Space-Based Gravitational-Wave Astrophysics in the US

Neil J. Cornish

- US Science Developments since LISA IX
- LISA-Pol: eLISA with a US boost?
- The Gravitational Wave Decade
- Refreshing the Science case - fertile areas for future research

US Science Developments since LISA IX

1207.4848 "Prospects for observing ultra-compact binaries with space-based gravitational wave interferometers and optical telescopes", Littenberg, Larson, Nelemans, Cornish

1209.6286 "Astrophysical Model Selection in Gravitational Wave Astronomy", Adams, Cornish, Littenberg

1211.0548 "Supermassive Seeds for Supermassive Black Holes", Johnson, Whalen, Li, Holz

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1307.3542 "Astrophysics of super-massive black hole mergers", Schnittman

1307.4116 "Detecting a Stochastic Gravitational Wave Background in the presence of a Galactic Foreground and Instrument Noise", Adams, Cornish

1306.3253 "Pointing LISA-like gravitational wave detectors", Karan, Finn, Benacquista

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1405.1414 "Stars as resonant absorbers of gravitational waves", McKernan, Ford, Kocsis, Haiman

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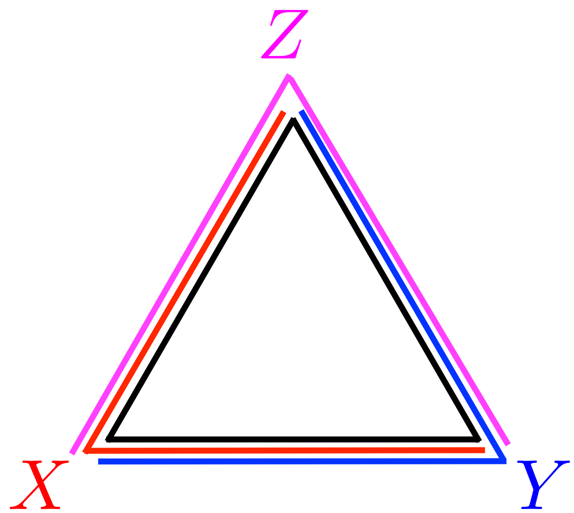
eLISA-Pol: Measurement benefits of 3-arms

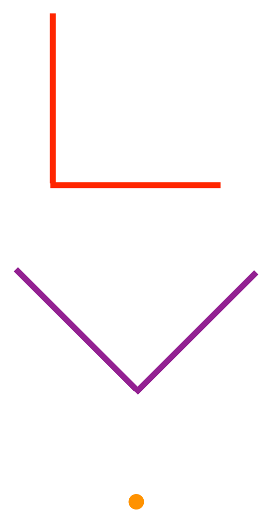


Three interferometers!

$$S_+ = \frac{\sqrt{3}}{2} X \quad \Rightarrow$$

$$S_\times = \frac{1}{2}(X + 2Y) \quad \Rightarrow$$

$$S_\odot = \frac{1}{3}(X + Y + Z) \quad \Rightarrow$$



Instantaneous measurement of both polarization states and increased signal-to-noise

Null channel to monitor average low frequency instrument noise

eLISA-Pol: Science Gain from 3-arms

- More Sources

- x 3 Extreme Mass Ratio Inspirals
- x 2 Galactic Binaries
- x 10 Low Mass Seed Black Holes

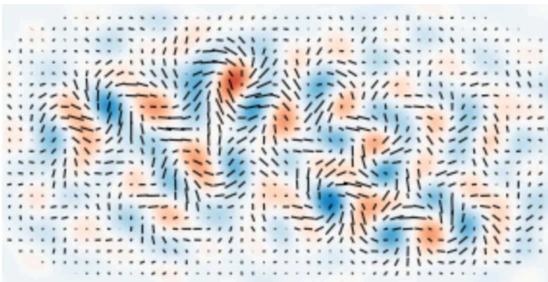
- Better Measurements

- x 1.5 Well Localized Galactic Binaries
- x 7 Well Localized Massive Black Hole Mergers
- x 5 Black Hole Systems with Precise Spin Determination

- Wider Discovery Space

- Enable the unambiguous detection of a stochastic background
- Confident detection and characterization of exotic signals

2010's: The Decade of Gravitational Waves

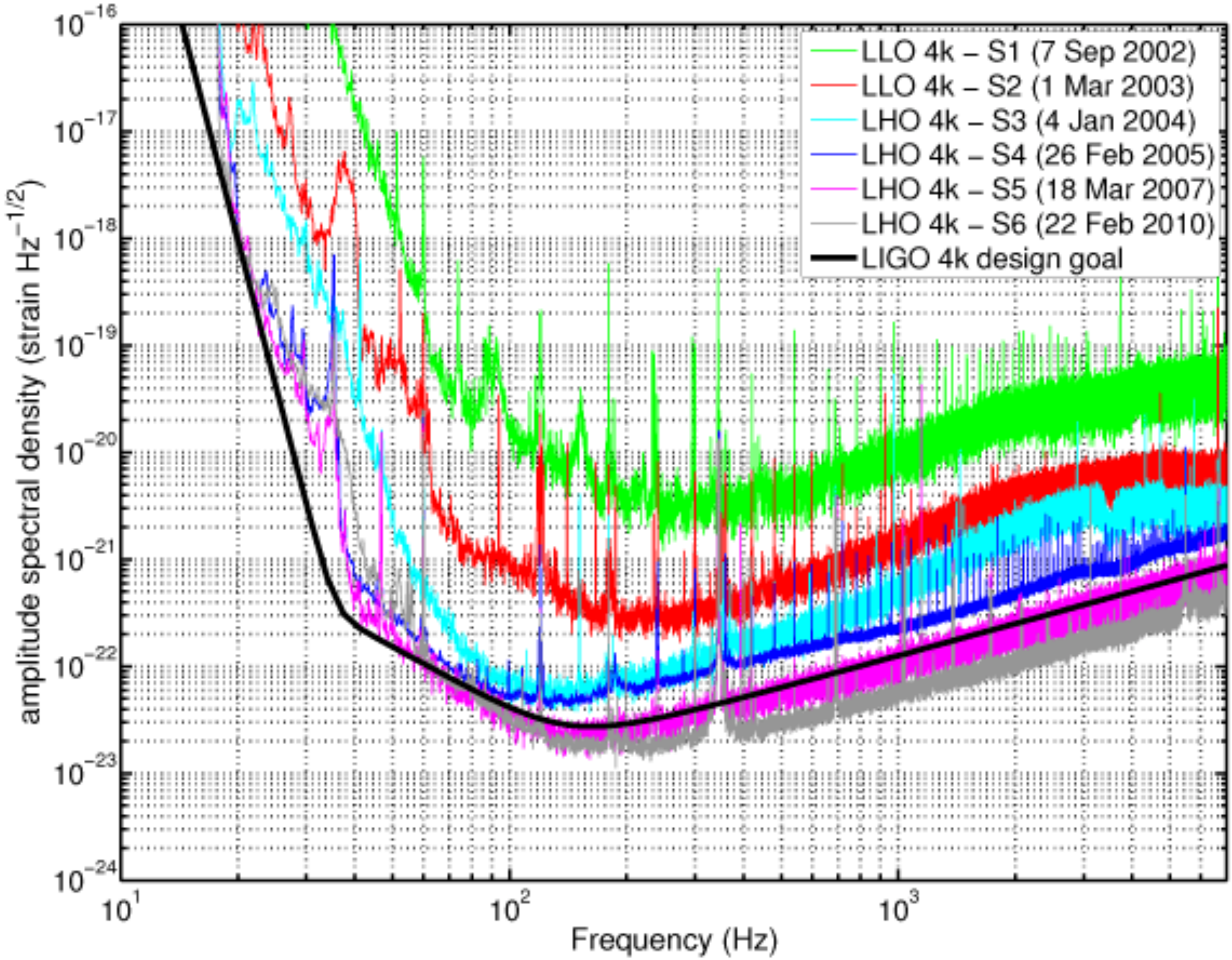


- BICEP2 detection in 2014

- LIGO/Virgo detection in ~ 2016

- IPTA detection in ~ 2018

LIGO sensitivity over time



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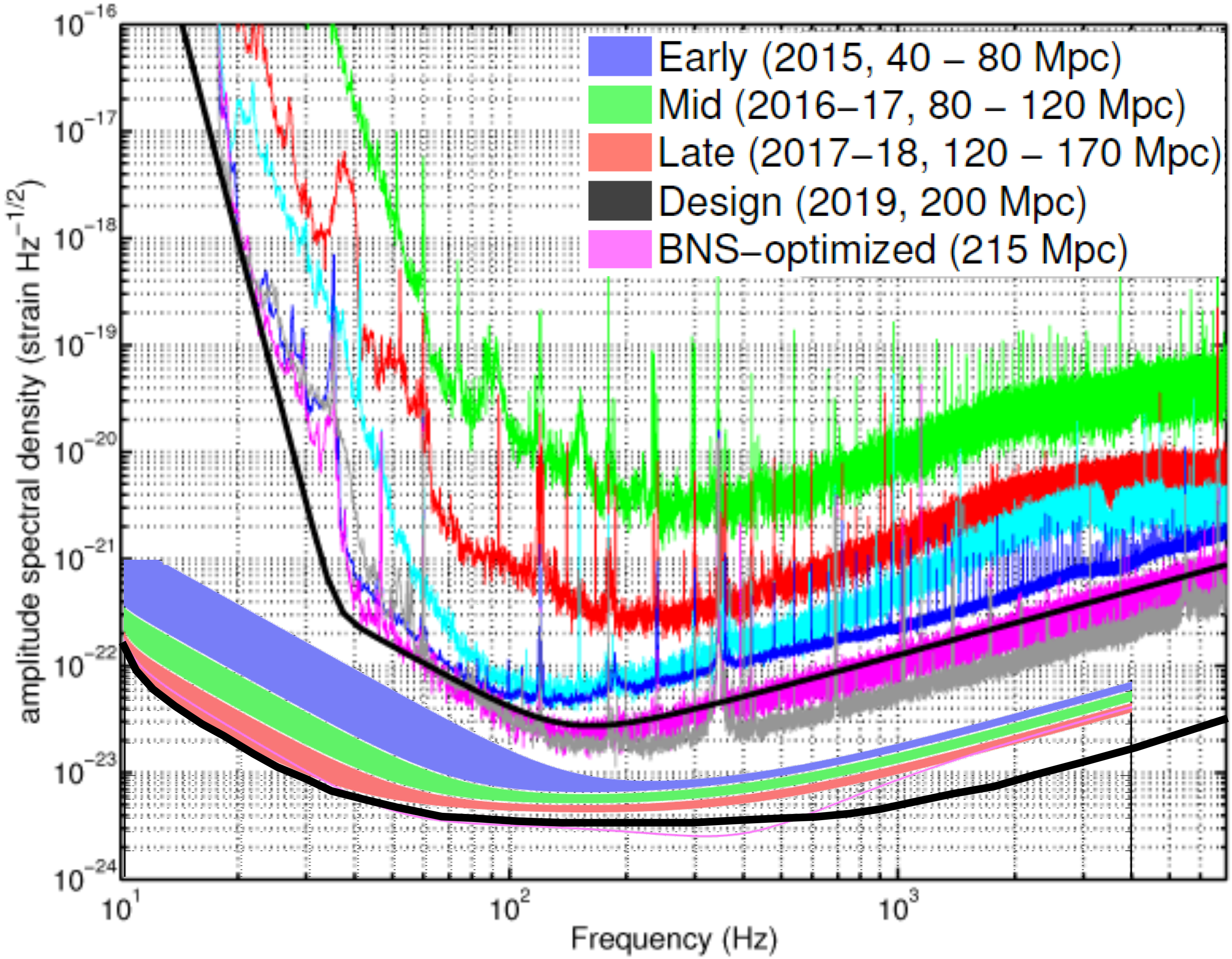
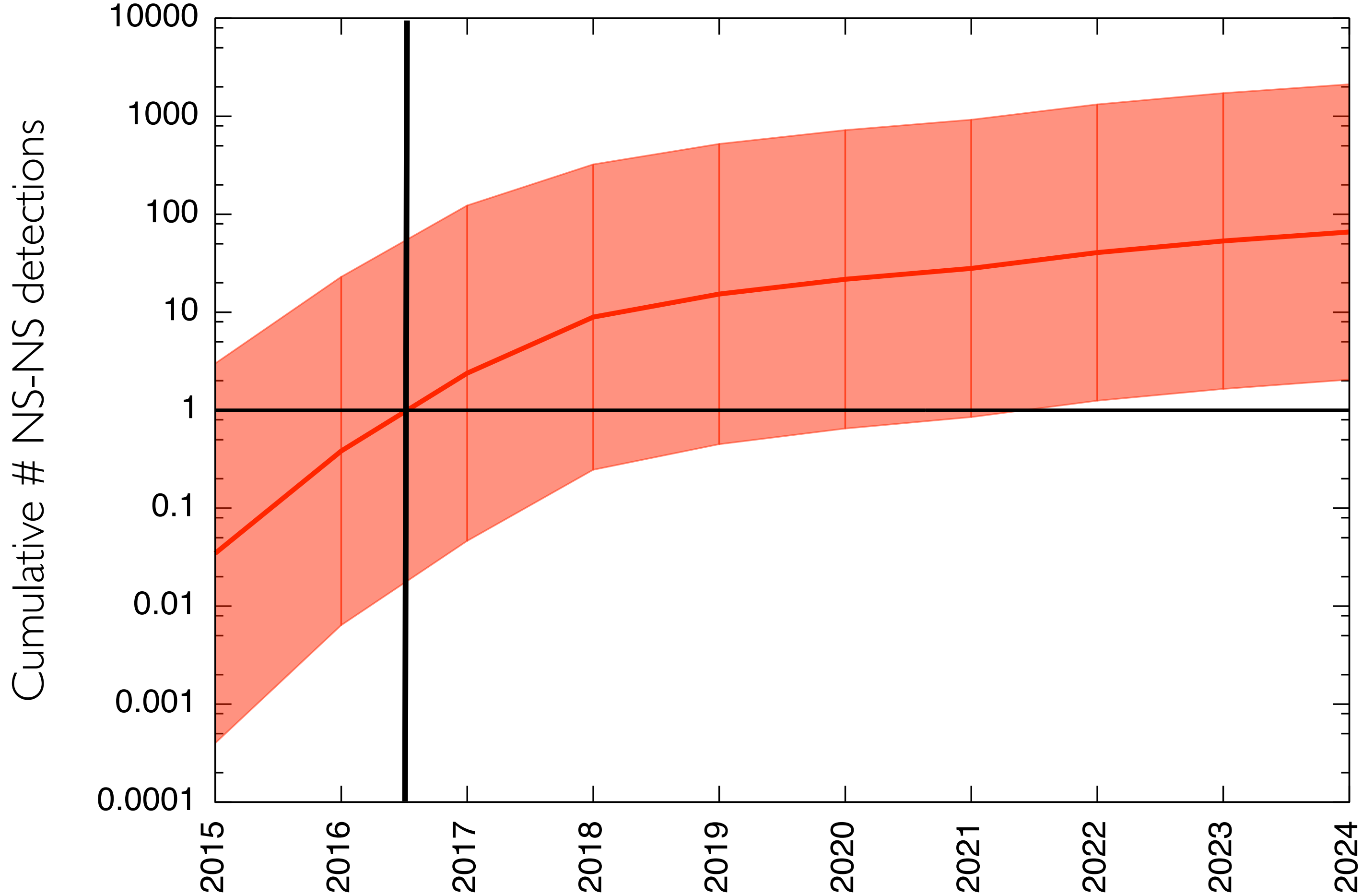
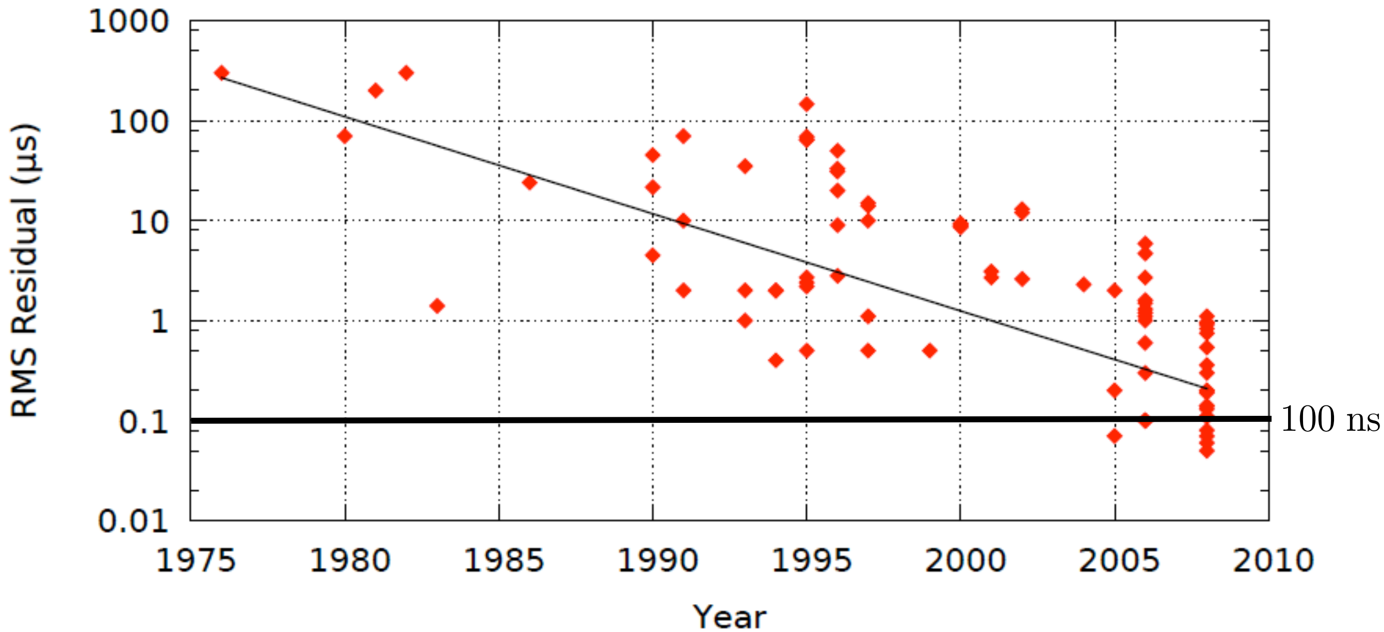


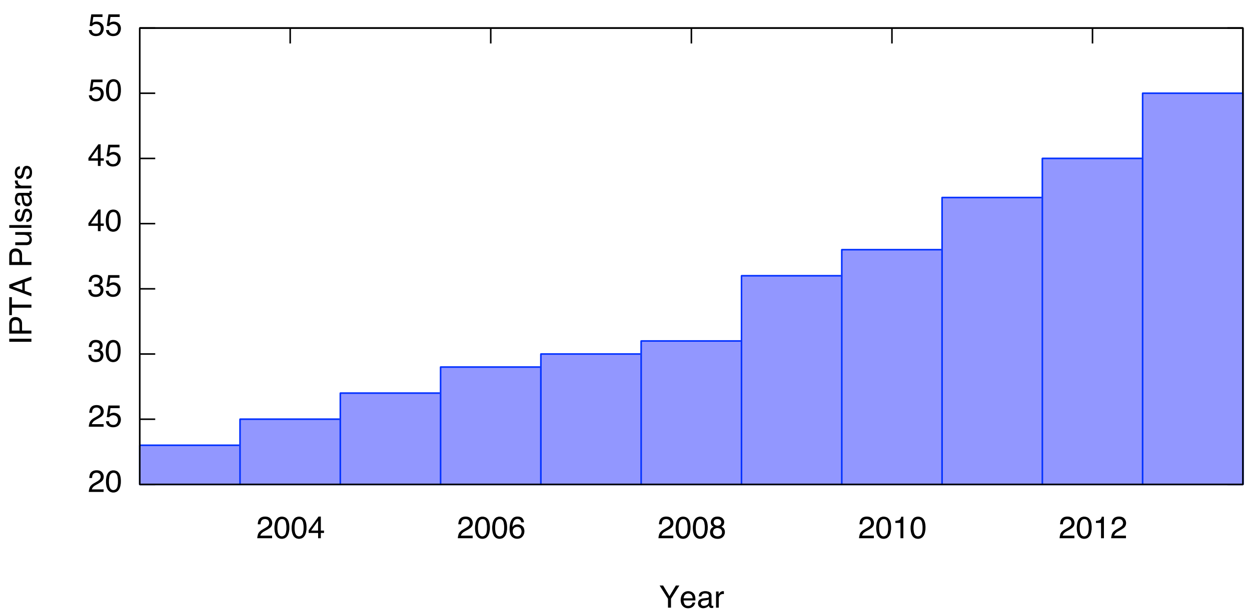
LIGO/Virgo Prediction



[LIGO & Virgo Collaborations, arXiv:1304.0670 (2013)]

Pulsar Timing in hot pursuit





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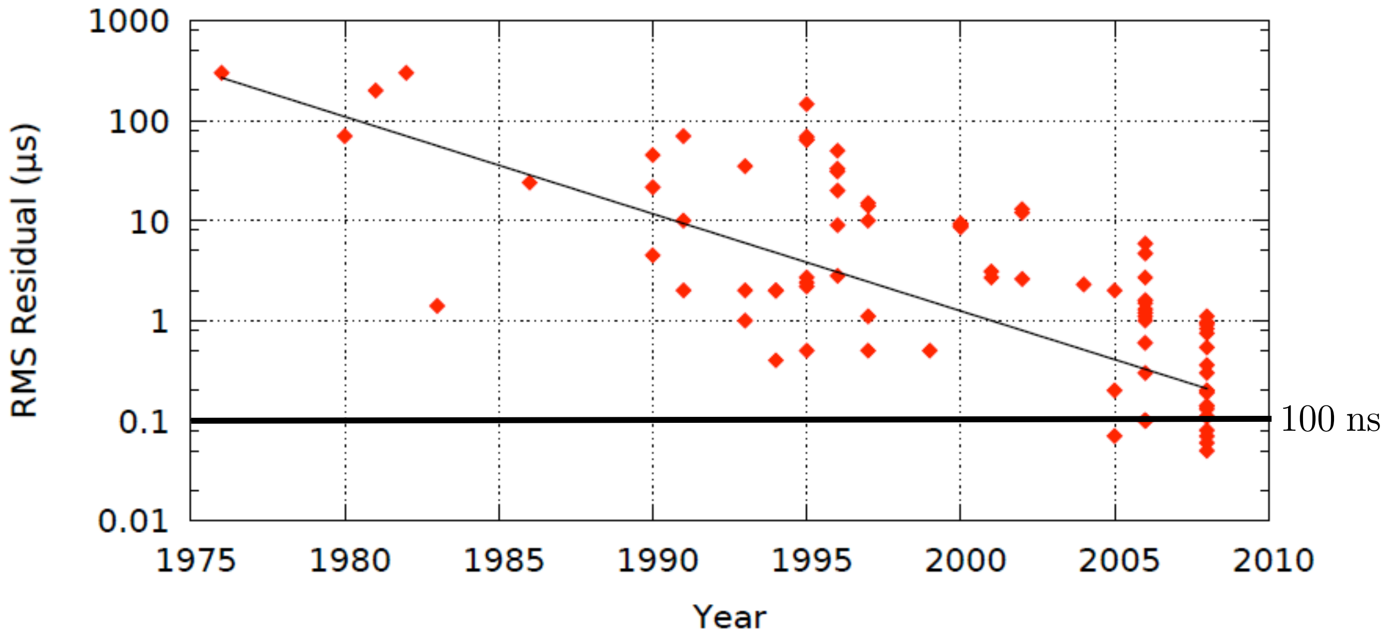
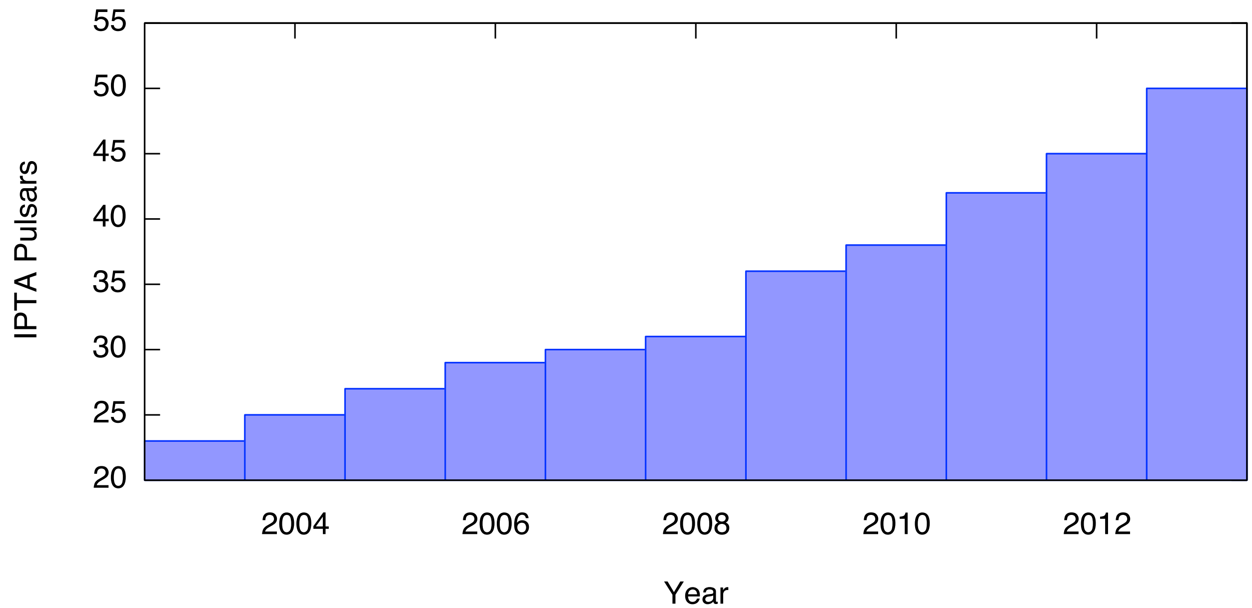
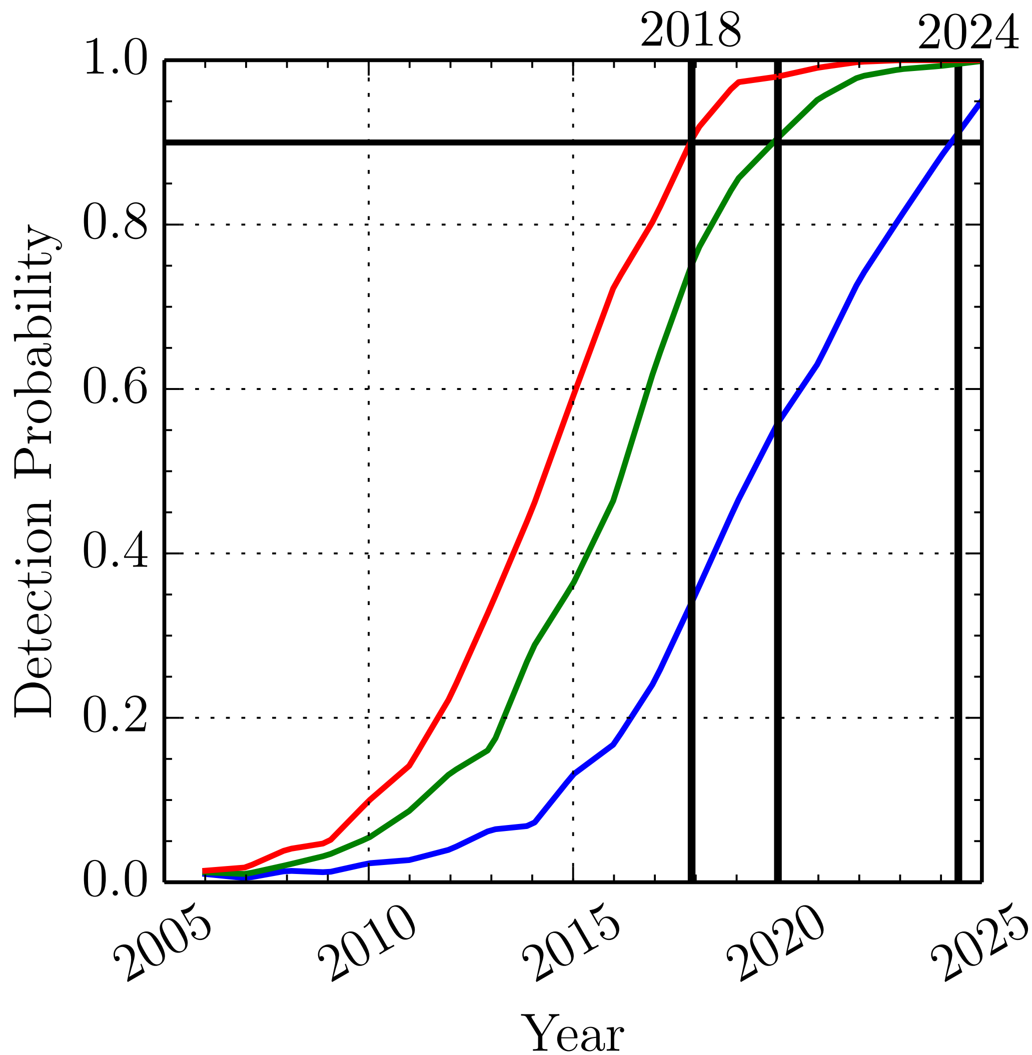


Likely detection with ~40 pulsars at ~100 ns timing accuracy



Pulsar Timing: NANOGrav Prediction



[X. Siemens, J. Ellis, F. Jenet, J. Romano, Class. Quant. Grav. 30, 224015 (2013)]

Refreshing and Expanding the Science Case

Fertile areas for study

(aka, pages from my last four grant proposals that NASA declined to fund)

BH Parameter Estimation

Fully consistent BH IMR waveforms, precession + higher harmonics now possible using the minimal rotation frame. Fast frequency domain implementation via the new uniform SPA technique (Klein, Cornish & Yunes).

Unexpected Sources

Develop data analysis for un-modeled signals (e.g. bursts).
2 arm versus 3 arm performance

Intermediate Mass Black Holes

Can these play a larger role in the science case?
Constraints on population synthesis models? EM counterparts?

Fertile areas for study

EMRI waveforms with resonances

Impact on detection algorithms and parameter estimation

Intermediate Mass Ratio Binaries

Hybrid waveforms (PN/Self Force)
Use in GR tests

Rare (yet loud) Galactic Binaries

Stellar BH-BH, BH-NS and NS-WD binaries
Overlap with LIGO/Virgo physics
Detect BH-BH binaries anywhere in galaxy for $f > 0.5$ mHz
Measure chirp mass of BH-BH binaries for $f > 1$ mHz