TEC reveal rapid transport of the low-latitude plasma to the cusp, across the polar cap, and its deposition around the nightside auroral oval. Incoherent scatter radars at Sondrestrom and EISCAT Svalbard provide vertical profiles through the TOI at polar latitudes, while radars at Millstone Hill and EISCAT Tromso detail the plasma characteristics at its source and at midnight-sector auroral latitudes. F-region TEC (below 1000 km altitude) observed with the Sondrestrom radar was > 120 TECu within the polar TOI, while TEC over the continental USA approached 300 TECu. During the November event, spatial gradients in TEC exceeded 100 TECu per degree of latitude over the northeast USA. No polar cap absorption event accompanied the Nov 2003 storm, and the SuperDARN radars provided full convection patterns over the northern polar latitudes. The continuous streams of thermal plasma TEC observed with the GPS mapping closely follow the convection streamlines simultaneously determined from the SuperDARN observations. GPS TEC observations now extend to high southern latitudes and we determine that the SED plumes and polar TOI imaged in the north appear simultaneously in the conjugate hemisphere.

## SH51A CC: 220 C-E Friday 0830h

## Violent Sun-Earth Connection Events of October-November 2003 I Posters

*(joint with SA, SM)*

***Presiding:*** **T H Zurbuchen,** University of Michigan**; Q Zong,** Boston University

### SH51A-01 0830h POSTER

### Photospheric field variations during the Oct. 28 and 29 solar events

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Solar photospheric magnetic field variations around the Oct. 28th and 29th, 2003 large flares and CMEs are investigated. The essential data for the study are the high cadence MDI full disk line of sight magnetograms. Abrupt and permanent changes of the field strength occur at the times of both X-flares (Oct. 28, 10:30UT and Oct. 29, 20:45UT). GONG+ magnetograms are used to provide a possible confirmation of the observed field changes. Velocity fields in the CME related active region and their evolution around the time of the events are obtained using the Local Correlation Tracking (LCT) technique on the MDI magnetograms. Some Mees/IVM vector magnetic field data analysis results may also likely be available.This level of observation of major active region fields spawning superstorm conditions is unprecedented.

### SH51A-02 0830h POSTER

### Evolution of the Coronal Magnetic Structures traced by X-ray and Radio Emitting Electrons during the Flare of 3 November 2003

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During their transit on the solar disk AR 0488 and AR0486 produced 12 X-class flares. Two of these flares (28 October 2003 and 3 November 2003) were observed at both X-ray/gamma-ray wavelengths by the RHESSI experiment and by the Nancay Radioheliograph. We shall present here results for the 3 November 2003 event which was observed and imaged up to several 100 keV by RHESSI and which produced at radio wavelengths a type II burst with an unusually high starting frequency and a long duration continuum extending from the low corona to the interplanetary medium. The combined analysis of RHESSI sources at energies above a few hundred keV and of metric/decimetric sources observed by the NRH shows a spatial extension of both X-ray and radio sources traced by energetic electrons between the impulsive part of the event and the late energetic X-ray phase associated with the radio continuum. This spatial extension will be discussed in the context of the shock-associated type II burst and of the CME onset. Analysis of radio and X-ray spectra will be tentatively done to investigate the nature of the radio continuum.

### SH51A-03 0830h POSTER

### UVCS Observations of CMEs from October-November 2003 Flares

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UVCS observed the CMEs associated with several of the powerful flares in late October and early November of 2003. While some of the observations were compromised by high particle background, useful observations of at least six events were obtained. In general, these events resemble the CMEs associated with X-class flares observed in 2002, in that low ionization spectral lines that dominate most UV spectra of CMEs are nearly absent. On the other hand, the [Fe XVIII] line formed at 65 MK is rarely seen in CMEs, but it is detected in many of these events. We discuss whether this means that no cool prominence material is ejected, or that the prominence material is heated so strongly that all the plasma reaches a high ionization state.

### SH51A-04 0830h POSTER

### Solar Flares in the UV from SORCE SOLSTICE

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The SOLar-STellar Irradiance Comparison Experiment (SOLSTICE) on the SOlar Radiation Climate Experiment (SORCE) measures the solar irradiance from 115-300 nm. During the solar storms of October and November of 2003, we observed large increases in the emission lines from many transition region species during several flare events. The greatest impact of a flare on the solar UV spectrum is in the brief impulsive phase. In the timespan of just a few minutes, the strength of an emission feature can rise by a factor of 10 and then subside back to its quiescent level over the course of an hour or more. The SOLSTICE observing technique scans the solar spectrum at a variety of rates, some scans taking 30 minutes to complete while others measure the entire wavelength range in a few minutes. Each flare reported here occurred while SOLSTICE was sampling a different piece of the spectrum. The combined information from all the observed flares provides new insight concerning the spectral signature of a flare as a function of both time and wavelength.

### SH51A-05 0830h POSTER

### The Role of a Nearby Emerging Active Region in the Events of October 2003

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On Oct 28, there was a large and complex magnetic region (10486) in the southern hemisphere. An X17 flare took place and a very high speed CME was launched and a Solar Energetic Particle (SEP) event took place. This was the first of the series of flare/CME/SEP events that occurred over the next few days. Series like this are typical of the major proton events that threaten damage to spacecraft systems and manned missions. Why did this active region produce a series of such fast CMEs? The release of this CME was preceded by a most remarkable flux emergence event. In the northern solar hemisphere, at approximately the same longitude as region 10486 a new major flux region began to emerge rapidly. When the new region(10488)began to emerge there were no obvious coronal structures connecting it with 10486 but the 10488 flux soon began to interact with the 10486 flux and a connecting structure could be seen in the EIT 195A. Connections between the two magnetic regions changed over the next 31 hours and Multiple connections could be seen just before the X17 flare and CME occurred. The connections seemed to be severed at the time of this CME but reformed later. We will discuss the series of connections and disconnections between the fluxes from 86 and 10488 in the context of the causes of ultra-high-speed CMEs.

### SH51A-06 0830h POSTER

### Sun-Earth Propagation Time of the October - November 2003 Shocks

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We computed the radial and expansion speed profiles of the CMEs that resulted in shocks detected at 1 AU, in order to evaluate the empirical shock arrival (ESA) model. The CMEs were observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board SOHO during October - November 2003 period. The shocks were detected by CELIAS/MTOF Proton Monitor on board SOHO and ACE spacecraft. The basic input to the ESA model is the CME speed. For limb events, we assume axial symmetry in order to obtain the most probable CME speed in the Sun-Earth direction. We apply the ESA model to obtain the travel times of shocks driven by Earth-directed and limb CMEs which had in situ observations at 1AU. For most cases the difference between the predicted and observed shock arrival times is negligible. We discuss these differences and their possible causes. Work supported by NASA/LWS and NSF/SHINE programs

### SH51A-07 0830h POSTER

### CME Cannibalism and Long-wavelength Radio Emission During the October-November 2003 Storms

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A spectacular interaction between two fast coronal mass ejections (CMEs) was observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board SOHO on November 4, 2003. The interaction resulted in a broadband radio enhancement in the dynamic spectrum of the Radio and Plasma Waves (WAVES) experiment on board Wind. The radio enhancement occurred when the second CME moving with a speed of 2700 km/s caught up with a slower CME ($\sim$ 600 km/s) and its dense core at a distance of 18 solar radii from the Sun. Direction finding from WAVES observations matched with the white-light location of the interaction region. The radio enhancement was brighter than the associated type II burst. We also show from the observed flux radio density and white-light source extent that the radio emission is nonthermal. The radio emission due to the colliding CMEs was also observed

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by Ulysses and CASSINI, which were at distances of 5 and 8.7 AU, respectively. The signatures arrived at CASSINI and Ulysses with a delay corresponding to the appropriate light travel times. Wind, Ulysses, and CASSINI were widely separated in heliocentric distance as well as angular separation, suggesting that the interaction signature is not narrowly beamed. Work supported by NASA/LWS and NSF/SHINE

## SH51A-08 0830h POSTER

### Halo CMEs in October - November of 2003: predictions and reality

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Recently we found that the intensity of Bz in the interplanetary magnetic field (IMF) is correlated with the projected speed of coronal mass ejections (CME). The relationship is better pronounced for very fast ejecta with speeds higher than 1200 km/s, while slower events display larger scatter. In turn, the Bz in IMF is correlated with the intensity of the Dst index of geomagnetic activity. Based on this result we are elaborating a procedure to routinely predict the magnitude of the Bz and the intensity of geomagnetic storms 1-2 days in advance by measuring speeds of halo CMEs as they propagate across the LASCO C3 field of view. Here we present our predictions made for 9 halo CMEs erupted during the period of violent solar activity in October-November 2003. The comparison between the forecasted values of the Bz and the Dst index and the observed data shows that we were able successfully predict all three major geomagnetic events when the Dst index decreased below -300 nT.

URL: http://www.bbso.njit.edu/˜vayur/halo_cme/

## SH51A-09 0830h POSTER

### Solar Particle Events Seen by the MOPITT Instrument

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The MOPITT instrument was launched on the Terra satellite on the 18th December 1999 to measure primary CO and CH4. However, from the MOPITT telemetry data, it is also possible to extract interesting information on other, very different, geophysical quantities. This paper reports on Device Single Events (DSEs) occurring in an accelerometer within the instrument, and their correlation with high-energy radiation environment and solar activity. During the period from March 2000 to Jan 2003 more than 1000 accelerometer outliers were recorded, a large enough set to apply a statistically meaningful analysis. The strong localization of these events in the South Atlantic Anomaly (SAA) indicate that these outliers are caused by the radiation environment (energetic particles), but strong signals from the polar regions, particularly the southern pole, occur during intense Solar Proton Events (SPSs). Analysis of these signals shows a direct correlation of the DSE daily rate with solar activity, a Day/Night asymmetry caused probably by interaction of trapped particles with the neutral atmosphere, and a direct correlation with high intensity solar proton events (SPEs). We have also found: 1) A direct correlation of the particle population responsible for DSEs in the piezoelectric accelerometer with solar activity as expressed by the F10.7 Solar Radio Flux but not by the Sun Spot Number (SSN). 2) The second sub-maximum of Solar Cycle SC23 is characterized by injection of more high-energy particles mainly via the poles, and a good proxy of Solar activity for this purpose is the F10.7 index. A preliminary analysis of DSEs collected during 2003, included the big Solar Event from 29 Oct/2003, is also presented.

## SH51A-10 0830h POSTER

### Scatter-free impulsive electron event from the October 28, 2003 X17 flare

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The October 28, 11 UT X-17 flare produced an impulsive electron event detected near the Earth by the WIND 3D Plasma & Energetic Particles instrument from 200 keV down to ∼1 keV, even though the flare was located around E08 and therefore unlikely to be magnetically connected to Earth. This impulsive event exhibited a fast rise and decay (∼10 min each), and was followed by a second, much slower rising event that lasted for many hours. The peak times of the impulsive event show clear velocity dispersion consistent with a path length of 1.27±0.1 AU, indicating that the electron propagation is essentially scatter-free. Onset time analysis reveal that the impulsive event electrons left the Sun at 11:14±3 UT, just after the end of a group of type III bursts seen at 14 MHz (11:03-11:11 UT) and when the type II burst reaches 14 MHz. Radio pulsations at 0.6-1.3 GHz were seen between 11:14:30 and 11:22:00 UT. The velocity dispersion seen in the peak times suggests that the peak of the injection occurred around 11:25±3 UT roughly consistent with the end of the decimeter radio emission. This impulsive electron event also was observed near Mars at energies from ∼1 to 20 keV by the Electron Reflectometer instrument on Mars Global Surveyor spacecraft.

## SH51A-11 0830h POSTER

### The October-November, 2003 Solar Events in the Context of Previous Events During Solar Cycle 23 and Earlier Cycles.

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We place the energetic solar events during October-November 2003 in the context of previous events and their interplanetary manifestations, such as shocks, ICMEs and cosmic ray effects, both in solar cycle 23 and previous solar cycles. We assess the degree to which this interval of enhanced activity during the declining phase is abnormal or unusual, and investigate the solar and interplanetary circumstances that lead to such extreme events.

## SH51A-12 0830h POSTER

### Energetic Particles From the October/November 2003 Solar Events: Ulysses Observations

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The effects of the intense solar activity that occurred in October and November 2003 were clearly observed at the Ulysses spacecraft. At the time of these events, Ulysses was located 6 degrees north of the solar equator, 120 degrees west of the Sun-Earth line, at a radial distance of 5.23 AU from the Sun. Solar wind conditions at Ulysses prior to the period of enhanced solar activity were dominated by a pattern of recurrent high-speed/low-speed stream interactions typical of the declining phase of the solar cycle. Energetic particle fluxes were predominantly SIR-related. As a result of the increased activity, and the associated (I)CMEs, this pattern was temporarily disrupted. In this paper, we report on observations of energetic particles in the 1-20 MeV/nucleon range as measured by the COSPIN/LET instrument on board Ulysses. We use the anisotropy and composition signatures to investigate the likely source of the populations contributing to the increased particle fluxes observed in connection with the Oct/Nov 2003 solar activity, and to draw conclusions concerning the relative importance of SEP versus SIR/CIR sources.

## SH51A-13 0830h INVITED POSTER

### GEOTAIL Observation of Interplanetary Shocks During the Solar Storm Season in October-November 2003

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Using GEOTAIL data, we study interplanetary shock (IPS) events and related phenomena in the solar storm season in 28 October - 6 November 2003. Four IPSs detected by GEOTAIL are, (1) ∼02 UT on 28 October, (2) ∼06 UT on 29 October, (3) ∼06 UT on 4 November, and (4) ∼20 UT on 6 November. (Another strong IPS detected by ACE at ∼16 UT on 30 October came was not seen by GEOTAIL since GEOTAIL was in the magnetosphere.) While IPS-1 and IPS-4 were relatively weak shock, IPS-2 was the fastest shock (average speed of ∼2200 km/s) ever detected by GEOTAIL. IPS03 was a moderately strong IPS with average speed of ∼1100 km/s. From the viewpoint of nonthermal particle acceleration, we are most interested in IPS-2 and related phenomena. Unfortunately, since the background of SEPs (solar energetic particles) above 10 MeV during the IPS-2 event was fourth-strongest in the satellite record, the low energy ion detector LEP/EAi was masked for the most of the event. However, from other instruments including the low energy electron detector LEP/EAe, the solar wind ion detector LEP/SWi, energetic particle and ion composition EPIC, the magnetic field detector MGF, the plasma wave instrument PWI, the electric field instrument EFD we could obtain valuable data for this interesting IPS event. We will discuss (1) local shock properties (such as the shock angle, propagation speed, and compression ratio), (2) activity of waves resonating with energetic protons as well as energetic electrons, and (3) particle acceleration and possible 'cosmic-ray-mediated' feature, namely preacceleration of the solar wind in the foreshock region ahead of the IPS.

## SH51A-14 0830h POSTER

### Shock Evolution During 29 - 06 November 2003 period of Solar-Flare-CME-Shock-Geomagnetic Storms

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During the period 29 October - 6 November four shocks were observed at Earth by ACE/SWEPAM/MAG and ACE/SWICS on 29 October, 30 October, 4 November, and 6 November. Two distinct and very intense geomagnetic storms, associated with the X17.2 and X10/2B flares, rank as the largest storms of Solar Cycle 23. For example, the X17.2 flare (28 October, S16E08 in AR0486), via its associated halo CME and shock wave, was responsible for the Dst = -347 nT index on 30 October 2003. We will present the use of an adaptive grid 2D MHD model to study these four shocks in detail. Accordingly, four separate pressure pulses, at the appropriate times and with different strengths and duration are introduced at the Sun to mimic the four flares. The results show that the simulated solar wind velocity time series successfully match the observations at L1.

### SH51A-15 0830h INVITED POSTER

## IMF and Ejecta Coherence Lengths During the Events of October-November 2003

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A three-spacecraft study is presented on coherence/correlation lengths of the IMF and interplanetary ejecta during the violent events of October-November 2003. The data come from ACE, orbiting around the L1 point, Geotail, following a trajectory in the dayside magnetosheath/ solar wind, and WIND, nominally located near midtail at ∼150 Earth radii downstream. The rapid flapping of the geomagnetic tail yielded long time intervals when Wind was in the downtail magnetosheath. Our primary aim is to compare the levels of correlation in the ACE-Geotail measurements and the ACE-WIND measurements, and examine them as a function of interplanetary structure and interspacecraft distance. To bring the results into proper perspective, another very active interval is examined. In this case, a repetitive sequence of solar transients gave rise to a periodic and high correlation length. The results are then intercompared.

### SH51A-16 0830h POSTER

## Giant X-Ray Bursts on Oct.28 and Nov.4, 2003 observed by Cluster

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Active region (Sunspot) 10486, which was about 15 times the size of Earth blasted off some mega-flares. The largest two of them were on 28 October and 4 November 2003. In fact, the Nov. 4, 2003 one saturated many X-ray detectors on the NOAA's GOES satellites and HESSI; the jury was therefore out for a while on the definitive classification of the flare (best estimate was made by NOAA X28, with a peak around 19:50 UT). It is a new #1 X-ray flare for the record books. The second-strongest flare in this historic two-week series was an X17 event on Oct. 28, 2003. However, those two giant X-ray bursts have been observed continuously by RAPID-IES onboard Cluster. Cluster was located on the duskside around 19 MLT near the magnetopause and not affected by any magnetospheric electron background at the time of the Oct. 28th and Nov 4th event. The obvious energy dispersion signatures, first from low energy to high followed by high energy to low versus time have been observed for both giant X-ray bursts. During Nov. 4, 2003 event, the RAPID instrument on s/c2 was in a mode that permitted the full 3D distribution (144 pixels) to be obtained over the unit sphere. All of the counts shown in the plot for s/c2 were registered by the two pixels that see the disk of the sun during the 4 sec rotation of the s/c. We will analyze and report on the energy dependent signature of the response of the IES sensors to these intense X-ray fluxes in terms of sensor implications and physical insights for the flare itself.

# SH51B CC: 518 A Friday 0830h

## Analysis of the 1859 Carrington Event and Other Major Superstorms II *(joint with SA, SM)*

***Presiding:*** **A J Ridley,** University of Michigan**; G Siscoe,** Center for Space Physics, Boston University

### SH51B-01 0830h INVITED

## R.C. Carrington and the 1859 Space Weather Event

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R.C. Carrington (1826-1875) is remembered in this session as the co-discoverer of the first solar flare ever reported - on 1 September 1859. The ensuing space weather event remains a "worst case scenario" for solar-terrestrial interaction. Carrington was one of the most accomplished solar astronomers of the 19th century and is credited with the discovery of differential rotation and the variation of sunspot latitude over the solar cycle. I will review Carrington's life, which ended soon and sadly after a brief but brilliant career, and the scientific times in which he worked. I will assess the contemporary impact of Carrington's flare observation and will briefly recount how the meaning of the tantalizing clue presented by this event gradually came to light.

### SH51B-02 0850h INVITED

## Historically Large Geomagnetic Storms and Potential Electric Power Grid Impacts

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While recent work has been done to examine the possible Dst Intensity of historically large geomagnetic storms, the impacts caused to modern day electric power grids from these storms occurs due to rapid rate-of-change of regional geomagnetic fields which in most cases are driven by large ionospheric electrojet current intensifications. These temporally and spatially dynamic disturbance morphologies are not well-characterized by Dst or other broad geomagnetic storm indices. For estimates of storm intensity that correctly scale the threat potential to electric power grids, it is necessary to describe the rate-of-change of geomagnetic field. The rate-of-change of the geomagnetic field (dB/dt usually measured in nT/min) creates at ground level a geoelectric field that causes the flow of geomagnetically-induced currents (GIC) through ground connection points in electric power grids. Therefore in general, the larger the dB/dt, the larger the resulting geo-electric field and GIC in exposed power grid infrastructures and the greater the operational impact these induced currents will have on the power grid. Both extensive modeling analysis and recent operational experience suggests that power grids are becoming more vulnerable to geomagnetic storms as they grow in size and complexity. Also, large power grid blackouts have occurred at relatively low geomagnetic storm intensities. For example, the regional disturbance intensity that triggered the Hydro Quebec collapse during the March 13, 1989 Superstorm only reached an intensity of 479 nT/min. Large numbers of power system impacts in the United States were also observed for intensities that ranged from 300 to 600 nT/min during this storm. Yet both recent and historical data indicate that storms with disturbance levels that range from 2000 nT/min to as much 5000 nT/min may be possible over extensive regions at latitudes of concern for large continental power grids across North America and Europe. Large GIC have also been observed in power grids at low latitude locations due to other geomagnetic storm processes that in combination have the potential to suggest global-scale power grid disruptions might be plausible for historically large storms. An overview of these findings will be provided.

### SH51B-03 0910h

## Historic Superstorms and their Effects on Ground Electrical Systems

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The 1859 superstorm produced widespread disturbances to the telegraph system. Such was the power of the induced electric fields that telegraph operators in the eastern US disconnected their batteries and used the "celestial power" to send messages. Since then there have been many evolutions in technology with messages now being transmitted under the oceans via optical fibre cables and power being transmitted over long distances on high voltage networks. However it seems that each technological development is followed by a magnetic superstorm to remind us of our vulnerablility to the solar-terrestrial environment. This presentation details the system disturbances observed in the superstorms of September 1859, March 1940, February 1958, August 1972, and March 1989, examines the features of the magnetic disturbances that caused the problems. Consideration is also given to the characteristics of the solar-terrestrial disturbances that would have produced these effects.

### SH51B-04 0925h

## Solar Proton Events for 450 Years: The Carrington Event in Perspective

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Using the impulsive nitrate measurements in polar ice as identifiers of solar proton events in the past, we have identified 19 events over the period 1561-1950 that equal or exceed the >30 MeV fluence measured during the August 1972 and October 1989 events. The largest nitrate deposition (and largest solar proton fluence above 30 MeV) occurred in late 1859 in time association with the Carrington flare of September 1859. The Carrington flare occurred near the central meridian of the sun; the interplanetary disturbance associated with the solar activity rapidly traveled toward the earth resulting in an extremely large geomagnetic storm commencing within 17.1 hours of the visual observation of the solar flare. While this event was remarkable by itself, historical records indicate that the Carrington event was part of a sequence of solar activity as an active region traversed the solar disk. We compare the derived solar proton fluence for the Carrington event of 18.8 x 10**9 above 30 MeV with the solar proton fluence from more recent episodes of solar activity.



### SH51B-05 0940h INVITED

## The Possible Magnetospheric, Ionospheric, and Thermospheric Response to the 1859 Carrington CME.

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The 1859 Carrington event is interesting because of the possible strength of the magnetic field and incredibly strong solar wind ram pressure. This is because the coronal mass ejection only took 18 hours to propagate from the Sun to the Earth, implying a speed of over 1700 km/s, with associated magnetic fields of over