SOLAR MYSTERIES

WINTER PROJECTS 2024

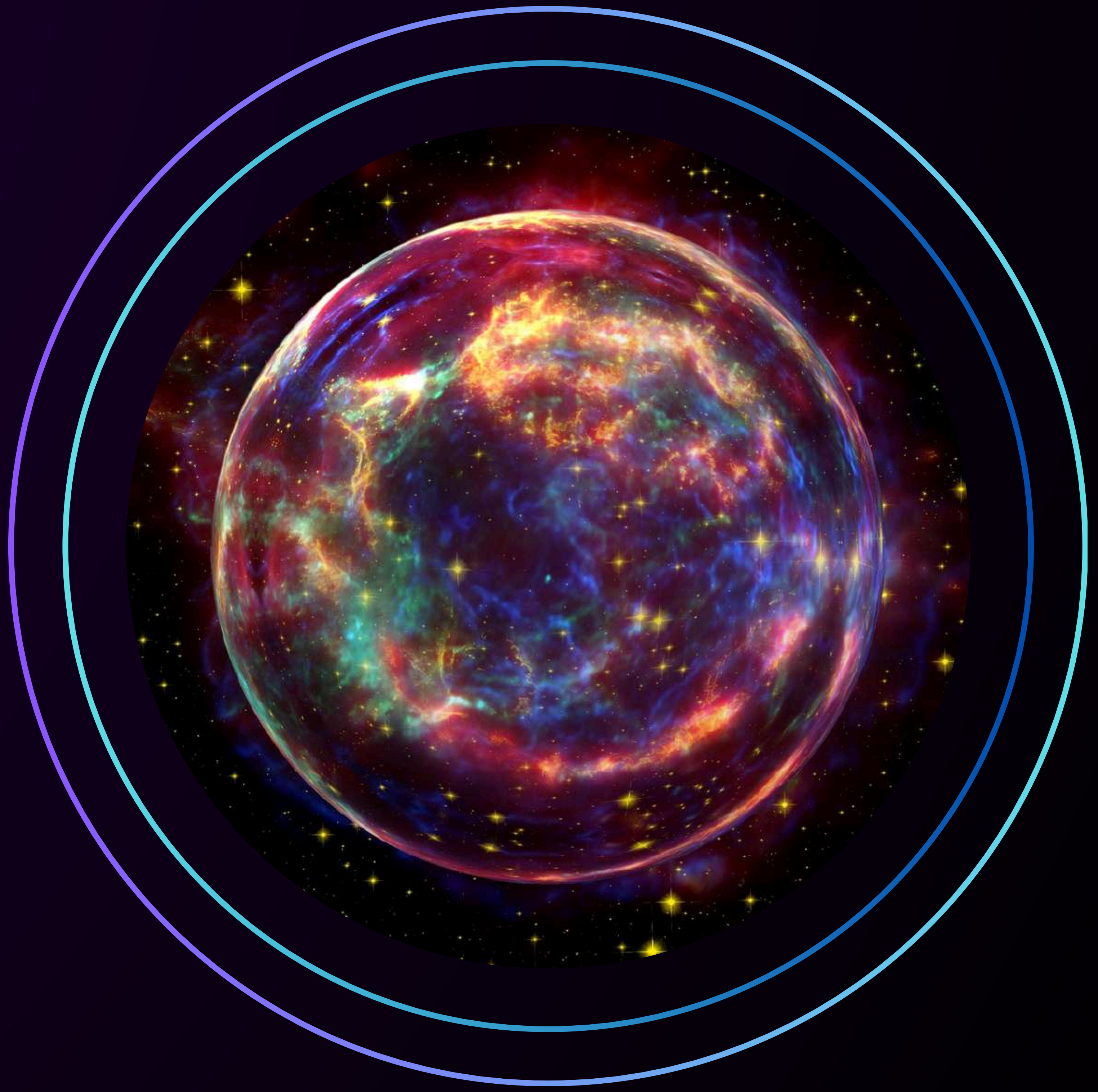
About the Project

Content:

- Aims to explore the life and evolution of stars from birth to death.
- Focus on computational tools and astrophysical datasets.
- Application of quantum mechanics to explain stellar processes.
- Importance of data-driven insights in modern astronomy.

Why do we study Stellar Lifecycles ?

- Stars are the universe's powerhouses, driving galaxy formation and evolution.
- Understanding stellar lifecycles helps unravel cosmic mysteries like supernovae and black holes.
- Contributions to fields like cosmology, exoplanet studies, and astrophysics.



Why is this project relevant ?

Scientific Impact:

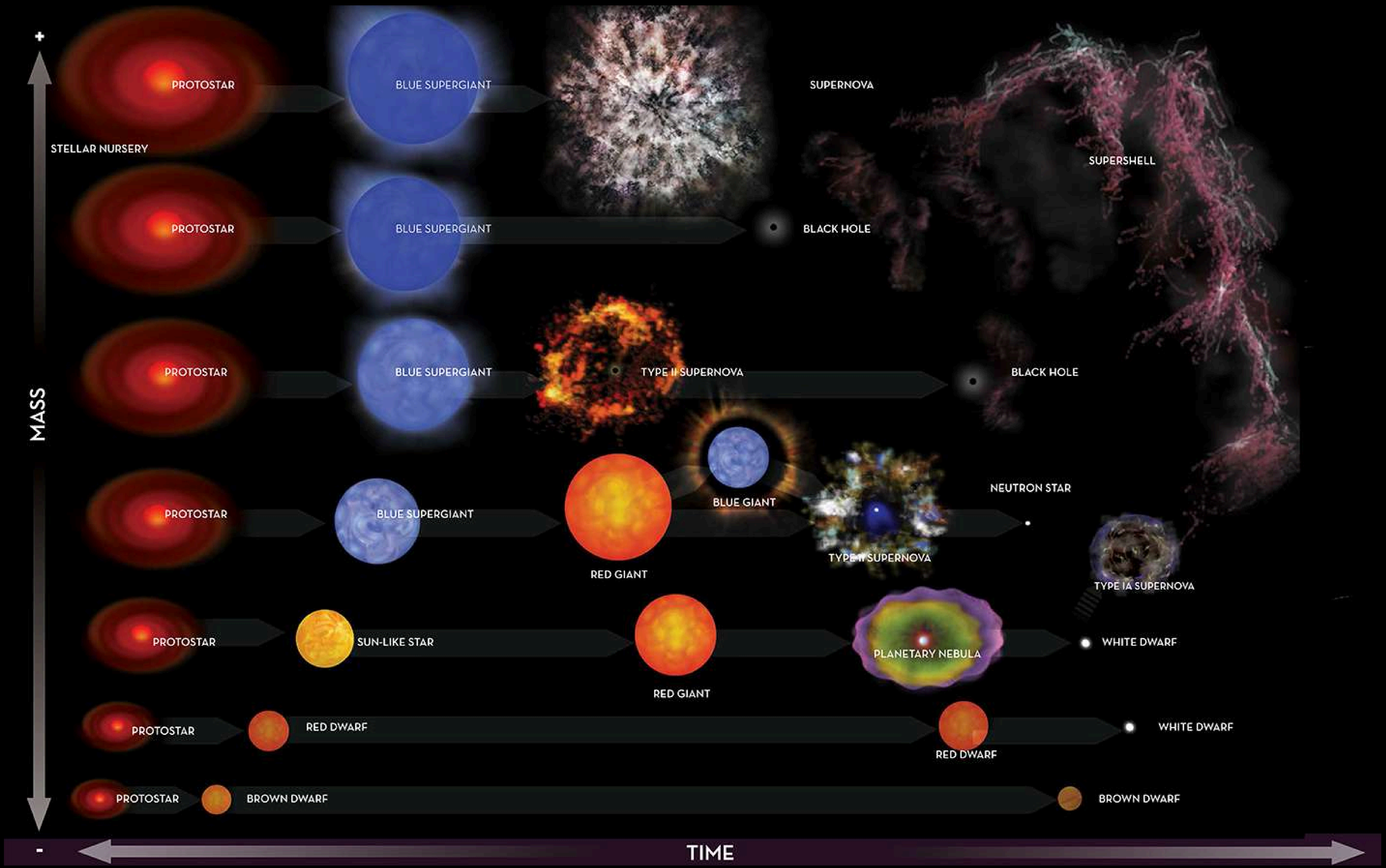
- Provides insights into energy generation and element formation.
- Contributes to modeling the universe’s evolution.

Practical Implications:

- Predictions of stellar behavior impacting Earth.
- Basis for technologies like nuclear fusion.

How does this contribute to Science ?

- Introduces computational techniques in astronomy to students.
- Fosters understanding of stellar physics and quantum mechanics.
- Builds foundational skills in data analysis and machine learning applications in space science.



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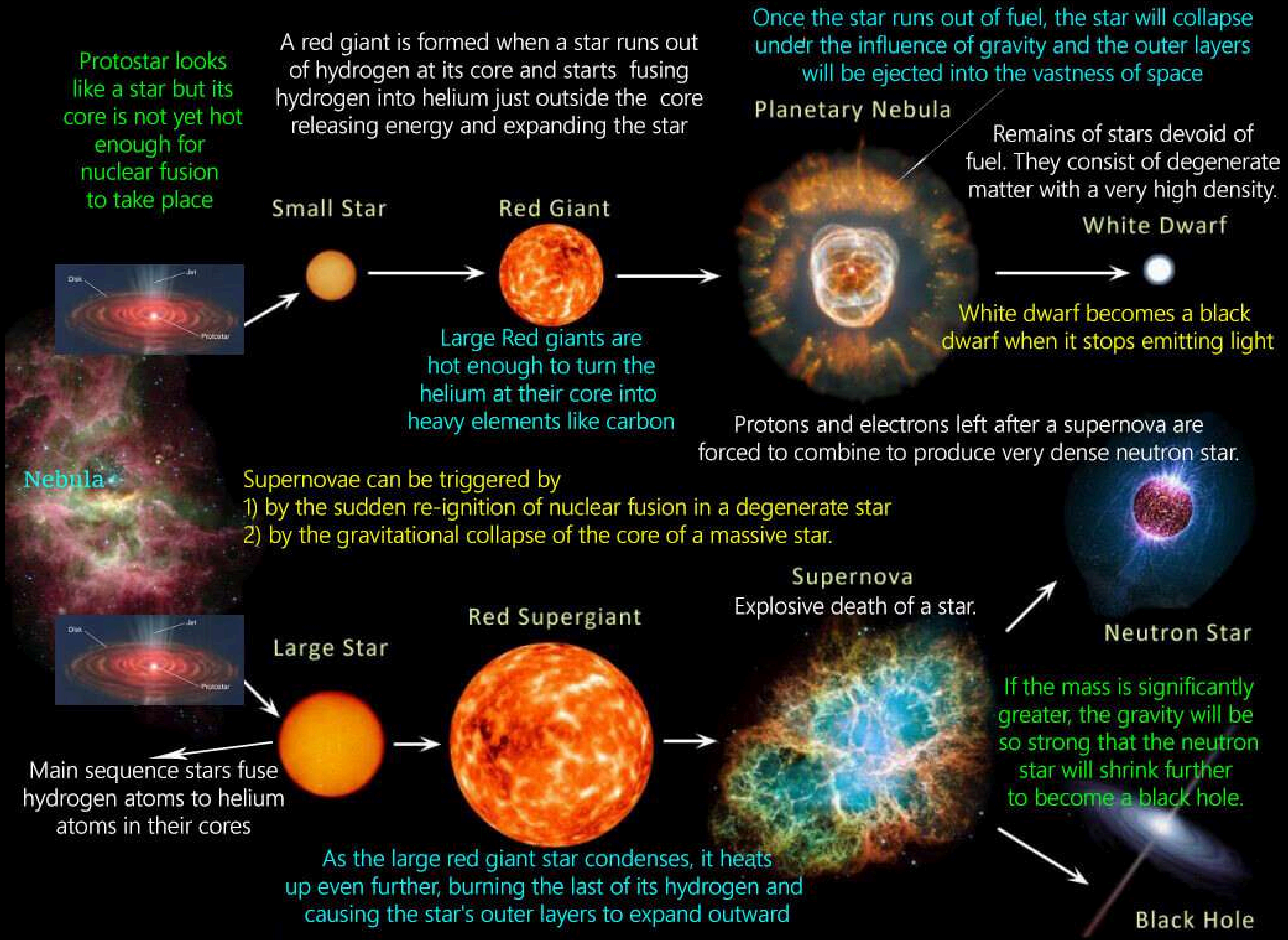
PROTOSTAR
BLUE SUPERGIANT
SUPERNOVA
STELLAR NURSERY
SUPERSHELL
PROTOSTAR
BLUE SUPERGIANT
BLACK HOLE
PROTOSTAR
BLUE SUPERGIANT
TYPE II SUPERNOVA
BLACK HOLE
MASS
BLUE GIANT
NEUTRON STAR
PROTOSTAR
BLUE SUPERGIANT
TYPE II SUPERNOVA
RED GIANT
TYPE IA SUPERNOVA
PROTOSTAR
SUN-LIKE STAR
PLANETARY NEBULA
WHITE DWARF
RED GIANT
PROTOSTAR
RED DWARF
WHITE DWARF
RED DWARF
PROTOSTAR
BROWN DWARF
BROWN DWARF
-
TIME



Protostar looks like a star but its core is not yet hot enough for nuclear fusion to take place
A red giant is formed when a star runs out of hydrogen at its core and starts fusing hydrogen into helium just outside the core releasing energy and expanding the star
Once the star runs out of fuel, the star will collapse under the influence of gravity and the outer layers will be ejected into the vastness of space
Planetary Nebula
Remains of stars devoid of fuel. They consist of degenerate matter with a very high density.
Small Star
Red Giant
White Dwarf
White dwarf becomes a black dwarf when it stops emitting light
Large Red giants are hot enough to turn the helium at their core into heavy elements like carbon
Protons and electrons left after a supernova are forced to combine to produce very dense neutron star.
Nebula
Supernovae can be triggered by
1) by the sudden re-ignition of nuclear fusion in a degenerate star
2) by the gravitational collapse of the core of a massive star.
Supernova
Explosive death of a star.
Red Supergiant
Large Star
Neutron Star
If the mass is significantly greater, the gravity will be so strong that the neutron star will shrink further to become a black hole.
Main sequence stars fuse hydrogen atoms to helium atoms in their cores
As the large red giant star condenses, it heats up even further, burning the last of its hydrogen and causing the star's outer layers to expand outward
Black Hole

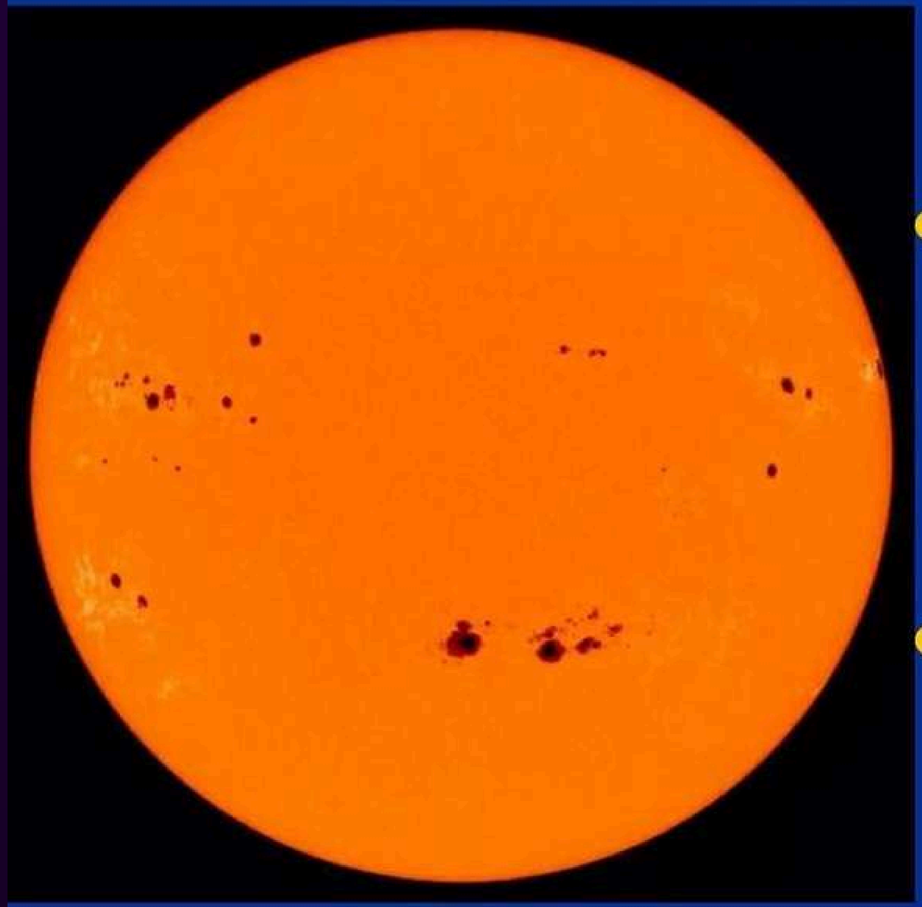
Evolution of stars

- When we talk about stellar evolution we mean on changes that occur in stars as they consume "fuel" , since their birth through their long life, and until they die.
- Understanding the evolution of stars help astronomers to understand:

- The nature and future fate of our Sun.
- The origin of our solar system.
- How we compare our solar system with other planetary systems
- If there could be life elsewhere in the universe.

The Ring Nebula, a dying star.
Source: NASA

Properties of the Sun: the nearest star
and how astronomers measure them – important!



The Sun.
Source: NASA SOHO Satellite

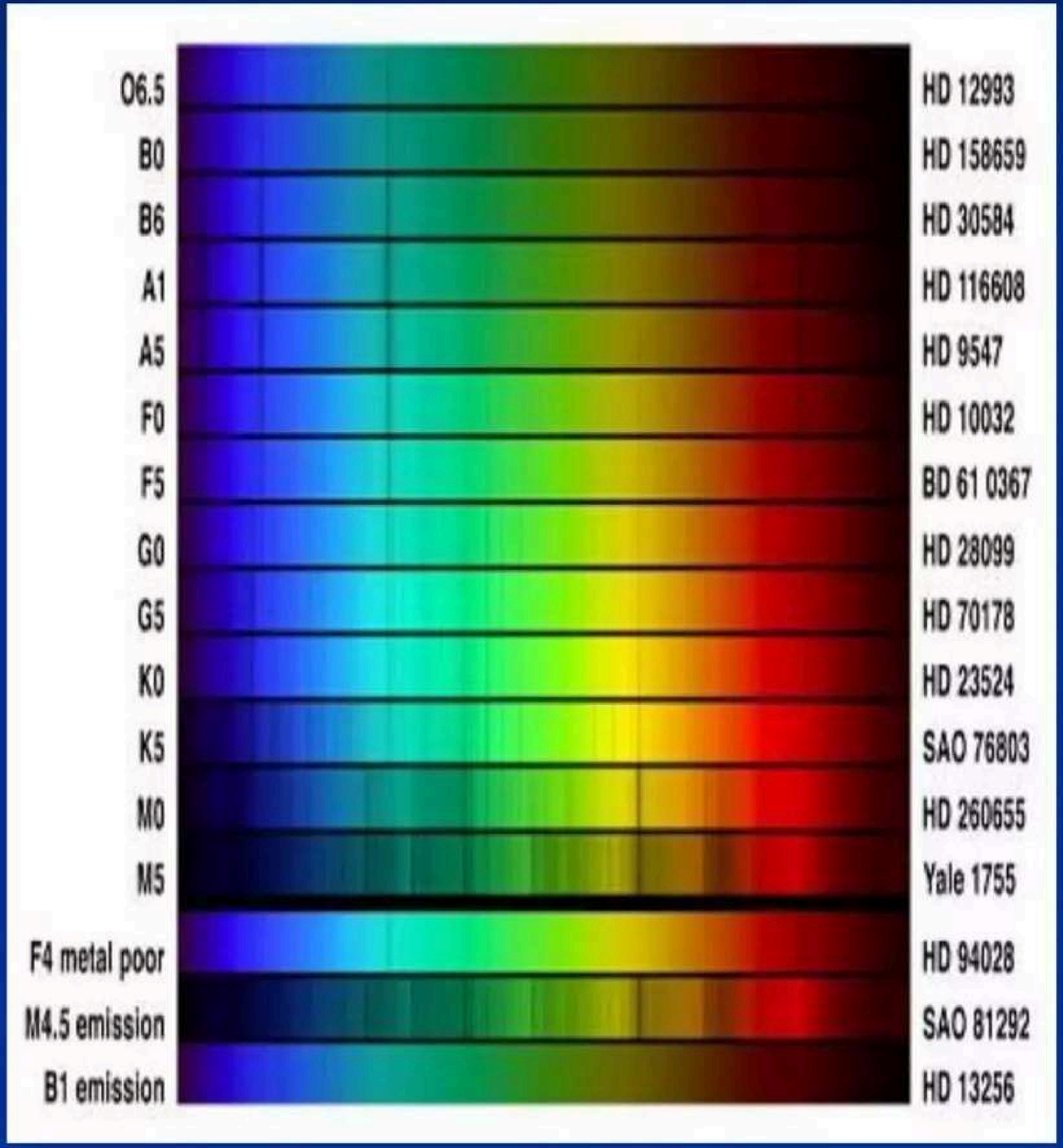
- **Distance: 1.5 x 10^{11} m,** reflecting radar waves from Mercury and Venus
- **Mass: 2 x 10^{30} kg,** measuring the movement of the planets that rotate around the Sun
- **Diameter: 1.4 x 10^{9} m,** from the apparent diameter (angle) of the Sun and its distance
- **Power: 4 x 10^{26} W,** from the distance and the measured power from Earth
- **Chemical composition:** 98% hydrogen and helium, studying its spectrum.

Properties of stars – distant suns
and how astronomers measure them – important!

Orion Constellation.
Source: Hubble, ESA, Akira Fujii

- **Distance:** from the parallax, or from the apparent brightness if the power is known.
- **Power:** from the distance and apparent brightness
- **Surface temperature:** From the color or spectrum
- **Radio:** From the power and surface temperature
- **Mass:** Using the observations of binary stars
- **Chemical composition:** from stellar spectra

The spectra of the stars:
starlight, decomposed into colors



- Astronomers learn about astronomical sources by studying the light that they emit
- The spectrum provides information on the composition, temperature, and other properties of stars

Left: the first 13 spectra of stars with different surface temperatures (the highest on top); the last three spectra were taken from stars with peculiar properties

Stellar Spectra
Source: US National Optical Astronomy Observatory

The Hertzsprung-Russell diagram

There is an order in the properties of stars!

- The Hertzsprung-Russell (HR) diagram, shows the power (brightness) as a function of temperature (spectral class); the ordinate "absolute magnitude" is a logarithmic measure of power.

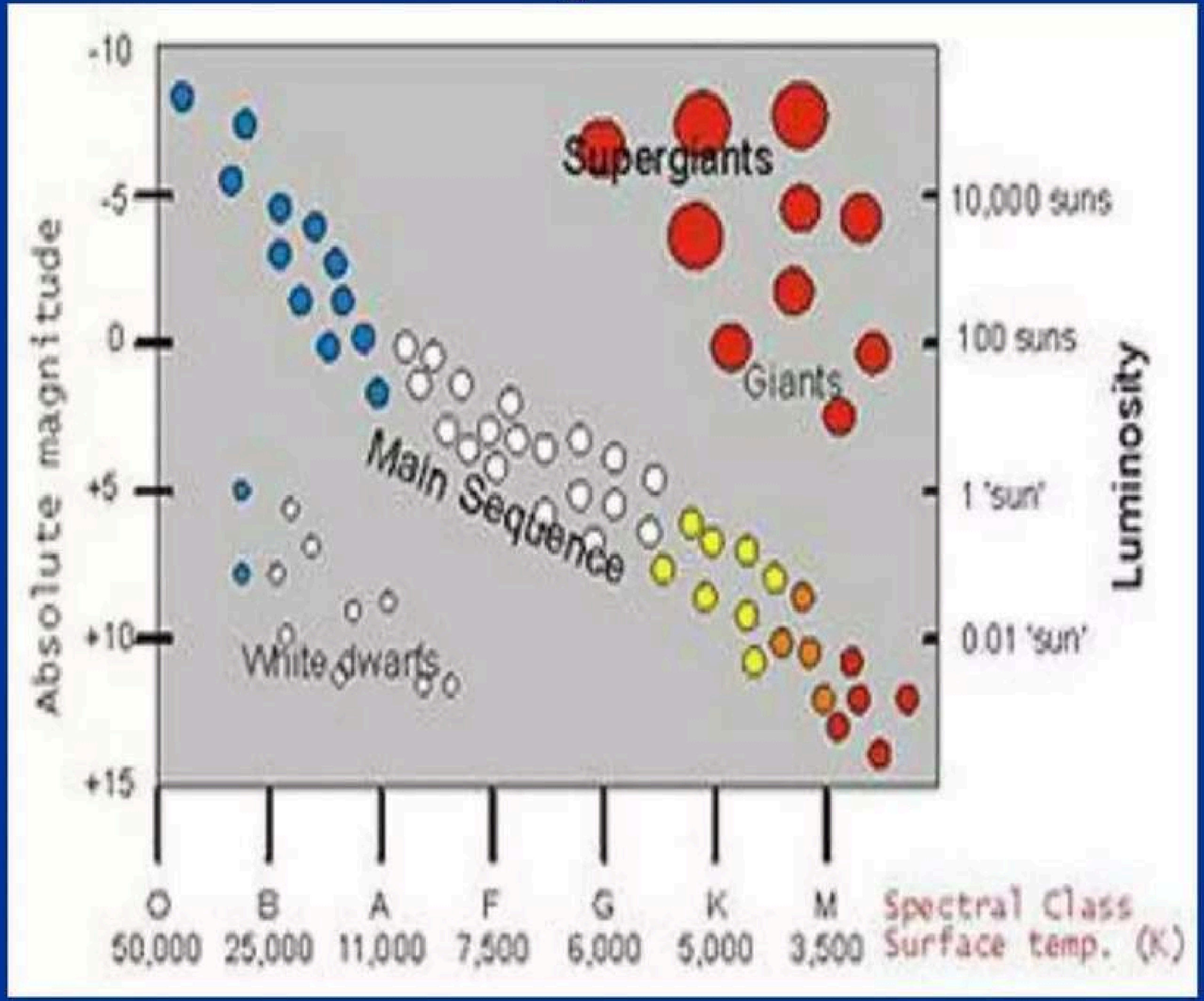
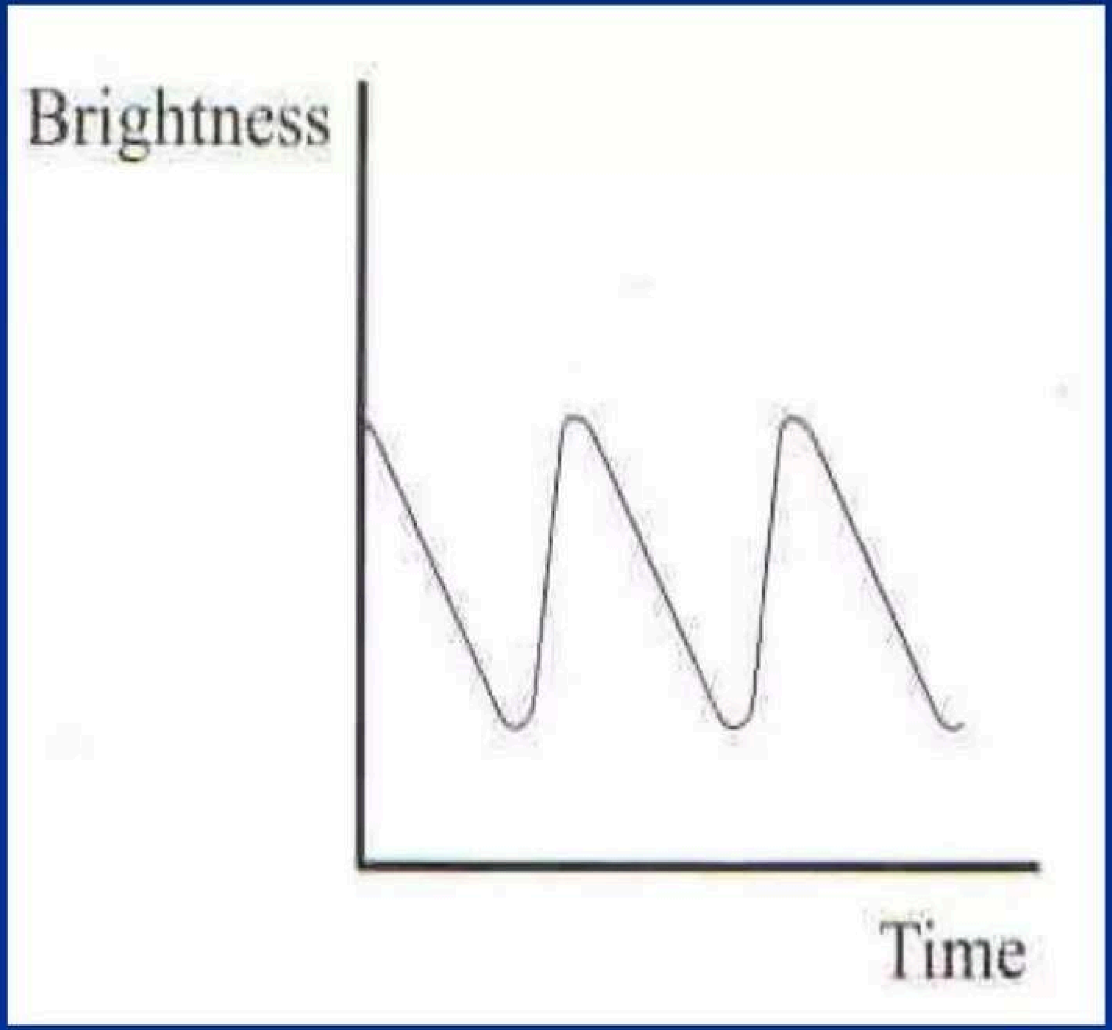


Diagram HR Source: NASA

- Most of the stars lie on the "main sequence": massive stars are hot and have high power (top left), while the small stars have lower masses, are cold and have low power (bottom right)
- The giant stars lie on the top-right part of the diagram, while the white dwarfs are on the bottom-left

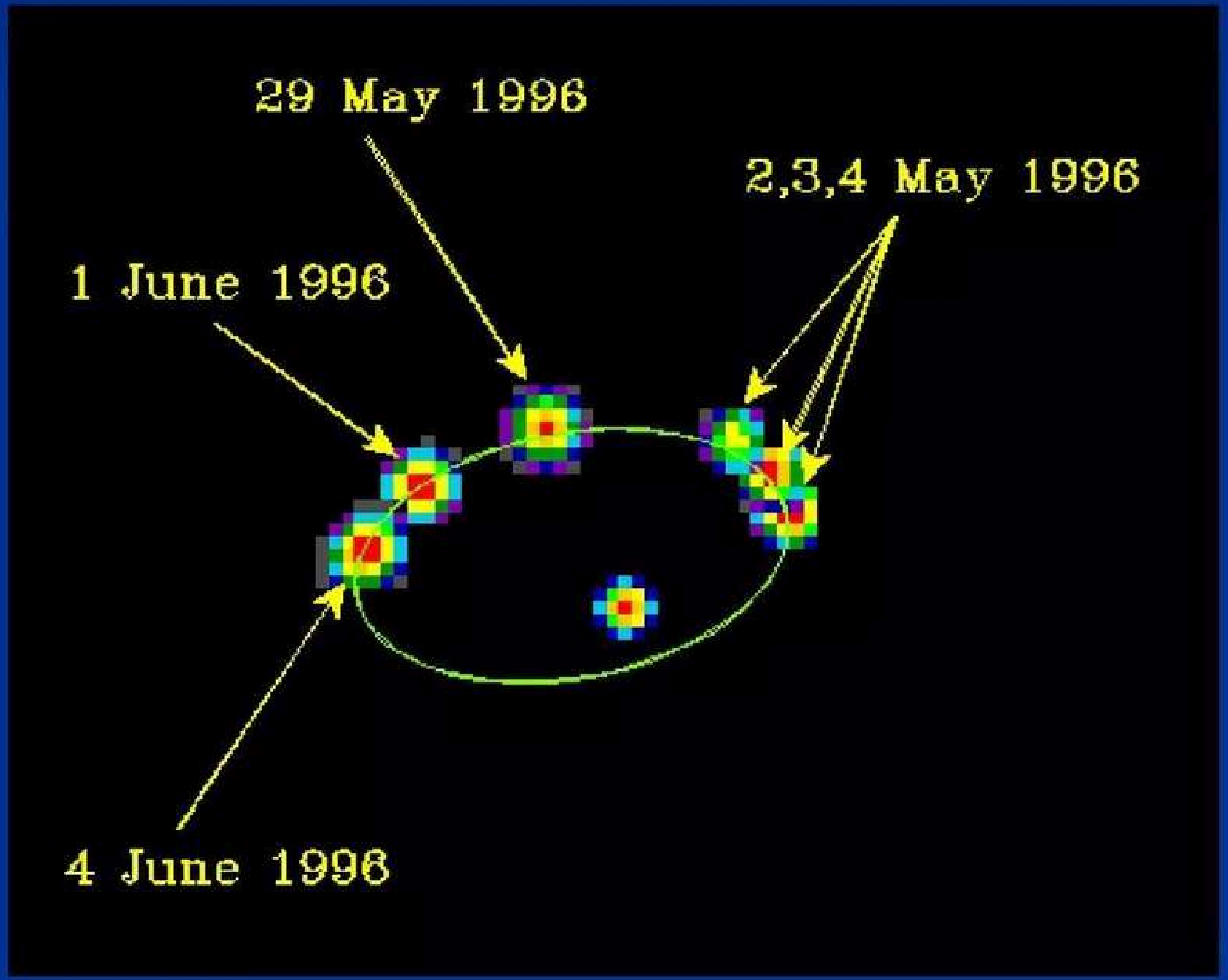
Variable Stars



Light curve: a graph of brightness vs. time.

- Variable stars are stars that change their brightness with time
- Most of the stars are variable; can vary because they vibrate, shine brightly, erupt or explode, or are eclipsed by a companion star or planet
- Variable stars provide important information about the stellar nature and evolution

Binary stars (double) and multiple



Orbital movement of Mizar, in Osa Major.
Source: NPOI Group, USNO, NRL

- Binary stars are pairs of stars that are close together due to gravity, and orbit around themselves. They can be visible directly (as in the image on the left), or detected by their spectra, or an eclipse between the stars.
- They are the most important tool to measure the masses of stars
- Multiple stars are three or more stars that are bonded together due to gravity

Star clusters
"Experiments of nature"

Open Cluster The Pleiades.
Source: Mount Wilson Observatory

- Star clusters are groups of stars that are close each other due to gravity, and move all together through the space
- They were formed at the same time and place, the same material, and are at the same distance, only differ in the mass
- Clusters are samples of stars with different masses but with the same age

What are the Sun and stars made of?

Abundances of chemical elements in the Cosmos: birdseed H (90%), rice He (8%), beans C, N, and O and a few of all the other elements (2%).

- Using spectroscopy and other techniques, astronomers can identify the "prime materials" that stars are made of
- Hydrogen (H) and helium (He) are the most abundant elements, and were formed with the formation of universe
- Heavier elements are million or billion times less abundant. They were formed inside the stars through thermonuclear reactions

THANK YOU

FOR YOUR ATTENTION