Abstract

Fast radio bursts (FRBs) are one of the main targets of astrophysics today. FRBs are bright radio transients, and their duration is of the order of milliseconds. From observed properties, most FRBs have been shown to have extragalactic origins. The luminosity is estimated to be of the order of $10^{42}\,\mathrm{erg\,s^{-1}}$, and the brightness temperature is $\sim 10^{36}\,\mathrm{K}$, which is extremely high and suggests coherent emission. Some FRBs show bursts repeatedly, and they are called repeaters. More than 700 bursts and 24 repeaters have been identified as of today. Although so many bursts have been observed, their source and emission mechanism are not understood.

Among many FRBs, some unique FRBs have been identified. Two FRBs, FRB 20180916B and FRB 20121102A, show periodic activity. For a period of the order of ten to a hundred days, FRBs are only detected in an active window of the order of a few tens percent. The origin of this period is not well understood. There are two main possible origins of this periodicity: binary orbital period and precession period of a source object. In this thesis, we first consider a binary as the origin of the periodicity. We develop "binary comb model", which was applied to FRB 20180916B by Ioka and Zhang, and apply the developed model to interpret FRB 20121102A and reinterpret FRB 20180916B. First, we introduce an eccentricity into the orbit. Second, we identify two new modes of the binary comb model, τ-crossing mode and inverse funnel mode, besides the original funnel mode of the binary comb model. Our developed model expands the applicable parameter space, allowing the companion star to be a massive star, a massive black hole, or a supermassive black hole. For FRB 20121102A, we show that a black hole binary or supermassive black hole binary has larger parameter spaces. These models are also consistent with other observations, such as the persistent bright radio counterpart associated with the source. For FRB 20180916B, we show that the massive star binary can explain the periodicity of the FRB. This result is the same conclusion as in the previous work, but our work has broadened parameter space as the source of the FRB.

Another unique FRB is the Galactic FRB, FRB 20200428A, which is associated with an X-ray flare from a magnetar, SGR 1935+2154. The luminosity of X-ray flare is about the same as other bursts from SGR 1935+2154, but the peak energy ($\sim 80\,\mathrm{keV}$) is higher than that of typical bursts. As FRB 20200428A shows, magnetar flares would be closely related to the origin of FRBs. In the later part of this thesis, we consider the dynamics of the fireball in the magnetar flare. Specifically, we consider a baryon-loaded fireball expanding along open magnetic field lines. An expanding fireball is likely to be involved as a mechanism for producing thermal radiation with observed high peak energy. The baryon loading on this fireball naturally occurs, but the dynamics of this fireball have not been investigated. We create a unified picture of this fireball, taking into account the photon escape via two processes (optical thinning and diffusion), the number density in a strong magnetic field, and the cross section in a strong magnetic field. Five cases of photon escape are identified. We show that the baryons loading increases the final Lorentz factor, and the kinetic luminosity of the outflow can be higher than the observed FRB luminosity for the observed X-ray photospheric luminosity. We also analytically evaluate the baryon loading parameter where the electrons associated with the baryons in the magnetar flare can affect the propagation.

By understanding these unique FRBs, we approach the possible origin and the emission mechanism of the FRBs.