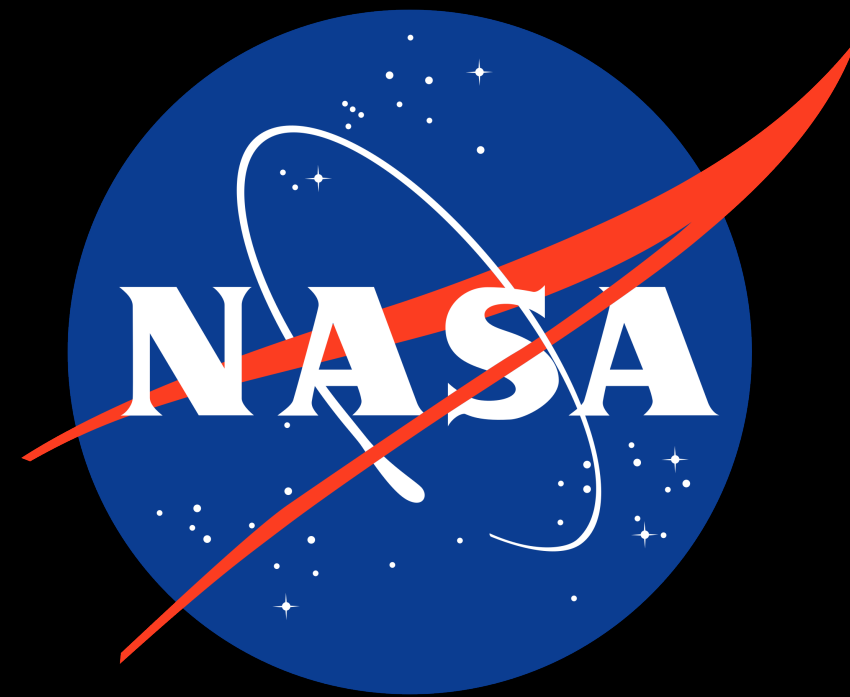


# Gravitational Wave Cosmology



Tyson B. Littenberg @ NASA Marshall Space Flight Center

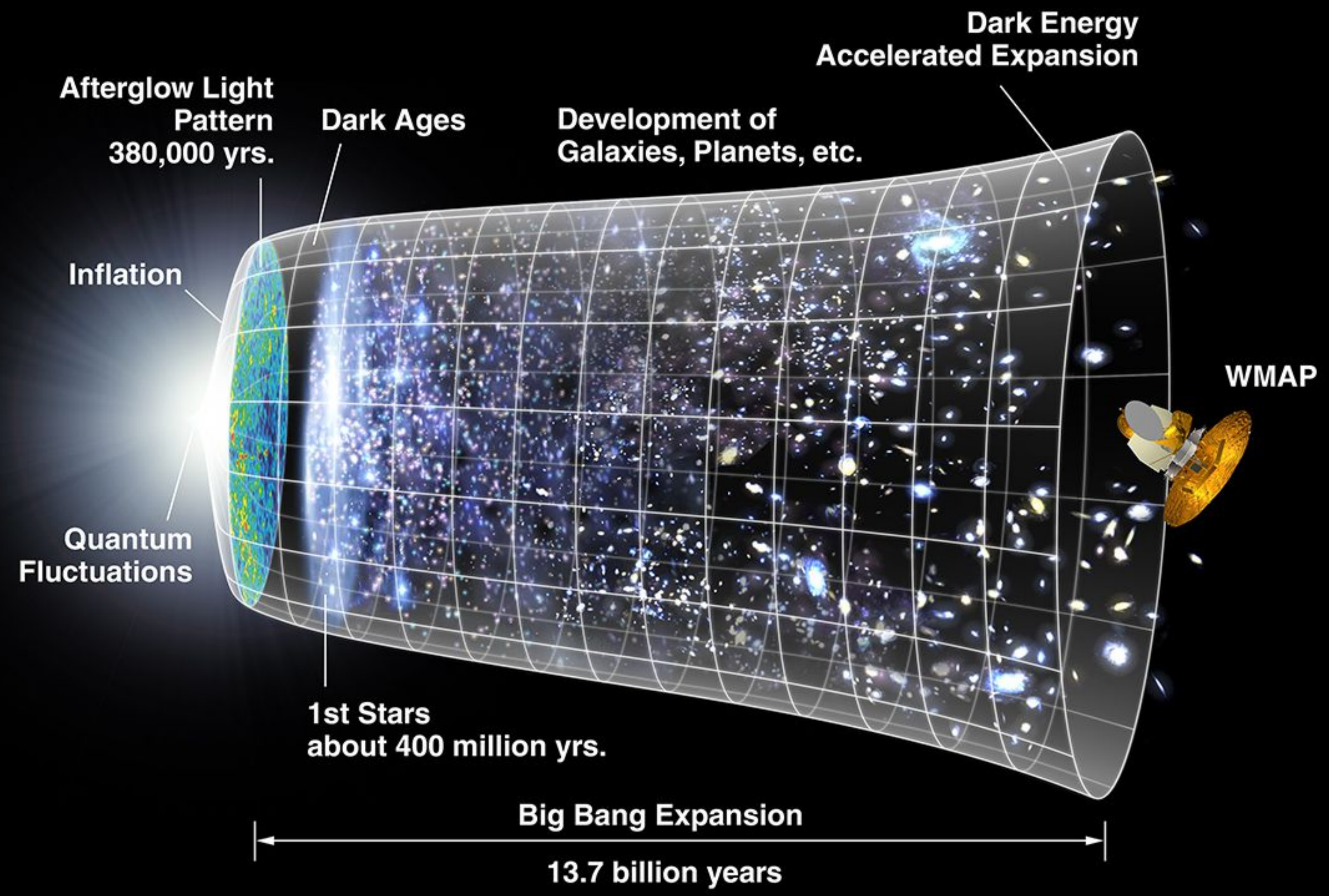
" ... 5-10 YEARS ... BE BOLD ... "

- THE S.O.C.

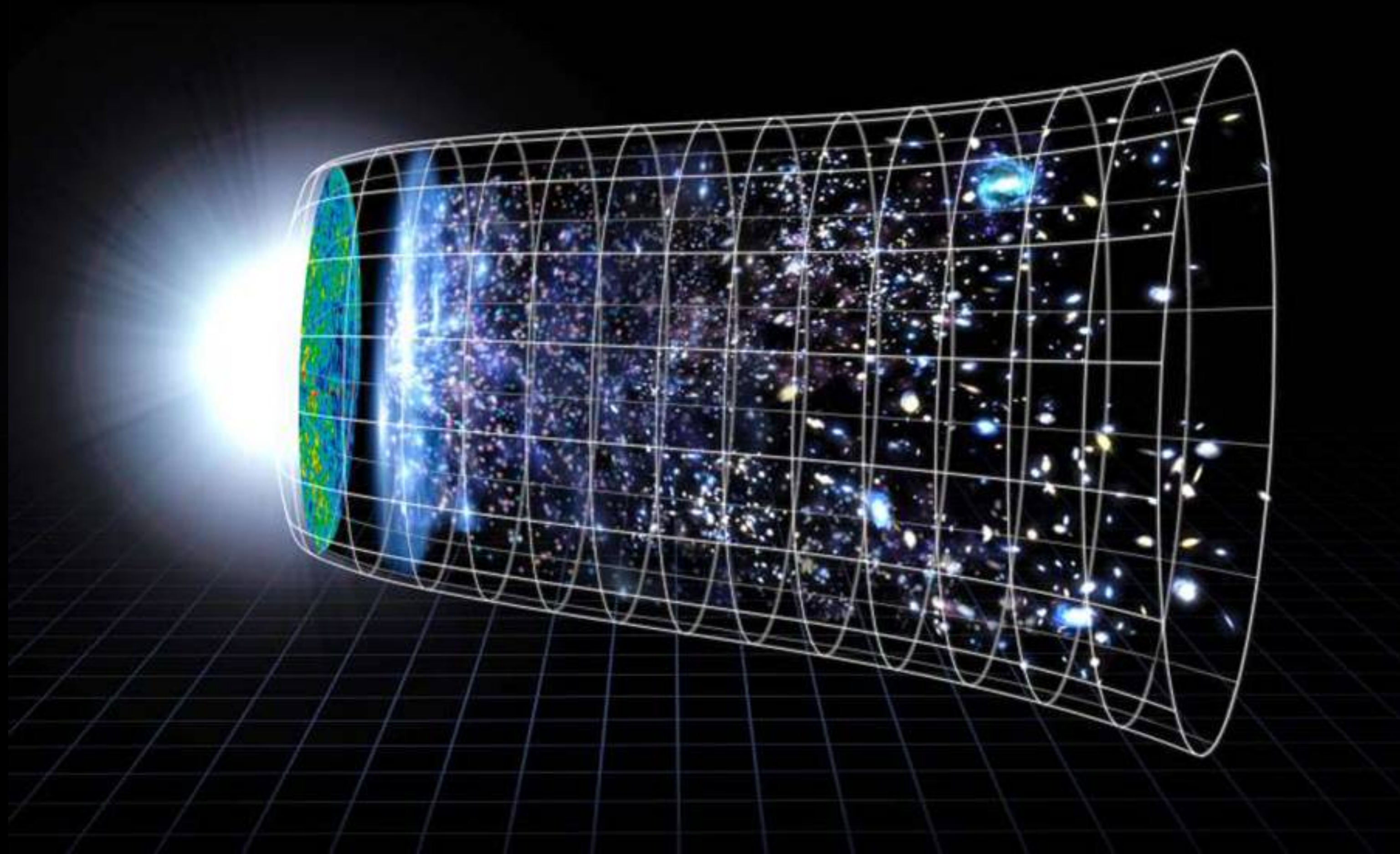
"... 5-10 YEARS ... BE BOLD ..."

- THE S.O.C.

$P(\text{TALK} \mid \text{EVERYTHING GETTING BUILT, A LITTLE AHEAD OF SCHEDULE})$

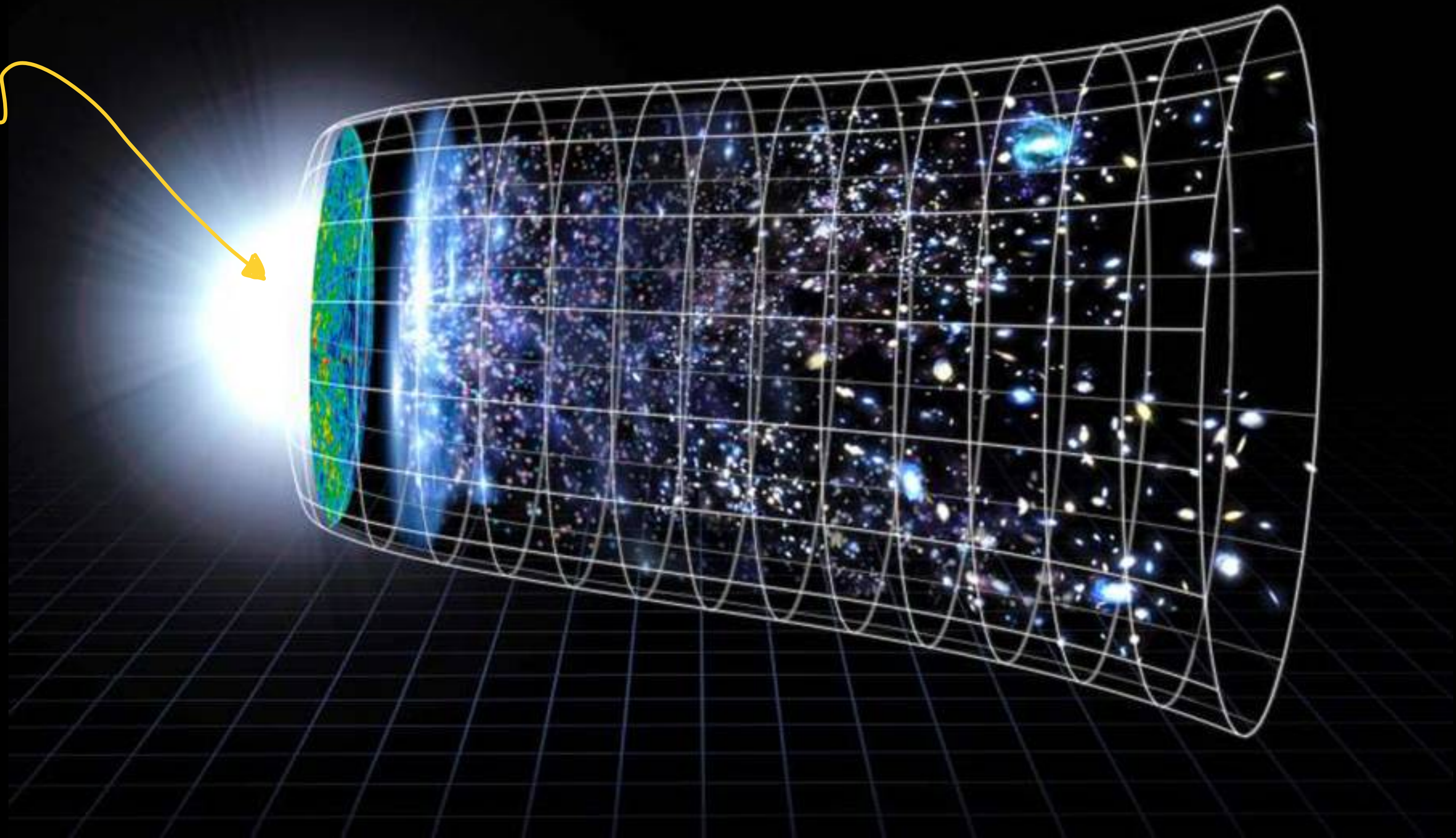
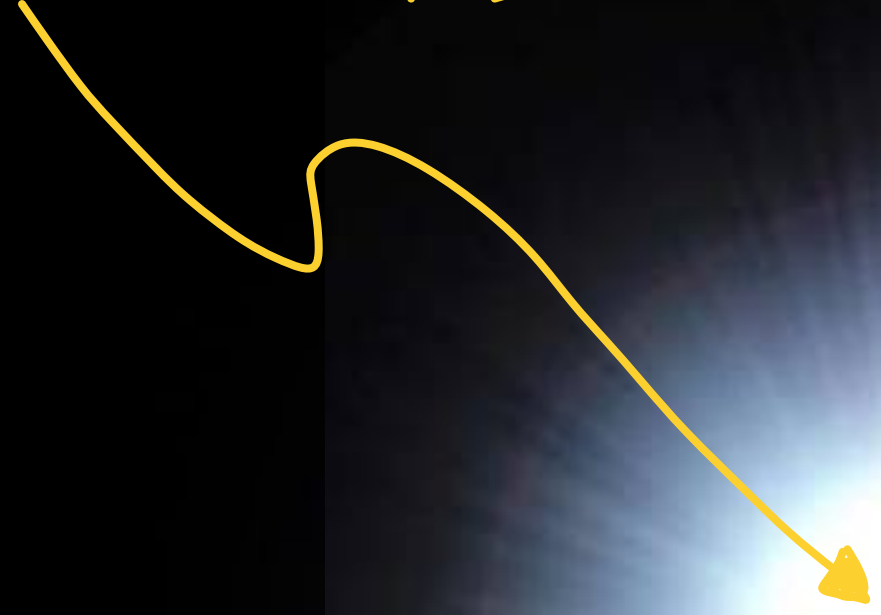


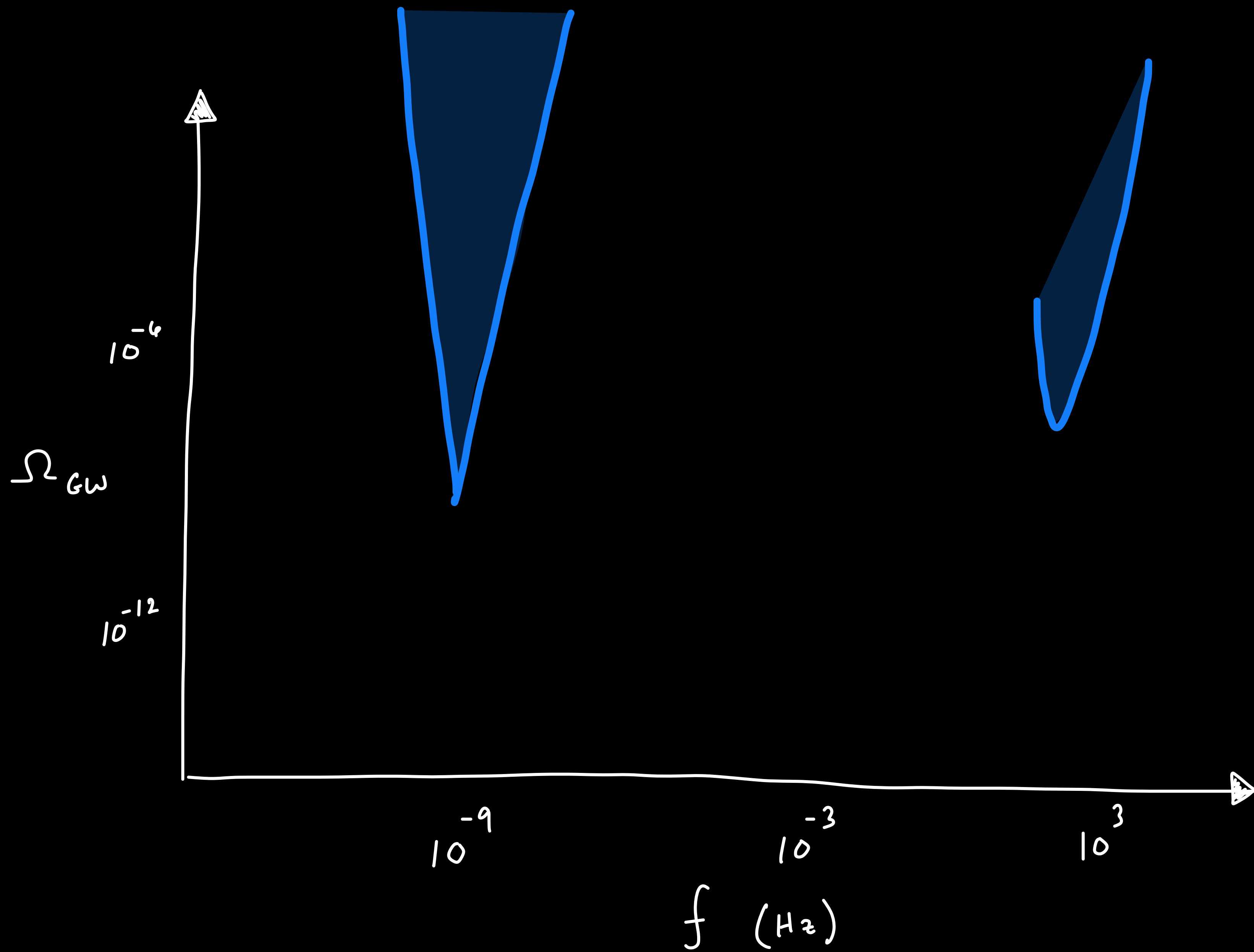


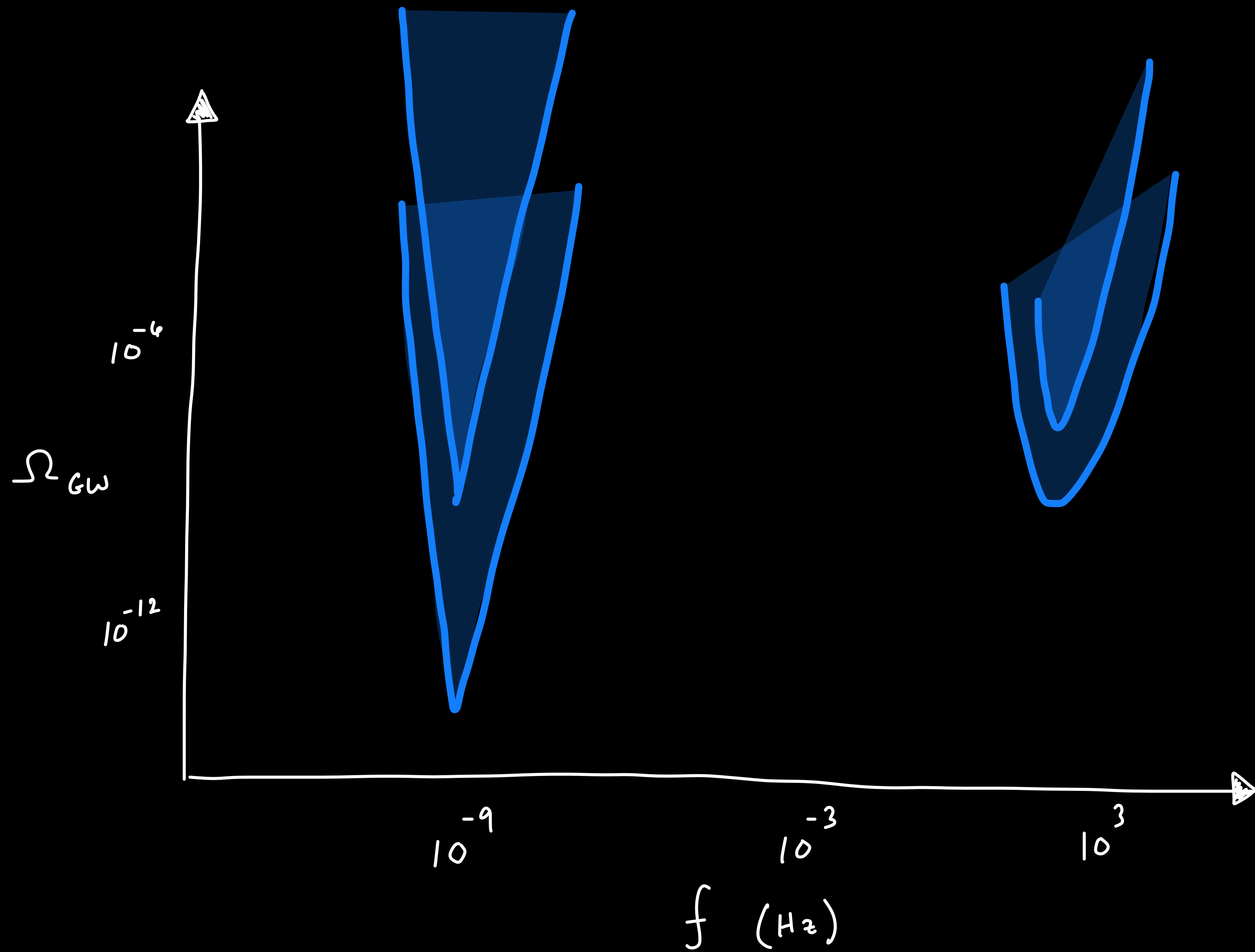




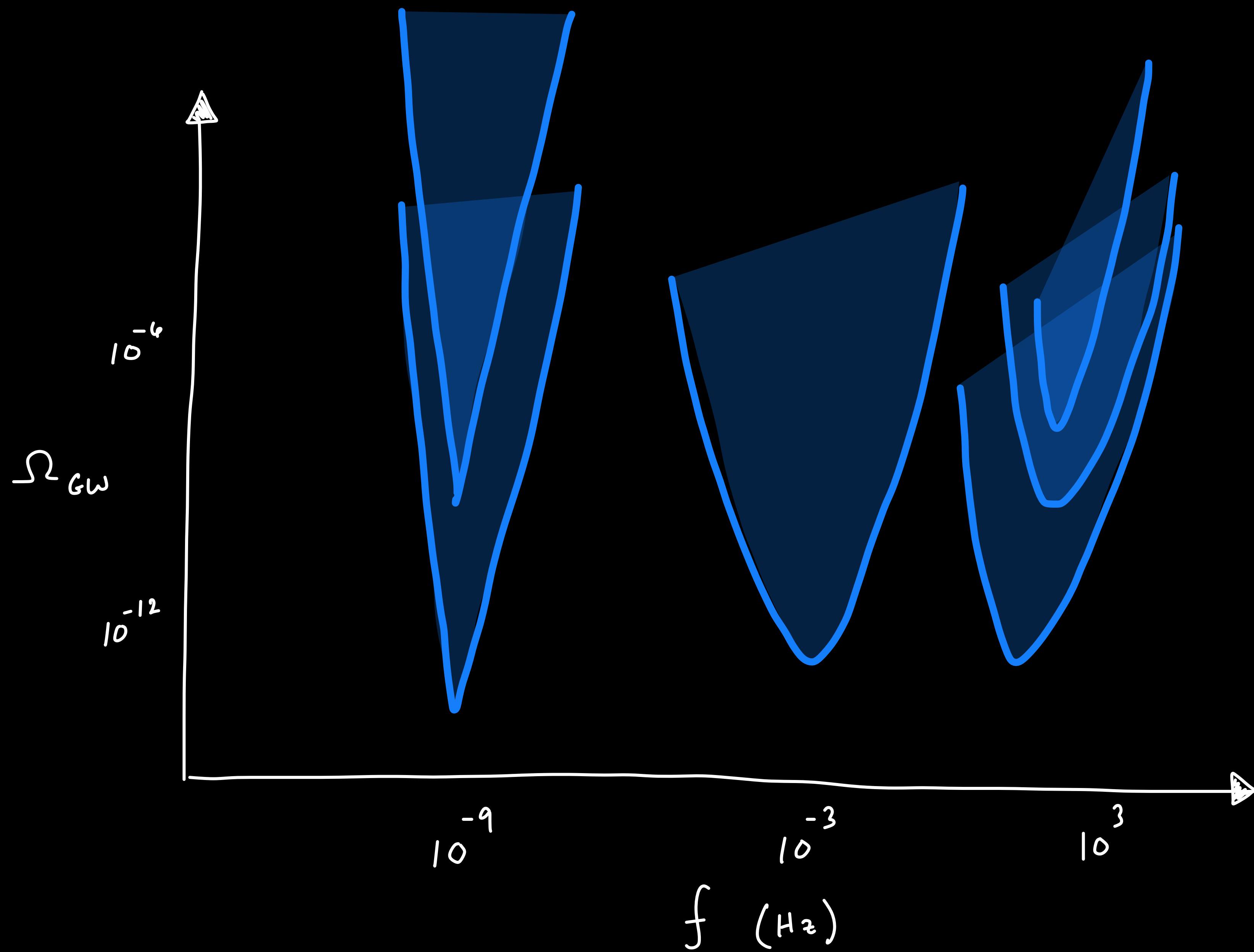
COSMOLOGICAL  
GW BACKGROUND

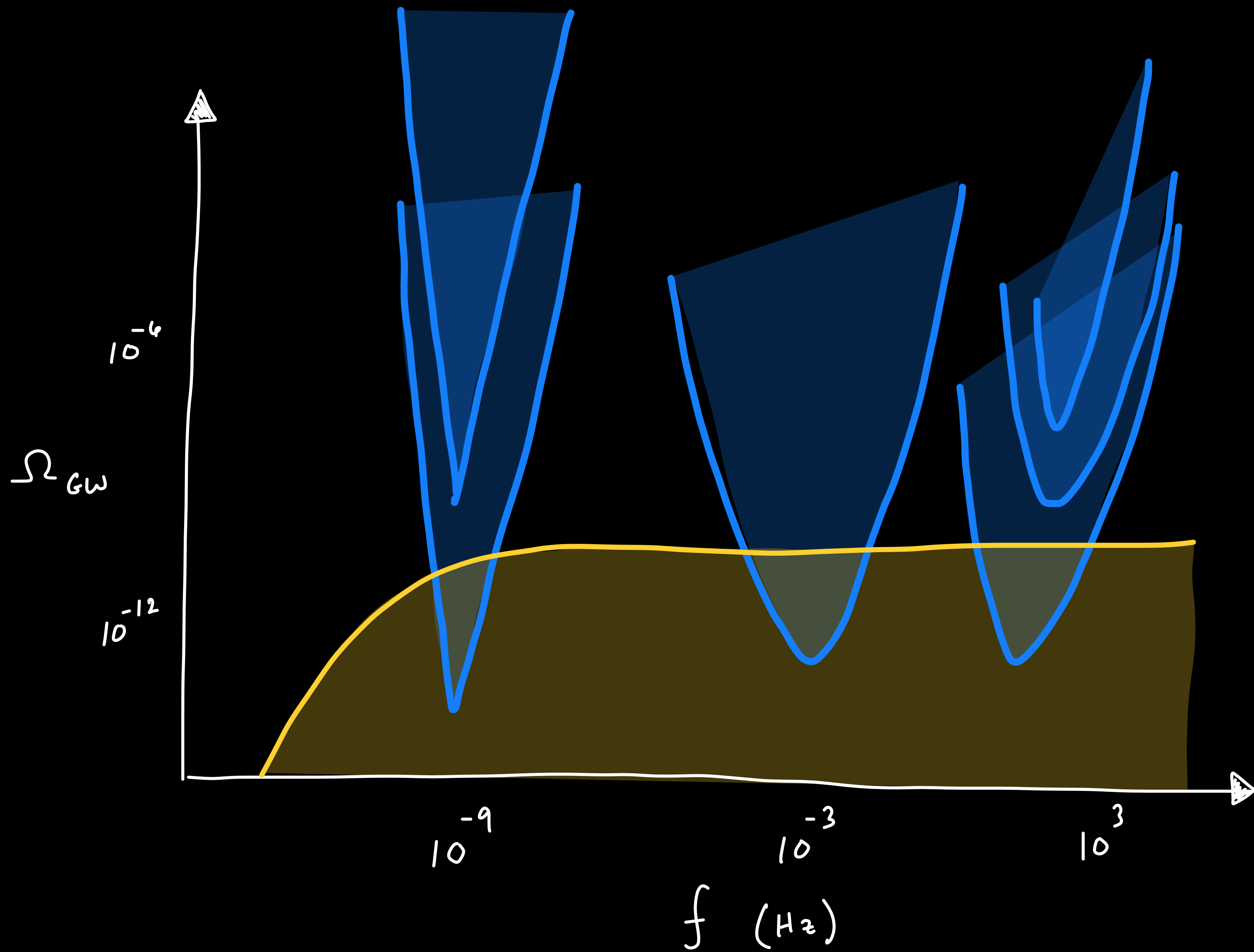




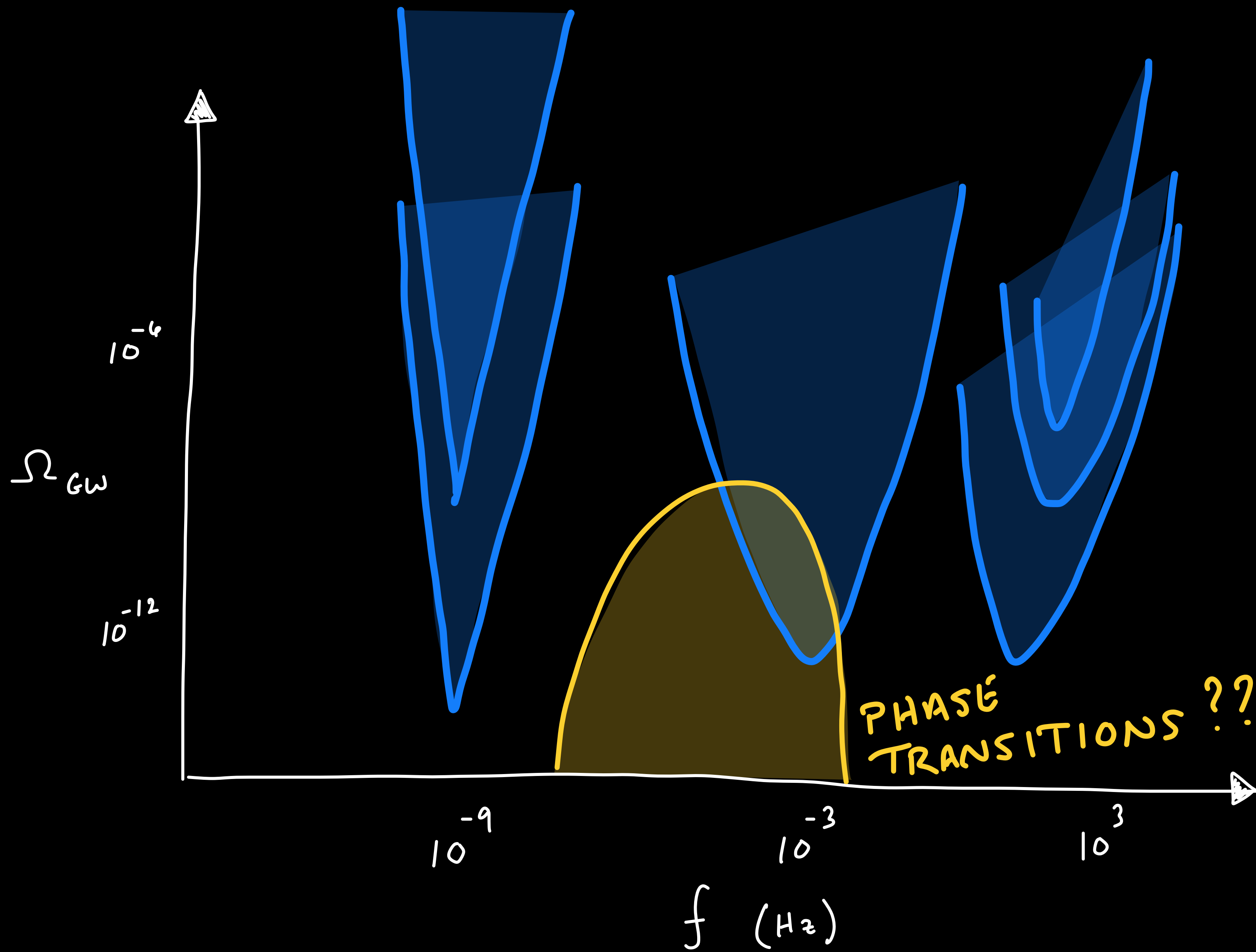




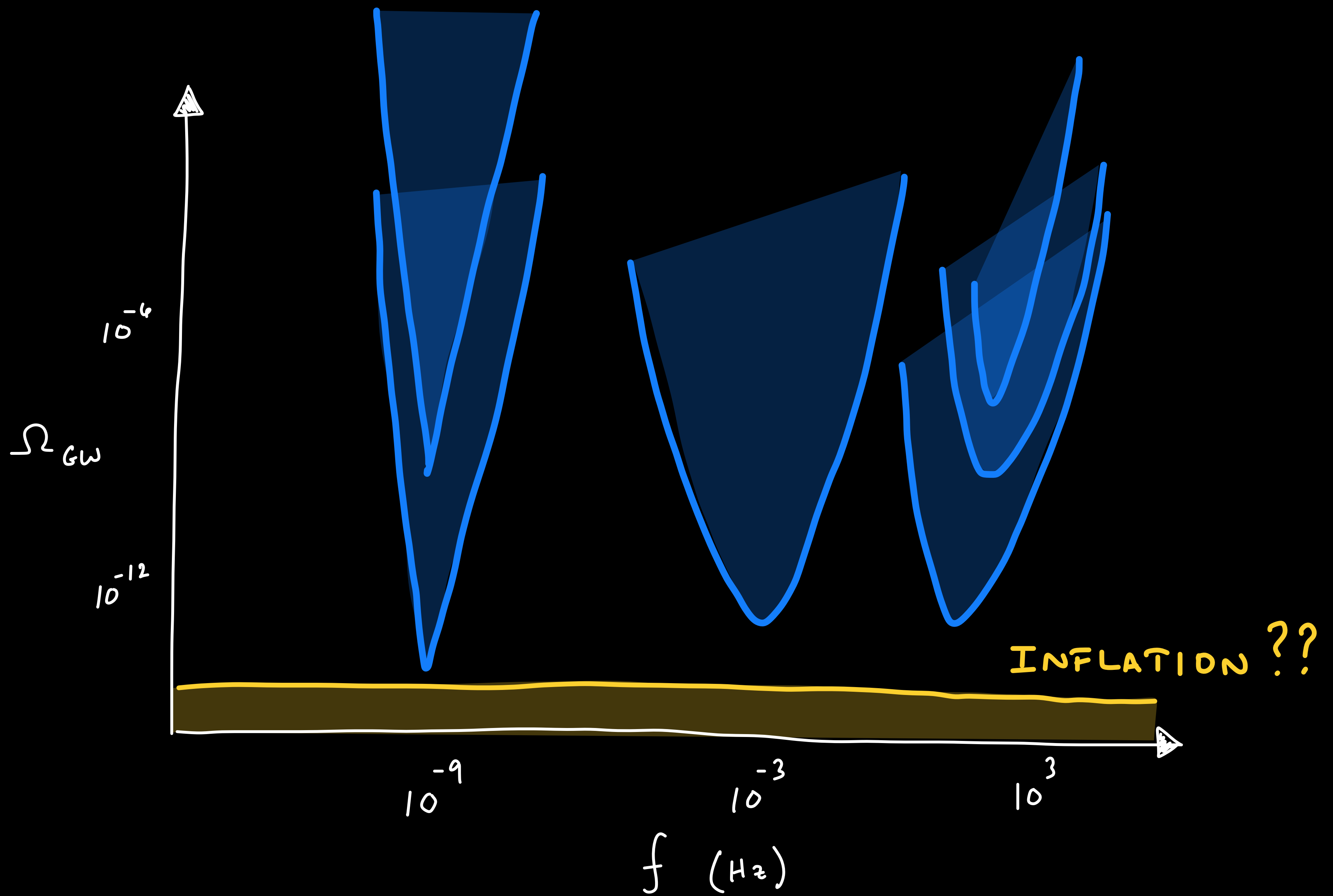


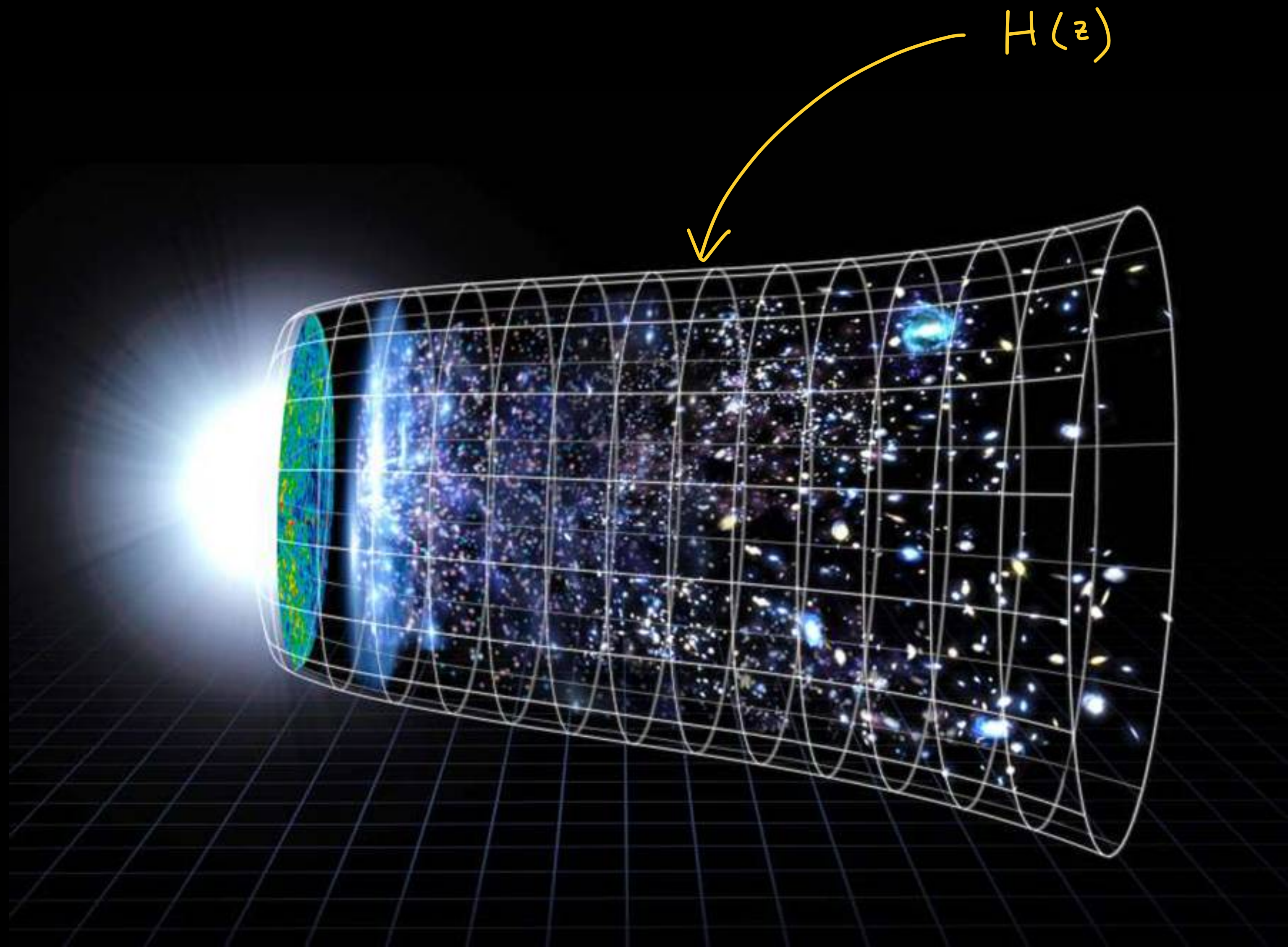


COSMIC STRINGS??









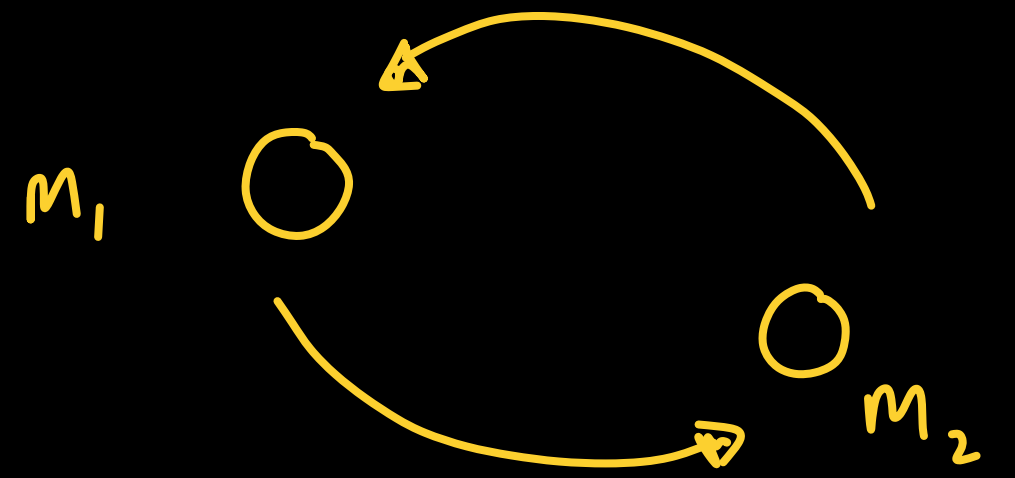
$$h \sim A e^{i\Phi}$$



$$h \sim \frac{A_*}{D_L} e^{i\Phi}$$

$$h \sim \frac{A_*}{D_L} e^{i\Phi}$$

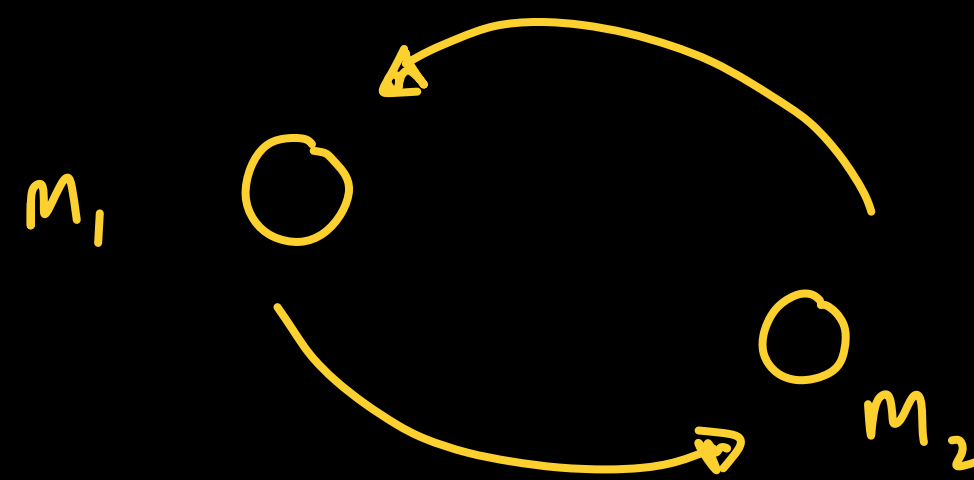
$$A_* \propto \mathcal{M}(1+z)$$



$$h \sim \frac{A_*}{D_L} e^{i\bar{\Phi}}$$

$$A_* \propto \mu(1+z)$$

$$\bar{\Phi} \propto (\mu(1+z))^{5/3} + \dots$$

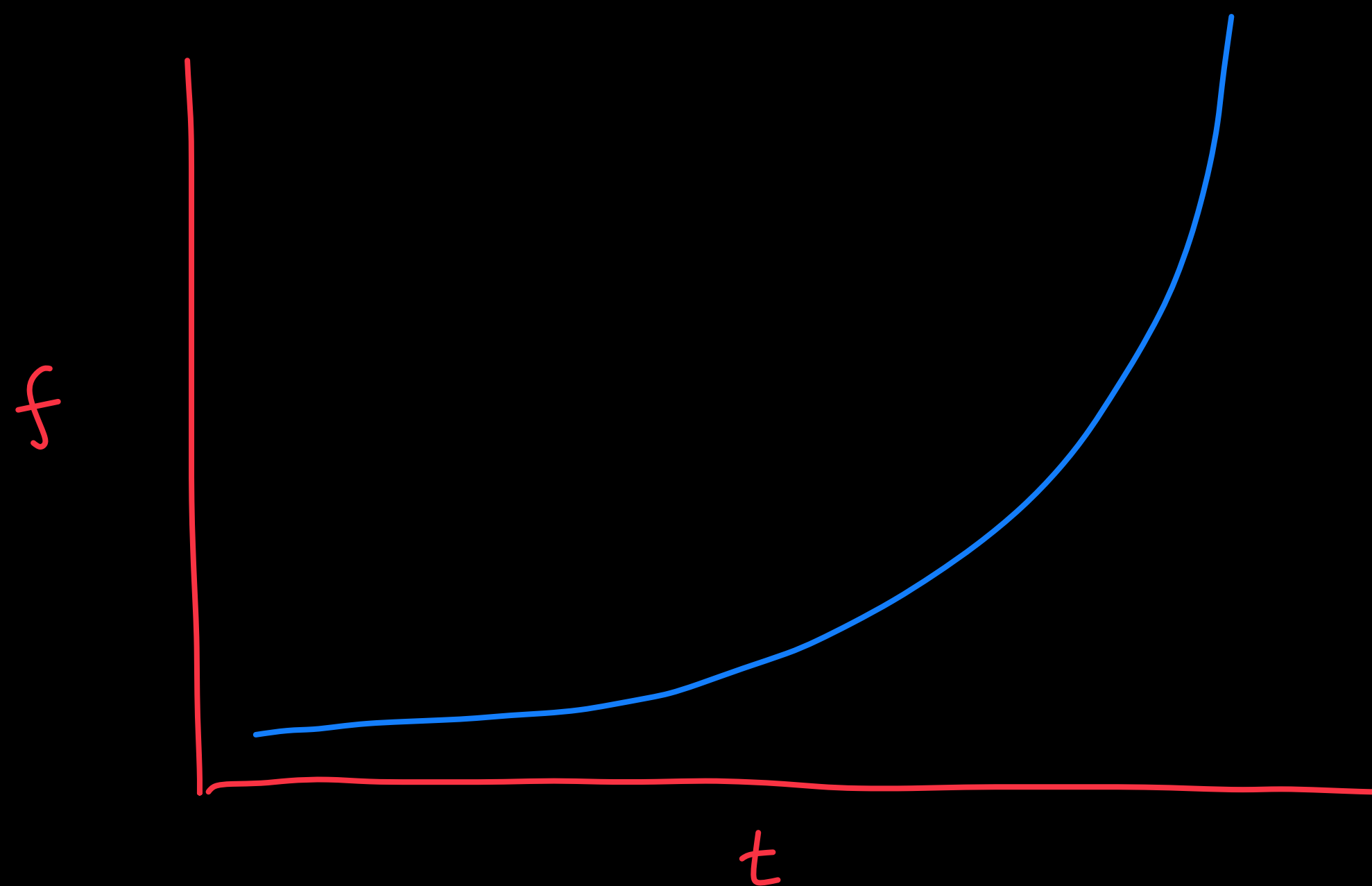
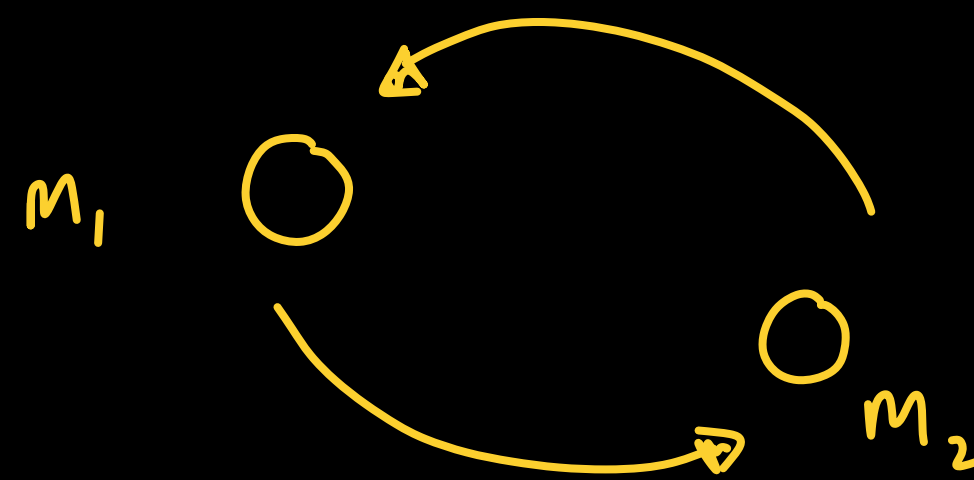




$$h \sim \frac{A_*}{D_L} e^{i\Phi}$$

$$A_* \propto \mu(1+z)$$

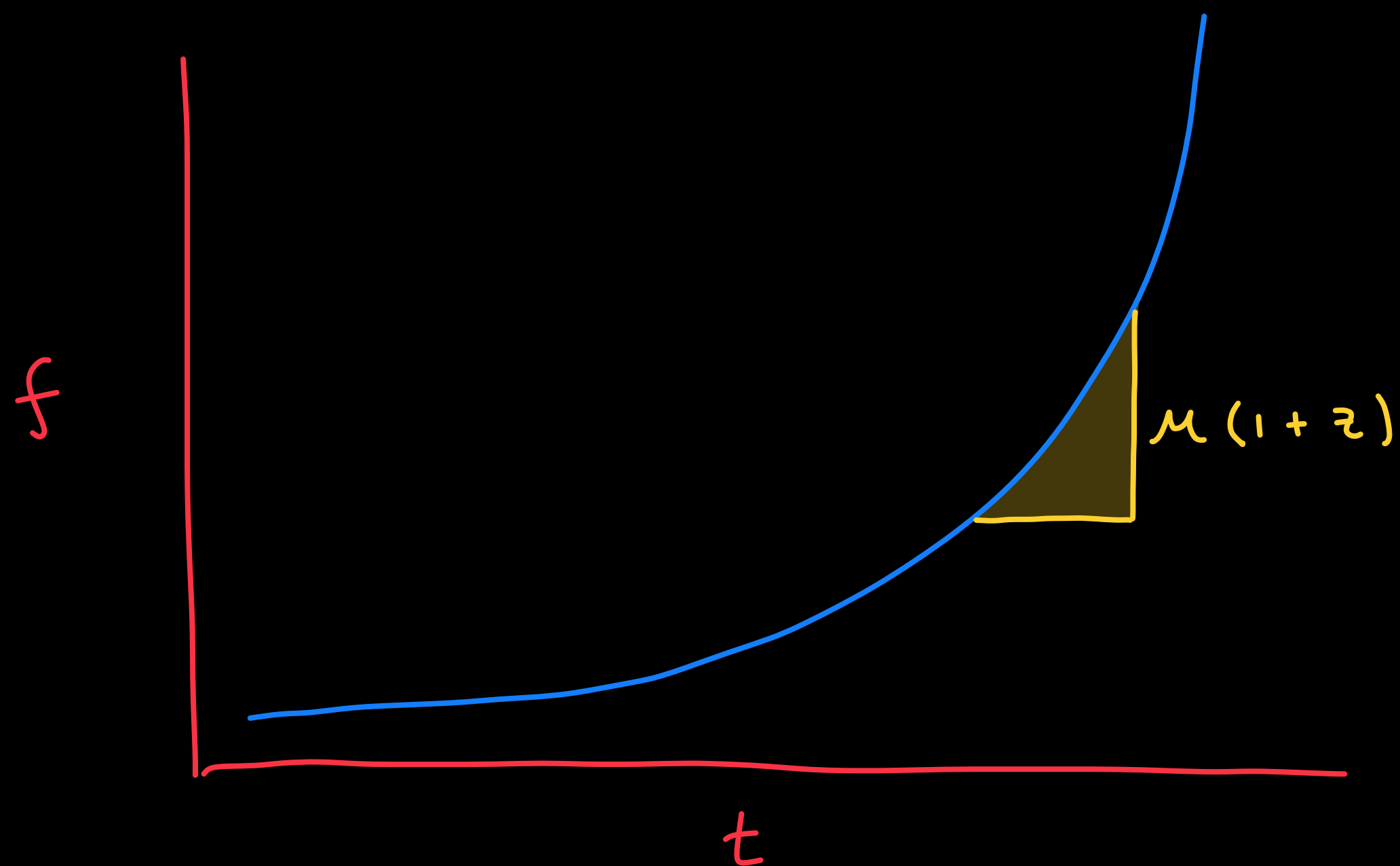
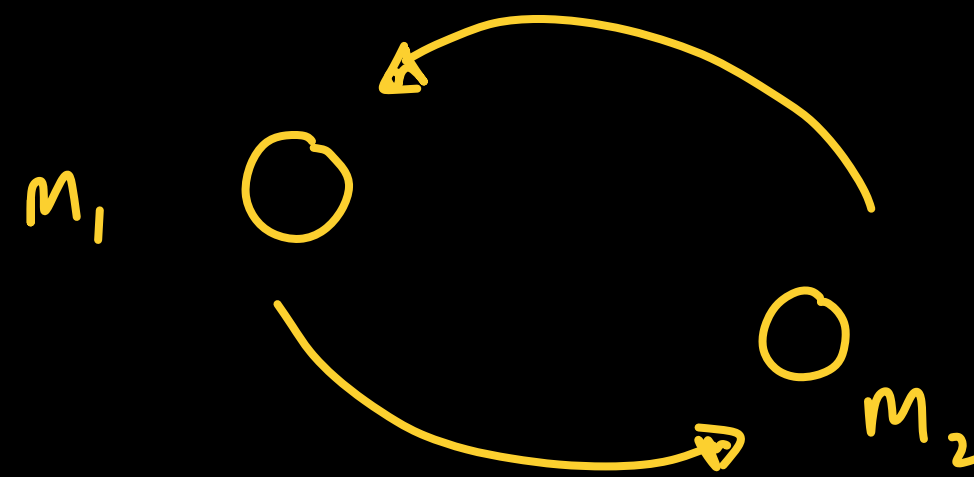
$$\Phi \propto (\mu(1+z))^{5/3} + \dots$$



$$h \sim \frac{A_*}{D_L} e^{i\Phi}$$

$$A_* \propto \mu(1+z)$$

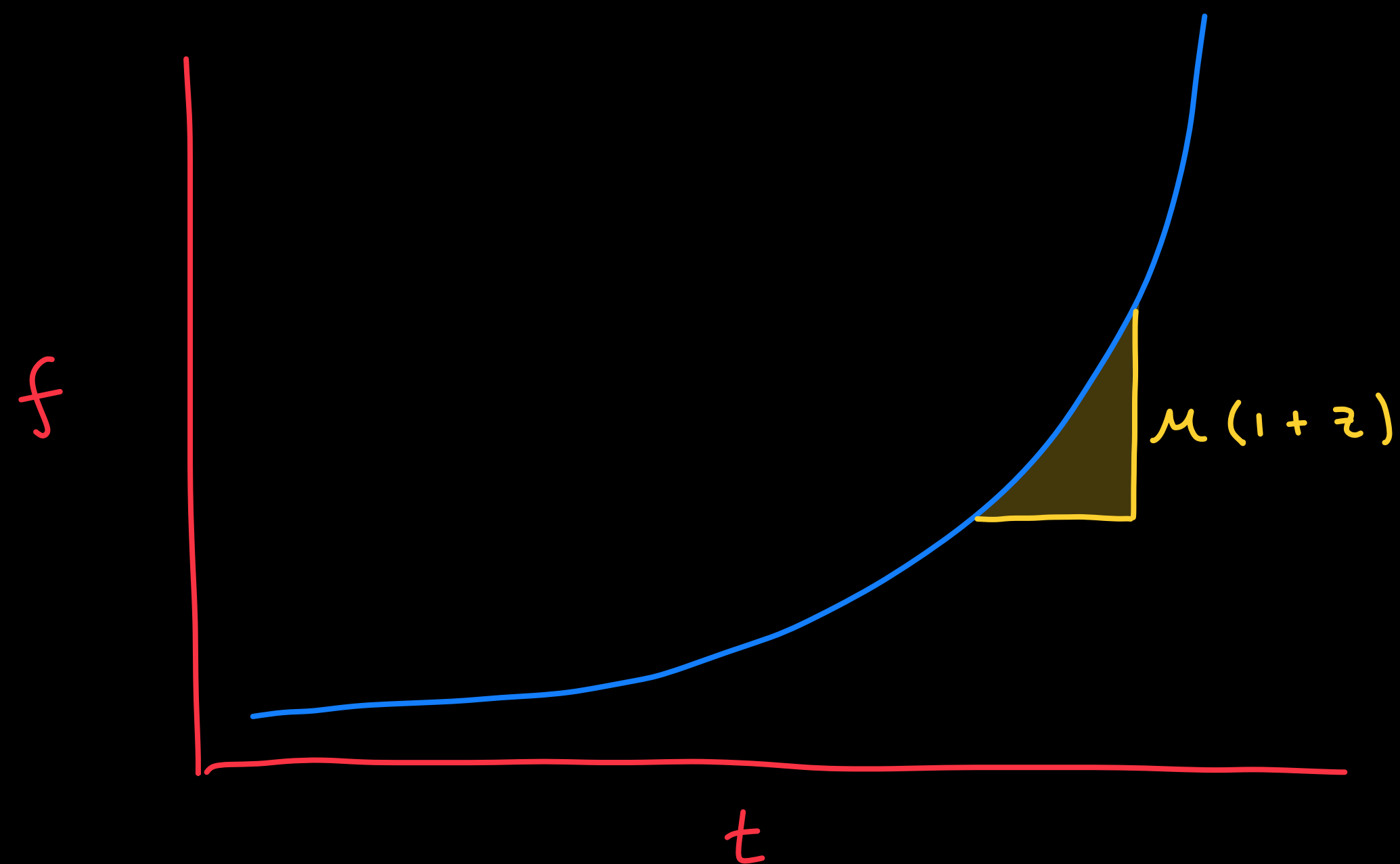
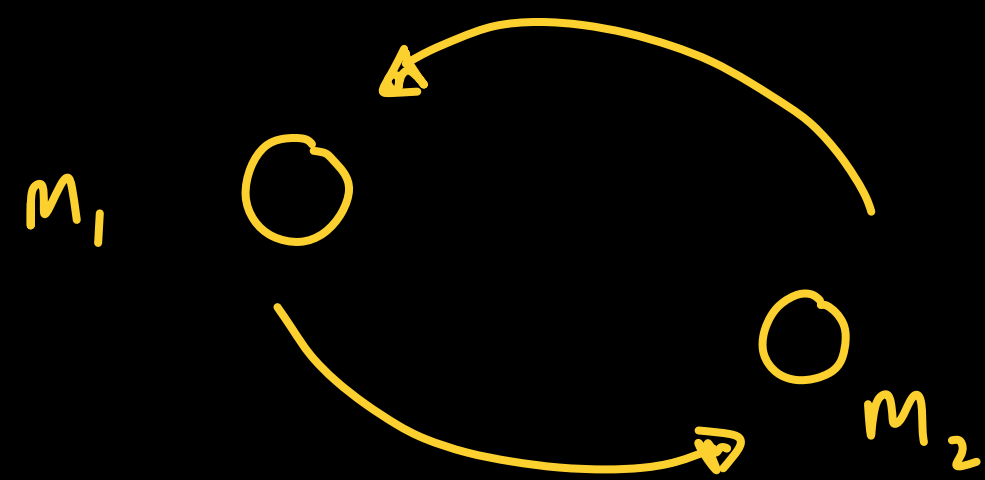
$$\underline{\Phi} \propto (\mu(1+z))^{5/3} + \dots$$



$$h \sim \frac{A_*}{D_L} e^{i\Phi}$$

$$A_* \propto \mu(1+z)$$

$$\Phi \propto (\mu(1+z))^{5/3} + \dots$$

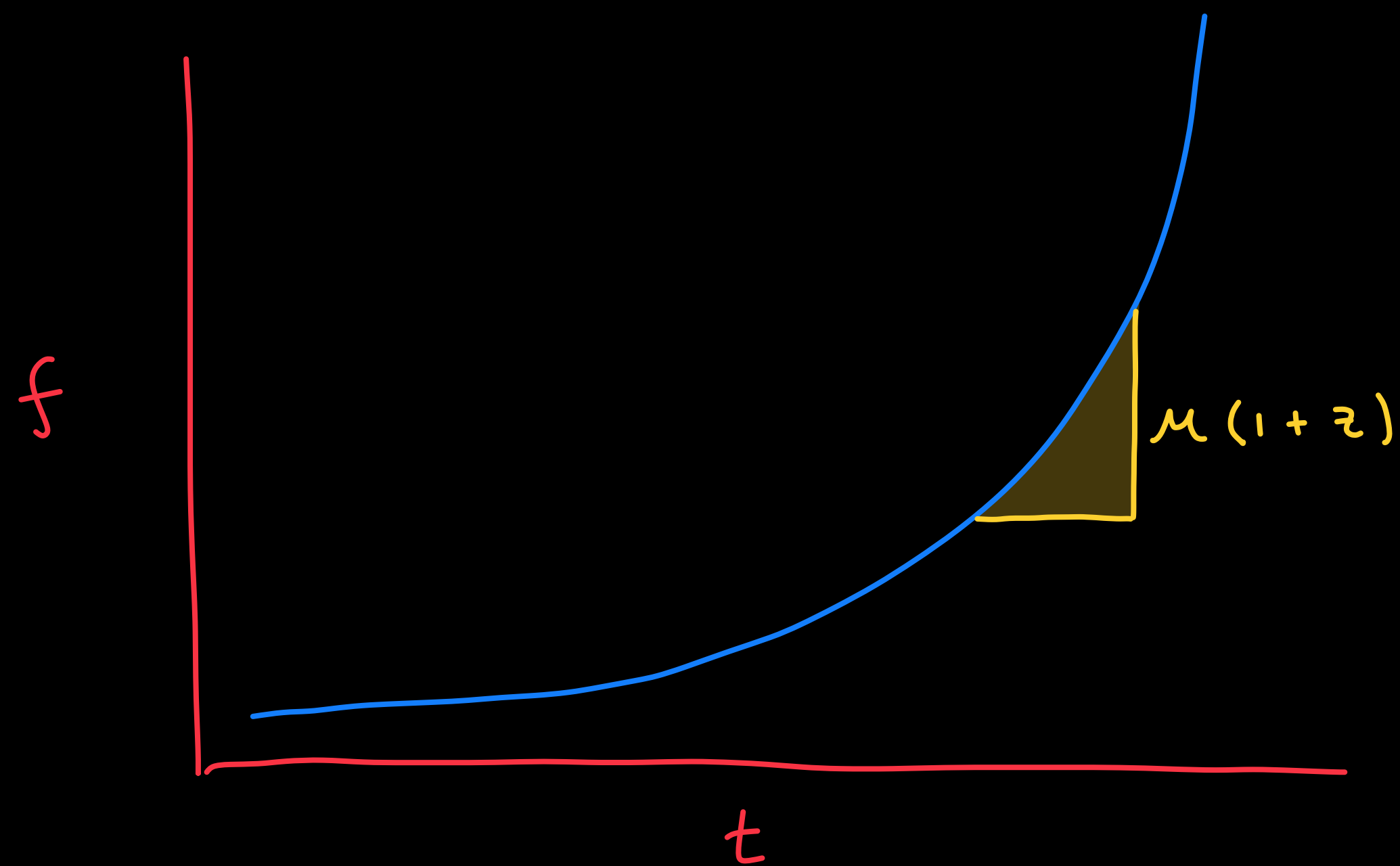
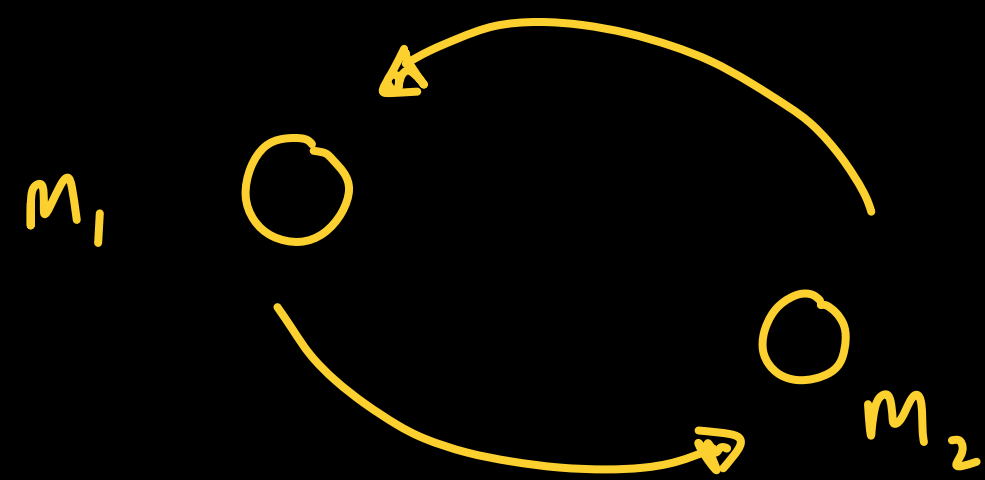


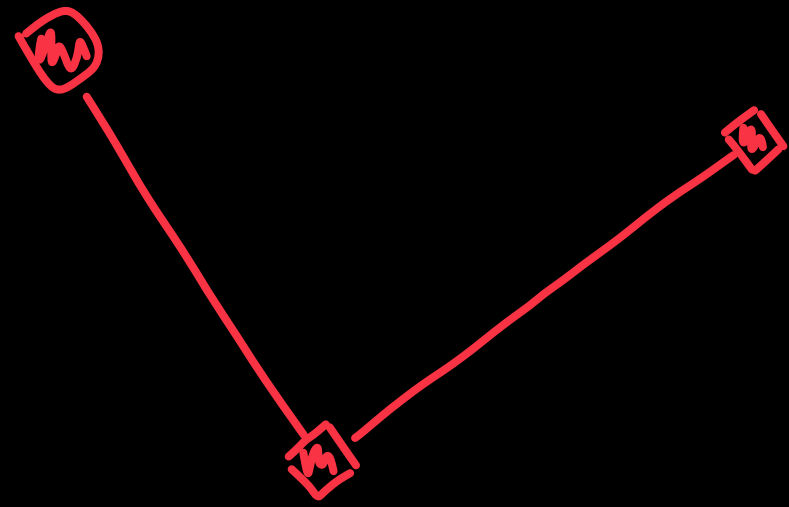
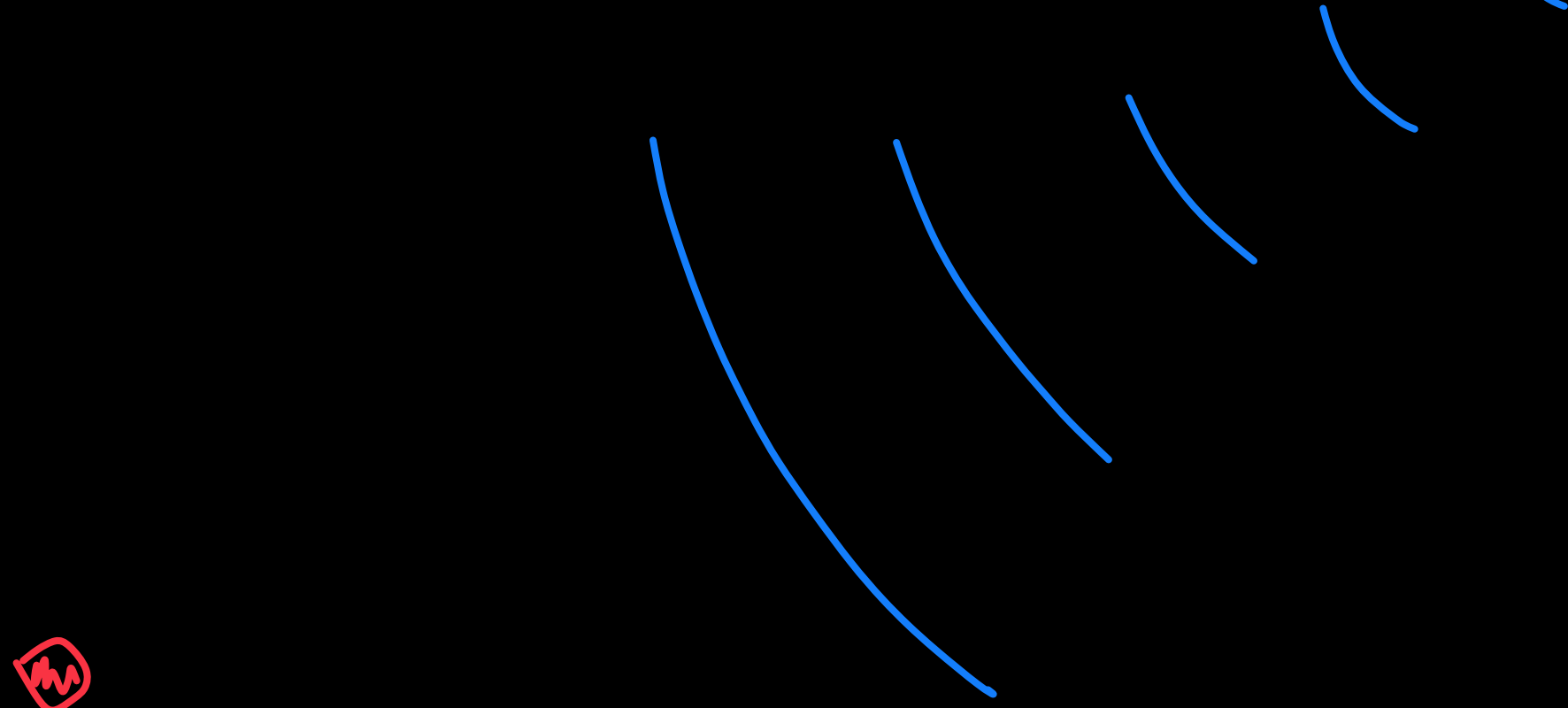
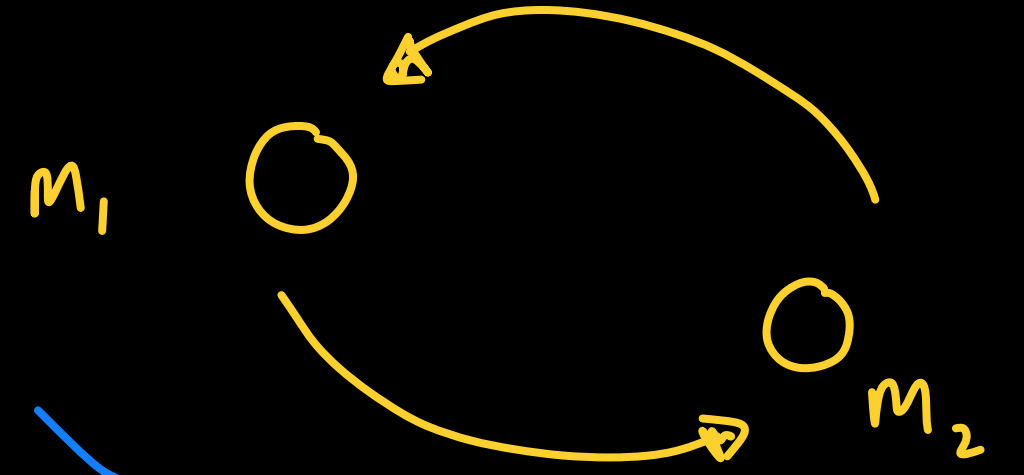
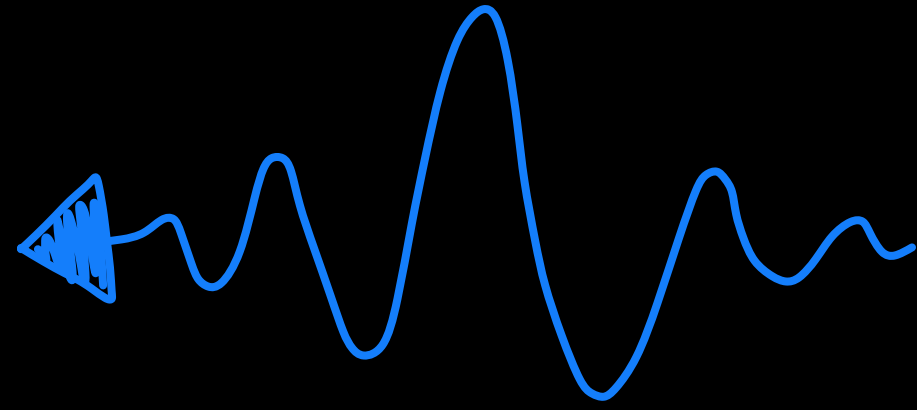


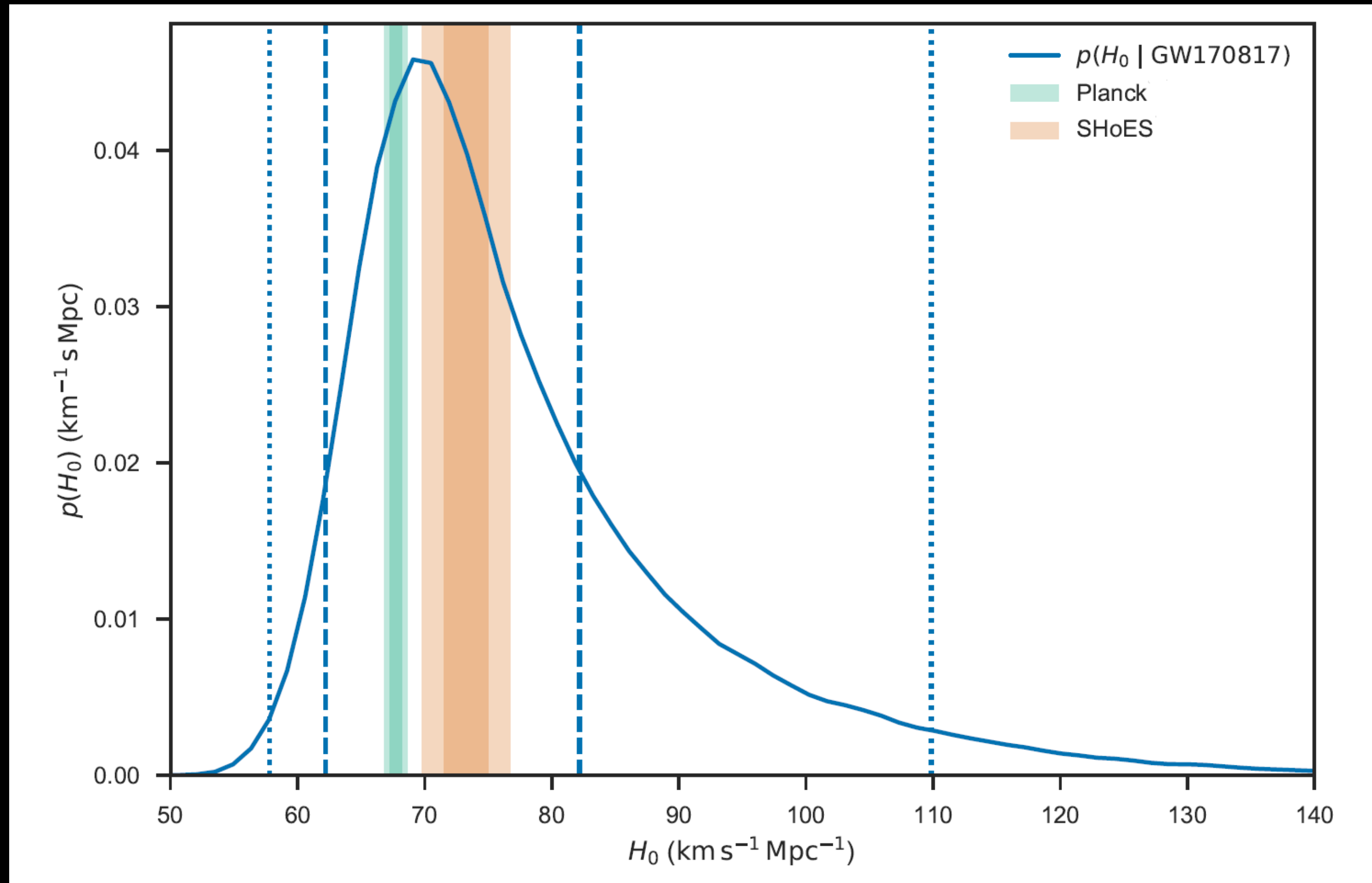
$$h \sim \frac{A_*}{D_L} e^{i\Phi}$$

$$A_* \propto \mu(1+z)$$

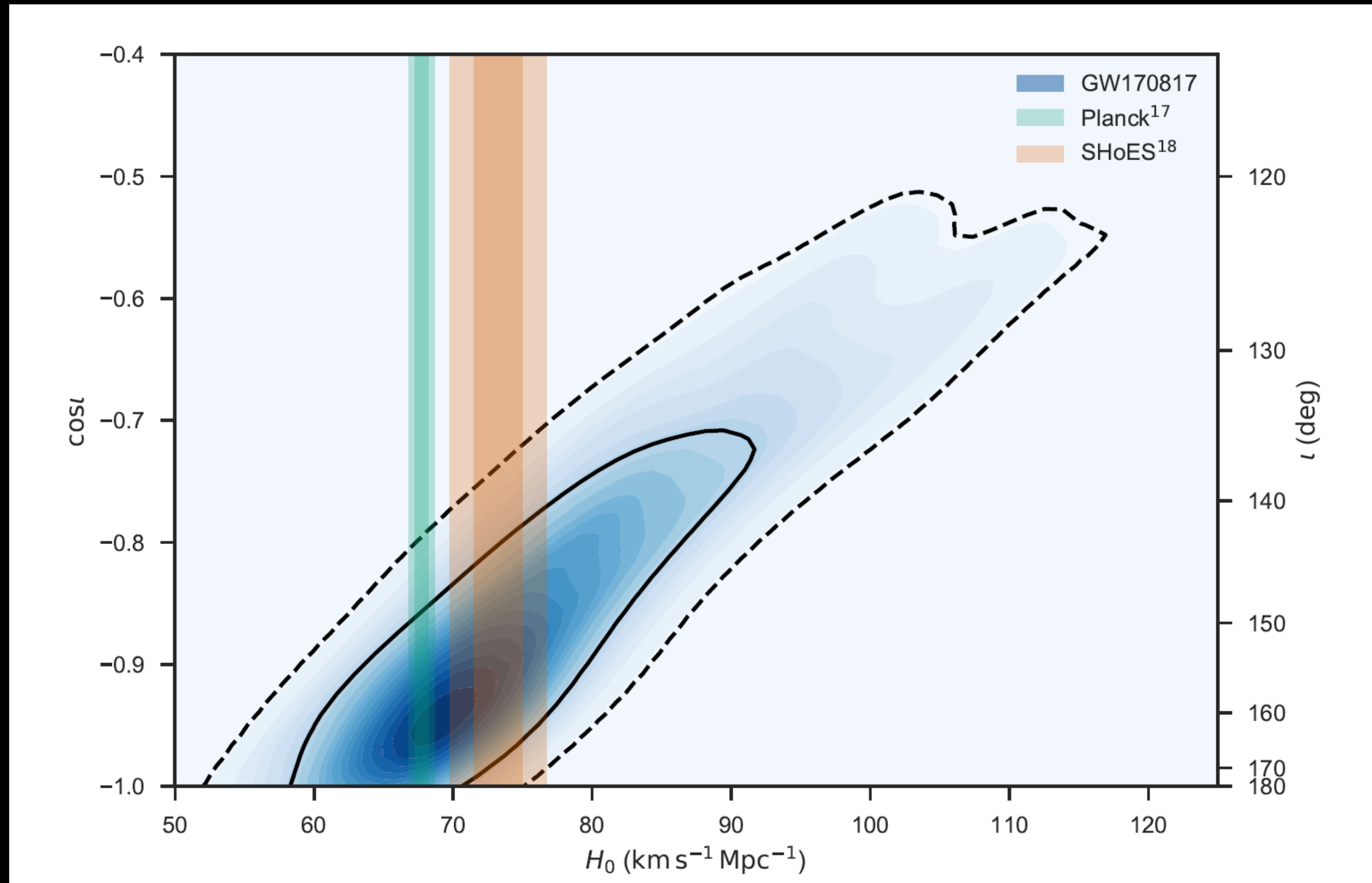
$$\Phi \propto (\mu(1+z))^{5/3} + \dots$$







All of Astronomy et al, *Nature* **551**, 85–88 (2017)

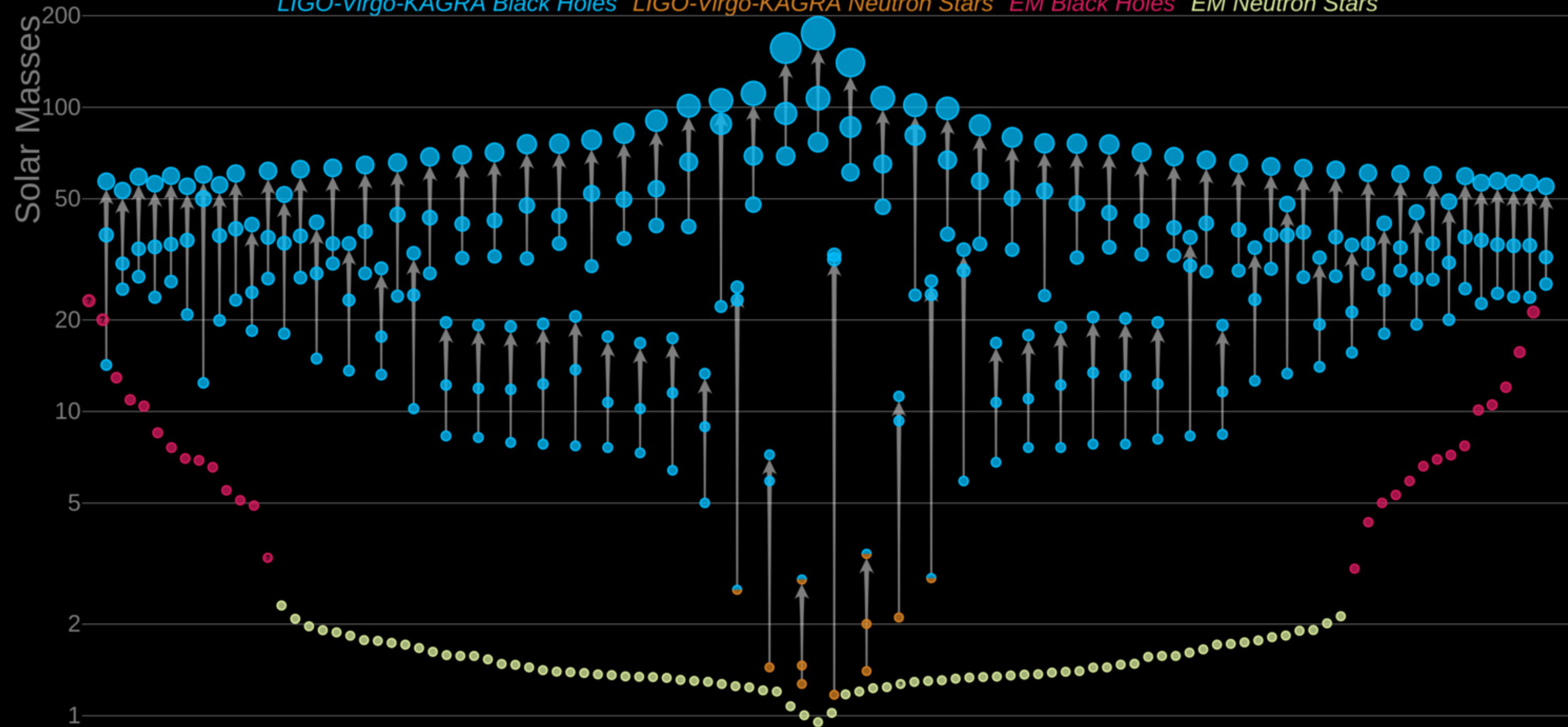


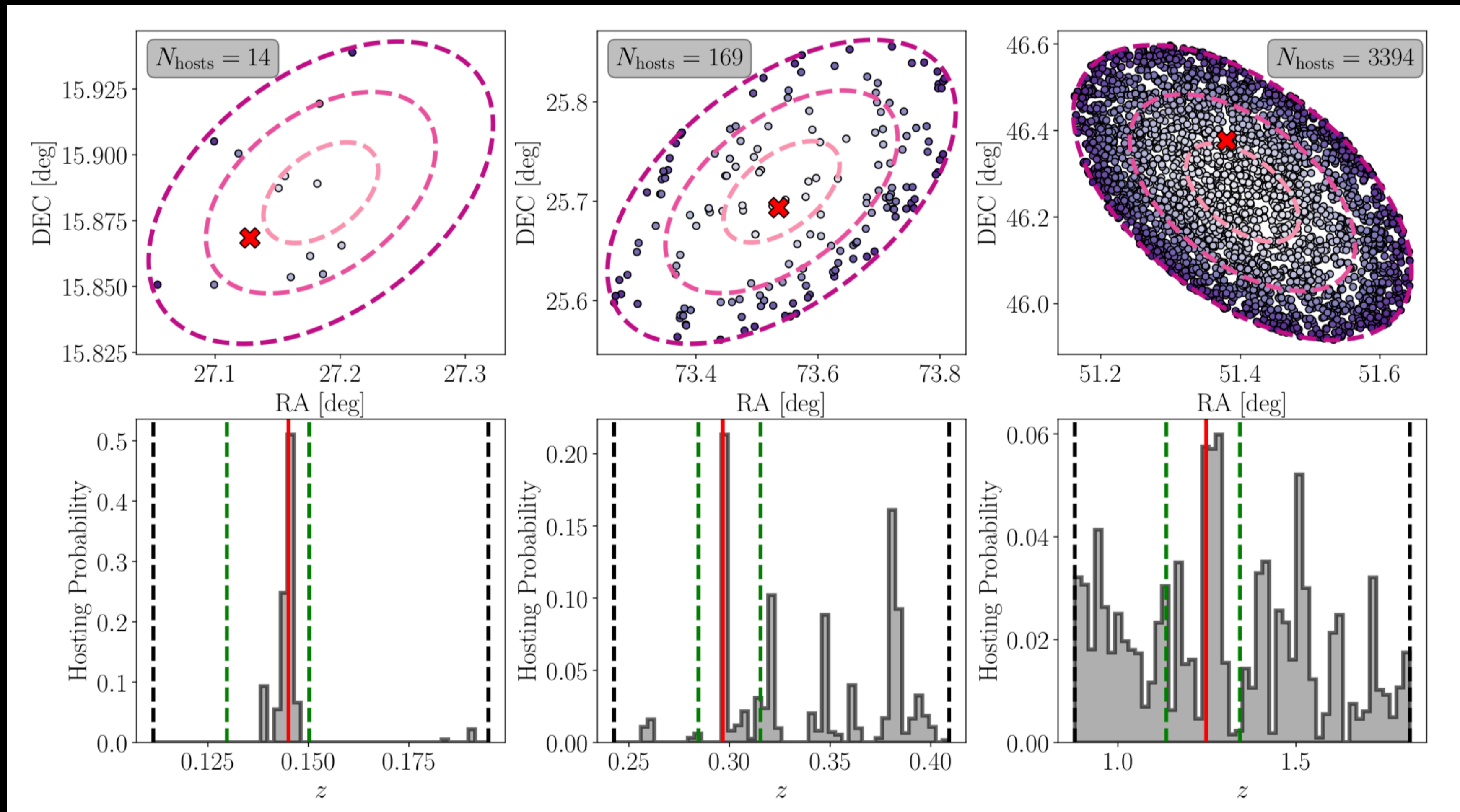
All of Astronomy et al, *Nature* **551**, 85–88 (2017)



# Masses in the Stellar Graveyard

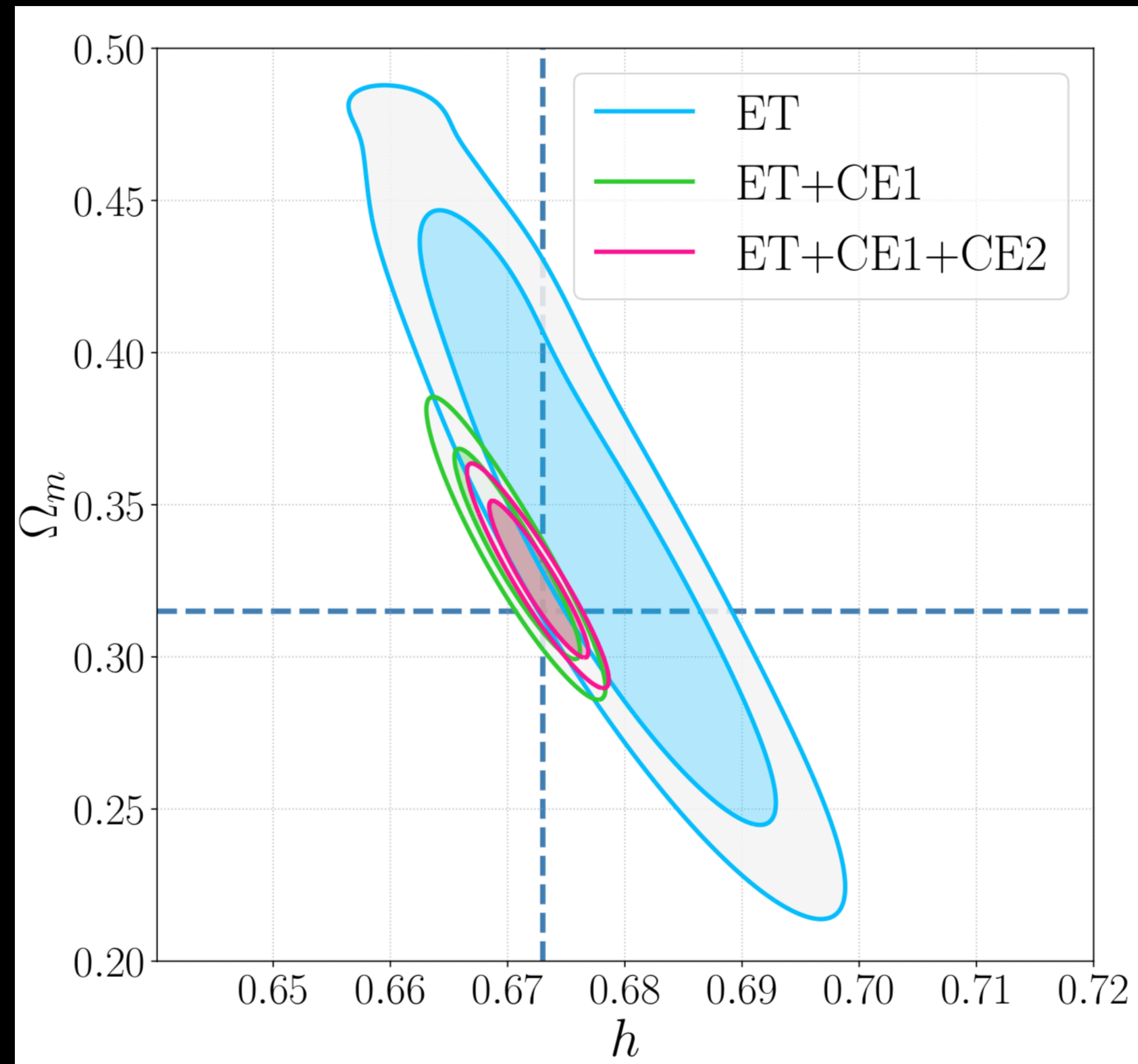
*LIGO-Virgo-KAGRA Black Holes* *LIGO-Virgo-KAGRA Neutron Stars* *EM Black Holes* *EM Neutron Stars*



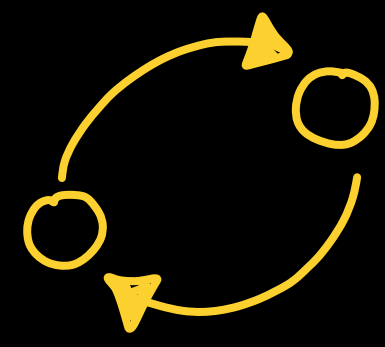
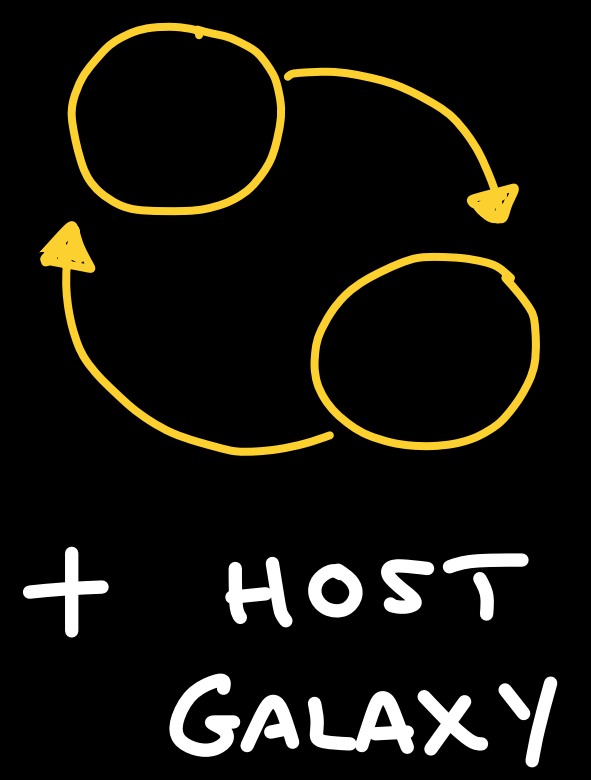
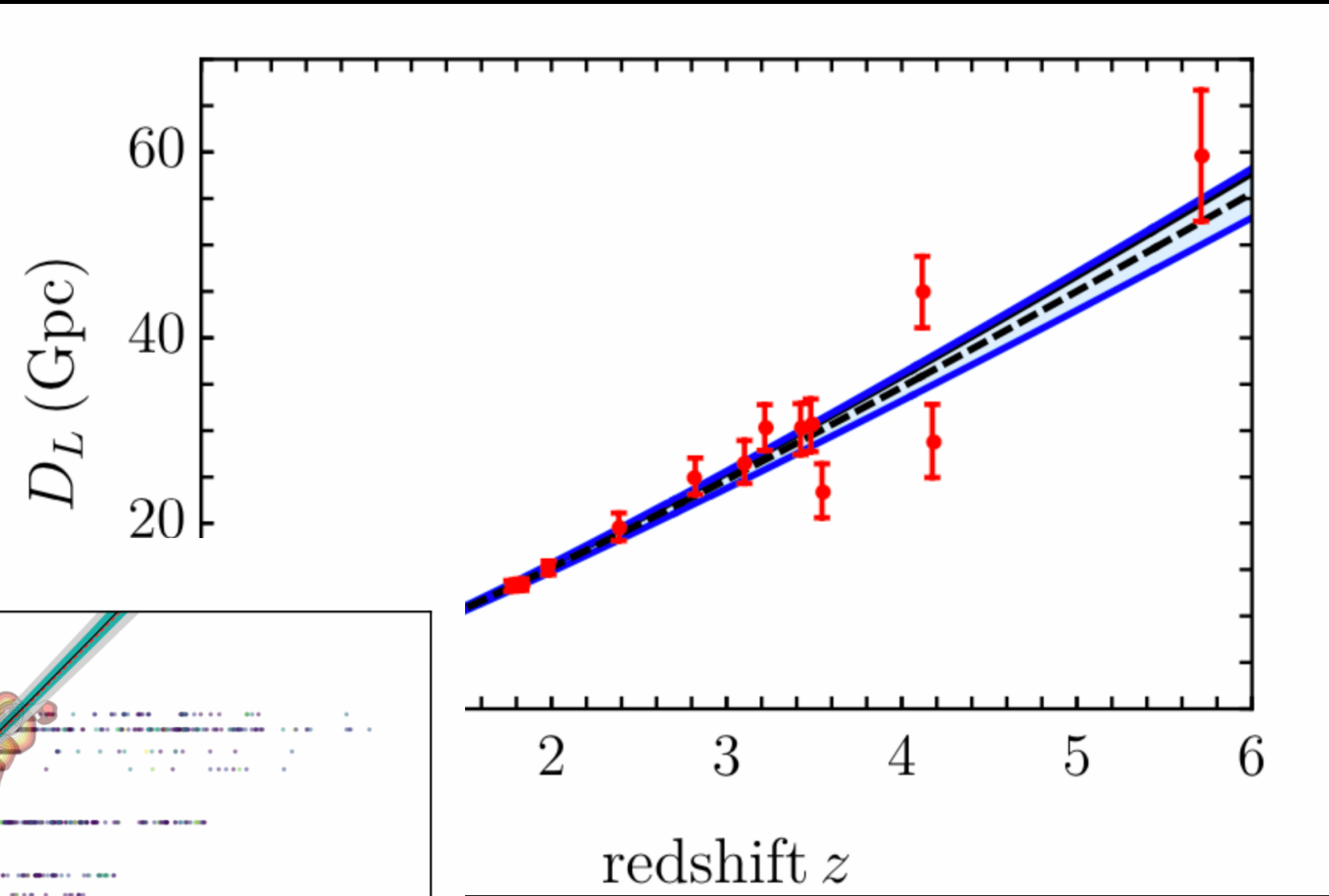
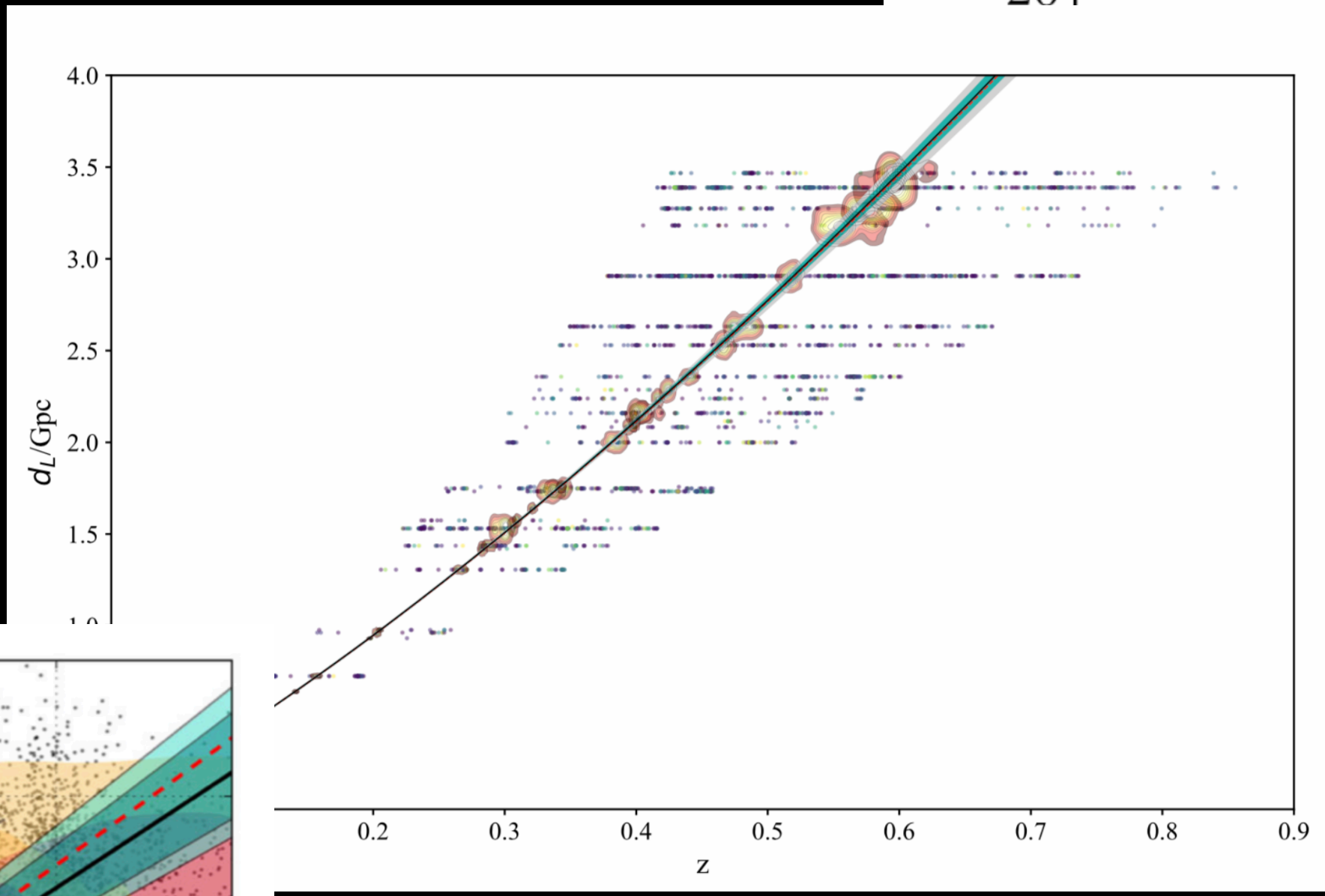
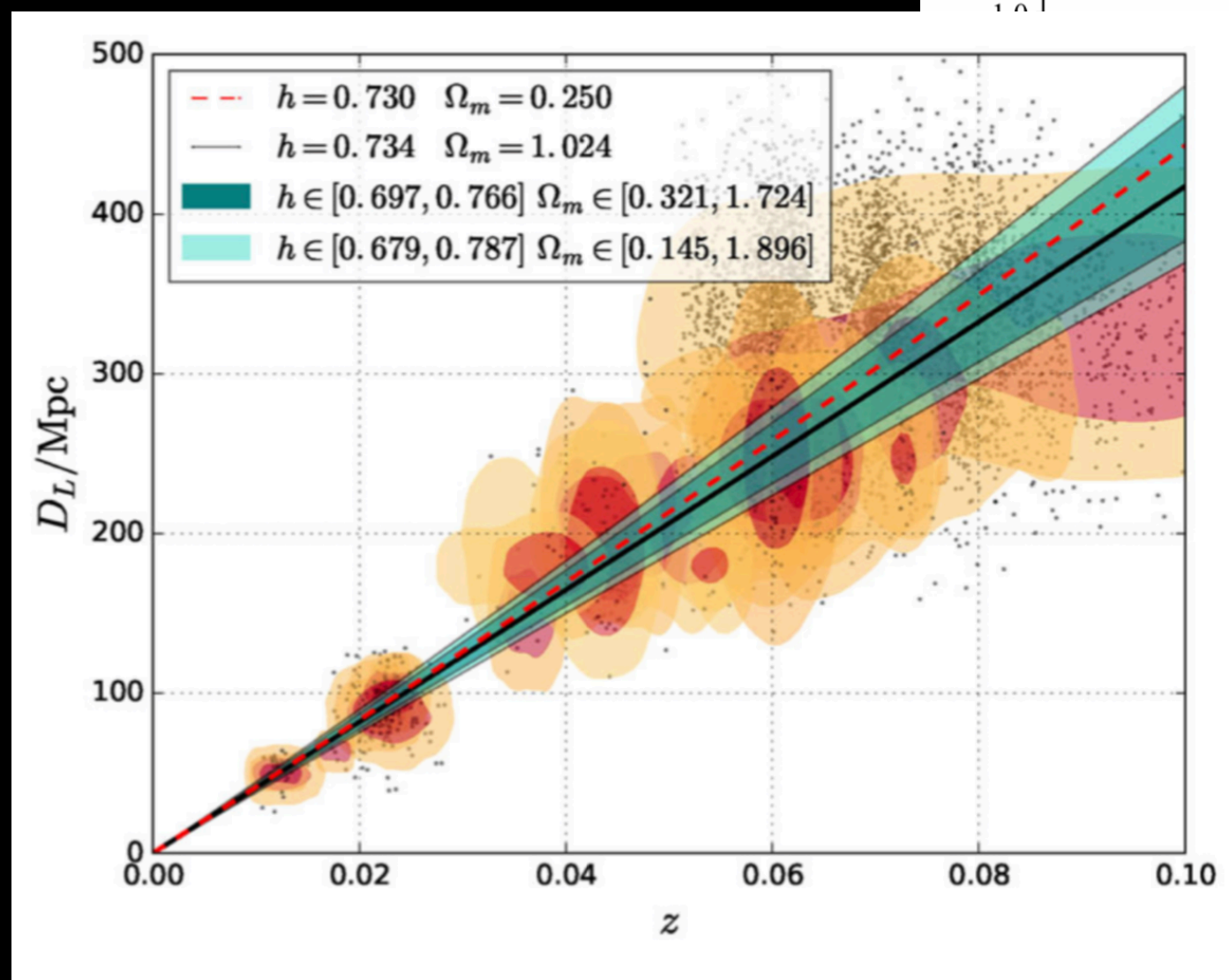


Mutoni et al, arXiv:2303.10693 [astro-ph.CO]

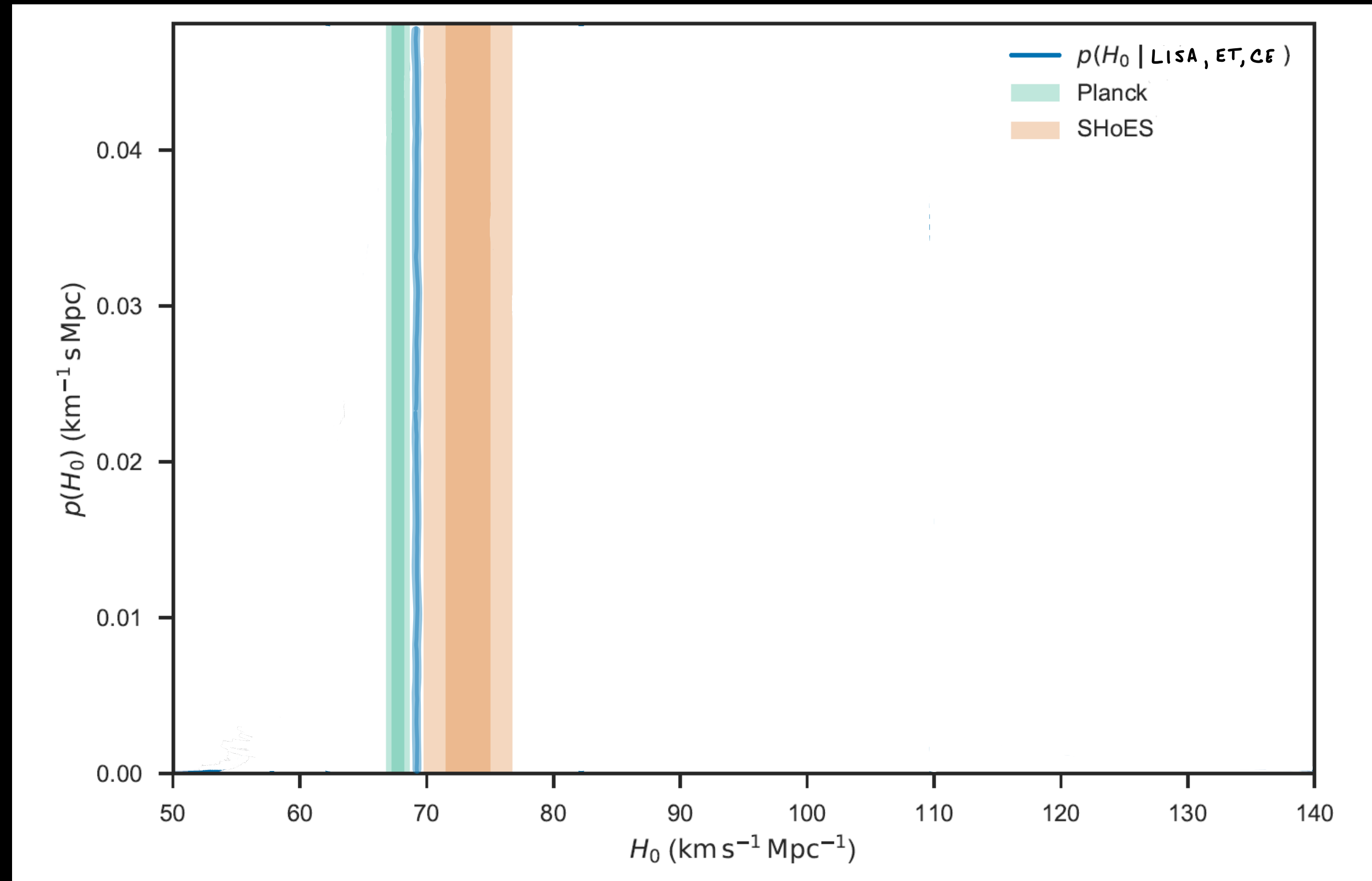




Mutoni et al, arXiv:2303.10693 [astro-ph.CO]

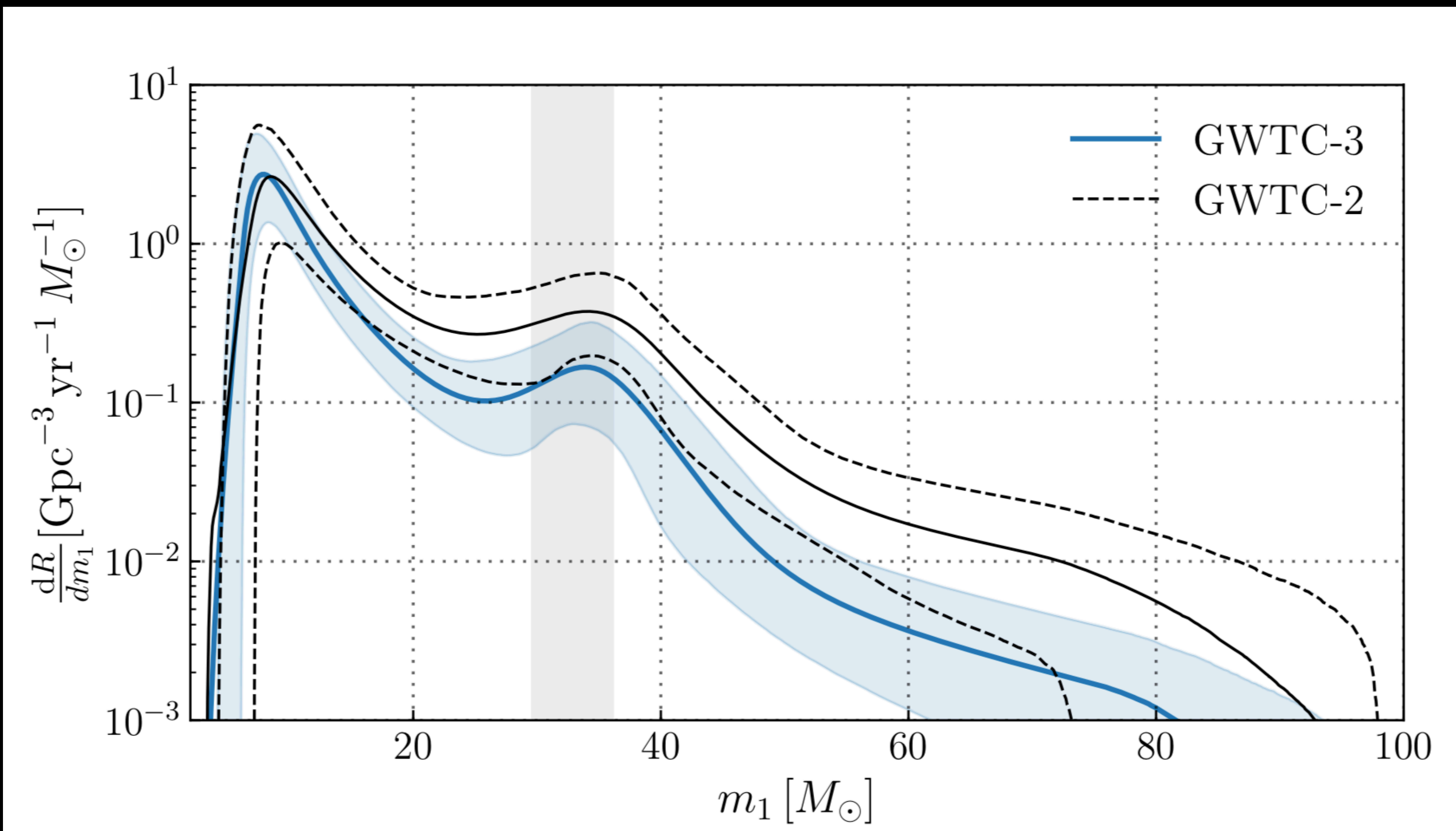




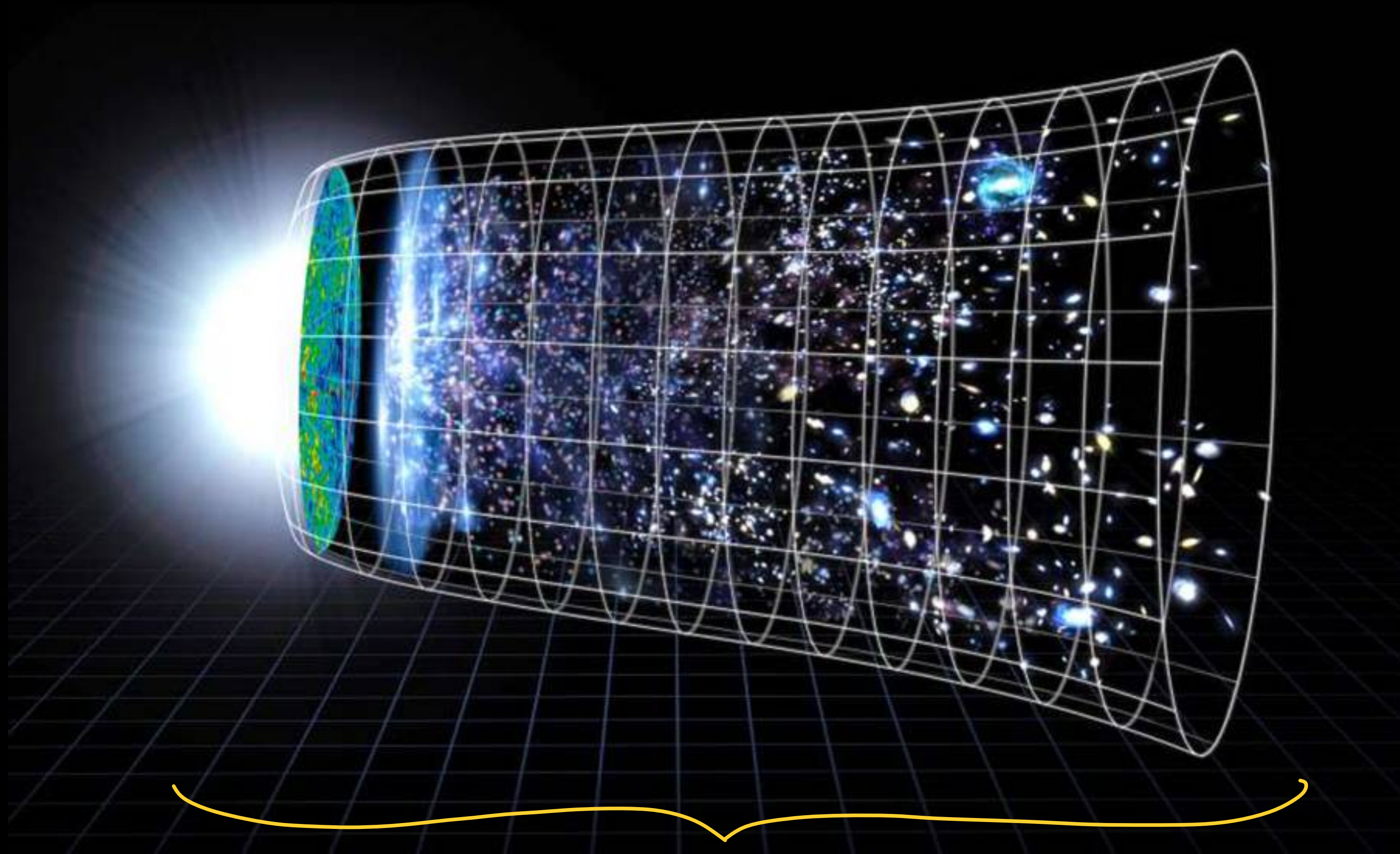


ADAPTED  
FROM

All of Astronomy et al, *Nature* **551**, 85–88 (2017)

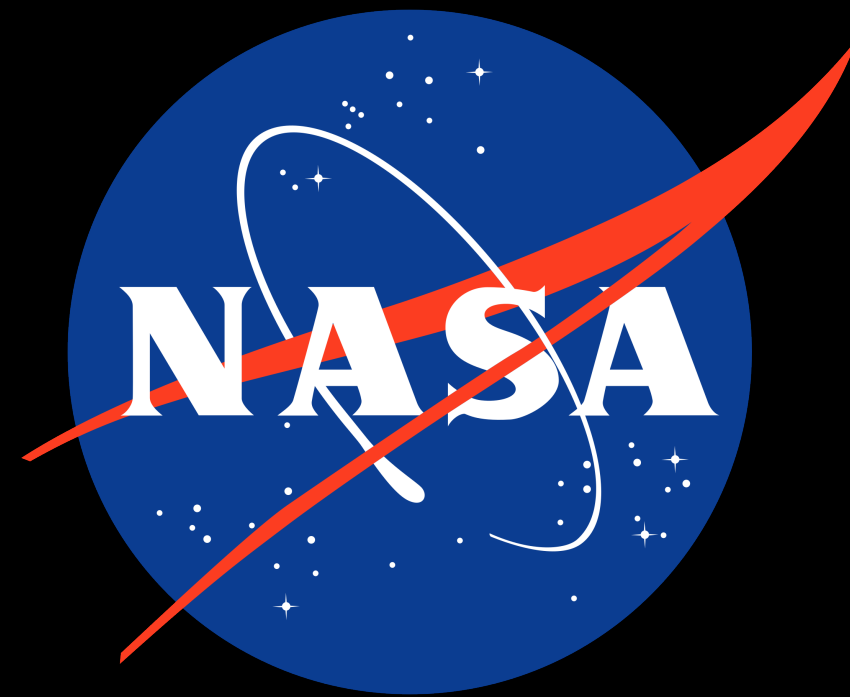






$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$

# Gravitational Wave Cosmology



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