9 September 1977, Volume 197, Number 4308 **SCIENCE**

The Voyager Missions

The missions of the Voyager spacecraft, which include rendezvous with Jupiter, its satellites, Saturn, its satellites, and possibly Uranus, and a much later destiny in some other stellar system, have multiple appeals. Most of the people around the world can have a sense of participation and wonderment as coded messages in their own language accompany the vehicles on their long journeys. These missions to the planet also touch a universal, restless component of the human spirit—a longing to explore. To those of an engineering bent, the excellence of the instrumentation must elicit admiration. Others, who are deeply interested in the frontiers of scientific knowledge, can anticipate a rich flow in information bearing on the formation of the solar system. A decade ago the level of knowledge concerning the planets and their satellites was such that almost any arm-waving explanation would fit the facts. This is no longer true. Ground-based optical and radio astronomy combined with spacecraft missions to Mercury, Venus, the Moon, Mars, and Jupiter have already limited the area of permissible speculation.

The quantity of information conveyed to the earth from the Voyagers will greatly surpass that of earlier missions. This will be true in spite of the technical problems inherent in communication at distances of the order of 800 million to 1600 million kilometers. In the dim reaches of Saturn, solar radiation is 1 percent that at the earth and temperatures are about 90°K—scarcely a favorable environment for instruments. However, the 11 pieces of complex apparatus will function, using a total of 88 watts for electronics and 16 watts for heating.

The instrumentation of each spacecraft includes an ultraviolet spectrometer covering the wavelength range 50 to 170 nanometers with a resolution of 1 nanometer. In the visible part of the spectrum the Voyager cameras will achieve a resolution and observing time at Jupiter better by a factor of 40 than those of the Pioneer spacecraft. The use of interference filters will permit observations at selected wavelengths from 300 to 650 nanometers. Photopolarimeter equipment will permit determination of the physical properties of particulate matter in the atmospheres of Jupiter and Saturn and in the rings of Saturn. Intensity and linear polarization of scattered sunlight will be measured at selected wavelengths in the spectral region 235 to 750 nanometers.

The infrared investigations on the Voyager missions use a Michelson interferometer which covers the infrared in the range 2.5 to 50 micrometers. With this broad coverage and the good resolution achievable by the interferometer much compositional information can be gathered. This will include determination of the relative amounts of such major components as H_2, CH_4, and NH_3. There is an expectation of obtaining information about such trace constituents as H_2O, PH_3, and CO. There is also a possibility that D/H and $^{13}C/^{12}C$ isotope ratios can be determined. The infrared equipment will permit examination of the surface composition of the satellites with good spatial resolution. In addition to measuring solid H_2O and NH_3, the spectrometers will be capable of detecting a number of silicate minerals.

This combination will be supplemented by radio science investigations. When a spacecraft moves behind a planet, as viewed from the earth, the radio paths traverse the planet's atmosphere and ionosphere. All of these regions affect the characteristics of the received radio signals. This will make possible a study of vertical structure in the atmospheres of the planets and also in Saturn's rings. When specially interesting objects are being examined, the radio infrared, visible, and ultraviolet instruments can all participate in a mutually reinforcing fashion.

This brief outline of only five of the 11 instrument packages on the Voyagers should make it clear that the visits to the planets will be exciting and worthwhile adventures.—PHILIP H. ABELSON