THE LOW ENERGY CHARGED PARTICLE (LECP) EXPERIMENT ON THE VOYAGER SPACECRAFT

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Abstract. The Low Energy Charged Particle (LECP) experiment on the Voyager spacecraft is designed to provide comprehensive measurements of energetic particles in the Jovian, Saturnian, Uranian and interplanetary environments. These measurements will be used in establishing the morphology of the magnetospheres of Saturn and Uranus, including bow shock, magnetosheath, magnetotail, trapped radiation, and satellite-energetic particle interactions. The experiment consists of two subsystems, the Low Energy Magnetospheric Particle Analyzer (LEMPA) whose design is optimized for magnetospheric measurements, and the Low Energy Particle Telescope (LEPT) whose design is optimized for measurements in the distant magnetosphere and the interplanetary medium. The LEMPA covers the energy range from ~10 keV to >11 MeV for electrons and from ~15 keV to >150 MeV for protons and heavier ions. The dynamic range is ~0.1 to ~10^{11} cm^{-2} sec^{-1} sr^{-1} overall, and extends to ~10^{13} cm^{-2} sec^{-1} sr^{-1} in a current mode operation for some of the sensors. The LEPT covers the range ~0.05 \leq E \leq 40 MeV/nucleon with good energy and species resolution, including separation of isotopes over a smaller energy range. Multi-dE/dx measurements extend the energy and species coverage to 300–500 MeV/nucleon but with reduced energy and species resolution. The LEPT employs a set of solid state detectors ranging in thickness from 2 to ~2450 \mu, and an arrangement of eight rectangular solid state detectors in an anticoincidence cup. Both subsystems are mounted on a stepping platform which rotates through eight angular sectors with rates ranging from 1 revolution per 48 min to 1 revolution per 48 sec. A ‘dome’ arrangement mounted on LEMPA allows acquisition of angular distribution data in the third dimension at low energies. The data system contains sixty-two 24-bit scalers accepting data from 88 separate channels with near 100% duty cycle, a redundant 256-channel pulse height analyzer (PHA), a priority system for selecting unique LEPT events for PHA analysis, a command and control system, and a fully redundant interface with the spacecraft. Other unique features of the LECP include logarithmic amplifiers, particle identifiers, fast (~15 ns FWHM) pulse circuitry for some subsystems, inflight electronic and source calibration and several possible data modes.

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1. Introduction

According to the best available estimates the solar wind extends as a supersonic flow to a heliocentric distance of the order of 50 AU or more, i.e., beyond the orbits of Neptune and Pluto (Axford, 1972). Thus the solar wind must interact with the magnetospheres of all the planets or with their atmospheres or surfaces in cases where the planets have no internal magnetic field. Furthermore, the solar wind must interact with the satellites of any planets which are not shielded by planetary magnetospheres.

The study of the physics of planetary magnetospheres is of considerable scientific interest in itself (Kennel, 1973). It is also of great importance in furthering our understanding of certain astronomical objects (notably pulsars and compact X-ray sources), the origin of satellites of the outer planets, and perhaps the origin of the Solar System itself (e.g., Cameron, 1973; Alfvén and Arrhenius, 1976). The existence of planetary magnetospheres presents opportunities for making direct in-situ observations of particle acceleration mechanisms, thereby leading to the possibility of achieving a better understanding of solar flare processes, cosmic ray acceleration processes, and processes in the Earth’s magnetosphere. In the case of the Jovian satellite Io (and possibly other planetary satellites) there is an apparent strong interaction with the magnetosphere of the parent planet which induces intense radio emissions by mechanisms which although not well understood at present, could be of importance for understanding other astrophysical radio sources. In addition there is some evidence that planetary magnetospheres can play an important role in determining the surface structure of satellites (Mendis and Axford, 1974).

To date spacecraft launched from Earth have probed the environment around five of the nine planets in the Solar System. Spacecraft instrumentation has also investigated various aspects of the satellites of Earth, Mars and Jupiter. The nature of the Earth’s magnetosphere has been investigated in considerable detail and a rather good morphological understanding of the phenomena that can occur has been obtained. Yet, understanding in depth of many detailed plasma processes remains elusive (Williams, 1975). The interaction of the solar wind with the Earth’s moon has been investigated extensively; this interaction is a clear case of the impinging of the solar wind plasma on an essentially non-conducting and non-magnetized body that does not have an atmosphere. The bow shock and magnetic tail of the Mercurian magnetosphere have been detected and it has been observed that electron acceleration seems to occur even in this relatively simple case where there are no complications induced by the presence of a planetary atmosphere or ionosphere (Ness et al., 1975). The magnetosphere situations around both Mars and Venus are somewhat unclear at the present time: there appear to be bow shocks and plasma tails associated with each planet and there is also some evidence for a Martian magnetic field of internal origin (Dolginov et al., 1972).

Of the giant planets, the Jovian magnetosphere has been examined during flybys of Pioneer 10 and 11. It is now well documented that for this planet (a) there are