

PLANEX

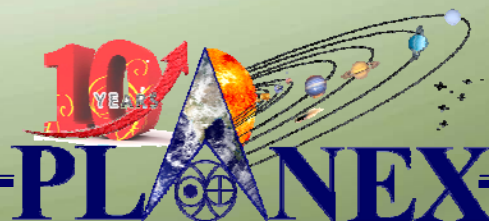
Planetary Sciences and Exploration Programme

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OCTOBER 2012



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COVER PAGE

Through the mosaic shown on the front page, planex newsletter pays tribute to the first man to land on the Moon, Neil Armstrong who recently passed away. The mosaic also illustrates recent historic events. The image at the centre shows one of the events recorded with the CMS detector in 2012 at a proton-proton centre of mass energy of 8 TeV, which was related to the observation of a new particle with a mass of 125 GeV, probably the Higg's Boson / the God Particle. The top left panel illustrates the historic launch of ISRO's 100th indigenous mission, PSLV-C21. The top right panel depicts Neil Armstrong and the Lunar Landing Module as a mark of respect to the great Astronaut. The bottom panel shows one of the panoramic images of Gale crater returned by Curiosity. An artist's impression of Curiosity can be seen in foreground. The lower right panel illustrates the artist concept of Curiosity Landing on Mars using a sky crane.
(Courtesy: www.isro.gov.in, www.nasa.gov, <http://cms.web.cern.ch>)

EDITOR'S DESK

READER'S COLUMN

Dear Readers! The field of Space science and exploration always provides us with remarkable feats to commemorate. This time also it's no different. Well, on the lighter side, I guess planets and the stars are definitely in the right position favouring the field astrologically ☺

This issue explores three major signature incidences which are bound to autograph the future of planetary sciences and propel it forward with more velocity. Discovery of the celebrity "God Particle" Higgs Boson at LHC, CERN that is claimed to have the potential to delve into the physics of early universe. With its hundredth indigenous venture PSLV-C21, ISRO achieved a laudable century, further boosting the plans for its ambitious planetary endeavours. Successful landing of Curiosity, the most versatile NASA rover, on the surface of Mars promises to fulfil several expectations. The present issue attempts to enlighten our readers more on these important happenings.

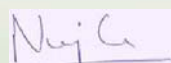
Dr. S. Ramakrishnan, Director, LPSC (ISRO), spotlights on ISRO's accomplishment with a stimulating article on **Access to Space through ISRO Launch Vehicles**, discussing the incubation, progress and current potential of the programme which has put India amongst the forerunners in the world.

An article on **The Higgs Boson** follows underlining its importance to particle physicists and investigating its popularly presumed Godly prodigy. An informative article elaborating on the **space weather and space climate of terrestrial planets** has been included. Discussing the strengths of Chandrayaan-1 data, an article on **Analysis of a volcanic lava tube on the Moon.....TMC sensors** follows this, which explores the suitability of a lunar site for possible human habitat in future. We conclude exploring the objectives of PLANEX program in this final issue of the present volume by including a special article focusing on the **Research and Developmental activities...** being carried out at the nodal centre during a decade of its existence. The series of such articles in Vol. 2 would serve as a guide for the students and professionals who aspire to make a mark in the field of *Planet. Sci. & Exp.* in the country.

The **Mission story** column discusses salient features and objectives of **Astrosat**, India's much awaited astrophysical observatory in space. Towards the end, an inspirational excerpt on **Brahmagupta**, the great astronomer and mathematician of Ancient India has been incorporated. Regularly awaited features like **News highlight, Mission updates, Events and Announcement of Opportunities** are there as usual. My heartfelt reverence to a star whose Small step on the Moon was a giant leap! For the Mankind. Mr. Neil Armstrong we salute you. R.I.P

Before I conclude, I would like to bid farewell to Mr. A. Bhattacharya who had been a prized member of the editorial team. Also, I welcome Dr. Ami J Desai into the team. We hope to receive her valuable contribution in the forthcoming issues.

Wishing you a Delightful Reading!



Neeraj Srivastava



"..... content-wise July issue was one of the best among the series. Kudos to the Editorial board! The article 'manual prediction of planetary positions in the sky' impressed me a lot. Inclusion of such contents will surely help an avid reader to understand the basics of observational astronomy, and to dwell more into the subject. The good aspect was that the content is good enough to let a programmer to develop a computer code to predict the same. Do include more such articles. I understood that Ancient India had a very good tradition of scientific lineage in almost all branches of science, engineering and technology. I suggest a series highlighting contributions in astronomy and planetary science could be a theme much needed right now. The article on Bhaskaracharya was an eye opener, but the title seems omitted from the contents"

K.B. Smart

Department of Atmospheric Sciences
Cochin University of Science and Technology
KOCHI, Kerala

"..... an amazing, sound current updater of Space Sciences and Exploration. Every page is informative and worthy. News Highlights, Articles, Mission Updates and A&O are too good. PLANEX Newsletter makes me aware about current research and technology of Planetary Sciences. The most important thing- the 'Language & Structure' of e-letter is technical though easy to understand. I appreciate this initiative, because Indian S&T Graduates/Scholars need their own stage to express and share views and this fantabulous booklet is best example. I hope TEAM PLANEX NEWSLETTER will work with more energy and enlighten us"

Prashant Dattatraya Wagh

Geo-Exploration, IIT Powai
Bombay

"Great going and wishing you all the very best!!"

Jayanta K. Pati

Department of Earth & Planetary Sciences
University of Allahabad, Allahabad

"A very good work done once again!! Keep it up!!"

M.S. Sisodia

JNV University, Jodhpur , Rajasthan

NEWS HIGHLIGHTS

Detection of Helium in Lunar Atmosphere

Helium (He), the lightest noble gas in the tenuous atmosphere of the Moon, has been detected by Lyman Alpha Mapping Project (LAMP) ultraviolet imaging spectrograph aboard Lunar Reconnaissance Orbiter (LRO). This finding also confirms measurements made by experimental study during moon-walking by Apollo 17 astronauts in 1972. In 2009, LRO was launched to identify, decipher, and understand the lunar resources. The LAMP is a compact but sensitive far ultraviolet (FUV) instrument designed primarily to map the entire lunar surface in far ultraviolet. Collected data revealed a few Rayleighs of emission from the He I 584 Å resonance line. Background He I 584 Å emission from the interplanetary medium (IPM) was deducted to determine the native lunar He signal from a set of observations at the spacecraft zenith. The actual He I

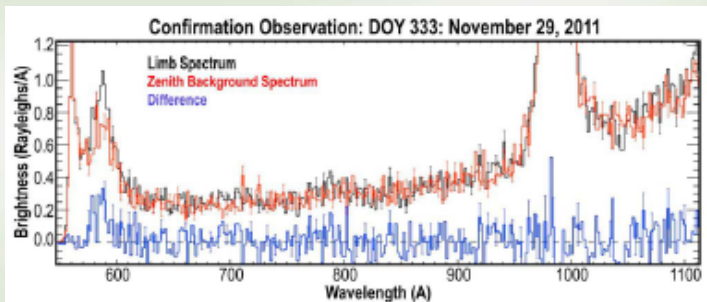


Fig.1: Net lunar He I emission brightness per Angstrom.

emission brightness per Angstrom was thus estimated after subtracting the zenith background from the corresponding limb atmospheric measurement. The measurement of He emission further raises the confidence towards using remote sensing as a comparably better tool to go forward and extend the He measurements across the Moon. An area of future investigation will be to further determine the latitudinal variation in He emission. Along with this, it is now also important to search for local He source regions, which may exist if radiogenic decay is responsible for a significant fraction of the lunar He.

Source: <http://dx.doi.org/10.1029/2012GL051797>

Cassini Reveals Massive Ice-Avalanche on Lapetus

Mass movement in the form of landslide or avalanche was observed on Lapetus, an ice satellite of Saturn with exceptional topographic relief. Landslides were identified in original Cassini mission images, with resolutions as good as 450 m per pixel on Lapetus's bright, trailing hemisphere and as good as 870 m per pixel on its dark,

leading hemisphere. The observed landslides were classified into two morphologic types: blocky and lobate; prominent avalanche scars were also noted. Thirty mass-movement features were positively identified: 17 of them were associated with crater rims (termed intra-crater) and the remaining 13 were associated with the equatorial ridge. Intra-crater landslides were found in craters that range in diameter ~17-500 km. Additionally, 18 potential landslides were also identified. The observations were supported by a mechanism, which suggests that frictional dissipation along cold sliding ice surfaces within and near the base of landslides on Lapetus may have raised temperatures on these surfaces into the slippery regime and permitted the relatively long run-outs. Such a

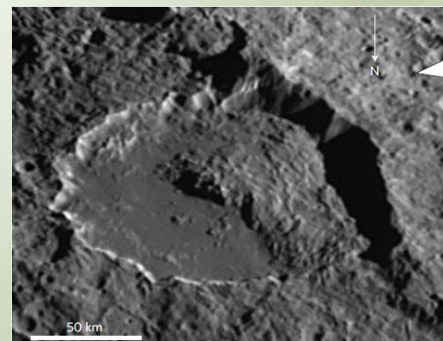


Fig. 2: Blocky landslide in Malun

mechanism implies a commensurate reduction in friction along faults within icy crusts, in a manner similar to that proposed for faults in rock.

Source: <http://dx.doi.org/10.1038/ngeo1526>

InSight mission: Looking at Meters inside Mars

A comparative planetology study has always been helpful in understanding how the planets have formed and evolved. Each of the terrestrial planets reached their current state and structure through differentiation process, which is poorly understood. Therefore, exploration of Mars becomes the top priority for the scientists to unravel the mystery and lay the groundwork for a future human mission there. NASA has selected a new mission,

Interior exploration using Seismic Investigations, Geodesy and Heat Transport (InSight), set to launch in 2016. InSight will place

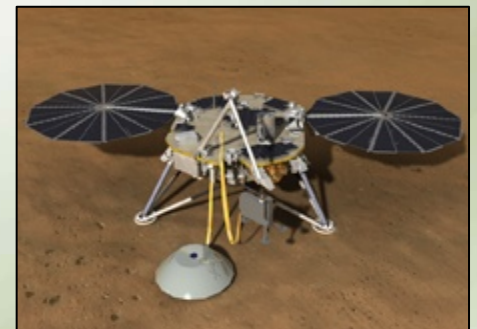


Fig. 3: Artist rendition of the proposed InSight Lander. Credit: NASA/JPL-Caltech

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sophisticated geophysical instruments on the Martian surface to investigate the planet's "vital signs": its "pulse" (seismology), "temperature" (heat flow probe), and "reflexes" (precision tracking). This will inform whether the core of Mars is solid or liquid like Earth's, and why Mars' crust is not divided into tectonic plates that drift like Earth's. InSight's story will unfold as real-time data about Mars' historical record comes back to Earth, and will be disseminated through various platforms, such as mobile applications, social media, video and podcasts, and visualization programs - to reach students in both informal and formal education settings.

Source: <http://insight.jpl.nasa.gov/>

Late-Accretion in the Solar System

The record of core formation of terrestrial planets is contained in the siderophile and chalcophile element contents in the mantle rocks. Certainly, these elements are much more depleted in the upper mantle than lithophile elements of similar volatility, which implies that they record a depletion event unseen by the lithophile elements. Understanding the origin of highly siderophile elements (HSE: Re, Os, Ir, Ru, Pt, Rh, Pd, Au) abundances in the silicate portions of planets can be done based on answers derived for "when and how processes of metal silicate equilibration and later accretion occurred." In an attempt to address these issues, a new petrology, trace-element and isotope geo-chemistry of diogenite meteorites have been recently analyzed. The range observed in HSE concentrations among Diogenites reflects variable contributions to mantle domains by late accretion that was not subsequently mixed out in a magma ocean, by mantle melting, or by subsequent solid-state mantle convection. This is consistent with late accretion following a short-lived magma-ocean phase, but during a period of mantle cooling, when magma lakes or seas generated by impacts could be partially mixed within the convecting mantle. That late accretion, immediately preceded large-scale differentiation of some planetary bodies, is also consistent with increased HSE abundances in the silicate portion of Mars. This study demonstrates that from early accretion to late accretion via core formation and primary differentiation were all accomplished in just 2 - 3 Myr after Solar System formation.

Source:

<http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo1527.html>

Curiosity Lands on the Red Planet

Curiosity, the most advanced rover of NASA weighing almost a ton and having a size of a car, finally touched the Martian surface on August 5, 2012, 10:32 PM (PDT) using highly sophisticated landing by the most advanced engineering and technology for space missions till date. The rover was carried by the spacecraft Mars Science Laboratory for 36 week long journey. After landing *Curiosity* has started its journey for two-year long exploration of Mars to reveal many unknown mysteries



Fig.4: Curiosity Lander photo, taken from its navigation camera, shows rover and its tracks on Martian

and scientific discoveries about the planet including the search for any microbial life there. *Curiosity* landed in the Gale Crater near the foot of a mountain. The first view of Mars

was a wide-angle scene of the planet near the rover. Landing of *Curiosity* was confirmed by an image from the NASA's orbiter, named Mars Odyssey. *Curiosity* carries 10 scientific instruments. Some instruments were sent for the first time on Mars like laser-firing instrument which will check the elemental composition of rocks by sending a laser beam from a distance. Also there is a drill provided at the end of the robotic arm that will help in taking the rock samples and soil from the surface and sending them for analysis using instruments inside the rover.

Source: <http://www.nasa.gov/mars>

First Taste of Martian Air

NASA's *Curiosity* Rover has sucked the Martian air for the first time after it had successfully landed near Gale crater on Mars. The rover had sniffed the air into its big Sample Analysis at Mars (SAM) instrument to reveal the concentration of different gases on the red planet. This instrument, when at its best performance, can measure gaseous contents in the order of parts per trillion, and the expected amounts based on measurements taken from

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orbit around Mars and from Earth telescopes is in the 10 to a few 10s of parts per billion. The result from these



Fig.5: SAM, pictured by one of Curiosity's cameras

initial tests indicates dominance of CO₂. However, the interest would be more fanatical, if Curiosity detects signal for methane. Methane should be short-lived and its persistence suggests a replenishing source of some kind - either biological or geochemical. It is hoped that SAM can shed light on the status of methane on Mars.

Source: <http://www.bbc.co.uk/news/science-environment-19513490>

Carbon Dioxide Snow Clouds on Mars

Mars Reconnaissance Orbiter (MRO) has confirmed the detection of carbon dioxide snows and clouds of the red planet's atmosphere, the only known phenomena in the

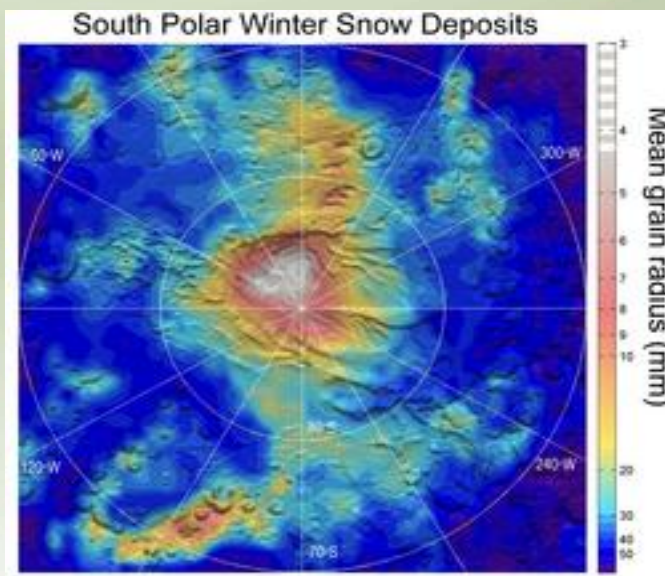


Fig.6: Carbon-Dioxide Snowfall on Mars

solar system. Frozen carbon dioxide, better known as "dry ice," requires temperatures of ~ -125°C, which is much colder than needed for freezing water. Mars' south

polar residual ice cap is the only place on the Red Planet where frozen carbon dioxide persists on the surface year-round. The data acquired by MRO's Mars Climate Sounder (MCS) from observations in the south polar region during southern Mars winter in 2006-2007, has helped in identifying a tall carbon-dioxide cloud about 500 kilometers in diameter persisting over the pole, while smaller, shorter-lived, lower-altitude carbon dioxide ice clouds hover around 70-80 degrees south latitudes. The infrared spectra signature of the clouds viewed from the instrument's direction pointed towards the horizon is clearly indicating that particles are of carbon-dioxide ice and they extend to the surface. Another line of evidence for validating snow is that the carbon-dioxide ice particles in the clouds are large enough to fall to the ground during the lifespan of the clouds. These intriguing results show that there exist small-grain carbon-dioxide ice deposits formed by snowfall over the south polar cap of Mars.

Source:

<http://www.agu.org/pubs/crossref/2012/2011JE004040.shtml>

Meteorite Found Using Metal Detector

A 13-year old boy Jansen Lyons has found a meteorite with the help of a homemade metal detector weighing < 1 kg. The meteorite is confirmed to be an L6 ordinary chondrite. This meteorite has been found in the suburban region of Rio Rancho, New Mexico. Usually hunt for meteorites is done in well known places like in existing craters or in fields by expert meteorite hunters, but finding a meteorite by this way is quite exceptional and a great achievement. The meteorite was found in September, 2011. Jansen was encouraged to the search of meteorites with the help of a book. He developed a homemade metal detector for searching these kinds of rocks from outer space with the help of his grandfather. After the finding was confirmed to be a meteorite it was named as *Rio Rancho* meteorite.

Source: <http://www.latimes.com/news/nation/nationnow/la-na-nn-boy-13-finds-meteorite-20120711,0,6778852.story>

Morpheus Lander Displayed in Media

On August 1, 2012 NASA's *Morpheus* Lander is displayed in front of media at Kennedy Space Centre, where it will undergo various types of tests in next three months *Morpheus* is one amongst the 20 projects under

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Advanced Exploration Systems (AES) program under NASA's Human Exploration and Operations Mission Directorate. AES projects primarily target on developing advanced prototypes for future missions including manned missions. *Morpheus* is basically a prototype of a Lander, which can be used to combine many types of advanced technologies for future spacecrafts, capable to land on various different bodies of the solar system. *Morpheus* also uses advanced technology in fuel propulsion system, where liquid oxygen and methane are used; these green fuels can be developed on other planetary bodies also. *Morpheus* also targets on the technology to enable accurate and safe landing of spacecraft on any planetary body. *Morpheus* has undergone many tests for its performance evaluation which included testing performed in a simulated hazardous terrain having rocks and craters. *Morpheus*' first successful tethered flight had just occurred on August 3; while during its second free flight test at Kennedy Space Center on August 9, it crashed and burned.

Source:

http://www.nasa.gov/home/hqnews/2012/jul/HQ_M12-141_Morpheus_at_Kennedy.html

Higgs Boson or Eureka?

Ms. Tanushree Basak of PRL has won the first prize in an essay competition on the topic, "What is the meaning of the discovery of the Higgs boson? If it is the 'Higgs', how would you like to name it?", held at SLAC Summer Institute, California. In her essay, she had mentioned, "The announcement on July 4, 2012 of the discovery of a 'new boson' of mass around 125 GeV (at the level of 5σ), by the ATLAS and CMS collaboration, is regarded as the triumph of particle physics. This new boson can be considered as the missing piece in the jigsaw of well-established Standard Model of particle physics. As we know that one of the important tasks of Standard Model Higgs boson is to give mass to W & Z bosons and masses, mixing to the fermions – without which no atom and hence no stable composite structures would have been formed." Further, she renamed Higgs boson as 'Eureka' (a short form of 'Eureka boson'), considering the discovery as a Eureka moment for the particle physics community.

FLASH NEWS

- Contributions of Asteroids to the volatile inventories of the terrestrial planets
url:<http://www.sciencemag.org/content/early/2012/07/11/science.1223474.full>
- Discovery of new Pluto moon by Hubble
url:<http://www.bbc.co.uk/news/science-environment-18803212>
- Mercury mysteries, raised by MESSENGER Spacecraft
url:<http://news.discovery.com/space/mercury-observations-raise-more-questions-than-answers-120703.html>
- Sharpest images of Sun's corona captured by NASA telescope
url: <http://www.nasa.gov/sdo>
- NASA's Hubble Space Telescope spots Galaxy filled with Hot Young Stars
url:<http://www.clarksvilleonline.com/2012/07/29/nas-hubble-space-telescope-spots-galaxy-filled-with-hot-young-stars/>
- Potential Supernova progenitor found!
url:<http://www.sciencedaily.com/releases/2012/08/120803103050.htm>
- Bizarre nanoparticles in glass bubbles of lunar soil
url:<http://www.sciencedaily.com/releases/2012/06/120613102442.htm>
- New geological mystery of Mars revealed
url:<http://www.jpl.nasa.gov/news/news.php?release=2012-290>
- Clues of plate tectonics on Mars!
url:<http://lithosphere.gsapubs.org/content/4/4/286.abstract>
- Planets of Sun-like stars found
url:<http://www.sciencedaily.com/releases/2012/09/120914133446.htm>
- Alien Soils for Heat Shield through Earth's atmosphere
Link:<http://www.sciencedaily.com/releases/2012/09/120914133446.htm>
- Different origin of Clays on Mars
url:<http://www.nature.com/ngeo/journal/vaop/ncurrent/full/ngeo1572.html>
- Signature of planetary tectonics on Vesta
url:<http://www.agu.org/pubs/crossref/pip/2012GL052959.shtml>
- Hydrated Minerals Found on Vesta
url: <http://www.nasa.gov/dawn>
- GSAT-10 satellite launched successfully
url:http://www.isro.gov.in/pressrelease/scripts/pressreleasein.aspx?Sep30_2012

ACCESS TO SPACE THROUGH ISRO LAUNCH VEHICLES

Introduction :

Climbing out of the Earth's gravity well and transcending the dense atmospheric shield is the most energy intensive crucial first step in the journey into space and the Launch Vehicles are the primary viable means of accomplishing this task. India acquired the capability to orbit a satellite in 1980, when SLV-3 the indigenously developed all solid launcher deployed the 40 kg Rohini satellite around earth. Tremendous progress has been made in this area in the last three decades and today, India is one among the leading space-faring nations with assured access to space through the work-horse operational launcher PSLV, the Polar Satellite Launch Vehicle.

PSLV which was developed for servicing the Indian Remote Sensing programme has performed an unbroken string of twenty-one successful missions, including Geosynchronous Transfer Orbit (GTO) deployment and the much acclaimed Chandrayaan-1, the mission to Moon. Progressive performance enhancement measures have improved the capability of PSLV, enabling passenger payloads to be carried along with the main satellite, opening up low cost launch opportunities for mini and micro satellites from across the globe. PSLV has so far successfully deployed about thirty auxiliary payloads including experimental satellites built by university students. PSLV is the launcher proposed to carry the Spacecraft for the first Indian Mars Mission.

Sounding Rockets V/S Launch Vehicles :

India's foray into space started in 1963 when the first NIKE APACHE rocket was launched from Thumba Equatorial Rocket Launching Station (TERLS), Trivandrum. Unlike other major space-faring nations where the space launchers were derived from already operational ballistic missiles, Indian Launch Vehicle development had its humble beginning in the form of producing indigenous Rohini sounding rockets. Design and production of these solid propellant motors gave a firm foundation in solid rocket technology based on which the first Satellite Launch Vehicle (SLV-3) was configured. The successful development of all solid four stage SLV-3 not only demonstrated the indigenous strength in solid propulsion which is one of the

subsystems of a complex launch vehicle but also the maturity attained in conceiving, designing and realizing other vital elements viz., control, guidance, navigation and staging systems. The nation's capability to plan, integrate and carry out a satellite launch mission which is truly a multi-disciplinary technological challenge was proved on July 18, 1980 when India successfully orbited Rohini-1 satellite on SLV-3 E02 flight.

While the sub-orbital sounding rockets which just carry the payload instruments upto a height of 100 to 200 kilometers have very few sub-systems apart from the propulsive device, a Satellite Launcher which has to impart a velocity of around 8 km/sec and precisely deliver the payload into a pre targeted injection vector in space has far more complex systems all of which have to function flawlessly for a successful orbital mission.

PSLV – The Operational Work-Horse :

While SLV-3 and follow on ASLV were the technology development launchers, PSLV – the Polar Satellite Launch Vehicle (Fig. 1) is the first operational launch vehicle which has currently matured as a reliable workhorse launcher providing India an assured access to space. The PSLV project was initiated in 1982 for establishing indigenous capability for launching the Indian Remote Sensing Satellite (IRS) of 1000 Kg class in Polar Sun synchronous Orbits. The sub-systems development took place over the course of next ten years. Some of the major technologies developed and employed for PSLV are large solid booster of 100 ton class, liquid propellant stages, light alloy structures, composite motor cases, closed loop control and guidance systems, redundant strap-down inertial navigation systems, etc. New facilities were set up for processing, handling and testing of various vehicle sub-systems. The 2.8 m diameter, 44 m tall four stage vehicle has a gross lift-off mass of about 300 tons.

The liquid propellant second stage based on the Viking engine technology was to meet the performance requirements, whereas the indigenous liquid upper stage was a functional necessity to carry out three-axis stabilized injection of operational IRS satellites. The induction of liquid stages and the quantum jump in the vehicle size demanded systematic approach to vehicle engineering aspects, structural characterization as well as launch pad interface management.

Today, PSLV has an enviable record of having performed an unbroken string of twenty-one successful missions in a row starting from PSLV-D2 in 1994 to the latest PSLV-C21/SPOT-6 mission in September 2012. The operational PSLV configuration has basically three

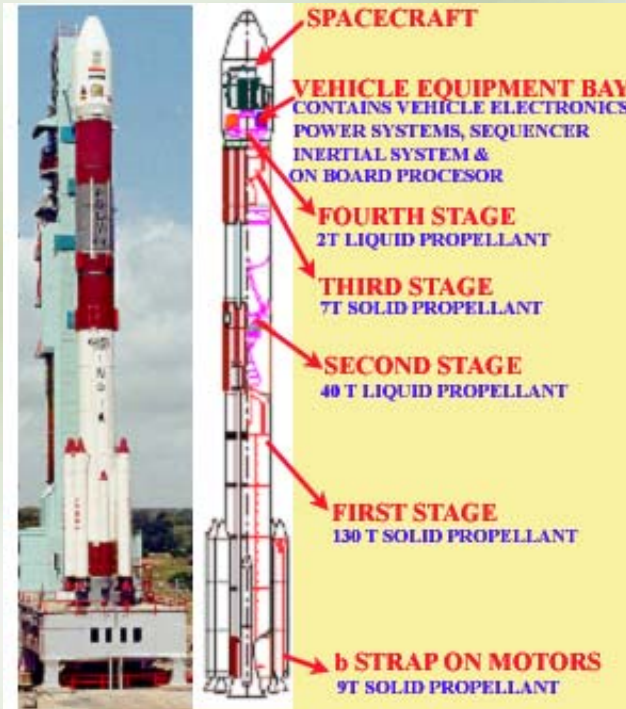


Figure 1: The Polar Satellite Launch Vehicle

options viz the Standard PSLV, the PSLV-XL version and the PSLV-Core Alone version with different performance capabilities to fit the specific mission requirements.

Passenger Payloads and Multi-satellite Mission:

The payload capability of PSLV made a quantum jump from 850 kg to 1200 kg in SSPO in the first operational mission PSLV-C1 and subsequently it has been steadily growing through progressive optimization of vehicle and mission design and currently touches around 1500 to 1700 kg (SSPO) and 1300 kg for GTO. To exploit the excess payload capability, specific interfaces were created in the Vehicle Equipment Bay deck to accommodate two auxiliary small satellites of 150 kg class along with primary spacecraft. PSLV-C2 was the first vehicle to carryout multi-satellite mission (Fig. 2) when along with IRS-P4 (Oceansat-I), KITSAT from South Korea and TUBSAT from Germany were deployed on commercial terms.

PSLV-C3 vehicle performed multi-orbit mission when it injected the primary satellite TES and passenger payload BIRD in the nominal 567 km orbit, and subsequently deployed the second auxiliary satellite PROBA of ESA into a higher orbit of 638 x 567 km.

PSLV has also demonstrated its capability to launch two primary payloads in a dual launch mode using a Dual Launch Adaptor (DLA). This configuration was first used to orbit the Space-capsule Recovery Experiment (SRE) module in PSLV-C7 along with the CARTOSAT-2. PSLV created a record when it successfully carried ten independent spacecrafts in a single launch mission (PSLV-C9) and deployed all of them perfectly in their designated orbits.

Multi-satellite deployment missions demand meticulous interface management for each of the payload including the operational aspects at the launch complex. Collision free smooth release of multiple spacecrafts during final injection demands detailed modeling and analysis of multi-body dynamics and specific maneuvers to avoid near term or long term re-contact between the different satellites.



Figure 2: Multiple Spacecraft Mission

PSLV/Payload Interfaces : While the main spacecraft interface with vehicle is through a standard 937Ø band clamp system, the passenger payloads have an option of adopting a variety of flight qualified ISRO Ball-lock separation systems viz, IBL 230, IBL 298 and IBL 358 (Fig. 3). Also, specific interfaces can be provided for mini/micro satellites as required. The DLA configuration (e.g. Fig. 4) offers another option for two primary

payloads. PSLV offers a cool environment to the spacecrafts in terms of dynamic loads as well as the vibration and acoustic levels and these have been measured and validated through several successful missions.

named the L-40 stage which is a variant of PSLV second stage, and replacing the two upper stages of PSLV with a single cryogenic stage (CS) procured from Russia (Fig. 5).



Figure 3: IBL Separation System for Auxiliary S/C

PSLV to GSLV :

As PSLV was taking shape and maturing into an operational workhorse for the polar orbit launches of remote sensing spacecrafts, a launch vehicle was conceived and developed to attain a capability to launch 2.5 t class of communication satellite into GTO. GSLV was essentially derived from PSLV modules by replacing the six solid strapon motors with four liquid boosters

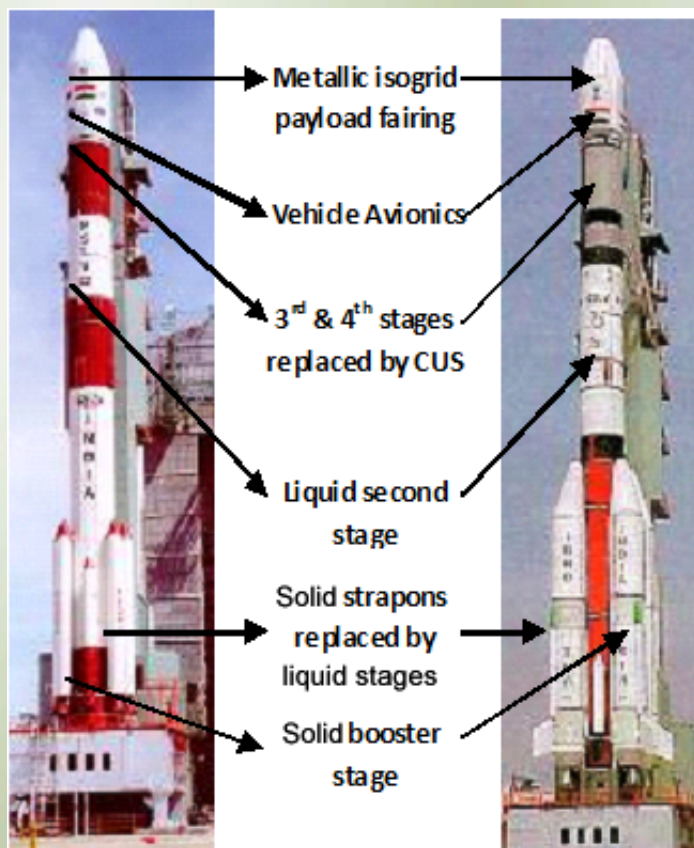


Figure 5: The transition from PSLV to GSLV

GSLV is three stage vehicle, 49 m tall, with a gross lift-off weight of about 415 tons. While most of the vehicle system elements including the navigation, guidance and control and other avionics modules were essentially adopted from PSLV. GSLV is yet to stabilize as an operational launcher. Seven launches have so far taken place out of which four were successful and three mission failures. Replacement of the Russian Cryo Stage with the indigenous Cryo Upper Stage (CUS) is imperative to sustain the GSLV programme. The first flight test of indigenous CUS on GSLV-D3 was not successful and the next attempt is targeted in the forthcoming GSLV-D5 flight.

GSLV has a capability to take upto 2.5 ton into GTO and can accommodate larger spacecrafts with a 4m dia payload fairing.

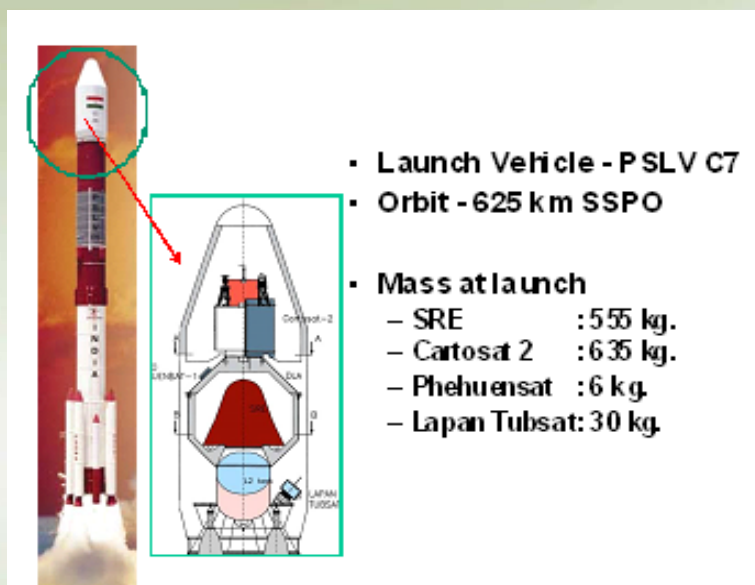


Figure 4: SRE Launch configuration

GSLV MkIII (LVM3):

While PSLV and GSLV will meet the indigenous launch requirements upto 2.5t in GTO and about 4.5t in LEO. GSLV Mk-III (Fig. 6) is planned as the logical next step in the development of higher capacity launch vehicle, to place 4 tons in GTO at half the launch cost per kg of satellite mass. It also targets to maximally utilize the developed technologies and infrastructure of

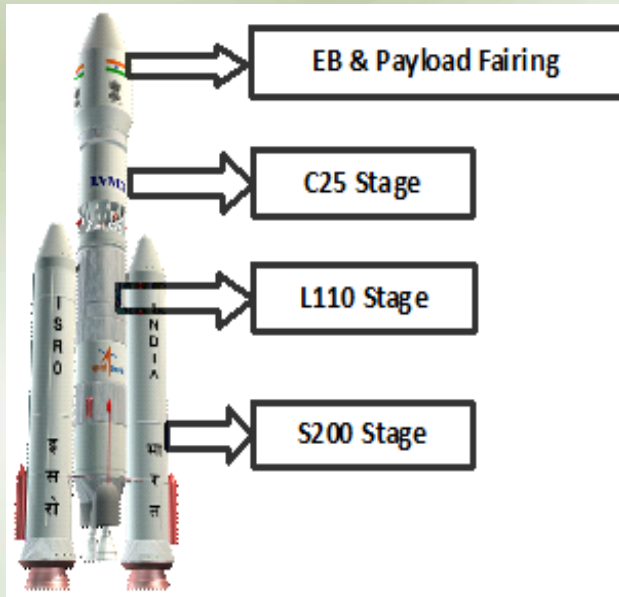


Figure 6: The GSLV MkIII

Each S200 has 200 tons of propellant loading.

The second stage is L110 stage which derives its heritage from the L-40 stage of GSLV. A twin-engine clustered configuration is adopted with similar stage engineering concepts as that of L-40. The third stage is a cryogenic stage with 25 tons of propellant loading and a single engine with 20 ton thrust. The new cryogenic stage draws the technological strengths from the development of the indigenous cryogenic stage (CUS) for GSLV. GSLV MkIII has advanced navigation systems and on-board electronics. It has a payload fairing of 5m diameter and 10m height.

Two out of three propulsive stages of LVM3, the S200 solid booster and the L110 liquid core have been developed and qualification tested. Work on the 25 ton indigenous Cryogenic Stage (C25) is progressing well. The first developmental launch of LVM3 is expected by 2014/15.

ISRO Launch Vehicles For Planetary Missions:

Indian first moon mission Chandrayaan-I was launched on PSLV-C11 flight (PSLV-XL) which deployed the 1380 kg Chandrayaan spacecraft into a 250x23000 earth bound orbit. While GSLV is identified to carry the

PSLV/GSLV.

LVM3 is a three stage vehicle of composition:

2S200+L110+C25

The solid strap-on stage (S200) derives its heritage from the PSLV/GSLV boosters. It incorporates flex nozzle control systems which is used in the third stage of PSLV.

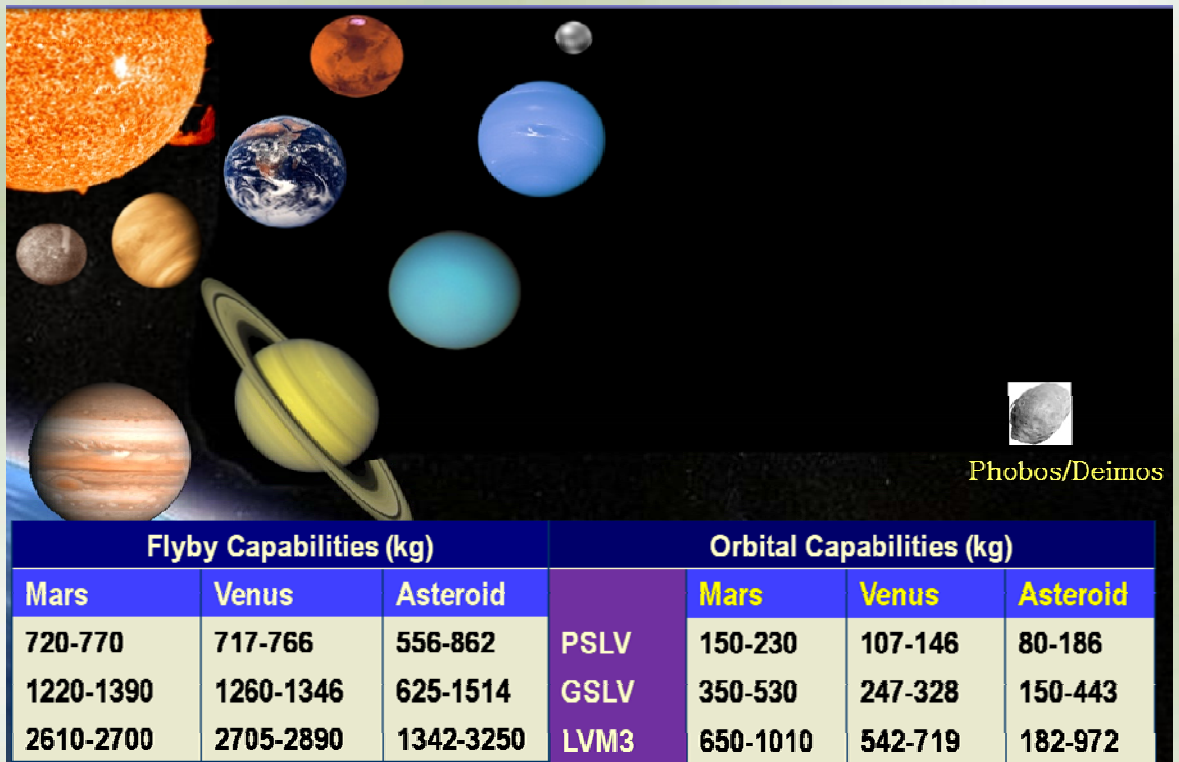


Figure 7: Flyby and Orbital capabilities of various Indian launch vehicles for Mission to Mars, Venus and Asteroids

heavier Chandrayaan-II spacecraft, it is again PSLV that is chosen to perform the challenging MARS mission, to dispatch the first Indian spacecraft towards Mars.

While with PSLV, very modest payloads can be deployed on fly-by missions to planetary bodies like Mars, Venus and some near earth asteroids (Fig. 7), operationalisation of GSLV and subsequently the LVM3 will substantially enhance this capability to deliver heavier spacecrafts on orbital/landing missions to planetary bodies. Indian launch vehicle programme is depicted in Fig. 8.

ramped up to touch five per year with the payloads and missions upto PSLV-C48 listed in the manifest during the time-frame 2012-2020. Commissioning of the Second Launch Pad (SLP) at SDSC/SHAR makes possible to sustain this enhanced launch rate of PSLV alongwith the missions planned on GSLV and the LVM3 launchers.

The availability of Passenger Payload (PPL) opportunities in many of the PSLV launches offer a low cost option for undertaking innovative small satellite missions for planetary exploration as well as earth

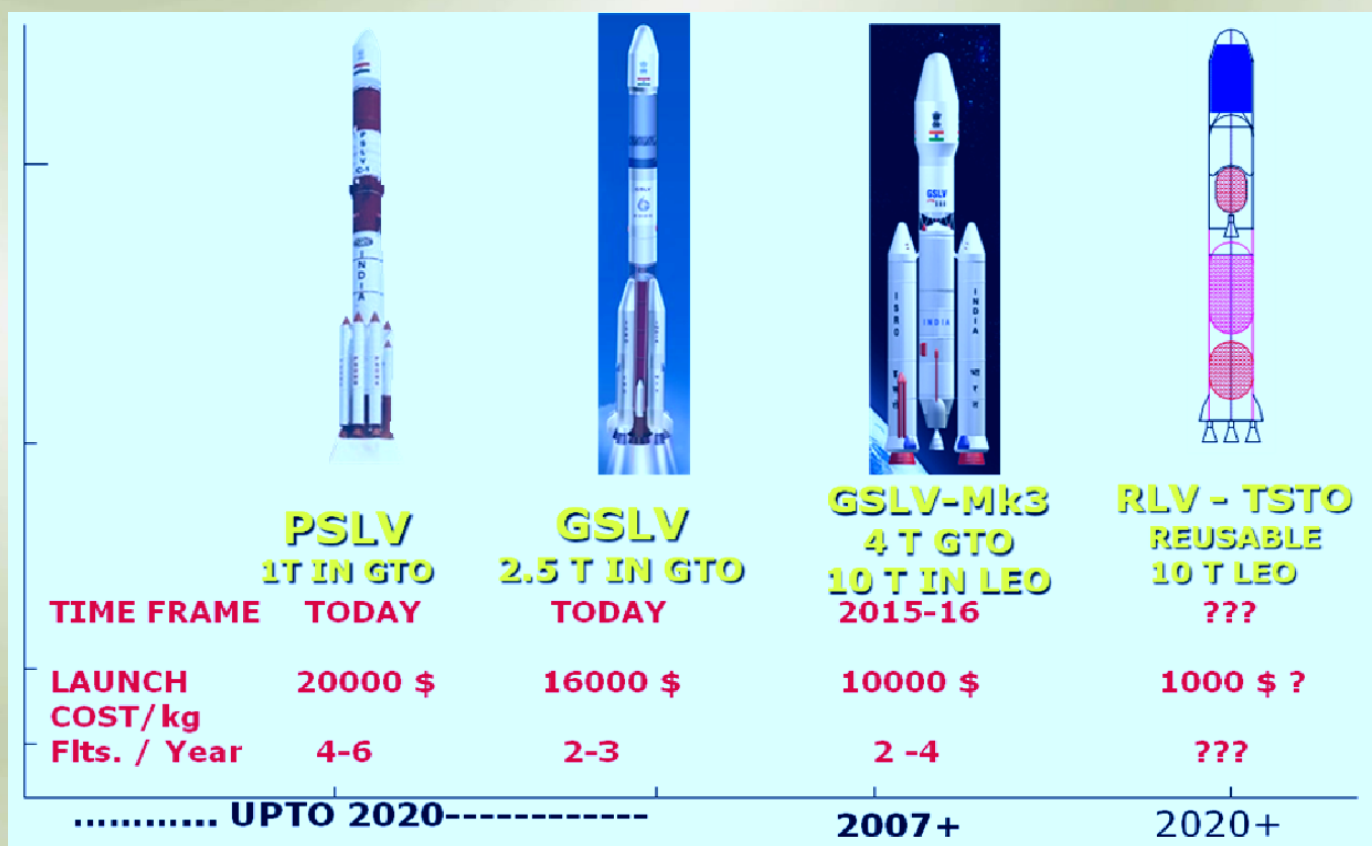


Figure 8: The Indian Launch Vehicle Programme

With the maturing of Electric Propulsion Systems (EPS) technology, it is feasible to embark on planetary reconnaissance missions with smaller spacecrafts such as the SMART mission to Moon by ESA, using modest launch capability.

Conclusion:

The Polar Satellite Launch Vehicle (PSLV), of India has proved its robustness and versatility by performing a variety of successful launch missions including SSPO, GTO, and Inclined orbits. PSLV launch rate is being

observation to the science community. The maturing of GSLV and subsequently the much bigger LVM3 will enable India to embark upon more ambitious missions to other celestial bodies in the Solar System.

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Research and Developmental activities at PLANEX, PRL

Planetary Sciences and Exploration Programme (PLANEX) at PRL envisage following major objectives.

- (1) Carrying out cutting edge research and development activities related to planetary sciences and exploration.
- (2) Encouraging planetary sciences research in the country by funding suitable project proposals from professionals across the country.
- (3) Building awareness and igniting young minds towards the excitement of planetary sciences and exploration by organizing regular workshops, training programs and through PLANEX Newsletter.
- (4) Providing a discussion forum for ISRO's current and future Planetary endeavors.

In the previous two issues of Volume 2, the decadal volume, we have tried to bestow a glimpse of the 2nd and the 3rd objectives listed above and the 4th one is regularly mentioned in different issues as and when the respective events occur. Here we intend to provide a summary of the 1st objective i.e. the research and developmental activities carried out at the nodal centre during the past decade.

Researches in the following diverse areas have been worked upon at the centre:

- *Study of meteorites, lunar samples and terrestrial impact glasses to understand early Solar System process, planetary differentiation and the impacts processes*
- *Analysis of remotely acquired reflectance and thermal data from the Moon and Mars to understand the surface geology and thereby infer their evolution*
- *Planetary Astronomy*
- *Theoretical estimation of X and γ ray signals from planetary surfaces and electromagnetic characterization of lunar soil simulant.*
- *Design and development of potential scientific instruments for India's planetary missions*

State of the art experimental facilities such as NGMS, EPMA, ICPMS and XRF, acquired and established at the centre as a part of the national facility and the facilities of Planetary Sciences Division (MC-ICPMS, Ion Micro Probe, NANO-SIMS) have been mainly used for petrological and chemical composition and isotopic studies of planetary samples and their terrestrial

analogues. Remote data analysis and modeling assignments have been carried out using up-to-date computational and image processing software's such as ENVI, Arc View, ERDAS Imagine, GEANT etc. For planetary astronomy, NICMOS spectrometer and the 1.2 m telescope at Gurushikar at Mt. Abu were used. Here, we provide a brief mention of some of the studies carried out in the above mentioned categories and major advancements made therein.

Study of Meteorites / Lunar samples and Terrestrial Impact samples:

Chemical and petrographic studies have been carried out on a number of meteorites that include several fresh falls in India and rare primitive meteorite falls, including Martian meteorites from elsewhere. In addition studies are also on for Apollo lunar samples and lunar meteorites. Through an MOU with GSI Kolkata, the official custodian of all meteorites in the country, PRL is mandated to study the cosmic ray produced radionuclides as well as classify the meteorite to assess its scientific importance for further intense investigations. Some important results from these investigations are

- The iron meteorite Kavarpura (IIE) has been found to contain solar gases. This has opened a way to understand the formation of IIE class of non-magmatic iron meteorites.
- Large meteorites (Kendrapara, Sulagiri, Katol) have provided the opportunity to investigate cosmic ray interactions, especially neutron effects in them.
- Short lived cosmogenic radioactive nuclides falling at different epochs of a solar cycle have acted as excellent probes to look at solar modulation effects on GCR as well as anomalous orbits of the meteoroids.
- Two sizes of diamonds have been identified as noble gas carriers in the unique ureilite Almahata Sitta, the only meteorite so far with an identified parent asteroid 2008TC₃.
- Several martian meteorites, including a recent fall have been investigated to decipher the composition of noble gases and nitrogen in the atmosphere and interior of Mars.
- Through study of individual ilmenite grains from Lunar Meteorite **Y983885** the source of excess Nitrogen on lunar surface samples has been identified to be IDPs. This 'lunar nitrogen problem' is awaiting solution for about 40 years.

- Noble gas isotopes have been demonstrated as unmistakable tracers in the identification of meteoritic signatures in the Lunar impact glasses.
- Search for indigenous volatile species in lunar materials is on through study of apatites and melt inclusions in mare basalts. A few hundred ppm (<250 ppm) water has been estimated in the parent melt of low titanium mare basalt, 15555. This study has the potential to unravel the control of volatiles on lunar mantle dynamics in the absence of plate tectonics.
- Finding of a new rock type on the Moon, which is Mg-spinel dominant using M³ hyperspectral data. The mafic component is either absent or present in negligible proportions (in collaboration with M³ science team, USA)
- Compositional variations occur between the three Gruithuisen domes NW, γ and δ based on study of reflectance and thermal emission data from M3 and DIVINER respectively. They would have tapped residual liquids from different locations of the residual magma chamber which was in constant mixing

Laboratory study of Mars analogues: There are several terrestrial analogue sites that represent the current/ancient geological environments of Mars, such as hot and cold deserts, basaltic and sedimentary basins, permafrosts etc. They provide an excellent opportunity to understand Martian processes (in the absence of returned samples). A new activity in this direction has been initiated a couple of years ago.

Remote Sensing of Planetary Bodies: Since PLANEX program was initiated in the backdrop of Chandrayaan-1, India's first remote sensing mission to the Moon, immediate attempts were made to acquire technical and scientific knowhow for analyzing the expected datasets and interpreting them in terms of lunar surface processes and evolution of the Moon. Initially, researches were carried out using existing datasets from NASA's Clementine mission which flew to the Moon in the year 1994. Thereafter, data acquired from Chandrayaan-1 mission and also missions from other space agencies such as Lunar Reconnaissance Orbiter (NASA) and Kaguya (JAXA) are being analyzed. Recently, study of existing data from Mars remote sensing missions such as Mars Reconnaissance Orbiter (MRO), Mars Express etc., have also been initiated to understand the surface geology of Mars. Some of the notable findings from these studies of the Moon and Mars are:

- The sub-surface crustal rocks in the equatorial region on the Moon might be titanium deficient based on compositional study of central peaks of lunar craters
- Areas within and outside lunar swirls, the anomalously bright regions on the Moon, show different maturity trends
- Discovery of surficial water on the Moon, even, in the non-polar areas using Moon Mineral Mapper (M³) data (in collaboration with M³ science team, USA). Previously, the Moon was considered to be bone dry

- Morphological and compositional evidences for post formation volcanic activity on the central peak of Tycho crater (in collaboration with SAC, Ahmedabad)
- Unique viscous flows in the Lowell crater, Orientale basin, a plausible candidate for topical volcanic activity on the Moon
- Discovery of extensive spinel deposits in and around Lowell crater, Orientale basin. The lower limit of their depth of occurrence could be ~ 6 km
- A small uplift at the centre identified as a characteristic feature of secondary craters. The discrimination between primary and secondary craters is important to precisely carry out crater chronology for dating planetary surfaces (in collaboration with NGRI)
- Coordinated morphological and topographical observations have indicated that Mars would have experienced extensive glaciations in the past

Planetary Astronomy: A couple of projects on observation of satellites and minor objects in the infrared wavelengths were initiated. These include studies of Titan and Jupiter in the near infrared bands (J, H, K) and of asteroids in visible and IR bands using the telescope at Mt. Abu. These studies led to detection of H₃⁺ molecule in Jupiter atmosphere and variation in IR emission from Titan's atmosphere that may be related to transient closed phenomena.

Payload Design and Development: Estimation of expected response from the targeted surfaces is a prerequisite for design and development of an adequate instrument for specific scientific measurements and analyzing the data thereafter. Towards realizing this, estimation of Low-energy (40-200 keV) gamma-ray fluxes from the Moon and preliminary calculations of solar X-rays spectra were made prior to the Chandrayaan-1 mission which carried a high energy and

a low energy X-ray spectrometer for studying Lunar radioactivity and surface composition respectively. The instrument HEX was designed and developed at PLANEX, PRL in collaboration with ISAC, Bangalore. Currently, the following payloads are being developed here which are meant to be onboard Chandrayaan-2 and other forthcoming planetary missions.

Alpha Particle X-ray spectrometer (APXS): Alpha Particle X-ray Spectrometer is a well proven instrument for quantitative elemental analysis of the planetary surface. In situ measurement of elemental composition of the Moon surface has been initiated few decades ago during surveyor missions through detection of backscattered alpha particles. Chandrayaan-2, ISRO's second lunar mission with an Orbiter, Lander and Rover gives us an opportunity to plan such measurements on the lunar surface with better detectors. New technology Silicon detector namely Silicon Drift Detector has been chosen for the APXS experiment. The developed lab model of the APXS experiment provides energy resolution of 150eV at 5.9 keV which is comparable with off-the-shelf X-ray spectrometers. The payload look alike engineering model fabrication is in progress.

Solar X-ray Monitor (XSM): To obtain the elemental composition of the moon through remote X-ray fluorescence spectroscopy, it is absolutely essential to have simultaneous measurements from both Sun and Moon for interpreting the X-ray fluorescence data and obtain the elemental abundances. We at PRL are involved in developing X-ray spectrometer to monitor the solar flux using Silicon Drift Detector (SDD). This is the first time SDD is used for solar observation with energy resolution around 200eV. The lab model of the experiment has been developed and tested for the performance requirements. Energy resolution of ~200eV at 5.9keV has been achieved. The major challenge in designing Solar X-ray monitor is to design a stable spectrometer to accommodate high X-ray event rates which are expected during large flares. The engineering model of the payload is under fabrication.

Gamma Ray Spectrometer: High energy (>100 keV) gamma ray spectroscopy is an important technique for remote sensing studies of chemical composition of planetary surfaces, and has been used to study surface composition of the Moon, Mars and Asteroids at various spatial resolutions. A LaBr₃:Ce gamma ray spectrometer is being developed for a future planetary mission. The specifications of the procured LaBr₃:Ce crystal has been

checked using a pulse shaping amplifier, and an Ortec MCA card. The different individual subsystems including shaping amplifier, peak detection, analog to digital conversion and high voltage unit have been developed. The bread board model for high voltage and shaping-peak detector-ADC has been developed by using a toroidal transformer with a three stage voltage multiplication circuit. At present with the data acquisition software we are able to get the counts from the bread-board model, and measure the different peaks using ²²Na source.

Wireless Sensor Network: This is a new technology with great potential for the study of planetary surfaces. We have initiated this development keeping in view of future exploration missions. Towards this end, a number of sensors for the detection of temperature, electrical, thermal properties and ambient light are being developed. Significant efforts so far have resulted in the development of an impedance sensor and an ambient light sensor. In addition, a chamber to simulate planetary environments (in terms of surface temperature, pressure and gas composition, soil type etc.) has been designed to facilitate ground based experimental simulations.

Plasma and Current Experiment (PACE): The Plasma and Current Experiment (PACE) proposes to study the escape processes of electrons and ions in the Martian atmosphere and is very significant in context of the evolution of the Martian atmosphere. PACE is a plasma analyzer instrument and consists of Electron Spectrometer (ES) and Ion Mass Spectrometer (IMS). The ES is composed of electrostatic analyzer (ESA) as charged particle (electrons) sensor, and MCP as the detector. It measures electrons of different energies in the dynamic range 1 eV to 30 keV. The IMS is composed of ESA, time-of-flight (TOF) unit and MCP to measure ions of different elements and energy. Currently bread board model has been realized.

Thus, the PLANEX programme at PRL is involved in multifaceted research and development activities aimed towards improving our current understanding of intricacies involved in Planetary Sciences and Exploration. With its continued involvement in enlightening the amateurs of planetary science, its efforts also offer a radiant environment and platform for aspirants to build up their skills and excel in these challenging, yet exciting areas of research and development.

The Higgs Boson

The discovery of a new particle expected to be the Higgs boson was announced by European Organization for Nuclear Research CERN on 4th July 2012. This was a culmination of more than 50 years of theoretical analysis of its properties and experimental efforts to discover it in the particle colliders. The idea of the Higgs boson was introduced by Steven Weinberg and Abdus Salam in 1967 to explain why weak interactions like beta decay of nuclei are much slower than electromagnetic processes such as transitions of electrons between different energy levels of the atom. Weinberg and Salam thus generalized the theory of electromagnetic interactions to include the weak interactions and proposed the Standard Model of particle physics for the first time (after the addition of strong interactions in the same framework). The origin of the idea of the Higgs boson was not to explain weak interactions but to find a way of evading what seemed a puzzle in particle physics which arose in theories with broken symmetries.

In ferromagnets, the state with the lowest energy is not where all the magnetic domains are randomly oriented and there is no net magnetization. Due to repulsion between the like poles of the magnetic domains, the random orientation of the domains is a state with higher energy, and is realized when the ferromagnet is heated. When the ferromagnet is cooled, the domains align themselves with each other along one direction and this spontaneously broken symmetry state has the lowest energy but a net magnetization. This idea of spontaneous symmetry breaking in ferromagnets was introduced by Hiesenberg in 1928.

The behaviour of superconductors was explained by Landau and Ginzburg in 1950 using the above ideas. These scientists showed that the superconducting state was a spontaneously broken symmetry phase with lower energy, and in this phase the photon becomes massive. In 1960, Nambu showed that the spontaneous breaking of the chiral symmetry in quarks resulted in the existence of almost massless particles - the pions. Pions are lighter compared to other strong interaction particles such as protons and neutrons.

This idea that in relativistic systems the spontaneous symmetry breaking was accompanied by a massless particle was proved mathematically by Jeffrey Goldstone

in 1961. These particles are now called Nambu-Goldstonebosons.

The necessary existence of Nambu-Goldstone bosons when there is a spontaneous symmetry breaking was considered a problem, as massless particles give rise to extra long range forces, which were not seen in experiment. It was the effort to find ways to evade the Goldstone theorem which led Peter Higgs and two other groups (Brout and Englert; Guralnik, Hagen and Kibble)

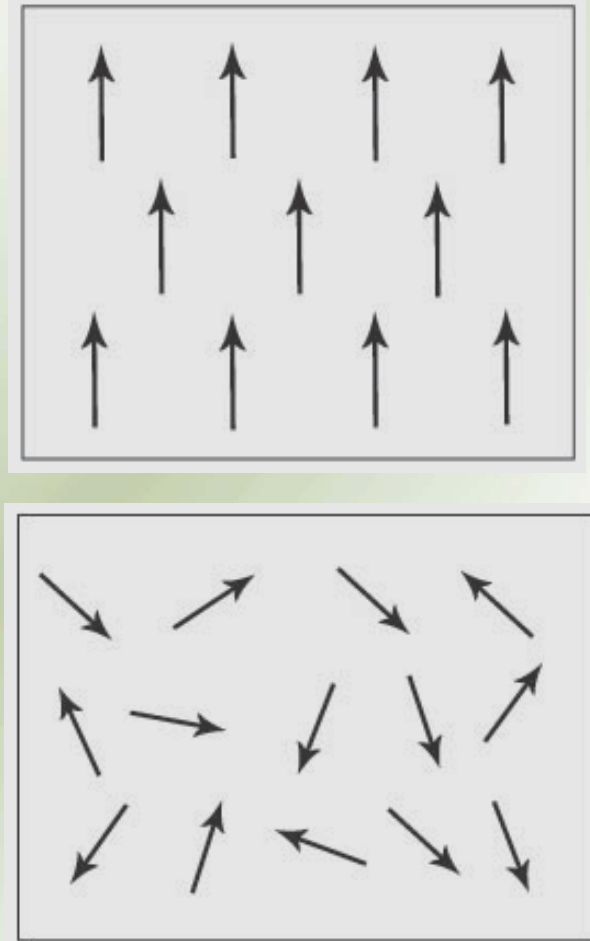


Figure 1: The Ferromagnet: The randomly oriented magnetic domains is the symmetric phase (bottom) and has higher energy than the broken symmetric phase (top). The state with a net magnetization has lower energy.

in 1964 to come up with what is now known as the Higgs mechanism. The idea of the Higgs mechanism was that if the symmetry that is broken is a gauged symmetry (like electromagnetism) with massless gauge bosons (like the photon), the Nambu-Goldstone boson does not exist after symmetry breaking, whereas the gauge bosons acquire mass after spontaneous symmetry breaking. Although,

construction of the Higgs mechanism was not directed at any specific physics problem, in 1967 Weinberg and Salam independently used this mathematical idea of Higgs and others to propose that the gauge bosons of the weak interactions (called the W and Z bosons) were massive due to spontaneous electro-weak symmetry breaking. They conjectured that the weak interaction theory was stable in the quantum theory due to the fact that the gauge invariance symmetry is broken only due to the Higgs mechanism. This conjecture was proved rigorously by t'Hooft and Veltman in 1971 whereby the Standard Model of electroweak interactions was put on a firm mathematical foundation.

According to the Higgs mechanism, there is a non-zero background of the Higgs field everywhere in the universe. This is so because the Higgs self interactions are constructed in such a way that the minimum value of the Higgs potential is attained at a non-zero value of the Higgs background field. This is similar to the case of the ferromagnet where the lowest energy state is the broken symmetry state with a net magnetization.

There was an unexpected byproduct of the Higgs mechanism which was explored by Higgs in a subsequent paper in 1966. If there is a background Higgs field then excitations of this field in a quantum theory would behave like spin zero particles of a definite mass. This spin zero particle was subsequently called the 'Higgs boson'. The first paper which drew attention to the fact that the Higgs boson associated with the Weinberg-Salam model of electro-weak symmetry could be produced and observed in particle accelerators was by Ellis, Gaillard and Nanopoulos in 1976. The search for this electroweak Higgs boson has been underway since then and this quest was finally realized at the Large Hadron Collider (LHC) in CERN in 2011-12.

The discovery of the Higgs boson at the Large Hadron Collider (LHC) was a monumental feat of technology. Protons were accelerated to energies of 7 Terrawatts each and collided with each other to produce new particles. One Higgs boson is produced in 10^{12} collisions and it decays into other particles within 10^{-22} seconds. By

measuring the energy and momenta of the decay products of the Higgs, its mass has been deduced to be around 125 Giga-electron volts. More precise measurements of the properties of the Higgs which would establish without doubt that the new particle that was discovered is indeed the Standard Model Higgs boson are underway at the LHC. Of course there may be further surprises as the new particle may not be the standard model Higgs but a Higgs boson of a bigger theory encompassing the Standard

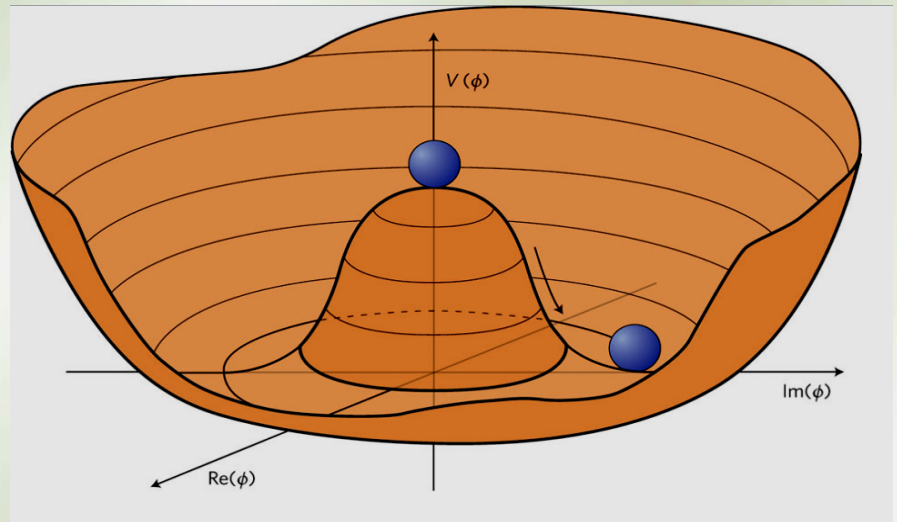


Figure 2: The Higgs potential is postulated to have a minimum at non-zero values of the Higgs field.

Model, like Supersymmetry.

A novel application of the universal Higgs background field which was not foreseen even by Higgs is that this field gives masses to not only the W and Z bosons but to all massive particles. In the Standard Model all particles are massless and acquire an effective mass due to their interactions with the ubiquitous Higgs field. It is this property of the Higgs field which has led some people to call it The God Particle (the source of this name is a book by this title by a Nobel Prize winning particle physicist Leon Lederman). Whatever the name and origin, a new particle is here and its study is certain to keep particle physicists busy in the coming decades.

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Space Weather and Space Climate: Terrestrial Planets

Introduction

The Sun is the primary source of space weather and the source of electromagnetic energy powering the atmospheric circulation and creating the plasma environments of all the planetary bodies including the terrestrial planets, the Earth, Venus and Mars. The various processes which affect the composition, constitution and dynamics of these bodies are directly influenced by the very complex behavior displayed by the solar spectral irradiance, from X-rays through the visible domain to the infrared. Satellite and rocket measurements during the last three decades have shown that the visible and the infrared radiation, which contributes more than 90% to this flux, remain constant. The more energetic part of the solar spectrum consisting mainly of UV, EUV and X-rays emitted by the chromosphere and the corona and contribute less than 10% of the total solar flux exhibit large variations. These variations could be periodic with time scales of a day, (diurnal), or of about a month (solar rotational) or of about 11 years (sunspot cycle). The most important of these variations is the one related to the 11 year sunspot cycle (the magnetic disturbances, occurrence of auroras at low latitudes, sporadic ionization above 80 km altitude, and - as a consequence of the latter - reduced quality of shortwave radio transmissions all follow the approximately 11-year solar activity cycle). This cycle is most distinctly seen in two observed parameters: the sunspot number and the 10.7 cm radiation. From solar maximum to solar minimum, for example the ultraviolet flux in the range 200-300 nm varies between 1-2%, Lyman alpha and EUV by a factor of 2 and X-rays by orders of magnitude. The total radiation flux (solar constant), however, changes by 0.1% to 0.2% from solar minimum to solar maximum and most of this is contributed by UV (200-300 nm), EUV (10-100 nm) and X-rays (<10 nm).

In addition to the periodic variations, there are short-term transient variations during events like solar flares, Coronal Mass Ejections (CMEs) and Coronal Holes known as “solar storms”. Enormous amount of energy is released during these explosive events. During solar flares, the solar spectrum in the X-rays and EUV hardens

resulting in extra ionization in the planetary environment. At the Earth, this excess ionization is in the D-region of the ionosphere which leads to several phenomena, collectively called as Sudden Ionospheric Disturbances (SIDs). These disturbances result in Short Wave Fadeouts (SWFs) thereby disrupting the HF communication as well as the VLF radio systems. During CMEs and Coronal Holes, bubbles and tongues of solar plasma, weighing billions of tons, are released violently along with the frozen-in magnetic fields. The material from these ejections takes several days to hit the planetary environments, but when they hit, the effects on the environment are spectacular. An important feature of solar flares, CMEs and coronal holes is that these events occur more frequently during the solar maximum than during the solar minimum. However, it is to be noted that the coronal holes are regions with open magnetic field lines in contrast to the anchored field lines observed in EUV or X-ray and only during a reconnection event between field lines originating from coronal holes and bipolar anchored field lines present in the vicinity of the holes, an energetic event may take place.

Apart from the EM radiations, the other source of energy from the sun is the solar wind – the solar corpuscular radiation blown continuously as a hydrodynamic expansion of the solar corona. Although the energy carried by solar wind is only one millionth of the energy in the solar spectral irradiance, variability in its velocity and plasma density could bring in profound effects in the planetary environments – at the Earth by influencing its magnetosphere and at Venus and Mars by interacting directly with their atmospheres and ionospheres. Near the Earth, for example, the solar wind velocity has been seen to vary by as much as a factor of five (200 km/s to 1000 km/s) while the density has been observed to vary by about a factor of 200 (0.4 cm^{-3} to 80 cm^{-3}). These variations give rise to significant changes in the dynamic pressure of the solar wind which is a key factor in controlling the planetary environments.

The periodic changes like the diurnal, seasonal and solar cycle in the solar irradiances determine the climate while solar flares and CMEs determine the weather of the planetary environments. These in together defines the Space environment of any planet.

The Earth :

The plasma environment of Earth has been under experimental investigation right from the second quarter of the last century, initially with ground-based instruments like ionosondes and later with several plasma probes flown on rockets and satellites.

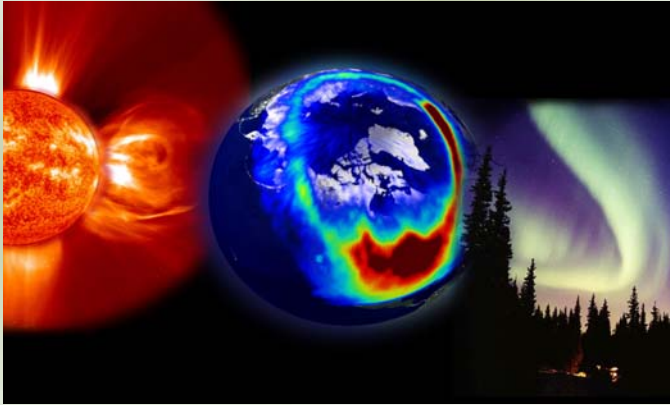


Figure 1: Schematic of Sun Earth energetic interaction with first of its visual signature: the Auroras

Another sophisticated technique, the incoherent –scatter radar, has also been in vogue since the early sixties. These ground based and space based techniques resulted in gathering of vast amount of experimental data. This data has since been used to construct empirical models of the Earth's plasma environment. These models take account of diurnal, seasonal and solar cycle changes in the plasma environment and thus are routinely used for specifying space climate of Earth one of the most often used model is the IRI (2000). However, space weather studies are still in an infancy stage and a lot of experimental, analytical and theoretical work needs to be done before reaching a modeling stage. In the following we discuss a few space weather issues which we propose to attempt in our work.

Solar flares and upper atmosphere / ionosphere:

Solar extreme ultraviolet (EUV) and X-ray photons ionize the atmospheres of Earth and other planets and create the planetary ionospheres. On terrestrial planets, photons in the main part of the solar EUV spectrum, from about 25 nm to 91 nm, create the upper part of the ionosphere, called the F-region; soft X-rays with wavelengths less than 15 nm create the E-region and on earth Lyman- α radiation, by ionizing the minor neutral constituent nitric oxide, create the D-region. However,

during occasional events like solar flares, as pointed out earlier, emissions in the X-rays and in some EUV lines get enhanced, with larger enhancements in wavelengths below 2.0 nm and relatively smaller enhancements in wavelengths higher than 2.0 nm. These enhanced emissions, as pointed out earlier, have been seen to cause sudden and intense ionization at various levels in the Earth's ionosphere, resulting in sudden ionospheric disturbances (SIDs) and radio fadeouts.

Ionospheric effects of these sudden enhancements in electron density have been extensively studied in the past and most of the early studies on ionospheric effects were based upon ground based experiments and generally dealt with the effects in earth's lower ionosphere, that is the ionospheric D-region and were identified on the various ionosphere monitoring instruments as: [1] sudden enhancement of atmospherics (SEA), [2] sudden phase anomaly (SPA), [3] sudden enhancement of field strength on LF and VLF (SES), [4] short wave fadeout (SWF) and [5] sudden cosmic noise absorption on HF (SCNA) . These effects were basically caused due to the creation of extra ionization in the lower ionosphere (i.e. D-region) produced by x-ray photons below wavelengths of 1.0 nm.

Early evidences of solar flare effects in the upper ionosphere were provided by ground based measurements from the; [1] increase in the critical frequency of the F2-region with ionosonde, [2] increase in electron density in the E and F1 regions with incoherent-scatter radar and [3] sudden change in frequency of the carrier of an ionospherically propagated HF wave, called sudden frequency deviation, SFDs, among others. Unfortunately, the first two techniques could not provide the desired high time-resolution, while the third technique had limitation on the spatial and altitude location of the effect. However with the advent of space based techniques, especially the radio beacons, it became possible to examine the solar flare effects in the upper ionosphere, not only with high time but spatial resolution also.

By the end of sixties and in the beginning of seventies, the solar flare effects in the upper ionosphere was identified from the sudden increase in the total electron content (SITEC) for different flares. A number of attempts were to present the global morphology of flare

impact using number of stations where a large increase was seen in lower latitude in comparison to others.

Studies on SITEC saw a high level of activity with the development of new technology of GPS ground and satellite receivers. Consequently GPS receivers at several stations were installed to monitor changes in TEC with high time and spatial resolution and soon solar flares in the upper ionosphere were examined. The four most intense flares measured - one on July 14, 2000 (Bastille Day event) and the other three during the Halloween events of October 28, 29 and November 04, 2003, generated a lot of activity on the study of solar flare effects with the GPS techniques.

CMEs and Solar Wind:

Among the other important space weather agents are the coronal mass ejections (CMEs), the large expulsion of mass from the Sun. These are generally associated with solar flares and the faster ones (1000 km s^{-1}) are sources of high energetic particles which result in severe geomagnetic storms. These storms occur with delays of 1 to 4 days after the release of the energetic particles.

Effects of these disturbances have generally been examined in the past under the broad area “magnetic storms”. We now know that magnetic storms do not affect the Earth’s space environment. These are indeed manifestations of solar disturbances which modify Earth’s magnetic field through changes in the solar wind conditions. The real parameters which, through a chain of processes, control the space weather are the solar wind, its dynamics pressure, and the direction of the Interplanetary Magnetic Field (Southward IMF is more geoeffective than the northward IMF). Ionospheric response to these disturbances may vary due to the time of occurrence, electrodynamical processes, chemical composition and neutral winds. These disturbances lead to positive or negative ionospheric storms. The geomagnetic storms, the after effects following CMEs, are accompanied by variety of ionospheric disturbances, which are basically caused by the intensification of the solar wind. In storm time, a portion of solar wind energy is transferred to the magnetosphere, causing earth’s magnetic field to change rapidly. The energy input from the magnetosphere during geomagnetic storms causes a sequence of rapid changes in the global upper atmosphere and ionosphere. High latitude ionospheric

electric fields promptly penetrate to low latitudes during the main phases of the storms. The electric fields known as prompt penetration electric fields (PPEF) have eastward polarity in the dayside and westward polarity in the nightside. The eastward PPEF enhances the net daytime eastward electric field over the equator. However, if the eastward PPEF occurs in the background of storm time disturbance dynamo electric fields (DDEF), which is westward during daytime, the net daytime electric field over the equator can be eastward or westward or null depending upon the strengths of the PPEF and DDEF.

Mars and Venus:

Magnetometer measurements on the Pioneer Venus Orbiter, PVO and the Mars Global Surveyor, MGS have established beyond doubt, that Venus and Mars are non-magnetic planets. As a result, solar wind interacts directly with the atmospheres and ionospheres of these planets. This direct interaction results in mass loading of the solar wind with the ions generated through the ionization of the neutral constituents. At the same time the ionospheres of these planets provide the highly conducting obstacle to the solar wind, the consequence of which is the formation of the ionopause – the upper boundary of the ionosphere of these planets. The ionopause, occurs at an altitude where the solar wind dynamic pressure is balanced by the ionospheric plasma pressure. During solar storms (i.e. Solar Flares, CMEs and Coronal Holes), the speed as well as the particle density of the solar wind goes through major changes thereby effecting the space environment of these planets.

Mars:

Mars is substantially exposed to the harshest elements of space weather. Unlike Earth, which sits inside a protective magnetic bubble called the magnetosphere, as mentioned before, Mars does not have a global magnetic field to shield it from solar flares and cosmic rays. Scientists aren't sure why, but Mars' internal magnetic dynamo turned off about 4 billion years ago. After that, the solar wind gradually eroded the martian atmosphere until, today, it is less than 1% as thick as Earth's. Absence of global magnetic field and a very thin atmosphere render Mars vulnerable to space radiation. Plasma environment of Mars has been under exploration right from the start of space era with missions like

“Mariners” by the USA and “Mars” by the USSR. The Martian ionosphere has been studied mainly by the radio occultation technique. In this technique a radio signal at a few cm wavelengths is transmitted by the spacecraft to Earth and as it enters behind or come out from the far side of the planet, the signal is modulated by the neutral atmosphere and ionosphere. There is a Doppler shift in the frequency of the signal received which is then used to derive neutral temperature of the lower atmosphere and electron density in the upper atmosphere. The radio occultation technique initially on Mariner 9, Viking 1 and 2 and recently on Mars Global Surveyor has provided a large data bank on the Martian ionosphere. MGS-RS data has been used extensively for studying atmospheric/ ionospheric dynamics, effect of solar irradiance on Mars ionosphere, Earth- Mars comparison, solar activity effects, morphology of near terminator ionosphere and on anomalous features related to ionospheric density profiles. However, there has been little work on space weather, except for a few studies on solar flare effects where elevated electron densities have been seen in the Mars E-region during all flares and in the F1-region during some flares. Solar wind interacts directly with the atmosphere and ionosphere of Mars and this makes the space weather at Mars very turbulent and uncertain. The electron density profiles observed at Mars have raised several questions. It has been pointed out by researchers that almost all the electron density profiles at Mars are greatly depressed. This depressed nature of topside profiles has been explained on the basis of strong horizontal magnetic fields observed by the MAG/ER instrument on the Mars-Global Surveyor spacecraft. These fields observed at Mars are expected to occur during “overpressure” conditions, when the solar wind dynamic pressure exceeds the ionosphere plasma pressure. At Mars this is often the case, since Mars ionosphere is rather weak. However, it has been noted that the horizontal ionospheric magnetic fields induced due to solar wind interaction do not affect the plasma distribution in the topside ionosphere of Venus. We know that the response to electron density profile because of solar flare is rather spontaneous (short lived) followed by the delayed effect shown due to solar wind. The depressed topside profiles at Mars and Venus in the ionopause regions by Viking 1 and Viking 2 are shown in Fig. 2.

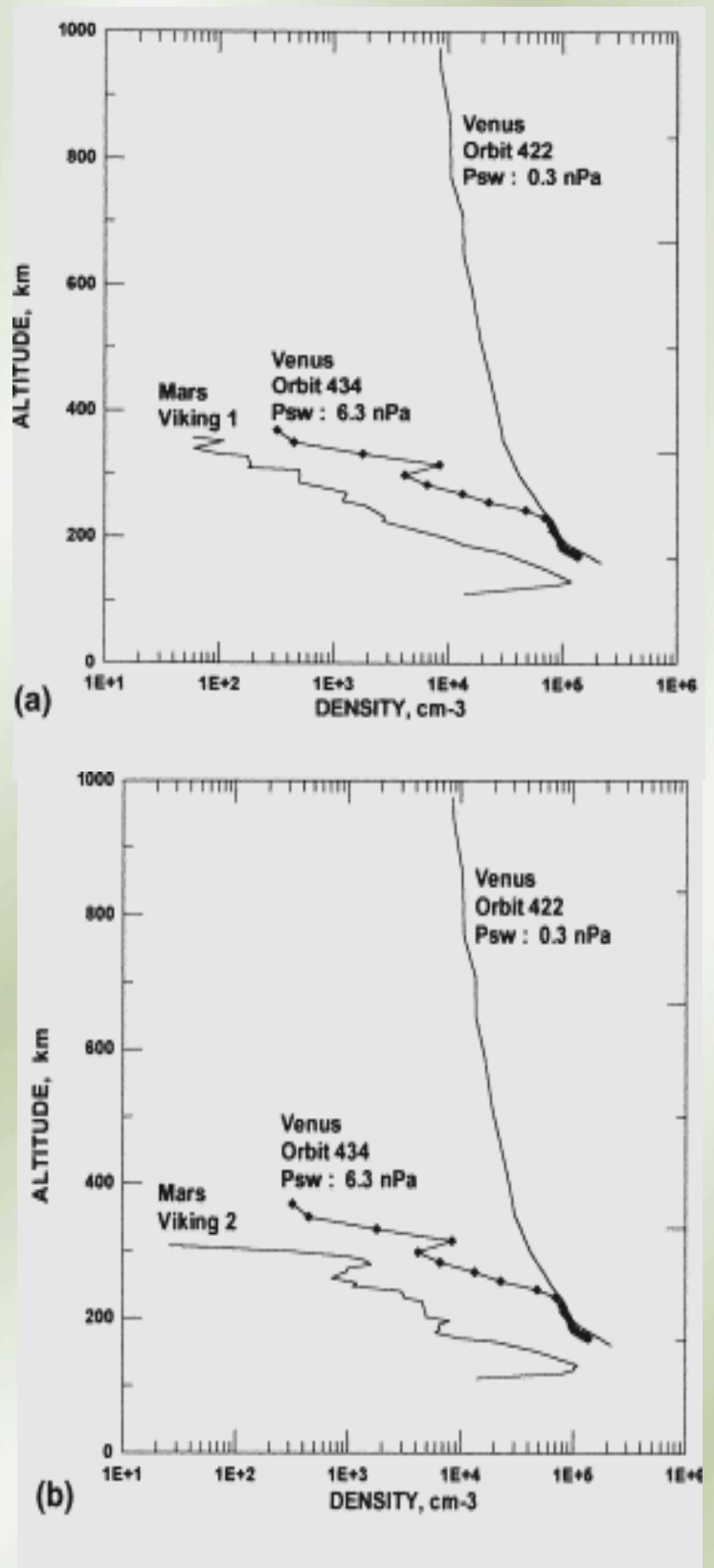


Figure 2 : A comparison of electron density profiles at Mars with those at Venus. For Venus sample profiles during low and high P_{sw} are given. The depressed topside profiles at Venus and Mars represent the ionopause regions; (a) Viking 1, (b) Viking 2.

There are rather insufficient simultaneous study of flare on Mars and Earth to see the effect of flare and solar wind (CME) The MAG/ER instrument on MGS has firmly established that a large-scale global intrinsic magnetic field is absent at Mars. However, some highly variable and very localized magnetic fields of crustal origin have been discovered there, which could be as high as 400 nT at 108—113 km altitude in the northern hemisphere and 1500 nT in the southern hemisphere. These regions have been given the name, regions of the magnetic anomalies.

Venus:

Plasma environment of the planet Venus has been under exploration right from the advent of space age. Mariner-2 was the first spacecraft to fly by the planet Venus in 1962 and as many as 17 spacecraft missions since then had Venus as their target. The climax however reached with Pioneer Venus Orbiter, PVO which provided a large amount of data on the space environment of Venus. The Pioneer Venus Orbiter had several atmospheric-ionospheric experiments onboard giving information on the atmospheric composition, ion composition, electron and ion concentration and their temperatures and ion drift velocities. This spacecraft provided altitude profiles of important ionospheric parameter by direct measurements for each Earth day for 600 days throughout the first phase of the mission. This covered almost three diurnal cycles.

The long set of direct measurements on the PVO for 3 diurnal cycles has provided a good data base of ionospheric parameters like electron density, electron temperature, ion and neutral density, neutral temperature, solar wind, magnetic field of Venus, especially during the year 1979-1980 when the periapsis was kept near 150 km, that is near the ionospheric peak. Based upon these measurements, empirical models of upper atmosphere and ionosphere of Venus, like the ones for the Earth, have since been generated and thus the “space climate” of Venus is now somewhat known. Further the electron density profiles and magnetic field data obtained from the Venus Express Radio Science Experiment (VeRa) on Venus Express will also be used to examine the Venus Ionosphere. However, as on the Earth, the space weather at Venus is quite uncertain, highly variable and mainly depends upon solar wind conditions, modulated by Solar Flares, CMEs and Coronal Holes.

Neutral Atmosphere of Venus:

Venus has about the same mass as the Earth and therefore due to its gravitational pull, it has an extended atmosphere. In the lower atmospheres, CO₂ dominates while O and He dominate at higher altitudes. Scale heights of the neutral constituents indicate exospheric temperature of about 300 K during the day and 100 K during the night. While the dayside temperatures are quite stable 300±10K, the nightside temperatures show a large variability 100 ±50K. This large variability is also seen in the densities. While one could explain this variability on the basis of a turbulent motion in the atmosphere below, a look for a causative mechanism of this motion is needed.

In addition to the large variability in the thermospheric temperatures and densities, Venus thermosphere was also found to nearly disappear on two occasions. That is the density values depleted by nearly an order of magnitude and then gradually recovered on subsequent orbits. This observation thus needs to be explained. A distinctive temperature enhancement was observed in the dayside thermosphere on one occasion when solar wind pressure (P_{sw}) was unusually high for a prolonged period. Minor enhancements of exospheric temperature (T_{ex}) were also observed in few cases with sustained but moderately high P_{sw} . However no linear relationship between P_{sw} and T_{ex} was found. This strange response of the dayside thermospheric behavior to solar wind is still an unresolved issue.

Plasma Environment at Venus:

PVO measurements indicate large diurnal and solar activity variations in the plasma densities of Venus. Although the dayside ionosphere is very stable, the “solar storms”, in the form of changing solar wind conditions, bring in a lot of variability in the Venus ionosphere following the large excursion in the upper boundary of the ionosphere. This boundary, called the ionopause (defined as 100e/cm³ altitude), could vary anywhere between 300 to 1000 km, in response to changes in solar wind dynamic pressure, obviously related to CMEs and Coronal Holes. These large excursions in the ionopause altitude result in large changes in the electron and ion concentration thereby resulting in very turbulent space weather in the Venus topside ionosphere.

While the changes in ionopause altitude have been extensively studied by several researchers, the structure of ionopause is still poorly understood. The plasma experiments have shown that the ionopause current layer is rather thick when it is located at lower altitudes (which happens during episodes of high Psw). However this current layer becomes thinner when the ionopause is located at higher altitudes (which happens during conditions of low Psw). While the low altitude thick ionopauses were explained on the basis of the role played by neutral atmosphere no suitable explanation is yet available for the existence of thin current sheet when the

ionopause occurs at higher altitudes. This is yet another problem area which needs to be resolved.

An important observation on the solar wind interaction at Venus has been the discovery of large scale horizontal magnetic fields during episodes of very high solar wind dynamic pressure, especially when this pressure is more than the ionospheric thermal pressure. Under these overpressure conditions, horizontal magnetic fields as high as 200 nT have been found to exist in the Venus ionosphere. These horizontal magnetic fields are expected to inhibit plasma diffusion at altitudes above about 200 km and grossly effect the shape of the plasma density profiles. An examination of several electron and ion density profiles measured by electron temperature probe and ion mass spectrometer on the PVO during episodes of overpressure conditions have shown that these profiles are not significantly affected by the horizontal magnetic field.

While the neutral atmosphere of Venus has shown some severe changes in its densities and some changes in the exospheric temperatures in response to high Psw conditions, the role of solar wind in heating the ionospheric plasma is not yet established. Although the gradients in the electron and ion temperatures at Venus were initially explained on the basis of solar wind heating, the discovery of horizontal and turbulent magnetic fields at Venus (which can inhibit electron and ion thermal conduction in the ionosphere) has provided alternate explanation for the observed plasma temperature profiles. Therefore, a detailed analysis of the measured plasma temperatures and the prevailing solar wind pressure, as well as of the observed ionospheric magnetic fields is necessary to settle the question of solar wind effect on plasma temperatures.

Conclusion:

The Sun is the primary source of the electromagnetic energy which creates the space environments of all the planetary bodies including the terrestrial planets, Earth, Venus and Mars. While space climatology of any planetary environment, conventionally defined as region more than 100 km above the surface, is essentially controlled by UV and EUV part of the electromagnetic spectrum, space weather, on the other hand, is dictated by events like solar flares and coronal mass ejections (CMEs). These events produce changes in solar photon fluxes and in solar wind dynamic pressure, by modulating its speed, particle density and temperature. On Earth, solar wind conveys its effects through a sphere of magnetic lines enveloping the earth, called the magnetosphere while on the non-magnetic planets like Venus and Mars, it interacts directly with neutral and plasma environment of these planets. Space Weather, at all the terrestrial planets is extremely variable and can show up in the form of significant changes in the neutral and plasma environment of these planets.

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Analysis of a Volcanic Lava Tube on the Moon Using Chandryaan-1 TMC Sensor. A Possible Habitat for Future Lunar Base

Chandryaan-1, India's first planetary mission to Moon was successfully launched on October 22, 2008. It was equipped with eleven scientific payloads useful for collecting wide range of lunar information. Amongst these, one of them was SAC's contribution; Terrain Mapping Camera (TMC)-having 5m spatial resolution. The camera had multi-viewing capability, enabling 3 dimensional view of the lunar surface fig. 1.

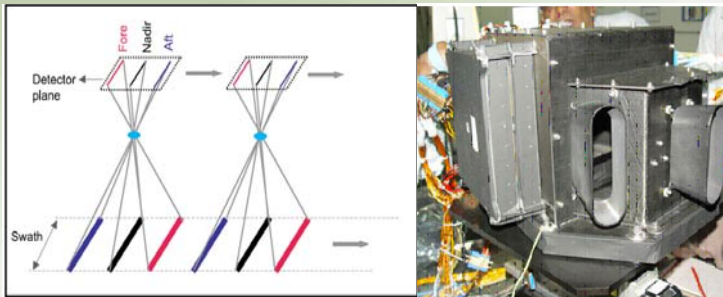


Figure 1: Viewing Geometry and flight model of TMC, Sources: Kiran Kumar and Chowdhury, 2005; www.isro.gov.in

It showcased its capability by capturing the lunar surface features with an intriguing clarity and technical fidelity. Since the Moon is devoid of atmosphere and intrinsic magnetic field, it is highly vulnerable to meteoritic impacts, radiations and energetic particles making human settlement entirely impossible. Despite of this, there are few regions such as volcanic tubes and rille systems, which are shielded from these effects and thus could possibly serve as significant favourable sites for a Permanent Base Station (PBS). These may be adequate for human settlement which is an important perspective for long term research and development in outer space.

Lava tubes are formed when an active low viscosity lava flow develops a continuous hard crust due to radiative cooling of its outermost part, which thickens and forms a solid roof above the still flowing lava stream beneath. At the end of the extrusion period, if the lava flow conditions were ideal in terms of viscosity, temperature, supply rate and velocity, an empty flow channel free from molten magma is left behind in the form of a tube. This is an approximately cylindrical shaped tunnel below the surface, termed as a volcanic tube. A rille is a remnant of volcanic tube, whose roof has capsized and a valley is created. However, at places the roofs of such tubes do not collapse and remain intact, with a hollow interior in most cases.

In terrestrial analogy, field data from Hawaii islands (Fig. 2a) have shown that majority of the lava tubes are partially empty i.e. approximately only 30% of the tubes are filled by the later flows and <1% of them are found completely filled by the later flows (e.g., Makapu'u Tube, Oahu, Hawaii). The inside view of a hollow lava tube in Hawaiian Islands is shown in Fig. 2b. The bench mark on the right wall indicates the level at which the lava flowed in the tube during a specific period of time. In general, planetary lava tubes are interpreted indirectly from the 'sky-light holes', believing them to be linked to imaginary hollow tubular structures beneath the surface.



Figure 2a(Top): A partially collapsed terrestrial lava tube in Hawaiian Islands. The intact roof of the hollow tube is seen on the far end.

Figure 2b(bottom): Thurston Lava Tube in Hawaii Volcanoes National park, Hawaii, Source: <http://en.wikipedia.org>

Until now, no significant effort has been made to envisage and assess the dimensionality and safety paradigm of any candidate lava tube as a potential habitable site. Here, an attempt has been made to study a

lunar lava tube in a non conventional way by scientifically analyzing the tube and its geologic vicinity.

box), whose roof has still remained intact over time, could be used for future habitability and a permanent base station on the Moon.

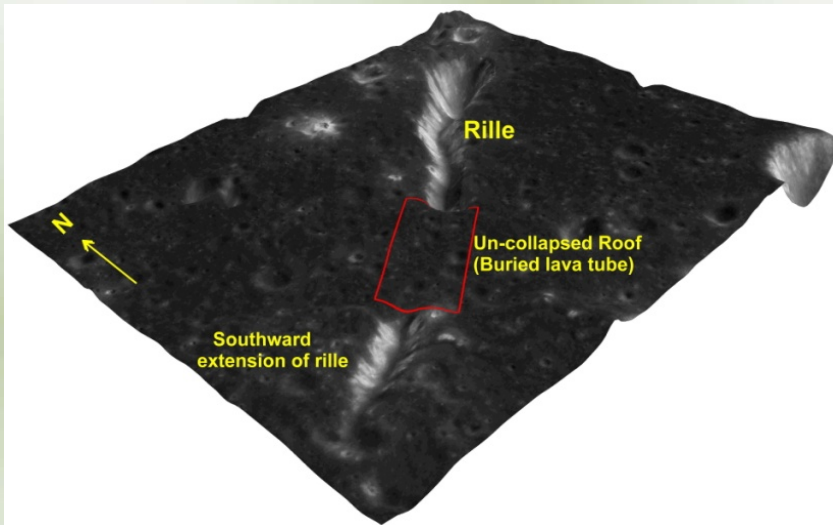


Figure 3: A 3D perception of the study area from TMC. The un-collapsed portion is shown enclosed in a red box (Source: Arya et al., 2011)

In the present work, a buried uncollapsed, near-horizontal lava tube has been detected and analyzed using TMC ortho-image as well as DEM (orbit 798). This is located between two collapsed rilles in Oceanus Procellarum (Fig. 3). Topographic profiles were studied across and along the lava tube. Further, the morphometry of the rille and its adjoining areas were also examined using TMC-DEM data. HySI (Hyper Spectral Imager) was used to decipher the variations in the surface composition. It was

Two rilles were identified of which the primary rille, a cobra-hood shaped feature has a length of around 3.9 km running in NE-SW direction whereas the other one is 1.9 km long and runs SW of the existing rille. It is plausibly an extension of the primary tube and the intermittent region between the two rilles appears to be a near-flat roof of an underground, still uncollapsed lava tube. In order to establish the spatial continuity between these two rilles, TMC stereo images have been used to derive cross sectional profiles to acquire information regarding the length, depth and slope. It has been observed that the smaller rille is aligned and lower compared to the main rille indicating its continuity with the primary rille.

A contour map (colour coded) of the area around the rille was generated using TMC-DEM (Fig. 4). The relief difference in the study area have been found to be ~240 meters, varying from -1120m to -1360m. A drop in the altitude from E to W, by about 150 m (-1150 to -1300 m depth) has been observed which rules out any likelihood of lava flow from the western regions filling the portion separating these two rilles after their emplacement.

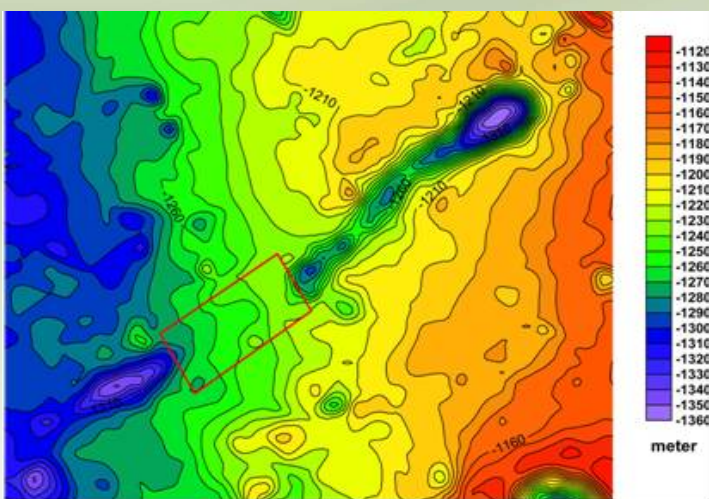


Figure 4: A contoured depiction of the study area (Source: Arya et al., 2011)

observed that the two rilles which may be sub-surficially connected by the undamaged lava tube (shown in red

The rille dimensions calculated using the ortho-image and DEM showed that the total length of the rille including the intermittent un-collapsed lava tube was approximately 7.36 km and the altitude varies from -1358 m to -1200 from E to W. Topographic profile along this rille was also analyzed in detail and the diameter of the assumed cylindrical tube has been estimated to be 120 m from the DEM. The length of the un-collapsed portion is 1.72 km and the approximate surface area and the volume have been found to be 0.65 km² and 0.02 km³ respectively. The roof thickness of the un-collapsed portion has been estimated using the empirical relation of crater geometry “ $t = d \times 0.25 \times 2$ ”, where t is the estimated thickness of the tube segment and d is the maximum crater diameter superposed on the tube segment. In

the present work, the maximum crater diameter on the un-collapsed portion of the lave tube has been found to be 140m therefore the estimated roof thickness is ~ 70m.

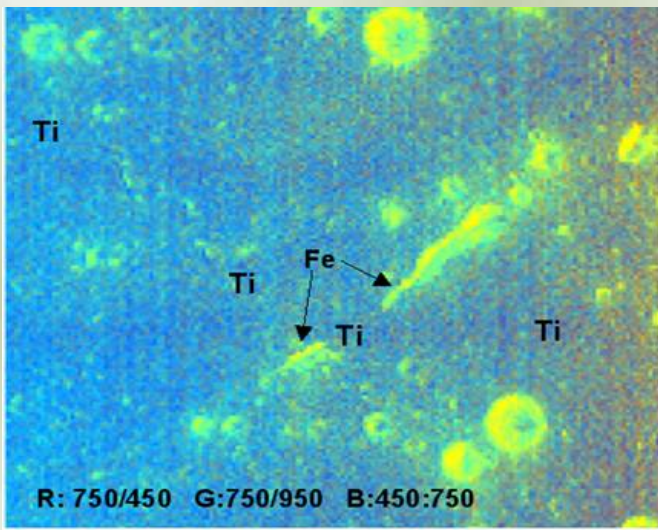


Figure 5 A HySI derived surface composition map of the study region showing variation in Fe and Ti (Source: Arya et al., 2011)

Surface compositional study using Hyper Spectral Imager (HySI) having 64 contiguous bands in the spectral range of 0.4 to 0.95 μm have also been carried out. The FCC of the lunar surface generated using R: 750/450; G: 750/950; B: 450/750 band combinations showed the iron rich surfaces as green to yellow while the titanium rich surfaces as blue. The areas within and outside the rilles have been found to be rich in Fe and Ti respectively, indicating compositional homogeneity within the un-collapsed part of the rille system and also within the surrounding areas. It also signifies that the portion between the two rilles may be the un-collapsed roof of one single lava tube. The surface composition map of the study area is shown (Fig. 5).

To further rule out possibility of lava flooding in the regions north and south of the rille/lava tube, crater-counting technique has been used to determine the age of these surface units. It has been estimated that age of the northern part is around 3.47 Ga whereas the southern part is 3.43 Ga old, which is nearly the same, minimizing the possibility of multiple effusion of mare basalts across the Rille.

Thus, from this study we infer that this lava tube can serve as a suitable and safe structure for future human habitation. Also, the estimated roof thickness is sufficient to protect the inhabitants and the engineering equipments

from the impacting bodies, exposure to extreme temperatures, energetic particles and cosmic rays and thus may possibly serve as a plausible lunar base on the Moon.

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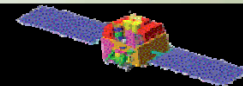
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MISSION STORY - ASTROSAT



After India's successful ongoing planetary endeavours, now it is all set for a long awaited Indian astrophysical observatory in space, ASTROSAT. ASTROSAT, short for Astronomy satellite, is the country's first mission devoted for astronomy and is a collaborative effort of ISRO and various astronomical research institutes across the nation along with foreign collaborators. For the first time, Astrosat will enable simultaneous multi-wavelength observations of cosmic sources of the universe on a single platform. The mission is expected to point and observe these celestial objects for long durations providing data from visible to hard X-ray energy band. It will also provide the best angular resolution UV images and very high time resolution X-ray timing data. The spacecraft with its suite of instruments will study sources ranging from new born stars, exotic stars in clusters, compact objects like neutron stars and black holes and distant galaxies. These observations will enable scientists to carry-out frontier research in multi-wavelength astronomy thus enabling them to understand the physical processes behind the phenomena and address many unresolved problems.

Launch and Mission Configuration: Astrosat is scheduled to be launched onboard PSLV around mid 2013 with an operating life span of 5 years. With a total launch mass of 1,550 kg and a payload mass of 750 kg, the satellite will orbit at a height of 650 km. The spacecraft utilises the heritage of IRS and Cartosat-2 for some of its sub-systems. The spacecraft will beam down the stored data in X-band at a rate of 105 Mbits/s during realtime passes.

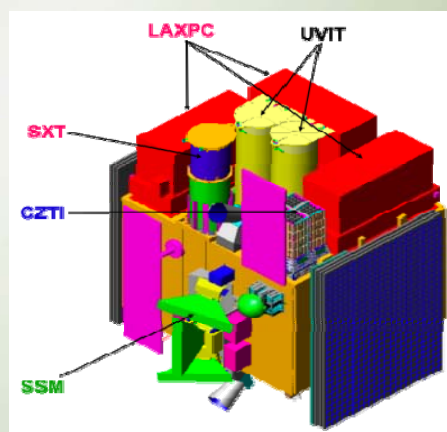
Science Goals: Astrosat is expected to carry out a range of experiments covering the UV, optical and X-ray bands. Broad band optical and hard X-ray observations are effective in investigating a range of astrophysical sources, covering compact binaries to galactic nuclei. The 5 instruments on-board will carry out observations in the visible (320-550 nm), near UV (200-300 nm), far UV (130-180 nm), soft X-ray (0.3-8 keV and 2-10 keV) and hard X-ray (3-80 keV and 10-150 keV) regions of the electromagnetic spectrum. It will also carry out low to moderate resolution spectroscopy covering wide energy band with its main interest on the studies of X-ray emitting objects. Some of the key goals of the mission are as follows:

- Simultaneous multi-wavelength monitoring of intensity variations of cosmic sources over a broad energy range.
- Monitoring the X-ray sky for new transients
- Sky surveys in the X-ray and UV bands of specific regions in the sky

- Broadband spectroscopic studies of X-ray binaries, AGN, SNRs, clusters of galaxies and stellar coronae
- Photometric and spectral study of UV emitting objects like young stellar objects, sources in stellar clusters, star formation regions etc.
- Studies of periodic and non-periodic variability of X-ray sources

Instruments:

ASTROSAT carries six payloads designed for various scientific investigations. The instrument design and description is given below:



The Ultraviolet Imaging Telescope (UVIT): It consists of two RC telescopes with photon counting detectors to carry out simultaneous imaging in three channels: near-UV, far-UV and visible bands- and to obtain slit less spectroscopy with a resolution of ~ 100 .

Soft X-ray imaging Telescope (SXT): An X-ray imaging telescope with conical foil mirrors and X-ray CCD detector, covering the energy range of 0.3 to 8 keV, designed to carry out broad band spectroscopy and arc min imaging.

The Large Area X-ray Proportional Counter (LAXPC): It consists of 3 Xenon filled proportional counters covering the energy range of 3-80 keV and will be used for X-ray timing and spectroscopic studies and observations at high energies.

Cadmium Zinc Telluride Code Mask Imager (CZTI): It carries a hard X-ray imager consisting of a pixilated Cadmium-Zinc-Telluride detector array with a coded mask aperture of $\sim 500 \text{ cm}^2$ geometric area with good detection efficiency.

Scanning Sky Monitor (SSM): Consists of three position sensitive proportional counters, each with a one-dimensional coded mask, will be used to detect and locate x-ray transients in the energy band of 2-20 keV.

Charged Particle Monitor (CPM): An auxiliary instrument used to signal regions of high charge particle background to aid the operations of the LAXPC, SXT and SSM

MISSION UPDATES

(Source: Websites of various space agencies, press releases and published articles)

Historic 100th mission, PSLV-C21, successfully launched by ISRO

The Indian Space Research Organisation (ISRO) successfully launches its 100th and historic mission PSLV-C21 on Sept. 9, 2012. A 760 kg French remote sensing satellite, SPOT-6, and 15 kg satellite, PROITERES from Japan have been placed in orbit. ISRO has so far launched 63 Indian satellites and 36 indigenous rockets making PSLV-C21, the 100th mission since the launch of its first satellite Aryabhata in 1975.

Indian Mars Mission formally announced

The prime minister of India, Dr. Manmohan Singh formally announced the first Indian Mission to Mars on the 66th Independence day, Aug. 15, 2012. Indian Mars Mission will be aimed at studying the Martian atmosphere and expected to be launched onboard an extended version of Polar Satellite Launch Vehicle (PSLV).

DAWN leaves VESTA, cruising towards CERES

On Sept. 4, 2012, the DAWN spacecraft has left the giant asteroid VESTA and now on its way to explore CERES. Earlier DAWN arrived at VESTA in July 2011 as a part of its 5-billion km journey to explore two massive objects of the asteroidal belt. DAWN is expected to reach CERES in early 2015. Using its hyper-efficient ion-propulsion system DAWN has gently spiralled away from the gravity of VESTA to cruise towards CERES. The spacecraft also captured two spectacular images of the giant asteroid while leaving to its new destination.

MSL rover Curiosity successfully lands on Mars

Mars Science Laboratory rover, Curiosity, lands successfully after adhering to the most complex landing ever attempted on the red planet on Aug. 5, 2012. Curiosity was landed using a sky crane near the foot of Mount Sharp inside Gale crater. Curiosity will spend next two years at the site to inspect whether there ever existed conditions favouring microbial life.

Curiosity starts rolling on after upgrade, returns high resolution images and voice

MSL rover Curiosity started its work on the red planet after initial checkups and a critical software upgrade. Soon after landing, Curiosity's redundant main computers have been installed with "smarts" software to augment surface operations on Mars. Curiosity now started returning spectacular high resolution color visuals of the Gale Crater. Curiosity also started a trek nearby from its landing site, now called as Bradbury. On the other hand, a pre-recorded voice message by NASA Administrator, Charles Bolden was beamed back to Earth via Curiosity. Curiosity is now preparing itself for science operations.

GRAIL twins in Extended Mission

After a successful primary phase, GRAIL twins, Ebb and Flow, now started collecting data on Aug. 30, 2012, in their extended science phase. The extended phase that will go through Aug. 30 - Dec. 3, 2012 is expected to have an even closer look at the lunar gravity field. The data collected during the primary phase is being currently analysed.

Juno performs Deep Space Maneuver, changes orbit

Jupiter-bound spacecraft, Juno, performs a deep space maneuver on Aug. 30, 2012 to refine its trajectory for a gravity-assist flyby of Earth on Oct. 9, 2013. With this configuration, Juno is expected to reach Jupiter on July 4, 2016. Juno has also executed a second successful Deep Space maneuver on Sept. 14, 2012.

Kepler outperforms reaction wheel failure, updates data and continues discoveries

Kepler spacecraft performance seems to be excellent even on three reaction wheels. It is known that one of the reaction wheels failed in mid-july due to an irrecoverable hardware failure. Monthly science data has also been recently downloaded during Aug. 29-30, 2012. Meanwhile Kepler discovered Multiple transiting Planets, Kepler-47b and Kepler-47c, orbiting two stars for the first time. This circumbinary planetary system is in the Cygnus constellation, 4900 light-years away from Earth.

Messenger celebrates 8th anniversary and releases data to PDS

Messenger, the first spacecraft to orbit mercury has completed eight years since its launch on Aug. 3, 2004 on a 5.9 billion-kilometer journey. Since its inception itself, the mission started capturing breakthrough images and science information from outer space. On reaching Mercury, the spacecraft has performed the first global reconnaissance of the planet. The mission is now operating in its extended phase. On the other hand, data collected by the spacecraft during seventh through twelfth month in orbit has been released to the public through the Planetary Data System.

Voyager completes 35, reaches stagnation region

Voyager 1 spacecraft launched to explore outer solar system objects has completed 35 years of its journey (of nearly 18.2 billion km) since its launch on Sept. 5, 1975. The spacecraft has now reached a new region called, stagnation region, between our solar system and interstellar space.

EVENTS

➤ **39th COSPAR Scientific Assembly, Mysore, India**

Recently Mysore has witnessed a conglomeration of global space scientists as a part of COSPAR Scientific Assembly, the world's largest inter-disciplinary forum of space scientists. Committee on Space Research (COSPAR) was found in 1958 by the International Council for Science (ICSU) and considered as one of the leading global space science research association. COSPAR, which is open to scientists of all disciplines of space science, aims to promote scientific research in space on an international level through exchange of results/information and providing a discussion forum for new ideas/pathways for future space exploration. To accomplish these objectives is COSPAR organises scientific assemblies. This biennial assembly which acts as a focal point for international space science is conducted in different member countries.

The 39th COSPAR Scientific Assembly with the theme “**Space - for the benefit of Mankind**” was recently organised during July 14-22, 2012 by the Indian Space Research Organisation (ISRO) at

Narayana Murthy Centre of Excellence (Infosys Training

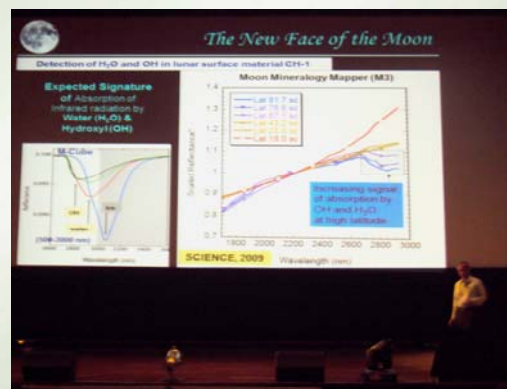
Centre), Mysore, Karnataka, India. Nearly 2500 delegates (Scientists and Students) from 75 countries attended the week-long meeting. The assembly included over 630 sessions and more than 3600 scientific papers and posters were presented. Apart from scientific sessions, Plenary sessions, Inter-disciplinary and Public lectures, Commission meetings, Award Ceremony and other Associated Events were also organized. As per the theme, the meeting was convened into four key topics: Fundamentals of Space Science, Relevance of Space Science, Applications and Technological innovations. The deliberations were held under various scientific sub commissions A-H of COSPAR. These Scientific Assemblies allow presentation of the latest scientific results, exchange of knowledge and also the discussion of space related problems.

COSAPR-2012 commenced with a special event - *International Academy of Astronautics (IAA) day* on July 14, 2012. Nearly 200 participants attended the IAA meeting. Discussions on various topics such as Meghatropiques, the role of clouds in earth's climate (Cloudsat mission), NASA's GRAIL mission etc. were held during the meeting. The IAA day concluded with *Heads of Space Agencies Summit Follow-on Round Table on Robotic Space Exploration* with NASA, ISRO, CNES and CSO. Discussions about involving space emerging countries into new space programs have been carried out by heads of various space agencies.

The formal inauguration of the assembly was held on July 16, 2012 which also included a round-table meeting of representatives of leading space-faring nations, *Space Vision 2020 – and Beyond* under the chairmanship of Prof. U.R.Rao, Former Chairman-ISRO. At this inaugural session, Dr. Radhakrishnan, Chairman, ISRO mentioned “The international synergy will cut cost of access to space resources and exploring inter-planetary solar system”. M.S. Allen (Director, NASA, US), Richard Bonneville (Dy. Director, CNES, France), H. Dittus (Executive, German Space Research and Technology Centre), D. Kendall (Director General, Canadian Space



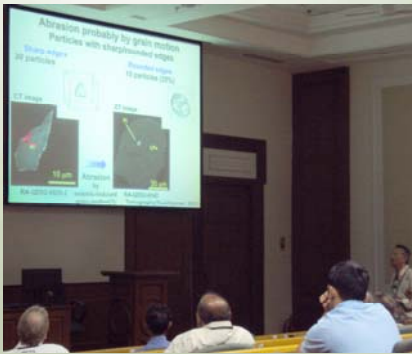
Representatives of various nations at “Space Vision 2020 and beyond” Round Table



Interdisciplinary lecture “The New Face of the Moon” by Prof. J.N. Goswami

EVENTS

Agency), E. Saggese (President, Italian Space Agency), Masato Nakamura (Research Director, Japan Aerospace Exploration Agency (JAXA)) and Thyrso Villela (Chairman, Brazilian Space Agency) participated in the two hour deliberation discussing the road map of future space exploration.



*A talk on results from Hayabusa
(Itokawa Samples)*

Apart from regular sessions, six interdisciplinary lectures were organised during the assembly. The first lecture in this series was delivered by Prof. J.N.Goswami, Director, Physical Research Laboratory on “The New Face of the Moon”. Changing perceptions about the Moon on the basis of recent findings was highlighted in this talk. A public lecture on “Exoplanets” was delivered by Willy Benz, Director, Physikalisches Institut, University of Bern, Switzerland.

All the discussions related to science and exploration of solar system bodies were held under COSPAR Scientific Sub-Commission B. There were a number of parallel sessions covering various aspects of science and exploration of the Moon, Mars, and other small solar system bodies like Vesta and so on. The authors presented recent and exciting results obtained from various missions. The

discussions also included various aspects of exploration of these bodies in future. Some of important discussions concern – an update on Chandrayaan-2 payloads, details of Japanese Lunar Landing Mission SELENE-2, LADEE and Dust measurements by lunar lander, Past, Present and Future of Lunar Seismology, Update on Hayabusa-2 mission, E-Sail Mission to Asteroids, a series of lectures on new measurements and insights about VESTA from DAWN, Atmospheric Helium observations on the Moon from LRO, The lunar Nitrogen Problem, Impact Seismology of Mars, Moon, Jupiter and Small bodies, Future missions such as Insight, Laboratory studies on Planetary analogues and many more. For more details, one can access these abstracts at <https://www.cospar-assembly.org/abstractcd/COSPAR-12/>. This grand event has been successfully concluded with COSPAR Council meeting on July 22, 2012.



*A talk on Seismometer
on INSIGHT for
MARS*

➤ “International Symposium on Atmospheres of Terrestrial Planets”

The study of evolving climate of planets engross co-ordinated understanding of planet's geological processes and morphological features that have formed and advanced while responding to the different stages of changing climate. In particular, the fundamental understanding of planet's climate evolution gears up after having the basic idea of how atmospheres behave and change in different time scales. Earth and Venus's atmospheres evolved to be so different (despite these two planets being very similar and so close to each other) and Mars' has a climate that has drastically evolved from what may have been a comfortable environment for life, to a cold, harsh, and barren world. To embark for answering these basic questions, researchers from across the world gathered to disseminate their knowledge in the “*International Symposium on Atmospheres of Terrestrial Planets*” organized in Physical Research Laboratory, Ahmedabad during July 23-24, 2012. The conference attendees were from all the related space agencies, institutes and laboratories across the world. This two day conference had included plenary sessions that were mainly focused on atmosphere of Sun and Earth, plasma environment of planets, and how the atmosphere of Mars, Venus and Titan have evolved. Recognizing this to be an imperative scientific need, the conference participants showcased their technocratic talents in discussing the complexity involved in developing payloads, that can be flown in future planetary missions for gathering meaningful scientific informations. The experts among the participants deliberately highlighted the key mysteries that are going to be unlocked by the new scientific generation coming-up in this field. The conference concluded after enriching and lightning-up the fundamental understanding of atmospheric evolution of planets and leaving behind several scientific questions, among which one of them that became very popular was, “Understanding the effect of solar wind disturbances on planet's plasma environment”.

ANNOUNCEMENT AND OPPORTUNITIES

- **Thirteenth PLANEX Workshop on “Impacts on Solar System Objects” will be held during 6-12 January 2013, at CSIR-NGRI, Hyderabad.** The Workshop will consist of lectures by experts, group discussions, tutorials, presentations by participants and a three day field trip to Lunar Impact Crater. Based on the performance at the Workshop, interested and highly motivated participants will be offered the opportunities for further intensive training in specialized fields in Planetary Sciences under the PLANEX programme. Final year M.Sc. students in Physics, Chemistry and Earth/Planetary/Space Sciences, final year B.E./B.Tech./M.Tech. students as well as Research Scholars working towards their Ph.D. degree may apply. Applications from Post-Doctoral Fellows and Teachers/Lecturers (below 35 years) will also be considered. Interested students/scholars may write or send e-mail to the following address [S.V.S. Murty (murty@prl.res.in) & P. Senthilkumar (senthilngri@yahoo.com)] before **10th October 2012**, enclosing a brief bio-data, research interests (in ~200 words) and a reference letter from Department Head/Research Supervisor.
- **Course on “Planetary Exploration” as a part of Structured Training Programme (STP) for ISRO Scientists/Engineers.** The course, STP/2012/19, is scheduled to be held at PRL during Dec. 19-21, 2012. The course will be structured to have 1) Lectures by experts, 2) Discussion sessions, 3) Case studies (small projects), 4) Visit to facilities and 5) Assignments and tests/evaluations. The course is open to candidates in the level of Scientist/Engineer E to G from all ISRO centers through nomination from respective center Directors.
- **“International Young Astronomer School on Exploiting the Herschel and Planck data”** will be organized during **April 15-19, 2013** at Observatoire de Paris-Meudon, France. The last date for submitting application is December 3rd, 2012. For more details visit: <http://ufe.obspm.fr/rubrique344.html>
- **“44th Lunar and Planetary Science Conference”** will be organized during **March 18-22, 2013** at Woodlands, TX. The last date for submission of abstract is January 8th, 2013. For more details visit: <http://www.lpi.usra.edu/meetings/lpsc2013/>
- **“Transformational Science with ALMA: From Dust to Rocks to Planets Formation and Evolution of Planetary Systems”** will be organized during **April 8-12, 2013** at Hilton Waikoloa Village, Hawaii. The last date for submission of abstract is October 31st, 2012. For more details visit: <http://www.cv.nrao.edu/rocks/index.html>
- **“Light Pollution: Theory, Modeling, and Measurements”** will be organized during **April 15-18, 2013** at Smolenice, Slovak Republic. The last date for submission of abstract is October 10th, 2012. For more details visit: <http://lptmm.org/>
- **“Astrobiological and cosmochemical implications of Marco Polo-R sampling of a primitive asteroid”** will be organized during **January 16-17, 2013** at Barcelona, Spain. The last date for submission of abstract is October 26th, 2012. For more details visit: http://www.ice.csic.es/research/Marco_Polo-R_2013/index_en.html
- **MAVEN (Mars Atmosphere and Volatile Evolution Mission) Science Community Workshop.** A one-day workshop for the Mars science community to discuss the MAVEN mission on December 2, 2012 at San Francisco. For more details visit: <http://lasp.colorado.edu/home/maven/2012/04/05/maven-science-community-workshop/>
- **“Waves and Instabilities in Geophysical and Astrophysical Flows”** will be organized during **February 3-8, 2013** at Les Houches, France. The last date for submission of abstract is November 30th, 2012. For more details visit: <https://www.irphe.fr/~meunier/Workshop2.html>
- **Morocco 2013 Mars Analog Field Simulation, Erfoud, Morocco.** Field crew will conduct experiments preparing for future human Mars missions, focusing on engineering, planetary surface operations, astrobiology, geophysics/geology, life sciences and other; 01 - 28 February 2013. For more details visit: <http://www.oewf.org/cms/mars2013.phtml>
- Students interested for admission in **PhD program** in Planetary Sciences Group, University of Central Florida may apply before **January 15th, 2013**. For more details visit: <http://planets.ucf.edu/academics/phd-program>
- **Post-Doctoral Fellowship in Cosmochemistry** at University of Bern, Switzerland for 2 years. For more details visit: <http://www.earthworks-jobs.com/geoscience/bern12081.html>
- **Tenure-track staff position in the Science of Earth and Planetary Materials** at the Bayerisches Geoinstitut (BGI), University of Bayreuth, Germany for 3 years. For more details visit: <http://www.earthworks-jobs.com/geoscience/bgi12081.html>

GROUP PHOTO



MY ASSOCIATION WITH PLANEX

Association with PLANEX Group as Project Associate has helped a lot to lay the foundation of my scientific career. The training has successfully inculcated a mindset to rely on basic scientific research as a means to develop and leverage large-scale developmental activities to foster national development in the arena of science and technology. I joined the PLANEX programme through the workshop held at Vikram Sarabhai Space Centre. As an associate, it was a remarkable opportunity to work on modelling of solar coronal continuum for the estimation of lunar x-ray fluorescence as part of Chandrayaan-1 mission. The work was done under the guidance of Prof. (Dr.) S.A. Haider, Space and Atmospheric Sciences Division. He has taken time and patience to stand with me to complete the assignment in time. I still cherish the life at PLANEX, the Friday talks, supportive colleagues, presentations in National Space Science Symposium, Kottayam; International Lunar Conference at Udaipur, all facilitated scientific conversations with peers and career growth. Even now, I consciously try to relegate the PRL culture and tradition in the institutions I belong.

Presently, I am a Full-time Research Scholar at Dept. of Atmospheric Sciences, Cochin University of Science and Technology, Kochi, Kerala. I work under the guidance of Dr. C.A. Babu, Professor, Dept. Atmospheric Sciences, Cochin University of Science & Technology and Dr. Anil Bhardwaj, Head, Planetary Sciences Branch, Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram. I work on photon and charged-particle interaction aspects to model the soft x-ray emission from the icy crust of Jovian Europa.

PLANEX is doing great co-ordination to unite the planetary science community and I feel proud to be a part of it. Best wishes for all its future endeavors.

K.B. Smart

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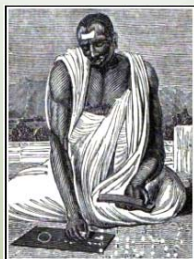


LIST OF REVIEWERS (VOLUME- 2)

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Brahmagupta: The Great Teacher, Astronomer and Mathematician of Ancient India



Brahmagupta (598 – 670 AD), the great 7th Century mathematician and astronomer, carried the testimony of Indian civilization among world's oldest and richest as bestowed with a strong tradition of Science and Technology. Brahmagupta's greatest works on astronomy, *Brahmasphutasiddhanta*, and *Khandakhadyaka*, spread to Europe via Arab, as mentioned by Al Beruni in his great book on India. It was through the *Brahmasphutasiddhanta* that the Arabs learnt Indian astronomy. He gave the first rules for dealing with “zero” as a number.

Brahmagupta was born in Bhillamala (Bhilmal city in Rajasthan) in 598AD. His Father Jisnugupta lived in Bhillamala during the rule of king Vyaghramukha. The suffix “GUPTA” indicates the family belonged to the vaisya caste (includes mostly farmers and merchants). Brahmagupta was called as Bhillamalacarya which means teacher of Bhillamala. He lived most of his life in Ujjain, which was the centre of Hindu astronomy and mathematics in his era, as the head of astronomical observatory and wrote four books on Astronomy and Mathematics. At the age of 30, he wrote his first book, the *Brahmasphutasiddhanta*. His other treatise, the *Khandakhadyaka*, is a *Karana* book, which was completed in 665 AD.

Brahmagupta is uniquely placed in the history of these great transitions of civilization across geographical and temporal boundaries and across different cultures. Virtually, every text that discusses Indian astronomy and mathematics describes or uses some aspects of his work. He was honored by the title given to him by a fellow mathematician Bhaskara II, as ‘Ganita Chakra Chudamani’, which is translated as ‘The gem of the circle of mathematicians’. The discoveries made by Brahmagupta influenced and pioneered many of the mathematicians of the Islamic world. Brahmagupta's “Applications of Mathematics to Astronomy” was mostly recognized by King Khalif Abbasid al-Mansoor (712–775 AD) and Arabic re-prints were produced, which had a major influence on the subsequent writers in the Arab world. Because of his great efforts and knowledge, he became head of the astronomical observatory at Ujjain in 665 AD. A line of Indian mathematicians and astronomers working at the Ujjain astronomical observatory revered Brahmagupta's work and extended his ideas over the next decades and centuries. George Sarton (Father of history of science) described Brahmagupta as “*One of the greatest scientists of his race and the greatest of his time*”. Distant from modern mathematics in time and place, Brahmagupta nevertheless exerted a definite influence on mathematics as the discipline is known today.

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