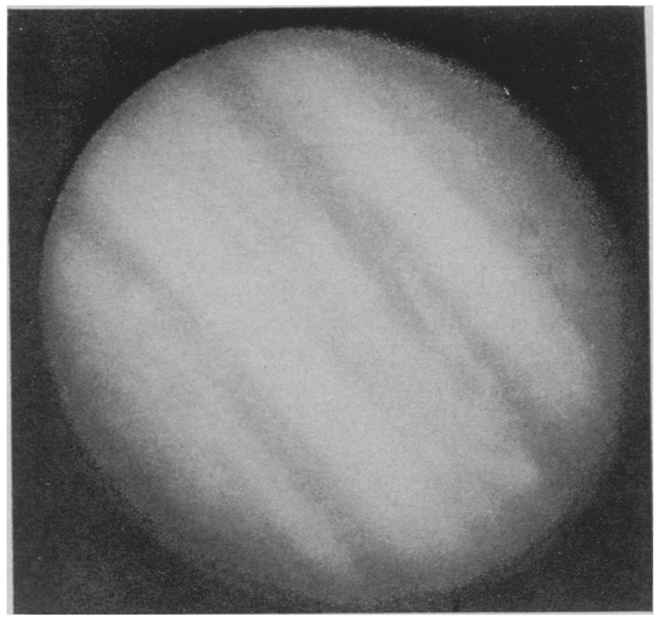
Microwaves from the planets



Jupiter/NASA

The solar system, once an astronomers' Siberia, is the center of renewed interest thanks to radio and other new observational techniques

by Dietrick E. Thomsen

Study of the solar system has been enjoying a renaissance for several years. New observational techniques are making available a much wider spectrum of information than can be obtained with ground-based visual telescopes. These include radio telescopes on the ground and in orbit, X-ray, ultraviolet and infrared sensors in orbit or on rockets, and particle counters on space probes that sample the interplanetary matter directly. All these kinds of instruments can be put on probes that go near the planets, and ultimately, scientists hope, on spacecraft that will land on the planets or penetrate their atmospheres.

Radio astronomy was the first of the new techniques to be applied to the planets, and there has probably been more observation of the planets by radio than by any technique except visible light. Nearly all the planetary radiations are thermal. Heating of the surface or atmosphere by the sun or some other source causes atomic and molecular vibrations that generate the microwaves.

Planetary radio astronomy is now to the point where it compiles radio spectra of individual planets and makes theoretical models of their physical composition. Discrepancies between the radio observations and theoretical expectation about the surface of Mars and the atmospheres of the outer planets have aroused great interest, as exemplified in a series of articles in the current issue of ICARUS.

The Martian data most discordant with theory concern radio wavelengths radiated by the planet's soil within a few centimeters of the surface. The theoretical prediction is derived from assumptions about the composition of the soil of Mars and the proposition that its temperature decreases with depth. This would be expected since the top layer of soil would be heated by the sun.

Because shorter wavelengths come from nearer the surface, the brightness temperature, or apparent temperature of the source of radiation, should rise as observation passes from the centimeter to the millimeter range of wavelengths. It ultimately should approach the infrared average of 235 degrees K. (For comparison room temperature is about 300 degrees K; water freezes at 273 and boils at 373.)

Unfortunately for the theory, the radio spectrum appears to remain flat or even turn down at short wavelengths. Since the brightness temperature depends on the radio emissivity of the substance radiating the waves as well as the true temperature, the presence of a substance with a lower emissivity in the outer part of the Martian surface could account for the turndown. It would give a lower brightness temperature than the soil just below it even though its actual temperature were higher.

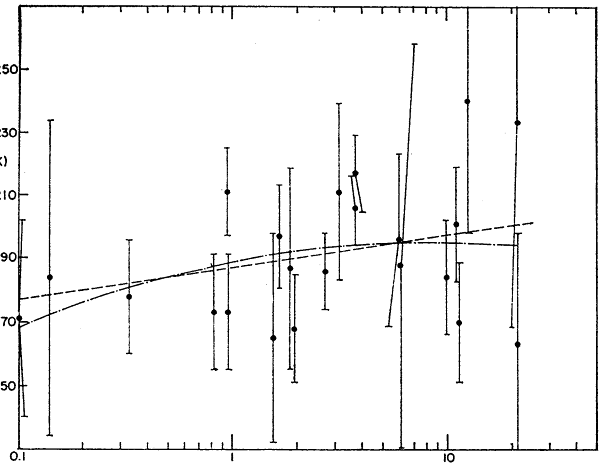
The observed situation "could be approximated," says Dr. Eugene E. Epstein of the Aerospace Corp. in Los Angeles, "if the top few centimeters of the surface material contain some liquid water. This water might result from the partial melting of a permafrost layer. . . ."

Drs. Carl Sagan and Joseph Veverka of Cornell University take up this idea more strongly. "There's no question that liquid water will give such a curve," says Dr. Sagan. "It's the only explanation. We tried everything else we could think of." That is, he says, unless the data are in error.

There is evidence for some water vapor in the Martian atmosphere, but there are arguments against liquid water on the surface. Dr. Andrew P. Ingersoll of the California Institute of Technology argues, in a paper published in SCIENCE a year ago, that under Martian conditions, atmospheric water vapor would condense to ice. The evaporation rate is so high, he says, that evaporation would keep the ice cooled below the freezing point regardless of any local heat sources. Pure ice would never melt, he says, and liquid water could exist only in concentrated salt solutions.

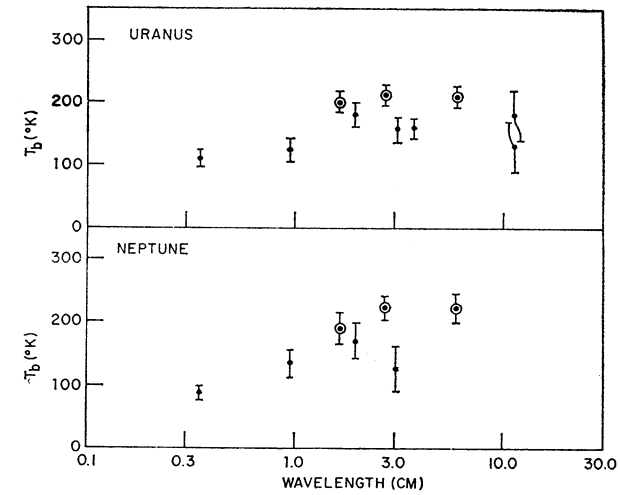
Dr. Ingersoll's argument notwithstanding, Drs. Sagan and Veverka find the idea of a melting permafrost layer attractive because their observations show that on the surface the temperature drops off as one looks toward the poles of Mars. This dependence of the temperature on latitude "could be due to heat sinks related to phase changes at the boundary of such a layer," they say.

Since the relevant electrical properties of ice are similar to those of rock,



Sagan/Icarus

Water may turn spectrum of Mars down instead of up.



Mayer/Icarus

Uranus and Neptune: Warmer than we used to think.

the permafrost would not affect the microwave emission of Mars unless it melted. The actual temperature of the Martian surface gets above 273 degrees K., they say, only in a relatively small area centered on the point directly under the sun. Thus, they believe that only about a third of the visible Martian disk is likely to be permeated with liquid water at any one time.

Drs. Sagan and Veverka go on to say that if the abundance of water near the surface represented a mean depth of 50 microns over the whole planet, and if its actual distribution were rather patchy, it would contribute to an environment in which microorganisms could flourish. Such a patchiness could be detected by a millimeter-wave radar, and Dr. Sagan would like to see such equipment on a Mars probe. Unfortunately none of this year's probes—the Soviet Union's Mars 2 and Mars 3 nor the United States' Mariner 9 carried such an experiment.

Jupiter, the next planet beyond Mars, is one of the strongest radio sources in the sky (in apparent, not intrinsic, brightness) and has been studied since the beginning of radio astronomy. It is the only planet that seems to have a nonthermal source of radio waves. These waves, in the decametric or 10-meter range, are believed to be generated by motions of magnetically trapped charged particles in the planet's outer atmosphere. Some observers see evidence that the decametric emissions are modulated by the passage of Jupiter's innermost satellite, Io (SN: 12/5/70, p. 424).

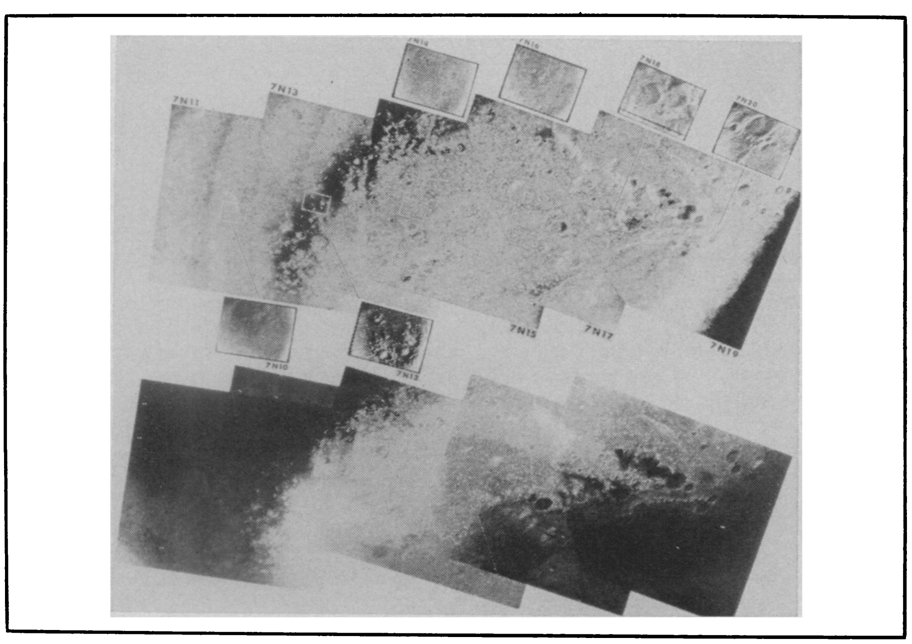
Of more recent radio astronomical interest are the farther-out planets, Saturn, Uranus and Neptune. For Uranus and Neptune Drs. C. H. Mayer and T. P. McCullough of the U.S. Naval Research Laboratory present centimeter-wave spectra that show brightness temperatures rising from about 100 degrees K. at a third of a centimeter to about 200 degrees at around 10 centimeters.

These measurements represent the temperature at different levels in the planets' atmospheres, says Dr. Mayer. It is unlikely, he believes, that the observations are reaching the solid surfaces at present.

The newer measurements confirm a finding, first noted some months ago by Drs. I. I. K. Pauliny-Toth and Kenneth I. Kellerman of the National Radio Astronomy Observatory, that the atmospheres of these planets are warmer than would be expected if their only source of heat is solar radiation.

"If you imagine the planets to be blackbodies heated only by the sun, the calculated temperatures come out very low," says Dr. Mayer. (As "probable temperatures" the 1971 World Almanac lists 61 degrees K. for Uranus and 33 degrees K. for Neptune.) Infrared observations, which represent the outermost regions of the atmospheres, "outside the visible clouds," says Dr. Mayer, tend to approximate the blackbody calculations. As one goes lower, the atmospheres appear to get warmer. Similarly anomalous temperatures are being found for Jupiter and Saturn.

The results "would indicate either an internal source of heat or a greenhouse effect in the atmosphere," says Dr. Mayer. In Jupiter's case some people suggest an internal heat source that is the dying remnant of a stellar core. Jupiter, they think, is a nearly dead star that the sun has captured. Jupiter's size would just qualify it as a very small star. But such an explanation is much less plausible for the other outer planets because they are smaller than Jupiter. □



NASA

Martian terrain: Maybe it's permeated with permafrost that melts in the sun.