THE SKY

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1 Introduction

The Earth rotates and orbits around the Sun: the sky above us is in constant apparent motion. Stellarium is the perfect tool to demonstrate the motion of the sky, the use of coordinates and to illustrate constellations.

2 Stellarium

Stellarium is a software that allows people to use their home computer as a virtual planetarium. It will calculate the positions of Sun and Moon, planets and stars, and draws the sky how it would be seen from an observer anywhere on the Earth and at any epoch. Stellarium can also draw the constellations and simulate astronomical phenomena such as meteor showers and solar or lunar eclipses.

Stellarium may be used as an educational tool for kids of all ages, as an observational aid for amateur astronomers wishing to plan an observing night, or simply to explore the sky (it is fun!). Stellarium shows a realistic sky in 3D, very close to what you see with naked eye, binoculars or telescope.

You can download Stellarium from the website http://www.stellarium.org.

3 The celestial sphere

The celestial sphere is a concept which helps us thinking about the positions of objects in the sky. Looking up at the sky, you might imagine that it is a huge dome or top half of a sphere, and that the stars are points of light on that sphere: we call it celestial sphere. The celestial sphere appears to rotate, in particular, stars seem to rotate around a static point with a period of one day. The apparent motion of the celestial sphere is an illusion, created by the revolution of the Earth around the Sun and the rotation around the polar axis.

The rotation is responsible for the day and night. The direction of the rotation axis is fixed, pointing to the north star (Polaris). There is no link between the Earth and the north star, the fact that the terrestrial axis points to the north star is casual. In reality the north star is very close to the celestial north pole but they do not match precisely. The rotation of Earth makes the observer to see the celestial sphere rotating around the north star, making a round in 24 hours. The stars closer to the north star are visible during all the night and are called circumpolar constellations. The other stars are instead seen to rise and set.

The revolution is responsible for the seasons. Due to the revolution during the night we see every season a different portion of the celestial sphere.

3.1 Example

1. Open the configuration window, select the location tab. Set the location to be somewhere in mid-Northern latitudes. Central Europe is an ideal location for this demonstration.
2. Turn off atmospheric rendering and make sure cardinal points are turned on. This will keep the sky dark so the Sun does not prevent us from seeing the motion of the stars when it is above the horizon.
3. Pan around until north appear in the window, and make sure the field of view is about 90 deg.
4. Pan up so the N cardinal point on the horizon is at the bottom of the screen.
5. Now increase the time rate. Press k, l, l, l, l.

This should set the time rate so fast that we can see the stars rotate around a point in the sky about once every ten seconds. If you watch Stellarium's clock you wll see this is the time it takes for one day to pass at this accelerated rate. The point which the stars appear to move around is one of the celestial poles. The apparent movement of stars around the celestial pole is due to the rotation of the Earth.

The location of the observer on the surface of the Earth affects how he perceives the motion of the stars. To an observer standing at Earth's north pole, the stars all seem to rotate around the zenith. Technically the zenith is the intersection of the vertical of the observer with the celestial sphere. In practise it is the point straight upon the head of the observer. As the observer moves South towards the equator, the location of the celestial pole moves down towards the horizon. At the Earth's equator, the north celestial pole appears to be on the northern horizon. Similarly, observers in the southern hemisphere see the South celestial pole at the zenith when they are at the south pole, and on the horizon when they are at the equator.

Leave time moving on fast and open the configuration window. Go to the location tab and set your location to the north pole. See how the stars rotate around a point right at the top of the screen. Stars moves on circles parallel to the horizon and do not rise and set.

Now return on the configuration again, and set a location little further South: you should see the positions of the stars jump, and the centre of rotation has moved a little further down the screen. Select a location on the equator. You should see the centre of rotation has moved on the horizon and the stars rise and set perpendicular to the horizon.

4 The celestial coordinates

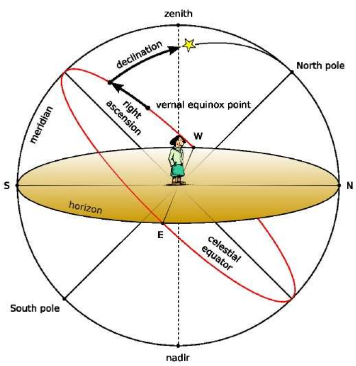
If we observe the celestial objects by naked eye, they appear fixed on the celestial sphere. Because we are interested only in the direction to look to observe celestial objects, not in their distances, we need only two coordinates to specify the positions of stars.

The projection of the terrestrial equator on the celestial sphere is called celestial equator, while the projection of the poles are called celestial north pole and celestial south pole. The point on the perpendicular of the observer (above his head) is called zenith.

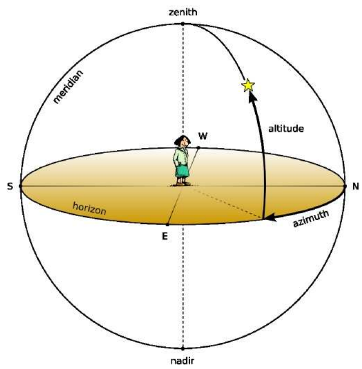
To localize a point on the celestial sphere two coordinate systems are used: equatorial and horizontal (fig. 1).

The **equatorial** coordinate system is similar to that used to localize a point on the Earth surface. On the celestial sphere a point is characterized by right ascension, that plays the role of terrestrial longitude, and declination, that plays the role of terrestrial latitude[1].

In the **horizontal** coordinate system a star is characterized by azimuth, the angular distance from the North cardinal point[2], and altitude, the high of the point above local horizon.



(a)



(b)

Figure 1: The equatorial and horizontal coordinate system.

[1]The right ascension is the angular distance of the star from a peculiar point of the celestial equator, called γ point. The γ point is the intersection of the celestial equator with the ecliptic (the path of the planets and the Sun on the sky, i.e. the projection of the plane of the Solar System). The declination is measured from the celestial equator.

[2]The azimuth is the angular distance of the point from the meridian, that is the line connecting the local north and south cardinal points passing through the zenith.

From the observer's point of view the most natural system is the horizontal one. Such system however is time and position dependent: we can see that the coordinates of the same star at the same epoch are different for different observers. For these reasons, the horizontal coordinates cannot be used, for instance, in star catalogues. Unlike Alt/Az coordinates, RA/Dec coordinates of a star do not change if the observer changes latitude, and do not change over the course of the day due to the rotation of the Earth. RA/Dec coordinates are frequently used in star catalogues.

4.1 Example

Stellarium can draw grid lines for RA/Dec and Alt/Az coordinates. To help with the visualisation of the celestial sphere, turn on the equatorial grid by clicking the button on the main tool-bar or pressing the "e" key. Now you can see grid lines drawn on the sky. These lines are analogous of longitude and latitude on the Earth, but drawn on the celestial sphere. The celestial equator is the intersection of the plane of the terrestrial equator with the celestial sphere. In other words it is a circle on the celestial sphere half way between the celestial poles, just as the Earth's equator is the circle half way between the Earth's poles.

Turn on the horizontal grid by clicking the button on the main tool-bar or pressing the "z" key. Accelerate the time rate and note that the positions of the stars remain fixed in time with respect the equatorial grid, while they change with respect the horizontal one.

5 The constellations

The constellations are patterns of stars that human eyes join to form figures often drawn from mythology. This is subjective process and stars in a constellation are not really connected in any physical way. In fact, different cultures have grouped stars into different constellations.

As an example, in figure 2 we show the constellation Ursa Major (Great Bear). On the left there is a drawing of the mythical Great Bear together with the constellation lines. The seven brightest stars of Ursa Major are easily recognised and are known as the "big dipper". This sub-grouping is an asterism, useful to orient ourselves on the celestial sphere. On the right, the drawing of the bear and the constellation lines have been removed: only a group of stars remains.

To the modern astronomer constellations provide a way to segment the sky into regions useful to locate celestial objects. In fact one of the first tasks for an amateur observer is learning the constellations, in which season they are visible, and which interesting objects reside in their region. Internationally, astronomers have adopted the Western (Greek/Roman) set of 88 constellations. Each constellation has a proper Latin name, and a three letter abbreviation of that name. For example, the abbreviation of Ursa Major is UMa.

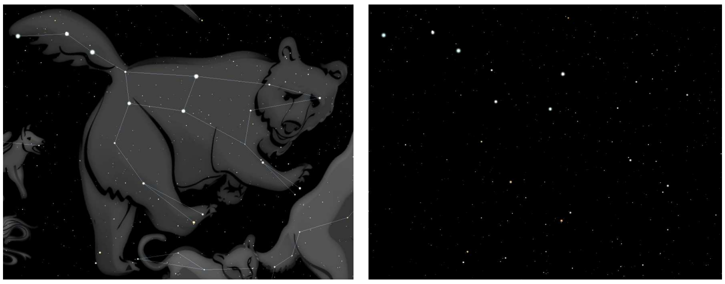


Figure 2: The constellation of Ursa Major.

5.1 Example

Stellarium can draw both constellation diagrams and artistic representations of the constellations. Multiple sky cultures are supported: Western, Polynesian, Egyptian, Chinese, etc. Set up a field of view of approximately 90 deg and watch in the North direction. Turn on constellation names and art: you should see the constellations of the Western sky culture. In the configuration tab select the Inuit sky culture: you should see different constellations made up with the same stars as before. Try the other sky cultures or invent your own constellations.

6 Light Pollution

Light pollution is the excess of light created by humans. Also called skyglow, it reduces the contrast between stars and galaxies in the sky and the sky itself, hindering fainter objects. Light pollution is most severe in highly industrialized, densely populated areas, but even relatively small amounts of light can create problems. This is one reason for building new telescopes in remote areas.

The night sky darkness of a particular location is measured through the Bortle dark-sky scale. It is a nine-level numeric scale that quantifies the observability of astronomical objects as modified by light pollution.

For example Bortle class 1 refers to an excellent dark sky site, you can see the Zodiacal light, M33 by naked eye, Jupiter and Venus affect night vision and horizon is almost invisible. At the other extreme Bortle class 9 is typical of inner city sky. The sky is brightly lit with even the main constellations only partially visible and only the Pleiades visible among Messier objects.

EXERCISES

▷ Exercise 1

Activity: Look up at the sky motion seen by several locations situated at different latitudes. Fill the table finding for each location which is the star that remains fixed in the sky and does not rotate, its altitude above local horizon, if there are constellations that do not rise and set and if so which ones.

Location (latitude)	**Which is the fixed star?**	**Altitude above the horizon**	**There are constellations that don't rise and set? If yes, which ones?**
North pole (90° North)			
Trieste (45° North)			
Equator (0°)			
South Africa (45° South)			
South pole (90° South)			

▷ Exercise 2

Activity: Look how different cultures see figures in the sky. Set time to midnight of January 1st, 2009 and select a location 45° of latitude North. Zoom out up to see all the hemisphere and change the sky culture in the configuration window. Fill the table with the number of constellation you see in each culture and the name of the constellation corresponding to Ursa Major.

Culture	**N. of constellations in the northern hemisphere**	**Constellation corresponding to Ursa Major**
Chinese		
Egyptian		
Inuit		
Lakota		
Navajo		
Norse		
Polynesian		
Western		

▷ Exercise 3

Activity: Look at the night sky with different levels of light pollution. Set the time to midnight and select a location at 45° of latitude North. In the configuration window try the levels of light pollution 1, 4 and 8 (Bortle Classes) and fill the table with the number of stars you can see on the lines of each constellation.

	Number of stars on constellation lines		
Constellation	**Bortle Class 1**	**Bortle Class 4**	**Bortle Class 8**
Ursa Major			
Ursa Minor			
Orion			
Cancer			
Cassiopeia			

SOLUTIONS

▷ Exercise 1

Activity: Look up at the sky motion seen by several location situated at different latitudes. Fill the table finding for each location which is the star that remains fixed in the sky and does not rotate, its altitude above local horizon, if there are constellations that do not rise and set and if so which ones.

Location (latitude)	**Which is the fixed star?**	**Altitude above the horizon**	**There are constellations that don't rise and set? If yes, which ones?**
North pole (90° North)	90°	YES	
Trieste (45° North)	45°	YES	
Equator (0°)	0°	NO	
South Africa (45° South)	45°	YES	
South pole (90° South)	90°	YES	

▷ Exercise 3

Activity: Look how different cultures see figures in the sky. Set time to midnight of January 1st, 2009 and select a location 45° of latitude North. Zoom out up to see all the hemisphere and change the sky culture in the configuration window. Fill the table with the number of constellation you see in each culture and the name of the constellation corresponding to Ursa Major.

Culture	**N. of constellations in the northern hemisphere**	**Constellation corresponding to Ursa Major**
Chinese	50?	Northern Dipper
Egyptian	16	Bull's foreleg
Inuit	10	Caribou
Lakota	12	Dipper
Navajo	5	Revolving Man
Norse	6	Man's Cart
Polynesian	6	The Seven
Western	33	Ursa Major

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	Number of stars on constellation lines		
Constellation	**Bortle Class 1**	**Bortle Class 4**	**Bortle Class 8**
Ursa Major	18	18	12?
Ursa Minor	7	7	3
Orion	19	19	8
Cancer	6	6	0
Cassiopeia	5	5	5