4. Conclusions

The major new finding of this study is the discovery of a large mass concentration at the centre of NGC 4594. Our strongest evidence is the detection of a sharp rise in the observed velocity dispersion of at least 59 km s^{-1} within the central 3″.5, although this is probably a lower limit. Under the assumption of spherical symmetry and an isotropic velocity distribution, the mass contained within r = 3″.5 of the centre of NGC 4594 is $M \simeq 1.3 \times 10^9 M_\odot$. Higher spatial resolution kinematic and surface photometry of the nuclear region of NGC 4594 in good seeing are urgently needed to put new constraints on this problem.

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Physical Studies of Asteroids

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Introduction

Photometric and spectroscopic observations of asteroids give important information on the physical properties of these bodies and increase our understanding of the origin and evolution of the asteroids. The 50-cm, 1-m and 1.5-m telescopes and the Schmidt telescope at ESO, Chile, have for almost ten years been used by us for such observations. These observations have so far resulted in more than 20 scientific papers. References to these may be found in (1). Here only a short summary of these results will be given.

Spin Properties of Asteroids

The ESO 50-cm telescope has been used for UBV and UBVRI photometry of asteroids with the intention of deriving lightcurves and broadband colours. These lightcurves give information about spin rates, and the lightcurve amplitudes give a hint of the asteroidal shapes. The study of colours and magnitudes as a function of solar phase angle (phase curve) give important constraints to the light scattering properties of the surface material. One night or a few consecutive nights of observations usually give a full coverage over all rotational phases and enable an unambigous construction of a composite lightcurve. The amplitude of this curve, which can amount to several tenths of a magnitude, gives important statistical information on asteroid shapes and albedo variegation (1, 4). Scenarios for the collisional evolution of the asteroid belt in general, and asteroid dynamical families and other subclasses in particular, may be tested against the wealth of spin rates that have been obtained from photometry. If observations of an object are carried out at several oppositions, the differing viewing geometry gives three-dimensional information which enables us to derive the axis and sense of rotation (6). Such pole information is of importance in the interpretation of most physical observations of asteroids (e.g. radar, infrared, etc.) as soon as the "spherical-featureless-nonrotating-model" is abandoned. One goal with these observations is to obtain an inversion of the full photometric information to interpretable constraints on shape and albedo variegation.

The M-type asteroids have attracted special attention from us in Uppsala since they seem to have different rotational properties from asteroids of other types (1, 5). In this report only the variation of spin rate with the mean distance from the sun will be discussed briefly. Figure 1 shows this variation for asteroids of type S and C. We use only data for asteroids smaller than 140 km in diameter since larger objects show a

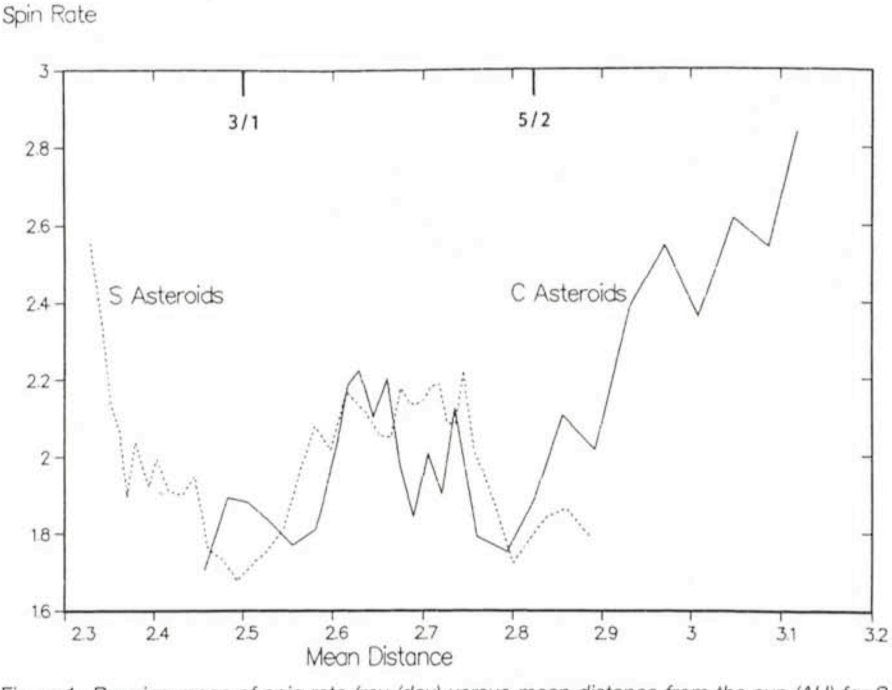


Figure 1: *Running mean of spin rate (rev./day) versus mean distance from the sun (AU) for S and C asteroids. The bin sizes are 15 and 10 objects, respectively.*

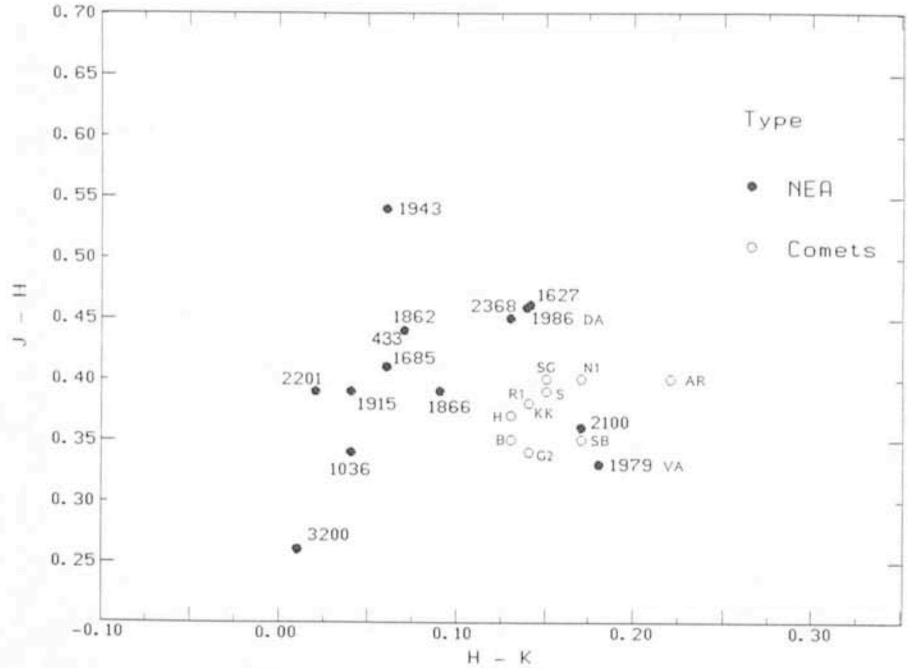
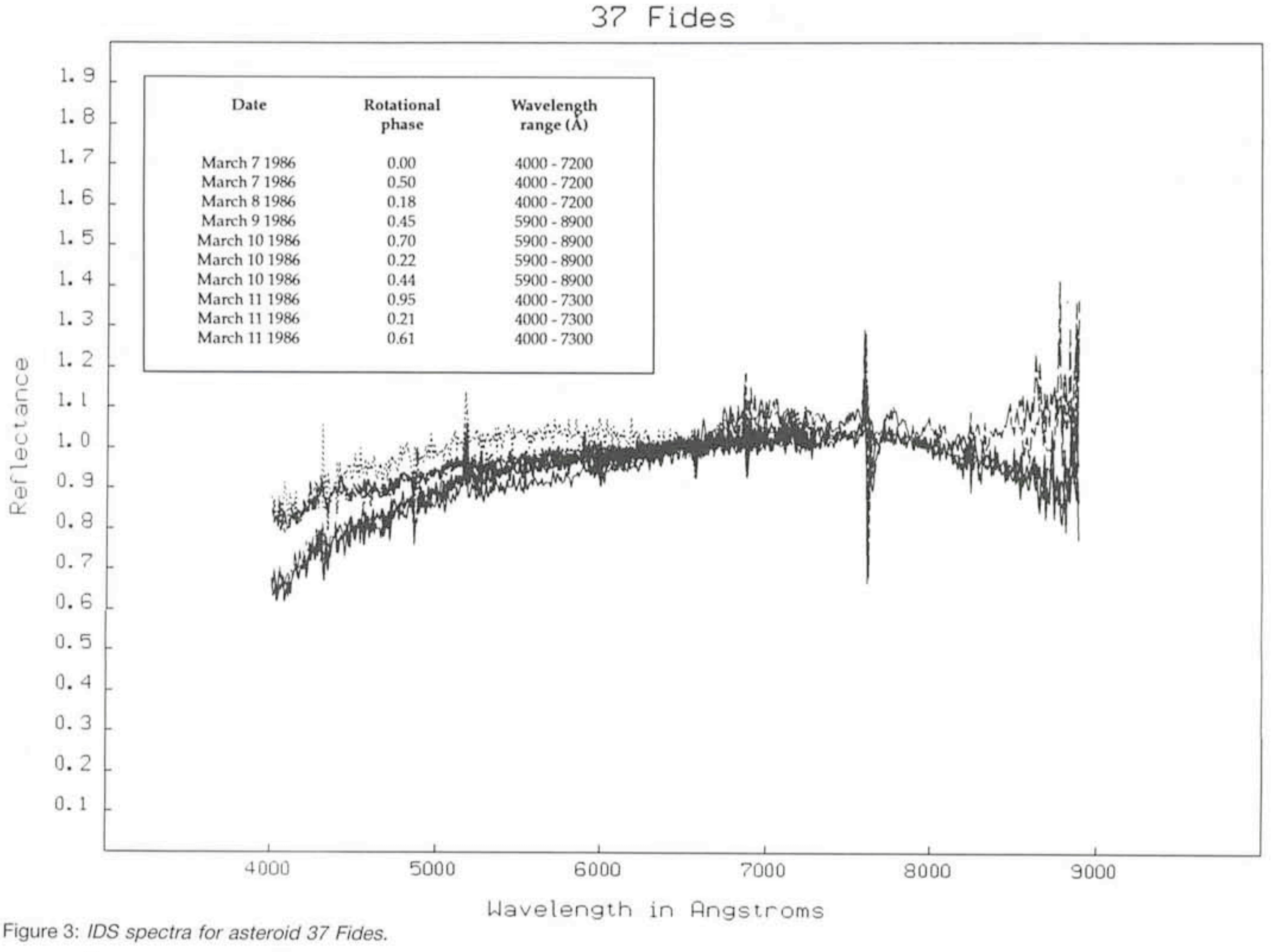


Figure 2: *JHK colours in magnitudes for Near-Earth asteroids and comets. (G2: Gehrels 2, SG: Swift-Gehrels, H.: Howell, B: Bowell, SB: Slaughter-Burnham, KK: Kearns-Kwee, R1: Reinmuth 1, S: Shoemaker, N1: Neujmin 1, AR: Arend-Rigaux).*

strong correlation between spin-rate and size (1). The running means of spin rate has been plotted using data for 36 C-type asteroids and 55 S asteroids with well determined periods. There is a peculiar trend for the S group which shows a steep rise of spin rate towards the inner edge of the main asteroid belt and a minimum (though statistically uncertain) near the 3 : 1 Kirkwood gap at 2.5 AU. Possibly a second minimum may be present at 2.8 AU where the 5 : 2 resonance gap is located. The general trend for the C-type asteroids seems to be the same but more data are needed to confirm these findings. Both data on small asteroids, asteroids at the resonances, and data for distant asteroids are desireable and will hopefully be obtained in the near future.

JHK Photometry

Broadband photometry gives colour indices which may be used for dividing asteroids into different taxonomic classes. An extension of the classification criteria into the infrared region of the spectrum is important since several absorption features that are characteristic for the various taxonomic types are present at these wavelengths. JHK observations of asteroids give thus a possibility to improve the definition of the taxonomic types and to look for interesting absorption features. The 1-m telescope was used during 1984–1986 to obtain JHK colours for 74 main belt asteroids



Date	Rotational phase	Wavelength range (Å)
March 7 1986	0.00	4000 - 7200
March 7 1986	0.50	4000 - 7200
March 8 1986	0.18	4000 - 7200
March 9 1986	0.45	5900 - 8900
March 10 1986	0.70	5900 - 8900
March 10 1986	0.22	5900 - 8900
March 10 1986	0.44	5900 - 8900
March 11 1986	0.95	4000 - 7300
March 11 1986	0.21	4000 - 7300
March 11 1986	0.61	4000 - 7300

Figure 3: *IDS spectra for asteroid 37 Fides.*

and 3 Apollo asteroids. Combined with previously published observations this gives a total sample of 151 asteroids with known JHK colours (2). Here we discuss only the results concerning the Apollo asteroids. Figure 2 shows J-H versus H-K for near-Earth asteroids and for comets. From the figure may be seen that there is a large spread in the JHK colours for these asteroids, maybe reflecting a variety of surface materials and different origins. Almost half the objects fall into the S-type domain which long seemed to be the dominating type among this kind of asteroids. The asteroids 1627 Ivar, 2368 Beltrovata and 1986 DA have almost identical JHK colours and lie in the part of the diagram where D-type asteroids and comets are found. These results are even more evident for the asteroids 2100 Ra-Shalom and 1979 VA rendering them candidates for being extinct cometary nuclei.

Figure 4: *The first picture of asteroid 2100 Ra-Shalom was taken with the ESO Schmidt telescope on October 2, 1975 (see also the* Messenger *No. 15, page 17). During the 60-min exposure, it moved more than 5 arcminutes. By coincidence, it was seen in front of the Sculptor dwarf galaxy.*

IDS Spectra of Asteroids

Spectra of asteroids give important contributions to the knowledge about the composition of the surfaces of the asteroids and a possibility to study albedo variegations. IDS and Reticon spectra were obtained with the ESO 1.5-m telescope during 1985–1986 and a total of 148 spectra of 45 asteroids were obtained. Additional CCD spectra have also been obtained. The spectral range was normally 3800–9000 Å and a typical resolution was 172 Å/mm. The intention was to cover as many asteroid types as possible in order to make it possible to draw conclusions about the surface composition and to improve the definitions of the taxonomic types. Some asteroids were also observed quite frequently in order to get spectra at different rotational phases for studies of surface variegations. In this short report we will only discuss some of our investigations of surface variegation (8).

For 37 Fides, an asteroid known to have quite complex lightcurves (3), we obtained 10 spectra. These are shown in Figure 3. As seen from the figure there are good reasons to believe that for 37 Fides we have albedo variegations over the surface. Another indication for albedo variegation comes from the unusually high odd Fourier terms in the lightcurves of Fides (4). With further UBV observations of Fides an accurate determination of the sidereal rotation period will be possible and thus a determination of the absolute rotational phase at the time of the spectroscopic observations.

Although we now have lightcurve information about more than 500 asteroids (7) there are still many interesting questions that are not settled yet. We still lack data on small asteroids to draw conclusions about spin properties of these asteroids. Outer-belt asteroids and Trojans are still a fairly unknown population although there are reasons to believe that these asteroids have a quite different evolution from that of main-belt asteroids. Data on more family asteroids are also higly warranted as are further studies on spin properties of different taxonomic types. More high-precision UBV photometry of already well-observed asteroids is needed in order to increase the knowledge about the pole orientations. Observations in order to improve asteroid magnitudes, and thus the sizes are also needed as well as studies of phase variations of magnitudes and colours. Further infrared observations and spectra will help to improve the definition of the taxonomic types and the knowledge about how common surface variegations are. Target asteroids for space projects such as VESTA, a proposed space mission to the asteroids by ESA, CNES and Interkosmos, should be studied extensively from the ground in order to complement space observations and to calibrate the ground data-base on asteroids in general.

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