The rotation rate of the Earth

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Abstract In this experiment, we attempt to measure the rotation rate of the planet Earth. Using the Sun as a reference point, we take a series of measurements of the Sun's zenith angle at various times over the course of 3 days. The Earth's rotation can be derived from the a sinusoidal period of the altitude/time plot, with a correct for angular speed of the Earth's orbit. This work was performed with lab partner Svante Clerk Hanbury-Brown.

Introduction Despite appearances, the Sun does not orbit the Earth. Instead, the Sun's apparent motion through the sky is due to (a) the fact that the Earth is spinning at some "sidereal" angular velocity ω_s, which we expect to be in the ballpark of $\omega_d = 2\pi/24$ rad/h, and (b) the fact that the Earth is orbiting the Sun at approximately $\omega_y = 2\pi/365$ rad/d, which we assume to be known precisely. The sum of these two is ω_{sun}, the apparent angular velocity of the sun, which we can measure.

Methods From Oct 28–Nov 3, 2012, at irregular intervals, we collected the following data from the plaza in front of Broida Hall, UCSB: the time, measured on a Motorola V52 cell phone (accurate to 30s); the Sun's zenith angle, measured using a shadow and a protractor, estimated accurate to 2 degrees. A total of 57 measurements were taken, including repeated measurements at each time point to help estimate uncertainties. Adjunct measurements, including hour angle and temperature were not used in the final analysis.

Results The data and fit are shown in Fig. 1. In an inset, we show the fit residuals (data minus a sinusoid fit), overlaid with our expected (not fit) error distribution, and the agreement confirms our estimate of the error bars. From the fit, we conclude that the Sun's apparent motion is $\omega_{sun} = 0.04176 \pm 0.00008$ rad h^{-1}, corresponding to a solar day of length 23.95 ± 0.05 hours. Subtracting the orbital frequency, we derive the angular velocity to be $\omega_d = 0.04165 \pm 0.00008$ rad h^{-1}, for a day length of 24.01 ± 0.05 hours, in agreement with other sources. Errors due to latitude uncertaintly, atmospheric refraction, and sunspots were analyzed and found negligible.

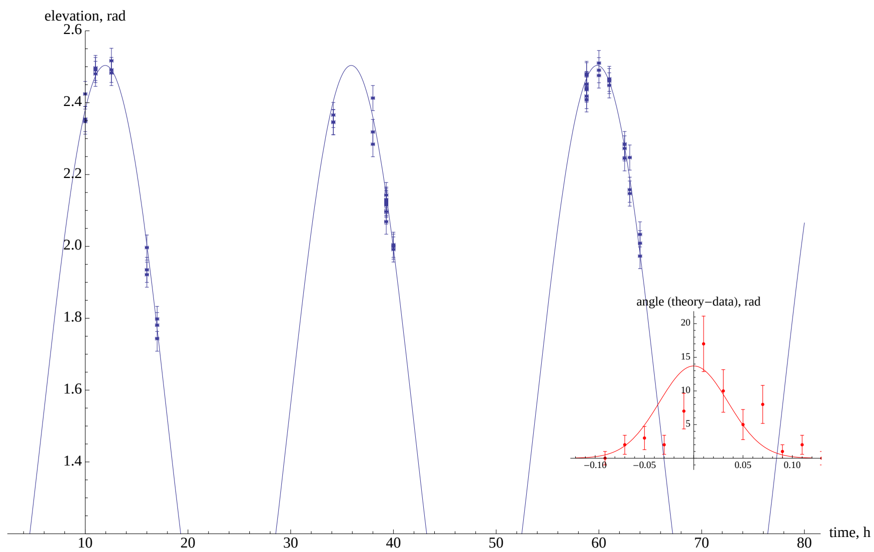

Figure 1: Solar elevation vs. time. Blue points are data; the blue curve is the best-fit sine wave. Inset in red is a histogram of the angle residuals, overplotted with a Gaussian showing the expected 2 degree error distribution.