Astro 301/ Fall 2005
(48310)

Introduction to Astronomy

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Lecture 2 + 3: Tu Sep 6, Th Sep 8
Topics in class this/next week

-- Math review and conventions adopted

-- ‘Natural’ units: Angstrom, Astronomical Unit, parsec and light year

-- Important astronomical objects and concepts
  Building blocks of matter: protons, electron neutrons and atoms
  Stars: Energy Generation
  Death of Stars: Planetary Nebulae, Supernovae Remnants
  Why is human life ‘star stuff’?
  Different types of Nebulae
  Planets, Brown Dwarfs, Moons and our Solar system
  Galaxies and the Milky Way
  The Local Group, Clusters of Galaxies
  Superclusters, voids and filaments

-- Distances: From the infinitesimal to the grandest scales
-- Timescales: From the earliest epochs to the present day
Lecture 2
Lecture 2: Announcements

1. The Co-op has 49 new textbooks as of Friday for this class
   “The Cosmic Perspective, 3rd edition, Media Update”

2. What is the difference between “The Cosmic Perspective, 3rd edition” and
   “The Cosmic Perspective, 3rd edition, Media Update”?
   The book contents are the same, but the media update version comes
   with a full e-book, Star Gazer software, and access to The Astronomy
   Place (a web based tutorial system). Both are at the same price.

3. QUIZ on Tuesday, Sep 13 based on lectures 2 and 3

   Class website: http://www.as.utexas.edu/~sj/a301-fa05
Cluster of bright young stars in center. Winds from young massive stars clearing out a hole in center; Outer layers of dust and hot glowing gas.
Astronomy

In this course we will address these issues

The present-day Universe from the infinitesimal to the grandest scales

How did the Universe begin in a Big Bang? What physical laws govern its evolution?

Over time, how did stars, planets, life, galaxies, and black holes form and evolve?

How did galaxies like our own Milky Way form?

What is the role of dark matter and dark energy?

What are predictions for the future of our Galaxy and of the Universe?

Can science solve the ultimate mystery of Nature?
Math Review: Practice from Appendix C.1 to C.4
Powers of 10 for very large and small numbers

Powers of 10

- 10 to the power of a positive number $n$ means 10 multiplied by itself $n$ times
  number between 1 and 9 inclusive is multiplied by a power of 10
  
  $10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000$

- 10 to the power of a negative number $n$ refers to reciprocal
  
  $10^{-4} = 1$ divided by $10^4 = 1/10^4 = 1/10000 = 0.0001$
**Scientific Notation for very large and small numbers**

**Scientific Notation**

- Refers to notation where a number between 1 and 9 inclusive is multiplied by a power of 10. Convenient to express very large and small numbers

**Example**

Radius of H atom = 0.00000000005 m = $5.0 \times 10^{-11}$ m  
Radius of Earth = 6,380,000 m = $6.38 \times 10^6$ m  
Radius of Sun = 696,000,000 m = $6.96 \times 10^8$ m  
Mass of H atom = $1.67 \times 10^{-27}$ kg  
Mass of Earth = $5.97 \times 10^{24}$ kg  
Mass of Sun = $2.0 \times 10^{30}$ kg
**Scientific Notation for very large and small numbers**

How to convert a number to scientific notation

- Move decimal point till it is after FIRST non-zero digit.
- Count the no of places \((n)\) the decimal point has moved
- If motion is to the left then the power of ten is \(10^n\) else it is \(10^{-n}\)

Example

\[
62050 = 62050. = 6.205 \times 10^4 \text{ m}
\]
\[
0.002401 = 2.401 \times 10^{-4} \text{ m}
\]
Radius of Sun = 696,000,000 = \(6.96 \times 10^8\) m
Radius of H atom = 0.00000000005 = \(5.0 \times 10^{-11}\) m

PRACTICE FROM APPENDIX
**Scientific Notation for very large and small numbers**

How to convert a number from scientific notation

- Power of 10 tells you how many places to move decimal point
- Positive power means move to the right, -ve to the left
- If by moving decimal places you create spaces, then fill them with zeros

Example

\[
6.205 \times 10^4 \text{ m} = 62050 \\
2.401 \times 10^{-4} \text{ m} = 0.0002401
\]

Radius of Sun = \(6.96 \times 10^8 \text{ m} = 696,000,000\)

Radius of H atom = \(5.0 \times 10^{-11} \text{ m} = 0.00000000005\)

PRACTICE FROM APPENDIX
**SI Units for measuring distance, mass, time....**

Metric or SI units

- m or km for length, kg for mass, s for time

Useful conversions to SI units (Appendix)

1 km = 1000 m = 0.62 mile = 1094 yards
1 kg = 1000 g = 2.205 pounds
1 h = 60 min = 3600 s
1 year = 365 days = 365 x 24 h = 365 x 24 x 60 s = 31,500,000 s
‘Natural’ units: Angstrom, Astronomical Unit, parsec and light year

See in-class notes
Building blocks of matter: protons, electron neutrons and atoms
Structure of an Atom

Ten million atoms could fit end to end across this dot.

The nucleus is nearly 100,000 times smaller than the atom but contains nearly all of its mass.

Atom: Electrons are “smeared out” in a cloud around the nucleus.

Nucleus: Contains positively charged protons (red) and neutral neutrons (gray).

See in-class notes
Structure of an Atom

atomic number 5  number of protons
atomic mass number 5  number of protons 1  neutrons

Hydrogen (\textsuperscript{1}H)
atomic number 1
atomic mass number 1
(1 electron)

Helium (\textsuperscript{4}He)
atomic number 2
atomic mass number 4
(2 electrons)

Carbon (\textsuperscript{12}C)
atomic number 6
atomic mass number 6
(6 electrons)

The number of electrons in a neutral atom equals its atomic number.

Isotopes of Carbon

\textsuperscript{12}C
(6 protons 1 6 neutrons)

\textsuperscript{13}C
(6 protons 1 7 neutrons)

\textsuperscript{14}C
(6 protons 1 8 neutrons)

Different isotopes of a given element contain the same number of protons but different numbers of neutrons.

Figure captions are misprinted in book : “5” should be “=“, “1” should be “+“
E.g., 2\textsuperscript{nd} caption should read : atomic mass number = number of protons + neutrons
Structure of an Atom

Electrons in an atom can only populate certain discrete quantized energy levels e.g., discrete levels for Hydrogen atom above.
Stars: Energy Generation
Stars: see in-class notes

Our Sun
Structure of a star like the Sun

- Nuclear fusion occurs in core where temp and pressure are very high.
- The energy released is transported from core to the cooler surface (called photosphere) where it is released as light and heat. This is the ‘surface’ where visible yellow light from the Sun comes from.
Corona of the Sun

As we move away from the photosphere (solar surface) temperature suddenly start to go up again…. Coronae at T=10^6 K emits most of Sun’s X-rays

X-ray image (Yonkoh Space Observatory)
Hot million-degree gas in Solar corona

X-ray image (NASA’s TRACE mission): hot million degree gas trapped in magnetic field
Death of Stars: Planetary Nebulae, Supernovae Remnants
When a low-mass (M=0.08 to 1.5 solar mass) star dies, its inert core becomes a white dwarf. Its outer layers of gas are ejected as a glowing hot ball of gas called a planetary nebula, which contains mostly H, He, C, but no significant amounts of O, N, Sulfur, Silicon, Iron. Glow fades within a million years as core cools and gas cools and disperses.

Planetary nebulae have nothing to do with planets!
When a high-mass (M $> 8$ solar mass) star dies
   its core becomes a neutron star or black hole,
   its outer layers of gas are blown by a supernova (SN) explosion into a glowing hot ball
   of gas called a SN remnant. The remnant contains H, He, C, and also heavy elements
   O, N, Sulfur, Silicon, Iron that were made via advanced fusion.

SN remnant called Cygnus loop;
HST/optical image: Blue, green = O, Red = S

Supernova remnant called Crab Nebula; VLT/Optical
Why is human life ‘star stuff’?
Elements produced a few minutes after the Big Bang, and before the first stars
  = H (~77%), He (~23%), Li (trace amounts)
  no C, N O in the primordial gas

But today, humans are made up of water (H₂O), carbon (O), N (protein, DNA)
  Earth’s atmosphere: mostly N, O

C, N and O are produced by advanced fusion in core and layers of high-mass (M> 8 solar mass)
  star. (Low mass stars may produce some C, but no significant N, O).

When the high mass star dies
  - its core becomes a neutron star or black hole,
  - its central and outer layers of gas containing
    H, He, C, and N, O, Sulfur, Silicon, Iron are
    blown out by a supernova (SN) explosion, and
    form a SN remnant, made of hot glowing gas.

The remnant enriches surrounding gas with these elements and the gas later collapses to
  form a new generation of stars and planets, where life based on C, N, O, Iron may develop
Lecture 3
Lecture 3: Announcements

QUIZ on Tuesday, Sep 13 based on lectures 2 and 3

Book is on reserve at the Physics, Math and Astronomy (PMA) library
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Different types of Nebulae
What is the difference between nebulae like Orion and a planetary nebula?
See in-class note

Part of Eagle Nebula
(5 ly across)

Orion Nebula
Planets, Brown Dwarfs, Moons and our Solar system
Planet: see in-class notes

- Mercury: heavily cratered, but also has long, steep cliffs—one is visible here as a long curve that passes through the center of the image.
- Venus: central structure is a tall, twin-peaked volcano.
- Earth: variety of geological features visible in orbit.
- Earth's Moon: surface is heavily cratered in most places.
- Mars: has impact craters like the one near the upper right, but it also has features that look much like dried up riverbeds.

Jupiter, Saturn, Uranus, Neptune

Mercury, Venus, Earth, E's Moon, Mars
Our Solar System

Distance between Earth and Sun = $1.5 \times 10^{11}$ m = 1AU ; Pluto-Sun ~ 39.5 AU
Titan, moon of Saturn is one of the largest moons in solar system. It is comparable in size to the planet Mars!

Earth’s moon has a heavily cratered surface
To boldly go where no one has before....

Apollo II i(1969). First landing on Earth’s moon!

“A small step for man, one giant leap for mankind”
Cassini-Huygens mission to Titan, the moon of Saturn

- Cassini-Huygens mission to Saturn: robotic spacecraft sent on to orbit Saturn and study the Saturnian system. Launch Oct 1997; 7 years to reach Saturn; study Saturn system for 4 years till 2008)

- Scientific probe Huygens: released in Nov 2004 from the main spacecraft; parachutes through the atmosphere and lands on the surface of Titan, Saturn’s largest moon.

Huygens= first spacecraft to land on a world in the outer Solar System. I
Cassini-Huygens mission to Titan, the moon of Saturn

Titan as seen from Cassini’s fly-by on August 22, 2005

Saturn’s rings have own atmosphere, composed principally of molecular oxygen
The nearest star from the Sun
Galaxies and our Milky Way
Galaxies: See in-class notes

Ubarred spiral

NGC1300; Barred spiral
150,000 ly across
Or Galaxy, the Milky Way is a barred spiral galaxy, 100,000 light years across, hosting our Sun and Solar system.
In-class demo: Zooming 26 orders of magnitude (part 1)

Human - Earth - Solar System - Alpha Centauri - Milky Way Galaxy
Groups and Clusters of Galaxies
The Local Group

See In-class notes
Brightest members of Local Group?
Closest galaxy neighbors of Milky Way? Interactions of Milky Way?

LMC; Irr;
Size = 30,000 ly Dist = 0.16 x 10^6 ly