YSPA 2017
Problem Set 2 (Mostly Classical Astronomy)
Due 11:59:59 EDT on Friday, July 6, 2018

Type up or write up your solutions and send them to **yalesummerastro@gmail.com** before the due date (you can scan your solutions or take a photo if you did any of the work by hand). Please write out your solutions in complete sentences (where appropriate) and explain your answers.

You should watch my tutorial videos, "Celestial Coordinates" and "Time in Astronomy", before attempting these questions. You may also find it useful to watch the "motions of the Sun and moon" and "Precession" videos.

Problem 1. You can use these UNL astronomy simulations to help you answer these questions and understand Celestial Coordinates better:

• Rotating Sky Explorer:
http://astro.unl.edu/classaction/animations/coordsmotion/celhorcomp.html
• Celestial Coordinate Demonstrator:
http://astro.unl.edu/classaction/animations/coordsmotion/radecdemo.html

a) What are the RA and Dec of the Sun on the Spring Equinox?
b) What are the RA and Dec of the Sun on the Summer Solstice?
c) What is the altitude of the Sun above the horizon when it transits on the Summer Solstice, as seen from New Haven?
d) What are the RA and Dec of an object that is opposite the Sun on the Celestial Sphere on the evening of the Summer Solstice (this is where our asteroids will be, mostly, since this is when they are closest to the earth in their orbits). At about what time (solar time...e.g., "sunrise", "noon", etc.), does an object at this position "transit" (cross the local Meridian)? What will be its maximum altitude as seen from New Haven?

The stars in the "Summer Triangle" have these names and coordinates:

Altair	RA = 19h 51m	Dec = +8° 52′
Vega	RA=18h37m	Dec= +38°47′
Deneb	RA = 20h 41m	Dec = +45° 19′

e) Of these three stars, which is furthest "north" on the Celestial Sphere? Which is furthest "east"? (Explain your answers).
f) At what latitude would Vega be circumpolar? At what latitude would you never be able to see it above the horizon?
g) In about what month would you expect to see Altair on the Local Meridian at midnight?

Problem 2. By now you should have installed "Stellarium" (**www.stellarium.org**) on your computer. This problem is intended to give you some experience with the program and also explore how the Sun moves around the Celestial Sphere and across the local sky. (You can use it to check your answers in Problem 1 above, after you've tried to figure them out without Stellarium.)

Launch the program and hit the "F6" key to bring up the location window. Change your location to New Haven, CT.

Hit “F4” to open the view window, go to “Markings” and turn on Constellation lines and labels. Also turn on “Equator (on J2000)” “Ecliptic (on J2000),” and “Meridian”. Close this window to get it out of the way.

Hit “F5” to open the date and time window, and set the date and time to July 8, 2018 at 12 pm EST (which is 1pm EDT). Hit the “7” key once to stop time. To look around, click and drag the screen. You can zoom in and out using your mouse scroll wheel or the Page up and Page down buttons, and the angular size of the field of view on the screen is shown in bottom panel (FOV=___°).

Hit the “A” to turn off the atmosphere. Drag the sky around until you are facing south, and click once on the Sun to select it. Information about the sun will appear in the upper left of the screen. Hit the space bar to keep the sun centered on the screen.

a) Rounding off to the nearest arcminute, what are the azimuth and altitude of the Sun at this time?
b) Hit the “Z” once to turn on the local sky grid and hit “;” to turn on the Local Meridian. Find due south (Azimuth=180°). Is the sun exactly on the Meridian at 12pm, noon, Eastern Standard Time on July 8? Would you expect the Sun to be on the Meridian at 12:00pm EST?
c) What are the Right Ascension and Declination of the Sun (shown as “RA/DE J2000” with the Sun’s information in the upper left)? Notice where the Sun is in the local sky relative to the Celestial Equator (the blue line that crosses the horizon due east and due west). Does this make sense, given the sign of the Sun’s Declination?
d) The path of the Sun across the Celestial Sphere, the Ecliptic, is shown as a red line. The constellations along the Ecliptic are the Zodiacal constellations. Which constellation is the Sun in on July 8?
e) Hit the “L” key three times to run time forward at 100x. Notice how the azimuth and altitude of the Sun change as time passes. Also notice how the stars, the Ecliptic, and the Celestial Equator move as time progresses. The Sun sets when its altitude is 0°. At what time does the Sun set on July 8 (to within 5 minutes)? What is the Sun’s azimuth when it sets? (Hint: you can hit “7” to stop the clock at any time, and you can use the “J” key to go back in time.)
f) Change the date to the spring equinox (March 20, 2018), and again determine the azimuth of the Sun at 12pm (eastern time), and the time of sunrise and sunset. Also record the RA and Dec of the Sun.
g) Change the date to the summer solstice (June 21), and one more time, determine the azimuth of the Sun at 12pm, the times of sunrise and sunset, and the RA and Dec of the Sun. What explains the difference between these times on the three different dates as seen from New Haven?
h) Hit the “F6” key to bring up the location window and change your location to Puerto Montt, Chile (close to 74° W, 42° S). Click on the “Date & Time” window and change the time back to 12pm on July 8, 2018. Determine the altitude, azimuth, RA, and Declination of the Sun at this time on this date as seen from Puerto Montt. Which of these coordinates have changed significantly and which have not? Does this make sense?

Try resetting your location back to New Haven, and make sure you understand the difference between the local sky (with altitude and azimuth coordinates) and the Celestial Sphere (with RA and Dec coordinates). You might try turning on both the “Azimuthal Grid” and the “Equatorial Grid” alternatively and at the same time while you change locations to see how these grids move around.

Problem 3. On what day does Local Sidereal Time equal Local Mean Solar Time? Explain your answer.
You may find it useful to play around with these UNL astronomy simulations:
Solar and Sidereal Time simulation:
http://astro.unl.edu/classaction/animations/coordsmotion/siderealSolarTime.html
Sidereal Time and Hour Angle Demo:
http://astro.unl.edu/classaction/animations/200level/siderealTimeAndHourAngleDemo.html

Problem 4. Write a python program that takes as input from the user:
1. the longitude of a location in decimal degrees, and
2. the decimal Julian Day Number at a given time,
and outputs the Local Sidereal Time at that longitude in hours, minutes, and seconds.

Hint: You may want to use the modulo operator, "%", which returns the remainder from the division of the first argument into the second, e.g., `print 23 % 7` gives the answer "2", since 7 goes into 23, 3 times with 2 left over. This is useful for figuring out how far through a cycle you are when you don't care how many full cycles have passed. For example, if you know something repeats every week, i.e., every 7 days, and 23 days have passed, then 23 % 7 = 2 tells you that you are 2 days (out of 7) into the cycle.

Use your program to figure out the LST at midnight, EDT (which is 04:00 UT) at the longitude of New Haven on the evening of July 10, 2018 (the early morning of July 11). You can check your answer in Stellarium to help you debug your program.

Problem 5. We will use the Horizons web interface to get the JPL ephemeris (the prediction of celestial coordinates for an object in the Solar System at a specific time) for our asteroids during the program, so we have an idea where to point the telescope and hopefully find our asteroids.

Go to this website: **http://ssd.jpl.nasa.gov/horizons.cgi**
Make sure the Ephemeris Type is "OBSERVER"
For a target body, let's get positions for the recently discovered asteroid "2011 GA62".
Observer Location should be "Yale Observatory", MPC observatory code "797"
Time Span: 2018-07-10 at 04:00 UT (midnight EDT) to 2018-08-04 04:00 UT, with a time step of one day
Table Settings: default

Click on "Generate Ephemeris", and scroll down past "Object Data Page" to the "Results" section. There are a lot of data here, but if you scroll down, you'll see columns of plain text with these headings:

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**************************************************************************************
 Date__(UT)__HR:MN     R.A._(ICRF/J2000.0)_DEC  APmag           delta      deldot    S-O-T /r
**************************************************************************************
```

These data are date and time, RA and Dec, brightness (as an apparent magnitude), distance (in units of AU), and then other stuff. The bigger the apparent magnitude, the fainter the object, and our 16-inch telescope at LFOP can only image asteroids up to about magnitude 18.

a) Given these data, what is the Hour Angle of the object at midnight (EDT) on the evening of July 10, 2018, as seen from New Haven? Given that, at about what time, EDT, does the object transit in New Haven on the evening of 2018-07-10? How high would it appear above the horizon at this time as seen from New Haven? Would it be best to observe it in the 9-10:15pm time slot, or the 10:15 – 11:30pm, 11:30 – 12:45am, or 12:45 – 2am time slots during YSPA 2018?