Effects of spin-orbit coupling on gravitational waveforms from a triaxial nonaligned neutron star in a binary system

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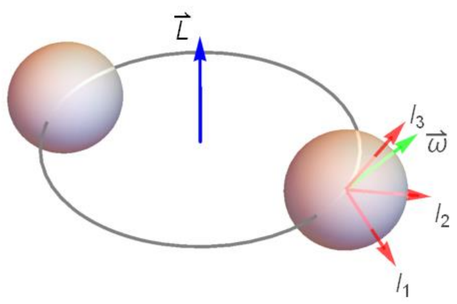
■ **Introduction** According to binary population synthesis simulations, future space-based GW detectors, such as LISA and TianQin, can potentially detect some double NS (DNS) systems with orbital periods shorter than 10min. The possibility of a successful directed search for continuous GWs from the spinning NS in such a binary system identified by LISA/TianQin will be significantly increased with the proposed next-generation ground-based GW observatories, such as Cosmic Explorer and Einstein Telescope.

■ Mass quadrupole radiation from NS

Searching for continuous GWs from the spinning NS in a tight DNS identified by LISA/TianQin requires consideration of the interaction of the spinning NS with its companion.

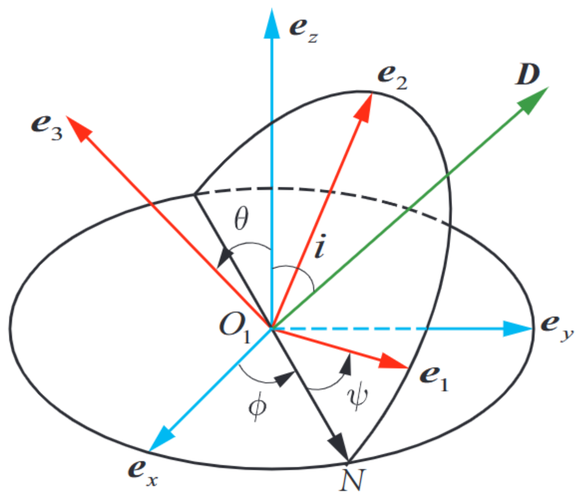


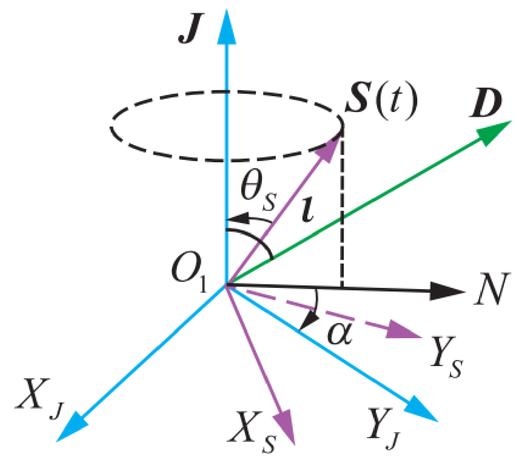
$$\epsilon \equiv \frac{I_3 - I_1}{I_3}$$
$$\kappa \equiv \frac{1}{16}\frac{I_3}{I_1}\frac{I_2 - I_1}{I_3 - I_2}$$
$$\gamma \equiv \frac{aI_1}{bI_3}$$

$$\dot{\hat{\mathbf{S}}} = \left(2 + \frac{3M_2}{2M_1}\right)\frac{\mathbf{J}}{r^3} \times \hat{\mathbf{S}}$$

■ GWs from spinning NS with spin-orbit coupling

We derive analytic approximations that describe the GWs emitted by a triaxial nonaligned NS in a binary in which the effects of spin-orbit coupling have been incorporated. (Body frame to S-aligned frame to J-aligned frame)





$$h_+ = -\frac{G}{c^4 D}[(\mathcal{R}_{y\mu}\cos\iota - \mathcal{R}_{z\mu}\sin\iota)(\mathcal{R}_{y\nu}\cos\iota - \mathcal{R}_{z\nu}\sin\iota) - \mathcal{R}_{x\mu}\mathcal{R}_{x\nu}]\mathcal{A}_{\mu\nu}$$
$$h_\times = \frac{2G}{c^4 D}(\mathcal{R}_{y\mu}\cos\iota - \mathcal{R}_{z\mu}\sin\iota)\mathcal{R}_{x\nu}\mathcal{A}_{\mu\nu}$$

■ Waveform components from NS

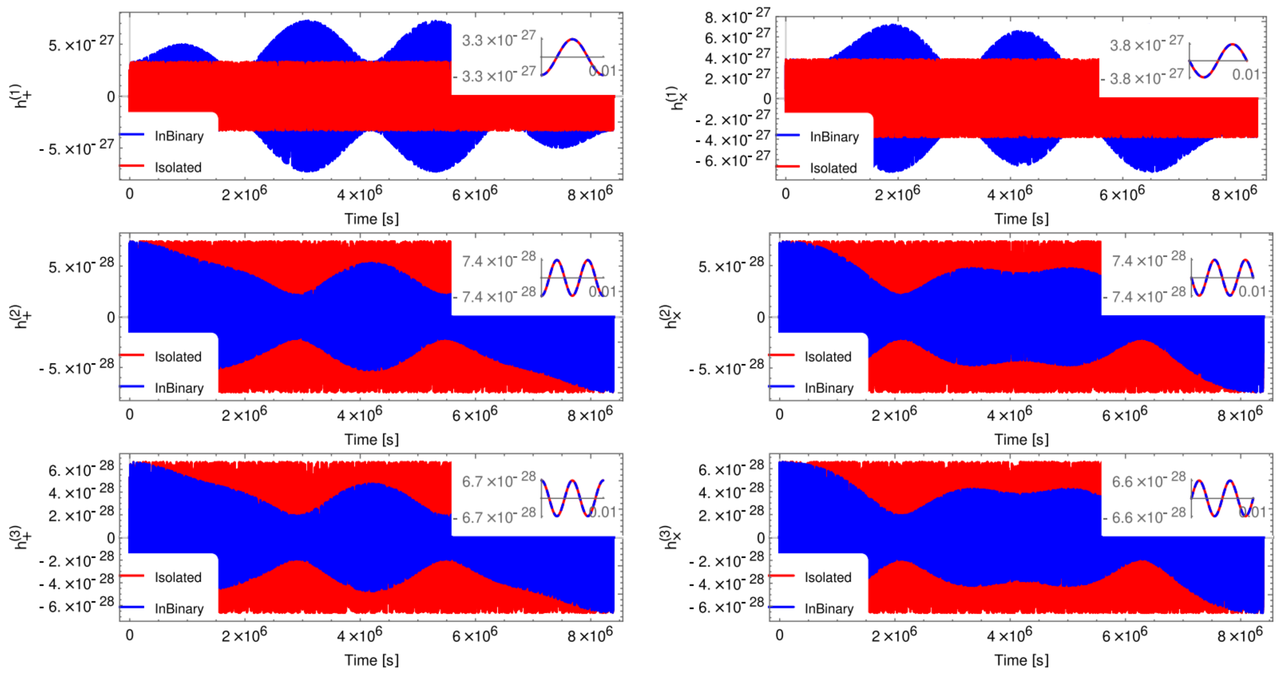
Expanded in terms of NS characteristic parameters

Comparison with and without spin-orbit coupling

Fitting factor < 0.97 after O(10^5s)

$O(\gamma)$ $O(\kappa)$ $O(\gamma^2)$

$$h_+ = h_+^{(1)} + h_+^{(2)} + h_+^{(3)} + \cdots \qquad h_\times = h_\times^{(1)} + h_\times^{(2)} + h_\times^{(3)} + \cdots$$



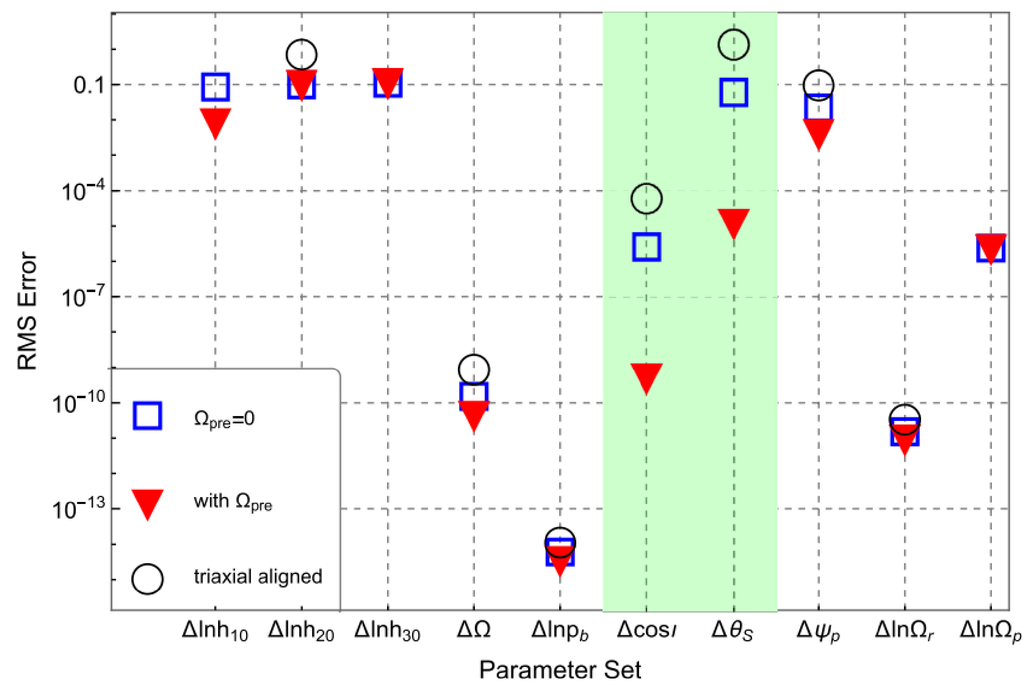
■ Detecting GWs from NS in a binary

➢ Incorporate Doppler modulation

$$\Delta f_{\mathrm{D}} \approx f_0\left(\frac{\boldsymbol{n}\cdot \mathrm{d}\boldsymbol{r}_{\mathrm{d}}/\mathrm{d}t}{c} + \frac{\boldsymbol{n}_{\mathrm{b}}\cdot \mathrm{d}\boldsymbol{r}_{\mathrm{l}}/\mathrm{d}t}{c}\right)$$

➢ Parameter estimation accuracy with Fisher matrix for Cosmic Explorer

Spin-orbit coupling has the potential to improve the estimation accuracy.



■ Conclusion

Importance of spin-orbit coupling for GW detection of the spinning NS in a LISA/TianQin DNS.

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