Interstellar Matter & Star Formation

Koupelis : chapter 13
OpenStax : chapter 20 & section 21.1

The most abundant constituent of Jupiter's atmosphere is

Helium.	0%
Carbon dioxide.	0%
Hydrogen.	0%
Ammonia.	0%
Suphuric acid.	0%

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The layer of the Sun that is visible to us is the

Chromosphere.	0%
Core.	0%
Photosphere.	0%
Corona.	0%
Solar Wind.	0%

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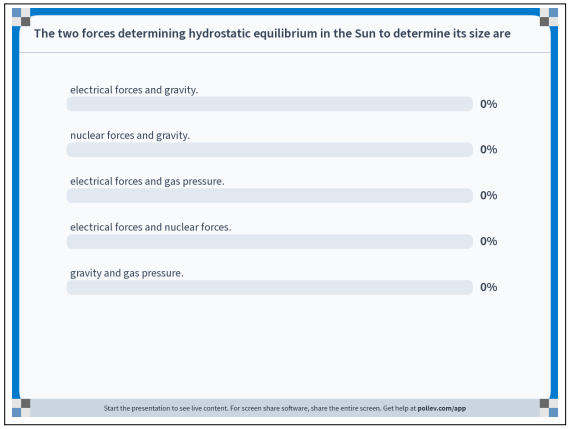
The two forces determining hydrostatic equilibrium in the Sun to determine its size are
electrical forces and gravity.
0%
nuclear forces and gravity.
0%
electrical forces and gas pressure.
0%
electrical forces and nuclear forces.
0%
gravity and gas pressure.
0%
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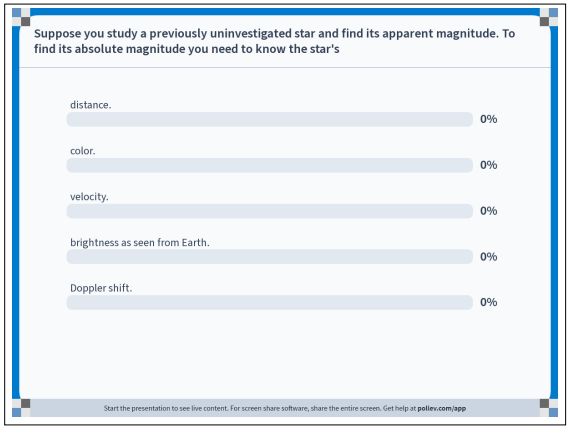
Suppose you study a previously uninvestigated star and find its apparent magnitude. To find its absolute magnitude you need to know the star's
distance.
0%
color.
0%
velocity.
0%
brightness as seen from Earth.
0%
Doppler shift.
0%
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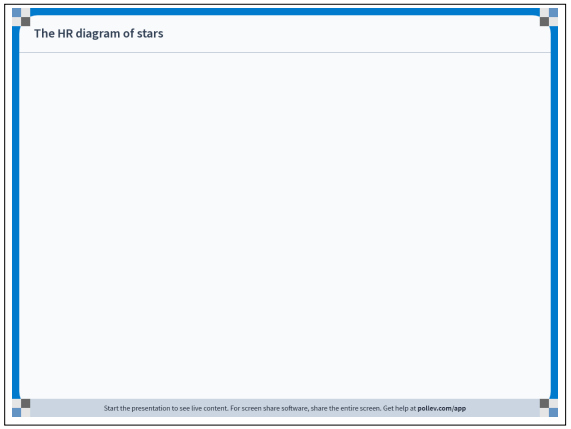
The HR diagram of stars
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The HR diagram of stars

The HR diagram of stars

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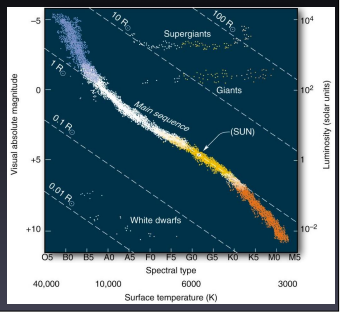
The intrinsic luminosity (Absolute Magnitude) of a star and its colour (spectral type) determine its position in the Herzsprung-Russell diagram :

Most stars lie on a narrow strip in the HR-diagram: the *Main Sequence*

Faint and bright stars exist for the same colour (temperature) :

⇒ Faint, cool stars have a small surface.

Bright, cool stars have a large surface.



The birth of stars

Stars form in groups from local concentrations of the interstellar matter.

Owl cluster

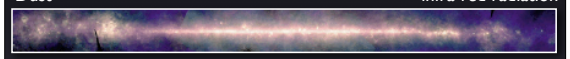
Orion Nebula

The Milky Way : many stars but also dark clouds!

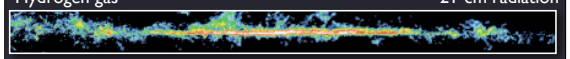
The Milky Way

Stars — visible light

Dust — infra-red radiation



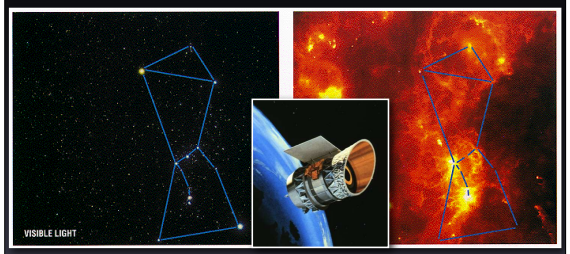
Hydrogen gas — 21-cm radiation



Different wavelengths indicate different components.

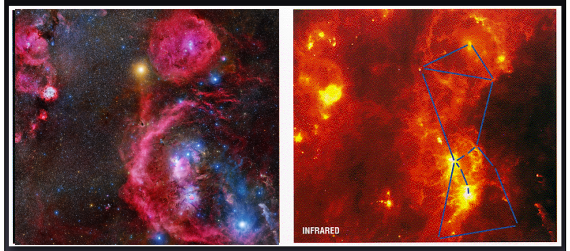
electron spin-flip → 21cm photon

Dust clouds in Orion



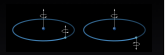
Dust clouds made 'visible' with IRAS (Infra-Red Astronomical Satellite).

Dust clouds in Orion

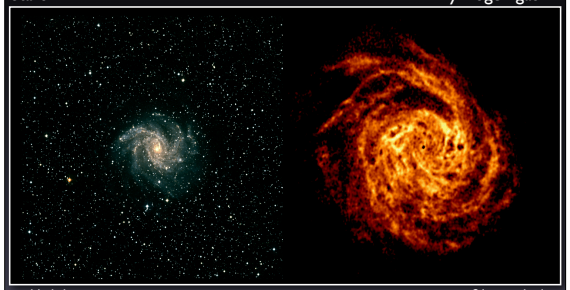


Dust clouds made 'visible' with the IRAS satellite.

NGC 6946



Stars Hydrogen gas



visible light Both images on the same scale. 21cm radio line

Properties of the Inter-Stellar Matter (ISM)

Composition:

~ 90-99% GAS
- Hydrogen (70%)
- Helium (28%)
- Carbon, Oxygen, Silicon (~2%)

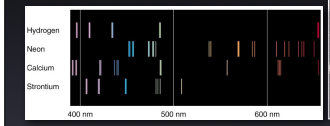
~ 10-1% DUST
- sand (silicates)
- soot (graphite)

⇒ dust particles smaller than cigarette smoke

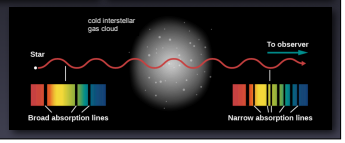
Observations of the interstellar matter

Gas : - Fluorescence caused by ionising radiation (UV) from nearby hot stars.

⇒ emission nebulae
contain 100 - 10,000 solar masses



- Absorption lines in the spectra of distant stars

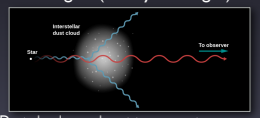


Observations of the ISM

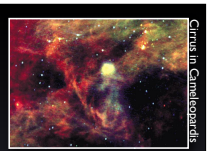
Dust : - Emission of infrared radiation by diffuse (cirrus) clouds and Giant Molecular Clouds (GMC)

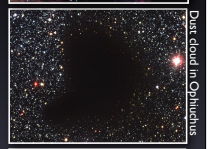
- Absorption and reddening of light from stars located behind dust clouds

- Reflection and scattering of starlight (mainly blue light)

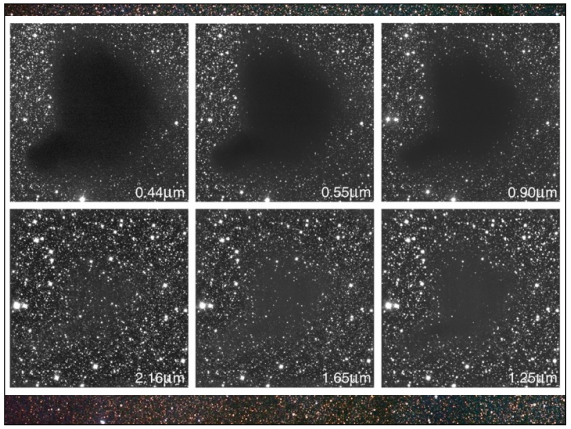


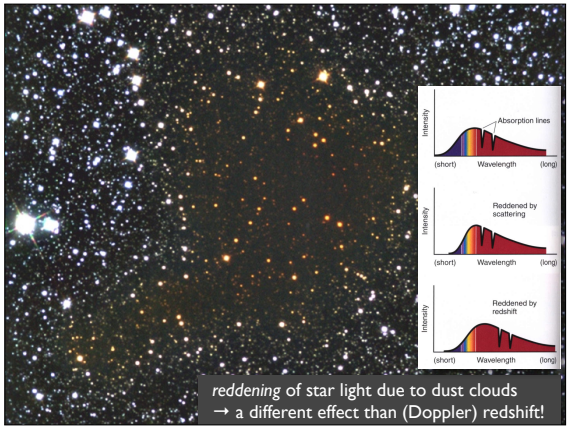
Dust clouds are almost transparent for infrared radiation!


Cirrus in Camelopardis


Dust cloud in Ophiuchus


Reflection in Pleiades





reddening of star light due to dust clouds
→ a different effect than (Doppler) redshift!

The density of the interstellar matter

		Temperature (Kelvin)	Density (particles/cm^3)
Warm atomic gas	:	10,000	1
Cool atomic gas	:	100	100
Dust clouds (cirrus)	:	30	10
(GMC)	:	10	1,000
(EGG)	:	100	10^7 - 10^9
Air at sea level	:	300	2×10^{19}

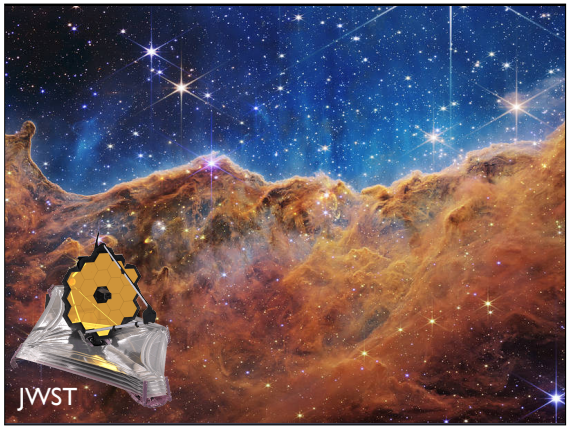
ISM is more tenuous than the best vacuum created on Earth, yet it contains enormous amounts of matter!
Concentrations in the ISM caused by shock waves and gravity
⇒ strongly inhomogeneous distribution of the ISM

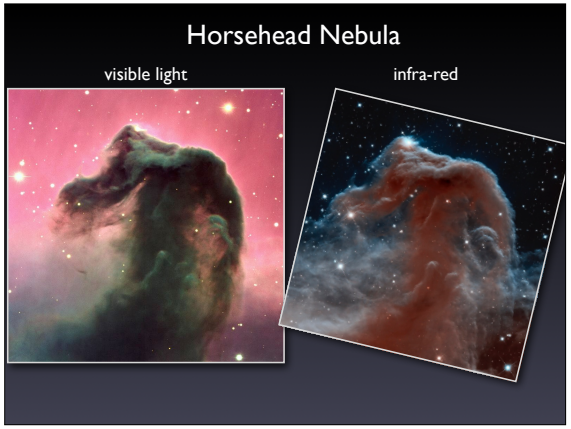
basic elements of a star forming region

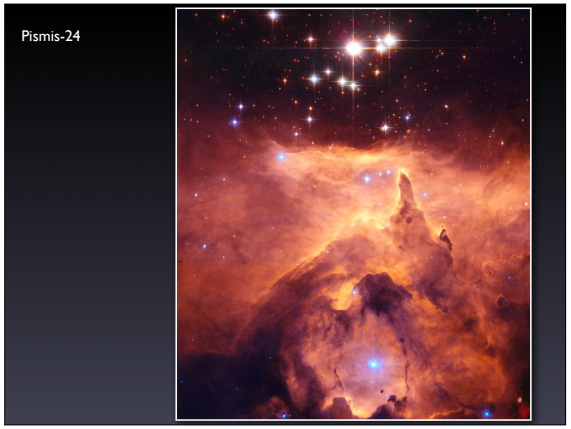
visible light

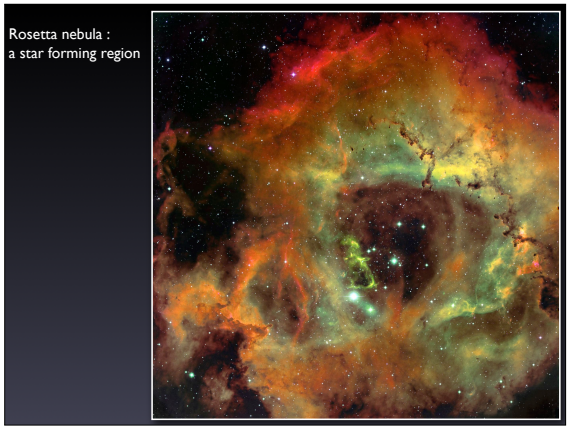
infra-red light

Trifid nebula in Sagittarius

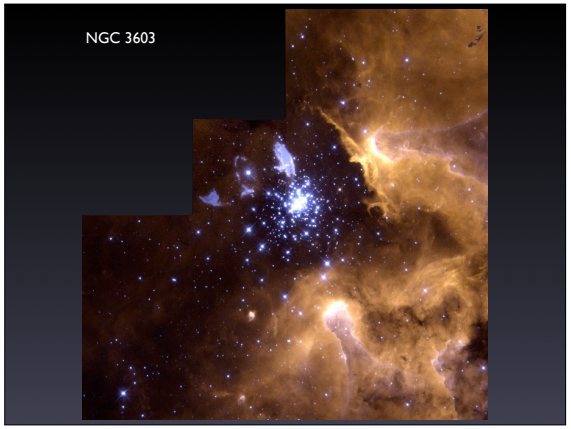


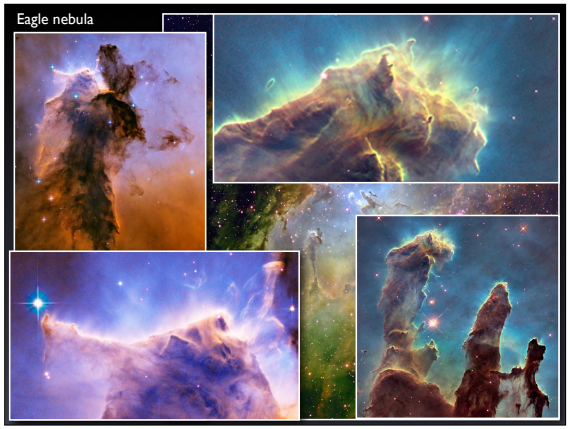

Horsehead Nebula
visible light
infra-red


Pismis-24

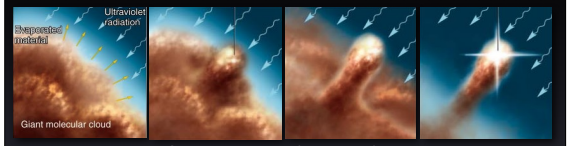

Rosetta nebula :
a star forming region


NGC 602


NGC 3603


Eagle nebula

From dust to stars…

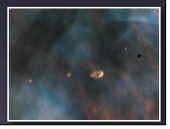


UV radiation evaporates the surface of a dust cloud

Concentrations in the cloud evaporate more slowly

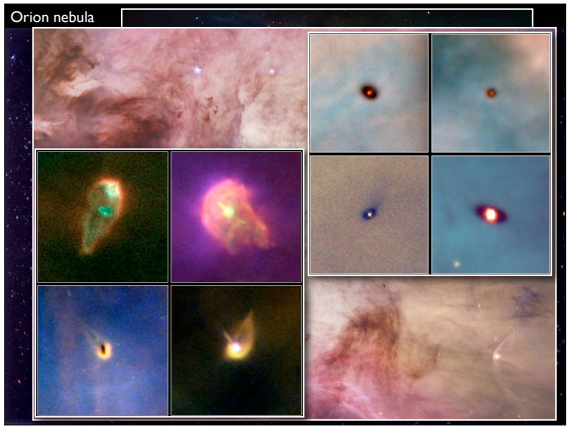
Shadow of an EGG protects the dust behind it

Eventually, a protostar becomes visible

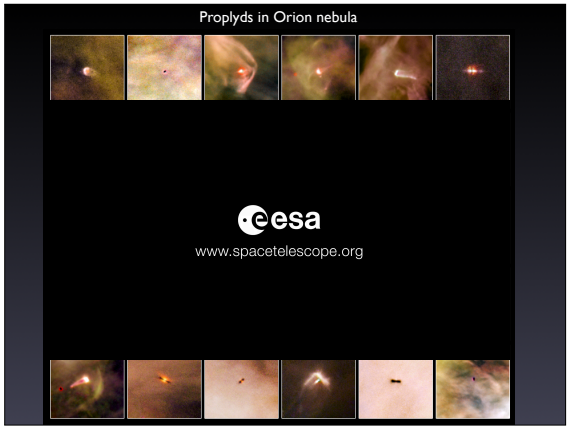


EGG : Evaporating Gaseous Globule

Orion nebula



Proplyds in Orion nebula



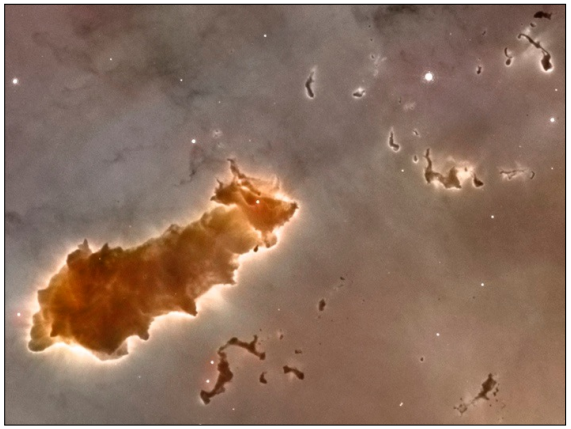
Animation of the 3-dimensional structure of the Orion nebula.

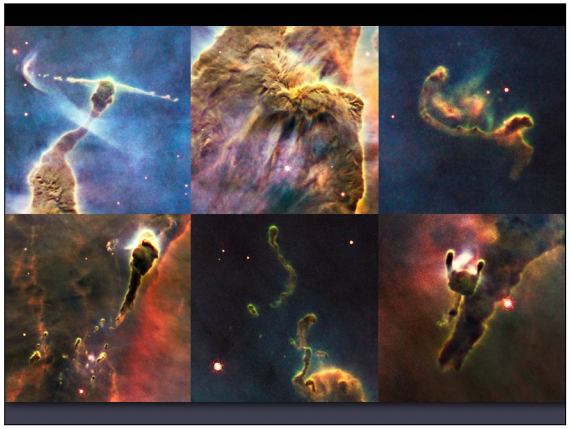
A star forming region in Carina

A star forming region in Carina

red : Sulfer
green: Hydrogen
blue : Oxygen

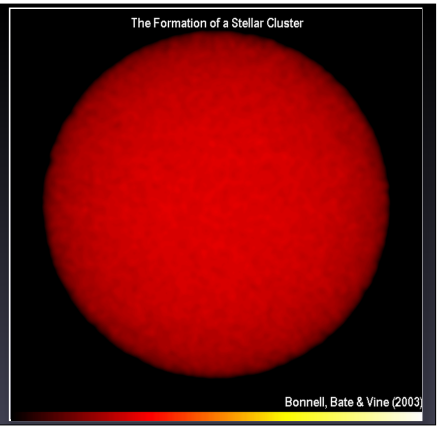
< 50 light years >



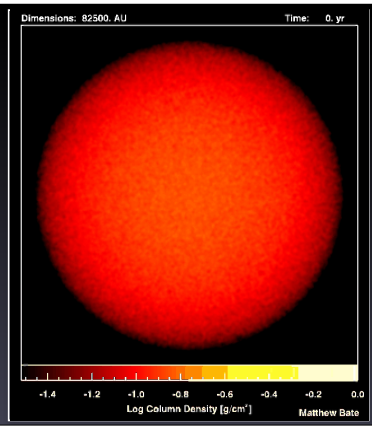


Computer simulation

a collapsing
G iant
M olecular
C loud



Computer simulation



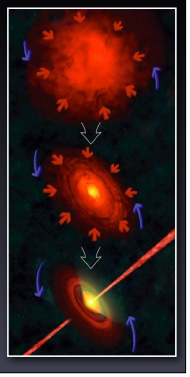
What happens in an EGG?

Gas and dust contract under the force of gravity.
⇒ cloud heats up and the gas pressure increases

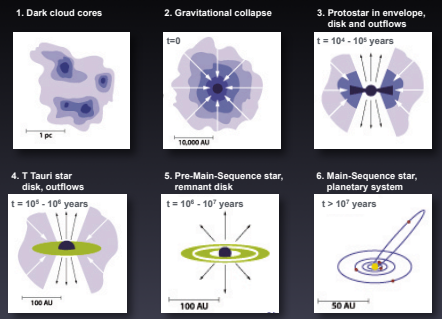
The core becomes very hot
and resists the gravitational force.
⇒ a protostar is born

The outer parts continue to contract
and the cloud begins to rotate faster and faster.

The material collects in a rotating disk
and the protostar emits jet streams.
The outer parts of the cloud are blown away.



Schematic of star formation process.



Many protostars produce jets

(but not all of them…)

Protostars loose material with these jet streams.

Herbig-Haro objects in star forming regions.

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(but not all of them…)

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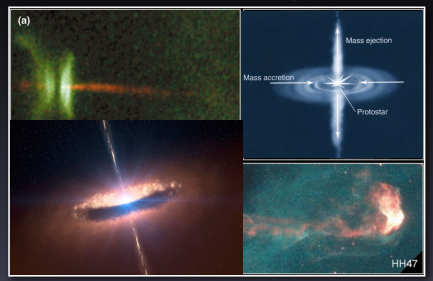


Herbig-Haro objects in star forming regions.

Many protostars produce jets

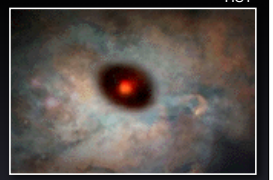
(but not all of them…)

Protostars loose material with these jet streams.

Herbig-Haro objects in star forming regions.

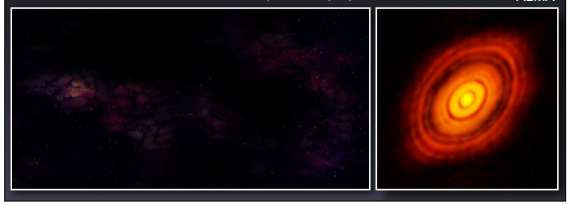
Proto-planetary disks

HST



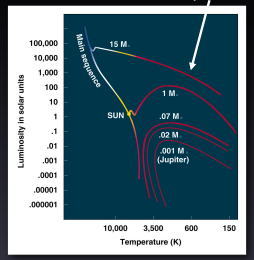
Animation of the formation of a planetary system.

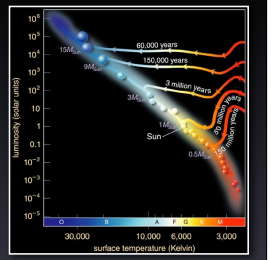
ALMA



Protostars evolve to the *Main Sequence* :

evolutionary tracks





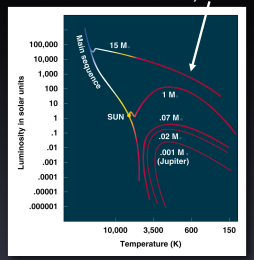
Just before a protostar arrives at the main sequence, the central pressure and temperature increase until nuclear fusion ignites.

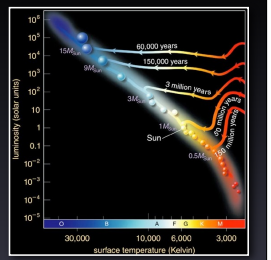
⇒ a star is born!

Note : there is a minimum and maximum mass for a star! (0.08 - 120 M_{sun})

Protostars evolve to the *Main Sequence* :

evolutionary tracks





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Note : there is a minimum and maximum mass for a star! (0.08 - 120 M_{sun})

Stars are formed in groups from GMCs

All stars in a group:

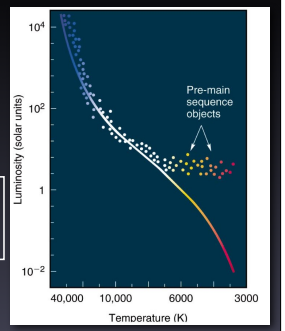
– are at the same distance

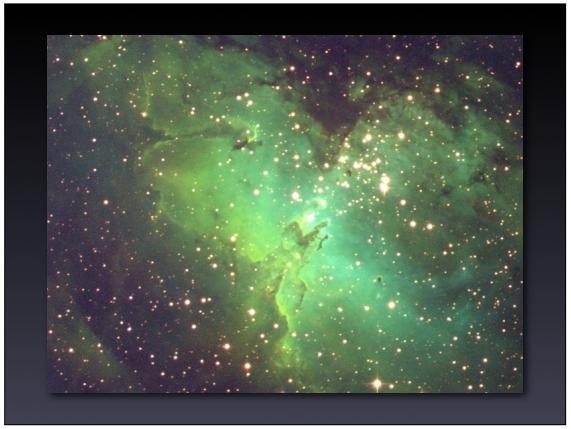
– have the same age

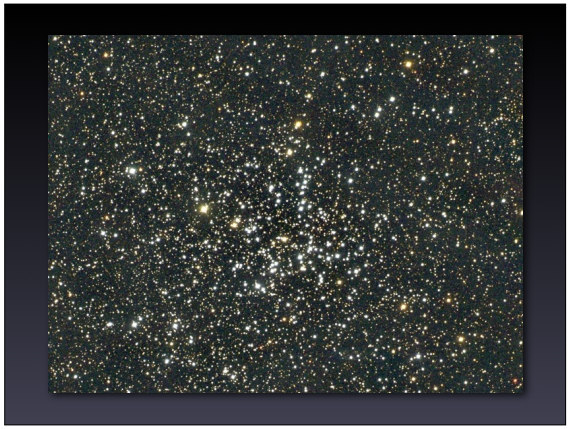
– have the same chemical composition

The number of stars that have not yet arrived on the main sequence reveals the age of the group

There are ~1200 groups or *open clusters* known, each containing 100-10,000 stars.







Stars on the Main Sequence

⇒ Stable equilibrium between gravity and gas pressure maintained by nuclear fusion.

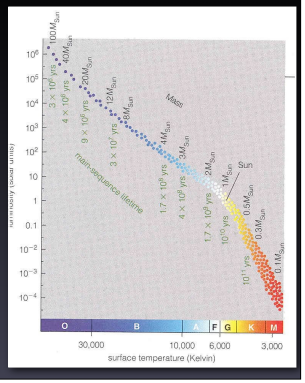
A Mass-Luminosity relation for stars on the main sequence:

$L_{\text{main sequence}} = \text{cst} \times M^{3.5}$

A star 3x more massive than the Sun is 47x brighter!

Stellar masses are calculated using binary stars.

This has important consequences for their life times!



Next lecture

Stellar evolution & death of stars