Astro 121, Fall 2005
Research Techniques in Observational Astronomy

Week 2 (September 7, 2005): Coordinate systems and time

Snacks: TBD

Resources and reading: All of these books are on reserve in Cornell unless otherwise noted. You don't have to read all of these; read what you need to understand the essential concepts and do the problems. Definitely read Bradt, then I'd recommend Chromey and/or Birney as good supplements, with the others as needed for more technical information.

- Bradt, *Astronomy Methods,* Chapter 4. Note that what Bradt calls *epoch* (for designating the date of origin of equatorial coordinates) is more properly referred to as *equinox* (though this usage is unfortunately fairly common). The term *epoch* refers to the date on which those coordinates are valid—often the date of the observation, unless they have been corrected for proper motion. A set of equatorial coordinates has both an equinox and an epoch, and they needn't be the same.
- *To Measure the Sky* by Fred Chromey, pp. 3-1 to 3-24 and pp. 3-32 to 3-40. This book is not yet published, so I'll make copies of the relevant pages. I'll also copy Chapter 4 for you, which has a good discussion of nomenclature.
- Birney, *Observational Astronomy*, Chapters 1 (Coordinate systems) and 2 (Time). I think Birney is a little clearer than Chromey in explaining the equation of time.
- *Astrophysical Formulae, Volume II: Space, Time, Matter, and Cosmology* (on the astronomy reference shelf one row back from the course reserve shelf, QB 461 .L36 1998). Section 5.1.2 on coordinates, Section 5.1.3 on transformation of coordinates (don't get bogged down in detailed formulae, but do understand precession and nutation), and Sections 5.3.1 to 5.3.7 on time. (Again, don't get bogged down in formulae, but do try to understand the concepts, especially UT, LST, Julian date, and the equation of time.)
- *The Explanatory Supplement to the Astronomical Almanac* has extensive discussions of coordinates (Chapter 1) and time (Chapter 2) if you want to look at a different discussion of anything you find in the other sources.

For some of the problems, you will find useful information in the *Astronomical Almanac*, also on reserve in Cornell.

Important terms and concepts:

- Coordinates: equatorial coordinates, galactic coordinates, equinox, epoch, precession, nutation
- Time: UT, LST, HA, Julian date, equation of time

1.
   a. An optically observed G dwarf has galactic coordinates $\ell = 283°$, b = –2°. What can you conclude regarding whether it is located in the disk or halo of the Galaxy?
   b. Same as (a), but for $\ell = 32°$, b = 87°.
   c. A radio source has galactic coordinates $\ell = 202°$, b = 3°. What can you conclude regarding its distance from the galactic center as compared to the Sun's distance from the galactic center?
   d. Same as (c), but for $\ell = 15°$, b = –2°.

2. We refer to the units of right ascension (RA) as hours, minutes, and seconds *of time* to distinguish them from arcminutes and arcseconds.

   a. Why is RA given in time rather than degrees? (It certainly *can* be given in degrees, and sometimes is, but usually not.)

   b. What kind of time is it? That is, is one second of RA a solar second or a sidereal second? What is the precise conversion factor between the two (and how might you derive it, at least to 3-4 decimal places or so)?

   c. How is the zero point of RA defined? At what time(s) of year could you observe an object with zero RA at optical wavelengths?

3. Consider two astronomical objects whose equatorial coordinates are 13 28 36.25 +43 18 31.2 and 13 28 39.13 +43 19 01.3, both equinox 2000.

   a. What is the angular separation (in degrees, arcminutes, and arcseconds) between the two objects?

   b. What is the precision with which the coordinates are given? In other words, what do you make of the fact that the seconds of RA are given to two decimal places and the seconds of declination are given to only one decimal place?

4. For this question, you may use any method you wish. There are coordinate precession and conversion facilities in IRAF and IDL, and a coordinate calculator on the NED web page. Alternatively, you may do the conversion analytically using data and formulae from the Astronomical Almanac. The choice is yours, but be sure to state what method you use and show your work as much as possible.

   You measure the position of an object on the Palomar Sky Survey (POSS I) prints to be 04 25 32.3 +62 18 19 (1950).

   a. What are the equinox 2000.0 coordinates of this object?
   b. What is the epoch of the equinox 2000 coordinates you found in part (a)?
   c. What are this object's galactic coordinates?

5. “Rule of thumb” department, part 1. (Throughout the semester we’ll derive various “rules of thumb” that are handy to know in observational astronomy.) Try to come up with a rule of thumb that would let you roughly calculate the coordinate change per year due to precession. You should

use the information given in Bradt, and also do some empirical investigation by picking some sets of equatorial coordinates (some near the poles, some near the equator) and precessing them from equinox 1950 to equinox 2000. Does one rule suffice for both RA and Dec? Is your rule equally good in all parts of the sky, or is the behavior dramatically different in different parts of the sky? If you have to choose between a rule that works well near the equator vs. one that works well near the poles, which would you choose, and why?

6. You are at the telescope and you receive word that a new extrasolar planet has just been discovered around a nearby star. You want to observe the star, but the only catalog you can find gives the coordinates of the star in equinox 1950, epoch 1962.5; it also lists the proper motion. The telescope control software requires that the coordinates be input in equinox 2000. Describe the steps you would go through to determine the proper coordinates to enter for pointing the telescope tonight (September 7, 2005).

7. The notes that explain the format of the 2MASS Point Source Catalog (a catalog of near-infrared measurements) have the following text:

   > "The Point Source Catalog has been ordered in 0.1 degree declination bins starting at –90 degrees. Within each declination bin the sources are in order of increasing right ascension. Sources with declination < 0 degrees are contained in 57 gzipped files (psc_aaa.gz to psc_ace.gz). Sources with declination > 0 degrees are contained in 35 gzipped files (psc_baa.gz to psc_bbi.gz). The declination bins may span file boundaries except at 0 degrees."

   Explain why there are 57 files for sources with negative declinations but only 35 files for sources with positive declinations, i.e. why there are so many more infrared sources south of the celestial equator than north of it.

8. As we have seen, it is possible to specify the position of an astronomical object in a variety of coordinate systems. When is it advantageous to use each? For each of the following types of coordinates, explain the circumstances (e.g., type of object, type of observation) under which it would be useful to use that coordinate system, and *why* those coordinates are the best ones to use.

   a. Equatorial coordinates

   b. Ecliptic coordinates

   c. Galactic coordinates

   d. Horizon (alt-az) coordinates

9. Our next seminar meeting will be on Wednesday, September 7, 2005, at 1:15 PM. Determine the following dates and times. (Again, you can do the calculations below by hand using information in the Astronomical Almanac, or you can find some computer program to do the calculation.)

   a. What is the Julian date at that time? Give your answer to three decimal places. (Why three places?)

b. What is the local sidereal time at that time? Before you look it up, work it out approximately from first principles. You should be able to get the right time to within less than an hour if you think it through carefully. Explain your reasoning, and then check it against the right time.
c. What is the Universal Time at that time?
d. What is the hour angle of the objects whose coordinates are given in problem 3?

10. On what date would you expect the following events to occur?

- The latest sunrise of the year.
- The earliest sunset of the year.

Before consulting any reference materials, write down what you think the answers should be and explain your reasoning. Then consult the Astronomical Almanac to check your answer. If it's not correct, figure out why and explain. (Also check the answer for other latitudes and see if you can understand what you find.)

11. Related to our discussion of nomenclature last week, here's a scavenger hunt. I'll give a (small) prize for the best answer to each of these:

a. What is the highest-numbered variable star name you can find? (A few minutes' thinking will help you figure out which constellation it's likely to be in.)

b. Which star (or other object) has the largest number of names listed in Simbad or NED?

I have no idea what the answer to (b) is, and a rough idea of the answer to (a).