

THE SKY

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Within this use case you discover the celestial coordinates allowing you to point and/or find a given star in the sky. You also learn how to use coordinate systems in order to learn the effects of Earth's rotation and revolution on the celestial sphere. Special topics are constellations and light pollution, both important for a basic appreciation of the night sky.

If used in the classroom, the exploration of the sky is simple and an initial demonstration will suffice to get pupils started on their own. Coordinate systems would require a proper mathematical/geometrical treatment as an introduction to the use case.

1 Introduction

The Earth rotates around its polar axis and orbits around the Sun: the sky above us (the celestial sphere) is in constant apparent motion. Stellarium is the perfect tool to demonstrate the motions of the sky, the use of coordinates and to illustrate constellations.

2 Stellarium

Stellarium is a free software that transforms a home computer in a planetarium. It calculates 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, very close to what you see with naked eye, binoculars or telescope. Stellarium gives astronomical data (coordinates, magnitude, distance, etc.) of most of the celestial objects visualized on the screen.

You can freely download Stellarium from our site <http://vo-for-education.oats.inaf.it> or from <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 alternate sequence of 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 stars close to the North Star are visible during the whole night and are called circumpolar constellations. The other stars are instead rising and setting.

The Earth revolution around the Sun is also responsible for the change of portion of the celestial sphere we see during a year. For this reason some constellations may not be visible during the whole year, depending on the position of the observer

3.1 Example

1. Open the the location window. 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 the N cardinal point appears on the horizon.
4. Set a field of view of about 90 deg (increase and decrease the field of view with the mouse wheel or PagUp/PagDown keys).
5. Now increase the time rate. Press k, l, l, l, l. This should set the time rate so fast that we can see stars rotate around a point in the sky about once every ten seconds. If you watch Stellarium clock you will notice this is the time it takes for one day to pass at this accelerated rate. The point around which stars appear to move around is the celestial North Pole.

The location of the observer on the surface of the Earth affects the apparent motion of stars. To an observer standing at Earth's North Pole, all stars seem to rotate around the Zenith. Technically the Zenith is the intersection of the vertical of the observer with the celestial sphere. In practice it is the point straight upon the head of the observer. As the observer moves South towards the equator, the apparent location of the celestial Pole moves down towards the horizon. At the Earth's equator, the celestial North Pole appears to be on the Northern horizon. Similarly, observers in the Southern hemisphere see the celestial South Pole at the Zenith when they are at the South Pole, and on the Southern horizon when they are at the equator.

Select a fast acceleration of time steps. Now open the location window. set your location to the North Pole. See how 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 location window again, and set a location little further South: you see that the positions of stars jump, and the centre of rotation moves a little further down the screen. Select a location on the equator. You see that the centre of rotation has moved on the horizon and stars rise and set perpendicular to it.

4 The celestial coordinates

Celestial objects observed by naked eye appear fixed on the celestial sphere. We need only two coordinates (or angles) to specify the position of a star. This is analogous to the two angles (latitude and longitude) which characterize a point on the Earth.

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.

The two coordinate systems that are most commonly used are the equatorial and horizontal systems (fig. 1).

In the equatorial system a star is characterized by right ascension and declination. 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.

In the horizontal coordinate system a star is characterized by azimuth, the angular distance from the North cardinal point⁽¹⁾, and altitude, the high of the point above local horizon.

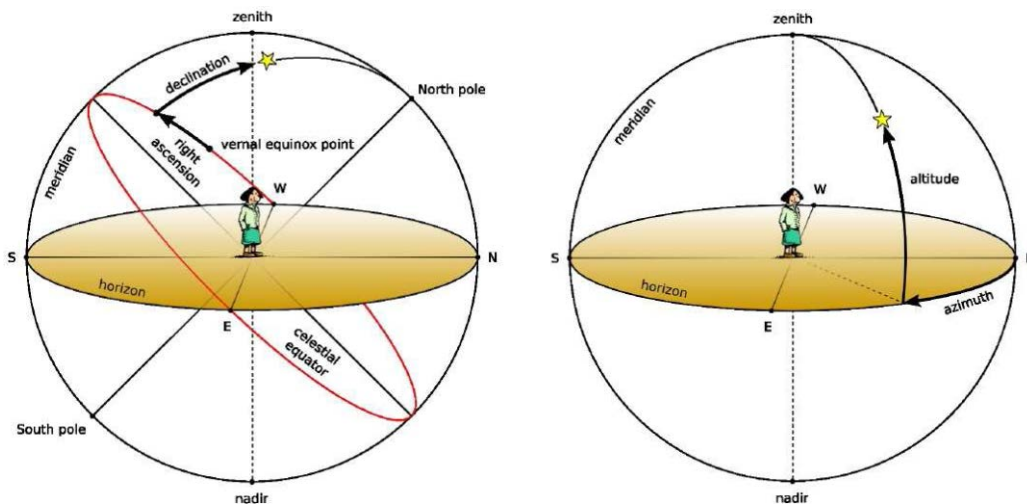


Fig. 1: The equatorial and horizontal coordinate systems.

From the observer's point of view the most natural system is the horizontal system. Such system however is time and position dependent: 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 horizontal coordinates, equatorial 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. Equatorial coordinates are frequently used in star catalogues.

4.1 Example

Stellarium can draw equatorial and horizontal coordinates. To help with the visualisation of the celestial sphere, turn on the equatorial system by clicking the button on the main tool-

¹ 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.

bar or pressing the “e” key. Now you can see equatorial lines drawn on the sky. The celestial equator is the intersection of the plane of the terrestrial equator with the celestial sphere.

In order to turn on the horizontal system click the corresponding button on the main toolbar or press the “z” key. Accelerate the time rate and note that positions of stars remain fixed in time with respect to the equatorial system, while they change with respect to the horizontal system.

5 The constellations



Fig. 2: The constellation of Ursa Major.

Constellations are patterns of stars that human eyes join to form figures often drawn from mythology. Constellations provide a mnemonic aid to the search of an object in the sky. This is a 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 of 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”. On the right, the drawing of the bear and the constellation lines have been removed: only a group of stars remains.

Constellations provide to modern astronomers a way to segment the sky into regions to locate celestial objects. In fact one of the first tasks for an amateur observer is to learn 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.

5.1 Example

Stellarium can draw both constellation diagrams and artistic representations. It supports multiple sky cultures: Western, Polynesian, Egyptian, Chinese, etc. In order to see constellation set up a field of view of approximately 90 deg and watch in the North direction. Turn on constellation names and art: you see constellations of the Western sky culture. In the starlore tab of the sky viewing and option window select the Inuit sky culture:

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you see different constellations including some of 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

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 do not rise and set? If yes, which ones?
North Pole (90° north)			
Trieste (45° north)			
Equator (0°)			
South Africa (34° south)			
South Pole (90° south)			

Exercise 2

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. Do not count constellations not fully visible.

Culture	Number of constellations in the northern hemisphere	Constellation corresponding to Ursa Major
Chinese		
Egyptian		
Inuit		
Mongolian		
Navajo		
Polinesia		
Western		

Exercise 3

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. Adjust the zoom in order to have a field of view (FOV) of about 100 degrees. In the configuration window try the levels of light pollution 1, 4 and 9 (Bortle Classes) and fill the table with the number of stars you can see on the lines of each constellation.

Constellation	Number of stars on constellation lines		
	Bortle class 1	Bortle class 4	Bortle class 9
Ursa Major			
Ursa Minor			
Orion			
Cancer			
Cassiopeia			

SOLUTIONS

Exercise 1

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 do not rise and set? If yes, which ones?
North Pole (90° north)	Polaris	90	Yes, all
Trieste (45° north)	Polaris	45	yes
Equator (0°)	/	/	no
South Africa (34° south)	/	/	yes
South Pole (90° south)	/	/	Yes, all

Exercise 2

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 (starlore) in the sky viewing and option window. Fill the table with the number of constellation you see in each culture and the name of the constellation corresponding to Ursa Major. Do not count constellations not fully visible.

Culture	Number of constellation in the northern hemisphere	Constellation corresponding to Ursa Major
Chinese	37	Northern Dipper
Egyptian	15	Bull's foreleg
Inuit	7	Caribou
Mongolian	2	Seven Buddah
Navajo	5	Revolving man
Polynesian	4	The seven
Western	27	Ursa Major

Exercise 3

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. Adjust the zoom in order to have a field of view (FOV) of about 100 degrees. In the configuration window try the levels of light pollution 1, 4 and 9 (Bortle Classes) and fill the table with the number of stars you can see on the lines of each constellation.

Constellation	Number of stars on constellation lines		
	Bortle class 1	Bortle class 4	Bortle class 9
Ursa Major	18	18	7
Ursa Minor	7	7	3
Orion	19	19	7
Cancer	6	6	0
Cassiopeia	5	5	3



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