NASA/JPL Plans for Fundamental Physics Research in Space

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Abstract

In 1998, about 100 researchers met twice to develop plans for the future in this research area. The results of these meetings have been collected in a package titled "A Roadmap for Fundamental Physics in Space". A summary of the Roadmap will be presented along with an overview of the current program. Research is being performed in Low Temperature and Condensed Matter Physics, Laser Cooling and Atomic Physics, and Gravitational and Relativistic Physics. There are currently over 50 investigators in the program of which 8 are being evaluated as potential flight experiments. The number of investigators is expected to grow further during the next selection cycle, planned to start toward the end of this year. In the near future, our investigators will be able to take advantage of long duration experimentation in Space using a suite of different carriers under development.

Keywords: Microgravity; International Space Station (ISS); Technology

1. Introduction

Science is driven by humankind's curiosity about nature. In fundamental physics, scientists want to uncover and understand the basic underlying principles that govern the behavior of the world around us. Fundamental physics therefore provides a foundation for many other branches of science and establishes the intellectual underpinning needed to maintain and further develop our high technology society.

The NASA program in fundamental physics has two burning quests that motivate our laboratory research and beckon us to do experiments in space. First, we seek to explore and understand the fundamental physical laws governing matter, space, and time. By looking deeply into the smallest and largest pieces that make up the fabric of our universe, we will understand better our basic ideas that describe the world. The space environment provides us access to different space-time coordinates and frees experimenters from the disturbing effects caused by gravity on the Earth. Second, we seek to discover and understand the organizing principles of nature from which structure and complexity emerges. While the basic laws of nature may be simple, the Universe that has arisen under these laws is amazingly complex and diverse. By studying nature apart from Earth's gravity, we can understand better how the Universe developed and how best to employ these principles in service to humanity.

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Gravity does not limit the attainable precision in most fundamental physics research. In the NASA program, we study those areas of physics where an Earth environment severely limits the achievable precision.

Our plan to pursue these two long-term quests is to perform research in Gravitational and Relativistic Physics (GRP), in Laser Cooling and Atomic Physics (LCAP), and in Low Temperature and Condensed Matter Physics (LTCMP). There is significant synergy across the three research areas both in terms of scientific overlap and overlap in experimental techniques. Over 100 scientists, technologists, and educators under the leadership of the fundamental physics Discipline Working Group have participated in the development of research plans for the future in this discipline.

2. Low Temperature and Condensed Matter Physics

To meet the needs of the community in this research area, NASA and JPL are building a versatile liquid helium facility that will operate on the International Space Station. It will provide researchers with a base temperature for an instrument insert of about 1.5 K for up to 6 months duration on-orbit. Requisite electronics to support the operation of the experiments will be provided. A standard cryogenic insert and electronic box is being developed for accommodating up to 2 different experiments during each flight opportunity. Each instrument can support many DC SQUIDS, germanium thermometers, paramagnetic salt thermometers, and other read-out devices. There are currently 5 experiments competing for space on the first 2 flights of this facility. Future flight experiments will be selected from upcoming NASA Research Announcements to fill future flight opportunities.

Experiments under development are mainly in the general area of critical phenomena, although non-equilibrium effects, finite size effects, and dynamic phenomena are also included. It is expected that new research directions will be pursued in future flights.

3. Laser Cooling and Atomic Physics

NASA and JPL are currently evaluating the best ways to accommodate planned research in this discipline on the ISS. For maximum flexibility, we are planning to develop a set of flight module components that can be used to customize future experiments. Current flight experiments aim to develop highly accurate clocks for use in Space. Future experiments will be selected from NASA Research Announcements. Likely candidates are studies of Bose-Einstein Condensation, measurement of the electric dipole moment of the electron, and experiments on atom lasers in space.

4. Gravitational and Relativistic Physics

The Satellite Test of the Equivalence Principle (STEP) is being studied as a potential free flying mission. STEP would test the validity of Einstein's Equivalence Principle with 6 orders of magnitude better precision than previously. The experiment would last for about 6 months on-orbit and make use of SQUID based differential accelerometers with a precision of 1 part in 10^{18}. Drag free space craft control using vented helium gas and release of charge accumulated from cosmic rays and trapped particles are other key technologies.

A microwave oscillator experiment is a candidate to fly on the second flight of the LTMPF. This clock can be used for a red-shift of general relativity, or for more elaborate tests of Einstein's theory.

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