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Exploring Venus

Our celestial neighbor Venus has long been a source of fascination for astronomers, stargazers, and science fiction buffs. Later this year, two different events will bring the planet even more strongly into the public spotlight.

Starting in early May, Venus will be the brilliant "morning star", rising just before the Sun does. Students who get up before sunrise will see it as a bright white light low in the east. (Near the horizon, turbulence in the air may make it seem to shimmer and even change color.) In June, two large Soviet robot spacecraft — already on their way and carrying an international load of experiments (including some designed by Americans) — will "invade" Venus by dropping a number of landers and balloon-carried probes into the planet's cloud-shrouded atmosphere. (The two main spacecraft themselves will continue on past Venus, speeding toward their ultimate goal: encounters with Halley's Comet next March.)

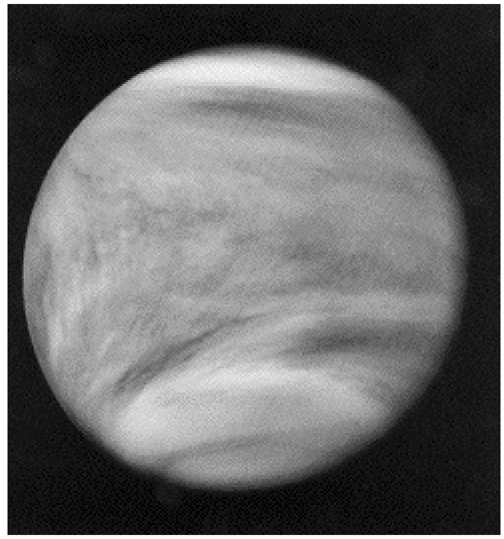
These two events — Venus's bright dominance of the pre-dawn sky and its impending encounter with a remarkable armada of new probes from Earth — will give you a unique opportunity to bring both the beauty and excitement of astronomy to your students. Thus, this issue of *The Universe in the Classroom* is devoted to Venus, the Queen of the Morning Sky this spring.

While Venus is sometimes called "Earth's sister planet", conditions on it are, as we will see, very un-earthlike! It is a frustrating planet for astronomers because its surface is perpetually veiled by layers of clouds that have not allowed us to see its surface. Recently we have begun to use radar to probe the planet's surface from Earth. In addition, more than 20 robot spacecraft have visited Venus since 1962, and (together with Earth-based studies), they have revealed our neighbor planet to be more alien than we had suspected.

Where is Venus and how big is it?

Venus is the second-closest planet to the Sun; little Mercury is the only one closer, and our planet Earth is next-farther out. Venus orbits around the Sun in a very nearly circular path, about 3/4 as far from our star as the Earth is, and takes about 225 Earth days to complete one orbit. It is almost exactly the same size and mass as the Earth, and like the Earth, it has a gaseous atmosphere. However, that's about the end of the similarities! (See the table "Venus and Earth" for a detailed comparison of the two planets' major characteristics and the "Activity Corner" for a way of bringing some of them to life for your students.)

Why is it so hot on Venus?



An ultraviolet image of Venus taken by the Pioneer Venus Orbiter spacecraft. (Photograph courtesy of NASA).

Soviet and American probes have landed at many places on the surface of Venus — and all have reported temperatures above 900° Fahrenheit, day or night. (For comparison, the temperature in an oven broiler is "only" 500°.) Part of the reason for the high heat is that Venus is closer to the Sun than we are — but that's by no means the whole story! Mercury is even closer to the Sun — but its surface is cooler than Venus's. Most of the heat on Venus is due to the peculiar heat-trap its atmosphere provides. (Mercury has no atmosphere to trap heat.)

Venus's massive atmosphere is made mostly of carbon dioxide, which has a peculiar property: it is transparent to visible light, but nearly completely blocks infrared — sometimes called "heat radiation". On Venus, intense sunlight filters through the clouds and heats up the rocks on the surface. Those rocks then "glow" infrared, but the carbon dioxide doesn't allow that infrared to get out. Instead, its energy is trapped in the atmosphere, adding to the heat provided by sunlight.

Ordinary window glass behaves in much the same way on Earth as carbon dioxide does on Venus. Imagine a car parked in a sunny parking lot with the windows rolled up. Sunlight gets through the windows, and warms up the car's interior. The seats then radiate infrared — which is trapped by the windows, because the glass doesn't allow heat radiation to escape easily. In part because of that, heat builds up in the car, and when you open the door... Whew! It's hot. In a way, Venus can be thought of as a car that's been left in a sunny parking lot for four billion years with the windows rolled up.

A Weather Forecast on Venus

This might be a weather forecast for a typical day on Venus: "Today's weather will be cloudy (as it has been for as long as anyone can remember). Temperatures will range from the low to high 900s, Fahrenheit. Atmospheric pressure will continue to be high — about 90 times has high as it ever gets on our neighbor planet, Earth. Winds will average around four miles per hour (but may still be able to knock you over because of the extremely high pressure), and there is the usual chance of misty precipitation of sulfuric acid. The Sun will set in the East about two months after sunrise."

You might assign composing such a forecast for Venus (and other planets) to your students.

What are Venus's clouds made of?

Venus's surface is perpetually shrouded by the clouds — but those clouds aren't like the puffy white water clouds of Earth. Instead, our "sister planet's" clouds seem to be made of sulfuric acid droplets. But lack of water doesn't mean lack of weather: strong lightning bolts have been recorded in Venus's atmosphere, and it is possible that the acid vapor occasionally precipitates into rain or fog — imagine a rain of 900° acid, complete with booming thunder-claps!

Is there water on Venus?

No. An American robot probe, dropped into Venus's atmosphere in 1978, found some evidence that there may once — hundreds of millions of years ago — have been some water vapor in Venus's atmosphere. But now there is almost no water there at all (even as vapor in the atmosphere.) Compared to Venus, the Sahara Desert is like a swamp.

What would daylight be like on Venus?

Under the clouds, on the surface of Venus, daylight is hazy yellowish, and about as intense as it is on Earth during an overcast day. Daylight persists for a long time — it's about two Earth months from sunrise to sunset on Venus. Also, if someone on the surface could see up through the clouds. the Sun would rise in the west and set in the east.

The reasons for the Sun's slow, backward path across Venus's sky have to do with the planet's rotation (spin). Most bodies in the solar system (including the Earth, the Sun, and all but a very few of the major planets and satellites) spin counterclockwise as seen from above their north poles. Venus spins clockwise (astronomers are not sure why). Venus spins much more slowly than the Earth does, too — so slowly, in fact, that its motion in orbit around the Sun plays as large a role in where the Sun appears to be in the sky as does its spin rate. This is very different from the Earth, where our 24-hour day is so much shorter than our year. Venus, on the other hand. takes 243 Earth days to spin once on its axis and 225 Earth days to go around the Sun. As a result it is not so straightforward to calculate the time between one sunrise and the next on Venus, which turns out to be 117 Earth days.

What have our radar experiments revealed about the surface of Venus?

The American *Pioneer Venus* Orbiter and the two 1983 Soviet *Venera* spacecraft (see table) each carry radar instruments which have been mapping Venus's surface through the clouds. Much information about the surface has also been obtained by radar from Earth.

These experiments have shown that most of Venus's terrain is low, rolling hills, and overall is much "flatter" than Earth's surface. There are two large, raised areas (perhaps similar to Earth's continental areas but, of course, not surrounded by water.) The larger of the two, called "Aphrodite Terra", is just south of Venus's equator and is about half the size of Africa. The other "Ishtar Terra" in the northern hemisphere, is about the size of Australia. Ishtar Terra has the highest point on Venus: Maxwell Montes, which is taller than Mt. Everest.

If Venus is such an uninviting place, why are we interested in it?

True, Venus is not likely to be a place for people to colonize — or even to visit on vacation — since its surface conditions are so vicious (at least to us). But it does show us what a planet much like the Earth (in overall characteristics) might be like if conditions were slightly different — and what Earth itself could become if we're not careful! By comparing weather patterns on Venus with those on the Earth, for example, we may be able to figure out more clearly what the factors are that determine the long-term climate of a world. Also, since carbon dioxide (the main villain in making Venus's conditions so hellish) is only a very minor component of Earth's atmosphere now — but is also a major and increasing by-product of fossil-fuel use — studying Venus's weather can provide potentially vital information concerning the future management of our own planet's atmosphere. And, too, Venus is the closest example of another world — and another global arena in which to exercise our curiosity.

Exploring Venus

Target: Venus
The Soviet VEGA Spacecraft

Two remarkable "busloads" of automated spacecraft were launched toward Venus by the Soviet Union in December of 1984. Each one contains three separate modules: one lander and one balloon-carried atmosphere probe to be dropped off at Venus in June, 1985, and one major package of instruments which will continue on to encounter Halley's Comet in March, 1986.

The two ensembles of instruments are called "VEGA-1" and "VEGA-2", abbreviations of the Russian words for Venus (*"Venera"*) and Halley (*"Gallei"*). They are now on their way toward their first target, Venus, and reportedly are working well. While the Soviet Union has a relatively long history of sending probes to Venus, these spacecraft are very unusual in two major ways. First, the deployment of the balloon-probes (if successful) will mark the first time any human-made spacecraft will float in another planet's atmosphere, and, second, the craft are truly international: they carry experiments from France — and from the U.S.!

The most fascinating of the VEGAs' experiments at Venus involve thhe two balloon-probes. After being jettisoned from the two main spacecraft, the two shrouded probelets will plummet to the middle layer of Venus's acid clouds. They will arrive on the night side of Venus, when the temperature in the middle cloud deck is expected to be between 60 and 160° Fahrenheit.

When the two spacecraft have fallen to the proper depth, their helium-filled, ten-foot-wide balloons will spring out. Then, tethered some 50 feet below each balloon, a five-foot-tall cylindrical gondola full of instruments will drift with the warm Venusian winds about 30 miles above the planet's superheated surface.

The gondolas carry a number of scientific instruments, including ones you might expect for a "weather balloon" here on Earth: thermometers and barometers, for example. Also, there are devices for monitonng lightning flashes, vertical wind speeds (for quick up- or down-drafts), and the density of the acid droplets in the clouds. (The density-measuring device was designed by NASA scientist Boris Ragent, working with France's National Center for Scientific Research, which is participating with the USSR on the VEGA missions.)

But perhaps the most important information will be simply the gondolas' *locations* — how they are carried around will disclose much about the unknown circulation patterns of Venus's atmosphere at that level. Radio signals from the floating spacecraft will be picked up on Earth (67 million miles away) by a global netvvork of large radio receivers, the most sensitive of which will be three enormous dish antennas operated by NASA. Computer analysis of the signals received by the network will allow extremely detailed track to be kept of precisely where the probes are and how fast they're moving. In fact, scientists expect to be able to "see" changes in balloon speed as small as 2 m.p.h.!

The batteries which power the balloon-borne instruments can operate for about 60 hours before they run down. but the Soviets expect the mission to end before then: after about 40 hours. the balloons are expected to cross from the night side of Venus to the day side. It's likely that heat from sunlight will cause the balloons to swell — and pop. Even so. they will almost certainly survive far longer than the total time logged so far by Venus landers.

Venus and Earth: A Comparison

	Earth	**Venus**

Average Distance from the Sun (millions of miles)	92.6	67.2
Orbit period (in Earth days)	365	225
Spin period[a]	23.9 hours	243 Earth days
Spin direction (as seen from North)	Counterclockwise	Clockwise
Mass (times Earth's)	1.00	0.815
Diameter[b] (miles)	7930	7520
Average density (times liquid water)	5.5	5.3
Surface gravity (times Earth's)	1.00	0.905
Number of natural moons	1	0
Number of working artificial satellites	hundreds	3[c]

Notes:
a — These are the planets' "sidereal" spin periods: the time they take to rotate with reference to the stars, rather than the Sun.
b — These are the planets diameters across their equators.
c — *Veneras* 15 and 16 and the *Pioneer Venus Orbiter*.

Exploring Venus

Resource Corner

Selected Readings

Beatty, J.: "Report from a Torrid Planet" in *Sky & Telescope*, May 1982,p.452.

Chapman, C.: "The Vapors of Venus and Other Gassy Envelopes" in *Mercury*, Sep/Oct 1983, p. 130.

Cordell, E3.: "Venus" in *Astronomy*, Sep. 1982, p. 6. Hunt. G. & Moore, P.: The Planet Venus (Faber 8L Faber. 1982)

Sagan, Carl: "Heaven and Hell" in *Cosmos* (1980, Random House) — This eloquent chapter from the best-selling book compares Earth and Venus.

Weaver, K.: "Mariner Unveils Venus and Mercury" in *National Geographic*, June 1975.

Slide Sets

The Solar System Close-Up (130 of the best spacecraft views of the planets and satellites. with detailed nontechnical captions) — available from the Astronomical Society of the Pacific

Pioneer at Venus (5 slides) — available from Hansen Planetarium

Films

Venus Pioneer (1979, 28 min. # NAV-042, available from NASA Audio-Visual offices around the country.)

The Solar System (1980, 20 min, National Geographic Society)

The Solar Svstem (1982, 28 min, International Film Bureau)

Close-up of the Planets (1982, 20 min, Walt Disney Educational Media)

Activity Corner: "Scaling Down The Solar System"

by John R. Percy, University of Toronto

The contemplation of distances in the universe is enough to strain and boggle the mind. It is one of the most fascinating but difficult aspects of astronomy. The following scale model may help to clarify matters for student and teacher alike. It is based on the scale of 1 to 3,000,000,000. On this scale, the Earth would be represented by a pea, and the Moon by a grain of sand 13 cm. away. (This then represents the distance which was traversed by the astronauts on the Apollo moon missions.) The inner part of the model can be set up in and around the school yard, but the outer part cannot. In fact, the nearest star on this scale would be on the opposite side of the Earth! The stars in our Milky Way galaxy would stretch all the way across the Earth's orbit, and the nearest large galaxy to our own (M31 — the Andromeda galaxy) would be on the edge of our solar system! You could make the scale ten times smaller, so that the solar system would fit within the school yard, but then the Earth would shrink to the size of a grain of sand.

When you set up your model, remember that the planets lie more or less in a plane (as they will in your model) but they do not generally lie in a line — so try not to put them that way. The nearest star is not in the same plane as the planets. The students can do some research on where it will lie in your model.

You can have older students try to fit other well known astronomical distances to this scale or experiment with changing the scale in different ways. Younger students will have an instructive time laying out the inner solar system in the classroom and outside and seeing where the limits of the school area can take them in the solar system.

Object	**Distance**		**Diameter**		**Represented by a**
	million km	**meters**	**thousand km**	**millimeters**	
Sun	n/a	n/a	1392	464	beach ball
Mercury	58	19	4.9	1.6	sand grain
Venus	108	36	12.1	4.0	pea
Earth	150	50	12.8	4.3	pea
Mars	228	76	6.8	2.3	rice grain
Jupiter	778	259	143	48	golf ball
Saturn	1430	477	120	40	pingpong ball
Uranus	2870	967	51	17	grape
Neptune	4500	1500	49	16	grape
Pluto	5900	1970	3	1	sand grain
Nearest Star	40×10^6	13300 km	1400	465	beach ball

These distances and diameters are taken from the *Royal Astronomical Society of Canada's Observer's Handbook* for 1985, edited by Roy L. Bishop.