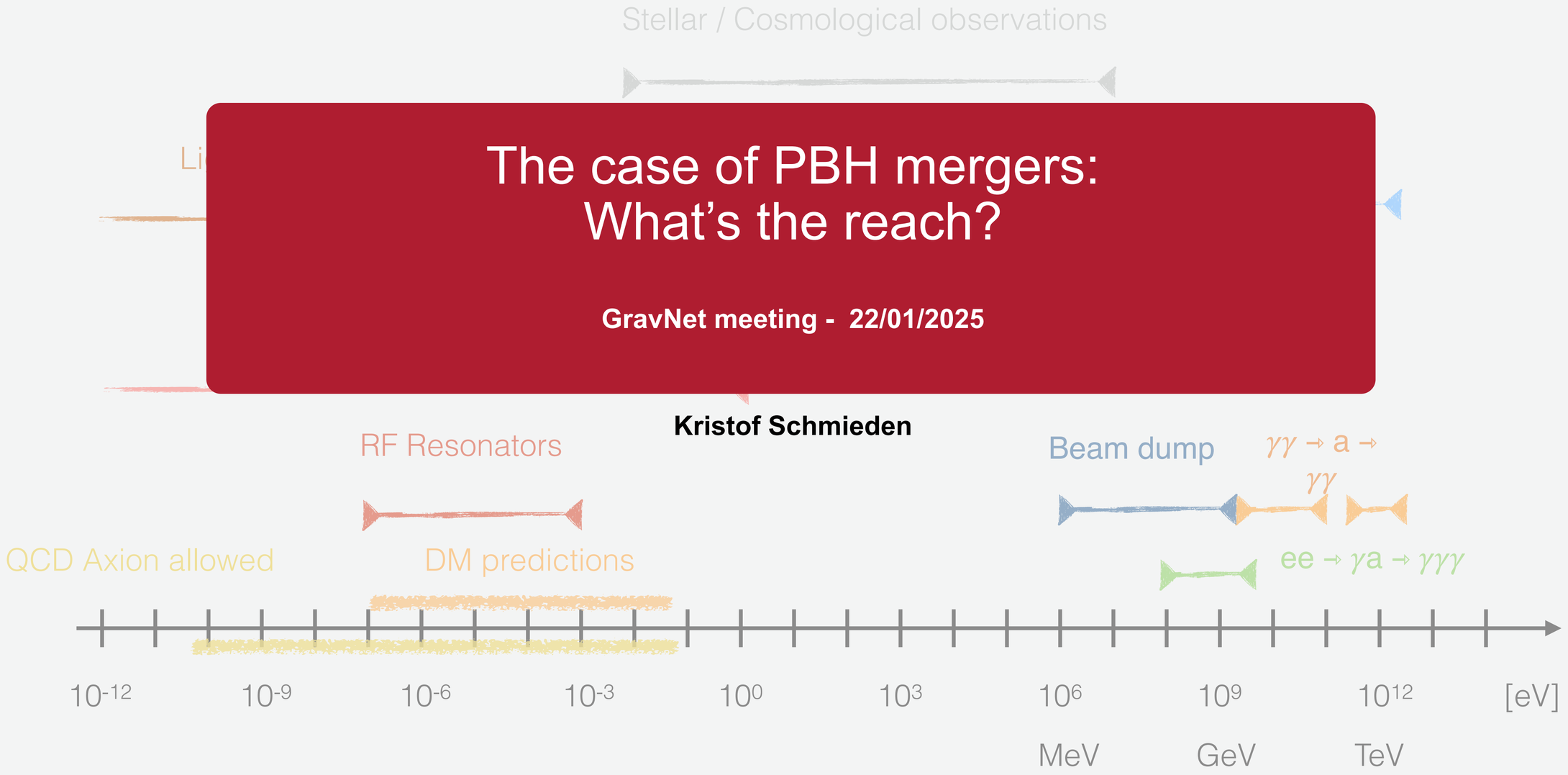
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

JG|U

The case of PBH mergers: What's the reach?

GravNet meeting - 22/01/2025

Kristof Schmieden



How many photons can we expect in a cavity?

- Signal strain:

$$h_0 = 9.77 \cdot 10^{-34} \left(\frac{f}{GHz}\right)^{\frac{2}{3}} \left(\frac{m_{PBH}}{10^{-12} M_\odot}\right)^{\frac{5}{3}} \left(\frac{d}{kpc}\right)^{-1} = 1.3 \cdot 10^{-22}$$ 2205.02153, eq. 2.29

- RF power:

$$P_{sig} = \frac{1}{2\mu_0 c^2} Q (2\pi f)^3 V^{\frac{5}{3}} (\eta h_0 B)^2 = 1.3 \cdot 10^{-24} W$$ 2303.06006, eq. 6

- **Assumptions:**
  - $m_{PBH} = 10^{-15}\, M_\odot$
  - Distance $d = 2.7 \cdot 10^{-15} kpc$
  - Cavity: $f_0 = 5\, GHz, V = 0.01\, m^3, Q = 10^5, \eta = 0.1$
  - $B = 12\, T$

- RF Energy deposited in cavity:
  - Time of signal Δt within cavity bandwidth $bw = f_0/Q = 50 kHz$:

$$\dot{f} = 4.62 \cdot 10^{11} Hz^2 \left(\frac{f}{GHz}\right)^{\frac{11}{3}} \left(\frac{m_{PBH}}{10^{-9} M_\odot}\right)^{\frac{5}{3}} = 1.7 \cdot 10^4 \frac{Hz}{s}$$ 2205.02153, eq. 2.35

$$\Delta t = \frac{bw}{\dot{f}} = \frac{f_0}{Q\dot{f}} = 3\, s$$

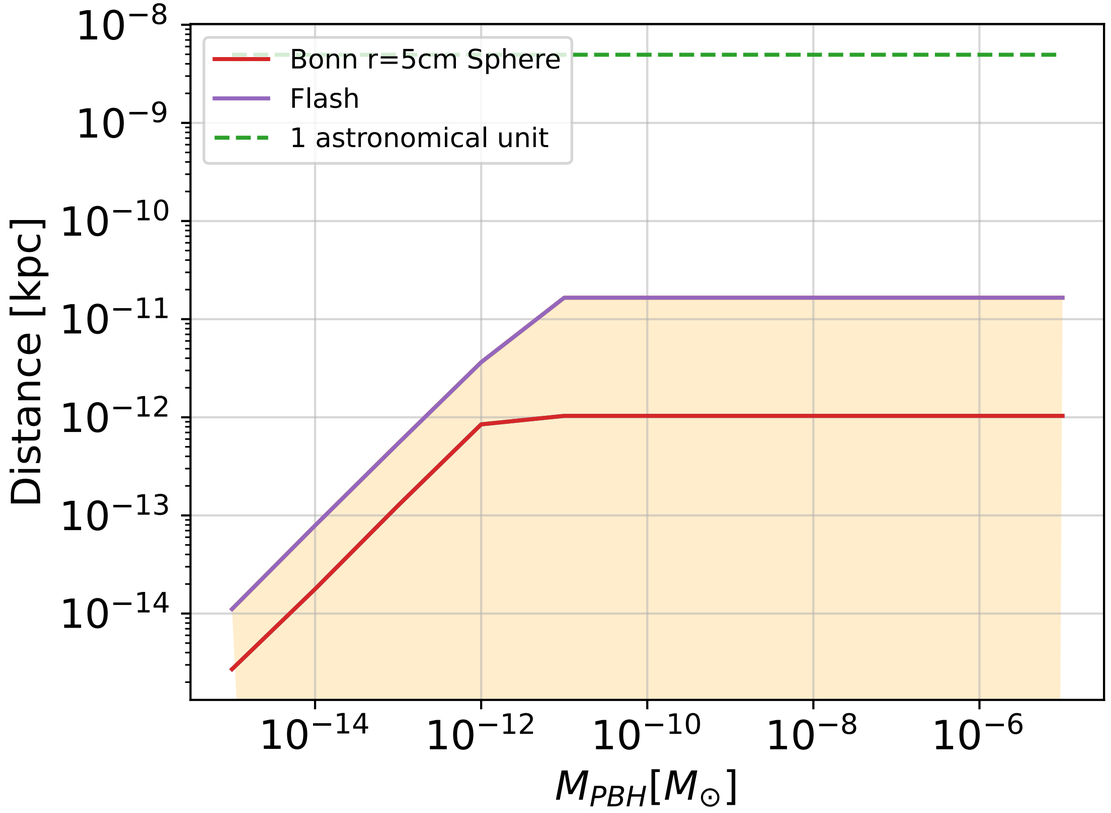
$$E_{sig} = P_{sig} \cdot \Delta t = 3.9 \cdot 10^{-24} J$$

$$N_\gamma = \frac{E_{sig}}{hf} = \frac{3.9 \cdot 10^{-24}}{3.3 \cdot 10^{-24}} \approx 1$$

$$N_\gamma \propto d^{-2} B^2 V^{\frac{5}{5}} f^{\frac{5}{3}}$$

How far can we look?

- Finding distance for which at least one photon is generated within the bandwidth of the cavity

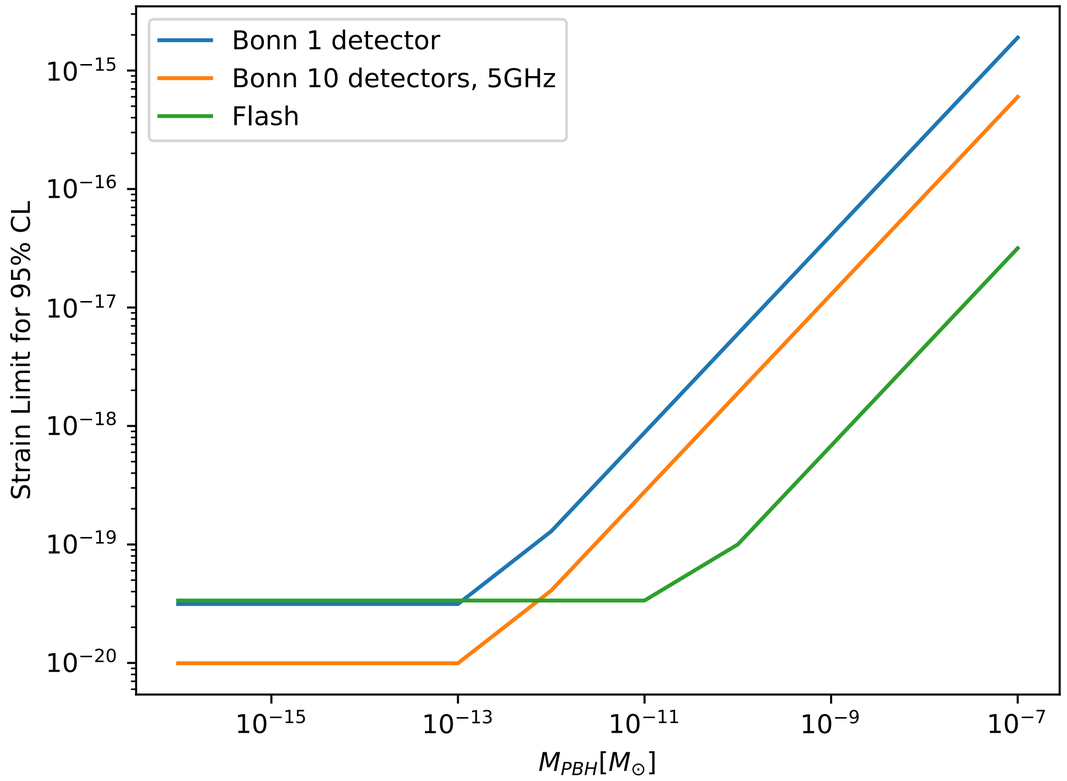


- Effective quality factor for fast transients:
  - $Q_{eff} = \min(Q, N_{cycles})$

New plots

Whats the limit on the strain that can be reached?

- Assuming only thermal noise
- Given a readout / integration time, what strain can be detected with a 95% CL given 1 event per year?
  - This is just using number of photons, assuming a detector with $\epsilon = 1$, capable of counting photons
- At least 1 photon is forced -> const. region in plot



Whats the limit on the strain that can be reached?

- Assuming only thermal noise
- Given a readout / integration time, what strain can be detected with a 95% CL given 1 event per year?
  - This is just using number of photons, assuming a detector with $\epsilon = 1$, capable of counting photons
- For long integration times > 1 second: SNR = 1 is chosen as figure of merit, in line with existing publications