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Probing the solar origin of energy build-up and release in solar energetic particles

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Abstract. We study the temporal and spatial evolution of magnetic field parameters, and multi-wavelength observations of the AR 11226 and AR 11261, observed during 02-09 June 2011 and 31 July to 06 August 2011 respectively, to probe the origin of the associated solar energetic particles (SEPs). The magnetic-field toplogy of both ARs shows complex magnetic structure of β and $\beta\gamma$ configuration. The X-ray observations by GOES and RHESSI reveal that the AR 11226 as well as AR 11261 has been most turbulent to produce flares accompanying CMEs and SEPs. We restrict our study of magnetic field evolution of ARs to helio-longitudes E20-W70. The AR 11226 produced 28 flares ($\geqslant$ GOES C-class) and 8 CMEs as well as 5 SEPs. On the other hand, the AR 11261 produced 29 flares ($\geqslant$ GOES C class), 8 CMEs as well as 5 SEPs. We study the temporal evolution of magnetic field parameters *viz.* gradient, shear, rotation to probe the origin of the energy release in the flare and associated CME and SEP. We do not find convincing relationship in view of predicting SEPs.

Keywords. Sun: flares, X-ray: flares, Sun: coronal mass ejections (CMEs), Sun: particle emission, Sun: magnetic fields

1. Introduction

Solar energetic particles (SEPs) are accelerated particles escaping from the Sun into the interplanetary space. Some particles are originating in solar flares, while other being accelerated in transient interplanetary shocks, driven by fast CMEs. The SEP events are characterized by abrupt enhancements in the proton flux in the energy range of keV to GeV as measured by spacecraft at 1 AU. The connection of SEPs with Flares and CMEs which are correlated with the magnetic field evolution have largely been studied by Jain R., (1986) and Nipa Bhatt, (PhDT, 2011) and reference therein.

The current understanding is that the phenomena are different form of same energy release process occurring in the corona. Therefore, we explore the SEP prouductivity of the flare-CME and ARs through correlating the evolution of photospheric magnetic field parameters *viz.* magnetic flux, gradient, rotation of the AR to the SEPs parameters.

2. Data Analysis, Results & Discussion

We analyze AR 11226 and 11261 observed during 02-09 June 2011 and 31 July to 06 August 2011 respectively, to probe the origin of the associated solar energetic particles (SEPs). The X-ray observations by GOES and RHESSI reveal that the AR 11226 as well as AR 11261 has been most turbulent during year 2010-12 to produce flares $\geqslant$ GOES C class. We restrict our study of magnetic field evolution of these two active regions to helio-longitudes E20-W70 in view of earlier investigations by Jain, R. (1986). Figure 1 shows the the *GOES* and ACE missions' observation of AR11261 during July 31 - August 6, 2011 respectively. It may be noted from the figure that there were

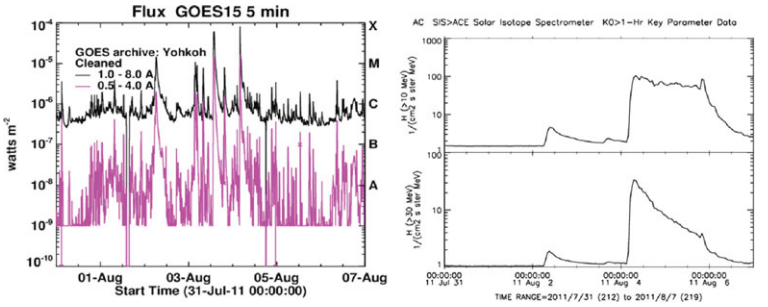

Figure 1. *Left and Right panels- GOES* intensity plot of SXR emissions in 1-8 and in 0.5-4 *Å* as well as SEPs during the evolution of AR 11226 respectively.

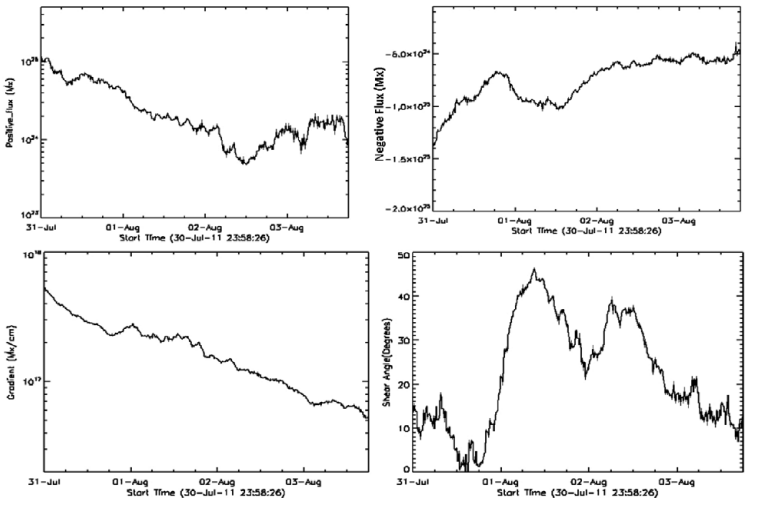

Figure 2. *Top & Bottom panels-* Time evolution of signed magnetic-flux, gradient and shear angle during July 31- August 4. respectively.

2 SEPs occured during the evolution. To estimate the evolution of magnetic-field parameters, we employ the observations of 12 min cadence from SDO/HMI mission and techniques as discussed in Jain *et al.*, 2011. Figure 2 shows the time evolution of the parameters *viz.* magnetic-flux, magnetic-field gradient and shear angle of the AR 11261.

It may be noted from the figure that there is no integrated obvious correlation visible in the evolutions except few fluctuations. However the shear angle shows a trend to decrease in counter-clock wise sense (increase in clock-wise sense) and may happen to be a good proxy for SEP productive flares. The statistical study involving more active regions is in progress and may shed light on the role of these parameters.

References

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