29 August 2019

WELCOME TO AST 106!

The Cosmic Origins of Life

The cosmic origins of life

We can see the building blocks of life, and potential habitats for both simple and intelligent life, in outer space.

- What does this tell us about our own origin and fate?
- What does it tell us about the diversity of life forms in the Universe?
- What can we learn about our chances to contact other civilizations?

Answers to these questions, and many more, this semester.

NASA Ames Research Center

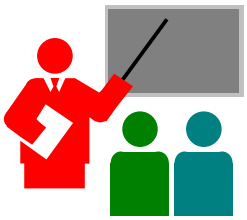
Our primary goals in teaching AST 106

- To demystify the genesis of the components and habitats of life in the Universe, and the degree to which civilizations like ours are common (or rare) in the Universe
- To enable you to evaluate all the reports and claims you will encounter in the mass media about the origins of life and the future and fate of our civilization
- To show you how scientific facts are found and theories are conceived and advanced, in general

In doing so we aim primarily at **non-science majors**, especially those who will use this class in a science cluster. But we will all probably find something new.

Human and printed features of AST 106

- People:
  - **Dr. Kelly Douglass**, professor
  - **Danielle Bovie**, teaching instructor
  - **Joshua Ratajczak**, teaching instructor
  - **Navya Uberoi**, teaching instructor



- Textbook:
  - *An Introduction to Astrobiology*, 3rd Edition (***required***)
  - There is an extensive list of recommended books in the syllabus, if you are interested in reading more about any of the topics we cover (or do not) in this course.

Electronic features of AST 106

- **Computer-projected lectures**, for greater ease in presentation of diagrams, astronomical images and computer simulations, and for online accessibility on our…
- **Website**, including all lecture presentations, new items, schedule, practice exams, and much more.
  - Primary reference for course
  - Lecture presentations contain links to the primary, up-to-date scientific literature so that you can trace the facts yourself.
- **WeBWorK**, a computer-assisted personalized homework generator

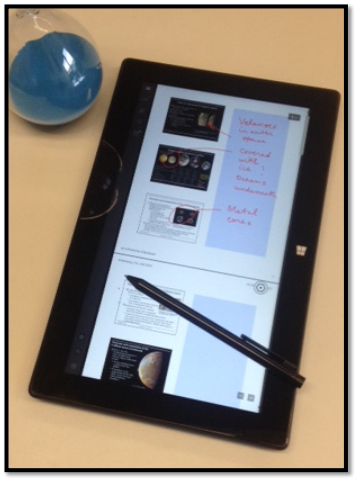
Use of electronics in AST 106

Please bring a tablet or laptop computer to every class:

- To download PDF copies of the lecture notes and type or write your own notes in real time

Please **DO NOT** use social media during class

Please **SILENCE** all cell phones during class



Onerous features of AST 106

The minimum of mathematics required to tell our story, but no less than the minimum

Class participation is a small (8%) part of your grade and is based on answering in-class questions and recitation attendance

Eight problem sets, all using WeBWorK, comprise 20% of your grade

Three exams, all in-class, comprise 72% of your grade. (There is no *comprehensive* final exam.)

Grades are assigned on a straight scale, not a curved scale.

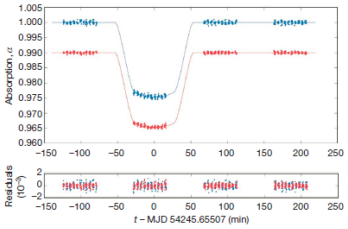
A few words about science for the non-science majors

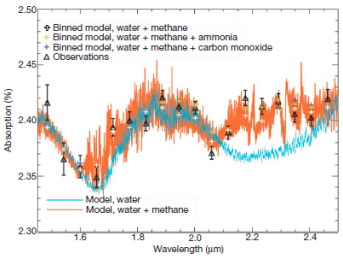
Scientific facts: the results of reproducible experiments with known accuracy

Scientific theories: logically-consistent expressions of the patterns which emerge from the facts

Scientific speculation: pushing theories past the range of the experiments

Making stuff up: everything else



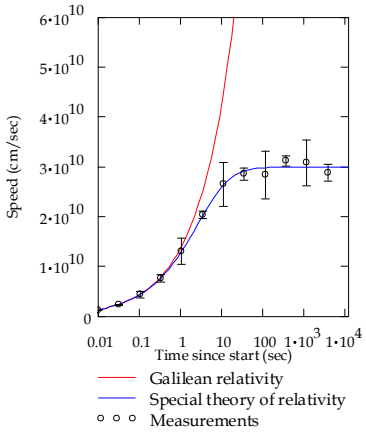


Detection of water and methane in an extrasolar planet (Swain et al. 2008)

Where do facts come from?

Facts are found by performing experiments. The rules for experiments:

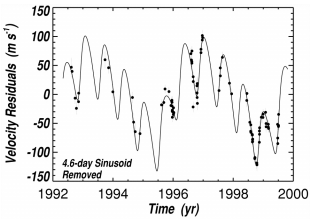
- They result in **measurements** of physical, real quantities: number, color, shape, length, time, mass, temperature, energy,…
- They can be reported **quantitatively**, as numbers with units
- The experimental **uncertainty** in the numbers must also be determined and reported
- The results must be **reproducible**: the same results obtained in all careful experiments on the same phenomenon



Facts

That means that in science, there is no such thing as different, conflicting sets of facts.

- That is, one cannot decide to have one's *own* facts which are contradicted by other experiments
- If differences in experimental results are found, more experiments must be conducted until the difference is understood
  - Usually, differences happen because of mistakes made in an experiment
- If one experiment is contradicted by a large body of other careful experiments, the burden of proof increases on that one experiment to show that they have not made any mistakes.

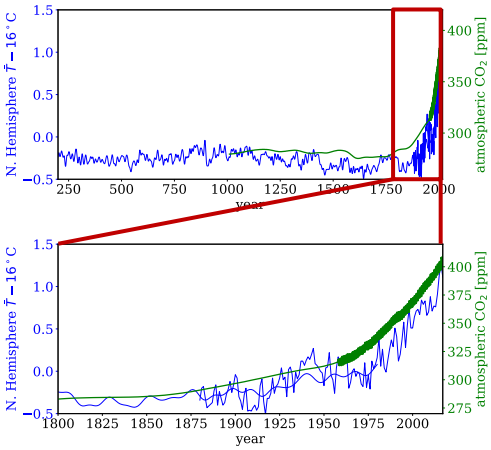


Discovery of the first known three-planet extra-solar system (Butler et al. 1999) with animation by Sylvain Korzennik (CfA)

Facts

Consider Prof. Richard Muller, UC Berkley, who once had his own set of facts.

- Until seven years ago, opposed the results of the rest of climate science, denying that global warming is real
- Criticized the methods and experiments done by others, notably the IPCC, on the history of Earth surface temperature
  - …though these experimenters supported their case well
- Finally decided to reanalyze the temperature record himself, using all of the experimental refinements he said would change the result
- Got the same result as everyone else



Facts

And though he came to the conclusions reluctantly (and he was not very nice about it when he revealed his team's results), he came around to accept the reality of global warming and the likelihood that human-generated CO_2 in the atmosphere is responsible.

This is how experimental science works, eventually.

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OPINION EUROPE

The Case Against Global-Warming Skepticism

There were good reasons for doubt, until now.

By RICHARD A. MULLER
October 21, 2011

Are you a global warming skeptic? There are plenty of good reasons why you might be.

As many as 757 stations in the United States recorded net surface-temperature cooling over the past century. Many are concentrated in the southeast, where some people attribute tornadoes and hurricanes to warming.

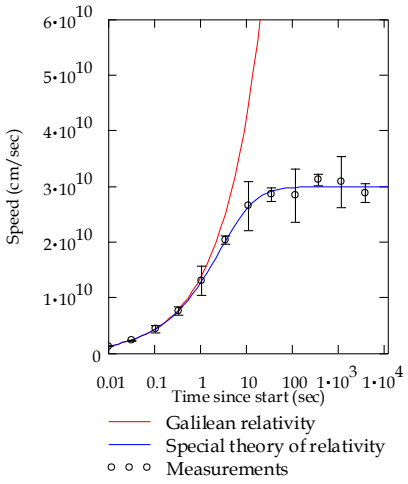
The temperature-station quality is largely awful. The most important stations in the U.S. are included in the Department of Energy's Historical Climatology Network. A careful survey of these stations by a team led by meteorologist Anthony Watts showed that 70% of these stations have such poor siting that, by the U.S. government's own measure, they result in temperature uncertainties of between two and five degrees Celsius or more. We do not know how much worse are the stations in the developing world.

Using data from all these poor stations, the U.N.'s Intergovernmental Panel on Climate Change estimates an average global 0.64ºC temperature rise in the past 50 years, "most" of which the IPCC says is due to humans. Yet the margin of error for the stations is at least three times larger than the estimated warming.

What are theories?

Theories are the logically-consistent **descriptions** we use for the patterns that emerge from experimental facts.

- In physics, astronomy, geology, chemistry, and engineering, it is common to express theories **mathematically**, as equations.
  - This is not a requirement, but it is done whenever possible because it helps enforce the logical consistency.
- Theories must make **predictions** of experimental results, and the predictions must be **quantitatively consistent with the facts**, within the experimental uncertainties.
  - If not, the theory is rejected or is acknowledged to be incomplete.



Theories

Careful, though; theories consistent with all experiments are not the same as truth. As was said by a great philosopher,

> In science, convictions have no rights of citizenship, as one says with good reason. Only when they decide to descend to the modesty of hypotheses, of a provisional experimental point of view, of a regulative fiction, may they be granted admission and even a certain value in the realm of knowledge – though always with the restriction that they remain under police supervision, under the police of mistrust.
>
> - Nietzsche, *The Gay Science*, section 344

All theories are at risk of being proven false, when predictions are not borne out by the facts. One cannot prove them true.

Theory vs. fact

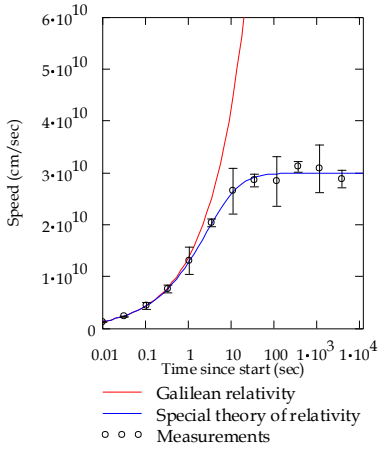
Be careful – it is easy to confuse theories with facts. For example:

- The **Big Bang** is an experimental fact, not a theory. We can actually see the expanding fireball. (See AST 102, offered next semester.)
  - **Inflation** is a theory that describes the early expansion of the Big Bang.
- **Evolution** is an experimental fact, not a theory, as we will see repeatedly this semester.
  - **Natural selection** is a theory that describes – extremely well – the evolution of species on Earth.
- **Global warming** and **increases in atmospheric CO_2** are experimental facts, not theories, as we will also see this semester.
  - That **the CO_2 increase causes global warming** is a theory which describes climate change very well.

Scientific speculation

The reason we make theories is to speculate: would the theories still work if we were to do the experiments in a new domain?

- Speculation is the **extrapolation** or extension of theoretical predictions into ranges in which the theory has not been tested by experiment.
- This is important for
  - Finding the limits of their application
  - The creation of new, possibly revolutionary and better theories
  - The discovery of new phenomena or the invention of new devices, when the theories turn out to break.



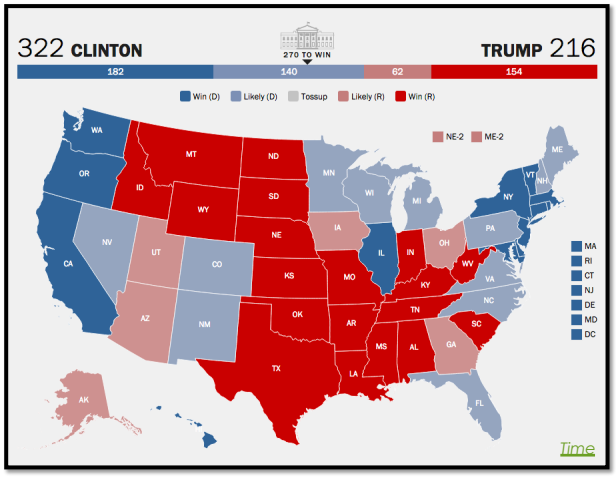
Examples of speculation

The standard model of elementary particles is a theory that accurately accounts for the existence and interactions of subatomic particles like lepton, quarks, and the Higgs boson.

But it is speculated, based in part on something called "string theory," that additional particles will exist with masses larger than the standard-model ones.

Thus, the Large Hadron Collider is searching for them, up to masses one hundred times that of the standard-model particles.

Site of the (underground) Large Hadron Collider (LHC)



An example of disappointment from a badly done experiment, a failure of scientific polling through misunderstanding of uncertainties.

Making stuff up

Science is not a work of fiction. Theories which are inconsistent or illogical and experiments without well-understood uncertainties have no place in science or in everyday life. It is not helpful to make stuff up.

The scientific study of the origins of life

We will stick to facts as much as possible in our study of the origins of life this semester.

- Good theories will be brought in as well, though without much math
- Speculation is too interesting to avoid, especially in the middle (the biological section) of the course
- And the making up of stuff, of which there is a lot related to the origins of life, will be discussed in the light of the facts