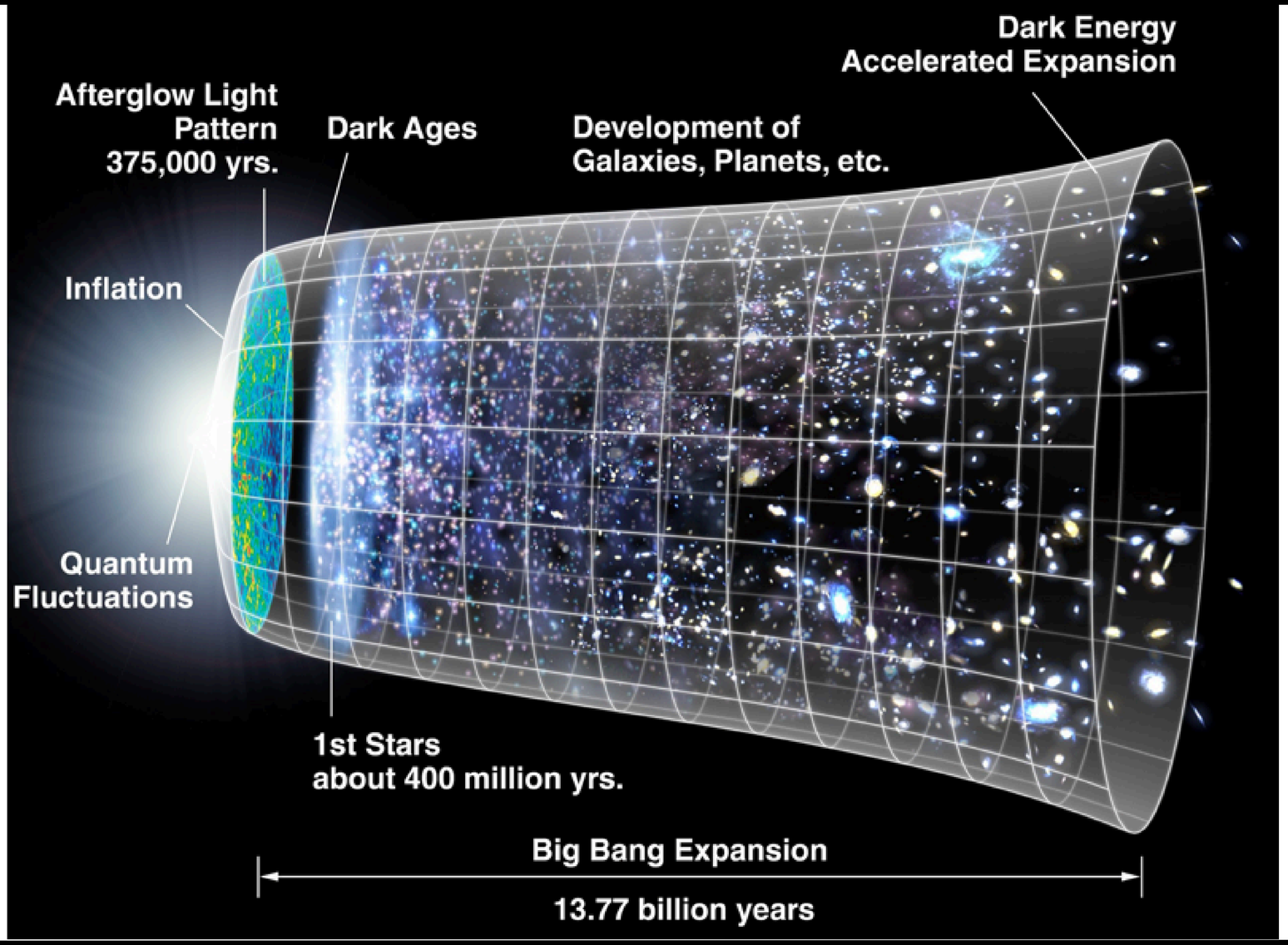
Chapter 25. Stars and the Universe



New Words

protostar, red giant, red supergiant, supernova, supernovae, bulge, recede, recession, scatter, spectrum, spectra, spectroscopy, luminosity

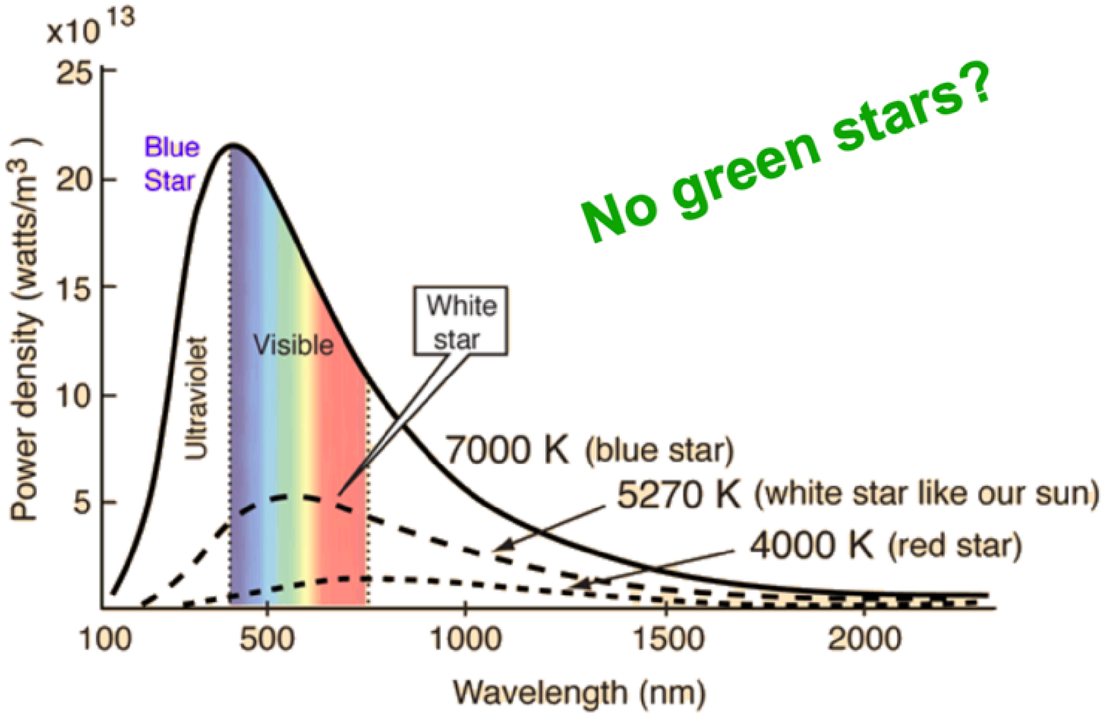
The Sun

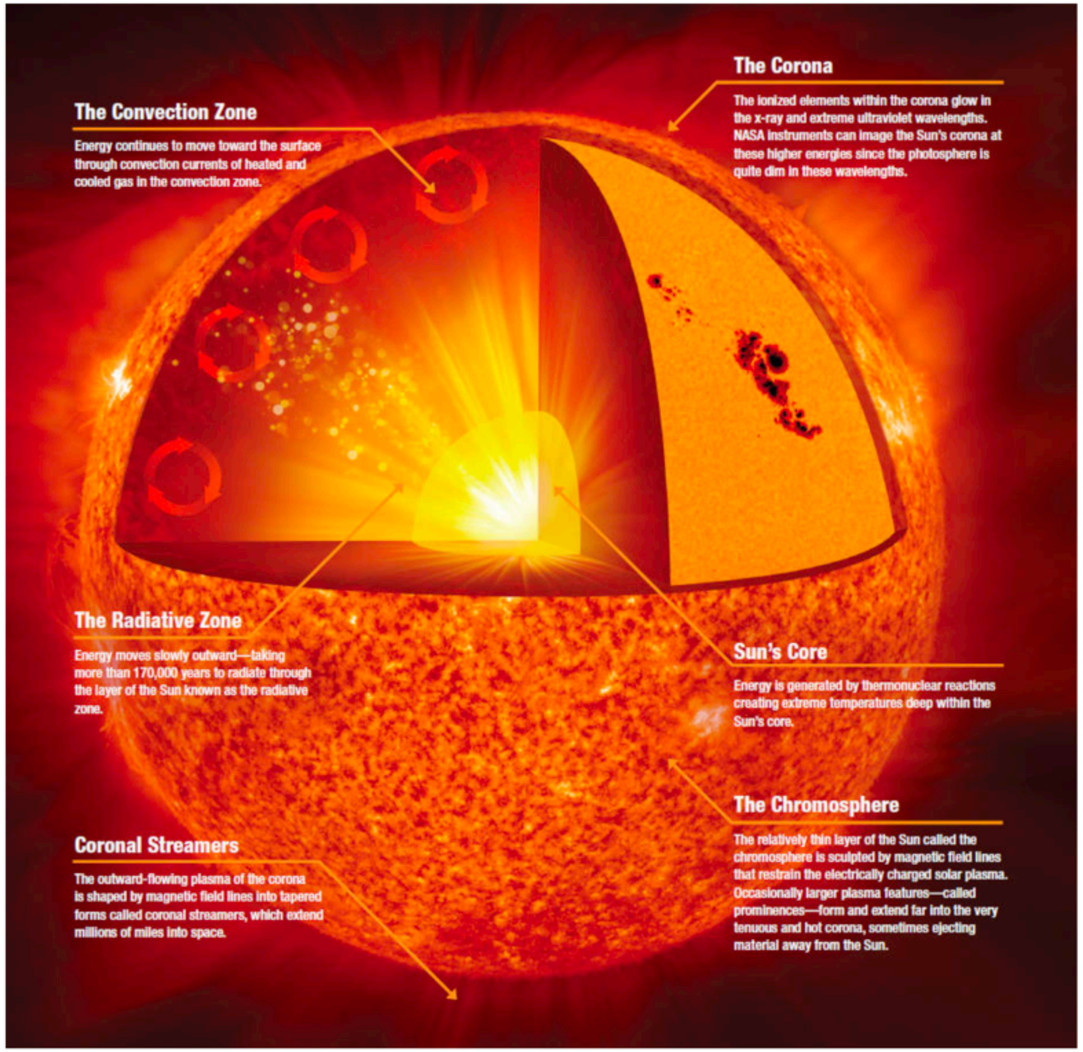
Size: Medium size

Elements: 75% H, 24% He, 1% the rest(O, C)

Spectrum: 50%IR, 40%visible light, 10%UV

(mostly UV absorbed by earth's atmosphere)





Exercise

Which frequencies of electromagnetic waves are emitted from the Sun?

A Infrared

B Ultraviolet

C X-rays

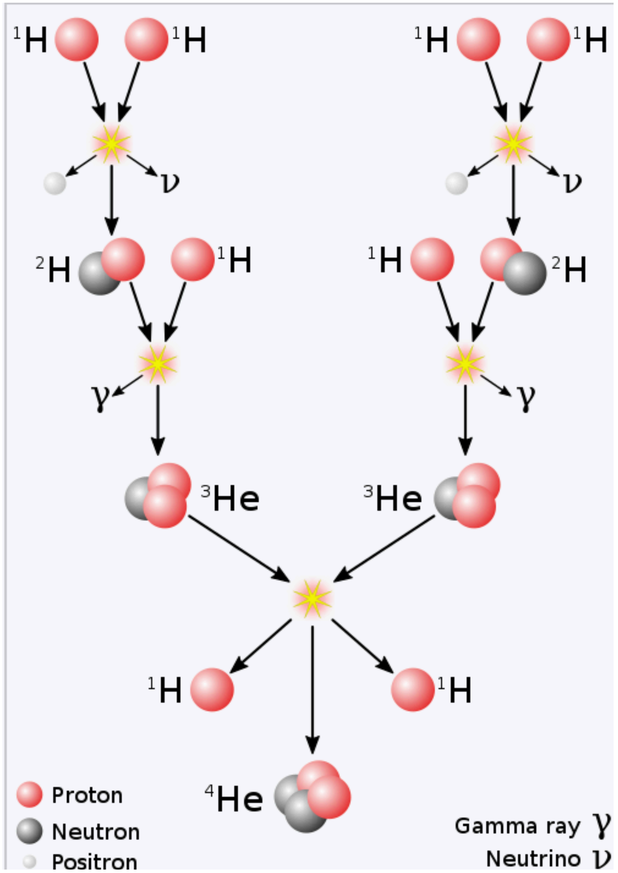
D All of the above

The Sun

Where does solar energy come from?

Nuclear fusion(core):
Temperature: core , surface 5800k;
Ions

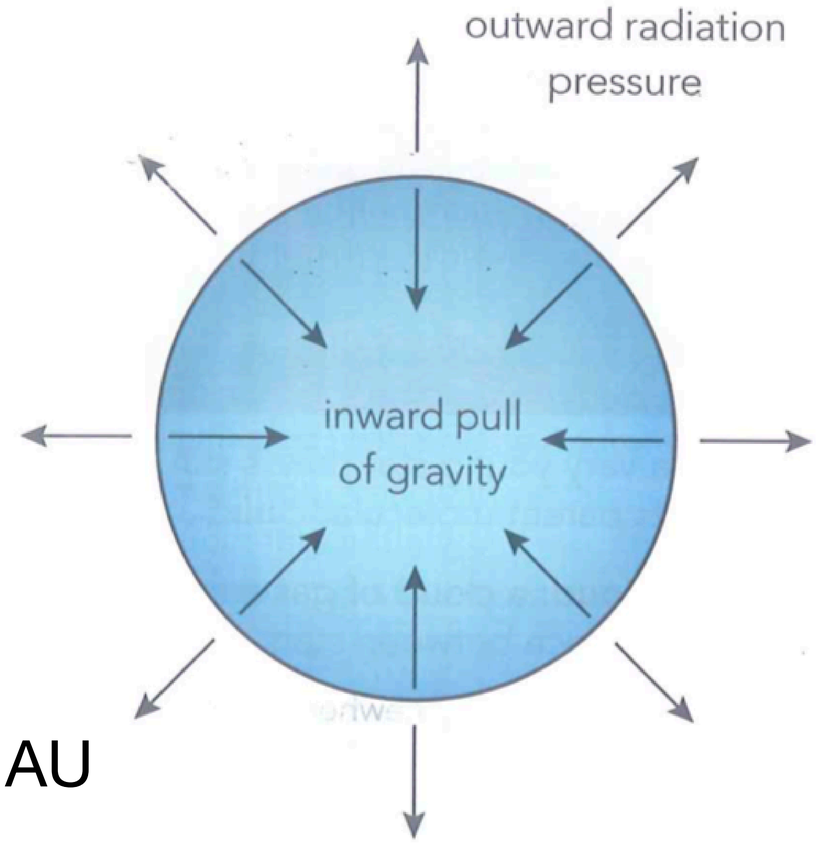
Sun: 75% H, 24% He => still young star, 4.6billion years old



The Sun

Stable star: not collapsing or expanding, same size;

gravity = radiation pressure



radiation pressure: hot body radiates heat, heat exert a force

Solar mass: $M_\odot \approx 2 \times 10^{30}\, kg$

Habitable zone: Sun-Earth distance=$1.5 \times 10^{11}\, m$= 1 AU
Liquid water, too close: vapor, too far: ice

AU: Astronomical Unit

The Sun

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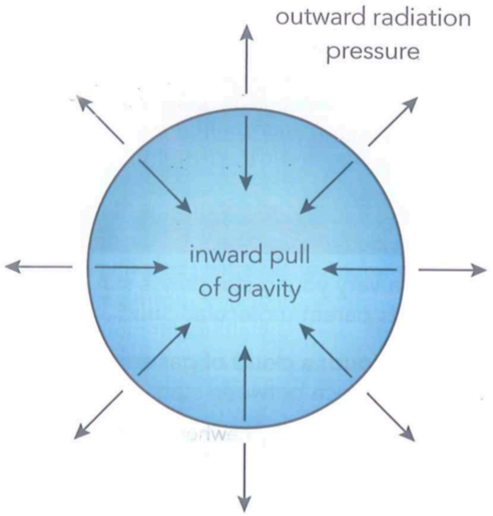


Nuclear fusion

Stable star: (inward) gravity **=** (outward)radiation pressure

Solar mass: $M_\odot \approx 2 \times 10^{30}\, kg$

Exercise

How long does it take light from the Sun to reach Earth?

Exercise

From which two elements is the Sun mostly made?

Exercise

Name the process that makes stable stars, such as out Sun, shine.

Imagine that the Earth orbited a star that gives off most of its energy in the ultraviolet region of the spectrum. Discuss whether our eyes would still have evolved to see visible light.

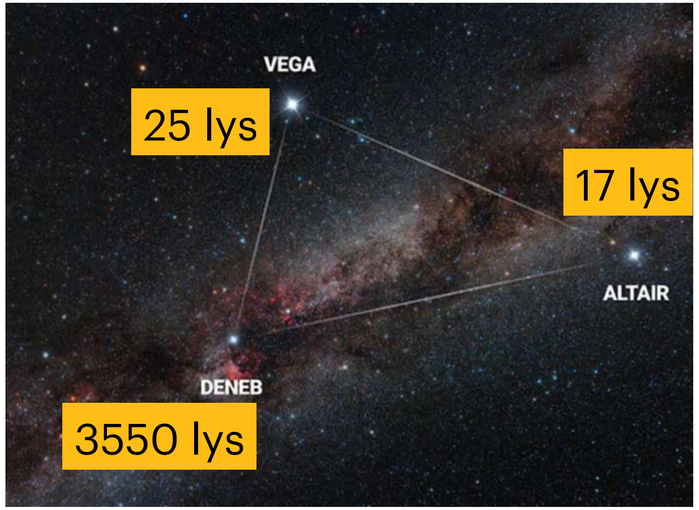
Stars and Galaxies

Do you know any other stars apart from Sun? And how far are they?

Vega: $2.4 \times 10^{17}\, m$ 25 lys

Closest star:proxima centauri, $4.0 \times 10^{16}\, m$

4.2 lys



light year: the **distance** that light travels through **space** in one year

$$3.0 \times 10^8 \times 365.25 \times 24 \times 3600 = 9.5 \times 10^{15}\, m$$

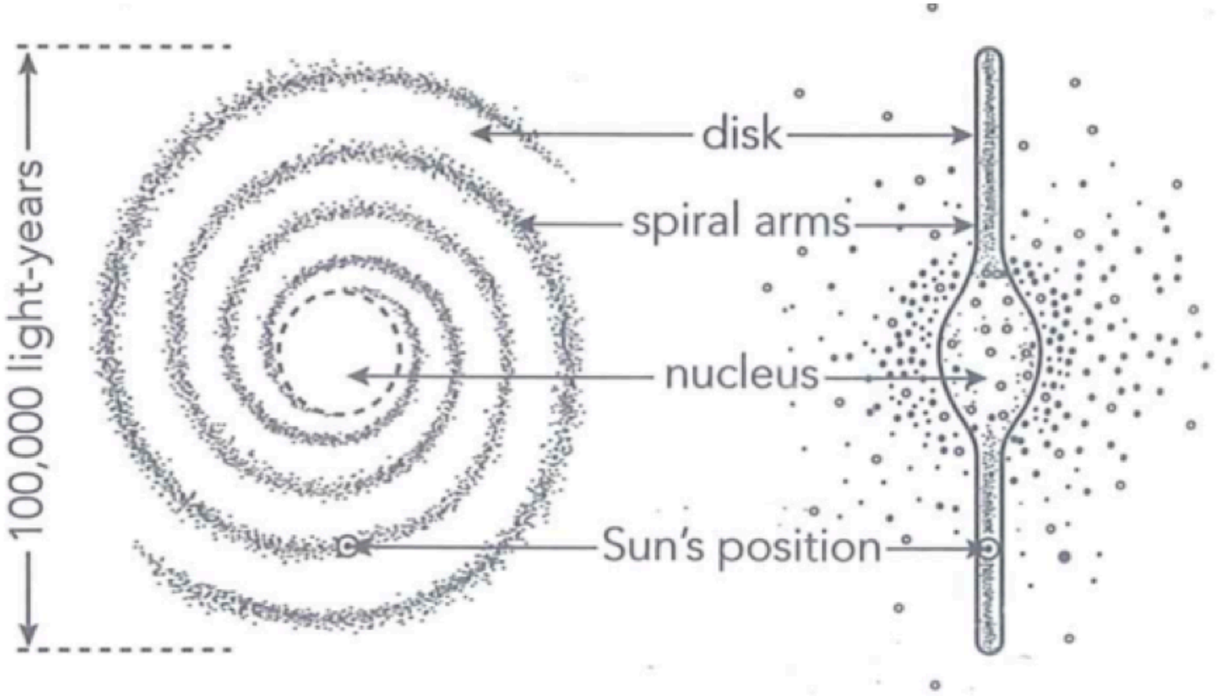
e.g. proxima centauri: means the star you see is 4.2 yrs ago. 「所见即过去」

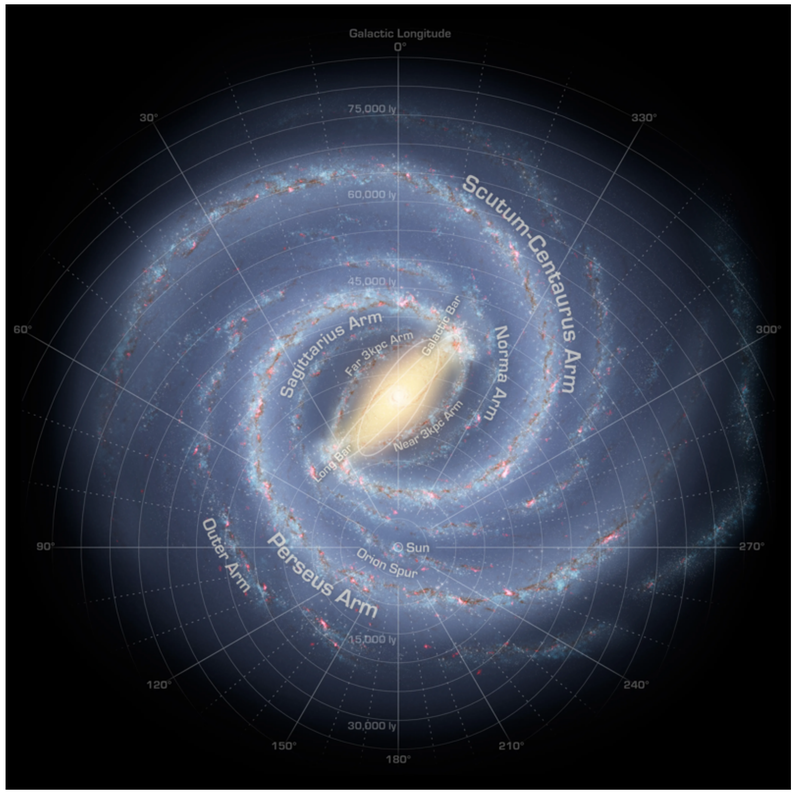
Stars and Galaxies

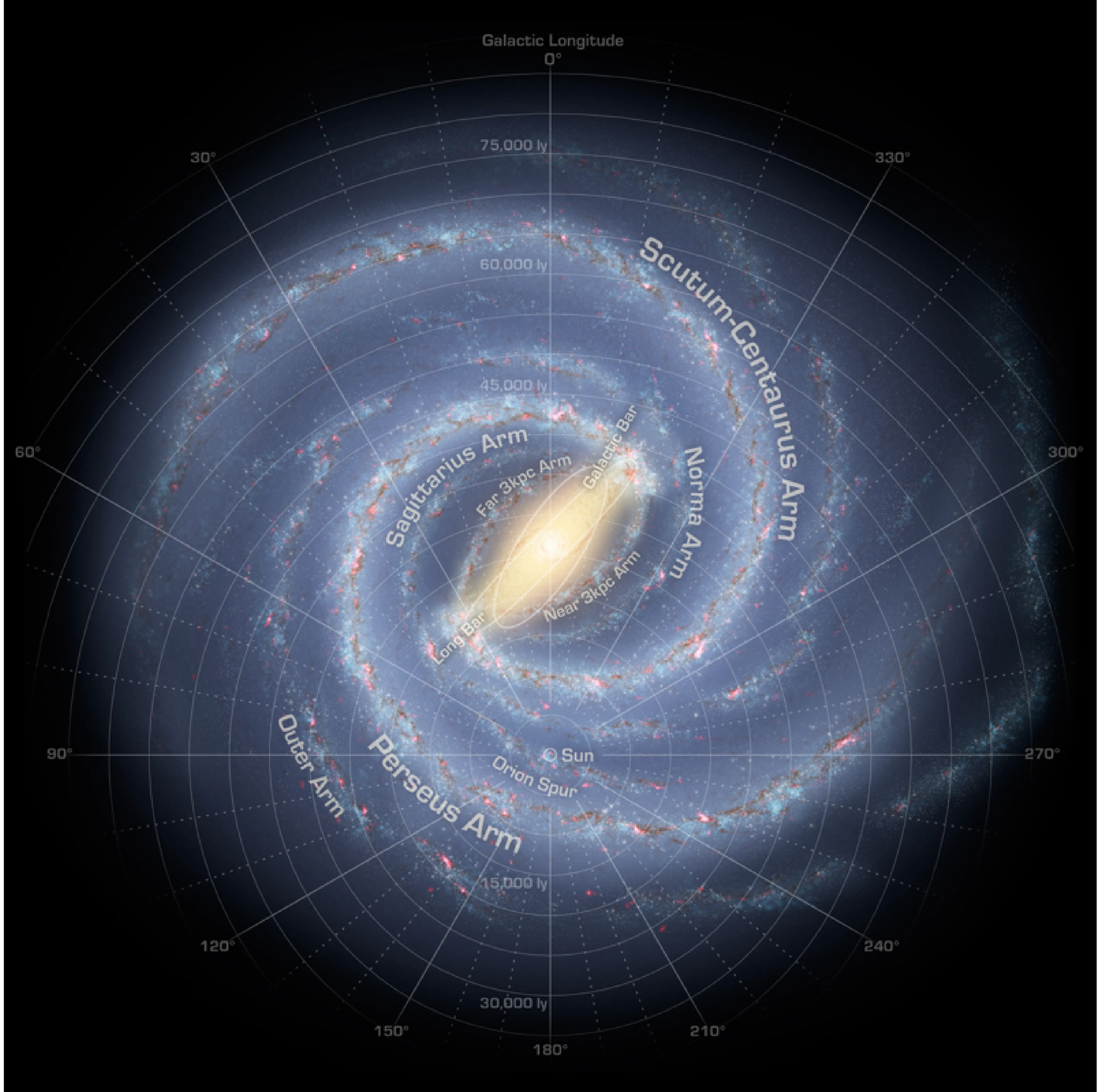
Galaxies: star groups pulled by gravity

Our own galaxy: **Milky Way** **diameter**: 100,000 lys thickness: 2000 lys

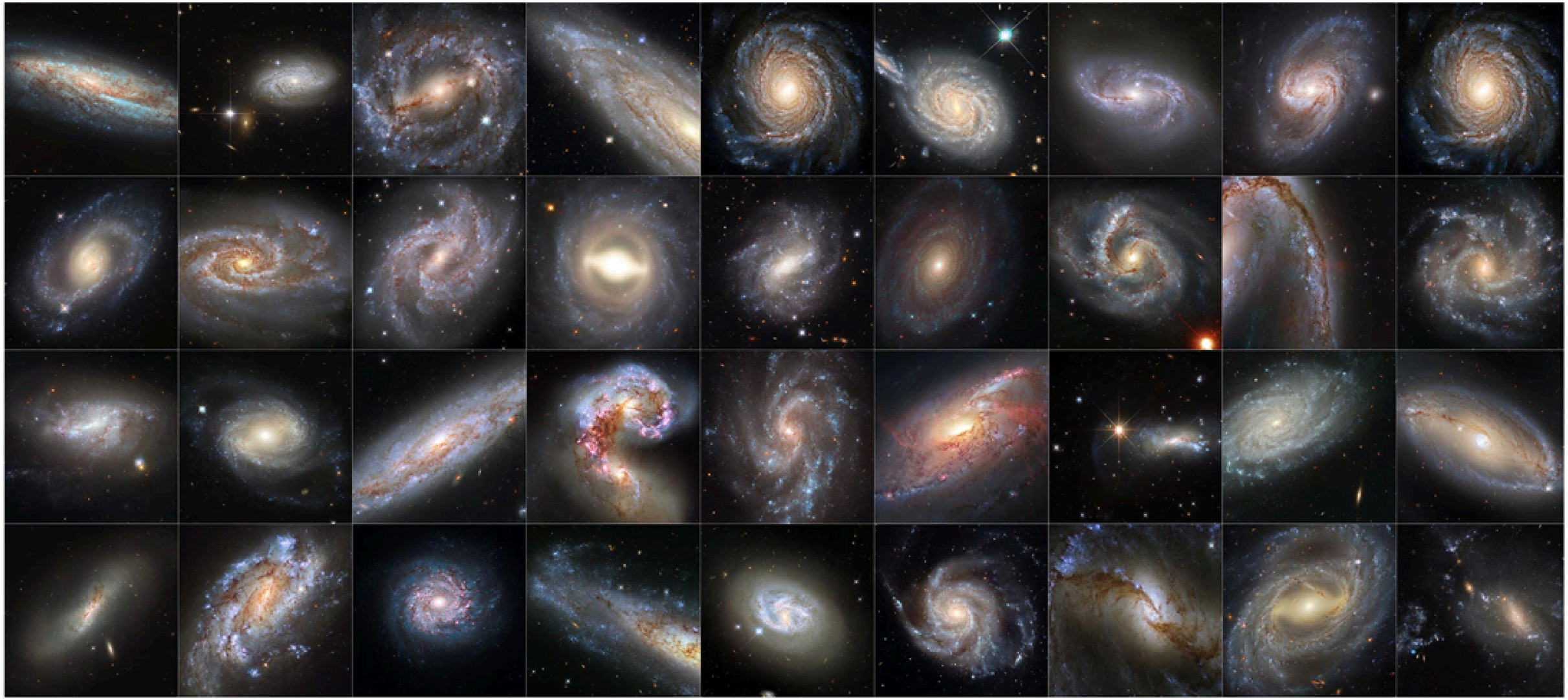
200 **billion** stars spinning



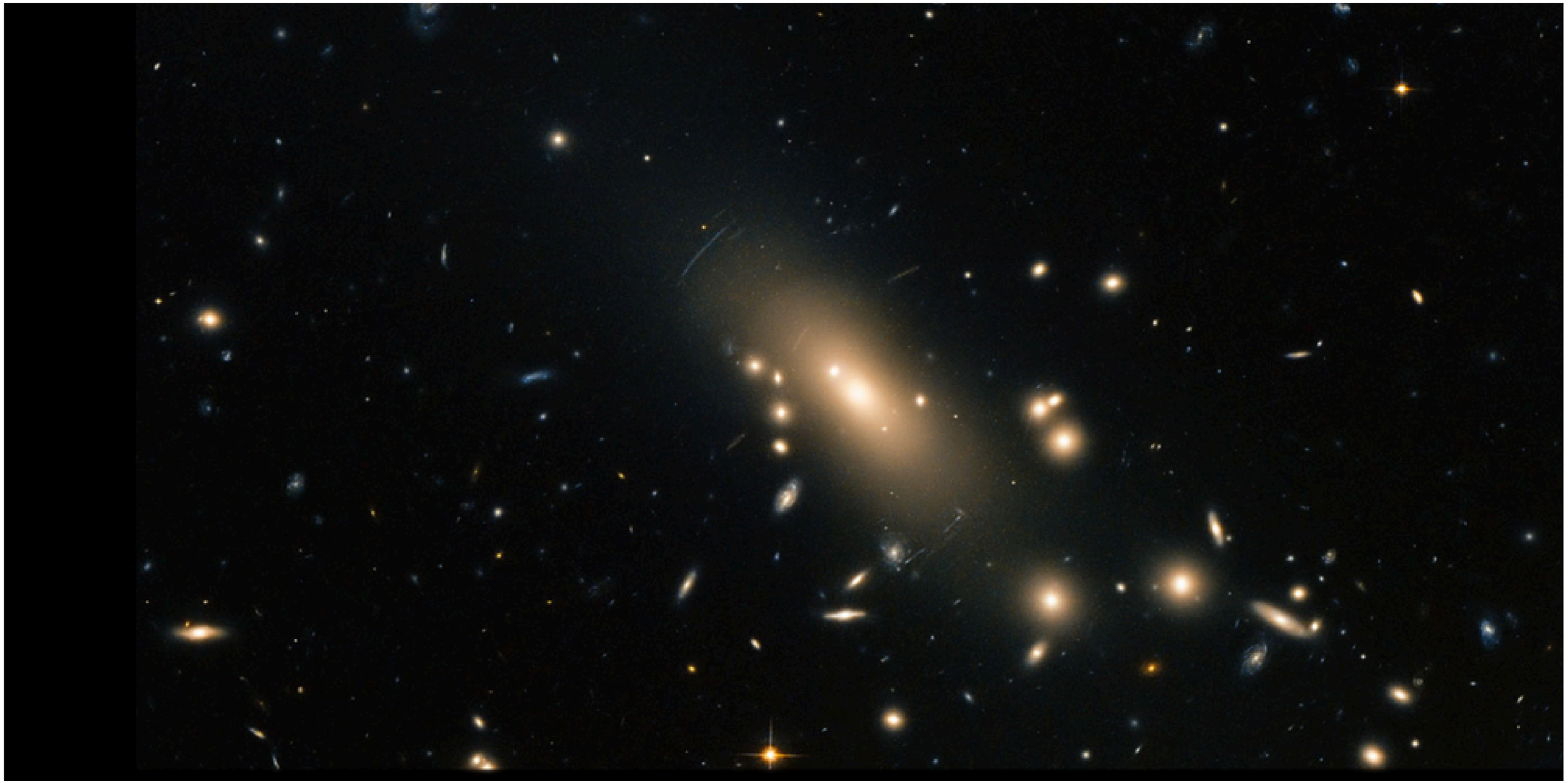


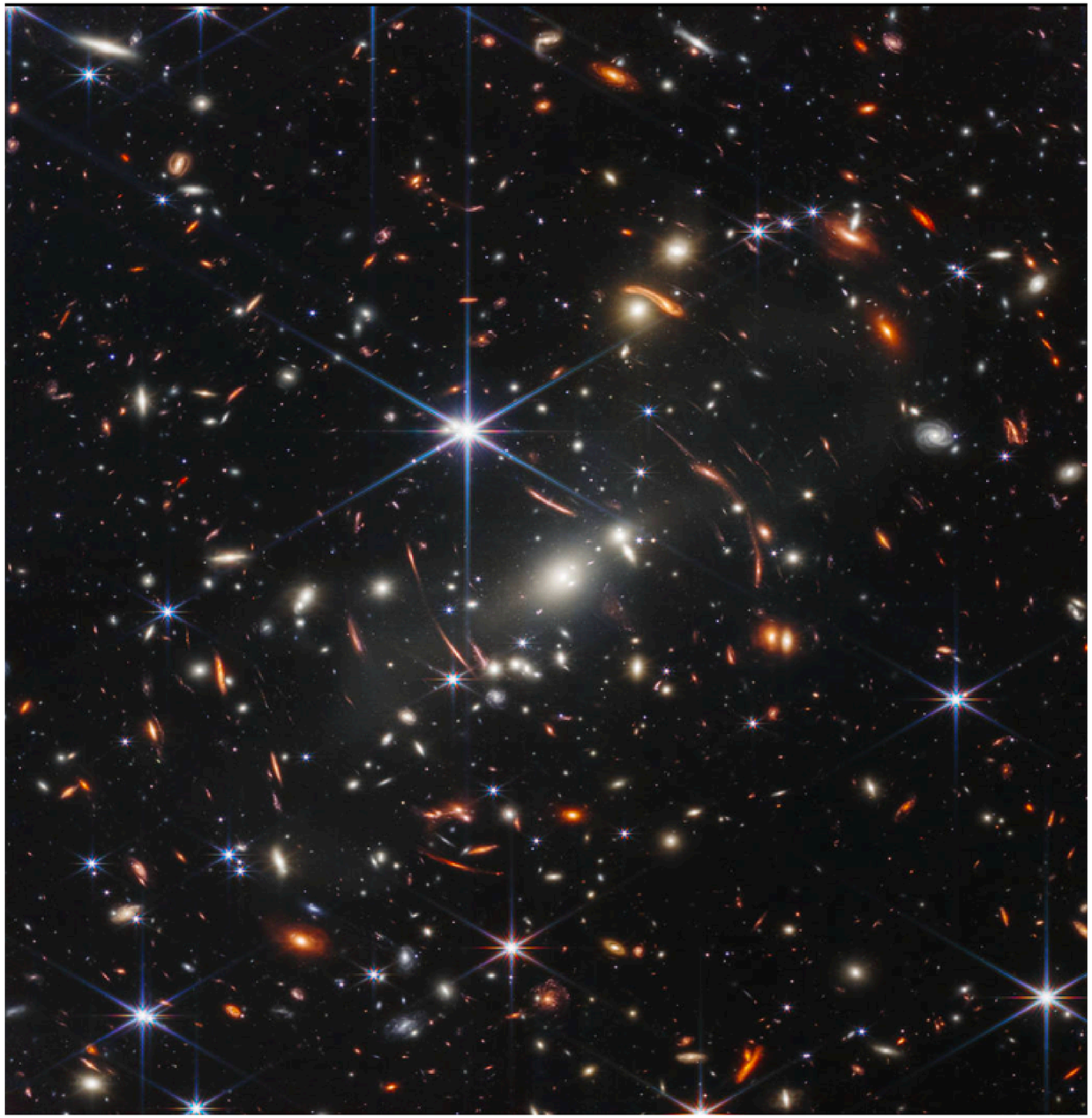

Galactic Longitude
0°
30°
330°
60°
300°
90°
270°
120°
240°
150°
210°
180°
75,000 ly
60,000 ly
45,000 ly
30,000 ly
15,000 ly
Scutum-Centaurus Arm
Sagittarius Arm
Norma Arm
Perseus Arm
Outer Arm
Far 3kpc Arm
Galactic Bar
Near 3kpc Arm
Long Bar
Sun
Orion Spur

Stars and Galaxies



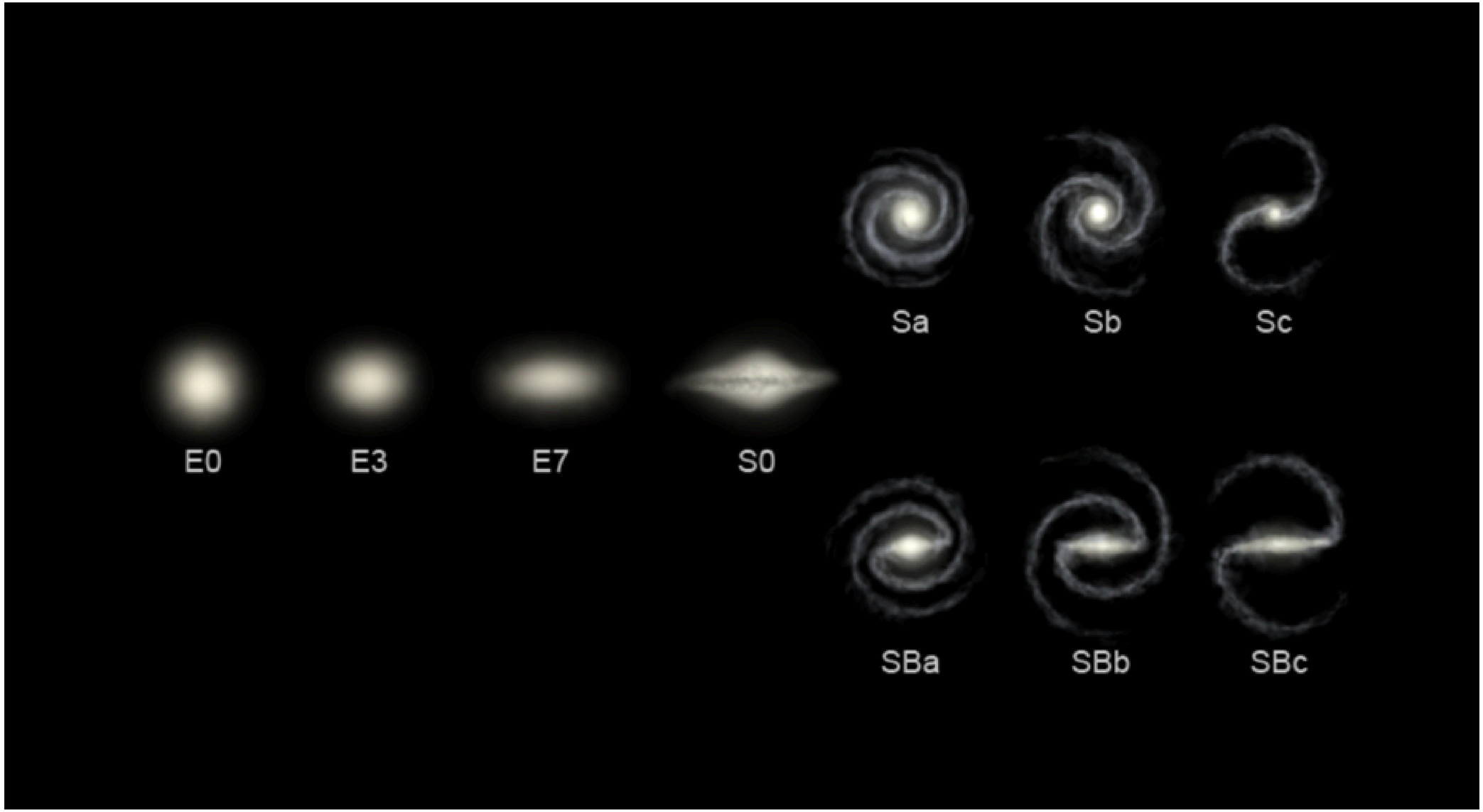
Stars and Galaxies





https://www.wtamu.edu/~cbaird/sq/2015/11/16/why-do-the-spikes-that-shoot-out-of-stars-form-perfect-crosses/
https://physics.stackexchange.com/questions/717316/why-space-telescopes-images-show-diffraction-spikes-around-stars-but-not-galaxi#:~:text=1%20Answer&text=The%20diffraction%20spikes%20are%20there,out%20and%20harder%20to%20see.

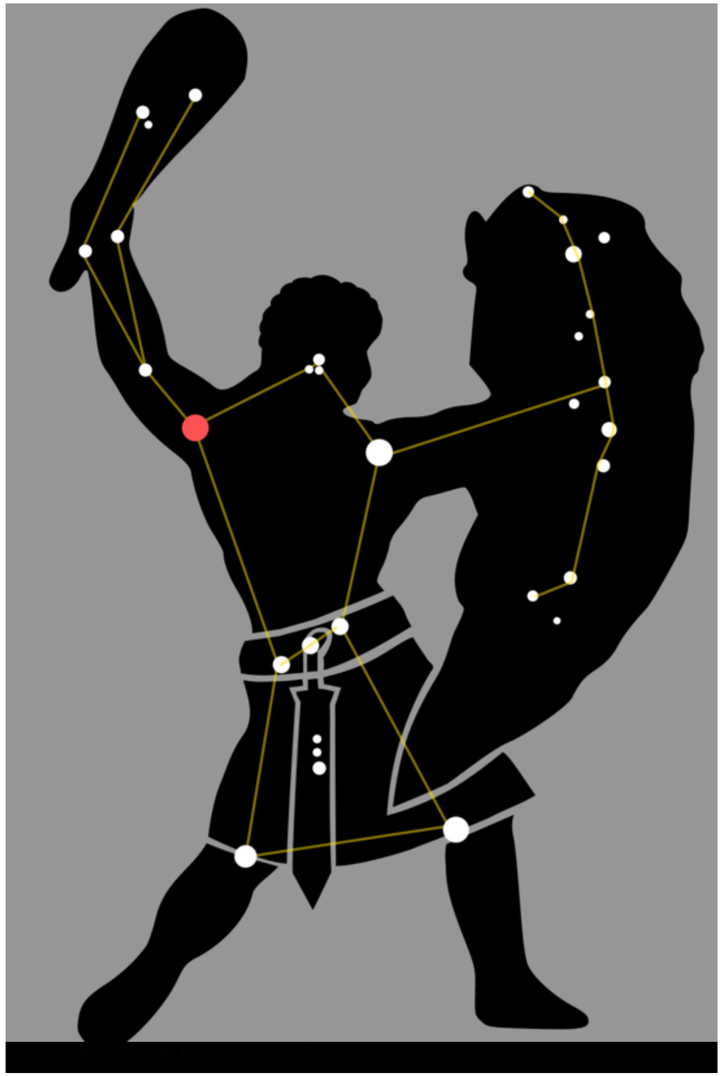
Stars and Galaxies



Stars and Galaxies

Our closest spiral neighbor galaxy: Andromeda

Stars and Galaxies



closest galaxy: Canis Major大犬座(dwarf galaxy) 250000lys（Sirius：夜空中最亮的星)

Protostar

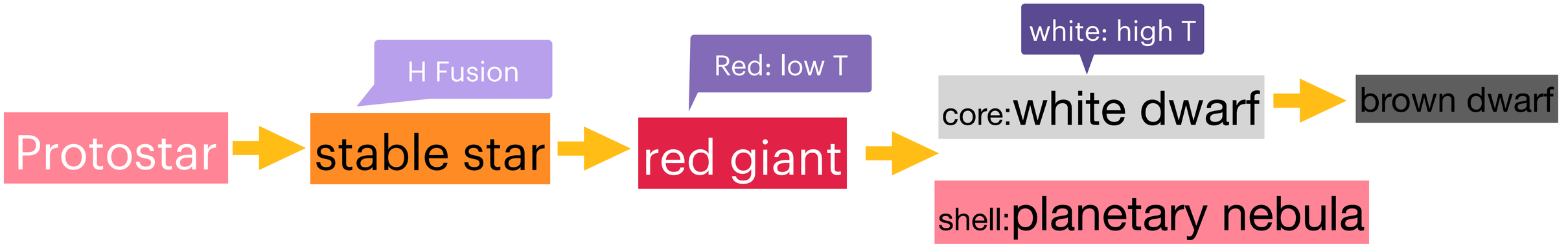
Molecul ostar
(spinnin

egins)

Figure 2
formatio

Life cycle of a less massive star like Sun

Life cycle of a less massive star like Sun



What would happen when Hydrogen are ***used up***?

H used up, star collapse, T increases, core helium fusion, shell H fusion and most outside shell expands

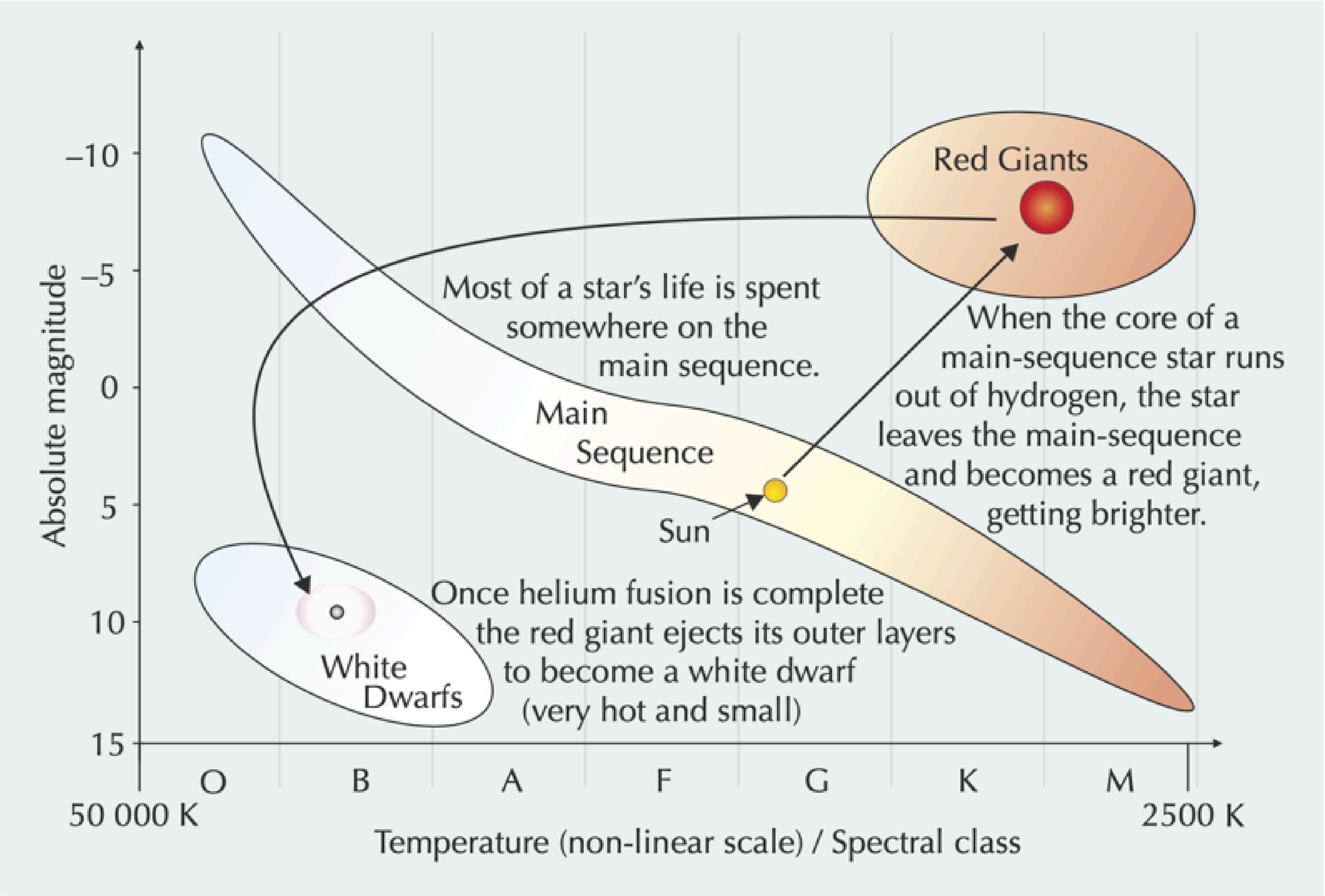
Size of a white dwarf?

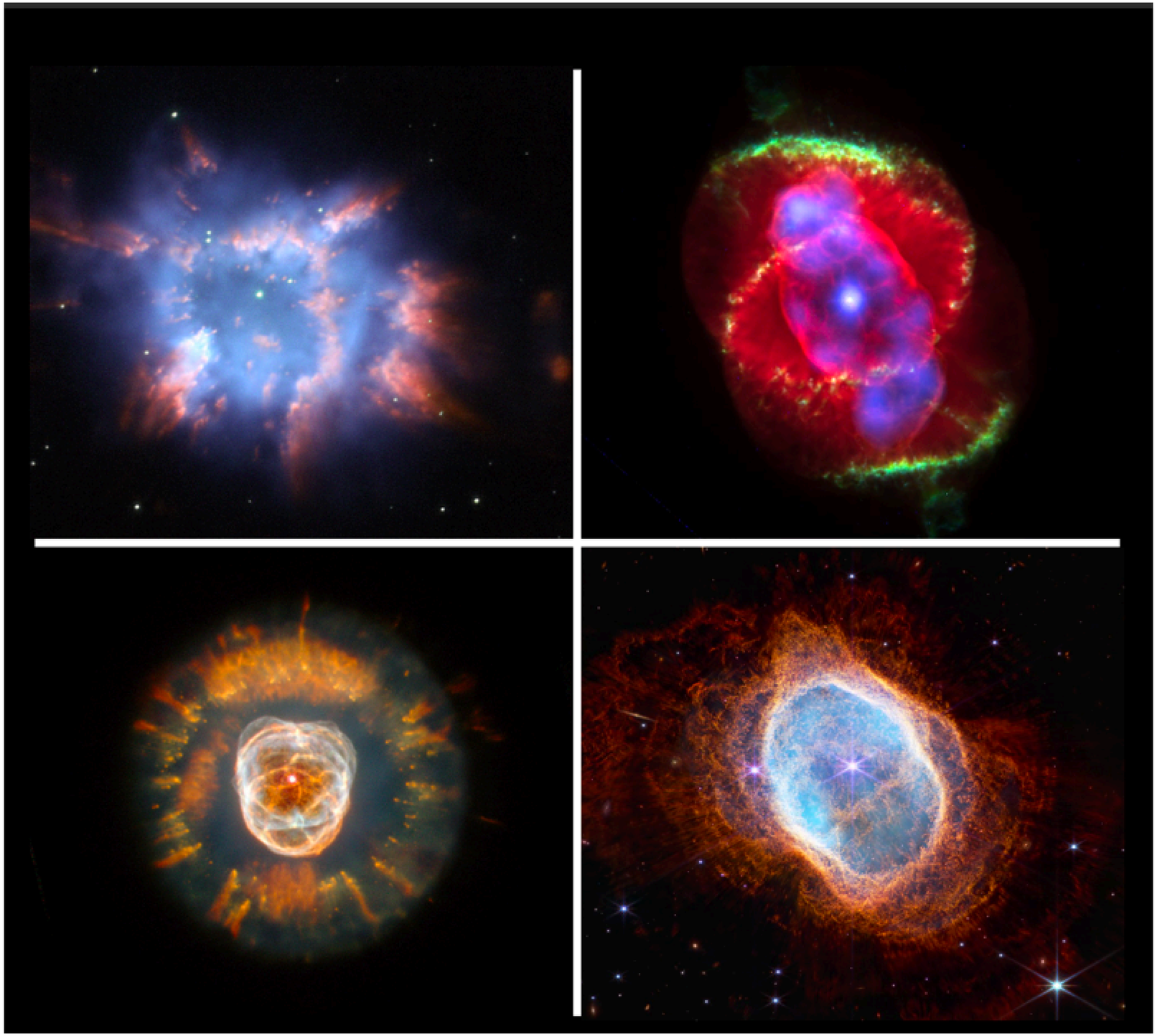
smaller than **1.4 solar mass**, size of earth(1000km)

「Chandrasekhar limit」

e.g. Sun: 4.6 b yrs old. In 5 billion yrs => RG => WD(r earth)

Hertzsprung-Russell diagram





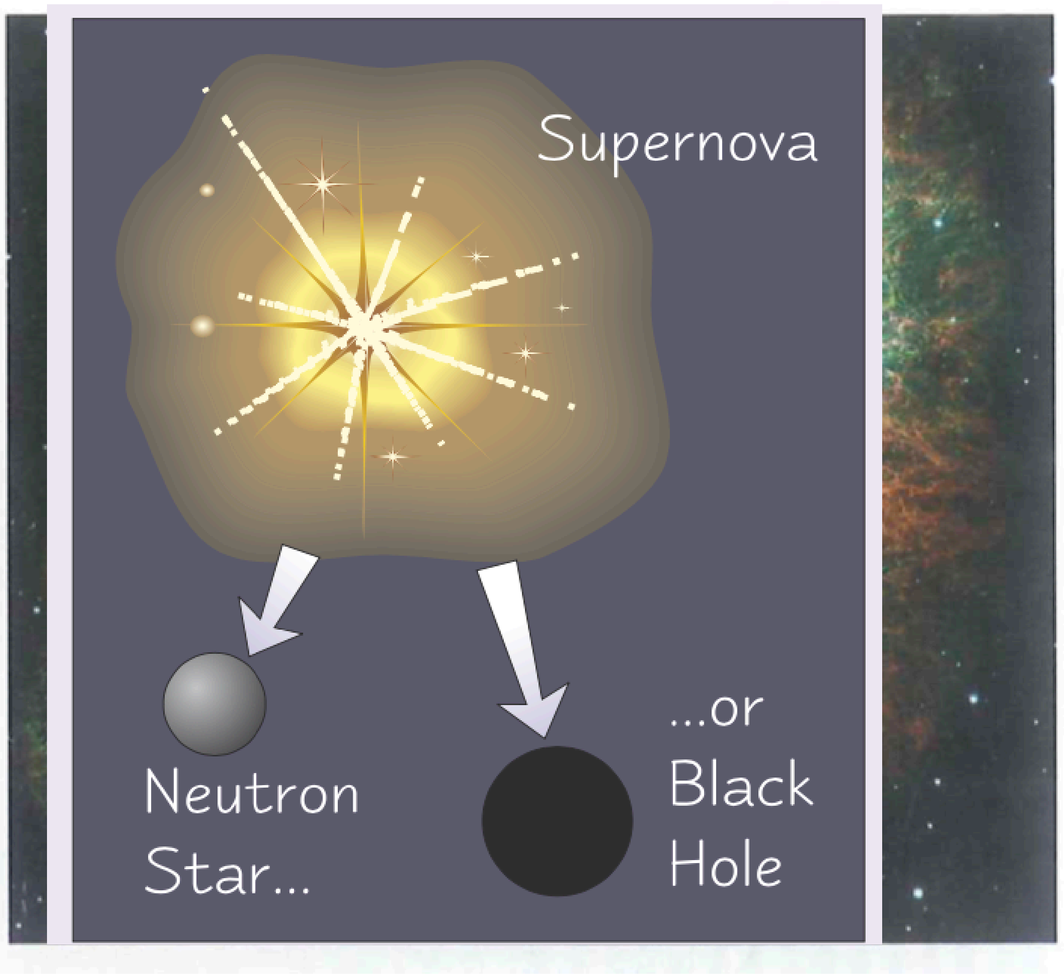

Crab Supernova Explosion, July 4, 1054

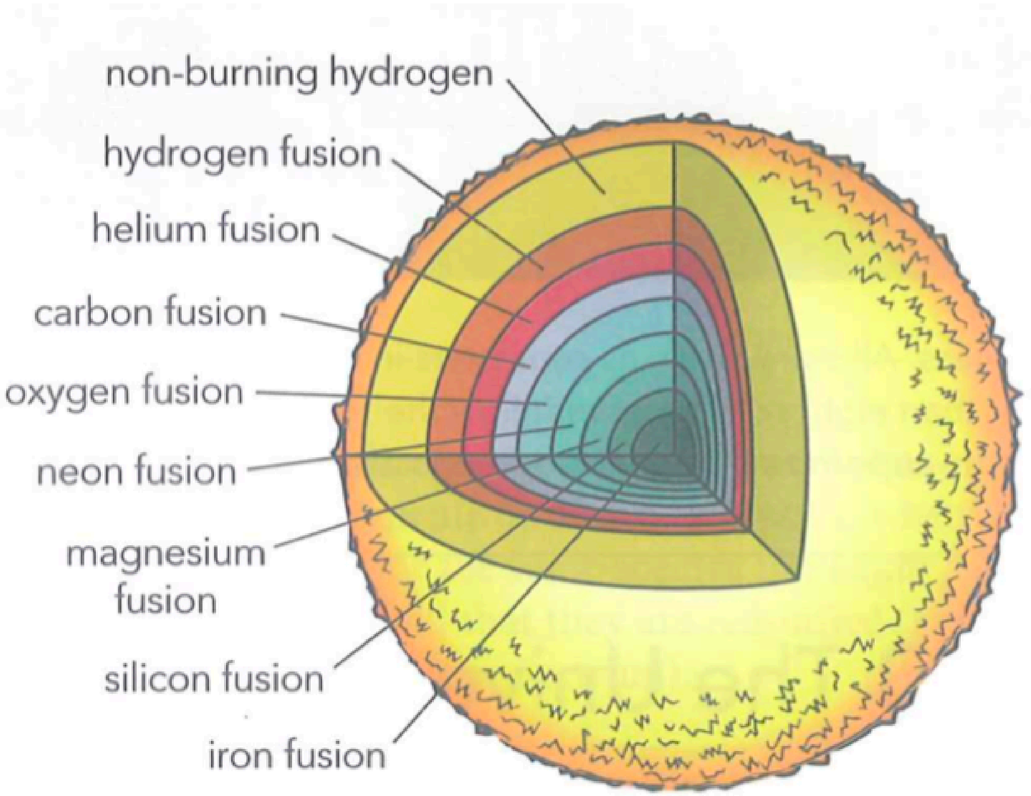
Life cycle of a star exceeding 8 solar masses

Life cycle of a star exceeding 8 solar masses

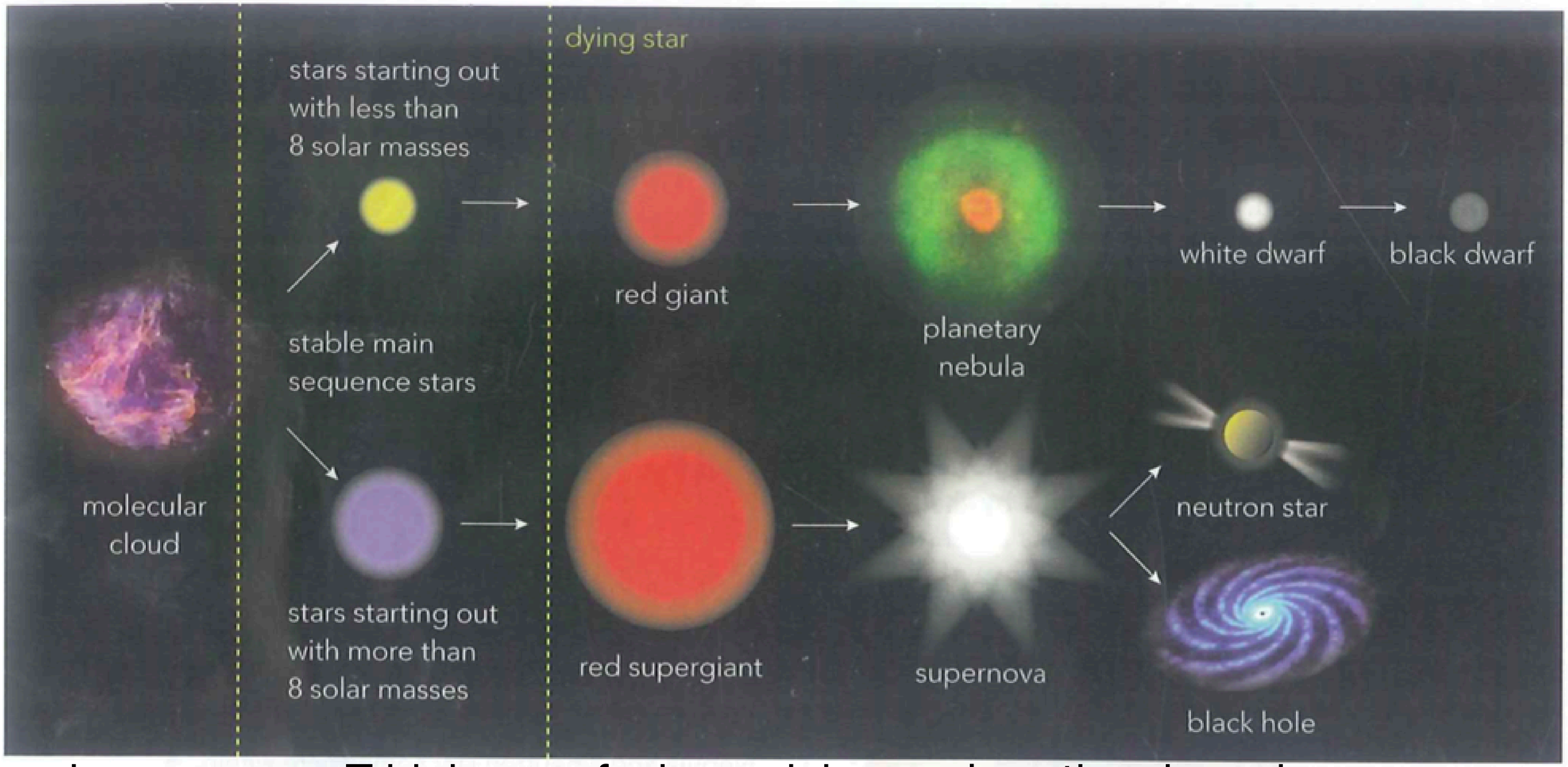
Protostar → stable star → red **super**giant → supernova → neutron star / black hole

nebula





Star Evolution:



Mass increases => T higher => fusion quicker => less time in main sequence

Exercise

When Earth's host star will die, it will first change into what?

A Supernova

B Nebula

C White dwarf

D Red giant

Exercise

Which type of nebula is formed when a dying sun-sized star begins to shed its outer layer?

A blue

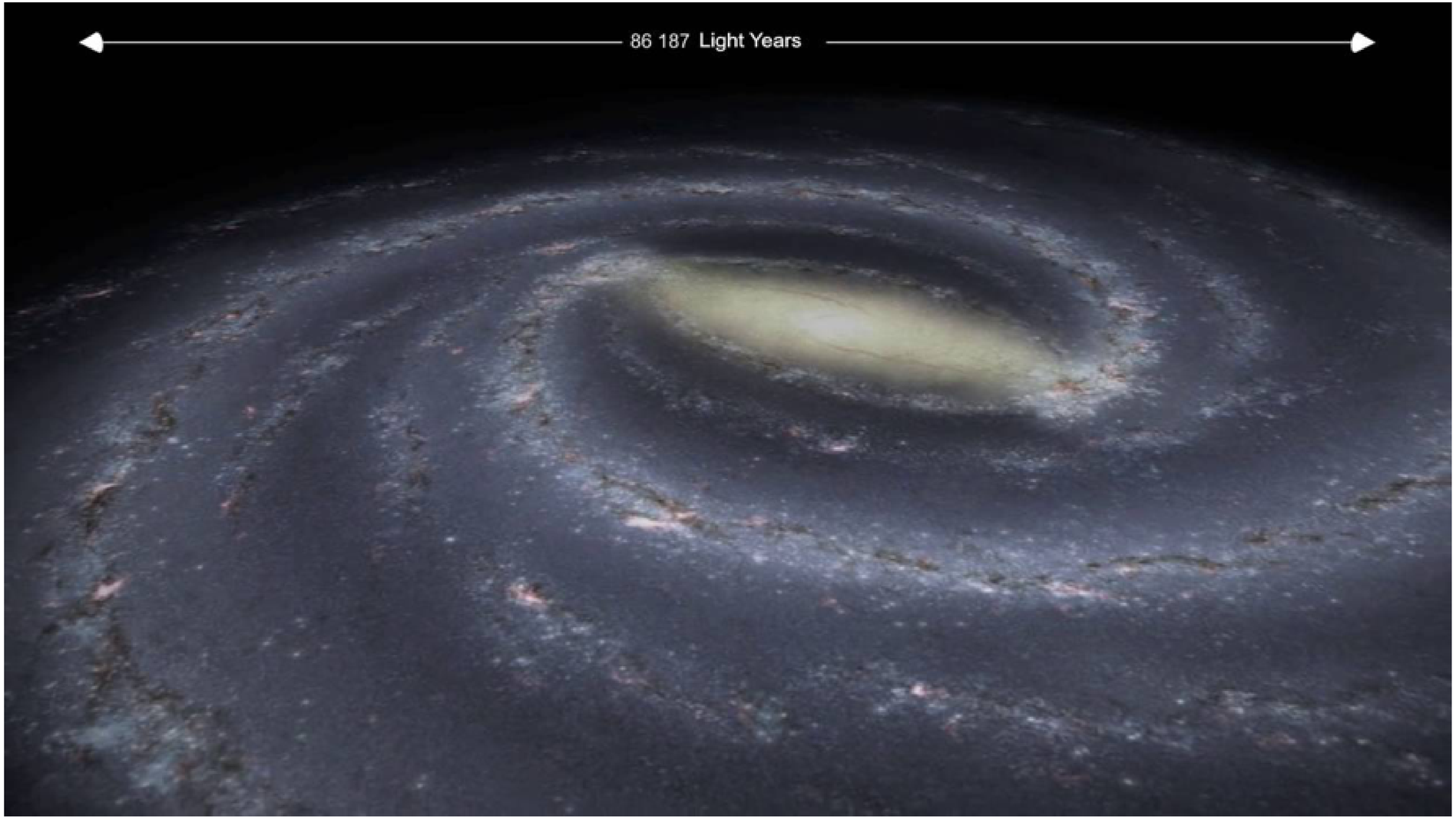
B crab

C emission

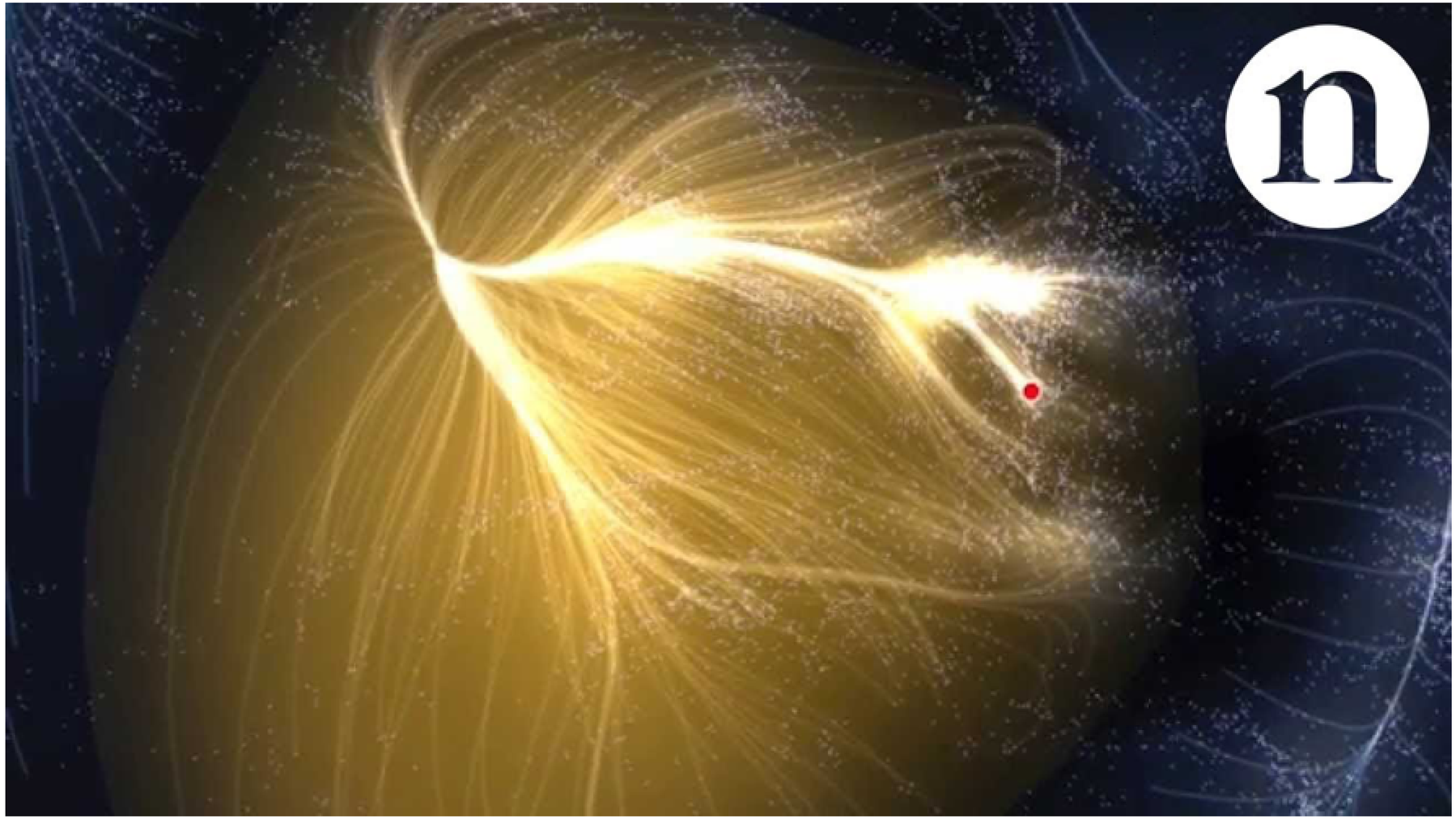
D planetary

The Universe

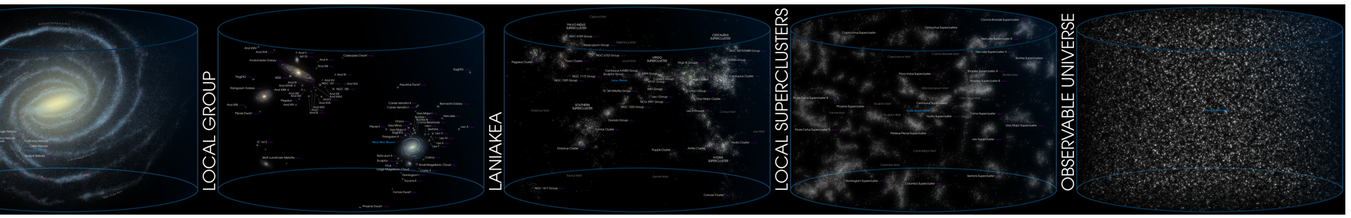
Hubble, 1925, hundred of billions galaxies in universe, MW is one of them



The Universe



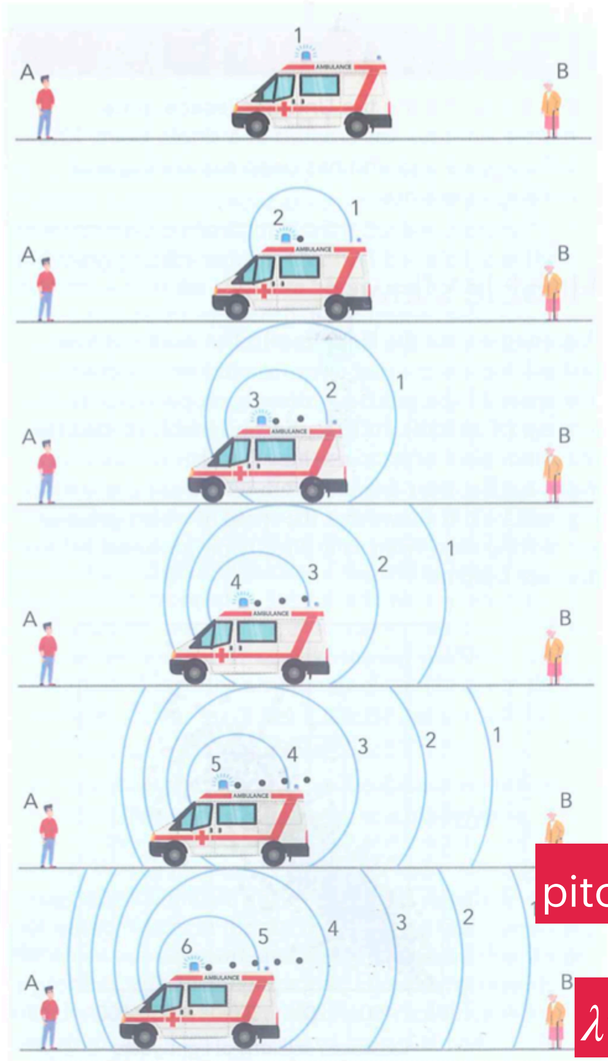
The Universe



Doppler Effect

Doppler Effect

Doppler Effect



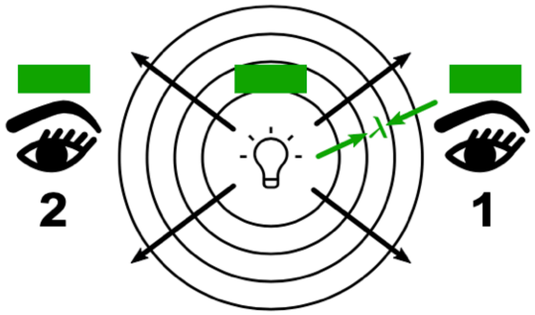
pitch↑

$\lambda\downarrow$

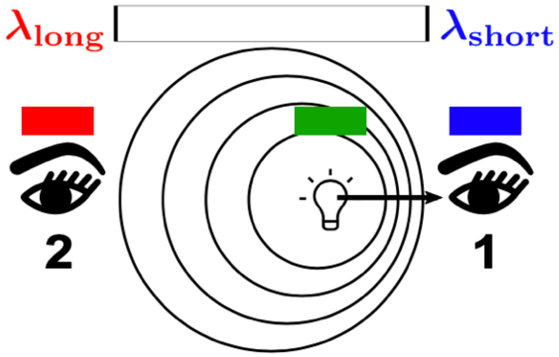
pitch↓

$\lambda\uparrow$

$v = \lambda \times f$



stationary source



moving source

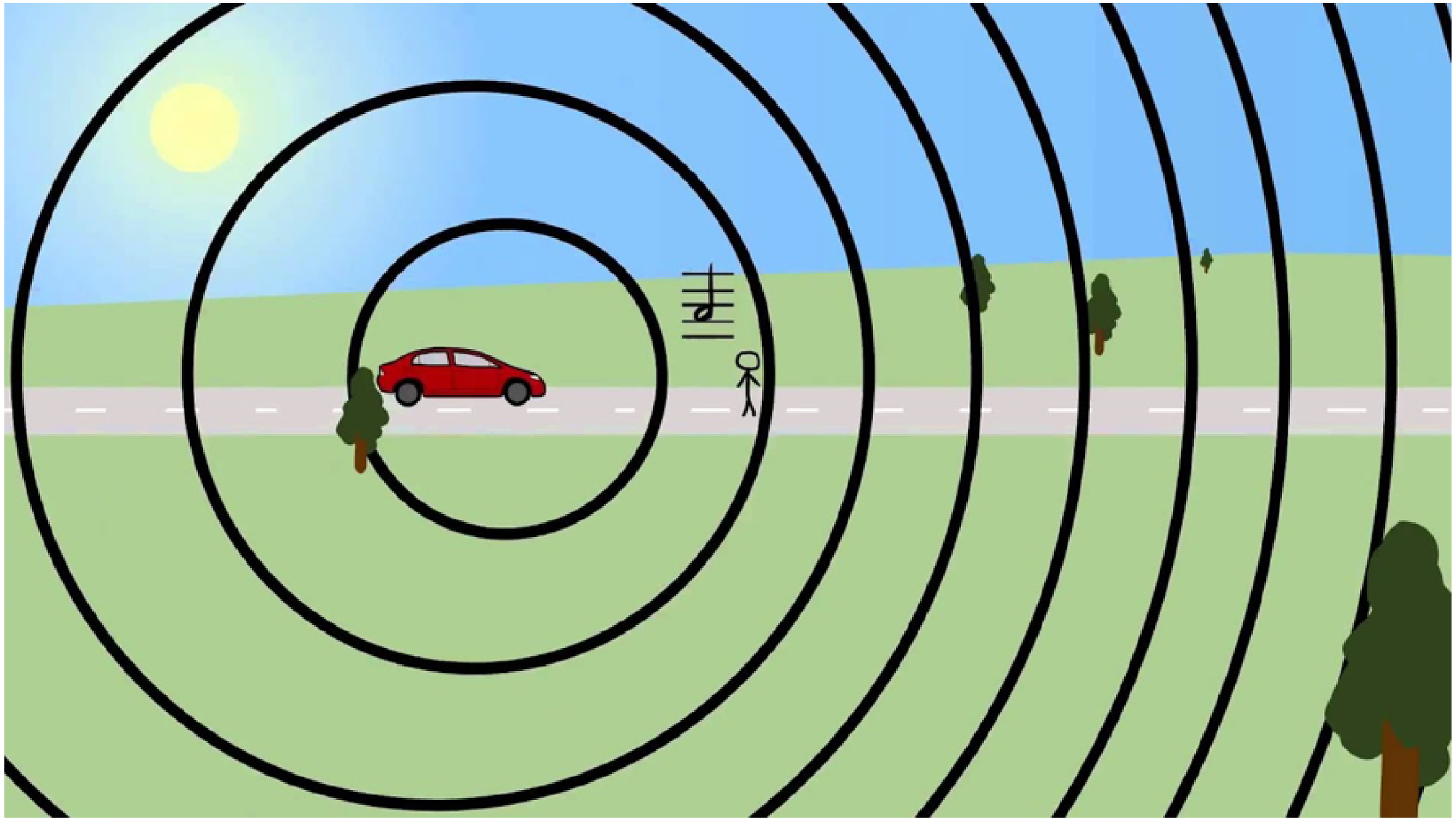
Doppler Effect applies to all waves

Source moving close: $\lambda_o < \lambda_s$ wavelength(λ) ↓ blueshift

Source moving away: $\lambda_o > \lambda_s$ wavelength(λ) ↑ redshift

$v \uparrow$ => redshift(z) ↑

Doppler Effect

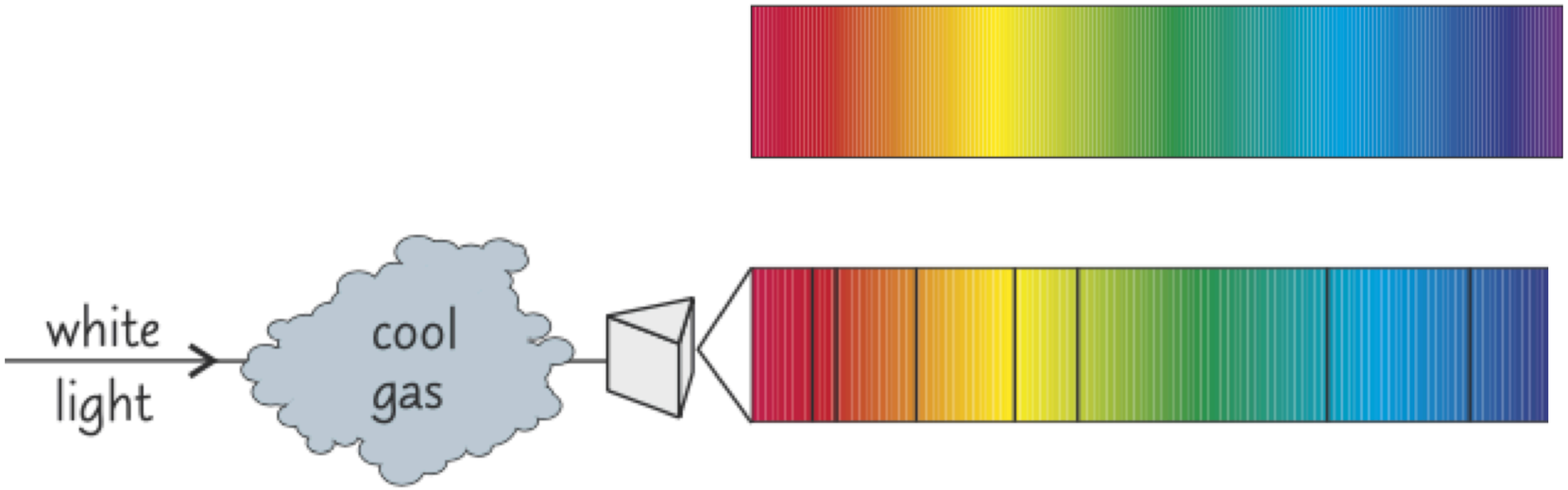


Spectroscopy

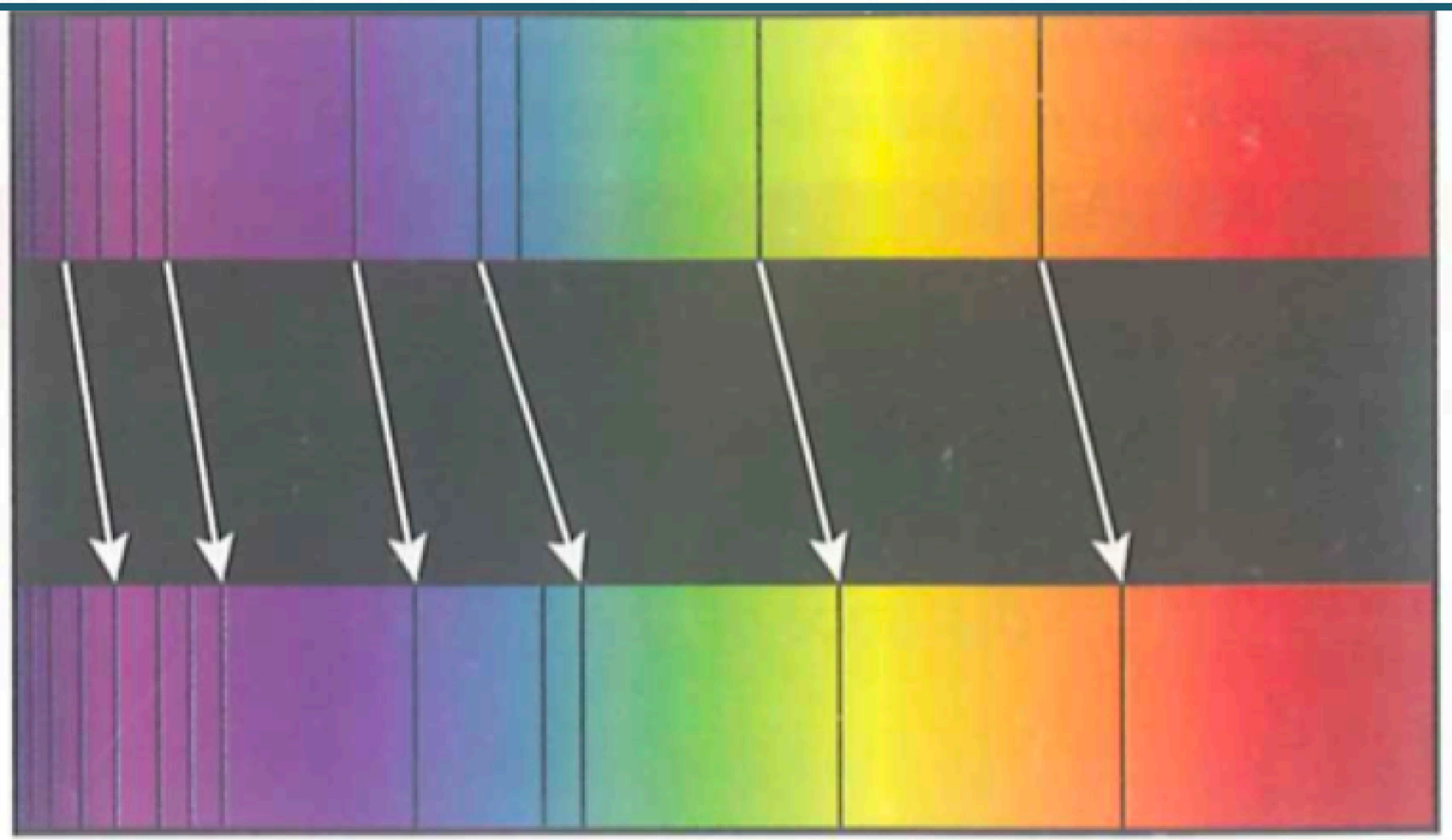
Continuous Spectra

Absorption lines: dark lines in a continuous spectra, caused by light of certain frequency being absorbed.

Absorption spectrum: A spectrum with absorption lines



The Big Bang Theory



Most of distant galaxies **redshifted**

=>they are ***moving away*** from us!!!

large redshift => large recession speed

Exercise

Which statement describes redshift?

A All the light emitted from all distant galaxies is at the red end of the spectrum.

B All the light emitted by a star in the Milky Way is at the red end of the spectrum.

C The light from all the stars in the Milky Way is moved towards the red end of the spectrum.

D The light from stars in all distant galaxies is moved towards the red end of the spectrum.

redshift: an increase in observed wavelength if electromagnetic radiation emitted from source when source moves away

Exercise

Which statement does **not** describe redshift?

A All the light emitted from all distant galaxies is at the red end of the spectrum.

B The light arriving at the Earth from a receding star is always redshifted.

C During redshift, the wavelength of the observed light is longer than it is if the redshift had not occurred.

D The light from stars in all distant galaxies is moved towards the red end of the spectrum.

The Big Bang Theory

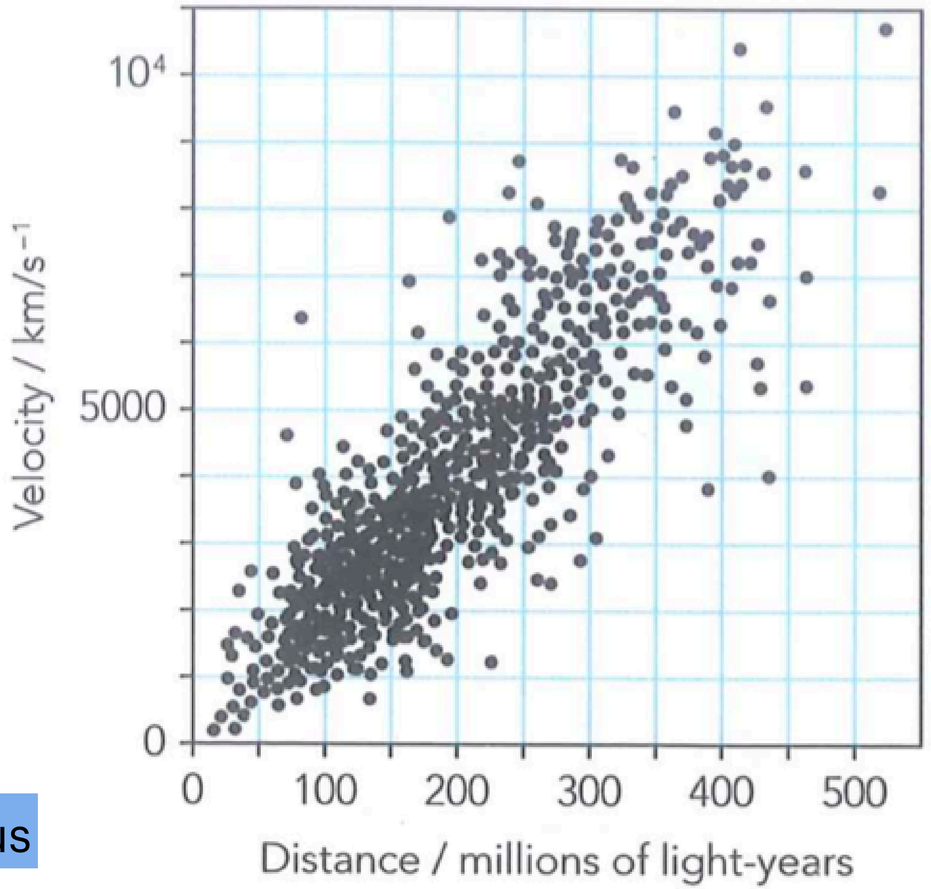
Hubble observation:

Distant galaxies are moving away from us

universe is expanding

In the past, galaxies were closer together;

Further back in time, the universe must have been much smaller than present (**singularity**)



The big bang theory:

～13.8 billion years ago, the universe(space, time, matter, energy) expands from an initial state of unimaginably high density and temperature.

Hubble's law:

$$v = H_0 d$$

further => faster

V: recession speed; d: distance from galaxy to us

The recession speed of a galaxy is proportional to its distance from us

H_0: Hubble constant, $2.2 \times 10^{-18}/s$

Exercise

What does the Universe contain? Choose **one** answer.

A the Solar System only

B the Milky Way only

C galaxies only

D everything that we can observe

Exercise:

Estimate the age of universe.

$$t_{universe} = \frac{1}{H_0} = 4.55 \times 10^{17} s = 14.4 \text{ billion years}$$

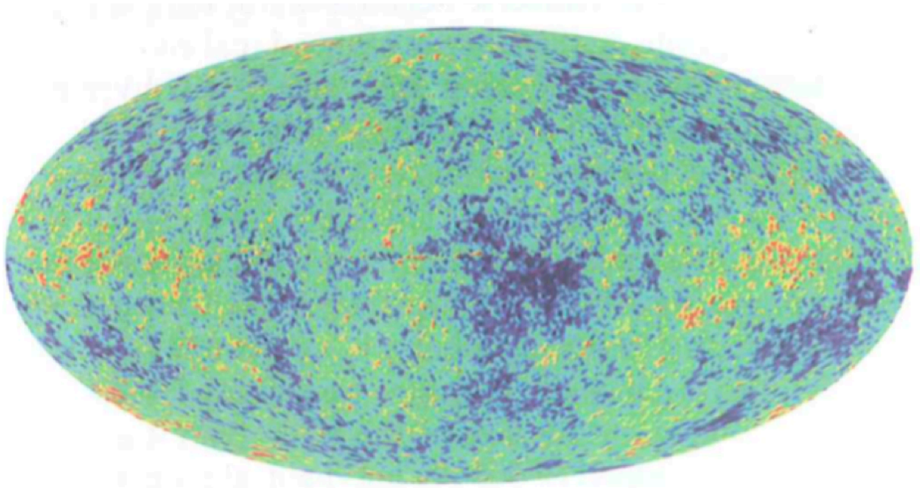
$\frac{1}{H_0}$: **Hubble time**

Cosmic Microwave Background Radiation

Early universe: unimaginably hot & dense => ions => radiation only scatter

t = 379000 year, T= 3000 k, atoms form => radiation can move through (universe becomes transparent)

this radiation(light) formed shortly after big bang has been ***expanded*** into the microwave region of the ***electromagnetic*** spectrum as the Universe expanded



Cosmic Microwave Background radiation(observed at all points in the universe) (***T = 2.726 k***)

The Big Bang Theory

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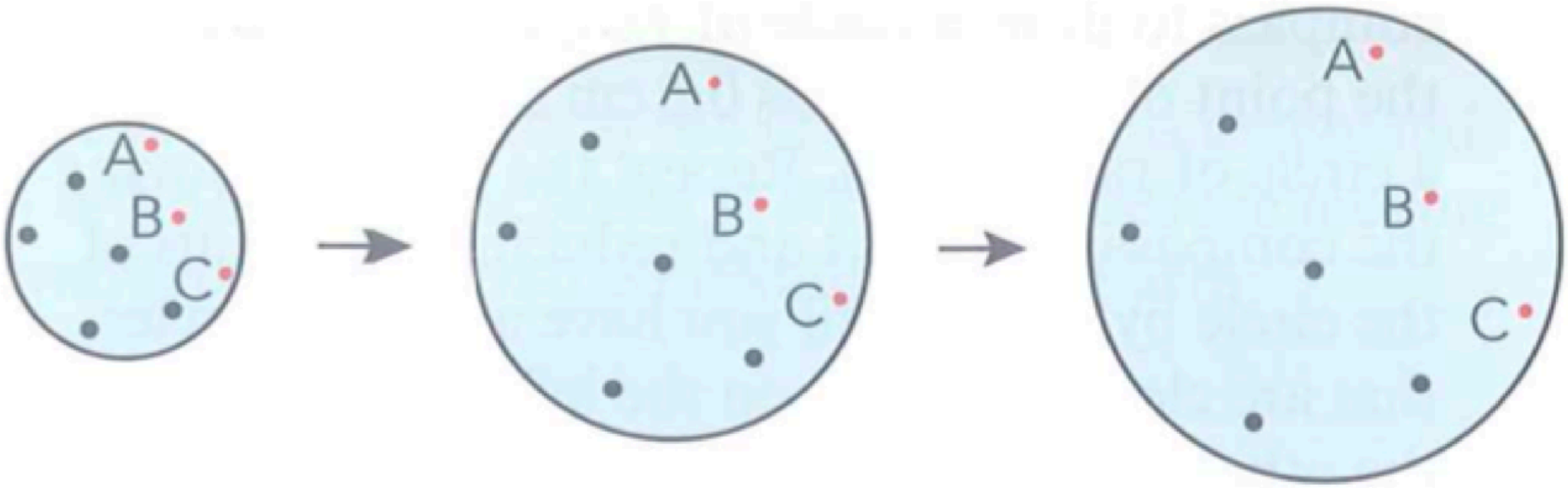


Exercise

There is microwave radiation in space that comes from all directions. What is thought to be the origin of this radiation?

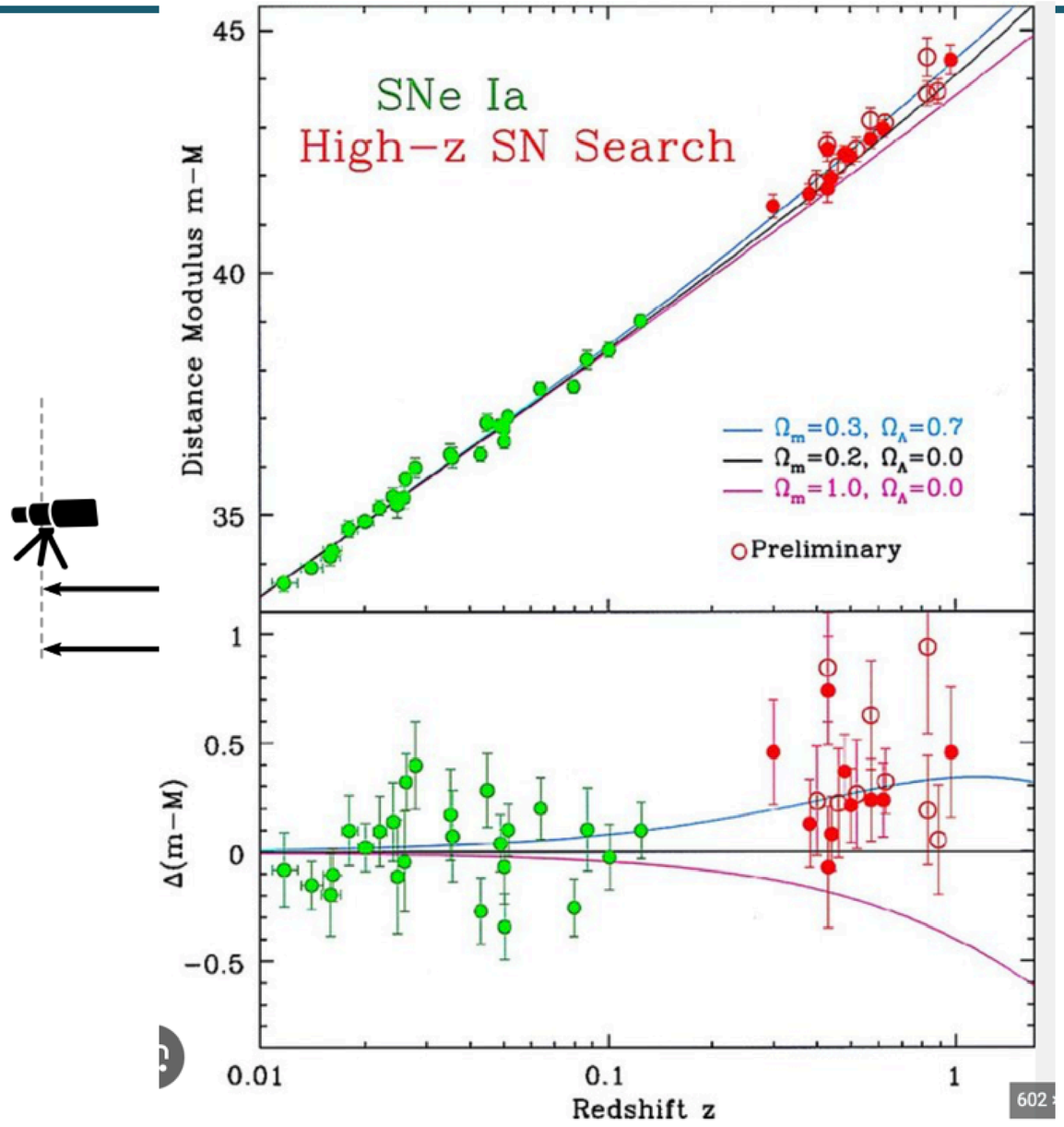
A Microwaves emitted from other galaxies.

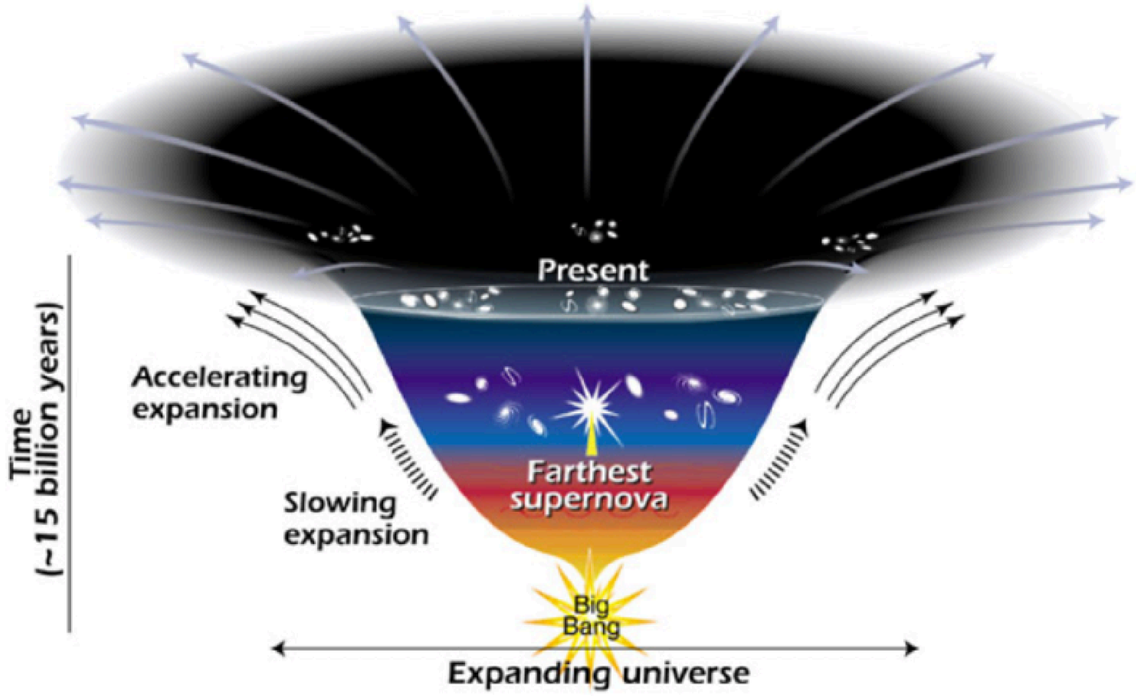
B Light from shortly after the Big Bang that has been redshifted.

C Ultraviolet radiation from distant galaxies that is redshifted.

D Microwaves emitted from stars that are running out of fuel.

Supernova — measuring distance





Supernova — measuring distance