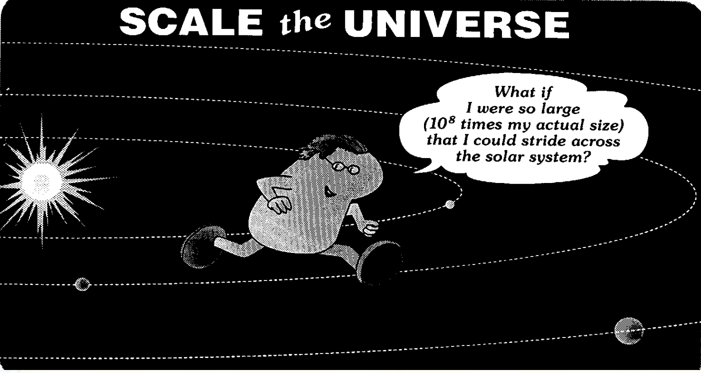
Scale the Universe

Exploring your Universe from Inner to Outer Space

Linda L. Smith

NASA Astrophysics Educator Ambassador

lsmith@paulsboro.k12.nj.us

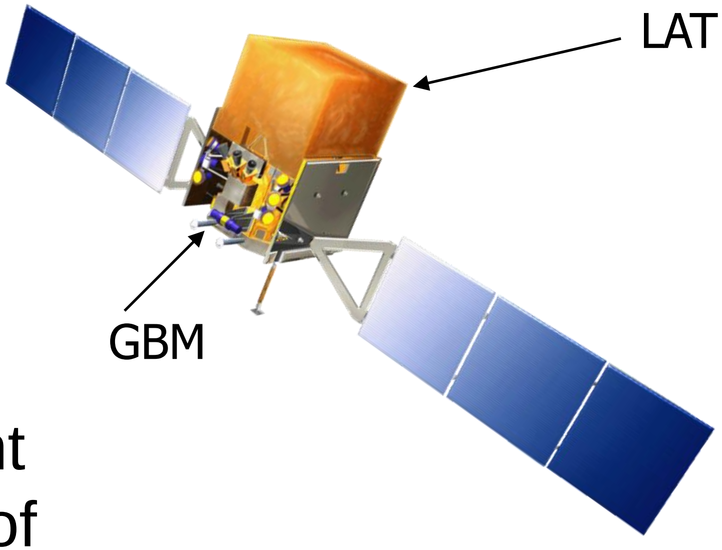


The Booklet

- This book is organized into 3-stand-alone sections:
  - A:
    - A1: Orders of Magnitude
    - A2: Unit Analysis
  - B:
    - B1: Ordering Distance – Sticky (What we will do!) and Cutout
    - B2: Using a Log Scale
  - C:
    - C1: Scale the Universe (1)
    - C2: Scale the Universe (2)
    - C3: Scale the Universe (3)
    - C4: Proportional Thinking
    - C5: Ordering Time

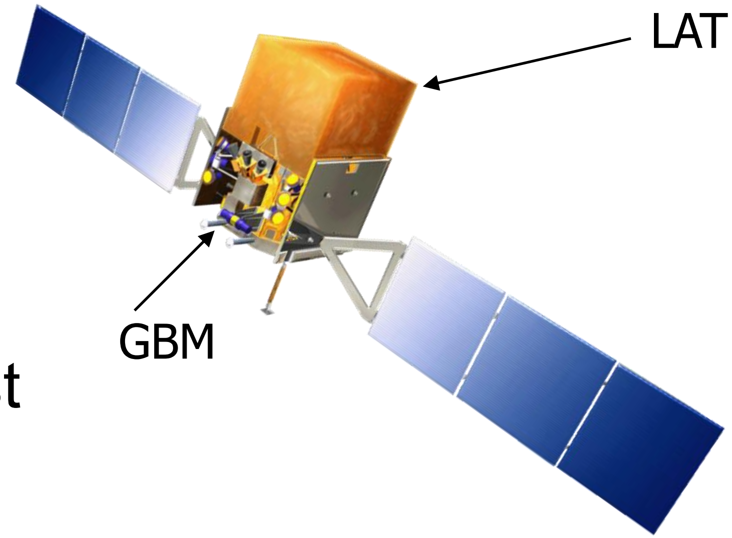
What is GLAST?

- GLAST: Gamma-Ray Large Area Space Telescope
- Planned for launch in Feb '08
- GLAST has two instruments:
  - Large Area Telescope (LAT)
  - GLAST Burst Monitor (GBM)
- GLAST will look at many different objects within the energy range of 10keV to 300GeV.



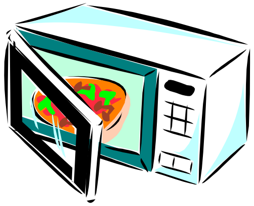
What is GLAST?

- 1st ever collaboration between the BIG (Astrophysics) and the small (Particle Physicists)
  - NASA & DOE
- By studying the largest most energetic things in the Universe (GRB’s), answers to the smallest subatomic particle/energy relationships are hoped for.

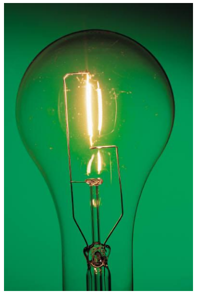


Electromagnetic Spectrum

Radio Waves



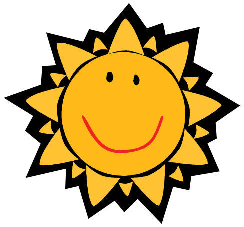
Microwaves



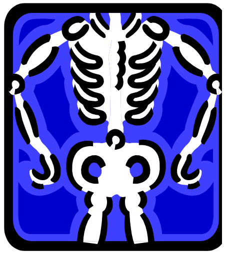
Visible Light Waves

Infrared Waves

Gamma Ray Waves



Ultraviolet Waves



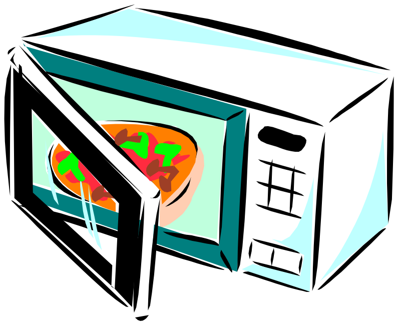
X-Ray Waves

How Do We Know

- Radio waves are energy that has long wavelengths and small frequencies.
- They are the kind of energy we attach radio signals to broadcast them.
- Stars and gasses in space also emit radio waves

How Do We Know

- Microwaves are about the size of a honeybee
- They make water molecules go nuts
- Microwave ovens and cell phone towers use microwaves

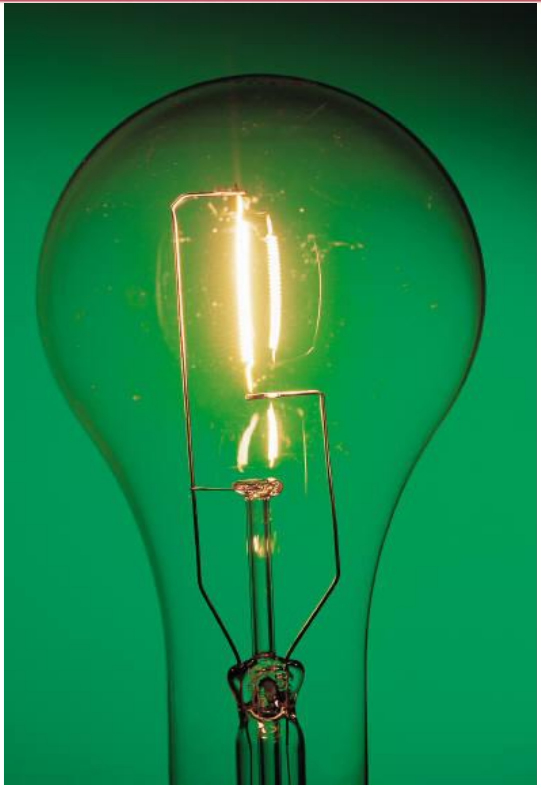


How Do We Know

- Infrared energy is used in heat lamps
- Since infrared energy waves are longer, they are easily absorbed into molecules, heating them up, like our french fries at MacDonald's
- The dust between the stars also gives off infrared energy

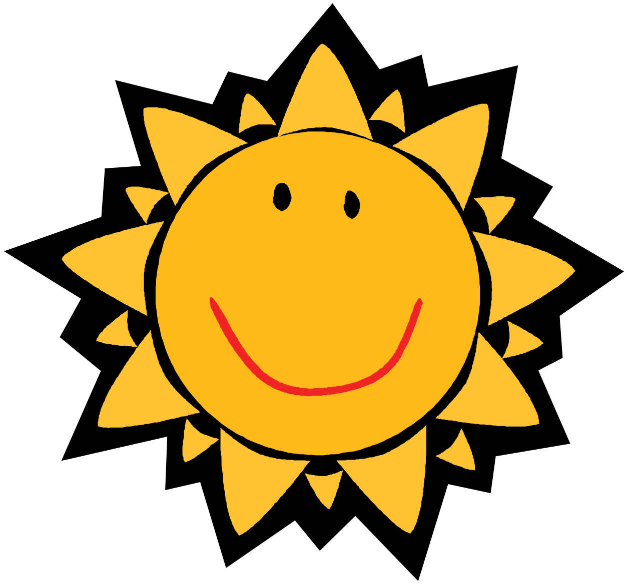
How Do We Know

- Medium range light is called Visible Light
- Visible light is the kind of energy that bounces off of me, into your eyes, and allows you to see me.
- Anything you can see with your eyes is in the visible light range



How Do We Know

- Ultraviolet wavelengths are very small. That makes their frequencies very high.
- A lot of waves can fit in a space, so they have a lot of energy
- The sun and other stars produce ultraviolet energy



How Do We Know

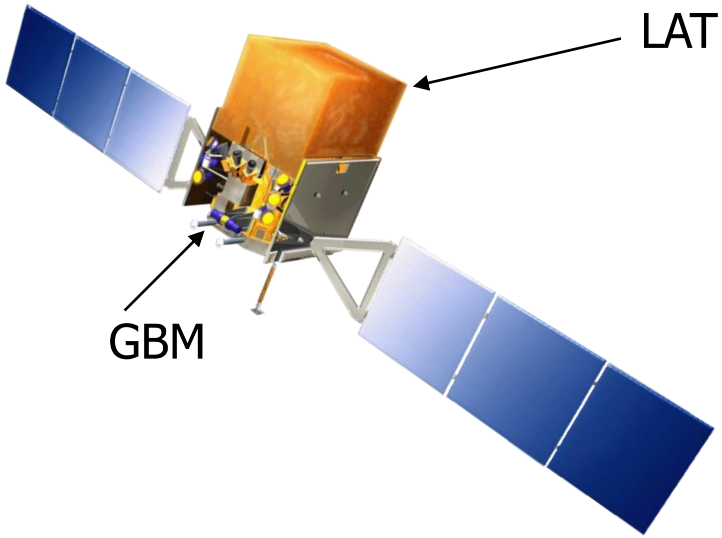
- X-rays are even smaller than Ultraviolet waves, so they have even more energy than ultraviolet rays
- Doctors use x-rays to look at your bones.
- Hot gases in space also emit x-rays

How Do We Know

- Gamma rays are even smaller than x-rays. They have even more energy.
- Radioactive materials, and particle accelerators make gamma rays
- The biggest producer of gamma rays is our universe

What is GLAST?

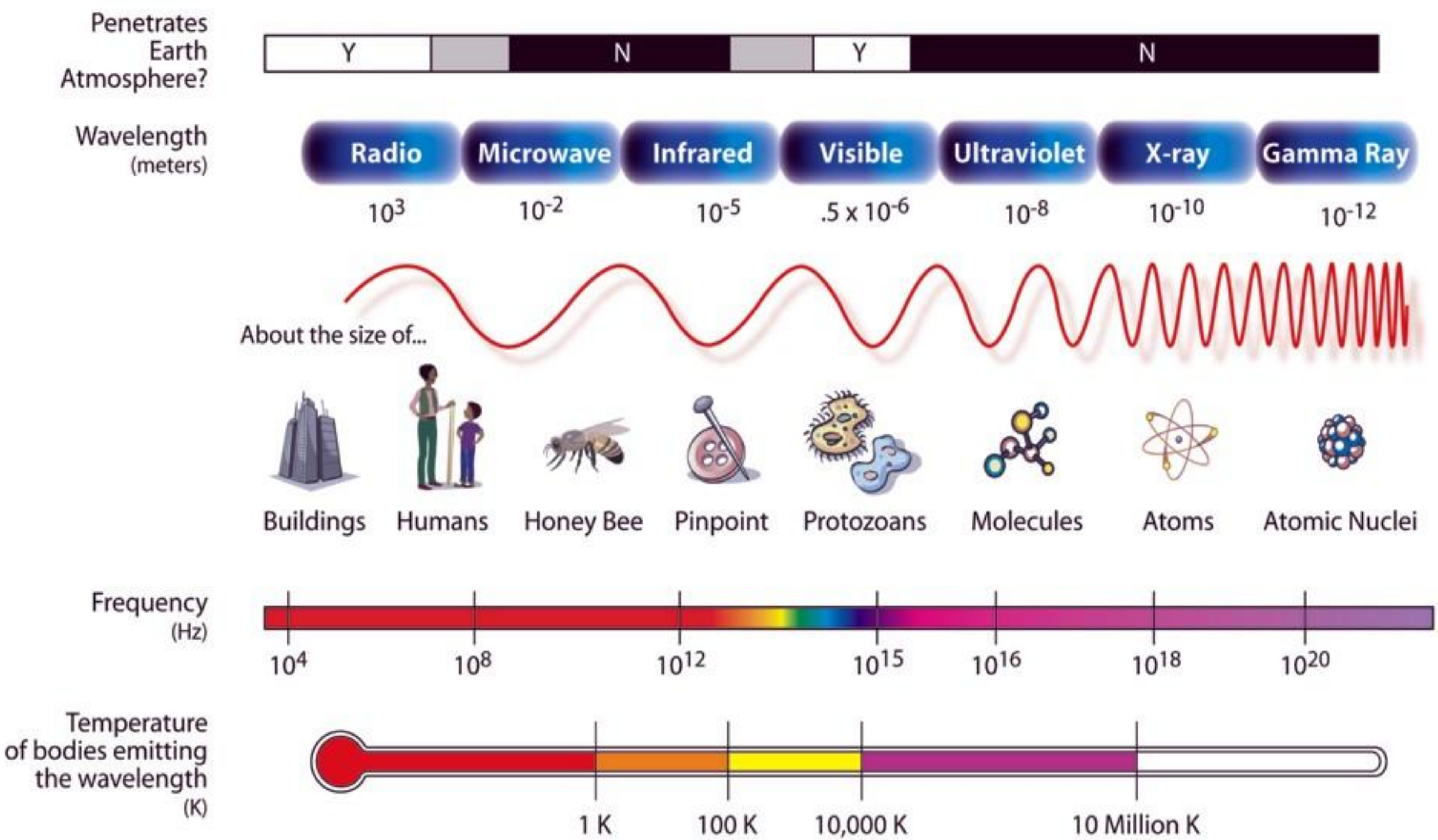
- 1st ever pair conversion telescope
  - Gamma rays are produced in the annihilation of electron-positron pairs as dictated by relativity.
  - The GBM operated on a backwards principle;
    - Turns gamma rays into electron-positron pairs that CAN be traced.



EM Spectrum

- Seven volunteers
  - Place the EM Spectrum stickers in order from smallest to largest wavelength
  - Review order and include specific sizes.

THE ELECTROMAGNETIC SPECTRUM



Smallest to Largest

- Name the smallest things that you can think of…
- What are some of the largest things you can think of?
- What about the most distant object?

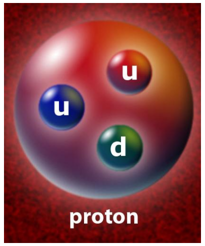
Distance Tabs

- On your desk there should be one or more pieces of colored paper.
- In colored groups - place these in order from smallest to largest.
  - Small on left, large on right.

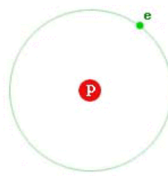
Distance Tabs

- As with the EM Spectrum stickers...
  - One group places their list on the wall by the EM stickers.
  - Report and record
  - Each group reviews and edits
  - Another group edits the 1st group's order
  - Discussion & review

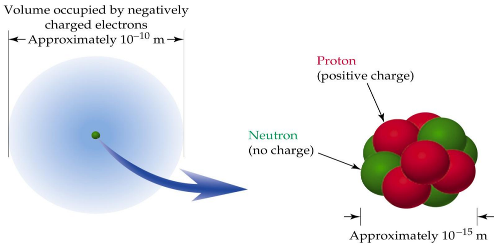
The Small Scale



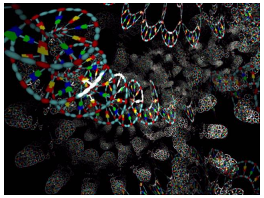
Radius Of A Proton



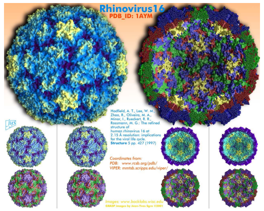
Radius of Hydrogen **Atom**



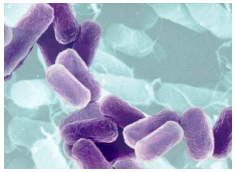
Radius of **Nucleus** of Gold Atom



Width of DNA Helix



Length of Average Virus



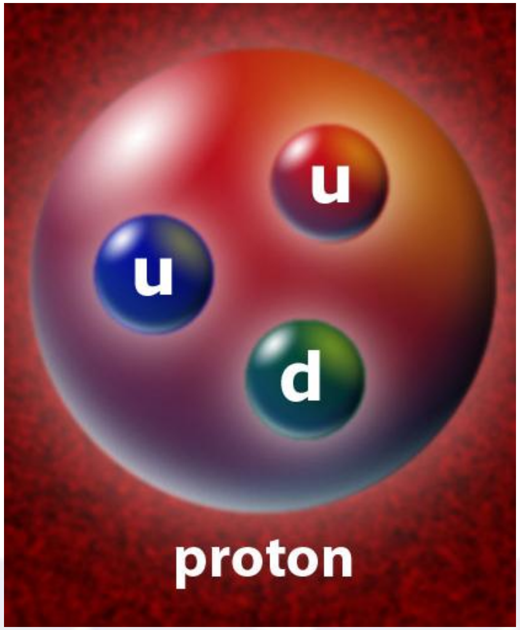
Length of average Bacterium

The Small Scale

- Six volunteers please
- Arrange the yellow papers from smallest to largest.

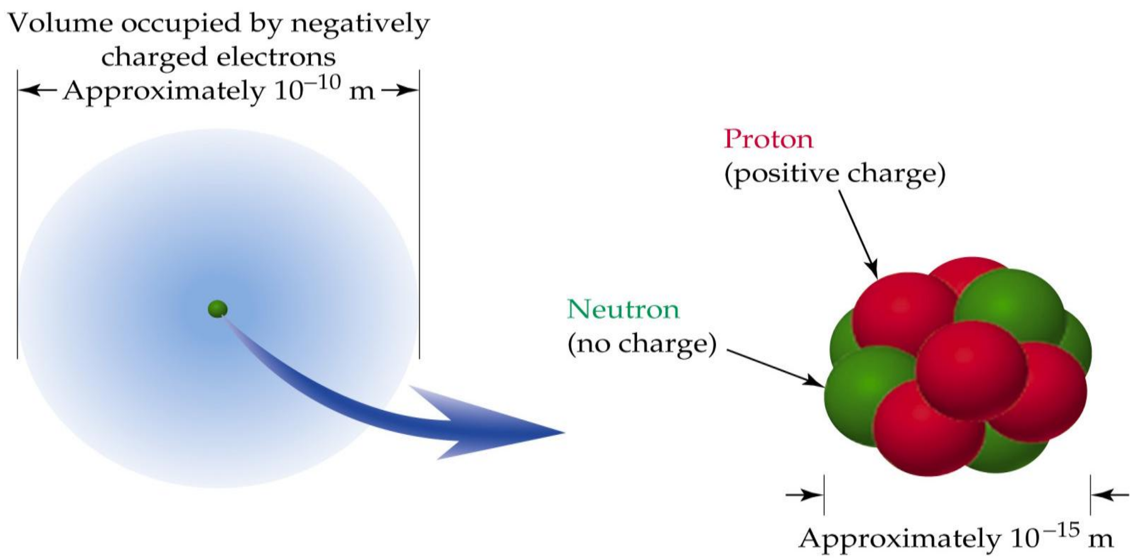
The Small Scale

- Radius of Proton
- (nucleus of hydrogen atom)
- 8.7×10^{-16} m (.00000000000000087 m)



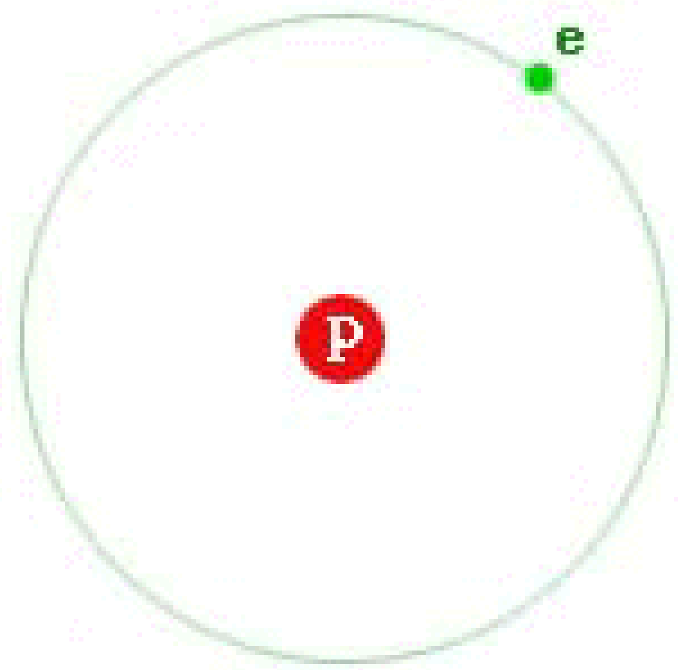
The Small Scale

- Radius of **Nucleus** of Gold Atom
- 7×10^{-15} m (.000000000000007 m)



The Small Scale

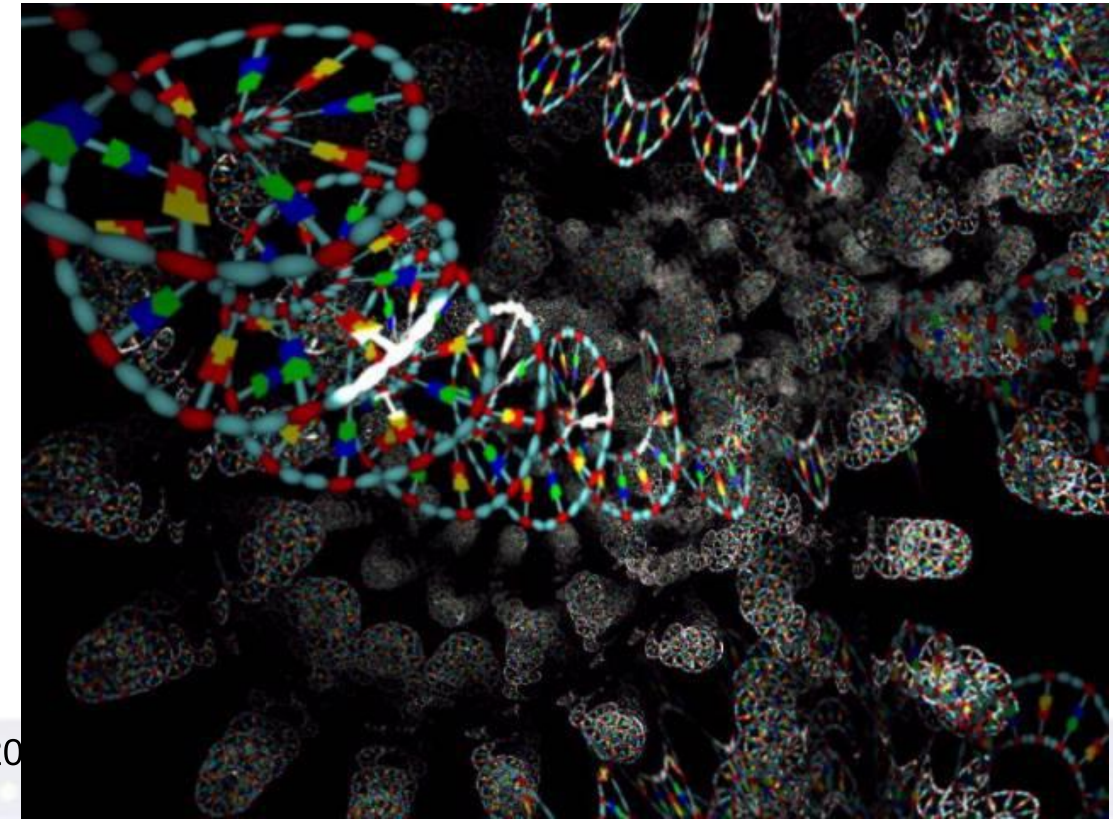
- Radius of Hydrogen **<u>Atom</u>**
- 5.29 x 10 $^{-11}$ m (.0000000000529 m)



The Small Scale

Width of DNA Helix

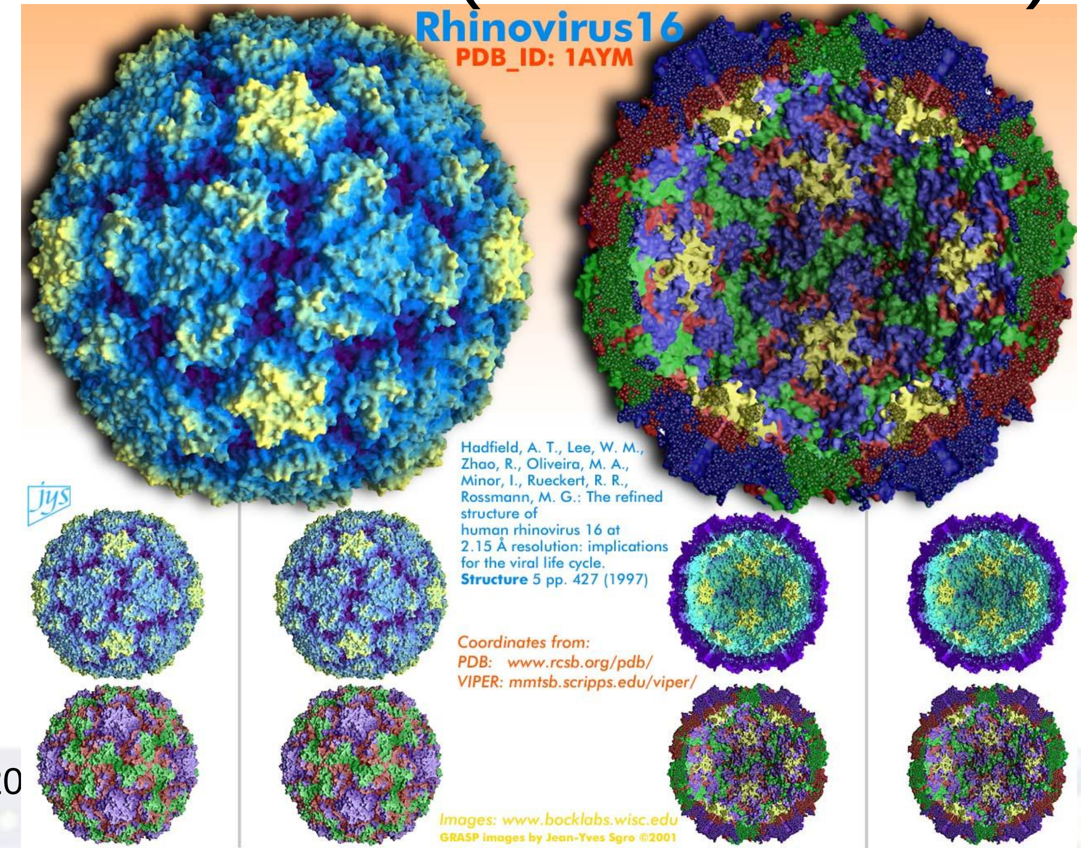
$2x10^{-9}$ m (.000000002 m)



The Small Scale

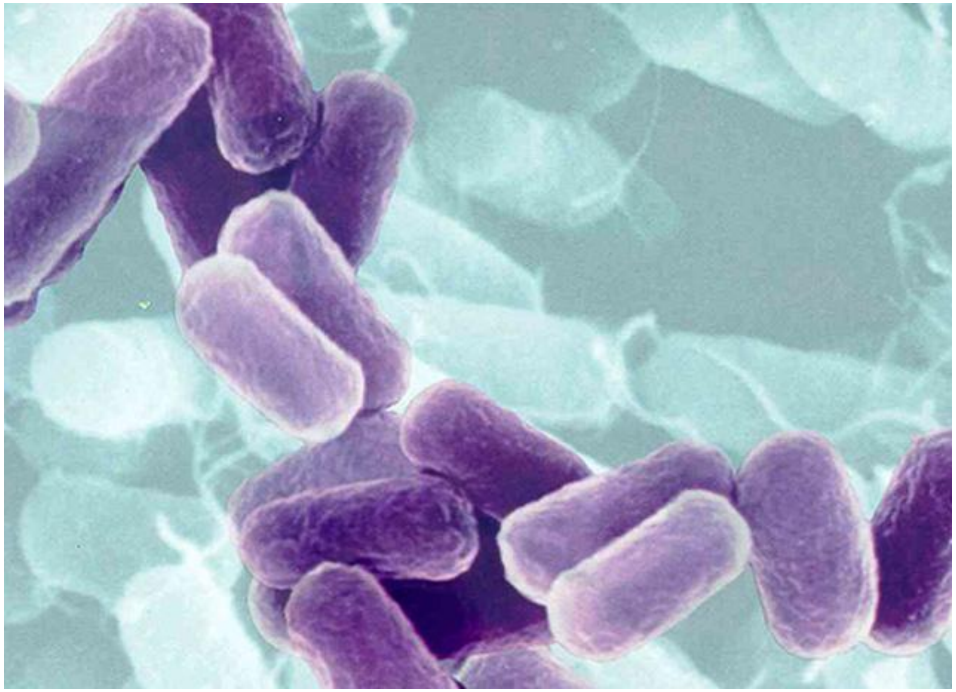
Length of Average Virus

7.5×10^{-8} m (.000000075 m)



The Small Scale

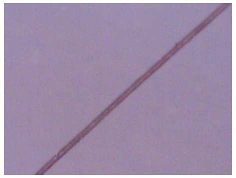
- Length of average Bacterium
- 2×10^{-6} m (.000002 m)



Small Objects…

- What was the most interesting thing that you found while lining up the small scale distance tabs?
- What do you think students would have the greatest difficulty with here?
- Sometimes I use the human scale first, as a matter of perspective.

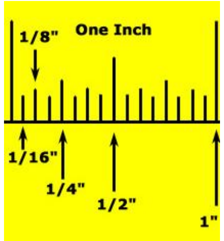
The Human Scale (1)



Width of a human hair

Radius of Pin Head

Basketball Court



One Inch

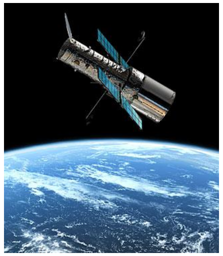
One Foot

Height of “Average” Human

The Human Scale (2)

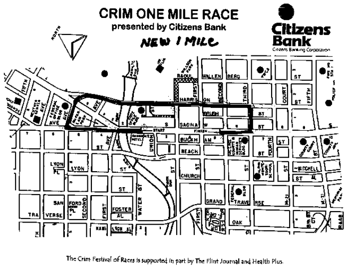
Distance Sound Travels in one second

(Thunder follows lightning one mile away by 5 seconds)



Altitude of GLAST Orbit

Football Field



One Mile

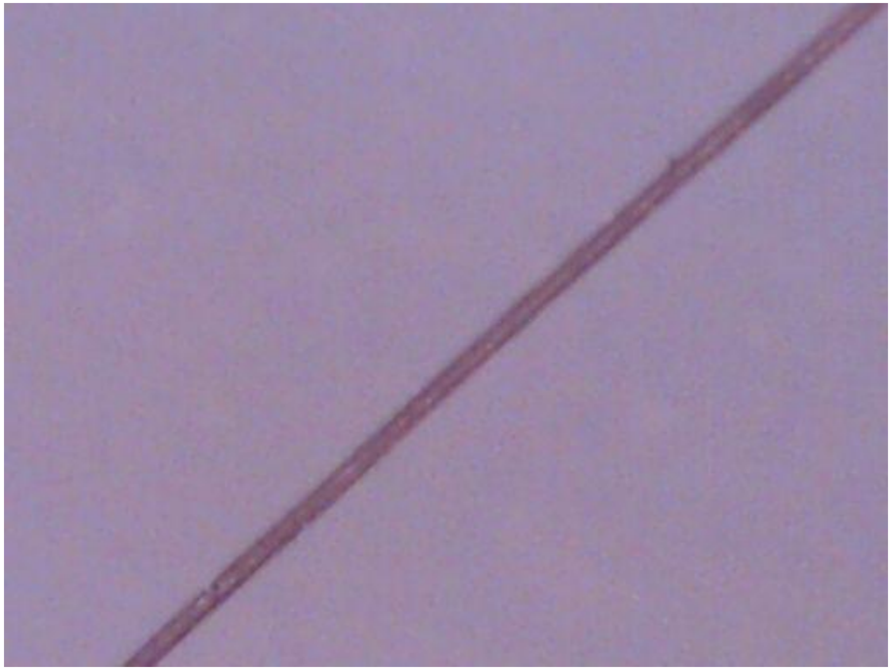
Mount Everest World's tallest mountain

The Human Scale

- 11 volunteers please
- Arrange the blue papers from smallest to largest.

The Human Scale

- Width of Human Hair
- 6×10^{-5} m (.00006 m)

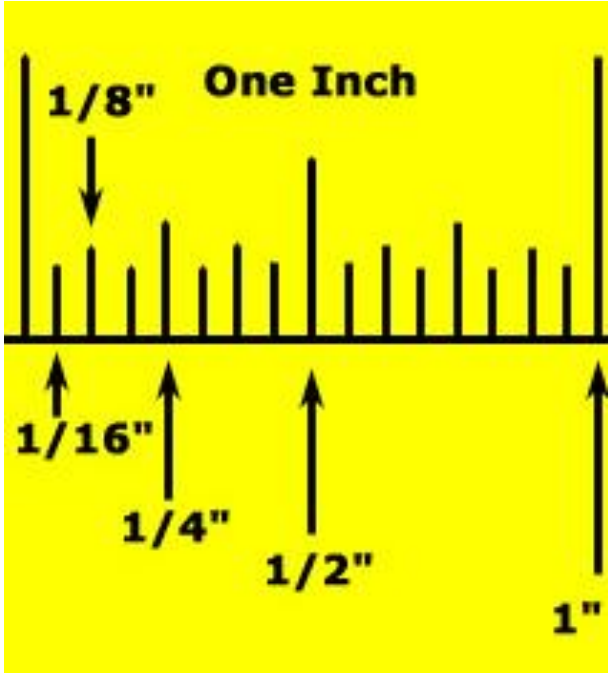


The Human Scale

- Radius of Pin Head
- 9 x 10 -4 m (.0009 m)

The Human Scale

- One Inch
- 2.54×10^{-2} m (.0254 m)



The Human Scale

- One Foot
- 3.05×10^{-1} m (.305 m)

The Human Scale

Height of “Average” Human

$1.7x10^0$ m (1.7 m)

The Human Scale

- Basketball Court
- 2.56×10^{1} m (25.6 m)

The Human Scale

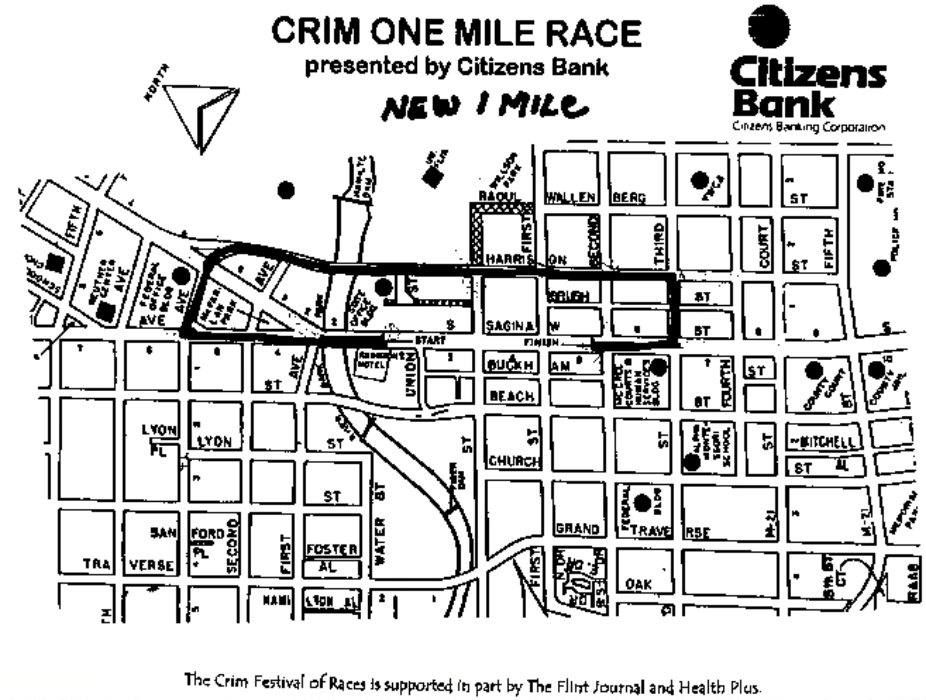
- Football Field
- 9.15×10^{1} m (91.5 m)

The Human Scale

- Distance Sound Travels in one second.
- Thunder follows lightning one mile away by 5 seconds.
- 3.43×10^{2} m (343 m)

The Human Scale

- One Mile
- 1.61×10^{3} m (1610 m)



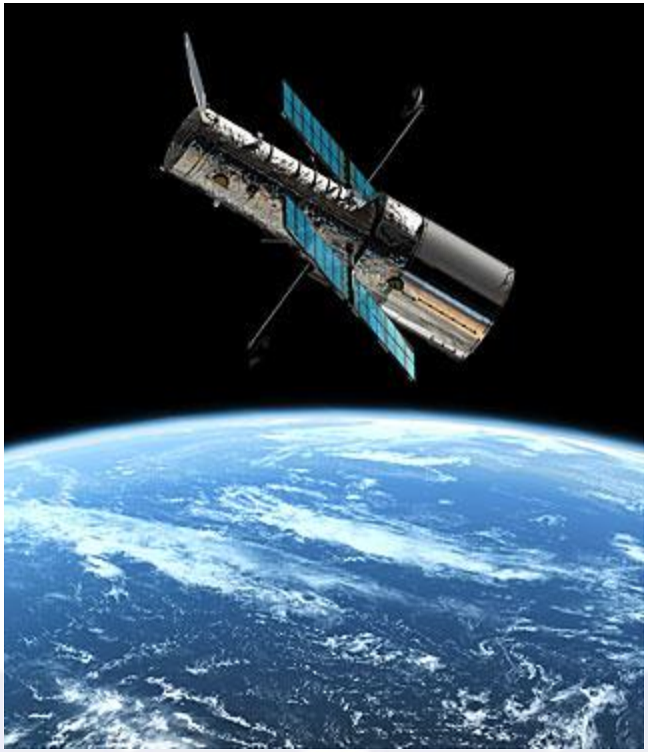
The Human Scale

Mount Everest, Earth's Tallest Mountain

8.85×10^3 m (8850 m)

The Human Scale

- Altitude of GLAST Orbit
- 5.5×10^{5} m (550,000 m)



The Human Scale…

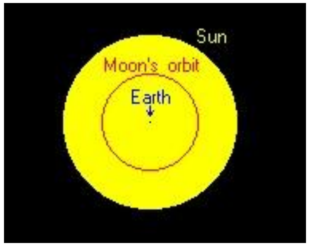
Any surprises?

Solar System & Nearby Stars

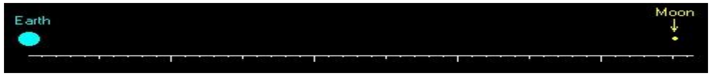
Radius of our Moon

Radius of the Earth

Radius of Jupiter

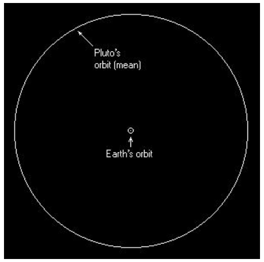


Radius of the Sun

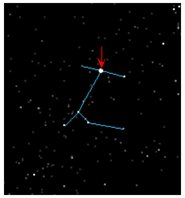


Radius of Moon’s Orbit

Solar System & Nearby Stars (2)

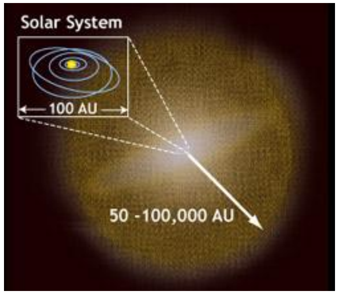


Distance from the Earth to Pluto



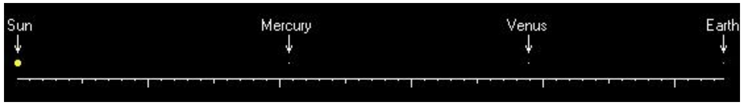
Distance to Sirius (the Dog Star) Brightest star in our night sky

HD70642
(A sun-like star with a Jupiter-like planet.)



Radius of Oort Cloud

(from the Sun to the outer edge of our solar system)



Distance from the Earth to the Sun (1 AU)

Solar System & Nearby Stars

- 10 volunteers please
- Arrange the green papers from smallest to largest.

Radius of our Moon

1.74×10^{6} m (1,740,000 m)

Solar System & Nearby Stars

Radius of the Earth

6.38×10^{6} m (6,380,000 m)

Radius of Jupiter

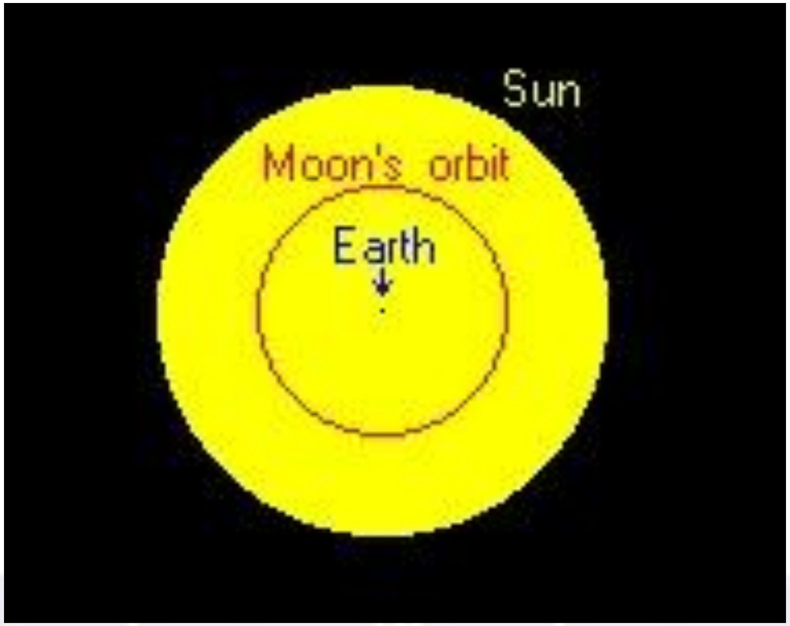
7.15 x 10 ^{7} m (71,500,000 m)

Solar System & Nearby Stars

Radius of Moon's Orbit

(average distance from Earth)

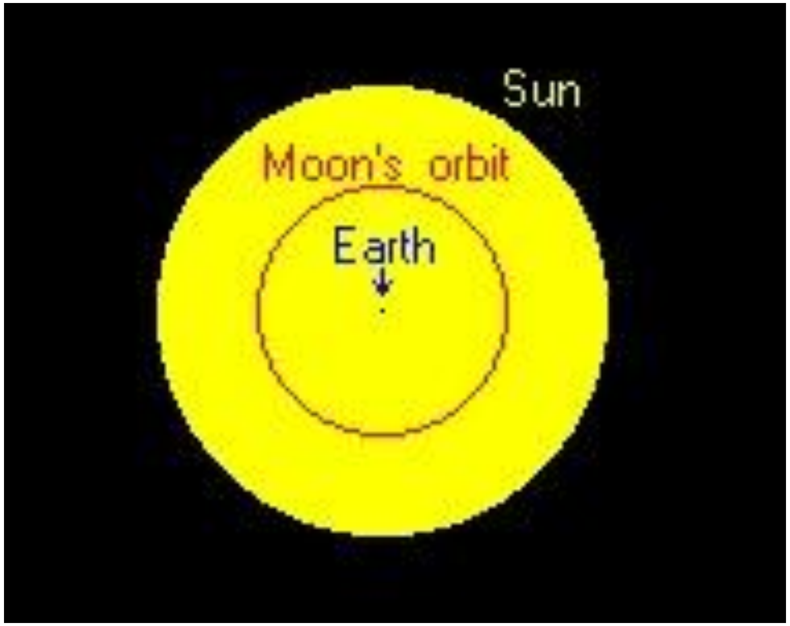
3.84×10^8 m (384,000,000 m)



Solar System & Nearby Stars

Radius of the Sun

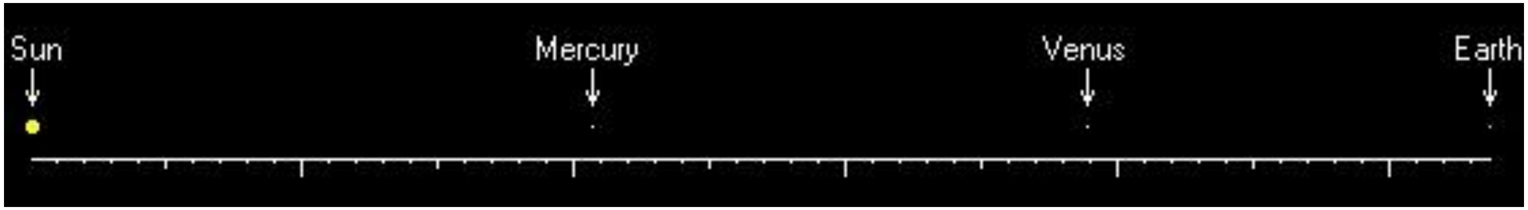
6.95×10^{8} m (695,000,000 m)



Solar System & Nearby Stars

Earth's Orbital Radius = 1 AU

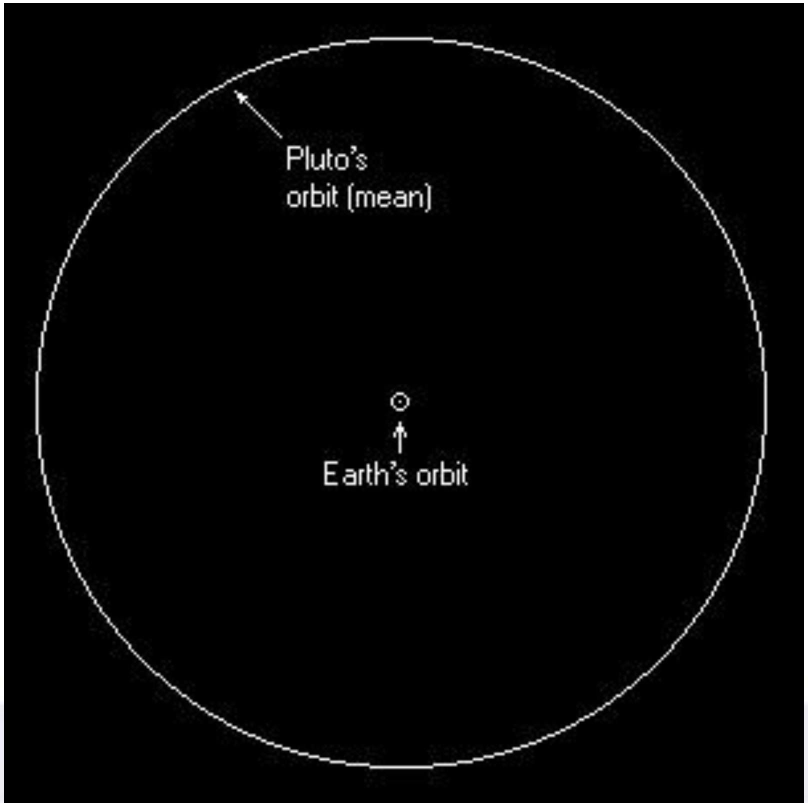
1.5×10^{11} m (150,000,000,000 m)



Solar System & Nearby Stars

Pluto's Orbital Radius

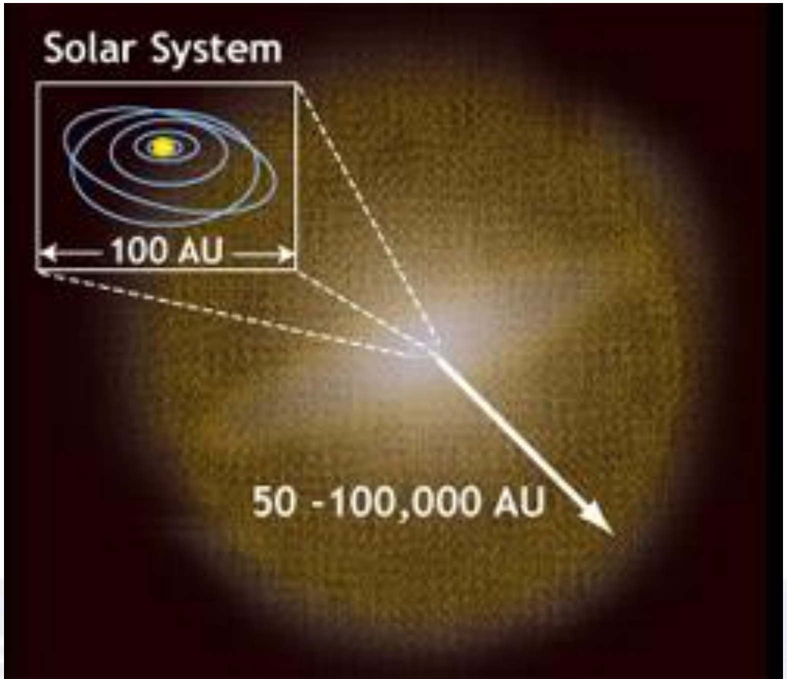
5.9×10^{12} m (5,900,000,000,000 m)



Solar System & Nearby Stars

- **Radius of the Oort Cloud**
- **Objects within this limit still orbit our Sun**

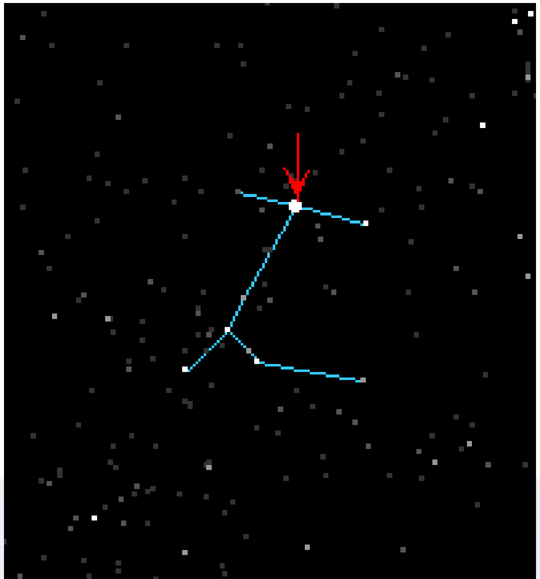
1.5 x 10 ^{16} m (15,000,000,000,000,000 m)



Solar System & Nearby Stars

- **Distance to Sirius (the Dog Star)**
- **Brightest star in our night sky**

8.6 x 10 ^{16} m (86,000,000,000,000,000 m)



Solar System & Nearby Stars

Distance to HD70642

(A sun-like star with a Jupiter-like planet.)

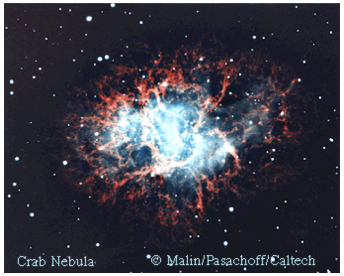
9.4 x 10^{17} m (about 94 light years)

Solar System & Nearby Stars

Any Difficulties?

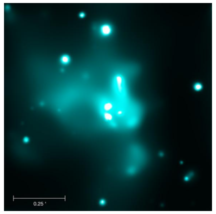
What will kids have difficulty with?

Astronomical Scale (1)



Distance to the Crab Pulsar

(Spinning neuron star in constellation Orion)



Distance to the Galactic Center of the Milky Way

Radius of Milky Way Galaxy

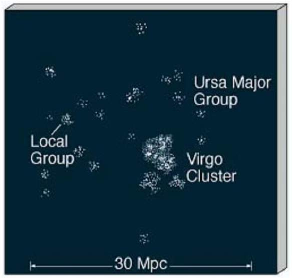
Distance to LCM – Large Magellanic Cloud

(A dwarf satellite galaxy of our Milky Way)

Distance to Andromeda

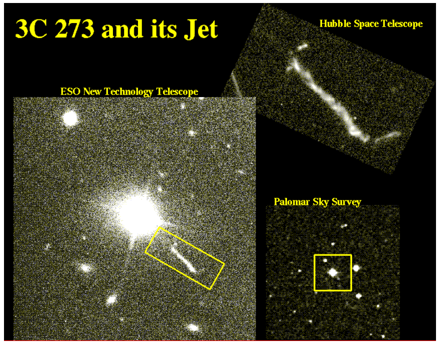
(Largest galaxy in our Local Group)

Astronomical Scale (2)



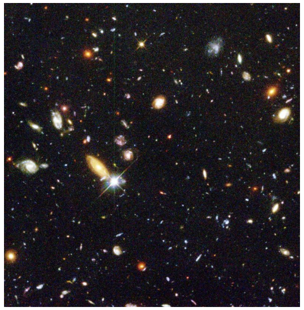
Radius of Virgo Supercluster

(Our Local Group of galaxies rotates near outer edge)

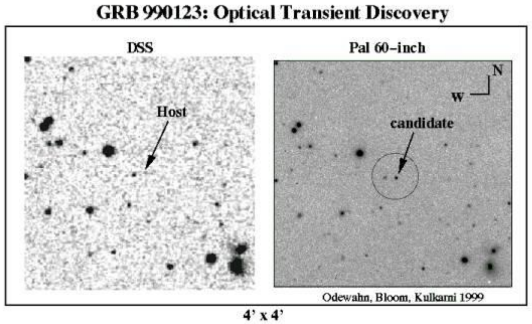


Distance to AGN 3C 273

(Sustained energy of a trillion suns)



Radius of Observable Universe



Distance to GRB 990123

(Equal to the energy of a billion-billion suns)

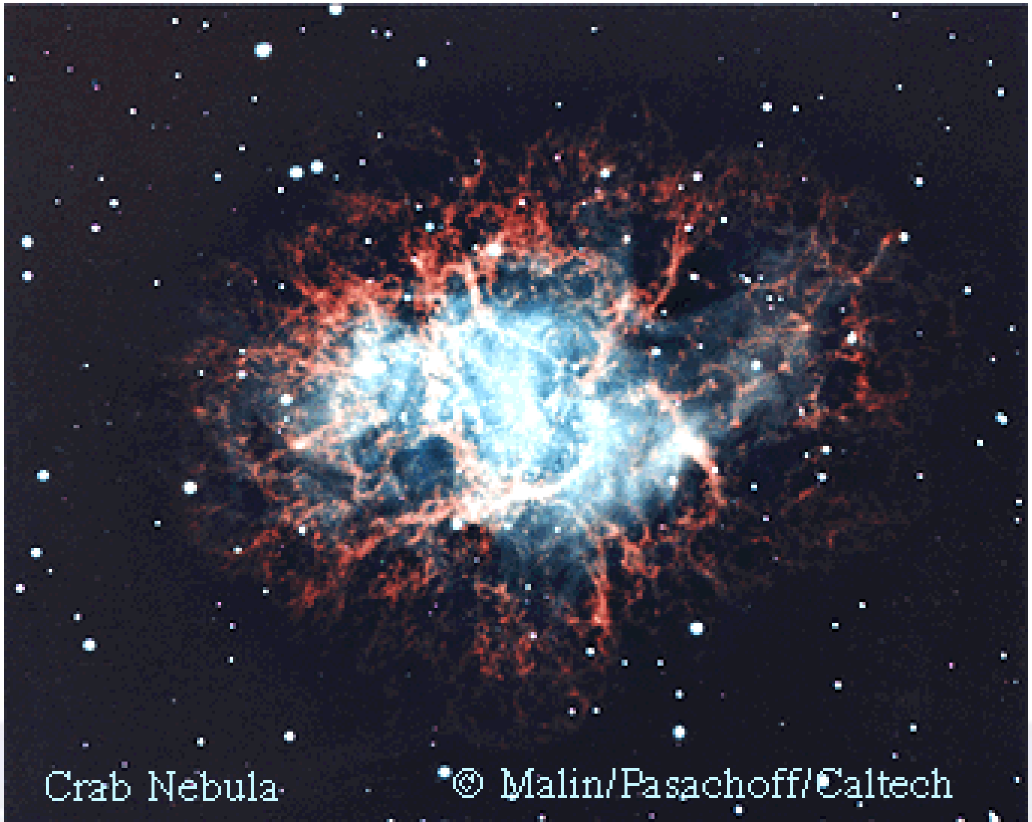
Astronomical Scale

- 9 volunteers please
- Arrange the red papers from smallest to largest.

Astronomical Scale

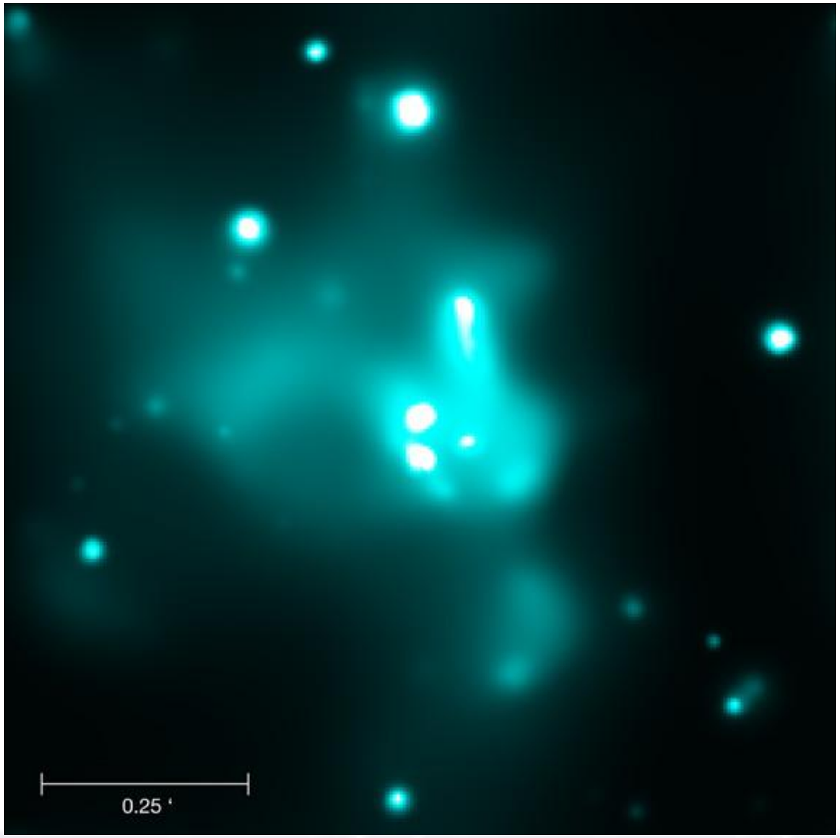
Distance to the Crab Pulsar, 7×10^{19} m

(Spinning neuron star in constellation Orion)



Astronomical Scale

- Distance to the Galactic Center of the Milky Way
- 2.6 x 10^{20} m



Astronomical Scale

Milky Way Galaxy

from center to edge = radius

5×10^{20} m

Astronomical Scale

Distance to LCM – Large Magellanic Cloud

(A dwarf satellite galaxy of our Milky Way)

1.8×10^{21} m

Astronomical Scale

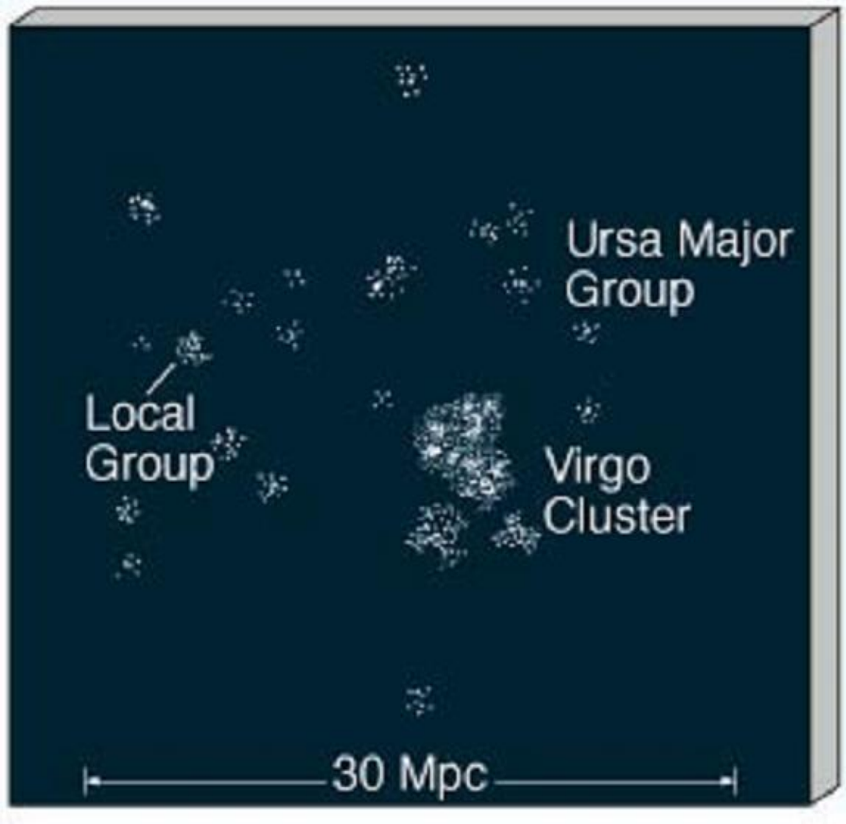
Distance to Andromeda

(Largest galaxy in our Local Group)

2.9×10^{22} m

Astronomical Scale

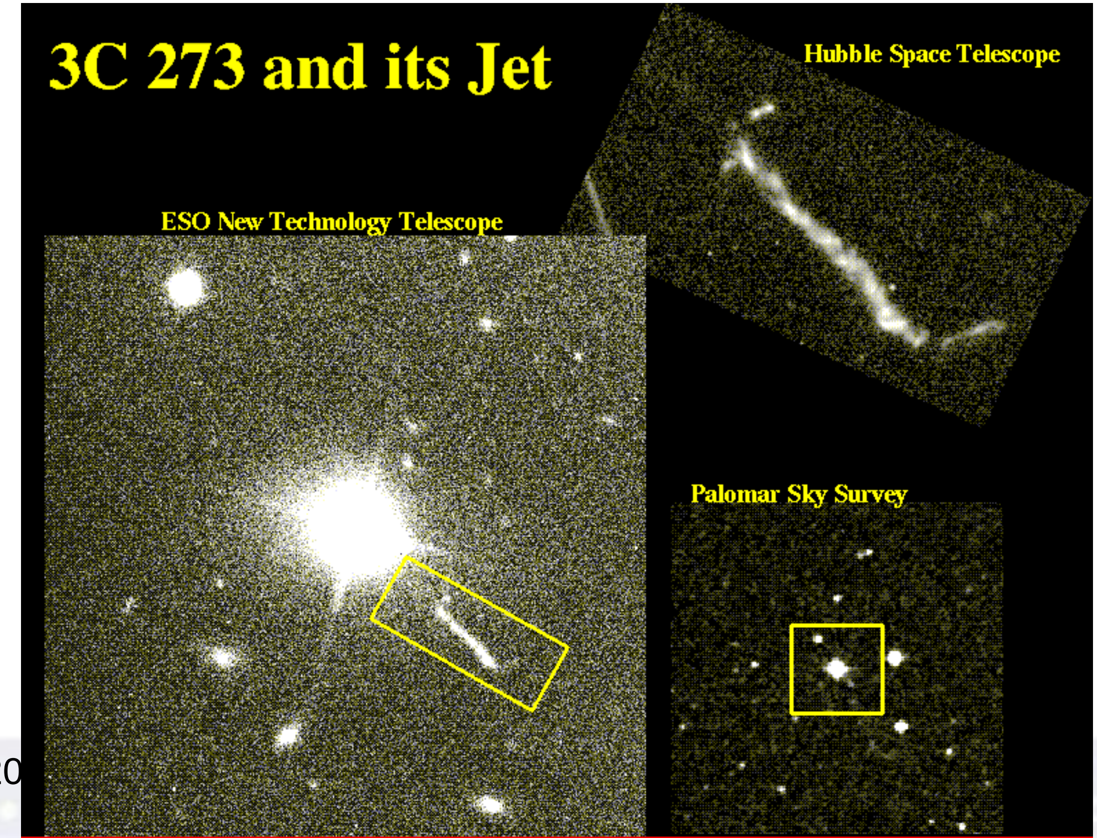
- Radius of Virgo Supercluster
- Our Local Group of galaxies rotates near outer edge
- 6×10^{23} m



Astronomical Scale

Distance to AGN 3C 273, 7 x 10^{25} m

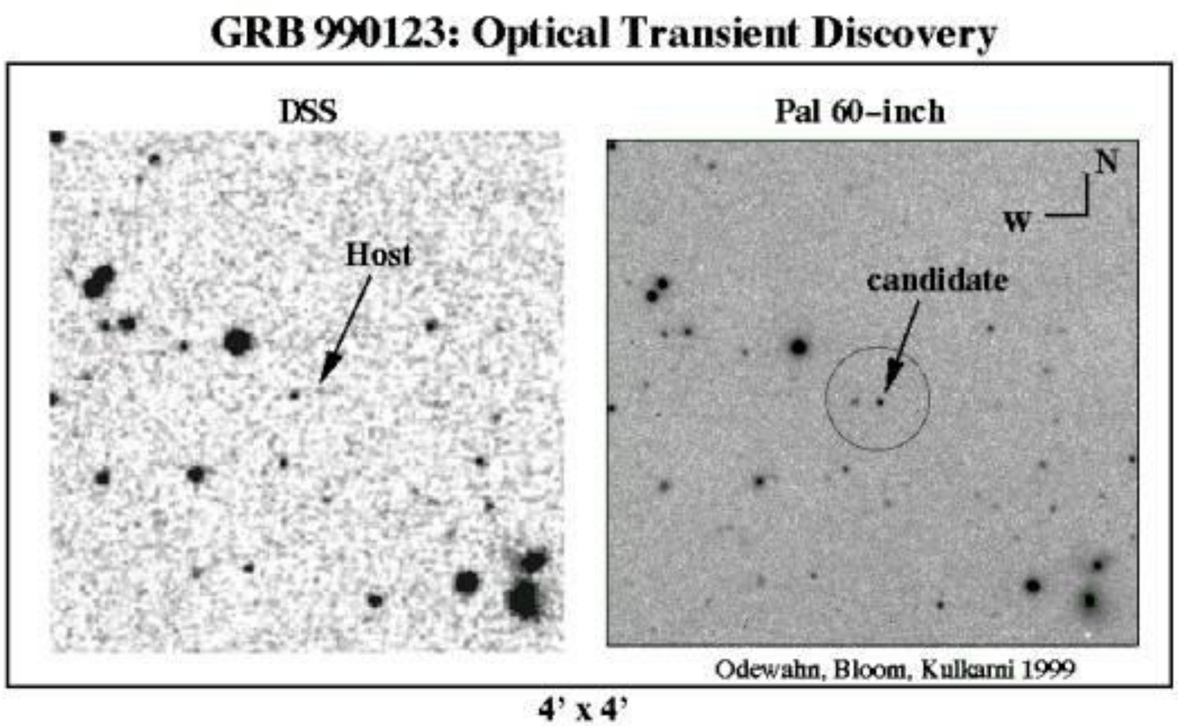
(Sustained energy of a trillion suns)



Astronomical Scale

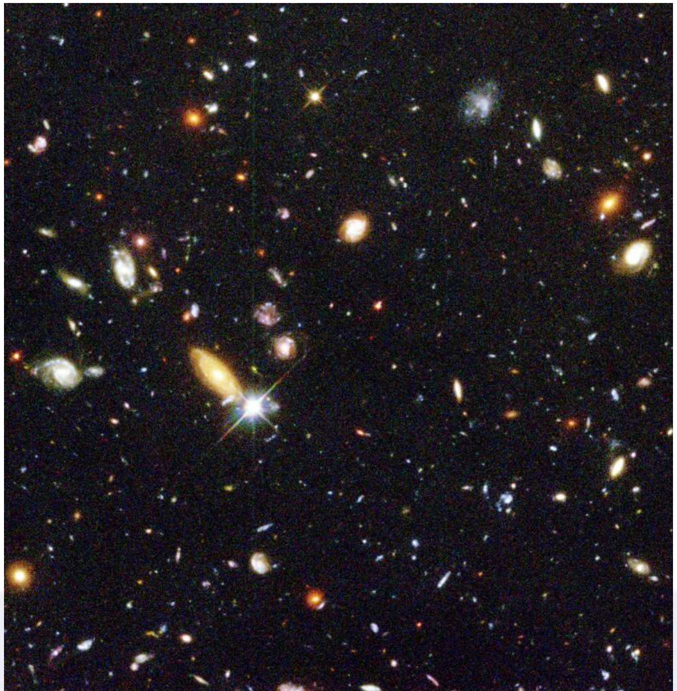
Distance to GRB 990123, 1 x 10^{26} m

(Equal to the energy of a billion-billion suns)



Astronomical Scale

- Radius of Observable Universe
- 1.4×10^{26} m
- About 14, 000,000,000 (14 billion) light years



The Universe is a VERY Big Place

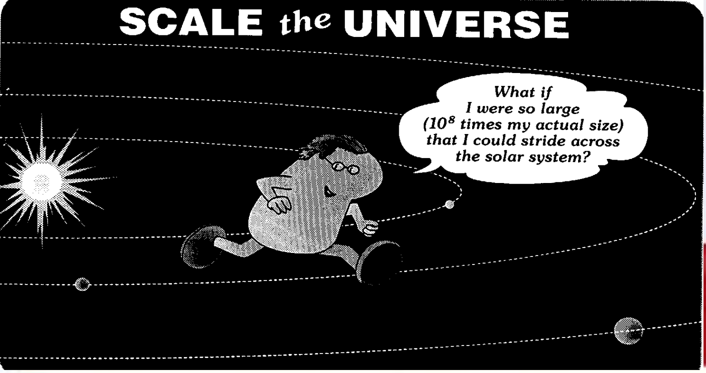
At least 14 billion light-years
(or about 100,000,000,000,000,000,000,000 kilometers)

It is full of very small & VERY BIG numbers!

Any Astronomical thoughts?

Brainstorm Time

- How can we use this in our science classroom?
  - Introductions and applications of scientific notation
  - Biology Lessons
  - Astronomy Lessons
  - Physics Lessons
  - ….



Ordering Time

- Repeat the steps of the “Ordering Distance” activity
  - Place in order from short to long duration
  - One group reports
  - Discuss and review

Ordering Time, FAST

- There are 11 tabs in the FAST section.
- We used 7 of them in the first EM ordering activity.
- “fast” = periods of EMRadiation

Ordering Time, Average

- There are 12 tabs in the Average section.
- “average” = 1 year or less of time

Ordering Time, SLOW

- There are 13 tabs in the section.
- “slow” = 1 year or more of time

Resources

- GLAST Education and Public Mission Website
  - http://glast.sonoma.edu
- Downloadable materials for this book (AND MORE):
  - http://glast.sonoma.edu/teachers/teachers.html
- More Great materials from TOPS:
  - http://topscience.org/

Scientific Notation and tens

$10000 = 1x\ 10^4$

$1000= 1x\ 10^3$

$100 = 1x\ 10^2$

$10 = 1x\ 10^1$

$1 = 1x\ 10^0$

$0.1 = 1x\ 10^{-1}$

$0.01 = 1x\ 10^{-2}$

$0.001 = 1x\ 10^{-3}$

$0.0001 = 1x\ 10^{-4}$

How this works:

Standard notation	Scientific notation
56,000,000 7 places to the left	5.6×10^{7}
0.0003099 4 places to the right	3.099×10^{-4}