

Moments after a major class X-6 solar flare erupted at 18:43:59 Universal Time on December 6, 2006, the National Solar Observatory's new Optical Solar Patrol Camera captured a movie of a shock wave 'tsunami' emerging from Sunspot 930 and traveling across the solar surface. The three images to the left show the progress of this Morton Wave. The moving solar gasses can easily be seen. You can watch the entire movie and see it more clearly (<http://image.gsfc.nasa.gov/poetry/weekly/MortonWave.mpeg>).

Note: because the event is seen near the solar limb, there is quite a bit of fore-shortening so the motion will appear slower than what the images suggest.

Problem 1: From the portion of the sun's edge shown in the images, complete the solar 'circle'. What is the radius of the sun's disk in millimeters?

Problem 2: Given that the physical radius of the sun is 696,000 kilometers, what is the scale of each image in kilometers/millimeter?

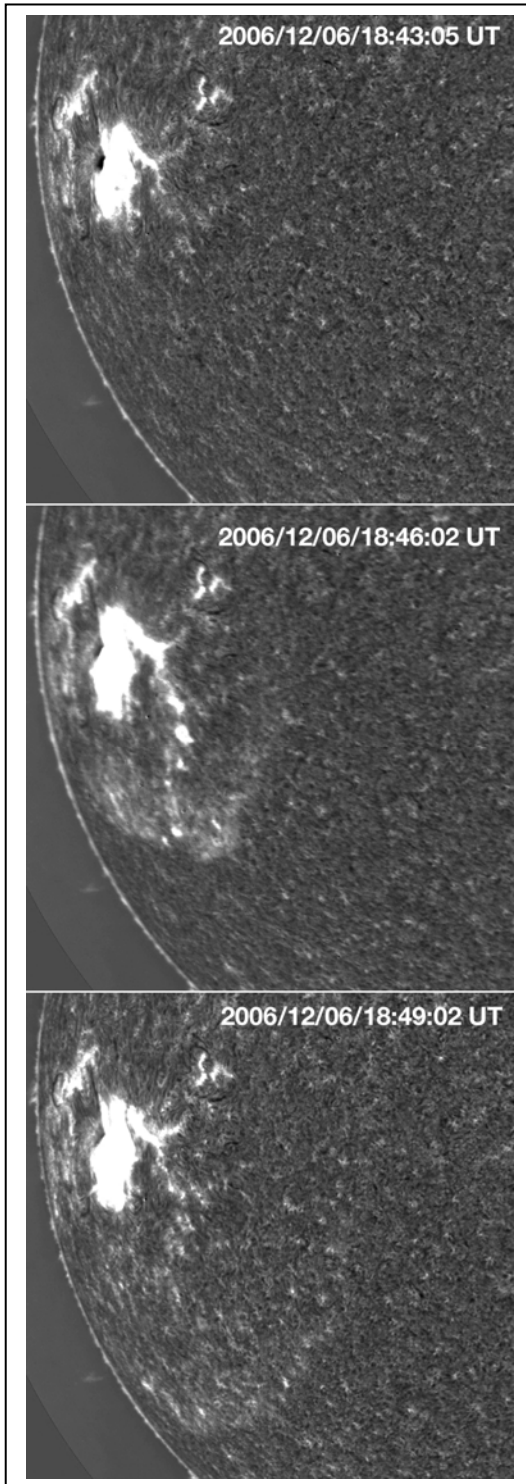
Problem 3: Select a spot near the center of the sunspot (large white spot in the image), and a location on the leading edge of the shock wave. What is the distance in kilometers from the center of the sunspot, to the leading edge of the shock wave in each image?

Problem 4: The images were taken at 18:43:05, 18:47:03 and 18:50:11 Universal Time. How much elapsed time has occurred between these images?

Problem 5: From your answers to Problem 3 and 4, what was the speed of the Morton Wave in kilometers per hour between the three images? B) did the wave accelerate or decelerate as it expanded?

Problem 6: The speed of the Space Shuttle is 44,000 kilometers/hour. The speed of a passenger jet is 900 kilometers/hour. Would the Morton Wave have overtaken the passenger jet? The Space Shuttle?

## Answer Key:



Problem 1: From the portion of the sun's edge shown in the images, complete the solar 'circle'. What is the radius of the sun's disk in millimeters?

Answer: About 158 millimeters using a regular dessert plate as a guide.

Problem 2: Given that the physical radius of the sun is 696,000 kilometers, what is the scale of each image in kilometers/millimeter?

Answer:  $696,000/158 = 4,405$  kilometers/millimeter

Problem 3: What is the distance in kilometers from the center of the sunspot, to the leading edge of the shock wave in each image?

Answer:

$$\text{Image 2} = 27 \text{ mm} = 27 \times 4405 = 119,000 \text{ km}$$

$$\text{Image 3} = 38 \text{ mm} = 167,000 \text{ km}$$

Problem 4: The images were taken at 18:43:05, 18:47:03 and 18:50:11 Universal Time. How much elapsed time has occurred between these images?

Answer: Image 1 - Image 2 = 3 minutes 58 seconds

Image 2 - Image 3 = 3 minutes 8 seconds

Problem 5: From your answers to Problem 3 and 4, A) what was the speed of the Morton Wave in kilometers per hour between the three images?

Answer:

$$V_{12} = 119,000 \text{ km} / 3.9 \text{ min} \times (60 \text{ min} / 1 \text{ hr}) \\ = 1.8 \text{ million kilometers/hour}$$

$$V_{23} = 167,000 / 3.1 \text{ min} \times (60 \text{ min} / 1 \text{ hr}) \\ = 3.2 \text{ million kilometers/hour}$$

B) Did the speed of the wave accelerate or decelerate?

Answer: Because  $V_{23} > V_{12}$  the wave accelerated.

Problem 6: The speed of the Space Shuttle is 44,000 kilometers/hour. The speed of a passenger jet is 900 kilometers/hour. Would the Morton Wave have overtaken the passenger jet? The Space Shuttle?

Answer: It would easily have overtaken the Space Shuttle! Because of fore-shortening, the actual speed of the wave was even higher than the estimates from the images, so the speed could have been well over 4 million km/hr.