The building blocks of the universe are described by the Standard Model of particle physics. Together with gravity, this theory can explain almost all phenomena we observe, from the smallest scales of fundamental particles to the largest scales of galaxies and clusters using a single framework.

However, the Standard Model must be incomplete, since it provides no explanation for the smallness of the Higgs mass, the existence of dark matter, neutrino masses or the predominance of matter compared to antimatter. One possibility to extend the Standard Model is to include supersymmetry (and its breaking at low energy), which doubles the particle content whilst maintaining a predictive framework for the possible interactions. However, up to now, searches for new physics in proton-proton collisions at the LHC have not yet found significant deviations from the Standard Model, strongly constraining conventional new physics models. In this thesis, we interpret a particular excess in ATLAS in a model with an extended supersymmetry breaking sector, which can evade the constraints from which the conventional models suffer.

On the other hand, we can also study the most extreme objects in the universe, such as active galaxies. Such objects emit high-energy cosmic rays, gamma rays and neutrinos, whose production is described by the Standard Model, as well as gravitational waves. By combining information from these different types of emission in a multimessenger approach, we can increase our understanding of their sources. While still unknown, the properties of possible neutrino sources are constrained by the gamma-ray background observed, since the processes which produce neutrinos must also produce gamma rays in similar quantities. The relative brightness of the diffuse neutrino and gamma-ray fluxes suggests that the neutrino sources must be obscured in gamma rays. We investigate the neutrino flux produced by a class of sources which exhibit signs of obscuration by gas. The presence of this gas can explain both neutrino production and gamma-ray obscuration. We find that a population of such obscured sources can account for the diffuse neutrino flux while alleviating the tension with the limits on the corresponding gamma-ray flux. Finally, we also investigate the limits on neutrino production from binary black hole mergers following the first ever detection of such an event in gravitational waves. We find that, currently, direct observations can not exclude a significant contribution of binary black hole mergers to the diffuse neutrino flux. With mild assumptions on their cosmological evolution, this possibility can be constrained in the following years.