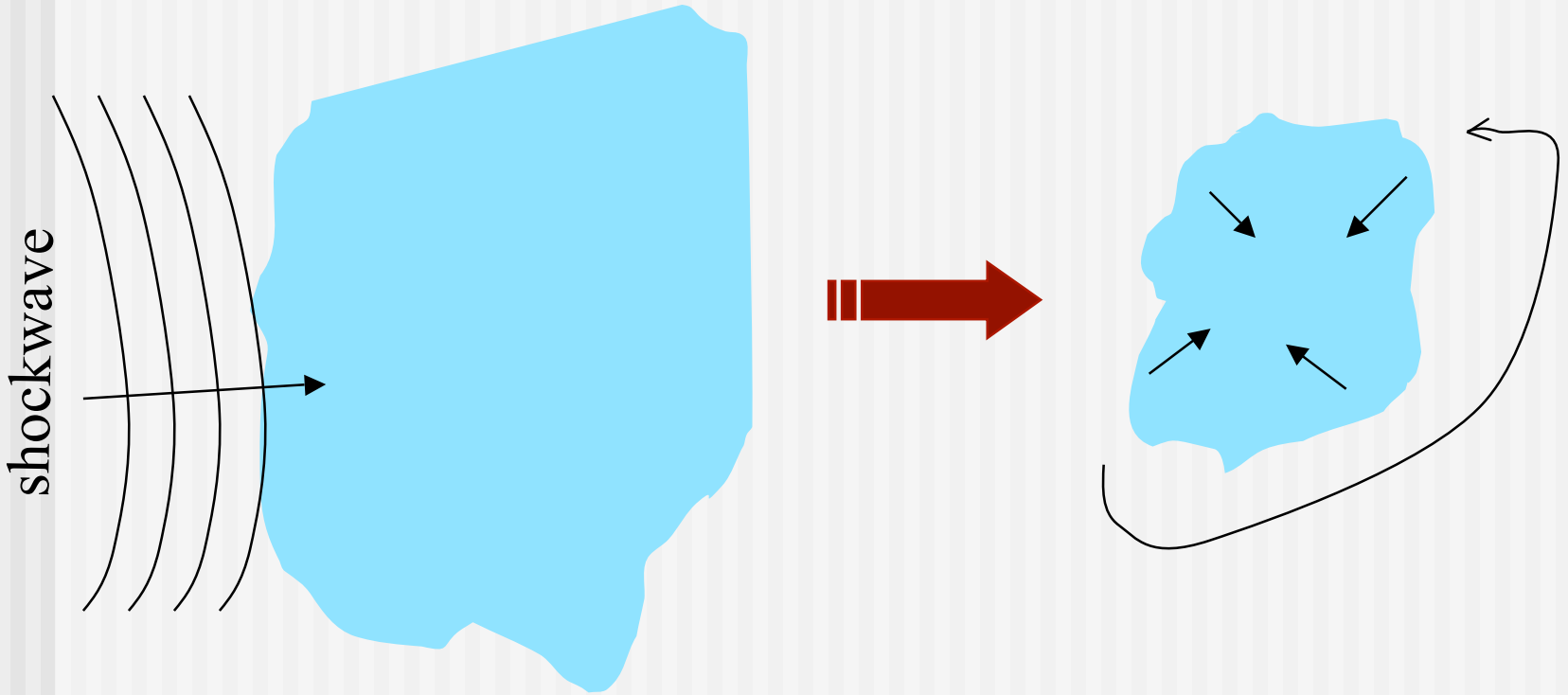
Stellar Evolution

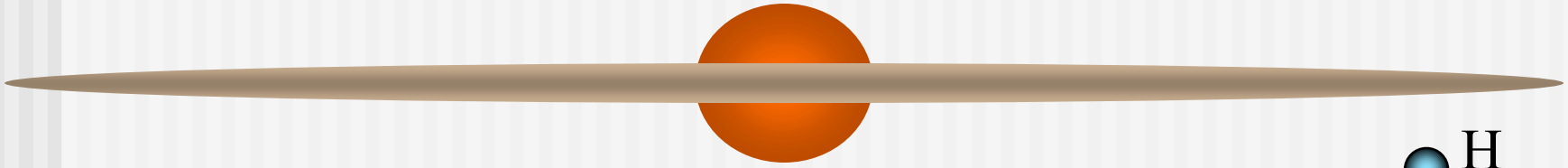
How do Stars Form?

- On macroscopic scale
  - Atoms electrically neutral: no electromagnetic forces over long distances
  - Strong and weak nuclear forces restricted to very small distances
  - Only gravity operates on large scales
- large clouds of gas and dust
  - may start contracting due to passage of shock wave
  - if massive enough, will begin contracting on own

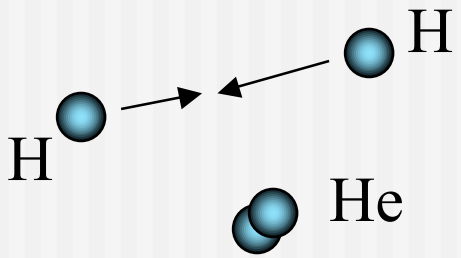


Stellar Birth and Youth

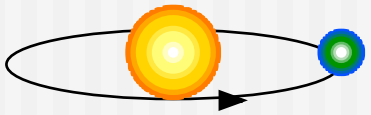
- warm protostar forms
  - Possible rotating disk or companion
  - Enormous amount of material collapsing down into star from cloud.
  - As collapse continues
    - Tremendous heat generated in center
    - Smaller star traps some of this heat: so energy of heat can support the material briefly
      - few 100,000 years

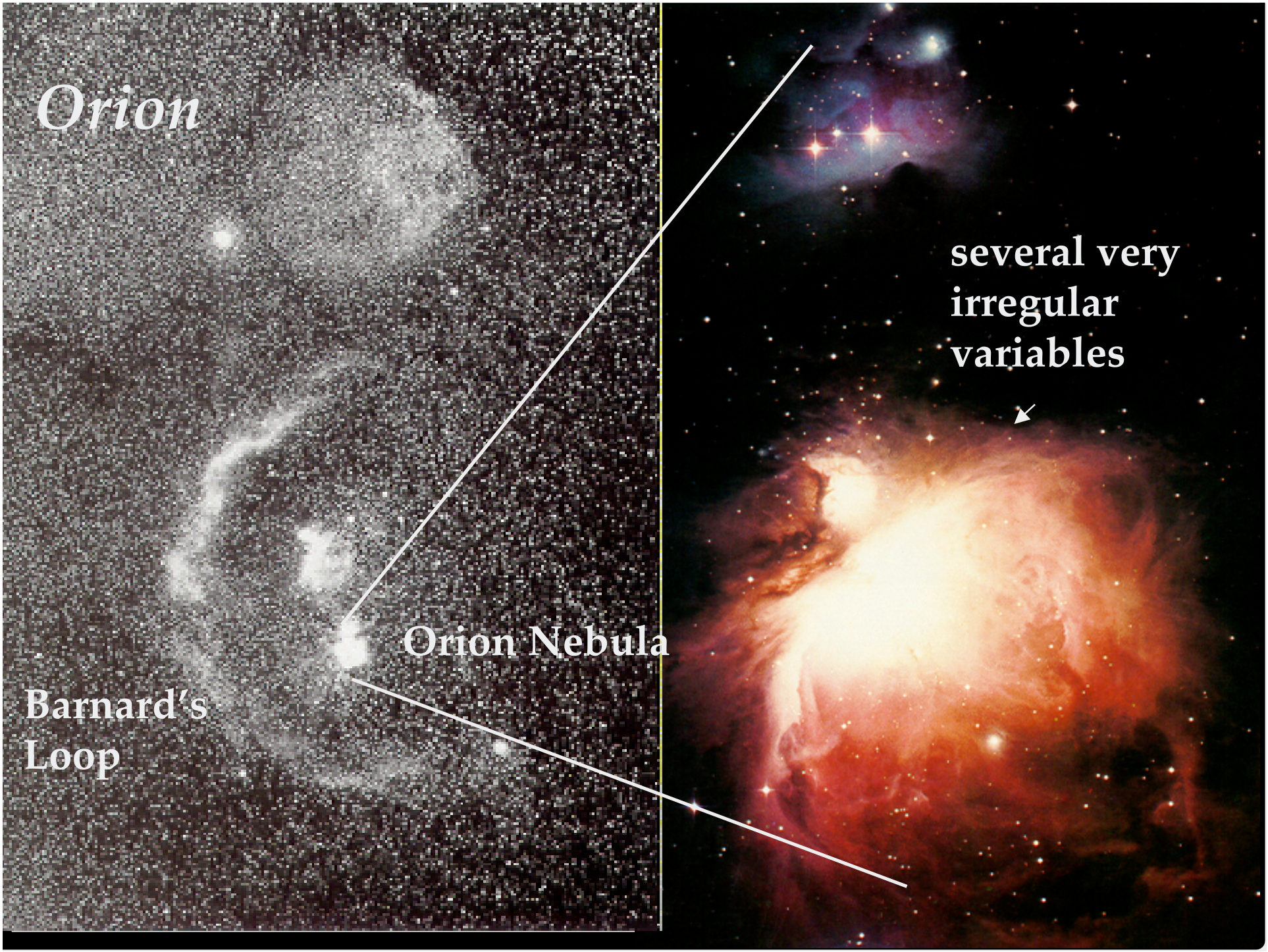


- But heat leaks away and star cannot support itself anymore
  - More contraction, more inense heat
  - thermonuclear reactions start
    - start by fusing Hydrogen into Helium
    - tremendous amount of energy produced
      - gas and radiation pressure
      - balances weight of overlying layers
- Early in life, light output may be unstable
  - But collapse stops for most of star's life



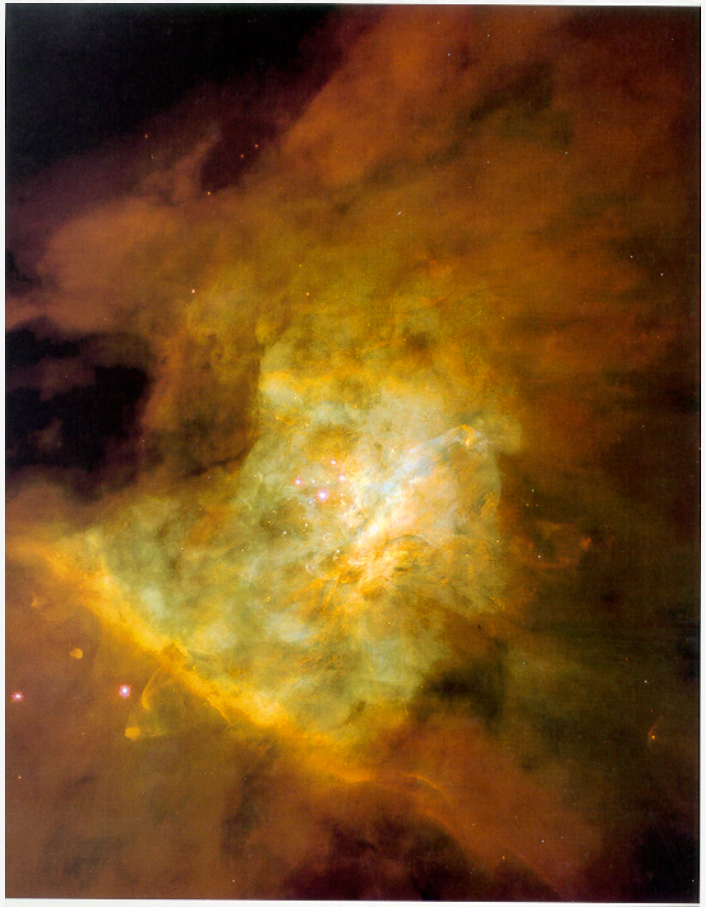
… a star + planets:




Orion
several very
irregular
variables
Orion Nebula
Barnard's
Loop

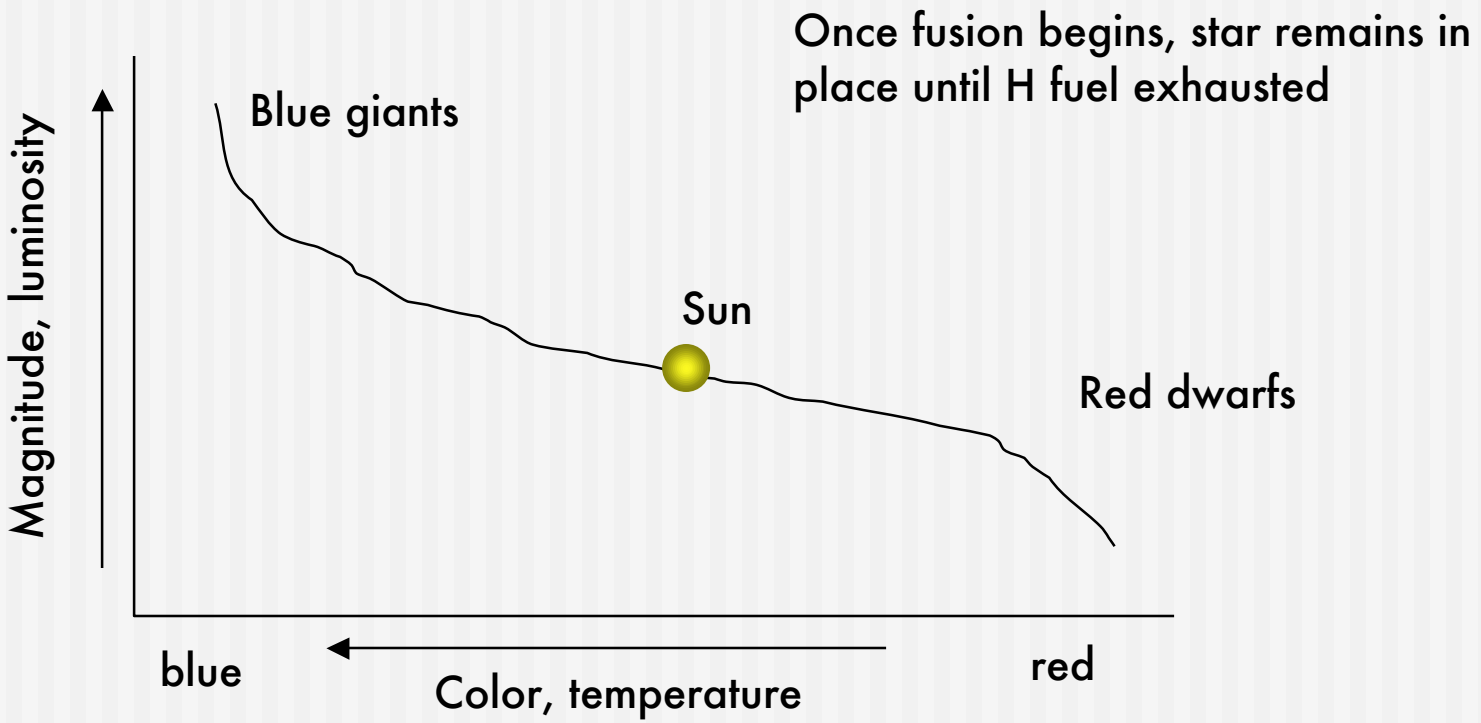
The Orion Complex

- enormous star-forming region
  - 300 light-years across
  - surrounded by Barnard's Loop
  - collapse start 3 to 5 million years ago
- Orion Nebula
  - in front of the larger nebula
  - can see many young variable stars



The Life of a Star

- Once the star begins burning Hydrogen to form Helium
  - Goes on for some time: 90% of raw material is Hydrogen, so there's lots of it
- Hertzprung-Russell, or color-magnitude diagram



Transience

- Stars which are very massive
  - Internal temperatures hotter
  - Larger volume of star converting H –> He
  - Burn much faster
    - Sun's lifetime expected to be 10 billion years
      - So we have 5 more billion, don't worry!
    - Blue giant might live 10 million years, or 1000x shorter!
- Stars do not live forever…

"Change is the essential fact of all existence."

Mr. Spock, Star Trek III

Radiation and Matter

- radiation has many forms
  - light
  - massive particles
  - neutrinos
- when interacts with other matter
  - changes its motion
    - hot atoms move faster than cold ones
  - tends to even out differences
  - eg. one part of a cloud hot, and another part cold
    - both regions will become warm
  - eg. one part of a cloud denser than another
    - if warm then there will be more tendency to even out the density

Variability

- uneasy stability
  - from radiation pressure for most of a star's life
  - Many stars 'pulsate'
  - as burn fuel
    - star makes slight adjustments to internal structure
      - may upset balance of gravity and pressure
  - sometimes changes deviate significantly from stability
    - might generate somewhat more energy
    - outer layer absorbs more radiation
    - star expands and overshoots stable point
    - outer layers absorb less energy and star contracts
  - very regular variations
    - pulsations occur in extreme outer layers
  - brightens when densest, smallest

Regular Variables - δ Cephei

- variations first recorded in 1784
- period 5.36 days
- variation due to alternating expansion and contraction of outer regions
- Henrietta Leavitt at Harvard
  - 1912 realized period-luminosity relation
    - longer variation means a brighter star
    - if know apparent magnitude and period, distance can be calculated
  - permits construction of distance ladder
- several related types of variable
  - also allow determination of intrinsic luminosity