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New structures and exotic properties of simple molecular systems under extreme conditions: using neutrons to explore planetary interiors

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Simple molecular systems—such as water, methane, ammonia, hydrogen, and their mixtures—play a central role across disciplines, from energy storage technologies to condensed matter and planetary physics [1]. They are abundant on Earth, widespread in planetary bodies throughout our solar system, [2] and have even been detected on newly discovered water-rich exoplanets, representing not only a vast natural resource but also a unique testing ground for fundamental science. Thanks to their simple stoichiometry and electronic structure, these systems serve as ideal model compounds for unraveling the physicochemical behavior of more complex molecular materials. When subjected to the extreme pressure–temperature conditions characteristic of planetary interiors, they exhibit remarkably rich phase diagrams, anomalous dynamical, thermal, and transport properties, enhanced solubility, as well as emergent phenomena such as superionicity, plasticity, and quantum entanglement.

In this talk, I will present our recent experimental insights into the structure and dynamics of simple molecular systems under extreme conditions, obtained through neutron, X-ray, and light scattering techniques [3–17]. I will also highlight their implications for planetary modeling and potential energy applications.

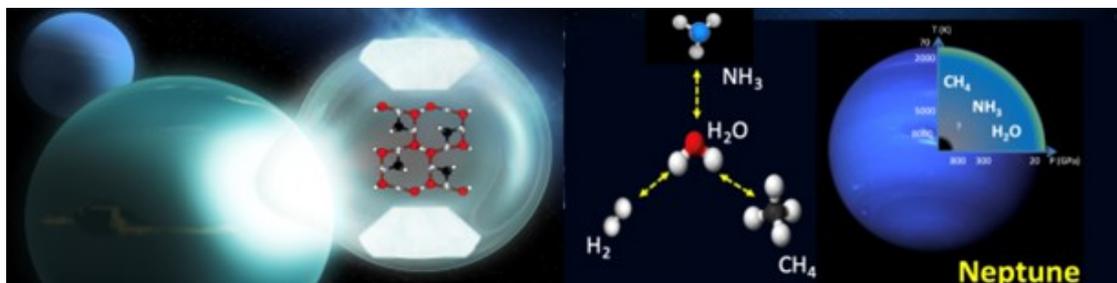


Figure 1: enter image description here

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