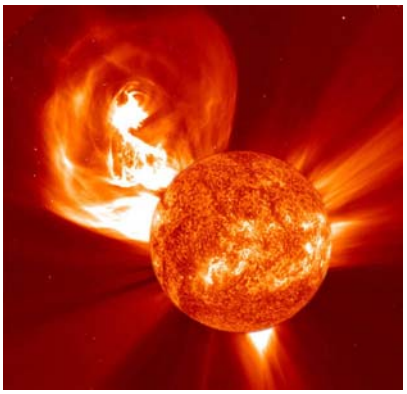

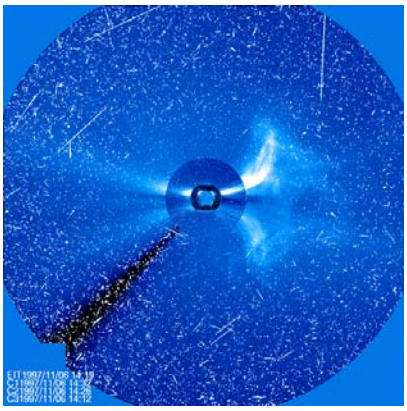

Every once in a while, the sun ejects huge clouds of heated gas, called plasma, which can contains billions of tons of matter and travel at speeds of millions of miles per hour. Occasionally these are directed at earth, and when they arrive they cause brilliant aurora. They can also cause problems for electrical systems on the ground and satellite systems in space.

The top image is a composite that shows the surface of the sun and one of these 'coronal mass ejections' being released. This one is directed away from earth and is harmless to us. When we spot a CME directed towards earth, the cloud seems to form a temporary 'halo' around the edge of the sun. These Halo CMEs are ejected from the sun, and can arrive at earth about 2 to 4 days later.

Soon after a Halo CME is ejected, satellites may detect a rain storm of radiation particles that were ejected from the sun at the same time. These travel so fast that they arrive at earth in only an hour or so. Also called Solar Proton Events (SPEs), these radiation storms are very harmful to astronauts in space and to sensitive satellite electronics. Predicting when SPEs will occur is an important goal of Space Weather Research.

The table below gives the dates for the CMEs detected during the 227 days from January 1, 2013 and August 15, 2013 during the peak of our sun's current storm cycle. Yellow shading indicates that a SPE occurred on the same date.

| Date | Type | Date | Type | Date | Type |
|---|---|---|---|---|---|
| 1-23 | Halo | 3-15 | Halo | 5-22 | Non-Halo |
| 1-31 | Halo | 4-11 | Halo | 6-20 | Halo |
| 2-1 | Halo | 4-20 | Non-Halo | 7-16 | Halo |
| 2-5 | Non-Halo | 4-21 | Non-Halo | 7-26 | Non-Halo |
| 2-9 | Halo | 5-17 | Halo | 8-6 | Halo |
| 2-20 | Halo | 5-19 | Halo | | |

**Problem 1** – What is the average number of days between all of the CMEs in this sample?

**Problem 2** – What percentage of CMEs are of the Halo-type?

**Problem 3** – What percentage of Halo CMEs seem to produce Solar Proton Events?

**Problem 4** – If you observed a CME, what is the probability that it may produce a harmful solar proton event?

**Problem 1** – What is the average number of days between all of the CMEs in this sample?

Answer: There are a total of 17 CMEs in 227 days so the average interval is about 227/17 = **13 days**.

**Problem 2** – What percentage of CMEs are of the Halo-type?

Answer: Of the 17 CMEs, 12 were Halo-type so the percentage is 100%x(12/17) = **71%**

**Problem 3** – What percentage of Halo CMEs seem to produce Solar Proton Events?

Answer: Of the 12 Halo-type events, 4 produced SPEs so 100% (4/12) = **33%**

**Problem 4** – If you observed a CME, what is the probability that it may produce a harmful solar proton event?

Answer: There were 17 CMEs total of which 6 produced SPEs, so 100% x (6/17) = **35%**.

Note: Of the 6 SPEs, four occurred with Halo CMEs so this means that 4/6 or 67% of all SPEs coincide with Halo-type CMEs, however it is also true that only 4/12=33% of all Halo-type CMEs produce SPEs. Not all Halo events produce solar proton events, so using halo events to predict whether an SPE will occur will lead to a large number of false-positives by about 8 false to 4 positives ( 8+4 = 12 halo events) for a 2:1 false positive rate.