



Week 4

Sacred Skies

Measuring – working with the sky

Bernadette Brady



Assignment 2 5000 word essay

Choose one of the following

Image and literature based

Compare and contrast the cultural expression or representation of the sky in three works of film, or music, or art, or architecture, or celestial cartography, or literature.
(You must get tutor approval for your selected representations).

Measurement based

Conduct a simple fieldwork exercise, investigating the likelihood of celestial alignments at prehistoric or sacred site(s).
(You must get tutor approval for your selected project).

Assignment 2 Proposal (Moodle) needs be sent to your tutor by
Friday 26 March

Your field work may depend on your local Covid-19 restrictions.

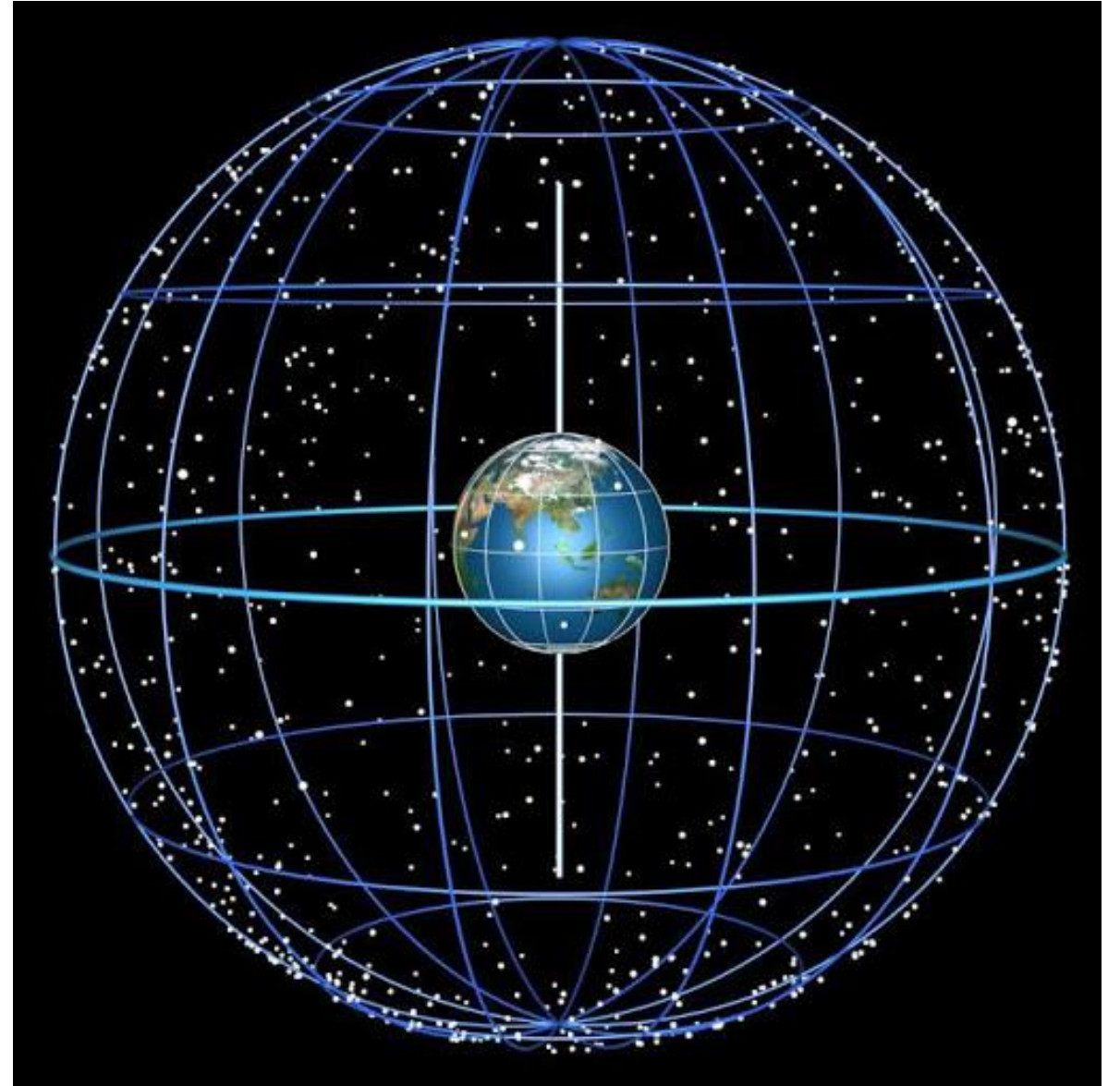
If you are using **virtual fieldwork** then the world is at your finger tips:

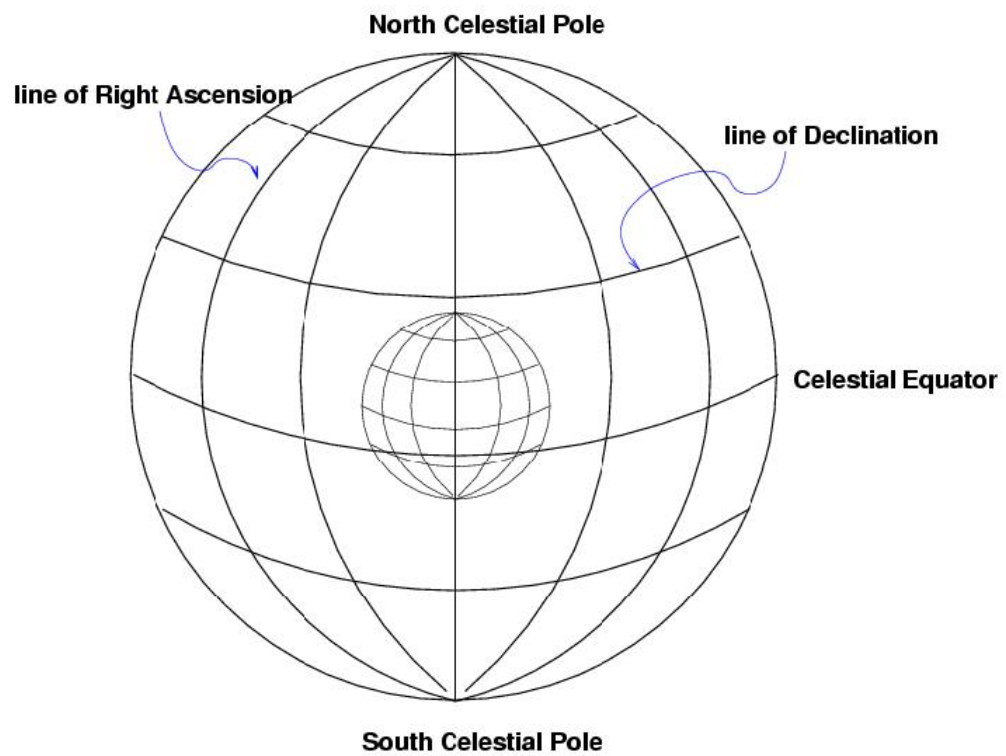
- You could measure a selection of churches in a given area.
- Or you could select some ancient sites that are clear from Google earth and measure those – but have a question you are asking about them that is not well established already in the literature.
- You could measure the grid system of an ancient city or medieval city.

If you are doing **ground field work** then:

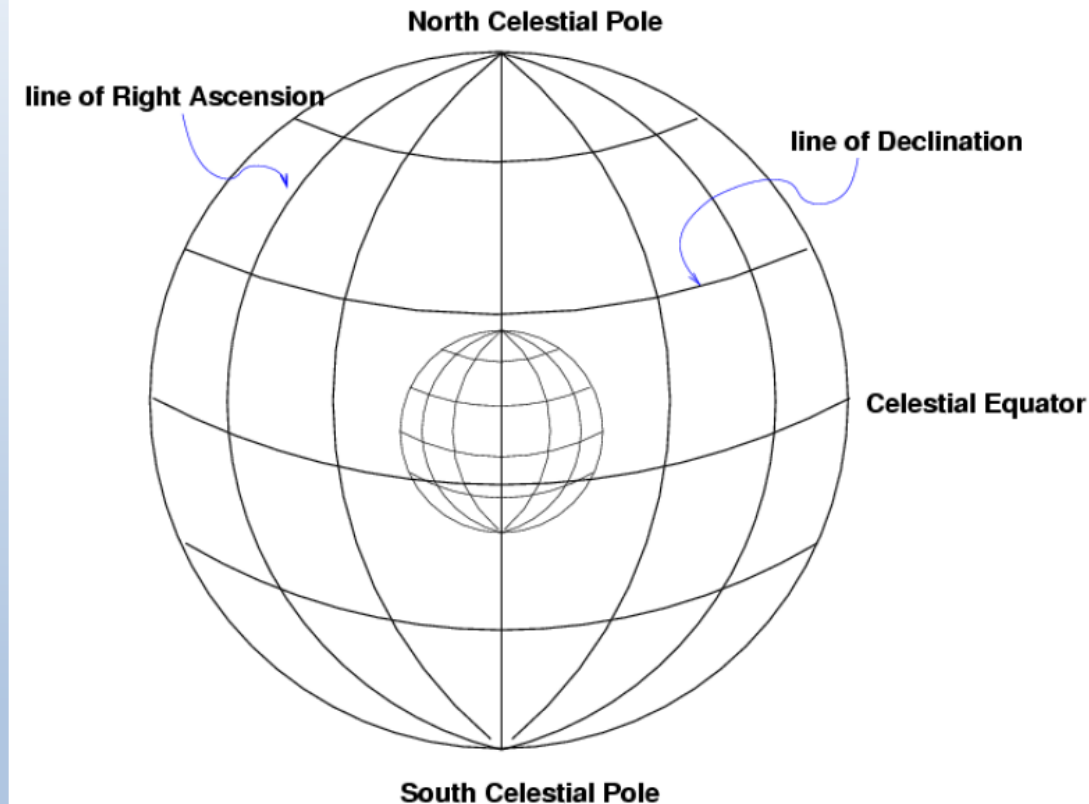
- You could measuring the orientation of some local churches in your area.
- If you live in a medieval town you could measure some of the street orientations.
- You could consider any structure in your area, that you think could have been placed in a particular relationship to the sky and explore it.

The Sky and its Numbers





Basic numbers you need to understand



The Fixed Address System

Just as cities have a longitude and latitude sky objects have a Right Ascension and Declination

**Declination is *like* latitude and
RA is *like* longitude (time based)**

The Fixed Address of the
star Sirius the star:

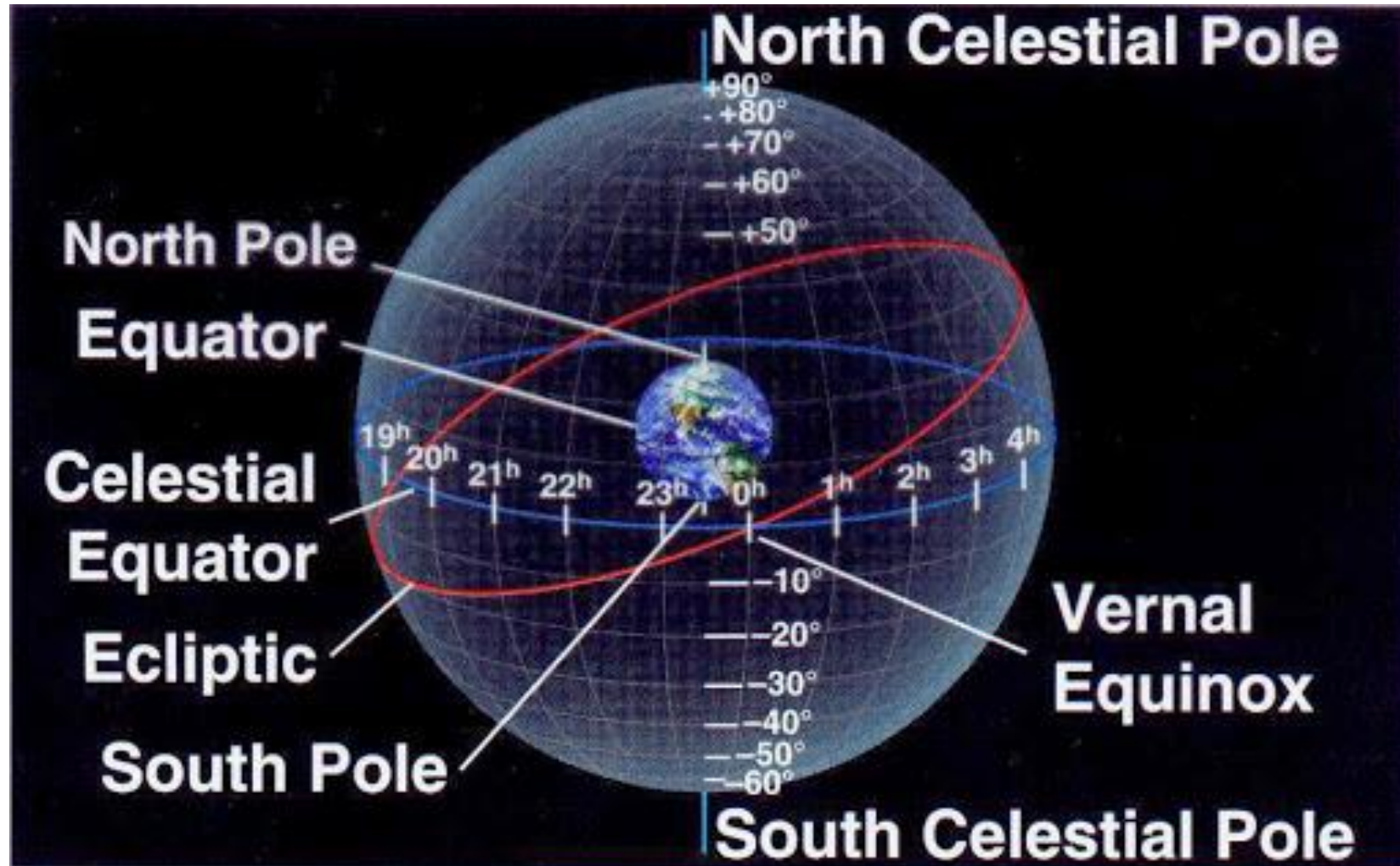
RA: 06:45:38

Dec: $-16^{\circ}44'$

Sirius will pass directly overhead once a day
if you are located at a latitude $16^{\circ}44'$ South,

The **ecliptic** 'cuts across' the declination grid. Thus as the sun, moon and planets move around the ecliptic they will change their declination.

The **sun's change of declination is directly linked to the calendar**. When the sun is at the extremes then it is at a solstice, summer or winter, if it is on the equator then it is an equinox.

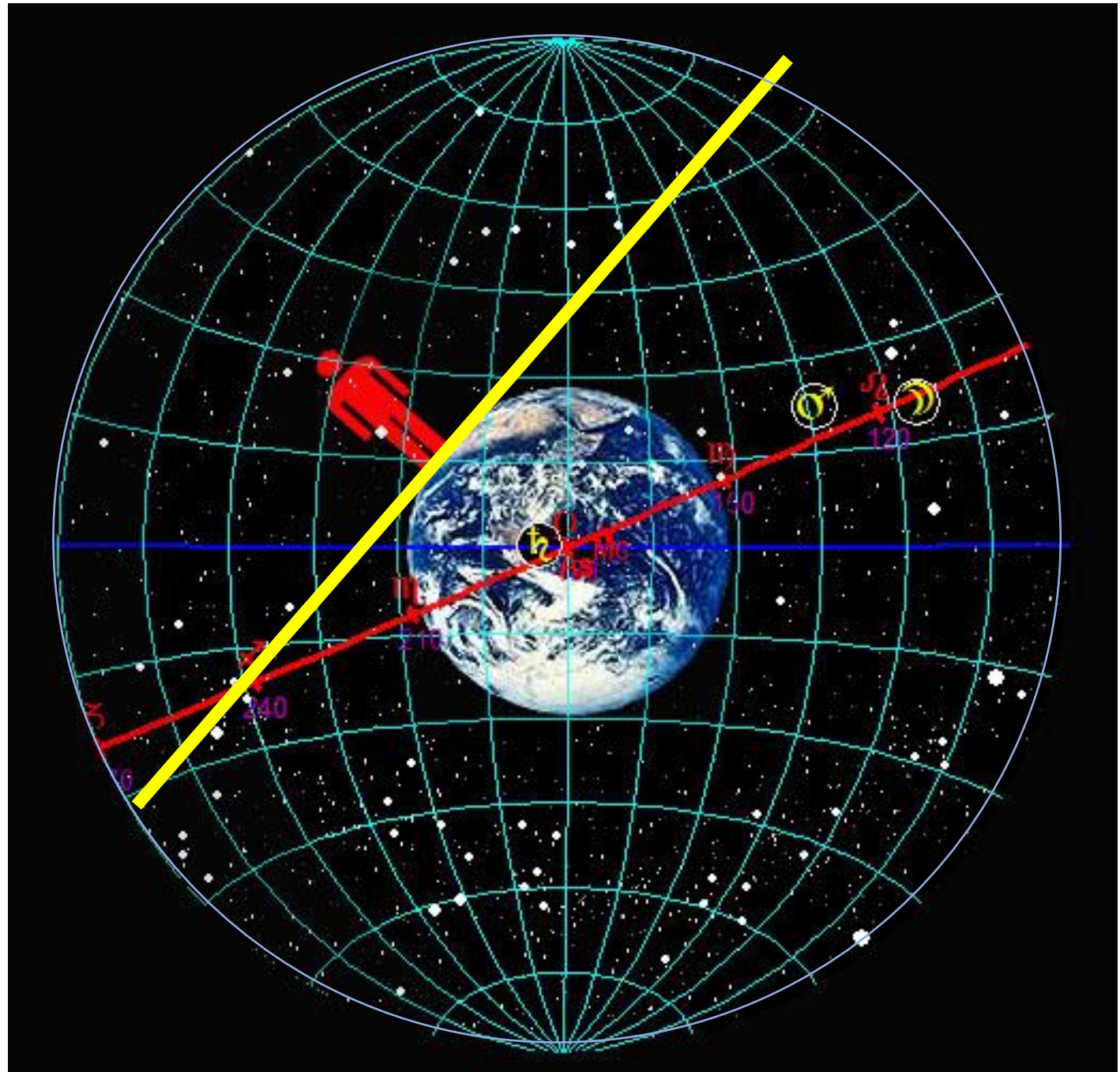


ADDITIONALLY....

The local horizon will be tilted according to the equator and its grid of declination.

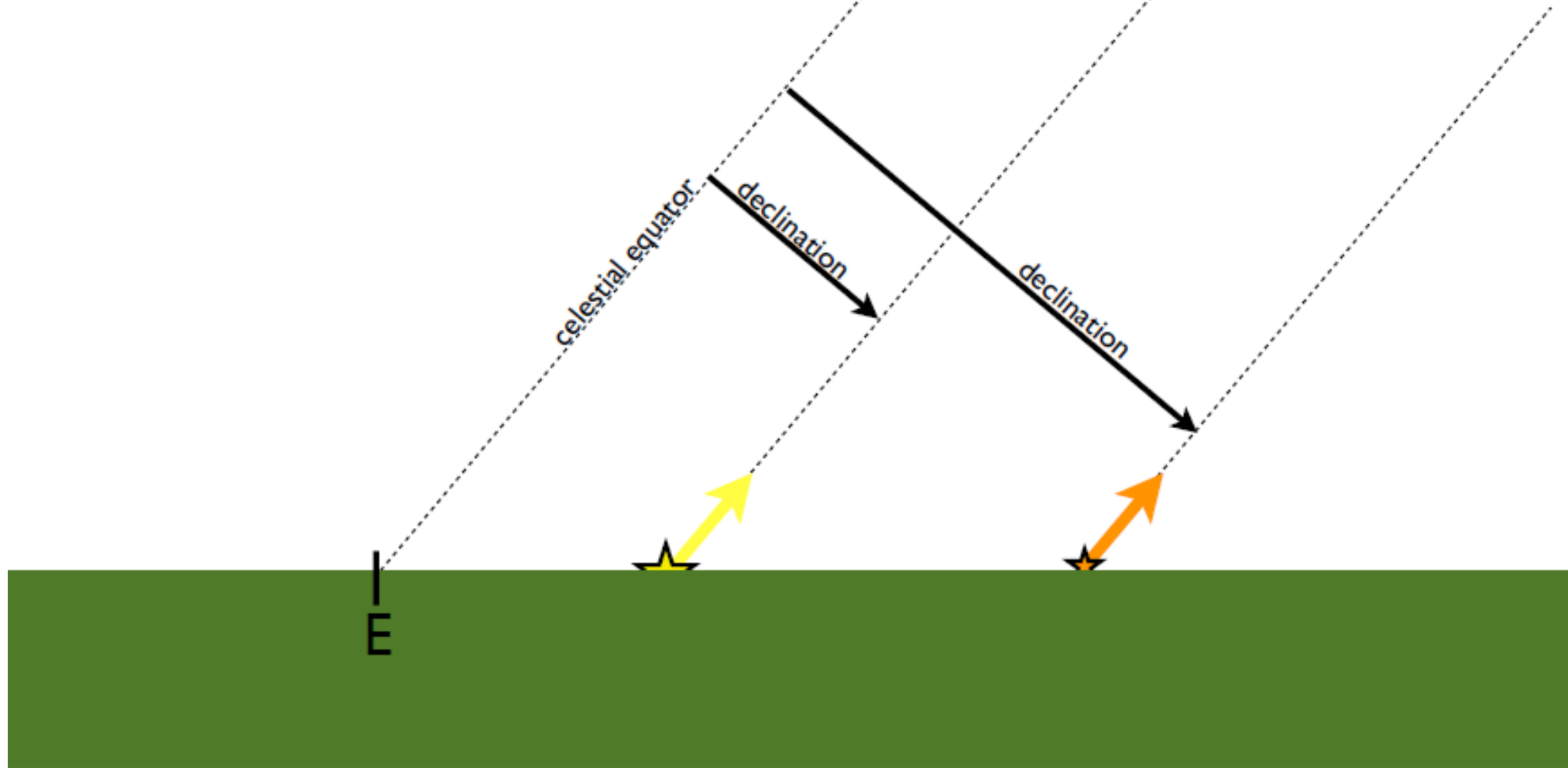
But this horizon tilt is constant for a given location as it is a reflection of a person's latitude.

Hence any **particular declination band** will always rise and set in the same place for a particular local horizon.



Where does a celestial object rise/set on the horizon?

Local
Horizon
view



There is a relationship between the declination of a celestial object and the position on the horizon where it rises.

Where does a celestial object rise/set on the horizon?

Local
Horizon
view



There is a relationship between the declination of a celestial object and the position on the horizon where it rises.

Eg. Objects with:

+ is North
- is South

1) **declination 0°** have an orbit that coincides with the celestial equator and therefore **rise at East** and **set at West**.

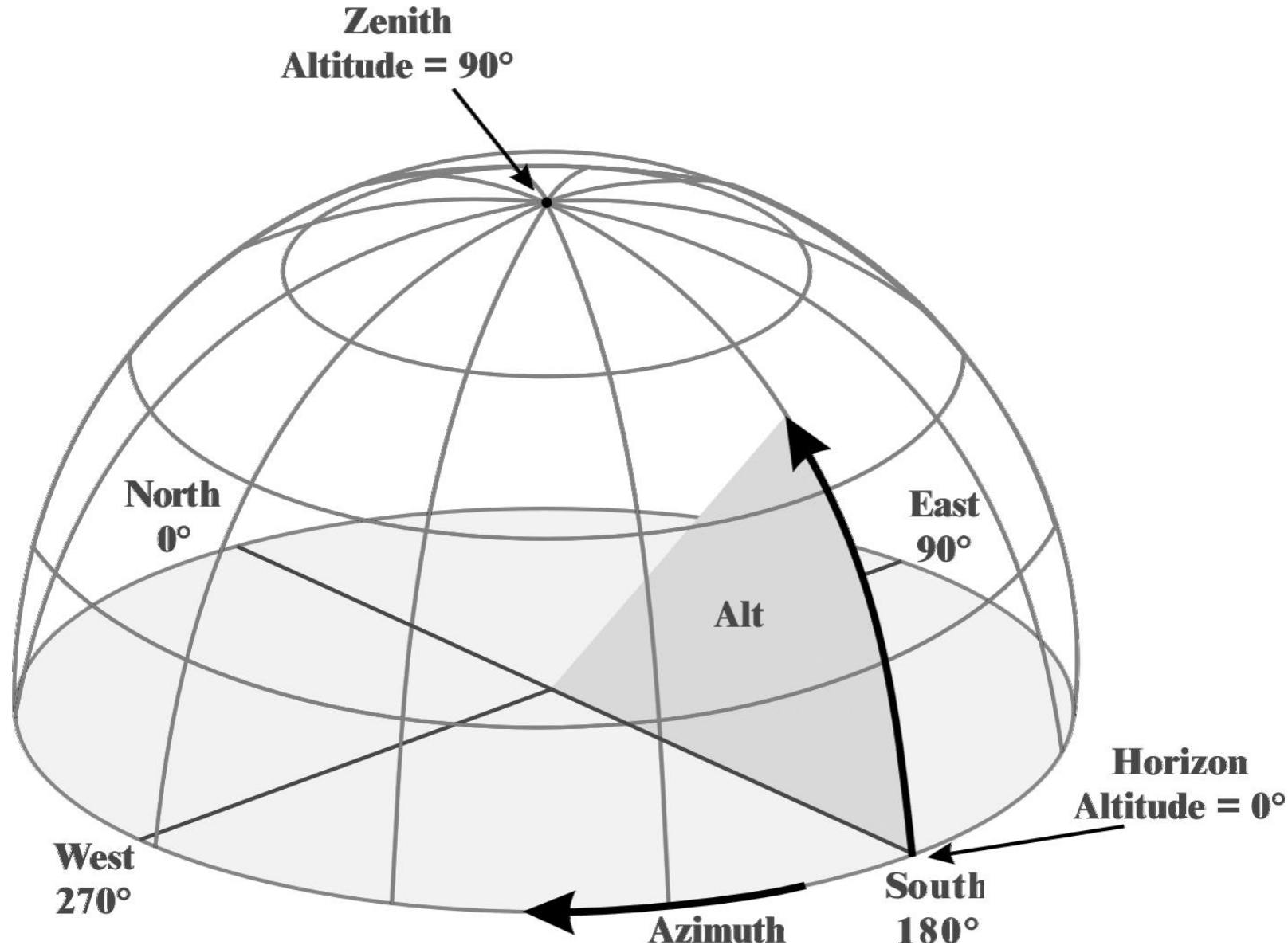
2) **positive declination** rise and set **north of East and West**, respectively.

3) **negative declination** rise and set **south of East and West**, respectively.



We cannot measure declination directly hence we have to work with the 'local' grid based on the local horizon and the local zenith – point directly overhead. This grid is made up of azimuth and altitude.

The “Moving” Addresses



Azimuth and Altitude

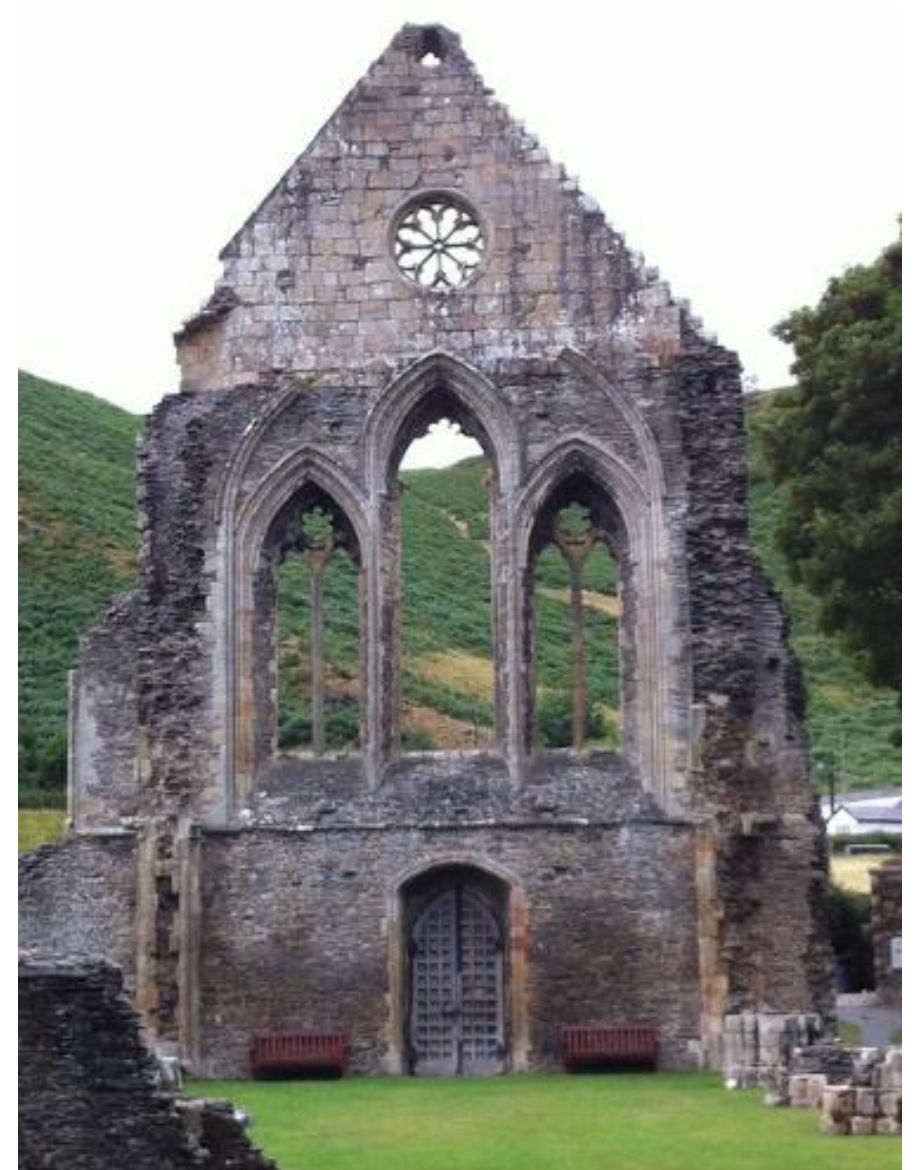
Fixed by the local horizon and the diurnal movement of the heavenly bodies cause them to move against this ‘net’

This is the ‘net’ that we are able to measure when looking at an horizon.

What needs to be measured

In the field we measure **azimuth** and **altitude** then we need to convert to the equatorial grid – declination!

Once you know the declination of a particular view you can then determine what, when and where a celestial body will rise or set on the local horizon.



What needs to be measured?

Azimuth and Altitude are the measurements of what is known as Horizon Astronomy

This is an informal terms used to describe an astronomy that is mainly concerned with events that occur at the horizon, e.g. sunrise/set, Moonrise/set, star-rise/set.



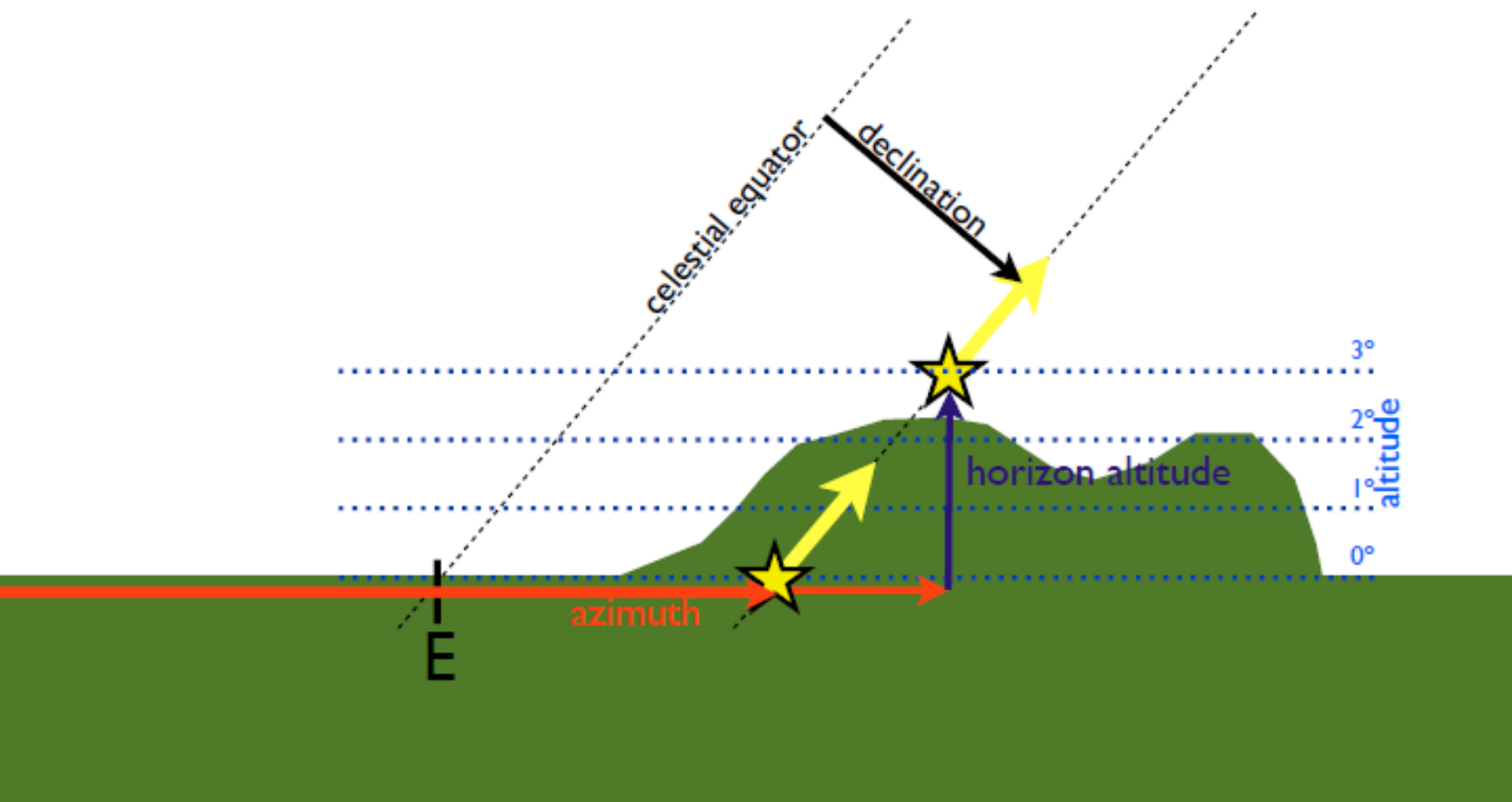
What needs to be measured

The numbers you need in order to find the declination are:

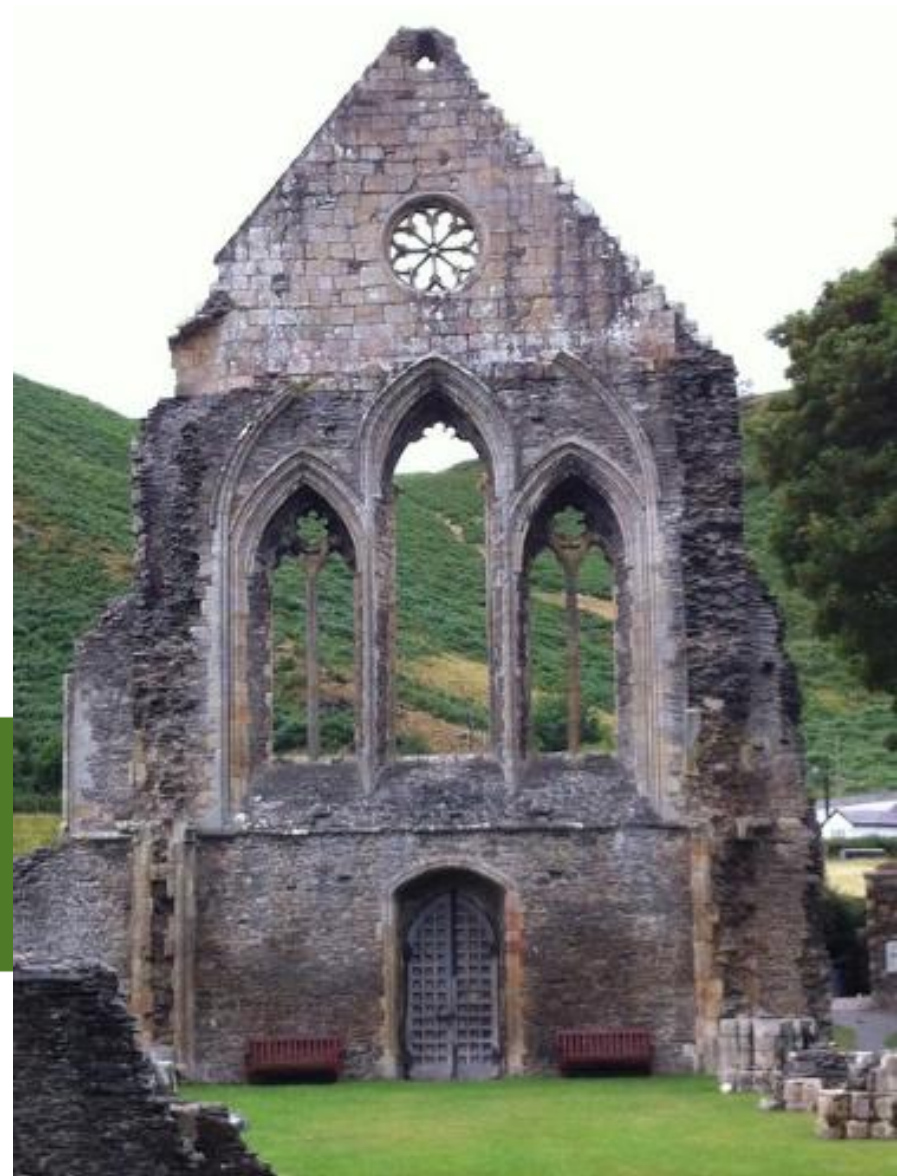
- **Azimuth** (measured from True North) – measured with a compass.
- **Altitude** (above or below the horizon) measured with a clinometer.
- **Latitude** – of your location measured by GPS.

All of these are measured in the field.

Why do I need the horizon altitude?



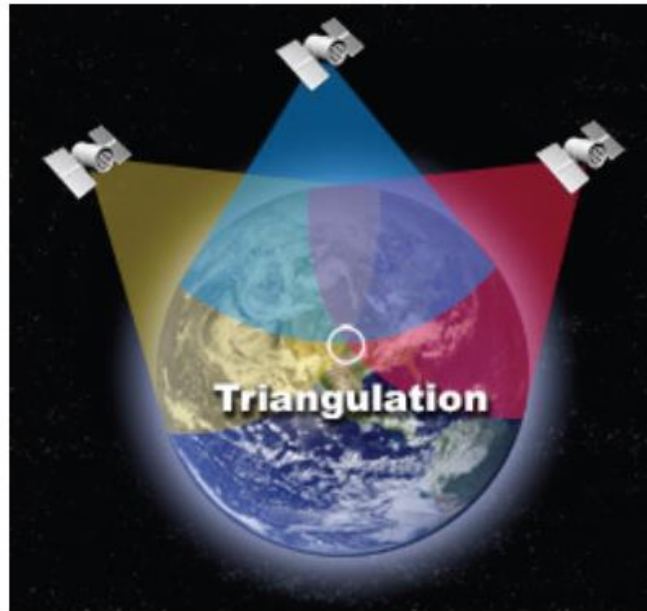
azimuth
latitude
horizon altitude } declination



Measuring Latitude

Using a handheld GPS

How does it work?



Using a handheld GPS



Garmin 12
black and white
accuracy: 15 metres



Garmin 76
colour
accuracy: 5 metres



Garmin eTrex 30
colour
accuracy: 5 metres

Car ('satnav') GPS
receivers not good
enough.

Latest smartphone
GPS receivers are
very good, however
you'll need to buy
an app that tells you
the latitude and
longitude

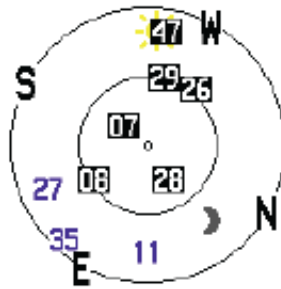
Measuring Latitude

Using a handheld GPS

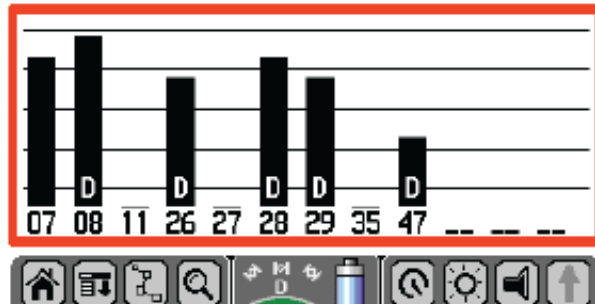
QueGPS

3D Differential Location

N 39°7.383' 13-OCT-03
W 121°2.450' 05:00:10pm



Speed:
2.5 mph
Elevation:
1690 ft
Accuracy:
20.3 ft



This show the satellites
you are connected to

each bar is a satellite

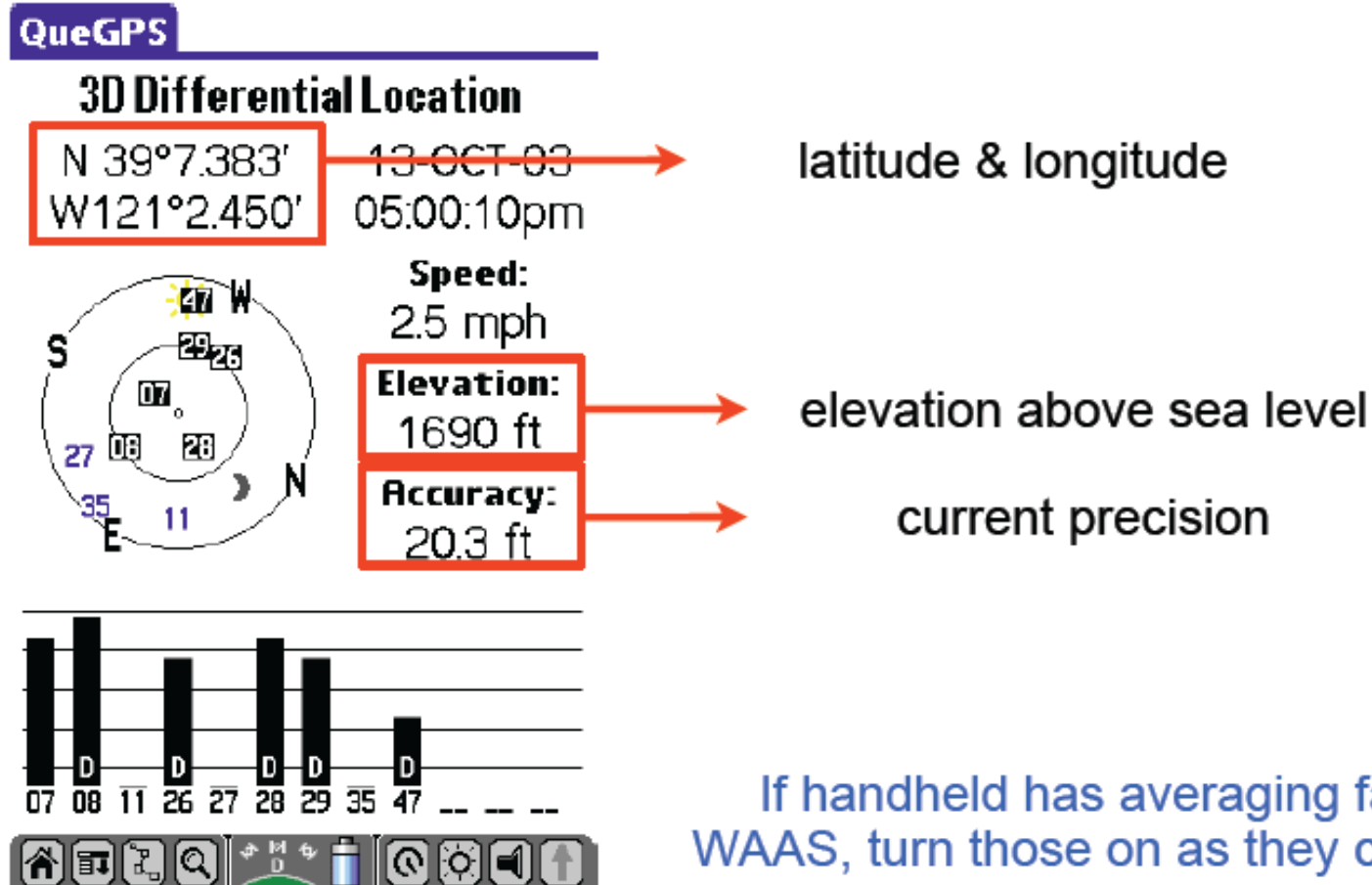
“the more the merrier”

Typical GPS screen

Measuring Latitude

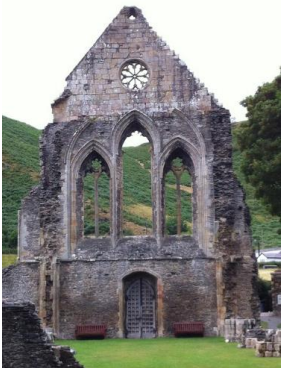
Using a handheld GPS

If possible
you can also
Check the
latitude using
Google
Earth!



Typical GPS screen

If handheld has averaging facility and/or WAAS, turn those on as they can dramatically increase the accuracy.



Measuring Altitude

In virtual field work you use HeyWhatsThat

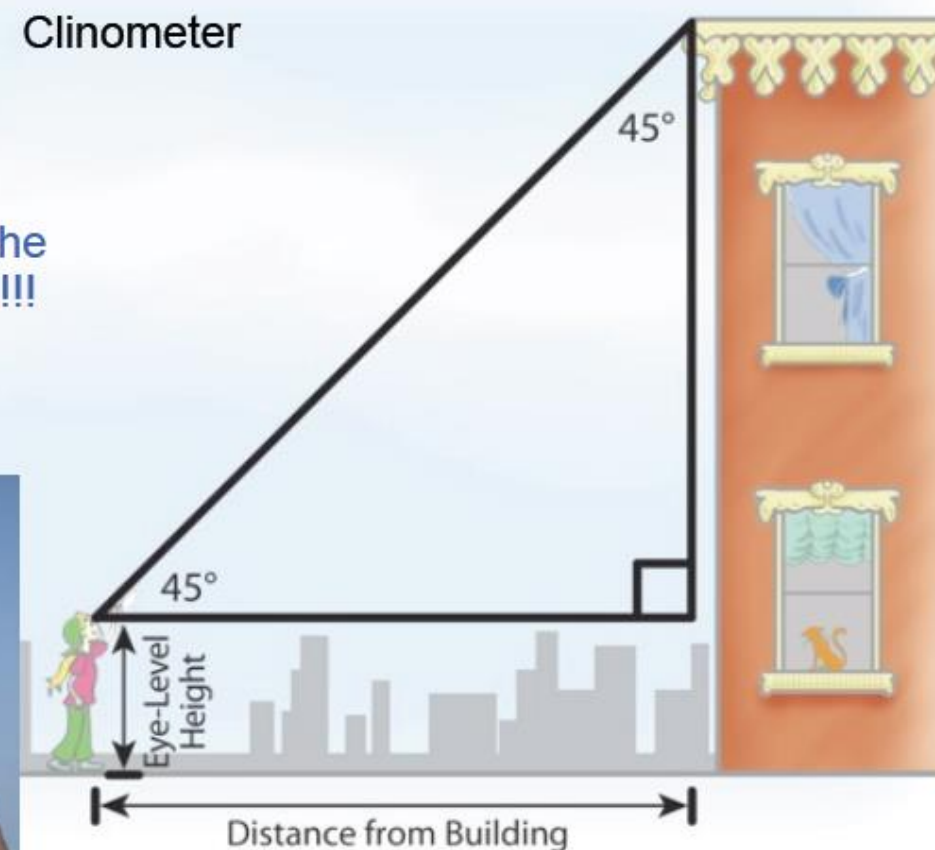
Using a compass / clinometer

Clinometer



Using a compass / clinometer

Make sure you are reading the $^{\circ}$ scale and not the % scale!!!!



Measuring Azimuth

In virtual field work you use Google Earth

Different
compass/clinometers
have different
precision.

You need to work with
on that has at least a
precision of 1°.

Using a compass / clinometer

Different styles of compass



Plate Compass

good for reading maps,
bad for surveying



Prismatic Compass

better



Sighting Compass

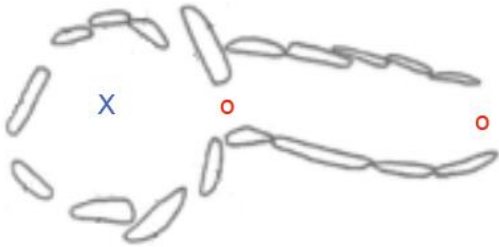
best



How to measure in the field

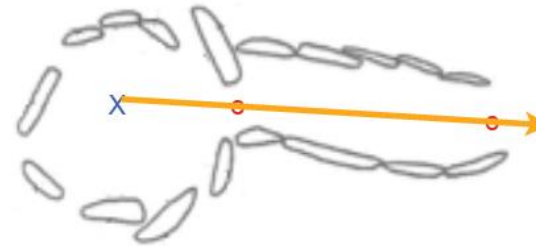
Using poles...

How to measure an orientation accurately?



2) Position yourself behind the backsight

How to measure an orientation accurately?



3) Align your compass with the back- and foresight and take a reading



Or you can
take the line
of a wall.

Sight along
it till the
edge just
disappears.



Sighting along the line of a wall



Check all your measurements while you are on site – make sure you have all you need.

Local Magnetic Anomalies

- Not to be confused with Magnetic Declination.
- This is the local variation of magnetic North due to magnetic fields in the surroundings. These can be ferromagnetic rocks, nearby power stations, power lines OR
- The batteries in your smartphone, camera, laptop or even the metal in your sunglasses!

Checking for Local Magnetic Anomalies

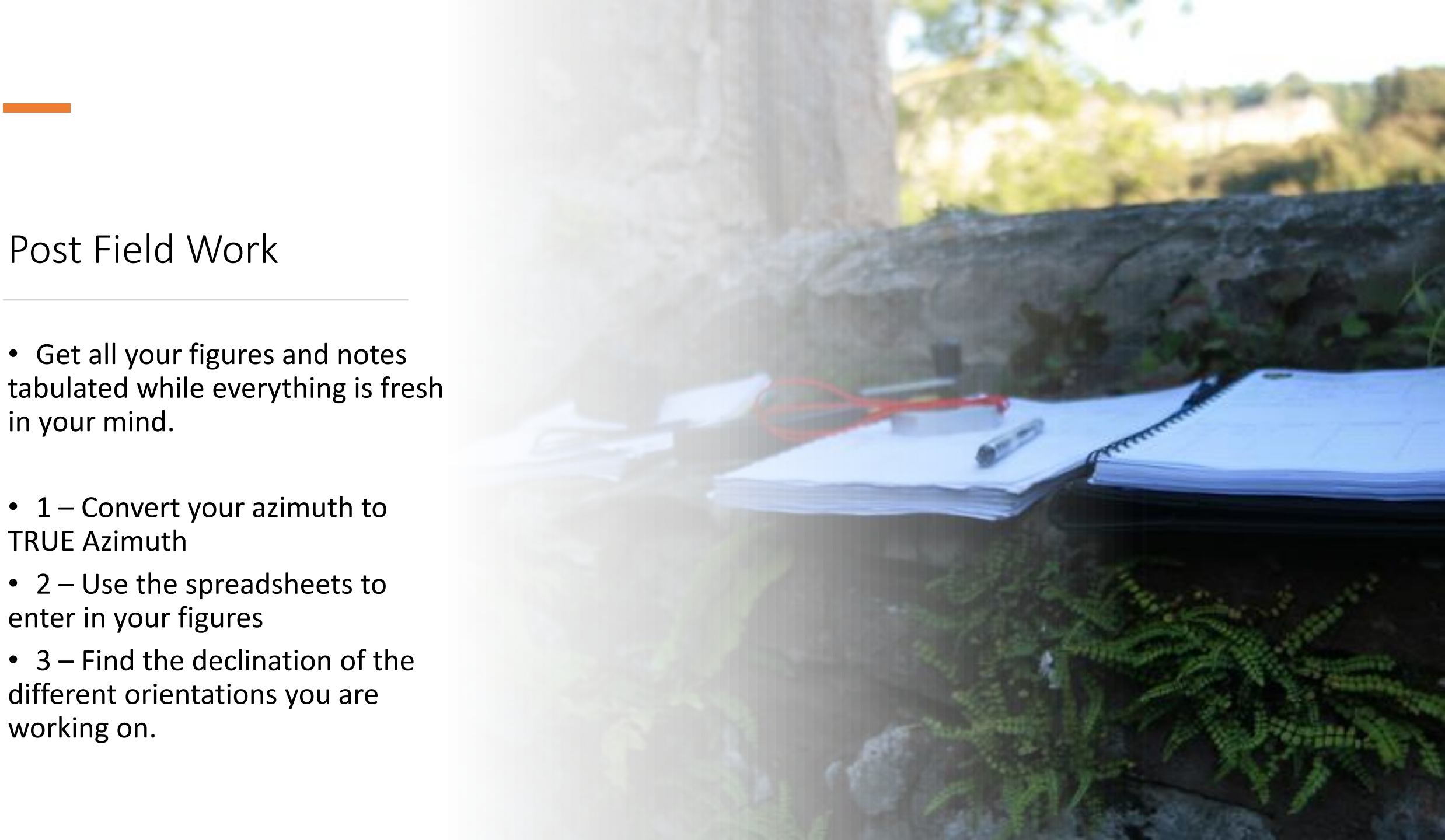
By ALWAYS taking a measurement from both directions you will see any local anomalies.

Your two readings should differ by $180^{\circ} \pm 1^{\circ}$

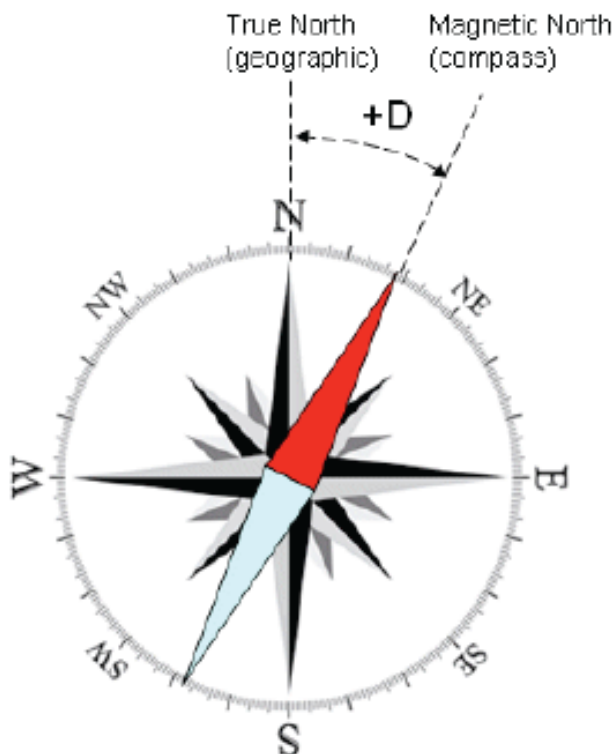


Post Field Work

- Get all your figures and notes tabulated while everything is fresh in your mind.
- 1 – Convert your azimuth to TRUE Azimuth
- 2 – Use the spreadsheets to enter in your figures
- 3 – Find the declination of the different orientations you are working on.



Magnetic Declination



True North and Magnetic North are not the same! Hence *true azimuth* and *magnetic azimuth* are not the same

The difference between the two is called
Magnetic Declination

When using a compass you are taking magnetic azimuth readings. You need to correct them for True North.

The Magnetic Declination varies from site to site and from year to year. This is found online.

<https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml>

Usually expressed as 3°E or 4°W or $+3^{\circ}$ or -4°

E (east) means you need to add this value to your compass azimuths,
W (west) means you need to subtract it.

- Play around with this online app you will see that even for a given date that the magnetic declination will vary from location to location.
- When you do your field work you enter in the DATE you took your compass reading along with the longitude and latitude of the location where you took the reading.

**NOAA** NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA > NESDIS > NCEI (formerly NGDC) > Geomagnetism

Magnetic Field Calculators

DeclinationU.S. Historic DeclinationMagnetic FieldMagnetic Field Component Grid

Magnetic Declination Estimated Value ⓘ

Declination is calculated using the most recent [World Magnetic Model \(WMM\)](#) or the [International Geomagnetic Reference Field \(IGRF\)](#) model. Prior to 1900 the calculator is based on the [gufm1](#) model. A smooth transition from gufm1 to IGRF was imposed from 1890 to 1900. The [Enhanced Magnetic Model \(EMM\)](#) is a research model compiled from satellite, marine, aeromagnetic and ground magnetic surveys which attempts to include crustal variations in the magnetic field too fine to appear in the World Magnetic Model. Declination results are typically accurate to 30 minutes of arc, but environmental factors can cause magnetic field disturbances. The calculator provides an easy way for you to get results in HTML, XML, CSV, or JSON programmatical information click the information button above.

Calculate Declination

Latitude: ☐ S ☒ N

Longitude: ☒ W ☐ E

Model: ☒ WMM (2019-2024) ☐ IGRF (1590-2024)
☐ EMM (2000-2019)

Date: Year Month Day

Result format: ☒ HTML ☐ XML ☐ CSV ☐ JSON ☐ PDF

Calculate

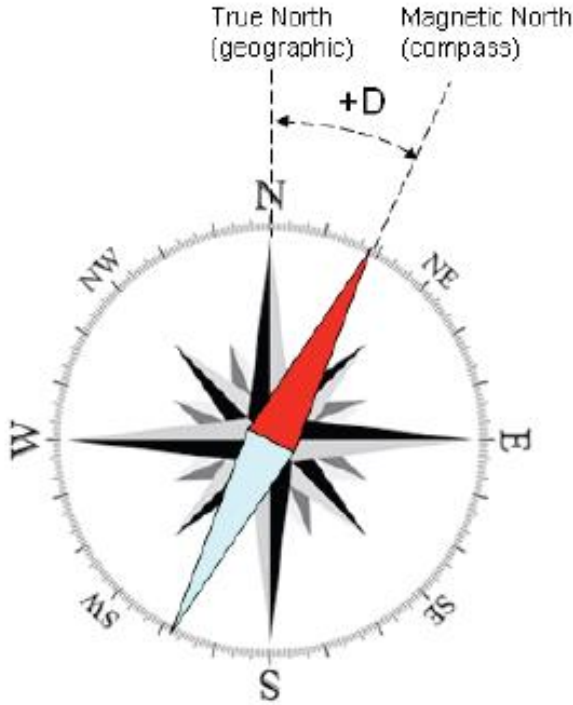
Lookup Latitude / Longitude

Enter a street address, street name, or street intersection. For best results, include as much location information as possible in your search, such as city, state, zip.

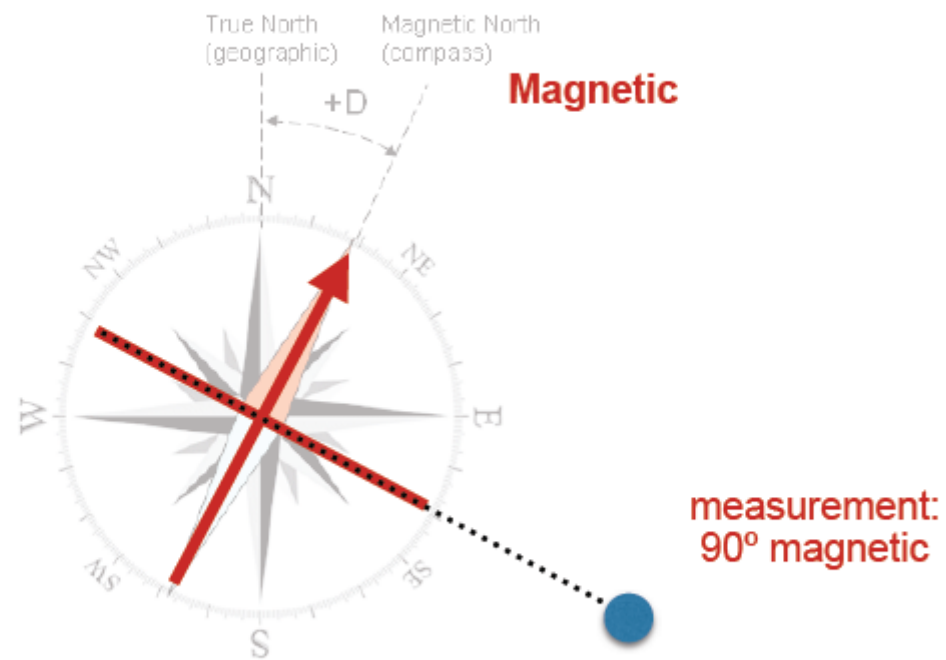
Location:

Get & Add Lat / Lon

Converting magnetic azimuth to True Azimuth - AzT



Magnetic Declination 29 ° East - or +29°



You measure, with your compass, an azimuth of 90°

Then you need to ADD the +29° to your 90° to find the TRUE Azimuth of 119° (AzT)

Conclusion

EAST is + which means you ADD to your AzM

WEST is – which means you subtract from your AzM

Taking your field work to your desk – finding the declination

Step 1 – find the magnetic declination.

Step 2 – Moodle page – TOOLS.

Download the Main Calculation Spreadsheet.

Step 3 – use the spreadsheet to enter in your values to find the declination.

Tools



Spreadsheets and Tables



MAIN - Calculation Spreadsheet

This spread sheet enables you to do all the calculations you need for the module. You can use this spreadsheet on line but it is easier to download it onto your own computer then you can save it with all your figures left in.



Reference Tables and Graphs - Fabio Silva

Instruments



Suunto Compass KB Series User Guide

This is the user guide for the Suunto Compass.



Youtube on the tandem Suunto compass and Clinometer

This Youtube is from a company that supplies equipment for satellite dish installation, but it does show you how the instrument is used.

Declination Tables

Sacred Skies – Moodle

Tools



Spreadsheets and Tables



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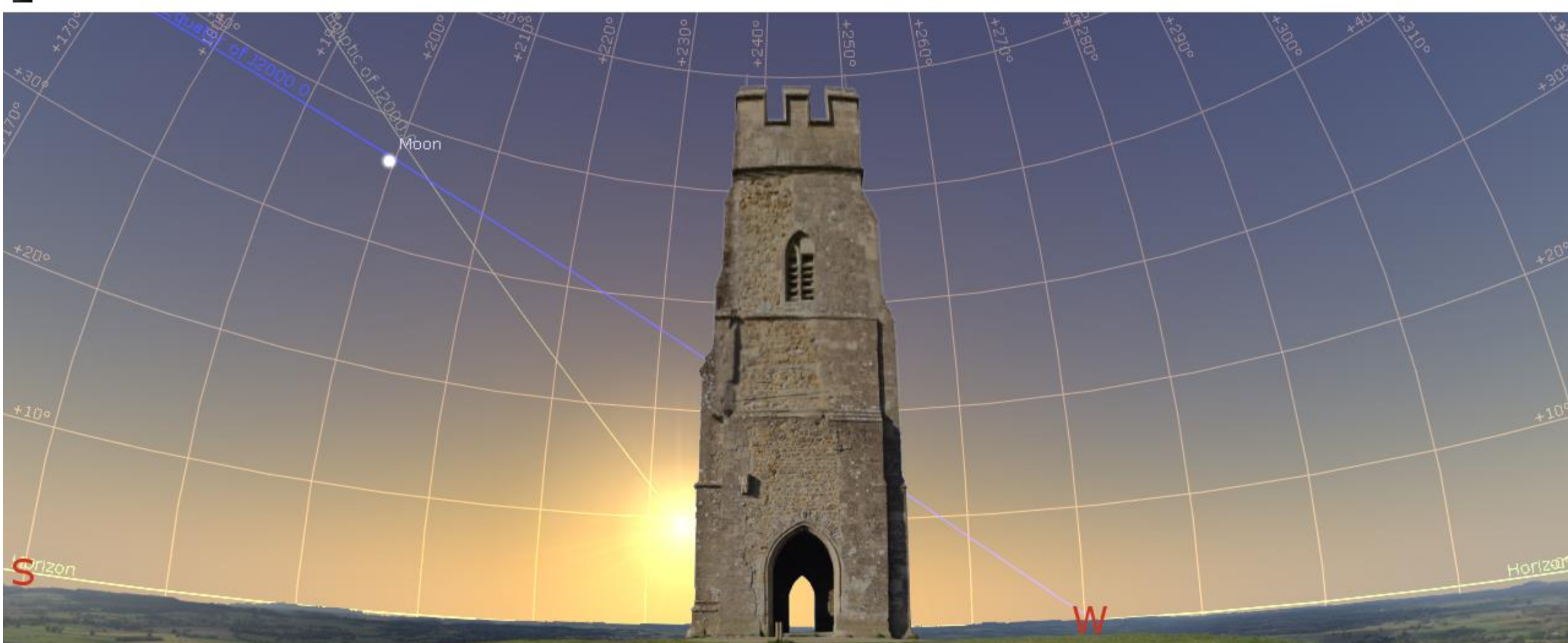


Reference Tables and Graphs - Fabio Silva

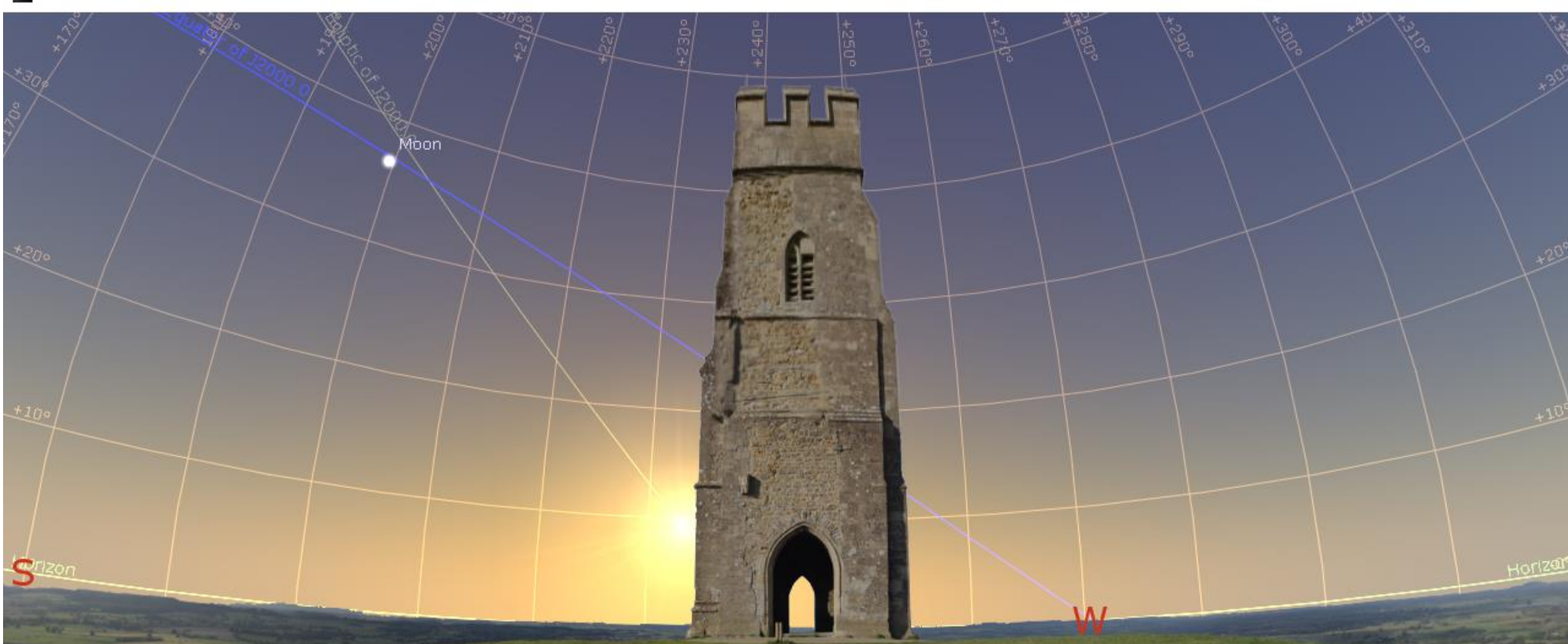
Instruments

Solar Declination Table

##	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
## 1	-23.03	-17.21	-7.36	4.77	15.25	22.13	23.07	17.87	8.07	-3.41	-14.61	-21.89
## 2	-22.95	-16.93	-6.98	5.15	15.55	22.26	22.99	17.61	7.70	-3.80	-14.93	-22.04
## 3	-22.86	-16.64	-6.60	5.53	15.85	22.38	22.91	17.35	7.33	-4.19	-15.24	-22.18
## 4	-22.76	-16.34	-6.21	5.92	16.13	22.50	22.82	17.08	6.96	-4.57	-15.55	-22.31
## 5	-22.65	-16.04	-5.82	6.30	16.42	22.61	22.73	16.81	6.59	-4.96	-15.85	-22.44
## 6	-22.54	-15.74	-5.44	6.67	16.70	22.71	22.63	16.53	6.22	-5.34	-16.15	-22.56
## 7	-22.42	-15.43	-5.05	7.05	16.98	22.81	22.52	16.25	5.85	-5.72	-16.45	-22.67
## 8	-22.29	-15.12	-4.66	7.42	17.25	22.90	22.40	15.97	5.47	-6.10	-16.74	-22.77
## 9	-22.16	-14.80	-4.27	7.80	17.51	22.98	22.28	15.68	5.09	-6.48	-17.02	-22.87
## 10	-22.01	-14.48	-3.87	8.16	17.77	23.05	22.16	15.39	4.71	-6.86	-17.30	-22.96
## 11	-21.86	-14.15	-3.48	8.53	18.03	23.12	22.02	15.09	4.33	-7.24	-17.58	-23.04
## 12	-21.71	-13.83	-3.09	8.90	18.28	23.19	21.88	14.79	3.95	-7.62	-17.85	-23.12
## 13	-21.54	-13.49	-2.69	9.26	18.53	23.24	21.74	14.49	3.57	-7.99	-18.11	-23.18
## 14	-21.37	-13.16	-2.30	9.62	18.77	23.29	21.59	14.18	3.19	-8.36	-18.37	-23.24
## 15	-21.19	-12.82	-1.90	9.98	19.00	23.33	21.43	13.87	2.80	-8.73	-18.63	-23.29
## 16	-21.01	-12.47	-1.51	10.33	19.23	23.37	21.26	13.55	2.42	-9.10	-18.88	-23.34
## 17	-20.82	-12.12	-1.11	10.68	19.46	23.39	21.09	13.23	2.03	-9.46	-19.12	-23.37
## 18	-20.62	-11.77	-0.72	11.03	19.68	23.42	20.92	12.91	1.64	-9.83	-19.36	-23.40
## 19	-20.42	-11.42	-0.32	11.38	19.89	23.43	20.74	12.58	1.26	-10.19	-19.59	-23.42
## 20	-20.21	-11.06	0.07	11.72	20.10	23.44	20.55	12.25	0.87	-10.55	-19.82	-23.43
## 21	-19.99	-10.71	0.47	12.06	20.30	23.44	20.35	11.92	0.48	-10.90	-20.04	-23.44
## 22	-19.77	-10.34	0.86	12.39	20.50	23.43	20.16	11.58	0.09	-11.25	-20.25	-23.43
## 23	-19.54	-9.98	1.26	12.73	20.69	23.42	19.95	11.24	-0.30	-11.61	-20.46	-23.42
## 24	-19.30	-9.61	1.65	13.05	20.87	23.40	19.74	10.90	-0.69	-11.95	-20.66	-23.40
## 25	-19.06	-9.24	2.04	13.38	21.05	23.37	19.52	10.56	-1.08	-12.30	-20.86	-23.38
## 26	-18.81	-8.87	2.43	13.70	21.22	23.34	19.30	10.21	-1.47	-12.64	-21.05	-23.34
## 27	-18.56	-8.50	2.83	14.02	21.39	23.30	19.08	9.86	-1.86	-12.98	-21.23	-23.30
## 28	-18.30	-8.12	3.22	14.33	21.55	23.25	18.84	9.50	-2.25	-13.31	-21.40	-23.25
## 29	-18.04	-7.74	3.61	14.64	21.71	23.19	18.61	9.15	-2.64	-13.64	-21.57	-23.19
## 30	-17.77	NA	3.99	14.95	21.85	23.13	18.37	8.79	-3.03	-13.97	-21.73	-23.13
## 31	-17.49	NA	4.38	NA	22.00	NA	18.12	8.43	NA	-14.29	NA	-23.05



We can measure the azimuth and altitude of the opening of the door of St Michael's Church on Glastonbury Tor. With that information we can calculate the declination that this would represent –We can then look at a table of the sun's declination and discover what date/s in the year the sun will SET shining through the doorway.



After measuring the azimuth, converting to TRUE azimuth, and measuring the altitude from our point of view you would find that the declination of the door was 14° South $30'$ or -14.5 .

Solar Declination Table

Declination of
Church Arch -14.5

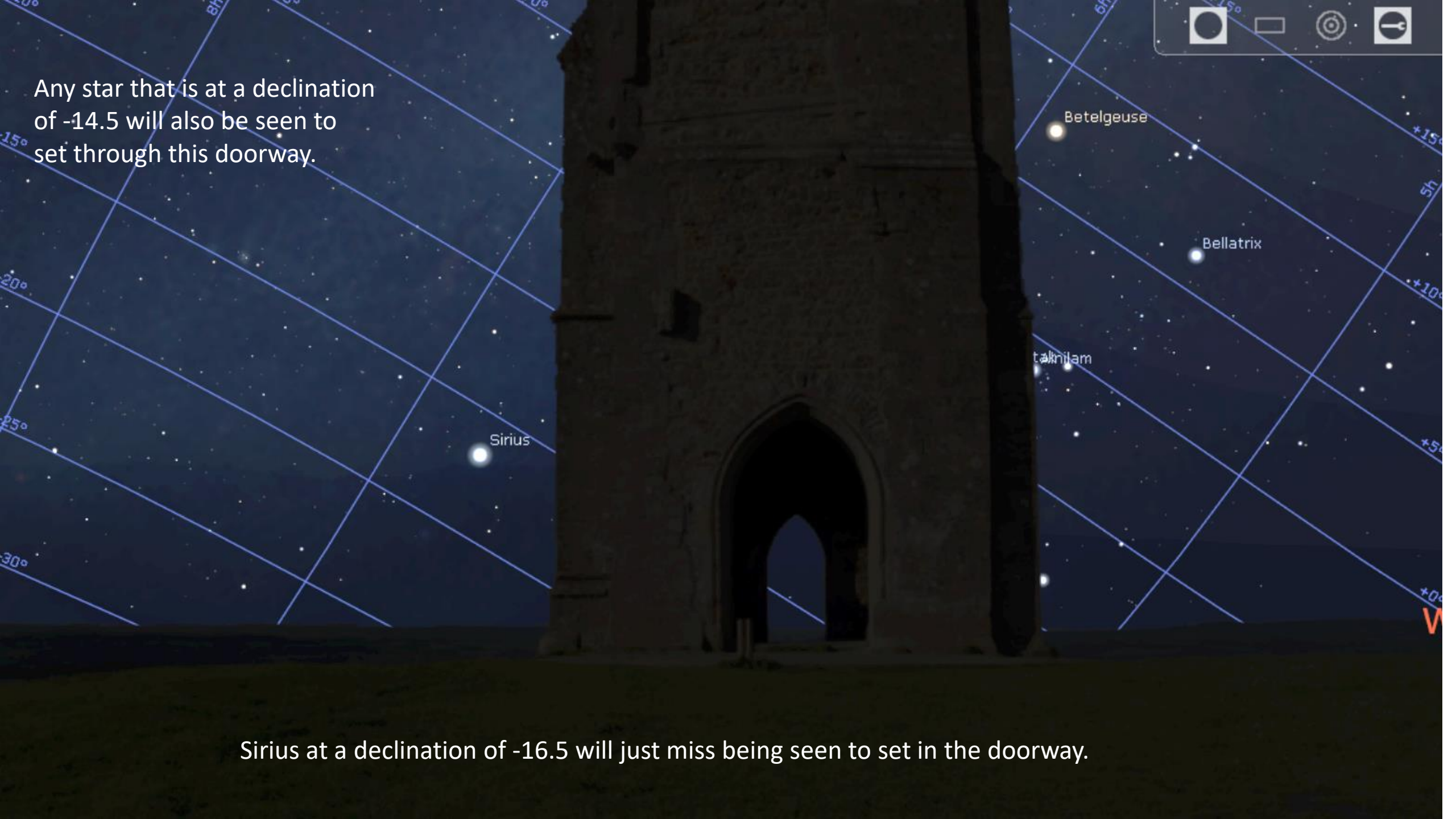
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## 3	-22.86	-16.64	-6.60	5.53	15.85	22.38	22.91	17.35	7.33	-4.19	-15.24	-22.18
## 4	-22.76	-16.34	-6.21	5.92	16.13	22.50	22.82	17.08	6.96	-4.57	-15.55	-22.31
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## 6	-22.54	-15.74	-5.44	6.67	16.70	22.71	22.63	16.53	6.22	-5.34	-16.15	-22.56
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## 9	-22.16	-14.80	-4.27	7.80	17.51	22.98	22.28	15.68	5.09	-6.48	-17.02	-22.87
## 10	-22.01	-14.48	-3.87	8.16	17.77	23.05	22.16	15.39	4.71	-6.86	-17.30	-22.96
## 11	-21.86	-14.15	-3.48	8.53	18.03	23.12	22.02	15.09	4.33	-7.24	-17.58	-23.04
## 12	-21.71	-13.83	-3.09	8.90	18.28	23.19	21.88	14.79	3.95	-7.62	-17.85	-23.12
## 13	-21.54	-13.49	-2.69	9.26	18.53	23.24	21.74	14.49	3.57	-7.99	-18.11	-23.18
## 14	-21.37	-13.16	-2.30	9.62	18.77	23.29	21.59	14.18	3.19	-8.36	-18.37	-23.24
## 15	-21.19	-12.82	-1.90	9.98	19.00	23.33	21.43	13.87	2.80	-8.73	-18.63	-23.29
## 16	-21.01	-12.47	-1.51	10.33	19.23	23.37	21.26	13.55	2.42	-9.10	-18.88	-23.34
## 17	-20.82	-12.12	-1.11	10.68	19.46	23.39	21.09	13.23	2.03	-9.46	-19.12	-23.37
## 18	-20.62	-11.77	-0.72	11.03	19.68	23.42	20.92	12.91	1.64	-9.83	-19.36	-23.40
## 19	-20.42	-11.42	-0.32	11.38	19.89	23.43	20.74	12.58	1.26	-10.19	-19.59	-23.42
## 20	-20.21	-11.06	0.07	11.72	20.10	23.44	20.55	12.25	0.87	-10.55	-19.82	-23.43
## 21	-19.99	-10.71	0.47	12.06	20.30	23.44	20.35	11.92	0.48	-10.90	-20.04	-23.44
## 22	-19.77	-10.34	0.86	12.39	20.50	23.43	20.16	11.58	0.09	-11.25	-20.25	-23.43
## 23	-19.54	-9.98	1.26	12.73	20.69	23.42	19.95	11.24	-0.30	-11.61	-20.46	-23.42
## 24	-19.30	-9.61	1.65	13.05	20.87	23.40	19.74	10.90	-0.69	-11.95	-20.66	-23.40
## 25	-19.06	-9.24	2.04	13.38	21.05	23.37	19.52	10.56	-1.08	-12.30	-20.86	-23.38
## 26	-18.81	-8.87	2.43	13.70	21.22	23.34	19.30	10.21	-1.47	-12.64	-21.05	-23.34
## 27	-18.56	-8.50	2.83	14.02	21.39	23.30	19.08	9.86	-1.86	-12.98	-21.23	-23.30
## 28	-18.30	-8.12	3.22	14.33	21.55	23.25	18.84	9.50	-2.25	-13.31	-21.40	-23.25
## 29	-18.04	-7.74	3.61	14.64	21.71	23.19	18.61	9.15	-2.64	-13.64	-21.57	-23.19
## 30	-17.77	NA	3.99	14.95	21.85	23.13	18.37	8.79	-3.03	-13.97	-21.73	-23.13
## 31	-17.49	NA	4.38	NA	22.00	NA	18.12	8.43	NA	-14.29	NA	-23.05



The sun when it is at a declination of 14° South $30'$... or -14.5 - which is the 8th and 9th February or the end of Oct beginning of Nov the Sun will set directly through this doorway.
Also any other celestial object. For example whenever the Moon sets and it is at a declination of -14.5 it will set in this doorway.

Stars also have declination and RA. Thus knowing the declination of the doorway means we can simple look up what stars have that same declination to find which stars will set at that particular azimuth .

Altair	297°55'	+08°55'
Ankaa	006°47'	-42°13'
Antares	247°37'	-26°28'
Arcturus	214°07'	+19°05'
Bellatrix	081°32'	+06°22'
Betelgeuse	089°02'	+07°24'
Canopus	096°06'	-52°43'
Capella	079°30'	+46°01'
Capulus	035°04'	+57°14'
Castor	113°56'	+31°51'
Deneb Adige	310°30'	+45°21'
Deneb Algedi	327°00'	-16°03'
Denebola	177°30'	+14°28'
Diadem	197°43'	+17°26'
Dubhe	166°13'	+61°39'
El Nath	081°52'	+28°37'
Facies	279°22'	-23°53'



Any star that is at a declination
of -14.5 will also be seen to
set through this doorway.

Sirius at a declination of -16.5 will just miss being seen to set in the doorway.

If you are going to use measurement in your assignment then make sure you are comfortable with all the material in the TOOLS section of Moodle.



Tools in Moodle

- The **main spreadsheet** for all your calculations – download this and get familiar with it.
- **Reference Tables and Graphs** - this is where the solar declination table is located.
- **The Instrument Section** – VIP if you are going to or are able to use instruments and to ground based field work.
- Digital Tools - the magnetic declination calculations
 - How to use Google Earth
 - Heywhatsthat
 - Example of doing a virtual project.



Welcome to Horizon
Astronomy!

By understanding these
tools and techniques
then you will be able to
determine, for any
structure when any
celestial body will
related to it in any way!

