Identification and Calculation of the Three-Dimensional Orbit of an Asteroid

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Asteroids are clumps of rock, the sizes of which range from less than a kilometer to a few hundred kilometers in diameter. They are generally found in the unusually large gap between Mars and Jupiter. There are probably more than 40,000 asteroids in this gap called the "asteroid belt." In this paper we describe our efforts in confirming the identity of an asteroid and then calculating its three-dimensional orbit around the Sun, given the six elements of orbit.

We took part in the International Astronomical Search Campaign (IASC) to confirm or discover asteroids that exist in the asteroid belt. IASC is an outreach program for high schools and colleges around the world and was developed by Patrick Miller of Hardin-Simmons University, Texas. IASC is also part of the NASA Wide-field Infrared Survey Explorer (WISE) program. Asteroid hunting has no cost to participating schools, and to date over 250 schools in over 25 countries located on five continents have participated in this program.[1] Schools can take part in this program by going to the IASC website.[2]

Astrometry

Students participate in IASC by downloading images that were taken by telescopes (24 in and 32 in) at the Astronomical Research Institute, Illinois, within the last few hours. These images must be downloaded and analyzed within three days.

A software package called Astrometrica, which can be downloaded from the IASC website, is used for the photometry. The telescopes take three images of the same part of the night sky where asteroids are assumed to exist. These images are taken at six-minute time intervals. During the six-minute time interval the asteroid would have moved noticeably (in the image about five pixels) relative to the distant background stars. Astrometrica highlights those objects that fit these criteria by marking a red circle around them (see Fig. 1).

In order to determine whether an object is an asteroid, students examine this positional change by carefully sorting image artifacts from moving celestial objects. Thus they examine the fit of the point spread function (inset of Fig. 1), the signal-to-noise ratio, and whether the visual magnitude of the object has changed in the three images. If the object has moved in a straight line, its visual magnitude is fairly constant, the signal-to-noise ratio is greater than five, and the object is approximately round, then it is likely that the object is an asteroid.

A typical asteroid campaign lasts about 45 days. If a new asteroid is discovered or confirmed, a report is sent to Professor Miller. He then sends the reports to three volunteers in Poland who run a series of statistical tests and calculate the orbits and check the results with the Minor Planet Center at Harvard University. If the results pass this point, then four

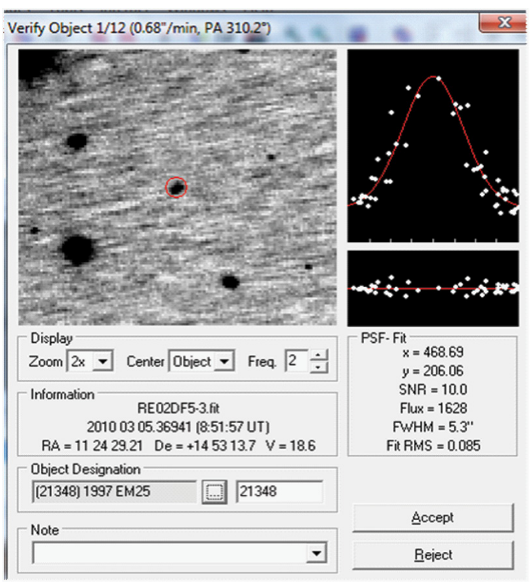

Fig. 1. Image taken by ARI telescope and Astrometrica software used to detect asteroids. The object in the red circle has moved in the three images. The right ascension, declination, and visible magnitude are shown. The fit to the point spread function is shown in the inset together with the signal-to-noise ratio.

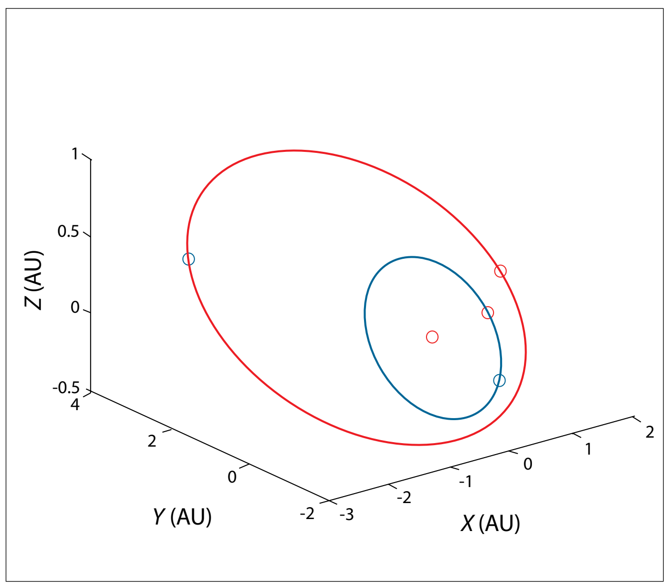

Fig. 2. Three-dimensional orbit of the asteroid (red circle) and the Earth (blue circle) around the Sun (center red circle). The closest approach of the asteroid to the Earth took place on September 29, 2007 (red circles on orbits), and the farthest distance of the asteroid from the Earth took place on August 9, 2009 (blue circles on orbits).

Table I. Elements of orbit for asteroid and Earth.

Element of orbit	Asteroid 2007 TD14	Earth
a	2.3637	1.0
e	0.4667	0.0165
Ω	185.9186	0.0
ω	127.3349	102.35
i	4.7814	0.0
T	06/25/2007	01/03/2007 01/03/2008 01/04/2009 01/03/2010

Table II. Positions of asteroid on various dates.

Date (2010)	Sun distance (AU)	Earth distance (AU)	RA	Dec
Feb. 1	2.983	2.274	12:11:14	-3.238
April 2	2.754	1.797	11:25:38	+2.676
June 1	2.48	2.16	11:10:50	+5.825
July 31	2.162	2.579	12:11:14	+0.211
Sept. 29	1.814	2.66	14:00:26	-10.06
Nov. 28	1.478	2.453	17:42:57	-19.51
Dec. 28	1.348	2.329	18:26:47	-20.55

other volunteers from Bulgaria, Russia, Italy, and the Netherlands coordinate follow-up images with the Sierra Stars Observatory Network in California. As the result of participating in this program, we confirmed the discovery of two asteroids, 2007 TD14 and 2010 FF7. Our names and schools were mentioned on the IASC website and we obtained two plaques from NASA for our efforts.

Three-dimensional motion of asteroid

The equations that describe the two- and three-dimensional motion of the asteroid are given in Refs. 3 and 4. The elements of the orbit of asteroid 2007 TD14 that were used to obtain the orbit are shown in Table I.[5]

The obliquity of the ecliptic used was $\epsilon = 23.45$. Figure 2 shows the three-dimensional orbit of the asteroid and the Earth around the Sun obtained by using the equations given in Ref. 4 and the values in Table I.

The period of the asteroid is 1327 days or 3.64 years. The asteroid is at the perihelion on June 25, 2007. Starting from this date and the time it takes for the asteroid to go once around the Sun, the closest approach of the asteroid to the Earth occurred on September 29, 2007 (0.679 AU, shown as red circles in Fig. 2), and the farthest distance of the asteroid from the Earth occurred on August 9, 2009 (4.397 AU, shown as red circles). The closest distance is greater than 0.05 AU, and thus asteroid 2007 TD14 is not considered a potentially dangerous object. The positions of the asteroid on various days in 2010 are given in Table II. More recent positions can be found in Ref. 6.

Final comments

In this paper we have shown how schools can take part in the IASC program to hunt for asteroids. Using the equations given in the references, the two- and three-dimensional orbit of an asteroid around the Sun can be obtained. These equations also show how to calculate the right ascension and declination and thus locate the asteroid in the night sky. Once the asteroid is located, students can then attempt to measure its rotation.

Acknowledgment

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