

ADITYA L1: Illuminating Insights and Innovations - A Review

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Abstract

This paper reviews the first Indian Space based observatory “Aditya L1”, which aims to study the Sun from a halo orbit around first Sun-Earth Lagrange Point (L1). Here we will discuss the mission in detail including its trajectory to L1, objectives, need, insights and indigenously developed scientific payloads.

Introduction

We, Homo-Sapiens are so much curious about the universe and its wonders. One of such wonders are stars, that twinkle in the night sky. Although we have studied so much about them but still we are far to understand them completely. One of such stars is our Sun and to understand it we have sent 23 missions^[1] including PIONEER 5^[1], 1960 (first mission to sun by NASA) to recent missions such as Parker Solar Probe (NASA,2018)^[1], Solar Orbiter (ESA,2020)^[1], CuSP (NASA, 2022)^[1] and Aditya L1 (ISRO, 2023)^[1].

Aditya L1 mission was originally announced in January, 2008^[2] by the name of Aditya 1 because Aditya means Sun in Sanskrit language and initially it was aimed to place the observatory in 800 km low Earth orbit but later ISRO decided to place it in a large halo orbit around Sun-Earth Lagrange point 1, which in turn led to change the name of Aditya 1 to Aditya L1^[2].

Aditya L1 was successfully launched on September 02, 2023 at 11:50 AM IST via Polar Satellite Launch Vehicle from the second launch pad of Satish Dhawan Space Centre, Shriharikota, Andhra Pradesh^[3].

This mission aims to provide crucial information to understand the problems of exceptional coronal heating, coronal mass ejection, pre and post flare activities, dynamics of space weather and fields in interplanetary medium by revolving in a halo orbit around Lagrange Point 1 with its seven scientific payloads. We will discuss all of this in details in the following sections.

Description

The Sun

Sun is the nearest star from earth and largest object in our Solar system which makes up about 99.86% of the total mass of the solar system^[4]. Estimated age of the Sun is about 4.57 billion^[5] years. It is a hot object consisting of hydrogen and helium gases and located around 150 million km from earth.

The core temperature of Sun is about 15 million Degree Celsius^[6] whereas the visible surface known as Photosphere is relatively cool having temperature of about 5500 Degree Celsius^[6] and weirdly the atmosphere of Sun known as Corona as hot as 2 million Degree Celsius^[6] and this is

still a mystery for scientific community because in general temperature goes down with respect to surface on increasing the distance.

Need

The first and foremost question arises to our mind is that why we need to study the Sun?

Answers are as follows:

- Since Sun makes up 99.86% mass of the total mass of solar system, so it is impossible to understand the Solar System without understanding the Sun^[7].
- The Sun is nearest star from Earth and therefore, can be studied in much more details as compared to other stars. These studies are expected to help us understand distant stars and galaxies too.
- By understanding the exceptional Coronal heating with respect to Photosphere, we can understand Coronal mass ejection (CME) and other eruptive phenomena which directly affect Earth's magnetic field and communication systems.
- Various thermal and magnetic phenomena on Sun are of extreme nature^[6] (that can't be created on Earth) thus it provides a natural laboratory for study such phenomena.
- The earliest life forms we know of were microbes that left their signal of presence in rocks about 3.7 billion years ago^[8], and the estimated age of our Sun is 4.57 billion^[5] years but it contradicts the fact that 3.7 billion^[8] years ago the Sun did not have that much amount of heat^[9] to sustain water in liquid form in the oceans of the Earth, and we know that life first started developing in oceans.
- By understanding the Sun and its eruptive phenomena we can take corrective measures against Carrington event^[9] (i.e., disruption of telegraph lines and power grids as observed in 1859) and Kessler Syndrome^[9] (malfunctioning of satellites which can lead to create huge space debris and badly affect our communication systems).

Lagrange Points

Lagrange points are some specific points in space where the gravitational pull of two large bodies equals to the necessary centripetal force required for a small object to move with them. These points act as parking spots for probes and can be used by the spacecrafts to remain at around this point with less fuel consumption, longer life, stability for smooth conduction of experiments and continuous signal transmission to the Earth.

As per plan Aditya L1 will be placed in a Halo orbit around Lagrange Point 1 and conduct experiments for five years^[10].

Insights

Why not from the Earth?

Earth's magnetic field doesn't allow the solar storms to enter the atmosphere of Earth. Also, Earth's atmosphere filters out most of the radiations from the Sun and hence, life is flourishing on Earth. This in turn leads to the loss of lots of information regarding the Sun and hence, we can't understand and study it efficiently.

Why L1?

As shown in figure 1, there are five Lagrange Points to the Sun-Earth system two of which (viz. L4, L5) were discovered by Lagrange in 1772^[11]. These points are far away as compared to L1. Other three Lagrange points (viz. L1, L2, L3) were discovered by Euler around 1750^[11] from which L3 is always behind the Sun with respect to Earth, L2 is located towards Mars and therefore at that point there will be eclipses from the Earth and Moon. Therefore we are left with L1 which is closer towards the Sun and there are no eclipses at this point and hence we can continuously observe the Sun from here.

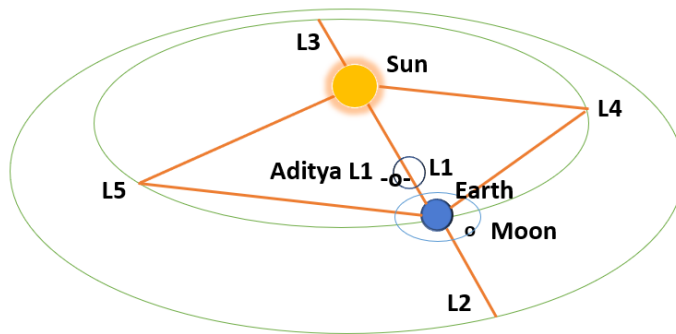


Fig. 1: Illustration of Lagrange Points

The mission: ADITYA L1

Aditya L1 is first Indian Space based observatory to study the Sun with major objectives^[12] as follows:

- Study the solar upper atmospheric (Chromosphere and Corona) dynamics.
- Study the Chromosphere and Coronal heating physics of partially ionized plasma and initiation of coronal mass ejection.
- Study the magnetic field topology and magnetic field measurement in the solar Corona.
- Study the development, dynamics and origin of Coronal mass ejection.
- Diagnostic of coronal and coronal loops plasma: temperature, velocity, density.
- Identify the sequence of processes that occur at multiple layers (i.e., Chromosphere base and extended Corona)
- Observe in-situ particles and plasma environment and provide data for the study of particle dynamics from the Sun.
- Study of physics for solar Corona and its heating mechanism.
- Study of drivers for space weather (origin, composition and dynamics of solar wind).

Payloads

For all of the mentioned objectives, Aditya L1 is onboard with seven scientific payloads^[13] which are as follows:

1. fluxgate MAGnetometer^[13] (MAG):

- It is a dual triaxial magnetic sensor.
- Major objectives:
 - Measure magnitude and direction of interplanetary magnetic field (IMF)
 - To study the Impact of extreme solar events in near Earth environment
 - Its observations will be supplement to other onboard payloads such as PAPA and ASPEX

2. Visible Emission Line Coronagraph^[13](VELC):

- It is designed as an internally occultated reflective coronagraph.
- Major objectives:
- Simultaneous observation of solar corona in three modes i.e., Imaging, Spectroscopy and Spectro-polarimetry.
- Diagnostics of coronal and coronal loops plasma (temperature, velocity, density)
- To work as onboard Artificial Intelligence (AI) for the detection of coronal mass ejection.

3. High Energy L1 Orbiting X-ray Spectrometer^[13](HEL1OS)

- HEL1OS is pronounced as Helios.
- It is a hard X-ray spectrometer designed to observe solar flares in X-ray energy range of 10-150 keV.
- Major objectives:
- To study the explosive energy release, acceleration and transportation of electron using high resolution spectra and fast timing measurements.
- To study the Quasi periodic pulsation of hard X-rays during impulsive phase of solar flares to understand its connection with particle acceleration mechanism.

4. Solar Low Energy X-ray Spectrometer^[13](SoLEXS):

- It is a soft X-ray spectrometer to study the Sun.
- Major objectives:
- Continuously measure soft solar X-ray flux between energy range of 1keV to 22keV
- Study of solar flares and coronal heating.
- To independently measure the coronal temperature as well as abundances of coronal plasma

5. Solar Ultraviolet Imaging Telescope^[13](SUIT):

- It provides unique opportunity to study spatially resolved solar spectral irradiance in near ultra violet range.
- Major objectives:
- To study coupling and dynamics of solar atmosphere.
- Study of mechanisms responsible for stability, dynamics and eruption of solar prominences.
- To find out at what wavelength do flares radiate most of its energy.

6. Aditya Solar wind Particle EXperiment^[13](ASPEX):

- It comprises low and high energy particle spectrometers to carry out in-situ measurement of solar wind particles near Lagrange point 1.
- Sub systems and their major objectives:
- Solar Wind Ion Spectrometer (SWIS): It is a low energy ion spectrometer which measures ion flux of protons and Alpha-particles in the energy range of 100eV. to 20keV.
- Supra thermal and Energetic Particle Spectrometer (STEPS): It is a high energy ion spectrometer which measures ion flux of protons and Alpha-particles in energy range of 20keV. to 5MeV.

7. Plasma Analyser Package for Aditya^[13](PAPA):

- It aims to study the composition of solar wind and its energy distribution.
- Sub systems and their major objectives:
- Solar Wind Electron Energy Probe (SWEEP): Consists of two guiding plates for directing the electrons and ions of solar flares for further energy analysis and smoothening the signal.
- Solar Wind Ion Composition Analyser (SWICAR): Used for energy and mass analysis of ions and electrons of solar flares.

Trajectory

Aditya-L1 was launched on September 02, 2023 at 11:50 AM I.S.T. by ISRO PSLV C57 rocket from the second launch pad of Satish Dhawan Space Centre (SDSC), Sriharikota. Initially the spacecraft was placed in a low earth orbit. Subsequently, the orbit was made more elliptical and later the spacecraft was launched towards the Lagrange point L1 by using on-board propulsion. As the spacecraft travels towards L1, it exited the earth's gravitational Sphere of Influence (SOI) (as per the data of September 30, 2023)^[14]. After the exit from SOI, the cruise phase is started and subsequently the spacecraft would be injected into a large halo orbit around L1. The total travel time from launch to L1 would take about 127 days^[3] for Aditya L1.

Analysis

- Aditya L1 is important for scientific communities because it is crucial for understanding the coronal mass ejection and its impact on space weather and Earth, which in turn comes out to be important mission to save life on Earth.
- With International collaborations like National Aeronautics and Space Administration (NASA)'s Parker Solar Probe and European Space Agency (ESA)'s Solar orbiter enhances data sharing and global understanding of the Sun.
- Aditya L1 enhances India's standing in the global space community and strengthens diplomatic ties with space faring nations.
- It also demonstrates India and ISRO's technological capabilities and its ability to undertake complex space missions.
- Last but not the least, Aditya L1 mission will act as an inspiring tool for the next generations of youth, scientists and engineers in India and beyond.

Conclusion

Space researches were the part and parcel of ancient Indian education but its scientific advancement hindered significantly during colonial rules. These researches again started in 1920's when scientist Dr. S.K. Mitra performed series of experiments on ionosphere and radio waves from Kolkata^[15], and in almost 100 years India is again setting milestones in this field by launching "Mangalyaan", "Chandrayaan-1, 2, 3" and "Aditya L1".

This review paper delved into various aspects of the mission including its objectives, instrumentation, trajectory and anticipated contribution to space science. With its cutting-edge instrumentation and international collaborations, the mission promises to provide valuable insights into solar dynamics, understanding the Sun and its eruptive phenomena, space weather and impact of coronal mass ejection on Earth.

As we look forward to the mission's data and discoveries, it is clear that Aditya L1 will stand as a testament to India and its growth in space research. It will undoubtedly strengthen its commitment towards advancing our understanding of the cosmos.

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