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Dr. Ghassem Asrar,
"Exploration Science White Papers"
Science Mission Directorate
Suite 5E39-A
NASA Headquarters
Washington, DC 20546-0001

Dear Dr. Ghassem Asrar,

The following is an "Exploration Science White Paper" to address the research focus for the Vision for Space Exploration. It is meant to address the question how the study of the heliosphere and its interaction with the local interstellar medium fits into this plan and what synergism it can create between in-situ space science and astrophysics.

Sincerely,

Dr. Eberhard Möbius
(Professor of Physics)

Exploration Science White Paper

Study of the Heliosphere and its Interaction with the Surrounding Interstellar Medium - An Interdisciplinary Endeavor between Space Science and Astrophysics and an Important Ingredient in Space Exploration

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The Sun is located in the outskirts of the Milky Way, about 30,000 light years from its center, embedded in a fairly dilute and warm cloud of interstellar gas, which consists of a mixture of neutral and ionized gas or plasma. This cloud material represents a sample of today's interstellar matter in our Milky Way Galaxy from which stars and planetary systems form. In the case of the Sun and its planets this occurred about 4.5 billion years ago. Differences in the composition of these two samples of galactic matter tell the story of the evolution of matter in the galaxy as heavy elements are added by dying stars. Therefore, the study of the elemental and isotopic composition of both solar system material and that of the surrounding interstellar cloud is an essential contribution to the question of the origin and evolution of star and planetary systems.

The solar wind, which expands radially from the Sun at supersonic speed, blows a cavity - the heliosphere - into the surrounding interstellar cloud, filling it with solar material and magnetic field. The plasma component of the interstellar gas and a large fraction of galactic cosmic rays are kept outside the heliosphere. By balancing the solar wind ram pressure, which is easily measured, against the pressure of the surrounding cloud, the size and shape of the heliosphere is determined. This controls the effectiveness of the first shield against cosmic rays for the living environment on Earth, the remaining two being the Earth's magnetic field and atmosphere. In a similar way this applies to other planets in the solar system, and for any interplanetary travel the heliosphere itself constitutes the only shield against galactic cosmic rays. Furthermore, over the past ten years astrospheres have been detected around other stars through their effects on their surrounding medium. These are important features that determine the environment around those stars, as the heliosphere defines ours. In the search for potentially life-bearing planets the environment in the host star system cannot be underestimated. Our heliosphere is the only astrosphere that we can study close-up and in detail, at least for the foreseeable future. In this sense the study of the heliosphere, its boundaries, and the boundary conditions outside our system provides a benchmark for the study of other remote star systems. This is a second link of this field for interdisciplinarity with astrophysics and makes it an essential building block in a vision of space exploration.

The neutral component of the local interstellar medium penetrates into the heliosphere like an interstellar wind, thus providing invaluable clues on the physical conditions and on the composition of the solar neighborhood for us to study with in-situ instrumentation in the inner solar system. The size and shape of the boundary and processes that lead to filtering of inflowing neutrals, to shielding against and modulation of cosmic rays, as well as to further acceleration of particles in the interaction are visible in various particle populations that can be observed from existing satellites and space probes and/or will become fully accessible with existing instrumentation on missions that are under study.

Recent coordinated observations and analysis of the interstellar helium distribution using ACE, EUVE, SOHO, Ulysses, and Wind has provided us with a benchmark set of the physical parameters of the neutral interstellar helium, which provides an excellent proxy for the dynamic conditions of the local cloud. The Voyagers are knocking at the first boundary structure of the heliosphere, the termination shock where the solar wind slows down to subsonic speed. Ulysses provides us with visibility into high latitudes in the heliosphere above and below the plane of the planets. With its observations of energetic neutrals generated in the interaction between the neutral gas of the Earth's exosphere and the energetic particle population of the magnetosphere IMAGE has demonstrated that the remote sensing of accelerated particle populations has become a reality, which brings imaging of particle acceleration at the termination shock that is bathed in the interstellar neutral gas within our immediate reach.

To accurately assess what the physical conditions and the detailed composition of matter in the local interstellar cloud are we need to know the processes that contribute to the filtering of interstellar gas in the heliospheric boundary. To understand the modulation of cosmic rays we need to know the size, shape and physical conditions of the boundary layers. To understand how effective further particle acceleration at its boundaries is we need a global picture of this giant acceleration region. And besides, the shape, size, and conditions of these critical regions vary substantially over the solar activity cycle of 11 years, which combines as two halves with opposite magnetic polarity into an overall cycle of 22 years. Both themes that have been outlined above as critical contributors to the space exploration vision require a working knowledge of these important regions.

Our current knowledge, the open questions, and current observational and modeling capabilities suggest a natural three-step approach for an "exploration of the heliosphere and its interaction with the interstellar medium": First, the existing assets in the from of operational solar and heliospheric missions, such as ACE, SOHO, Ulysses, Voyager and Wind, "our great solar and heliospheric observatory", should be utilized through further coordinated observation and analysis efforts in conjunction with an ongoing strong effort to model processes and the global structure of the interaction region between the heliosphere and the interstellar medium. Right now with the Voyagers reaching the termination shock a unique constellation of spacecraft is in place that is a once in a lifetime opportunity to carry out these tasks. As the full solar activity cycle, which is relevant to most large-scale heliospheric processes, spans 22 years, a long-term database with these assets is needed. Second, dedicated small missions are envisioned that take the important step towards a global study of the energetic particle population at the termination shock and to study the interstellar gas inflow quantitatively with neutral gas imaging. Also the detailed study of the composition of the inflowing neutral gas utilizing pickup ions with large collection power instrumentation is a small incremental step in implementation, but a large step in return. Finally, an investment into the development of the means and instrumentation for a frontier Interstellar Probe should be made to push the space exploration vision into the immediate neighborhood of our home system.

In closing it should be noted that the upcoming International Heliophysical Year in 2007/8, on the 50^{th} anniversary of the highly successful International Geophysical Year, will provide an excellent forum to crystallize and to publicize this vision of exploration into our interstellar neighborhood. 50 years ago we raised our head above the Earth's atmosphere for the first time; now we are about to stick our head beyond the boundary of the heliosphere.