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Magnetic Cavities in Space Plasmas: Observations and Kinetic Models

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Magnetic cavities, sometimes referred to as magnetic holes, are quasi-symmetric structures in the space plasma environment characterized by depressed magnetic field strength, strongly anisotropic particle distributions, and enhanced plasma pressure. These structures have been observed in a variety of regions such as magnetosheath, magnetotail, solar wind, heliosheath and planetary or cometary environments. Typical cavity sizes range from fluid down to ion or sub-ion kinetic scales, with recent observations also identifying nested cavities that may indicate cross-scale energy cascade.

Although identified and heavily investigated in space, magnetic cavities have analogs in laboratory plasmas, the classical theta-pinches. Here, we develop equilibrium solutions[1,2] of Vlasov-Maxwell equations in cylindrical coordinates (in similar format to theta-pinch models), to establish kinetic models of magnetic cavities that could be used to reconstruct the electromagnetic profiles and particle distributions observed by the four-spacecraft MMS mission. These kinetic models are applied to two different events, which show a nested configuration[1] and a helical geometry[2], respectively. In both events, the kinetic models demonstrate excellent agreement with the observational data (see Figure 1 for the reproduction of the nested magnetic cavity) to indicate the formation of quasi-equilibrium cavities during the turbulent evolution of space plasmas.

References

[1] J.-H. Li et al., Nature Commun., 11, 5616 (2020)

[2] J.-H. Li et al., Geophys. Res. Lett., 48, 2021GL092383 (2021)

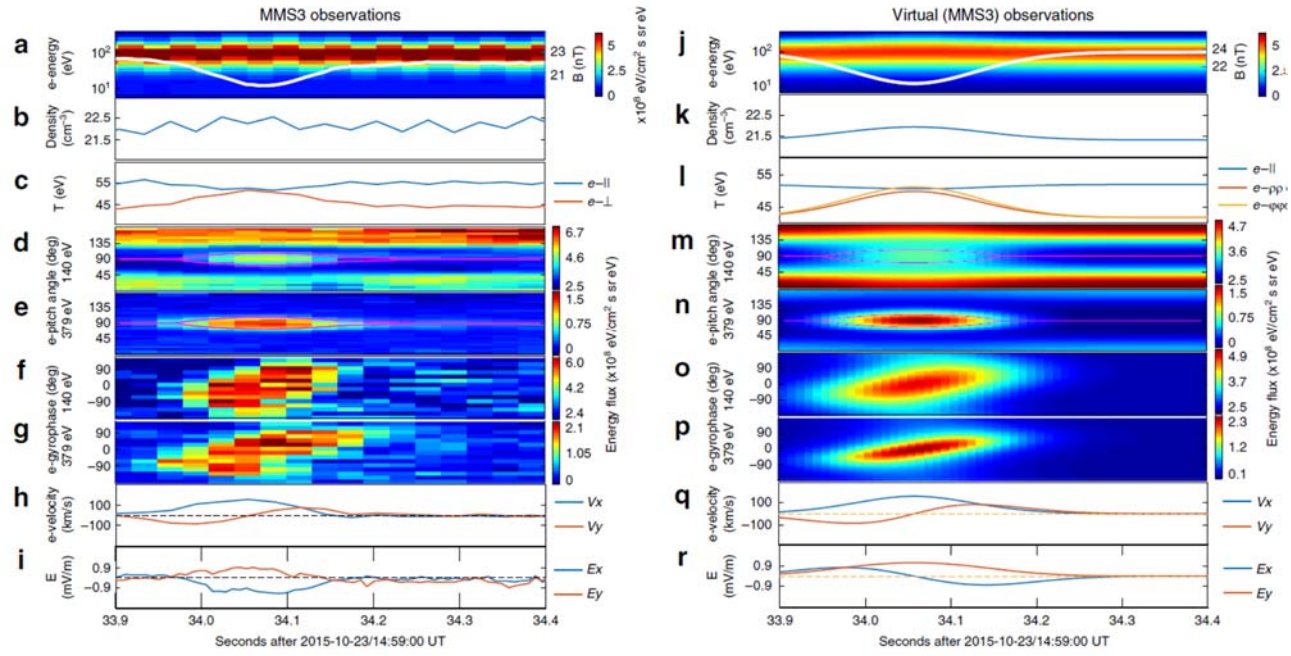

Figure 1. Comparison between (left) MMS3 observations of a nested magnetic cavity on 23 October 2015 and (right) virtual spacecraft observations across the equilibrium kinetic model.