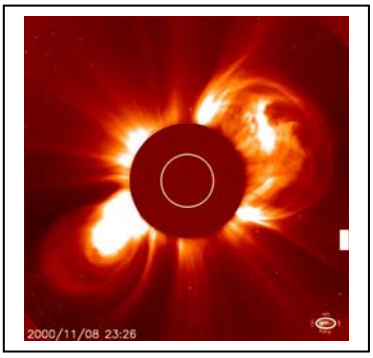
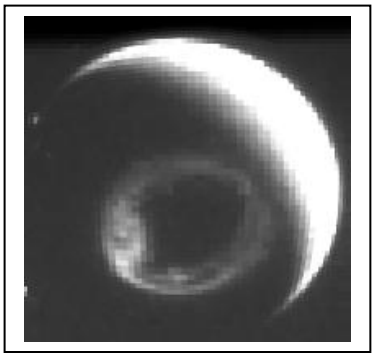
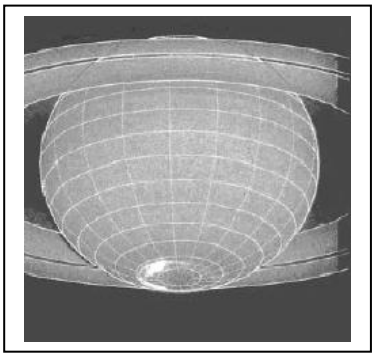



Sun - CME



Earth - Aurora



Saturn - Aurora

On November 8, 2000 the sun ejected a blast of plasma called a coronal mass ejection or CME. On November 12, the CME collided with Earth and produced a brilliant aurora detected from space by the IMAGE satellite. On December 8, the Hubble Space Telescope detected an aurora on Saturn. During the period from November to December, 2000, Earth, Jupiter and Saturn were almost lined-up with each other. Assuming that the three planets were located on a straight line drawn from the sun to Saturn, with distances from the sun of 150 million, 778 million and 1.43 billion kilometers respectively, answer the questions below:

1 – How many days did the disturbance take to reach Earth and Saturn?

2 – What was the average speed of the CME in its journey between the Sun and Earth in millions of km per hour?

3 – What was the average speed of the CME in its journey between Earth and Saturn in millions of km per hour?

4 – Did the CME accelerate or decelerate as it traveled from the Sun to Saturn?

5 – How long would the disturbance have taken to reach Jupiter as it passed Earth's orbit?

6 – On what date would you have expected to see aurora on Jupiter?

On November 8, 2000 the sun ejected a blast of plasma called a coronal mass ejection or CME. On November 12, the CME collided with Earth and produced a brilliant aurora detected from space by the IMAGE satellite. On December 8, the Hubble Space telescope detected an aurora on Saturn. During the period from November to December, 2000, Earth, Jupiter and Saturn were almost lined-up with each other. Assuming that the three planets were located on a straight line drawn from the sun to Saturn, with distances from the sun of 150 million, 778 million and 1.43 billion kilometers respectively, answer the questions below:

1 – How many days did the disturbance take to reach Earth and Saturn?
**Answer:** Earth = 4 days; Saturn = 30 days.

2 – What was the average speed of the CME in its journey between the Sun and Earth in millions of km per hour? **Answer:** Sun to Earth = 150 million km. Time = 4 days x 24 hrs = 96 hrs so Speed = 150 million km/96hr = 1.5 million km/hr.

3 – What was the average speed of the CME in its journey between Earth and Saturn in millions of km per hour? **Answer:** Distance = 1,430 – 150 = 1,280 million km. Time = 30 days x 24h = 720 hrs so Speed = 1,280 million km/720hrs = 1.8 million km/hr.

4 – Did the CME accelerate or decelerate as it traveled from the Sun to Saturn? **Answer:** The CME accelerated from 1.5 million km/hr to 1.8 million km/hr.

5 – How long would the disturbance have taken to reach Jupiter as it passed Earth's orbit?
**Answer:** Jupiter is located 778 million km from the Sun or (778 – 150 = ) 628 million km from Earth. Because the CME is accelerating, it is important that students realize that it is more accurate to use the average speed of the CME between Earth and Saturn which is (1.8 + 1.5)/2 = 1.7 million km/hr. The travel time to Jupiter is then 628/1.7 = 369 hours.

6 – On what date would you have expected to see aurora on Jupiter? **Answer:** Add 369 hours ( ~ 15 days) to the date of arrival at Earth to get November 23. According to radio observations of Jupiter, the actual date of the aurora was November 20. Note: If we had used the Sun-Earth average speed of 1.5 million km/hr to get a travel time of 628/1.5 = 418 hours, the arrival date would have been November 29, which is 9 days later than the actual storm. This points out that the CME was accelerating after passing Earth, and its speed was between 1.5 and 1.8 million km/hr.

For more details about this interesting research, read the article by Renee Prange et al. "An Interplanetary Shock Traced by Planetary Auroral Storms from the Sun to Saturn" published in the journal Nature on November 4, 2004, vol. 432, p. 78. Also visit the Physics Web online article "Saturn gets a shock" at http://www.physicsweb.org/articles/news/8/11/2/1