Quiz 6 this Wednesday, April 9

Last one of the semester!

Material covered

- March 31: stars (chapter 11)
- April 2: star birth, maturity, old age (chapter 12)
- April 7: star death (chapter 12)

Material in today’s notes under “Stellar Corpses” will be covered next week.

Homework 6 assignment sheet will be available Wednesday, due April 16.

Homework 5 is graded and available for pickup in back.
1. Which of these groups of particles has the greatest mass?

(a) A helium nucleus with two protons and two neutrons

(b) Four individual electrons

(c) Four individual protons

Others . . . ?
About shows at Ritter Planetarium

Friday evenings at 7:30 PM:

- “Spring Skies over Toledo,” April 4 - 11, 2008. Currently visible stars, planets, constellations; more.


Saturday afternoons at 1 PM: “Don’t Duck, Look Up,” April 5 - 26, 2008. Introduction to daytime and nighttime sky. Especially well suited for pre-school children: acceptable for this class, but Friday shows may be more useful.
The April Brooks Observatory sessions

Because of our poor weather this semester, additional observing sessions have been scheduled for ASTR 1010, beginning at 8:45 PM each evening:

- Thursday, April 10
- Sunday, April 13 through Wednesday April 16

Not required if you have already been to Brooks this semester & written a report. If you attend this time, report due Wednesday, April 23

As before, take elevator to 5th floor of this building, walk up to 6th floor. Bring your blue ticket with your name and my name (Nancy Morrison) written on it. Extra blue tickets are available.
If you don’t have a red (planetarium) or a blue ticket (observatory), write your name and my name (Nancy Morrison) on a sheet of paper and turn it in.
The most recent supernova visible to the unaided eye: Supernova 1987A

- In a neighboring galaxy, the Large Magellanic Cloud, about 160,000 light years away
- **Discovered in February**, was still unaided-eye in June 1987
- Because of its nearness, the star that exploded has been identified. It was a *blue supergiant* star.
• **Supernova remnants**
  
  – Rapidly expanding clouds of gas
  
  – Famous example: Crab Nebula
  
  – At location in sky where Chinese astronomers observed a bright new star in 1054 AD
  
  – Another famous example, much older: **Veil Nebula**
Overview of the stellar life cycle

Formation or birth by gravitational contraction from interstellar gas clouds

Main-sequence stage: fusion of hydrogen to helium in core, exterior unchanged

Exhaustion of hydrogen, brief existence as red giant

Fusion of helium to carbon and oxygen

Review energy conversion processes:

1. Gravitational contraction
2. Nuclear fusion
3. Simply cooling off
Low-mass stars (less than 8 Suns)
- Formation of electron-degenerate core
- Gentle shedding of outer layers
- Carbon-oxygen white dwarf remnant; cooling, no further change

High-mass stars (more than 8 Suns)
- Continue nuclear fusion, making heavier elements up to iron
- Explosion as supernova, dispersing nuclear fusion products into surroundings
- Neutron star or black hole left as remnant
Some time later, formation of next generation of stars from “enriched” interstellar gas

Over billions of years, the interstellar gas has become more and more enriched with heavy elements.

When they form, stars have the same composition as their birth clouds. As they age, their interiors change, but their exteriors do not.

If all this is true, older stars should have an even lower concentration of heavy elements than younger stars. In general, this is what is observed.

Without the heavy elements, there wouldn’t be planets — or people.

Star ages - 3 methods

1. Age of Sun - from primitive meteorites.
2. High-mass stars - age must be less than 10 to 20 million years.
3. Star clusters - age is given by main-sequence life span of most massive main-sequence stars in cluster. Oldest clusters: 10 to 13 billion years.
Stars and the origin of the elements

Hydrogen: primordial. Protons and electrons came into being a split second after the universe itself did.

Helium: originated before any of the stars. We’ll discuss this more thoroughly later.

Lithium, beryllium, boron: rare, special cases, another origin.
“We are star stuff” — Carl Sagan

All other elements: made in and by stars.

- Thermonuclear fusion in the core makes the most common elements up to and including iron.

- Other processes occurring in supernova explosions, etc., make the other elements, including the ones heavier than iron.

- Some of the heavy elements made in a massive star’s core are thrown out into space during the supernova explosion.

- There, they form part of the interstellar material.

- Later, may be incorporated into a star or planet
Are stars the only thing that could have made the heavy elements?

- Elements including carbon and heavier: the only known process is nuclear fusion in stars.

- Thousands of generations of massive stars have lived and died, enough to produce the heavy elements existing today.

- Stars make helium, but they also destroy it, so they can account for only a small fraction of the helium in the universe. We’ll account for it by nuclear fusion, but in another setting.
Lives of Binary Stars

Star pairs can be close or wide

The two stars form at the same time

The more massive one completes the main sequence first, turns into a red giant

If it swells beyond a certain point, material will travel from it to the other star: mass transfer

It may never become a full-fledged red giant, but may go straight to the white dwarf stage.

Or it may survive to the red giant stage and explode as a supernova (if a massive star) leaving behind a neutron star.
Therefore, we find examples of binary stars in which one member is still on the main sequence, while the other (which started life with more mass) has now evolved to its end point: a white dwarf, a neutron star, or a black hole.

**Stellar Corpses**

White dwarfs

- Mass: usually 0.5 to 1.3 solar mass
- Radius: similar to Earth (10,000 kilometers approx.)
- Density: 10,000 to 100,000 grams per cubic centimeter

---

Neutron star: similar mass as the Sun but only 10 miles across. Black hole: light cannot escape.