Is Venus Prolate?

The results from Mariner V and Venera 4 force us to reexamine many cherished concepts about the planet Venus. On the one hand, the surface temperature of 544°K, measured by Venera at the nightside equator, is conspicuously less than the 700°K deduced from the microwave data (*1*), both ground-based and from Mariner II. Even Sagan, a proponent of the model which proposes a very hot, dry surface for Venus admits (*1*) that "the strictures against life at the very poles may be slightly relaxed."

On the other hand, the temperature measured by the Soviet probe is about 100°K higher than the surface temperature at the nightside equator predicted for a model by Plummer and Strong (*2*). This probably means that their assumption (that 30 percent of the microwave brightness is of nonthermal origin) is too high.

Recently, Libby (*3*) has revived the attractive notion, which dates back to Menzel and Whipple (*4*), that Earth and Venus are of similar overall chemical composition and volcanic history. Rubey's argument (*5*) for the gradual simultaneous liberation of terrestrial CO_2 and H_2O by volcanic action is generally accepted. Rubey also claims that the CO_2 in the total amount of limestone on Earth would result in a pressure of 18 atm if all the CO_2 were present as gas. Since a pressure of 18.5 atm was measured by Venera 4 and the atmospheric composition was found to be 90 ± 10 percent CO_2, one is led to ask (*3, 4*): "Why doesn't Venus form $CaCO_3$?" and "Where is Venus's water?"

The idea that oceans cover the entire planet (*4*) is ruled out by the high equatorial surface temperature. Libby (*3*) suggests that great ice caps, perhaps 5 km or more in thickness, may store the water, thus preventing the formation of significant amounts of limestone with the result that the atmosphere is overwhelmingly composed of CO_2, as observed.

There is, however, a significant weakness in Libby's argument for temperatures of 273°K at the polar regions. His hypothesis relies simply on the greater thickness (2.5 to 3 times) of the atmosphere of Venus through which polar surface emissions travel, as determined either from Earth or from the instruments on Mariner II (this spacecraft traveled essentially in the equatorial plane of the planet). Libby argues that scattering and absorption would affect the accuracy of the microwave observations.

From either the analysis of Clark and Kuz'min (*6*) or simple considerations of the radiation geometry for a purely spherical planet, one expects temperatures at the poles to be about 25 percent lower than at the equatorial antisolar point. Taking the Venera 4 value of 544°K for the equatorial antisolar temperature, one estimates a polar temperature of 407°K. This estimate neglects heat flow to the polar regions of this very slowly rotating planet (the Venus solar day is about 117 terrestrial days).

The surprisingly large vertical temperature gradient measured by Venera 4, which amounts to a lapse rate of 10°K/km, is thus pertinent. If Venus is prolate so that the radius of the planet at the pole is roughly 15 km greater than the radius at the equator, then the expected temperature in the polar region is close to 273°K, ice caps can be sustained, and the general notion that Earth and Venus have similar overall chemical composition and volcanic history is upheld. The "degree of prolateness" of the Venus radius is only about 0.0025, whereas Earth's radius has a "degree of oblateness" of about 0.003. A possible major source of error in such a model is the unknown rate of heat flow to the polar regions of Venus; large-scale computer calculations of the atmospheric circulation on Venus may supply some limits on the heat flow for reasonable atmospheric models.

Once the first layer of the polar ice sheet forms, the high reflectivity of the ice aids in maintaining the sheet, despite the solar radiation that penetrates the clouds. Furthermore, as the ice cap thickens, its weight, which is greatest at the poles, causes the underlying planetary surface to be depressed; this gives the surface a general bowl-shaped appearance, as seen approximately in Antarctica and in Greenland (*7*). Presumably, various high-pressure forms of ice with different crystalline structures, such as ice VII, will be formed (*8*).

It is necessary to ask whether such a slightly prolate planet is physically reasonable. On geological grounds, a prolateness of 15 km out of about 6000 km should be sustained for a very slowly rotating planet. The oblate nature of Earth is usually associated with its moderately high axial rotational velocity and is not an a priori argument against a prolate Venus. The marked deviations of Earth from hydrostatic equilibrium suggest that similar deviations may be found on other planets (*9*).

Nevertheless, a critic who assumes the modern theory of the origin of the solar system may argue that, when the planets condensed out of clumps of solar material ejected from a contracting sun, angular momentum must have been conserved; thus even Venus and Mercury had high axial rotational velocities when they were formed and were thus necessarily slightly oblate or at least spherical.

To answer this objection, we first note that the most common explanation for the fact that the planets have almost all the orbital angular momentum of the solar system, despite their very small total mass as compared to the sun, is "magnetic braking" during the formation of the solar system. Second, the axial rotational energies of Mercury and Venus are small, whereas those of Earth and Mars are larger and those of Jupiter and Saturn are very large.

Third, we may assume that the strong magnetic field characteristic of the early sun decreased rapidly as the distance from the center of the sun increased. Using the mechanism of the electromagnetic interaction of a hot, spinning, conducting protoplanet with the strong magnetic field of the contracting sun, one can argue that Mercury and Venus could have lost most of their axial rotational velocity before their final shape or "figure" was determined; this makes it equally likely that a slight oblateness or prolateness would occur.

Finally, the assumption that the overall chemical composition of Earth and Venus are similar is not made capriciously or merely for simplicity. With the knowledge of cosmic chemistry that we now possess, that is, of solar elemental abundances and the processes of probable formation, it is difficult to imagine a planet like Earth being formed without an abundance of water; if the mass of the planet is so large that the escape velocity for the water molecule is too high, one must account for the presence of water in some other manner.

One possible explanation is the photochemical reaction of sunlight with water molecules high in the atmosphere, thereby providing an escape route with the hydrogen leaving the planet

$$H_2O + h\nu \rightarrow 2H + O \quad (1)$$

where h is Planck's constant and ν is the frequency of light. However, the oxygen cross section for the absorption of photons in the pertinent range of energy is so large that the net reaction rate for the relatively small number of water molecules high in the atmosphere is quite small. Thus, this method for the removal of water from the planet is not realistic.

It should be emphasized that, if the last Venera 4 measurements were not from the surface of Venus as reported, then the arguments for the ice cap model and the above considerations are weakened.

HOWARD D. GREYBER
Martin Marietta Corporation, Denver, Colorado 80201

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Positions of Ribosomal Subunits

Morgan believes that he has located the exact positions of the large (50*S*) and the small (30*S*) ribosomal subunits in a three-dimensional array of ribosomes known as the chromatoid body (*1*). We suggest that it is unlikely that he has done so.

In electron micrographs of longitudinal sections through the chromatoid body, one sees an array of closely packed fibers. Optical diffraction patterns of the electron micrographs show the fibers to be helical chains of subunits (ribosomes) (*2*). Making use of the helical nature of the fibers, Morgan says he was able to calculate "the distribution of electron density within one ribosome, which the data of Fig. 2 [an optical transform of a longitudinal section] implies" (*1*). The calculation is based on an inverse Fourier-Bessel transformation for which one needs to supply both the phases and amplitudes of the Fourier-Bessel coefficient; however, only the amplitudes are directly available from the optical transform. The result was a density map which shows a large peak and a small peak in the asymmetric unit. Morgan then supposes that these peaks correspond to the large and small subunits of the ribosome.

We raise three objections.

1) The amplitudes required for the calculation of the density map were measured from photographs of the optical diffraction pattern. A rigorous application of the Fourier-Bessel transformation requires that the amplitudes of the coefficients correspond to a single helical chain. Morgan, however, has substituted amplitudes which correspond to some portion of a tightly packed array of chains and has ignored the effects on his density map of not dealing with a single chain.

2) The prospect of Morgan's having a correct density map is made even more unlikely because his calculation was carried out with assumed phases rather than with phases corresponding to those of the actual chain of ribosomes. It is fairly well known (*3*) that if the amplitudes of one structure are assigned the phases of another, the resulting density map bears no resemblance to the structure from which the amplitudes are obtained but that it resembles the structure from which the phases are obtained. The phases for Morgan's calculation were obtained by his assuming that the phases of a helical chain of points approximate those of a helical chain of ribosomes. Therefore, Morgan's density map, at best, describes a ribosome only to a resolution at which a ribosome looks like a point. One is suspicious of the two peaks in the map, moreover, because, as Morgan himself points out, the choice of phases constrains the two peaks to sit on dyad axes although a priori there is no such constraint on the ribosomal subunits. Rather than assign physical significance to these two peaks, it is more reasonable to suppose that they were the result of some mathematical artifact, for example, series termination in the transformation. Finally, of course, the correctness of the result could have been checked by ascertaining whether the model could be used to reproduce the distribution of density in the electron micrographs.

3) We object to Morgan's basic approach to the interpretation of electron micrographs. By relying entirely on a photograph of the optical diffraction pattern which records intensities only, he has unnecessarily placed himself in the awkward position of having to guess at phases. As we have pointed out (*4*), the phases are contained in the electron micrograph. We have set out procedures for obtaining the phases from the electron micrographs as well as procedures for the final three-dimensional reconstruction of the structure.

D. J. DEROSIER
A. KLUG
Medical Research Council Laboratory of Molecular Biology, Hills Road, Cambridge, England

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