Observational Astrophysics

Practice 1: Stellarium

1 Objectives

Learn to work with planetarium-type programs that simulate the behavior of the sky and the stars. Become familiar with the use of *Stellarium*. Understand the movement of the celestial sphere visually. Obtain relevant information on celestial phenomena.

2 Introduction

Using planetarium-type programs is very useful for the planning of observing nights. This kind of software helps us to find out what objects can be seen and when, and gives us a general idea of what the sky will look like. But even more than that, they are very useful for visualizing and better understanding the sky dynamics.
With these programs, you can "travel" to other places and see how the sky changes in other parts of the planet (and even on other planets). It also allows us to travel through time and see what the skies were like for our ancestors and what our future descendants will see. In this practice, we will delve deeper into the use of *Stellarium*.

3 The *Stellarium* software

3.1 Basic Controls

- With the left mouse button pressed, or with the arrow keys, you control the direction of the field of view.
- With the mouse scroll you control the size of the field of view.
- The l and j keys allow you to advance or go back in time. Use k to set it to normal speed and 8 to return to the current date and time. Note: to stop time, once it is running in normal mode, press j.
- The N, S, E, W keys direct you to the cardinal points north, south, east or west respectively. The Z key directs you to the zenith.
- Show the azimuthal coordinates with z.
- Show the absolute equatorial coordinates with e.
- Show the Ecliptic with the comma key ",".
- Show the Equator with the period key ".".
- Show the constellations with c.
- Show the name of the constellations with v.
- Show the mythological or artistic images of the constellations with r.
- Show the borders of the constellations with b.
- Turn on and off the effects of the atmosphere with the a key.

- Move forward one day with “=”.
- Move back one day with “-”.
- Move forward one sidereal day with Alt + “=”.
- Move back one sidereal day with Alt + “-”.
- Moving the cursor to the bottom left of the screen displays a vertical and a horizontal bar with icons that allow you to implement the functions described and several others. Moving the cursor over the icons provides information on the function that is executed when you press them.

3.2 *Stellarium* guided practice

Once you feel comfortable with the *Stellarium* program, we will use it to investigate and find some phenomena discussed in the syllabus. You can use a sheet of paper to write down your impressions. It is advisable that you do this exercise sequentially.

3.2.1 The celestial sphere

First, position yourself in Burjassot (use the location window and find “Burjassot, Spain”) on the current date. You can control the size of the field of view (FoV). Its current value is displayed in the bottom toolbar. A FoV of about 100° is the most comfortable to work with. Look to the east. Make time advance a little faster (by increasing the time speed a couple of times in the bottom toolbar or using the l key). What happens to the stars? Do they rise, set, or alternate between the two types of movement? What angle do you think this movement forms with the horizon?
Repeat the operation looking west. Now look north and let time advance a little faster again. Do you notice anything special? What is it? The star that is almost in the center of the spin is Polaris, the pole star, at the end of the tail of the Little Dipper constellation (Ursa Minor, abbreviated UMi). It always points north and is the only star in the sky that (practically) does not move. All the other stars rotate around it counterclockwise.
Now change your latitude, placing yourself closer to the North Pole. To do this, go to the location window (F6) and change only the latitude value by pressing Enter when finished. When you change latitude, what happens to Polaris?
Place yourself at a point very close to the North Pole ($\Phi = 90°$) and then at a point very close to the Earth's Equator ($\Phi = 0°$). Where is the North Star? You can display the azimuthal coordinates to help you by pressing z. What is its height above the horizon? What can we conclude from this?

3.2.2 The movements of the Sun

Put yourself back in Burjassot on today's date by pressing 8 and searching for ”Burjassot, Spain” in the location window. Turn off the azimuthal (z) coordinates. Search for the Sun using the search window. Once you have it, set your clock to 12 noon today and try to figure out what time the Sun rose and what time it set (Hint: remember what the equatorial time coordinates mean, you can display the equatorial coordinates with e).
Now, make time pass a little faster so that you can see several sunrises and sunsets. Does it rise and set exactly due east and west, or further north and further south of those cardinal points? What can we deduce from this? Notice that *Stellarium* uses the computer's date and time, so for this exercise we may need to turn off the daylight saving time change on the system.
Now go back to today's date, but choose 12 noon as the time. Look to the south. Is the Sun located exactly due south? Raise your viewpoint above the horizon a few degrees and let time move forward quickly, this time in intervals of one month (use the date and time window). What happens to the height of the Sun? What happens to its position relative to the south? What conclusions can you offer about this phenomenon? How does the Sun move throughout the year? This figure that the Sun forms in the sky is called the Analemma.

Highlight the Ecliptic using the comma key (,). The Ecliptic is the projection of the Earth's orbit on the sky. Does the Sun move far away from the Ecliptic when you move time forward in fractions of months? Now find several planets and move time forward in monthly steps. Are the planets far from the Ecliptic compared to the Sun? Show the celestial constellations and their borders (keys c, v, b). Write down the constellations through which the Sun passes during the year (or, in other words, those that are cut by the Ecliptic). Do their names sound familiar? Since most of these constellations are named after animals, this band was called Zoodiacus. Now place yourself on the date of your birth. In which constellation is the Sun located? Does it match your zodiac sign?

3.2.3 The movements of the planets

Let's now study the motion of the planets. Zoom in at a FoV of about 100°. Stand at 12 noon and show the planets Mercury and Venus. Make time pass in days. What happens with Mercury and Venus? Is it the same with Mars? Why do you think this is so?
Let's continue working with Mars. Stand at the South Pole. Connect the equatorial coordinate system (*e*). The date will be January 1, 2001. Find Mars and let time advance in days (to help you, you can remove the contribution of the atmosphere with the *a* key, look at the stars in the background). Do you observe any anomalous movement between May and July 2001? If so, use the grid to measure the amplitude of this movement. This characteristic movement is called retrograde motion.

3.2.4 The movements of the Earth

Turn the atmosphere back on (*a*) and place yourself in Burjassot ("Burjassot, Spain") again on today's date and time. Just as we started with the North Star, to finish, let's work with it again. Locate the North Star again. Now go back in time 1 000 years, and let time advance until nightfall. What happened? (use the equatorial coordinates, *e*). Is the behavior of the North Star any different from what you observed at the beginning of this exercise?
This phenomenon is known as precession of the equinoxes and is due to the fact that the Earth's axis of rotation does not always point in the same direction but rather spins and moves like a top. Now go back to the year 12 000 BC (enter it in the date and time window as -12 000). What happens now? What star could be considered the North Star then? After this, go forward to the present time again and from that moment forward in time thousands of years. In the future, what happens to Polaris?

4 Ejercicios

1. Stand in the city where you live. Look east and move time forward. Estimate the angle that the stars' paths form with the horizon of the place. Did you expect this value?
2. From your own city, what is the height above the horizon of the North Star or the South Pole, if you live in the southern hemisphere? Give the name of 3 circumpolar stars.
3. From your own city and at the present time, indicate the times of sunrise and sunset of the Sun on the dates of the equinoxes and solstices.
4. Find the Moon and position yourself at a time when the Moon is visible (above the horizon). Move forward in time in steps of one day. Does the Moon's position change a lot from one day to the next or a little? How many years does it take for it to be (approximately) in the same area of the sky again? Does this position change much from the initial position?
5. Stand in Burjassot and change the date to October 3, 2005, at 8 a.m. Locate and fix the Sun with the search window. Get close enough and let time go by. Do you see anything out of the ordinary? Would the same phenomenon be observed in your city?

6. Draw the Analemma from your city.
7. Make a systematic study of the position of the Sun throughout a year. Note the dates between which the Sun is passing through a certain constellation. To do this, obtain the limits of the constellations (b). When you finish, indicate if you have detected anything unexpected.
8. Stand at the North Pole. The start date will be January 1, 2000. Study the positions of Jupiter and Saturn as the days go by. Do their movements resemble that of Mars? Do they differ from the movement of Mars?
9. Take a screenshot of the *Stellarium* of the North Celestial Pole from Kitt Peak Observatory on the date 1 000 AD. Locate Polaris and explain its position. How many degrees is it from the North Celestial Pole?
10. Choose an observatory and indicate its geographic location. Obtain, for each of the following astronomical objects, a range of dates in which they are visible at night. Find for each object and a specific date the height at the time of its highest peak.

    Objects: M31, M51, Barnard star, Jupiter, the Pleiades.

5 Useful links

- Official web page and download:

  http://www.stellarium.org
- Wiki (wit all information about *Stellarium*):

  https://github.com/Stellarium/stellarium/wiki/
- *Stellarium* user guide:

  https://stellarium.org/files/guide.pdf