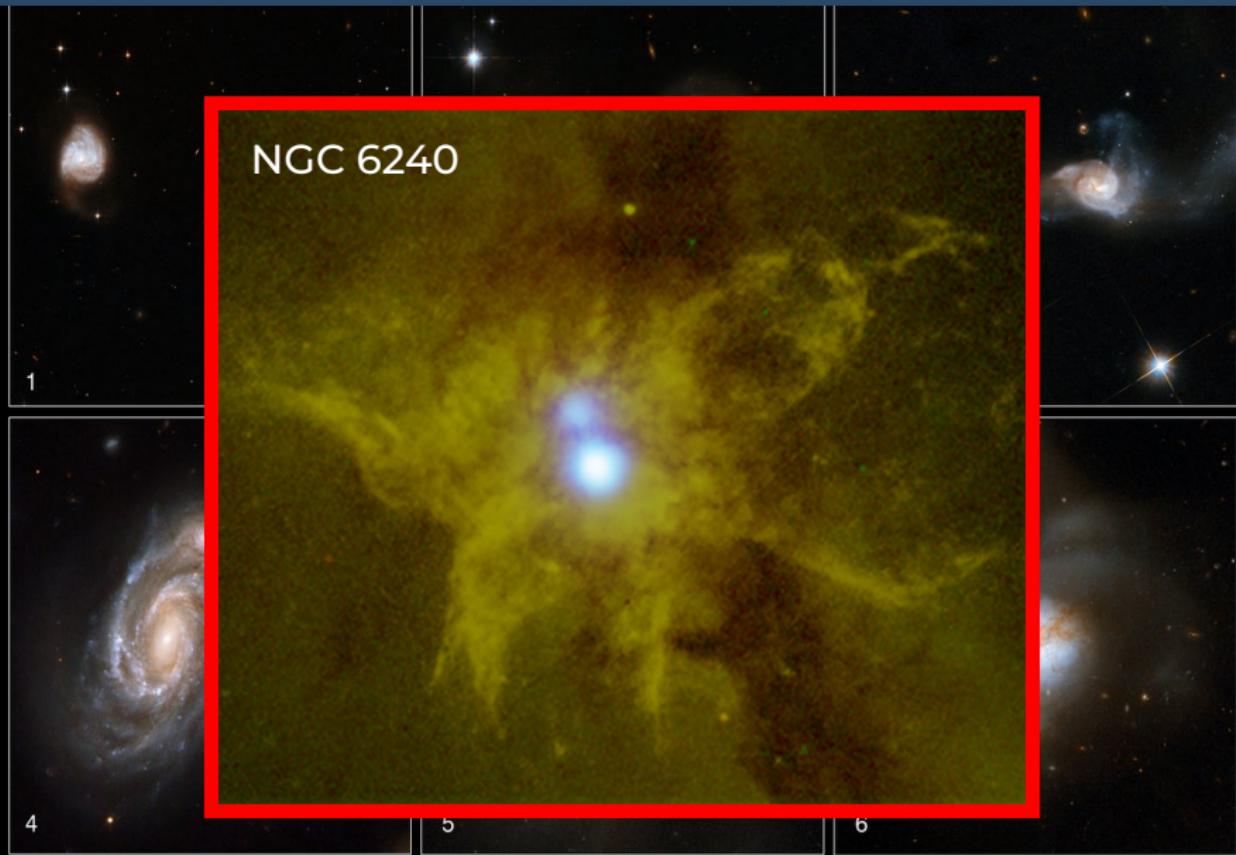


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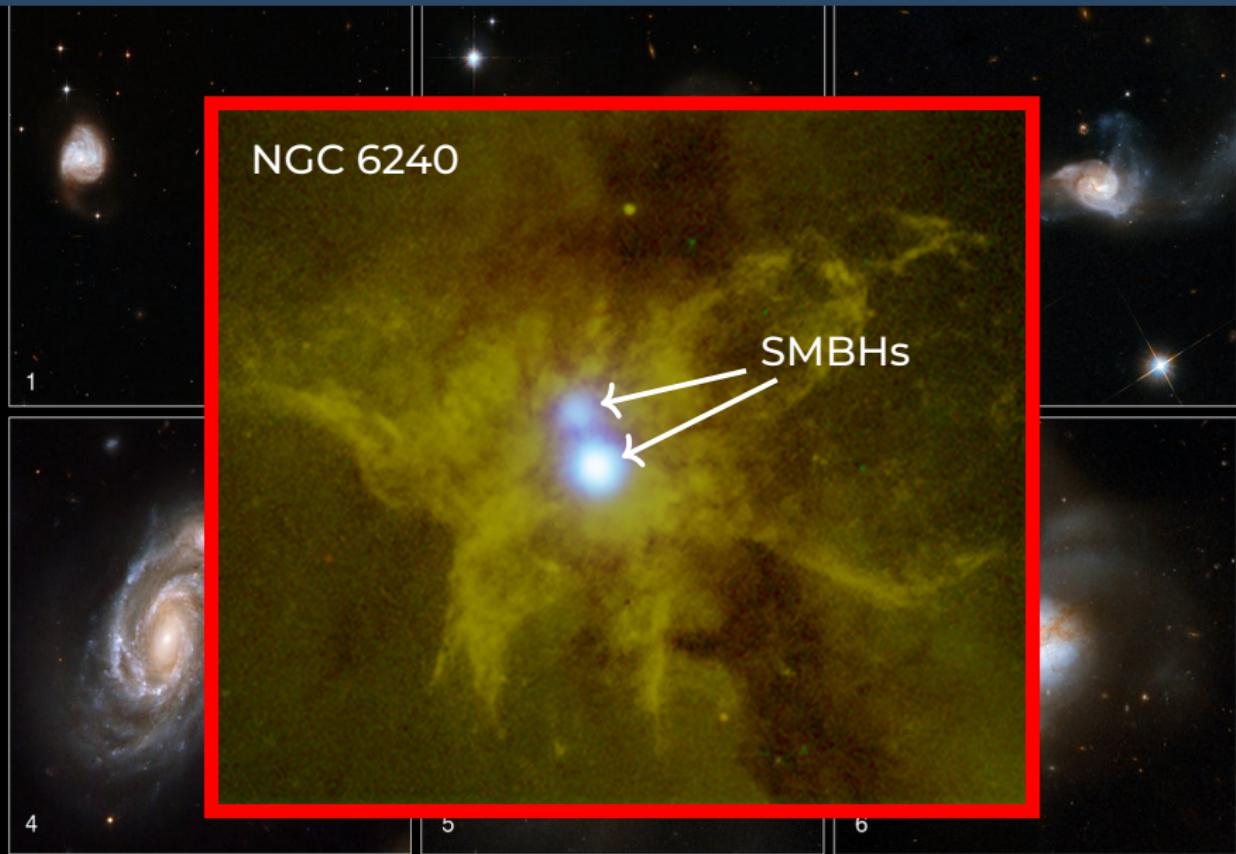


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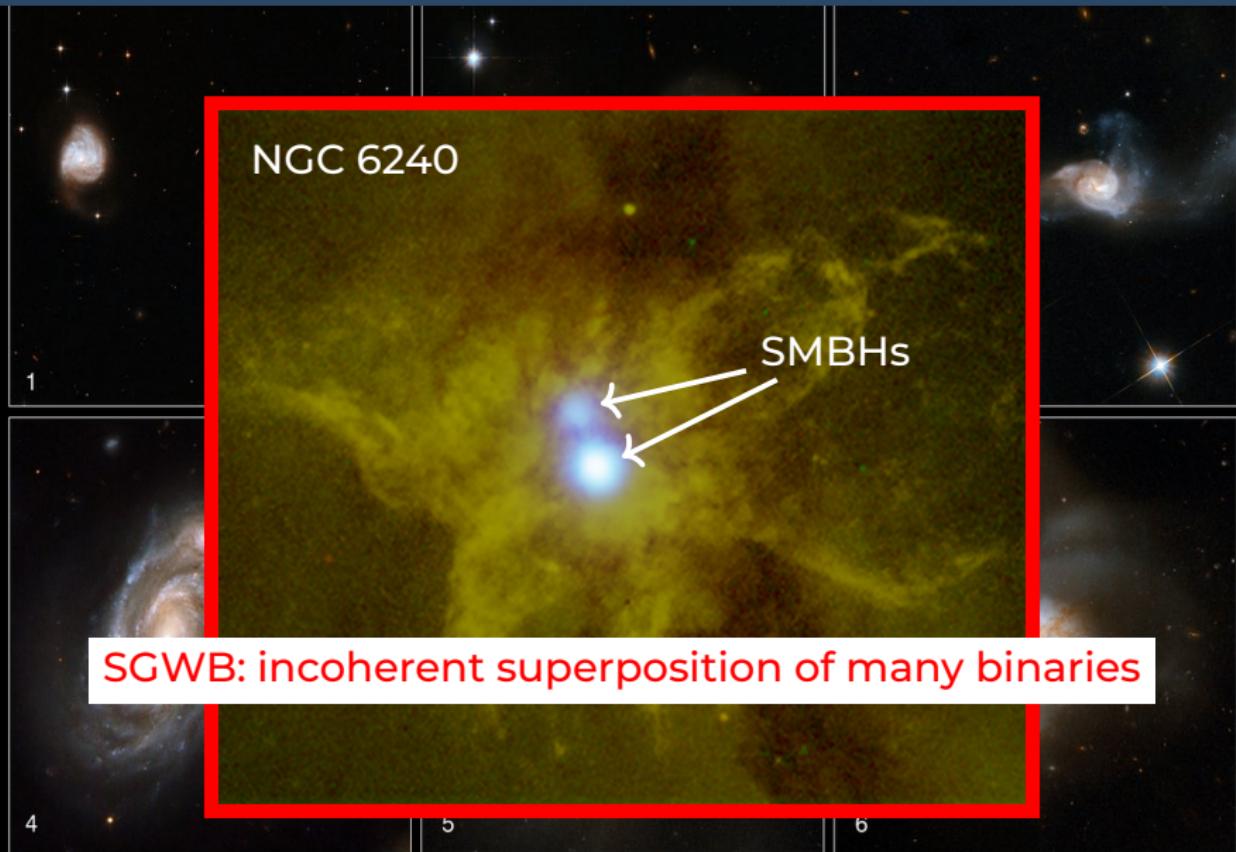
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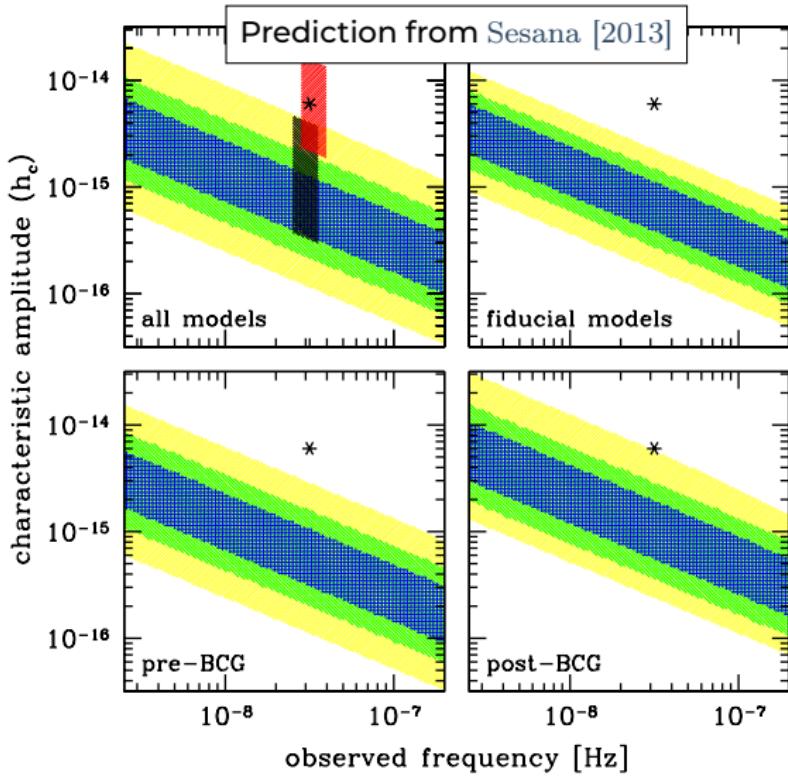
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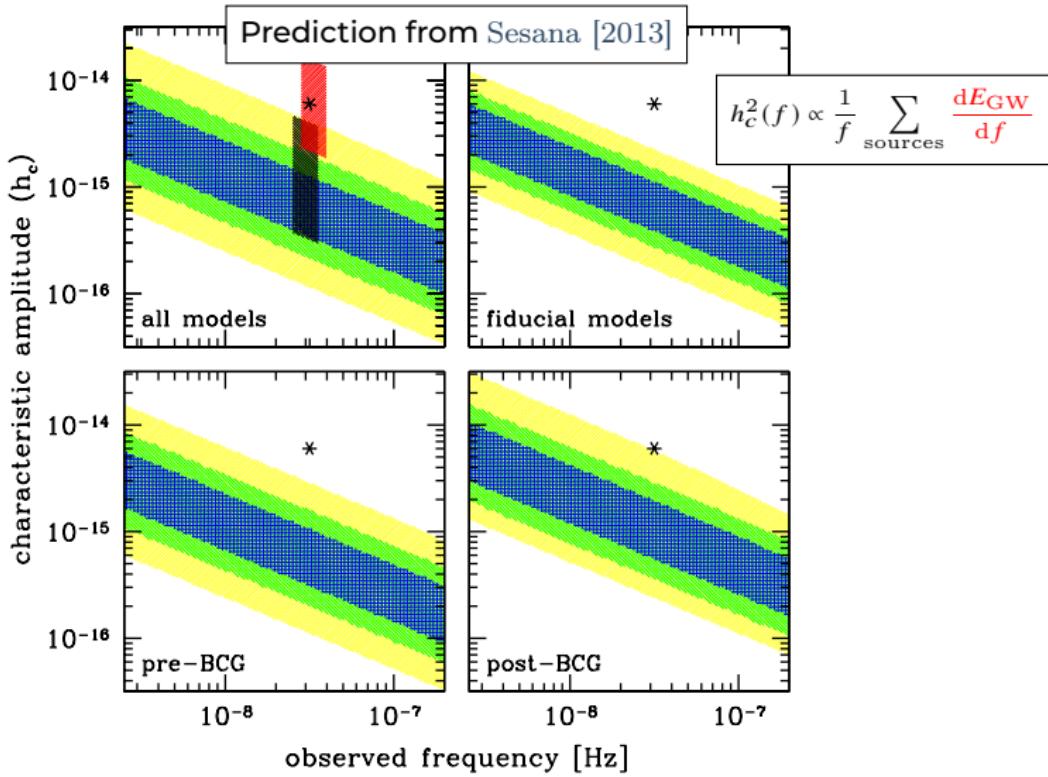
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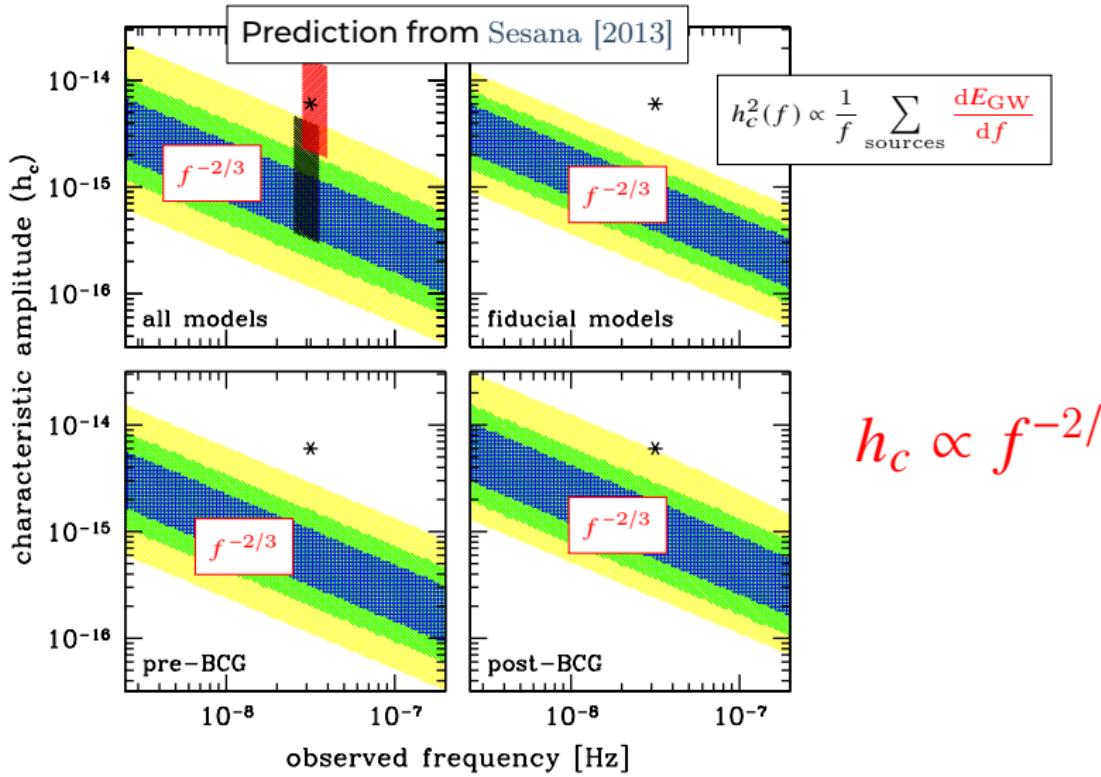
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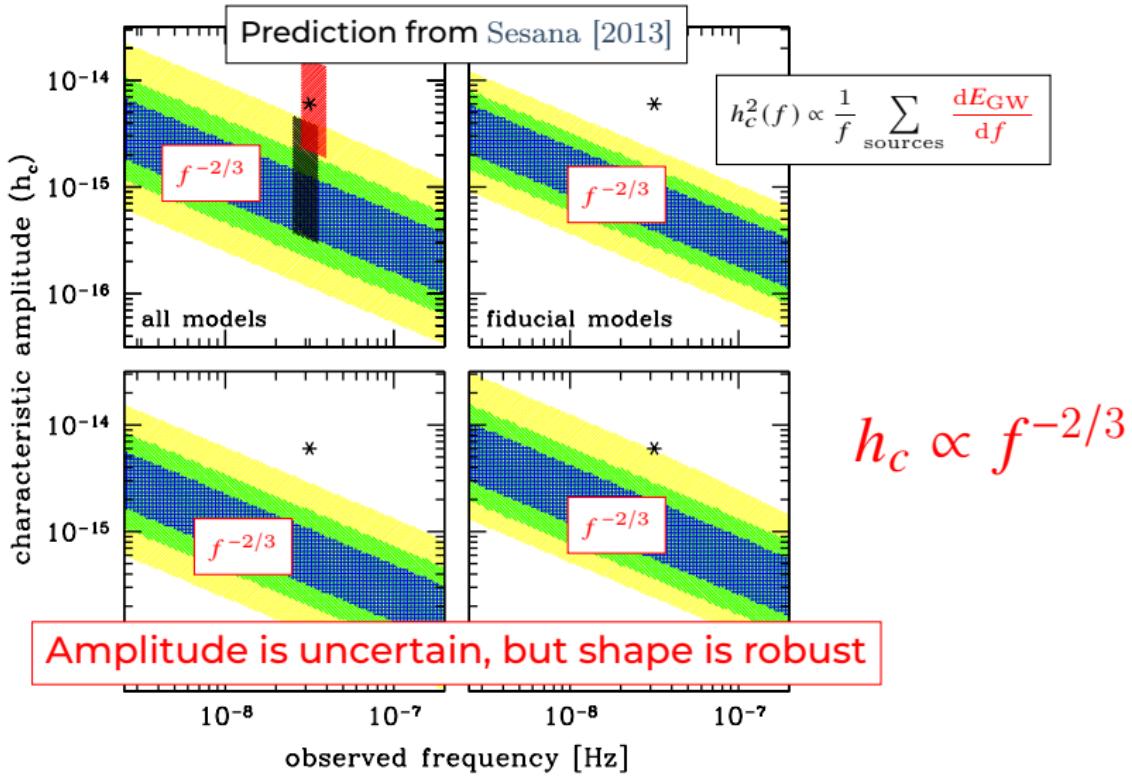
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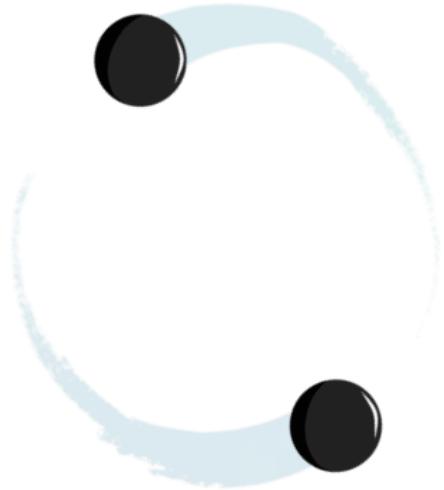


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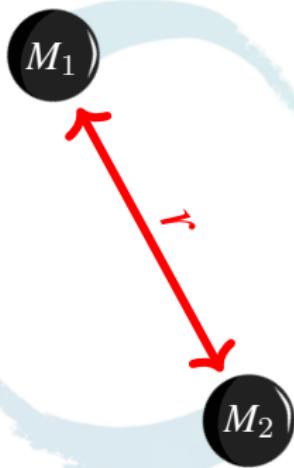
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Gravitational waves drive the evolution of the binary



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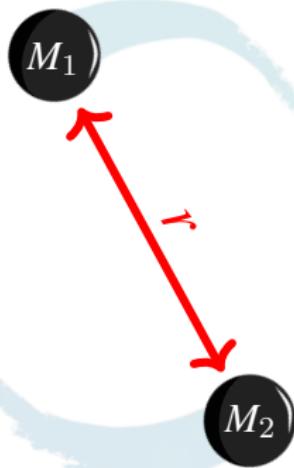
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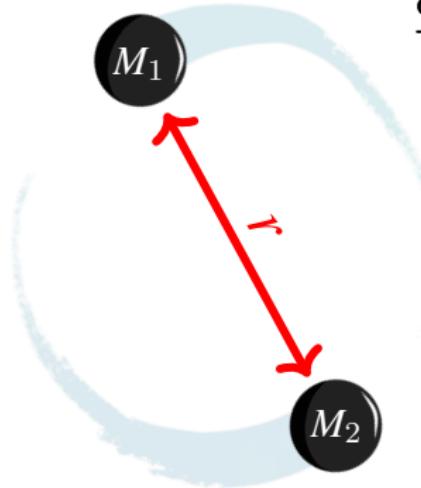


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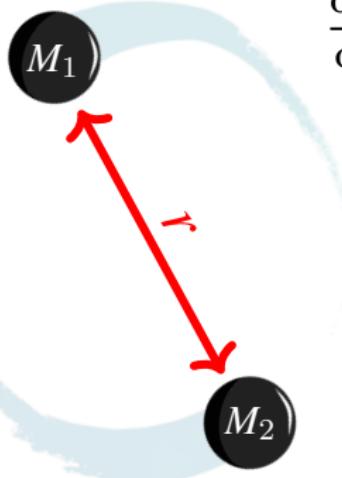
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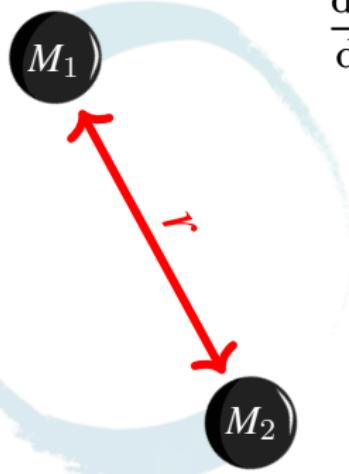


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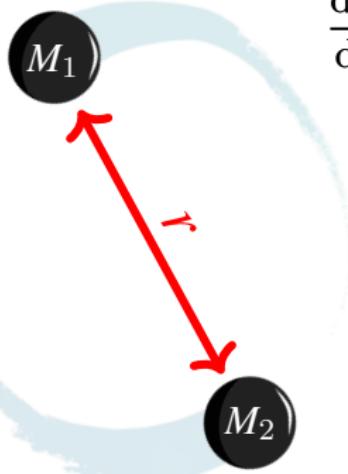
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[Phinney, 2001]

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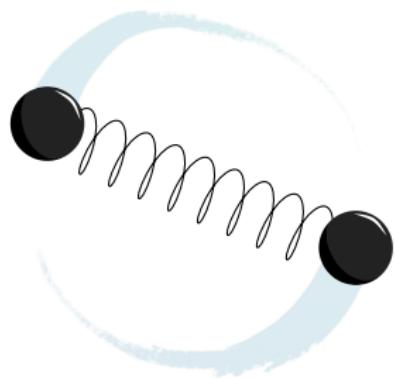
[Phinney, 2001]

New physics can break this prediction

# Assumptions are made to be broken

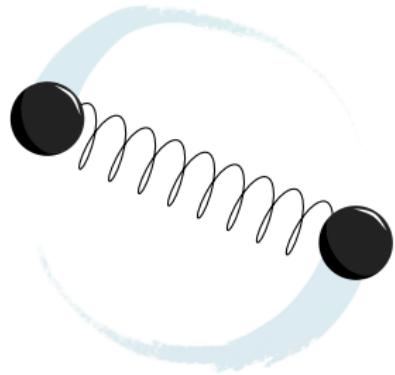
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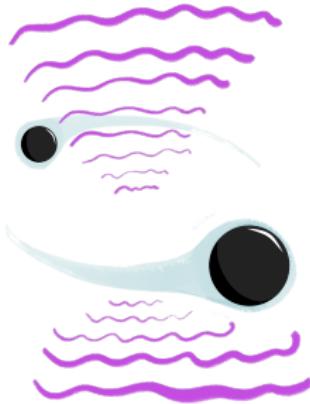


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Additional dynamics spoil the  $-2/3$

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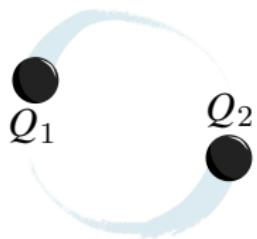
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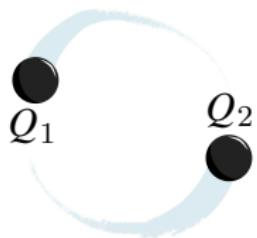


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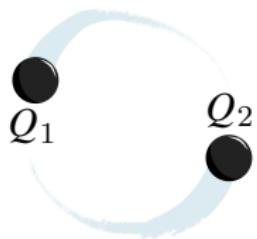


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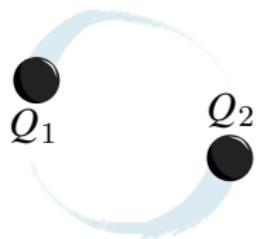


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## Charge parameters

$$\underbrace{\alpha = \frac{Q_1 Q_2}{G M_1 M_2}}_{\text{Force}}$$

$$\underbrace{\gamma^2 = \frac{1}{G} \left( \frac{Q_1}{M_1} - \frac{Q_2}{M_2} \right)^2}_{\text{Radiation}}$$

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**Toy model assumption:**

charge is pointlike relative to binary separation

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New force and radiation modify the spectrum

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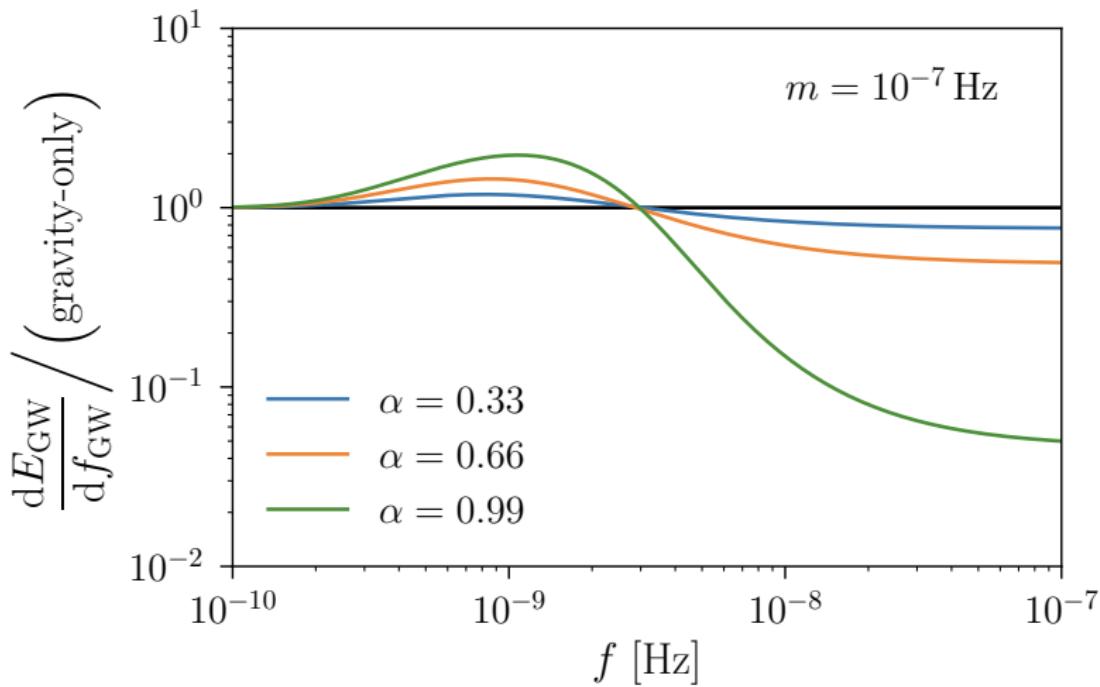
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$\omega = 2\pi f_{\text{orbit}}$

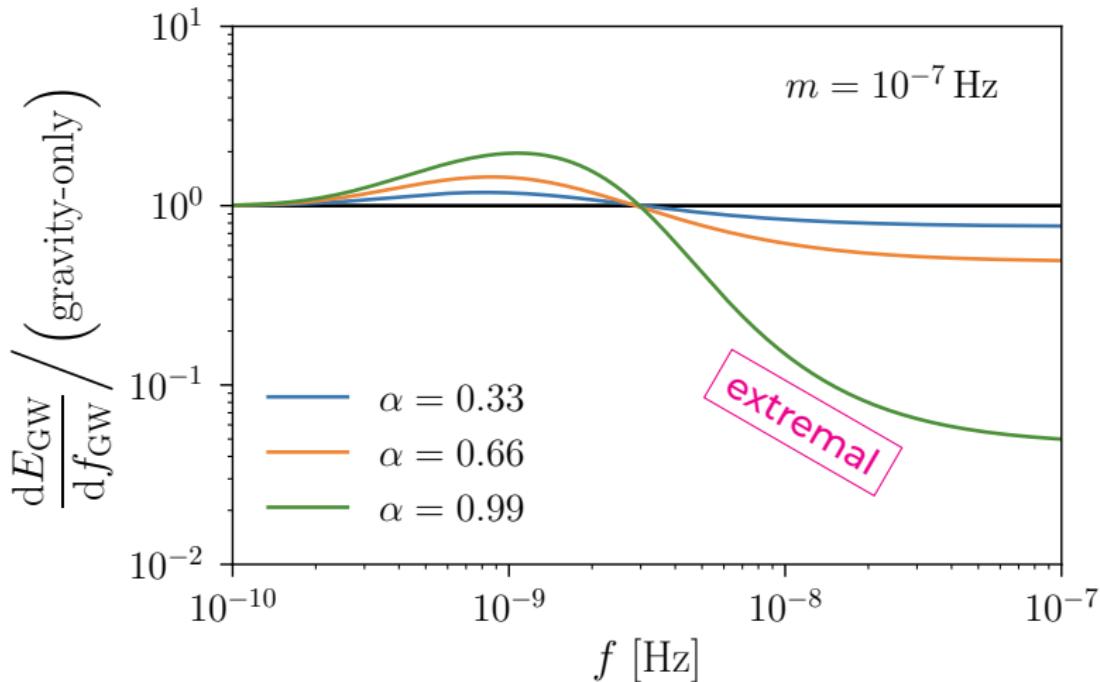
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$$P_{\text{new}} = \frac{1}{3} G \gamma^2 \mu^2 r^2 \omega^4 \operatorname{Re} \left[ \sqrt{1 - \frac{m^2}{\omega^2}} \right] \begin{cases} \left( 1 - \frac{m^2}{2\omega^2} \right) & (\text{scalar}) \\ 2 \left( 1 + \frac{m^2}{2\omega^2} \right) & (\text{vector}) \end{cases}$$

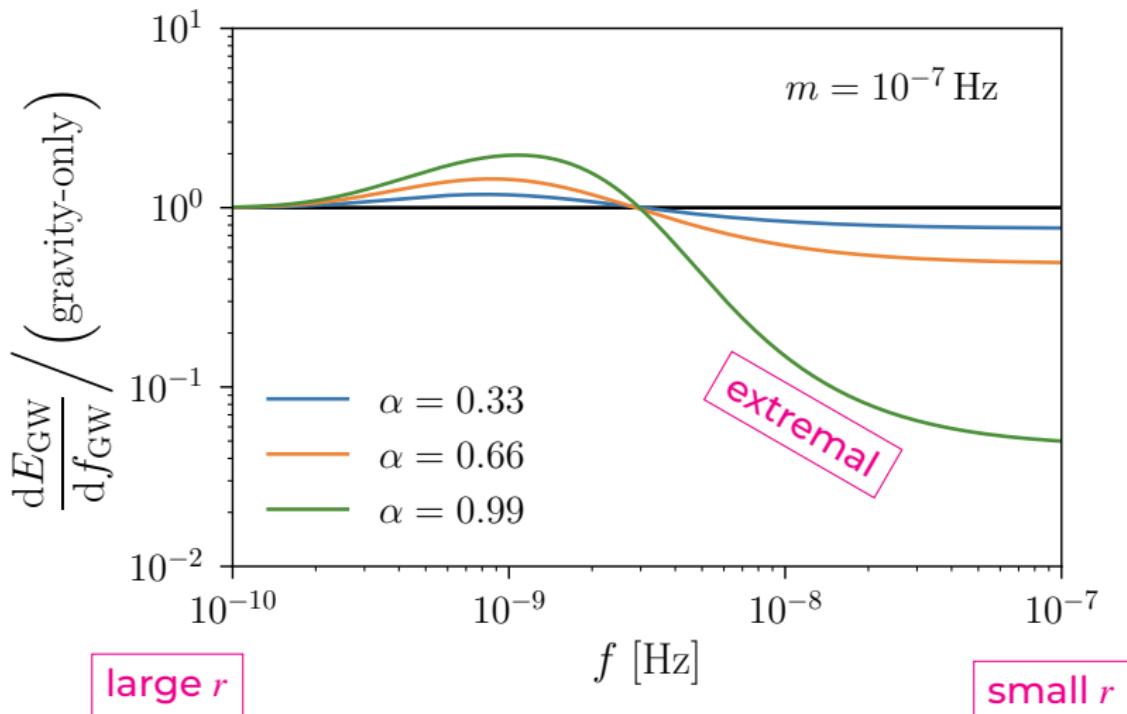
# Modifying the force law ( $\alpha \neq 0$ )



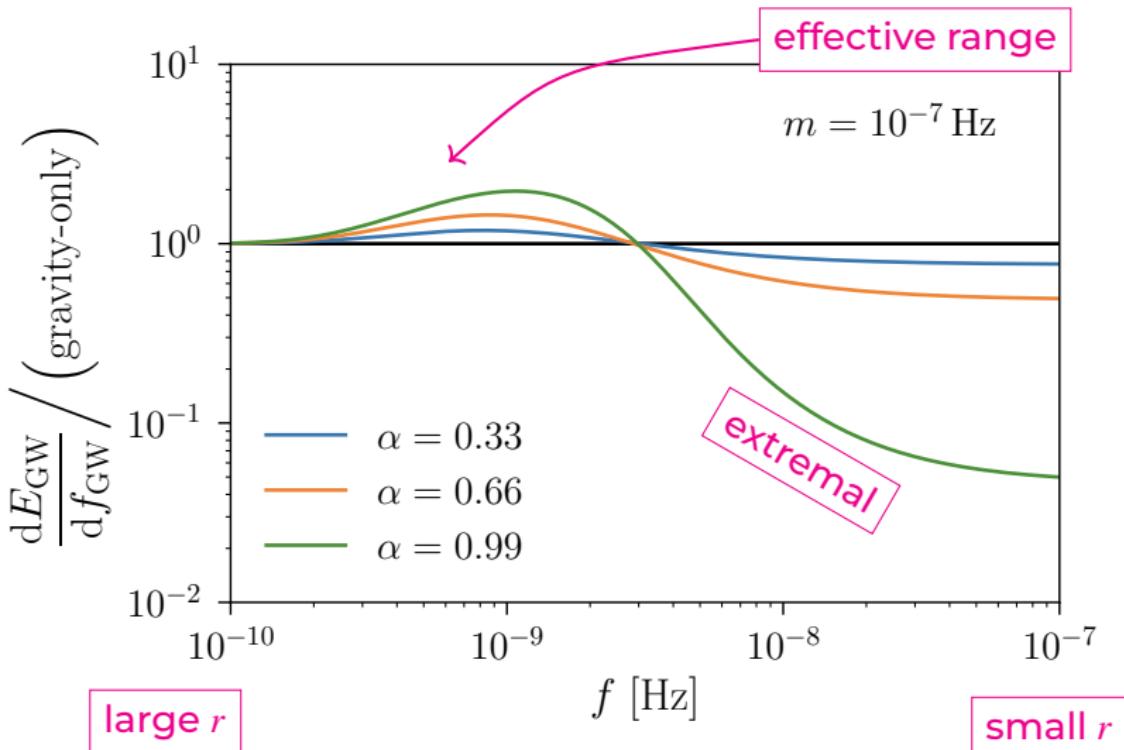
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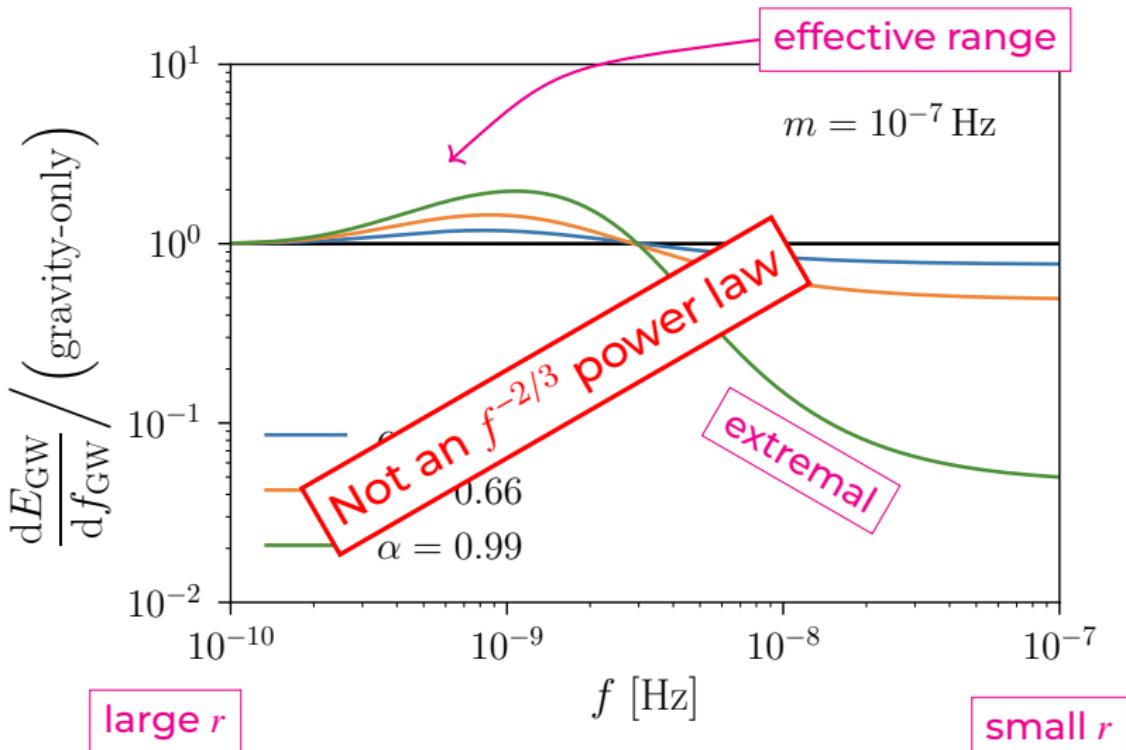
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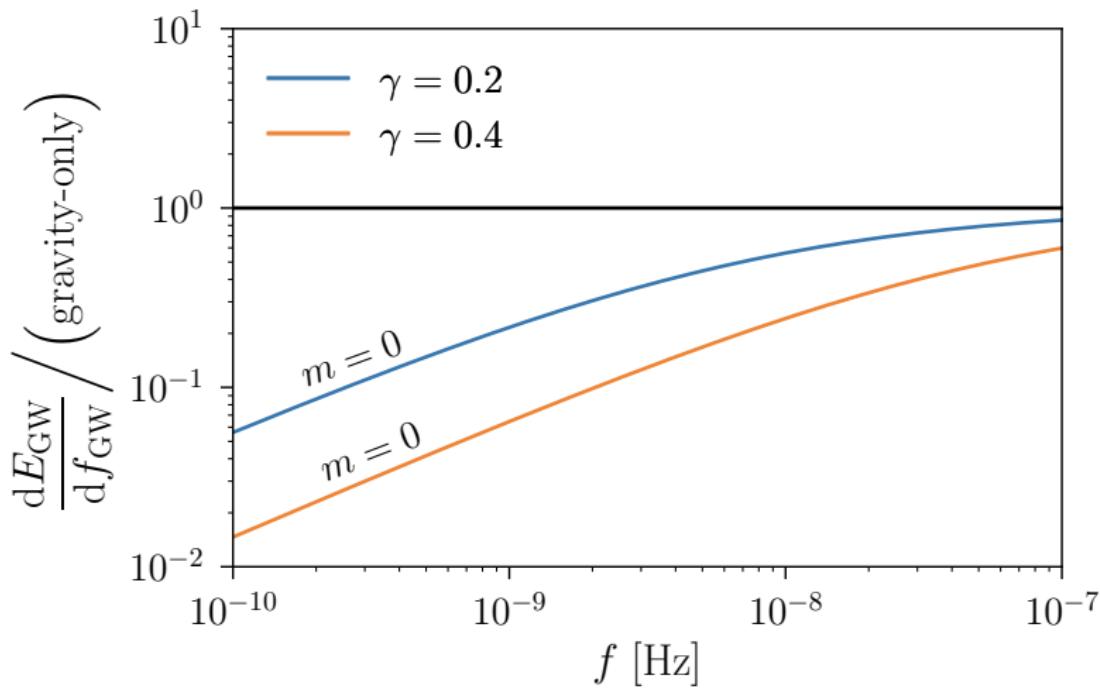
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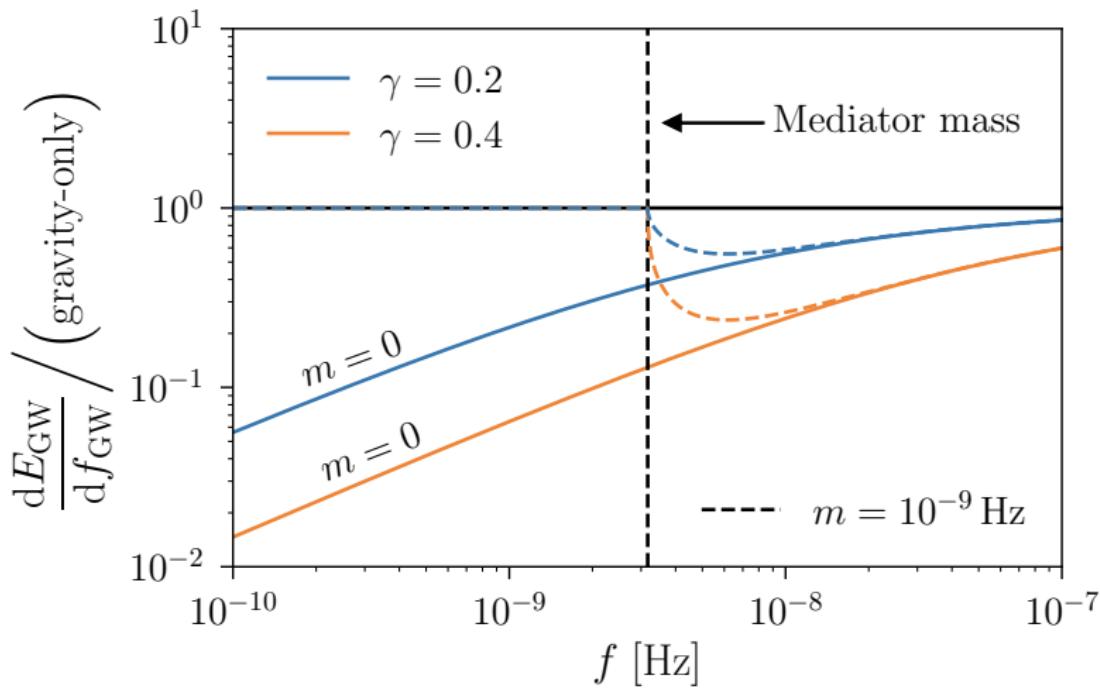
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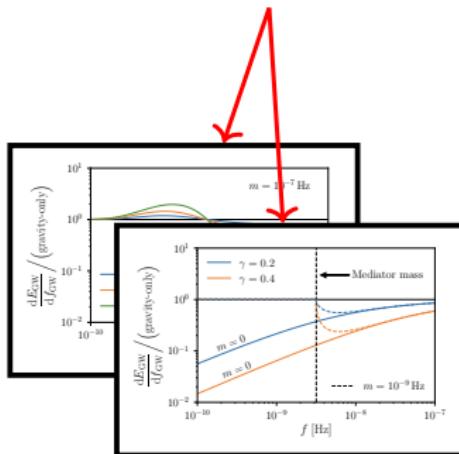


# From single sources to $h_c$

$$h_c^2(f) = \int dz dM_1 dM_2 \frac{dn_G}{dz dM_1 dM_2} \frac{f_s}{1+z} \frac{dE_{GW}}{df_s} \frac{3H_0^2}{2\pi^2 \rho_c^2}$$

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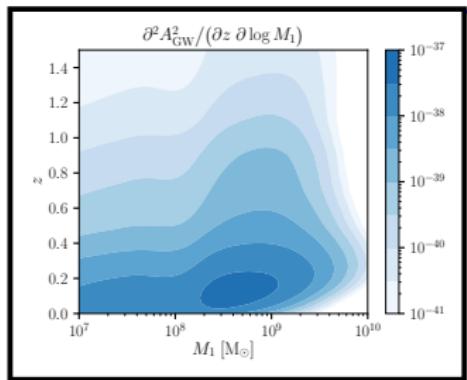
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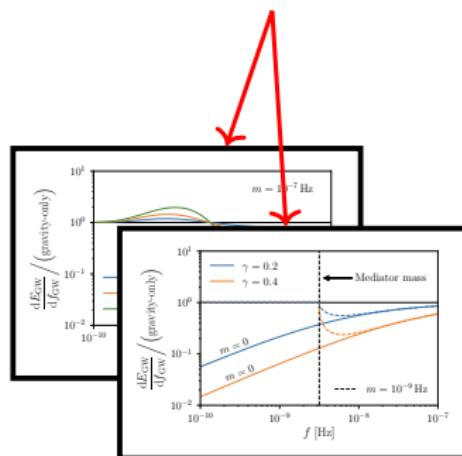
Single-source spectrum

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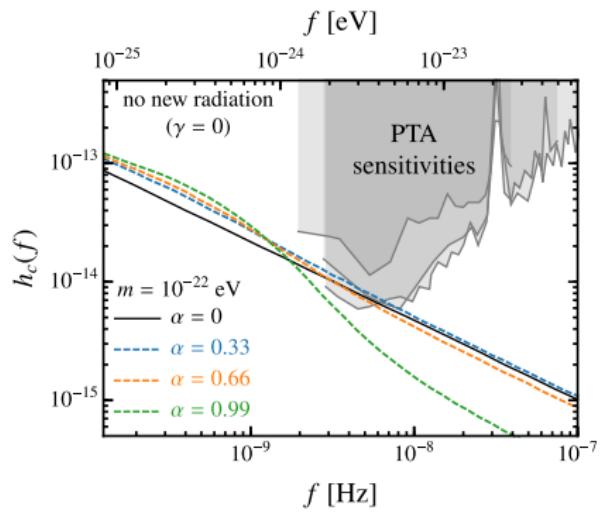
Source distribution



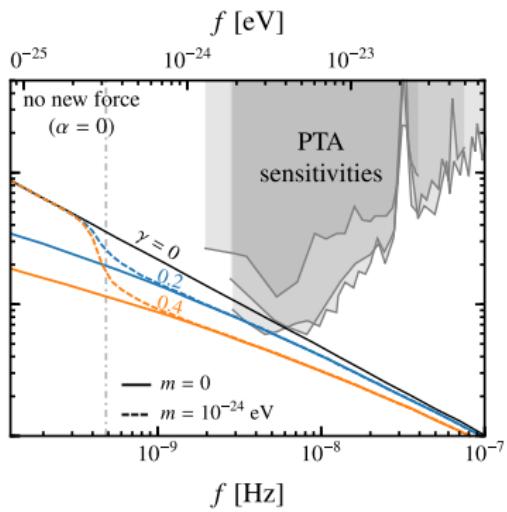
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# Observables

Force law ( $|\alpha| > 0$ )

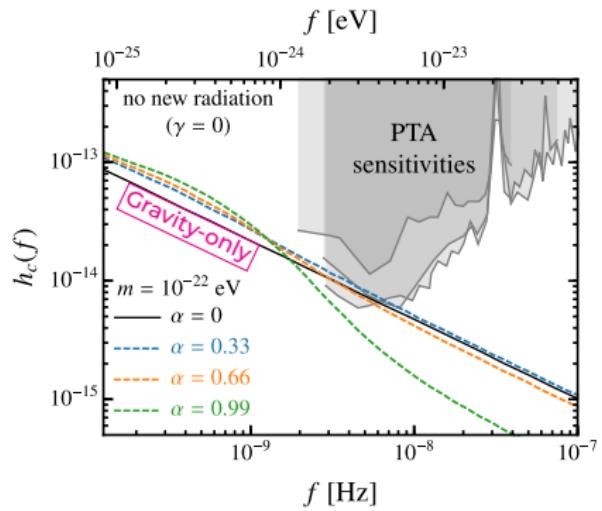


Dipole radiation ( $|\gamma| > 0$ )

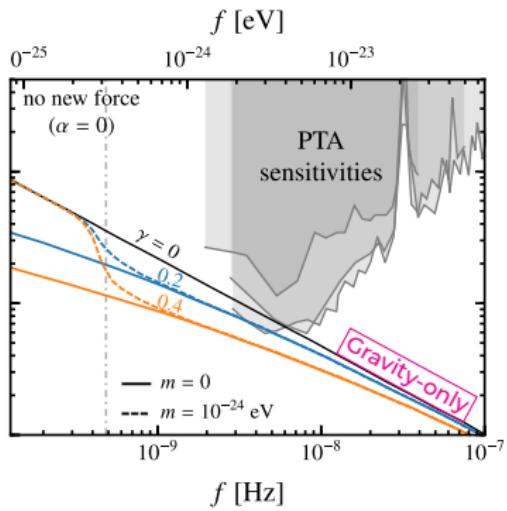


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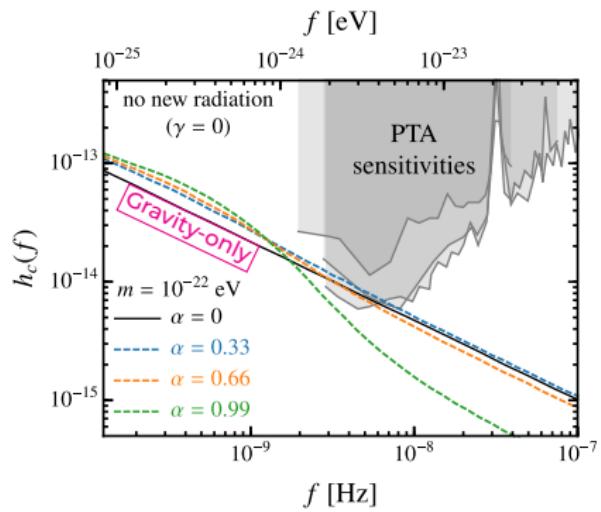


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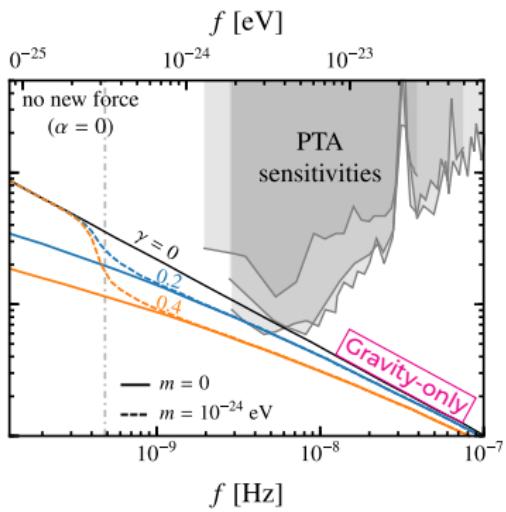


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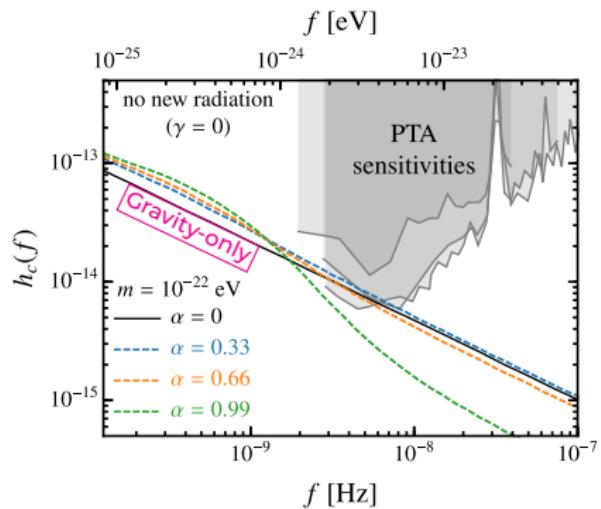
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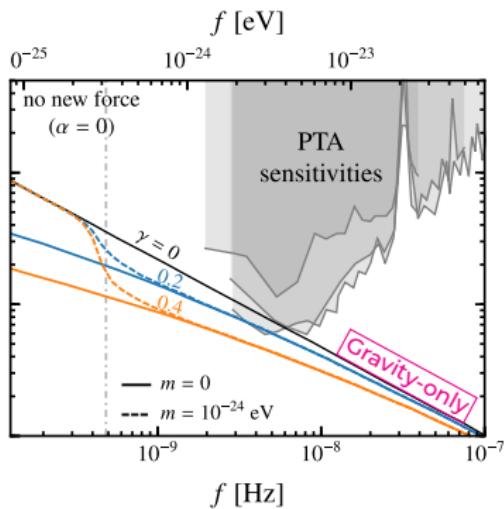
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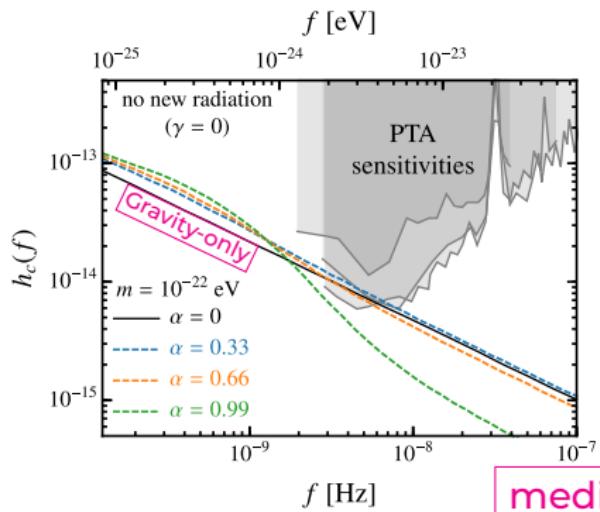
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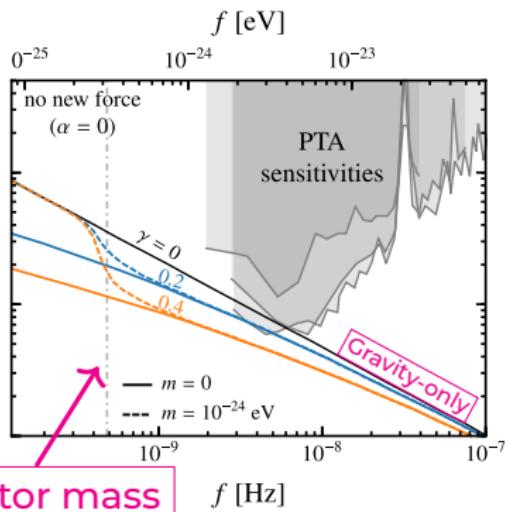
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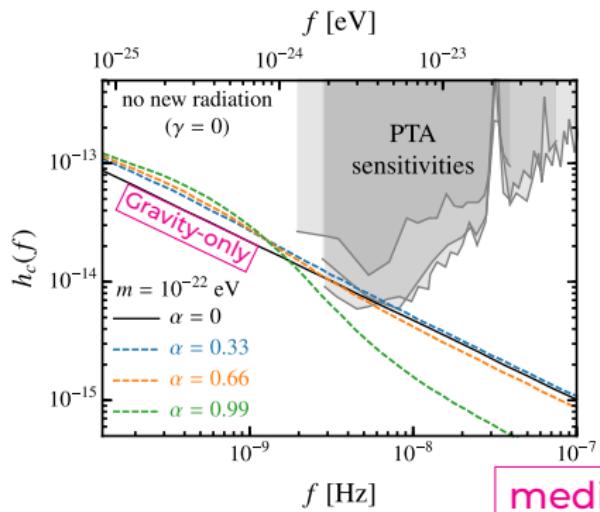


mediator mass

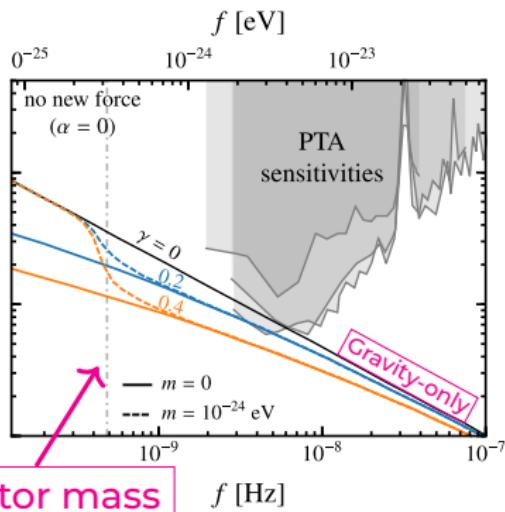
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Dipole radiation ( $|\gamma| > 0$ )



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- ③ Sensitivity curves: this is happening **NOW**

# Current data

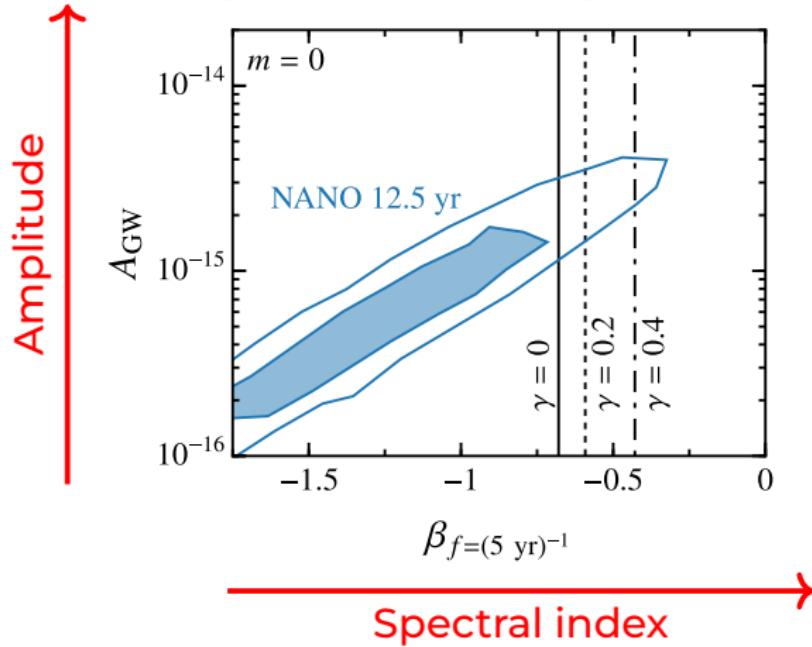
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[Arzoumanian et al., 2020]

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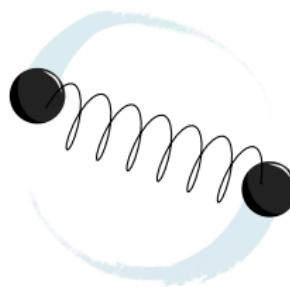
SGWB discovery  
is imminent

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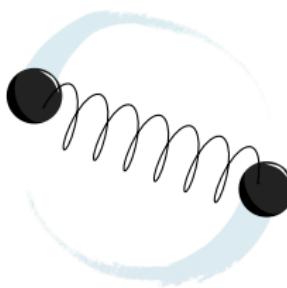
Long-range forces  
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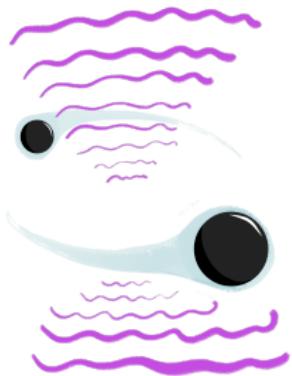
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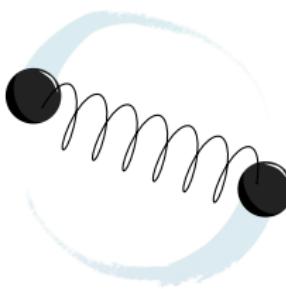
SMBHs can probe  
many NP scenarios

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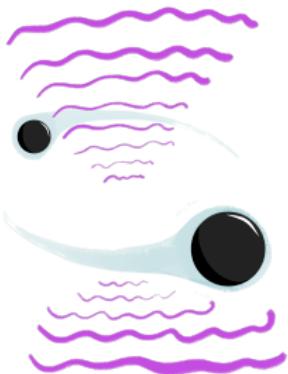
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Data is on the way!

# References I

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