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The MarcoPolo-R target asteroid (175706) 1996 FG3: hydrated minerals and a variable spectral slope

A. S. Rivkin[1], E. S. Howell[2], F. E. DeMeo[3], R. J. Vervack[1], R. P. Binzel[3], C. Magri[4], M. C. Nolan[2], Y. R. Fernandez[5], A. F. Cheng[1], M. A. Barucci[6], P. Michel[7], J. de León[8], D. Perna[9]. [1]JHU/APL, Laurel MD (andy.rivkin@jhuapl.edu), [2]Arecibo Observatory, Arecibo PR, [3]Massachusetts Institute of Technology, Cambridge MA [4]University of Maine, Farmington ME [5]University of Central Florida, Orlando FL, [6]University Paris Diderot, CNRS, Observatory of Paris, France, [7]University of Nice, CNRS, Côte d'Azur Observatory, France, [8]Inst. Astro. Andalucia, Spain, [9]Univ. di Roma, Italy.

Abstract

(175706) 1996 FG3 is the target asteroid of the MarcoPolo-R sample return mission concept, a finalist in ESA's Cosmic Vision competition. Its reflectance spectrum has a 3-µm band, interpreted as due to hydrated minerals (those with OH or H_2O). In addition, repeated observations show a spectral slope varying from more C-like to more X-like.

1. Introduction and Motivation

A combination of a highly-accessible orbit and a C-class spectrum has made the asteroid (175706) 1996 FG3 of great interest to the science and engineering communities. Its accessibility and likely-primitive (rather than igneous) mineralogy [1] has led to its status as the prime target for the *MarcoPolo-R* sample return mission proposal, currently under consideration by the European Space Agency. In addition, it has been identified to be a binary object, which further increases its scientific value [2].

The asteroid 1996 FG3 made a close pass to the Earth in late 2011 and early 2012, when it was observed by several teams. This provided an opportunity not only to confirm its C-complex classification and low albedo, but also to extend spectral data to 4 µm, where relatively few NEOs have been observed.

2. Observations

The SpeX instrument on the NASA Infrared Telescope Facility (IRTF) was used to observe 1996 FG3 in prism (0.8-2.5 µm) and long-wavelength cross-dispersed (LXD: 2.1-4.2 µm) modes. Prism data were obtained on four dates (28 November, 6, 24, 30 December 2011 UT), with LXD data obtained on the first three dates. Standard stars were obtained often and at similar airmasses to 1996 FG3, as well as an additional stage of data reduction fitting and removing a model atmosphere using ATRAN in order to minimize the effects of airmass mismatch and sub-pixel shifts. This stage is now commonly used in SpeX reductions [3].

Because of 1996 FG3's low albedo (0.045: [4]) and its small solar distance during these observations (~1-1.2 AU) a significant thermal flux was generated, swamping the reflected signal. A version of the Standard Thermal Model (STM: [5]) was used to calculate and remove the thermal flux. The input parameters are all known for 1996 FG3 save the "beaming parameter" (η), which can be fitted. The thermal model we use differs from the STM by allowing η to vary rather than fixing it at a default value.

In addition, a set of *VJHK* spectrophotometric observations were obtained on 25 January 2012 to characterize spectral variation with rotation.

3. Results

The LXD observations show evidence of an absorption near 3 µm (Figure 1), usually attributed to hydrated/hydroxylated minerals [6]. While the band depth is sensitive to the thermal model chosen, the existence of these minerals on the surface of 1996 FG3 would make it only the second known NEO to with a 3-µm band [7], and make it even more attractive as a sample return target. While hydrated minerals are common in carbonaceous chondrites, they have been more elusive in the NEO population for reasons that are still under investigation.

The prism-mode spectra taken during the 2011 apparition are all consistent with one another and are classified in C-complex or X-complex in the Bus-DeMeo taxonomy [8], similar to the carbonaceous chondrites (for instance, a prism-mode spectrum of Kaidun returns a Cgh classification while Renazzo returns an Xk classification).

The 2011 observations differ significantly in spectral slope from the 2009 observations of the MIT–UH-IRTF Spectral Survey (MINUS)[9], though they are similar to the observations of De Leon et al. (2011)[10]. While this difference may appear to require significant compositional differences on the surface of 1996 FG3, the CV3 meteorites show a range of spectral slopes consistent with what is seen on the asteroid (Figure 2). Indeed, the CV3 meteorites appear to be a reasonable quantitative match to 1996 FG3, although the match is not perfect (for instance, in the 1-µm region) or unique, and additional quantitative modeling is required to strengthen this proposed linkage. Other carbonaceous chondrite groups may also provide similar ranges of spectral slopes.

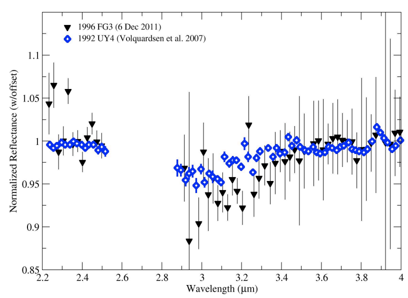

Figure 1: 1996 FG3 (closed symbols) shows evidence of an absorption in the 3-µm region, interpreted as evidence for hydrated minerals. 1992 UY4 (blue open symbols) is the only other NEO seen to have a 3-µm band.

The known pole position for 1996 FG3 [12] allows us to estimate the sub-Earth latitudes for the various observations of the object. These suggest that the recent apparition has been centered on the mid-latitudes of the southern hemisphere, while the MINUS observations were more equatorial. However, the spectral variation seen in the prism-mode spectra of 1996 FG3 does not appear to be simply related to sub-solar latitude. The nature of this variation as we best understand it will be discussed.

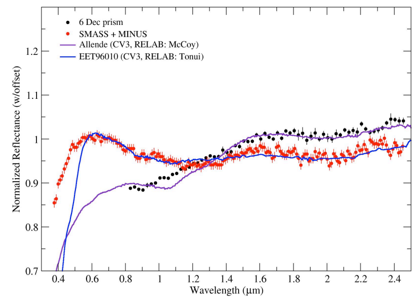

Figure 2: The 0.8-2.5 µm spectrum of 1996 FG3 appears different in its 2011 apparition than in 2009, in particular showing a different spectral slope. However this range in slopes is also seen in the carbonaceous chondrites. The solid lines show two different CV3 meteorite spectra downloaded from the RELAB database (Allende: McCoy PI, EET 96010: Tonui PI), demonstrating that 1996 FG3 is consistent with a CV composition. Further work is needed to rigorously model this proposed linkage as well as to investigate other carbonaceous chondrite groups.

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