Ranging to deep-space missions for gravitational waves and dark matter

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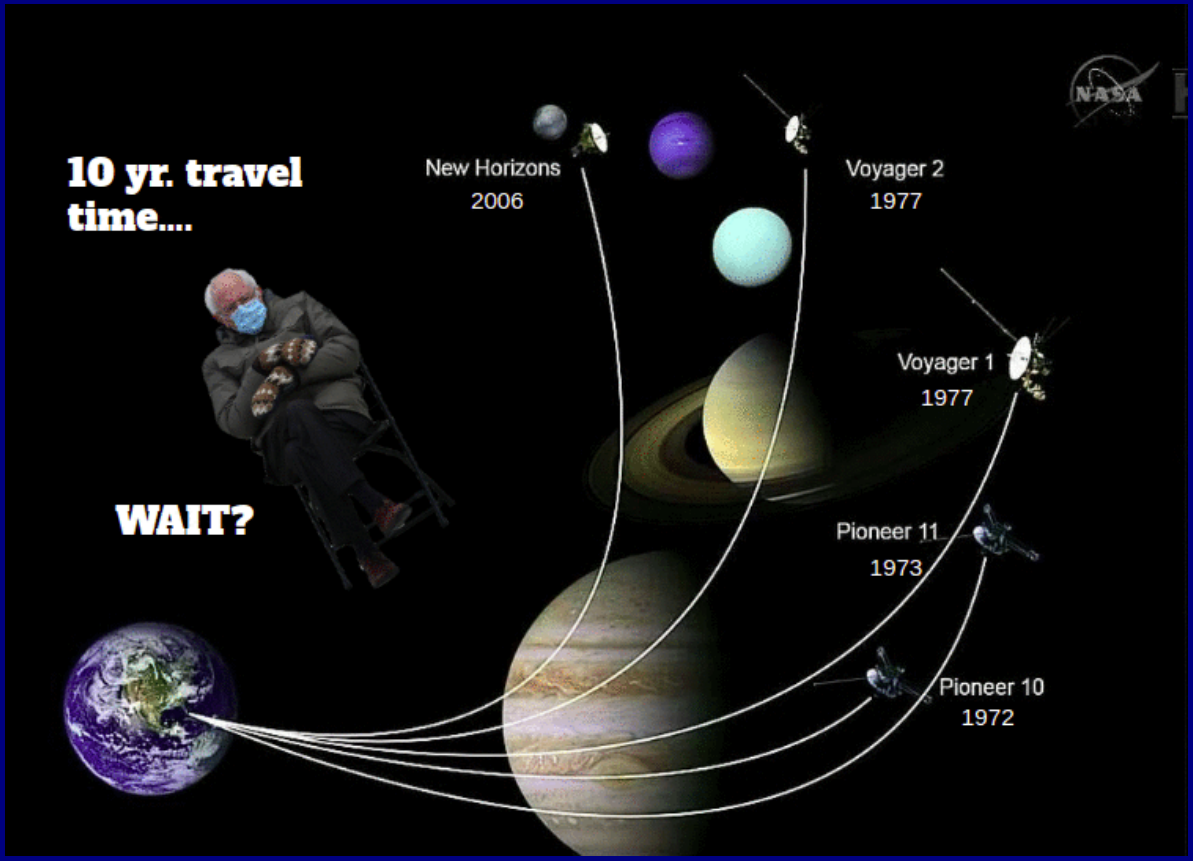
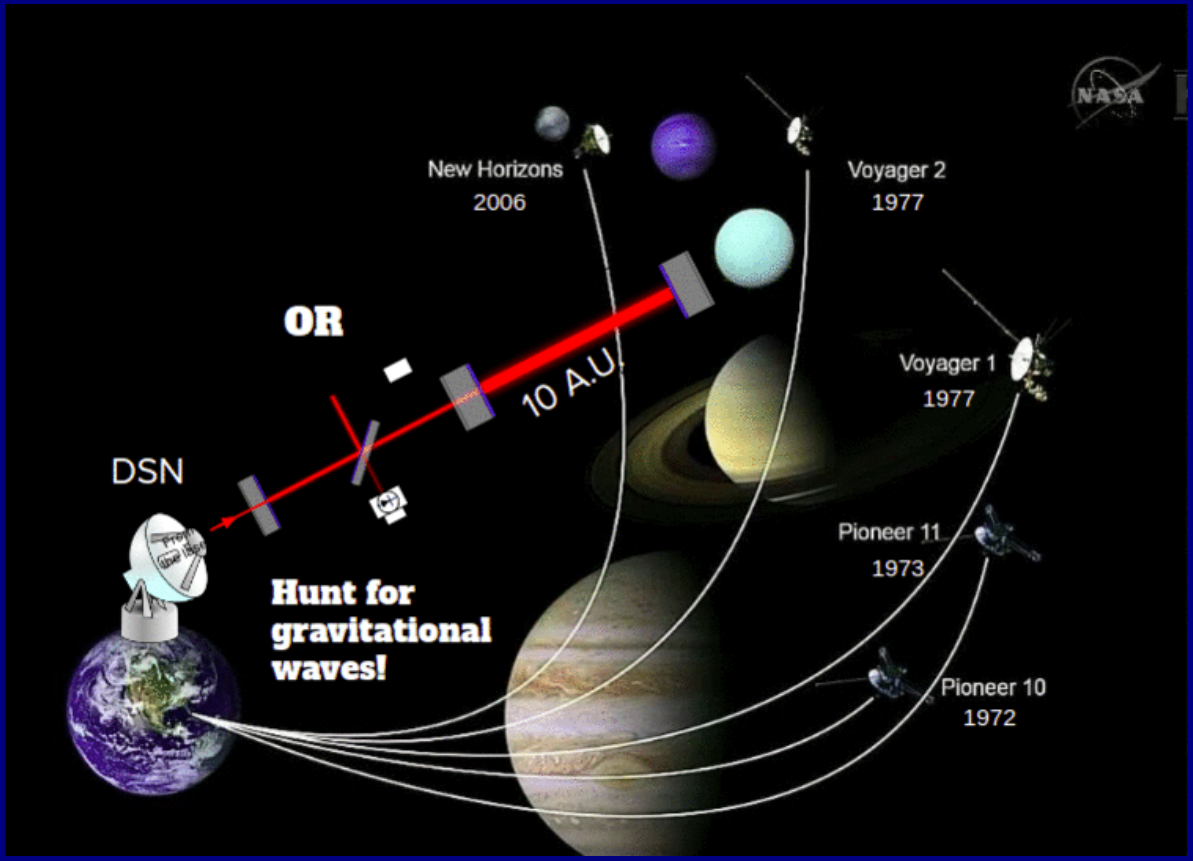


Credits: NASA + astrobites



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Deep-space ranging with SKA?

	2.4GHz	A_{eff} @ 2.4 GHz	8 GHz	A_{eff} @ 8 GHz	32 GHz	Multi-beams (fov)	Sky coverage
Large-N Small-D	Yes	100%	yes	100%	yes	no	good
Phased Array	Maybe	20%	no	-	no	yes	good
LAR	Yes	100%	yes	90%	no	no	limited
Luneburg lens	Yes	50%	maybe	10%	no	yes	good
Cylindrical array	Yes	100%	yes	90%	no	no	good
KARST	Yes	100%	maybe	-	no	no	limited
PPD dishes	Yes	100%	Yes	25%	no	no	good

From *Spacecraft Tracking Applications of the Square Kilometre Array* by J.G. Bij de Vaate, L.I. Gurvits, S.V. Pogrebenko, C.G.M. van 't Klooster (2004).

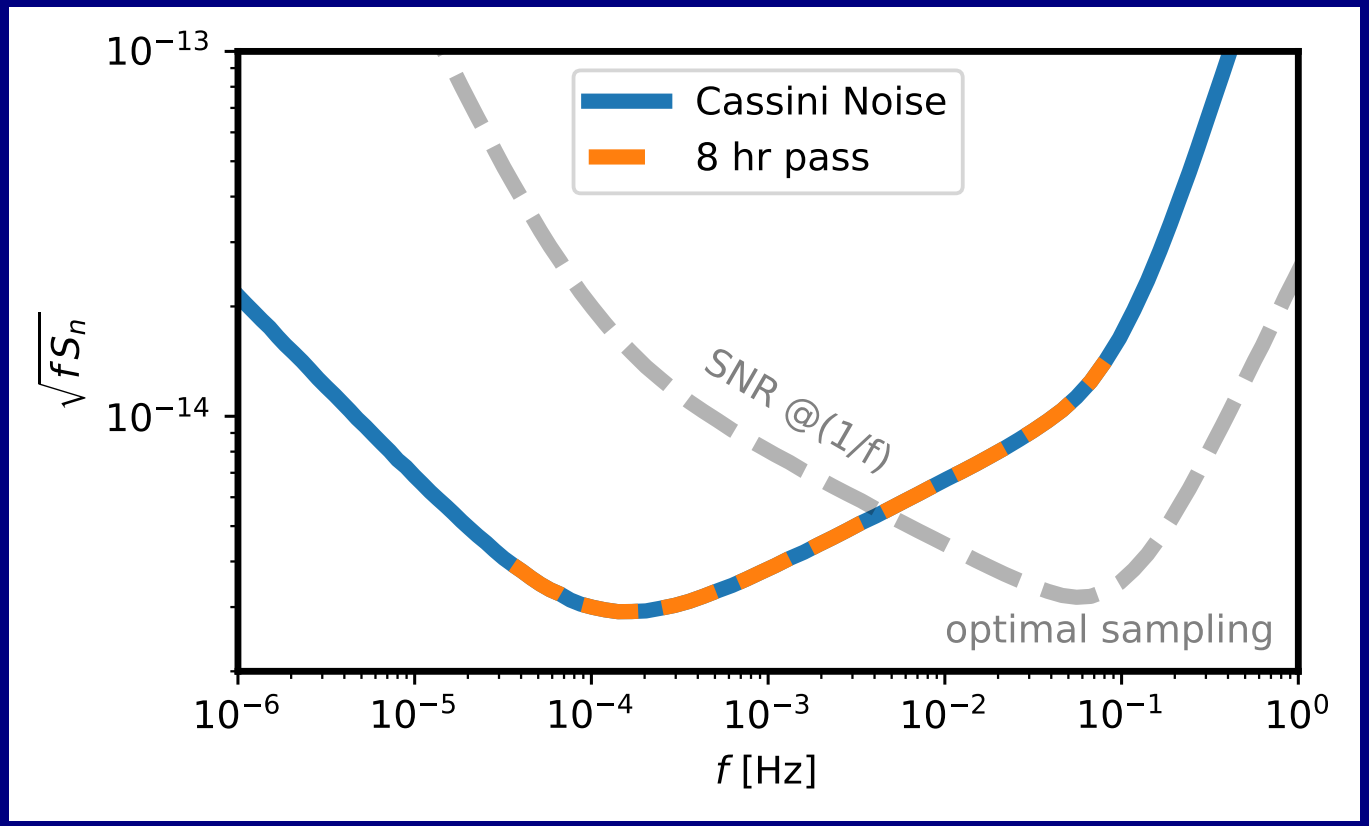
GW Signal

Gravitational waves induce frequency modulation in ranging signal:

$$\frac{\mu-1}{2}\Psi(t) - \mu\,\Psi\left(t - \frac{\mu+1}{2}T\right) + \frac{\mu+1}{2}\Psi(t-T)$$

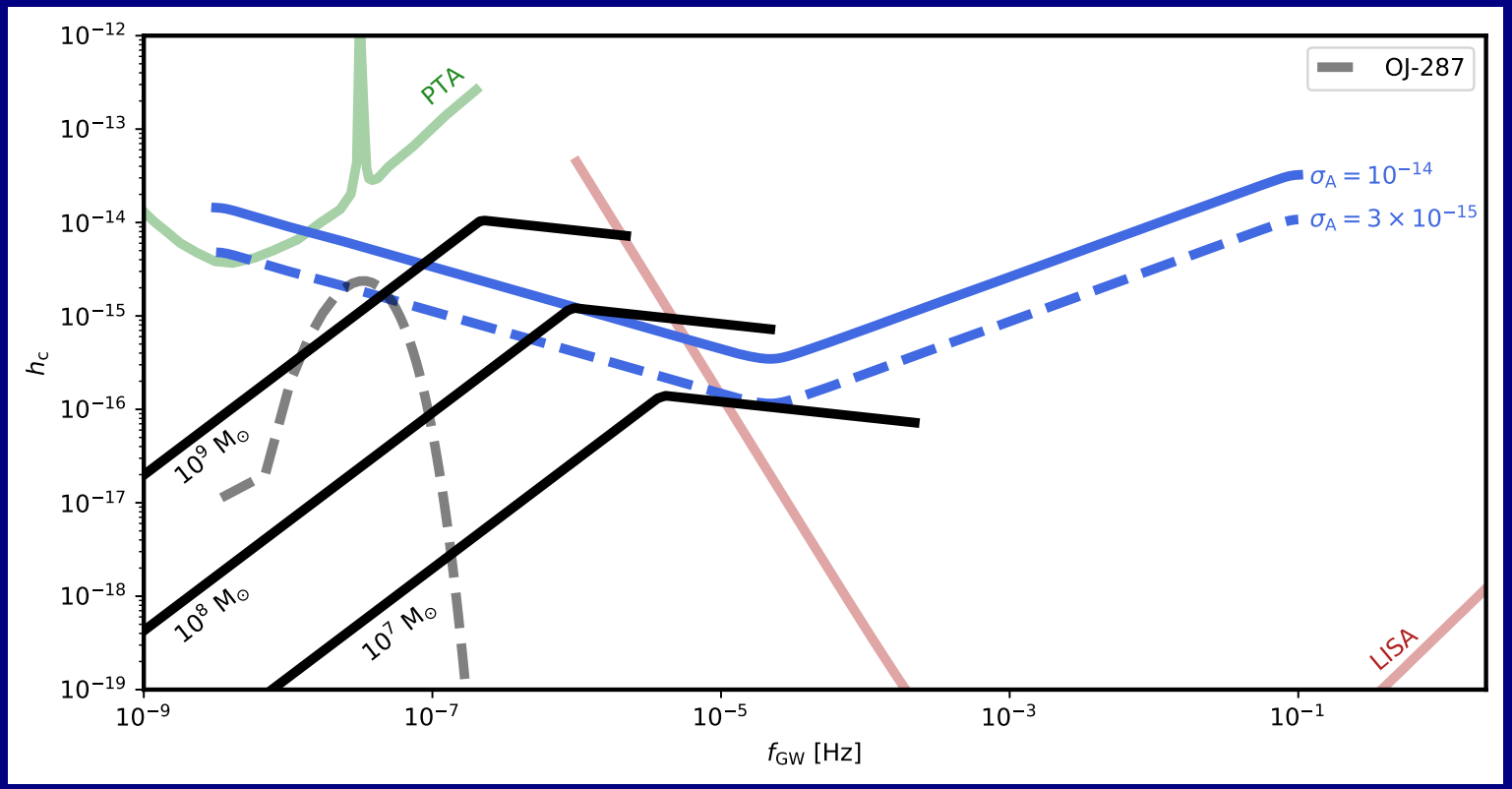
- T is two-way light travel time.
- Ψ is GW amplitude projected on the los.
- μ is GW propagation unit vector projected on the los.

The ranging noise



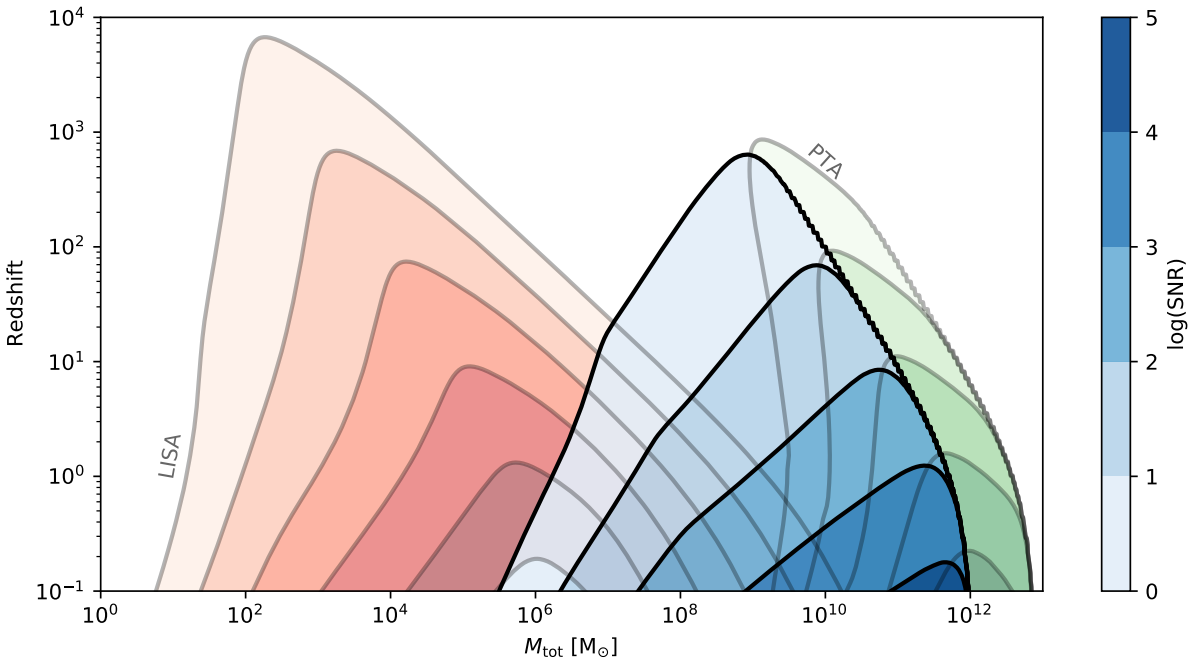
Ranging data best sampled every $\sim 0.1\,\mathrm{s}$.

Some potentially detectable signals



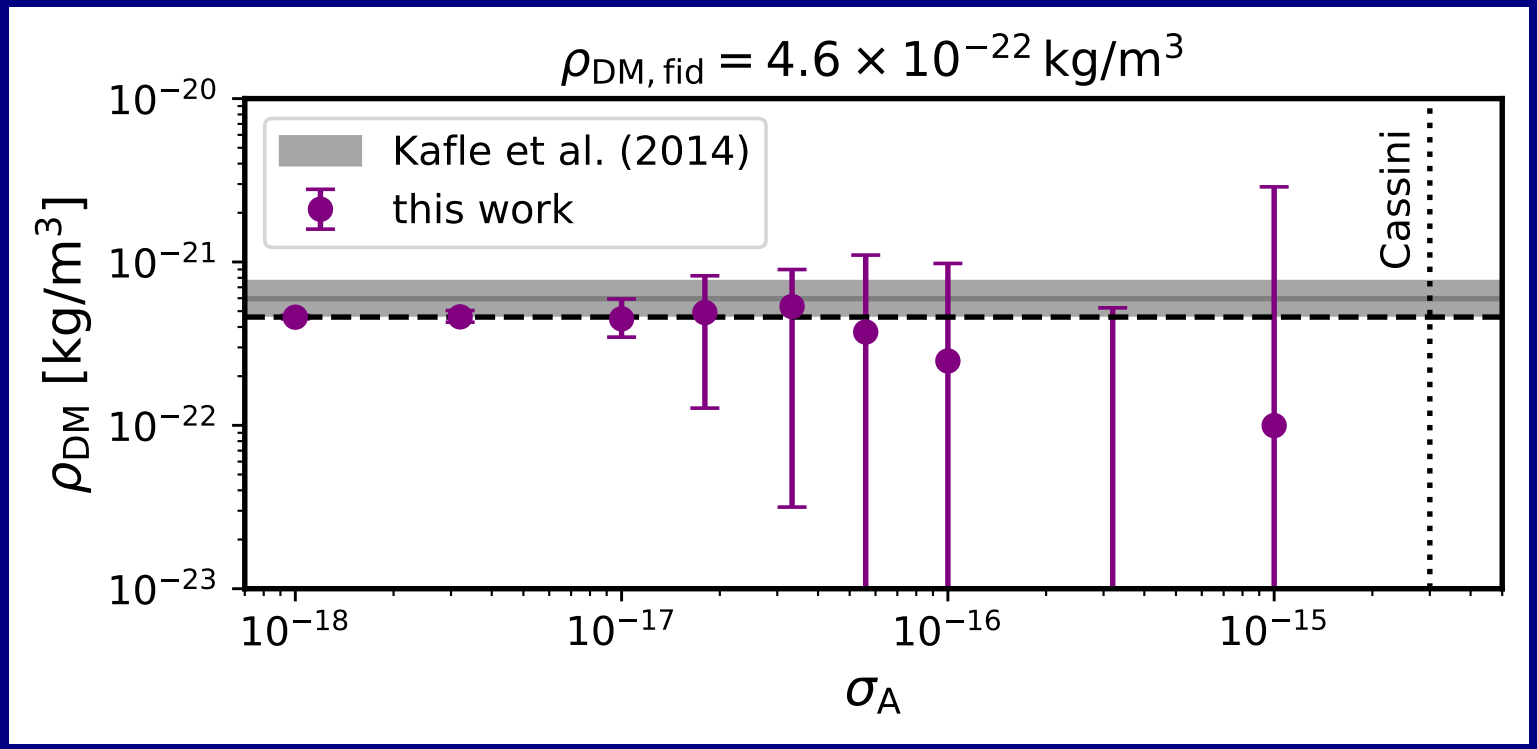
Possible example SMBHs at $z = 1$ and OJ 287.

LISA vs Uranus-mission vs PTA



Deep-space ranging fills a gap between LISA and PTA.

Local dark matter?



Detection needs new ranging developments (optical links?)