



Detecting Supermassive Black-Hole Binaries with Pulsar Timing Arrays

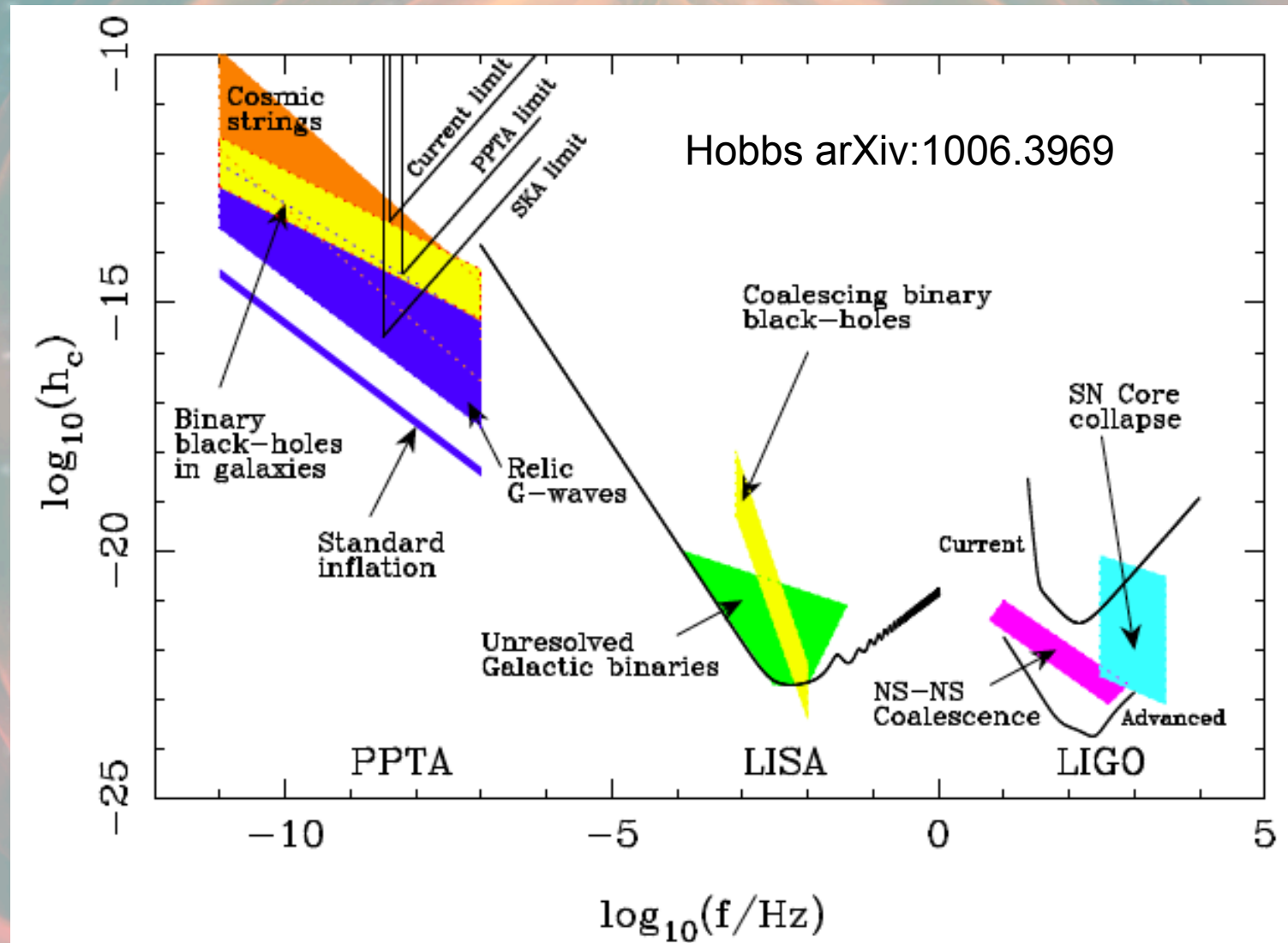
Based in part on
Signatures of merger-dominated galaxy evolution at $z < 1$
STM, J. P. Ostriker, and F. Pretorius, in preparation

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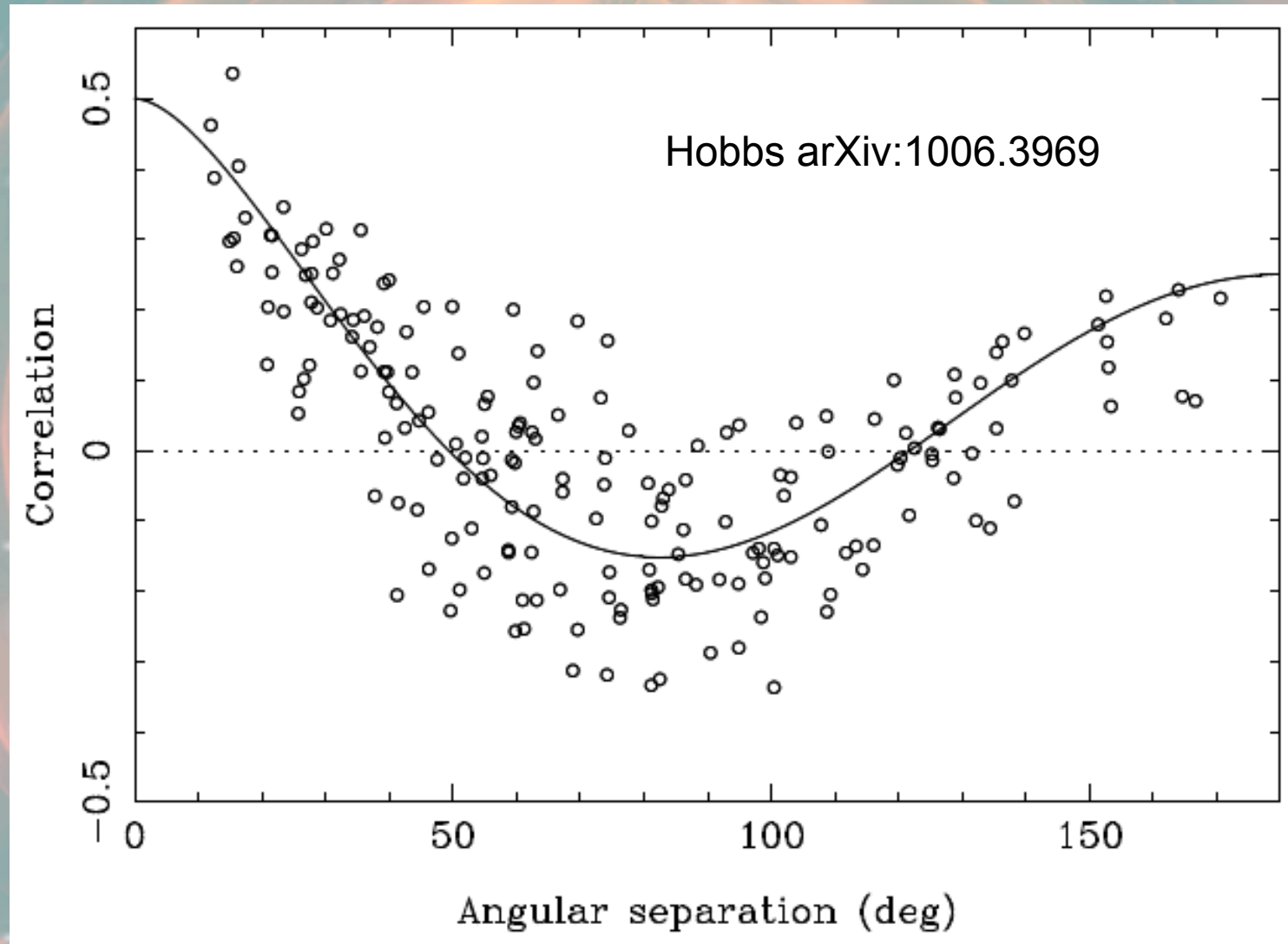
Chirps, Mergers and Explosions, KITP, Santa Barbara, CA

July 26, 2012

GW strain from nano to kilo-Hz



Pairwise correlation of pulsar R's for GW background



GWs from SMBHBs: Evolution of the Mass Function



$$\phi(M) dM \equiv (\phi_{\text{low}} + \phi_{\text{BCG}}) dM = \varphi M^{\alpha} \exp(-M) dM \\ + \varphi \exp \left[-\frac{1}{2} \left(\frac{2.5 \log M}{\sigma_M} \right)^2 - 1 \right] dM.$$

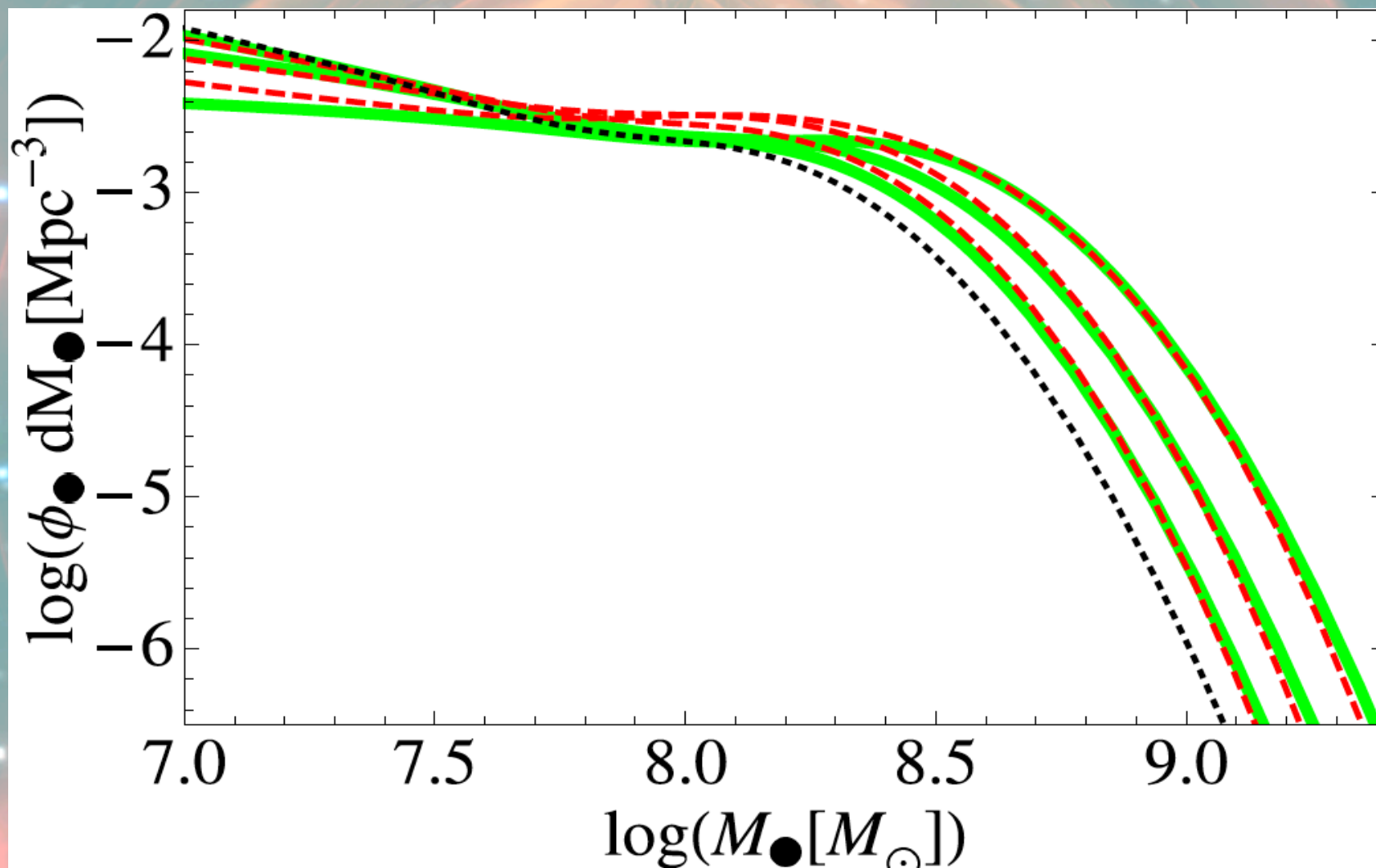
$$\frac{\partial^3 \phi_{\{\text{low}, \text{BCG}\}}}{\partial M' \partial M'' \partial z} dM' dM'' dz = P(z) dz \phi_{\{\text{tot}, \text{BCG}\}}(M') dM' \phi_{\{\text{tot}, \text{low}\}}(M'') dM''$$

$$\left[\frac{\partial}{\partial z} \phi_{\{\text{low}, \text{BCG}\}}(\hat{M}) \right]_{\text{si}} = P(z) \int_{10^6 M_{\odot}}^{10^{11} M_{\odot}} \phi_{\{\text{tot}, \text{BCG}\}}(\hat{M}) \phi_{\{\text{tot}, \text{low}\}}(M') dM'$$

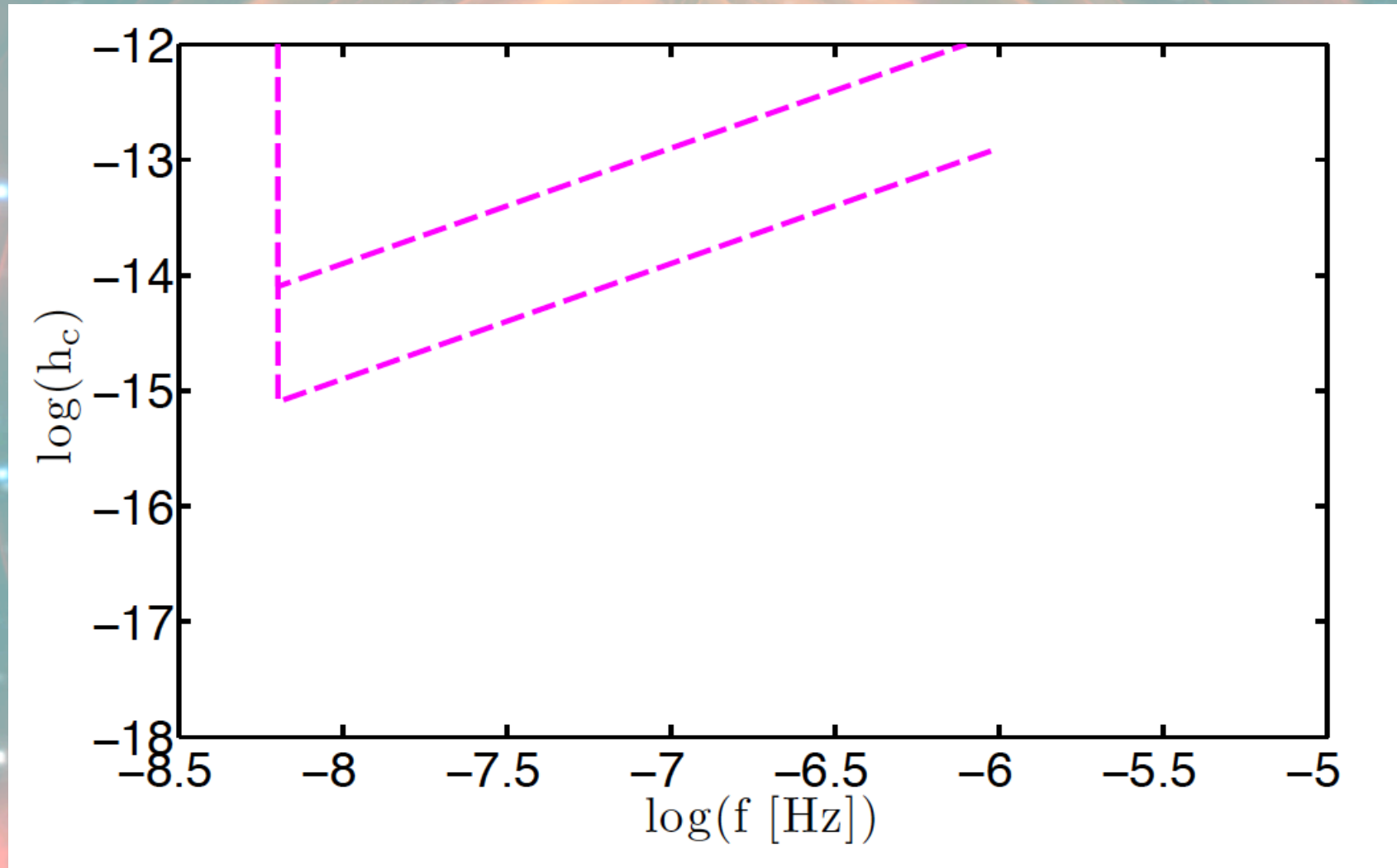
$$\left[\frac{\partial}{\partial z} \phi_{\{\text{low}, \text{BCG}\}}(\hat{M}) \right]_{\text{so}} = P(z) \int_{10^6 M_{\odot}}^{\hat{M} - 10^6 M_{\odot}} \int_{10^6 M_{\odot}}^{\hat{M} - 10^6 M_{\odot}} \delta(\hat{M} - M' - M'') \phi_{\{\text{low}, \text{BCG}\}}(M') dM' \phi_{\{\text{low}, \text{low}\}}(M'') dM'' \\ = P(z) \int_{10^6 M_{\odot}}^{\hat{M} - 10^6 M_{\odot}} \phi_{\{\text{low}, \text{BCG}\}}(M') \phi_{\{\text{low}, \text{low}\}}(\hat{M} - M') dM'$$

$$h_c^2(f) = \int_0^1 dz \int_{10^6 M_{\odot}}^{10^{11} M_{\odot}} dM_2 \int_{10^6 M_{\odot}}^{M_2} dM_1 N h^2 \frac{d^4 p}{dM_1 dM_2 dz df}$$

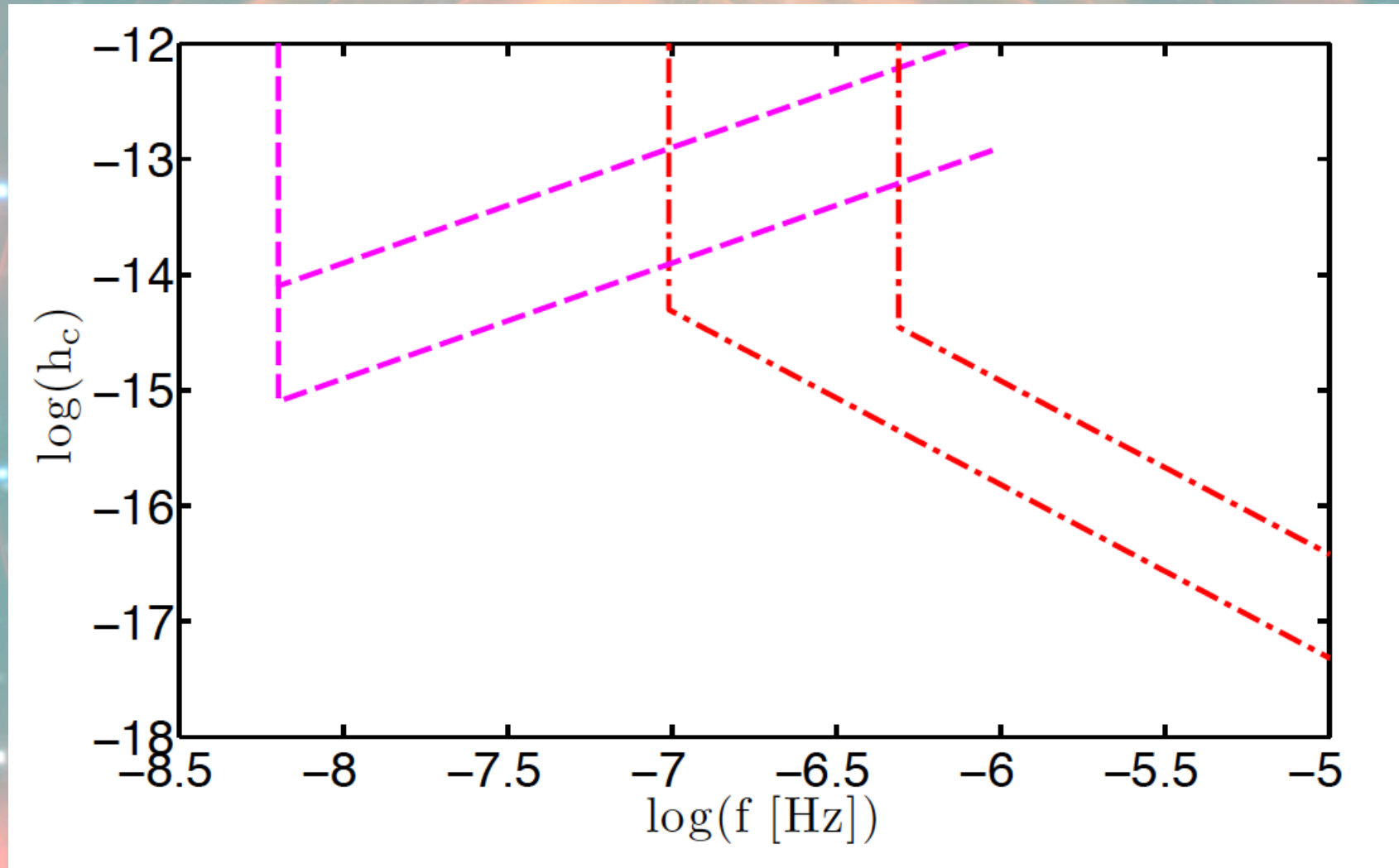
Evolution of the Mass Function



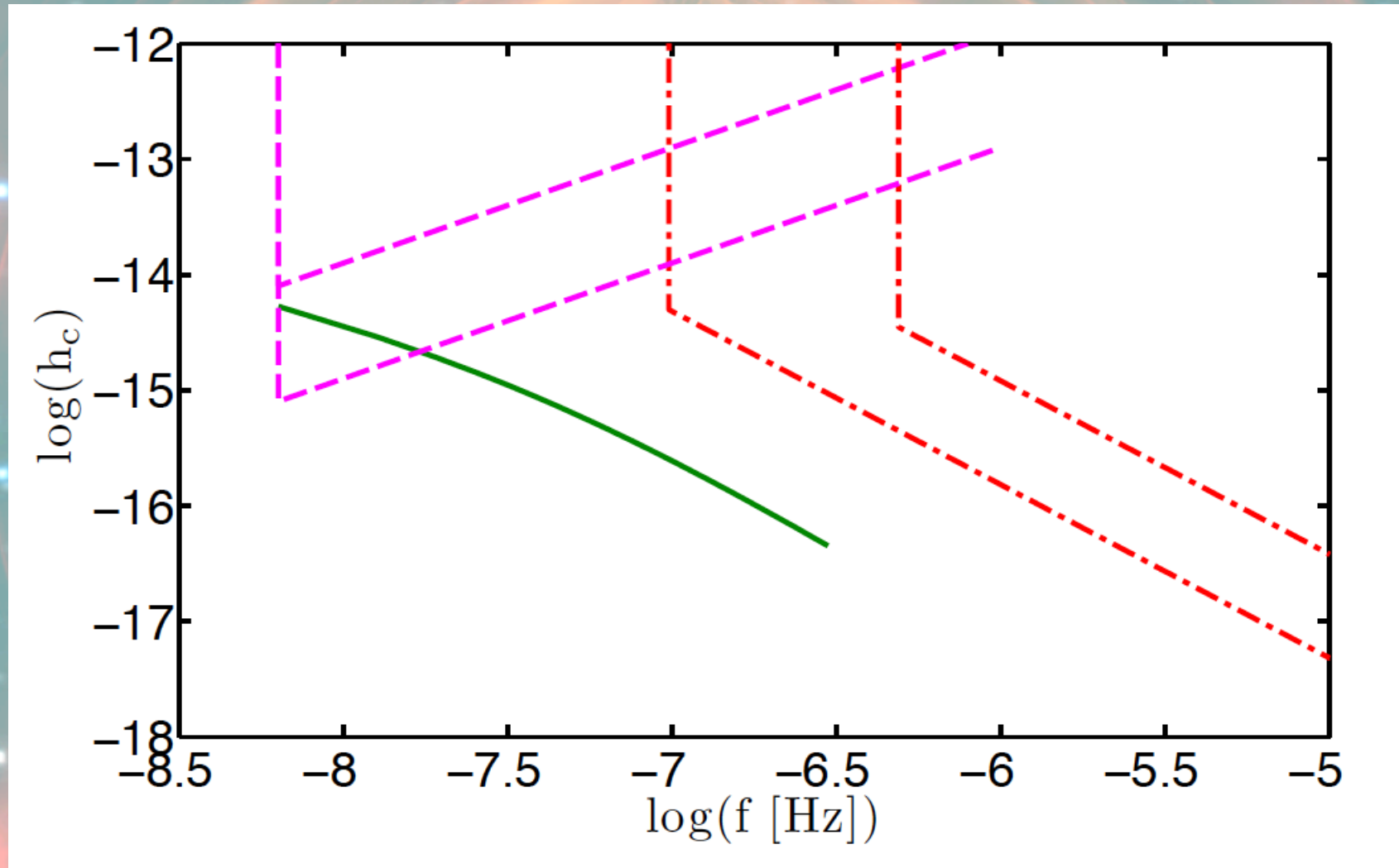
SMBHB GW detection with PTAs



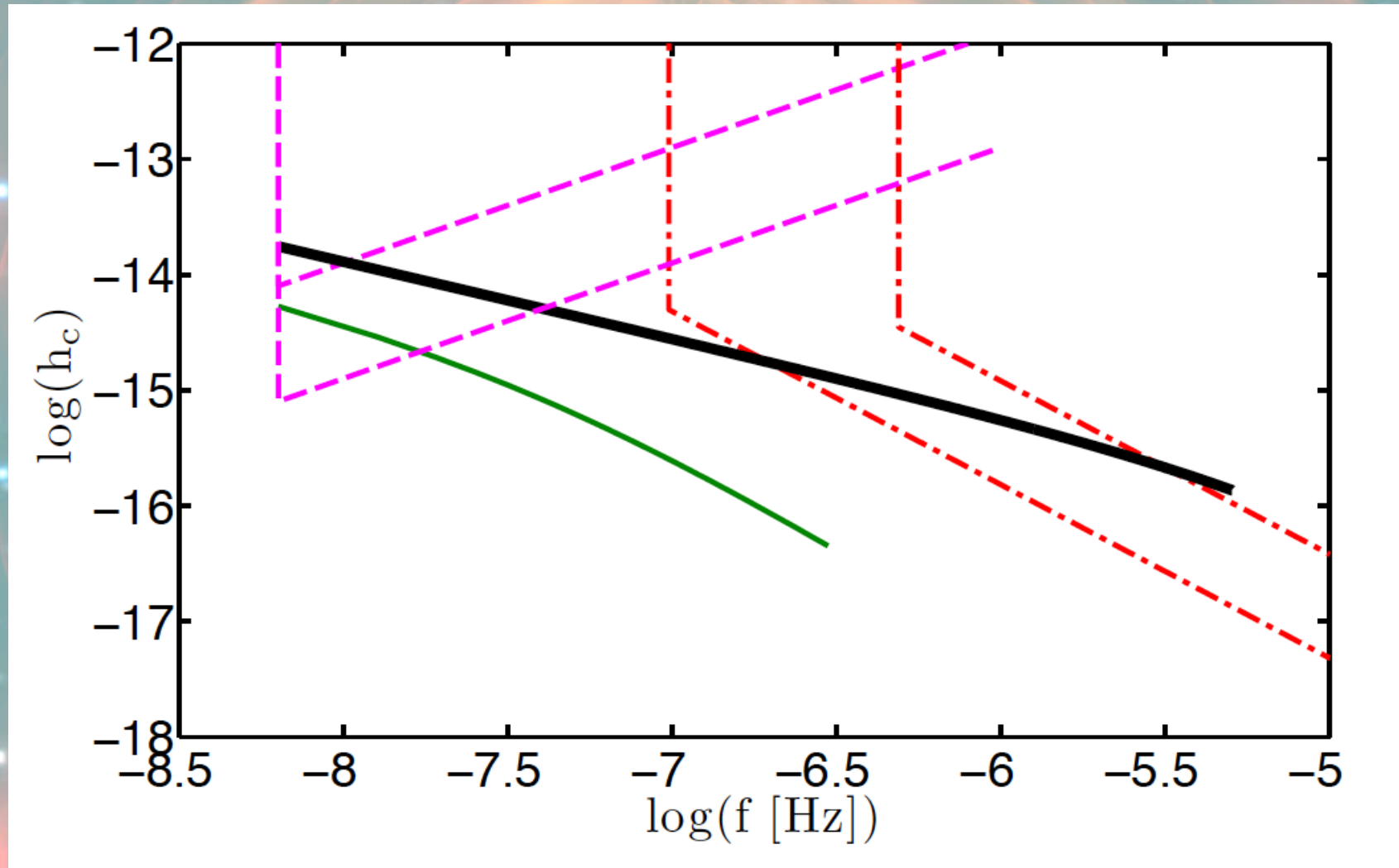
SMBHB GW detection with PTAs



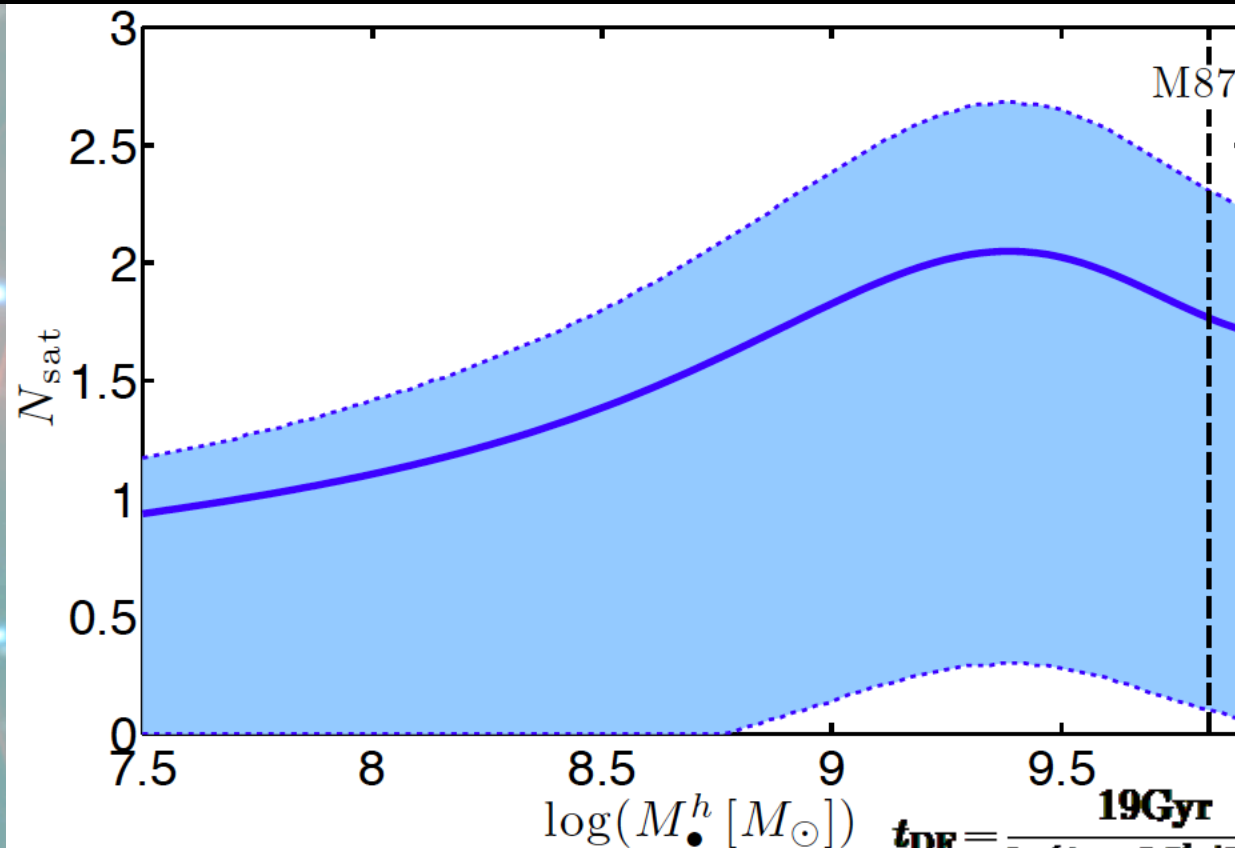
SMBHB GW detection with PTAs



SMBHB GW detection with PTAs



SMBHB GW detection with PTAs



$$L_B = \eta \dot{M}_B c^2 = 4\pi\eta (\alpha G M_\bullet^s)^2 \rho_\infty v^{-3}$$

$$= 3 \times 10^{39} \text{ erg/s} \left(\frac{\eta}{0.1} \right) \left(\frac{M_\bullet^s}{2.2 \times 10^5 M_\odot} \right)^2 \left(\frac{n}{100 \text{ cm}^{-3}} \right) \left(\frac{v}{190 \text{ km/s}} \right)^{-3}$$

$$t_{\text{DF}} = \frac{19 \text{ Gyr}}{\ln(1 + M_\bullet^h / M_\bullet^s)} \left(\frac{R_e}{5 \text{ kpc}} \right)^2 \frac{\sigma(R_e)}{200 \text{ km/s}} \frac{10^8 M_\odot}{M_s}$$

$$\approx \frac{4.5 \text{ Gyr}}{q(6.9 - \ln q)} \left(\frac{M_\bullet^h}{10^8 M_\odot} \right)^{2/3} (1+z)^{-3/2},$$