VELC on board Aditya-L1 reveals asymmetric expansion of solar eruption that could impact space weather

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India's first space-based solar observatory, Aditya-L1 has helped scientists take a peek into the nature of expansion of a solar eruption or a coronal mass eruption (CME) and gain new insights into it. This could be important for space-weather studies and thereby affecting our satellites and communication networks.

Aditya L 1 satellite launched in September 2023 is now operational at the Sun–Earth L1 point, providing continuous observations of the Sun. It carries 7 payloads, of which the Visible Emission Line Coronagraph (VELC), the primary payload, is an internally occulted coronagraph designed to observe the solar corona simultaneously in various modes.

By combining data from the Visible Emission Line Coronagraph on Aditya-L1 with complementary observations from NASA's SDO spacecraft and three-dimensional modeling, scientists from the Indian Institute of Astrophysics (IIA), an autonomous institution of the Department of Science and Technology (DST) were able to reconstruct the full 3-D geometry and dynamics of solar eruptions.

Their study published in Astrophysical Journal Letters, showed, for the first time, that the CME did not expand outward from the Sun like a simple symmetric bubble, as previously thought. Instead, it underwent non-uniform expansion and developed an asymmetric shape. These differences in CME expansion can affect its speed as it travels towards Earth causing space-weather disturbances.

The VELC studies nascent CMEs through spectroscopy in the 530.3 nm wavelength green emission line due to highly ionized iron atoms in the corona. This line emission captures hot coronal plasma which is at temperatures of around 1.8 million Kelvin. The Doppler shift, or the change in the wavelength of this emission line provides information about plasma velocity along the line of sight, and close to the solar disk.

The VELC, with this unique capability, was designed and fabricated by the IIA at its MGK Menon Lab for Space Sciences on the CREST campus in Hosakote, with substantial support from ISRO.

“We observed the CME that occurred on 5 August 2024 using the VELC as well as data from the Atmospheric Imaging Assembly (AIA) onboard NASA’s Solar Dynamics Observatory (SDO)”, explained Saurabh Tripathi, a PhD student at IIA, and lead author of the study. The CME was launched from an active region near the western limb of the Sun. VELC’s spectroscopic data show an unusual yet distinct Doppler pattern of blueward and red-ward shifted emission, which arises from plasma moving towards and away from us, respectively.

“Our results show that the CME did not expand uniformly. The AIA images captured how the CME propagated across the sky, while VELC revealed the motion of the expanding CME bubble towards and away from us,” Tanmoy Samanta, a solar astronomer at IIA and the corresponding author of the study elaborated. Together, these observations reveal that the CME did not expand like a simple spherical bubble. Instead, its uneven expansion caused it to develop an asymmetric shape.

“To understand the unusual spectral pattern observed by VELC, we then developed a 3-D geometric-kinematic model of an expanding CME”, said Jayant Joshi of IIA and a co-author. The model was used to test how the CME’s orientation and uneven sideways expansion could produce the spectral structures observed by VELC. A model with symmetric expansion could not reproduce the observed pattern. Instead, a model of an inclined CME axis and asymmetric lateral expansion produced a spectral pattern and temporal evolution similar to those observed by VELC. The researchers plan to use this technique on other CMEs, to reconstruct their motion without relying entirely on multi-viewpoint imaging from telescopes in space. This complementarity is particularly valuable in the lower corona, where CMEs evolve rapidly, and their motion along the line of sight cannot be obtained from imaging alone.

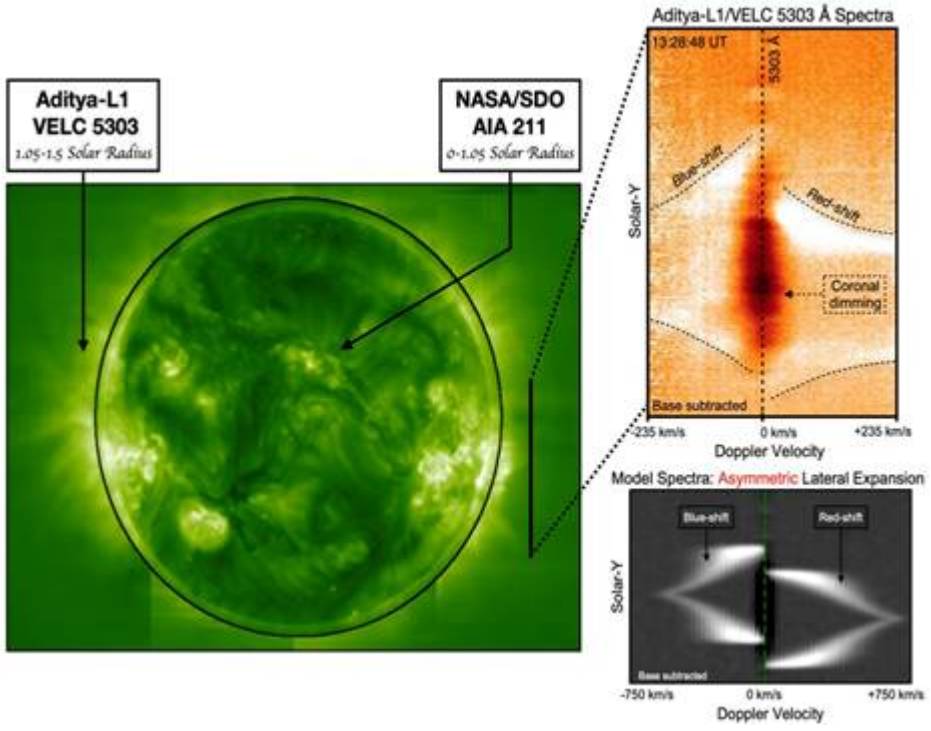


***Fig**. (Left) Composite image of the Sun’s corona combining data from India's Aditya-L1/VELC (outer part, 1.05–1.5 solar radii) and NASA’s SDO/AIA (inner disk). (Top right) Aditya-L1/VELC spectra recorded during the eruption, showing two distinct branches of emission — one shifted toward shorter wavelengths (plasma moving toward us) and one*

toward longer wavelengths (plasma moving away) — the spectral signature of a three-dimensional, asymmetric solar eruption. (Bottom right) Model spectra reproducing the observed pattern, confirming asymmetric lateral expansion of the CME in the inner corona

"The asymmetric shape of an early CME can have important implications for how it interacts with the solar wind and experiences drag during its propagation through the heliosphere. Such effects can influence the CME's speed and, ultimately, its arrival time at Earth", said Joshi.

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