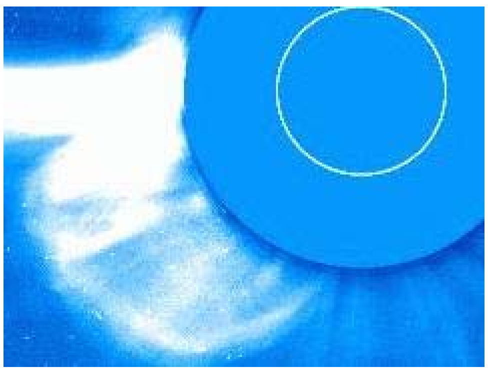
**How Fast is that CME Going?**[1]

**Objective:** Use a series of images taken by the SOHO satellite to estimate the velocity of the solar material leaving the sun.

**Materials:** ruler, calculator, coronagraph image sheets

**Background and Procedure:** During a CME (coronal mass ejection), huge bubbles of gas are ejected from the Sun over the course of several hours. Space weather scientists are interested in the velocity of the CME material. The SOHO satellite contains an instrument called the Large Angle Spectrometric Coronagraph (LASCO) which takes images of the sun. A coronagraph is a telescope that is designed to block light coming from the solar disk, in order to see the extremely faint emission from the region around the sun, called the corona.

An example of a coronagraph image is shown below. The white circle represents the size and location of the sun.



Courtesy of SOHO/LASCO consortium. SOHO is a project of international cooperation between ESA and NASA

Using a series of images and tracking the position of a particular portion of a CME, you can estimate the speed of the solar material being ejected. This is similar to monitoring the position of a person in a crowd leaving Fenway Park (Red Sox 12, Yankees 0) using a series of overhead photographs. Just as you would keep looking at the same person in each photo, you will need to measure the position of a particular part of the CME in each coronagraph image. This can be tricky – good luck!

Remember that average velocity is change in position divided by time. Our initial zero position will be the position of the CME in the first image. Successive positions will be recorded from this zero position. Positions should be recorded in units of kilometers (km), and time in units of seconds (s).

How do we measure our distances and times? The times are easy since each coronagraph image includes a date and time. The time is universal time listed in hour:minute format. For example, 17:18 means 17 hours 18 minutes. Taking the difference of the times listed on two successive images would result the time elapsed. Determining the distance is more involved. There is one known distance on each image that can be used as a scale. Recall that the white circle represents the size of the sun. The diameter of the sun is 1.4 million kilometers ($1.4 \times 10^6$ km). You will need to use this scale and your ruler to make your measurements.

Fill in the table below with your data and average velocity calculations. You are to perform a velocity calculation for the CME in each successive picture.

| Universal Time | Change in time | Position | Change in Position | Average Velocity |
|---|---|---|---|---|
| | 0 | 0 | 0 | 0 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Questions:**

1. Show a sample calculation for an average velocity calculation.

2. Are you familiar with any object that moves at the calculated average velocity?

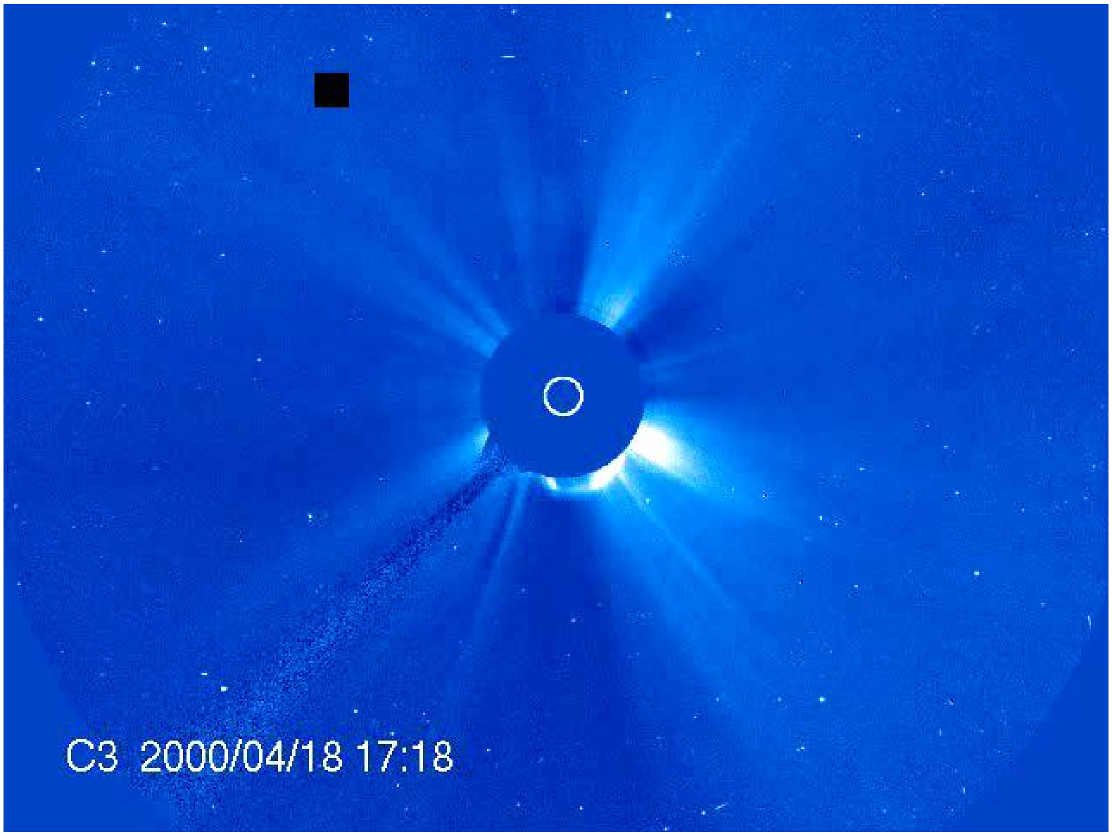
3. Select one of the average velocity values and describe what it really means. (For example, a car traveling at 25 mi/h really means that every hour the car travels 25 mi)

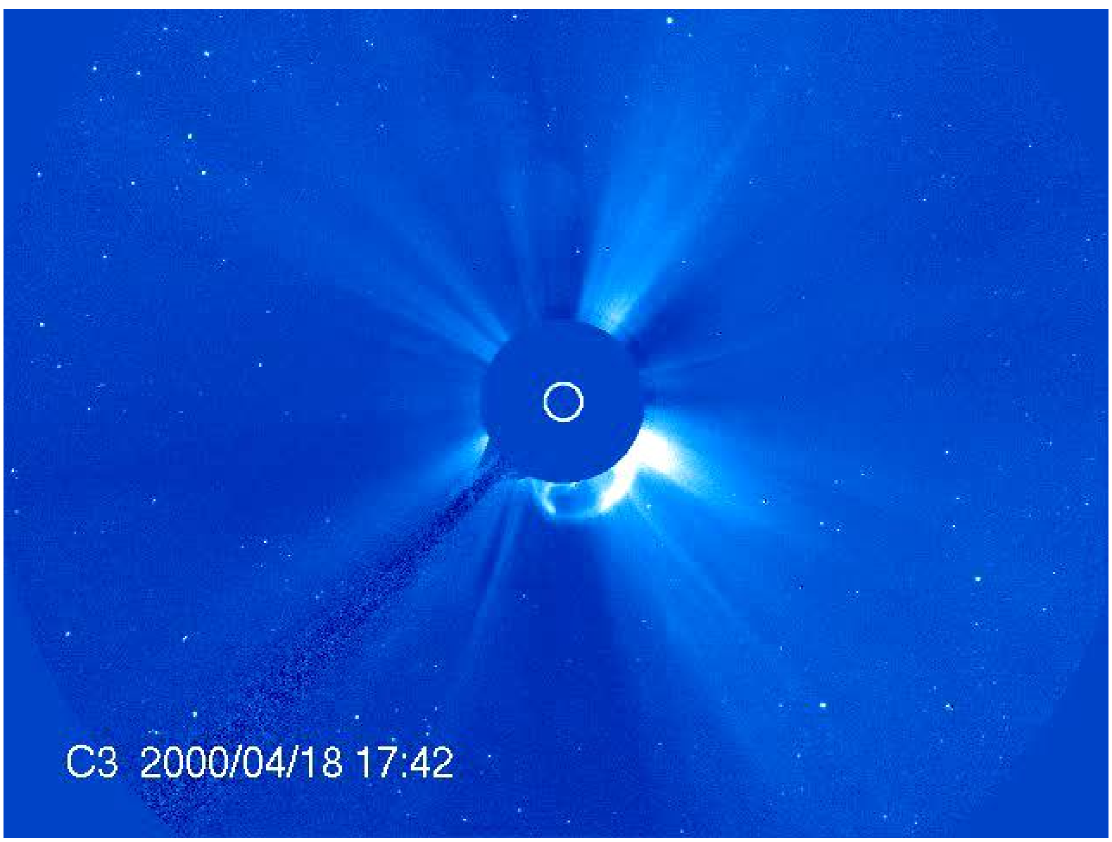
4. At your selected velocity, calculate the time it would take the CME material to reach the earth.

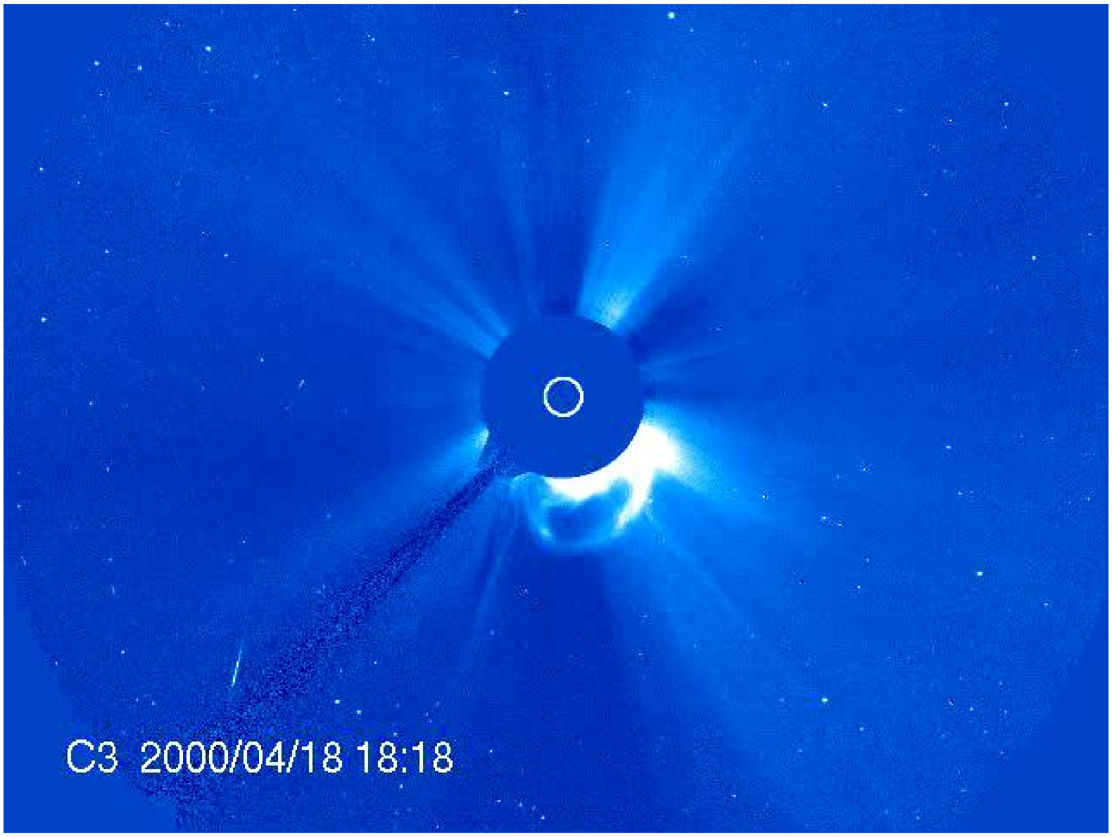
5. How consistent were the velocities? If they were changing, what could this mean about the motion of the CME near the sun?

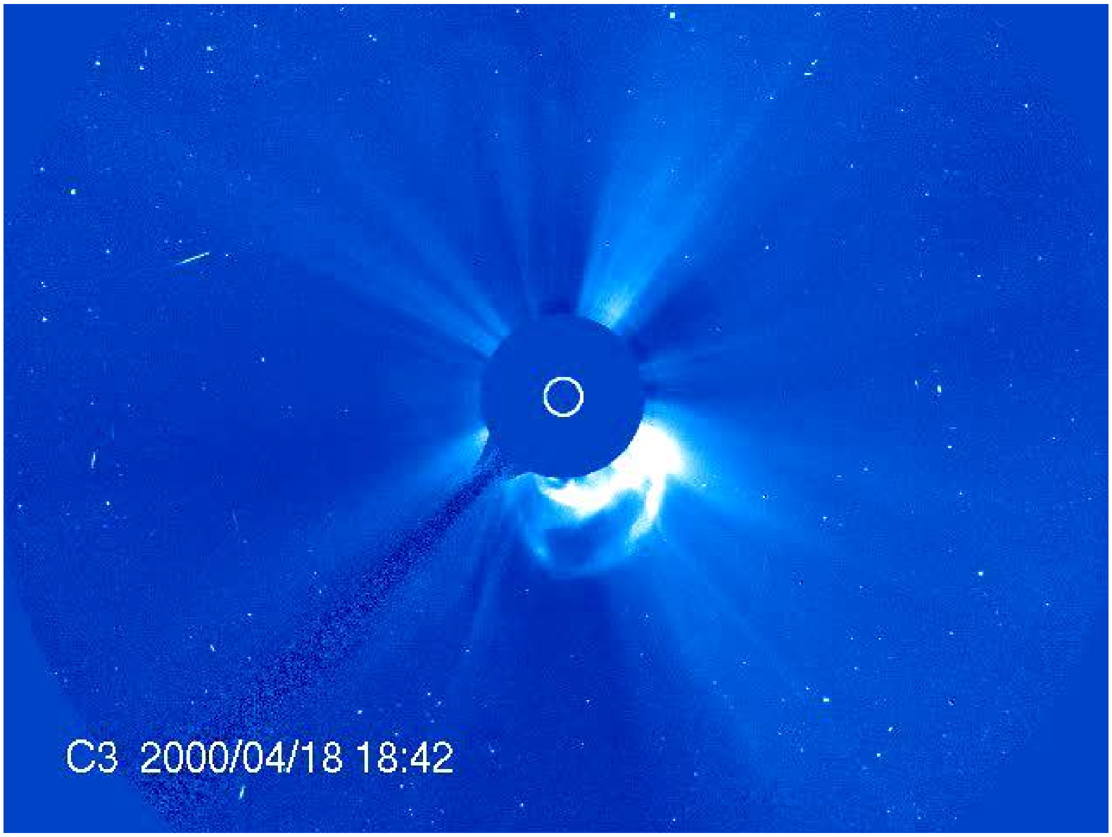
[1] This activity is based on "Sun-Centerd Physics,"a set of lesson plans developed by Linda Knisely.

All of the following images are courtesy of SOHO/LASCO consortium. SOHO is a project of international cooperation between ESA and NASA

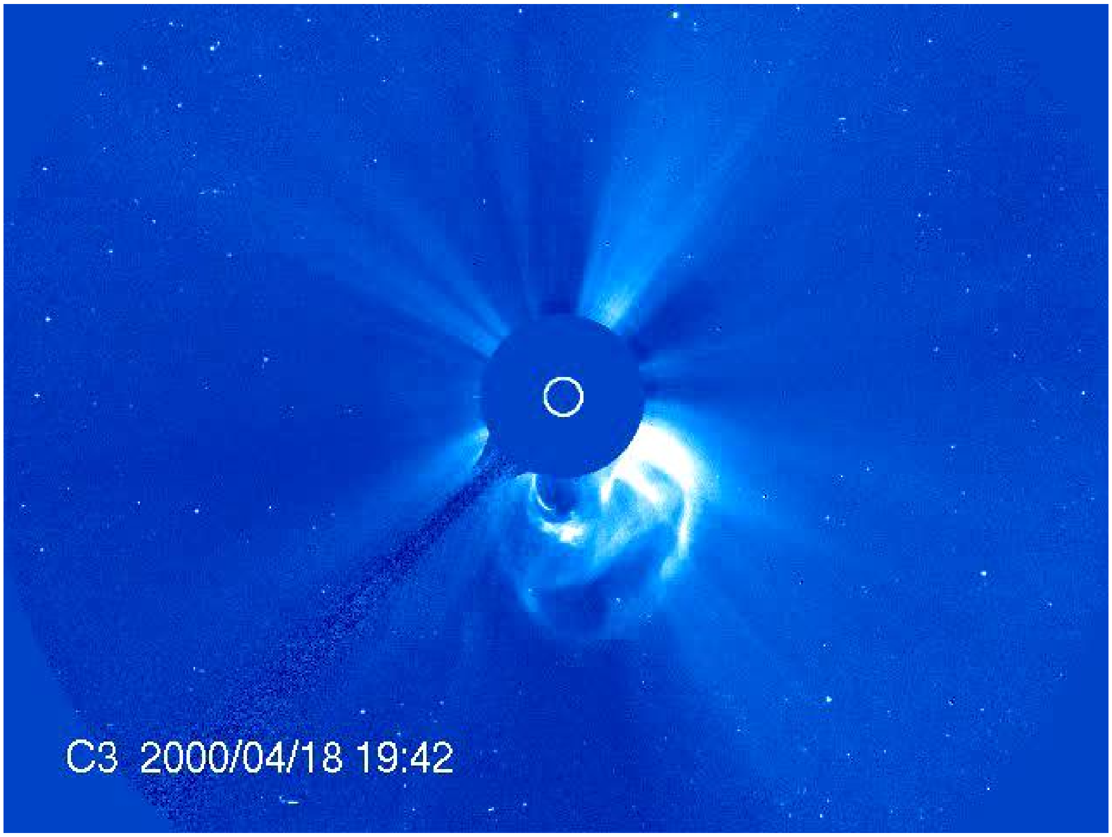


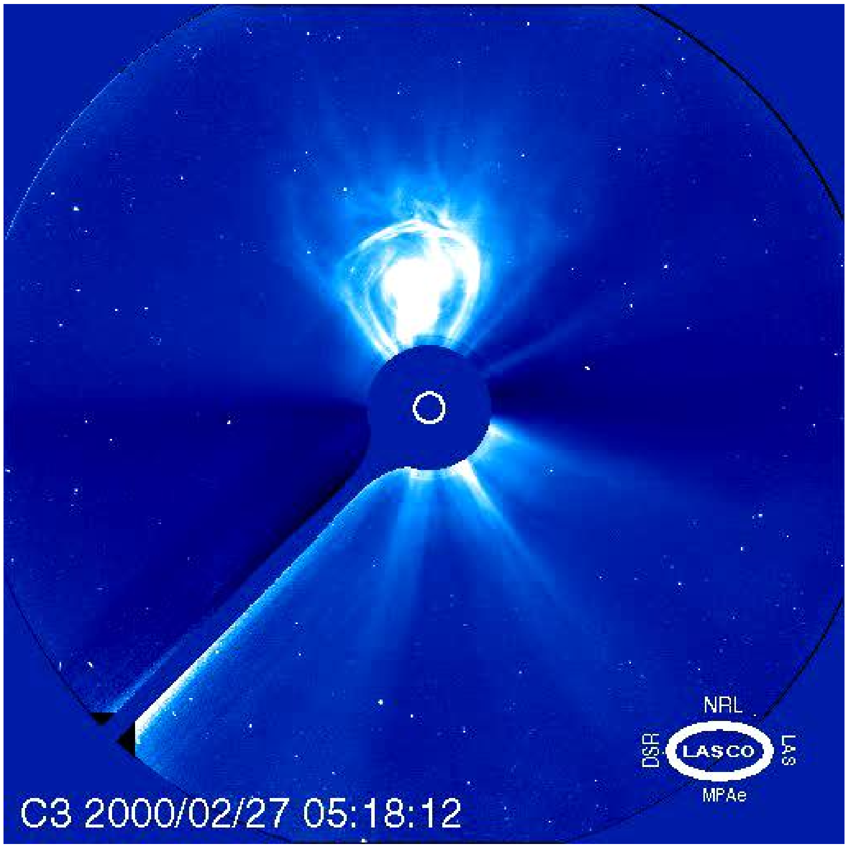



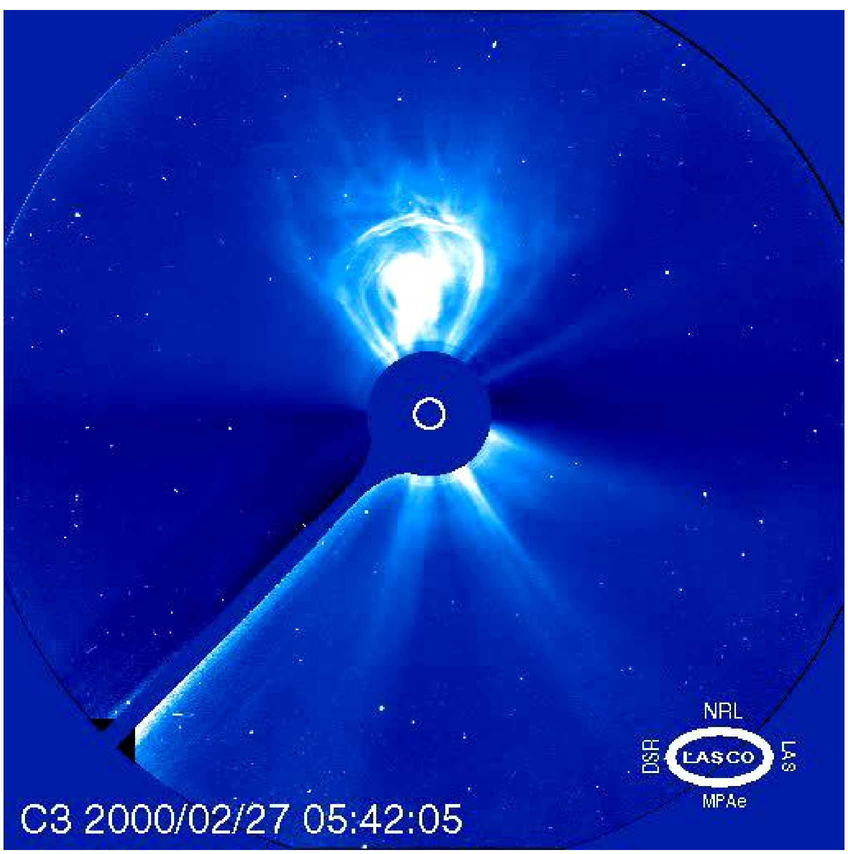


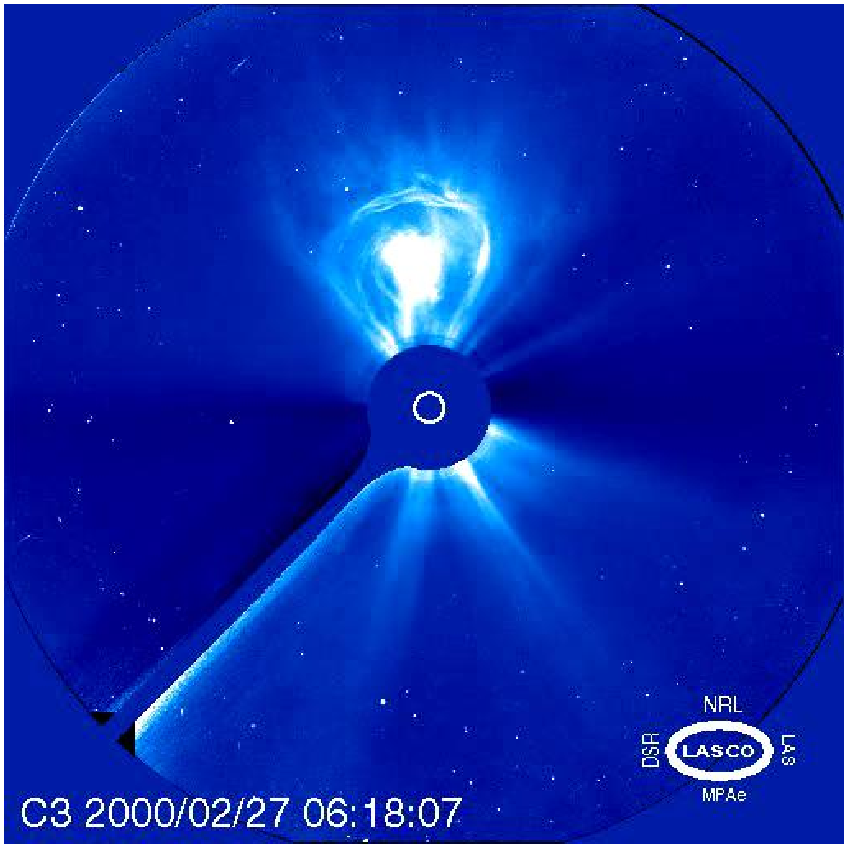



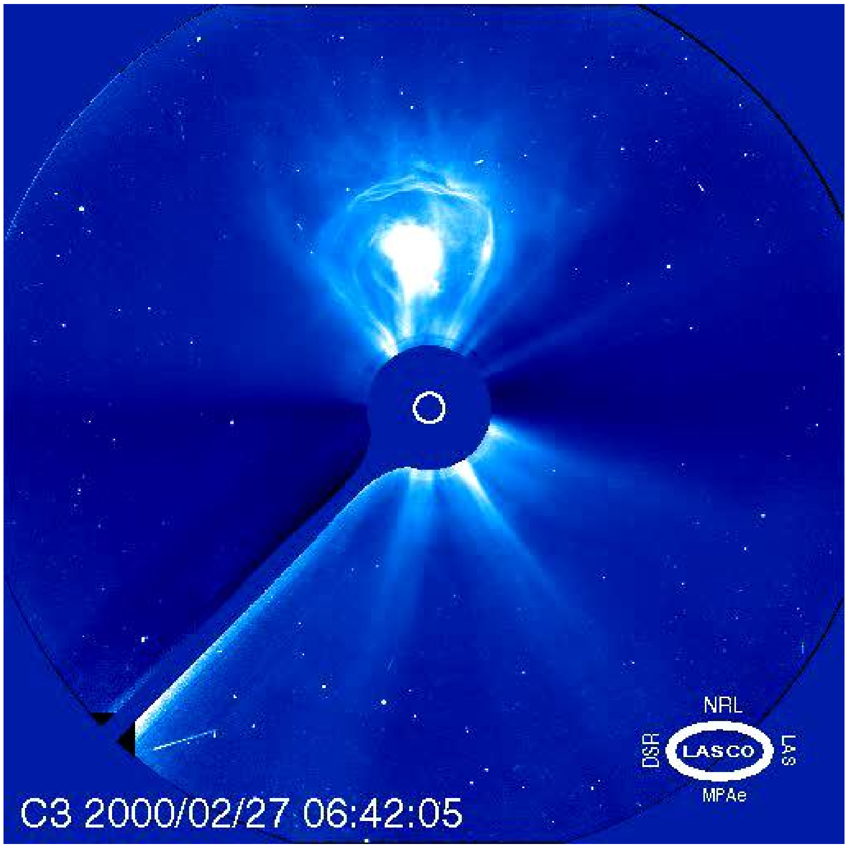

Chuckran/Hill 2007


C3 2000/04/18 19:42

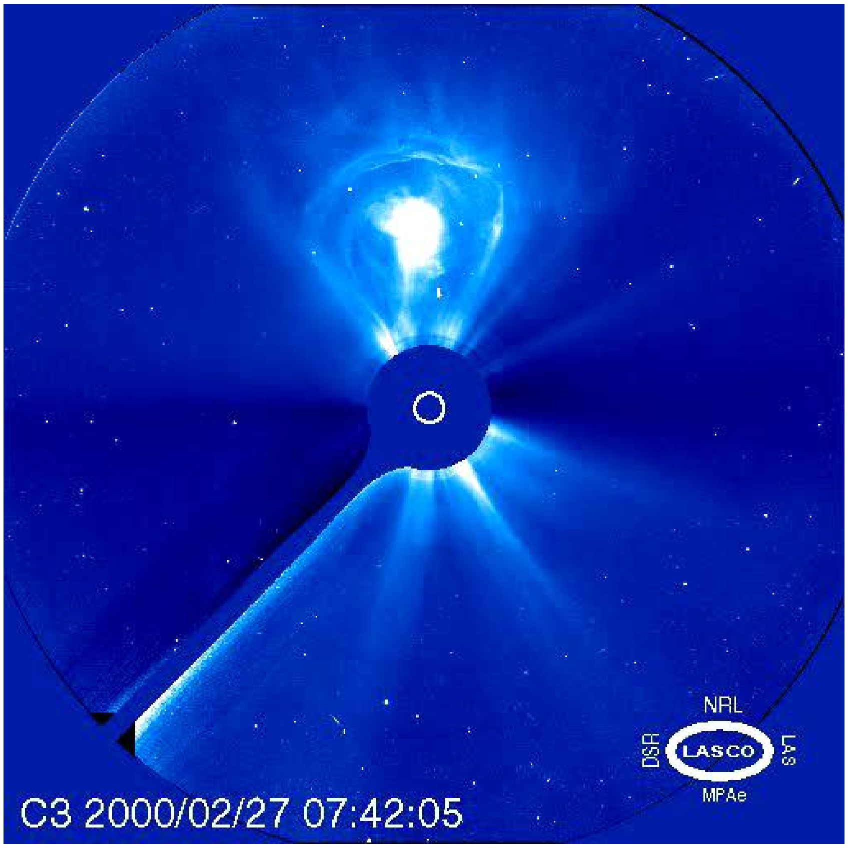

NRL
DSR
LASCO
LAS
MPAe
C3 2000/02/27 05:18:12


NRL
DSR
LASCO
LAS
MPAe
C3 2000/02/27 05:42:05




Chuckran/Hill 2007


C3 2000/02/27 07:42:05
NRL
DSR
LASCO
LAS
MPAe