Explosive plasma events in the Universe and how to study them

Although non-plasma states of matter such as solids and liquids are the predominant building blocks on Earth, the vast majority of visible matter in the Universe is actually in the plasma state, typically with magnetic fields embedded within. Thus, much of the dynamics of various objects in our Universe, most notably astrophysical objects such as our Sun, black hole and neutron star magnetospheres, and the interstellar medium, are governed by magnetized plasma dynamics. Because these objects generally store astronomically high energies, mechanisms that release these energies are often explosive in nature. A prime example of this explosion is a magnetized plasma phenomenon called magnetic reconnection, in which a change in magnetic topologies induces energy conversion from magnetic energy to plasma kinetic energy. This process is known to be responsible for important energetic events in the Universe such as gamma ray bursts and stellar flares, and so significant effort has been dedicated to its study. In this talk, I first review the conventional path of research conducted in magnetic reconnection, focusing on the usage of 19th century physics such as electromagnetism, Newtonian magnetohydrodynamics, and Vlasov theory. Then, I introduce the exciting future steps in this research field, namely the incorporation of 20th and 21st century physics such as relativity and quantum electrodynamics. It will be shown how the state-of-the-art laser systems and electron beams can be utilized to study this new regime, which has mostly been probed within theoretical and numerical frameworks.