*RevMexAA (Serie de Conferencias)*, **24**, 188–191 (2005)

# ASTEROID AND MINOR BODIES SCIENCE WITH THE LARGE MILLIMETRIC TELESCOPE

P. S. Barrera-Pineda,[1] A. J. Lovell,[1,2] F. P. Schloerb,[3] and L. Carrasco[1]

RESUMEN

Presentamos las futuras contribuciones a la ciencia de asteroides y cuerpos menores con el LMT. Las dos principales ventajas observacionales del LMT sobre telescopios actuales son la alta sensibilidad y el mapeo de alta velocidad. En la ciencia de asteroides y cuerpos menores, la alta sensibilidad nos permitirá observar un gran número de objetos cercanos a la Tierra y los principales asteroides del cinturón, además de objetos del Cinturón de Kuiper y de Centauro en el sistema solar exterior. Las instalaciones del LMT proporcionarán también soporte observacional crítico a las futuras misiones espaciales relacionadas con asteroides. Las observaciones simultáneas con el LMT y el GTC serán muy importantes para entender el comportamiento térmico tanto sobre la superficie de cuerpos menores, como debajo de ésta.

ABSTRACT

We present the future contributions to asteroid and minor bodies science with the LMT. The main two observational advantages of the LMT over current telescopes are the high sensitivity and high speed mapping. In asteroid and minor bodies science the high sensitivity will allow us to observe a large number of Near Earth Objects and main belt asteroids, plus Centaurs and Kuiper Belt Objects in the outer solar system. The LMT facility will also give critical observational support for the upcoming asteroid space missions. Simultaneous observations with the LMT and the GTC will be very important to understand the thermal behavior on and under the surface of minor bodies.

*Key Words:* **MINOR PLANETS, ASTEROIDS — PLANETARY SYSTEMS: FORMATION — SOLAR SYSTEM: GENERAL**



## 1. INTRODUCTION

Observations of continuum thermal emission from asteroids and minor bodies of the solar system at submillimetric and millimetric wavelengths have been carried out for the last three decades (e.g Althenoff *et al.*, 1994, 1995, 1996, 2001 & 2004; Andrews 1974; Briggs 1973; Conklin 1977; Johnston 1982 & 1989; Redman 1990a, 1990b, 1992, 1995 & 1998; Ulich 1976; Webster 1987, 1988, 1989a and 1989b). The importance of this work is that observations at these wavelengths allow us to sample the temperatures from layers under the surface of the asteroids, where the thermal emission originates. From these observations we can infer the thermophysical properties of the material on and below the surface of asteroids. Figure 1 shows a selection of brightness temperatures for Ceres.

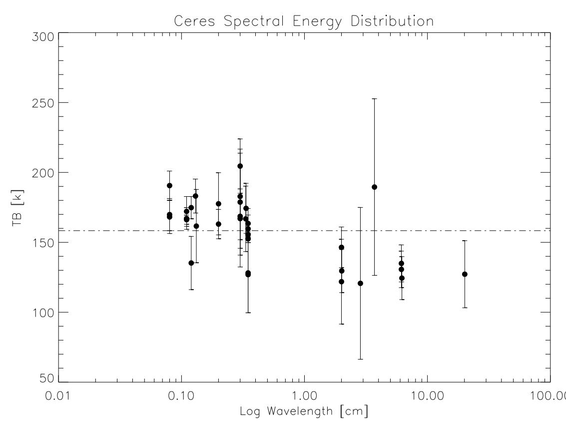


Fig. 1. Brightness temperatures of Ceres versus wavelength, from data published in the literature. The dash-dotted line shows the average temperature of all observations. The thermal behavior of an asteroid may be complex and is not consistent with a single temperature at all wavelengths.

## 2. LMT OBSERVATIONAL ADVANTAGES

The sensitivity of the Large Millimeter Telescope (LMT), with nearly $2000m^2$ of collecting area and a surface accuracy better than existing telescopes, will exceed that of its nearest competitors by a wide margin. This basic sensitivity is enhanced, for continuum observations, by the single dish's ability to

[1]Instituto Nacional de Astrofísica Óptica y Electrónica.
[2]Department of Physics and Astronomy, Agnes Scott College.
[3]Department of Astronomy, University of Massachusetts.

TABLE 1

SENSITIVITY OF SPEED AT FOUR WAVELENGTHS

| $\lambda$ (mm) | Sensitivity (mJy/$\sqrt{Hz}$) |
|---|---|
| 2.1 | 1.3 |
| 1.4 | 2.1 |
| 1.1 | 2.7 |
| 0.8 | 4.9 |

from Wilson *et al.*, (2003)

make use of incoherent detectors. The observational capabilities will increase with the installation of a new generation of instruments for continuum observations, most currently in development or in final engineering tests. In the next two sections we make a brief explanation of these instruments and how they can be used to enhance the current state of long-wavelength investigations of minor bodies.

### 2.1. *BOLOCAM II*

The first-light instrument for continuum observations on LMT will be BOLOCAM II, a focal-plane array of 144 bolometers with bandpasses at 1.1mm 1.4mm and 2.1mm. Engineering tests of a first generation instrument have been carried out on the Caltech Submillimetric Telescope (CSO) (Glenn *et al.* 2003), and when these tests end the construction of BOLOCAM II will start. While this instrument should be available at first light, it is very likely that even more sensitive instrumentation will be available for asteroid observations after commissioning.

### 2.2. *SPEED*

The SPEED (SPEctral Energy Distribution) camera is a four pixel array, made by FSB (Frequency Selective Bolometers), allowing simultaneous observations at four wavelengths: $800\mu m$, 1.1mm, 1.4mm and 2mm. The development and construction of this camera is currently underway, with a prototype being built for initial use at the Sub Millimeteric Telescope (SMT) at the University of Arizona. These tests are planned to begin during the second semester of 2004. This instrument will be two to five times more sensitive than currently-available bolometers, and will also enable multi-wavelength operations, probing several depths in the thermal wave simultaneously.

## 3. ASTEROIDS AND MINOR BODIES SCIENCE

The sensitivity of LMT will enable observation of a wide sample of objects and permit the first mm-wave survey of asteroid properties. Like the IRAS Minor Planet survey (Tedesco *et al.*, 2002), and the 2MASS Asteroid Survey (Sykes *et al.*, 2000), such a survey should be able to produce flux, brightness temperature, and lightcurve amplitudes for a large sample of asteroids over a range of heliocentric distances. Using estimated sensitivities for the first-light LMT instruments, we are able to calculate minimum detectable diameters for objects at various heliocentric distances. Unfortunately, for most minor bodies, diameters are quite uncertain and are estimated based on the absolute magnitude H, according to (Fowler and Chillemi 1992)

$$D = \frac{1329}{\sqrt{p}} 10^{-0.2H} \quad (1)$$

Shown in Table 2 are minimum diameters detectable with 30 minutes of integration ($t$) of BOLOCAM on LMT ($D_{\rm Tel} = 50$). Shown in Figure 2 are the semi-major axes and absolute magnitudes of more than 240,000 minor bodies. Superimposed on these data are curves representing the threshold for detection of these objects, for three different albedos: any object lying above the threshold can be detected in thirty minutes at a signal-to-noise of 10 with the 42-GHz bandwidth (B) BOLOCAM on the LMT operating at 1.1mm wavelength ($\lambda$). In order to make these estimates, we assume blackbody temperatures for the asteroids, an atmospheric temperature ($T_{\rm ATM}$) of 273 K, an opacity ($\tau$) of 0.1, and an aperture efficiency ($\eta$) of 0.5. The minimum diameter ($D$) (Redman *et al.*, 1995) is given by

$$D \geq 2\sqrt{10}\frac{\Delta}{\sqrt{\eta}}\Big(\frac{T_{\rm ATM}}{T_{AST}}\Big)^{1/2}(e^{\tau}-1)\Big(\frac{\lambda}{d_{\rm Tel}}\Big)(Bt)^{-1/4} \quad (2)$$

## 4. LMT-GTC OBSERVATIONS

With the first light of GRANTECAN (GTC) and LMT, a new type of asteroid and minor bodies will be possible. Simultaneous observations at the millimetric and infrared wavelengths will allow us to know the behavior of the thermal wave under the surface of these bodies, infer the thermophysical properties of the material on and under the surface, estimate with greater precision the diameters of a large number of objects, estimate rotation periods, study rotational brightness variations, and make long-wavelength color-color diagrams.

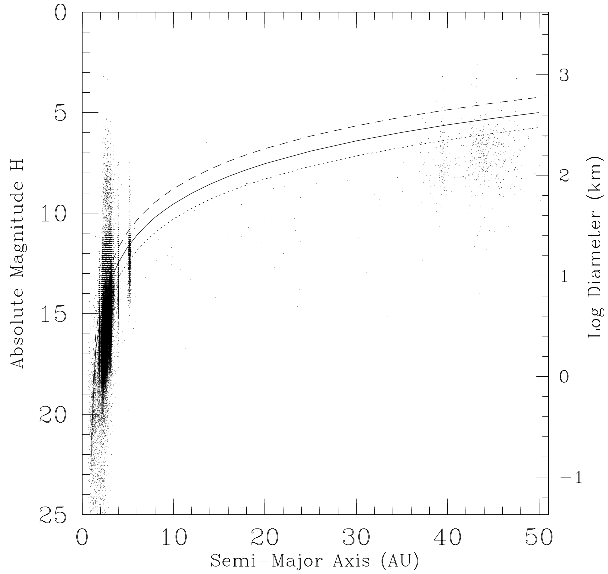


Fig. 2. Absolute Magnitudes versus semi-major axis of the orbits of more than 240,000 minor bodies in the Solar System. Easily seen are the various groupings of objects – Near-Earth objects (< 1.5 AU), the Main Asteroid Belt (2-4 AU), Jupiter Trojans (near 5.2 AU), Centaurs (5-35 AU), and the Kuiper Belt (>39 AU). Overlaid on the data are three curves, suggesting the detection threshold for bolometer observations described in the text. The solid curve assumes an albedo of 0.1, the dotted curve 0.05, and the dashed curve 0.2. Any object lying above a given curve (at smaller magnitudes or larger diameters) on the figure will be detectable with a bolometer on the LMT, given a favorable observation geometry.

TABLE 2

MINIMUM DIAMETER OF DIFFERENT TYPES OF MINOR BODIES THAT CAN BE OBSERVED WITH THE LMT

| Object class | $\Delta$ (AU) | Diameter (km) |
|---|---|---|
| NEO's | 0.05 | 0.4 |
| | 0.1 | 0.8 |
| Main | 1 | 9 |
| Belt | 2 | 20 |
| Trojans | 4 | 45 |
| Centaurs | 14 | 205 |
| KBO's | 38 | 708 |
| | 49 | 971 |

Table 3 shows the statistical sampling of several categories of minor bodies, at different heliocentric distances. On the order of a few percent of the total number of objects will be observable in a given category. Assuming that a few percent – the largest objects – are representative of the whole category, we can make arguments about the thermal properties of each class of minor bodies. In the case of NEOs, it is theoretically possible to detect several hundred objects; however, the orbital geometries only enable close encounters with approximately 100 of these objects in the operational lifetime of the LMT. The detection thresholds in Table 3 and Figure 2 are conservative estimates, and it is quite likely that a larger sampling will be possible with instruments available after commissioning of the LMT.

TABLE 3

SAMPLING OF MINOR BODY CATEGORIES

| Object class | Total | Obs. Fraction | % |
|---|---|---|---|
| NEO's | 2670 | 100 | 4 |
| Main Belt | $\sim$ 70000 | 1500-1800 | 2-2.5 |
| Trojans | 1642 | 74-342 | 4.5-21 |
| Centaurs | 148 | 31 | 21 |
| KBO's | 764 | 12 | 1.5 |

## 5. CONCLUSIONS

Asteroid and minor body observations with the LMT will extend our knowledge of the thermal and physical structures of these objects, allowing us to understand better the first stages of planetary formation. With the capability to make a statistical sampling of many categories of minor bodies, we can investigate the formation and evolution of the solar neighborhood.

This work was funded by CONACYT beca nacional de doctorado 113294. Millimeter-wave asteroid research is also supported by NASA grant NAG5-10677.

## REFERENCES

Altenhoff, W. J., Chini, R., Hein, H., Kreysa, E., Mezger, P. G., Salter, C., & Schraml, J. B. 1988, A&A, 190, L15

Altenhoff, W. J., Johnston, K. J., Stumpff, P., & Webster, W. J. 1994, A&A, 287, 641

Altenhoff, W. J. & Stumpff, P. 1995, A&A, 293, L41

Altenhoff, W. J., Baars, J. W. M., Schraml, J. B., Stumpff, P., & von Kap-Herr, A. 1996, A&A, 309, 953

Altenhoff, W. J., Menten, K. M., & Bertoldi, F. 2001, A&A, 366, L9
Altenhoff, W. J., Bertoldi, F., & Menten, K. M. 2004, A&A, 415, 771
Andrew, B. H. 1974, Icarus, 22, 454
Briggs, F. H. 1973, ApJ, 184, 637
Conklin, E. K., Ulich, B. L., Dickel, J. R., & Ther, D. T. 1977, IAU Colloq. 39: Comets, Asteroids, Meteorites: Interrelations, Evolution and Origins, 257
Crovisier, J. 1996, in Proceedings of the ESO-IRAM-NFRA-Onsala Workshop held at Garching, Germany, 11-13 December 1995, ed. P. A. Shaver. (Springer-Verlag), 316
Fowler, J.W., & Chillemi, J.R. 1992, in Tech. Rep. PL-TR-92-2049, Phillips Laboratory, Hanscom AF Base, MA, 17
Glenn, J., et al. 2003, in Millimeter and Submillimeter Detectors for Astronomy, ed. T. G. Phillips & J. Zmuidzinas, Proceedings of the SPIE, Volume 4855, 30
Johnston, K. J., Seidelmann, P. K. and Wade, C. M. 1982, AJ, 87, 1593
Johnston, K. J., Lamphear, E. J., Webster, W. J., Lowman, P. D., Seidelmann, P. K., Kaplan, G. H., Wade, C. M. and Hobbs, R. W. 1989, AJ, 98, 335
Redman, R. O., Feldman, P. A., Halliday, I., & Matthews, H. E. 1990, Asteroids, Comets, Meteors III, 163
Redman, R. O., Feldman, P. A. and Halliday, I. 1990, in Submillimetric Astronomy, (eds.) Watt G. D. and Webster A. S., Kluwer Academic Publishers, 293
Redman, R. O., Feldman, P. A., Matthews, H. E., Halliday, I., & Creutzberg, F. 1992, AJ, 104, 405
Redman, R. O., Feldman, P. A., Pollanen, M. D., Balam, D. D., & Tatum, J. B. 1995, AJ, 109, 2869
Redman, R. O., Feldman, P. A., & Matthews, H. E. 1998, AJ, 116, 1478
Sykes, M. V., Cutri, R. M., Fowler, J. W., Tholen, D. J., Skrutskie, M. F., Price, S. and Tedesco, E. F. 2000,Icarus, 146, 161
Tedesco, E. F., Noah, P. V., Noah, M. and Price, S. D. 2002, AJ, 123, 1056
Ulich, B. L. and Conklin, E. K. 1976, Icarus, 27, 183
Webster, W. J. 1987, PASP, 99, 1009
Webster, W. J., Johnston, K. J., Hobbs, R. W., Lamphear, E. S., Wade, C. M., Lowman, P. D., Kaplan, G. H., & Seidelmann, P. K. 1988, AJ, 95, 1263
Webster, W. J. & Johnston, K. J. 1989, Asteroids II, 213
Webster, W. J. & Johnston, K. J. 1989, PASP, 101, 122
Wilson, G. and 10 colleagues 2003, in Millimeter and Submillimeter Detectors for Astronomy, ed. T. G. Phillips & J. Zmuidzinas, Proceedings of the SPIE, Volume 4855, 583



P. S. Barrera-Pineda and L. Carrasco: Instituto Nacional de Astrofísica Óptica y Electrónica. Luis Enrique Erro # 1, Santa María Tonantzintla, Puebla, México, CP 72840 (pbarrera, carrasco@inaoep.mx).

A. J. Lovell: Department of Physics and Astronomy, Agnes Scott College, 141 East College Avenue, Decatur, GA 30030, USA (alovell@agnesscott.edu).

F. P. Schloerb: Department of Astronomy, University of Massachusetts, 619 Lederle Graduate Research Center, University of Massachusetts, Amherst, MA 01003, USA (schloerb@astro.umass.edu).