1) Dark Matter
2) Particle Physics
3) Telescopes
Announcements

- **Final Exam will be held in Ruby Diamond Auditorium**
  - NOTE THIS!!!
  - not UPL
  - Dec. 11, 2002 10am-noon

- **Lenoid shower**
  - tonight 4am-sunrise
  - the Earth will pass through the remnants of the tail of Comet Tempel-Tuttle
  - last chance – won’t happen again for some time
Review of Galaxies

- **Messier objects**
- **Galaxies**
  - spiral, elliptical, irregular
- **Active Galactic Nuclei (AGNs)**
- **Spiral Galaxies**
  - Disk
  - Arms
  - Bulge
  - Halo
- **Globular clusters**
Rotation Speeds of Galaxies

- Most of the visible material of a galaxy is near the center
  - material thins out as you move outward
- For spiral galaxies, this means stars farther out should be moving slower
- But we see them all moving with the same speed!
  - must have an explanation

Dark Matter!
What is Dark Matter?

- Dark matter is material we can’t see
- We have various evidence the Universe has lots of matter we can’t see
  - rotation speeds of galaxies
  - movement of global clusters around galaxies
  - more in the coming weeks
- Two primary theories
  - **MACHOs** - MAssive Compact Halo Objects
    - planets or brown dwarfs or low-mass black holes
    - unlikely, people are looking, have seen a few, but not enough
  - **WIMPs** - Weakly Interacting Massive Particles
    - new type of elementary particle
Building Blocks

- Materials are made of atoms and molecules
  - Molecules are made of atoms
- Atoms are made of electrons around a nucleus
- A nucleus is made of protons and neutrons

Particle physics tries to determine what are the building blocks of Nature and how they interact
How to Determine If A Particle Is Elementary

- Slam particles together VERY hard
- Determine if particles have structure
  - will behave differently
- Create new particles
- Most particle physics done at large laboratories with particle accelerators
Fermi National Accelerator Laboratory

- Slam protons into antiprotons
- World’s highest energy accelerator
- Outside of Chicago
Protons and neutrons are made of smaller particles - quarks
  - three quarks in each proton and neutron

Six types of quarks
  - up, down, strange, charm, beauty, top

Quarks can only be observed with partners
  - two or three together
  - no quarks in isolation
Table of Elementary Particles

- Most basic particles we know of
  - leptons
  - quarks
  - bosons
More Particles

- There are a number of interesting theoretical ideas for new particles
  - supersymmetry, extra dimensions, string theory, leptoquarks, ...
- These particles must
  - be massive
  - rarely interact with normal matter
- If these were not true, we would have observed them already
- These could be dark matter candidates
  - WIMPS - Weakly Interacting Massive Particles
A Great Question

- The nature of dark matter is one of the great questions of astronomy
- Could have very important implications on our understanding of the Universe
  - something is out there which we do not understand
  - could radically change how we think about many things
- Pay attention to this issue in the coming decades...
Cosmic Rays

- Charged particles are constantly hitting our atmosphere
  - most come from Sun
  - most energetic cosmic rays come from outside of our Galaxy

- These cosmic rays interact in our upper atmosphere
  - creates showers of particles

- Cosmic rays give us another view of the Universe
Cosmic Rays on Earth

- The spark chamber is observing parts of cosmic ray showers
- these particles are passing around us all the time
Intro to Telescopes

- Telescopes:
  - collect electromagnetic waves (light)
  - magnify
  - focus it on eye, camera, readout device
Attributes of Telescopes

- **Focal length**
  - determines separation between objects

- **Resolution**
  - determines smallest object visible

- **Light collection**
  - determines dimmest object visible

- **Which is most important?**
Reflecting Telescopes

- You can use a mirror to have a long focal length with a short physical size
- Keck Observatory
  - located on Mauna Kea, Hawaii
  - twin, 10-meter diameter reflecting telescopes
Atmospheric Effects

- Atmosphere blocks certain wavelengths
- Humidity affects light transmission
- Moving air influences light transmission
  - “twinkling” of stars
- It is best to put telescopes on mountains in stable weather
Different Kinds of Telescopes

- Different instruments do different things
Would the Moon Be a Good Place to Put a Telescope?
Satellites

- Good for getting out of the Earth’s atmosphere
  - can observe other wavelengths
- Hubble Telescope
  - 2.4 meter reflecting telescope in space
  - multiple readout instruments
- COBE satellite
  - high resolution microwave satellite