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44 NYSA: AN IRON-DEPLETED ASTEROID

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ABSTRACT

The minor planet 44 Nysa has a unique combination of photopolarimetric parameters, with the most nearly neutral *UBV* colors, the shallowest negative polarization branch, and by far the highest polarimetric albedo yet obtained for any asteroid. Its surface apparently consists of a low-opacity, iron-free silicate strongly suggestive of enstatite achondrites.

Subject headings: asteroids — meteorites, meteors

Table 1 gives linear polarizations of sunlight reflected from asteroid 44 Nysa, measured in mid-1974 as part of an extended survey of asteroid polarimetric properties (Zellner, Gehrels, and Gradie 1974). In *UBV* colors this object is the bluest, i.e., the most nearly neutral with respect to sunlight, of any asteroid yet observed (e.g., Fig. 2 of Chapman, Johnson, and McCord 1971). Nysa is an elongated or irregularly shaped object showing a photometric light-curve amplitude of up to 0.48 mag with a rotation period of 6.42 hours (Taylor 1971). As is the case for most asteroids, the surface seems to be uniform without noticeable rotational variation in color and polarization.

Figure 1 shows for 44 Nysa a polarization-phase curve that is unique among the approximately 60 asteroids similarly observed to date, with depth $P_{\min}$ of the negative polarization branch near 0.30 percent. Linear regressions fitted to points on the ascending branch give slopes h near 0.004 percent per degree and inversion angles near 18°.1 in both filters. According to the well-calibrated empirical relationship between h and the geometric albedo p of a diffusely reflecting surface (Veverka and Noland 1973; Bowell and Zellner 1974; Zellner *et al.* 1974), the albedo is expected to be near $p_V = 0.4$; with $V(1, 0) = 7.35$ from Taylor (1971), the mean diameter is then 70 km. Matson (1972) obtained a model diameter of 140 km, implying $p_V = 0.1$, from a single radiometric observation of 44 Nysa at 11.6 μ wavelength. While differences between asteroid diameters indirectly determined by the radiometric and polarimetric technique are not uncommon (e.g., Morrison 1974), the discrepancy of a factor of 4 in albedo for 44 Nysa is an extreme case. However both the polarimetric slope and the radiometric diameter are poorly defined observationally, and it seems likely that the true geometric albedo is near 0.3, i.e., the highest value yet found for any asteroid except possibly 4 Vesta.

Figure 2 illustrates the well-defined S (silicaceous or stony-iron; $0.1 \lesssim p_V \lesssim 0.2$) and C (carbonaceous;

TABLE 1

Polarization Observations of Asteroid 44 Nysa

Date UT 1974	Tel.	Phase	Filter	P%	ϵ_p%	θ_r	P_r%
March 26.44....	C1.5	21.06	G	0.18		1.0	+0.18
March 26.46....	C1.5	21.06	B	0.14		− 2.8	+0.14
April 10.49.....	S2.3	18.09	G	0.04		43.5	+0.00
May 14.25......	C1.5	6.08	G	0.30	±0.05	96.5	−0.29
May 14.28......	C1.5	6.07	B	0.30	0.01	91.0	−0.30
June 2.26.......	S2.3	3.69	G	0.28	0.03	92.2	−0.28
June 7.20.......	S2.3	5.63	G	0.31	0.03	91.3	−0.31
June 7.22.......	S2.3	5.63	B	0.28	0.03	91.3	−0.28
June 23.30......	C1.5	11.85	B	0.26	0.09	8.9	−0.26
July 12.24......	S2.3	17.36	B	0.13	0.06	60.2	−0.07
July 24.21......	C1.5	19.64	B	0.10	0.02	−15.6	+0.08
July 24.23......	C1.5	19.64	G	0.07	0.05	3.8	+0.07
Aug. 10.14......	C1.5	21.40	B	0.09	0.06	−33.1	+0.04
Aug. 11.19......	C1.5	21.46	B	0.18	0.06	− 1.4	+0.18
Aug. 11.20......	C1.5	21.46	G	0.10	0.09	26.9	+0.06
Aug. 26.15......	S2.3	21.76	B	0.19	0.03	− 6.9	+0.18
Aug. 26.17......	S2.3	21.75	G	0.17	0.06	− 7.1	+0.16
Aug. 27.15......	S2.3	21.74	G	0.20	0.04	1.0	+0.20

Note.—C1.5 denotes the 1.54-m Catalina reflector of the Lunar and Planetary Laboratory and S2.3 the 2.29-m reflector of Steward Observatory. The position angle θ_r and polarization component P_r are defined with respect to the normal to the plane of scattering as by Zellner *et al.* (1974).

$p_V \lesssim 0.07$) compositional groups which make up a large fraction of the asteroid population (Morrison 1974; Zellner *et al.* 1974; Chapman, Morrison, and Zellner 1975). Atypical objects previously identified include the unique object 4 Vesta with a basaltic achondrite surface; a few objects suspected of a metallic or metal-rich enstatite composition (16 Psyche and 22 Kalliope in Fig. 2); and 349 Dembowska, which closely resembles some ordinary chondrites in spectral properties (McCord and Chapman 1975). Asteroid 44 Nysa not only falls far outside the *S* and *C* groups but also grossly violates the general albedo-color-P_{min} relationships.

A shallow negative branch indicates either (1) a well-consolidated, dust-free surface, or (2) a low-opacity particulate material in which internal transmissions and high orders of scattering wash out the microshadowing effects needed to produce net negative polarization (Dollfus 1971; Bowell and Zellner 1974; Wolff 1975). Dust-free surfaces are usually associated with inversion angles less than 12°, the only noted exceptions being the microscopically very rough surfaces of certain high-albedo lunar breccias (Bowell, Dollfus, and Geake 1972). A dust-free surface for 44 Nysa also appears unlikely on more general grounds; the very small (1–20 km diameter) Earth-approaching asteroids as well as the largest asteroids all show polarimetric evidence for surface dust (Zellner *et al.* 1974). Thus the observations of 44 Nysa are consistent with a translucent, almost colorless silicate powder.

The iron-rich olivine and pyroxene assemblages that dominate most stony meteorites invariably show reflection spectra that turn down toward shorter wavelengths in the *UBV* spectral range (e.g., Hunt and Salisbury 1970; McCord and Gaffey 1974), as a result of very broad ultraviolet charge-transfer absorptions among transition-metal ions, primarily iron. The general trend among asteroids for lower albedos and larger values of P_{min} to be associated with more neutral colors results from increasing amounts of opaques such as carbon dispersed through the ferromagnesian silicates. Bright, low-opacity, colorless silicates which could be identified with 44 Nysa are rarely found in meteorites without associated iron-bearing minerals. A good candidate is provided by the enstatite achondrites (aubrites), which are composed of almost pure, iron-free enstatite. As demonstrated in Figure 1, polarization

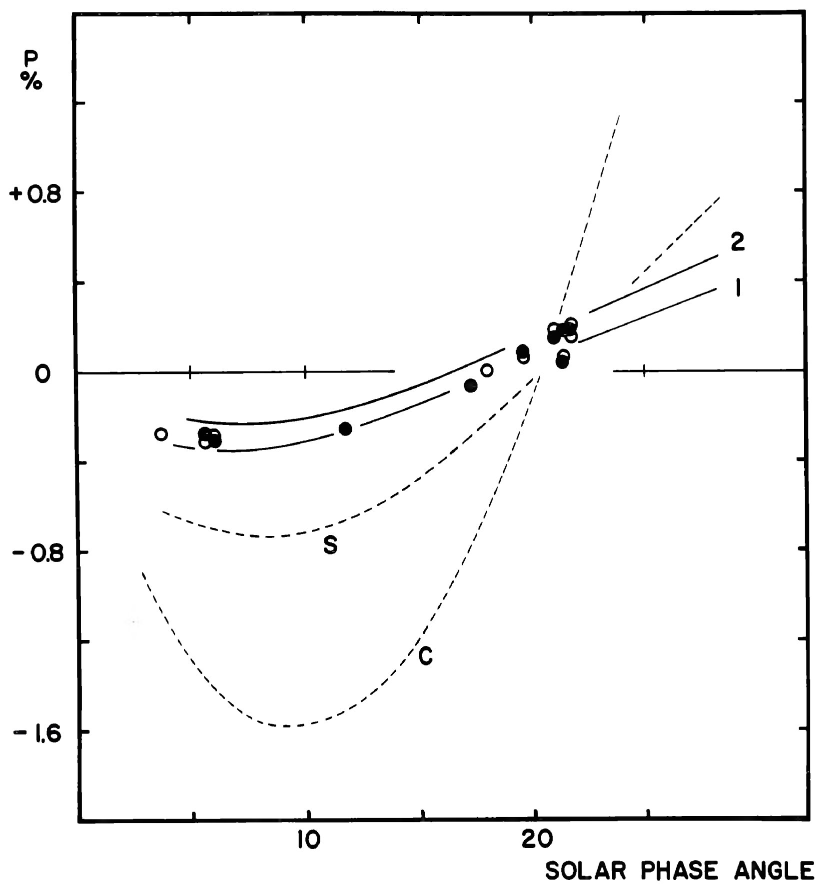

FIG. 1.—Polarization versus solar phase angle observed for asteroid 44 Nysa in blue (*filled circles*) and green (*open circles*) light. For comparison are given polarization-phase curves (*dashed lines*) for typical silicaceous (*S*) and carbonaceous (*C*) asteroids. Actually the *S* curve is a composite of 3 Juno and 7 Iris ($B - V \approx 0.81$, $p_V \approx 0.18$), and the *C* curve is a composite of 19 Fortuna, 324 Bamberga, and 511 Davida ($B - V \approx 0.72$, $p_V \approx 0.045$).

Solid lines represent laboratory observations in orange light of enstatite achondrites, pulverized with grains smaller than 20 μ, from Dollfus *et al.* (1971); curve 1 is Bishopville, albedo 0.35, and curve 2 is Bustee with albedo 0.28.

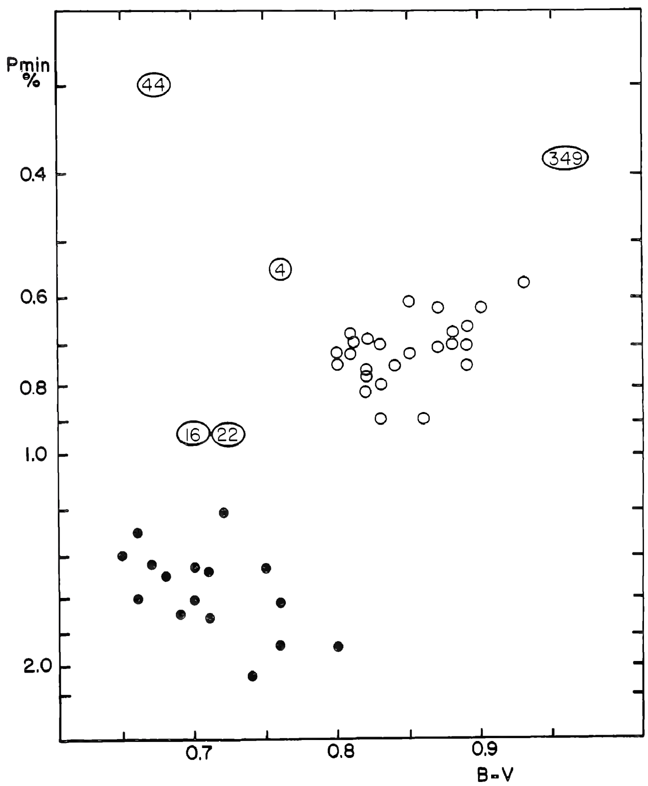

FIG. 2.—Distribution of asteroids in $B - V$ color and depth $P_{\min}$ of the negative polarization branch. Open circles represent S (silicaceous or stony-iron) bodies, and filled circles C (carbonaceous) objects according to the criteria of Chapman *et al.* (1975). Atypical asteroids are identified by number.

measurements by Dollfus, Bowell, and Titulaer (1971) of two powdered aubrites with geometric albedo near 0.3 provide quite satisfactory agreement with the polarization-phase curve of 44 Nysa.

The physical processes of reduction and iron depletion that led to the formation of enstatite achondrites are somewhat obscure but probably involved melting and gravitational separation in a parent body of enstatite-chondritic composition (Mason 1962; however, compare Wasson and Wai 1970; Boynton and Schmitt 1973). The size and shape of 44 Nysa are appropriate for a large collision fragment, and the relatively uniform low-opacity regolith may conceal subsurface variegation involving metallic phases of greater crushing strength.

If 44 Nysa indeed has an aubrite surface, its reflection spectrum should be essentially flat throughout the visible and near-infrared (Gaffey 1974), and a high albedo should be confirmed by thermal radiometry near 10 and 20 μ; because of its nonspherical shape, it is essential that radiometry be accompanied by visual photometry. In 1975 June, Nysa again becomes visible, with opposition at eleventh magnitude on September 2. Physical observations will hopefully then be given a high priority.

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