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CHANDRAYAAN INSTRUMENT HELPS UNRAVEL THE MYSTERIES OF SOLAR CORONA

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Not sedate: Huge solar flares and coronal mass ejections spew material from the solar surface into outer space | Photo Credit: SOHO

An instrument on board India's Chandrayaan-2 mission has provided outstanding science results on the solar corona and heliophysics, the Indian Space Research Organisation (ISRO) said.

Though we have a fairly good understanding of the origin of energy and other various aspects of the Sun, several potentially life-changing phenomena still remain a mystery, notes the Bengaluru-headquartered space agency.

Some of these mysteries are related to the hot outer atmosphere of the Sun, known as corona, which emits profusely in ultra-violet and X-ray wavelengths of the electromagnetic spectrum.

It is known that the corona consists of ionised gas at temperatures exceeding one million Kelvin, which is much higher than photospheric temperature of 6000K, the visible surface temperature of the Sun.

Sunspots help understand life around other stars

However, this observation is against the natural expectation that the temperatures should reduce as we go away from the source of energy, and this is known as the 'coronal heating problem.' From observations, such as the presence of even hotter corona, called active regions above the Sunspots (dark patches seen in visible images of the Sun) where the magnetic fields are known to be stronger, it is suggested that the magnetic fields have an important role in the coronal heating, according to the ISRO.

While there are different theories regarding the actual mechanism, one of these relies on the occurrence of a large number of small solar flares called nanoflares.

Another puzzling observation about the corona is that certain elements are found to have abundances three to four times higher in active regions than in the photosphere.

This happens for elements which are easier to ionise, or require lesser energy to ionise. In more technical terms, these elements have their First Ionisation Potential (FIP) lower than 10 eV, and hence this phenomenon is generally termed as FIP bias.

Global magnetic field of Sun's atmosphere measured for the first time

The exact reason behind the FIP bias and its origin remains an open question. A team of scientists from Ahmedabad-based Physical Research Laboratory (PRL), a unit of Department of Space, used observations of the Sun in soft X-rays with Solar X-ray Monitor (XSM) on board ISRO's Chandrayaan-2 mission during the deepest solar minimum of the past hundred years to learn exciting details about the solar corona, an update on the ISRO website said.

"For the first time, absolute abundances of elemental Mg, Al, Si in the quiet solar corona are

derived. The team discovered and characterised around 100 sub-A class microflares in the quiet corona providing new insight into coronal heating puzzle", it said.

The XSM, designed and developed by PRL with support from various ISRO centres, provides measurement of soft X-ray (1- 15 keV) spectrum of the Sun.

The XSM also supports the quantitative measurements of elemental abundances of the lunar surface using the companion payload CLASS (Chandrayaan-2 Large Area Soft X-ray Spectrometer) developed by URSC (U R Rao Satellite Centre), an ISRO centre, which measures the X-ray fluorescence spectrum from the lunar surface.

Solar probe reveals sun's tiny 'campfires' in closest-ever photos

At present, XSM is the only instrument that provides soft X-ray spectral measurements of the Sun, i.e., measures the intensity of X-ray in different energies over the 1 to 15 keV.

More importantly, XSM provides such measurements with very good energy resolution at every second, the highest cadence for any instrument so far, the ISRO update said.

XSM started observations of the Sun in September 2019, during the period of solar minimum when typically there were very few Sunspots and active regions on the Sun.

The solar minimum of 2019-2020 was even more peculiar as the Sun was extremely quiet, and its activity was at the lowest level over the past century, the space agency said.

This provided a unique opportunity for XSM to observe the quiet corona without active regions for long periods.

The solar X-ray flux was observed by the XSM during this period when no active regions were present on the solar disk.

The Sun brings out a fresh batch of sunspots

A remarkable and surprising observation is the detection of a large number (98) of extremely small flares in the quiet corona.

These flares are so small that their intensity is well below the standard scale to classify solar flares (i.e. A, B, C, M, and X class flares, where each class is 10 times more intense than previous), and hence these are termed as sub-A class microflares.

Using the X-ray spectra of these microflares obtained with the XSM and contemporary images in Extreme Ultra-violet obtained with the Atmospheric Imaging Assembly (AIA) of NASA's Solar Dynamics Observatory (SDO), the energy content of these flares could be estimated, ISRO said.

"This was the first observation and statistical study of such a large sample of microflares in the quiet Sun, supporting the hypothesis of the presence of even smaller scale flares everywhere on the solar corona that could be responsible for the coronal heating," the update said.

The X-ray emission over these 76 days, excluding the durations of the microflares, is unusually constant.

This is the lowest intensity of X-ray emission observed from the Sun since space-borne observations began, the ISRO said.

Analysis of the XSM spectra of the quiet Sun, excluding the microflares, provided the measurement of abundances of various elements.

The abundances of the low FIP elements Mg, Al, and Si were estimated and found to be lower than the abundances seen in active region corona but higher than that in the photosphere.

“This is the first report of measurement of abundances as well as reduced FIP bias in the quiet Sun.

Our observations of FIP bias in the quiet Sun provides significant inputs towards understanding the FIP bias and suggests that it arises due to the presence of Alfvn waves in the closed magnetic loops”, the ISRO said.

These outstanding science results on the solar corona and heliophysics obtained during a unique solar extremely quiet period using a sensitive instrument XSM aboard Chandryayaan-2 observations are published in two companion papers in the May issue of the *Astrophysical Journal Letters*.

“Both the Chandrayaan-2 orbiter and the XSM instrument are performing extremely well, and expected to provide many more exciting and new results”, the update added.