The Pennsylvania State University
The Graduate School

NEUTRINO AND ELECTROMAGNETIC COUNTERPARTS OF GALAXY AND ASTROPHYSICAL BLACK HOLE MERGERS

A Dissertation in
Physics
by
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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 γ-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 γ-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 γ-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.

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