Title: Solar Energetic Particle Spectrum on 2006 December 13 Determined by IceTop
Authors: Abbasi, R. and many others

Publication: The Astrophysical Journal, Volume 689, Issue 1, pp. L65-L68. (ApJ Homepage)
Publication Date: 12/2008
Origin: UCP
ApJ Keywords: Sun: Flares, Sun: Particle Emission

DOI: 10.1086/595679
Bibliographic Code: 2008ApJ...689L..65A

Abstract

On 2006 December 13 the IceTop air shower array at the South Pole detected a major solar particle event. By numerically simulating the response of the IceTop tanks, which are thick Cerenkov detectors with multiple thresholds deployed at high altitude with no geomagnetic cutoff, we determined the particle energy spectrum in the energy range 0.6-7.6 GeV. This is the first such spectral measurement using a single instrument with a well-defined viewing direction. We compare the IceTop spectrum and its time evolution with previously published results and outline plans for improved resolution of future solar particle spectra.

Title: Short-lived Absorptive Type III-like Microwave Bursts as a Signature of Fragmented Electron Injections
Authors: Chen, Bin; Yan, Yihua

Publication: The Astrophysical Journal, Volume 689, Issue 2, pp. 1412-1420. (ApJ Homepage)
Publication Date: 12/2008
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Flares, Sun: Radio Radiation

DOI: 10.1086/592762
Bibliographic Code: 2008ApJ...689.1412C

Abstract

In this paper, we devote ourselves to interpreting the short-lived absorptive type III-like microwave bursts in the 2006 December 13 flare event observed with high temporal and spectral resolutions (8 ms and 10 MHz) by the Chinese Solar Broadband Radio Spectrometer (SBRS/Huairou) at 2.6-3.8 GHz. In the decimeter-centimeter wavelength range, we first present the observations of short-lived bursts represented as a number of absorptive ``spikes'' superposed on the type IV continuum that can be connected by fast-drifting lines. The mean drift rate, the instantaneous bandwidth, and the absorption depth of these absorptive spikes are about -12 GHz s^{-1}, 70 MHz, and 40%, respectively. The duration at a single frequency band can be less than the instrument resolution of 8 ms. On the basis of numerical investigations of the loss-cone instability, we suggest that fragmented electron injections with durations of as short as several milliseconds into the loss cone could be the most appropriate mechanism with which to explain the bursts. The length of an electron beam is estimated to be about 400 km, on the basis of the

observational results. These injections may be related to the fragmented energy release processes during the flare. We also observe some absorptive type III-like bursts accompanying ordinary type III bursts with reverse drifts. They start at the same frequency, and the starting frequency slowly drifts to the low-frequency region. This could be a signature of propagating bidirectional electron beams originating near the reconnection region.

Title: A Comprehensive View of the 2006 December 13 CME: From the Sun to Interplanetary Space
Authors: Liu, Y.; Luhmann, J. G.; Müller-Mellin, R.; Schroeder, P. C.; Wang, L.; Lin, R. P.; Bale, S. D.; Li, Y.; Acuña, M. H.; Sauvaud, J.-A.
Publication: The Astrophysical Journal, Volume 689, Issue 1, pp. 563-571. (ApJ Homepage)
Publication Date: 12/2008
Origin: UCP
ApJ Keywords: Shock Waves, Sun: Solar-terrestrial Relations, Sun: Solar Wind, Sun: Coronal Mass Ejections (CMEs), Sun: Particle Emission, Sun: Radio Radiation

DOI: 10.1086/592031
Bibliographic Code: 2008ApJ...689..563L

Abstract

The biggest halo coronal mass ejection (CME) since the Halloween storm in 2003, which occurred on 2006 December 13, is studied in terms of its solar source and heliospheric consequences. The CME was accompanied by an X3.4 flare, EUV dimmings, and coronal waves. It generated significant space weather effects such as an interplanetary shock, radio bursts, major solar energetic particle (SEP) events, and a magnetic cloud (MC) that were detected by a fleet of spacecraft including STEREO, ACE, WIND, and Ulysses. Reconstruction of the MC with the Grad-Shafranov (GS) method yields an axis orientation oblique to the flare ribbons. Observations of the SEP intensities and anisotropies show that the particles can be trapped, deflected, and reaccelerated by the large-scale transient structures. The CME-driven shock was observed at both the Earth and Ulysses when they were separated by 74° in latitude and 117° in longitude, which is the largest shock extent ever detected. The ejecta seem to have been missed at Ulysses. The shock arrival time at Ulysses is well predicted by an MHD model that can propagate the 1 AU data outward. The CME/shock is tracked remarkably well from the Sun all the way to Ulysses by coronagraph images, type II frequency drift, in situ measurements, and the MHD model. These results reveal a technique that combines MHD propagation of the solar wind and type II emissions to predict the shock arrival time at the Earth, which is a significant advance for space weather forecasting, especially when in situ data become available from the Solar Orbiter and Solar Sentinels.

Title: Detection of high energy solar protons during ground level enhancements
Authors: Karapetyan, G. G.
Publication: Astroparticle Physics, Volume 30, Issue 5, p. 234-238. (APh Homepage)
Publication Date: 12/2008

Origin: ELSEVIER
Abstract Copyright: Elsevier B.V.
DOI: 10.1016/j.astropartphys.2008.09.007
Bibliographic Code: 2008APh....30..234K

Abstract

Registration of high energy solar protons by middle and low latitude particle monitors during ground level enhancements (GLE) is investigated. We have developed a comprehensive method, for revealing weak GLE signals. The main result of the method is estimation of probability of error for given value of observed signal amplitude. We derived, that for middle energy protons, the 99% confidence limit of GLE signal detection is determined by ˜4.3σ of observed signal, whereas for highest energy protons it is determined by ˜3.7σ. Applying this method to GLE-65 at 28 October 2003, GLE-69 at 20 January 2005 and GLE-70 at 13 December 2006, we make conclusions about the maximal energy of protons during these events. We claim on the presence of >20…30 GeV protons in GLE-65 with the probability of error ˜7% and in the GLE-69 with the probability of error ˜0.4%. However, during GLE-70 maximal energy of protons was ˜10 GeV.

Title: Solar Radio Spikes in 2.6 – 3.8 GHz during the 13 December 2006 Event
Authors: Wang, S. J.; Yan, Y. H.; Liu, Y. Y.; Fu, Q. J.; Tan, B. L.; Zhang, Y.
Publication: Solar Physics, Online First (SoPh Homepage)
Publication Date: 11/2008
Origin: SPRINGER
Keywords: Sun, Flare, Radio emission, Spikes
Abstract Copyright: (c) 2008: Springer Science+Business Media B.V.
DOI: 10.1007/s11207-008-9278-5
Bibliographic Code: 2008SoPh..tmp..182W

Abstract

On 13 December 2006, some unusual radio bursts in the range 2.6 – 3.8 GHz were observed during an X3.4 flare/CME event from 02:30 to 04:30 UT in active region NOAA 10930 (S06W27) with the digital spectrometers of the National Astronomical Observatories of China (NAOC). During this event many spikes were detected with the high temporal resolution of 8 ms and high frequency resolution of 10 MHz. Many of them were found to have complex structures associated with other radio burst types. The new observational features may reflect certain emission signatures of the electron acceleration site. In this paper, we present the results of the analysis of the new observational features of the complex spikes. According to the observed properties of the spikes, we identify five classes. Their observational parameters, such as duration, bandwidth, and relative bandwidth, were determined. Most spikes had negative polarization, but spikes with positive polarization were observed during a short time interval and were identified as a separate class. Based on the analysis of observations with Hinode/SOT (Solar Optical Telescope) we suggest that the sources of the spikes with opposite polarizations were different. Combined observations of spikes and fiber bursts are used to estimate the magnetic field strength in the source.

Title: Study of Magnetic Channel Structure in Active Region 10930
Authors: Wang, Haimin; Jing, Ju; Tan, Changyi; Wiegelmann, Thomas; Kubo, Masahito
Publication: The Astrophysical Journal, Volume 687, Issue 1, pp. 658-667. (ApJ Homepage)
Publication Date: 11/2008
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Flares, Sun: Magnetic Fields

DOI: 10.1086/592082
Bibliographic Code: 2008ApJ...687..658W

Abstract

The concept of ``magnetic channel'' was first introduced by Zirin & Wang. They were defined as a series of oppositely directed vertical-field inversions separated by extremely narrow elongated transverse fields. In this paper, we utilized unprecedented filtergraph and spectropolarimetry observations from Hinode, and studied the evolution and physical properties of channel structure of AR 10930 in detail. We found the following: (1) Channels are associated with new flux emergence in the middle of existing penumbra connecting the δ sunspot. (2) The width of each channel is in the order of 1" or less. (3) The line-of-sight magnetic gradient is highest in the channel, 2.4-4.9 G km^{-1}. (4) The fields are highly sheared and inclined with a median shear angle around 64° and inclination angle around 25°. (5) Using nonlinear force-free field (NLFF) extrapolation, we derive a near surface current system carrying electric current in the order of 5×10^{11} A. (6) The X3.4 flare on 2006 December 13 occurred during the period that the channels rapidly formed, but a few hours before the maximum phase of channel structure development. Based on the observational evidence, we propose that the channels are formed during the emergence of a sequence of magnetic bipoles that are squeezed in the compact penumbra of the δ sunspot and they are highly nonpotential. Formation of channels might be a precursor of major flares.

Title: Ground level enhancement of December 13, 2006 observed by means of muon hodoscope
Authors: Timashkov, D. A.; Balabin, Yu. V.; Barbashina, N. S.; Kokoulin, R. P.; Kompaniets, K. G.; Mannocchi, G.; Petrukhin, A. A.; Saavedra, O.; Shutenko, V. V.; Trinchero, G.; Vashenyuk, E. V.; Yashin, I. I.
Publication: Astroparticle Physics, Volume 30, Issue 3, p. 117-123. (APh Homepage)
Publication Date: 10/2008
Origin: ELSEVIER

DOI: 10.1016/j.astropartphys.2008.07.008
Bibliographic Code: 2008APh....30..117T

Abstract

A wide-aperture hodoscope URAGAN detected a muon rate increase during GLE of December 13, 2006 at six sigma level (for ten-minute bins). Maximum of the enhancement was observed at 03:00 UTC. Capabilities of muon hodoscopes allow obtaining 2D-images of muon flux and for the first time the two-dimensional dynamics of GLE event was measured. Due to the fact that asymptotic view cone of the hodoscope appeared looking along IMF, it was possible to trace in details the evolution of a short-lived and highly collimated relativistic particle bunch in the initial phase of the event.

Title: Strongly Blueshifted Phenomena Observed with Hinode EIS in the 2006 December 13 Solar Flare
Authors: Asai, Ayumi; Hara, Hirohisa; Watanabe, Tetsuya; Imada, Shinsuke; Sakao, Taro; Narukage, Noriyuki; Culhane, J. L.; Doschek, G. A.
Publication: The Astrophysical Journal, Volume 685, Issue 1, pp. 622-628. (ApJ Homepage)
Publication Date: 09/2008
Origin: UCP
ApJ Keywords: Sun: Corona, Sun: Flares, Sun: Transition Region, Sun: UV Radiation, Sun: X-Rays, Gamma Rays

DOI: 10.1086/590419
Bibliographic Code: 2008ApJ...685..622A

Abstract

We present a detailed examination of strongly blueshifted emission lines observed with the EUV Imaging Spectrometer on board the Hinode satellite. We found two kinds of blueshifted phenomenon associated with the X3.4 flare that occurred on 2006 December 13. One was related to a plasmoid ejection seen in soft X-rays. It was very bright in all the lines used for the observations. The other was associated with the faint arc-shaped ejection seen in soft X-rays. The soft X-ray ejection is thought to be a magnetohydrodynamic (MHD) fast-mode shock wave. This is therefore the first spectroscopic observation of an MHD fast-mode shock wave associated with a flare.

Title: Perturbation of Nuclear Decay Rates During the Solar Flare of 13 December 2006
Authors: Jenkins, Jere H.; Fischbach, Ephraim
Publication: eprint arXiv:0808.3156
Publication Date: 08/2008
Origin: ARXIV
Keywords: Astrophysics
Comment: 13 pages, 7 figures
Bibliographic Code: 2008arXiv0808.3156J

Abstract

Recently, Jenkins, et al. have reported the detection of correlations between fluctuations in nuclear decay rates and Earth-Sun distance, which suggest that nuclear decay rates can be affected by solar activity. In this paper, we report the detection of a significant decrease in the decay of 54Mn during the solar flare of 13

December 2006, whose x-rays were first recorded at 02:37 UT (21:37 EST on 12 December). Our detector was a 1 uCi sample of 54Mn, whose decay rate exhibited a dip coincident in time with spikes in both the x-ray and proton fluxes recorded by the GOES-10 and 11 satellites. A secondary peak in the x-ray and proton fluxes on 17 December at 12:40 EST was also accompanied by a coincident dip in the 54Mn decay rate. These observations support the claim by Jenkins, et al. that nuclear decay rates vary with Earth-Sun distance.

Title: Correlation between the Sharp Variation of the Transport Rate of Magnetic Helicity and Solar Eruptive Events
Authors: Zhang, Yin; Tan, Baolin; Yan, Yihua
Publication: The Astrophysical Journal, Volume 682, Issue 2, pp. L133-L136. (ApJ Homepage)
Publication Date: 08/2008
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Flares, Sun: Magnetic Fields

DOI: 10.1086/591027
Bibliographic Code: 2008ApJ...682L.133Z

Abstract

In this Letter we report a close relationship between the variations of the transport rate of magnetic helicity (dH/dt) and a microwave burst. The latter may be regarded as a prompt signal of nonthermal energetic particles originating from the magnetic reconnection during solar flaring events. We analyze the observations of magnetograms of MDI/SOHO and SOT/Hinode and the high-cadence microwave observation at 2.84 GHz obtained by the Chinese Solar Broadband Radiospectrometer (SBRS/Huairou) of a flare/CME event that occurred in NOAA Active Region 10930 on 2006 December 13. We find that there is a sharp jump of dH/dt around the onset and quench of a microwave burst at a frequency of 2.84 GHz: the rate of dH/dt changes from negative to positive around the start of the eruption and recovers to negative when the eruption stopped. Furthermore, the temporal profile of dH/dt is consistent with that of a microwave burst. These results indicate that sharp variations of dH/dt are closely related to the solar eruption.

Title: Modeling a mixed SEP event with the PATH model: December 13, 2006
Authors: Verkhoglyadova, Olga P.; Li, Gang; Zank, Gary P.; Hu, Qiang
Publication: PARTICLE ACCELERATION AND TRANSPORT IN THE HELIOSPHERE AND BEYOND: 7th Annual International Astrophysics Conference. AIP Conference Proceedings, Volume 1039, pp. 214-219 (2008). (AIPC Homepage)
Publication Date: 08/2008
Origin: AIP
Keywords: astronomical observatories, particle accelerators, solar flares, solar wind, interplanetary magnetic fields, shock wave effects, plasma magnetohydrodynamics, plasma turbulence

DOI: 10.1063/1.2982448
Bibliographic Code: 2008AIPC.1039..214V

Abstract

There are often two particle components which form a major SEP event, one originating from a solar flare and the other from solar wind particles accelerated at a traveling CME-driven shock [1]. If a CME and a flare are part of the same process, then the interplay between corresponding energetic particle components may yield temporal, spectral, and compositional differences in observations. Depending on spacecraft location and magnetic connection to either a flare site or a CME-driven shock (or both), we expect to observe distinct signatures in the time intensity profiles. Following an approach by Li and Zank [2], we apply the Particle Acceleration and Transport in the Heliosphere (PATH) one-dimensional numerical code developed at University of California in Riverside to model the mixed SEP event of December 13, 2006. We initiate the code by modeling a quiet-time solar wind. Observed shock parameters at 1 AU and flare characteristics then are used as input into the code. We model energetic particle acceleration at a traveling quasi-parallel CME-driven shock and subsequent transport throughout the interplanetary medium to 1 AU. Time-intensity profiles and spectra of proton and heavy ions are presented and compared with in situ measurements by ACE. Contributions from the solar wind suprathermal and flare particles to the resultant SEP event are discussed.

Title: Unusual Observations during the December 2006 Solar Energetic Particle Events within an Interplanetary Coronal Mass Ejection at 1 AU
Authors: Mulligan, T.; Blake, J. B.; Mewaldt, R. A.; Leske, R. A.
Publication: PARTICLE ACCELERATION AND TRANSPORT IN THE HELIOSPHERE AND BEYOND: 7th Annual International Astrophysics Conference. AIP Conference Proceedings, Volume 1039, pp. 162-167 (2008). (AIPC Homepage)
Publication Date: 08/2008
Origin: AIP
Keywords: astronomical observatories, solar flares, astronomical telescopes, interstellar matter, chemical analysis, solar wind, shock wave effects

DOI: 10.1063/1.2982440
Bibliographic Code: 2008AIPC.1039..162M

Abstract

In mid December 2006 several flares on the Sun occurred in rapid succession, spawning several CMEs and bathing the Earth in multiple solar energetic particle (SEP) events. One such SEP event occurring on December 14 was observed at the Earth just as an interplanetary CME (ICME) from a previous flare on December 13 was transiting the Earth. Although solar wind observations during this time show typical energetic proton fluxes from the prior SEP event and IP shock driven ahead of the ICME, as the ICME passes the Earth unusual energetic particle signatures are observed. Measurements from ACE, Wind, and STEREO show proton flux variations

at energies ranging from ~3 MeV up to greater than 70 MeV. Energetic electron signatures from ACE show similar variations. Within the Earth's magnetosphere Polar HIST also sees these proton flux variations at energies greater than 10 MeV while crossing open field lines in the southern polar cap. Although no such variation in the energetic proton flux is observed at the GOES 11 spacecraft in geosynchronous orbit near the subsolar region, differential fluxes observed at GOES 11 and GOES 12 in the 15-40 MeV energy range do show some variability, indicating the signature is observable near dawn and dusk.

Title: Examination of the Last Large Solar Energetic Particle Events of Solar Cycle 23

Authors: Cohen, C. M. S.; Mason, G. M.; Mewaldt, R. A.; Cummings, A. C.; Labrador, A. W.; Leske, R. A.; Stone, E. C.; Wiedenbeck, M. E.; von Rosenvinge, T. T.

Publication: PARTICLE ACCELERATION AND TRANSPORT IN THE HELIOSPHERE AND BEYOND: 7th Annual International Astrophysics Conference. AIP Conference Proceedings, Volume 1039, pp. 118-123 (2008). (AIPC Homepage)

Publication Date: 08/2008

Origin: AIP

Keywords: astronomical observatories, solar flares, particle spectrometers, solar corona, plasma magnetohydrodynamics, shock wave effects, solar wind, chemical analysis

DOI: 10.1063/1.2982432

Bibliographic Code: 2008AIPC.1039..118C

Abstract

The last two large solar energetic particle (SEP) events of solar cycle 23 were observed in December 2006 by several spacecraft including ACE and STEREO. Active region number 10930 rotated over the eastern limb of the Sun already generating intense x-ray flares. As it crossed the disk, it produced 4 X-class flares and at least 3 halo coronal mass ejections. The two dominant SEP events occurred when the region was at ~E 70 and ~W 25. We have combined particle observations from the Solar Isotope Spectrometer (SIS) and the Ultra-Low Energy Isotope Spectrometer (ULEIS) on ACE and the Low Energy Telescope (LET) on STEREO for each event. Energy spectra for many heavy ion species integrated over the duration of each SEP event show distinct differences between the two events. We find the second event (on December 13) has a much harder spectrum above 10 MeV/nucleon and a 12-60 MeV/nucleon composition substantially enriched in elements with Z>14 as compared to the first event (on December 6). While the December 6 event is similar in Fe/O to other events with comparable fluence in solar cycle 23, the December 13 event has the highest Fe/O ratio of all events with Si fluence >100$(cm^2\ sr\ MeV/n)^{-1}$. In composition, this second event is most similar to the event of November 6, 1997.

Title: Intermittency in the Photosphere and Corona above an Active Region

Authors: Abramenko, Valentyna; Yurchyshyn, Vasyl; Wang, Haimin
Publication: The Astrophysical Journal, Volume 681, Issue 2, pp. 1669-1676. (ApJ Homepage)
Publication Date: 07/2008
Origin: UCP
ApJ Keywords: Sun: Corona, Sun: Magnetic Fields, Sun: Photosphere

DOI: 10.1086/588426
Bibliographic Code: 2008ApJ...681.1669A

Abstract

Recent studies have demonstrated without doubt that the magnetic field in the photosphere and corona is an intermittent structure, opening new views of the underlying physics. In particular, such problems as the existence in the corona of localized areas with extremely strong resistivity (required to explain magnetic reconnection at all scales) and the interchange between small and large scales (required in the study of photospheric-coronal coupling), to name a few, can be easily captured by the concept of intermittency. This study focuses on simultaneous time variations of intermittency properties derived in the photosphere, chromosphere, and corona. We analyze data for NOAA Active Region 10930 acquired between 2006 December 8, 12:00 UT, and December 13, 18:45 UT. Photospheric intermittency is inferred from Hinode magnetic field measurements, while intermittency in the transition region and corona is derived from Nobeyama 9 GHz radio polarization measurements and high-cadence Hinode XRT (thin-Be) data, as well as GOES 1-8 Å flux. The photospheric dynamics and its possible relationship with the intermittency variations are also analyzed by calculating the kinetic vorticity. In this case study, we find the following chain of events: The intermittency of the photospheric magnetic field peaked after the specific kinetic vorticity of plasma flows in the active region reached its maximum (4 hr time delay). In turn, a gradual increase of coronal intermittency occurred after the peak of the photospheric intermittency. The time delay between the peak of photospheric intermittency and the occurrence of the first strong (X3.4) flare was approximately 1.3 days. Our analysis seems to suggest that the enhancement of intermittency/complexity first occurs in the photosphere and is later transported toward the corona.

Title: Predicting interplanetary shock arrivals at Earth, Mars, and Venus: A real-time modeling experiment following the solar flares of 5-14 December 2006
Authors: McKenna-Lawlor, S. M. P.; Dryer, M.; Fry, C. D.; Smith, Z. K.; Intriligator, D. S.; Courtney, W. R.; Deehr, C. S.; Sun, W.; Kecskemety, K.; Kudela, K.; Balaz, J.; Barabash, S.; Futaana, Y.; Yamauchi, M.; Lundin, R.
Publication: Journal of Geophysical Research, Volume 113, Issue A6, CiteID A06101 (JGRA Homepage)
Publication Date: 06/2008
Origin: AGU
AGU Keywords: Solar Physics, Astrophysics, and Astronomy: Flares, Interplanetary Physics: Plasma waves and turbulence, Magnetospheric Physics: Numerical modeling, Magnetospheric Physics: Forecasting (7924, 7964),

Space Weather: Space radiation environment

DOI: 10.1029/2007JA012577
Bibliographic Code: 2008JGRA..11306101M

Abstract

A 3-D, kinematic, solar wind model (Hakamada-Akasofu-Fry version 2 (HAFv.2)) is used to predict interplanetary shock arrivals at Venus, Earth, and Mars during a sequence of significant solar events that occurred in the interval 5-14 December 2006. Mars and Venus were on the opposite side of the Sun from Earth during this period. The shocks from the first two east limb events (5 and 6 December) were predicted to interact to form a single disturbance before reaching Earth and Venus. A single shock was indeed recorded at Earth only about 3 h earlier than had been predicted. The composite shock was predicted by HAFv.2 to arrive at Venus on 8 December at ~0500 UT. Solar energetic particles (SEPs) were detected in Venus Express Analyzer of Space Plasmas and Energetic Atoms-4 data for some 3 d (from <0530 UT on 6 December), and an energetic storm particle (ESP) event signaled the arrival of a single shock wave at 0900 UT on 7 December. SEPs were correspondingly recorded at Mars. However, the eastern flank of the composite shock was predicted to decay to an MHD wave prior to reaching this location, and no shock signature was observed in the available data. The shocks generated in association with two flare events that occurred closer to the West Limb on 13 and 14 December were predicted by HAFv.2 to remain separate when they arrived at Earth but to combine thereafter before reaching Mars. Each was expected to decay to MHD waves before reaching Venus, which was at that time located behind the Sun. Separated shocks were observed to arrive at L1 (ACE) only 8 min earlier than and 5.3 h later than their predicted times. The western flank of the combined shocks was predicted to arrive at Mars early on 20 December 2006. An indication of the passage of this shock was provided by a signature of ion heating in Mars Express IMA (ion mass-resolving analyzer) data from <0424 UT on 20 December. The predictions of the HAFv.2 model for Earth were each well within the +/-11 h. RMS error earlier found, on the basis of significant statistics, to apply at 1 AU during the rise and maximum phases of solar cycle 23. Overall, the model is demonstrated to be capable of predicting the effects produced by shocks and by the background solar wind at Venus, Earth, and Mars. It is suggested that the continuous presence of solar wind monitors (plasma and interplanetary magnetic field observations) at ``benchmark planets'' can constitute a necessary and valuable component of ongoing and future space weather programs for the validation of solar wind models such as HAFv.2.

Title: Non-Gaussian Line Profiles in a Large Solar Flare Observed on 2006 December 13
Authors: Imada, S.; Hara, H.; Watanabe, T.; Asai, A.; Minoshima, T.; Harra, L. K.; Mariska, J. T.
Publication: The Astrophysical Journal, Volume 679, Issue 2, pp. L155-L159. (ApJ Homepage)
Publication Date: 06/2008
Origin: UCP
ApJ Keywords: Sun: Corona, Sun: Flares

DOI: 10.1086/589444
Bibliographic Code: 2008ApJ...679L.155I

Abstract

We have studied the characteristics of the non-Gaussian line profile of the Fe XIV 274.20 Å line in and around a flare arcade. We found that broad non-Gaussian line profiles associated with redshifts are observed in the flare arcade. There were two typical types of broad line profiles. One was a distorted line profile caused by multiple flows, and the other was a symmetric line profile without any additional component. We successfully distinguished those two types using higher order statistical moments or M-the additional component contribution-defined in this Letter. The distorted/symmetric broad line profiles were preferentially observed in new/old flare loops, respectively.

Title: 3D Magnetic Field Configuration of the 2006 December 13 Flare Extrapolated with the Optimization Method
Authors: Guo, Y.; Ding, M. D.; Wiegelmann, T.; Li, H.
Publication: The Astrophysical Journal, Volume 679, Issue 2, pp. 1629-1635. (ApJ Homepage)
Publication Date: 06/2008
Origin: UCP
ApJ Keywords: Sun: Flares, Sun: Magnetic Fields

DOI: 10.1086/587684
Bibliographic Code: 2008ApJ...679.1629G

Abstract

The photospheric vector magnetic field of the active region NOAA 10930 was obtained with the Solar Optical Telescope (SOT) on board the Hinode satellite with a very high spatial resolution (about 0.3"). Observations of the two-ribbon flare on 2006 December 13 in this active region provide us a good sample to study the magnetic field configuration related to the occurrence of the flare. Using the optimization method for nonlinear force-free field (NLFFF) extrapolation proposed by Wheatland et al. and recently developed by Wiegelmann, we derive the three-dimensional (3D) vector magnetic field configuration associated with this flare. The general topology can be described as a highly sheared core field and a quasi-potential envelope arch field. The core field clearly shows some dips supposed to sustain a filament. Free energy release in the flare, calculated by subtracting the energy contained in the NLFFF and the corresponding potential field, is 2.4×10^{31} ergs, which is ~2% of the preflare potential field energy. We also calculate the shear angles, defined as the angles between the NLFFF and potential field, and find that they become larger at some particular sites in the lower atmosphere, while they become significantly smaller in most places, implying that the whole configuration gets closer to the potential field after the flare. The Ca II H line images obtained with the Broadband Filter Imager (BFI) of the SOT and the 1600 Å images with the Transition Region and Coronal Explorer (TRACE) show that the preflare heating occurs mainly in the core field. These results provide evidence in support of the tether-cutting model of solar flares.

Title: Characteristics of relativistic solar cosmic rays during the event of December 13, 2006
Authors: Vashenyuk, E. V.; Balabin, Yu. V.; Gvozdevsky, B. B.; Shchur, L. I.

Publication: Geomagnetism and Aeronomy, Volume 48, Issue 2, pp.149-153
Publication Date: 04/2008
Origin: SPRINGER
Keywords: 94.20.Wq
Abstract Copyright: (c) 2008: MAIK Nauka
DOI: 10.1007/s11478-008-2003-6
Bibliographic Code: 2008Ge&Ae..48..149V

Abstract

The characteristics of relativistic solar protons have been obtained using the methods of optimization based on the data of ground detectors of cosmic rays during the event of December 13, 2006, which occurred under the conditions of solar activity minimum. The dynamics of relativistic solar protons during the event has been studied. It has been indicated that two populations (components) of particles exist: prompt and delayed (slow). The prompt component with a hard energy spectrum and strong anisotropy manifested itself as a pulse-shaped enhancement at Apatity and Oulu stations, which received particles with small pitch-angles. The delayed component had a wider pitch-angle distribution, as a result of which an enhancement was moderate at Barentsburg station and at most neutron monitors of the worldwide network. The energy spectra obtained from the ground-based observations are in good agreement with the direct measurements of solar protons on balloons and spacecraft.

Title: Changes of Magnetic Structure in Three Dimensions Associated with the X3.4 Flare of 2006 December 13
Authors: Jing, Ju; Wiegelmann, Thomas; Suematsu, Yoshinori; Kubo, Masahito; Wang, Haimin
Publication: The Astrophysical Journal, Volume 676, Issue 1, pp. L81-L84. (ApJ Homepage)
Publication Date: 03/2008
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Corona, Sun: Flares, Sun: Magnetic Fields
Abstract Copyright: (c) 2008: The American Astronomical Society
DOI: 10.1086/587058
Bibliographic Code: 2008ApJ...676L..81J

Abstract

Recent observations demonstrated that sunspot structure can change rapidly and irreversibly after flares. One of the most puzzling results is the increase in magnetic shear around the flaring magnetic polarity inversion line after flares. However, all these observations were made at the photosphere level. In this Letter, we study the altitude variation of the nonpotentiality of the magnetic fields associated with the 4B/X3.4 flare of 2006 December 13. The vector magnetograms with unprecedented quality from Hinode before and after the flare are used as the boundary conditions to extrapolate the three-dimensional nonlinear force-free magnetic fields and the potential fields. The former are computed with the optimization algorithm and the latter with the Green's function method. At the photosphere boundary, magnetic shear increases after the flare in a local area close to the flaring magnetic polarity inversion line. Two measures of the magnetic nonpotentiality, the weighted mean

shear θ_w and the total magnetic shear $\theta_w B$, are calculated in this area at progressively higher altitude. By comparing their altitude variation profiles before and after the flare, we find that the nonpotentiality of the local area increases after the flare below ~8 Mm and decreases from that height to ~70 Mm. Beyond 70 Mm, the magnetic fields approach potential for both times.

Title: Microwave and Hard X-Ray Spectral Evolution for the 13 December 2006 Solar Flare
Authors: Ning, Zongjun
Publication: Solar Physics, Volume 247, Issue 1, pp.53-62 (SoPh Homepage)
Publication Date: 01/2008
Origin: SPRINGER
Keywords: Flares, Radio radiation, Hard X-rays

DOI: 10.1007/s11207-007-9101-8
Bibliographic Code: 2008SoPh..247...53N

Abstract

This paper explores the time evolution of microwave and hard X-ray spectral indexes in the solar flare observed by Nobeyama Radio Polarimeters (NoRP) and the Ramaty High Energy Solar Spectroscopy Imager (RHESSI) on 13 December 2006. The microwave spectral index, γ_{MW}, is derived from the emissions at two frequencies, 17 and 35 GHz, and hard X-ray spectral index, γ_{HXR}, is derived from RHESSI spectra. Fifteen subpeaks are detected at the microwave and hard X-ray emissions. The microwave spectral indexes tend to be harder than hard X-ray spectral indexes during the flare, which is consistent with previous findings. All detected subpeaks follow the soft-hard-soft spectral behaviours in the hard X-ray rise-peak-decay phases. However, the corresponding microwave subpeaks display different spectral behaviour, such as soft-hard-soft, soft-hard-harder, soft-hard-soft + hard or irregular patterns. These contradictions reveal the complicated acceleration mechanism for low- and high-energy electrons during this event. It is also interesting that the microwave interpeak spectral indexes are much more consistent with one another.

Title: Using PFISR measurements and gravity wave dissipative theory to determine the neutral, background thermospheric winds
Authors: Vadas, Sharon L.; Nicolls, Michael J.
Publication: Geophysical Research Letters, Volume 35, Issue 2, CiteID L02105 (GeoRL Homepage)
Publication Date: 01/2008
Origin: AGU
AGU Keywords: Atmospheric Processes: Theoretical modeling, Ionosphere: Wave propagation (0689, 3285, 4275, 4455, 6934), Ionosphere: Active experiments, Ionosphere: Ionosphere/atmosphere interactions (0335)

DOI: 10.1029/2007GL031522
Bibliographic Code: 2008GeoRL..3502105V

Abstract

Understanding the propagation and dissipation of an atmospheric gravity wave (GW) in the thermosphere requires an accurate dissipative GW dispersion relation, the GW's horizontal wavelength and period, and the background neutral winds and temperatures. Conversely, if the GW's horizontal wavelength, period, and vertically-varying vertical wavelengths are known instead along with the background temperatures, then the background, horizontal neutral winds along the GW propagation direction can be calculated using GW dissipative theory. Recent daytime observations using the Advanced Modular Incoherent Scatter Radar (AMISR) located in Poker Flat, Alaska, the Poker Flat Incoherent Scatter Radar (PFISR), have obtained these latter parameters. Using PFISR data for a GW on December 13, 2006, we calculate the average, background, horizontal neutral winds at z ~ 160-240 km.

Title: Spatial Distribution of Magnetic Reconnection in the 2006 December 13 Solar Flare as Observed by Hinode
Authors: Jing, Ju; Chae, Jongchul; Wang, Haimin
Publication: The Astrophysical Journal, Volume 672, Issue 1, pp. L73-L76. (ApJ Homepage)
Publication Date: 01/2008
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Flares, Sun: Magnetic Fields
Abstract Copyright: (c) 2008: The American Astronomical Society
DOI: 10.1086/526339
Bibliographic Code: 2008ApJ...672L..73J

Abstract

A massive two-ribbon flare and its source magnetic field region were well captured by the Solar Optical Telescope (SOT) on board Hinode in the Ca II H spectral line and by the Spectro-Polarimeter of SOT, respectively. Using the high-resolution Hinode data sets, we compare the spatial distribution of the local magnetic reconnection rate and the energy release rate along the ribbons with that of G-band kernels that serve as a proxy for the primary energy release. The G-band kernels spatially coincide with the maximum of both modeled quantities, which gives strong support for the reconnection model. We also investigate the magnitude scaling correlation between the ribbon separation speed V_r and magnetic field strength B_n at four 2 minute time bins around the maximum phase of the flare. It is found that V_r is weakly and negatively correlated with B_n. An empirical relation of $V_r \sim B_n^{-0.15}$ is obtained at the flare peak time with an correlation coefficient ~-0.33. The correlation is weaker at other time bins.

Title: The Microwave Pulsations and the Tearing Modes in the Current-Carrying Flare Loops
Authors: Tan, Baolin; Yan, Yihua; Tan, Chengming; Liu, Yuying
Publication: The Astrophysical Journal, Volume 671, Issue 1, pp. 964-972. (ApJ Homepage)
Publication Date: 12/2007
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Flares, Sun: Oscillations, Sun: Radio Radiation
Abstract Copyright: (c) 2007: The American Astronomical Society

DOI: 10.1086/522327
Bibliographic Code: 2007ApJ...671..964T

Abstract

Solar microwave observations of the X3.4 Flare/CME event observed in Chinese solar broadband radiospectrometer (SBRS/Huairou) on 2006 December 13 show a series of very short period pulsations (VSP) with the period of <1.0 s in the frequency range of 2.60-3.80 GHz. Many pulsating events have the period of only several tens of milliseconds. These pulsations are quasi-periodic, broad bandwidth, and ubiquitous during all the phases of the flare/CME event. Based on theoretical analysis of the temporal behavior of the resistive tearing mode in the electric current-carrying flare loops, we propose that microwave pulsations are a result of the modulation of the tearing-mode oscillations in the current-carrying flare loops. Our calculation of the period of the tearing-mode oscillations are in good agreement with the observations.

Title: Initial Observations of Sunspot Oscillations Excited by Solar Flare
Authors: Kosovichev, A. G.; Sekii, T.
Publication: The Astrophysical Journal, Volume 670, Issue 2, pp. L147-L149. (ApJ Homepage)
Publication Date: 12/2007
Origin: UCP
ApJ Keywords: Sun: Flares, Sun: Oscillations

DOI: 10.1086/524298
Bibliographic Code: 2007ApJ...670L.147K

Abstract

Observations of a large solar flare on 2006 December 13 using Solar Optical Telescope (SOT) on board the Hinode spacecraft revealed high-frequency oscillations excited by the flare in the sunspot chromosphere. These oscillations are observed in the region of strong magnetic field of the sunspot umbra and may provide a new diagnostic tool for probing the structure of sunspots and understanding physical processes in solar flares.

Title: Diagnostics of Radio Fine Structures around 3 GHz with HinodeData in the Impulsive Phase of an X3.4/4B Flare Event on 2006 December 13
Authors: Yan, Y.; Huang, J.; Chen, B.; Sakurai, T.
Publication: Publications of the Astronomical Society of Japan, Vol.59, No.s3, p.S815-S821 (PASJ Homepage)
Publication Date: 11/2007
Origin: PASJ
Bibliographic Code: 2007PASJ...59S.815Y

Abstract

On 2006 December 13 during the solar minimum, the superactive region NOAA 10930 at the S05W33 disk location produced an X3.4/4B flare at 02:40UT. Fine

structures were observed in the radio spectra, which included spikes, reverse slope-type III bursts, type-U burst, V-shaped burst, pulsations, zebra patterns, and firstly discovered sub-second spiky zebra-like structures, superimposed on the 2.6-3.8GHz type IV bursts. The radio fine structures during the impulsive phase of the flare may be closely associated with coronal structures during the magnetic-reconnection process, as revealed by Hinode soft X-ray images. Thus, these microwave fine structure observations may provide very useful diagnostics at the primary energy release sites when they occur in the impulsive flare phase. For this flare event, the estimated coronal magnetic field is about 50-170G in the rising phase of the flare with a source density of about 1^{-3} around the flare maximum.

Title: Flare Ribbons Observed with G-band and FeI 6302Å, Filters of the Solar Optical Telescope on Board Hinode
Authors: Isobe, H.; Kubo, M.; Minoshima, T.; Ichimoto, K.; Katsukawa, Y.; Tarbell, T. D.; Tsuneta, S.; Berger, T. E.; Lites, B.; Nagata, S.; Shimizu, T.; Shine, R. A.; Suematsu, Y.; Title, A. M.
Publication: Publications of the Astronomical Society of Japan, Vol.59, No.s3, p.S807-S813 (PASJ Homepage)
Publication Date: 11/2007
Origin: PASJ
Bibliographic Code: 2007PASJ...59S.807I

Abstract

The Solar Optical Telescope (SOT) on board the Hinode satellite observed an X3.4 class flare on 2006 December 13. A typical two-ribbon structure was observed, not only in the chromospheric CaII H line, but also in the G-band and FeI 6302Å line. The high-resolution, seeing-free images achieved by SOT revealed, for the first time, sub-arcsec fine structures of the ``white light'' flare. The G-band flare ribbons on sunspot umbrae showed a sharp leading edge, followed by a diffuse inside, as well as a previously known core-halo structure. The underlying structures, such as umbral dots, penumbral filaments, and granules, were visible in the flare ribbons. Assuming that the sharp leading edge was directly heated by a particle beam and the diffuse parts were heated by radiative back-warming, we estimated the depth of the diffuse flare emission using an intensity profile of the flare ribbon. We found that the depth of the diffuse emission was about 100km or less from the height of the source of radiative back-warming. The flare ribbons were also visible in the Stokes-I images indicates that the FeI 6302Å line was significantly deformed by the flare, which may cause such a magnetic transient.

Title: Discovery of a Temperature-Dependent Upflow in the Plage Region During a Gradual Phase of the X-Class Flare
Authors: Imada, S.; Hara, H.; Watanabe, T.; Kamio, S.; Asai, A.; Matsuzaki, K.; Harra, L. K.; Mariska, J. T.
Publication: Publications of the Astronomical Society of Japan, Vol.59, No.s3, p.S793-S799 (PASJ Homepage)
Publication Date: 11/2007

Origin: PASJ
Bibliographic Code: 2007PASJ...59S.793I

Abstract

We present Hinode/EIS raster scan observations of the plage region taken during the gradual phase of the GOES X3.2 flare that occurred on 2006 December 13. The plage region is located 200^{-1}). All velocities are below the sound speed. The trend of the upflow dependence on temperature dramatically changes at 1MK. These results suggest that heating may have an important role for strong upflow.

Title: Evolution of the Sheared Magnetic Fields of Two X-Class Flares Observed by Hinode/XRT
Authors: Su, Y.; Golub, L.; van Ballegooijen, A.; Deluca, E. E.; Reeves, K. K.; Sakao, T.; Kano, R.; Narukage, N.; Shibasaki, Andk.
Publication: Publications of the Astronomical Society of Japan, Vol.59, No.s3, p.S785-S791 (PASJ Homepage)
Publication Date: 11/2007
Origin: PASJ
Bibliographic Code: 2007PASJ...59S.785S

Abstract

We present multi-wavelength observations of the evolution of the sheared magnetic fields in NOAA Active Region 10930, where two X-class flares occurred on 2006 December 13 and December 14, respectively. Observations made with the X-ray Telescope (XRT) and the Solar Optical Telescope (SOT) aboard Hinode suggest that the gradual formation of the sheared magnetic fields in this active region is caused by the rotation and west-to-east motion of an emerging sunspot. In the pre-flare phase of the two flares, XRT shows several highly sheared X-ray loops in the core field region, corresponding to a filament seen in the TRACE EUV observations. XRT observations also show that part of the sheared core field erupted, and another part of the sheared core field stayed behind during the flares, which may explain why a large part of the filament is still seen by TRACE after the flare. About 2-3 hours after the peak of each flare, the core field becomes visible in XRT again, and shows a highly sheared inner and less-sheared outer structure. We also find that the post-flare core field is clearly less sheared than the pre-flare core field, which is consistent with the idea that the energy released during the flares is stored in the highly sheared fields prior to the flare.

Title: Hinode Observations of a Vector Magnetic Field Change Associated with a Flare on 2006 December 13
Authors: Kubo, M.; Yokoyama, T.; Katsukawa, Y.; Lites, B.; Tsuneta, S.; Suematsu, Y.; Ichimoto, K.; Shimizu, T.; Nagata, S.; Tarbell, T. D.; Shine, R. A.; Title, A. M.; Elmore, D.
Publication: Publications of the Astronomical Society of Japan, Vol.59, No.s3, p.S779-S784 (PASJ Homepage)
Publication Date: 11/2007
Origin: PASJ

Bibliographic Code: 2007PASJ...59S.779K

Abstract

Continuous observations of the flare productive active region 10930 were successfully carried out with the Solar Optical Telescope aboard the Hinode spacecraft during 2006 December 6 to 19. We focused on the evolution of photospheric magnetic fields in this active region, and the magnetic field properties at the site of the X3.4 class flare, using a time series of vector field maps with high spatial resolution. The X3.4 class flare occurred on 2006 December 13 at the apparent collision site between the large, opposite polarity umbrae. Elongated magnetic structures with alternatingly positive and negative polarities resulting from flux emergence appeared one day before the flare in the collision site penumbra. Subsequently, the polarity inversion line at the collision site became very complicated. The number of bright loops in CaII H increased during the formation of these elongated magnetic structures. Flare ribbons and bright loops evolved along the polarity inversion line and one footpoint of the bright loop was located in a region having a large departure of the field azimuth angle with respect to its surroundings. SOT observations with high spatial resolution and high polarization precision revealed temporal change in the fine structure of magnetic fields at the flare site: some parts of the complicated polarity inversion line then disappeared, and in those regions the azimuth angle of the photospheric magnetic field changed by about 90°, becoming more spatially uniform within the collision site.

Title: Interaction between a Fast Rotating Sunspot and Ephemeral Regions as the Origin of the Major Solar Event on 2006 December 13
Authors: Zhang, Jun; Li, Leping; Song, Qiao
Publication: The Astrophysical Journal, Volume 662, Issue 1, pp. L35-L38. (ApJ Homepage)
Publication Date: 06/2007
Origin: UCP
ApJ Keywords: Sun: Activity, Sun: Atmospheric Motions, Sun: Flares, Sun: Magnetic Fields

DOI: 10.1086/519280
Bibliographic Code: 2007ApJ...662L..35Z

Abstract

The major solar event on 2006 December 13 is characterized by the approximately simultaneous occurrence of a heap of hot ejecta, a great two-ribbon flare, and an extended Earth-directed coronal mass ejection. We examine the magnetic field and sunspot evolution in NOAA AR 10930, the source region of the event, while it transited the solar disk center from December 10 to 13. We find that the obvious changes in the active region associated with the event are the development of magnetic shear, the appearance of ephemeral regions, and fast rotation of a smaller sunspot. Around the area of the magnetic neutral line of the active region, interaction between the fast rotating sunspot and the ephemeral regions triggers continual brightening and finally the major flare. This indicates that only after the sunspot rotates up to 200° does the major event take place. The sunspot rotates at least 240° about its center, the largest sunspot rotation angle that has been reported.