Asteroid Prudentia

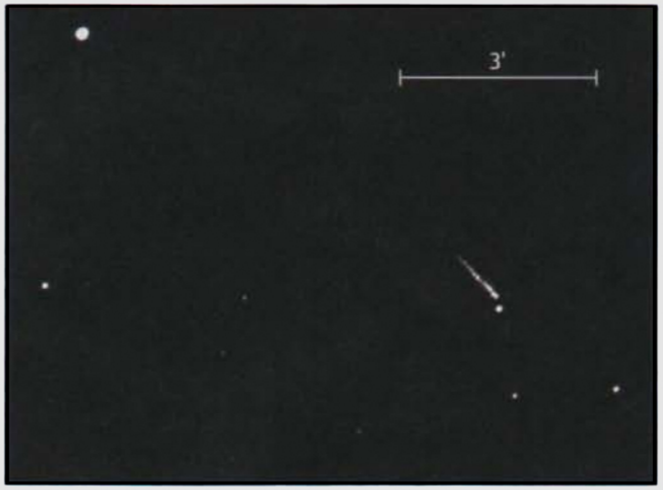
A Backyard Project

Today's amateur equipment makes it fairly easy for anyone to measure the a.u. All you need are reasonably good views of the east and west horizons and a quality telescope and CCD camera. Close passes of Eros come infrequently, but there are lots of other asteroids out there. On almost any night at least one is having a relatively close opposition, making it a good target.

We measured the a.u. last summer from a backyard in suburban New Jersey. On the afternoon of August 8th, we looked at our planetarium program (*Cartes du Ciel*, but any such program will do) to see what asteroids were near opposition. We picked 474 Prudentia because it was particularly close to Earth — according to *Cartes du Ciel*, it was only 0.9309 a.u. distant at the time. We confirmed this value by a visit to the invaluable Horizons solar-system data and ephemeris computation service, offered by the Jet Propulsion Laboratory at http://ssd.jpl.nasa.gov/?horizons.

That evening we set up our telescope in the yard. After polar-aligning it we used the scope's Go To system to point to Prudentia. We had to wait 20 or 30 minutes for the asteroid to clear the trees. Then we took 10-second exposures every 10 minutes for about 90 minutes. Next, one of us set the alarm clock for 3:30 a.m. and returned to take 10-second exposures every 5 minutes (just to be sure) for about an hour prior to dawn. The next evening we repeated the procedure, collecting a third set of CCD images.

An asteroid moves a fair amount in both right ascension (RA) and declination in 24 hours: the total angular displacement for Prudentia was about 15 arcminutes. Superimposed on this essentially uniform, linear motion is an apparent oscillating motion caused by our backyard swinging around Earth's axis once a day. Since Earth rotates about a fixed polar axis, we only need to measure the asteroid's oscillation in RA.



The authors used the 10-inch telescope pictured on page 91 and a Starlight Xpress SXV-H9 CCD camera to capture this streak of the 12th-magnitude asteroid 474 Prudentia. It's a stack of 12 unfiltered 10-second exposures taken at 5-minute intervals on August 9th Universal Time.

We used *MaxIm DL*'s astrometry tool to determine the asteroid's RA and declination relative to the stars in each of our images. The diagram below shows a raw plot of RA versus time. Clearly, it is dominated by the asteroid's uniform linear motion. It's easy to estimate this motion just by comparing two images 24 hours apart. We can then subtract it out to see Prudentia's *residual motion*, as shown in the diagram at lower right. We know that the residual motion has

Asteroid Prudentia

to be a nearly-24-hour sine curve. Shown in the diagram is the curve of this type that best fits our data.

Our observing site was at latitude 40° 27′ north. Simple trigonometry tells us that the baseline for this latitude is 9,693 km (the diameter of Earth is 12,738 km, which we multiply by the cosine of our latitude to get the baseline). From the diagram below, it's clear that the peak-to-peak RA oscillation (θ) was about 13 arcseconds. To determine θ as accurately as we could, we did a regression analysis (using a quadratic rather than a simple linear equation for the background motion), which gave a peak-to-peak value of 14.47 arcseconds.

Given the known baseline (b) in kilometers and the angle, we could compute the distance (d) in kilometers to Prudentia using the formula $d = b/2\sin(\theta/2)$, which gives 138,200,000 km. Therefore 1 a.u. equals 138,200,000 km divided by 0.9309 a.u. (the ephemeris distance that we looked up), or 148,500,000 km. That's only 0.7% below the correct value!

In just 26 hours and armed only with hobby equipment, we measured the a.u. almost as well as David Gill did – with a small fraction of his skill and effort. The result could surely be improved by conducting many observations over many nights, and from a site closer to the equator (giving a longer baseline), and in better seeing. But it's amazing to realize how easy it is these days to measure a fundamental quantity that many ancient and medieval astronomers would have gladly given their lives to learn.

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		Right Assension			Declination		
Month	Date.time	hr	min	sec	deg	min	sec
08	10.09520	21	42	37.64	-06	50	57.2
08	10.09156	21	42	37.74	-06	50	55.1
08	10.08792	21	42	37.89	-06	50	52.3
08	10.08428	21	42	38.08	-06	50	50.2
08	10.08065	21	42	38.20	-06	50	47.4
08	10.07700	21	42	38.39	-06	50	45.8
08	10.07337	21	42	38.51	-06	50	42.9
08	10.06973	21	42	38.66	-06	50	40.8
08	10.06610	21	42	38.79	-06	50	38.1
08	10.06247	21	42	38.94	-06	50	35.9
08	10.05498	21	42	39.24	-06	50	31.2
08	10.05087	21	42	39.41	-06	50	29.0
08	09.39650	21	43	03.85	-06	43	41.2
08	09.38921	21	43	04.12	-06	43	37.0
08	09.38556	21	43	04.29	-06	43	34.2
08	09.38190	21	43	04.42	-06	43	32.2
08	09.37825	21	43	04.57	-06	43	30.1
08	09.37461	21	43	04.71	-06	43	28.0
08	09.37096	21	43	04.86	-06	43	25.6
08	09.36731	21	43	05.01	-06	43	23.2
08	09.36367	21	43	05.15	-06	43	21.0
08	09.35990	21	43	05.31	-06	43	19.1
08	09.35263	21	43	05.59	-06	43	14.2
08	09.35069	21	43	05.67	-06	43	13.1
08	09.11303	21	43	15.45	-06	40	46.3
08	09.10593	21	43	15.74	-06	40	41.8
08	09.09882	21	43	16.04	-06	40	37.2
08	09.09168	21	43	16.31	-06	40	33.0
08	09.08455	21	43	16.59	-06	40	28.5
08	09.07744	21	43	16.90	-06	40	24.3
08	09.07032	21	43	17.14	-06	40	19.5
08	09.06258	21	43	17.47	-06	40	14.9
08	09.05623	21	43	17.71	-06	40	11.0

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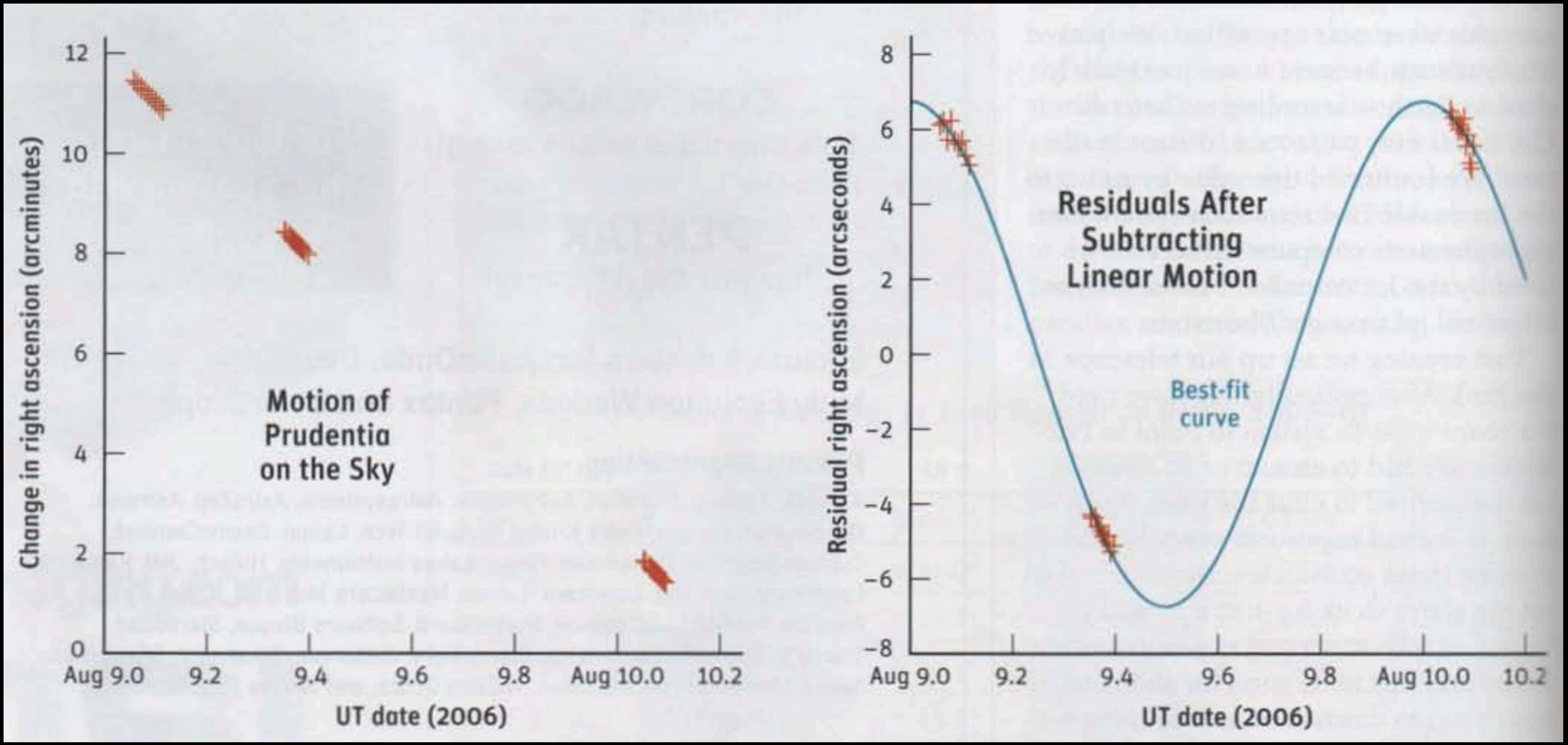

Click on the diagram or here to see the Sky & Telescope article.