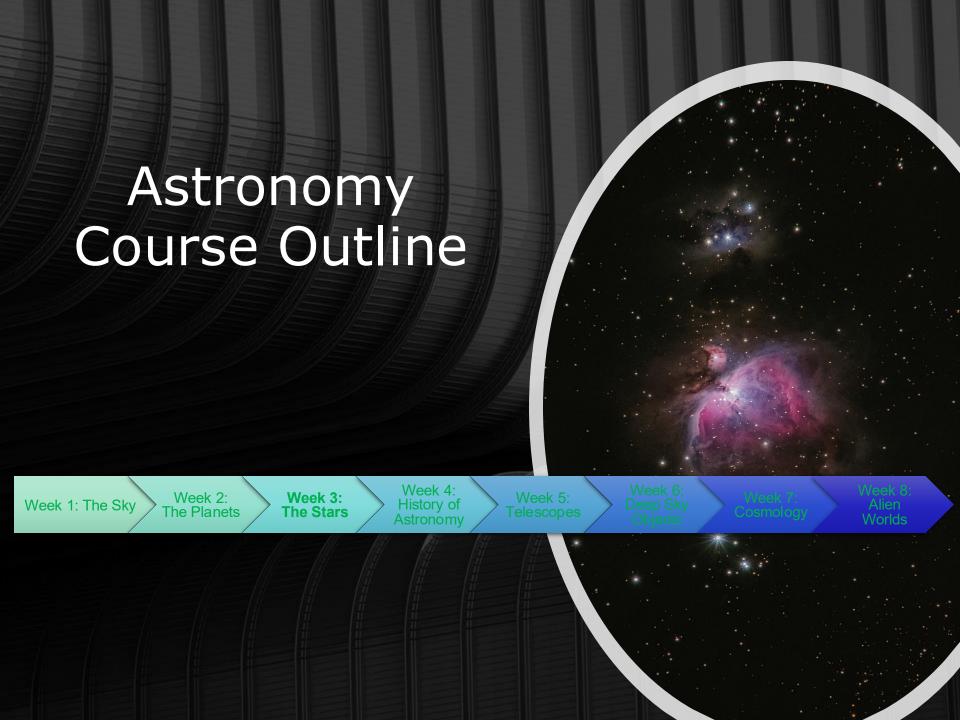


Evening Classes
Week Three
The Sun and Stars

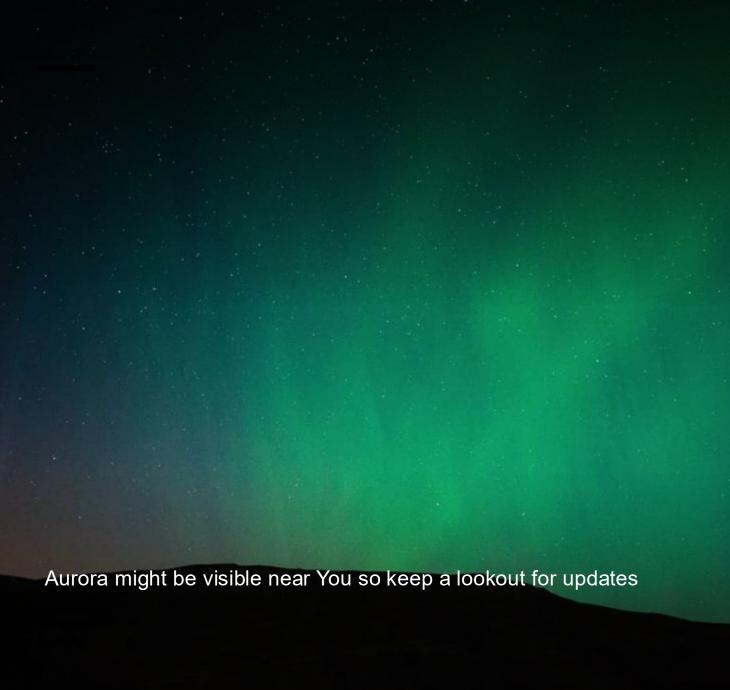
Presented by John Campbell



Updates/Reminders



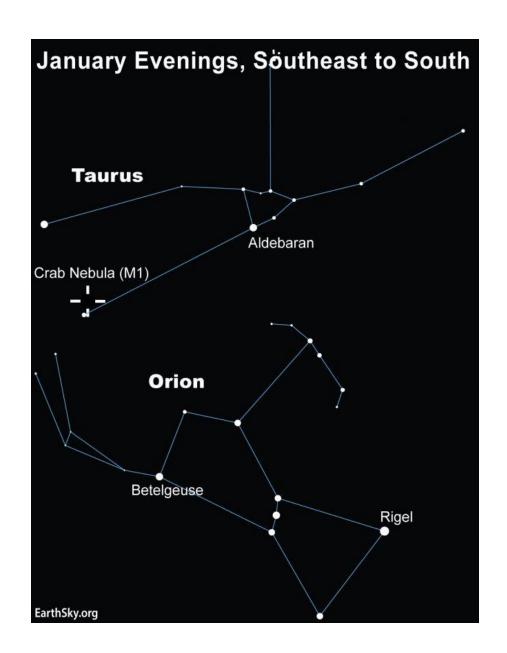
Week 5 Live Telescope Class/Viewing In Astronomy Ireland Blanchardstown Sat 29th





If the Planets were "the actors" across the stage of the sky, the stars could be the backdrop (the trees, mountains, etc) - they seem unchanging over the timescale of a human lifetime of viewing the sky...but they do change

The crab
nebula — was
once a red
giant star in
Taurus now a
nebula — what
happened?

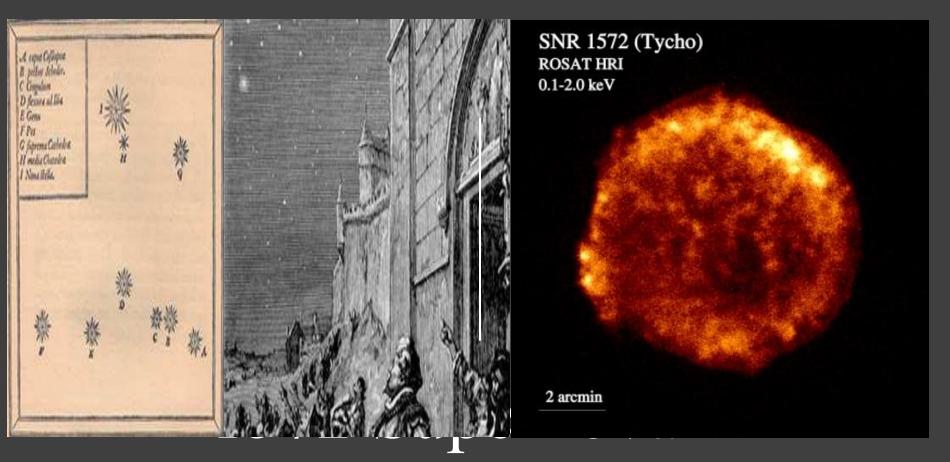




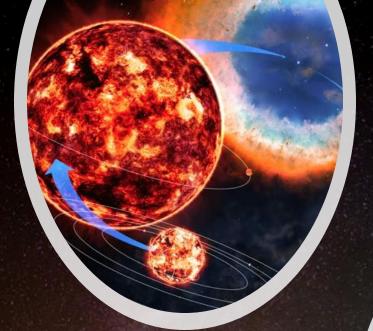




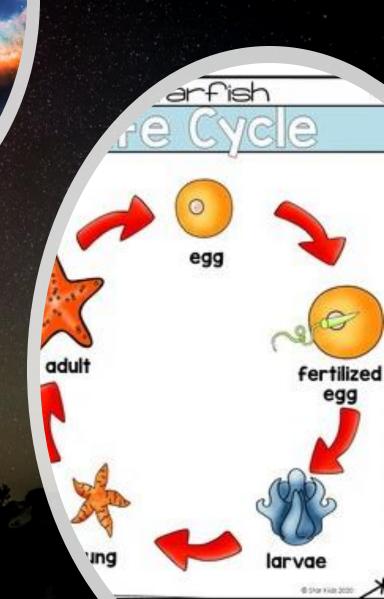
In 1054 AD around 5th June the star became a supernova which shone bright as a full moon for over 2 years



Cassiopeia - "Tycho's Supernova"

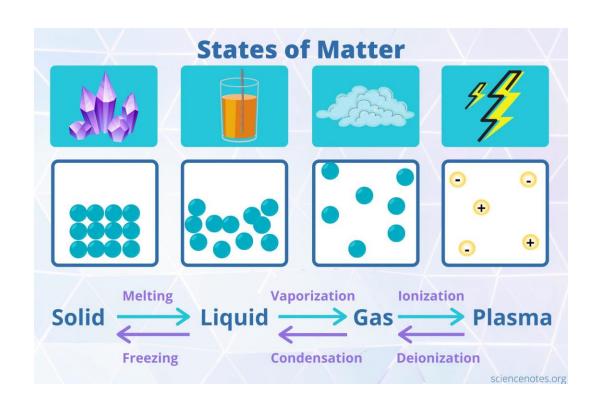


So do stars have a life cycle of sorts? when we look at the stars, seemingly fixed in space, are they at different stages of life?



Just what is a star anyway? What is the structure inside and out?

Are stars made of matter?
If so in what state?



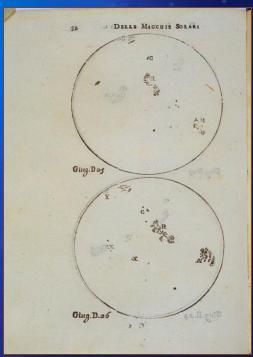
Our Nearest Star The Sun

Enter the telescope

In 1609, the Italian astronomer Galileo purchased in Venice an exemplar of a curious object, which was sold as a toy. It was a very primitive version of what later on would be called a telescope.

He used it to observe dark sunspots on the solar surface. These changed over time, with new ones emerging while old ones disappeared.

This was at odds with the conventional view of the heavens being perfect and unchanging.



Galileo's drawings of the sunspots (from the Istoria e Dimostrazioni, Florence 1613).

mage: IYA2009 S

Solar Activity – Sunspots

Sunspots are one of the oldest known types of solar activity.

In these active regions of the Sun, magnetic field lines trap the solar plasma, and convection stops. With no means of transporting energy, the plasma cools down to about 4500 degrees, becoming black spots in contrast with the rest of the bright photosphere.

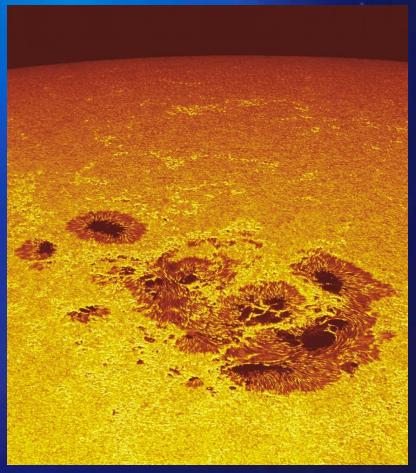


Image: Dutch Open Telescop

A large group of sunspots, observed in 2003 by the Dutch Open Telescope.

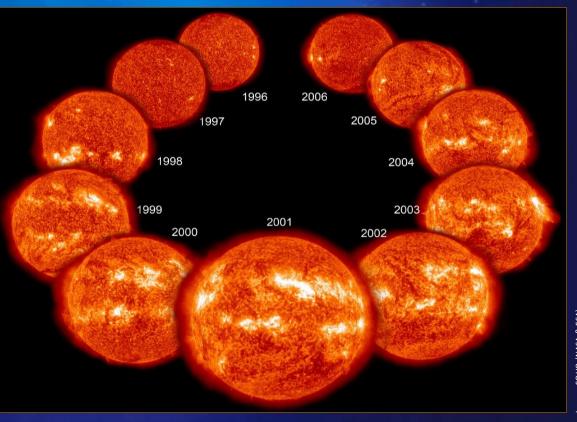
Solar Cycle

The solar cycle is our star's "everyday" life.

Solar activity has a cycle of about 11 years, but it can take up to 13 years.

During this time we see the Sun going from a calm star, to a very turbulent active star, and switching the polarity of the poles.

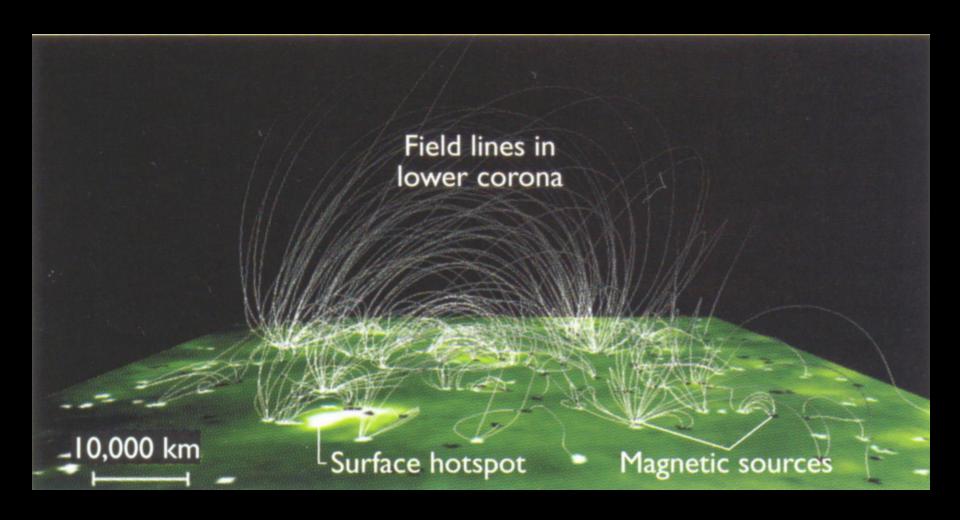
The easiest activity indicator to detect are sunspots.



Almost a full solar cycle, from minimum in 1996, to maximum in 2001, back to (almost) minimum again in 2006.

Image: SO HO (NASA & ESA)

Causes of sunspots – dynamism in the solar magnetic fields



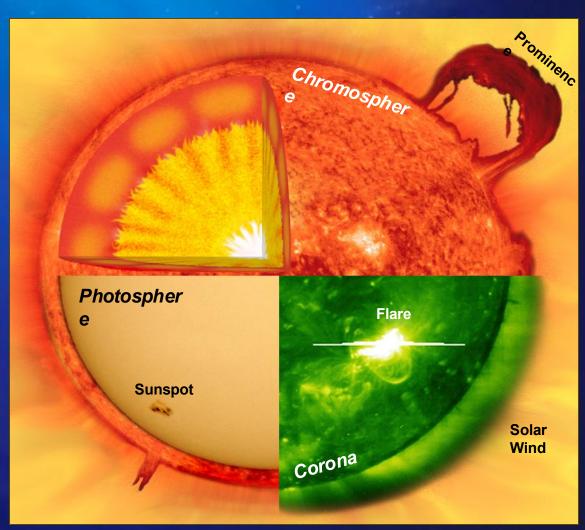
Solar Structure - Exterior

The Sun's visible layer is called the *Photosphere*, and has a temperature of about 5500 degrees.

Above it you find the solar atmosphere.

Its first layer is the **Chromosphere**, visible as a red contour during solar eclipses.

During eclipses you can also see a bright halo around the Sun. This is the outer layer of the atmosphere: the *Corona*.



Solar Activity – Flares

Flares are one of the most violent type of energetic phenomena in the Sun.

In just a few seconds, these solar explosions release the same energy as a billion megatons of TNT, or about 50 billion times more energy than the Hiroshima atom bomb.

This energy release is detected in every wavelength, from radio waves to gamma rays.



In this extreme ultraviolet image of the Sun, the solar flare shines brighter than other areas of the Sun.

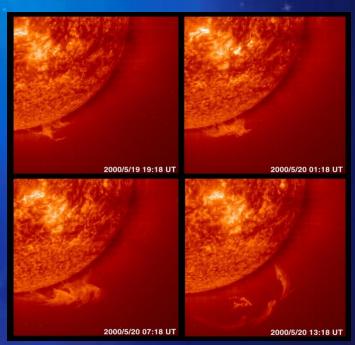
age: SO HO (NASA & E

Solar Activity – Prominences

When magnetic fields lines ascend above the surface of our star, they drag with them the solar plasma, forming arcs – prominences.

The field lines support the plasma, and while they are stable, so are the prominences. But with time, the base of these magnetic arcs breaks and the plasma no longer has support.

Floating high above the solar surface, this plasma can then be released into space, as an eruptive prominence.



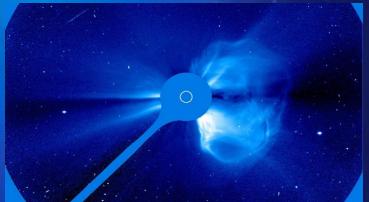
An eruptive prominence in the process of being released into space.

age: SO HO (NASA & ESA)

Solar Activity – Coronal Mass Ejections

Similar to prominences in its genesis, coronal mass ejections (CMEs) take a different route. They are created when magnetic field lines form a bubble. They cut loose from the Sun, dragging with them the solar plasma.

Travelling at speeds between 200 and 600 km/s, CMEs can reach the Earth in just two days, where they interact with the magnetosphere and the atmosphere.



CME seen from one of SOHO's coronographs.



The aurorae are among the most beautiful interactions between solar activity and our atmosphere

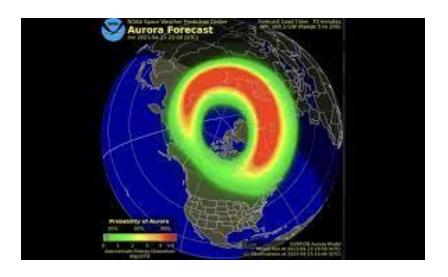
Image: SO HO (NASA &

Image: Senior Airman J

We are Exiting a Period of Solar Maximum Right Now! (2024-2025)

- What this means is more coronal mass ejections, flares and on Earth's s more prominent Aurora!
- Great photography opportunities this winter (into 2026)
- Solar maximum reached a peak before Mid-2025
- The Key is to get a clear horizon towards the North of the sky
- (use Polaris to guide You!)
- Drones can help if you have one!
- Often need to do exposure stacking to get the postcard style images (software such as Sequator can help)
- Keep up to date, weather forecasts can help





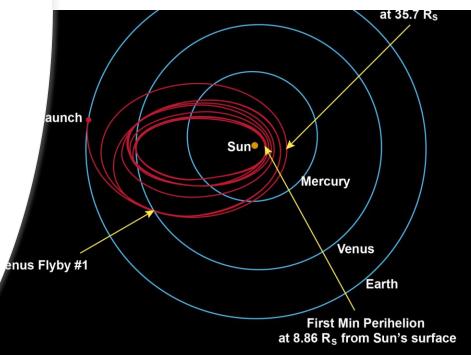
How do we know its solar maximum

- By recording an increase in flares and also sunspot activity
- Increased sunspots can help predict flares before they happen
- A fleet of space probes dedicated to space weather are also orbiting close to the Sun itself to help forecast space weather

Solar spacecraft

- European Space Agency's Solar
 Orbiter and famous The Solar and
 Heliospheric Observatory (SOHO)
- NASA's <u>Parker Solar Probe</u>
- <u>In progress ISRO's Aditya-L1</u>
- China's Advanced Spacebased Solar Observatory (ASO-S)



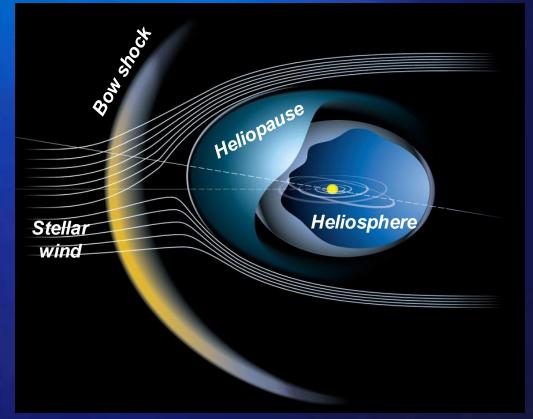


Solar Activity - Solar Wind

The solar wind is a constant jet stream of charged particles from the solar corona, with a temperature of a million degrees, and speeds of around 450 km/s.

It travels beyond Pluto's orbit, where it meets the wind from other stars. This is the frontier of our Solar System – the Heliopause.

Some evidences for solar wind comes from observing the tails of comets. Pushed by the solar wind, they always point away from the Sun.



The heliosphere and the heliopause.

Observing from space

Solar observation used to be restricted to instruments on the ground, but in this modern age, space observatories provide us with a wealth of information.

These missions observe the Sun across many wavelengths and in more detail than ever before.

Space weather and other phenomena are being constantly observed by these vigilant spacecraft, like SOHO, Hinode, and STEREO, among others.



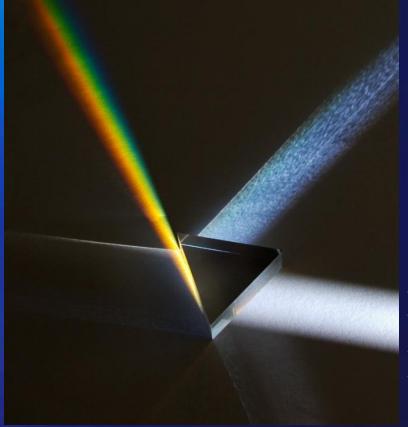
The NASA/ESA Solar & Heliospheric Observatory (SOHO) craft studies the Sun from its position in space.

Dissecting the Sun

In the 1670s the great scientist
Isaac Newton turned his attentions to the Sun.

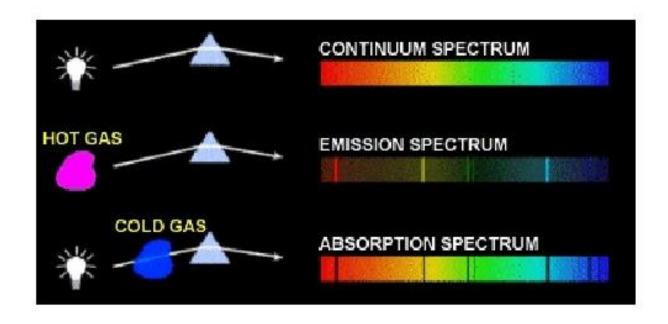
Using a prism, he separated light from the Sun into different colours, which he then recombined using a second prism.

The Sun is a complex object, but it was finally being studied in a scientific manner.



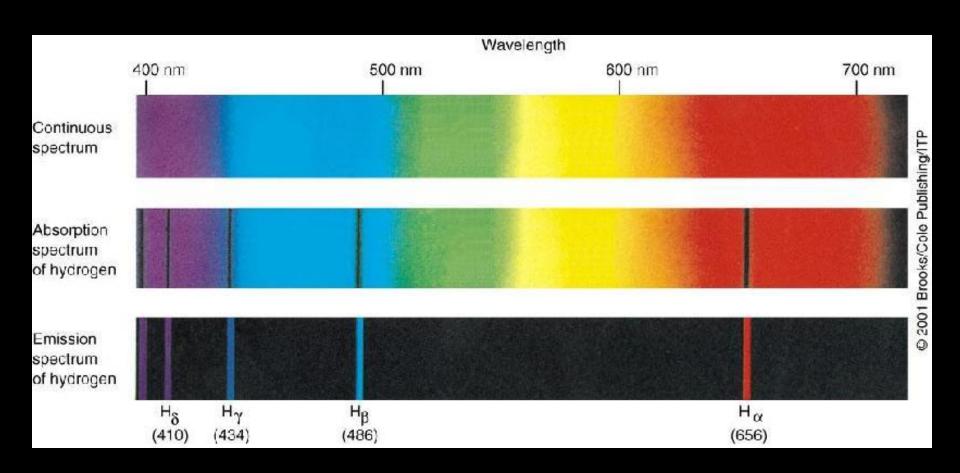
A prism "splits" light.

Three types of Spectra

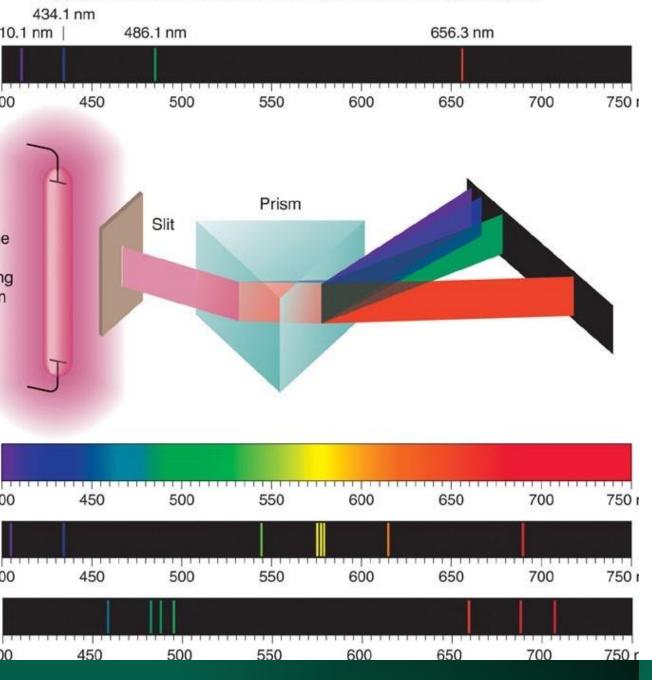


Continuous, Emission, and Absorption

Emission & Absorption Spectra of the Sun -Realising the Sun is made of matter (plasma = ionised gas) that can be Detected remotely using spectroscopy

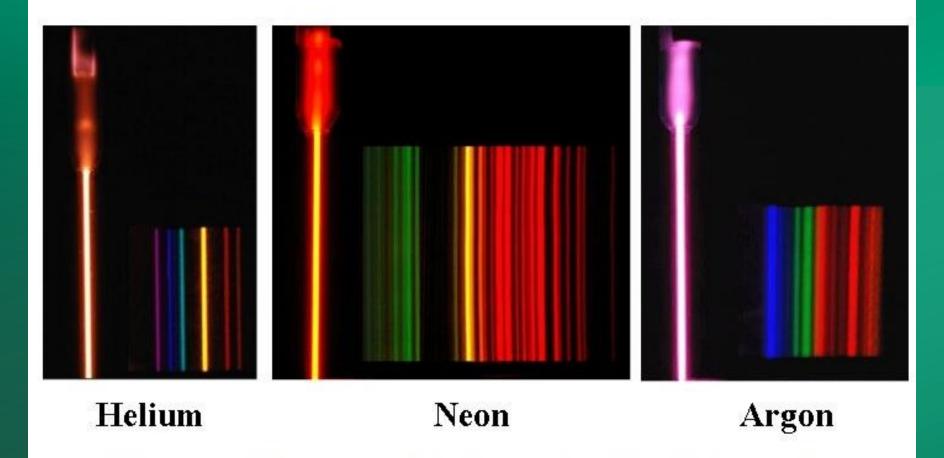


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- On Earth, Scientists can make "fingerprints" of every element or molecule using spectroscopy and identify them in stars, planets, nebula, galaxies across the universe!
- Spectroscopy shows not only that stars in distant galaxies are made of the same matter as on earth, but the same rules of quantum mechanics work everywhere in the universe!

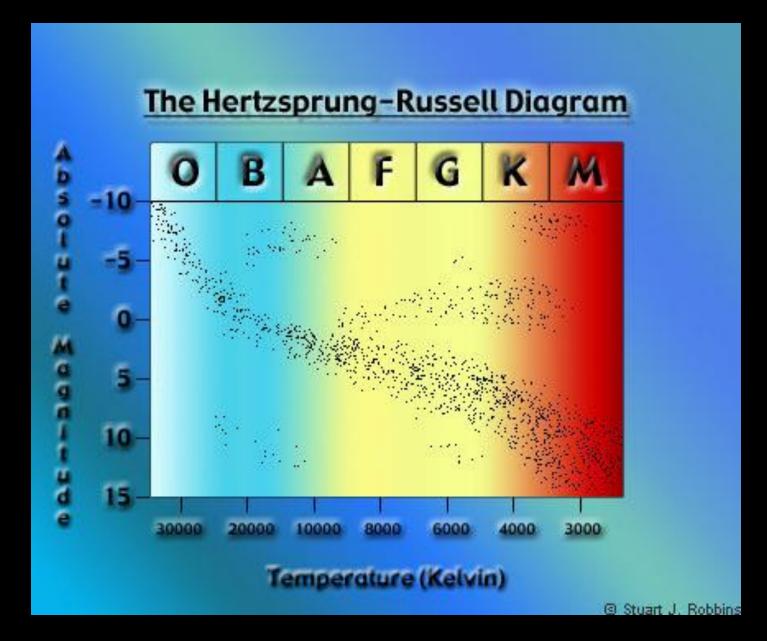
Atomic Spectra of Noble Gases



The Atomic Spectra will be determined for Hydrogen & the Noble Gases by looking at the gas discharge tubes.



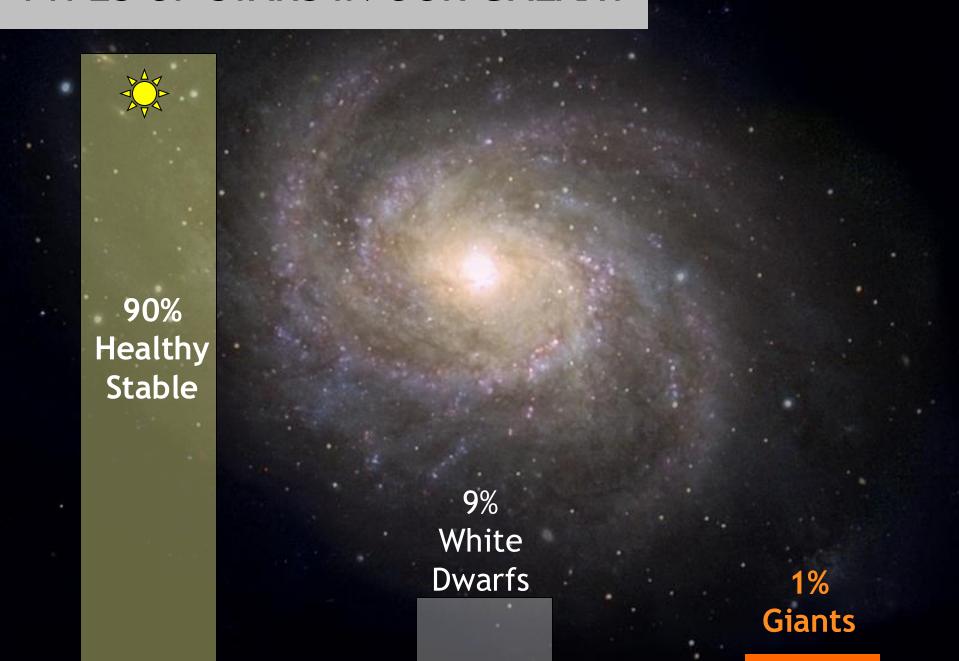
Stellar Classes



Where are the Stars like our Sun?

Are all the stars we see in the night sky like our Sun?

TYPES OF STARS IN OUR GALAXY



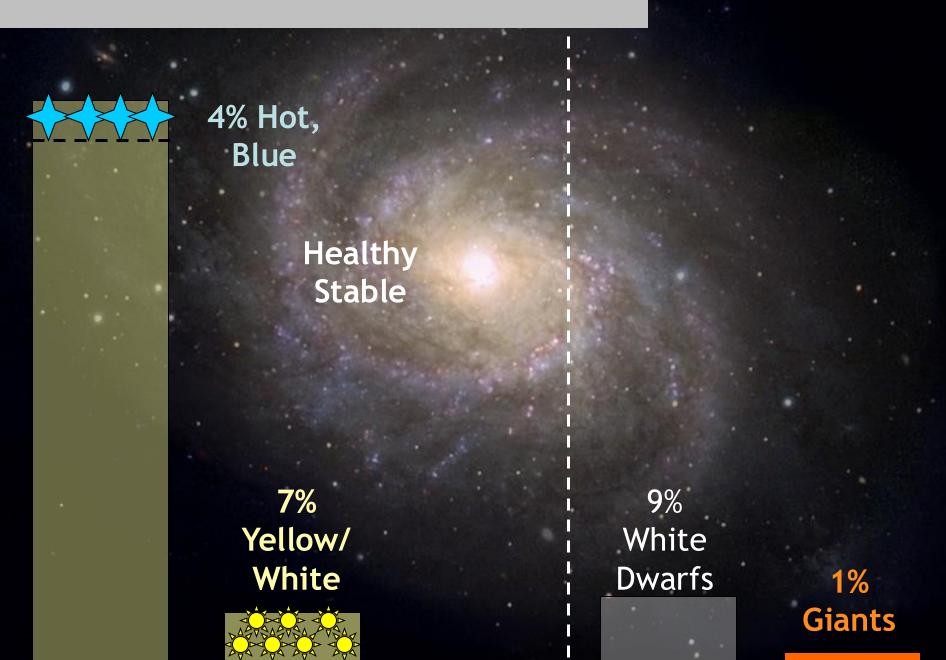
TYPES OF STARS IN OUR GALAXY



9% White Dwarfs

1% Giants

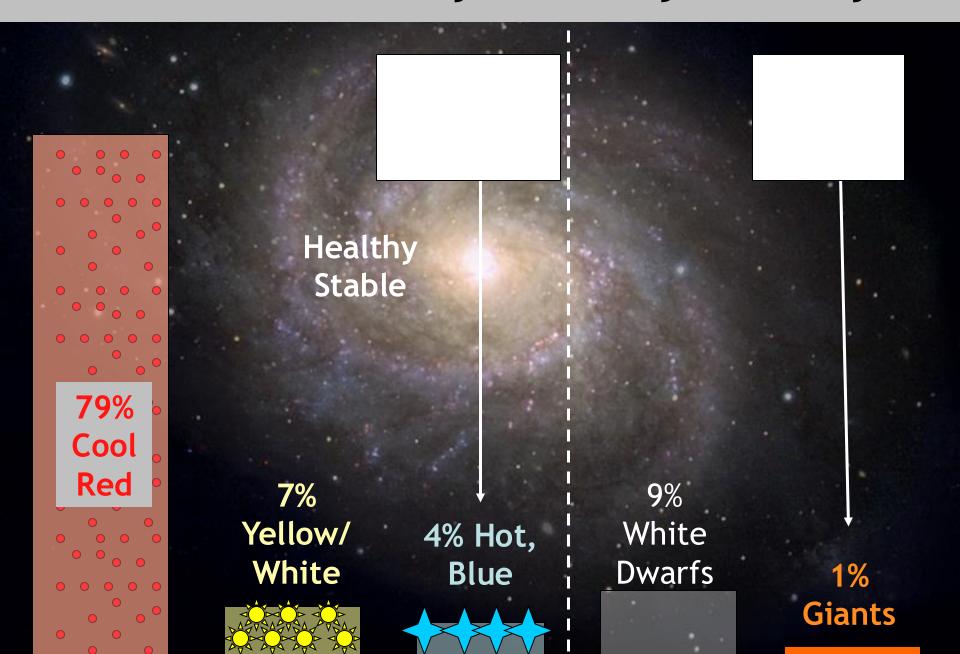
TYPES OF STARS IN OUR GALAXY



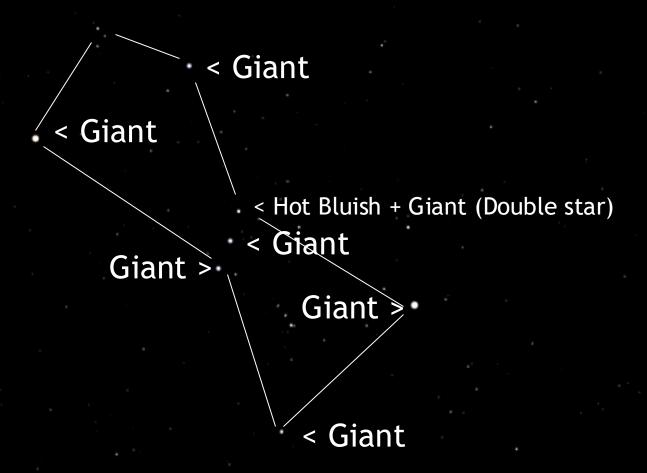
TYPES OF STARS IN OUR GALAXY



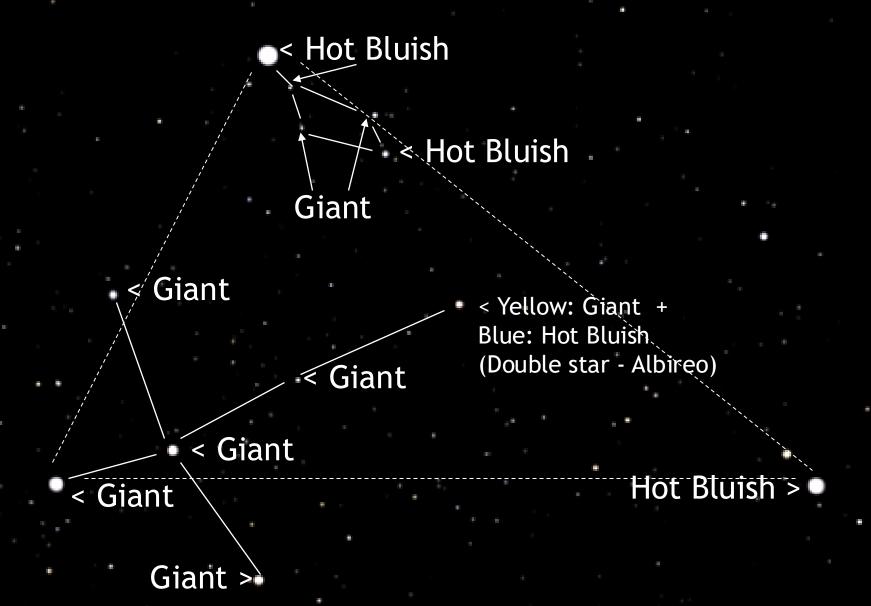
But what do we mostly see with just our eyes?



Orion



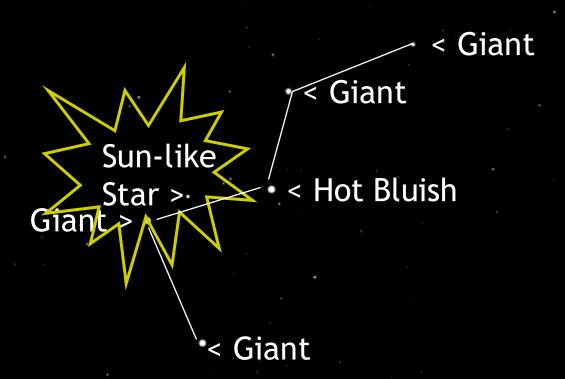
Triangle



"Plough/Big Dipper" & Polaris

Polaris: Giant >, < Hot Bluish < Mizar & Alcor: Both are Hot Bluish < Hot Bluish Hot Bluish > Giant Hot Bluish > Hot Bluish >

Cassiopeia

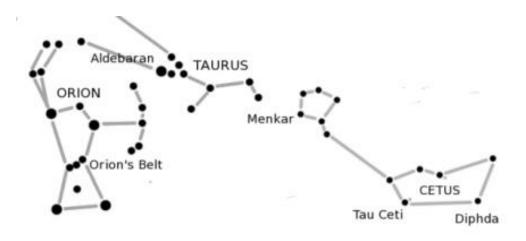




Double star system in cassiopeia (Achird)

Cetus

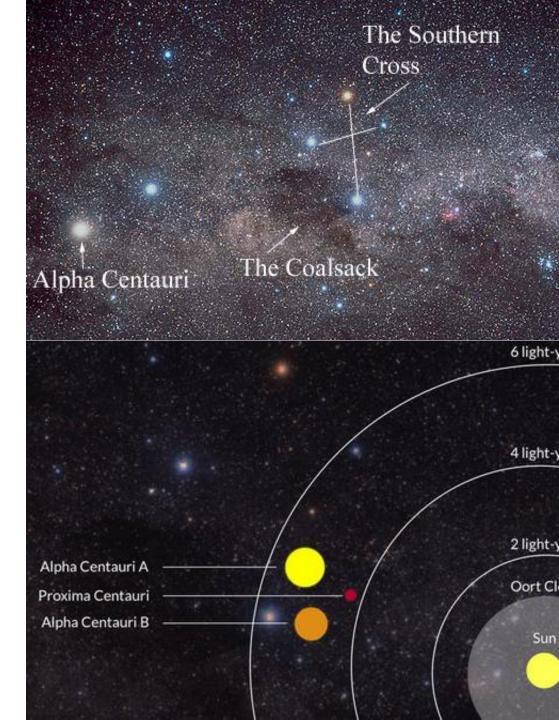






Use Orion and Taurus to find Eridanus the river and Cetus the Whale - in Eridanus we have Epsilon Eridani, 10.5 Lyr distant and in Cetus we have Tau Ceti (11.5 lyr). These are The nearest Sun-like stars visible in the Northern Hemisphere

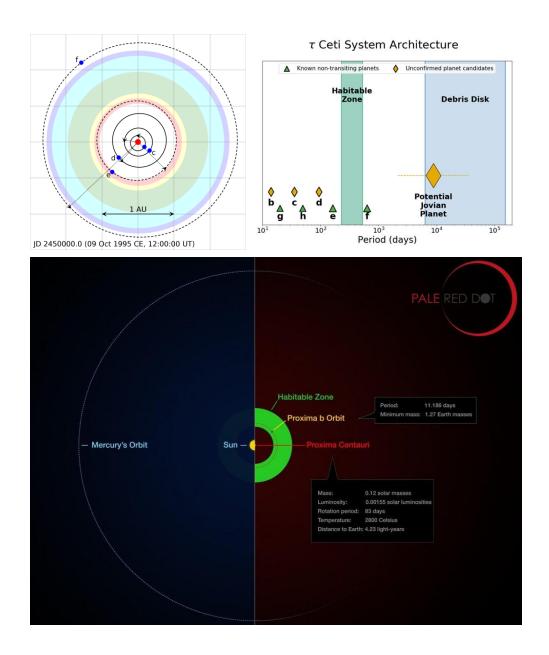
In southern hemisphere you can see the closest stars to our own – Alpha Centauri System

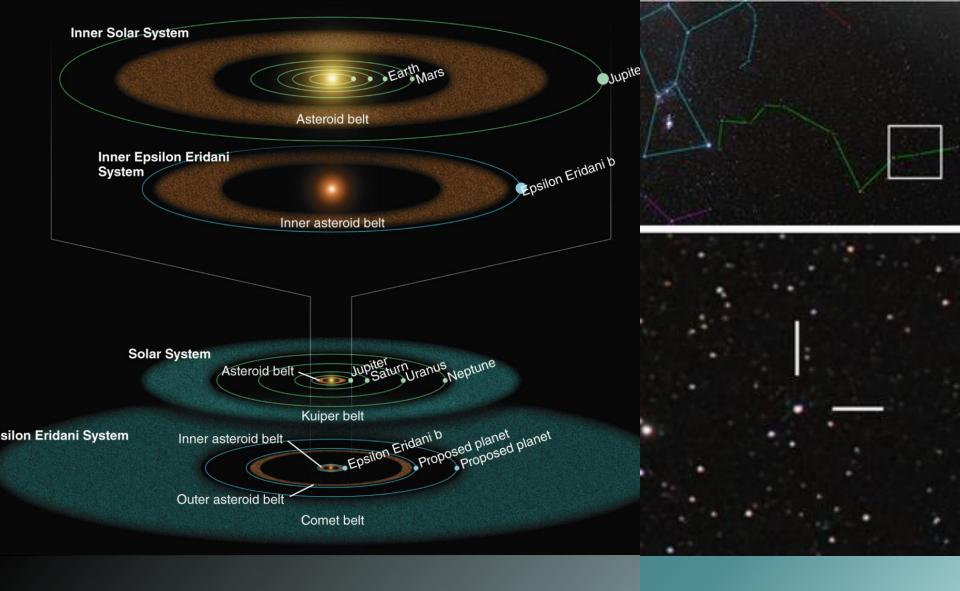


Closest Stars to our Sun



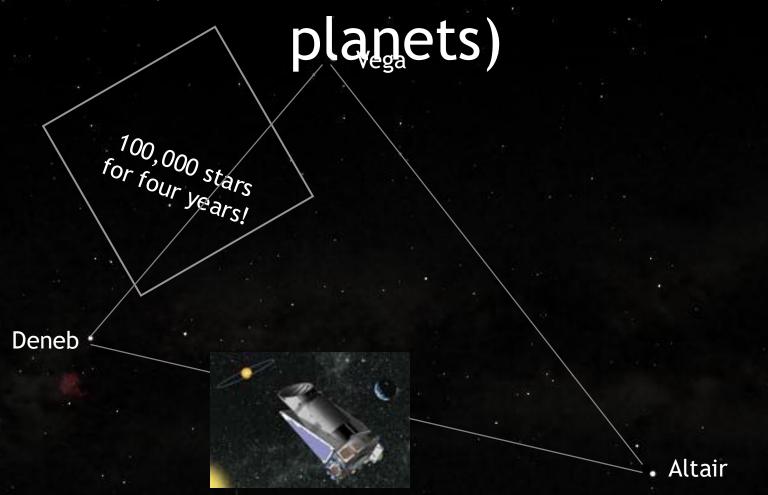
Do these stars have planets? Some nearby



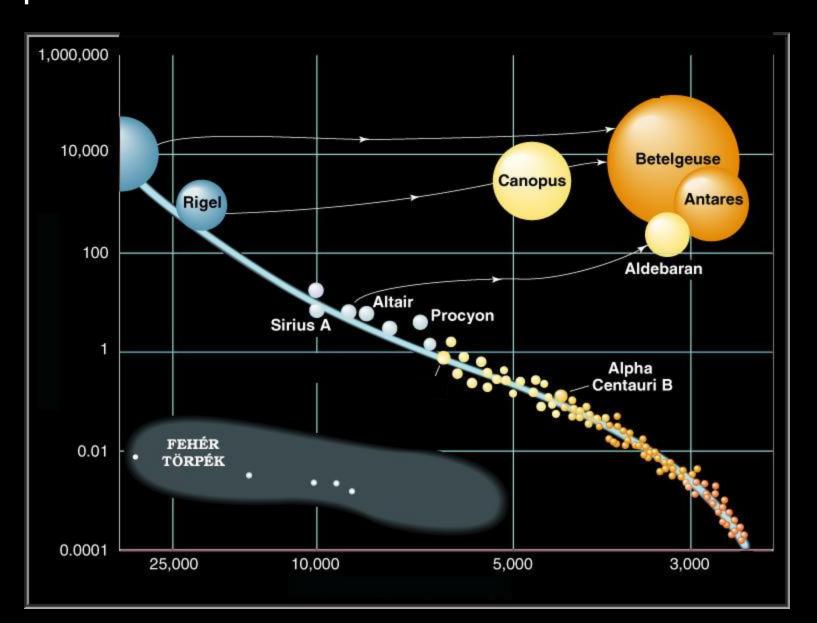


Epsilon Eridani System – Somewhat like the Sol System

Kepler Search Area (low mass stars (lower than the sun)with



"Life Diagram of Stars" - Hertzprug-Russel Spectral Class of some well known stars



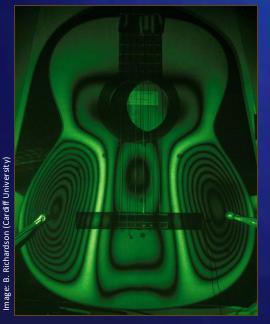


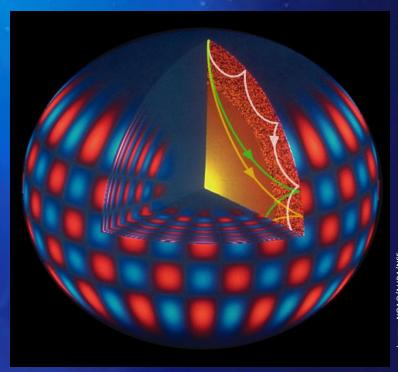
The Inside of Stars

What's Going On Inside the Sun?

Helioseismology

Helioseismology is the study of the solar oscillations observed at the surface, to probe the inner structure and the dynamics of the Sun. This works in a similar way as Earth seismology with the study of earthquakes.



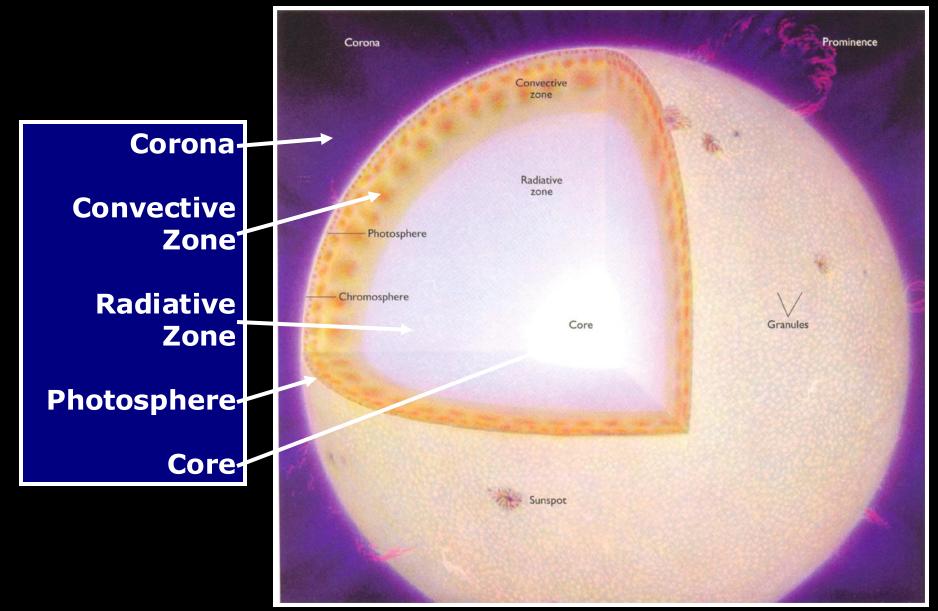


The waves of these "Sunquakes" penetrate the Sun to different depths, revealing the interior of the Sun.

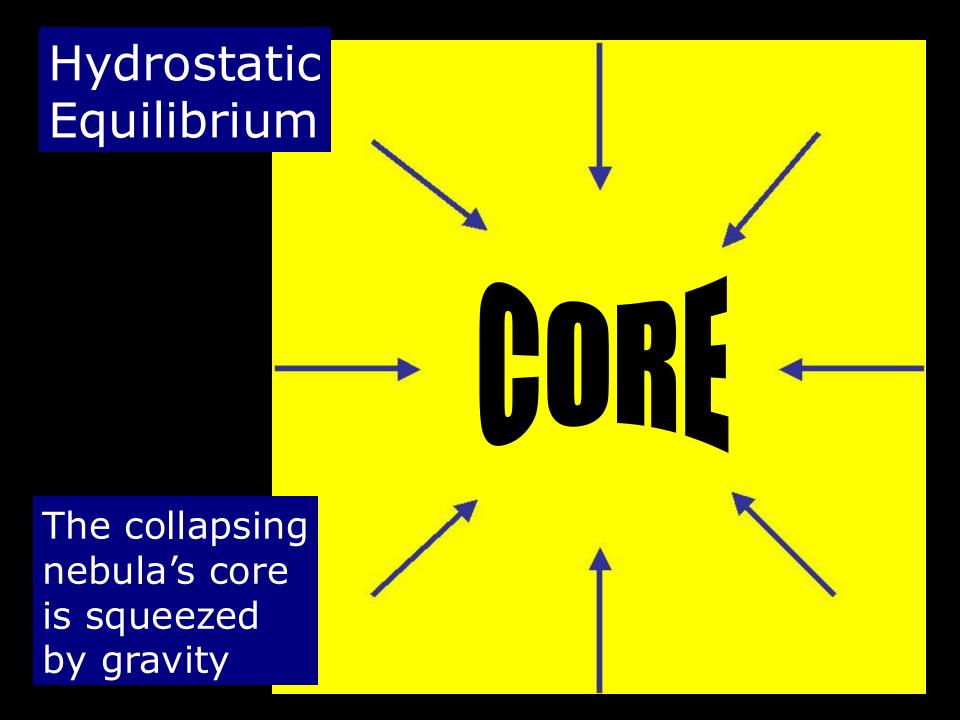
The technique is comparable to determining the shape of musical instruments from the sounds they make.

For a more detailed description of Helioseismology, check the HELAS outreach webpage: http://www.helas-eu.org/outreach/

Helioseismology helped develop models of The Interior of the Sun (and other stars)



Hydrostatic Equilibrium



Hydrostatic Equilibrium

YDROGE

It reaches 10 million degrees.



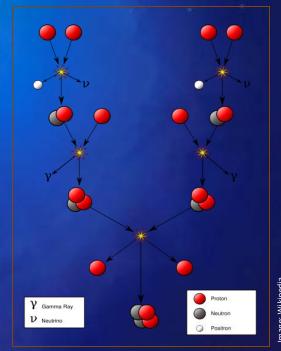
In a sense, a star's overall "behavior" is a result of constantly burning energy to avoid collapse. If the star is "stable" then it has not exhausted its fuel and is in the main sequence of its life.

Thermonuclear Fusion – The Source of the Star's power

The Sun's energy was a puzzle that was only solved in the early 20th Century. Before the age of nuclear physics, chemical burning and thermal physics could not explain how stars could burn their gaseous fuel for so long.

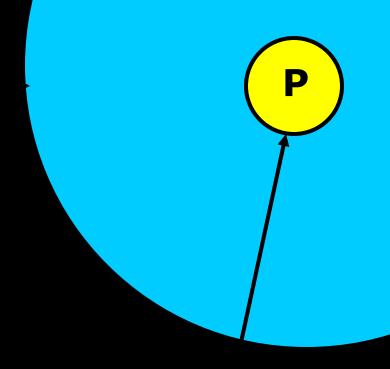
It was proposed that temperatures in the core were so hot (about 15 million degrees) that nuclear fusion would take place.

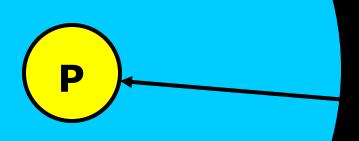
Each second, 700 million tons of Hydrogen are transformed in 695 million tons of Helium. The rest is transformed into energy, which sustains the Sun for billions of years.



Nuclear fusion is very powerful as mass is converted into energy.

Extent of electromagnetic force (repulsive)

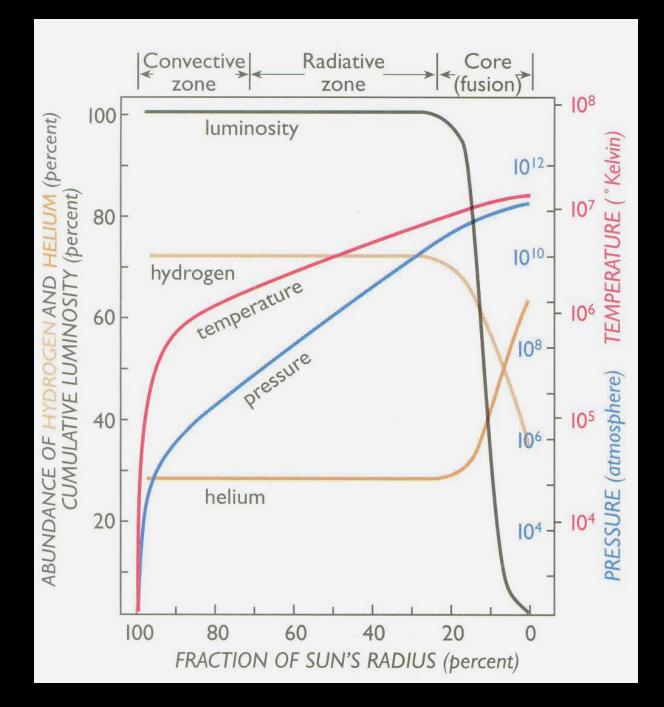




Extent of strong nuclear force (attractive)

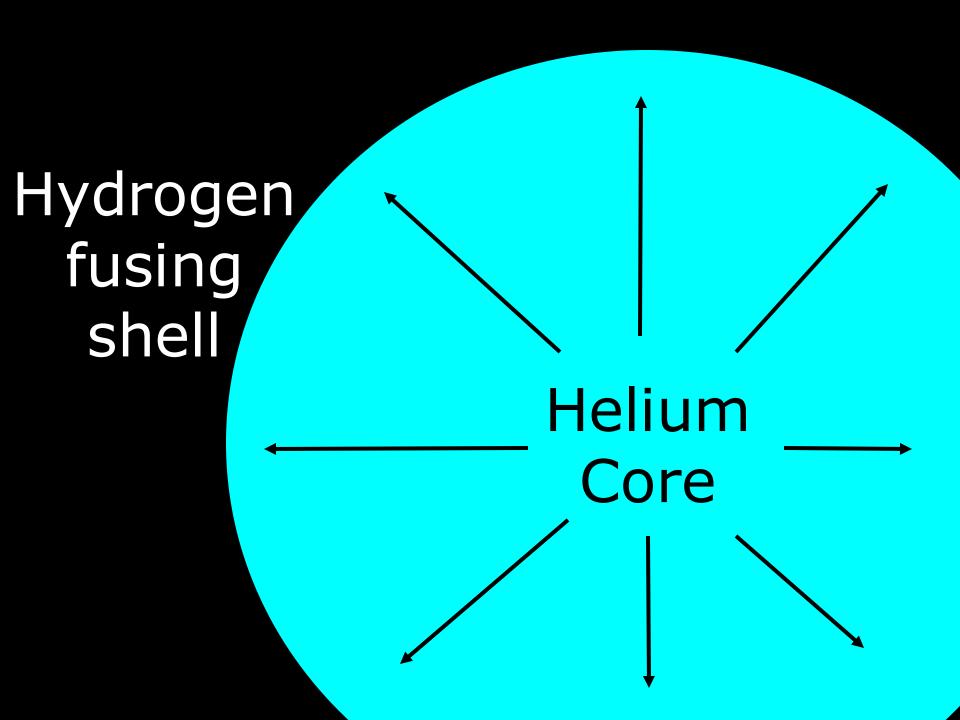
Hydrostatic Equilibrium Balance between gravitation & thermal expansion

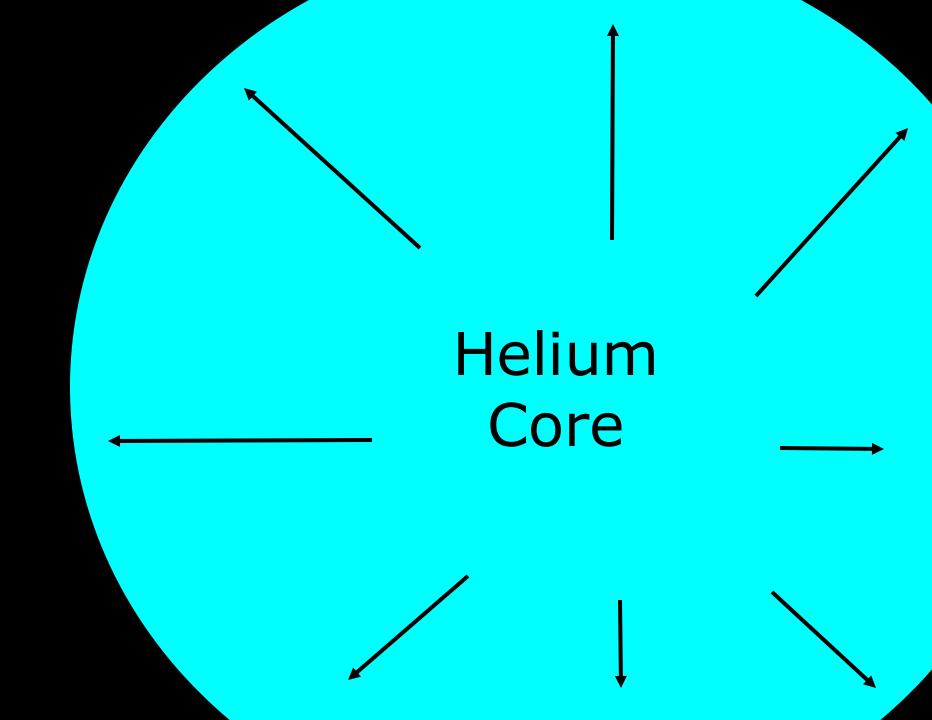
Core Helium Enrichment



Hydrogen fusing shell

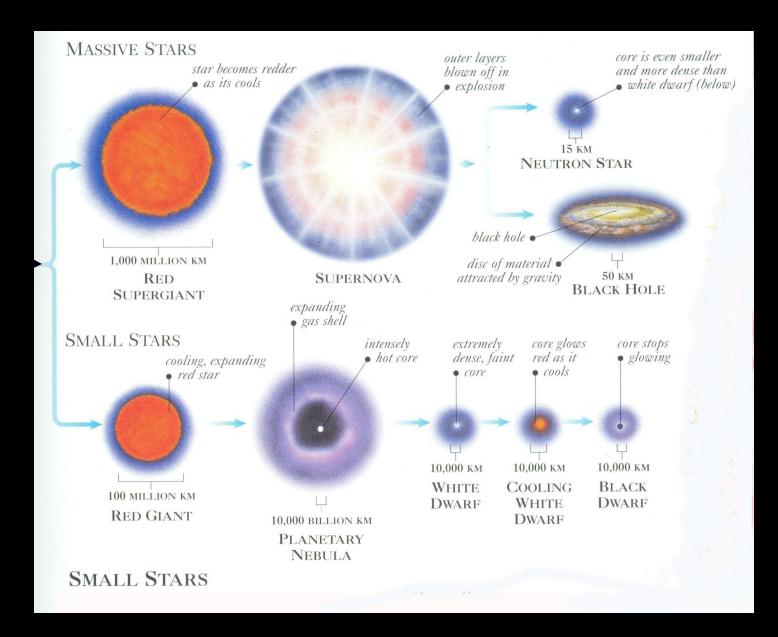
Helium Core

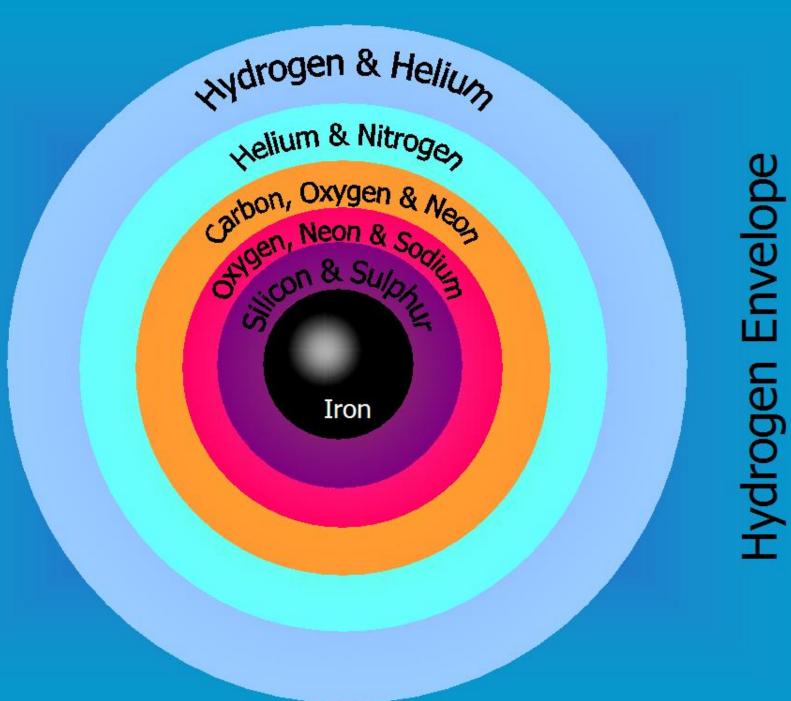




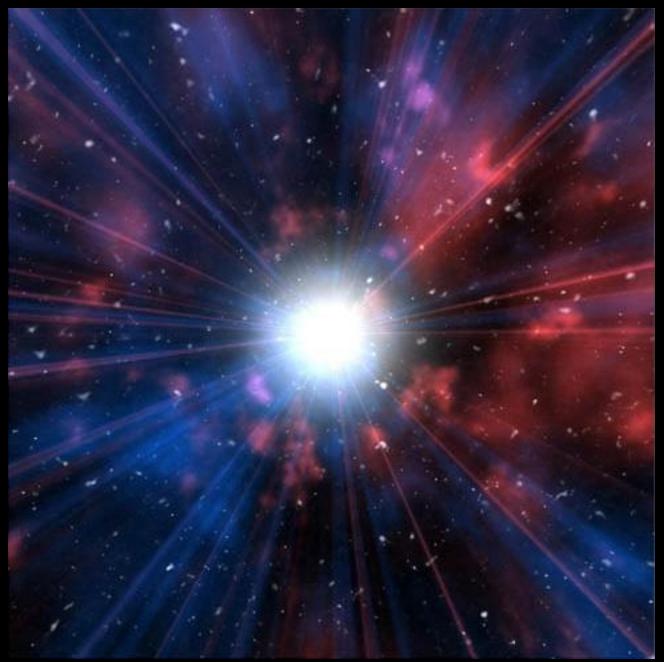
A Star's Death

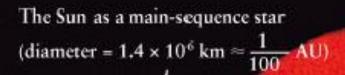
After the main sequence





Supernovae





The Sun in 5 billion years

The Sun as a red giant (diameter ≈ 1 AU)

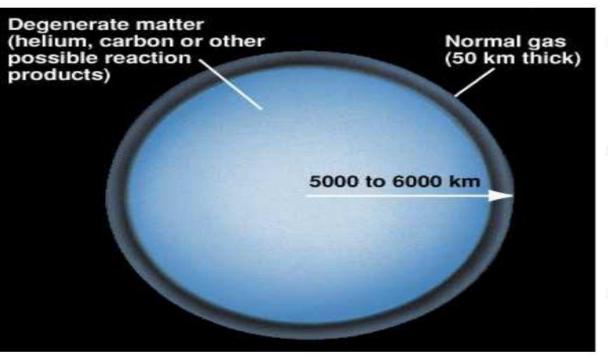
Planetary Nebulae- beautiful stellar graveyards



White Dwarfs



Death of low-mass star: White Dwarf

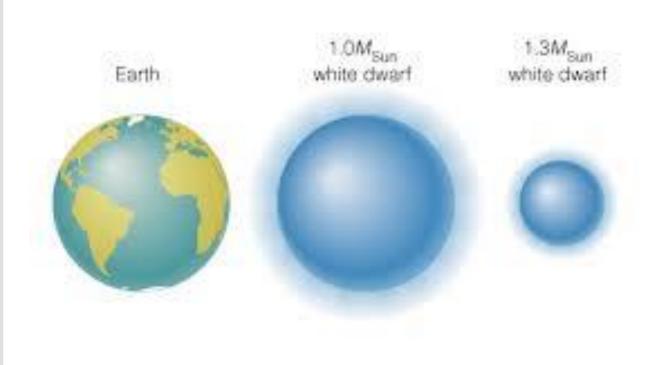


- White dwarfs are the remaining cores once fusion stops
- Electron
 degeneracy pressure
 supports them
 against gravity
- Cool and grow dimmer over time

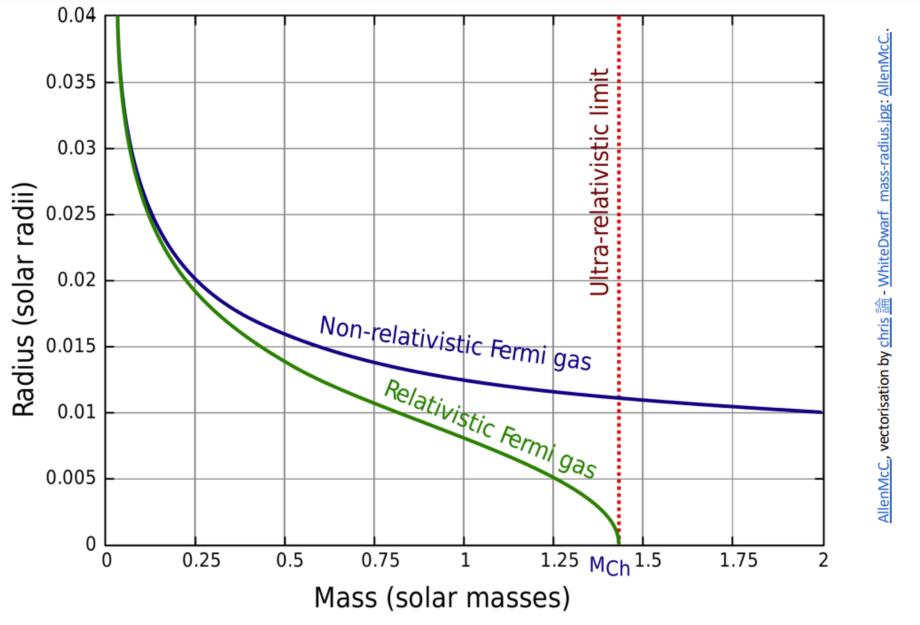
FREE ELECTRON GAS IN METALS

FERMI DIRAC DISTRIBUTION LAW OF ENERGY AMONG ELECTRONS





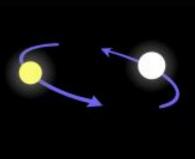
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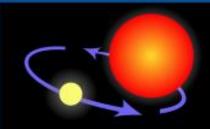
Graph plotting the radius (in standard solar radii) against the mass (in standard solar masses) for a model white dwarf star consisting of a cold Fermi gas. The blue curve shows a nonrelativistic model and the green curve a relativistic model. The molecular weight per electron has been taken to be 2. M_{Ch} denotes the Chandrasekhar mass limit.

The progenitor of a Type Ia supernova

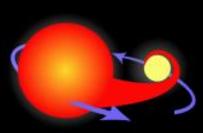
A White Dwarf in a binary system can lead to another end stage of a "sun-like" star, a sort of "back door" entry to a more dramatic demise! A Type 1A Supernova



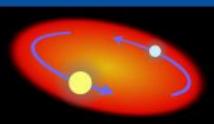
Two normal stars are in a binary pair.



The more massive star becomes a giant...



...which spills gas onto the secondary star, causing it to expand and become engulfed.



The secondary, lighter star and the core of the giant star spiral toward within a common envelope.



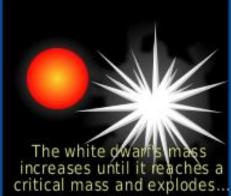
The common envelope is ejected, while the separation between the core and the secondary star decreases.



The remaining core of the giant collapses and becomes a white dwarf.

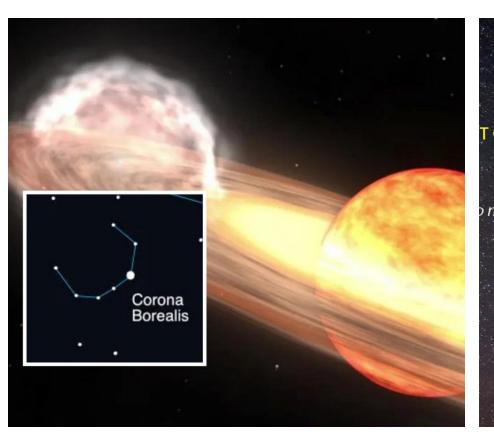


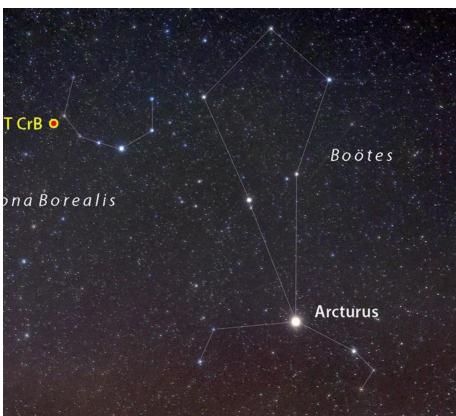
The aging companion star starts swelling, spilling gas onto the white dwarf.

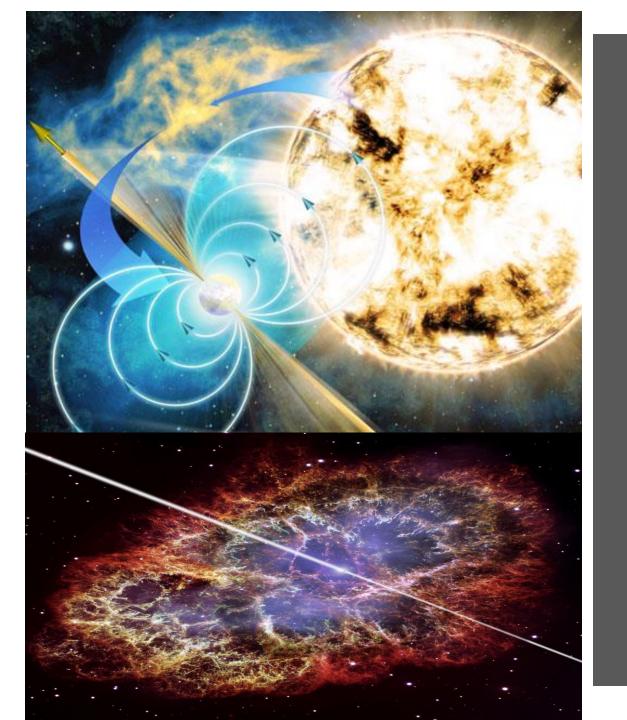


...causing the companion star to be ejected away.

One Upcoming? Once in every 80 Years we get an Eruption from T Corona Borealis Could be any day, month, year now!

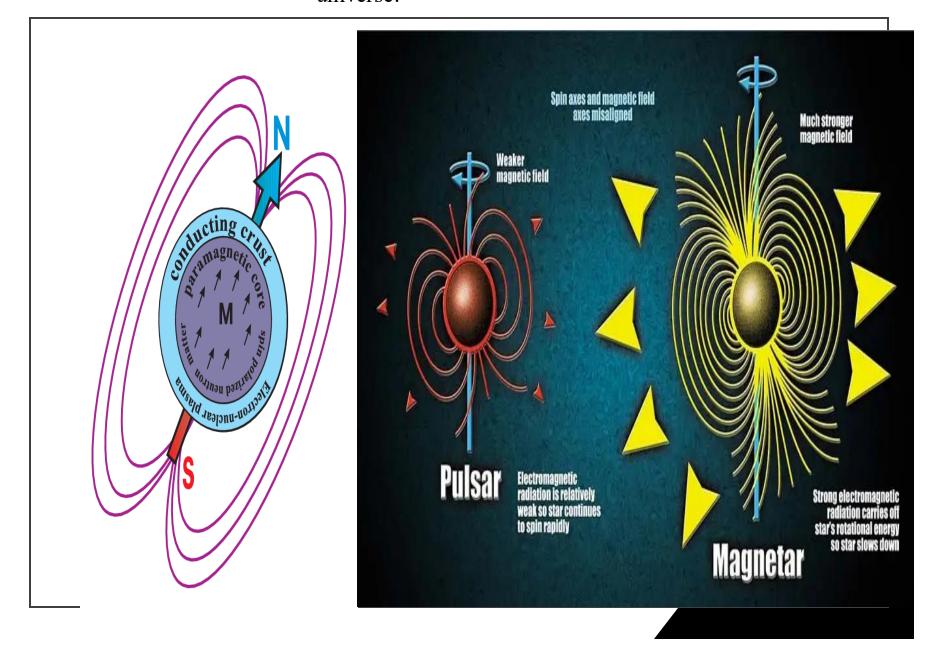






- The "Real" Supernova End stages of the largest stars
- Lead to Neutron Stars and Pulsars and Black Holes
- -Giant stars go through their fuel in hundreds of millions of years, fusing to helium, carbon, through to iron.
- Each new fusion stage swells the star into a bigger and bigger red supergiant.
- The iron core implodes into a neutron star, and its energy explodes the outer gases in a supernova.
- This is what happened in the Crab Nebula in 1054 AD
- The crab pulsar sits in the middle of the crab nebula

• Strongest magnets in the universe!



Giant stars range from about 3 times the mass of our Sun up to the hypergiants, which can be a 100 times the Sun's mass. The core of a giant star is under extreme and constant pressure from the weight of itself.

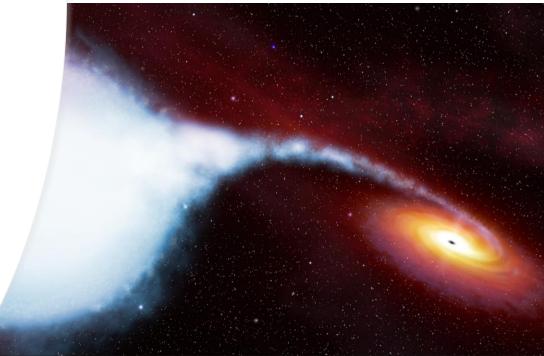
Its atoms fuse furiously to give off the huge amounts of energy needed to hold up its heavy burden of gas.

- giant stars fuse through their fuel in only a few million years, sometimes bloating into red supergiants, but other times not, remaining blue hot until their cores implode.
- The collapsing object is so dense that the pull of gravity near its surface is stronger than the speed of light. If light cannot shine off of its surface, we cannot see it directly, and we call such a corpse a stellar black hole.

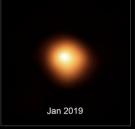


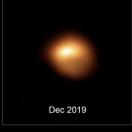
- Infalling matter interacts with the strong gravitational fields surrounding stellar black holes, it gives off radio waves, gamma rays.and these heat up the matter orbiting around the black hole forming an accretion disk.
- The accretion disk is detectable and is the evidence of a black hole.
- Sometimes however a black hole has a companion star
- Such is the case with a famous black hole, Cygnus X-1 and its partner Blue Giant Star HDE 226868
- Cygnus X-1 is a relatively close black hole (~7,000 lyr)and was one of the first detected in the mid 1960s owing to its bright x-ray and radio emissions









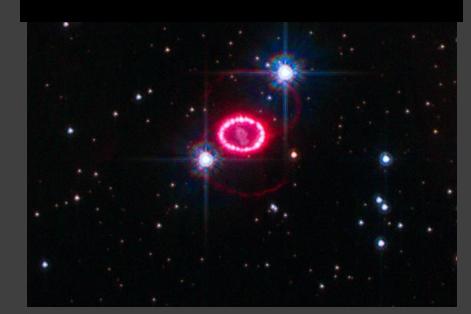








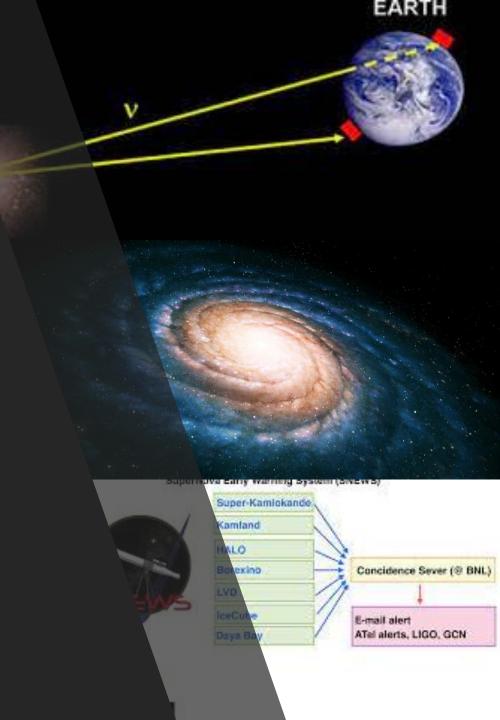
Supernova in LMG in 1987



How to detect Supernovas? with Supernova Early Warning System: https://snews.bnl.gov/

SN

Linking Neutrino detectors across the earth to give an early warning of a corecollapse supernova event





Useful websites
www.astronomy.ie/handouts
www.stellarium.org

Thank You