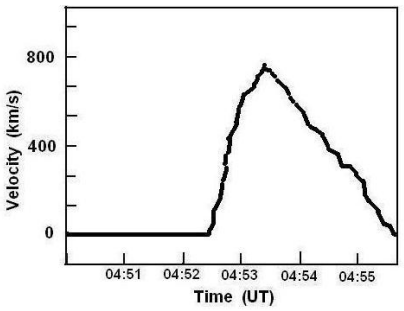
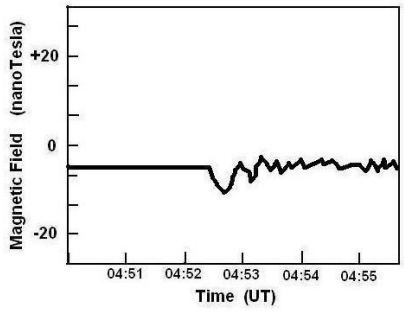
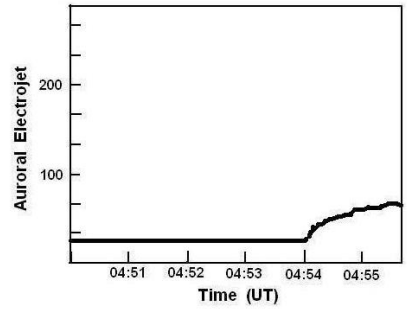
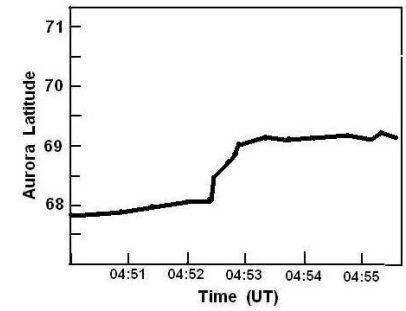
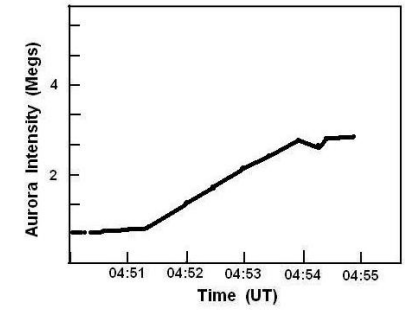
THEMIS: A Magnetic Case of 'What came first?'











The NASA, THEMIS satellite constellation consists of five satellites, P1, P2, P3, P4 and P5, launched on February 17, 2007. The scientific goal was to determine the sequence of events connecting disturbances in Earth's distant magnetic field (a process called magnetic reconnection), with the start of magnetic storms and aurora near Earth.

The science team assembled the data shown in the graphs to the left. The event that triggered this sequence was a 'magnetic reconnection' in Earth's magnetic field that took place at about 4:50:03 at a location about 160,000 km from Earth. (Note these plots have been greatly simplified for clarity! See the original article in the journal *Science*, August 15, 2008, vol. 321, pp.931: Figure 2 and 3)

Problem 1 - At about what times do each of the plots note a significant change in the quantity being measured?

Problem 2 - What is the time sequence of events based on your answers to Problem 1?

Problem 3 - How long was the elapsed time between the increase in particle velocity at the P3 satellite, and the enhancement of the auroral electrojet?

Problem 4 - The P3 satellite was located 74,000 km from Earth. If the auroral electrojet is a stream of charged particles that flows in Earth's upper atmosphere (300 km from the surface) what was the speed of the event in km/sec between the P3 location and when the electrojet started to form?

Problem 5 - What was the time difference between the magnetic reconnection event at 04:50:03 and the start of the auroral change in latitude?

Problem 6 - How fast did the particles travel from the reconnection region to the Earth when the auroral 'substorm' began?

Problem 7 - Before the THEMIS observations, one theory said that the disturbances near the P3 satellite would come before the reconnection occurred. What does the data say about this theory?

Answer Key

Problem 1 - Answer: The times below were reported in the scientific journals based on the actual data. Student answers may vary slightly depending on their ability to interpolate the values on the horizontal axis. For best results, use a millimeter ruler to determine the scale of the axis in seconds/mm.
Plot 1: Particle velocity increase detected at P3: **4:52:27**
Plot 2: Magnetic field change at P3: **4:52:27**
Plot 3: Auroral electrojet amplification in the ionosphere: **4:54:00**
Plot 4: Substorm expansion; Latitude increase northwards: **4:52:21**
Plot 5: Auroral intensity change; arrival of particles at Earth that were generated by magnetic reconnection. **4:51:39**

Problem 2 - Answer:
4:51:39: Auroral intensity change; arrival of particles at Earth generated by the magnetic reconnection.
4:52:21: Substorm expansion: Latitude increase northwards
4:52:27: Particle velocity increase detected at P3 due to earthward flow of particles.
4:52:27: Magnetic field change at P3
4:54:00: Auroral electrojet amplification in the ionosphere.

Problem 3 - Answer: 4:54:00 - 4:52:27 = 1minute and 33 seconds = **93 seconds.**

Problem 4 - Answer: 74,000 km / 93 seconds = **796 km/sec.**

Problem 5 - Answer: 4:52:21 - 4:50:03 = 2m 18s = **138 seconds.**

Problem 6 -Answer: The distance traveled was 160,000 kilometers in 138 seconds, for an average speed of 160,000 km /138s = **1,160 km/sec** if no allowance is made for the radius of the earth (6378km) and the height of the ionosphere (300 km). If these allowances are made, then (160,000 - 6378 - 300) km /138s = **1,110 km/sec.**

Problem 7 - Answer: Because the reconnection event happened at 04:50:03 ,this was about 2:27 before the disturbances at P3 in the particles speeds were recorded, so the theory in which P3 happened first is not consistent with the new data.