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GROUND-BASED OBSERVATIONS OF 951 GASPRA: CCD LIGHTCURVES AND SPECTROPHOTOMETRY WITH THE GALILEO FILTERS [1]

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ABSTRACT

This paper reports the observations of 951 Gaspra carried out at the European Southern Observatory (La Silla, Chile) during the 1991 apparition, using the DLR CCD Camera equipped with a spare set of the Galileo SSI filters. Time-resolved spectrophotometric measurements are presented. The occurence of spectral variations with rotation suggests the presence of surface variegation.

INTRODUCTION

CCD photometry and spectrophotometry of 951 Gaspra have been undertaken 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.

At the time of the 1991 apparition, we performed observations of 951 Gaspra with the ESO 1-m telescope, using the DLR CCD Camera equipped with a subset of filters of the Galileo Solid-State Imaging (SSI) subsystem (Fig. 1). This campaign has been mainly devoted to the study of the spectrophotometric properties of this small-sized and atypical S-type asteroid. The acquisition of high time-resolution, high signal-to-noise lightcurves in different spectral channels made it possible to search for the occurence of surface heterogeneity on a hemispherical scale.

INSTRUMENTATION AND DATA REDUCTION

The DLR CCD camera houses a Thomson 384x576 pixel TH-7882 Charge Coupled Device with a readout noise of 7 electrons RMS. The front side of the detector is coated with a down-converting phosphor dye in order to extend the sensitivity of the device to the blue and ultraviolet regions of the spectrum. As a result the spectral coverage is $250 \leq \lambda \leq 950$ nm with a quantum efficiency $\geq 10\%$. A computer-driven filter-wheel houses the spare set of the Galileo (GLL) interference filters. The integration times were chosen accordingly to the sensitivity of each spectral channel, typically ranging between 2 and 10 minutes.

Several comparison stars were present each night in the same CCD field of the asteroid, and a careful placement of the asteroid's image in the frame allowed the stars to advance across the image still remaining in the same field of the asteroid for the whole duration of the observations. For the purpose of spectral calibration we used the stars Tau Sco and 42 Lib, selected from the catalogs of Aller et al. (1966) and Cochran (1980), respectively. Due to the small angular distance between the asteroid and the calibration stars ($\leq$ 10 deg), it was possible to observe the stars each night at airmasses very close to that of the asteroid, thus minimizing the contribution of the extinction uncertainty on the overall error budget.

Flat fields were obtained each night in every filter from exposures of regions of the sky taken at dawn and dusk; they were successively bias-subtracted and averaged to improve the signal-to-noise ratio.

The data reduction was performed using the software package for CCD image processing in use at DLR. A version of this code available on a portable computer allowed us to perform the complete reduction of the data during daytime after each observing night. The first step of the processing consisted in the bias subtraction and flat-fielding of the scientific frames. After the images were decalibrated, the instrumental fluxes of each source in the field were evaluated by applying a synthetic aperture photometry procedure.

[1]Based on observations collected at the European Southern Observatory, La Silla (Chile).

Typical apertures had a diameter of 8 - 10 arcsec. Differential photometry between the asteroid and the field stars resulted in lightcurves with an internal consistency better than 0.008 mag in the GLL filters 3 and 7, and better than 0.003 in the other three channels.

OBSERVATIONS AND DISCUSSION

We obtained high-quality lightcurves of 951 Gaspra during three nights in May 1991 in five spectral channels. The log of the observations is reported in Table 1. Conditions were photometric with good seeing on all three nights. On May 16 and 17, full cycle lightcurves were obtained with the GLL filters 1, 2 and 3, 7 respectively, and a partial coverage on May, 13 (three hours of time interval) with the GLL filter 4.

The folding of the lightcurves in all channels with a Fourier analysis fitting procedure (Harris et al., 1989) yields a synodic rotational period $P = 7.0394 \pm 0.0002$ hr.

The mean magnitude values of the lightcurves in these five spectral channels have been corrected for the changing phase angle and sun- and earth-asteroid distance variations. Phase reddening has been neglected, since in the phase angle range of interest this effect is in the millimag range. The resulting reflectance spectrum is shown in Fig. 2. The reflectivities are scaled to unity at λ= 560 nm, corresponding to GLL filter 1. For the purpose of comparison, the data of the ECA survey (Zellner et al., 1985) are also shown. The two spectra are in good agreement and exhibit a strong drop-off towards the UV, a maximum in reflectance near 760 nm and the presence of the 1-μm absorption band.

Table 1. Aspect data of 951 Gaspra.

Date (UT)	Long.1950 (deg)	Lat.1950 (deg)	r (AU)	Δ (AU)	Phase (deg)	Filter
1991 05 13.3	243.3	-1.7	2.490	1.492	-4.8	GLL 4
05 16.2	242.6	-1.6	2.486	1.482	-3.4	GLL 1,2
05 17.2	242.3	-1.6	2.485	1.478	-2.9	GLL 3,7

For further evaluation, we have combined the lightcurves obtained with the GLL filters 1, 2, 3 and 7 (Fig. 3) into a composite. This has been successively fitted with a low order Fourier expansion, in order to derive the "mean" lightcurve. To detect possible spectral variations with rotation, we have then plotted the difference between the single lightcurves and the Fourier expansion (Fig. 4).

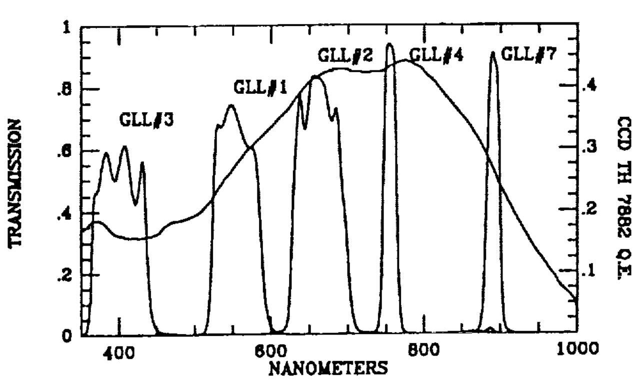

Fig. 1. Quantum efficiency of the TH 7882 CCD and spectral transmission of the GLL filters used in this work.

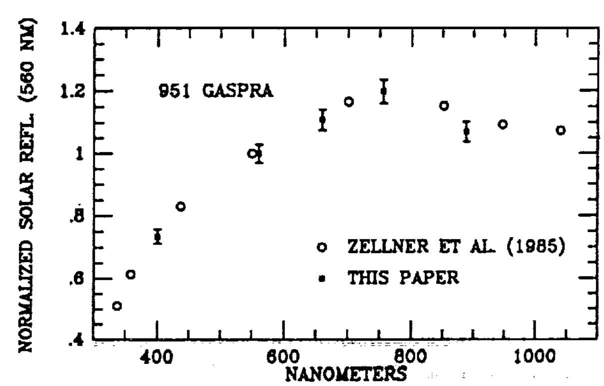

Fig. 2. Spectral reflectance of 951 Gaspra obtained with the GLL filters. The ECAS spectrum is also shown.

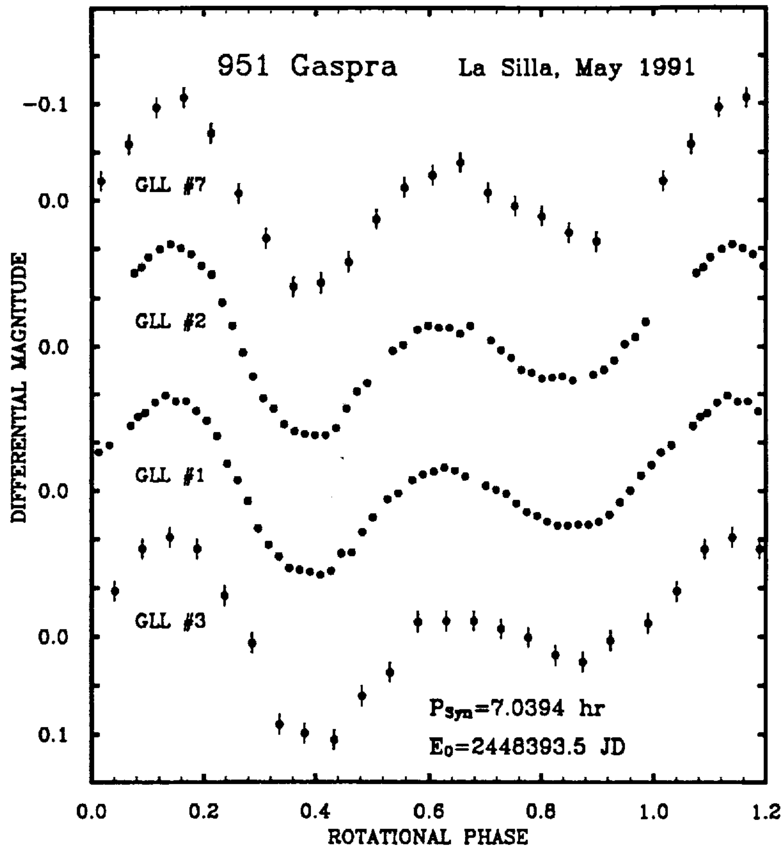

Fig. 3. Lightcurves of 951 Gaspra obtained with the GLL filters. The data points beyond the rotational phase 1.0 are repeated.

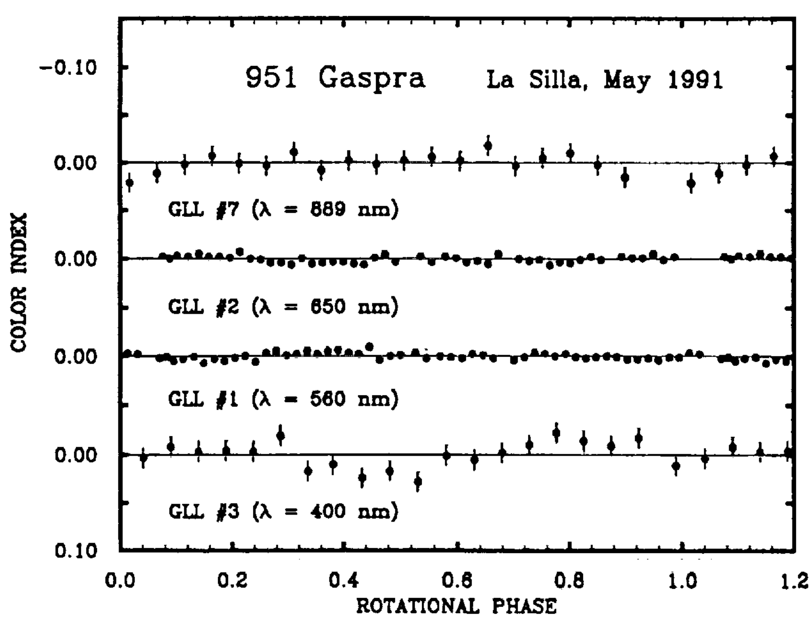

Fig. 4. Differences between the lightcurves in each filter and the mean lightcurve (see text).

The most evident feature is a spectral variation in the GLL filter 3. This has an approximately double-periodic sinusoidal shape, with an amplitude of about 0.035 mag. This variation is detected at a level of about 2 σ, signifying that there is a probability of 95% that this feature is real and not due to a random variation associated with the noise of the measurements. A second spectral variation is detected in the GLL filter 7, with an amplitude of about 0.03 mag. Although not fully characterized, due to a short gap in the data acquisition sequence, this variation has a detection significance between 1 and 2 σ (probability$\geq$65%). Subtle changes in the spectral channels GLL 1 and 2 are detected at a very low confidence level, thus being compatible with no spectral variations at these wavelengths.

Before giving any intepretation of the observed spectral variations, we have checked whether spurious effects could account for the color changes. Variability in the atmospheric extinction, in the comparison stars, the close appulse of the asteroid to a faint background star during the observations, have been detected and accounted for when performing the data reduction, and are not likely to explain the observed behavior. It is also unlikely that an incorrect flat-fielding could produce such variations and the fact that the telescope has been tracked at the asteroid motion rate definitely rules out this possibility. However, since it was not possible to repeat the measurements, the possibility that some observational or data reduction error produced the observed effect there exists, although we cannot identify any reasonable cause.

Gradie and Veverka (1981) have demonstrated that the rotation of a non-spherical body with uniform surface composition and texture can induce spectral variations. However, this effect accounts for an increase of the reflectance in the UV at the minimum of the lightcurve, which is not present in our measurements. Therefore we consider the observed spectral variations in the UV and IR as indicators of surface heterogeneities of 951 Gaspra.

The minimum in the UV at about 0.45 rotational phase is not likely to be due to a textural variation, since any change in the grain size would also affect the overall spectral contrast, especially the depth of the 1 μm-band. In fact, no spectral variations are detected in the green, red, and infrared filters at this rotational phase. Therefore, this spectral variation most likely provides the evidence for a compositional heterogeneity of Gaspra's surface, which causes an increased absorption in the UV due to charge transfer processes.

The IR minimum close to 1.0 rotational phase represents an increase of the 1 μm absorption and could be due either to a lower olivine to pyroxene ratio or to an augmented content of mafic minerals. There appears to be a possible correlation between the variation in the IR and a minor darkening in the UV at this rotational phase. If this is true, the presence of additional textural surface variegations cannot be excluded. Changes in the content of a metallic phase are known to alter the overall slope of the spectral reflectance. A reddening of the spectrum would indicate a higher amount of pure metal. Such an effect, however, is not observed near 0.45 and 1.0 rotational phase. Thus, significant differences in the metallic content can be excluded.

The observed variations, if confirmed to be real, imply that the composition and possibly the texture of Gaspra's surface are heterogeneous. The possible confirmation of this result will come when the multi-spectral spatially resolved data of the Gaspra surface will be available from the Galileo flyby.

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