Week 15 Report Spring 2019: Thesis Results and Conclusions

Sam Frederick

Comparing Ellipticity Results Against Published Work

- Compute equilibrium configuration (perturbed stellar structure due to B-field) via relativistic equations.
- “Mean deformation rate”, similar calculation to what we call

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Relativistic stars with purely toroidal magnetic fields

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$$\bar{e} = \frac{I_{zz} - I_{xx}}{I_{zz}}$$

Appear analogous calculations to me.

Simple deformations [edit]

In simple contexts, a single number may suffice to describe the strain, and therefore the strain rate. For example, when a long and uniform rubber band is gradually stretched by pulling at the ends, the strain can be defined as the ratio ϵ between the amount of stretching and the original length of the band:

$$\epsilon(t) = \frac{L(t) - L_0}{L_0}$$

where L_0 is the original length and $L(t)$ its length at each time t. Then the strain rate will be

$$\dot{\epsilon}(t) = \frac{d\epsilon}{dt} = \frac{d}{dt}\left(\frac{L(t) - L_0}{L_0}\right) = \frac{1}{L_0}\frac{dL}{dt}(t) = \frac{v(t)}{L_0}$$

where $v(t)$ is the speed at which the ends are moving away from each other.

Deformation ***rate***??

Wikipedia: Strain rate

Qualitative Comparison: Relativistic Results vs. Newtonian

TABLE I. Global physical quantities for the maximum gravitational mass models of the constant magnetic flux sequences of the nonrotating stars.

Φ (10^{22} Wb)	ρ_c (10^{15} g/cm^3)	M ($M_\odot$)	M_0 ($M_\odot$)	R_{cir} (km)	B_{max} (10^{18} G)	$H/\lvert W\rvert$	$\bar{e}$
			$k=1$				
0.000×10^0	1.797×10^0	1.719×10^0	1.888×10^0	1.180×10^1	0.000×10^0	0.000×10^0	0.000×10^0
1.616×10^0	2.032×10^0	1.843×10^0	2.014×10^0	1.457×10^1	1.008×10^0	1.253×10^{-1}	-4.284×10^{-1}
2.155×10^0	2.026×10^0	1.935×10^0	2.107×10^0	1.667×10^1	1.129×10^0	1.737×10^{-1}	-6.933×10^{-1}
2.694×10^0	1.914×10^0	2.041×10^0	2.210×10^0	1.951×10^1	1.168×10^0	2.186×10^{-1}	-1.012×10^0
			$k=2$				
0.000×10^0	1.797×10^0	1.719×10^0	1.888×10^0	1.180×10^1	0.000×10^0	0.000×10^0	0.000×10^0
1.077×10^0	2.032×10^0	1.855×10^0	2.055×10^0	1.361×10^1	8.023×10^{-1}	8.068×10^{-2}	-3.874×10^{-1}
1.347×10^0	2.039×10^0	1.920×10^0	2.128×10^0	1.444×10^1	8.630×10^{-1}	1.024×10^{-1}	-5.315×10^{-1}
1.616×10^0	2.126×10^0	1.990×10^0	2.210×10^0	1.516×10^1	9.205×10^{-1}	1.198×10^{-1}	-6.721×10^{-1}

We Find:

$\varepsilon(t = 5\ s)$ = **-7.1×10^{-2}**

$d\varepsilon / dt\ (t = 5\ s)$ = **-2.7×10^{-2}**

Our *Newtonian* results

The Main Point: Gravitational Wave Strain Estimates

- I realize the wavestrain value I computed earlier was FAR too high, realized where I went wrong.
- Using this expression, we find wavestrain is ~ 10^{-28} for galactic magnetar sources.

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Gravitational Waves from Neutron Stars: A Review

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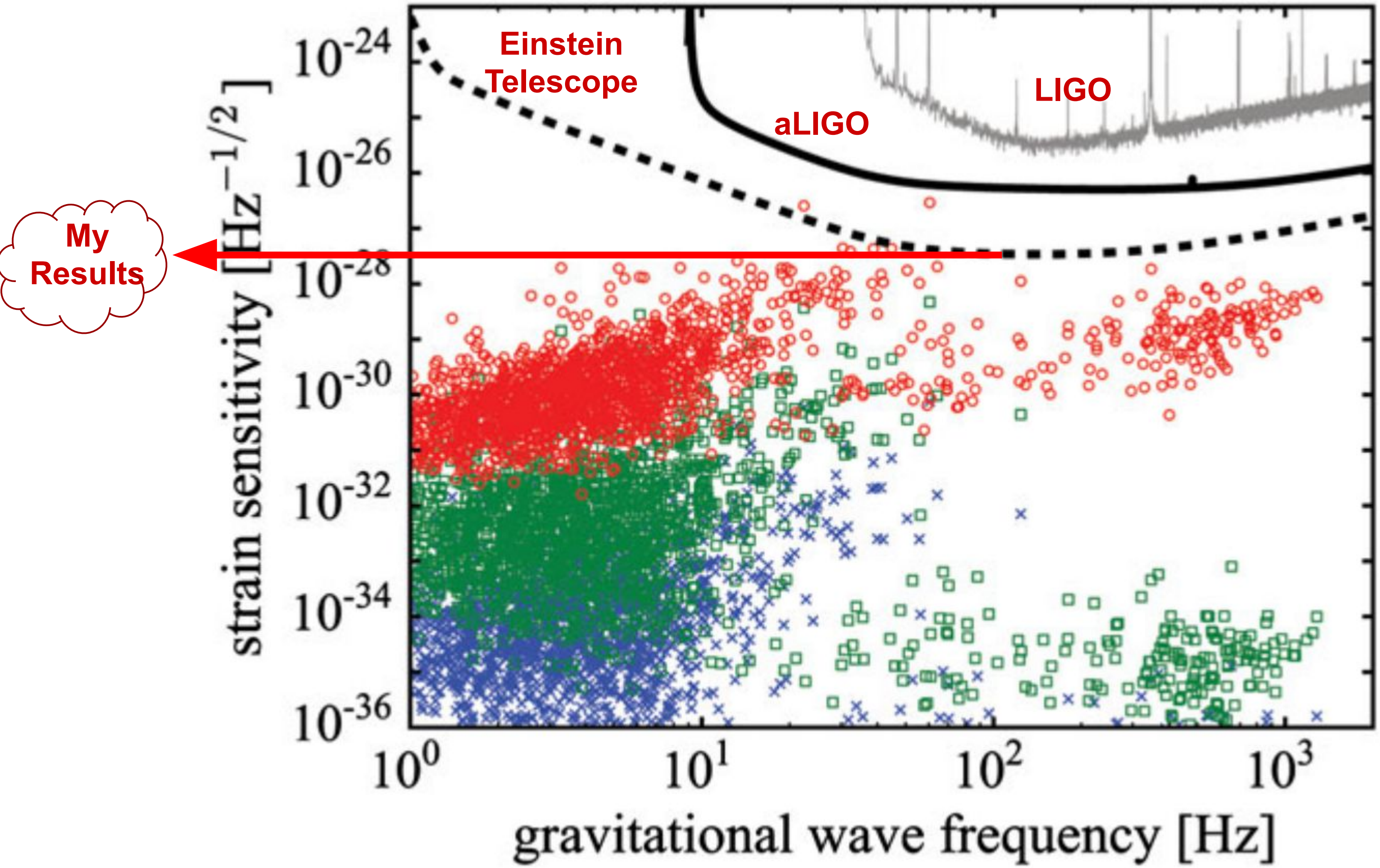
$$h_0 = \frac{4\pi^2 G}{c^4} \frac{I_{zz} f_{gw}^2 \epsilon}{d}$$

$$= 4.2 \times 10^{-26} \left(\frac{\epsilon}{10^{-6}}\right) \left(\frac{P}{10\,\mathrm{ms}}\right)^{-2} \left(\frac{d}{1\,\mathrm{kpc}}\right)^{-1}$$


Einstein Telescope
aLIGO
LIGO
My Results
strain sensitivity [Hz$^{-1/2}$]
10^{-24}
10^{-26}
10^{-28}
10^{-30}
10^{-32}
10^{-34}
10^{-36}
10^{0}
10^{1}
10^{2}
10^{3}
gravitational wave frequency [Hz]

The Future

- Current detectors can't pick up NS continuous GW signals.
- LISA (Laser Interferometer Space Antenna) will operate from .1 mHz to 1 Hz. Will be able to detect GWs from magnetars!

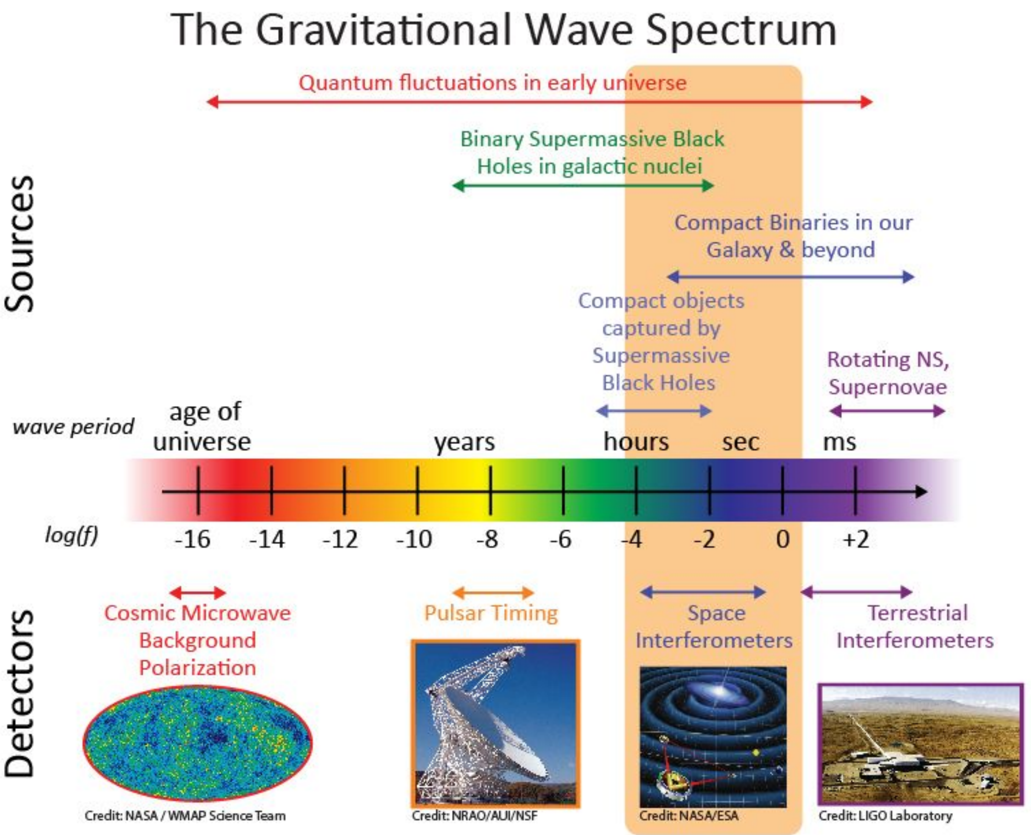


Image Credit: NASA