

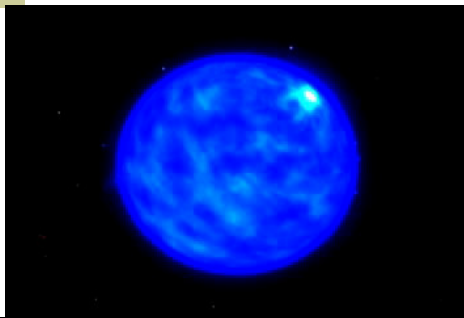
Introduction to Lab

(belatedly)

Some Cool News Yesterday

- This powerful burst was detected September 4. It marks the death of a massive star and the birth of a black hole. It comes from an era soon after stars and galaxies first formed, about 500 million to 1 billion years after the Big Bang.
- "We designed Swift to look for faint bursts coming from the edge of the Universe," said Swift principal investigator Dr. Neil Gehrels of NASA Goddard Space Flight Center in Greenbelt, Md. "Now we've got one and it's fascinating. For the first time we can learn about individual stars from near the beginning of time. There are surely many more out there," he added.

Animation of GRB



The Scientific Method

- Observe
- Tentative hypothesis
- Predict
- Experiment or more observations
 1. **If** results compatible with hypothesis, more credibility
 2. **Else** if results incompatible, revise or throw out

What's your role in lab?

Your Role: The Scientific Method

- Observe
 - Tentative hypothesis
 - Predict
 - Experiment or more observations
- Carryout experiment
- Understand the hypothesis & prediction
- Evaluate which of these applies
1. **If** results compatible with hypothesis, more credibility
 2. **Else** if results incompatible, revise or throw out

How “Science” Works:

- ◆ Researchers publish a description of:
 - What they did
 - What they saw
 - What they think it means
 - An analysis of their errors
- ◆ Researchers read journals/articles and either:
 - Argue that the article is wrong/flawed
 - Attempt to repeat/extend the results

What happens when Scientists Disagree?

- ◆ Happens often
- ◆ Examples:
 - Is information lost in black holes?
 - Is Universe chronologically protected?
 - Did the Universe have a big bang or is it in a steady state?
 - Others?
- ◆ Disagreement is fine, eventually will work itself out with new data or a new theory

What happens when Scientists Agree?

- ◆ Consensus builds, becomes accepted wisdom
 - Standard model for particle physics
 - Big Bang theory
 - Earth not center of the universe
 - evolution
- ◆ Scientists ideally open minded if presented with legitimate, scientific evidence to contrary
- ◆ However, in the face of overwhelming evidence (e.g. Earth rotates around Sun), burden increases

What happens when Scientists are Wrong?

- ◆ Never happens, science is infallible!

What happens when Scientists are Wrong?

- ◆ Never happens, science is infallible!
Just kidding!
- ◆ Part of process...revise or throw out and repeat!

What happens when Scientists’ Theories Don’t Always Work?

- ◆ Again, happens often, Examples:
 - Newton’s gravity doesn’t work for strong gravity
 - Quantum Mechanics doesn’t work with gravity
- ◆ It’s okay to say a theory works for certain “regimes” w/ expectation of a new theory to fix problems...as long as still reliably useful for the regimes in which it applies

What happens when Scientists' Theories Don't Answer Every Question?

- ♦ Again, happens often, Examples:
 - What happened before the Big Bang?
 - Why is the cosmological constant so small?
 - Why is the charge of the electron the value it is?
- ♦ Doesn't mean you need to throw out the theory...someone may come along and find an answer, or find a new theory which does answer

Science & Religion

- ♦ Do we want to discuss?
- ♦ My \$0.02:
 - Science doesn't tell anyone what to believe
 - It essentially establishes facts (Earth moves around Sun), but people don't have to accept them
 - Unfair to say science is a religion of its own...scientists accept or not, based on scientific arguments...no true dogma
 - Many religious scientists for whom no conflict

Practical Lab Tips

The Error and Percent Error

- ♦ Can only compute "the error" when we have a known or accepted value
- ♦ Percent Error:

$$\left(\frac{\text{Theoretical} - \text{Experimental}}{\text{Theoretical}} \right) \cdot 100 \%$$

- ♦ If no accepted, you might compute percent difference:

$$\left(\frac{1}{2} \left(\frac{\text{Theoretical} - \text{Experimental}}{\text{Theoretical}} + \frac{\text{Experimental} - \text{Theoretical}}{\text{Experimental}} \right) \right) \cdot 100 \%$$

Uncertainty

- ♦ Every measurement has uncertainty
- ♦ Guess how tall am I?
 - 6'
 - 6' 1"
 - 6' 1.2"
 - 6' 1.23"

Uncertainty

- ♦ If you measure something about 10cm long with a ruler, what might you get?
- ♦ Say you get 9.1 cm
- ♦ Someone else comes along, will they measure the same thing? Might they get 9.2cm? No way?

Uncertainty

- ♦ Give a confidence interval, say:
 $9.1 \pm 0.1 \text{ cm}$
- ♦ This means:
 - Your best guess is 9.1cm
 - Confident anyone else w/ any instrument will get somewhere between 9.0 and 9.2 cm

Scientific Notation

- ♦ Really small and large numbers, eg:
 0.0000002334 $1,234,000,000$
 - ♦ Are more conveniently written as
 - A number between 1 and 10
 - Multiplied by a power of 10
- 2.334×10^{-7} 1.234×10^9

Significant Digits/Figures

- ♦ What's the difference between:
 2.1 cm 2.100 cm

Significant Digits/Figures

- ♦ What's the difference between:
 2.1 cm 2.100 cm
- ♦ Depends on context:
 - Lecture/Numerically: No difference
 - Lab: One asserts more **precision**

Significant Digits/Figures

- ♦ When reporting a **measurement**, report as many digits as you can reasonably guess
- ♦ When reporting a **computation**, report the proper number of digits according to rules

Significant Digits/Figures

- ♦ Addition or Subtraction:
 1.234
 $+ 0.005678$
- ♦ Calculator gives:
 1.239678
- ♦ Clearly too many digits!

Significant Digits/Figures

- ♦ Addition or Subtraction:

$$\begin{array}{r} 1.234??? \\ + 0.005678 \\ \hline \end{array}$$

$$\begin{array}{r} 1.239??? \\ 1.239678 \\ \hline \end{array}$$

- ♦ Rule: Round to the smallest place which all measurements in the sum/sub have

$$1.240 \quad \text{Final Answer!!}$$

Significant Digits/Figures

- ♦ Multiplication/Division:

$$1.234 * 234,567.1 = 289,455.8014$$

- ♦ Way too many digits!

- ♦ Mult/Div Rule: Determine the minimum number of sig. digits for all the numbers in the calc, and report the answer to that many sig. digits:

$$2.895 \times 10^5$$

Finally

- ♦ Do the lab
- ♦ Read Ch. 3 and take "Basic" Quiz for next week