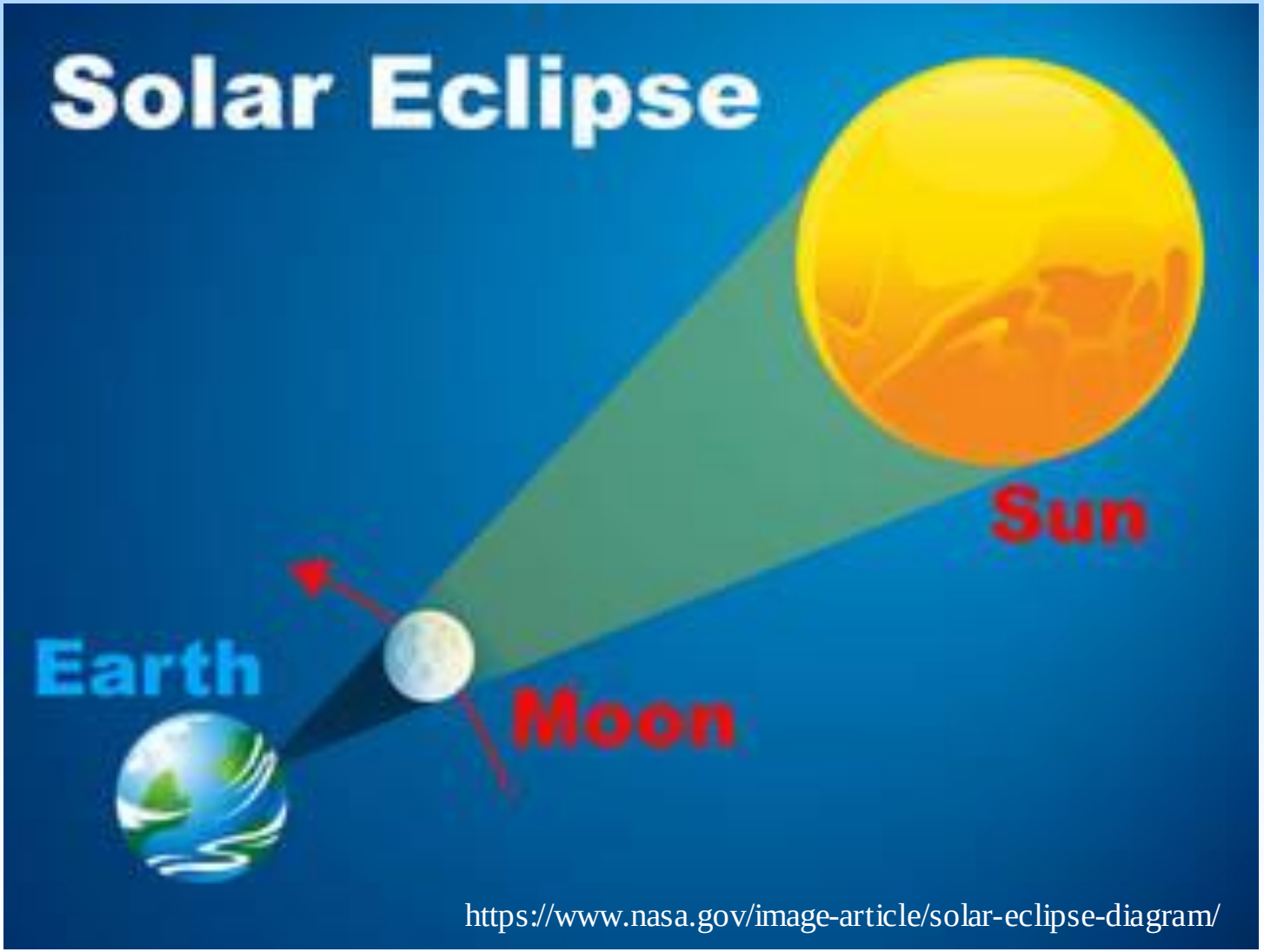
Total Solar Eclipse 2024

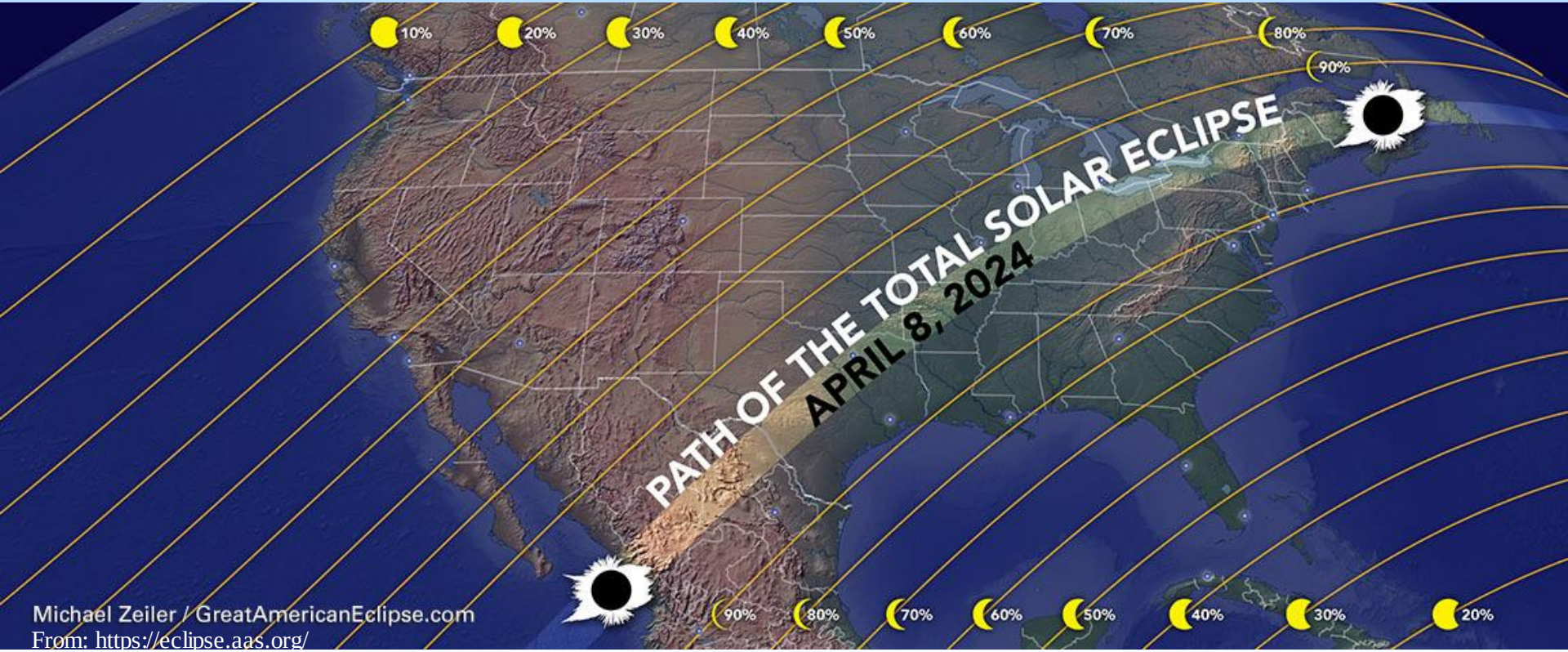
Alphonse Sterling
NASA/MSFC

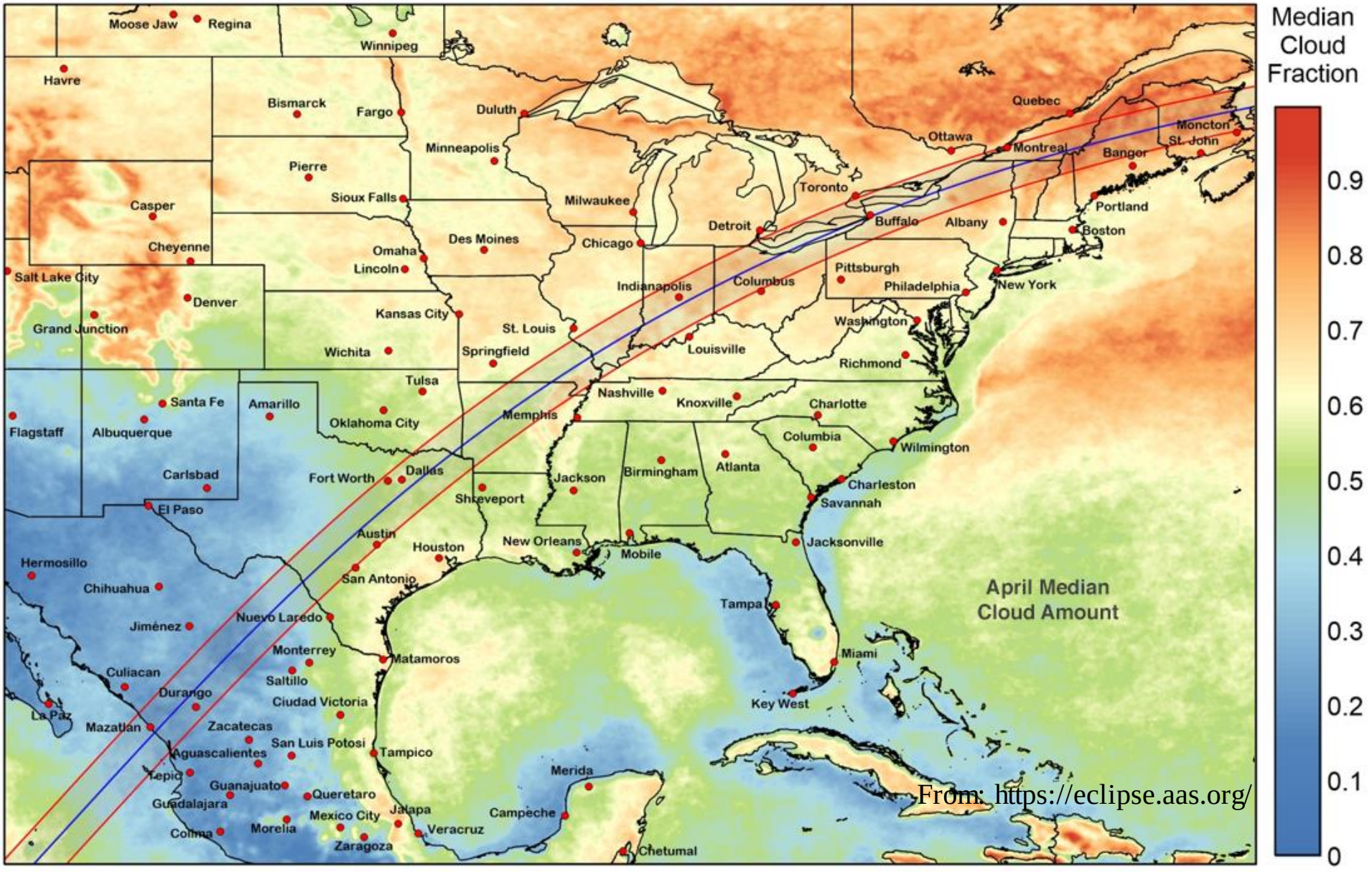
What are Eclipses?

One celestial body falls into the shadow of another.

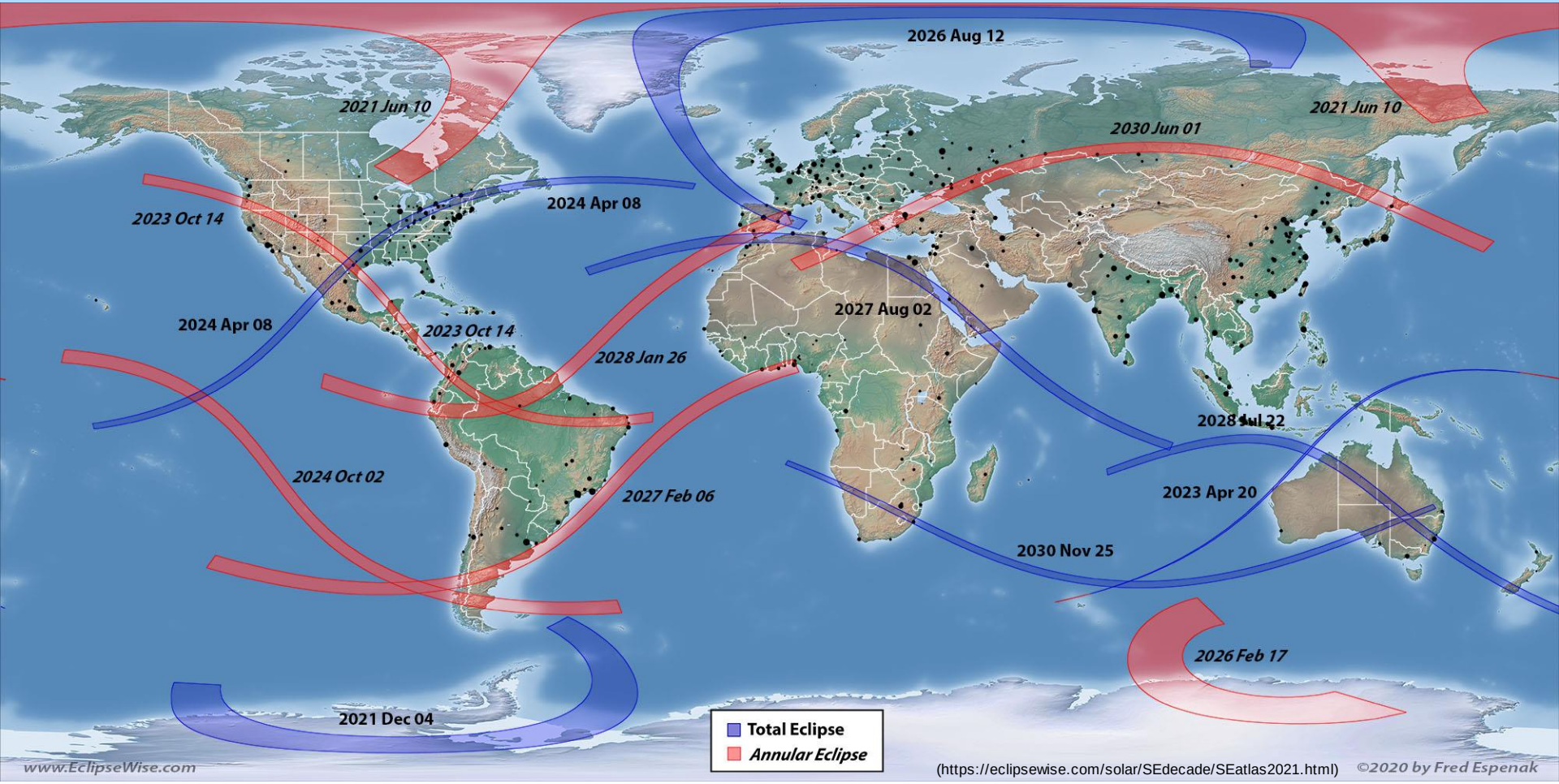


https://www.nasa.gov/image-article/solar-eclipse-diagram/


10%
20%
30%
40%
50%
60%
70%
80%
90%
PATH OF THE TOTAL SOLAR ECLIPSE
APRIL 8, 2024
Michael Zeiler / GreatAmericanEclipse.com
From: https://eclipse.aas.org/


Median Cloud Fraction
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
April Median Cloud Amount
From: https://eclipse.aas.org/
Moose Jaw
Regina
Winnipeg
Havre
Bismarck
Fargo
Duluth
Minneapolis
Pierre
Sioux Falls
Casper
Cheyenne
Des Moines
Omaha
Lincoln
Salt Lake City
Denver
Grand Junction
Kansas City
St. Louis
Wichita
Springfield
Tulsa
Santa Fe
Amarillo
Flagstaff
Albuquerque
Oklahoma City
Carlsbad
Fort Worth
Dallas
El Paso
Austin
Houston
San Antonio
Hermosillo
Chihuahua
Jiménez
Nuevo Laredo
Monterrey
Matamoros
Culiacan
Saltillo
Durango
Ciudad Victoria
La Paz
Mazatlan
Zacatecas
San Luis Potosi
Aguascalientes
Tampico
Tepic
Guanajuato
Queretaro
Guadalajara
Mexico City
Jalapa
Colima
Morelia
Veracruz
Zaragoza
Merida
Campeche
Chetumal
Milwaukee
Chicago
Indianapolis
Louisville
Nashville
Memphis
Jackson
Shreveport
New Orleans
Mobile
Birmingham
Atlanta
Columbus
Detroit
Toronto
Buffalo
Pittsburgh
Philadelphia
Albany
New York
Washington
Richmond
Knoxville
Charlotte
Columbia
Charleston
Savannah
Wilmington
Jacksonville
Tampa
Miami
Key West
Ottawa
Montreal
Quebec
Moncton
St. John
Bangor
Portland
Boston

Solar Eclipses 2022-2030



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

Viewing Options:

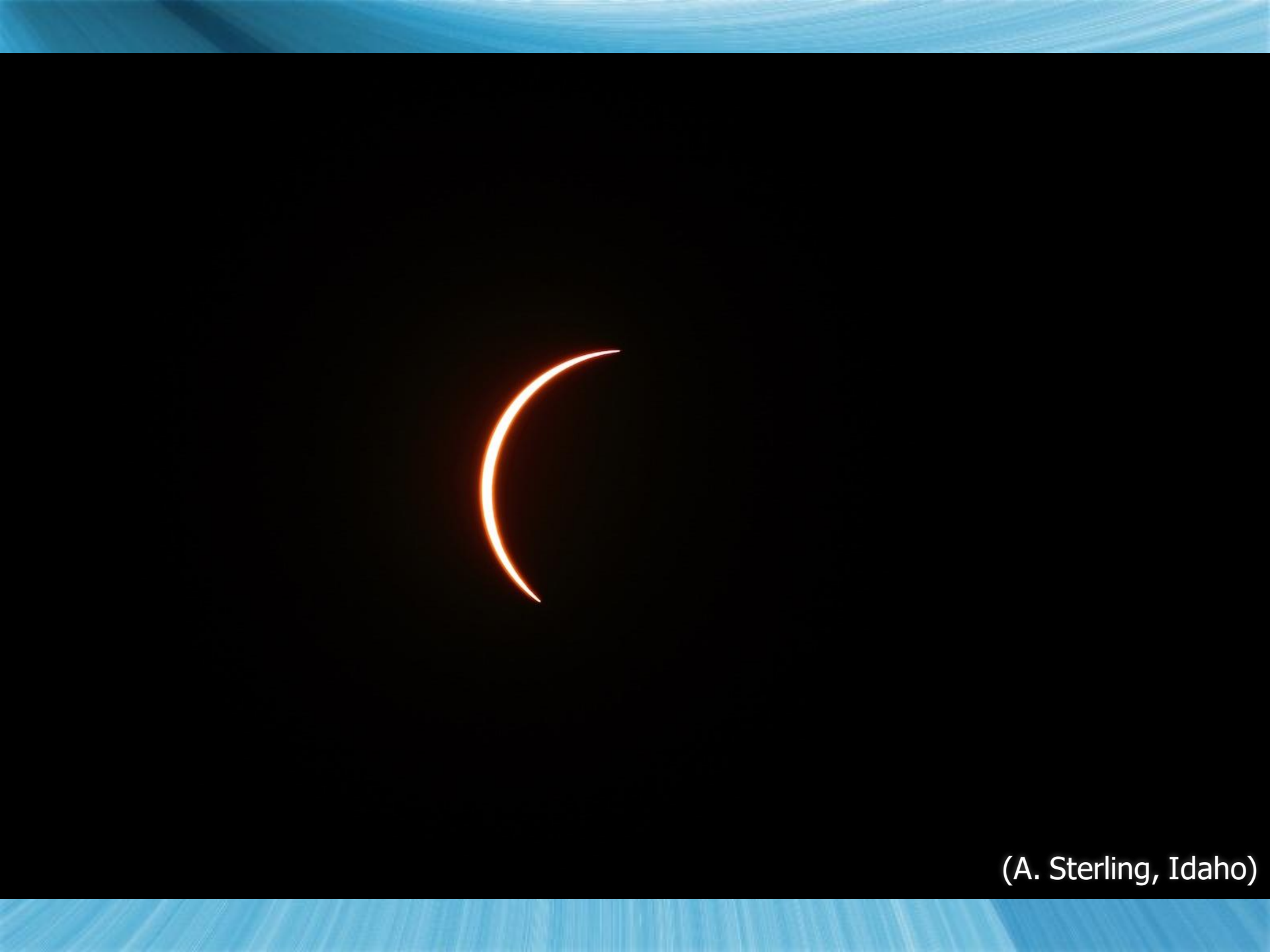
- Eclipse glasses (official ones!)
- Welding glass - shade 14.
- Indirect methods; pinhole camera (two pieces of cardboard/heavy paper). This is the safest method.
- Best to avoid telescopes/binoculars without specific special filters!

What to Expect

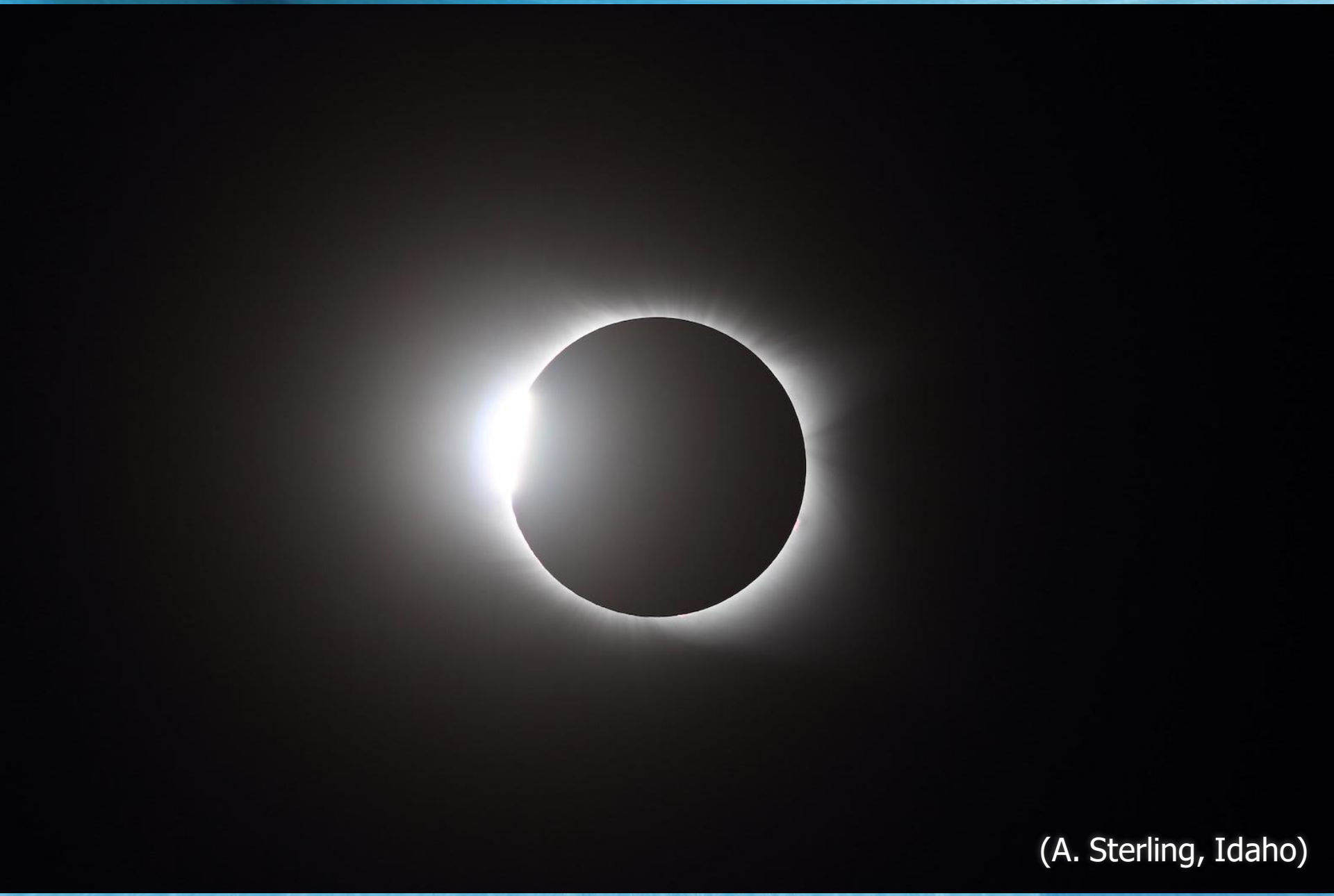
(A. Sterling, Texas 2023)

(A. Sterling, Texas 2023)

(A. Sterling, Texas 2023)

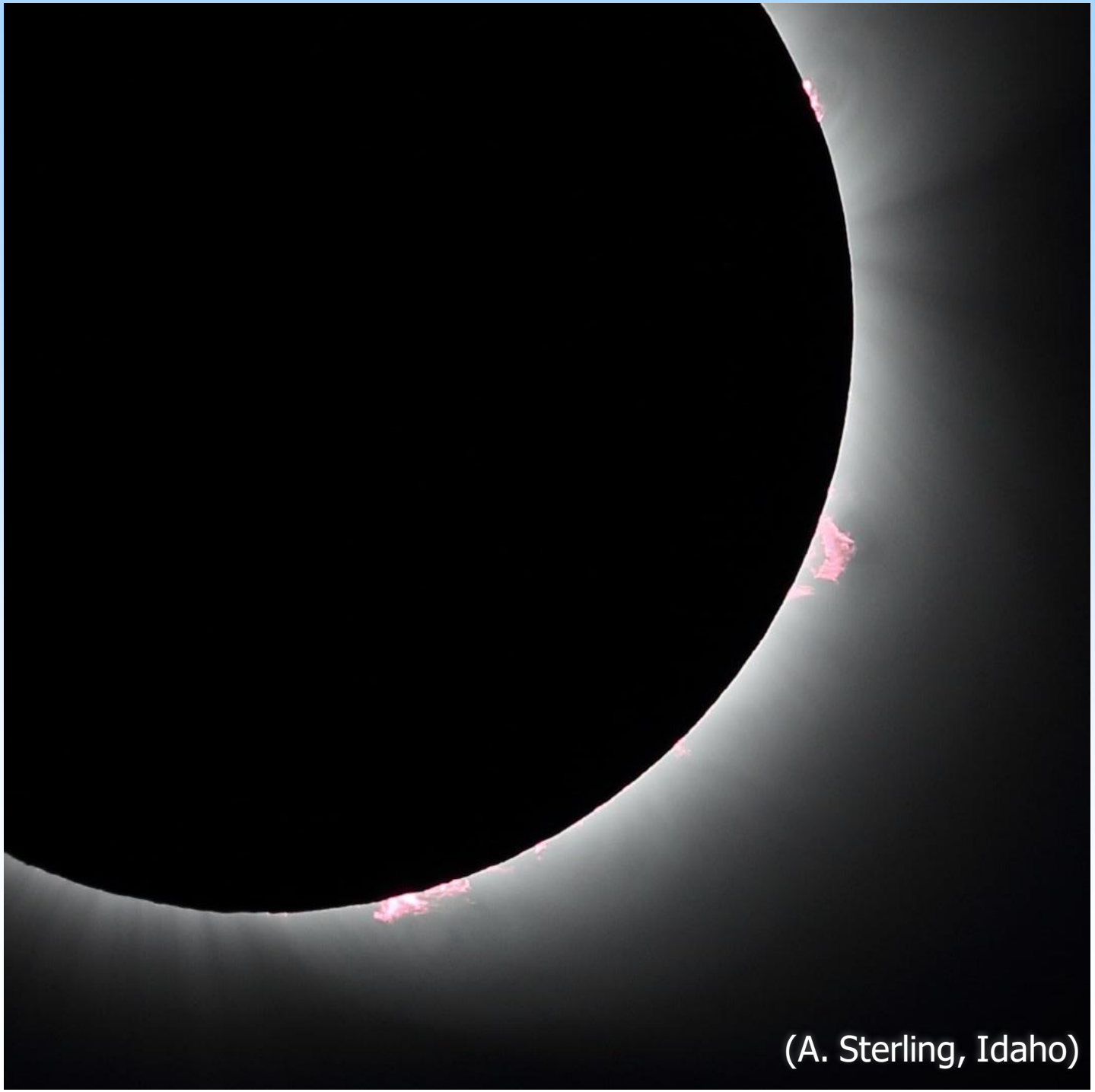


(A. Sterling, Idaho)



(A. Sterling, Idaho)

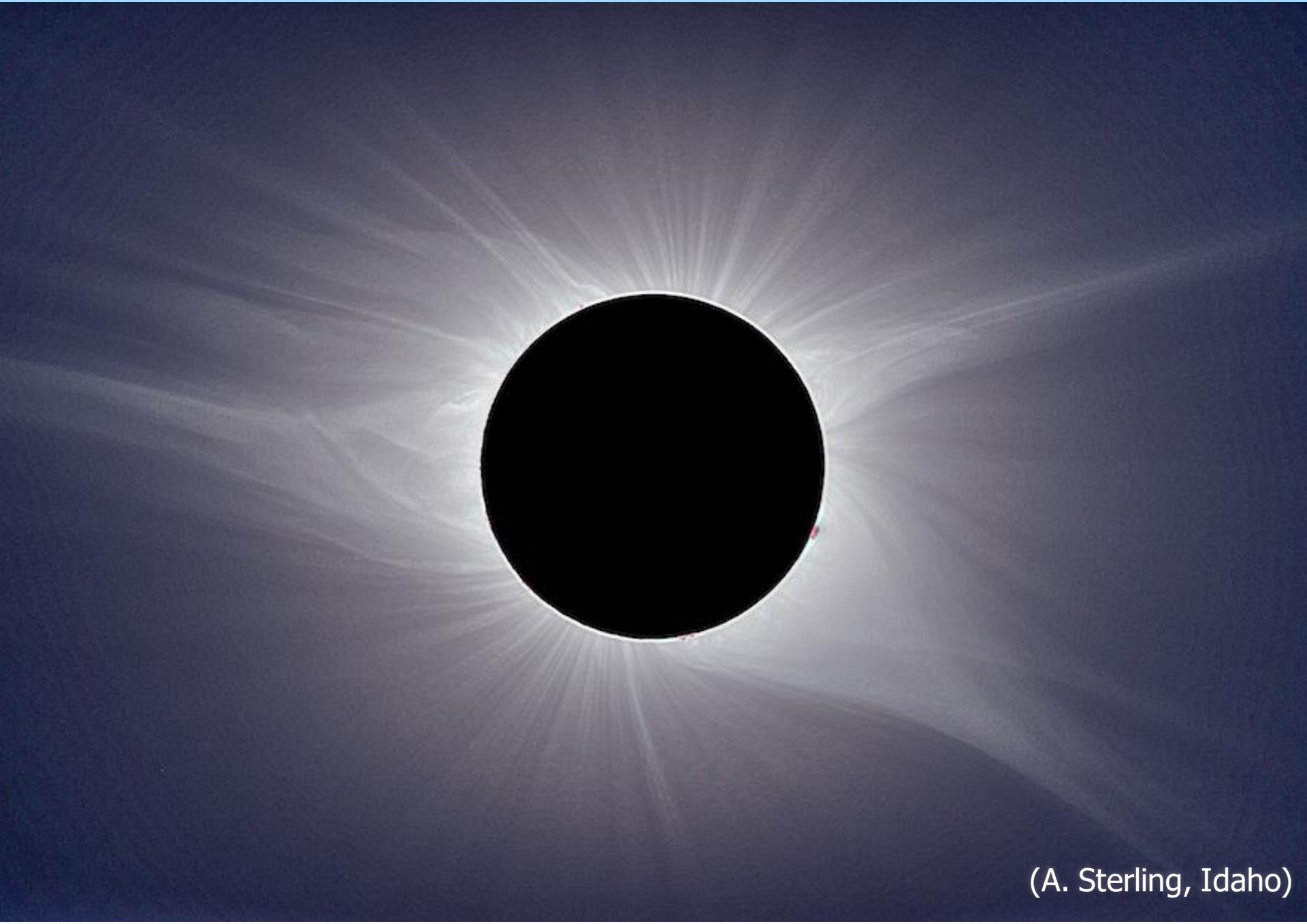
(A. Sterling, Idaho)


(A. Sterling, Idaho)


(A. Sterling, Idaho)


(A. Sterling, Idaho)


(A. Sterling, Idaho)



(A. Sterling, Idaho)

Other Aspects:

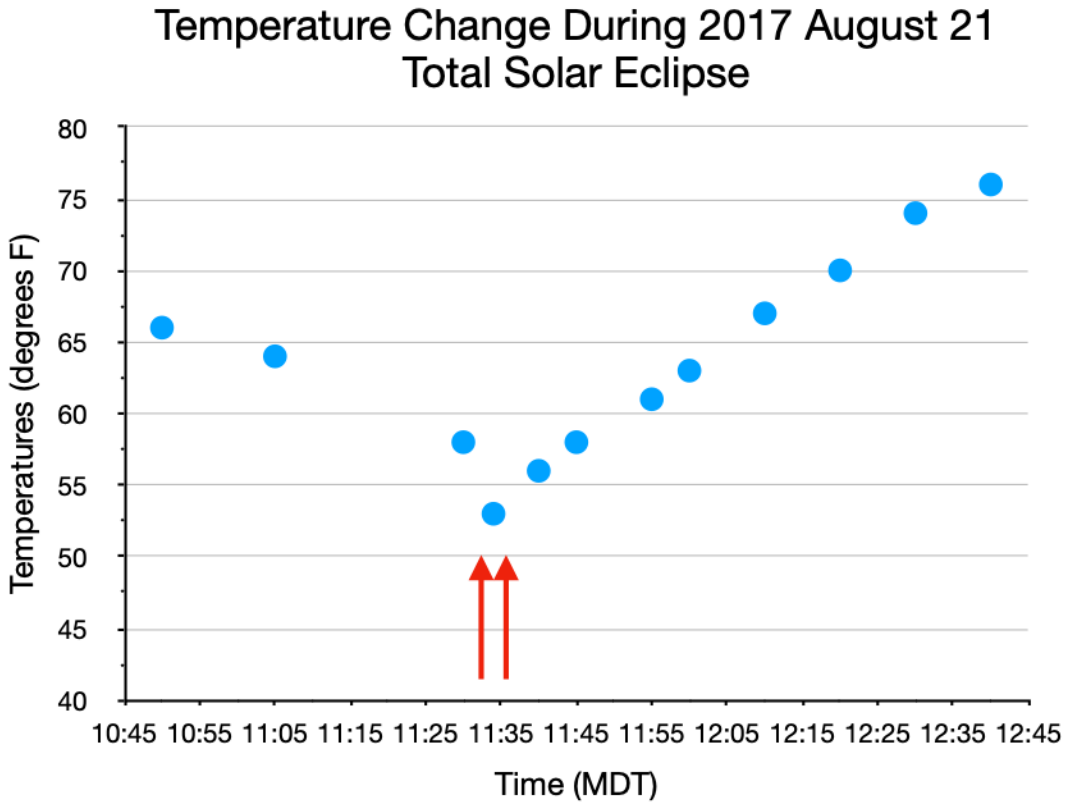
- Planets and bright stars visible.
- Temperature changes.
- Shadow bands.
- …

Air Temperatures During 2017 August 21 Total Solar Eclipse

Location: Lewisville, Idaho, USA.
Totality at 11:32:44 MDT, for 2:18 s. Eclipse end at 13:50.

Values recorded by Keiko Nakajima Seaman. (Project by A. C. Sterling, K. Nakajima Seaman, & C. H. Seaman.)

Time (MDT=UT-6)	Temperatures (F)
10:50	66
11:05	64
11:30	58
11:34	53
11:40	56
11:45	58
11:55	61
12:00	63
12:10	67
12:20	70
12:30	74
12:40	76



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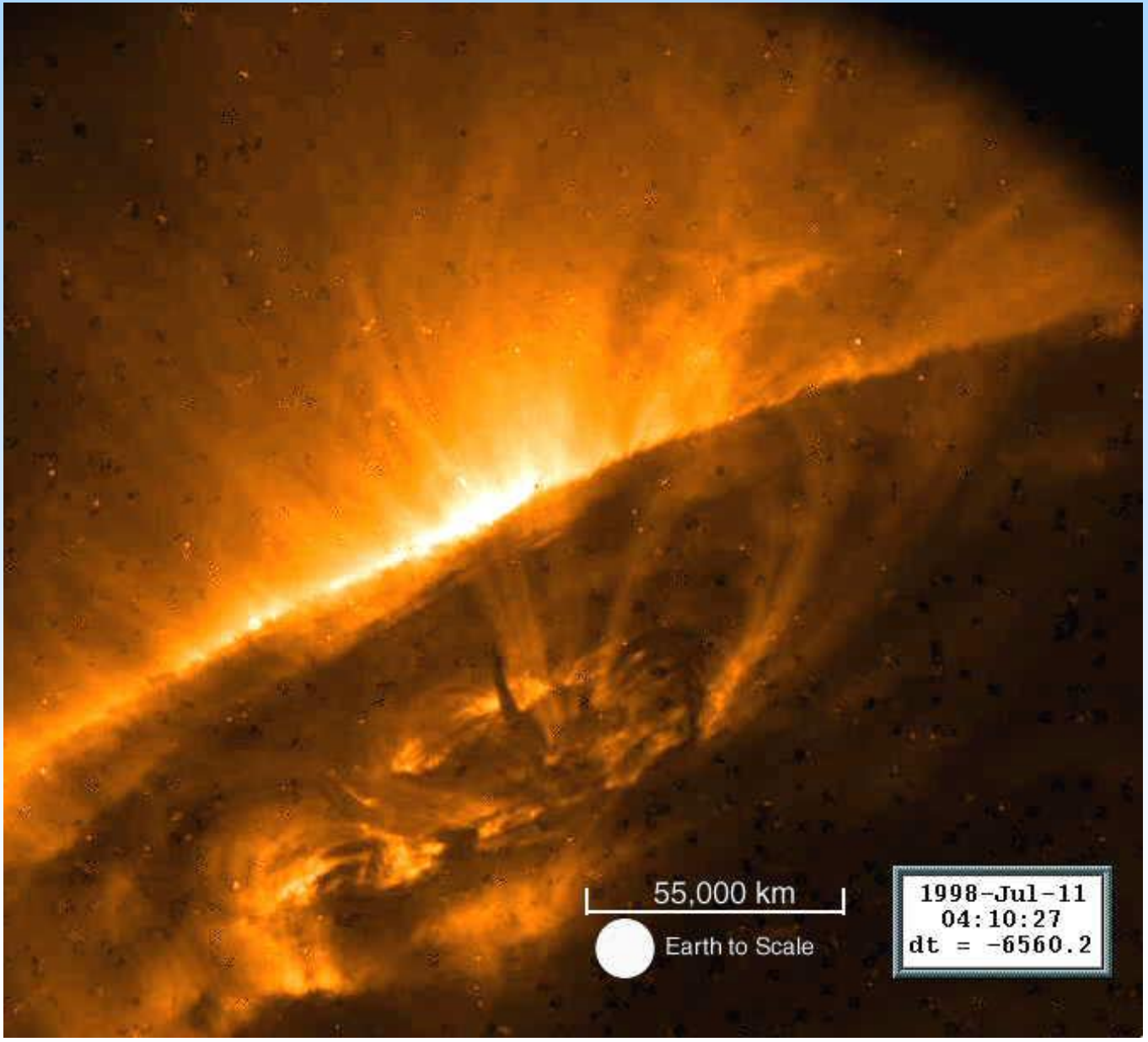
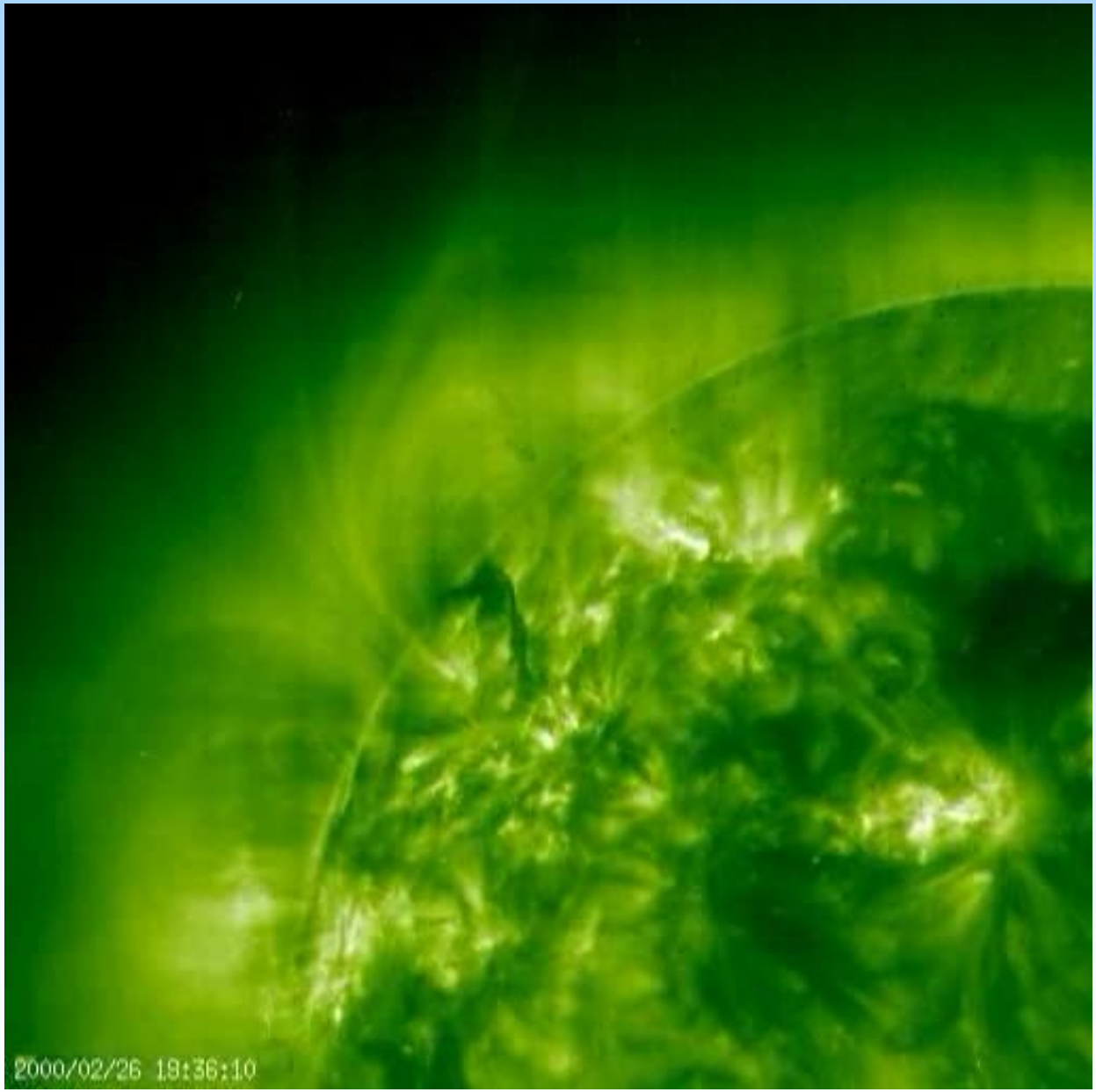
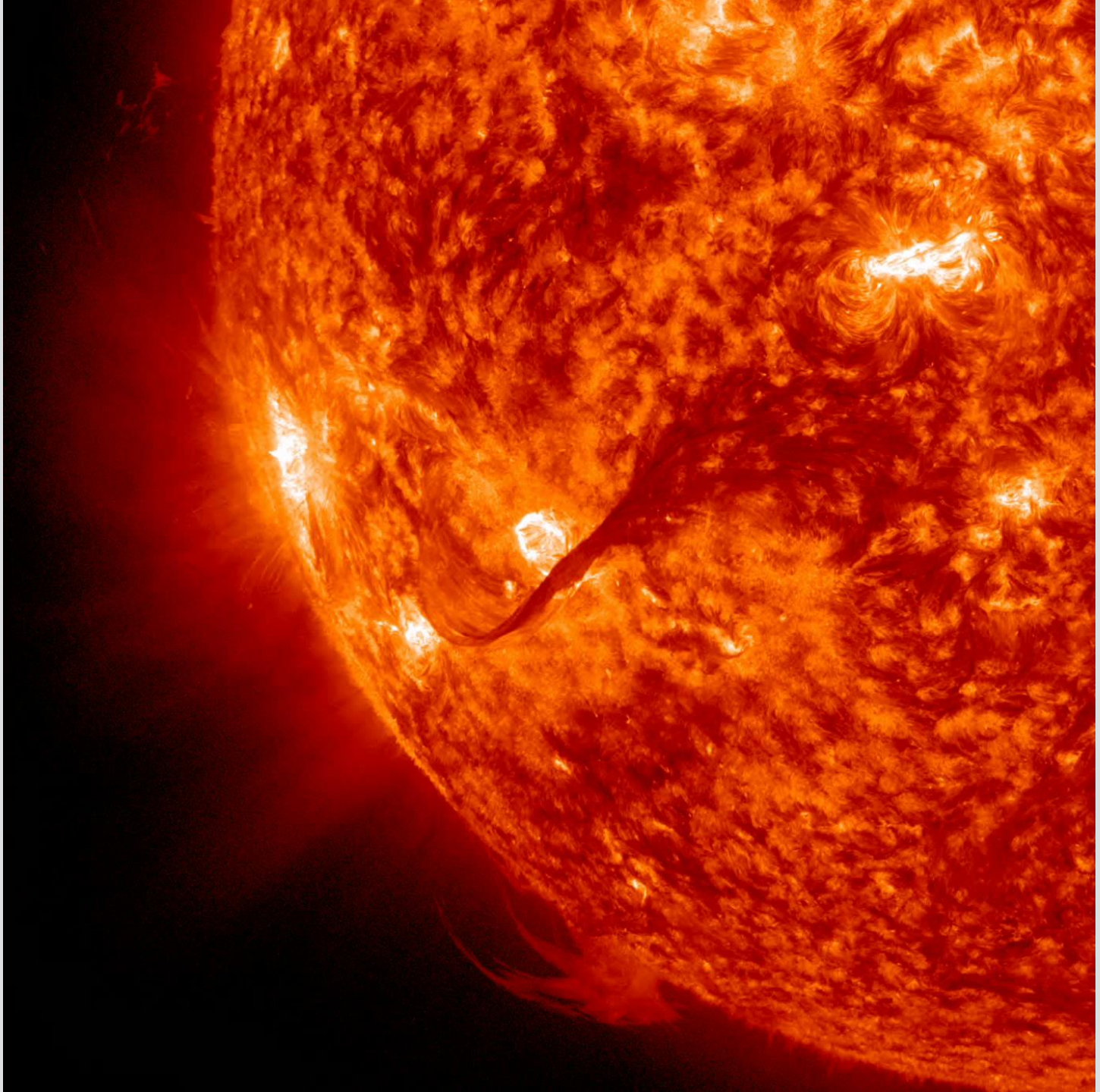
Solar Eruptions

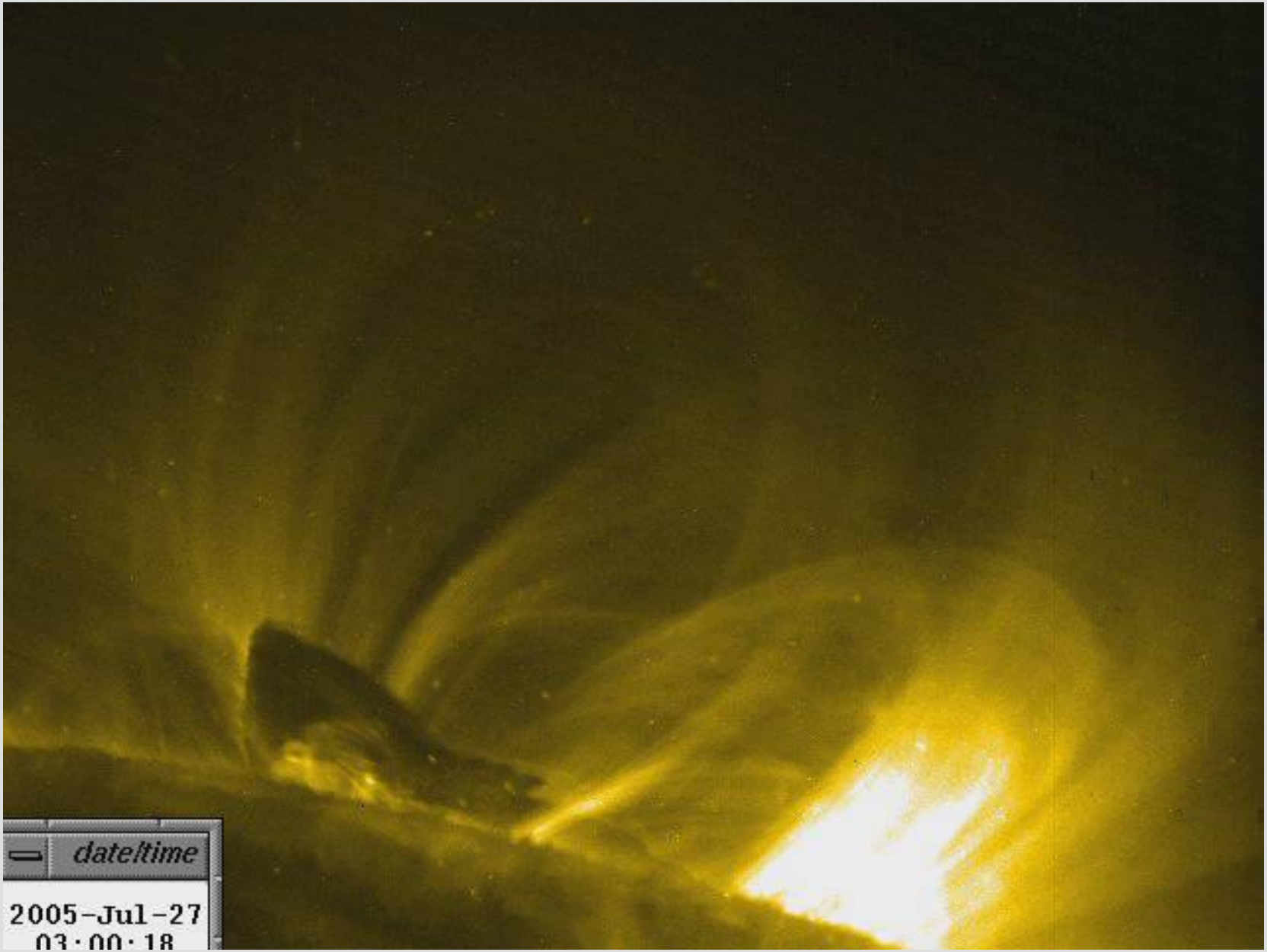

55,000 km
Earth to Scale
1998-Jul-11
04:10:27
dt = -6560.2

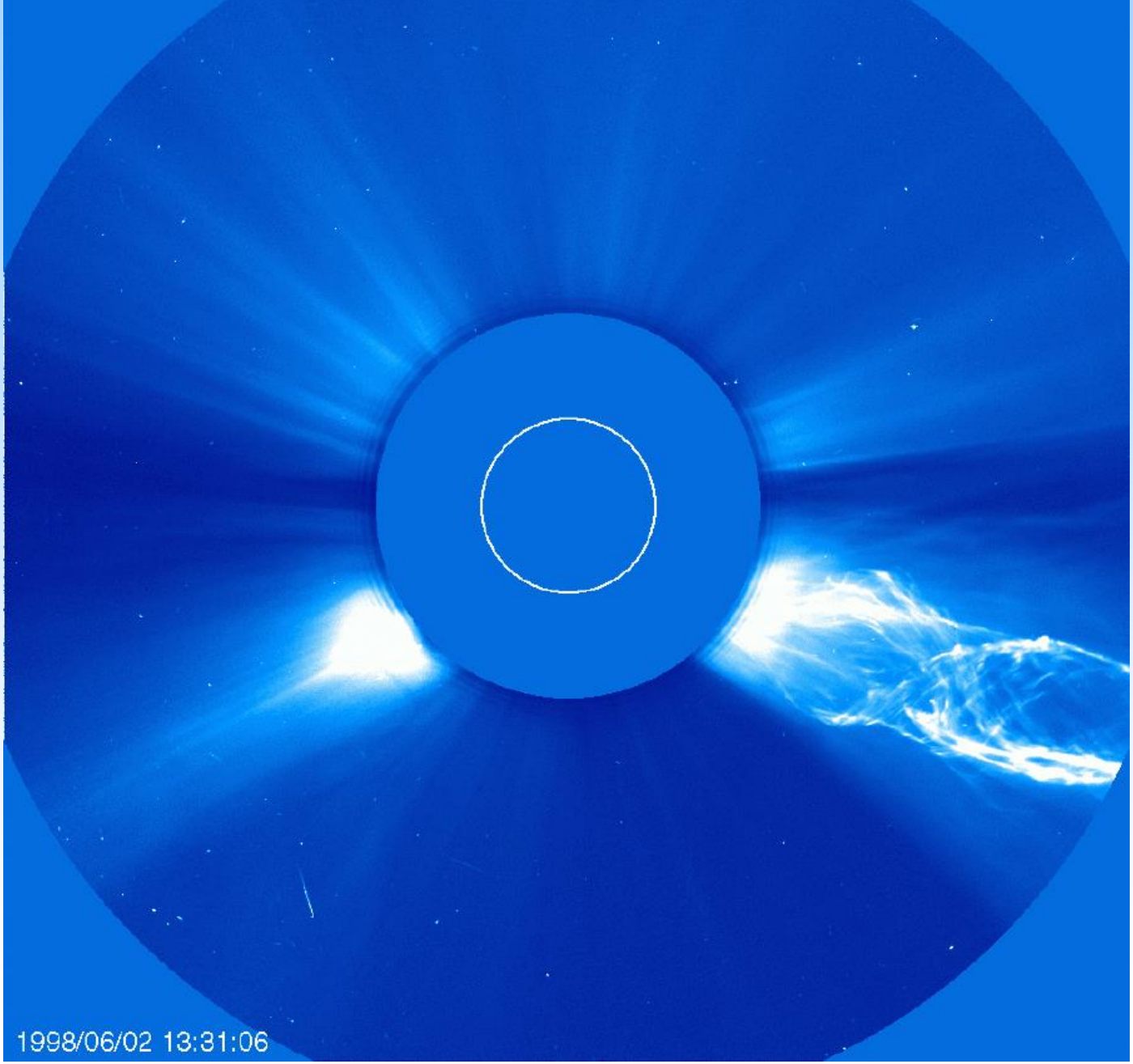


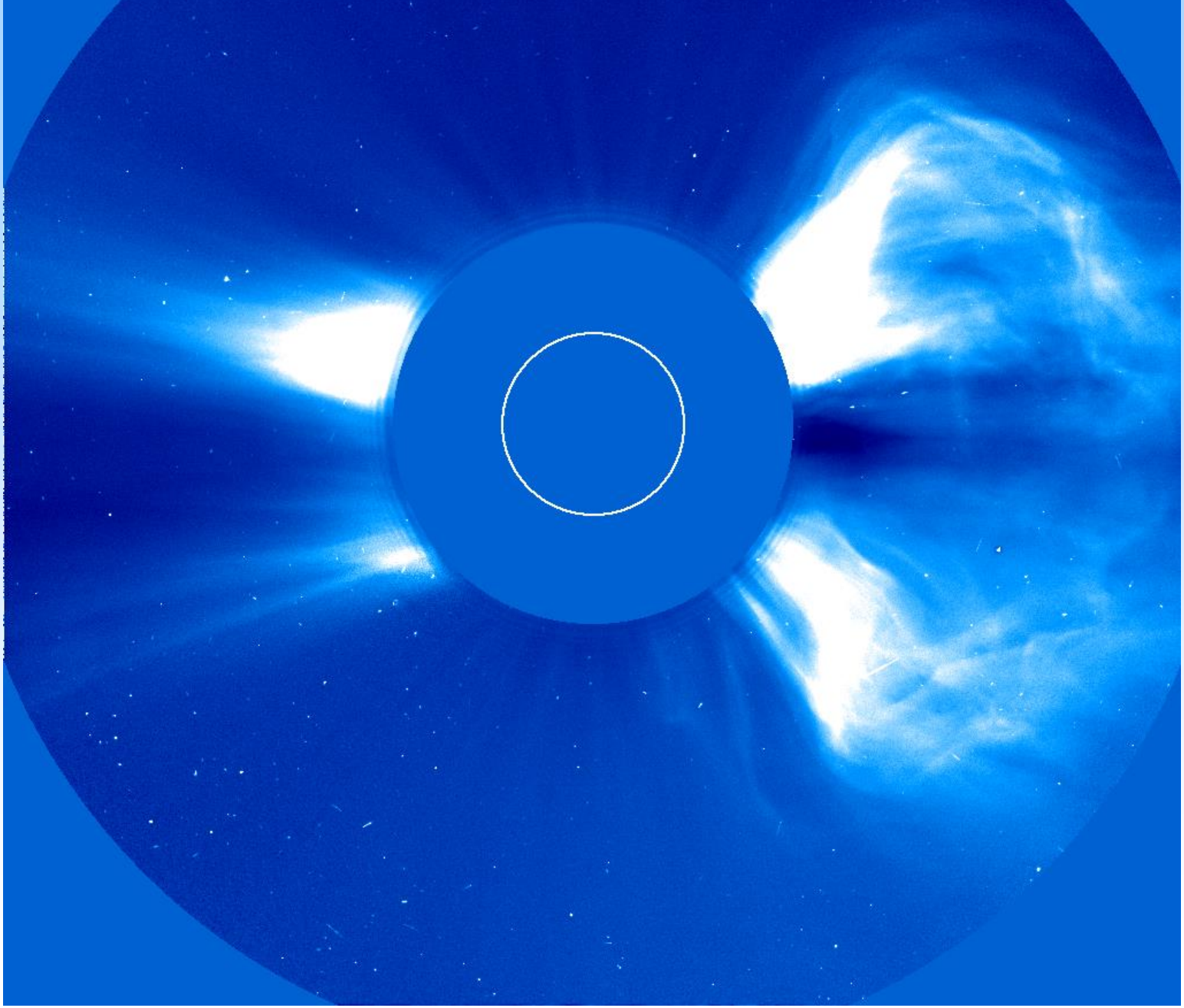
(Sterling & Moore 2004)

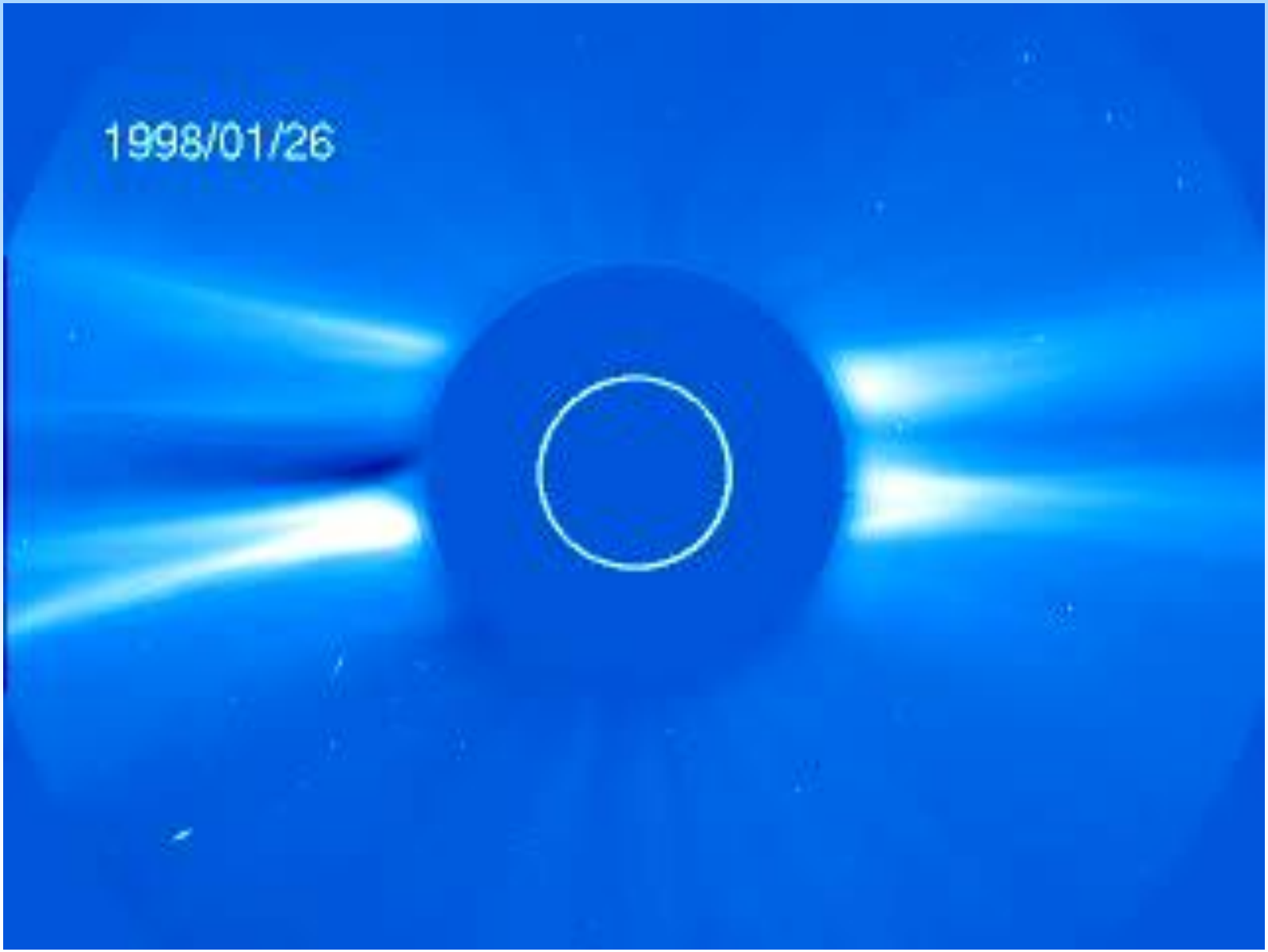


(TRACE 171)




1998/06/02 13:31:06




1998/01/26

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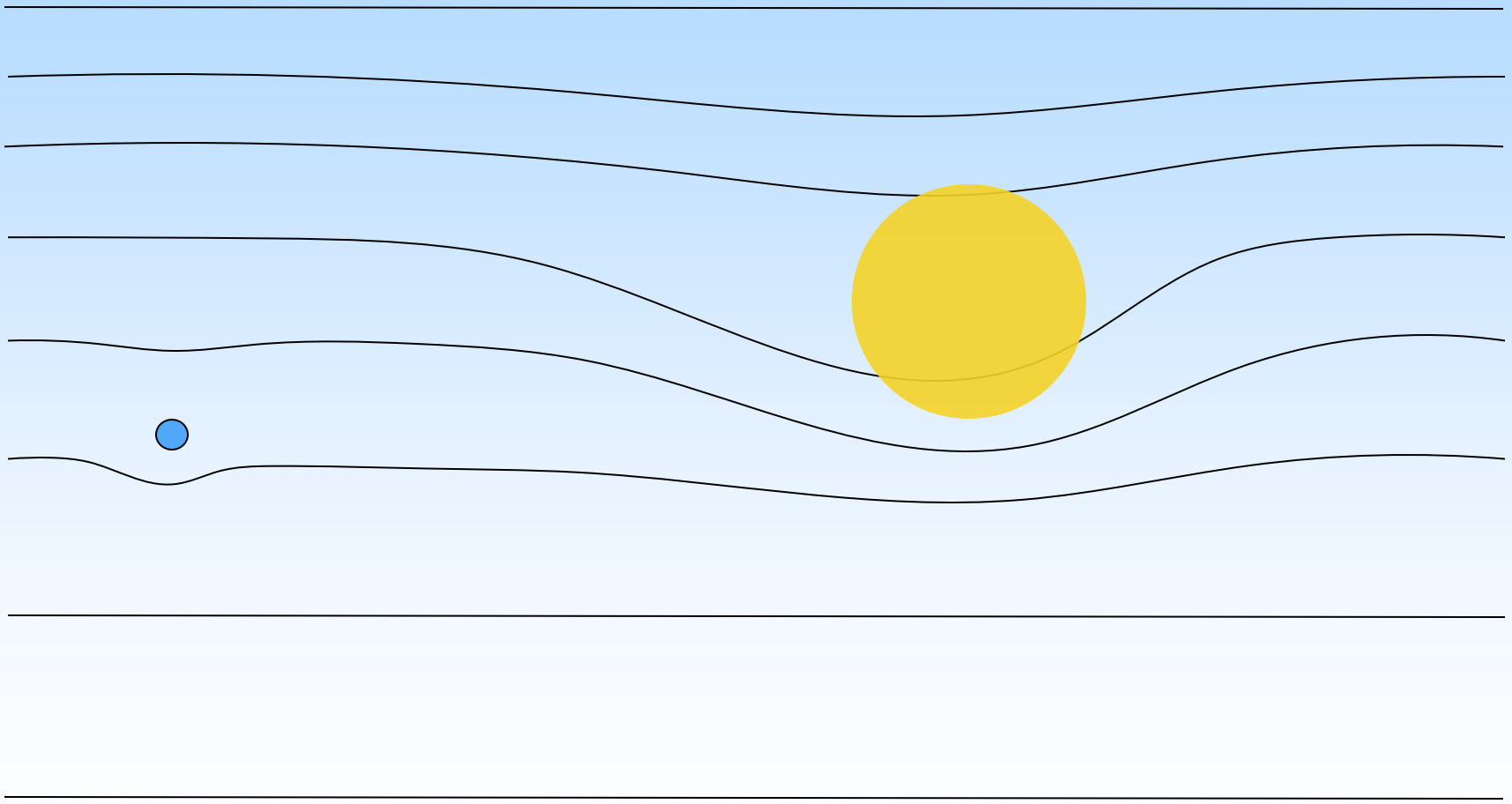
Some Solar Eclipse Science

The Most Famous Solar Eclipse Experiment

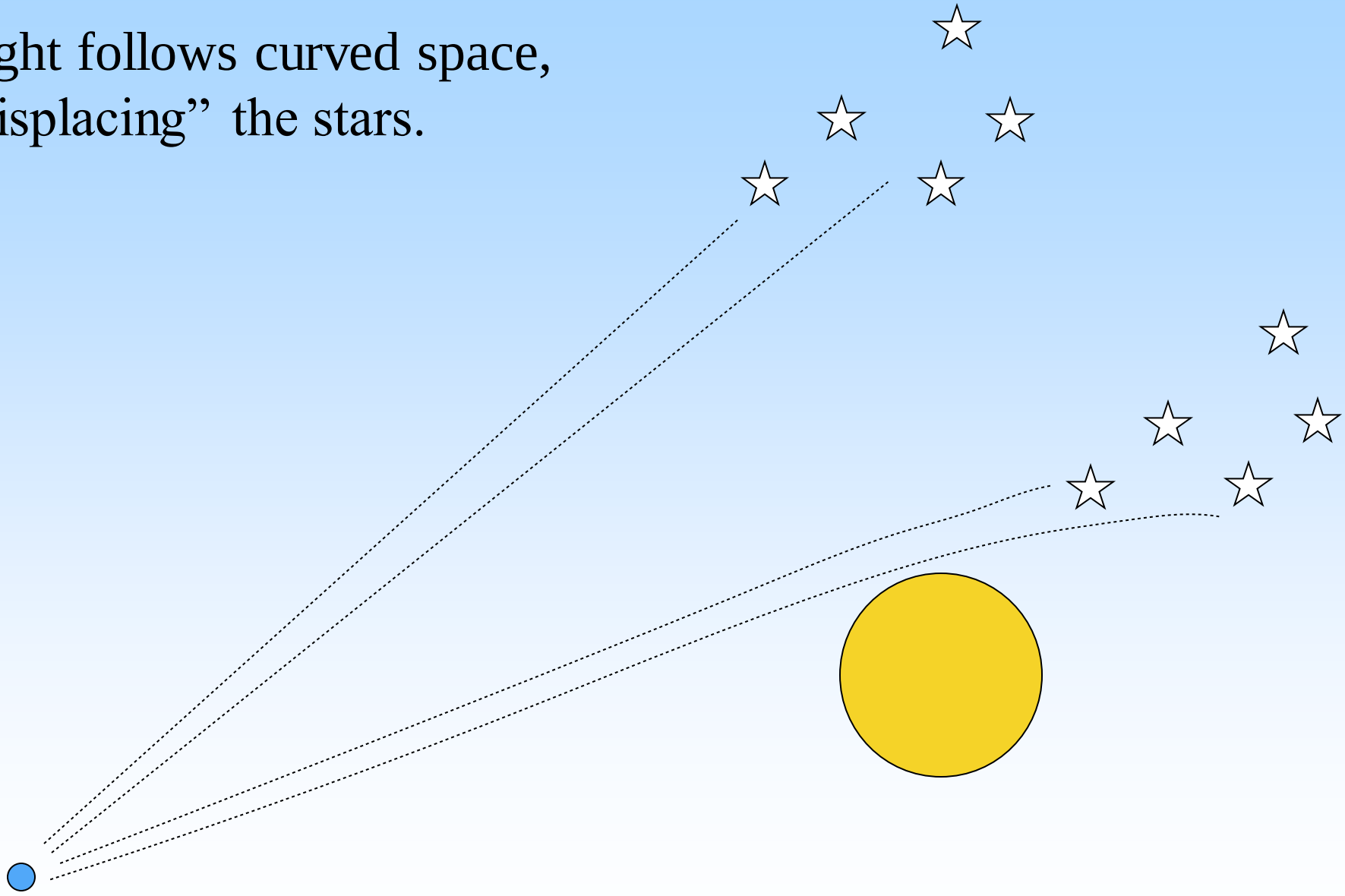
- 1919 total solar eclipse, tested Einstein's General Theory of Relativity.
- This theory says that space is curved, with more massive objects curving it more than less-massive objects.
- Light follows the path of curved space.
- The effect is subtle for most objects, and to see the effect a very massive 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.



Sir Arthur Eddington tested this idea in the1919 total solar eclipse, in what is now São Tomé and Principe.

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

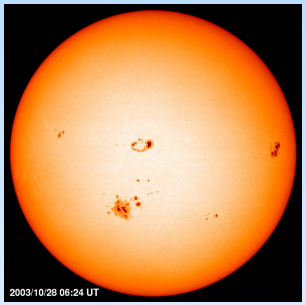
Einstein became an instant celebrity, and this is largely why his name is still so well known today.

Information on the Sun's Outer Atmosphere

Solar Interior and Atmosphere(s)

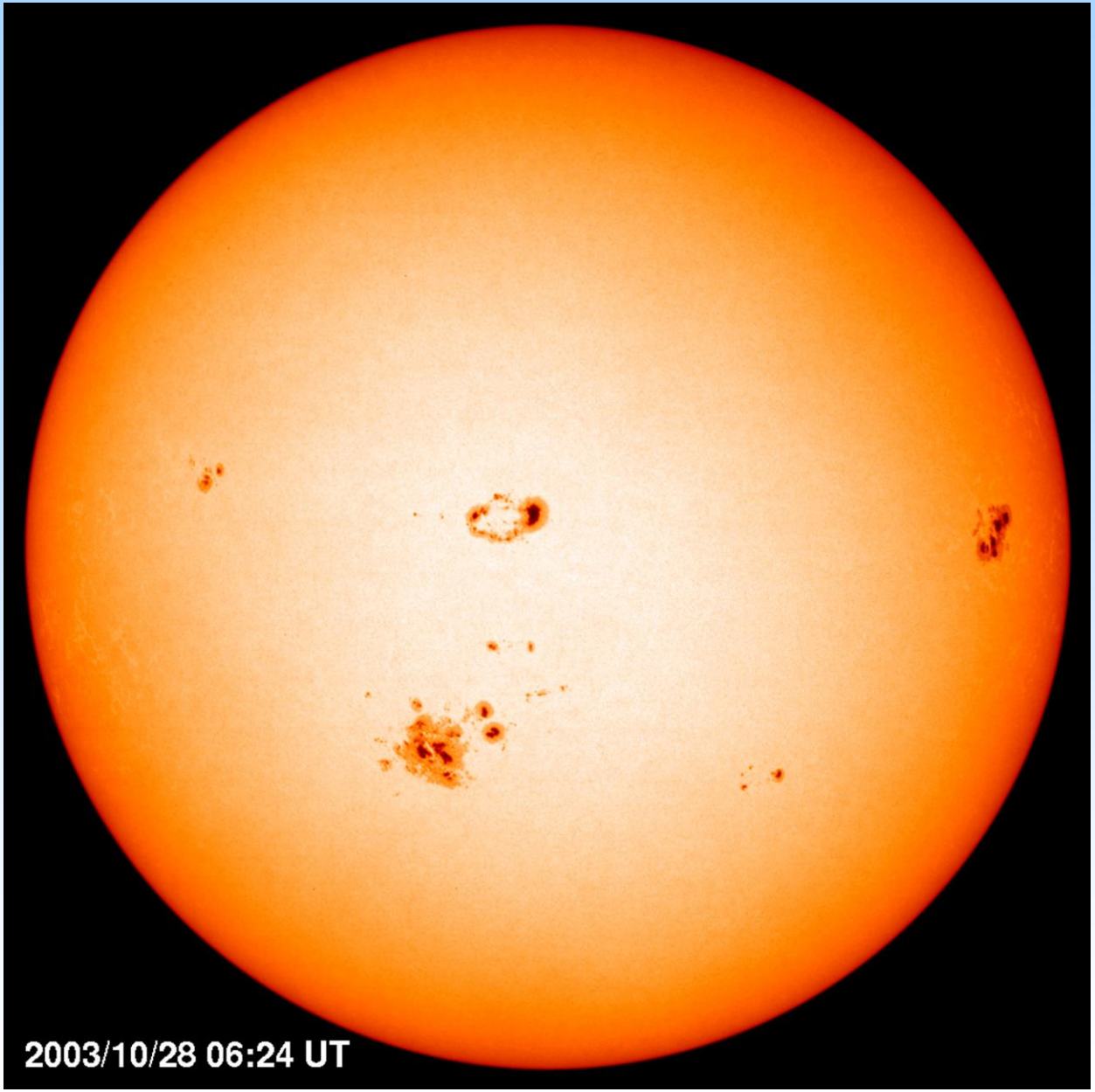
The Outer layers (Atmospheres) of the Sun:

- Photosphere

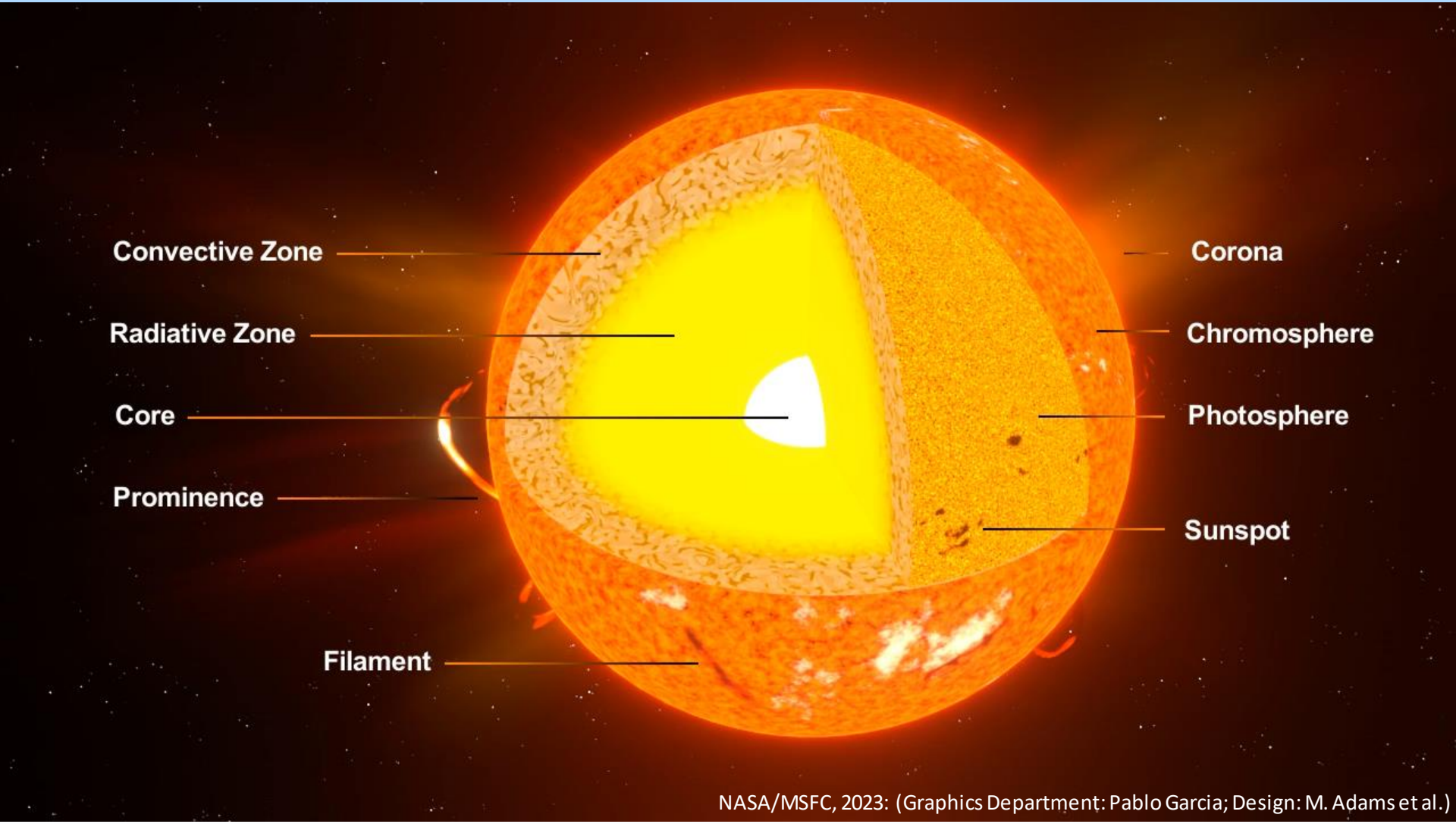


- Chromosphere

- Corona

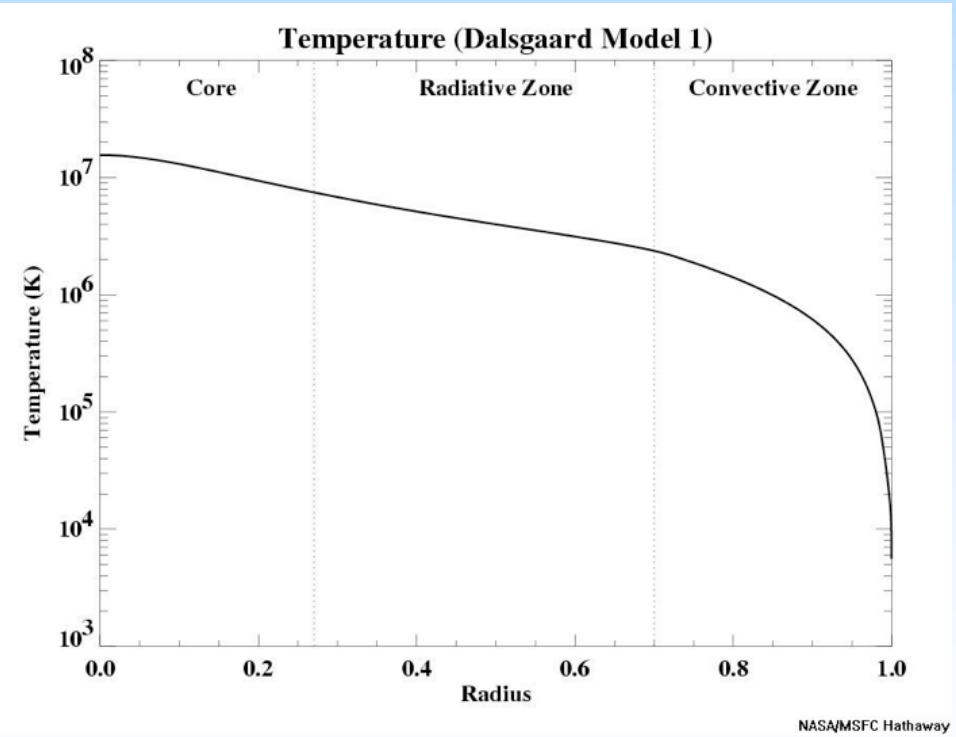


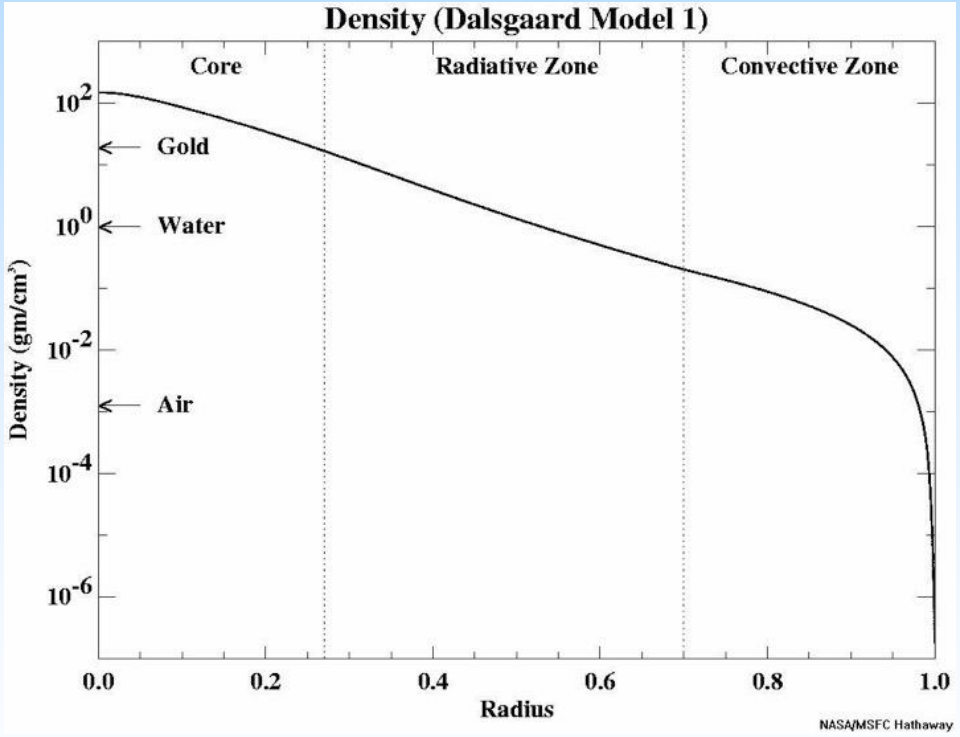
The Photosphere



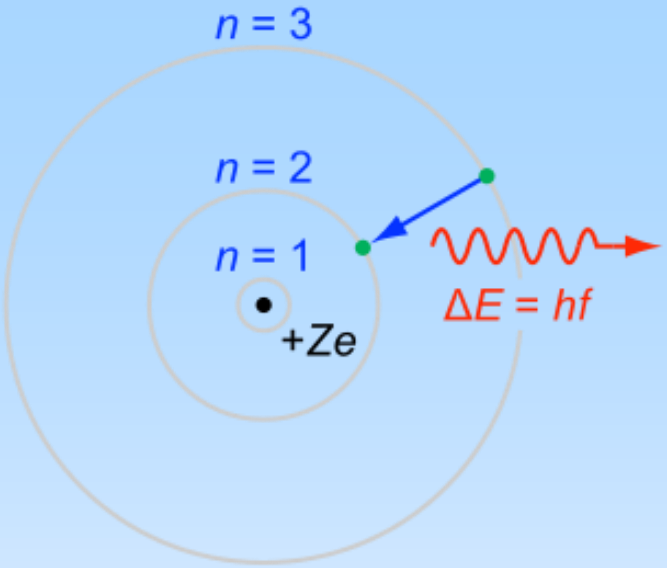
NASA/MSFC, 2023: (Graphics Department: Pablo Garcia; Design: M. Adams et al.)

The Solar Interior's Temperature Distribution

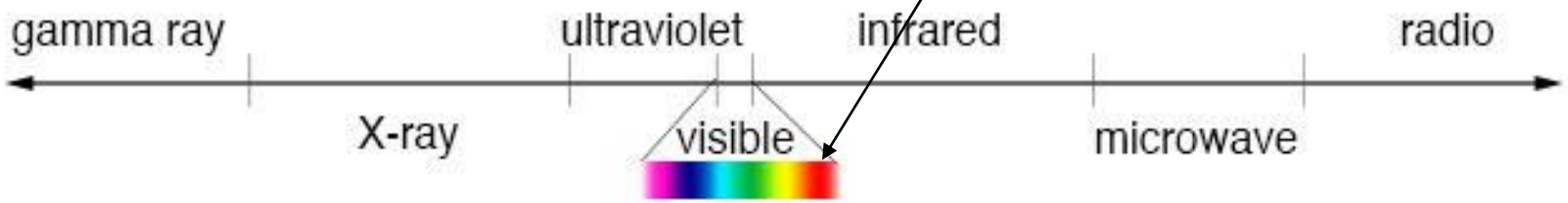


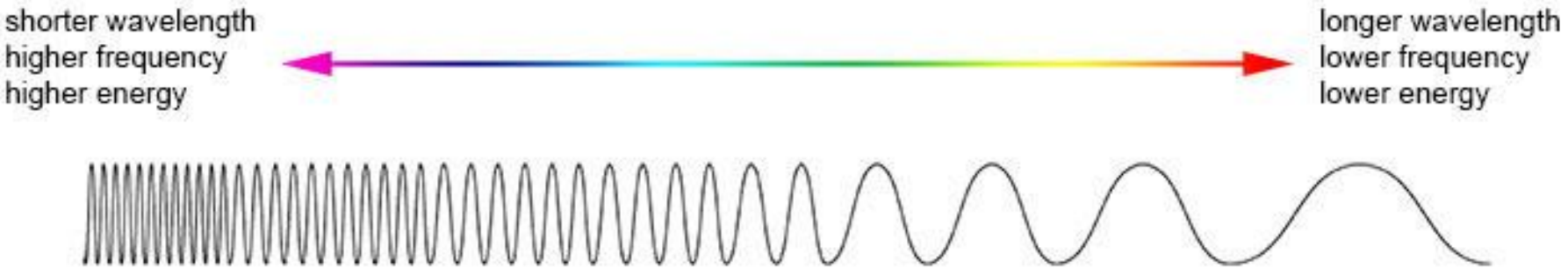


Chromosphere



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



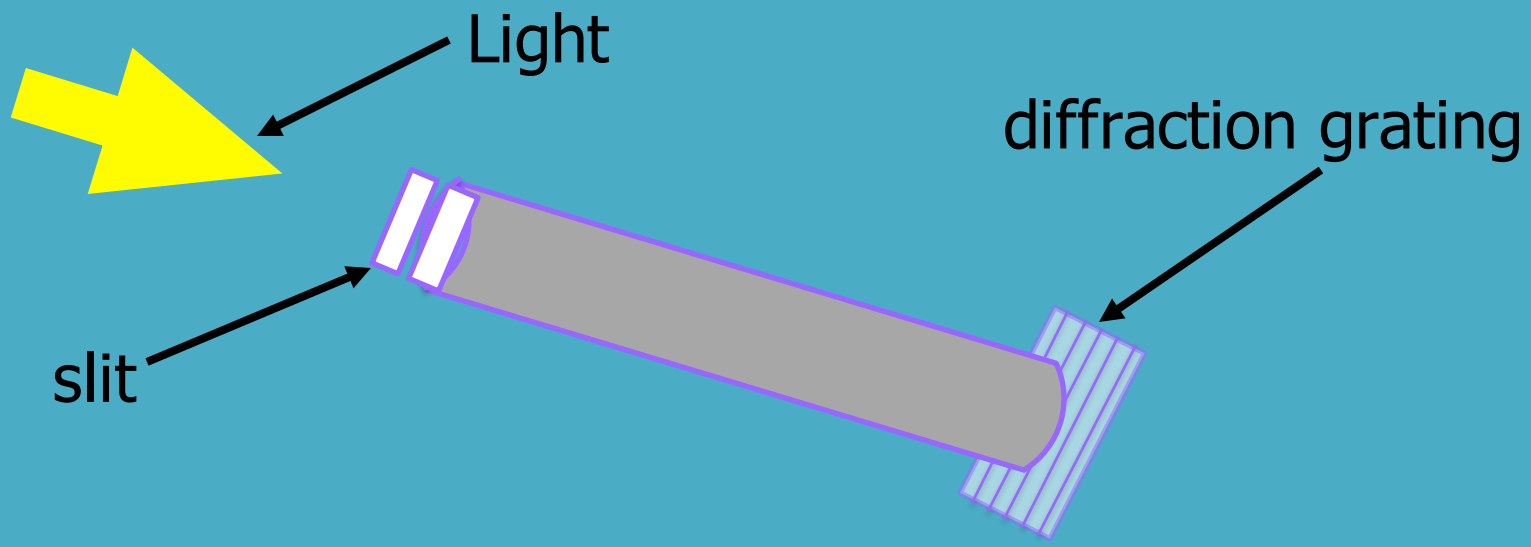


(from imagine.gsfc.nassa.gov)

The Corona

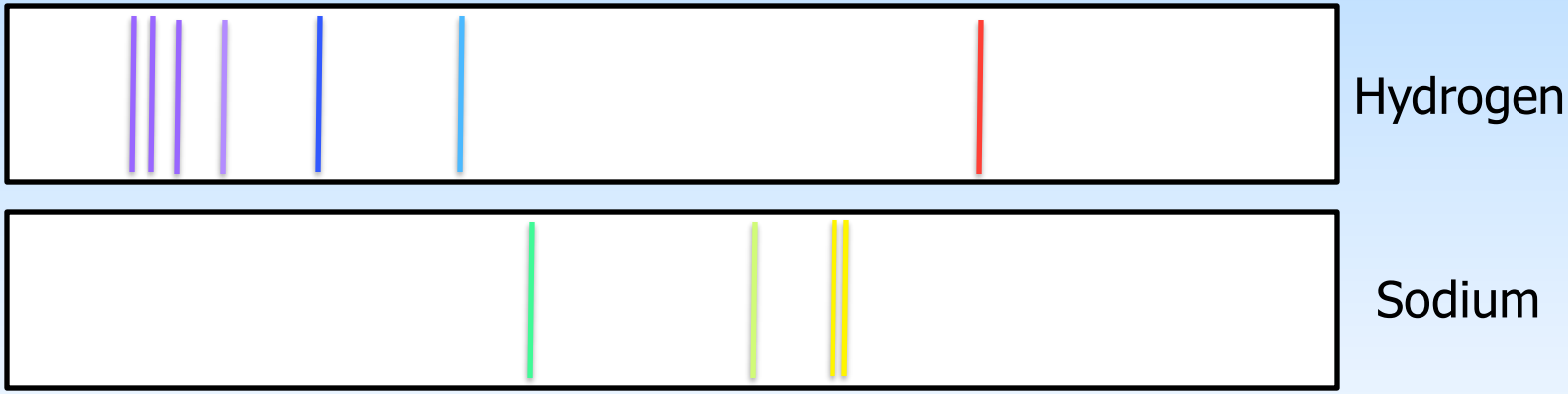
Interlude: "Flash spectrum" from the 2017 USA total solar eclipse

- Normal spectrograph:



Spectra

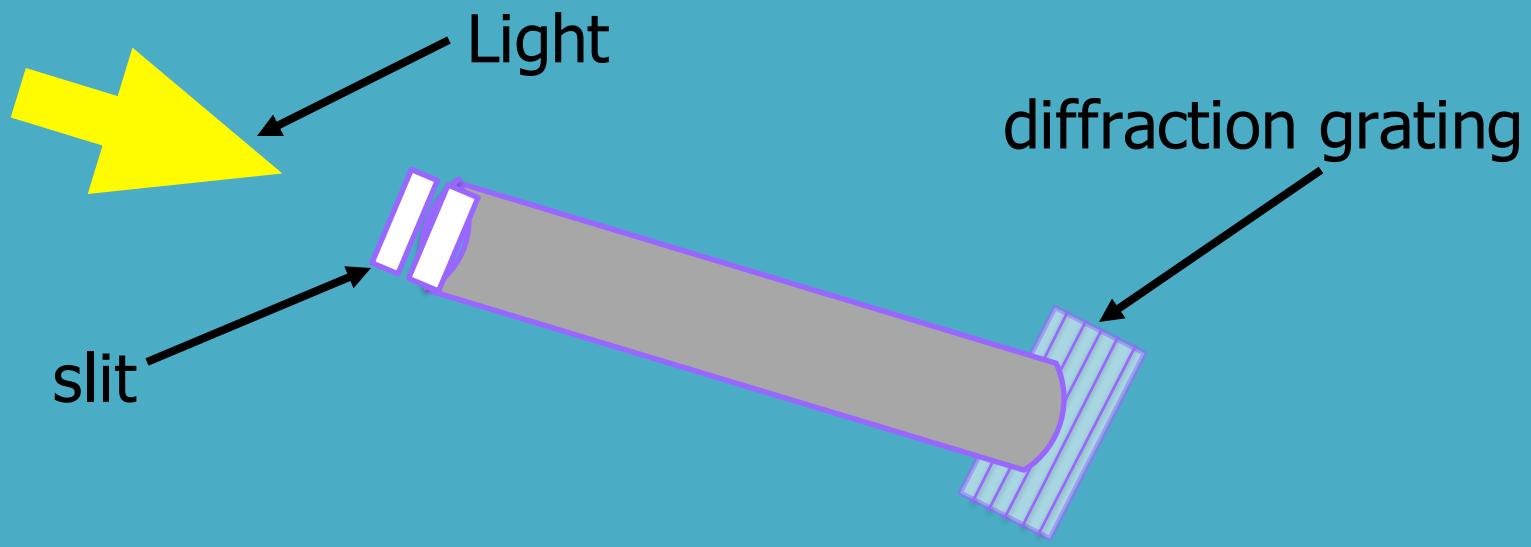
- Breaks light into “rainbow” colors, with lines.
- Different elements produce different lines.
- So these lines are like “fingerprints” for elements.



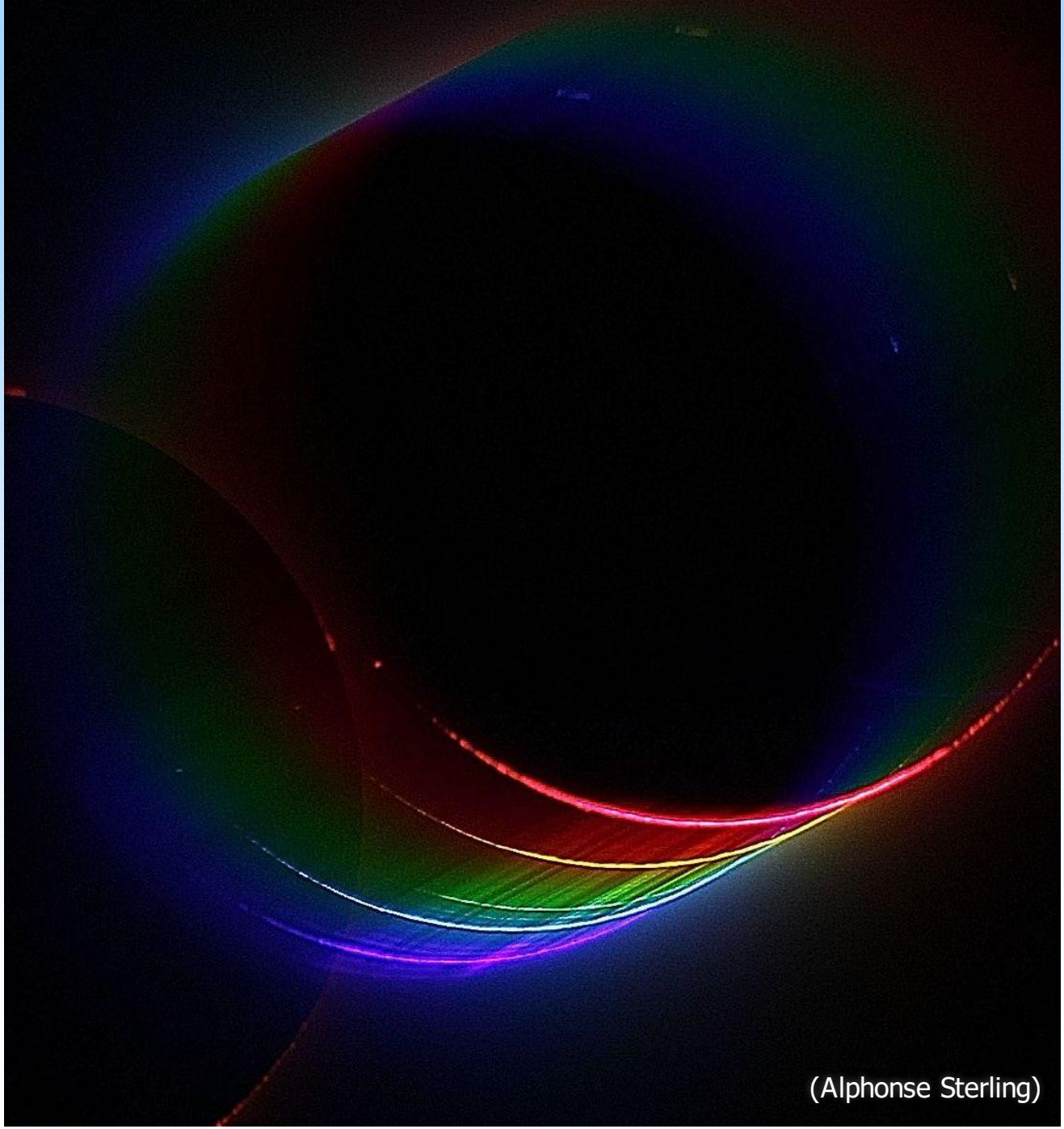
- Hence, spectra can be used to determine the composition of far-away objects, like the corona.

Interlude: "Flash spectrum" from the 2017 USA total solar eclipse

- Normal spectrograph:

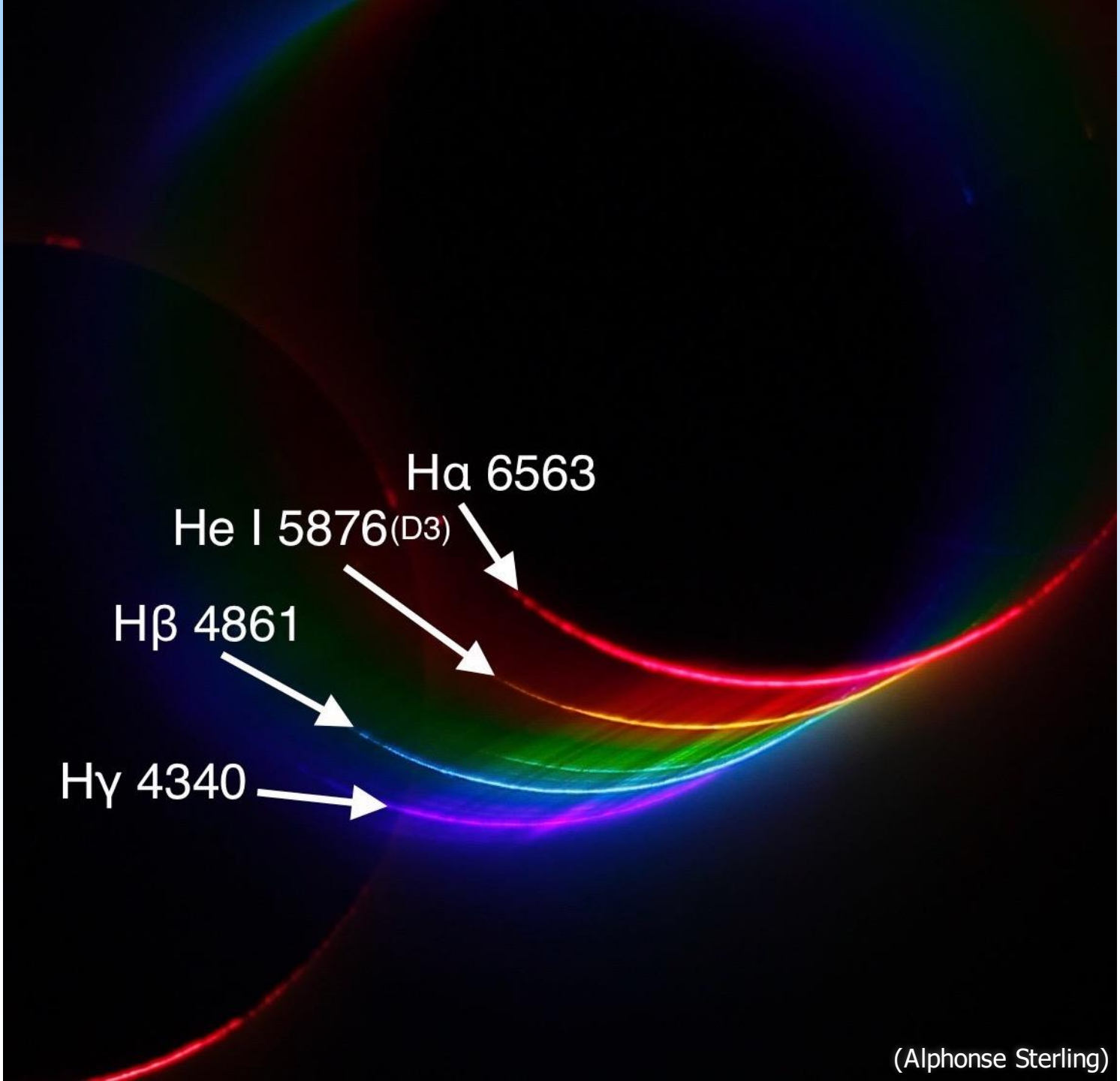


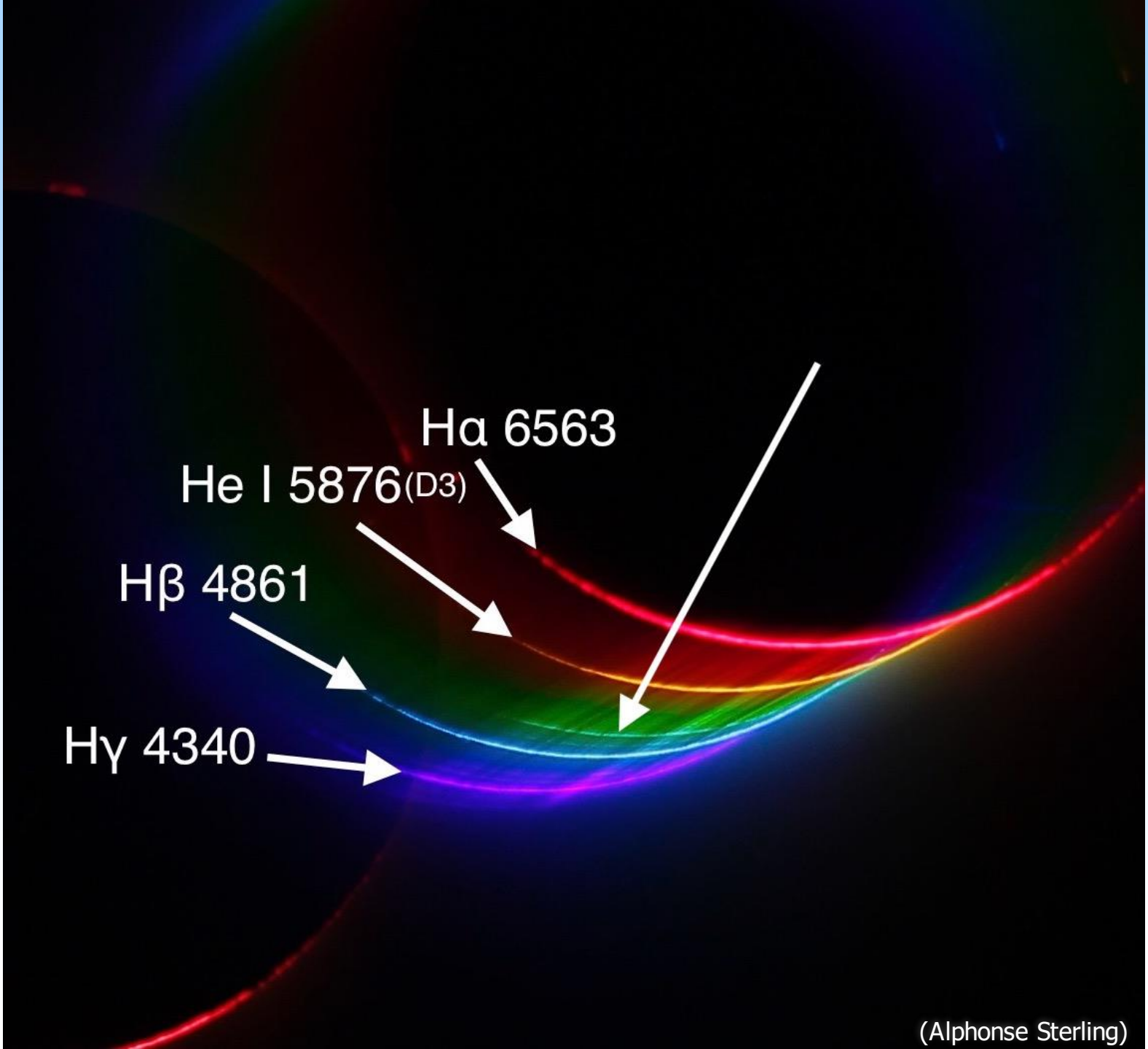
- In this case, let the Moon be the slit!
- Diffraction grating in front of a DSLR.
- (The "Star analyser," SA-100; Canon DSLR.)


(Alphonse Sterling)

The Corona

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


Hα 6563
He I 5876(D3)
Hβ 4861
Hγ 4340
(Alphonse Sterling)



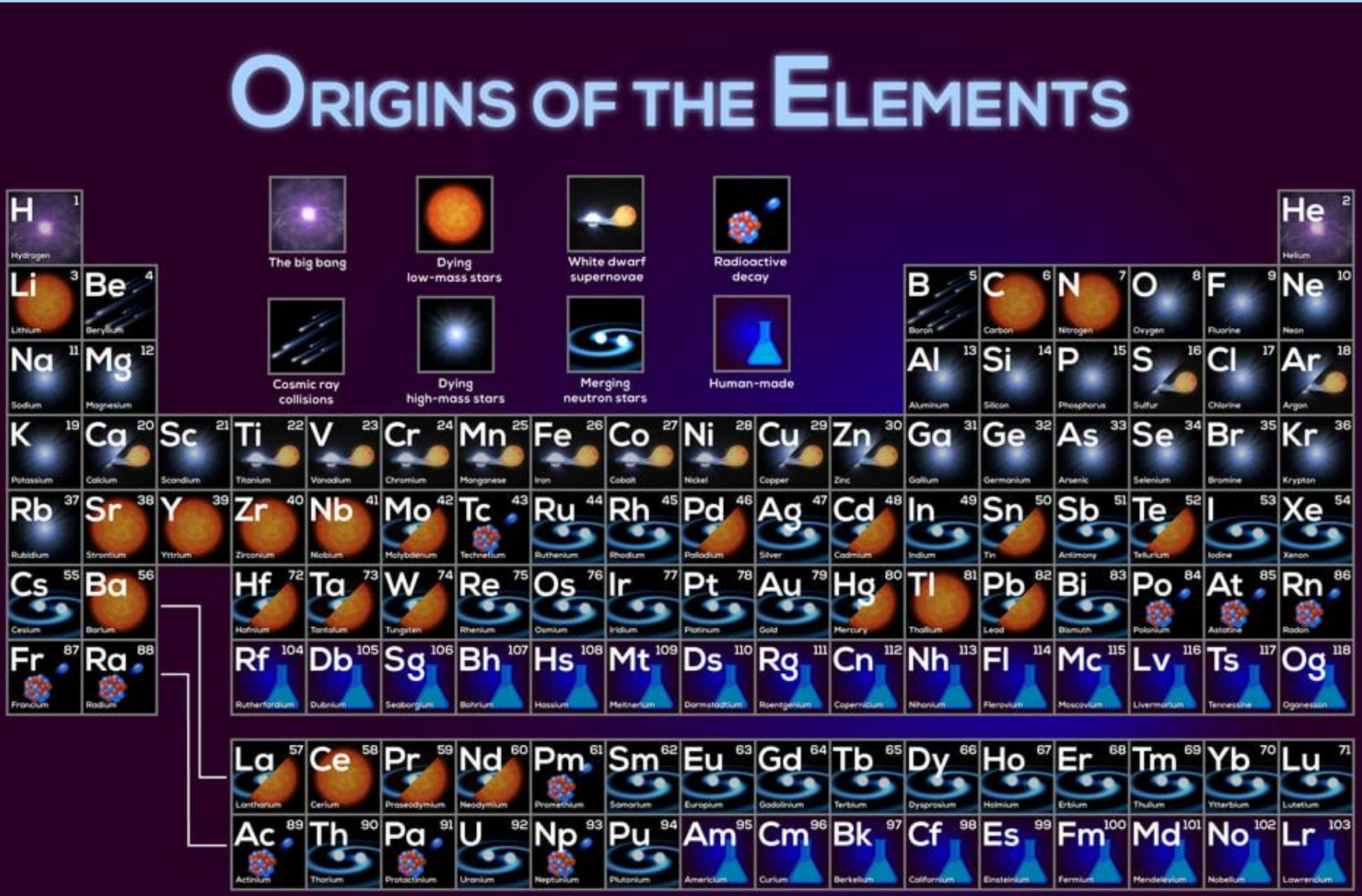
(Alphonse Sterling)

The Corona

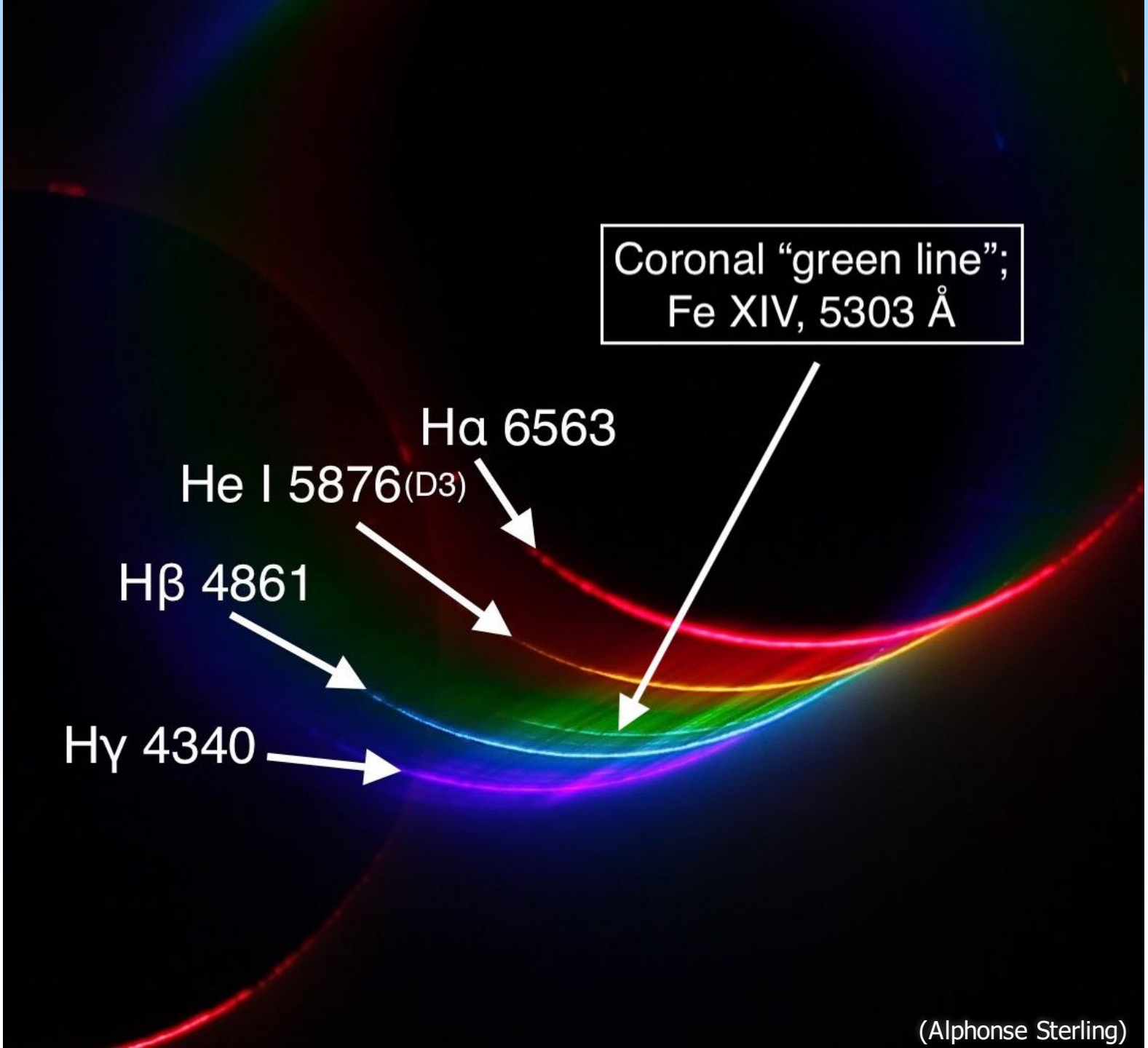
- Expected to be cool, but found strange spectral lines, first during 1869 eclipse.

- Many explanations considered, including a "new" element: *coronium*.

- **But this didn't work....**



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

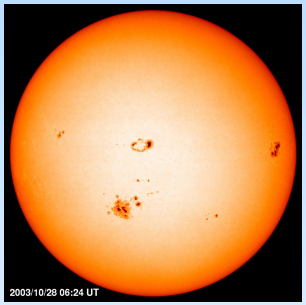

Coronal “green line”;
Fe XIV, 5303 Å
Hα 6563
He I 5876(D3)
Hβ 4861
Hγ 4340
(Alphonse Sterling)

- 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



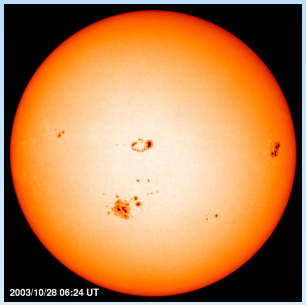
• Chromosphere

•Corona

What's Special About a Solar Eclipse?

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

- Photosphere (6000 K)

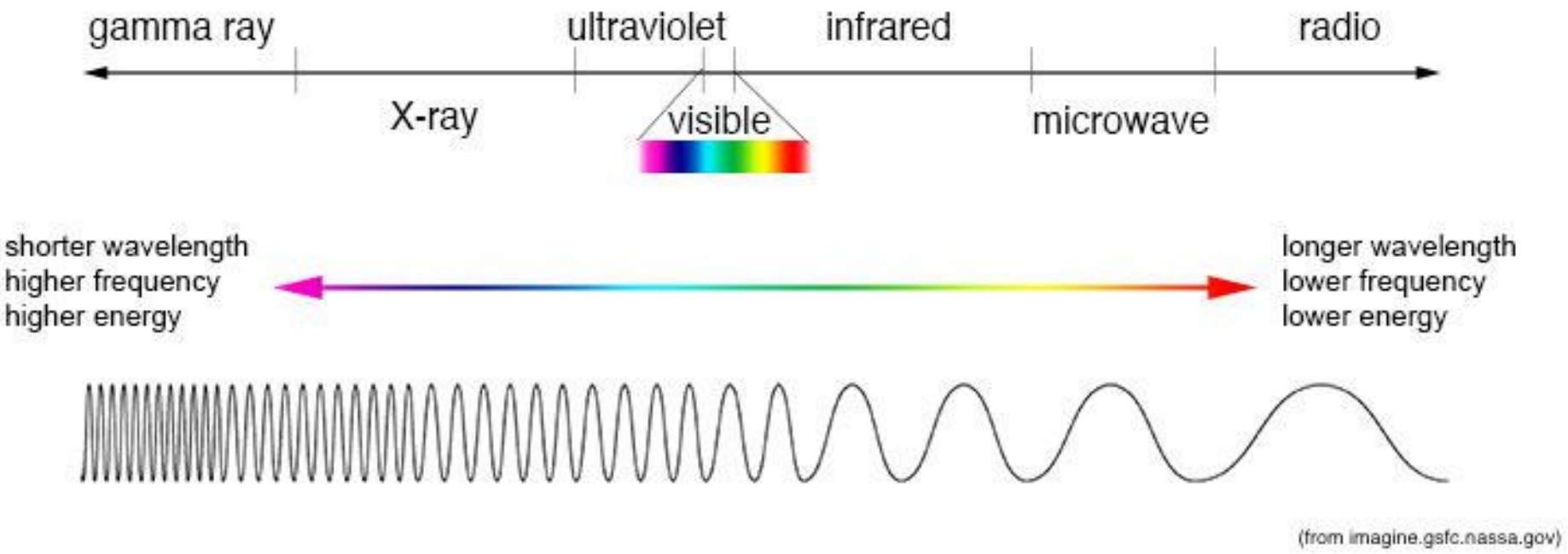


- Chromosphere (~10,000 K)

- Corona (~1-3 MK)

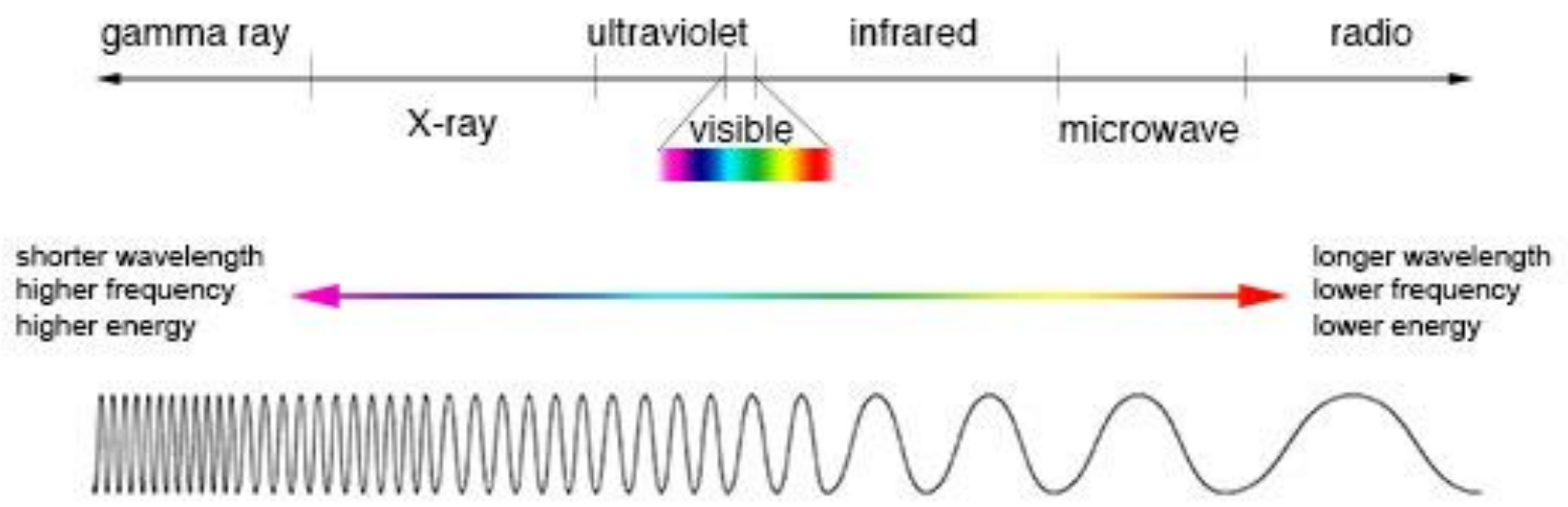
We have to go to ***space*** to see the Sun's outer atmosphere with regularity.

The Electromagnetic Spectrum

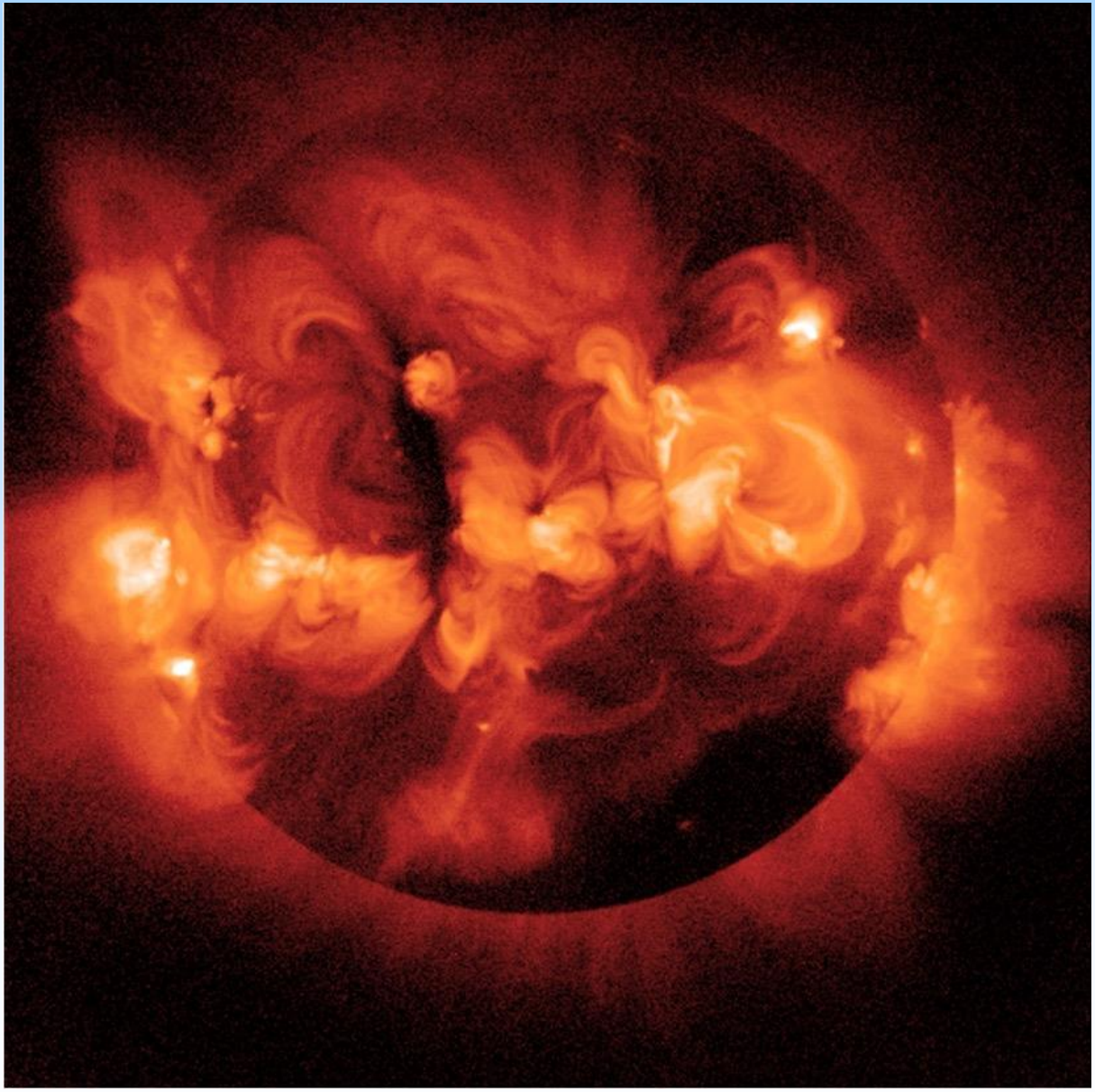


We have to go to ***space*** to see the Sun's outer atmosphere with regularity.

The Electromagnetic Spectrum

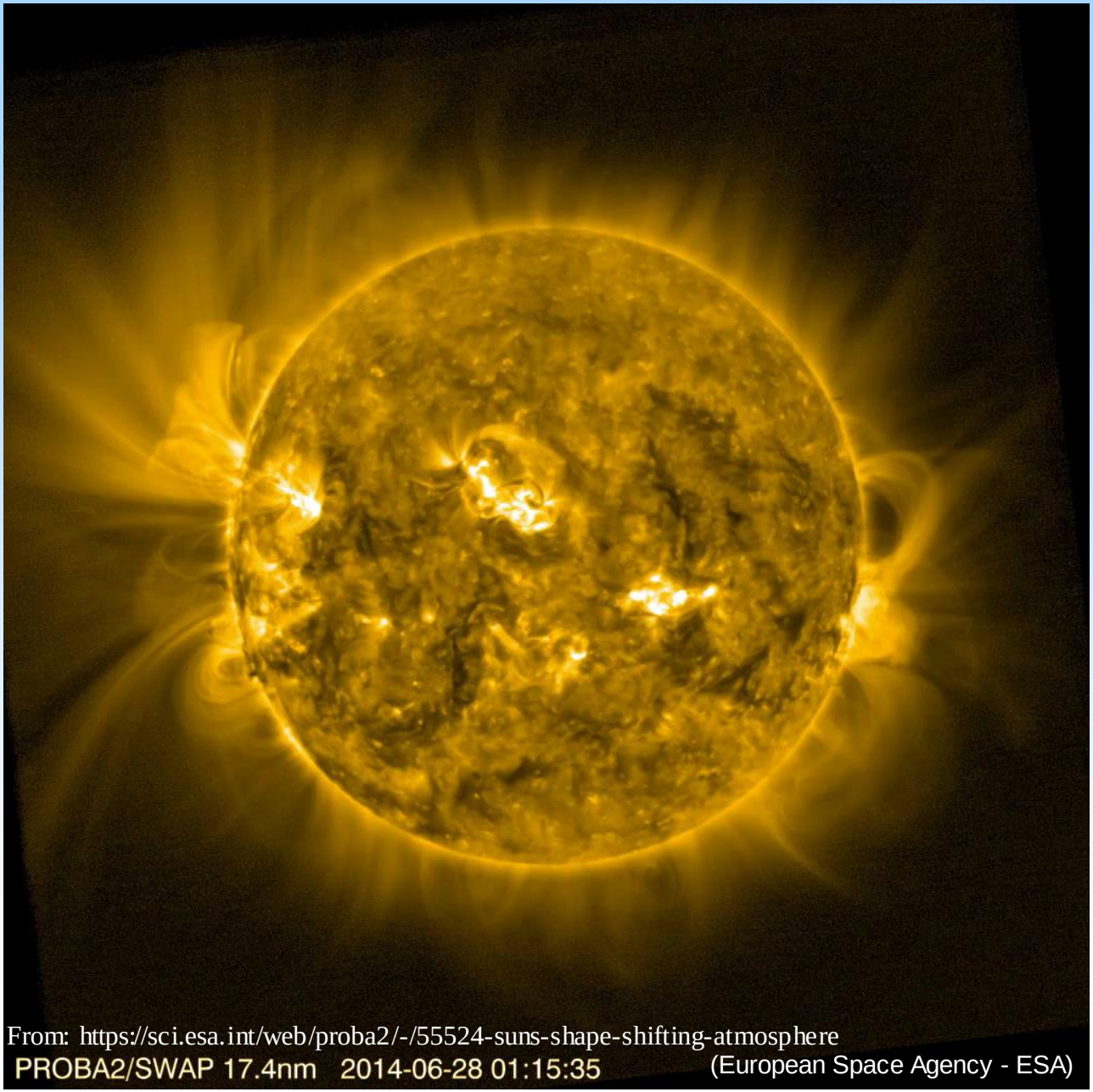


(Credit: NASA's Imagine the Universe - From: https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html



The Corona from Yohkoh/SXT

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

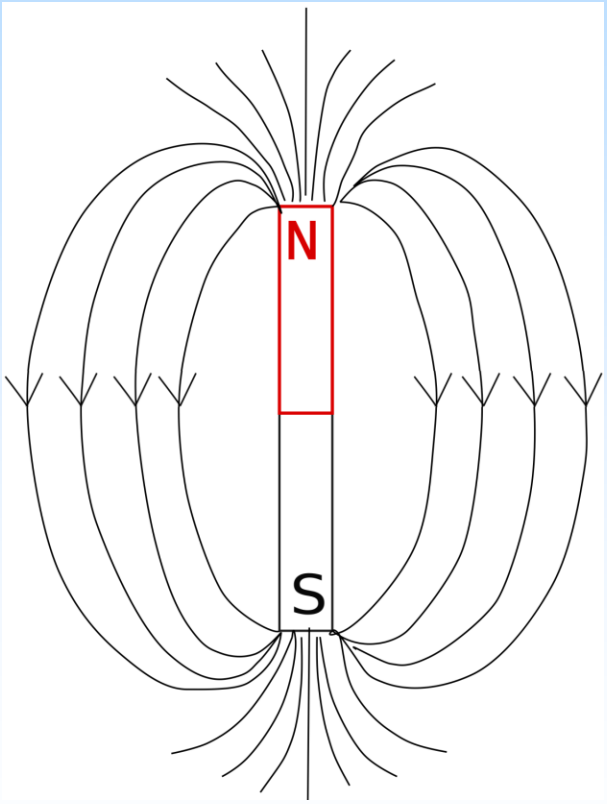


From: https://sci.esa.int/web/proba2/-/55524-suns-shape-shifting-atmosphere

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)

(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 established 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

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Reserve Slides

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
FSQ106ED f/5, EM11, EOS500D, 100, 1/125
ISAS, Sagamihara, Kanagawa, Japan
Alphonse Sterling

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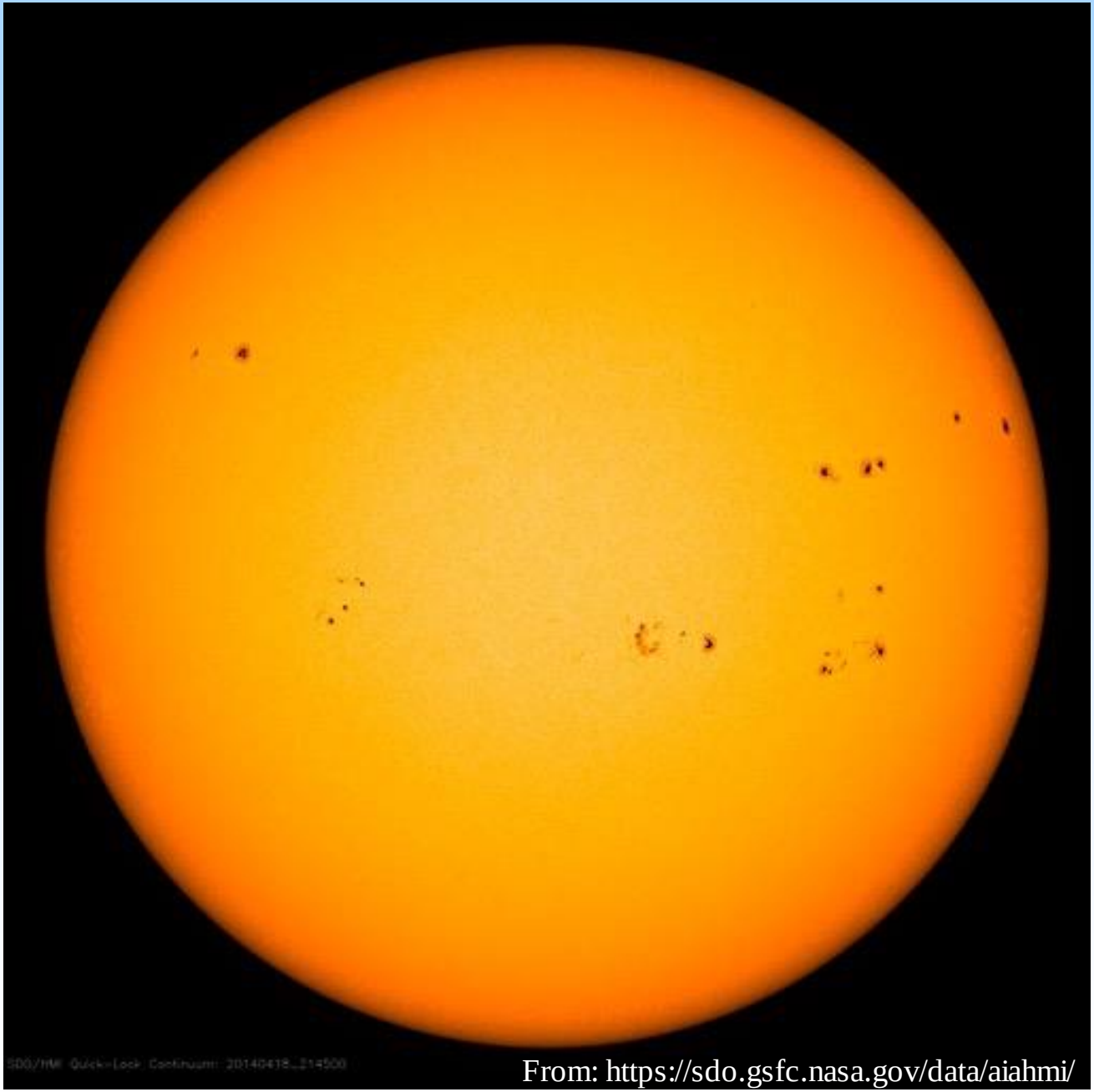
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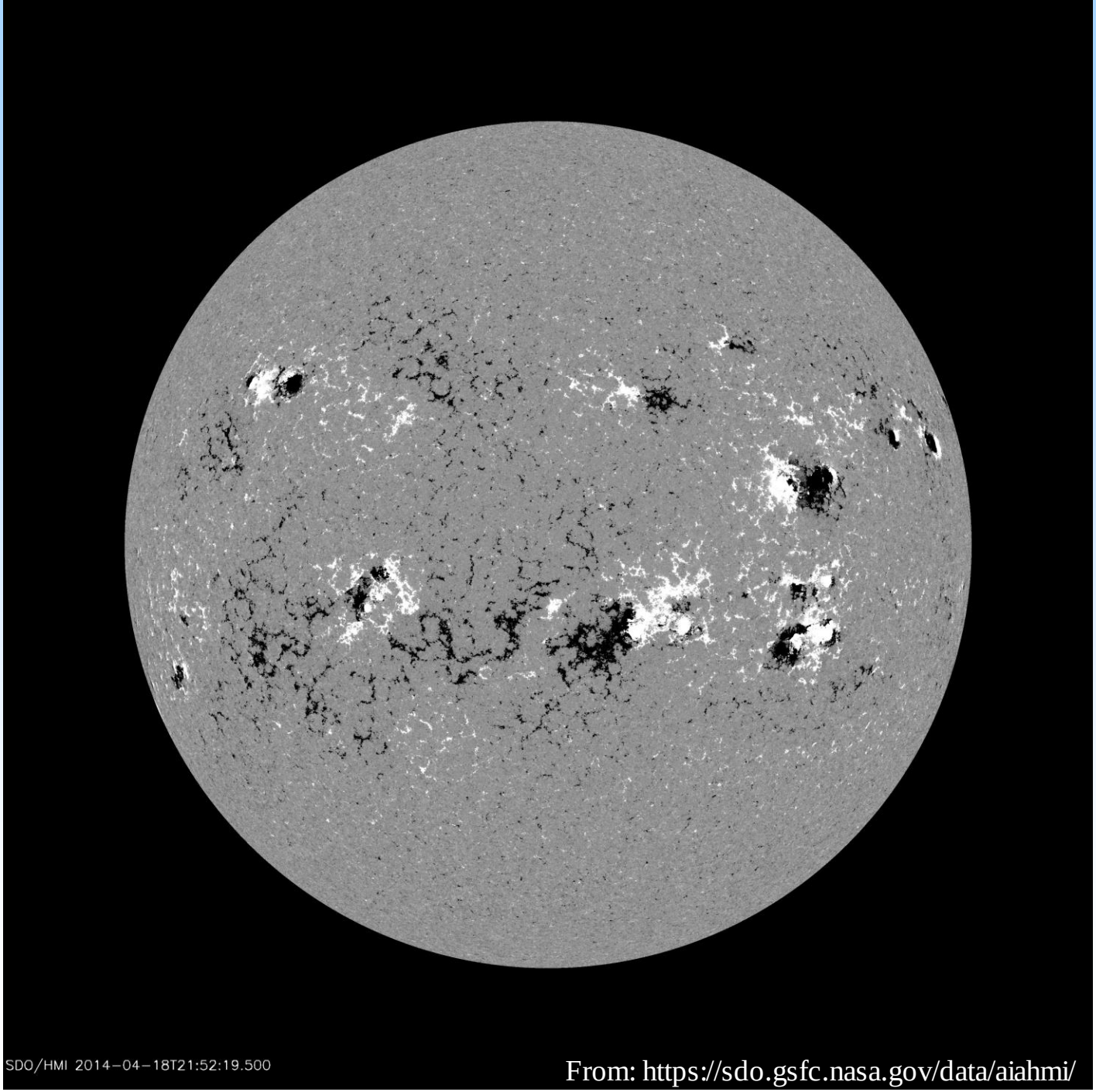

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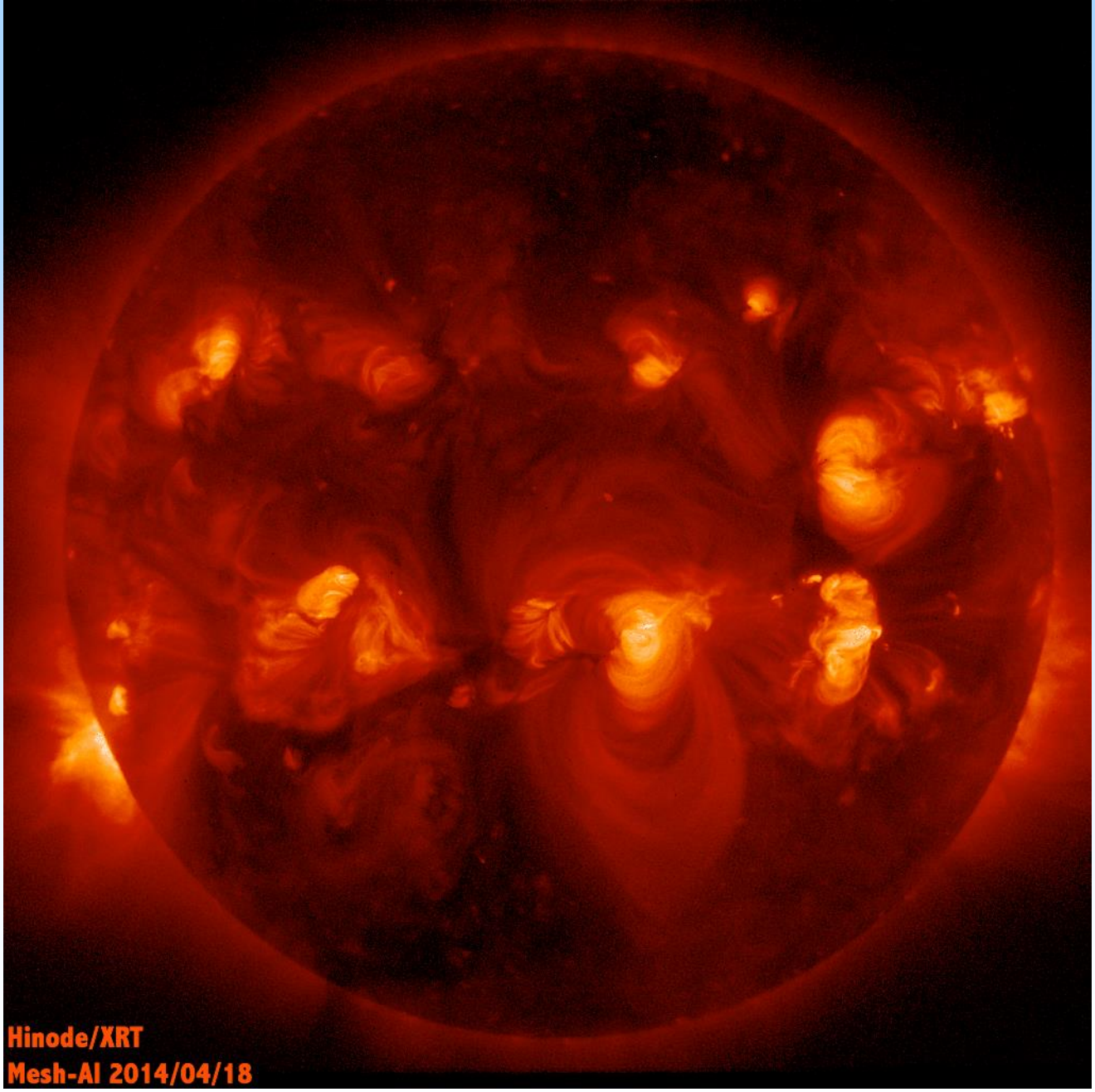
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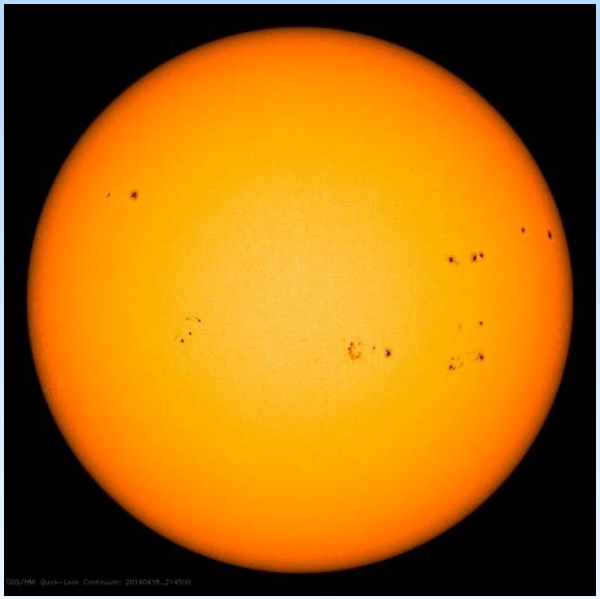
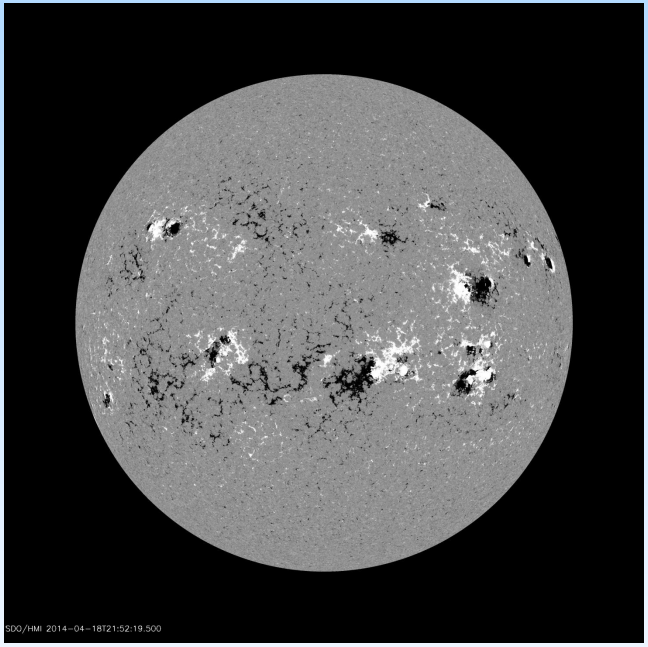
Mesh-Al 2014/04/18

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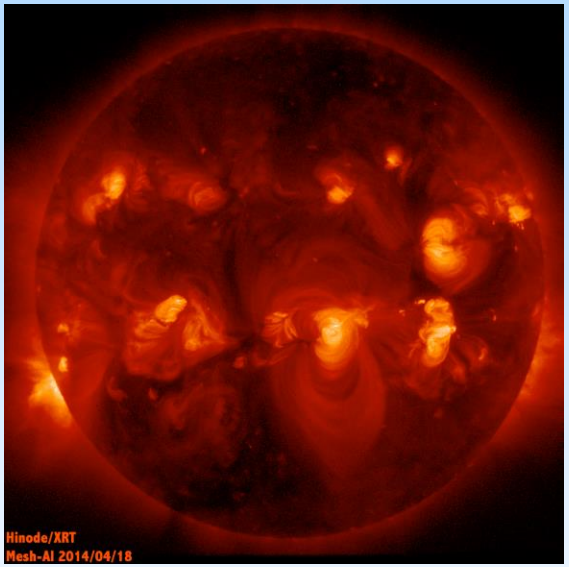
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