CAN PBHS EXPLAIN PULSAR TIMING ARRAYS AND JWST LATEST RESULTS?

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Consequences of PBHs as CDM for structure formation

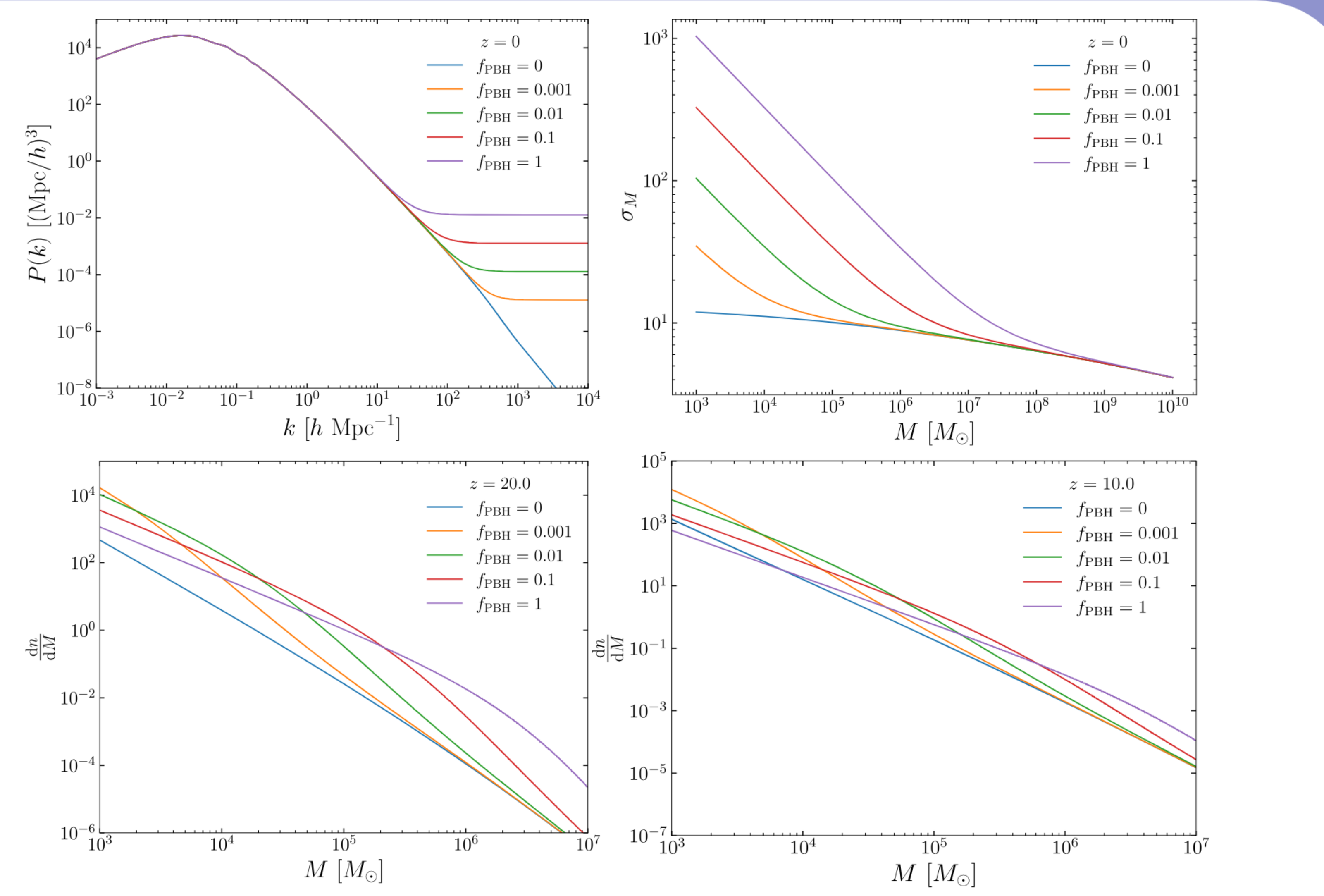
PBHs as CDM add a granulation component to the structure formation, which can be modeled adding an isocurbature component to the power spectra, Afshordi et al. 2003; Kashlinsky 2016 and 2021:

$$P(k) = P_{\Lambda\mathrm{CDM}}(k) + 1.28 \times 10^{-6} f_{\mathrm{pbh}} \left(\frac{100}{z+1}\right)^2 \quad (1)$$

This component makes the haloes to colapse earlier and the onset of star formation also starts earlier, Atrio-Barandela 2022. In the following work, the density of haloes can be then computed with the Press-Schecter formalism:

$$\frac{\mathrm{d}n}{\mathrm{d}M} = \sqrt{\frac{2}{\pi}} \frac{\rho_0}{M} \frac{\delta_{cr0}}{\sigma^2} \left|\frac{\mathrm{d}\sigma}{\mathrm{d}M}\right| \exp\left\{-\frac{\delta_{cr0}^2}{2\sigma^2}\right\} \quad (2)$$

In the figures we can see the modification of the power spectra, the variance and the number density of haloes.



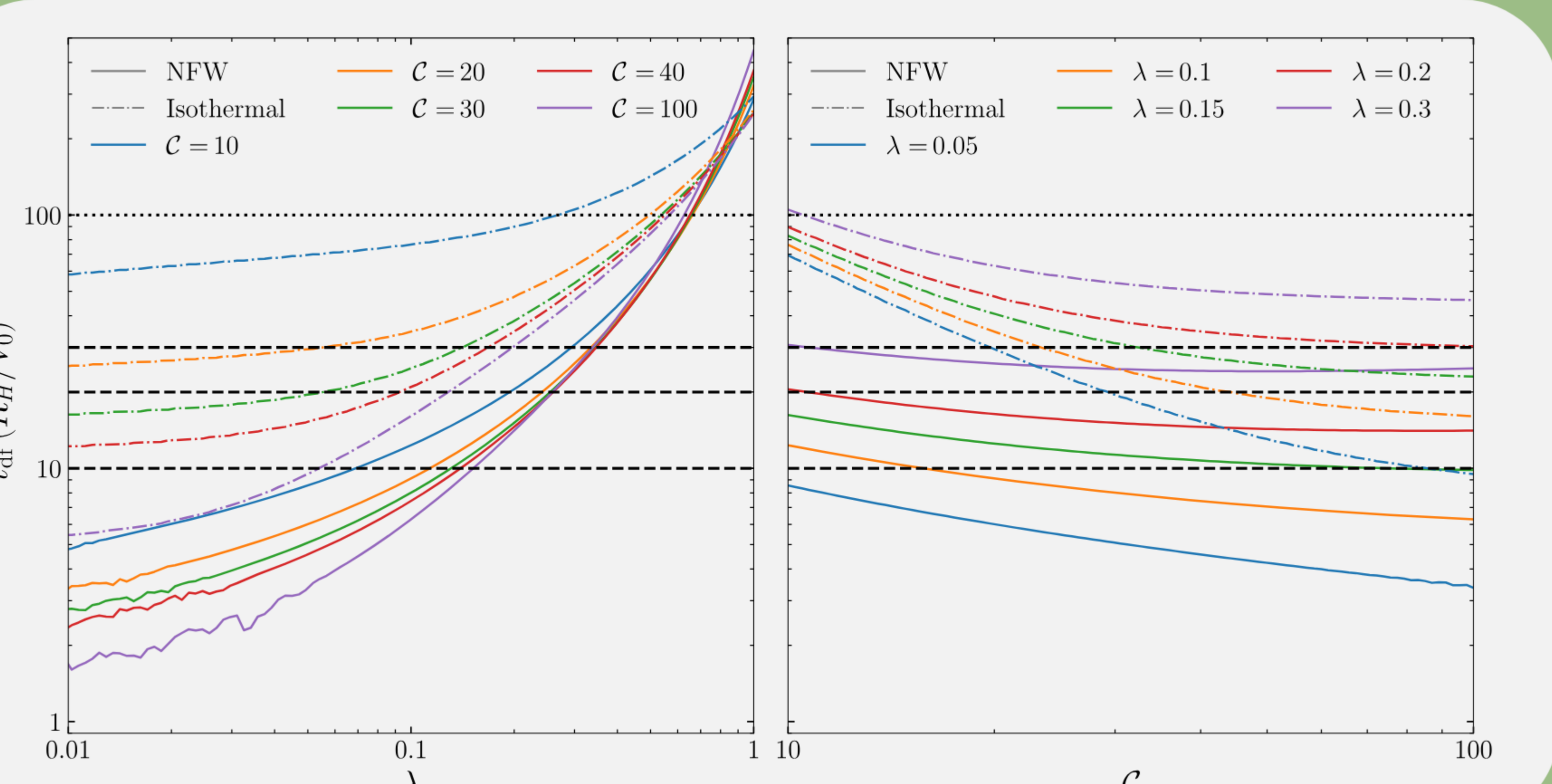
UHZ1 type sytems

Kashlinsky, A.; Atrio-Barandela, F.; Martín-González, D. 2025

In haloes made of PBHs, the most massive ones will fall to the center of their host haloes via dynamical friction. This allows a cental BH of $10^7\ M_\odot$ to form by z~10. Like the ones observed in the UHZ1 like symstems by JWST, Ákos Bogdán et al. 2024.

$$\begin{cases} \ddot{r} &= -\frac{\dot{r}}{v}\frac{G(m_\bullet \ln\Lambda)}{R_H^2}\left(\frac{v}{V_0}\right)^{-2}[3\Psi(r/R_H)]f(<v) \\ & -\frac{V_0^2}{R_H}\left[\frac{W(r/R_H)}{r/R_H}\right] + \frac{J^2}{r^3} \\ \dot{J} &= -\frac{J}{v}\frac{G(m_\bullet \ln\Lambda)}{R_H^2}\left(\frac{v}{V_0}\right)^{-2}[3\Psi(r/R_H)]f(<v) \end{cases} \quad (3)$$

The figure shows the DF times for the characteristics of these systems. We find that only PBHs with $J \leq 0.1 J_c$ could fall to the centre of the halo by z~10. Assuming a Maxwellian distribution of the angular momenta and a log-normal distribution for the PBHs, we find that 1% of the halo mass consists of falling PBHs. Including gas accretion in this model allows us to explain the growth of the observed central BH.



Consequences for PTAs

Martín-González, D.; Atrio-Barandela, F.

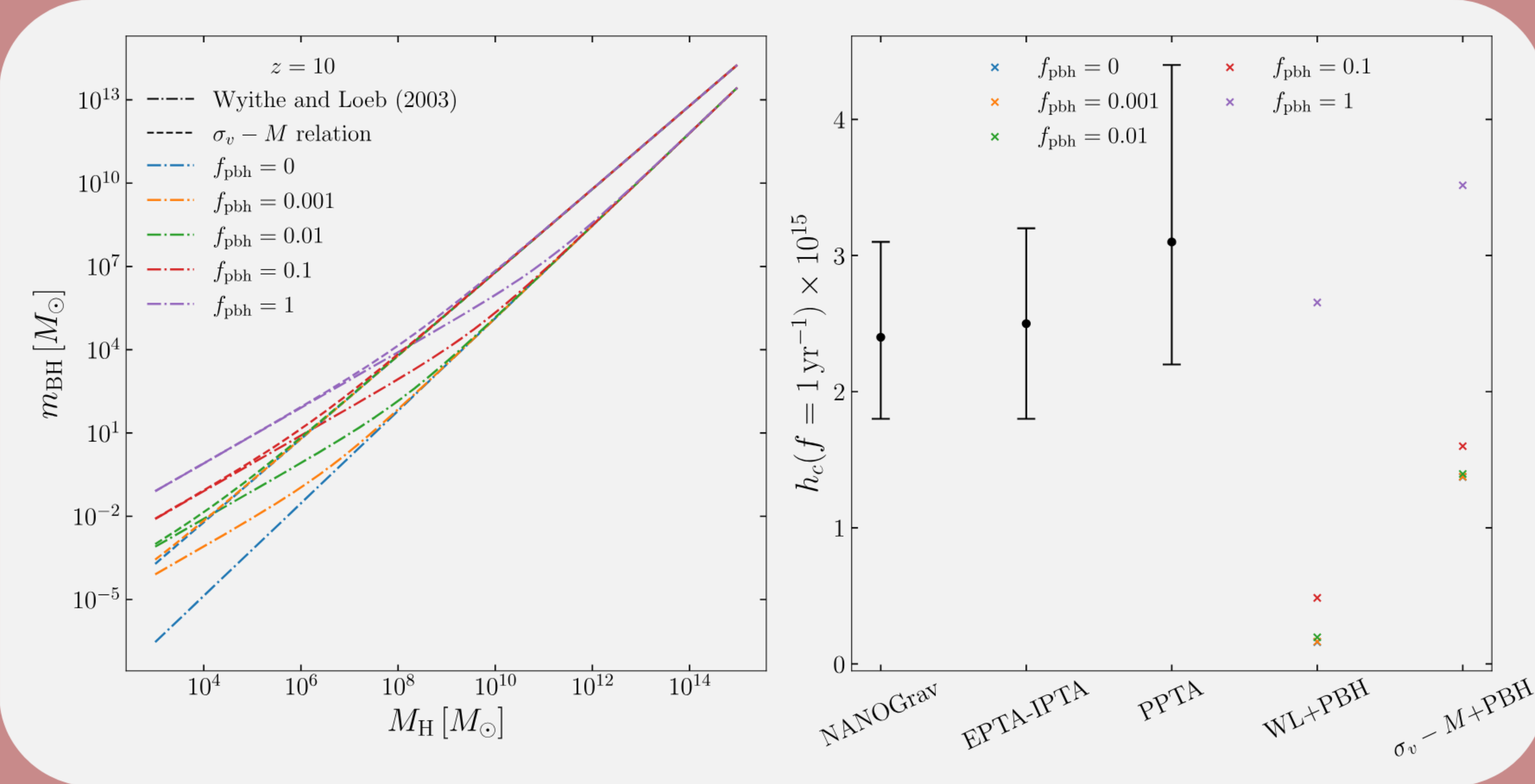
The predicted GW amplitude for the merger of SMBH is 2-3 times smaller than the amplitude measured by PTAs, Sato-Polito et al. 2024. We propose that the presence of PBHs in haloes would have produced a higher merger rate, thus increasing the amplitude of the resulting GW to the measured levels. PBHs also have another advantage: if they are produced in clusters, they will evolve faster, overcoming the last parsec problem. The expected amplitude is given by the expresion:

$$h_c^2(f) = \frac{4G}{\pi c^2 f^2}\int \frac{\mathrm{d}z}{1+z}\int \mathrm{d}m_1 \mathrm{d}m_2 \frac{\mathrm{d}R_{\mathrm{BH}}}{\mathrm{d}z\mathrm{d}m_1\mathrm{d}m_2}\left(\frac{\mathrm{d}E_{GW}}{\mathrm{d}\log f_r}\right)_{f_r=(1+z)f} \quad (4)$$

The merger ratio is usually computed using the Extended Press-Schechter formalism and converted from halo mergers to BH mergers. The growth rate of the central BH due to PBHs subducted to DF can be modeled as:

$$\frac{\mathrm{d}m_{\mathrm{BH}}}{\mathrm{d}t} = \left.\frac{\mathrm{d}m_{\mathrm{BH}}}{\mathrm{d}t}\right|_{\mathrm{accre}} + \frac{1}{t_{\mathrm{df}}}\mathcal{F}(\overline{J}, \overline{m}, \varepsilon_{\mathrm{GW}}, z) f_{\mathrm{pbh}} \frac{\Omega_{CDM}}{\Omega_m} M_{\mathrm{H}} \quad (5)$$

In the figure we show the modified BH-Halo mass relation for PBHs (left) and the amplitudes compared to NANOGrav, EPTA-IPTA and PPTA measures (right).



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