

Astronomy in Physics (and Chemistry)

John Percy

Department of Astronomy & Astrophysics
and

OISE Science, Math and Technology Ed
University of Toronto

john.percy at utoronto.ca

Why?

Applications of physics and chemistry

Cross-curricular connections add breadth

Integrated approach to science

Engage and inspire the students

Students love it!

Some Goals

- Understand, and be engaged by the “big ideas”
- Think critically about these and other topics
- Appreciate the roles of observation and simulation
- Appreciate the historical and cultural dimensions of astronomy
- Connect with the sky and the universe out there!
- Connect with (and understand) awesome images
- Carry out at least one authentic astronomical activity
- Communicate astronomy through print, electronic or other means
- Visit an observatory or planetarium; connect with an astronomer

Inspiration!

Something has blown this star to smithereens,
and created the atoms of which you are made.
[It was recorded by Chinese astronomers in 1054
during the European “Dark Ages”]



What physics is shown in this image?

Grade Nine Astronomy

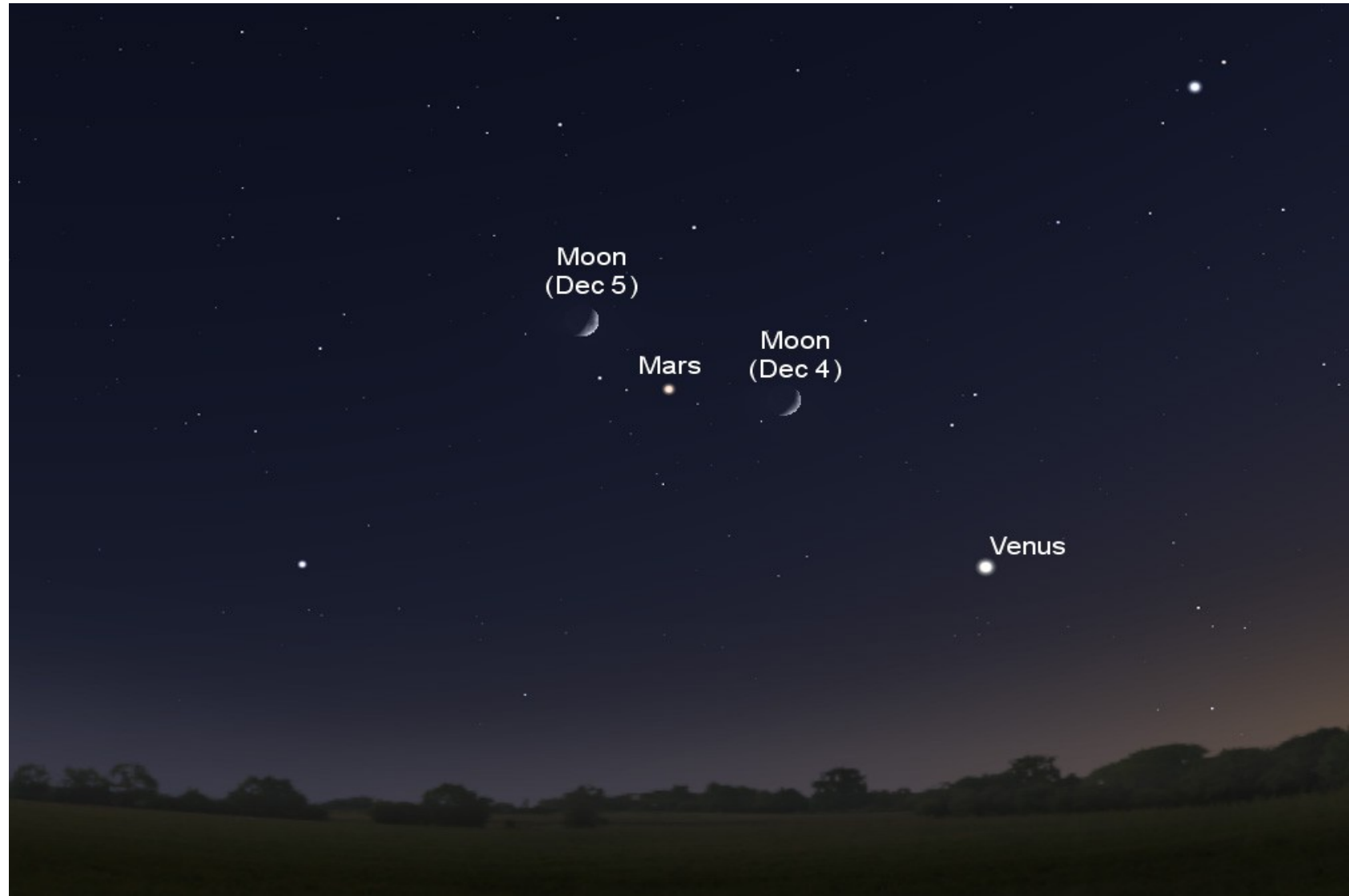
<https://stao.ca/resources/Gr9AstroHandout.pdf>

<http://www.astro.utoronto.ca/~percy/EPOindex.htm>

<http://www.astro.utoronto.ca/~percy/grade9workshop.htm>

Motion

The Sky Tonight: what does this tell us about the laws of motion?



South-western sky in the evening

Why Does A Satellite Orbit Earth?



Impact Craters

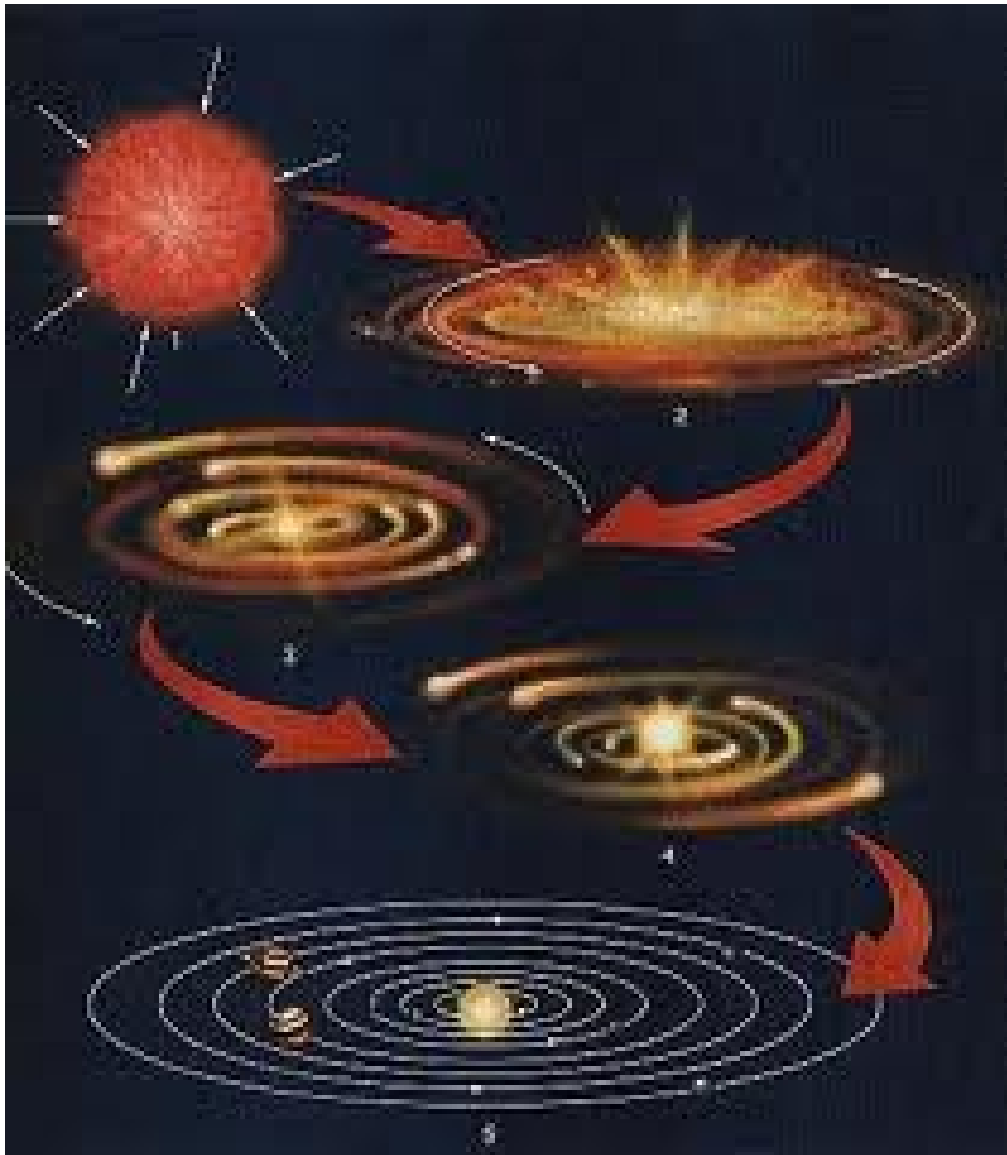
- What are the energy transformations in the formation of an impact crater, caused by a meteorite impact?



Manicouagan – 75 km across



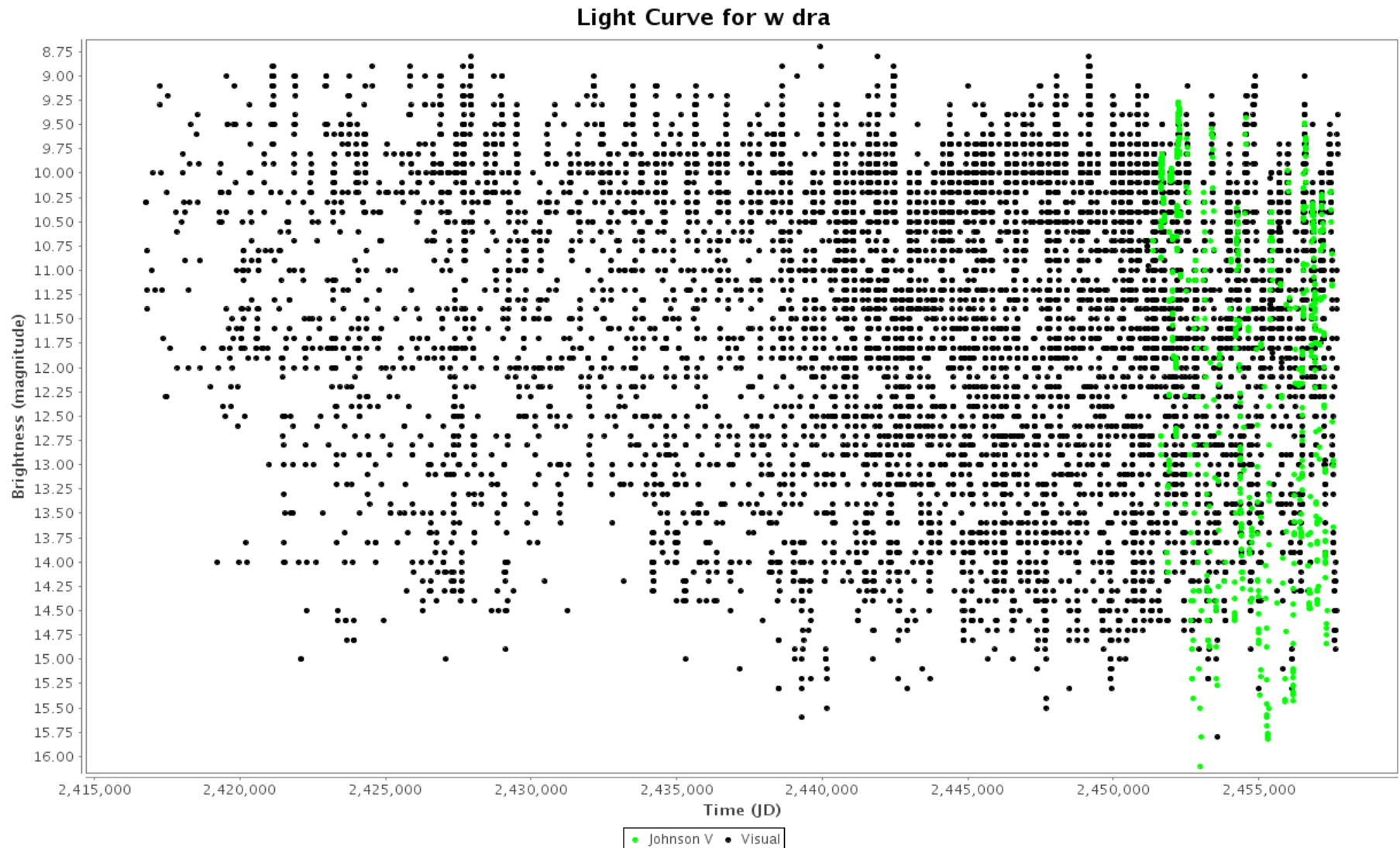
Planetary System Formation



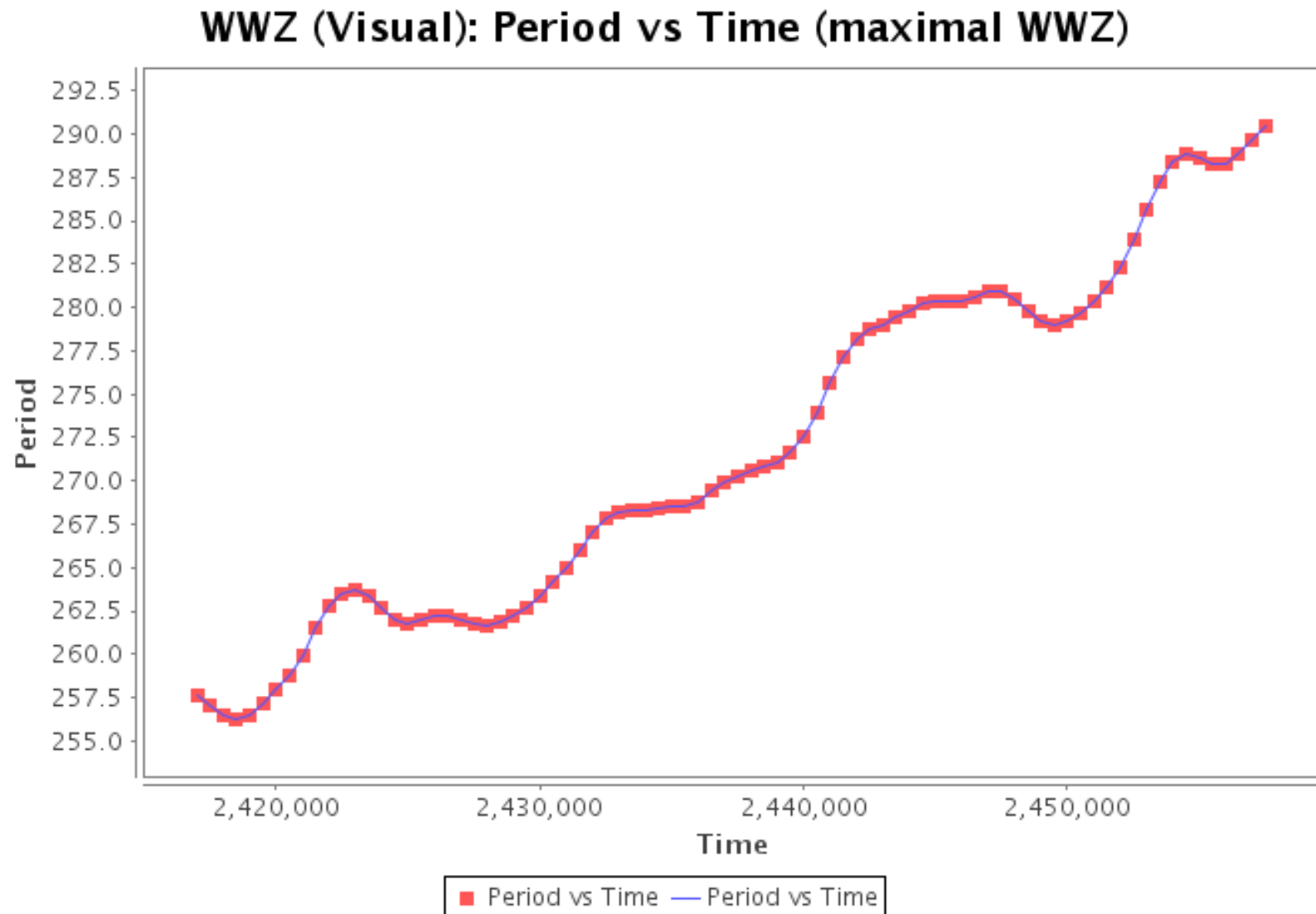
- What are the most significant properties of the solar system?
- How are they explained (or not) by current models of how planetary systems form?

Stars can vibrate! From this,
astronomers can detect and measure
the evolution of the star, because the
period of vibration varies as $\text{radius}^{1.5}$ and
 $\text{mass}^{-0.5}$

Measurements of the brightness versus time of the red giant star W Dra from amateur variable star observers all over the world. Black: visual; green: photometric



The vibration period, in days, of the red giant star W Dra as a function of time in days



Gravity

Why are Astronauts Weightless?



What do you think that most peoples' answer would be?

Gravity and Stars



- What supports the sun from collapsing under its own weight?
- What would happen if that support were to disappear?

Detecting Exoplanets by their Gravity



- The nearest star to the sun, Proxima Centauri, has an earthlike planet!
- Why is this discovery so significant?

A black hole is an object whose gravity is so strong that nothing can escape, not even light.

In that case, how can we detect and “weigh” a black hole?

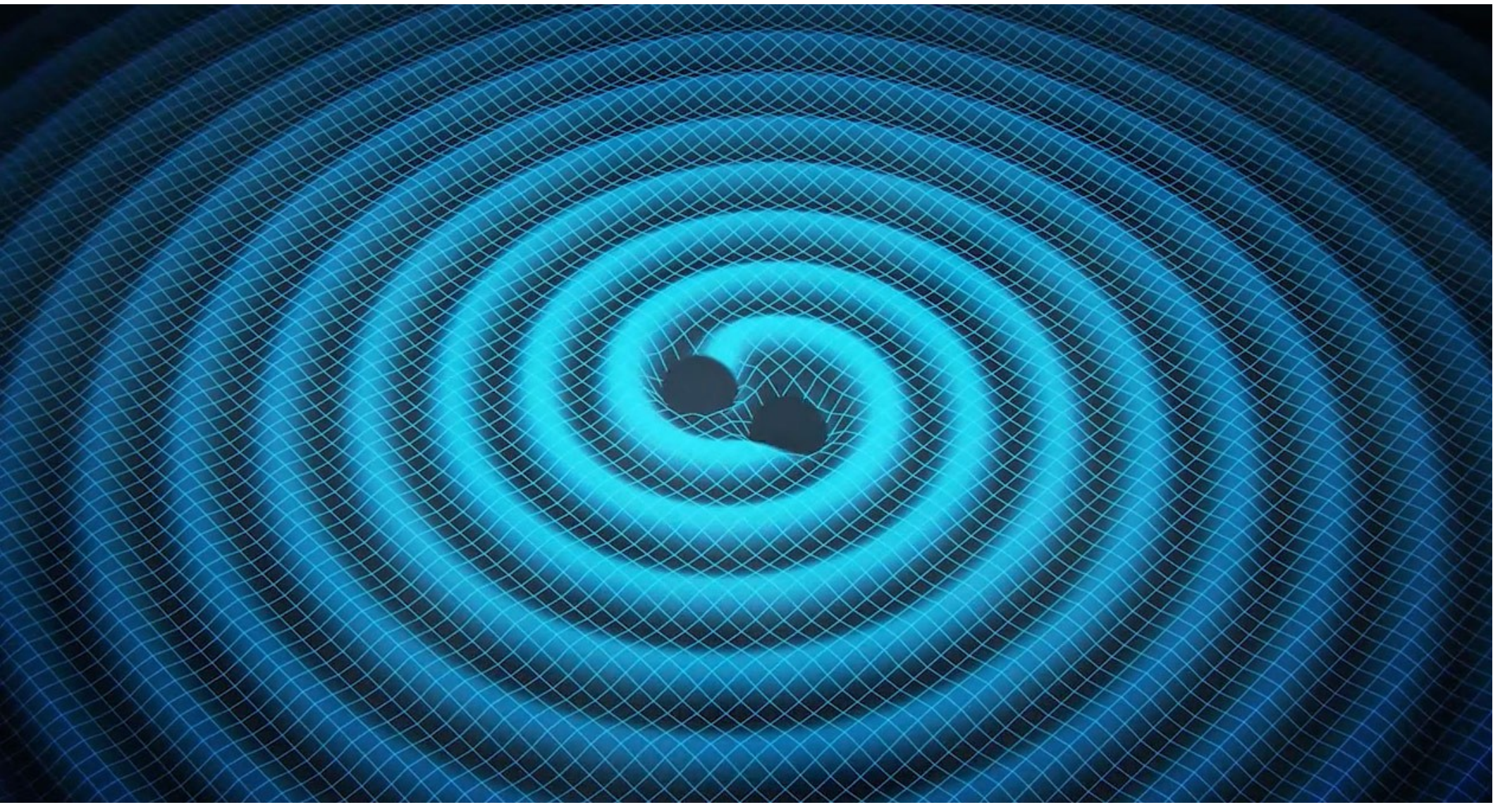
Black Holes

The first black hole in space was co-discovered at the Dunlap Observatory, U of T



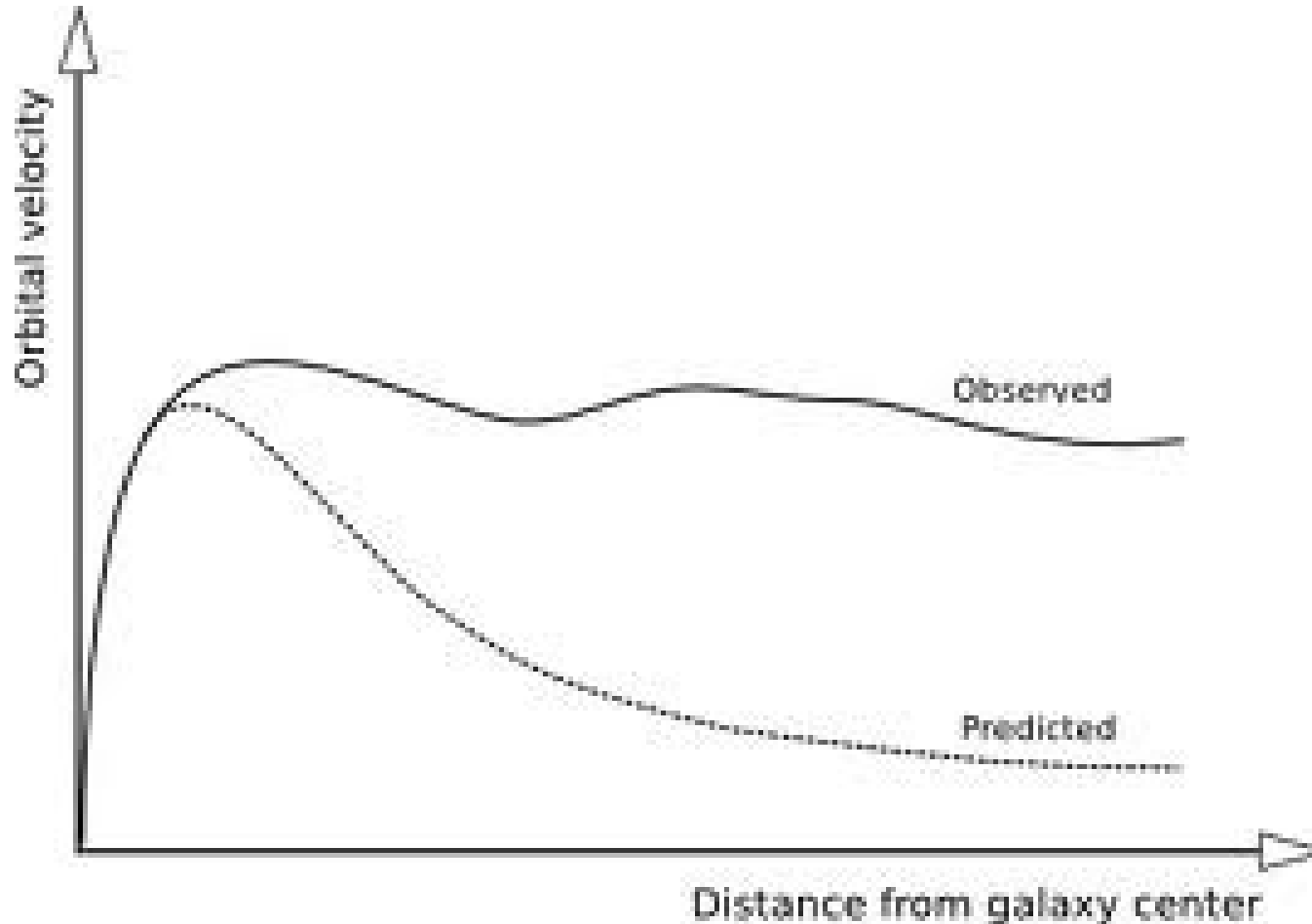
The Eventual Fate of this Pair?

The normal star is very massive, and should form a black hole when it collapses



Detecting “Dark Matter” by Gravity

The measured mass is 10 x the mass of visible stars, gas, and dust. 90% is “dark matter”



$$\text{Enclosed mass} = 1/G \times \text{orbital radius} \times (\text{orbital radius})^2$$

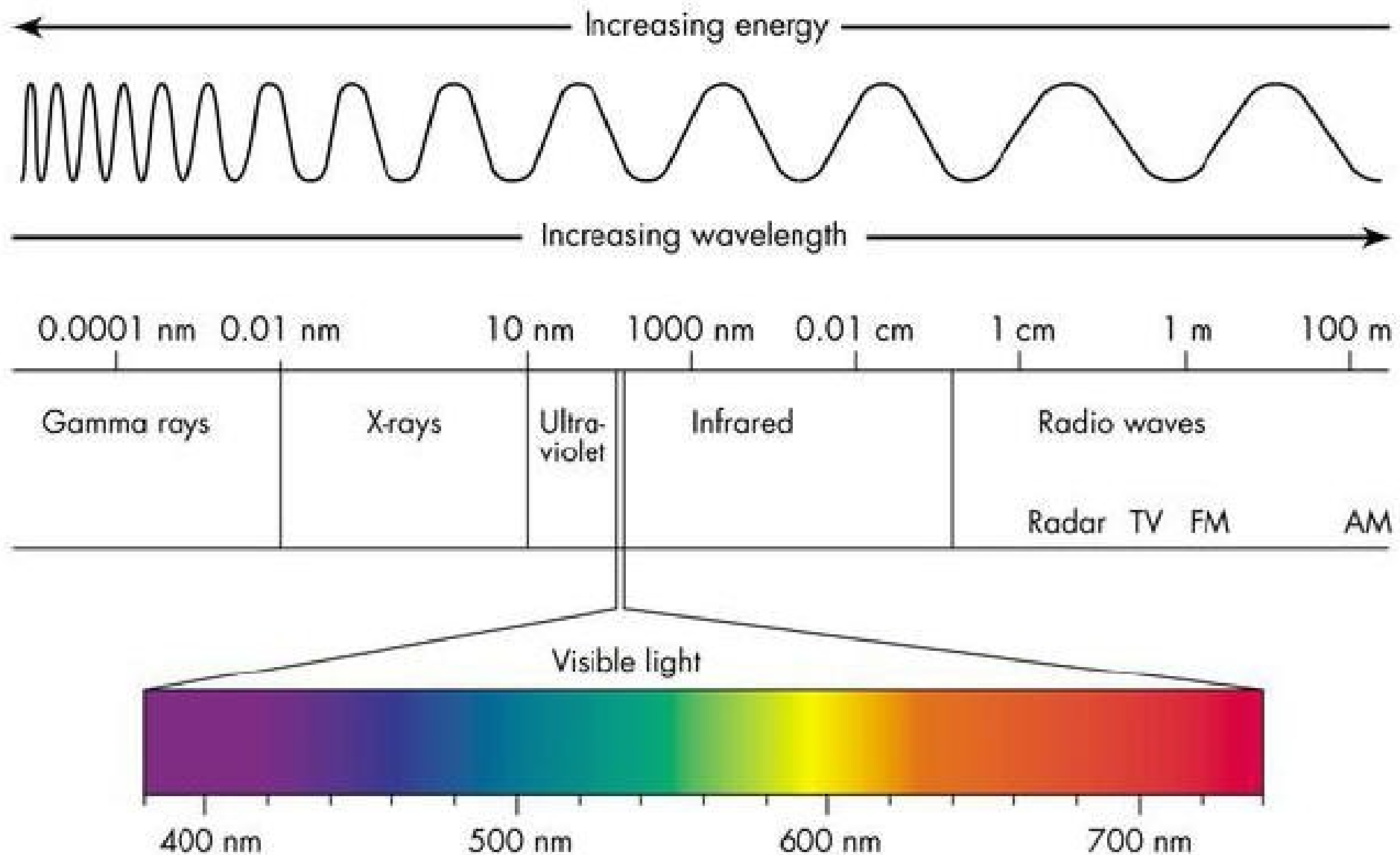
The Accelerating Universe



- The universe of galaxies is expanding at an accelerating rate
- What can you conclude?

Time is measured upward

Electromagnetic Radiation



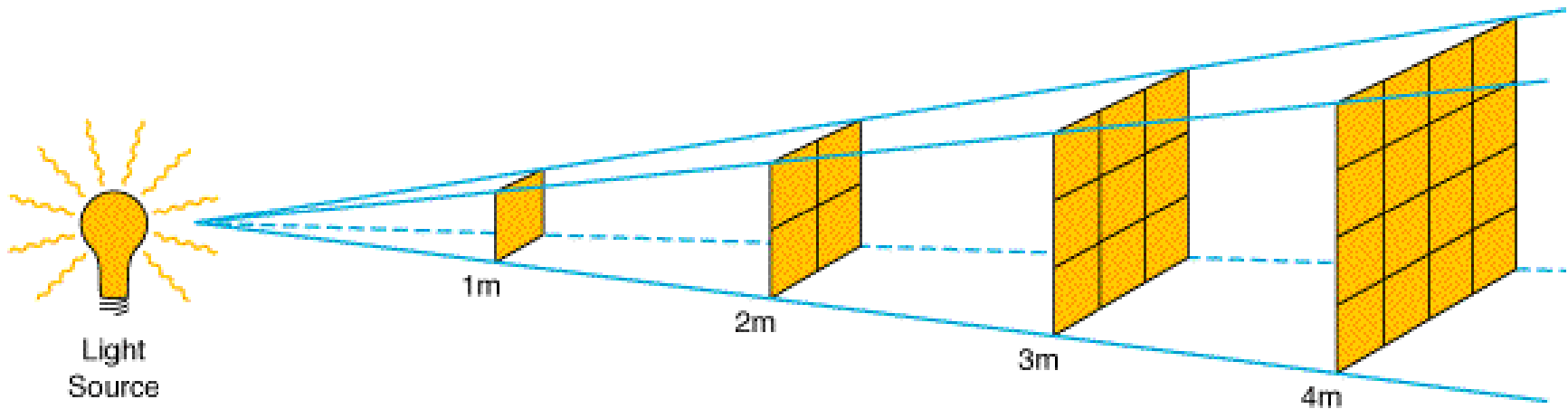
The Finite Speed of Light

Because of the finite speed of light, we see distant objects as they were in the past. The faintest points on this image are galaxies, seen as they were, billions of years ago. **How do you know which are most distant?**

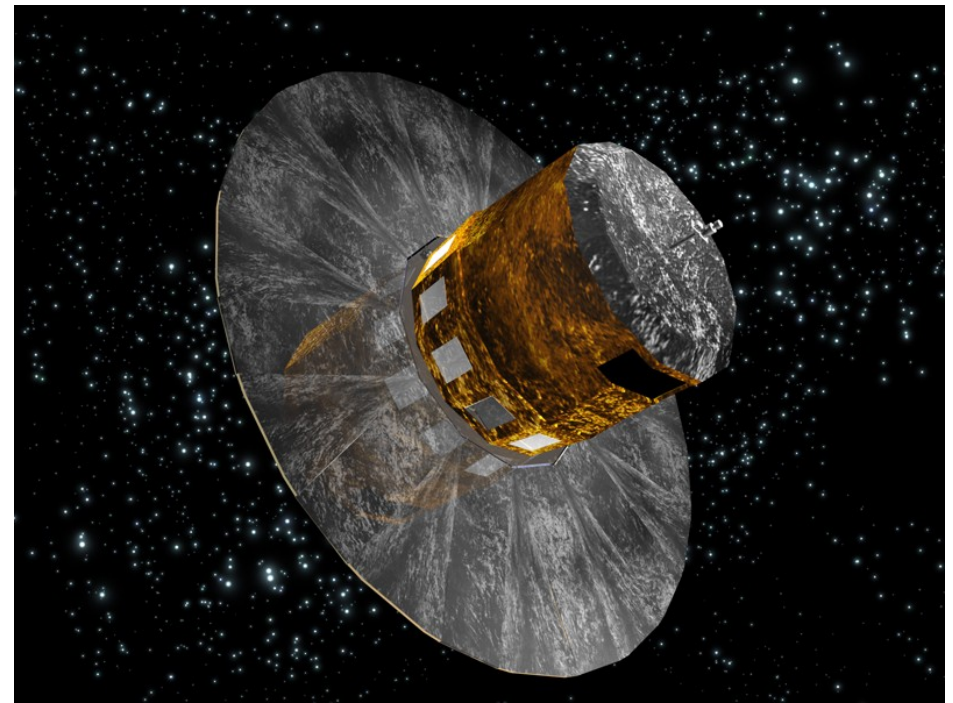
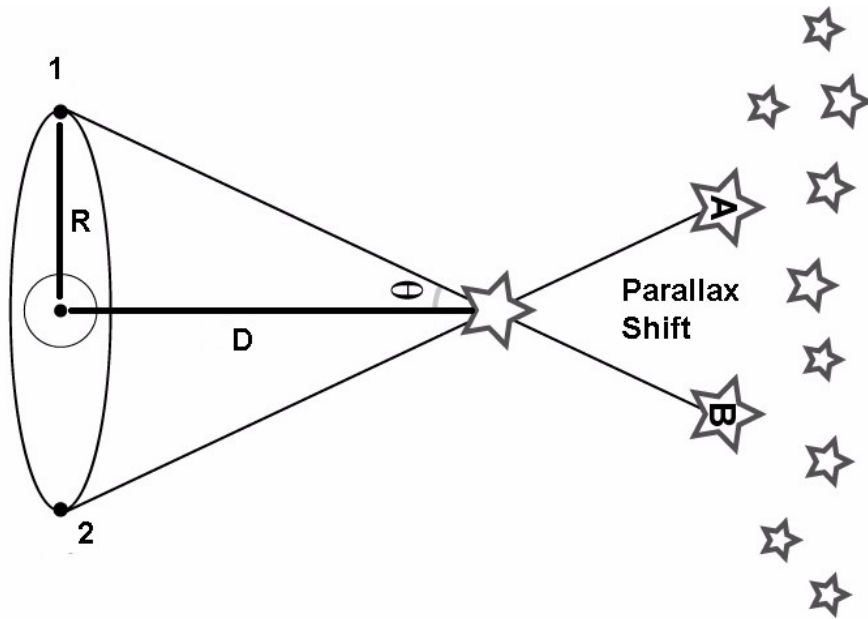


Inverse-Square Law of Brightness

- Brightness is proportional to power divided by the square of the distance

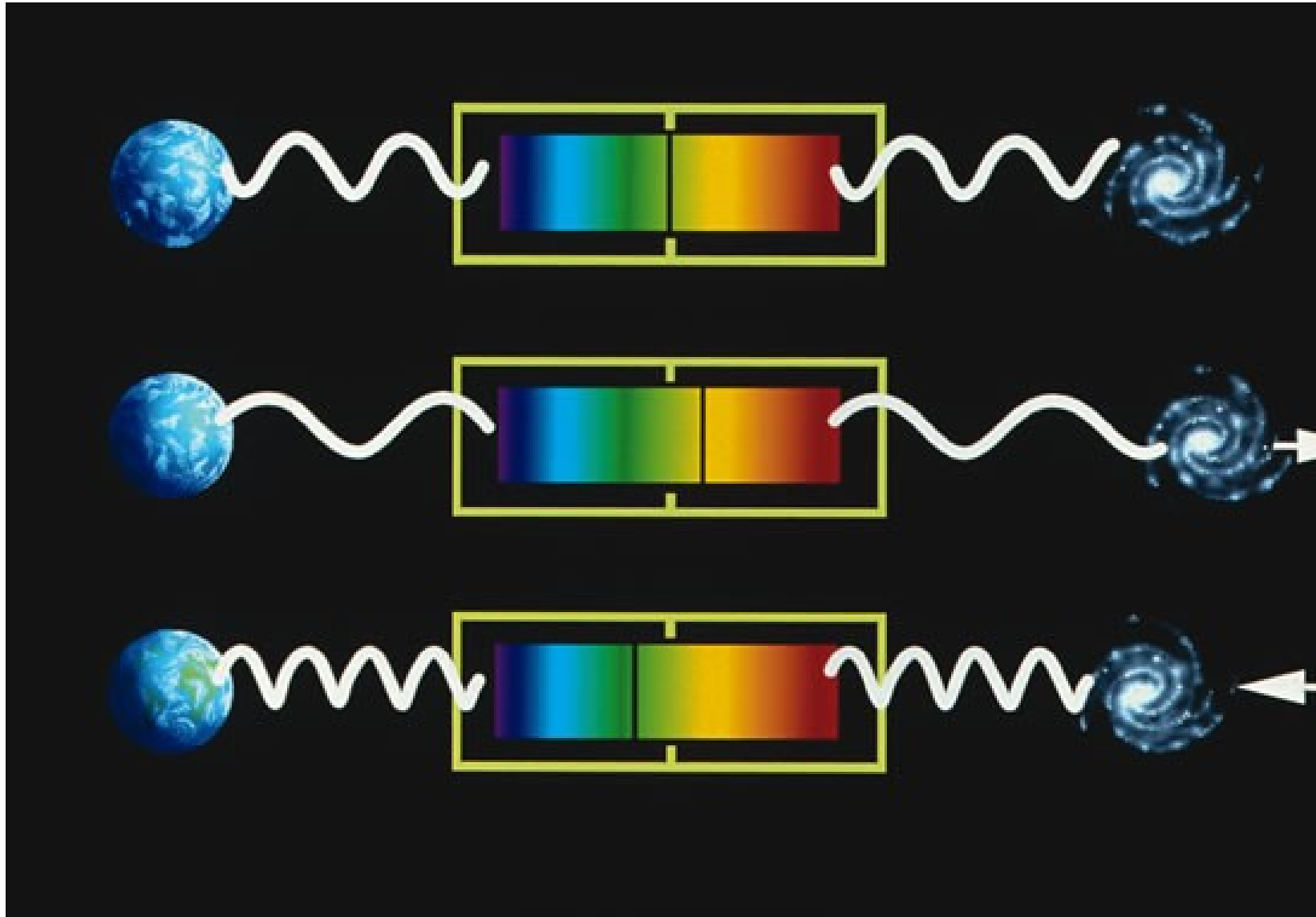


Surveying our Galaxy



GAIA: the ESA mission that you have never heard of!

The Doppler Effect



Optics – Telescopes



- To gather light (light-gathering power)
- And bring it to a sharp focus (resolving power)
- For analysis with instruments

Telescopes



The Gemini
optical telescope



CHIME: Canada's radio telescope
with no moving parts – all electronic!

Science and Society



- Should a thirty-meter telescope be built on Mauna Kea, which is considered sacred by native Hawaiians?
- Many telescopes are already located there



Light Pollution

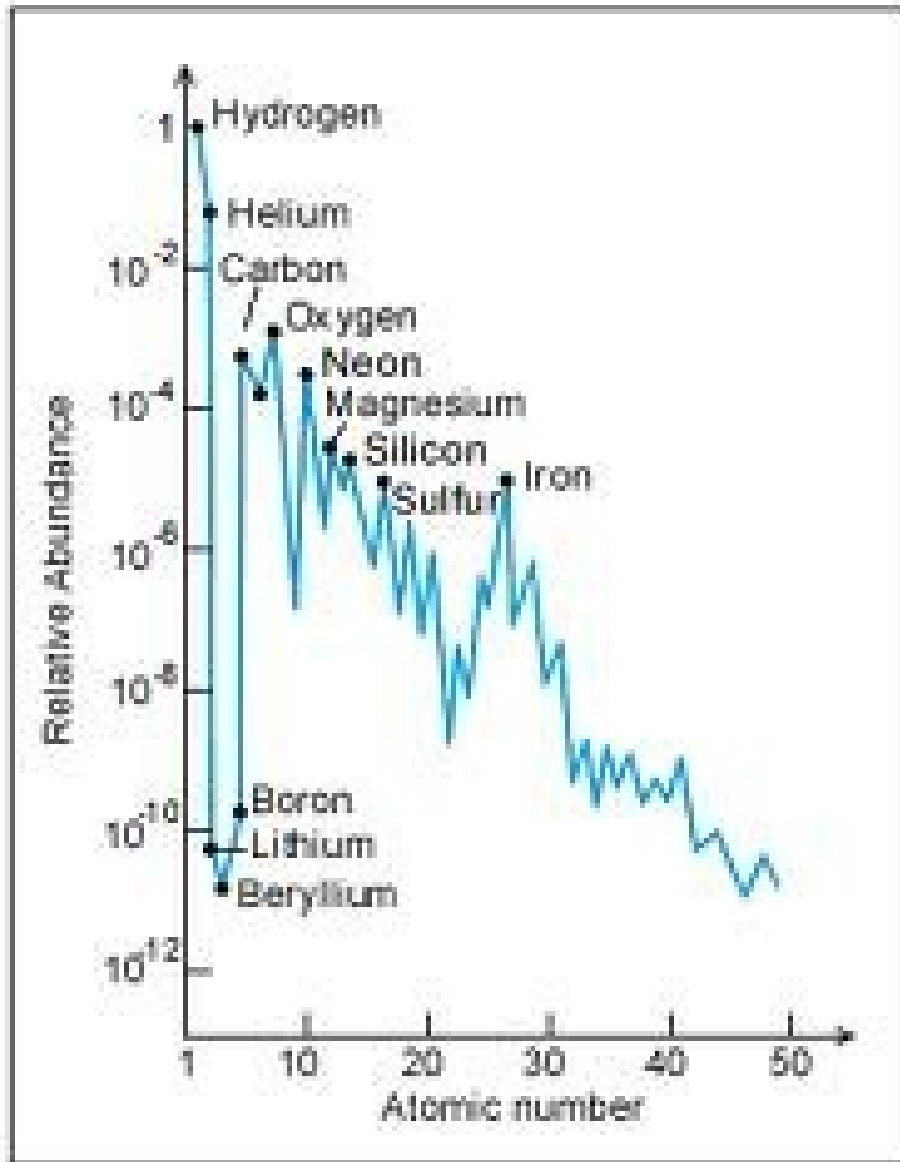
Light, Energy, Society: STSE



<https://astrosociety.org/edu/publications/tnl/44/lightpoll.html>

Nuclei

What is the Universe Made Of?



- Describe this graph in words
- How did these abundances come about?

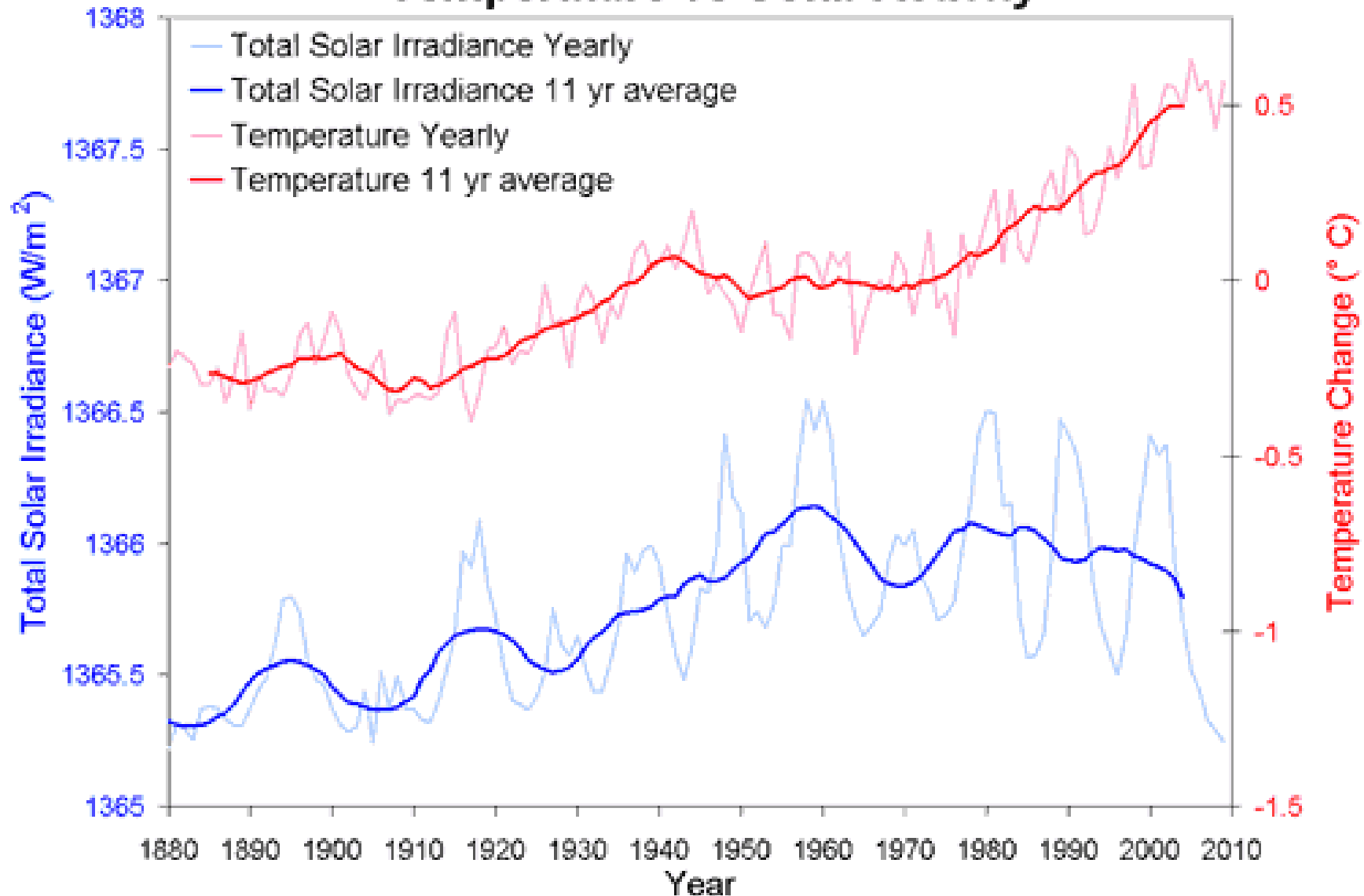
Thermonuclear Fusion



- The sun shines with the power of 400 million million million million Watts, and has done so for 4.5 billion years
- How does this process work?

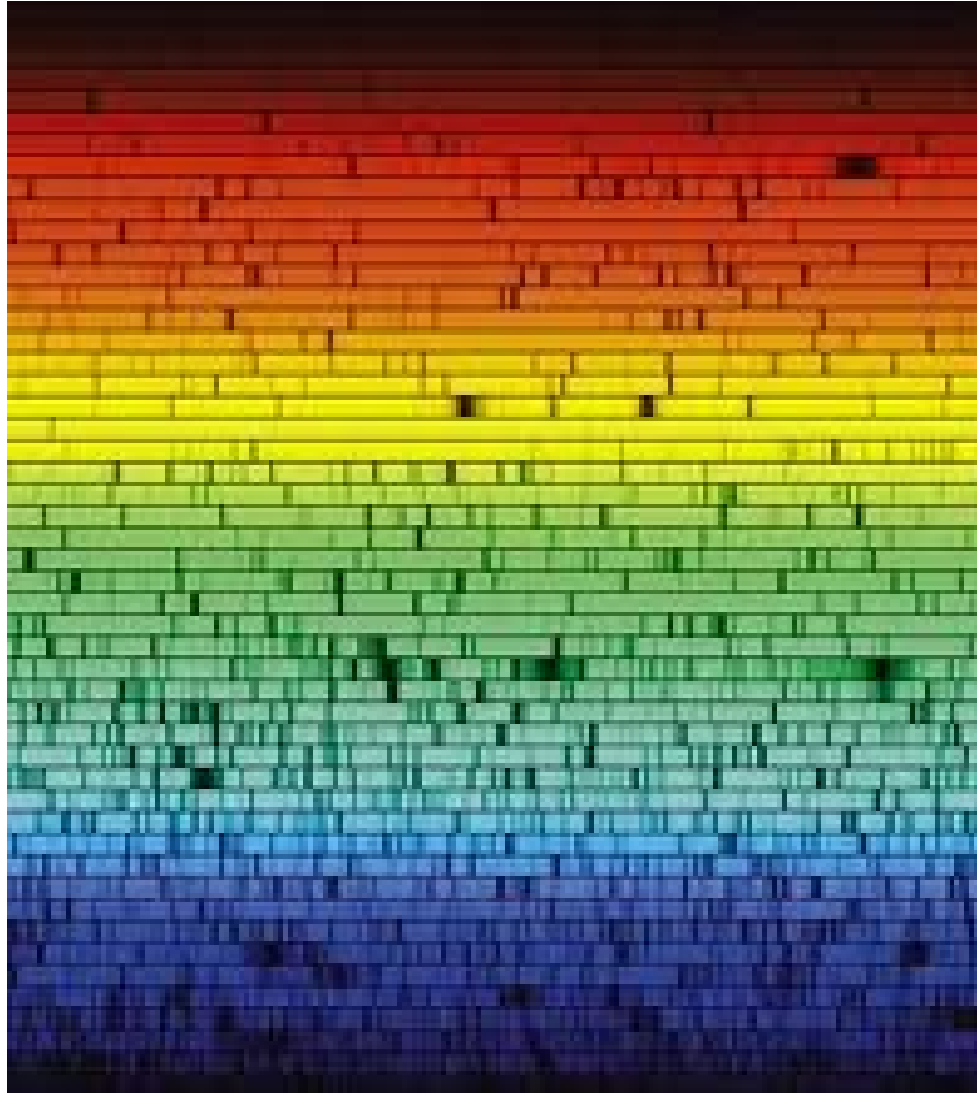
Can the Sun Explain Climate Change?

Temperature vs Solar Activity



Atoms

How Do We Know Cosmic Abundances?



Molecules

How Did Life Begin?

Miller (left)-Urey Experiment: simple molecules, plus energy, produce complex prebiological molecules. The same molecules are found in carbonaceous chondrite meteorites (right). Complex molecules form easily and naturally.



Career Considerations

- Astronomy education prepares for a wide variety of careers
- Women and some minorities are still under-represented in astronomy and other STEM areas
- Astronomy – including research, outreach, and communication -- can be done as a hobby

Resources