Last time: More bizarre endings - black holes etc.

• even neutron degeneracy can’t stop collapse of most massive remnants
• gravity’s ultimate victory: black holes
• finding black holes by their influence on their surroundings

Today: The InterStellar Medium and the Galaxy

• stuff (gas and dust) between the stars is visible via emission lines, absorption lines, or scattering (reflection)
• wide range of densities, but still way less than Earthly ‘vaccums’
• ISM is recycled - incorporated into stars, processed, & ejected
• Stars, gas, dust, cluster are all part of the Milky Way Galaxy
• The MW Galaxy has neighborhoods, populations, etc. that belie the history of its formation and evolution

ashes to ashes, dust to dust...
the Interstellar Medium
- gas and dust between the stars

• Evidence (subtle)
  • interstellar absorption lines (seen in spectra of background stars)

• interstellar “reddening”
• dark clouds - interstellar absorption

• More Evidence (not subtle)
  • interstellar emission line clouds
    • clouds glowing by excitation from star(s)
    • vivid colors - few spectral lines - “neon signs”
  • reflection nebulae
Interstellar Atomic Emission Line Clouds

- **HII (“H two”) Regions**
  - bubbles of ionized gas around hot stars
  - O stars → big HII regions (~ 250 pc)
  - B stars → smaller HII regions (~ 10 pc)

- **Planetary Nebulae**
  - remnants of giant star envelopoes
  - “forbidden line” of Oxygen, Nitrogen, etc.

- **Neutral Hydrogen (H1 -or- “21 cm”) Clouds**
  - spin-flip of e⁻ in HI involves low-E photon
  - wavelength of 21 cm
  - rare event, but strong signal (LOTS of hydrogen!)
  - important probe of gas in galaxies

Interstellar Molecules ...

- Absorb/emit over broad bands in wavelength
- Infrared and Radio wavelengths
- molecules present where ISM is cold
- associated with star formation complexes
  - $H_2$, OH, $H_2O$, CO, CN, CH$_4$, CO$_2$,
  - $C_2H_5OH$, $CH_3NH_2$
  - ... amino acid building blocks!

and Interstellar Dust ...

- dust grains: “large” aggregates of interstellar matter
- grain size ~ wavelength of visible light
- transparent to long wavelength (red) light
- dust (and atoms) scatter short wavelength (blue) light

sunsets are RED but the sky is BLUE: why?
Interstellar Reddening

- dust removes blue light . . . stars viewed through dust look redder
- dust can absorb visual light heavily . . . up to 99.999999% (20 magnitudes) or more
- extinction decreases with increasing wavelength . . . IR, radio observations “see through” dust

IN GENERAL:
  - red cloud is gas (hydrogen emission)
  - blue cloud is starlight scattered by dust and/or gas

- Note: interstellar ‘baseballs’ would be completely invisible
We’ve now studied:

- stars
- star clusters
- molecular clouds (stellar nurseries...)
- stellar corpses (white dwarfs, neutron stars, ...)
- interstellar gas (HI, HII, ...) and dust

All are components of our GALAXY: the Milky Way

Views of Spiral Galaxies
Stellar Populations in the Milky Way

- **Population I** - Stars in the Disk
  - massive stars (open clusters)
  - orbit within disk of galaxy
  - “metal” abundance same as Sun or more

- **Population II** - Stars in the Halo
  - very low metal abundances
  - orbits way out of galactic plane
  - low mass stars (globular cluster)

**Populations as clues to the formation of the Milky Way**

- **Pop II stars**: relics of earliest star formation in the M.W.
  - MOTION: initial collapse of the Galaxy
  - LOW METALS: primordial (uncooked) material

- **Pop I Stars**: more recently formed
  - HIGH METALS: stars formed from debris of older stars