The Sky

N.G. Schultheiss
translated and adapted by K. Schadenberg

1 Introduction

This module 'The Sky' is a first in a series which includes the 'The Universe' and 'The Expanding Universe'. This module tries to explain the different ways in which locations of celestial bodies can be defined using angles.

2 Angles

In figure 2.1 you can see an image of the Earth from the software program Google-Earth. The location 51°27'29.94" N 2°36'07.09" W points toward the centre of Bristol, the top of the Physics building of the University of Bristol to be exact.[1] In this notation the number of degrees North (52) can be easily recognised. The second number in the first set (27) is the number of (arc)minutes. Like an hour, a degree can be divided into 60 (arc)minutes. You can now probably guess what the third number is, the number of (arc)seconds. Using this notation an angle can be represented very accurately.[2]

These angles need to be reported from a specific reference point to indicate a location. We can draw imaginary circles across the surface of the Earth. Lines running from the North to the South pole are called meridians. By definition the prime meridian (or 0° meridian) runs through Greenwich in England. The prime meridian divides the Earth into two halves, everything west of this line is on the Western Hemisphere (0° to 180° West longitude) and every thing to the east is on the Eastern Hemisphere(0° to 180 ° East longitude). All meridians meet at the poles where they intersect at a certain angle. The angle between the meridians running through Greenwich and Bristol is 2°36'07.09" towards the West.

With the second number we represent the distance from the equator. We can draw circles across the surface of the Earth which are perpendicular to the meridians; these are circles of latitude. Starting at the equator we need to go 51°27'29.94" North to end up in Bristol.

We can convert our notation using degrees, minutes, and second to one which uses only degrees:

$$4°53'35.84'' = 4° + \left(\frac{53}{60}\right)^\circ + \left(\frac{35.84}{3600}\right)^\circ = (4 + 0.883333 + 0.009956)^\circ = 4.893289^\circ$$

[1] Also the location of HiSPARC detector 13001.

[2] An alternative to the number of seconds is decimals of a minute (e.g. 52°22'.29).

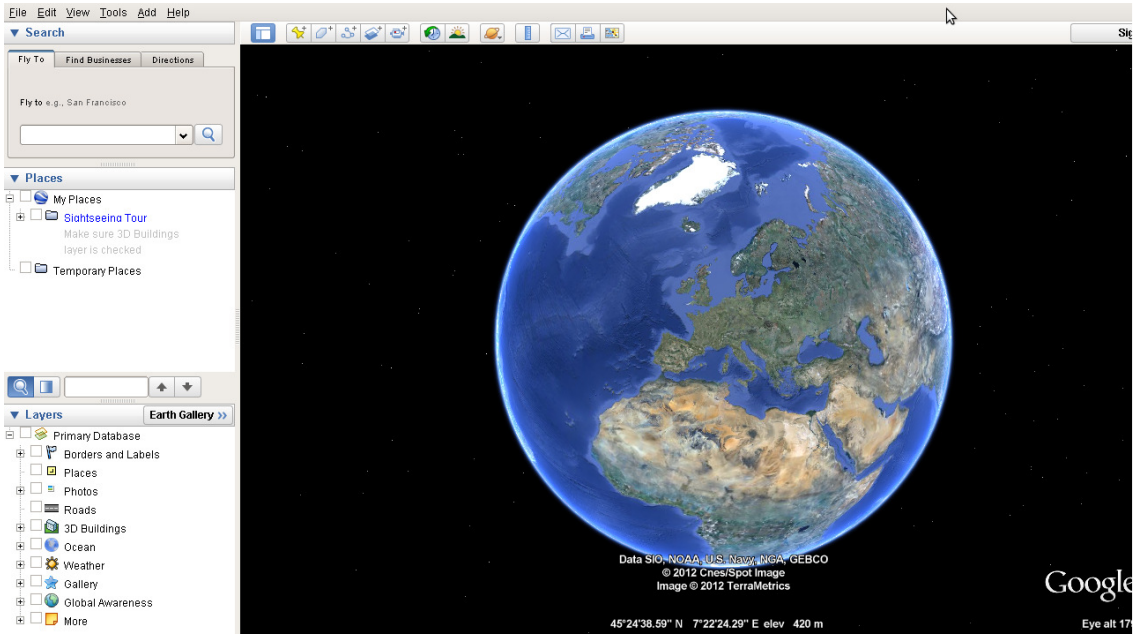

Figure 2.1: The Earth in Google-Earth.

In a similar fashion we can convert an angle using only degrees into one using degrees, minutes, and seconds:

$$13.236782^\circ = 13^\circ + 0.236782^\circ$$
$$13^\circ + 0.236782^\circ = 13^\circ + 60 \cdot 0.236782' = 13^\circ 14' + 0.206921'$$
$$13^\circ 14' + 0.20692' = 13^\circ 14' + 60 \cdot 0.20692' = 13^\circ 14' 12.42''$$

Exercise 1 : We measured an angle of 24.7381°. Convert this angle into degrees, minutes, and seconds.

Exercise 2 : We measured an angle of $52^\circ 23'17''$. Convert this angle into degrees.

3 The Sky

At the top of the Google-Earth window there is a small icon of Saturn. Clicking on this icon shows the stars present in the (night) sky.

Figure 3.1 shows the stars in the Northern hemisphere. The mouse cursor points towards Polaris, the Pole or North Star. In the bottom of the screen the location of the cursor is represented as RA 7h10m00.00s en Dec $89^\circ 15'45.11''$.

The abbreviation RA stands for Right Ascension, it is the celestial equivalent of the longitude on Earth. Dec is the abbreviation for Declination, this is the celestial equivalent of latitude.

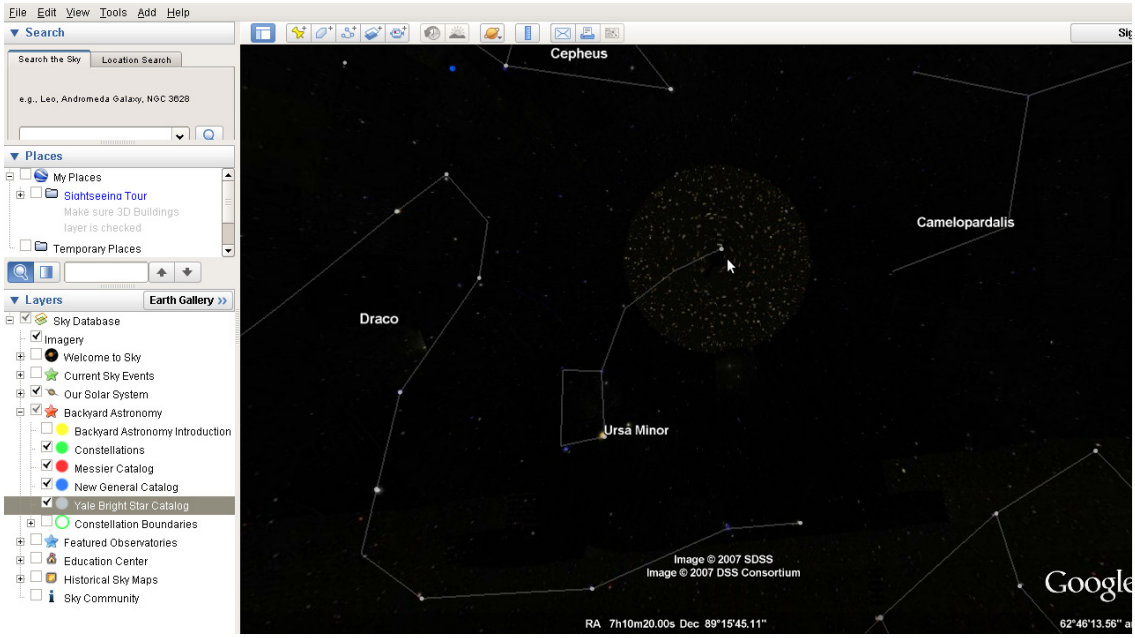

Figure 3.1: The sky according to Google-Earth.

Where are the celestial equator and prime meridian? The celestial equator is the projection of the Earth equator onto the (imaginary) celestial sphere. Celestial objects on the equator have zero declination. Towards the North pole is positive declination, towards the South pole negative.

The Earth axis of rotation is at an angle with respect to the Sun. This means that the Sun does not move across the Celestial equator but on a different line, called the Ecliptica. The Ecliptoca intersects the Celestial equator two times, at the Spring equinox and Autumnal equinox (also March and September equinox). The Celestial meridians are measured from the Spring equinox.

Exercise 3 : Use Google-Earth to look at Ra 0h0m0s Dec 0°0 0. In which constellation / near which constellation lies this point?

Exercise 4 : Use Google-Earth to look at Ra 2h0m0s Dec 0°0 0. In which constellation / near which constellation of the zodiac lies this point? Repeat this for 4h0m0s, 6h0m0s, 8h0m0s, 10h0m0s, 12h0m0s, 14h0m0s, 16h0m0s, 18h0m0s, 20h0m0s, and 22h0m0s. List all the names in a table. Observe that the declination of the zodiac is not always 0°0 0. After 24 hours the circle is complete.

At the start of Spring the Sun lies in the constellation Pisces.[3] Celestial time is measured from this point. This time is different from Earth time, which is measured with respect to the Sun. Time measured with respect to the stars is called Sidereal time.

[3]According to astrology the Spring equinox lies in the constellation Aries, however the axis of rotation of the Earth has changed in the past 2000 years changing the relative locations.

Exercise 5 : Complete the following table:

Earth	Sky
Length	
	Declination
Equator	

4 Herschel and Messier

Fredrich Wilhelm Herschel made his living as a musician and wrote multiple symphonies. But he also had a great interest in the sky and therefore build a number of refractor telescopes to study it more closely.

At roughly the same time Charles Messier was also taking a closer look at the skies. He made the now famous list of 110 Messier objects.[4] Messier was a comet hunter, he became frustrated by objects strongly resembling comets but which were in fact not comets. In modern catalogues the original Messier objects can still be recognised by their names; M001 to M110. Herschel was impressed by Messiers work and started doing deep sky (far away) surveys to make his own catalogue. Eventually he published three catalogues together containing over 2500 objects.

Exercise 6 : Lets see if we can find one of Herschels objects with Google-Earth. Go to 'AR 37 / H969-3' located at RA 11h32m30s Dec +74°32'. At this exact position you will not find anything, there are however two objects from the NGC list nearby. Can you give an explanation why there is nothing at the location reported by Herschel?

The first telescopes where rather cumbersome compared to their modern counterparts. In figure 4.1 you can see Herschels first telescope. This telescope could only be moved up or down, rotating involved lifting the entire telescope and repositioning it. If the telescope is precisely aligned along a meridian, the rotation of the Earth makes sure that the telescope can look around the entire sky. A complete circle across the stars takes 24 hours.[5] This is why right ascension is given in a time format and not as an angle.

[4] The original list of Messier only contained 103 objects, other astronomers added a further 7.

[5] We do have to use the correct time. We can define a day, containing 24 hours, as one rotation of the Earth around its axis with respect to the Sun, but also with respect to the stars. The difference between the two is roughly one day per year, or almost 4 minutes per day. Try to find out why. In the module 'Periodical data' you can find more information about the two different time systems.

Figure 4.1: Herschels first telescope.

Name	Type	R. A.	Dec	Size	Mag	Con	Herschel
AR 37	Open cluster	11:32.5	+74˜32			Dra	H969-3
IC 434	Nebula	5:41.0	- 2˜24	60.0		Ori	H35-5 Barnard's Loop
IC 2995	Galaxy	12:05.8	-27˜56	3.1	13.5	Hya	H382-3
IC 4051	Galaxy	13:00.9	+28˜00	1.1	13.2	Com	H363-3
NGC 12	Galaxy	0:08.7	+ 4˜37	1.9	14.1	Psc	H868-3
NGC 13	Galaxy	0:08.8	+33˜26	2.7	13.6	And	H866-3
NGC 14	Galaxy	0:08.8	+15˜49	3.0	12.1	Peg	H591-2
NGC 16	Galaxy	0:09.1	+27˜44	2.1	12.0	Peg	H15-4 vF interacting pair
NGC 23	Galaxy	0:09.9	+25˜55	2.3	12.0	Peg	H147-3
NGC 24	Galaxy	0:09.9	-24˜58	5.5	11.5	Scl	H461-3 Nearly edge-on
NGC 29	Galaxy	0:10.8	+33˜21	1.8	12.6	And	H853-2
NGC 36	Galaxy	0:11.4	+ 6˜23	2.4	14.4	Psc	H456-3
NGC 39	Galaxy	0:12.3	+31˜03	1.1	13.5	And	H861-3
NGC 40	Planetary neb	0:13.0	+72˜32	.3	10.7	Cep	H58-4 "400"
NGC 52	Galaxy	0:14.6	+18˜33	2.4	13.3	Peg	H183-3
NGC 57	Galaxy	0:15.4	+17˜18	2.6	11.6	Psc	H241-2 = H243-2
NGC 61A	Galaxy	0:16.5	- 6˜14	1.1	14.7	Psc	H428-3
NGC 68	Galaxy	0:18.3	+30˜04	1.5	13.0	And	H16-5
NGC 95	Galaxy	0:22.2	+10˜30	1.9	12.6	Psc	H257-2 asym uneven arms

Table 1: Part of Herschels catalogue