Gravitational wave signals from the ensemble of rotating neutron stars in the Galaxy

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INNOVATIVE ECONOMY
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Parameters of a neutron star

Population model

In our calculations we use a model of population that sets **the supernova birth every 100yr, the initial values of the kick velocities, the rotation periods (1-10ms) and the magnetic fields (log(B/Gauss)$\sim$12.5)**. Then it is evolved in time. Position and velocity of each pulsar is calculated from gravitational potential of the Galaxy. Finally we obtain population of, for example, **10000 stars with age below 1Myr**.

Parameters of a neutron star

When a neutron star is rotating and has some distortion it generates gravitational waves. The model parameters are:
P (rotation period),
r (distance),
B (magnetic field),
I (moment of inertia, constant - $10^{38} kg\, m^2$),
ϵ (distortion value, constant - 10^{-5}),
α (angle between rotation axis and distortion axis, $0^o - 90^o$),
i (inclination from $asin(0.0 - 1.0)$).
We may determine some characteristic value for any pulsar:

$$h_0 = -\frac{16\pi^2 G}{c^4} \frac{I\epsilon}{P^2 r}$$

Neutron stars may have ellipsoidal distortion due to magnetic field. The shorter rotation period the stronger emission is. When distortion axis is aligned with rotation axis there is no emission.

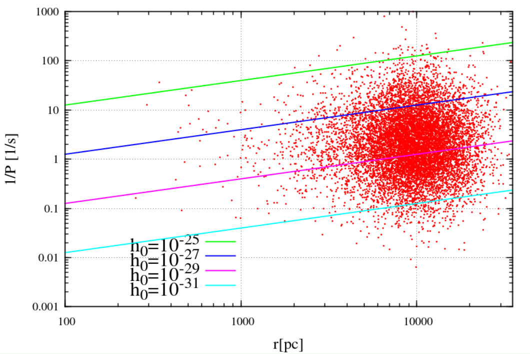
Signal from a single neutron star

We use the equations from Bonazzola, Gourgouhlon (1996):

$$h_+ = h_0 \sin(\alpha)[\frac{1}{2}\cos(\alpha)\sin(i)\cos(i)\cos(\Omega(t-t_0)) - \sin(\alpha)\frac{1+\cos^2(i)}{2}\cos(2\Omega(t-t_0))] \quad (1)$$

$$h_\times = h_0 \sin(\alpha)[\frac{1}{2}\cos(\alpha)\sin(i)\sin(\Omega(t-t_0)) - \sin(\alpha)\cos(i)\sin(2\Omega(t-t_0))] \quad (2)$$

Population of neutron stars



Frequency versus distance of an object for a population of 10000 neutron stars. Lines with constant values of h_0.

Signal from an ensemble of the neutrons stars

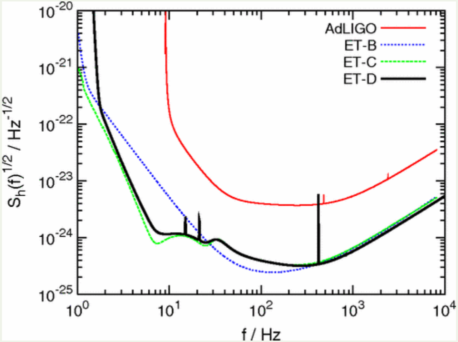
Assumptions

signal **not coherent** so we take a sum of $h^2(t)$ instead of $h(t)$
signal calculated on a **time intervals** $P \ll \tau \ll day$
Earth rotation changes relative position of the object and the detector $F(t)$

Average squared signal calculated by the formula from Giazotto, Bonazzola, Gourgouhlon (1997):

$$< h^2(t) >= 2 \sum_{i=1}^{N} \frac{[F_+^i(t)]^2}{\tau} \int_t^{t+\tau} [h_+^i(t')]^2 dt' \tag{3}$$

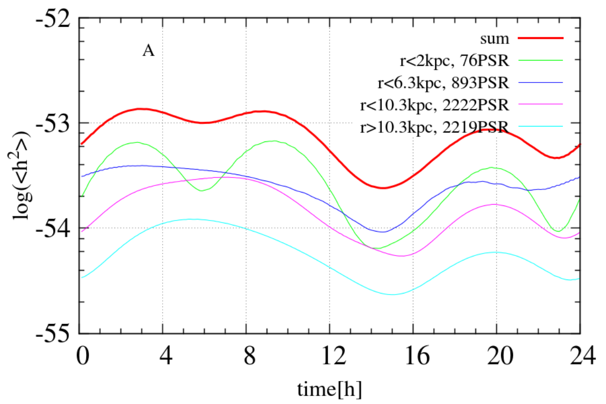
Detectors



Stephen R. Taylor & Jonathan R. Gair, 2012

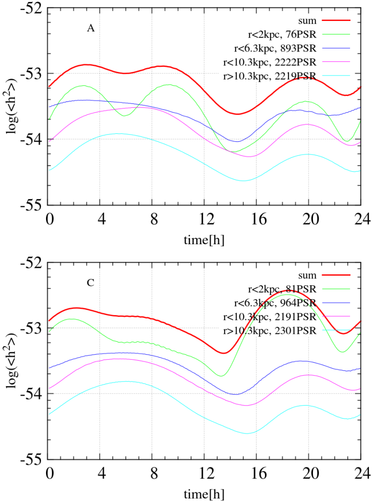
Single rotating neutron stars may be observed by AdvancedLigo, AdvancedVirgo and Einstein Telescope. For AdvancedLigo and AdvancedVirgo observation frequency range is above 10Hz, for Einstein Telescope above 1Hz.

Frequency range 1-10Hz

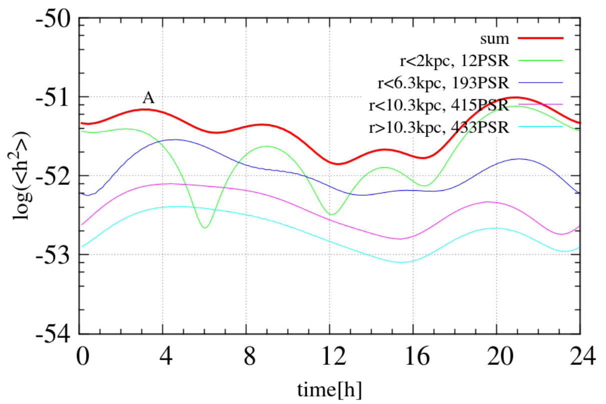


Squared signal for population of neutron stars with rotation frequency 1-10Hz. There is total signal and components for different distance ranges.

Frequency range 1-10Hz

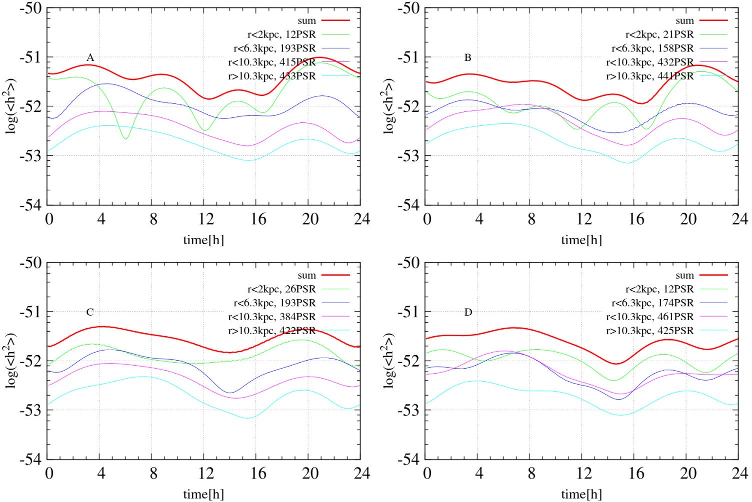


Frequency range 10-30Hz

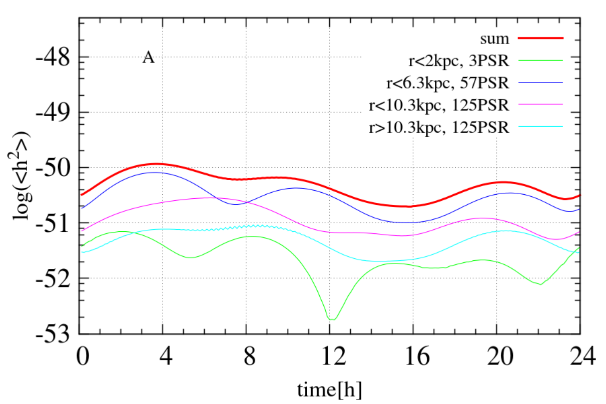


Squared signal for a population of 10000 neutron stars with rotation frequency 10-30Hz. There is total signal and components for different distance ranges.

Frequency range 10-30Hz

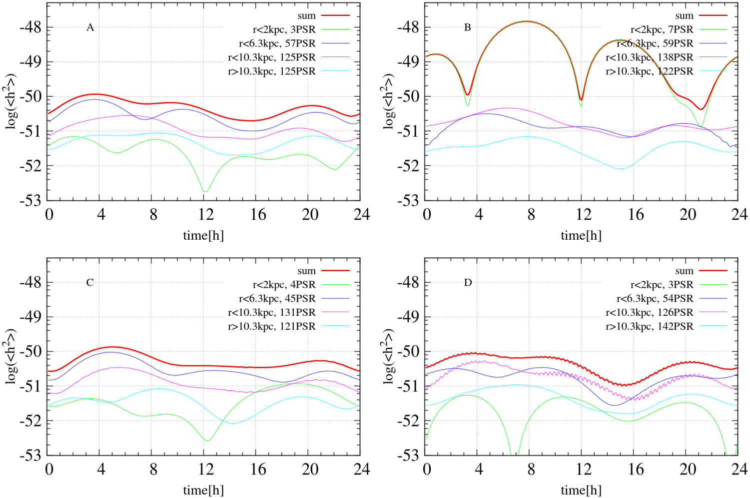


Frequency range 30-100Hz

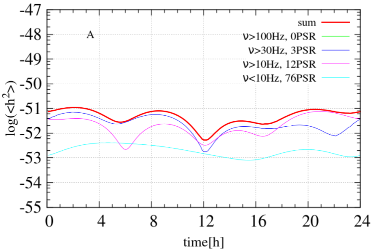


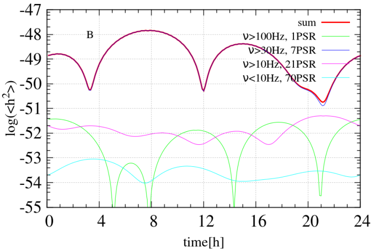
Squared signal for a population of 10000 neutron stars with rotation frequency 30-100Hz.

Frequency range 30-100Hz

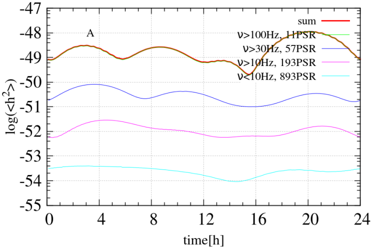


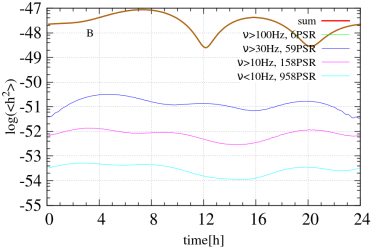
Distance range <2kpc



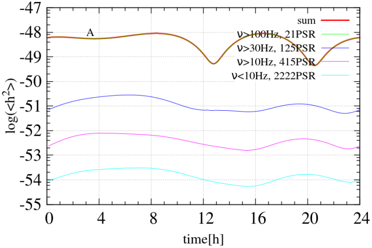


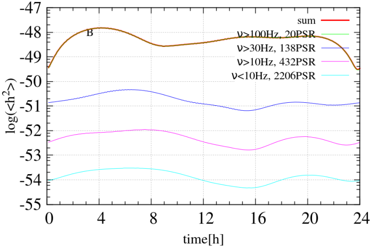
Distance range 2-6.3kpc



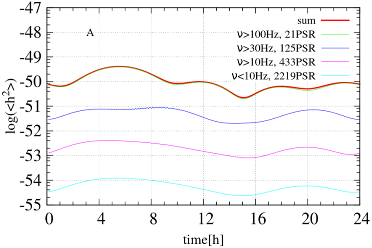


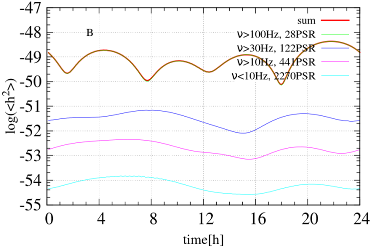
Distance range 6.3-10.3kpc





Distance range >10.3kpc





Conclusions

- close objects or/and with high frequency, in most cases dominate the total signal
- for close objects the signal varies between the realizations and depends on the number of the neutron stars that happen to be close
- for larger distances and lower frequencies, the profile of the signal is similar within the realization, only with changed level of the signal,
- for larger distances the signal doesn't vary significantly between the realizations for smaller frequencies,
- when we consider larger number of the neutron stars the signal almost don't change, for ranges with few/tens objects the signal vary between the different realizations

Thank you for attention