



The Mercury MESSENGER



Issue 2

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Revised Atmospheric Species Abundances at Mercury: The Debacle of Bad g Values

Only two of the five known elements in the atmosphere of Mercury, sodium and potassium, can be observed from Earth. Our knowledge of the other elements in the atmosphere of Mercury is derived almost entirely from the Mariner 10 extreme ultraviolet experiment. The existing reference data on the abundances of atomic hydrogen, helium, and oxygen has been the report of *Broadfoot et al.* (1976). Questions raised during work on a recent review of the sodium atmosphere (*Hunten et al.*, 1988) have prompted me to reexamine the scattering probabilities for solar radiation (g values) that are required to obtain abundance estimates from the measured emission intensities.

Unfortunately, there appears to be no record of the g values used to calculate the abundances given in *Broadfoot et al.* (1976). As one of the authors of that paper I have concluded that a further search for the original calculations would be of little use because we now have much better information on the required parameters. I have recalculated the g values for hydrogen, helium, argon, and oxygen based on current estimates for the solar flux at the relevant wavelengths, and these are listed in Table 1 together with the resulting subsolar point densities for each species. Sodium and potassium have been included also (see *Hunten et al.*, 1988 for a discussion of the two H distributions). The largest deviations from the previously accepted values are for hydrogen and oxygen: the new abundance for hydrogen is 2.3 times that reported in *Broadfoot et al.* (1976), while for oxygen the abundance is 6.2 times their quoted value.

The Mariner 10 data were obtained when Mercury was at aphelion so that values of g at the line center were appropriate. Footnotes to Table 1 discuss the value for the solar flux used in each case to calculate the g value for hydrogen, helium, oxygen, and argon.

Two are discussed in detail here. The H Ly α solar flux for 16 March 1975 was predicted by using the solar He 10830A equivalent width for 16 March 1975 normalized to the Solar Mesospheric Explorer (SME) data from 1982 (see *Skinner et al.*, 1982). The value obtained is similar to that obtained using the Pioneer 10 data for H Ly α from the local interstellar medium (*Shemansky et al.*, 1984). The H Ly α does not appear to change shape over the solar cycle (*Ajello et al.*, 1987). The g value for O I 1304A is based on the work of *Dymond et al.* (1987). They obtained line shapes and relative intensities of the O I (3P-3S0) triplet from the Solar Maximum Mission data, and the absolute intensity from the SME data.

The revised abundances listed in Table 1 have now elevated oxygen to the status of the dominant species, providing some relief for the problem of finding an explanation for the presence of large amounts of sodium.

TABLE 1.
Revised g values at Mercury.

Species	Wave-length (A)	g(s ⁻¹)	N ⁰ (cm ⁻³)
H*	1216	5.3 × 10 ⁻³	23,230
He [†]	584	5.1 × 10 ⁻⁵	6 × 10 ³
OI [‡]	1304	2.1 × 10 ⁻⁵	4.4 × 10 ⁴
Ar [§]	867	5.5 × 10 ⁻⁸	<6.6 × 10 ⁶
N _α	5890, 5896	2.45, 1.22	1.7-3.8 × 10 ⁴
K	7664, 7699	3.24, 1.67	5 × 10 ²

*I = 2.25 × 10¹¹ Ph cm⁻² s⁻¹ at 1 AU;
I_v/I = 1.42 × 10⁻² cm.

†I = 1.28 × 10⁹ Ph cm⁻² s⁻¹ at 1 AU;
I_v/I = 3.52 × 10⁻² cm.

‡I = 5.19 × 10⁹ Ph cm⁻² s⁻¹ at 1 AU;
I(1,2)/I = 0.25; I(1,1)/I = 0.333;
I(1,0)/I = 0.417; I_v/I = 7.9 × 10⁻² cm.

§I_v = 5.86 × 10⁵ Ph cm⁻² s⁻¹ (cm⁻¹)⁻¹ at AU.

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In This Issue

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Mayan Owls and Mercury

The Quiché Maya people live in the highlands of Guatemala. They speak a Mayan language, say prayers to Mayan mountains and Mayan ancestors, and keep time according to the Mayan calendar. For them, it is not that the time of Mayan civilization has passed and has been followed by the time of European civilization, but that the two have begun to run alongside one another. The *Popul Vuh* is the Quiché Mayan book of creation, the Mayan bible, and is considered one of the most important texts in any of the native languages of the Americas. The *Popul Vuh* was set down in alphabetic Mayan during the middle of the sixteenth century by members of the lordly lineages that had once ruled the Quiché kingdom, and who had been taught to read and write by the Spanish priests.

A recent translation and analysis of the *Popul Vuh* by Dennis Tedlock, who was trained by a native Quiché master, has shed some light on the astronomy of the Quiché Maya, and includes some interesting comments relative to Mercury (Tedlock, 1985).

The Mayan underworld was called Xibalba, and was ruled by seven lords, whose chief was called One Death. The underworld lords had four messengers that were used to carry messages to and from the upper world. These were all owls, called Shooting Owl, One-legged Owl, Macaw Owl, and Skull Owl, respectively. Tedlock suggests that these correspond to the planet Mercury, with perhaps one pair of owls for its waxing and waning morning star aspect, and the other pair for its evening star aspect. The basis for his suggestion is that the movements of the four owls, as described throughout the text of the *Popul Vuh*, match the movements of the planet Mercury. In addition, the appearance of the planet only during dawn and evening twilight corresponds well with the habit of owls, who normally can be seen to fly in daylight only during twilight times.

The name Shooting Owl is best interpreted as "stoop like a hawk." This owl was the first-ranking Military Keeper of the Mat. One-legged Owl is described as the second-ranking Military Keeper of the Mat. The Maya point out that owls only stand on one leg at a time, so One-legged Owl may resemble a standing owl. Macaw Owl is described as having the head and wings of an owl, but the tail and red back of a macaw.

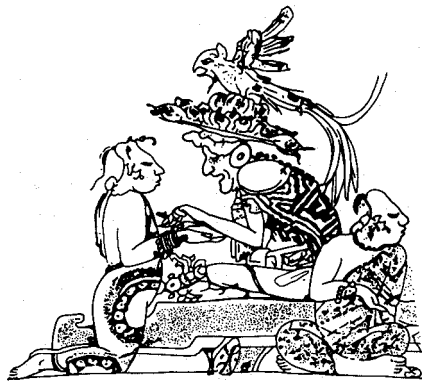


Figure 1.

He is the third-ranking Military Keeper of the Mat. Skull Owl, who is the fourth-ranking Military Keeper of the Mat, has only a head and wings, and no legs.

Macaw Owl is illustrated in Fig. 1, shown perched on the head of One Death. Prehispanic representations of owls, as published by de Ruiz (1979), yield one illustration that might be identified as Shooting Owl. This is shown in Fig. 2, where an owl in the act of swooping down on his prey is depicted. Another illustration might be a representation of Skull Owl, as shown in *The Mercury Messenger* logo. It is certainly an owl with a skull for a head, but differs from the *Popul Vuh* description in that it has legs.

As depicted here, Skull Owl appears to be a rather cheerful and alert fellow, gritting his teeth to overcome difficulties, perhaps those encountered as the lowest ranking of the messengers. He might be a fitting symbol for the present-day Mercury researcher, who faces many difficulties but still remains optimistic.

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Figure 2.



Mercury Orbiter Science Working Team

Even after the Mariner 10 flybys in 1974-1975, little is known about Mercury's surface, interior, composition, and geologic history. Constraints on the size of Mercury's fluid outer core are quite broad because of the large uncertainties in the areal distribution of thrust faults and their heights. This is due to the Mariner 10 imaging of less than 40% of the surface, with only ~25% at high phase angles. Because of this and other limitations of the Mariner 10 observations, there are many questions that remain about the planetology of Mercury, including its origin, magmatic and thermal history, internal structure, impact processes, tectonics, and gravity field. A fully instrumented orbiter would answer many of these questions, providing comparative planetological insights into the conditions under which processes dominate.

Magnetospheric Physics

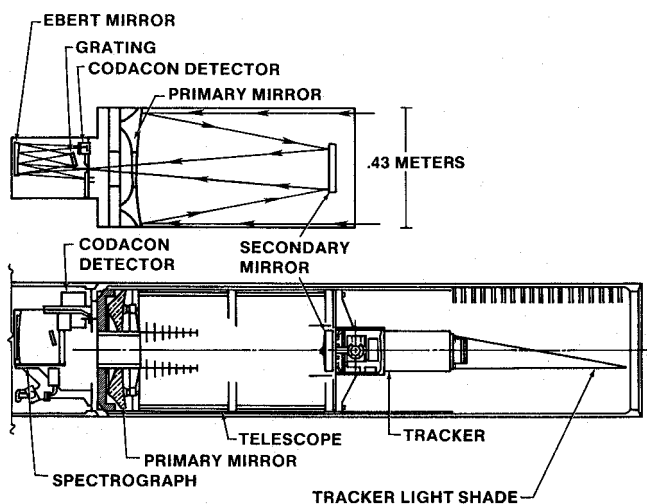
Mercury also offers an exciting and unique opportunity in comparative magnetospheric physics. It is the only planet with a magnetosphere similar to that of Earth's but with fundamental differences suggesting that a study of phenomena at Mercury would provide insight into the fundamental physics of both environments. Major differences from the Earth include the lack of an appreciable ionosphere, the large size of the planet compared to the magnetosphere, the rapid time scale of substorm processes (minutes vs. hours at Earth), and the possibility of a plasma dominated by heavy ions (e.g., sodium). The rapid dynamic time scales and small spatial scales at Mercury allow orbiting spacecraft to gather information at a rate not possible at Earth. Thus a Mercury orbiter can explore questions about magnetospheric structure and dynamics in a manner possible at no other planet.

Focus of Study Team

The present focus of the study team, which last met in April 1988, is on magnetospheric, solar wind interaction, and solar effluent physics studies. The objective is to define a moderate cost mission with highly elliptical, low-periapsis (200-300 km altitude) spacecraft to be launched in 1997 or 1999 on Titan IV/Centaur class vehicles.

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Observing Mercury from Venus Orbit Using The Pioneer Venus UV Spectrometer



Schematic diagram of proposed UV spectroscopic sounding rocket experiment for observing Mercury in 1800-3000 Å spectral range.

The Pioneer Venus Orbiter has been in orbit about Venus since late 1978 (Colin, 1980). The Ultraviolet Spectrometer (UVS) aboard that spacecraft was designed to study the UV spectrum of the Venus airglow, the Venus hydrogen corona, and the Venus clouds (Stewart et al., 1980). In addition, the UVS has also observed the emission spectra of four comets: P/Halley, P/Giacobini-Zinner, and P/Encke (Combi et al., 1986), and Wilson (Stewart, 1987).

The UVS contains a 0.125-m Ebert-Fastie scanning grating monochromer with a small cassegrain telescope and dual PMT detectors. The UVS is an f/5 system and Al/MgF₂ optics are employed. The grating is blazed at 1600 Å, and can be moved in 4.4 Å steps in the range 1100-3300 Å. The instrumental resolution is 13 Å; the FOV is 0.14 × 1.4°. An integral sunshade provides solar rejection of 10⁻⁴ at 1.5° off-axis, and an additional factor of 10 rejection for each succeeding 6°.

The UVS is offset from the spacecraft spin axis. As PV spins at 5 rpm, the UVS traces out a 1.4° swath over a 60° half cone. To calculate the time needed to acquire UVS data at a point source, the 1:2200 duty cycle generated by the spinning PV bus and the instrument TM sampling rate duty cycle must each be accounted for.

However, because off-Venus observations require expenditure of onboard propellant and the suspension of Venus data acquisition, prospective Mercury observations must be scientifically justifiable. Two important experiments come to mind: determining Mercury's UV color, and monitoring the time dependence of Mercury HI and OI emissions. The UV color and albedo of Mercury have not been measured between 1800 and 3300 Å. Although Mercury will appear as a point source to the UVS, spatial resolution can be inferred from observations at different disk illumination geometries. Monitoring of the Ly α and OI signatures of Mercury is important to understanding the orbital variations in Mercury's atmospheric bulk and magnetospheric trapping efficiency.

Calculations demonstrate that a UVS measurement of Mercury's UV reflectance at 2500 Å would require a week to obtain. However, measuring the ~150 Rayleigh Ly α and OI (1304 Å) signatures of Mercury would require just 12 hours.

I have spoken with Ian Stewart, the principal investigator on the Pioneer Venus UVS instrument, and Ian has encouraged me to determine if an effort should be made to observe Mercury from PV. Those with expressions of interest (or new ideas!) should contact me at the following address:

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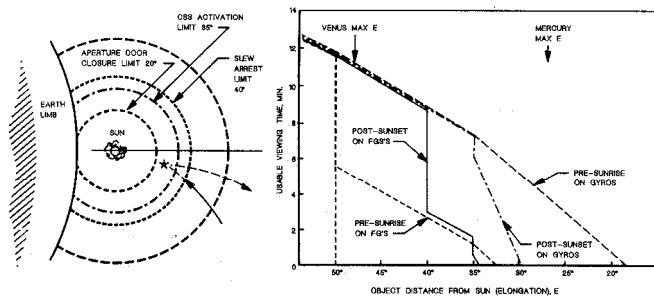
The Hubble Space Telescope Observations of Mercury

The Hubble Space Telescope (HST), to be launched in late 1988, will start a broad and varied observation program. With a 2.4-m aperture, the telescope will produce an image of better than 0.1 arcsec resolution. Although the telescope will contain six focal plane instruments, the only instrument that will be able to observe Mercury will be the Planetary Camera, because only the field of view of the Planetary Camera is large enough to include Mercury when pointing using gyro reference only. The Mercury data must be taken during short specific intervals and, in general, there will not be time to access the fine guidance star sensors.

The HST has a 50° solar avoidance zone, and, because Mercury always lies within 28° of the sun when viewed from the Earth, special arrangements must be made to take pictures of Mercury with the Planetary Camera. This obstacle was studied by the Lockheed Missiles and Space Company, with results described in their report *Design Reference Mission, SE-01*, February 24, 1984.

Mercury can be viewed by using the Earth as an "occluding disk" in the morning before sunrise. The HST is slewed into position to view Mercury while the Earth is shielding the sun; data are taken as Mercury rises above the Earth's limb. The HST is then slewed away from the rising sun before the coarse sun sensor signals aperture door closure. Because the viewing time is short, there is not time to acquire guide stars and pointing must be carried out on gyros. Mode 3 (blind pointing) target

(continued on next page)



Geometry for HST observations of objects within 40° angular separation from the sun at sunrise and sunset (Sherrill, Design Reference Mission, SE-01, Lockheed Missiles and Space Company, Inc., LMSC/D613561B).

Hubble Space Telescope (continued)

acquisition must be used will all four CCDs to assure that Mercury will be in the field of view.

The available time to view Mercury varies linearly with the elongation (distance from the sun) and is about 4.2 min at 28° elongation and 0 min at 18.4° elongation. The time for a short exposure (0.11 to 40 sec) of the Planetary Camera and for readout of the four CCDs is 2 min. Since readout can occur as the spacecraft is slewing, the number of available exposures varies from one at elongation 18.5° to three at elongation 28°. Data can be taken on successive orbits with different filters. The UV or blue filter should be used to obtain the best surface resolution.

The pixel size of the Planetary Camera is 0.043 arcsec; at the distance to Mercury at maximum elongation, this corresponds to approximately 30 km. If there is time for more than one exposure, a slew of 1/2 pixel horizontal can be made between the first and second frames and a slew of 1/2 pixel vertical can be made between the second and third frames. These pictures can then be processed in the computer to improve the quality of the combined image.

*Merton E. Davies
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About This Newsletter

The establishment of a Mercury Orbiter Science Working Team indicates a new awareness of the central role Mercury may play in our developing understanding of the solar system. Much of what we have included in this report relates to past, present, or future studies from space. Observations of the planet Mercury from ground-based telescopes can also lead to a new understanding of the planet. In particular, several groups are now making infrared observations of Mercury. We hope that we will receive contributions on the progress being made with ground-based observations for upcoming issues of the newsletter.

We will be pleased to accept new additions to the mailing list. If you are interested in Mercury, please write us at the following address:

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