Basrah Journal of Science (A) **Vol.32(1),168-181, 2014**

A new approach in the observation of two successiveCoronal Mass Ejections

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Abstract:

On 2000 February 17-19 and 2000 April 04-06 ,the Energetic and Relativistic Nuclei and Electron (ERNE) instrument onboard Solar and Heliospheric Observatory (SOHO) observed gradual solar energetic particle events(SEPs). These events associated with two solar eruptions. The event 2000 February 17-19, is association with two solar flares (M1.3,C1.1) and halo Coronal Mass Ejections (CMEs) separated by ~ 13hours, while on 2000 April 04-06, the event was associated with two CMEs separated by ~8hours .The observational data make a proposal that the second acceleration of various protons energy occurred behind the first CME and it was not an obstaclefor the new particles to reach 1AU in both events. The magnetic field and plasma measurements show that the shock wave of the first CME was an efficient, decelerate, soften, and become transparent for the protons produced by the second eruption.

Key word: - Sun, coronal mass ejection, Multi Eruption Solar Energetic Particle (MESEP), SOHO.

1-Introduction:

Solar Energetic Particles(SEPs) in their intensity-time profile, energy spectra, elemental, isotopic, and ionic charge composition carry fundamental information on the source region of their acceleration and propagation processes. The occurrence of SEP events is directly related to flares and Coronal Mass Ejections(CMEs) (Klecker2006) and with interplanetary shocks(Sheeley 1985, Reams 1999).CMEs are known to be of the most important coronal phenomena contributing to interplanetary solar winddisturbances. Dynamical parameters of CMEs are directly involved on the possible effects on space weather conditions (Schwenn 2006).

The observation of the first non-scattered relativistic particles is one tool to establish the connection between sudden rise in the intensity-time profile for many particle species which occur after flares or CMEs (Sheeley 1985). Note that these measurements are background dependent unless the background of the intensity-time profile is clear enough and not masked by previous events, the exact association of the SEP events with the eruption cannot be accurate. In this manner it is not possible to know whether the CMEs or solar flare which occurred after the first eruption have injected/accelerated by SEPs since intensity-time profiles are masking the possible effect of the SEPs related to such eruptions.

Furthermore, even in some single eruptive SEP events we can find more than one acceleration phase (Al-Sawad 2006, Bombardieri 2006).A gradual SEP event might not be due to one single eruption, CME or solar flare. Al-Sawad (Al-Sawad 2009, & 2012) concludes that the continuity of high intensities due to coronal or interplanetary shock wave might come from several eruptions, which might end in showing one single prolonged intensity–time profile. In such case a continuing intensity – time profile can be due to MultiEruption Solar Energetic Particle (MESEP) events.

Particle acceleration at collisionless shock can be observed best at planetary bow shocks and travelling Interplanetary(IP) shocks. There are different physical mechanisms involved in the particle acceleration at interplanetary shocks (1) the shock drift acceleration (SDA), sometimes also called scatter-free acceleration, in the electric induction field in the shock front;(2) the diffusive shock acceleration due to repeated reflec-tions in the plasmas converging at the front, and (3) the stochastic acceleration in the turbulence behind the shock front (kallenrode2004).

Two separate energy bands could discuss the energetic particles accelerated at interplanetary shocks (a) a low-energy component with ion energies up to a few hundred keV/nucl and electron energies up to some tens of kiloelectronvolts; and (b) a high –energy component with ion energies in the megaelectron-volts and tens of MeV/nucl range and electron energies in the hundreds of kiloelectronvolt to megaelectronvolts range. One reason for such a separation is the break in the ion spectrum (kallenrode2003, Reames, 1999).

The type of shock is dependent on the propagation speed of the surface in relation to the characteristic speeds of the medium (Parks 1991, Burlaga 1991). In space, the most likely type is the fast one, characterized by an increase in the interplanetary magnetic field(IMF) strength, while the slow one is characterized by a decrease in the IMF strength. Both fast and slow shocks that move radially away from the Sun are socalled forward shocks, and the ones that move toward the Sun relatively to the solar wind are named reverse shocks. In the IP space, the forward shocks are normally formed as a consequence of the propagation of structures such as CMEs and identifiedby the sensors onboard satellites in orbit. In general, when a mass flux through the shock is observed, and subsequently the solar wind parameters and the entropy of the system increase abruptly, a shock wave is identified.

The shock analysis based on one spacecraft observation is in general be tested by satisfying the Rankine-Hugoniot (R-H) relations. The well-known method is the magnetic coplanarity theorem (Colburn and Sonett 1966).One can determine shock normal only with up- and down-stream averaged magnetic fields. This theorem is very frequently used. A mixed data method called velocity-magnetic field coplanarity was proposed by(Chao 1970) and also (Abraham-Shrauner 1972).This method requires up- and down-stream magnetic fields and velocities to determine the shock normal. Therefore the shock normal, magnetic fields, and velocity difference lie on the same plane, called a coplanar plane. These two methods can be reliable if the data are accurate. The velocity-magnetic field should more reliable than the magnetic coplanarity theorem if the data have more or less errors.

In the present paper we studied two double-eruption events that associated with two CMEs. Examine the 4He/p ratio, in-situ magnetic field and plasma param-eters , and the associated flares and CMEs that occurred less than a day separated from each other, shows a new Solar Energetic Particle(SEP) acceleration due to second CME from behind the previous CME driven shock. The spacecrafts SOHO ,WIND, and Advanced Com-position Explorer(ACE) observation have been registered the shock wave passage time where after the second eruption which might have penetrated the interplanetary shock to reach the Earth. These observations can be sample to the shock behavior in interplanetary space.

2-Observations and Results

We used both the low-energy and high-energy particle detectors, LED and HED, of the ERNE instrument (Torsti *et al.*, 1995, 1997) on board SOHO, to look for SEP events in the energy range 1–100 MeV, with 1 minute resolution. ERNE data can be retrieved through the data finder program at http://srl.utu.fi/erne_data/(Valtonen2001).

WIND/The Solar Wind Experiment (SWE) (Ogilvie *et al.* 1995), and ACE /The Solar Wind Electron Proton Alpha Monitor (SWEPAM) have been used for plasma data ,as well as the magnetic field data from theWIND/ Magnetic Fields Investigation (MFI)(Lepping *et al.*1995), and The ACE/ Magnetic Field Experiment (MAG)(Smith *et. al.* 1998). LASCO catalog (Brueckner *et al.*, 1995)occupied to estimate the heliocentric location of the CME for the first injected protons intensity by employed the injection time to the quadratic fit.

On17 February 2000,and 04 April 2000,the proton intensity obtained from dataon board SOHO/ERNE. The intensity were rose up to tens MeV energies over the cosmic ray back-ground in each event that indicate a clear SEP event that was related to eruptions at the Sun. In 2000 February 17 event the proton intensity-time profile shows an enhancement of the first eruption and a decay,followed by a second rise with maximum associated with second CME2 (Fig.1). The SEP onset observed by SOHO/ERNE at 21:05 UT that associated with halo CMEat 21:30 UTof a linear speed 728 kms^{-1},acceleration of -22.9 ms^{-2}at 5.6 R_{Θ} , and anX-ray flare of class (M1.3)which started between 20:17-21:07 UT at location S29E07, from NOAA active region 8872 that detected by *GOES*observation.The CME liftoff time is 20:18 UT ±11 min according to quadratic fit. At 20:42 UT metric type II observed.

The halos CME combined with radioemission and solar flares,type II metric radio emission which indicates shock waves propagating in the solar corona while decametric type II attribute to shock wave driven ahead of CME piston.

The time of second enhancement on 18 February 2000 at 09:44 UT for proton energy > 90 MeV and maximum of SEP at 10:11 UT. After ~13 h from first SEP event onset,by this time the CME had been at ~0.14 AU a new CME at 09:54 UT at a location 4.15 $R_{\odot}$, with linear velocity 890 Km s^{-1},acceleration -9.6 ms^{-2}, associated with C1.1 solar flare at 09:21 UT lasting 6 minute from 8867 active region while Hα at location S16W78.

The Interplanetary(IP) shock is the result of the difference between the propagatingstructure (upstream) and the medium (downstream) speeds. The selected up- and downstream time intervals (10 min) for obtained the magnetic fields, plasma densities, and plasma velocitiesare shown in Figure (2) to get the shock parameters for WIND observation.

The associated CME-driven shock with this event arrived at WIND,ACE, and SOHO spacecraft at about (21:00, 20:40, and 20:56) UT respectively on 20 February 2000. The transit time from liftoff on the Sun to arrival later spacecraft was(71.5,71.1,and 71.3) hr, implying an average transit speed of (581,584, and582)kms^{-1}.Comparison of the transit speed with the plane of sky CME speed 728 kms^{-1} near the Sun indicate that the CME must have decelerated as it propagated from the Sun to 1AU. We used Vinãs and Schudder method to solve the Rankine-Hugoniot equations (Vinãs 1986)to calculate the shock parameters. The shock normal was (-0.876, -0.271, -0.39), which was quasi-perpendicular (θ_{Bn}=85˚),with Mach no. (0.91).The shock speed was calculated to be 450.44 km/s , and compression ratio is (2.15).

The shock parameters were calculated to test it for understand-ing the ability of accelerated solar protons to penetrate through the shock of CME1 without strong scattering.

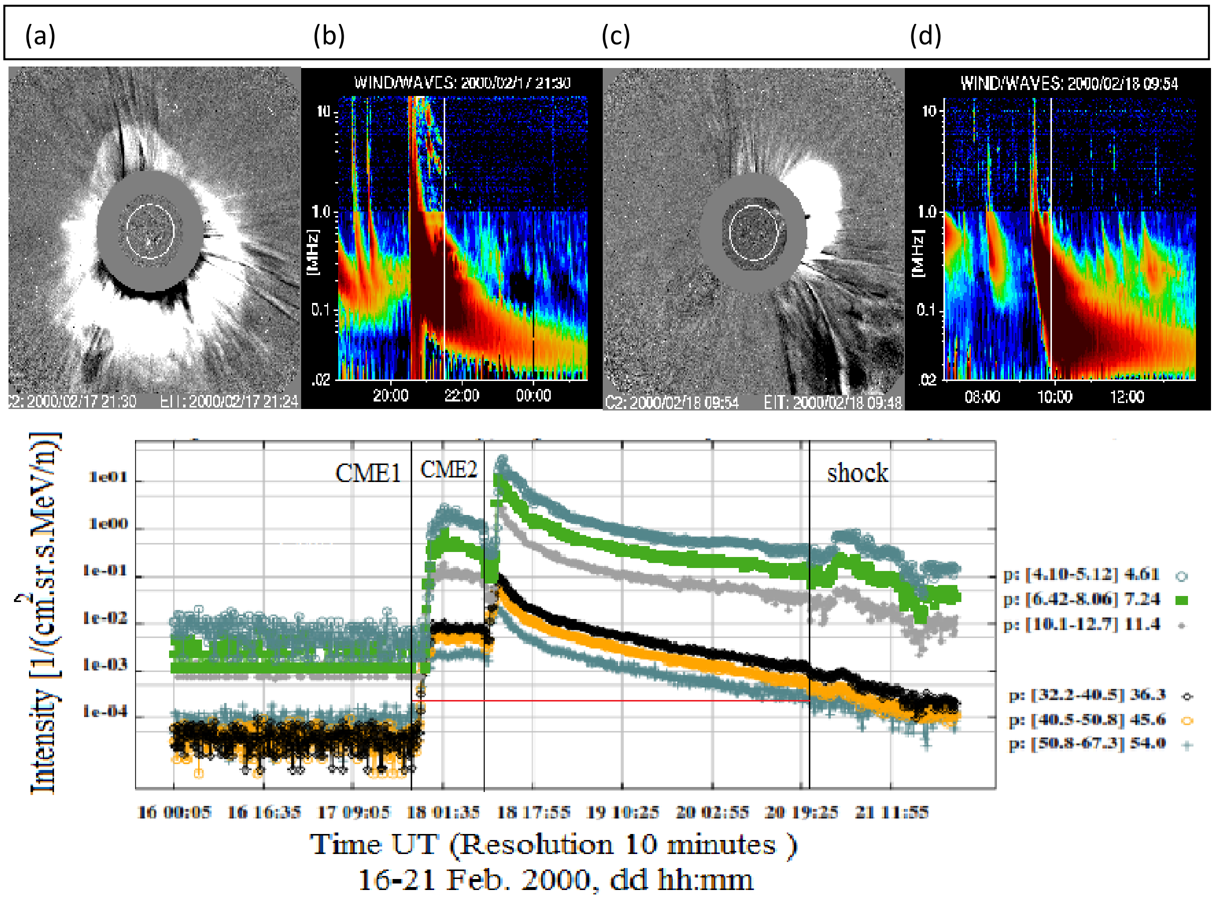


Figure (1):View plots of event 17 Feb.2000, top panel (a, c)the LASCO C2 CME observed, (b, d) WIND/WAVES radio emission observation. Bottom the intensity time profile from SOHO/ERNE.

Table 1 shock parameters for 20.02.2000

Parameter(GSE)	value
shock normal **n**	**-0.876, -0.271, -0.39**
Mach no. ($M_{ch)}$**0.911**	
shock velocity $V_s$km/s	**450.44**
Shock normal angle θ_{Bn}**85**$^{\circ}$	
Compression ratio	**2.15**
Transit shock velocity Km/s	**581**

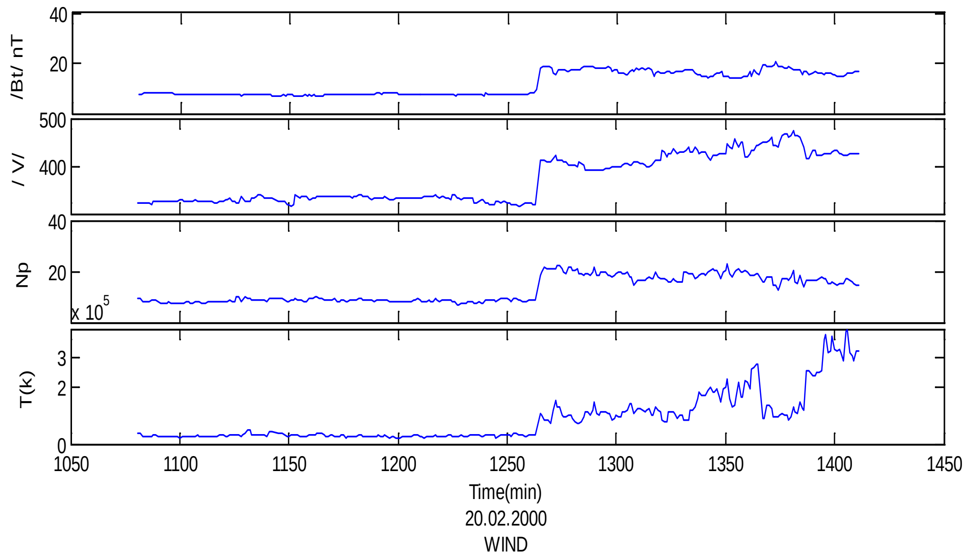


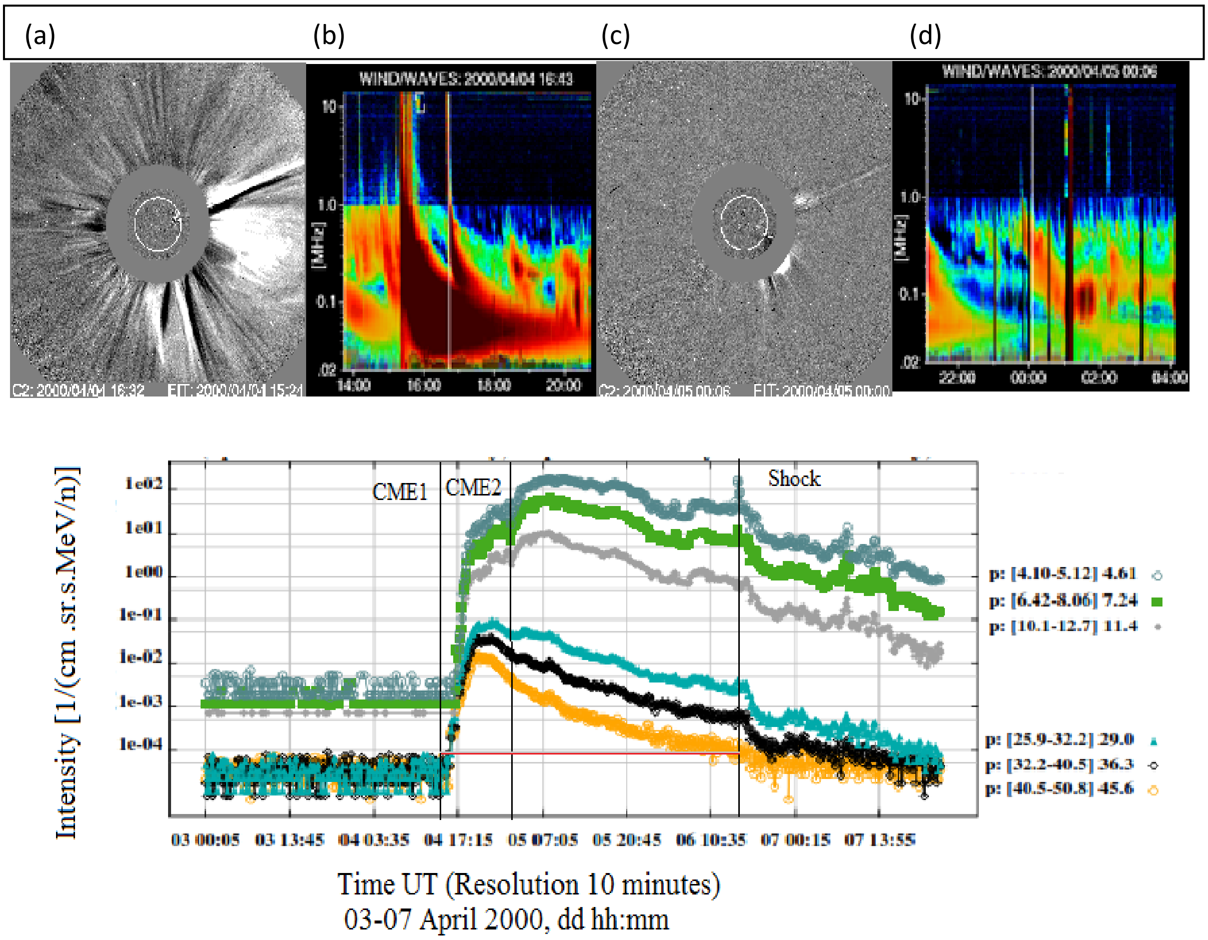
Figure (2): Magnetic field intensity (|Bt|), proton speed (/V/), proton density (Np), proton temperature (T) of IP shocks observed byWIND for 20.02.2000event.WINDmagnetic field and plasma data are plotted at resolution 1 minute.

The second event ,on 04 April 2000, which is among the major SEP events of solar cycle 23(Gopalswamy 2003) associated withhalo CME has angular width of 360° , linear speed 1188 km s^{-1} and acceleration of 12.8 ms^{-2} at 16:32 UT with X-ray flare of class(C9.7) from NOAA active region 8933 at location N16W66 that detected by *GOES*(Fig(3)). The CME liftoff time is 14:47 UT ± 05 min taking as an average value for the linear and quadratic fit. The SEP onset time was 15:45 UT for energy 45.5 MeV.

While CME1 was travelling in the interplanetary space toward the Earth, at 00:06 UT on April 05, another CME appeared on the southwest of the solar disc, at 2.48$R_{\odot}$ first seen around 212° central position angle with width of 68,° linear speed 898 kms^{-1}, and acceleration -2.0 ms^{-2}. At that time, the previous CME heliocentric distance was 0.3 AU, the shock driven by CME1was not obstacle for the new SEP to directly access to 1 AU. Although there were no radio emission type II associated with the later CME, and no solar flare combined. The first SEP eruption had masked the ascend phase of the new solar particle event. The event has rich helium and constant He/p ratio(Fig.(3)).

Where the data of magnetic field, density, proton temperature, and plasma velocity are shown in Figure (4) for IP shock at 06 April 2000 that WIND observed at 16:27 UT.The selected up- and downstream time intervals (10 min) for magnetic fields, plasma densities, and plasma velocities.

For determine the shock parameters that listed in Table 2



Fig***ure (3):***View plots of event 04 April 2000, top panel (a, c)the LASCO C2 CME observed, (b, d) WIND/WAVES radio emission observation. Bottom the intensity time profile from SOHO/ERNE.

Table 2:Shock parameters for 06.04.2000

Parameter(GSE)	value
shock normal **n**	**0.953, 0.161, 0.258**
Mach number (M_{ch})	**0.98**
shock velocity V_s km/s	**681.039**
Shock normal angle θ_{Bn}	**71°**
Compression ratio	**3.71**
Transit shock velocity Km/s	**867**

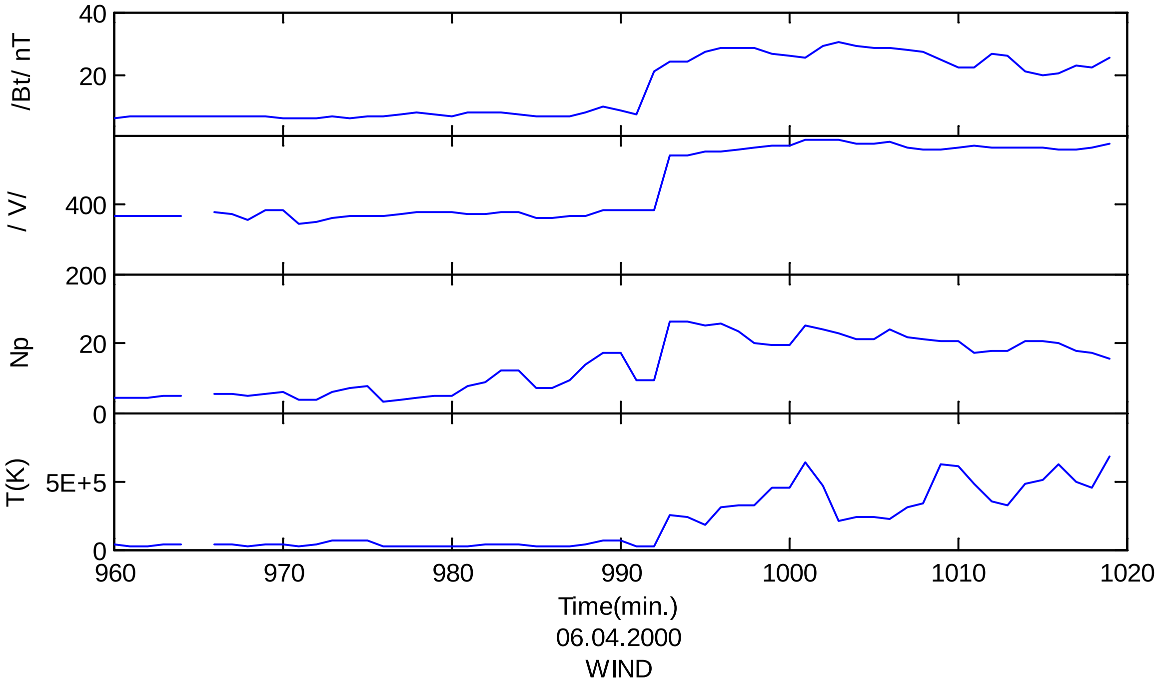


Figure 4: Magnetic field intensity (|Bt|), proton speed (|V|), proton density (Np), proton temperature (T) of IP shocks observed byWIND for 06.04.2000event.WIND magnetic field and plasma data are plotted at resolution 1 minute.

3-conclusion:

- The time-intensity profiles of gradual SEP events show a wide variety of spatial and temporal variations which depend on factors such as spacecraft position with respect to the CME, local plasma conditions at the spacecraft location, efficiency of the acceleration, and particle transport in the IP space.
- With this analysis for the events we saw the CME heliocentric height was located ~ 1-5 solar radii for first proton injection timewhich agreement with previous study (Kahler 2006,Reams 2009).
- The efficiency of CME-driven shocks as particle accelerators varieswith longitude (as the observer establishes magnetic connection to different regions of the shock front)and with time (as the shock travels away from the Sun). Shocks when are close to the Sunare able to accelerate protons to GeV energies (~ 3-5 solar radii), while when reach 1 AU they are hardly accelerate ions above 20 MeV/n. The angle θ_{Bn} between the shock normal and the direction of the upstream magnetic field plays an essential role in determining the mechanism of particle acceleration at shocks.

4-Reference

Abraham-Shrauner B. and J. Geophys. Res., (1972) 77, 736.

Al-SawadA., Torsti J., Kocharov L., Huttunen-Hiekinmaa K. J. Geophys. Res., 111, A10S90 (2006).

Al-Sawad A., SaloniemiO .,Laitnen T. and Kocharov L. ,(2009) ,A&A 497, Issue1, L1-L4.

Al-Sawad A.,Allawi H., Al-Ramdhan W., andValtonen E., (2012)Astrophysics and Space Sciences Transactions, 8, 1-5.

Bombardieri D.J., Duldig M.L., Michael K.J. and Humble J.E. ApJ, (2006) 644, 565-574.

BruecknerG.E., Howard R. A., Koomen M. J., KorendykeC. M., Michels D. J., Moses J. D., Socker D. G., Dere K. P., Lamy P. L., Llebaria A., Bout M. V., Schwenn R., Simnett G. M.,

Bedford D. K., Eyles C. and J.Solar Phys. , (1995), 162:357.

BurlagaL., II: (1991)New York, U.S.A.: Springer, 1–22.

Chao, J. K., (1970) Rep. CSR TR70-3,Mass. Inst. of Technology, Center for Space Res., Cambridge, Mass,.

Colburn D. S., and C. P. Sonett, ,(1966)Space Sci. Rev., 5, 439.

GopalswamyN., Geophys. Res.Lett. ,30,8013,(2003).

Kahler S. and Ragot B. R., Asriphys. J., (2006)646, 634,.

Kallenrode M.B., J. Phys. (2003) G29, 965-981.

KallenrodeM. B., (2004) An Introduction to Plasma and Particles in the Heliosphere and Magnetosphere .

Klecker B.,Cane H. V.,Dalla S., Heber B., KecskemetyK., KleinK. L., Kota J., KucharekH., LarioD., Lee M.A., PopeckiM.A.,Posner A., Rodriguez-PachecoJ., Sanderson T., Simnett G. M., and RoelofE.C., (2006):Space Sci. Rev. ,123, 217.

Lepping R. P., Acuna M.H., Burlaga L. F., Farrell W. M., Slavin J. A., Schatten K. H., Mariani F., Ness N. F., Neubauer F. M., Whang Y. C., Byrnes J. B., Kennon R. S., Panetta P. V., Scheifele J. , and Worley E. M.,(1995)Space Science Reviews, 71:207-229.

Ogilivie K. W., Chornay D. J., Fritzenreiter R. J., Hunsaker F., Keller J., Lobell J., Miller G., Scudder J. D., Sittler E. C., Torbert R. B., Bodet D., Needell G., Lazarus J. A., Steinberg J. T., Tappan J. H., Marvretic A., and Gergin E., (1995) SWE, Space Science Reviews,71:55-77.

ParksG. K. ,(1991)Physics of space plasmas - an introduction.

Reames D., V., Space Sci. Rev. ,90, 413 (1999).

Reames D.V. (2009a). Astrophys. J. 693, 812.

Schwenn R., ,(2006).space weather,

Sheeley N.R. Jr., Howard R.A., KoomenM. J., Michels D.J., SchwennR., MuhlhauserK.H.,and RosenbauerH.,J. Geophys. Res., (1985) 90, 163-175.

Smith C. W., L'Heureux J., Ness N. F., Acuna M. H., Burlaga L. F., & Scheifele, J., , (1998) Space Sci. Rev., 86, 613.

Torsti J., Laitinen, L., Vainio R., Kocharov L., Anttila A., & Valtonen A., (1997) solar physics, 175,771-784.

Torsti J., Valtonen E., and Lumme M., solar physics, V01, 162,505-531,(1995).

Valtonen E., Riihonen E., Huttunen K., Eronen T., Laitenen T., Teittine M. and Torsti J., (2001)space research laboratory, university of Turku.

Vinãs A. F. and Scudder J.D., J. Geophys. Res., (1986)91, 39-58.

اسلوب جديد لرصد كتلتي الاهليل الشمسي المتعاقبة

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الخلاصة:

رصد كاشف الجسيمات الطاقية والنسبية *ERNE*الموجود على المركبة الفضائية *SOHO* احداث جسيمات شمسية ذات طاقات عالية تدريجية في الفترات*17-19.02.2000*و *04-06.04.2000*. هذه الاحداث تكون مرافقة للانفجارات الشمسية، في الفترة *17-19.02.2000*الحدث يكون مرافق للتوهج الشمسي (solar flare)ذو الشدة(*M1.3,C1.1*) والفترة الزمنية الفاصلة بين كتل الاهليل الشمسي (*CMEs*) تقريبا 13 ساعة، بينما في الحدث *04-06.04.2000* الفترة الزمنية كانت 8 ساعات. اوضحت البيانات المرصودة بان التعجيل لمختلف طاقات البروتونات الناتجة من الانفجار الثاني لم تحجز من قبل كتل الاهليل الشمسي المرافقة للانفجار الاول للوصول للمراصد الارضية (*1AU*) في كلا الحدثين. قياسات المجال المغناطيسي والبلازما بينت بان الموجة الصادمة المرافقة لكتل الاهليل الاولى غير فعالة، تتباطئ، ذات سمك قليل، وتصبح شفافة للبروتونات المنتجة من الانفجار الثاني.