AN OVERVIEW OF THE CHANDRAYAAN-1 MISSION. J. N. Goswami, Physical Research Laboratory, Ahmedabad-380009, India (goswami@prl.res.in).

Introduction: Chandrayaan-1 was launched on 22nd October, 2008 using a variant of the Indian Polar Satellite launch Vehicle (PSLV-XL). The spacecraft was inserted into an elliptical lunar polar orbit on 8th November and was placed in the desired 100km orbit on 12th November. The Chandrayaan-1 mission successfully operated until 28th August, 2009, when a communication failure led to loss of contact and the mission was called off on 30th August. Chandrayaan-1 marks the beginning of India's planetary exploration programme initiated by the Indian Space Research Organization (ISRO). Apart from five Indian built payloads (TMC, HySI, LLRI, HEX and MIPS), it also carried two Indo-Foreign collaborative payloads (C1XS and SARA) and four foreign payloads (M^3, mini-SAR, SIR-2 & RADOM) [1]. Chandrayaan-1 mission represents a truly international effort in planetary exploration.

Fig.1. Chandrayaan-1 Spacecraft

The Mission details: After reaching the designated lunar polar orbit and checks of various spacecraft sub-systems and parameters, the Moon Impact Probe (MIP) was released on 14th November to reach a designated area near the South Pole. Images captured by the camera on board MIP allowed identification of its impact point. This followed commissioning of the scientific payloads. One of the payloads, the Radiation Dose Monitor (RADOM), was switched on soon after lift-off and the Terrain Mapping Camera (TMC) was commissioned during one of the early earth bound orbits. The other eight payloads were commissioned one by one between November 16 and December 9. The mission operation was relatively smooth until April 26th, 2009, when the failure of star sensor led to the decision to raise the spacecraft orbit from 100 to 200 km to reduce the number of maneuvers needed for orbit maintenance. On August 28, loss of communication with the spacecraft led to termination of the mission.

Lunar Coverage: In spite of the early termination of the mission most of the payloads collected large volume of data of excellent quality. The radiation dose monitor (RADOM) started monitoring energetic proton and electron fluxes soon after launch that continued for the entire period of the mission. The imaging instruments, Hyper-Spectral Imager (HySI) and the Terrain mapping Camera (TMC), covered ~50% of the lunar surface with significant coverage of the polar region. The Moon Mineralogy Mapper (M^3) covered more than 90% of the lunar surface, while the infrared spectrometer (SIR-2) collected high spectral resolution data. The Lunar Laser ranging Instrument (LLRI) and the Miniaturized Synthetic Aperture Radar (Mini-SAR) made extensive coverage of the lunar polar areas. The Sub-keV Atom Reflecting Analyzer (SARA), with its broad field of view, has covered the whole lunar surface. The Chandrayaan-1 X-ray Spectrometer (C1XS) provided very high quality data, although it suffered from the lack of the expected high level of solar activity. The High Energy X-ray Spectrometer (HEX) could not be operated during noon-midnight orbit due to inadequate detector cooling and collected limited data.

Salient Results: The detection of H_2O and OH on the lunar surface material is a major discovery by the Chandrayaan-1 Mission [2]. The data also revealed their enhanced abundance towards the polar region (Fig. 2). These results were independently confirmed by analysis of both new and archived data from two other missions.

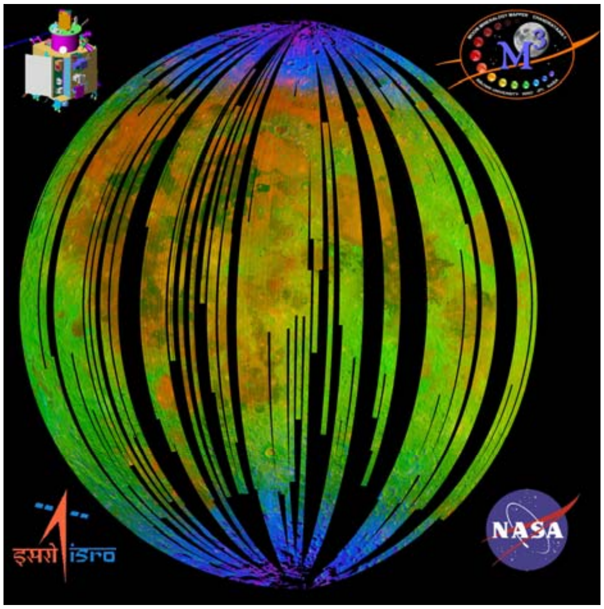

Fig.2. A colour composite of NIR reflected solar radiation measured by M^3 from the lunar near side. Blue indicates 3μm absorption due to OH/H_2O.

The mass spectrometer on board MIP has detected signals at various masses, including prominent signals at masses 1, 18, 44 and also at higher masses during its decent to the lunar surface. In the absence of en-route or on-orbit calibration, the possibility that species with these masses are present in the tenuous lunar atmosphere cannot be ascertained unequivocally. The data obtained by the imaging spectrometers on board Chandrayaan-1 and Kaguya missions, presented during the last LPSC, confirmed the existence of huge exposures of crystalline feldspar in lunar highlands validating the global magma ocean hypothesis [3, 4]. The terrain mapping camera (TMC) on Chandrayaan-1 has provided unprecedented details of lunar topography including those for Apollo 15 and 17 sites [5 & this conference]. TMC data, coupled with HySI, M3 and SIR-2 data, are providing new insights on lunar surface composition and also led to the detection of new spinel-rich rock type on lunar farside [this conference]. Performance of the Chandrayaan-1 X-ray Spectrometer (C1XS) was excellent. It detected characteristic X-ray signals from lunar surface even during weak solar flares. Unfortunately extensive lunar coverage with C1XS could not be achieved due to lack of solar flare activity. Nonetheless, the data obtained will provide the first set of high resolution X-ray spectra to infer the abundances of Mg, Al, Si, Ca (and perhaps Ti and Fe) at several locations of the lunar surface. The much shorter operation period of the High Energy X-ray spectrometer (HEX), hampered a quantitative study of transport of volatiles on moon

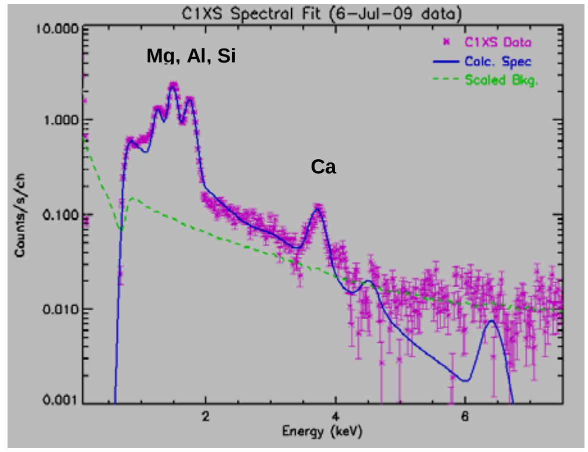

Fig.3. Data obtained by C1XS during a solar flare showing well-defined peaks from Mg, Al, Si and Ca.

using radioactive ^{222}Rn as tracer. A limit on the rate of volatile transport on moon may be provided from this limited data set. The Mini-SAR payload obtained excellent data for regions around both the North and South poles. Signatures in the data for the possible presence of sub-surface ice in the permanently shadowed polar region are being investigated. A major

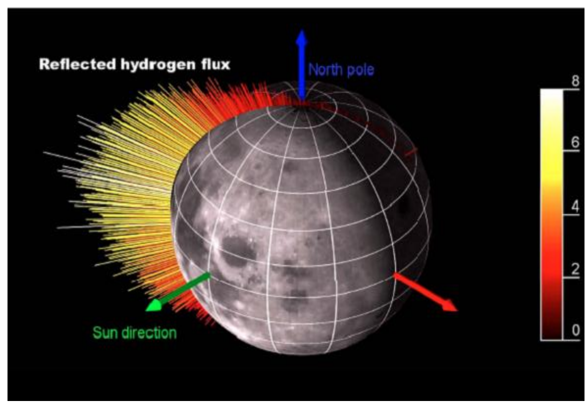

Fig.4. Reflected hydrogen from the lunar surface detected by SARA.

new finding by the SARA experiment is the unexpected detection of reflected hydrogen, amounting up to 20% of the incident solar wind protons, from the lunar surface [6].

The Chandrayaan-1 mission has contributed significantly to our understanding of the moon, and generated an excellent data set that will be very useful for planetary scientists in the coming years.

References: [1] Goswami J. N. & Annadurai M. (2009) *Curr. Sci.* 96, 486-491. [2] Pieters C. M. et al. (2009) *Science* 326, 568-572. [3] C. Pieters et al (2009) *LPSC40*, 2052pdf [4] Ohtake M. et al. (2009) *Nature* 461, 236-240. [5] Chauhan P. et al. (2009) *Curr.Sci.* 97, 630-631. [6] Wieser M. et al. (1999) *Planet Sp. Sci.* (In press).