

Total Solar Eclipse 2024

Alphonse Sterling
NASA/MSFC

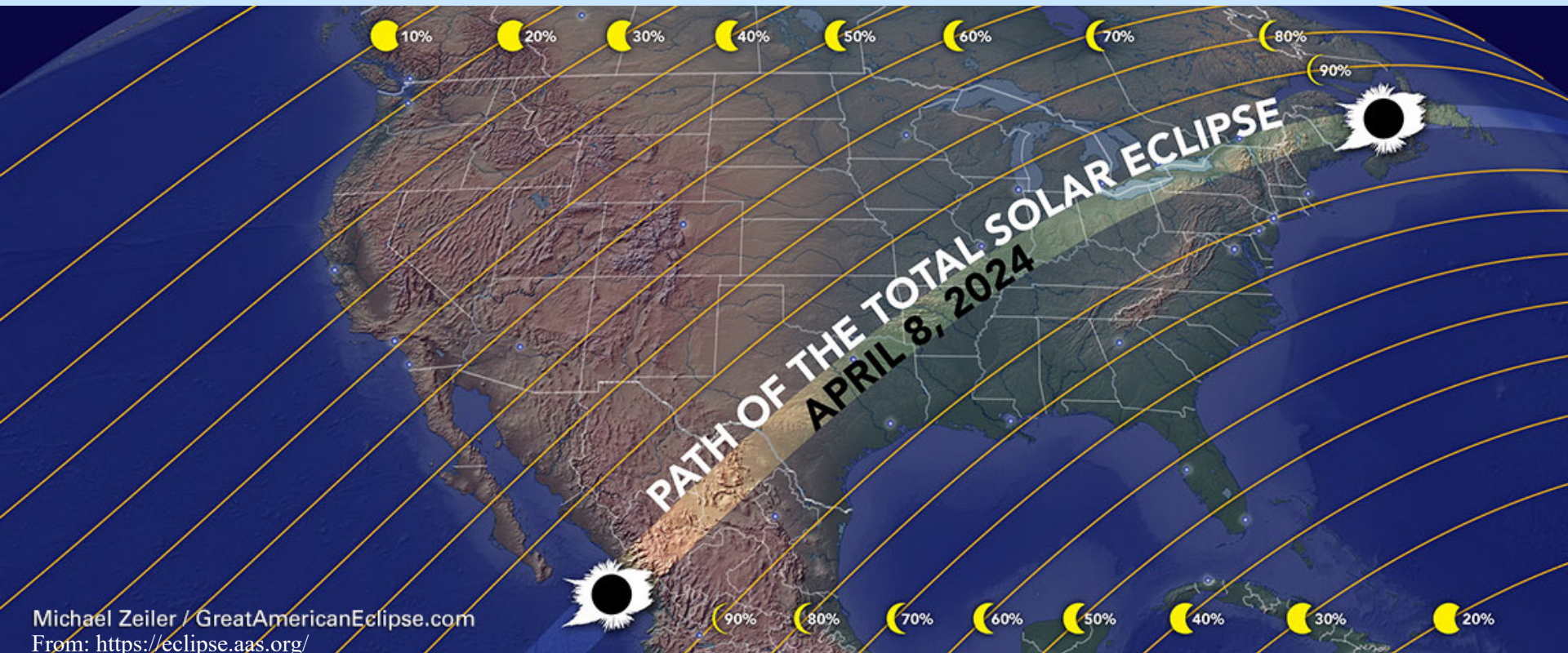
What are Eclipses?

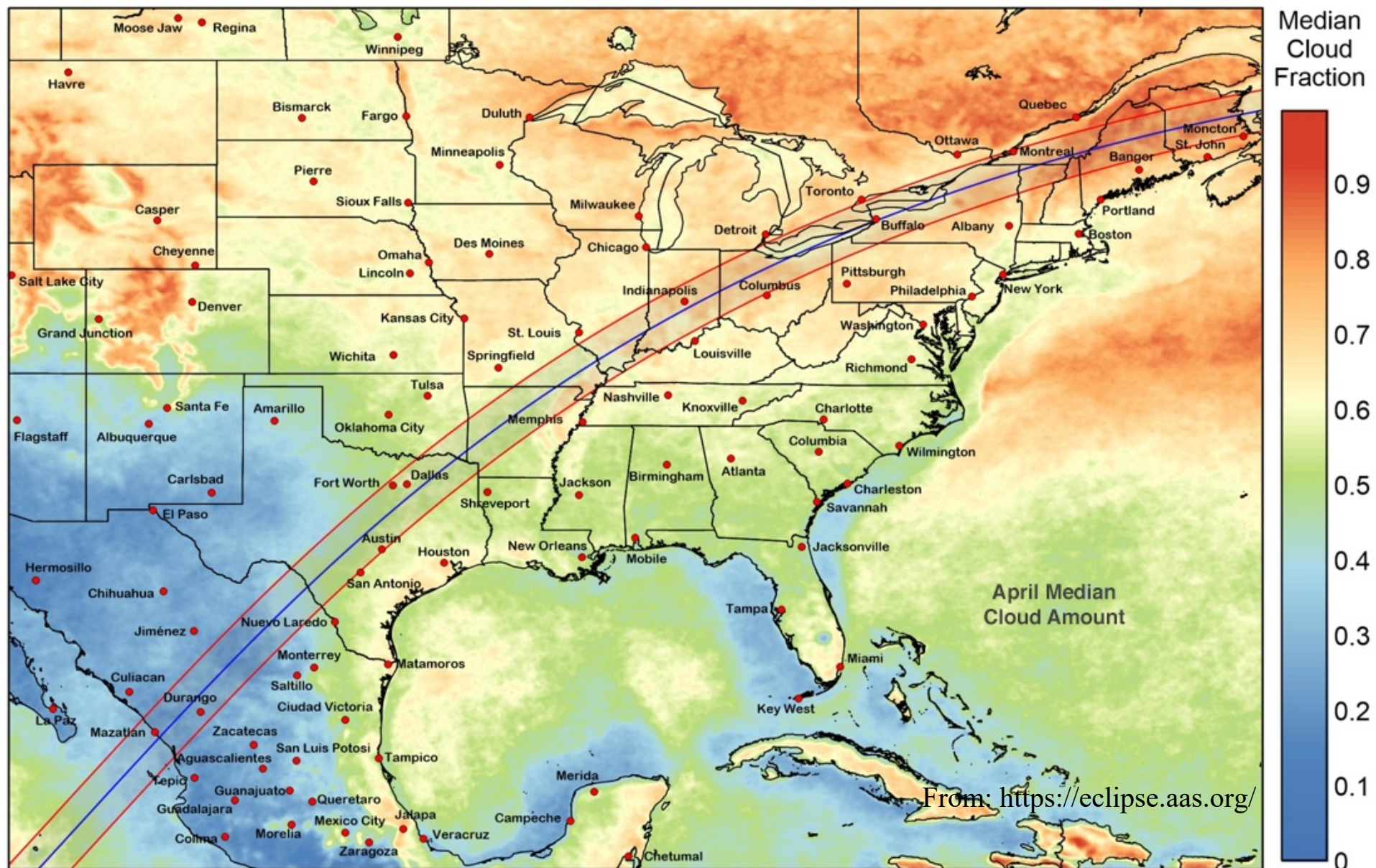
One celestial body falls into the shadow of another.

Solar Eclipse

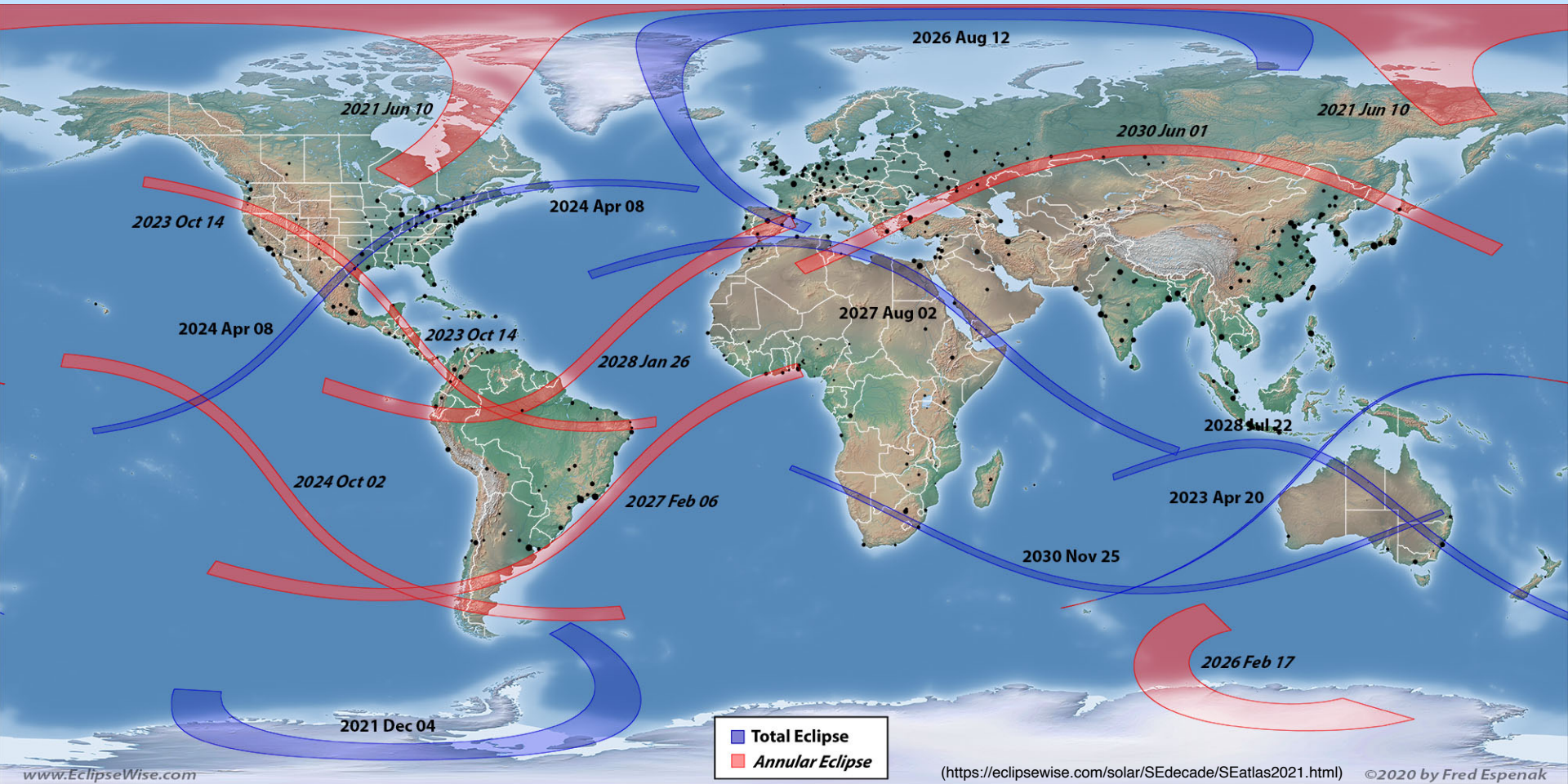


<https://www.nasa.gov/image-article/solar-eclipse-diagram/>





Solar Eclipses 2022-2030



Never look at the Sun Directly
with your unprotected eyes!!

What to Expect



(A. Sterling, Texas 2023)



(A. Sterling, Texas 2023)



(A. Sterling, Texas 2023)



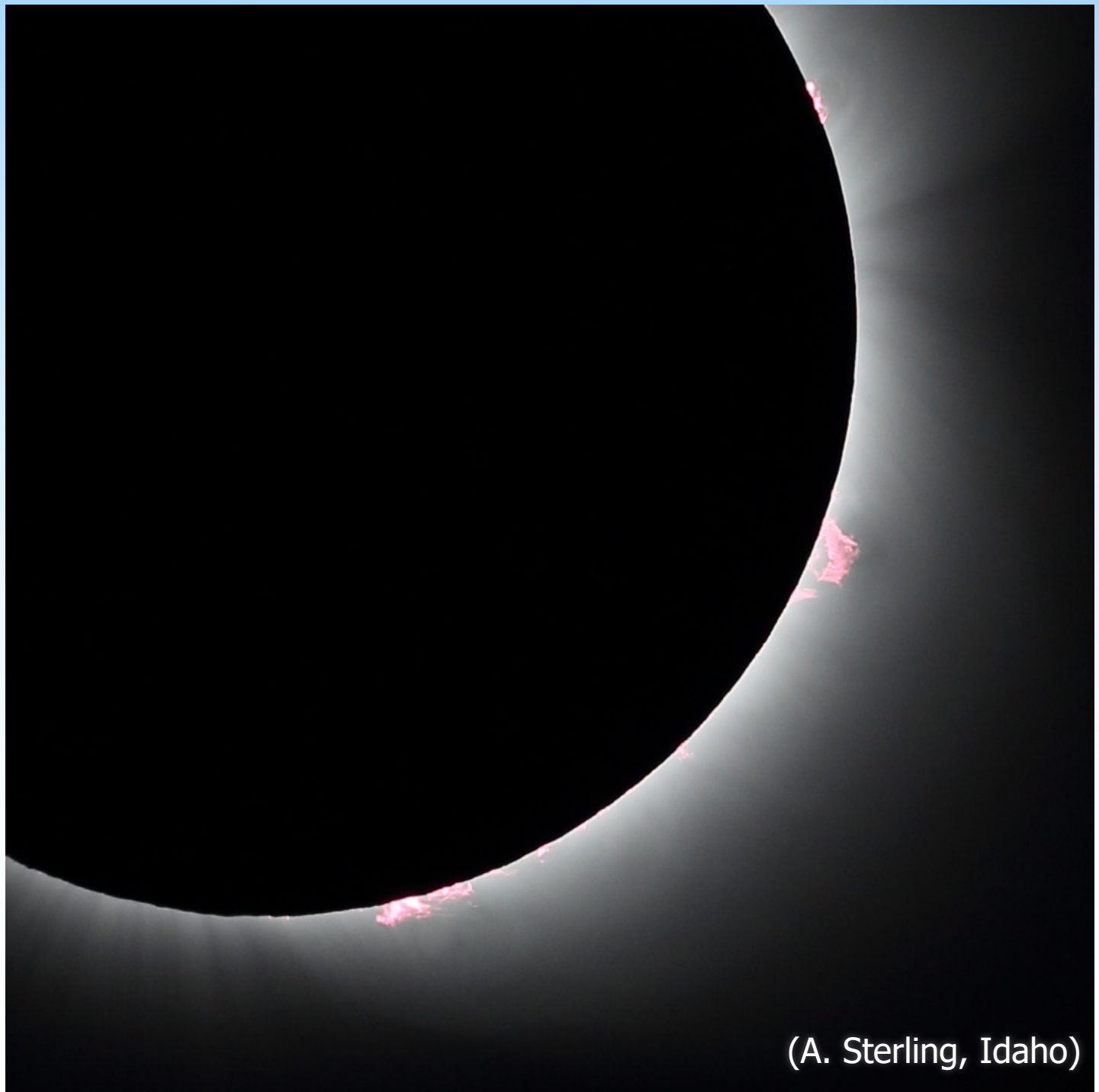
(A. Sterling, Idaho)



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(A. Sterling, Idaho)



(A. Sterling, Idaho)



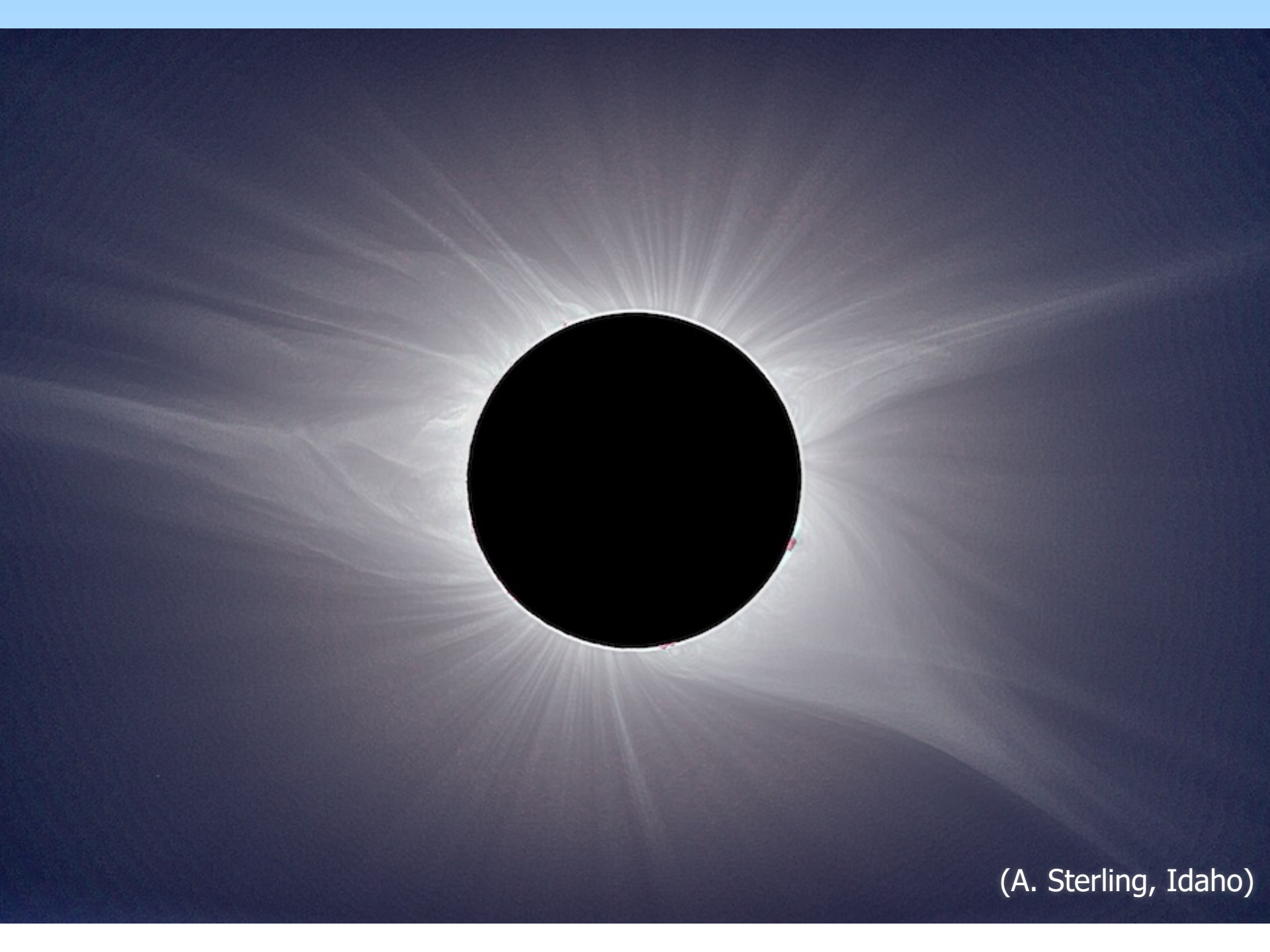
(A. Sterling, Idaho)



(A. Sterling, Idaho)



(A. Sterling, Idaho)



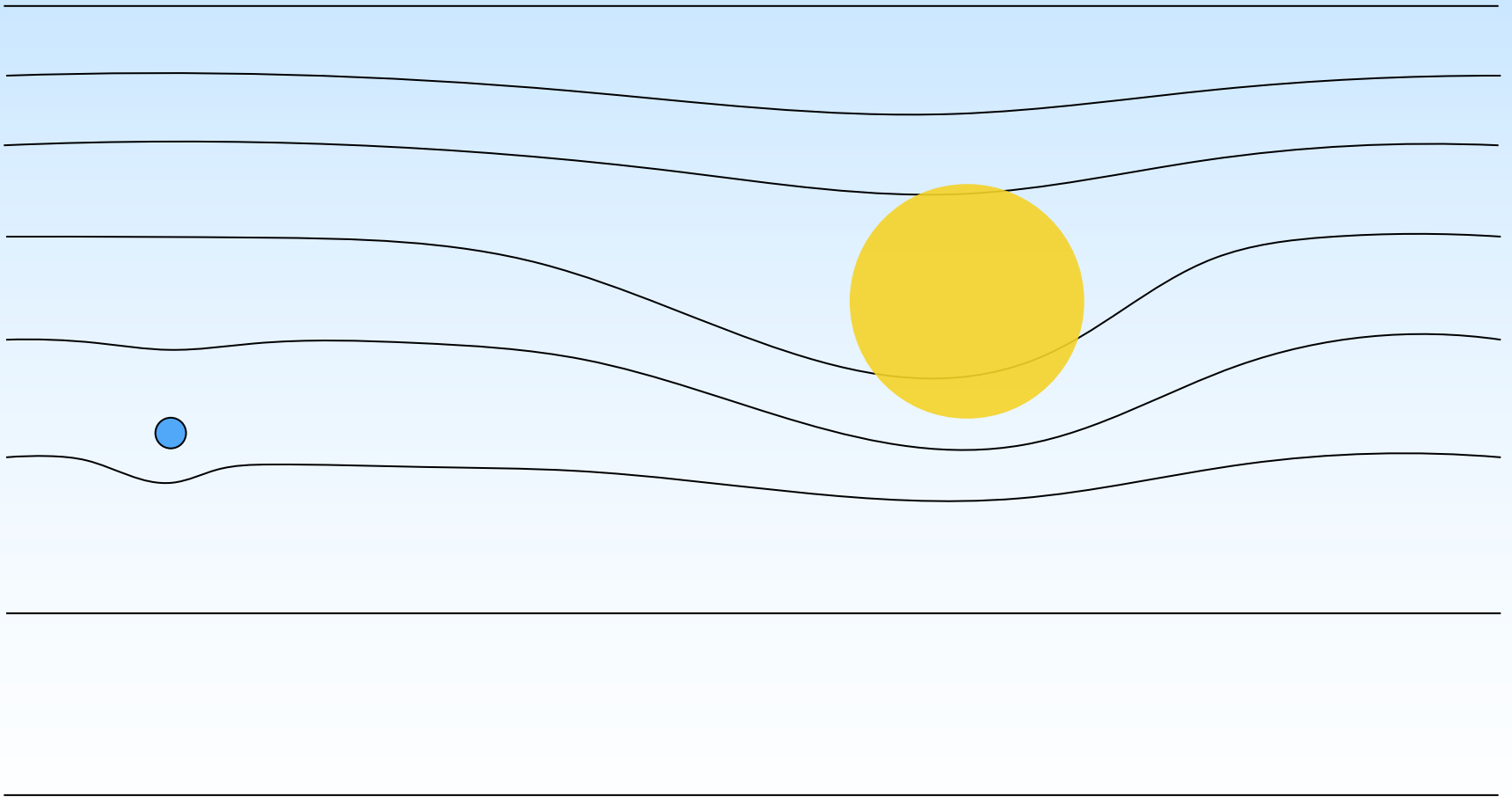
(A. Sterling, Idaho)

Some Solar Eclipse Science

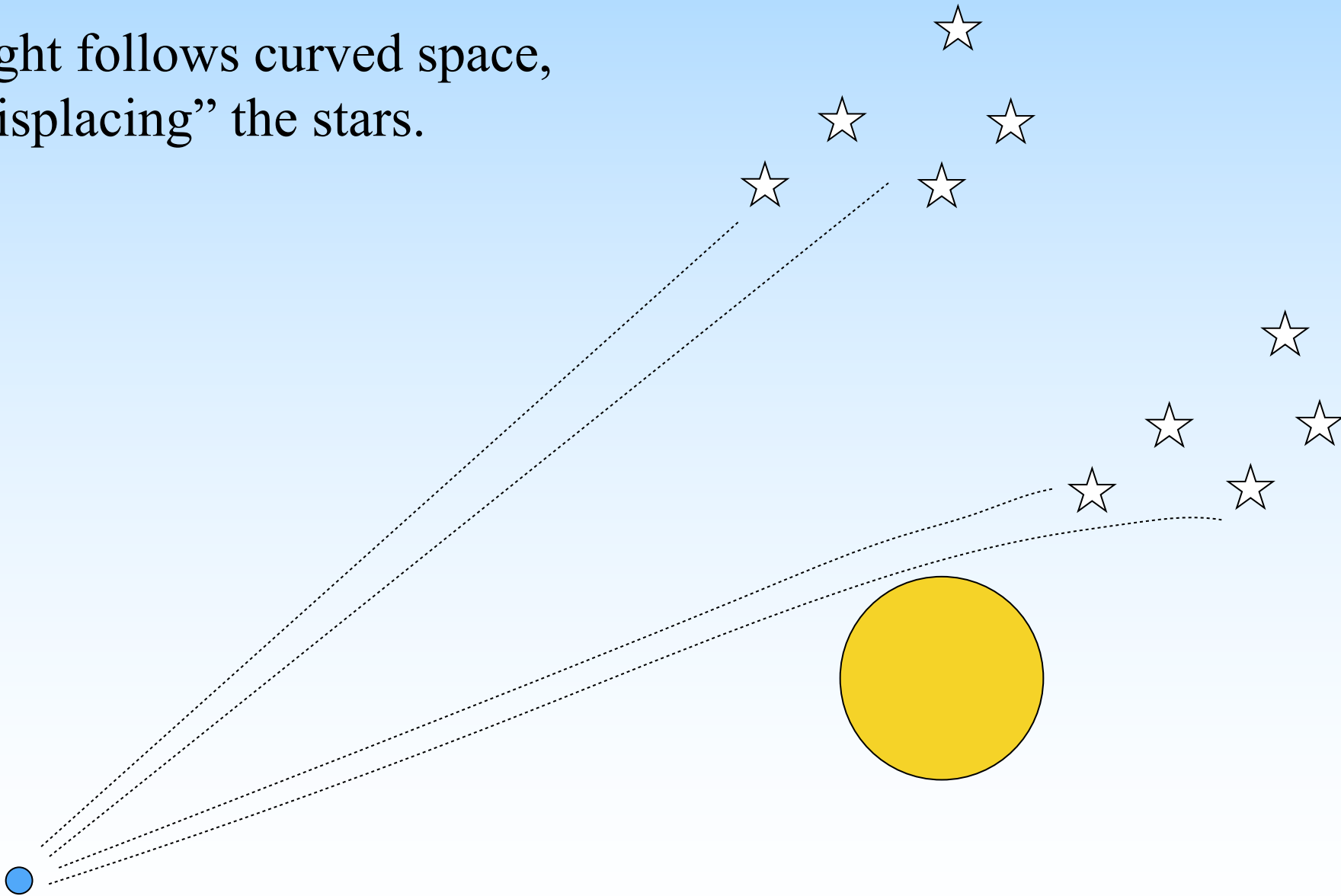
The Most Famous Solar Eclipse Experiment

- 1919 total solar eclipse, tested Einstein's General Theory of Relativity.
- This theory says that space is curved, with more massive objects curving it more than less-massive objects.
- Light follows the path of curved space.
- The effect is subtle for most objects, and to see the effect a very massive object is needed.
- Stars near the Sun could show the effect, but normally the Sun is too bright to see stars near it.
- But they can be seen during an eclipse!

Einstein (1915): General Theory of Relativity: Space is curved; more massive objects curve it more.

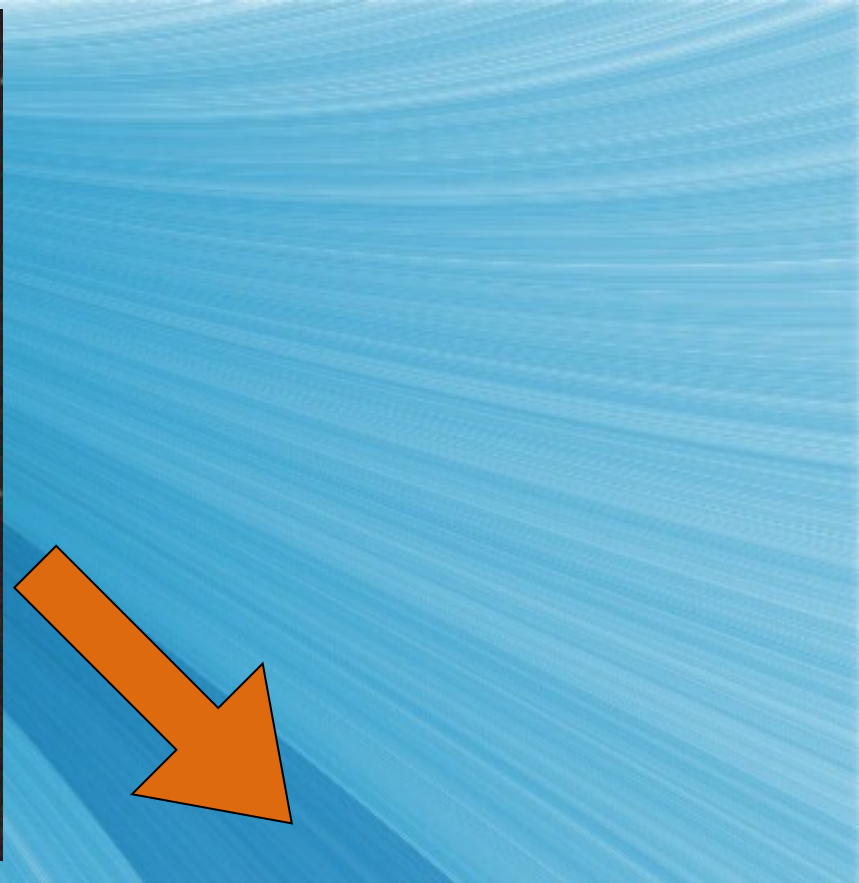


Light follows curved space,
“displacing” the stars.





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© Alphonse Sterling 2021

Sir Arthur Eddington tested this idea in the 1919 total solar eclipse, in what is now São Tomé and Príncipe.

It was found that the stars near the Sun were displaced by the predicted amount, establishing the validity of the theory.

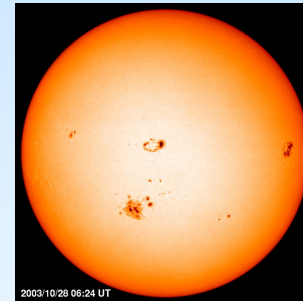
Einstein became an instant celebrity, and this is largely why his name is still so well known today.

Information on the Sun's Outer Atmosphere

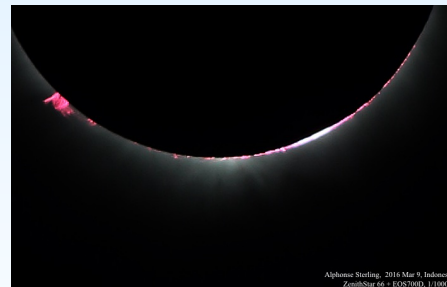
Solar Interior and Atmosphere(s)

The Outer layers (Atmospheres) of the Sun:

- Photosphere

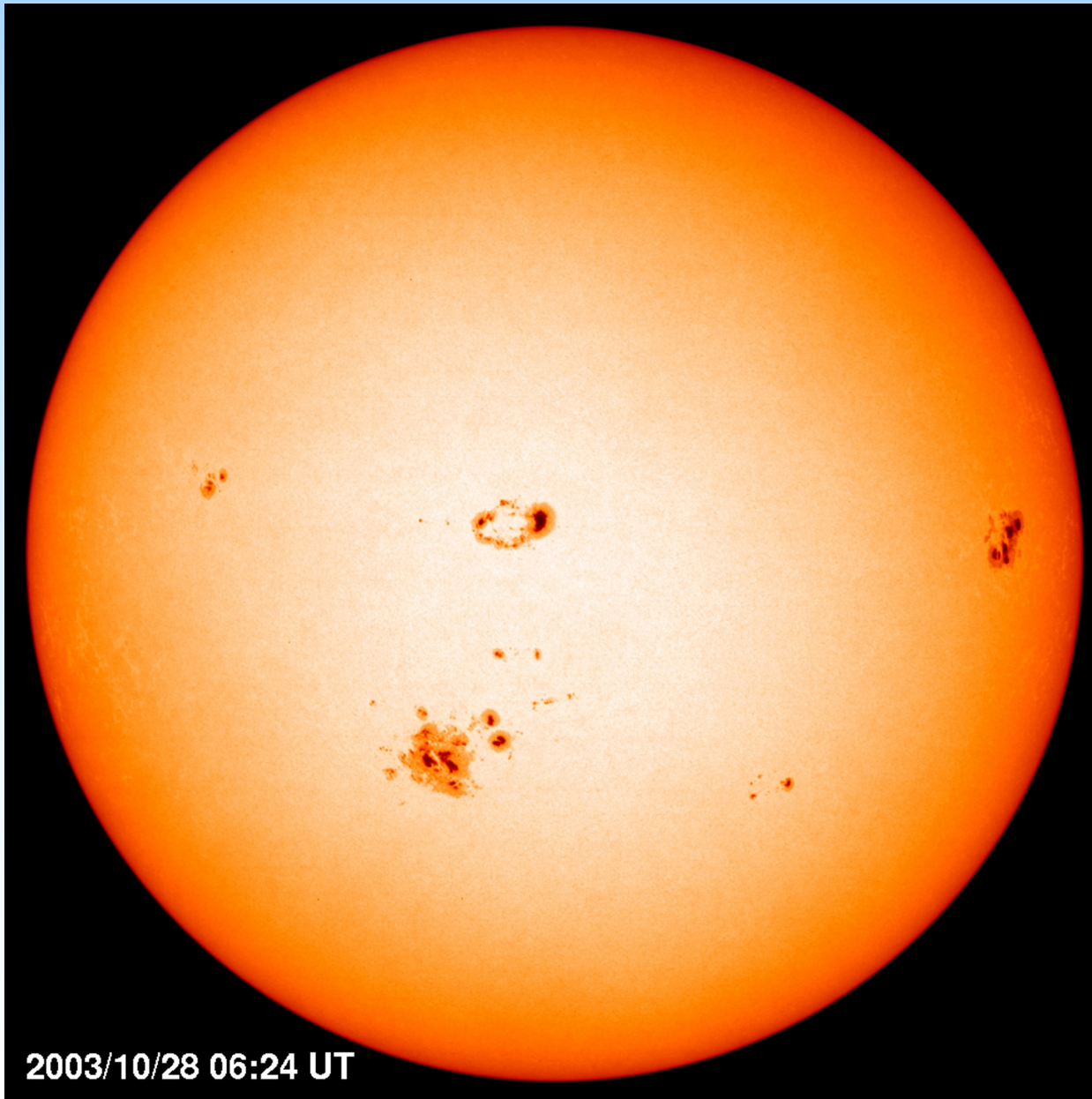


- Chromosphere



- Corona





The Photosphere

Convective Zone

Radiative Zone

Core

Prominence

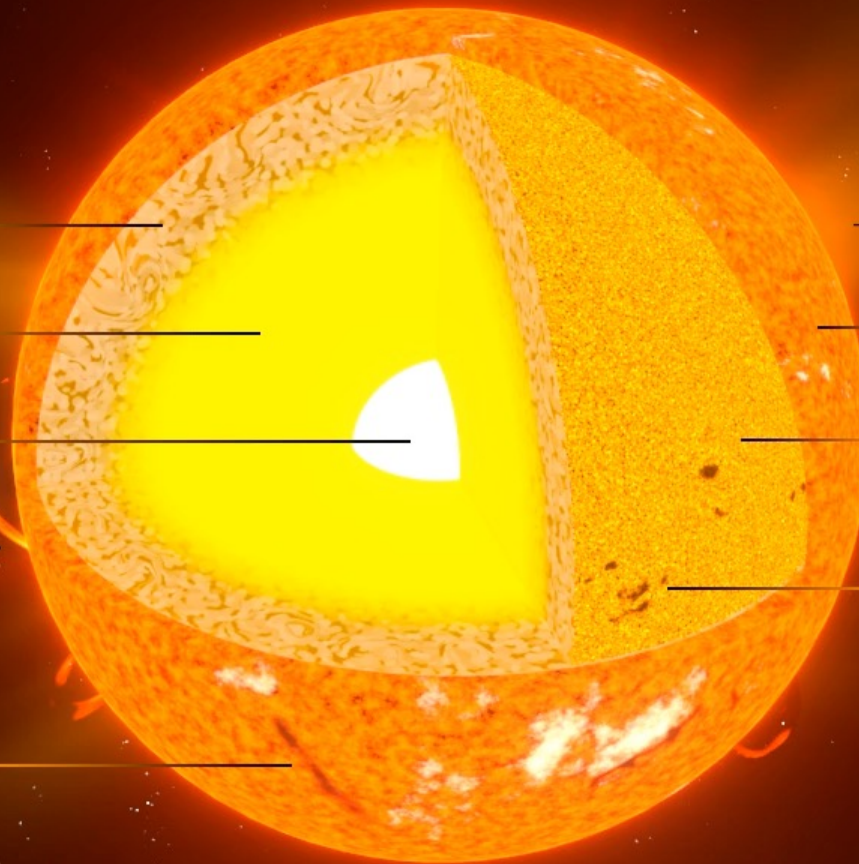
Filament

Corona

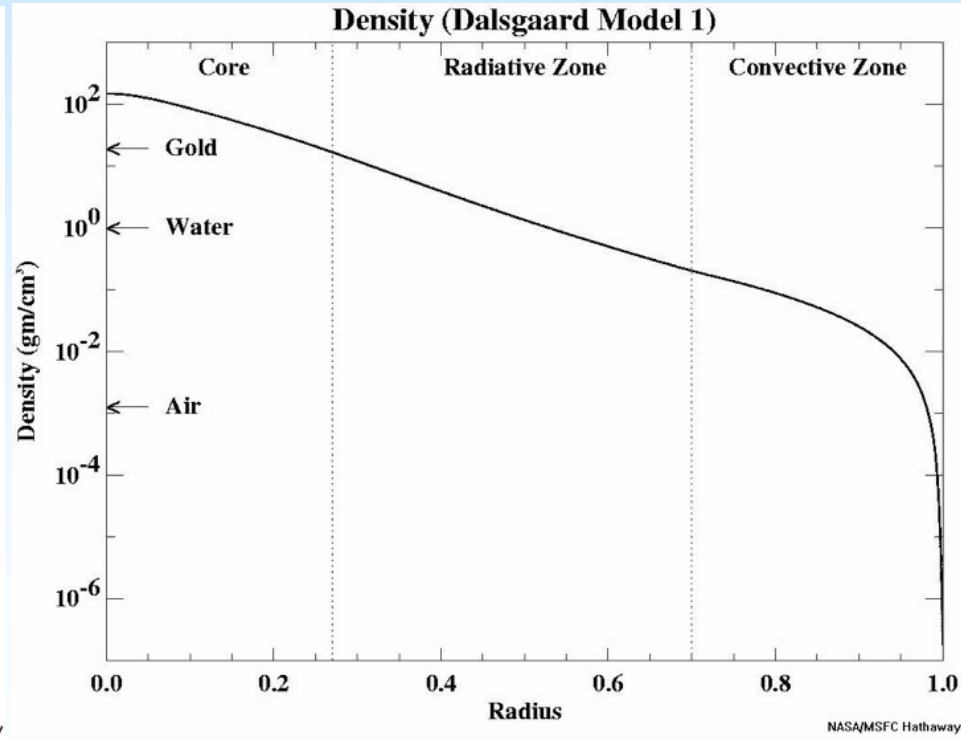
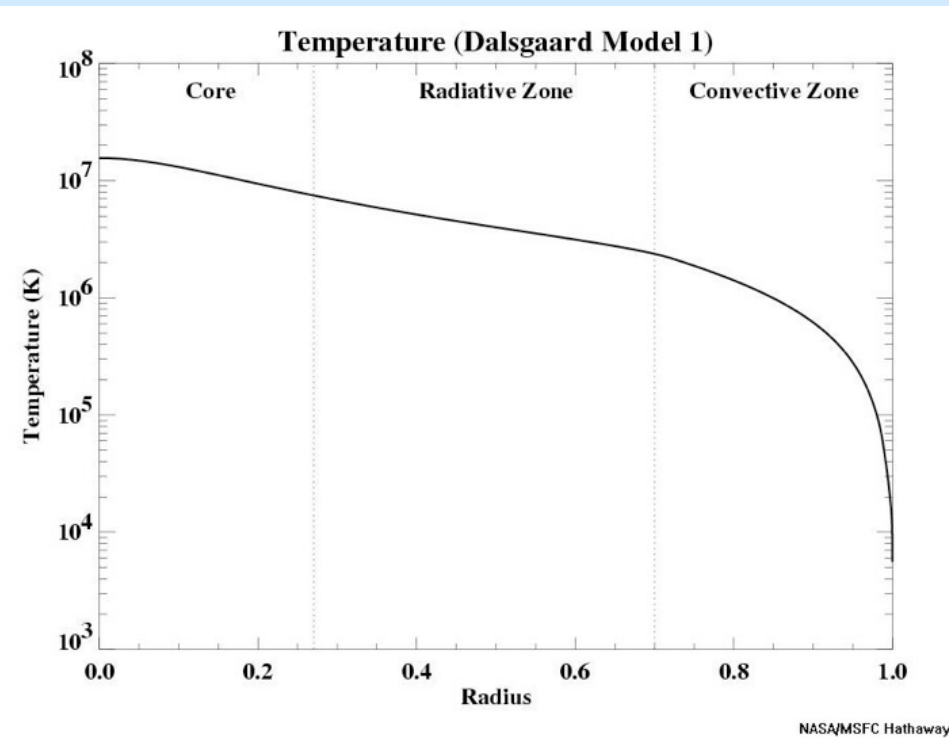
Chromosphere

Photosphere

Sunspot



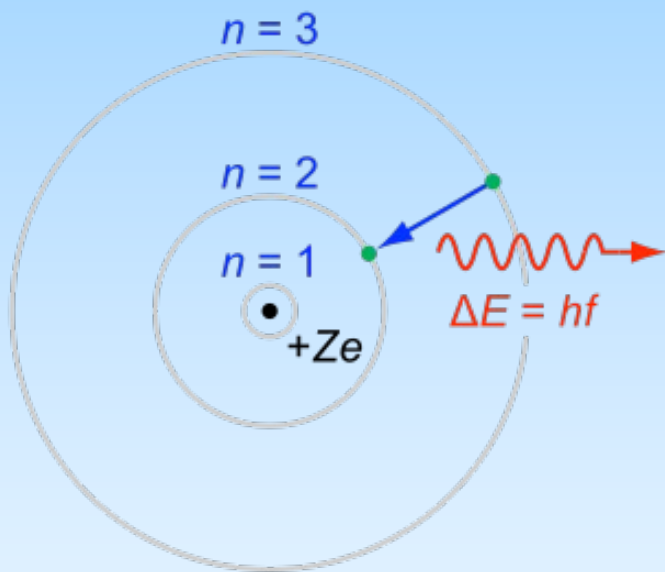
The Solar Interior's Temperature Distribution



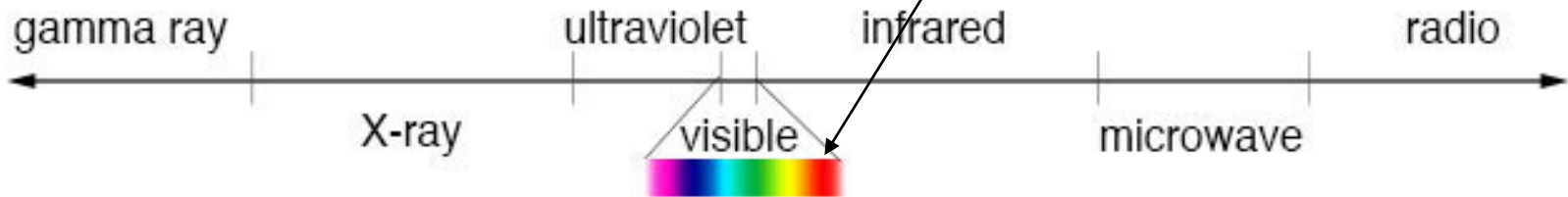


Alphonse Sterling, 2016 Mar 9, Indonesia
ZenithStar 66 + EOS700D, 1/1000 s

Chromosphere



H-alpha ($H\alpha$) transition in hydrogen atom; 656.3 nm.



shorter wavelength
higher frequency
higher energy

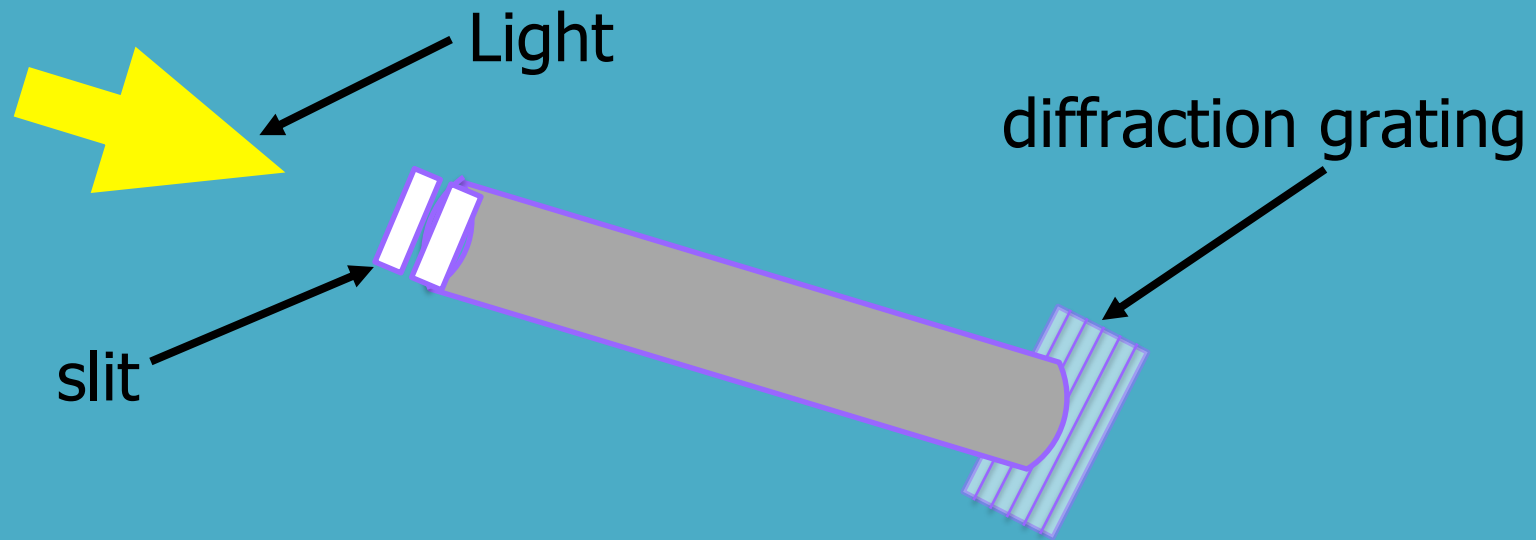
longer wavelength
lower frequency
lower energy



The Corona

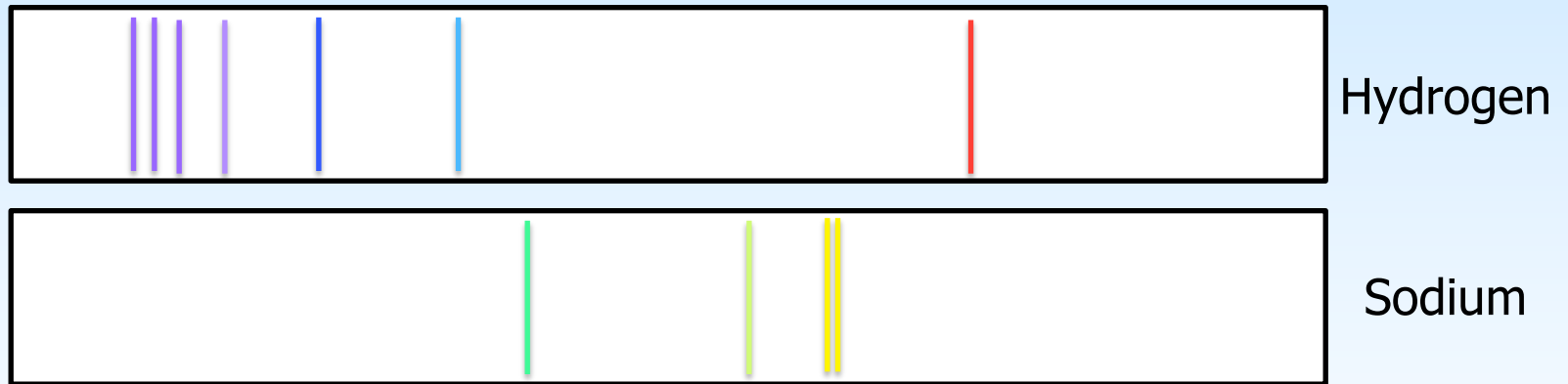
Interlude: “Flash spectrum” from the 2017 USA total solar eclipse

◆ Normal spectrograph:



Spectra

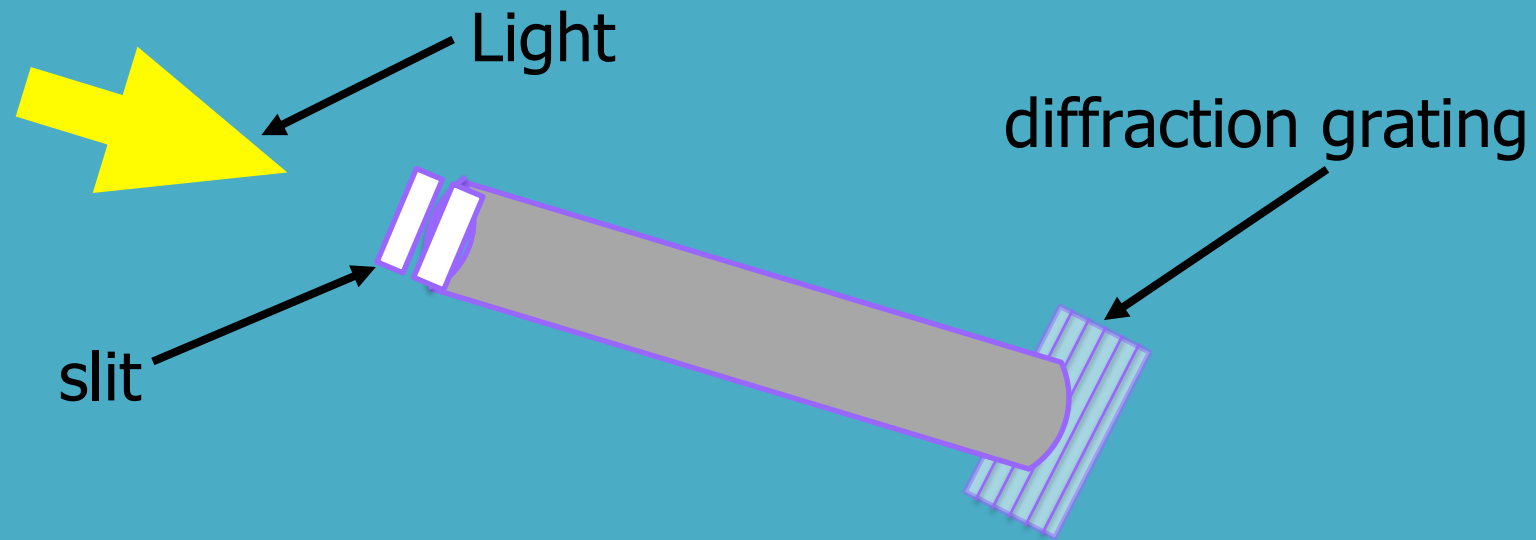
- Breaks light into “rainbow” colors, with lines.
- Different elements produce different lines.
- So these lines are like “fingerprints” for elements.



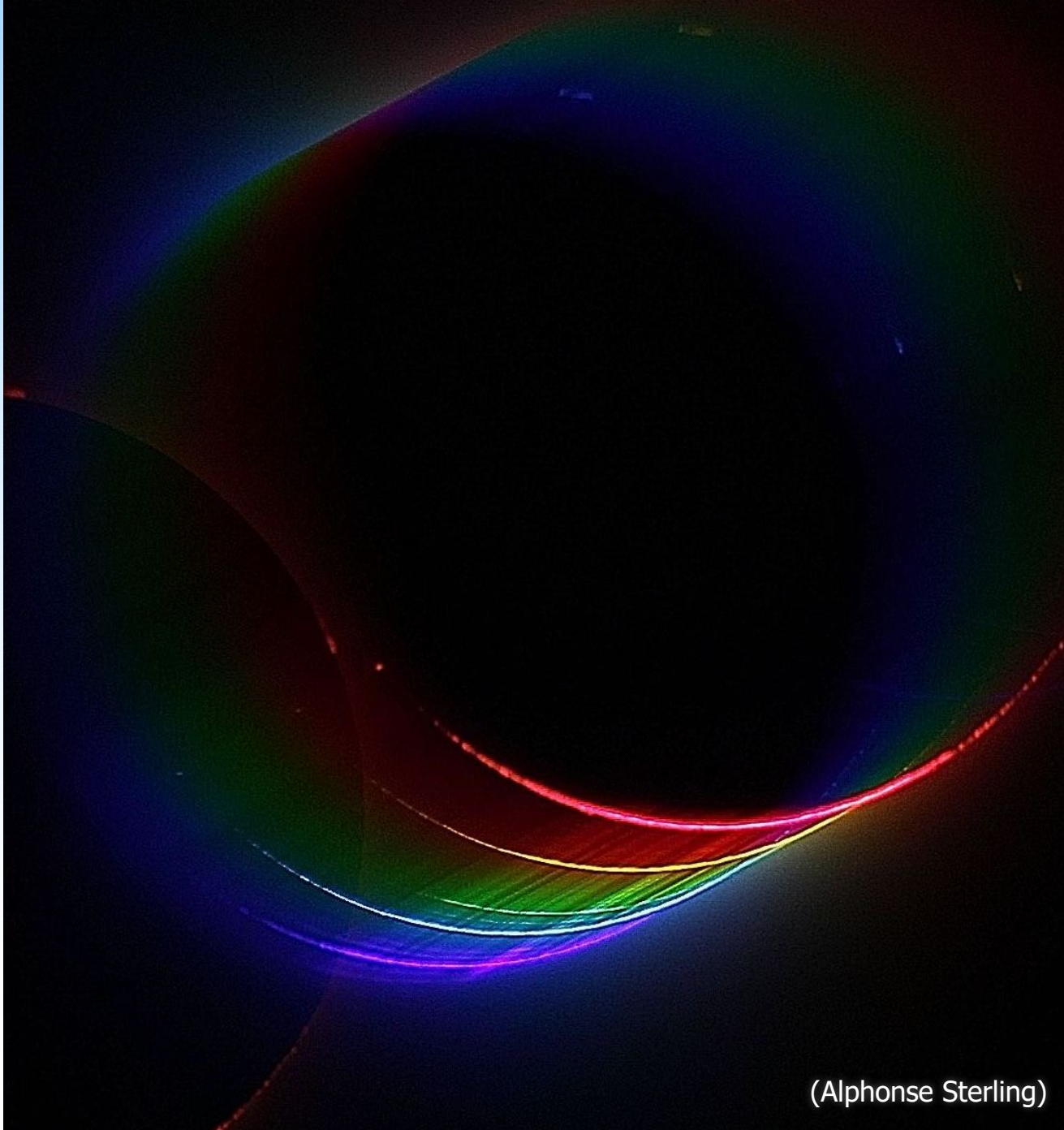
- Hence, spectra can be used to determine the composition of far-away objects, like the corona.

Interlude: “Flash spectrum” from the 2017 USA total solar eclipse

◆ Normal spectrograph:



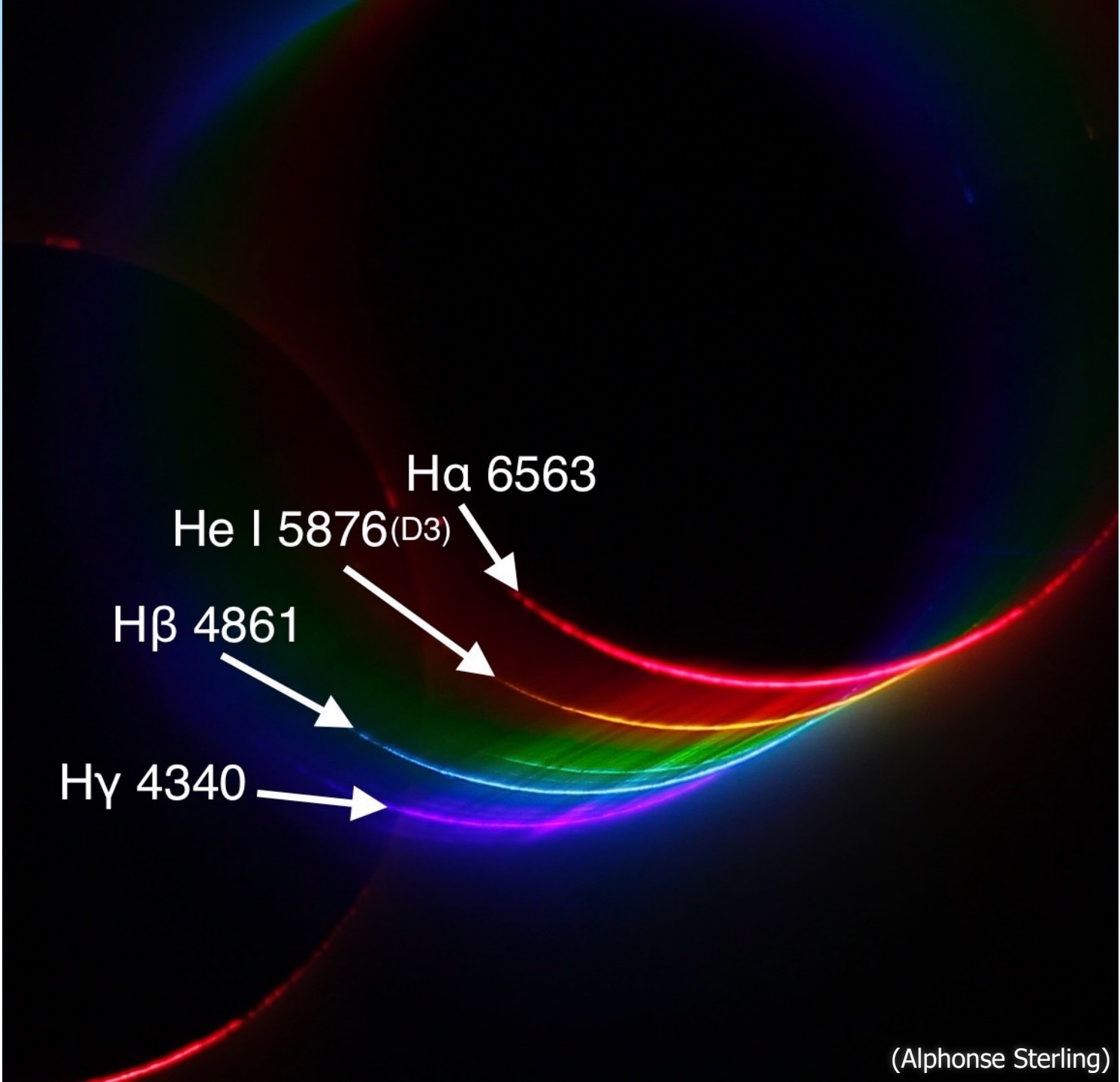
- ◆ In this case, let the Moon be the slit!
- ◆ Diffraction grating in front of a DSLR.
- ◆ (The “Star analyser,” SA-100; Canon DSLR.)



(Alphonse Sterling)

The Corona

- Expected to be cool, but found strange spectral lines, first during 1869 eclipse.



A photograph of a star's spectrum showing several prominent emission lines. The lines are curved and colored, with red at the top and blue/purple at the bottom. White arrows point from text labels to specific lines.

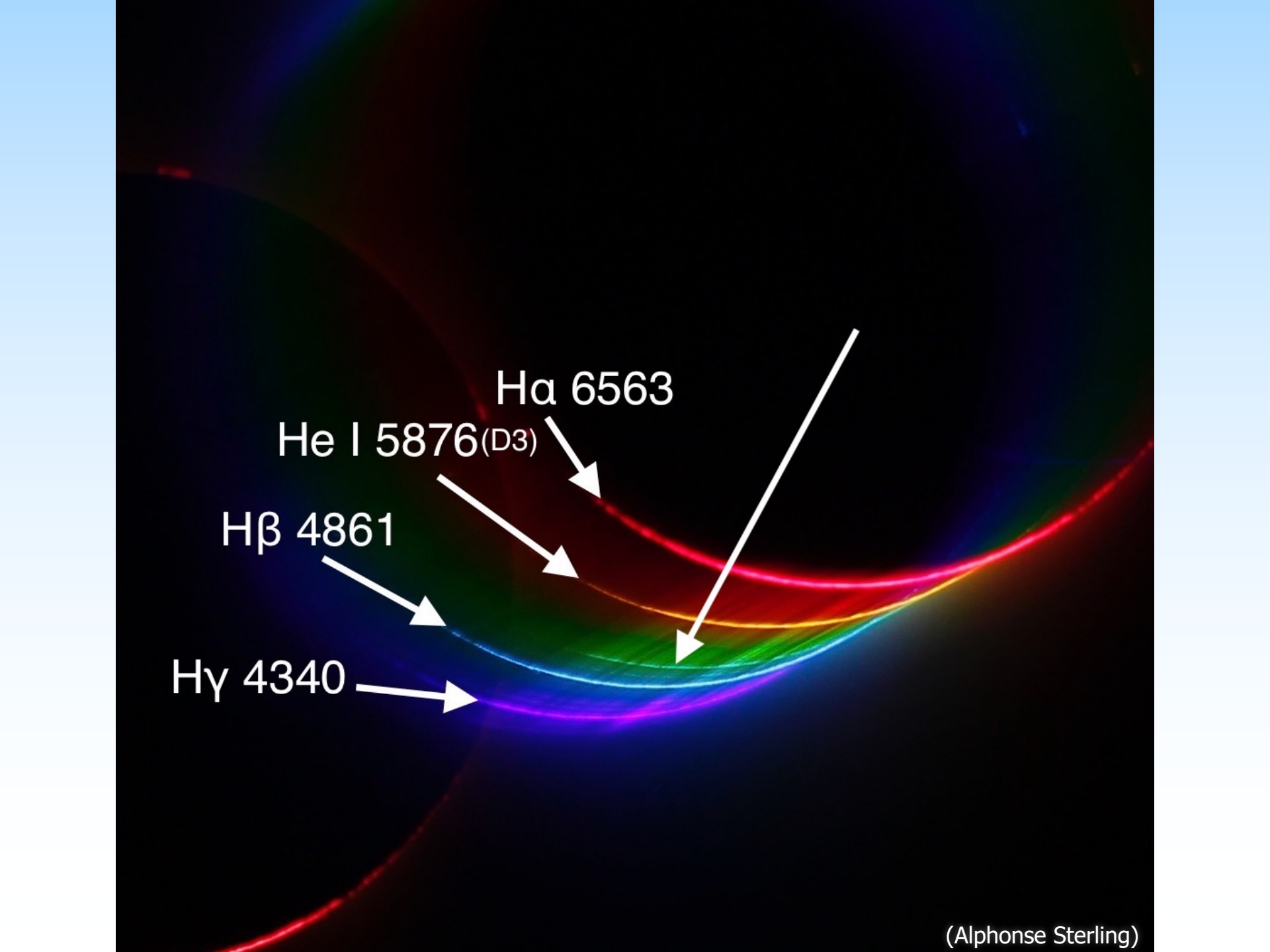
H α 6563

He I 5876_(D3)

H β 4861

H γ 4340

(Alphonse Sterling)



A photograph of a nebula's emission spectrum, showing several distinct, curved lines of light against a dark background. The lines are color-coded: red for the longest wavelength, followed by orange, yellow, green, blue, and purple for the shortest wavelength. White arrows point from text labels to specific lines.

H α 6563

He I 5876(D3)

H β 4861

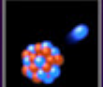
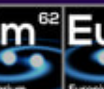
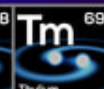
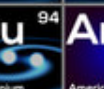
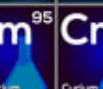
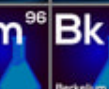
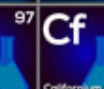
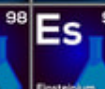
H γ 4340

(Alphonse Sterling)

The Corona

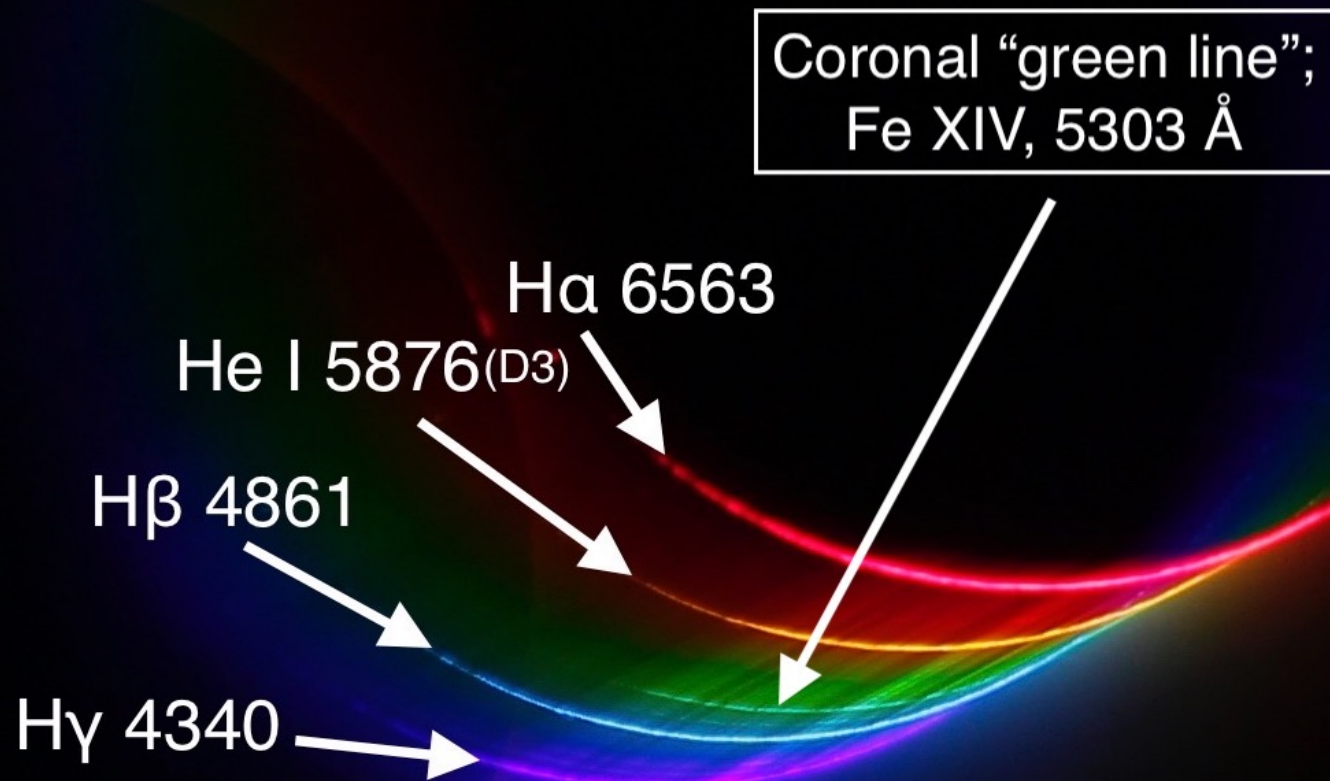
- Expected to be cool, but found strange spectral lines, first during 1869 eclipse.
- Many explanations considered, including a “new” element: *coronium*.
- **But this didn't work....**

ORIGINS OF THE ELEMENTS

H1 Hydrogen	 The big bang  Dying low-mass stars  White dwarf supernovae  Radioactive decay																He2 Helium																
Li3 Lithium	Be4 Beryllium																	B5 Boron	C6 Carbon	N7 Nitrogen	O8 Oxygen	F9 Fluorine	Ne10 Neon										
Na11 Sodium	Mg12 Magnesium	 Cosmic ray collisions  Dying high-mass stars  Merging neutron stars  Human-made																Al13 Aluminum	Si14 Silicon	P15 Phosphorus	S16 Sulfur	Cl17 Chlorine	Ar18 Argon										
K19 Potassium	Ca20 Calcium	Sc21 Scandium	Ti22 Titanium	V23 Vanadium	Cr24 Chromium	Mn25 Manganese	Fe26 Iron	Co27 Cobalt	Ni28 Nickel	Cu29 Copper	Zn30 Zinc	Ga31 Gallium	Ge32 Germanium	As33 Arsenic	Se34 Selenium	Br35 Bromine	Kr36 Krypton																
Rb37 Rubidium	Sr38 Strontium	Y39 Yttrium	Zr40 Zirconium	Nb41 Niobium	Mo42 Molybdenum	Tc43 Technetium	Ru44 Ruthenium	Rh45 Rhodium	Pd46 Palladium	Ag47 Silver	Cd48 Cadmium	In49 Indium	Sn50 Tin	Sb51 Antimony	Te52 Tellurium	I53 Iodine	Xe54 Xenon																
Cs55 Cesium	Ba56 Barium																	Hf72 Hafnium	Ta73 Tantalum	W74 Tungsten	Re75 Rhenium	Os76 Osmium	Ir77 Iridium	Pt78 Platinum	Au79 Gold	Hg80 Mercury	Tl81 Thallium	Pb82 Lead	Bi83 Bismuth	Po84 Polonium	At85 Astatine	Rn86 Radon	
Fr87 Francium	Ra88 Radium																	Rf104 Rutherfordium	Db105 Dubnium	Sg106 Seaborgium	Bh107 Bohrium	Hs108 Hassium	Mt109 Meitnerium	Ds110 Darmstadtium	Rg111 Roentgenium	Cn112 Copernicium	Nh113 Nihonium	Fl114 Flerovium	Mc115 Moscovium	Lv116 Livermorium	Ts117 Tennessine	Og118 Oganesson	
																		 Lanthanum  Cerium  Praseodymium  Neodymium  Promethium  Samarium  Europium  Gadolinium  Terbium  Dysprosium  Holmium  Erbium  Thulium  Ytterbium Lutetium															
																		 Actinium  Thorium  Protactinium  Uranium  Neptunium  Plutonium  Americium  Curium  Berkelium  Californium  Einsteinium  Fermium  Mendelevium  Nobelium Lawrencium															

This periodic table depicts the primary source on Earth for each element. In cases where two sources contribute fairly equally, both appear.

NASA's Goddard Space Flight Center From: <https://svs.gsfc.nasa.gov/13873/>

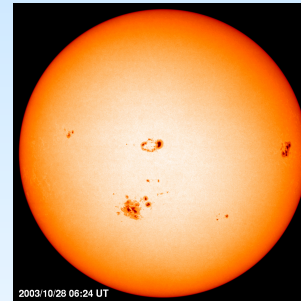


- The mystery spectral lines were assumed to be due to a new element, “*coronium*.” But it would not fit on the periodic table, and so the mystery persisted for decades.
- They were found to be due to very hot (“highly-ionized”) familiar elements ~1940.
- The implication is that the corona is very hot, compared to the photosphere; $\gtrsim 1$ MK cf. 6000 K.

What's Special About a Solar Eclipse?

Can see the outer layers (Atmospheres) of the Sun:

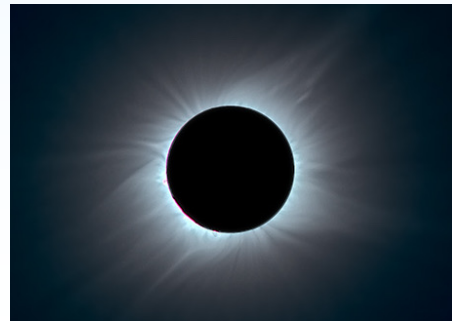
- Photosphere
(6000 K)



- Chromosphere
(~10,000 K)

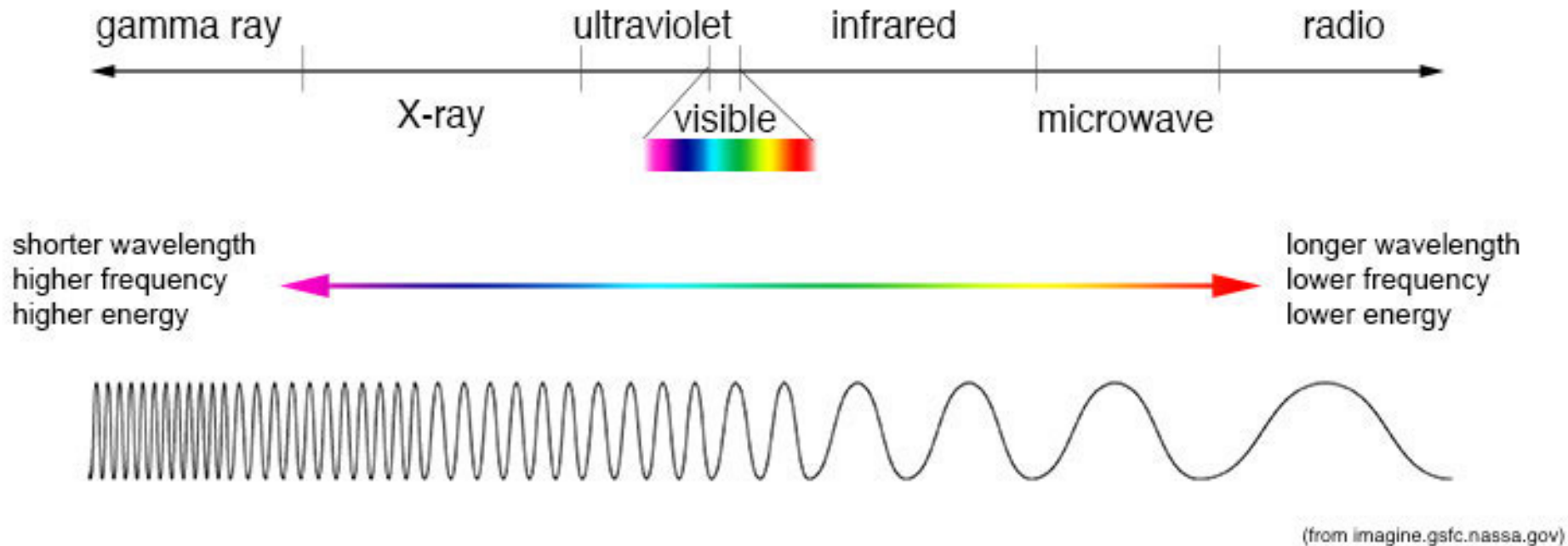


- Corona
(~1-3 MK)



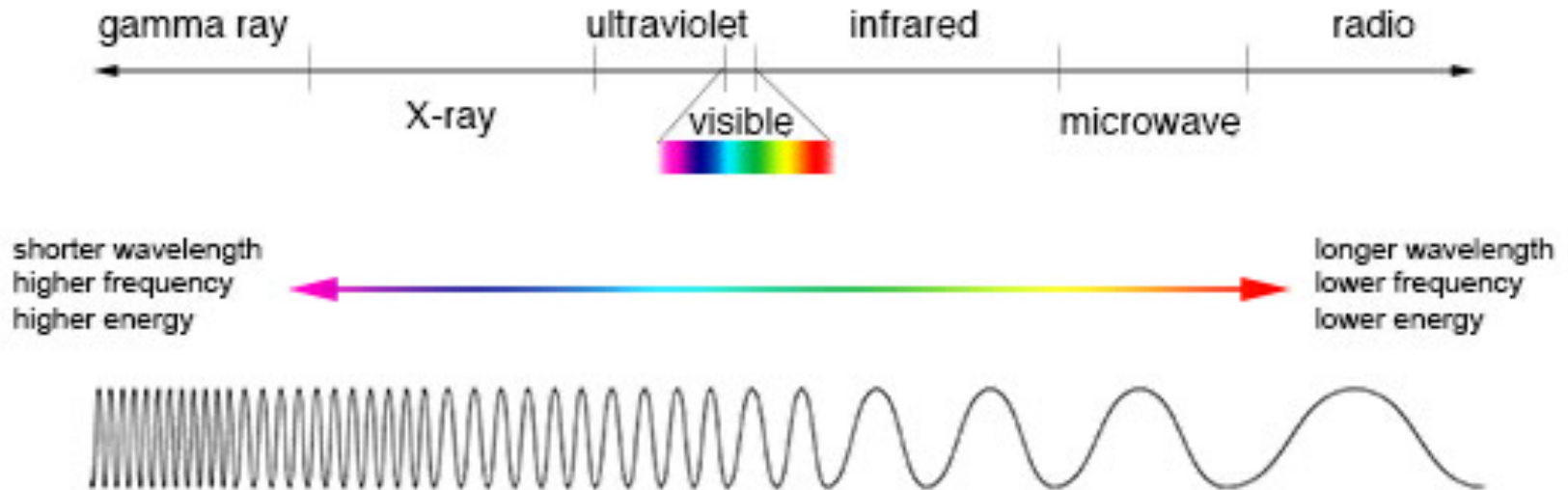
We have to go to *space* to see the Sun's outer atmosphere with regularity.

The Electromagnetic Spectrum

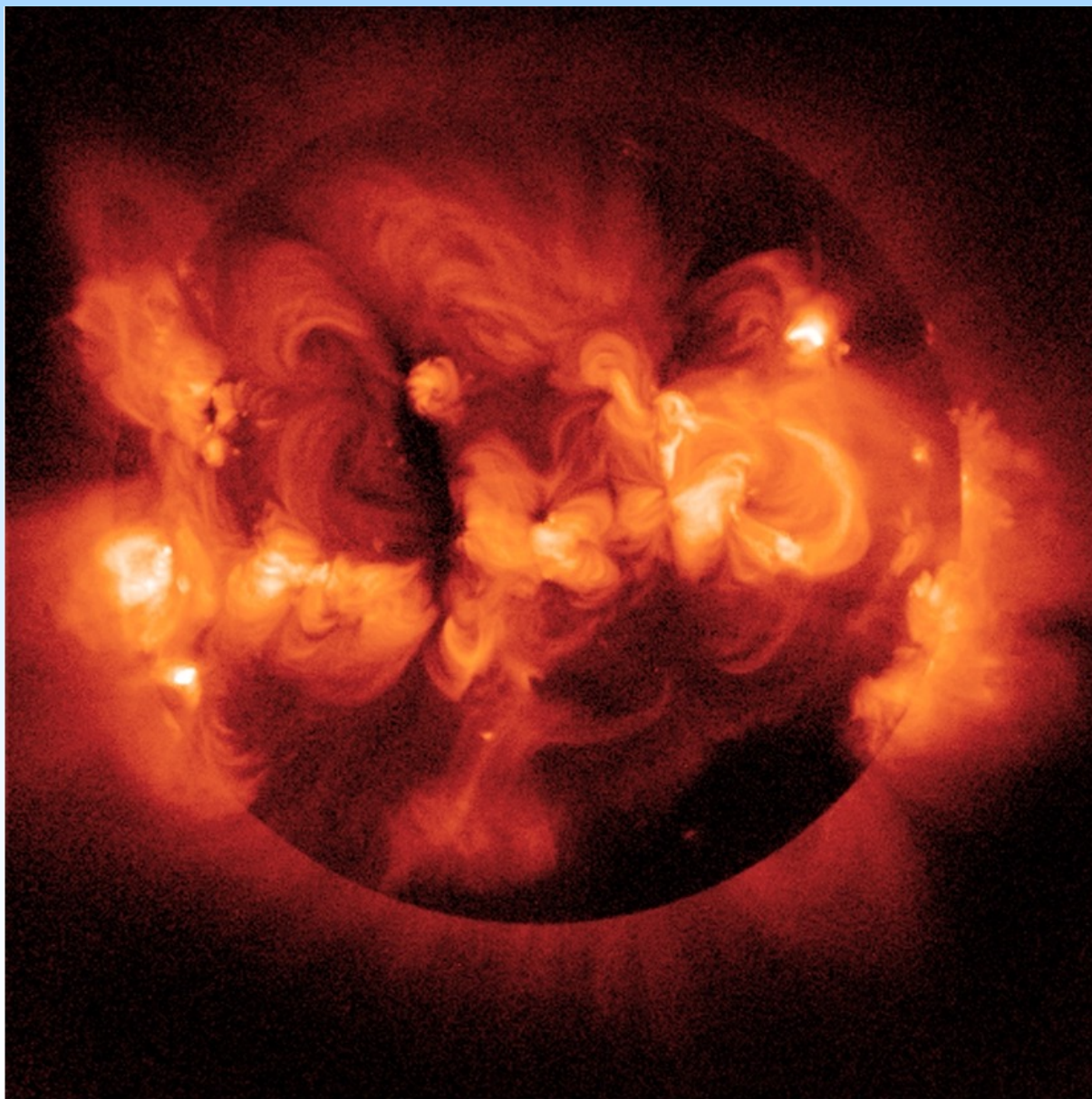


We have to go to *space* to see the Sun's outer atmosphere with regularity.

The Electromagnetic Spectrum

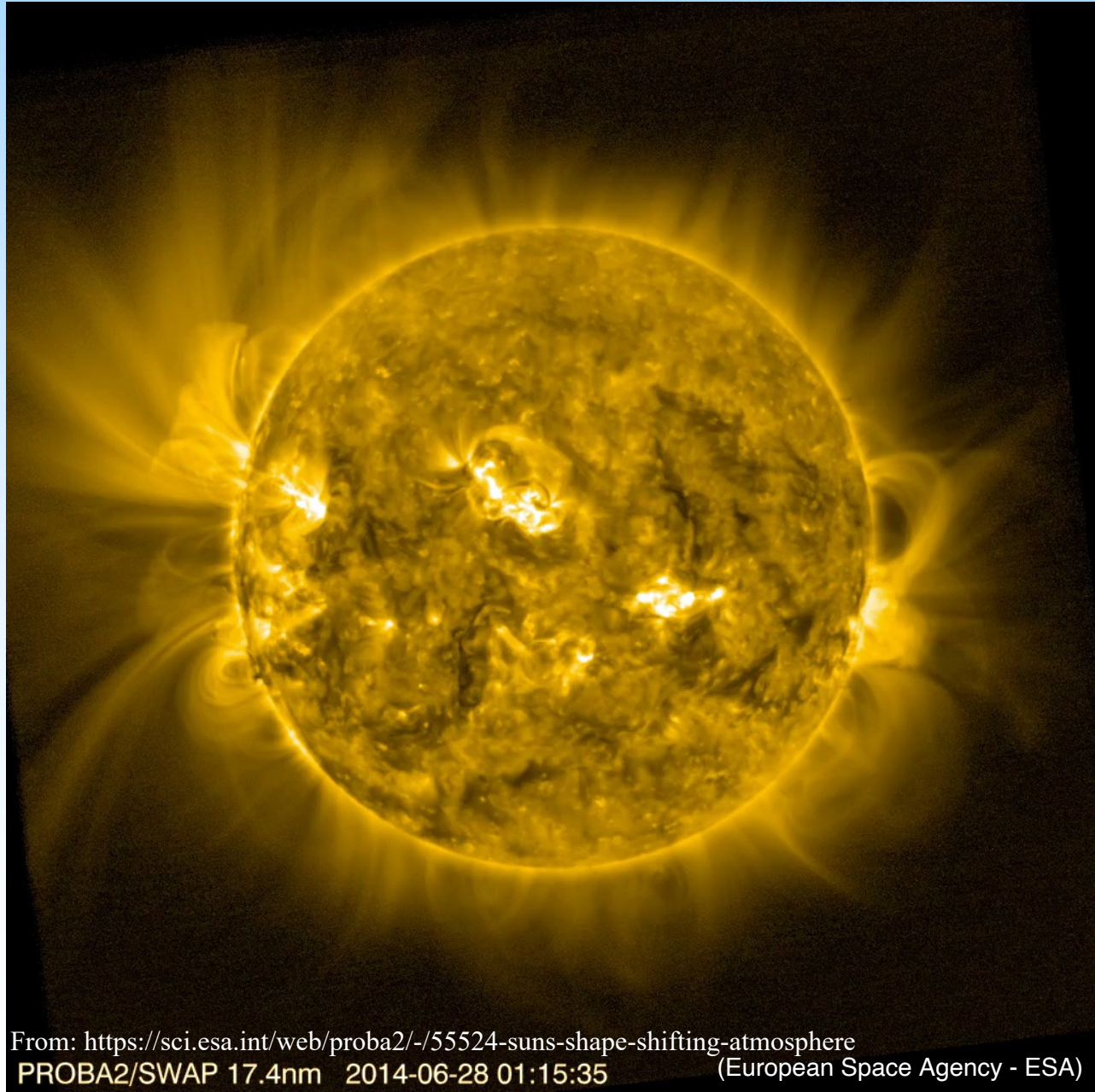


(Credit: NASA's Imagine the Universe - From: <https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html>)



The Corona from Yohkoh/SXT

Courtesy of the Yohkoh Legacy data Archive
(<http://solar.physics.montana.edu/ylegacy>)
at Montana State University.

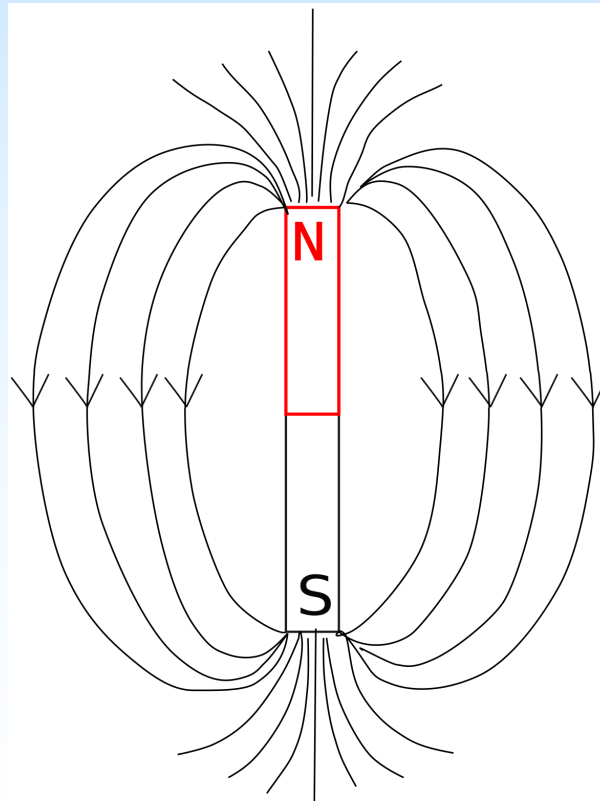


From: <https://sci.esa.int/web/proba2/-/55524-suns-shape-shifting-atmosphere>
PROBA2/SWAP 17.4nm 2014-06-28 01:15:35 (European Space Agency - ESA)

The Corona: Continued...

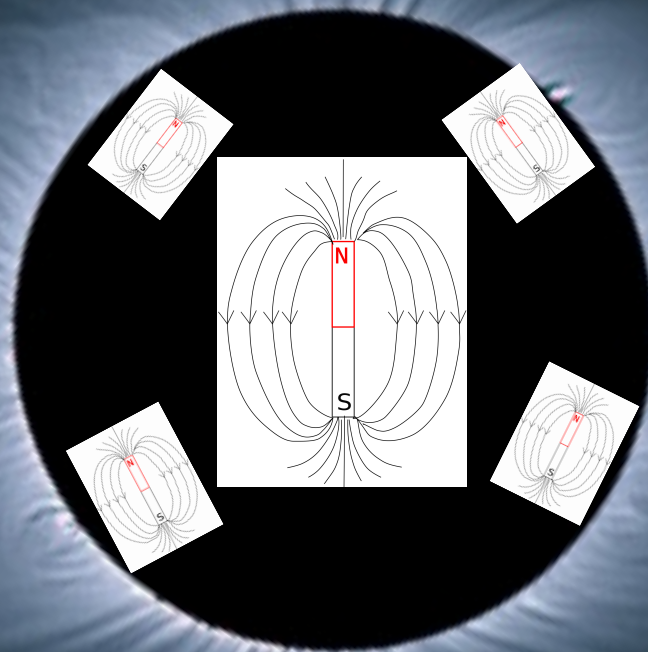
- Structured with loops; late 1960s and 1970s observations from balloons, Skylab, etc.
- This structure due to the Sun's *magnetic field*.

Magnetism is the key to why the corona is hot. (It is also responsible for many of the changing features of the Sun.)





(Alphonse Sterling 2008, China)



Examples of Current-day Eclipse Science Studies

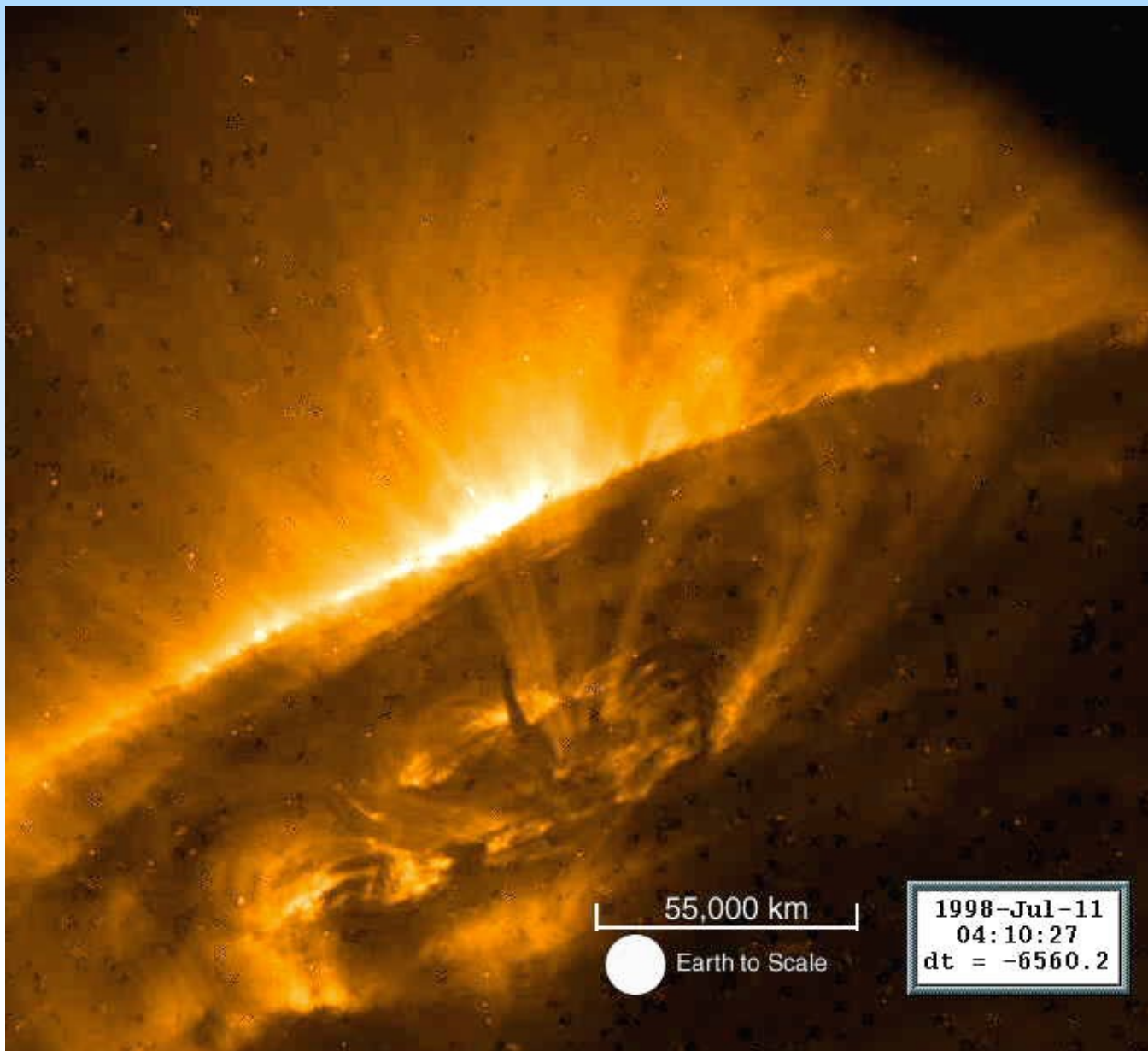
- Studies looking for coronal heating mechanism; e.g., high-cadence imaging looking for waves.
- Looking at the corona in “new ways” (different spectral ranges).
- Studies of coronal structures, such as polar plumes.
- Testing of new corona-observing equipment, perhaps for later use on satellites.
- Characterization of optics (can do with annular also).
- Several studies of the Earth’s ionosphere (e.g., “SuperDARN” radars).

Summary of Eclipse Science

- Solar eclipses offer a special opportunity to undertake specialized studies, but for a limited period of time.
- Helped to establish Einstein's General Theory of Relativity.
- Led to realization that the corona is much hotter than the Sun's surface.
- Coronal and other solar studies are continuing with nearly every total solar eclipse. Generally tuned to investigations not otherwise available currently.
- Additional investigations include the Earth's ionosphere, and other studies such as animal behavior.

Image:
Alphonse Sterling
21 August 2017,
Lewisville, Idaho

Solar Eruptions

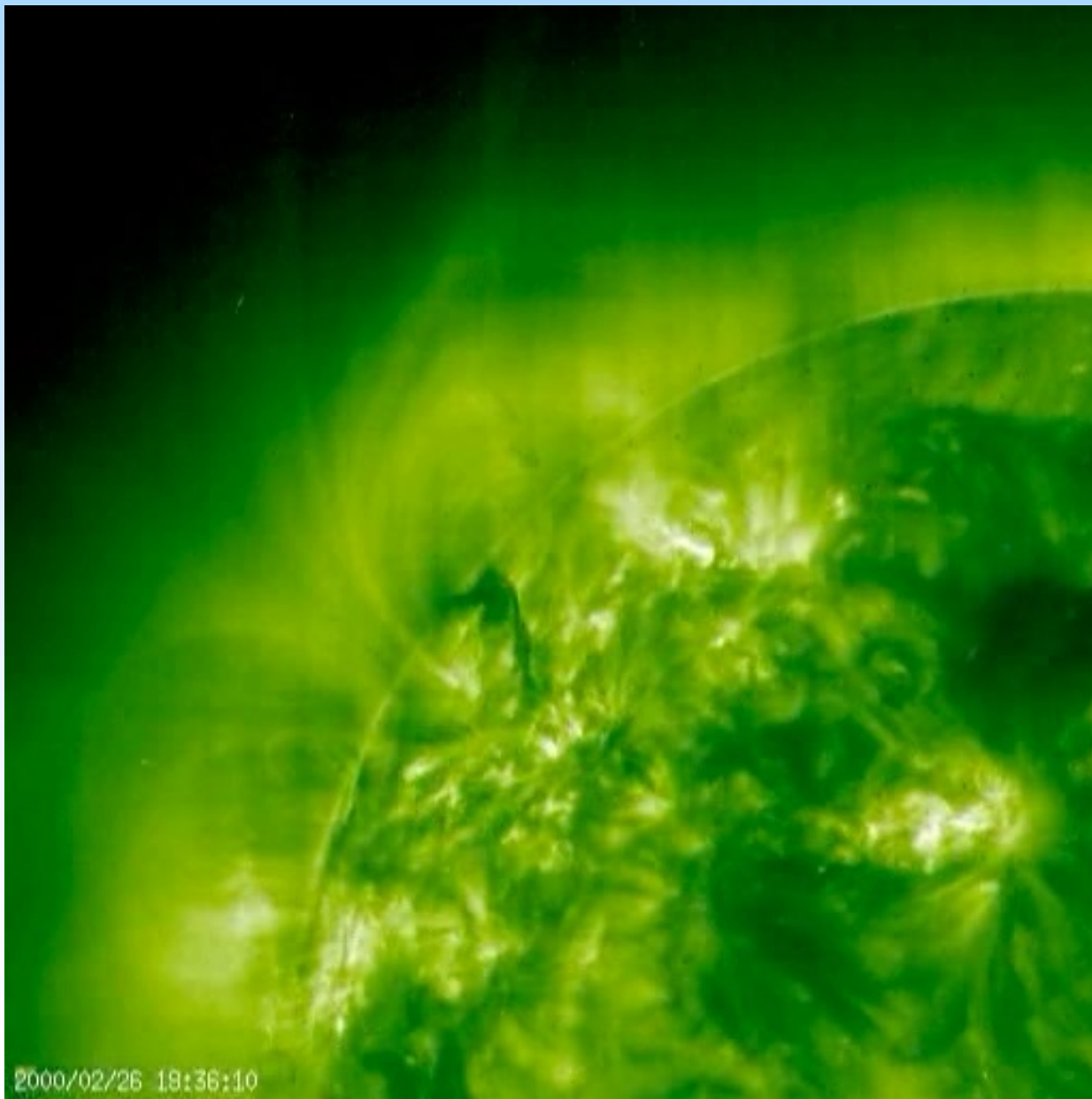


55,000 km

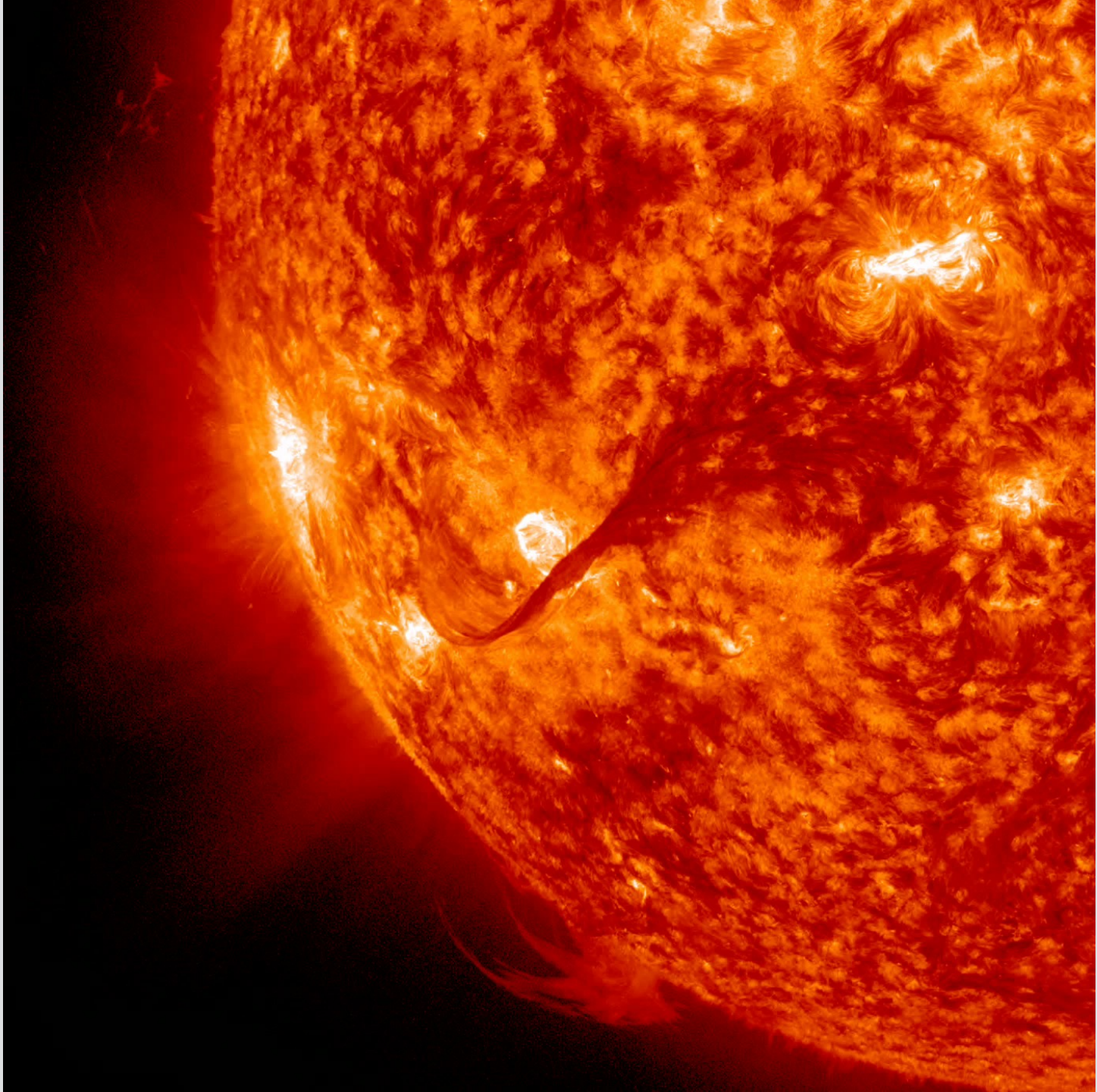


Earth to Scale

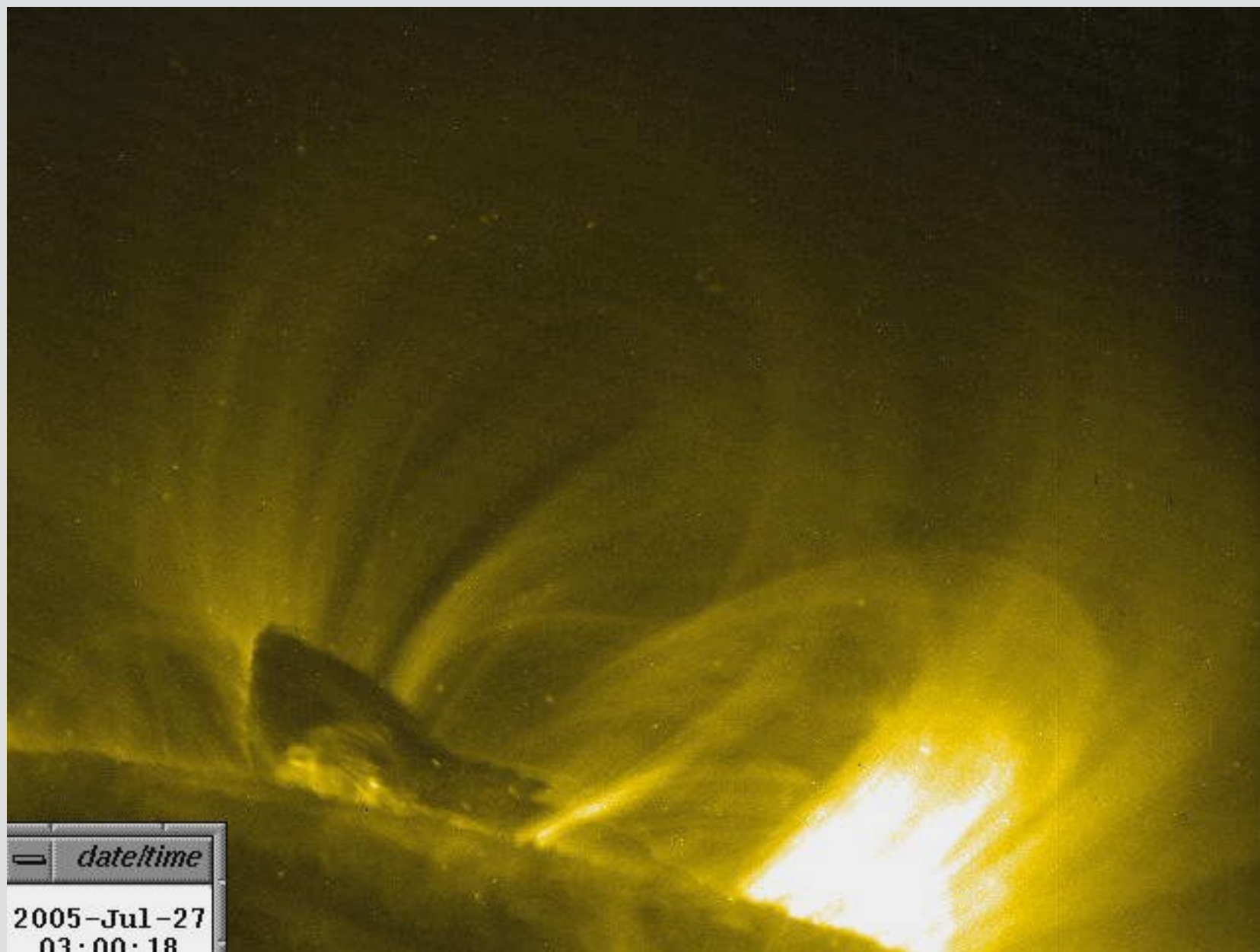
1998-Jul-11
04:10:27
dt = -6560.2

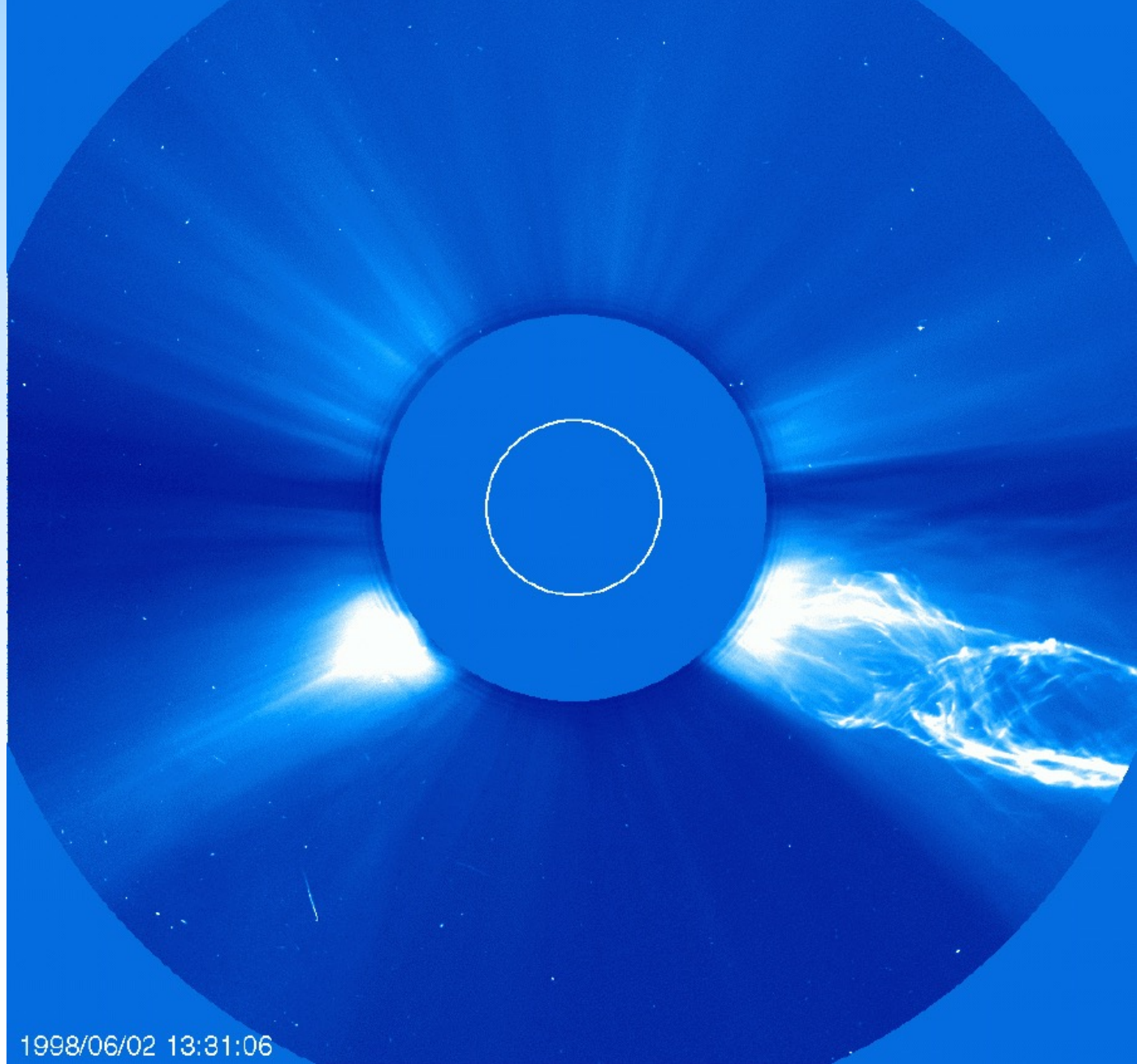


(Sterling & Moore 2004)

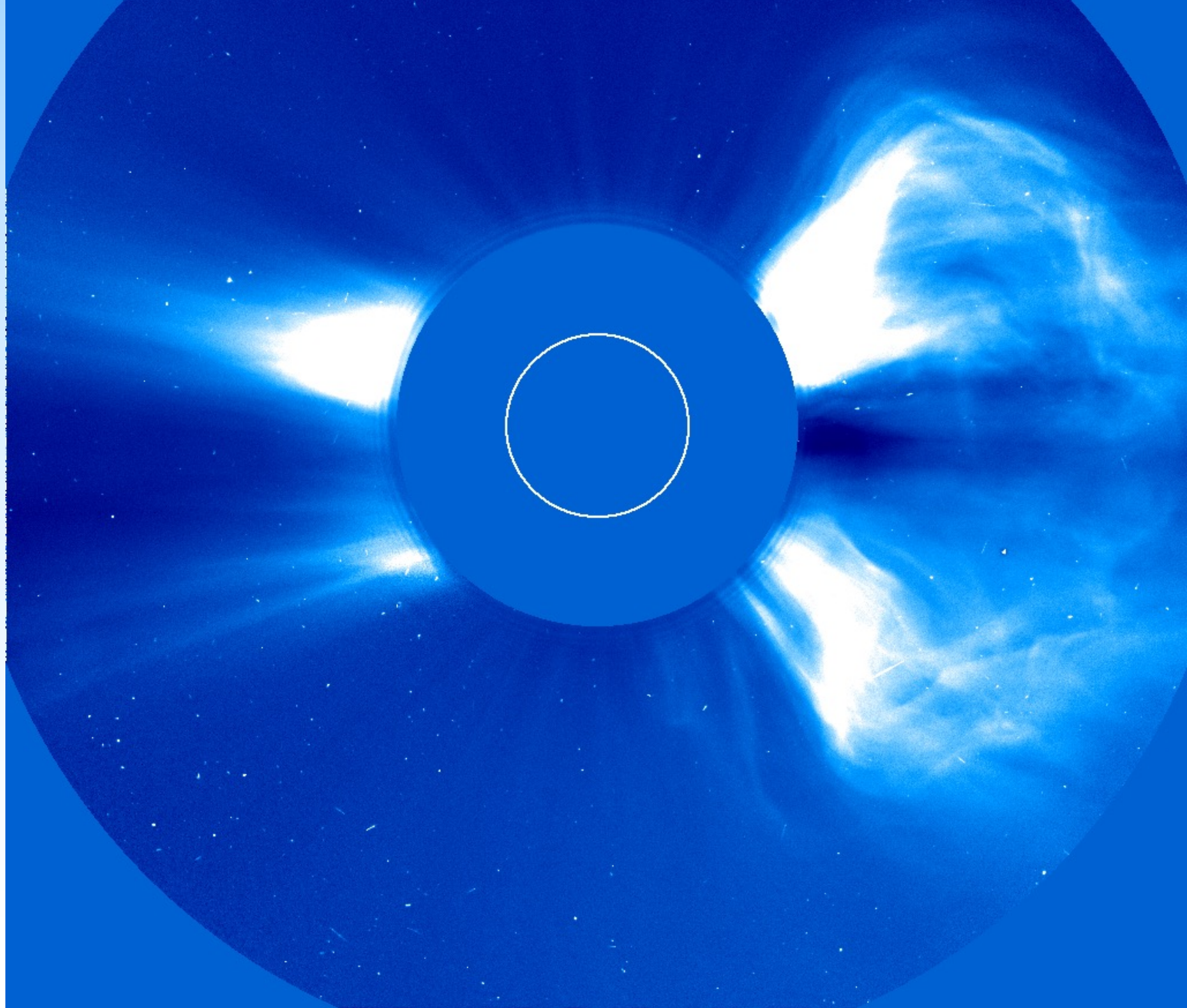


(TRACE 171)

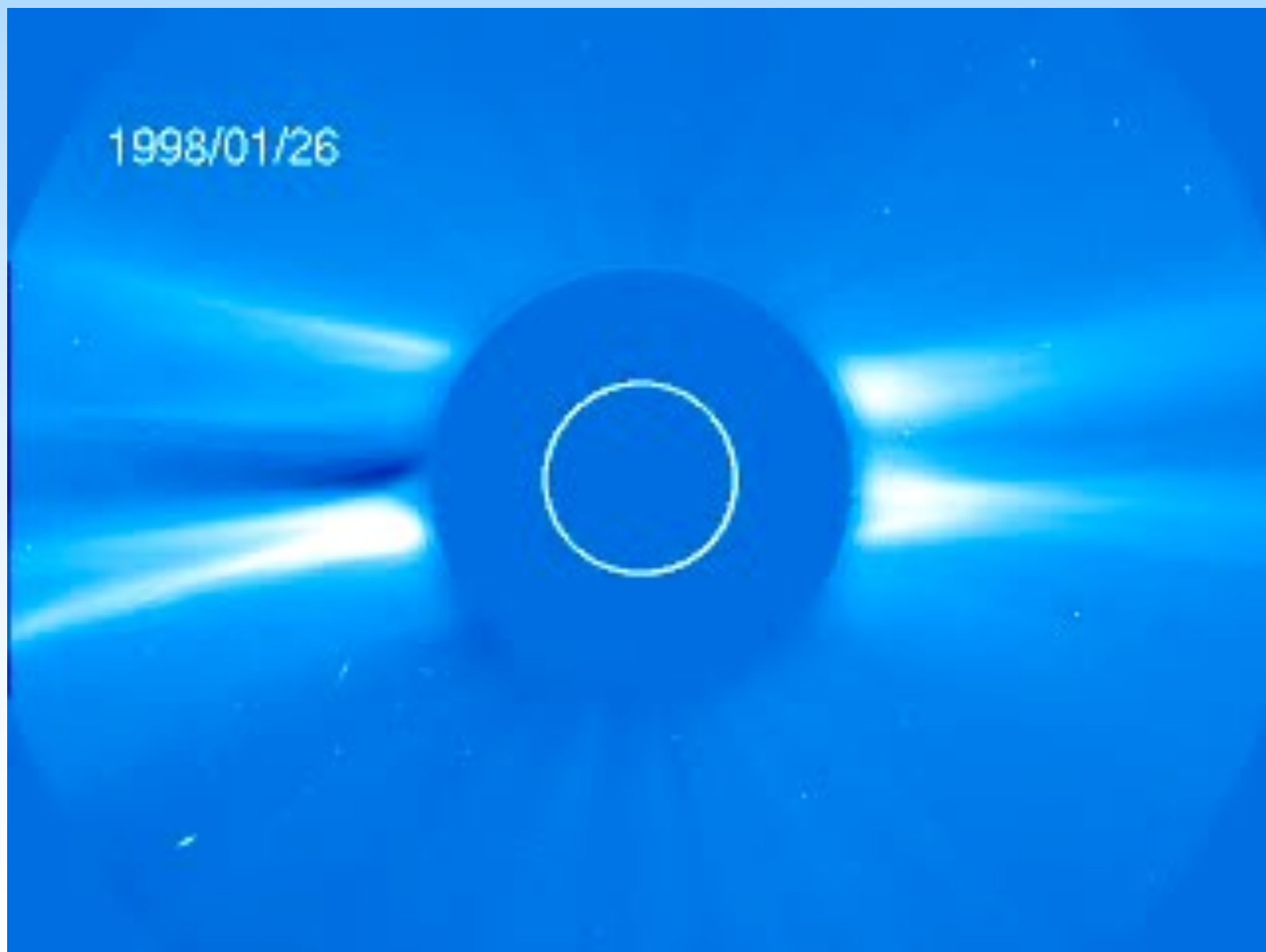




1998/06/02 13:31:06



1998/01/26



Reserve Slides



(A. Sterling, Idaho)

Annular Eclipse: 2023 October 14, Harper, Texas



(A. Sterling, Texas 2023)



(A. Sterling, Texas 2023)



(A. Sterling, Texas 2023)



(A. Sterling, Texas 2023)



(A. Sterling, Texas 2023)



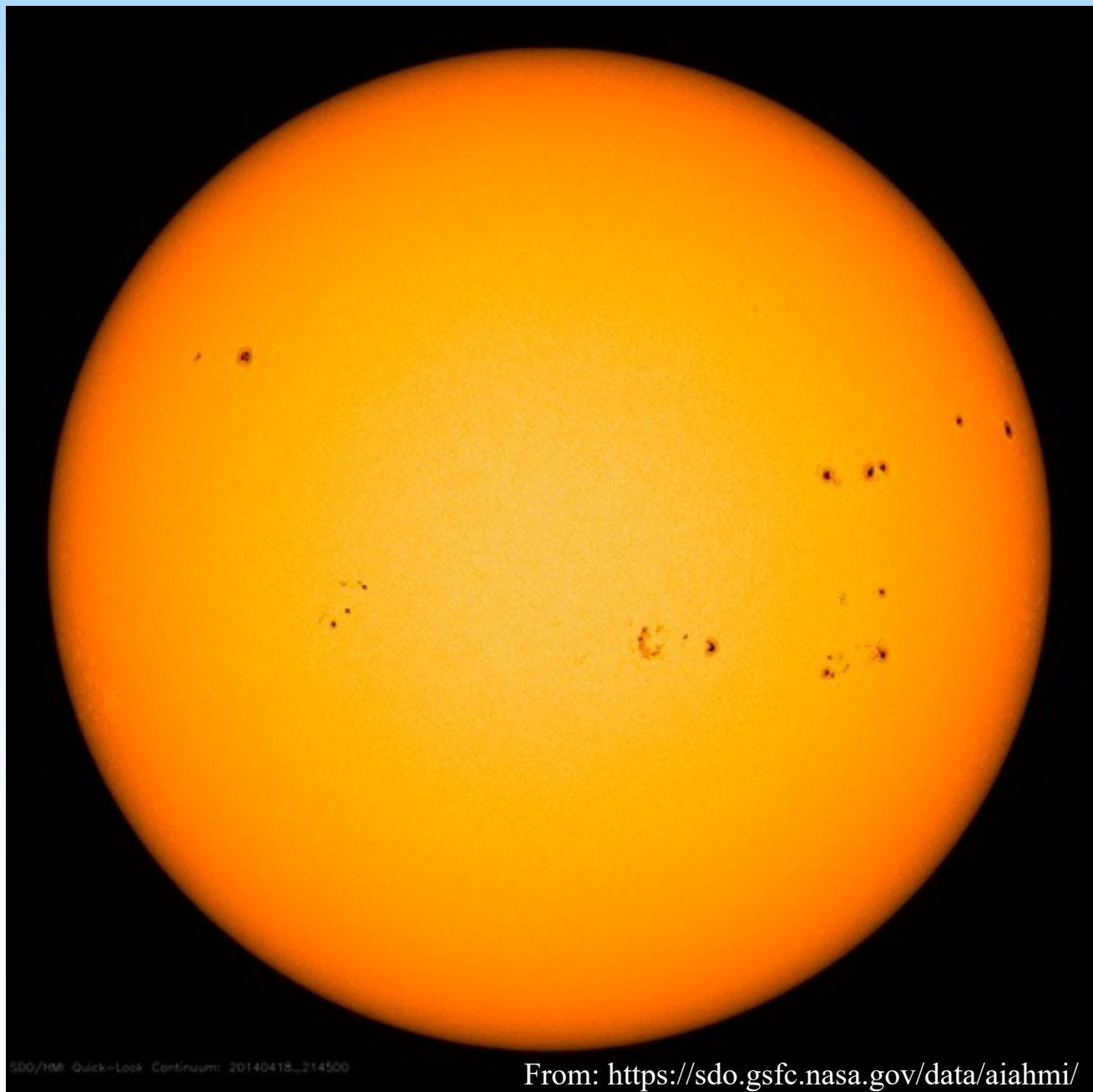
(A. Sterling, Texas 2023)



20 May 2012 22:37:33+-5s UT
FSQ106ED f/5, EM11, EOS500D, 100, 1/250
ISAS, Sagamihara, Kanagawa, Japan
Alphonse Sterling

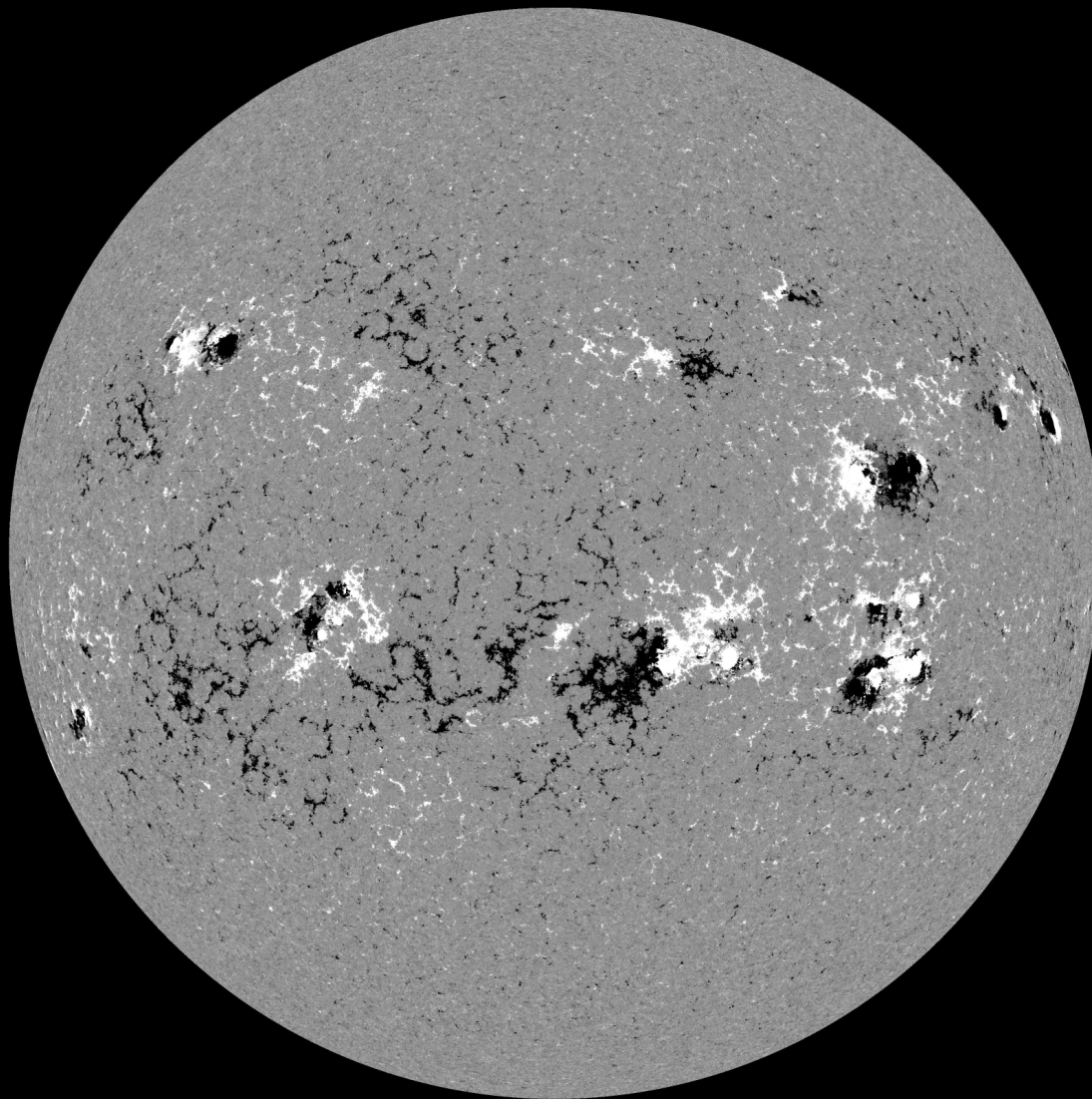


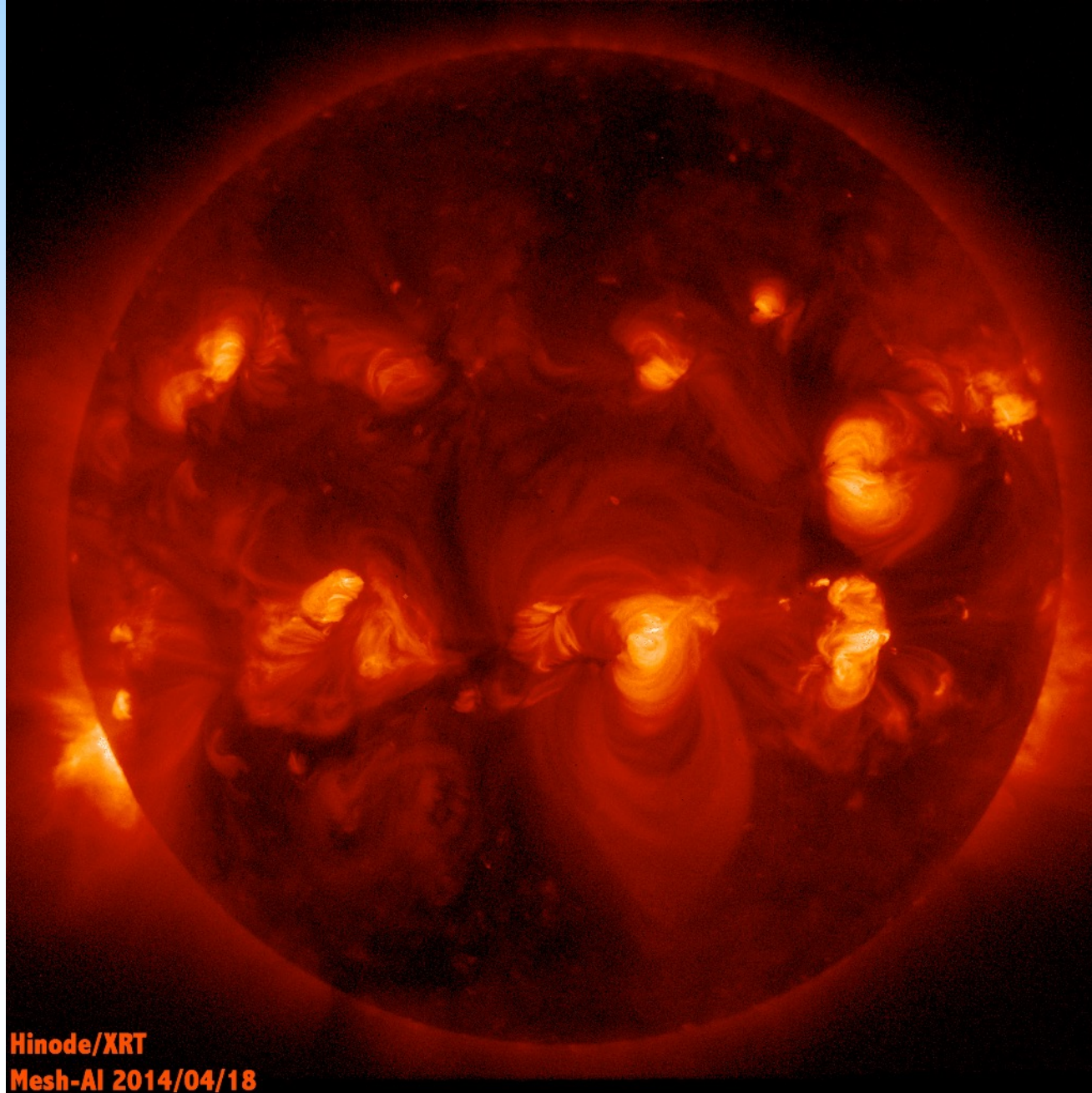
20 May 2012 22:34:57+-5s UT
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ISAS, Sagamihara, Kanagawa, Japan
Alphonse Sterling



SDO/HMI Quick-Look Continuum: 20140418_214500

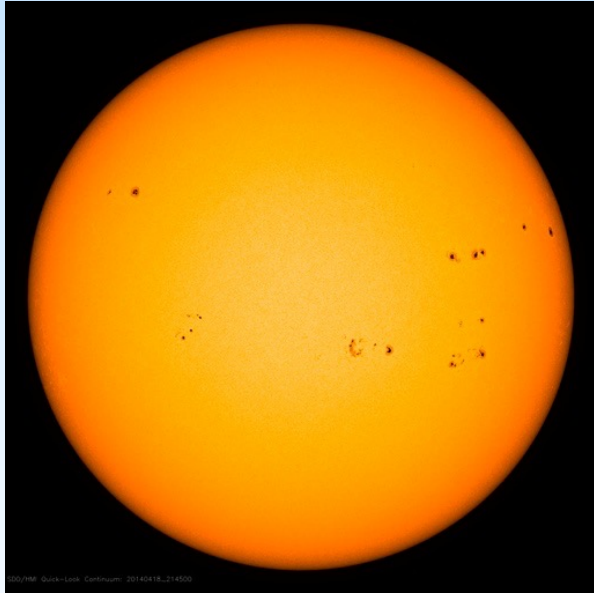
From: <https://sdo.gsfc.nasa.gov/data/aiahmi/>



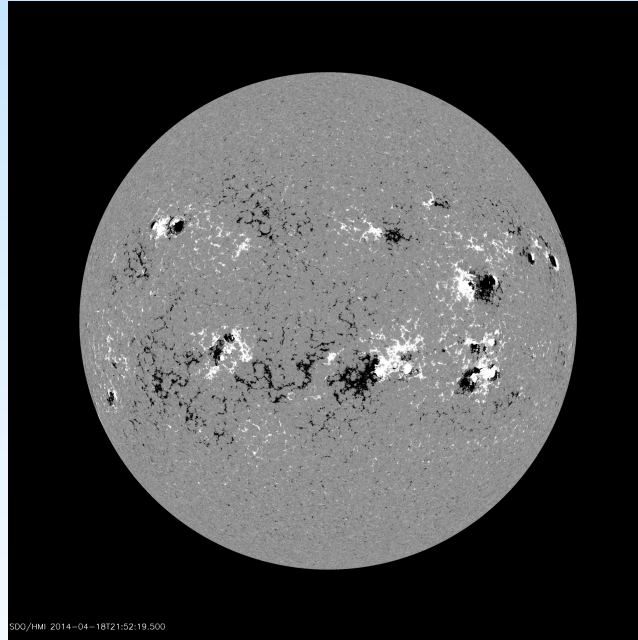


Hinode/XRT

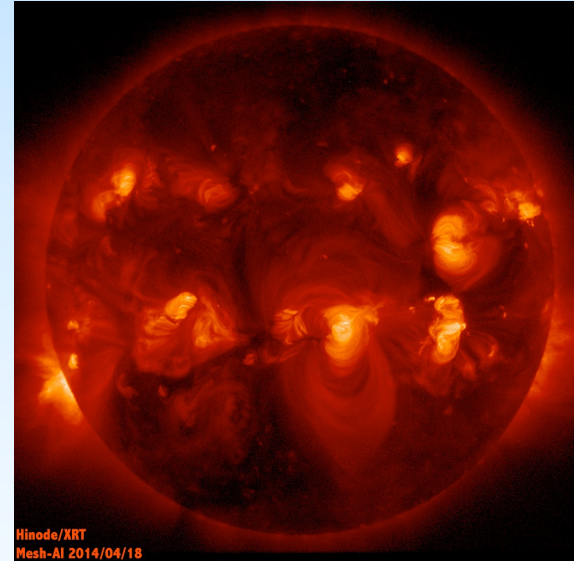
Mesh-AI 2014/04/18



SDO/HMI Sun-Look Continuum 20140418_214500



SDO/HMI 2014-04-18T21:52:19.500



Hinode/XRT
Mesh-AI 2014/04/18