Ring-Up of MAGO-Like Cavity

Tom Krokotsch, 20.03.2024

Avoiding the mechanical ring-up time

A resonator takes the time $\mathrm{T}_{\mathrm{ring-up}} = Q/\omega_{res}$ to reach 40 % of its maximal amplitude

Wall vibration: $\mathrm{T}_{\mathrm{ring-up}} = 17\ \mathrm{min}\ \frac{Q_m/10^6}{\omega_0/\mathrm{kHz}}$

Ring-Up significantly lowered if driven off resonance:

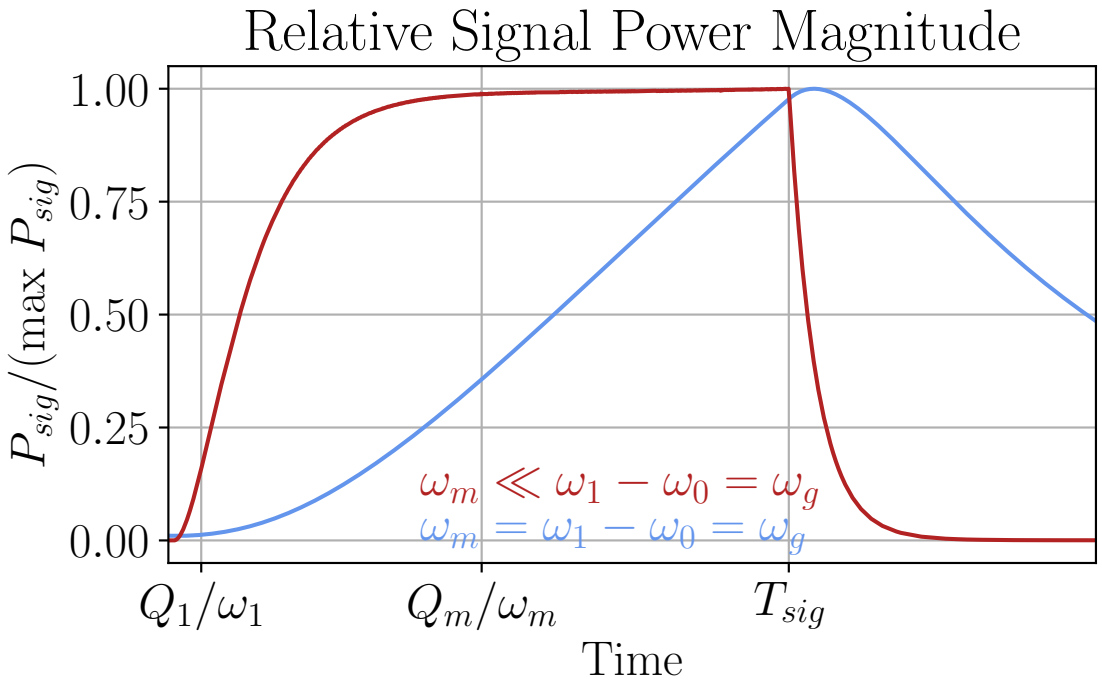
⇒ For transient sources we need $\omega_m \neq \omega_{GW}$

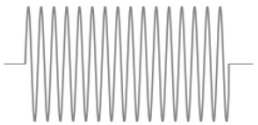
⇒ Signal b(t) becomes independent of ω_m and Q_m

⇒ Vibrational noise goes off resonance too

→ SNR not necessarily lower than on resonance

⇒ Good, since for HFGWs we likely have $\omega_m \ll \omega_{GW}$ anyway



For a pulse  signal

Lowering the EM ring-up time

EM modes: $\mathrm{T_{ring-up}} = 10\ \mathrm{s}\ \frac{Q_m/10^{10}}{\omega_0/\mathrm{GHz}}$

Ring-Up significantly lowered if we couple out more power (overcouple):

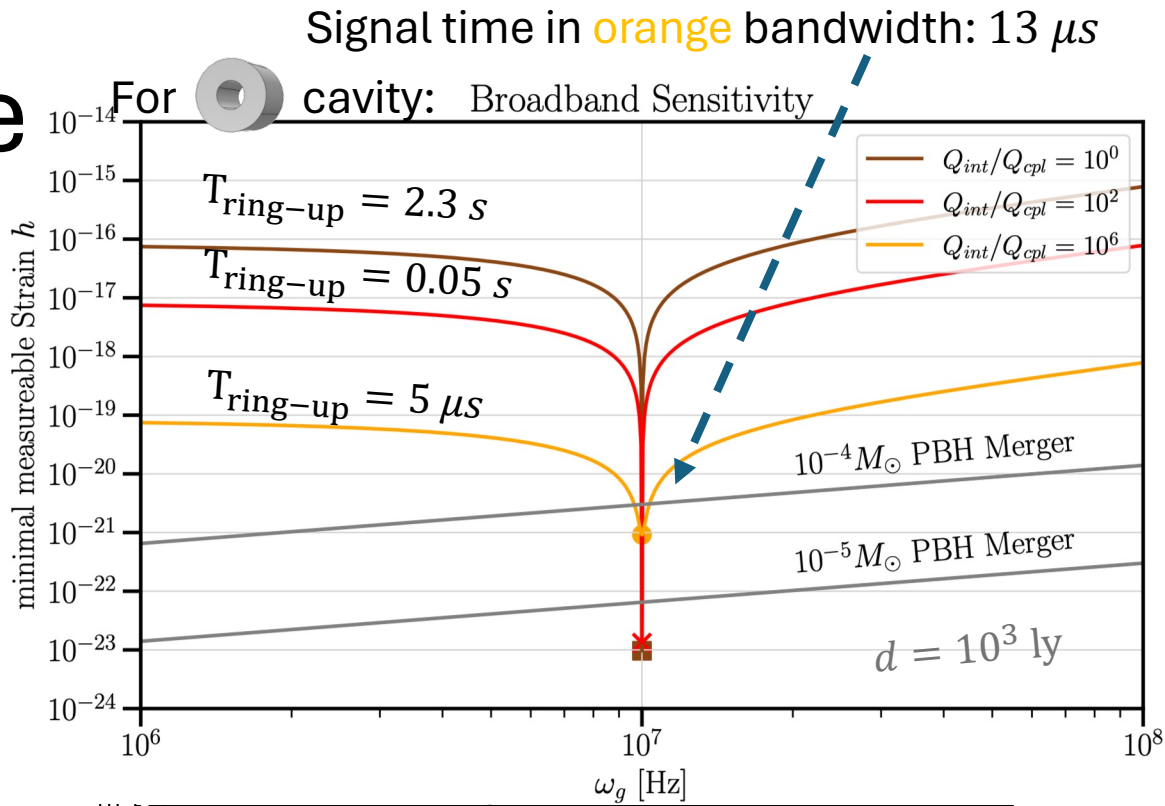
⇒ Q_{loaded} is lowered ($Q_{cpl} << Q_{int}$)

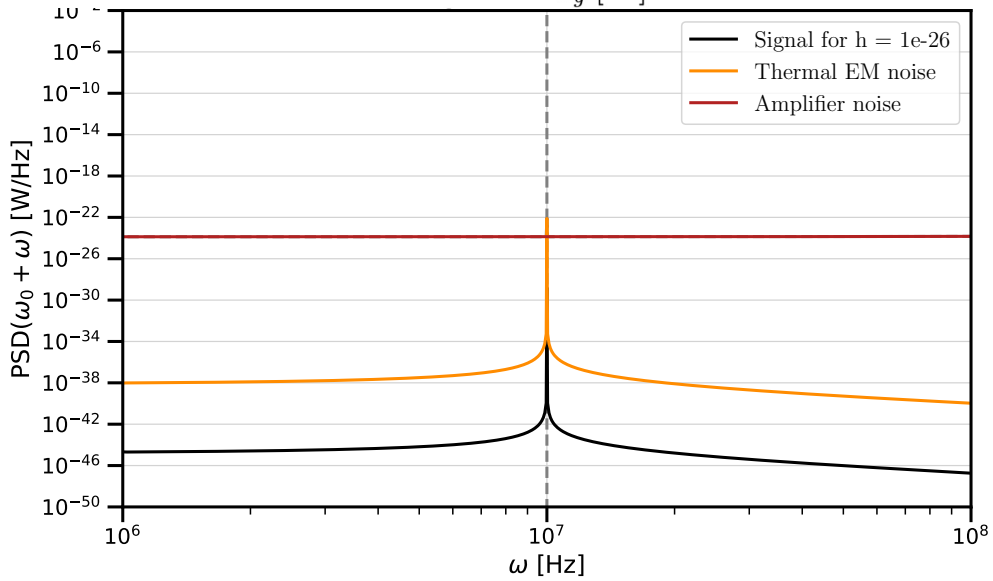
⇒ Signal on resonance is lowered

⇒ Signal off resonance enhanced (if amp noise dominates)

⇒ Bandwidth is broadened

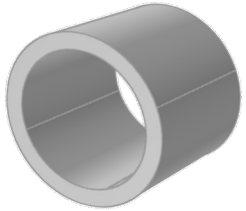
⇒ May allow *some* PBH merger sensitivity

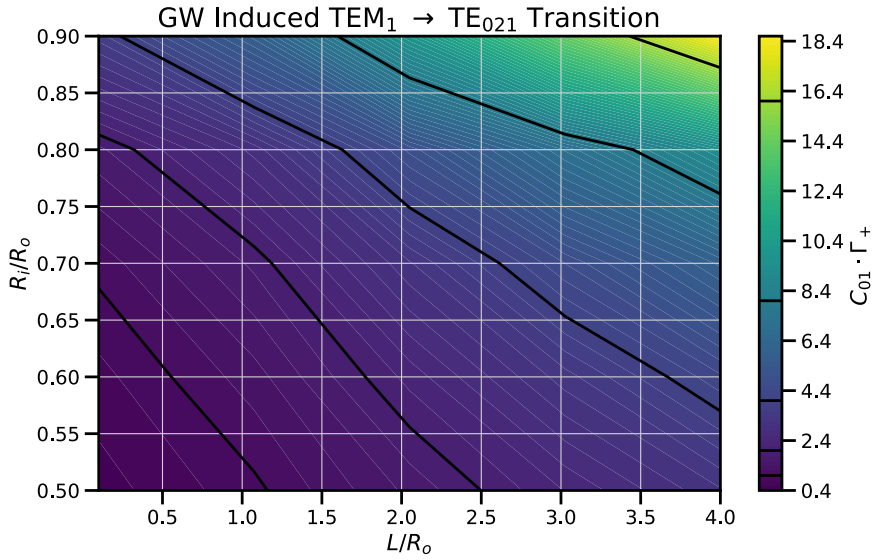


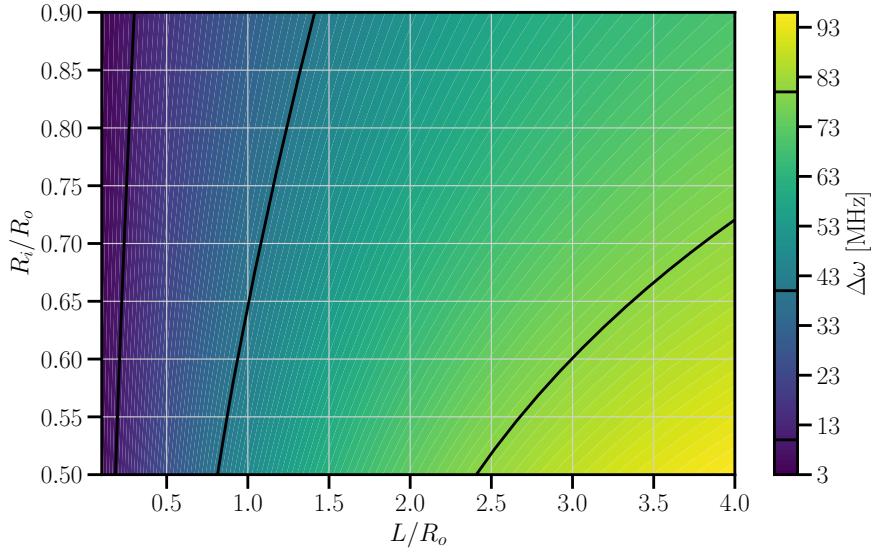


Cavity Details And Assumptions

Outer Radius:	$1.4\ \mathrm{m}$
Inner Radius:	$1.1\ \mathrm{m}$
Length:	$0.4\ \mathrm{m}$
Volume:	$1\ \mathrm{m}^3$
$\omega_1 - \omega_0$:	$(356 - 348)\ \mathrm{MHz} = 8\ \mathrm{MHz}$
Q_{EM}:	10^{10}
$Q_{\mathrm{vibration}}$:	10^6
$\omega_{\mathrm{quad.\ vibration}}$:	$1\ \mathrm{kHz}$
E_{pump}:	$400\ \mathrm{J}$
Temperature	1.8 K

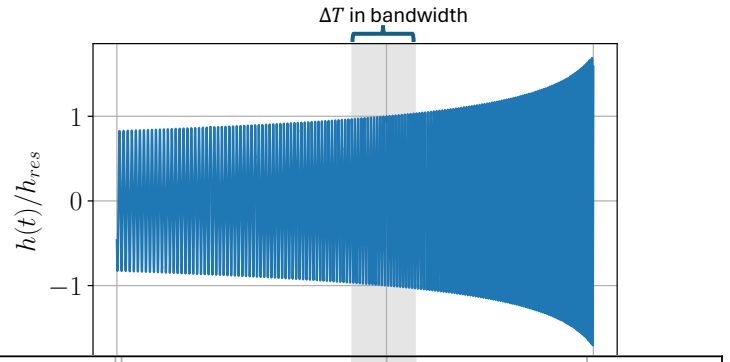




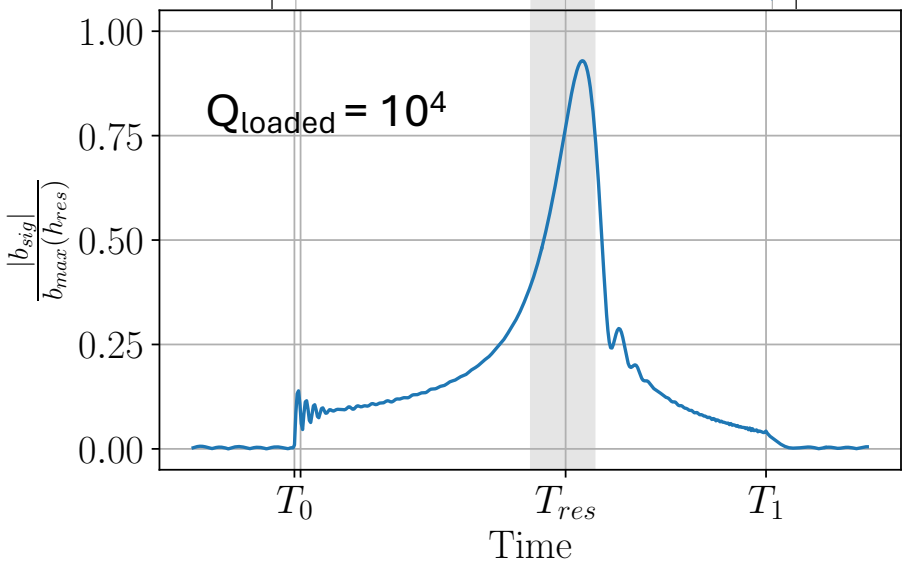


Realistic Chirp Signal

GW signal:

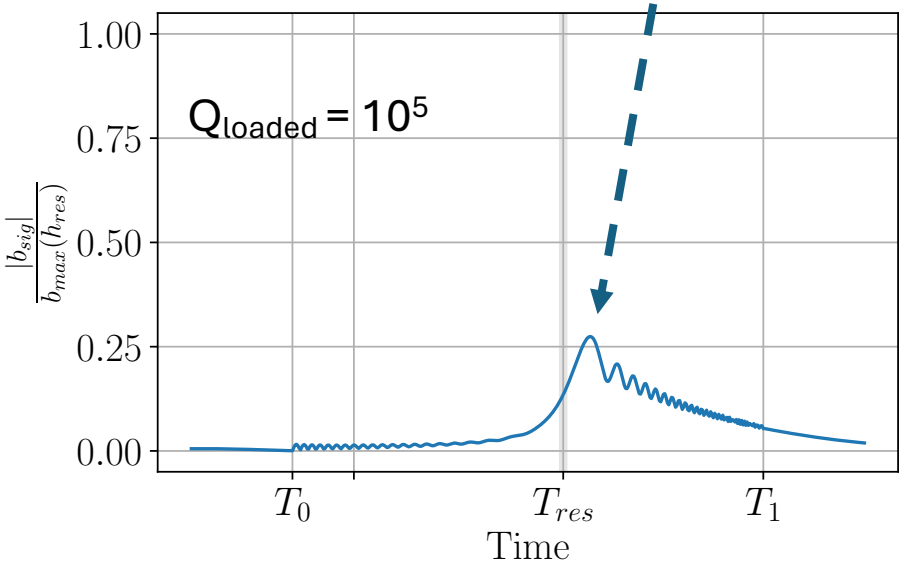


Output:



y-axis means:
relative signal b-field amplitude, if the GW would fully ring up the cavity with the strain it has at frequency $\omega_1 - \omega_0$

Only 25% of the fully rung up sensitivity is reached

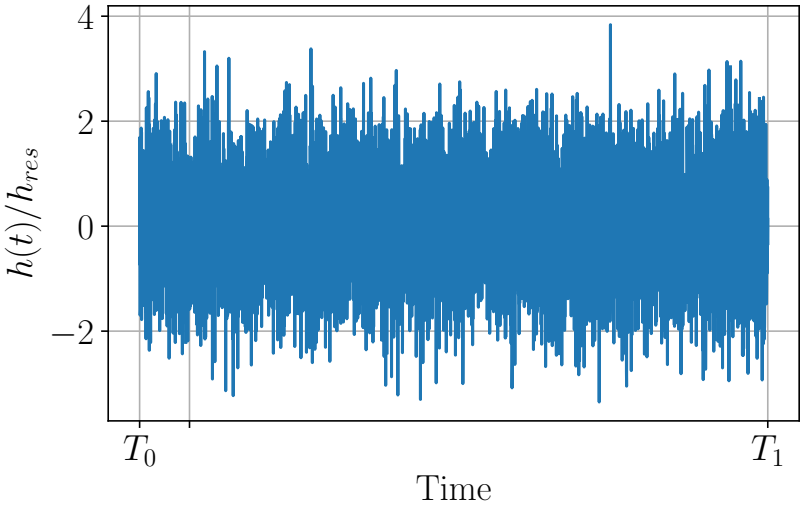


Assuming here:
$\omega_0 =$ GHz
$\omega_1 = \omega_0 + 2$ MHz

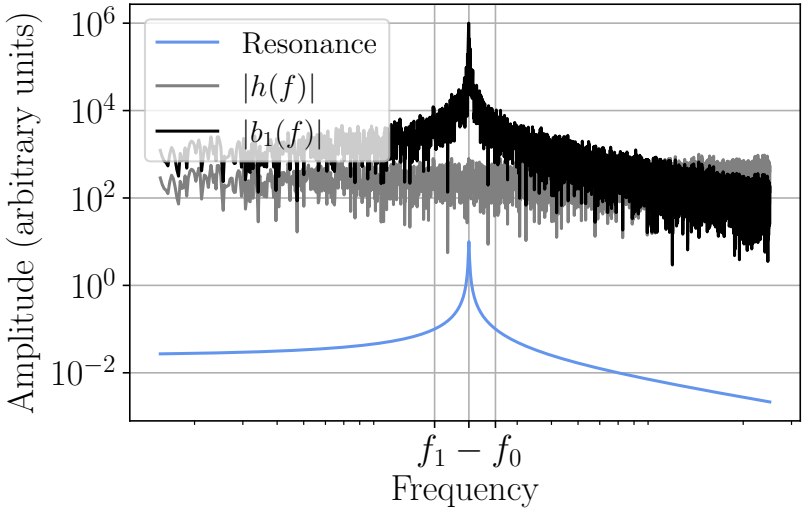
Stochastic Backgrounds

- Does a stochastic background resonantly excite a cavity at all?
- If not, shouldn't most noise *not* ring up a cavity too?

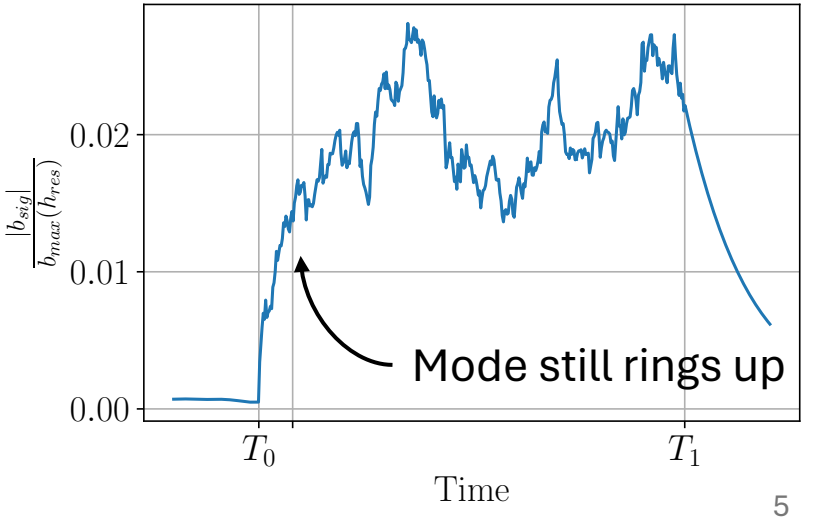
E.g. Gaussian Signal:



Spectra



Signal in Cavity



(ensemble average over 10 realizations)