Radiometric size, distance and orbit constraints for unknown asteroids seen in JWST MIRI images

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Introduction. The radiometric method is a powerful tool to derive physical and thermal properties of asteroids from thermal infrared (IR) data (e.g. [1]). But the current techniques require that the object's orbit is known and that the illumination and observing geometry at the IR epochs can be calculated. In JWST MIRI images one can find many new and currently unknown objects where these standard methods cannot be applied, and due to the faintness of the targets, follow-up observations from ground are not possible. We present a new method which allows to estimate the object's size and constrain its orbit just based on multi-band MIRI detections [2], and we discuss strategies to find and characterize 100 m objects in MIRI data.

"STM-ORBIT" method. We searched the JWST archive for public MIRI imaging data at low ecliptic latitudes. Blinking between level-2 data products shows moving background targets (see Fig. 1).

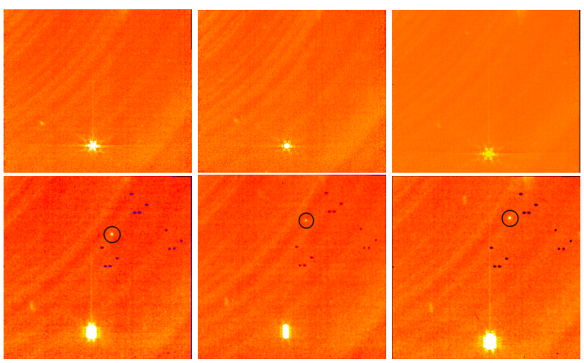

Fig. 1: *MIRI imaging (10, 11.3, and 12.8 μm bands from left to right) of asteroid 10920 (top) and a new object (encircled) in its reference frame (bottom). The FOV is about 50"x40", integration time is about 35 s.*

We extracted astrometric information (JWST-centric R.A./Dec., apparent motion, solar elongation) and used it in a ranging approach [3,4] to produce compatible artificial orbits (about 10 000). Then, we predict the corresponding thermal fluxes via the Standard Thermal Model (STM) [5] and compare them with the extracted MIRI fluxes via a simple χ^2 analysis. The new object shown in Fig. 1 (bottom, encircled) was detected in all 9 MIRI bands. Our "STM-ORBIT" method revealed that it was located in the inner main-belt region during the JWST observations, it has a low orbital inclination ($0.7^\circ < i < 2.0^\circ$), and a size of 100-230 m.

Strategy for finding 100 m objects. Following up from our first successful application of the "STM-ORBIT" method [1], we used a sky background model[1] and combined it with STM predictions for 100 m size objects located at different distances. As JWST is sky-background limited up to ~ 15 μm, we only considered the dominating zodiacal light background for SNR estimates (see Fig. 2).

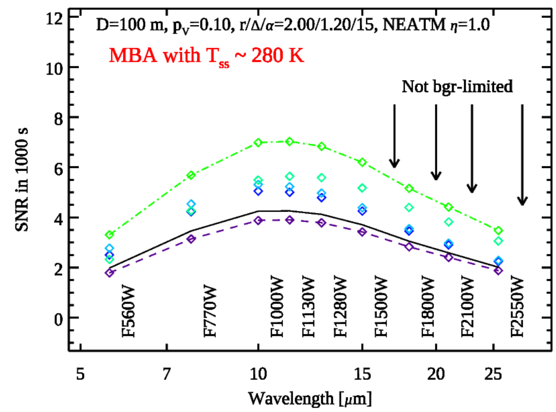

Fig. 2: *The estimated SNR of a 100 m object with 10% albedo, located at r_{helio}=2 au. The solid line shows SNRs in the ecliptic plane and at $(\lambda - \lambda_\odot) = 90^\circ$. The color points indicate SNR for other elongations (85°-135°) and ecliptic latitudes (-30° < β < +30°).*

We find that NEAs (with surface temperatures well above 300 K) produce the highest SNR in the two shortest-wavelength channels (F560W and F770W), while MBAs (with temperatures of 280 K down to 200 K) have their peak SNR in the 10-15 μm, despite the much higher background levels. SNRs improve at higher latitudes and larger elongations. MIRI can detect 100 m objects even in the outer main-belt region.

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References: [1] Delbó et al. (2015) *Asteroids IV 107-128*. [2] Müller et al. (2023), *A&A 670, A53*. [3] Virtanen et al. (2001), *Icarus 154, 412*. [4] Oszkiewicz et al. (2009), *M&PS 44, 1897*. [5] Lebofsky et al. (1986), *Icarus 68, 239*.

[1] *https://irsa.ipac.caltech.edu/applications/BackgroundModel/*