



QUANTUM
TECHNOLOGY
INITIATIVE

EC(H)Os in the dark

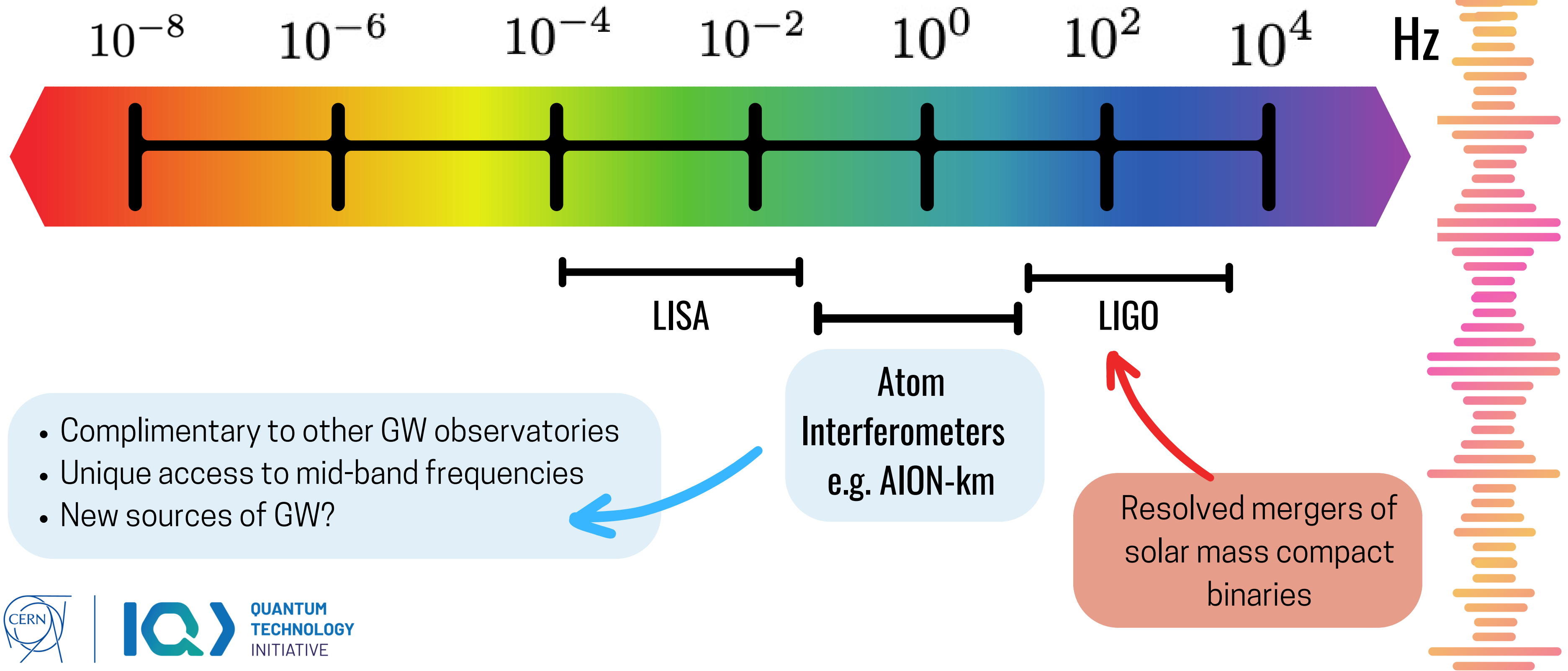
Hunting for **Exotic Compact Objects**
(ECOs) with Gravitational Waves at **Atom**
Interferometers

Hannah Banks

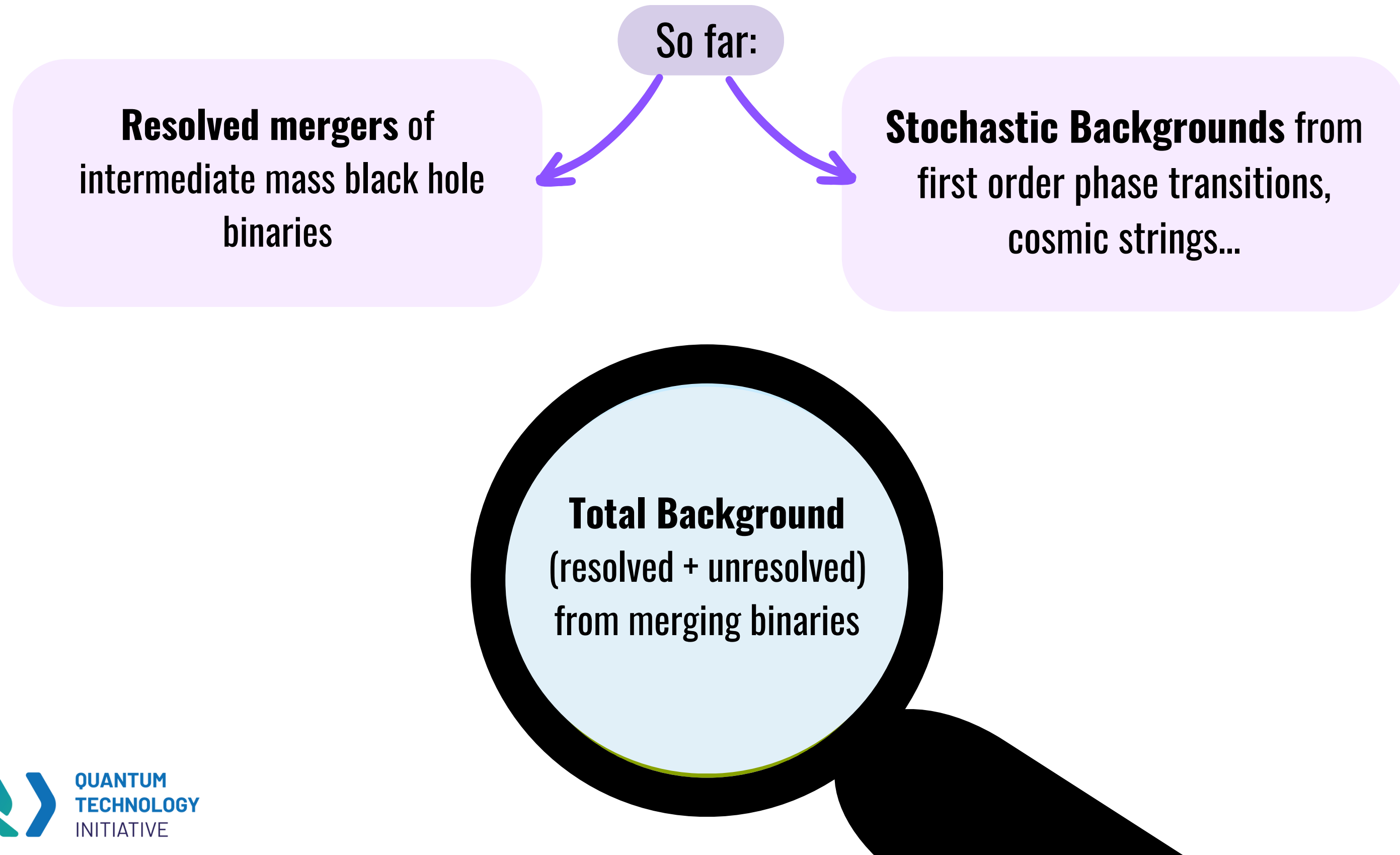
Based on **arXiv:2302.07887** with Matthew McCullough & Dorota Grabowska



The GW Detector Landscape



Gravitational Waves @ Atom Interferometers ...



Gravitational Wave Backgrounds

Characterise by:

$$\Omega_{GW}(f) = \frac{f}{\rho_c} \frac{d\rho_{GW}(f)}{df}$$

For a population of binary compact objects:

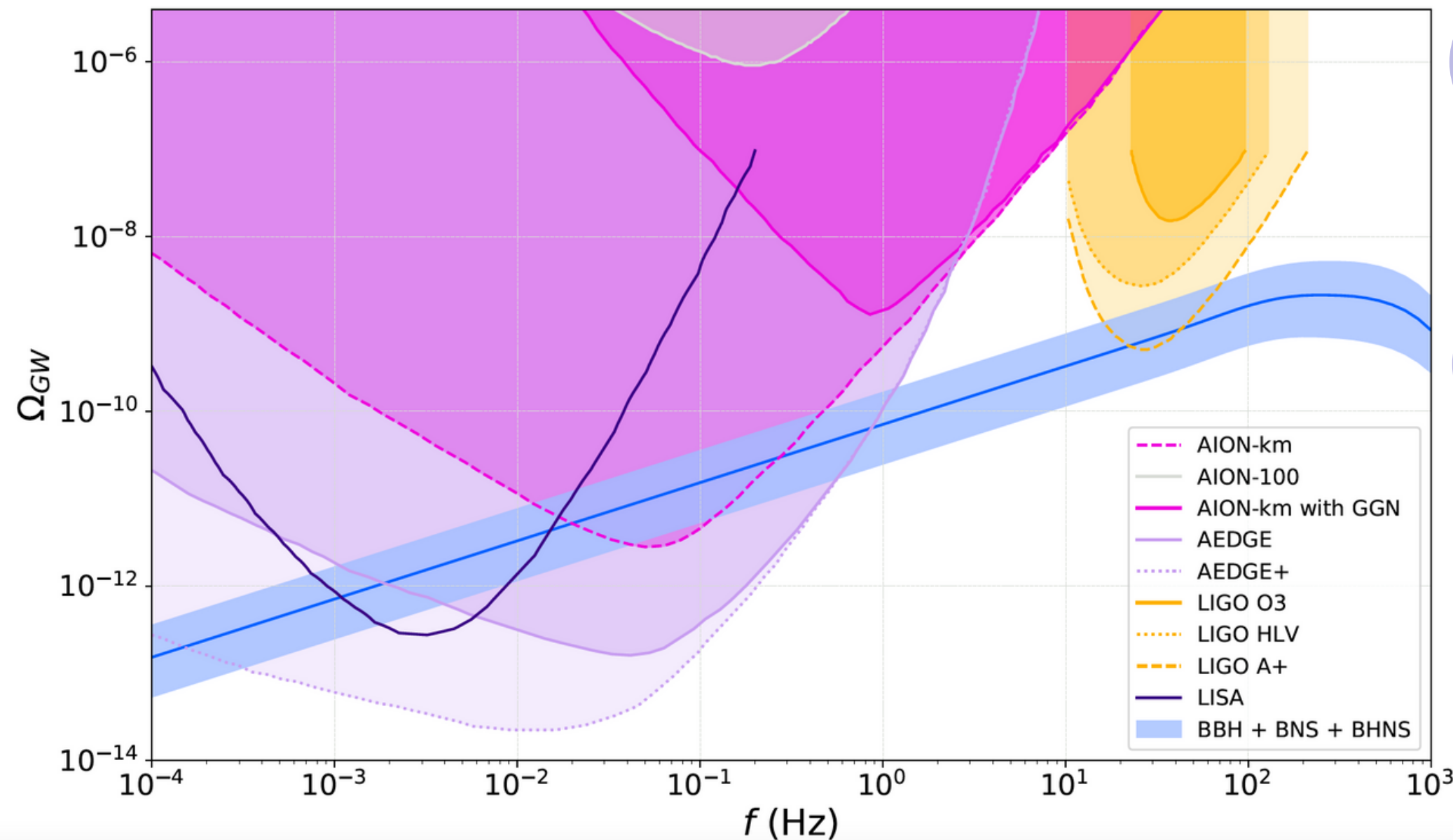
$$\Omega_{GW} = \int dm_1 dm_2 \int \frac{1}{\rho_c} \frac{dV_c}{1+z} \frac{d\mathcal{R}(z)}{dm_1 dm_2} \frac{d\tilde{\rho}_{GW}(m_1, m_2)}{df}$$

- Present-day merger rate
- Mass Distribution
- Redshift Distribution

Waveforms of inspiral, merger, ringdown



LIGO Stellar Mass Compact Binaries



1

Relevant **background** to other searches

2

Interesting **signal**:

- Access **high z** population
- Determine **population characteristics** (e.g. mass, angular momentum)
- Test **astrophysics** (stellar formation rates, evolution of metallicity with redshift etc.)

Exotic Compact Objects (ECOs) ?

- SM is **extraordinarily rich and diverse** - same true of Dark Sector?
- Possibility of **new states over a great range of scales** which could **coalesce** under gravity to form **extended macroscopic objects**

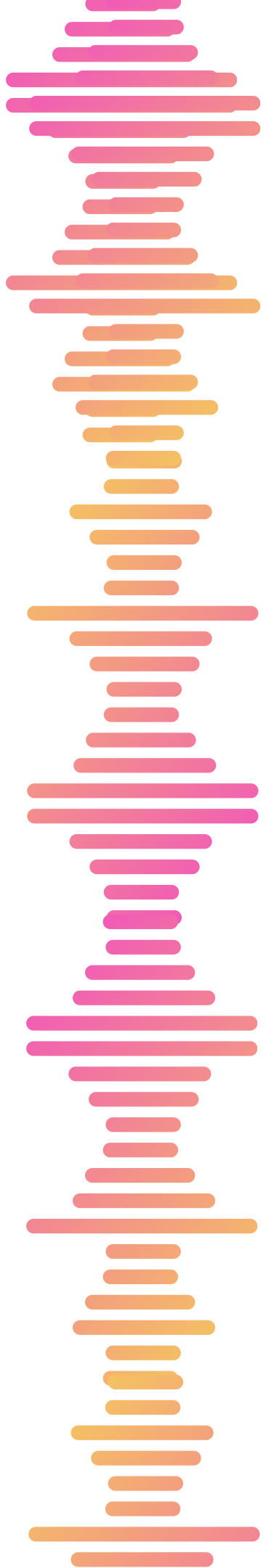
ECOs may include:

Fermion Stars

Boson Stars

Dark Matter Stars

If form **binaries**, would produce **GWs!**



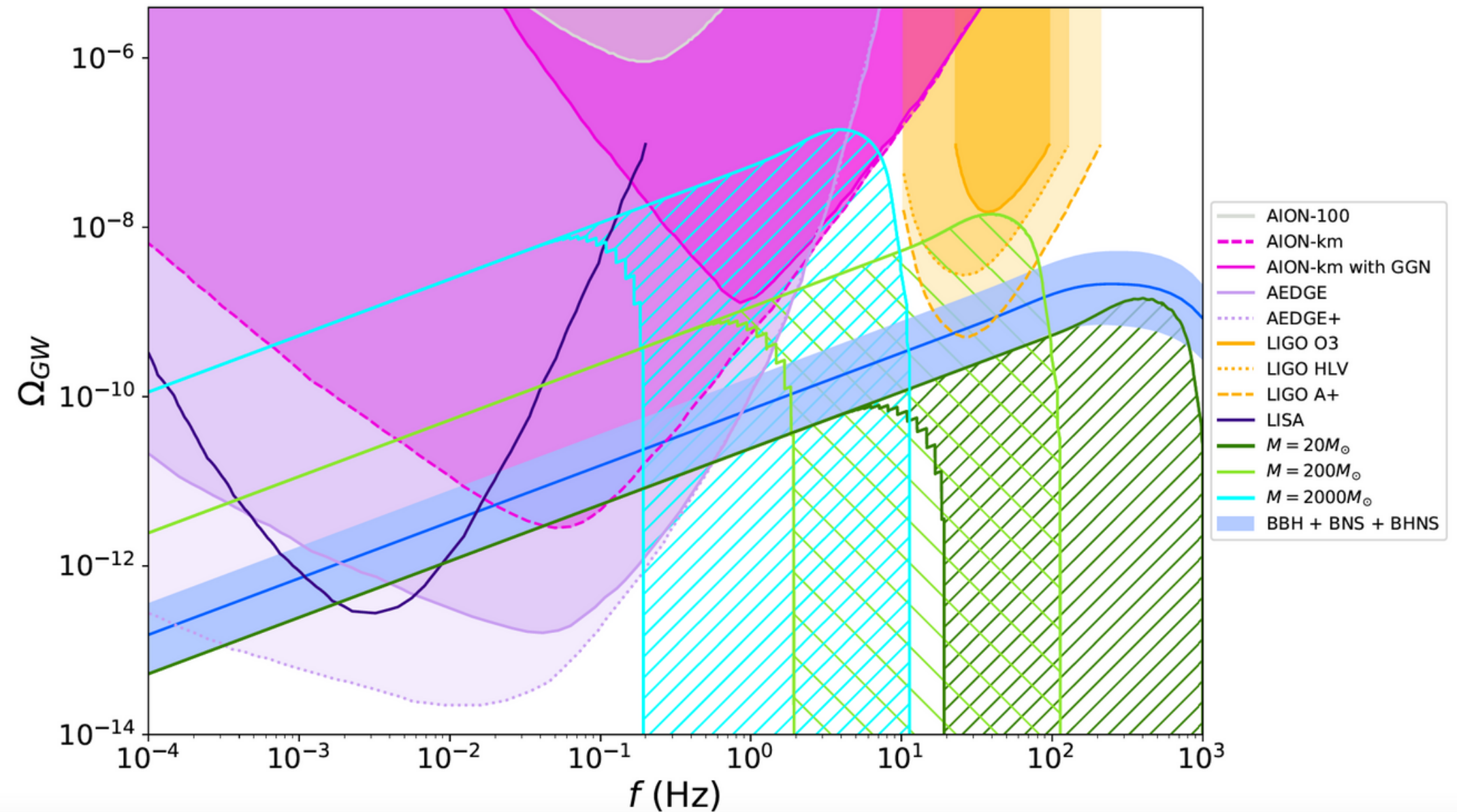
GWs from ECOs...

Assume:

- Population of equal mass objects in binaries
- Same redshift distr. & merger rate as LIGO BH
- Either:
 - Inspiral only up to

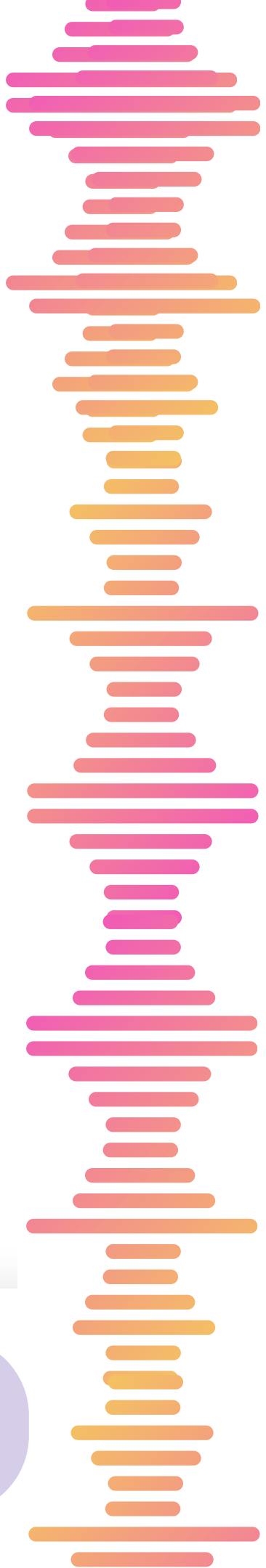
$$f_{ISCO}^{ECO} = \frac{C^{3/2}}{3^{3/2}\pi GM} \quad C = \frac{M}{R}$$

- BH waveforms for ringdown/merger



Higher masses = lower cut off

Mismatch between detectors = **probe** of **dark sector complexity**



Summary

- **Background** from LIGO stellar mass binaries **will be observable** at atom interferometers
- Opportunity to **extract** lots of **interesting information**

- **ECOs** harbouring just **tiny fractions of DM** abundance could produce **significant signals**
- Spectrum **cut-off sensitive to ECO mass** - probe of **dark sector complexity**

