Binary neutron stars with Einstein Telescope: constraining their parameters and EoS with different designs

Phys. Rev. D 108, 023018

arxiv:2308.12378

ET monthly meeting
5th September 2023

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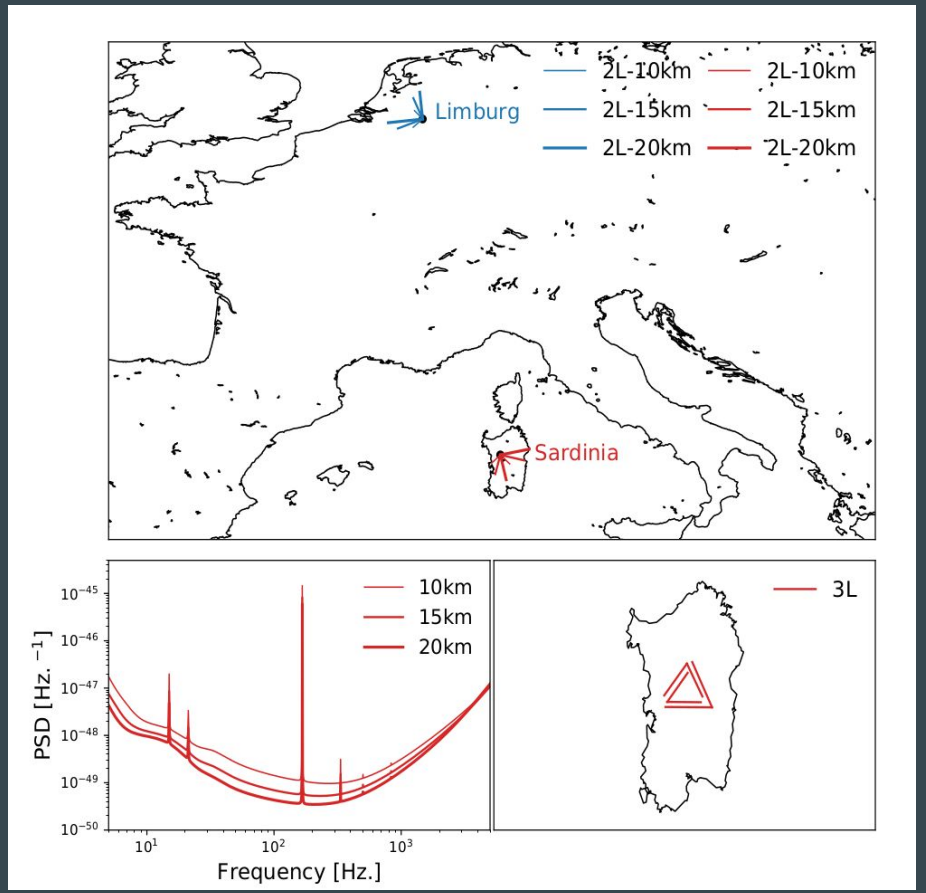
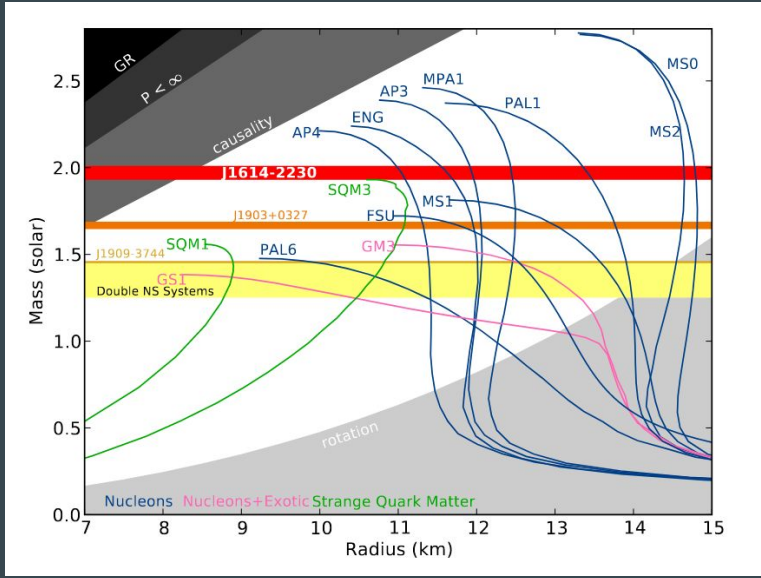
ET configurations

CoBA paper *JCAP07(2023)068*: impact of different configurations on the science output

- Triangular: 10 km
- 2L aligned: 15 or 20 km
- 2L misaligned: 15 or 20 km



Neutron stars Equation of State



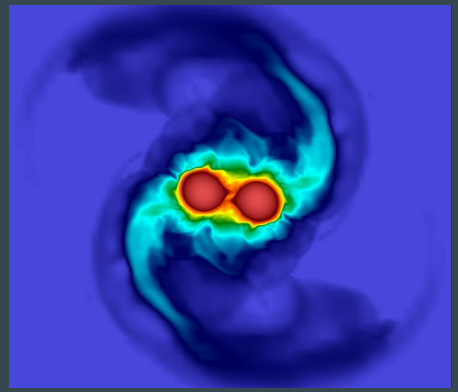
Demorest *et al. Nature* **467**, 1081–1083 (2010)

Neutron stars: supranuclear-dense matter

Equation of state:
relation between pressure and density

⟺ mass - radius

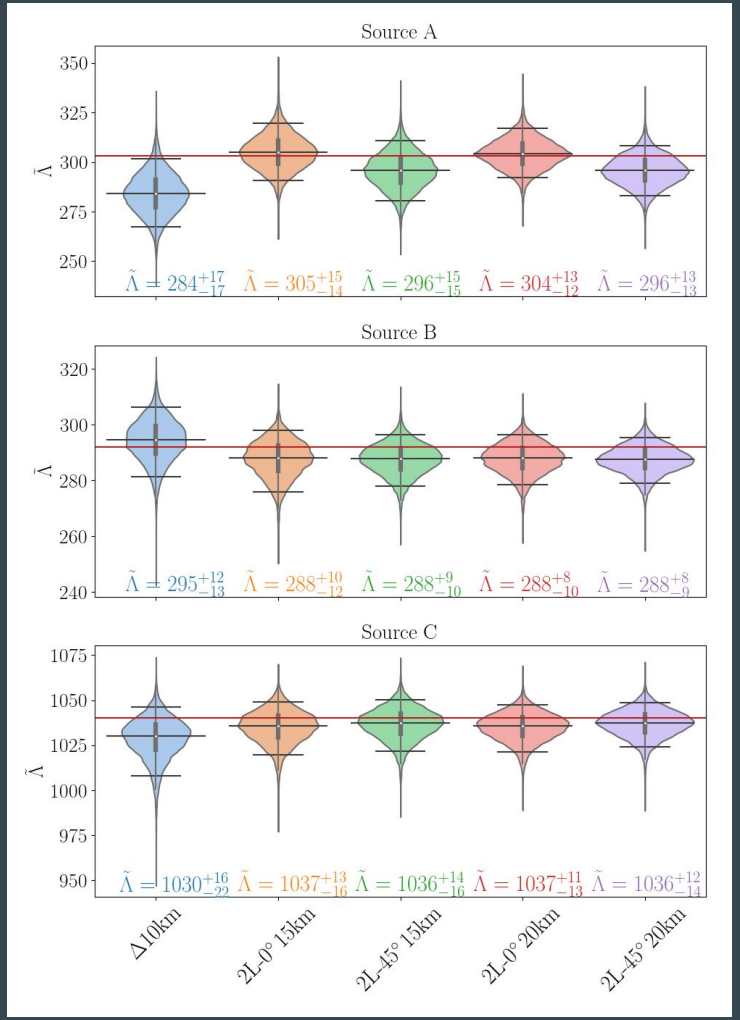
⟺ mass - tidal deformability parameter



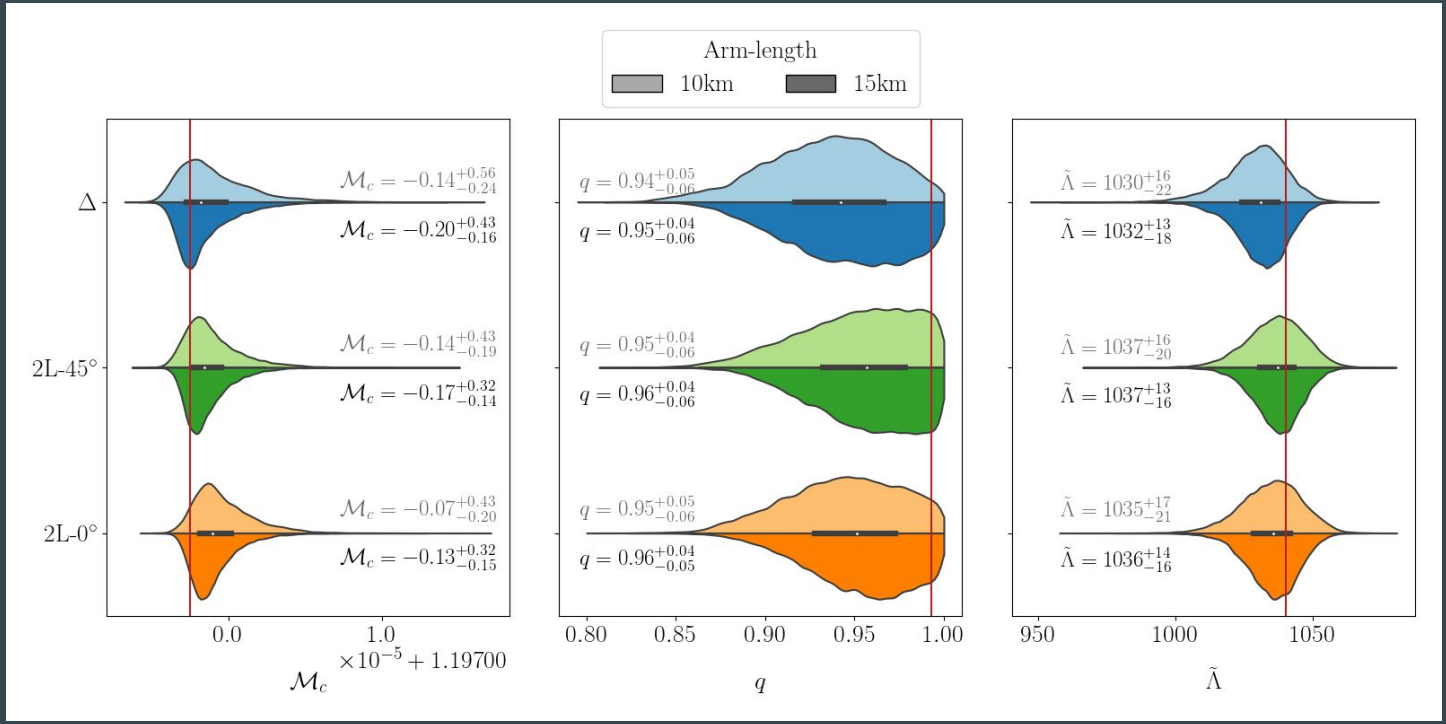
University of Birmingham

Parameter estimation: tidal deformability recovery

- Simulate signals for 3 different sources
- Repeat analysis with the different ET configurations
- Triangular 10 km: wider posterior

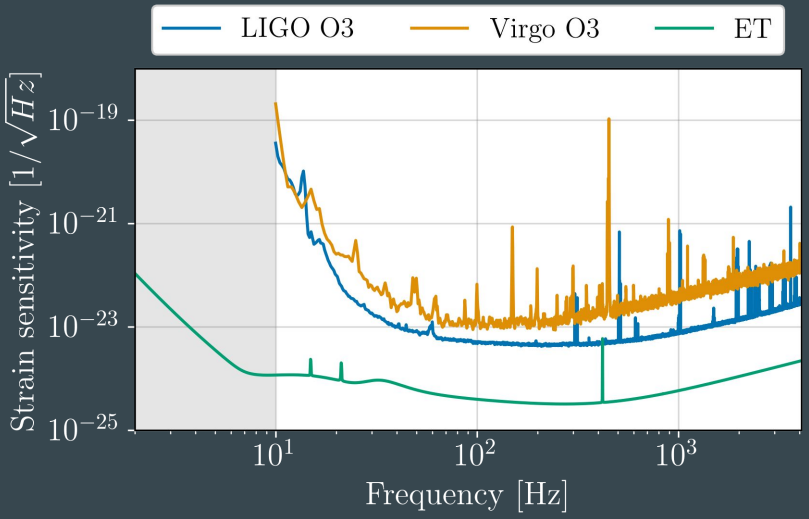


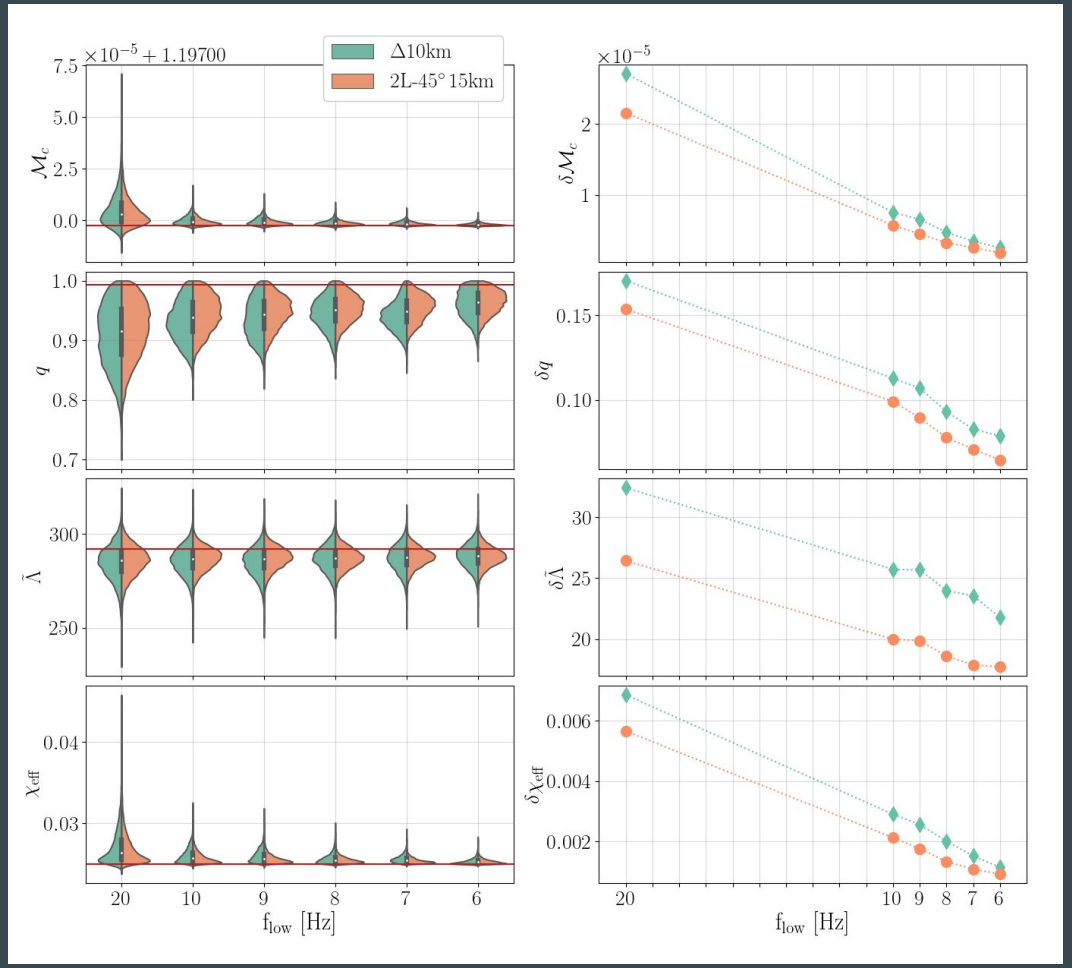
Parameter estimation: tidal deformability recovery



Configuration does not affect results, but arm-length does

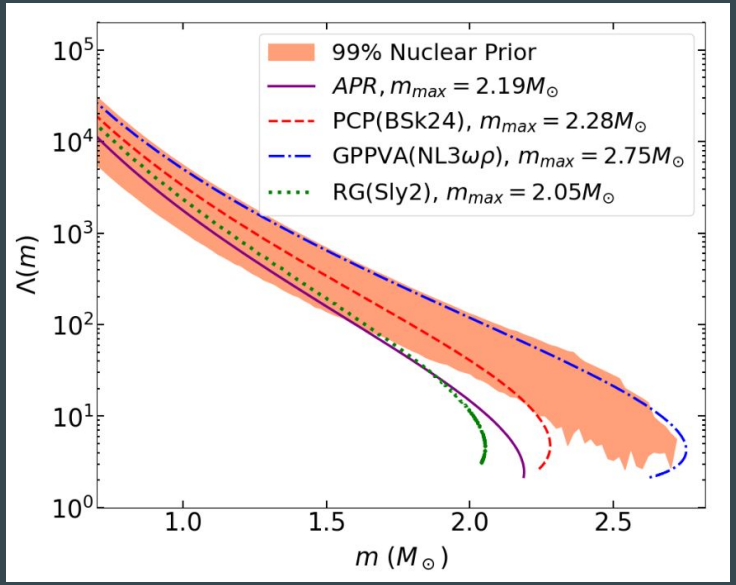
Parameter estimation: effect of varying minimum frequency

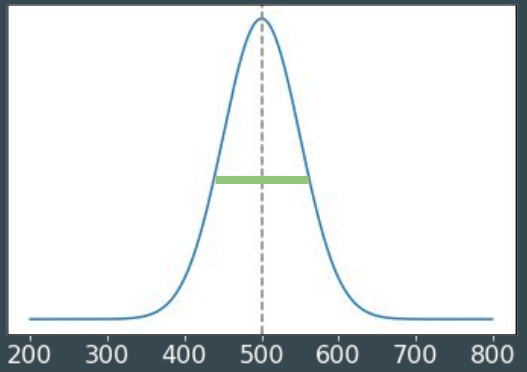




Large number of detections

- $O(10^4)$ detections per year
- Fisher matrix formalism to obtain **accuracy** on parameters' measurements





- Study equation of state with nuclear meta-model:
  - 17 parameters that characterize density dependence of energy
  - Allows to incorporate knowledge from nuclear experiments
- Four different equations of state

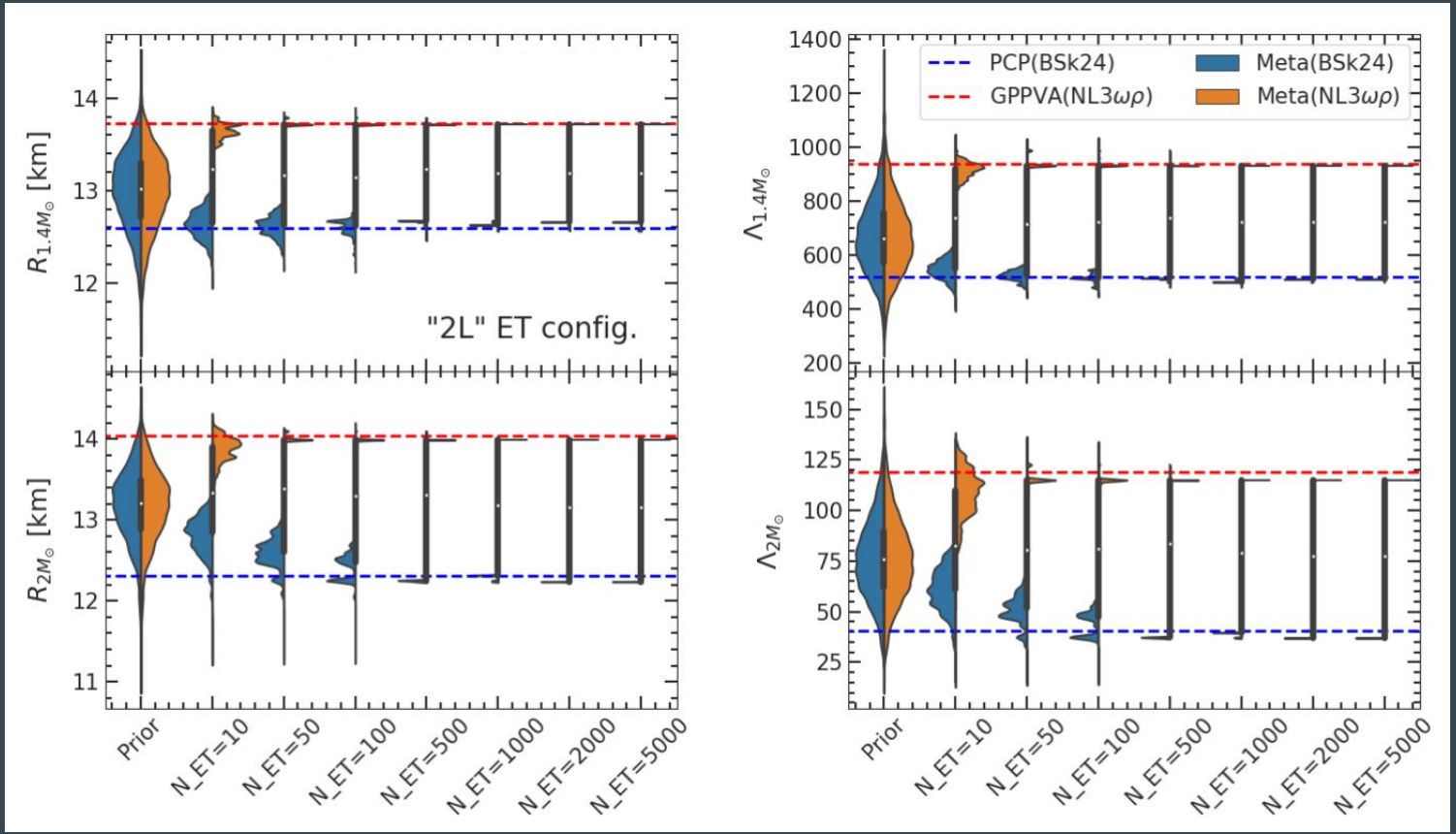
Large number of detections: tidal deformability

1000 detections

EoS	$\Lambda_{1.4M_\odot}$			$\Lambda_{2M_\odot}$		
	Injected	2L 15 km	Δ 10 km	Injected	2L 15 km	Δ 10 km
PCP(BSk24)	518.3	$512.10^{+3.18}_{-0.37}$	$512.65^{+2.63}_{-0.92}$	40.6	$37.19^{+0.09}_{-0.25}$	$37.26^{+0.01}_{-0.32}$
GPPVA(NL3$\omega\rho$)	936.7	931.54^{+2e-6}_{-2e-6}	931.54^{+2e-6}_{-2e-6}	118.8	114.96^{+2e-7}_{-2e-7}	114.96^{+2e-7}_{-2e-7}
RG(Sly2)	309.0	306.15^{+3e-6}_{-3e-6}	306.15^{+8e-6}_{-8e-6}	11.4	11.16^{+8e-6}_{-8e-6}	11.16^{+2e-5}_{-2e-5}
APR	248.0	$266.28^{+0.01}_{-0.01}$	$266.28^{+0.02}_{-0.02}$	14.7	$22.38^{+0.003}_{-0.003}$	$22.38^{+0.004}_{-0.004}$

No significant difference between different geometries

Large number of detections: source properties



Conclusions

- Parameter estimation studies: the accuracy on estimates of source properties depends on the detector's arm-length, but not on its geometry; starting the analysis at lower frequencies brings an additional improvement

- Many detections (Fisher matrix): with roughly 500 detections the neutron star properties can be recovered with great accuracy; no dependence on the detector geometry

- In general, Einstein Telescope will allow us to study neutron stars properties and their equation of state with an unprecedented accuracy