Aditya-L1 mission

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Aditya-L1 is the first Indian space mission to study the Sun. The mission is aimed at studying the Sun from a halo orbit around the Sun–Earth Lagrangian point 1, which is about 1.5 million kilometres from the Earth. It carries seven payloads to observe the photosphere, chromosphere and the outermost layers of the Sun, the corona, in different wavebands. The spacecraft and payloads are under development. Aditya-L1 is expected to be launched during the 2019–20 timeframe by PSLV-XL.

Keywords: Corona, mission, payloads, Sun.

Introduction

THE Sun being our nearest star, has been studied in great detail. It has been observed for over 300 years, and solar physics has attained the status of a mature and independent discipline in astrophysics. Although both observations and modelling have improved tremendously over the years, there are still a number of outstanding scientific questions which remain unanswered. One example of the exciting challenges posed by the Sun, the mystery of the missing solar neutrinos, was solved after decades of extensive and diligent experimental observations and theoretical framework, which led to fresh insights on the fundamental properties of neutrinos and particle physics. For several decades now, the puzzle of what are the sources that heat the chromosphere, the transition region and the solar corona, above the much cooler photosphere, still remains. Similarly, eruptive phenomena of flares and coronal mass ejections (CMEs) which expel huge amounts of particulate matter and energy into the interplanetary space which have direct consequences on space weather and its effects on the Earth, are still difficult to comprehend. The possible methods of ‘coronal heating and confining plasma’ have potential applications for constructing viable fusion reactors, and understanding the ‘solar eruptions’ will help protect the terrestrial power and communication systems from serious disruptions. In an attempt to understand some of these mysteries, the first Indian mission to study the Sun, Aditya-L1 is planned with a suite of instruments to obtain a better understanding of the star.

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Aditya-L1: enhanced Aditya-1 project

Aditya-1 was meant to observe the solar corona. The mission was conceived as a 400 kg-class satellite carrying one payload, the Visible Emission Line Coronagraph (VELC) to study the corona from 1.05 to 1.5 solar radii. It was planned to be launched in an 800 km Sun synchronous orbit.

However, the requirements of the payload demanded a much larger satellite platform. Hence it was decided by the ISRO’s Advisory Committee for Space Science (ADCOS) that a full-fledged large satellite be designed with many more payloads, which could be launched into a halo orbit around the Sun–Earth Lagrangian point 1 (L1). This allows for observations of the Sun without any occultation/eclipse and to study the Sun in a more comprehensive manner. With this in view, the Aditya-1 mission has been revised to ‘Aditya-L1 mission’. The satellite will be inserted in a halo orbit around L1, which is 1.5 million kilometres from the Earth. Aditya-L1 is a 1500 kg-class satellite carrying seven payloads. The payloads cover the Sun’s photosphere (ultraviolet (UV) and soft and hard X-rays), chromosphere (UV) and corona (visible and NIR). In addition, particle payloads will study the particle flux emanating from the Sun and reaching the L1 orbit, while the magnetometer payload will measure the variation in magnetic field strength at the halo orbit around L1. These payloads will make *in situ* measurements and therefore have to be placed outside the interference from the Earth’s magnetic field for useful measurements to study the incoming effects from the Sun.

Payloads and their objectives

Indian Space Research Organisation (ISRO) made an announcement of opportunity (AO) and invited payload proposals from various Indian research institutions and universities. In response, several proposals were received. Seven payloads were selected based on their scientific merit and technical feasibility. The main payload continues to be the coronagraph of Aditya-1 with enhanced capabilities of spectroscopy and spectro-polarimetry.

The payloads on-board Aditya-L1 are as follows:

(i) Visible Emission Line Coronagraph: To study the diagnostic parameters of solar corona, and dynamics and origin of CMEs (three visible and one infrared (IR) channels); magnetic field measurement of solar corona down to tens of Gauss.

(ii) Solar Ultraviolet Imaging Telescope (SUIT): To image the spatially resolved solar photosphere and chromosphere in near UV (NUV; 200–400 nm) and measure solar irradiance variations.
(iii) Solar Low Energy X-ray Spectrometer (SoLEXS): To monitor the X-ray flares for studying the heating mechanism of the solar corona.
(iv) High Energy L1 Orbiting X-ray Spectrometer (HEL1OS): To observe the dynamic events in the solar corona and provide an estimate of the energy used to accelerate the particles during the eruptive events.
(v) Aditya Solar Wind Particle Experiment (ASPEX): To study the variation of solar wind properties as well as its distribution and spectral characteristics.
(vi) Plasma Analyser Package for Aditya (PAPA): To understand the composition of solar wind and its energy distribution.
(vii) Magnetometer: To estimate the magnitude and nature of the interplanetary magnetic field (IMF).

Combined observations of each of these payloads can also lead to several other important analyses. Solar eruptions like flares and CMEs originate in the outer layers of the chromosphere and the corona, but have their magnetic connection down to even below the photosphere. The SUIT instrument will therefore be able to study the intensity enhancement at the chromospheric layers, the SoLEXS and the HEL1OS instruments will provide observations on the initiation of the impulsive phase of the flares, and VELC will enable the study of the dynamics at the corona. This combination of measurements will help in providing a comprehensive picture of the eruptive events and help fine-tune models providing a physical understanding of these events, and hence the drivers affecting space weather. The PAPA, ASPEX and MAG instruments will measure the particulate flux and IMF at the L1 orbit.

Current and future missions

Aditya-L1 is primarily a mission to study the solar corona and processes leading to changes in the same. There are two imaging payloads for Aditya-L1.

The main payload, VELC will study the solar corona in the visible band and also in one of the IR lines to estimate the magnetic field of the corona from space for the first time. The VELC payload will study the diagnostic parameters of the coronal plasma like velocity, temperature and density, and also perform spectroscopic studies in three wavebands. It will study the dynamics and origin of CMEs at coronal distances from 1.05 solar radii all the way to 1.5 solar radii, with a field of view (FOV) covering 3 solar radii. The IR channel enables spectro-polarimetry and hence magnetic topology and magnetic field measurements of the solar corona, albeit down to only tens of Gauss sensitivity with long integrations. This experiment is similar to the Large Angle and Spectrometric Coronagraph (LASCO-C1), one of the experiments on Solar and Heliospheric Observatory (SOHO). SOHO is a very large solar mission of NASA with 610 kg payload mass, which is about 2.5 times that of Aditya-L1. Compared to LASCO-C1 which could observe from 1.1 to 3 solar radii, VELC is expected to observe closer to the Sun, from 1.05 to 3 solar radii, and can therefore extend observations into the inner part of the corona, with the important additional feature of providing coronal magnetic field data. VELC also has a better image (2.5 arcsec/pixel) and spectral resolution (0.0065 nm for Fe XIV line) than LASCO-C1 (5.6 arcsec/pixel and 0.065 nm for Fe XIV). It may be noted that although SOHO has had a long mission life (it was launched in 1995), LASCO-C1 could make measurements only for about two years, after which no data were available. Hence an instrument to study the inner corona is extremely important.

The second instrument, SUIT, is expected to image the Sun in specific filters of the near UV band (200–400 nm). In order to understand the footprints of solar eruptive events, SUIT will image the solar photosphere, chromosphere and part of the transition region right up to 1.1 solar radii in the near-UV band. In addition, SUIT will enable the study of solar irradiance variations which are closely connected with magnetic activity on the solar disc. The near UV waveband is best suited for this because 60% of solar irradiance variations are believed to occur in this band, although it constitutes only 8% of the total solar irradiance. Most satellites have experiments operating in the extreme UV (EUV) region, since this is useful to study the higher temperature regions better. The NUV region enables us to study the photosphere, chromosphere and a portion of the transition region between the chromosphere and the corona. These observations will also allow the study of variabilities in the irradiance of the Sun in the UV band, in which variations are maximum. The only other satellite which has NUV instrumentation is the Interface Region Imaging Spectrograph (IRIS) mission of NASA. IRIS is a multi-channel imaging spectrograph with a 20 cm UV telescope which operates in the wavelength range 133–135 nm and 139–140 nm in far UV, and 278–283 nm in NUV. When compared to IRIS, SUIT can do full disk observations with an FOV of 33–35 arcmin which has overlap with VELC, whereas FOV of IRIS is only 2 arcmin. SUIT has broadband and narrow-band filters (totally 10) for UV observations, thus addressing individual lines when compared to IRIS which has four pass bands. It is expected that the ten filters will allow for a ‘layered’ study of some of the eruptive events like prominences.

The initiation and impulsive phases of the solar flares are best studied in the X-ray bands. Two instruments, SoLEXS and HEL1OS, will study the X-ray spectrum all the way from 1 to 150 keV. The X-ray spectrometer will also provide an independent measure of temperatures leading to the flare processes. The X-ray instruments operating in a wide X-ray band will help in studying solar X-ray flares with good spectral resolution. SoLEXS is comparable to the X-ray spectrometer flown on RHESSI spacecraft by NASA. SoLEXS will have a much lower energy threshold starting from about 1 keV compared to 3 keV of RHESSI, thus enabling a better modelling of the solar X-ray spectrum. It will also have a better spectral resolution (by a factor of 3–4; ~250 eV at 6 keV) compared to RHESSI (<2 keV below 1 MeV) and the upcoming STIX payload on Solar Orbiter (1 keV at 6 keV and 15 keV at 150 keV). The resolution of HEL1OS is ~1 keV at 22 keV and ~5 keV at 60 keV.

There is a large amount of ionized matter and energy which blows out of the Sun which is known as the solar wind. This increases by several orders of magnitude when there is a CME. A study of the composition of the solar wind and the particulate emissions during the occurrence of CMEs compared to the quiet phase of the Sun will be done using the PAPA and the ASPEX. These experiments taken together with the magnetometer will help in understanding the solar wind and its changes during activity on the Sun. There are many satellites carrying particle experiments and magnetometer, like the ACE, WIND and DSCOVR. The DSCOVR mission launched on 11 February 2015 to the L1 orbit carried a Plasma-Magnetometer (PlasMag) along with two Earth science instruments. PlasMag will measure the solar wind activity, including the magnetic field and the velocity distribution (magnitude and direction) of solar wind particles.

These, however, are independent satellites to mainly measure the solar wind, to provide inputs for space weather and prediction of solar-related events on Earth. They do not study the Sun per se. The only other spacecraft which carried both solar and particle experiments was again the SOHO, which was a much bigger satellite. In Aditya-L1, the particle instruments and the magnetometer are expected to provide inputs on the variation in flux of charged particles and magnetic fields from the Sun that reach L1, as a tool leading to overall understanding of the Sun, and so will complement the measurements done with the other instruments on CME events. Though not a primary objective, these instruments can contribute to the overall database on space weather.

Amongst the other upcoming international missions, the Solar Orbiter, a joint mission of ESA and NASA which is to be launched in the 2017–18 timeframe, will have a coronagraph which could observe the corona from 1.4 to 3.0 solar radii and also have an EUV imager. To recall, VELC is expected to have the capability to observe the corona from 1.05 solar radii.

The Solar Probe plus spacecraft of NASA planned during 2018 will reach about 5.9 million kilometres from the Sun, well within the orbit of Mercury and about eight times closer than any spacecraft. It has a Heliospheric Imager which will provide context for the *in situ* instruments and be able to tomographically reconstruct the three-dimensional density structure of the corona. The 160° FOV is sufficiently large to view the corona from near the solar limb to beyond the zenith.

Launch and operations

Aditya-L1 is expected to be launched during the 2019–20 timeframe by PSLV-XL from Sriharikota. The lift-off mass of the spacecraft is about 1500 kg. The satellite will be launched into an elliptical Earth Parking Orbit of 245 km by 21,000 km. The satellite propulsion is employed to carry out orbit manoeuvres to raise the orbit, transfer around the L1 point, insertion and maintain orbit about L1. The insertion around L1 will take place in about 100 days from the launch. The nominal satellite orbit lifetime is about 5 years.

The ground segment elements include Spacecraft Control Centre (SCC) at ISRO Telemetry Tracking and Command Network (ISTRAC), Indian Deep Space Network (IDSN) and the Indian Space Science Data Centre (ISSDC). The existing Telemetry and Tele-Command (TTC) network of ISTRAC will support the TTC functions. For the initial phase operations, the network will be augmented with additional network stations from other agencies. The payload data will be acquired through IDSN. These data will be processed and disseminated through ISSDC.

Conclusion

The Aditya-L1 mission is expected to provide a multi-pronged holistic approach to the understanding of some of the outstanding problems of solar physics.

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