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THERMAL INFRARED OBSERVATIONS OF ASTEROID 2005YU55 DURING CLOSEST APPROACH

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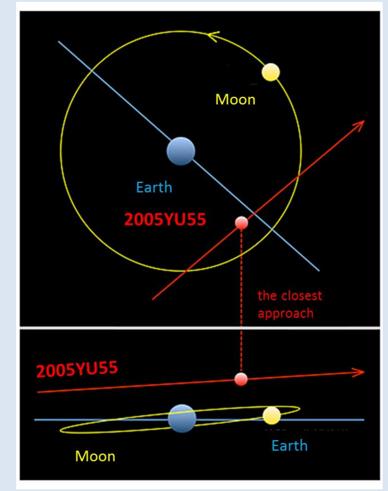
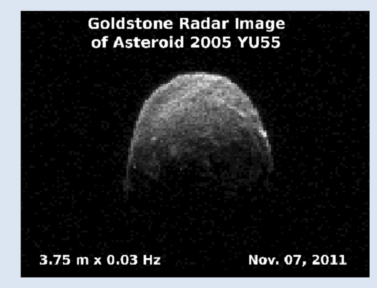
Introduction

Since asteroids approaching to the earth are potentially hazardous to the human race, study of them is strongly demanded. Such asteroids have surface temperature of 200-300K, and emit thermal radiation with spectral peaks in the 10-20 µm region. Observations at these mid-infrared wavelengths therefore are quite important for studying details of them. However adequate observations have not been carried out because of the limited number of mid-infrared cameras in addition to limited opportunities of the observations.

Asteroid 2005YU55 was made an exceptionally close approach to the Earth, passing within 0.0217 AU (325,000 KM) on 2011-Nov-08 23:24. Such a closet approach was incredibly rare event and a valuable opportunity to study near earth asteroids in detail. We carried out mid-infrared observations of the asteroid 2005YU55 and successfully obtained photometric variation at the 10 and 20 µm wavelengths during the closet approach.





Telescope and Instrument

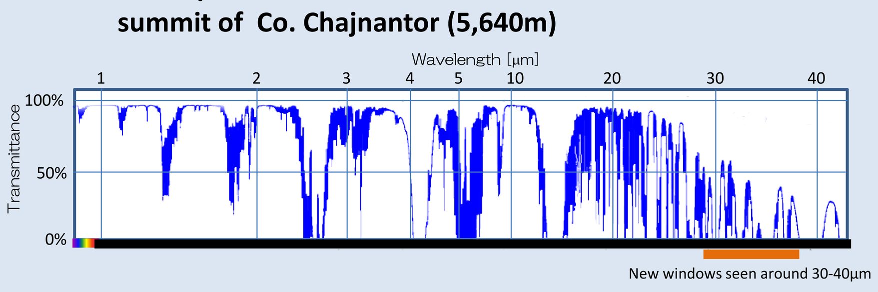
A mid-infrared camera MAX38 attached on a mini-TAO telescope was used for this observation.

Mini-TAO 1m telecope

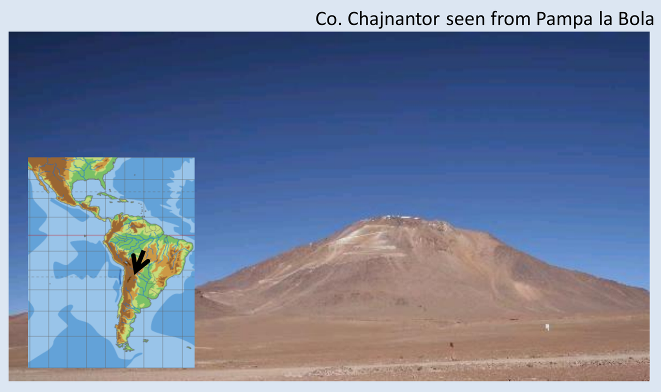
A mini-TAO telescope is an infrared telescope with a diameter of 1 meter at the summit of Co. Chajnantor in the Atacama desert, Chile. It locates at an altitude of 5,640m and is the Highest Astronomical Observatory in the World*1. Thanks to the high altitude and dry weather condition of the Atacama desert, it is an extraordinary site for astronomical observations especially at the mid-infrared wavelengths. Figure-1 shows the atmospheric transmittance calculated with the ATRAN model. The transmittance at the Q-band (16-26µm) reaches 90%. There are atmospheric windows between 30-40 µm in which the atmosphere is completely opaque even in the Mauna-Kea site (altitude of 4,200m).

The mini-TAO telescope is a pilot facility of the forthcoming 6.5m TAO telescope (Yoshii+ 2010 *2) as well as to carry scientific observations. It has two infrared cameras. One is ANIR (Atacama Near-InfraRed camera) to carry out imaging observations at optical and near-infrared wavelengths*3. The other is a mid-infrared camera MAX38.

Figure-1
Atmospheric transmittance at the summit of Co. Chajnantor (5,640m)



Co. Chajnantor seen from Pampa la Bola



*(*1) This was certificated by the Guness Wold Records in 2009*
*(*2) Details of the TAO project including the science cases can be seen in "TAO Project Book (Japanese only)" published in 2012. It can be read at the web http://www.ioa.s.u-tokyo.ac.jp/TAO*
*(*3) Specifications of the ANIR can be seen at http://www.ioa.s.u-tokyo.ac.jp/kibans/anir*

Mid-infrared camera : MAX38

MAX38 is an our-own developed mid-infrared camera for the mini-TAO telescope (Miyata+ 2008, Asano+ 2012). It is not only a rare camera which covers the Q-band wavelengths in the south hemisphere, but also an unique one having a capability of imaging at the 30 µm wavelength range (Nakamura+ 2010). Specifications of the MAX38 are summarized in Table-1.

In addition to the observing capabilities at 20 and 30 µm wavelengths, the miniTAO/MAX38 has a remarkable advantage of relatively flexible operation. Observing time is not so competitive in comparison with large telescopes/satellites. The miniTAO/MAX38 can carry out observations not only in nighttime but also in daytime. These flexibilities are quite important for monitoring observations.

Daytime observations

MAX38 attached on the miniTAO telescope

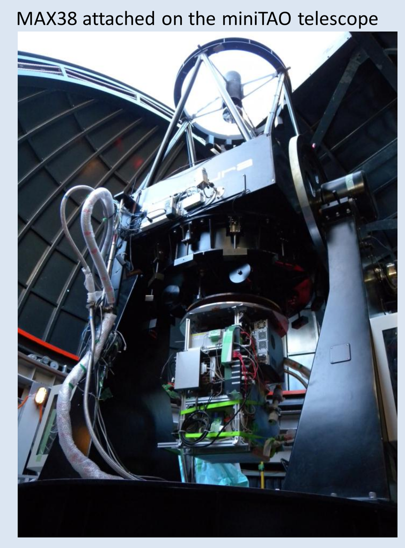


Table-1
Specifications of MAX38 attached on the miniTAO telescope

Parameter	Value	Comment
Wavelength Coverage	8 -38µm	
Detector	Si:Sb BIB MF-128	By DRS
Pixel Format	128x128	
Field of View	2.6arcmin x 1.3 arcmin	
Pixel Scale	1.26 arcsec/pix	
Chopping Frequency	Up to 6 Hz	
Chopping Throw	Up to 50 arcsec	
# of Filters	7	
Sensitivity	3Jy at 9.8µm 5Jy at 18.7µm 20Jy at 31µm 40Jy at 37µm	1sig1sec for point sources ** Sensitivity at 31/37um strongly depends on weather condition*

Observations and Reduction

We observed the asteroid 2005YU55 from 2011-Nov-08 23:04 to 25:51 and Nov-09 23:56 to 26:04. It covered the closet approaching time and 24 hours later to the approach. The weather conditions were excellent through the observations. Imaging observations in the 8.9µm (Δλ= 0.9µm), 12.2µm (0.5µm), and 18.7µm (0.9µm) were carried out. Observing log is summarized in Table-2, and the variations of the sun-asteroid-observer angle and the miniTAO-centric distance during the observations are plotted in Figure-2.

The near earth asteroid apparently moved very fast on the sky. To follow the asteroid movement, the telescope was pointed at repeated intervals. The intervals were set to 1 minute and 3 minutes on Nov. 8 and 9, respectively. Normal sidereal tracking was applied in the period between the telescope pointings. Images were taken at a frame rate of 3.8 Hz with an effective integration time of 0.197 sec. The frame rate is fast enough not to extend the image of the asteroid on each frame. Chopping technique was not applied because background can be canceled out with using frames just before or after an object frame.

On Nov. 8, the asteroid was so bright that it was detectable on each frame. We applied aperture photometry with an aperture radius of 3″ for each frame and averaged every 5 minutes. On Nov. 9, it was difficult to detect the asteroid on each frame. We added every 92 frames into one frame with shifting pixels to compensate the asteroid movement on the sky. The asteroid was detected in the added frame as a point-like source. We applied aperture photometry for the subtracted images and averaged all the photometric values as a result.

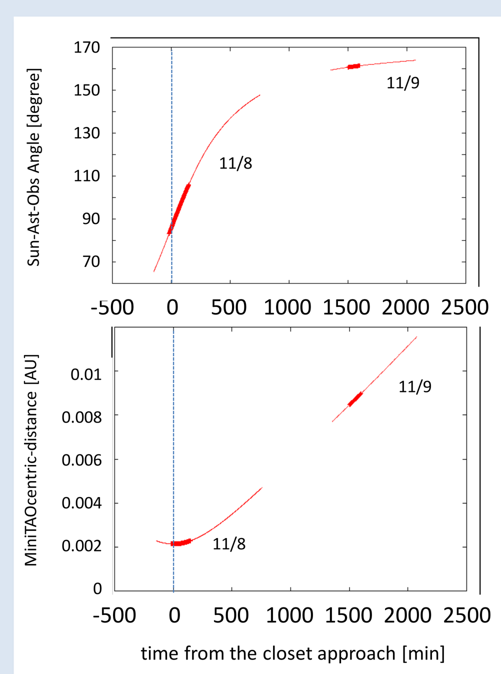


Figure-2
The Sun-Ast-Obs. angle and the miniTAO-centric distance during the observation

Table-2
Observing log

Date (UT)	Start	End	Filter	# of frames	Note
2011/11/08	23:04	24:15	18.7	20196	Includes the closet approach
	24:30	24:41	8.9	2550	
	25:11	25:24	12.2	1734	
2011/11/09	23:56	24:50	18.7	12288	
	25:38	26:04	8.9	4982	

Results

Figure-3 displays examples of the reduced images taken at the closet approach. One can clearly see that the asteroid moves from right (west) to left (east). Figure-4 plots the photometric results.

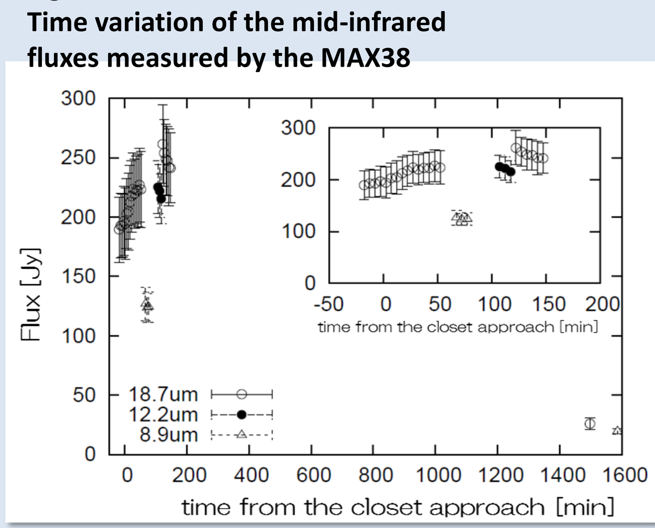
18.7um
The measured flux apparently increased in time between -20 and 60 min, and decreased in time after 120 min. The brightness peak seems to be located around 90 min while it was not practically observed. The flux on Nov. 9 was approximate 16 % of the flux at the closet approach.

12.2um
The flux increased in time between 100 and 120 min as the same as the 18.7µm.

8.7µm
Significant time variations were not detected on Nov. 8. On Nov. 9 it decreased approximate 11 % of the flux at the closet approach.

Figure-3
Examples of the images.

Figure-4
Time variation of the mid-infrared fluxes measured by the MAX38



Thermophysical Model Analysis

Photometric data in the thermal infrared wavelength range are very useful for modeling the asteroid. We applied thermophysical model (TPM) analysis for the presented mid-infrared data and far-infrared data at 70 and 160 micron obtained by Her-shell/PACS (Mueller+ 2011). We assumed

- A spherical body
- Rotation period : 19.31±0.02h (Warner+ 2012 in this conference)
- Spin Vector orientation : given in Merline+ 2012 in this conference
- H_V = 21.3 ±0.1mag
- G-slope : -0.15

The TPM solution fit the data set of MAX38 and Herschel very well.

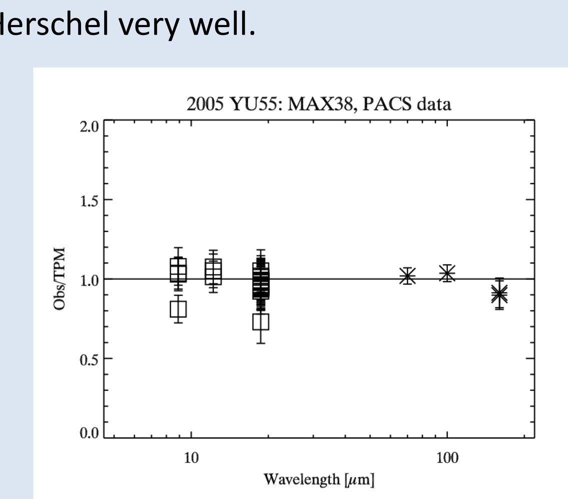


Figure-5
The observation/TPM ratios based on the MAX38 and the Herschel observations

Due to the degeneracy between roughness and thermal inertia there are two reasonable solutions.

prograde rotator
- size 338-344 m
- albedo 0.055-0.057
- thermal inertia 500-900
- low/intermediate surface roughness required

retrograde solution
- size 298-304 m (well outside the radar range)
- albedo 0.069-0.073
- thermal inertia 100-550
- high surface roughness required

a. assuming nominal roughness would point to a prograde solution of a body with about 340 m size and an albedo of 0.056, but this is in contradiction with the radar SV-solution.
b. assuming an extremely high roughness (rho=1.0, f=1.0) would change the situation: the radar SV-solution is now more likely and produces a "reasonable" thermal inertia of about 550, but the corresponding size is then only 298 m and the albedo 0.073 which is in clear contradiction to the radar results.
c. also the Keck AO solutions (Merline+ 2012, Warner+ 2012, Busch+ 2012, Lim+ 2012) seems to favor now also the retrograde solution (warm terminator during close approach)

Cooperative observations using miniTAO/MAX38 are very Welcome!

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http://www.ioa.s.u-tokyo.ac.jp/kibans/max38

MAX38 Search