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Heliophysical Research in Greece: The Space Weather Perspective

Olga E. Malandraki
National Co-ordinator International Space Weather Initiative (ISWI)
National Observatory of Athens, Athens, Greece

International Conference, SOLAR AND HELIOSPHERIC INFLUENCES ON THE GEOSPACE
Bucharest, Romania, 4 October 2012

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University of Athens

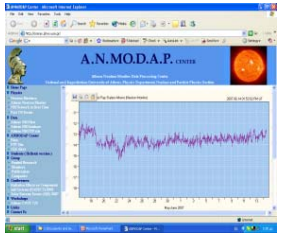
Space Weather Forecasting Center at the University of Athens

H. Mavromichalaki, M. Gerontidou, A. Papaioannou, P. Paschalis, C. Plainaki, C. Sarlanis, G. Souvatzoglou, M. Papailiou, E. Paouris

Nuclear and Particle Physics Section, Physics Department, Athens University, 15783 Athens, GR

Athens Neutron Monitor station

Cosmic ray measurements at Athens initiated in November 2000 with a standard Super 6NM-64 neutron monitor. Athens station was the fourth one to present both graphical and digital data in real time with resolution of 1 hour, 1 min and 1 sec.



Type: Super 6NM-64
Cut-off Rigidity: 8.53 GV
Cord.: 37^0 53′N , 23^0 43′E
Altitude: 260 m
Mean Atm. Pressure: 780 mbar

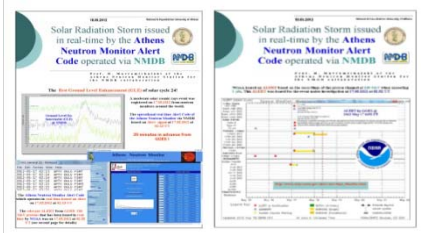
(http://cosray.phys.uoa.gr)

A wide European collaboration of twelve countries for the implementation of the first real time database of Neutron Monitors started in 2008. Athens Neutron Monitor Station, due to its hardware & software development skills was the leader of the upgrading of all NM stations. Also, a mirror server of the NMDB database was set up and is in operation at the Athens NM station.

GLE Alert System

The Alert software is able to determine in real-time the onset of a forthcoming Ground Level Enhancement (GLE) using the 1-min NM database of the Athens station.

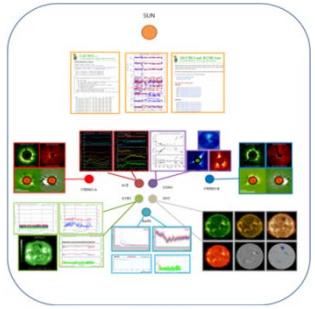
Real-Time GLE Alert on 17 May 2012 (GLE71) !



(http://www.nmdb.eu)

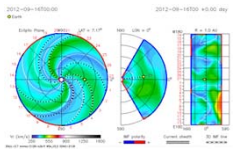
Forecasting Geomagnetic Conditions

Estimation of the Ap index with a set of rules that include a number of known parameters/properties of Ap index, as well as current observations of the Sun and near-Earth space



Athens Daily **Forecast Report**

Real time MPEG movies from SOHO SDO PROBA STEREO A and B via **Media Download developed by Athens Cosmic ray group**



WSA –ENLIL CONE model-CME evolution

Autoregressive model (AR model) a) Solar events, CMEs and Coronal holes
b) Magnetic activity 27-days before
c) Phase of solar cycle

(http://spaceweather.phys.uoa.gr)

Contact: emavromi@phys.uoa.gr

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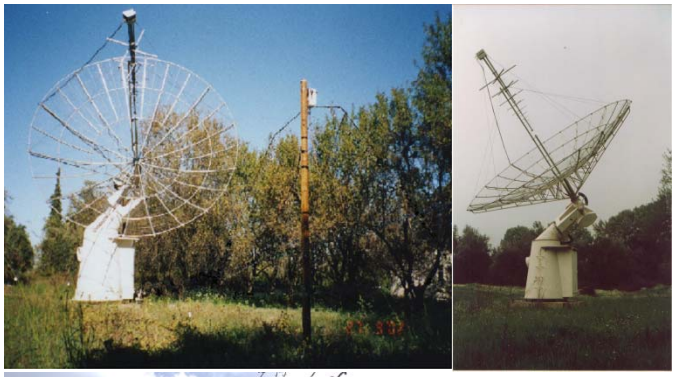
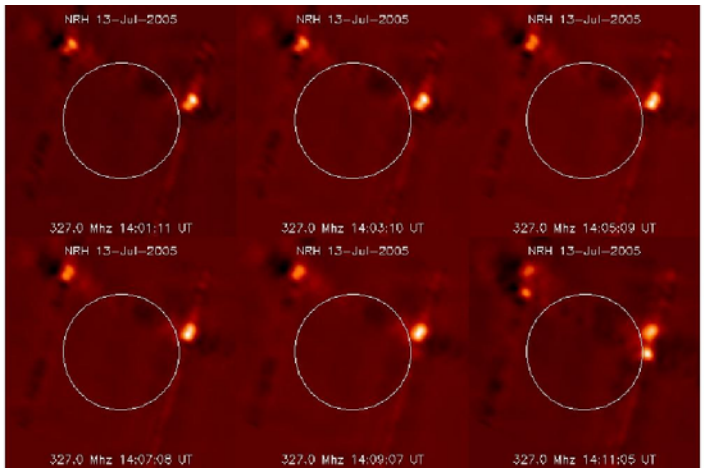
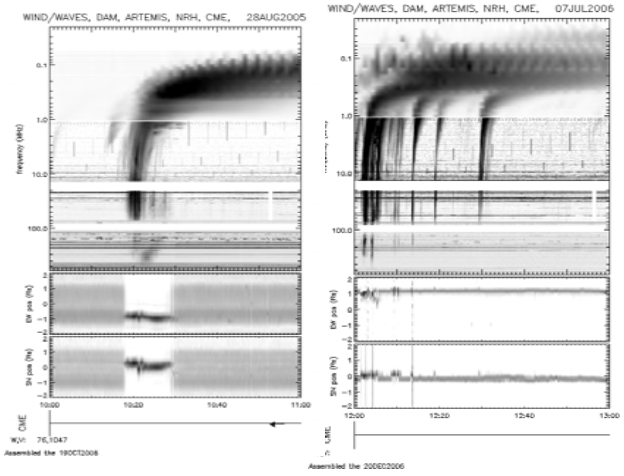
ARTEMIS-IV Radio Spectrographers

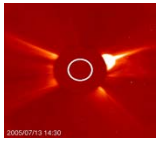


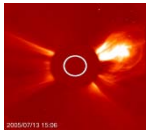
Thermopyles, Lamia, Greece
(650-20 MHz)

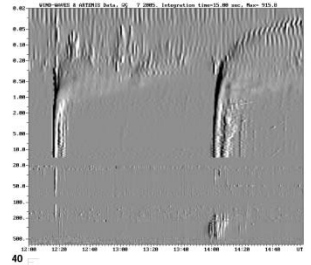


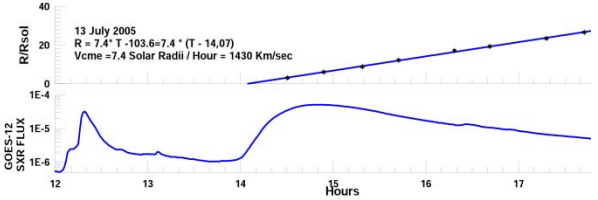
ARTEMIS-IV collaborates with
WIND/WAVES

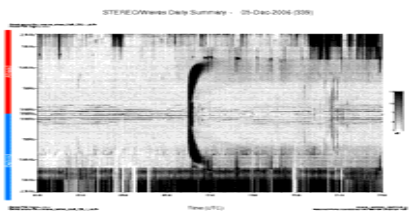












ARTEMIS-IV collaborates with
STEREO/WAVES

(www.web.cc.uoa.gr/~artemis)

Contact: ppreka@phys.uoa.gr

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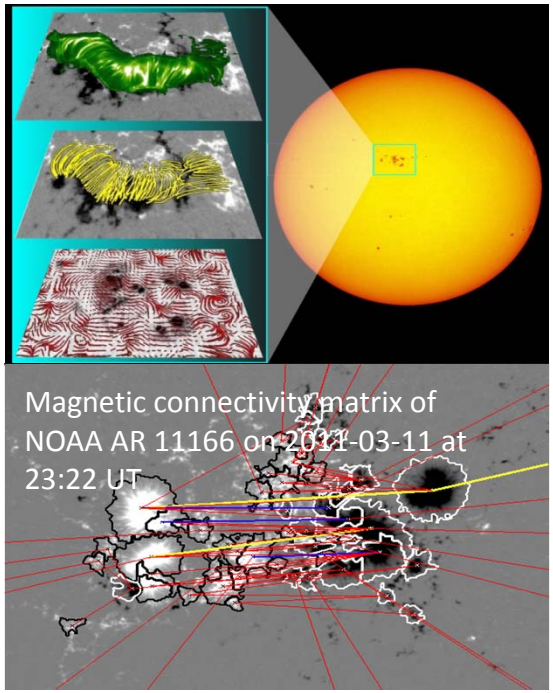
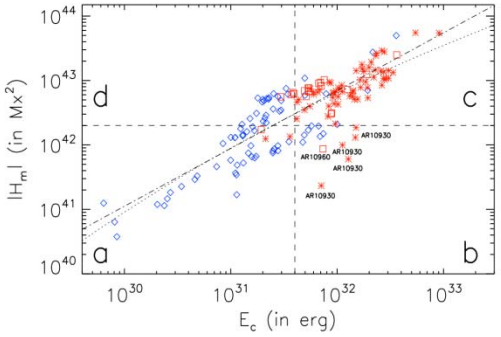
Research Center for Astronomy and Applied Mathematics of the Academy of Athens

QUANTITATIVE SOLAR MAGNETIC FIELD MODELING

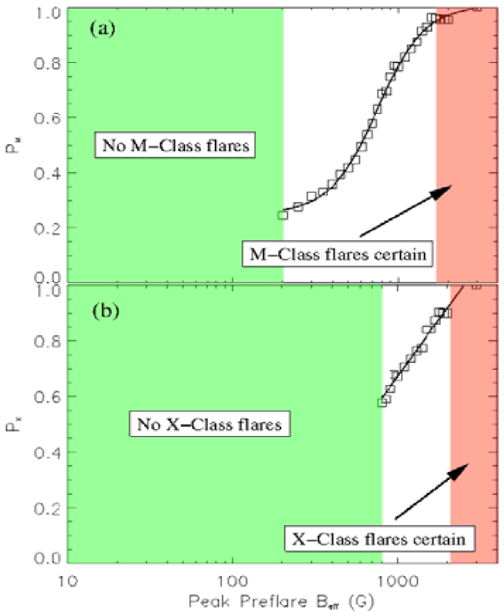
Simulated and observed magnetic and flow configuration of NOAA AR 9077:
-- EUV observations (top left)
-- extrapolated magnetic field lines (middle left)
-- inferred flow velocity fields (bottom left)



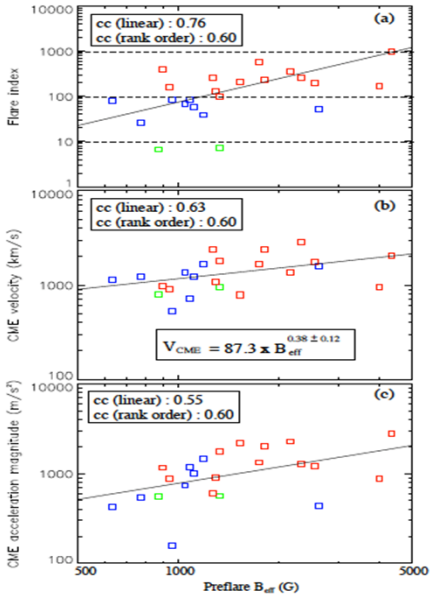


Detailed magnetic energy & helicity calculations of ARs (Georgoulis et al., *ApJ*, 2012; Tziotziou et al. *ApJ Lett.*, 2012)

AND ASSOCIATED FLARE / CME PREDICTION



Photospheric complexity vs. flare likelihood (Georgoulis & Rust, *APJ Lett.*, 2007)



Photospheric complexity vs. eruption (CME) properties (Georgoulis, *GRL*, 2008)

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SEPServer: Data Services and Analysis Tools for SEP Events and Related EM Emissions

✓ The project is funded through the 7th Framework Programme of the EU (Contract No 262773) and coordinated by the University of Helsinki.

✓ It will combine data and knowledge from **11 European partners** and several collaborating parties from Europe and US.

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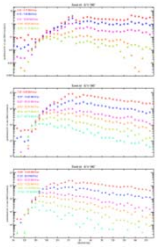
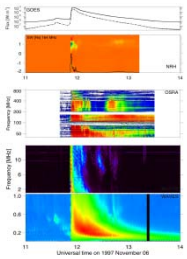
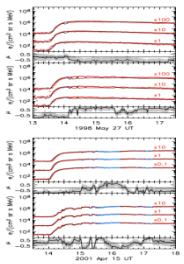
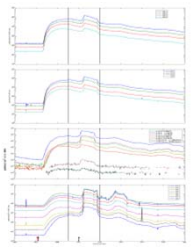
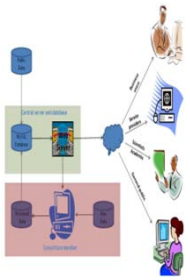
SEPServer

WP1	WP2	WP3	WP4	WP5	WP6	WP7
						
leader **UH**	leader **CAU**	leader **CNRS**	leader **UB**	leader **NOA**	leader **DHC**	leader **UH**
Management	**SEP Observations**	**EM Observations**	**Simulations / inversion methods**	**Scientific data analysis**	**Server development**	**Dissemination of results and external coordination**

✓ The SEPServer project will **produce a new tool**, which greatly facilitates the investigation of solar energetic particles (SEPs) and their origin. This will be **an Internet server** providing:

- **high-quality SEP data**
- **related electromagnetic (EM) observations and state-of-the-art analysis methods**
- **a comprehensive catalogue of the observed SEP events**

will **provide educational** and **outreach material** on solar eruptions and space environment on its website.

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Facts & Figures:

✓ The project started in **December 2010** and will last **36 months**. The most significant milestones are planned as follows:

- **The prototype server populated with the first data sets has been running since October 2011**
- **The 1st catalogue of SEP events has been published on the project website in February 2012**
- **The server will be released in September 2013.**

✓ The consortium will also **analyse the data** using the ***data-driven methods*** and ***numerical-simulation based inversion methods*** to be developed during the project.

✓A **scientific Workshop**, access by invitation, **on SEP event analysis** will be organised in Paris in spring 2013 (March)

✓ In addition the consortium will provide **educational** and **outreach material** on solar eruptions and space environment on its website

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Datasets:

✓ SEPServer will provide **public access** to a number of **SEP datasets** that **have been previously either unavailable or available only through the PI team**. SEP experiments to be included in the database come from a number of European and American missions:

- **SOHO: COSTEP, ERNE (electrons 44 keV – 9 MeV, ions 1 – 100 MeV/n)**
- **ACE: SIS, EPAM (electrons 40 – 310 keV, ions 0.05 – 100 MeV/n)**
- **Wind: 3DP (electrons 30 – 500 keV, protons 0.07 – 7 MeV)**
- **STEREO: SEPT and LET (electrons 30 – 400 keV, ions 0.07 – 30 MeV/n)**
- **Helios: E6 (electrons 0.3 – 2 MeV, ions 2 – 50 MeV/n)**
- **Ulysses: COSPIN/KET and LET, HI-SCALE (electrons 30 keV – GeV, ions 50 keV – 2 GeV/n)**

SEPServer will **also provide streamlined access to the data from ground-based Neutron monitors**.

✓ In addition to energetic particle data, SEPServer will provide access to a comprehensive set of electromagnetic emissions related to the SEP events. These include:

- **Spectrographic radio observations from AIP/Tremsdorf, ARTEMIS, Nancay Decameter Array and Wind/WAVES.**
- **Radio imaging observations from Nancay Radioheliograph**
- **Microwave observations from the University of Bern**
- **X-ray and gamma-ray observations from INTEGRAL, RHESSI, GRANAT/Phebus, Compton/BATSE**

All datasets will be accompanied with **reports** on the **assessment of their quality**

SEPServer data server

✓Available @ http://server.sepserver.eu

Functionality of the database

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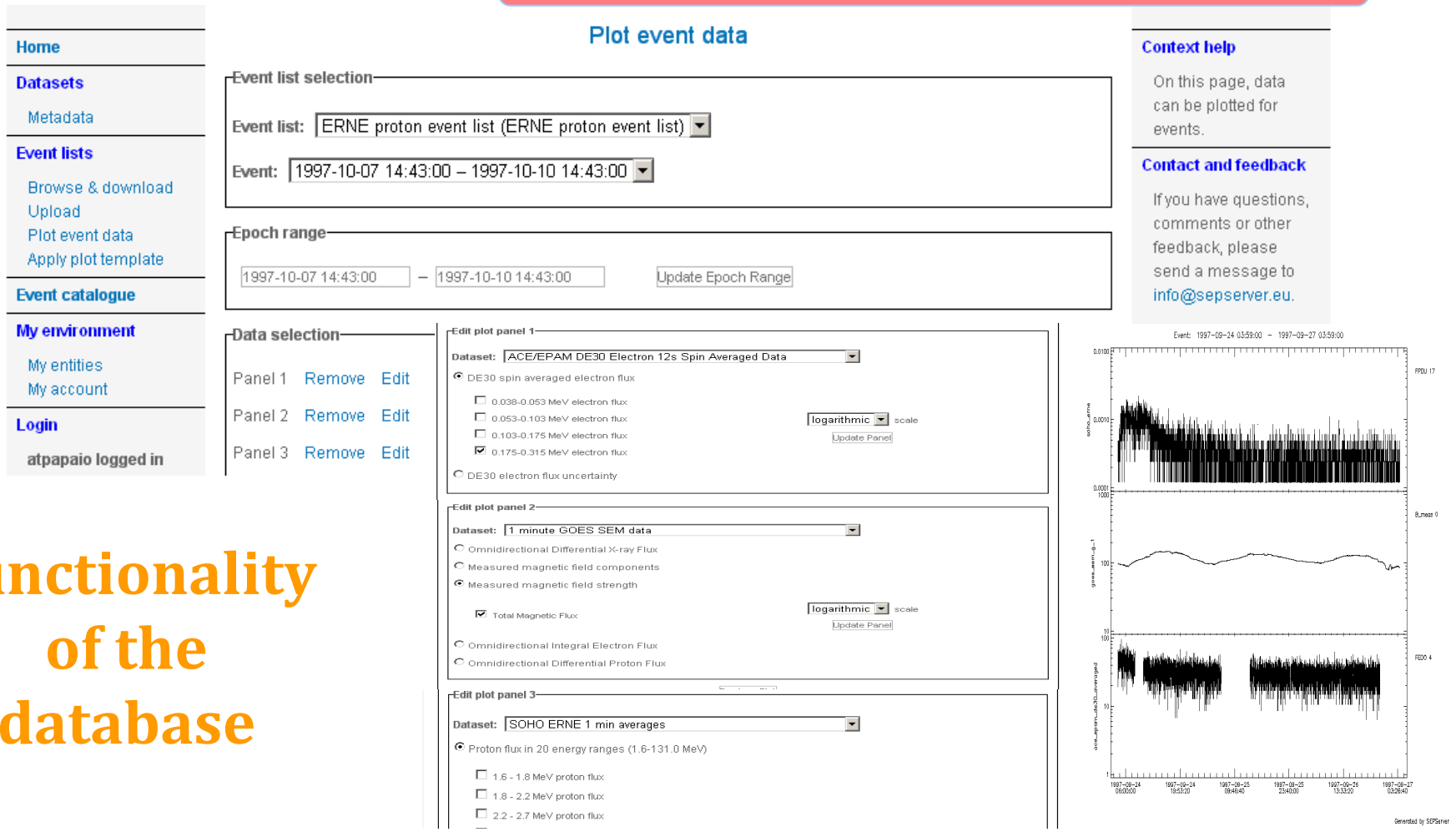
✓Available @ http://server.sepserver.eu



Functionality of the database

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A sample of the 1st SEPServer SEP event list

✓Available @ http://server.sepserver.eu

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Event catalogue

SEPServer Catalogue		SEP Observations						Solar observations		Comments
		SOHO/ERNE		SOHO/EPHIN e⁻ onset		ACE/EPAM (0.18-0.31 MeV)				
#	Date	p⁺ onset (55-80 MeV)	$I_{p,max}$	0.3-0.7 MeV	0.7-3.0 MeV	e⁻ onset	e⁻ PAD	start time	end time	
0000	24.09.1997	03:59	1.5E-03	03:12	03:14	03:43	irregular			
0001	07.10.1997	14:43	8.0E-04	13:15	13:23	13:45	moderate	12:00	15:00	
0002	04.11.1997	06:41	1.5E-01	06:16	06:16	06:19	beam			
0003	06.11.1997	12:37	1.5E-01	12:23	12:23	12:37	moderate	11:00	14:00	
0004	13.11.1997	22:26	2.0E-03	21:39	21:47	21:42	beam			
0005	14.11.1997	14:29	1.0E-03	13:45	13:46	13:59	moderate			
0006	20.04.1998	11:13	1.0E-01	10:30	10:33	10:43	moderate			
0007	02.05.1998	14:10	1.0E-01	13:47	13:47	13:46	beam	13:00	16:00	
0008	06.05.1998	08:29	4.0E-01	08:05	08:05	08:09	bad μ-coverage	07:00	10:00	
0009	09.05.1998	04:32	6.0E-03	04:18	04:20	04:18	isotropic			
0010	16.06.1998	20:35	1.0E-03	18:59	19:03	19:40	bad μ-coverage			
0011	18.10.1998	22:22	4.0E-03	21:30	21:32	22:06	moderate			
0012	14.11.1998	06:16	1.5E-01	05:36	05:47	05:28	moderate			
0013	22.11.1998	07:17	8.0E-03	07:03	07:00	07:12	moderate			
0014	24.11.1998	02:53	6.0E-03	02:42	03:07	02:55	isotropic			
0015	24.04.1999	14:30	3.0E-03	13:38	13:47	13:49	moderate	12:30	15:30	
0016	09.05.1999	18:40	2.0E-03	18:13	18:17	18:20	beam*			
0017	27.05.1999	11:16	1.0E-02	10:58	11:00	11:06	beam	10:00	13:00	
0018	01.06.1999	19:49	1.8E-02	19:21	19:20	19:30	bad μ-coverage			

Context help

On this page, the event catalogue can be consulted.

The event information is presented by means of pop-up windows which can be opened by clicking on the various column items for each event.

Information on the column contents is made visible when hovering the mouse pointer over the column headers in the last row of the table header (e.g. 'Date'). Clicking on the ? icons will open a pop-up window with more detailed information.

Some entries provide a double or triple action: `Click`, `Ctrl+Click` and/or `Shift+Click`, which will present different information.

Contact and feedback

If you have questions, comments or other feedback, please send a message to info@sepserver.eu.

Event Catalogues

Catalogue #0

1 AU

~70MeV SOHO/ERNE protons

115 events

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Multiple levels of information

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- Simulation datasets
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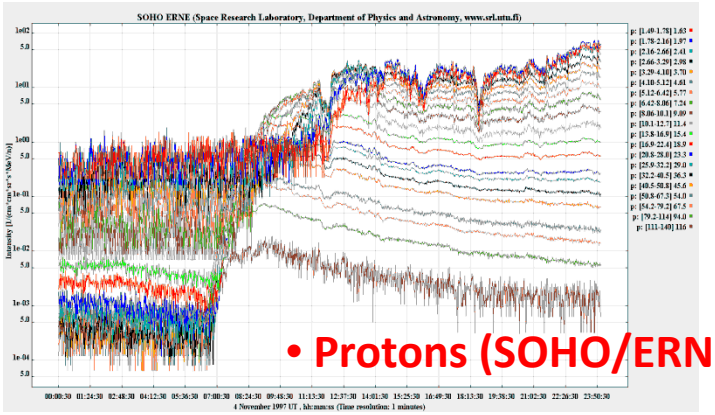
- My environment
  - My entities
  - My account
- Login

atpapaio logged in

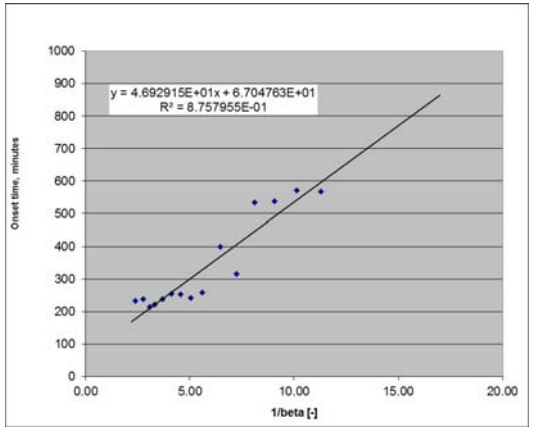
Log out

SEPServer Catalogue — SOHO/ERNE

#	Date	p^+ onset (55-80 MeV)	$I_{p,max}$	0.
0000	24.09.1997	03:59	1.5E-03	03
0001	07.10.1997	14:43	8.0E-04	13
0002	04.11.1997	06:41	1.5E-01	06
0003	06.11.1997	12:37	1.5E-01	12
0004	13.11.1997	22:26	2.0E-03	21
0005	14.11.1997	14:29	1.0E-03	13
0006	20.04.1998	11:13	1.0E-01	10
0007	02.05.1998	14:10	1.0E-01	13
0008	06.05.1998	08:29	4.0E-01	08
0009	09.05.1998	04:32	6.0E-03	04
0010	16.06.1998	20:35	1.0E-03	18
0011	18.10.1998	22:22	4.0E-03	21
0012	14.11.1998	06:16	1.5E-01	05
0013	22.11.1998	07:17	8.0E-03	07
0014	24.11.1998	02:53	6.0E-03	02
0015	24.04.1999	14:30	3.0E-03	13
0016	09.05.1999	18:40	2.0E-03	18
0017	27.05.1999	11:16	1.0E-02	10
0018	01.06.1999	19:49	1.8E-02	19



• Protons (SOHO/ERNE)



Velocity dispersion fit

Channel	Nom	beta	1/beta	Observed onset Hour	Min	Time Stamp [min]
1	1.63	0.05887	16.98715	#N/A	#N/A	
2	1.97	0.06470	15.45606	22	33	
3	2.41	0.07154	13.97899	2	43	
4	2.98	0.07951	12.57689	2	32	
5	3.7	0.08855	11.29353	9	28	568
6	4.61	0.09877	10.12496	9	32	572
7	5.77	0.11039	9.05851	8	57	537
8	7.24	0.12351	8.09621	8	54	534
9	9.09	0.13820	7.23611	5	16	316
10	11.4	0.15448	6.47331	6	40	400
11	15.4	0.17898	5.58707	4	19	259
12	18.9	0.19774	5.05712	4	2	242
13	23.3	0.21880	4.57030	4	13	253
14	29	0.24303	4.11471	4	15	255
15	36.3	0.27038	3.69846	3	58	238
16	45.6	0.30091	3.32325	3	42	222
17	54	0.32539	3.07322	3	35	215
18	67.5	0.36017	2.77648	3	59	239
19	94	0.41693	2.39848	3	53	233
20	116	0.45602	2.19290	#N/A	#N/A	

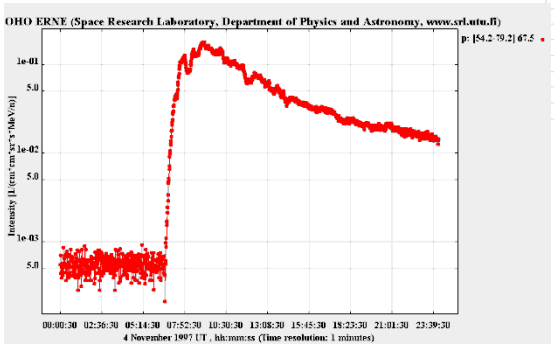
t(1/beta) = t0 + a/beta

a = 8,33 (min/AU) * s
= 46.92915 min

t0 = 67.04763 min
= 1:07:02

==> Apparent path length, s = 5.634 AU
+/- 0.31 AU

==> Release time = 01:07
+/- 26 min



Velocity Dispersion Analysis

Onset time @ 67.5 MeV

Ipmax @ 67.5 MeV

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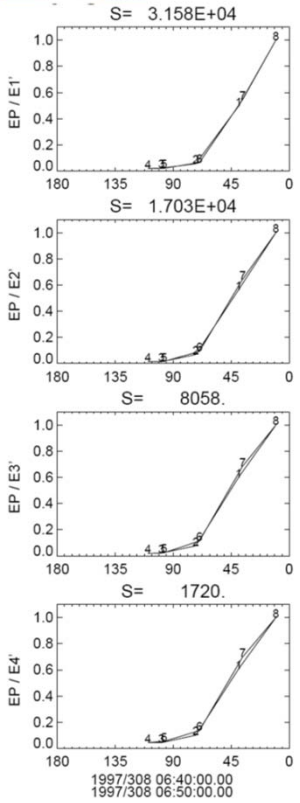


Pitch-Angle Distributions

Time-Shifting Analysis

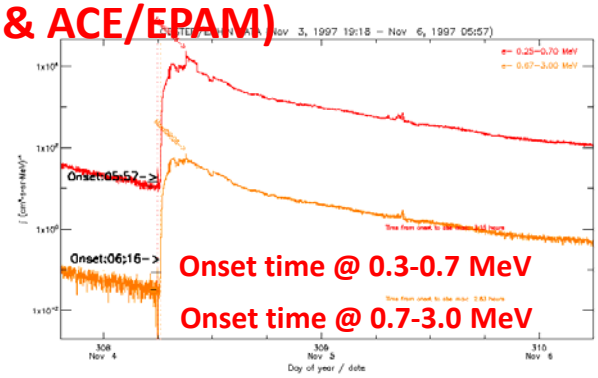
Vsw (Km/s) *	L (AU)	Travel time (sec)	Travel time (min)	Anticipated release time #
350	1,19	815,07	13,58	6:13

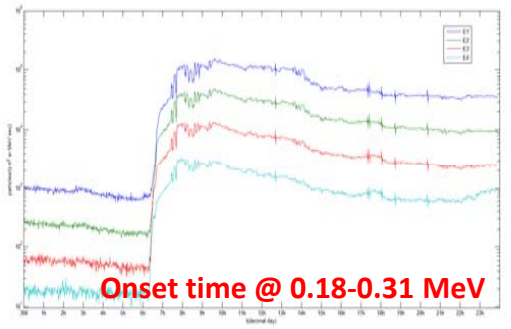
• Electrons (SOHO/EPHIN & ACE/EPAM)

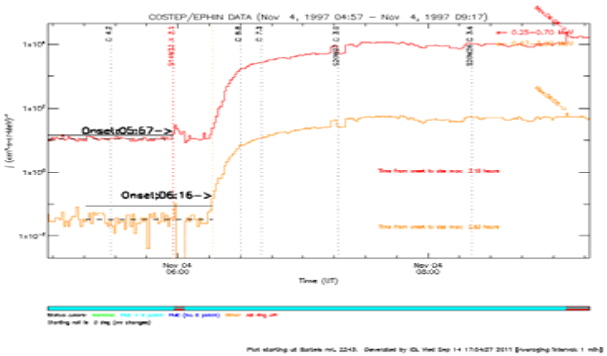
Event catalogue

SEP Observations

SOHO/EPHIN e⁻ onset		ACE/EPAM (0.18-0.31 MeV)	
0.3-0.7 MeV	0.7-3.0 MeV	e⁻ onset	e⁻ PAD
03:12	03:14	03:43	irregular
13:15	13:23	13:45	moderate
06:16	06:16	06:19	beam
12:23	12:23	12:37	moderate
21:39	21:47	21:42	beam
13:45	13:46	13:59	moderate
10:30	10:33	10:43	moderate
13:47	13:47	13:46	beam
08:05	08:05	08:09	bad μ-coverage
04:18	04:20	04:18	isotropic
18:59	19:03	19:40	bad μ-coverage
21:30	21:32	22:06	moderate
05:36	05:47	05:28	moderate
07:03	07:00	07:12	moderate
02:42	03:07	02:55	isotropic
13:38	13:47	13:49	moderate
18:13	18:17	18:20	beam*
10:58	11:00	11:06	beam
19:21	19:20	19:30	bad μ-coverage







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•Solar Observations

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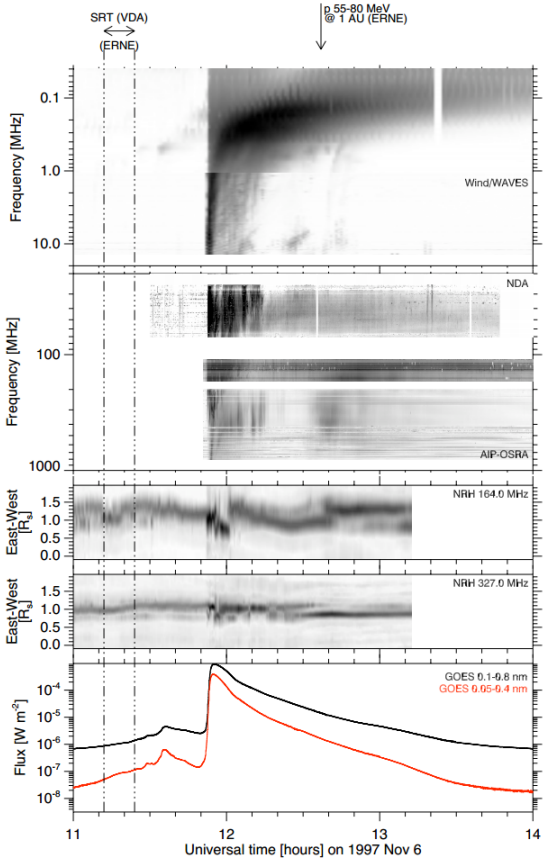
SEPServer Catalogue

#	Date
0000	24.09.1997
0001	07.10.1997
0002	04.11.1997
0003	06.11.1997
0004	13.11.1997
0005	14.11.1997
0006	20.04.1998
0007	02.05.1998
0008	06.05.1998
0009	09.05.1998
0010	16.06.1998
0011	18.10.1998
0012	14.11.1998
0013	22.11.1998
0014	24.11.1998
0015	24.04.1999
0016	09.05.1999
0017	27.05.1999
0018	01.06.1999



Relevant Solar Observations

* including VDA results + p Onset from SOHO/ERNE for comparison

Solar observations		Comments
start time	end time	
12:00	15:00	
11:00	14:00	
13:00	16:00	
07:00	10:00	
12:30	15:30	
10:00	13:00	

Context help

On this page, the event catalogue can be consulted.

The event information is presented by means of pop-up windows which can be opened by clicking on the various column items for each event.

Information on the column contents is made visible when hovering the mouse pointer over the column headers in the last row of the table header (e.g. 'Date'). Clicking on the ? icons will open a pop-up window with more detailed information.

Some entries provide a double or triple action: `Click`, `Ctrl+Click` and/or `Shift+Click`, which will present different information.

Contact and feedback

If you have questions, comments or other feedback, please send a message to **info@sepserver.eu**.

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The first SEPServer event catalogue
+
statistical comparative analysis

Paper submitted

SWSC Journal of Space Weather and Space Climate

submitted to **Journal of Space Weather and Space Climate**

The first SEPServer event catalogue

~68-MeV solar proton events observed at 1 AU in 1996–2010

R. Vainio[1], E. Valtonen[2], B. Heber[3], O. E. Malandraki[4], A. Papaioannou[4], K.-L. Klein[5], A. Afanasiev[1], N. Agueda[6], H. Aurass[7], M. Battarbee[2], S. Braune[7], W. Dröge[8], U. Ganse[8], C. Hamadache[9], D. Heynderickx[10], K. Huttunen-Heikinmaa[2], Y. Kartavykh[8], J. Kiener[9], P. Kilian[8], A. Kopp[3], A. Kouloumvakos[11], S. Maisala[1], A. Mishev[12], R. Miteva[5], A. Nindos[11], T. Oittinen[1], O. Raukunen[2], E. Riihonen[2], R. Rodríguez-Gasén[5,9], O. Saloniemi[2], B. Sanahuja[6], R. Scherer[3], F. Spanier[8], V. Tatischeff[9], K. Tziotziou[4], I. G. Usoskin[12], and N. Vilmer[5]

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[2] Department of Physics and Astronomy, University of Turku, Finland
[3] Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany
[4] Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Greece
[5] CNRS-LESIA, Observatoire de Paris, Meudon, France
[6] Dept. d'Astronomia i Meteorologia & Institut de Ciències del Cosmos, Universitat de Barcelona, Spain
[7] Solar Physics Group, Leibniz Institut für Astrophysik Potsdam, Germany
[8] Lehrstuhl für Astronomie, Julius-Maximilians Universität Würzburg, Germany
[9] CSNSM Orsay, CNRS-IN2P3 et Université Paris-Sud, France
[10] DH Consultancy BVBA, Leuven, Belgium
[11] Department of Physics, Section of Astrogeophysics, University of Ioannina, Greece
[12] Sodankylä Geophysical Observatory, Oulu Unit, University of Oulu, Finland

Submitted: 20 June 2012

Abstract

SEPServer is a three-year collaborative project funded by the seventh framework programme (FP7-SPACE) of the European Union. The objective of the project is to provide access to state-of-the-art observations and analysis tools for the scientific community on solar energetic particle (SEP)

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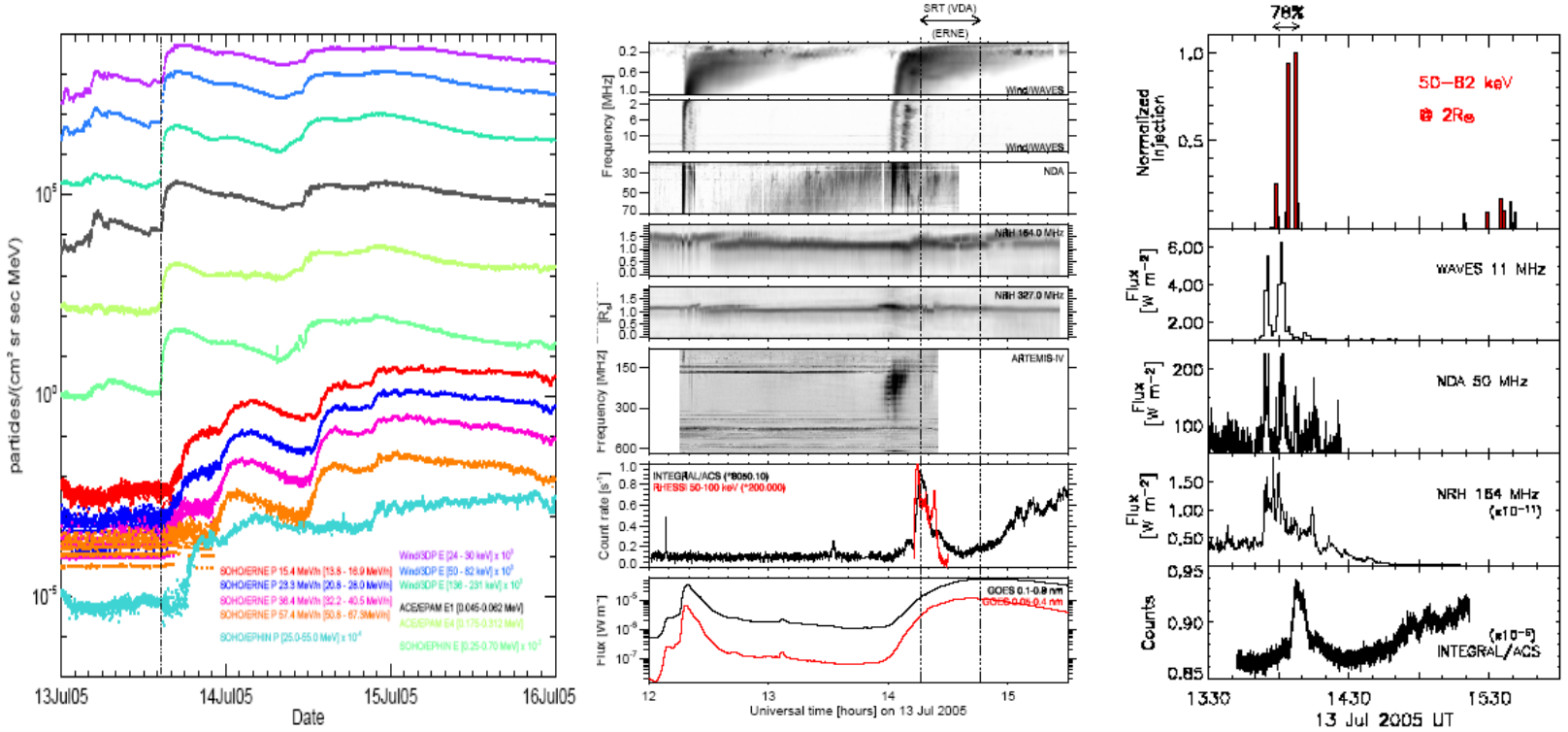
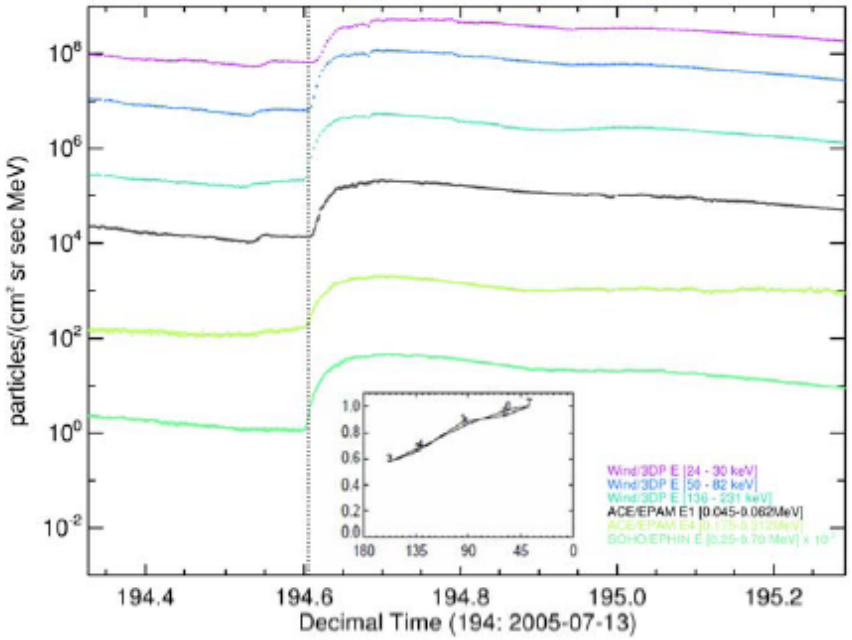
(!) First comparative results of SEPServer

Case Study:
The SEP event of 13 July 2005

Particle Observations + **EM Observations** + **Simulations**



Pitch-Angle Distributions (PADs)



✓ PADs were calculated for all E's channels of ACE/EPAM. Moderate anisotropic characteristics was revealed and sector 7 of E'4 was directed along the magnetic field.

Onset Time Determination

$$(I) + n \cdot \sigma_I$$

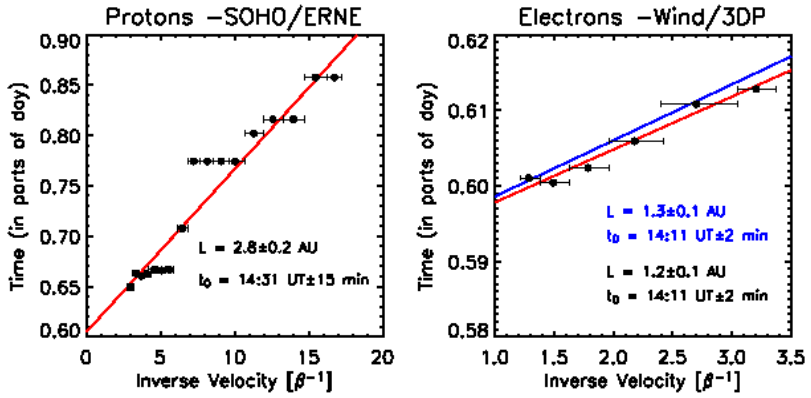
Instrument	Channel	Onset time	Sector
ACE/EPAM	E'4 (0.175-0.312 MeV)	14:33	7
Instrument	**Channel**	**Onset time**	
SOHO/EPHIN	Electrons (0.25-0.70 MeV)	14:27	

✓ Onset times for ***ACE/EPAM*** and ***SOHO/EPHIN*** have been determined based on the criterion of ***> I+3σ*** or ***>I+4σ***

Velocity Dispersion Analysis (VDA)

$$t_{onset}(E) = t_0 + 8.33\frac{[\mathrm{min}]}{[\mathrm{AU}]} \cdot s \cdot \beta^{-1}(E)$$

✓ ***Wind/3DP*** and ***SOHO/ERNE*** onset times have been determined by the *Poisson-CUSUM* method. VDA has been applied to these results.



Anticipated Release Time Determination

✓ The SOHO/ERNE VDA presents, based on onset times determined by the Poisson-CUSSUM method, a path length of ***2.84 AU*** and an Anticipated release time of ***14:31 ± 15 min*** based on onset times determined by eye, a path length of ***2.32 AU*** and an Anticipated release time of ***14:40 ± 17 min***

✓ The Wind/3DP VDA presents an anticipated release time ***14:11 ± 2 min*** when the path length is considered to be ***1.2 AU***

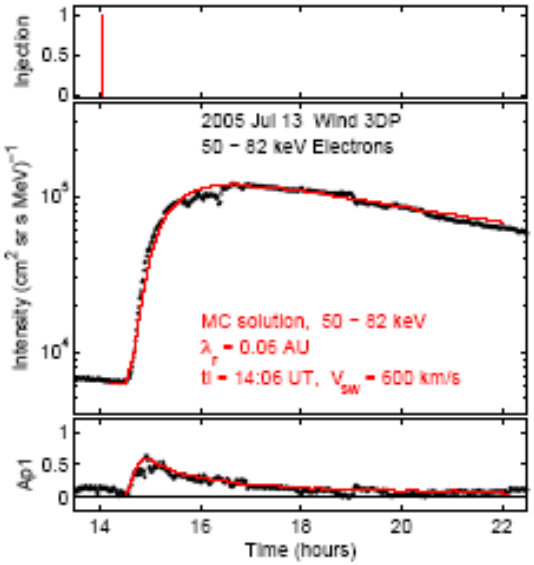
Instrument	Path length (AU)	Release time (UT)
Wind/3DP Electrons (0.025-0.65 MeV)	**1.2**	**14:11 ± 2 min**
SOHO/ERNE Protons (1.58-67.30 MeV)	**2.84** **2.32**	**14:31 ± 15 min** **14:40 ± 17 min**

Modeling results

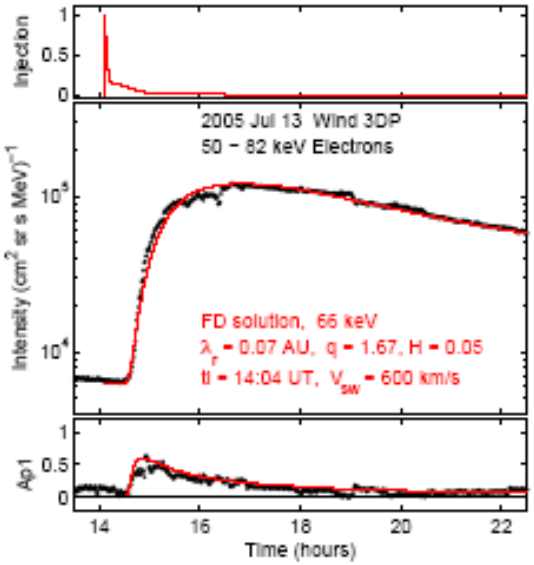
$$\frac{\partial f}{\partial t} + v\mu\frac{\partial f}{\partial z} + \frac{1-\mu^2}{2L}v\frac{\partial f}{\partial \mu} - \frac{\partial}{\partial \mu}\left(D_{\mu\mu}\frac{\partial f}{\partial \mu}\right) = q(z,\mu,t)$$

Numerical Methods Applied

Monte Carlo (MC)



Finite Differences (FD)



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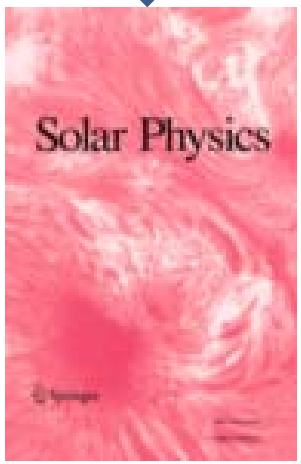
Comparative analysis and DDA of various datasets available via SEPServer

Paper accepted



Solar Physics
DOI: 10.1007/•••••-•••-•••-••••-•

Scientific Analysis within SEPServer — new perspectives in Solar Energetic Particles research : the case study of 13 July 2005

O.E. Malandraki[1] · N. Agueda[2] · A. Papaioannou[1] · K.-L. Klein[3] · E. Valtonen[4] · B. Heber[5] · W. Dröge[6] · H. Aurass[7] · A. Nindos[8] · N. Vilmer[3] · B. Sanahuja[2] · A. Kouloumvakos[9,8] · S. Braune[7] · P. Preka-Papadema[9] · K. Tziotziou[1] · C. Hamadache[3] · J. Kiener[3] · V. Tatischeff[3] · J. Kartavykh[6] · R. Rodríguez-Gasén[3] · R. Vainio[10]

Abstract Solar energetic particles (SEP) are a key ingredent of solar-terrestrial physics both for fundamental research and space weather applications. Multi-satellite observations are an important and incompletely exploited tool for studying the acceleration and the coronal and interplanetary propagation of the particles. While STEREO uses this diagnostic with two identical sets of instrumentation, there are many earlier observations carried out with different spacecraft. It is the aim of the SEPServer project to make these data and analysis tools

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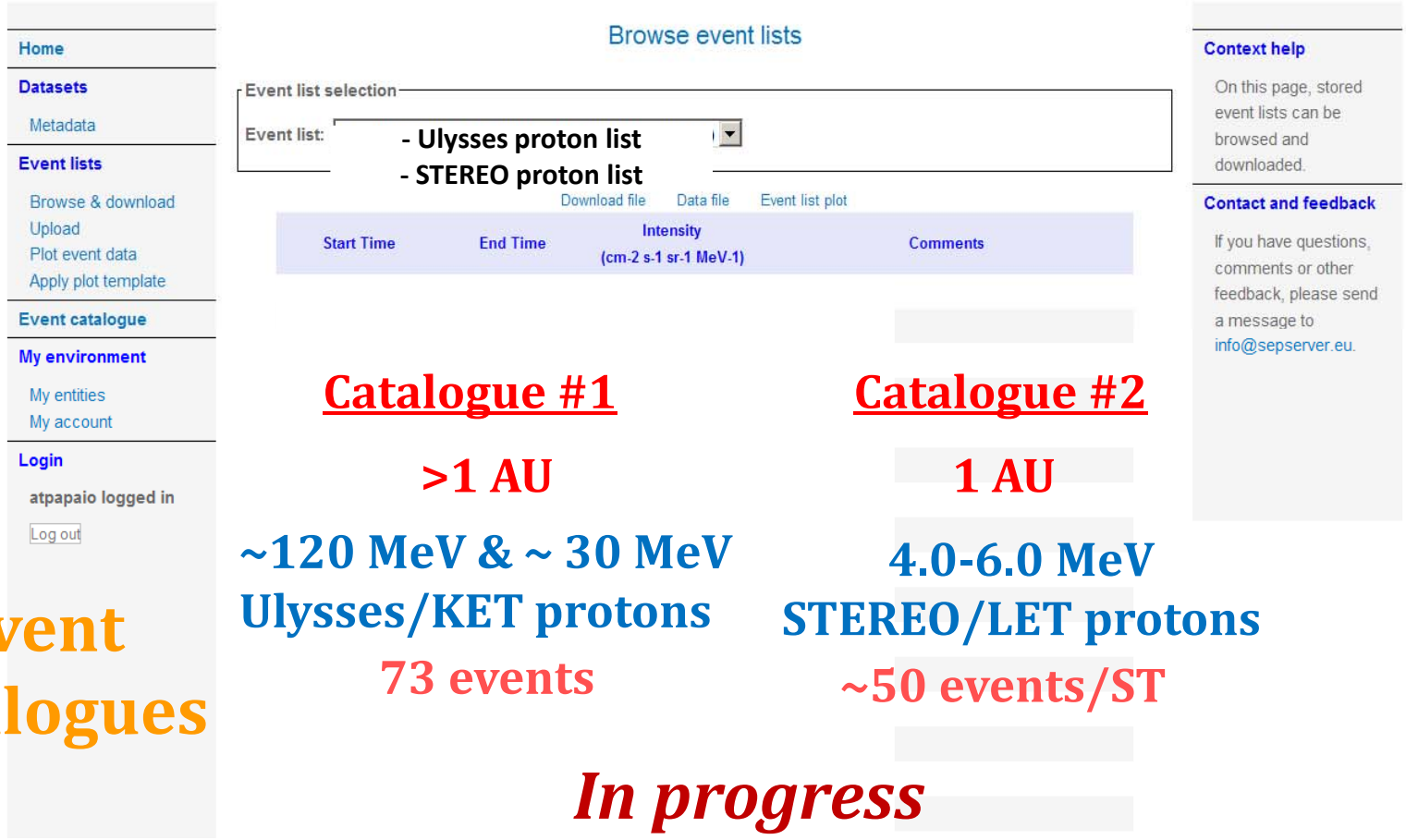
SEPServer data server

Future work:



Event Catalogues

Catalogue #1

>1 AU

~120 MeV & ~ 30 MeV

Ulysses/KET protons

73 events

Catalogue #2

1 AU

4.0-6.0 MeV

STEREO/LET protons

~50 events/ST

In progress

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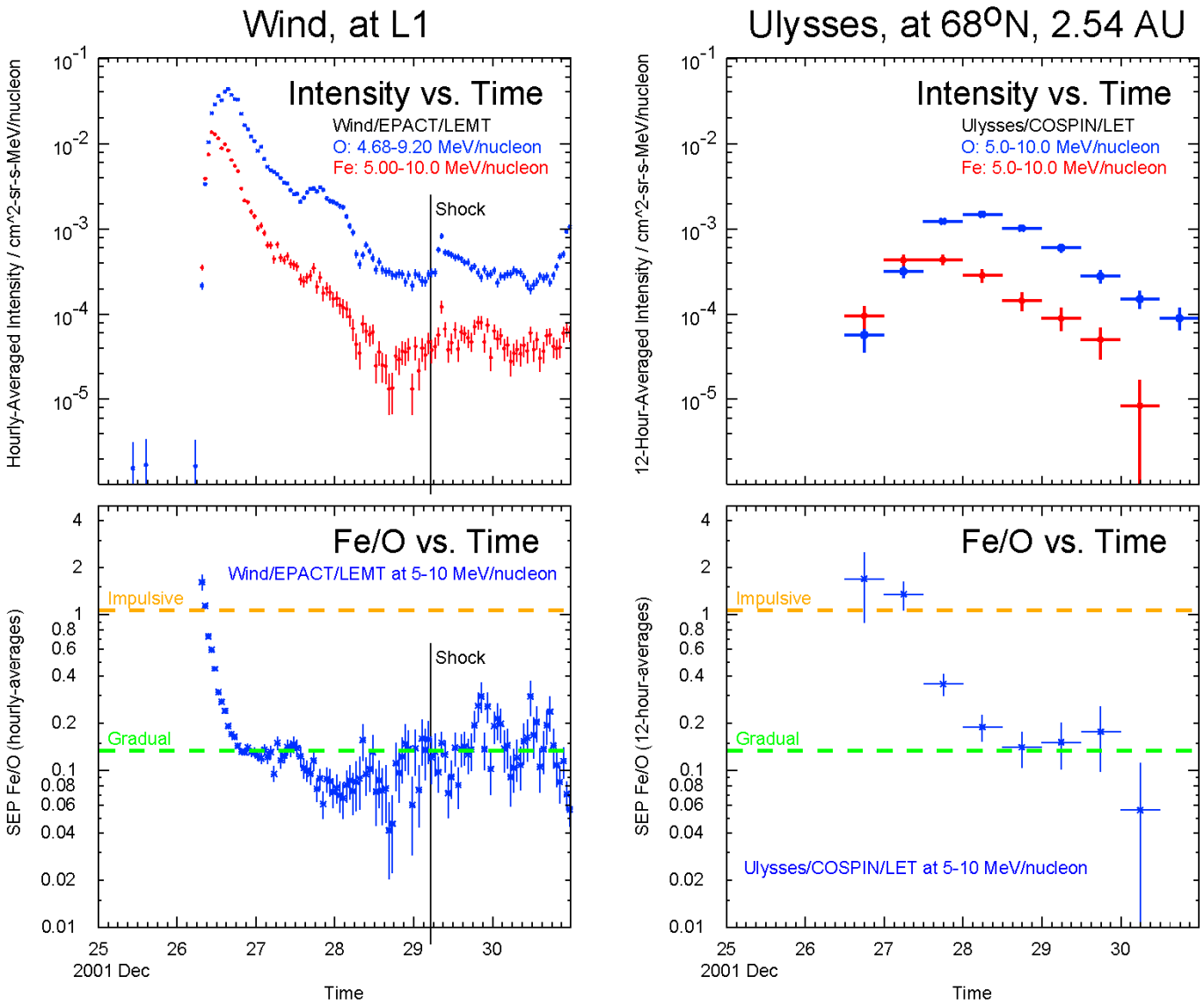
Initial Fe/O enhancements in Large, Gradual, SEP events: Observations from Wind and Ulysses

- In large gradual SEP events, the Fe/O ratio above ~MeV/nuc shows a very strong enhancement at the onset of the event with Fe/O~1 - typical of impulsive events

- As intensities grow the Fe/O typically decreases and approaches the nominal coronal value Fe/O~0.1

- 'Hybrid' events: both flare- and shock-acceleration contribute directly to the SEPs (*Cane et al*. 1991; *Cliver* 1996; *Cane et al.,* 2003)

2001 December 26 SEP event



Ulysses

- ✓ Fe reaches its maximum before the O intensity, just as observed at L1
- ✓ Evolution in the Fe/O ratio like that at L1 is evident

- **However, the temporal evolution of Fe/O including the initial enhancement can be generated by rigidity-dependent IP transport starting from a nominal Fe/O~0.1 at the acceleration site (*Ng et al.* 1999, 2001, 2003; *Mason et al.* 2006)**

- **The initial Fe/O enhancement occurs when:**

$$(M/Q)_{Fe} > (M/Q)_O$$

$$\lambda_{mfp} < L_{path}$$

M/Q: the ion's mass-to-charge ratio.

$(M/Q)_{Fe}$ ~4.0, $(M/Q)_O$ ~2.3 $\Rightarrow$ The Fe ions have a longer λ

If $\lambda_{mfp} < L_{path}$ the transport process will be diffusive

$\Rightarrow$ The Fe intensity will rise more rapidly and reach its max before O

$\Rightarrow$ initial enhancement in Fe/O that dies away as the event progresses

- **We expect to see initial Fe/O enhancements even on widely-separated s/c at least one of which is unlikely to be magnetically well-connected to the flare site**

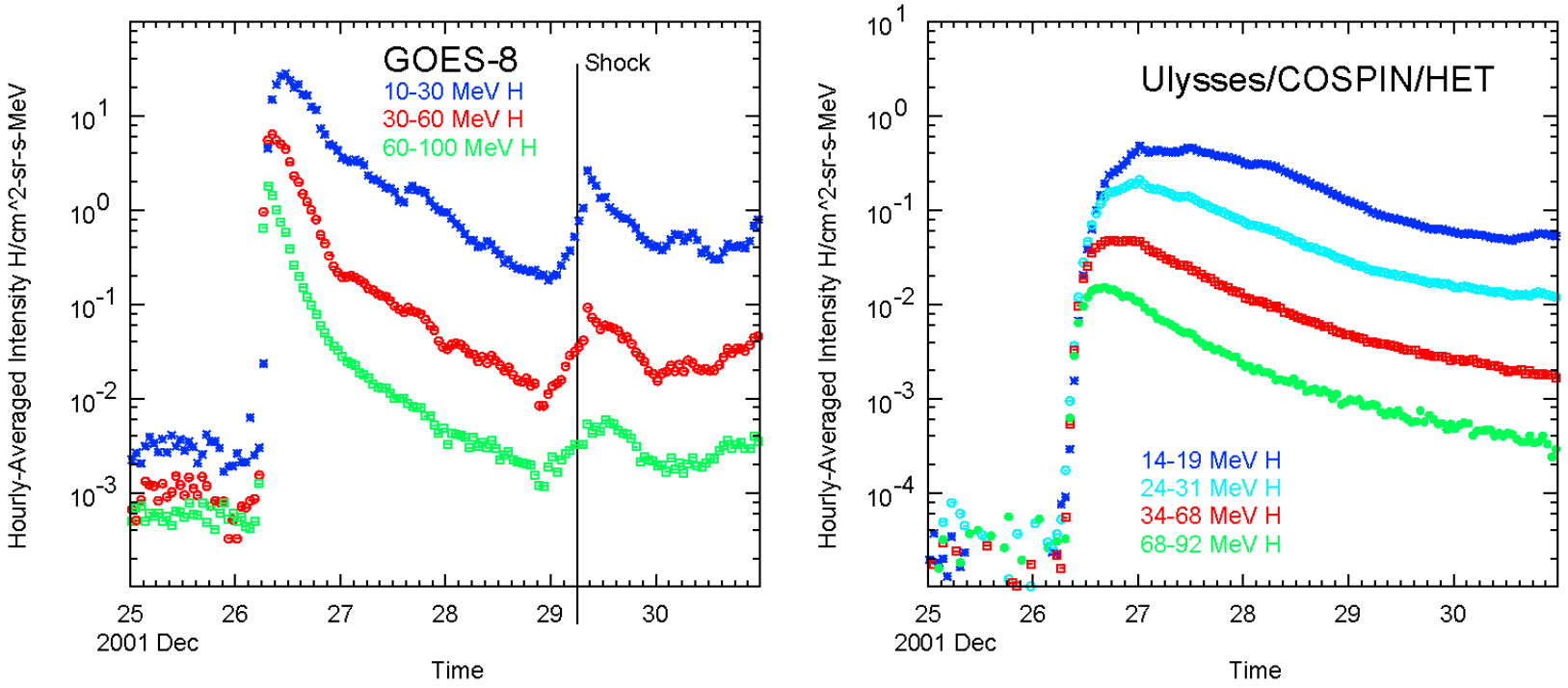
- **Observations used:**

EPACT/LEMT onboard WIND, G= 51 cm^2/sr
COSPIN/LET onboard Ulysses, G= 0.58 cm^2/sr

- ***We surveyed LET observations for 1997-2006 for events with initial Fe/O > 0.8 and sufficient ion statistics in 12-hour bins to follow the evolution in the ratio over at least 2 days.***

- ***2 SEP events identified associated with CMEs that erupted on 2001 August 15 and 2001 December 26***

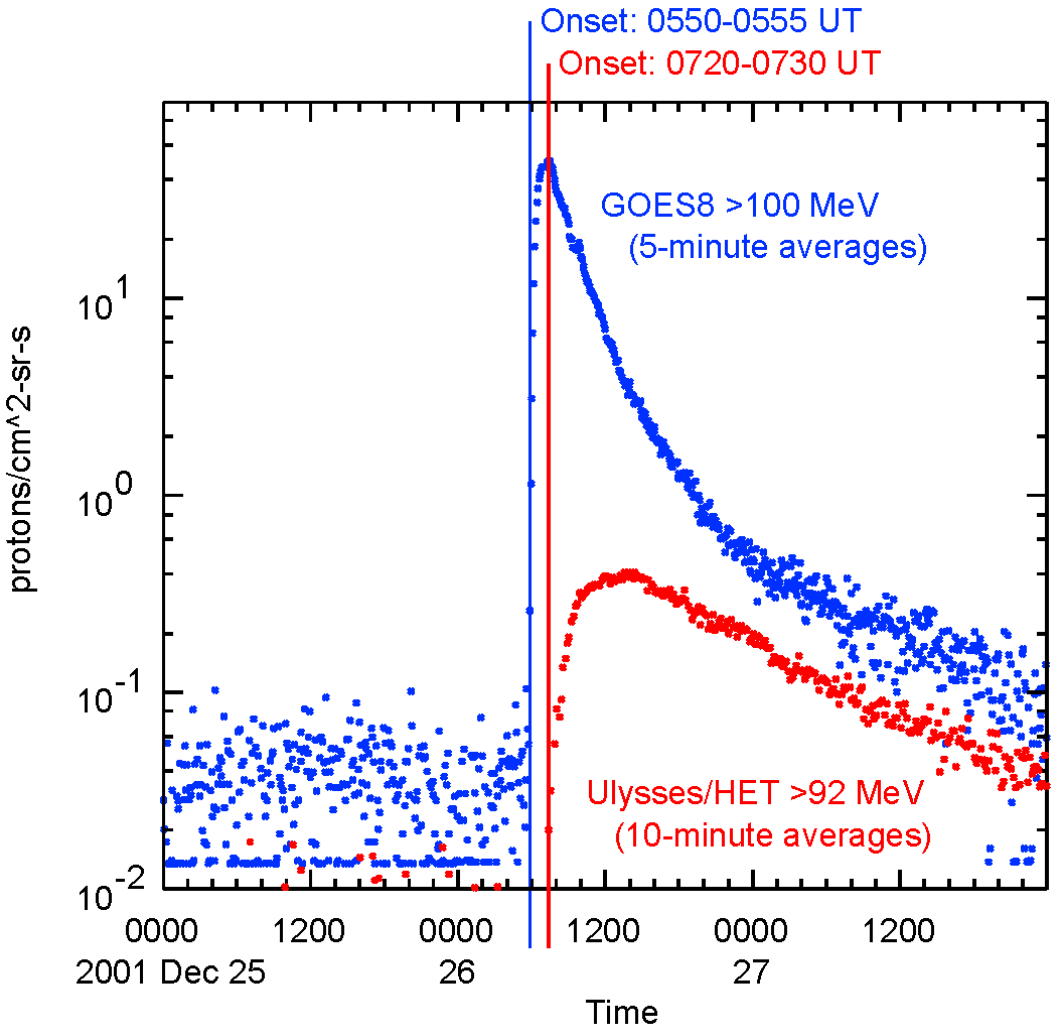
2001 December 26 SEP event



- **Comparison of the proton intensities at 10-100 MeV observed by GOES-8 &COSPIN/High Energy Telescope (HET) on Ulysses**

- **The well-behaved time profiles indicate that both GOES-8 & Ulysses intensities were dominated by a single event, at least until 29 December.**

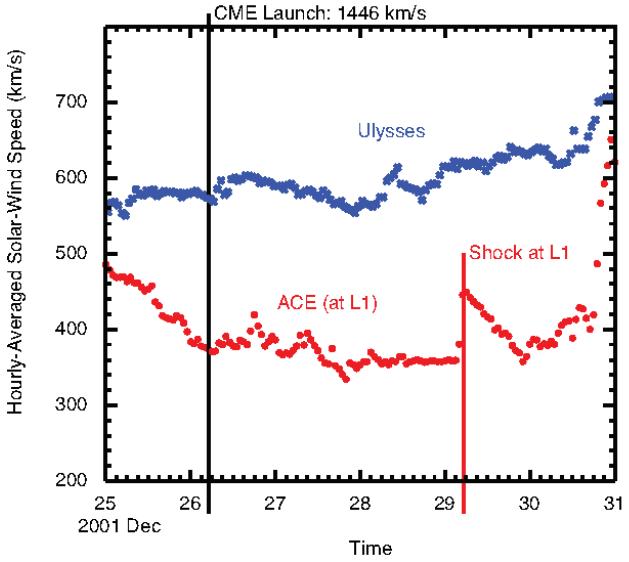
2001 December 26 SEP event

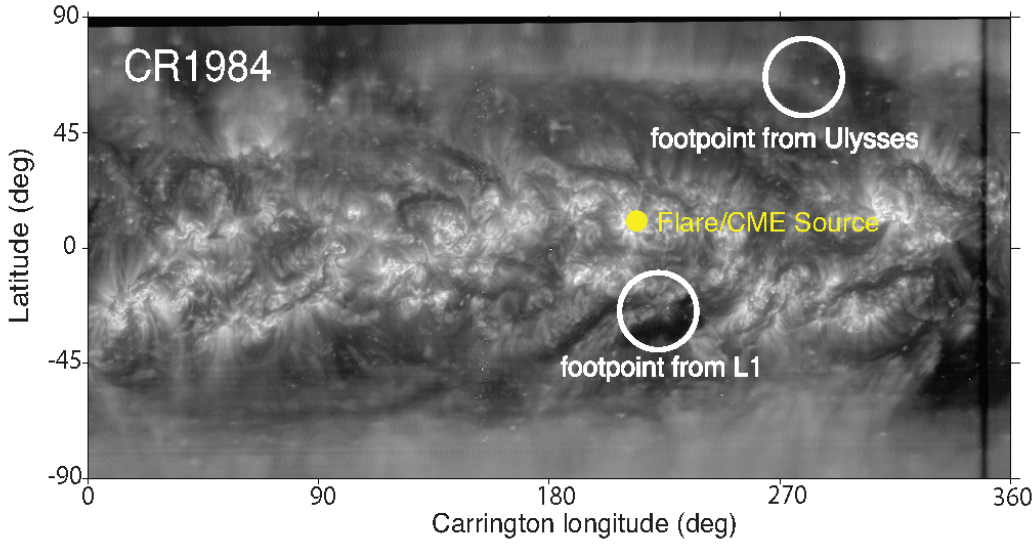


- Comparison of simultaneous observations of > 92 MeV protons from Ulysses and >100 MeV protons from GOES-8 with 10- and 5- minute averages respectively

- The event onset occurred at Ulysses ~90 minutes after onset at GOES-8

2001 December 26 SEP event

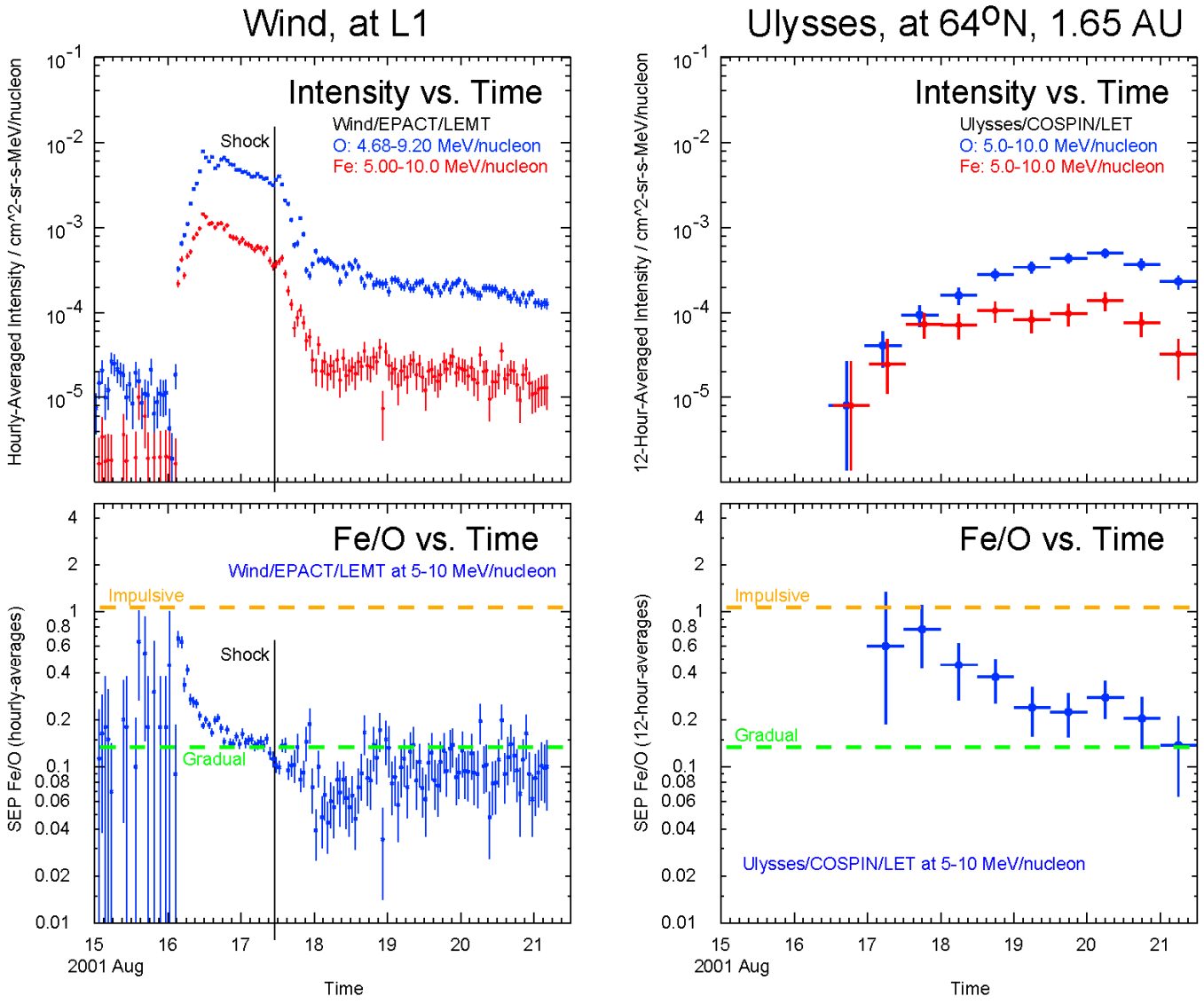




Solar wind speeds observed by ACE at L1 and by Ulysses during the event. Ulysses resides in a high-speed stream; L1 does not

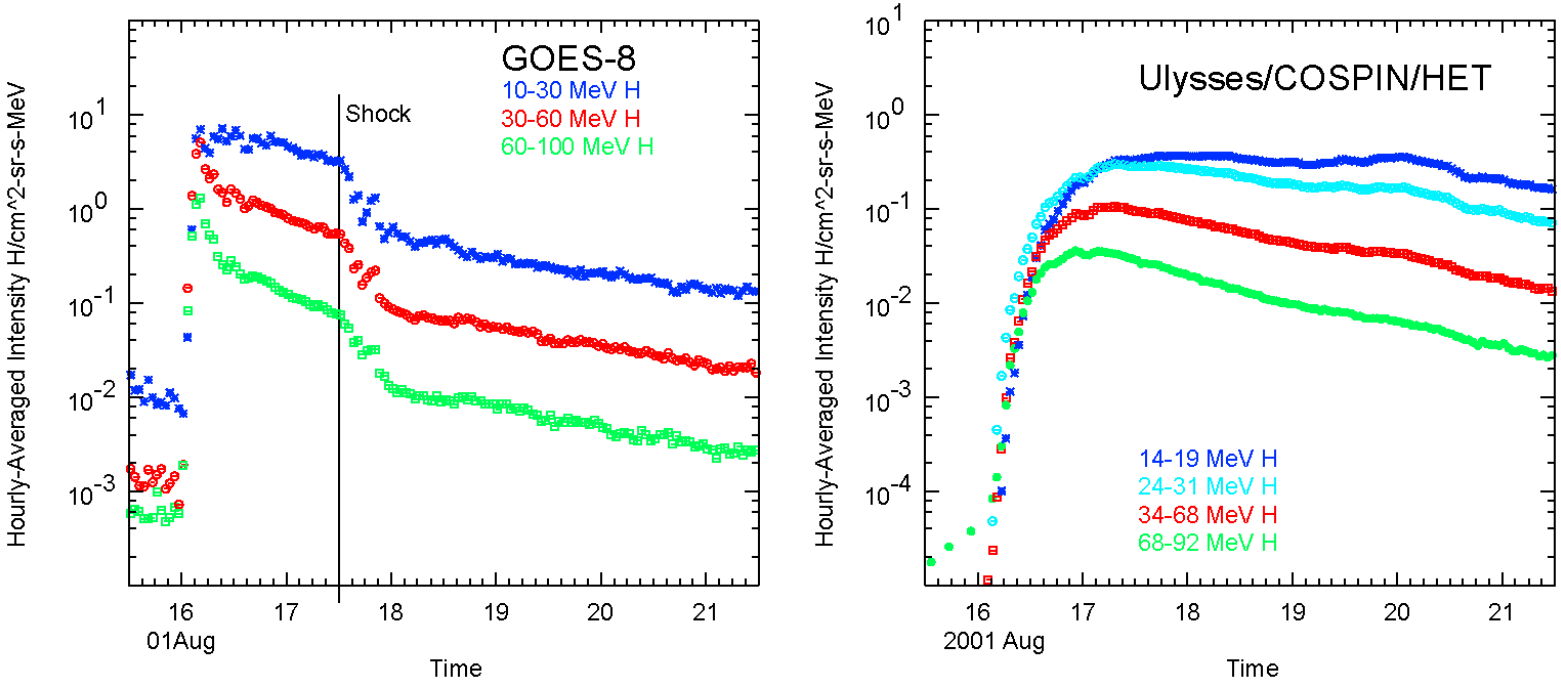
- **Synoptic map of the Sun from SOHO/EIT observations for the CR containing the event**
- **Angular separations between Flare location and the:**
  - **L1 footpoint: 35°(12° in longitude)**
  - **Ulysses footpoint: 74° (68° in longitude)**

2001 August 16 SEP event

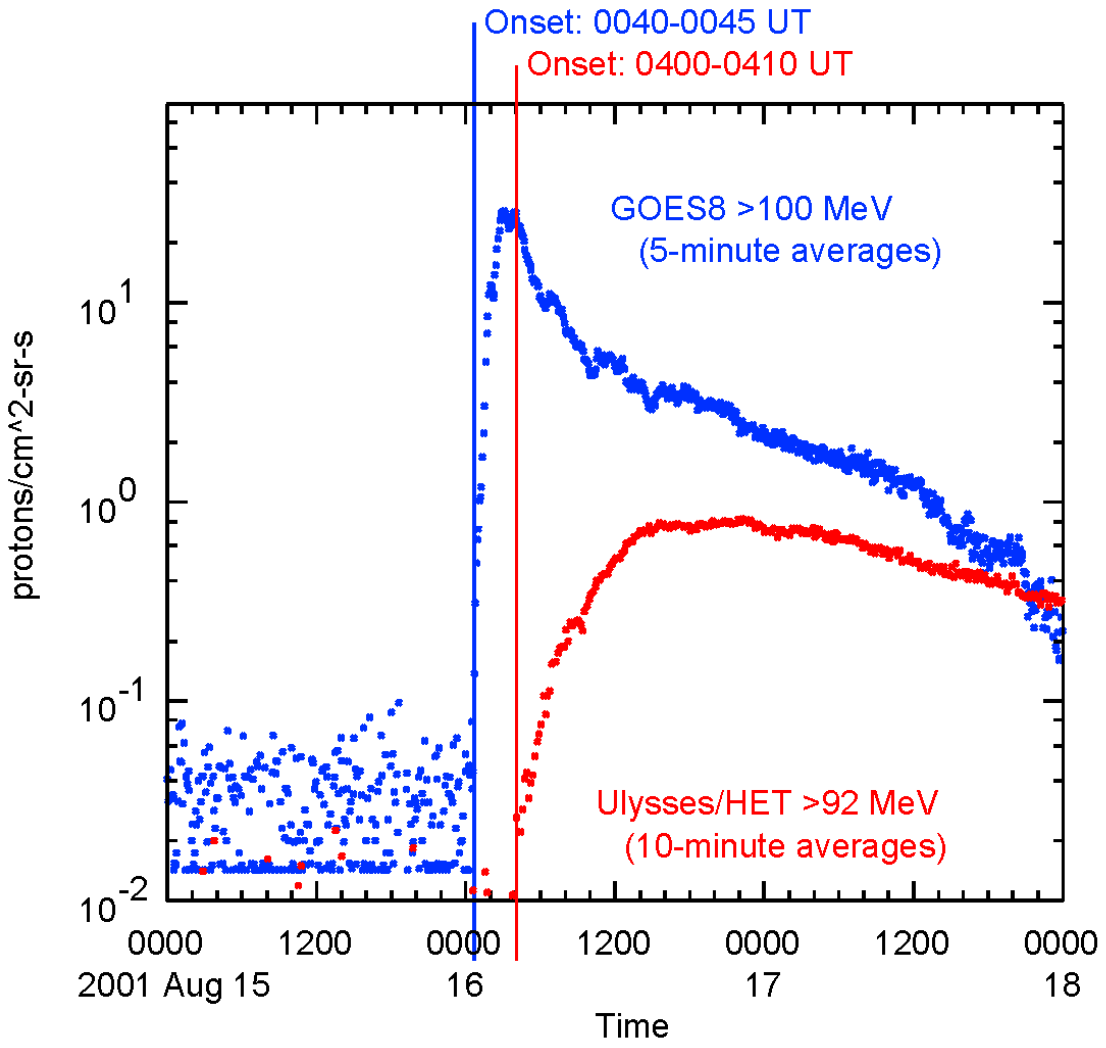


- Well-known 'backside' event associated with a source region at W180-195 (*Cliver et al.* 2005)
- Ulysses ion statistics poor at the onset
- Fe/O enhancement becomes clearly observable only 24 hours into the event

2001 August 16 SEP event



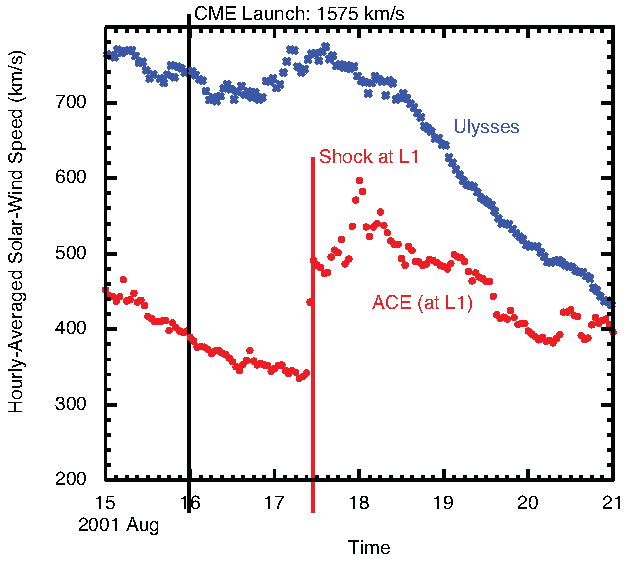
2001 August 16 SEP event

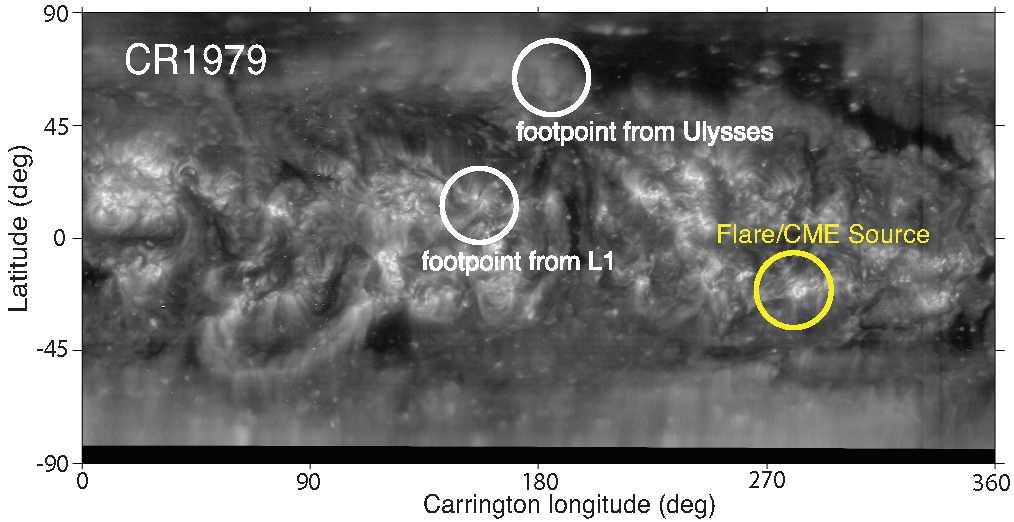


A delay of more than 3 hours between the GOES-8 and Ulysses onsets is observed

Part of delay may be due to directionality in the expansion of the CME-driven shock (recent STEREO observations, *Rouillard et al*. 2012)

2001 August 16 SEP event





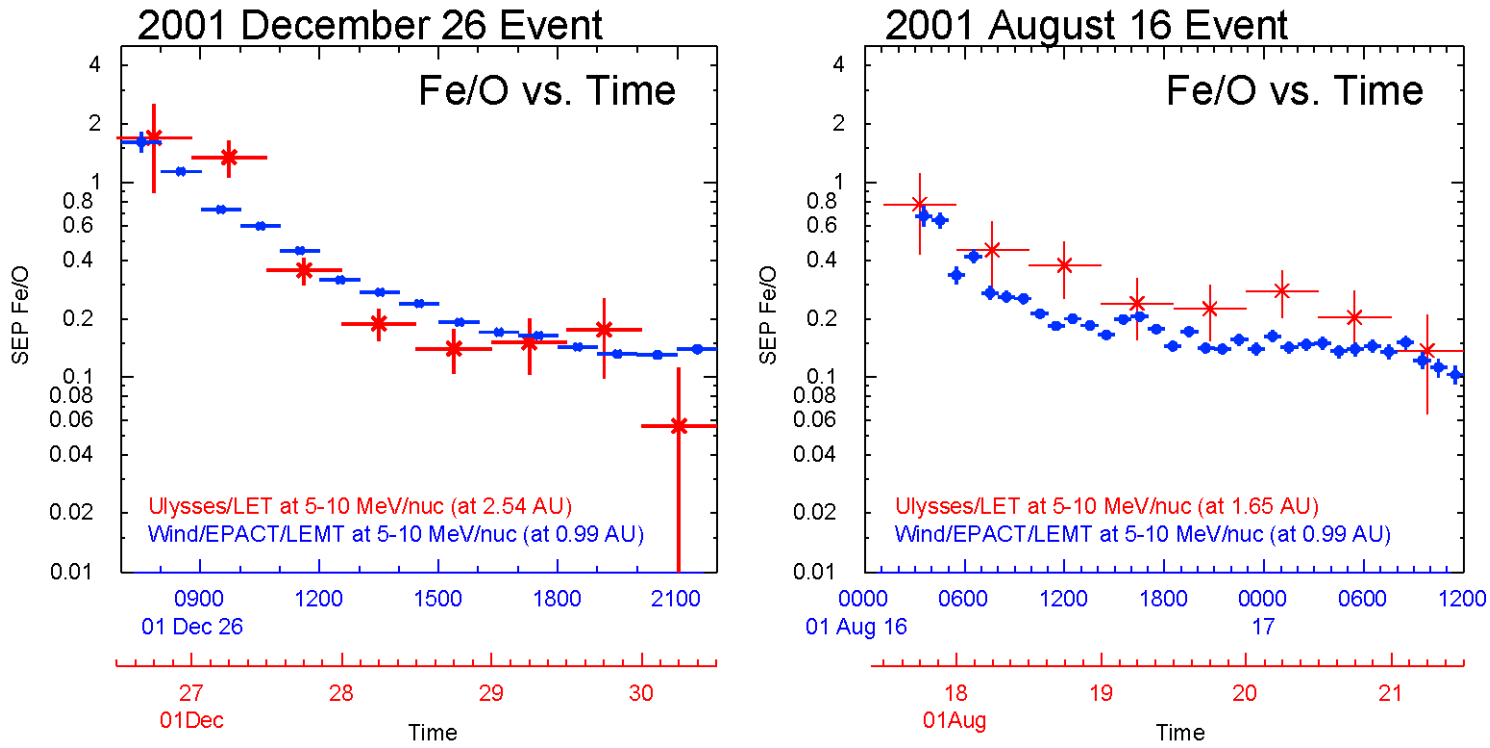
L1 and Ulysses were in different solar-wind streams for at least 30 hrs of the event.

Angular separations between Flare location and the:

- **L1 footpoint: 126°(124° in longitude)**
- **Ulysses footpoint: 112° (97° in longitude)**

Neither L1 nor Ulysses is magnetically well-connected to the flare site

How do we expect the temporal evolution in Fe/O at L1 and Ulysses to compare?



The time scales at L1 have been dilated by factors of $R^2 = (2.54/0.99)^2$ and $(1.65/0.99)^2$ for the Dec and Aug events respectively. The correspondence in the Fe/O profiles after application of the time-dilation factor is quite good.

Discussion and Conclusions

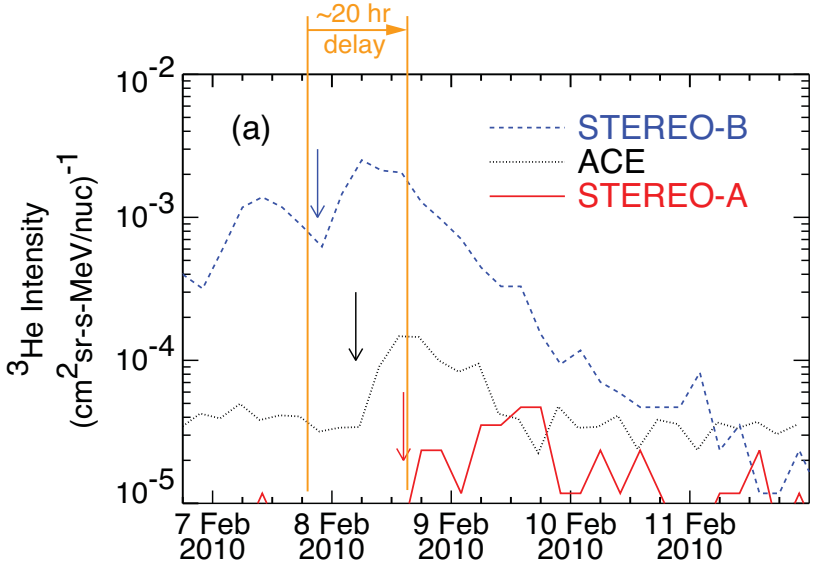
➢ *Wiedenbeck et al.*, 2011: small, ^{3}He-rich impulsive event observed on s/c separated by 120^o in longitude. However, the longitudinal transport processes implied are too slow and too weak to explain our observations.

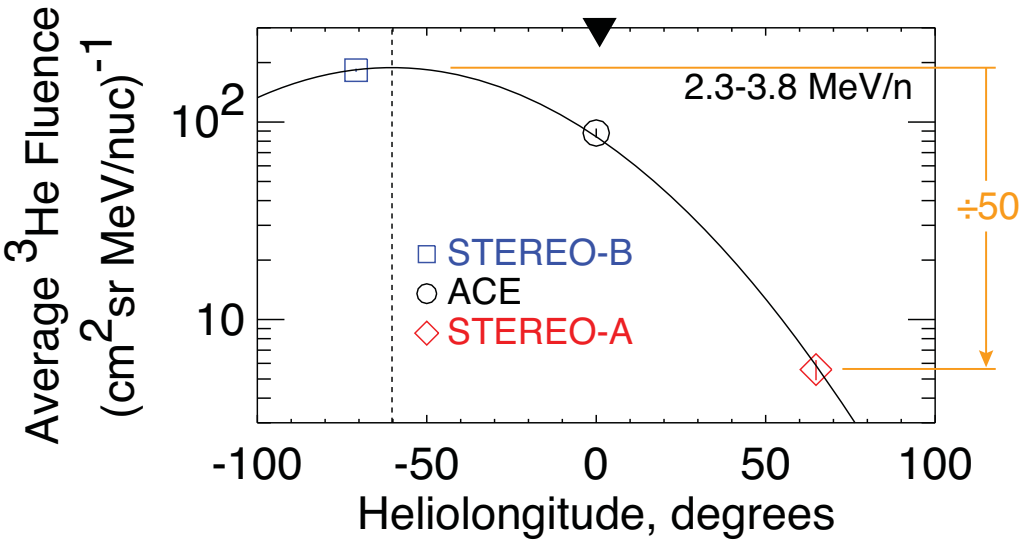
Impulsive event: ~20 hours for ~3 MeV/nuc ions to spread over 120^o

2001 August 16 event: ~3 MeV/nuc covered this same longitude range ~ 5 hours

Impulsive event: intensities at the distant longitude were smaller by a factor of ~50.

In our events (after correcting intensities by a factor of R^2 factor), the Ulysses intensities are smaller than WIND's by only a factor of 3 or 4.





- Only the L1 observations of the 2001 Dec 26 event can possibly be classified as 'well-connected', with the possibility of a direct contribution from flare-accelerated ions.

However if two different mechanisms were involved (i.e. direct flare origin at Wind/transport effect at Ulysses) the remarkably good radial scaling found would be surprising. More likely explanation: Particle transport responsible for the Fe/O enhancement at both locations.

- 2001 August 16 event: it is likely that neither L1 nor Ulysses was 'well-connected' to the flare site. Both transient Fe/O enhancements most likely due to rigidity – dependent transport.

- Given that initial Fe/O enhancements are seen at widely-separated s/c even when one or both is not magnetically well-connected to the flare site it is likely that the initial Fe/O enhancement is generally a transport effect.

- Initial Fe/O enhancements are expected on the STEREOs and ACE/Wind at L1 when the SEP events of Cycle 24 become sufficiently large. Future iron charge state measurements could be used to address the issue of a direct flare contribution component.

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Initial Fe/O Enhancements in Large, Gradual, Solar Energetic Particle Events: Observations from Wind *and* Ulysses

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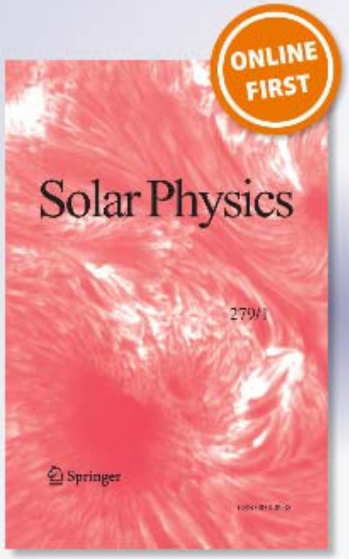
Solar Physics
A Journal for Solar and Solar-Stellar Research and the Study of Solar Terrestrial Physics

ISSN 0038-0938

Sol Phys
DOI 10.1007/s11207-012-0064-z



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