Amazing Space and India's Space Exploration Endeavour

Context of ISRO's START programme

What is **Space** and how to study it?

India's Space Exploration

Relevance of the '**START**' programme

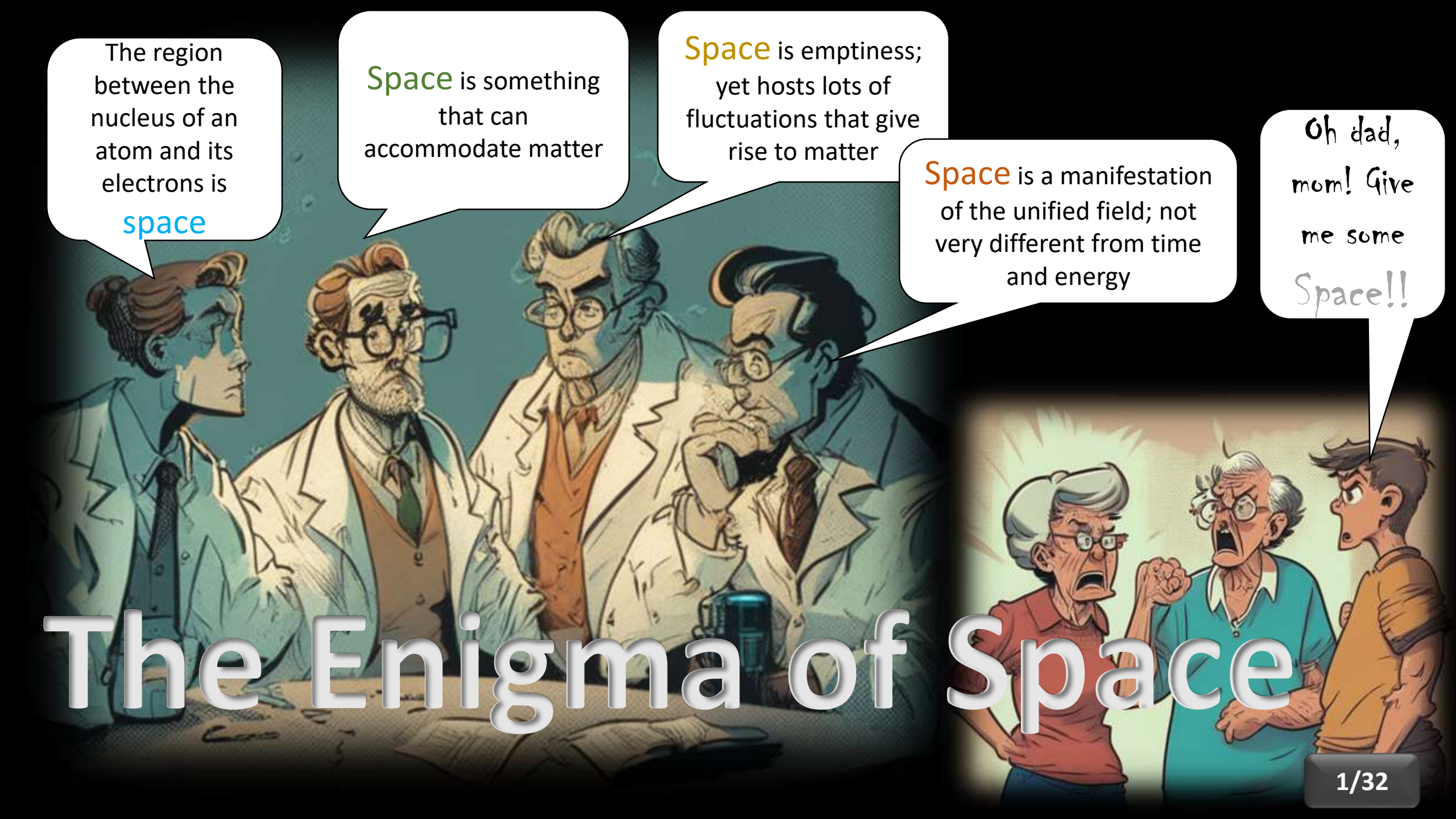
An Overview Lecture meant for the Students and Space Enthusiasts

July 20, 2023, Thursday, after the inaugural session

Dr. Tirtha Pratim Das
Director,
Science Programme Office, ISRO Headquarters

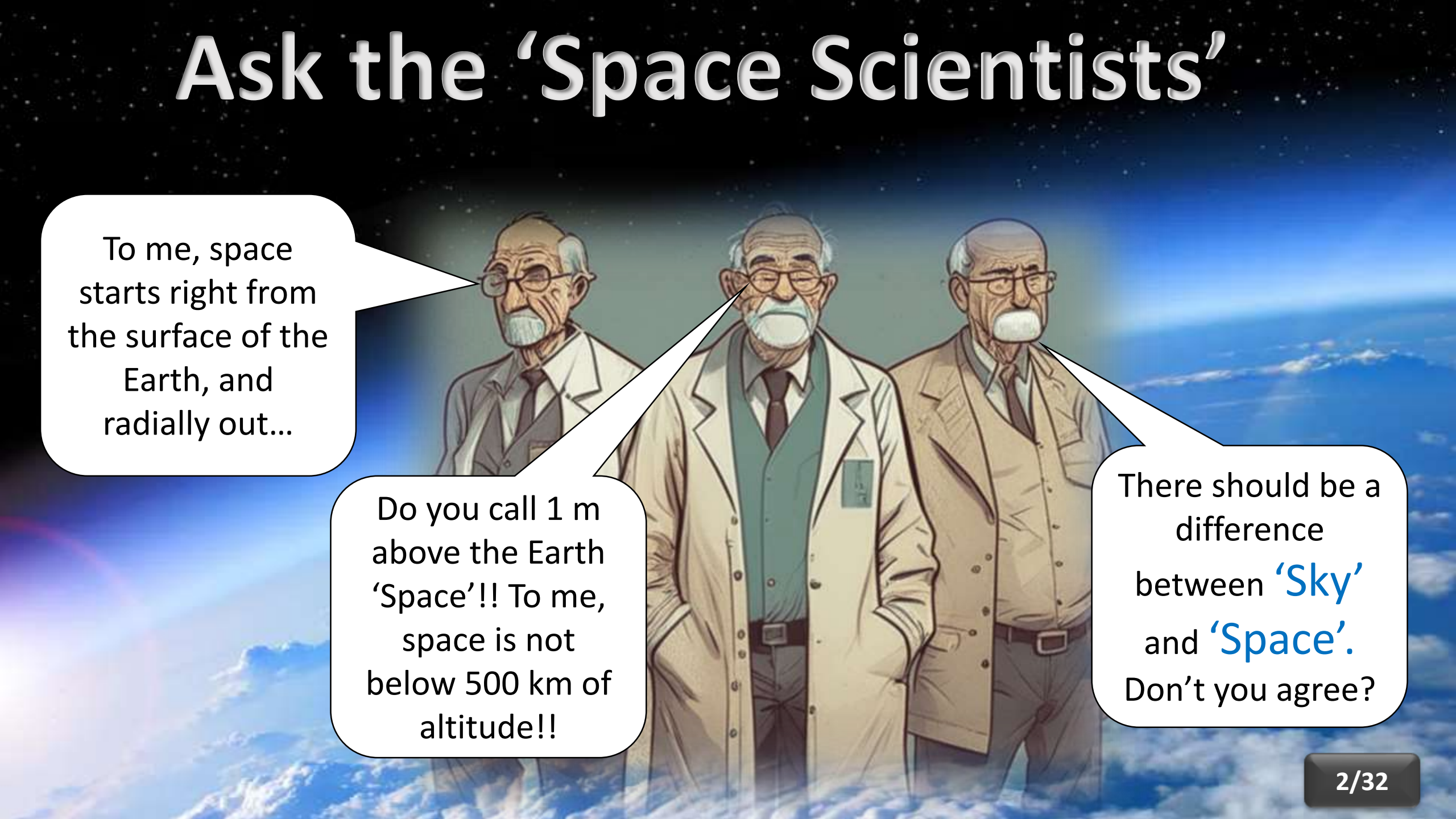
Part-1

What is Space ?
&
How to study it ?



The Enigma of Space

Ask the ‘Space Scientists’



The ‘Sky’ and the ‘Space’: Context of Earth

The Boundary between Aeronautics and Astronautics

Theodore von Karman
(1881-1963)

Astronautics

Aeronautics

Karman line

100 km altitude

Earth’s Surface

In 1 m^3 volume, you have ~10^{-7} kg of atoms/molecules

In 1 m^3 volume, you have ~1.1 kg of atoms/molecules

Exponential function with scale height ~8.5 km

Altitude

Number density of atoms / molecules

Balloons can be supported till ~30-50 km

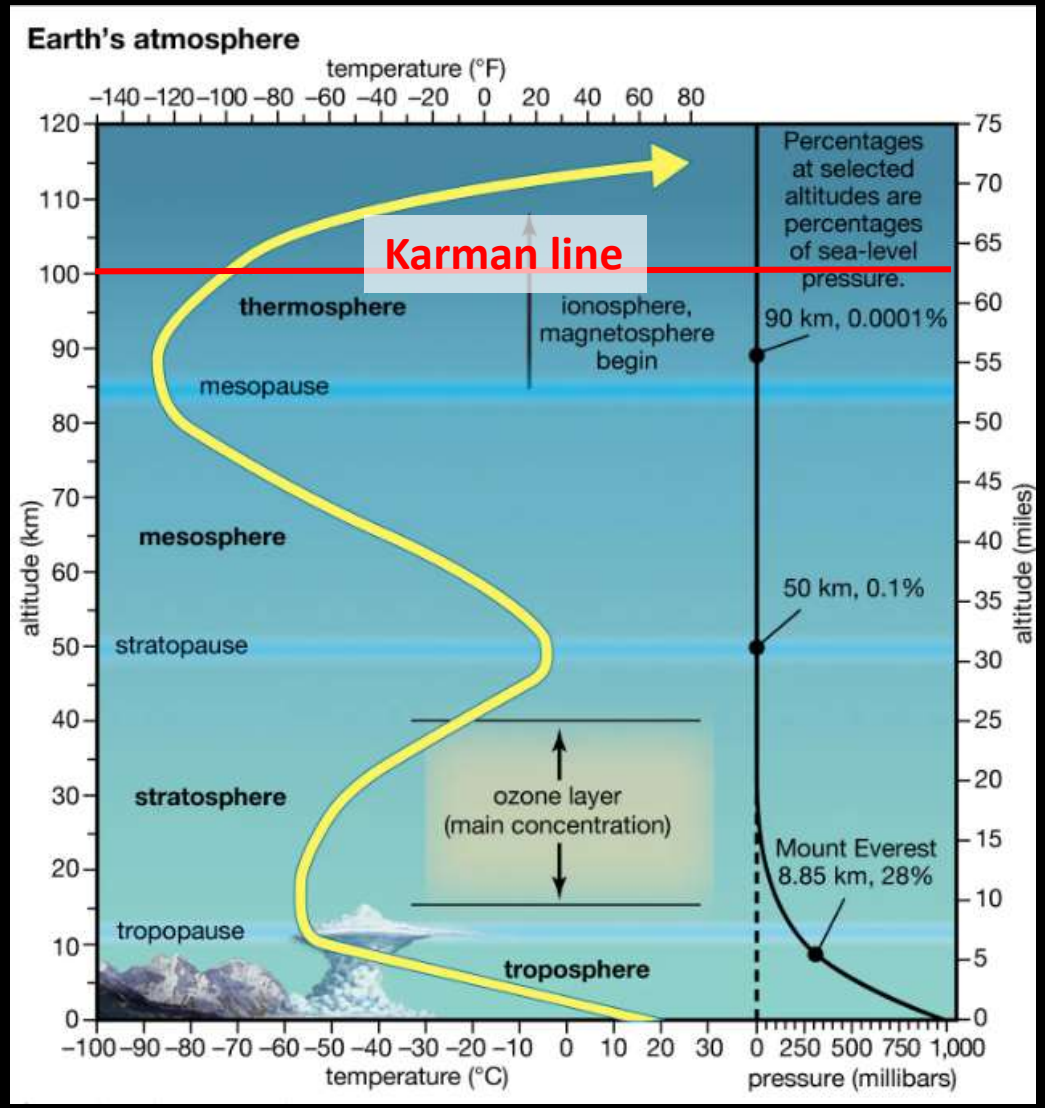
~10 km altitude: Aero planes fly through this region

EARTH

Geosphere | Biosphere

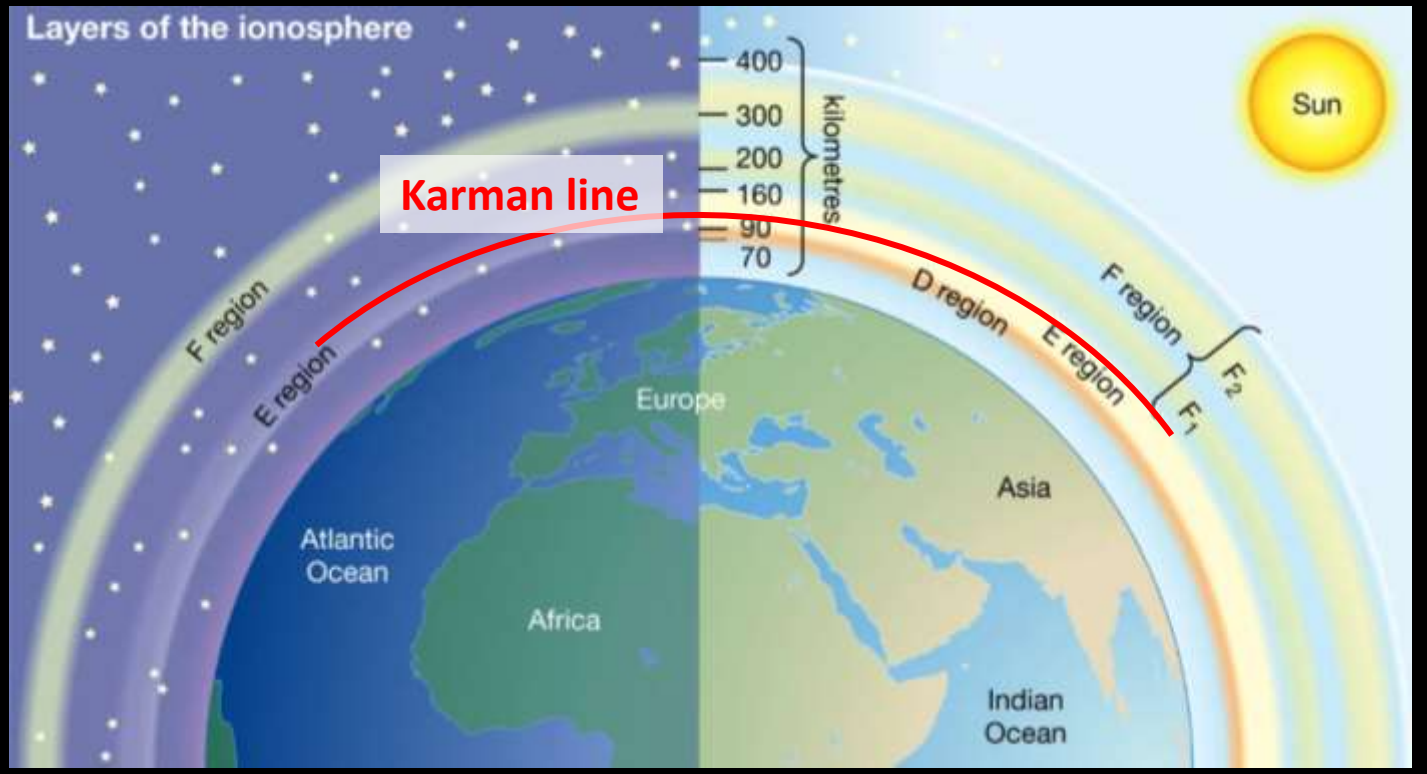
Weather | Climate

The ‘Space’ just around the Earth



Layers of the neutral atmosphere around the Earth, based on the temperature profile

Interesting phenomena take place even below the Karman line

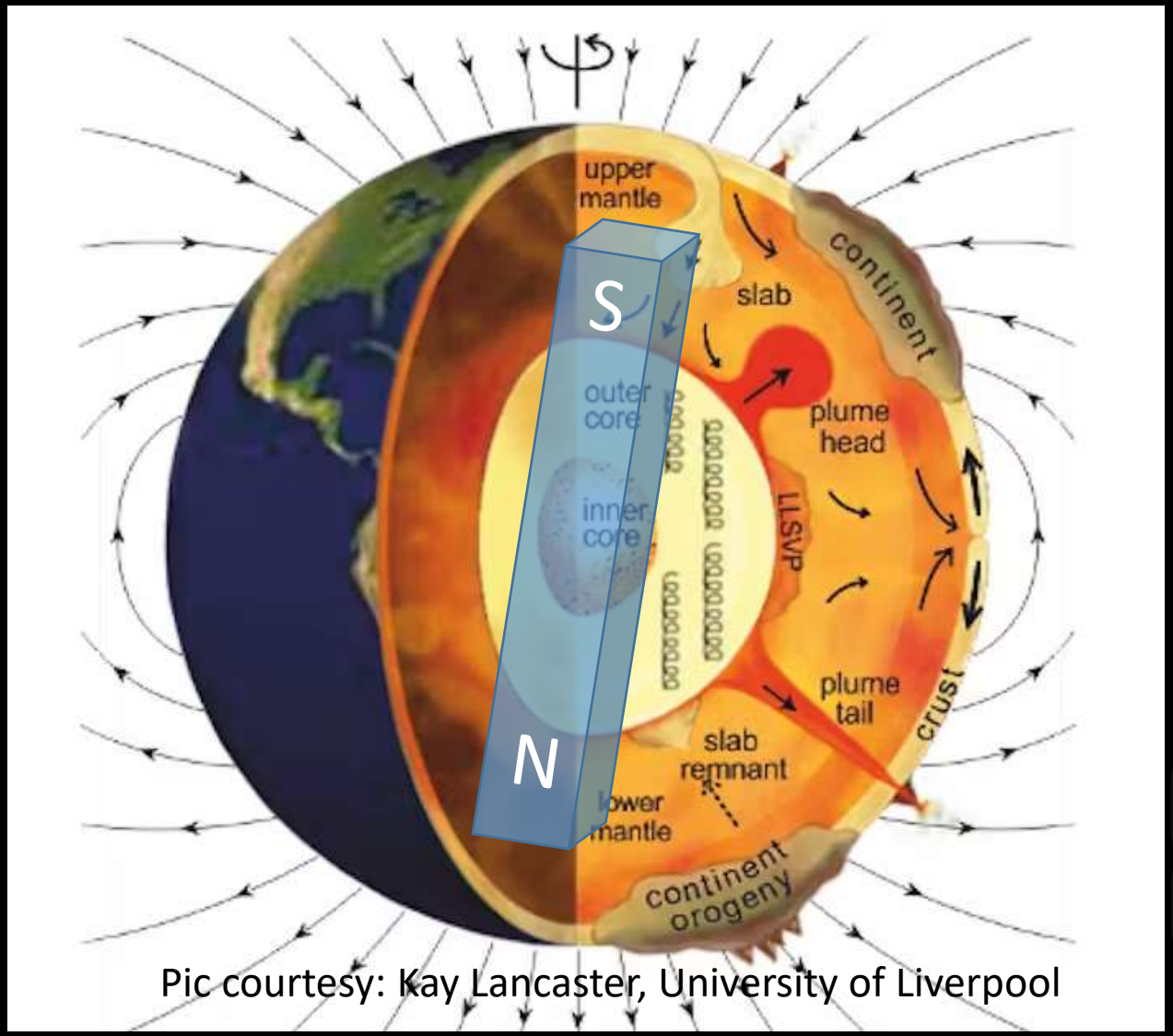


Layers of ions around the Earth, forming the system of ionosphere

Atmospheric layers | Ionosphere

Picture Courtesy: Encyclopedia Britannica Inc.

The ‘Magnetic Drama’ makes things complex



Pic courtesy: Kay Lancaster, University of Liverpool

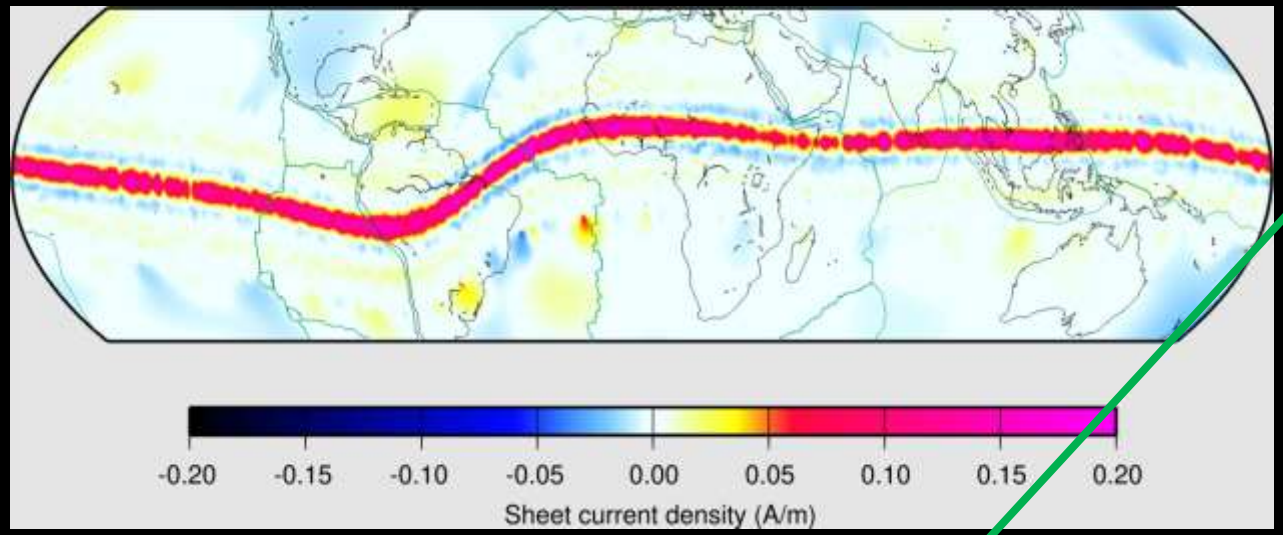
The molten ‘geodynamo’ causes a magnetic field around Earth

Earth

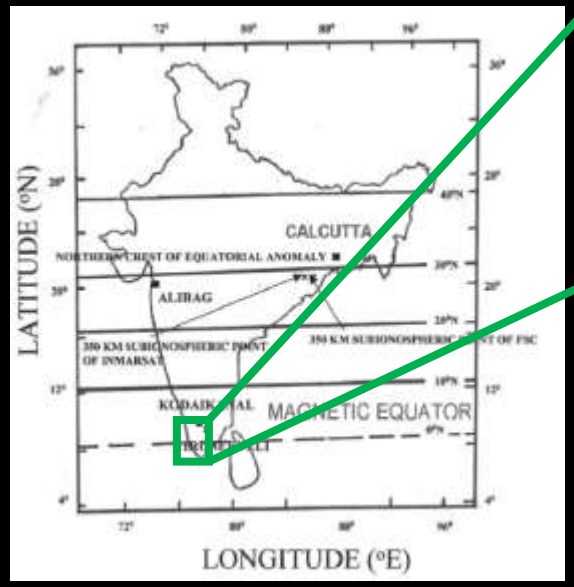
Geodynamo | Geomagnetism | Magnetic Poles

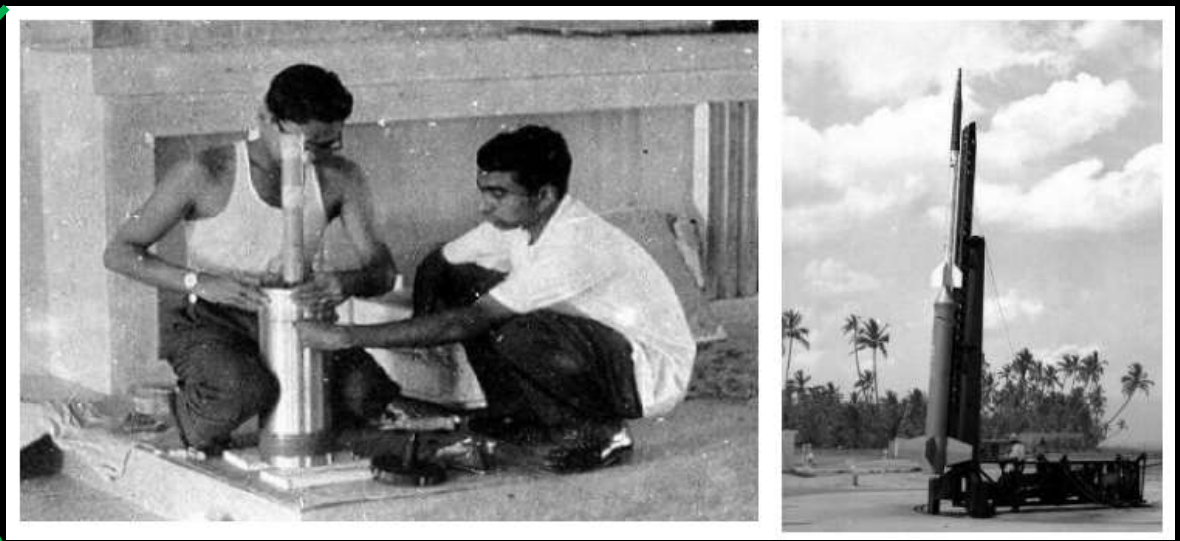
Ionosphere & Geomagnetism | Magnetic equator

The Current at the Magnetic Equator



Equatorial Electrojet: Courtesy: CHAMP satellite





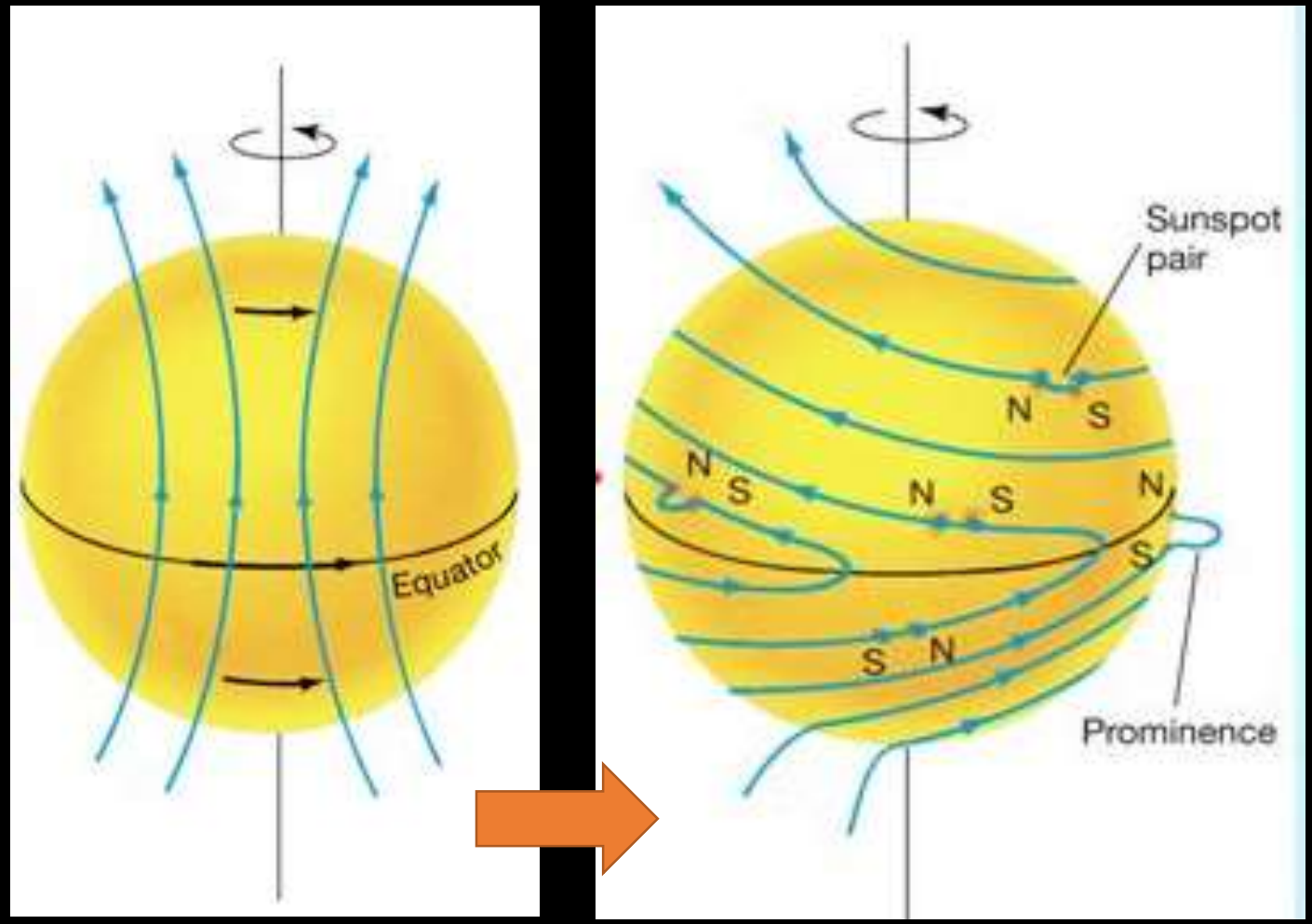
Sounding Rocket based Space Exploration Programme from Thumba

Equatorial Ionosphere

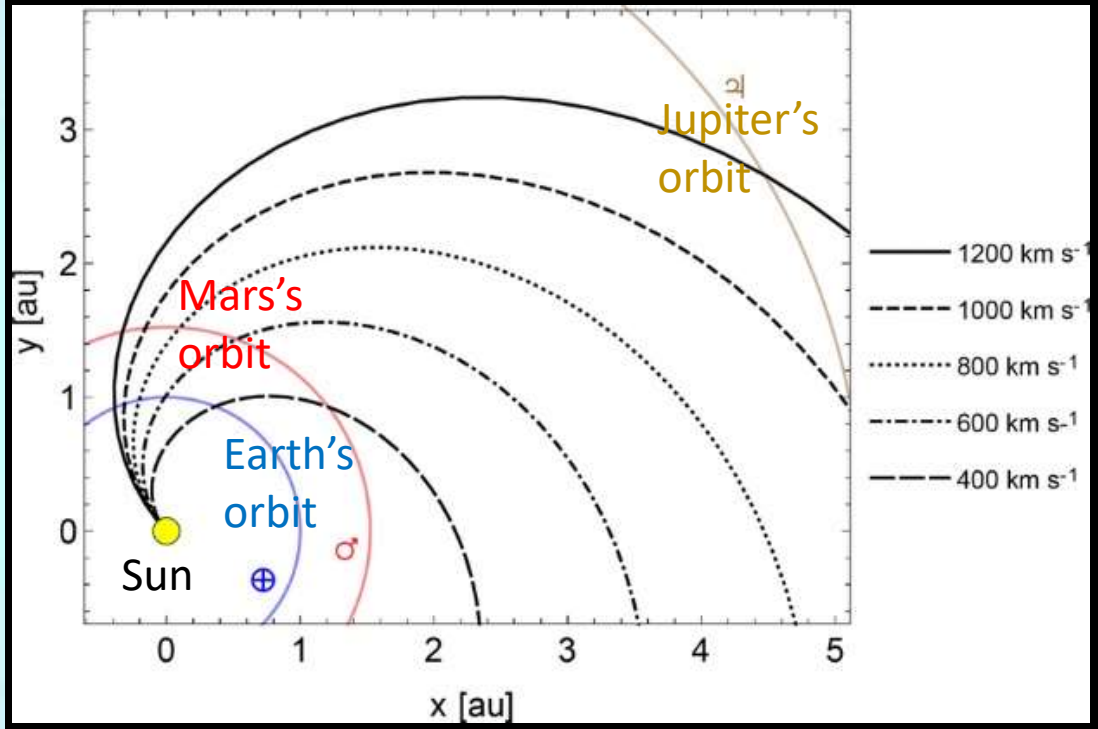
Establishment of TERLS

The ‘Magnetic Drama’ makes things complex

Sun



Sun, a soup of charged particles (plasma), has a magnetic field



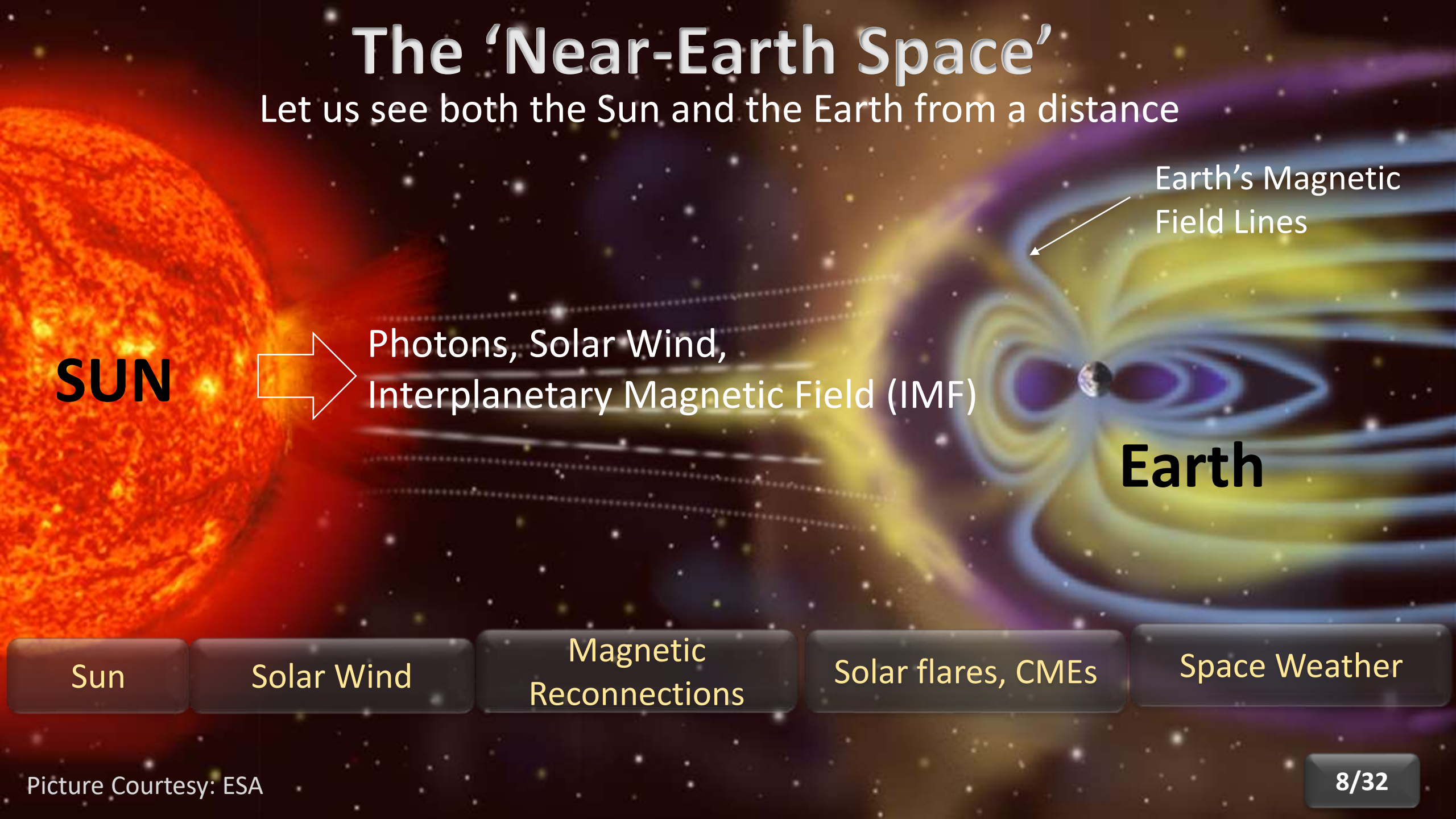
Parker Spiral Spiral. Courtesy: Lhotka and Narita, 2019

Solar magnetism (IMF)

Parker Spiral

The ‘Near-Earth Space’

Let us see both the Sun and the Earth from a distance



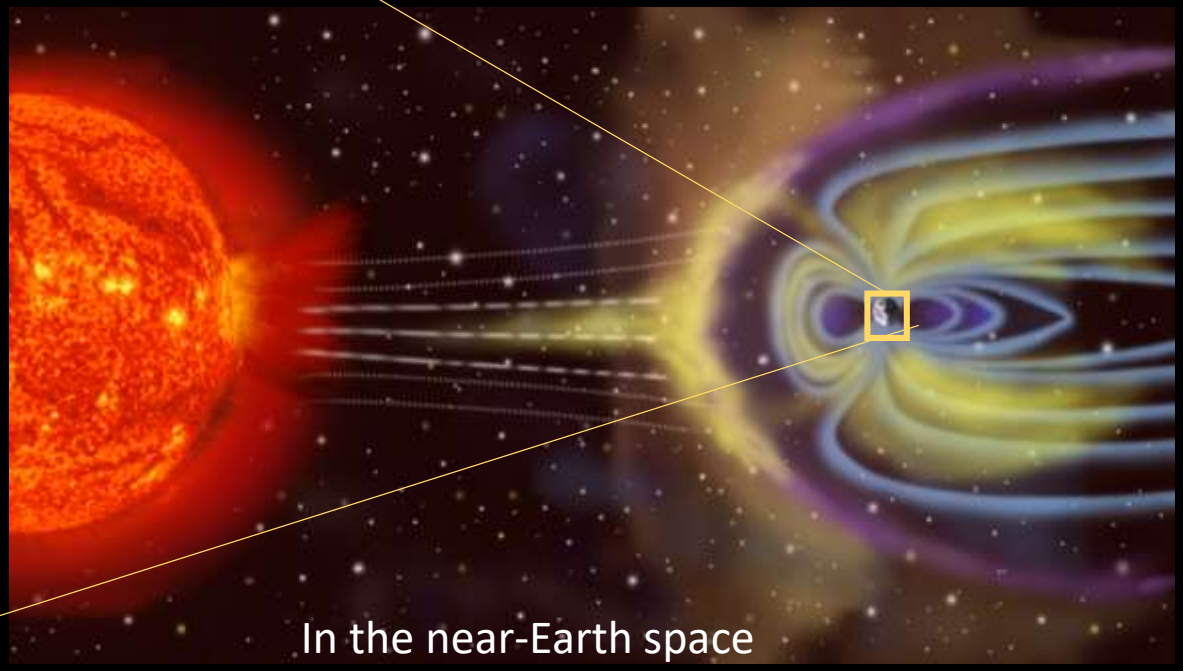
Sun | Solar Wind | Magnetic Reconnections | Solar flares, CMEs | Space Weather

Picture Courtesy: ESA

‘Weather’ and ‘Space Weather’

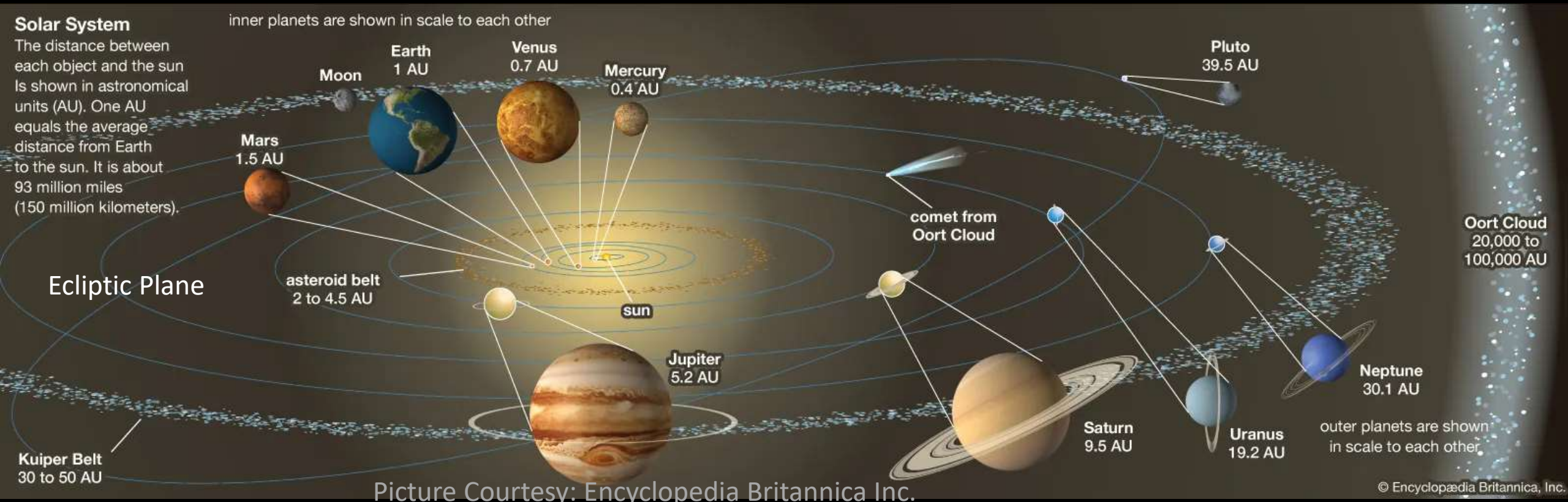
Somewhere on Earth

Space Weather



In the near-Earth space

The Solar System



Picture Courtesy: Encyclopedia Britannica Inc.

Planets

Natural Satellites

Comparative Planetology

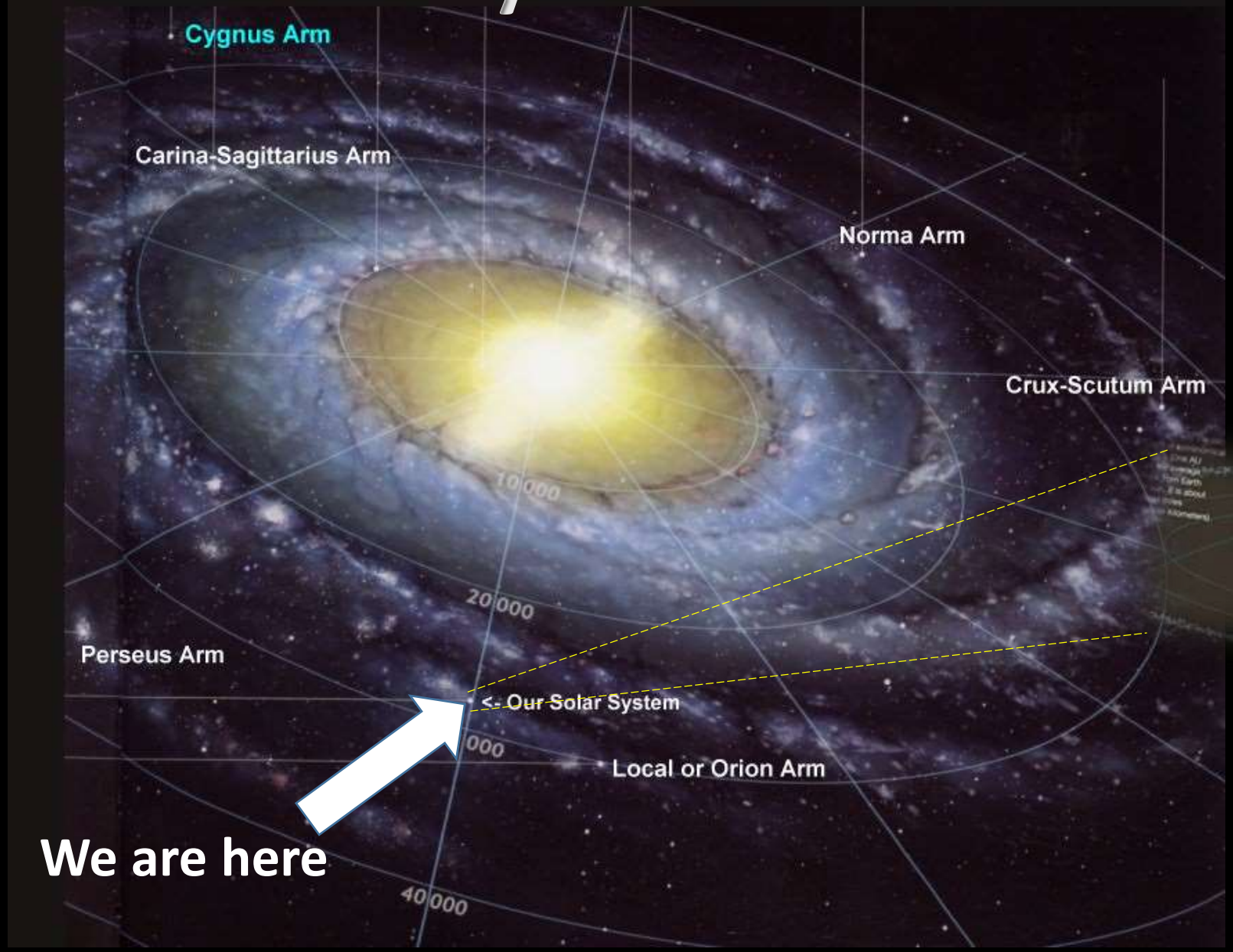
Dwarf Planets

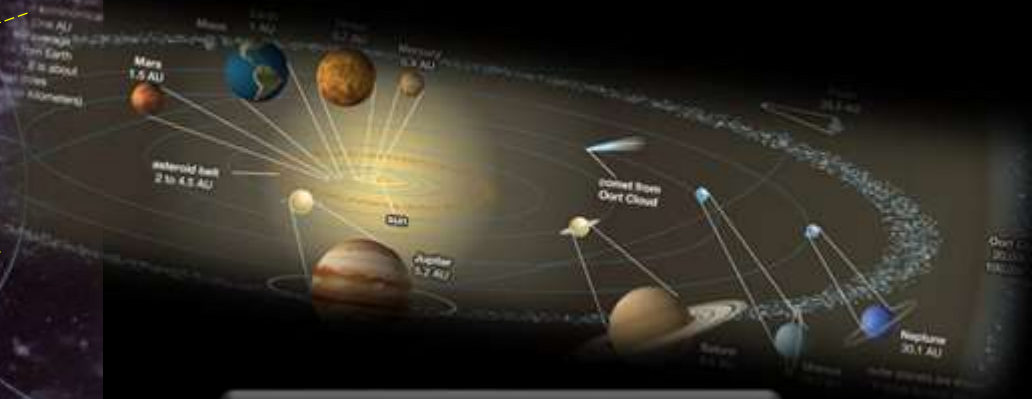
Comets, Asteroids, Meteorites , Meteoroids, Meteors

What happened to Pluto?

Kuiper Belt, Oort Cloud

Our Solar System in the ‘Milky Way’ Galaxy





Milky Way Galaxy

Solar System within it

Context of Study Space Research & Exploration

How the Universe Works ?

& How do we fit there?

- Observable Universe: ~ 93 billion light years in diameter
- The Virgo Supercluster (centre of the picture) is the home of the Milky Way (just a dot)
- Our solar system is at one edge of the Milky Way
- Solar system → habitable zone → life, intelligence, consciousness → Endeavour to know the Universe

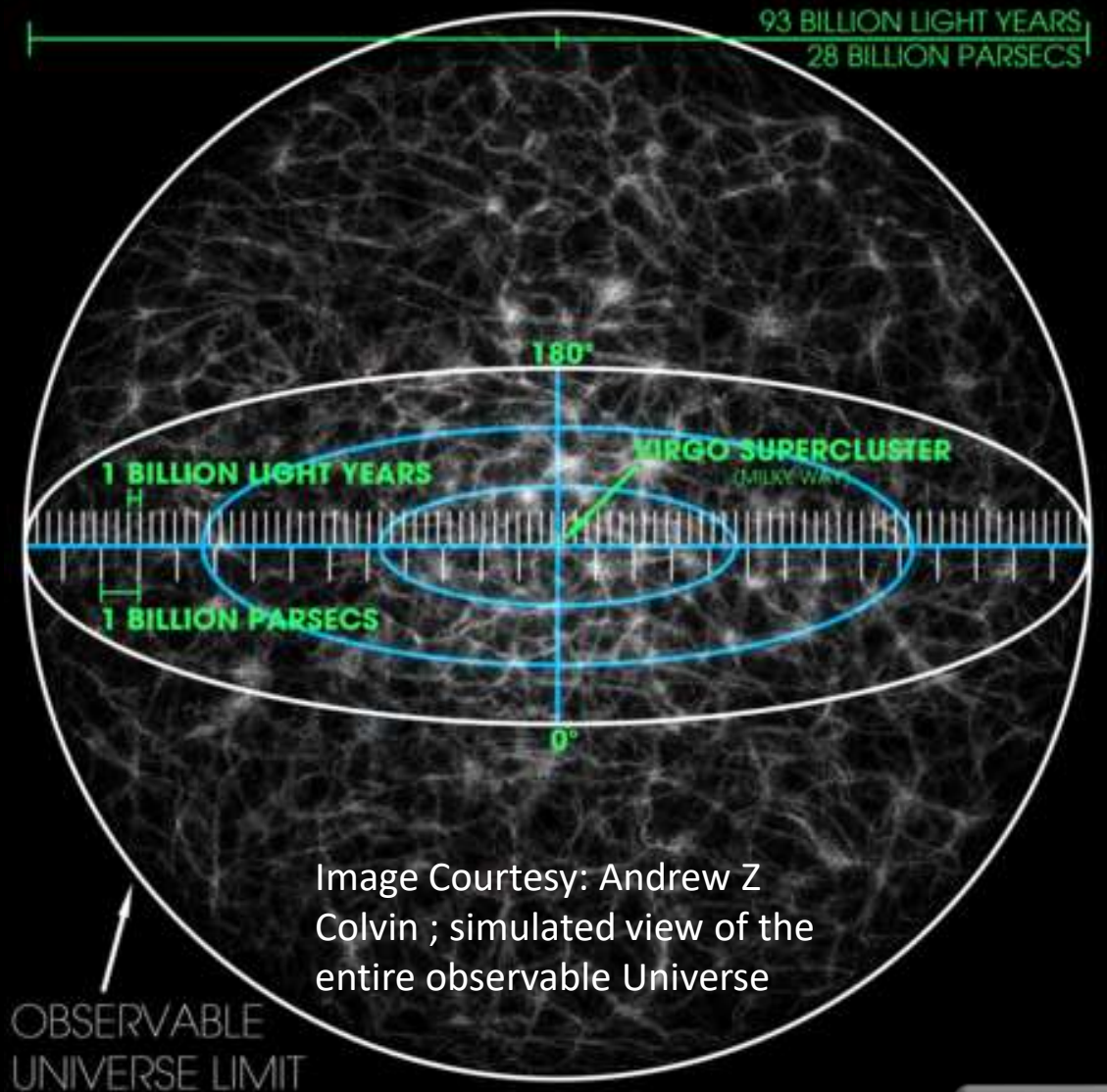
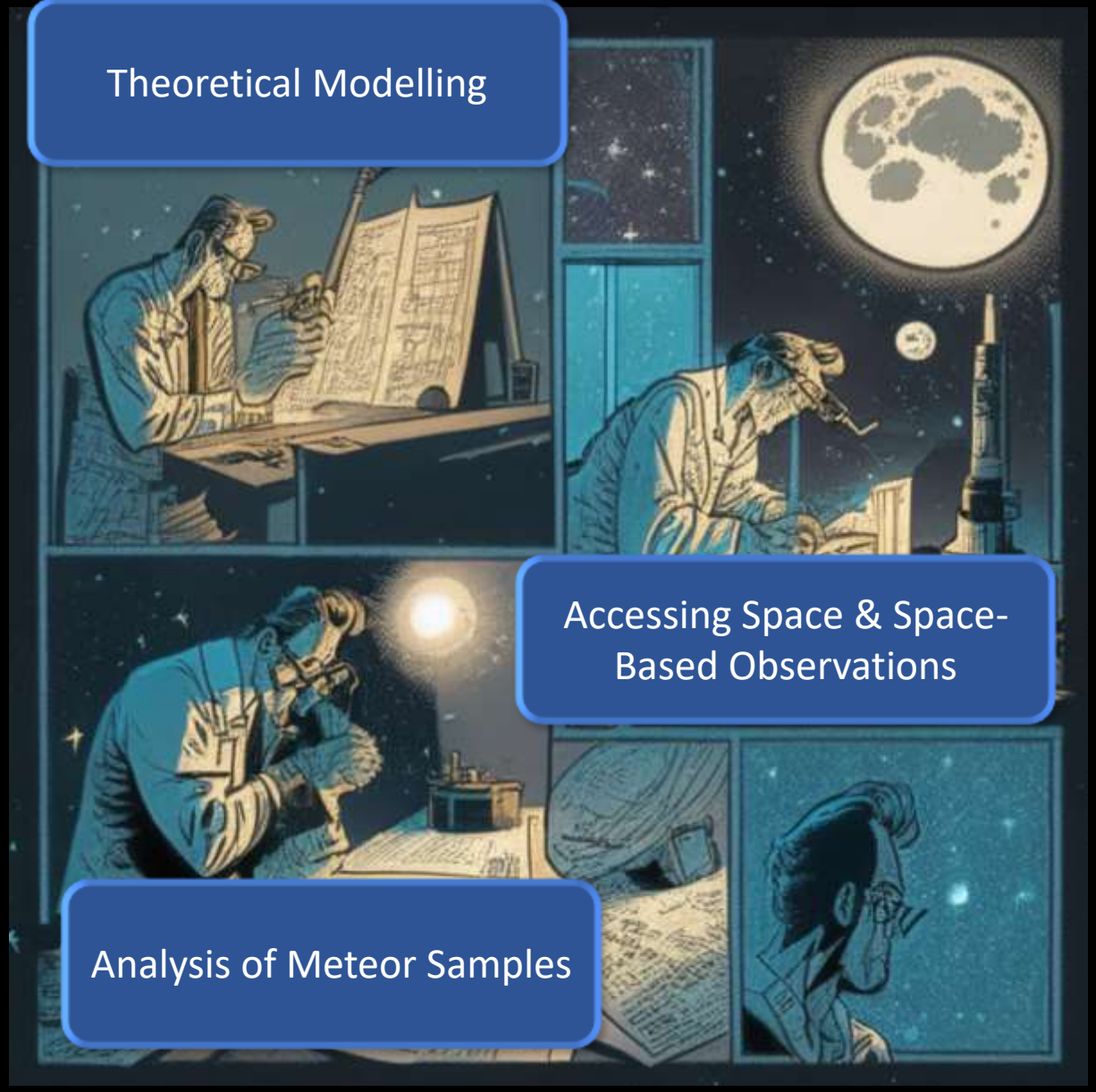


Image Courtesy: Andrew Z Colvin ; simulated view of the entire observable Universe

How to Study Space ?

Techniques in Space Research



Theoretical Modelling

Accessing Space & Space-Based Observations

Analysis of Meteor Samples

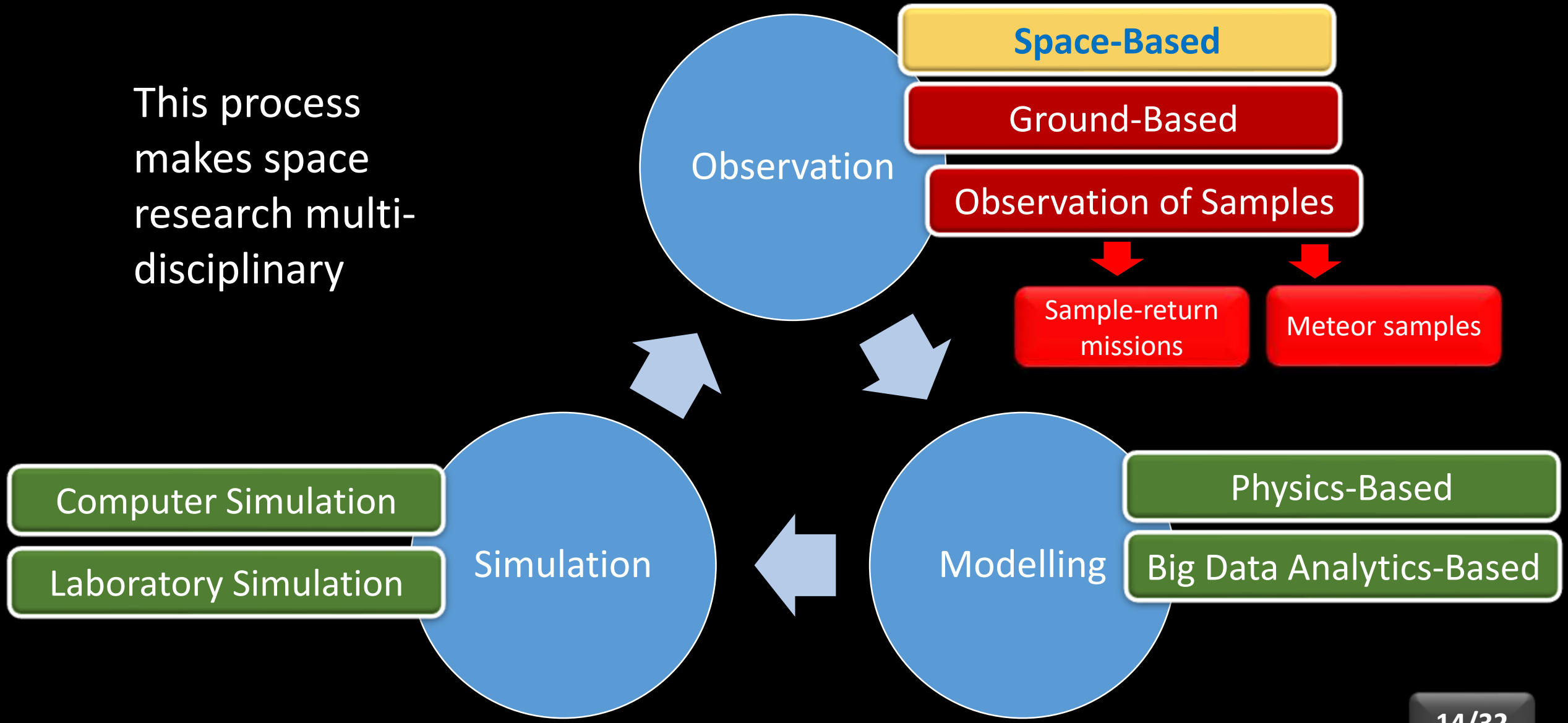
Ground-based observations

Computer Simulations

Laboratory Simulations

Modelling, Simulation, Observation: A Process

This process makes space research multi-disciplinary



What all to Observe?
& Who all Carry the Information?

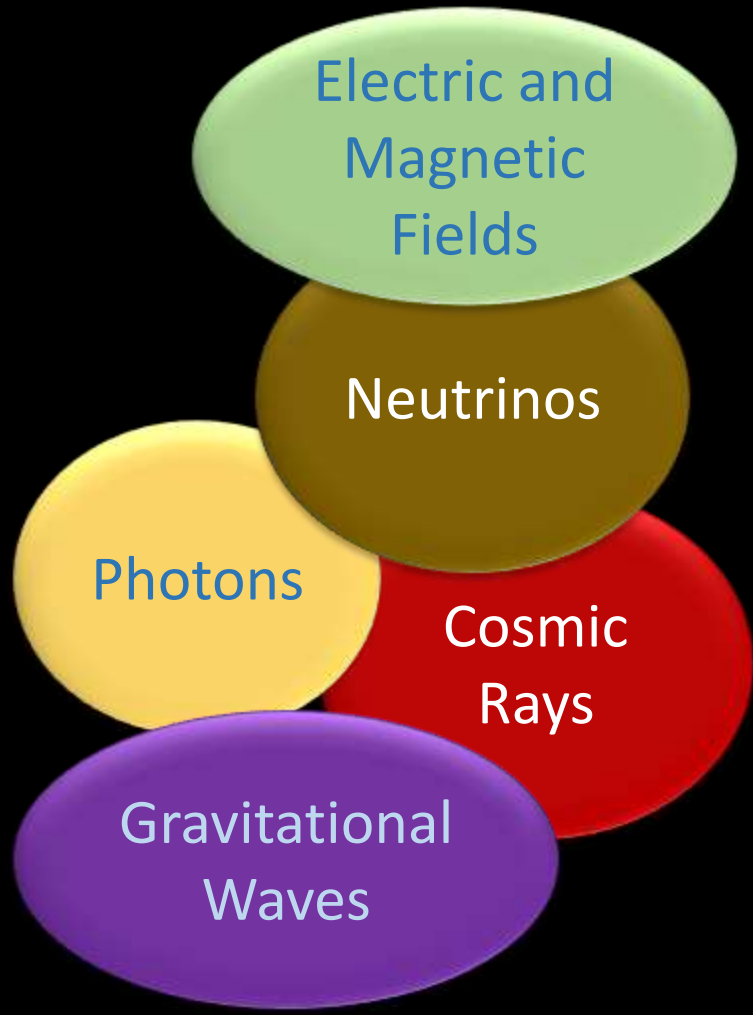
Celestial Bodies / matter

- Stars
- Planets
- Natural Satellites
- Particles, Dust, etc.

Interior, Structure, Surface, Atmosphere, etc..

Processes

- Merger of celestial objects
- Burst of Photons
- Explosion of celestial objects, etc.

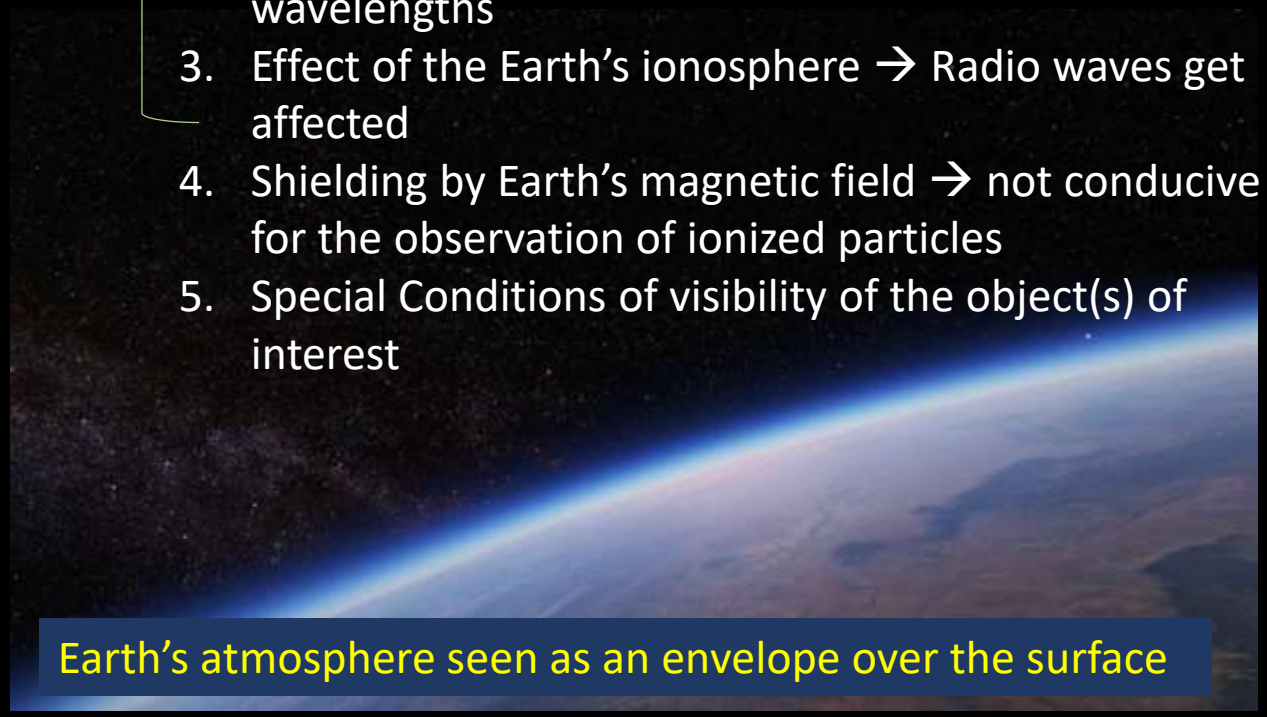


There are multiple messengers who carry the information; scientists know whom all to ask and make the story complete

Merits of Space-Based Observations

Ground-Based Observations:

A
1. Atmospheric haze → Visible wavelengths get affected
2. Atmospheric absorption → Selective absorption of wavelengths
3. Effect of the Earth's ionosphere → Radio waves get affected
4. Shielding by Earth's magnetic field → not conducive for the observation of ionized particles
5. Special Conditions of visibility of the object(s) of interest

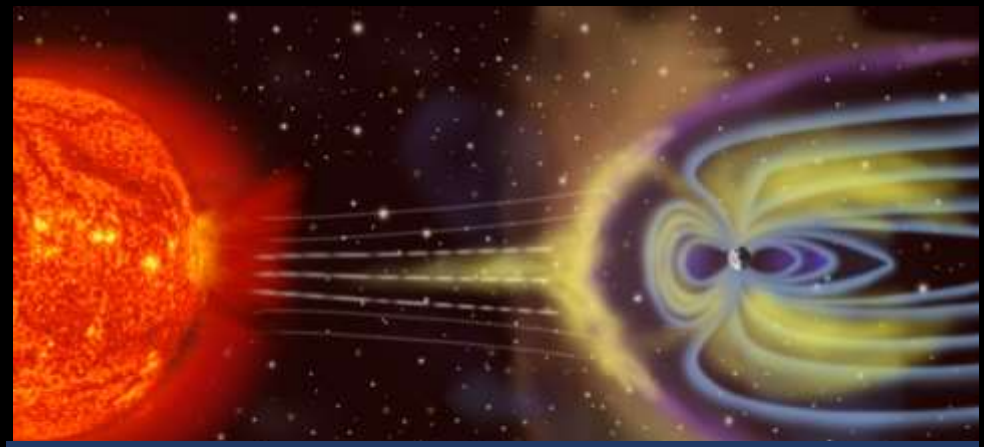


Earth's atmosphere seen as an envelope over the surface

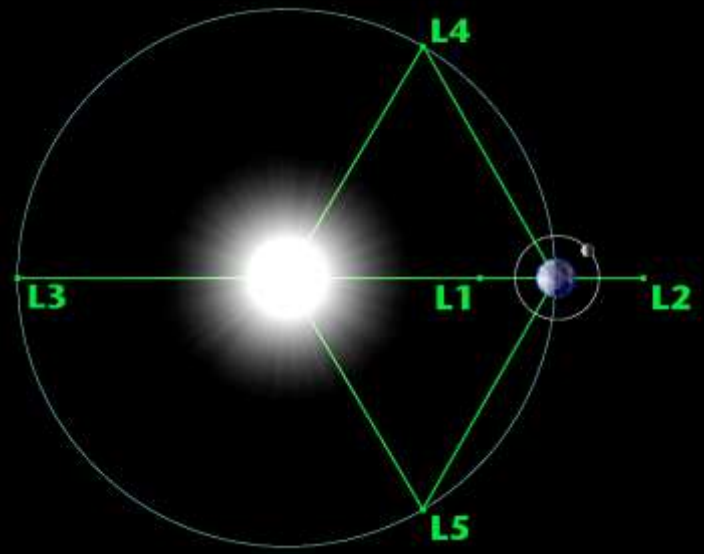
A→ Above 400 km from the Earth's surface is sufficient

4→ Need to be stationed beyond Earth's Magnetosphere

5→ Need to be stationed at suitable Lagrange Points



Earth's magnetosphere extends up to ~6-10 R_E from the Earth's surface, in the Sun-facing face



The five Lagrange points in a two-body system

Types of Space Exploration Platforms

Image courtesy: NBF, TIFR

1 **Scientific Balloons**

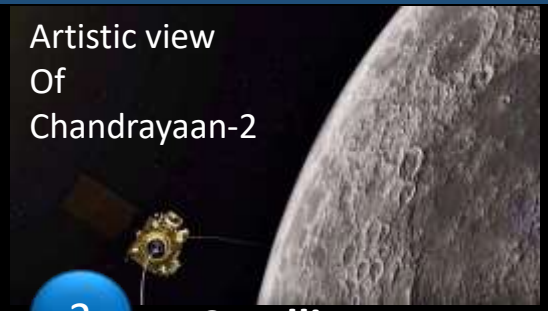
(~40-50 km above Earth's surface)

RH 560 on launch pad

RH560 Sounding Rocket:
Image courtesy: ISRO

2 **Sounding Rockets**

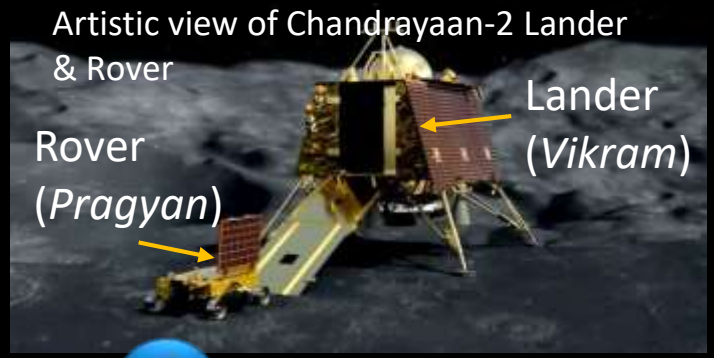
(~70 km to ~500 km above Earth)



Artistic view
Of
Chandrayaan-2

3 **Satellites**

- Around the Earth (> ~ 400 km)
- Around any other Celestial body



Artistic view of Chandrayaan-2 Lander & Rover

Rover (*Pragyan*)

Lander (*Vikram*)

4 **Landers / Impactors**

- Surface studies
- Soft landers: prolonged experiments

5 **Rovers**

- Multi-point measurement of surface

Artistic view of the Cassini spacecraft during Titan flyby: Courtesy NASA

6 **Fly-by missions**

- The spacecraft passes close by a celestial body and conducts scientific observation

Artistic view of the SOHO Heliophysics observatory : Courtesy NASA

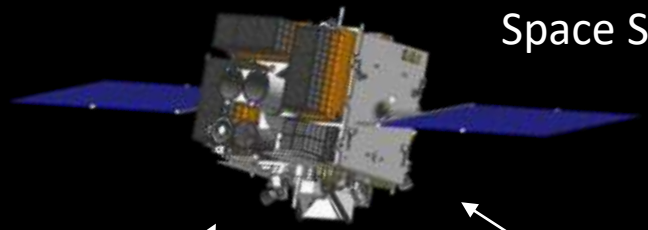
7 **Space Observatories**

- The observatory is launched to space to observe celestial bodies and astronomical sources

How is a Space Science Mission Planned ?

1. Start from a fundamental question
2. Split the fundamental question to a set of specific questions: *Set your target*
3. *Identify the domains* that need to be studied; e.g. surface, interior, atmosphere, etc.
4. *Identify the parameters* that need to be studied; then specify the ranges and identify suitable technique(s) → science payloads
5. Define the (i) *exploration platform* (fly-by, orbiter, lander, rover, etc.), (ii) *Observation plan* (ii) *Ground stations*

Major Components of Space Missions



Space Segment: Satellites, Space-probes

Access to Space: Space Transportation Systems (Launch Vehicles)

Ground Segment: Mission Control Centre for Tracking and commanding

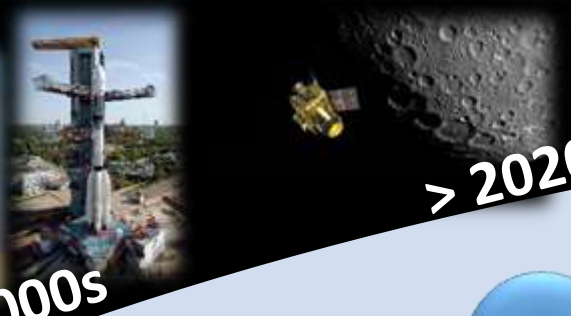
Ground Segment: Data Reception and archival Centre

Part-2

India’s Journey to Space

Legacy of the Indian Space Programme

- 1920s: S K Mitra's radio-sounding experiments on ionosphere
- 1940s: Establishment of TIFR and PRL by Dr. Bhaba and Dr. Sarabhai respectively
- 1950: DAE was set up
- 1962: INCOSPAR was set up under DAE
- 1969: ISRO was founded
- 1972: Space Commission and DoS were set up; ISRO came under DoS



1960s-70s

Initiation Phase

-Vision

-Scientific quest

- Capacity building

-International cooperation

1980s

Experimental Phase

- Experimental missions

- End-to-end capability

- Research

- Prototyping

1990s

Operational Phase

- Operational missions

- National services

-Wide user base

- Institutional framework

2000s

Expansion Phase

- Space science missions

- Innovative techniques

- Newer services

- Global outreach

- Commercial solutions

> 2020

Inclusion Phase

- Space sector reforms

- Release of Space Policy

Roadmap of the Space Exploration Programme

2015: AstroSat
Multi-wavelength Astronomy

2019: Chandrayaan-2
Surface, subsurface and exosphere

2023: Aditya-L1
Solar observatory at L1

2023: XPoSat
X-Ray Astronomy

2023: Chandrayaan-3
Lunar surface and seismicity

2013: Mars Orbiter Mission
Martian surface and exosphere

2011: YouthSat
Ionospheric studies

2009: RT-2 Gamma Telescope
Solar studies

2008 : Chandrayaan-1
Surface composition, mineralogy, Exosphere

2003 : Solar X-ray Spectrometer (SOXS)
Solar studies

1996 : Indian X-ray Astronomy Experiment (IXAE)

X-Ray Atronomy

1994 : SROSS C2

Gamma Ray Burst

1975 : Aryabhatta

X-ray Astronomy, Aeronomy & Solar Physics

1969
ISRO was founded

Formative years for space-borne experiments

1960s: Sounding rocket borne experiments: Upper Atmosphere

1940s: Balloon-based experiments on Cosmic Rays

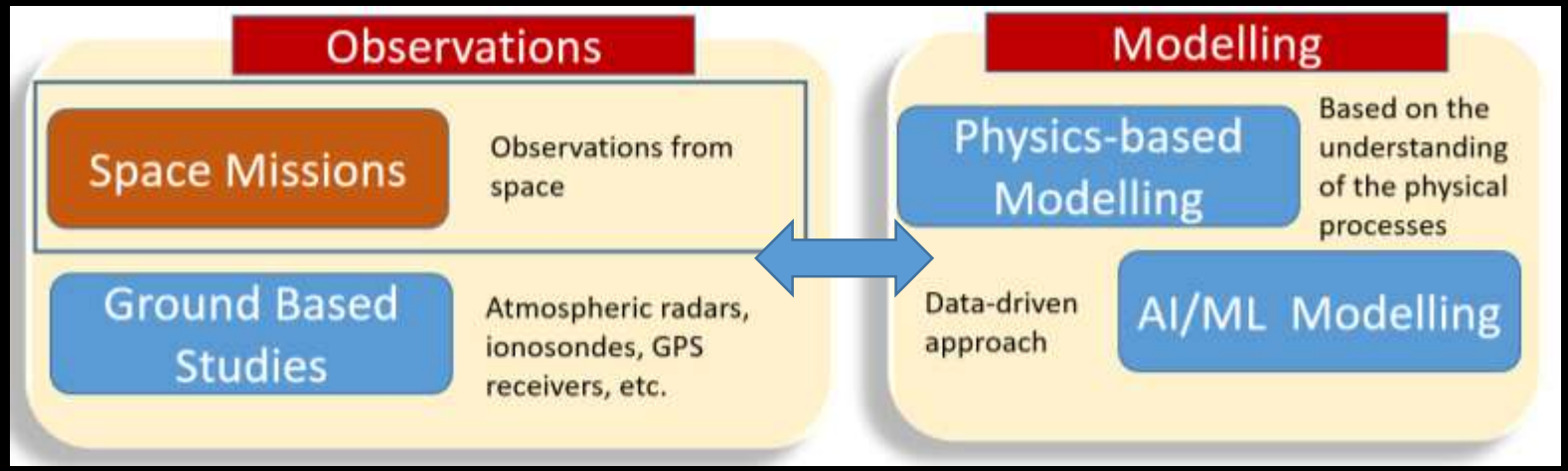
Balloon-borne experiments from TIFR, Hyderabad

Sounding rocket experiments from TERLS

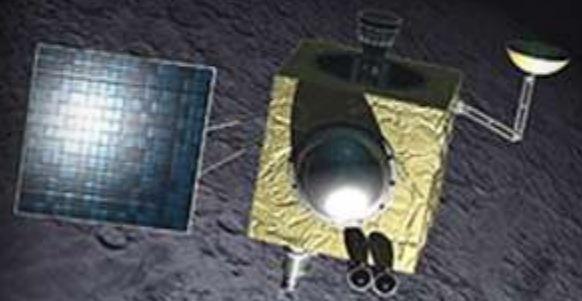
Major Verticals in India's Space Exploration

Vision: Scientific Exploration of the Solar System and beyond: Understanding how the Universe works; and use space for fundamental science experiments

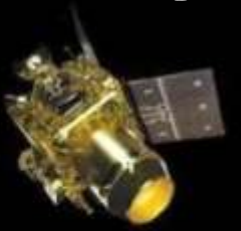
- **Astronomy & Astrophysics**
- **Heliophysics & Space Weather Studies**
- **Planetary Exploration**
- **Upper Atmospheric Studies-Aeronomy**



India's Space Exploration: Solar System

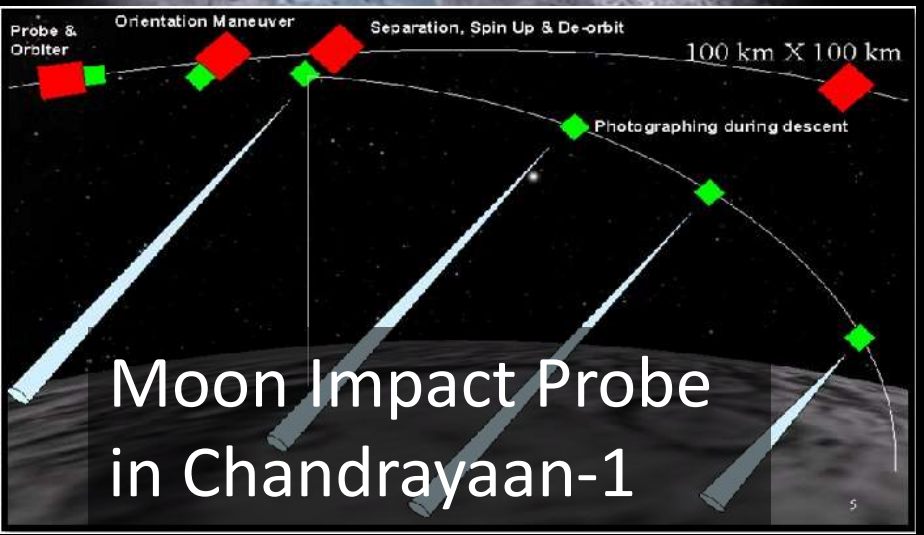


Chandrayaan-1
(2008-2009)



Chandrayaan-2
(2019-)

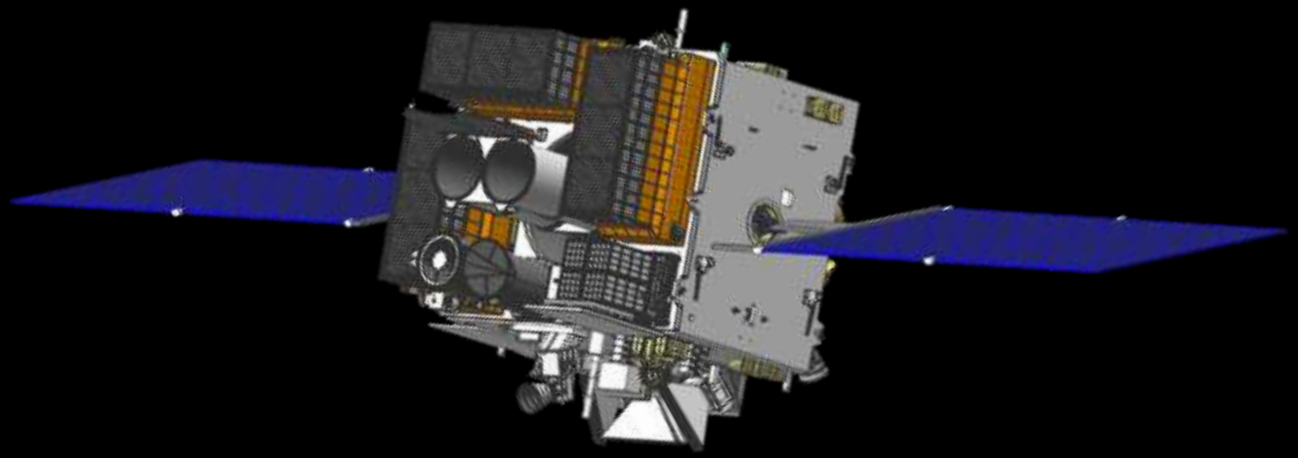
Chandrayaan-3
(2023-)



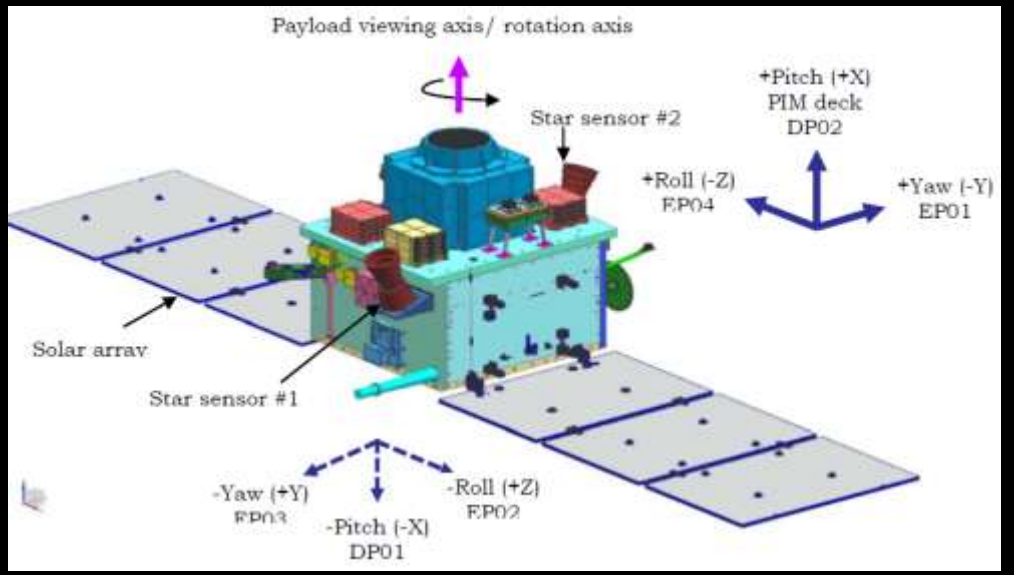
Moon Impact Probe
in Chandrayaan-1

Mars Orbiter Mission
(2014-2022)

India’s Space Exploration: Astronomy



AstroSat (2015-)



XPoSat (Upcoming)

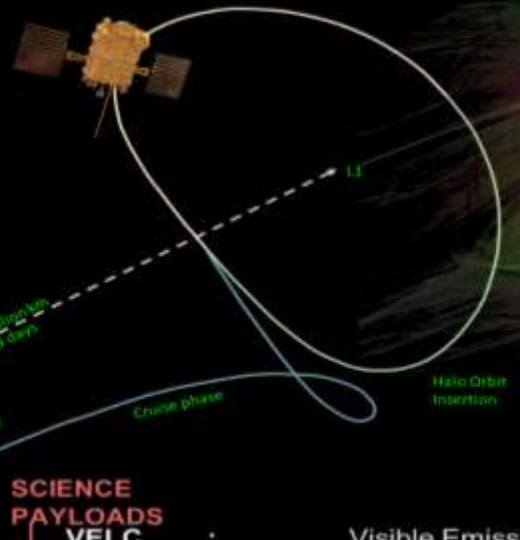
India's Space Exploration: Solar & Heliophysics

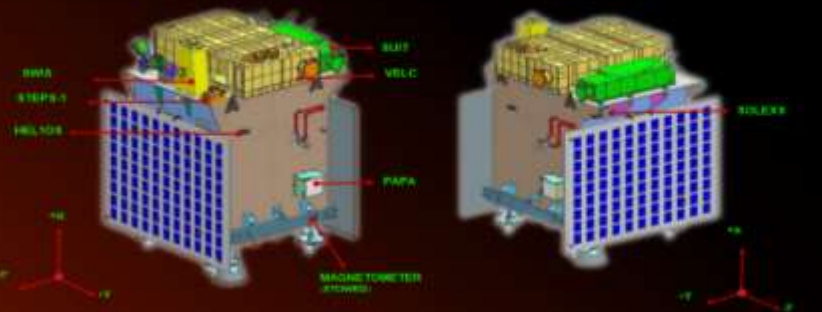
ADITYA-L1 MISSION (Upcoming)

First Indian observatory class mission for solar & heliospheric studies.
Mission planned life – 5-years.
Continuous observation of the sun from Earth-Sun Lagrange point L1

SCIENCE OBJECTIVES

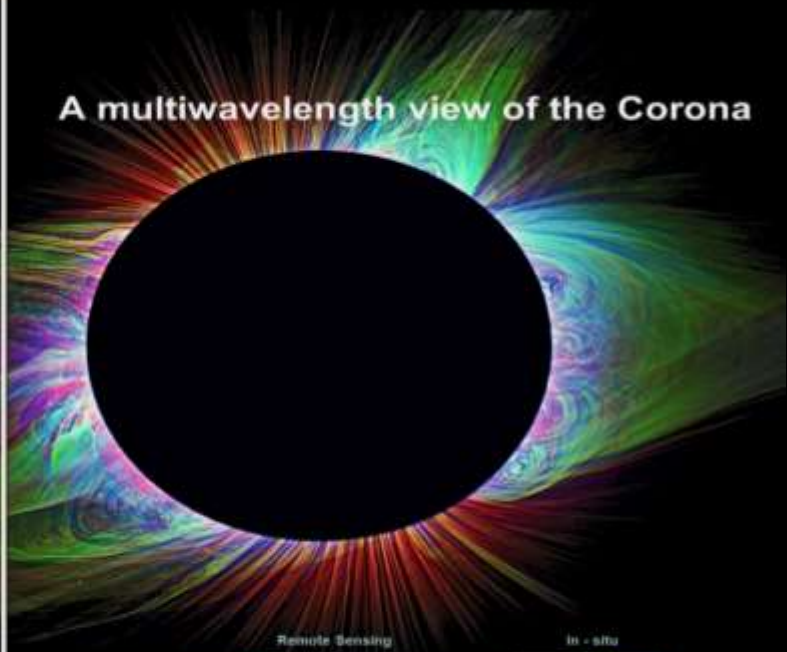
- Understanding Coronal Heating and Solar Wind Acceleration
- Understanding initiation Of Coronal Mass Ejection (CMEs), flares and near-earth Space weather
- Understand Coupling and Dynamics of the solar Atmosphere
- To understand Solar wind distribution and temperature anisotropy.

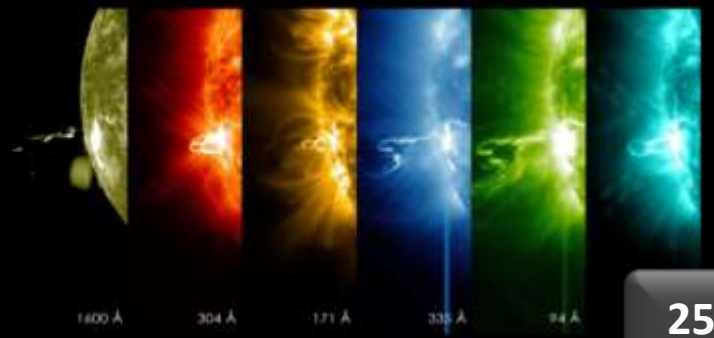




SCIENCE PAYLOADS

VELC : Visible Emission Line Coronagraph
HEL1OS: High Energy L1 Orbiting X-ray Spectrometer
SUIT : Solar Ultraviolet Imaging Telescope
SoLEXS: Solar low energy X-ray Spectrometer
PAPA : Plasma Analyzer Package for Aditya
ASPEX: Aditya Solar wind Particle





Repository of the Space Science Data

भारतीय अंतरिक्ष विज्ञान आँकडा़ केंद्र (आई.एस.एस.डी.सी)
इसरो दूरमिति, अनुवर्तन तथा आदेश संचारजाल (इस्ट्रैक)
अंतरिक्ष विभाग , भारत सरकार

Indian Space Science Data Center (ISSDC)
ISRO Telemetry, Tracking and Command Network (ISTRAC)
Department of Space, Government of India

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Major Ground Based Observatories in Astronomy (including Solar)

- Gurushikhar Observatory – Operated by PRL
- Udaipur Solar Observatory – Operated by PRL
- Vainu Bappu Observatory – Operated by IIA
- Gauribidanur Radio Observatory – Operated by IIA
- Indian Astronomical Observatory (IAO) – Operated by IIA
- Neutrino Observatory – Operated by TIFR
- Gamma Ray Astronomy PeV EnergieS (GRAPES) at Ooty – Operated by TIFR
- Giant Metrewave Radio Telescope (GMRT) – Operated by NCRA-TIFR
- Ooty Radio Telescope – Operated by BCRA-TIFR
- Devasthal Optical Telescope – Operated by ARIES
- GROWTH-India Telescope – Operated jointly by IIT-Mumbai and IIA

The list is not exhaustive

Part-3

Why ‘START’ ?

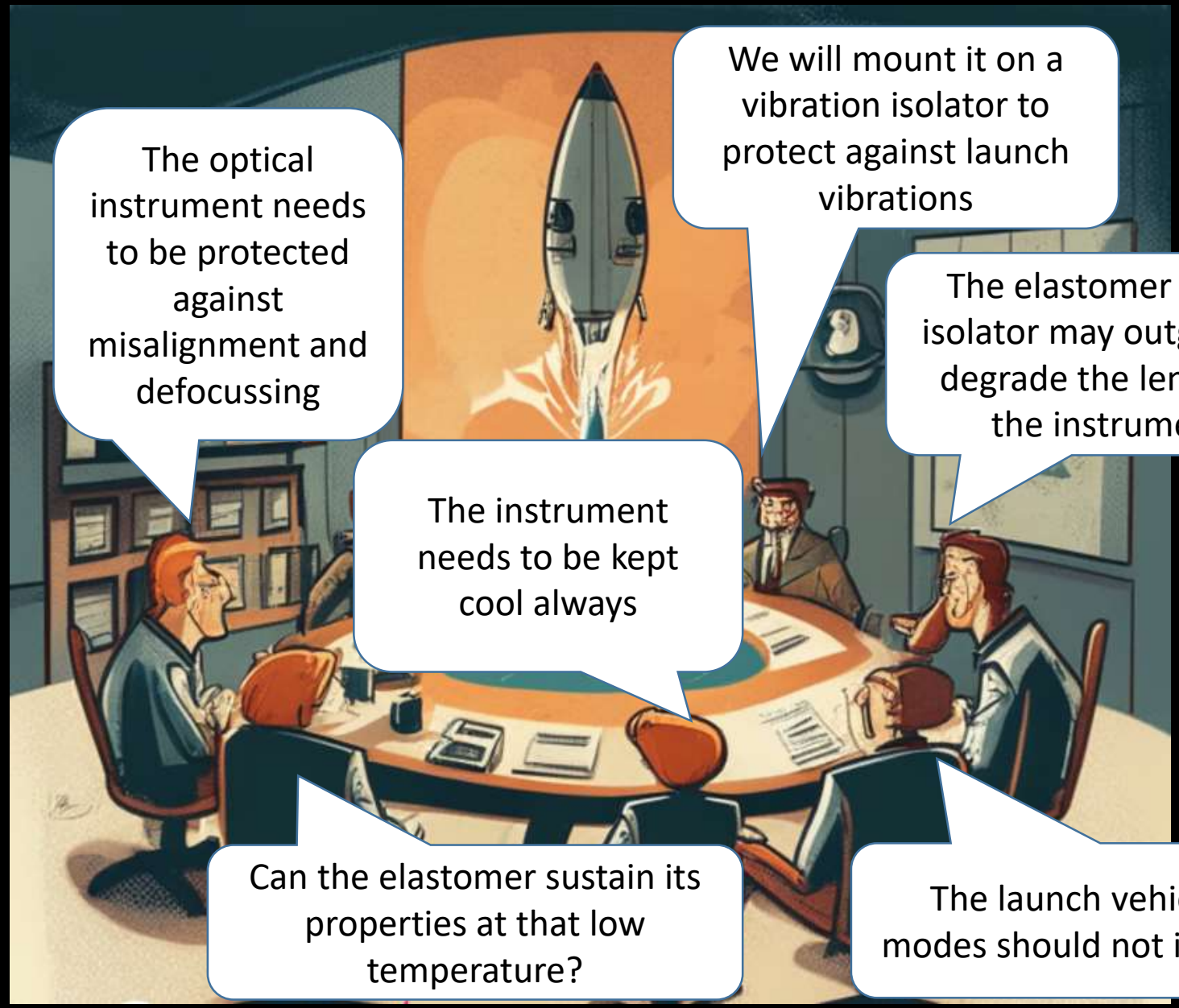
Future Directions: A Guide to Logical Thinking

Survey literature: Identify the Open Problems in the field	Often you need a Guru here
What are known till date, and how do they possibly connect to the unknown (open problems)?	It is you, who have to introspect
Can you conjecture? Can you put up a hypothesis? Can you design an experiment to 'test the hypothesis' ?	Don't ignore your 'gut feelings'
Theoretical modelling → Simulation → Plan for observation	You need to decide what are you good at: Theory, Simulation or Instrumentation ?
Technology Gaps; Realistic Constraints; System-level thinking	Being realistic and informed matter a lot !
Birth of New Scientific Missions	You create opportunities for scientists and engineers!

Space Science is an Amalgamation of all Subjects

Physics
Chemistry
Mathematics
Computer Science
Electronics and Communication
Electrical Engineering
Mechanical Engineering
Civil Engineering
Robotics
Aeronautical Engineering
Propulsion Engineering

System-Level Thinking & Cross-Disciplinary Views



Space exploration requires a system-level thinking approach that transcends the boundaries of individual subjects.

Relevance of the START Programme

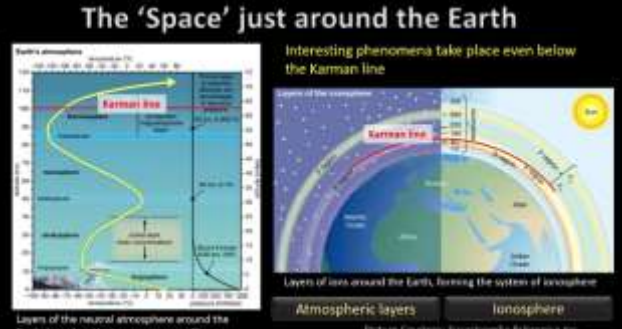
Why?

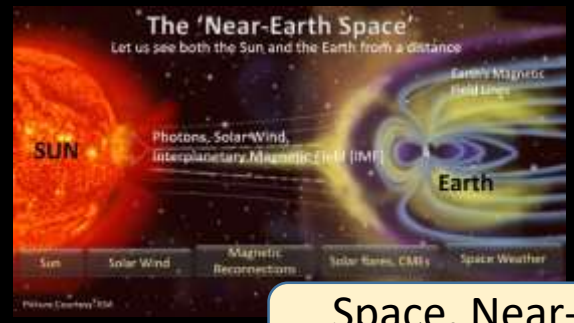
- To create awareness about the fields of space science and technology
- Introduction to the different facets of Space Science and Technology
- Awareness about the cross-disciplinary nature of space science and technology activities
- Promote System-level thinking
- Will help to understand how do different subjects fit to different aspects of space science and exploration.

Bigger Goal

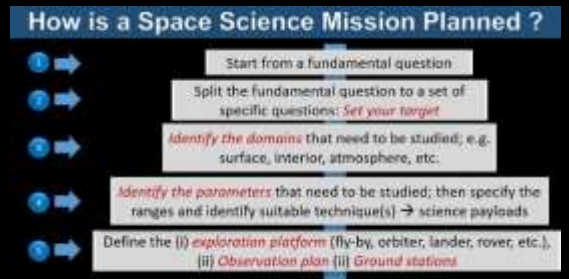
- Generate awareness about the Indian contributions to the domains of space science and exploration, and how do they fit in the global arena of exploratory endeavors.
- May sow the seed of preparing future leaders to take forward the country's space exploration programme.

Summary

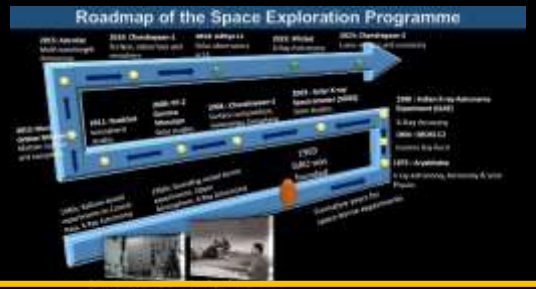




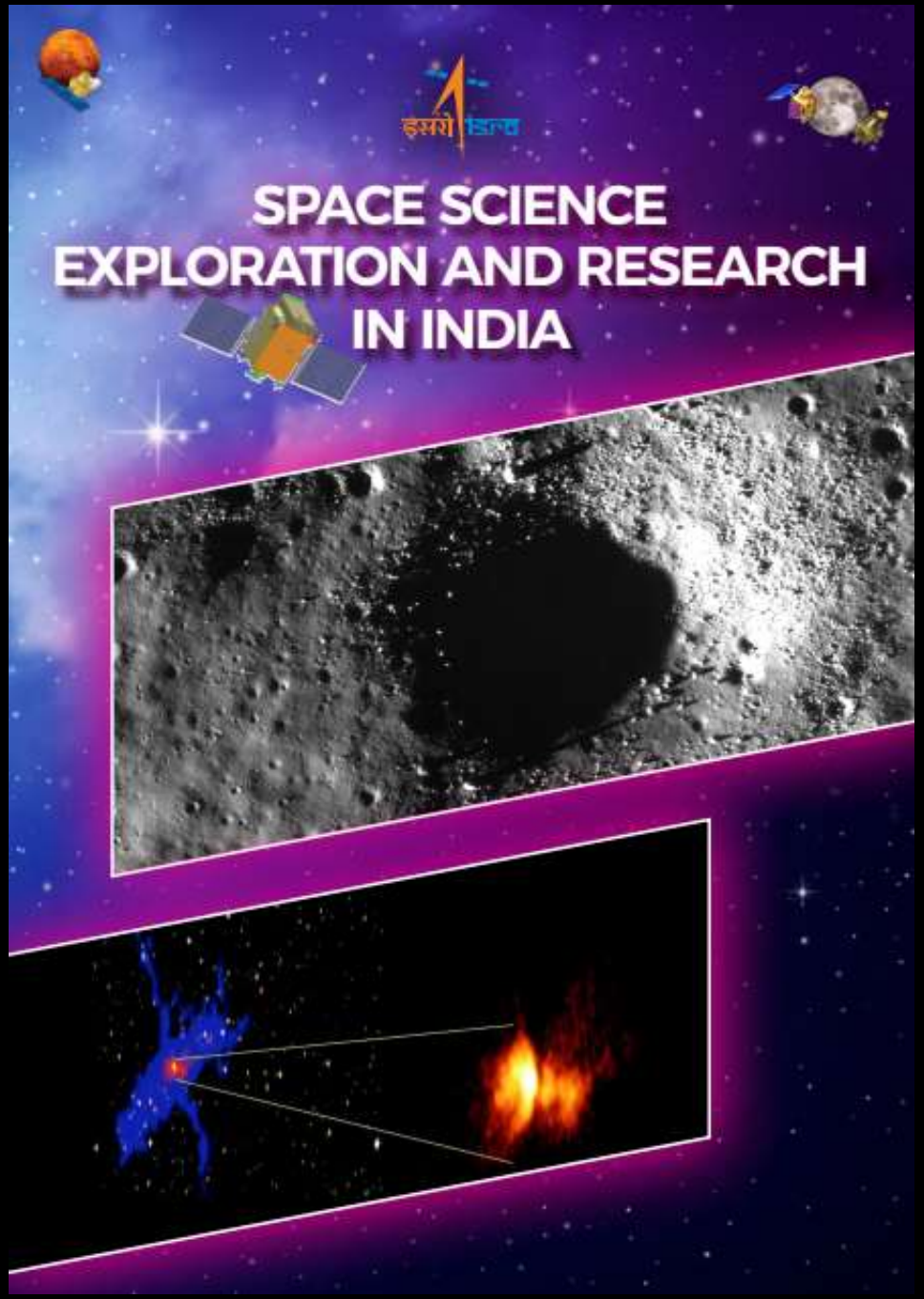
Space, Near-Earth Space, Space Weather, Bigger Perspective of Space and Universe

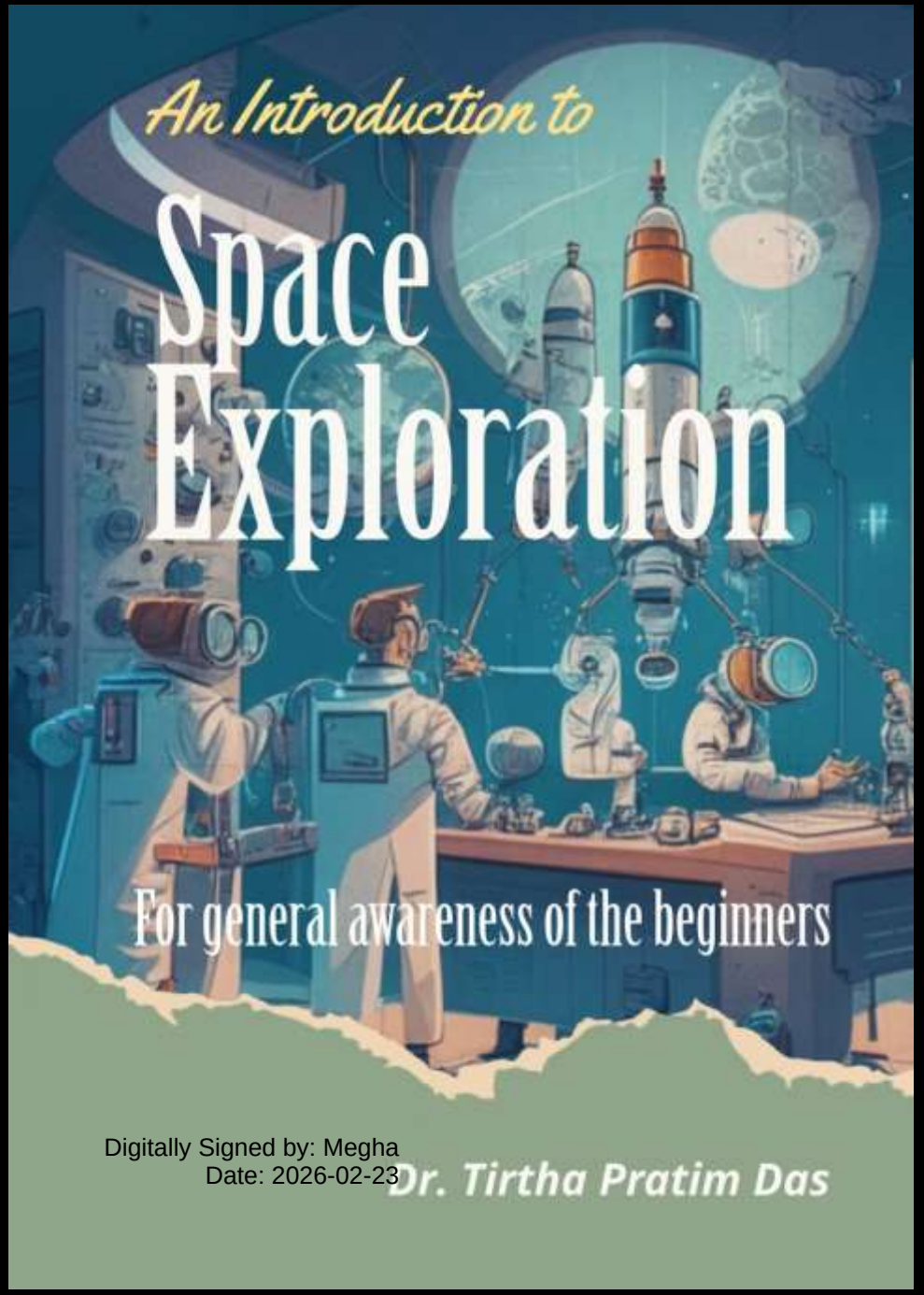


Space research techniques; exploration platforms; mission design, ground & space segments



India's Space exploration; missions; data centre, relevance of START; relevance of system-level thought; Pan-India studies on space science





Digitally Signed by: Megha
Date: 2026-02-23

Thank you for your attention