# Radio to (sub)millimeter observations of astrophysical plasmas

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This talk will aim to give an overview of the recent observational advances in radio to millimeter/submillimeter wavelengths to unveil astrophysical plasmas in a various class of objects. Specifically, I will briefly review the following three topics:

(1) Fast Radio Bursts (FRBs) are short-duration (typically a few milliseconds) intense radio bursts observed using low-frequency radio telescopes like Parks 64-m telescope. Recently one of such sources, FRB121102, is found to be at a cosmological distance (i.e., a redshift of 0.193) and they are expected to be a unique probe of cosmological missing baryon, and one of the candidates is low-density plasma [1].

(2) The Sunyaev-Zel'dovich effect (SZE) arises from the inverse Compton scattering of electrons in galaxy clusters, which are filled with low-density plasma. Recent developments of large-area sky surveys by state-of-the-art mm/submm-wave telescopes like the South Pole Telescope and the Plank satellite have enlarged the sample of galaxy clusters, including a few 500 new detections of galaxy clusters [2]. Atacama Large Millimeter/submillimeter Array (ALMA) has been used to spatially resolved SZE images of bright galaxy clusters like RX J1347-1145, giving an insight on the spatial distributions of electron density and temperature [3].

(3) co-evolution of accreting super-massive black holes and their host galaxies, where interactions between ultra-fast outflows of plasma (seen in X-ray) and the surrounding cold molecular medium (observed in mm/submm bands) play a crucial role to regulate the growth of galaxies [4]. Recent Northern Extended Millimeter Array and ALMA observations of cold and dense molecular gas in the nuclei of galaxies reveal a wide variety of physical properties of cold molecular outflows, bringing new challenges in astrophysics [5,6].

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