Journal of Space Exploration
ISSN: 2319-9822
Commentary Article | Vol11 Iss11

Observed by Chandrayaan-2 XSM: Coronal Elemental Abundances During A-Class Solar Flares

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Received: November 2, 2022**,** Manuscript No. tsse-22-82962; **Editor assigned:** November 4, 2022, PreQC No. tsse-22-82962 (PQ); **Reviewed:** November 11, 2022, QC No. tsse-22-82962 (Q); **Revised:** November 18, 2022, Manuscript No. tsse-22-82962 (R); **Published date:** November 28, 2022**.** Doi: 10.37532/2319-9822.2022.11 (11).243

Abstract

The FIP effect is the three to four time's greater (FIP bias) abundance of low First Ionization Potential (FIP) components in the closed loop active corona than in the photosphere. Evidence suggests that different coronal structures have varied abundances. Here, we investigate the FIP effect using a variety of soft X-ray spectroscopic observations taken by the Chandrayaan-2 orbiter's Solar X-ray Monitor (XSM). A-class flares were seen at solar cycle 24's minimum. We determine using time-integrated spectral analysis the four element abundances of Mg, Al, Si, and S, as well as the average temperature and emission measurement. While the measured abundances indicate an intermediate FIP bias for lower A-flares (such as A1), and the FIP bias is near unity for higher A-flares, the temperature and emission measure scale with the flares sub-class. We conduct a time-resolved spectral analysis for a sample of the A-class flares and look at the evolution of temperature, emission measure, and abundances to further investigate it. In the impulsive phase of the flares, we observe that the abundances shift from their coronal values toward their photospheric values, and that they swiftly revert to their typical coronal values after the impulsive phase.

Introduction

Modeling the solar environment can benefit greatly from knowledge of the elemental abundances at various Sun layers. This could help us better understand how mass and energy are transferred from the photosphere to the corona via the chromosphere, most likely via coronal loops. Elements having a low First Ionization Potential (FIP 10eV) are more prevalent in the closed loop active corona than in the photosphere. The FIP effect, as this phenomena is now known, has been confirmed by study in the years since it was first seen. It is also known that the FIP bias varies according to the coronal features being seen. While fresh loops in active regions have a photospheric composition and gradually develop the coronal FIP bias of 3 to 4, quiet coronal regions have a FIP bias. It is further demonstrated that the FIP bias and the solar cycle phase have a strong correlation using measurements of the sun as a star. It has been noticed that the solar wind's speed affects the FIP fractionation. The FIP bias of the fast solar wind is much smaller than that of the slow solar wind, which has a range of 2 to 5. Studies on relative abundances of elements like Mg and O have also been done for greater flares and surges. For big flares, the absolute abundances of S, Ca, and Fe. The abundances of low FIP elements during flares are reported to be close to their photospheric levels by continuum observations using more ad-

Citation: Wang K. Observed by Chandrayaan-2 XSM: Coronal Elemental Abundances During a-Class Solar Flares. J Space Explor.2022; 11(11).243

-vanced spectroscopic instruments. for four long-duration flares of GOES class M or higher, the absolute abundance of K and the relative abundances of Ar and S. for 20 flares, the absolute abundances of Fe, Ca, Si, and S Low FIP elements are more plentiful by a factor of two while the intermediate FIP and high FIP elements continue to have abundant photospheric distributions during the flare peak, respectively. There have been some attempts to analyse the evolution of the abundances during powerful solar flares, and one of these studies found spectroscopic evidence of the modulation of the Ca abundance in high-temperature solar flare plasmas. For the elements Fe, Ca, Si, and S, a different FIP bias is present during more intense M-class flares. They observed that sulphur, a mid-FIP element, has the lowest variation. They also demonstrated that FIP bias tends to be lower for stronger solar flares. Although prior spectroscopic observations for both larger and smaller flares up to B-class showed the variation of the abundances (or FIP bias), a thorough analysis for the much smaller A-class flares was lacking (or below) Flares were challenging due to their weak signals. Due to their frequent occurrence in active regions and potential role in the characteristics of quiescent active region emission, these smaller flares are of tremendous interest to the entire field of solar physics. In this study, we have performed spectroscopic analysis to examine the elemental abundance and its evolution using the XSM observations of relatively smaller GOES A-class flares.

Conclusion

We provide the results of X-ray spectroscopic measurements of the plasma temperature, emission measure, and elemental abundances (Mg, Al, Si, and S) for a significant number of A-class flares detected by XSM/Chandrayaan-2 at the minimum of solar cycle 24. During these eruptions, time-integrated spectrum analysis reveals that the typical Temperature and emission measurements scale with the flare sub-class, however the behaviours of the elements' FIP bias is different. Even in A-class flares, these observations point to the existence and role of flare-driven Alfven waves in increasing the fractionation rate and transporting fractionated plasma to the corona via evaporation processes. Additional simulations and spectroscopy smaller flare measurements with future instrumentation will aid in our understanding of the subject.