



An Introduction to the
Night Skies
Week 4

Presented by:
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Centre

An Introduction to the Night Skies

▶ Week 1

- Opening Discussion Practical astronomy, telescopes, binoculars, star-finders
- Terms and reading materials

▶ Week 2

- An astronomical timeline – prehistory to present day

▶ Week 3

- Astronomical objects and how to find them
- Measurements, Tools and Techniques

▶ Week 4

- An introduction to cosmology
- Software solutions
- Resources



Introduction to Cosmology

The Milky Way from "outside"



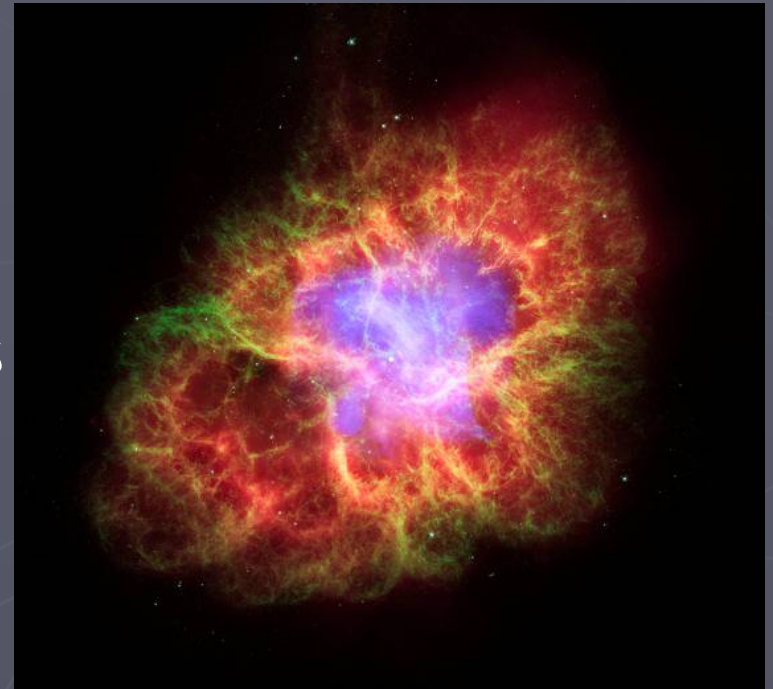
Supernova in 1054 CE (Crab Nebula)

A new “star” appeared in Taurus outshines Venus.

Chinese, Japanese, and Native American observe it. It is not recorded in Europe, most likely as a consequence of lack of study of nature during the Dark Ages.

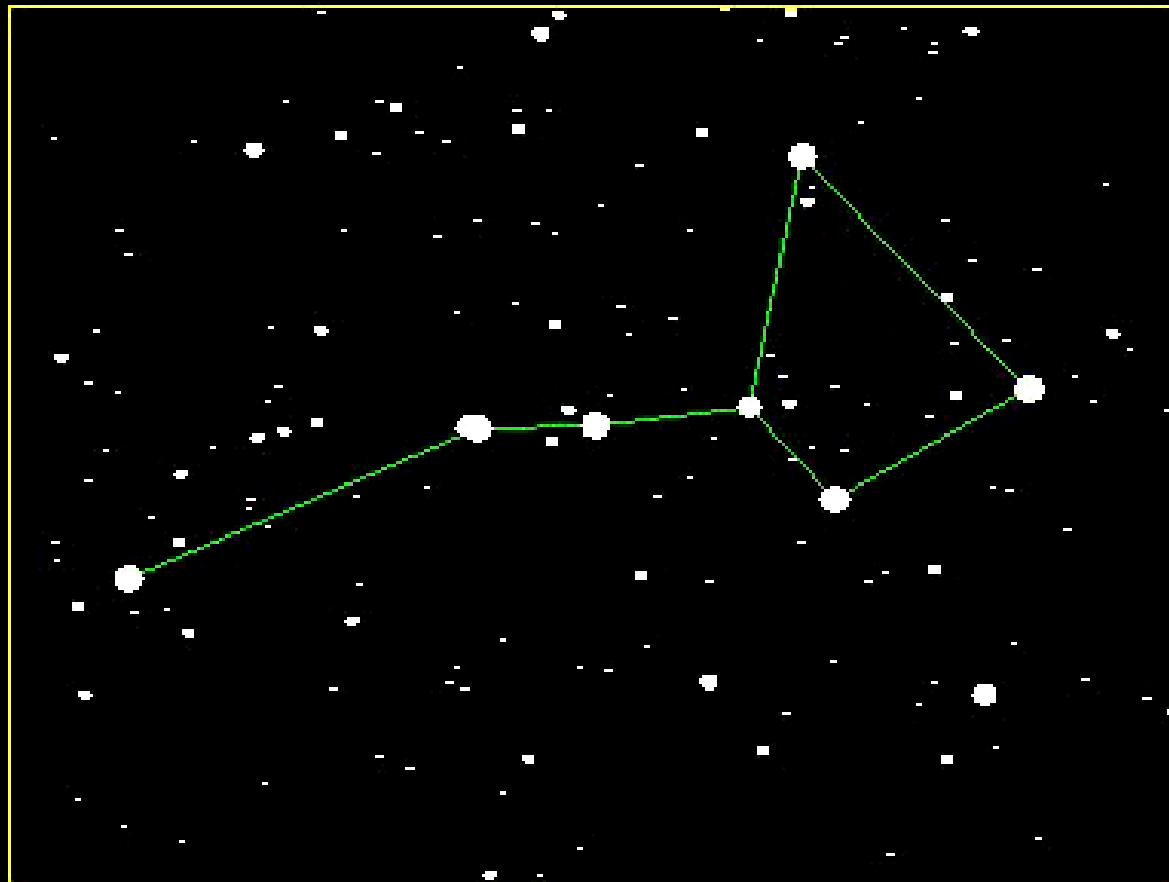
The remnants of this explosion are visible today as the Crab Nebula.

Within the nebula, astronomers have found a pulsar, the ultra-dense remains of a star that blew up.



How the "Big Dipper" stars will move

100000 BC



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"Look! It's the Milky Way!"



Enter the Cosmologists

The Big Bang Theory

- ▶ Currently the dominant theory
- ▶ First iteration proposed by Georges Lemaître in 1927. He observed the red shift in distant nebulae and invoked relativity.
- ▶ Hubble found experimental evidence (1929) – galaxies are moving away from us with speeds proportional to their distance.
- ▶ Theory suggested because it explains the expansion & predicts the existence of cosmic radiation (leftover photons) & nucleosynthesis.
- ▶ 1964 cosmic radiation discovered (Arno Penzias & Robert Wilson who won the Nobel Prize).

Big Bang – what is it?

- ▶ Collapsing cloud of interstellar dust.
- ▶ Cloud dense and cold so collapses under its own self-gravity (cold gas has less internal pressure to counteract gravity).
- ▶ Once collapsed, it immediately warms up because of release of gravitational energy during collapse.
- ▶ All mass and energy concentrated at a geometric point.

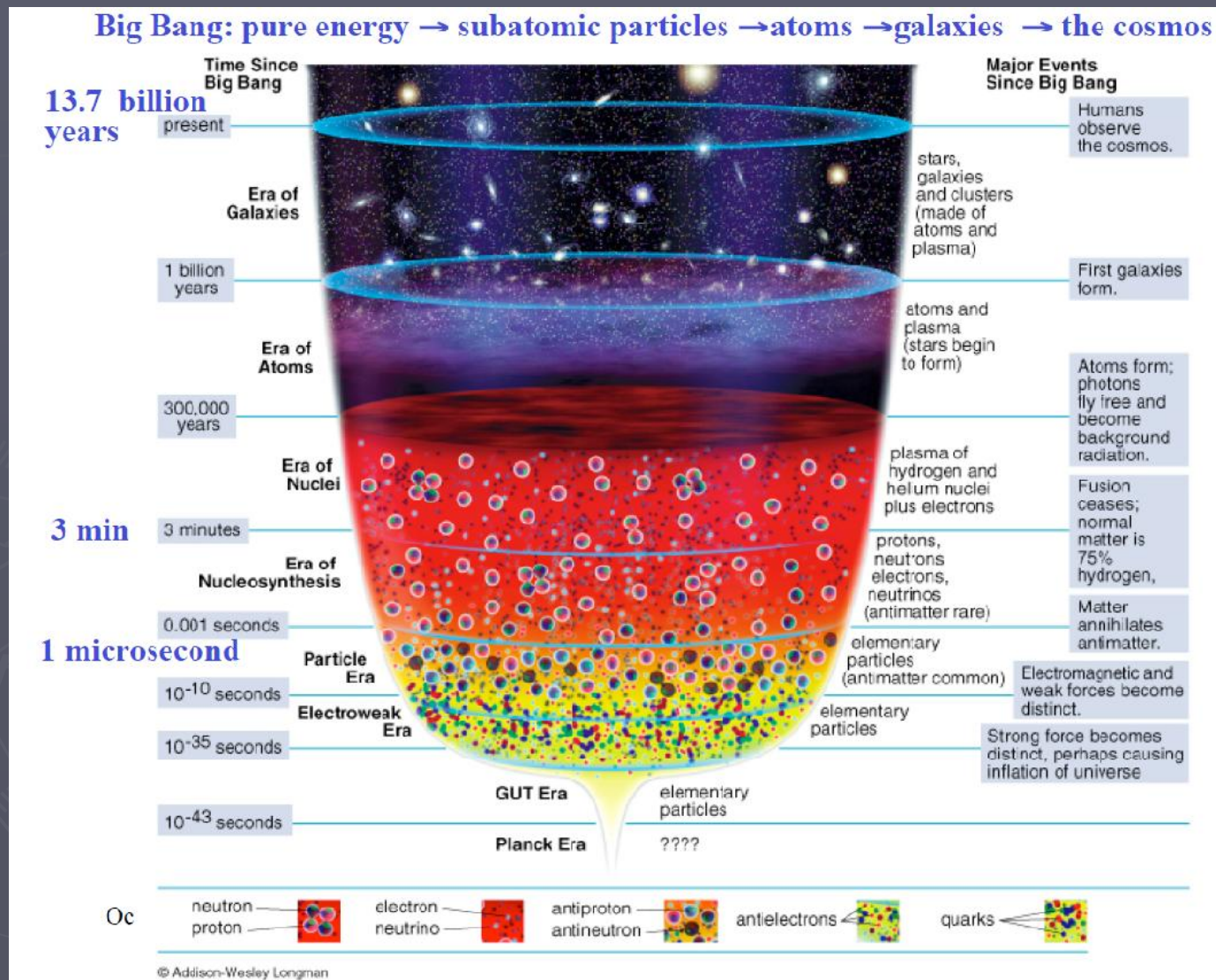
Big Bang

- ▶ ~14 or 15 billion years ago
- ▶ Beginning of space and time
- ▶ Expansion/cooling of universe began
- ▶ Protons and neutrons form
- ▶ Cooling initiated the formation of atoms – first mostly H (the most abundant form of matter in the universe) and He (two lightest elements)

The Universe

- ▶ H₂ and He gas are still the dominant elements in the universe
 - Still about 99% of all material
- ▶ Giant gas and dust clouds form
 - Clouds begin to break into megaclouds
 - Megaclouds organised into spiral and elliptical shapes due to rotational forces
 - Galaxies or nebulae are the gases and dust in the disk
- ▶ Some of the gas in these galaxies broke up into smaller clusters to form stars
 - Gravitational collapse of stars produces heat
 - Initiates fusion reactions that make other elements

Timeline of the Big Bang



Formation of galaxy and stars

- ▶ Galaxy – rotating aggregation of stars, dust, gas and debris held together by gravity
- ▶ Stars are massive spheres of incandescent gases
- ▶ 100's of billions of galaxies in the universe and 100's of billions of stars in the galaxies
- ▶ Sun is a star
- ▶ Sun plus its family of planets is our solar system
- ▶ Our solar system formed about 5 billion years ago

Stars

- ▶ Stars have many features that can be measured by studying the light they emit:
 - temperature
 - spectrum or wavelengths of light emitted
 - brightness
 - luminosity
 - size (radius)
 - mass
 - movement (toward or away from us, rate of spin)

Star - Temperatures and Spectra

- ▶ Some stars are extremely hot, while others are cool. A blue or white star is hotter than a yellow star, which is hotter than a red star.
- ▶ By measuring the strongest color or wavelength of light emitted by the star you can calculate its temperature.
- ▶ A star's spectrum can also tell you the chemical elements that are in that star because different elements absorb light at different wavelengths.

Star – Brightness and Luminosity

- ▶ When you look at the night sky, you can see that some stars are brighter than others as we noticed with Orion.
- ▶ Two factors determine a stars' brightness:
 - luminosity - how much energy it puts out in a given time
 - distance - how far it is from us

Stars - Classification

- ▶ In the early 1900s, two astronomers, Annie Jump Cannon and Cecilia Payne, classified the spectra of stars according to their temperatures.
- ▶ Cannon actually did the classification and Payne later explained that a star's spectral class was indeed determined by the temperature.

Stars - Classification

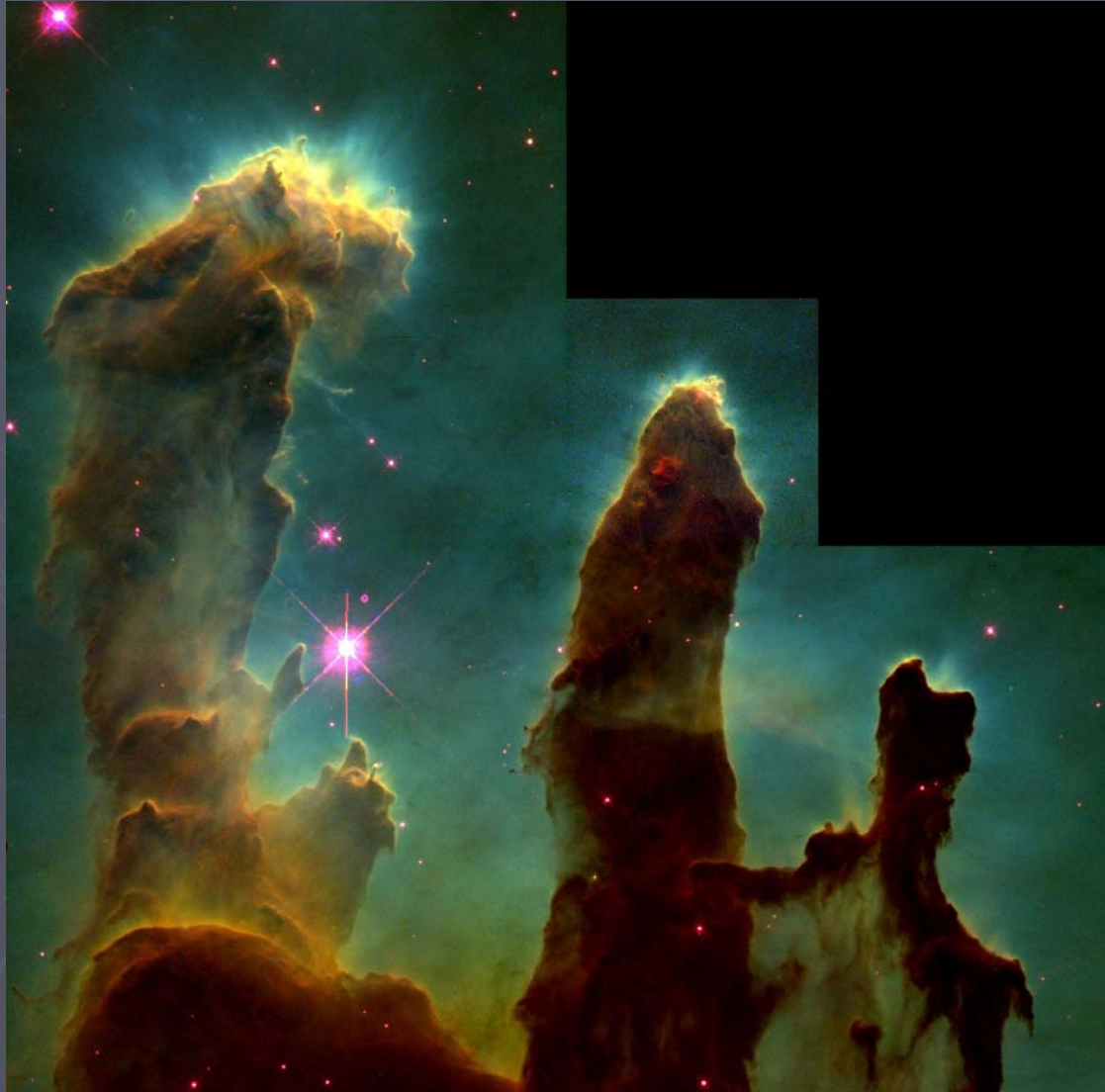
Spectral Classes of Stars

Spectral Class	Color	Ave.Temp. (K)	Familiar Examples
O	Blue-violet	30,000	Mintaka (delta Orionis)
B	Blue-white	20,000	Rigel, Spica
A	White	10,000	Vega, Sirius
F	Yellow-white	8,000	Canopus, Procyon
G	Yellow	6,000	Sun, Capella
K	Orange	4,000	Arcturus, Aldebaran
M	Red-orange	3,000	Antares, Betelgeuse

How stars form

- ▶ New stars form from large, cold (10 degrees Kelvin) clouds of dust and gas (mostly hydrogen) that lie between existing stars in a galaxy.
- ▶ Clumps form inside the cloud, and collapse inward drawing gas inward by gravity.
- ▶ The collapsing clump compresses and heats up.
- ▶ The collapsing clump begins to rotate and flatten out into a disc.
- ▶ The disc continues to rotate faster, draw more gas and dust inward, and heat up.
- ▶ After about a million years or so, a small, hot (1500° Kelvin), dense core forms in the disc's center called a proto-star.

Gas clouds



“Pillars of Creation”

**A star forming region
in the Eagle Nebula (M16)**

Image from Hubble Space Telescope

How stars form

- ▶ When the temperature of the proto-star reaches about 7 million degrees Kelvin, hydrogen begins to fuse to make helium and release energy.
- ▶ If the proto-star gains sufficient mass and the temperature gets hot enough for sustained fusion, then the proto-star has a massive release of gas in the form of a jet called a bipolar flow.
- ▶ If the mass is not sufficient, the star will not form, but instead become a **brown dwarf**.

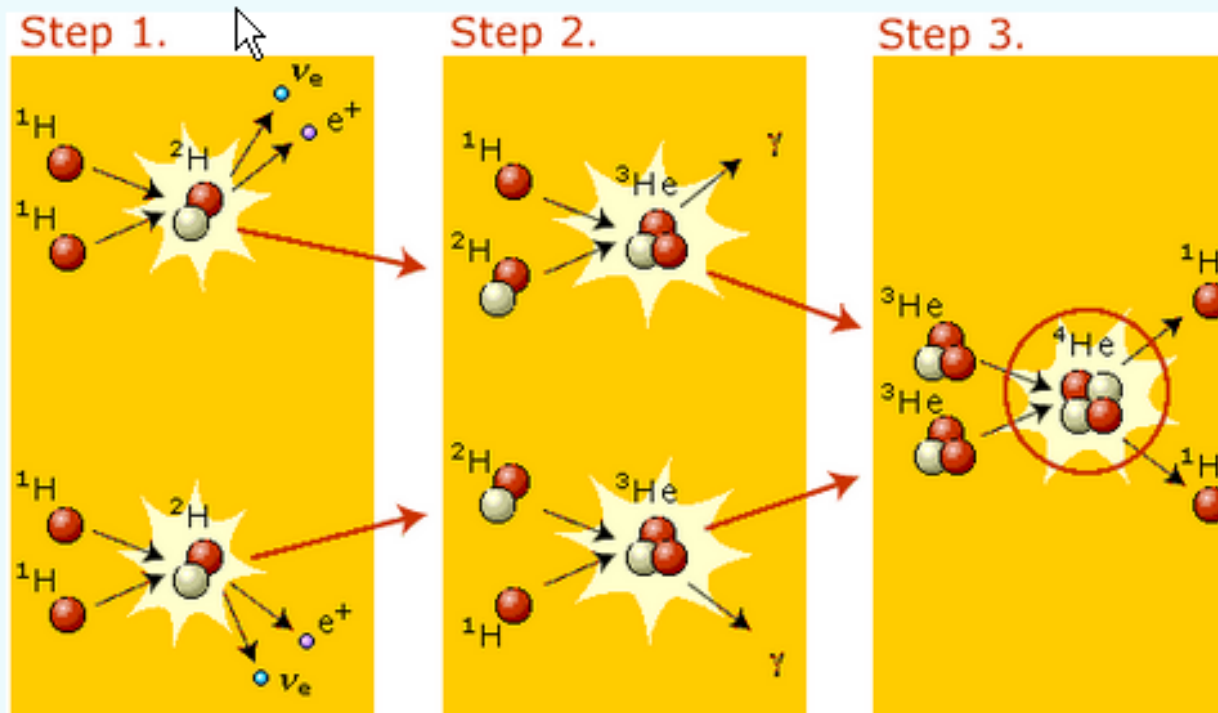
How stars form

- ▶ The gas release clears away gas and dust from the young star. Some of this gas and dust may later collect to form planets.
- ▶ The young star is now stable in that the outward pressure from hydrogen fusion balances the inward pull of gravity. The star enters the **main sequence**.
- ▶ This is how our Sun formed.

How stars form

- ▶ Eventually the gas (H and He nuclei) is hot enough to produce collisions where nuclear fusion can take place. In the centre of the sun the temperature is about 15 million °C and it is even hotter in other stars.
- ▶ Protons (hydrogen nuclei) are making fusion reactions and produce helium according to the proton-proton cycle or to the carbon cycle, proposed by Hans Bethe in 1939. Bethe received the 1967 Nobel Prize in Physics.

The nuclear fusion reactions



Step 1. Hydrogen + Hydrogen \longrightarrow Deuterium + Positron + Neutrino

Step 2. Deuterium + Hydrogen \longrightarrow Helium-3 + Photon

Step 3. Helium-3 + Helium-3 \longrightarrow Helium-4 + Hydrogen + Hydrogen

Supernova explosion

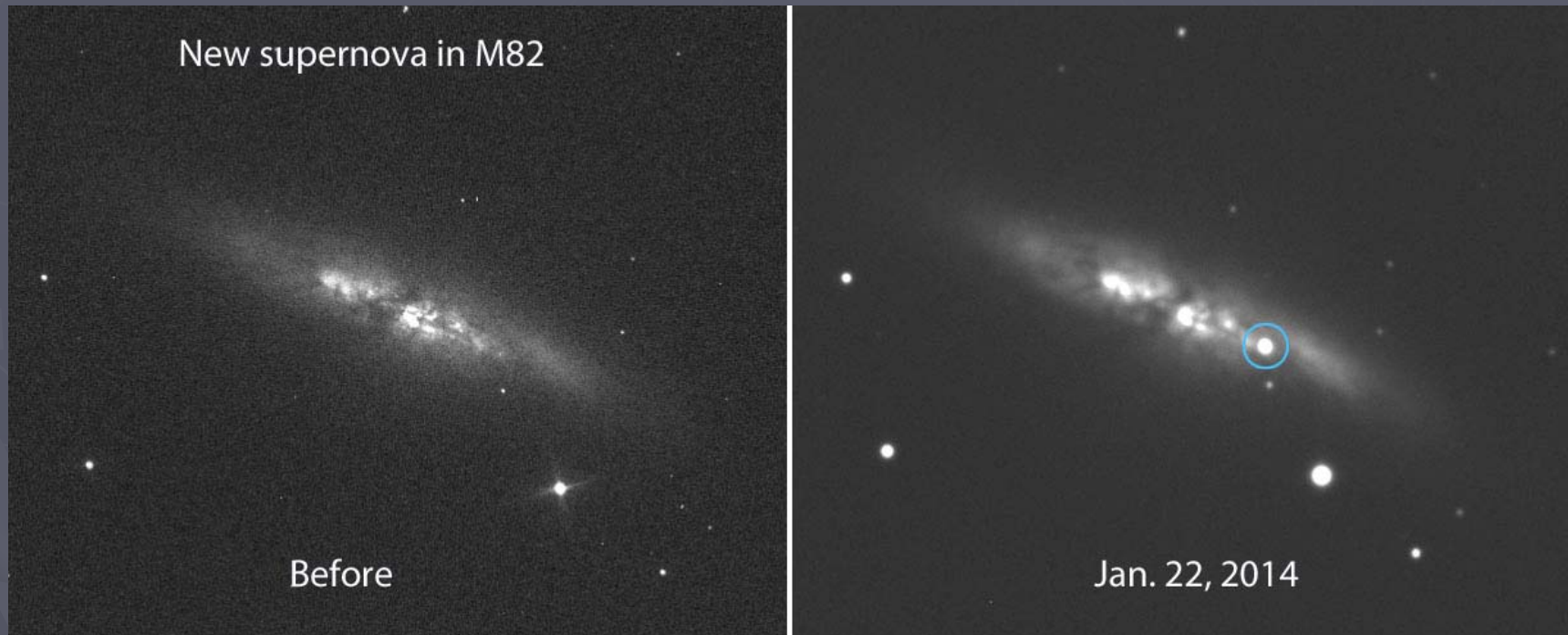
- ▶ When the hydrogen in a star is exhausted, the star contracts due to gravitation. The temperature increases, and helium can start to fuse. This process continues until iron is formed.
- ▶ If the mass is large enough the gravitation is so strong that the star collapses and becomes a neutron star (all protons being transformed into neutrons) or a black hole. This explosion is called a supernova.

Life cycle of a star



Source: www.nobelprize.org

One Wednesday, 11.5 million light years ago....

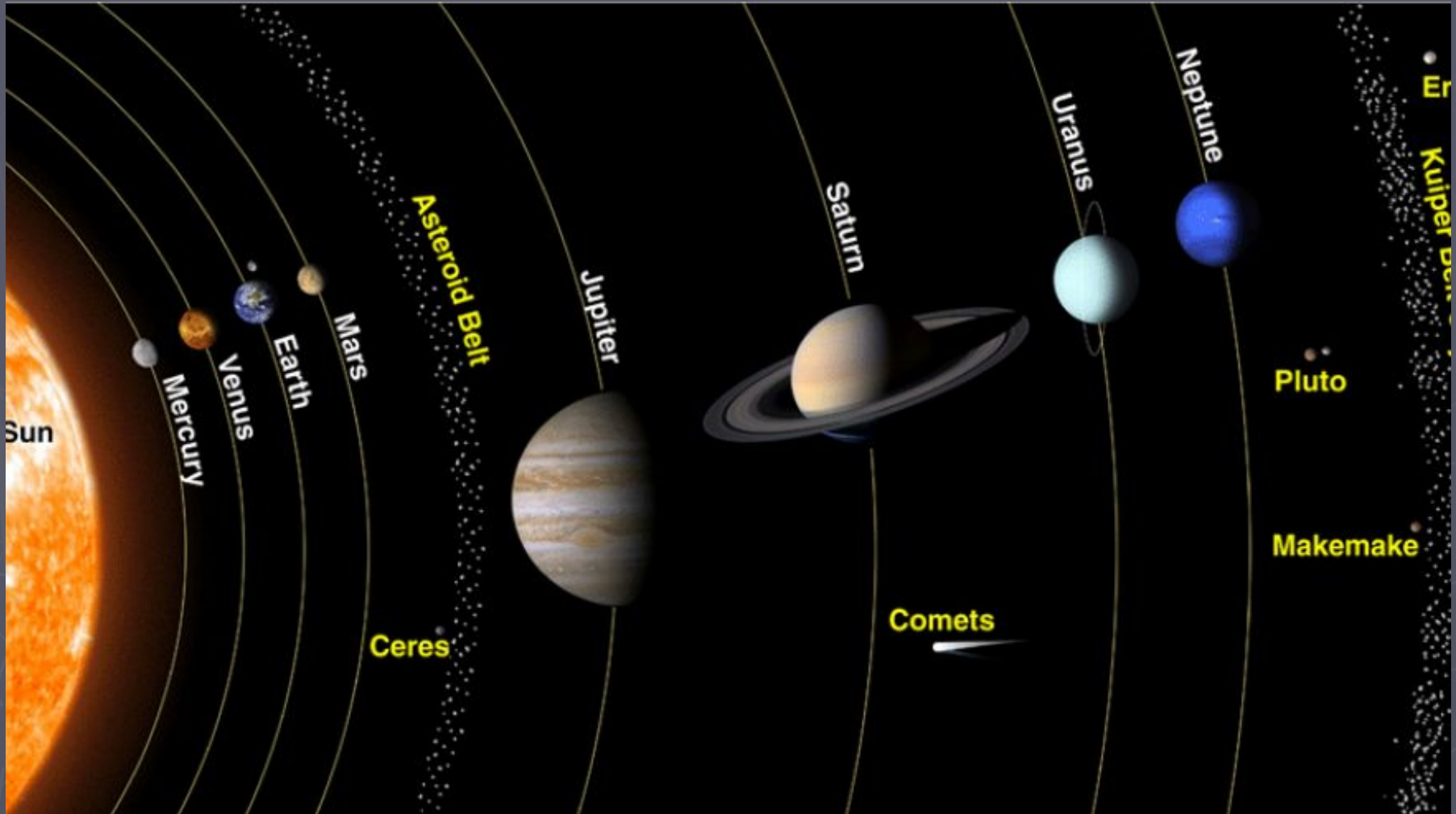


Supernova are happening all the time, somewhere in the universe, occasionally we spot one.

Solar systems

- ▶ A solar system is a star plus any planets, comets, asteroids, or other small objects that orbit the star.
- ▶ Our own Solar System consists of the Sun, the eight planets, Pluto, the asteroids, all the comets that we know, else that is orbiting the sun.
- ▶ The next-closest solar system to our own, the alpha Centauri system, is four light years away.

Solar systems



Source NASA

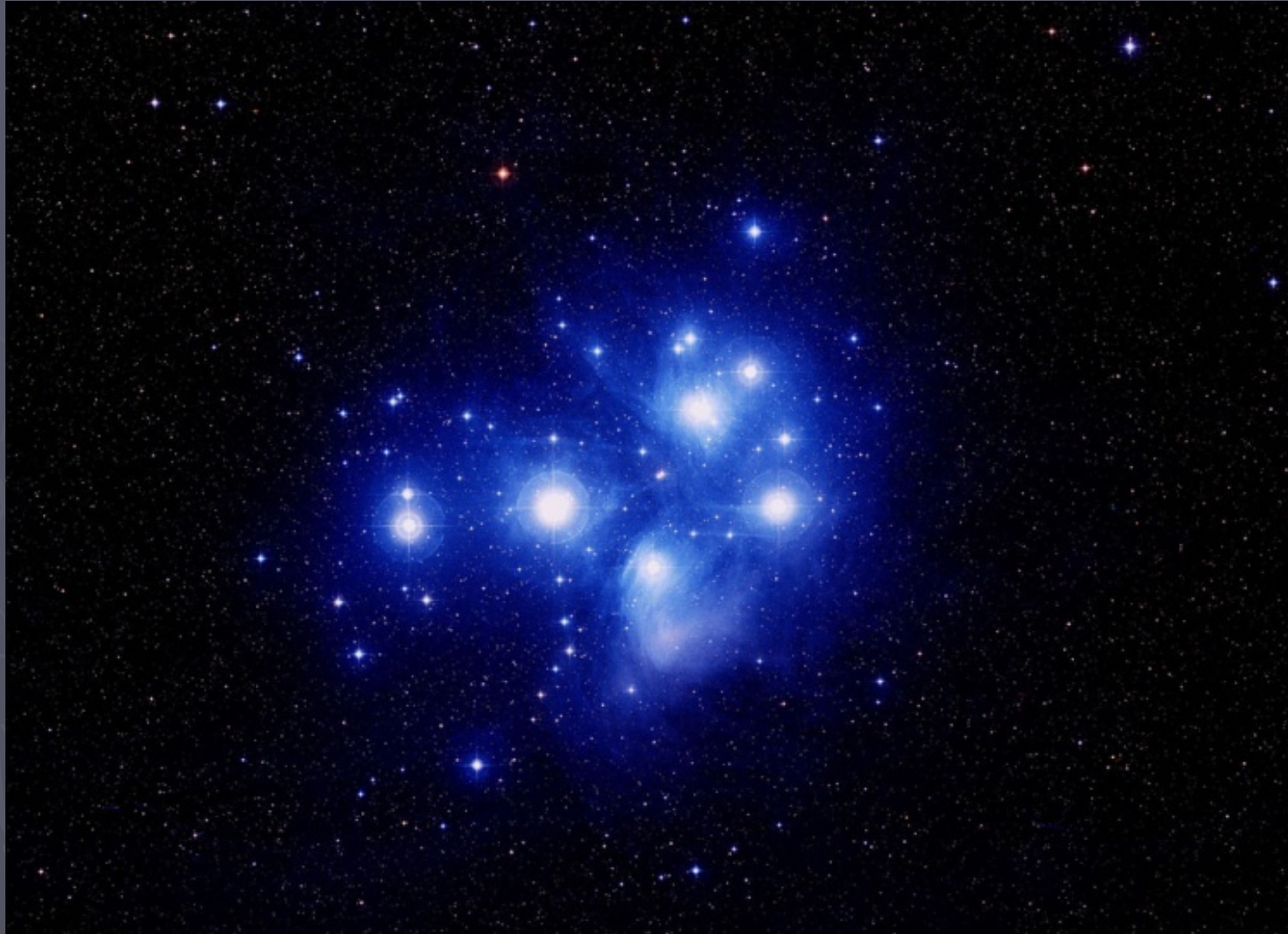
Star Clusters

- ▶ Clusters are groups of stars, loosely bound by gravity. All of the stars in a star cluster were born at the same time out of the same cloud of gas.
- ▶ There are two types of star clusters:
 - Globular clusters are tight groups of hundreds of thousands of very old stars
 - Open clusters are more loosely clustered groups of stars, generally contain fewer than a few hundred members, and are often very young.

Globular clusters (M13 in Hercules)



Open clusters (The Pleiades, M45)



Nebula

- ▶ A cloud of gas and dust in space
 - May have stars inside
- ▶ Most of the ones we see are inside our Milky Way Galaxy
- ▶ There are several different types:

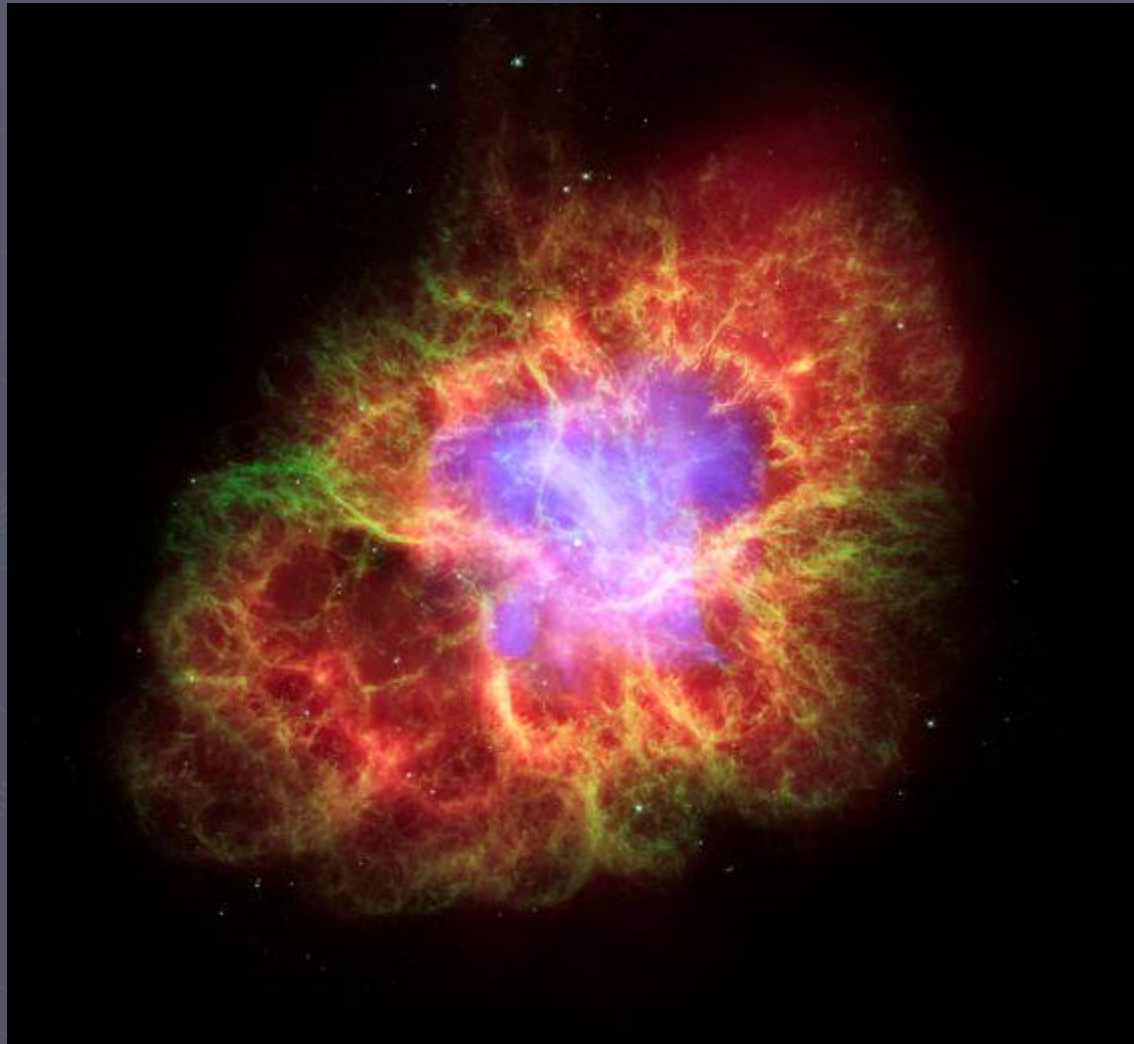
The Orion Nebula



Emission Nebula,
-The hot gas is emitting light

<http://hubblesite.org/>

Supernova remnant (Crab Nebula, M1)



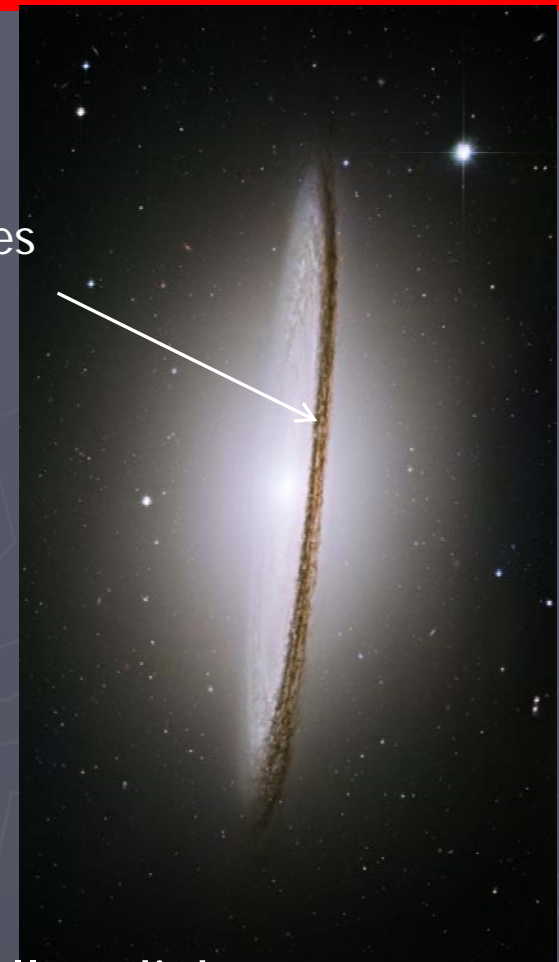
Galaxies

- ▶ Galaxies are huge collections of solar systems and star clusters, often containing billions or trillions of stars. Galaxies are held together by gravity.
- ▶ Our Solar System and *every single star we see* in the sky are part of the much larger Milky Way galaxy. The Milky Way is about 100,000 light years across.
- ▶ There are several different types:

Galaxies (ARP273 in the Andromeda constellation)



Galaxy structure



The dust lane is a thinner area than the stellar disk
The thin gas/dust disk is the fuel for the next generation of stars

Galaxy types - Elliptical



M104
Sombrero Galaxy

Galaxy types - Irregular

NGC 1427A

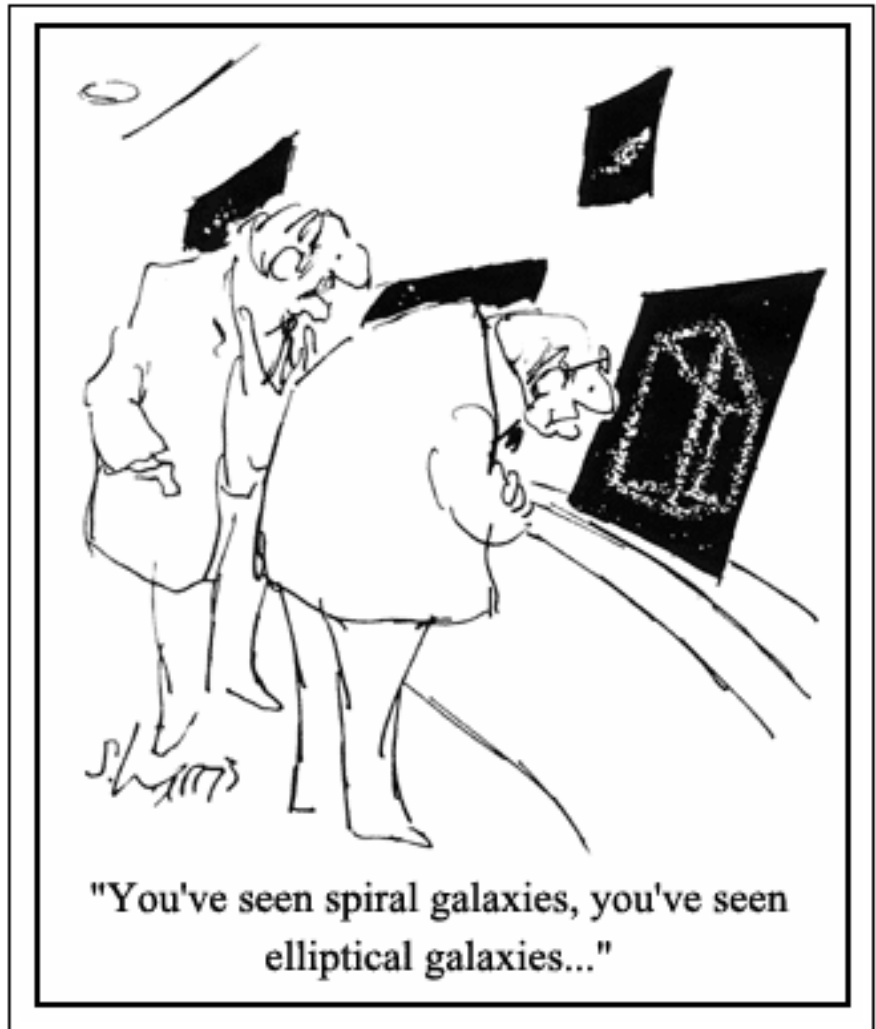


Cosmology by Sidney Harris

THE UNIVERSE
THE BIG
(ACTUAL



TRYING TO DESCRIBE
SIZE OF THE BIG



"You've seen spiral galaxies, you've seen
elliptical galaxies..."

Credits

- ▶ Some material included in this presentation was taken from online sources. Particular credit for key slides describing the BigBang to:
 - ▶ Old Dominion University, Norfolk, VA
- ▶ Also to:
 - RASC Canada
 - New Mexico State University, Las Cruces, NM

A vibrant astronomical image of a galaxy, likely a star-forming region, featuring a dense field of stars in various colors including bright blue, orange, and red, set against a dark cosmic background. The text "Thank You!" is overlaid in the center in a bold, yellow font.

Thank You!