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Chord lengths across main belt asteroids from stellar occultations in the near infrared

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Abstract. An asteroid occultation of a stellar source provides a direct measurement of the chord length across the asteroid with excellent precision. The method is independent of the brightness of the asteroid as well as its location anywhere in the solar system. At present stellar occultation predictions of main belt asteroids are available with sufficient precision to merit observations. At the 1.2 m telescope of Mt. Abu Observatory at Gurushikhar, a few well predicted main belt asteroidal occultations of stars mostly in the near IR J band (1.25 μm) have been successfully carried out in the last few years. The NICMOS IR array camera was used in the fast subarray mode for this purpose. Details of the observations and results are discussed.

Keywords : asteroids, occultations, infrared: stars

1. Introduction

Stellar occultations by asteroids are unique events occurring along narrow strips of land on the earth's surface which, if successfully recorded, provide direct determinations of the size of the occulting bodies with good precision. While multi-station observations of the event are required to derive the limb profile of the asteroid, it is in principle possible to determine the diameter of the body from a single station, if the diffraction fringe pattern of the star light occulted by the asteroid can be recorded with good S/N and time resolution. (Reitsema et al. 1981). The method assumes a smooth spherical shape for the asteroid. From the temporal spacing of the diffraction fringes at immersion and emersion the velocity component perpendicular to the limb of the asteroid can be

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derived. This value together with the chord length then uniquely determines a circle whose diameter can be deduced. In the absence of bright star occultations needed for recording such diffraction fringes, observations of the duration of a few well predicted near central occultation events can still provide a good measure of the size of the occulting body from a single observatory. Even for a non-central occultation a departure of upto 10% of the diameter from the central line would result in a chord length equal to the diameter of a spherical asteroid within a few per cent. A strong departure from sphericity of the asteroid, which is quite probable for small asteroids, can also lead to a different occultation size depending on the geometry of the event. In recent years for main belt asteroids with well determined orbits, fairly reliable occultation predictions of bright stars have become possible making occultation observations worthwhile to attempt. It must be pointed out that the method has the unexplored potential of providing size determinations of outer solar system objects - Trans Neptunian Objects (TNOs) and Kuiper Belt Objects (KBOs) whose sizes and shapes are largely unknown.

In this paper we discuss five successful asteroid occultation events observed in the near IR J and H bands at Mt. Abu Observatory.

2. Observations

Observations were carried out at the 1.2 m telescope of Mt. Abu Observatory at Gurushikhar (24^o 39^o 10N, 72^o 46 47E, 1680 m) using the NICMOS IR array camera. The camera was used in AOI (Area of Interest) subarray mode to reduce the field of view and the sampling time. Details of AOI mode of operation can be found in an earlier paper dealing with lunar occultations with subarrays (Chandrasekhar et al. 2003). Typically in an asteroid occultation observing run, 2400 sub frames of size 20×20 pixels are recorded in 254 seconds for a sampling time of 106 millisec. The field of view of the subarray is usually $10'' \times 10''$. The star to be occulted is centered in the sub frame and data acquisition started 2 minutes before predicted event time. In the last 10 seconds the star is drifted out of the sub frame to record adjacent sky frames. Optical monitoring using an image intensifier CCD was possible for a few events. It has also been possible to video tape a few events.

Predictions of occultation events along with event parameters are obtained from the web site (http://www.asteroidoccultation.com) updated and maintained by Steve Preston (steve@acm.org).

Details of asteroid occultations successfully observed are given in Tables 1 and 2. The IR magnitudes are derived from 2 MASS all sky catalogue. The JHK magnitudes are used to decide on the observability of the event with the NICMOS camera. Under good conditions, with the present system, it should be possible to observe events upto $m_J \sim 11$. Near Infrared occultations have the added advantage over optical in being observable even if the phase of the moon is not optimal. Four of the five events were

Table 1. Event parameters.

Sr.	Asteroid	Star	m_v	m_j	alt (deg)	Shadow Speed km/s	Event Date	Mid Event UT Time h m s ± 0.5 s
1.	259 Aletheia	TYC 6256-00276-1	10.2	9.22	24	26.95	2003 Feb.27	23 02 40
2.	747 Winchester	SAO 141390	9.1	6.79	37	17.07	2003 Jun.04	15 57 47
3.	551 Ortrud	TYC 6213-00982-1	10.9	8.21 m(H)	44	14.07	2004 May 28	18 47 00
4.	7 Iris	HIP 83097 SAO 184864	8.3	7.65	34	12.76	2005 May 22	21 59 07
5.	11 Parthenope	TYC 1286-0615-1 SAO 94297	9.1	8.03	75	12.02	2005 Dec. 09	23 35 27

Table 2. Observations and results.

Asteroid No.	Bond Albedo	NICMOS Sub frame Used (pix)	NICMOS Integ.Time (millisec)	Sampling Rate (millisec)	Obs. Duration of Occultation (sec)	Derived Asteroid chord Length(km)	IRAS Diameter (km)
259	0.037	40×40	200	421.5	7.2 ± 0.4	194±10	185±7
747	0.047	20×20	100	206.7	11.8±0.2	201±3	178±4
551	0.041	20×20	100	205.8	5.8±0.2	82±3	81±3
7	0.21	20×20	100	106	15.2±0.1	194±1	203±5
11	0.15	20×20	100	106	11.5±0.1	138±1	162±3

observed in the J band and one event (551 Ortrud) in the H band. There is a GPS clock in the observatory but it was not synchronised with the data acquisition system. Hence absolute time accuracy of mid time of the events is only ± 0.5 s. However the relative time accuracy in determining chord lengths is limited only by the sampling time and is much better reaching down to about 100 ms in a few cases.

In addition to the five successfully observed events observations were also attempted for five other events : 343 Dembowska (20/2/2004), 433 Eros (8/1/2005), 173 Ino (12/2/2006), 602 Marianna (8/5/2006) and 402 Chloe (25/9/2006). While the Eros event did not happen, the other events were affected by poor weather. Recently alerted by R. Vasundhara (private communication) of the predictions by the French group (J. Berthier & J. Lecacheux, private communication) a rare event – a possible stellar occultation by a satellite (Romulus) of main belt asteroid 11 Sylvia was attempted from Gurushikhar. The star ($m_J \sim 10$) was monitored throughout the expected period of the event under clear skies but the satellite event did not happen.

3. Results

Figures (1-5) show the observed occultation light curves. They have been derived by subtracting the recorded sky subframe from each of the event subframes and then summing up the counts in a subframe. The chord lengths in km are then determined from the predicted shadow speed on the ground and the duration of the event observed. Table 2

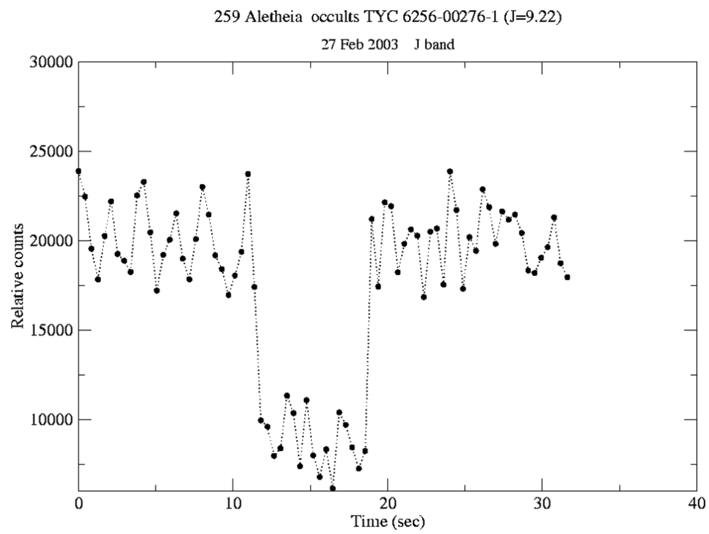

Figure 1. 259 Aletheia occultation: X axis- Time since 23:02:25 UT.

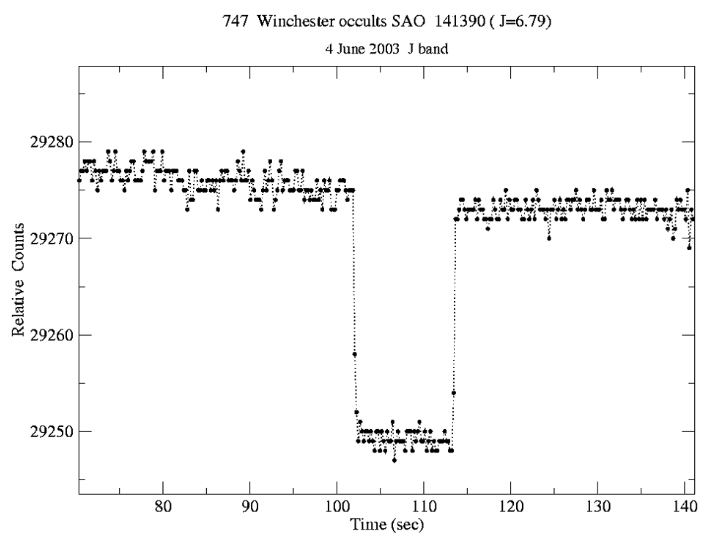

Figure 2. 747 Winchester occultation: X axis- Time since 15:56:00 UT.

lists the chord lengths derived across the 5 asteroids along with the errors. Also listed along side for comparison are the radiometric (IRAS) diameters of these asteroids derived from the IRAS survey and listed in Tedesco (1989). The radiometric method is based

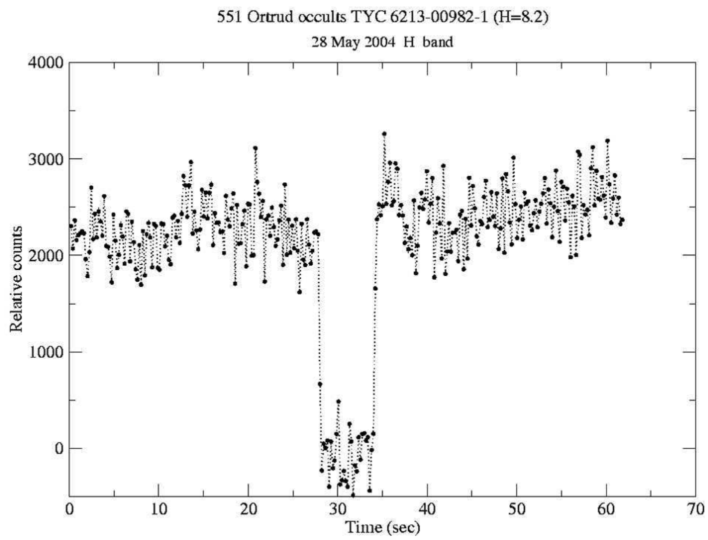

Figure 3. 551 Ortrud occultation: X axis- Time since 18:46:29 UT.

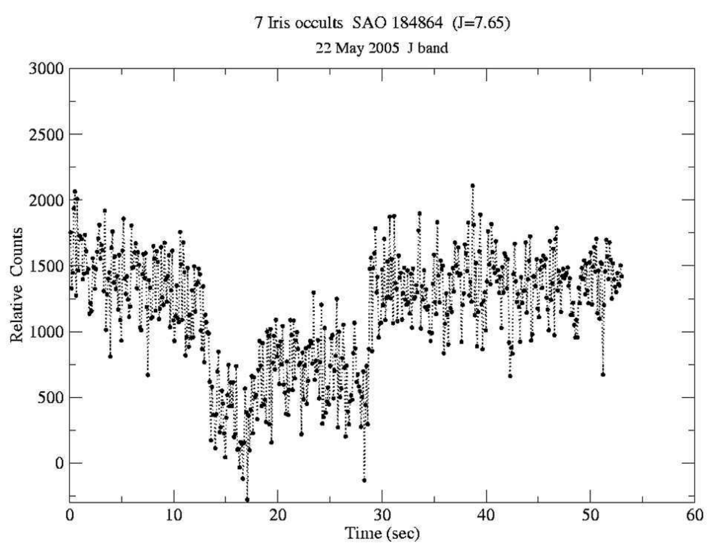

Figure 4. 7 Iris occultation: X axis- Time since 21:58:46 UT.

on finding a diameter and albedo that will match the observed reflected and thermal emission from the object and is model dependent (Lebofsky & Spencer 1989).

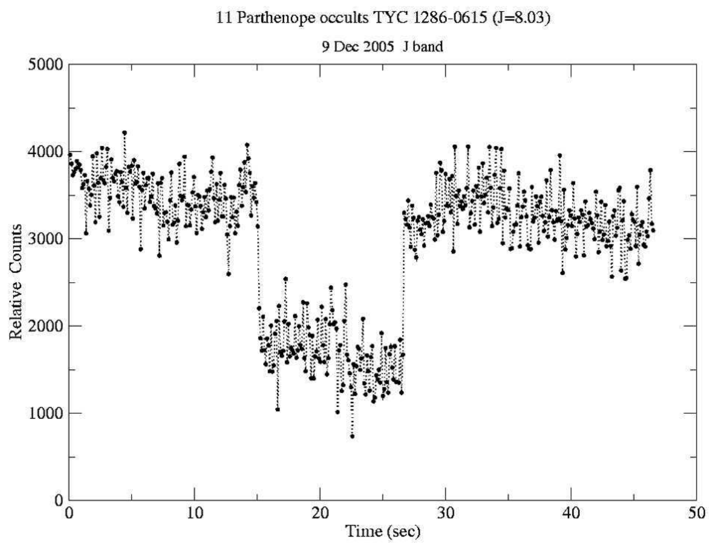

Figure 5. 11 Parthenope occultation: X axis- Time since 23:35:06.5 UT

It can be seen that our measured chord lengths generally match fairly well with the IRAS diameters. In three of the occultations (7 Iris, 11 Parthenope and 747 Winchester) light curve variations are known which imply a non spherical rotating body. In the case of 11 Parthenope the observed chord length (138 $\pm$ 1 km) is less than the IRAS value of 162 $\pm$ 3 km which suggests a non central event. However 11 Parthenope also exhibits a light curve with a periodciity of 7.83 hours and a varying amplitude (0.07 - 0.12) indicating a nonspherical shape. Similarly 7 Iris has a well defined period of 7.139 hours and a large variation in the amplitude of its light curve (0.04-0.29) Asteroid 747 Winchester also exhibits a light curve periodicity of 9.4 hours and on amplitude of 0.13 (Lagerkvist et al. 1989). In the other two cases (259 Aletheia and 551 Ortrud) light curve variations are not reported.

In spite of the limitations due to departures from sphericity, well observed near central asteroid occultation events can provide direct measurement of the sizes of the bodies. The serendipitous recovery of satellites to the occulting asteroids is also an important consideration in observing those events.

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