Telling time by the stars
Due Wednesday April 16, 2008

You may carry out this project with an observing partner, if you so choose. Or you can do it on your own if you like. But do **not** *make up your data. You need observations of the real sky.*

As discussed in class, a useful celestial coordinate system for observers on the Earth is that of equatorial stellar coordinates. The two coordinates are called **right ascension** (RA) and **declination** (DEC). DEC is the north-south coordinate and RA is the east-west coordinate.

The star chart given out in class with copies of this text shows the northern constellations centered on the North Celestial Pole (near the star Polaris). Note that the right ascension is given around the circular chart in Roman numerals. The smallest marks correspond to increments of 5 minutes of RA.

The celestial meridian is the imaginary line in the sky that separates the eastern half from the western half. It is a line that passes from the north point on the horizon through the North Celestial Pole (near Polaris), then through the zenith ("straight up") and down to the south point on the horizon.

Sidereal time is "time by the stars". The right ascension corresponding to the celestial meridian above the north celestial pole is called the **local sidereal time** (LST), which changes continuously as the Earth turns.[1] If the LST = 5h 30m, Orion must be on the meridian. If the Big Dipper is high in the northeast, the LST could easily be 8 hours.

The **hour angle** is the number of hours, minutes, and seconds that an object is west (or east) of the meridian. By convention, positive hour angle is west and negative hour angle is east. Thus, an object on the celestial equator with an hour angle of +6 hours is setting. To an observer at mid-northern latitudes, a celestial object with hour angle of −2 hours is high in the northeast, east, or southeast.

Hour angle, right ascension, and local sidereal time are related as follows:

$$HA = LST - RA \quad .$$

Thus, if the LST is 8 hours, the stars alpha and beta Ursae Majoris (with RA ≈ 11h 00m) have an hour angle of approximately *minus* 3 hours.

[1] The stars between the north celestial pole and the north point on the horizon are said to be at their "lower culminations". They are as low in the sky as they get. Their right ascensions are equal to the local sidereal time ±12 hours.

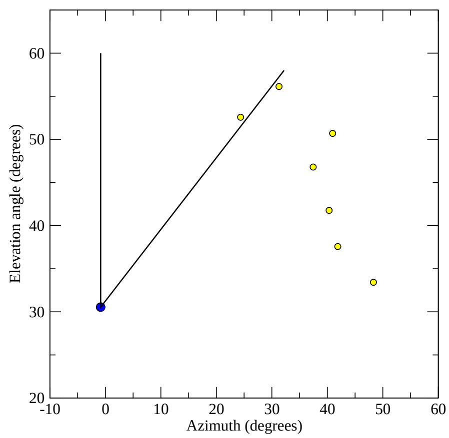

Figure 1. The position of Ursa Major on a spring evening, as viewed from College Station, TX. The vertical line is part of the celestial meridian. One our later the stars will have rotated 15 degrees counterclockwise. Eventually the Big Dipper will be on the west side of the meridian.

Consider the star chart showing the circumpolar stars visible in the northern hemisphere. As the sky appears to rotate counterclockwise about the north celestial pole (NCP), the star β (beta) Cas leads the bright stars of Cassiopeia around the NCP. Similarly, on the opposite side of the NCP (but not *exactly* opposite) are the pointer stars of the Big Dipper, α (alpha) and β Ursae Majoris (UMa). They have right ascensions very nearly equal to 11 hours.

Our clock time is also known as **mean solar time**. For our purposes here, it is the hour angle of the Sun. Central time, for example, is mean solar time adjusted to the 90 degree line of longitude, which is to say, 90 degrees west of Greenwich, England. At Texas A&M, the longitude is actually 96^o $20'$ $26''$. Call it 96.3406 degrees. So we are $(96.3406 - 90) = 6.3406$ degrees west of the reference longitude for Central time. Since the Earth turns one degree every 4 minutes, we are 6.3406 deg $\times$ 4 min/deg = 25.4 minutes of time west of the 90 degree meridian.

One of the first things you must do is to figure out the direction of north in the sky. Texas Avenue runs very nearly northeast-southwest. If you are in College Station looking towards Bryan, north is roughly 45 degrees to the right of the direction that Texas Avenue runs northwest. Polaris will be roughly 30 degrees above the north point on the horizon. Cassiopeia will be in the northwest. The Big Dipper will be in the northeast.

The easiest way to estimate the local sidereal time is to mount a copy of the circular star chart on a piece of stiff cardboard. Stick a pin through the star Polaris at the center of the circle. Make a plumb bob by tying a piece of thread to a small metal object (such as a washer) and letting it hang down from the pin stuck in the position of Polaris. This gives us a vertical reference.

We want to orient the circular star chart so that it looks like the orientation of the northern constellations at some moment in time. Since the sky turns 15 degrees per hour, your chart's orientation will change over the course of only a few minutes. Over the course of a whole night the chart will have to be rotated 180 degrees counterclockwise.

The local sidereal time will be equal to the right ascension corresponding to the **top** of the clock face. Since the plumb bob hangs *down*, we will have to carry out one extra step to get the LST.

Say the thread hanging down crosses the circular outline three little tick marks from "21" toward the "20" on the clock face. Each tick mark corresponds to 5 minutes of time, so the thread would correspond to 20h 45m. The LST will be 12 hours less than this, or 8h 45m.

To determine the hour angle of the Sun, we need to know the right ascension of the Sun. This is zero on the first day of spring, and changes roughly 4 minutes per day.

The coordinates of the Sun at noontime can be obtained from this website:

http://faculty.physics.tamu.edu/krisciunas/ra_dec_sun.html

Making the observations and calculations

1. Glue a photocopy of the northern constellation chart to a piece of stiff cardboard. Stick a pin in the location of Polaris and hang a plumb bob from the pin. This is your stellar clock face.

2. Determine the direction towards the north point on the horizon at a location where you can see the stars.

Parts 3 through 10 should be done three times. These could be observations made over the course of a single night (spread out over several hours), or observations on different nights.

3. Orient the stellar clock face so that it matches what you see in the sky as closely as possible. In the evenings of March and April Ursa Major should be found to the right and higher in the sky than Polaris.

4. Using the plumb bob hanging from Polaris in your stellar clock face, determine where the thread crosses the graduated circle. Estimate this to the nearest five minutes.

5a. Subtract 12 hours from the time you get from part 4. This will be the local sidereal time − the right ascension corresponding the meridian above Polaris.

5b. If the date of your observations is earlier than March 20th, now add 24 hours to the LST. This will make the arithmetic easier later.

6. Look up the right ascension of the Sun corresponding to the date of your observations. Since the table at the website gives the RA at noontime, you should interpolate between one date and the following date. (Basically, this is just adding 2 minutes to the time corresponding to the earlier date. Example: March 5, 2008, $RA_{\odot}$ = 23 hours 06 min 46 sec $\approx$ 23 h 07 m. Half a day later, when it is nighttime, the RA would be about 2 minutes more, or 23 h 09 m.)

7. Subtract the RA of the Sun (in hours and minutes) from the local sidereal time (in hours and minutes). The result is the hour angle of the Sun (in hours and minutes).

8. We switch over to Daylight Savings Time at 2 AM on March 9, 2008. If your observations are made on the evening of March 9th or later this spring, add 1 hour to your result.

9. Add 25 minutes to your answer from #8. This corrects the local solar time to the 90 degree meridian, giving your estimate of the Central Standard Time (CST) or Central Daylight Time (CDT) in "hours and minutes since noon" (or PM). If you get between 12 and 13 hours, that would be 12:something AM. If you get more than 13 hours, then subtract 12 hours to get hours and minutes AM (in the middle of the night).

10. Compare your estimate of the Central Standard Time or Central Daylight Time to the clock time of your observation. *Make sure you write down the month, day, and year.* An observation without a good time stamp is not a good observation.

Accurate clock time can be obtained from the website:

http://wwp.greenwichmeantime.com/

If you are more than one hour in error, you might have made some arithmetic error, or are looking at the wrong constellation. Ask for some help long before the due date.

To turn in

A proper scientific report usually contains one or more diagrams, some text, and some calculations. There should be an *explanation* of what you did. You should not just hand in a bunch of numbers.

For each of your three observations hand in:

1. A drawing of the northern sky used for the calculations.

2. All calculations outlined in the previous section.

3. A brief discussion and summary. How accurately can one determine the clock time by a proper orientation of the stellar clock face?