ASTROFAX

BULLETIN OF THE ATA ASTRONOMY STUDY UNIT
VOLUME 32, ISSUE 1
Spring 2024
WHOLE NUMBER 125
https://www.astronomystudyunit.net/

Check out the top 10 Astrophilately stamps for 2023 posted on the ASU website: https://www.astronomystudyunit.net/astrophilately-top-10-in-2023

Call for article contributions to Astrofax! We would love to hear from you! Please consider writing a short article (any length will do) on your favorite astronomy stamps, your fav collection, or anything related to astronomy and philately!

In This Issue

Planetary Environments Part 4: Venus

by Garry Toth and Don Hillger (Un-manned Satellite Philately)

This is the fourth article in the *Astrofax* series on planetary environments. The first three appeared in the previous three issues:
1. *Planetary Environments, Part 1: Introduction* (Volume 31, Issue 2, Summer 2023)
2. *Planetary Environments, Part 2: The Moon* (Volume 31, Issue 3, Fall 2023)
3. *Planetary Environments, Part 3: Mercury* (Volume 31, Issue 4, Winter 2023)

Venus is at 0.72 astronomical units (au) from the Sun, so that when aligned with Earth on the same side of the Sun, the two planets are only 0.3 au apart. The two are similar by mass, size, and geology, but their atmospheres and surfaces and space environments are very different.

Other than the Moon and the Sun, Venus is the brightest celestial object. It is sometimes referred to as the morning star or the evening star because it appears at dawn or at dusk. The ancient Egyptians considered it to be two different heavenly bodies, as did the early ancient Greeks who called it *Hesperus* (the star of the evening) and *Phosphorus* (the bringer of light) or *Eosphorus* (the bringer of dawn). Pythagorus (c. 570 – c. 490 BC) recognized that the two were a single heavenly body, which came to be identified with the Greek goddess of love and beauty, *Aphrodite*, and later with the Roman equivalent, *Venus*. It is the only planet named after a female deity.

The Maya observed Venus closely and based their religious calendar in part on its movements. The *Dresden Codex* (Fig 1) includes such observations, possibly from the first half of the 10th Century, in the form of an almanac that presents the full cycle of Venus' motions.

Figure 1. Germany (DDR), Sc 2208, 1981

Figure 2. Denmark, Sc 1035, 1995

In early Europe, the Alphonsine and Prutenic ephemerides provided the positions of celestial bodies, but while Tycho Brahe (1546-1601) was a young student at Leipzig, he found them to be wildly inaccurate. He therefore undertook a grand project of painstaking visual observations of stars and planets at his Uranienborg Observatory (Fig 2). His data (essentially, his life's work) would serve as the basis for the new Rudolphine astronomical tables, which were finally published by Kepler (1571-1630) in 1627.

Galileo (1564-1642) made his first telescopic observations of Venus in early 1610. He found that the planet has phases like those of the Moon and that it changes its apparent size, in a repeating cycle. This was evidence that Venus orbits the Sun rather than the other way around.

Venus transits (passages in front of the Sun as seen from Earth) are rare, occurring in pairs 8 years apart, with the pairs separated by more than a century. Most astronomers ignored the 1631 and 1639 transits because there was uncertainty about them in the Rudolphine tables. However, English amateurs Jeremiah Horrocks (1618-1641) and William Crabtree (1610-1644) swam against the current and ended up observing the 1639 transit. Horrocks wrote a paper titled *Venus in sole visa* (Venus viewed against the Sun), but he and Crabtree died before it could be published. It remained unknown until the Dutch astronomer Christiaan Huygens (1629-1695) came across it in 1661 and gave it to the Polish astronomer Johannes Hevelius (1611-1687) (Fig 3), who published it in 1662 along with his own work on the 1661 transit of Mercury. The newly formed Royal Society was chagrined to find that such important work, by two Englishmen, had been ignored for so long. Their observation of the 1639 transit of Venus came to be considered as the birth of modern British astronomy.

Figure 3. Poland, Sc 2828, 1987

Venus is almost featureless in an optical telescope. Nevertheless, Huygens speculated that it has an atmosphere. In Book 2 of *Cosmothereos* (published posthumously in 1698) he wrote *"What then, must Venus have no Sea, or do the Waters there reflect the Light more than ours do, or their Land less? Or rather* (which is most probable in my opinion) *is not all that Light we see reflected from an Atmosphere surrounding Venus, which being thicker and more solid than that in Mars or Jupiter, hinders our seeing any thing of the Globe it self, and is at the same time capable of sending back the Rays that it receives from the Sun?"* This idea would turn out to be correct.

In modern terms, the "albedo" of a planet is the amount of incident solar energy that is reflected back into space. Venus is bright: its cloud cover gives it an albedo of around 71%. For comparison, Earth's average albedo is around 39% (but is highly variable regionally and temporally because of characteristics such as surface type, season, latitude, cloud cover and time of day). The Moon is dark, with an albedo of around 7%. On the other hand, Saturn's little ice-covered moon Enceladus reflects more than 90% of the solar energy that it receives. It has the highest albedo of any body in the solar system.

In Saint Petersburg in 1761, the Russian polymath Mikhail Lomonsov (1711-1765) studied the refraction of solar rays around the disk of Venus as it entered a solar transit and again as it exited the transit. He concluded that only the presence of a sufficiently thick gaseous envelope could explain his observations, and so is generally credited with the discovery of the Venusian atmosphere. The SS1 in Fig 4 reproduces some of the diagrams he made as part of that work. Lomonosov believed that Venus' atmosphere could be even more dense than that of Earth, which as we shall see was a prescient hypothesis. Even Captain Cook (1728-1779) got involved with Venus: he was tasked with observing the 1769 transit of the planet in Tahiti (Fig 5). Some later scientists such as Dominique François Arago (1786-1853) (Fig 6) agreed with Lomonosov's conclusion, but further knowledge was hard to come by because Venus' cloud cover continued to hinder optical telescopic observations.

Figure 4. Central Africa, Mi BL2297, 2021

Figure 5. Norfolk Island, Sc 122, 1969

Figure 6. France, Sc B575, 1986

Measurements at non-visible wavelengths were eventually made. Infrared studies starting in 1932 showed that the Venusian atmosphere is composed primarily of carbon dioxide (CO_2). The astronomer Rupert Wildt (1905-1976) built on that idea and calculated in 1940 that the surface of Venus could be at around 400 K (127 °C) (as he pointed out, hotter than the boiling point of water!), because of the heat-trapping properties of CO_2. Could that be true? In the early 1820s, the French mathematician Jean-Baptiste Fourier (1768-1830) (Fig 7) was the first person to propose that Earth's atmosphere acts as a sort of insulator, like the panes of glass of a greenhouse. The British physicist John Tyndall (1820-1893) made the first experimental measurement of this effect in 1859. It has since come to be called the "greenhouse effect" (Fig 8). Because of the insulating effect of greenhouse gases such as CO_2, Earth's average near-surface temperature, 15 °C, is approximately 33 °C warmer than it would be in the absence of an atmosphere.

Figure 7. Liechtenstein, 2014

Figure 8. Great Britain, Sc 1465, 1992

The idea of extreme heat at the surface of Venus nevertheless remained controversial. Some, encouraged by science fiction writers, dreamed of a lush tropical climate beneath the Venusian clouds, but starting in 1956, microwave observations found surface temperatures greater than 600 K (327 °C) there! After that startling result, a scientific consensus about a "runaway greenhouse atmosphere" on Venus gradually developed (for example, in publications by the physicist Thomas Gold (1920-2004) in 1963, and the astrophysicist James B. Pollack (1938-1994) in 1971). The reader is invited to consult The Discovery of Global Warming for a fuller discussion of that idea in the context of Venus (and Mars) along with a large list of references.

The first successful radar observations of Venus were made in 1961 by the Goldstone (California) and Haystack (Massachusetts) Observatories. They demonstrated the extremely slow (and retrograde!) rotation of Venus. The Arecibo Observatory later did similar work. By the mid-1980s, some Venusian surface features as small as a few km in size could be resolved, but the geographical coverage was limited, and the technique provided no information about its atmosphere.

With the Space Age came the possibility of instrumented spacecraft that would be able to obtain much more detailed data about Venus than Earth-based techniques. Wikipedia provides a general list of 46 missions that went to Venus or picked up a gravity assist as they flew by to other destinations. For more detail, the reader can consult this list, which provides links to individual satellite pages at the NASA Space Science Data Coordinated Archive.

In what follows, the old pressure unit "bar" is used as a convenient shorthand for the approximate pressure at Earth's surface. In the 20th Century, isobars in weather maps had units of "millibars" (1000 mb = 1 bar). In the 21st Century, the SI unit "hectopascal" has come into use (1 hPa = 1 mb).

The Soviet Union actively explored Venus in its *Venera* program in the 1960s through the mid-1980s, with a lot of failures early on, followed by some major successes. The Mariner program provided the first American spacecraft that studied the planet.

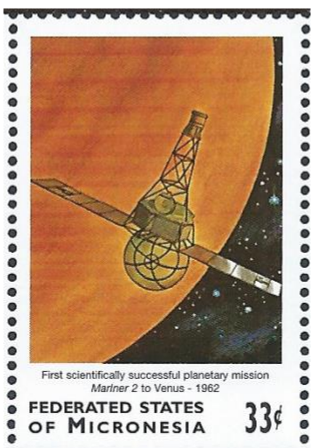

Figure 9. Micronesia, Sc 344c, 1999.

Mariner-2 was the "first scientifically successful planetary mission" (Fig 9). In 1962, it became the first spacecraft to fly by and observe another planet. It returned data on Venus' slow retrograde rotation, hot surface (428 °C), high surface pressures, predominantly CO_2 atmosphere, and cloud layers topped at about 60 km. It found no detectable magnetic field. As if all that weren't enough, the spacecraft had also, during its outbound journey, made the first measurements of the solar wind in interplanetary space!

Both the USA and the USSR had nearly simultaneous successes in 1967. *Venera-4* became the first spacecraft to return in-situ observations from the atmosphere of another planet when on 18 October it released an instrumented probe, which measured 90-95% CO_2, a few percent of nitrogen, and trace amounts of oxygen and water vapor. It observed a temperature of 40 °C high in the atmosphere and continued to transmit data until it reached around 25 km altitude, where it succumbed due to the ambient pressure (22 bars) and temperature (280 °C). On 19 October, *Mariner-5*, in a close flyby, remotely sensed the surface temperature (527 °C) and pressure (75 to 100 bars). Like *Venera-4*, it found no planetary magnetic field or radiation belts, but was able to determine that the dayside ionosphere induces a bowshock that deflects the solar wind around the planet (a sort of "induced

Figure 10. Yugoslavia, Sc 1049, 1971

magnetosphere" which is a weak analogue of Earth's magnetosphere). Fig 10 depicts both *Mariner-5* and *Venera-4* and its instrumented capsule descending by parachute.

Venera-5 through -8 (Fig 11 depicts Venera-8) were improved versions of *Venera-4*. On 22 July 1972, *Venera-8's* lander/capsule detected sulfuric acid in the clouds, made the first observations of wind speed as it descended through the atmosphere, and then made a successful soft landing (the second on another planet – the first was the short-lived Soviet *Mars-3* on Mars on 2 December 1971). For 63 minutes *Venera-8* transmitted data from the surface, where it measured a temperature of 470 °C and a pressure of 90 bars and found that there was enough light for photography.

Figure 11. USSR, Sc 4044, 1972

Figure 12. Guinea-Bissau, Mi 8074-8077, 2015

In October 1975 *Venera-9* (Fig 12) and *Venera-10* deployed landers to the surface and became the first spacecraft to orbit Venus. The landers' objectives were to make further in-situ measurements of the atmosphere and study the surface where they landed. *Venera-9* found clouds 30-40 km thick with bases at 30-35 km altitude and its lander transmitted the first black-and-white images from the surface of another planet. They show a barren, dim, and rocky landscape. *Venera-10* produced a profile of temperatures and pressures versus altitude and then transmitted photos from the surface. The four subsequent Venera spacecraft did not go into orbit but did deploy similar landers. In December 1978, the *Venera-11* and *-12* twin landers measured electrical discharges (possible lightning) and sulfur and chlorine in the cloud layers. In March 1982, the *Venera-13* (Fig 13) and *-14* twin landers detected three distinct cloud layers and returned the first color images from the surface.

The *Venera-15* and *-16* twins (Fig 14) were different. They were orbiters with radar mappers to study the planet's surface. Following their arrival in October 1983, they operated for 8 months and mapped the area from the North Pole to 30 degrees north.

Figure 13. Niger, Sc 1078c, 2001

Figure 14. Germany (DDR), Sc 2530, 1986

The ambitious *Vega-1/Vega-2* twins were the last Soviet Venus missions. In June 1985, each deployed a lander (like the *Venera*-9 to *-14* landers) and an instrumented balloon before speeding off to an encounter with Halley's Comet. The balloons floated in the clouds at around 53 km altitude and measured temperature, pressure, light, vertical motion, and concentrations of cloud particles. They were also tracked to record their positions and calculate their velocities. The *Vega-1* balloon provided data for around 47 hours during which it travelled 11,600 km at an average speed of 69 m/s. The "Venus-Vega" SS1 (souvenir sheet of one) of Fig 15 shows a *Vega* spacecraft and its balloon above *Aphrodite Terra* (a large highland area on Venus) in its stamp, while its left margin depicts the two *Vega* balloons and the descent of a *Vega* lander (erroneously identified in small text as "Venera-15"). The landers measured temperature profiles down to the surface.

Figure 15. Guinea, Sc 1086a, 1988

Figure 16. Paraguay, Sc 1713d, 1976

The last of the Mariner series, *Mariner-10* (Fig 16), flew by Venus in February 1974 while on its way to Mercury. From its closest approach of 5000 km, it took the first UV images of Venus and confirmed the planet's feeble magnetic field and its bow shock. *Mariner-10* also measured cloud-top temperatures and found a Hadley-type circulation in the clouds. On Earth, the average global circulation transports heat northward and southward from the equatorial region. This was the first hint of something similar in the clouds of Venus. On Earth, ocean currents also transport massive amounts of heat away from the equatorial regions, but there is no analogue for that on Venus.

The American *Pioneer-12* (*Pioneer-Venus-1*) went into orbit around the planet in December 1978. It was the first Venus orbiter with a radar surface mapper. It also carried a suite of remote sensing instruments to measure a variety of cloud properties and atmospheric characteristics. The clouds were found to consist mainly of sulfuric acid (H_2SO_4). *Pioneer-12* lasted until 1992 – far longer than its design lifetime. *Pioneer-13* (*Pioneer-Venus-2*) carried one large and three small atmospheric probes. They were released into the atmosphere in November 1978. The large probe measured temperature, pressure, and cloud characteristics as it descended by parachute into the equatorial nightside. The small probes had simpler instruments and no parachutes. The four probes were spread around Venus: two went to the dayside and two to the nightside. One of them even survived contact with the surface for a short time. Radio signals from all four were used to calculate atmospheric winds and turbulence. In Fig 17, *Pioneer-12* is at the left and *Pioneer-13*, including its four probes, is at the right.

Figure 17. Ghana, Sc 684, 1979

Figure 18, Malagasy, Sc 970a, 1990

The next Venus mission was the ambitious *Magellan* (Fig 18). It was the first interplanetary spacecraft to be deployed by a Space Shuttle (in May 1989, by STS-30R) and entered orbit around Venus in August 1990. By late 1994, when the mission ended, *Magellan's* radar had provided a high-resolution map of 98% of the planet's surface (Fig 19). The data showed no evidence of plate tectonics but did indicate that past vulcanism was extensive. Contrary to the situation on Earth's Moon and Mercury, there are few mid-sized craters on Venus, and *no* craters smaller than 1.5 km in diameter! Meteors of

Figure 19. Indonesia, Sc 1927c, 2001

the size that might cause them must have been ripped apart, before hitting the surface, by the aerodynamic stresses that they encounter in Venus' dense atmosphere. *"The dynamic pressure on a body deep in the atmosphere of Venus is roughly 100 times as high as at a comparable altitude on Earth"* (Ref 1, p. 120). Such airbursts should therefore be more frequent on Venus than Earth. Some do occur on Earth, though. The best example is the Tunguska event of 1908. It was a huge meteoritic airburst over Siberia that extensively damaged the forest but left no crater. It is the largest such event in recorded history. The Russian mineralogist Leonid Kulik (1883-1942) finally investigated the site in 1927 (Fig 20). *"Studying Venus with the* Magellan *radar mapper has given us truly enlightening insights into the phenomenon of breakup of incoming projectiles"* (i.e. meteors) in Earth's atmosphere (Ref. 1, p. 123).

Figure 20. USSR, Sc 2088, 1958

Magellan did not make atmospheric measurements. It did have a radiometry mode to measure the surface temperature. Figure 18 (above) includes in its right margin a graphic of temperature versus height. The x-axis is labeled with temperature values in degrees Celsius. The y-axis has no labels, but each division may represent 12 km. The temperature profile, of unknown source, is not from Magellan. It is too warm at its upper levels but does present a rough idea of the temperatures in the Venusian atmosphere.

ESA's *Venus Express* (Fig 21) went into orbit around the planet in April 2006 with the goal of making detailed, long-term studies of the atmosphere, the surface, and the space environment. The mission lasted until 2014. Soon after *Venus Express* entered its orbit, it recorded a spike in atmospheric SO_2. That spike may have been caused by a plume of gases from a major volcanic eruption. If Venus is photographed in UV light, its clouds show up with more detail than in visible light. Such images can be used to track cloud elements and calculate the winds. Fig 22 shows a *Venus Express* UV image taken on 23 July 2007 from 35,000 km above the surface. The spacecraft made a wide variety of scientific observations. It confirmed the existence of cloud-level zonal super-rotational winds of 300 km/h or more (which may be related to an energy transfer from the warmer dayside to the cooler nightside). It found that the induced magnetosphere is more active than previously thought. It measured the loss of hydrogen (one component of water) to space, a loss driven by the solar wind. It found possible evidence of atmospheric lightning. It found that the dayside cloud layer, exposed to the Sun for long periods due to the planet's slow

Figure 21. Guyana, Sc 3929, 2006

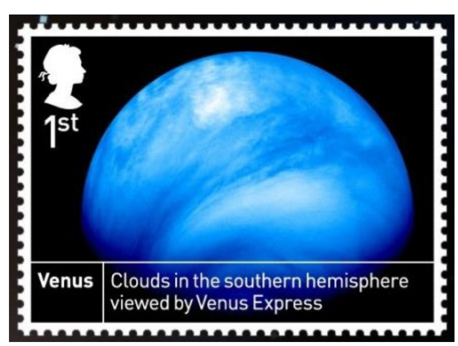

Figure 22. Great Britain, Sc 3114, 2012

rotation, absorbs enough solar radiation to form roiling pockets of convective clouds, which may be part of a poleward transfer of energy in the main cloud deck (this result has tantalizing similarities with some of *Mariner-10's* observations). It confirmed the existence of anticyclonic vortices in the clouds near the Poles, which may be related to warming via subsidence in their centers.

Figure 23. Gambia, Sc 3647, 2015

The Japanese *Akatsuki* (*Venus Climate Orbiter*) (Fig 23) is the most recent mission to Venus. It missed its first orbital attempt in 2010 and had to settle for a less-than-optimal orbit in 2015. It has five cameras (three IR, one UV and one for visible light) to "see" into different depths of the clouds to study the planet's super-rotational winds. It found that they are strongest near the equator. Other goals are to confirm the presence of lightning and active volcanoes, but the authors are not aware of any progress in those areas.

Venus is the hottest planet in the solar system (even hotter than Mercury!) because of the runaway greenhouse effect. The atmosphere (96.5% CO_2, 3.5% nitrogen, and trace amounts of everything else) is so dense that it has some characteristics of a liquid in its lower levels. The surface (with a pressure is 93 bars) is covered with a sort of "ocean" of supercritical CO_2 which is so dense that its motion is more like a water current than blowing wind, so that it can move sand and small pebbles even though the "wind" speed is small. The Venusian surface temperature, 470 °C, varies little in space or time, which is consistent with the fact that supercritical CO_2 transfers heat very efficiently. The clouds appear to produce sulfuric acid rain but are so high that it evaporates as it falls and never reaches the surface (on Earth, this is known as virga).

Venus has almost no water, though it may have been like Earth in the earliest days, with water oceans. Where did the water go? Why did the greenhouse effect become so strong? Where did all the carbon come from? What photochemical processes create the sulfuric acid clouds? Why are they so high? Can lightning develop in them? Was Venus more volcanically active in the past than it is now? Are volcanoes the source of the atmospheric sulfur? What physical mechanisms cause the atmospheric circulations (such as the super-rotational winds) and heat transfers? What is the effect on the atmosphere of the solar wind and bow shock and the associated induced magnetosphere?

Future spacecraft will attempt to answer those and other questions. An Indian Venus orbiter, *Shukrayaan*, is planned for 2028. NASA is developing *DAVINCI+* (*Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging*) for a possible 2031 launch, and its *VERITAS* (*Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy*) counterpart would follow soon thereafter. ESA's *EnVision*, planned for the early 2030s, will study the planet from its core through to its upper atmosphere, to try and determine why Earth and Venus evolved in such different ways.

The MS2 (minisheet of two) in Fig 24 features some spacecraft missions to Venus along with the inscription *Prévision météo de Vénus* (Weather forecast for Venus). However, text such as *Étude de l'atmosphère de Vénus* (Studying the Venusian atmosphere) would more accurately describe a significant part of the scientific work of instrumented spacecraft exploring other worlds in the solar system. In its broadest sense, that phrase refers not only to planetary weather and climate, but also to related surface features and space weather effects. The authors will continue to apply that framework in Part 5 of this series, which will feature Mars.

Figure 24. Togo, Sc 345a, 1978

Extensive lists of stamps and covers for the spacecraft discussed above (and many more) are found in the Planetary Spacecraft page of the authors' Un-manned Spacecraft website. Our list of philatelic items for Planetary Environments is also available online.

References

Ref. 1: Lewis, John L., 1996: *Rain of Iron and Ice*, Helix Books, Addison-Wesley Publishing Co., ISBN 0-201-48950-3, Ch. 9, pp. 120 and 123.

About the Authors

Garry Toth, M.Sc., now retired, worked many years with the Meteorological Service of Canada. Correspondence to gmt.varia@gmail.com is welcome.
Don Hillger, Ph.D., now retired, was a research meteorologist with the National Oceanic and Atmospheric Administration (NOAA) and held a cooperative position at Colorado State University. Correspondence to don.hillger@colostate.edu is welcome.

We have researched and written extensively about weather, climate, and unmanned spacecraft on stamps and covers, as well as some other topics. See our complete list of our publications, with electronic reproductions.

The Great North American Total Solar Eclipse

by Gene R. Major

As I'm sure all of our readers are aware, there will a total solar eclipse on 8 April 2024 extending from Mexico, across the U.S. and over eastern. Exact timing depends on where you are. Check out these resources: