The Stuff Between the Stars
Learning Objectives

- What is the composition of the ISM from which new stars form? How is this similar to the composition of our Sun?
- What is interstellar dust and why can we peer through it if we look using infrared light instead of optical light?
- How do stars form from giant molecular clouds? What is a protostar and what powers it? Why do protostars move across the H-R diagram as they heat up to form stars?
- Do protostars of different masses collapse in the same time? In a star cluster, which color of stars would turn on first? Do low-mass protostars always achieve fusion?
- Why do stars tend to form in clusters that drift apart? Why do hot, blue stars trigger this star formation?
The Birthplace of Stars

- Young stars are associated with clouds of gas (called nebulae)
- The Solar System probably formed from a nebula about 4.6 billion years ago
- Star formation is ongoing right now throughout our Galaxy and other galaxies
Orion Nebula • OMC-1 Region

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The Interstellar Medium

- Nebulae like these are part of what we call the *interstellar medium (ISM)*
- The ISM is about 10% of our Galaxy’s mass
- Consists of about 90% hydrogen, 9% helium, and 1% other things (similar composition to the Sun)
- The ISM comes primarily in two forms:
  - Cold *giant molecular clouds of hydrogen gas and dust*
  - Ionized hydrogen near hot young stars
Effects of Dust

- Interstellar clouds, contain both gas and dust
- The dust grains are a few microns across, which is the ideal size to deflect (or “scatter”) optical light
- Scattering depends on wavelength, such that that blue light is scattered more by interstellar dust
Dust scatters blue more than red light, so all objects in the universe appear a bit redder (and dimmer if you look at them through a blue filter) than they really are.

Not all of the blue light is scattered to longer (redder) wavelengths - a small amount does reach us on Earth.
Peering Through the Dust

The Dark Cloud B68 at Different Wavelengths (NTT + SOFI)
Star Formation

- Giant molecular clouds are the sites of star formation.
- In these clouds are small clumps, called dense cores, that become gravitationally unstable and start collapsing.
- You know the rest of the story, from the Making a Solar System lecture...
Star Formation Summary

Giant molecular cloud

Dust-shrouded core

Protostar

With a Protoplanetary disk

A protostar is powered by gravitational contraction until fusion occurs

Main-sequence star powered by Hydrogen fusion (if > 7 million K is achieved from gravitational contraction)
As protostars heat up they move left on the HR-diagram until they hit the Main Sequence.

- Protostars are *larger* and *cooler* than Main Sequence stars.
- More massive protostars collapse, and achieve fusion, more quickly.
- They have more gravity and hydrogen to fuel fusion.
Brown Dwarfs: $M < 0.08 \, M_{\text{Sun}}$

- These are stars with less than 80 times the mass of Jupiter.
- Their protostar’s core temperature did not get large enough to fuse hydrogen.
- But it is possible to fuse deuterium ($^2\text{H}$) at only about 1 million K.
- As brown dwarfs’ cores are \(~7\) times cooler than Main Sequence stars, their surfaces are also \(~7x\) cooler than MS stars.
Star Clusters

- Stars are commonly found in clusters.
- Clusters are groups of stars that formed at the same time from the same cloud of gas and dust.
- Young clusters are often near collapsing nebulas (big clouds of gas) and contain several very hot (so very blue) young stars.
- Hot stars shine in the UV, sending large amounts of energy into the ISM that triggers new waves of star formation.
Trapezium Cluster • Orion Nebula
WFPC2 • Hubble Space Telescope • NICMOS

NASA and K. Luhman (Harvard-Smithsonian Center for Astrophysics) • STScI-PRC00-19
Star Clusters Trigger New Star Formation
Next Time

The Death of Stars I