The Galileo Encounter with Venus: results from the Near Infrared Mapping Spectrometer

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This issue of Planetary and Space Science includes six papers which present results from the Near Infrared Mapping Spectrometer (NIMS) observations at Venus, expanding upon our preliminary report (Carlson, et al., 1991). This short introduction briefly describes the instrument and the mission, and summarizes the principal results.

The NIMS instrument has been described previously (Carlson et al., 1992) so only a brief description is presented here. NIMS is an imaging spectrometer, operating in the spectral range 0.7 to 5.2 µm. The combination of imaging and spectroscopy provides a powerful tool to study planetary atmospheres and surfaces, and the broad spectral coverage allows one to study a wide variety of physical processes and altitude regimes, from the surface to the mesosphere in the case of Venus. NIMS is a line-scan imager, with internal mirror motion producing a one-dimensional scan of 20 pixels and spacecraft scan-platform motion production the orthogonal dimension of spatial scanning. For each spatial pixel, a spectrum is obtained with a diffraction grating spectrometer and seventeen individual detectors. If the grating is scanned over its full range of 24 positions, then a spectrum of 408 elements is generated. If the grating is fixed, then one obtains information in 17 spectral channels. Both of these instrument modes were used at Venus.

The ultimate destination for Galileo is Jupiter, however because of limited launch capabilities, a gravity-assist trajectory using Venus and Earth flybys was used (D'Amario et al., 1992). The Venus flyby occurred on 10 February 1990, with Galileo approaching the dark side of Venus from slightly north of the Venus equatorial plane and at an asymptotic approach phase angle of 155 deg. During approach, three nightside observational sequences were performed and the corresponding data form the basis for the following NIMS papers. Dayside observations were also obtained, but are not reported here. The three nightside observations are referred to as VPDIN-1, VPDIN-2, and VJBARS. In the two VPDIN (for Venus Partial Disk Imaging-NightSide) sequences, the grating was fixed, allowing images to be obtained at 17 wavelengths. Complete spectra were obtained in the VJBARS period, with the spatial pattern resembling three north-south oriented bars, A summary of observational parameters is given in Table L

Table 1
Approach Observing Periods

Observation Name	Time Period[1]	Resolution (km/pixel)	Phase Angle[2]	Sub-spacecraft latitude, longitude
VPDIN-1[3]	4:20-3:37	51-49	148	14.0 N, 349.1 W
VJBARS[4]	2:28-2:07	26-22	143	7.4 N, 356.3 W
VPDIN-2[3]	2:07-1:05	22-11	140	4.9 N, 358.9 W

1) Time before closest approach, hours: minutes.
2) At start of period.
3) 17 wavelengths: 0.80,0.94, 1.18, 1.46, 1.74,2.02, 2.30, 2.58, 2.87,3.15,3.43, 3.71,4.00, 4.28,4.56,4.84, 5,13 pm.
4) 408 wavelengths, 0.7 -5.2 µm.

The NIMS instrument was designed and built before it was known that the Galileo mission would include a close flyby of Venus. Nevertheless, the concept of an imaging spectrometer turned out to be ideal for investigating the night-side emissions from Venus in the near infrared part of the spectrum. These emissions, which were first detected in ground-based measurements from the Earth, (Allen and Crawford, 1984) originate as thermal emission from the hot lower atmosphere of Venus which then diffuses through the cloud layers to space. The observed spectrum is blacked out inside strong molecular bands, especially those of carbon dioxide, but the regions between the bands have been shown (Kamp et al., 1988) to contain information about the composition of the lower atmosphere, as well as about the properties of the clouds themselves. The NIMS spectra are generally superior in radiometric accuracy and spatial resolution to those obtained from the ground, although they cover a time period of only a few hours. So far, they have been used mainly to study the cloud structure, and spatial variations in this and in the atmospheric composition.

In the papers which follow, Carlson et al. (1993, this issue) show that the cloud properties mapped by the NIMS spectral measurements exhibit variations across the disc of the planet. The main variable appears to be the mean size of the particles in the cloud, with a relatively greater abundances of large particles in the northern than in the southern hemisphere. Overall, the planet has an irregular banded appearance in terms of cloud particle size which hints at variable large-scale meteorological processes. Rather more oddly, Collard et al. (1993, this issue) show that the distribution of carbon monoxide in the deep atmosphere is not uniform, and that a region of high CO was observed at high latitudes in the northern hemisphere. This effect might be connected with the general circulation of Venus' atmosphere, since CO is more abundant at high altitudes where CO_2 is dissociated by solar UV radiation and a region of predominately downward motion could show an enhanced abundance of CO. Alternatively, the CO may have a volcanic origin: the high CO values are found over the mountainous Ishtar region. The presence of water vapor features in the NIMS spectra permitted a search by Drossart et al. (1993, this issue) for any global variation in the abundance of this molecule, but in this case none was found which exceeded the estimated error in the measurements of about 20%. Similarly, the vertical profile of water vapor was found to be constant with height at a mixing ratio value of 30 ± 15 parts per million. In addition, these spectral measurements show spatial enhancements in the $O_2(^1\Delta)$ airglow which is photochemically produced in the mesosphere.

Two further papers deal with the structure of the clouds, and aim to extend cloud models developed on the basis of earlier measurements by the Pioneer Venus mission. Roos et al. (1993, this issue) use limb-darkening measurements to determine the scale height of the clouds at their upper boundary, some 65 km above the surface of Venus. In the equatorial region, where the limb-darkening technique works best, the scale height is found to be constant with latitude at a value of approximately 5.2 km. Grinspoon et al. (1993, this issue) characterize the deep clouds, showing that the opacity variations which give Venus its contrast-rich appearance at near infrared window wavelengths (in contrast to its bland visible appearance) are due mainly to variations in the lower cloud layer.

Finally, a paper describing NIMS observations of the Earth during the December 1991 flyby is included (Drossart et al. 1993, this issue). These were mainly made for purposes of calibration and validation, but they also allow some interesting comparisons of Earth and Venus spectra in the near-ir.

Near-ir observations of Venus, from the Earth's surface and from Galileo, have revealed the planet's atmosphere to be much more inhomogeneous than previously observed or expected. The ground-based data suggest that large changes occur in time as well. It is to be hoped that the serendipitous observations by Galileo will be the precursor for dedicated remote sensing studies from a future orbiter, when high spectral resolution and long time sequences could be employed to provide observations which our present studies suggest will be rich in details about the dynamics and meteorology of Venus' deep atmosphere, a subject blessed by much interest but little information at present.

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