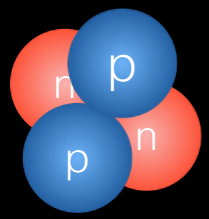
How Solar Eclipses Enable Scientific Discovery

Jim Brau
University of Oregon
August 21, 2017

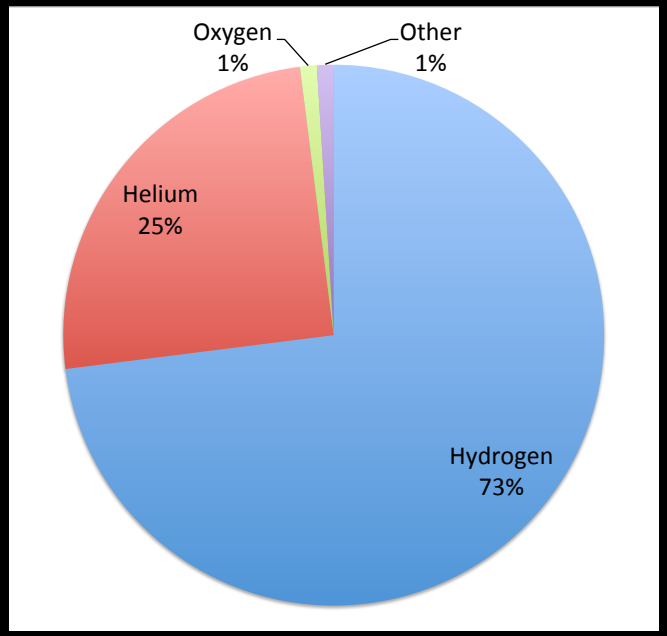
Photo from NASA

UNIVERSITY OF OREGON

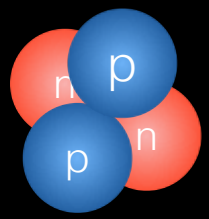


Discovery of Helium

- Second lightest and second most abundant element.
- Big bang created universe where atomic matter is dominated by hydrogen and helium.



Relative Abundance of Elements of Universe by Weight



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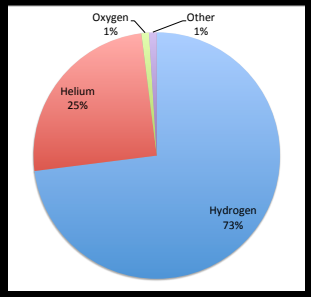

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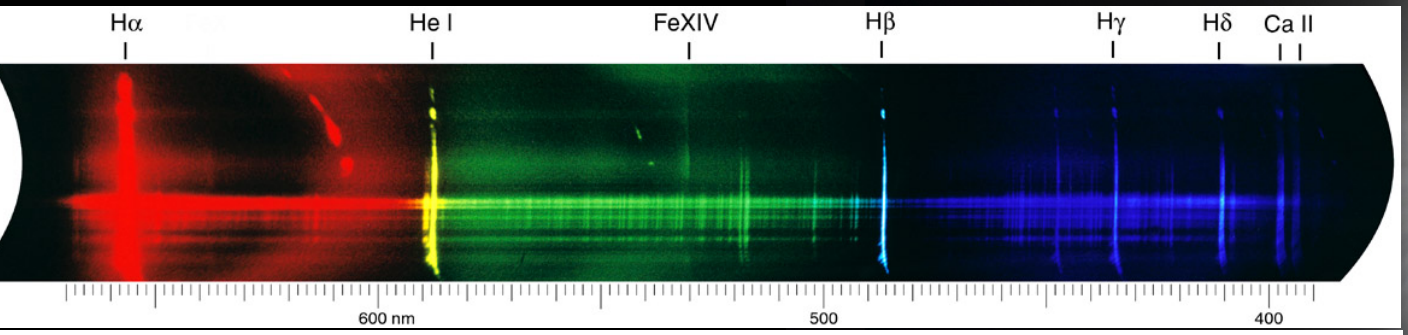
- French astronomer Jules Janssen discovered helium August 16, 1868, during total solar eclipse in India.



1999 Hungary eclipse, http://www.eurastro.de

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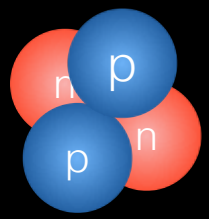

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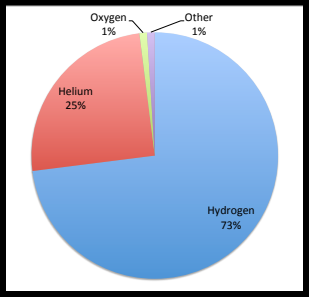
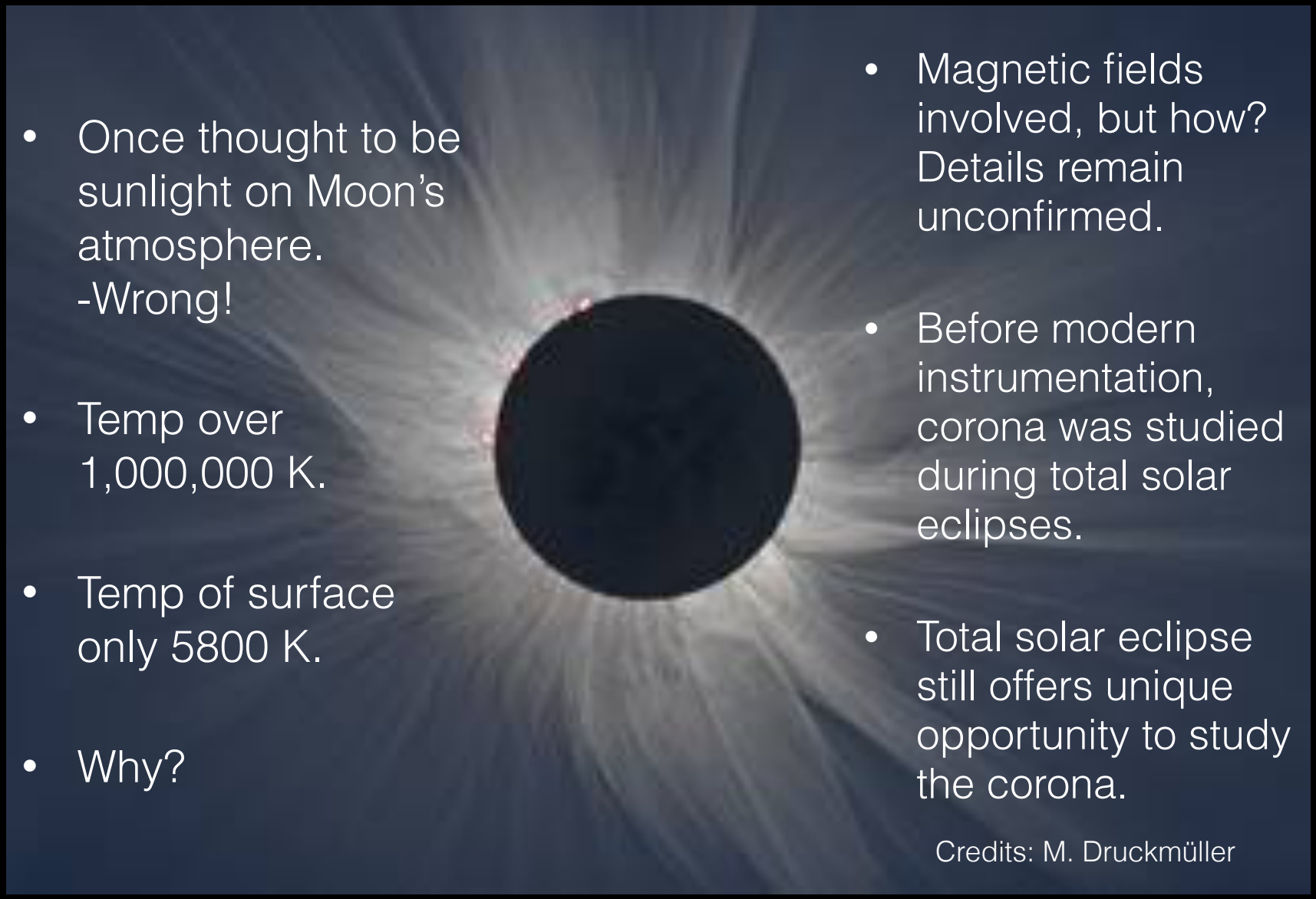


- Second lightest and second most abundant element.
- Big bang created universe where atomic matter is dominated by hydrogen and helium.
- French astronomer Jules Janssen discovered helium August 16, 1868, during total solar eclipse in India.
- Named after the Greek Sun god: Helios.
- Helium finally discovered on Earth 1895.

Studies of Solar Atmosphere or Corona

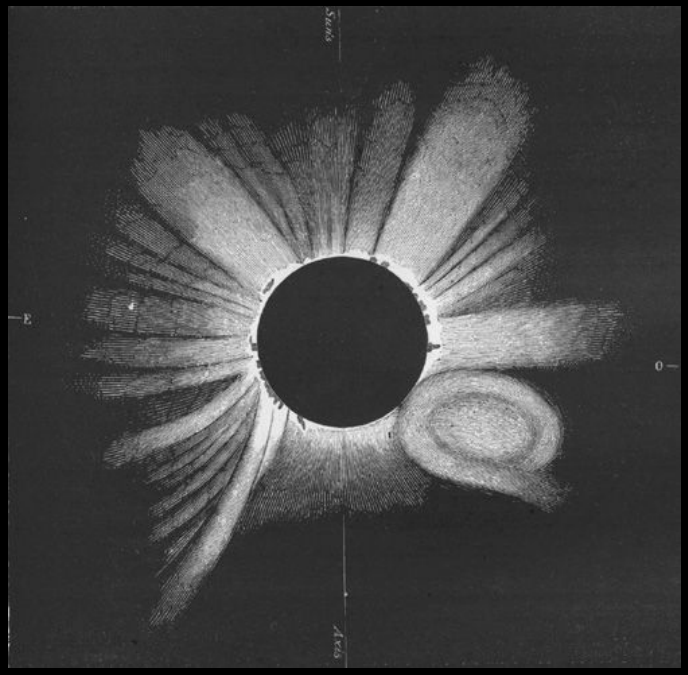


- Once thought to be sunlight on Moon's atmosphere. -Wrong!
- Temp over 1,000,000 K.
- Temp of surface only 5800 K.
- Why?
- Magnetic fields involved, but how? Details remain unconfirmed.
- Before modern instrumentation, corona was studied during total solar eclipses.
- Total solar eclipse still offers unique opportunity to study the corona.

Credits: M. Druckmüller

Space Weather

- The Sun's variable activity changes environment of Solar System including the Earth.
  - Solar Wind of charged particles from Sun.
  - Occasional large ejection of plasma mass (Coronal Mass Ejection).



July 18, 1860 eclipse, Gugliemo Temple drawing, during solar max.

from: eclipse2017.nasa.gov

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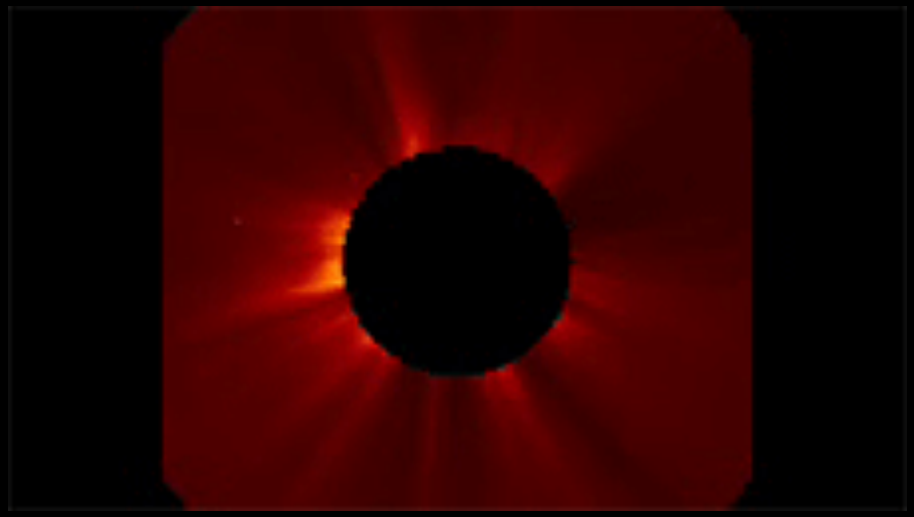


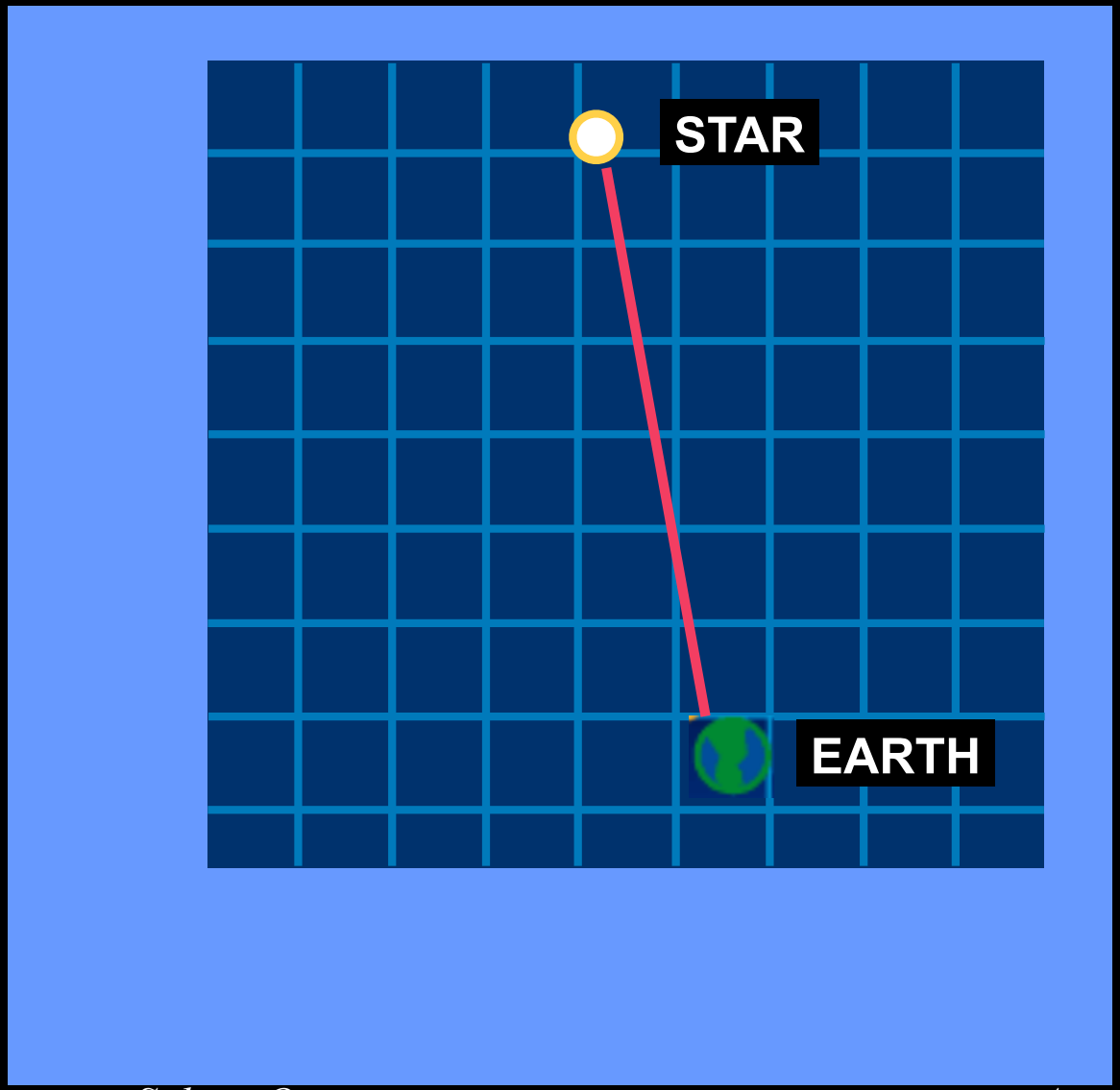
March 5, 2013, CME as seen by the Solar and Heliospheric Observatory. Such imagery combined with state-of-the-art models helps scientists better understand how CMEs move toward, and affect, Earth.

Credits: ESA/NASA/SOHO/Jhelioviewer

Space Weather

- The Sun's variable activity changes environment of Solar System including the Earth.
  - Solar Wind of charged particles from Sun.
  - Occasional large ejection of plasma mass (Coronal Mass Ejection).
- Impacts:
  - Satellite and ground communication.
  - Aircraft navigation systems.
  - Power grids.
  - Threaten lives of astronauts.
- NASA monitors solar activity to respond to these threats - will be learning more about processes during eclipse.

Test General Relativity



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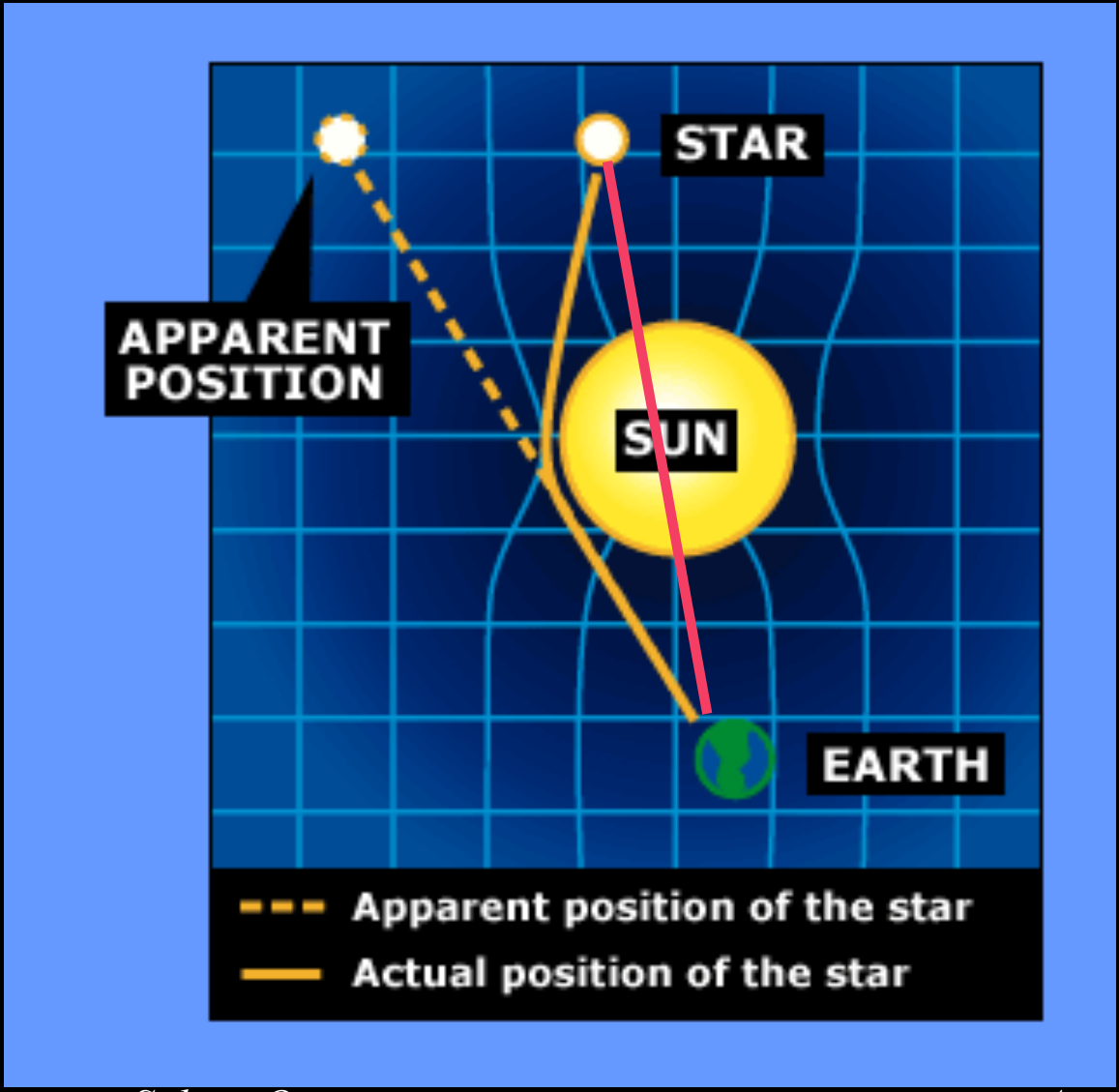

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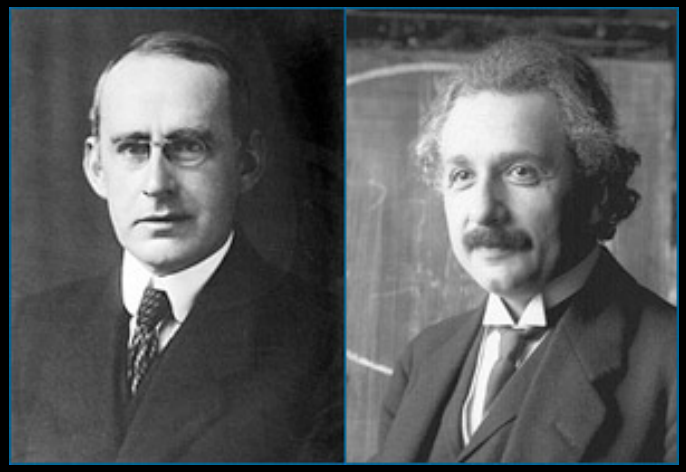
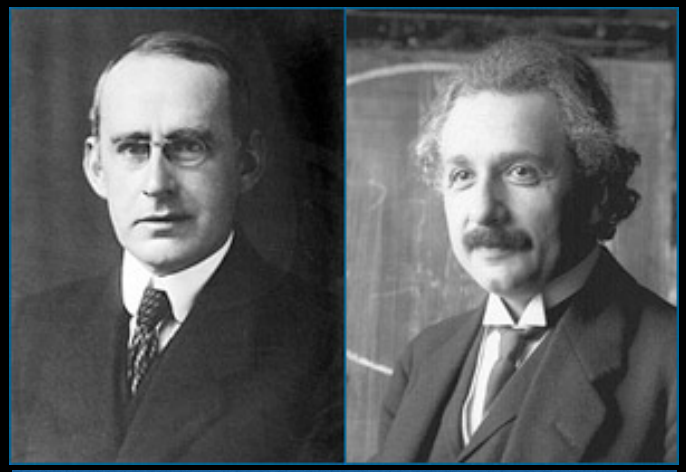


Arthur Eddington

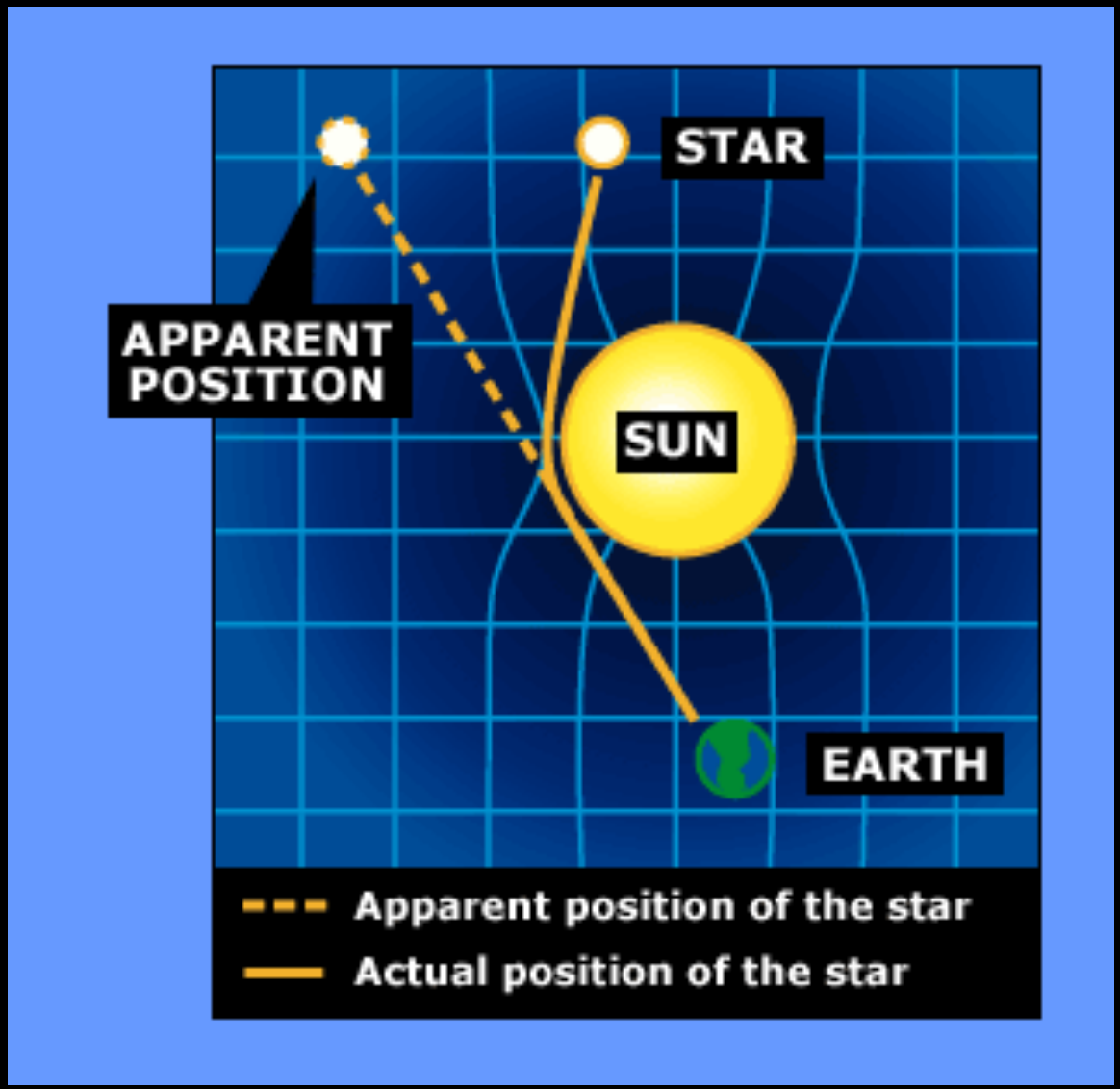
Albert Einstein

Test General Relativity

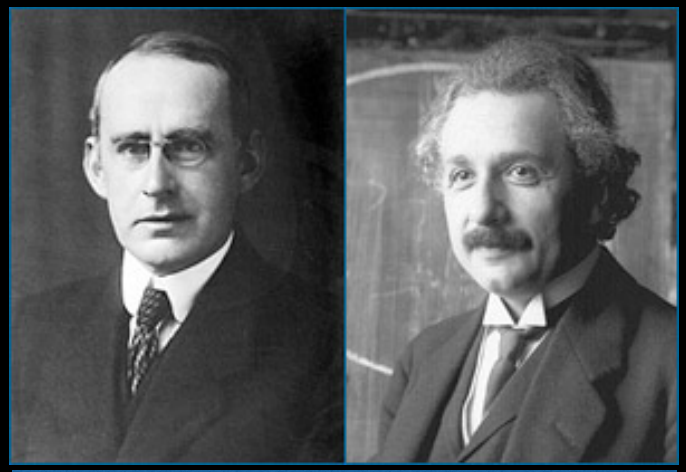


1915 - Einstein's General Relativity - new theory of gravity - predicts bending of light by gravity

May 29, 1919 - Eddington leads expedition to test bending of starlight during TOTAL SOLAR ECLIPSE



Test Genera



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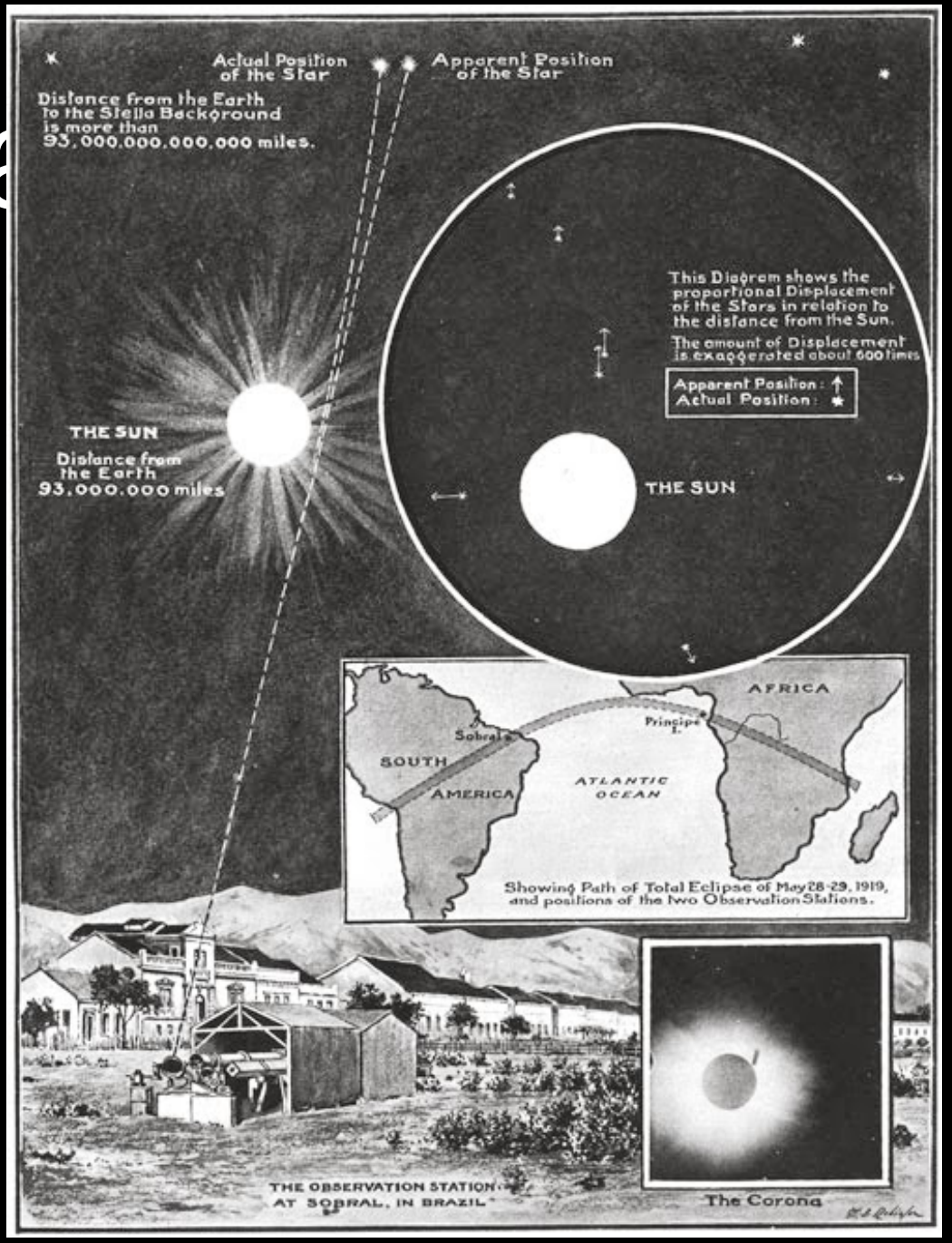
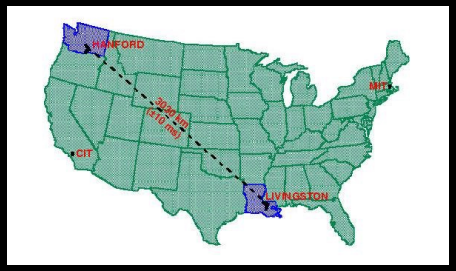


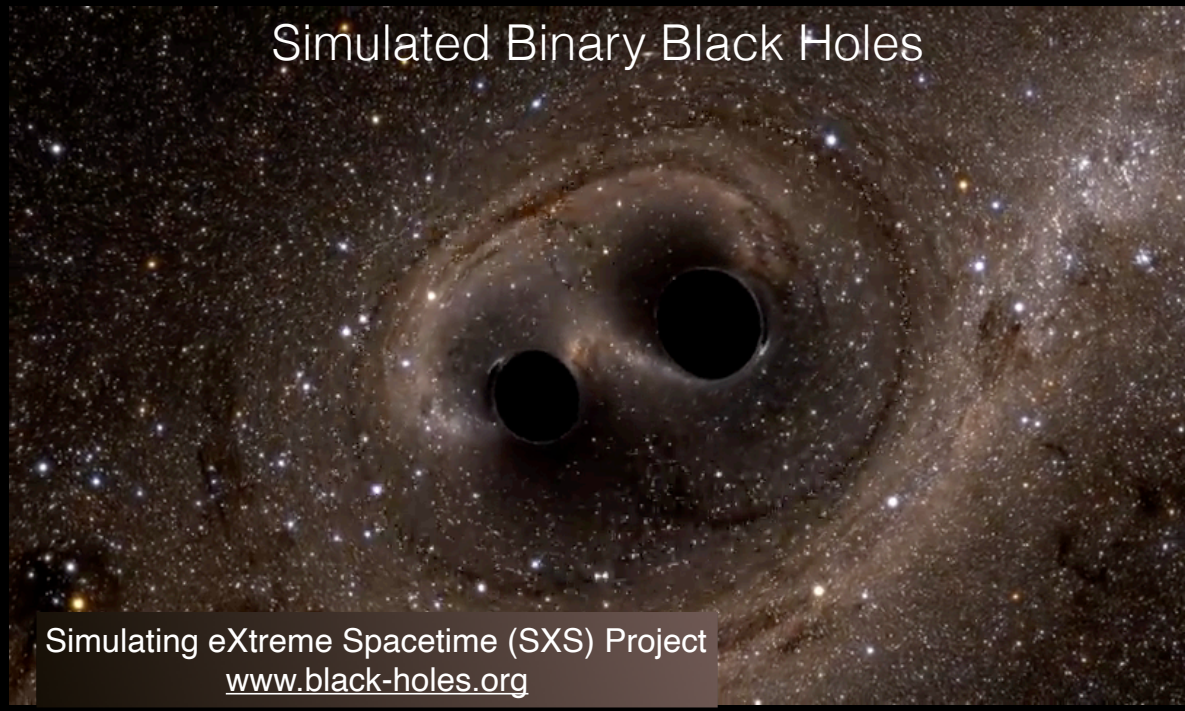
Credit: Illustrated London News, 22 November 1919

Jim Brau, Salem, Oregon *August 21, 2017*

General Relativity and Gravitational Waves

- Einstein's general relativity confirmed by **Solar Eclipse** predicted gravitational waves, which we discovered in 2015 with LIGO.





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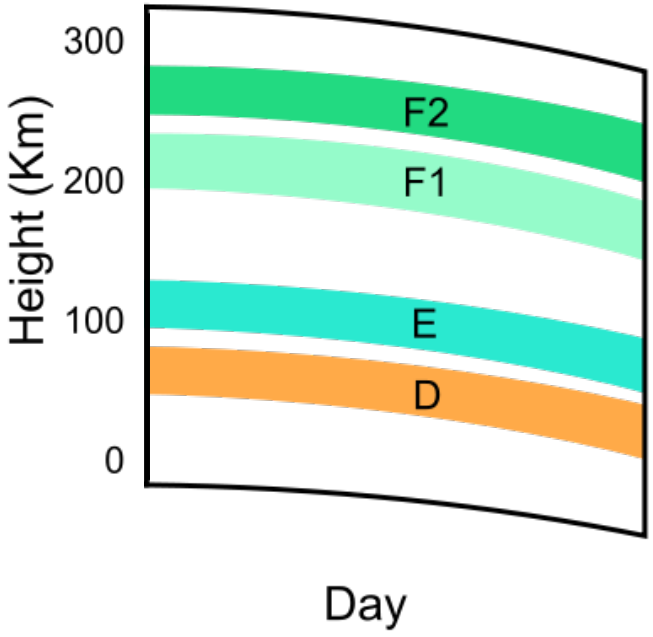
Eclipse Alters Earth's Ionosphere

Shell of ionization surrounding the Earth primarily from UV radiation from the Sun.



Affects radio communication
and communication with spacecraft and satellites.

Credit: Naval Postgraduate School

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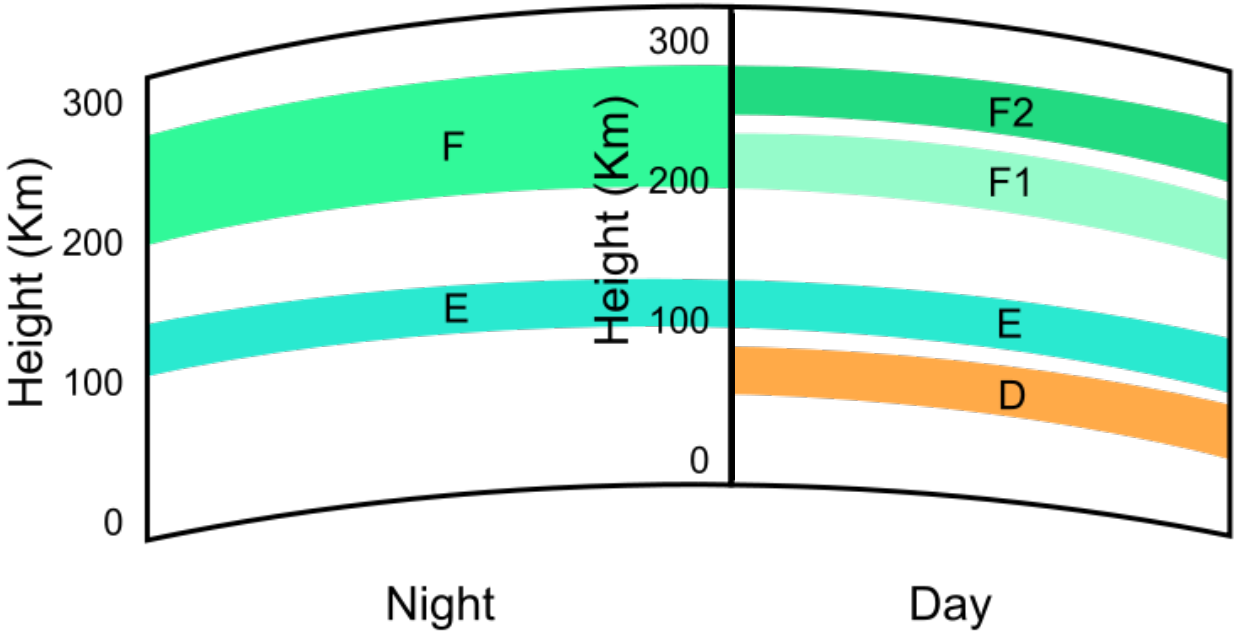

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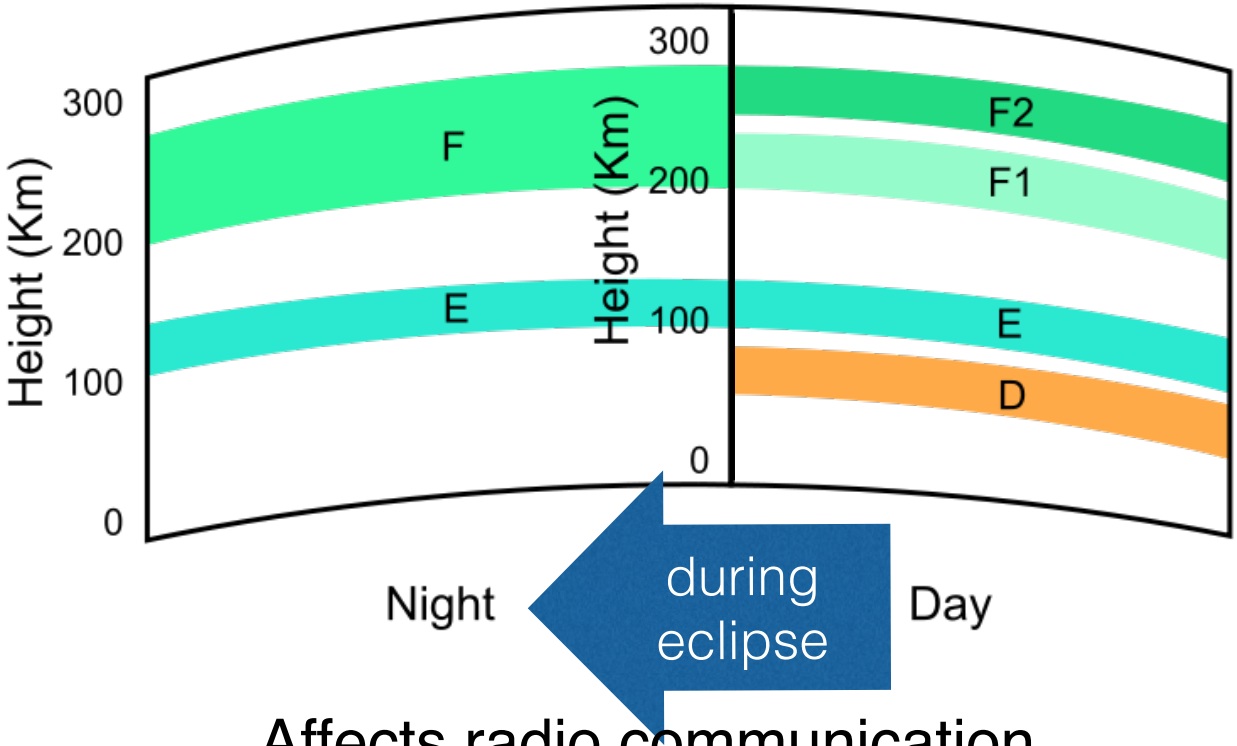

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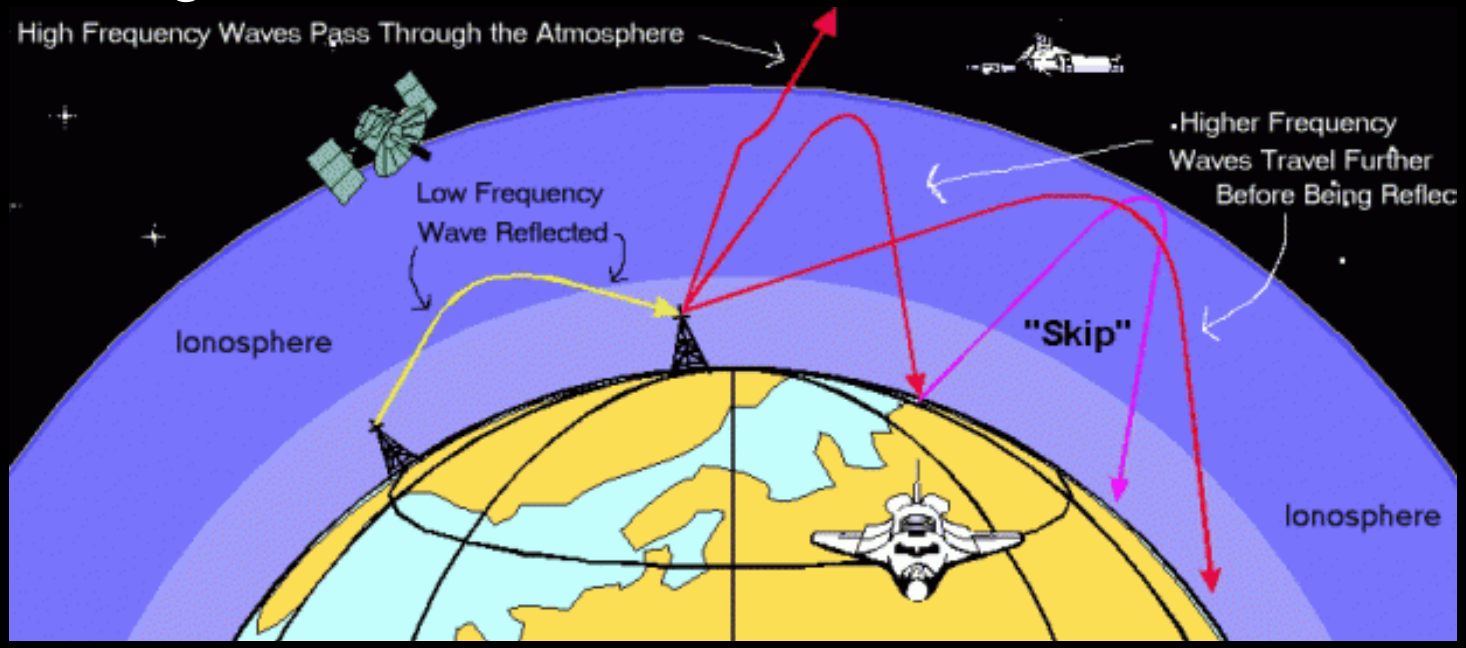
Eclipse Alters Earth's Ionosphere

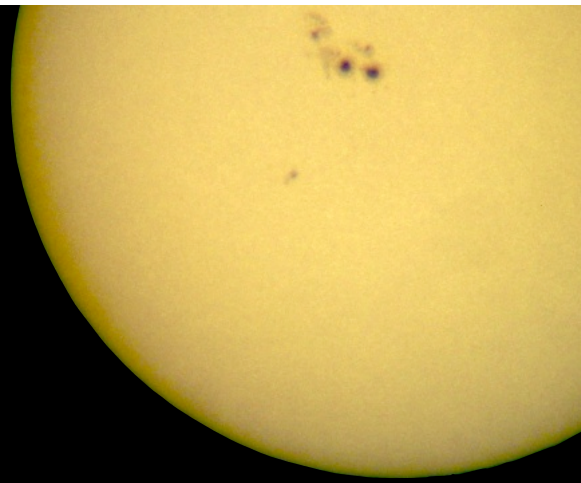
- Many radio signals absorbed in daytime; travel longer distances at night.
- Some radio stations can be heard across great distances only at night.



Eclipse Alters Earth's Ionosphere

- Many radio signals absorbed in daytime; travel longer distances at night.
- Some radio stations can be heard across great distances only at night.
- During a total solar eclipse, for a few minutes, radio waves can travel farther than normally during daytime.
- You may hear radio stations normally only heard at night.
- You may "listen" to the total eclipse, outside totality.

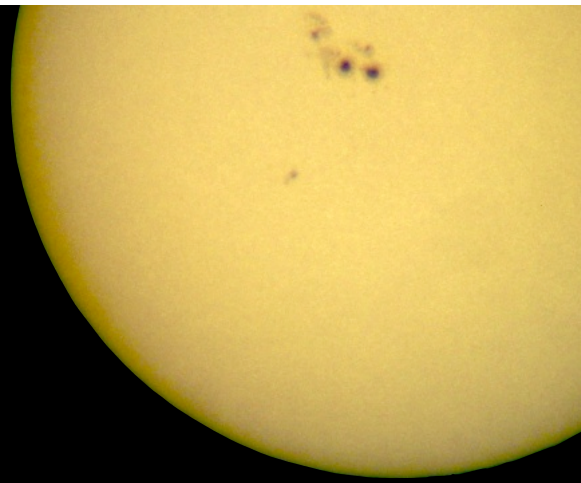
Power of Sun



- Sun delivers 1400 Watts per square meter to Earth.
- Given Sun's distance (93,000,000 miles) we determine total power released in the Sun is 4×10^{26} Watts.

  400,000,000,000,000,000,000,000,000 Watts

Power of Sun



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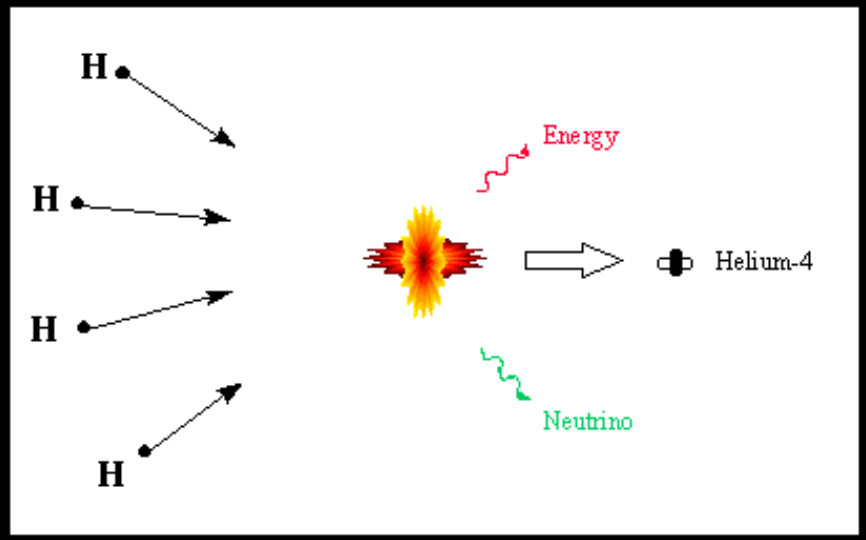
- Given Sun's distance (93,000,000 miles) we determine total power released in the Sun is 4×10^{26} Watts.
- Given properties of Sun, not possible by conventional means, such as oil or coal burning, etc.
- Explaining this was a major mystery 100 years ago, before discovery of nuclear physics.

Power of Sun

- Temperature Sun's center is 15,000,000 Kelvin (or 27,000,000 Fahrenheit).
- Light elements (such as hydrogen) fused into heavier elements (such as helium and carbon), releasing energy.
- Neutrinos are also released.
- There are a billion times as many neutrinos as atoms in the universe.



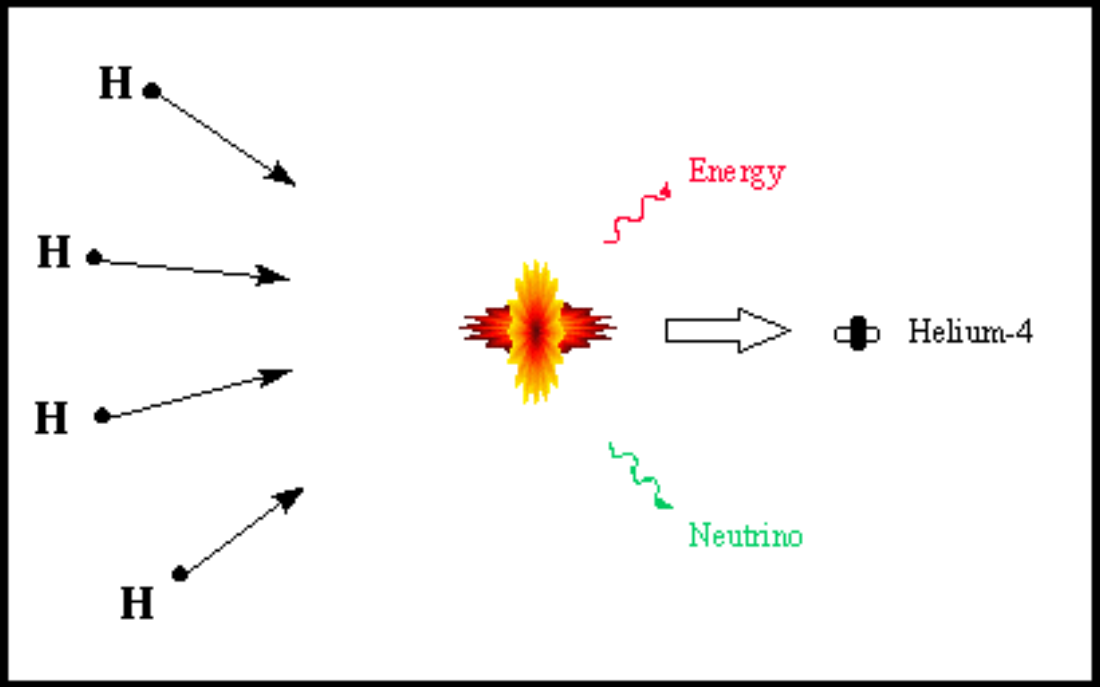
The “Ghost Particle” fills our space

- During this lecture
  - more than 100,000,000,000,000,000 neutrinos will have passed through you …
  - Did you feel any? - there is a minuscule chance that any one will have interacted in any one of us.

- http://shushi168.com/ghost-image.html

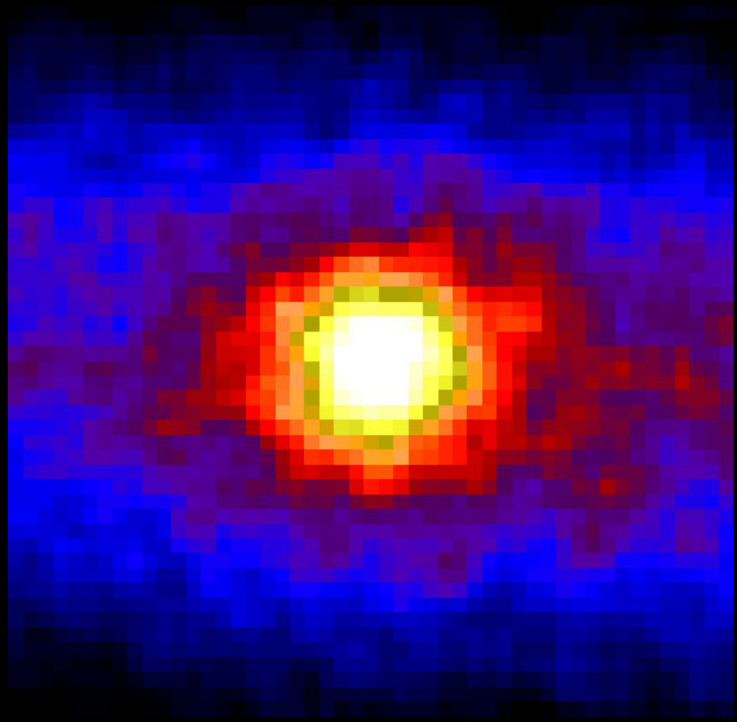
Neutrinos from the Sun

- Nuclear reactions in the Sun produce its energy and also produce neutrinos.



Neutrinos from the Sun

- Nuclear reactions in the Sun produce its energy and also produce neutrinos.
- Almost all of the released energy goes into the Sun's thermal radiation, but a small fraction goes into neutrinos.
- The neutrino image of the Sun is visible underground and will (in principle) be unaffected by the Solar Eclipse.



http://nngroup.physics.sunysb.edu

Image of Sun Before Eclipse

http://www.solarham.net

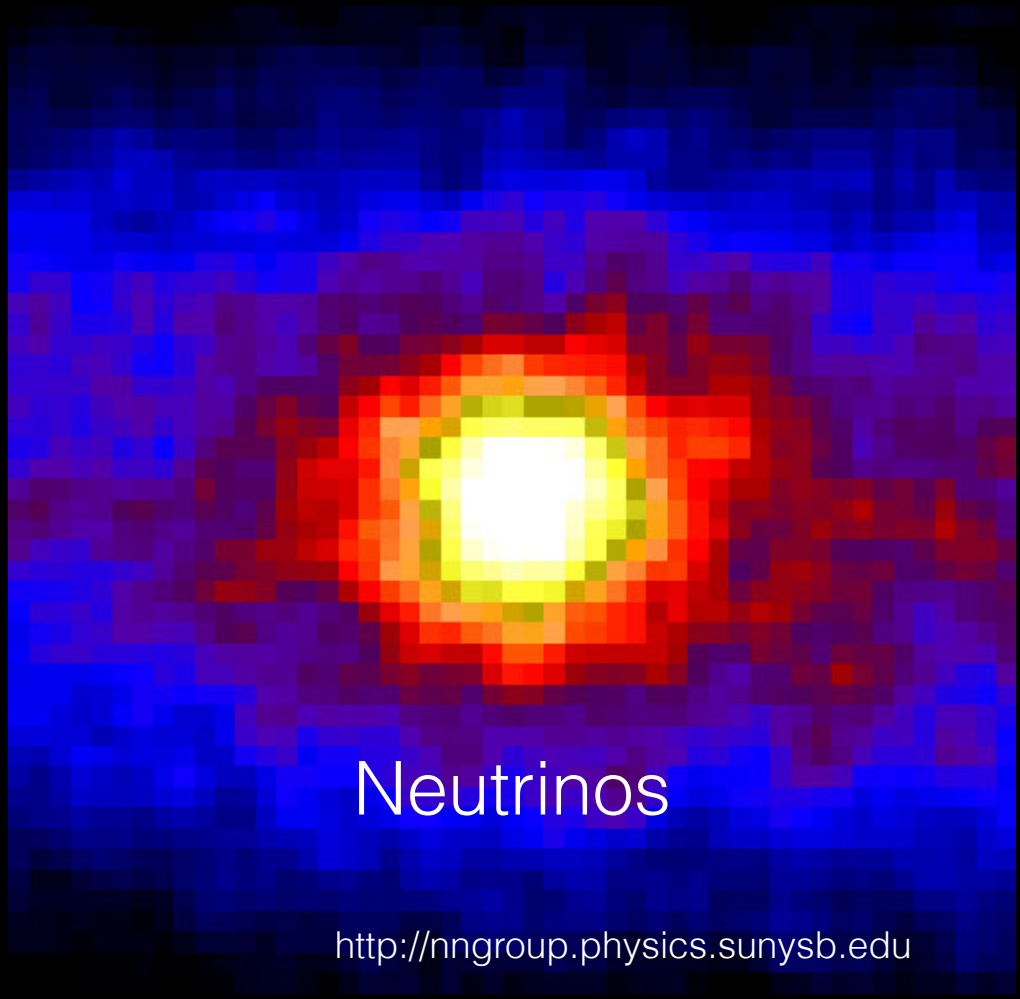


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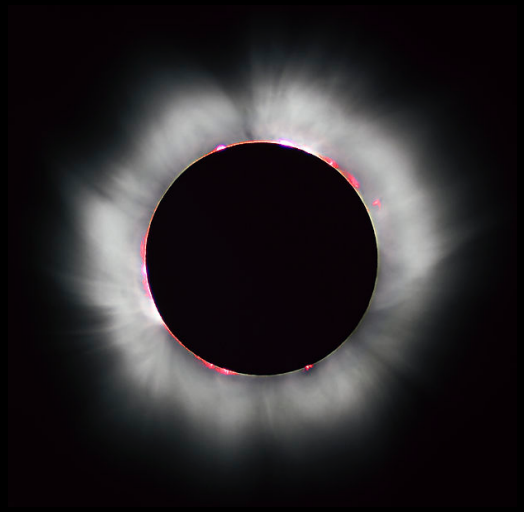
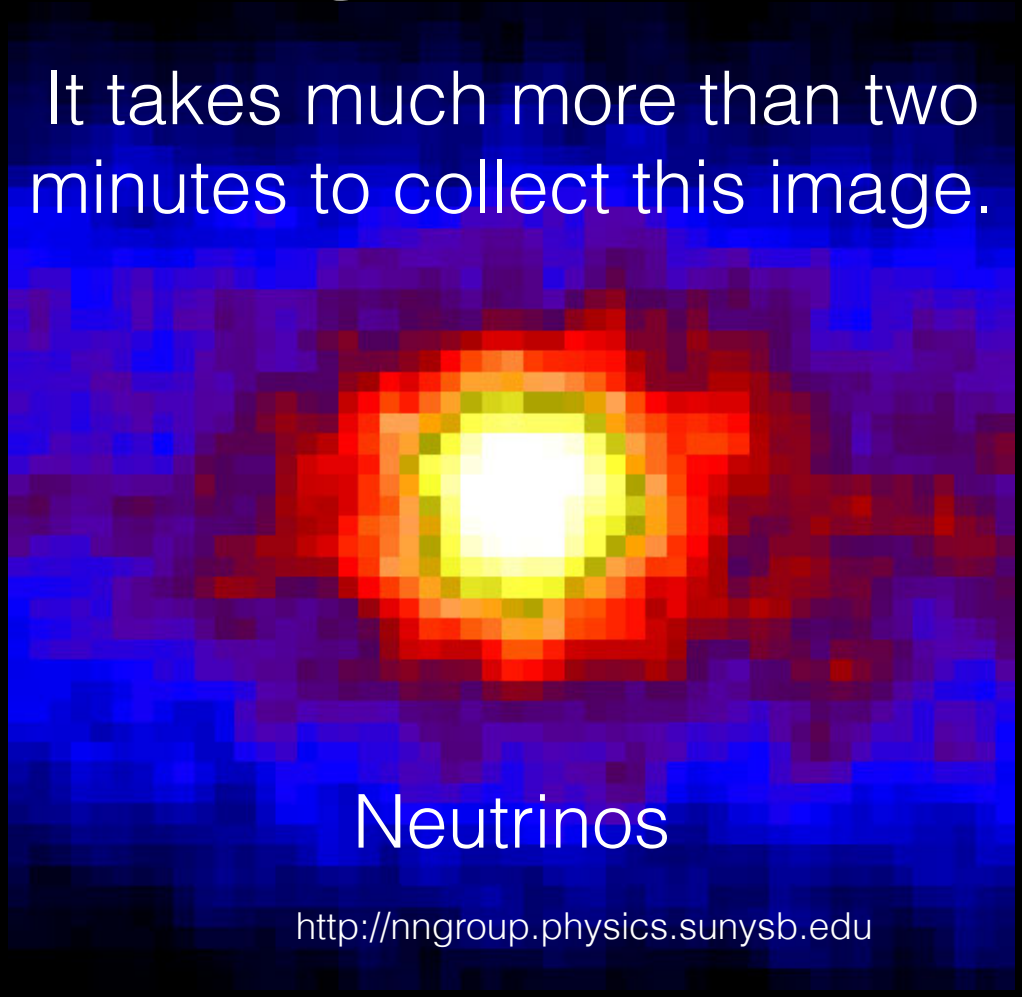
Image of Sun During Eclipse



Visible Light

https://en.wikipedia.org/wiki/Solar_eclipse

It takes much more than two minutes to collect this image.

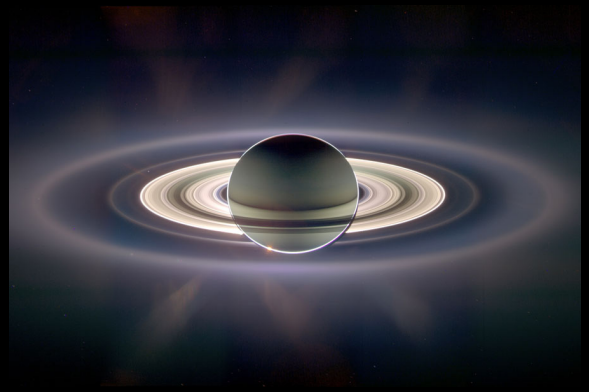


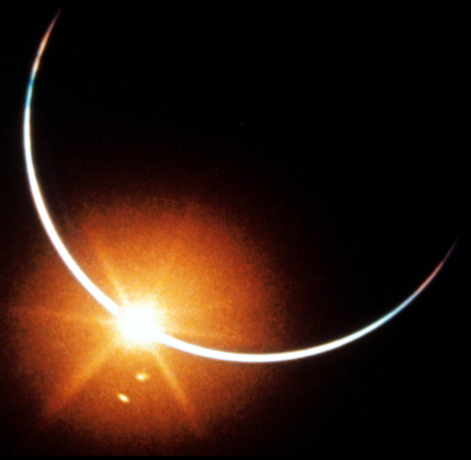
Neutrinos

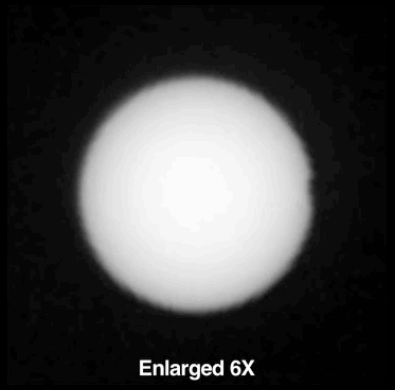
http://nngroup.physics.sunysb.edu

- Neutrinos pass right through the Moon without loss!

Eclipses/transits Beyond Earth-Moon System







Jim Brau, Salem, Oregon

August 21, 2017

September 4, 2011

Cassini spacecraft observed Sun eclipsed by Saturn

November 24, 1969

Apollo 12 photo of Earth eclipsing Sun
during journey home from the Moon.

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Solar Transit of Venus

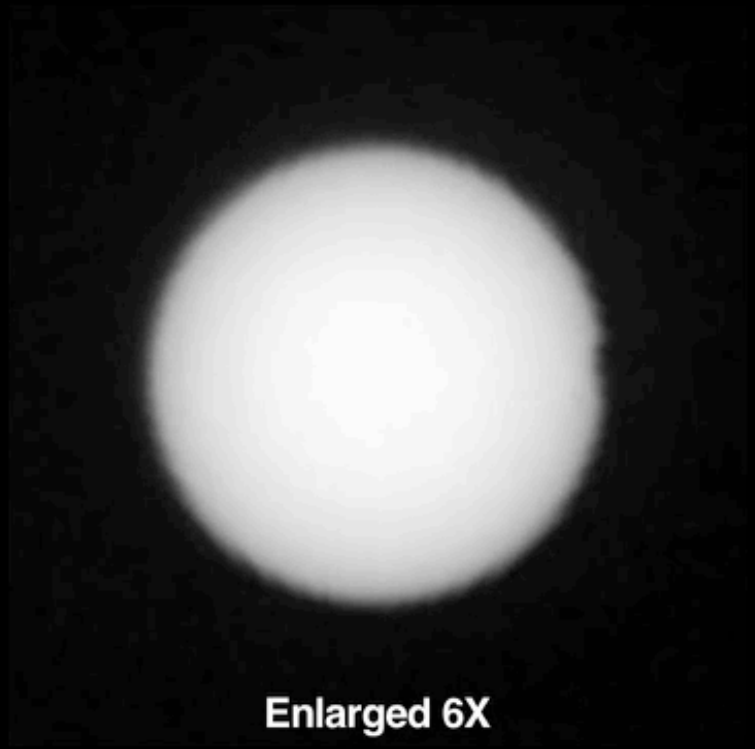
Transit of Venus Time Lapse - June 5, 2012
Once in a Lifetime
Next Venus Transit in 2117

- Transits of Venus are rare
  - Two in 21st century
  - Mercury transits are more common
    - 13 or 14 per century
    - next Mercury transit Nov 11, 2019
- Venus transit on June 5, 2012

Credit: YouTube - bobbfwed

Phobos Eclipsing the Sun on Mars

- The larger of the two moons of Mars, Phobos, orbits close to Mars and in line with its equator.
- Because of this configuration transits of Phobos occur somewhere on Mars on most days of the Martian year.
- Curiosity rover, on the surface of Mars, captured this image of the passage of Phobos directly in front of the sun on 20 August 2013.



Credit: NASA JPL

Search for Exoplanets

Kepler Space Telescope

Few thousand exoplanets discovered by transit.

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Acknowledgments

RESEARCH SUPPORTED BY

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NATIONAL SCIENCE FOUNDATION

Philip H. Knight

University of Oregon Physics
and Center for High Energy Physics

Conclusion

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Conclusion

- Many other examples of discovery during eclipse:
  - Around 150 B.C.E, Hipparchus of Nicaea determined distance of Moon with 20% accuracy.
  - Revealed history of Earth's spin.
  - Show ripples in Earth's atmosphere.
- A Total Solar Eclipse is a great discovery opportunity.