

Selected Studies in Exobiology, Planetary
Environments, and Problems Related
to the Origin of Life

Semiannual Progress Report No. 3

for the period 1 October 1966

through 31 March 1967

Grant No. NGR-09-015-023

Principal Investigator

Carl Sagan

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Astrophysical Observatory
Cambridge, Massachusetts, 02138

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During the first year of this two-year grant, primary attention was devoted to theoretical studies, and a number of new results have been achieved. In the second half of this grant, attention will be shifted more toward laboratory and observational endeavors. Theoretical, observational, and laboratory work done during the third quarter of this grant is covered below.

(1) Theoretical

Further work on the windblown dust model of Martian seasonal and secular changes has been performed. Particular attention has been devoted to the mechanics of lifting of fine-dust grains on the Martian surface, the wind velocities required for the lifting, and the wind velocities theoretically expected from recent models of Martian meteorology. In work that relates to many problems of the Martian surface, we have, in collaboration with the Stanford University group, made a detailed reassessment of the probability of release, survival, dissemination and growth of terrestrial microbial contaminants on the Martian surface. The focus of this work is the question of biological contamination.

In a new theoretical program carried out and completed during this six-month period the contribution of protons from the solar wind to ionization of the Martian atmosphere was examined. It was found that such contributions will be significant, and suggested that the 95-km subsidiary electron density maximum found in the Mariner 4 microwave occultation experiment is due to solar protons. In this case, the major 120-km maximum must be an F2 region.

A theoretical program is being devised for calculating (from planetary albedo, surface thermal inertia, axial inclination, and orbital elements) the surface and subsurface temperature distribution on airless planets. Corrections for the effects of radiative and conductive exchange with the atmosphere are also being made. Applications of these computer programs to the study of Mercury and Mars are anticipated. In the case of Mercury, appropriate integrations of subsurface temperatures to give predicted microwave brightness temperatures will be carried out.

In the case of Venus, major effort has been put into better definition of the nongray greenhouse models of the planetary atmosphere, using a wide range of carbon dioxide and water vapor mixing ratios. The question of convective instability in the atmosphere is also being tested. We are now in a position to apply our tests of alternative nonthermal emission mechanisms and the successful thermal emission mechanisms to the question of life on the planet.

(2) Observational

The principal observational development is the successful testing and the garnering of significant new data with the planetary camera at the 82-inch reflecting telescope of MacDonal Observatory between March 20 and April 2. Kodak 1-N and 1-Z hypersensitized plates were taken of Mercury, Venus, Mars, and Jupiter, as well as the more usual UBV photography. Among the interesting new results are a continuous variation in the configuration of features on Jupiter with wavelength, and one of the best photographic detections of the dark polar collar around the Martian polar cap. Attempts to detect detail on Venus and particularly Mercury were hampered by bad daytime seeing. The camera is scheduled for another run at MacDonal Observatory for a two-week period in June.

A program of microwave observations of Venus at 2-cm wavelengths at the National Radio Astronomy Observatory was also instituted. The objective is to obtain better phase data for Venus in this spectral region where the opacity is changing rapidly.

Through the kind cooperation of Dr. William Sinton, 8- to 13- μ radiometric observations of Mars, taken with the 200-inch Hale reflector, and previously unreduced, are now being reduced at Smithsonian Astrophysical Observatory. It is hoped that this reduction will give better information on the thermal inertia of the Martian surface material and on the question of the equator-to-pole temperature gradient and the related issue of the nature of the polar caps.

Our attempts to detect elevation differences on Mars from CO₂ absorption lines have been unsuccessful, but the upper limit on elevation differences set by this technique is larger than the elevation differences predicted from our radar results. Further efforts at improving the signal-to-noise ratio in this data reduction are being made.

(3) Laboratory

Within the limitations of funds, major efforts are being made in the laboratory phase of this program. (Owing to a general unavailability of funds, our request for a supplementary grant was denied.) The combined distillation system and gas handling apparatus, using a Mercury diffusion pump, and with pressure capabilities of 10⁻⁶ mm of mercury, have been successfully completed and tested. A chamber for ultraviolet irradiation of sufficiently long paths of gases to ensure substantial absorption is being completed in collaboration with the G. C. A. Corporation. The system employs a magnetic piston and has the possibility of continuously dissolving synthesized gases in liquid water while avoiding boiling. With the existing distillation apparatus three programs are in progress:

(a) A measurement of the equilibrium vapor pressure of water vapor over various hydrated ferric oxides, suspected as major constituents of the Martian surface. The problem of the stability of such molecules is a difficult one; thermodynamic data obtained at high temperatures have previously been extrapolated to Martian temperatures, but this is a very risky procedure because the assumption of temperature constancy of the derivatives is involved. This method is much more direct.

(b) A study of the possibility of liquid water on the Martian surface. While the average partial pressure of water on the Martian atmosphere is far below the equilibrium vapor pressure, there are a number of conceivable scenarios in which liquid water could be present in isolated times and places. For example, the frost point is reached every night on Mars just before sunrise, and the atmospheric water is then condensed out in a complex pattern of hoarfrost on the surface. As this material is heated, water vapor is evolved, and will tend to be trapped in the hoarfrost and soil interstices. Building up of the water-vapor partial pressure in such locales may permit the temporary existence of liquid water. The problem is a complicated one involving, for example, the freezing due to evaporation of a pool of liquid water, thus sealing off the water. The problem can be attacked experimentally in a distillation system where the Martian conditions are simulated. Such programs are under way.

(c) Examination of the complete infrared spectrum (out to 50 μ) of a variety of gases recently identified or suggested in the atmospheres of Mars, Venus, and Jupiter, using the Perkin-Elmer Model 621 spectrophotometer. These measurements are directly relevant to questions of infrared opacity and surface temperature in the atmospheres of these planets.

Column chromatographic searches for amino acid-homopolynucleotide interaction are continuing. A program of search for amino acids in dust at least partially of extraterrestrial origin recovered from the Greenland ice cap is about to begin.

(4) Bibliography

The present papers were either published, accepted for publication, or prepared in the interval since the last report:

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5. Thermodynamic Equilibria in Planetary Atmospheres, Astrophysical Journal 147, 753, 1967.
6. A Statistical Analysis of the Martian Wave of Darkening and Related Phenomena, Planetary and Space Science, in press.
7. A Critical Test of the Electrical Discharge Model of the Venus Microwave Emission, Astrophysical Journal, in press.
8. An Analysis of the Mariner II Microwave Observations of Venus, Astrophysical Journal, in press.
9. Martian Ionosphere: A Contribution due to Solar Protons, to be published.
10. A Model of the Clouds and Atmosphere of Venus, in press in Infrared Astronomy, A. G. W. Cameron, editor. (Reprint copies are not currently available.)