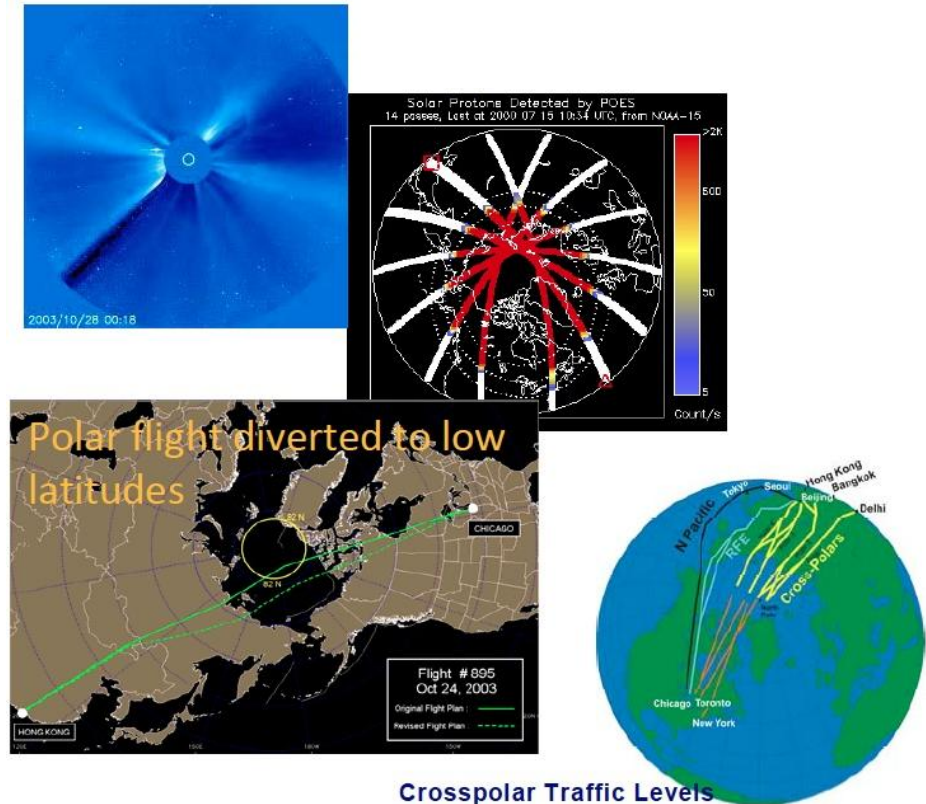


Solar Energetic Particles: Operational needs and L5

R.D. Bentley. UCL-MSSL

Why are we interested in energetic particles?

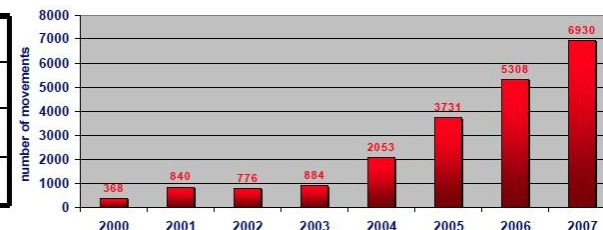
- Effect: High energy (>10 MeV) protons alter the ionosphere and increase absorption of HF communication
- Affected: Polar airline flights
- Impact:
 - Complete loss of communication above 85 degrees.
 - Planes diverted to lower latitude increasing cost (100K/flight) and delays (hours).
 - Radiation health risks.



Crosspolar Traffic Levels from 2000 through 2007

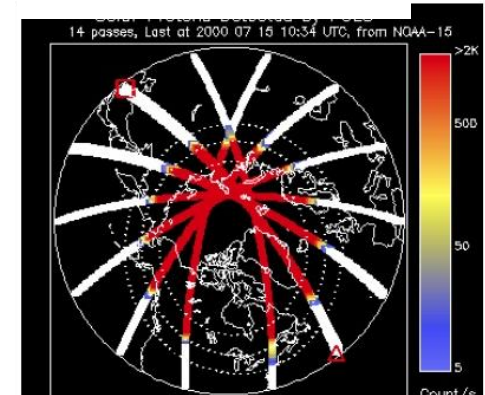
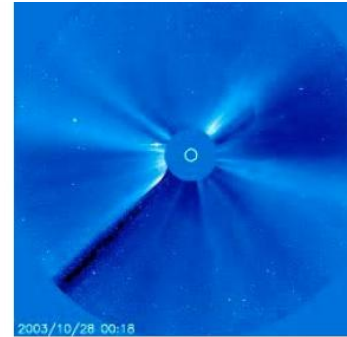
<i>Polar Route Passenger Movement</i>				
	2004	2009	2014	2019
Capacity	228,000	384,000	972,000	1,768,000
AAGR		13.9%	20.4%	12.7%

AAGR - Average Annual Growth Rate



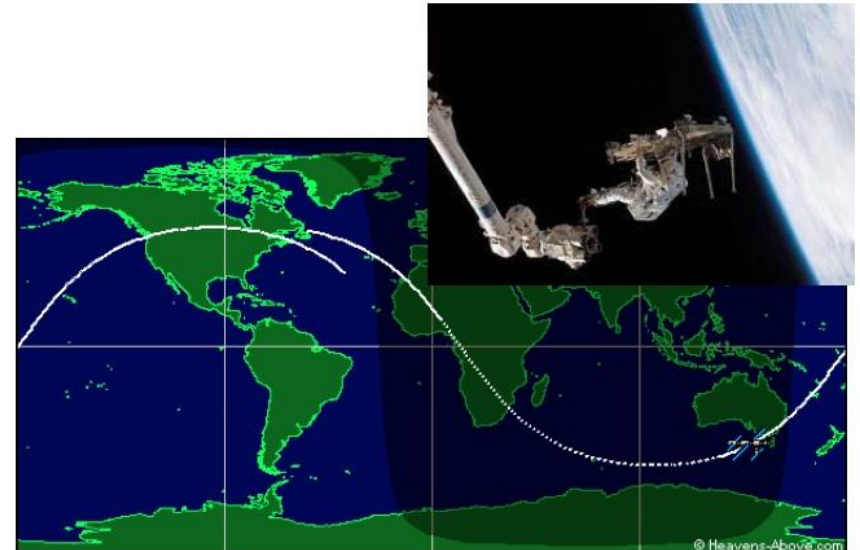
Why are we interested in energetic particles?

- Effect: High energy protons gain access to low latitudes
- Affected: People in space
- Impact:
 - Health risk to astronauts and space tourists
 - Affect of spacecraft electronics



Space Tourism:

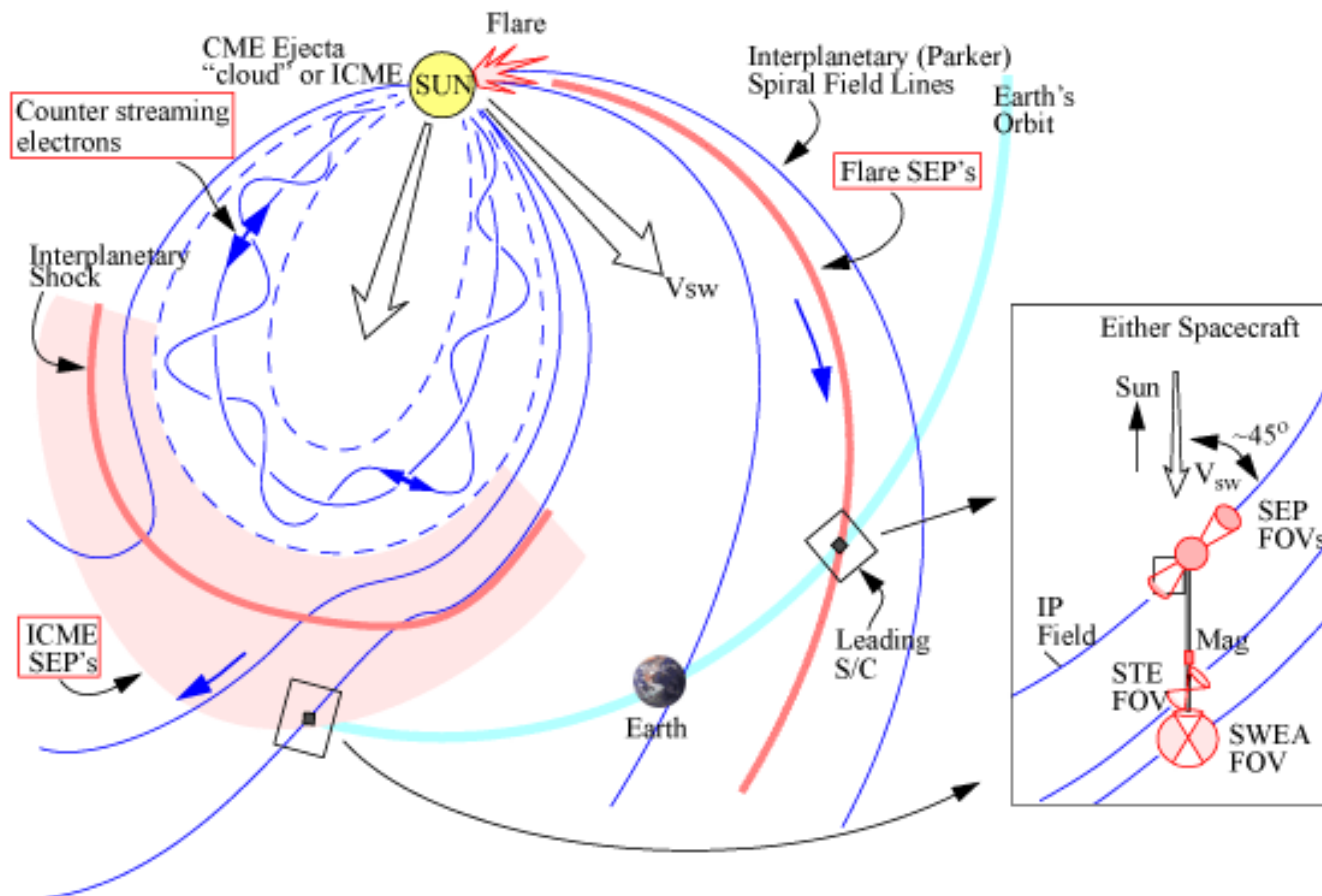
- Virgin Galactic – tourism flights planned
- Space transportation scenario by 2030 suggests 5 million passengers into space per year (CNN Science & Space Friday, September 24, 2004)



What do we need to observe?

- Effects at o communications high result latitudes caused by relatively low energies
 - >10 MeV protons need to be observed
- Effects on human health at aircraft altitudes cause by higher energies
 - >100 MeV protons more relevant than 10 MeV
 - Current Radiation Alerts based on NOAA/SWPC scale misleading

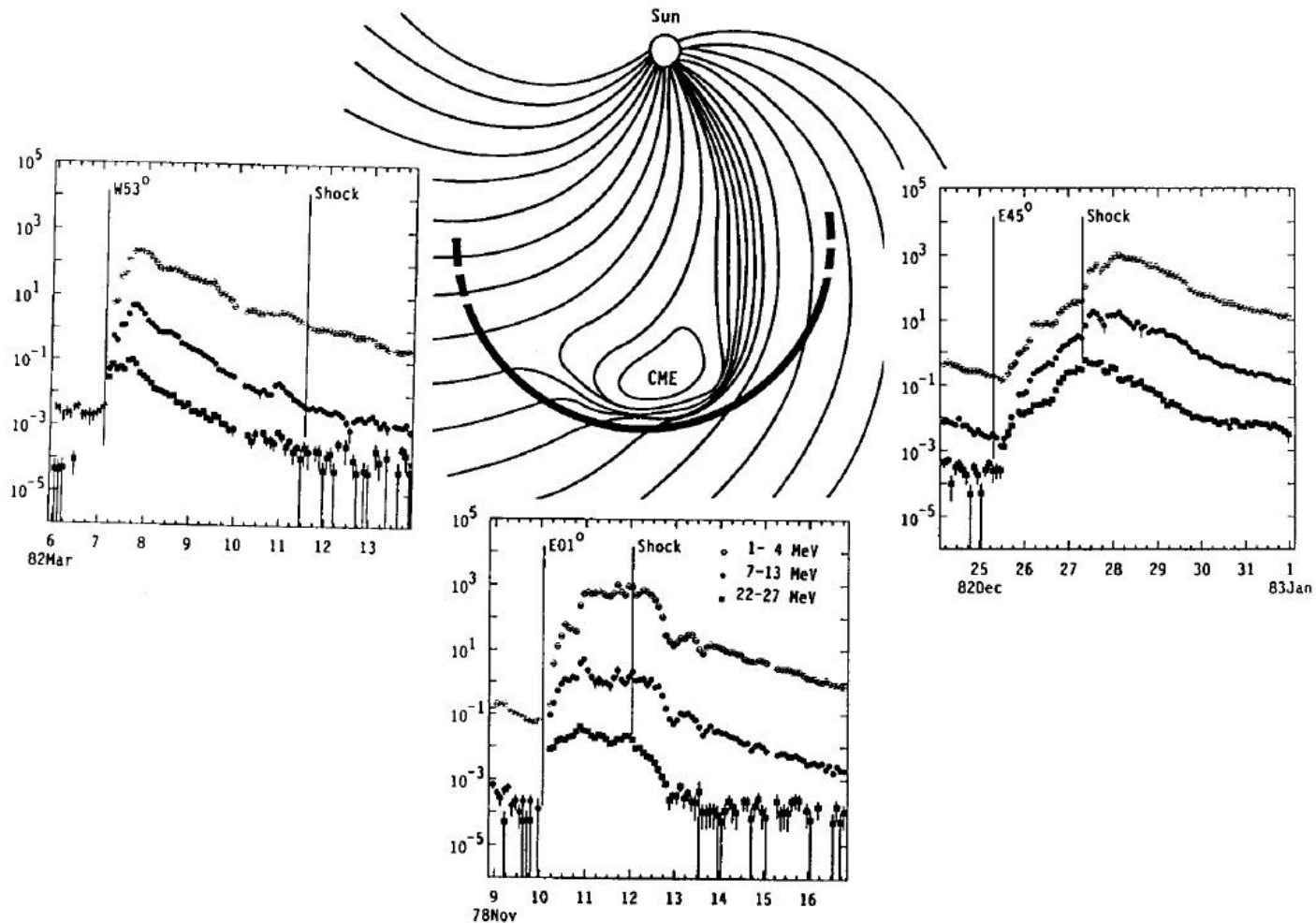
Where and when are SEPs created?



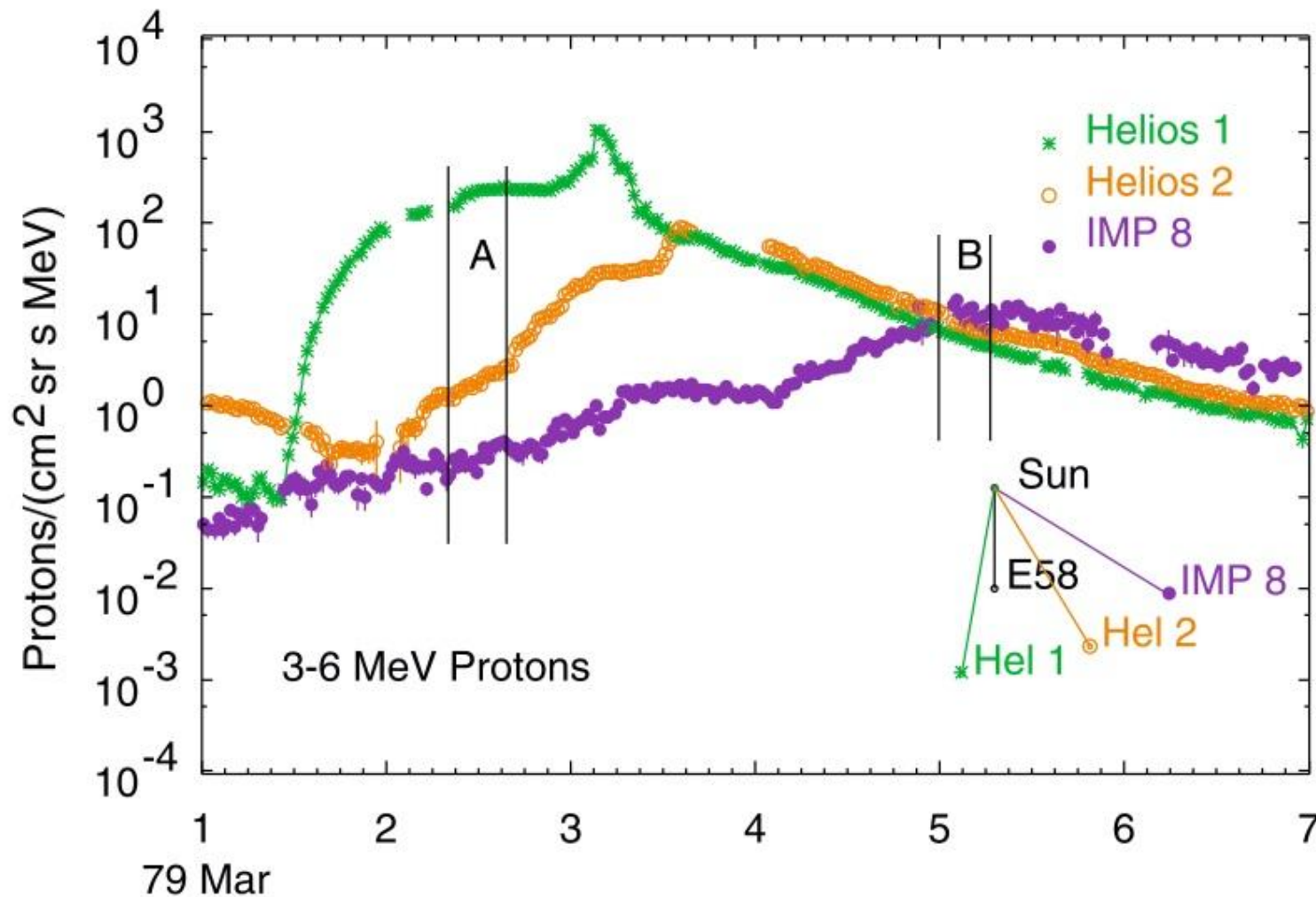
- Energetic particles originate from two sources
 - Impulsive pulse caused by flares
 - Gradual events caused by acceleration processes in CME shock front

Where and when are SEPs created?

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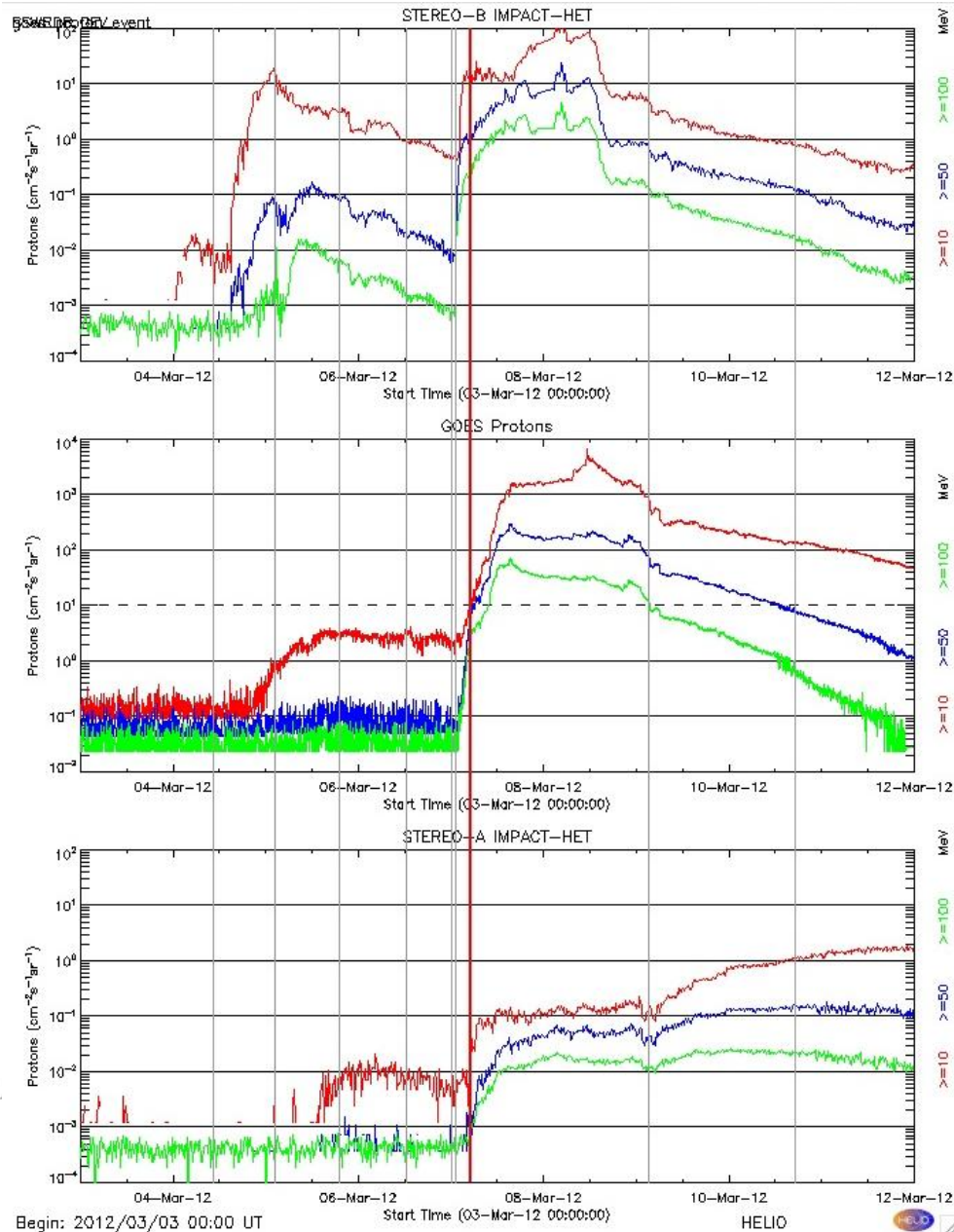
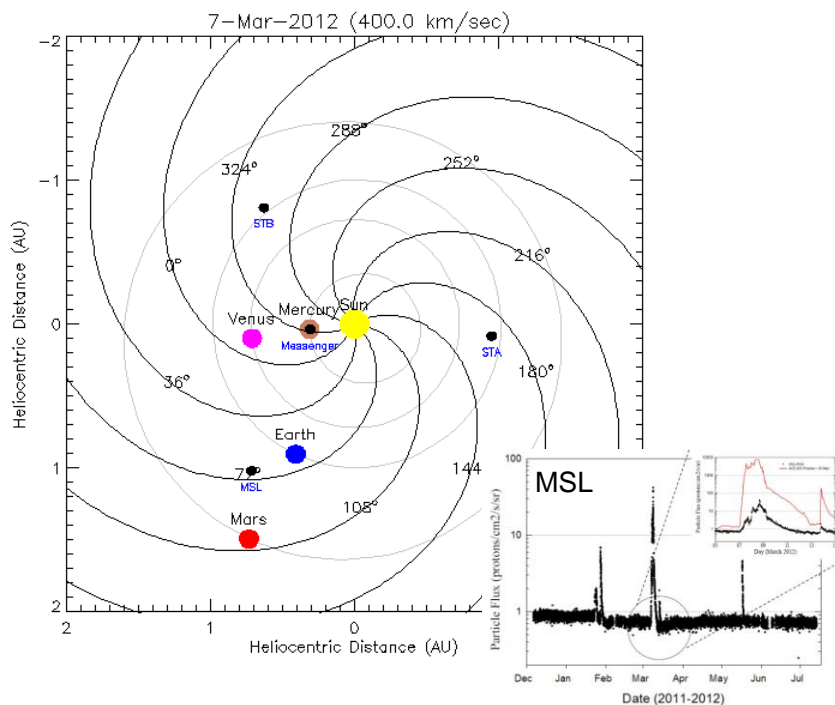
D. Reames / *Radiation Measurements* 30 (1999) 297–308

Where and when are SEPs created?



Where and when are SEPs created?

- Observed at all 3 spacecraft, 120° apart
- CME went out across Mercury, between STEREO-B and Earth



Many events seen from all 3 spacecraft



Heliophysics Event Catalogue



energetic_sep_multipoint	2006/12/05	2013/12/28	209	event	closed	>25 MeV SEP events observed at STEREO-A, -B and SOHO [Richardson et al., 2014]
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select * from energetic_sep_multipoint where time_start>='2004-04-09 00:00:00' AND time_start<='2015-05-09 23:59:59' and (int_stb>0.5 or int_soho>0.5 or int_sta>0.5)

time_start	time_onset_sep	long_hg_stb	int_stb	long_hg_soho	int_soho	long_hg_sta	int_sta	xray_class	type_3	type_2	pa_width	v	comment
2006-12-13 02:00:00.0	2006-12-13 02:00:00.0	23	10.0	23	10.0	23	10.0	X3.4	1	2	360	1774	CDAW LASCO
2011-03-21 02:00:00.0	2011-03-21 03:00:00.0	-127	8.0E-4	138	0.11	50	12.0		1	2	360	1341	CDAW LASCO
2011-06-04 22:00:00.0	2011-06-04 22:00:00.0	-100	0.08	165	0.04	70	13.0		1	2	360	2425	CDAW LASCO
2011-06-07 06:00:00.0	2011-06-07 07:00:00.0	147	-9988.0	54	0.7	-41	-9988.0	M2.5	1	2	360	1255	CDAW LASCO
2011-08-04 03:00:00.0	2011-08-04 05:00:00.0	129	0.0040	36	1.1	-64	0.0050	M9.3	1	2	360	1315	CDAW LASCO
2011-09-22 10:00:00.0	2011-09-22 10:00:00.0	18	10.0	-78	0.08	-179	0.04	X1.4	1	2	360	1905	CDAW LASCO
2011-11-03 22:00:00.0	2011-11-03 23:00:00.0	-50	0.06	-152	0.04	103	2.0		1	2	360	991	CDAW LASCO
2012-01-23 04:00:00.0	2012-01-23 04:00:00.0	135	0.6	21	20.0	-87	0.1	M8.7	1	2	360	2175	CDAW LASCO
2012-01-27 17:00:00.0	2012-01-27 19:00:00.0	-175	-9988.0	71	10.0	-37	0.3	X1.7	1	2	360	2508	CDAW LASCO
2012-03-07 00:00:00.0	2012-03-07 01:00:00.0	91	10.0	-27	10.0	-137	0.09	X5.4	1	2	360	2684	CDAW LASCO
2012-03-13 17:00:00.0	2012-03-13 18:00:00.0	179	-9988.0	61	10.0	-48	-9988.0	M7.9	1	2	360	1884	CDAW LASCO
2012-03-21 07:00:00.0	2012-03-21 07:00:00.0	-81	-9988.0	160	-9988.0	50	0.8		1	1	360	1178	CDAW LASCO
2012-03-24 00:00:00.0	2012-03-24 00:00:00.0	-50	0.03	-169	0.0010	80	1.3		1	2	360	1152	CDAW LASCO
2012-03-26 22:00:00.0	2012-03-27 00:00:00.0	-5	0.6	-124	-9988.0	125	-9988.0		1	1	360	1390	CDAW LASCO
2012-05-17 01:00:00.0	2012-05-17 02:00:00.0	-166	0.0010	76	0.6	-39	0.0020	M5.1	1	2	360	1582	CDAW LASCO
2012-07-12 15:00:00.0	2012-07-12 17:00:00.0	109	0.2	-6	0.8	-126	-9988.0	X1.4	1	2	360	885	CDAW LASCO
2012-07-17 12:00:00.0	2012-07-17 15:00:00.0	180		65	0.8	-55	0.0010	M1.7	1	2	176	958	CDAW LASCO
2012-07-19 04:00:00.0	2012-07-19 08:00:00.0	-145		100	0.8	-20	-9988.0	M7.7	1	2	360	1631	CDAW LASCO
2012-07-23 02:00:00.0	2012-07-23 03:00:00.0	-105	0.5	140	0.15	20	50.0		1	2	360	2003	CDAW LASCO
2012-08-31 19:00:00.0	2012-08-31 20:00:00.0	74	20.0	-42	0.037	-165	8.0E-4	C8.4	1	2	360	1442	CDAW LASCO
2012-09-20 15:00:00.0	2012-09-20 15:00:00.0	-40	0.2	-158	0.0030	77	5.0		1	2	360	1202	CDAW LASCO
2013-03-05 03:00:00.0	2013-03-05 03:00:00.0	-1	0.4	-141	0.0060	88	30.0		1	1	360	1316	CDAW LASCO
2013-04-11 06:00:00.0	2013-04-11 07:00:00.0	130	5.0	-12	2.0	-146	0.0010	M6.5	1	2	360	861	CDAW LASCO
2013-05-13 15:00:00.0	2013-05-13 16:00:00.0	47	1.0	-95	0.01	129	0.0040	X2.8	1	2	360	1850	CDAW LASCO
2013-05-22 12:00:00.0	2013-05-22 13:00:00.0	-149	0.0030	70	20.0	-67	0.06	M5.0	1	2	360	1466	CDAW LASCO

Summary of effects

- Signature of SEPs that are observed is very dependant on the causal phenomena and the location of the observer
 - Impulsive event best observed if the observer is connected magnetically to the flare site
 - Parker spiral can be distorted by passage of CMEs
 - Gradual event observed over a much wider range of longitudes
 - Isotropic emissions from CME shock front
- Onset time of the SEP event as observed depends on the causal phenomena and the location of the observer
 - Rise in counts seen earlier at certain locations

Would a monitor at L5 help?

- Impulsive SEP events
 - Those that are geo-effective probably not seen at L5
 - Those seen at L5 may not be geo-effective
 - Connection to the surface can be distorted by CMEs, etc.
- Gradual SEP Events
 - Signature observed at L5 and Earth are different
 - For CME travelling outwards on paths behind the Earth, a monitor at L5 could give warning that event is starting
- Overall help in understanding of how active regions are evolving
 - Regions often produce more than one SEP event

Conclusion

- For SEP emission related to CMEs that are on certain trajectories, a monitor at L5 could provide a warning
- A monitor would help build up an understanding on a regions that may affect the Earth in the next few days
 - Needs to be supported by observations of surface by an EUV Imager and a Magnetograph
- Probably a lower priority instrument than some others
- If the desire if to do space weather forecasting for more than just Earth, the conclusion may be different
 - Support for a mission to Mars?