ASTRONOMY LAB
STELLARIUM

INTRODUCTION

Stellarium (http://www.stellarium.org) is a free, open source software package that yields a planetarium view of the sky. It has many features that make it ideal for exploring a variety of astronomical details. Stellarium has been installed on the computers in the lab. Of course, you can also install it at home, if you like it.

This lab is an introduction to using Stellarium. You will also learn diurnal (daily) changes, seasonal changes, and astronomical coordinate systems. In the process, you will get to explore one of Stellarium’s most interesting features: time travel!

STARTING UP STELLARIUM

Work in teams of 2 members. Each team should have access to one of the Windows machines in the lab.

1. Find the Stellarium icon on the computer desktop, or find the program in the menu of programs. Start Stellarium. The initial full-screen view is a view of the horizon looking toward the South cardinal point (labeled “S”), with stars visible in the sky above the horizon. Some stars may be labeled with their common names (e.g., “Betelgeuse” is an example of such a name, but it is very unlikely that Betelgeuse will be visible in the initial view you see).

Notice the status bar at the bottom of the screen. It gives the location of the observer, the field of view of the scene (FOV), graphics performance in frames per second (an irrelevant number for anything we will do), and the current simulation date and time as it would be displayed on a 24-hour clock --- most likely to be the time your computer (i.e., the date and time in Blacksburg). Fill in the following information, from the status bar:

What is the displayed time: _______20:15:00______

Is the displayed time equal to the current time in Blacksburg? Yes [ ] No ______

Move the mouse cursor over the status bar, and it will reveal a tool bar that can give you quick control over the program. If you now move the cursor to the left side of the screen a vertical tool bar will also open up. Move the cursor over some of the icons on both bars and see what they are named (the command names will pop up near/above the icons).
2. You need to set the location of the observer to Blacksburg. To do so click on the Location window icon on the left, vertical tool bar. In the window that pops up, there is a text entry box at the middle right. Type Blacksburg in the box and click on the “Blacksburg, UnitedStates” choice that appears. Enter the information that appears, below:

   Latitude of Blacksburg: $N\ 37°13'48''$
   Longitude of Blacksburg: $W\ 80°25'48''$

Check to see that the status box at the bottom of the screen shows Blacksburg as the location. Close the Location window.

3. Note: if the twinkling of the stars is annoying, or becomes annoying, you can turn that option off in the Sky and viewing options window, available on the vertical tool bar.

**HORIZON COORDINATES**

1. Click on the Azimuthal grid icon in the lower tool bar. Notice that a grid of coordinate lines appears on the sky. The labels on the horizontal grid lines in the view are in degrees and increase as one goes upward from the horizon. These horizontal lines display the altitude of a location on the sky, running from zero at the horizon, to 90 degrees at the point overhead (called the zenith). The labels on the vertical lines are also in degrees and increase from left to right in the view. The vertical lines display the azimuth of a location on the sky, running around the horizon from zero degrees at due north.

   You can think of using altitude and azimuth to specify a location as if they were “instructions” given to an observer: “Start out facing North, then turn rightward (toward the East) a total number of degrees equal to the azimuth of the sky location you are seeking. Now look upward from the horizon a total number of degrees equal to the altitude of the sky location. You will be looking at the spot you are seeking!” Actually, these are exactly the directions given to a computer-driven “alt-az” telescope mount to make the telescope point at a specific spot on the sky.

The Dobsonian telescopes in this lab course are alt-az telescopes. On the internet find an example of a large professional astronomical telescope that uses an alt-az mount. Such telescopes can move around in a horizontal plane, and tip up and down vertically. Fill in the info about the telescope asked for below. Also, give the web address of where you found the info.

   Telescope/Observatory Name: __________________________________________
   Telescope Diameter: ________________________________________________
   Telescope location on Earth: _________________________________________
   Web address: ________________________________________________________
2. What is the altitude and azimuth of the point on the horizon, due west?

Altitude = \[0^\circ\]

Azimuth = \[270^\circ\]

3. What is the altitude of the zenith point? \[90^\circ\]

4. Try **clicking and dragging** anywhere in the sky --- left, right, up, and down. You should see your field of view shift. To zoom in or out, use the **Page Up** or **Page Down** buttons on the keyboard. (If, instead of clicking and dragging, you mistakenly left-click anywhere in the sky and some object becomes selected – circled -- just right-click in the sky and the selection will be undone.)

Drag and zoom out sufficiently to produce a “standard” planetarium view --- with the zenith point at the center of the view and the horizon represented by a full circle centered on the zenith point. This is a view of the inside of the entire hemisphere of sky above our horizon. Put the South point on the horizon at the bottom of your displayed sky (by dragging the sky, if necessary). Ask your Teaching Assistant to demonstrate, if you need assistance. This view is a relatively standard way of representing the sky in a computer program (or on a star wheel).

Notice that the altitude coordinate grid lines now appear circular and the azimuth lines appear to extend radially outward from the zenith point. The degree markings may seem to have disappeared, but toggle-off the horizon, by clicking on the **Ground** icon on the tool bar (it looks like spherical trees sitting on a hill), and you will see some of those labels again.

Given what you see, what can you say about the value of the azimuth of the zenith point?

\[\text{It is "undefined" (or similar)}\]

5. Click on the **Search window** icon on the vertical tool bar. Enter the star name Polaris in the window and hit the Enter key on the keyboard. They planetarium view will put a circle on the star Polaris (the “North Star”) and possibly flip the sky around to put the horizon point nearest to Polaris at the bottom of the view. This is standard behavior for Stellarium: it sets the azimuth of your view equal to the azimuth of the object you have selected.

To make sure you have this all set up nicely, click on the **Center on selected object** icon in the tool bar and Polaris will be centered in your Field of View and the horizon point will be set to almost due North.

What are the altitude and azimuth of Polaris? (This information is displayed in the upper left corner, along with a great deal of other information about Polaris.)
Altitude of Polaris: $+37^\circ 49' 40''$

Azimuth of Polaris: $359^\circ 33' 36''$

How does the altitude of Polaris compare with the latitude of Blacksburg?

≈ Same!

Hmm… why is the azimuth of Polaris (the “North Star”) not exactly equal to zero degrees?

It’s not supposed to be exactly! It’s “just a star”!

**Equatorial Coordinates**

1. Toggle-off the horizon coordinates by clicking on the *Azimuthal grid* icon in the lower tool bar. Toggle-on the equatorial coordinate grid by clicking on the *Equatorial grid* icon. Notice that this coordinate grid has lines that go around a certain point on the sky, but it is not the zenith.

Look at the equatorial coordinate grid lines. You should now see that one set of lines is circular and centers on a point that is nearly on Polaris. This point is called the *North Celestial Pole* and corresponds to an extension of the North Pole of the Earth up into the sky.

Toggle-off the horizon (*Ground icon*). The circular grid lines should appear to be part of a full sky coordinate system centered on the North Celestial Pole. If you look carefully at the top-right of the field of view you will see that the circular grid lines have labels, in degrees. These circular lines correspond to latitude lines on the Earth, projected onto the sky. This is why this coordinate grid is called equatorial coordinates — they match the equator-based coordinates on Earth. But on the sky the coordinate that corresponds to latitude on Earth is called *Declination* (often abbreviated as Dec.). Toggle-on what astronomers call the *celestial equator* (to toggle-on the celestial equator, use the tool bar icon *Sky and view options window, Celestial Sphere, Equator line*). Notice that the celestial equator corresponds to one of the declination circles. Somewhere almost off the right edge there will be a circular line labeled -20 degrees. Then, as you move toward the North Celestial Pole, the next circular grid line is -10 degrees, then zero degrees, then +10 degrees.

What is the declination of the celestial equator? ____________0__________

Count along for the remaining circular grid lines until you find out the declination of the North Celestial Pole.

Declination of the North Celestial Pole: ____________90__________
2. There are also a set of grid lines that radiate outward from the North Celestial Pole. These lines are analogous to the longitude lines on Earth. Notice that these lines are also labeled. The labels are not in degrees, but “hours” (e.g., “21h”). If you look carefully the labels run from 0h to 24h (well, you should see labels like ...21h, 22h, 23h, then 0h, 1h, ...; 0h is the same as 24h on this 24-hour clock). This coordinate is called Right Ascension, abbreviated as R.A.

To see why it makes sense to label the Right Ascension lines with “time” first toggle-on the meridian line (Sky and view options window, Celestial Sphere, Meridian). The meridian is the line that goes from the North Celestial Pole, through the zenith (overhead point) to the South point on the horizon. Now click a few times on the “fast-forward” time-icon on the tool bar just below the current time, and watch how objects rise near the East, approach the meridian overhead, cross the meridian, then go on to set near the West. Also, notice that how Right Ascension lines spin across the sky. If you watch the Right Ascension values crossing the meridian as time progresses, you will see that each value represents a successive hour of the passage of time.

Click on the “play” time-icon to turn off the fast-forward time flow and return to normal time flow. Then click on the time icon between the “fast-forward” and “play” time-icons, which will set the simulation time to the current computer time.

Any object in the sky has a Right Ascension coordinate and a Declination coordinate, just as any city on Earth has a longitude and a latitude. Look at the star Betelgeuse. Using the displayed equatorial coordinate grid, estimate the Right Ascension and Declination of Betelgeuse.

Estimated R.A. of Betelgeuse: \( \approx 6 \text{h} \)

Estimated Declination of Betelgeuse: \( \approx +10^\circ \)

Now click on Betelgeuse, and read off its Right Ascension and Declination from the data supplied by Stellarium. But, which listed RA and Dec should you use, “J2000” or “of date”? For now, let’s use “of date”. The difference between these two values is an “advanced topic.” Enter the values below. Note that the Right Ascension coordinate is broke up into smaller units than hours – it includes minutes and seconds, i.e., fractions of an hour. Of course the Declination coordinate is also broken up into smaller units than degrees – arcminutes (') and arcseconds (") --- there are 60 arcminutes in a degree, and 60 arcseconds in an arcminute.

Actual R.A. of Betelgeuse: \( 5^h 55^m 43^s \)

Actual Declination of Betelgeuse: \( +7^0 24' 29" \)
3. Find the objects located at the given R.A. and Declination coordinates (J2000), and write in their names:

<table>
<thead>
<tr>
<th>Right Ascension</th>
<th>Declination</th>
<th>Object Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>07h 39m 18.1s</td>
<td>+05° 13’ 28.6”</td>
<td>Procyon</td>
</tr>
<tr>
<td>04h 35m 55.2s</td>
<td>+16° 30’ 33.2”</td>
<td>Aldebaran</td>
</tr>
<tr>
<td>07h 34m 35.9s</td>
<td>+31° 53’ 17.2”</td>
<td>Castor</td>
</tr>
</tbody>
</table>

4. By clicking and dragging, and using Page Up and Page Down, set up a “standard” planetarium view with the zenith at center surrounded by a circular horizon. Set things up so South is at the bottom of the field of view.

Use the “fast-forward” time-icon to set the sky in motion and watch the stars cross the meridian. This is the view you see when facing South – toward Robeson Hall from the Derring Hall deck. This fast-forward time-lapse view should look very realistic (yet faster than normal).

Watch for the star Arcturus to rise. When Arcturus rises, hit the “play” time-icon to stop the fast-forward action. Click on Arcturus to bring up its data. Now, click a few times on the “fast-forward” time-icon to set the sky in motion, and watch the R.A./Dec. and Alt/Az coordinates for Betelgeuse. (R.A. and Dec. and labeled as “RA/DE” in Stellarium.)

How do the R.A. and Dec. of Arcturus change as time progresses and Arcturus approaches the meridian, crosses the meridian, and proceeds toward the western horizon?

They do not change

How do the altitude and azimuth of Arcturus change as time progresses and Arcturus approaches the meridian, crosses the meridian, and proceeds toward the western horizon?

altitude: ↑ then ↓
azimuth: ↑

(If, to complete the above questions, you need to reset the time and start again, just click on the “play” time-icon to stop the “fast-forward” time flow, then click on the icon between “fast-forward” and “play” to reset the time to now. Then, you can start the “fast-forward” time flow once again.)

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OBJECTS OF INTEREST IN THE WINTER AND SPRING SKY

1. Click on the Search Window icon in the vertical tool bar. We want to find the Orion Nebula, also called M42. Type M42 in the Stellarium search text box. M42 is the Messier catalog number for the Orion Nebula. Up will pop info about M42 (NGC 1976, the “Great Nebula in Orion”). What are the equatorial coordinates of the Orion Nebula (“of date”)?

   R.A. of the Orion Nebula: \[
   5^h\ 35^m\ 54^s
   \]

   Declination of the Orion Nebula: \[
   -5^\circ\ 26\ 39\''
   \]

2. What does the word “nebula” mean? (Look it up on the internet!)

   \[\text{an interstellar cloud of gas or dust}\]

3. When did Messier compile his catalog of objects? How many objects are in the Messier Catalog? Why did Messier compile such a list?

   \[1771\]

   \[103\ (or\ so)\]

   \[\text{He was looking for comets, and wanted to ignore these!}\]

4. What does “NGC” stand for? [Hint: “C” stands for catalog.] How many objects are in the catalog? When was it published?

   \[\text{New General Catalog}\]

   \[7840\]

   \[1880;\]

5. In the displayed data for Orion Nebula, there is listed the “Hour Angle.” What is the Hour Angle for M42?

   Hour Angle: \[
   \approx 23^h\ 30^m\ (\text{depends on when they do this})
   \]

   \[\text{could be } \approx 24^h\]

   \[\approx 0^h,\ \text{about that value}\]
6. There are many nebulae visible in the Winter and Spring sky. As the night progresses, objects rise in the east, cross the meridian, and set in the west. Each object is easiest to observe when high in the sky --- when it is near the meridian. As time progresses, objects of increasing Right Ascension (R.A.) cross the meridian. Since there are 24 hours of Right Ascension around the sky, it takes one day (one "sidereal day" to be exact) for all the objects to cross the meridian.

At some specific moment (e.g., right now!) the R.A. of objects on the meridian is called the Local Sidereal Time, or LST. (LST is on a 24-hour clock.) So to see if an object is currently on the meridian, you need to know the current LST and the RA of the object. There is a link to a sidereal clock at the US Naval Observatory on the course website (the clock is at http://tycho.usno.navy.mil/sidereal.html). Enter “Blacksburg” and “VA” in the appropriate locations (or the longitude of Blacksburg, from Stellarium), and hit the Compute button to get the current LST. Enter that value here

LST: \(\sim 5 \text{ h} \) (depends on when they do this)

7. So, to see if the Orion Nebula, for example, is near the meridian, subtract the R.A. of the Orion Nebula from the current LST. Express the answer in hours and minutes. If the answer is negative, add 24 hours. If the answer is greater than 24 hours, subtract 24 hours. The final answer has to be between 0 and 24 hours. Write the answer below

LST – R.A.: hours \(\sim 0 \text{ h} \) minutes \(\sim 30 \text{ m} \)

How does your calculated result compare with the displayed Hour Angle for the Orion Nebula?

\(\sim \text{ Same!} \)

The easy way to remember what Hour Angle means is to think of Hour Angle as Hours Ago --- the number of hours ago that the object crossed the meridian. An Hour Angle (H.A.) within a few hours of 0 (or 24) means the object is near the meridian and easy to observe.

**THE FUTURE**

1. Right click anywhere in the sky to remove the focus from M42. Click on the fast-forward time-icon a few times until the alternation of day and night takes about 5-10 seconds. Watch and appreciate the diurnal (i.e., daily) progression of objects from east to west across the sky.
Now, find the Moon as it appears in the night sky (it is labeled). Watch its east to west motion, which is like that of everything else. But, in addition to its east to west motion can you see any motion of the moon relative to the stars? In other words, does it move westward with respect to the stars, or eastward, or not at all (i.e., not at all = it travels across the sky at exactly the same speed as the stars)?

It appears to move W to E with respect to the Stars

2. When the Moon is in the night sky, click on the “play” time-icon so the fast-forward time flow is stopped. Now, use the keyboard command Alt+ to advance time by one sidereal day (hold down the Alt key and hit the = sign key). A sidereal day is the time it takes for the stars to appear to complete one rotation around the Earth (in other words, it is the exact rotation period of the Earth). Using successive Alt++ commands, watch how the stars do not change location from one sidereal day to the next, but the Moon does. As the days progress, which way does the Moon move with respect to the stars, westward, or eastward?

Definitely W to E!

Other commands for “time travel” (i.e., changing the date and time), and other display changes, can be found by clicking on the Help window icon (the question mark) in the left, vertical tool bar.

3. Open the Date/time window using the appropriate icon on the vertical tool bar. Enter the date 2010, 6, 21 and time 0, 0, 1. This would be 1 second after midnight on June 21, 2010. Note the sky is now as it would appear on about the first night of summer in 2010, at just after midnight. Vega is high in the sky, near the meridian. Open the Sky and viewing options window (vertical tool bar), Markings tab, and enable “Show lines” for the constellations so you can see the constellations.

Watching the locations of Polaris, and of Vega in the sky, as you advance the year by thousands (2010, 3010, 4020, 5020,...). WTF? Isn’t the “North Star” supposed to be at/near the North Celestial Pole (NCP)? Well, no. It happens that Polaris is near the NCP now, but in the future (and in the past) it has not been that way. Following the changes millennium by millennium, in what year (3010, 4010,...) does Vega get closest to the NCP?

Next millennium when Vega is closest to the NCP:

\[ \approx 14010 \]

...and the subsequent millennium when Vega is again closest to the NCP:

\[ \approx 40010 \]

Difference, in years, between those two closest approaches:

\[ \approx 26,000 \]
Here's what is going on: the Earth is a spinning top, spinning once per day. But this top is being pulled on by gravitational forces from the Moon and Sun, causing the top to wobble—the technical term for this is precession. The period of the Earth's wobble, or precession, is what you just determined. As the Earth precesses, the equatorial coordinate system attached to the Earth also "wobbles" across the sky. Even the location of the Sun at the beginning of Spring (i.e., at March 21) gradually progresses all the way around the zodiac due to this effect. For this reason, this motion of the coordinate system is called the "Precession of the Equinoxes."

4. Set the year to 40010. Find Betelgeuse using the Search window (it may be below the horizon, but that doesn't matter for this question). What is its R.A. and Dec. (of date).

R.A. of Betelgeuse, 40010: \[17^\text{h} \ 9^\text{m} \ 37.5^\text{s}\]
Declination of Betelgeuse, 40010: \[-38^\circ \ 54' \ 56"\]

5. Compare your values for R.A. and Dec in 40010 to those in 2010. Compare your 2010 values to those for J2000. For what year are the J2000 values valid, do you think?

40010 very different from 2010!
J2000 = year 2000!

6. Just to check your understanding, why are the 40010 R.A. and Declination values so different than those in 2010?

precession occurred

7. Click anywhere to get the focus off Betelgeuse, and go back to the standard, full sky planetarium like view with South at the bottom of the screen. Set the date to 2010, 2, 1 (February 1, 2010). Find the Big Dipper and Orion. Sketch their appearances in the space below.

Big Dipper (2010):

Orion (2010):
8. Set the year to 40010. Find the Big Dipper and Orion and sketch them again. You may have to adjust the month, and remove the Ground, to find Orion in the night sky.

Big Dipper (40010): 

Orion (40010):

Note that the constellations have changed a bit. Which, the Big Dipper or Orion, has changed the most?

Big Dipper

9. Set the year to 80010. Again find the Big Dipper and Orion, and sketch them. If you have trouble finding the Big Dipper, try entering “alpha UMa” in the Search window; “alpha UMa” is the star alpha in the constellation Ursa Majoris (the Big Bear) in which lies the asterism known as the Big Dipper.

Big Dipper (80010): 

Orion (80010):

(very different from in 2010!)

(essentially same as in 2010)
Again, which constellation has changed the most since 2010?

Big Dipper

Assuming all stars in the Galaxy move about with similar speeds (but in different random directions), and so, therefore, closer stars will appear to have moved more across the sky during a thousand years, what can you say about the relative distances of the stars in the Big Dipper versus the stars in Orion?

Orion stars much farther away!

10. Find some other constellation that has changed even more dramatically, over the thousands of years since 2010. (Constellation labels can be added. See vertical tool bar for Sky and viewing options.) Draw its shape in 2010 and in 40010.

Constellation: __________________________

Shape in 2010: __________________________

Shape in 40010: __________________________
DISCUSSION QUESTIONS

1. Set the year and date to the birthday of you or your lab partner. Set the time to 1 second after midnight. Find the Sun. Remove the Ground. What constellation was the Sun in on the date of your (or your partner's) birth? What is your astrological sign? Are they the same?

(Virgo, Libra, not same.)

2. Set the year to 4000 B.C. (i.e., -4000). Find the Sun. Remove the Ground. What constellation was the Sun in on the date of your (or your partner's) birth in the years -4000? Does this constellation correspond to your astrological sign? (Or, is it at least much closer than in question 1?) (Astrology was invented around 4000 B.C., and so the location of the Sun on your birthday in 4000BC is what astrologers are going by. If the constellation in which the Sun is found at your birth has some power over your life, don't you think astrologers should update the assigned astrological signs?)

Scorpio/Libra

They need to rethink that junk.

3. Explain the difference in results for questions 1 and 2.

Precession!

4. What is your impression of Stellarium?

Great!

[When you are done with Stellarium, close the program by clicking on the on/off button in the tool bar at the bottom of the screen.]