Upper Limit Map of a Stochastic Gravitational Wave Background

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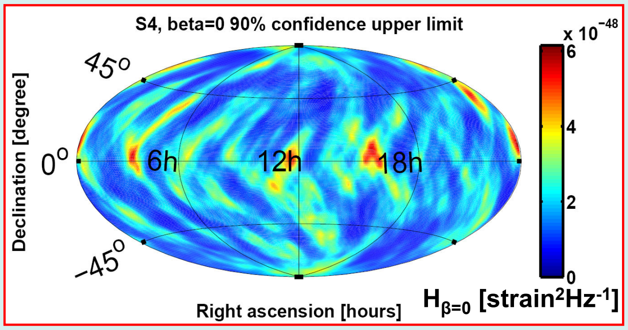


Preliminary upper limit map on point sources with a broadband, frequency independent strain power spectrum $H(f)=H_{\beta=0}$.

Directional Upper Limit on GW Background

We analyzed the data from the LIGO S4 science run for an anisotropic background of gravitational waves using a method that is optimized for point sources. This is appropriate if, for example, the gravitational wave background is dominated by astrophysical sources.

No signal was seen. Preliminary upper limits were set on broadband radiation originating from any direction, as well as narrowband radiation arriving from the brightest X-ray source in the sky, Sco-X1, a Low-Mass X-ray binary.

Introduction

LIGO can get position information from the time shift between the two spatially separated sites and from the antenna pattern. Both are modulated by the earth's rotation.

Cross-Correlation

$$Y = \sum_{t_{\mathrm{sidereal}}} \int_{-\infty}^{+\infty} df\, \tilde{s}_1^*(f)\, \tilde{s}_2(f)\, \tilde{Q}(t_{\mathrm{sidereal}}, f)$$

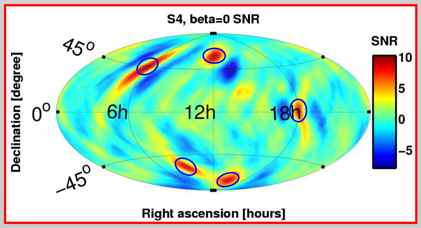
$$\sigma_Y^2 = \sum_{t_{\mathrm{sidereal}}} \int_{-\infty}^{+\infty} df \left|\tilde{Q}(t_{\mathrm{sidereal}}, f)\right|^2 P_1(f) P_2(f)$$

$$\tilde{Q}(t,f) = N \frac{\gamma_\Omega(t,f) H(f)}{P_1(f) P_2(f)}$$

$$\gamma_\Omega(t,f) = \frac{1}{2} \sum_{A=+,\times} e^{i 2\pi f \hat{\Omega} \frac{\Delta\vec{x}(t)}{c}} F_{1,t}^A(\Omega) F_{2,t}^A(\Omega)$$

Y	cross - correlation output
σ_Y	Standard deviation of Y
s_i	Data from detector i
Q	Optimal filter for point source
H	$= H_\beta \left(\frac{f}{100\mathrm{Hz}}\right)^\beta$ Source Strain Power Spectrum
P_i	Noise spectrum of detector i
γ_Ω	Geometry factor for point source
$F_i^A(\Omega)$	Response of detector i to GW with ploarization A from direction Ω
N	Normalization, such that $\langle Y \rangle = H_\beta$

Injected Point Sources



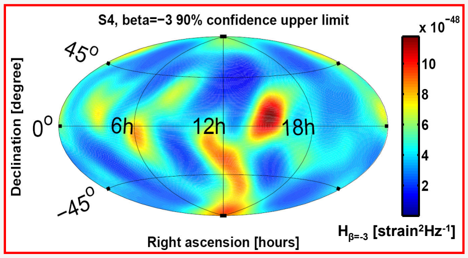
Five point sources with $H_{\beta=0}=10^{-47}$strain^{2}Hz^{-1} were injected in software (blue circles). Analysing the same injection for an isotropic background only yields a SNR 1.2 result.

Preliminary Results from S4

The S4 run lasted one month, with 16 days of usable coincidence data.

Power law	Upper limit range (90% C.L.)
$H_{\beta=0}(f/100\mathrm{Hz})^0$	$H_{\beta=0} < 0.85 \ldots 6.1 \; [\times 10^{-48}\,\mathrm{Hz}^{-1}]$
$F_{\beta=2}(f/100\mathrm{Hz})^2$	$F_{\beta=2} < 2.7 \ldots 19 \; [\times 10^{-6}\,\mathrm{erg\,cm^{-2}\,Hz^{-1}}]$
$H_{\beta=-3}(f/100\mathrm{Hz})^{-3}$	$H_{\beta=-3} < 1.2 \ldots 12 \; [\times 10^{-48}\,\mathrm{Hz}^{-1}]$
$F_{\beta=-1}(f/100\mathrm{Hz})^{-1}$	$F_{\beta=-1} < 3.8 \ldots 38 \; [\times 10^{-6}\,\mathrm{erg\,cm^{-2}\,Hz^{-1}}]$

Preliminary upper limits on the Source Strain Power Spectrum H(f) and corresponding energy flux F(f) for broadband gravitational point sources. The range refers to maximum and minimum of the corresponding maps (see title and below).



Preliminary upper limit map on point sources with a broadband, frequency independent strain power spectrum $H(f)=H_{\beta=-3}(f/100Hz)^{-3}$

Sco-X1 (LMXB)

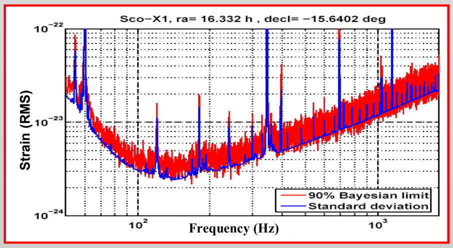
If the accretion torque acting on the neutron star is balanced by GW radiation, Sco-X1 is expected to radiate GW at 2x the (unknown) spin frequency with a luminosity

$$L_{GW} \approx \frac{f_{spin}}{f_{Kepler}} L_X$$

where L_X is the X-ray luminosity.

The binary's orbital motion shifts a 1kHz signal by 0.25Hz peak-to-peak.

Sco-X1, Preliminary Results



Standard deviation σ_Y (blue) and 90% C.L. upper limit (red) on RMS strain amplitude in each 0.25Hz bin for radiation arriving from Sco-X1. At the most sensitive point (140Hz) this upper limit is about 60 times the value inferred from the X-ray luminosity

The two LIGO observatories are located in Hanford, WA and Livingston, LA. The Hanford facility harbors two interferometers, one with 4 km and one with 2 km arm length. The Livingston site has one 4 km interferometer. The two observatories are separated by 3000 km.

LIGO Hanford Observatory

LIGO Livingston Observatory

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