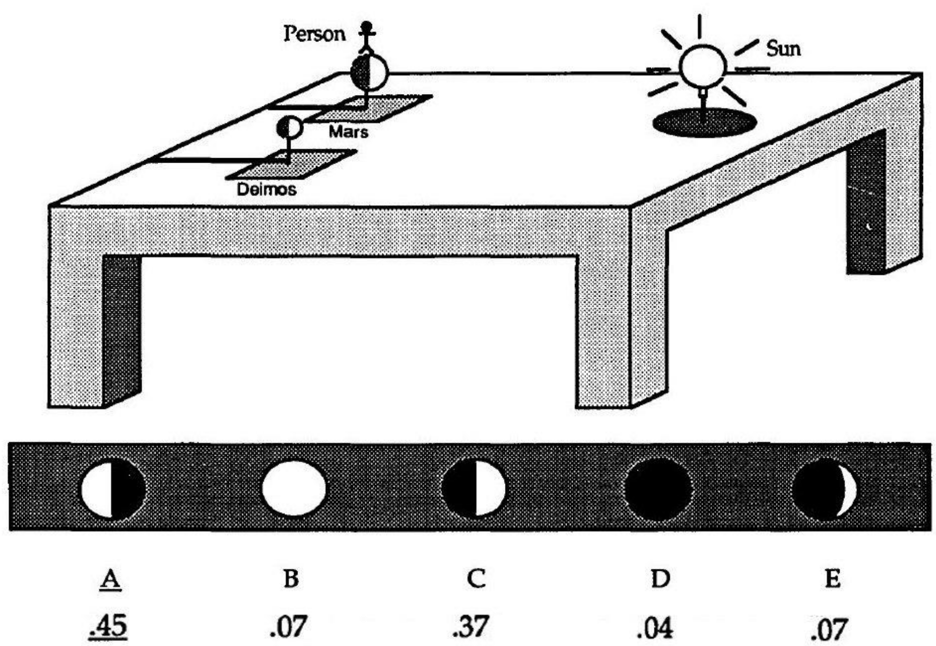
# Storytelling with Uniview #11:
# Earth's Daily Motion

May 9, 2014

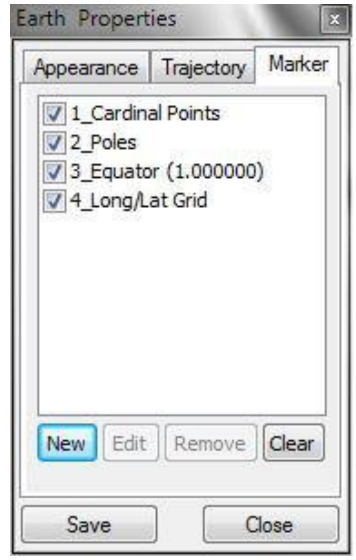
Ka Chun Yu
kcyu@dmns.org

Teaching about the daily motion of Earth—and as a by-product, the apparent daily motions of the Sun, Moon, and stars—to the public is not as trivial as you might think. For some young children, when asked about their concept of day and night, they answer that that Sun rises into the sky straight up from the ground, and then drops back down (Plummer 2009). When asked where the Sun goes at night, even younger children may think it has gone hiding behind trees or clouds. How the Sun moves in the sky is not an intuitive concept. This makes some sense. For some people, the idea of Sun-rises-in-the-east-and-sets-in-the-west has been explicitly explained to them early in life. If not, in order to build a correct mental model of the Sun's motion in the sky, you would have to pay attention to which direction the Sun is at different times of the day, and integrate your observations into a coherent explanation. I suspect it may be even harder for kids today, who have many more distractions to keep them from paying attention to the Sun when they are outside.

We understand the daily celestial motion of the Sun, Moon, and stars to be the result of the rotation of Earth on its axis. If we look down at the North Pole, we will see Earth rotating counter-clockwise. From our Earthbound perspective, this translates to objects in the sky rising from the east, circling around us over the course of a day, setting in the west, and then repeating roughly 24 hours later. Although we can understand the rotation of Earth on its axis just by looking at the motion of a real (or virtual) globe, the connection between a space-based perspective and what we can observe from the ground is not always clear. In fact it can be difficult for many, including children, to look at a model showing spatial relationships, and to imagine how those relationships would look from a different perspective.



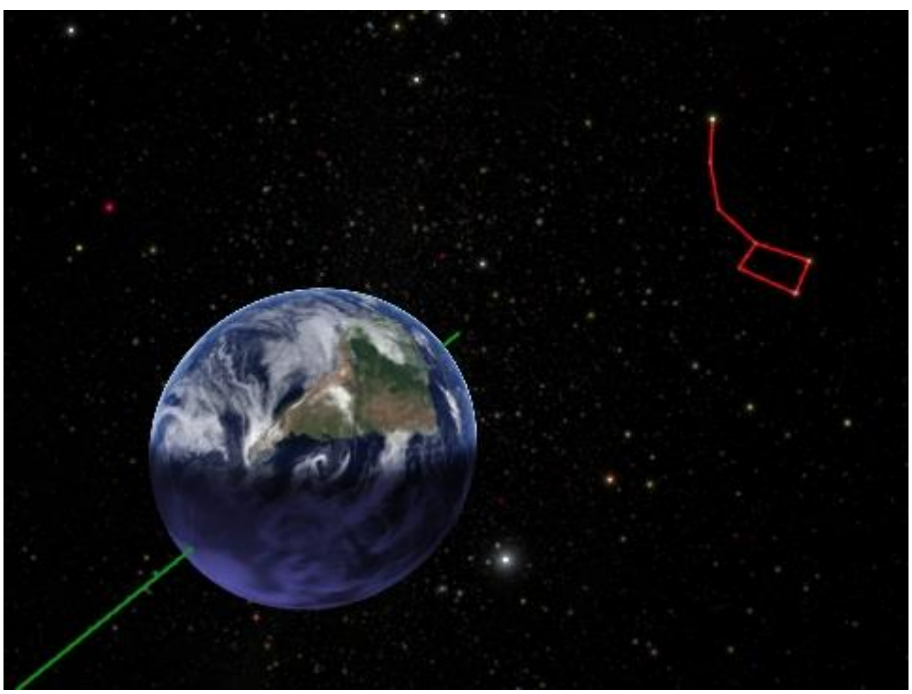

Take this example at the right from a test question administered to 1400 high school students by astronomy education researcher Philip Sadler. Students are asked to look at a model depicting Mars, its moon Deimos, and the Sun, and to pretend they are the figure at the top of Mars. How would that stick-person see Deimos? The tabulated numbers at the bottom show the fraction of students who picked each of the five multiple choice answers. The correct answer is A, with the illuminated side on the left, accounting for 47% of the responses. However the next most popular choice is C with 37% of the total responses, where the lit side of Deimos is on the right. So clearly, imagining a perspective that is turned around 180° can be difficult even for such a simple model.




So understanding of even the concept of Earth's daily motion could be fraught with difficulty, especially if the perspective is changed to one on the surface of a sphere.

What can we do in Uniview? First let us define some Earth markers that will be useful. To create these (if you don't have them already), right click Earth in the Object Tree, and click on "Properties" in the pop-up menu. The word "Earth" will now show up at the top of the Properties window. Now select the Marker tab. If no markers are already defined, you can click on the *New* button to load a new one. Make markers for *Cardinal Points, Pole Lines, Equator, Altitude-Azimuth Grid*, and *Long/Lat Grid*.

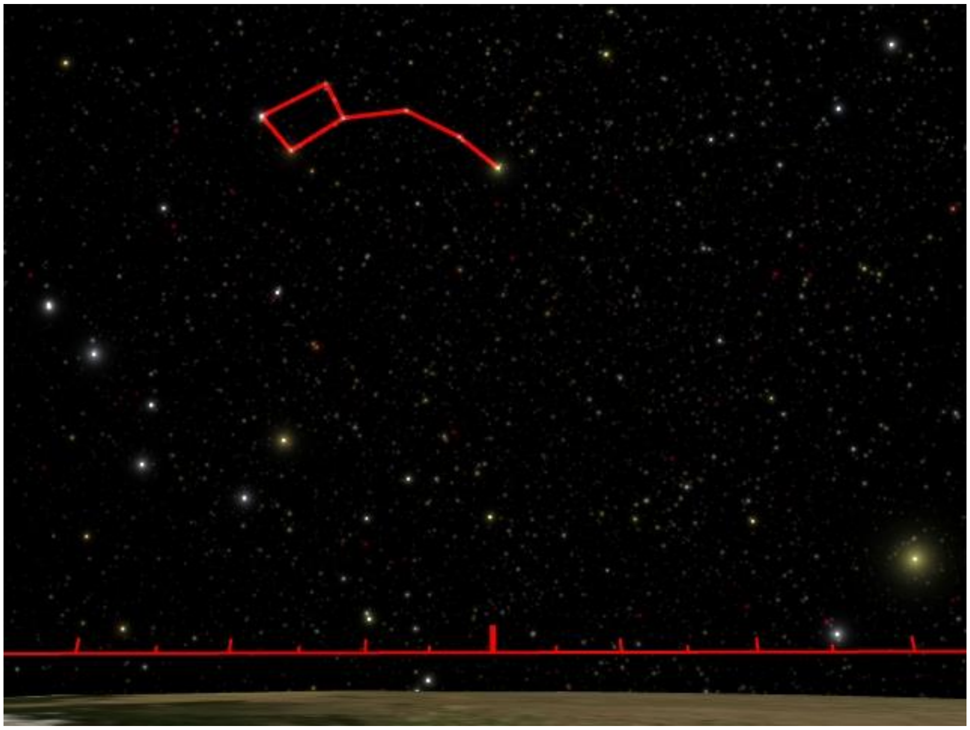
Once you have these, you are ready to start. Before talking about the daily rotation of Earth, it's best to toggle on the *Pole Lines*. (The *Long/Lat Grid* and *Equator* are optional, since they could make the scene look too crowded.) Set the simulation date and time to a day in December, and start time moving forward, 1 hour per second. The rotation axis of the spinning Earth will be clearly marked by the green *Pole Lines*. Not only will you know the exact locations of the North and South Pole on Earth, but you can use the *Pole Lines* to find the Celestial Poles, the points in the sky that the Earth's North and South Poles are pointing to. There isn't anything bright at the South Celestial Pole, but the star Polaris, at the end of the handle of the Little Dipper/Ursa Minor, is very close to the North Celestial Pole. You may have to wiggle the camera around the Earth a bit to convince your audience that the green line representing the North Pole is indeed lined up with Polaris (*screenshot below*).



Now after establishing what daily motion looks like from space, let's take a look from the surface. Instead of flying down to a familiar location like Denver, drop down to the North Pole instead. This may take some tricky re-orienting of the camera especially in single-screen mode at the Orbits Table. Make sure you lock the camera to Earth's surface (by hitting the F5 button or clicking on the menu Camera→Lock to Current Target), and to use Ctrl+Left Mouse Button to maneuver the camera until you have the view you want.

Once you land, you can point out that Polaris and the North Celestial Pole are now directly overhead. As time continues to move forward, the rotation of Earth on its axis now translates to the circular motion of the entire sky around the North Celestial Pole/Polaris.

Because you are at the North Pole, the celestial bodies in the sky do not rise and set. Instead they move in circular tracks parallel to the horizon. (And since we are in December, the Sun isn't visible in the sky to confuse things.) This gives a much more direct connection with the space-based perspective that we saw earlier. Instead of the Earth spinning and the Little Dipper stationary, we now see the Earth motionless, and the Little Dipper along with the rest of the sky rotating about the Celestial Pole. The motions have flipped as we transfer our perspective from a space-based one looking back at Earth, to an Earth-bound one looking out into space.



Now let's stay on the surface but move further south. Turn on the *Cardinal Points* marker that you created earlier. (Since you are at the North Pole, it doesn't matter which direction you go; you'll still be heading south.) Instead of flying forward to lower latitudes, keep the Little Dipper in front of you and back up (using Left Mouse Button to move the virtual camera across the landscape). As the North Pole recedes ahead of you, and you move further south, the North Celestial Pole/Polaris should start descending from its zenith position in the sky to an increasingly lower elevation angle. If you drop 15° in latitude on Earth—from 90° to 75°—then Polaris will also drop 15° in the sky. You can do this all the way to Denver's latitude of 39.8°, at which point Polaris will be 39.8° below the zenith or conversely (since there is 90° between the horizon and zenith), it is 50.2° above the horizon (*screenshot above*). If you have the time and interest, you can continue moving the camera south all the way to the equator at which point Polaris will be sit on the northern horizon. Move any further south from the equator and Polaris will drop below the northern horizon.

As you move the camera south, keep the simulation time moving forward as well. Thus the visitor will see how the paths of celestial bodies in the sky change. Point out that instead of daily motions parallel to the horizon, their tracks increasingly tilt down. When you are stopped at Denver's latitude, point out how different the daily paths are. Celestial bodies rising in the east do not just shoot straight up from the ground; their trajectory is at an angle to the horizon. Similarly the Sun does not just drop straight down when it sets. Furthermore, its motion is restricted to the southern part of the sky; it never reaches the zenith on any day of the year.

During these demonstrations, reinforce the fact that the daily motion of the sky, a direct result of a rotating Earth, gives rise to the familiar observation from Denver (or anywhere else on Earth away from the poles): celestial bodies rise in the east and set in the west. If you have managed to get your audience to connect the space- and Earth-based views of daily motion, then this new spatial understanding will be a foundation that prepares them for more complicated astronomical topics.

**Further Tips:** Leaving the *Cardinal Point* markers on will help the visitor understand which part of the sky they are looking at. You can also toggle on the *Altitude-Azimuth* grid to help visitors get a sense of how high up the Sun or Moon gets in the sky.

In the dome, you and the audience get a good view of almost half the sky. However if you are in a single-screen rectangular projection mode (like at the Orbits Table), your view will seem very constricted. That is because Uniview starts with a default horizontal field-of-view (FOV) of 40°. With such a narrow FOV, it can be difficult to see more than one constellation in its entirety on-screen at once. There is a FOV slider at the bottom of the main Uniview Theater window (where the simulation graphics appear). If you are in fullscreen mode already, type F11 to get out (or alternatively in the Input window, click on the menu Windows→Toggle Full Screen). Use the slider to change the FOV to at least 60-75°. When you switch back to fullscreen, there should be more breathing room in the scene, and you won’t have to pan around as much to follow daily motions in the sky when viewed from Earth.

**References**

Plummer, J.D. 2009, “A Cross-Age Study of Children’s Knowledge of Apparent Celestial Motion,” *International Journal of Science Education*, 31, 1571-1606.