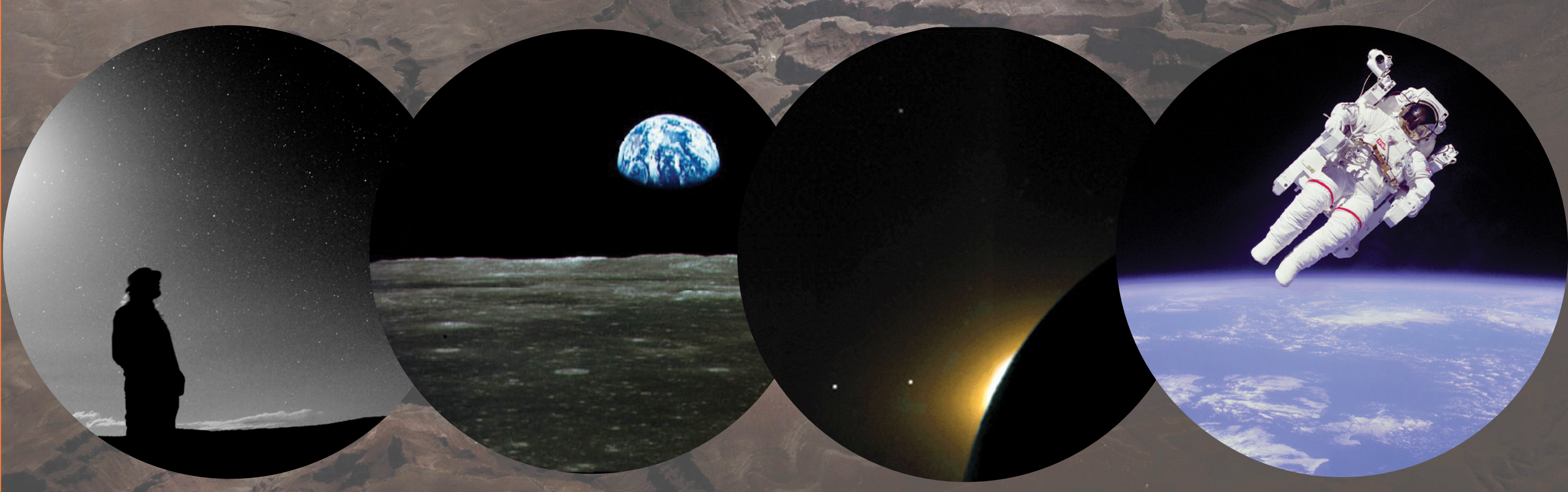
STAR GAZING

WEEK ONE

Introduction



Haritina is a life scientist who is also trained in public relations, international security and outreach. She loves to travel and share her passion about astronomy, astrobiology and space.

Haritina believes that scientific education is a gatekeeper of peace, making humankind a better place for all of us. For that reason she became a StarryTeller.

In 2009 she was awarded the International Year of Astronomy Certificate of Appreciation for her outstanding contribution to the promotion of the Year in New Zealand. She also produced New Zealand's first astrophotography magazine: The Milky Way Kiwi.

Haritina's stellar job of planetarian at Carter Observatory, Wellington provides her with the best facility on Earth to give lectures about the night sky and to show the wonders of the Universe through Carter's historic time-machines.

Haritina is actively involved in the Mars Desert Research Station (MDRS) analog Mars exploration programme and is part of the MDRS Astronomy Outreach Crew. The research station is in Utah, USA.

Haritina would love to see humanity become a space-faring civilisation. Also she would love to see that more people on Earth discover who they really are and follow their dreams; their real dreams that should come true even if it would take stars to wish upon.

Travelling from one side of Earth to the other, she is now convinced that culture is merely a set of instructions handed down from our ancestors to ensure our best survival. That culture is shaped merely by geographical constraints and it's not worth going to war over. The study of stars can help decipher culture. At the same time, it can be a catalyst for the future global society, in which knowledge is shared and progress attained by working together. Because otherwise extinction is forever.

But more than anything Haritina wishes that people realize we are really made of stardust.

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STAR GAZING

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Spacehead

Front cover image: The Grand Canyon from Space

Copyright: Travis Odgers

Back cover image: Orion nebula

Located 1,500 light years away, along our spiral arm of the Milky Way, the Orion nebula is located in the middle of the Sword region of the constellation Orion the Hunter.

Source: NASA, C.R.O.

Contents

WEEK ONE

Thanks

Thank you to George Jones, Alan Gilmore and Peter Detterline for their stellar help and suggestions!

Terminology

For some of you, there may be many new words and phrases in this course. If you're not sure what something means, you might want to check an online glossary.

If you're still confused, feel free to ask me or your classmates in the forum.

WEEK ONE

Introduction

Welcome to the STARGAZING online course book. In this first chapter, we'll introduce you to some of the key concepts and vocabulary useful for stargazing. We won't spend much time on where to find heavenly bodies in the night sky (will leave that for later). Instead we'll talk about where we are in the Universe, how objects move in the sky, and how you might track and record what you notice from your observations.

Our Solar System formed 4.5 billion years ago in a region of clouds of gas and dust. These were the remnants from earlier stars that had already passed through their full lifetimes since the Universe was formed over 13 billion years ago.

A nearby supernova blast triggered the formation of a dense cloud called a pre-solar nebula. The immense pressure at the heart of the cloud ignited the Sun. The rest of the cloud clumped to form planets, asteroids and comets. This is what we today call the Solar System, our home.

We were born of stars. But not only did they give us life, as true parents they also taught us how to survive.

> “
> *Somewhere there is something incredible waiting to be known...'*
>
> **CARL SAGAN**

Human civilization as we know it now was forged through two major experiences: migration and agriculture. Taking directions from sensing the time by the stars kept us alive.

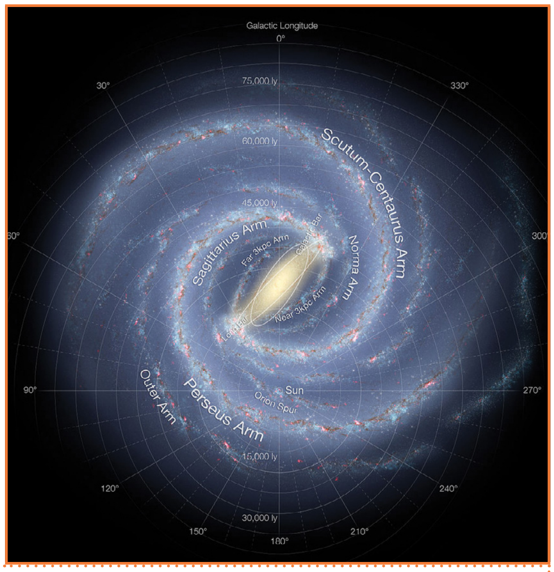
Everything that is related to the advanced sciences today is a direct result of our striving to understand the stars: mathematics, physics, navigation... Yet after thousands of years amongst the stars we are now getting disconnected from them as we switch on the lights at night in our cities.

Knowing about the stardust of which we are made, I pledged long ago that I would keep watch over their descendants – the stars that twinkle in our night skies, for as long as I can.

This is how STARGAZING was born.

Distances in Astronomy

The Hubble Ultra Deep Field.



Artist's impression of the Milky Way as seen from above. Source: *Wikipedia.*

Where are we?

We could say the Universe is huge, but that would be an understatement.

The picture above is called the 'Ultra Deep Field' and was taken by the Hubble Space Telescope. Most of the objects in this picture are galaxies.

In the Milky Way

Our own galaxy is called the Milky Way. It is our home amongst billions of other galaxies making up the Universe.

The Milky Way is a barred-spiral galaxy about 100,000 light years in diameter that looks like two saucers placed face-to-face. The Sun is about two thirds of the way out from the centre.

Can you find the Sun in this view? It's near the part of the picture marked 'Orion Arm'.

Part of the Solar System

Inside the Milky Way, a star formed 4.5 billion years ago. That star is now called the Sun, Te Ra, Soarele, Die Sohne, Amaterasu and many other names, in different languages.

The Sun is at the centre of our Solar System.

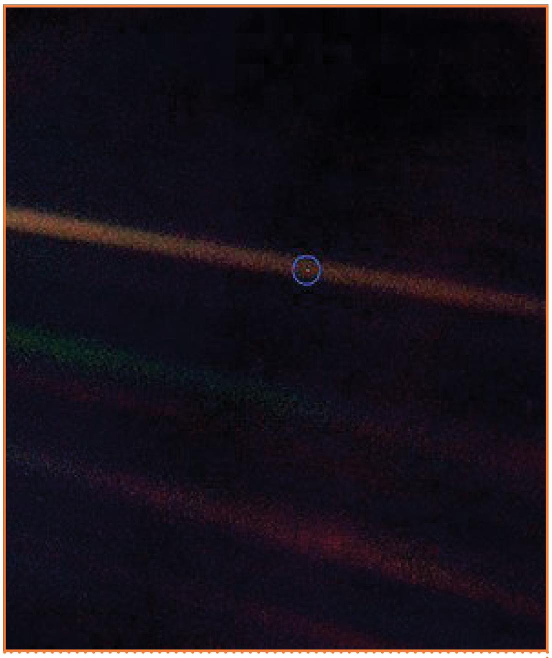
Suspended in the immensity of space, we are to be found on a tiny planet of our Solar System, a Pale Blue Dot.

The Pale Blue Dot is our home, and the only place we know to harbour life.

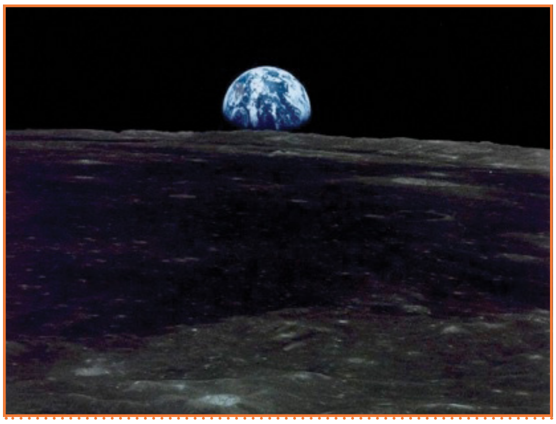
Many photographs have been taken of our Pale Blue Dot from spacecraft, including Voyager and Cassini from long distances

Photographs of our planet have also been taken from our Moon, the furthest that mankind has ventured so far.

Only in the last half-century have humans been able to reach out and touch the Moon. Even so, the progress of humankind is impressive, given that we started our journey as a race only about a couple of hundred thousand years ago.



Earth – the 'Pale Blue Dot'. Picture taken by Voyager 1 in 1990.



Earth from the Moon. This was one of the pictures that raised awareness of Earth as a liferaft in space, carrying all life of which we are aware, and making people concerned that it might be fragile.

Looking back to the stars

Please take a deep breath...and we will look back at the Universe.

The best place to do this, if you ask me, is in the Southern Hemisphere, anywhere on the latitudes of southern Australia and New Zealand. These latitudes are the only places on Earth where the center of our galaxy, the Milky Way, climbs to the top of the skies, so we can see it above our heads. This is unique to this part of the world. So yes, here we do have window seats for looking at the stars! I also think that

Milky Way in the morning night sky.
Source: *Wikipedia.*

seeing the Southern Hemisphere's sky should be included in the 100 things to do before you die. It's that spectacular!

The Milky Way contains about 400 billion stars, which is roughly four times the number of neurons in our brains. Carl Sagan, one of the people who inspired me the most, said this first in his Cosmos TV series[1]. I love to think about that and ponder about the universe that we, people, have inside ourselves.

On the other hand, I always felt that counting stars is like counting sheep, who can stay awake to count them all? Yet there are rumours saying that with the naked eye one can see about 2,000 to 4,000 stars on a clear night[2].

New Zealand could be one of the best places in the world to view the heavens, as long as there is no 'Long White Cloud' in the way[3]. Due to Earth's tilt, we happen to have the best view of the central region of the Milky Way, teeming with billions of stars!

1 An article in Scientific American March 2013, p. 28 confirms: 100 billion neurons in our brains.
2 Nowadays we can rely on computers to do star-counting, this is how we extrapolated the figure of 400,000,000,000 stars for the Milky Way.

3 The country of the long white cloud – Aotearoa, the Māori name for New Zealand.

Yours truly and the Andromeda Galaxy – marked with a green loop. January 2011 at the Mars Desert Research Station in Utah.

Andromeda galaxy photographed through a ground-based telescope.
Credit: Adam Evans.

Seeing the furthest light

The furthest object we can see with the naked eye is the Andromeda Galaxy, also known as M31, about two and a half million light years from us.

About distances in space

It takes light about 2.5 million years to reach our eyes coming from Andromeda, and light travels with the fastest possible speed, about 300,000 km/sec. You could try to calculate the distance to it in kilometres. Have fun with that![4]

For stargazing purposes we don't measure the distance from Earth to stars or from one star to another. We measure their angles, which makes life so much easier!

4 It's not that hard. There are about 31,000,000 seconds in a year. So the distance to the Andromeda Galaxy is about 300,000 x 31,000,000 x 2,500,000 km.

Some Key Terminology

Let's cover some key words and phrases you'll need to know if you want to speak or read about the position of objects in the night sky.

The Celestial Sphere

Celestial sphere is the best analogy that we found to explain how we see the stars at night.

The convention is that each of us, at any given moment, is at the center of that sphere. In other words, you are the center of the Universe! And if anyone tells you otherwise, please send them to me!

Of course, there is a difference between what we think we see with our human eyes (1), how we try to explain it (2), and what is truly out there (3).

(1) What I first saw in the sky on starry moonless nights was something that looked like a rounded ceiling, painted with random dots of light, which covered Earth like a lid. Sounds familiar?

How many times did you look at the sky and thought, wow this 3D field of stars is really amazing, star trek-ian, I can so see the stars suspended in the fabric of space!? It's a rhetorical question!

(2) The Celestial Sphere concept is a very convenient way of mapping the stars as we look at them from Earth, exactly as we do with places on Earth. We pretend that Earth is at the center of the celestial sphere.

Earth has poles, Equator and a First Meridian. Modern navigation uses the Global Positioning System (GPS), which tells us the latitude and longitude of any given place, which is how far away the place is from the Equator and the First Meridian.

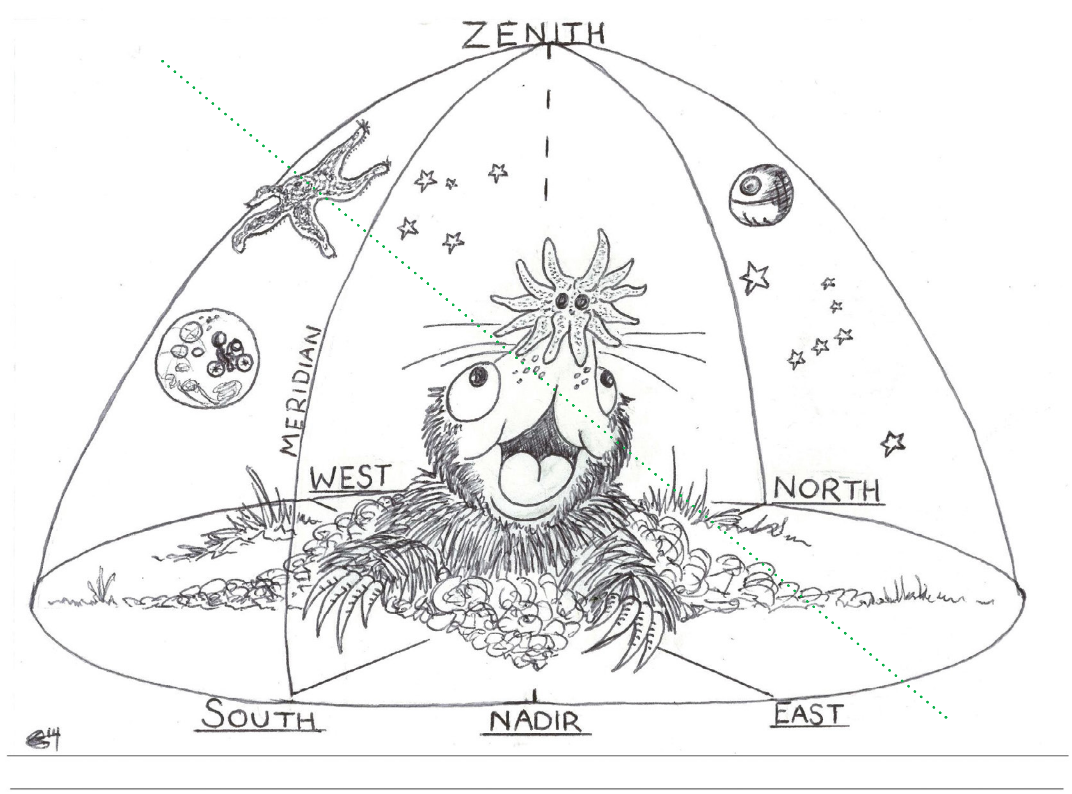
The celestial sphere has poles, equator and meridian, which are the projections of those we have on Earth, and has a radius of any length we wish to give it.

The convention is that the stars are dots of light stuck on the celestial sphere. The celestial equivalent of latitude is Declination and the equivalent of longitude is Right Ascension. The entire sphere looks like it's slowly drifting westwards as the Earth is rotating every day.

Observed from Earth, stars revolve once every 23 hours and 56 minutes[5].

Please note that the GPS coordinates do not include elevation. In other words, standing on the ground floor of a building, or standing 100 floors up will not change your latitude and

5 You will see in w 3, 'Planes, planets and points of view' why that is.



Star-nosed mole.
Illustrator: Eugene Georgiades, marine scientist extraordinaire.

longitude. Stars lie in space at different distances yet their projections can all be jam-packed on the surface of a sphere, which is why we see the Milky Way like a band. The two concepts are similar.

Stars take thousands of years to visibly shift their position in the night sky. Not that they don't move, they move all the time. They orbit around the galaxy, around each other, get eaten by black holes etc. But humans don't live long enough to see that happening so our constellations are almost the same as they were a few thousand years ago. I checked that with planetarium software. Patterns of stars become unrecognizable about every 4000 years.

(3) Astronomers will tell you that the Universe is unfolding in every direction. But nobody really knows how far, where it ends, and other interesting things like that. Nevertheless, efforts are made to understand this.

Back to stargazing. It makes no difference if we know the exact distance to the stars (although that may come in handy later on if you are thinking of a career in the space industry). But it pays to remember where things are. Once you've got past stargazing and be able to use telescopes to find objects in the sky, you will be amazed of what you'll find out there!

So instead of using distances we use the angles between objects in the sky, to figure out where they are. In order to do that, we need a point of origin. And that is… YOU!

Since some of us think deep inside that we are still the centre of the Universe (well, I do), I think it is quite ok to use ourselves as points of origin. Technically we always are at the centre of the celestial sphere, no matter where we are on Earth, because the Universe is so huge. There is no physical meaning to the 'end' of the Universe. What we see from Earth is only our own bubble; we call that the 'Observable Universe'.

Video of the Celestial Sphere

Have a look at the video trailer of Tale of the Stars: **Eternal Shine (English version) by Kagaya Studio.**

This is a trailer of the Japanese artist Kagaya's planetarium show. From minute 01:15 to 01:20 there is a very good representation of the celestial sphere. Earth is located in the middle of the sphere.

Angular distances

In all natural sciences, the angular distance (or angular separation) is the size of the angle between two objects (stars) – see 'I need a hand!' below.

On Earth we can pinpoint a location with the help of latitude and longitude (measured in degrees or radians as well as hours, minutes and seconds).

In the same, way we can pinpoint where a star lies in the sky using Declination (Dec.) and Right Ascension (RA).

Zenith and Nadir

Look up in the direction pointing directly above your head. That is 'Zenith'.

To locate islands in the Pacific Ocean, the Polynesian navigators had to memorize which star they could see at Zenith for each particular island. New Zealand's Zenith constellation is 'Te Matau a Maui' – the fishing hook of Maui.

Zenith is straight overhead, 90 degrees up from the horizontal. Nadir is the opposite of Zenith, straight down, 90 degrees below the horizontal.

Meridian

The meridian is an imaginary circle in the sky that stretches from the cardinal point North to the cardinal point South passing through Zenith and Nadir.
In this picture we can see the upper meridian. You can imagine the lower meridian on the other side of Earth.

The meridian is fixed to the local horizon and is a very important (albeit imaginary) arch. When the Sun crosses the meridian we say that the Sun is at its highest position in the sky.

Circumpolar stars are the stars we always see in the sky at a particular latitude and they always move in circles around the poles – hence circumpolar (see chapter 3, Constellations). They also cross the meridian above and below the celestial pole. When they cross it below we say that these stars are at 'lower culmination', their lowest point in the sky.

We call the midday Sun the 'Sun at meridian'.

The word 'meridian' comes from 'meridies' which means 'midday' and 'South' in Latin, 'meridional' – southern. That is because in the Northern Hemisphere the Sun goes through the southern part of the sky – from left to right, and south is the sunniest side of the world there. Of course, in the Southern Hemisphere, the Sun travels the skies through the Northern side…, from right to left! So here everyone wants to buy houses which look North, to have lots of Sun, of course! Confused? I believe you, it's not 'just jet lag'.

At night the Polynesians used pairs of stars that lined up with the meridian to determine the North (Raki) – South (Tonga) directions.

Measuring Positions

How to measure

Hold your hand at arm's length, and let's estimate angles using the following techniques.

The width of your little finger at arm's length is 1 degree. This is twice as big as the Full Moon or the Sun. (Both are 0.5 degrees in diameter.)

Stretch your thumb and little finger as far from each other as you can. The span from tip to tip is about 20 degrees.

Do the same with your index finger and little finger. The span is 15 degrees.

Clench your fist at arm's length and hold it with the back of your hand facing you. The width is 10 degrees.

Hold your three middle fingers together. They span about 5 degrees.

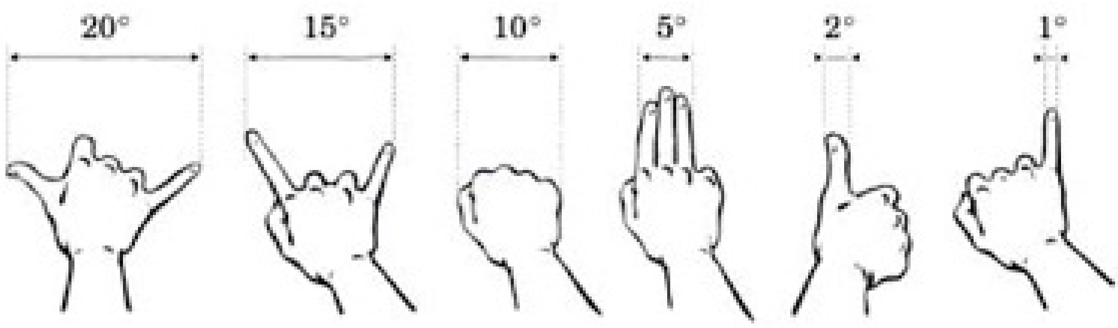
I need a hand!

The good news about measuring angles in the sky rather than (trillions of) kilometres, is that, for stargazing literally we will only need a hand! Both the position of objects on the celestial sphere and the time to when they set can be easily approximated if we use our hand and fingers.

Warning!

NEVER LOOK AT THE SUN WITH THE NAKED EYE, WITHOUT PROPER EQUIPMENT!

You will get retina burns that are not reversible and you will not even feel it! Read up about eye safety during solar eclipses and please observe the Sun safely.



How to estimate how long it will take for any celestial object to set, from any given location

Let's estimate how long it takes for the Sun to move across the sky and set.

This is very easy to calculate if you remember just a few things:

1. The path of the stars, Sun and Moon in the sky is either circular or it makes an arch from horizon to horizon. The rest of the arch is below the horizon and completes a circle.
2. You can either measure a circle in degrees (we also use degrees for Declination and latitude) or in hours (we use hours to measure Right Ascension and longitude).

It takes 360 degrees or 24 hours to make a full circle.

360 degrees/24 hours = 15 degrees for one hour of time.

60 minutes in an hour.

So 1 degree takes 60/15 = 4 minutes (the width of your little finger at arm's length).

Now use your fingers, fist etc (as you have learned above) to see how many times you can fit them from where the Sun lies in the sky to the position where the Sun would set, following along the arch that makes the Sun's path. For each outstretched hand add 80 minutes, for each fist add 40 minutes and each little finger add 4 minutes.

That's the easiest way to estimate the Sun's setting time in the woods providing that:

- you don't have any network connection to reach Google or
- you left your phone somewhere else and you must know how long it will take until you will
  - get eaten by the wild animals of the night (Australia) or
  - scared of the dark (New Zealand – we only have kiwis roaming free at night here and they avoid people most of the time).

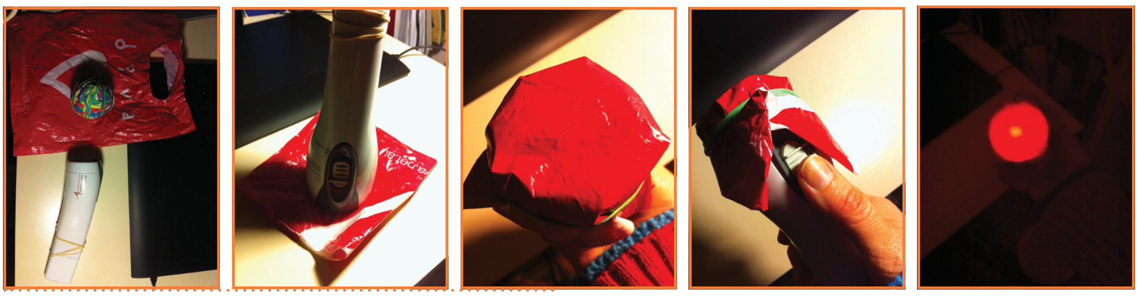
You can do the same for finding the setting time for the Moon or any other star, given that you can estimate the angle that particular star will make on the celestial sphere.

Stargazer's Kit

'Professional' stargazing requires a basic kit to start with. You will need:

1. An Observation Diary – either the one you can download from the course home page or one you make up for yourself. I suggest you keep a hard copy handy during the night so that you can scribble your findings in it. See below.
2. A pencil (not a pen – they tend to stop writing in the middle of the night). A space pen is good too. They sell them at the Carter Observatory in Wellington or at any of the NASA shops, whichever you can reach first. It writes no matter the weather, position or absence/ presence of a gravity field.
3. A red torch – to protect the dark adaptation of your eyes during an observing session you must construct a red torch. You need a low-light torch and a piece of red plastic (for example, from a plastic bag) stuck on the top of it.
4. Warm clothes. You do not move around very much whilst observing and you will get cold very quickly if you are not dressed properly. Get some gloves too, even if you think it's ridiculous because it is summertime. Just trust me.
5. Something to nibble and drink. I always indulge myself in hot chocolate, and lately I discovered chocolate tea... (from T2, it's called 'cocoa loco'). Really it felt like a 3rd degree encounter!
6. If you could grab a pair of binoculars, it would be great! However this is not a must if you don't have them. 10x50 are the most popular size. Make sure you add a tripod to them as well if you can.
7. Maps – Ideally you should have some maps of the sky, will worry about those later starting from week four, when we talk about constellations.

Now all you have left to do for our introductory lesson is to get your Observation Diary sorted.



Making a red torch.

Equipment: A word about telescopes, binoculars and planispheres

Many astronomy enthusiasts will buy a telescope and, without knowing their way around the sky, they will use it to look at the stars.

Because we can only see a small field of view through a telescope (about 1-2 degrees compared with 180 degrees for human eyes) often they will end up seeing just a dark patch of the sky.

Before thinking of buying any astronomical instrument, I recommend you familiarize yourself with the night sky and learn the most important constellations and sky objects. This is how I started too.

My personal advice to the progression of astronomical instruments and aids in your life is as follows:

Planisphere – binoculars – telescope

I have been practicing astronomy for many years and I have not owned a telescope until October 2013, when I was gifted one. (Thank you PD for Te Hiko!) I always had access to professional instruments though. And I do have an impressive collection of astronomical binoculars.

As soon as we talk about the constellations, you may like to buy (or start using) a planisphere. It is a sophisticated celestial map that shows which constellations are visible in the sky at a specific time and place. A planisphere is a great orientation tool as the sky does change from month to month.

Starting an Observation Diary

You could start by looking at this Observation Diary.

Your forum task for this week is to start using the Observation Diary provided and upload that for me to see.

Astronomers since antiquity have kept detailed observing logs every time they examined astronomical objects.

Your Observation Diary will be your workbook. If you write it well it will be useful for years to come.

Note: There are no good or bad diaries. I prefer the ones that have the information structured as it's easy to get back to read the notes.

An Observation Diary is a great tool for learning your way around the sky and keeping track of it. The celestial sphere – the sky – slowly shifts every day and so the stars from any given constellation rise every day four minutes earlier (we will talk about why that is in chapter 3 – Planes, planets and points of view). For that reason, the sky after sunset seems visibly different from month to month. The same stars will come back to the after-dusk sky in one year's time, and the pattern repeats annually.

I felt very happy a year after I started my own stargazing journey. All I did afterwards was to review the information or add anything new I had discovered.

What else?

Draw lots of pictures! Mark the path of the Sun in the sky, the path of the Moon and draw dot-to-dot pictures of the constellation's stick figures. You only need to record once the observations you make about the constellations or the path of the Sun and Moon. They will remain constant year after year. What will change will be the sky conditions, the location of the planets, different and interesting 'visitors' in the sky such as comets or supernovae and, of course, unidentified flying objects (the other name for Venus).

Also, and very important, please record observational information on seeing, transparency and darkness, which are the qualities of the sky. 'What is that?' you may ask. That is a teaser for chapter six, so I can promise you that we will talk about them in six weeks. However I can tell you in advance that seeing, transparency and darkness are very important. Watching the dynamics of the sky in that respect can help us figure out if the quality of it is affected in any way by light pollution (will talk about that as well). Remember, the less light pollution the more stars for us to gaze. So join the revolution for dark skies, I am so looking forward to lure you to the dark side! That was the reason I wrote this course anyway!

Key data to include in your diary

Time and date

- Record start and end time and date for your observations. Write your local time and the UT (Universal Time). You can find the conversion here: http://www.timeanddate.com/worldclock/. Keeping both dates helps you identify astronomical events across the globe. Because New Zealand is among the first to change its date, most events will occur here a day ahead of everyone. To avoid the confusion, wherever you are on the globe it's a good idea to use both local and Universal Time. (It may look like I just like more work but I think it's fun to use them both. Makes me feel more like a global citizen.)
- If you observe overnight the date should be recorded as 13/14 August, indicating that you were observing on the evening of 13 August and possibly into the morning of 14 August.

VERY useful website: Heavens-Above

I suggest you start by creating an account with Heavens-Above.

This is the best website I have found to give basic information about your local latitude, longitude, rise and set times for the main celestial objects. It also has all the information you need on satellites (including passing times of the ISS) and it's a lot of fun to watch them. Just like an online almanac, it tells you what constellations are visible from your location, the local and the universal time. All this data is rocket fuel for the astronomer and you will be writing a lot of these in your Observation Diary.

Your location

Record the latitude and longitude of your observing site with as much detail as possible. (Google Maps: right click on site, click What's here?)

Other details

You should include as much detail as you can in your observation of astronomical objects. Your first task will start you off by finding:

- the relative positions of these objects in the sky;
- the direction you observed them in (e.g., N, SSE, SW, etc.);
- how high above the horizon they were (by measuring their height in degrees – use your hands!).

Your turn – have a go!

At home, choose a high reference point for your observations (porch, balcony, deck, driveway and standing or sitting).

Choose well. You want a good place from where you will be able to see most of the sky.

It would be great if you could use your camera, or a pencil and paper, to take or draw a panoramic picture of the horizon as you see it from that particular location and add it to the diary. Mark the spot in some way! Name it 'Centre of the Universe (COU)' because for you it represents exactly that. You could mark it with your favourite chair or with a hammock if you wish; anything that would hold you comfortably whilst looking at the stars or you could simply stand tall :)

All we need now is a clear night so let's look for one!

Useful website:

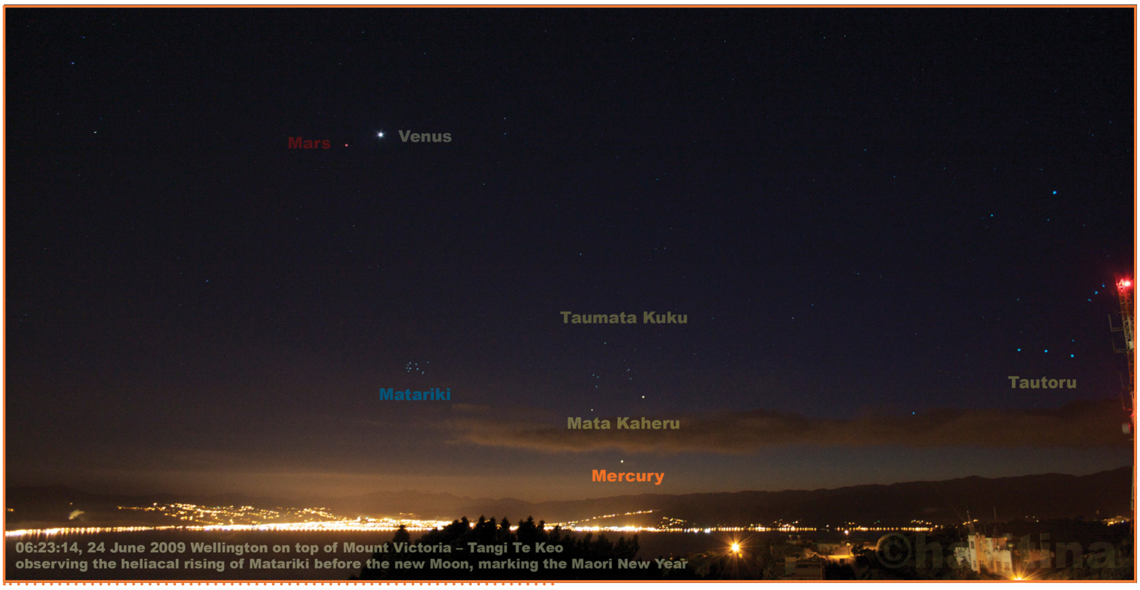
MetVUW

The best site I found in New Zealand. Good to find out how your sky will behave almost two days in advance is http://www.metvuw.com/**. The Met Office's (New Zealand Meteorological Service) 3-day forecast is also very good now. The site also features nice pictures of the sky uploaded by contributors like you or me, and good satellite imagery at** http://www.metvuw.com/satellite **which is updated often.**

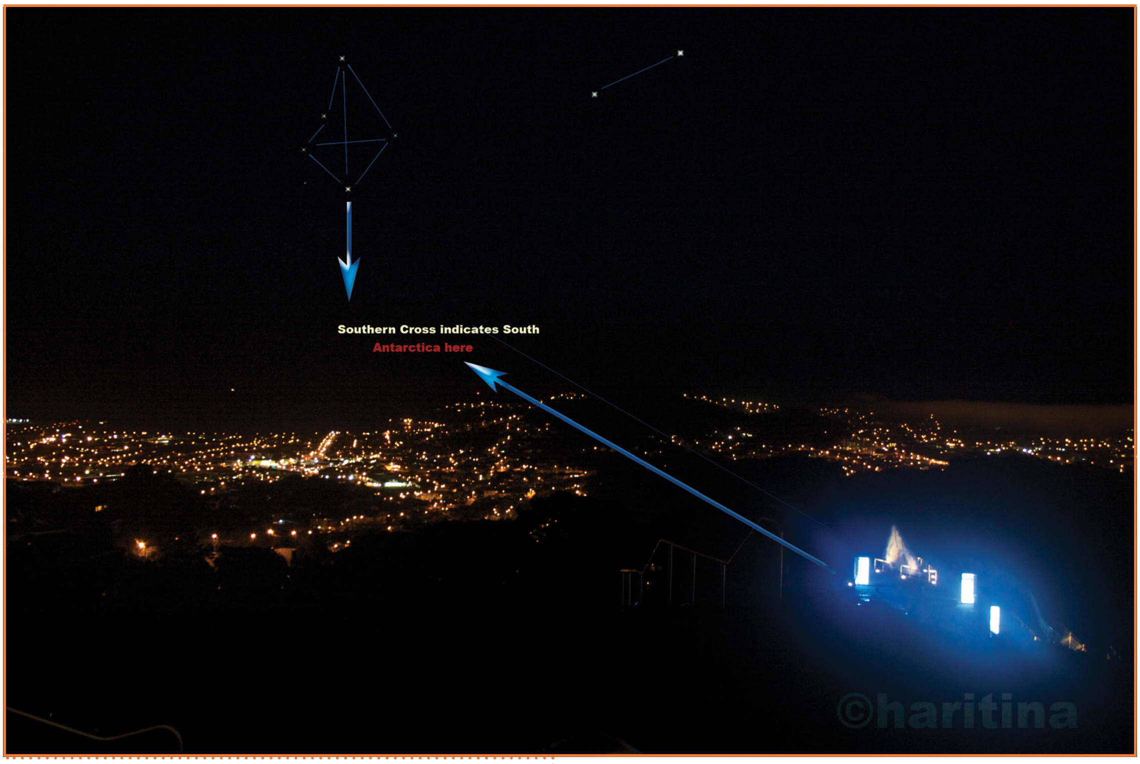
And last but not least, I know from experience that if you want clear skies it helps to start practicing the astronomer's salute on a daily basis:

Clear skies!

My 'choice' Centre of Universe as seen from top of Mount Victoria in Wellington.



Looking Northeast. Orion, being on the Equator, rises due East. Venus never gets to be due North of us in the dawn or evening sky.



Looking South.

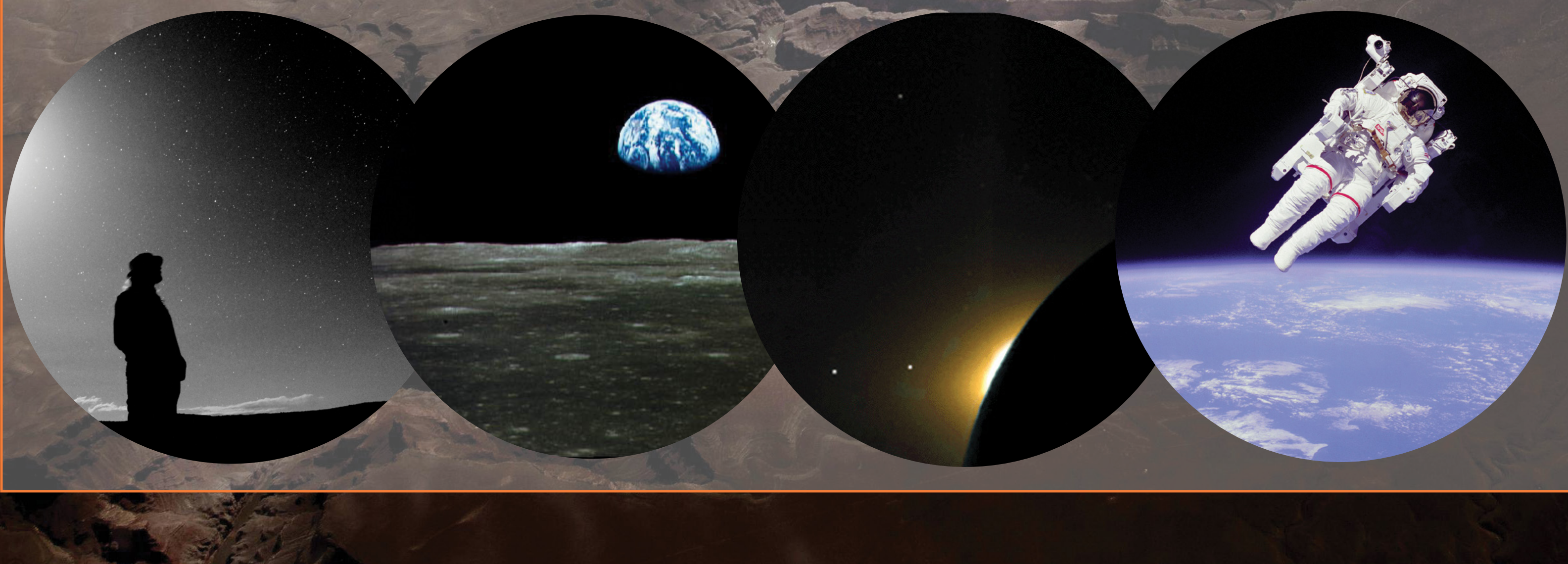
Notes

STAR GAZING

STAR GAZING

WEEK TWO

The Moon



Front cover image: The Grand Canyon from Space

Copyright: Travis Odgers

Back cover image: Orion nebula

Located 1,500 light years away, along our spiral arm of the Milky Way, the Orion nebula is located in the middle of the Sword region of the constellation Orion the Hunter.

Source: NASA, C.R.O.

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For some of you, there may be many new words and phrases in this course. If you're not sure what something means, you might want to check an online glossary.

If you're still confused, feel free to ask me or your classmates in the forum.

WEEK TWO

The Moon

Welcome to the second week of our stargazing journey.

The topic this week is the Moon.

I never really liked the Moon! It spills too much light and it's on the way to the stars. So when I heard that I should consider writing about the Moon in a STAR GAZING course, my first reaction was: 'Uh..., why?'. That's when 'they' gave me the look. You know which look… And something in the air told me that I have to go back to the drawing board to think of things I like about the Moon.

So here is some cool stuff about it:

The Moon is... so out there!

We have been to the Moon, drove on it, brought bits of it back to Earth. If you have not touched the Moon before, Carter Observatory has a piece of Moon rock on which you can try your tactile receptors (fancy for touch it).

Most cultures talk about the Moon as being a woman and I prefer to keep it that way.

Although NASA officially confirmed that it's not made of cheese, the Moon still impacts on our culture, civilisation and science.

By the time you have read the notes and completed your Week Two assignments you will be able to:

- Refresh your knowledge of cool things about the Moon;
- Recognise the phases of the Moon and memorise its rising and setting times throughout the month's quarters (easiest thing to do);
- Understand Lunar calendars;
- Understand the effects of the Moon on Earth.

The Moon (capital M[1]) is our natural satellite. A satellite is an object orbiting the Earth or another planet.

If you are familiar with Google Earth, check out Google Moon! Going through the maps you can literally feel that you are 'on the Moon'.

Why do we have a Moon, in the first place?

There are many theories on how the Moon was formed. The current favourite says that a Mars-sized planetoid hit the embryo-Earth about 30 million years after Solar System's genesis. The core of the two planetoids merged, the outer crust and mantle coalesced (formed) into what we know today as the Moon.

Who knows for sure? This is just one of the hypotheses. Fraser Cain makes here a great resume of the possible explanations. My favourite explanation, however, lies at the end of the movie 'The Fifth Element'.

1 By convention, our Moon has capital M and other planets moons are just moons.

Source: NASA's Johnson Space Centre.

And how far away is it?

The Moon is the closest planetary body to Earth. Light reflected from the Moon reaches us in over a second. Even though light travels really fast, this makes for approximately 390,000 km between us and the Moon. The distance varies because the path of the Moon is an ellipse. It took Apollo astronauts about three days to reach the Moon by rocket. If you are thinking of driving to the Moon at New Zealand's road speed limit it would take over five months.

We can see the Moon in the daytime because it's big and close enough to Earth for us to see it.

Why can I see dark areas on the Moon?

The Moon has mountains, seas (mare[2]) and scars. People called darker areas on the Moon seas, because they thought they were just that, seas. We figured out that they aren't.

The scars are left by asteroids and comets crashing into the lunar surface. Since there is no atmosphere on the Moon, the impact craters look exactly as they were a few million years ago. The most famous of all is called Tycho.

2 In Romanian, which is part of the Latin languages family, 'mare' means 'big'. My ancestors were also using this word to name the sea.

This crater is so big that it can be easily observed from Earth with the naked eye. With a good pair of binoculars it is spectacular! 'Tycho is grand!' says Sky&Telescope.

Tycho is also the name of a dog that went to the Moon in a kids' favourite planetarium show. Have a look for Tycho on the Moon on a moonlit night and let me know in the forum if you saw it!

You can help explore the Moon

Sign up for MoonZOO and you will be doing real science. The latest fashion for doing science nowadays is called citizen science. This means that anyone can contribute to the creation of scientific knowledge, even though they are not formally trained as a scientist. Standing proof is the Moon Zoo community. It has already visually classified more than three million images from NASA's Lunar Reconnaissance Orbiter (LRO).

How to take part in the MoonZOO project.

When will we go back to the Moon?

Hopefully soon. Here is what Google Lunar XPrize say: 'In case you haven't heard, the Moon is trending again…' and in a big way. Like in the glory days of the 1960s and 1970s, our big white space neighbor is enjoying the attention of lunar explorers. Only this time, they're going back to the Moon for good. The planetarium show in question has music composed by our amazing Wellingtonian, Rhian Sheehan, my favourite starry composer. I've been listening to his music since I arrived in New Zealand in 2005 and it is absolutely perfect for stargazing!

Interesting Facts About the Moon

The Moon looks upside down when you travel to the other hemisphere

If you travel to the other hemisphere at about the same latitude, say Spain, the Moon will seem upside-down. Theoretically, we would be almost upside-down compared to New Zealand. This is why we have a rabbit in the Moon in New Zealand but the European Moon looks like a face. I have spent my first months in New Zealand almost standing upside-down trying to figure out the sky (and I won!).

However, the reality is that we live on a sphere. 'Down' means towards the centre of the Earth and 'up' means away from Earth.

The Moon is leaving us

The Moon is going away from us (sigh?) about 38 mm per year. You can find out here an excellent explanation of why this happens.

The Moon rotates on its axis

That's why we can only see one side of the Moon, the so called 'near side'. The Moon is tidally locked to Earth: which means that it always keeps the same face to us. Thus, seen from another planet, the Moon would appear to rotate once a month as it circles Earth. The Moon turns around its axis in about the same time it takes to orbit the Earth. What happens if Earth became tidally locked? Earth is not yet tidally-locked to the Moon. Pluto and its moon Charon are tidally-locked.

The Moon makes tides

More precisely, the spin of Earth, the Sun and the Moon make tides. In fact the power of the Sun's gravitational field, even from so far away, is contributing half to Earth's tides. The Moon however, is the reason why the tides can get so big. Tides are the rise and fall of the sea level. Probably the most important information to know if you go fishing is when the tides occur. For me, equally important was to understand why tides occur.

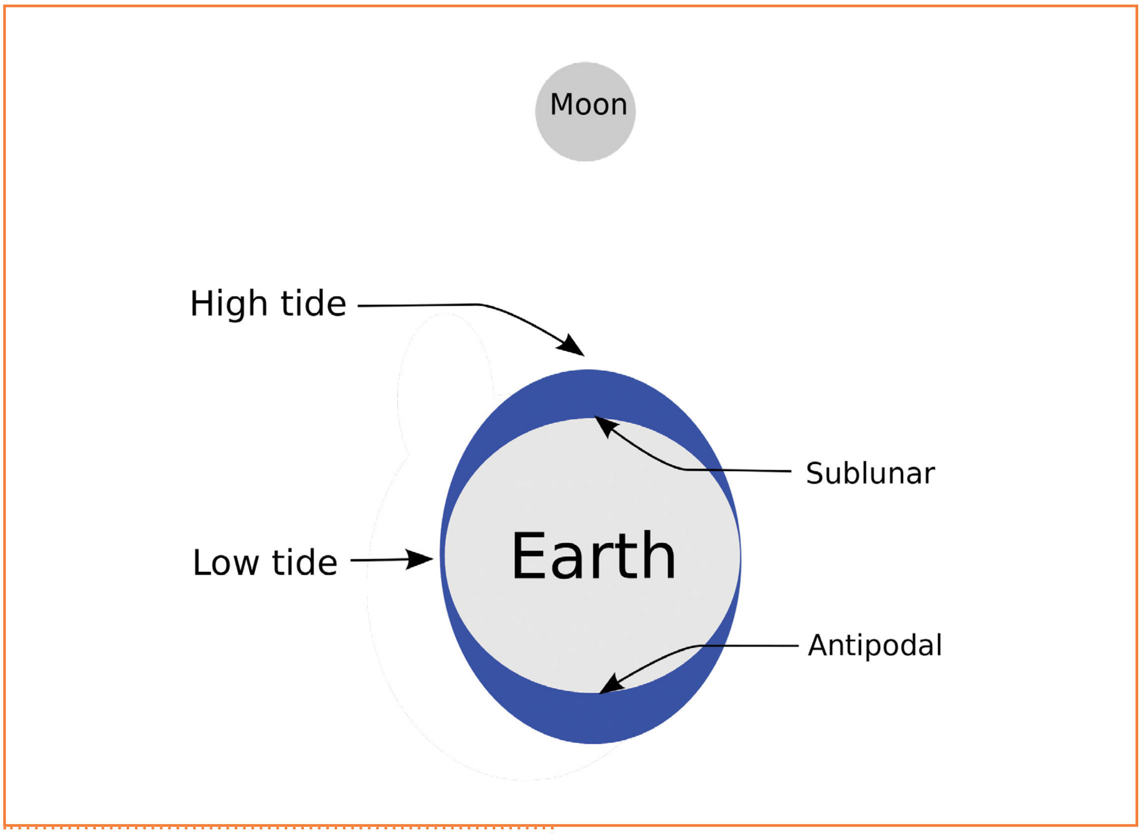


Diagram of tidal action.

The Moon does not have its own light

The Moon does not generate its own light. It simply reflects the sunlight shining on it. As seen from Earth, the Moon is the second brightest object after the Sun.

The dark side of the Moon is not always dark

The other side of the Moon is often called the 'far side' or the 'dark side'. People called it dark side because we see so little of it from Earth. In reality it's illuminated as often as the near side – once per lunar day.

Total eclipses are not inevitable

The Moon is exactly 400 times smaller than the Sun, but 400 times closer to Earth. This was a pure coincidence, a serendipitous moment in the making of the Solar system and boy we're lucky!

Both the Sun and the Moon appear to be roughly the same size in our sky (half a degree – half your little finger at arm's length).

Due to this apparent equal size we can get an eclipse of the Sun when the path of the Moon crosses exactly in front of it. This doesn't happen every full Moon. The plane in which the Moon orbits around Earth is slightly tilted to the path of Earth orbiting around the Sun. So only when 'the planets align' do we have eclipses. Eclipses of the Sun and Moon occur in a pattern called the 'Saros Cycle'.

We take this for granted, but how fortunate we are to witness it! By the way, its harder to see Lunar eclipses than Solar eclipses.

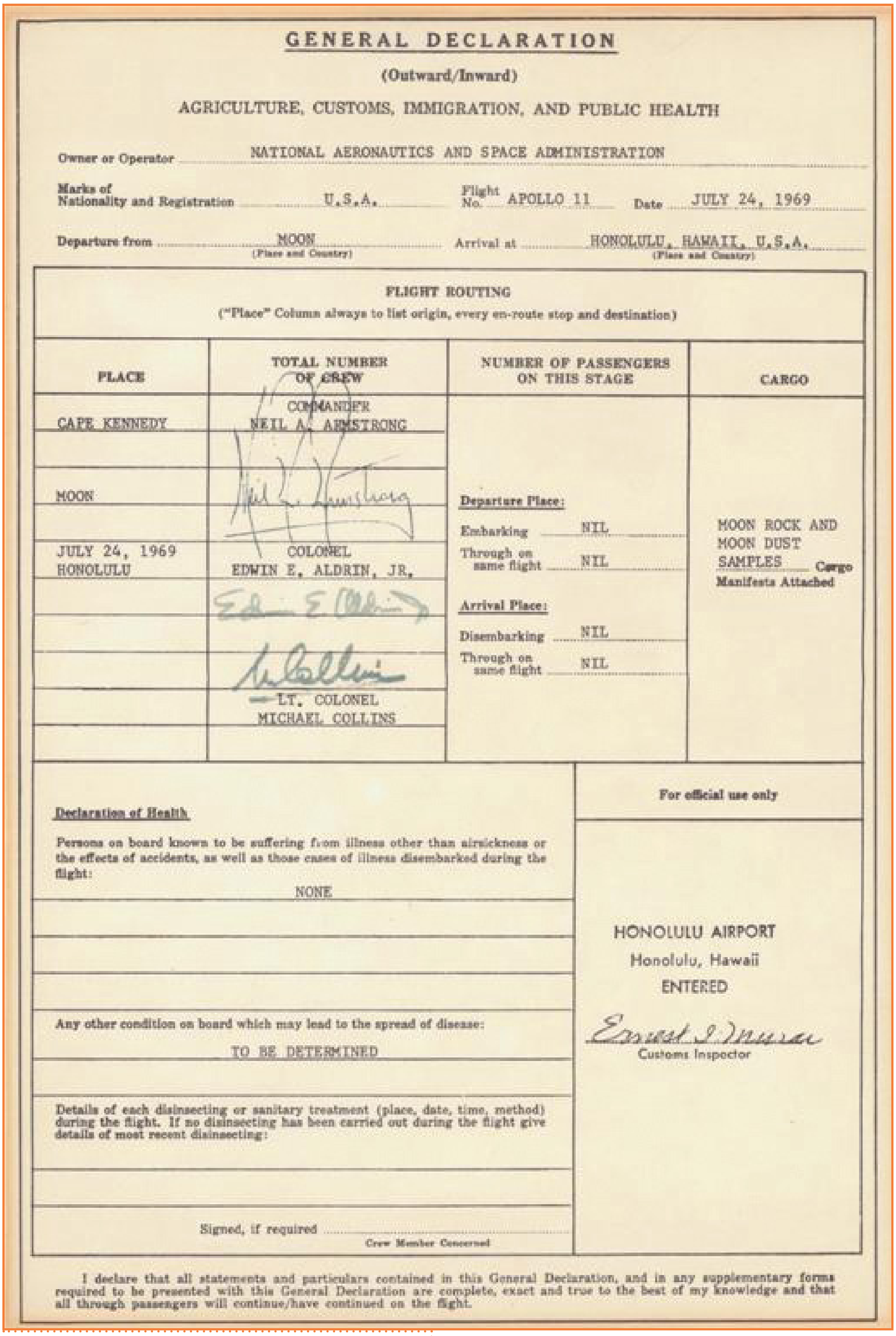
Interested in future eclipses?

From Earth we can see more than half of the lunar surface

Although we only seem to 'see' one side of the Moon, more than half, 57%, of the lunar surface is visible throughout the month. This is possible due to Moon's orbit and the tilt of its axis. Watch this movie on how tilt and orbit cause the Moon to wobble.

The wobble is also known as 'libration'.

Apollo 11 had to fill in a customs phytosanitary (agriculture, customs, immigration and public health) declaration. I happen to have a framed copy of that on my wall at home. The declaration mentions the Moon as place of origin of a cargo made up of Moon dust and rocks.



GENERAL DECLARATION

(Outward/Inward)

AGRICULTURE, CUSTOMS, IMMIGRATION, AND PUBLIC HEALTH

Owner or Operator: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Marks of Nationality and Registration: U.S.A. Flight No.: APOLLO 11 Date: JULY 24, 1969

Departure from: MOON (Place and Country) Arrival at: HONOLULU, HAWAII, U.S.A. (Place and Country)

FLIGHT ROUTING

("Place" Column always to list origin, every en-route stop and destination)

PLACE	TOTAL NUMBER OF CREW	NUMBER OF PASSENGERS ON THIS STAGE	CARGO
CAPE KENNEDY	COMMANDER NEIL A. ARMSTRONG		
MOON		Departure Place: Embarking NIL; Through on same flight NIL	MOON ROCK AND MOON DUST SAMPLES Cargo Manifests Attached
JULY 24, 1969 HONOLULU	COLONEL EDWIN E. ALDRIN, JR.	Arrival Place: Disembarking NIL; Through on same flight NIL	
	LT. COLONEL MICHAEL COLLINS		

Declaration of Health

Persons on board known to be suffering from illness other than airsickness or the effects of accidents, as well as those cases of illness disembarked during the flight:

NONE

Any other condition on board which may lead to the spread of disease:

TO BE DETERMINED

Details of each disinsecting or sanitary treatment (place, date, time, method) during the flight. If no disinsecting has been carried out during the flight give details of most recent disinsecting:

Signed, if required .... Crew Member Concerned

For official use only

HONOLULU AIRPORT
Honolulu, Hawaii
ENTERED
Customs Inspector

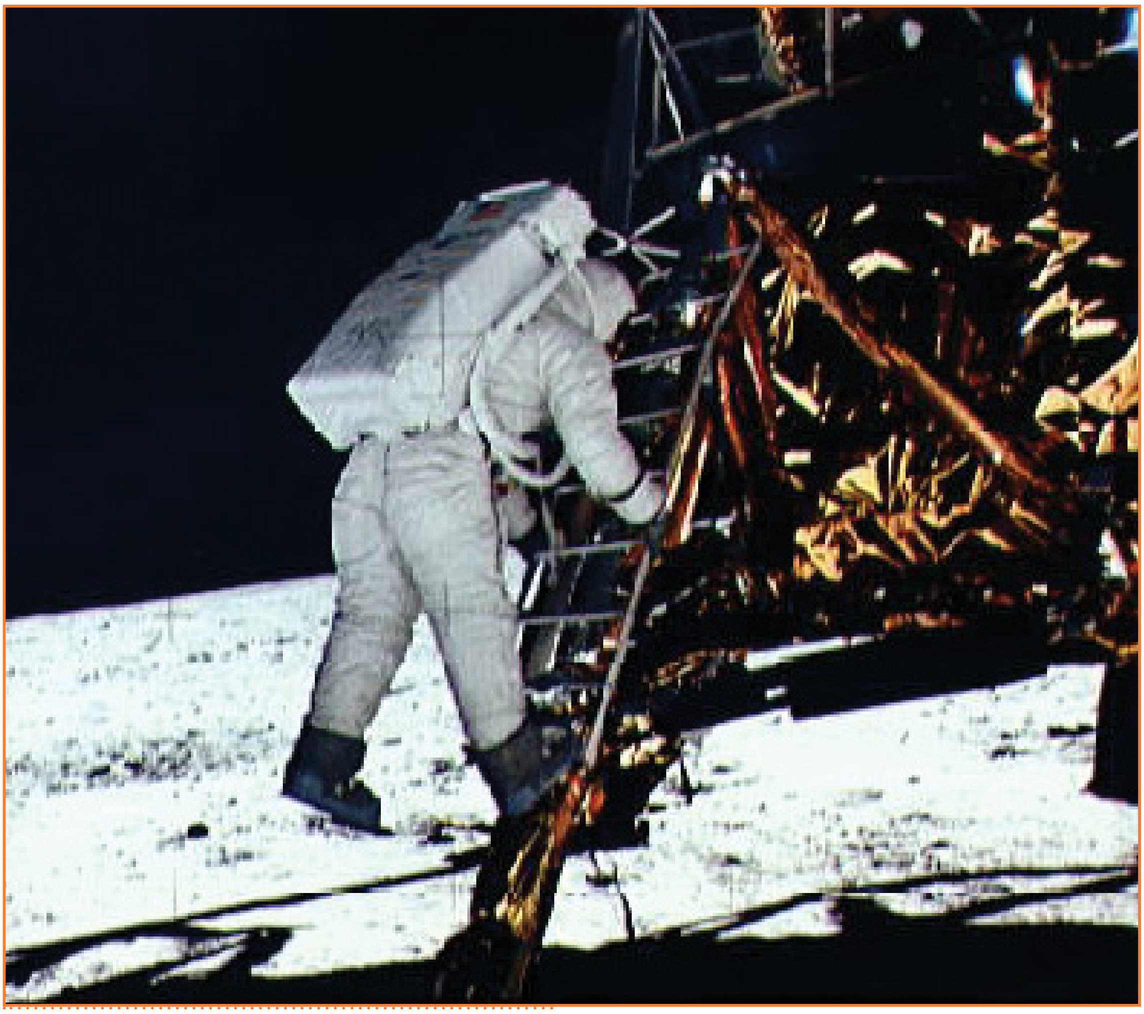
I declare that all statements and particulars contained in this General Declaration, and in any supplementary forms required to be presented with this General Declaration are complete, exact and true to the best of my knowledge and that all through passengers will continue/have continued on the flight.

Apollo 11 customs declaration.

Astronauts drove buggies on the Moon

Being so close to Earth made it possible to send human crews to the Moon. Astronauts walked and drove on the Selenian surface. I loved hearing about the driving! It's my favourite thing about the Moon. And I am very grateful that the TV era allowed us to see the movies of that.

What an extraordinary achievement for the human race to send people to the Moon! The Apollo space missions brought back soil, rocks and dust samples. By studying them, scientists figured out that Moon and Earth have similar isotopic composition, which means that there is a high chance both came from the same place.



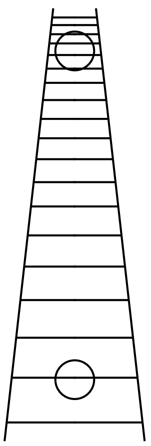
Astronaut Edwin E. Aldrin Jr., Lunar Module Pilot, descends the steps of the Lunar Module (LM) ladder as he prepares to walk on the Moon. He had just egressed the LM. This picture was taken by Astronaut Neil A. Armstrong, Commander, with a 70mm lunar surface camera. Source: NASA.

The giant Moon is an illusion...

Which for me, was mind blowing.

One of my favourite things about stargazing is how it helped me realize that humans are extraordinary. In this case, the Moon Illusion deals with the human brain and our great survival skills!

We know now that humans see objects at the horizon bigger than they appear!!! This has three exclamation marks because I believe it is outstanding. We have our own personal magnifying glass inside our brain. Why?



Everything seems closer and bigger at the horizon.

Selene was the Greek Goddess of the Moon. The word 'Selenian' is used to describe something that is like or of the Moon. The science of studying the Moon is called 'Selenography'.

To give us time to flee in front of the enemy? Think of 3.5 billion years of adaptation and selection since the first archaea. And check with your finger. Not only does the Moon seem closer and bigger at the horizon but also everything else (including incoming ferries entering Wellington port).

NASA blames it all on the Moon Illusion.

The Moon as a Timekeeper

Being so close to us, conveniently visible in the daylight and repeating the same pattern every 29.5 days, it only seems logical that we first looked at the Moon for timekeeping.

As human civilisation spread from Africa, the environment was friendly for most of the journey. We encountered no real winters until we reached ancient Europe. Then, things started to get complicated as the 29.5 days cycle of the Moon does not synchronize with the beginning of the seasons. To survive, our ancestors had to make sure they got out of the winter alive.

Central and Northern European winter time is when the soil is frozen, nature seems dead, there are no green leaves, and worse than that, all is covered with a white blanket of snow. How long does it last? One cannot tell that by looking at the Moon. The most important knowledge for the old people of Europe was to determine the middle of the winter. Why middle of the winter? So that they would know how much food they had left till spring comes. This is why, in that part of the world and driven by survival, we switched the Moon calendars to more sophisticated, star-based calendars. The rest of Earth's population, living at more mild temperatures, kept track of time by the Moon.

Lunar calendars

Lunar literarily means 'of the Moon'. A lunar calendar is based, of course, on the cycle of the Moon. The Islamic calendar, the Jewish, Chinese and Polynesian, all use the Moon to keep track of time. My favourite lunar calendar is the Māori calendar, 'Maramataka'. While the Muslims, Jews, Chinese and Indian people use a combination of the stars from the zodiacal band and the Moon, the Polynesians only use the Moon.

Why?

Every day of Maramataka has a special meaning. There are different instructions as to what to do each day. Is this a good day for fishing? Is it good for travelling? It occurred to me that the Polynesians use a purely lunar calendar because they were ocean farers. In the Pacific Ocean[3], it pays to know the tides. And anyway, who has heard of 3 months of snow at the equator?

3 Not all oceans have tides. The smallest tides are found in the Adriatic Sea. http://www.astronomyknowhow.com/moon-tides.htm

A lunar calendar is organised according to the phases of the Moon. If a month is the time between two Full Moons there are 12 or 13 months in a year. This is the reason why all Lunar celebrations – like Easter, Ramadan, Diwali, Matariki, are always falling at slightly different dates.

See you in a Moon! (It was an astronomer's joke, I was kidding, I will see you again in another quarter Moon actually.)

Explanation: In all Latin languages there is only one word to describe the Moon and the month; 'Luna' for the satellite and 'luna' for the month. In English the two names resemble each other a lot; 'Moon' and 'month', which is derived from the older 'moonth'.

Planting by the Moon

When I was a student, I had the chance to take a paper in 'Planting by the Moon'. Planting by the Moon was and is very en vogue. We even experimented with it (tried to see what happens when you grow things by the Moon). I have really enjoyed my degree in horticultural engineering and this particular paper was for my Masters in Environmental Management. Knowing it all about planting and growing plants, and given my heavenly passion for the stars, I was very excited to learn more about planting by the Moon.

The paper was very much referenced to astrology. In general, any literature search on the subject brings back astrological practices. Astrology, the grandmother of astronomy[4], is also included in biodynamic agriculture. This is different from organic farming, as is planting by the Moon.

Many modern cultural groups make reference to planting by the Moon. I was curious to understand if the astrological practice of planting by the Moon fits in with the cycles of Nature. In modern times, we seem to go back more and more to seek ancient wisdom. It makes sense, many times, the ancient wisdom is packed with great instructions.

In my own culture, based on agriculture and dating back thousands of years, I have never heard of planting by the Moon. I find this 'detail' very intriguing. Why did my ancestors, who built one of the most complex agricultural civilisations I have ever came across, completely ignore the Moon for planting? I do not know. They even ignored the stars for timing planting, even more puzzling. Many scholars believe sideral calendars were used for planting, yet my folk disregarded those as well. However, my ancestors did have a very sophisticated solar calendar which functioned by the Saros cycle. Am I missing something here? Again, I do not know.

But in my quest to get my head around the stars, I started to believe that people's cultural practices, especially those related to the stars and Moon are cyphers of ancient ways of living. The ancient ways have long since disappeared. Mostly, they can only be accessed through folklore and traditions. And like any cypher, it is possible there is more underneath than what it seems.

I am very interested in deciphering these messages from our ancestors. They are the key to understanding what we call 'culture'. This, I believe, is the sum of instructions that our ancestors produced, to ensure that their descendants will successfully survive in more or less hostile environments. Culture is always specific to geography. So is starlore. And it's truly remarkable that around the world, the legends of the Moon and the stars are so different from culture to culture.

The phases of the Moon

'A lunar phase or phase of the Moon is the appearance of the illuminated (lighted) portion of the Moon as seen by an observer, usually on Earth.'
Source: *Wikipedia*.

The phases of the Moon and its setting and rising times are quite easy to remember. Because the Moon is not always in the sky all night, nor can we see it all day long. I remember how much this puzzled me when I was little. Why sometimes can you see the Moon and why sometimes you cannot? Shouldn't it be there all night long? And what's with it, changing shape all the time?

4 According to my personal opinion.

If you are like me and don't want the Moon out there when you look at the stars, then it's good to know how each phase of the Moon is linked with it's rising/setting times.

I was going to find a link on that to show you, with fancy graphics and nice narration. When I looked online I realised that all fancy pages are explained for the Northern Hemisphere. I can understand that, as most of the Earth's landmass/people are in the Northern Hemisphere. Hence the Maps hang from North, most of them at least. But what about the people travelling to the Southern Hemisphere, the Hemisphere of the tides? They come all the way here only to discover they are confused by the way the Moon appears in the sky!

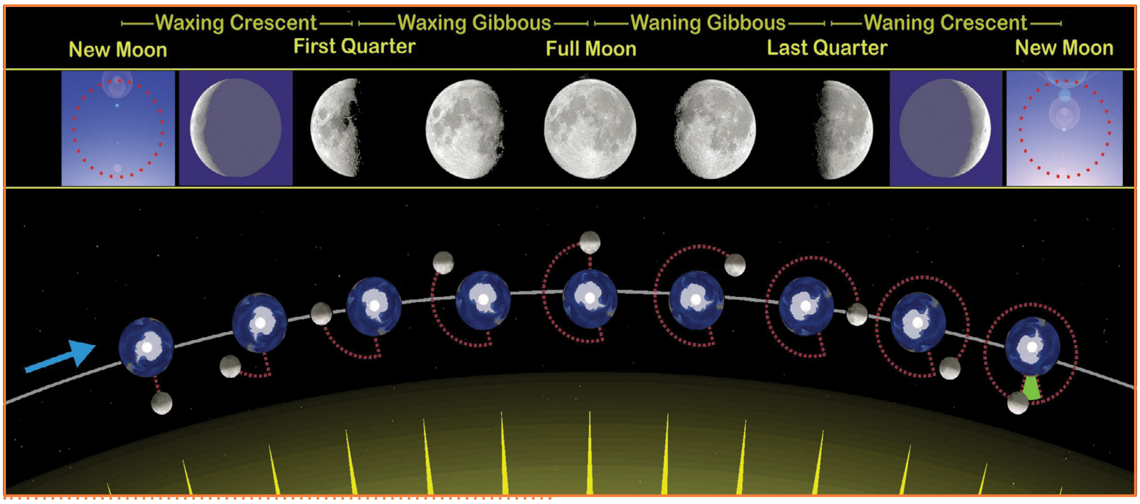
Things are very different here to what we are accustomed to see in the northern sky. Here is the reason why: in the Northern Hemisphere 'the Moon is a liar', we say. It's a Crescent Moon when it looks like a D and it's Decreasing, getting smaller, when it looks like a C!

In the Southern Hemisphere the Moon is WYSIWYG[5].

5 . WYSIWYG – what you see is what you get.

Phases of the Moon – for the Southern Hemisphere	What is actually happening there	Rises at	Sets at
New Moon	No point in looking for the Moon at night, you will not see it, which is why its called 'New'. The Moon renews itself, or at least that's what the ancients thought. This is PRIME TIME for deep sky observing, especially if you use a telescope.	Sunrise	Sunset
First Quarter (Crescent Moon) C	Looks like a filled C (from the Latin word 'crescent' – 'growing'). The Moon is growing in size.	Midday	Midnight
Full Moon	You can see the Moon, all of it, all night long and you can't sleep well either because of too much light! That is the reason why some people were called lunatics. Besides that these people did not have drapes, they were just sensitive to light pollution.	Sunset	Sunrise
Last Quarter (Decreasing) D	A week after Full Moon phase, the Moon will start looking like a D and you can remember that from now on, it will only decrease in size every day until the New Moon.	Midnight	Midday

REMEMBER: C for Crescent Moon and D for Decreasing.



Phases of the Moon.

Epilogue

The famous Anglo-Australian astronomer Fred Watson said about the Moon (amongst other things in his excellent book 'Why is Uranus upside down?' – 'You have to love the Moon simply because: (a) it's romantic; (b) if it wasn't for the Moon we might not be here…'

These, he also said to me after hearing my anti-Moon speech, should be good reasons to love the Moon if everything else fails.

Fact

Talking about the meaning of words, the opposite of 'cult' is 'occult' – 'hidden'.

When the Moon passes in front of a star or a planet we say that the Moon occults that object; it hides it.

Concerning satellites

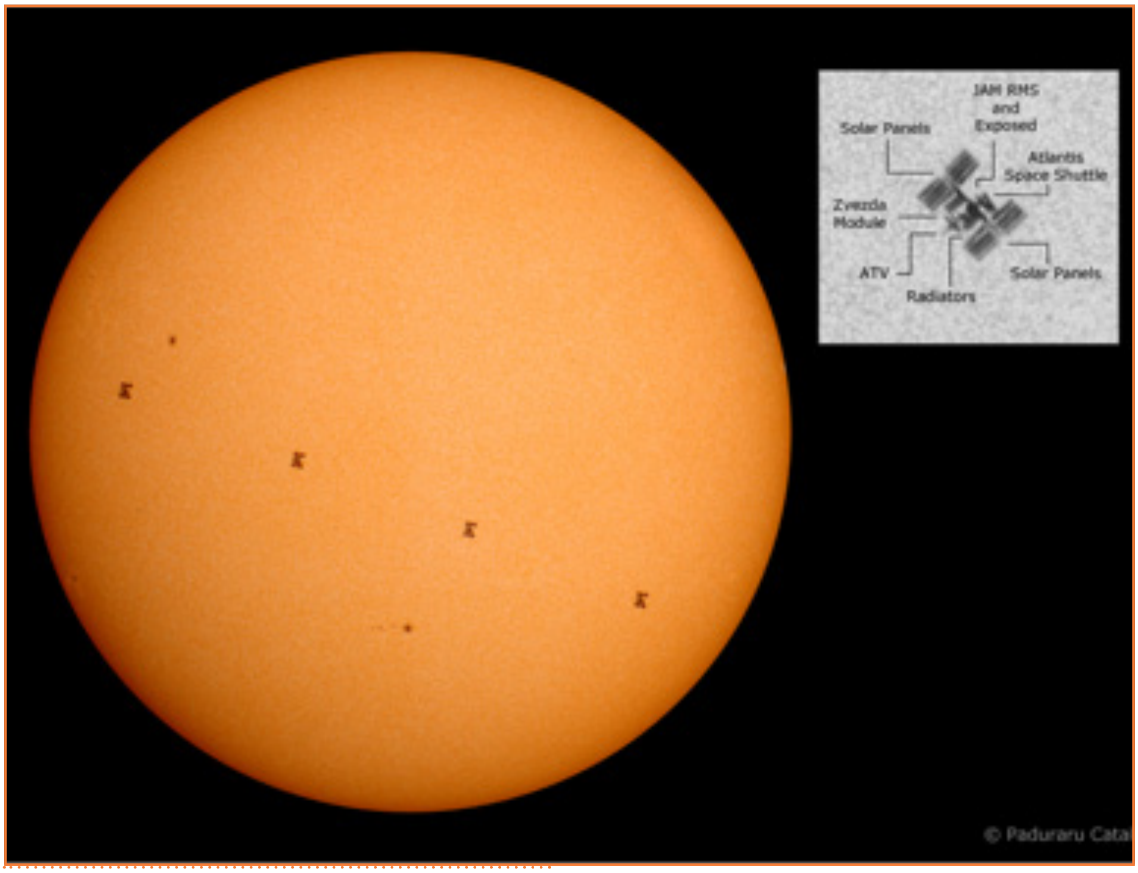
The Moon is Earth's natural satellite. And for that matter any natural satellite of a planet is called a moon.

The Moon is not the only satellite of Earth. Starting with the launch of Sputnik on 4th of October 1957, the space around our planet is getting overcrowded.

If you are in New Zealand and wish to know more about the sky above us, artificial moons and everything else about space you need to check out the KiwiSpace website! We are pretty groovy if I can say so myself!

The most famous artificial (man-made) object that we can observe in the sky is the International Space Station (ISS).

On the next page is a composite of four images taken by a friend of mine, Catalin Paduraru. He photographed the ISS during the day against the backdrop



International Space Station (ISS) during the day against the backdrop of the Sun. You can even see the last space shuttle, Atlantis, docked with the ISS.

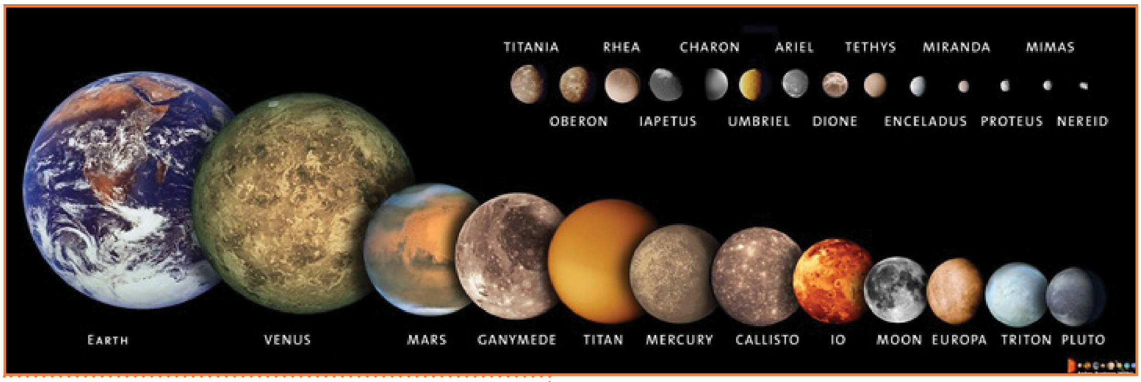
of the Sun. If you look carefully you can also see (the last space shuttle to fly to space) Atlantis[6] docked with the ISS.

You can also 'chase' ISS and many other satellites. The best site to get information about them is Heavens-Above or you can simply subscribe to the KiwiSpace calendar on the KiwiSpace website.

6 Bragging rights – Atlantis launched on its last flight exactly on my birthday and hour! What a cool nerdy birthday present!

About other moons

Other moons don't have a capital letter in their name. So we can say the moons of Mars, Jupiter, Saturn, Uranus and Neptune. Even Pluto has moons! We cannot say however the moons of Mercury and Venus, for as far as we know, they don't have any! We cannot see the other moons with the naked eye from Earth.

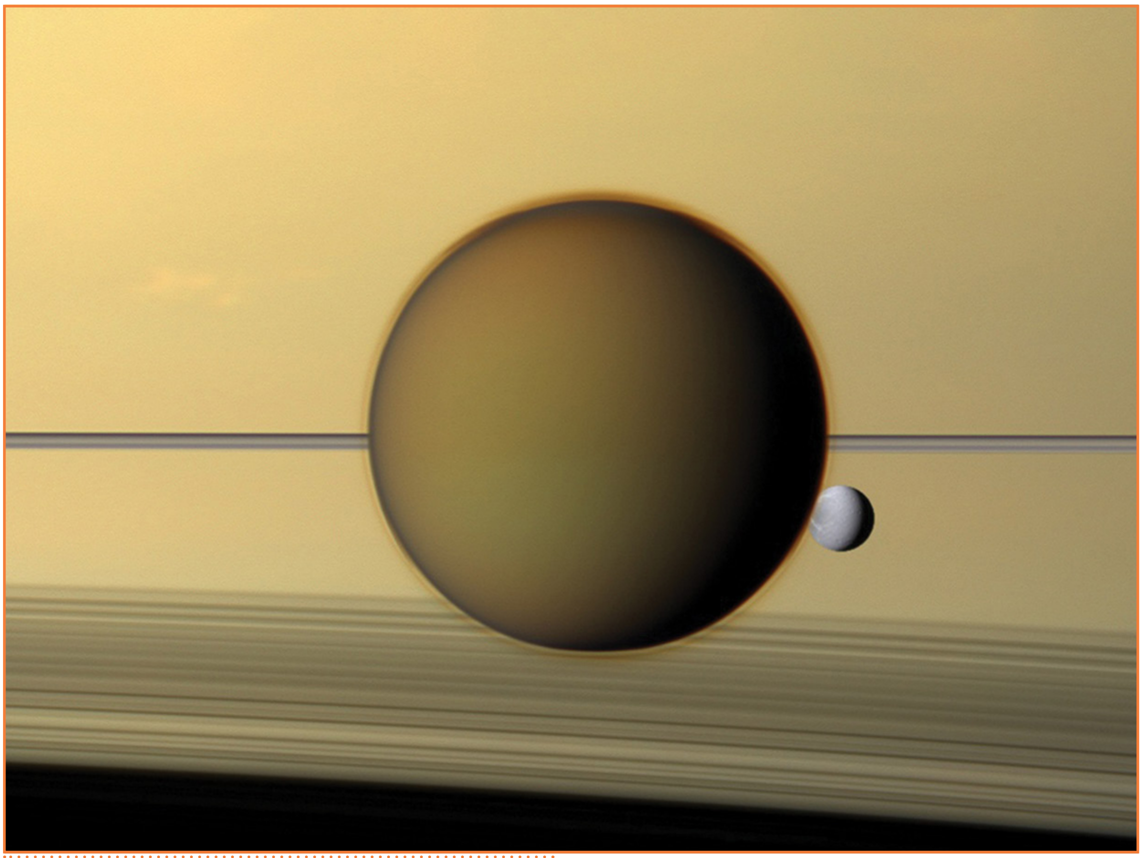


Comprative sizing of objects in Solar System.

How did other moons form? Good question, we will discuss it in the next chapter when we will think about how our solar system formed.

There is … one moon in the Solar System, that I absolutely adore!
It's Titan!

Last but not least, about the romantic side of the Moon. Writing this chapter also reminded me how much I love Belinda Carlisle's song 'La Luna'.



Titan as photographed by Cassini.

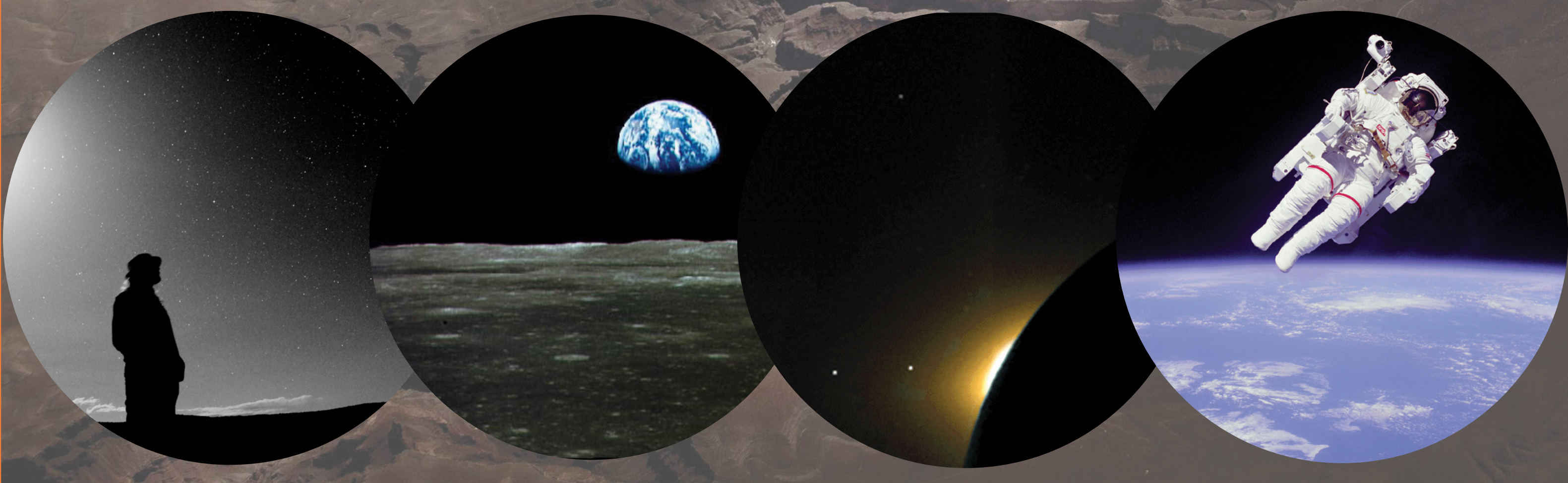
Notes

STAR GAZING

STAR GAZING

WEEK THREE

Planets and Points of View



Front cover image: The Grand Canyon from Space

Copyright: Travis Odgers

Back cover image: Orion nebula

Located 1,500 light years away, along our spiral arm of the Milky Way, the Orion nebula is located in the middle of the Sword region of the constellation Orion the Hunter.

Source: NASA, C.R.O.

Contents

WEEK THREE

Thanks

Thank you to George Jones, Alan Gilmore and Peter Detterline for their stellar help and suggestions!

Terminology

For some of you, there may be many new words and phrases in this course. If you're not sure what something means, you might want to check an online glossary.

If you're still confused, feel free to ask me or your classmates in the forum.

WEEK THREE

Planets and Points of View

Welcome to week three of your STARGAZING journey. I hope that your Observation Diary rocks and you already started noting and writing about interesting things you saw in the sky.

This week, we will talk about the planets:

- where to find them in the sky;
- why they can only be found in that particular part of the sky and, most importantly;
- when can we see them.

I will also mention the zodiacal band, because it's what's behind the paths of the planets. And it's important. To finish with, I will share some thoughts on mindsets and perspectives.

Points of view

Points of view are all about perspectives.

I hope that the first STARGAZING chapter brought some perspective on our place in space. Now, we're coming back to Earth.

With different perspectives come different points of view.

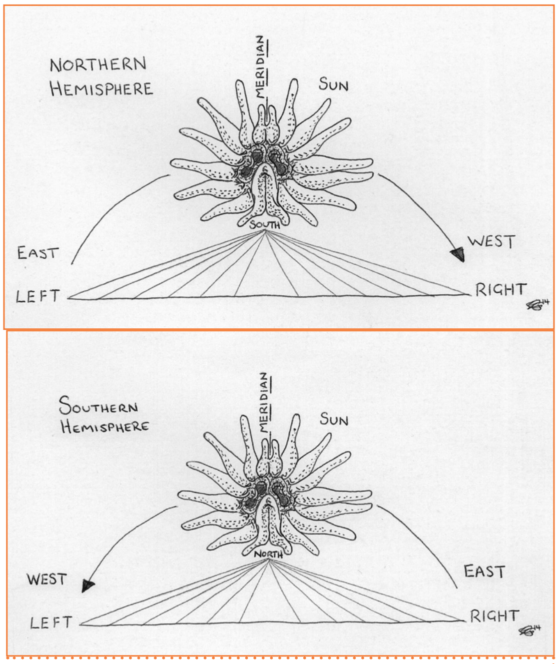
Many times I felt confused, when looking at the night sky from (only) one location, back home in Europe.

Throughout the night, the stars would slowly drift westwards. Looking up, different stars would come into sight every hour. Looking up at the same hour of the night but in different months, the sky would be different again. It took me years to figure out there was a pattern to all that change.

Imagine my surprise, when I realised that more confusion was about to come my way. Arrived in the southern hemisphere, I had to put up with a 'je ne sais quoi' about the sky. And this time, something about the sky felt really strange, also during daylight.

After a while, it started pouring data:

- the Sun travels through the wrong part of the sky!



Illustrations by Eugene Georgiades.

- the morning's shadow of Southern Hemisphere has exactly the same angle (orientation) as the afternoon's shadow[1] of the Northern Hemisphere!
- the Moon is WYSIWYG (see chapter 2);
- Constellations look upside down;
- plus there is an entire part of the sky I had never seen before.

I can assume that anyone from the Southern Hemisphere would experience the same confusion when travelling to the Northern Hemisphere. Even more if going without stopovers.

And I can think of at least three reasons why we can be easily confused when travelling across the world:

1. Earth has a tilt.
2. Compared to the other hemisphere we are upside down (the advantage of living on a sphere).
3. By human nature, we can get biased very easily. Luckily, living on Earth, although it produces biases, it can also teach us a lot about biases!

Let's recap from childhood, what do we see in the sky?

1. From Earth, the first celestial object we see is **the Sun**. (**DON'T LOOK AT IT WITHOUT PROTECTION!**) Every day, the Sun rises in the East and climbs to the meridian (see chapter 1). It reaches meridian at midday. Then it goes down, towards the western horizon. The Sun travels through the southern part of the sky in the northern hemisphere, and through the northern part of the sky in the southern hemisphere.

We all know that the Sun does not really move. It is the Earth turning (rotating) around its axis[2] that makes day and night.

2. The second big thing we see in the sky is **the Moon**. The Moon goes roughly through the same part of the sky as the Sun does, which is important to remember.

The Moon does not make day and night, but sometimes when it is full, makes so much light that some people can't sleep. These are known as lunatics. For a long time it was thought there was something wrong with these people. Science has demonstrated that they are just very sensitive to light pollution.

3. The third category of things we see in the sky are the **brightest stars and the planets**. I put them in the same basket as, from Earth, they all look the same.

The planets are usually very bright, hence in some countries they are known as 'Luceafăr' – the shiny ones.

4. Then, only to briefly mention them, we might see **deep sky objects** and

1 That's why, morning always felt like afternoon here, at least for the first few months. There might not have been anything wrong with me, after all!

2 The Sun does move too – around the Galaxy, but we are ignoring that for now. Besides humans don't live long enough to see the effects of that in the sky. Giordano Bruno died for supporting these ideas. Spacecraft and modern science proved he was right. Giordano Bruno was someone able to see more than one perspective.

anything else you can imagine, like **meteors, comets, satellites, ISS, UFOs, airplanes, weather balloons**...

The Planets

For an amazing concert by Holst packed with entertaining imagery from NASA, look here.

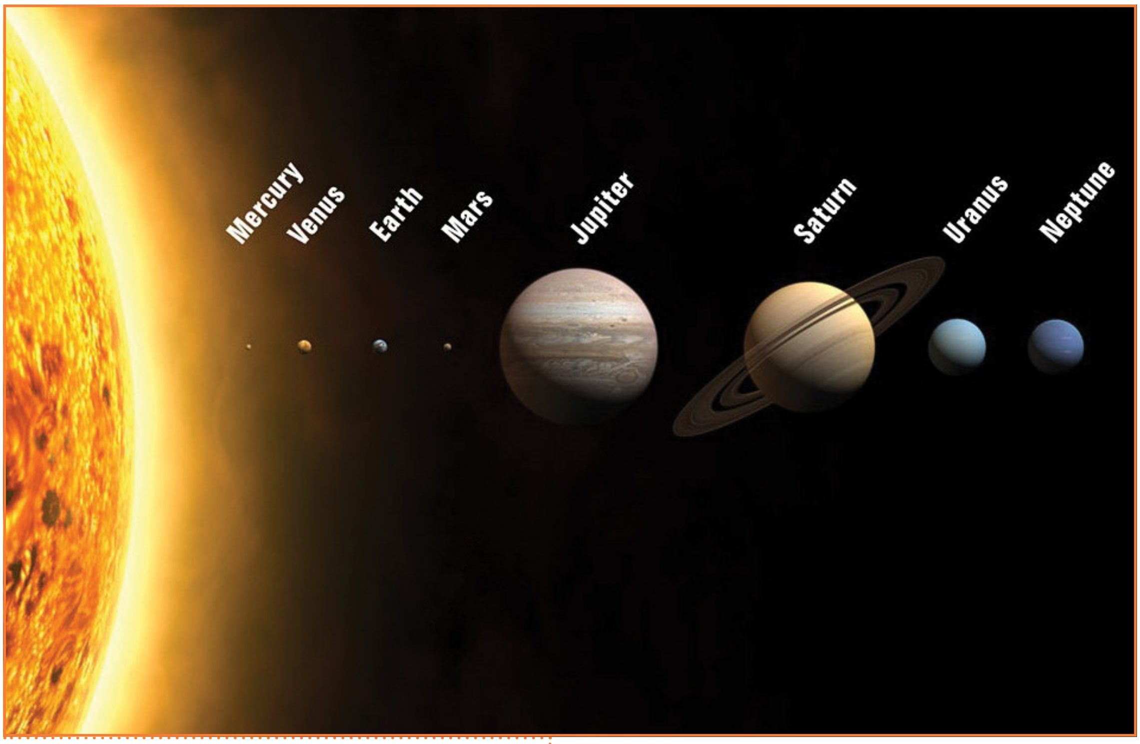
What is the difference between a planet and a star?

Well, it depends who you ask. There is observational difference and physical difference. Believe it or not there is a different cultural interpretation too.

I will talk about observational differences a bit later in this chapter. However, to understand that and where to find the planets in our sky, it is important to first look at the physical difference between stars and planets.

First of all, planets are made of stardust. But then so are people and buildings and dogs and chocolate. (Many scientists believe that for real, myself included.)

Stars and planets differ based on two properties: whether or not they burn hydrogen in their cores and the way they form. Of course if we are talking about a rocky planet, like Mercury, Venus, Earth and Mars it is less likely that these would have a core of hydrogen, let alone burn it. But the gaseous planets: Jupiter, Saturn, Uranus and Neptune are made of a lot of hydrogen. But it is very likely they may have rocky cores too.



The size of our Sun and planets to scale.
Distances are not to scale.

Fraser Cain argues that the real difference between a star and a planet is actually mass. 'If an object has about 80 times the mass of Jupiter then it should be able to ignite solar fusion in its core', he says. In our Galaxy, the Milky Way, we can see that many solar systems have at least two stars, if not three. Imagine how the sky would look like from a planet orbiting those.

HOW DO PLANETS FORM?

Stars form when a cloud of gas collapses under its own gravity. Planets form when leftovers from the cloud of gas, which gave birth to the star, begin to condense around rock or ice cores. So planets form after the stars formed, from their leftovers.

Stephen Hawking wrote a great explanation about how our Solar System came to be, which I really enjoyed watching.

But for stargazing, all you need to remember, in order to understand where to look for planets in the sky, is that during the process of planetary formation, the entire solar system looks first like a bubble, then like a disc. And that along the way, the initial bubble formed by gravity gets flattened by rotation into a disc.

Stellar nursery in Eta Carina.

This particular theory of the formation of stars and planets is supported by observations. We see stars forming all the time, inside deep clouds of gas. We call these clouds nebulae. Then, all planets in our Solar System orbit the Sun in the same direction, even most of the moons rotate in the same direction. This is exactly what they should be doing if they formed from a disc of debris around the proto-Sun[1].

Then, we can also see that rocky planets are closer to the Sun and gaseous planets are further away, as most of the gas was blasted by the initial thermonuclear reaction which ignited the Sun. And of course, the gaseous planets of our Solar System have rocky moons!

Last but not least, according to this theory, the Sun should be composed mostly of hydrogen. And it is!

But from time to time, new discoveries question old theories. This is the curious case of the exoplanet HD 106906 b, which is more than twenty times farther from its star than Neptune is from our Sun. How did it get there? Everyone wonders!

1 A fancy name for the baby-Sun.

Where in the sky can we see the planets?

From Earth, planets too can be seen roughly in the same part of the sky where you would see the Sun and the Moon. We call that part of the sky the Zodiacal band.

Seen from above, all planets orbit around the Sun in circles (actually ellipses). Luckily they also orbit around the Sun in the same plane, called the plane of the ecliptic. I explained above why.

We could compare the Solar System to a big plate. Imagine that you are at the dinner table. Dinner is served. Whilst eating it, you see the plate from above. It looks like a disk[3,4]. Have you ever looked at your plate from the side? Maybe when is in the dishwasher? What does it look like then? A thick line? Exactly.

The same applies to our solar system. From Earth, we look at our Solar System sideways and from within. Which is why earthlings see the Sun and the Moon moving along paths that look like arches instead of straight lines. The arches stretch from the eastern to the western horizon. Planets go in loopy paths, following roughly the arches of the Sun and Moon.

3 A disc (British English) or disk (American English), from Latin *discus* which itself derives from Greek δίσκος, is a flat circular object.' Wikipedia.
4 Of course you can serve dinner in square or rectangular plates too – like I have, but the round plate explanation works best.

> **Ecliptic means two things:**
>
> 1. **'the apparent path that the Sun follows through the sky over the course of the year, relative to the stars, as seen from the vantage point of the Earth. Wikipedia.**
> 2. **the plane in which all planets orbit around the Sun.**

Always look for planets in the northern part of the sky if you are in the Southern hemisphere and in the southern part of the sky if you are in the Northern hemisphere.

How can you tell a planet from a star?

Unless it's Venus, you can't really tell a planet from a star, especially if you are on the ocean or around New Zealand's shore. But there are some tricks you could use to differentiate between a planet and a star (also known as observational difference).

1. Is it near the path of the Sun/ Ecliptic?
2. Is it bright? **Planets produce no visible light of their own. You see them by reflected sunlight.** Being close to Earth they are brighter than the average stars.
3. Is the light steady? Planets don't twinkle as much as stars, unless you are out on the ocean or in New Zealand (a renowned turbulent place, everything twinkles here, including the light from the street lamps).

If your answer is yes for all three questions then probably you are looking at a planet.

If you still can't tell or wonder which planet that may be, here is the news: We might not know either! The good news is that special tables, called ephemerides[5], tell us when and where we can see the planets in the sky.

What's in a name?

People in ancient times observed that some 'stars' behaved differently in the night sky. Behaved is a good choice of word and the ancients gave those stars God-like powers. They could visibly 'move along' though the background constellations.

In chapter 1, we discussed how from Earth, we perceive all stars as stuck to the celestial sphere. We also said that it takes thousands of years for stars to shift from their places. The planets revolve around the Sun in less than a thousand years. Some do that in less than a year! During our lifetime, we can actually see them clearly shifting positions amongst the background stars – they actually shift their positions all the time! The Greeks called them wandering stars – 'planith aster', from which the word planet is derived.

5 Also a Greek word, 'ephemeris' means 'diary'.

Inferior planets

No need to feel bad about calling them that!

You can classify planets in many ways, inferior versus superior, rocky versus gaseous, etc. The reason I chose to use the inferior/superior classification is because this course is about stargazing. Knowing whether a planet is inferior or superior, we can tell exactly when they are visible in the night sky.

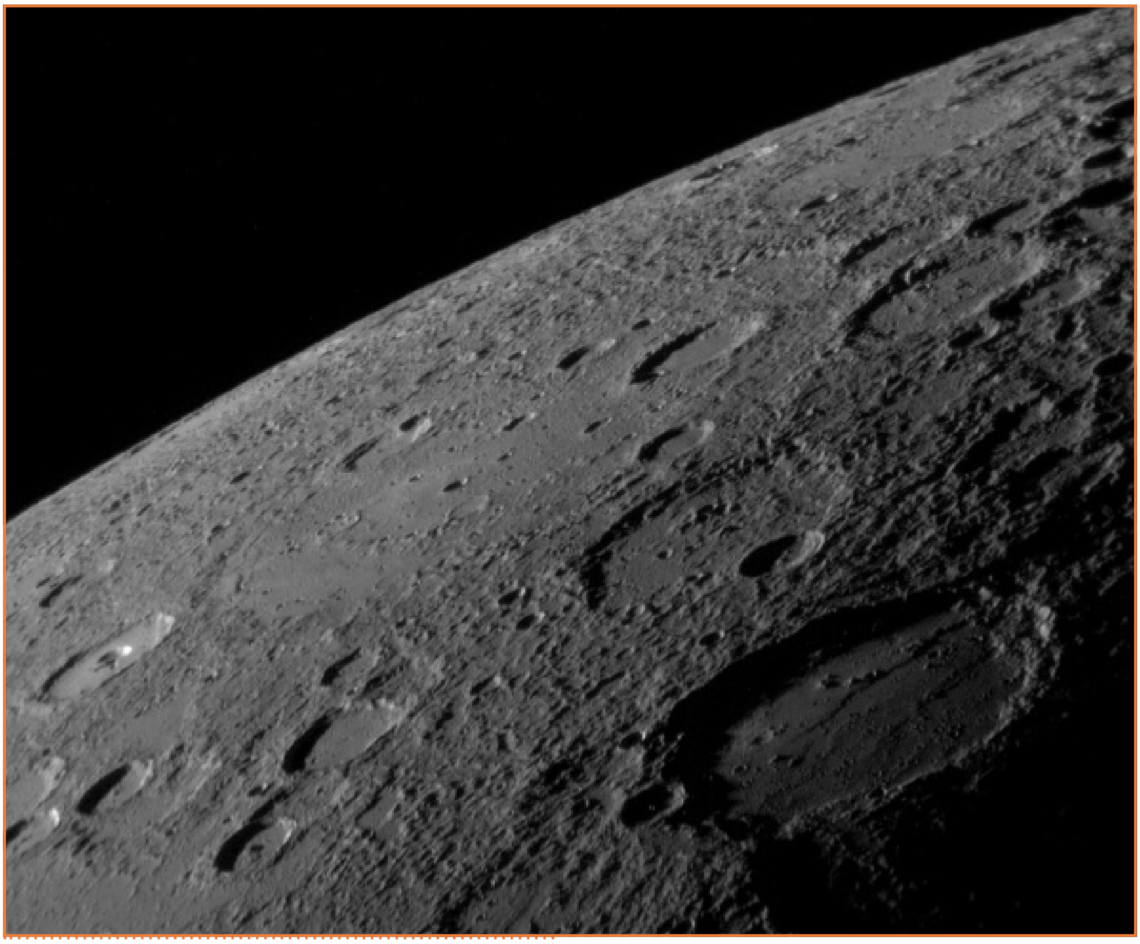
The two planets placed between Earth's orbit and the Sun – Mercury and Venus – are 'inferior planets'. Their distance from the Sun is less than (or inferior to) the Earth's distance from the Sun.

Due to their proximity to the Sun, the inferior planets can only be seen just after sunset or just before sunrise. You will not be able to see Mercury or Venus throughout the night even if you wanted to! They will never be opposite the Sun as seen from Earth.

Just like the Moon, the inferior planets go through phases. You can see that if you look at Venus through a telescope.

MERCURY, THE WINGED MESSENGER

The closest planet to the Sun, Mercury was the God of merchants and thieves, messenger to all Gods. He took people to the underworld after they died. The



Aleichem crater on Mercury.

planet's short orbit around the Sun (88 days, nearly 3 months) makes it appear in the sky for very brief periods of time. It's visible only at dawn and dusk, just like a messenger on an ephemeral (but regular) visit. Many pictures and sculptures show Mercury with wings at his feet!

It looks like rocky Mercury also has water ice and organic molecules. Who would have thought, being so close to the Sun?

I found a great podcast in which you can hear everything you wish to know about Mercury. Also check the NASA page for Mercury.

VENUS, THE BEAUTIFUL

Of course the real question is not if you can tell whether Venus is a star or a planet but whether it is Venus or a UFO?

Goddess of beauty, Venus owes her name (and the UFO buzz) to her

Artist impression of the venusian surface. Copyright: ESA.

brightness. Venus is the third brightest object in the sky and just like Mercury it is only visible at dawn and dusk. From outside she looks like the twin of Earth. It's almost the same size as our home planet. A rocky planet, Venus takes almost six months to go around the Sun once.

But as beautiful as it may be, Venus is literally the 'hottest' planet in our Solar System. That makes it one of the deadliest places you can think of. If you ever visit Venus and don't die from the tremendous pressure on its surface you will certainly find it hard to stay in one piece inside that venusian atmosphere. Made of dense clouds of sulphuric acid, it resembles the conditions inside a car battery. Venus stinks!

More?

The 400+ degree Celsius atmosphere will melt you instantly. Last but not least, there is no ozone on Venus so deadly UV radiation will go through you as a hot knife goes through butter. Sometimes I wonder if one could simply almost die only by thinking of being on Venus!

More painful details in this Venus podcast. And of course, NASA has an entire page for Venus.

By the way, Venus, seen in a dark sky, is bright enough to cast a shadow on a white surface.

Solar Transits

Seen only at dusk and dawn as Morning Star and Evening Star, Venus and Mercury, every so often, cross the disk of the Sun!

The phenomenon is called a planetary transit, the passing of an inferior planet in front of its star. This is similar to what we see in an eclipse.

Mercury transits the Sun 13-15 times in a century. Transits of Venus are about 120 years apart.

Transits (like eclipses) usually occur in pairs, eight years apart. Each pair is close to the same date in each of the years. The timings of each transit are often about 12 hours different. One side of the Earth sees the first transit, then the other side sees the next, eight years later.

Transits were instrumental in determining the 'astronomical unit' (the distance between the Earth and the Sun, about 150 million km). However the transit method was only, at best, about 1% accurate.

Transits are also part of New Zealand's history. Captain Cook sailed to Tahiti to measure the transit of Venus. In Aotearoa the transit of Mercury was observed. The two sites are named after the observations – Venus Point and Mercury Bay.

It takes 5 hours for Mercury and 6 hours for Venus to transit the Sun.

The transits are observable only during daytime. Both Mercury and Venus can be seen as tiny disks wandering across the Sun.

I saw the transits of Mercury and Venus in the Northern Hemisphere. They were spectacular. I missed both of them in the Southern Hemisphere because the sky was cloudy those days!

Observing Mercury and Venus as gibbous or nearly full phase proved to be critical in deciding between a Earth-centred model or a Sun-centred model for the Solar System.

The last visible transit of Venus from Earth for the next hundred or so years was seen from the Southern Hemisphere in 2012.

Superior planets

The planets outside Earth's orbit are called 'superior planets'. They are: Mars, Jupiter, Saturn, Uranus and Neptune. **The superior planets can be seen all night long unless they are close to or behind the Sun.**

MARS, THE GOD OF WAR

Mars, my second favourite planet (after Saturn of course), gets its name from its reddish tint. Because of that, people associated it with blood, wars or famine. In Greek starlore Mars is a young, handsome and reckless God (the God of War).

Funnily enough, today we know that Mars is the only planet of our Solar System suitable for terraforming, therefore supporting and not destroying life. It has a 24 hour day, something which resembles an atmosphere and its gravity is $^1/_3$ of Earth's. Curiosity rover finds out great stuff about Mars every day. The temperatures around Mars's equator can be as high as 18 degrees Celsius. Robert Zubrin, compared it once with Norway, but I am not sure which season.

Mars is the last of the rocky planets.

I have a special interest in Mars since 2010. Starting 2011, I had the chance to go to the Mars Desert Research Station (MDRS) in Utah, USA, to simulate living on Mars. There, we built a solar garden, a solar clock and a Māori star compass. We also gazed at the North American night sky with the naked eye and through a C-14 telescope on site.

More on Mars and MDRS in my World Space Week podcast. Also, my awesome Mars adventures are collated on the Milky Way Kiwi website, under the community projects page. This means, if you are interested on any of those projects, drop me a line!

Mars rocks!

NASA page for Mars is also awesome!

The main star of the zodiacal constellation Scorpius, Antares, owes its name to Mars. Antares' name 'The Rival of Mars' comes from 'Anti' – 'against' and 'Ares' – the Greek name for Mars.

Antares is located close to the ecliptic. The two 'celestial bodies' can be seen together from time to time, when Mars wanders through the constellation of Scorpius.

A red giant, Antares has the same red hue as the warrior planet.

Antares and the Fishing Hook of Maui at the Mars Desert Research Station.

If we lived on Mars (which I personally hope will happen one day) we could also see the Earth going through phases. If we lived on Jupiter we could see Mercury, Venus, Earth and Mars with phases. From Jupiter all these planets would be inferior planets as their distance to the Sun would be less than Jupiter's.

Ad Ares! (On to Mars!). Credit: Haritina Mogosanu.

JUPITER, THE OLYMPIAN

The youngest brother of all Olympian Gods, Jupiter ruled the sky and the Earth from Mount Olympus. (Located on the planet Mars, Olympus Mons is the tallest mountain in the Solar System.)

Jupiter rules!

It's the biggest of all the eight planets and has the highest number of satellites. Jupiter is a gas giant, which can be seen with the naked eye at night. Jupiter is second only to Venus as the brightest 'star' in the sky.

The Chinese were amongst the first to use Jupiter for timekeeping. It takes about 12 Earth years for Jupiter to orbit the Sun. This is also how long a cycle of the Chinese zodiac lasts.

My favourite thing about Jupiter is its moon, Europa. It is a very hot topic and highly debated whether it can harbour life or not (see here for 'or not'). Europa, is one of the four galilean moons.

Nasa Jupiter page is full of details about Jupiter.

Jupiter and moon Europa rising.

If you ever consider buying a telescope, please remember that it was Jupiter that intrigued and inspired Italian astronomer Galileo Galilei to affirm that the Sun is at the centre of the Solar System.

Jupiter was the first object observed by Galileo Galilei with the help of his new device, the telescope. He realised he was looking at a planet and its satellites. Just like us, Galileo had an Observations Diary where he kept a detailed track of what he saw. He published these later in Siderium nuncius, The Starry Messenger. Because he was the first person to write about his observations and the moons, the four largest moons of Jupiter are also called 'Galilean moons'. However Galilei was not the first to look at the stars through a telescope. A good argument for publishing your work before anyone else writes about it!

SATURN, THE WISE

Saturn was the God of time to the ancient Greeks. It's my absolute favourite thing in the sky. Why? I can't answer that if you have never seen Saturn through a telescope. And wait, for more 'wow' sounds, you should definitely see Saturn though Cassini!

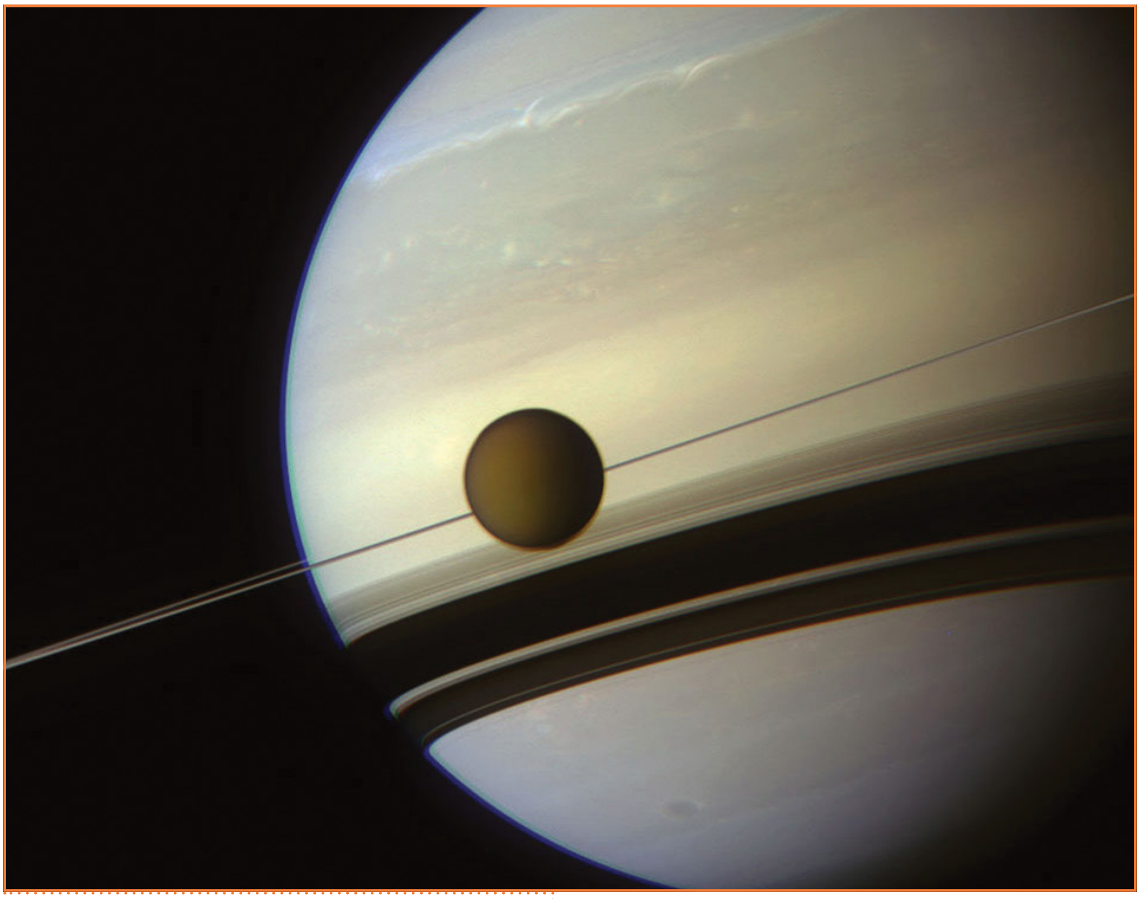
A planet of rare beauty, the elegant Saturn is a gas giant world caught in a frozen water-ice ring. I'd love to go skiing one day on the ice mountains from the rings. Some are as high as 2.5 kilometres.

Saturn's satellite Mimas looks just like the Death Star. Titan, another one of its satellites, is an amazing world. It's the only satellite of our Solar System to have an atmosphere, albeit of methane, with methane rivers and lakes. I am good friends with Saturn's moon, Titan, on Facebook. This is how we discovered that most of the mountains on Titan are named after Tolkien's fictitious peaks.

It takes Saturn 29.4 Earth years to go around the Sun once.

Saturn is bright enough to be seen with the naked eye in the night sky. It has a yellow hue.

NASA Saturn's page



Saturn and moon Titan.

URANUS, THE STARRY SKY

...other than the fact that this planet was firstly called George...

I am only mentioning Uranus and Neptune because I feel like I have to – when you talk about the planets you might as well talk about all of them. But both these planets cannot really be seen with the naked eye.

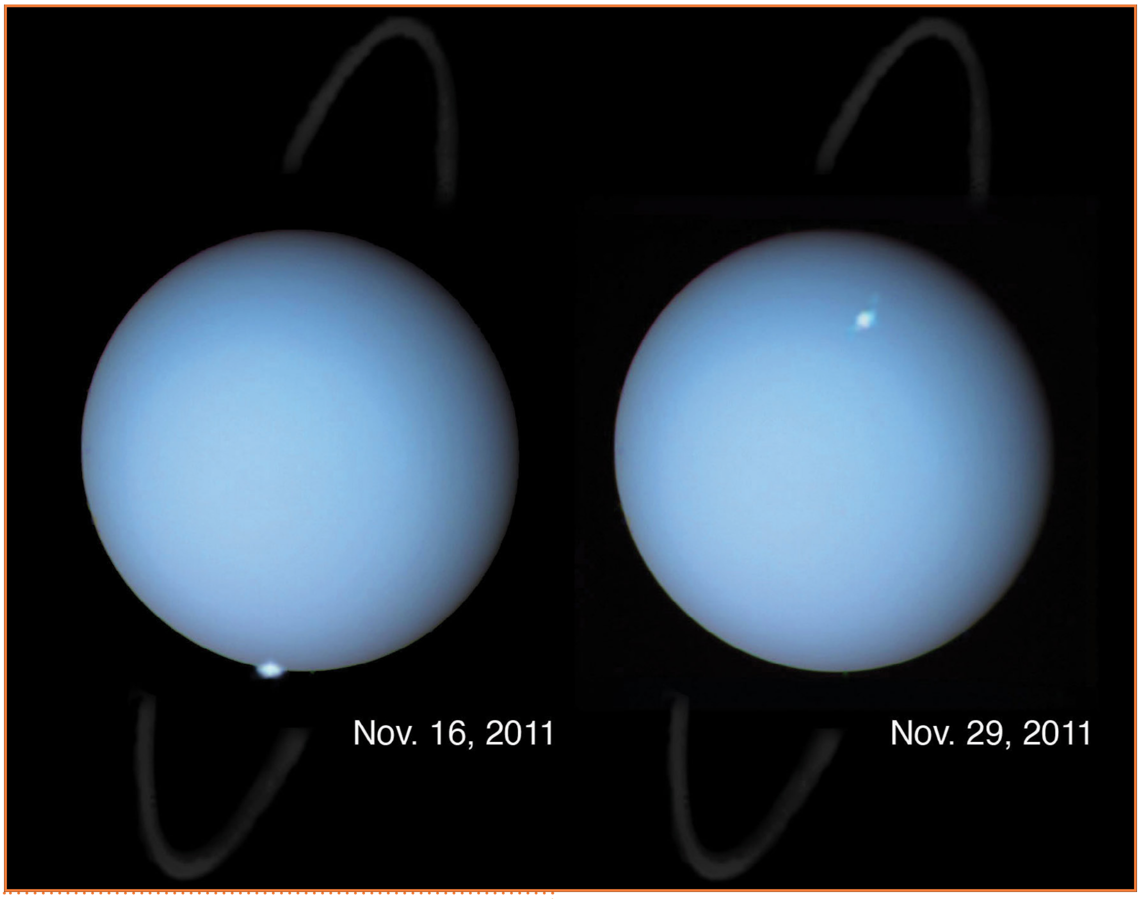
It was discovered relatively recently (in 1781). Often being mistaken for a star, Uranus got its current name because nobody wanted to keep calling it George. Herschel, its discoverer, thought that Uranus was not a planet but a comet, as he could see a small disk through his telescope. Uranus was known to the astronomers decades before Herschel figured it out, and everyone believed it was a star.

Uranus is just visible to the naked eye – 8th magnitude (I challenge you to that) and easily found using binoculars.

Another frozen world rolling around the Sun side-on like the wheel of a bicycle, Uranus is the only planet to orbit the Sun sideways.

It takes Uranus around 83 Earth years to complete a full orbit. Because it's axis is inclined to 97.7 degrees, each pole 'sees' 42 years of darkness and 42 years of light.

NASA page for Uranus



Aurora on Uranus

NEPTUNE, THE GOD OF THE SEAS

Neptune, the last giant outpost of the Solar System, is too dim for the naked eye. It was discovered by mathematical calculations correlated with telescope observations, based on its effect on the orbit of Uranus. Its name comes from the Greek God of the seas.

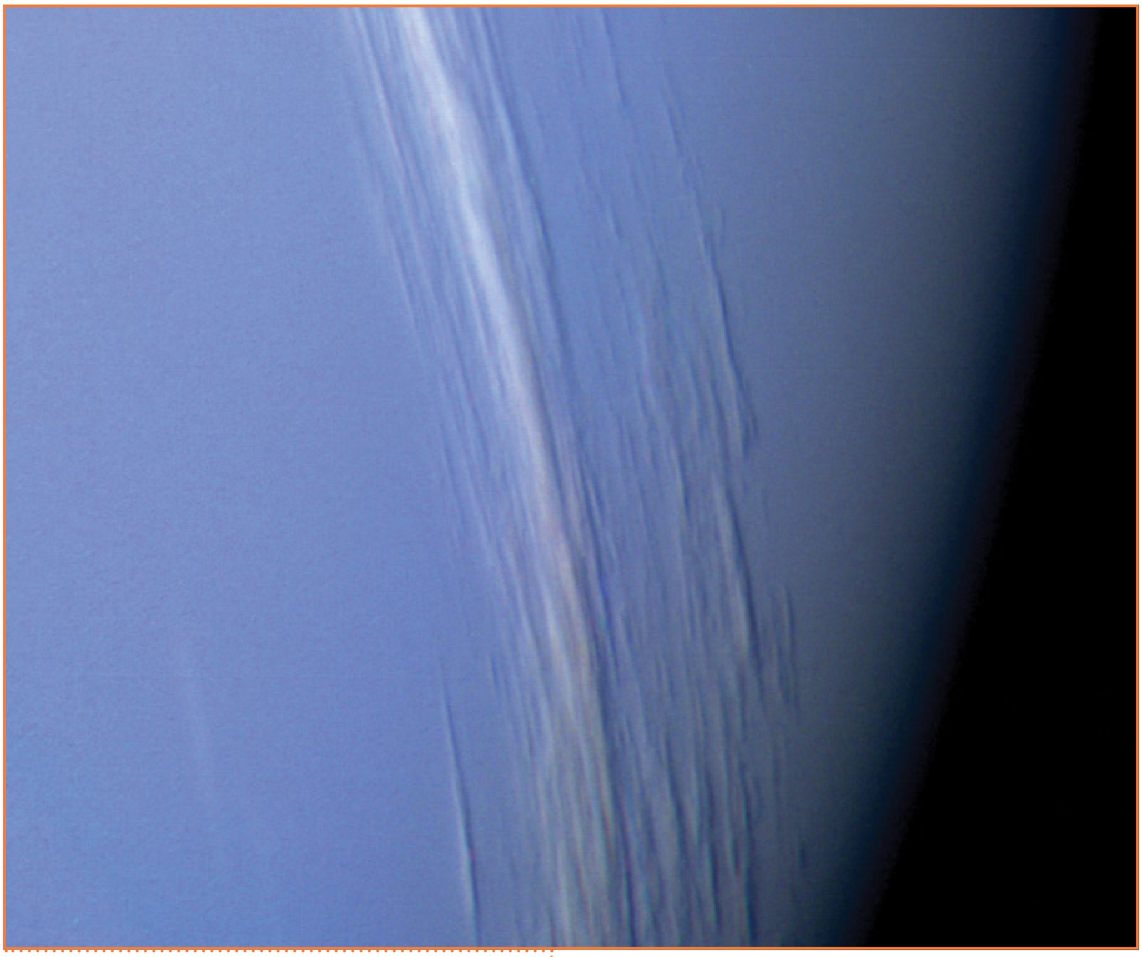
Find out here how long does it take for Neptune to orbit the Sun.

Neptune holds one of the most amazing meteorological phenomena in the Solar System. Scientists now believe that on Neptune it rains diamonds.

What more can I say about Neptune? Umm... it's got a hexagon on its south pole. 'Jaw dropping!' says everyone.

NASA page for Neptune

The modern names of the God-planets are taken from the Roman 'pantheon' (derived from Greek) although at one point in time Uranus (which means 'the starry sky' in Greek) was in danger of being called 'George'.



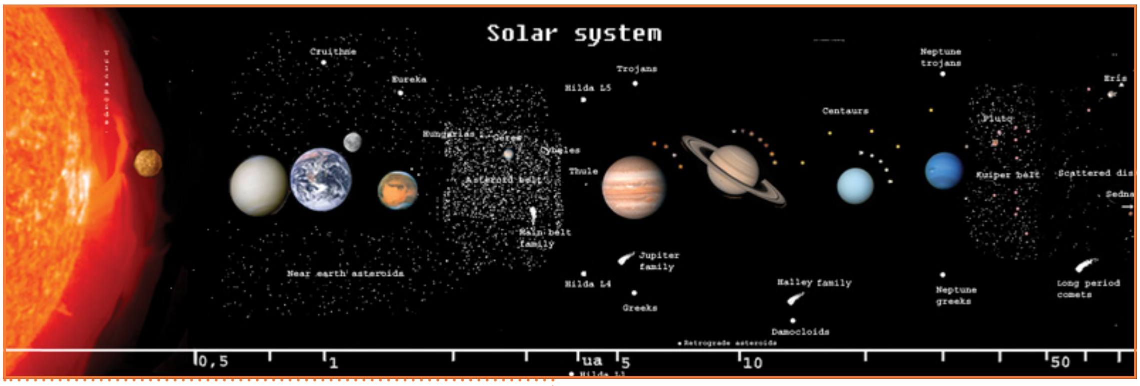
Cirrus clouds on Neptune imaged by Voyager 2.

THE REST OF THE SOLAR SYSTEM

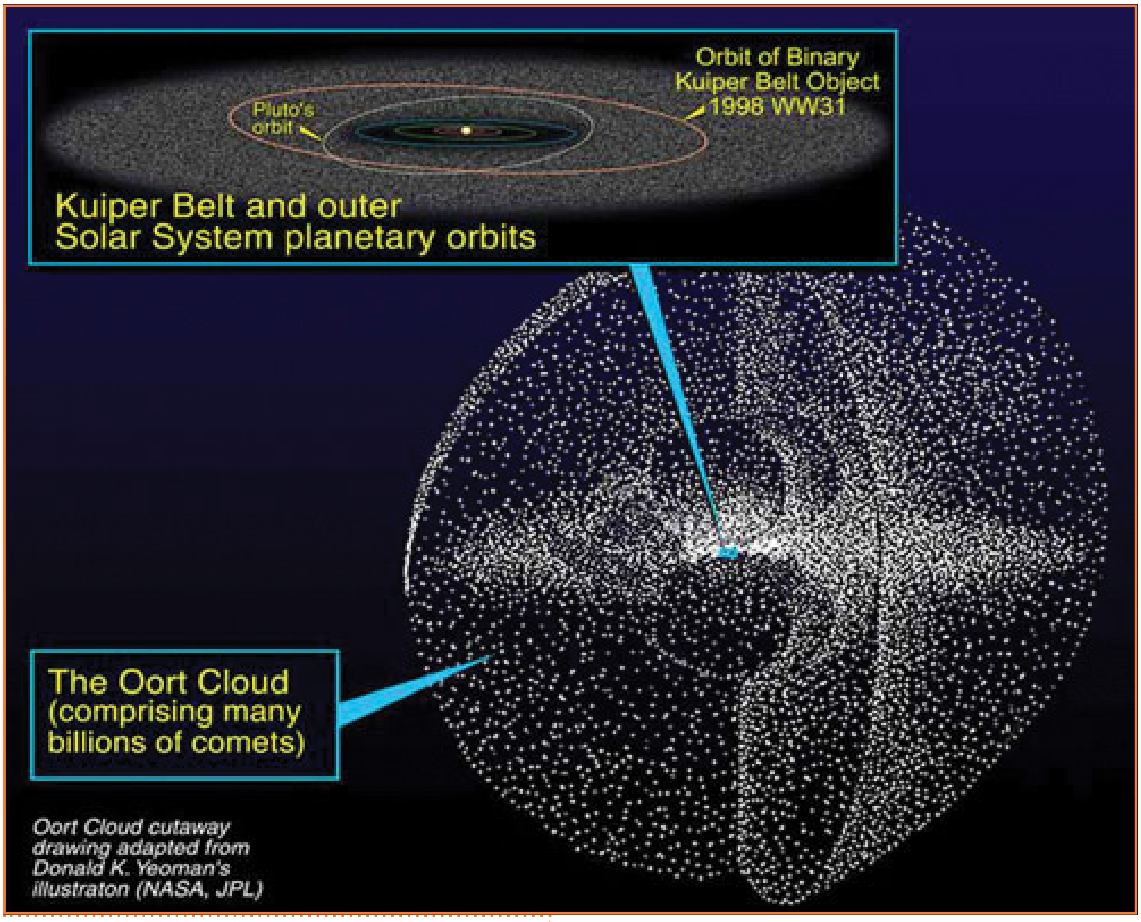
The Solar System does not really stop at Neptune. There is the Kuiper Belt and the Oort cloud. And now there is a magnetic highway just discovered by Voyager 1!

Also, closer to home, between Mars and Jupiter there is an asteroid belt. All these are not naked eye objects.

If you are curious to know where the edge of our solar system is, we are not really sure, but do keep an eye on the Voyagers. They tweet back spectacular news!



What else is there?



This is our solar system.

PLUTO?

'Not a full-time planet anymore'.
(I had the chance to tell my version of this story in the Dominion Post in Wellington, a few years ago, in reply to a letter from a school student! Out of all the questions I could have been asked about astronomy… they picked the Pluto one…!)

More cool stuff about the planets

- Dava Sobel's book The Planets is a great resource to learn more about the planets and so is the movie 'The Clash of the Titans'. On a cloudy night, you could watch that instead… :)
- The days of the week are named from the planets for both Latin and Norse people. Here is more to read, I believe that this is a well written wikipedia page!
- Behind the planets lie the Zodiacal Band. It is made of all the stars which kind of fit within the paths of the planets. The people of old must have thought it was very important, for many reasons. After all, the Planets move through it. The Zodiacal band was humankind's first calendar. The Zodiacal band is very important and I will talk about it in detail in the next chapter, the constellations.

To close this section on the planets, I have chosen a National Geographics movie on 50 years of exploration of our Solar System. It's a story mainly about the people who worked in space exploration and their achievements. Because of these people we now know so much more today!

One last thing on points of view

A teacher's tale

My very good friend Chris, who is a teacher, said to me: 'sometimes its very hard, at school, to change kids' minds once they are set onto something'. He quoted Merry Browne: 'Preconceived notions are the locks on the door to wisdom.' 'When students think they already know, he said, it is difficult to convince them otherwise (especially stroppy teenagers!!).'

I'm not a teacher but I do know that grown-ups still start wars because of preconceived mindsets. Often, there is no teacher left there for them, having killed them in the war. Grown-ups who never put themselves in other people's shoes think they know everything. 'Understanding' is just a word in a dictionary and so is 'tolerance'.

I experienced a lot of frustration myself by coming to the Southern Hemisphere. I did not understand why people kept doing things that made no sense, just because it was traditional to do so. I failed to interpret the environment properly. Back home I could find North with my eyes closed, here nothing made sense anymore. I felt very confused. It haunted me to understand why.

To (jet)lag or not to (jet)lag

For a long time, I believed in the story of the jet lag. Whilst that might have been true as well, it did not explain why besides feeling confused, 'my brain hurts'. Later on, whilst learning about the human mind from an excellent book by Richards Heuer Jr: Psychology of Intelligence Analysis, I understood why it took me so long to get my head around everything. My brain was swamped with biases. And apparently, biases happen because of the way the brain stores the information in the long-term memory.

That's all.

Now I'll tell you how my stars shed light into all that.

But first, a bit more about the brain.

'Biology gives you a brain. Life turns it into a mind.'

– Jeffrey Eugenides

Everything we see, touch, smell or hear is collected by our body's receptors and sent through the nerves to our brain where it enters the 'sensory information storage (SIS)[6]. From there, the information is downloaded into our short-term memory (STM)[7], for interpretation. The interpreted/selected information is then stored for good in the long-term memory (LTM). This is a very crude picture but in essence, scientists believe this is the pathway to memory.

Each of these three types of memory (SIS, STM and LTM) operates in a different way. They differ by how they hold the information, for how long and how much of it.

Whilst the first two types of memory are used mainly to collect data, the long-term memory is responsible for storage. You can store anything and everything in the long-time memory. There is only a small problem with it: how we retrieve what is stored.

Information is stored interconnected: we can scent a perfume and will remind us about a person, or a place. We also store information making use of patterns, the same way we remember the constellations. These are patterns of stars.

To remember lots of things, (aka transfer information effectively from the short to the long-term memory, otherwise an excellent skill for survival) the brain overlays new information on top of patterns already available in memory.

Heuer says: 'Once people have started thinking about a problem one way, the same mental circuits or pathways get activated and strengthened each time they think about it. This facilitates the retrieval of information. These same

6 The Sensory Information Storage, SIS, holds information (everything) for a few tenths of a second. Close your eyes, and you will be able to see how you can still see things for a fraction of a second before the image is fading.

7 The short-term memory stores the interpretation of what comes from our senses via the sensory information storage (SIS). This interpretation is meant for further processing, which can last from a few minutes to a few tens of minutes. The short-term memory has very little capacity for storage. Which is why we can only remember five to six things at the same time (±3). On top of that, we must refresh the memory of these constantly. 'People make a choice where to focus their attention,' says Heuer. I say, 'That's why lists are good.' Chanting may work too, I think!

pathways, however, also become the mental ruts that make it difficult to reorganize the information mentally so as to see it from a different perspective.'

Even now, after ten years in the other hemisphere, my lovely brain, which otherwise I am very fond of, keeps delivering things like: wrong shadow, wrong part of the sky, wrong season, things are upside down, etc. Ironically, this also helped me figure how exactly how the Polynesians could navigate such a vast ocean without getting lost.

'There are no facts, only interpretations.'

– Friedrich Nietzsche

Interpretations are all the result of the perspectives generated by different points of view.

Polynesians are great storytellers. Europeans too, but they have different stories. I'm only talking about European and Polynesians because I have only lived amongst these people, enough to understand what makes us different and what unites us.

In Europe we only have one name for a group or cluster of stars. For instance, Orion will be Orion no matter what time of the year/night you see it and the same for Scorpius and the Pleiades. But Polynesians have at least three names for their main clusters of stars. Moreover, the same stars are grouped in different combinations throughout the year. For instance, the Pleiades are called Matariki around the Māori New Year (as seen in the morning sky). The same cluster is part of Te Wakaa o Tamarereti in November's evening sky. In March, the cluster is marking the first step of the Stairway to Heaven.

When I arrived in New Zealand, I registered first that Matariki was another name for the Pleiades and therefore I was pointing at it also outside of the New Year season. Only that I was told repeatedly by the Māori people I spoke to, that one can only see Matariki one time of the year. No explanation, no other detail.The mystery puzzled me so much that I could not think of anything else for a while. Then, one night I recalled a forgotten conversation I had in a different instance about the three names of Scorpius: Manaia ki te Rangi, Te Matau a Maui, Te tau ihu o Te Waka O Tamarereti… and I finally clicked!

It's like this: you think you speak their language but in fact you only hear their words.

Who would have thought they have three different interpretations for ALL major asterisms of the sky and that outside those interpretations the individual constellations did not exist? And furthermore, constellations' names are seasonal... Never heard of that before!

'To strive, to seek, to find, and not to yield.'

– Ulysses

The human brain loves information[8], which it feeds on. This makes it want to rather have the wrong information, which later it can correct, than no information at all. It's a snowballing effect. Back to biases, 30 years in the Northern Hemisphere, made it very hard for me to unlearn my language. Even today I get in the wrong side of the car!

It takes an out-of-ordinary event to break the cycle. Shadows and seasons and in general the way in which we rationalize things in Europe, all helped me, the hard way, along with the cultural shock, to understand my new cultural landscape.

Our very different traditions showed me clearly how most of our European culture is land-based. Even when navigating, we are still fixated on the land. Our GPS coordinates – a direct result of our methods of navigation – are fixed points on Earth.

Polynesians, on the other hand, have been using the concept of the celestial sphere all along, and had their gaze fixed to the skies.

'What you have to have in your mind is a vision or picture of the land you're trying to get to. And then what happens is that once you get out on that canoe you've got to keep that picture of where you're suppose to be going in your head. And then what you do is

8 Professor Dirk de Ridder explains that beautifully in a great interview for Radio NZ.

MataOra – a celebration of the Celestial Navigation. Credit: Haritina Mogosanu.

slightly make that picture get closer and closer to you. And so what is actually happening you're working almost in a scenario where the canoe is sitting still, and then as this voyage progresses the land is getting closer, and it's as if the land is coming towards you. And if you can keep that image of your target island in your head, you know where that is and you know where you're supposed to be, everything else should fall into place.'

Hoturoa Barclay-Kerr talking about celestial navigation in the movie 'The Sky Whisperers – Ranginui'.

Culture and bias, how they go hand in hand! I did say in chapter 2 (talking about the Moon) that I believe culture is just a set of instructions left by our ancestors for us to survive. Culture means, in my mother language, something you do repeatedly and in plain sight. We do follow these instructions repeatedly and in plain sight. And, when the constraints that made them are not there anymore, we still follow them, for the silliest of reasons. To preserve the culture without understanding why, is one good silly reason. For that matter, survival based on bias becomes, I think, a sword with two edges.

When I finally unlearned all the instructions that I brought with me, only then could I understand the night sky from the perspective of the Polynesians. And figured out how they could remember it all, as they cyphered it into amazing stories.

And realised, that for the rest of my existence, I'll have to watch out for biases, as if my life depended on it. And finally I felt at peace, knowing that curiosity will always keep me safe to strive, to seek, to understand, and not to yield.

Clear skies!

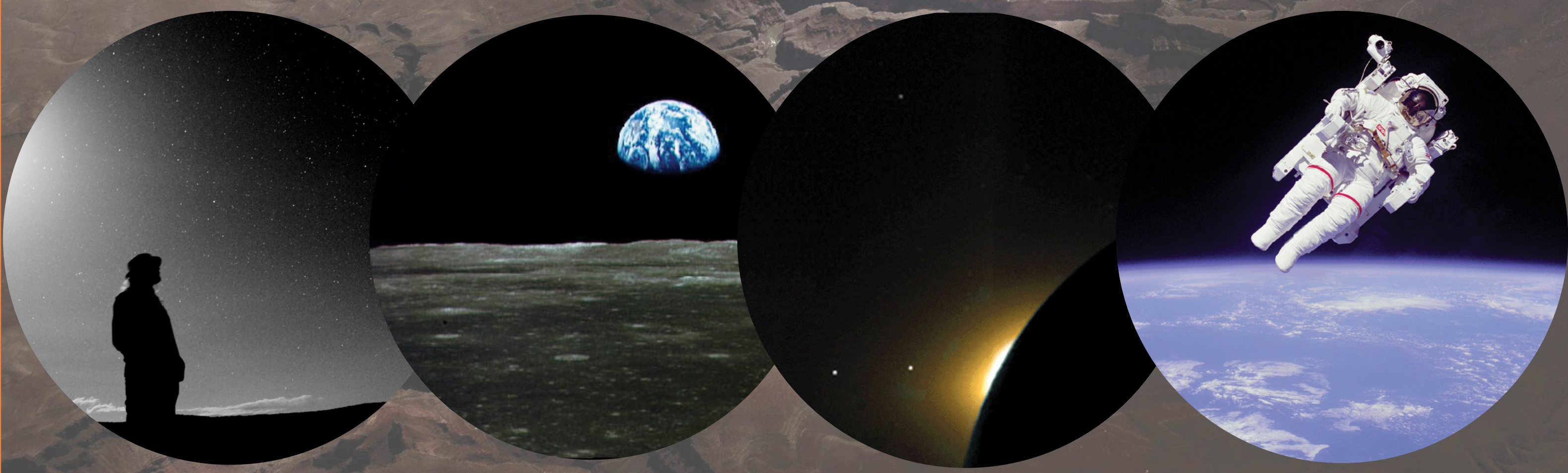
Notes

STAR GAZING

STAR GAZING

WEEK FOUR

The Constellations



Front cover image: The Grand Canyon from Space

Copyright: Travis Odgers

Back cover image: Orion nebula

Located 1,500 light years away, along our spiral arm of the Milky Way, the Orion nebula is located in the middle of the Sword region of the constellation Orion the Hunter.

Source: NASA, C.R.O.

Contents

WEEK FOUR

Thanks

Thank you to George Jones, Alan Gilmore and Peter Detterline for their stellar help and suggestions!

Terminology

For some of you, there may be many new words and phrases in this course. If you're not sure what something means, you might want to check an online glossary.

If you're still confused, feel free to ask me or your classmates in the forum.

WEEK FOUR

The Constellations

Welcome to week four! This week we will talk about constellations and what they really are; also what we use to help us find constellations on the sky.

The word constellation means congregation of stars: 'con' – 'together', 'stella' – 'star'.

From the movie Shrek

LATER THAT NIGHT

Shrek and Donkey are sitting around a campfire. They are staring up into the sky as Shrek points out certain star constellations to Donkey.

SHREK

And, uh, that one, that's Throwback, the only ogre to ever spit over three wheat fields.

DONKEY

Right. Yeah. Hey, can you tell my future from these stars?

SHREK

The stars don't tell the future, Donkey. They tell stories. Look, there's Bloodnut, the Flatulent. You can guess what he's famous for.

DONKEY

I know you're making this up.

SHREK

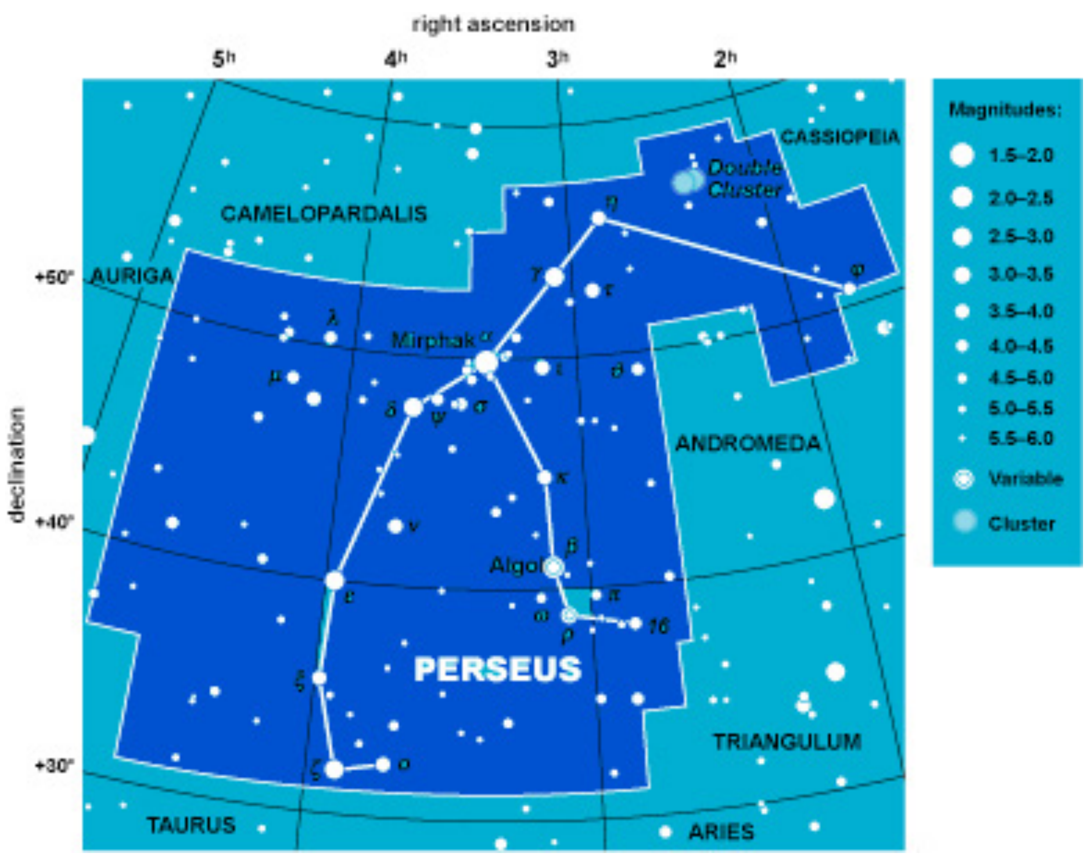
No, look. There he is, and there's the group of hunters running away from his stench.

DONKEY

That ain't nothin' but a bunch of little dots.

SHREK

You know, Donkey, sometimes things are more than they appear. Hmm?…



Very few people know that a constellation is actually a patch of the sky.

In this representation of (modern) Perseus, the constellation is literally everything inside the dark blue patch. The stars marked by the white line are just making a stick figure – sometimes mistaken for a constellation.

So what exactly is a constellation, and how can we tell them apart?

Each ancient civilisation tells a different story about how constellations were formed. It is interesting how these seem to be linked to the geographical locations on Earth and how those people were spending their time. For instance, Polynesians talk about waka and fishing hooks. Romanians have ploughs, fountains and crosses. Arab traditions tell about crabs, scarabs, scorpions and deserts, Greeks have centaurs and sailboats.

All these 'constellations' are made from the same stars we see in the sky, across the world. Yet, the same stars meant different things to different people. Listening to everyone's legends about the stars, the story of the sky reminds me of the story of the Tower of Babel. Everyone is speaking a different language, but most likely about the same stars.

I believe that in ancient times the common man did not care what other countries were saying about stars. There was no cross-cultural *starrytelling,* like we do nowadays in the planetaria. *Starrytelling* in most of Europe was a localised knowledge dissemination.

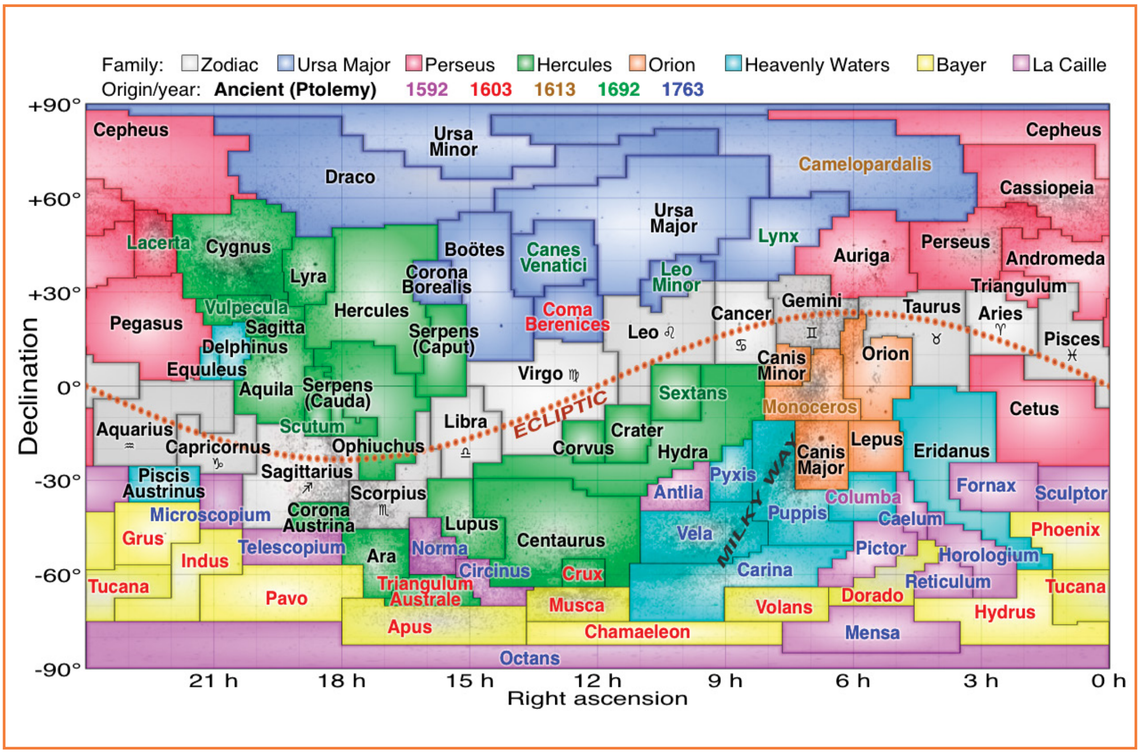
In Polynesia, the Māori shared their constellations across what is now divided into many regions and countries of the Pacific. They centralised their information and systematically disseminated the constellations to all other island nations as a means of improving on navigational techniques. The Polynesians looked at the stars to determine how to move between certain islands and tidal current systems.

Many centuries have passed and, towards the end of the 1800's, when science advanced and people discovered globalisation, collaboration increased the sharing of scientific data. In the astronomical world, it became more and more difficult to align the names of the stars from so many languages, let alone the constellations they belonged to. To solve the first problem, the astronomers adopted international catalogues for stars. To sort out the second, around 1930, the International Astronomical Union declared constellations to be patches on the celestial sphere, shapefiles.

Although located at different distances in space, stars are mapped onto the celestial sphere just like places are on Earth. Each is pinpointed via Right Ascension – RA (aka celestial longitude) and Declination – Dec. (aka celestial latitude).

Don't try to learn the constellations' borders by heart! Leave that for the pedantic scientists. For stargazing however, it would be fun to learn the major stars and make up most of the stick figures.

The History Channel has a great video about the constellations.



Think of a constellation as you would think of a country on Earth. It has boundaries, neighbours and only one star that shines brighter than all the rest, just like a capital city. Scorpius, for instance is the zenith constellation of New Zealand. It's brightest star (or 'lucida' – Latin for 'brightest') is Antares.

Peering Into the Future

Have you ever wished upon a star?

I can't say for sure what will happen to you if you do, but it's definitely worth a try. It always worked for me.

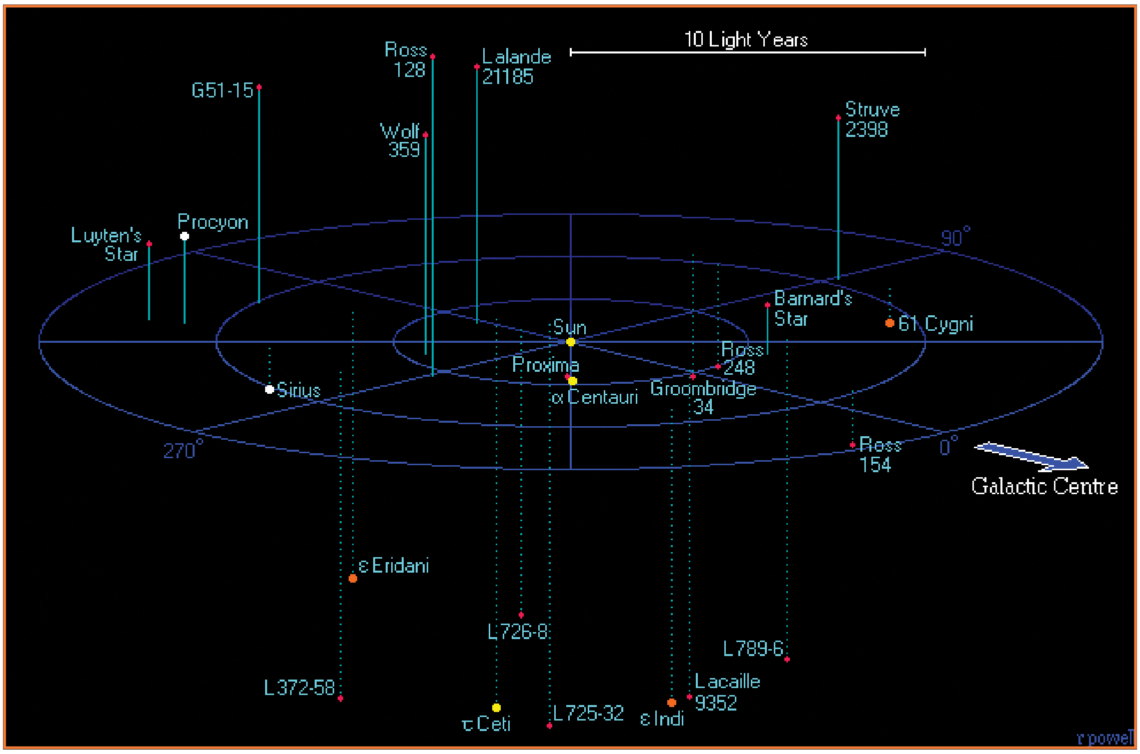
And moving towards a bit more complicated topic: Have you ever wanted to know in advance what will happen to you in a few months time?

Well, personally I always did want to know everything in advance and this is exactly why the zodiacal constellations fascinated me; they do have a certain aura of mystery, you know...

The zodiacal constellations

Tiny specks of light, which glow trillions of kilometres from Earth suspended onto the velvety black of the heavens, make the zodiacal constellations. How far away are they?

The nearest star to Earth, Alpha Centauri is 39,900,000,000,000 km away. And Alpha Centauri is not part of any zodiacal constellation. But of course by now we know that stars, which seem to be part of the same constellation, lie in reality at very different distances in space.



The Universe within 12.5 light years, the nearest stars (click on this; it's interactive).

Through our telescopes we can now see that they can tell us how far away stars are. Our ancestors saw something else: codes and messages, summaries and memory aids, containing information on how to stay alive.

The word zodiac comes from the Greek 'zoon' – 'animal'.

We can see some of the zodiacal constellations, if we look towards the ecliptic in the evening. They are the stars behind the planet's paths. There are twelve of them, although modern astrologers now argue about the exact number.

During one year, the Earth circles the Sun once. As seen from Earth, our Sun seems to be shifting through every single zodiacal constellation.

I found this great trailer of a planetarium show 'Tale of the Stars: Eternal Shine'. Please watch it in detail and watch it again if you need to. It shows, amongst other things, the zodiacal constellations, in a sequence until minute 1:30.

The images that you need to take with you from this video are:

- the Sun gliding along the constellations of the zodiac, and
- the celestial sphere with its belt made of the twelve zodiacal constellations: Scorpius, Sagittarius, Capricornus, Aquarius, Pisces, Aries, Taurus, Gemini, Cancer, Leo, Virgo, and Libra.

Now, back to Earth. Are the stars from the zodiacal constellations at the same distance in the sky? Do they really lie on a belt/band? Not really, no. Then why people believe they can influence the future?

Why are the zodiacal constellations important

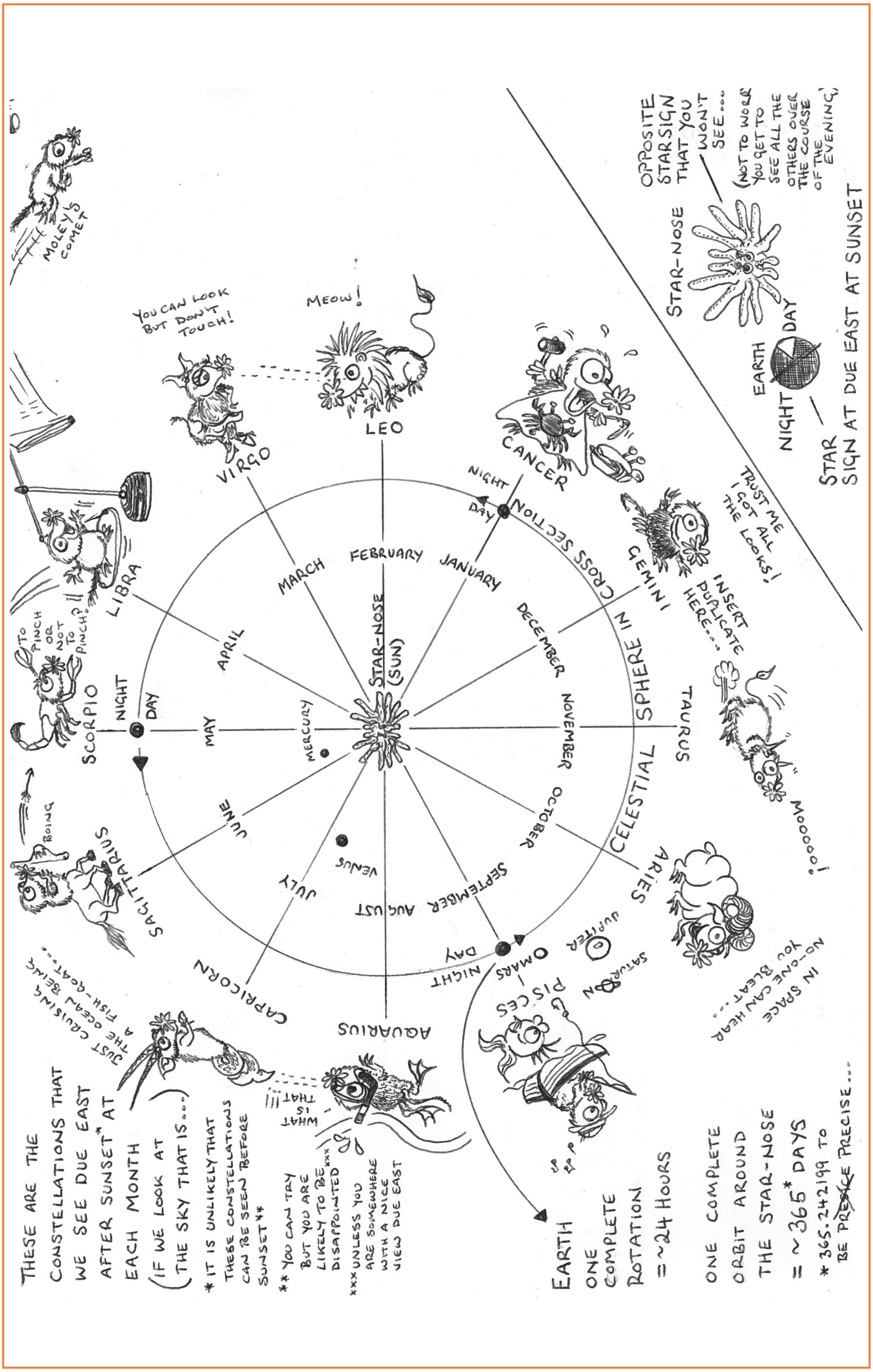
The zodiacal constellations are very important. Judging by their age, they probably are the most important constellations in the history of humankind, not including the people from the Americas and the Pacific who have not heard of them until after the European 'invasion'.

It all comes back to geography, again. Approximately between 10 and 20,000 years ago some of our ancestors chose to travel from Africa towards the Northern part of the Northern Hemisphere, exploring new lands. Why did they do that? We are not sure but, we do know they managed to survive the months of snow without modern technology… scary!

After many years as planetarium presenter, I feel compelled to say this: wintertime in Europe is almost like being in Antarctica (in summertime). I figured out that not everyone knows this, or more precisely, not everyone knows how that feels. Many people have not even seen snow for real in their lives.

Wintertime in Northern Europe can be very cold indeed. You can only see snow everywhere you look. Plants seem dead and everything else is frozen solid. Knowing how long the winter lasts and when to start the countdown to springtime, was vital information for our ancestors, which allowed them to ration the food gathered in autumn and survive wintertime.

Being able to foretell the middle of winter become very important knowledge held by a special caste of people, like the priests or the druids who used the stars to predict their people's 'future'. For instance how many full moons they could see until the spring would come. For us today, this may seem silly, for them, 10,000 years ago it made the difference between life and death.


THESE ARE THE CONSTELLATIONS THAT WE SEE DUE EAST AFTER SUNSET* AT EACH MONTH (IF WE LOOK AT THE SKY THAT IS...)
* IT IS UNLIKELY THAT THESE CONSTELLATIONS CAN BE SEEN BEFORE SUNSET**
** YOU CAN TRY BUT YOU ARE LIKELY TO BE DISAPPOINTED***
*** UNLESS YOU ARE SOMEWHERE WITH A NICE VIEW DUE EAST
JUST CRUISING THE OCEAN BEING A FISH-GOAT...
BOING
TO PINCH OR NOT TO PINCH?
MOLEY'S COMET
YOU CAN LOOK BUT DON'T TOUCH!
MEOW!
WHAT IS THAT!!!
SCORPIO
SAGITTARIUS
LIBRA
VIRGO
LEO
CANCER
GEMINI
TAURUS
ARIES
PISCES
AQUARIUS
CAPRICORN
NIGHT
DAY
MAY
JUNE
APRIL
JULY
MARCH
MERCURY
VENUS
AUGUST
STAR-NOSE (SUN)
FEBRUARY
JANUARY
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
MARS
JUPITER
SATURN
CELESTIAL SPHERE IN CROSS SECTION
EARTH
ONE COMPLETE ROTATION = ~24 HOURS
ONE COMPLETE ORBIT AROUND THE STAR-NOSE = ~365* DAYS
* 365.242199 TO BE PRECISE...
IN SPACE NO-ONE CAN HEAR YOU BLEAT...
MOOOOOO!
INSERT DUPLICATE HERE...
TRUST ME I GOT ALL THE LOOKS!
STAR-NOSE
OPPOSITE STARSIGN THAT YOU WON'T SEE...
(NOT TO WORRY YOU GET TO SEE ALL THE OTHERS OVER THE COURSE OF THE EVENING)
EARTH
NIGHT
DAY
STAR SIGN AT DUE EAST AT SUNSET

Located behind the ecliptic, the stars from the zodiacal band rise every day four minutes earlier, as Earth travels around the Sun. Earth travels almost one degree per day around the Sun[1]. The shift of the Sun through the zodiacal constellations becomes more visible if we compare the night sky view across seasons: different constellations will appear on the evening sky in autumn, spring, winter and summer.

At night Earth looks away from the Sun towards the stars, whilst revolving around the Sun each day little by little. A year later, as we tour the Sun once again, the view 'resets'. Going the full circle brings back into the view the same constellations.

1 360 degrees of a circle divided by 365 days on a year equals 0.98 degrees of a circle, which Earth travels a day. 1 minute of time equals 0.25 degrees of a circle (360 degrees divided by 24 hours times sixty minutes each = 0.25) So one degree of a circle equals four minutes of time.

The zodiacal constellations are mostly (with few exceptions) symbolised by animals. Not necessarily because they looked like animals but mainly because they were marking important moments, for instance the lambing season, the hunting season, the flooding of the Nile and how these occurrences affected animals or creatures.

It is a work of genius how ancient people adapted this information into what we now call the modern calendar. So yes, the zodiacal constellations are humanity's first calendar. We still consider them very important today, albeit some of their original meanings were lost, obsessing still on how they can predict the future for some, but isn't this what a modern calendar does today also?

The Rest of the Sky

Other than the 12 zodiacal constellations, the sky is made of 76 more.

The 'other' constellations are equally significant and useful, but mostly for navigation rather than season/time-telling. They are a great aid to find the direction south and north (Ursa Major and Ursa Minor, or Crux). Another example is Orion, with its star Mintaka, which rises exactly from east and sets in west.

Ancient constellations

Some of the constellations we know today were described in old Mesopotamia many thousands of years ago. The Egyptians talked about Sirius the Dog and his mate Procyon barking each side of the Milky Way. They were warning shepherds of the floods of the Nile. The good old 'dog days of the summer' expression also originates from those times as the dog star Sirius, nicknamed 'the scorching one', was on the summer sky.

The ancient Greek made a major contribution to the development of the modern constellations. They coded their maritime adventures into the first 48 known constellations. Some of these were taken from previous cultures, with which the Greek shared almost the same geographical location: the Mesopotamians, Babylonians and Egyptians.

The first written compendium, which talks about stars and constellations was authored by the Greek Ptolemy – the Almagest. The name is a latin translation of the Greek word 'megiste' – 'greatest'. Ptolemy's work was influential for centuries and although modern times disagree with his geocentric view of Earth, the mathematics, trigonometry and knowledge he otherwise had, were astounding.

The 48 constellations listed in Ptolemy's Almagest are:

- 21 NORTHERN CONSTELLATIONS: Andromeda, Aquila, Auriga, Boötes, Cassiopeia, Cepheus, Corona Borealis, Cygnus, Delphinus, Draco, Equuleus, Hercules, Lyra, Ophiuchus, Pegasus, Perseus, Sagitta, Serpens, Triangulum, Ursa Major, Ursa Minor.
- 12 ZODIACAL CONSTELLATIONS: Aries, Aquarius, Cancer, Capricornus, Gemini, Leo, Libra, Pisces, Sagittarius, Scorpius, Taurus, Virgo.
- 15 SOUTHERN CONSTELLATIONS: Ara, Argo Navis, Canis Major, Canis Minor, Centaurus, Cetus, Corona Australis, Corvus, Crater, Eridanus, Hydra, Lepus, Lupus, Orion, Pisces Austrinus.

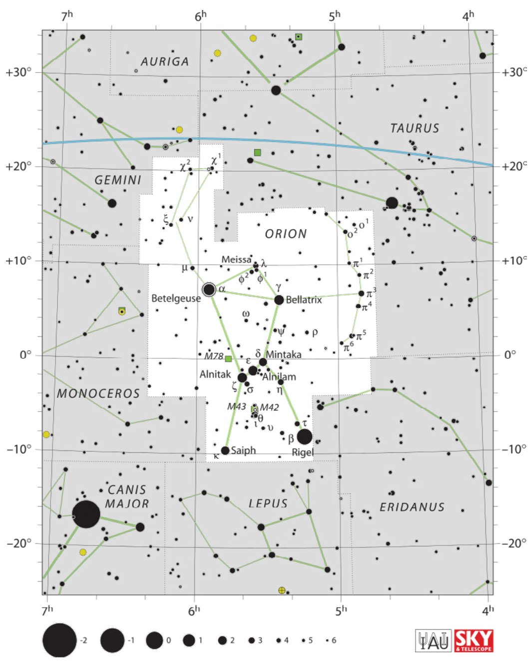
Modern constellations

The birth of the modern constellations saw the division of the sky in areas. In 1922, the International Astronomical Union proposed 88 official constellations to cover the whole sky. Six years later they were approving their boundaries. They did not seem to do this in a hurry, but in the grand scale of the Universe, the decision was taken in the blink of an eye. By 1930 the Union had it all sorted.

Note the boundaries and the notations in Greek letters next to the stars on the constellation of Orion in the picture below.

The constellations' boundaries used to be almost straight, along lines of RA and Dec. for the equinox (not epoch) of 1875. Precession has caused the boundary lines to become angled to the current RA and Dec. lines.

The biggest officially defined constellation in the sky is Cetus – the Whale, and the smallest one is the Southern Cross.



Source: *Wikipedia.*

More reading about constellations

- if you wish to see a star map of the night sky from your nearest major city.
- what the International Astronomical Union has to say about constellations.
- what someone with very artistic views thinks of the 88 constellations.
- more Kagaya's awesome planetarium shows.
- some more history about constellations.

Asterisms

An asterism is a pattern of stars. They can be smaller or bigger than a constellation. The Pleiades (Matariki) is an asterism. So are the pointers with the Southern Cross (also known as the famous 'fish in the frying pan').

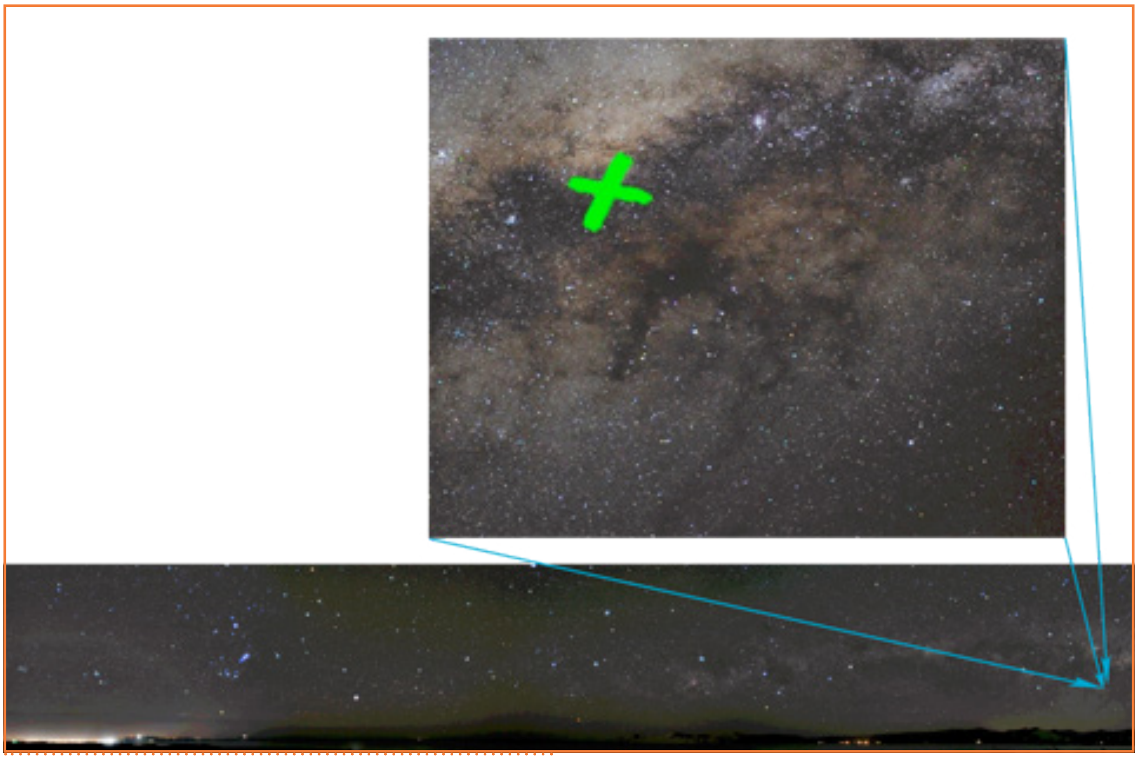
The word asterism comes from the ancient Greek 'aster' – 'star'. An asterism can be located within a constellation or stretch across many.

To exemplify, I choose Te Waka o Tamarereti, my favourite asterism in the sky. Well, it is almost as big as the whole sky! It stretches on 270 degrees around the horizon. As we look at Te Waka o Tamarereti we are actually looking at the Milky Way lining up around the horizon. Telling the story of the Māoris' safe return to Hawaiki, te Waka O Tamarereti is visible from New Zealand after sunset during Orongo (around November).

In the picture below (our modern) setting Scorpius marks the front of the waka – Te Tau Ihu (the prow). Moving left, are the two pointers Te taura or the rope that is tied to the Southern Cross – Te Punga. In the time of Matariki,June, as well as during Orongo, Te Punga is one time its size above the southern horizon at Wellington NZ's latitude.

This is the anchor of the waka. Canopus or Atutahi is Tamarereti in his waka, Takurua – Sirius is the right hull and Orion's belt is Te Taurapa (the sternpost) followed by the the head of Taurus being the rear steering paddle rigging or te Kakau. On the far left, at the end of the picture, you can also see Pleiades. At this time of the year they are the ripples left on the water by the steering oar of the waka.

It is truly spectacular to see both Orion and Scorpius in the sky. This feature is visible only to us lucky ones who are located in the Southern Hemisphere. At the front of the waka, is a more modernised celestial feature of a very Aotearoan Milky Way Kiwi; its' beak



Te Waka o Tamarereti – a Māori constellation used for navigation on the evening sky in November. Copyright: John Drummond, Director of Astrophotography Section, RASNZ.

is turned towards the waka as if still inside the sacred forest of Tāne from where the waka was carved. The Milky Way Kiwi holds the galactic centre on its head just like a crown. I marked the centre of our galaxy (also known as the Sagittarius A zone) with a green cross. The distance to there is around 25-28,000 light years.

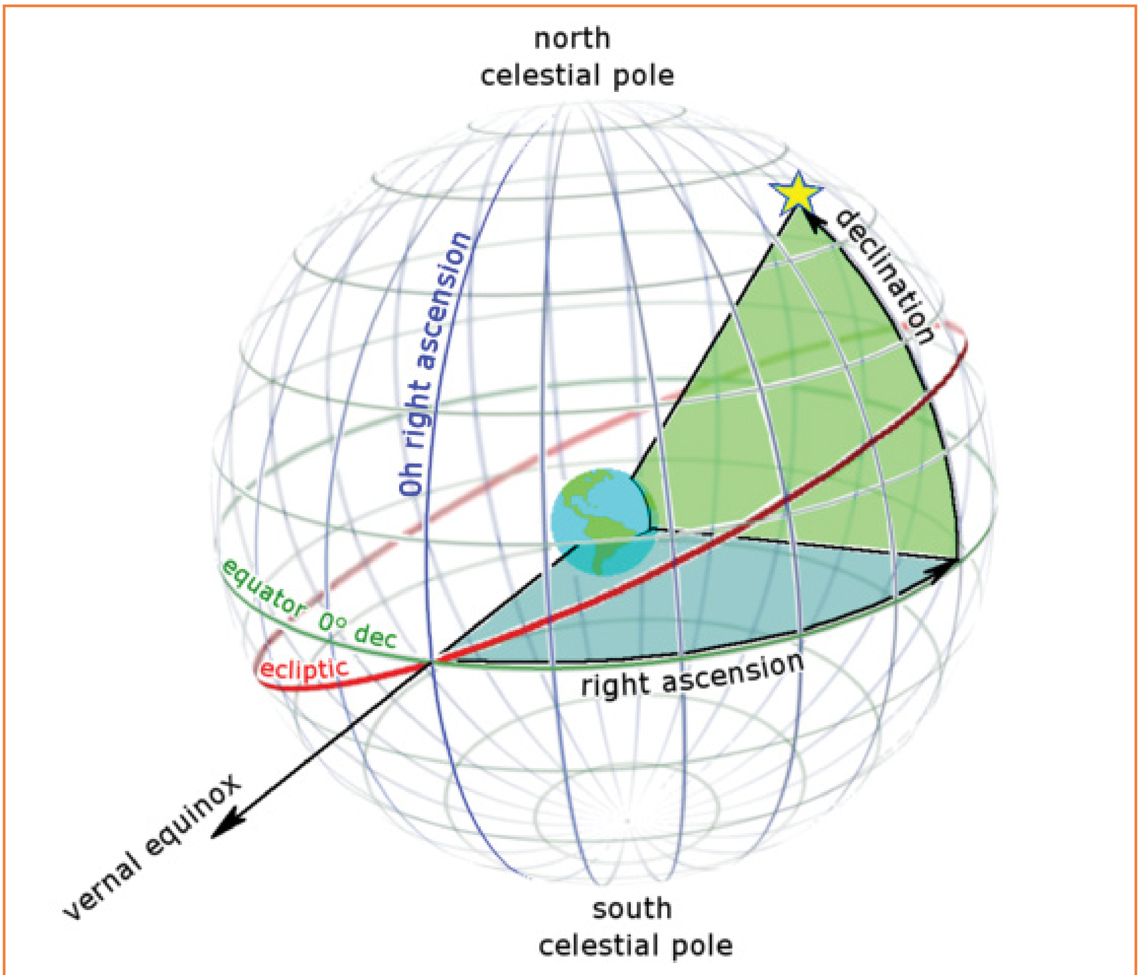
Get yourself a clear night with a dark sky after Orongo (last quarter of the Moon) and look at the galaxy flowing around the horizon like a huge river made of billions of stars! On it, Te Waka o Tamarereti awaits to take you to the centre of our galaxy and the Universe!

Celestial coordinates: Dec. and RA

Even though the constellations are patches in the sky, we still need to know exactly where each star is located. Just like latitude and longitude on Earth are used to mark geographical positions on the globe, Right Ascension and declination mark the position of the stars on the celestial sphere.

Declination

Abbreviated dec, symbol δ, declination is the equivalent of latitude. Latitude refers to the imaginary lines that run 'around' the Earth. Declination is



measured in degrees, minutes and seconds North and South of the (celestial) equator.

North of the celestial equator declination is listed as positive (+) and South is listed as negative (-). Most of the stars visible in the Southern Hemisphere have negative declinations; they are located South of the celestial equator.

Alpha and Beta centauri (the pointer stars), as well as Mimosa (Beta Crucis) and Achernar (Alpha Eridani), all have approximately '- 60' declination. They are part of the South Celestial Circle which is roughly what we call the circle of bright stars that happen to be close to 60 degrees South and includes the pointers, Crux, Canopus and Achernar.

Right Ascension

Abbreviated RA, symbol α, Right Ascension is the equivalent of longitude. Longitude refers to the lines that run 'up and down' the Earth.

If latitude on Earth can be easily measured by the stars or using the length of the shadows at noon, there is no way in which you can tell the longitude unless you have a precise clock, or you are a tohunga tarai waka (Polynesian expert navigator). However, tohunga had a completely different approach to navigation and, whilst the two systems evolved in parallel, Right Ascension is linked to the Western world.

A most beautiful book 'Longitude', by Dava Sobel, tells the story of how the chronometer (our modern watches and clocks) saved lives at sea by enabling the navigators to precisely measure our coordinates on Earth. Just like longitude on Earth, Right Ascension is measured in hours, minutes and seconds. One hour is equivalent to 15 degrees, and 24 hours makes a whole circle (360 degrees).

(Very) Technical note: Right Ascension is measured to the East of the celestial meridian. The meridian is the line passing through both celestial poles and the point on the celestial equator called the First Point of Aries, or the vernal equinox.

With a 'GoTo' telescope you can easily find any star in the sky if you know its Right Ascension and Declination. (A GoTo Telescope is a modern telescope with a computer that knows the exact locations of the stars. Most of telescopes now have this function.) All that a user needs to do when they buy such a telescope is to polar align the telescope (to the celestial pole) so that the telescope memorises the axis of the Earth, which is how it will always find its reference point or zero point.

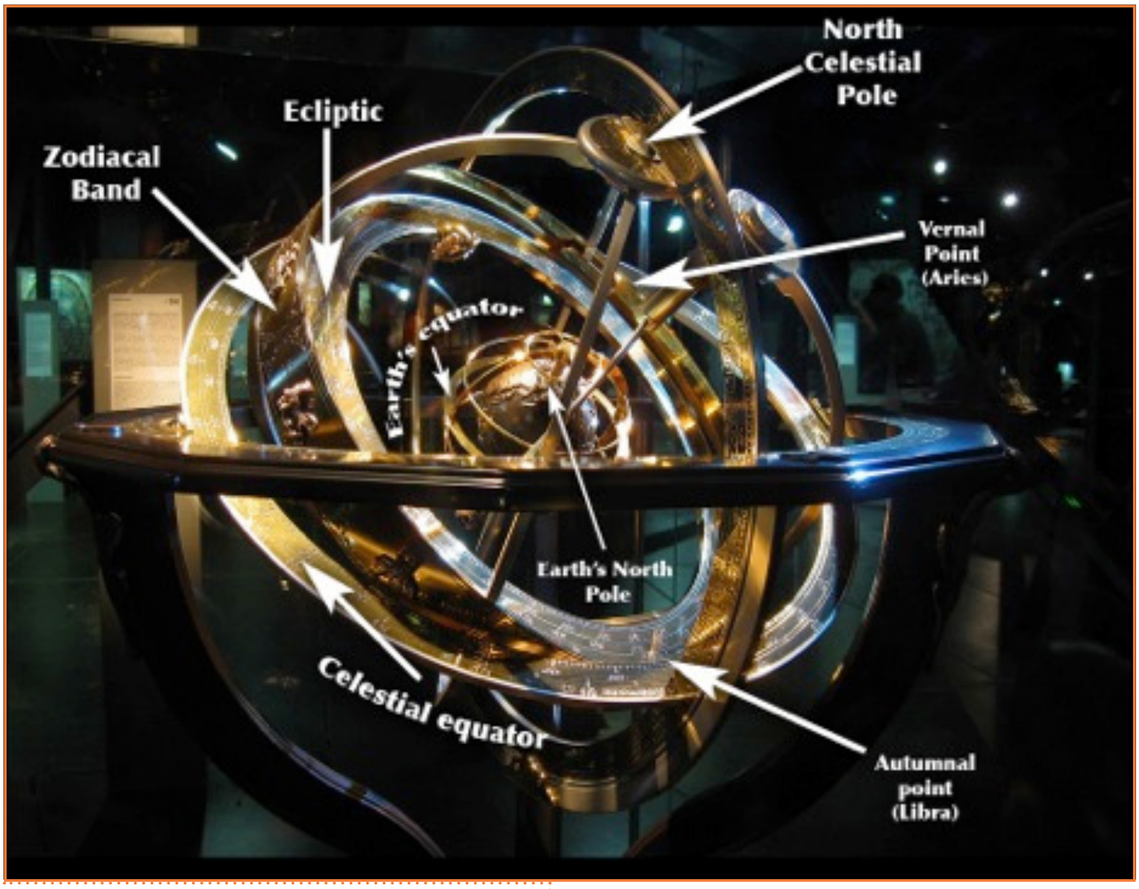
Aids for Identifying Celestial Objects

We all need some visual aids to remember where the stars are, whether they are stories or sky maps. Charts are very good, planispheres are great, or you could use some cool software. I will start with my favourite, the armillary sphere, that I consider to be the mother of the planisphere and grandmother of the cool software.

The armillary sphere

The armillary sphere is a great tool to demonstrate the terrestrial and celestial poles, the Equator and the ecliptic, the points of equinox, the Right Ascension and Declination. The armillary sphere is an old mechanism. Its creation was attributed to the Greek Eratosthenes who lived from 276-194 BCE (before current era). Greek or not, the current name of the sphere derives from the Latin 'armilla' – 'circle', 'bracelet', which describes perfectly its structure.

The circles in question go around the celestial sphere like meridians and parallels go around Earth. The armillary sphere has features related to the real sphere on which we live. 'In Heaven as it is on Earth' to paraphrase an ancient prayer. If we take another look at Kagaya's video at minute 1:16 you can see the animation of the celestial sphere surrounding the Earth for a few



The armillary sphere.

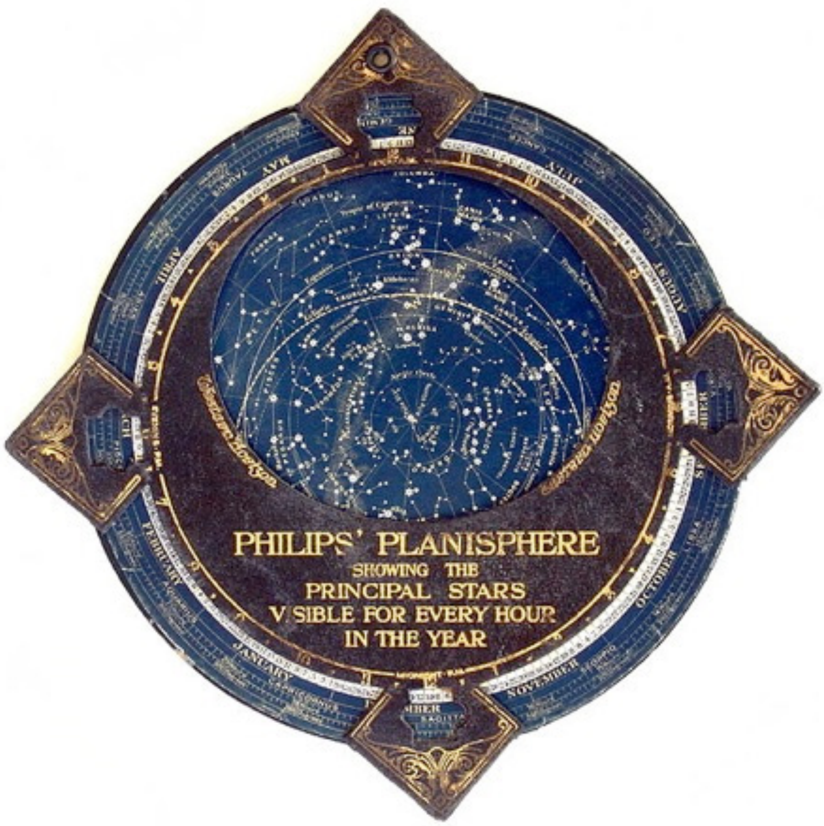
seconds. Around minute 1:30 here comes the armillary sphere!!! Can you find the ecliptic and the zodiacal band in the armillary sphere picture?

The planisphere

A planisphere is a magical 2D little star chart consisting of two circles that rotate on a common pivot. It gives an idea what constellations are visible in the night sky at certain times of the year, from certain latitudes. The planisphere is a projection of the celestial globe for a particular latitude.

Just like with the Moon, I never really liked planispheres. Firstly, because I was unable to find any stars on the sky anyway with or without one. Secondly, after I learned where all the stars were, I didn't need one! Besides, constellations on them look kind of distorted… However, if you chose to ignore me, and I think in this case you should :), there are many great YouTube video explaining in detail how to operate a planisphere. All about Planispheres also shows why constellations look distorted on the planisphere disk.

If you need a map of a particular constellation here is where to print a good copy, or use Astroviewer. You should not really need maps of constellations for stargazing, but you do for later on when you will be using a telescope. Or binoculars.



Philip's planisphere.

Note that if you are buying a planisphere you must make sure it is for your hemisphere. Any serious observatory would have one, but ask and just in case, double check.

Computer-generated software, such as Google Night Sky, Stellarium or smart phone applications are excellent sources of information. Smart phones and tablets are great tools with some excellent star chart software available and goto functions. Basically all you need to do is press a button and then guess what you're looking at. That is because, unless you have a military issue smartphone, the civilian GPS (global positioning systems) devices are not that accurate.

But even so, it's much easier nowadays to identifying the planets, the stars and then the constellations without much human help.

I use Night Sky on a daily basis. It won the Best Application Award in 2010 and it is fully endorsed by the International Astronomical Union and IYA 2009 but please feel free to explore, and choose the one you think works best for you.

I spent many sleepless nights not able to figure out the many constellations of the sky. I could not 'see' anything beyond Polaris, the Big Dipper and the Rake.

Well, the Big Dipper was easy to distinguish. Even the small kids could see it. It's always in the sky in the Northern hemisphere, just like the Southern Cross is here. One could easily find Polaris if you knew where the Big Dipper was, and I could see the Rake from time to time in the Northern Hemisphere's winter sky (December to January).

We did not have access to interactive planetaria, software or smart technology to show us the way. They were not invented yet. Still all those other constellations were there.

But where were they?

All the celestial maps I had did not tell me a thing. And I could not work out any of the distorted figures from planispheres, which is why I never got one.

Was I the last senseless person in the world who looked but could not see?

...

Many years have passed since that. I grew up into a biologist. Hubble was launched to space. The Internet was invented. One day, browsing the internet for star stuff, I put my hand up to translate 'Hallo Northern Sky', a planetarium program, from English to Romanian. (We did not have Google translate either, what am I saying, Google itself was not even invented yet!)

Looking through the screens of the software, I realised that the very bright group of three stars that my grandfather presented to my child's eyes as the rake, with which God gathers the stars from the morning sky, had to be the famous Orion's Belt.

Where I come from, one only uses rakes in summertime to gather hay, or at the beginning of autumn for fallen leaves. That is July/August and September. Orion only appears at that time of the year in the morning sky. That information helped me figure out I was right!

I will remember that 'Eureka!' day forever. It was the day I started to read the sky. From Orion, I made up the rest of the constellations.

Then I discovered that Bucharest also had an astronomy club. I liked the people from there so much that we remained best friends even after more than twenty years!
My new astro-friends showed me where the ecliptic lay and we worked out the constellation shapes from the of stars. With their help, in the light-polluted skies of my home city, I learned about half of the zodiacal constellations in only one night. The other half was behind Earth.

Light pollution was good for one time in my life. Being able to see only the brightest stars, definitely helped. You can get the same result with the Moon in the sky.

That night I also saw Saturn through a telescope, for the first time. It was the first thing I have ever seen through a telescope! You should have heard MY wow! Saturn still is the most amazing thing in the sky to me, even today.

Not that the other stuff I see is not spectacular, but Saturn... is just…wow!...

Before I'll get carried away with Saturn again, the story finishes with me returning to the countryside at my grandparents' house keen to do some more observing. I was eager to absorb, like a sponge, new information. I wanted to map my discoveries and engrave them in my mind forever.

There, in my grandparents' backyard, I raised my sight upwards. There were so many stars that I got completely lost (countryside, 20 years ago, no light pollution).

Back to square one, and not being able to make up any constellation because of the myriad of scintillations, I took a blanket and just lay on my hammock. But this time it did not matter that I could not tell the stars apart. My journey to becoming a starryteller had already begun and I knew it.

Without further ado I simply let myself float amongst the colours of the black sky, whilst allowing the summer night scent to invade my senses.

And right there, surrounded by the warmth of the summer, I could clearly see, how we were all made of stardust.

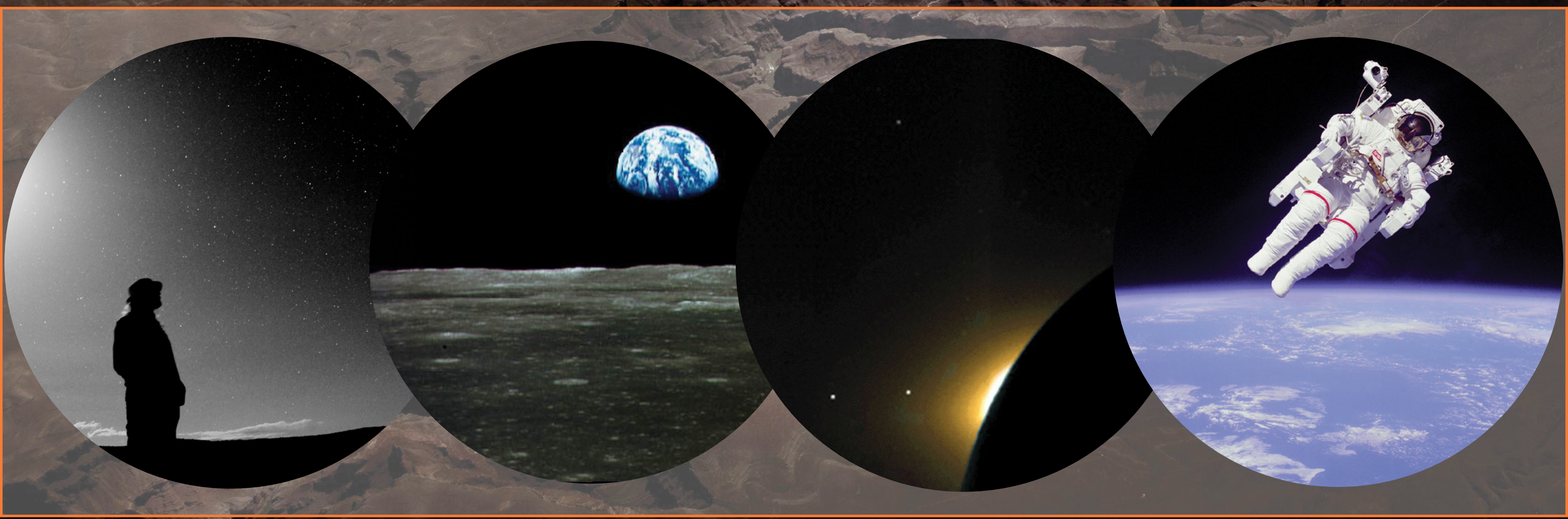
Notes


STAR
GAZING

STAR GAZING

WEEK FIVE

The Changing Earth and Sky



Front cover image: The Grand Canyon from Space

Copyright: Travis Odgers

Back cover image: Orion nebula

Located 1,500 light years away, along our spiral arm of the Milky Way, the Orion nebula is located in the middle of the Sword region of the constellation Orion the Hunter.

Source: NASA, C.R.O.

Contents

WEEK FIVE

Thanks

Thank you to George Jones, Alan Gilmore and Peter Detterline for their stellar help and suggestions!

Terminology

For some of you, there may be many new words and phrases in this course. If you're not sure what something means, you might want to check an online glossary.

If you're still confused, feel free to ask me or your classmates in the forum.

WEEK FIVE

The Changing Earth and Sky

Welcome to week five of our stargazing journey. I hope you have had lots of fun looking at the constellations last week. Did you pick a favourite yet? I have asked myself many times this question. And I think my favourite constellation is Corvus. Why Corvus… because everytime I look at it, I feel happy knowing Scorpius is following soon, dragging the galactic center…into our sight. And seeing that, is the best part of being in the Southern Hemisphere.

Stargazing the first four weeks, we looked mostly at what we see in the sky, from our place here on Earth: the clouds, the Sun, the blue sky (why is the sky blue anyway[1]?), the Moon, Planets and Stars. Now it's time to talk about EARTH!

This week is all about Earth:

What does Earth do in space and how does the sky above change as a consequence of that? What does that mean? Would that be useful information nowadays? What about in the past? Can we understand our culture and traditions better if we take all that into account?

Stargazing from Earth

Again, it all comes to what we think we see, how we try to explain it and what is really going on out there.

1 Will look at that next week in 'Starting to see' chapter.

Stargazing in solitude by Mark Gee.

If we don't understand how Earth rotates around the Sun, and what happens as a consequence of that, then the patterns of seasons and how the temperature changes on Earth could be a confusing matter. At least that's how I felt for a long time. And only when I understood what happened up there, and made the link to down here, only then I started to felt safe in my environment as I travelled around the world.

Having said that, for today's humans it's not a matter of life and death to remember when seasons change. Most of Earth's population is now safe from freezing winters or blazing 'dog days of the summer'.

But as the society and the world evolved, there are new changes that our civilization set in motion. For instance, we don't entirely know what effect can have on the environment the massive migration of people to cities. An example is light pollution, which is light coming from the cities at night. That light is killing plants and animals and disrupts natural cycles of habitats. Light pollution disconnects us from our stars.

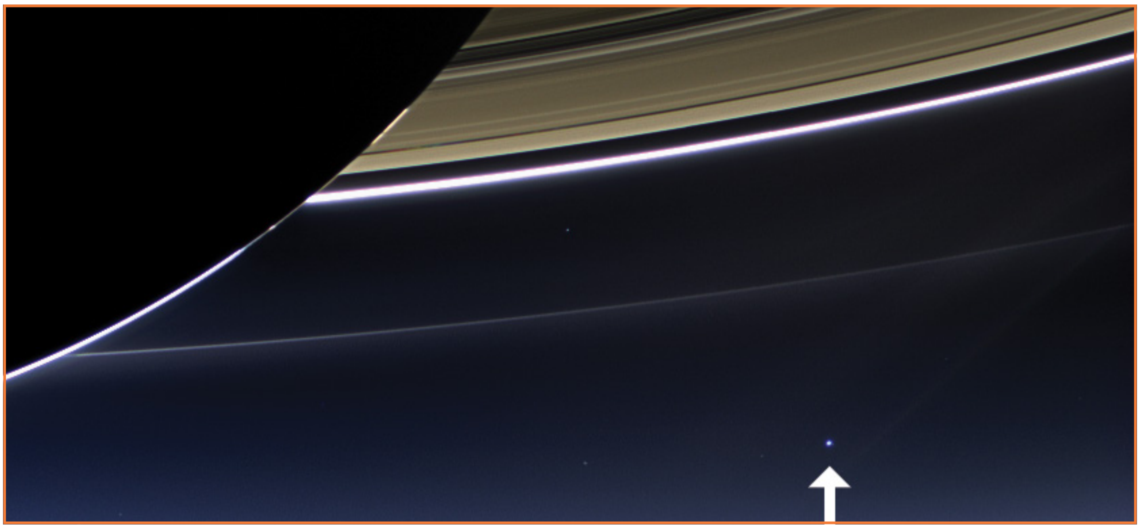
Understanding the sky is part of understanding how our environment, as a whole, works. It's part of the systems thinking education that future generations will have to embrace, if we wish to survive as a race.

On a personal note, I believe it's good to remember from time to time that humans also survived by ciphering (information into) and deciphering the sky. And keep the stars alive. Keep them alive in our hearts and on the night sky for as long as we live.

Home

Earth is our home.

The picture below is a retake of the famous Pale Blue Dot, which you have seen in chapter one. This time, the Cassini Spacecraft took took a picture whilst orbiting around Saturn. Earth is the tiny blue dot at the end of the arrow.



This is what Carl Sagan, who had the idea to take the picture of the Pale Blue Dot, said in 1990 after seeing it:

'Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every 'superstar,' every 'supreme leader,' every saint and sinner in the history of our species lived there-on a mote of dust suspended in a sunbeam.

'[...] The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand.'

You can also listen to it here.

About planet Earth

All you need to know about Earth – by Vangelis.

If you wish to know more, please also note that Earth is a rocky planet, the third from the Sun. Known as Gaea to my ancestors. Home, in Romania, we have this saying, which I remember from when I was a kid: whoever was not behaving, Gaea would have taken them[2]…

One amazing thing I re-discovered about Earth is that the temperature at its core is as high as the temperature from the surface of the Sun:
5-6000 degrees Celsius!

Earth is located in the Goldilocks zone, not too far and not too close its star, but just right so that it can support life. We should not take that for granted just because we are alive here on Earth. Because life is yet the most wonderful mystery. You will have to believe me when I say to you that as of this moment, when I write this, **nobody knows**:

A. **how life occurred on Earth**, and

B. **whether we are or not alone in the Universe**.

There are, however, many hypotheses of what could have happened. I can only hope that one day during my lifetime, we will find out for sure.

2 As it was never specified where exactly, for most of my childhood I have pictured Gaea as an enormous airy-fairy flying black 'thing', which from time to time takes naughty kids to the sky and not what it really was: Mother Earth.

It is said that life could have formed on Earth because of so many differences in temperature, and light and because we have day and night. The conditions on Earth are indeed diverse but not too extreme, we could say that they are mild as compared to Jupiter, for instance. On Earth, the outside temperature can go from 53 degrees Celsius (the highest proposed is 53.9 at Death Valley, USA) to -89 (89.2 at Lake Vostok in Antarctica). These are weather records, of course, but they exist.

A friend of mine was also wondering whether our eyes developed from the alternance day and night. Usually, this change happens over a 24 hours cycle. But on Earth we also have places where we can see the Sun continuously for up to six months at the time (this is one polar day).

So why are the conditions on Earth so diversified? It's easy:

Earth... moves, it's dynamic

1. Earth turns around it's axis, which gives day and night. At night, the temperature drops because we are not in direct sunlight.
2. As Earth turns in space, it has a lean to the plane of the ecliptic. This makes some places on Earth, like the equatorial zone, to be always exposed to sunlight. Some other places, like the poles, only receive light when the tip of the Earth leans towards the Sun.
3. Earth goes around the Sun. Because of (2) and (3) we have seasons. When the tip of the Earth leans away from the Sun, it receives less light and therefore less heat.

When I finally made the link between what happens in space and how that affects weather on Earth, it was much easier for me to understand seasons and weather patterns. And I could associate the night sky changes with the seasons on Earth, just like my ancestors did thousands of years ago.

I realised that the sky changes at night from hour to hour because the Earth is turning around its own axis. I also understood that as we visit different places around Earth, the sky changes too. That is because different places on Earth, bring different windows, or perspectives to the Universe. The Polynesians, who went very far across the Pacific understood it and used the night sky to travel, by celestial navigation.

For instance, from the Northern Hemisphere we can see Polaris, the North star. From the Southern Hemisphere we cannot see Polaris, but we can see the Southern Cross. Why is that? Because Earth is in the way. If Earth were transparent, we still could not have seen the entire celestial sphere at once, because the Sun would have washed all the stars away.

Seasons happen because as we travel around the Sun, we get more or less light from it. Which means more heat, therefore the temperature increases and with it all sort of changes happen. 'Dynamic Earth' is a great planetarium movie that I recommend watching, it's also got a great soundtrack and the voice of Liam Neeson!

Below is the best interactive tool I have found online to explain our dynamic Earth. Go to this link http://astro.unl.edu/naap/motion1/animations/seasons_ecliptic.swf and play with it! it's awesome!!

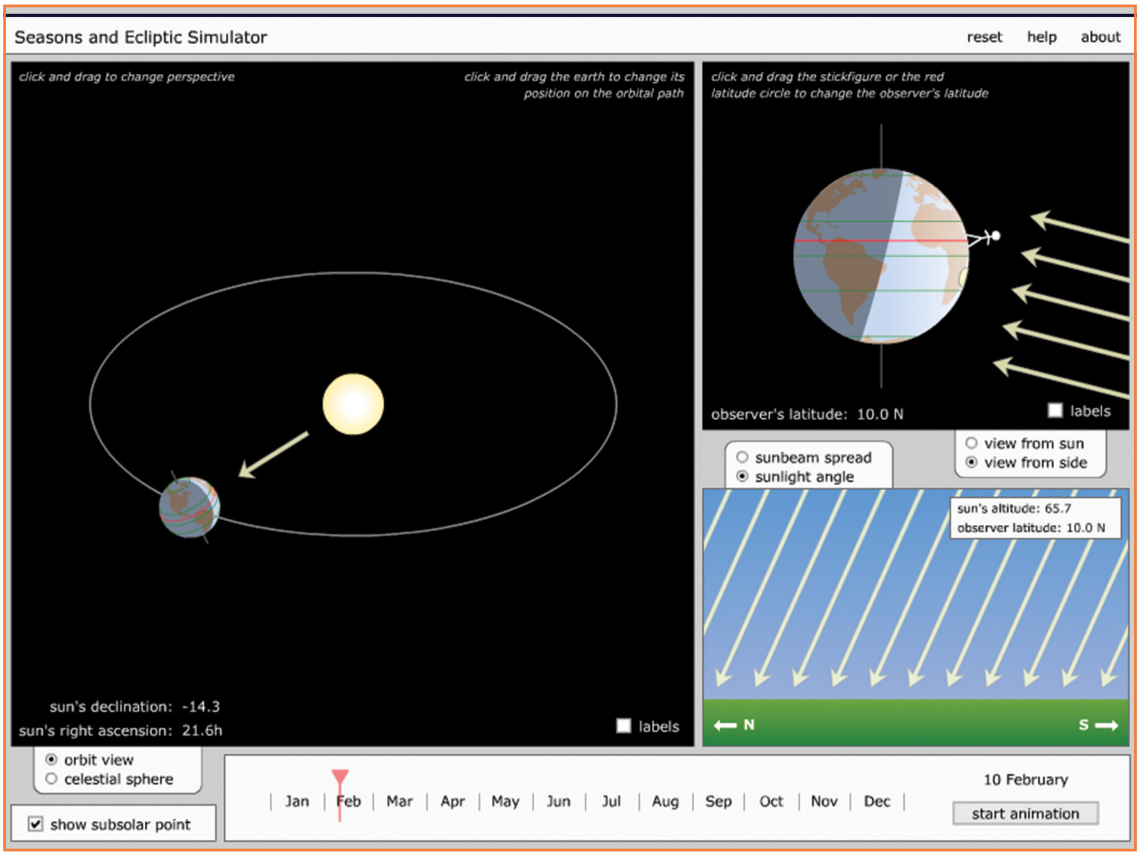
I also found a video which explains this to my liking.

Getting back to Earth:

It goes around the Sun

To be pedantic, the Earth actually 'falls' around the Sun. So does the Moon and the International Space Station, they fall around the Earth. We fall around the Sun at about 107,000 km/hour!

We call the free-fall movement of Earth around the Sun, revolution.

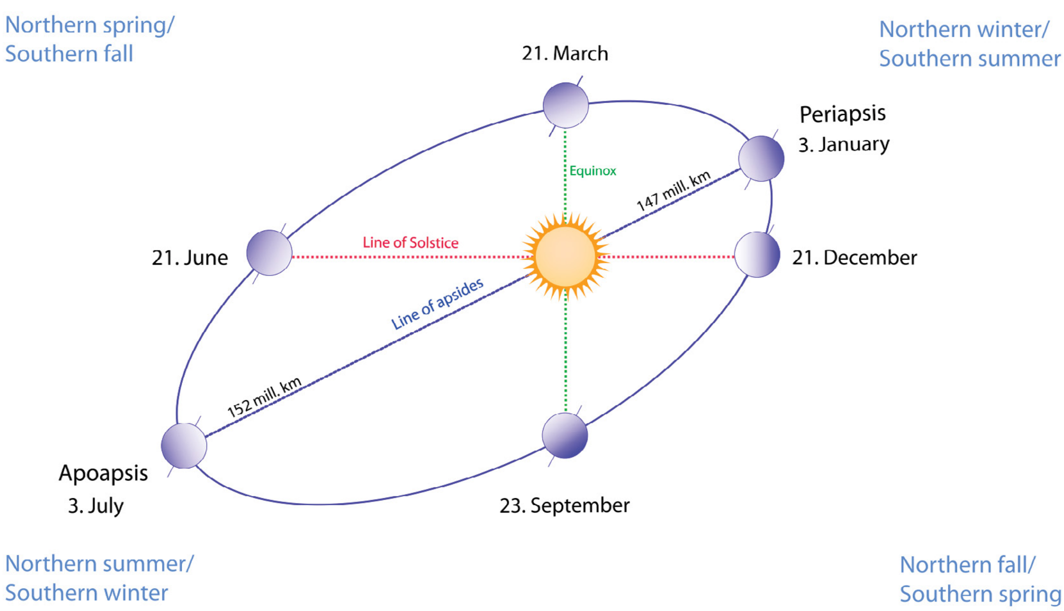


'Eppur si muove' – 'and yet it moves' – the legend goes, muttered Galileo Galilei before the inquisition, when forced to withdraw his statement that Earth goes around the Sun. Yet it does, and what does that mean for us?

It means that we have seasons – for those who have seasons.

'By one astronomical convention, the four seasons are determined by flanges, the solstices – the point in the orbit of maximum axial tilt toward or away from the Sun – and the equinoxes, when the direction of the tilt and the direction to the Sun are perpendicular. In the northern hemisphere winter solstice occurs on about December 21, summer solstice is near June 21, spring equinox is around March 20 and autumnal equinox is about September 23. The axial tilt in the southern hemisphere is exactly the opposite of the direction in the northern hemisphere. Thus the seasonal effects in the south are reversed.'

(**Wikipedia**)



It also means that the astronomers have another chance to complicate our lives and tell us that in fact there are two types of days out there: solar and sidereal days. Actually three: solar, stellar and sidereal, but who's counting? They are the result of Earth spinning around its axis, 'falling' around the Sun and wobbling.

PERIHELION AND APHELION

Marks the closest and the furthest place of Earth from the Sun.

Earth circles the Sun in an ellipse as every other planet does (and not in a circle).

The eccentricity of Earth's orbit changes its distance from the Sun by 4%.

This means that sometimes we are closer (at perihelion) to the Sun and some other times we are further away (at aphelion). Note the same letter 'A' – away and aphelion. When we are close to the Sun we orbit faster, and when we are far away... slower.

In the Southern Hemisphere summertime happens when we are closest to the Sun. That does not only mean we get more heat but the duration of summertime will be shorter here[3]. There are 178 days between the September equinox and the March equinox. There are 187 days between the March equinox and the September equinox.

If you wish to do more reading on this, NASA has a very interesting and detailed article on aphelion and perihelion. The most important thing to remember from it is that being closer or further from the Sun does not give us the seasons. The tilt of Earth does.

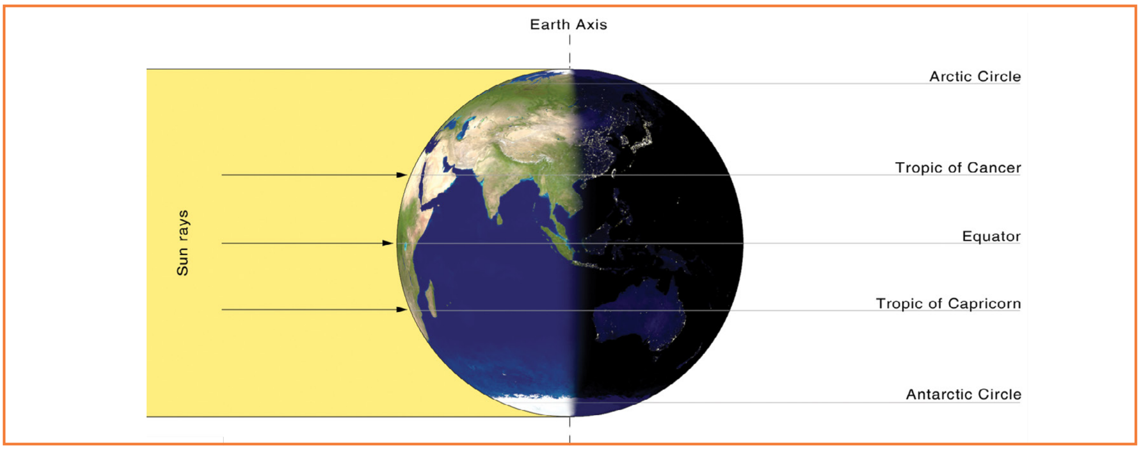
VERNAL AND AUTUMNAL EQUINOX

...marks the spring and the autumn. The equinox happens when the length of the day is equal to the night.

At the Equator, during the equinoxes, the midday Sun goes vertically overhead (at Zenith).

The vernal Equinox occurs on March 20/21 and the autumnal equinox occurs on September 22/23.

3 Not fair!



After the vernal equinox, the North Pole will start receiving more light from the Sun. In the Northern Hemisphere, summer will begin. In the Southern Hemisphere autumn will start.

> **Note:**
>
> **The vernal point is also known as the First Point of Aries. The First Point of Aries is the point in the sky where the celestial equator, the ecliptic and the equivalent of the Prime Celestial Meridian meet. It is the 00 point from where we start counting most celestial coordinates.**

The Earth spins

'The sunrise doesn't exist', says Neil DeGrasse-Tyson in the new Cosmos series! It's an illusion created by the spinning Earth.

And we spin pretty fast! At Equator, we rotate at 1,675 km/hour. But when I landed in Singapore, it felt no different than in New Zealand, although we turn slower here. At the Poles, exactly where the axis goes out of the Earth (figuratively speaking) there is hardly any speed! I haven't been there yet.

In relation to the Sun, the Earth rotates once every 24 hours on average. This is called a **solar day.** In relation to the stars, the Earth takes approximately 23 hours and 56 minutes[4] to do one rotation. This is also known as a **stellar day**. There is also a **sidereal day**[5].

The difference between those two and the solar day is caused by the Earth circling the Sun. This causes the Sun to appear to move a little to the East each day against the background stars. The movement is about 1 degree.

KEEPING TIME

So if the Earth orbits the Sun faster when is near perihelion and slower when is at aphelion, what does it mean for us here on Earth? Can we feel or see that from here?

The Sun's eastward movement is indeed slower at some times of the year (near aphelion or apoapsis) and faster at others (near perihelion or periapsis).

Our civil time is reckoned by the Sun. We build into it the Sun's average daily shift eastward. The average or 'mean' shift of the Sun is what gives the 'Mean' in Greenwich Mean Time.

The really awesome thing that came out of that.., is the solar annalema.

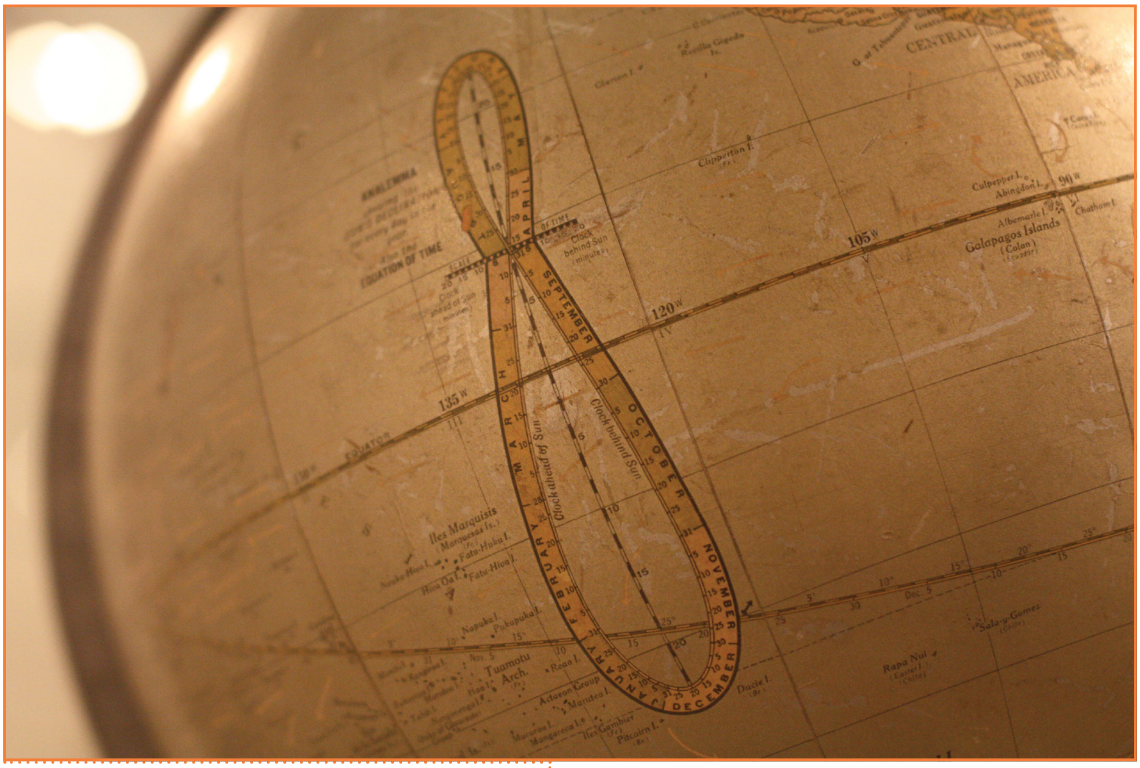
4 'Earth's rotation is slowing slightly with time; thus, a day was shorter in the past. This is due to the tidal effects the Moon has on Earth's rotation. Atomic clocks show that a modern day is longer by about 1.7 milliseconds than a century ago.' (Wikipedia)

5 Astronomers like to define things very precisely. The difference between a stellar day and a sidereal day is of about 8.4 milliseconds. Sidereal day also takes precession into consideration.

THE SOLAR ANALEMMA

'…Analemma is a plot of the Sun's Declination versus its equation of time.'

One of my favourite things ever is to talk about it.



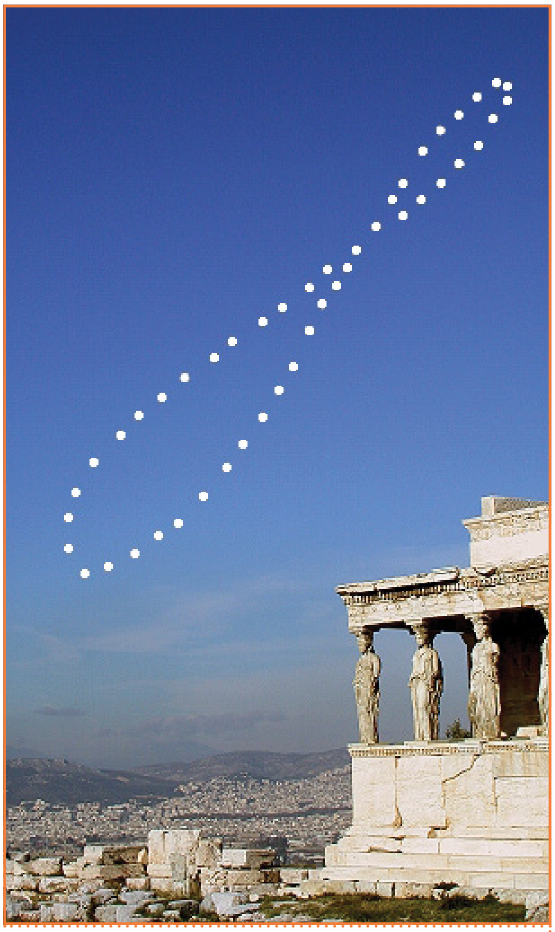
Analemma printed on a globe, Globe Museum, Vienna.

If you take pictures of the Sun every day at the same hour (say noon) and stick them all together, after a year you will see this: a pattern that looks like an 8 leaning on a side.

This cypher, Analemma, and the equation of time, is the result of both the Sun's change in Declination and the eccentricity of the Earth's orbit.

The lines of RA are closer together at Declinations away from the Equator. When the Sun is at its northern and southern Declinations it is crossing RA lines faster because they are closer together. So it gets ahead of its mean position. When it is near the Equator it moves slower than its mean speed. That is the main reason for the figure-8 shape of the Analemma.

Anthony Ayiomamitis has a very comprehensive site about all things astronomical and probably the most beautiful pictures of analemmas that I have seen. Make sure you check the astro-jokes page too! I'm not going to order you to laugh at them but some stuff in there is very nerdy and I could so totally see myself in it. If I might say, before considering a career in amateur or professional astronomy, read that first as a disclaimer.



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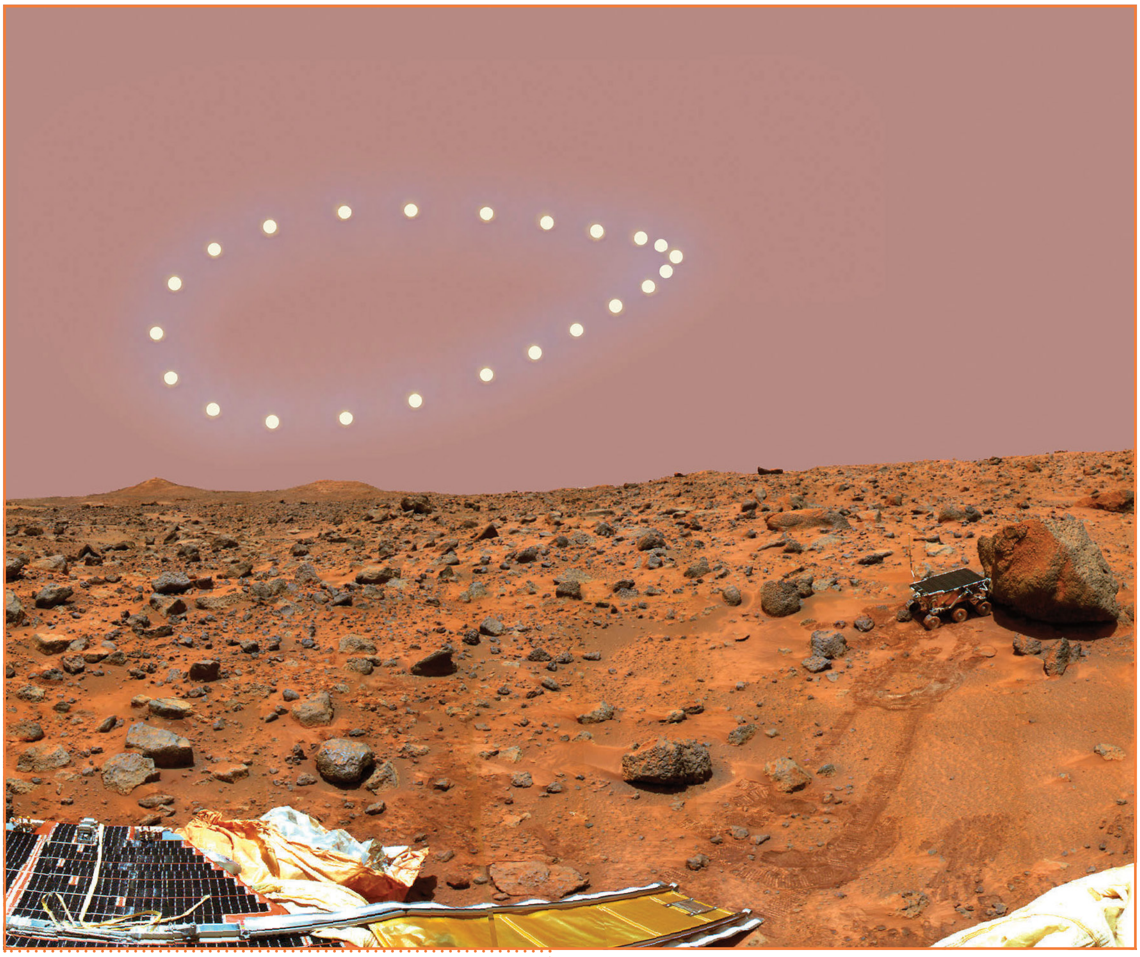
The Sun's movement along the ecliptic speeds up and slows down depending on our distance from the Sun. So the Sun moves East against the background stars faster in the southern summer (perihelion) and slower in the northern summer (aphelion). This also affects its position in relation to the mean Sun.

The two effects together give the equation of time. It is the change in orbit speed that makes the figure-8 smaller at the North end than it is at the South end.

To us on Earth, it looks like the Sun draws an 8-shaped figure in the sky. This happens because, as strange as it may sound, although we take the picture each day at noon, measured by our clocks, the real noon does not occur every day at 12:00 PM. Clocks are set to keep the time at a constant rate (mean time) but the truth is that in November the apparent time (based on the solar day) can be ahead by as much as 16 minutes and in February can be behind by almost 14 minutes to the 'real' noon.



Analemma from Mars.

This difference between the 'apparent' solar time and 'mean' solar time is called 'equation of time'.The 'apparent' solar time is the real time when the Sun arrives at meridian. The 'mean' solar time is the time kept by clocks on Earth.

The pattern made by Analemma confirms Kepler's laws of planetary motion. It is also a useful reference when building solar dials which I hope we will do together.

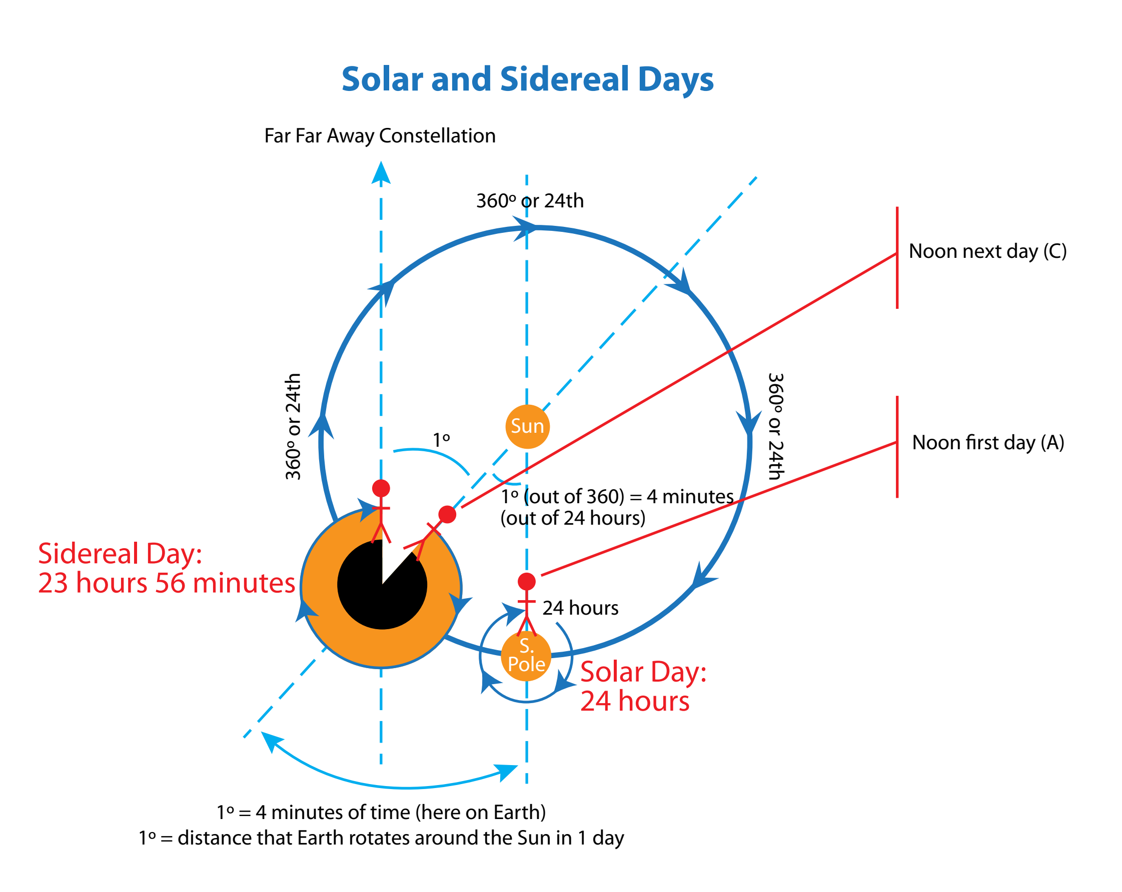
Someone made a picture of a Moon analemma and there is also a tutulemma! I will let you with the pleasure to discover what that is :)

THE SIDEREAL DAY

Astronomers are interested in where the stars are, so they care about sidereal time.

Sidereal time, or star time, is very useful when pointing telescopes, measuring star positions and the like. There are 23 hours 56 minutes and 4 seconds of solar time in a sidereal day. That means that a star appears to do one rotation through the sky in that time. This makes stars to rise 4 minutes earlier every day. This is how our ancestors worked out calendars 'to predict the future'.
As seen from Earth, the background stars seem to shift westward by one degree every day.

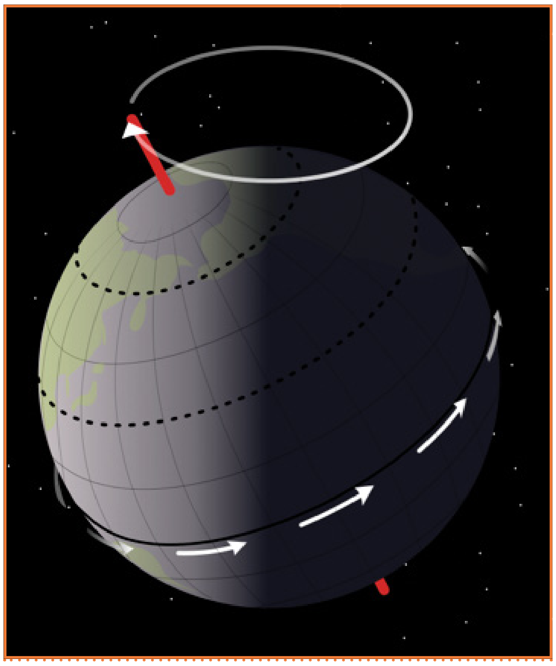
Astronomers use sidereal time to keep track of the direction where to point their telescopes to view a star. From a given observation point, a star found at one location in the sky one night will be found at the same location on another night when observed at the same sidereal time and that will come useful to know when you too will be around a telescope.



Solar and sidereal days.

Falling around the Sun is the least complicated movement of Earth. Unless you wish to pursue a career in physics, for now and for our peace of mind, let's just pretend there is only one more thing that Earth does:

It wobbles



Precession. Source: *Wikipedia.*

Earth wobbles. The wobble takes about 25,800 years to complete and it alters the direction where our rotational axis points. The consequence of that is that in about 6,000 years from now, the Northern Hemisphere's North Pole indicator, will be taken by Alderamin (from the constellation of Cepheus). That will happen in the year 8,000 AD. In 15,000 AD, the star called Vega (from Lyra) will be the new North Pole star. At the end of this cycle, Polaris will become the North Star again.

We can already see the effects of the precession on the alignment of the zodiacal constellations with the seasons. Did you think that your star sign is really the one advertised in the newspaper column? Think again! Since 2,500 years ago, when the first star signs were named, the Sun's position along the ecliptic shifted by about 36 degrees which is about 1/10 of the way around.

That makes someone like me, born in the first week of July and considered a Cancerian, to actually have the star sign Gemini.

And what about someone born between 29th of November and 17th of December? Here's the great news: you are an Ophiucan which may be a good thing if you like snakes. (Ophiucus holds a snake).

In reality most of astrologers pay little attention to the actual constellations and measure the position of the Sun and the planets on the ecliptic in 'sections' that no longer match the constellations' true position in the sky.

Interestingly enough, the astrologers of old times used to update their horoscopes to take account of the precession. This practice stopped during the 'Dark Ages' – the period of time from the falling of the Roman Empire to the Renaissance period – and that makes most of the astrological charts used today about 1,000 years behind. This site is the only astrology site that I could find to be keeping up with the times!

Precession makes the First Point of Aries (which marks the celestial prime meridian, from which Right Ascension is calculated) to move along the ecliptic approximately 1 degree every 70 years so now the First Point of Aries is in... Pisces.

The precession of the equinoxes (aka the wobble) is caused by the Sun pulling on the bulge of the Earth. The Earth is slightly wider at the Equator than at the poles. The bulge on the Sun side is pulled toward the Sun a little more than the opposite side. This has the effect of trying to make the Earth's axis stand vertical to the orbit plane. This is like gravity trying to pull a spinning top downward. The reaction to this is precession. (Try turning a spinning wheel.) The difference between the Earth and a spinning top is that the Sun is trying to make the Earth 'stand up'. So the Earth and the top precess in different directions.

Some astronomers quote an 'epoch' (a specific moment in time) when discussing the position of the stars. The current epoch is 1st of January 2000.

Strictly we should label charts and catalogues by equinox, not by epoch. The equinox refers to the zero of RA and declination used. Currently we use the equinox of 2000 as our standard.

Epoch refers to the time when the star positions were measured. As the stars have proper motion we have to correct for their movement since that Epoch if we are doing precise measurements. Some catalogues do this correction so the equinox and epoch are the same, as in the Smithsonian Astrophysical Observatory Star Catalog. It was compiled in the 1960's.

How is the dynamic Earth affecting us?

It makes seasons

So many people believe summer occurs as a result of Earth's proximity to the Sun! This is not the case[6]. As discussed in the previous paragraphs, being closer to the Sun only influences the length of the seasons.

Seasons are caused by the amount of light that tilted Earth gets from the Sun. The key to understand that is to remember that in our journey around the Sun, the tilt of Earth does not change as Earth travels around the Sun. With 'small' exceptions (see precession) the north pole will always point at Polaris and the south pole will point at *Sigma Octans*.

In summertime, on our tip of the world, the South Pole is leaning towards the Sun. From Earth, we can see the Sun going higher in the sky (we say that the Sun is changing declination). Days are

6 In fact Earth's orbit is almost circular (after all that hard work trying to convince you that Earth's orbit is an ellipse).

longer and, due to longer exposure to its heat, temperatures are higher. (You can feel this in the air here especially in our humid Wellington.)

Six months later, in wintertime, the South Pole is leaning away from the Sun. Days are shorter and temperatures are lower.

Otherwise in Wellington, there are always green leaves, flowers and birds singing. The differences between seasons are not that dramatic. Before I came here, someone back home called Wellington the 'eternal spring'. True for me! The differences in temperature that we experience in here during the entire year are only within the springtime range back there.

In spring and summer, Earth's axis is parallel to the Sun, therefore the amount of light – respectively heat – is the same. We receive the same amount of heat on both hemispheres.

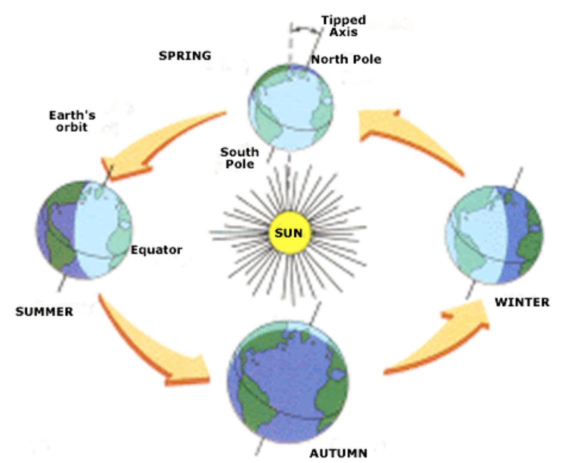
Not everyone on Earth experiences seasons. The reason for it lays in the tilt of Earth, combined with the spinning and the rotation around the Sun.

It creates very different environments around the world

From Kenya to Asia to Europe to Polynesia to Northern Europe to America to Easter Island... to Aotearoa – Terra Australis – the sky has only one Moon but the orientations of the stars' patterns change. The world and the landscapes change as well, modelled by the weather.

The curvature of the stars' paths across the sky changes. Our latitude on Earth determines the height of the celestial pole in the sky. For instance an observer standing at the South Pole will have the South celestial pole just above their head, at Zenith. An observer at the Equator would see both celestial poles as they lie on the horizon.

The angle of the celestial pole above your horizon is the same as your latitude. Wellington, New Zealand, is 41 degrees South. So at Wellington the SCP is 41 degrees above the horizon.



AT THE EQUATOR

Starting from the Equator…

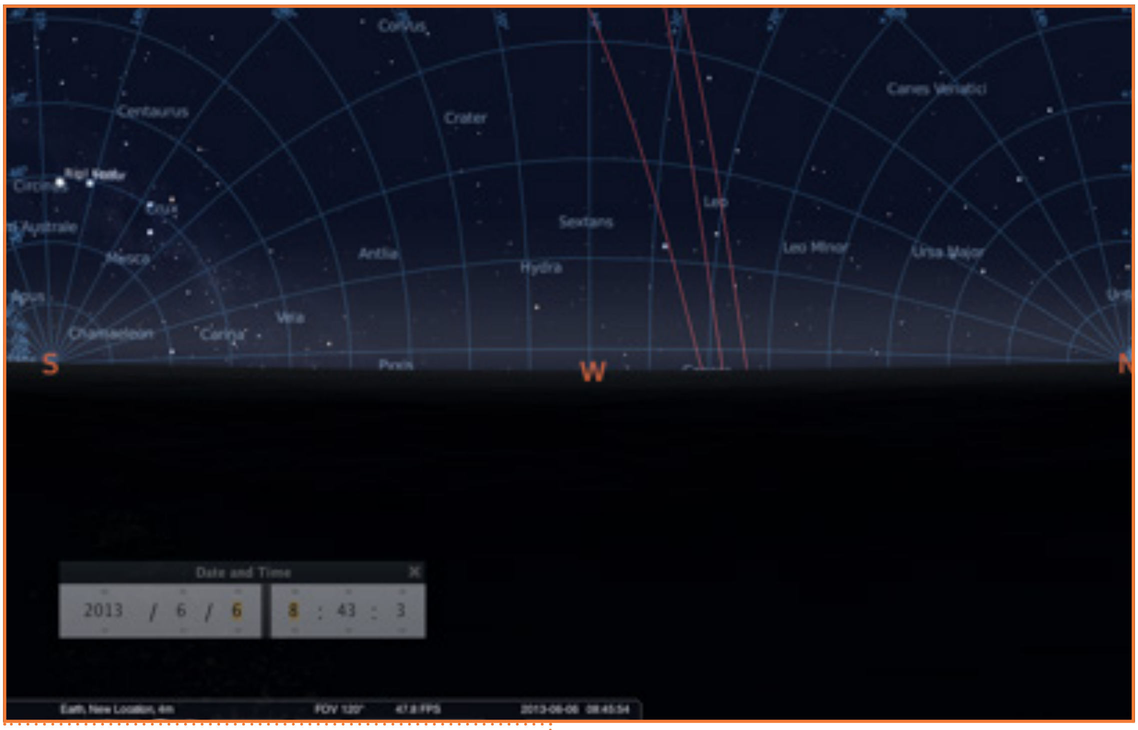
Our equator is located at 0 degrees latitude (North or South), is 24,901.55 miles (40,075.16 km) long and divides planet Earth in two halves; the Northern and Southern Hemisphere.

...stars and other celestial objects, observed from the Equatorial zone appear to rise vertically from East, go overhead, and then fall vertically in West. The stars near North and South will make half circles in the North or South.

Providing there are no obstructions around the horizon, one could see stars that are very close to both South and North celestial poles (providing there are such stars there). Well, there is one – Polaris. For the other one, Sigma Octans, at the South Celestial Pole, you need binoculars. Seen from the Equator the celestial poles are on the North and South horizons.

The perimeter of the Equator is Earth's biggest circle. It would take approximately 20 days to drive around non-stop in a car at about 90 kph.

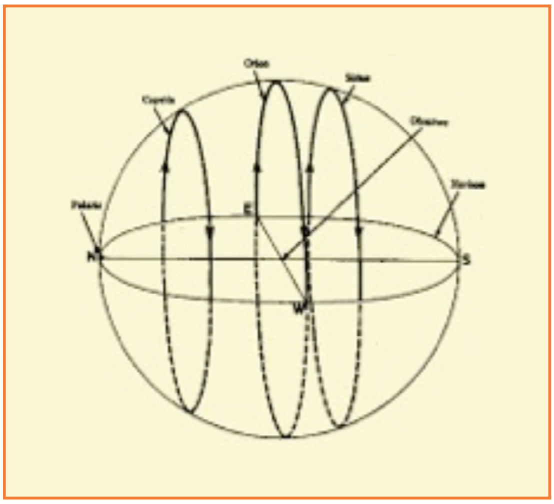
The Equatorial zone has days and nights of equal length. They last 12 hours each – just like we get temperate zones get twice a year, at the equinoxes. The length of the days at the Equator does not change throughout the year so there are no dramatic changes in the seasons either because there are no changes in temperature

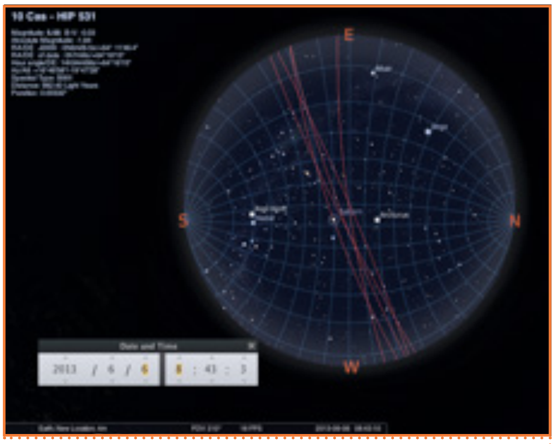


Equatorial sky—note how NCP and SCP (marked N and S) lay on the horizon.

from season to season. The climate is mild. People use lunar calendars to measure the passage of time.

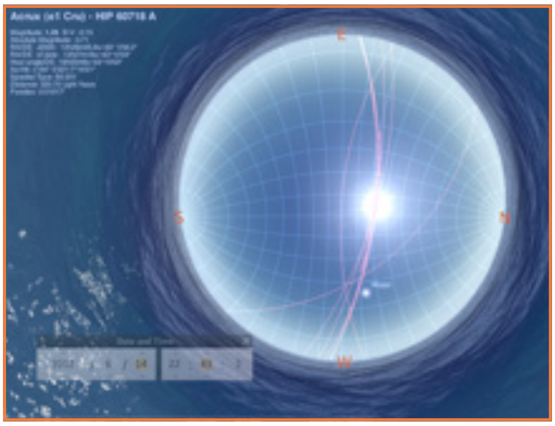
Twice a year the Sun at noon is exactly at Zenith, i.e., directly overhead. This happens during the spring and autumn equinox.



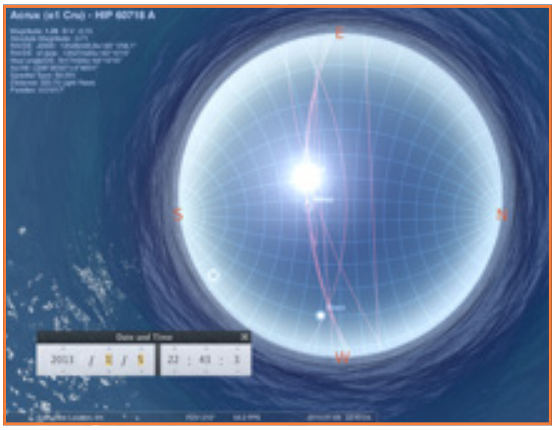


A flat projection of the stars at the Equator.

As seen from there, the Sun leans towards North from April to September.

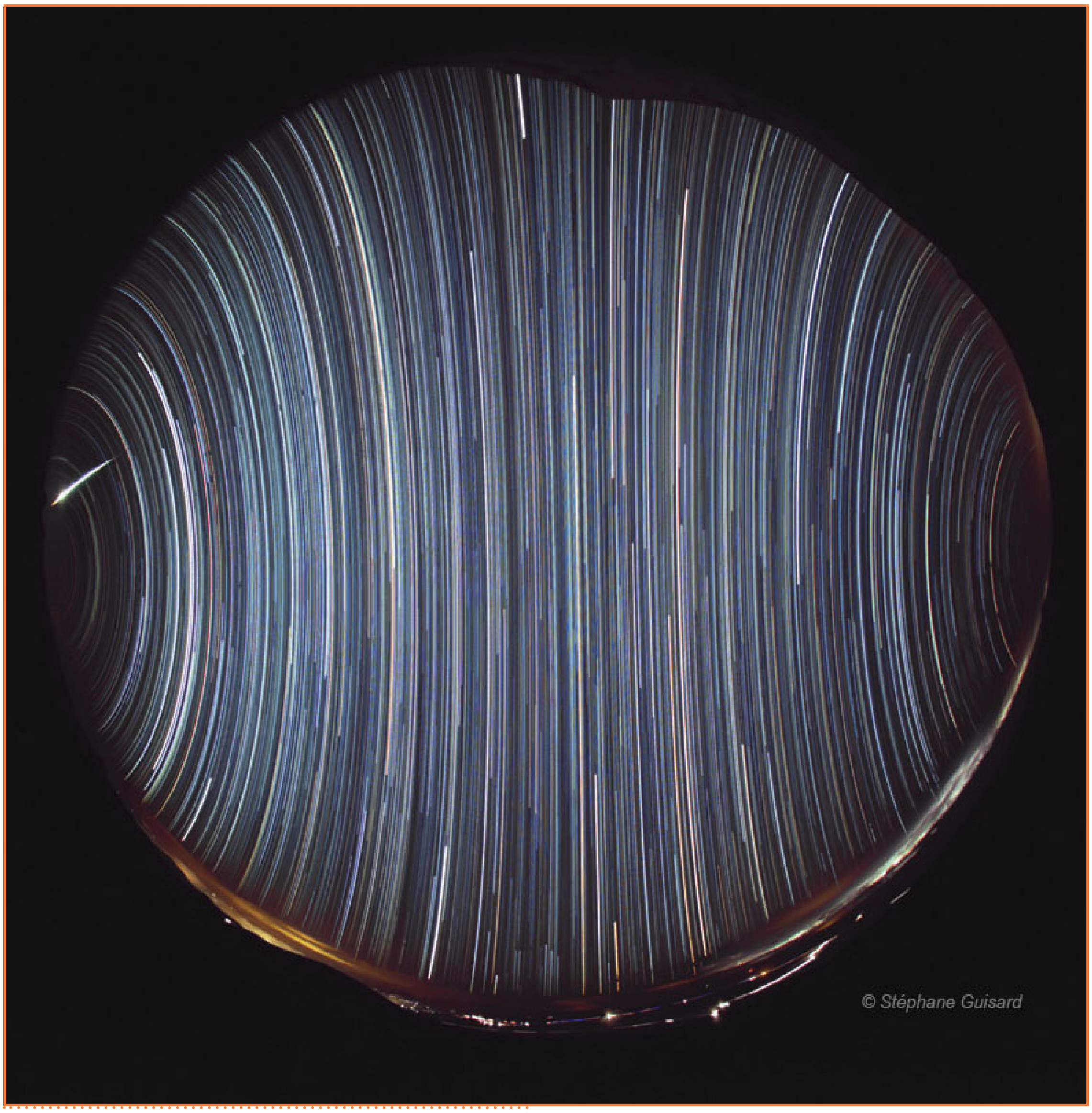


And towards South from October to March.



Curious to find out which hemisphere has summer or winter? Simply look up!

Singapore is a great location to do that as it's close to the Equator at 1 degree 22 minutes N and on the pathway of the major airlines.



Stephane Guisard

Have a look at this astounding image by Stephane Guisard!

It's a fish eye lens of the equatorial sky. There is more where that comes from.

At the same page there is an entire 'Virtual Reality' tour of the stars in trail view. You can move the panorama yourself with your mouse or use the arrow keys (click and drag the mouse to move Left/Right/Up/Down, Shift/Ctrl keys or mouse wheel to zoom In/Out). Try the full-screen mode (Click the arrowed 'X' on the animation command symbols). Find the 'hot spots' on the panorama with your mouse pointer and check out the descriptions that will appear (Southern Pole, Northern Pole, Orion, Mars, Big Dipper...).

THE TROPICS

Monsoon, desert, jungle, delta, sea – altogether to the South and the North of the Equator up to where the Tropic of Cancer and the Tropic of Capricorn lie. This is the cradle of humankind and most of Polynesia lays in between these latitudes too. Shown in a lighter blue colour on the globe map this region is also known as the tropics.

There is no dramatic change in seasons here, as the Sun is consistently high in the sky throughout the year. Lunar calendars reign all the way through (less in the Americas but they were different anyway) and the world is evolving around the dry and the wet season.

'The tropics' is roughly around where the great civilisations took shape. Western civilisations began in Mesopotamia and places west of there; 35 degrees North. The Nile Delta is 30 degrees North. Much of China is north of 30 degrees. The Indian civilisations are close to the northern tropic. The central American civilisations began between the tropics. From here people started the great migrations in search for more food, more fertile grounds or who knows what else, maybe just exploring for fun...

There are two great circles marking the start of the tropics:

Tropic of Capricorn at 23.26 degrees South. The Sun is directly overhead at noon on the solstice day, between December 21 and 22.

The Tropic of Cancer marks the latitude 23.26 degrees North, where the Sun is directly overhead at noon on June 20-21.

You will find the tropics at exactly same latitude North and South in degrees; 23.26 as the value of the Earth's tilt. If Earth's tilt changed, the position of the tropics would shift accordingly.

The tropics' names might need a bit of updating as well. Two thousand years ago, the Sun as seen from the Northern Hemisphere, lay in the constellation of Capricorn during winter solstice. During summertime, lay in the constellation of Cancer; hence their names. But just like the First Point of Aries which is now in Pisces this does not happen anymore due to the precession.

THE TEMPERATE ZONE

The Natufians, the first city of the world – Ur, the first great pyramids, the starting of agriculture: this is the temperate zone. We believe that calendars and agriculture were invented here at the same time, intertwined. One describing the movements of the stars and Moon, the other taking lead from the first. There is still a huge debate as to how agriculture started. It looks like it could have been after a great drought when the Natufian people, who loved pistachio as the archeologists found out, discovered that you can take seeds from plants from one place and seed them in another place. Which once came first, agriculture or calendars, may still be a chicken and egg situation to solve. It sure sounds great as a book title!

The temperate zone extends from the tropics to the great circles of the Arctic and Antarctic. Within this latitude there is a clear delimitation between the four seasons; spring, summer, autumn (or fall) and winter. New Zealand too is located in the temperate zone. Most stars rise in East, cross the sky obliquely from right to left and then set in the West. Circumpolar objects circle the celestial pole.

If we stay awake long enough we can see most of the stars in the sky with the exception of those circumpolar to the opposite celestial pole. We also miss the area of sky hidden by the Sun. The area of sky we don't see is the same as the area of the circumpolar sky we always see.

THE ARCTIC AND THE ANTARCTIC

Beyond the Arctic Circle lays the realm of the Norse Gods. The frozen Norse world is a place like no other. The Sun can remain below the horizon for days, even months, the further North you go. At the winter solstice, Sol (the Sun in Norse) lies directly over the tropic of Capricorn and it's not visible from latitudes above the Arctic Circle. Amazing auroras blaze the dark sky in a stargazer's heaven!

http://en.wikipedia.org/wiki/File:Polarlicht_2.jpg

In the dark nights all the stars circle the sky anti-clockwise around 'the star that does not walk', the peg that holds the centre of the Universe – Polaris. In Between the long day and the long night, there are weeks of twilight. When Sol returns in summertime it lingers in the sky until midnight and beyond. And so does the Moon, pirouetting around the horizon, catching up with the Sun, or completely gone out of sight! Since the Full Moon is opposite the Sun, the Full Moon will be circumpolar in the Arctic winter.

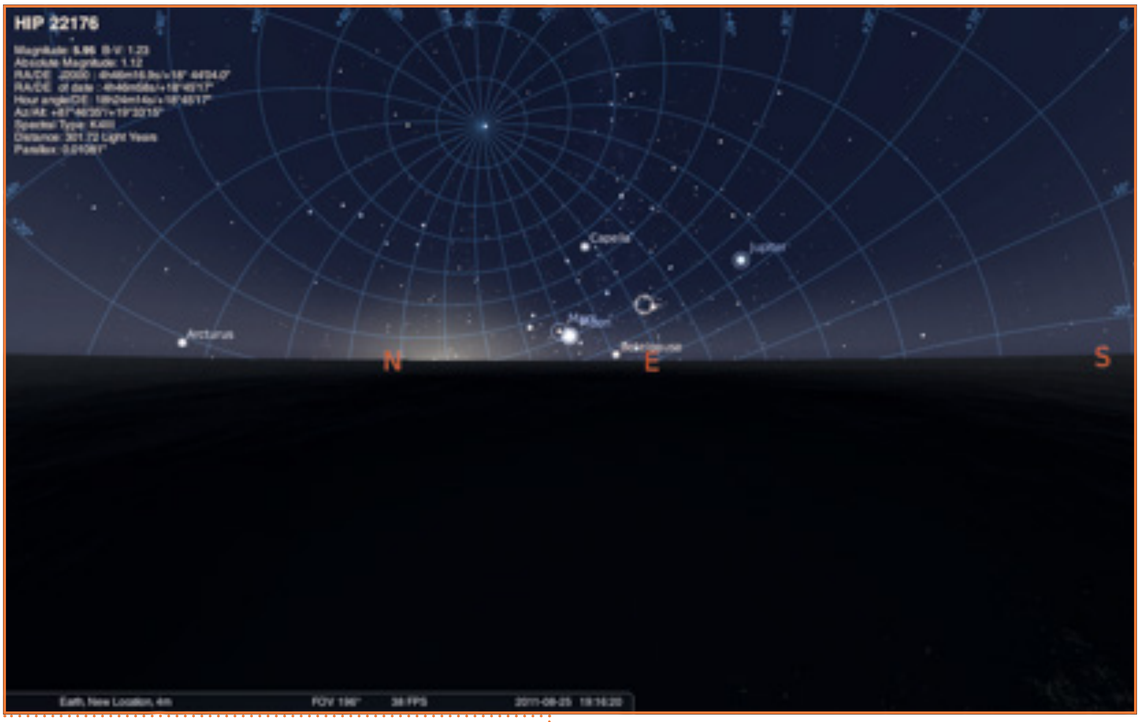
The Norse Gods are still watching over us: Tiw on Tuesday, Odin on Woenesdaeg – Wednesday, Thor on Thursday, Frigga or Freija on Friday.

And they still send Santa Claus around the world every year near the winter solstice.

THE ARCTIC CIRCLE

...is one of the five major circles of Earth. Its exact location changes slightly each year. Currently it's positioned at 66 degrees 33 degrees 44 degrees (or 66.5622 degrees) north of the Equator.

Just like Mars, Ares, has a rival in Antares so does the realm of the bear 'Arctic' (meaning 'near the bear' in Greek) opposing the Antarctic.



Here is how the sky looks at the Arctic Circle.

THE ANTARCTIC CIRCLE

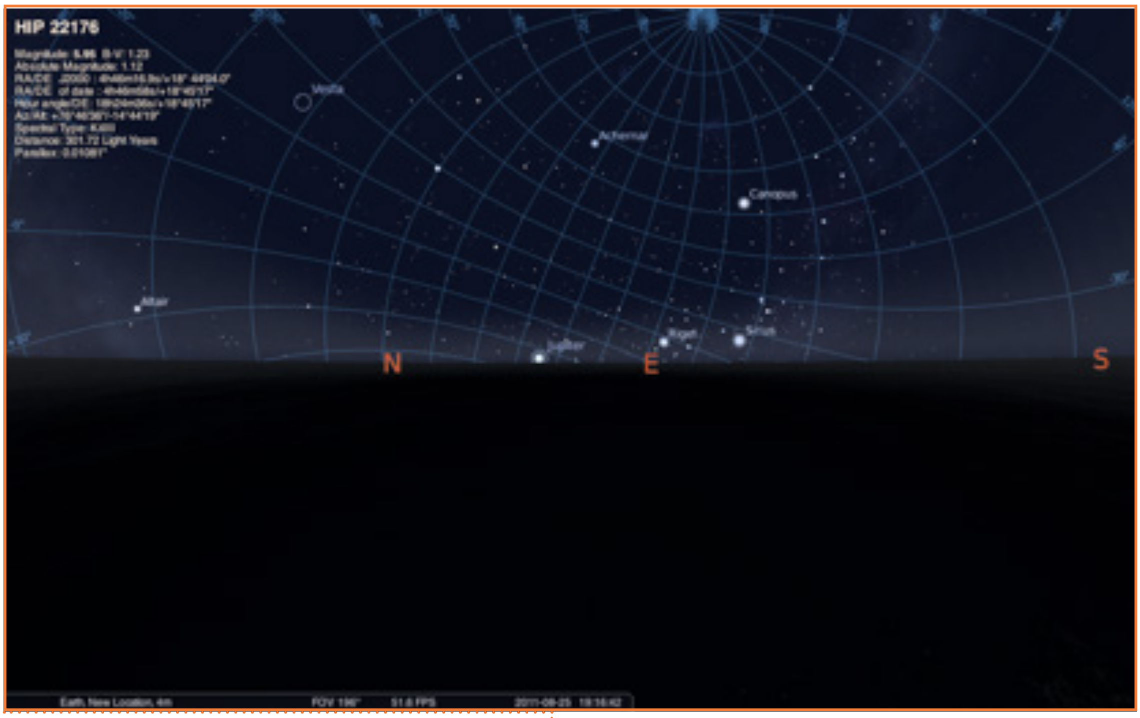
...is located at 66 degrees 33 degrees 44 degrees (or 66.5622 degrees) south of the Equator.

Beyond that, lays the white continent of Antarctica, almost twice as big as Australia, where you can find the South Pole and more than 90% of the world's ice. Inspiration – to write the Space Treaty, was also found there, by modelling it on the Antarctic Treaty.

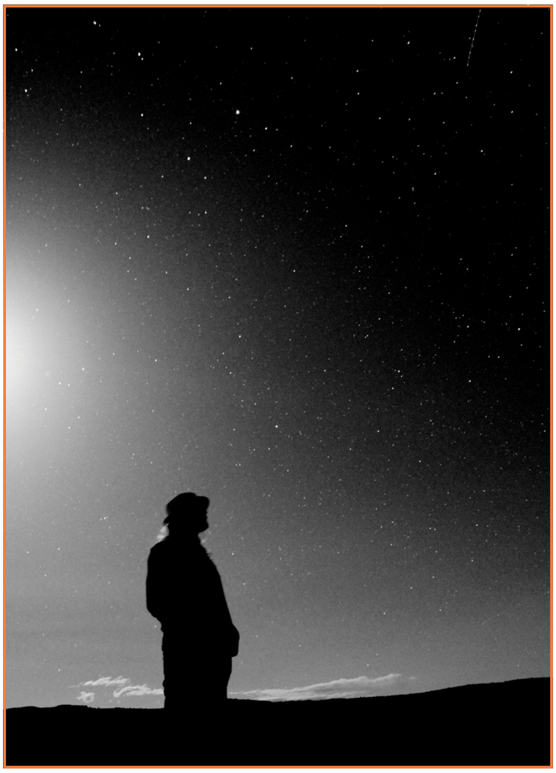
My favourite composer Vangelis, who wrote amazing soundtracks (perfect for stargazing), was also inspired by this addictive, strange place. He wrote the amazing Antarctica.

The last place on Earth to be touched by civilisation opened a space for pure science. There are international research stations in Antarctica now, peering both into the past and the future of humankind through their undertakings trying to understand life.

Just like at the Arctic, here the days and nights have their own timing. The sunsets and sunrises are equally spectacular and the stars gyrate the celestial pole at night, which is up at zenith.



Here is how the sky looks at the Antarctic Circle.



What do you see when you look at the stars?

The dynamic Earth inspired us to reinvent ourselves. The stars helped us to do it. And we survived.

Survival was linked to our ability to travel (in case of the great migrations) and to foretell the length of the winter (for agricultural, land-bound societies). Both strategies have been achieved with some help from the stars.

Not only did stars give us life, it so happened they also supported our development as a conscientious race. Just like true parents do, stars gifted us inspiration, direction and a measure for the right time. Migratory or land-bound, human societies lived in a dynamic and complex environment where all that knowledge came in handy.

We have swapped most of it today for the concrete jungle, through which we navigate with the help of GPS devices. Here, we all thrive soaked in advanced scientific knowledge. It amazed me to figure out that the basis of all our knowledge was created by our ancestors by simply observing their environment, recognising patterns and drawing upon the familiar.

The star lore they created is the story of their lives. They figured out how to connect the sky with the Earth. They cyphered that in stories. Looking back at the stars they told stories to remember all that vital information.

Can one find directions by the stars?

People travelled. It's a fact. They started in Africa and then spread to Middle Asia. From there, some went to Europe, some to Asia. The last to reach were the Americas. Or so we think. However, no race travelled using the stars to guide them, like the Polynesians did.

THE POLYNESIANS DO IT

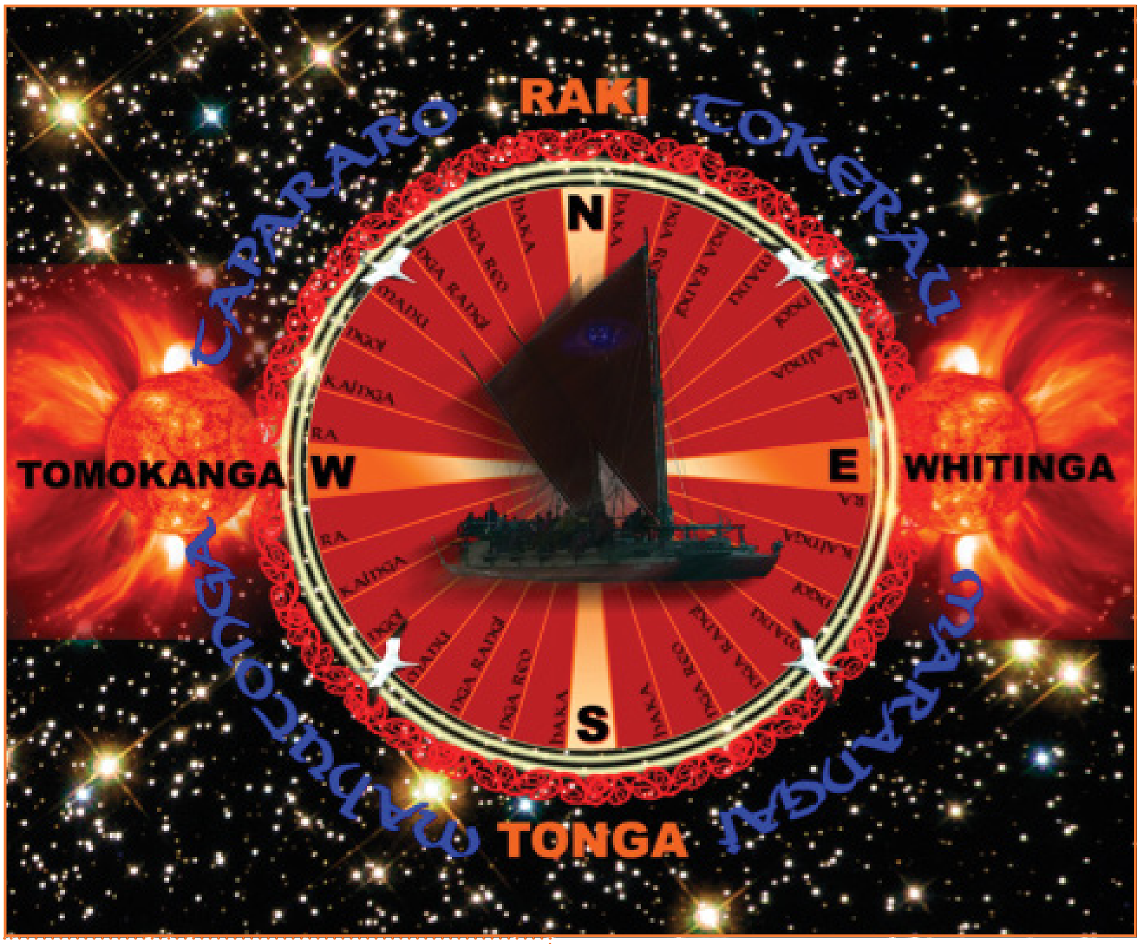
The Polynesians are the masters of wayfinding. Unlike their European counterparts, the Polynesians effectively used the celestial sphere to navigate. Because of that they were never lost!

To find directions, Polynesians use a combination of stars near the horizon and at Zenith. In addition to that, they also look at pairs of stars at meridian, to find the direction North-South.

The graph below is a give-away chart I made for our first Mata Ora in 2006. It explains the four quadrants and the 32 houses of the Māori compass. You need to hold it horizontally so that the circle is parallel to the circle of the horizon.

At night time try and match each house with the horizon and note what stars can you recognize rising from each house. Note the date and the time of your observations.

As it goes with most of Māori names and traditions, the names of the houses and quadrants can vary from tribe to tribe. So this is not the definitive answer to the Māori Compass but one of them.



The Māori star compass and waka Te Aurere at the centre.

There is a great science museum in San Francisco, called the explOratorium. It's my favourite science museum in the world. I found there a great planetarium simulation and awesome live explanations of the Polynesian skies.

I loved watching Hoturoa's explanation on how the navigator thinks of the waka as being still in the ocean. And how the island comes to the waka and not the other way around. It never occurred to me that it was the waka that was the fixed one! But it makes sense:

The Polynesians split the circle of the horizon in 32. They called each of the 32 spaces a 'whare' (house) in Māori. They then memorised the stars as they were rising and setting, at different latitudes from each house.

The same stars will rise and set from different houses at different latitudes. If you know exactly how the pattern of stars should look above you at destination, you could say that the only thing that changes is the sky. Out of that ocean, the island comes to you.

This is of course a very simplistic explanation of how they were doing it. Just as the Europeans did not need a calendar to know when to plant in spring or when to harvest in autumn[7], so the Polynesians were also looking at the waves, the whales, the birds and everything else they could pick from the air. To quote their tohunga, the navigator is the bird, the wave, the whale and the waka.

I have watched the master navigators sharing this amazing knowledge with us, since 2005 when I started working as a planetarian at Carter Observatory and during Mata Ora, the Polynesian Navigation Festival I organised in 2006, 2007 and 2009. It was for me jaw dropping to watch these people talking about their adventures at sea. I was very lucky to be able to hear straight from the grand masters.

If you wish to know more about Polynesian navigation and how Māori do it, Te Ara has a great page, Sciencelearn too and I would also recommend the official page of Te Aurere.

As discussed previously, the Polynesian navigation is sky-based whereas most of our western navigation is land-based. Travelling vast distances, the sky was continuously changing and moving for the Polynesians, which is why they also had different names for stars even at different times of the year.

Polynesians discovered the world at once, and the sky above it.

7 As they could look at other signs of nature – like leaves, flowers clouds and outside temperatures.

THE LAND-BASED SOCIETIES TRIED AS WELL

I will not dwell in here. But I always thought that the Mediterranean sea looks just like a kitchen sink compared to the Pacific Ocean. You can't really get lost in there, not the way you can get in the Pacific anyway. People of ancient times from Europe and Middle East had to put up with a lot of land compared to the Polynesians. Hence our navigation is looking at landmarks. I have attended this wonderful talk by a linguist, where he mentioned the beach people – our foremost ancestors. When they migrated out of Kenya they did so along beaches.

The way Europeans conceptualised navigation brought us the latitude and the longitude. This led to the modern GPS – if you have a smartphone, you are already using it.

So I will argue that, by Western ways of navigation, even when we use the stars to find directions (because we do that also), we do it to pinpoint places on Earth. Our waka is always on the move.

One exception is probably made by the Arab societies. The astronomy nerd in me loves the fact that Mecca is marked by a giant meteorite. The Arabs needed to know the exact direction for Mecca no matter where they were and they figured out a way. A lot of our modern astronomical knowledge came from their ancient wisdom. A land-based society, they also travelled well at night, by the stars, through the desert.

People could estimate pretty well the latitude since ancient times by putting sticks in the ground (stadies) and looking at how long their shadows were in different places of Earth. Eratosthenes[8] calculated Earth's circumference like that and he did a pretty good job for someone who lived about two thousand years ago. It took another 2000 years after Eratosthenes was born for people to figure out the longitude. In 1773, John Harrison was rewarded for the invention of the chronometer (the modern clock/watch). At last longitude could now be calculated with precision.

The length of a stick's shadow cast at noon was a hint which led the ancient Greek to believe Earth may be round. They were so right!

Eratosthenes heard that the noonday Sun shone straight down a well in Siene (South Egypt) at the northern summer solstice.

From Alexandria it was 7 degrees off the zenith. From the estimated distance between the places, and the angle, he calculated the circumference of the Earth.

8 276 BC – c. 195/194 BC.

MODERN CAVE-MAN WAYFINDING

The cave-man of today still likes to find directions by the stars. But in modern days, he does it mostly for fun (or for showing off). The luddite does it because he or she believes in it!

I'm in the caveman's camp. But one time, this knowledge came in handy for me. Many years ago when smartphones were not invented, I figured out by looking at the Southern Cross, that I was driving in the wrong direction. If it wasn't for the stars, I could have gotten very lost here, in wild New Zealand. And who knows, eaten by all those kiwi birds.

After that 'scary' experience, I now preach for teaching wayfinding by the stars to astronauts, just in case. We do it at the Mars Desert Research Station anyway. I always say, Mars doesn't have a consistent magnetic field, there is no way a compass would work there! It's better to be safe than sorry!

It's not easy to navigate at night and by the stars. But it's entertaining. Our ancestors did it because they had no choice. As for us, STARGAZERS, I'd be very happy if we learn the bear necessities for figuring directions:

- how to find the North Celestial Pole – this will show you north
- how to find the South Celestial Pole – this will reveal south
- where to find Orion. This will give you precisely the direction East and West.
- where to find the center of our Galaxy (just because we can). We already talked about that last week when we looked at Te Waka O Tamarereti.

North and South by the stars

The easiest way to figure out South and North Celestial Pole is by taking startrails pictures.

The North Celestial Pole (NCP) and the South Celestial Pole (SCP) are extensions in the sky of Earth's North and South Pole, along the axis of rotation of Earth. Anything near SCP and NCP seem stationary. No wonder the Northern Hemisphere star, Polaris, is also known as 'the peg'.

South Celestial Pole revealed by
11 Hour Star Trails.
Credit and Copyright: Josch Hambsch

The photograph of the star trails was taken with the camera on a tripod and you can do it in your backyard. I tried it and it works (see next picture). All you need is a camera that can take at least a 30 second exposure. If you follow the hyperlink you will learn how.

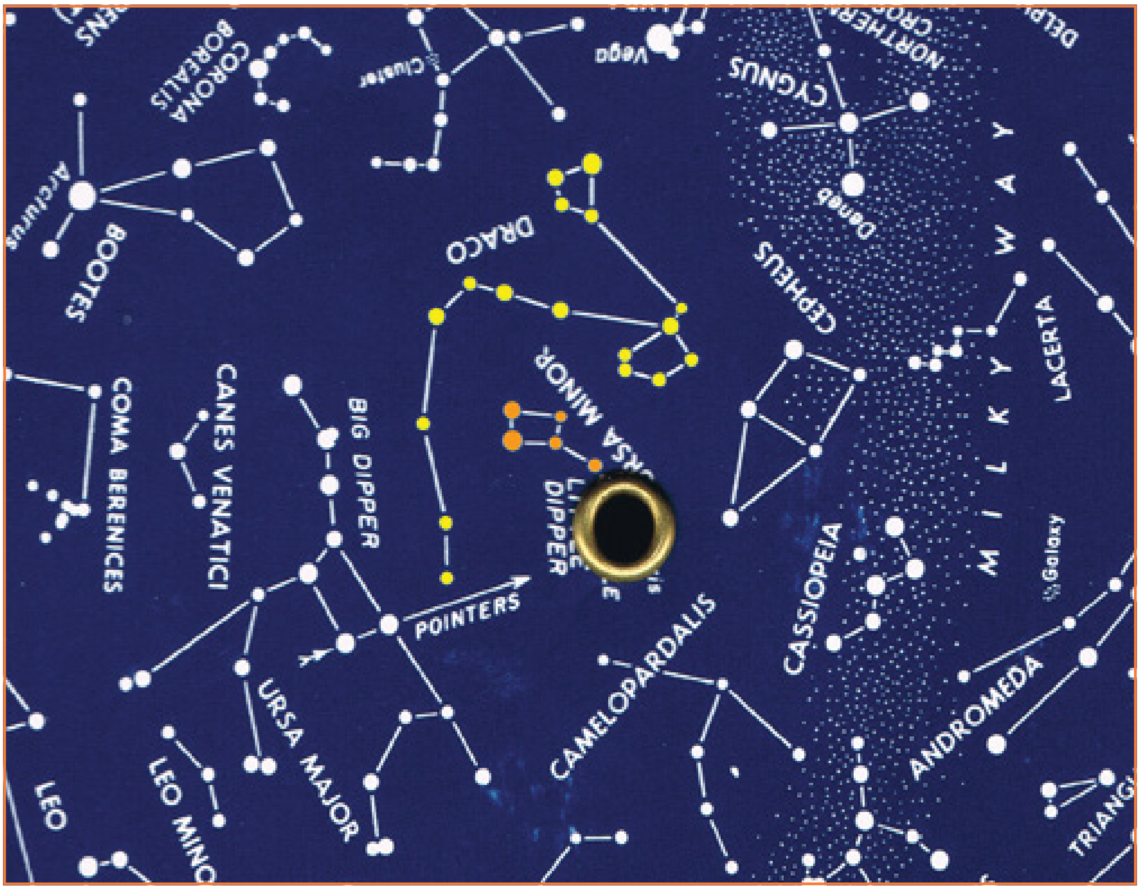
The best person in New Zealand to teach you how to take pictures of the night sky is Mark Gee, who makes awesome seminars and workshops. If you can't reach Mark Gee, there are other methods you can use to find North and South (see further down).

THE DIRECTION NORTH

Use the big and small dipper – or bears (Ursa Major and Ursa Minor). Polaris comes right on the tail of the small one. Here is the link to the very complicated process to find the North Pole Star. :)

The quick way is to find Ursa Major in the sky and use two of its stars, known as the Northern Hemisphere pointers. You can find these hidden in the planisphere below. At night, if you can see the Milky Way in the sky, draw a line from the pointers towards it. Polaris will be somewhere along that line, about halfway through. Equal distance from Polaris if you keep going you will find Cassiopeia. Cassiopeia, just like the Southern Cross, is embedded in the Milky Way.

Nothern Hemisphere star trails at the Mars Desert Research Station in Utah.



THE DIRECTION SOUTH

Back in the Southern Hemisphere, the star marking the South Celestial Pole (SCP), is very dim. *Sigma Octans* it's so dim that you cannot see it without binoculars…. But finding south is easy.

In the Southern Hemisphere, we can find SCP using the stars that are always in the sky, the circumpolar stars[9]. In particular, we like to use the Southern Cross. This is the most famous constellation of New Zealand (and Australia?). It's the smallest constellation in the sky and fits right inside the Milky Way. If you are lucky enough to see the Milky Way, just follow it through and at any time of the night you will find the Southern Cross.

If you did figure out which part is South, even roughly, look for a big cross and two other bright stars, which seem like the handle of the cross. They can be anywhere in the sky so don't aim. At Wellington's latitude, lowest you will see it, will be one time its height above the horizon; highest you will see it, is about 60 degrees above the horizon.

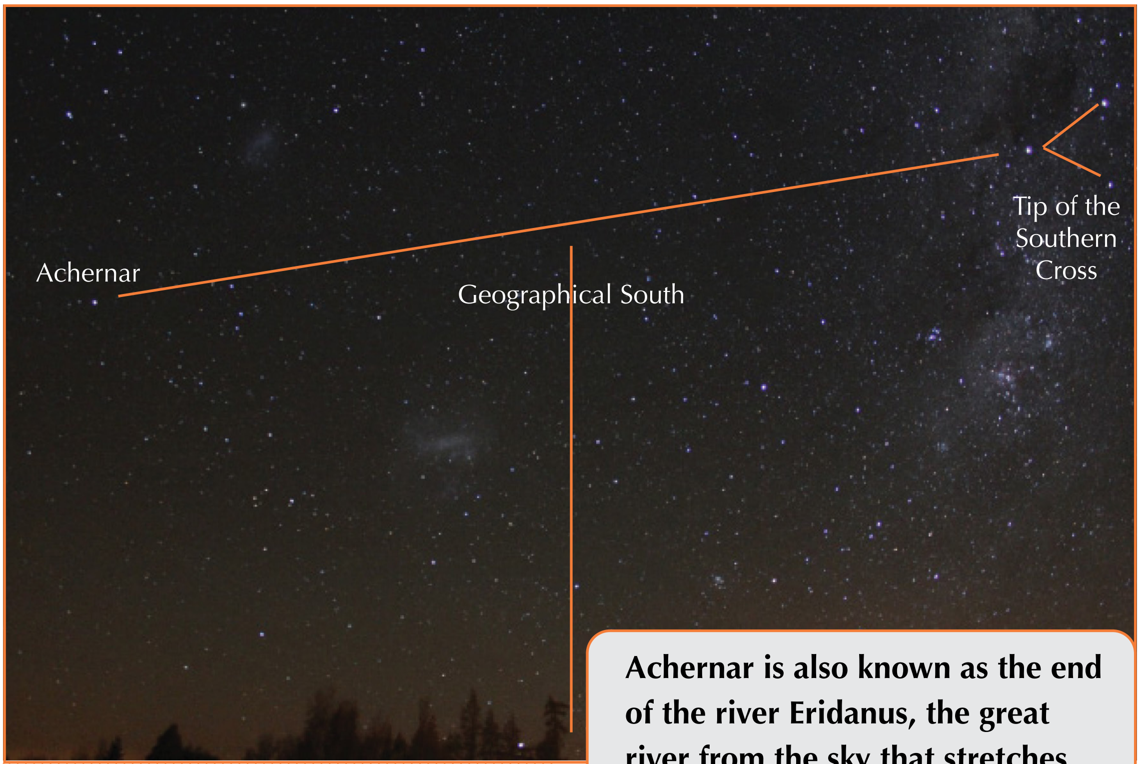
I always thought that Southern Cross looks like the small hand of the clock of the heavens. I invented that as well (I hope! I did not really publish any paper on my idea but I also never heard anyone else talking about it). I call it the big clock of the skies because stars

If you cannot see the Milky Way and it's night time, turn your back to that part of the sky where you think you saw the Sun earlier. Sun goes through North in the Southern Hemisphere. If you cannot remember where you saw the Sun earlier and it's still night, try and locate the Moon. The Moon goes through the Northern part of the sky too. So if you turn your back to that, you are looking roughly South. If no memory of the Sun, or no Moon and no Milky Way then wait until Eugene Georgiades and I will publish the engineers guide to finding South. There are detailed instructions there on how to do star-hopping. Will get you South, that's a promise!!

turn here, in the Southern Hemisphere, clockwise. And counterclockwise, of course, in the Northern Hemisphere.

So if Southern Cross is at 6 o'clock then the pointers will be to the right. If it's at 9 o'clock, it will look as if it leans on a side and the pointers will be underneath it. When the Southern Cross is at 12 o'clock the pointers will be to the right and at 3 o'clock above it. You can be sure it's the Southern Cross if you can fit three fingers (index, middle and ring finger at arm length) in between the two pointers or the short axis of the Southern cross, or four fingers on its long axis.

9 Depending on your latitude on Earth, some stars will always be in the sky, unless you are at the Equator. At the Equator you can see all the stars but not in the same time. The stars that are always in the sky are called circumpolar. They go in circles ('circum') around the celestial pole ('polar').



Finding South. Same stars as in the previous picture but no trails.

Achernar is also known as the end of the river Eridanus, the great river from the sky that stretches all the way from Orion.

Once you found the Southern Cross, then picture it as a huge arrow. Follow the direction indicated by its longer side and about 2 times the length of your shoulders or 3 times the distance between your thumb and middle finger (at arm length) you will find another star, Achernar.

Southern Cross will ALWAYS point at Achernar (at least during our lifetime)!

Achernar is the 9th brightest in the sky and kind of the only one that bright in that area of the sky.

Now... (drumroll) stretch your arms and place one hand on Achernar and the other hand on the Southern Cross...

And clap!

You have just found the South Celestial Pole. Let your hands go down and you have found geographical South (and did a bit of stretching at the same time! Not bad...)

Last time I checked there were about 27 ways in which one could find South.

I have learned about this one from a group of scouts (not more than 10 years old) who came at Carter Observatory many years ago. I never had the chance to thank them enough for enlightening, amusing and entertaining me! So thank you, and… Clear skies, guys, wherever you are!

East and West by the stars

If you know where Orion is in the sky – that's all you need to know for figuring the directions east and west. The catch is that you have to wait until it sets – or it rises, for that matter. And you can't see it all the time in the sky either! Orion disappears from the night sky for about a month, that is in June.

Orion is a constellation that straddles the celestial equator. Orion's Belt – the line of three stars that make the bottom of the Pot – is close to the equator. Mintaka, the right-hand star of Orion's Belt, is on the equator. Because of that, Orion's Belt rises due East and sets due West. Mintaka rises last and sets first.

My most beautiful memory I have of Orion is from when I was travelling across the Equator in a Jumbo Jet at 37,000 feet up in the air. I saw these stars reflected in the wing of the airplane just like in a huge mirror. They were shiny and beautiful. Through the humming of the flying bird engine I thought once again of the bravest voyagers on Earth and how they used the stars to find their way.

The Sun also rises and sets straight due East and West… at the equinoxes. Curious to know when they occur during the year just follow the link.

Important dates by the star(s)

SOLSTICES

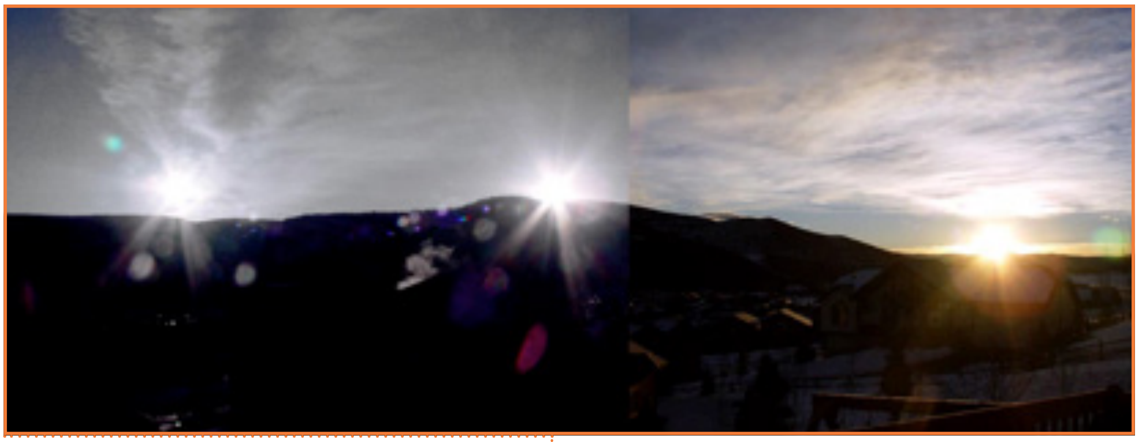
Early Māori noticed that the Sun (Tamanui Te Ra) had two wives; Hine Takurua (The Winter Maid) and Hine Raumati (The Summer Maid). During summer, Tamanui Te Ra lived with Hine Raumati whose house was on land, to the South. During winter, he lived with Hine Takurua, whose house lay in the sea, to the North.

You could try this: take your camera and capture some shots of the eastern or western horizon every day on sunrise or sunset from your Centre of Universe.

You will see that the exact point from where the Sun rises or sets changes every day little by little. The Sun will slowly drift along the horizon every day.

- In the Southern hemisphere, it would drift southwards in the summertime and northwards in winter.
- At equinoxes (find out here when that is this year) the Sun will rise straight from East and set straight West.
- In the Northern hemisphere, it would drift northwards in summertime and southwards in the winter.

The arch that the Sun makes in the sky, the ecliptic, is larger in the summertime (the Sun stays longer in the sky, days are longer) and smaller in the wintertime. In reality, the Declination of the Sun in the sky is changing as we circle around it. It's because of the tilt of the Earth. Being so close, the Sun is the only star that visibly changes declination.



This photo is made of three photos showing the rising Sun in Utah photographed at solstices and equinox.

During the year the Sun only shifts along the horizon as far left as the point marked Summer Solstice and as far right as the point marked Winter Solstice. The black arrows indicate the direction and path of the Sun, the ecliptic. Since the picture is from the Northern Hemisphere, the Sun moves from left to right. When the Sun reaches either of the solstices it seems to stop for a couple of days. In reality it doesn't.

CHRISTMAS

Ever wondered why we the urge to decorate the trees at Christmas? To remember summertime? To celebrate life? Wintertime feels white, raw and hostile in the temperate and Arctic zones. Any reason to be that happy then? Yes, the thought of knowing that the springtime, and with it all life, will come back. We could easily measure it once we've learned where to look: at the rising or setting Sun. But although the Sun reaches the winter solstice point on the 22nd of December, it takes 2-3 more days to actually see it shifting back in the other direction. 22 + 2 = 24 and so in the morning of the 25th of December is when you can be absolutely sure that the Sun moves back along the horizon and that the days will get longer again.

The winter is half way through – and that is great to know when you need to provision your food. The coldest temperatures of the year are only a couple a weeks away, around the 8th of January.

All is calm, all is bright, all is white.

Orion and the dogs guard the night time from the skies.

MATARIKI

Matariki marks the beginning of the Māori New Year. It is observed at the heliacal rising (before the Sun) of Matariki, usually in late June after the longest night, after the first Full or New Moon (depending on which tribe you belong to).

Matariki is also not a point in time and lasts for about a month until the next New or Full Moon. The Fishing Hook of Maui (Scorpius) drags Te Ikaroa (the galaxy) down from the top of the heavens at night. Orion can only be seen at dawn.

SÂNZIENE

Sânzienele are celebrated just after the summer solstice in Romania, on the 24 June. They are solar fairies. On *Sânziene* night, the skies open and two worlds become one.

EQUINOXES

Equinoxes occur when the day equals the night. That is when the Sun crosses the celestial equator.

The vernal equinox occurs in late March. (This is the beginning of spring in the Northern Hemisphere and the beginning of autumn in the Southern Hemisphere). Orion and its dogs are slowly setting in the evening. In the Southern Hemisphere, Orion looks like a butterfly now.

The autumnal equinox occurs in late September. This is the beginning of fall (or autumn) in the Northern Hemisphere and beginning of spring in the Southern Hemisphere. After sunset, the Milky Way is halfway on its way down to the horizon, te Matau a Maui is pulling it hard across the sky.

EASTER

Originally from the Northern Hemisphere, Easter is a traditional spring equinox celebration that falls on the first Sunday after the first Full Moon visible after the Northern Hemisphere's vernal equinox.

In ancient times, the Romans used to start the new year in spring when all nature seemed to came back to life.

About wintertime in the Northern Hemisphere

In November, temperatures in the northern parts of the Northern Hemisphere drop below zero. The sap of the deciduous trees slows down, making the leaves change colour and fall on the ground.

In North America autumn is also known as fall. Why? Did the people who have arrived there first never have seen forests with leaves that fall every autumn? Anyway, it must be very impressive if they call it that.

Winter in the Northern Hemisphere spreads from December to February. The days are short and the nights are long. The most important celebration is Christmas on the 25th of December. During wintertime all is white. All is covered in snow that squeaks under your feet and you can see your breath in the frozen air, and no two snowflakes are the same**. January is the coldest month of the year.**

For the ancient Romans wintertime belonged to the double-faced God Janus. Janus gives its name to the month of January, the same month when we celebrate Saint John (Jon, Ion, Jan, etc.). The feminine manifestation of Janus was Goddess Diana (Iana, Ioana, Joanne, Jana, Jane). Diana is the Goddess of the Moon.

In more modern times, Janus is one of Saturn's moons.

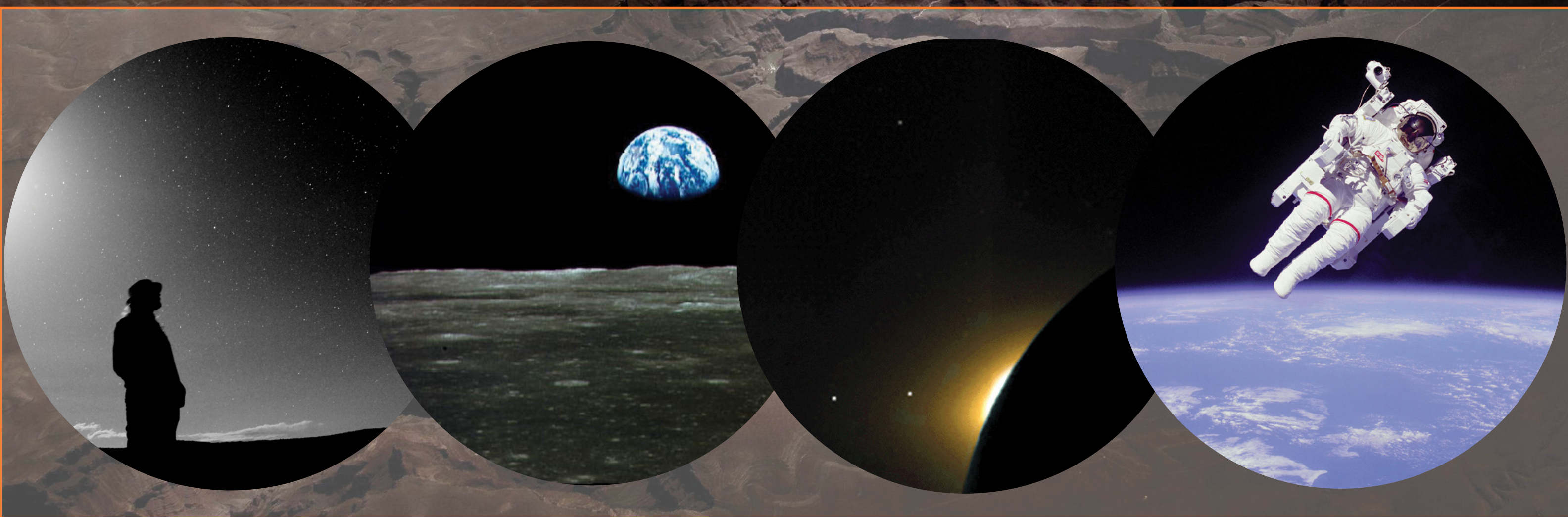
Looking simultaneously into the future and back to the past, Janus, my favourite God, is the God of transitions, gates beginning and endings.


STAR
GAZING

STAR GAZING

WEEK SIX

Starting to See



Front cover image: The Grand Canyon from Space

Copyright: Travis Odgers

Back cover image: Orion nebula

Located 1,500 light years away, along our spiral arm of the Milky Way, the Orion nebula is located in the middle of the Sword region of the constellation Orion the Hunter.

Source: NASA, C.R.O.

Contents

Thanks

Thank you to George Jones, Alan Gilmore and Peter Detterline for their stellar help and suggestions!

Terminology

For some of you, there may be many new words and phrases in this course. If you're not sure what something means, you might want to check an online glossary.

If you're still confused, feel free to ask me or your classmates in the forum.

WEEK SIX

Starting to See

'What do you see when you look at the stars?'

Lots of people asked me this whilst I was manning telescopes and I always quoted my favourite line from the movie Blade Runner: 'I see things you people wouldn't believe!'

To see these things we need clear and unpolluted skies.

So this chapter will discuss about the 'qualities' of the sky, like seeing and transparency. Will look into why some stars are brighter than others and find out about peripheral vision. Light pollution (too much light in the night sky) is a big nuisance these days so we will also contemplate what we can do to keep away from it.

The course we are just finishing is mostly about looking at the stars at night. But let's face it, really, we humans are a diurnal species. Our body adapted to functioning in the light. We sleep most of the night. We are 'wired' to look around the horizon and not up. I reckon that if we were designed to live at night and look at the stars, we probably would have had big morepork eyes, all placed on the top of our heads aiming at Zenith; or something… But we don't. So is there anything that we can do (other than eating carrots and fish) to improve our night vision?

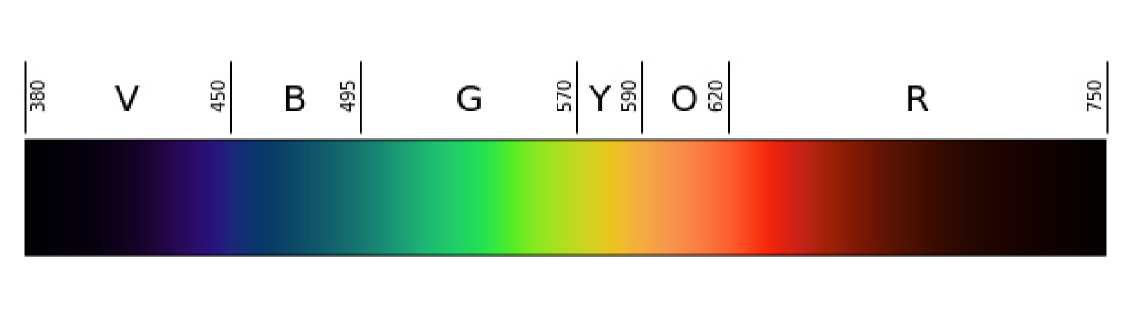
Well, there are a few tricks astronomers use when they look at the night sky. And they do manage to see fainter objects than the rest of us, the mere mortals. I will teach you those tricks because at the end of our six week journey, I truly hope to happily leave you in the dark, by yourselves, to look at the stars!

Tricks for seeing better at night

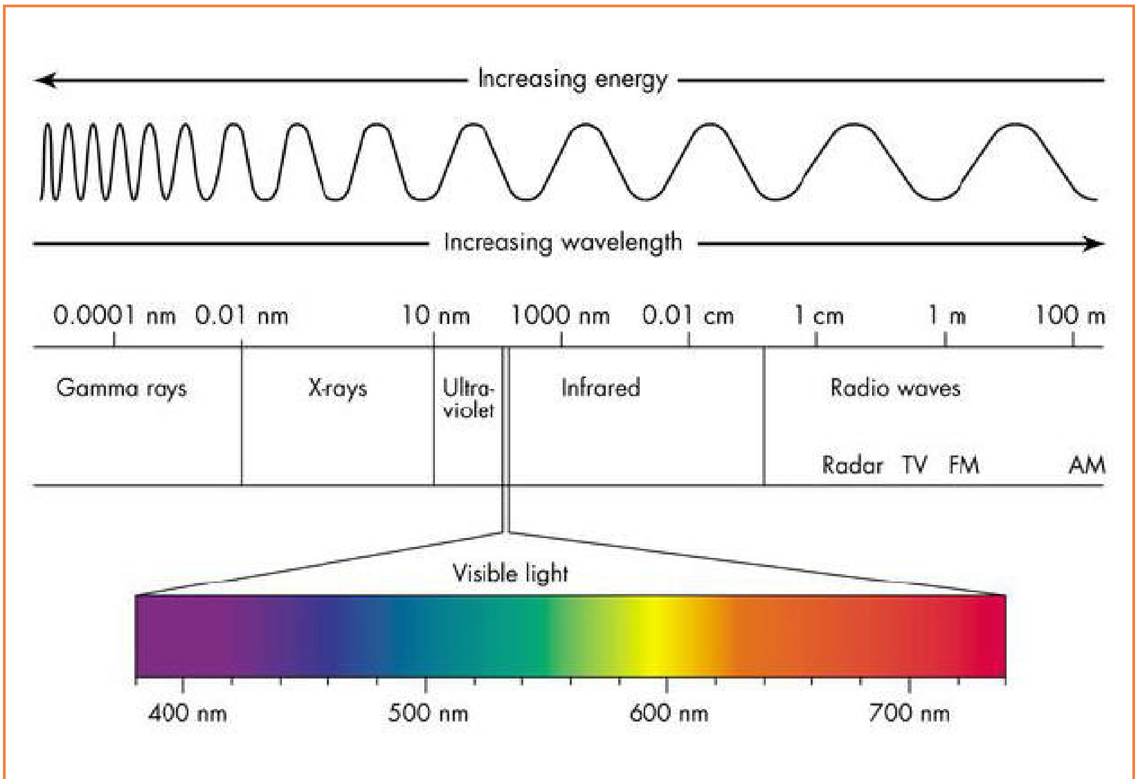
Know thy human eye

Our retina is packed with receptors that constantly harvest light. These are the rod and the cone cells. Cone cells are densely positioned around the fovea centralis region of the eye whereas the rod cells are concentrated on the edge of the retina. Used for peripheral (or averted) vision, the rod cells are almost entirely responsible for our night vision.

Our cones and rods pick up electromagnetic radiation (light)! The light we see is only a tiny part of the electromagnetic spectrum. Each part of it has a particular wavelength. Colours are our interpretation of the different wavelengths of what we call the visible spectrum.



Linear visible spectrum.



Wavelengths.

Red and yellow light falls in the long part of the spectrum, green has a medium wavelength and blue has a very short wavelength. That is probably why the colour we see furthest away is red; car tail lights for instance. Red light is less scattered over long distances than are other colours. What's your favourite colour? Mine is blue.

CONE CELLS

Cone cells see colour. They are activated by lots of light. Humans normally have three kinds of cones:

- Long: are sensitive to long wavelengths and peak at a yellowish colour (named 'L' for 'long').
- Medium: abbreviated to 'M' for 'medium' and responds most to light of medium wavelength peaking at a green colour. The plants are green.
- Short: Are designated 'S' for 'short' and respond to short wavelength light of a bluish colour. The sky is blue.

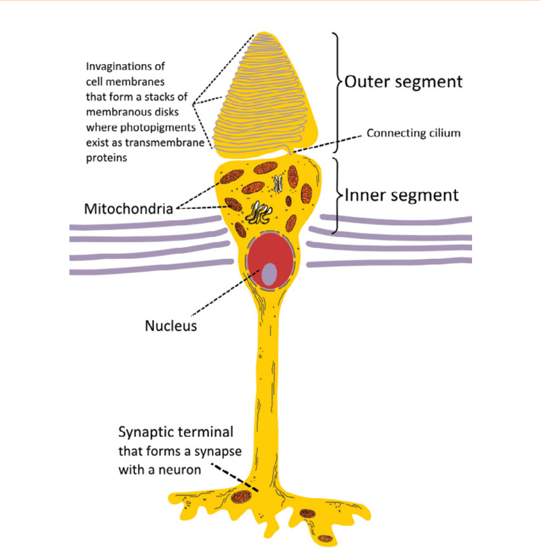
We have cone cells that respond to red, yellow and blue. We humans have receptors for three colours. We see the colours that those receptors detect. Birds and reptiles have four colour receptors. We lost one in the evolution of mammals.

ROD CELLS

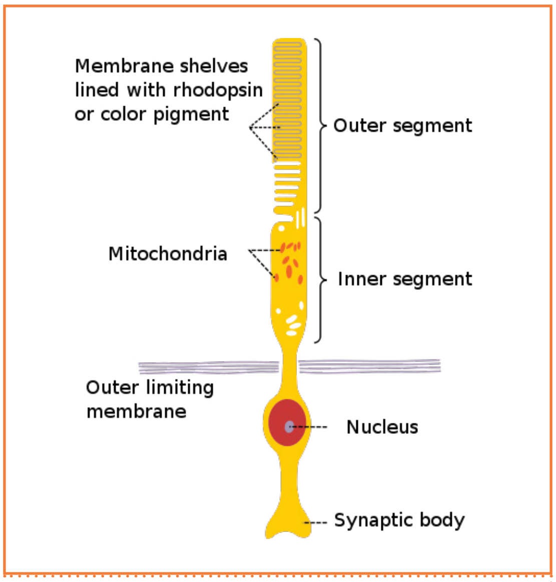
The rod cells are less numerous than the cone cells and are located towards the periphery of the retina. When we see things moving with the tip of our eyes during daytime, it's the rod cells that help us perceive that. At night, they show us the stars.

This is possible because the rod cells are producing a substance called rhodopsin that facilitates our dark adaptation. It takes 20 to 30 minutes for the rhodopsin to be made inside our rod cells and accidentally that is exactly the length of the sunset around the tropics-temperate zone.

If you are out observing and someone shines a flashlight near your eyes (it happened to me many times, mostly people who were trying to be helpful) the rhodopsin breaks down under the light. Just like that, in a moment all the night vision is lost. It will take another 20 to 30 minutes for a new rhodopsin



The cone cell.



The rod cell.

batch to be produced and start seeing in the dark again. SO please USE RED LIGHTS ONLY WHEN OBSERVING! Red light is the least hostile to rhodopsin. That is why, your first task, at the beginning of this course was to make a red torch.

Rod cells are mostly sensitive to blue-green light and least sensitive to the red light. The rod cells are almost 100 times more sensitive to a single photon than the cone cells. It is said that you can actually see a single photon of light with the naked eye, which I find remarkable.

The rod cells rock!

OUT OF THE CORNER OF YOUR EYE: AVERTED VISION

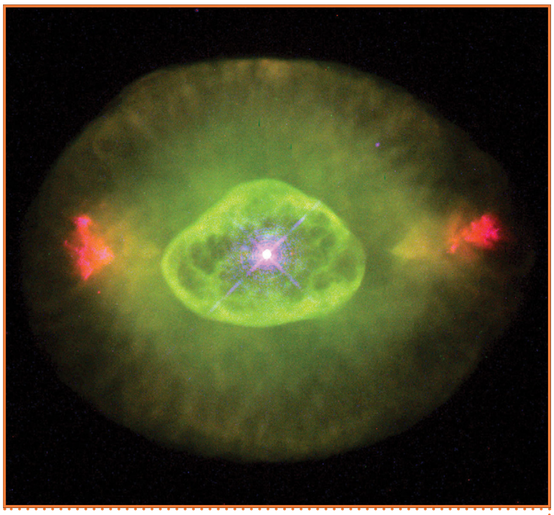
Let's use our rod cells! Avert your vision!

Averted vision is a technique used to view faint objects, such as the stars at night. It involves not looking directly at object but sideways whilst concentrating on something else but the thing we want to see. So if you will use the right eye, place the object you wish to observe in the direction of your nose but look straight ahead. Try the same thing with your left eye.

After I have tried this many times, I can say that averted vision definitely works better at night when looking for faint objects! It works because there are no rods in the fovea (the small area in the centre of our eye), but only cone cells. Aristotle used it too in ancient times to look at the stars.

Good to know

The blinking nebula, NGC 6826, is an object that most dramatically demonstrates averted vision. Stare through a telescope directly at this blue-green planetary nebula and you see only the dim central star. Look slightly to the side and the faint nebula around the star appears suddenly. When you switch from straight to averted vision the nebula appears to blink on and off.



The blinking nebula, NGC 6826.
http://en.wikipedia.org/wiki/NGC_6826

Things to consider under the starry sky

Apparent magnitude

Looking up at night it is obvious that some stars are brighter than others. The Sun, a star itself, is the brightest of them all, because it's very close to us.

So some stars are bright just because they are closer. We call that 'apparent magnitude'.

The magnitude of the stars measures their brightness according to a system invented by the Greek astronomer Hipparchos who lived more than 2,000 years ago. Hipparchos, who was also the inventor of trigonometry, was the first to classify the stars by assigning them orders of magnitude. He produced a star catalogue around 129 BC. Brightest stars were assigned to magnitude 1, dimmer than that magnitude 2, and so on.

The difference between magnitudes is not linear. What does it mean?

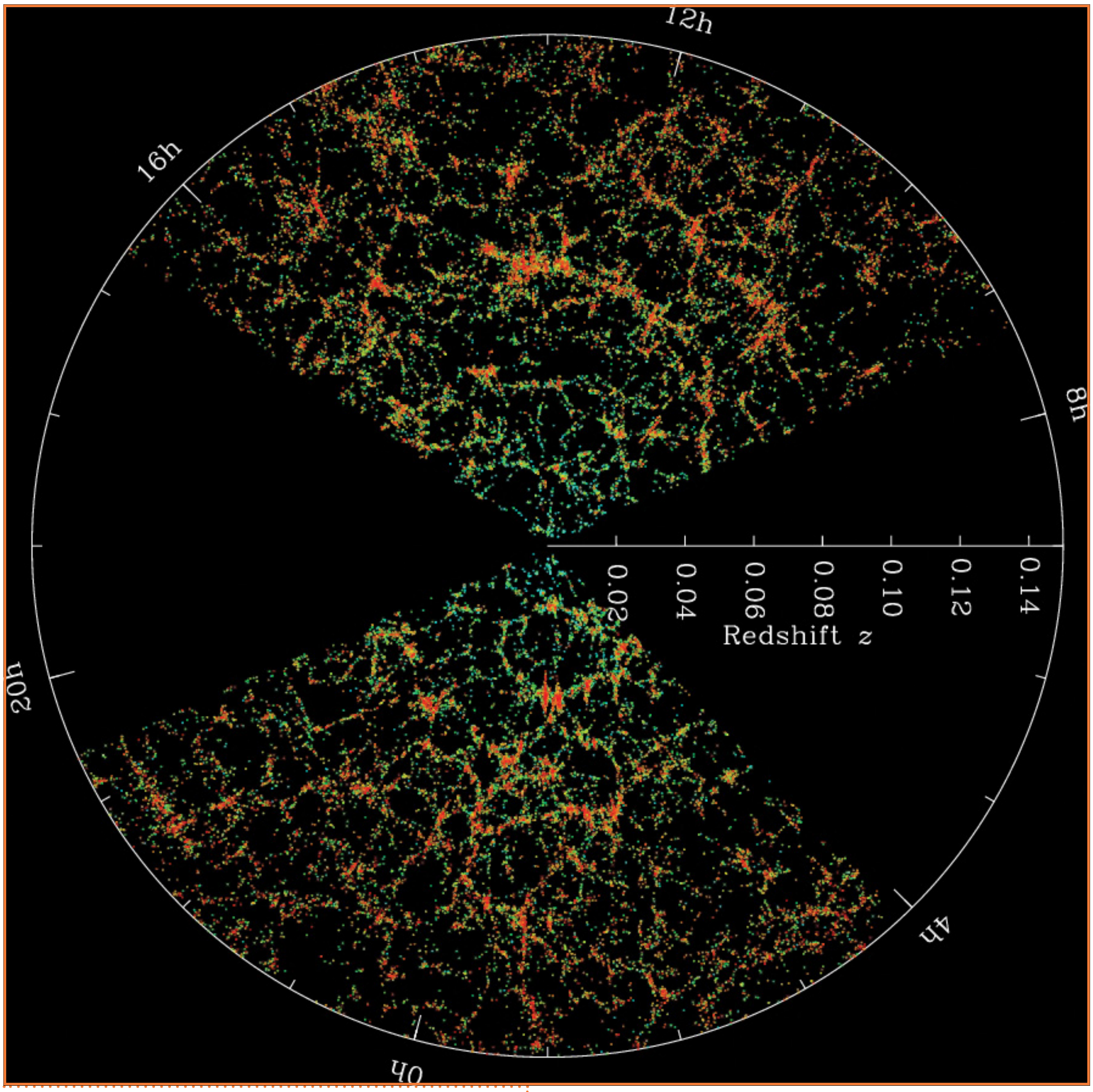
Five stellar magnitudes measure across 100 brightness units: a star of magnitude 1 will be 100 times brighter than a star of magnitude 6. So if we do the maths, a magnitude 4 star would be 2.512 times more luminous than the magnitude 5, magnitude 3 would be 6 times more luminous than magnitude 5, magnitude 2 would be 16 times, magnitude 1 would be 40 times more luminous than magnitude 5 and finally the magnitude 0 star would be 100 times more luminous than the magnitude 5 star. The dimmer the star the bigger the number of magnitude.

The Sun has a magnitude of -26, the Moon is -11 and the third brightest object Venus is -4. Jupiter is also bright with -2 magnitude.

You might find this strange but in fact our senses are tuned so that sound, smell, touch, sight are perceived on a logarithmic and not on a linear scale. We discovered that only recently, upon the advent of technology, which made possible precise measurements.

Humans can see with the naked eye down to magnitude 6, if we are lucky to have good eyes and a dark sky. From a light-polluted city... we would struggle to see any stars. Very sad!

When Galileo turned his telescope to the sky saw more stars than with the naked eye. These stars were dimmer than Hipparchos' magnitude 6. Nowadays, the depth into which we can peer in space is simply astounding, we can also see galaxies, quasars and even the microwave background radiation, which is very old and dim. Sometimes I like to imagine what Hipparchos would have thought of that had he known there was a way to look into the invisible.



http://www.sdss.org/includes/sideimages/sdss_pie2.html

This picture redefined the notion of 'dim' for me. Each dot is a galaxy. They have been mapped by the Sloan Digital Sky Survey.

To find out about the furthest distance where it is now possible to 'see', have a look here.

Absolute magnitude

Absolute magnitude determines how bright stars really are, as viewed from a standard distance. Absolute magnitude measures the intrinsic brightness of a star as if viewed from a distance of 32.6 light years (10 parsecs), which is the standard **luminosity** distance.

The luminosity of a star is the true brightness of the star. There is really little need to mention luminosity at this level.

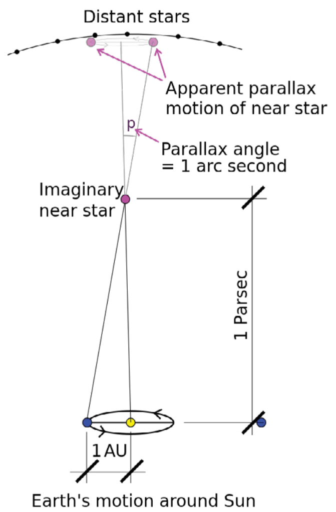
A parsec is a distance corresponding to a parallax of one second ('par' – 'sec'). 'One of the oldest methods to calculate the distance to a star was to record the difference in angle between two measurements of the position of the star in the sky. The first measurement was taken from the Earth on one side of the Sun, and the second was taken half a year later when the Earth was on the opposite side of the Sun.

Thus, the distance between the two measurements was known to be twice the distance between the Earth and the Sun. The distance to the star could be calculated using trigonometry.'

Source: *Wikipedia*.

At 1 parsec the radius of the Earth's orbit would subtend to 1″ (one second of arc). A 10-cent coin viewed from 2 km is 2″ across, the same angle that the Earth's orbit subtends from 1 parsec. The Full Moon is about 1800″ across. You might note that no star is as close as 1 parsec.

If you are still wondering what parallax is, please hold your finger still in the front of your nose at arm's length. Look at it with only one eye at the time. Whilst you are doing this, the finger would seem to move, but in reality is not. The distance between the two images of the finger can be measured in degrees – just like we do with the stars. This is the best explanation I found to understand the parallax.



A parsec is the distance from the Sun to an astronomical object which has a parallax angle of 1 arcsecond. (1 AU and 1 pc are not to scale. 1 pc = 206265 AU.)

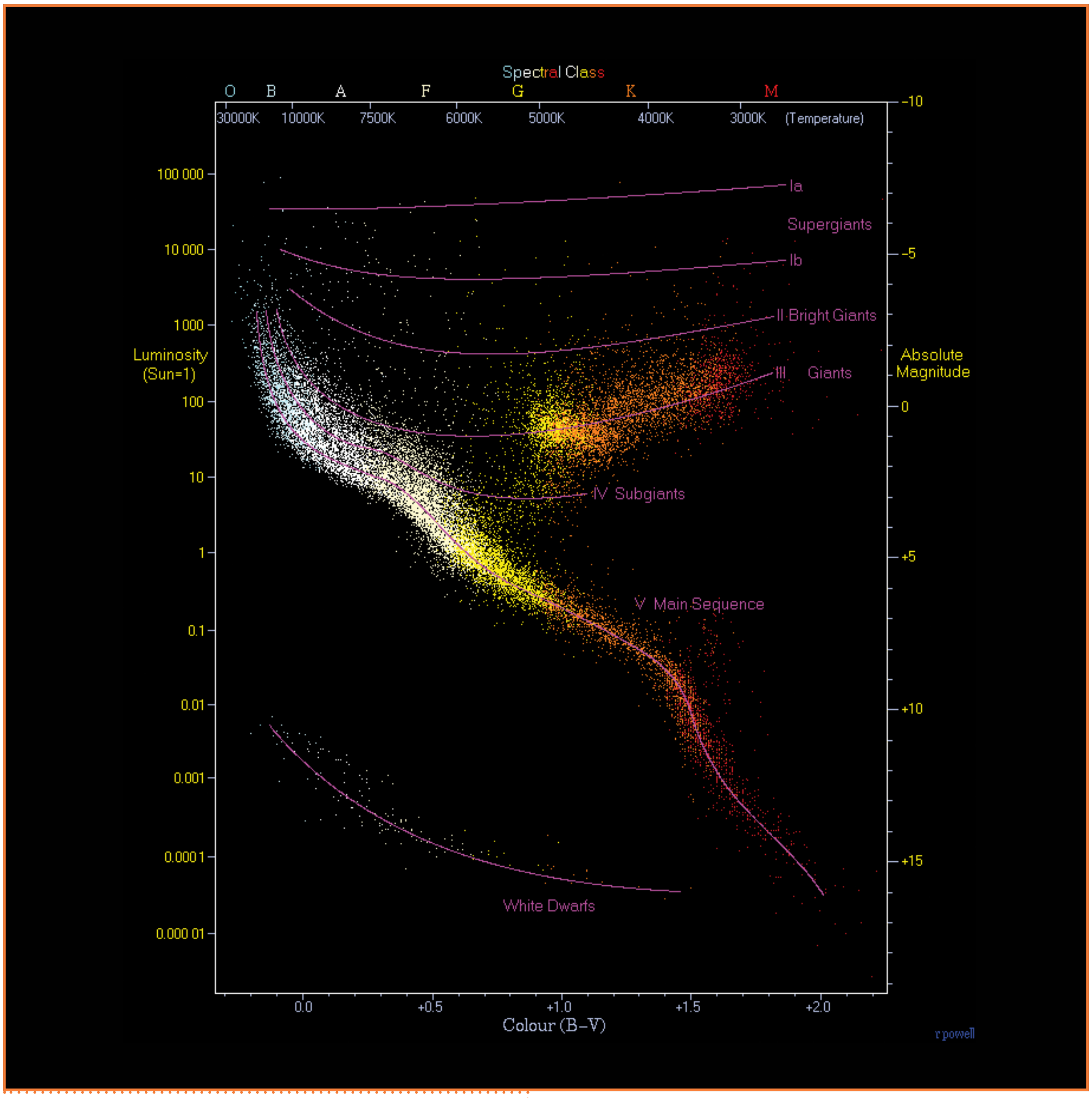
Luminosity

The true brightness (luminosity) of a star depends on how big the star is (size) and also how hot (temperature). According to that, stars are grouped in five classes:

- supergiants
- bright giants
- normal giants
- sub-giants and dwarfs.

Oh be a fine girl, kiss me!

At night, if we gaze long enough, we can clearly see that some stars twinkle blue (such as Rigel) or red (such as Betelgeuse). Some other stars have a yellow hue and some are white. Herzsprung Russell diagram, that groups stars according to their size, age and colour teaches us that the colour of each star is determined by its temperature. This is the story of the fine girl (which is in reality a great mnemonic).



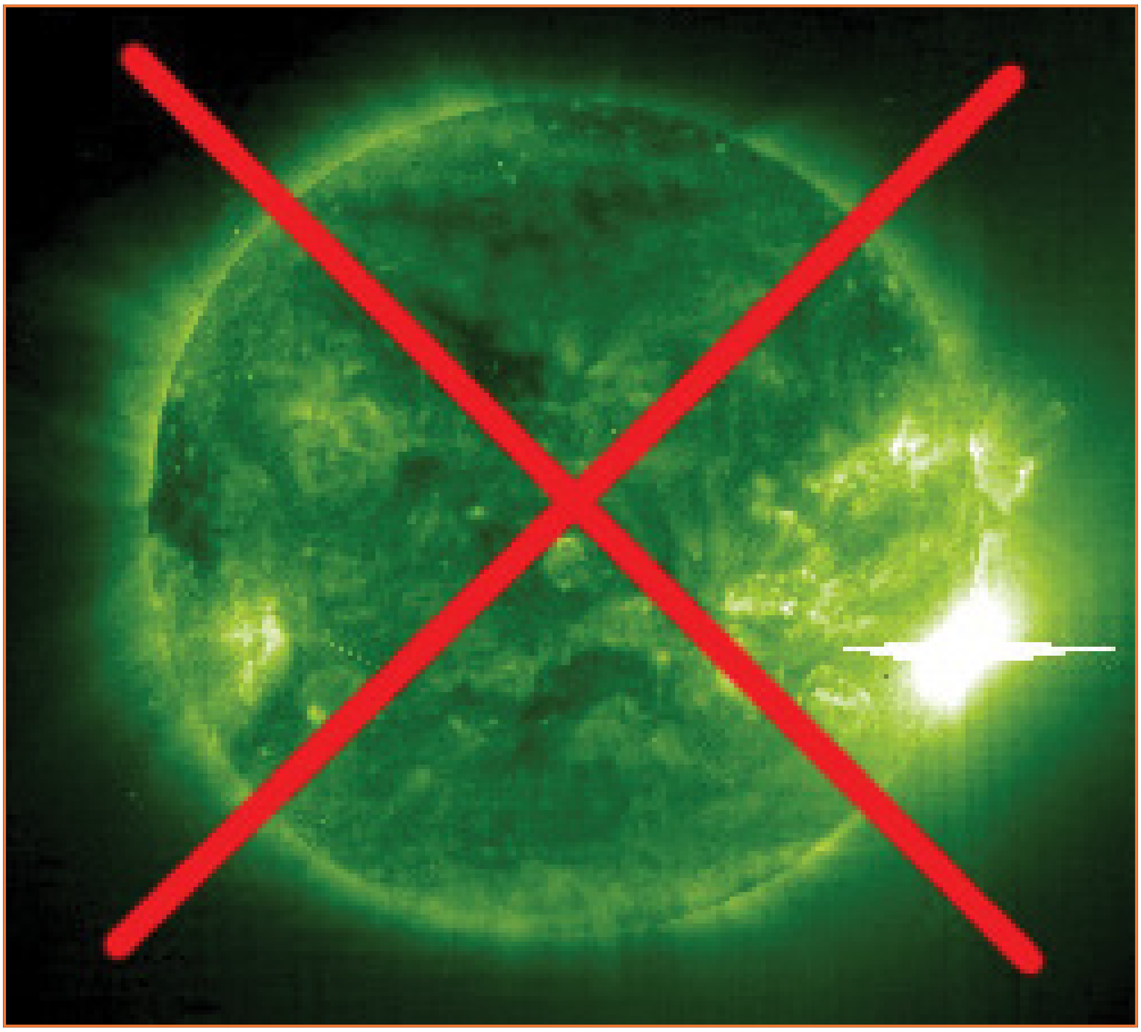
Herszprung Russell Diagram.

Here is a famous video for you to watch, a comparison of the sizes and colours of the stars.

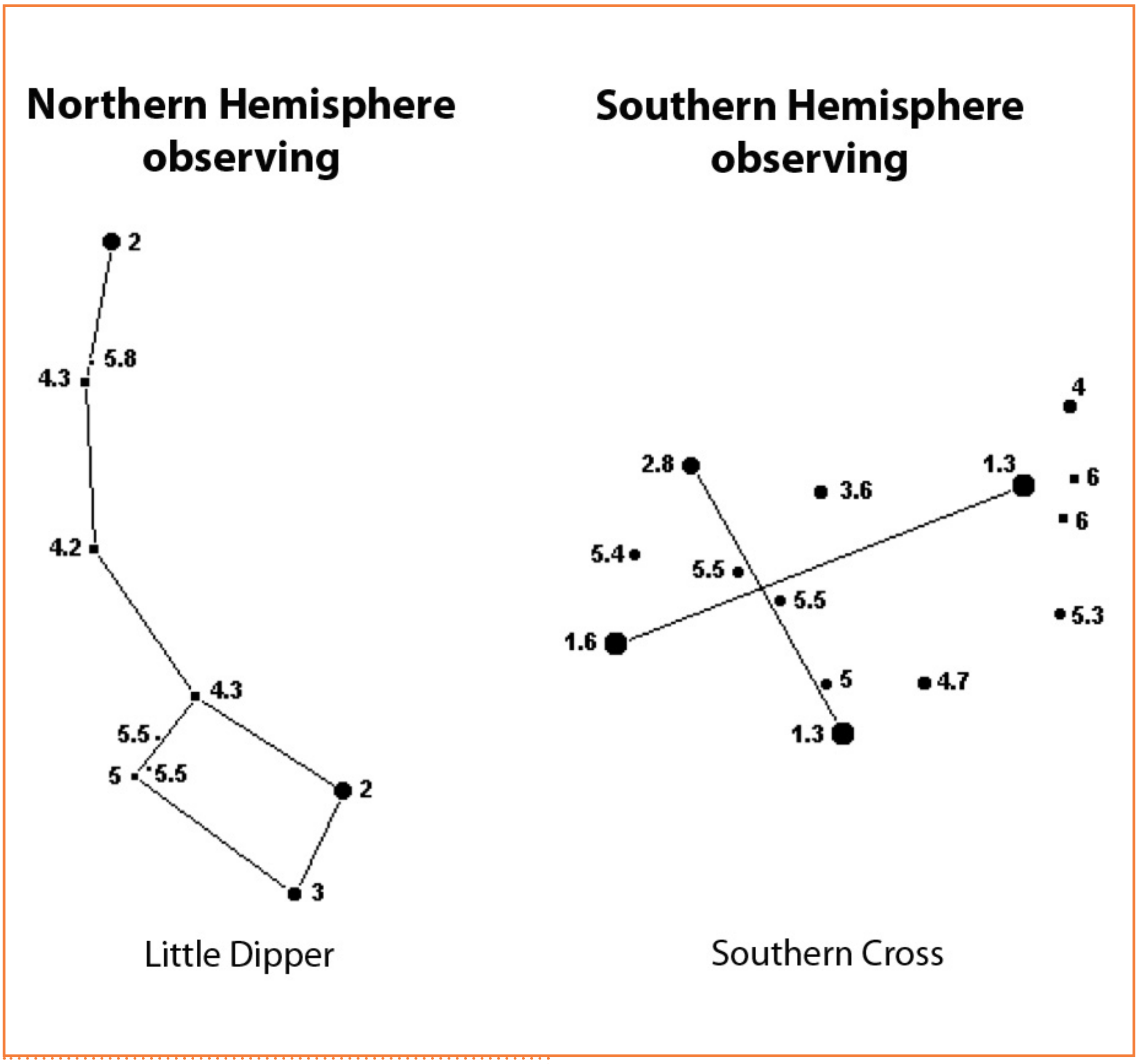
Where are all the green stars?

How can we explain that stars have all sorts of colours but green? (In my culture you can see green stars too but the sighting is 'reserved' for when someone hits their head hard.)

Ummm… first of all, colour doesn't exist! It is only a translation of the different wavelengths of light into a language, secretly spoken amongst the pigments in our retina! (True). Then our brain interprets the signals coming from those and… colour is created from the invisible, deciphered from the sky, just like sound!



Find out all about green stars from Phil Plait and Fraser Cain, my two favourite science communicators.



The Polar Sequence.

The 'polar sequence' is a must-do exercise for your observing session just after you've got your dark adaptation sorted.

Take the polar sequence map with you when you go outside. Look at the stars. Can you see all of them? Which is the faintest star you can see? Write down the number of magnitude it has. That is your limiting magnitude for the night. You will also find the polar sequence map in your observation diary template.

The qualities of the sky

Most of the time, astronomers worry about the quality of the sky when they look up and they keep a record of it.

In your celestial diaries, you too should by now have a space where you can describe the night's seeing, transparency and darkness.

Transparency

Have you ever looked at the sky only to discover that is cloudy? That is when you cannot see any star and, no, you cannot see the stars even through a telescope when the sky is overcast. Sometimes, there is only a thick layer of clouds and you can still see the stars but very badly. The less clouds, smog or atmosphere between us and the sky the more transparent the sky will be. Transparency is given by the faintest star that you can see with the naked eye.

Usually, my sky's transparency is to about 5 or 5.5 magnitude stars if I'm lucky. I dare you to find spots where you can see better than that. I imagine that there are plenty around in New Zealand :). Of course that transparency also depends on the observer's eyes as much as the clouds and air, and that's assuming the sky is completely dark. Most people can tell if there is cloud or smoke in the air. By the way, talking about invisible things, I am told that at Mt John in the South Island we can see down to magnitude 6.4.

Seeing

Seeing is about the steadiness of the atmosphere.

Twinkle twinkle little star, I know exactly what you are.

The amount of twinkling that we can observe for a star is the 'seeing'.

Do we see it as a steady point of light or not? If the air is steady – has little turbulence – then stars appear as sharp points of light in a telescope. We say the 'seeing' is good.

When the air is turbulent the stars appear as fuzzy blobs in a telescope. The bigger the blobs, the worse the seeing. The atmosphere bends the light a bit like sunlight going through rippled water. In good seeing the water is calm. In bad seeing the water has a lot of ripples in it.

Here are two great videos of seeing Jupiter. Bad Jupiter seeing and good seeing of Jupiter.

Seeing is the reason why professional telescopes are placed up high on mountains and in the desert as you get less atmospheric turbulence at high altitudes.

You can find out more about seeing here and here.

Darkness

The Bortle Scale of Light Pollution

At last, we talk about light pollution: too much light in the sky, preventing us from seeing the stars. Light pollution is not exclusively due to street lights but also happens when the Moon is in the sky.

Bortle Dark Sky Scale is a nine-level numeric scale that measures what can we see in the sky at a particular location. It quantifies the astronomical observability of celestial objects versus the interference caused by light pollution and skyglow.

Bortle Scale has been criticised for the faintness of stars that are said to be visible to the naked eye. For physiological reasons it is unlikely that anyone can see stars fainter than magnitude 6.5, anywhere.

Naked Eye Limiting Magnitude is the magnitude of the faintest star you will observe. The sad reality is that most city skies have become virtually empty of stars. We are getting gradually disconnected from our stars and we don't even know it. That is one of the reasons why the Southern Hemisphere is the astronomer's paradise! We can still see lots of stars here!

Light is damaging to our physiology. Too much light at night makes us sick. It can cause cancer and it does not let us rest properly. In the old times some people called 'lunatics' were in fact those feeling restless during full Moon nights, seeing too much light at night-time.

There are many things to be said about light pollution. Birds are dying and entire ecosystems are destroyed. Not mentioning the power bills that go through the roof especially due to bad public lighting!

I came to the Southern Hemisphere to see the stars and I thought I did.

I will never forget my first night here, second of March, 2005. I almost froze to death, holding a celestial map in my hand, waiting. Waiting for what? Well, waiting for what I thought it was a 'cirrus' cloud to go away. The cloud was exactly where I was supposed to see the Large Magellanic Cloud. Only that I discovered I could have waited there for the next 250 million years or more[1] because that particular cloud was not going to go anywhere in my near future. I was actually looking straight at the Cloud of Magellan. What is it with women that they can't read maps, even when they have instructions on how to do that?

Fast forward six years, in April of 2011 I was invited to do a talk at Stonehenge Aotearoa in Wairarapa. Whilst being there, I got called outside by my hosts to see a most amazing Milky Way slowly rising. I was blown away...

And then I had the chance to go to Lake Tekapo in August 2012. There, on the top of Mount John, where the Earth meets the sky, I saw the galactic Milky Way Kiwi with the naked eye!

Three nights of magic in one lifetime of searching – worth waiting for.

1 The Clouds of Magellan are only passing by and are not satellite galaxies of Milky Way.

Class	Title	Colour key	Naked eye limiting magnitude	Stellar limiting magnitude (with 12.5″ reflector)	Description
1	Excellent dark-sky site	black	7.6-8.0	19 at best	Zodiacal light, gegenschein, zodiacal band visible; M33 direct vision naked eye object; Scorpius and Sagittarius regions of the Milky Way cast obvious shadows on the ground; airglow is readily visible; Jupiter and Venus affect dark adaptation; surroundings basically invisible.
2	Typical truly dark site	gray	7.1-7.5	17 at best	Airglow weakly visible near horizon; M33 easily seen with naked eye; highly structured summer Milky Way; distinctly yellowish zodiacal light bright enough to cast shadows at dusk and dawn; clouds only visible as dark holes; surroundings still only barely visible silhouetted against the sky; many Messier globular clusters still distinct naked eye objects.
3	Rural sky	blue	6.6-7.0	16 at best	Some light pollution evident at the horizon; clouds illuminated near horizon, dark overhead; Milky Way still appears complex; M15, M4, M5, and M22 distinct naked eye objects; M33 easily visible with averted vision; zodiacal light striking in spring and autumn, colour still visible; nearer surroundings vaguely visible.
4	Rural/ suburban transition	green yellow	6.1-6.5	15.5 at best	Light pollution domes visible in various directions over the horizon; zodiacal light is still visible, but not even halfway extending to the Zenith at dusk or dawn; Milky Way above the horizon still impressive but lacks most of the finer details; M33 a difficult averted vision object only visible when higher than 55 degrees; clouds illuminated in the directions of the light sources but still dark overhead; surroundings clearly visible even at a distance.

5	Suburban sky	orange	5.6-6.0	15 at best	Only hints of zodiacal light are seen on the best nights in autumn and spring; Milky Way is very weak or invisible near the horizon and looks washed out overhead; light sources visible in most, if not all, directions; clouds are noticeably brighter than the sky.
6	Bright suburban sky	red	5.1-5.5	14.5 at best	Zodiacal light is invisible; Milky Way only visible near the Zenith; sky within 35 degrees from the horizon glows grayish-white; clouds anywhere in the sky appear fairly bright; surroundings easily visible; M33 is impossible to see without at least binoculars, M31 is modestly apparent to the unaided eye.
7	Suburban/ urban transition or Full Moon	red	4.6-5.0	14 at best	Entire sky has a grayish-white hue; strong light sources evident in all directions; Milky Way invisible; M31 and M44 may be glimpsed with the naked eye but are very indistinct; clouds are brightly lit; even in moderate-sized telescopes the brightest Messier objects are only ghosts of their true selves. On a Full Moon night the sky is not better than this rating even at the darkest locations with the difference that the sky appears more blue than orangish-white at otherwise dark locations.
8	City sky	white	4.1-4.5	13.5 at best	Sky glows white or orange – one can easily read; M31 and M44 are barely glimpsed by an experienced observer on good nights; even with telescope only bright Messier objects can be detected; stars forming familiar constellation patterns may be weak or completely invisible.
9	Inner-city sky	white	4.0 at best	13 at best	Sky is brilliantly lit with many stars forming constellations invisible and many weaker constellations invisible; aside from Pleiades, no Messier object is visible to the naked eye; only objects to provide fairly pleasant views are the Moon, the planets, and a few of the brightest star clusters.

What can we do?

In New Zealand we have the Dark Skies section of the Royal Astronomical Society of New Zealand, a proactive member of the Dark Skies Association.

We also have a world famous Dark Sky Reserve that was awarded 'Golden Status' – only four like these in the world and it's here at Lake Tekapo for us to treasure and enjoy.

In New Zealand I saw the stars, in Wairarapa I saw the galaxy and at Lake Tekapo I saw the centre of it marked by the Milky Way Kiwi!

I don't know about you but every time I see all these I feel like I am one with the Universe. Not dwarfed, not reduced to a grain of sand and in no way overwhelmed but energised and grateful for the knowledge and the consciousness.

Join me as newly professional stargazers to save the night sky together – lest we forget the stories of the stars!

Clear and dark skies!


STAR
GAZING