

# Atoms and Stars

## IST 2420

Class 14, April 23  
Winter 2007

Instructor: David Bowen

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# Agenda

- Assignments, passbacks, initial signin sheet
- Pick up:
  - Notes for Class 14
- Class information
  - Special Grade Request if much work will be late
- Updating the course
- Review of readings
- Emphasizing main points one more time
- Review for Final

# Upcoming ...

- Tonight is the last regular class
  - Essay 2 due
  - Review for Final Exam
- April 30: nothing that night but the Final Exam
- Opportunities for extra help:
  - Review Session during class
  - 5 – 6 PM before Final (April ~~30~~26)
  - Telephone, email, set up a time

# Upcoming ...

- Second makeup for Midterm:
  - Tomorrow April 24, 6 PM, 223 State Hall

# Semester is Ending!

- If you have been relying on being able to turn work in late, *it is late!*
  - Alternatives: D, E, I, W (drop) – see counselor!
- Getting ready for Final:
  - Read Information Sheet carefully – a lot of information there
  - Look at Final Topics carefully
  - Use Review Session!
    - Final Where-Is handed out at the previous class

# Course Grades

- If you are turning a bunch of work in at the end, I may not get it graded in time for the regular grades (see the Syllabus).
- If this is you (turning it in late), what grade do you want for the regular grade? D, E, W, I
- Fill in the Grade Request form (get a copy from me) to let me know – otherwise it's my choice.
- You can withdraw (W) through Tuesday April 24 using Pipeline
- Medical Withdrawal

# Your Current Status

- Grades I have for you:
  - Online Grade Report, link off the course web site (see first slide)
  - Enter first name, last name, password the get report
- Grade you are headed for:
  - Grade What-If on course web site
- Ask for help with these if you are having problems

# Makeup for Final Exam

- Let me know by email that you want a makeup, within 24 hours after the Final (University regulation)
- Date / Time, building and room to be settled by email.

# Lab 11: Orbiting Bottle

- If your two results (A & B) for the horizontal (inward) force,  $F_H$ , agree, then your data are consistent with Newton's Laws (including Universal Law of Gravitation).
- See Theory section for the proof of this

# Doppler Effect (Review)

- Video
- Frequency of wave higher if source is moving towards us, lower if moving away
- Evidence that stars are moving away from us
  - Colors shifted redder (“red shift”)
  - First evidence for Big Bang

# Expanding Circles

- Review: science started out as isolated areas
- Then areas expand – science always pushing its boundaries
- Implication #1: What happens when two expanding circles meet?
- Implication #2: What happens when circles fill the space?
  - My answer: science drives technology (C11S15-19)

# Expanding Circles

- Implication #1: What happens when two expanding circles meet? I promised three examples (Q15)
  - Example 1: Newton uniting celestial (stars) and terrestrial (on land) – already done (C10S32-33)
  - Examples 2 and 3 now.

# Expanding Circles (Q15)

## Example 2: Statistical Mechanics

- Ludwig Boltzmann, end of 19th century
  - Physicists had never accepted idea of atoms
  - Boltzmann (Austrian physicist) one of first
  - Worked out Newtonian mechanics for a gas of colliding atoms and molecules - Statistical Mechanics
    - With J. Willard Gibbs – now his own stamp
  - DB: “Atomic Theory meets Isaac Newton”
  - Same results as Thermodynamics (accepted)
    - Also explained how those results came about (explanatory)
- Other physicists still sharply rejected these ideas
  - May have contributed to Boltzmann's 1906 suicide

# Expanding Circles

## Statistical Mechanics

- Theory: molecules in a gas move and collide randomly, governed by laws of statistics
- Once particles mix, essentially no chance of their separating again
- [Computer simulation](#)

# Expanding Circles

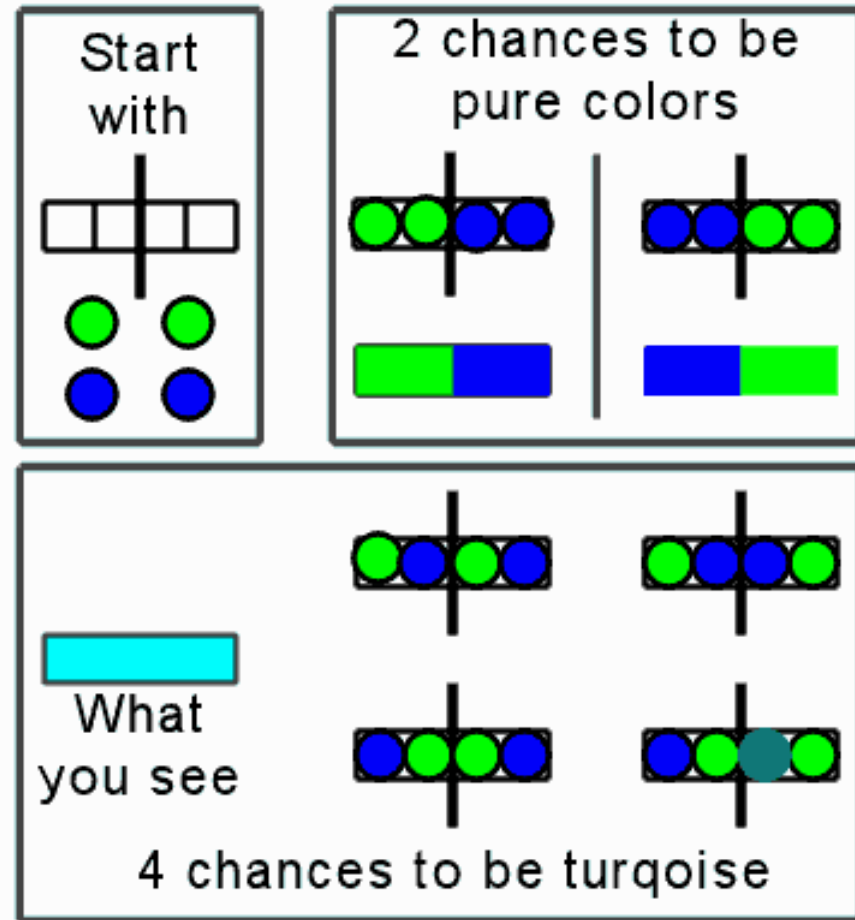
- Now Boltzmann honored as pioneer
  - Statistical Mechanics very important
    - Significantly modified by Quantum Mechanics.
- Second Law of Thermodynamics
  - If a hot object and a cold one are in contact, energy always goes from hot to cold
    - Atoms in hot object more energetic (Rumford), travel more
    - Slowed down by collisions with slower atoms from cold object, but these are sped up
    - Statistical Mechanics explains why this happens
    - Demonstration – diffusion – atoms of dye

# A Taste of Statistical Mechanics

- See next slide, but here is the explanation
  - “Gas” with spaces for 4 atoms
  - Gas divided into left & right halves
  - Two green atoms, two blue
  - In each half, the 4 atoms arrange randomly
  - Atoms too small to see, we see the average color in each half
  - One chance for left being green, right blue
  - Another chance for the opposite
  - 4 chances for mixed – turquoise
- Chances get more lopsided with more atoms

# A Taste of Statistical Mechanics

- Start with gas (4 slots) and atoms
- We see average of color in each half
- Most common is mixed
- Odds more lopsided with more atoms



# Expanding Circles

## Example 3: Electromagnetism:

- Greeks : Electricity and magnetism separate
  - o Electricity: static electricity
  - o Magnetism: compasses
- 1775 – 1890 they became practical
  - o Electric (E) and Magnetic (B) fields
  - o Generators, motors, some E-B interaction
  - o Volta, Ampere, Ohm, Joule, Hertz (and our own Benjamin Franklin)

# Expanding Circles

- 1865 James Clerk Maxwell wrote equations for electricity and magnetism
- Noticing that the laws as known then said that a changing  $B$  could produce an  $E$  but not the reverse, Maxwell boldly added a term so that a changing  $E$  could produce a  $B$
- Then a changing  $E$  could produce a changing  $B$  which produced an  $E$  again

# Expanding Circles

- $\frac{\partial^2 E}{\partial x^2} = \varepsilon_0 \mu_0 \frac{\partial^2 E}{\partial t^2}$  ( $\varepsilon_0$  &  $\mu_0$  previously known)

- But the equation of a wave was known to be:

$$\frac{\partial^2 Q}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 Q}{\partial t^2}$$

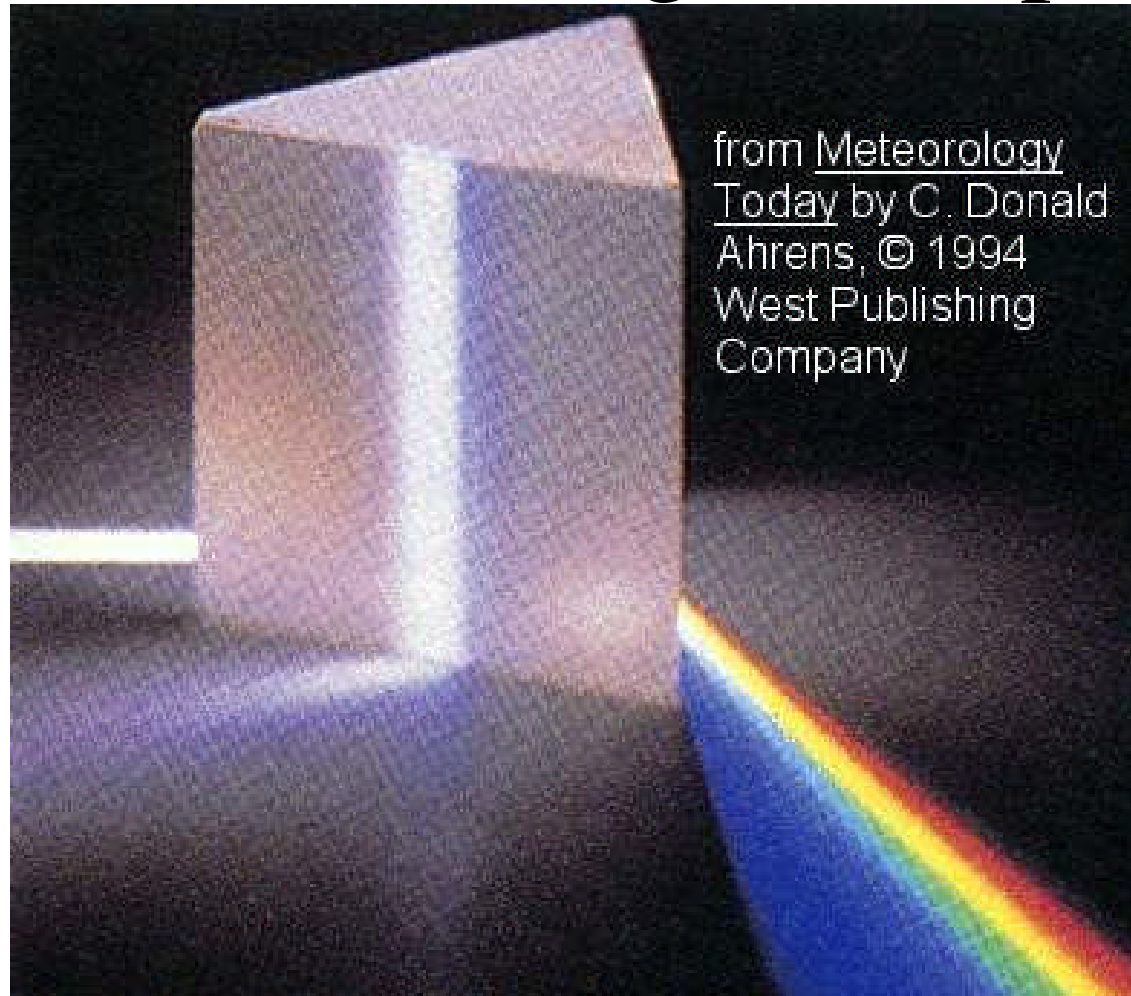
- So electricity and magnetism must coexist in waves with speed

$$v = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 186,000 \text{ miles per second}$$

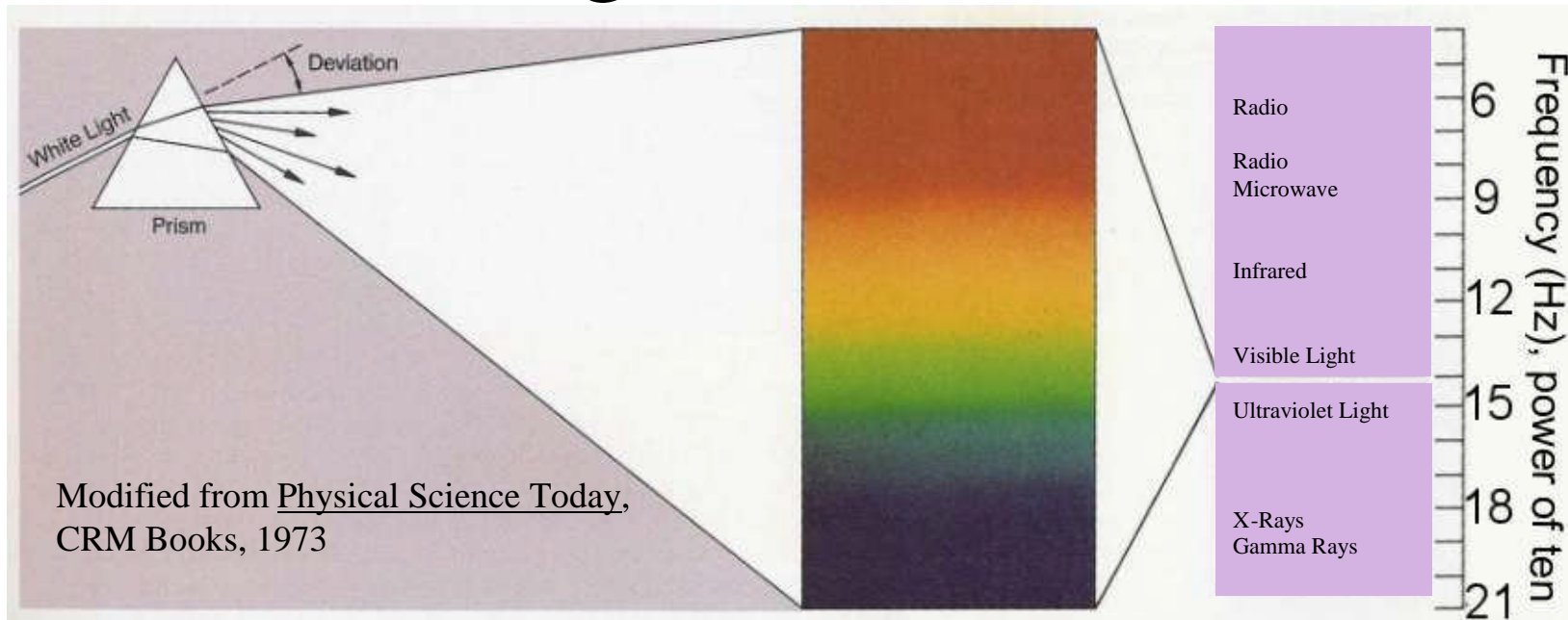
# Expanding Circles

- Maxwell confirmed in all respects
- In other words, we now know that light is electromagnetic waves
  - Thomas Young had shown light to be waves in 1801, not particles as Newton had said
  - Speed known since Roemer in 1676
- Maxwell (a) hypothesized complete laws for electricity and magnetism, and (b) showed what light was (bonus)

# Visible Electro-Magnetic Spectrum



# Electromagnetic Radiation...



- **Spectrum of Electromagnetic Radiation**
  - Numbers = power of ten in frequency (Hertz, Hz)
  - Examples: 6 means MHz =  $10^6$  Hz, 9 means GHz =  $10^9$  Hz
    - WDET: 101.9 MHz, wireless phones: 5.8 GHz

# Back to: Expanding Circles

- Expanding Circles – Implication 1, three examples
  - When two domains meet, become fused into one with a bonus
  - Not a compromise – both areas transformed, improved
- Implications:
  - This is additional evidence for science
    - If theories were imaginary, different imaginations would rule
  - Hard to attack just one area of science, since they are becoming more tightly tied together
    - Creationists and Intelligent Design advocates finding they have to attack 4.5 billion year age of earth, Big Bang, etc. (readings)

# Re-emphasizing Main Points

- Two pillars of science
  - Experiment: makes science reliable
    - Scientists led astray by logic (Aristotle) and belief (church and geocentrism, Inquisition)
    - Experiments base science on direct experience
  - Theory: makes science valuable
    - Once you have a reliable theory, it tells you the answer in advance, can use it as technology
    - Two quotes from Copi, Reader Pg 8

# Re-emphasizing Main Points

- I have the experiments in this course to:
  - Give you direct experience
  - Illustrate experiments described in class
  - Illustrate social nature of science within the lab groups

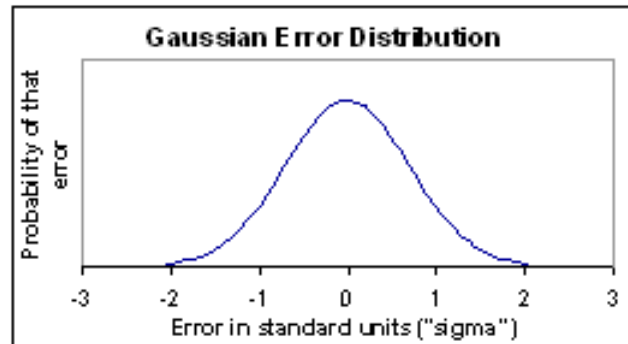
# Readings: Knowledge or Certainty

Jacob Bronowski

- Absolute certainty is impossible in science
  - Looking at an object with infrared, then visible, then x-rays should yield greater detail. Infrared is very blurry, visible is pretty good, but x-rays are too high energy to be focused. Perfect detail of “God’s-eye” view is impossible
  - Statistical uncertainty in measurements - Gauss

# Knowledge or Certainty

- 1795



- Science is discussion and argument preceding knowledge
- Also Uncertainty Principle 1927 Werner Heisenberg – cannot locate particle exactly
  - o Irreducible uncertainty or fuzzy focus

# Knowledge or Certainty

- No practical effect at

$$\sigma(\mathbf{x}) \times \sigma(\mathbf{v}) = \frac{\text{a very small number}}{\text{mass}}$$

- macroscopic level, but a philosophical problem with The Mechanical Universe and with “The God’s eye view”
- But certainty leads to tragedy – Nazis
- (DB) Certainty and power combined

# What is Science?

Moti Nissani, What Is Science?

- Difficult or impossible to give a dictionary-type definition for science
- (DB) Working scientists rarely think about the history or philosophy of science
- Start with philosophy of Thales – free inquiry

# What Is Science? (cont'd)

- Then hypothesis and experiment (Torricelli)
- Falsifiability – reason and logic have not been not sufficient to discover the truth in science (DB: belief, either)
  - o But contradiction by experiment does not always mean rejection of hypothesis – can lead to reexamination of experiment or modification of hypothesis
  - o Scientists “on the trail” have personal concerns

# What Is Science? (cont'd)

- o Scientists “on the trail” have personal concerns
  - Argument and community lead to progress
- o Semmelweis and deaths in maternity ward
  - Neighboring ward far safer
  - Did priest’s visit scare patients?
  - Washing hands – doctors did dissections beforehand
  - This fixed the problem
  - Profession slow to accept this change
  - Even scientists can be closed-minded, resist change

# What Is Science? (cont'd)

- Theories unify many hypotheses and experiments
  - Price is often inaccessibility to non-scientists
- Scientists usually not concerned with these issues or with philosophical uncertainty
- Science many not be perfect, but it can still be very good
- Many use technology but not the scientific foundation

# Physical Science: Current Status

- Newton's Laws, Maxwell's Equations and similar classical theories (before ~ 1900) describe world we know and see
- For things the size of molecules and smaller, need Quantum Mechanics
- Very fast, need Special Relativity
- Very heavy, need General Relativity
- All three have weird things going on

# Special Relativity

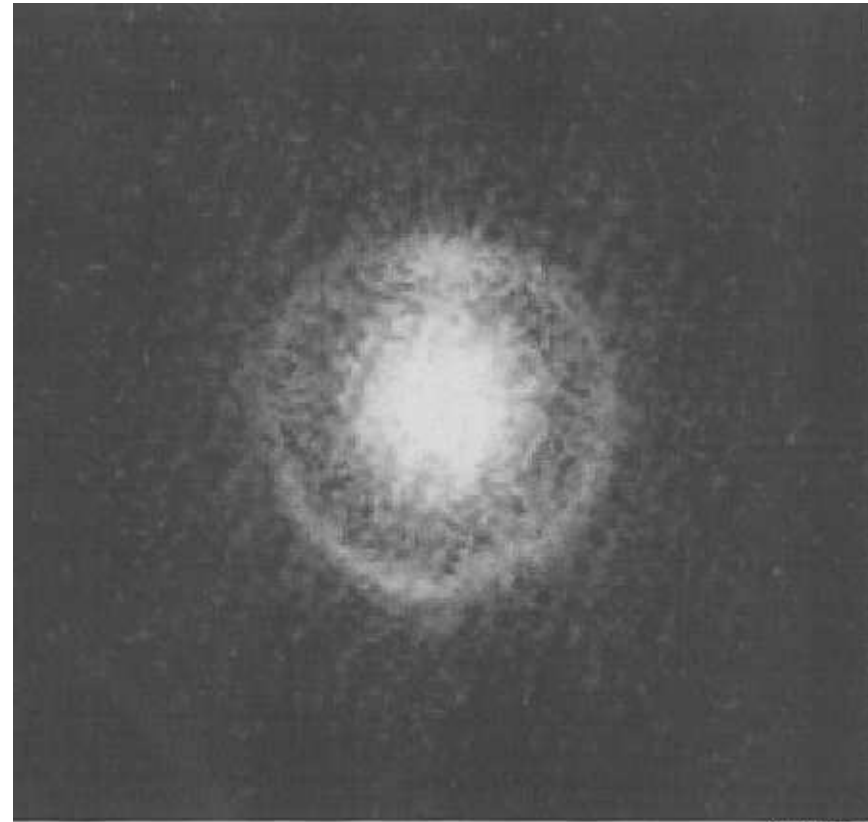
- For fast-moving objects
  - Max speed =  $c$  (speed of light)
  - Objects foreshortened
  - Time slows down
  - But the traveling person says the same about you!
  - Space and time  $\rightarrow$  space-time
  - $E = mc^2$ 
    - $\therefore$  light has mass, is bent by gravity

# General Relativity

- For very heavy objects
  - Space and time warp, cause gravity
  - Perihelion (closest approach to sun) of Mercury's ellipse not fixed as in Newton's Laws, but advances 43 seconds of arc per century (observed), other effects in addition
  - Says light bends twice as much as Special Relativity says, observed 1918

# General Relativity (cont'd)

- “Einstein Halo” – light from far galaxy bent by near galaxy
- Variation on gravitational lens
- 12 found so far
- Picture: New York Times, 12/6/05, Pg D4 (Science)



NASA/E.S.A.

# Quantum Mechanics

- At molecular level and smaller, waves and particles merge – everything is both
  - Wave – spread out, cannot contain it
  - Particle – have it or don't
  - Q.M.: wave gives chance of “catching” particle
    - Cannot be made certain
- Uncertainty Principle

$$\sigma(x) \times \sigma(v) = \frac{\text{a very small number}}{\text{mass}}$$

- Carries over to regular world, makes clockwork universe impossible over age of universe

# Quantum Mechanics (cont'd)

- Accounts for properties of ordinary materials
  - Theoretical: keeps matter from collapsing
  - Color
  - Solid (strength), elastic, gaseous
  - Solid state electronics – semiconductors
  - Forces – due to exchanges of particles
    - No Newtonian “action at a distance”
    - E.g. electrical force carried by photons – particles of light

# Conflict!

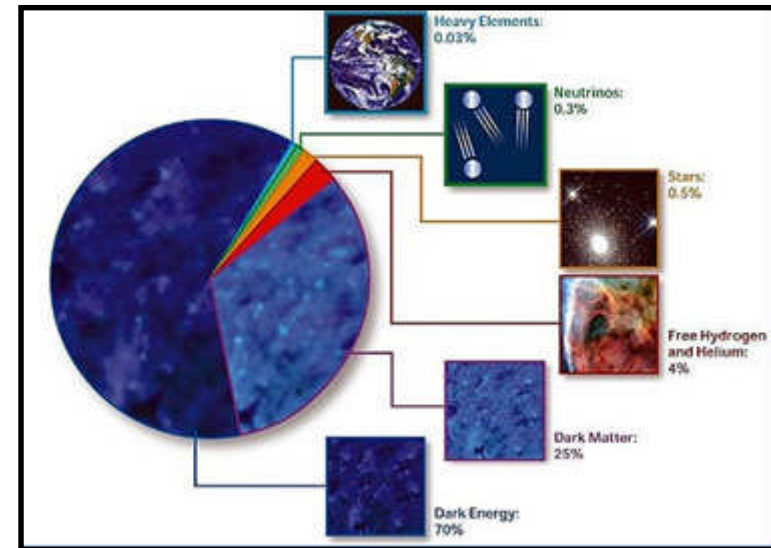
- Heavy (G.R.) and small (Q.M.) – mathematical conflict. Example: Black Hole
  - Competing theories of gravity – “embarrassing”
    - G.R.: gravity caused by masses warping space-time
    - Q.M. – gravity due to exchange of “gravitons” (not found yet)
  - “String Theory” might unite these two
    - “Theory of Everything” – accelerating expansion(!)
    - Matter and energy composed of elemental vibrating strings and membranes
    - Eleven dimensions, seven curled up too small to experience directly – may have indirect experience
    - Theory still developing, no unique experimental evidence yet

# Issues:

- “Anthropic Principle” – physical rules seem to favor life
  - Room for God inside science?
  - But “Inflationary Universe” may explain this
- Dark Matter
  - Galaxies spinning fast, not enough mass to hold them together so they should be flying apart but this is not observed
  - Must be Dark Matter at center of galaxies

# Issues (cont'd):

- Dark Energy
  - Big Bang should be slowing down
  - But outer half of universe is *accelerating*!
  - Current hypothesis is that dark energy at outside fringe is attracting the inner parts.



Source: NASA

- Between these two, we see only 5%. The universe is still surprising us!

# The end of the ride

- Strong dose of the value of science here
- One more time, about science:
  - Two pillars – repeatable experiment (what makes it reliable) and explanatory theory (what makes it valuable)
    - Developed 1600 – 1800 AD: Copernicus to Dalton
  - Developing hypotheses and theories is creative
  - Has a boundary but expands aggressively
    - ∴ not a complete basis for living
  - Now drives technology
  - We all use it
  - Conflicts with some, but not all, religious beliefs
  - People of all ethnicities have been able to contribute

# 1. SET

- IST 2420, CRN 23981
- David Bowen

# 2. Review for Final