Spectroscopy of Solar System Objects

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Spectroscopic observations of the solar system with ISO have gratified planetary scientists with a wealth of new findings.

ISO measurements of the giant planets have led to the detection of new hydrocarbon species: methyl radical (CH_3) in Saturn and Neptune, ethylene (C_2H_4) in Neptune, methyl–acetylene (CH_3C_2H) in Jupiter and Saturn, diacetylene (C_4H_2) in Saturn, and benzene (C_6H_6) in Jupiter and Saturn. These detections show that methane photochemistry produces substantial amounts of complex hydrocarbons in the upper atmospheres of these planets. Benzene and diacetylene may in addition be important components or precursors of the hazes present in their stratospheres. The chemical schemes leading to these hydrocarbons are not yet fully understood. The SWS on ISO detected the presence of water vapor in the stratospheres of the four giant planets and of Titan. Carbon dioxide was also seen except on Uranus. These detections were unexpected on thermochemical grounds, and point to exogenic sources of oxygen. Interplanetary dust is likely a major component but micrometeorite erosion from either the rings or icy satellites may be significant. ISO has provided a new determination of D/H in the four giant planets through the first detection of HD rotational lines. In the case of Jupiter and Saturn, the derived D/H ratio is in agreement with the value measured by the Galileo probe in Jupiter. This ratio is higher in Uranus and Neptune, leading to a value in the ices that formed the cores of the two planets, intermediate between the protosolar value and that measured in comets. Other significant results on the giant planets include the first firm spectral identification of ammonia ice particles in Jupiter, a determination of the $^{14}N/^{15}N$ isotope ratio in the upper troposphere, and evidence for a strongly undersaturated abundance of water vapor in the troposphere of Saturn.

A careful analysis of Mars spectra recorded with the SWS reveals weak mineralogic features near 6, 7, 11, and possibly 31 μm, that may be associated with the presence of carbonates. If confirmed, the long-seaked presence of this mineral at the surface of the planet would have broad implications on the evolution of the early Martian atmosphere.

Finally, Comet C/1995 O1 (Hale–Bopp) could be observed by ISO as a "target of opportunity". Vibrational bands of H_2O, CO, and CO_2 were detected; the relative production rates of the three compounds could be determined as a function of heliocentric distance, showing large variations. In both comets Hale-Bopp and P/Hartley 2, the observation of several ro-vibrational lines from the ν_3 band of water vapor provided an accurate determination of the rotational temperature and ortho-to-para ratio of water. The latter indicates a spin temperature of 25–35 K, possibly "frozen" from the formation of cometary water. Mg-rich crystalline olivine was clearly detected in the thermal emission spectrum of Hale-Bopp. Crystalline silicates were also detected in P/Hartley 2, a Jupiter-family comet.