

# Voyage to the Planets

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# Modern Astronomy: Voyage to the Planets

## Lecture I

# Introduction to the Solar System *and* The Earth as a Planet

University of Sydney  
Centre for Continuing Education  
Autumn 2005

This course is about the solar system as we know it in the era of planetary probes and space missions.

1. Introduction; the Earth
2. The Moon; Spaceflight
3. The inner planets: Mercury and Venus
4. Mars, the Red Planet
5. \* Rocks in space: asteroids, comets and meteorites
6. Jupiter
7. Saturn
8. The outer planets: Uranus, Neptune and Pluto
9. Formation of the Solar System
10. Extra-solar planets



There is a web-site for the course at

<http://physics.usyd.edu.au/~helenj/VoyagetothePlanets.html>

where I will put copies of all the lecture notes.

There will be an evening of star viewing in the Blue Mountains, run by Dr John O'Byrne. The proposed date for this is

Saturday April 9th.

This year, we may also have an extra evening of planet viewing from the roof of the Physics building, where we have a 30cm and a 20cm telescope, from which we should get good views of the Moon, Jupiter and Saturn.



Tonight: a quick overview

- The solar system from the outside: a brief tour
- The Earth as a planet

# The solar system from outside

What would the solar system look like to an objective observer?

Imagine we are an astronomer in another solar system. What would we see, if we looked at the Sun and its surrounds?

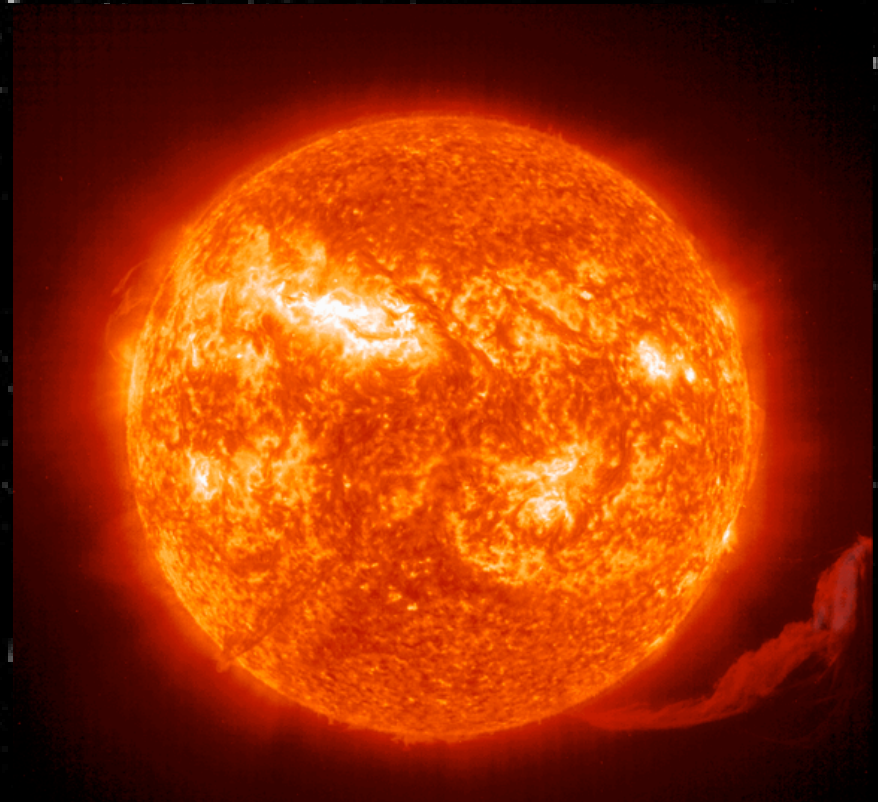


# The Sun

Most of all we would see the Sun: a G2 type star.

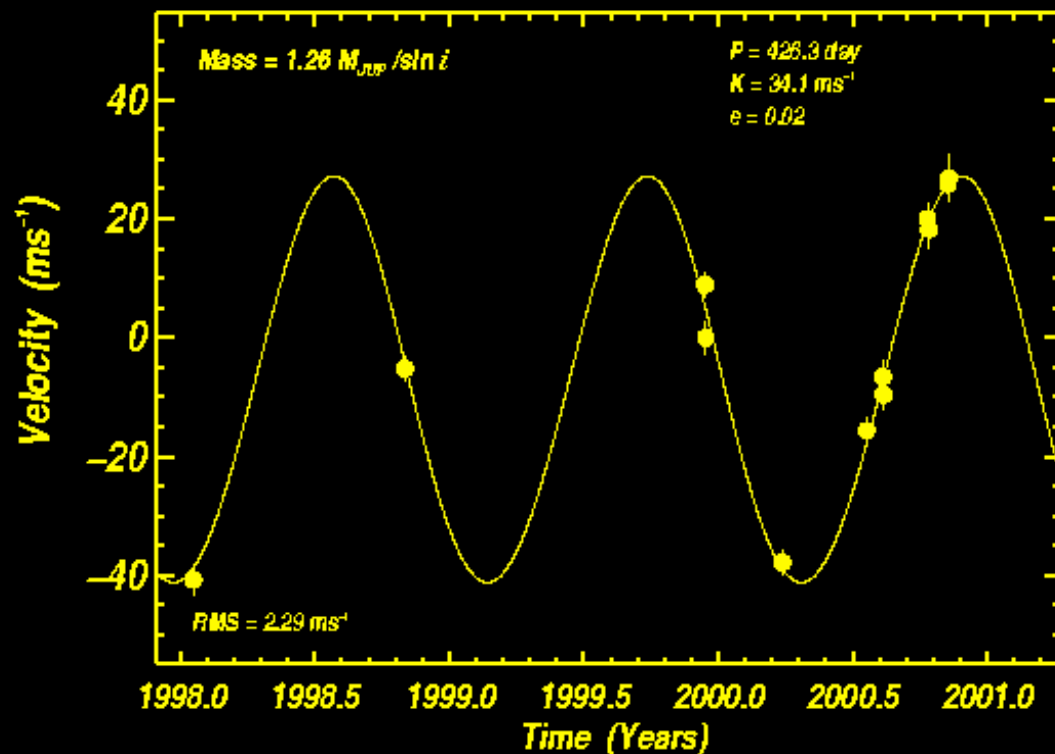
*“Far out in the uncharted backwaters of the western spiral arm of the Galaxy lies a small unregarded yellow sun...”*

— Douglas Adams, *The Hitchhiker's Guide to the Galaxy*





If we had very good measuring instruments, and could measure tiny shifts in the spectrum of the Sun of 13 m/s, or 43 parts per billion, we could deduce the presence of a planet orbiting the Sun: Jupiter.



*The Doppler shift of the star epsilon Reticulum, indicating the presence of a planet of at least 1.2 Jupiter masses in a 1.1 AU orbit. Even a planet this close to the star induces a total wobble of only 34 m/s.*

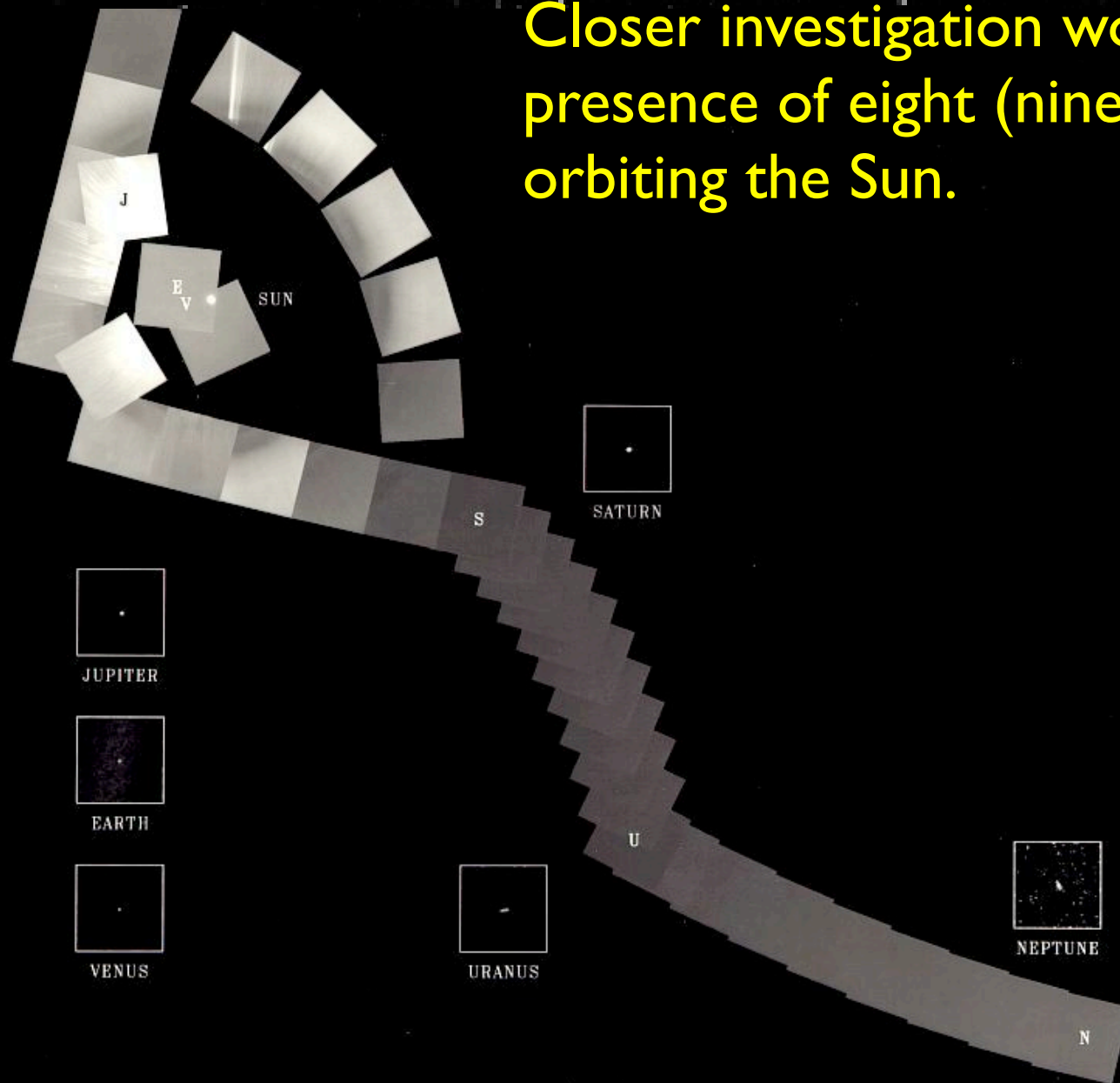
The background of the slide is a deep black space filled with numerous small, white and yellowish stars of varying brightness. Some stars appear as distinct points of light, while others are slightly blurred, creating a sense of depth and vastness.

The Sun contains over 99.8% of the mass of the solar system.

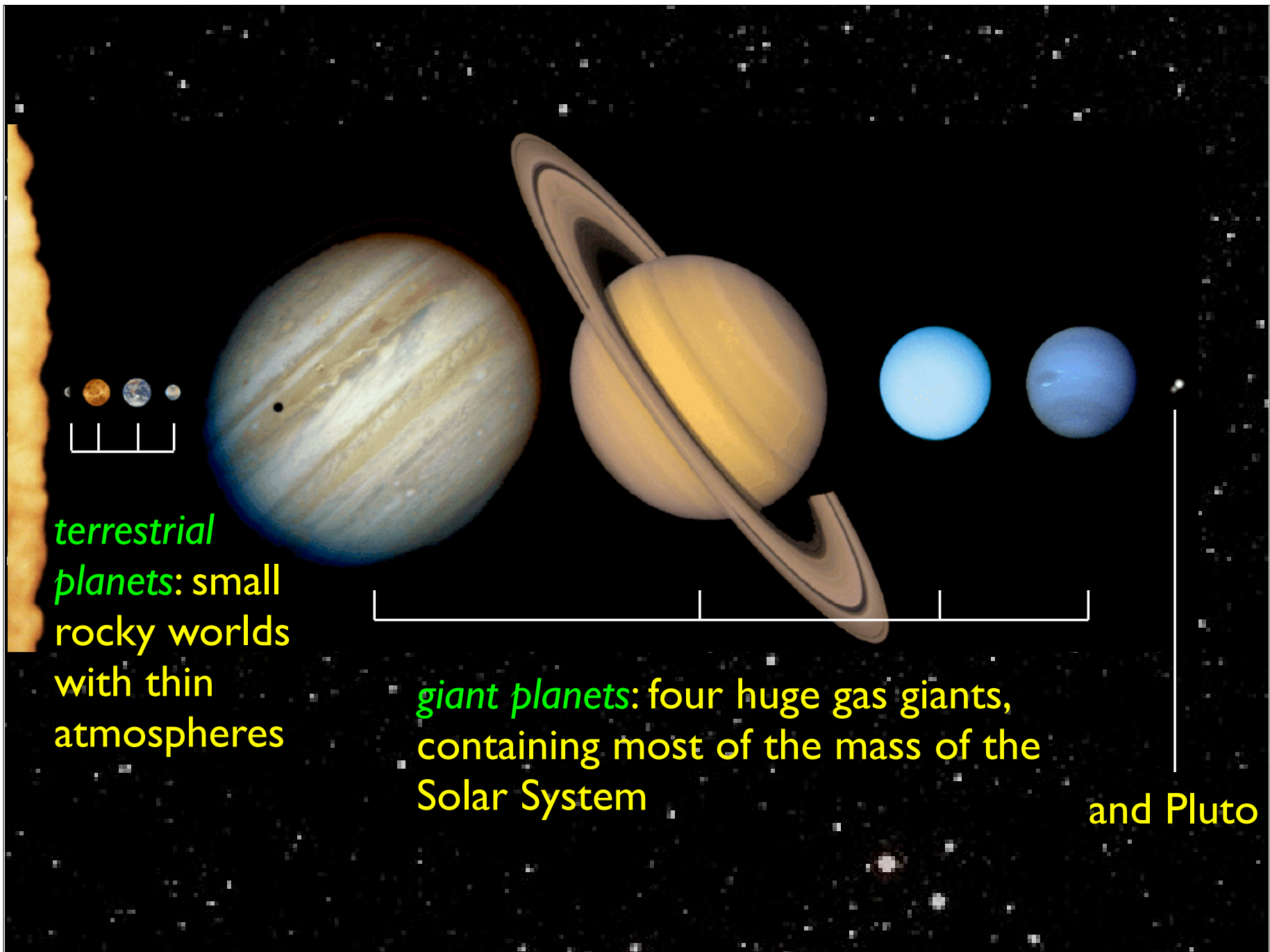
To very good approximation, the solar system consists of the Sun plus some debris.

To second approximation, the solar system consists of the Sun plus Jupiter plus some debris.

Closer investigation would yield the presence of eight (nine?) planets orbiting the Sun.



*Portrait of the Solar  
System taken by Voyager 1  
on 14 February 1990*



*terrestrial*  
*planets:* small  
rocky worlds  
with thin  
atmospheres

*giant planets:* four huge gas giants,  
containing most of the mass of the  
Solar System

and Pluto

# Pluto may lose planet status

Date: March 10 2003

**By Stephen Cauchi**

The solar system, we've been told since primary school, has nine planets. But a fierce debate raging among astronomers could mean that number being revised to as low as eight or as high as 12, if not more.

Quaoar, Varuna and Ceres are names students may one day start learning alongside Mars and Venus. And tiny Pluto may become an asteroid or "Kuiper-belt object" rather than a planet.

Gibor Basri, an astronomer at the University of California, is about to submit a controversial proposal to the International Astronomical Union (IAU), which has naming rights to space objects, that would increase the number of planets to 12. The IAU has a working group considering the definition of "planet".

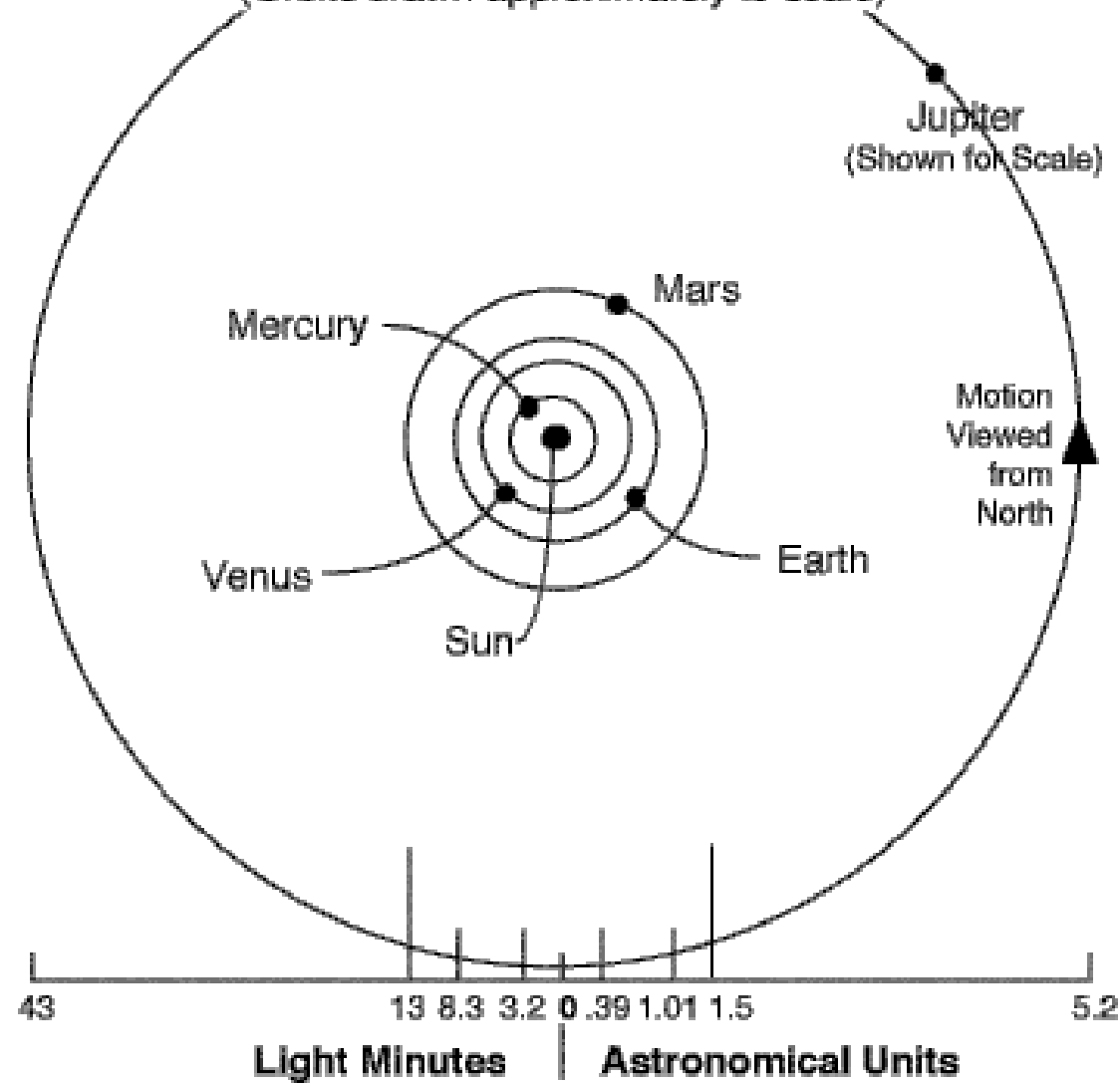
"It's something of an embarrassment that we have no definition of what a planet is," Professor Basri told his campus newspaper, *Berkeley News*. "People like to classify things. We live on a planet; it would be nice to know what that was."

Professor Basri said that recent discoveries of large asteroids in the Kuiper belt, on the solar system's fringes, had tested the

	<b>Mercury</b>	<b>Venus</b>	<b>Earth</b>	<b>Mars</b>	<b>Jupiter</b>	<b>Saturn</b>	<b>Uranus</b>	<b>Neptune</b>	<b>Pluto</b>
Mean distance (AU)	0.387	0.723	1.00	1.52	5.20	9.58	19.20	30.05	39.24
Inclination of orbit (deg)	7.0	3.4	0.0	1.9	1.3	2.5	0.8	1.8	17.2
Orbital eccentricity	0.205	0.007	0.017	0.094	0.049	0.057	0.046	0.011	0.244
Diameter (km)	4,879	12,104	12,756	6,794	142,984	120,536	51,118	49,528	2,390
Mass (Earth=1)	0.0553	0.815	1.0	0.107	317.8	95.2	14.5	17.1	0.0021
Density (g/cm <sup>3</sup> )	5.43	5.24	5.52	3.93	1.33	0.69	1.27	1.64	1.75
Surface gravity	0.378g	0.907g	1g	0.377g	2.36g	0.916g	0.889g	1.12g	0.059g
Rotation period	58.65 d	-243 d	23h 56m	24h 37m	9h 56m	10h 40m	17h 14m	16h 6m	6d 9h
Length of day	175.9d	116.8d	24h	24h 42m	9h 56 m	10h 40m	17h 14m	16h 6m	6d 9h
Length of year	88.0 d	224.7 d	365.2 d	687.0 d	11.9 y	29.4 y	83.7 y	163.7 y	248.0 y
Number of moons	0	0	1	2	63	33	27	13	1
Atmosphere	Almost none	CO <sub>2</sub>	Nitrogen Oxygen	CO <sub>2</sub>	Hydrogen Helium	Hydrogen Helium	Hydrogen Helium Methane	Hydrogen Helium Methane	None (?)
Space missions	Mariner 10	Mariner 2,5 Mariner 10 Venera Vega 1 Vega 2 Pioneer Venus Magellan		Mariner 4,6 Mars 2,3 Mariner 7,9 Mars 5,6 Viking 1,2 Phobos Pathfinder Global Surveyor Mars Express	Pioneer 10 Pioneer 11 Voyager 1 Voyager 2 Galileo	Pioneer 11 Voyager 1 Voyager 2 Cassini	Voyager 2	Voyager 2	-

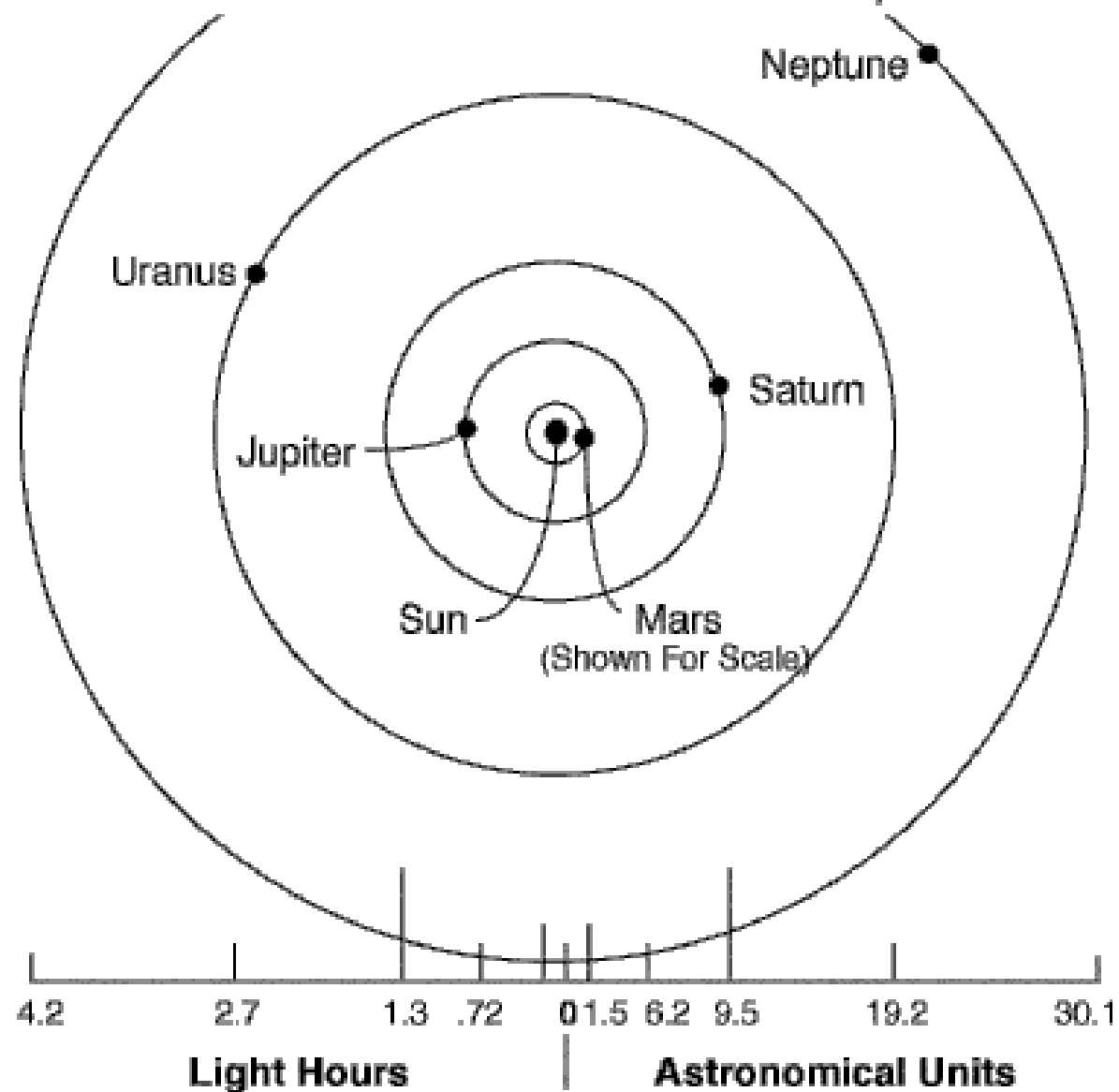
## Mean Distances Of The Terrestrial Planets From The Sun

(Orbits drawn approximately to scale)



## Mean Distances Of The Jovian Planets From The sun


(Orbits drawn approximately to scale.  
Pluto omitted to accommodate scale)





In 1766, Johann Titius proposed an empirical rule for the distances of the planets from the Sun, popularised by Johann Bode. Take the series 0, 3, 6, 12, 24, 48... then add 4 and divide by 10. The answers approximate rather well most of the distances of planets in AU from the Sun:

	Distance (AU)	Bode-Titius rule
Mercury	0.39	0.3
Venus	.72	0.7
Earth	1.0	1.0
Mars	1.52	1.6
		2.8
Jupiter	5.20	5.2
Saturn	9.54	10.0
Uranus	19.2	19.6
Neptune	30.1	38.8
Pluto	39.5	77.2

The image is a composite of several astronomical photographs. On the left, Saturn is shown with its prominent rings, next to the heavily cratered surface of Mars. To the right, Jupiter is depicted with its characteristic bands and the Great Red Spot. Below Jupiter, two of its moons are visible. The background is a deep black space filled with numerous stars. The text is overlaid on the lower-left portion of the image.

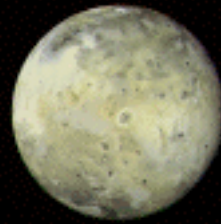
Most of the planets (all except Mercury and Venus) have moons in orbit around them. The giant planets all have large satellite systems, consisting of several large- and medium- size moons, as well as many smaller moons and rings.

Earth



Moon

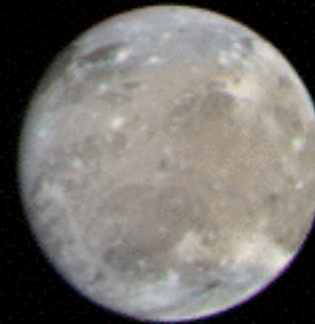
Jupiter



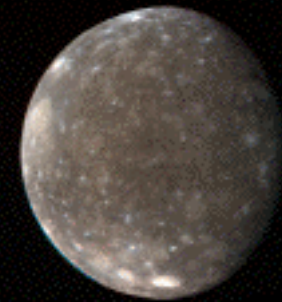
Io



Europa

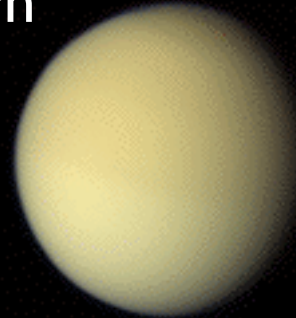


Ganymede



Callisto

Saturn



Titan

Mimas

Enceladus

Tethys

Dione

Rhea

Hyperion

Iapetus

Phoebe

Uranus



Miranda



Ariel



Umbriel



Titania



Oberon

Neptune



Triton

Proteus

Nereid

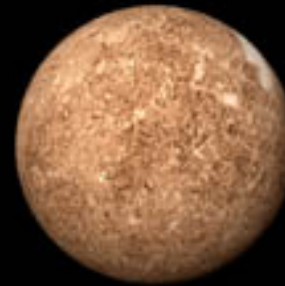
The largest of these satellites are larger than some of the planets.



**Ganymede**  
5262 km



**Titan**  
5150 km



**Mercury**  
4880 km



**Callisto**  
4806 km



**Io**  
3642 km



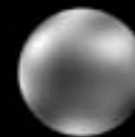
**Moon**  
3476 km



**Europa**  
3138 km



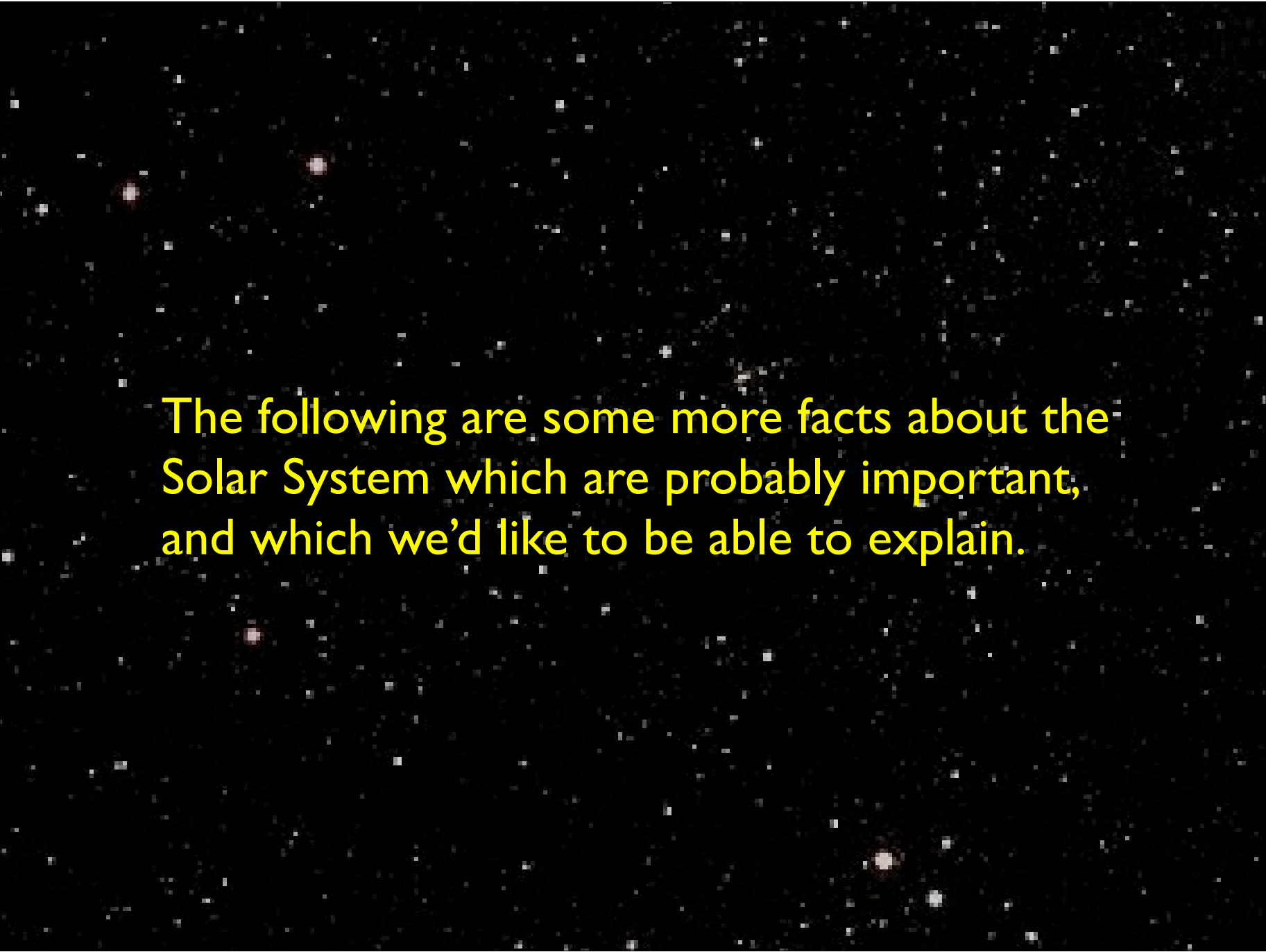
**Triton**  
2706 km



**Pluto**  
2300 km



**Titania**  
1580 km

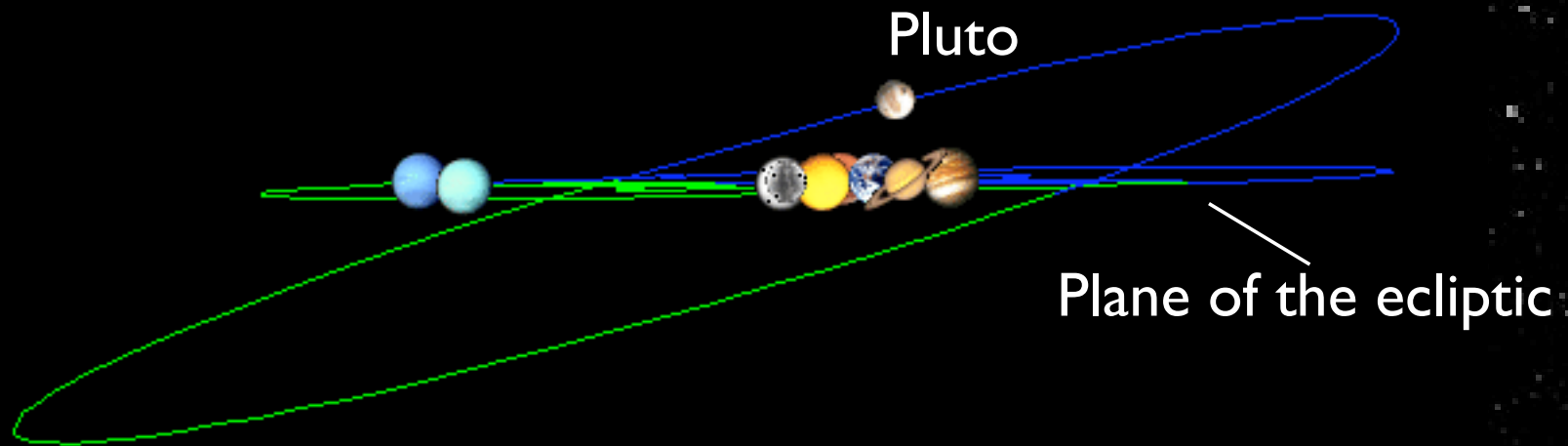
A deep space photograph showing a dense field of stars against a black background. The stars vary in brightness and size, with some appearing as distinct points of light and others as faint, diffuse clouds. The overall scene is a vast, dark expanse of the universe.

The following are some more facts about the Solar System which are probably important, and which we'd like to be able to explain.



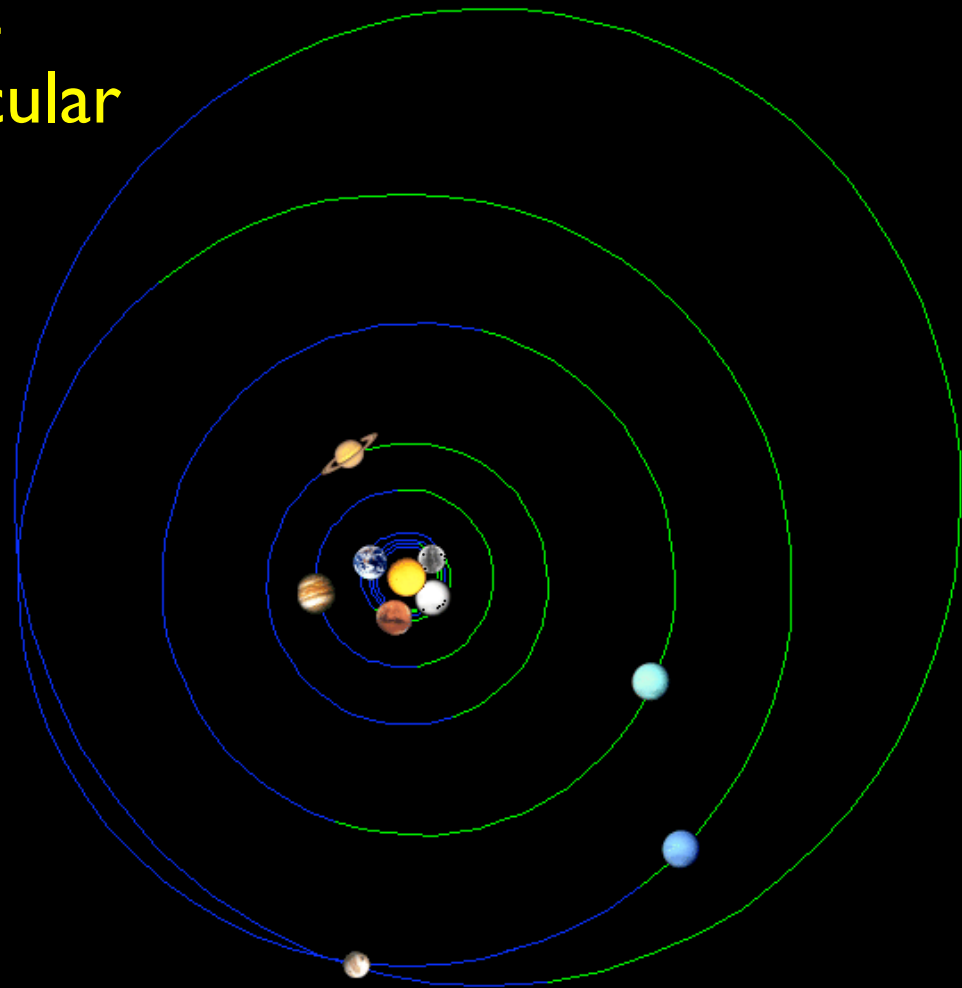
# Co-planar orbits

All the planets (except Pluto) orbit in the same direction and in the same plane (the ecliptic), to within  $6^\circ$ .



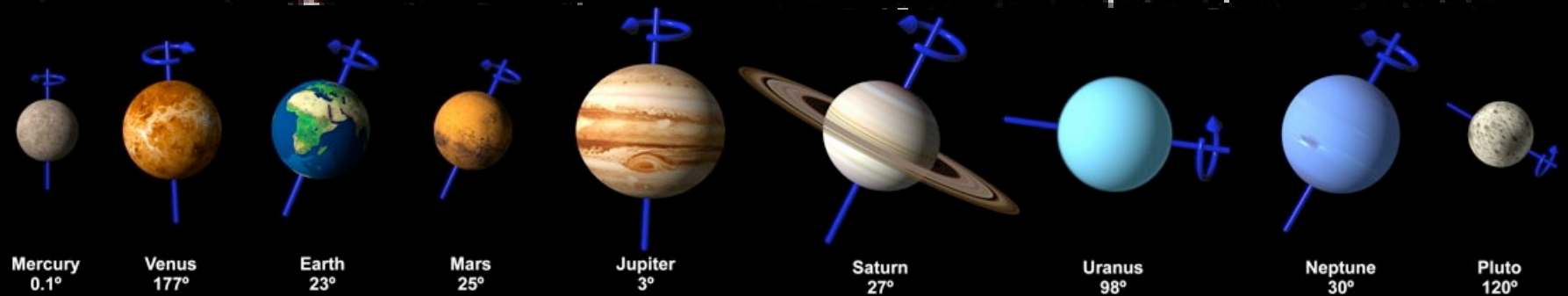
# Circular orbits

All the planets (except Pluto) have almost circular orbits.

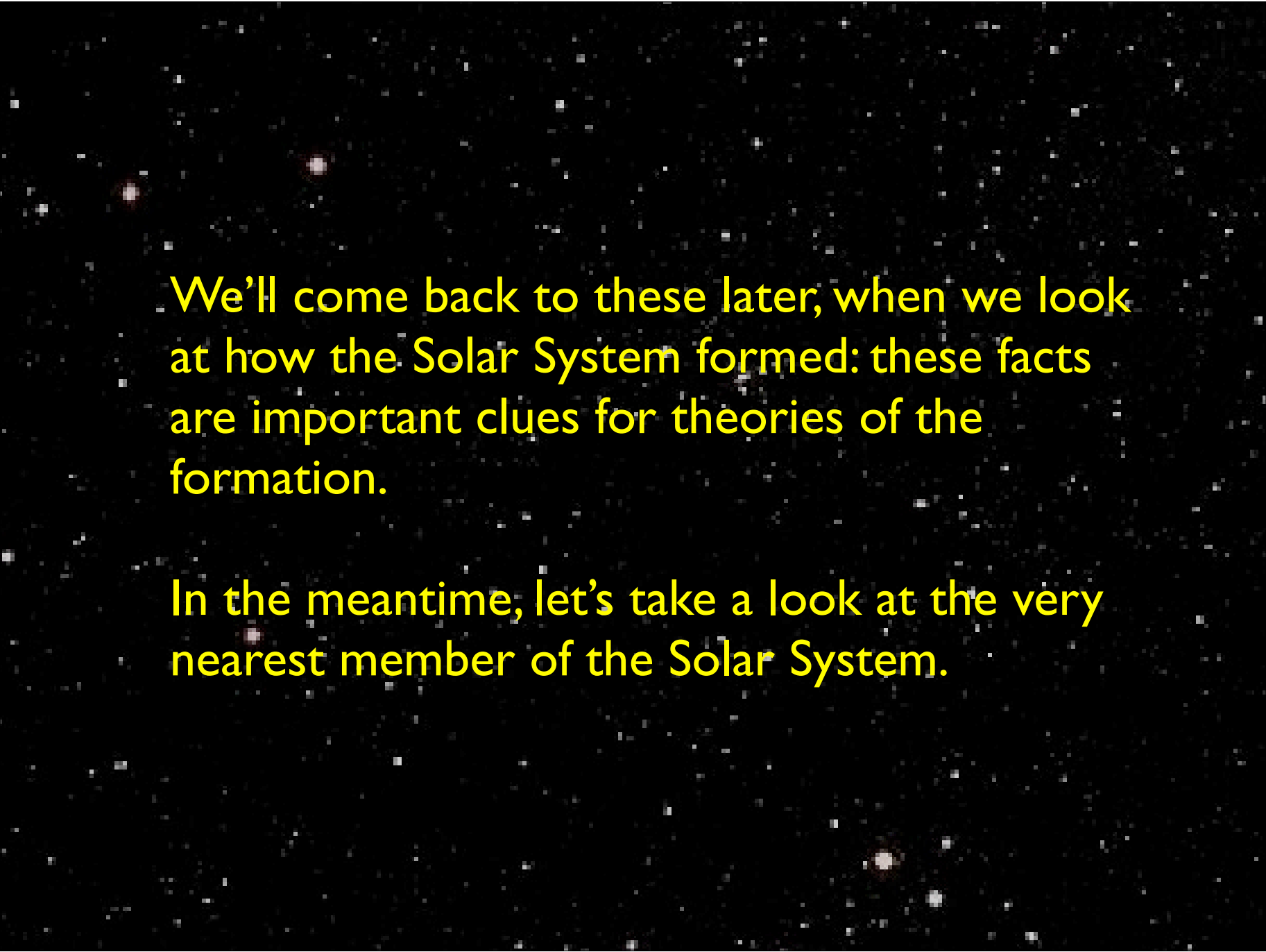


# Prograde orbits

All the planets go around the Sun in the same direction. Most moons go around their primaries in the same direction, and most (but not all) of the planets spin in the same direction as well.





A deep space photograph showing a dense field of stars against a black background. The stars vary in brightness and size, with some appearing as distinct points of light and others as slightly larger, more diffuse clouds. The overall scene is a vast, dark expanse of the universe.

We'll come back to these later, when we look at how the Solar System formed: these facts are important clues for theories of the formation.

In the meantime, let's take a look at the very nearest member of the Solar System.

# The Earth as a planet



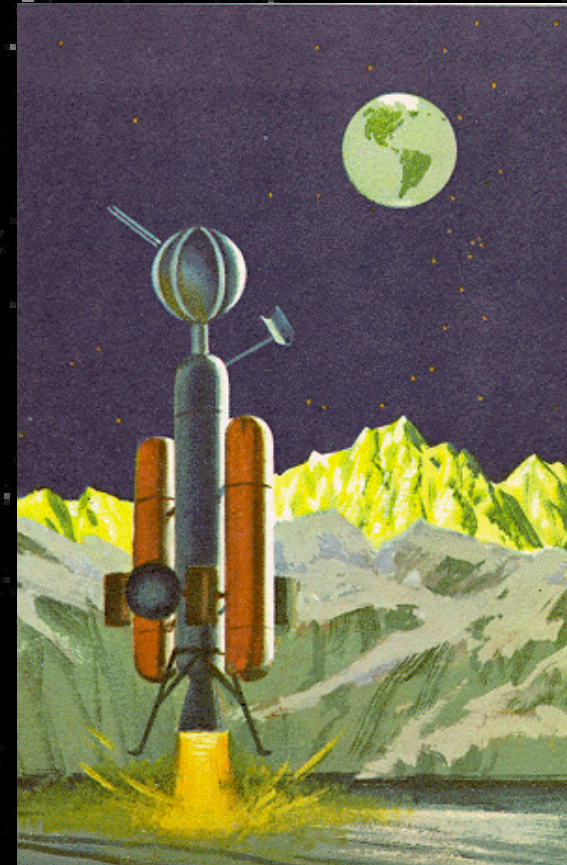
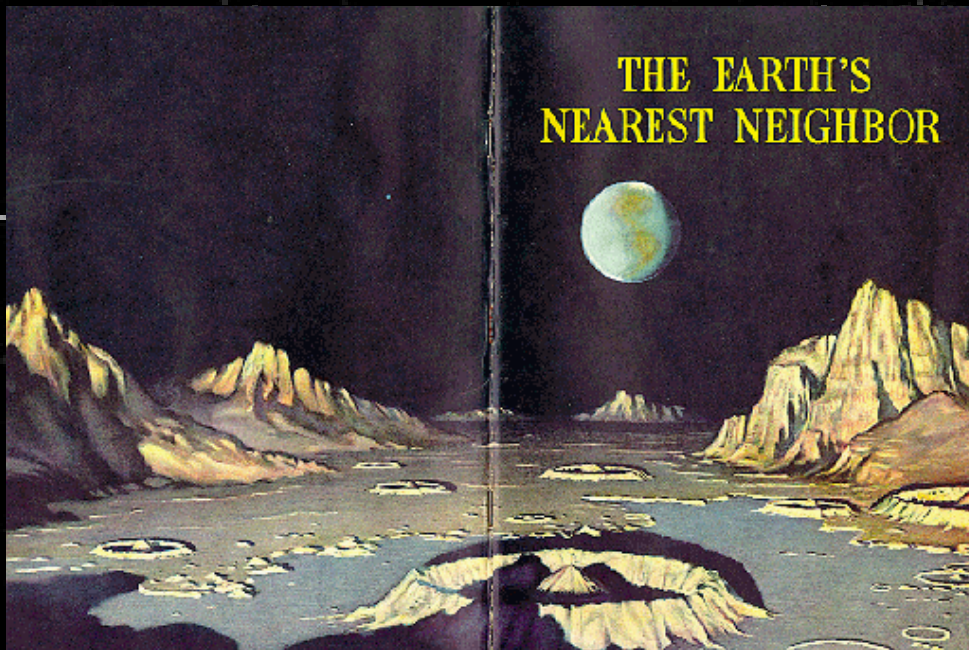
# Basic data

## Earth

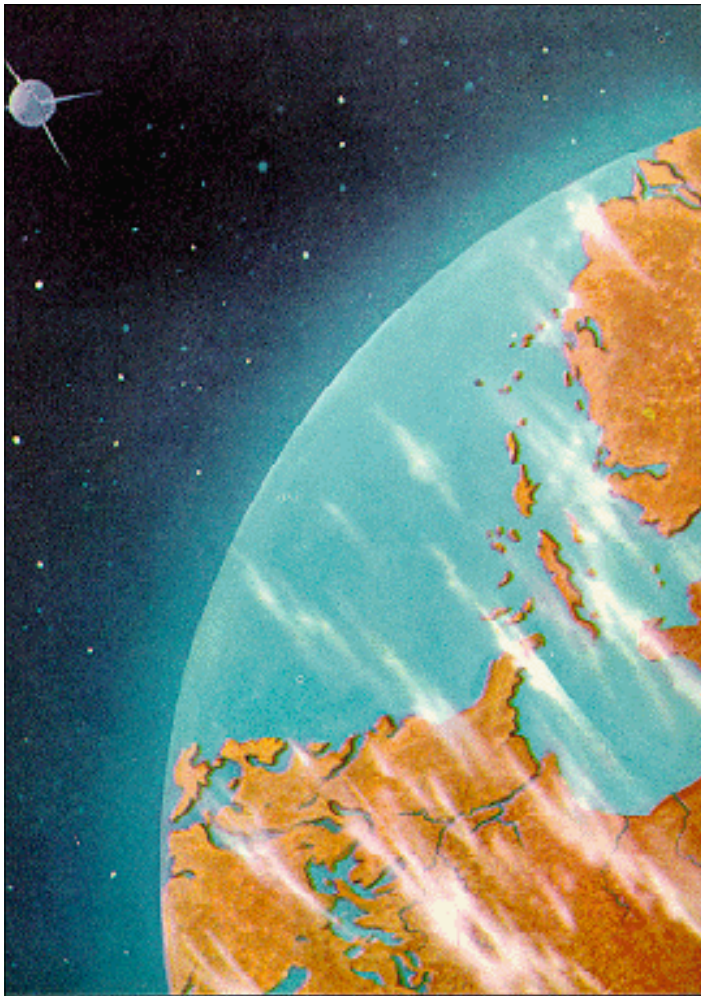
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Mass	$5.9736 \times 10^{24} \text{ kg}$
Radius	6378.1 km
Mean density	$5.515 \text{ g/cm}^3$
Gravity	$9.798 \text{ m/s}^2$
Semi-major axis	$149.60 \times 10^6 \text{ km}$
Period	365.256 d
Orbital inclination	$0.0^\circ$
Orbital eccentricity	0.0167
Rotation period	23.9345 h
Length of day	24.0000 h

Pre-space age depictions of Earth invariably described or depicted the planet as “blue-green”.





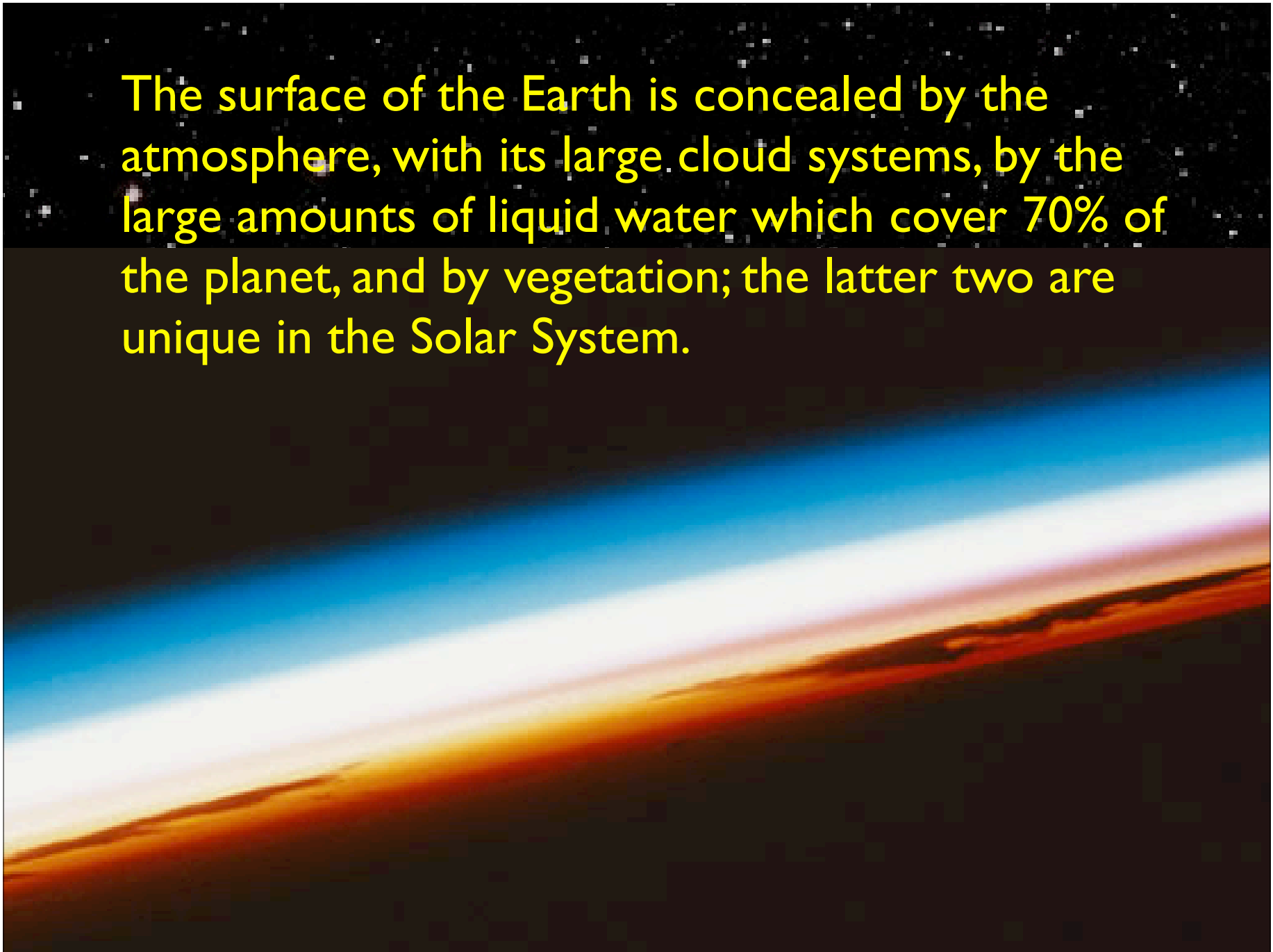


If they showed clouds at all, it was the small, wispy variety.

No-one seems to have imagined the continent-spanning cloud that is common-place, or anticipated that the Earth from space is far more *blue-white* than *blue-green*.

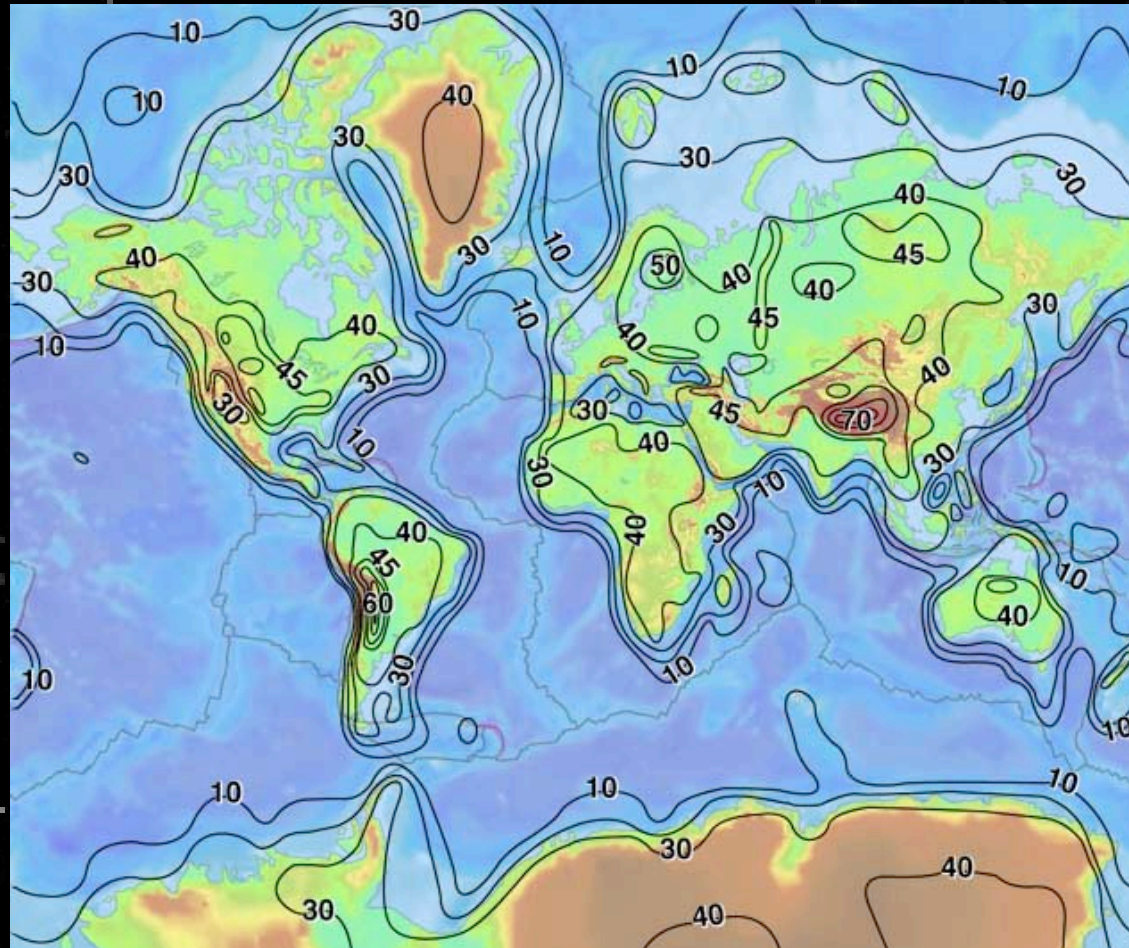


The surface of the Earth is concealed by the atmosphere, with its large cloud systems, by the large amounts of liquid water which cover 70% of the planet, and by vegetation; the latter two are unique in the Solar System.





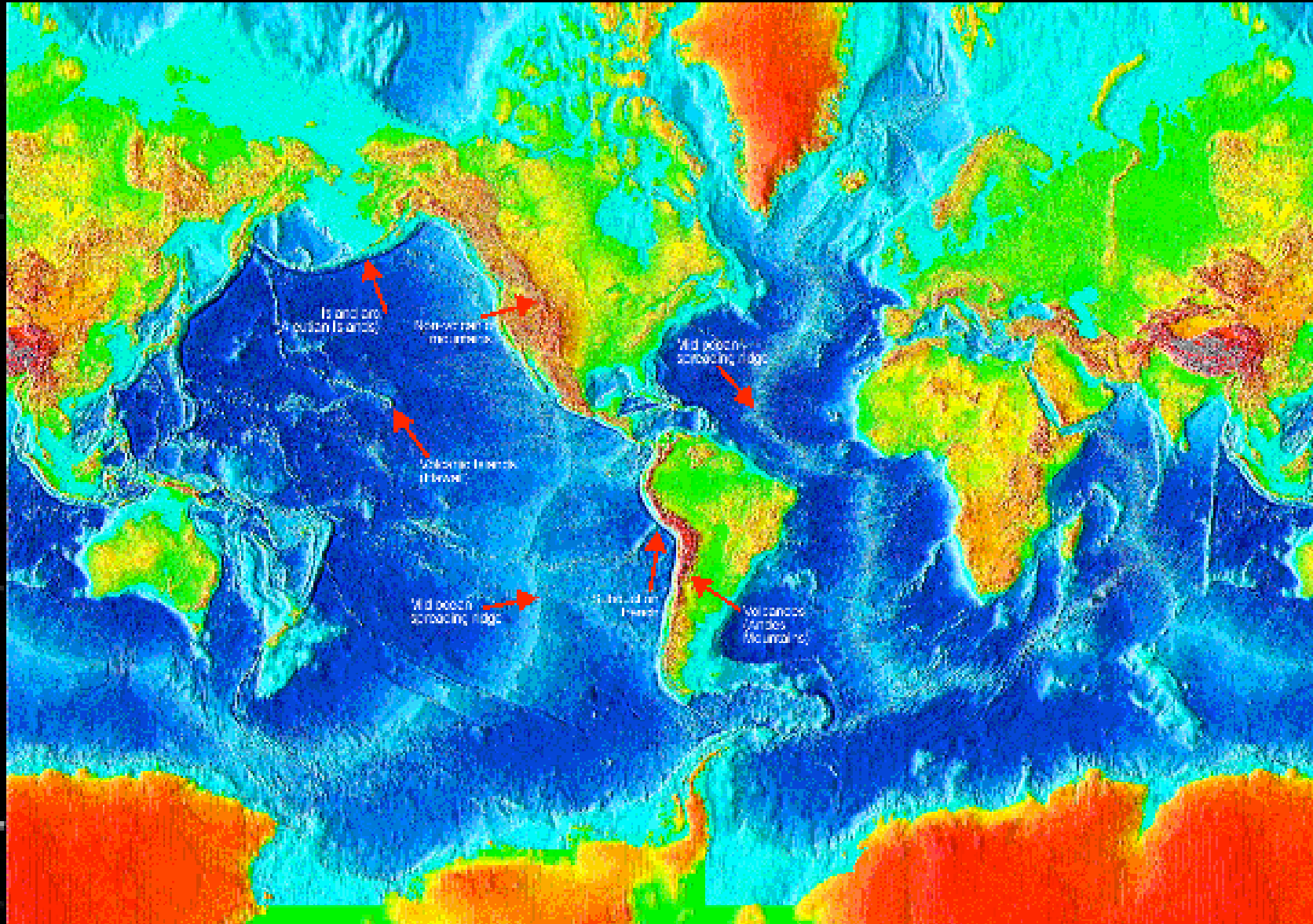
Underneath these layers, the Earth's surface is made of rock. The rock that makes up the continent is thick, that beneath the oceans is much thinner.



Thickness of the Earth's crust, with 10 km contour levels. The continents are essentially outlined by the 30 km contour.

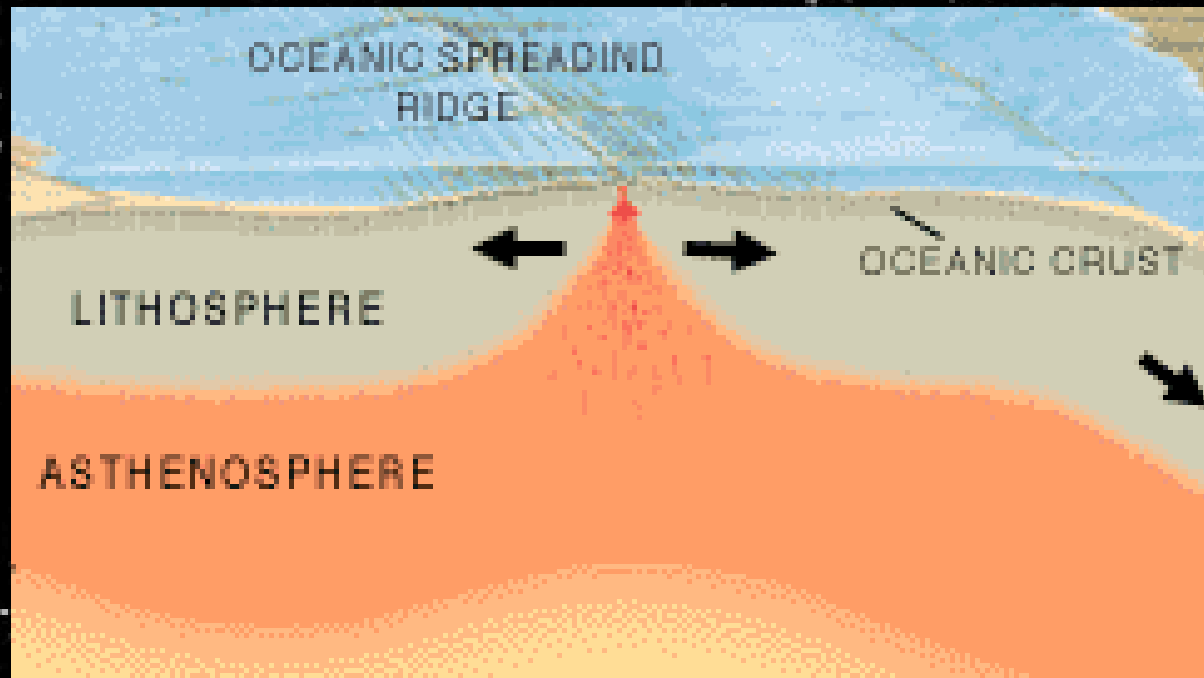


## Topographical map of the Earth, showing continental and sea-floor features

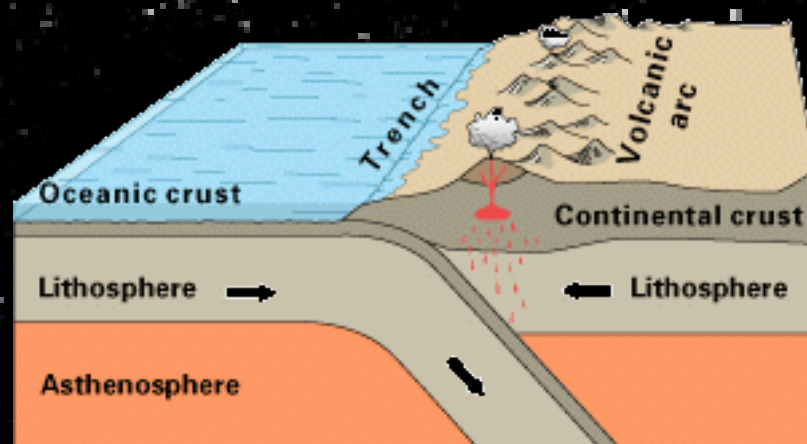


# Plate tectonics

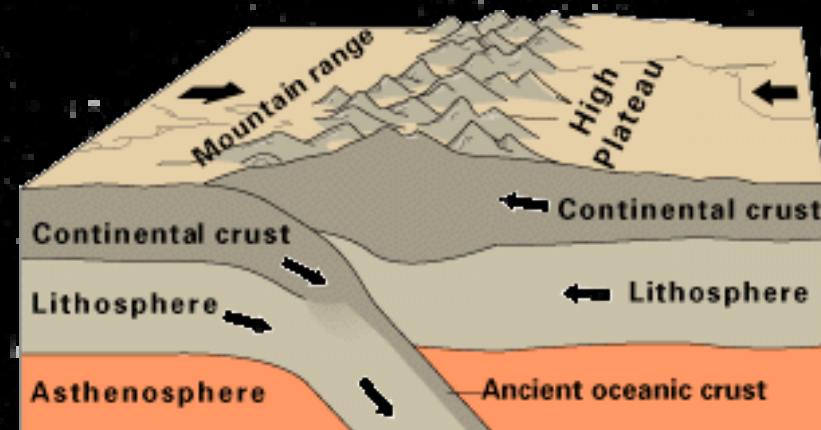
The earth's surface is divided into ten large rigid plates, which move as units. Where two plates move apart, lava rises from below to fill the gap, and the plates grow as they separate: *sea-floor spreading*.



Where two plates move together, the edge of one plate is forced beneath the other. The continental material, being lighter, is forced upwards and crumples, forming mountain ranges, while the sea-floor material is dragged downwards, forming deep sea trenches.

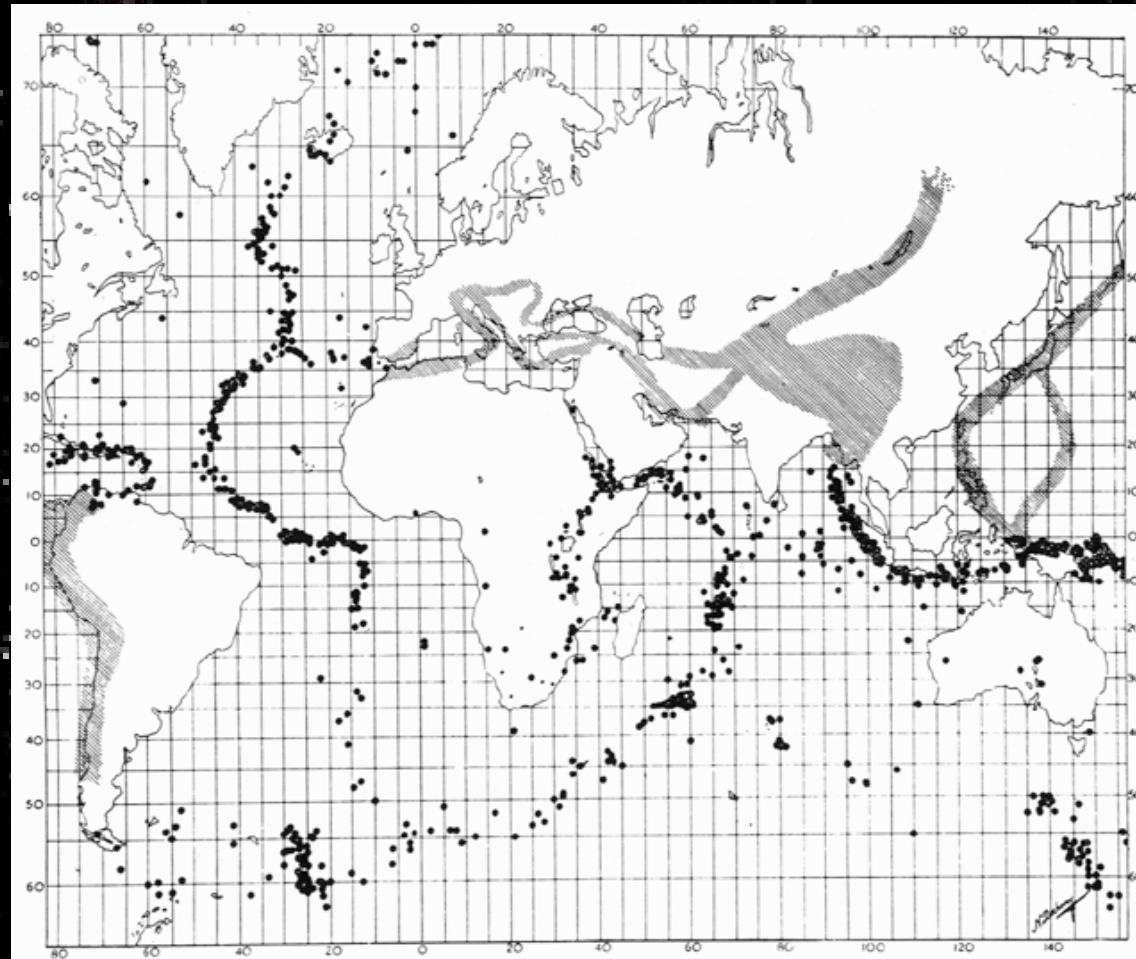


Oceanic-continental convergence



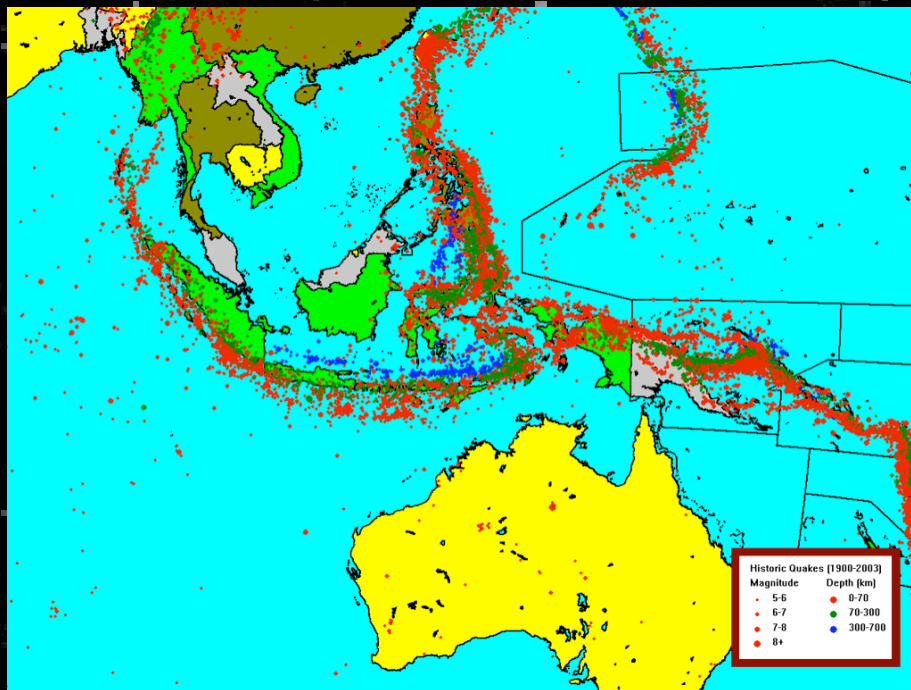
Continental-continental convergence

Great earthquakes occur along the contact between the plates.

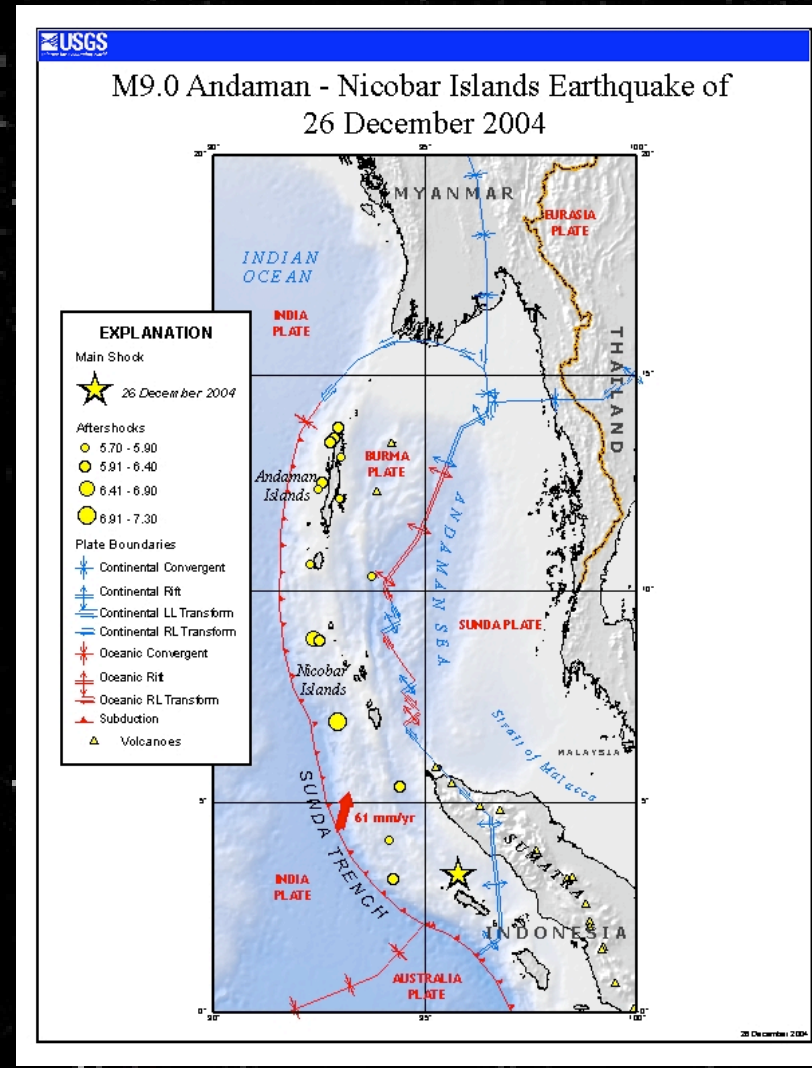


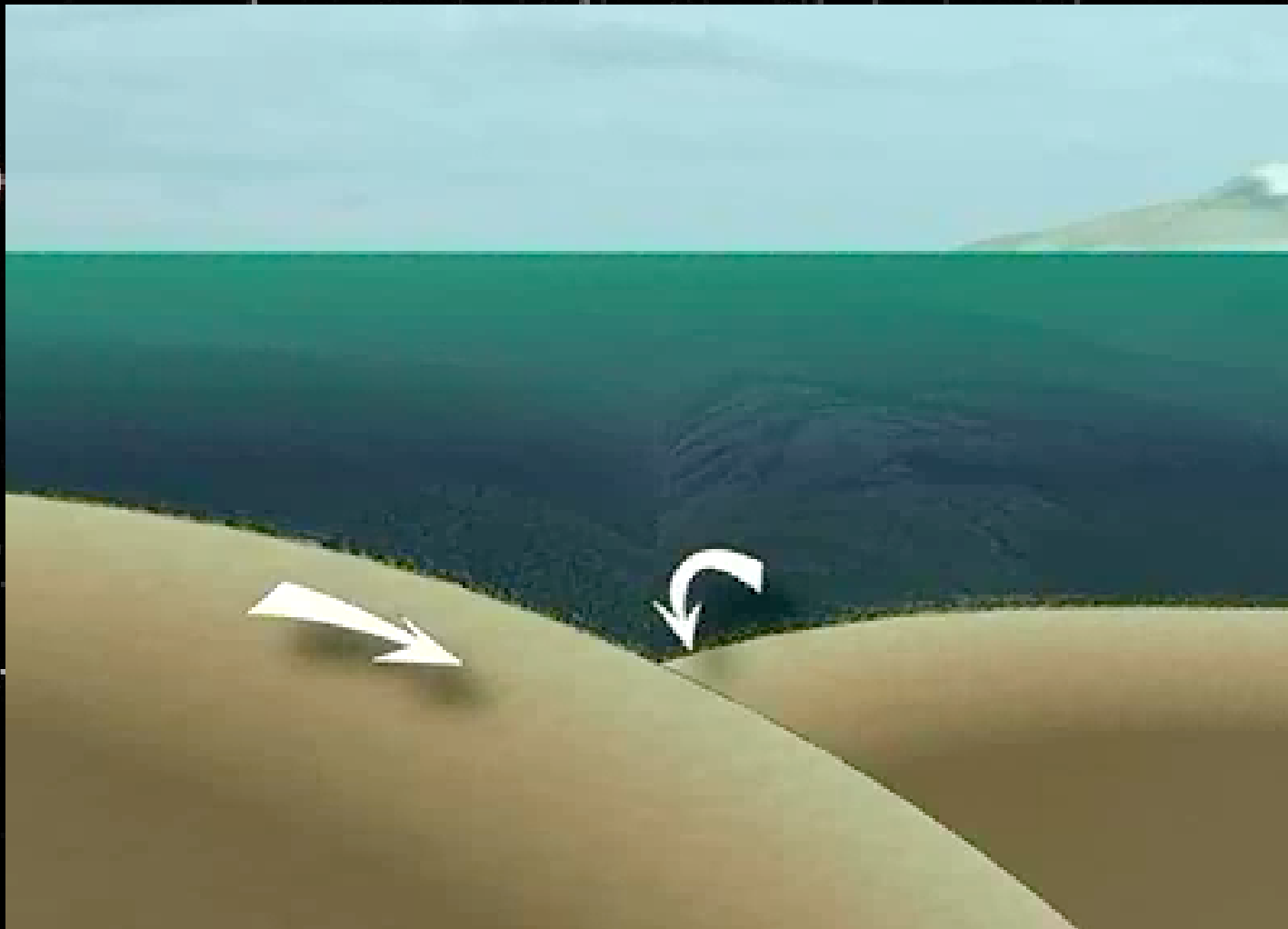
A 1954 map showing the concentration of earthquakes indicated by dots and cross-hatched areas.

The devastating Indian Ocean tsunami on 26 December last year occurred on one of these plate boundaries,



Earthquakes in the region from 1900–2003.

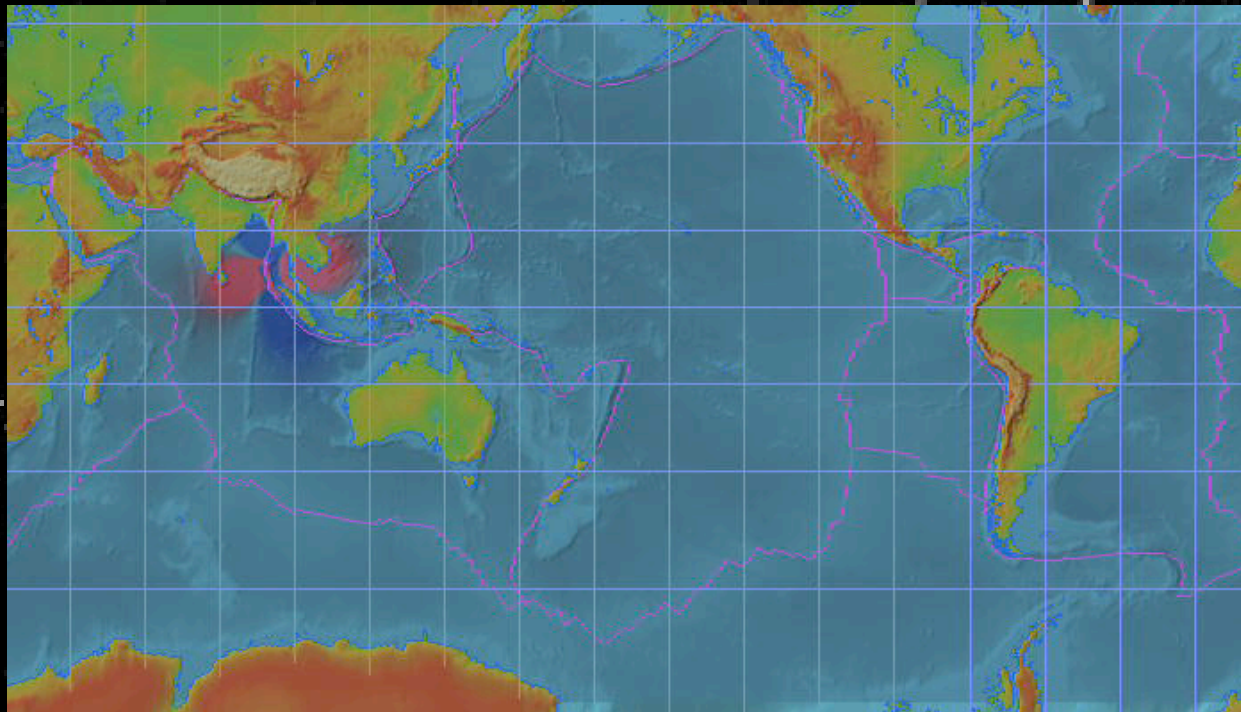




*Simulation of the creation of a tsunami by a subduction zone earthquake.*



In reality, the varying depth of the water means the wave does not propagate in a circle.



This evidence leads to the following picture of the plates

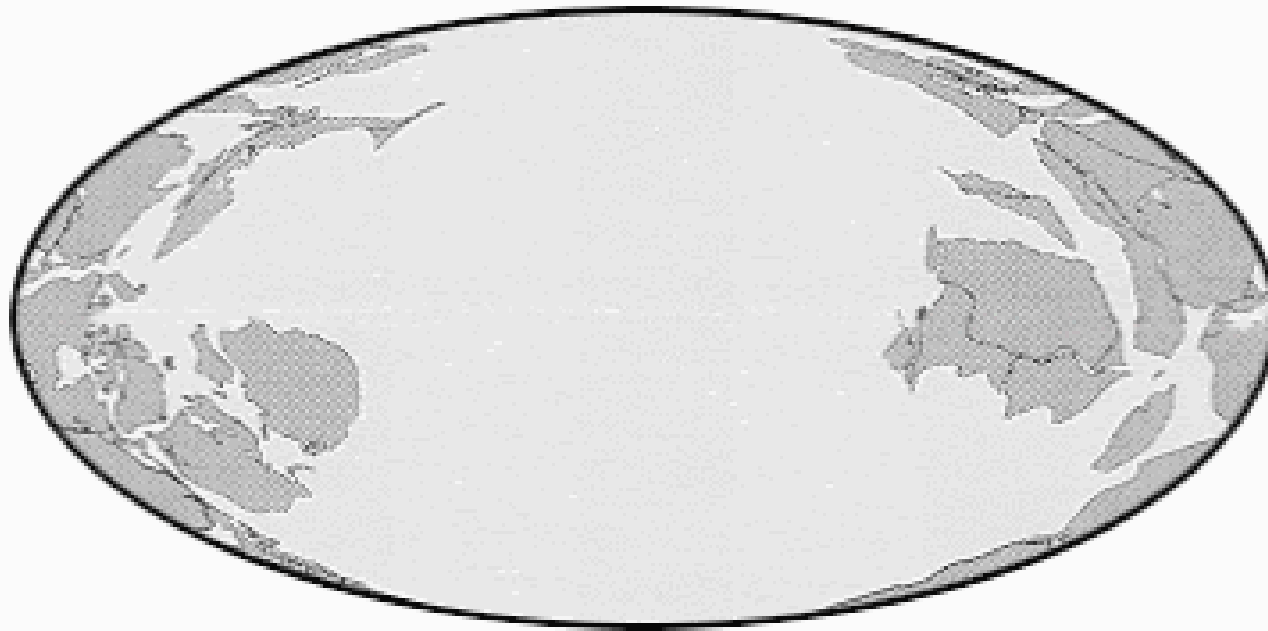




Fossil evidence indicates that the continents were once joined into a giant supercontinent called Pangaea, about 250 million years ago. Pangaea then split into two large fragments, with all the southern continents joined as Gondwana. The plates moved and split further, resulting in the present geography.



Here is an animation of the drift of the continents over the past 750 million years.



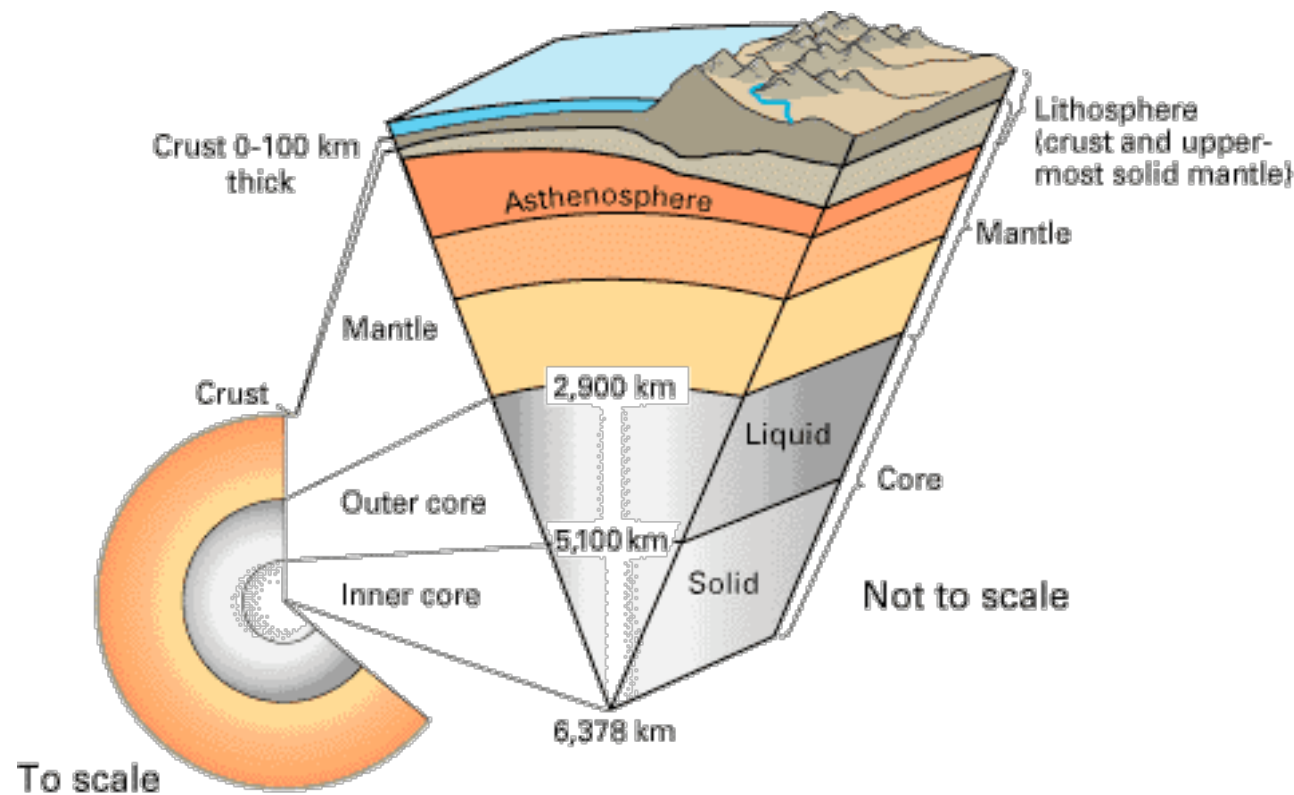
*Cenozoic*

*Mesozoic*

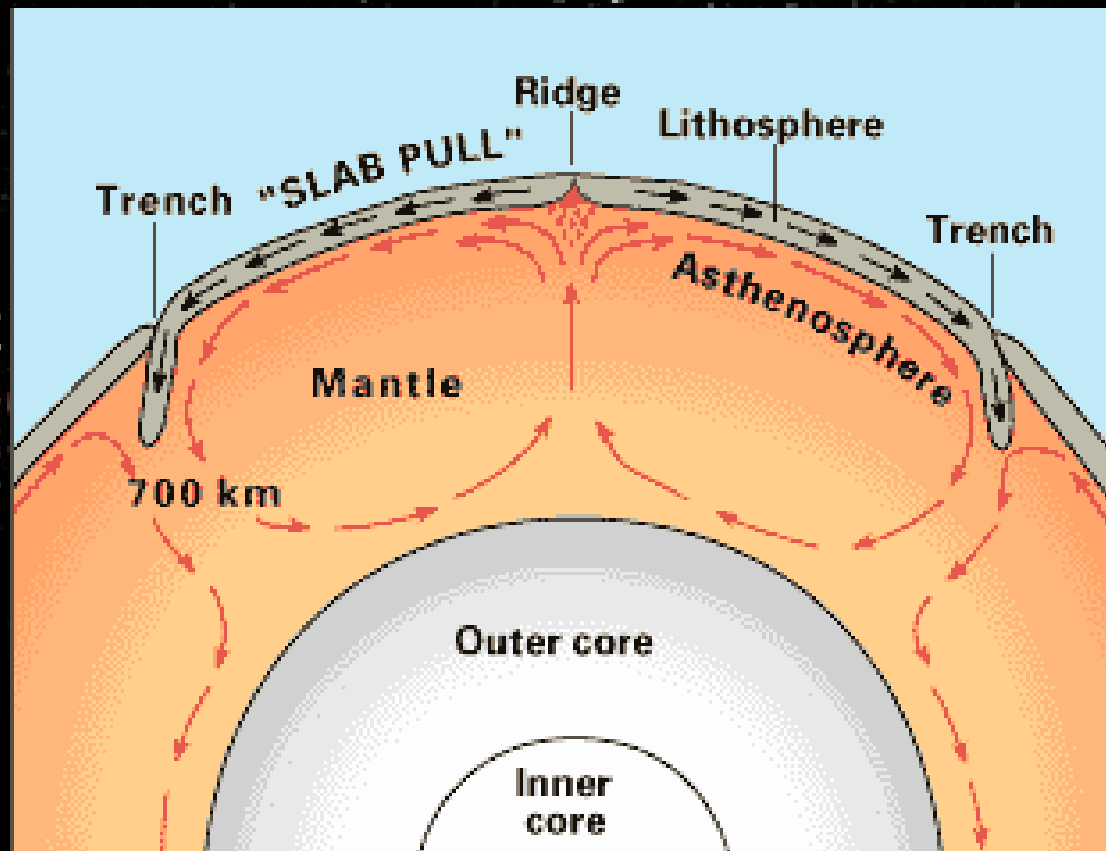
*Paleozoic*

*Precambrian*

The Earth's interior is divided into several zones. There is a dense iron core, a thin crust composed of lighter elements, and a mantle between.



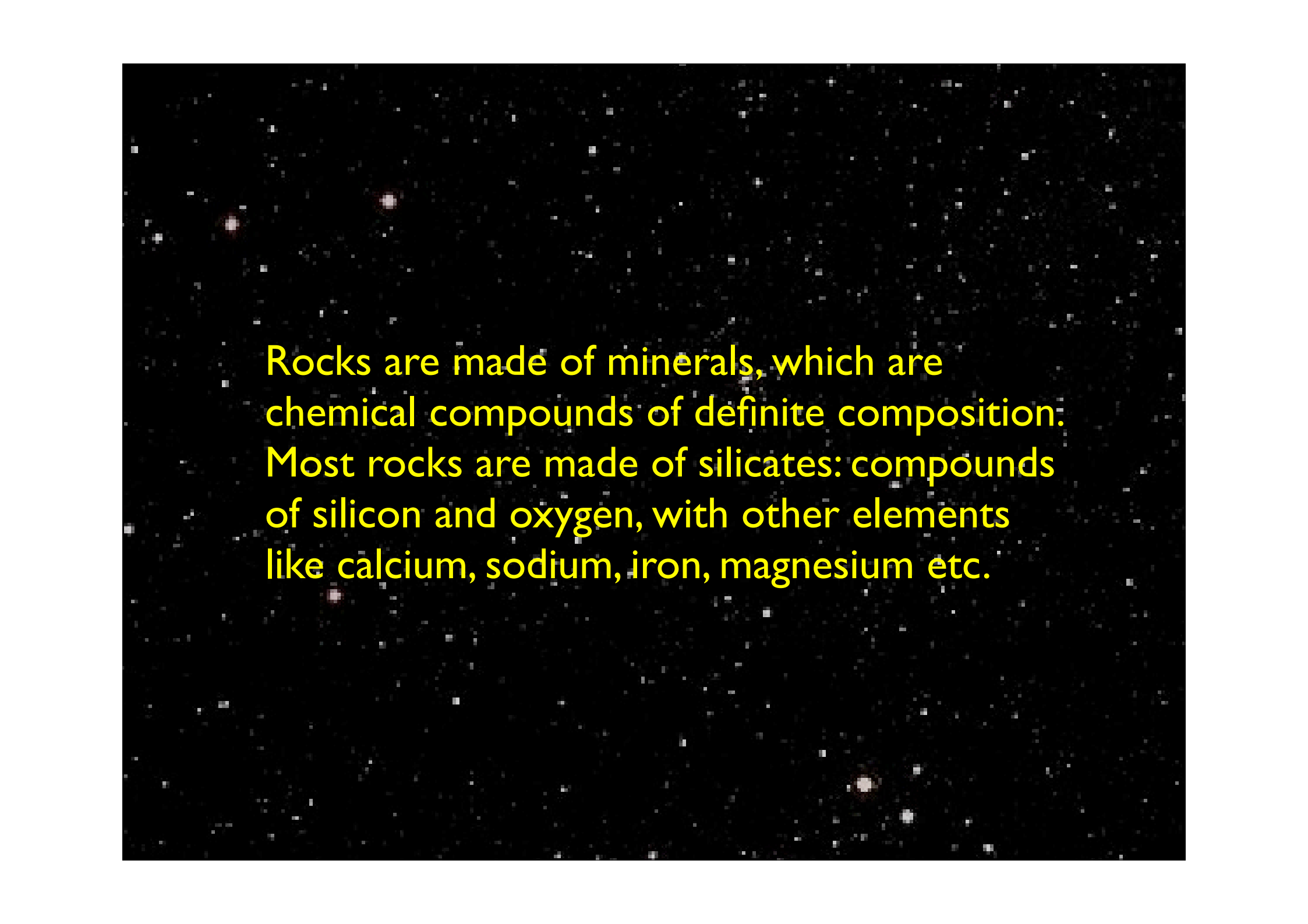
The most likely driver for the motion of the plates is convection in the softened mantle, which carries the solid plates along. Below about 700 km the descending slabs melt and lose their form.



One consequence of this is that the surface of the Earth is very *young*: old sea-floor is constantly being destroyed in subduction zones, and old continental rock is deformed beyond recognition in mountain ranges. Only in the very interior of the oldest continental chunks will truly old rocks be found. Rocks from central Canada, for instance, have been dated to 2.5 billion years old. The oldest rocks found were in southwest Greenland, where a 3.8 billion year old rock has been found. As we will see, we have to look elsewhere than Earth to find rocks older than this.

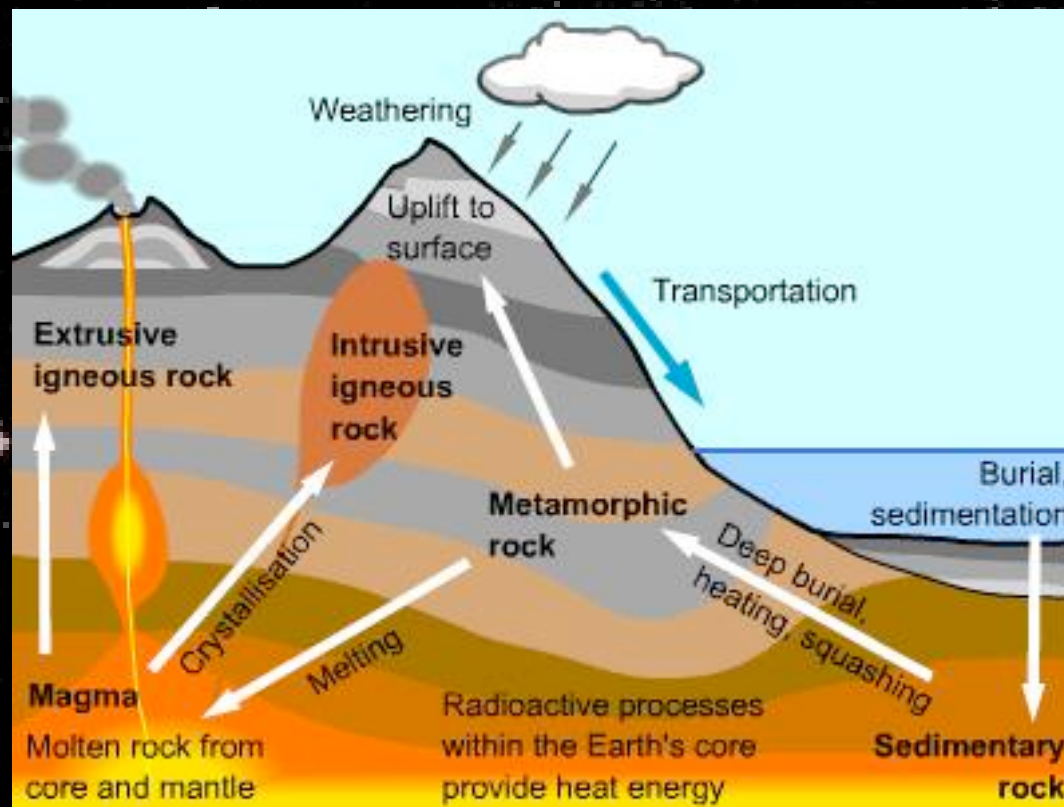
We find three main types of rocks on Earth:

- *sedimentary*, formed from sediments precipitating out of water. Examples are shales, sandstone.
- *igneous*, formed from cooling molten rock. Examples are basalt, granite.
- *metamorphic*, formed when existing rock is transformed by increased temperature and/or pressure. Examples are slate, marble.



Rocks are made of minerals, which are chemical compounds of definite composition. Most rocks are made of silicates: compounds of silicon and oxygen, with other elements like calcium, sodium, iron, magnesium etc.

Rocks on Earth are formed, eroded, recycled in a variety of ways: the **rock cycle**. The Earth's surface is constantly changing in this way.





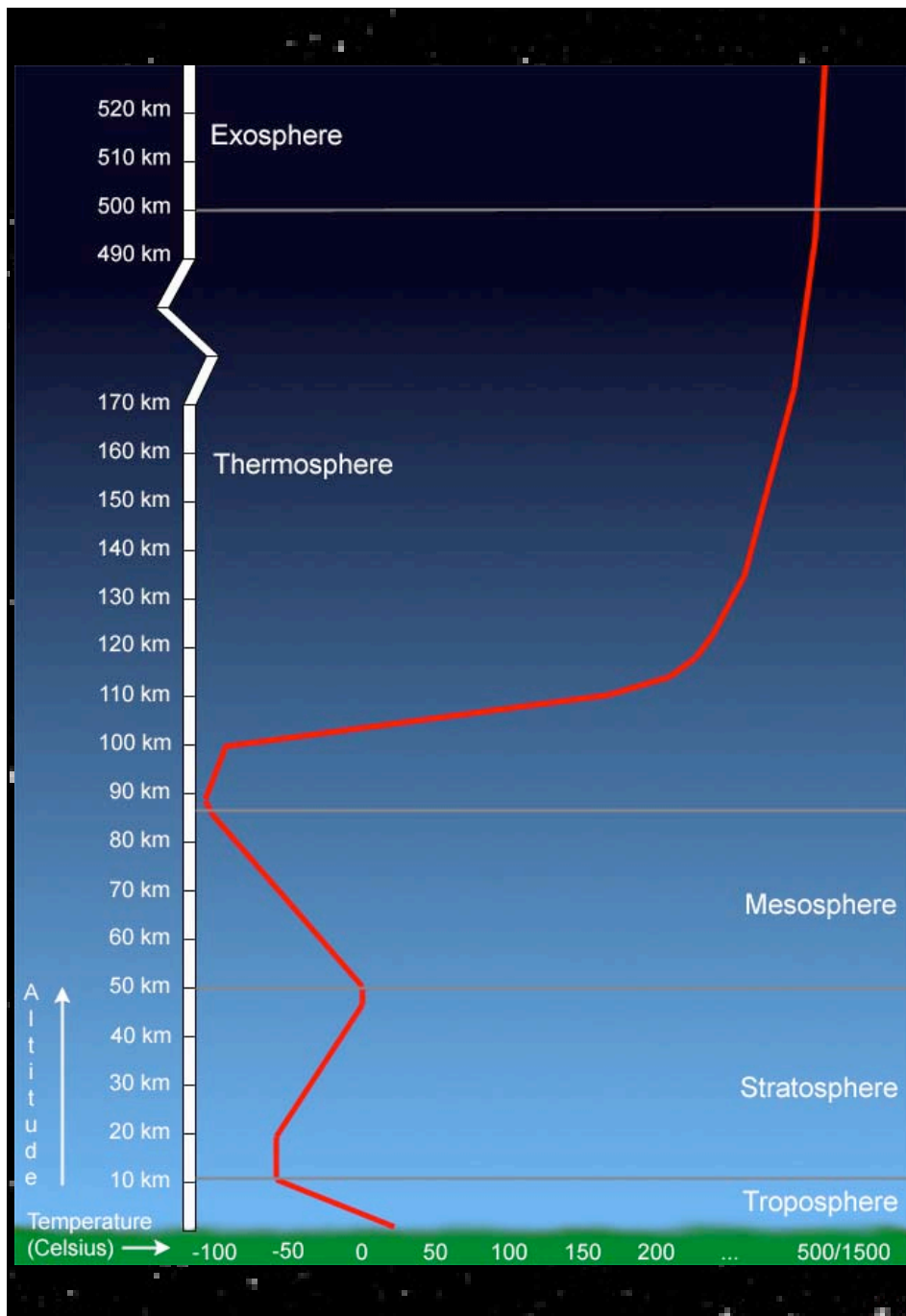
There are 160 terrestrial impact craters known.



Barringer Meteor Crater in  
Arizona: 1.2 km in diameter,  
49,000 years old

Wolfe Creek Crater in the  
Kimberleys, Western Australia.  
880 m diameter, 300,000 years old.

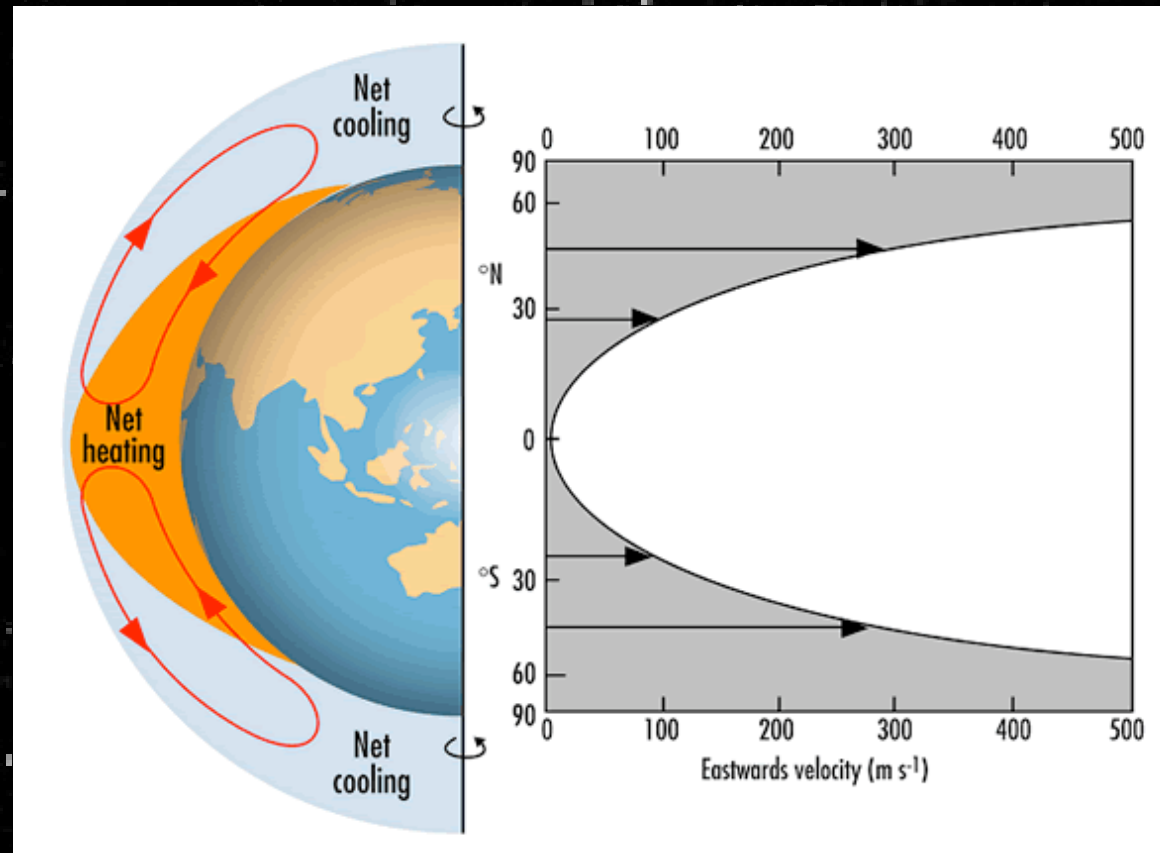




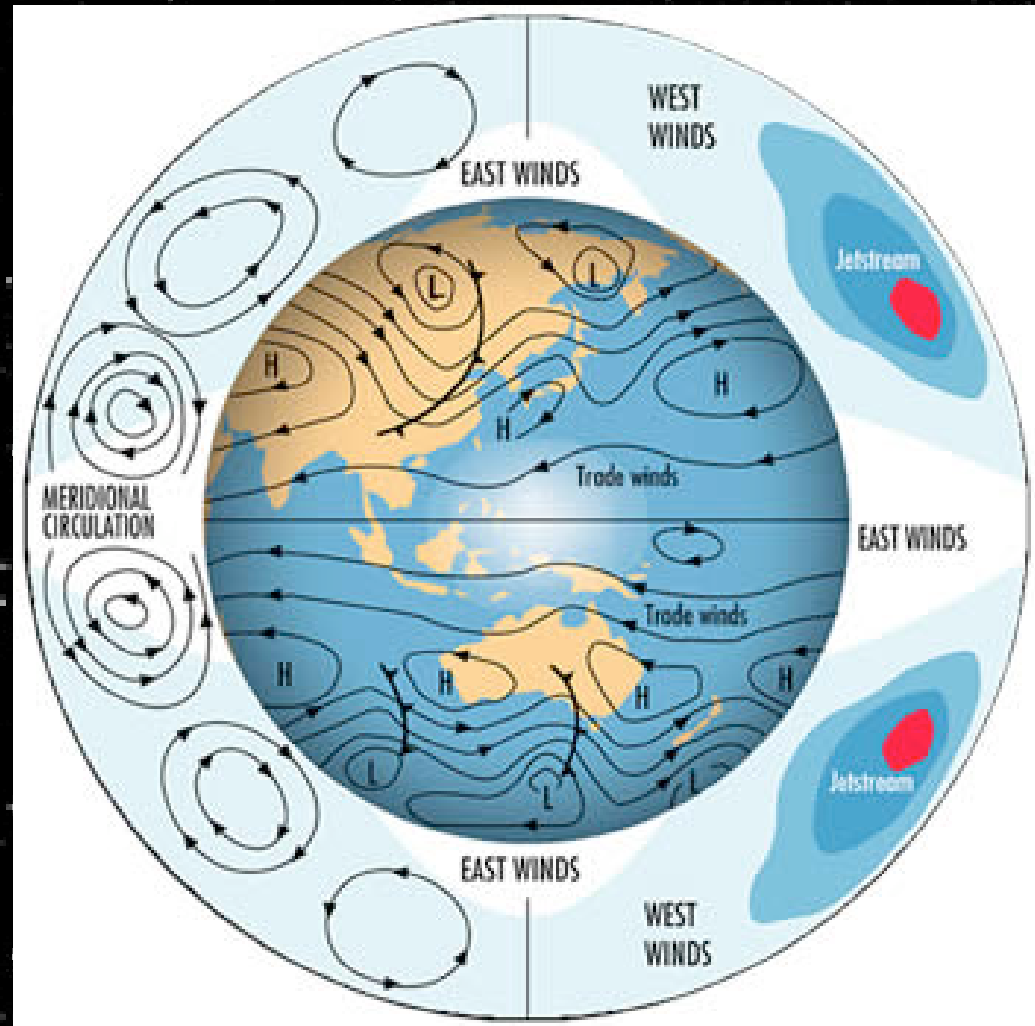
The Earth's atmosphere is divided into 5 layers:

- *troposphere* – contains half the atmosphere. Weather happens here.
- *stratosphere* – where aircraft fly. Contains the ozone layer.
- *mesosphere* – where meteors burn up
- *thermosphere* – where aurorae form
- *exosphere* - where the atmosphere merges into space

The atmosphere is not static, but has large-scale circulation patterns. Solar heating causes air to rise at the equator and sink at the pole; but the rotation of the Earth means that as the air moves poleward, it is moving faster than the surface.



This “Coriolis deflection” short-circuits the circulation cell, and three circulation cells exist in each hemisphere, each about  $30^\circ$  wide.







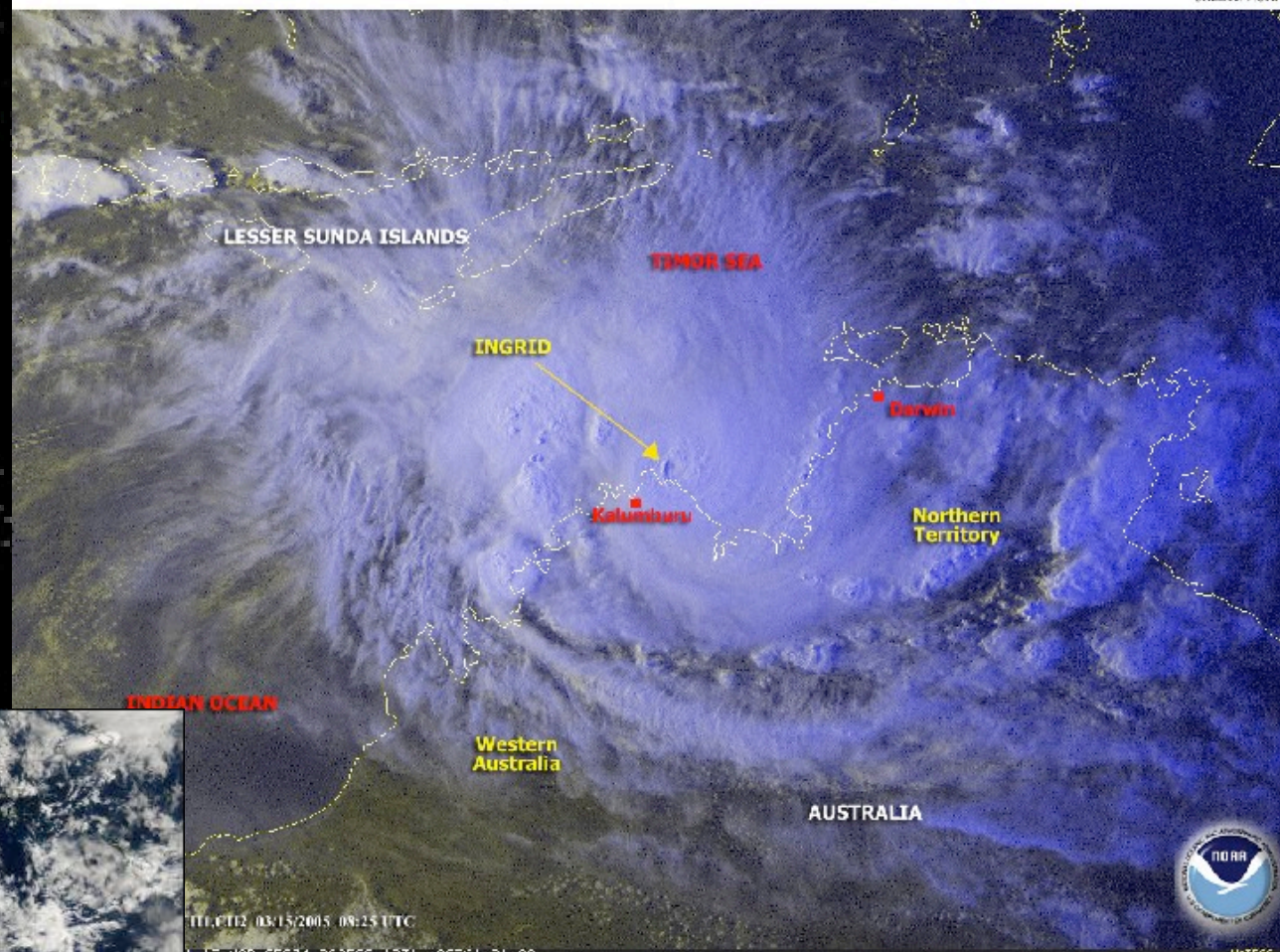
The atmosphere is also  
the site of our weather.





This GOES-9 satellite image taken at 08:25 UTC March 15, 2005 shows the very powerful Cyclone Ingrid just about to make landfall along Australia's North Kimberly coast. At the time of this image wind speeds were approximately 160 knots (185 MPH) with gusts to over 170 knots (195 MPH) thus making Ingrid a Category 5 storm.

CRED: NOAA



TIME: 03/15/2005 08:25 UTC  
 1 IS 4NR CEG\*4 DS:ECC 1031- 0001 01 00

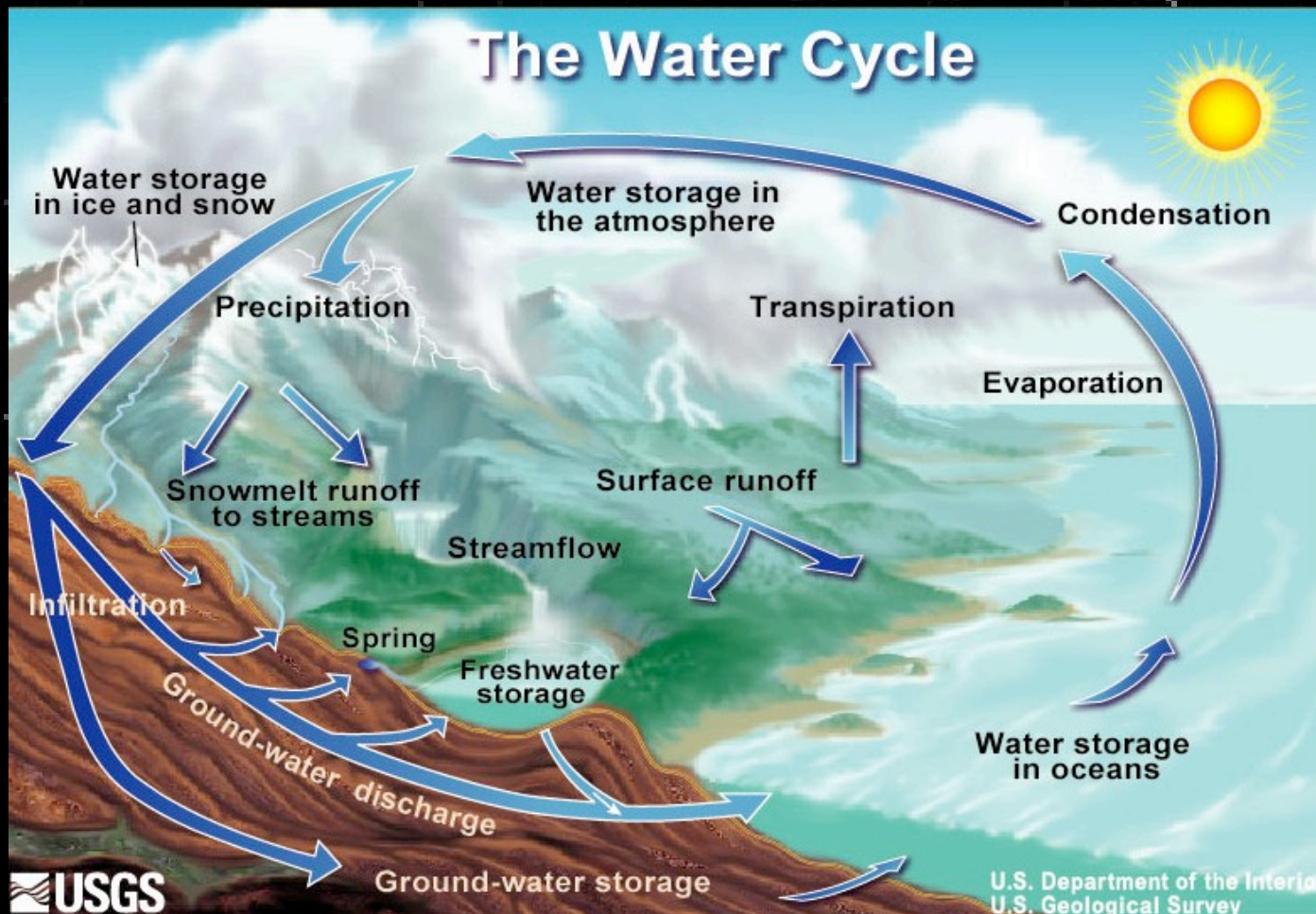
INTEGR



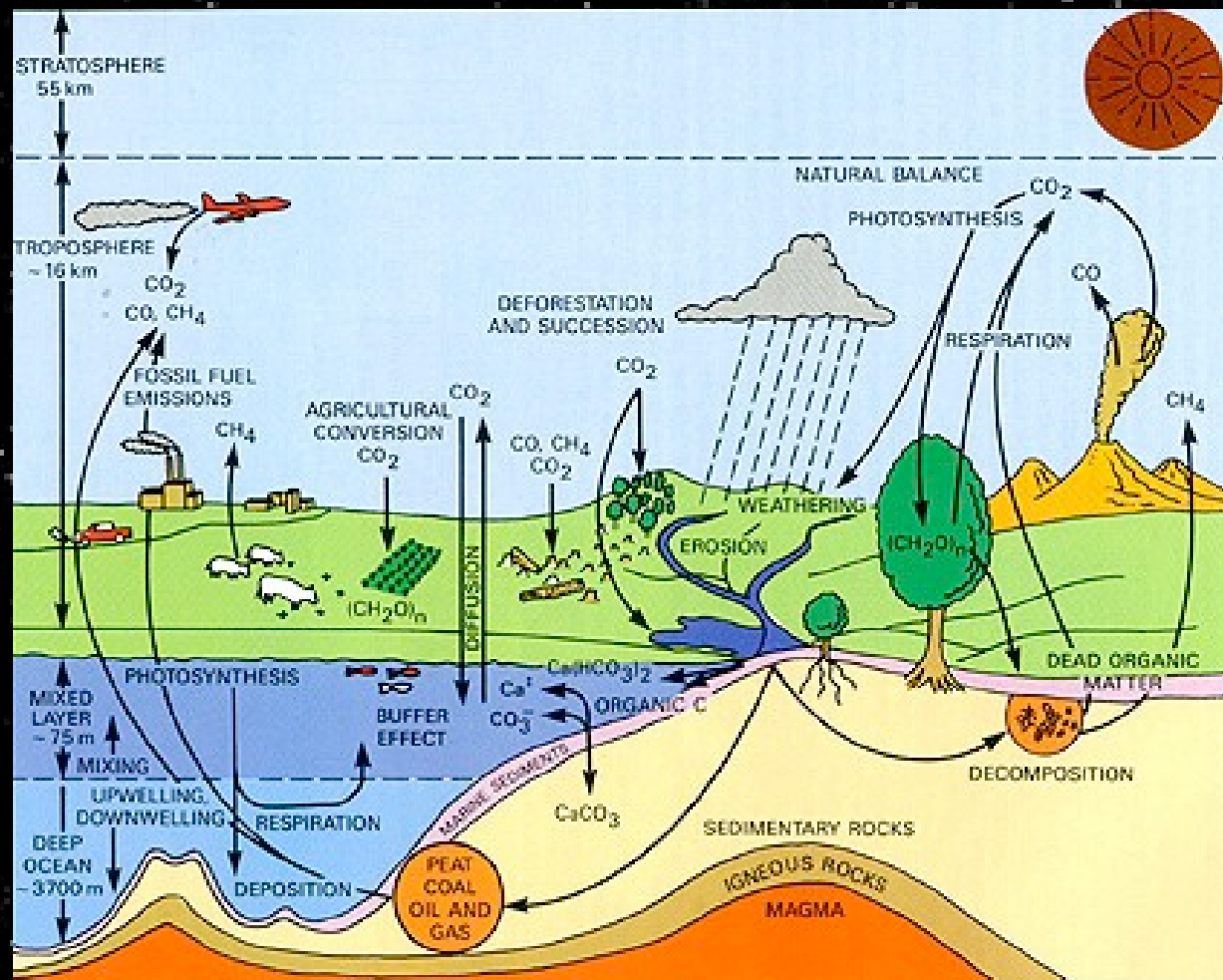
Tropical Cyclone Ingrid, March 2005



The atmosphere and the oceans interact together in complex chemical cycles, most notably the **water cycle**.



The *carbon cycle* is also vitally important, not only for us, but for maintaining the Earth's atmosphere and climate.



It's possible our visiting alien may notice signs of intelligent life...



Interestingly, the Galileo spacecraft, on its way past Earth to Jupiter, trained all its instruments on Earth to see what it would detect.



It detected several signs that Earth may contain life:

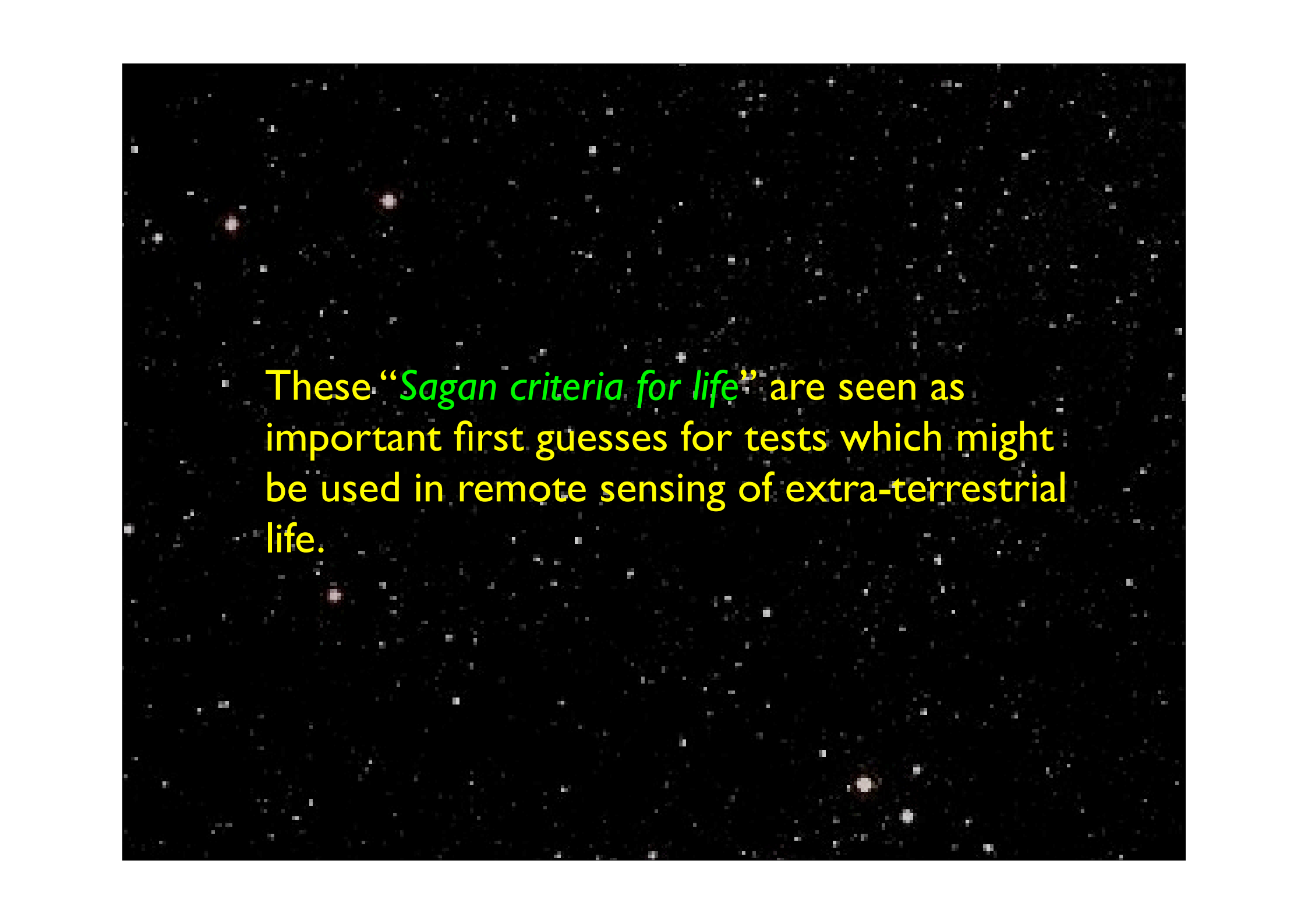
- I. strong absorption of red light, particularly over continents
- II. an atmosphere rich in molecular oxygen
- III. spectral lines of methane, which is unstable in an oxygen-rich atmosphere
- IV. modulated narrowband radio transmissions, unlike natural sources like lightning



“From the Galileo flyby, an observer unfamiliar with the Earth would be able to draw the following conclusions: The planet is covered with large amounts of water present as vapour, as snow and ice, and as oceans. If any biota exists, it is plausibly water-based. There is so much  $O_2$  in the atmosphere as to cast doubt on the proposition that UV photodissociation of water vapour and the escape of hydrogen provide an adequate source. An alternative explanation is biologically mediated photo-dissociation of water by visible light as the first step in photosynthesis. An unusual red-absorbing pigment that may serve this purpose corresponding to no plausible mineral is found widely on land.”

– Carl Sagan, “Search for Life on Earth”





These “*Sagan criteria for life*” are seen as important first guesses for tests which might be used in remote sensing of extra-terrestrial life.

# Next week...

we'll look at the Moon, our nearest neighbour,  
and compare it to the Earth;

then we'll look at spaceflight, and how to get  
rockets and probes to all these exciting places

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# Further reading

## For the whole course:

There are many good introductions to the planets around. Here are a few I have found to be particularly useful.

- Up-to-date planet information can be found at the **NASA Planetary Sciences page** [http://nssdc.gsfc.nasa.gov/planetary/planetary\\_home.html](http://nssdc.gsfc.nasa.gov/planetary/planetary_home.html)  
This includes data on the planets, images, and information on the space missions, as well as links to other useful resources.
- If you like your data in book form,  
“**The Cambridge Planetary Handbook**” by Michael E. Bakich (Cambridge UP, 2000) is an excellent up-to-date reference to planetary data.
- “**The Cambridge Photographic Guide to the Planets**” by F.W. Taylor (Cambridge UP, 2001) is a lovely book, which contains very good descriptions of what is known about each planet, together with spectacular pictures.
- There is an absolutely gorgeous book called “**Beyond: Visions of the Interplanetary Probes**” by Michael Benson (Harry N. Abrams, 2003). The author has compiled and digitally processed the best images sent back by the space probes into one of the most beautiful collections you’ll ever see.

- **“The New Solar System”** by Beatty, Petersen and Chaikin (Cambridge UP, 4th edition, 1998) is a really good guide to recent work on the solar system, with chapters written by various world experts. It’s at a nice level: more than just pretty pictures, but doesn’t assume too much prior knowledge.
- A wonderful book, though at quite a high level, which covers everything you could ever want to know about the planets is **“Planetary Sciences”** by Imke de Pater and Jack J. Lissauer (Cambridge UP, 2001). It is horrendously expensive (A\$165), but if you really need to chase up some nitty-gritty of the physics, chemistry or geology of planets, this is the place to look.
- The BBC documentary **“The Planets”**, available on video or DVD. An excellent introduction to the solar system and its formation, including some wonderful interviews with many of the project scientists for Voyager and other missions.
- **“The Nine Planets: A Multimedia Tour of the Solar System”** by Bill Arnett <http://seds.lpl.arizona.edu/nineplanets> has lots of good pictures and links
- **“Views of the Solar System”** by Calvin J. Hamilton, <http://www.solarviews.com/eng/homepage.htm>, is an excellent collection of images and animations of the solar system.
- **“Solar System Live”** at <http://www.fourmilab.ch/solar/solar.html> enables you to show the positions of all the solar system bodies at any time you like. Great fun to play with. You can even plot the positions of comets or asteroids to see where they are too.



## For the Earth:

- **“Earth”** by Frank Press and Raymond Siever (W.H. Freeman) is an excellent introduction to the geology of the Earth, as unified by the theory of plate tectonics.
- **“Mysteries of Terra Firma: The Age and Evolution of the Earth”** by James Lawrence Powell (The Free Press, 2001) is a popular-level history of the three major controversies in geology: the age of the Earth, plate tectonics, and the impact theory. A very nice read.
- The US Geological Survey has a site called **“This Dynamic Earth: the story of plate tectonics”** at <http://pubs.usgs.gov/publications/text/dynamic.html>, which covers the basics of geology very nicely.

## Sources for images used:

- Sun: SOHO image of the Sun, taken in ultraviolet light. <http://sohowww.nascom.nasa.gov>
- Doppler velocity of epsilon Reticulum, obtained with the Anglo-Australian Telescope. [http://www.aao.gov.au/press/aatplanets\\_dec00.html](http://www.aao.gov.au/press/aatplanets_dec00.html)
- Voyager Solar System Family Portrait: from NSSDC Photo Gallery, [http://nssdc.gsfc.nasa.gov/photo\\_gallery/](http://nssdc.gsfc.nasa.gov/photo_gallery/)
- Solar system montage: The Sun and nine planets approximately to scale. <http://www.solarviews.com/eng/solarsys.htm>
- Planetary data: from NSSDC Planetary Fact Sheets, <http://nssdc.gsfc.nasa.gov/planetary/planetfact.html>
- Sizes of orbits: from <http://www.solarviews.com/eng/solarsys.htm>
- Jupiter and Saturn families of moons: from NSSDC Photo Gallery, [http://nssdc.gsfc.nasa.gov/photo\\_gallery/](http://nssdc.gsfc.nasa.gov/photo_gallery/)
- Moons: from Paul Schenk, "Satellites of the Outer Planets – An Image Tour" <http://www.lpi.usra.edu/research/outerp/moons.html>
- Moons by size: <http://www.solarviews.com/eng/solarsys.htm>
- Co-planar and circular orbits: generated using "Solar System Live" <http://www.fourmilab.ch/solar/solar.html>. These particular positions are for 1 March 2005, viewed from heliocentric latitude  $0^\circ$ , longitude  $180^\circ$  and latitude  $90^\circ$ , longitude  $0^\circ$ .
- Earth: view from Apollo 17, Astronaut Photography of the Earth, <http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=AS17&roll=148&frame=22727>; Galileo image of Earth, <http://www2.jpl.nasa.gov/galileo/images/australia.html>; image of jet stream from Views of the Solar System, <http://www.solarviews.com/cap/earth/jet.htm>
- Atmosphere viewed from space: from "The Greenhouse Effect and Climate Change", Australian Bureau of Meteorology, <http://www.bom.gov.au/info/climate/change/gallery/>
- Thickness of crust: from USGS <http://quake.wr.usgs.gov/research/structure/CrustalStructure/>
- Topography of the sea floor: from Windows to the Universe, at <http://www.windows.ucar.edu/>
- Tsunami maps: from Asian Tsunami Imagery, <http://www.globalsecurity.org/eye/andaman-maps.htm>
- Tsunami animations: from "Teaching Geoscience with Visualizations: Tsunami" <http://serc.carleton.edu/NAGTWorkshops/visualization/collections/tsunami.html>



- Plate tectonics diagrams: from “This Dynamic Earth: The Story of Plate Tectonics” , online edition <http://pubs.usgs.gov/publications/text/dynamic.html>
- Plate tectonics animation: from UC Berkeley Geology: Plate Tectonics <http://www.ucmp.berkeley.edu/geology/tectonics.html>
- Rock cycle: from <http://www.bbc.co.uk/schools/gcsebitesize/chemistry/geology/rockcyclerev2.shtml>
- Craters: from Windows to the Universe, at <http://www.windows.ucar.edu/>
- Atmosphere temperature profile: from Windows to the Universe, at <http://www.windows.ucar.edu/> Atmospheric circulation: from “The Greenhouse Effect and Climate Change”, Australian Bureau of Meteorology, <http://www.bom.gov.au/info/climate/change/gallery/>
- Cyclone off Brazil: from Astronomy Picture of the Day, 2004 April 6; Cumulonimbus clouds over Siding Spring mountain: photo by author; Lightning over Kitt Peak, from Astronomy Picture of the Day, 200 July 17, <http://antwarp.gsfc.nasa.gov/apod/ap000717.html>
- Tropical Cyclone Ingrid: from NOAA Image of the Day 15 March 2005, <http://www.osei.noaa.gov/OSeliod.html>, and from Scoop: Tropical Cycone Ingrid approaching Darwin, 14 March 2005, <http://scoop.co.nz/stories/SC0503/S00040.htm>
- The water cycle: from USGS Water Science Basics, <http://ga.water.usgs.gov/edu/watercycle.html>
- The carbon cycle: from NASA’s Remote Sensing Tutorial, Section 16: Earth System Cycles, [http://rst.gsfc.nasa.gov/Sect16/Sect16\\_4.html](http://rst.gsfc.nasa.gov/Sect16/Sect16_4.html)
- Earth at night: <http://earthobservatory.nasa.gov/Newsroom/BlueMarble/>
- Galileo image of Earth: from the NSSDC Photo Gallery: Earth [http://nssdc.gsfc.nasa.gov/photo\\_gallery/photogallery-earth.html#galileo](http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-earth.html#galileo)
- Carl Sagan, “A search for life on Earth from the Galileo spacecraft”, Nature 1993, 365:715-21