The black hole-neutron star (BH-NS) binary mergers are among the most promising sources of gravitational waves, and the information provided by the detection of gravitational waves will surely open the door to the new aspects of the universe. Because the BH-NS binary contains a NS, electromagnetic counterparts would associate with the merger events. The so-called kilonova/macronova is the one of the most promising electromagnetic counterparts. The simultaneous observation of the kilonova/macronova and gravitational waves would provide rich information about the merger events. To maximize the scientific outcome at the detection of the merger events, the nature and the diversity of the BH-NS mergers should be clarified. To achieve this, we studied the BH-NS merger focusing on the next two topics in this thesis.

First, we studied the parameter dependence of the BH-NS merger for the case that the BH spin is not aligned with the orbital axis and the orbit precesses. We performed numerical-relativity simulations for the merger of BH-NS binaries with various BH spin misalignment angles, employing four models of nuclear-theory-based EOSs described by a piecewise polytrope. Particularly, we focused on the case that the mass ratio and the BH spin parameter are 5 and 0.75, respectively, for which the misalignment of the BH spin has a significant effect on the NS tidal disruption. We investigated the dependence of the orbital evolution in the late inspiral phase, tidal-disruption process of the NS, properties and structures of the remnant disk and ejecta, properties of the remnant BH, gravitational waveforms and their spectra on the BH spin misalignment angle and the EOS of the NS. We also proposed a new method for extracting the cutoff frequency from the gravitational waveforms for the case that the binary is precessing.

Second, we studied the parameter dependence of the kilonova/macronova from BH-NS merger. For this purpose, we derived a semi-analytic model in next three steps. First, we derived the fitting formulas for the mass and the velocity of the ejecta by using the results of the numerical simulations obtained in this work and previous studies. Second, we derived the semi-analytic model for the BH-NS kilonova/macronova lightcurve by using the results of a radiative-transfer simulation performed in *Tanaka & Hotokezaka (2014)*. Finally, we combined the ejecta fitting formula with the kilonova/macronova lightcurve model, and studied the dependence of the kilonova/macronova lightcurve in a wide range of binary parameters.

The main results of this thesis are as follows:

1. We clarified the quantitative dependence of the disk mass and the ejecta mass on the initial misalignment angle, $i_{\rm tilt,0}$, and the NS EOS for the case that the BH mass is 6.35 $M_\odot$, the NS mass is 1.35 $M_\odot$, and the BH spin magnitude, χ, is 0.75, respectively. Monotonic dependence of the remnant disk mass and the ejecta mass on the misalignment angle was found. Both disk mass and ejecta mass decrease as the initial misalignment angle increases. We found that if the compactness of the NS is moderate (0.160), BH-NS mergers can produce disks massive than $0.1 M_\odot$ if the initial misalignment angles are $\lesssim 50^\circ$. The ejecta mass with $> 0.01\ M_\odot$ is achieved for the case that the initial misalignment angles are $< 85^\circ$, $< 65^\circ$, and $< 30^\circ$, with the NS compactnesses 0.140, 0.160, and 0.175, respectively.

2. We showed that the mixing among the components of spherical harmonics occurs and causes the modulation in gravitational waveforms for the misaligned-spin case. For all the models, the modulation in the waveforms is suppressed and the bumpy structure in the spectra is removed in the precessing-frame waveforms. The cutoff frequency is well-defined in the waveforms in the precessing frame, and its dependence of the NS EOS is clearly seen. We also compared the cutoff frequency obtained in the precessing frame with the fitting formula for the cutoff frequency calibrated by the aligned-spin BH-NS merger simulations derived by the previous study. We found that the fitting formula reproduces the cutoff frequency in the precessing

frame within $\sim 9\%$ even for the misaligned-spin BH-NS merger if we employ the effective spin parameter defined by $\chi_{\rm eff} = \chi \cos i_{\rm tilt,0}$. We also proposed a new method, the mode extraction procedure, to remove the modulation in the waveforms. The cutoff frequency measured from the mode extracted waveforms agrees with the one measured from the precessing-frame waveforms within $\sim$ 10–15%.

3. By using the results for the misaligned-spin BH-NS merger obtained in this work and the results for the aligned-spin BH-NS merger obtained by the previous study, we derived fitting formulas for the mass and the velocity of dynamical ejecta from a BH-NS merger in a wide range of binary parameters. We combined these fitting formulas with a semi-analytic model of the BH-NS kilonova/macronova lightcurve that reproduces the results of radiative transfer simulations with a small error. Specifically, the semi-analytic model reproduces the results of each band magnitude obtained by existing radiation transfer simulations within ~ 1 mag.

4. By using the semi-analytic model for the BH-NS kilonova/macronova, we show that the kilonova/macronova can be observed in optical wavelength by 8-m class telescopes within 3 days from the merger if $\chi_{\rm eff} \gtrsim 0.23\ (\mathcal{M}_{\rm ch}/M_\odot) - 0.18$ for the case that the NS radius is larger than ~ 11 km, where $\mathcal{M}_{\rm chirp}$ is the chirp mass of the system. On the other hand, if the optical-wavelength emission is observed by 8-m class telescopes for the case that $\chi_{\rm eff} \lesssim 0.67\ (\mathcal{M}_{\rm ch}/M_\odot) - 1.45$, the origin of the emission may not be the kilonova/macronova from the dynamical ejecta but some other components unless the NS is larger than 13.6 km. In near-infrared wavelengths, the follow-up observation of kilonova/macronova by space telescopes is useful because the emission can be bright and last long enough to be detected for the wide parameter space of a BH-NS merger. Particularly, if the NS radius is 11.1 km, the emission can be detected even at ~ 14 days after the merger for the case that $\chi_{\rm eff} \gtrsim 0.46\ (\mathcal{M}_{\rm ch}/M_\odot) - 0.72$. We also applied our model to GRB130603B as an illustration, and clarified the parameter region of the BH-NS merger which is consistent with the observation. Particularly, we showed that a BH-NS merger with a rapidly spinning BH or a large NS radius is favored for the kilonova/macronova associated with GRB130603B, which is consistent with the previous studies.