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THE REFLECTANCE SPECTRUM AND TAXONOMIC TYPE OF ASTEROID (704) INTERAMNIA

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ABSTRACT

This study presents new evidence supporting the periodic occurrence of sublimation-driven activity on the main-belt asteroid (704) Interamnia, initially detected near perihelion in 2012. New low-resolution $R \approx 600$ reflectance spectra of Interamnia were obtained on 10 February 2025 at the Assy-Turgen Observatory using the 1.5-meter AZT-20 telescope, covering the 3500–7500 Å spectral range. At the time of observation, the asteroid's heliocentric distance was approximately 3.499 AU, placing it near aphelion (≈ 3.53 AU). The spectra reveal a broad absorption feature centered around 0.45–0.50 μm and an overall negative spectral slope. The observed spectrum was compared with averaged data from the SMASSII and Gaia DR3 surveys. Taxonomic classification using a template-matching approach identifies the asteroid as belonging to the F-type group, with weak spectral indications of sublimation activity. A comparison with modeled spectra of carbonaceous chondrite analogs suggests a composition dominated by CM and CI chondrites, which are rich in volatiles and hydrated minerals. These findings indicate that Interamnia is a dark, carbonaceous body with a primitive composition. The presence of transient sublimation activity, along with its low albedo and thermal properties, supports the hypothesis that (704) Interamnia is a large, partially degassed primitive object. Continued spectroscopic monitoring will be essential to further constrain the nature and extent of its activity.

Key words: Minor planets, asteroids: individual: (704) Interamnia – asteroid surfaces – sublimation – reflectance spectroscopy

1 INTRODUCTION

While Main Belt Asteroids (MBAs) were traditionally considered inert remnants from the early Solar System, recent observations—including spectroscopic analyses, infrared data, and direct missions—have revealed a more complex nature. Evidence suggests the presence of hydrated minerals, seasonal or intermittent activity (such as dust ejection and sublimation), and comet-like behaviors in some of these bodies. The observed sublimation activity, in particular, indicates a more intricate thermal and dynamical evolution for MBAs. Consequently, these objects are now recognized as crucial for understanding the origin of water, the evolution of the early Solar System, and for informing future space missions.

(704) Interamnia, one of the largest Main Belt Asteroids (MBA), is classified as a dark carbonaceous body. The mean diameter and geometric albedo of (704) Interamnia are 307.31 km and 0.08, respectively, according to WISE spacecraft data Masiero et al. (2014). Its semimajor axis and orbital eccentricity are 3.059 AU and 0.155, respectively. Interamnia is classified spectrally as either type "F" Tholen (1989) or type "B" Bus & Binzel (2002), both of which are characterized by a broad absorption band beyond $\sim 0.5\,\mu$m in combination with an overall negative spectral slope.

Recent advancements in observational spectroscopy, thermal modeling, and shape reconstruction have provided compelling evidence of complex surface processes, including episodic sublimation activity Busarev et al. (2016); Savelova et al. (2023). Table 1 presents a list of objects exhibiting spectral features of an intermediate type or transitional morphology between C-type and B/F-type asteroids. With an estimated volume comparable to that of (10) Hygiea (another MBA and candidate dwarf planet) and a low albedo ($\sim$ 0.05) Masiero et al. (2014); Vernazza et al. (2020), it has garnered interest as a transitional object between the taxonomic C-type group and the more bluish B/F-types.

Sublimation activity on Interamnia is considered atypical for a MBA, suggesting it may be a partially devolatilized body that retains primordial material in its subsurface layers. Research indicates that sublimation on Interamnia oc-

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curs unevenly and sporadically Busarev et al. (2016), pointing to a seasonal or trigger-driven nature of the activity. As the asteroid approaches perihelion, increased solar insolation may heat deeper surface layers, causing subsurface volatiles to sublimate. The resulting gas pressure beneath the surface crust can lead to fracturing of the asteroid and the ejection of dust and gas into the near-surface environment, resembling weak cometary activity. These outbursts likely occur locally within fractures or craters where the regolith layer is thinner.

All of this supports the interpretation of Interamnia as a potentially transitional object, not only in terms of composition, but also in terms of its evolutionary status. Interamnia occupies an intermediate position between typical B-type asteroids (characterized by carbonaceous surfaces and low albedo) and dormant comets that have lost most of their surface volatiles Busarev et al. (2016); Savelova et al. (2023). Such bodies are of particular interest for understanding the distribution of water and organic compounds in the early Solar System.

2 OBSERVATION AND METHODS

Spectral observations of the asteroid were conducted on April 4, 2024 and February 10, 2025 at the Assy-Turgen Observatory using a long-slit spectrograph based on volume-phase holographic gratings (VPHG), mounted at the prime focus of the AZT-20 telescope with an aperture of 1.5 meters and a focal length of 5.72 meters (f/3.8). The focal lengths of the spectrograph's collimator and camera are 130 mm and 85 mm, respectively. The spectrograph is equipped with an iXon Ultra 888 EMCCD detector, featuring a resolution of 1024×1024 pixels and a physical pixel size of 13 μm, resulting in an image scale of 0.717 arcseconds per pixel.

The observations were carried out in low spectral resolution mode ($R = 600$) using a 360 lines/mm VPHG with a dispersion of 4.25 $\AA$ per pixel, in first binning mode with the EMCCD operated at a gain factor of 2.4 and an exposure time of 60 seconds. The slit width was set to 9 arcseconds. Wavelength calibration was performed using spectra of a standard He–Ne–Ar lamp. The asteroid spectrum was measured using a differential method, comparing the radiation flux from the object to that of a standard star. Solar analog stars (G-type) were used as spectrophotometric standards.

Asteroid's orbital data at the time of the observations are provided according to the Minor Planet Center and summarized in Table 2 (columns 3–9). The last rows of the table contain the details of the EMCCD operating mode used during observations. According to the orbital data for Interamnia, its perihelion distance is $q = 2.58$ AU, and its aphelion is approximately $Q \approx 3.53$ AU.

The primary research method involves the accurate acquisition and analysis of spectra of sunlight reflected by the asteroid, as well as spectra of solar-type stars. Data reduction was carried out using the Image Reduction and Analysis Facility (IRAF) software package. Wavelength calibration was performed using spectra from a standard He–Ne–Ar lamp. The spectra of the asteroid and the calibration source were processed using identical procedures, with consideration given to changing air mass during the observations.

The calibrated spectra of standard stars and asteroids, observed on the same night, were normalized to the flux at a wavelength of 0.55 μm. The resulting normalized reflectance spectra of the asteroids were obtained by dividing the asteroid spectrum by the spectrum of a standard star, or by an averaged spectrum of several standard stars. This procedure introduces additional noise into the final result due to the intrinsic noise present in the spectra of solar analog stars.

A Butterworth filter was utilized to smooth the reflectance spectra Serebryanskiy et al. (2022). Reflectance spectra errors were estimated through the averaging of multiple spectra, rather than derived from the formal signal-to-noise ratio of individual spectra, thereby incorporating fluctuations due to varying observational conditions. The ultimate error, even with the smoothing procedure, remains below 10% of the reflectance spectrum value. A substantial increase in error at wavelengths shorter than 4000 $\AA$ imposes corresponding limitations on the usable wavelength range of the analyzed spectra.

3 RESULTS AND DISCUSSION

Figure 1 shows the reflectance spectra obtained with the AZT-20 telescope, as well as the averaged spectra obtained with SMASSII and the Gaia DR3 catalog Gaia Collaboration et al. (2023). These reflectance spectra are in good agreement with each other.

Figure 2 illustrates a comparison between the reflectance spectrum observed in this work on February 10, 2025, and the average spectrum obtained on September 13, 2012, by Busarev et al. Busarev et al. (2016), with corresponding designations provided in the figure legend. The green-shaded area in the figure highlights the template range for the F-type taxonomic class. This range is based on the maximum and minimum albedo values reported by Tholen Tholen (1989).

It should be mentioned that the observations of Interamnia on September 13, 2012 were conducted near perihelion. According to JPL Horizons (or equivalent ephemerides), the heliocentric distance of Interamnia around midday on that date was approximately 2.59 AU, indicating that the object had either just passed or was approaching perihelion. On February 10, 2025, at the time of our observations, the heliocentric distance was $r \approx 3.499$ AU, which is close to aphelion $Q \approx 3.53$ AU, as expected for the midpoint between the 2023 perihelion and the next one, anticipated around 2028.

Figure 2 illustrates that Interamnia exhibits signs of sublimation as it approaches perihelion, as evidenced by the reflectance spectrum from Busarev et al. Busarev et al. (2016). Conversely, our observations on February 10, 2025 suggest it remains in a quiescent state near aphelion.

In the study by Savelova et al. Savelova et al. (2023), the authors estimated the asteroid composition by modeling its reflectance spectra using meteorite analogs. According

Table 1. Asteroids exhibiting transitional properties between C-type and B/F-type

Asteroid	D (km)	Type	Sublimation activity	Peculiarities
(1) Ceres	940	G/C	Yes	Dwarf planet, icy mantle Park et al. (2016).
(10) Hygiea	∼434	C/B	No (possibly in the past)	Almost spherical, potentially a dwarf planet candidate Vernazza et al. (2020).
(24) Themis	∼202	B/C	Yes	Presence of ice, comet-like activity Campins et al. (2010); Rivkin & Emery (2010).
(52) Europa	∼314	B/C	Not detected	Evidence of differentiation Hanuš et al. (2017).
(65) Cybele	∼290	P/B?	Assumed	Low density, possibility of ice presence Licandro et al. (2011).
(145) Adeona	∼150	C	Yes	Sublimation features in the spectra Busarev et al. (2016).
(704) Interamnia	∼332	F/B/C	Yes	Almost spherical, icy, active Busarev et al. (2016); Savelova et al. (2023).
(779) Nina	∼80	F	Yes	Reflection surges in the blue spectral range Busarev et al. (2016).
(1474) Beira	∼78	C/F?	Yes	Anomalous spectral features Busarev et al. (2016).

Table 2. Log of observations. All observations were obtained at $\Delta = 2.509$ AU and $r = 3.408$ AU for 704 Interamnia.

Date (y m d)	UT (h m s)	R.A. (h m s)	Decl. (° ′ ″)	Elong (°)	Ph (°)	V (mag)	Airmass	Exp Time (s)	Standards HD / Type
704 Interamnia									
2025 02 10	17:20:52	10 25 44.2	-11 41 42	151.4	8.0	11.6	2.400	60	81809
2025 02 10	17:21:57	10 25 44.1	-11 41 42	151.4	8.0	11.6	2.388	60	81809
2025 02 10	17:23:47	10 25 44.1	-11 41 42	151.4	8.0	11.6	2.367	60	81809
2025 02 10	17:24:51	10 25 44.1	-11 41 42	151.4	8.0	11.6	2.356	60	81809
HD 81809									
2025 02 10	17:43:40.5	09 27 43.2	-06 04 15.6	–	–	–	1.628	5	G1.5IV–V
2025 02 10	17:43:52.5	09 27 43.2	-06 04 15.6	–	–	–	1.628	5	G1.5IV–V
2025 02 10	17:44:53.5	09 27 43.2	-06 04 15.6	–	–	–	1.625	3	G1.5IV–V
2025 02 10	17:45:00.5	09 27 43.2	-06 04 15.6	–	–	–	1.625	3	G1.5IV–V

TEMP = −60°C (matrix cooling temperature)
READTIME = 1.0×10^{-6} s (pixel readout time)
GAIN = 5 (signal gain factor)

to the modeling results, Interamnia belongs to the F class. The asteroid composition was modeled as a mixture of three carbonaceous chondrites: CM2, CI1 and C1/2, corresponding to possible meteorite analogs of F-type asteroids Gaffey et al. (1989); Savelova et al. (2023). CI chondrites are the most primitive and water-rich carbonaceous chondrites. They contain a high proportion of water and other volatiles and very few chondrules. CM chondrites contain chondrules, but are also rich in water and organic compounds, a prominent example of which is Murchison. Ivuna, a CI-type carbonaceous chondrite, is one of the most primitive known meteorites, with a composition similar to that of the solar photosphere. It is characterized by a high water content and a fine-grained matrix consisting of phyllosilicates, magnetite, sulfides, and sulfates. According to Savelova et al. Savelova et al. (2023), the composition of asteroid (704) Interamnia can be described as follows: approximately 55% Murchison (CM2), 43% Ivuna 700 (CI1), and 2% Yamato 82162 (C1/2). Figure 3 presents the data from the study by Savelova et al. Savelova et al. (2023), where the solid black line is the normalized reflectance spectrum of the asteroid (704) Interamnia from the SMASSII database, the solid red line corresponds to the modeled spectrum based on meteorite analogs, and the green curve is the reflectance spectrum of Interamnia obtained in this study. Comparative analysis shows that the normalized reflectance spectrum of the asteroid (704) Interamnia obtained in this work and from the SMASSII database have similar features in the region of ∼ 0.45–0.5 μm and a negative gradient and are close to the model reflectance spectrum Gaffey et al. (1989); Savelova et al. (2023).

The complex composition of (704) Interamnia—represented as a mixture of CM2, CI1, and C1/2 chondrites—may contribute to its spectral variability and heterogeneous sublimation behavior Busarev et al. (2016); Gaffey et al. (1989); Savelova et al. (2023). Each chondrite type contains differing proportions of hydrous minerals, organics, and other volatile-rich phases that sublimate or thermally decompose at different temperatures and depths. For example, CI-type material such as Ivuna is rich in phyllosilicates and sulfates, which can release water vapor and sulfur-bearing

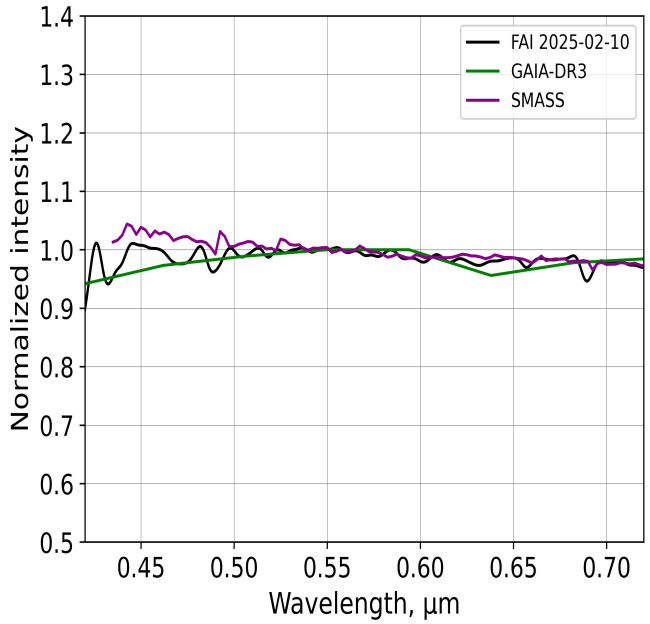

Figure 1. Comparison of averaged spectra from SMASSII and Gaia DR3 Gaia Collaboration et al. (2023) for taxonomic class F and the reflectance spectrum obtained on February 10, 2025 on AZT-20

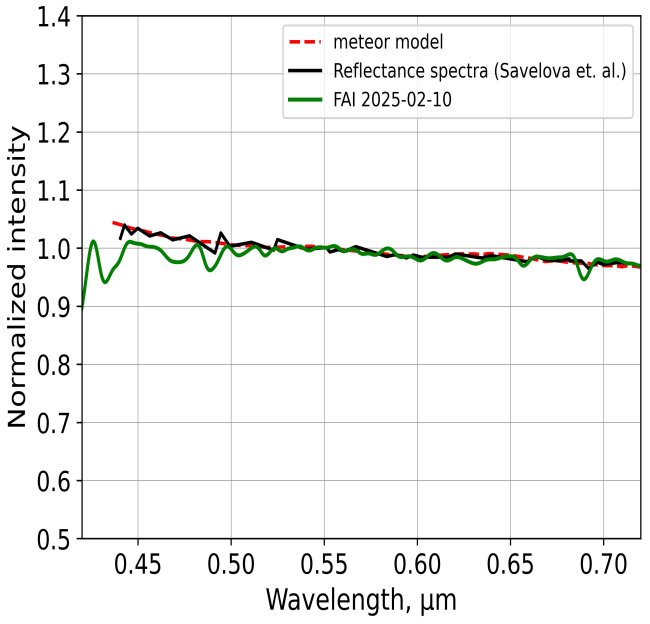

Figure 3. Comparison of the composition of asteroid (704) Interamnia based on reflectance spectra using meteorite analogs Savelova et al. (2023) and the reflectance spectrum obtained on February 10, 2025 using AZT-20

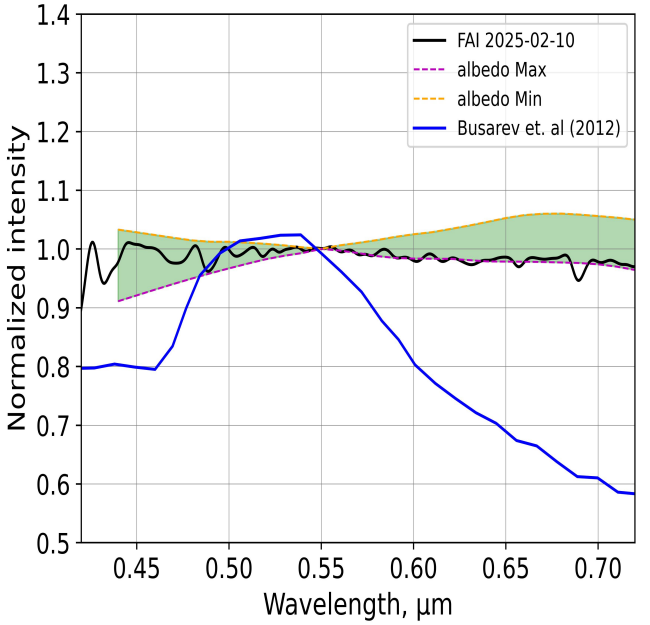

Figure 2. A comparison of the reflectance spectra of (704) Interamnia near perihelion Busarev et al. (2016) and aphelion (FAI data 2025-02-10) and the spectral range for taxonomic class F Tholen (1989)

gases at moderate heating. In contrast, CM-type chondrites, while also hydrated, may contain more refractory organic compounds and carbonates that sublimate under slightly different thermal conditions. C1/2-type meteorites (e.g., Yamato 82162) may include transitional material with intermediate thermal stability.

As a result, the surface or near-surface layers of Interamnia may undergo localized or transient degassing processes depending on the spatial distribution and burial depth of each volatile phase. This heterogeneity may lead to spectrally variable features, especially in the visible and near-infrared range. Differences in the depth and shape of absorption bands (e.g., near 0.45–0.5 μm) may explain the episodic and irregular sublimation activity observed in different studies Busarev et al. (2016); Savelova et al. (2023). These findings support the hypothesis that volatiles on Interamnia are distributed heterogeneously and that sublimation is not a uniform process across the surface, but rather dependent on local activation conditions such as solar heating.

4 CONCLUSIONS

The reflectance spectrum of asteroid (704) Interamnia, obtained on February 10, 2025 using the AZT-20 telescope at Assy-Turgen Observatory, exhibits a broad absorption band in the $\sim$ 0.45–0.5 μm range along with an overall negative spectral slope. Template-based taxonomic analysis indicates that the asteroid belongs to the F-type class Tholen (1989);

Bus & Binzel (2002); Gaia Collaboration et al. (2023); Gaffey et al. (1989); Savelova et al. (2023). Interamnia is a dark, carbonaceous body composed primarily of CM and CI chondrites, which are rich in water and other volatiles Gaffey et al. (1989); Savelova et al. (2023). Comparison with the data from Busarev et al. Busarev et al. (2016) confirms that sublimation activity on (704) Interamnia occurs in an irregular and episodic manner, suggesting a seasonal or trigger-driven activation mechanism.

Further spectroscopic monitoring of Interamnia at perihelion in 2028 will be necessary to confirm the nature and extent of this activity, as this will allow a more detailed study of the sublimation activity of this class of objects and shed light on their nature.

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