

The Pennsylvania State University  
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**NEUTRINO AND ELECTROMAGNETIC COUNTERPARTS OF  
GALAXY AND ASTROPHYSICAL BLACK HOLE MERGERS**

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# Abstract

The historical coincident detection of gravitational waves (GWs) and electromagnetic (EM) counterparts from the binary neutron star merger event GW 170817 heralds a new era in multi-messenger astronomy. At the same time, since the first discovery of the high-energy astrophysical neutrinos in 2012 by IceCube, neutrino astrophysics has made significant progress and has started playing an increasingly important role in multi-messenger analyses. We are currently in the stage where we can probe the nature of the extreme astrophysical phenomena with the synergies between EM photons, neutrinos, GWs, and cosmic rays.

In this dissertation, I start with an overview of the development of multi-messenger astrophysics and its application to astrophysical mergers. I will present our work on the cumulative diffuse neutrino background from galaxy/cluster mergers and show that our scenario can explain the diffuse neutrino flux without violating the extragalactic  $\gamma$ -ray background constraints (chapter 2). We further demonstrate that the synchrotron and inverse Compton emissions produced by secondary electrons/positrons are consistent with the radio and X-ray observations of merging galaxies such as NGC 660 and NGC 3256 (chapter 3). In chapters 4 & 5, we focus on the jet-induced neutrino and EM counterparts from supermassive black hole (SMBH) mergers subsequent to GW radiation and discuss the detection perspectives for the ongoing and next-generation neutrino, optical, and GW missions. The short  $\gamma$ -ray bursts, which are generally thought to arise from compact binary object (CBO) mergers, could be promising candidates for multi-messenger studies. We then consider a special scenario where short GRBs are embedded in disks of active galactic nuclei (AGN) and investigate their GeV signatures in chapter 6.

In a separate effort, we study the stacking and multiplet constraints on the blazar contribution to the cumulative diffuse neutrino flux, assuming a generic relationship between neutrino and  $\gamma$ -ray luminosities (chapter 7). We show that these two limits are complementary, and our results support the argument that blazars are disfavored as the dominant sources of the 100-TeV neutrino background. This work provides rather general and stringent constraints for future studies of blazar neutrinos.

# Table of Contents

List of Figures	vii
List of Tables	xv
Acknowledgments	xvi
<b>Chapter 1</b>	
<b>Introduction</b>	<b>1</b>
1.1 The Multi-Messenger Astrophysics . . . . .	1
1.1.1 Electromagnetic (EM) Photons . . . . .	1
1.1.2 Cosmic Rays (CRs) . . . . .	3
1.1.3 High-Energy Astrophysical Neutrinos . . . . .	4
1.1.4 Gravitational Waves (GWs) . . . . .	7
1.1.5 The Physical Picture of Multi-Messenger Astrophysics . . . . .	9
1.2 Astrophysical Mergers in the Era of Multi-Messenger Astrophysics . . . . .	10
1.2.1 Galaxy and Cluster Mergers . . . . .	10
1.2.2 Supermassive Black Hole Mergers . . . . .	11
1.2.3 Compact Binary Mergers . . . . .	13
<b>Chapter 2</b>	
<b>Cumulative Neutrino and <math>\gamma</math>-Ray Backgrounds from Galaxy and Cluster Mergers</b>	<b>17</b>
2.1 Introduction . . . . .	17
2.2 Halo Mass Function . . . . .	19
2.3 Merger Rate and Cosmic-ray Luminosity Density . . . . .	21
2.3.1 Gas Fraction $\xi_g(M, z)$ . . . . .	22
2.3.2 Shock Velocity $v_s$ . . . . .	23
2.4 Neutrino and $\gamma$ -Ray Production . . . . .	25
2.4.1 Galaxy Mergers . . . . .	26
2.4.2 Interactions in the Host Cluster and Cluster Mergers . . . . .	28
2.5 Diffuse Neutrino and $\gamma$ -Ray Spectra . . . . .	29
2.6 Conclusion and Discussion . . . . .	33
2.7 Summary . . . . .	36
2.8 Appendix 1: Halo Merger Rate . . . . .	37

## Chapter 3

<b>Secondary Radio and X-Ray Emissions from Galaxy Mergers</b>	<b>39</b>
3.1 Motivation . . . . .	39
3.2 Secondary Electron Spectrum and Electromagnetic Emissions . . . . .	41
3.3 Radio and X-Ray Constraints on $M_g$ and $v_s$ . . . . .	48
3.3.1 NGC 660 . . . . .	48
3.3.2 NGC 3256 . . . . .	53
3.4 Summary and Discussion . . . . .	55

## Chapter 4

<b>High-Energy Neutrino Emission Subsequent to GW Radiation from SMBH Black Hole Mergers</b>	<b>59</b>
4.1 Introduction . . . . .	59
4.2 Physical Conditions of the Premerger Circumnuclear Environment and the Jet . . . . .	61
4.2.1 Premerger Circumnuclear Environment . . . . .	63
4.2.2 Postmerger Jet Structure and CR Acceleration . . . . .	65
4.3 Interaction Timescales . . . . .	69
4.3.1 Nonthermal Target Photon Fields . . . . .	69
4.3.2 Timescales for the CRs and Pions . . . . .	73
4.4 High-Energy Neutrino Emission from Shocks in the Jets . . . . .	75
4.4.1 Neutrino Fluences . . . . .	75
4.4.2 Detectability . . . . .	80
4.4.3 Cumulative Neutrino Background . . . . .	82
4.5 Summary and Discussion . . . . .	85
4.6 Appendix 1: Uncollimated Jets with Accurate $\xi_w$ . . . . .	87
4.6.1 Average Wind Density $\hat{\rho}_w$ . . . . .	88
4.6.2 Jet Collimation Condition . . . . .	89
4.6.3 Results . . . . .	90

## Chapter 5

<b>Post-Merger Jets from SMBH Coalescences as Electromagnetic Counterparts of GW Emission</b>	<b>93</b>
5.1 Introduction . . . . .	93
5.2 Jet Dynamics . . . . .	94
5.3 Electromagnetic Emission from Post-Merger jets . . . . .	97
5.4 Summary and Discussion . . . . .	101

## Chapter 6

<b>GeV Signatures of Short GRBs in Active Galactic Nuclei</b>	<b>104</b>
6.1 Introduction . . . . .	104
6.2 Cavity Formation and Disk Photon Spectra . . . . .	107
6.2.1 Cavity Formation . . . . .	107
6.2.2 Disk Photon Spectra . . . . .	109

6.3	Non-Thermal Electrons . . . . .	111
6.4	Results . . . . .	112
6.4.1	$\gamma$ -Ray Spectra . . . . .	112
6.4.2	Detectability with Fermi-LAT and VHE $\gamma$ -Ray Facilities . . . . .	117
6.4.3	Prompt Emission . . . . .	118
6.5	Summary and Discussion . . . . .	119
<b>Chapter 7</b>		
<b>Complementarity of Stacking and Multiplet Constraints on the Blazar</b>		
<b>Contribution to the Cumulative Diffuse Neutrino Flux</b>		<b>122</b>
7.1	Introduction . . . . .	122
7.2	Implications of Stacking Limits . . . . .	124
7.3	Implications of High-Energy Neutrino Multiplet Limits . . . . .	129
7.4	Discussion . . . . .	134
<b>Chapter 8</b>		
<b>Summary and Outlook</b>		<b>137</b>
8.1	Summary . . . . .	137
8.2	Outlook . . . . .	139
<b>Bibliography</b>		<b>142</b>

# List of Figures

1.1	Differential sensitivities for CTA (50 hours), MAGIC (50 hours), VERITAS (50 hours), HESS (50 hours), HAWC (5 years), LHAASO (1 year), SWGO (5 years), and <i>Fermi</i> Large Area Telescope ( <i>Fermi</i> -LAT), to obtain $5\sigma$ detection of a point-like source. . . . .	2
1.2	All particle CR energy spectrum (multiplied by $E^{2.6}$ ) from air shower measurements [1]. See the text for a detailed description. . . . .	3
1.3	Source candidates that satisfy the Hillas criteria in the $B$ - $R$ plane. The dashed lines correspond to the CR energies $E_{\text{cr,max}}=10^{14.5}$ eV (knee), $10^{18.5}$ eV (ankle), and $10^{19.6}$ eV (GZK). . . . .	5
1.4	Schematic picture of the IceCube Observatory. IceCube is a cubic-kilometer detector located at the Antarctic. It consists of 5160 digital optical modules attached on 86 vertical strings. The detector measures the Cherenkov light from the secondary particles induced by the high-energy neutrinos. . . . .	6
1.5	GW frequency bands of various source populations, ranging from $10^{-9}$ Hz to $10^4$ Hz [2]. GW telescope classes are shown below the frequency spectrum. . . . .	8
1.6	A schematic demonstration of the propagation of astrophysical messengers (high-energy $\gamma$ -rays, neutrinos, GWs, and CRs) after leaving the source. . . . .	9
1.7	A snapshot of the density distribution of the circumbinary disk around the binary SMBH system and the mini-disks around each SMBH. The simulation was performed by Bowen et al. in 2019 [3]. . . . .	12
1.8	Evolution channels and fates of compact binary mergers including NS-NS mergers (upper channel), NS-BH merger (middle channel), and BH-BH mergers (bottom channel). Credit: Imre Bartos and Marek Kowalski [4]. . . . .	14

2.1	Dark matter halo mass function $dN/d \ln M$ at $z = 0, 1, 2, 3, 4, 5$ . Here, we use the fitting formula from [5]. . . . .	20
2.2	Redshift-dependent gas fraction $\xi_g(z)$ (red solid line) compared to a constant gas fraction $\xi_g = 0.05$ (red dashed line) for redshift-dependent shock velocity with $\sigma_0 = 300$ (blue solid line) and with $\sigma_0 = 500$ (blue dashed line), respectively. . . . .	24
2.3	CR energy input rate versus redshift. The red lines correspond to a redshift-dependent gas fraction $\xi_g^{\text{evo}}$ and the blue lines are for a redshift-independent gas fraction $\xi_g = 0.05$ , while the solid lines are for $\sigma_0 = 300$ and the dashed are for $\sigma_0 = 500$ , respectively. The dashed and dash-dotted magenta lines are LM and HM components of $(\sigma_0 = 300, \xi_g^{\text{evo}})$ scenario. Here LM and HM denote the low-mass ( $10^{10} \text{ M}_\odot - 10^{13} \text{ M}_\odot$ ) and high-mass ( $10^{13} \text{ M}_\odot - 10^{15} \text{ M}_\odot$ ) intervals, respectively. . . . .	30
2.4	Left panel: Neutrino (all flavor) and $\gamma$ -ray fluxes from halo mergers with redshift-evolving gas fraction $\xi_g^{\text{evo}}$ , $R_{g,0} = 10 \text{ kpc}$ , $H_{g,0} = 500 \text{ pc}$ . The shock velocity is obtained using $r_0^{\text{sc}}(z)$ and $\sigma_0 = 300$ . The magenta line is the neutrino spectrum while the green line is the corresponding $\gamma$ -ray spectrum. Galaxy and cluster contributions to the neutrino flux are illustrated as the dashed and dash-dotted lines, respectively. Right panel: same as left panel except $\sigma_0 = 500$ is utilized for $v_s$ . . . . .	32
2.5	Left panel: same as Fig. 2.4 (a), $\sigma_0 = 300$ , except that $\xi_g = 0.05$ is used to estimate the redshift evolution of the halo gas fraction. Right panel: same as left figure except with $\sigma_0 = 500$ . . . . .	32
2.6	The neutrino fluxes for different compression ratios and CR power-law indices. The black, magenta, blue and greens lines correspond to the power-law indices $s = 2.2, 2.0, 1.5$ and $1.03$ . . . . .	35
2.7	Merger rates from Eq. (22). The blue line represents the whole mass range ( $10^{10} \text{ M}_\odot \sim 10^{15} \text{ M}_\odot$ ) and the red line corresponds to $10^{12} \text{ M}_\odot < M_h < 10^{13} \text{ M}_\odot$ . . . . .	38
3.1	Schematic figure showing the merger of two galaxies. The shock was simplified as a straight line across the dense core region. It is also in the core region where interactions occur and neutrinos as well as electromagnetic radiation are produced. . . . .	42



- 3.2 Electron loss rates versus electron energy  $\varepsilon_e$ . Solid lines correspond to cooling rates due to synchrotron radiation in different magnetic fields, e.g.  $5\mu\text{G}$  (green),  $15\mu\text{G}$  (red) and  $30\mu\text{G}$  (black). The cyan dash-dotted line is the cooling rate of inverse Compton scattering (SSC+EIC). Blue and magenta dotted lines illustrate the contributions of CMB and EBL to the EIC cooling rate, while the black, red and green dotted lines are SSC cooling rates at the magnetic fields  $5\mu\text{G}$  (green),  $15\mu\text{G}$  (red) and  $30\mu\text{G}$  (cyan), respectively. Magenta and blue dashed lines are the escape rate and the reciprocal of dynamic time, respectively. . . . . 45
- 3.3 Secondary electron-positron spectra at different times assuming the magnetic field  $B = 5 \mu\text{G}$ . The parameter  $\eta = t/t_{\text{dyn}}$  represents the time of electron-positron injection. Thin lines are numerical solutions to the CR transport equation while the thick red line is the analytical steady-state solution  $N_e^{\text{steady}}$ . To separate  $N_e^{\text{steady}}$  from numerical solutions, we multiply  $N_e^{\text{steady}}$  by a factor of 10. . . . . 46
- 3.4 Constraints on  $M_g - v_s$  plane from radio, UV and X-ray tolerance areas. From upper left, upper right to the bottom panels, magnetic fields are assumed to be  $B = 11 \mu\text{G}$ ,  $16 \mu\text{G}$  and  $21 \mu\text{G}$ , respectively. In each figure, blue and red areas correspond to the radio and X-ray constraints and the black line shows the upper boundary under the UV constraint. The vertical dashed line and gray area show the constraints from the core region gas density  $n_g \lesssim 100 \text{ cm}^{-3}$ , whereas the horizontal dashed lines and gray area correspond to the strong shock requirements ( $\mathcal{M} \simeq 10$ ) for the temperature  $10^4 \text{ K}$  and  $10^3 \text{ K}$ . The magenta dash-dotted contours correspond to different  $pp$  optical depth  $f_{pp,g}$ . The orange star in the overlapping region labels the test case:  $B = 21 \mu\text{G}$ ,  $v_s = 240 \text{ km s}^{-1}$ ,  $M_g = 10^8 M_\odot$ . . . . . 49
- 3.5 Left panel shows the spectral energy distribution for NGC 660, extending from the radio band to the X-ray regime. Blue points are radio fluxes at various frequencies and the red points are X-ray data in the energy range  $0.2 - 10 \text{ keV}$ . Observations from microwave to UV are illustrated as magenta points in the inset. The gray line is the Planck-function approximation to the IR/optical data. The bulk of the microwave, IR and optical spectrum is due to starlight and dust re-radiation. The fitting areas of radio, UV and X-ray data are shown as the blue, magenta and red areas, respectively. The black, cyan and orange lines are spectra that correspond to the black wedge, cyan circle and orange star in the right panel. In the right panel, the gray and green areas are X-ray and radio constraints on  $s - B$  plane. The red area shows the constraints on the magnetic from previous polarization studies,  $16 \pm 5 \mu\text{G}$ . . . . . 50

3.6	Left panel: The spectral energy distribution for NGC 3256. Blue and red points are radio and X-ray fluxes, respectively. The observations from the infrared band to the UV band, which are mainly attributed to dust and starlight, are shown as magenta points. The blue, green and red lines are best-fitting spectra obtained from three selected points in the right panel for different magnetic fields. The dashed and dash-dotted lines correspond to the synchrotron and IC components. The right panel shows the X-ray (yellow area) and radio constraints for the magnetic fields $17 \mu\text{G}$ (blue area), $25 \mu\text{G}$ (green area) and $33 \mu\text{G}$ (red area). The gray areas, black dashed lines and magenta dash-dotted lines have the same meaning with Fig. 3.4. . . . . .	54
4.1	Schematic description of the merger of SMBHs with minidisks. The black wavy lines in the first and second panels illustrate the disk wind that forms the premerger circumnuclear material. The second panel shows the evolution of the circumbinary disk after the merger, while the third panel shows the postmerger jet-cocoon system. The stages of the evolution are marked on the time arrow below the figures. . . . .	62
4.2	Schematic description of the structure of the collimated jet, where CS, IS, FS and RS stand for collimation shock, internal shock, forward shock and reverse shock. The contact discontinuity is illustrated as the dashed line. . . . .	65
4.3	Radiation constraints, $\tau_{i,u} < 1$ , on $\theta_j - L_{k,j}$ plane at $t_j = 10^{-3}$ yr (left panel) and $t_j = 10^{-2}$ yr (right panel) for $i = \text{CS}$ (orange lines), IS (green lines), FS (red lines) and RS (blue lines). The magenta stars show the parameters that are used, $\theta_j^{-1} = 3$ and $L_{k,j} \simeq 3.4 \times 10^{46} \text{ erg s}^{-1}$ . The black solid line in each panel corresponds to the jet collimation condition, $R_{\text{cs}} \lesssim R_h$ . The blue and red areas illustrate the FS and RS constraints respectively, whereas the overlapped areas represent the joint constraints. . . . .	67
4.4	Collimation shock photon density distribution in the jet comoving frame at $t_j = 0.01$ yr (blue lines) and $t_j = 1$ yr (orange lines) for the super-Eddington accretion rate $\dot{m} = 10$ . The synchrotron and SSC components are shown as dashed and dash-dotted lines, respectively. The parameters, $\epsilon_e = 0.1$ , $\epsilon_B = 0.01$ , $\dot{m} = 10$ and $\Gamma_{\text{cj}} = \theta_j^{-1} = 3$ are used. . . . .	72
4.5	Snapshots of cooling, acceleration and dynamic timescales for CS (left up), IS (right up), FS (left down) and RS (right down) at $t_j = 10^{-2}$ yr. The vertical line represents the maximum proton energy from acceleration, $\varepsilon_{p,\text{acc}}$ , whereas the hatches imply the unreachable proton energies. The parameters, $\epsilon_e = 0.1$ , $\epsilon_B = 0.01$ , $\dot{m} = 10$ , $\Gamma_j = 10$ and $\Gamma_{\text{cj}} = \theta_j^{-1} = 3$ are used. . . . .	74

- 4.6 Muon neutrino fluxes versus jet time  $t_j$  for the CS (up left), IS (up right), FS (bottom left) and RS (bottom right) scenarios. The optimistic parameters (e.g.,  $\dot{m} = 10$ ,  $\epsilon_p = 0.5$ ) are used. The blue, orange and green curves correspond to the specified neutrino energies in the observer's frame  $E_\nu = 100$  TeV, 1 PeV and 10 PeV. For the FS and RS cases, the neutrino emissions are isotropic and  $L_{k,j}$  is used in Eq. (4.26) instead of  $L_{k,\text{iso}}$ . The relativistic jet is on-axis and located at  $z = 1$ . . . . . 76
- 4.7 Observed muon neutrino fluences for the CS (up left), IS (up right), FS (bottom left) and RS (bottom right) scenarios at various observation times  $t_\nu^{\text{obs}} = 10^{-2}$  yr (blue lines),  $10^{-1}$  yr (orange lines) and 1 yr (green lines) after the merger. The optimistic parameters (e.g.,  $\dot{m} = 10$ ,  $\epsilon_p = 0.5$ ) are used to obtain these curves. The solid lines are obtained from fiducial parameters, e.g.,  $\eta_w = 0.01$ , whereas  $\eta_w = 0.1$  is used for the thin dashed lines as a reference. For the FS and RS cases, the neutrino emissions are isotropic and  $L_{k,j}$  is used in Eq. (4.26) instead of  $L_{k,\text{iso}}$ . The relativistic jet is on-axis and located at  $z = 1$ . . . . . 77
- 4.8 Differential contributions to the diffuse neutrino intensity  $z \times \sum_i E_\nu^2 (d\Phi_{\nu,i}/dz)$  for the optimistic case at  $E_\nu = 1$  PeV (blue line) and 10 PeV (orange line). The cyan line depicts the contributions ( $\times 0.25$ ) from starforming/starburst galaxies (SFG/SBG) [6] at  $E_\nu = 1$  GeV. . . . . 82
- 4.9 Redshift-integrated all-flavor diffuse neutrino flux expected from relativistic jets in SMBH mergers. The CS, IS, FS and RS components are illustrated as blue, orange, green and red lines. The solid and dashed lines respectively correspond to the optimistic ( $\dot{m} = 10$ ,  $\epsilon_p = 0.5$ ) and conservative ( $\dot{m} = 0.1$ ,  $\epsilon_p = 0.5$ ) cases. The fiducial value  $\eta_w = 0.01$  is adopted for both cases. Parameters for these two cases are listed in table 4.2. For each case, we use  $t_\nu = 100$  yr as the rest-frame duration of the neutrino emission in the jets. The 90% C.L. Sensitivities of current (black-dashed; IceCube [7]) and some future ultrahigh-energy neutrino detectors (gray lines; ARA/ARIANNA, POEMMA, CHANT, GRAND) are also shown. . . . . 83
- 4.10 **Left panel:**  $\xi_w$  v.s.  $R_h/R_{\text{Sch}}$  calculated with the spherical approximation (type I, black solid line), the linear approximation (type II, yellow line) and the accurate approach (type III, dashed green line). **Right panel:** Comparison of the accurate  $R_{\text{cs}}$ ,  $R_h$  (black lines) with previous ones (blue lines). . . . . 88

4.11	Time evolution of neutrino fluxes from the IS, FS and RS regions with the corrected $R_{\text{cs}}$ and $R_h$ . The jet is on-axis and located at $z = 1$ . The parameters, $\eta_w = 0.5$ , $\theta_j = 0.33$ , $\dot{m} = 10$ and $\eta_j = 1.0$ , are assumed. . . .	90
4.12	All-flavor diffuse neutrino flux obtained from the accurate $\xi_w$ , $R_{\text{cs}}$ and $R_h$ . The CS, IS, FS and RS components are illustrated as blue, orange, green and red lines. The same parameters with Fig. 4.11 are used. . . .	91
5.1	Schematic description of our model. <b>Left panel:</b> pre-merger disk winds launched from the circumbinary disk. The green arrows illustrate the disk-driven outflows that form a wind bubble. Mini-disks around each SMBH are also shown. <b>Right panel:</b> post-merger jets launched by a merged SMBH. The forward shock region is shown as the purple area. The cocoon is not depicted. . . . .	95
5.2	<b>Left panel:</b> Non-thermal energy spectra expected for uncollimated post-merger jets from a SMBH merger located at $z = 1$ . The solid and dashed lines represent the synchrotron and SSC components. The dash-dotted lines show the sensitivity curves for current and future detectors. <b>Right panel:</b> Multi-wavelength light curves. The yellow and blue dashed vertical lines illustrate respectively the characteristic times, e.g., $T_{\text{ssa}}$ , of 100 GHz and 5 GHz emissions. The used parameters are $\dot{m} = 0.5$ , $M_{\text{BH}} = 10^6 M_{\odot}$ , $\tilde{\eta}_w = 10^{-1.5}$ , $\eta_j = 1$ , $\theta_j = 10^{-0.5}$ , $s = 2.0$ , $\zeta_e = 0.4$ , $\epsilon_e = 0.1$ and $\epsilon_B = 0.01$ . . . . .	97
5.3	Detection horizons for multi-wavelength detectors, e.g., SKA, VLA, EVLA, ALMA, HST, JWST, LSST and Chandra. The horizontal dotted line shows the 100 GHz detection window for ALMA assuming a source located at $z = 3$ . Similar to Fig. 5.2, the dotted vertical lines are the characteristic times of 5 GHz and 100 GHz signals. . . . .	100
6.1	Schematic picture of the CBO mergers embedded in AGN disks. A cavity is formed due to the powerful outflows from the circumbinary disk. In this configuration, $\psi$ represents the angle between the CBO orbital plane and the AGN disk, and $R_d$ is the distance between the CBO and the central SMBH. Non-thermal electrons accelerated in the internal dissipation region are responsible for the production of $\gamma$ -rays. These electrons can upscatter the disk photons, leading to the EIC emission. . . . .	106

- 6.2 *Left panel:* Energy loss rates of accelerated electrons in the internal dissipation region. The green solid and red dash-dotted lines respectively show the synchrotron and SSC rates. From thick to thin, the blue dashed lines depict the EIC cooling rate for the CBOs at  $\mathcal{R} = 10, 10^2$  and  $10^3$ , respectively. The reciprocals of the dynamic and acceleration times are illustrated as the yellow dotted and black solid lines. *Right panel:* The electron number spectra as functions of the electron Lorentz factor. The minimum injected Lorentz factor is  $\gamma'_{e,m} = 100$ . The blue solid, green dashed and red dash-dotted lines correspond to  $\mathcal{R} = 10, 10^2$  and  $10^3$  cases. The black solid line is the electron injection function. . . . . 110
- 6.3 The blue ( $\mathcal{R} = 10$ ), yellow ( $\mathcal{R} = 10^2$ ) and red ( $\mathcal{R} = 10^3$ ) lines are the optical depth  $\tau_{\gamma\gamma}$  for  $\gamma\gamma$  annihilation between  $\gamma$ -rays and disk photons. The solid and dashed lines correspond to the inclination  $\psi = 0$  and  $\psi = 45^\circ$ . The optical depth to cosmic  $\gamma\gamma$  annihilation becomes greater than 1.0 in the energy range  $E_\gamma \gtrsim 220$  GeV (the gray shaded area), assuming that the CBO merger is located at  $z = 1.0$ . . . . . 113
- 6.4 The observed  $\gamma$ -ray spectra from embedded short GRBs at  $z = 1$  with distances  $\mathcal{R} = 10$  (left panel),  $10^2$  (middle panel) and  $10^3$  (right panel) to the central SMBH. The GRB parameters used here are the fiducial parameters assumed in Sec. 6.3, e.g.,  $L_{j,\text{iso}} = 10^{48.5}$  erg s $^{-1}$ ,  $\Gamma_j = 50$ ,  $\epsilon_B = 0.01$ , and  $\epsilon_e = 0.1$ . The blue, yellow and red solid lines show the synchrotron, SSC and EIC emission after  $\gamma\gamma$  attenuation. The dotted lines in the corresponding colors depict the unattenuated fluxes. The cascade emissions are depicted as the green lines. The magenta dashed lines show the disk target photon fluxes (multiplied by  $10^4$ ). In both cases,  $\psi = 0$  is applied. The gray dash-dotted lines indicate the CTA flux sensitivity for the  $10^3$  s observation time. . . . . 114
- 6.5 *Left panel:*  $\gamma$ -ray fluxes at 1 GeV (yellow lines), 25 GeV (blue lines) and 100 GeV (red lines) as functions of  $\mathcal{R}$ . The thick lines are obtained with  $L_{j,\text{iso}} = 10^{48.5}$  erg s $^{-1}$  and  $z = 1.0$ , whereas a closer short GRB at  $z = 0.1$  is considered for the thin yellow line. The point-source performance for *Fermi*-LAT and CTA at corresponding energies are shown as the yellow, blue and red areas, respectively. The upper and lower bounds show the sensitivities for the observation time  $T_{\text{dur}} = 10^2$  s and  $T_{\text{dur}} = 10^3$  s. *Right panel:* The red solid lines from thick to thin show the  $\mathcal{R}$ -dependence of 300 GeV  $\gamma$ -ray fluxes from the embedded short GRBs at  $z = 0.1, 0.2$ , and  $0.3$ . The horizontal dashed lines from top to bottom correspond the sensitivities of LHAASO-WCDA, MAGIC, H.E.S.S., VERITAS, and CTA. 116

7.1	The fraction of <i>Fermi</i> -LAT-resolved blazars in the cumulative neutrino flux, $\mathcal{F}(\gamma_{lw})$ . The thick and thin lines are calculated for the neutrino spectral indices $s = 2.0$ and $s = 2.5$ . The blue dashed, black solid and red dash-dotted lines correspond to the minimum luminosities $L_{ph,min} = 10^{41} \text{ erg s}^{-1}$ , $10^{42} \text{ erg s}^{-1}$ and $10^{43} \text{ erg s}^{-1}$ , respectively. The upper limit is fixed to be $L_{ph,max} = 10^{50} \text{ erg s}^{-1}$ . . . . .	128
7.2	All curves and data points in this figure illustrate all-flavor neutrino fluxes. Left panel: Stacking constraints on the contributions of all blazars to the cumulative neutrino flux ( $L_{ph,min} = 10^{42} \text{ erg s}^{-1}$ is used) and high-energy neutrino multiplet constraints on the blazar contributions in the neutrino sky for an $\varepsilon_\nu^{-2}$ neutrino spectrum. The magenta and green areas correspond to the all-blazar upper limit from <i>Fermi</i> -LAT-2LAC and <i>Fermi</i> -3LAC equal weighting analysis, respectively. The cyan horizontal area shows the cumulative neutrino flux detected by IceCube. The blue dashed, red dash-dotted and thick black lines illustrate the $m \geq 2$ multiplet constraints for FSRQs, BL Lacs and all blazars whereas the corresponding areas show the uncertainties. The thin black line is the $m \geq 3$ multiplet constraint for all blazars. Right panel: the energy-dependent upper limits from the stacking analysis for the all-blazar contributions, assuming a neutrino spectral index $s = 2.5$ . . . . .	129
7.3	The redshift evolution factor $\xi_z$ for FSRQs (blue area), BL Lacs (red area) and all blazars (black area). The solid and dashed boundaries correspond to different schemes of $L_{ph,min}$ and $L_{ph,max}$ . . . . .	131
7.4	Left panel: The effective gamma-ray luminosity for FSRQs (blue dashed line), BL Lacs (red dash-dotted line) and all blazars (black line). The dotted horizontal line indicates the luminosity of TXS 0506+056, one blazar that features an intermediate luminosity, $L_{TXS} \simeq 10^{46.3} \text{ erg s}^{-1}$ [8]. Right panel: The effective local number densities for different source classes. The line styles in this panel have the same meaning as the left panel. . . . .	131

# List of Tables

4.1	Detectability of jet-induced muon neutrino emissions by IceCube (IC) and IceCube-Gen2 (IC-Gen2) . . . . .	79
4.2	Neutrino detection rate $\dot{N}_{\nu,i}$ for SMBH mergers within the LISA detection range $z \lesssim 6$ [yr <sup>-1</sup> ] . . . . .	92

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