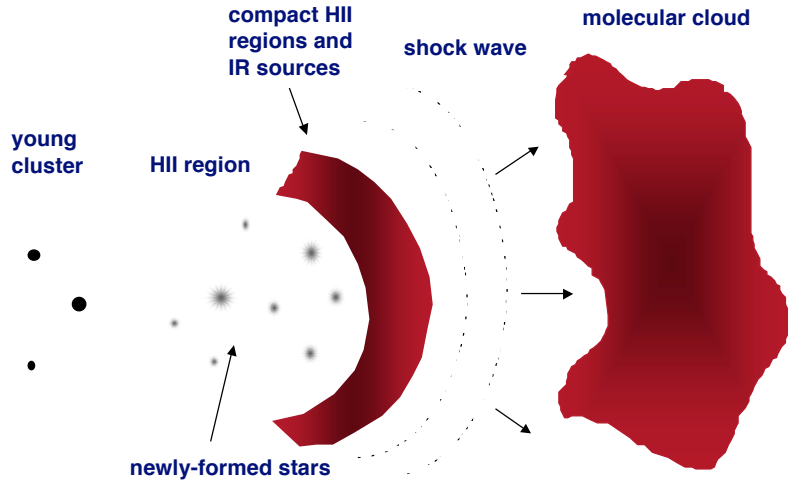
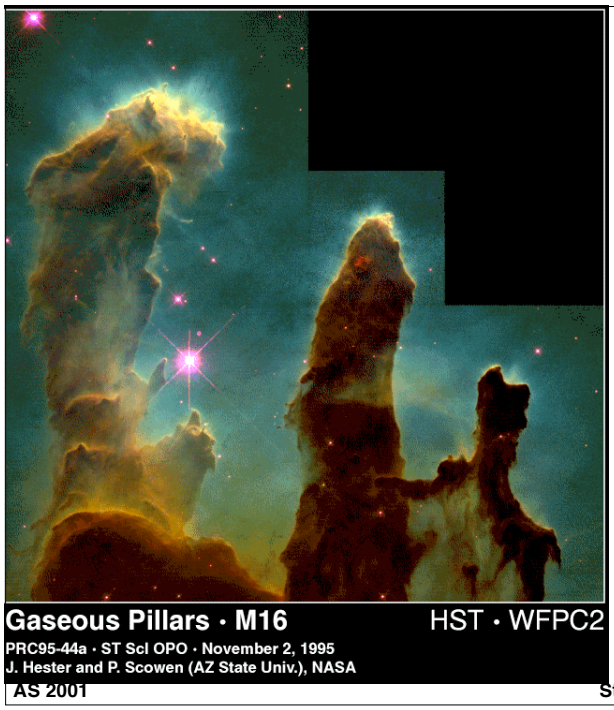
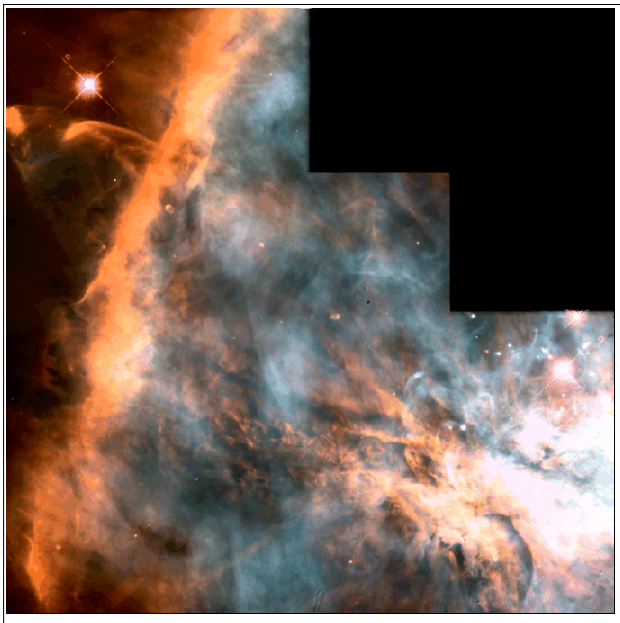
STELLAR EVOLUTION





Intense radiation and winds from young, newly-formed stars blasts away the gas in the nearby molecular cloud.

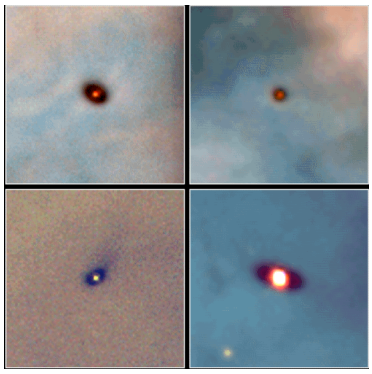
Star formation in the Orion nebula - zoom in central region



Can now see individual protoplanetary disks - zoom in even further

Protoplanetary discs in Orion

- **Dusty discs with sizes comparable to the solar system surrounding newly-formed stars in the Orion nebula.**
- **These are at the limit of the Hubble Telescope's resolution.**



Formation of stars: protostars and pre-main sequence stars

- **In molecular clouds T < 20 K, n ~ 10^9 m^{-3}, masses ~ 10^3 - 10^5 M_{Sun}**
- **Identified by emission bands in IR, mm, radio, H, C, O molecules**
- **Formed by collapse of part of cloud induced by**
  - **supernova explosion nearby**
  - **spiral density wave**
  - **other young stars**

Models for protostars

Initial collapse

- Collapse starts as free-fall under effects of gravity (ie negligible pressure, no collisions).
  - Free fall time $t_{ff} = (3 \pi / 32 G \rho_0)^{1/2}$
    where ρ_0 is the initial density of the cloud
    For $\rho_0 = 3.3 \times 10^{-17}$ kg m^{-3}
    $t_{ff} \sim 10^5$ yrs

- uneven collapse - centre more dense ∴ core collapse more rapid than outer layers →
- formation of small core in hydrostatic equilibrium accreting from infalling envelope
- dust grains + mantles of molecules collide, heat up and radiate in IR, mm

- Free-fall continues as long as radiation escapes (ie optical depth ≤ 1);
- as density rises, cloud becomes opaque to its own radiation - radiation pressure slows the collapse → equilibrium core (a protostar) formed
- time scale ~ 10^5 yrs

Another glitch..

- Due to infalling envelope, core mass & temp increase (until now, radiation escaping → temp ~ 10 - 20 K)
- Once core temp reaches ~ 2000K, H_2 dissociates absorbing some thermal energy → drop in pressure support →
- LOSS OF EQUILIBRIUM !!
- free fall (..here we go again) until gas pressure sufficient to oppose collapse

Approaching the main sequence

- Slow contraction phase as PRE-MAIN-SEQUENCE STAR
- total time so far ~ 10^6 yrs for $1M_{Sun}$ star
- Structure: equilibrium core + low temp, high opacity envelope with convective energy transport
- Once core temp reaches ~ 10^6 K, nuclear fusion starts, slow contraction ends →
- ZERO-AGE MAIN SEQUENCE

Note:

- For high mass stars ($M \geq M_{Sun}$) fusion starts before accretion from envelope stops. Emission of lots of UV radiation ($\lambda < 912$ A) ionises H atoms → H II region
- Formation process may include production of flattened discs, breaking up into multiple objects - binaries, triple systems etc