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# Miranda: A Jigsaw Puzzle World

When the *Voyager 2* spacecraft flew by the planet Uranus in January 1986, astronomers were treated to their first close-up glimpse of the satellites that orbit the seventh planet. In fact, the *Voyager* team discovered 10 new moons around Uranus during the spacecraft's brief visit, bringing the total number up to 15. But by far the most intriguing of those 15 satellites was a jigsaw-puzzle world called **Miranda**.

In a way, it was remarkable that we obtained any pictures of Miranda at all. Uranus is about 20 times farther from the Sun than the Earth is — which means sunlight is 400 times dimmer at Uranus than here.

How dark was it at Miranda? One of the *Voyager* scientists put it this way: Taking pictures in the Uranus system is like trying to do photography in a ballpark at night when the only light comes from a single candle. Clearly, the *Voyager* cameras would have to take *long-exposure* photographs — but there was a small additional problem.

The *Voyager* cameras were not sitting still — they were attached to a spacecraft that was moving rapidly through space —, and *Voyager*'s speed when it flew by Miranda was 43,000 miles per hour (about 12 miles each second). If the scientists left the camera shutter open for ten seconds, the spacecraft in that time had already sped 120 miles farther on.

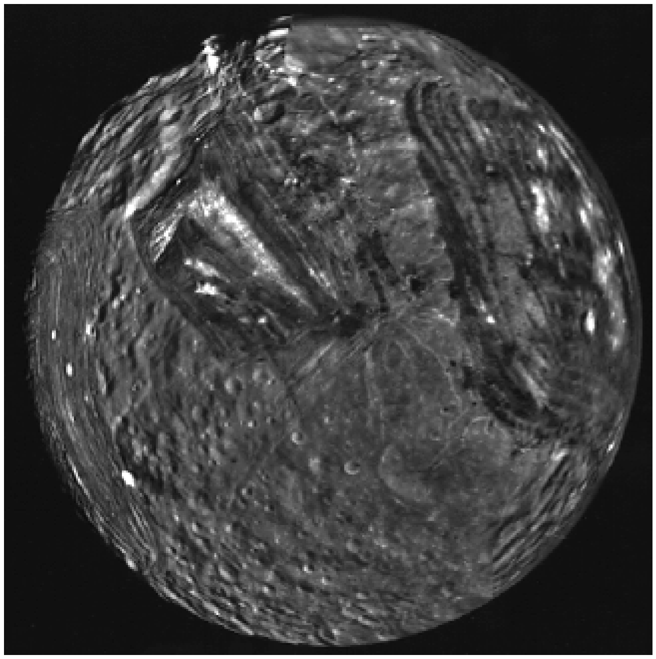
The only solution was to swing the spacecraft's camera steadily backward during the exposure, at just the right speed to make up for *Voyager*'s forward motion. To make matters even more complex, this backward swing had to be *pre-programmed* into the spacecraft's computers. This was because instructions sent by radio from Earth took about two and three-quarters hours to get to Uranus, much too late to do any good.

It is a tribute to the scientists and engineers who designed and built *Voyager* that we obtained a treasure-trove of clear, detailed pictures (and many other forms of scientific information) of Uranus, its thin rings, and its fascinating moons.

But there is no question that one of the most interesting of all the worlds we saw this time around was little Miranda. Only about 300 miles across and with only 1/1000 the mass of the Earth's moon, Miranda was the smallest of Uranus's moons that was known before the *Voyager* visit. (The new moons *Voyager* discovered all turned out to be smaller yet.) Miranda is so close to giant Uranus that it takes only about one and a half days to go around.

What makes Miranda so interesting to astronomers is that it seems to be several worlds in one. The region everyone notices first on Miranda is what looks like a bright check mark or number "7'' on a darker wrinkled background. Two other such mysterious blocks of ground are also seen elsewhere on Miranda. We know these places must be younger than the rest of the satellite because we see very few craters on them.

Craters are formed on an airless world like Miranda when small chunks of material coming from space hit the moon and blast a hole on impact. The longer a particular piece of ground has remained unchanged, the longer it has served as a target for craters. In fact, most of Miranda's surface is made of old rolling terrain, with many craters dotting the landscape. For some reason we don't understand, the regions like the checkmark must have formed or changed later in Miranda's history.



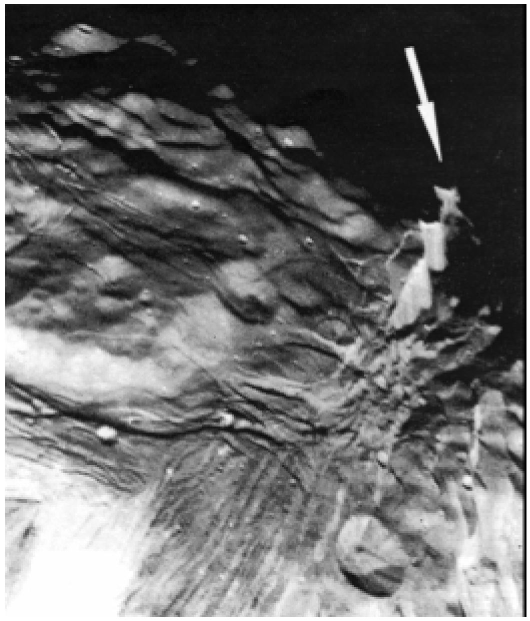
Miranda (NASA photograph).

Miranda also has vast cracks in the surface where the land seems to have shifted, exposing giant cliffs that would put many a mountain cliff on Earth to shame. The most impressive of these cliffs towers some 6 to 9 miles above its valley floor. (Compare this to the Grand Canyon in Arizona, which is only about a mile deep.) Furthermore, gravity is so weak on this little world that if you were to drop a rock from Miranda's tallest cliff, it would take a full five minutes to reach the bottom.

Miranda also has several other kinds of surface features and reminded the scientists who first looked at the *Voyager* photos of a giant cosmic geology museum. How did this little moon get such a complicated, mixed-up surface? It's far from certain yet, but at least one group of planetary scientists has come up with a very interesting suggestion. What if, long ago, Miranda had been hit by a large chunk of material, such as an asteroid or a small moon? If the incoming chunk were large enough and moving fast, its impact could have broken Miranda into pieces. When the pieces came back together again, there would be no reason for the landscapes to line up or for parts that were inside to remain on the inside. It may even be that the chunk that caused the impact remained close to the scene of the accident and was included in the new Miranda. This would explain why Miranda's surface today is such a crazy-quilt of different kinds of material, with different ages and geology.

Interestingly enough, *Voyager 2* only saw half of Miranda — the hemisphere illuminated by the Sun. Like Uranus, Miranda was tilted so its South Pole was pointed directly toward the Sun as *Voyager* passed. Thus our brief glimpse was only of its Southern Hemisphere. We can only wonder what sights await us on the other half of the satellite.

At the very least, Miranda teaches us that we cannot take anything for granted when we look at a planet or satellite for the first time. It is precisely because nature always seems to have a few surprises in store for us that astronomers have been urging NASA not to eviscerate the planetary exploration program that has given us so much exciting information on the worlds with which we share our solar system.



A cliff nearly 10 miles high on Miranda (NASA photograph).


# Miranda: A Jigsaw Puzzle World

## Activity Corner

### Constellation Activities

by John R. Percy, University of Toronto

Constellations are star patterns on the sky — celestial "connect the dots'' activities that the ancients used to help them keep track of the heavens. Today, astronomers have given constellations another (but related) meaning; they are regions of the sky, defined by boundaries, like countries on the Earth. Every star or galaxy we see can then be located on one of the 88 constellations into which we have divided the sky (coincidentally, the same number as there are keys on the piano.) Each of the 88 regions takes its name from the best-known star group or picture in that region, so the constellation Orion is the sector of the sky that includes the easily recognized star-pattern of Orion the Hunter.

Usually, the stars in a constellation have no physical connection with each other. They are at quite different distances from Earth, and it is only by accident that we see them in the same general direction on the "dome'' of the sky.

Different civilizations have seen very different patterns among the stars, inventing different constellations and attaching their own characteristic stories to them. Indeed, the constellations are like a cosmic Rorschach Test, by which cultures put their own psychological imprint on the heavens. Most of our constellations have been passed down from the ancient Greeks and Romans, although a few were invented in later times when European seafarers first mapped the Southern sky.

Probably the best known constellation is Ursa Major, a large pattern of stars that represents a great bear. Within Ursa Major, seven stars make up a smaller pattern (or "asterism'') called the Big Dipper.

Memorizing the constellations from a book and then trying to find then outside can be a very frustrating experience to most students. Here are a series of activities to enhance learning, teaching, and enjoying the constellations.

### Visit a Planetarium

The best place to learn the constellations is where the ancients learned them — outside on a clear, dark night under the dome of the sky. For a variety of reasons — not the least of which is light pollution from our cities — this learning experience is not practical for most classes. An excellent alternative is your local planetarium, where a complex projection instrument simulates the sky. Most planetaria have a regular program for school visits or can set one up if you request it in advance. If you are not sure where the closest planetarium is, call a nearby science museum or college physical science department.

### Constellation Stories

An interesting classroom or homework activity is to have your students investigate the stories attached to the different constellations. This can be particularly rewarding if it can be connected with the study of myths and legends from around the world in another course.

Some good references for constellation stories include:

- Allen, R.: *Star Names: Their Lore and Meaning.* 1899, 1965, Dover Books reprint.
- Gallant, R.: *The Constellations: How They Came to Be.* 1979, Four Winds Press.
- Gingerich, O.: "The Origin of the Zodiac'' in *Sky & Telescope* magazine, March 1984, p. 218.
- Kyselka, W. & Lanterman, R.: *North Star to Southern Cross.* 1976, University Press of Hawaii.
- Olcott, W. & Mayall, R.: *Field Book of the Skies.* 1954, Putnam's.
- Proctor, P.: *Star Myths and Stories.* 1972, Exposition Press.
- Staal, J.: *Stars of Jade.* 1984, Writ Press, P.O. Drawer R., Decatur, GA 30031.

**Invent a Constellation**

To demonstrate that there is nothing sacred about the star patterns after which the constellations are named (and to have some fun), you might have your students invent their own constellations. Provide them with a star chart that does not have the standard constellations marked on it and ask them to find star patterns that appeal to them on the chart and to make up stories to go with them. (The *Sky Challenger Star Wheels* kit — see below — includes a blank star chart for just this purpose.)

**Constellations on Computer**

For schools that have microcomputers there are several good programs on learning the constellations, available for such popular machines as Apple, IBM, and Commodore.

**Constellation Slides**

Although I do not recommend that your students memorize (and be examined on) the appearance of dozens of constellations, it is worthwhile to reinforce the appearance of a few of them. Ursa Major, Orion, Leo, and Pegasus, for instance, are relatively easy to find, and can be useful for locating other constellations or celestial objects. Constellation slides can be a useful visual aid for learning the basic star patterns.

**1. Real Constellation Slides**

Color slides of the constellations capture the subtle brightness and color differences among the stars, as well as showing their patterns. Commercial constellation slides can be purchased from various suppliers, such as:

- Hansen Planetarium, 1098 South 200 West, Salt Lake City, UT 84101
- MMI Corporation, 2950 Wyman Parkway, Baltimore, MD 21211

You might want to try taking your own constellation slides. This is fairly easy to do, provided you are away from the light pollution of a city. You will need a camera with a time exposure setting, a wide-open lens, fast color film (that means a high ASA number), and a tripod to keep your camera steady. Point your camera at the desired constellation and then expose the film for 20 to 40 seconds. At these short exposure times, you will not have to guide the camera to compensate for the motion of the Earth. An inexpensive cable release may be useful for not rocking the camera as you hold down the shutter button.

Some handy references:

- Scott, R. "Photographing the Night Sky Without a Telescope'' in *Science Teacher*, November 1983.
- *Astrophotography Basics*, booklet available from the Kodak Corp., Rochester, NY 14650 (ask for pamphlet AC-48; cost was 50 cents last time we checked.)

**2. Pinhole Constellation Slides**

These are fun to make and can be used in standard slide projectors. You will need stiff cardboard such as Bristol Board, sewing pins, and star charts or other diagrams of constellations.

1. Cut out enough 5 cm by 5 cm (2 x 2 inch) squares of card board for each student.
2. Have each student choose a constellation and copy the significant stars in the pattern onto a square of cardboard, leaving a barder about 0.5 cm (1/4 ") around the edge.

3. Depending on the age of the students (and safety considerations) either you or they can then make holes in the cardboard slides for each star using the sewing pin or needle. Make a larger hole for the brighter stars by pushing the pin all the way into the cardboard; use only the point of the pin to make smaller holes for the fainter stars.
4. Put the slides into the projector and show them on a screen. Remember that to show the constellations right side up, the slide must be turned upside down. On the other hand, students can try their hand at identifying constellations in a variety of orientations.
5. Younger students can play a game identifying constellations. One or more students can be responsible for learning and telling the stories attached to each constellation. For older students, each group may also want to learn something about the stars that make up the constellation pattern and even about other objects (galaxies, nebulae, double stars, etc.) that can be found within the boundaries of that constellation.

### Resources for Learning About the Constellations

*Tours of the Night Sky* (Designed for home use, to teach the constellations while you are looking at the night sky, includes a sky tour for each season, full transcripts, and seasonal star maps.)

*Sky Challenger Star Wheels* (Activity kit developed by the Lawrence Hall of Science, with 6 interchangeable star wheels for teaching constellations, including: Invent Your Own Constellations, Native American Constellations Binocular Treasure Hunt and Star Clock.) Available at many museum or science stores.

Burnham, R. *The Star Book.* 1983, Kalmbach or Cambridge U. Press.

Chartrand, M. *Starguide.* 1982, Golden Press.

Menzel, D. & Pasachoff, J. *A Field Guide to the Stars and Planets*, 2nd ed. 1983, Houghton-Mifflin.

Rey, H. *The Stars: A New Way to See Them.* 1976 Houghton-Mifflin. (A good basic book for the novice.)