Crank Astronomy As A Teaching Tool*

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Many astronomers – and indeed, scientists in general – have dealt with them: You receive one or more emails from intense individuals who insist that your interpretation of any data is wrong and THEIR idea is Truth (with a capitol "T"). The person contacting you might have some scientific background, or none at all. You might respond to the individual, trying to be helpful, perhaps pointing out some misinterpretation they have of your results, or a fatal flaw their idea. They respond with accusations of ignorance, incompetence and conspiracies, and it goes rapidly downhill from there.

While most scientists consider these individuals – some of whom are part of more organized groups with various non-scientific agendas – as a nuisance, it might be better to regard them as an opportunity to improve classroom teaching.

A surprising number of the claims from these individuals can be addressed at the level of introductory physics or other science classes. They provide simple examples of hypotheses that do not work making them valuable for teaching science and critical thinking. These skills are important for any member of the scientifically literate public and are imperative for any scientist.

We present some crank astronomy claims with a focus on heliophysics which are suitable for actual analysis by students with undergraduate-level physics background. The analyses may also be suitable for high school physics classes.

We also encourage educators interested in using examples of where people go wrong in their thinking to use these as teachable examples. Some lessons, writing assignments, or extra credit can be assigned to students to require them to use both critical thinking and the information learned in class to counter these kinds of claims. In doing so, one not only encourages the development of a student's critical thinking that will serve them in any field, but the student is also better prepared when they will face similar types of claims in the future.

I. INTRODUCTION

The Internet has grown as a research reference of first choice among students and interested amateurs. However, the Internet, once the domain of professional scientific and technical researchers, has become the distribution mechanism of choice for a variety pseudo-sciences propagated by individuals and groups with various economic, political and religious agendas. Through search engines, those seeking scientific information can find themselves directed towards pseudo-science as easily as real science with no indication of the quality of the information. While this can create a problem in teaching science, it also creates an opportunity to teach how science works.

We present a few claims that have been espoused by groups such as young-Earth creationists, "Electric Universe" supporters (a variation on Velikovsky's claims) and various Internet cranks. We illustrate some simple analyses of why these claims don't work that could be accessible at levels ranging from self-study to introductory physics or astronomy classes. These analyses provide examples of how science rules out various claims, as well as illustrating simple physical principles.

Like biology and geology, astronomy relies on observations, plus small-scale laboratory testing, mathematically applied to scales in distance and time too large to test in the laboratory. This makes them easier targets for pseudo-scientific claims.

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The major goal of this approach is to improve emphasis in science classes on how hypotheses FAIL, and therefore demonstrate why these ideas are not incorporated into accepted science. These failures are of two types.

1. Lack of a usable model, or a poorly defined model.
2. Minimal or no numerical predictive power.

Crank astronomy claims provide plenty of source material for scientific models that fail. Some crank claims were even legitimate scientific hypotheses at one time, but their failures have long since been forgotten.

Currently the coverage of this content is rather spotty, generally done by a wide-range of individuals who have not traditionally coordinated their efforts.

The goal of this project is to develop a set of content resources suitable for use in classrooms and in informal education venues. To achieve this goal, several steps are needed to rovide a more consistent set of resources for instructors to deal with pseudoscience issues in astronomy at a variety of classroom levels.

1. Collect and coordinate existing resources;
2. Explore existing resources and determine gaps in coverage of topics;
3. Fill in some of the gaps related to issues not addressed;
4. Determine what resources can be used at specific classroom levels;
5. Conduct classroom testing for effectiveness and iterate for optimal results;

In addition, these materials need to be collected and maintained in a consist form for future use. After all, dealing with pseudo-science is not a one-shot deal. It is an ongoing maintenance task.

II. WHICH PSEUDO-SCIENCES ARE OF GREATEST CONCERN FOR ASTRONOMY?

Currently, there are two major semi-organized groups of concern for astronomy.

Young-Earth Creationism (YEC) Earth and Universe are 'young', i.e. less than about 10,000 years. This system of belief is probably the best known as it is often taught in a number of more fundamentalist religious institutions.

- Omphalos argument or "Appearance of Age". In astronomy, this argument often creates theological problems for its advocates as it requires light (and sometimes particles such as neutrinos) to be created 'in transit' representing events that never happened.
- "Accelerated processes" in the past give the appearance of age, implemented via changing physical constants or relativistic means.
- Biblical geocentrism

Young-Earth creationists are not monolithic in their organization. There are several organizations that advocate their own set of solutions to cosmological issues.

Electric Universe (EU) A merging of Velikovsky ("Worlds in Collision") and Plasma Cosmology (Alfven & Peratt). This group is currently less known in the classroom but much better known in the solar and magnetospheric community.

- Galaxies formed at intersections of giant Birkeland currents (Peratt Model)
- Stars are powered not by nuclear energy but external electrical currents.

Both of these pseudo-sciences often include denial of relativity and many of the results of modern cosmology. In addition to these more organized groups, there are various smaller groups and individuals who offer their own flavors of some of the above ideas.

Then there are the more seasonal pseudo-sciences, such as 2012 doomsday claims, comets harboring flying saucers, the 'face on Mars' as well as claims of alien structures seen in images of the Moon and Mars. These are often propagated by various self-promoters and doomsayers-for-profit.

III. WHY SHOULD TEACHERS BE CONCERNED?

Some polls suggest as much as 50% of U.S. citizens believe in some version of Young-Earth Creationism. Some YECs are even incorporating EU claims into their 'theories' cafeteria-style, perhaps due to EUs history with Velikovsky who based many of his ideas on Biblical events.

- Both groups are using 'grass roots' organizing techniques.
- The online presence of both ideas has a growing profile in search engines. Students can easily find this info and have no way to evaluate its value or accuracy.
- Both of these groups often invoke the same 'problems' of mainstream astronomy as evidence for their particular cosmology!

The more organized pseudo-science groups such as Young-Earth Creationism and Electric Universe have sufficient funds to prepare professional-looking publications targeting students. Don't be surprised if you encounter these publications and others in the classroom!

IV. CLASSROOM SCENARIOS

How many people doing REAL science today had explorations into the paranormal, UFOs, "Ancient Astronauts", Velikovsky, etc. in their formative years, usually middle-school? While not universally true, the lead author of this paper (Bridgman) did go through such a phase. This supports the idea that even this thinking can be changed.

So what makes the difference between those who go into legitimate science and those who adhere to the bad science?

Perhaps it is better access to reliable information. Teachers have a chance to provide that additional reliable information. An interest in pseudo-science expressed in the classroom can provide a powerful opportunity

1. Exercise caution: Is the student a 'true believer' in the pseudo-scientific claim, or are they just expressing natural curiosity in something where they don't have clear knowledge? In the first case, your real audience is not the 'true believer'. Odds are you will not convince them.
2. Your *real* audience is the other students in your classroom who really don't know, but want to know. Handling the query well can mean the difference between the student understanding real science or becoming a participant in some online crank science forum.
3. In responding, stick to the SCIENCE. Do not form the argument as anti-religion.
4. Don't be afraid to say you don't know, but be prepared to say you'll try to find out (avoid 'argument from authority'). Make sure you follow-thru on the inquiry. There are lots of resources available to assist with finding answers! The goal of this effort is to develop, organize, and find good solutions for what works.

While such topics might be raised by students, there are advantages to integration of these topics into regular teaching. One advantage of approaching these issues as part of a structured lesson is there is less opportunity for confrontation and the instructor enters the situation better prepared.

Science involves testing which ideas work and which ideas don't work. Crank astronomy claims provide a reservoir of failed ideas available for demonstration.

Exercise:

- Assume crank claim is true.
- What are the additional implications which are testable?
- Is there already data available for these tests, or is new research necessary?
- What does the data indicate?

These demonstrations can be useful for instructor-led samples, one or more class sessions on crank astronomy topics, or more advanced student study projects.

Demonstrations provide opportunities to introduce other physical concepts and principles of how real science analyzes and solves problems.

V. BENEFITS OF THIS APPROACH

- Gives students 'hands-on' experience with analyzing valid *and invalid* claims.
- Provides a demonstration of how science tests various hypotheses.
- Student participation in the analysis gives experience with how the peer-review process works

These processes have dual benefits

- They help clarifies a popular misconception
- They reduce the influence of specific crank claims

Models are a key product of scientific research. A model provides a method for other researchers to apply, test, and extend the work as well as apply in technologies. But a model is not perfect. No models exist which can compute quantities to arbitrary levels of precision that we can measure in the real world, but that does not stop them from being of value.

> "*All models are wrong, but some are useful.*" - George E. P. Box

Crank models are often worse than wrong. They are useless. The advocates of these models are the only ones who obtain the 'desired' results as they will rely on *ad hoc* physical assumptions and invalid mathematical manipulations. Most crank astronomy claims often avoid numerical predictions and mathematical models completely - preferring very descriptive 'predictions' which are easier to massage to any real outcome! These failings are often promoted as a *feature* of their model. But if they can't build a mathematical model that *others* can use, then they aren't doing science. Schrodinger's equation became important because other researchers could apply, test, and extend his work. This work made lasers and semiconductor electronics possible today.

VI. CLOSING

This is not a new approach. Other instructors have implemented similar approaches for their particular classroom situation but they are largely doing this on their own, without feedback and support from the wider community.

What we call for is *expanding* the approach and make it part of regular science teaching.

Science literacy isn't just for scientists. Science literacy is vital in a free, democratic and *technological* society.

VII. EXISTING RESOURCES

Resources from the authors.

"Crank Astronomy" (`crankastronomy.org` and `DealingwithCreationisminAstronomy.blogspot.com`)

> **Topics:** Young-Earth Creationism, Electric Universe, Geocentrism, Relativity denial
>
> **Format:** Blog posts, topical papers. Coming soon: Topical Wiki

"Exposing PseudoAstronomy" (`pseudoastro.wordpress.com`)

> **Topics:** Image analysis, New Age claims, Planet X, general misconceptions
>
> **Format:** Podcasts (30-50 minutes long, with transcripts), Blog posts

"The Sun Today" (`TheSunToday.org`)

> **Topics:** Solar claims, comets, bizarre Sun-Earth connections
>
> **Format:** Blog posts

This is far from an exhaustive list. A few more items available around the web.

Talk Origins: The long-standing web site affiliated with the talk.origins USENET group. `talkorigins.org`

David Dixon, Tales from the Box: Video: "Amateur Scientists vs. Cranks". `http://boingboing.net/2013/07/01/amateur-scientists-vs-cranks.html`

David Dixon, Teaching Science with Pseudoscience: http://www.randi.org/site/index.php/swift-blog/1897-teaching-science-with-pseudoscience.html

Doug Duncan, Teaching the Nature of Science using Pseudoscience: http://casa.colorado.edu/~dduncan/pseudoscience/

The Sun Today: Do Solar Flares Cause Earthquakes? http://www.thesuntoday.org/solar-facts/flares-and-earthquakes/

The Cosmos In Your Pocket: How Cosmological Science Became Earth Technology. Historical connections between astrophysical science and technology. http://arxiv.org/abs/0710.0671

Useful resources for the Sample Problems.

Crank Astronomy: A Changing Speed of Light? "Issues on Barry Setterfield's Claims of a Recently Decaying Speed of Light, 2nd Edition (DRAFT)". http://www.crankastronomy.org/cdecay/index.html

DwCiA: Challenges for Electric Universe 'Theorists' Blog posts related to Electric Universe claims. http://dealingwithcreationisminastronomy.blogspot.com/p/challenges-for-electric-universe.html

Exposing PseudoAstronomy: Planet X Blog posts and podcasts related to the many stories of Planet X. https://pseudoastro.wordpress.com/category/planet-x/

VIII. SAMPLE PROBLEMS

A. A Changing Speed of Light?

A popular way for Young-Earth Creationists to solve the light-travel time problem of how a universe that appears to be 14 billion year old can actually be $\lesssim 10,000$ years old is to assume the speed of light was MUCH higher in the not-so-distant past. This idea is still popular because it is easy for many to understand.

Level: Basic Calculus

Consider the possibility that the speed of light was much higher in the past. This would enable light from distant stars to reach the Earth even if the Universe were very young. But is that the *only* implication?

Consider a simple model for a changing speed of light:

1. Choose a simple model for a time-varying speed-of-light: $c(t) = c(today)(1 + ke^{-at})$ or $c(t) = c(today)(1 + k(t - \tau)^2)$, where t is time and the speed of light is in units such that the present-day value is unity. The primary constraint is the speed should be very close to unity for $t = 10,000$ years and much greater than unity for $t = 0$. The values of k, τ and a will be determined in a later step based on constraints to be determined.

2. Integrate the equation to compute the distance of light travel, $s(t_1, t_2)$, between any two times, t_1 and t_2.

$$s(t_1, t_2) = \int_{t_1}^{t_2} c(t)dt \tag{1}$$

3. Choose variables, such as k, τ, a above, so between the values of $t = 0$ (defining the moment of creation) to $t = 10,000$ years correspond to a travel distance of about 13,700,000 light years.

4. Derive the Hubble Law for this configuration. For an object at some distance d, emitting light of some wavelength, λ_0, compute the change in wavelength on arrival at the Earth, λ. Consider the problem as tracking two wave crests as they leave the emitting object to when they arrive at the observer. Then compute redshift, $z = (\lambda/\lambda_0) - 1$. Examine the expected behavior of this Hubble law by comparing measured d and z for some nearby galaxies, preferably nearer galaxies with distances determined by Cepheid variables. Are the distances and redshifts consistent?

5. For an object at a fixed distance, compute the arrival times of photons departing the object at $t = t_0$, $t_0 + \delta$, $t_0 + 2\delta$, etc. where δ is a time step convenient for the problem, such as seconds for pulsars or days for binary stars. Compare the observed changes in photon arrivals to period variations observed for other objects such as pulsars, pulsating stars (such as Cepheid variables) even binary stars.

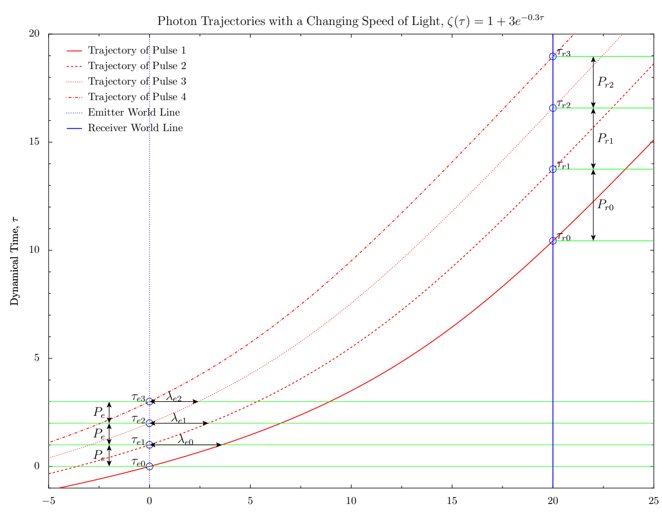


FIG. 1: Trajectories of photons with a changing speed in (x, t).

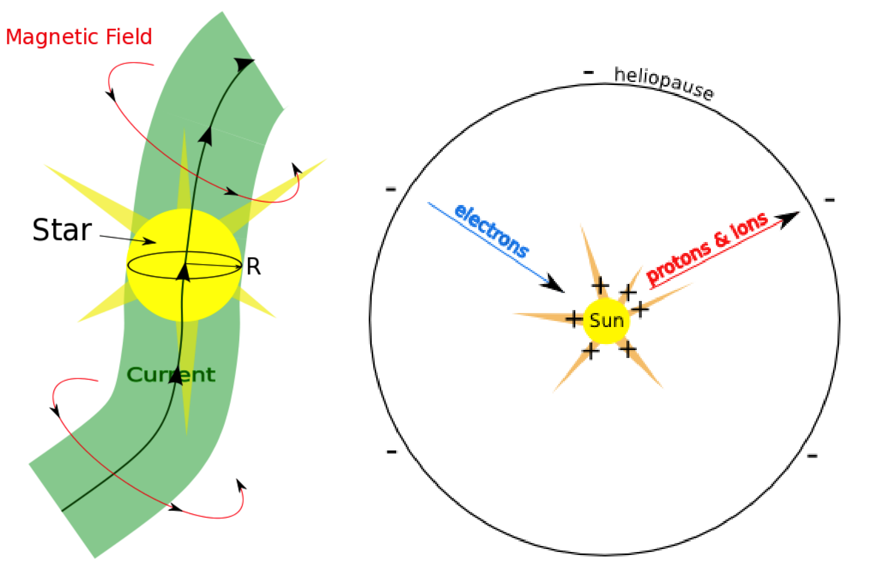
B. Electrically-Powered Stars

Electric Universe claims provide some of the most interesting problems accessible to students with a knowledge of basic electromagnetism. Claims such as electrically-powered stars are particularly easy to rebut as they have strong implications for the particle and field environment in the solar system where we have an abundance of freely available data from spacecraft. These models also have implications for how we build and navigate interplanetary spacecraft.

Level: Basic dynamics and electromagnetism.
A large segment of astronomical pseudoscience is any derivative of the "Electric Universe," which posits that everything in the Universe is electrical and acts and reacts because of electrical interactions and that these are far more powerful than the gravitational interactions. Included in that is the Sun and, by extension, all stars. Consider two possible configuration for stars powered by external electrical currents.

Resistor Model A star as a ball of gas along an electric current stream, similar to a resistor on a wire.

Spherical Capacitor Model A star functions like a spherical capacitor, with the anode (source of protons) at the photosphere and the cathode (source of electrons) at the heliopause.



(a)The Sun powered like a resistor along a wire.

(b)The Sun powered like a spherical capacitor.

FIG. 2: Two popular Electric Universe models for the Sun

Now examine some implications of these two configurations:

1. Compute necessary incoming electron energies & fluxes of sufficient energy to produce solar luminosity for the two configurations described.

2. For the 'resistor' model, compute the magnetic field of the current stream (magnitude & direction) by treating it as a long wire.

3. For the 'spherical capacitor' model, compute the average inbound electron and outbound proton & ion fluxes you would expect to measure at the orbit of the Earth, using particle conservation.

4. For a more advanced class, consider the possibility that an electric voltage difference exists between the stellar photosphere and the heliopause, perhaps driven by a net charge on the star. Apply conservation of energy to determine the energy the electrons and ions would have at the orbit of the Earth.

5. Compare results to publicly available data, such as solar wind speed, density, and magnetic field strength available at `http://www.spaceweather.com`.

6. Can you identify other testable problems with these models?

C. Planet X

Planet X claims are amazingly popular, promoted through various online forums and radio shows. They can often be tied to apocalyptic thinking.

Level: High-School students, algebra

A popular meme for the last 100 years has been the idea of a “Planet X” that lurks “out there” in the solar system. This has taken on numerous forms, perhaps best popularized most recently by Zecharia Sitchin or by the general 2012 paranoia. Could an unknown planet ‘sneak up’ on the Earth from the far side of the Sun without astronomers (professional AND amateur) seeing it?

1. What are the orbit dimensions for a planet with a claimed orbital period of 3600 years?
2. How would a massive object on a radically different orbit affect the other planets, or asteroids (hints: occultation timing, discovery of Neptune).
3. Could such a planet approach undetected from the direction of the South Pole? How about from ‘opposite the Sun’? How much of the sky can you see over the course of a night, a month, a season, a year?
4. Consider other missions around the Solar System which can see in these ‘hidden’ regions, such as STEREO-A & STEREO-B. This provides an excellent opportunity for students to explore real NASA data and data tools.

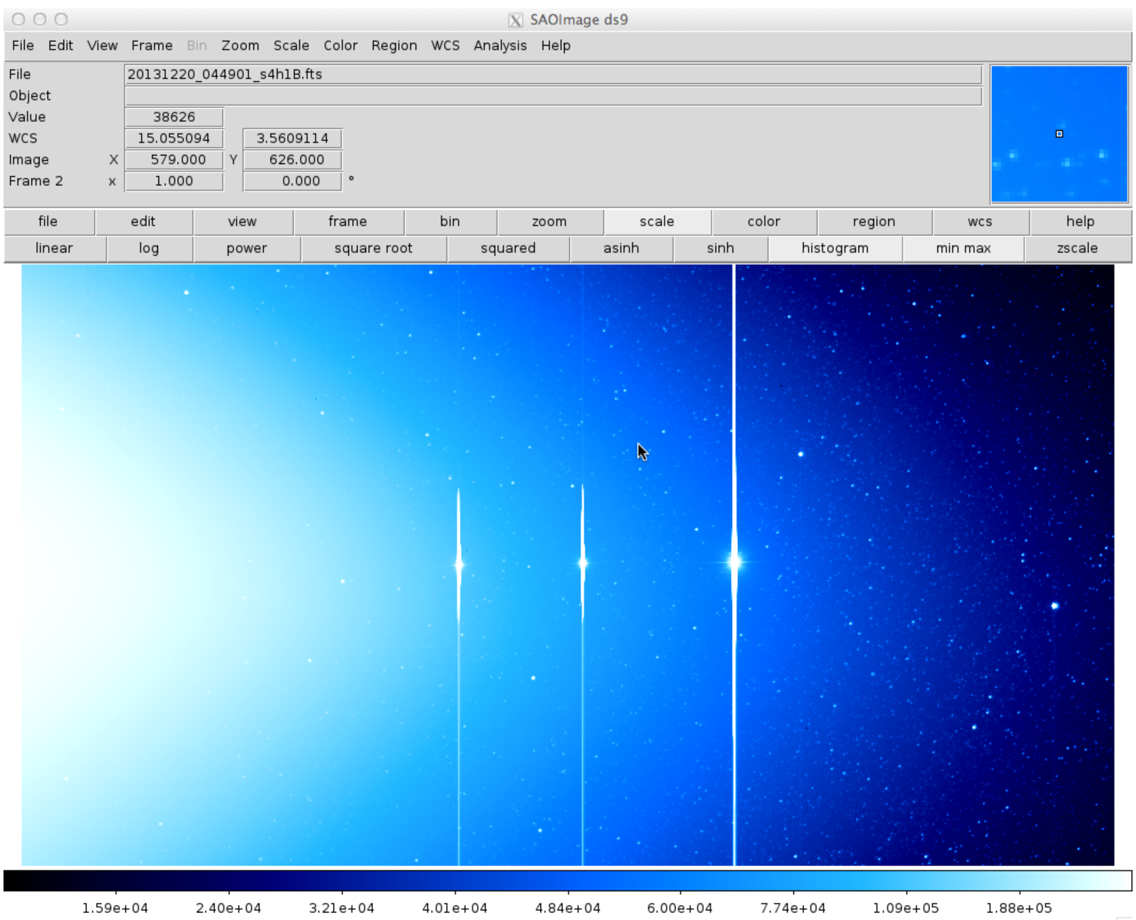


FIG. 3: A view of Jupiter, Earth and Venus from STEREO-B. The bright vertical line through each planet is an artifact of the imaging system.