Everyday Astrophysics

Astronomical Horizons Public Lecture

Abrams Planetarium

September 18, 2014

Justin Linford

Image from frenzyofnoise.net

The Most Personal Impact?

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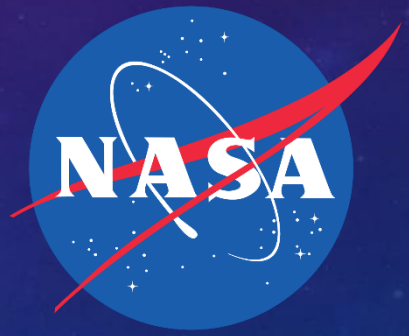
The Most Personal Impact?

Your Tax Dollars at Work

- 2014 National Science Foundation Budget was $7.172 billion
  - Of that, astrophysics received about $250 million

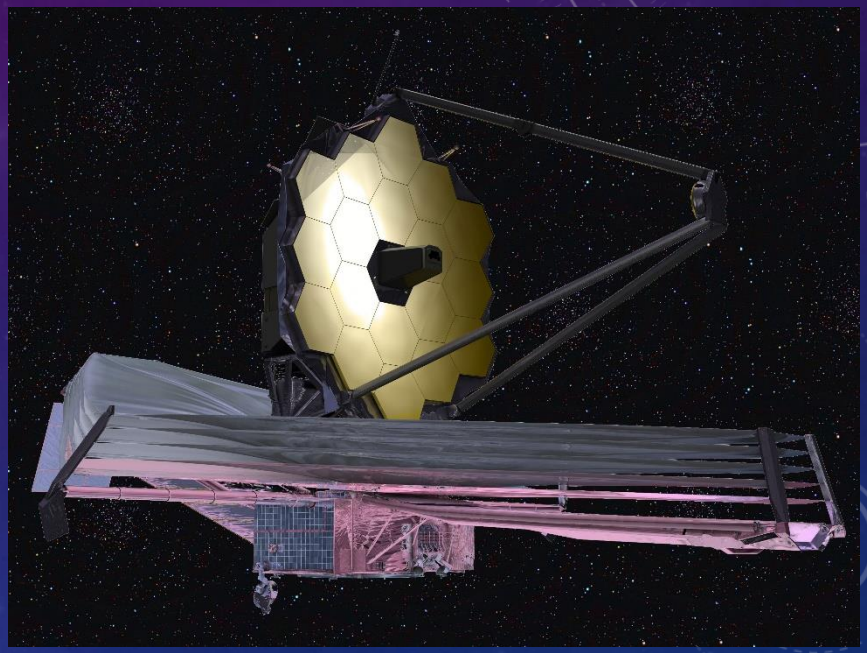
- 2014 NASA budget was $17.715 billion



- The NSF and NASA budgets combined make up only about 0.7% of the total federal budget

The Big Ticket Items

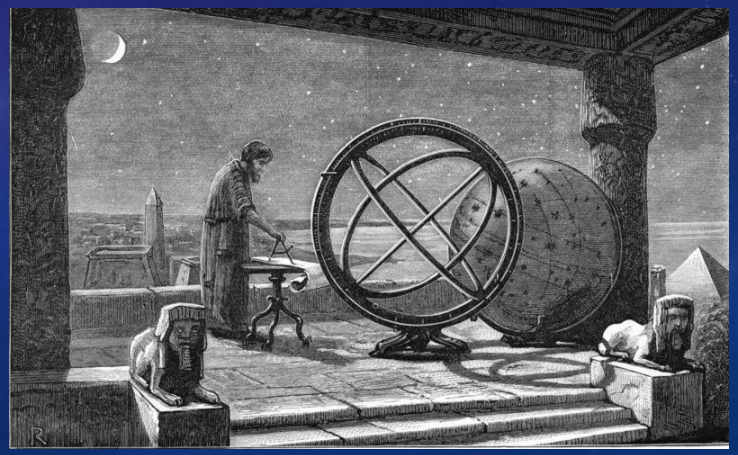
ALMA (NSF/NRAO): $34 million per year



JWST (NASA): about $638 million per year ($8.9 billion total cost)

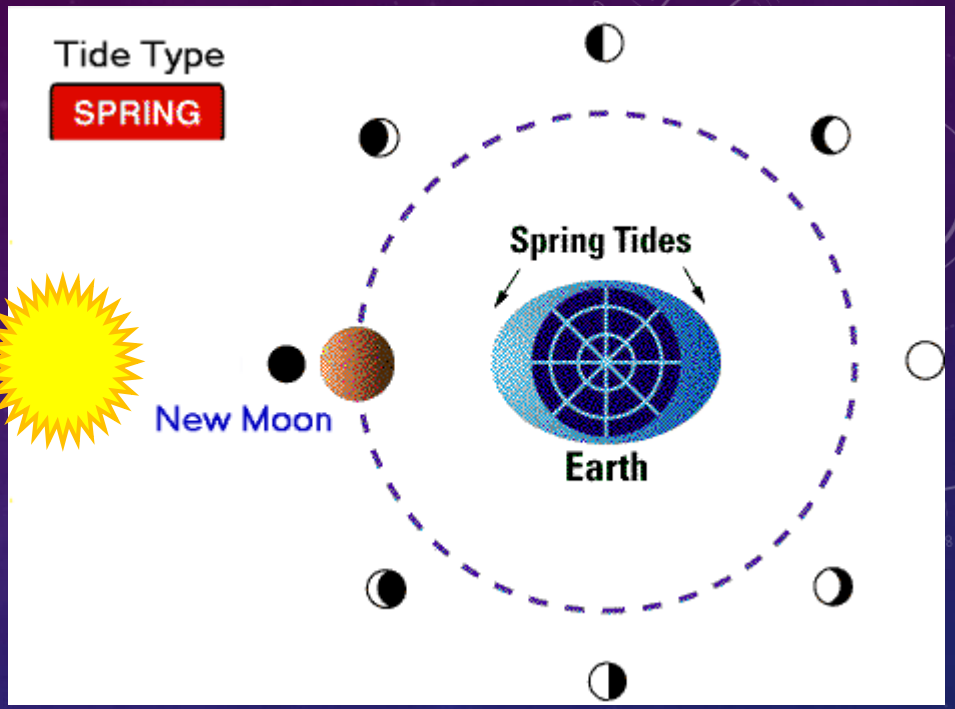
The Early Days of Astronomy

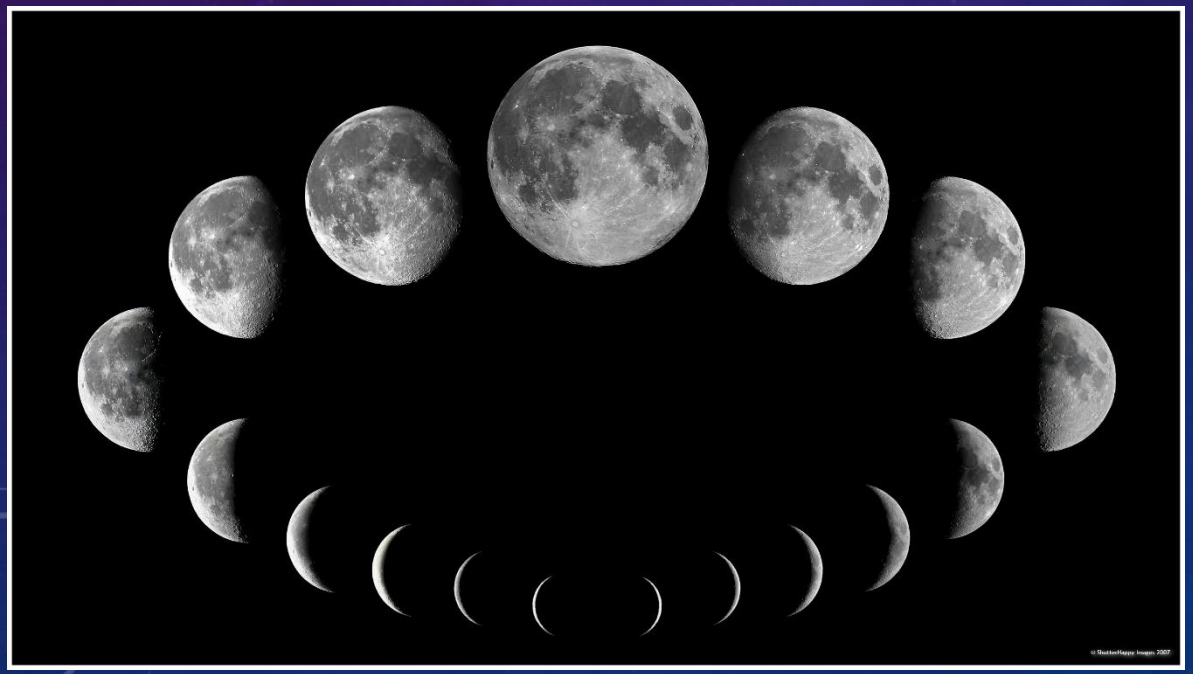
- Early astronomers noticed patterns in the movements of objects in the sky
- They also noticed that some objects didn't move with the rest of the stars
  - They called these weird objects "planeta" or "wanderer"
- The more the watched the skies, the more patterns they saw
- Certain cycles appeared to correspond to important events

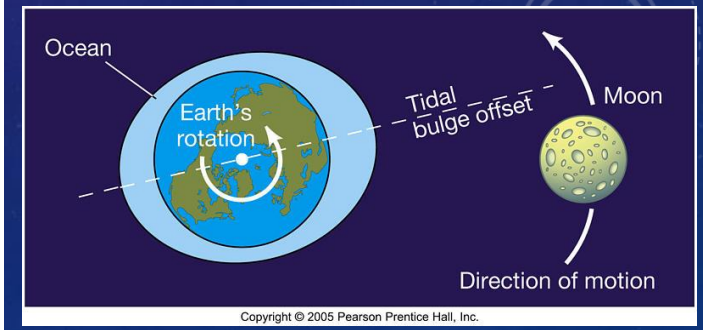


Easy Patterns

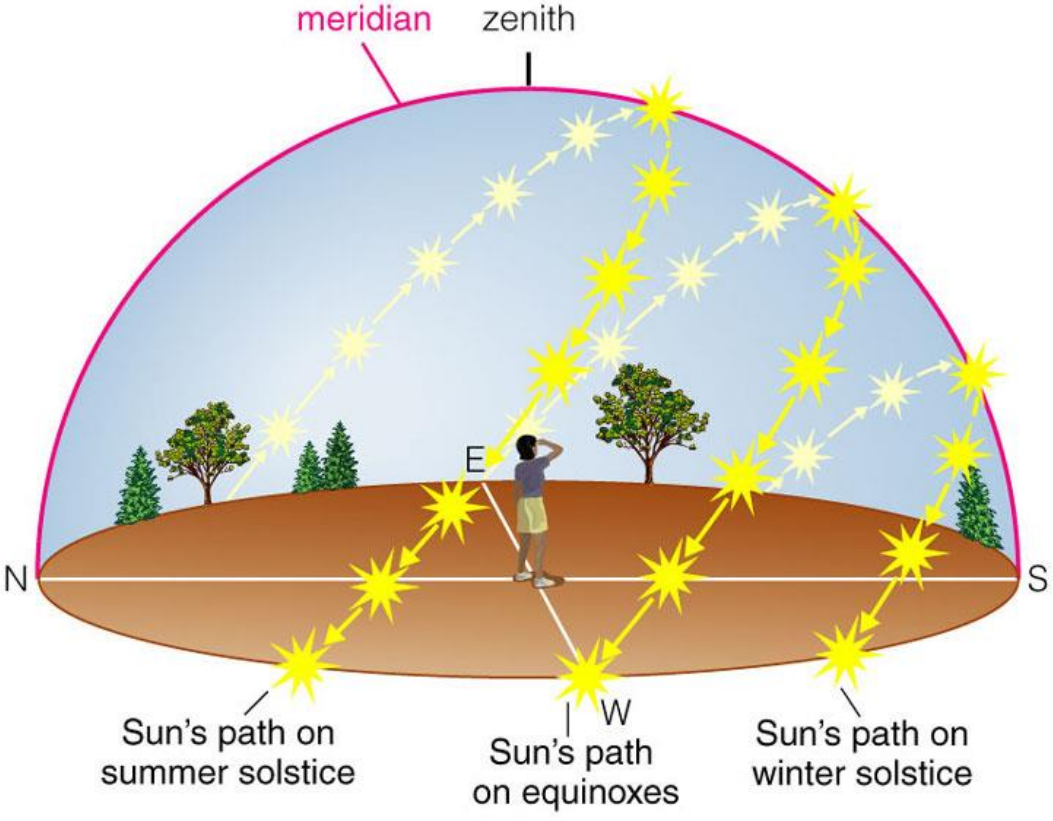
- The phase of the moon is related to tides







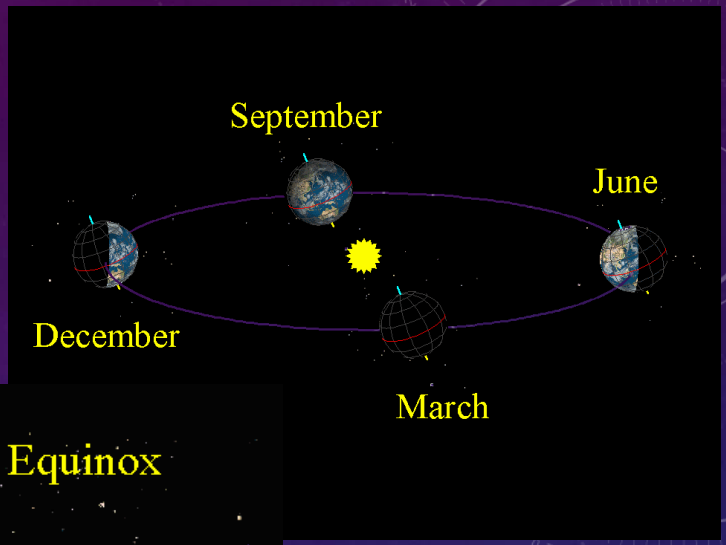
Easy Patterns

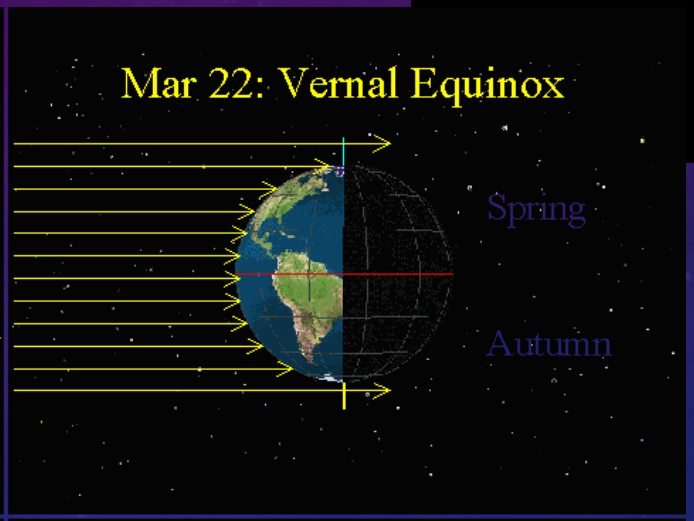


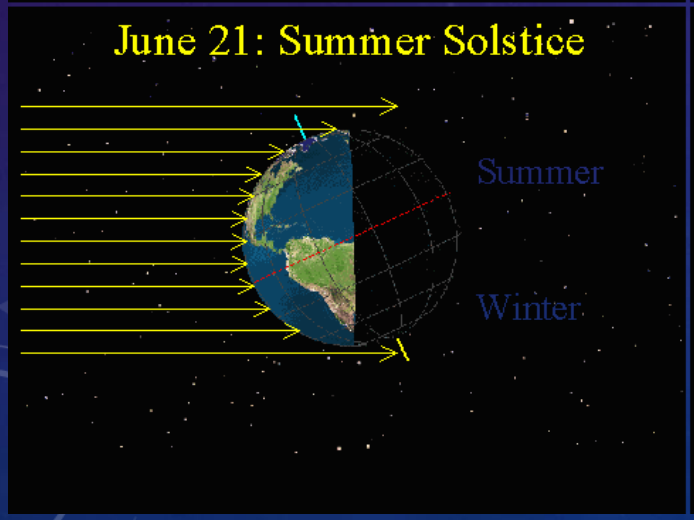
- The position of the sun in the sky relates to the seasons
- Most noticeable at sunrise and sunset
- As summer approaches, the sun sets further toward the north
- As winter approaches, the sun sets further toward the south

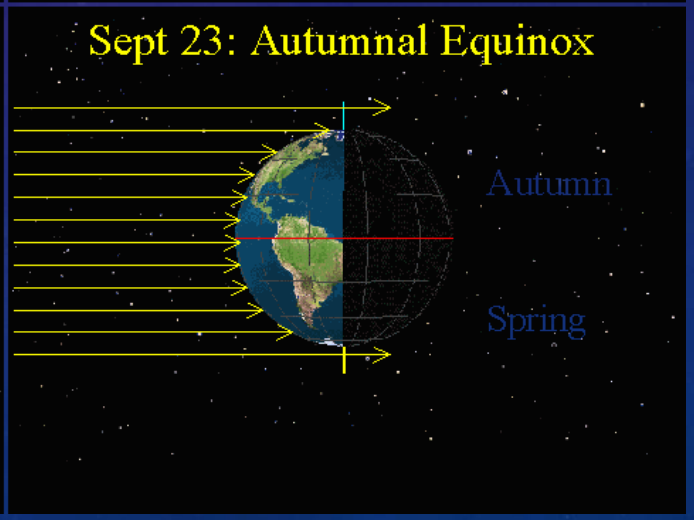
Note: these statements are only true if you are living in the northern hemisphere

What Causes the Seasons?









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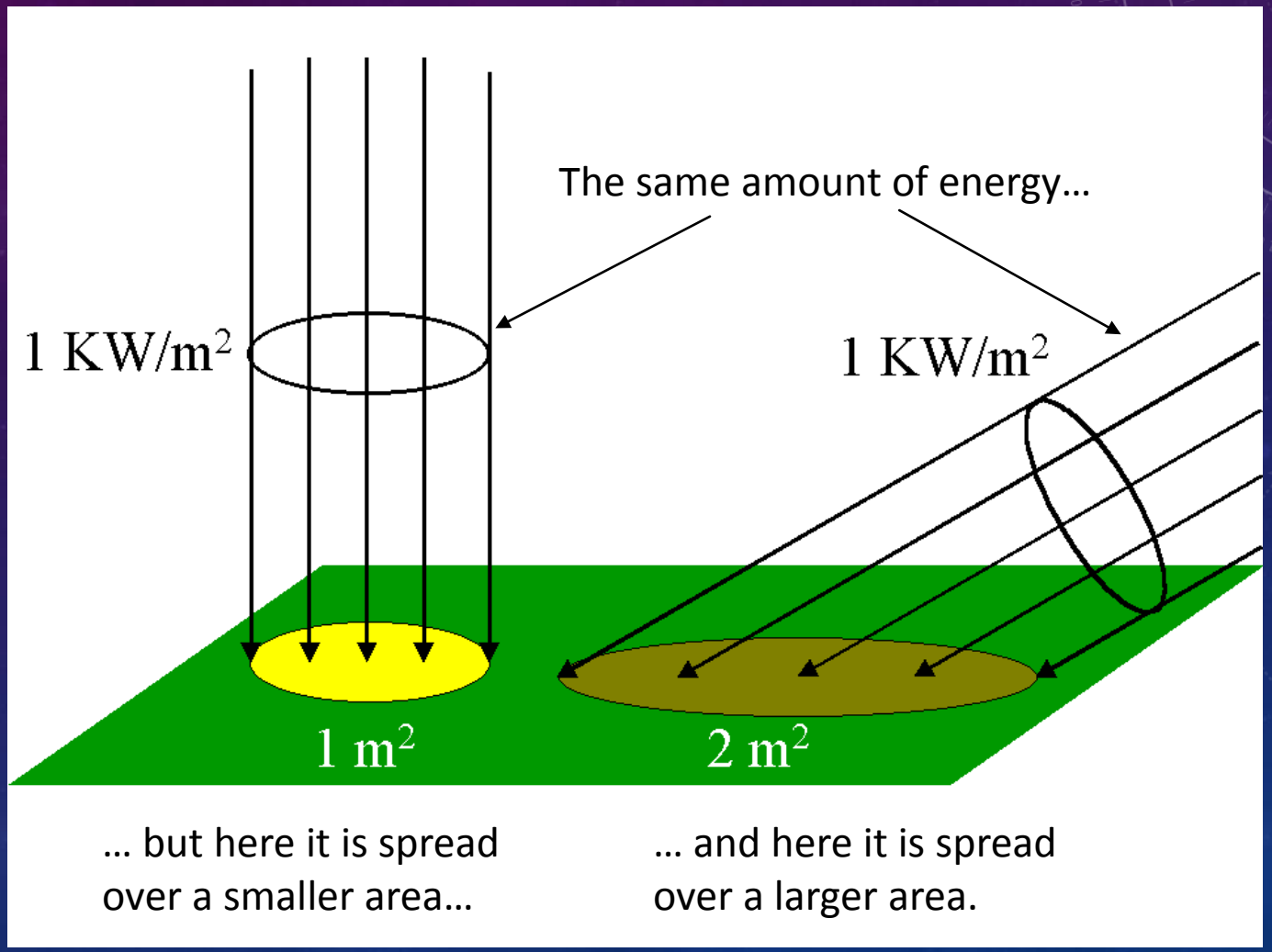
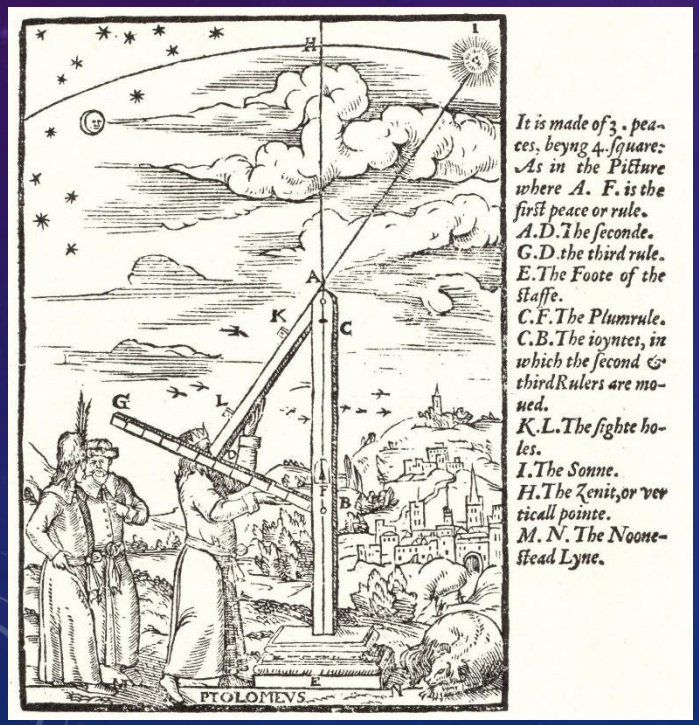
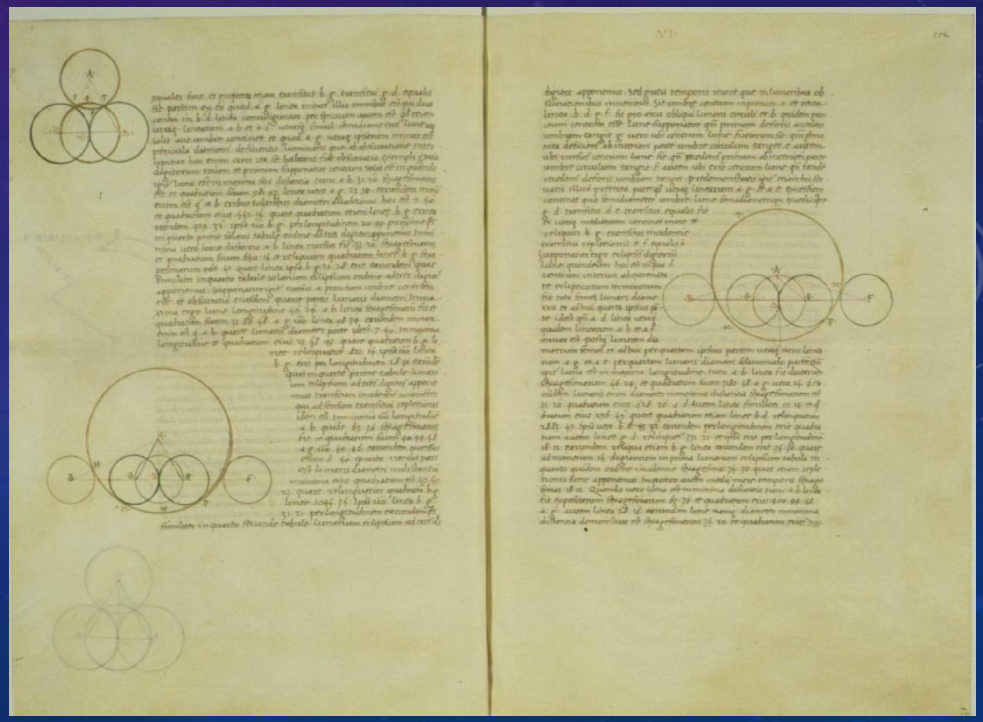



BRACE YOURSELVES
WINTER IS COMING

Tougher Patterns

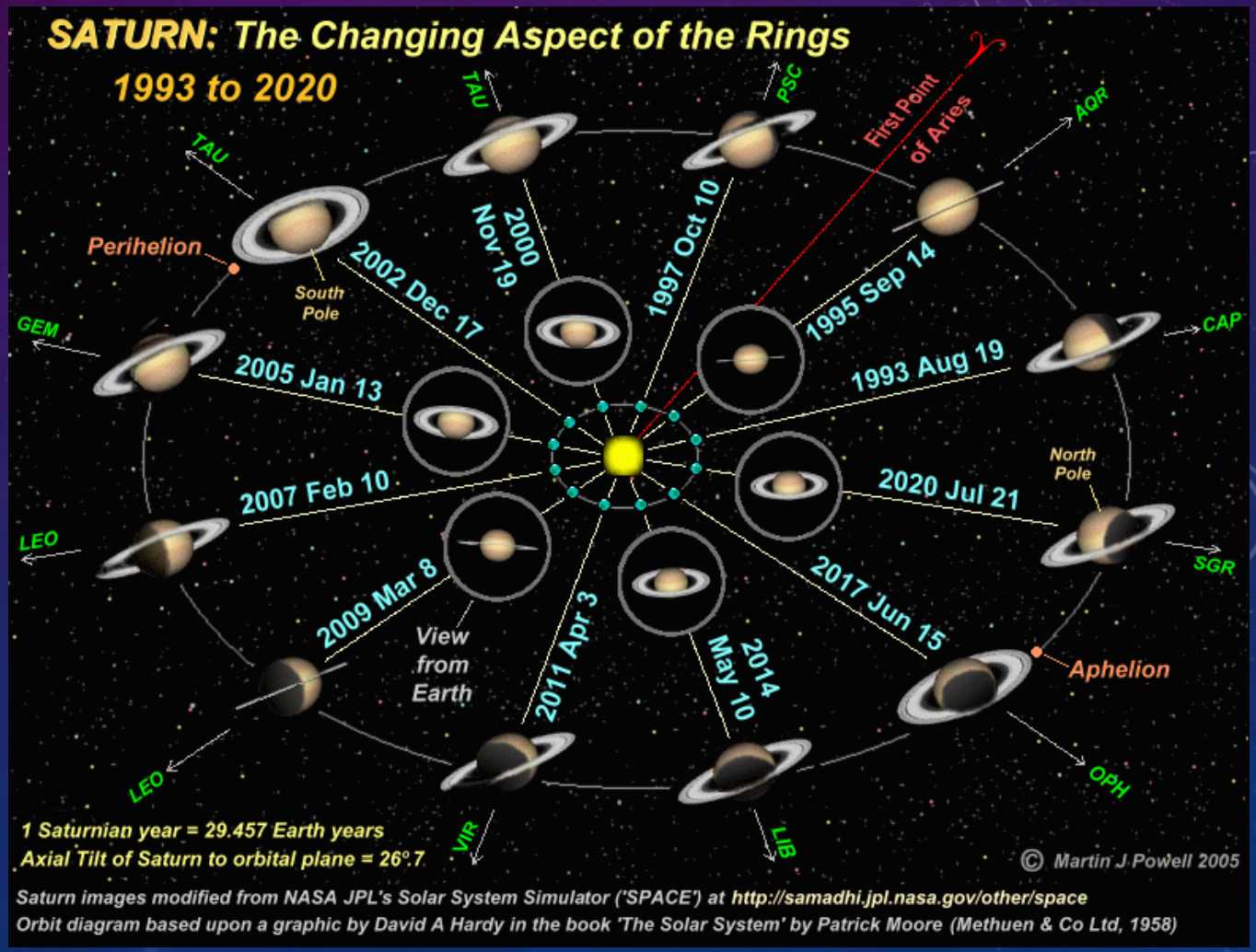
- Longer cycles are harder for people to notice because they can take multiple human lifetimes to pin down
- This is where writing becomes very important so multiple people can observe the same object over hundreds of years.





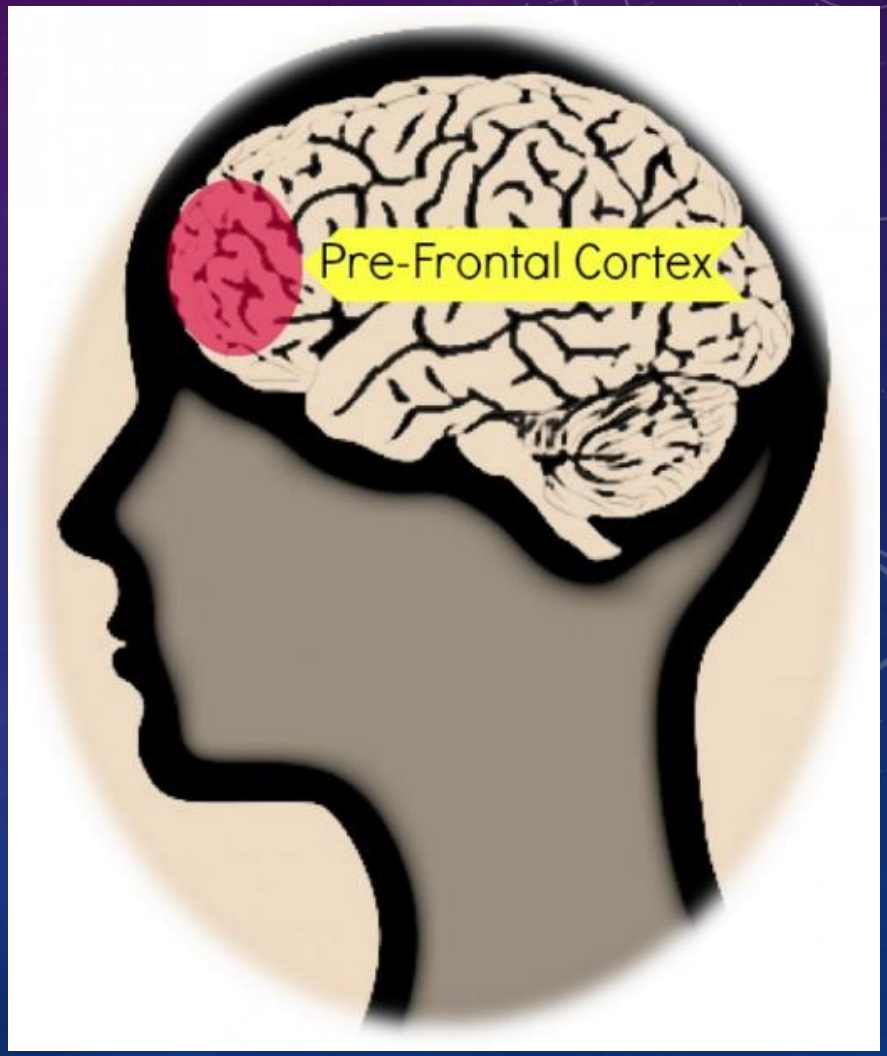
The Return of Saturn

It takes Saturn about 29.5 years to complete one orbit

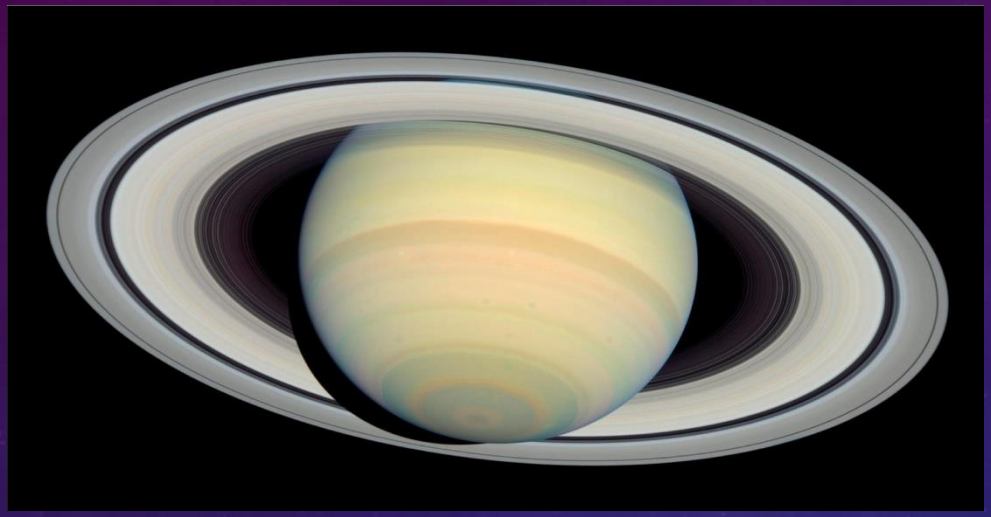


The Return of Saturn

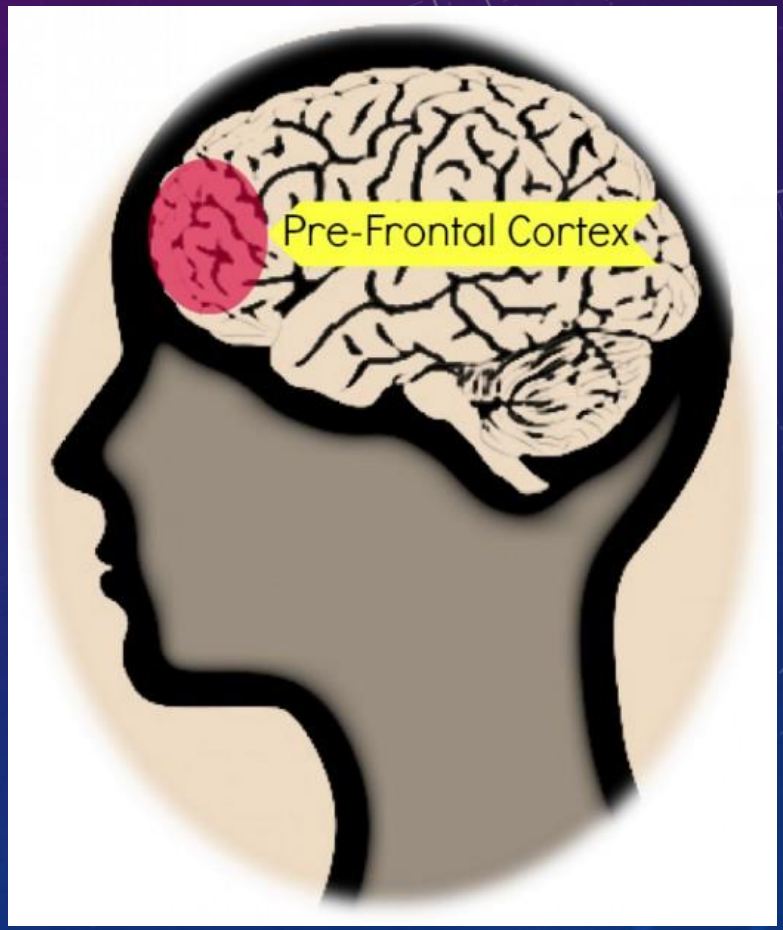
- It takes about 25 years (or longer) for the prefontal cortex of the human brain to fully mature
- The prefontal cortex is responsible for decision making, planning, and social behavior, as well as some personality traits (including depression)



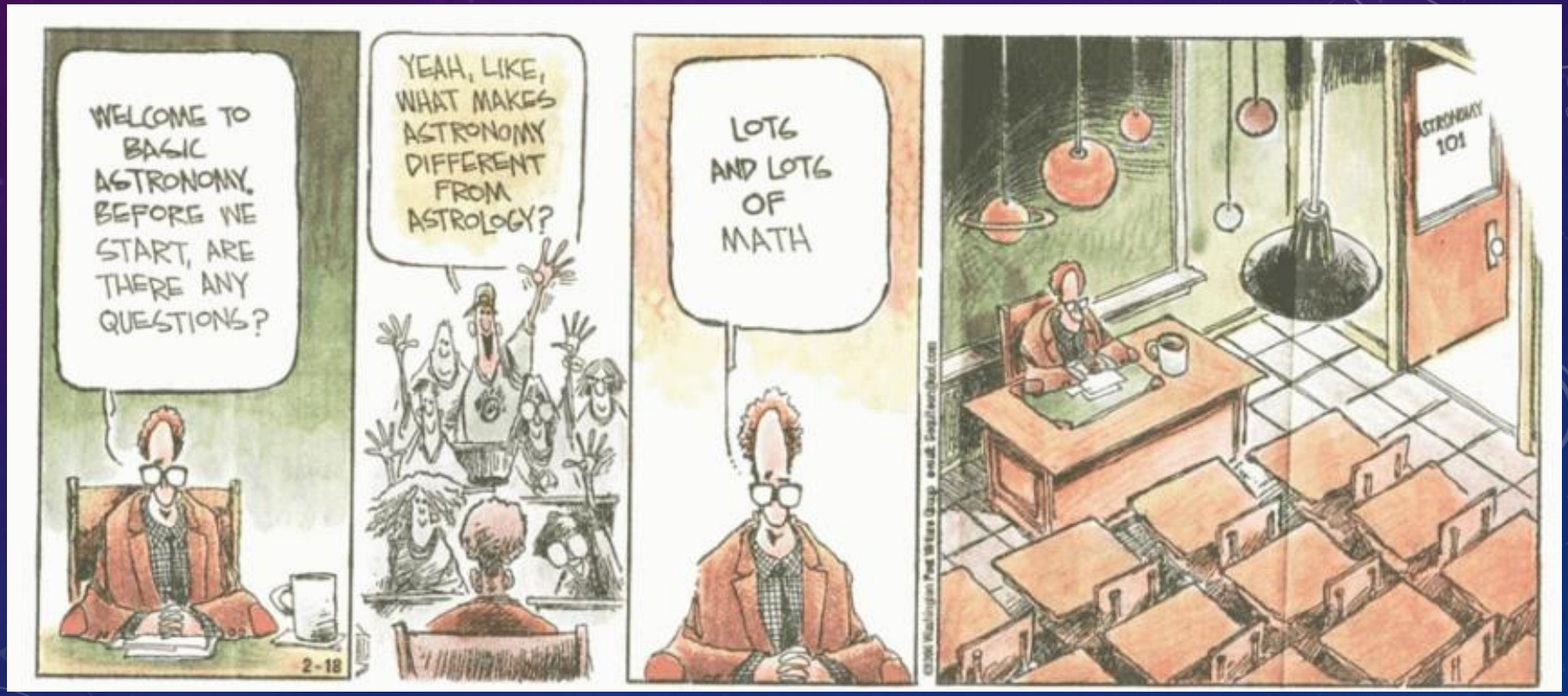
The Return of Saturn



- So, by the time Saturn returns to the same position in the sky as the day you were born, you've been making better decisions for a few years and your life has probably undergone some serious changes
- Early sky watchers thought these two events were connected, but it's just a coincidence

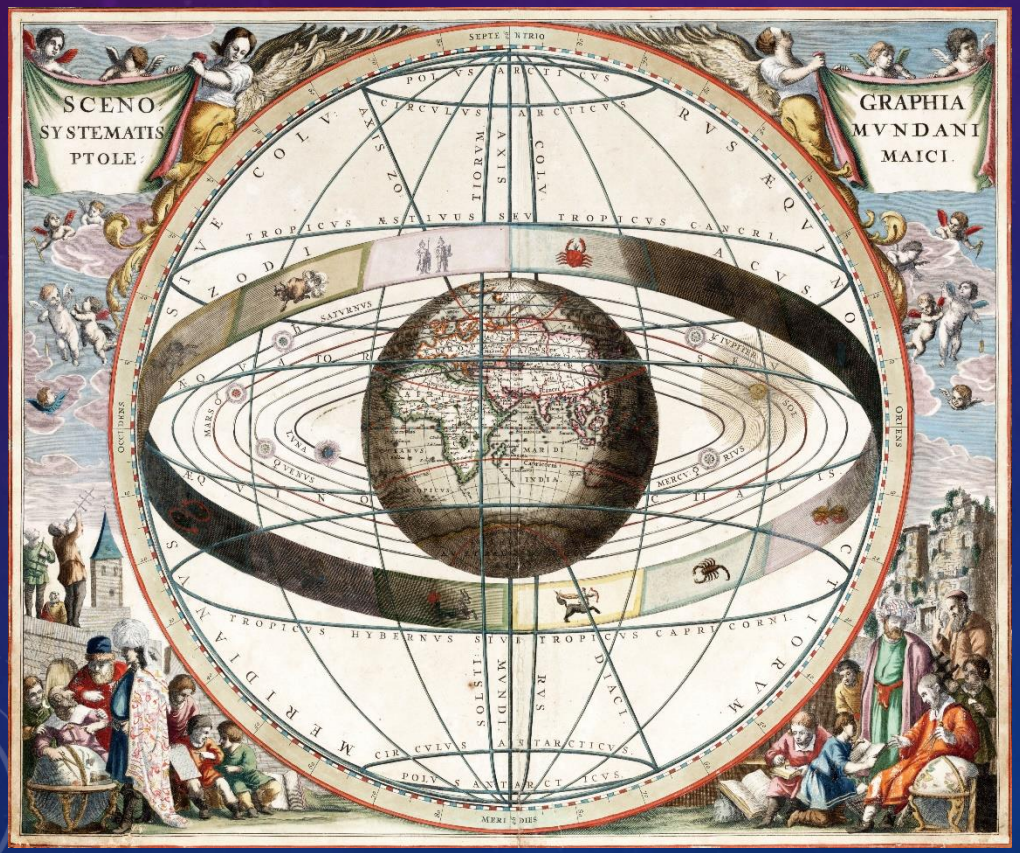


Astronomy vs Astrology



Cycles, Patterns, and Time

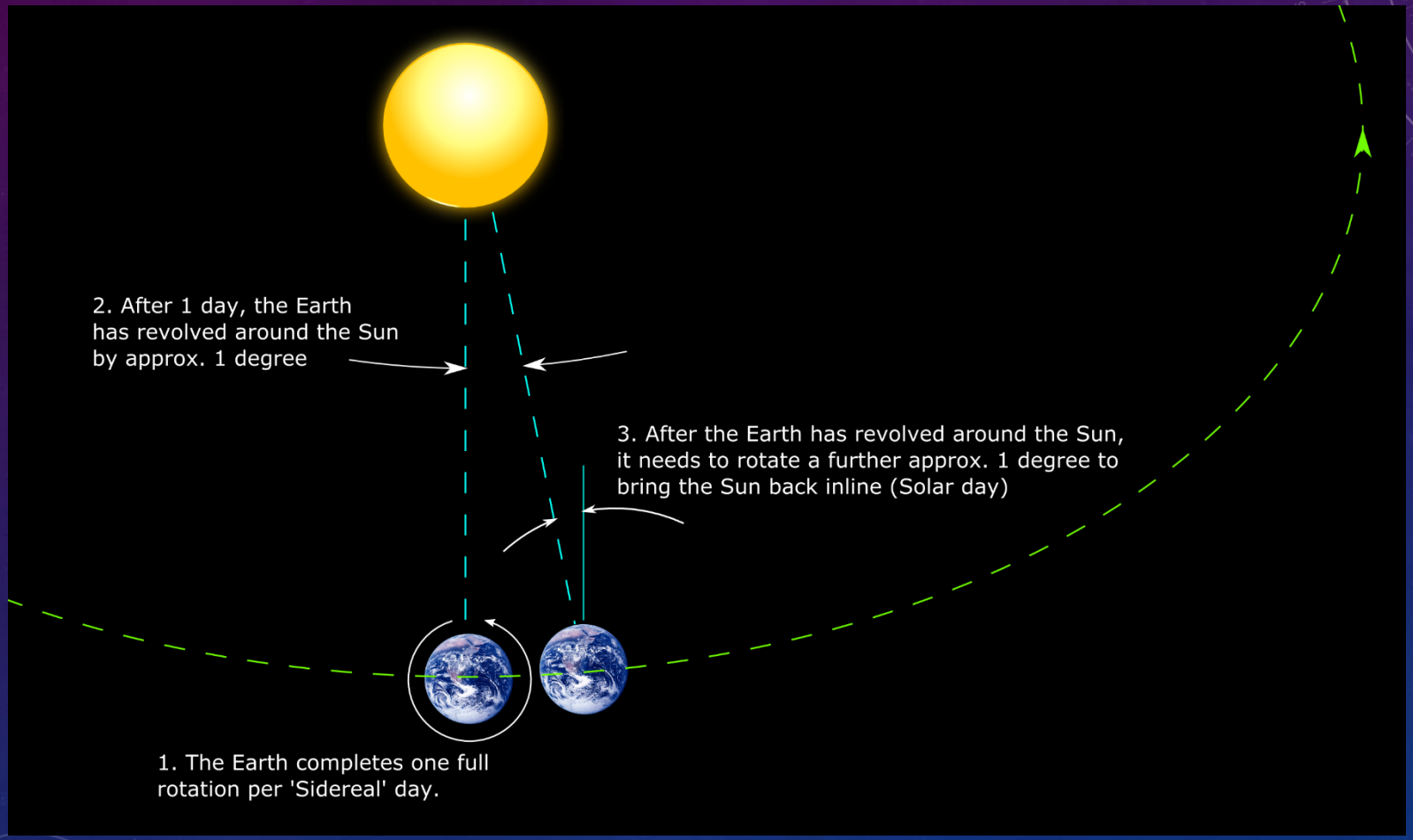
- Astronomy basically began as a way to keep track of time
- It's still a major role of astronomy today



The mission for the United States Naval Observatory:

- Determine the positions and motions of celestial bodies, motions of the Earth, and precise time.
- Provide astronomical and timing data required by the Navy and other components of the Department of Defense for navigation, precise positioning, and command, control, and communications.
- Make these data available to other government agencies and to the general public.
- Conduct relevant research, and perform such other functions as may be directed by higher authority.

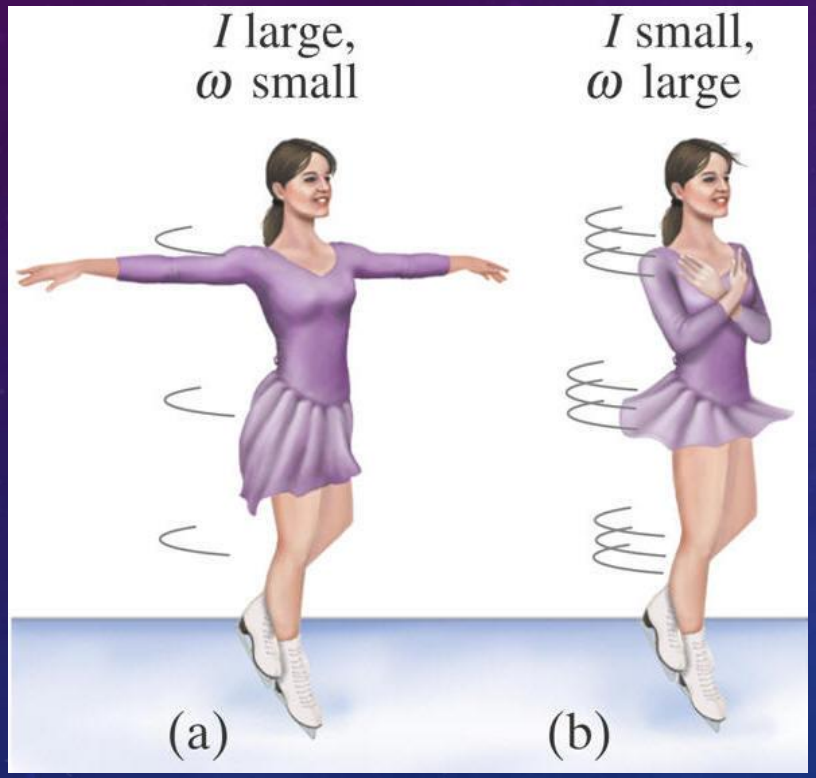
What Time Is It?: Two Kinds of Days



Sidereal Day: 23 hours 56 minutes and 4 seconds

Solar Day: 24 hours (exactly)

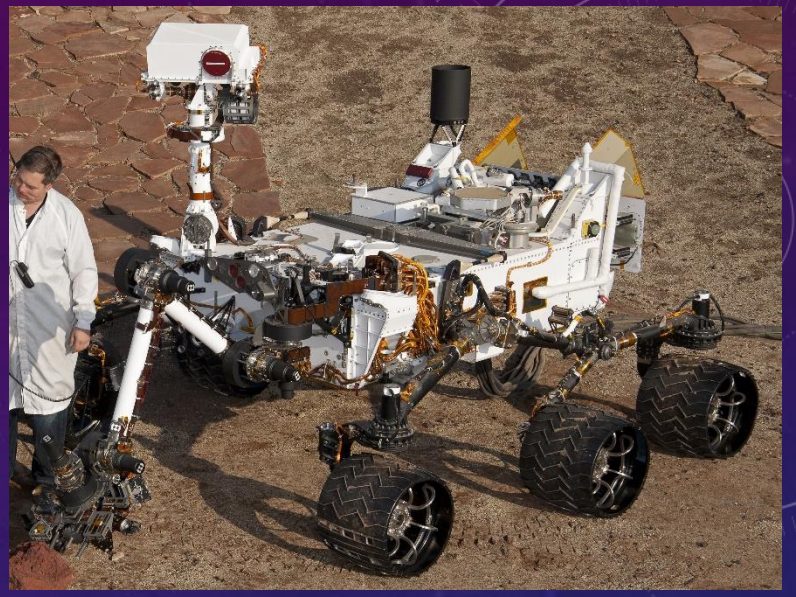
Angular Momentum and Time



- An earthquake in Chile in 2010 shifted enough mass to shorten the day by 0.00000126 seconds.

Astrophysics in your pocket

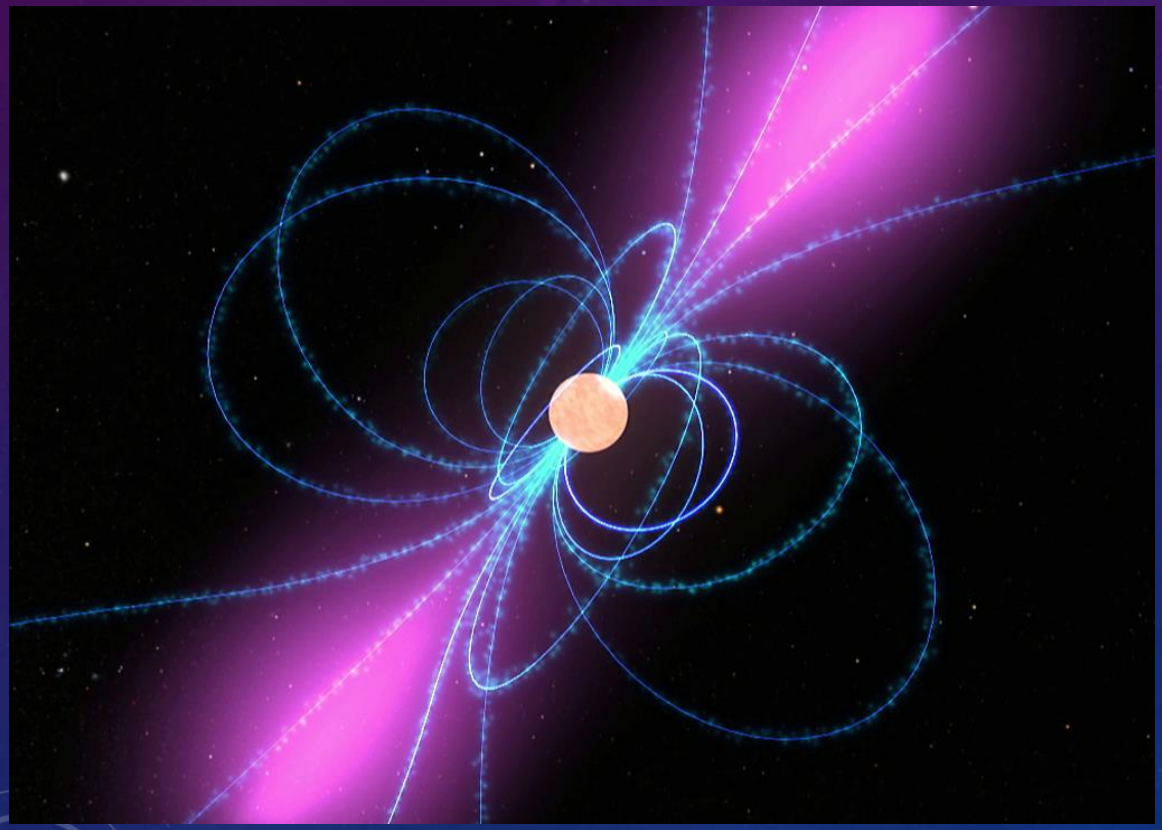
- Astrophysical research has led to many technological developments
- One of them is probably in your pocket right now



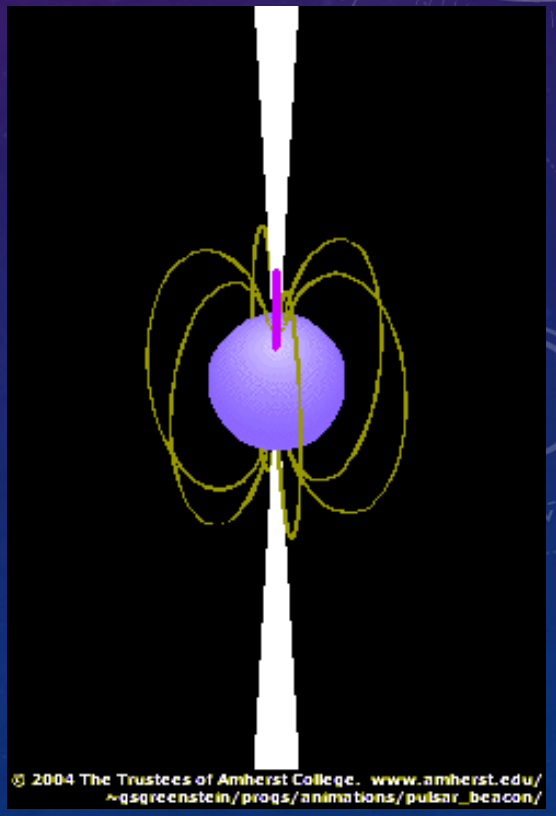

What is a pulsar and what does it have to do with your cellphone?

Pulsar

- Neutron star: the remnant of a star at least 8 times more massive than the sun.
- Magnetic field axis and rotation axis are offset
- Spins very fast



NASA



Crab Pulsar

- X-ray image of the pulsar in the Crab Nebula

NASA/CXC/ASU/J. Hester et al.

So what does that have to do with me?

- Because pulsars spin so fast, you need extremely accurate clocks to study them

What else requires accurate timing?

What else requires accurate timing?

What else requires accurate timing?

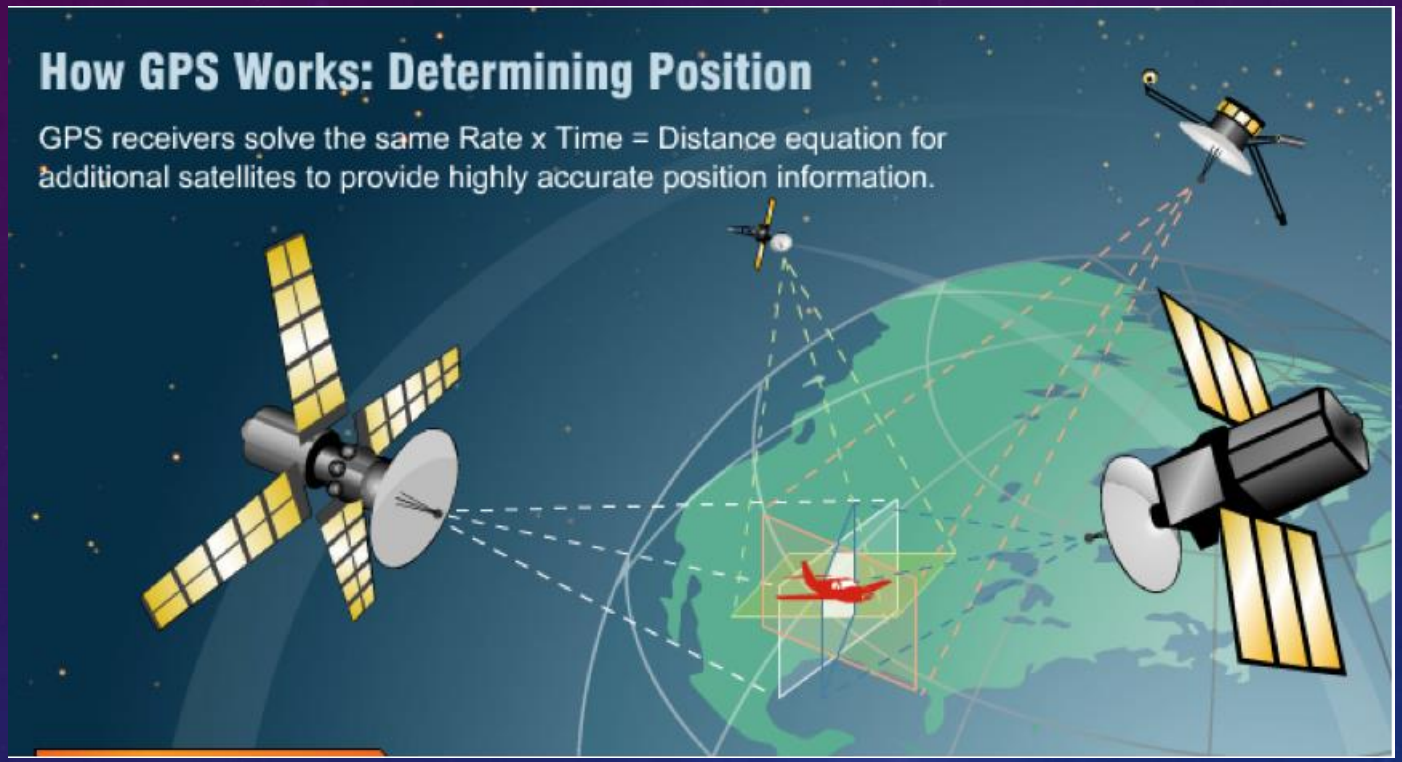
Well, yes. But not that kind of timing…

GO GREEN!

GPS – Global Positioning System

- GPS works entirely by keeping track of the difference between when a signal is sent and when it is received.

GPS – Global Positioning System



From avionicswest.com

- Relies on the fact that the speed of light is (pretty much) always the same

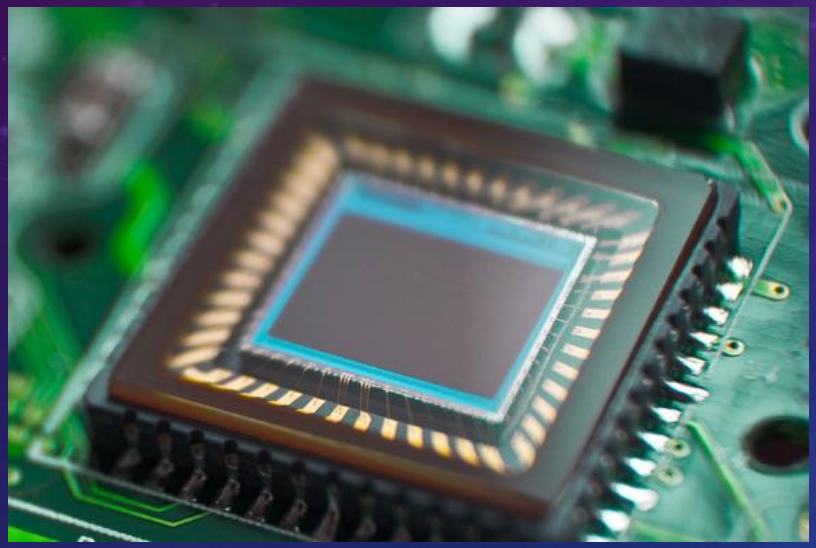
GPS – Global Positioning System

- GPS satellites also need to know exactly where they are compared to the Earth
- To do this, they use observations of objects like quasars that are billions of light years away.
- The positions of these quasars must be known to high precision, which require radio telescopes and interferometers.

Do You Post Selfies? Thank an Astronomer

- Another piece of astronomy tech in your pocket – the CCD on your phone's camera

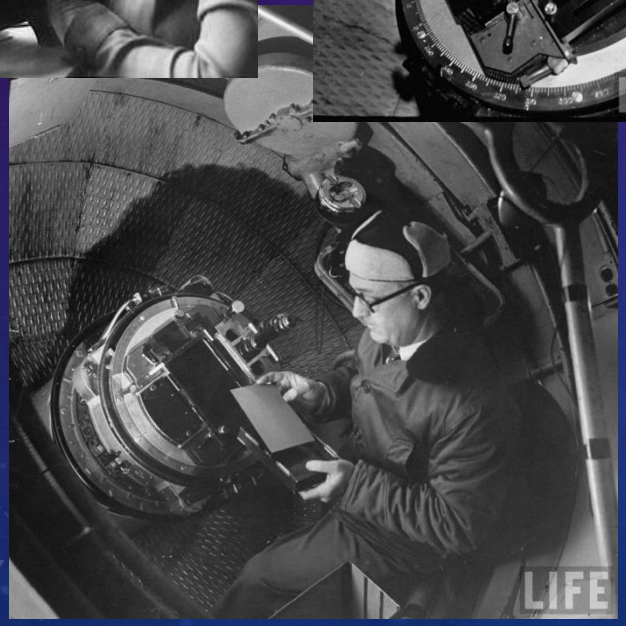
CCD – CHARGED COUPLED DEVICE



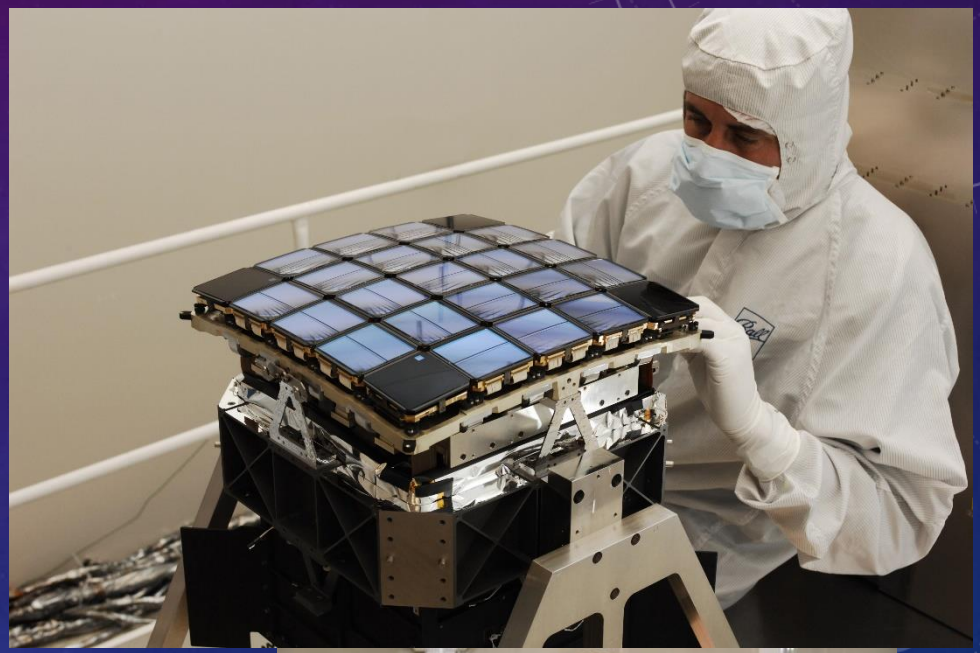
- Behind the lens on your camera is a CCD (or sometimes a CMOS, but basically the same thing)
- CCDs were first developed to replace photographic plates on astronomical telescopes

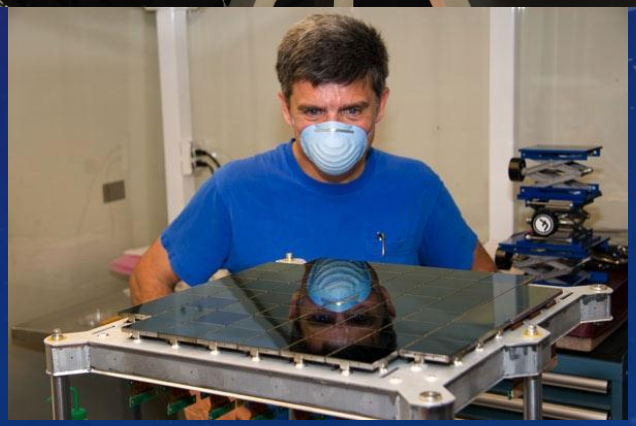
Plates & Chips

Old School

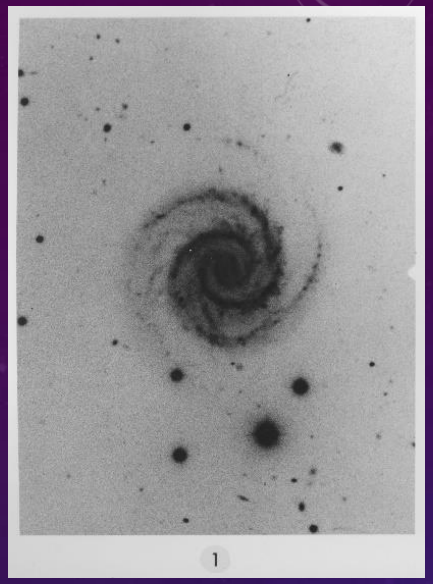


Modern





Why CCDs?



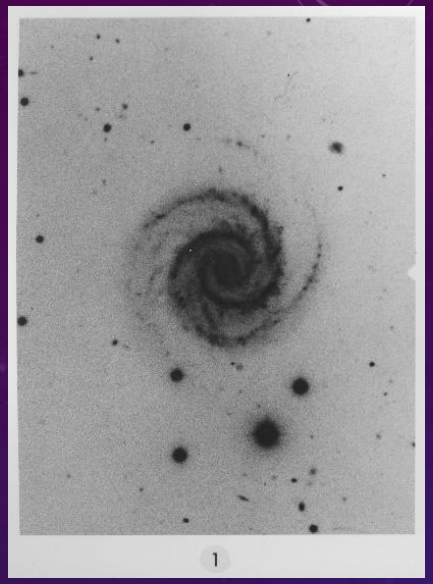
Spiral Galaxy NGC 2857

Palomar plate

Photographic Plates

- Long exposures needed
- Non-linear scale
- Easily broken
- Degrade over time
- Expensive (especially if you make a mistake and the whole plate is ruined)
- Had to analyze by eye
- Black and white only

Why CCDs?



Palomar plate

Spiral Galaxy NGC 2857

SDSS image

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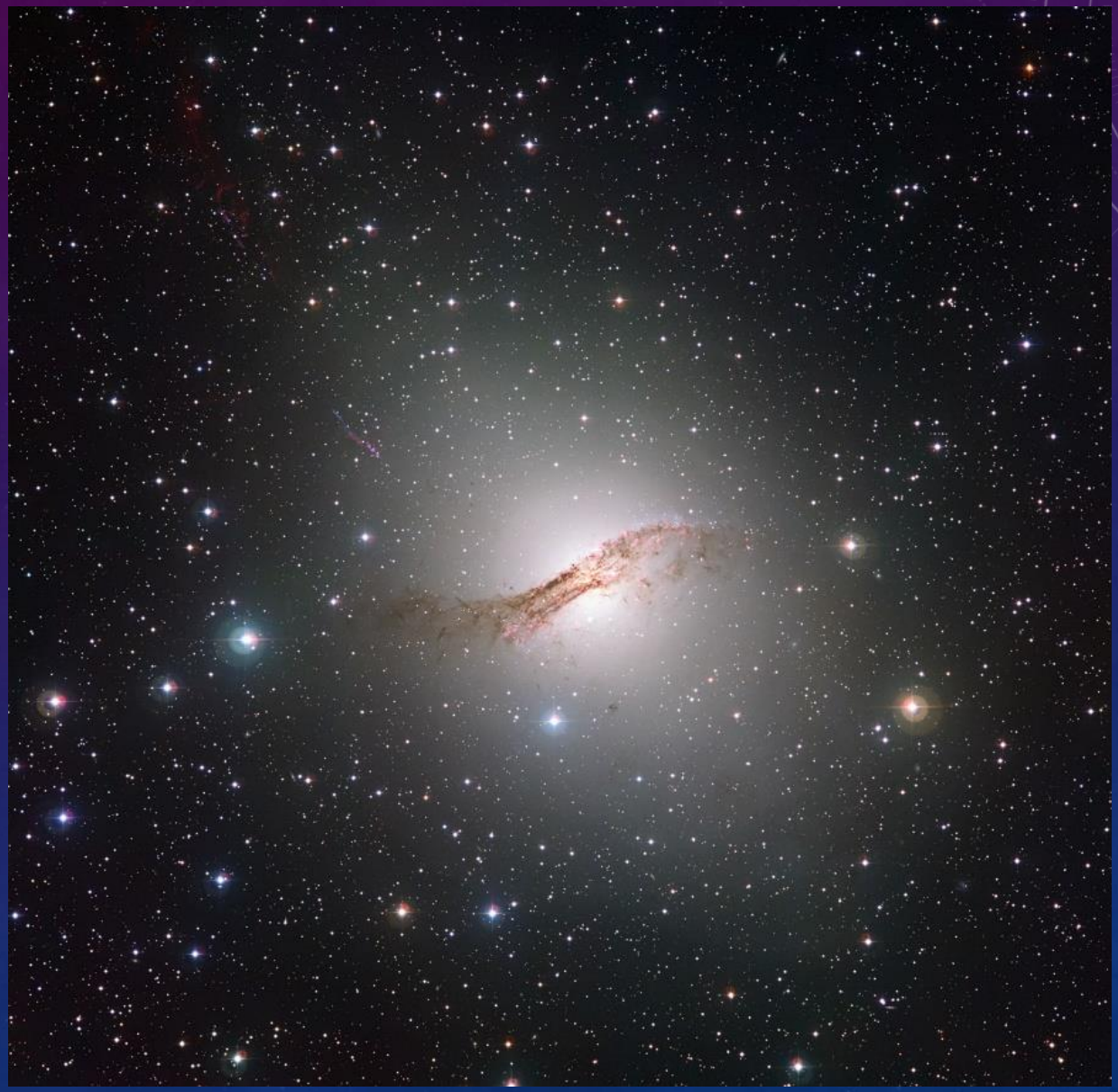
CCDs

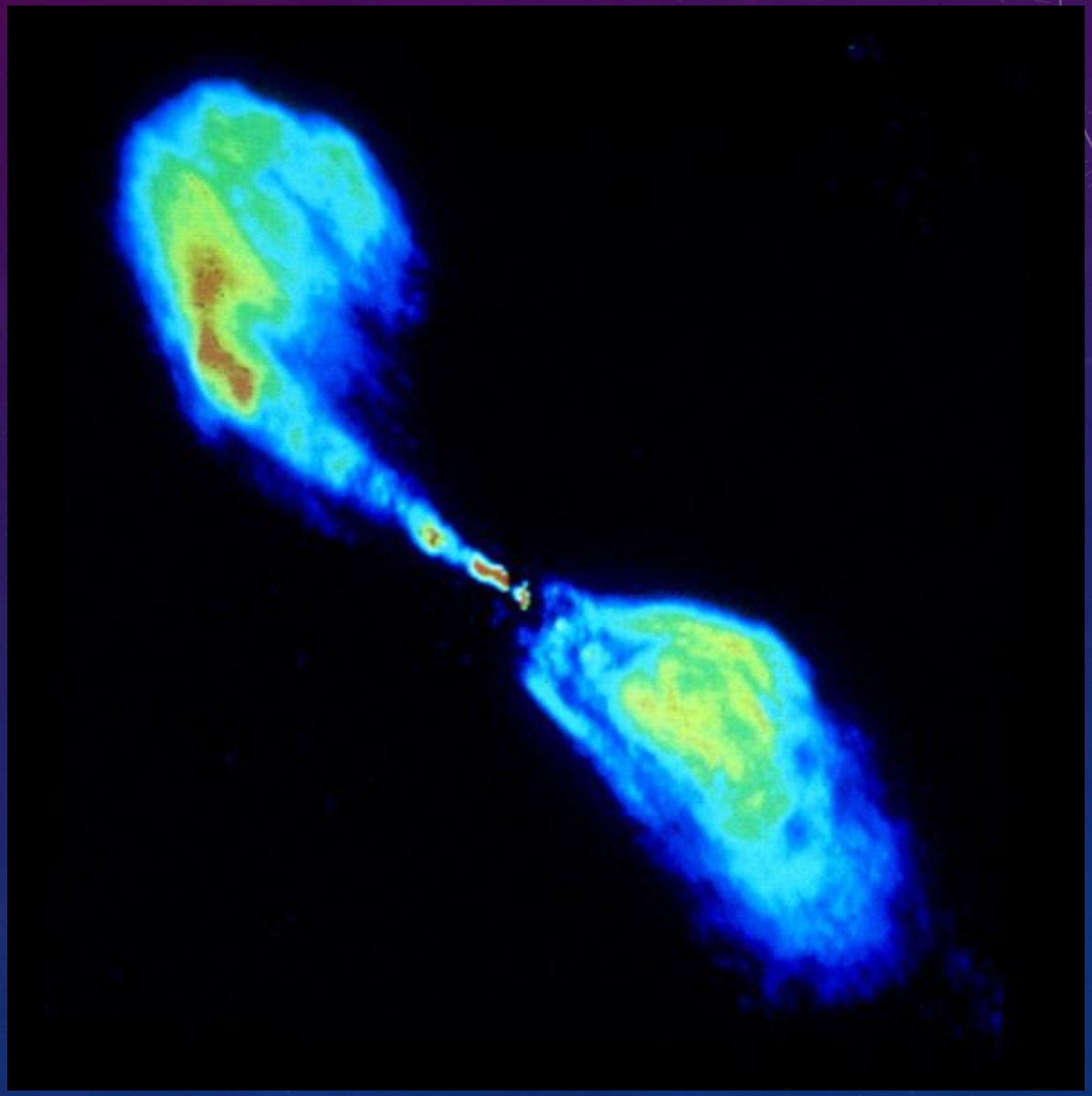
- Can use shorter exposures
- Linear scale
- Data does not degrade
- Can analyze on a computer
- Can easily make color pictures
- Can combine images from multiple telescopes into a single image

Centaurus A: The Best Galaxy Ever!

MPG/ESO 2.2 m telescope in Chile

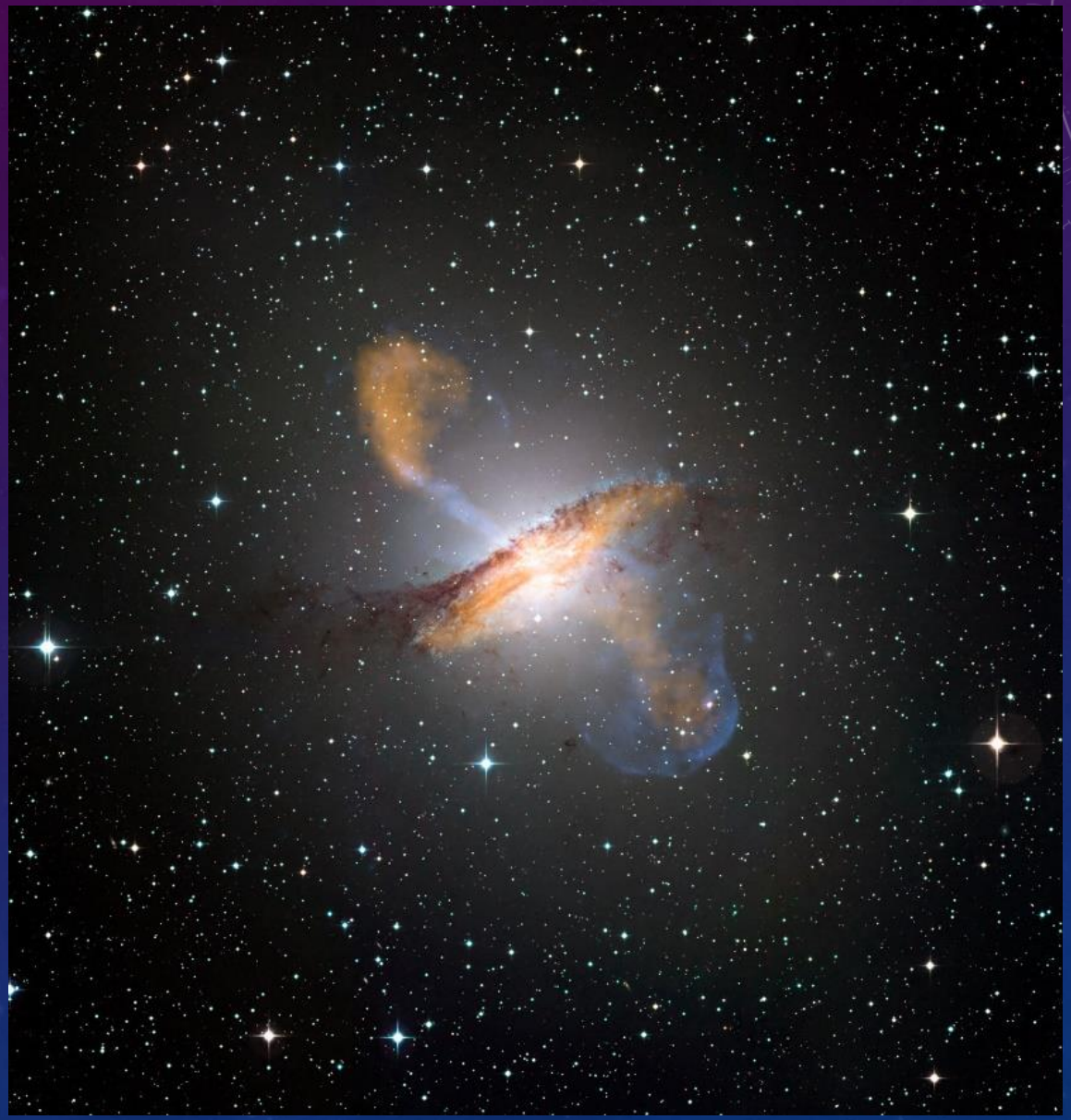


Centaurus A: The Best Galaxy Ever!



VLA 6 cm
Burns & Price
1983

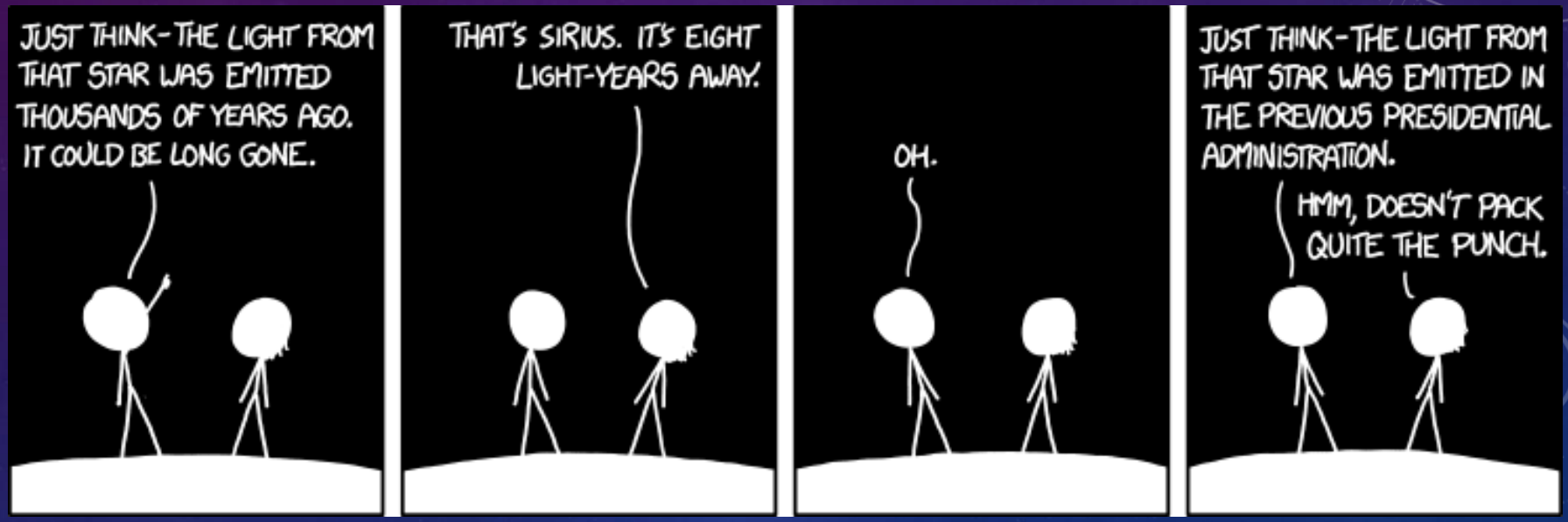
Centaurus A: The Best Galaxy Ever!



X-ray (blue), optical (white), and radio (orange)

Credit: X-ray: NASA/CXC/Cfa/R. Kraft et al.: sub-millimeter: MPIfR/ESO/APEX/A.Weiss et al. Optical: ESO/WFI

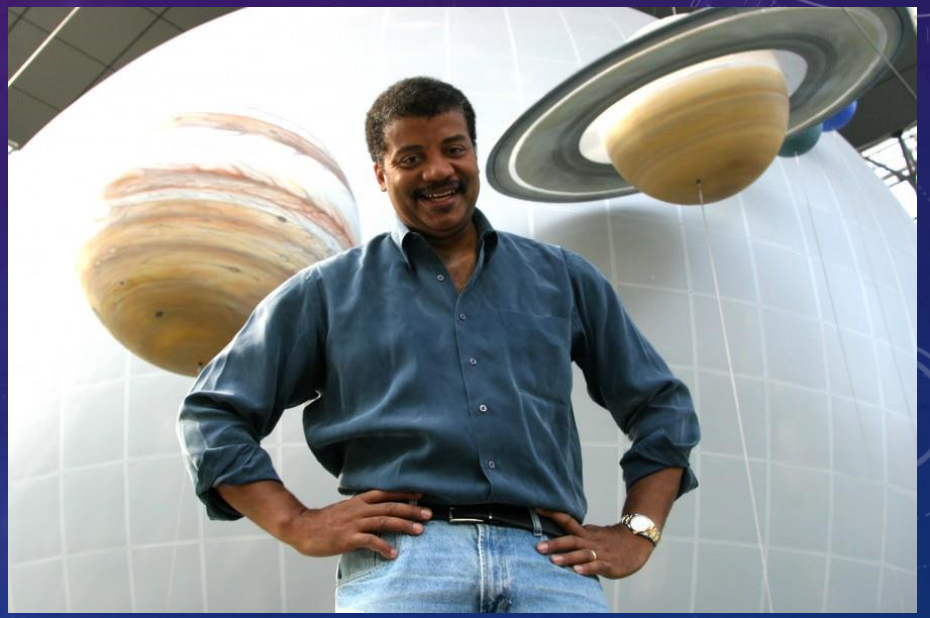
Intermezzo



XKCD

Medical Technology

Doctor



Not that kind of doctor

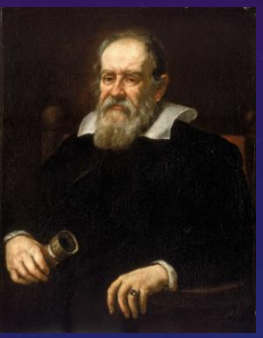
WARNING

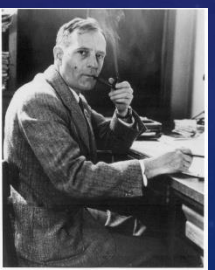
THERE IS AN EQUATION ON THE NEXT SLIDE

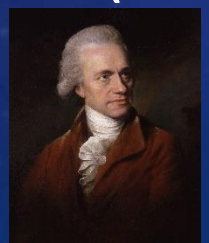
BUT ONLY ONE, AND IT'S REALLY SIMPLE

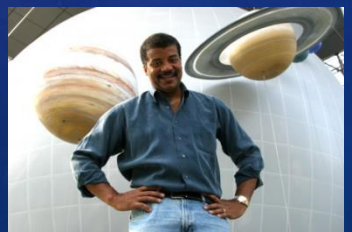
WHAT EVERY ASTRONOMER WANTS

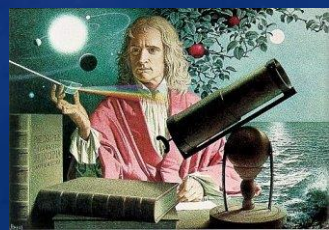
- Astronomy: the continuing quest for more photons and better resolution
  - Sensitivity is proportional to the collecting area of your telescope
    - Bigger telescope means more sensitivity
  - Angular resolution = observed wavelength ÷ telescope diameter (Equation: $\theta=\lambda/D$)
    - Bigger telescope means better resolution
- So, bigger telescopes give you everything you ask for (kind of)





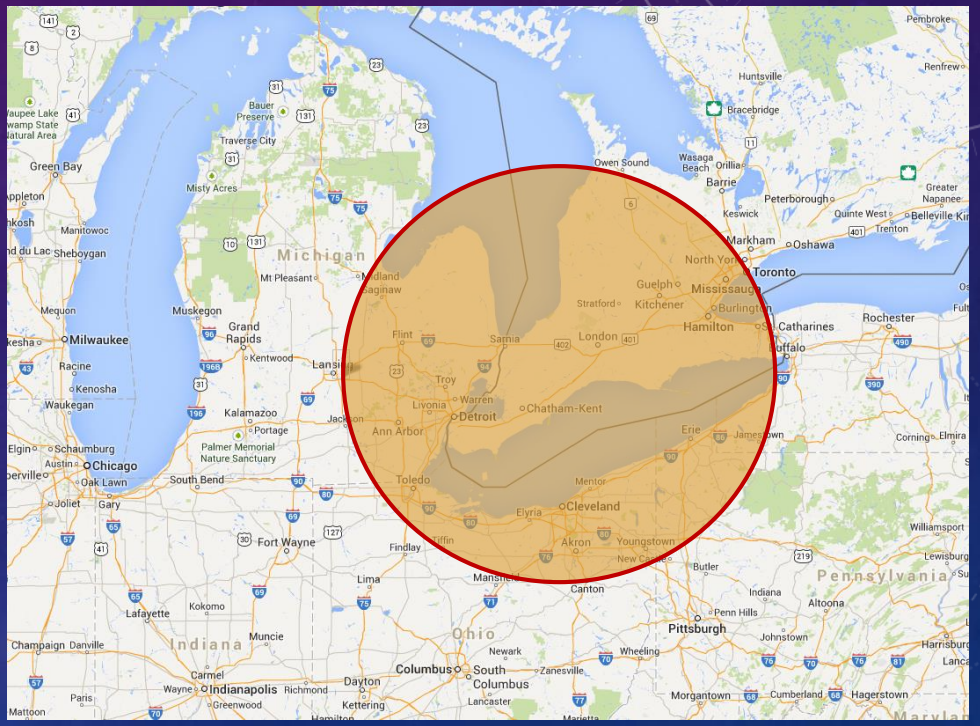






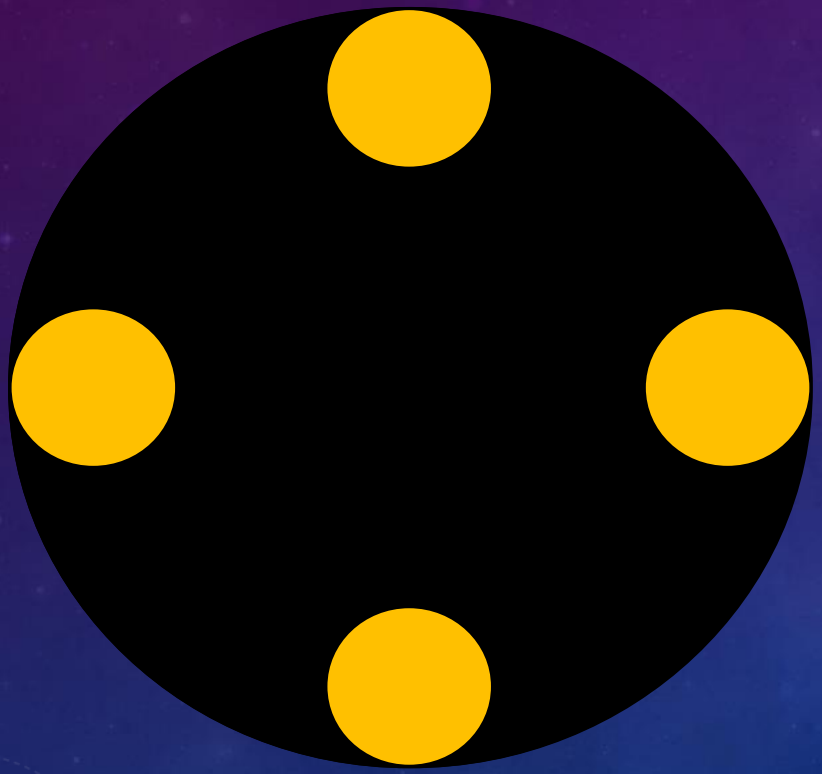
RADIO RESOLUTION

- Because radio waves have such a long wavelength, you need REALLY big telescopes to get good resolution
- At a wavelength of 21 cm, to get resolution similar to an optical telescope, we would have to build a telescope 269 miles in diameter
  - A little less than the distance from East Lansing, MI, to Buffalo, NY



Map from Google Maps

The Radio Resolution Solution*

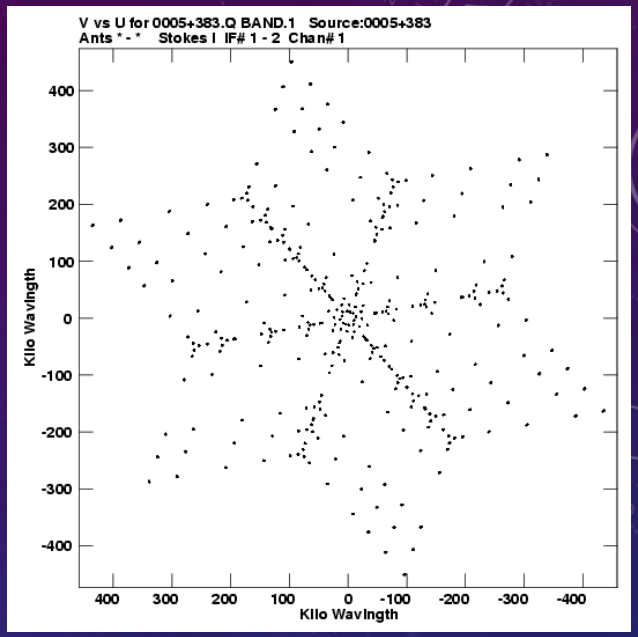


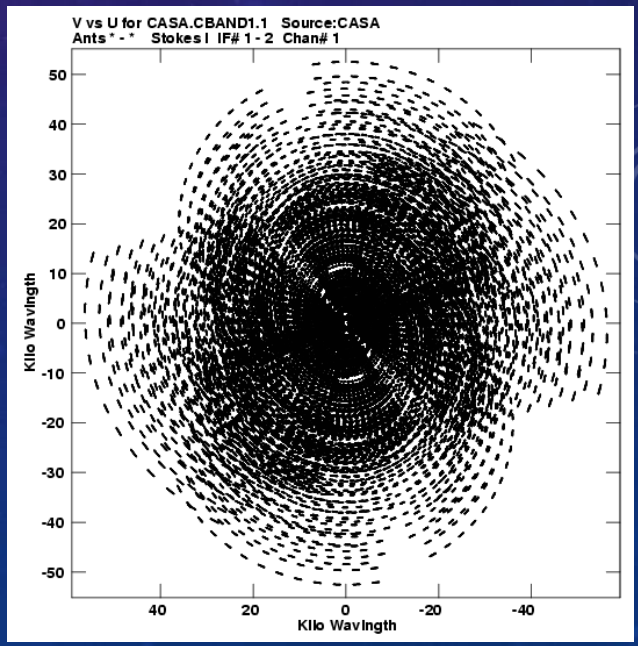
- In the 1940s, astronomer Martin Ryle solved the problem
- To get high resolution, you don't actually need the whole telescope.
- You just need pieces of it that are far away from each other…

*sorry, I couldn't help myself…

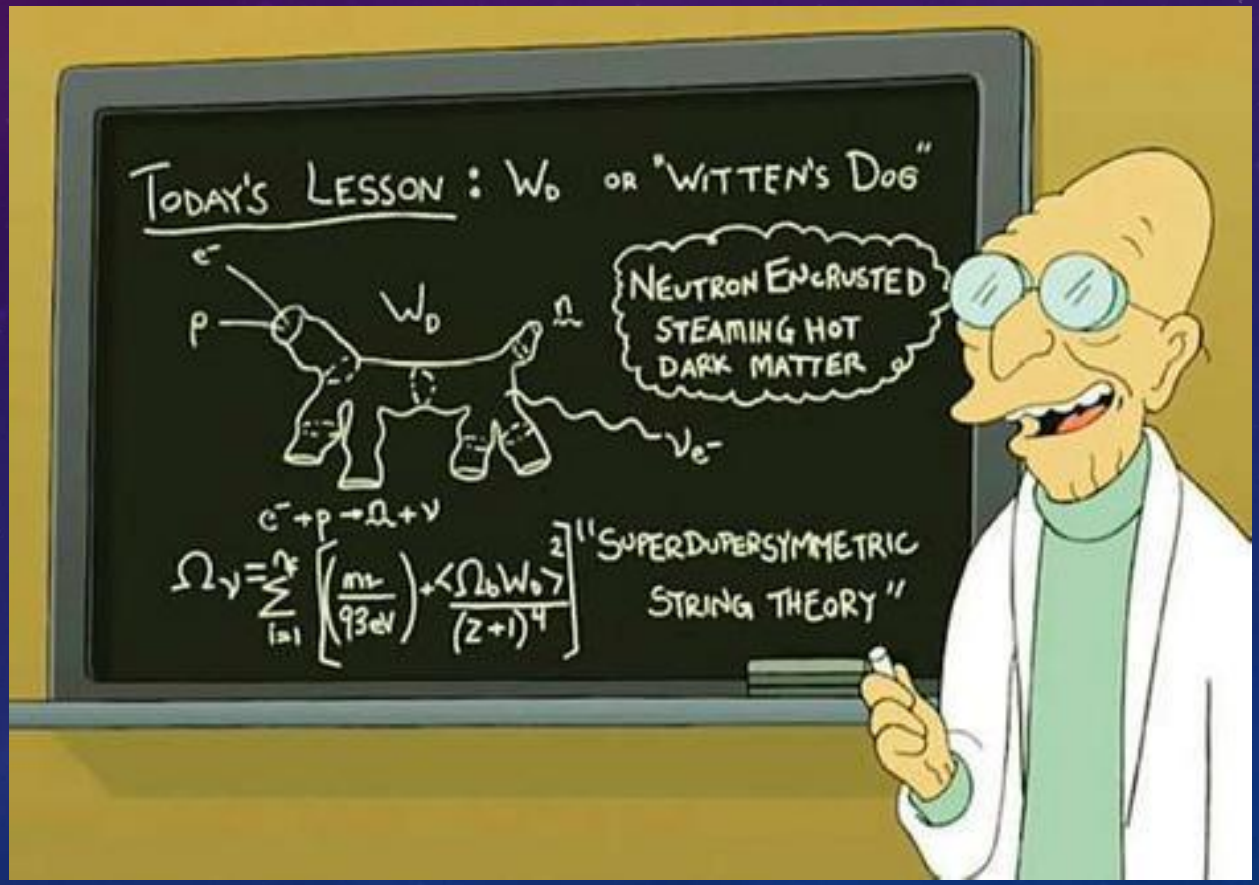
Aperture Synthesis

- Also called “interferometry”
- You have to use computers to create a synthetic telescope



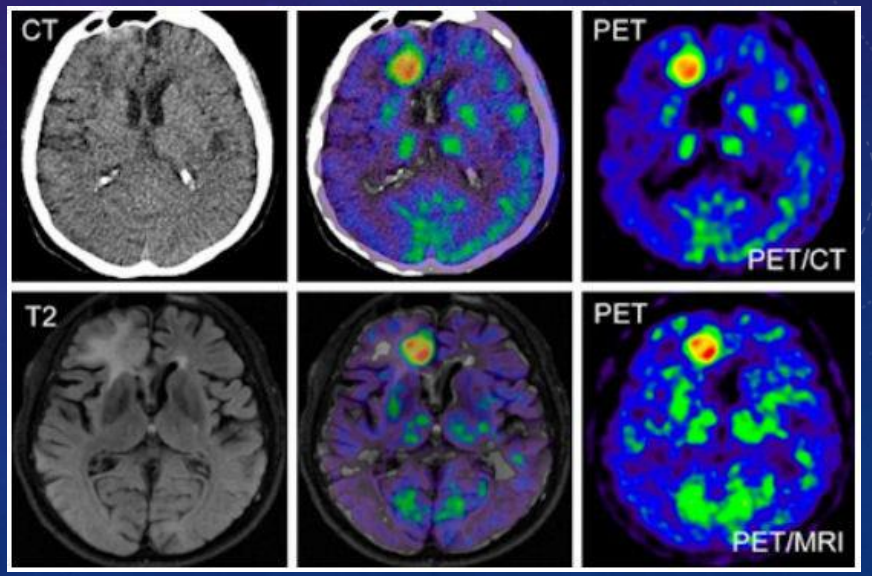


Okay, That's Neat. So What Does That Have To Do With Medical Technology?



Medical Imaging

- MRI, CT, and PET scanners use the same techniques as radio aperture synthesis



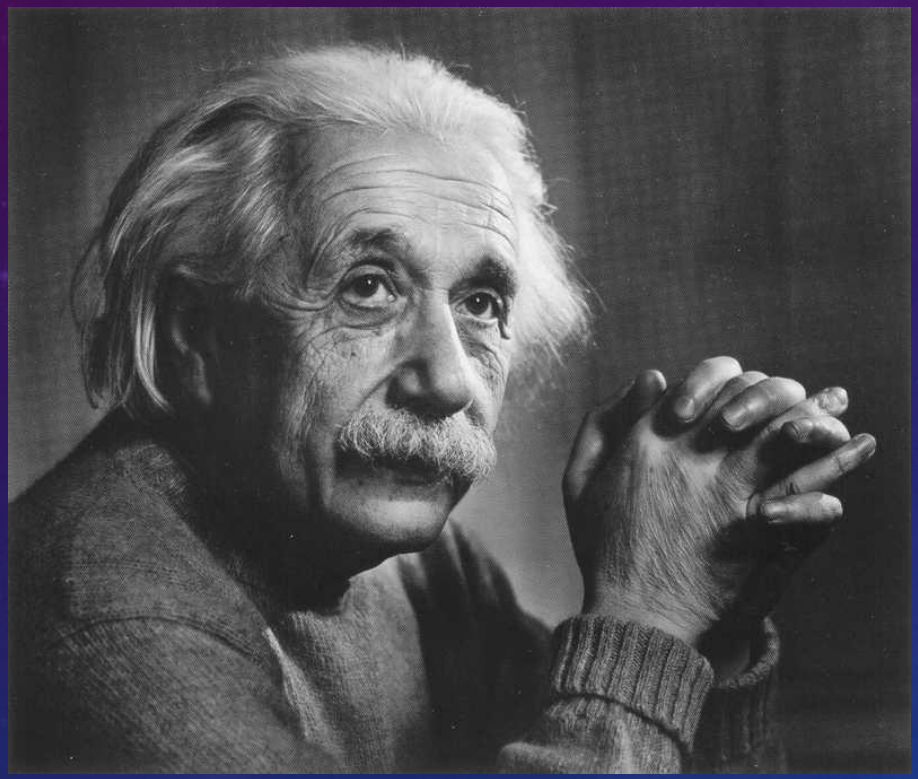
Clean Rooms and Hospitals

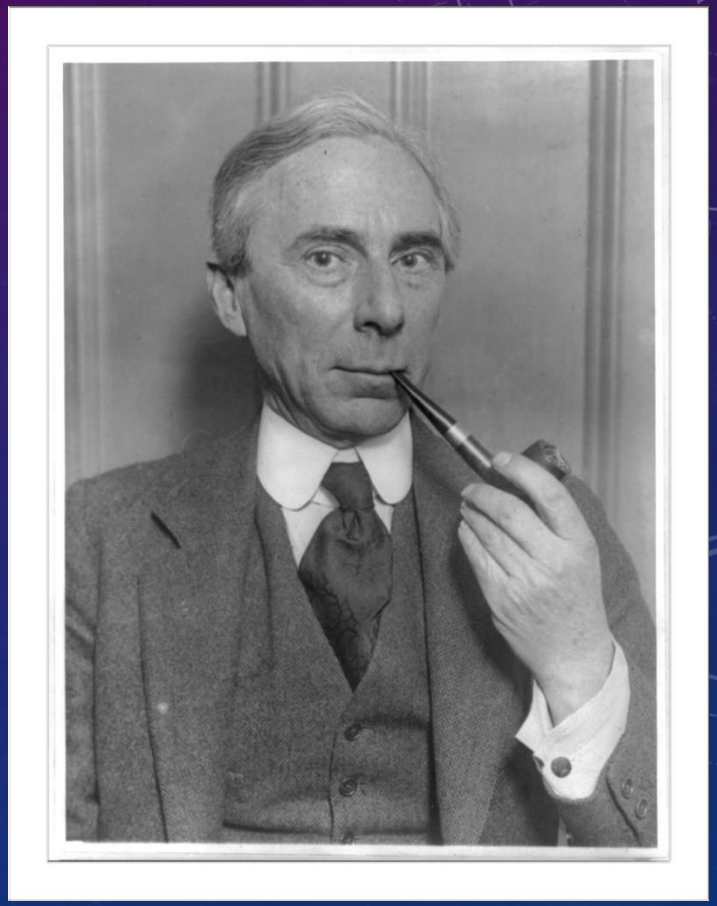
- The technology developed by NASA for assembling satellite components prior to launch led directly to the sterile environment suits, air filters, and protocols used in hospitals

NASA

Havelland Clinics

Scientific Diplomacy





In 1955, Albert Einstein and Bertrand Russell wrote an open letter to the scientific community urging them to set aside their personal politics and the politics of their countries and make a effort to talk to each other as a way to deter nuclear war

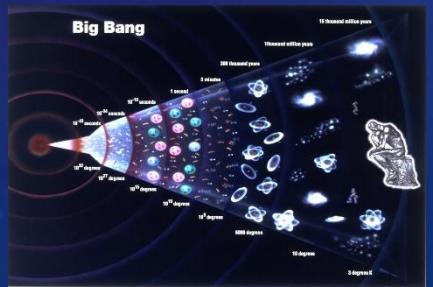
Scientific Diplomacy

- The Einstein & Russell manifesto led to the creation of the Pugwash Conferences on Scientific and World Affairs
- First held in 1957 in Pugwash, Nova Scotia, Canada
- Awarded the Nobel Peace Prize in 1995

The Everyday Impacts of Astronomy

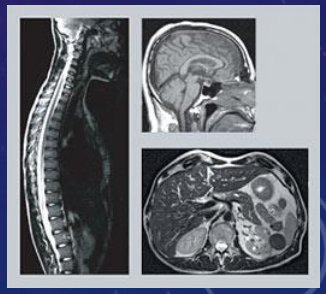
Direct

- You know exactly what time it is
- You know when winter is coming
- You know where you are in the universe
- Our understanding of the universe is constantly growing



Indirect

- Technology
  - GPS
  - Digital cameras
  - Medical scanners
  - Robotics
- International communication and good will
  - Even when countries are hostile to one another, astronomers still talk to each other



SOME WORDS OF WISDOM

- Don McCarthy, director of the Arizona Astronomy Camp

SOME WORDS OF WISDOM

- Don McCarthy, director of the Arizona Astronomy Camp

  "Those are all benefits of doing astronomy, but the only reason to do astronomy is because it's damn interesting."