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A theorists' expectation for the Cross-Scale mission: Boundary layer science

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The magnetopause and its boundary layers can be characterized as a current sheet and/or velocity shear layer across which collisionless plasmas of different nature exist. They can be the sites for various instabilities and processes, such as magnetic reconnection, Kelvin-Helmholtz instability (KHI), current-driven and drift instabilities, and mode conversion, but the ultimate mechanism for efficient mass transport across this boundary remains unknown because the boundary layer is a cross-scale coupled system. Full understanding of this coupling process is important from the astrophysical point of view as well, since similar boundaries are ubiquitous in space, such as at the interfaces between astrophysical jets and ambient gases, and those between interstellar gases and intergalactic gases. In this talk, we raise key questions that we should pursue for the coming era of the Cross-Scale multi-spacecraft mission, by referring to some illustrative examples from Cluster-based and numerical simulation studies. The magnetopause current layer is substantially different from the magnetotail current sheet in that (1) it is highly asymmetric in density and temperature; (2) there exist significant plasma flows toward and/or tangential to the layer; and (3) fields and flows in one external (magnetosheath) region are often turbulent. Important questions to ask for such a boundary system are: - What is the microphysical transport/heating process embedded in large-scale structures, such as MHD-scale vortices developed through the KHI? How and over what temporal/spatial extent does the microphysical process become operative in the context of large-scale structures/phenomena? - What boundary/initial condition controls the process of plasma transport/heating? How do the instabilities and consequent transport/heating depend on the nature of noise/turbulence present in the magnetosheath as seeds? How do the boundary processes affect/adjust the external conditions such as beta and turbulence properties? - What is the mechanism that de-

termines the steadiness of magnetopause reconnection and the length, orientation, and number of X-lines, in particular under the conditions of turbulent magnetosheath? We expect that answering these questions provide insights into astrophysical phenomena such as angular momentum transport in accretion disks and plasma heating, e.g., in advection-dominated accretion flows.