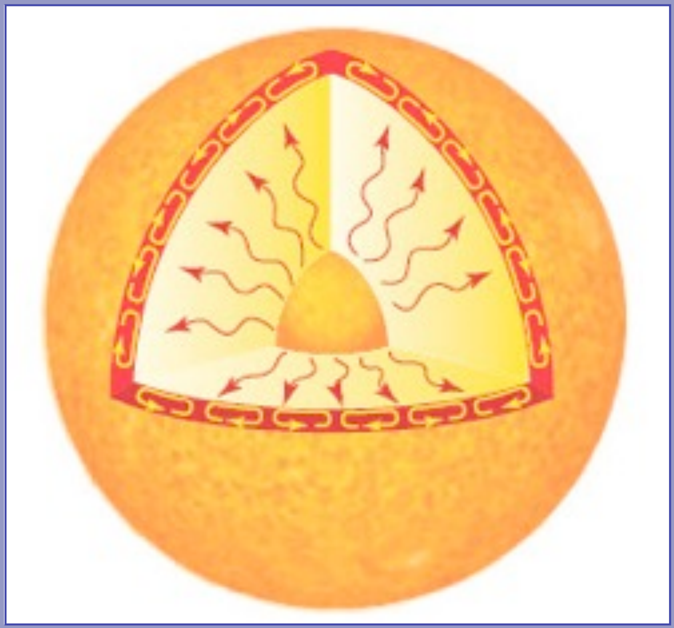
A Star is born: The Sun

SNC1D7-Space

Exploring the Sun

Our Sun, a star, is the most important celestial object for life on Earth. The **solar nebula theory** is the current theory used to explain the formation of the Sun.



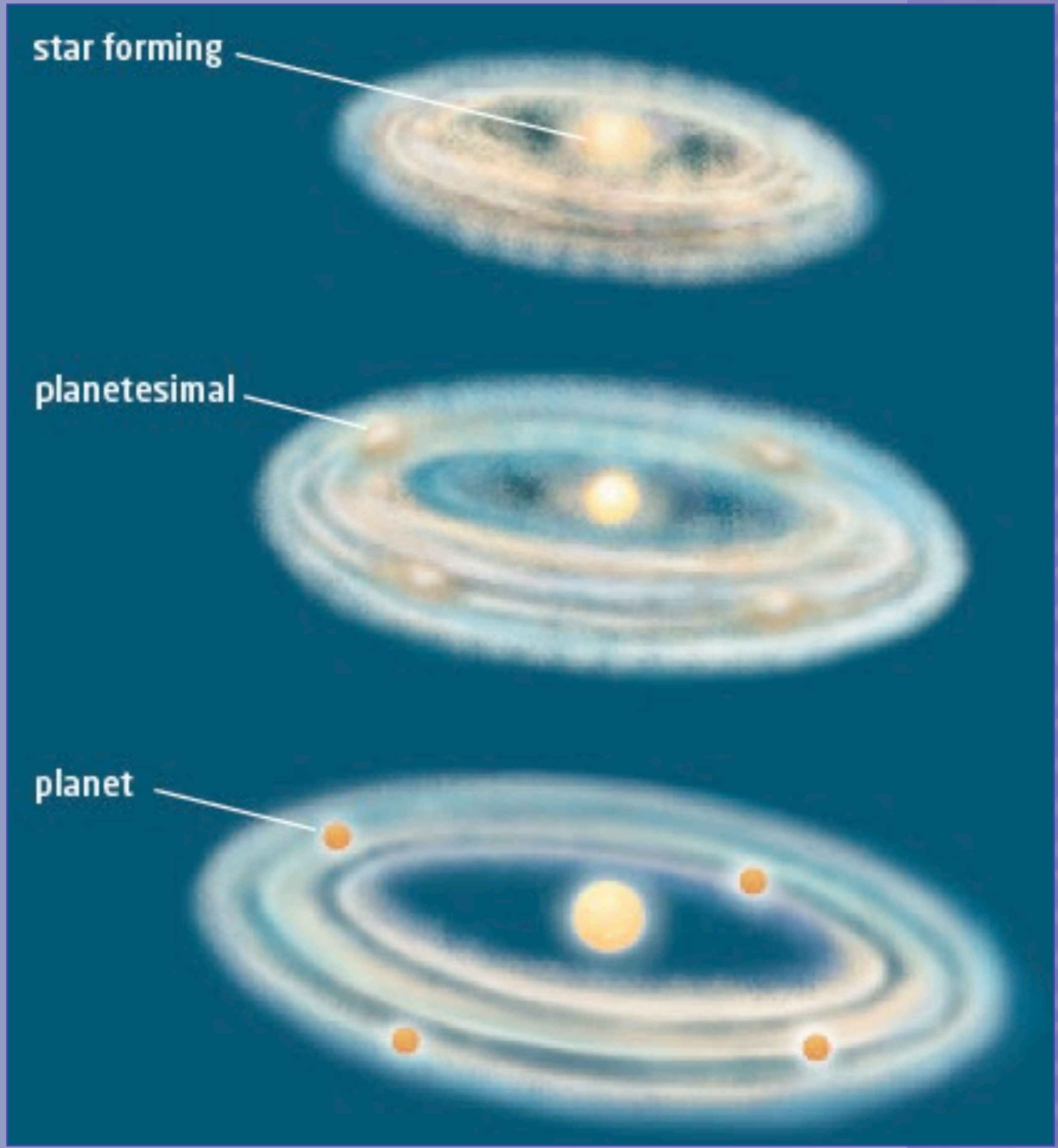
Stars are celestial bodies made of hot gases, mainly hydrogen and some helium.

The **solar nebula theory** describes how stars and planets form from contracting, spinning disks of gas and dust. **Nebulas** are vast clouds of gas and dust that may be the birthplace of stars and planets.

How the Solar System Formed

How does a solar system form? It is believed that gravity sets the gas and dust particles of a nebula in motion around the core of a young star or **protostar** (a condensed, hot object at the middle of a nebula).

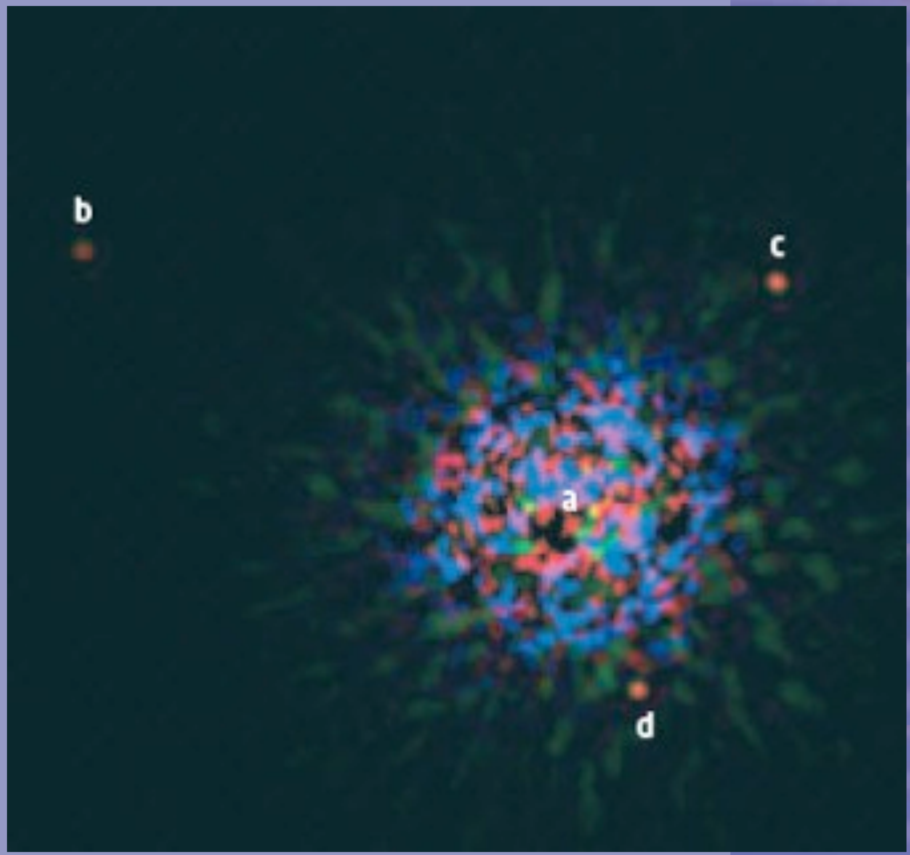
Particles begin to gather in the centre of the spinning cloud. As the spinning nebula begins to contract, tiny grains start to collect and eventually clump into **planetesimals**. If the planetesimals survive, they may eventually form planets like those in our solar system.



Craters on rocky planets could have formed during early formation.

A Flat, Rotating Disk

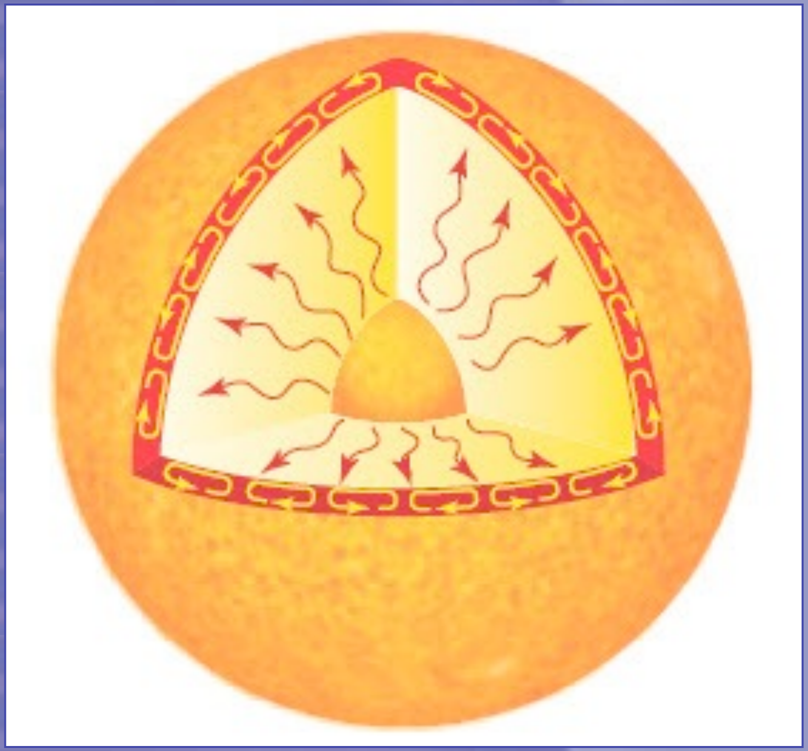
As nebulas spin, they flatten into a disk-like shape while spinning in one direction. Astronomers theorize that any planets and other bodies that form at this stage would form in the flat plane of the disk. The planets would then orbit in that same direction.



Astronomers have discovered over 300 planets orbiting stars other than the Sun. These planets are called **extrasolar planets**. Several extrasolar planets (a-d) are shown orbiting the star HR8799.

How the Sun Formed

When a star-forming nebula collapses and contracts, the gas compresses and the temperature of the protostar increases. When the temperature reaches around 10 000 000^{o}C, **nuclear fusion** begins.



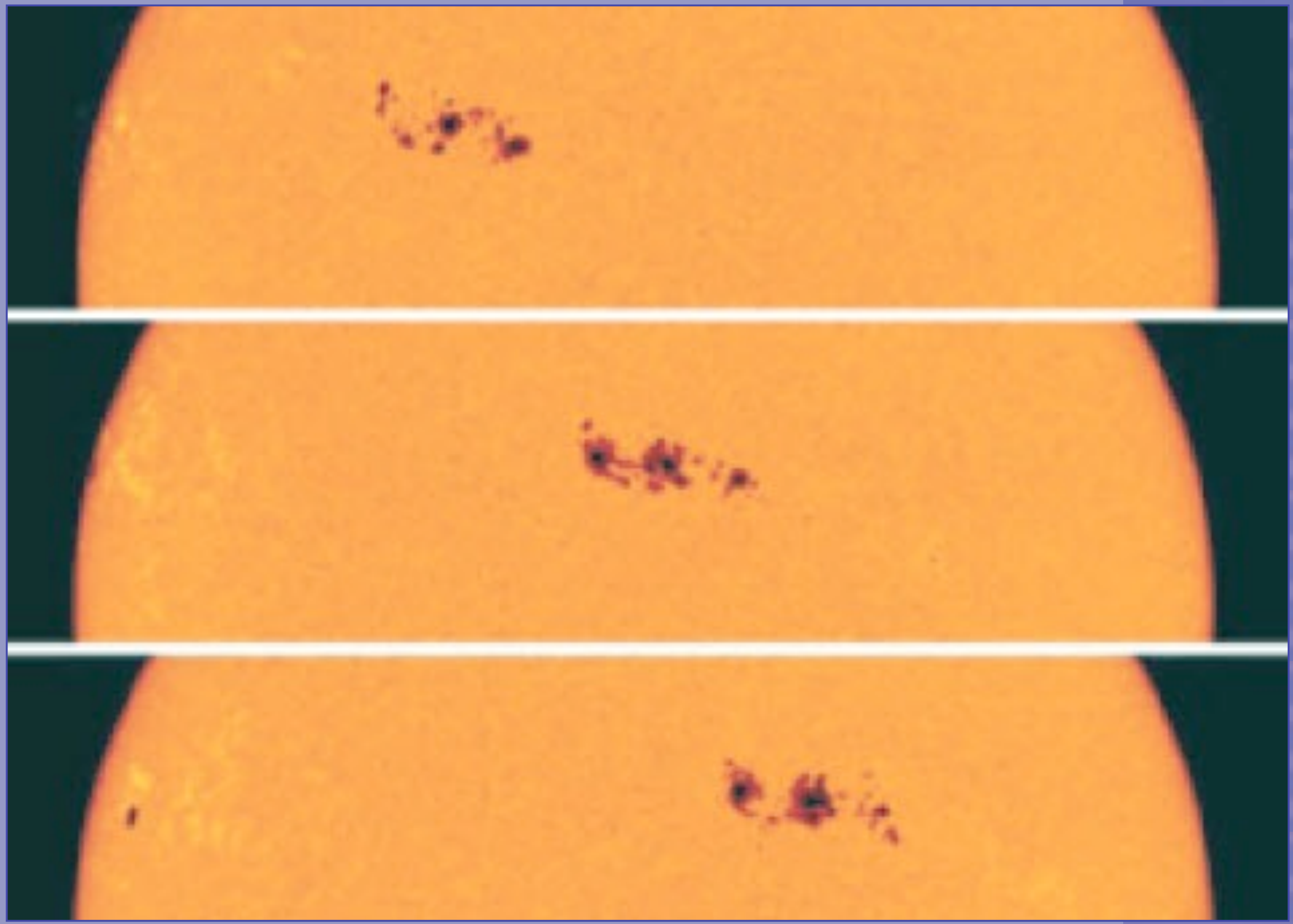
Nuclear fusion is the process of energy production in which hydrogen nuclei combine to form helium nuclei.

Once the fusion process begins, the protostar starts to consume the hydrogen fuel. The denser helium builds up in the star's core, and the core continues to heat up, increasing the pressure and temperature. The continuing hydrogen fusion increases the size of the core.

Features of the Sun

The surface layer of the Sun is known as the **photosphere**. This layer is several thousand kilometres deep. Dark spots on the photosphere, called **sunspots**, are areas of strong magnetic fields. The sunspots look dark because they are cooler than the surrounding photosphere.

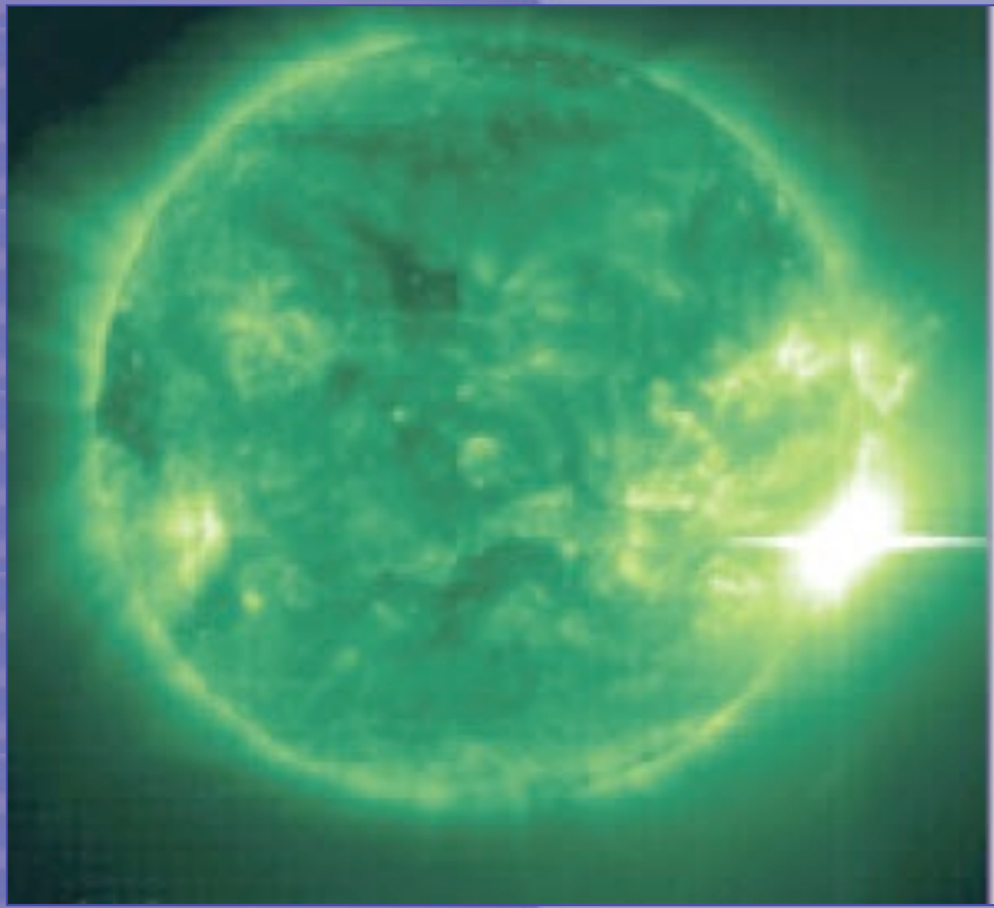
Astronomers have observed that sunspots near the Sun's poles take about 35 days to complete one rotation while sunspots near the equator take 27 days. This proves that the Sun rotates but faster at its equator than at the poles.

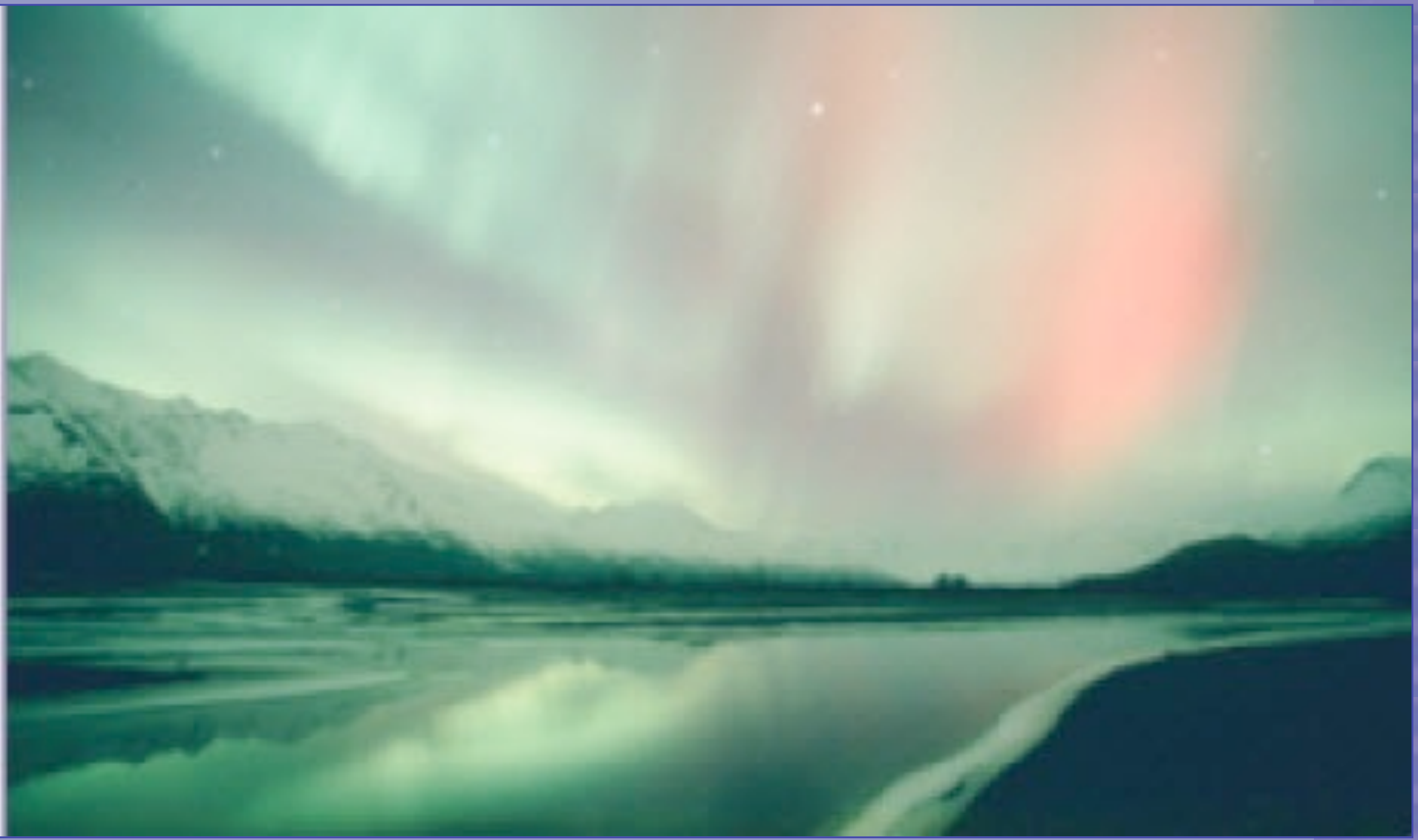


Sunspot activity occurs in 22 year cycles, peaking every 11 years.

Solar Flares

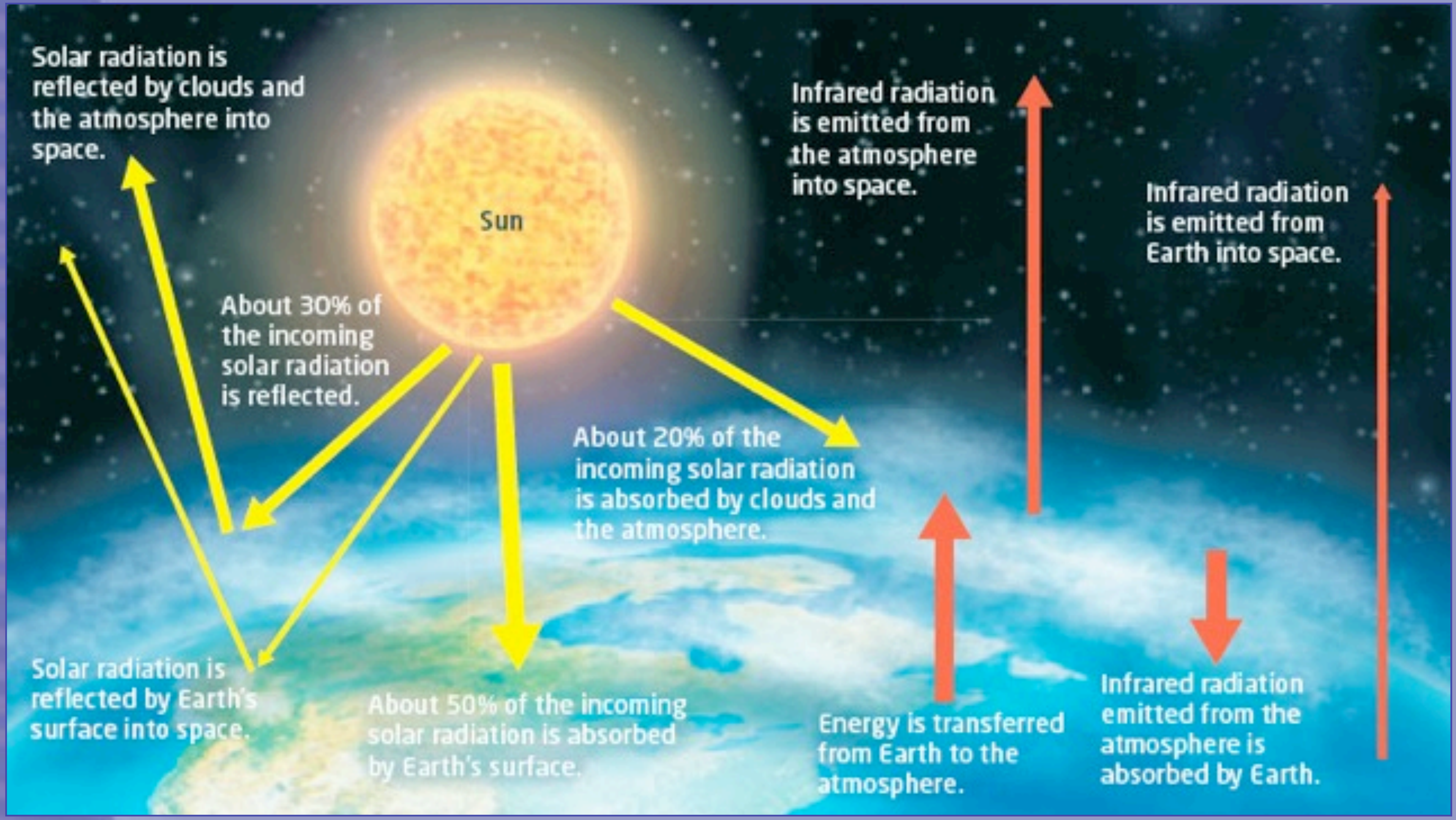
Occasionally **solar flares** can occur where there are complex groups of sunspots. Solar flares eject intense streams of charged particles into space. If one of these streams, called **solar wind**, hits Earth, spectacular auroras can be produced by Earth's magnetic field. These events, called **solar storms**, can disrupt telecommunications, damage electronic equipment on spacecraft, and overload Earth's electrical power network.





The Importance of the Sun

The Sun drives most processes on Earth that support our daily activities. It powers the winds and ocean currents, drives all weather, and provides the energy for the photosynthesis that provides food at the base of all food chains and the oxygen we breathe.



The Sun produces radiation across the entire electromagnetic spectrum, including the radiation that heats Earth.

Your Homework!

Learning Check

1. What is the solar nebula theory?

2. List three pieces of evidence that support the solar nebula theory.

3. Define *protostar*.

4. Name and describe the process that fuels the Sun.

5. Name the two most abundant elements that the Sun is composed of, and identify which element is in the higher proportion.

6. What is the difference between a solar flare and the solar wind?

7. Explain why sunspots look dark.

8. If you were an astronaut on the International Space Station, would you be concerned about solar flares? Why or why not?

What about all the other stars?

8.3 Exploring Other Stars

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The night sky is filled with stars that shine at different levels of brightness. The brightness of the stars we observe can be related to the size of the star or its distance from Earth.

The brightness or **luminosity** of a star is described as its energy output per second. The star's power is measured in joules per second (J/s). The **absolute magnitude** of a star is the brightness we would observe if the star were placed 32.6 light-years from Earth.

Our Sun has an absolute magnitude of 4.7. By universal standards, this is quite dim.

The Colour, Temperature, Composition, and Mass of Stars

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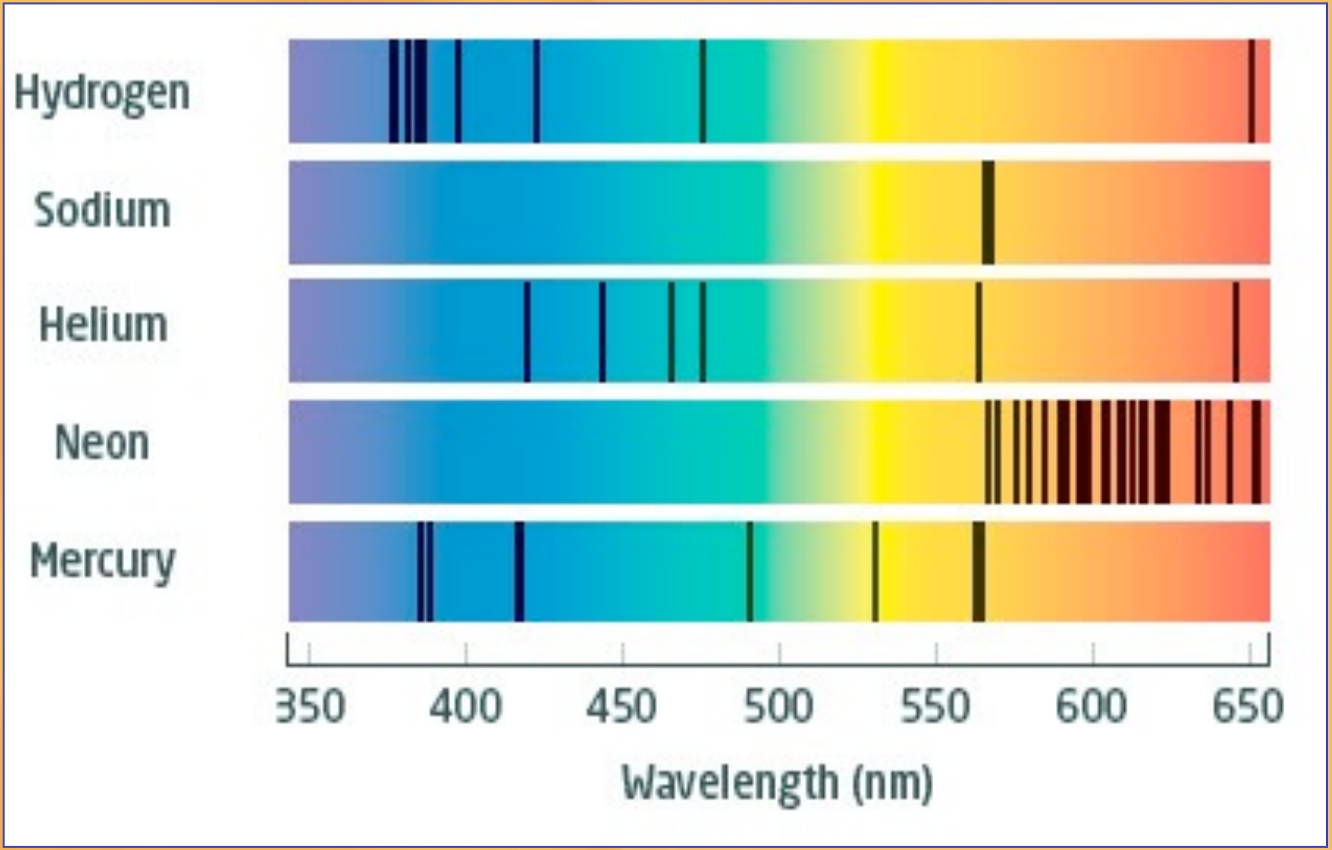
Astronomers use the colour of stars to determine temperature. In order of increasing temperature, stars can be red, orange, yellow, or blue.



Spectroscopes (devices that produce a spectrum from a narrow beam of light) produce **spectral lines** that can be used to determine the chemical composition of a star. The spectral lines produced by the spectroscope have black lines that indicate the presence of specific elements.

A star's mass can be determined if it is part of a **binary star system**. Binary stars orbit each other. Stars range from 0.08 to over 100 solar masses. Our Sun is 1 solar mass.

The Hertzsprung-Russell Diagram

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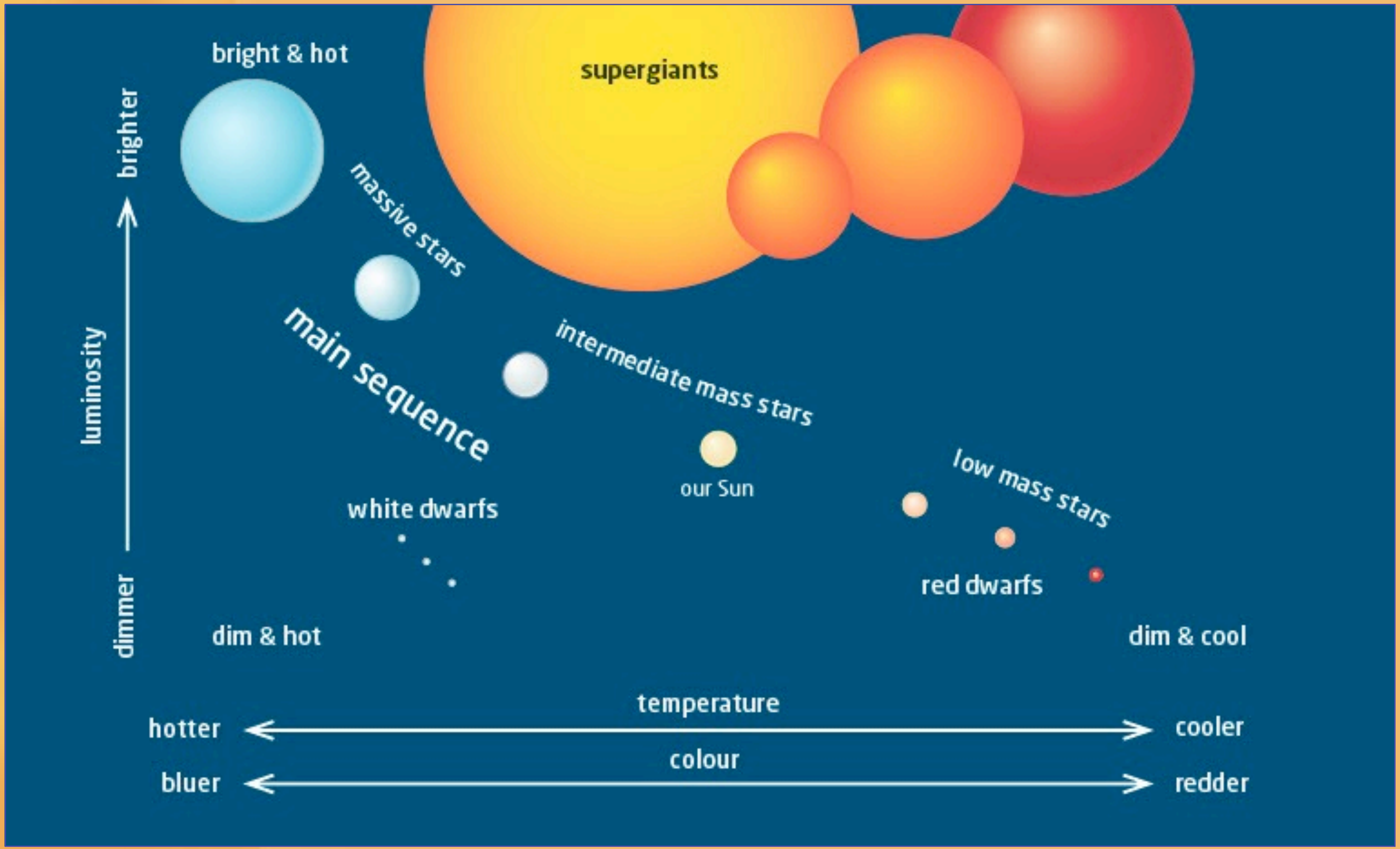
The **Hertzsprung-Russell (H-R) diagram** is a graph that compares the properties of stars. The graph compares absolute magnitude/ luminosity on the y-axis to temperature/colour on the x-axis.



The Main Sequence

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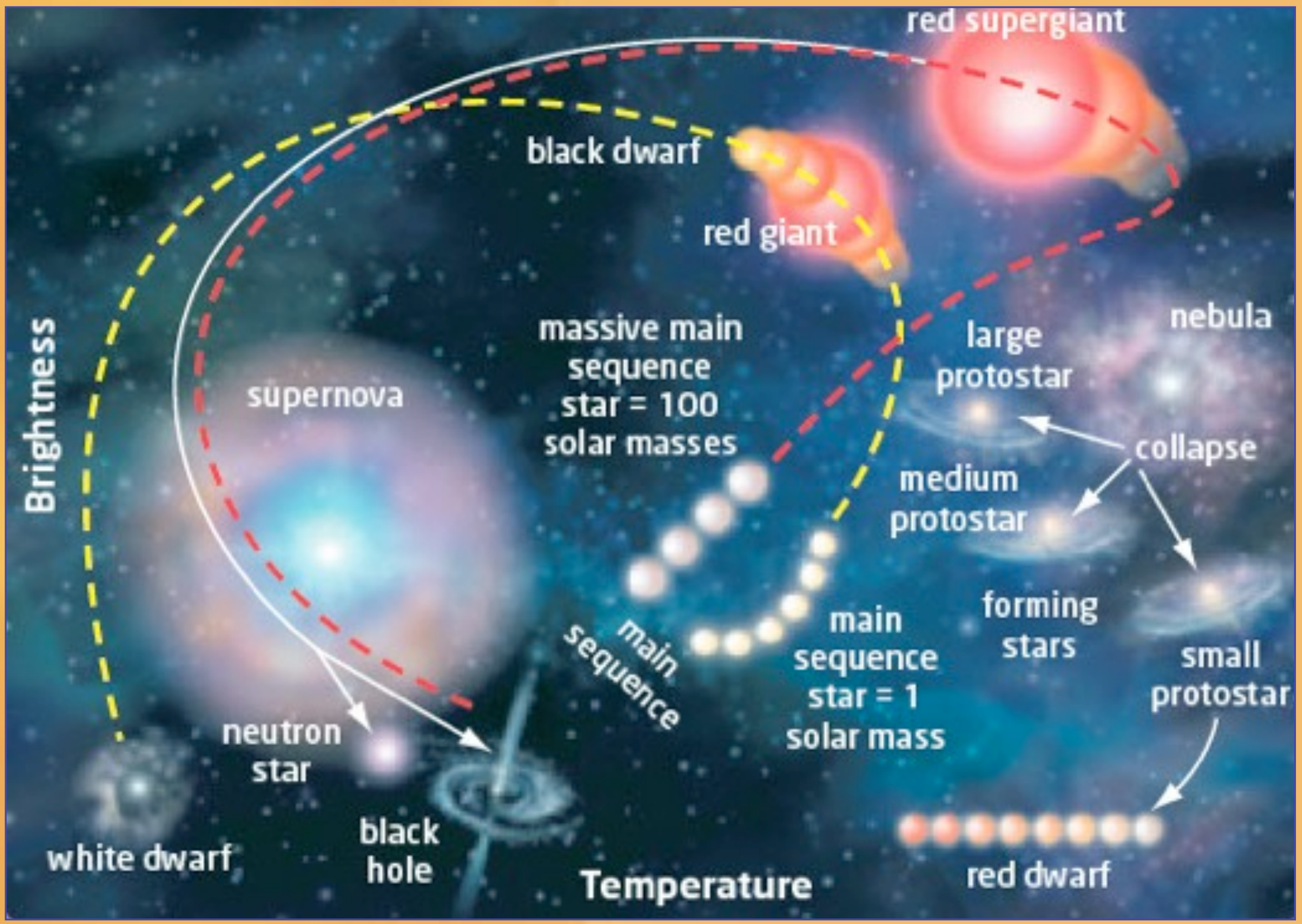
The **main sequence** is a narrow band of stars on the H-R diagram that runs diagonally from the upper left (bright, hot stars) to the lower right (cool, dim stars). About 90% of all stars, including the Sun, are in the main sequence. Some main sequence properties are listed below.

Colour	Surface Temperature (°C)	Mass*	Luminosity*
Blue	35 000	40	405 000
Blue-white	21 000	15	13 000
White	10 000	3.5	80
Yellow-white	7 500	1.7	6.4
Yellow	6 000	1.1	1.4
Orange	4 700	0.8	0.46
Red	3 300	0.5	0.08

Astronomers are not sure why all stars do not fall into the main sequence.

How Stars Evolve

Stars, in general, do not change very rapidly. Many stars shine for billions of years with no change. Eventually a star will run out of fuel and will start undergoing changes as it nears the end of its life.



Low-mass stars (red dwarfs) have less mass than our Sun. They slowly burn their fuel for up to 100 billion years and then end up as small, dim hot stars called **white dwarfs**. When cooled, they become **black dwarfs**.

Intermediate-mass stars, like our Sun, consume their fuel within 10 billion years. They cool, and the outer layers expand the star into a **red giant.** The layers disappear and eventually they become **white dwarfs**.

How Stars Evolve

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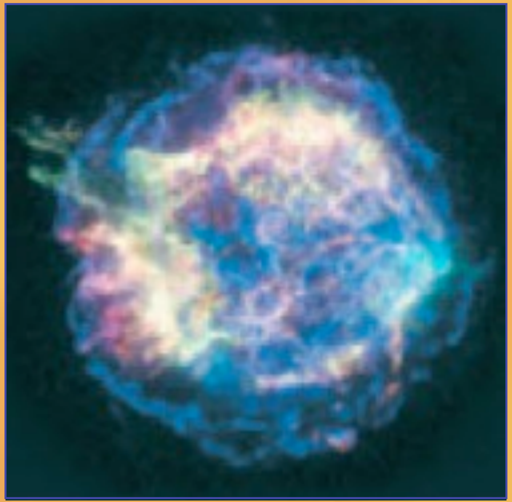
High-mass stars are 12 or more times more massive than our Sun. These stars consume their fuel faster than intermediate-mass stars and die more quickly and violently. Heavy elements form by fusion, and the star expands into a **supergiant**. An iron core forms that eventually collapses, resulting in a massive explosion of the outer part of the star. This spectacular explosion is called a **supernova**.



Supernova explosions can be millions of times brighter than the original star.

Elements from the explosion are ejected into the universe, later becoming part of new stars and planets.

Neutron Stars

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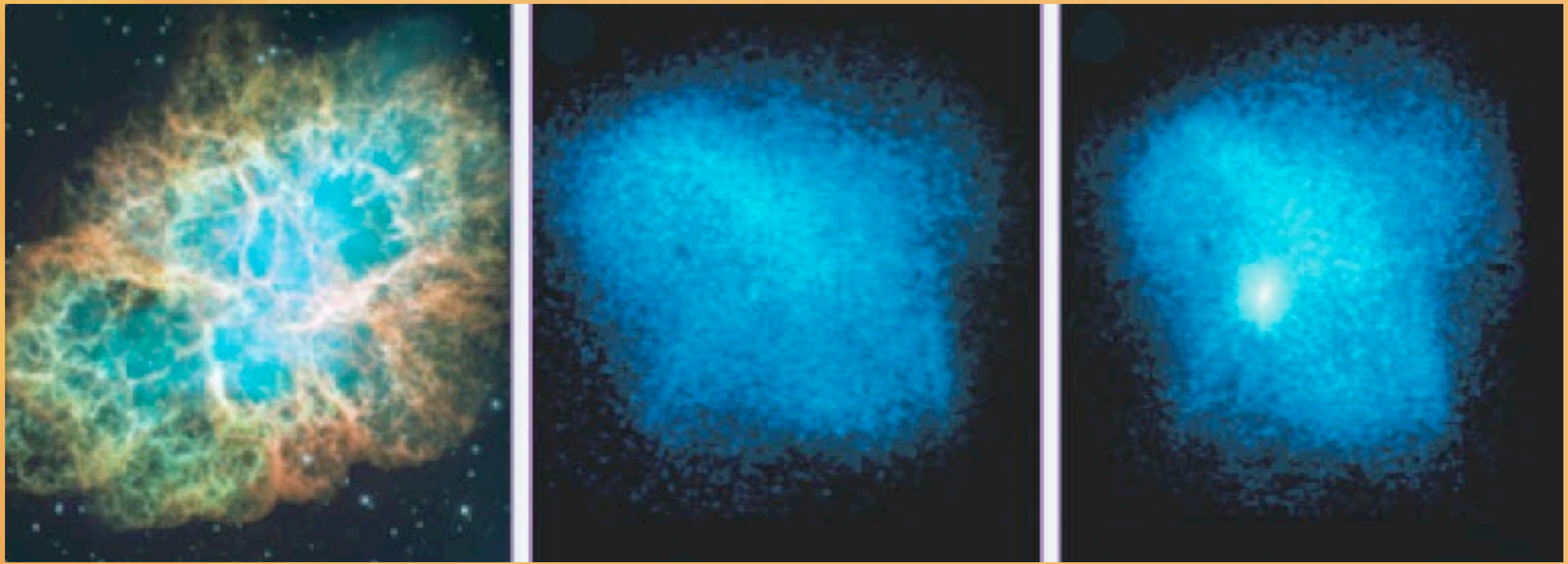
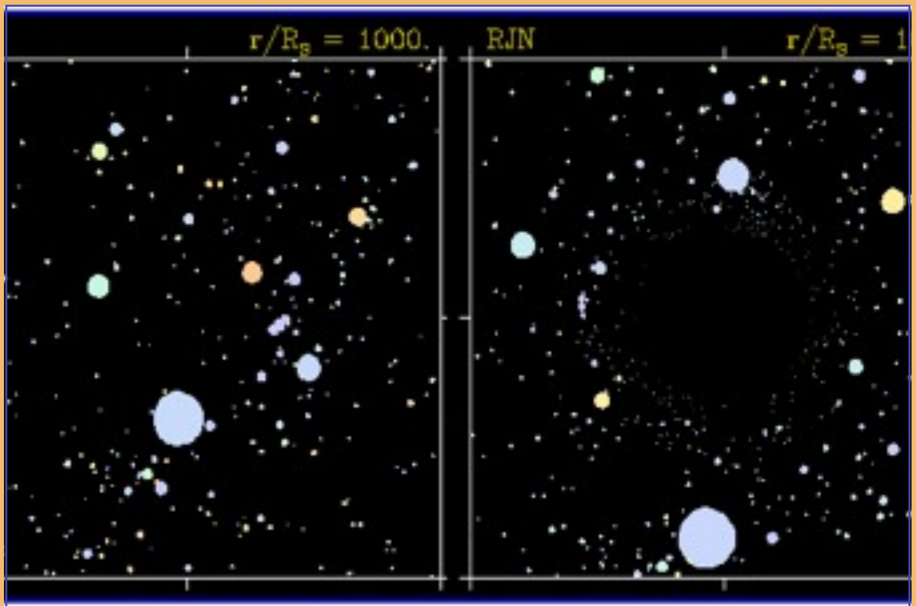
A **neutron star** is a star so dense that only neutrons can exist at the core. This type of star forms when a star of about 12 to 15 solar masses shrinks to approximately 20 km in diameter. The pressure is so great that electrons are squished into protons.



A neutron star in the Crab Nebula behaves as a **pulsar** (a type of neutron star), sending pulses of radiation into space like a giant searchlight.

Black Holes

Stars of over 25 solar masses experience the most spectacular deaths. The remnant of the supernova explosion is so massive that gravity overwhelms all other forces, and the remnant is crushed into a **black hole**. The black hole is a tiny patch of space that has no volume but has enormous mass. The gravitational force of a black hole is so strong that nothing can escape it, not even light.



Too Close to a Black Hole
Credit & Copyright: Robert Nemiroff (MTU)

How do scientists find a black hole? Scientists detect the gravitational effect it exerts on the space around it.

Review

Concepts to be reviewed:

- *What does a star's apparent brightness depend on?*
- *What is the significance of the Hertzsprung-Russell (H-R) diagram?*
- *What determines a star's position in the H-R diagram?*
- *What determines the changes a star will go through during its evolution?*