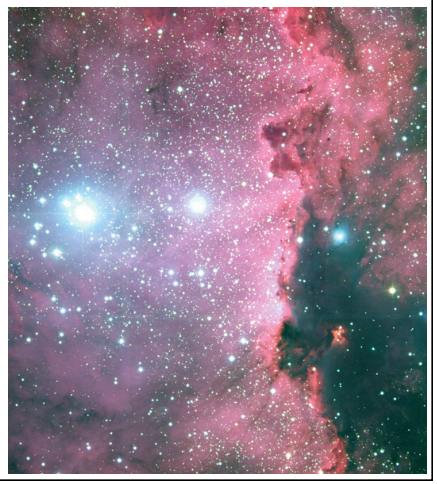
## Lecture 8: Interstellar clouds and the birth of stars

- The interstellar medium - gas, dust and nebulae
- Star formation and protostars
- Star clusters and associations
- Evolution onto the main sequence

## The interstellar medium (ISM)

The space between the stars in a galaxy is not empty, but is filled with tenuous gas of cosmic abundance (i.e. mostly hydrogen and helium), with typical density of about 1 atom per $cm^3$ (but a large range).

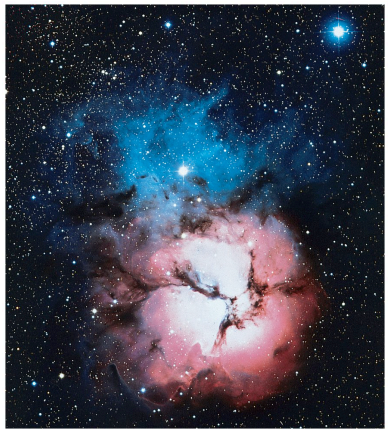
Where this gas is excited by radiation from nearby stars, it glows pink, due to strong emission in the Balmer lines of H (see lecture 4), especially the H$\alpha$ line at 656 nm, in the red part of the spectrum. Such diffuse illuminated regions are called nebulae.



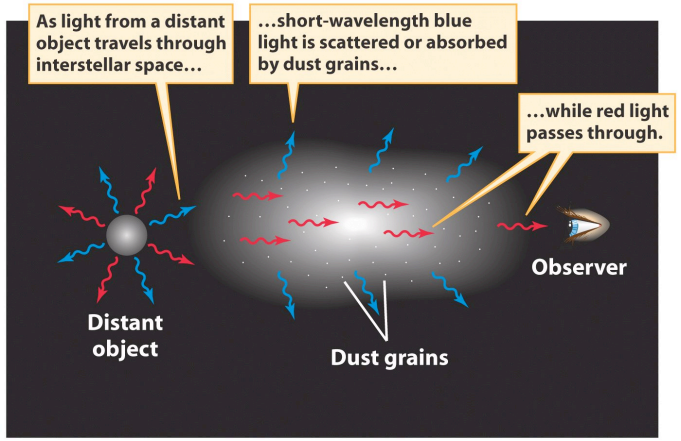
## Interstellar dust

There are blue nebulae, as well as pink ones. These result from the action of microscopic dust particles in interstellar space, composed of some of the heavier elements, such as C, O, Mg, Al, Si and Fe, which have condensed out of the gas phase.

Interstellar dust particles both absorb and reflect radiation.



## Dust - absorption and reflection

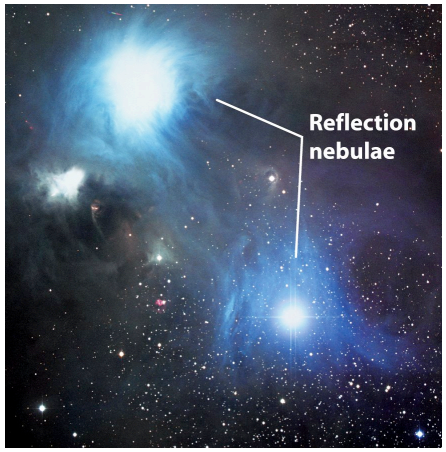



How dust causes interstellar reddening

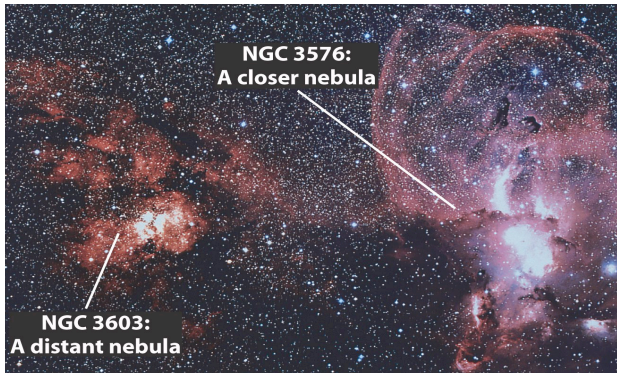
## Reflection nebulae

So, since blue light is more effectively scattered, nebulae which are luminous due predominantly to *reflected* light (as opposed to excitation and subsequent *emission* from atoms) will have a blue colour.

The same phenomenon is responsible for the fact that the daytime sky is blue on Earth.

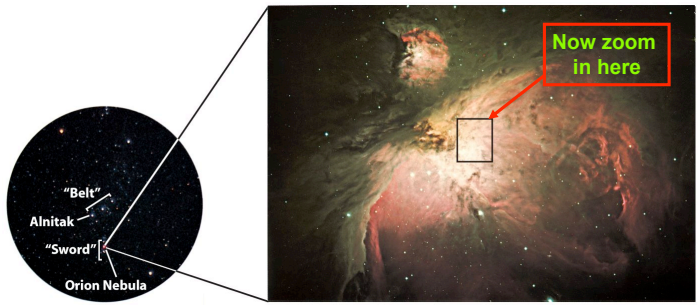



## Absorption and reddening




- Conversely, long wavelength radiation is most likely to penetrate through dust, so that obscured objects tend to look red (like the setting sun).
- Distant objects will generally be redder and dimmer, since there is likely to be more dust between us and them (if they lie in the Galactic plane).

## The ISM and star formation

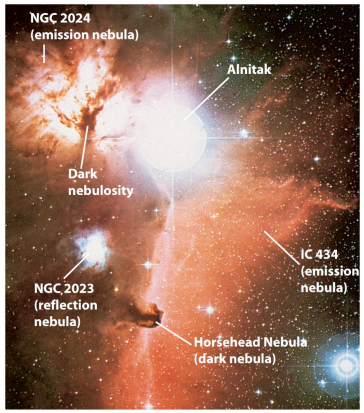



(a) A wide-angle view of Orion. (b) A closeup of the Orion Nebula.

Stars form from the gravitational collapse of gas clouds, so that young stars are born within nebulae.

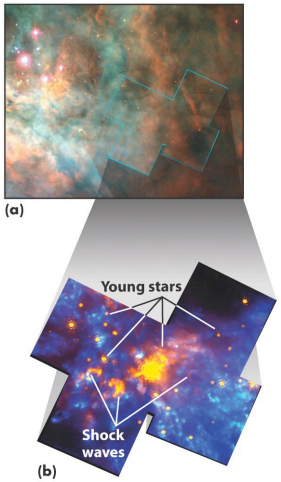
The Orion nebula is one of the closest major star formation regions.

## Some features within the Orion Nebula



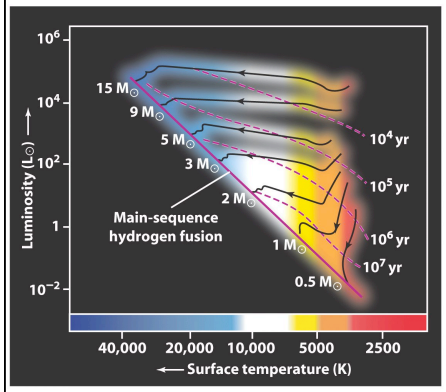

- Dark nebulae, like the Horsehead, are so dense that they are opaque, and appear as dark blots against a background of distant stars
- Emission nebulae, or H II regions, are glowing, ionized clouds of gas, powered by UV light which they absorb from nearby hot stars
- HII (pronounced "h-two") is ionized hydrogen (neutral H is referred to as HI). In an HII region, most of the H is ionized, due to absorption of UV radiation
- Low mass stars have cooler surfaces (lecture 5) and emit little UV radiation, so that HII regions are generated around *massive* stars
- Since massive stars have short lives, HII regions represent regions of current or very recent star formation

## Protostars form in cold, dark nebulae




- Star formation begins in dense, cold nebulae, where gravitational attraction causes a clump of material to condense into a protostar - a star which has not yet commenced nuclear fusion in its core
- As a protostar grows by the gravitational accretion of gas, compression causes the gas to heat, so that it radiates in the IR
- Images of a portion of the Orion nebula show (bottom) IR emission escaping from protostars which are entirely obscured in the optical (top)

## Protostars evolve into main sequence stars




- A protostar's relatively low temperature and high luminosity place it in the upper right region on an H-R diagram
- Further evolution of a protostar causes it to move toward the main sequence on the H-R diagram, as it contracts and gets hotter, via

$$<T>=\frac{\eta GM\mu}{3kR}$$ (V.T.)

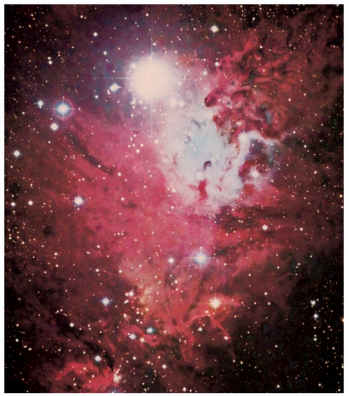
- When its core temperatures become high enough (~$10^7$ K) to ignite steady hydrogen burning, it becomes a main sequence star. This happens more quickly in more massive stars

## Star clusters

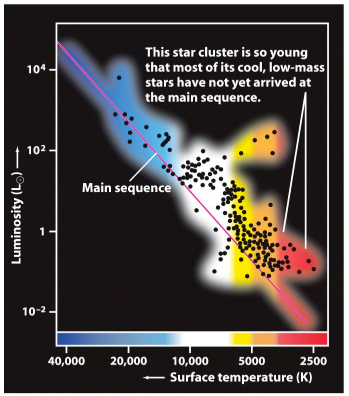
- Stars often form in *groups* within a collapsing interstellar cloud
- These are called open clusters, as distinct from the much denser and more massive globular clusters, which are formed only under special circumstances
- These clusters are bound by gravity, but gradually "evaporate" as faster moving stars escape
- A stellar association is a group of newborn stars which are only loosely bound, and are evaporating rapidly
- Star clusters are very useful for studying the evolution of stars on the H-R diagram
- Since all stars in a cluster are at the same distance, their *relative* luminosities are immediately known, so it is easy to construct an H-R diagram (using *apparent* magnitudes if necessary)



## A very young star cluster

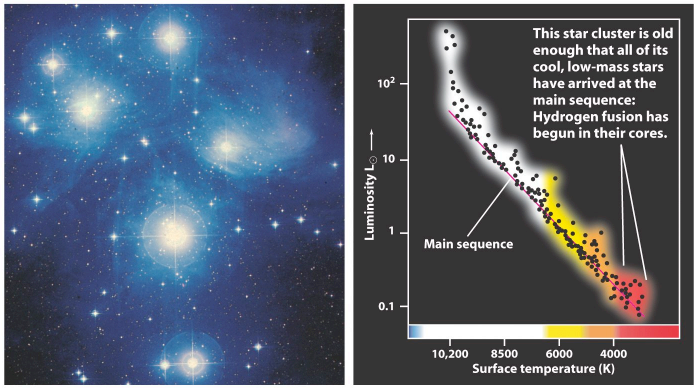


(a) The star cluster NGC 2264




(b) An H-R diagram of the stars in NGC 2264

# An older star cluster



(a) The Pleiades star cluster




(b) An H-R diagram of the stars in the Pleiades