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A double neutron star binary is one of the most fascinating astrophysical targets in the era of multi-messenger astronomy. Recently, a coalescence of a double neutron star binary (GW170817) was observed by gravitational wave detectors and worldwide electromagnetic telescopes. This event allowed us to restrict nuclear equations of state, to estimate the production of r-process elements by kilonova (also called macronova), and to discuss the progenitors of short gamma-ray bursts. In addition, the merger rate of neutron star binaries was estimated to be $1540^{+3200}_{-1220}\,\mathrm{Gpc^{-3}yr^{-1}}$ (Abbott et al. 2017). This rate indicates that, in our Galaxy, there would be a number of neutron star binaries which merge in 10^5years (corresponding to an orbital period of ~10 minutes).

In this thesis, we concentrate on radio pulsars in such relatively tight binaries. Radio pulsars are considered to have strong magnetic fields and emit electromagnetic radiations through their magnetospheres. Therefore, we can expect that, as the orbits of the neutron star binaries shrink due to gravitational radiation reaction, their magnetospheres contact with each other, depending on the spin periods. By observing radio pulses affected by such interacting magnetospheres, we might obtain crucial information on the structure of the magnetospheres and the poorly-understood radiation processes. Furthermore, after long-term monitoring of such tight binary pulsars, we might place better constraints on some of modified gravity theories.

Even though the above-mentioned rate indicates the existence of multiple Galactic neutron star binaries with the orbital periods less than 10 minutes, it would not be straightforward to discover them with radio pulsar surveys. For finding isolated pulsars in the data streams of radio channels, a signal analysis based on the Fast Fourier Transformation (FFT) is a traditional and powerful method. We can search concentrations of radio powers at the frequencies corresponding to the inverse of the spin period and its harmonic overtones (Lorimer & Kramer 2005). However, the orbital motion of a binary pulsar induces the Doppler modulation to the pulse arrival time, and accordingly spreads the power over nearby frequency bins. As a consequence, the signal-to-noise ratio (SNR) would be decreased significantly. This Doppler smearing is known to be a serious obstacle for finding binary pulsars.

The Square Kilometer Array (SKA) is a large radio telescope, planned to be finalized in the 2030s with the total collecting area of ~1 million square meters. It is estimated that SKA could find more than ten thousand pulsars (Keane 2014), but a significant fraction of short period binary pulsars might not be detected, due to the serious Doppler smearing. By assuming the relevant orbital parameters and correcting the smearing, we can, in principle, recover the concentration of the radio power. However, we need to explore a huge number of parameters. Indeed, for a blind search (namely without knowing the sky position and the binary orbital parameters), it might be difficult to practice such a search, because of a limitation of available computational resources. Therefore, an efficient search strategy could be highly beneficial for finding short-period binary pulsars.

Here, we discuss the impact of the Laser Interferometer Space Antenna (LISA) that is scheduled to be launched in 2034. A neutron star binary with an orbital period of ~10 minutes emits gravitational waves at ~3 mHz. For a binary at a Galactic distance, LISA can detect these waves with a high SNR, and can provide us with its sky location and basic orbital parameters. These data would be crucially helpful for subsequently identifying the radio signals of the involved pulsar with SKA. More specifically, with the LISA observation, we can limit the follow-up survey directions of SKA and drastically reduce the parameter space for correcting the Doppler smearing. In this thesis, we quantitatively examine the prospects of this multi-messenger strategy for LISA and SKA. We estimate the total number of floating-point operations required for correcting the Doppler smearing, both with and without LISA data. It is shown that, if LISA data is available, we can take a long integration time (e.g. 12 hours) and identify a very faint pulsar, correcting the Doppler smearing appropriately. In addition, while we can estimate the orbital phase of a binary from LISA data, its error grows rapidly, when extrapolating the phase estimation beyond the operation period of LISA. Therefore, in order to maximize the synergy effects, it is preferable to operate LISA and SKA simultaneously.