Cosmological context of stars and planets

Architecture of the Solar System:

- Sun (mass 2 x 10^{30} kg - 1 “Solar mass”)
- 4 rocky, terrestrial planets in the inner Solar System (Earth: 6 x 10^{24} kg)
- 2 gas giants (Jupiter, Saturn), mostly made of gas but **not** of Solar composition
- 2 ice giants (Uranus, Neptune) - about 10 Earth mass cores with few Earth mass atmospheres
- small bodies (asteroids, comets, Kuiper belt)

Scale: mean distance between Earth - Sun is defined as 1 astronomical unit = 149,598,000 km

“Size” of the Solar System is ~50 AU

Distances to stars are measured in light years - distance that light travels in 1 year.

Speed of light c = 300,000 km/s

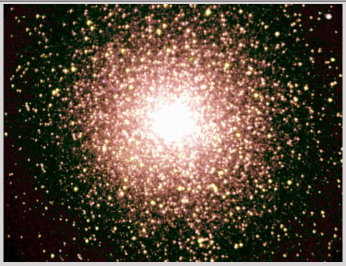
In one year there are 365.25 x 24 x 3600 s = 3.16 x 10^7 s

1 light year = 3.0 x 10^5 km/s x 3.16 x 10^7 s
= 9.5 x 10^{12} km

…about 60,000 AU

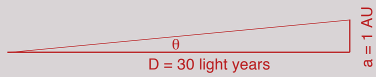
Nearest star is ~4 light years away - 240,000 AU

Solar System is *extremely* small on the scale of distances to other stars



SALT first light image: 47 Tuc

Places in the Universe where stellar density is ~10^6 times higher… even here stars very rarely interact with each other. Can consider stars to be the “building blocks” of the Universe.



What is the angular separation between a planet orbiting a nearby star and the star?

$$\tan\theta = \frac{a}{D}$$

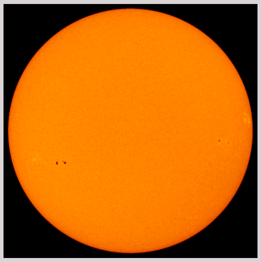
Simplify: small angles tan θ = θ

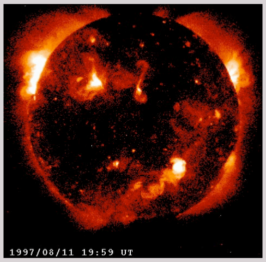
$$\theta \approx \frac{a}{D} = \frac{1.5\times10^{8}\ \text{km}}{30\times9.5\times10^{12}\ \text{km}}$$
$$= 5\times10^{-7}\ \text{radians}$$

Other units: 3 x 10^{-5} degrees or 0.1 arcseconds (3600 arcseconds = 1 degree)

0.1 arcsec is similar to the resolution of best current telescopes, BUT currently not possible to image planets due to glare of nearby star

Stars





Sun is a relatively common type of star:

- surface temperature T ~ 6000 K
- radius 700,000 km (~100 times radius of Earth)

Energy source of stars

Sun (+other stars) derives energy from nuclear **fusion**, Specifically the reaction:

$$4 \times H \rightarrow {}^4_2He$$

Mass of 4 hydrogen nuclei is very slightly larger than the mass of one helium nucleus - excess Δm is released as energy according to:

$$E = mc^2$$

…where c is the speed of light.

Sun is 4.6 billion years old - enough hydrogen in the core to sustain Sun for a total of about 10 billion years.

Classification of stars

Mass of stars ranges from ~0.1 Solar masses up to ~100 Solar masses. Low mass stars are much more common than high mass stars.

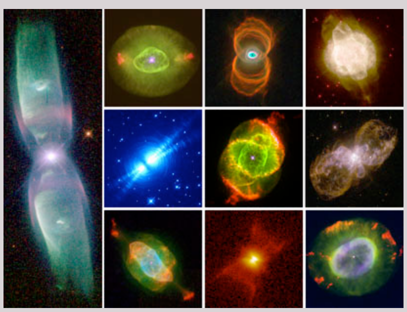
Low mass stars: M < 2 Solar masses

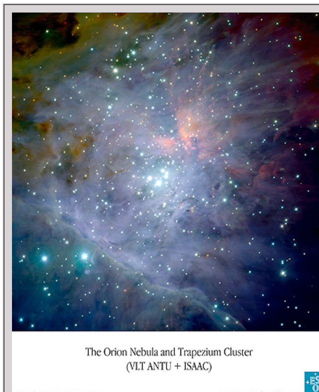
Greatest interest for astrobiology as *long lived*: "main sequence" lifetime (while fusing H -> He in the core) is billions of years

Luminosity slowly increases over time

After all the hydrogen is consumed, further fusion reaction form carbon, nitrogen and oxygen

Endpoint of such stars is a planetary nebula and a white dwarf:





Nearby place where *massive* stars can be found is in the Orion Nebula - region of current star formation

Massive stars: M > 8 Solar masses

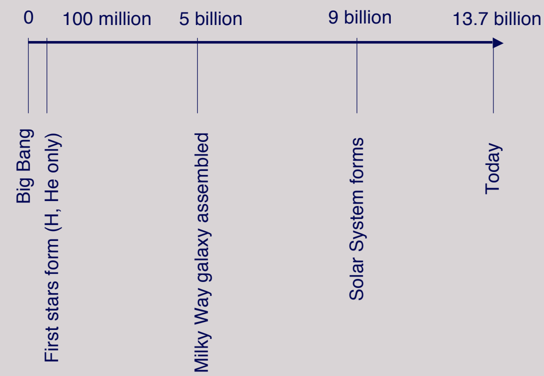
- short lived (~100 million years or less)
- rare
- after fusing H -> He, go on to form many heavier nuclei via subsequernt fusion - all the way up to iron
- finally explode as **supernovae**, leaving behind a neutron star or black hole

Explosion ejects products of stellar fusion back into the gas of the Galaxy - forms the raw material for new generations of stars "galactic recycling".

Strong evidence that the *only* elements formed in the Big Bang were hydrogen and helium

All the heavier elements (carbon, oxygen, nitrogen, iron etc) were formed in the cores of stars

- we are literally star dust (or, nuclear waste)
- since heavy elements are needed to make terrestrial planets, very first stars to form would not have had any planets suitable for life… on time scale of the Universe cosmos is becoming more hospitable for life



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