Fundamental bosonic fields of arbitrary spin are predicted by generic extensions of the Standard Model and of General Relativity, and are well-motivated candidates to explain the dark components of the Universe. One of most promising channels to look for their presence is through their gravitational interaction with compact objects. Within this context, in this thesis I study several mechanisms by which bosonic fields may affect the dynamics and structure of black holes and neutron stars.

The first part of the thesis is devoted to the study of massive spin-2 fields around spherically symmetric black-hole spacetimes. Massive spin-2 fields can be consistently described within theories of massive gravity, making it possible to perform a systematic study of the propagation of these fields in curved spacetimes. In particular, I show that due to the presence of additional degrees of freedom in these theories, the structure of black-hole solutions is richer than in General Relativity.

In the second part of the thesis, I discuss in detail superradiant instabilities in the context of black-hole physics. I show that several mechanisms, such as massive bosonic fields and magnetic fields, can turn spinning black holes unstable against superradiant modes, which has important implications for astrophysics and for physics beyond the Standard Model.

In the last part of this thesis, I present a study of how bosonic dark matter condensates interact gravitationally with compact stars. In particular, I show that stable stellar configurations formed by a perfect fluid and a bosonic condensate exist and can describe the late stages of dark matter accretion onto stars, in dark matter rich environments.