N91-26002

Near-Infrared Reflectance Spectra-Applications to Problems in Asteroid-Meteorite Relationships.

Lucy A. McFadden, Alan Chamberlin (California Space Institute, UCSD, La Jolla, CA 92093-0216), Faith Vilas (NASA/JSC, Houston, TX 77058)

Near-infrared spectral reflectance data were collected at the Infrared Telescope Facility (IRTF) at Mauna Kea Observatories in 1985 and 1986 for the purpose of searching the region near the 3:1 Kirkwood gap for asteroids with the spectral signatures of ordinary chondrite parent bodies. We are looking at 12 reflectance spectra.

The presence of ordinary chondrite parent bodies among this specific set of observed asteroids is not obvious. Though our sample is biased towards the larger asteroids in the region due to limitations imposed by detector sensitivity. Our data set, which was acquired with the same instrumentation used for the 52-color asteroid survey (Bell et al., 1987), also present some additional findings.

We note the range of spectral characteristics that exist among asteroids with the same taxonomic type. This is not a surprise but is a point that is worth illustrating. Tholen's taxonomic classification system designates an individual letter to a group of asteroids covering a specific range of photometric properties. With the single letter designation, we tend to think that all S-type or all P-type asteroids are alike. Our data remind us of the variability in the spectral properties and thus the mineralogy and/or surface texture or structure of the asteroid surfaces.

Another quickly drawn conclusion about the asteroids near the 3:1 Kirkwood gap is that they are all S-type asteroids, because this region of the asteroid belt is in the inner belt, where S-type asteroids predominate. However, when we look at the available data for this region, an equal number of asteroids are dark and not S-types.

One of the major differences between the reflectance spectra of ordinary chondrites and S-type asteroids is that the near-infrared reflectance of the S-asteroids has been believed to be significantly higher than the spectra of ordinary chondrites measured in the laboratory. It seems that with the availability of the 52-color asteroid survey, and the careful photometric calibration that has gone into that work and was used in reduction of the data presented here, that clearly not all S-type asteroids have a high IR reflectance. The availability of photometric data in the near-infrared of moderate spectral resolution may reduce some of the restrictions in finding asteroid analogues to the ordinary chondrites that were thought to exist with a less complete data set (Feierberg et al., 1982). Although the requirement that the positions of the 1- and 2-mm pyroxene and olivine bands be consistent with the chemistry of ordinary chondrite silicates remains the strictest requirement for finding ordinary chondrite analogues among the asteroids.

SPIN VECTORS OF ASTEROIDS 21 LUTETIA, 250 BETTINA, 337 DEVOSA, AND 694 EKARD; T.Michałowski, and T.Kwiatkowski, Astronomical Observatory, Adam Mickiewicz University, ul. Słoneczna 36, 60-286 Poznań, Poland

Lightcurve amplitudes, magnitudes and epochs of extrema of brightness are used in order to obtain the spin vectors of asteroids 21, 250, 337, and 694. There are no previous results for 250 and 337 - in cases of 21 and 694 we compare our poles with those already obtained by the others.

SECULAR RESONANCES AND ASTEROID FAMILIES

A. Milani, Univ. Pisa and Z. Knežević, Astron. Obs., Belgrade

We have developed a new analytical theory for secular resonance location. It is complete to degree four in the eccentricity and inclination of both the planets and the perturbed bodies, and to order two in the masses of the planets. The mixed effects resulting from the interactions of perturbations from different planets are accounted for. Not only the classical resonances associated with combinations of two secular frequencies, but also those associated with combinations of four frequencies can be studied. The algorithm can be applied to examine the regions with moderate eccentricity and inclination over the entire solar system.

We have applied this theory to the asteroid main belt, also to investigate how the distribution of the asteroids in the phase space is affected by the secular resonance surfaces. Apart from the well established fact that the classical resonances bound the densely populated portion of the main belt, and isolate smaller groups of asteroids, we discuss some interesting and somewhat puzzling features of the four frequencies resonances. As an example the secular resonance associated with the combination $g+s-g_6-s_6$ cuts across the large and well identifiable Eos family; apparently it does not result in long term dynamical erosion of the identifiable family, although the proper element theory has to be suitably adapted not to loose the accuracy. The theory for the Eos family accounting for this resonance allows to explain the uneven distribution of the argument $\varpi + \Omega$ among the family members, without assuming a recent formation; on the contrary, lower limit for the age can be derived.

GROUND-BASED OBSERVATIONS OF 951 GASPRA: CCD LIGHTCURVES AND SPECTROPHOTOMETRY WITH THE GALILEO FILTERS

S. Mottola ‡, M. Di Martino *, M. Gonano-Beurer ‡, H. Hoffmann ‡, and G. Neukum ‡;
‡DLR German Aerospace Research Establishment, D-8031 Oberpfaffenhofen,
*Osservatorio Astronomico di Torino, I-10025 Pino Torinese, Italy

CCD photometry and spectrophotometry of 951 Gaspra have been carried out by our group since the apparition of 1988 to characterize the physical and dynamical properties of this asteroid. The aim of this work is to provide a ground-based reference to be integrated and compared with the data which will be obtained during the Galileo encounter of October 1991.
In the frame of an international campaign (Di Martino et al., 1990) we observed 951 Gaspra during the apparitions of 1988 and 1990. As a result of these reconnaissance observations, which spanned over a long time interval and covered 20 deg. solar phase angle, we have determined for the first time the magnitude-phase and amplitude-phase relationships (Blanco et al., 1990; Barucci et al., 1990). From these measurements we could also derive the values of the parameters for the Bowell-Harris-Lumme photometric model: H= 11.788 $\pm$ 0.018 and G=0.217 $\pm$ 0.025 , the measured value of G being within the average for S asteroids (G=0.22 $\pm$ 0.03, Skoglöv et al., 1990). Data were achieved in the BVR filters, giving the following color indices B-V= 0.80 $\pm$ 0.05 and V-R= 0.50 $\pm$ 0.05.
Moreover from these observations it was possible to determine for the first time a sidereal period for this object, Psid= 7.0422 $\pm$ 0.0002 hr, and to obtain the indication of its prograde sense of rotation, applying the technique proposed by Taylor and Tedesco (1983).

During the apparition of 1991 of 951 Gaspra, we will carry out observations from the European Southern Observatory (La Silla,Chile), using the DLR CCD Camera equipped with a spare set of the Galileo SSI filters. These filters, which cover the wavelength range 0.4 - 1.0 μm, will be used for the first time to take measurements of this object.
The campaign will be mainly devoted to the study of the spectrophotometric properties of this small-sized and atypic S-type asteroid (Veverka et al., 1990) and will allow to obtain an homogeneous data set to be directly compared with the measurements returned by the spacecraft. The acquisition of high time-resolution, high SNR lightcurves in the different spectral channels will make it possible to search for the occurence of surface heterogeneities, linked most probably to a different content of metal and mafic silicates, and albedo spots (morphological/textural variegations) on hemispherical scale.
At present only a tentative solution for the orientation of the rotational axis has been derived on the base of the available data set for three oppositions (Chapman, 1990). The results of the 1991 apparition should also allow to give additional inputs for an accurate determination of the direction of the spin axis.

REFERENCES

Barucci M.A., C. Blanco, G. De Angelis, M. Di Martino, M. Fulchignoni, M. Gonano, J. Lecacheux, S. Mottola, G. Neukum, W. Wisniewski, *BAAS*, vol.22, n. 3, p. 1113 (1990).
Blanco C., M. Di Martino, W. Ferreri, M. Gonano, S. Mottola, G. Neukum, Photoelectric and CCD Photometry of 951 Gaspra, *Advances in Space Research*, in press, (1990)
Chapman C.R., private communication (1990).
Di Martino M., W. Ferreri, M. Fulchignoni, G. De Angelis, M.A. Barucci, J. Lecacheux, R. Burchi, A. Di Paolantonio, *Icarus* 87, 372-376 (1990).
Skoglöv E., C-I. Lagerkvist, P. Magnusson, in: *Asteroids Comets and Meteors III*, eds. C-I. Lagerkvist, H. Rickman, B.A. Lindblad, M. Lindgren, Univ. Uppsala 1990, p. 183.
Taylor R.C. and E.F. Tedesco, *Icarus* 54, 13-22 (1983).
Veverka J., Y. Langevin, R. Farquhar and M. Fulchignoni in: Spacecraft Exploration of Asteroids: the 1988 perspective, *Asteroids II* , eds. R.P. Binzel, T. Gehrels, M.S. Matthews, Univ. Arizona, Tucson 1989, p. 970

CCD-PHOTOMETRY OF COMETS AT LARGE HELIOCENTRIC DISTANCES;

B.E.A. Mueller, Kitt Peak National Observatory, Tucson AZ 85719

CCD imaging and time series photometry are used to determine the state of activity, nuclear properties and eventually the rotational motion of cometary nuclei. The rather surprising outburst of P/Halley at 14.3 AU (Hainaut, Smette & West, 1991, *IAU Circ.* **5189**; Meech 1991, *IAU Circ.* **5196**) proves that cometary activity and mantle evolution are not yet fully understood. On the other hand Tempel 2 had an activity onset during its last apparition at a heliocentric distance of only 1.9 AU (Boehnhardt et al. 1990, *Icarus* **86**, 58). It is thus very important to understand the temporal evolution of comets and therfore the differences between new and old comets and a possible realation to asteroids.

CCD-photometry of comets at large heliocentric distances is presented. The photometry contains mostly R-band data, however some data also exist in the V- and the I-bands. Preliminary results of this long-term program on activity status and rotational state of the objects are introduced. The objects observed include P/Giacobini-Zinner, P/Churyumov-Gerasimenko, P/Tempel 2, and 2060 Chiron.

ASTEROID ORBITAL ERROR ANALYSIS: THEORY AND APPLICATION

K. Muinonen and E. Bowell
Lowell Observatory, Flagstaff, Arizona, U.S.A.

We present a rigorous Bayesian theory for asteroid orbital error estimation in which the probability density of the orbital elements is derived from the noise statistics of the observations. For Gaussian noise in a linearized approximation, the probability density is also Gaussian, and the errors of the orbital elements at a given epoch are fully described by the covariance matrix. The law of error propagation can then be applied to calculate past and future positional uncertainty ellipsoids (cf. Yeomans *et al.* (1987), *Astron. J.* **94**, 189).

A number of analytical results can be derived from the covariance matrix in a two–body orbit approximation (with minor changes, the results are valid for integrated orbits). For example, as an observational arc is lengthened, the accuracy of the semimajor axis is improved much faster than that of the other orbital elements. Moreover, the variances of the mean, eccentric, and true anomalies have a quadratic time dependence. It is also worth noting that the correlations among the orbital elements are relatively insensitive to the arc length. This is due to the geometric restrictions of optical ground–based observations, and could be alleviated by radar or spacecraft observations. In ephemeris prediction, the error ellipse is usually very elongated and aligned with the line of variation.

Selected applications of orbital error analysis:

- In orbit computation, the behaviour of the covariance matrix serves as a guide for eliminating poor observations and suggests a way to automate the process.
- In the case of newly discovered asteroids, a strategy for follow–up or recovery can be devised. For example, one may decide whether an asteroid having a one–apparition orbit is recoverable using a narrow– or wide–field instrument and what the breadth of the search should reasonably be.
- A figure of merit is associated with each possible future observation, thereby suggesting an observational strategy that would optimize the orbit improvement and avoid making observations that would not contribute significantly.
- A criterion for numbering an asteroid can be established on the basis of the predicted ephemeris uncertainty over a suitable interval. For example, an ephemeris accuracy of 10 arcsec or better over 20 years might be required.
- Ephemeris uncertainty predictions can be used for observations made in the past, thus allowing the identification of images on archive plates.
- Knowledge of the accuracy of orbital elements can be used to decide whether it is appropriate to calculate proper elements.
- Uncertainties in occultation ground tracks can be determined.
- A linearized approximation has been applied to spacecraft trajectory error analysis (cf. Cappellari *et al.* (1976), Eds., GSFC Report X–582–76–77).