Teacher's Guide   CME Speed Activity

Introduction

Coronal Mass Ejections are major storms on the Sun which can hurl billions of tons of matter into space in a matter of a few hours. Traveling at millions of kilometers per hour, some of these clouds occasionally collide with the Earth and have produced power blackouts and satellite damage. CMEs can start out with a size of only a few 100,000 kilometers, but fan out to tens of millions of kilometers by the time they reach Earth's orbit.

Objective

Students will use pictures of CME activity near the Sun taken by the NASA/ESA SOHO satellite, and calculate the speed of a CME

Procedure

1...Have the students select one or two features on the accompanying satellite photograph that they will track from frame to frame.

2...The student will calculate, for each frame, how far the feature is located from the center of the Sun. They will do this by using a millimeter ruler to measure the distance, and then using the physical diameter of the Sun (white circle) as a reference to establish the image scale. The scale is roughly 126,500 kilometers per millimeter.

3...Students will use the time information to calculate how many kilometers the feature traveled between each frame, and how long this took. From this they will calculate the average speed of the feature.

4...They will use the time information to calculate the elapsed time of the frame, fro the start of the motion in Frame 1. Example, if the average speed is computed from Frame 2 and 3, the elapsed time is defined to be the time between Frame 1 and 2.

5...The student will plot the elapsed time on the horizontal axis, against the calculated speed on the vertical axis. Instruct the students to connect the points that correspond to the SAME feature as it moves.

6...Invite the students to answer the questions on their worksheet.

The students will note that some, or all, of the features they selected are decelerating since the time of the ejection. This can be due to the effect of gravity. Some features may be accelerating. This can be due to a positive, outward, pressure provided by magnetic fields or gas bouyancy.

The arrival time at the Earth may be from 2-3 days. CMEs directed at the Earth usually look like an emerging halo of gas that encircles most or all of the Sun's disk. these 'halo CMEs' can be detected easily. The CME event studied by the students is not such a halo CME event and is directed nearl perpendicular to the Earth-Sun line, missing the earth entirely.

Materials

—Student work page
—Calculator
—Millimeter ruler

The diameter of the Sun is 1,390,000 kilometers. The diameter of the white 'sun disk' in the frames below is 11 millimeters. the scale of the frames is 1,390,000/11 = 126,500 kilometers per millimeter. Students may select any set of features they can see in the image that can be traced from frame to frame as the feature moves.

1...Measure the distance from the center of the Sun to a spot on the CME in millimeters.
    Example: **Frame 2 = 14**   **Frame 3 = 19**   **Frame 4 = 25 mm.**
2...Convert this into physical distances from the Sun's center using the scale factor of 126,500 km/
    Example: **Frame 2: 14 mm x 126,500 km/mm = 1,771,000 km**
                    Frame 3: 19 mm x 126,500 km/mm = 2,403,500 km
                    Frame 4: 25 mm x 126,500 km/mm = 3,162,500 km
3...Compute the distance traveled between Frame 2 and 3, and between Frame 3 and 4.
    Example: **Frame 3-Frame2 = 632,500 km**   **Frame 4 - Frame 3 = 759,000 km**
4...Compute the time difference between the frames in hours
    Example: **Frame 3 - Frame 2   = 15:21 - 14:59   = 22 minutes = 0.37 hours**
                    Frame 4 - Frame 3   = 15:52 - 15:21   = 31 minutes = 0.52 hours.
5...Compute the speed of the CME in each time interval
    Example: **Frame 3 - Frame 2 =   632,500 km /0.37hr = 1,709,500 km/hour**
                    Frame 4 - Frame 3 =   759,000 km/0.52hr = 1,459,500 km/hour

6...Have the students plot on a common graph the speed of the CME/feature they have calculated in Step 5 vs the time of the measurement in minutes from the start of Frame 1. Connect the points from the SAME feature by a single line. Students will see that the speeds are not constant from one moment to the next because the CME may be accelerated or decelerated as it moves.

This CME was detected by the NASA/ESA Solar Heliospheric Observatory (SOHO) on April 7, 1997. The disk of the Sun is blocked to re-move its bright light. The white circle shows the size of the Sun.

Here are the times for the images:

Frame 1: 14:27 UT
Frame 2: 14:59 UT
Frame 3: 15:21 UT
Frame 4: 15:52 UT
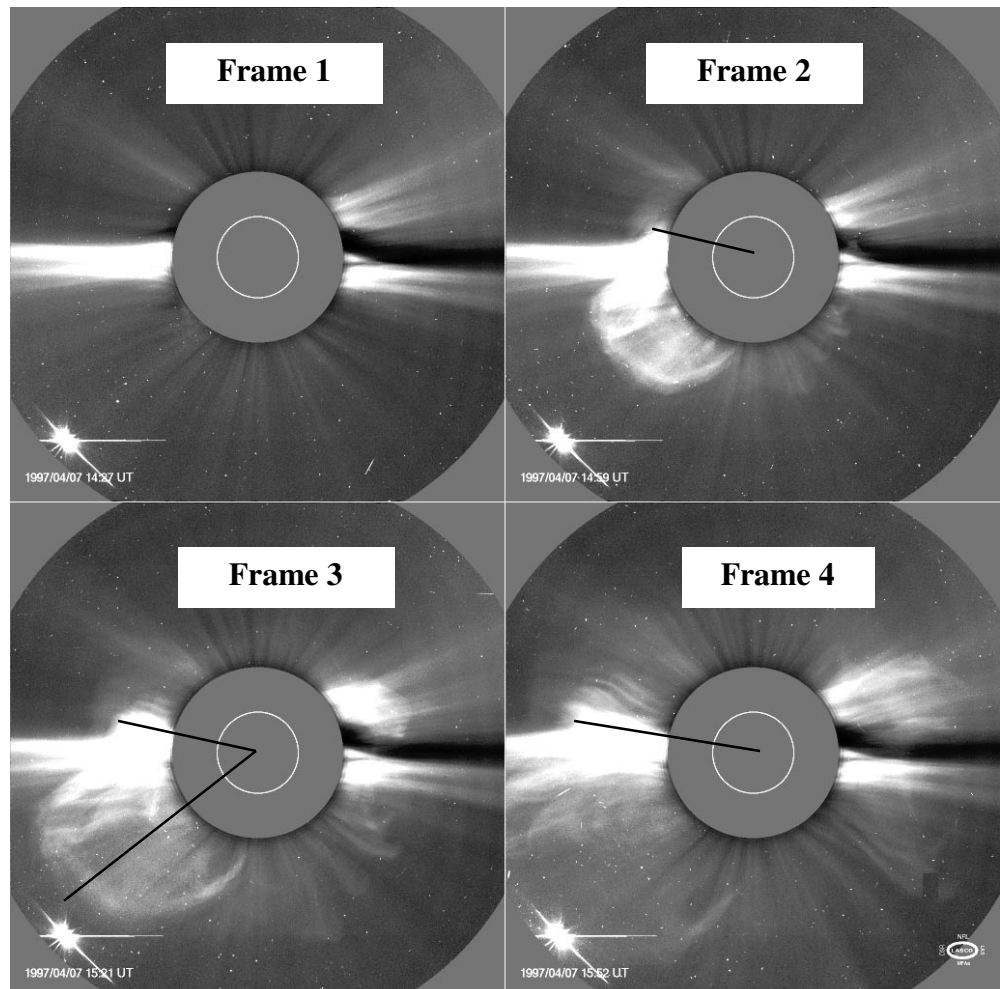
Frame 1

Frame 2

Frame 3

Frame 4

In the pictures below, you can see material being ejected from the Sun. The elapsed time between Frame 1 and Frame 4 is 85 minutes.

Select a feature in the expanding gas CME and follow its distance from the Sun from one frame to the next.

Using the time information in the box below, and the fact that the diameter of the Sun is 1,390,000 kilometers, calculate the speed of the feature you have selected.

On an 'X-Y plot', plot the speed of the feature on the Y-axis, and the time of the measurement since the beginning of Frame 1.

Question 1.   What is the average speed of the material being ejected by the Sun
Question 2:   How fast is this speed in miles per hour
Question 3:   How fast is this speed compared to the speed of light
Question 4:   How long would it take to travel the 147 million km (93 million miles) to earth
Question 5:   Is the material accelerated or decelerated as it leaves the Sun
Question 6:   Can you explain, physically, your answer to Question 5?

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