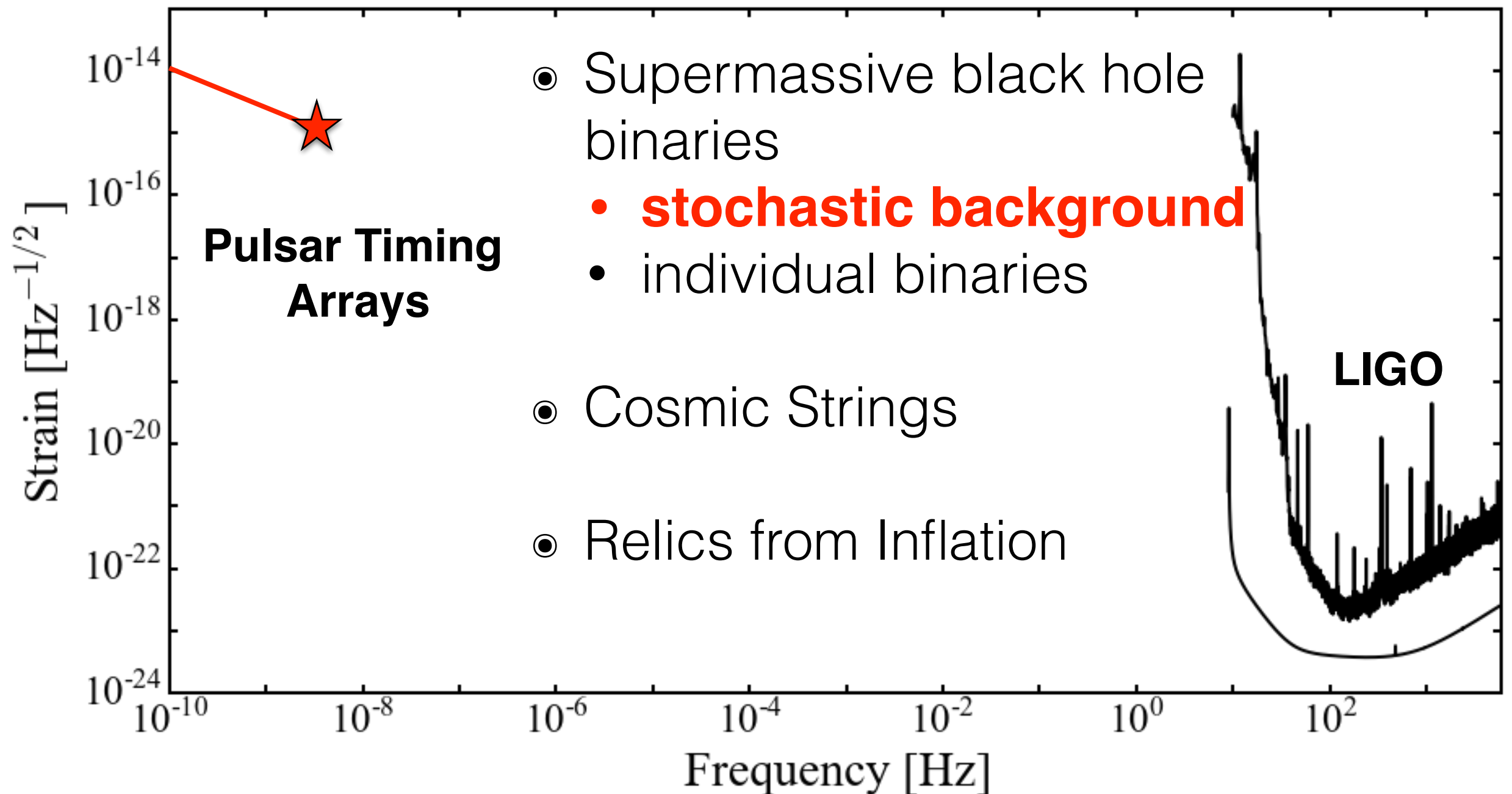


Gravitational waves from binary supermassive black holes missing in pulsar observations

Paul Lasky, on behalf of the  PPTA

Shannon et al., 2015 (Science)

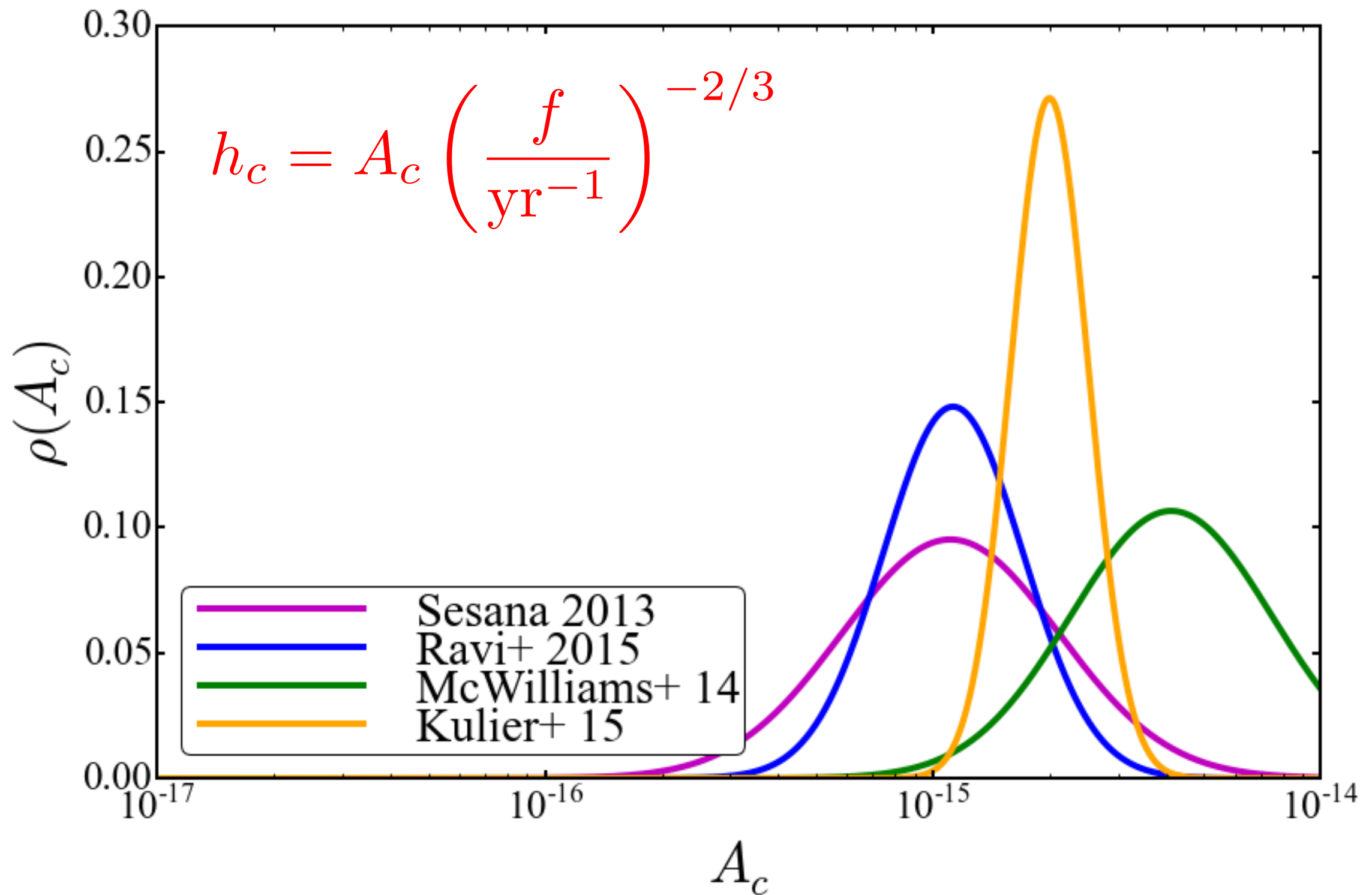
$$h_c = A_c \left(\frac{f}{\text{yr}^{-1}} \right)^{-2/3}$$



Supermassive black hole mergers

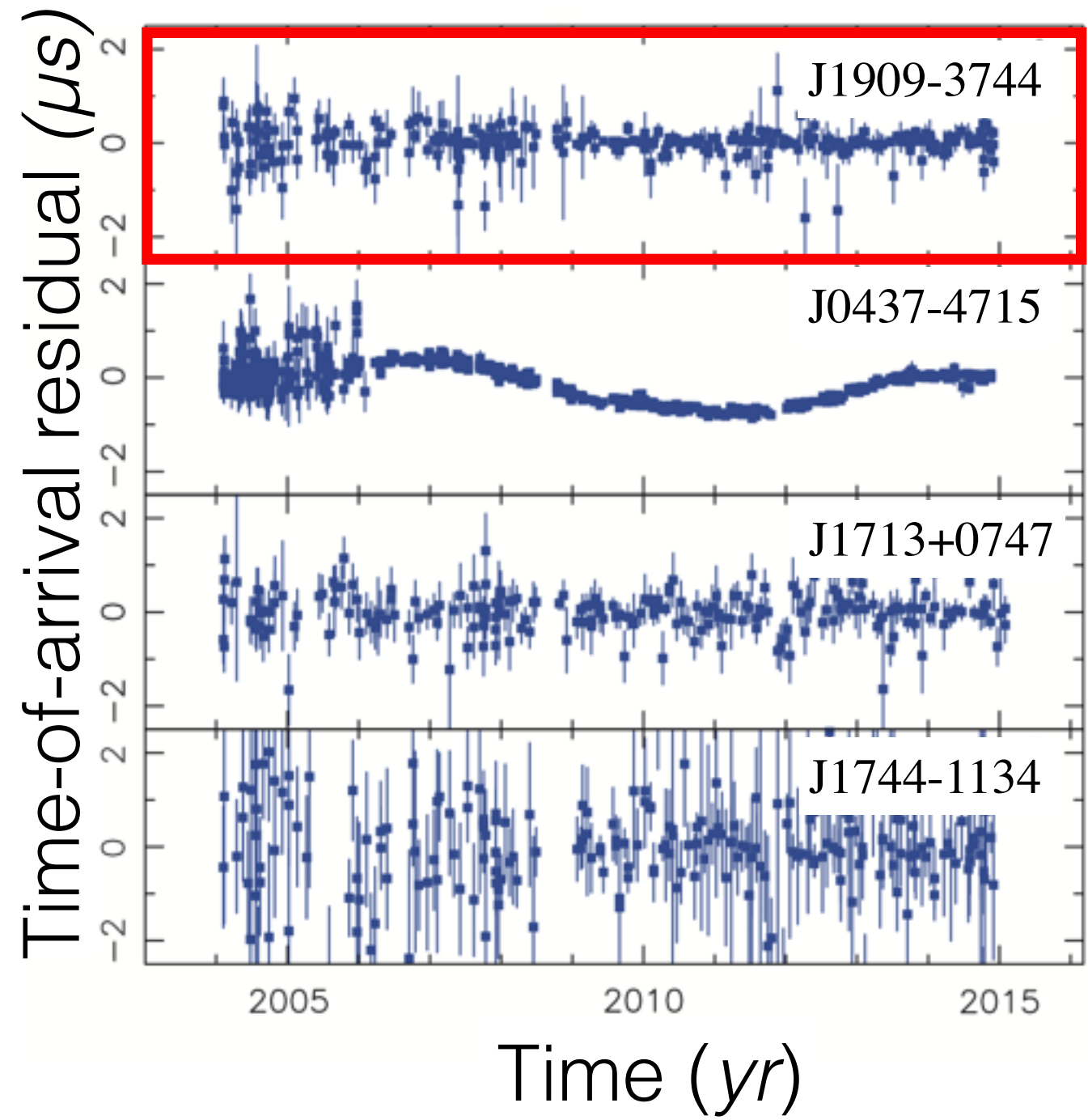
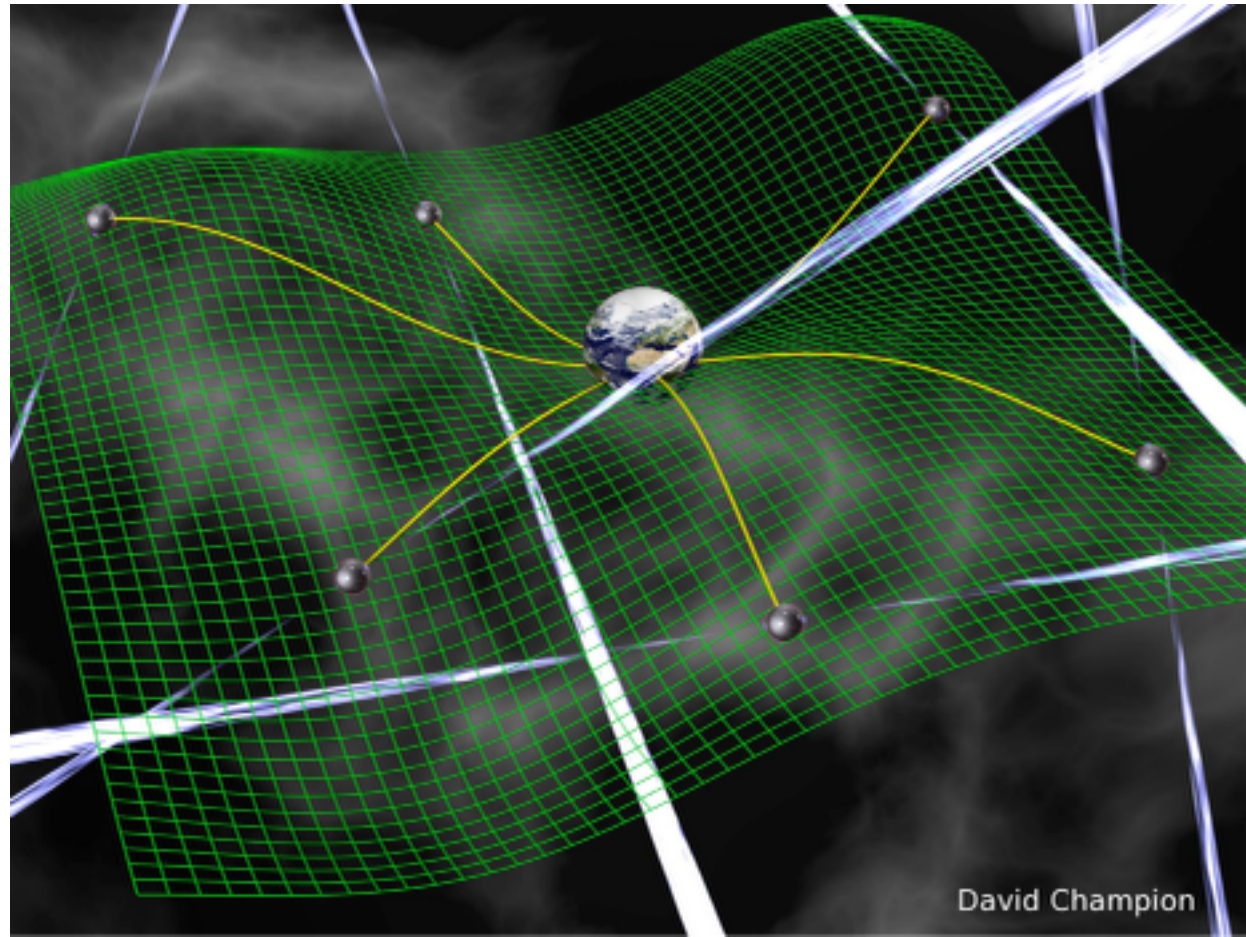
- ◉ Assume all galaxies host a SMBH
- ◉ Use observed BH-Galaxy mass relations
- ◉ Assume BH merger rate traces galaxy merger rate
- ◉ Assume GW dominated mergers (circular, ...)
- ◉ ...
- ◉ Sum up contribution from all SMBHs mergers in Universe





shared assumptions

- all binaries have circular orbits
- all binaries driven through band by GW emission



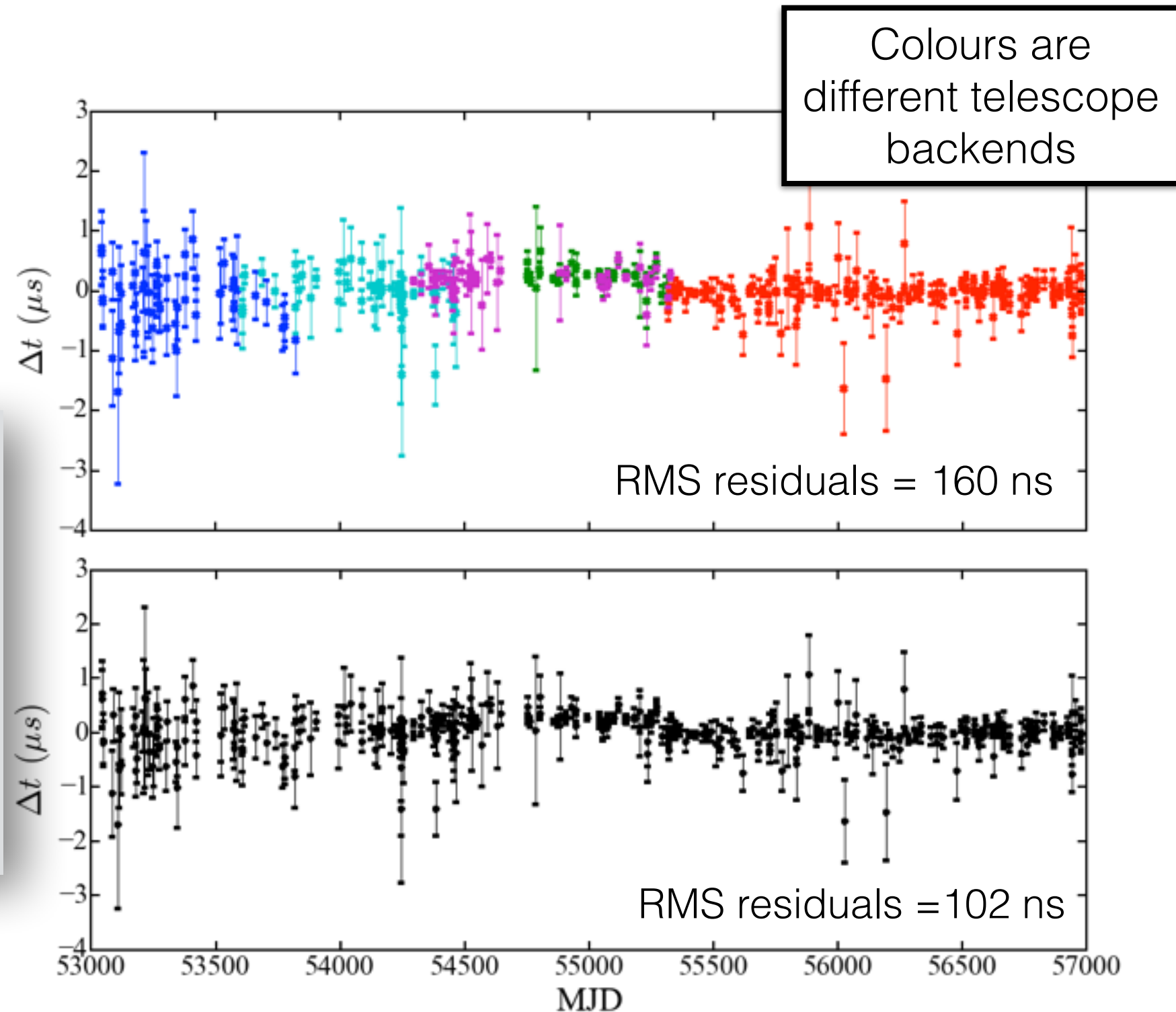
PSR J1909-3744

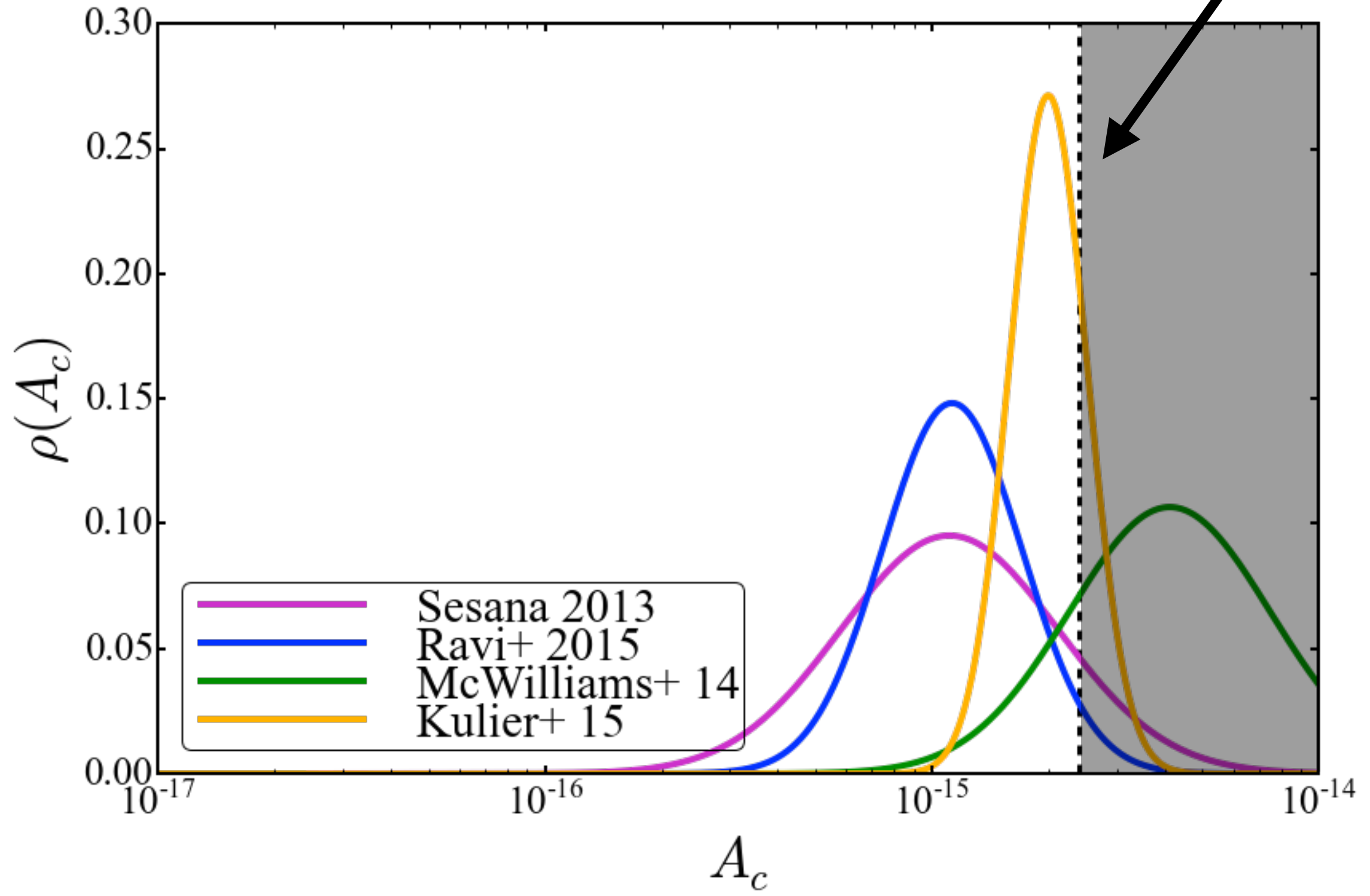
$$f = 339.31568728824556 \pm 0.00000000000000016 \text{ Hz}$$

$$\text{DM} = 10.4 \text{ pc cm}^{-3}$$

3 improvements

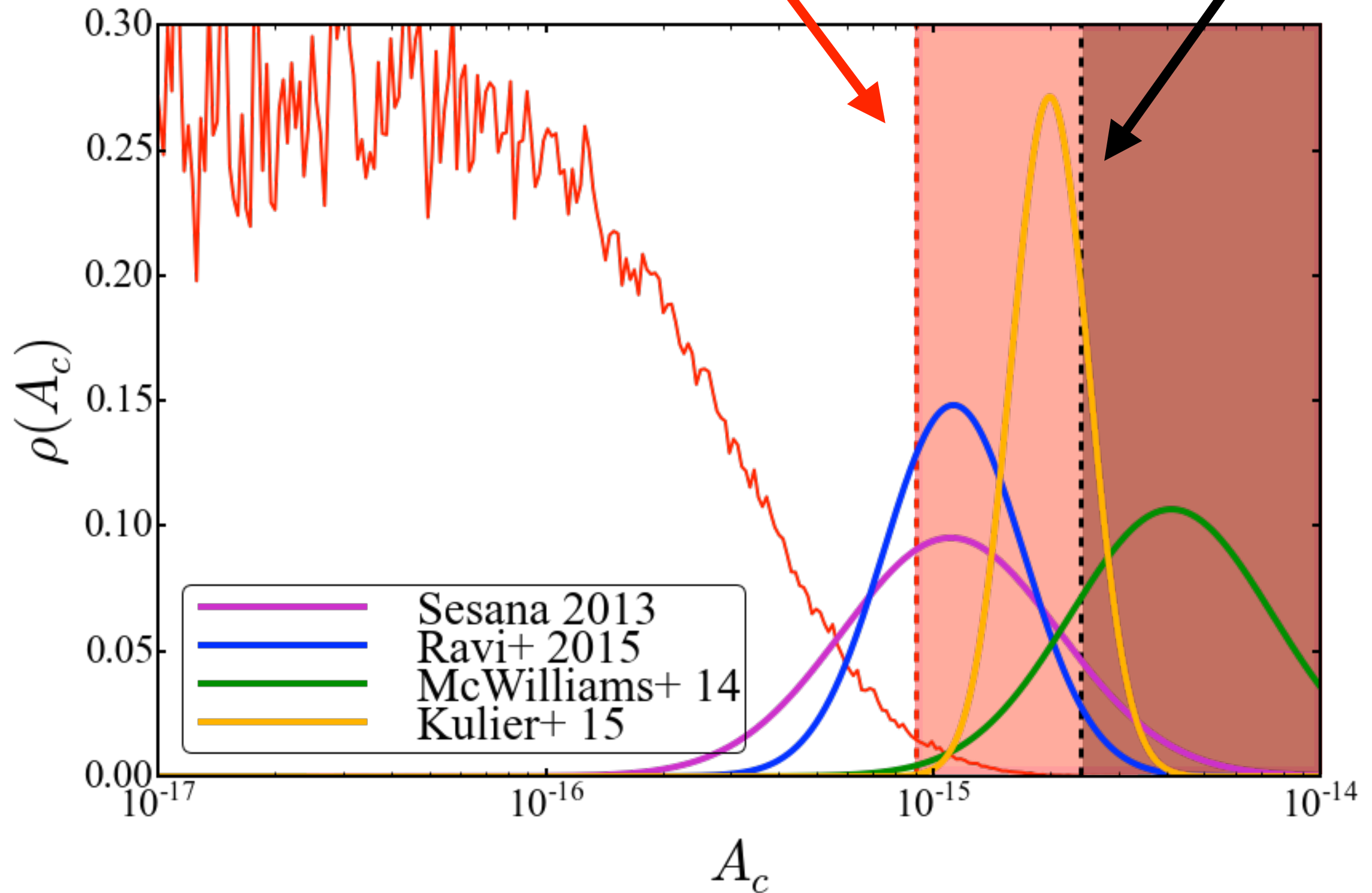
- longer baseline (+3yr)
- discrete phase offsets
- short λ obs. only



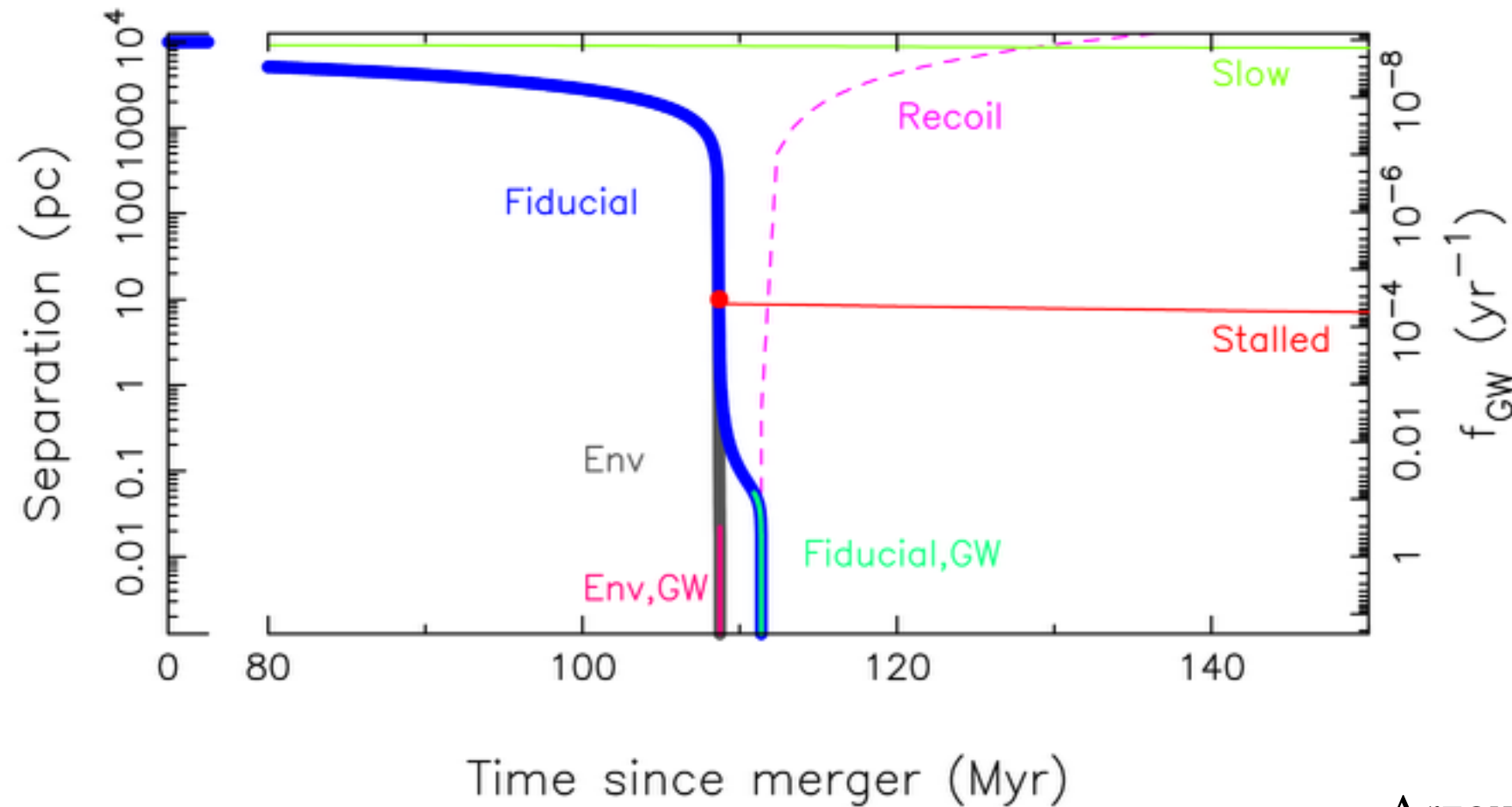


Shannon et al.
(2015)

Shannon et al.
(2013)

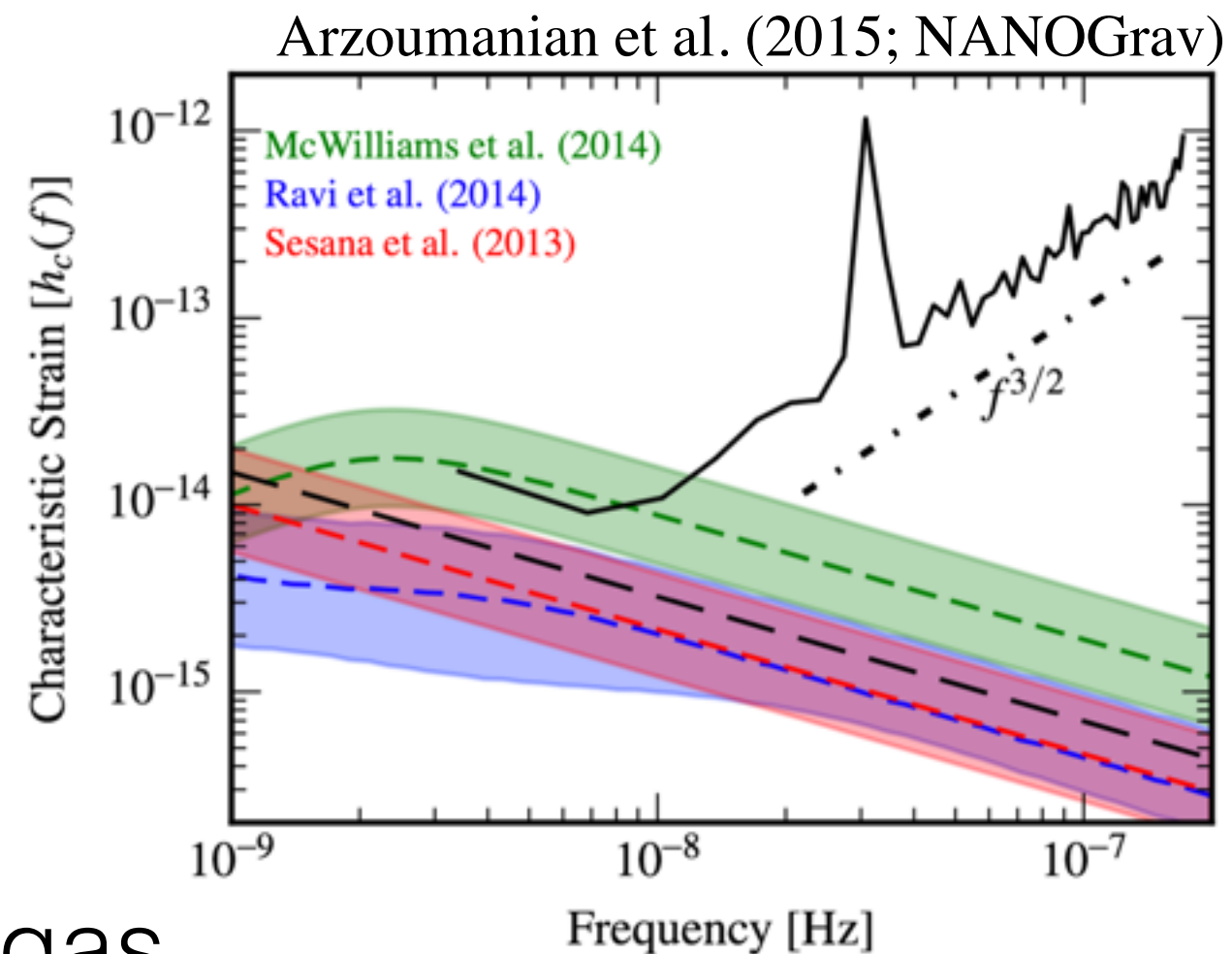


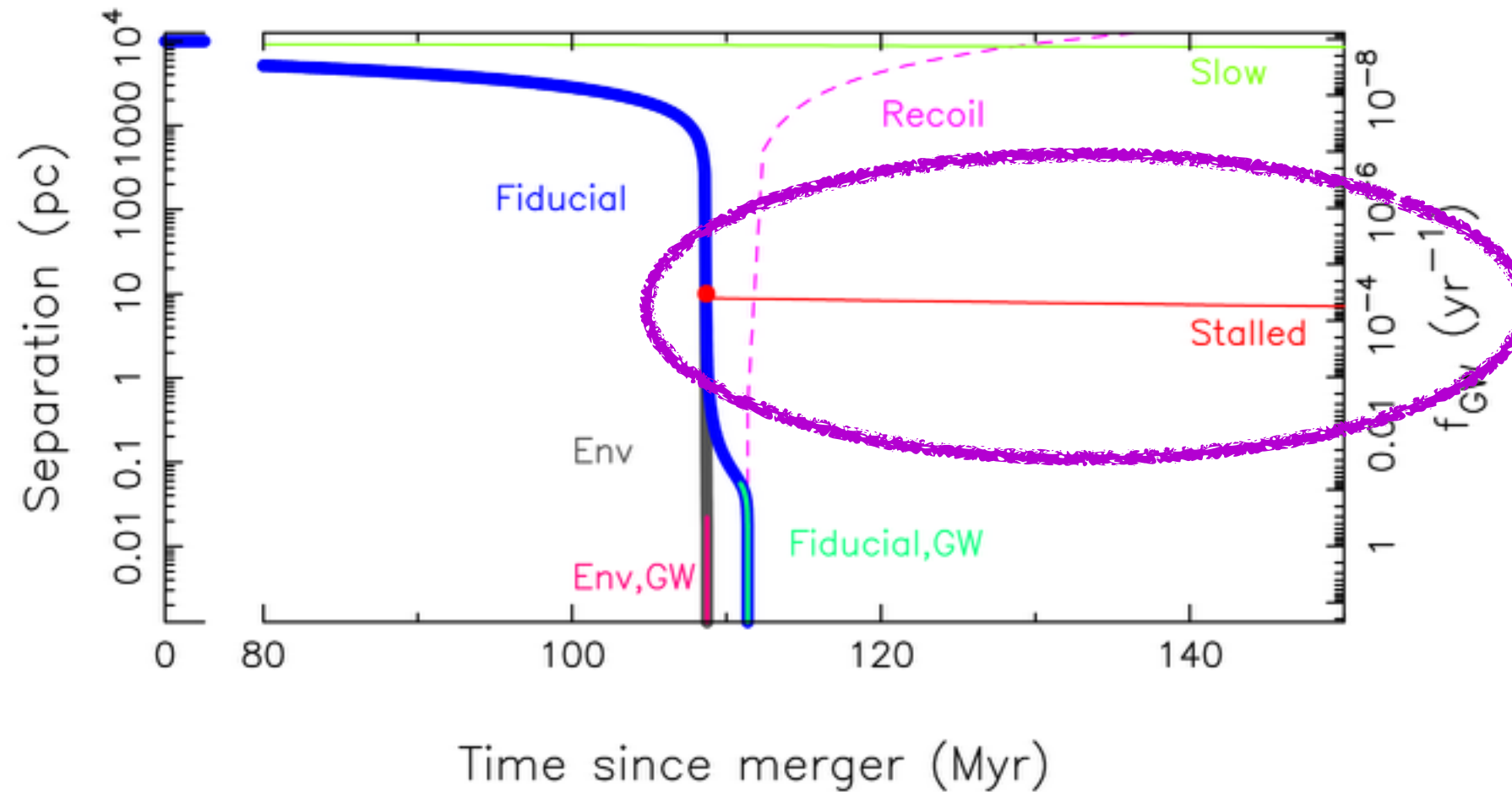
P_{model}	0.09	0.06	0.002	0.005
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Astrophysical Inference

- Black hole mass function at $z \sim 2$?
- Galaxy merger rate?
- Environmental factors: stars, gas, ...



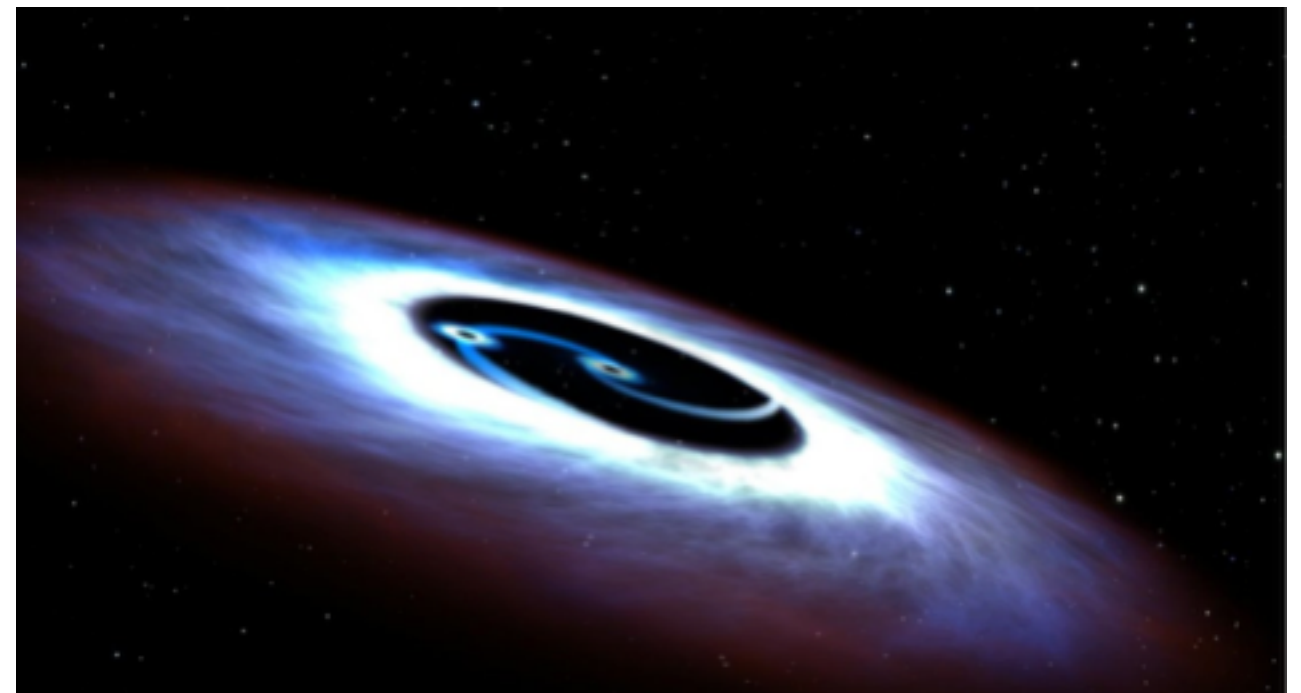


Is the final parsec problem solved?

sciencedaily.com

Stalled evolution:

- many binary systems
- rogue, isolated BHs from 3-body interactions



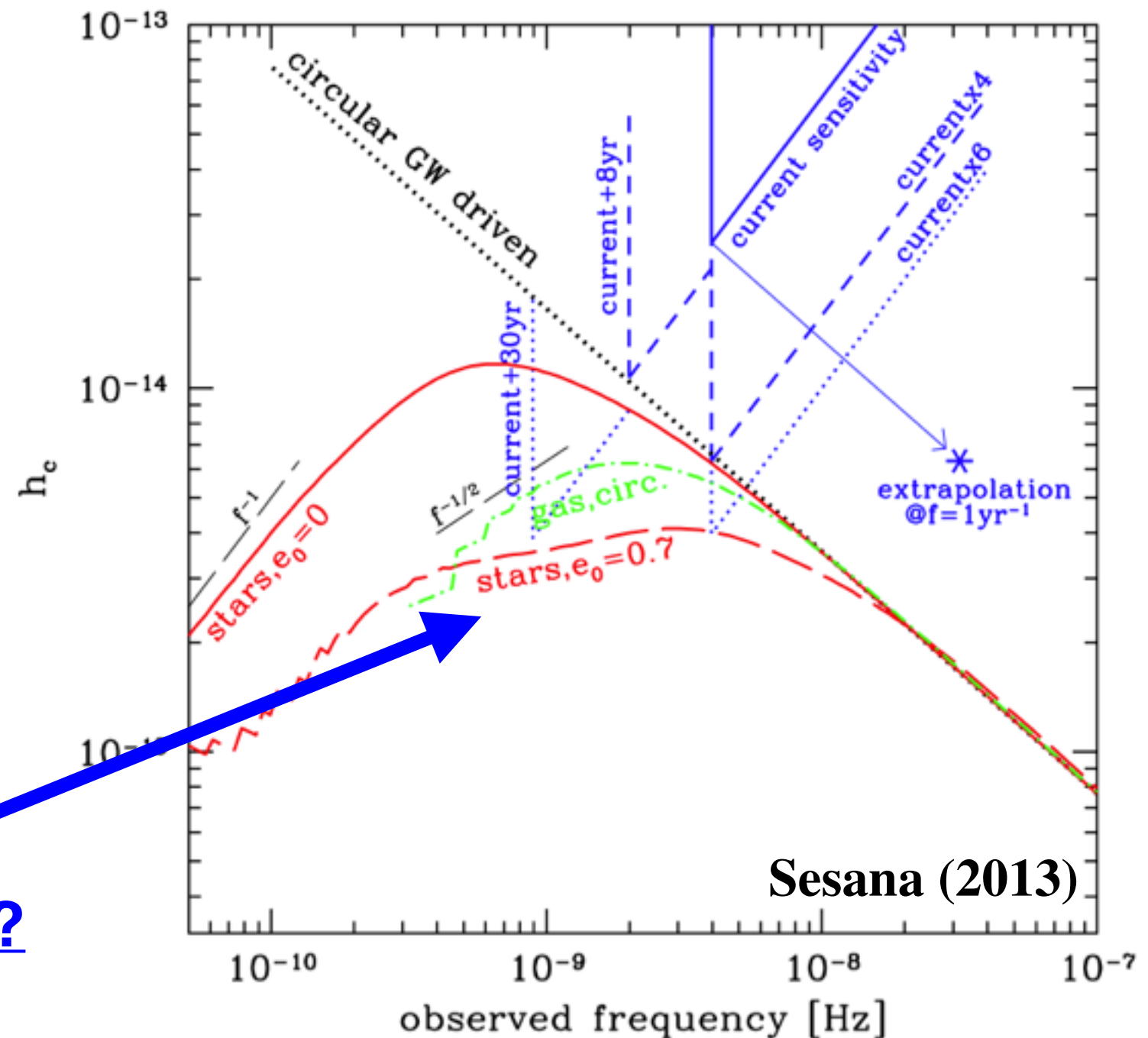
The Environment

Circular inspiral

GWs: $h_c \propto f^{-2/3}$

Stars: $h_c \propto f$

Gas: $h_c \propto f^{1/2}$



Where is the 'knee'?

need to understand:

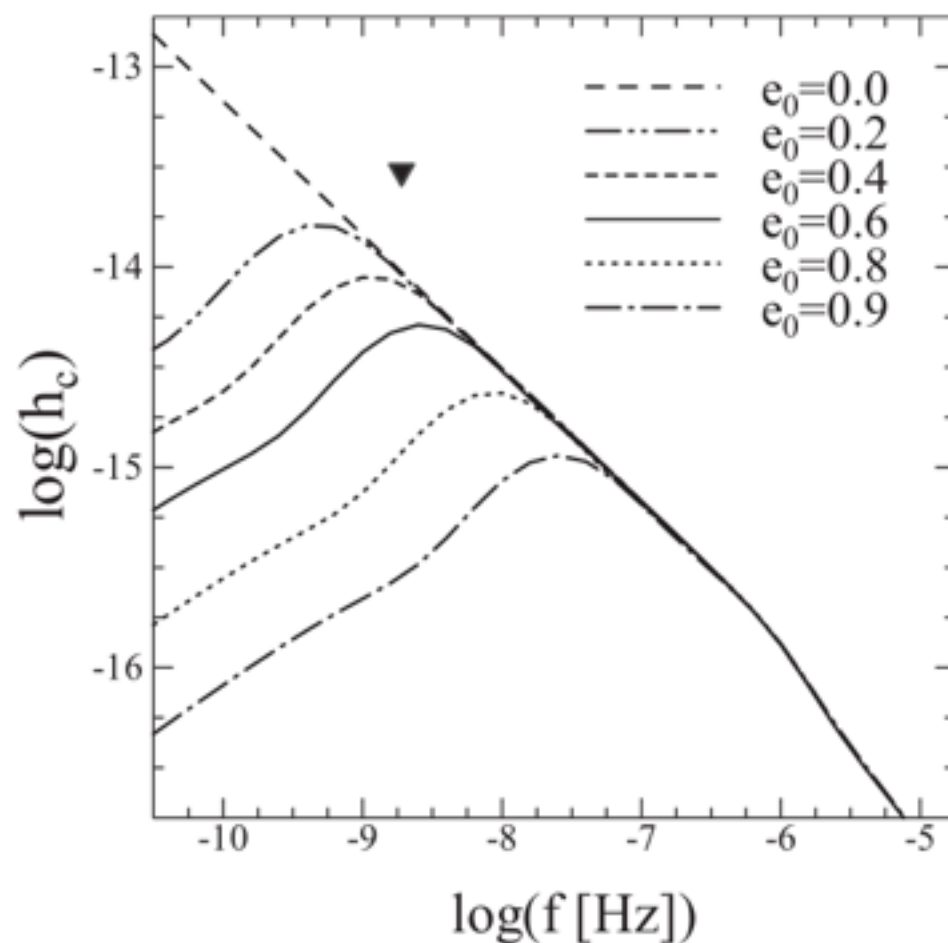
- gas/stellar density in galactic cores?
- actual masses of supermassive BHs?
-

The Environment

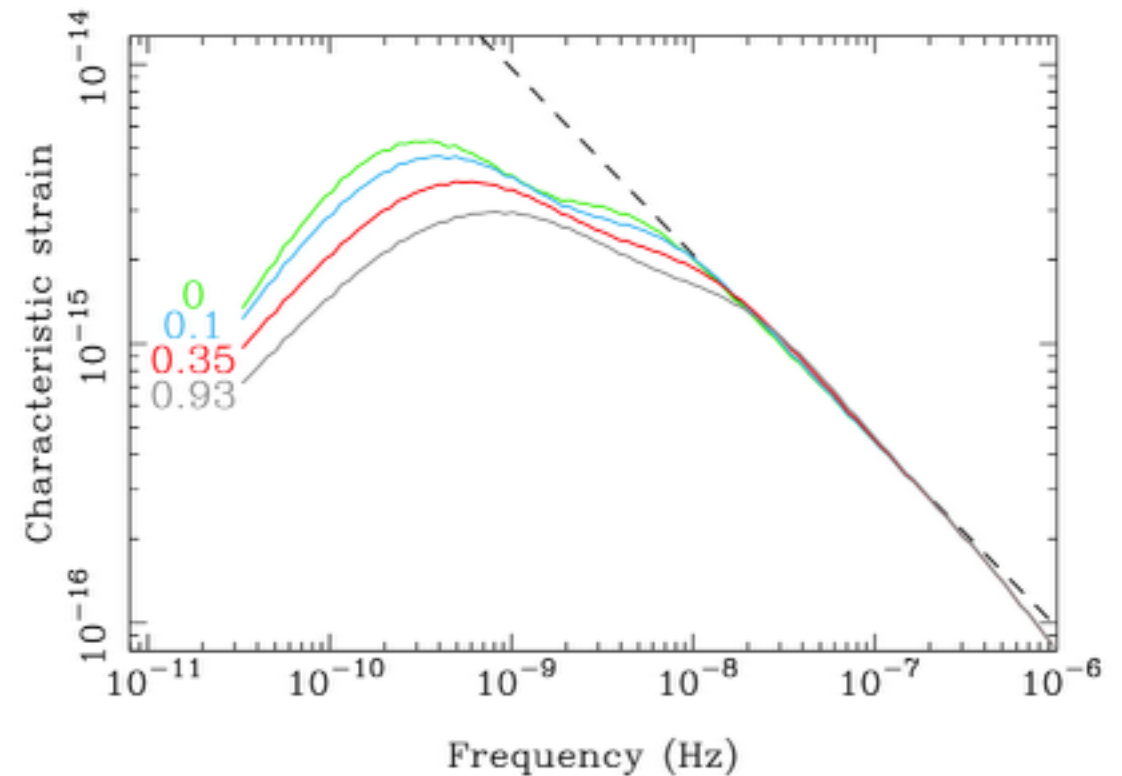
non-zero eccentricities

GWs circularise orbits

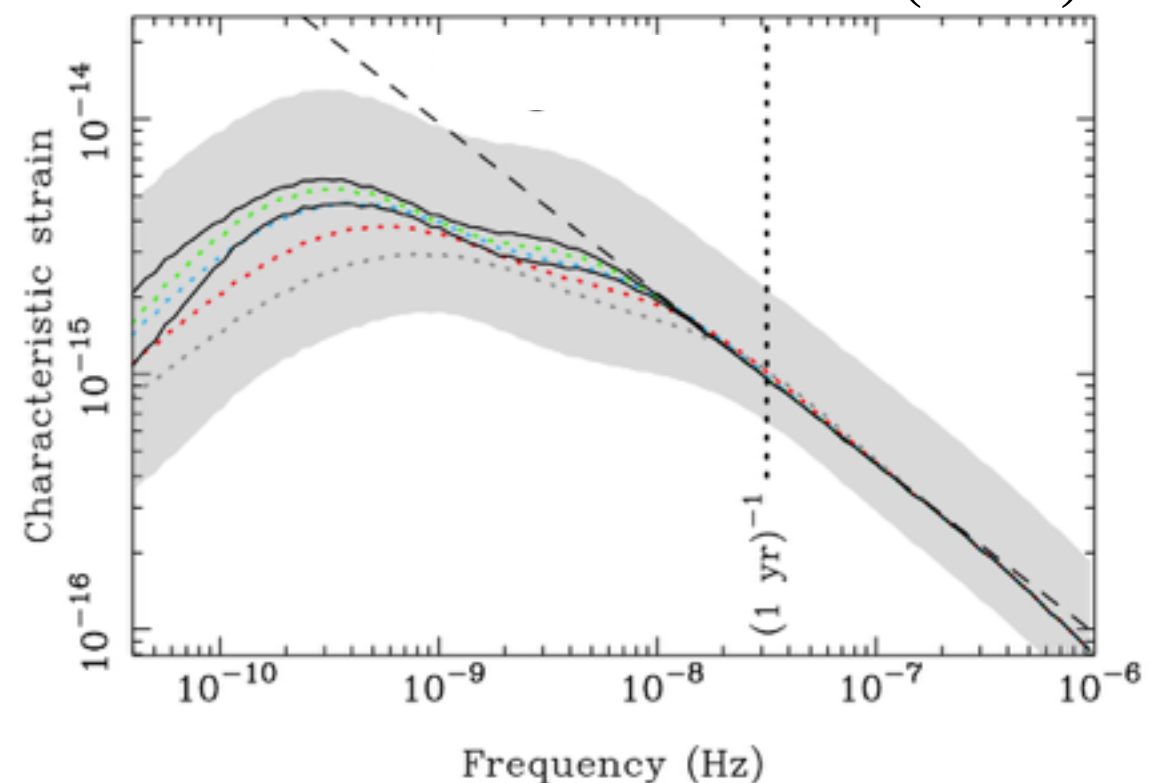
some other effects drive eccentricity up:
e.g., retrograde circumbinary accretion, ...



Enoki & Nagashima (2007)



Ravi et al. (2014)

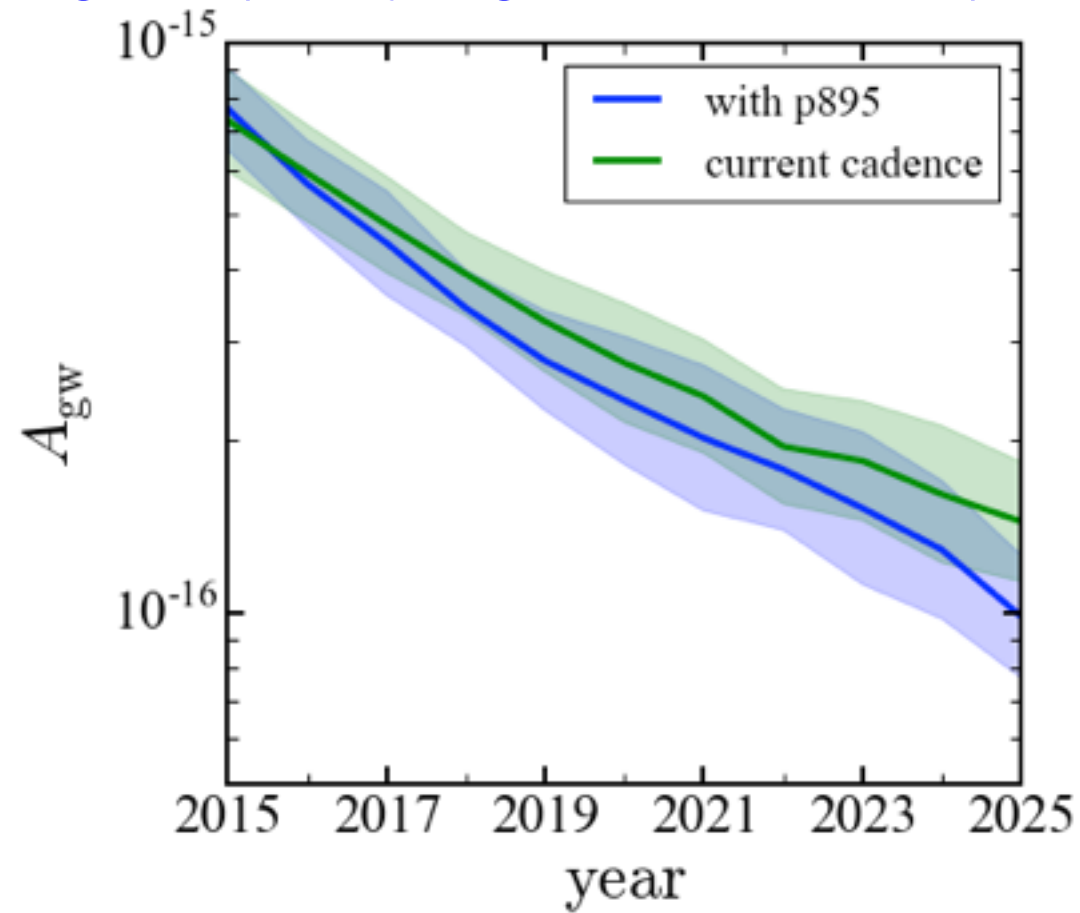


What Next?

Paul Lasky

keep observing...

(high frequency, high cadence, best pulsars)



combined datasets



future telescopes

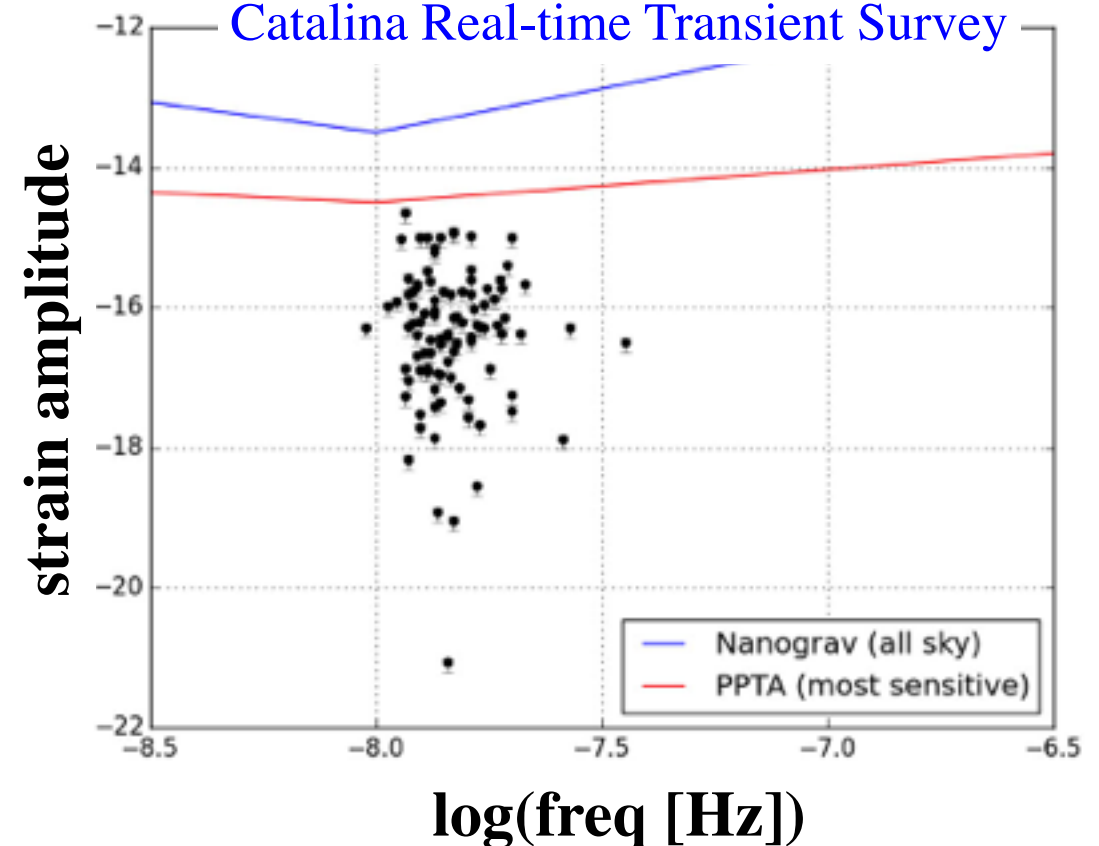
SKA, FAST, ...



single sources

e.g., Graham et al. (2015)

Catalina Real-time Transient Survey



Conclusions



- © **PPTA currently doing cosmology with non-detections!**
- © **Our understanding of galaxy/black hole evolution needs updating**

Extra Slides

