

Measuring the Gravitational Memory due to Anisotropic Neutrino Emission from a SN with AION/AEDGE

Recap on Gravitational Memory
Anisotropic Neutrino Emission from a SN
Calculation of Memory Effect
Recap of AION and AEDGE
Capabilities for Gravitational Memory Detection



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Gravitational Memory

- GR predicts that the passage of matter or radiation from an asymmetrically-emitting source causes a permanent change in the local space-time metric - the **Gravitational Memory** effect

$$h_{\mu\nu}(\mathbf{x}, t) = 4G \int d^3\mathbf{x}' \left(\frac{S_{\mu\nu}(\mathbf{x}', t - |\mathbf{x} - \mathbf{x}'|)}{|\mathbf{x} - \mathbf{x}'|} \right)$$

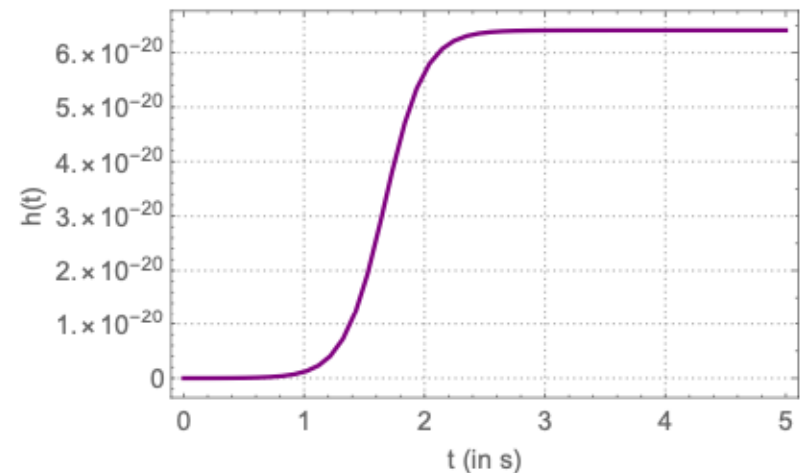
Zel'dovich & Polnarev, 1974
Braginskii & Thorne, 1987

- Sourced, e.g., by SN neutrinos

$$h(t) = \frac{2G}{r} \int_{-\infty}^{t-r} dt' L_{\nu}(t') \alpha(t')$$

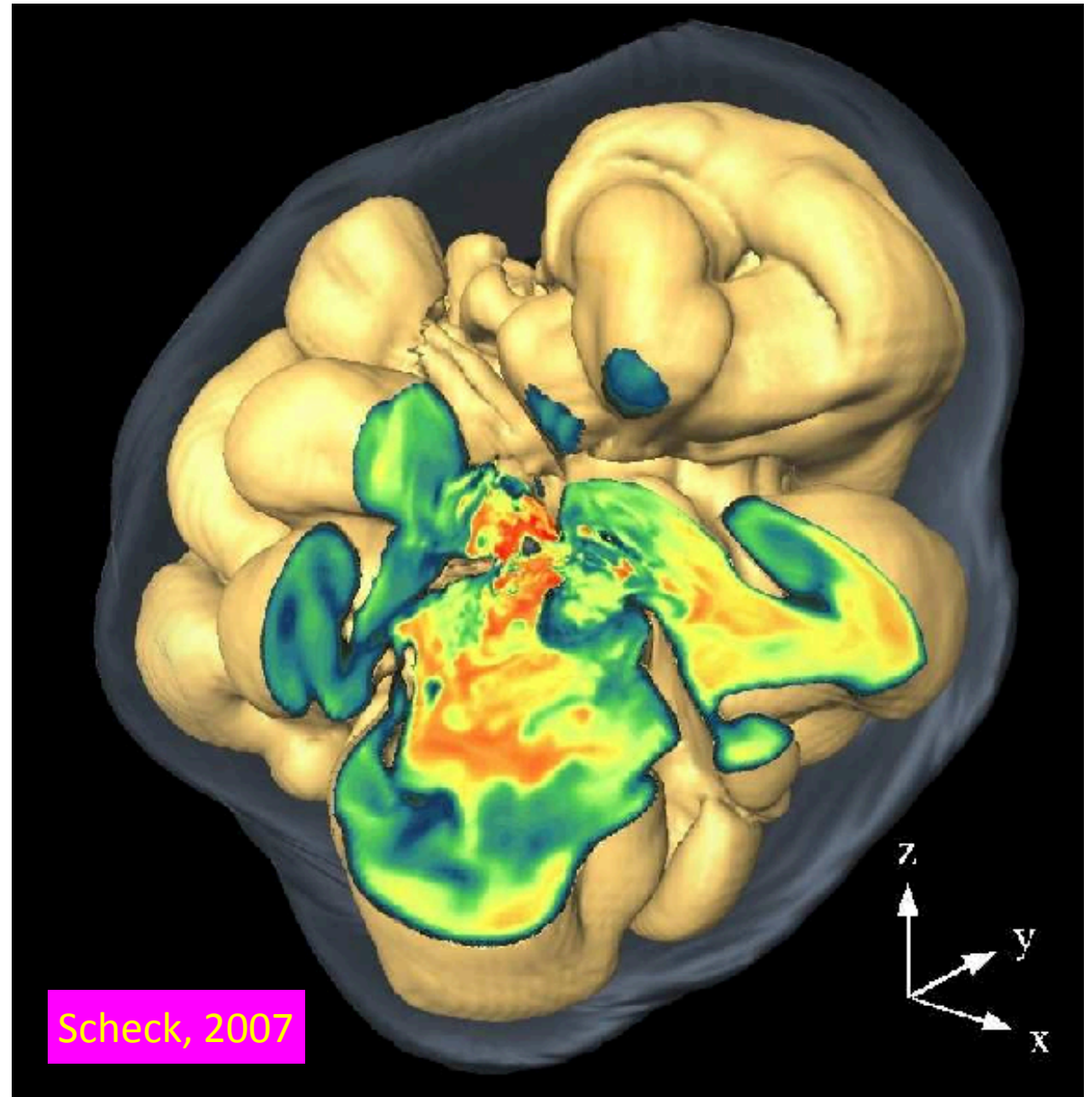
Epstein, 1978

- Where $L_{\nu}(t)$ is neutrino luminosity,
 $\alpha(t)$ its anisotropy
- Sketch of typical strain profile
- NB: also nonlinear memory from GWs



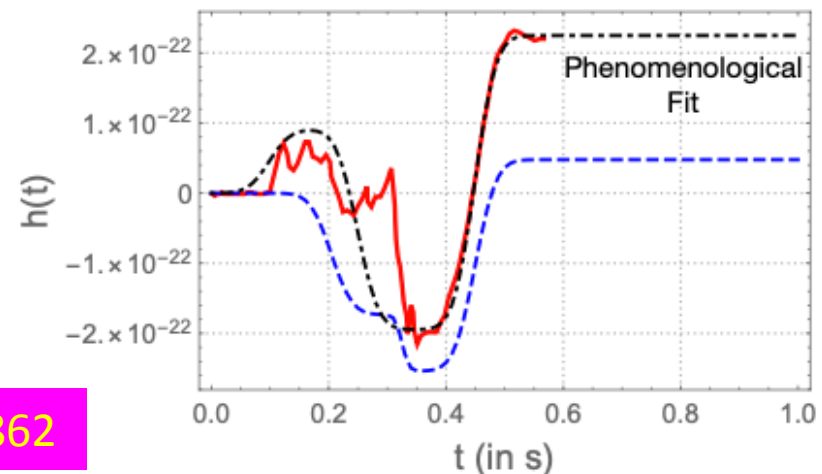
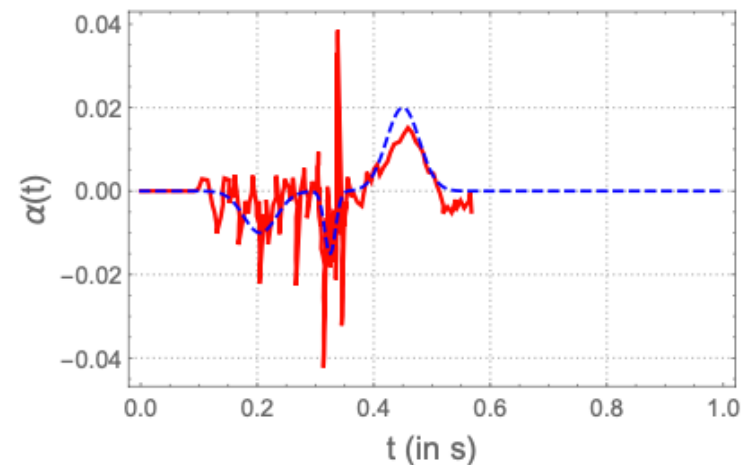
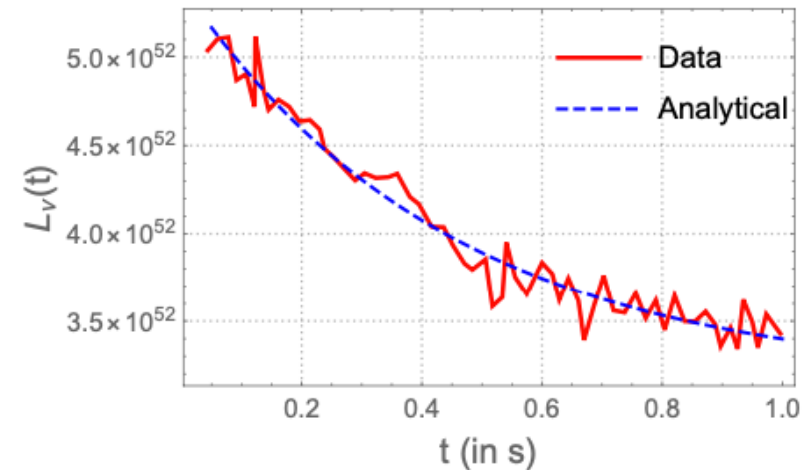
Anisotropic Supernova Explosions

- Three-dimensional simulations of supernovae typically exhibit anisotropies
- Anisotropy of neutrino emissions is supported by high velocities of supernova remnants



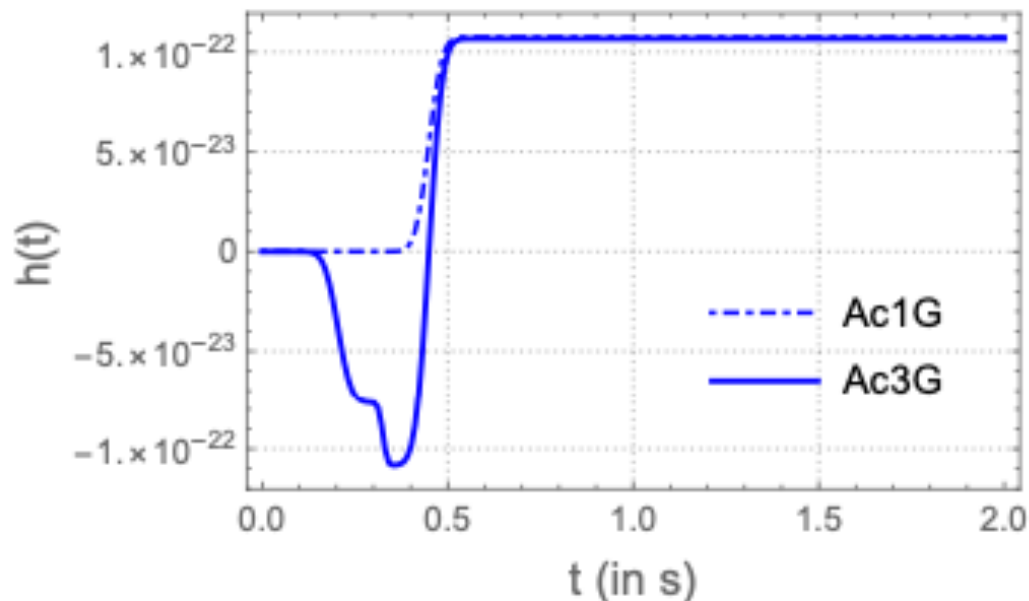
Supernova Neutrino Emission

- Neutrino luminosity:
typical duration of
accretion phase $\mathcal{O}(1)$ sec
- Anisotropy of neutrino emissions:
fluctuating, % level,
typical duration $\mathcal{O}(0.5)$ sec
- Gives order-of-magnitude estimate
of frequency support $\mathcal{O}(1)$ Hz

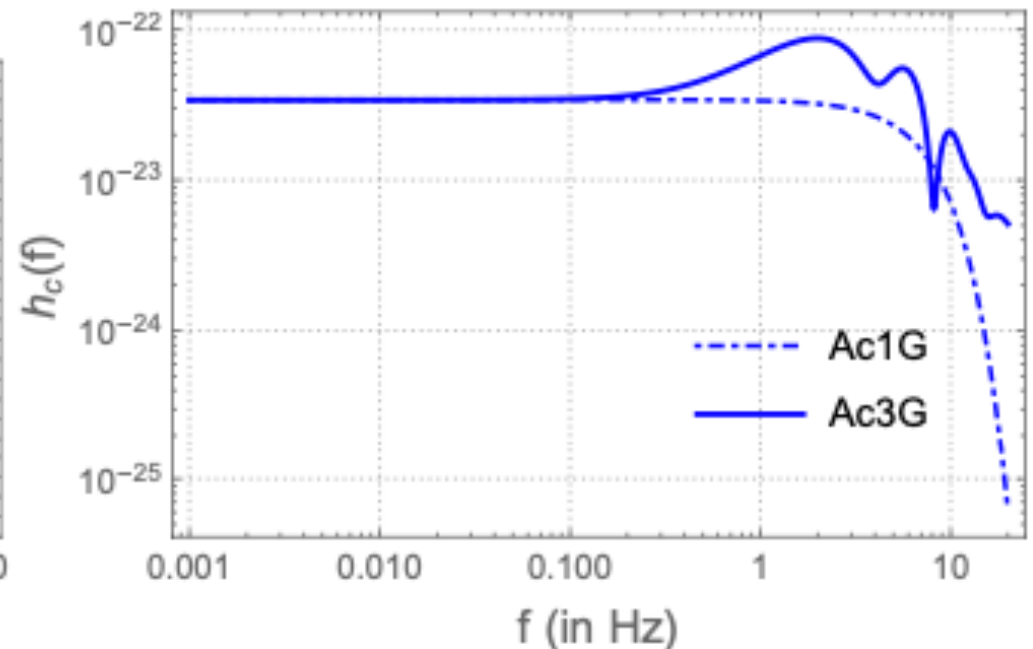


Gravitational Wave Memory Strain from a Supernova

As function of time

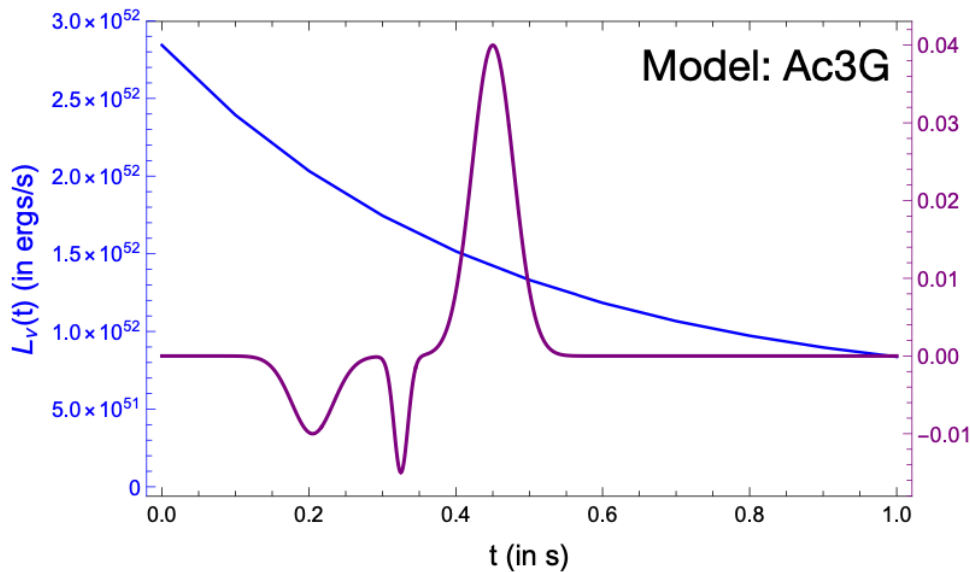


Frequency Spectrum

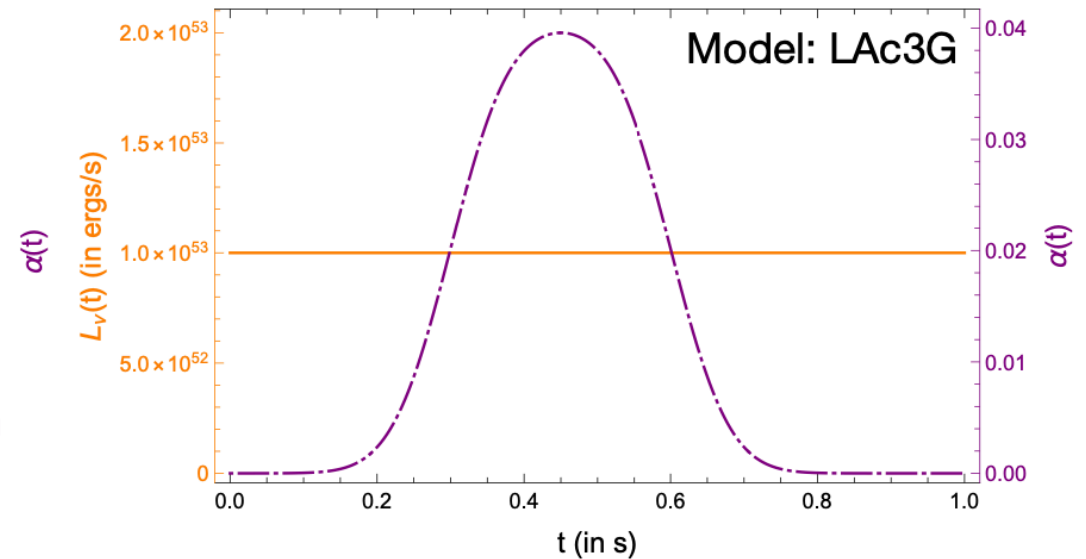


Gravitational Wave Memory Strain from a Supernova

Baseline model

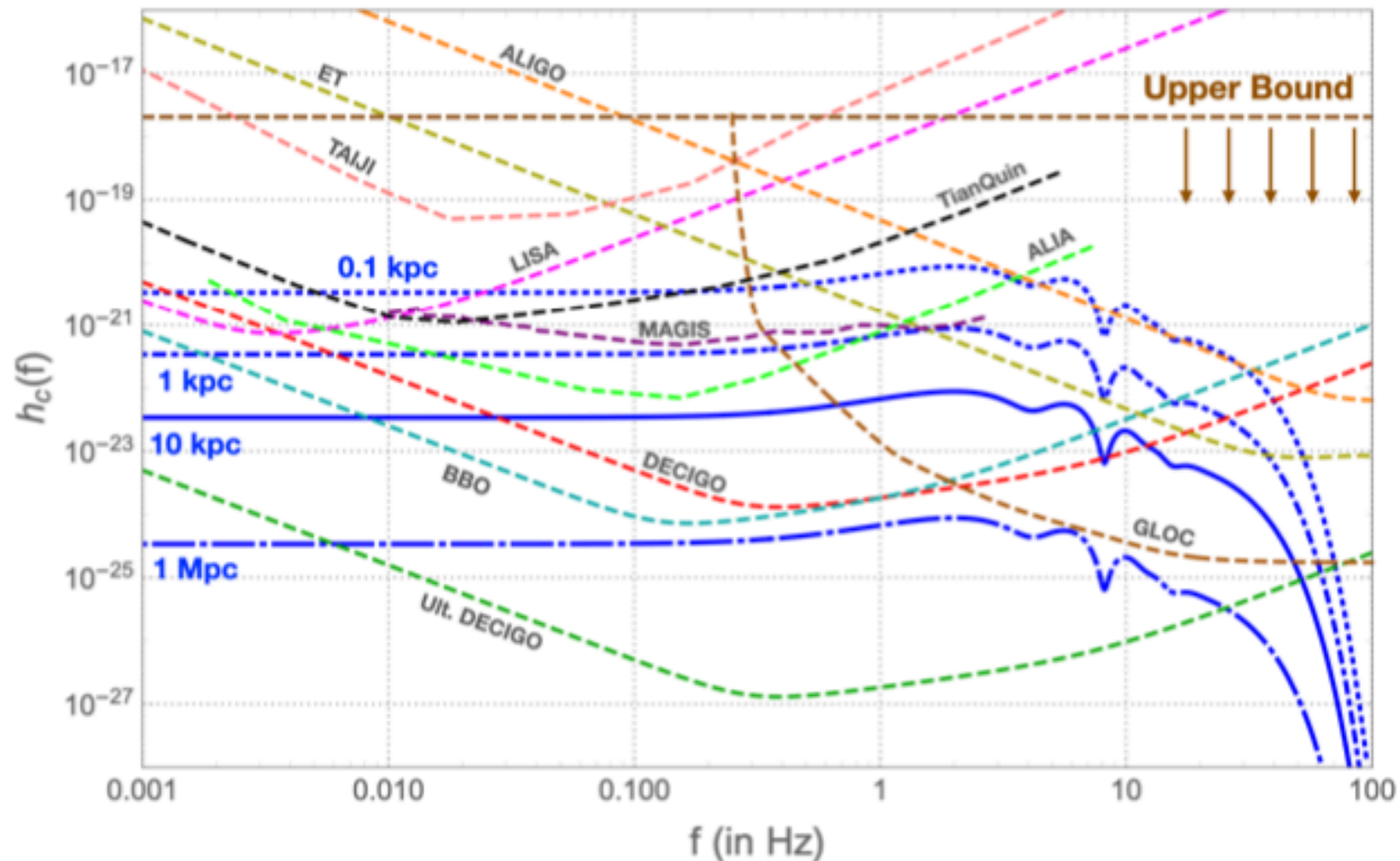


Optimistic model



Gravitational Wave Memory Strain from a Supernova

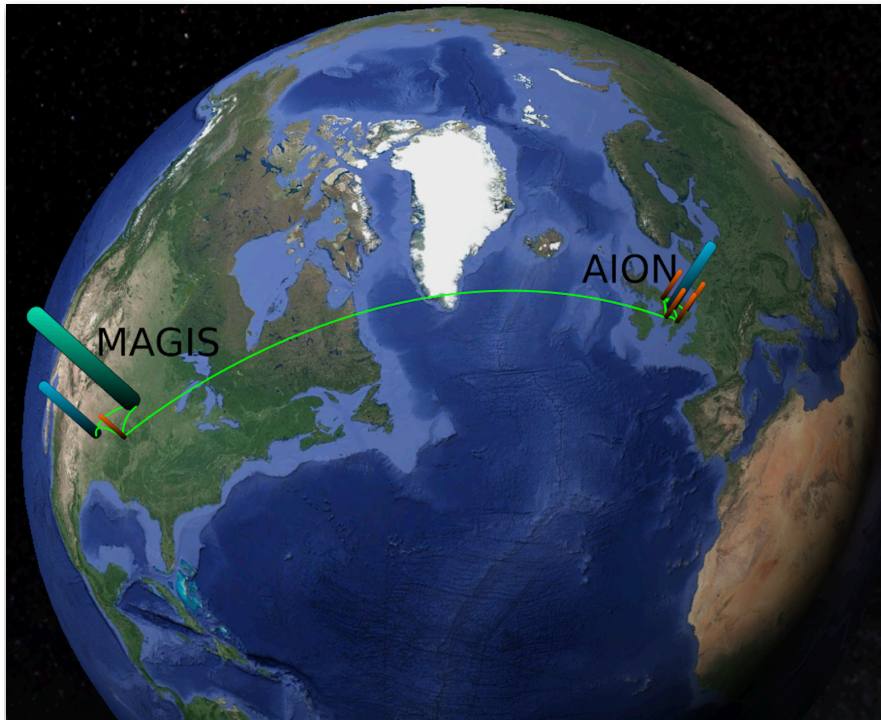
Comparison with experimental sensitivities



AION Collaboration

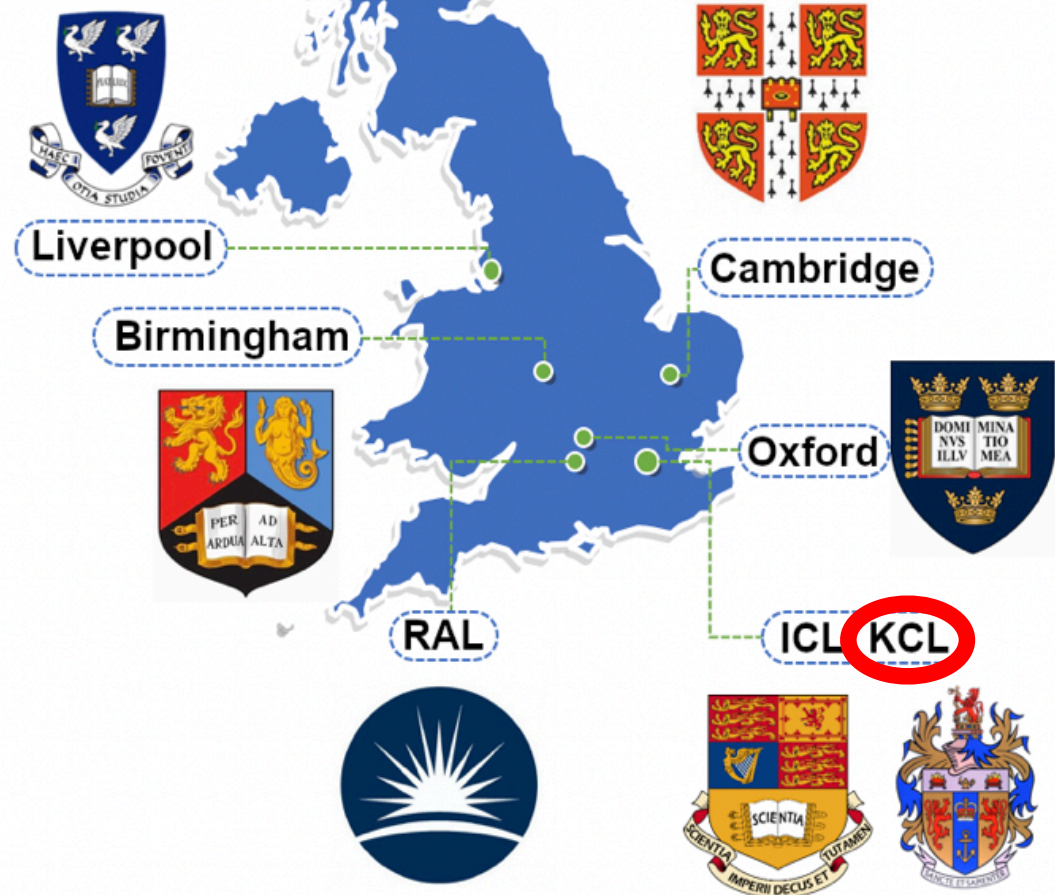
L. Badurina¹, S. Balashov², E. Bentine³, D. Blas¹, J. Boehm², K. Bongs⁶, A. Beniwal¹,
 D. Bortoletto⁶, J. Bowcock⁵, W. Bowden^{6,*}, C. Brew⁷, O. Buchmueller⁶, J. Coleman⁷,
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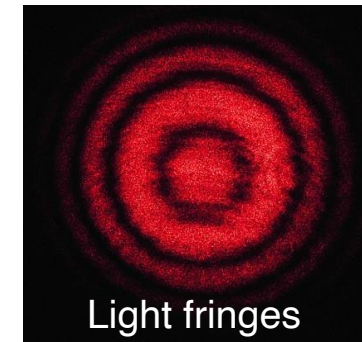
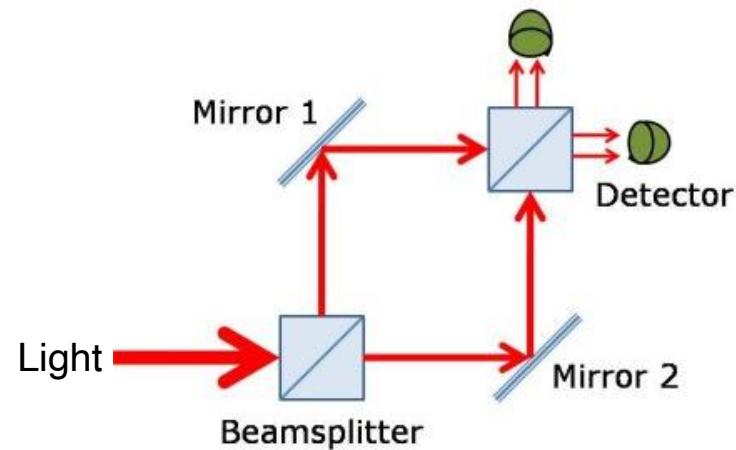
Network with MAGIS project in US

MAGIS Collaboration (Abe et al): arXiv:2104.02835

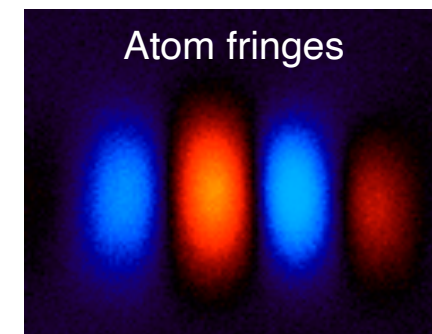
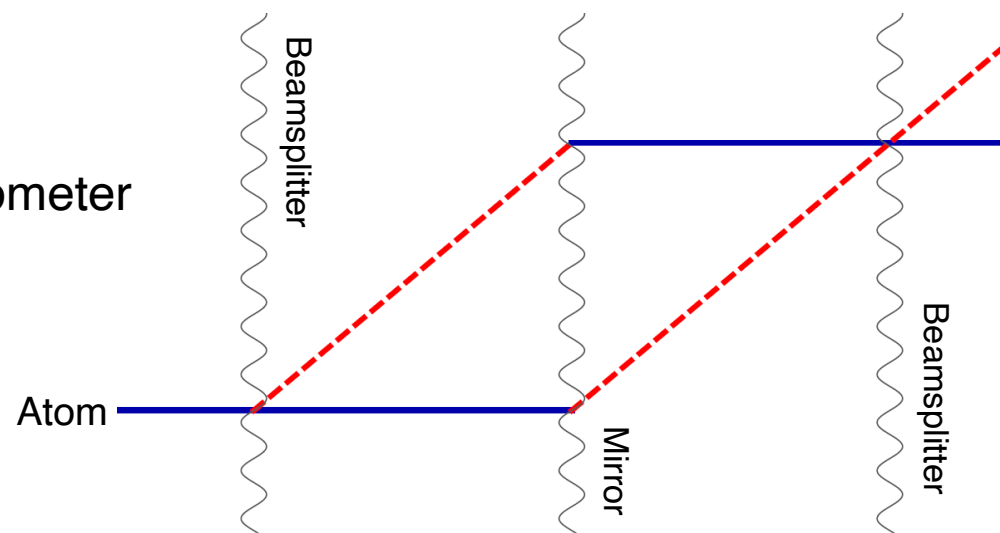


Principle of Atom Interferometry

Light interferometer



Atom interferometer



AION – Staged Programme

- AION-10: Stage 1 [year 1 to 3]
 - 1 & 10 m Interferometers & site investigation for 100m baseline
- AION-100: Stage 2 [year 3 to 6]
 - 100m Construction & commissioning
- AION-KM: Stage 3 [> year 6]
 - Operating AION-100 and planning for 1 km & beyond
- AION-SPACE (AEDGE): Stage 4 [after AION-km]
 - Space-based version

Initial funding from UK STFC

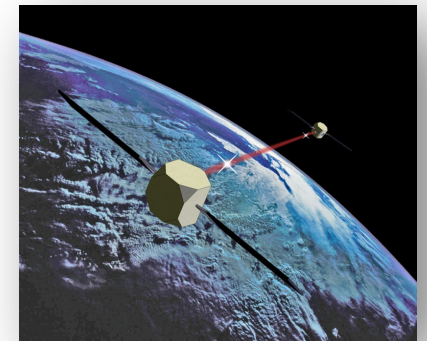
And then?

AEDGE:

Atomic Experiment for Dark Matter and Gravity Exploration in Space

Beyond LISA

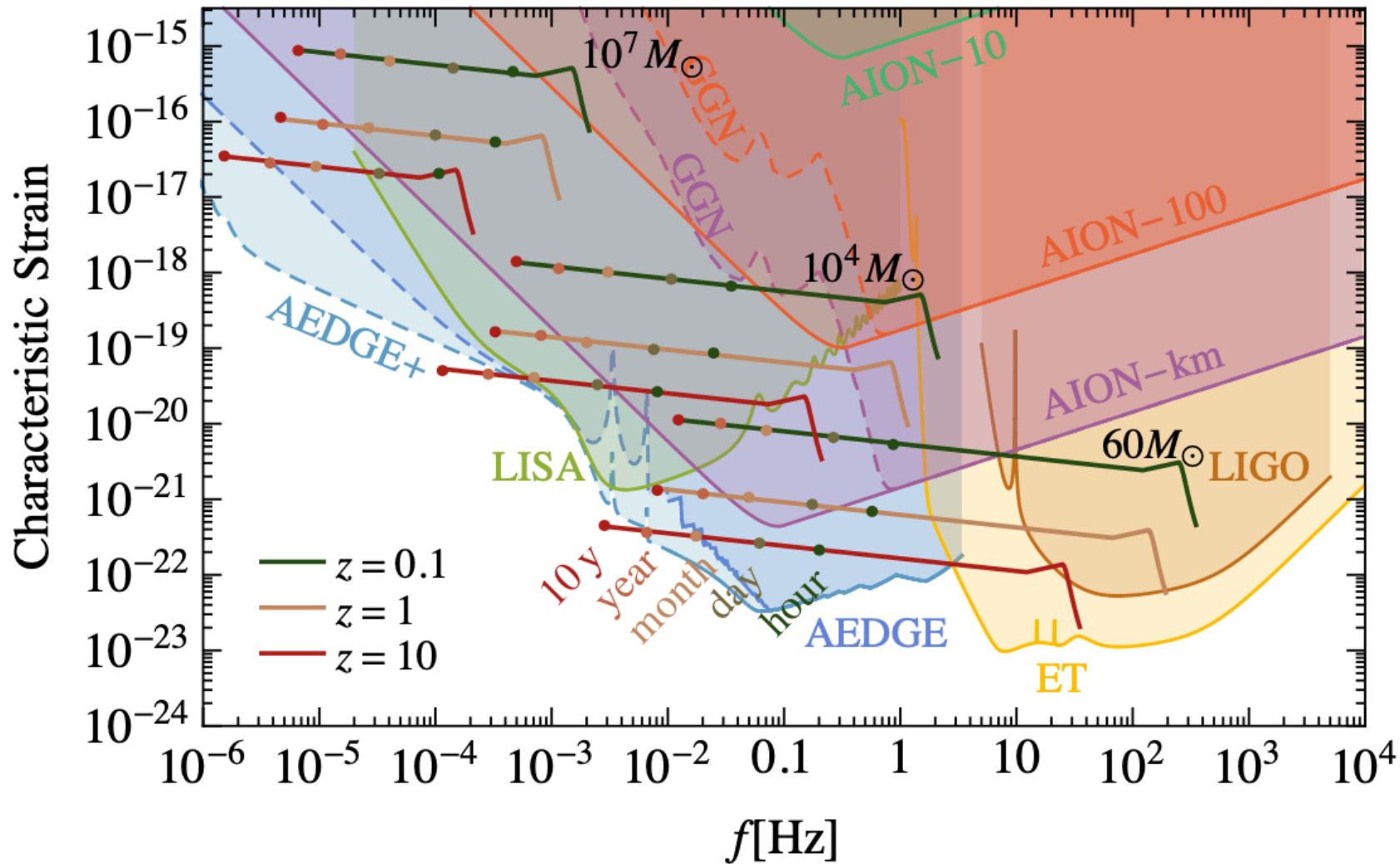
Yousef Abou El-Neaj,¹ Cristiano Alpigiani,² Sana Amairi-Pyka,³ Henrique Araújo,⁴
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White paper
submitted to
ESA Voyage
2050 Call

Abou El-Neaj, ..., JE et al:
arXiv:1908.00802

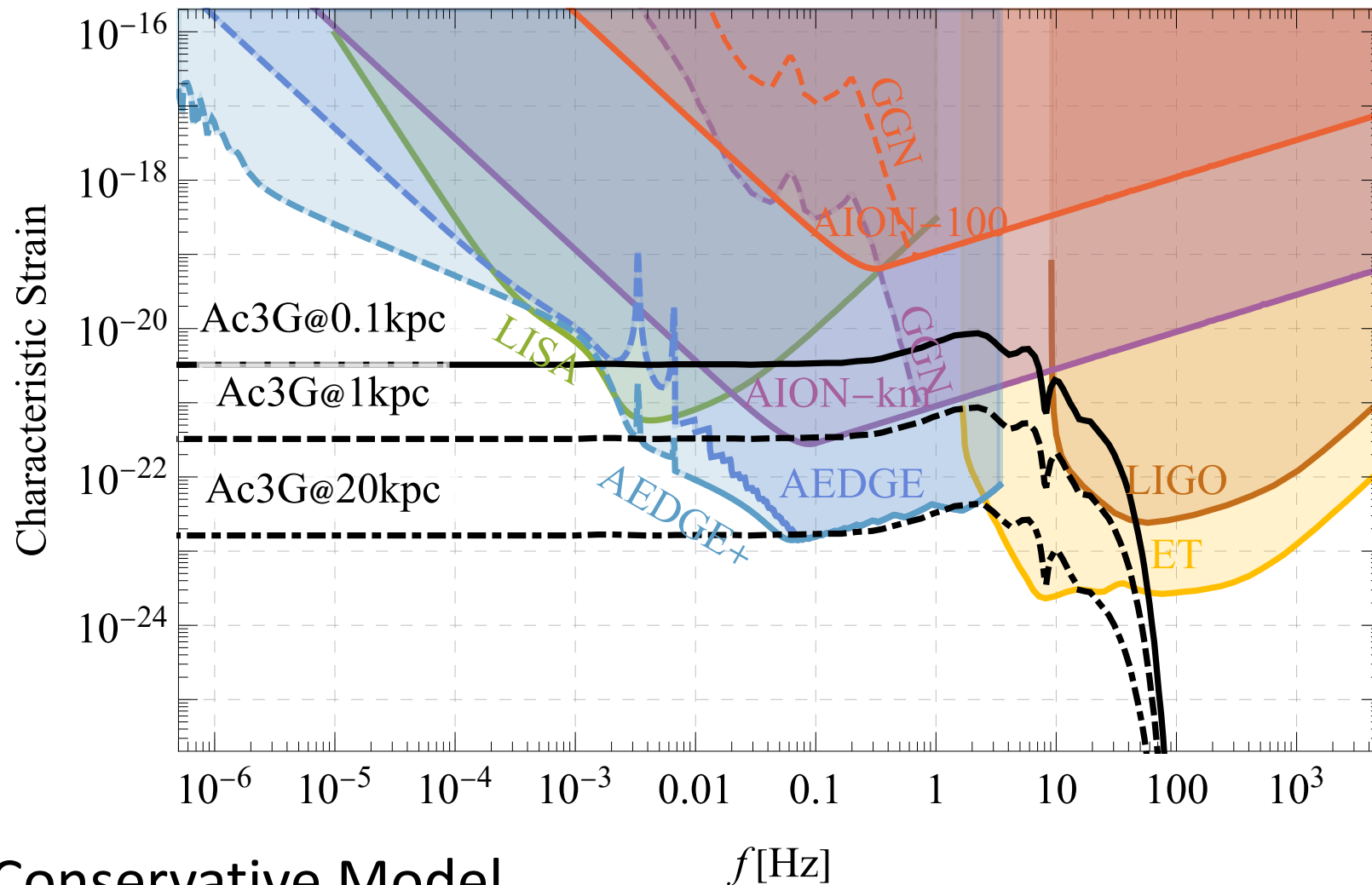
Gravitational Waves from IMBH Mergers



Probe formation of SMBHs

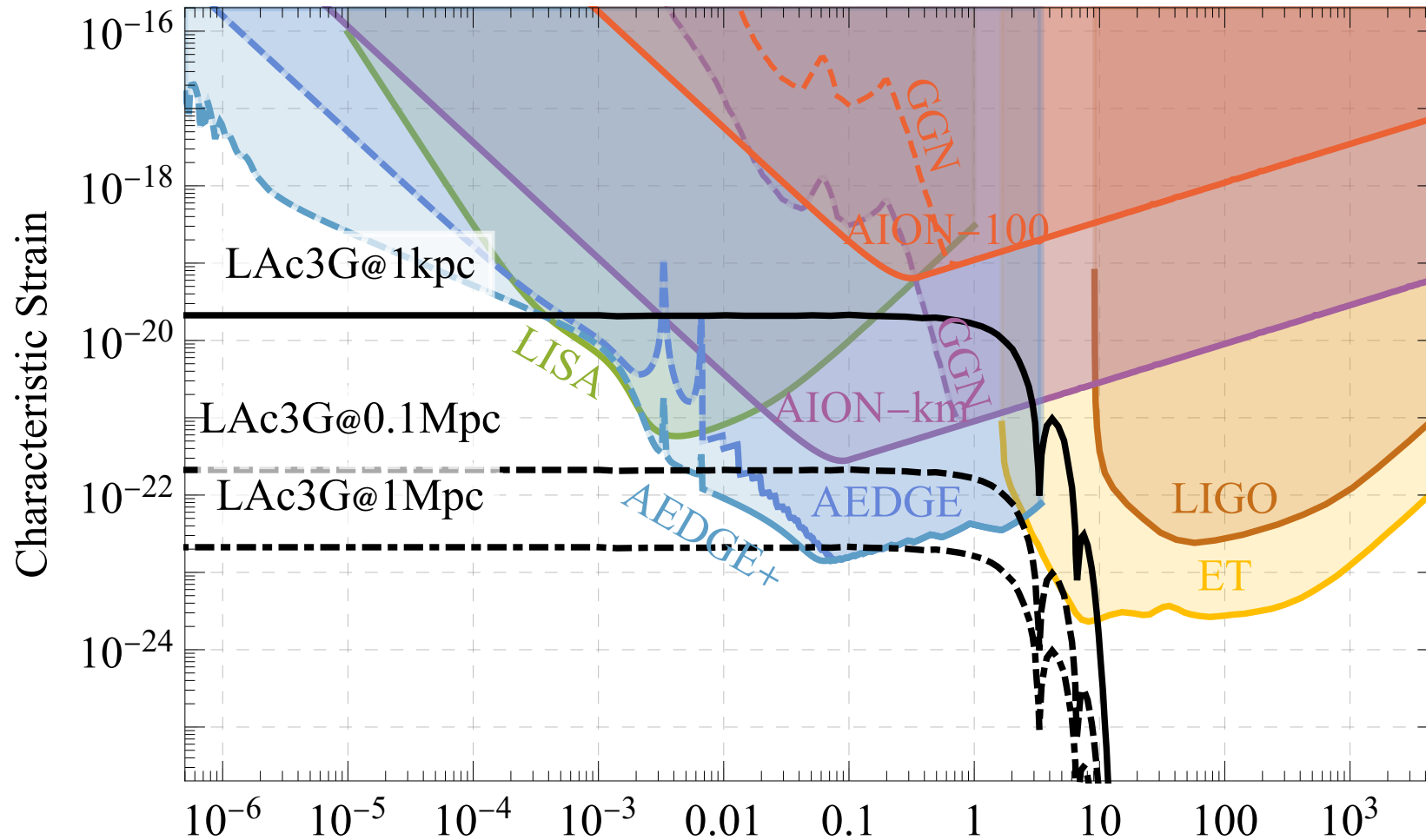
Synergies with other GW experiments (LIGO, LISA), test GR

AION/AEDGE Sensitivities to Gravitational Memory of Supernova Neutrinos



Conservative Model
Sensitivity to SN within the Milky Way

AION/AEDGE Sensitivities to Gravitational Memory of Supernova Neutrinos



More optimistic model f [Hz]
 Sensitivity beyond the Milky Way



*“... the place you return to is always slightly different
from the place you left.”*

Haruki Murakami, *Drive my Car*

