Telling time by the stars
Due: Wednesday, November 18

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 Cassiopeia is high in the northeast, the LST could easily be 21 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 21 hours, the star beta Cassiopeia (with RA ≈ 0h 09m) has an hour angle of approximately *minus* 3 hours.

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[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.

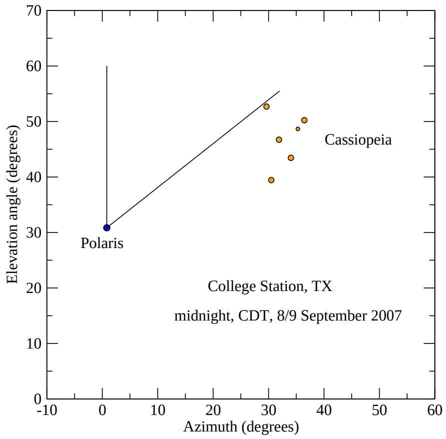

Figure 1. The position of Cassiopeia in the sky on the evening of 8/9 September 2007, as viewed from College Station, TX. The vertical line is part of the celestial meridian.

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 × 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 northwest-southeast. 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. In the autumn the Pointer Stars of the Big Dipper are of very little help, unfortunately. The Big Dipper is very low in the sky, on the northern horizon. In the middle of the night in October the constellation Cassiopeia will be high in the northeast. It is shaped like the letter "W" lying on its side.

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 "10" toward "9" on the clock face. Each tick mark corresponds to 5 minutes of time, so the thread would correspond to 9h 45m. The LST will be 12 hours more than this, or 21h 45m.

To determine the hour angle of the mean Sun, we need to know the right ascension of the mean Sun. This is zero on the first day of spring, and it changes 3.9426 min/day. The first day of spring this year (2009) was on March 20th, which was the 79th day of the year. October 1st was the 274th day of the year and November 1st will be the 305th day of the year. Example: the RA of the mean Sun on October 12th is (285−79 days)*3.9426 min/day = 812 minutes (to the nearest minute), or 13 hours 32 minutes.

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 should be observations done on three different nights, or over the course of *several* hours on a single night. Observations made over the course of an hour and a half on the same night are not acceptable.

3. Orient the stellar clock face so that it matches what you see in the sky as closely as possible. In the evenings of October and November Cassiopeia 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.

5. Add 12 hours to the time you get from part 4. This will be the local sidereal time. (If your observations are being made towards dawn and Cassiopeia is on the west side of the

celestial meridian, you should *subtract* 12 hours from your answer to #4.) Your goal here is to find the sidereal time at the *top* of the chart.

6. Calculate the RA of the mean Sun given the method mentioned above. Determine how many days have transpired since the first day of spring, March 20th. Multiply that number of days by 3.9426 min/day and convert to some number of hours and minutes.

7. Subtract the RA of the Sun from the local sidereal time. This is the hour angle of the Sun. Keep track of hours and minutes of time.

8. We are using Daylight Savings Time until the first Sunday in November (as opposed to Standard Time). If your observations are made before 2 AM on November 1st, add 1 hour.

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 Time in "hours and minutes since noon" (or PM). Obviously, 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 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?