

6.4.12 References for notes

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- “Space probes reveal Solar System’s bullet shape”. *COSMOS magazine*. May 11, 2007. Retrieved 2007-05-12.

6.4.13 External links

- Moving into Interstellar Space (Artist Concept)
- “Cassini Data Helps Redraw Shape of Our Solar System” 2010
- Publications in Refereed Journals
- Voyager Interstellar Mission Objectives
- The Heliosphere (Cosmicopia)
- NASA GALEX (Galaxy evolution Explorer) homepage at Caltech
- The Solar and Heliospheric Research Group at the University of Michigan
- Ribbon at Edge of Our Solar System: Will the Sun Enter a Million-Degree Cloud of Interstellar Gas this century ?
- A Big Surprise from the Edge of the Solar System (NASA 06.09.11)
- Schwadron, N. A. et al. (6 September 2011). “Does the Space Environment Affect the Ecosphere?”. *Eos (American Geophysical Union)* **92** (36): 297–301. Bibcode:2011EOSTr..92..297S. doi:10.1029/2011eo360001.

Old theories

Warning, content may be outdated

- The Heliosphere, MIT Space Plasma Group
- UI’s Don Gurnett Says Voyager 1 Is Approaching Edge Of Solar System December 8, 2003 Univ. of Iowa Press release
- NASA’s Interstellar Probe (2000)
- CNN: NASA: Voyager I enters solar system’s final frontier – May 25, 2005

- *New Scientist*: Voyager 1 reaches the edge of the solar system – May 25, 2005
- Surprises from the Edge of the Solar System – Voyager 1 Newest Findings as of September 2006
- The heliospheric hydrogen wall and astrospheres
- Heliosphere, has a diagram.
- Heliosphere Astronomy Cast episode #65, includes full transcript.

6.5 Pale Blue Dot

This article is about the photograph. For other uses, see [Pale Blue Dot \(disambiguation\)](#).



Seen from about 6 billion kilometers, Earth appears as a tiny dot (the blueish-white speck approximately halfway down the brown band to the right) within the darkness of deep space

Pale Blue Dot is a photograph of planet Earth taken on February 14, 1990, by the *Voyager 1* space probe from a record distance of about 6 billion kilometers (3.7 billion miles, 40.5 AU), as part of the *Family Portrait* series of images of the Solar System.

In the photograph, Earth's apparent size is less than a pixel; the planet appears as a tiny dot against the vastness of space, among bands of sunlight scattered by the camera's optics.^[1]

Voyager 1, which had completed its primary mission and was leaving the Solar System, was commanded by NASA to turn its camera around and take one last photograph of Earth across a great expanse of space, at the request of astronomer and author Carl Sagan.^[2]

6.5.1 Background

On September 5, 1977, NASA launched *Voyager 1*, a 722-kilogram (1,592 lb) robotic spacecraft on a mission to study the outer Solar System and eventually interstellar space.^{[3][4]} After encountering the Jovian system in 1979 and the Saturnian system in 1980, the primary mission was declared complete on November 20 of the same year. *Voyager 1* was the first space probe to provide detailed images of the two largest planets and their major moons.



The *Voyager 1* spacecraft

The spacecraft, travelling at 40,000 miles per hour (64,000 km/h), is the farthest man-made object from Earth and the first one to leave the Solar System.^[5] Its mission has been extended and continues to this day, with the aim of investigating the boundaries of the Solar system, including the Kuiper belt, the heliosphere and interstellar space. Operating for 37 years, 6 months and 20 days as of today (March 27, 2015), it receives routine commands and transmits data back to the Deep Space Network.^{[3][6][7]}

Voyager 1 was initially expected to work only through the Saturn encounter. When the spacecraft passed the planet in 1980, Sagan proposed the idea of the space probe taking one last picture of Earth.^[8] He pointed out that such a picture would not have had much scientific value, as the Earth would appear too small for *Voyager*'s cameras to make out

any detail, but it could have been meaningful nevertheless as a perspective on our place in the universe.

Although many in NASA's *Voyager* program were supportive, most were of the opinion that taking a picture of Earth close to the Sun risked damaging the spacecraft's video system, preventing more pictures from being taken.^[9] It was not until 1989 that Sagan's idea was put into practice, but then instrument calibrations delayed the process further, and the personnel who devised and transmitted the radio commands to *Voyager 1* were also being laid off or transferred to other projects. Finally, NASA Administrator Richard Truly interceded to ensure that the photograph was taken.^{[5][10][11]}

6.5.2 Camera

Voyager 1's Imaging Science Subsystem (ISS), now disabled, consisted of two cameras: a 200 mm focal length, low-resolution wide-angle camera (WA), used for spatially extended imaging, and a 1500 mm high-resolution narrow-angle camera (NA) – the one that took *Pale Blue Dot* – intended for detailed imaging of specific targets. Both cameras were of the slow-scan vidicon tube type and were fitted with eight colored filters, mounted on a filter wheel placed in front of the tube.^{[12][13]}

The challenge for NASA's imaging team was that, as the mission progressed, the objects being photographed were getting farther away from the spacecraft, therefore appearing fainter and requiring longer exposures and even slewing (panning) of the cameras to achieve good quality. The telecommunication capability also decreased with distance, limiting the number of data modes that could be used by the imaging system.^[14]

After taking the *Family Portrait* series of images, which included *Pale Blue Dot*, NASA mission managers commanded *Voyager 1* to power its cameras down, as the spacecraft was not going to fly near anything else of significance for the rest of its mission, while other instruments that were still collecting data needed power for the long journey to interstellar space.^[9]

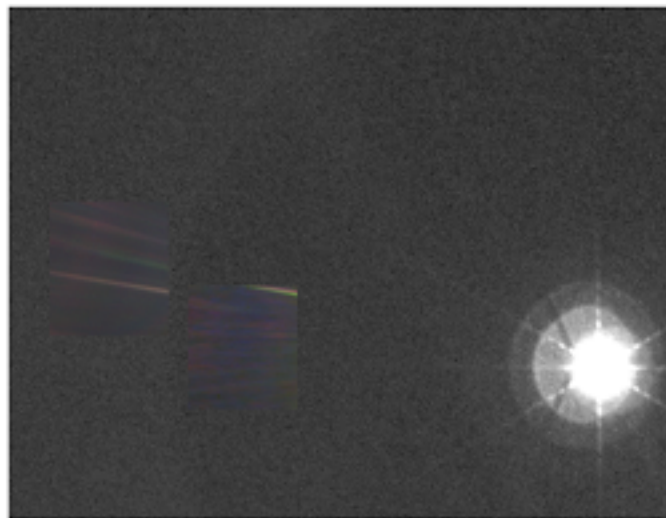
6.5.3 Photograph

The design of the command sequence to be relayed to the spacecraft and the calculations for each photograph's exposure time were developed by space scientists Candy Hansen of NASA's Jet Propulsion Laboratory (JPL) and Carolyn Porco of the University of Arizona.^[10] After the planned imaging sequence was taken on February 14, 1990, the data from the camera was stored initially in an on-board tape recorder. Transmission to Earth was also delayed by the

Magellan and Galileo missions being given priority over the use of the Deep Space Network. Then, between March and May 1990, *Voyager 1* returned 60 frames back to Earth, with the radio signal travelling at the speed of light for nearly five and a half hours to cover the distance.^[15]

Three of the frames received showed the Earth as a tiny point of light in empty space. Each frame had been taken using a different color filter: blue, green and violet, with exposure times of 0.72, 0.48 and 0.72 seconds respectively. The three frames were then recombined to produce the image that became *Pale Blue Dot*.^{[15][16]}

Of the 640,000 individual pixels that compose each frame, Earth takes up less than one (0.12 pixels, according to NASA). The light bands across the photograph are an artifact, the result of sunlight scattering off parts of the camera and its sunshade, due to the relative proximity between the Sun and the Earth.^{[15][17]} *Voyager's* point of view was approximately 32° above the ecliptic. Detailed analysis suggested that the camera also detected the Moon, although it is too faint to be visible without special processing.^[16]



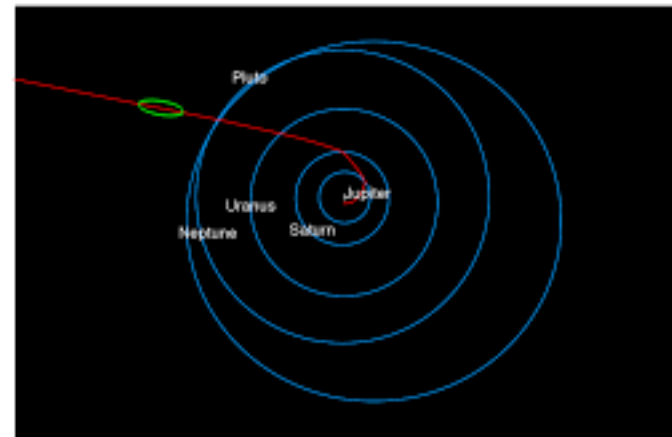
The wide-angle photograph of the sun and inner planets (not visible), with Pale Blue Dot superimposed on the left, Venus to its right

The pale blue color of the dot is the result of polarization and scattering of the light reflected from Earth. The polarization in turn depends on various factors such as cloud cover, exposed areas of oceans, forests, deserts, snow fields etc.^{[18][19]}

Pale Blue Dot, which was taken with the narrow-angle camera, was also published as part of a composite picture created from a wide-angle camera photograph showing the Sun and the region of space containing the Earth and Venus. The wide-angle image was inset with two narrow-angle pictures: *Pale Blue Dot* and a similar photograph of Venus. The wide-angle photograph was taken with the darkest filter (a methane absorption band) and the shortest possible exposure (5 milliseconds), to avoid saturating the camera's

vidicon tube with scattered sunlight. Even so, the result was a bright burned-out image with multiple reflections from the optics in the camera and the Sun that appears far larger than the actual dimension of the solar disk. The rays around the Sun are a diffraction pattern of the calibration lamp which is mounted in front of the wide-angle lens.^[16]

6.5.4 Distance



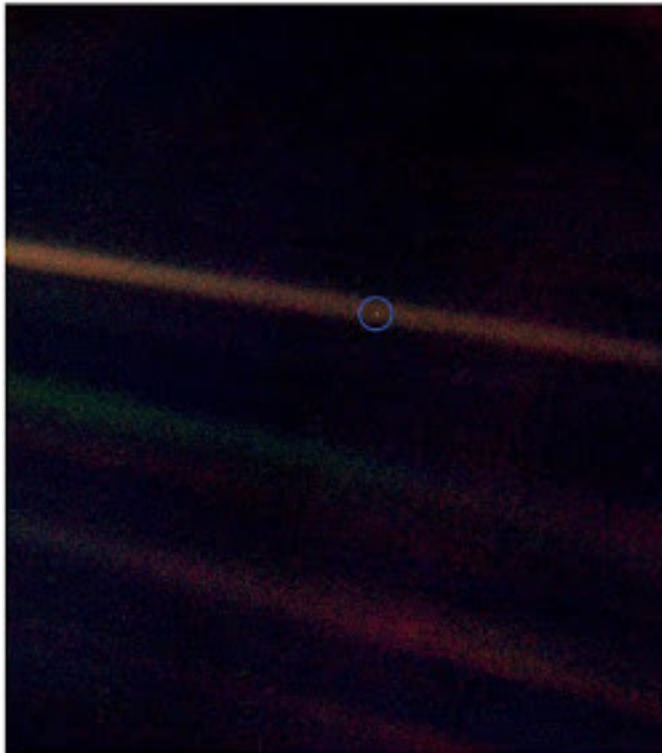
The approximate location of Voyager 1 while the photograph was taken is shown in green

According to NASA's Jet Propulsion Laboratory's HORIZONS tool, the distances between *Voyager 1* and the Earth on February 14 and May 15, 1990, were as follows:^[20]

6.5.5 Reflections by Sagan

Carl Sagan titled his 1994 book *Pale Blue Dot: A Vision of the Human Future in Space* after the photograph. In it, he expresses his thoughts on a deeper meaning of the image:^{[21][22]}

From this distant vantage point, the Earth might not seem of any particular interest. But for us, it's different. Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint



Sagan pointed out that "all of human history has happened on that tiny pixel," shown here inside a blue circle, "which is our only home" (speech at Cornell University, October 13, 1994).

and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam.

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that in glory and triumph they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner. How frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds. Our posturings, our imagined self-importance, the delusion that we have some privileged position in the universe, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity – in all this vastness – there is no hint that help will come from elsewhere to save us from ourselves.

The Earth is the only world known, so far, to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment, the Earth is where we make our stand. It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny

world. To me, it underscores our responsibility to deal more kindly with one another and to preserve and cherish the pale blue dot, the only home we've ever known.

—Carl Sagan, *Pale Blue Dot: A Vision of the Human Future in Space*, 1997 reprint, pp. xv–xvi

6.5.6 See also

- The Blue Marble
- Earthrise
- Family Portrait (MESSENGER)
- The Day the Earth Smiled

6.5.7 References

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- [8] "It's our dot : For Carl Sagan, planet Earth is just a launch pad for human explorations of the outer universe". pqasb.pqarchiver.com. Retrieved 2011-07-28.
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6.5.8 Further reading

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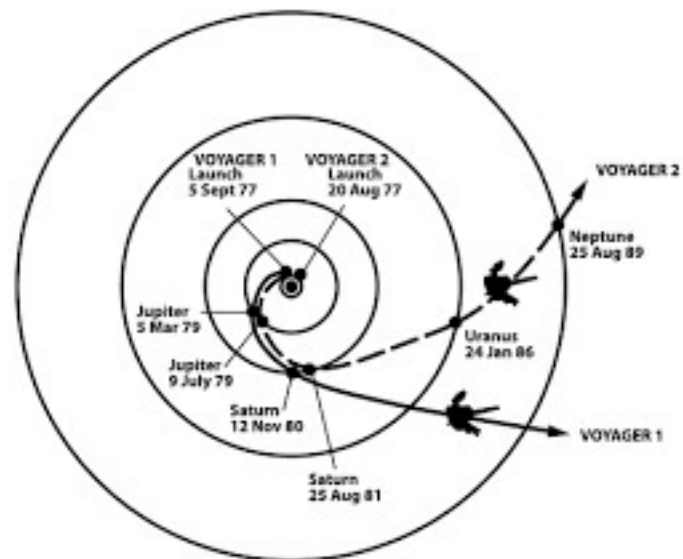
6.5.9 External links

- Audio recording of Carl Sagan reading from *Pale Blue Dot*, from the US Library of Congress, Seth MacFarlane Collection of the Carl Sagan and Ann Druyan Archive
- Video produced for Pangea Day with Sagan reading from *Pale Blue Dot*
- Sagan's rationale for human spaceflight – Article on *The Space Review*

6.6 Planetary Grand Tour

For other uses, see Grand Tour (disambiguation).

The **Planetary Grand Tour** was a plan to send unmanned



The trajectories that enabled NASA's Voyager 1 and 2 spacecraft to tour the four gas giant planets and achieve velocity to leave the Solar System.



Voyager 1's close view of Titan, attempted in place of a Pluto flyby.

probes to the planets of the outer Solar System. Conceived by Gary Flandro of the Jet Propulsion Laboratory in 1964,^{[1][2]} the Grand Tour would exploit the alignment of Jupiter, Saturn, Uranus, Neptune, and Pluto, an event