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Unique heliophysics science opportunities along the Interstellar Probe journey up to 1000 AU from the Sun

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The Interstellar Probe is a space mission to discover physical interactions shaping globally the boundary of our Sun`s heliosphere and its dynamics and for the first time directly sample the properties of the local interstellar medium (LISM). Interstellar Probe will go through the boundary of the heliosphere to the LISM enabling for the first time to explore the boundary with a dedicated instrumentation, to take the image of the global heliosphere by looking back and explore in-situ the unknown LISM. The pragmatic concept study of such mission with a lifetime 50 years that can be implemented by 2030 was funded by NASA and has been led by the Johns Hopkins University Applied Physics Laboratory (APL). The study brought together a diverse community of more than 400 scientists and engineers spanning a wide range of science disciplines across the world.

Compelling science questions for the Interstellar Probe mission have been with us for many decades. Recent discoveries from a number of space missions exploring the heliosphere raised new questions strengthening the science case. The very shape of the heliosphere, a manifestation of complex global interactions between the solar wind and the LISM, remains the biggest mystery. Interpretations of imaging the heliosphere in energetic neutral atoms (ENAs) in different energy ranges on IBEX and Cassini/INCA from inside show contradictory pictures. Global physics-based models also do not agree on the global shape. Interstellar Probe on outbound trajectory will image the heliosphere from outside for the first time and will provide a unique determination of the global shape.

The LISM is a completely new area for exploration and discovery. We have a crude understanding of the LISM inferred from in-situ measurements inside the heliosphere of interstellar helium, pick-up-ions, ENAs, remote observations of solar backscattered Lyman-alpha emission and absorption line spectroscopy in the lines of sight of stars. We have no in-situ measurements of most LISM properties, e.g. ionization, plasma and neutral gas, magnetic field, composition, dust, and scales of possible inhomogeneities. Voyagers with limited capabilities have explored 30 AU beyond the heliosphere which appeared to be a region of significant heliospheric influence. The LISM

properties are among the key unknowns to understand the Sun`s galactic neighborhood and how it shapes our heliosphere. Interstellar Probe will be the first NASA mission to discover the very nature of the LISM and shed light on whether the Sun enters a new region in the LISM in the near future.

In this presentation we give an overview of heliophysics science for the Interstellar Probe mission focusing on the critical science questions of the three objectives for the mission. We will discuss in more details a need for direct measurements in the LISM uniquely enabled by the Interstellar Probe.