When Will We Detect Gravitational Waves:
Sensitivity Projections for Pulsar Timing Arrays

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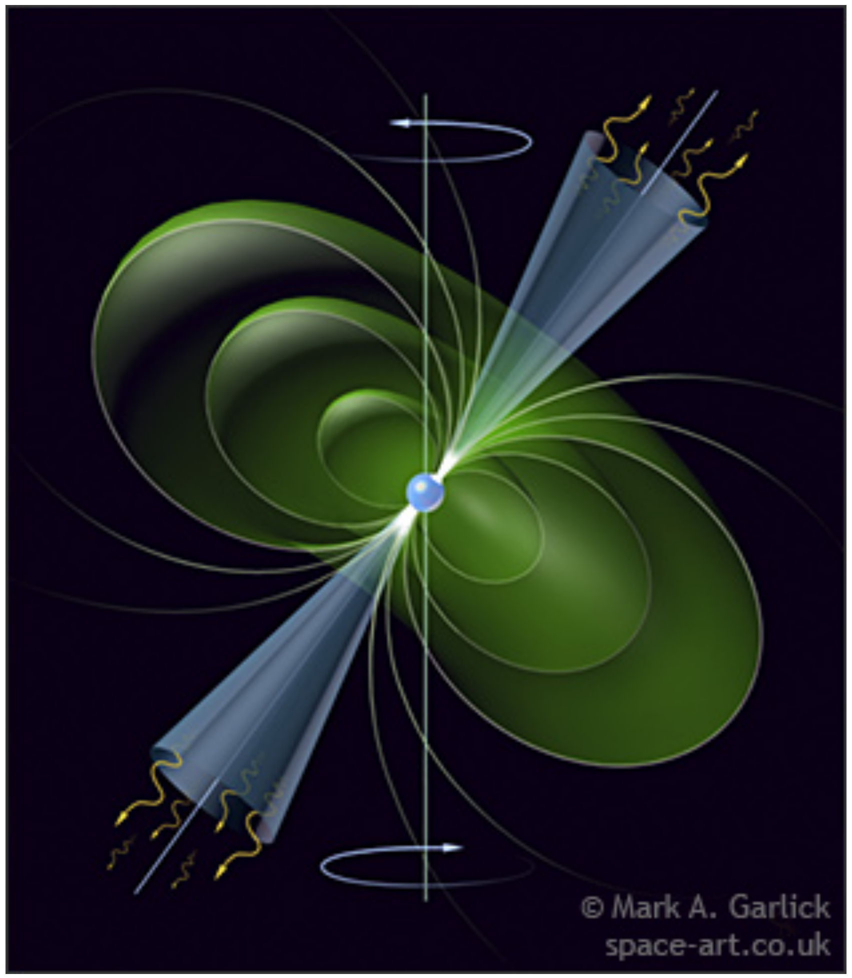
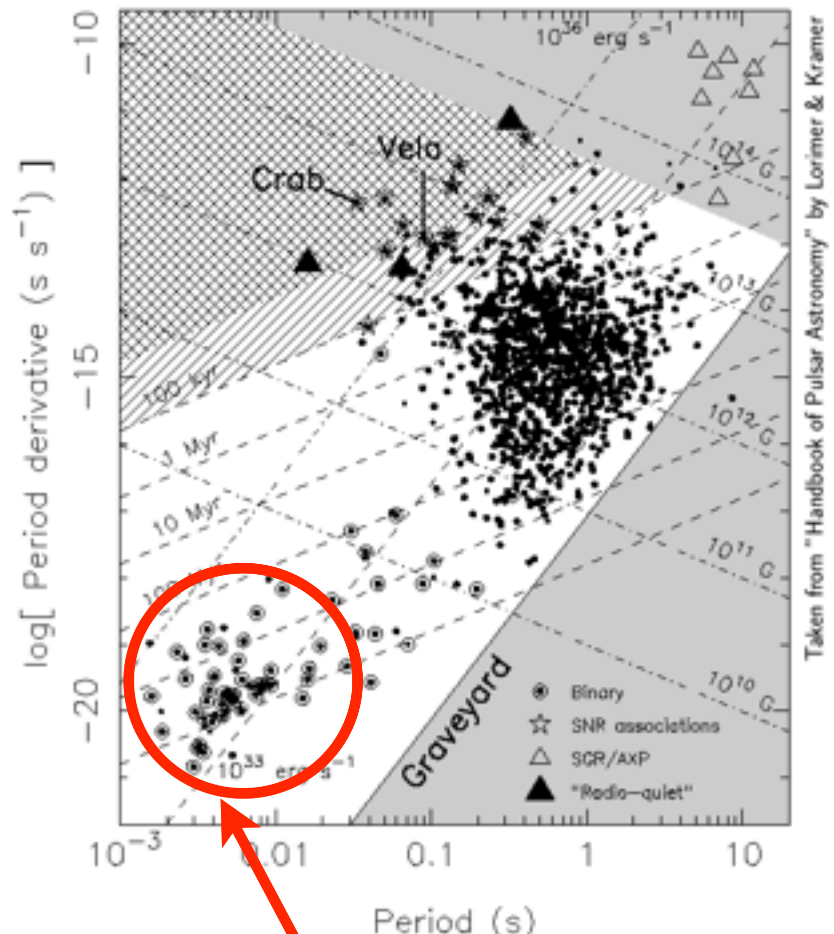
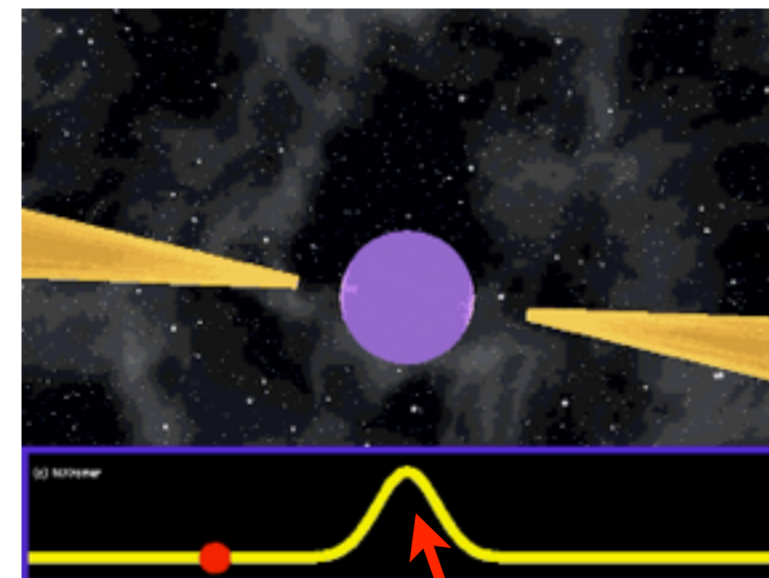
Pulsar Timing Preliminaries



Highly magnetized rotating neutron star



Extremely stable clocks



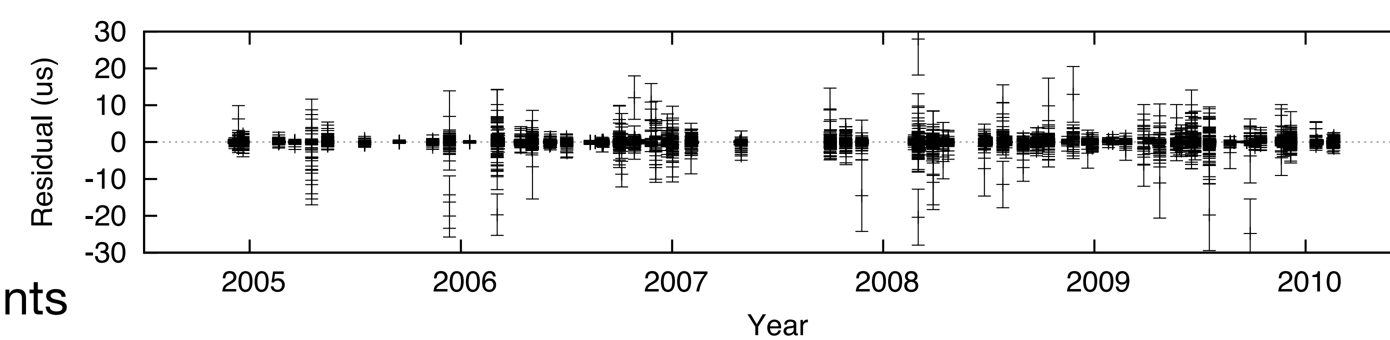
time-of-arrival (TOA)

$$\delta t = t_{\mathrm{measured}} - t_{\mathrm{model}}$$

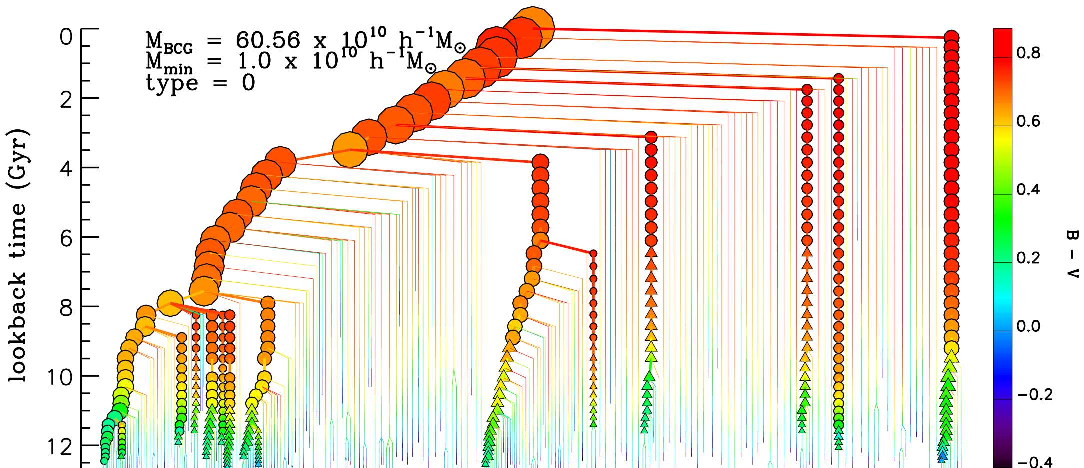
Pulsar Timing "Residual"

Measured Pulse time-of-arrival (TOA)

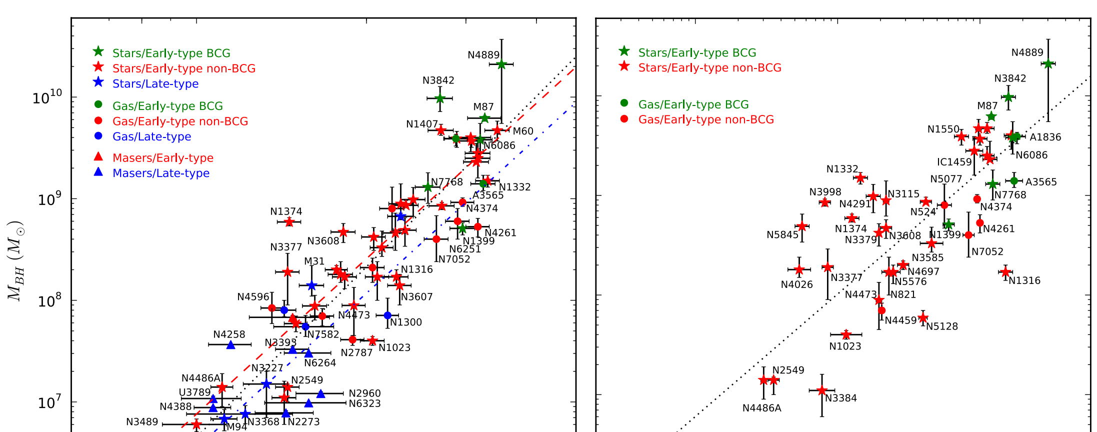
Model that accounts for many delay factors but not GWs



Sources of GWs: SMBHBs

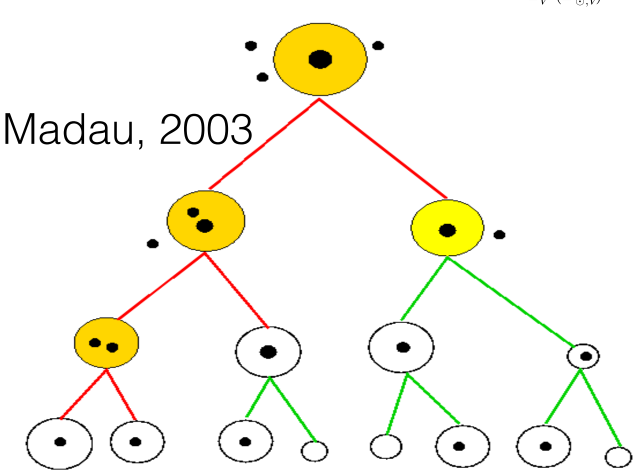


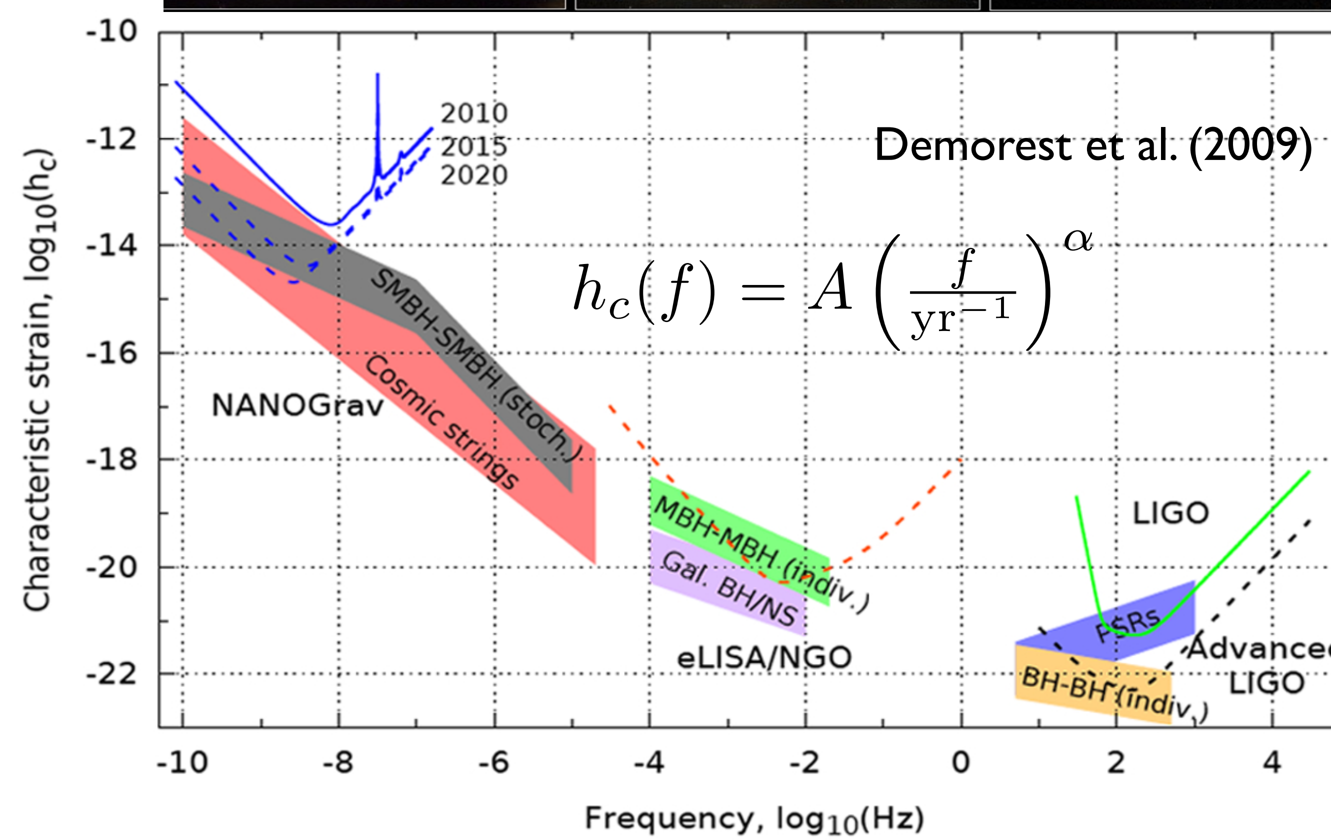
De Lucia et al, 2006



McConnell & Ma 2012

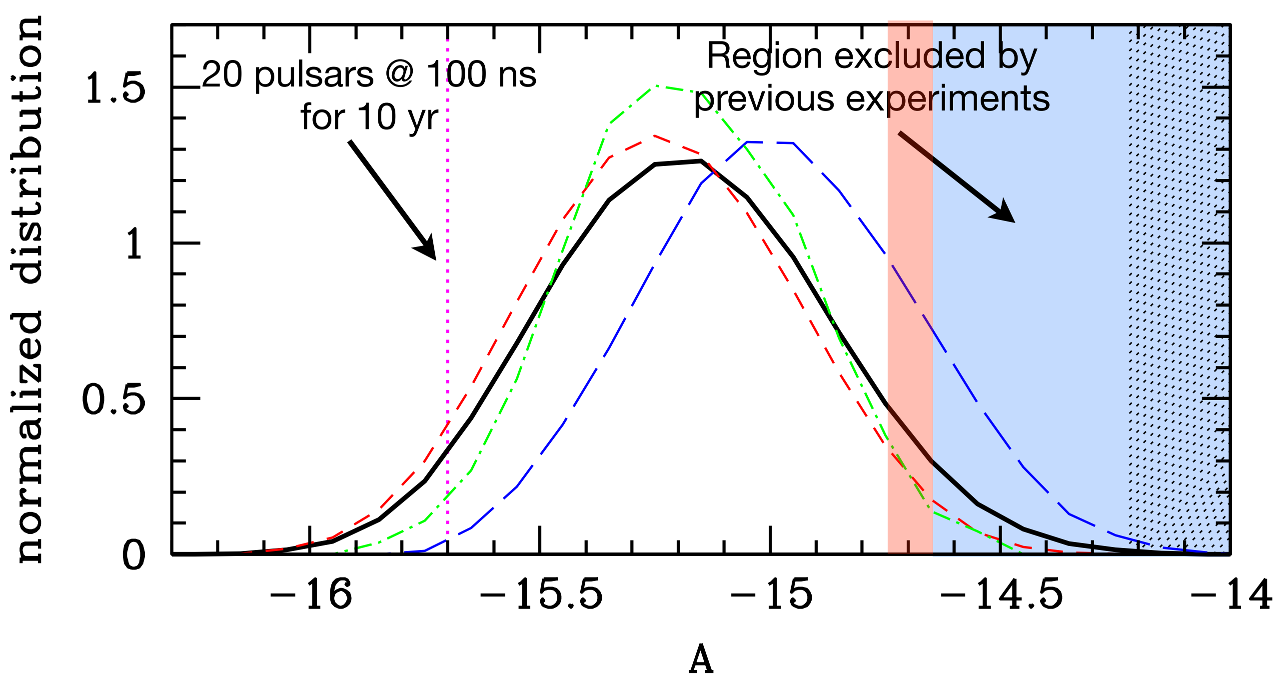
Vononteri, Hardt & Madau, 2003





Expected level of SMHB Stochastic Background

Sesana et al, (2012)

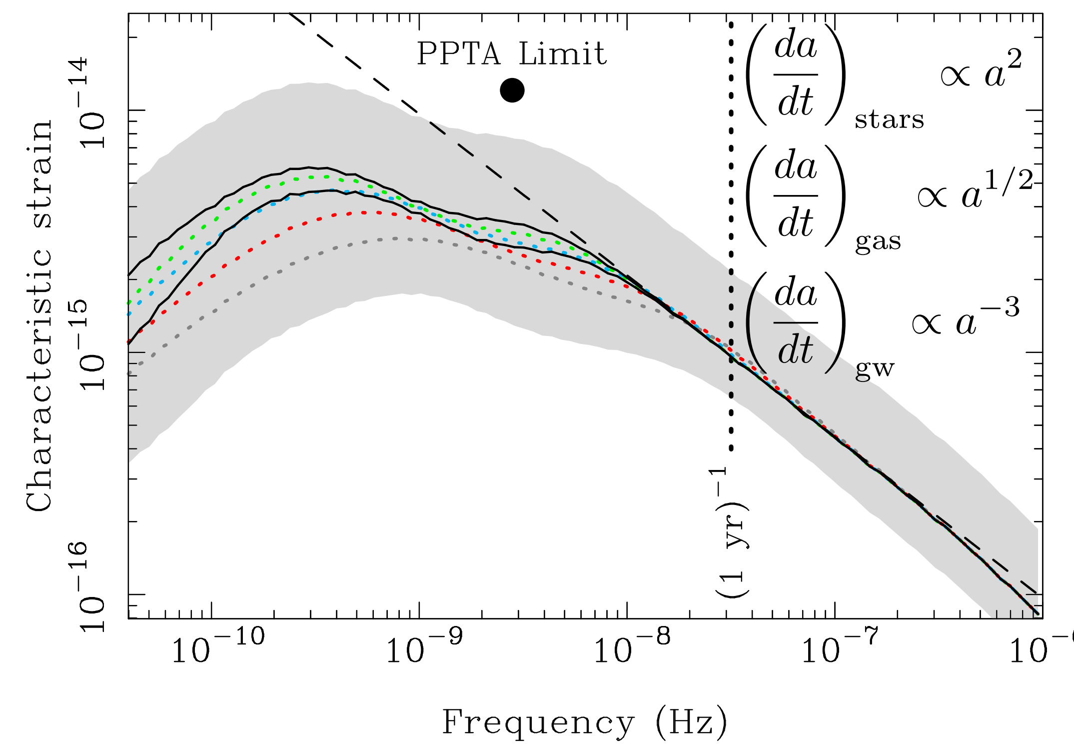


1-sigma bounds on amplitude are

$$5.6 \times 10^{-16} < A < 2 \times 10^{-15}$$

with a mean of $\langle A \rangle = 1 \times 10^{-15}$

Ravi et al. (2014)



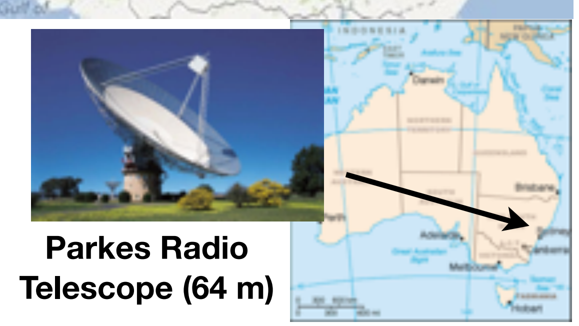
Large uncertainty in signal amplitude at low frequencies due to very poorly understood binary-environment interactions.

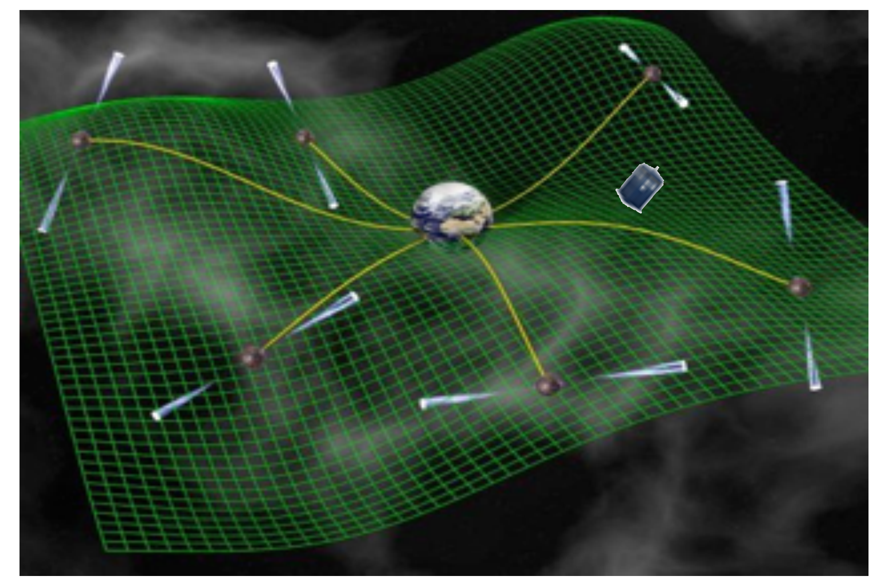
Bottom Line: Predictions of the SMBHB stochastic background amplitude based on observations and more reliable models are larger than previously thought, but there could be some depletion of the signal at low frequencies.

Pulsar Timing Arrays

- PTAs (**N**orth **A**merican **N**anohertz **O**bservatory for **Grav**itational Waves, **E**uropean **P**ulsar **T**iming **A**rray, **P**arkes **P**ulsar **T**iming **A**rray)

Together, form **I**nternational **P**ulsar **T**iming **A**rray

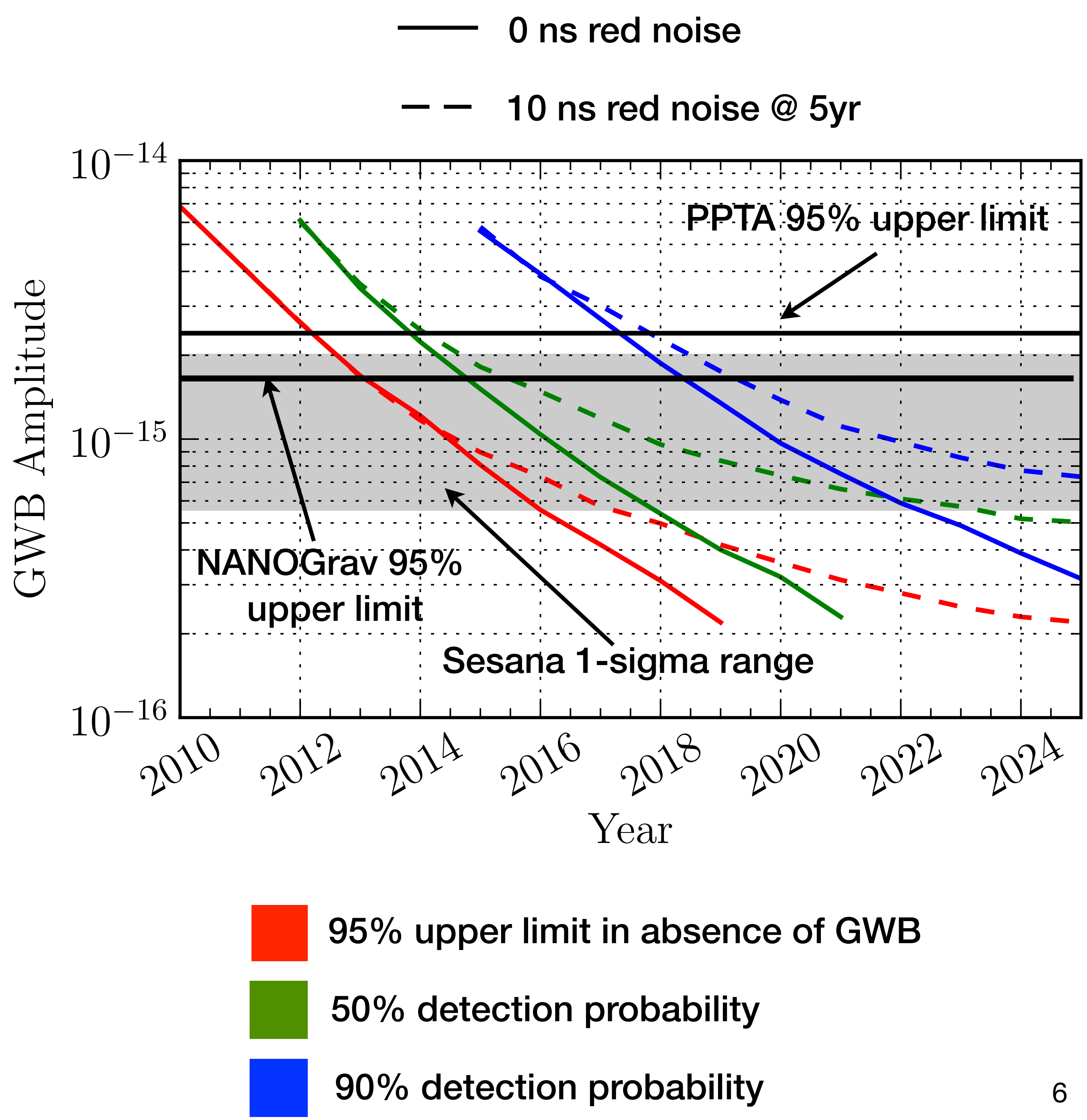




Use an array of extremely well timed pulsars to search for GWs. Currently we have >40 pulsars timed at or below the microsecond level

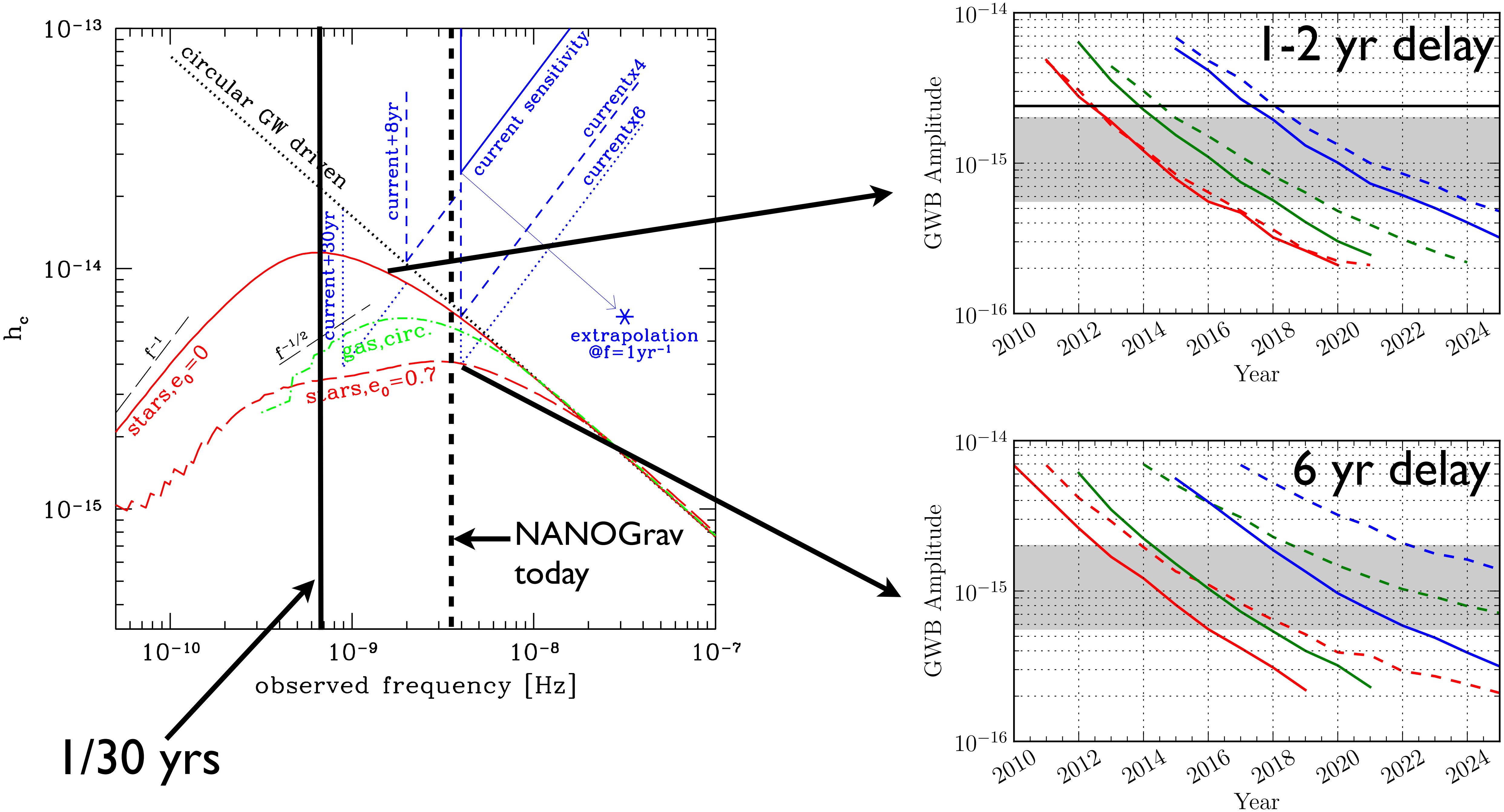
When will we detect the GWB?

- Simulate *isotropic GW-driven* background
- Used currently timed (scheduled) pulsar properties up until 2014 using harmonic mean RMS
- Added 4 pulsars per year: 2 with median rms from Arecibo and 2 with median rms from GBT
- Red noise level uses spectral index of 5 (Shannon and Cordes 2010) with a level of 0 (solid) to 10 (dashed) ns measured at 5 yrs



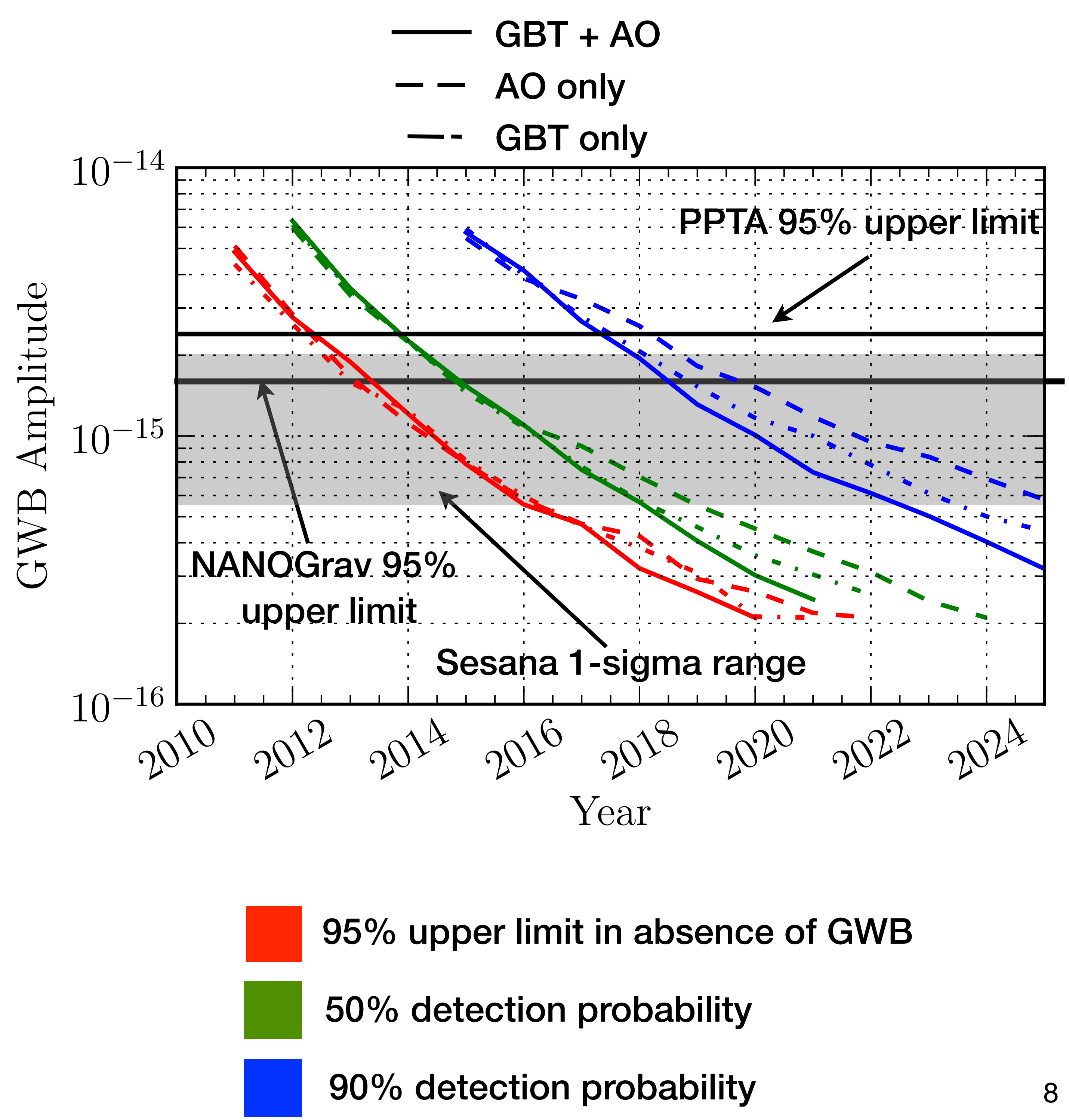
When will we detect the GWB: SMBHB uncertainties

- Several recent works predict that the SMBHB environment plays an important role in the system evolution at relevant orbital separations



When will we detect the GWB: telescope uncertainties

- Simulate *isotropic GW-driven* background
- Used currently timed (scheduled) pulsar properties up until 2014 using harmonic mean RMS
- For GBT-only case, still add 4 pulsars per year and reduce cadence by 1/2 on all pulsars
- For AO only case we only add 2 pulsars per year at AO and stop timing all GBT pulsars.



Conclusions

- We expect a large population of SMBHBs radiating GWs
- The GW spectrum of this background is heavily dependent on the binary environment.
- Based on reasonable assumptions about future observations, a detection of GW background could be made as early as 2017
- Sensitivity to the GW background is fairly robust to telescope availability
- Sensitivity is very strongly affected by the orbital separation of the binary at time of decoupling from environment.