

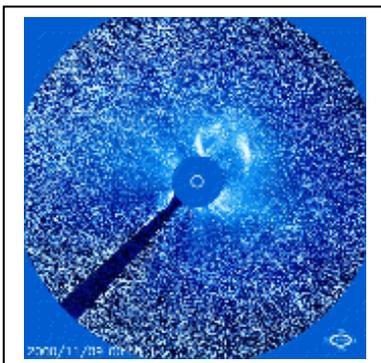
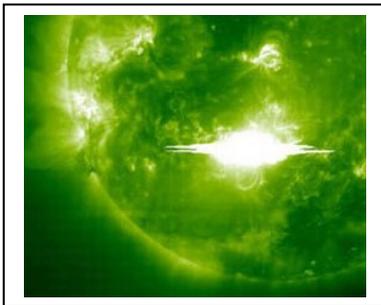
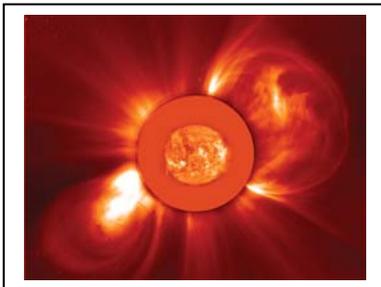
One of the most basic activities that scientists perform with their data is to look for correlations between different kinds of events or measurements in order to see if a pattern exists that could suggest that some new 'law' of nature might be operating. Many different observations of the Sun and Earth provide information on some basic phenomena that are frequently observed. The question is whether these phenomena are related to each other in some way. Can we use the sighting of one phenomenon as a prediction of whether another kind of phenomenon will happen?

During most of the previous sunspot cycle (January-1996 to June-2006), astronomers detected 11,031 coronal mass ejections, (CME: Top image) of these 1186 were 'halo' events. Half of these were directed towards Earth.

During the same period of time, 95 solar proton events (streaks in the bottom image were caused by a single event) were recorded by the GOES satellite network orbiting Earth. Of these SPEs, 61 coincided with Halo CME events.

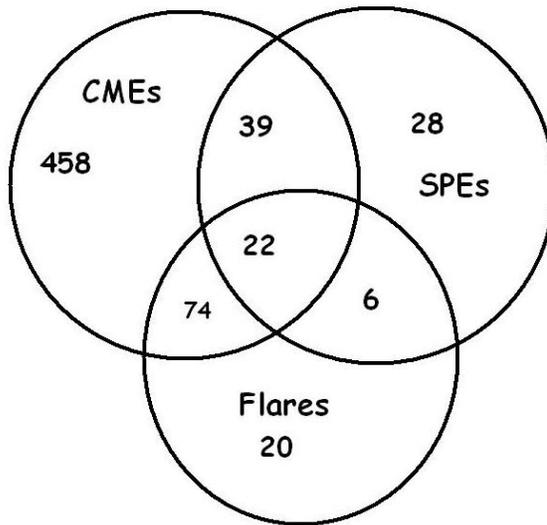
Solar flares (middle image) were also recorded by the GOES satellites. During this time period, 21,886 flares were detected, of which 122 were X-class flares. Of the X-class flares, 96 coincided with Halo CMEs, and 22 X-class flares also coincided with 22 combined SPE+Halo CME events. There were 6 X-flares associated with SPEs but not associated with Halo CMEs. A total of 28 SPEs were not associated with either Halo CMEs or with X-class solar flares.

From this statistical information, construct a Venn Diagram to interrelate the numbers in the above findings based on recent NASA satellite observations, then answer the questions below.



- 1 - What are the odds that a CME is directed towards Earth?
- 2 - What fraction of the time does the sun produce X-class flares?
- 3 - How many X-class flares are not involved with CMEs or SPEs?
- 4 - If a satellite spotted both a halo coronal mass ejection and an X-class solar flare, what is the probability that a solar proton event will occur?
- 5 - What percentage of the time are SPEs involved with Halo CMEs, X-class flares or both?
- 6 - If a satellite just spots a Halo CME, what are the odds that an X-class flare or an SPE or both will be observed?
- 7 - Is it more likely to detect an SPE if a halo CME is observed, or if an X-class flare is observed?
- 8 - If you see either a Halo CME or an X-class flare, but not both, what are the odds you will also see an SPE?
- 9 - If you observed 100 CMEs, X-class flares and SPEs, how many times might you expect to see all three phenomena?

## Answer Key:



## Venn Diagram Construction.

1. There are 593 Halo CMEs directed to Earth so  $593 = 74$  with flares +  $39$  with SPEs +  $22$  both SPEs and Flares +  $458$  with no SPEs or Flares..

2. There are 95 SPEs.  $95 = 39$  with CMEs +  $6$  with flares +  $22$  with both flares and CMEs +  $28$  with no flares or CMEs

3. There are 122 X-class flares.  $122 = 74$  With CMEs only +  $6$  with SPEs only +  $22$  both CMEs and SPEs +  $20$  with no CMEs or SPEs.

1 - What are the odds that a CME is directed towards Earth?  $593/11031 = 0.054$  **odds = 1 in 19**

2 - What fraction of the time does the sun produce X-class flares?  $122/21886 = 0.006$

3 - How many X-class flares are not involved with CMEs or SPEs?  $122 - 74 - 22 - 6 = 20$ .

4 - If a satellite spotted BOTH a halo coronal mass ejection and an X-class solar flare, what is the probability that a solar proton event will occur?  $22/(74+22) = 0.23$

5 - What percentage of the time are SPEs involved with Halo CMEs, X-class flares or both?  
 $100\% \times (39+22+6 / 95) = 70.1 \%$

6 - If a satellite just spots a Halo CME, what are the odds that an X-class flare or an SPE or both will be observed?  
 $39+22+74 / 593 = 0.227$  so the odds are  $1/0.227$  or about **1 in 4**.

7 - Is it more likely to detect an SPE if a halo CME is observed, or if an X-class flare is observed?

$$(6+22)/95 = 0.295 \text{ or 1 out of 3 times for X-flares}$$

$$(39+22)/95 = 0.642 \text{ or 2 out of 3 for Halo CMEs}$$

It is more likely to detect an SPE if a Halo CME occurs by 2 to 1.

8 - If you see either a Halo CME or an X-class flare, but not both, what are the odds you will also see an SPE?

$$39+6 / 95 = 0.50 \text{ so the odds are } 1/0.50 \text{ or } \mathbf{2 \text{ to } 1} .$$

9 - If you observed 100 CMEs, X-class flares and SPEs, how many times might you expect to see all three phenomena?

$$100 \times 22/(95+122+593) = \mathbf{3 \text{ times}}$$