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ORIGINAL ARTICLE

Investigation on spectral behavior of Solar transients and their interrelationship

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Abstract We probe the spectral hardening of solar flares emission in view of associated solar proton events (SEPs) at earth and coronal mass ejection (CME) acceleration as a consequence. In this investigation we undertake 60 SEPs of the Solar Cycle 23 along with associated Solar Flares and CMEs. We employ the X-ray emission in Solar flares observed by Reuven Ramaty Higly Energy Solar Spectroscopic Imager (RHESSI) in order to estimate flare plasma parameters. Further, we employ the observations from Geo-stationary Operational Environmental Satellites (GOES) and Large Angle and Spectrometric Coronagraph (LASCO), for SEPs and CMEs parameter estimation respectively. We report a good association of soft-hard-harder (SHH) spectral behavior of Flares with occurrence of Solar Proton Events for 16 Events (observed by RHESSI associated with protons). In addition, we have found a good correlation ($R = 0.71$) in SEPs spectral hardening and CME velocity. We conclude that the Protons as well as CMEs gets accelerated at the Flare site and travel all the way in interplanetary space and then by re-acceleration in interplanetary space CMEs produce Geomagnetic Storms in geospace. This seems to be a statistically significant mechanism of the SEPs and initial CME acceleration in addition to the standard scenario of SEP acceleration at the shock front of CMEs.

Keywords Solar transients · Solar flares · Solar energetic particles · Coronal mass ejection

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1 Introduction

Solar transients; Solar Flares, Coronal Mass Ejections (CMEs), Solar Energetic Particles (SEPs) are the drivers of the Space Weather Effect in Geo-Space. There is a great discussion, in the community working in Space Weather research, on the association of these solar transients with each other. Sun in itself is a natural laboratory which provides us an opportunity to study the acceleration process of charged particles up to MeV–GeV energies. Solar Energetic Particles can escape into interplanetary space through open field lines and can be observed with in situ particle detectors, allowing the sampling of particles accelerated at Sun. The energy release through X-rays in solar flares is mostly due to bremsstrahlung emission. Good correlation has been found between spectral hardness of non-thermal HXR emission and X-ray flux at the corresponding energy (Grigis and Benz 2004; Fletcher and Hudson 2002) with initially soft spectrum before the peak flux, becoming harder as the flux increases, and becoming again soft as the flux decays, following a pattern soft-hard-soft (SHS) behavior. SHS behavior is thought to be a result of the electron acceleration mechanism in solar flares (Grigis and Benz 2006). Other possible causes are propagation effects of electrons traveling along flare loops and return currents caused by self-induced electric fields (Zharkova and Gordovskyy 2006). Instead of having SHS behavior some flares exhibit a HXR spectrum that successively