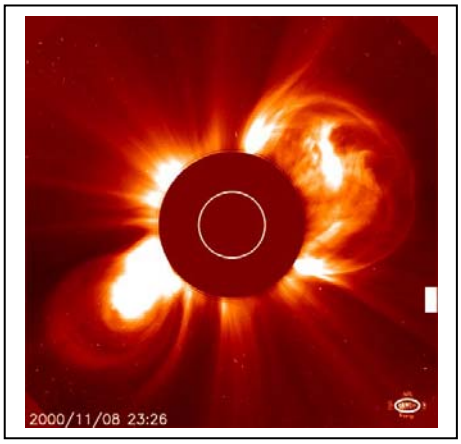
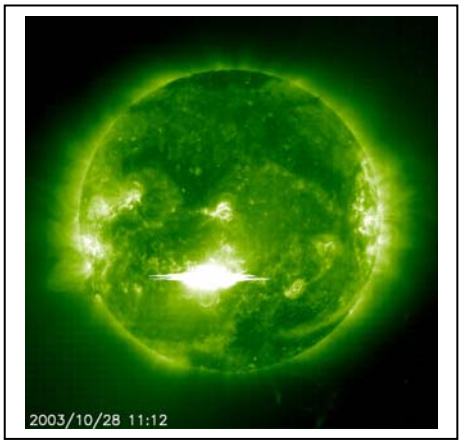
Do Fast CMEs produce intense SPEs?





The sun produces two basic kinds of storms; coronal mass ejections (SOHO satellite: top left) and solar flares (SOHO satellite: bottom left). These are spectacular events in which billions of tons of matter are launched into space (CMEs) and vast amounts of electromagnetic energy are emitted (Flares). A third type of 'space weather storm' can also occur.

Solar Proton Events (SPEs) are invisible, but intense, showers of high-energy particles near Earth that can invade satellite electronics and cause serious problems, even malfunctions and failures. Some of the most powerful solar flares can emit these particles, which streak to Earth within an hour of the flare event. Other SPE events, however, do not seem to arrive at Earth until several days latter.

Here is a complete list of Solar Proton Events between 1976-2005: http://umbra.nascom.nasa.gov/SEP/

Here is a complete list of coronal mass ejections 1996 - 2006: http://cdaw.gsfc.nasa.gov/CME_list/

Between January 1, 1996 and June 30, 2006 there were 11,031 CMEs reported by the SOHO satellite. Of these, 1186 were halo events. Only half of the halo events are actually directed towards Earth. The other half are produced on the far side of the sun and directed away from Earth. During this same period of time, 90 SPE events were recorded by GOES satellite sensors orbiting Earth. On the next page, is a list of all the SPE events and Halo CMEs that corresponded to the SPE events. There were 65 SPEs that coincided with Halo CMEs. Also included is the calculated speed of the CME event.

From the information above, and the accompanying table, draw a Venn Diagram to represent the data, then answer the questions below.

Question 1: A) What percentage of CMEs detected by the SOHO satellite were identified as Halo Events?
B) What are the odds of seeing a halo Event?
C) How many of these Halo events are directed towards Earth?

Question 2: A) What fraction of SPEs were identified as coinciding with Halo Events?
B) What are the odds that an SPE occurred with a Halo CME?
C) What fraction of all halo events directed towards earth coincided with SPEs?

Question 3: A) What percentage of SPEs coinciding with Halo CMEs are more intense than 900 PFUs?
B) What are the odds that, if you detect a 'Halo- SPE', it will be more intense than 900 PFUs?

Question 4: A) What percentage of Halo-SPEs have speeds greater than 1000 km/sec?
B) What are the odds that a Halo-SPE in this sample has a speed of > 1000 km/sec?

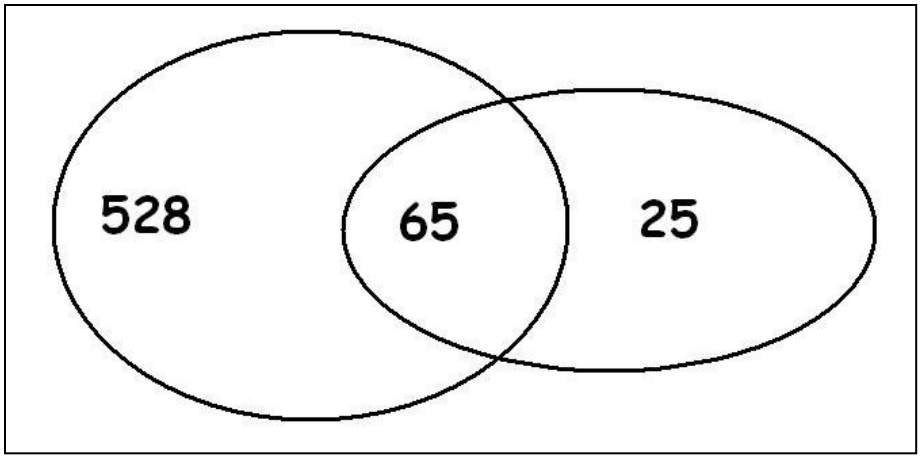
Question 5: From what you have calculated as your answers above, what might you conclude about Solar Proton Events and CMEs? How would you use this information as a satellite owner and operator?

Data Tables showing dates and properties of Halo CMEs and Solar Proton Events.

Date	CME Speed (km/s)	SPE (pfu)
November 4, 1997	785	72
November 6, 1997	1556	490
April 20, 1998	1863	1700
May 2, 1998	938	150
May 6, 1998	1099	210
May 3, 1999	1584	14
June 1, 1999	1772	48
June 4, 1999	2230	64
February 18, 2000	890	13
April 4, 2000	1188	55
June 6, 2000	1119	84
June 10, 2000	1108	46
July 14, 2000	1674	24000
July 22, 2000	1230	17
September 12, 2000	1550	320
October 16, 2000	1336	15
October 25, 2000	770	15
November 8, 2000	1738	14800
November 24, 2000	1289	940
January 28, 2001	916	49
March 29, 2001	942	35
April 2, 2001	2505	1100
April 10, 2001	2411	355
April 15, 2001	1199	951
April 18, 2001	2465	321
April 26, 2001	1006	57
August 9, 2001	479	17
September 15, 2001	478	11
September 24, 2001	2402	12900
October 1, 2001	1405	2360
October 19, 2001	901	11
October 22, 2001	618	24
November 4, 2001	1810	31700
November 17, 2001	1379	34
November 22, 2001	1437	18900
December 26, 2001	1446	779

Date	CME Speed (km/s)	SPE (pfu)
January 8, 2002	1794	91
January 14, 2002	1492	15
February 20, 2002	952	13
March 15, 2002	957	13
March 18, 2002	989	19
March 22, 2002	1750	16
April 17, 2002	1240	24
April 21, 2002	2393	2520
May 22, 2002	1557	820
July 15, 2002	1151	234
August 14, 2002	1309	24
August 22, 2002	998	36
August 24, 2002	1913	317
September 5, 2002	1748	208
November 9, 2002	1838	404
May 28, 2003	1366	121
May 31, 2003	1835	27
June 17, 2003	1813	24
October 26, 2003	1537	466
November 4, 2003	2657	353
November 21, 2003	494	13
April 11, 2004	1645	35
July 25, 2004	1333	2086
September 12, 2004	1328	273
November 7, 2004	1759	495
January 15, 2005	2861	5040
July 13, 2005	1423	134
July 27, 2005	1787	41
August 22, 2005	2378	330

Note: Solar Proton Event strengths are measured in the number of particles that pass through a square centimeter every second, and is given in units called Particle Flux Units or PFUs.



Question 1: A) What percentage of CMEs detected by the SOHO satellite were identified as Halo Events?
1186/11031 = 11%

B) What are the odds of seeing a halo Event?
1 / 0.11 = 1 chance in 9

C) How many of these Halo events are directed towards Earth?
From the text, only half are directed to Earth so 1186/2 = 593 Halos.

Question 2: A) What fraction of SPEs were identified as coinciding with Halo Events?
65 table entries / 90 SPEs = 72%

B) What are the odds that an SPE occurred with a Halo CME?
1 / 0.72 = 1 chance in 1.38 or about 2 chances in 3

C) What fraction of all halo events directed towards Earth coincided with SPEs?
65 in Table / (528+65) Halos = 11%

Question 3: A) What percentage of SPEs coinciding with Halo CMEs are more intense than 900 PFUs?
From the table, there are 12 SPEs out of 65 in this list or 12/65 = 18 %

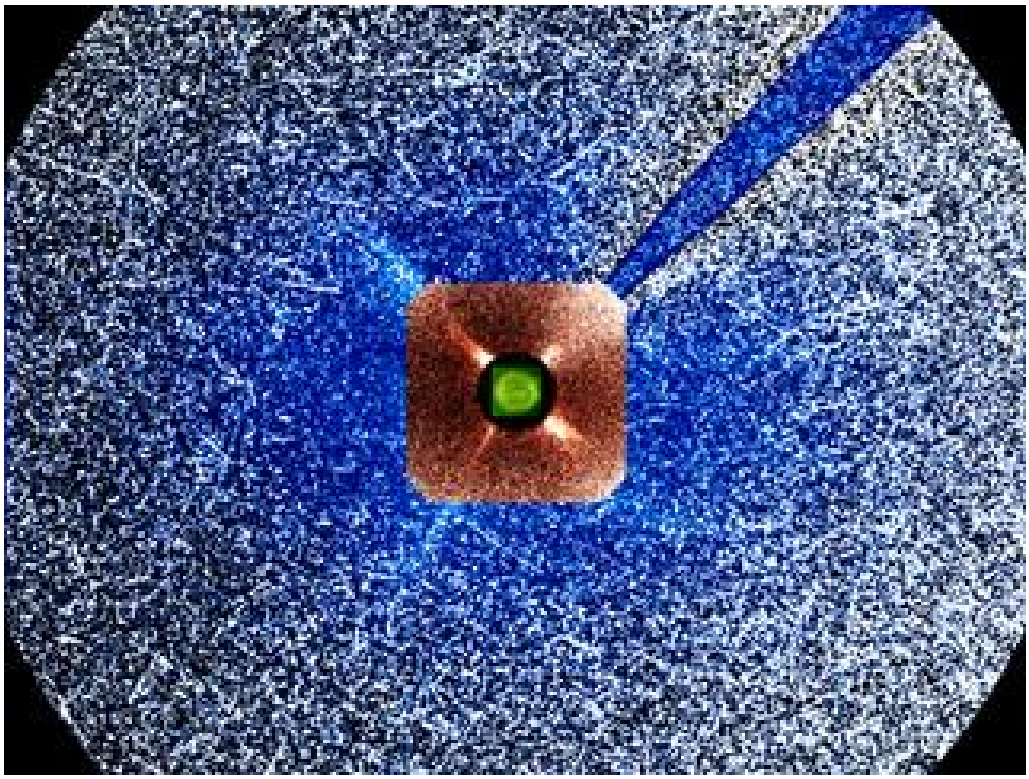
B) What are the odds that, if you detect a 'Halo- SPE', it will be more intense than 900 PFUs?
1 / 0.18 = 1 chance in 5.

Question 4: A) What percentage of Halo-SPEs have speeds greater than 1000 km/sec?
There are 50 out of 65 or 50/65 = 77%

B) What are the odds that a Halo-SPE in this sample has a speed of > 1000 km/sec?
1 / 0.77 = 1 chance in 1.3 or 2 chances in 3.

Question 5: From what you have calculated as your answers above, what might you conclude about Solar Proton Events and CMEs? How would you use this information as a satellite owner and operator?

A reasonable student response is that Halo CMEs occur only 11% of the time, and of the ones directed towards Earth only 1 out of 9 coincide with SPEs. However, in terms of SPEs, virtually all of the SPEs coincide with Halo events (2 out of 3) and SPEs are especially common when the CME speed is above 1000 km/sec. As a satellite owner, I would be particularly concerned if scientists told me there was a halo CME headed towards Earth AND that it had a speed of over 1000 km/sec. Because the odds are now 2 chances out of 3 that an SPE might occur that could seriously affect my satellite. I would try to put my satellite in a safe condition to protect it from showers of high-energy particles that might damage it.



The January 20, 2005 solar proton event (SPE) was by some measures the biggest since 1989. It was particularly rich in high-speed protons packing more than 100 million electron volts (100 MeV) of energy. Such protons can burrow through 11 centimeters of water. A thin-skinned spacesuit would have offered little resistance, and the astronaut would have been radiation poisoned, and perhaps even killed.

The above image was taken by the SOHO satellite during this proton storm. The instrument, called LASCO, was taking an image of the sun in order for scientists to study the coronal mass ejection (CME) taking place. Each of the individual white spots in the image is a track left by a high-speed proton as it struck the imaging CCD (similar to the 'chip' in your digital camera). As you see, the proton tracks corrupted the data being taken.

The high-speed particles from these proton storms also penetrate satellites and can cause data to be lost, or even false commands to be given by on-board computers, causing many problems for satellite operators.