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DEIMOS: A REDDISH, D-TYPE ASTEROID SPECTRUM

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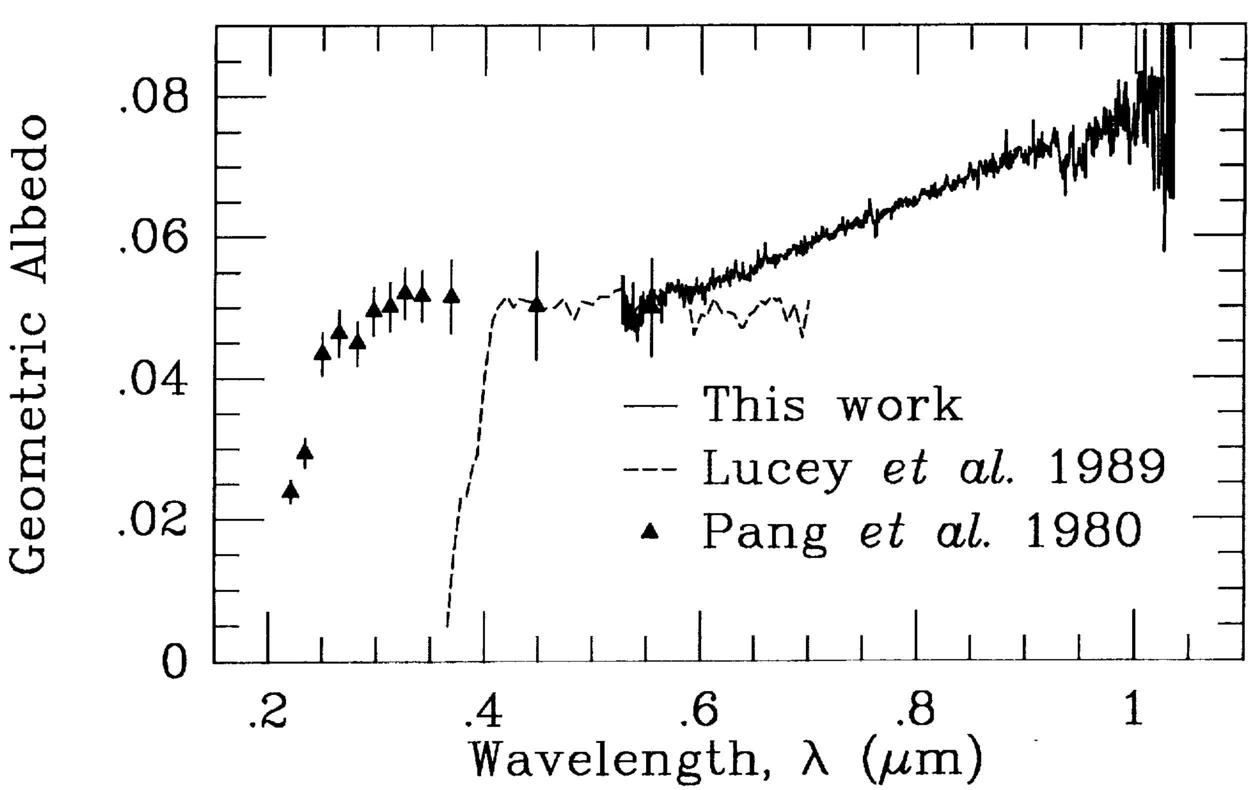
We have obtained high quality CCD spectra of Deimos from 0.5 to 1.0 μm at a spectral resolution of 15 Å. The spectra are remarkably red, similar to the spectra of D type asteroids rather than those of carbonaceous chondrites or C type asteroids.

During the 1988 opposition of Mars, we obtained new CCD spectra of its outer satellite, Deimos. The data were obtained over a 2½ hour period on the night of October 9, using the 1.54 meter Catalina telescope and the LPL long-slit CCD spectrometer. From 0.5 to 1.1 μm, the spectrum is dispersed across an 800×800 Texas Instruments CCD chip at a scale of 7.21 Å per pixel for an effective $\lambda/\Delta\lambda \approx 500$.

The primary observational difficulty in ground based spectroscopy of Deimos was its proximity to Mars. To minimize scattered light from Mars, Deimos was observed near greatest elongation. The spectrograph slit was narrowed to 2.5 arcseconds, slightly larger than the seeing disk. An apodizing mask at the re-imaged telescope primary, to remove the diffraction cross of Mars light caused by the telescope's secondary mirror mount. Residual scattered light was modeled and removed in data reduction. Solar analog stars BS560, BS2007, and BS8931 were observed to allow removal of telluric absorptions. The resulting spectrum is plotted with other data in Fig. 1.

Fig. 1 Composite of Deimos Spectra



Our spectrum has not been smoothed; the signal-to-noise ratio and the resolution are significantly higher than previously available spectra of Deimos. Also plotted in Fig. 1 are the spectra of Pang *et al.* (1980) and Lucey *et al.* (1989). The geometric albedo normalization is from Pang *et al.* and may be an underestimate (Zellner *et al.* 1974, Klaasen *et al.* 1979, Veverka *et al.* 1980). At wavelengths longer than 0.6 μm, the spectrum has a markedly red slope, increasing in albedo by a factor of ~50% over one octave in wavelength. Between 0.4 and 0.6 μm, the albedo shows little wavelength dependence (Veverka *et al.* 1977). Other than this change in slope (perhaps caused by a broad, shallow absorption feature around 0.5 μm), the spectrum is remarkably featureless at visible and longer wavelengths. At shorter wavelengths, the albedo falls off sharply. The ground based spectrum of Lucey *et al.* is not consistent with the Mariner 9 spectrometry of Pang *et al.* in the ultraviolet and does not show the red slope we observe at longer wavelengths.

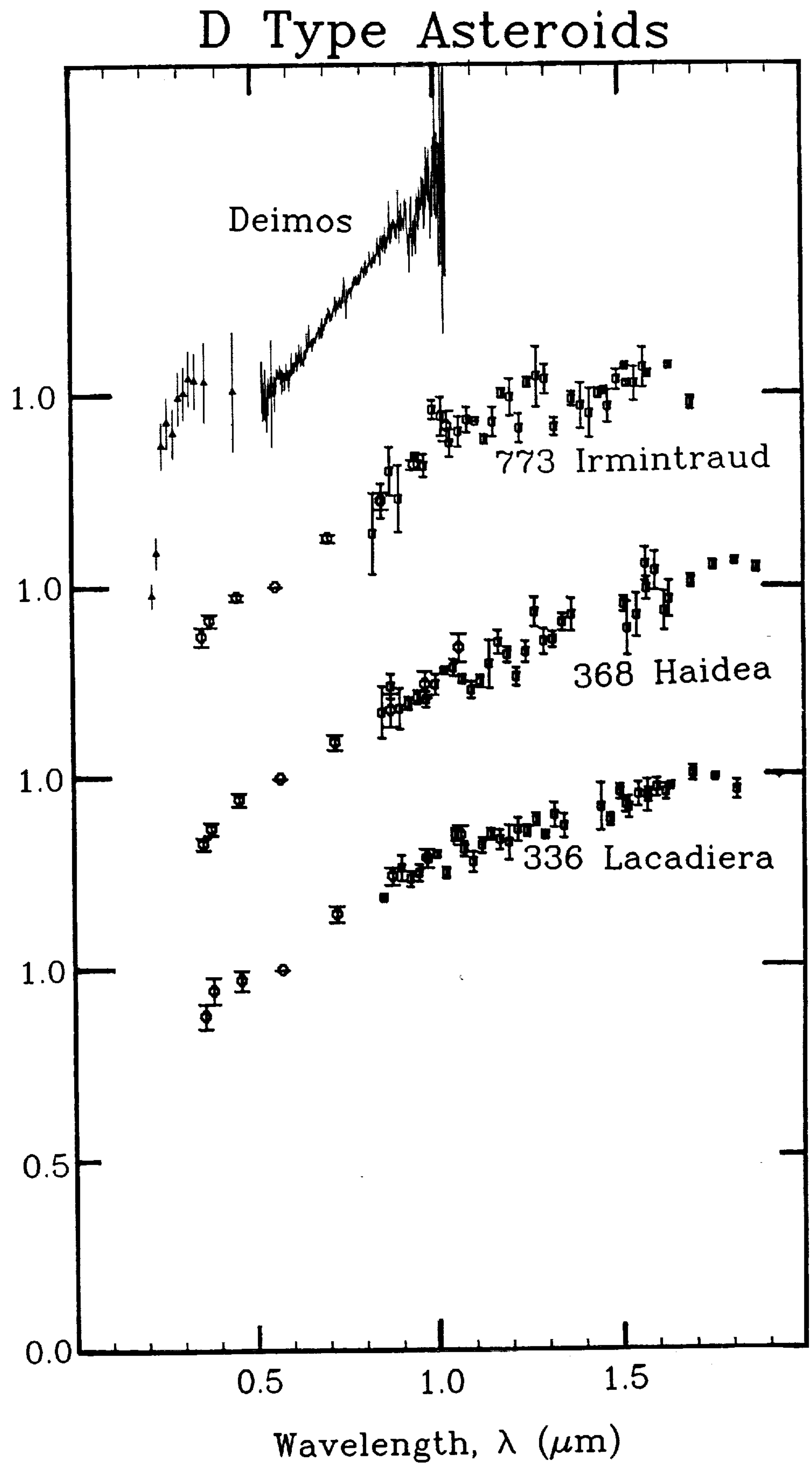
The absence of VNIR (visible and near infrared) absorption bands in the spectrum of Deimos is in marked contrast with Martian surface spectra, observed contemporaneously. No trace of the Fe^{2+} electronic transition absorption band around 1 μm is observed. Its absence would rule out the presence of significant quantities of minerals such as pyroxenes and olivines on the surface of Deimos, were it not for the fact that fine grained dark materials are remarkably effective at masking mineral absorption bands. At present it is not possible to derive much compositional information from such a dark, featureless spectrum.

Based on the short wavelength spectra, the surface of Deimos has been interpreted as being similar to powdered carbonaceous chondrites and thus to C type asteroids (Pang *et al.* 1980, Veverka *et al.* 1980, French *et al.* 1988, Lucey *et al.* 1989). We are not aware of carbonaceous meteorites with VNIR spectra as red as that of Deimos. The same is true of C type asteroids. There may be some surface process which renders ordinary or carbonaceous chondritic material dark and red under the conditions experienced in Mars orbit. Shock effects of micrometeoroid bombardment may disperse blebs of elemental iron and nickel and degrade the crystal lattice sites which produce the electronic transition absorption bands in silicate minerals (McFadden 1983). It is not possible to dismiss some sort of surface processing of carbonaceous chondrite material as the explanation for the spectrum of Deimos, but the black chondrites which are thought to result from these processes acting on ordinary chondritic material are not spectrally similar to Deimos. Black chondrites display a residual Fe^{2+} band around 0.9 μm and a more neutral continuum (Gaffey 1974).

An alternate interpretation arises from the Tholen asteroid taxonomic system (Tholen 1984, Tholen *et al.* 1989). In that system, dark, red asteroids are classified as types T, P, and D. Spectra of T asteroids tend to flatten at wavelengths longer than 0.8 μm, unlike the spectrum of Deimos. Although it has been suggested that Deimos may be like the P asteroid 65 Cybele based on infrared spectroscopy (Bell *et al.* 1989), P asteroids are less red than Deimos. D asteroids are quite red at wavelengths longer than 0.55 μm and are more neutral at shorter wavelengths, much like Deimos. Fig. 2 shows that the composite spectrum of Deimos is quite close to those of three D type asteroids (Bell *et al.* 1987) but exhibits a red slope from 0.5 to 1.0 μm slightly stronger than the most red of these asteroids, 773 Irmintraud.

That Deimos should have a composition similar to D or P type asteroids is surprising. These asteroids are generally found among the Cybeles, Hildas, and Trojans - at heliocentric distances much greater than main belt asteroids. No meteorite analog for the dark, red asteroids has been recovered, but their spectra and large heliocentric distances suggest that

Fig. 2


D Type Asteroids
Deimos
773 Irmintraud
368 Haidea
336 Lacadiera
1.0
1.0
1.0
1.0
0.5
0.0
0.5
1.0
1.5
Wavelength, λ (μm)

their surfaces are rich in dark organic materials and partially hydrated clay minerals. It is possible that Deimos is composed of such material scattered from further out in the early solar system and captured into Mars orbit. If Deimos is indeed made of such exotic, primitive materials, it is the most easily accessible example of such a body. A detailed chemical and physical study, as attempted by the Soviet Phobos probes, could be extremely valuable.

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