

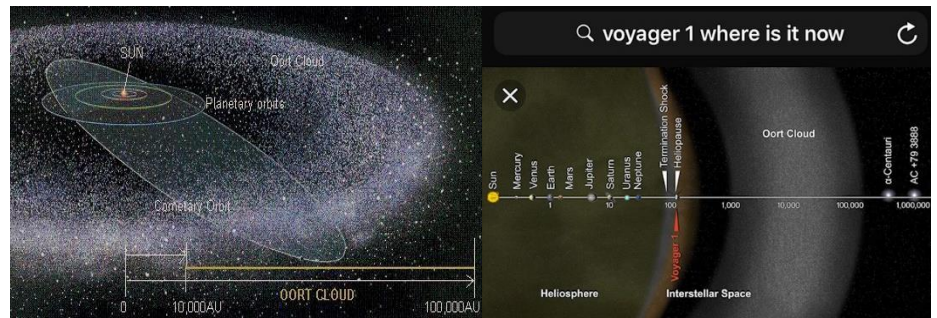
KINEMATICS

Units 4 & 5 , Dr. John P. Cise, jpcise@austincc.edu & NYTimes, Dec. 11, 2018

By Kenneth Chang, Dedicated to John W. Cise, MS, Prof. Engineer, General Electric Jet Engine Department, Cincinnati, Ohio

Voyager 2 Has Entered the Space Between Solar Systems

It is the **second spacecraft to make the crossing into interstellar space**, providing a new look at what lies beyond our local galactic neighborhood. Long after they have stopped communicating with Earth, the twin Voyager spacecraft will forever drift among the stars. The Voyager 2 spacecraft is now in interstellar space, NASA announced on Monday, making it the second human-made machine to cross a boundary that divides our solar system from the rest of the Milky Way galaxy. "We've been waiting with bated breath for the last couple of months for us to be able to see this," Nicola Fox, director of NASA's heliophysics division, said during a news conference at a meeting of the American Geophysical Union in Washington. Voyager 2 follows its twin, Voyager 1, which made the crossing in 2012. This time the passage into interstellar space is yielding a different set of readings, with new clues to how the sun affects space in the far reaches of the solar system. The two plutonium-powered spacecraft, **launched in 1977 to make a tour of the giant planets**, are still operational and continue to explore. "Now we are fortunate enough to have two very brave sentinels that have left our heliosphere and are out truly looking at the other side of the boundary in our interstellar medium," Dr. Fox said. The heliosphere is a bubble of gases emanating outward from our sun, and it is buffeted by winds of interstellar particles that blow through the Milky Way. At greater distances, the solar wind diminishes and is overtaken by the interstellar flow. "We're inside this bubble the sun creates around itself," said Edward C. Stone, the project scientist for the mission. "When Voyager was launched, we didn't know how large the bubble was, we didn't know how long it would take to get there, and we didn't know if the spacecraft could last long enough to get there." Crossing the boundary, the spacecraft observed a distinct change in its environment. "There are two winds pushing on each other," Dr. Stone said, "the solar wind from the inside pushing out and the interstellar wind pushing back in, in balance."



NASA engineers working on the Voyager 2 spacecraft in 1977. Credit NASA/JPL-Caltech

For **Voyager 2, now more than 11 billion miles(X)from Earth**, that change occurred on Nov. 5. On that day, instruments aboard the spacecraft detected an increase in the strength of magnetic fields from the interstellar region, and the number of galactic cosmic rays, which originate from far beyond the solar system, jumped. At the same time, the solar wind petered out.

"We're not seeing the solar wind any more," said John Richardson, the principal investigator for the plasma science experiment.

"That means we must be in the interstellar medium." **The transition to interstellar space did not exactly mirror Voyager 1's.**

Dr. Stone said that Voyager 2 is headed in a different direction, and six years later, the sun is at a different point in its 11-year cycle.

"We're learning a lot about the differences as well as the commonalities," he said. Voyager 2's plasma science experiment provided the first direct look at what happens to the solar wind as the spacecraft enters interstellar space. (Voyager 1 was not able to gather that data, because its plasma instrument failed in 1980.) Dr. Richardson said the speed of the plasma dropped quickly just in front of the boundary. "We thought it would be a much more gradual decrease," he said. The Voyager mission will continue for some time.

While the Voyagers, **speeding away at more than 34,000 miles per hour(v)**, are now in interstellar space,

they are still considered to be within the solar system, because they have not yet slipped the grip of the sun's gravity. **In about 300 years(t₁), Dr. Stone said, they will enter the Oort cloud**, a distant reservoir of comets orbiting the sun. And it **will take about 30,000 years(t₂) for the two spacecraft to come out the far side of the Oort cloud and definitively leave the solar system.**

QUESTIONS: (a) Knowing article states distance to voyager 2 is 11×10^9 miles and time from launch(1977) is 41 yrs., **find current speed is close to (as stated) 34,000 mph?**

(b) $1 \text{ AU} = 1.5 \times 10^{11}$ meters, voyager is now heading to Oort Cloud 900 AU away. Find number of years to get there?

Article claims it takes about 300 yrs.,(c) The icy Oort cloud of asteroids (see above graphics) is about 90,000 AU thick. The article says it will take about 30,000 yrs. to come out the

other side of Oort cloud. Find how thick Oort cloud is in miles?
(d) At 34,000 mph speed of Voyager, find time(in years) to pass through 90,000 AU thick Oort cloud?

HINTS: 0.62 km./mi., $X = v t$, 365 days/yr./ 24 hrs./day

ANSWERS: (a) $v \approx 30,600$ mph (close to article stated 34,000 mph).

(b) $t_1 \approx 281$ yrs. (close to stated 300 yrs.), (c) $X_{\text{Oort cloud}} = \sim 0.837 \times 10^{13}$ mi.,
(d) $t_2 \approx 28,000$ yrs. (close to 30,000 miles stated in article)