

# Can Electric Probes Measure Super-Sonic Plasma Flows?

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Although we have observed supersonic plasma flows at the edge of tokamaks, at the exit of space propulsion systems, and in simulators of astrophysical phenomena such as Hawking radiation and plasma bubble expansion, the measurement of them is not easy due to lack of interpretation tool by electric probes, and due to the limitation of detection for hydrogen isotope by optical tools. Electric probes have been used to measure hydrogen and deuterium plasmas at the edge of tokamaks as a form of Mach probe(MP) for the last 40 years under the assumption of collisionless strongly magnetized diffusive plasmas, even for the case of collisional and supersonic plasmas. For the case of un-magnetized plasmas, there have been various models with ambiguities of the sheath since Langmuir [1]. A typical MP is composed of two directional electric probes located at opposite sides of an insulator, called as a parallel MP, while two cylindrical probes are located perpendicularly each other in a perpendicular MP(pMP). Models for the interpreting various MPs seem to be well established for the case of collisionless sub-sonic plasma flows with and without magnetic field [2]. Although these models could be extended to the super-sonic case, its validity is questionable due to formation of the sheath, since they have to take the ion saturation currents at the sheath to deduce the Mach number from the ratio of current densities. Existing theories of MPs are to be introduced in terms of kinetic and particle-in-cell models or self-consistent and self-similar methods, or in terms of geometry of probe (cylindrical, planar, spherical probes). Kinetic model will be used to explain the sheath formation and to show the range of Mach number in terms of the ratio of ion to electron temperature. There are not many experimental data of relevant models: a few for the sub-sonic flow, and almost none for the super-sonic flow. For the super-sonic flow measurement in the experiment of space propulsion systems, pMP has been introduced by several authors mostly based upon the neutral approximation. Evolution of these models is to be explained and comment on the usage of them would be given.

[1] H.M. Mott-Smith and I. Langmuir, Phys. Rev. **28** (1926) 727.

[2] Kyu-Sun Chung, Plasma Sources Sci. and Technol. **21** (2012) 063001.