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10 Hygiea: ISO Infrared Observations[1]

M. A. Barucci

LESIA, Observatoire de Paris, France
E-mail: antonella.barucci@obspm.fr

E. Dotto

INAF, Osservatorio Astronomico di Torino, Italy

J. R. Brucato

Osservatorio Astronomico di Capodimonte, Italy

T. G. Müller

ISO Data Centre, Astrophysics Division, Space Science Department of ESA, Villafranca, Spain

P. Morris

IPAC, Caltech, Pasadena, California

A. Doressoundiram

LESIA, Observatoire de Paris, France

M. Fulchignoni

LESIA, Observatoire de Paris, France; and Université de Paris VII, France

M. C. De Sanctis

IAS, CNR, Rome, Italy

T. Owen

University of Hawaii, Honolulu, Hawaii

J. Crovisier

LESIA, Observatoire de Paris, France

A. Le Bras

LESIA, Observatoire de Paris, France; and IAS, Orsay, France

and

L. Colangeli and V. Mennella

Osservatorio Astronomico di Capodimonte, Italy

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Observations of emissivity features of 10 Hygiea have been made for the first time in the relatively unexplored thermal-infrared wavelength region with the ISO (Infrared Space Observatory) satellite. Spectrophotomer (PHT-S) and short wavelength spectrometer (SWS) spectra of 10 Hygiea, obtained at 5.8–11.6 and 7–45 μm, respectively, are presented. In order to remove the thermal emission continuum, an advanced thermo–physical model has been applied to the observational data. To better interpret the spectral features above the thermal emission continuum, we compared the ISO observations with laboratory spectra available in the literature.

[1] Based on observations with ISO, an ESA (European Space Agency) project with instruments founded by ESA Member States (especially the PI countries: France, Germany, the Netherlands, and the United Kingdom) with the participation of ISAS and NASA.

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Several laboratory experiments on minerals and meteorites have been performed to complete the analysis and to study the spectral behavior at various grain sizes. A possible spectral similarity with CO carbonaceous chondrites at small grain size is demonstrated.

Key Words: **asteroids; 10 Hygiea; infrared observations; spectroscopy; ISO.**

1. INTRODUCTION

Observations of the asteroid 10 Hygiea have been performed for the first time in the wavelength range 5.8–45 μm by the Infrared Space Observatory (ISO), an ESA project launched on November 1995 and operative until April 1998 (Kessler *et al.* 1996). These observations allowed us to investigate the surface composition of this object, which belongs to the C taxonomic type (Barucci *et al*. 1987, Tholen 1989, Tedesco *et al*. 1989, Bus 1999). The C class contains primitive dark objects whose visible to near-IR wavelength characteristics are similar to those of carbonaceous chondrite meteorites (Chapman and Salisbury 1973, Gaffey *et al*. 1993, Hiroi and Vilas 1995). These asteroids are very common, especially in the outer part of the main belt, and their investigation should yield information about the early chemical and physical processes operating in this portion of the Solar Nebula. Lebofsky (1980) and Jones *et al*. (1990) presented the first evidence of the presence of aqueous alteration products on C-type asteroids. Aqueous alteration products are linked with the strong absorption feature at about 3 μm due to water of hydration. Aqueous alteration is a low temperature chemical alteration of materials by liquid water. This could indicate the presence of water ice originally in these asteroid types which were heated sufficiently to melt, producing water responsible for this chemical alteration. Selective induction heating may have produced aqueous alteration at the surface, resulting in the carbonaceous chondrite parent bodies. Vilas *et al*. (1994), on the basis of visible observations, proposed that a particular region of the outer main belt (between 2.6 and 3.5 AU) seems to be characterized by objects which have undergone some kind of aqueous alteration process. Barucci *et al*. (1998) confirmed the existence of this zone and found that 70% of C-class asteroids located there show evidence of aqueous alteration.

Asteroid 10 Hygiea, named in honor of the Greek goddess of health, daugther of Aesculapius, was discovered in 1849 by A. de Gasparis in Naples. It is the fourth largest asteroid, after 1 Ceres, 2 Pallas, and 4 Vesta, with an IRAS diameter of 407 km and an albedo $pv = 0.07$ (Tedesco *et al*. 1992). Hygiea rotates around its principal axis in a retrograde sense with a period of 27.63 ± 0.02 h (Michalowski *et al*. 1991, Erikson and Magnusson 1993, and López-González and Rodríguez 2000). On the basis of Speckle interferometry, Ragazzoni *et al*. (2000) found a shape with an average diameter of 444 ± 35 km and a semimajor axis ratio $a/b = 1.11$. Storrs *et al*. (1999) observed Hygiea with the Hubble Space Telescope (HST), obtaining only marginal resolution of the object, and they did not detect any companion down to a limit seven magnitudes fainter than the primary asteroid. Aqueous alteration products have been detected on Hygiea's surface by Jones *et al*. (1990) and Vilas (1994) on the basis of 3.0-μm and 0.7-μm absorption features. Other observations in the visible region were performed at different epochs, but the 0.7-μm absorption feature (Bus 1999, Fornasier *et al*. 1999) was not detected. These results may imply compositional variation on the surface. Tentative characterization of the surface composition has been made by Lebofsky *et al*. (1985), who studied the thermal properties of Hygiea (observations at 2.2, 10.6, 21, 370 and 770 μm) and concluded that Hygiea is a dusty object, whose surface could be dustier and more mature than the surface of the Moon. Johnston *et al*. (1989), on the basis of microwave observations of Hygiea at 2 and 6 cm, derived a regolith layer of depth greater than 8 cm. Rivkin (1997), looking for variation in the 3-μm spectral region, found some latitudinal variations that were due to possible excavations of interior layers, but he found no clear evidence of variation with the rotation. The latter was found, however, by Mothé-Diniz *et al*. (2001) on the basis of visible data only. Comparing reflectance spectra of a few selected C, G, B, and F asteroids with spectra of a few tens of carbonaceous chondrites, Hiroi *et al*. (1996) found a good match between the 0.3–3.6-μm spectrum of Hygiea and an unusual CI/CM meteorite (Y-82162).

2. OBSERVATIONS

The Hygiea observations were performed with ISO using the imaging photopolarimeter ISOPHOT (Lemke *et al*. 1996) and the short wavelength spectrometer (SWS) (de Graauw *et al*. 1996). In particular, we used the subsystem spectroPhoTomer (PHT–S), which consists of two low-resolution grating spectrometers which cover the wavelength range 2.5–5 μm (PHT–SS) and 6–12 μm (PHT–SL). PHT–SS and PHT–SL have a common square entrance aperture of 24×24 arcsec. The resolution $\lambda/\Delta\lambda$ is about 85 for PHT–SS and about 95 for PHT–SL.

The PHT observations were performed in staring mode with a default of 32 sec dark exposure at the beginning of the measurement. ISOPHOT interactive analysis (PIA[2]) V7.3.3 was used for the standard data reduction up to signal level, including linear ramp fitting, deglitching on ramp and signal level, and orbit-dependent dark signal subtraction (Gabriel *et al*. 1997). The calibration of the derived signal was done with the *dynamic calibration* method (Laureijs *et al*. 2001) using two calibration standards for each detector pixel, combined by weighting the ratios between the target and calibrator signals.

The SWS was employed in a mode designed to yield maximum spectral resolution (astronomical observing template 6; de Graauw *et al*. 1996) with its grating sections, $\lambda/\Delta\lambda = 1500$–3200. The two grating sections separately cover 2.38–12.0 and 12.0–45.2 μm and are independently wavelength and flux

[2] PIA is a joint development by the ESA Astrophysics Division and the ISOPHOT consortium.