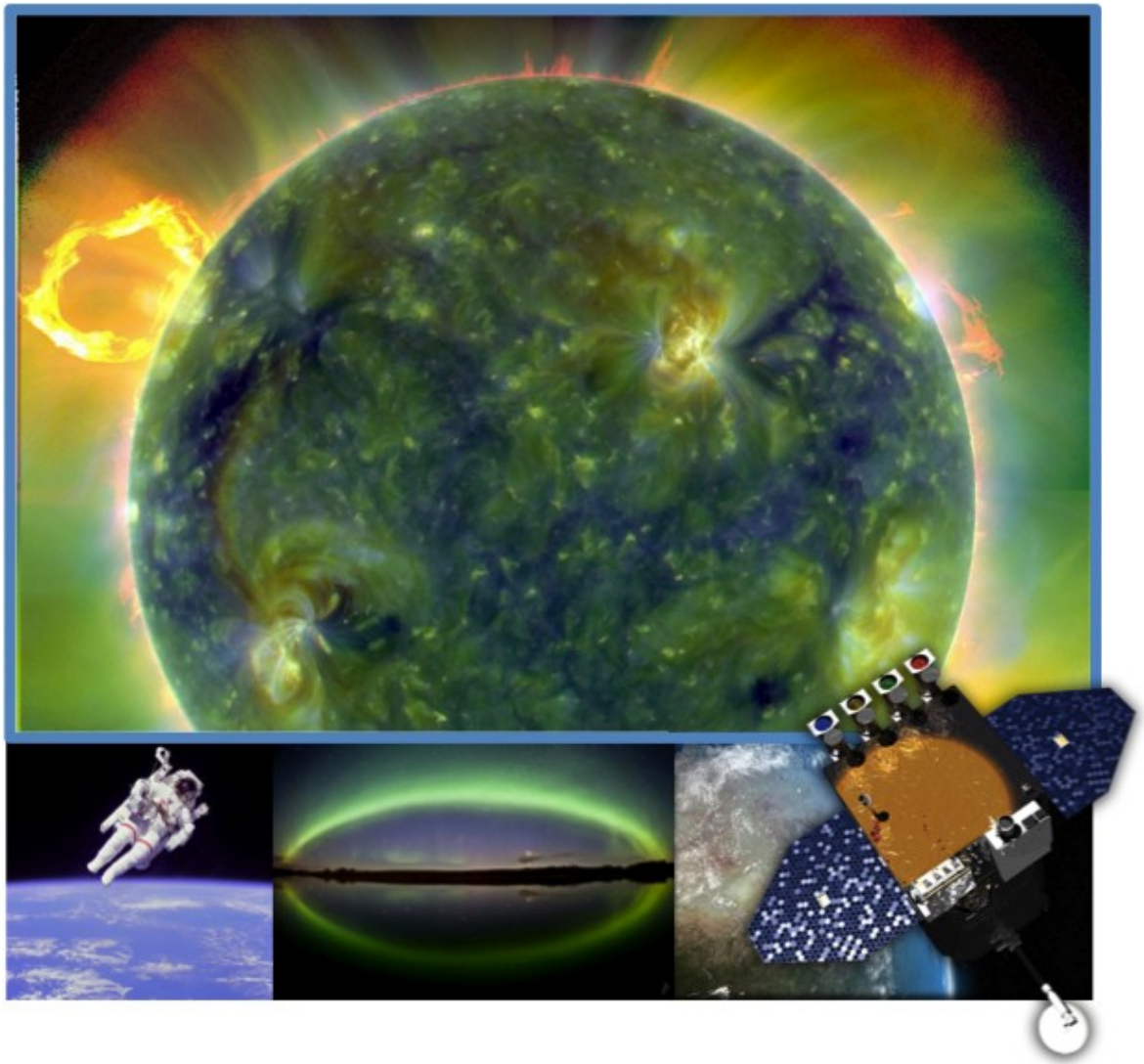
New Our Eye on the Sun

Tom Woods

University of Colorado
in Boulder

Many contributions
from the SDO team
and Dean Pesnell
(GSFC SDO Project Scientist)

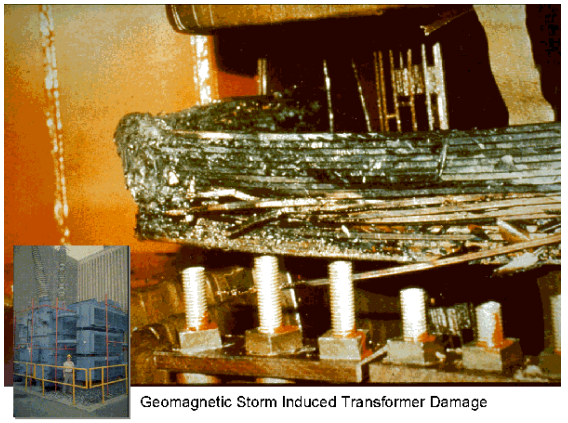


Space Weather

how solar storms affect us and our technology

GPS Navigation

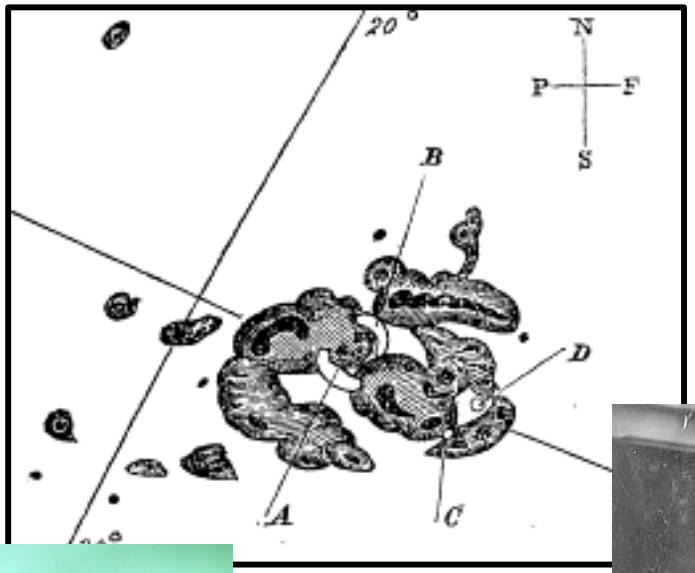
Gasoline Production & Sales



Geomagnetic Storm Induced Transformer Damage

Electrical Power Plants

First Space Weather Event



Carrington obs
hite-light flare
mber 1, 1859

What is the Sun doing today?

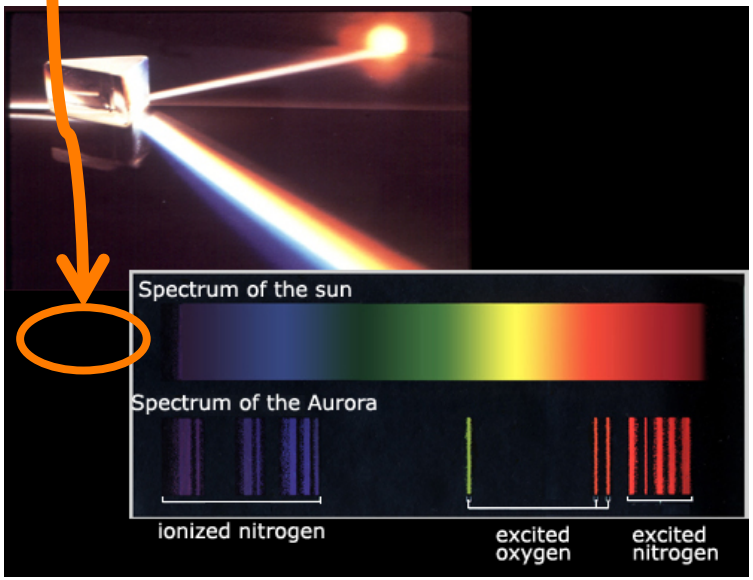
Solar Image

Visible Light (450 nm)

From

http://sdowww.lmsal.com/suntoday

Extreme Ultraviolet (EUV) highlights the solar corona



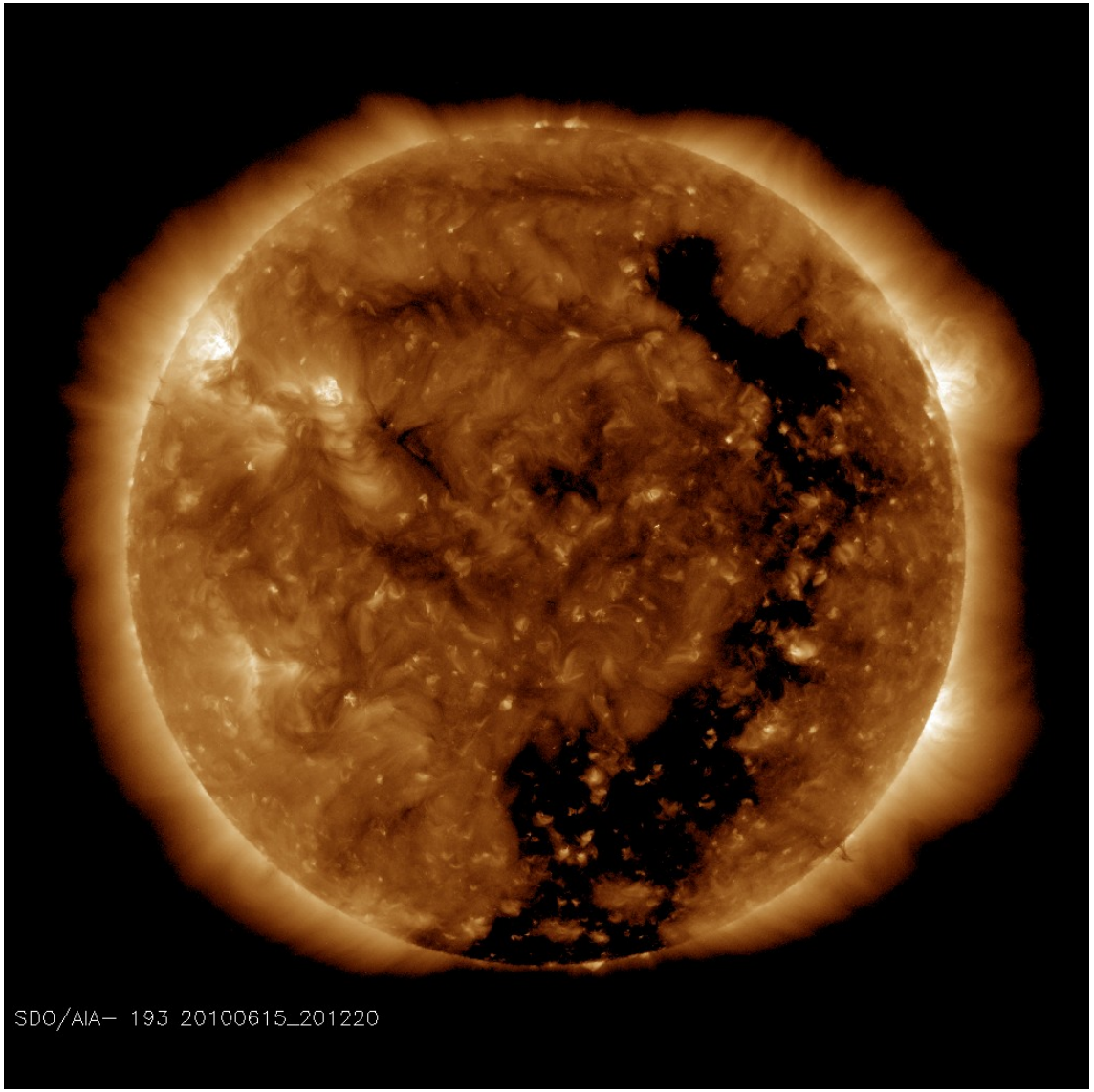
Solar Image

Fe XII 19.3 nm

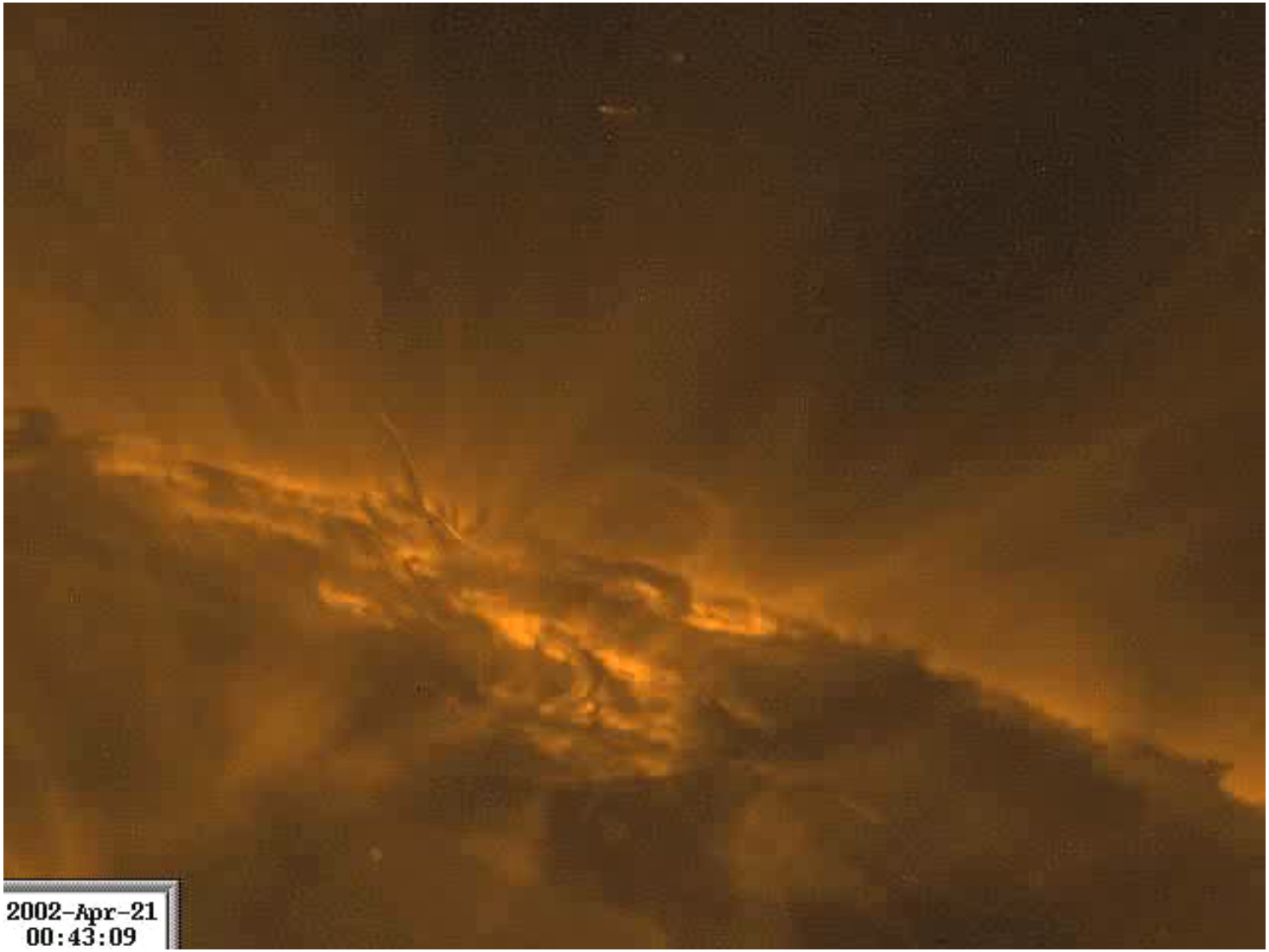
(roughly 1.5 million K)

From

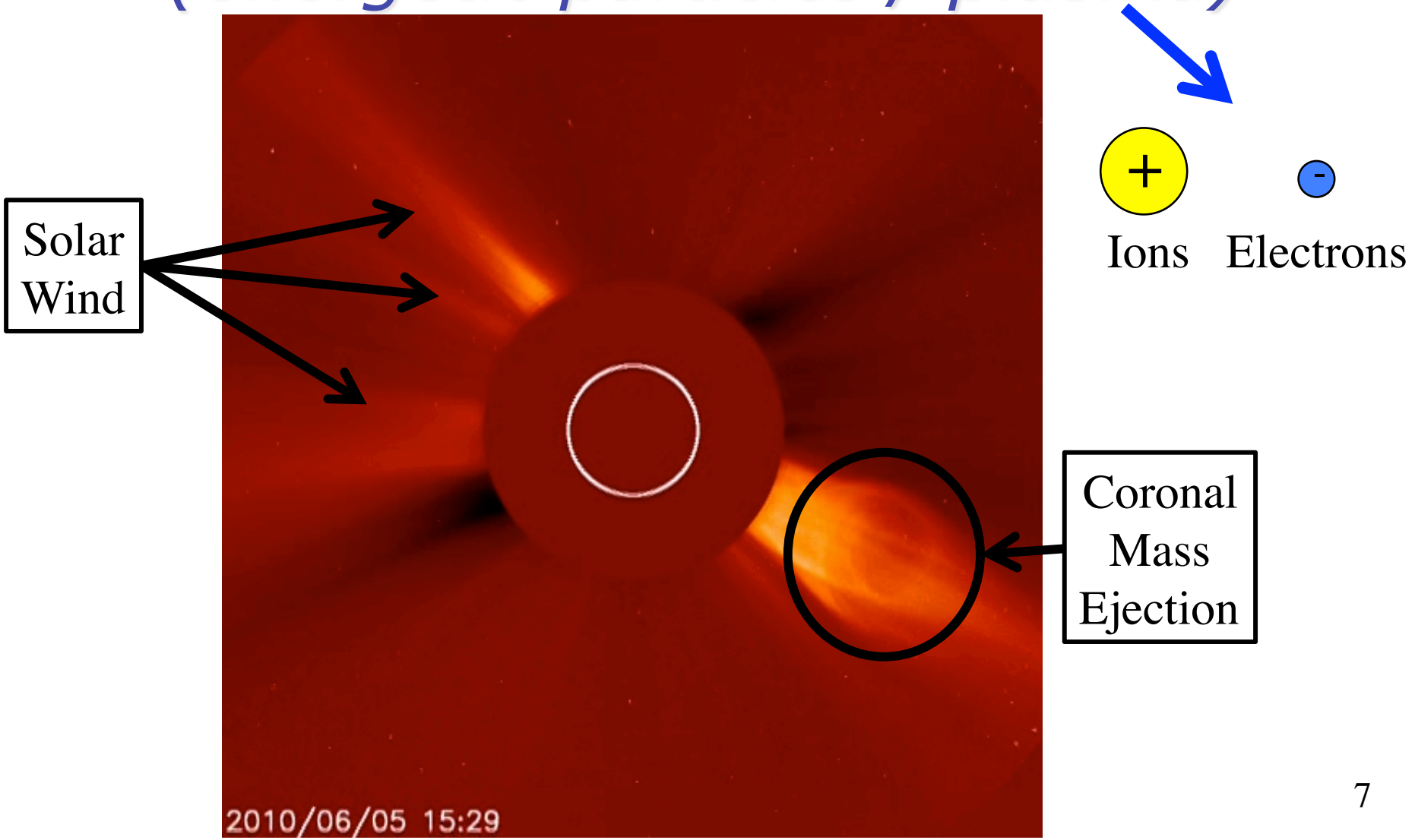
http://sdowww.lmsal.com/suntoday



We watch for flares… (X-ray & EUV photons)



and watch for CMEs… Coronal Mass Ejections (energetic particles / plasma)



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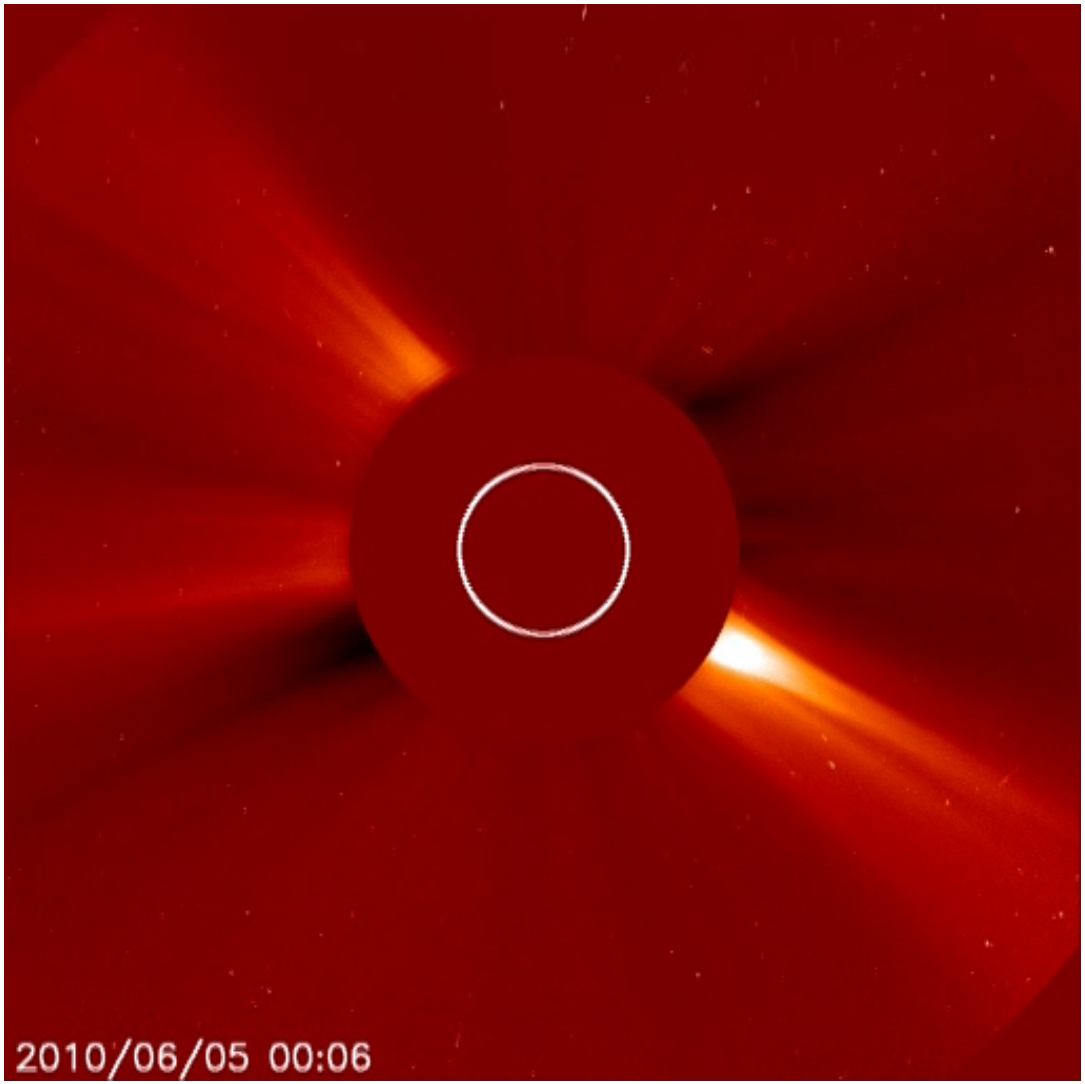
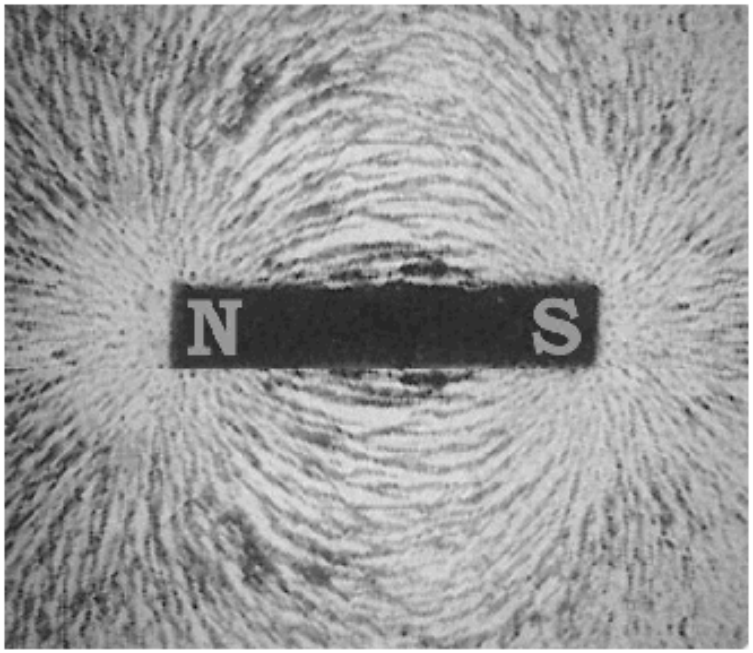
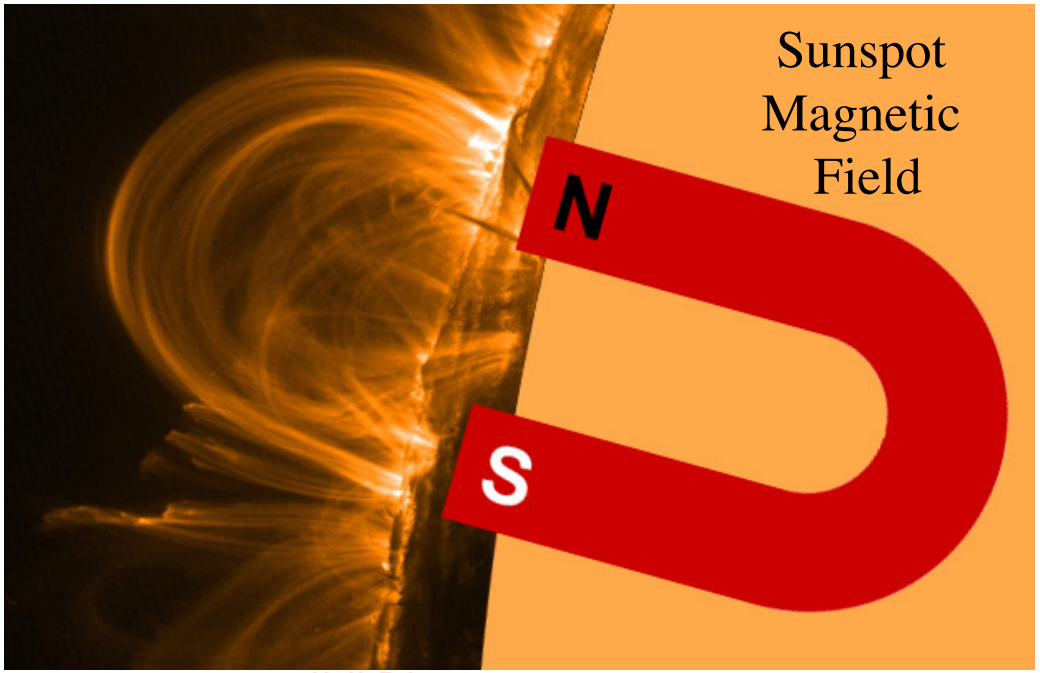
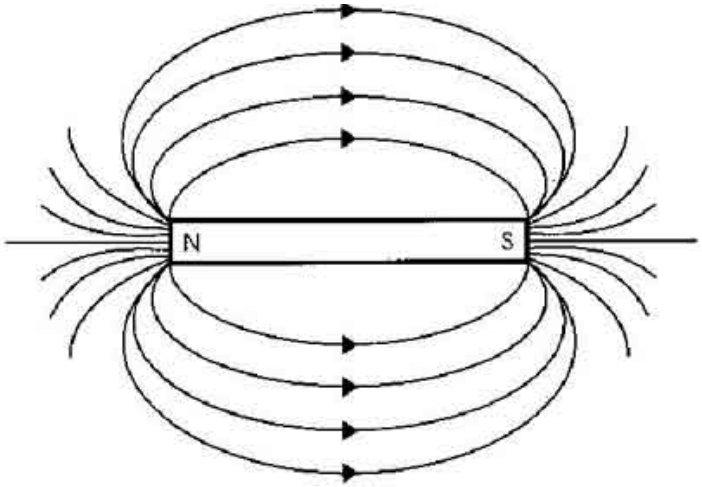
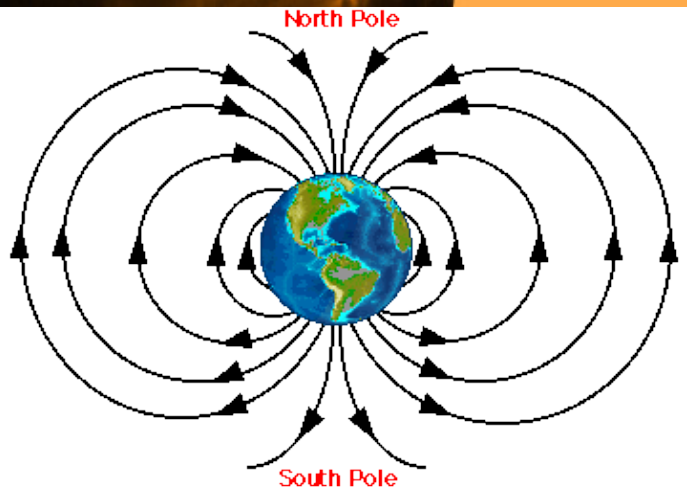


Solar Activity is largely controlled by Magnetic Fields



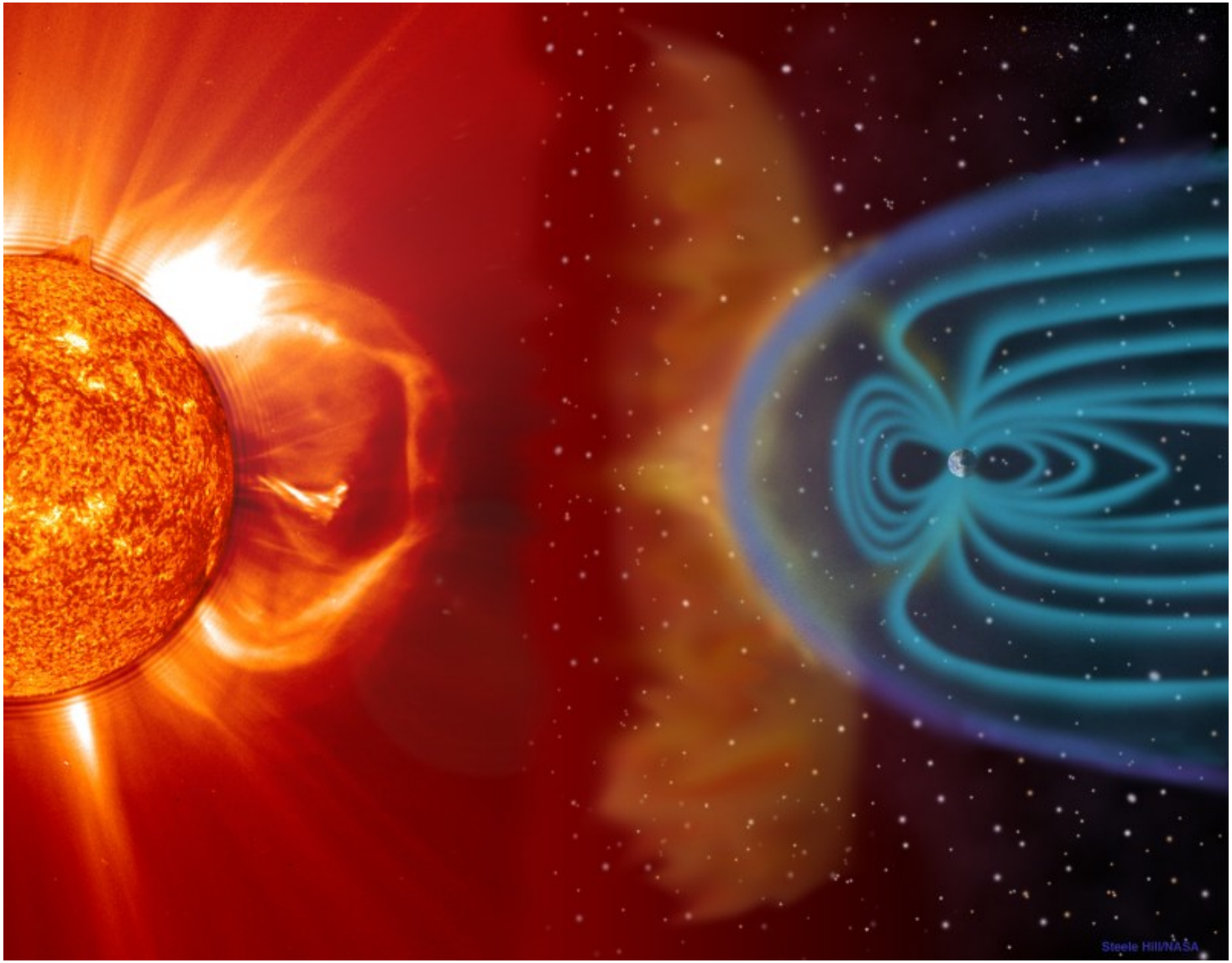






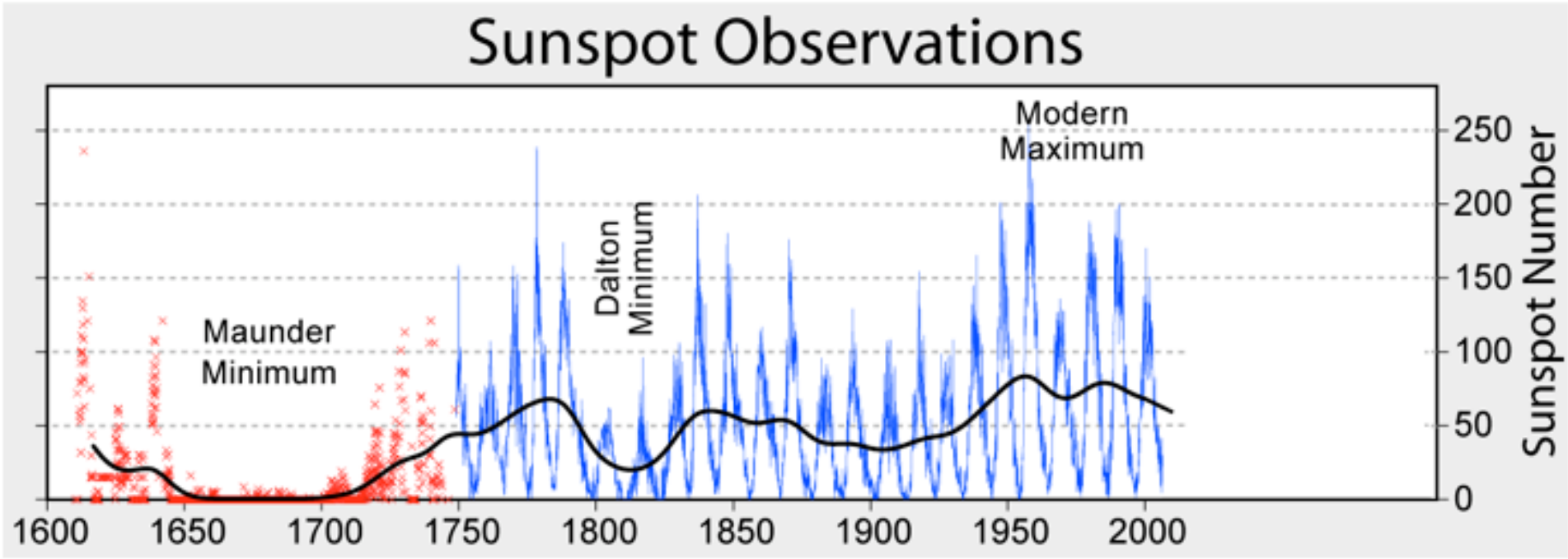
Earth's Magnetic Field

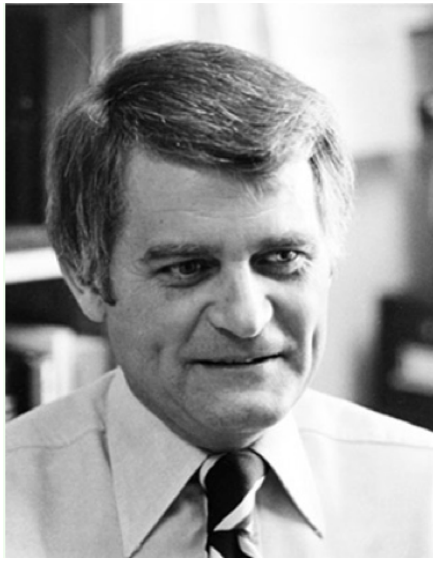
Earth's Magnetic Field helps to protect us from solar particles



- Walter Orr Roberts
  - High Altitude Observatory (HAO) director
  - shown with coronagraph in 1940

Sun Climate



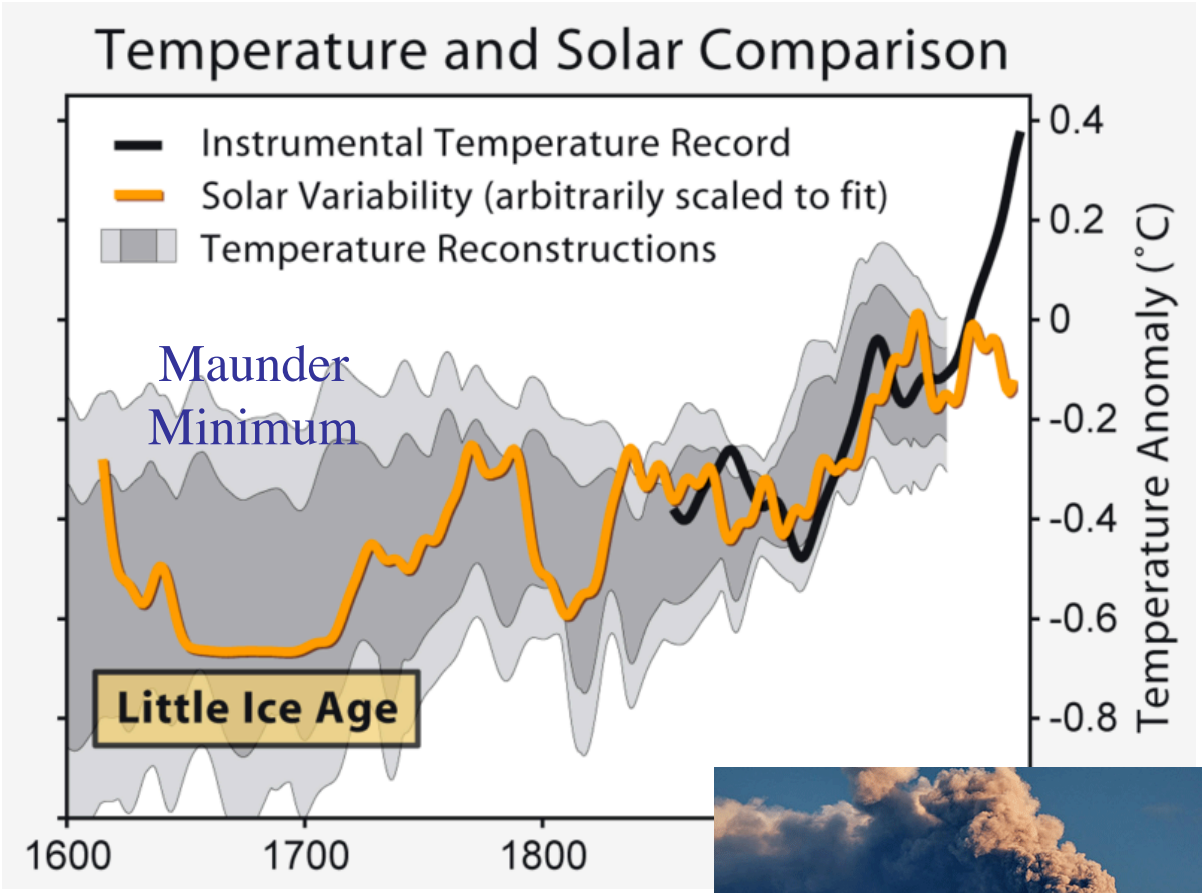


Carrington
Super Flare

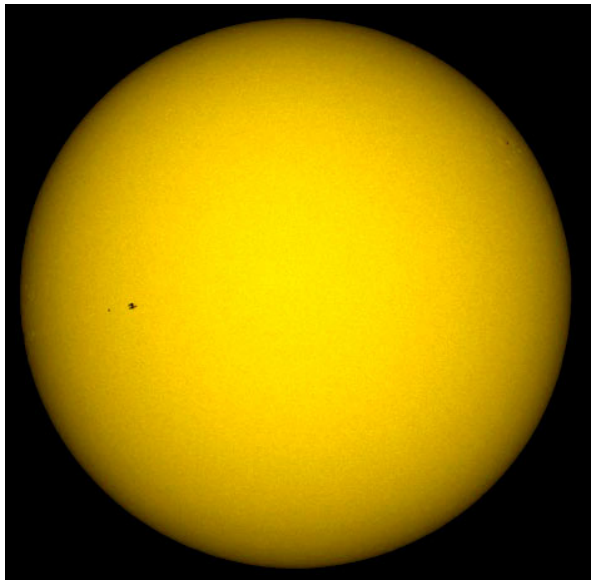
HAO

- John Allen "Jack" Eddy
  - March 25, 1931 – June 10, 2009
- "The Maunder Minimum," *Science*, 1976

The Sun is the Driver of Climate Change prior to 1950

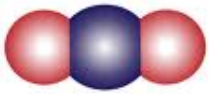


Credit: Robert A. Rohde



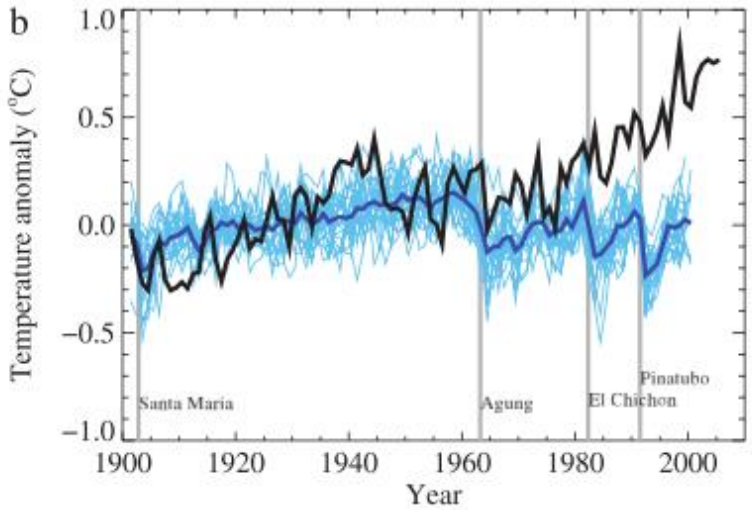
The Sun provides 99.9% of Earth's energy.

Carbon Dioxide (CO_2)



O=C=O

The Sun Takes Back Seat after 1960



Natural Forcings Only
Sun
Volcanoes

Credit: IPCC 2007 Report

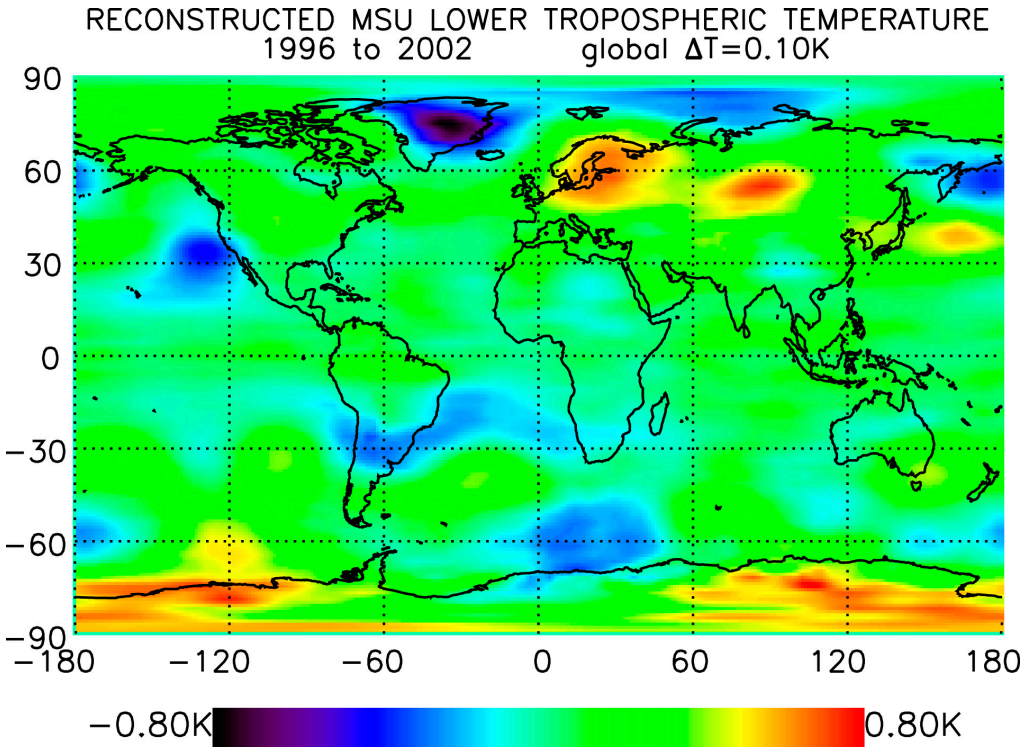
How much of modern global warming is due to natural solar variability?

- Solar forcing is 1 of 4 primary contributions to climate change over the past decade [Judith Lean, *Solar Physics*, 2005]
  - Solar forcing and greenhouse gases (GHGs) contribute to long-term warming
  - El Nino (ENSO) and volcanoes (aerosols) contribute to short-term changes

➢ ***Solar forcing is about 1/5 of modern global warming***

➢ ***11-year Solar Cycle*** Results

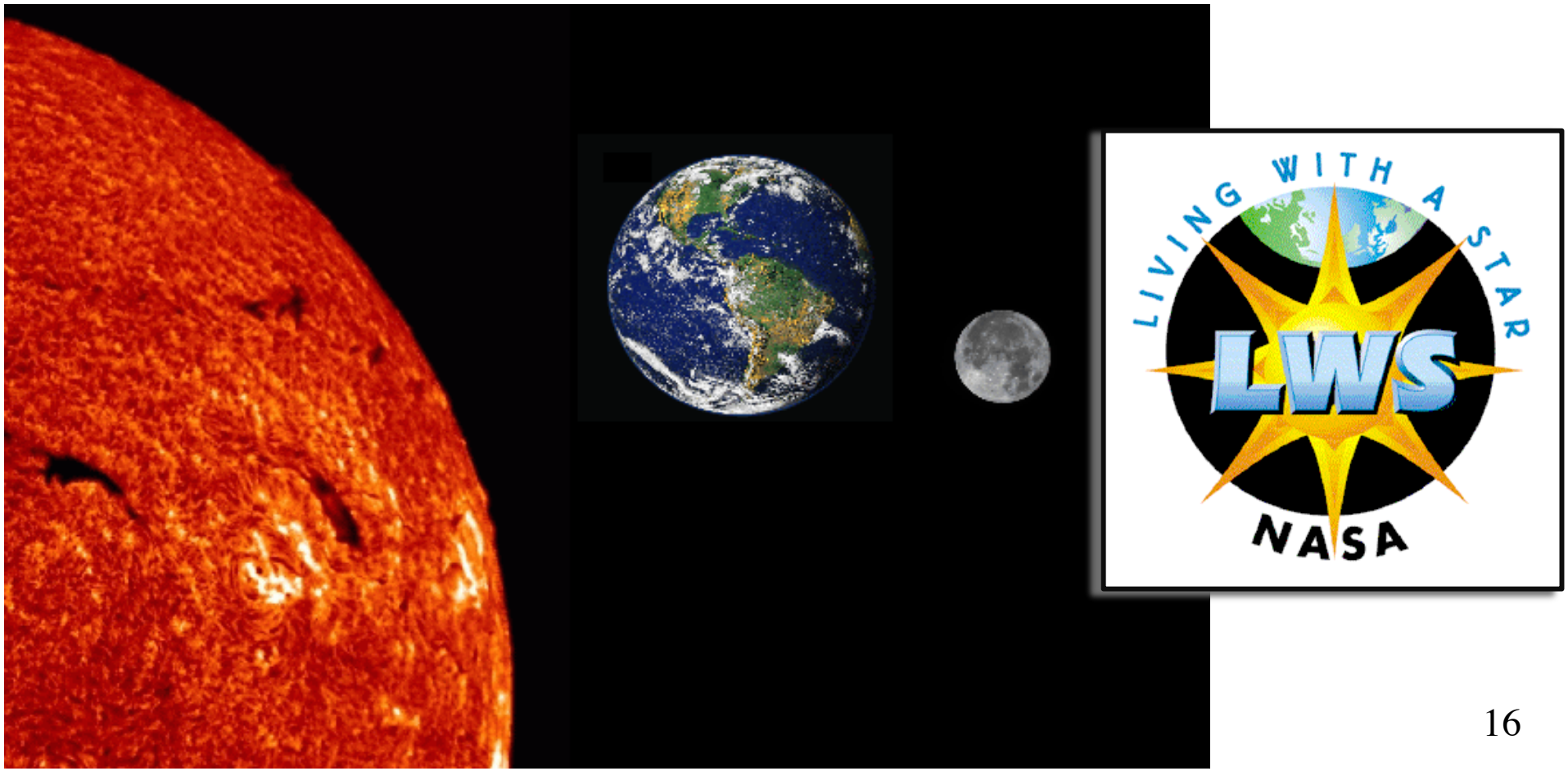
- ***Global*** change is 0.1 K
- But ***regional*** temperature changes are much larger
  - some hotter
  - some cooler



[figure from Woods and Lean, *EOS*, 2007]

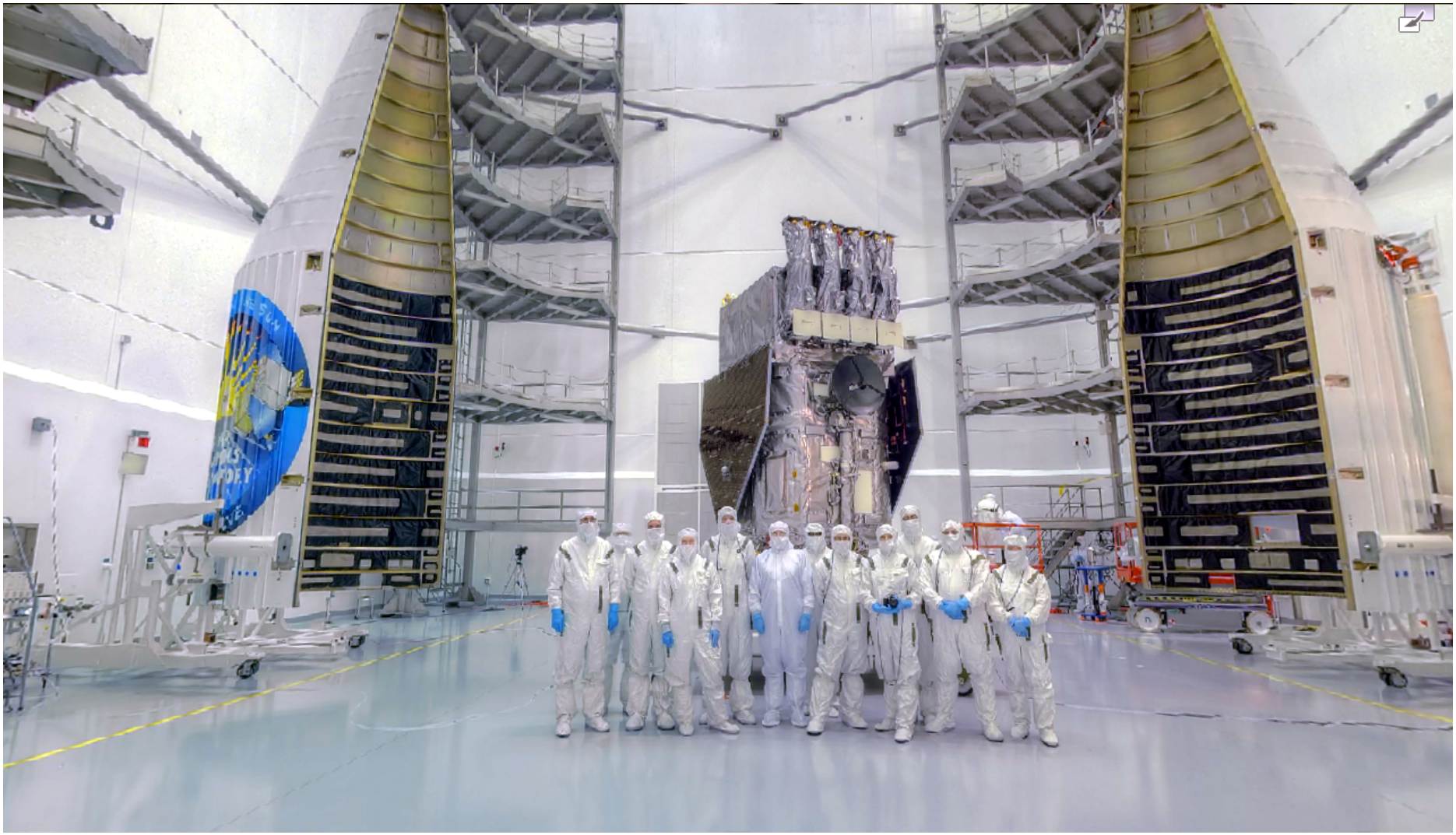
NASA's Living With a Star

- How and why does the Sun vary?
- How does the Earth respond?
- What is the effect on life and technology?

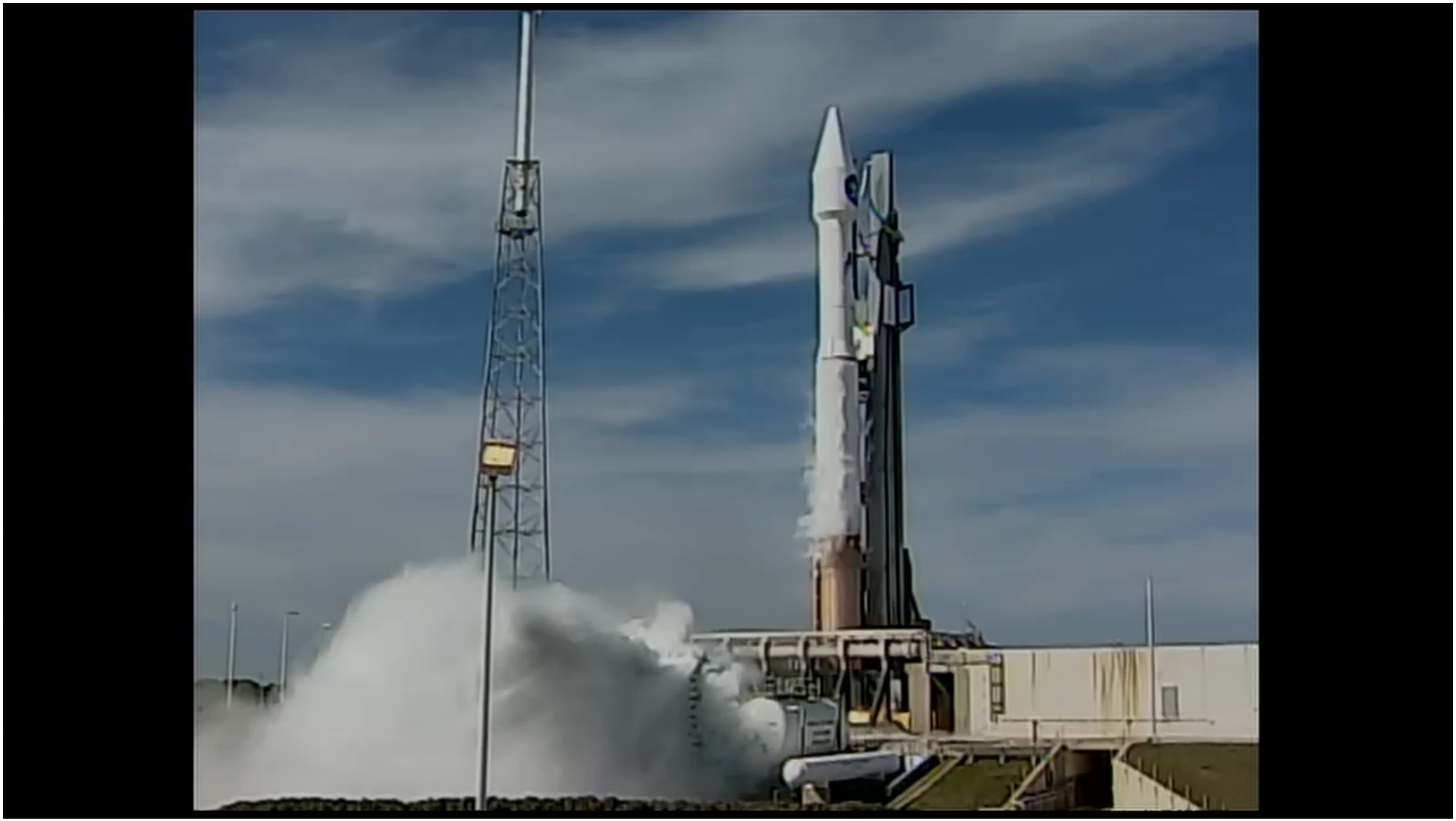


Solar Dynamics Observatory

SDO is First LWS Mission

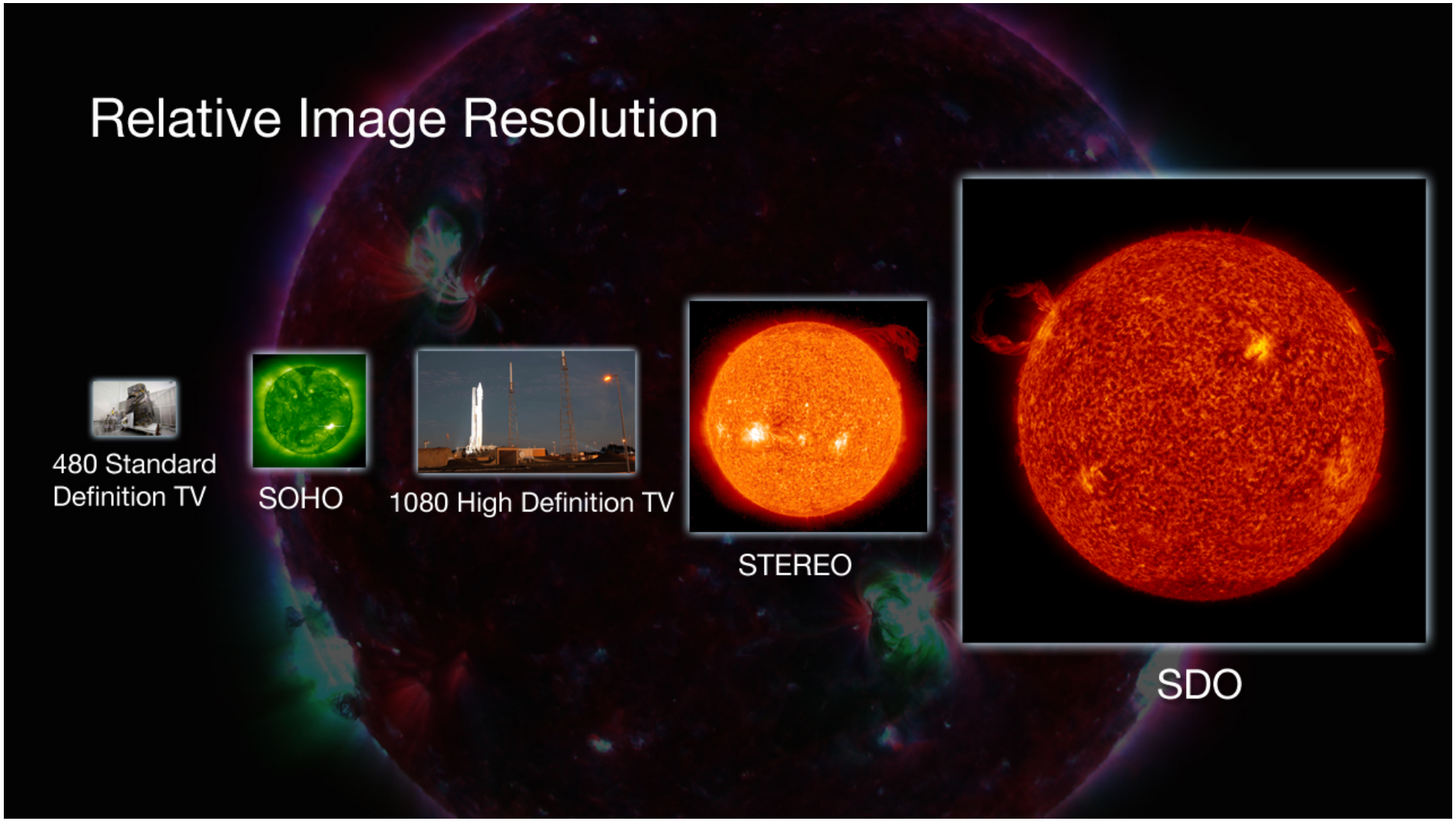


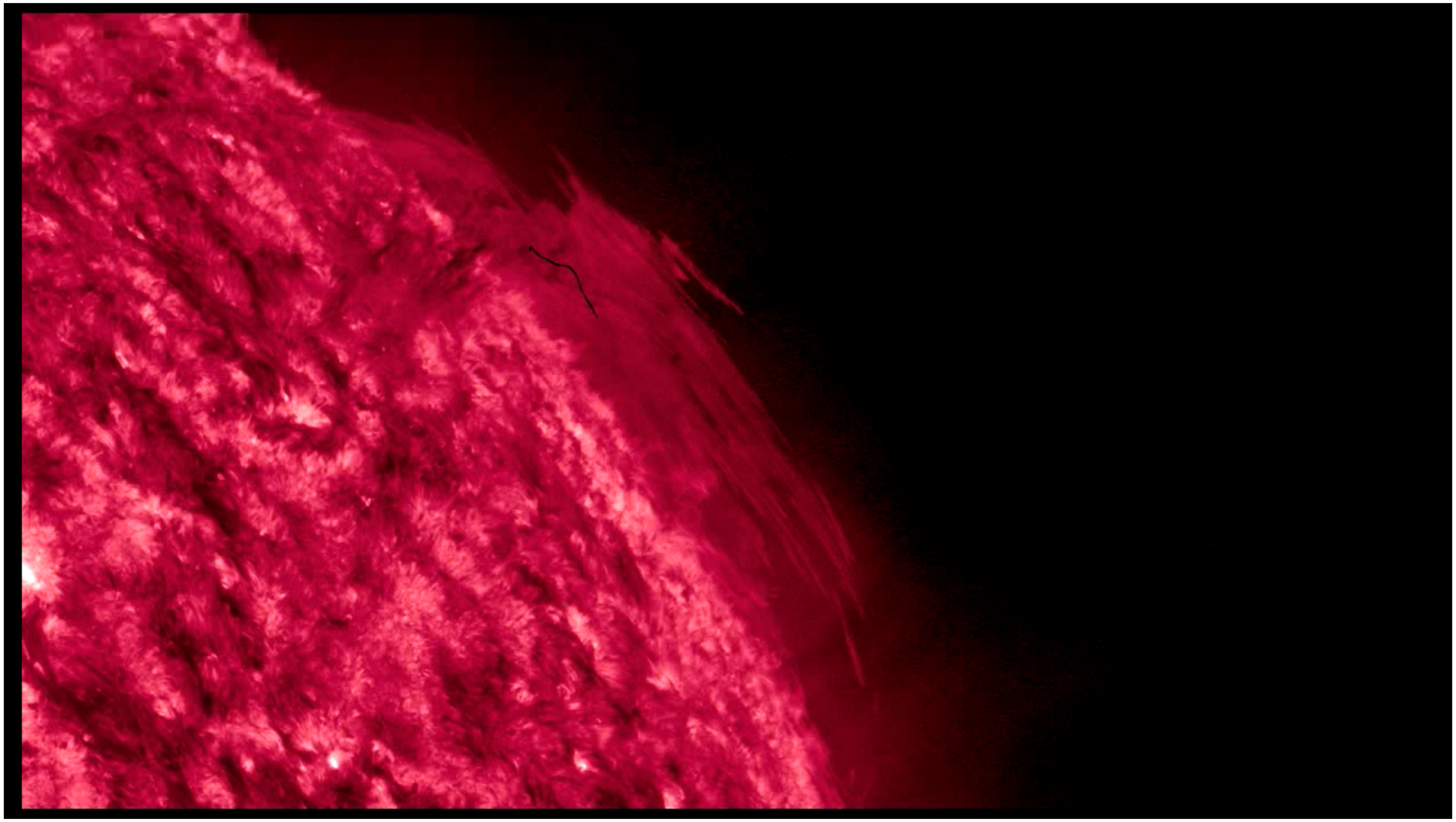
A Perfect Launch



SDO: Our Eye on the Sun

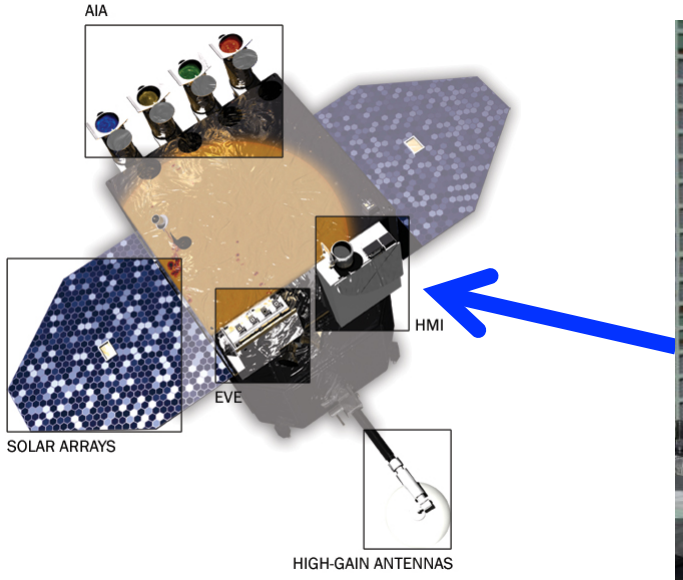
has 8 times better resolution than HD TV

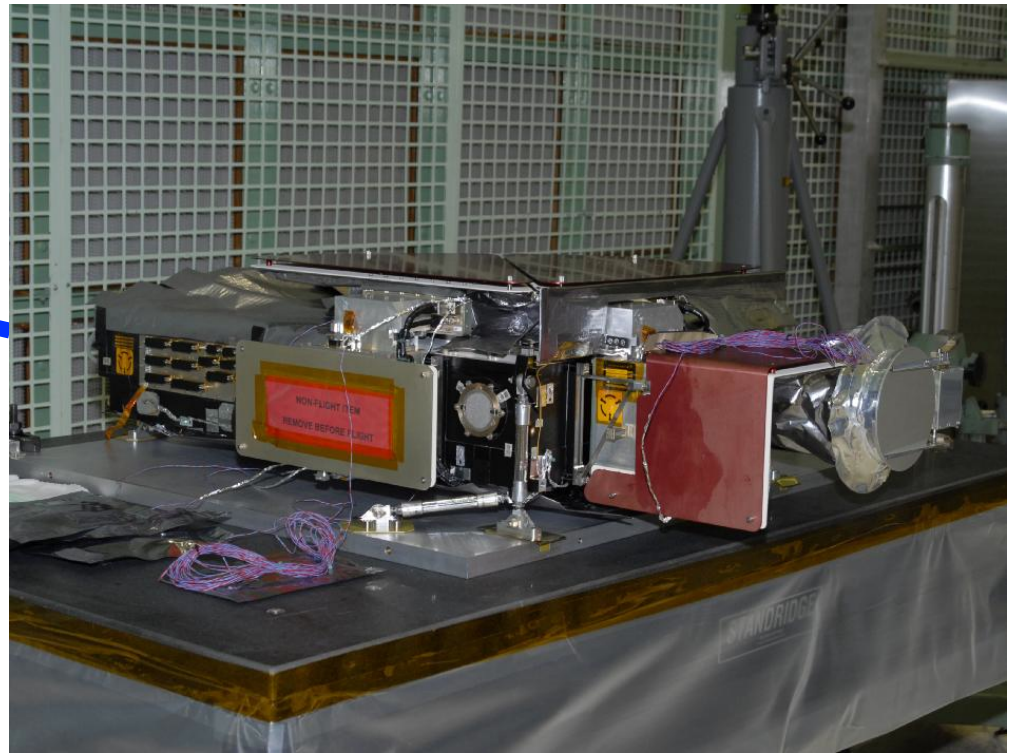




Credit: AIA Team

HMI
Helioseismic & Magnetic Imager

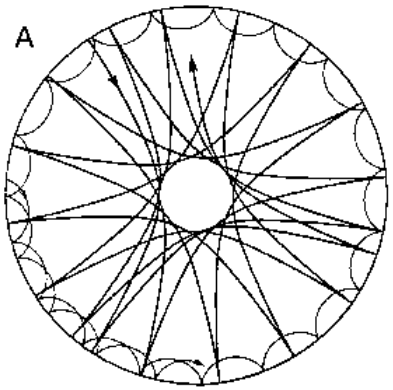




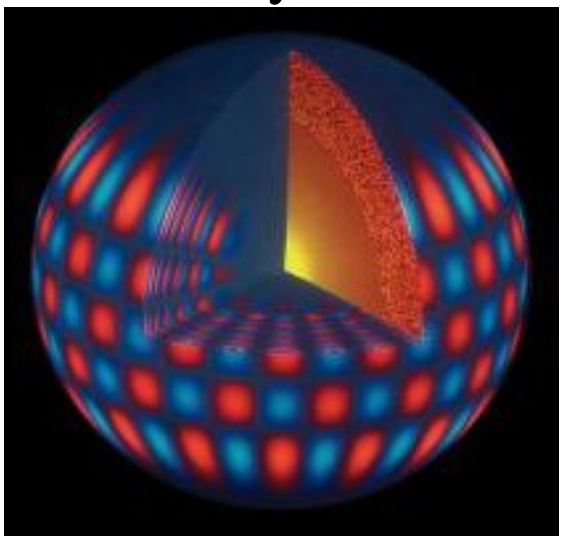
- Built at Stanford University and Lockheed Martin in Palo Alto, CA
- HMI images the solar magnetic fields and local oscillations that provide a view to the core of the Sun (helioseismology)

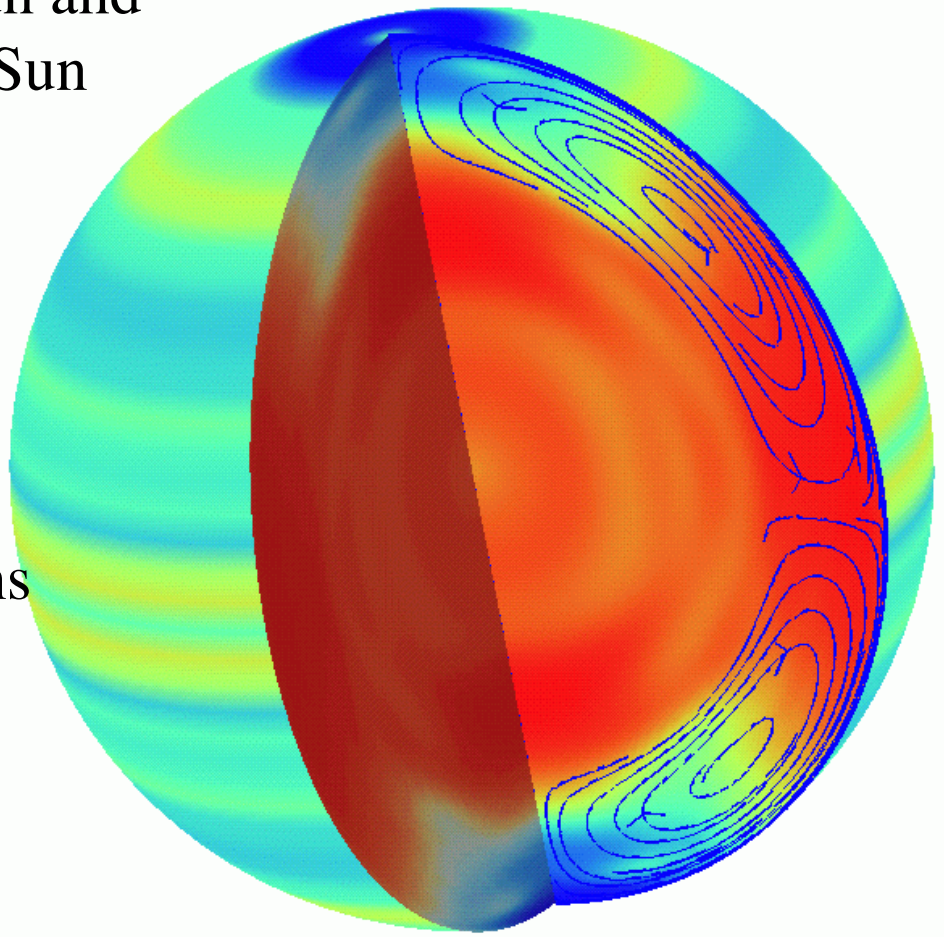
Helioseismology

Sound waves travel around the Sun and probe into different depths of the Sun



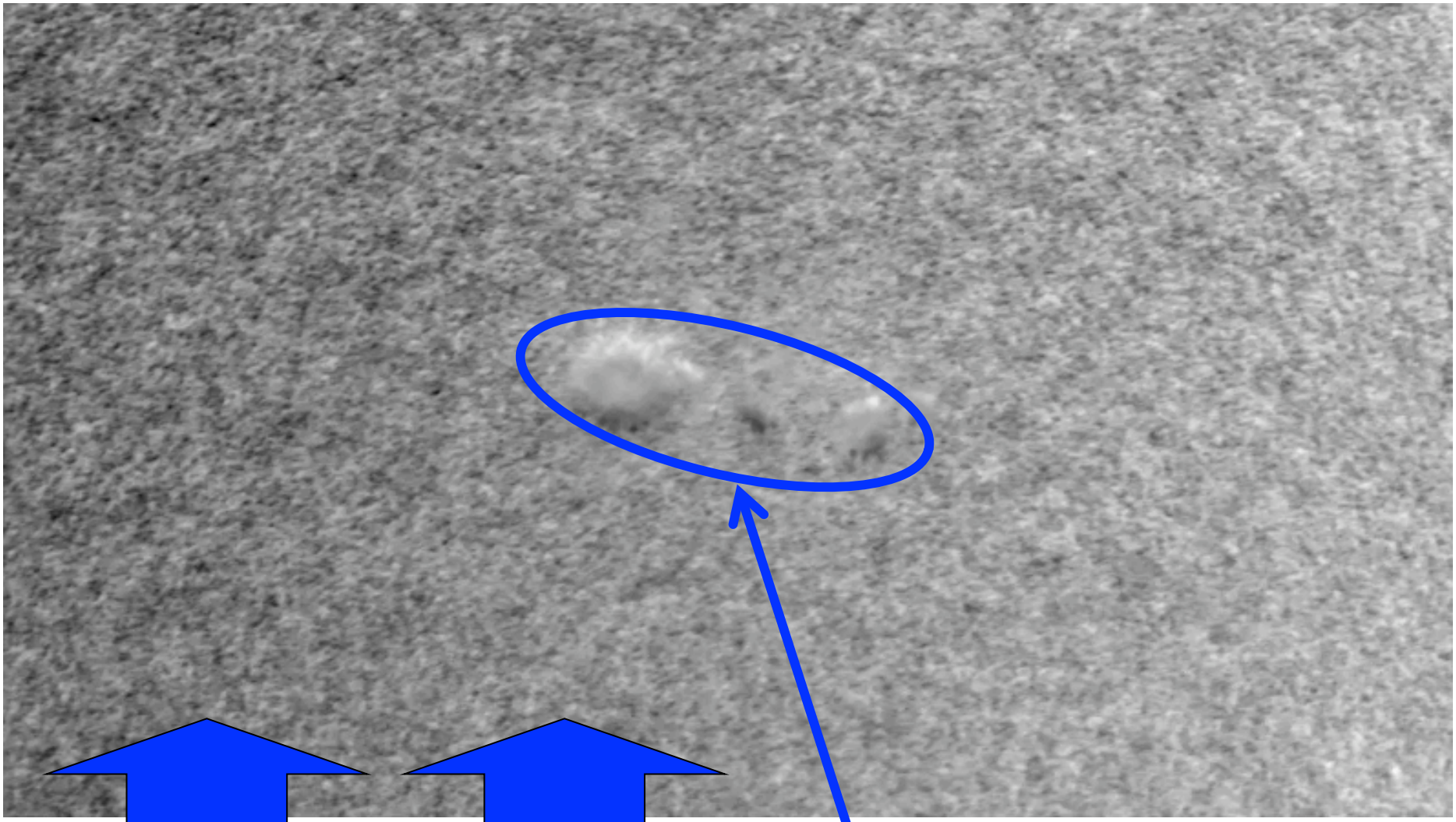
Sun has many different oscillations





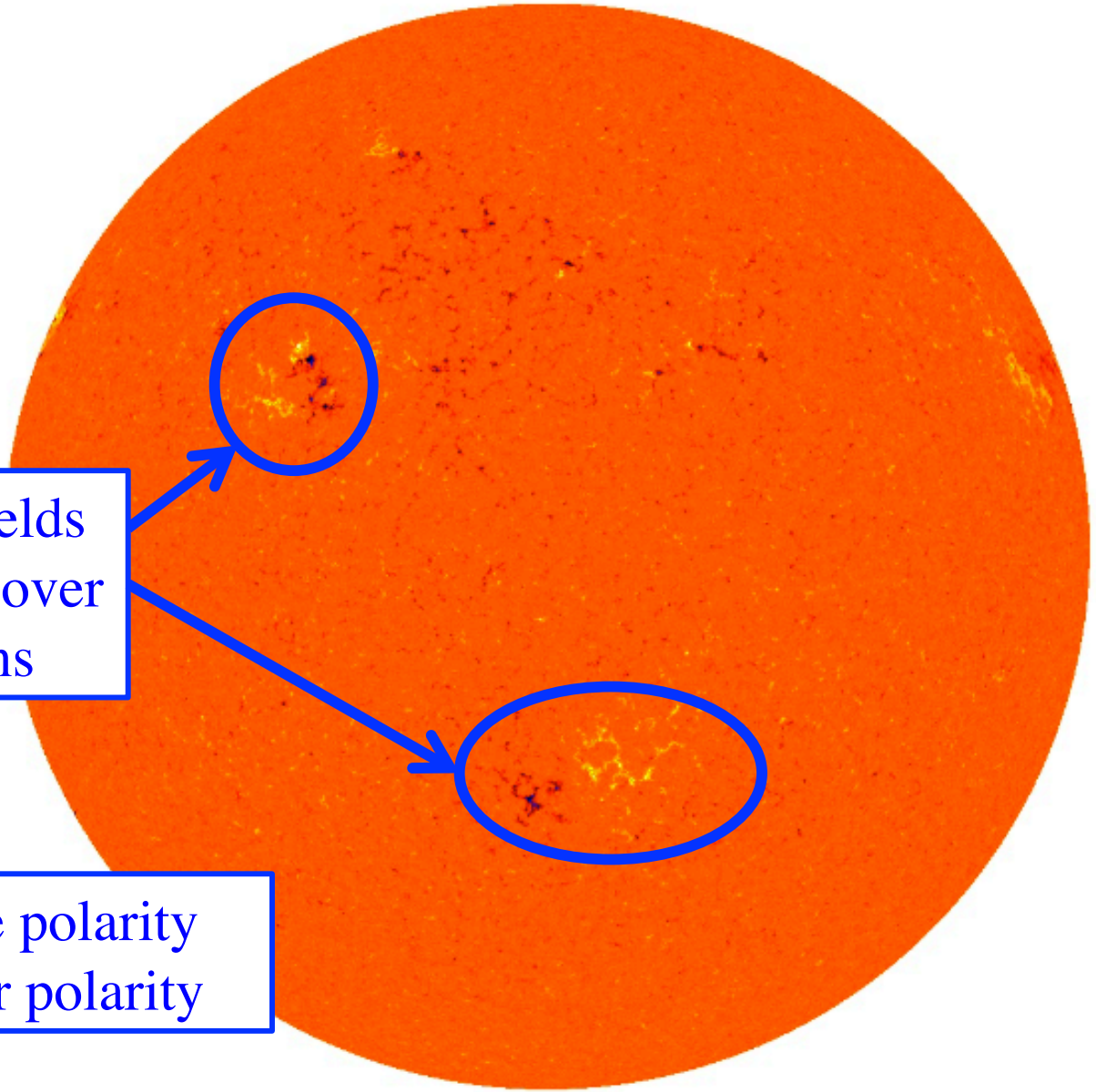
Analysis of these sound wave pressure modes at the Surface allow glimpse of what is inside the Sun

HMI Dopplergrams



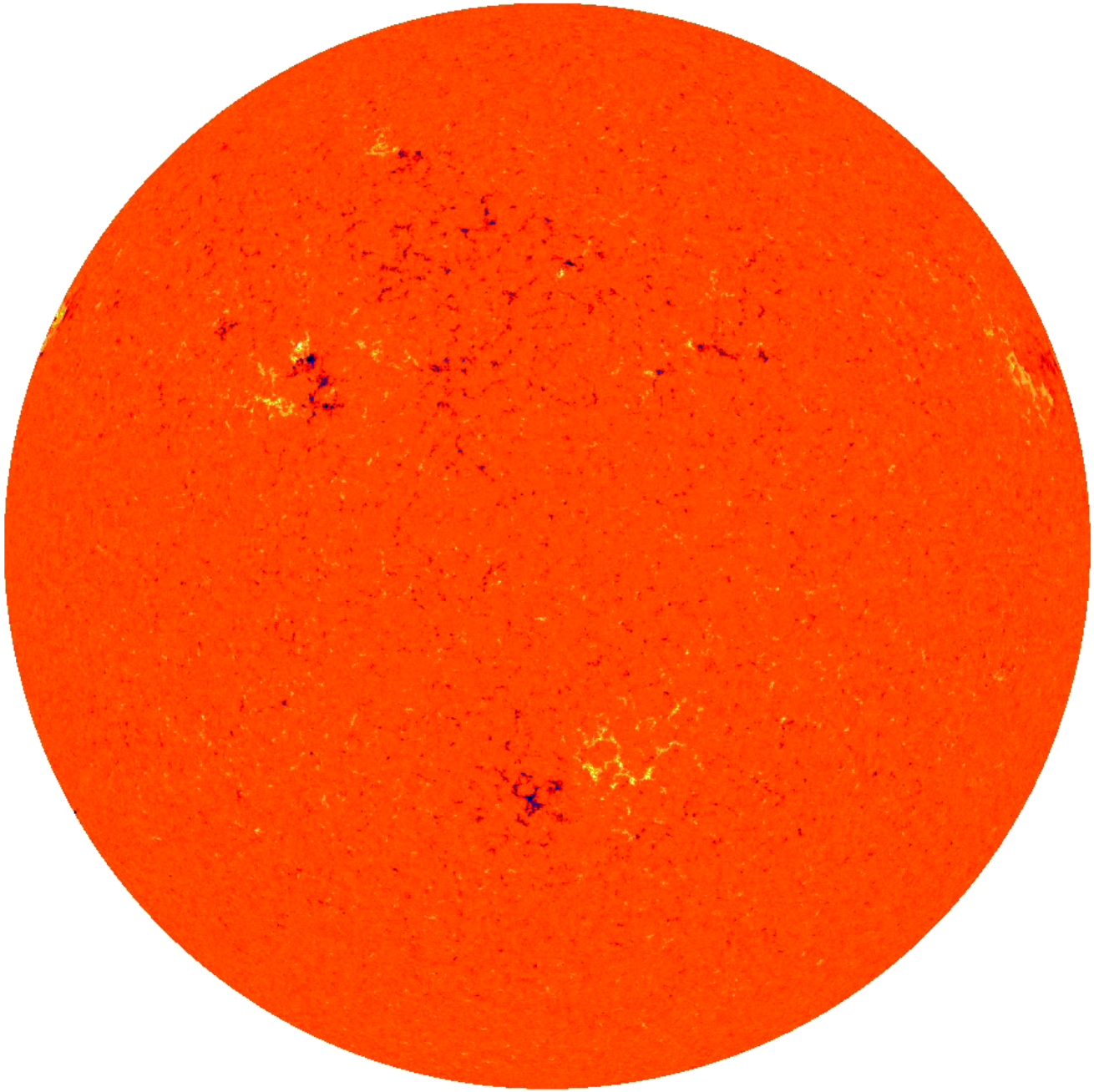
HMI Dopplergrams

First Solar Rotation



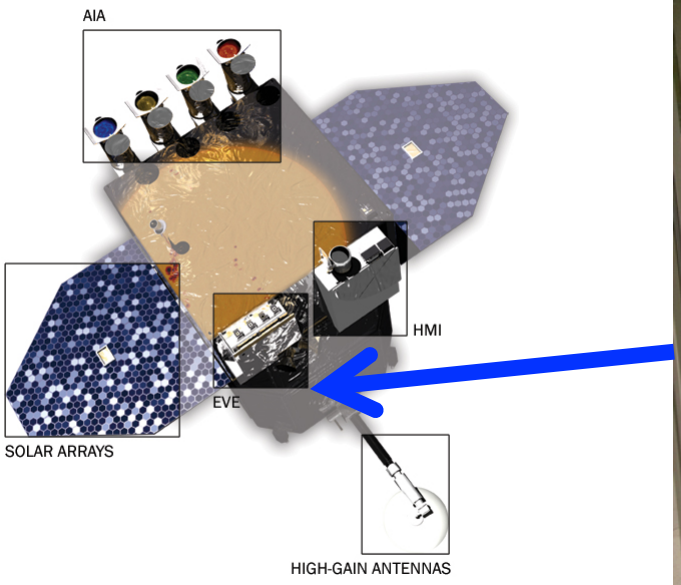
Magnetic Fields are stronger over active regions

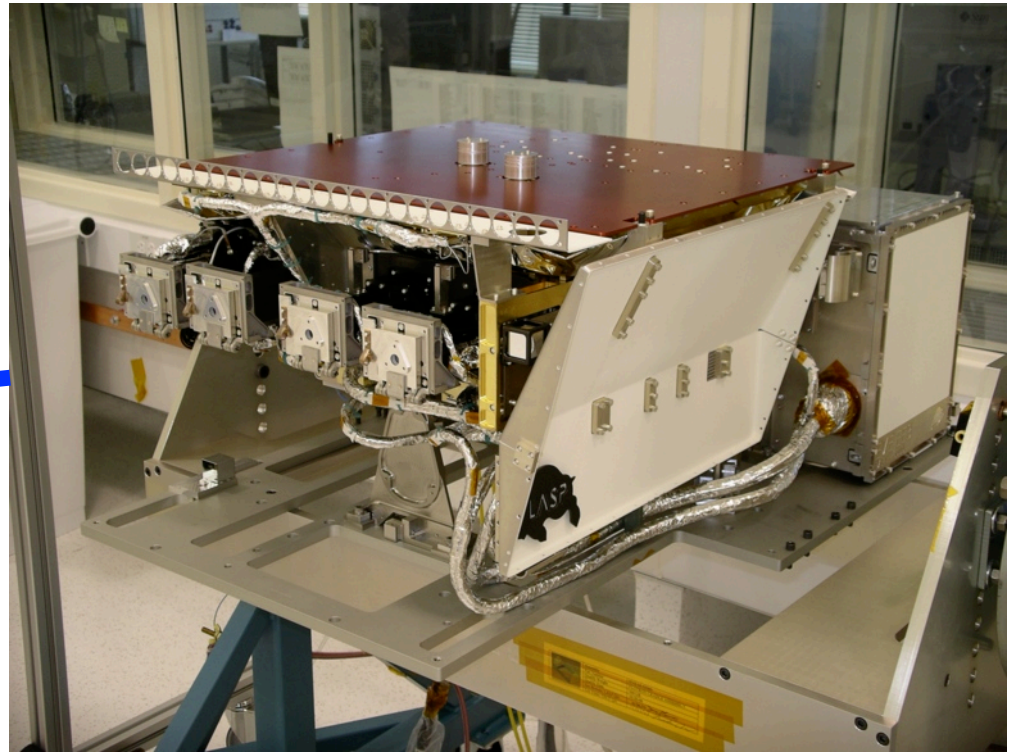
Yellow: one polarity
Black: other polarity



EVE

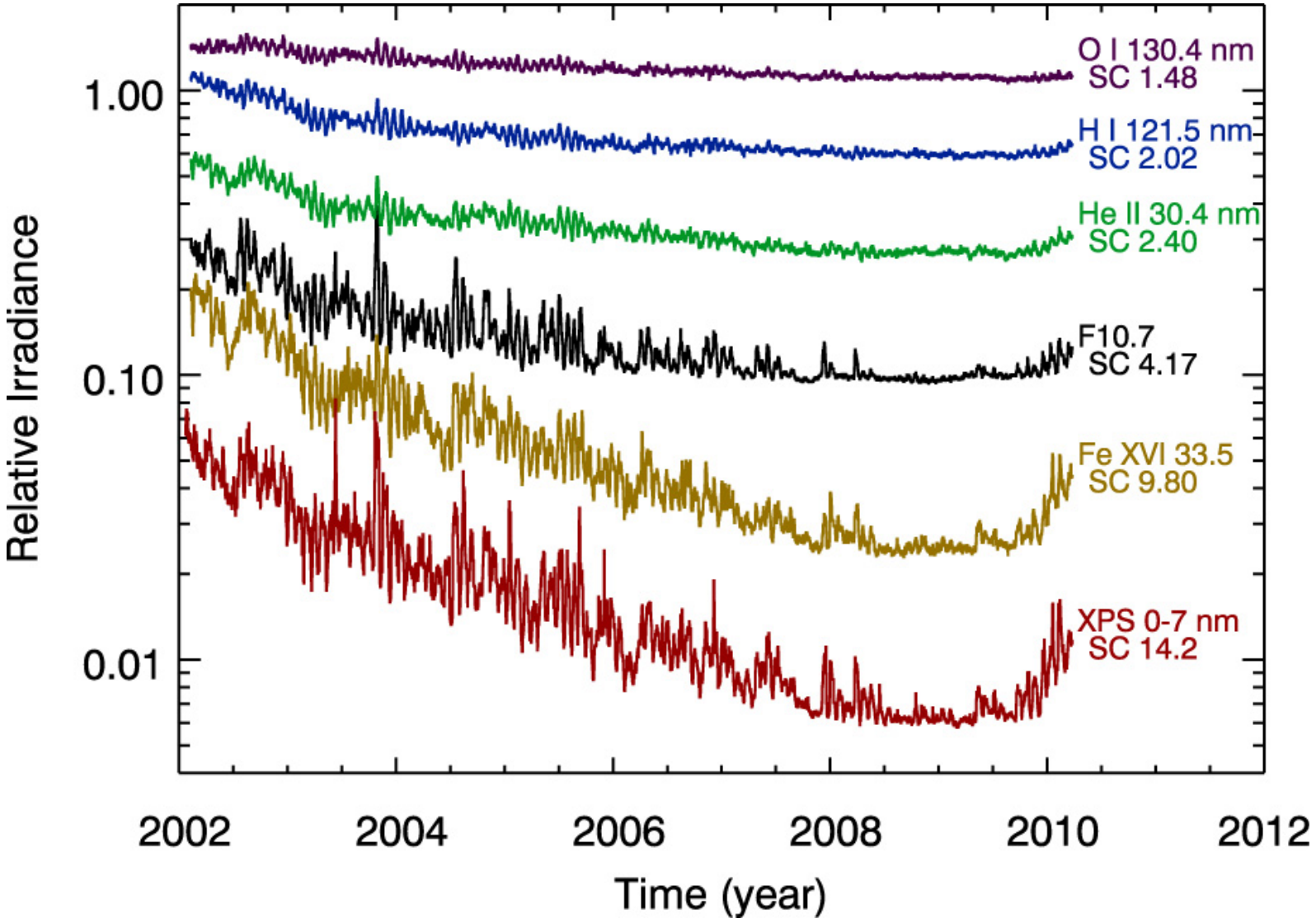
Extreme ultraviolet Variability Experiment



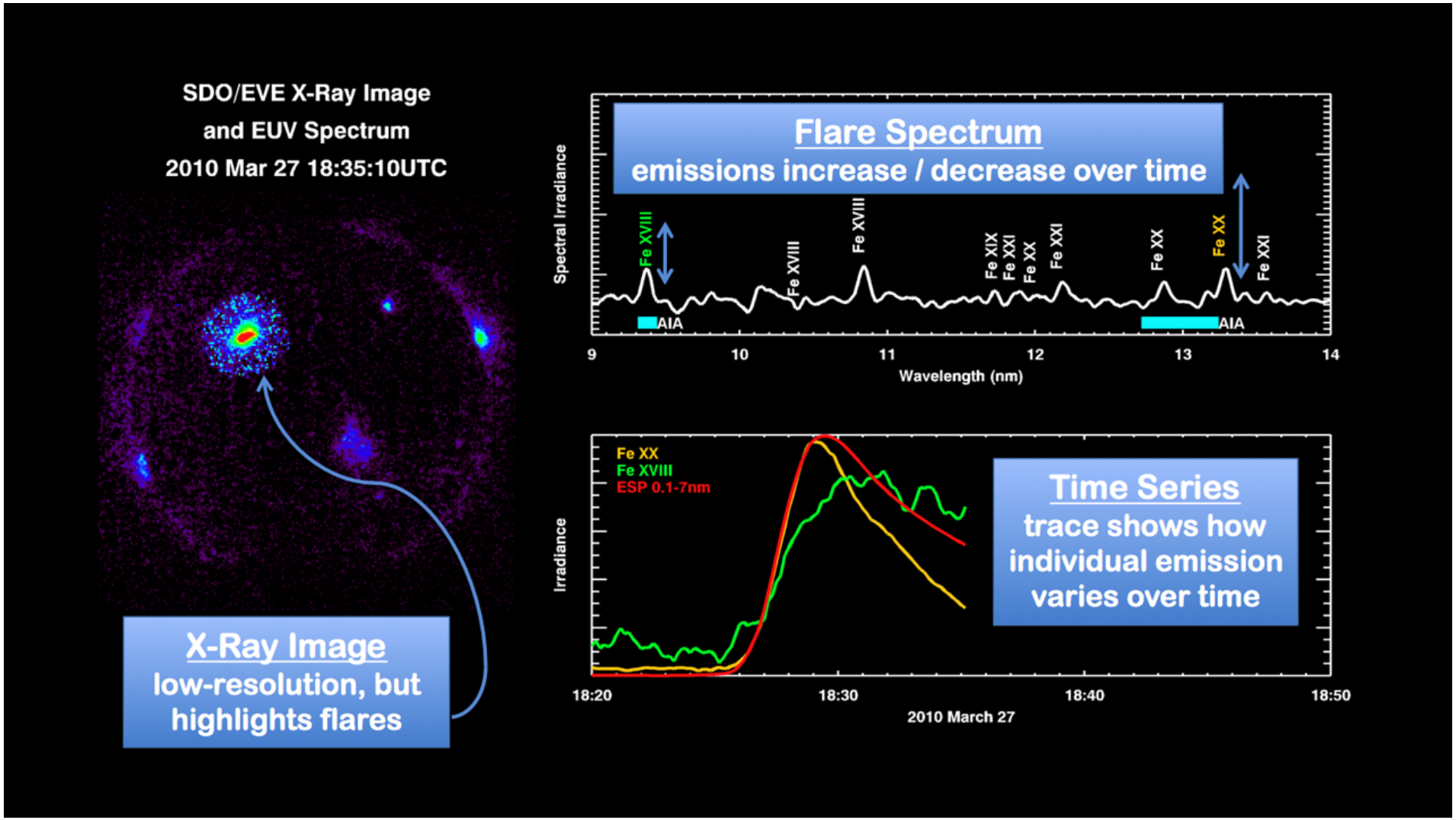


- Built by the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder, CO
- EVE uses gratings to disperse the solar light into different wavelengths
  - Observes solar flares (X-ray and EUV photons)
  - Its space weather data are used in modeling Earth's atmosphere

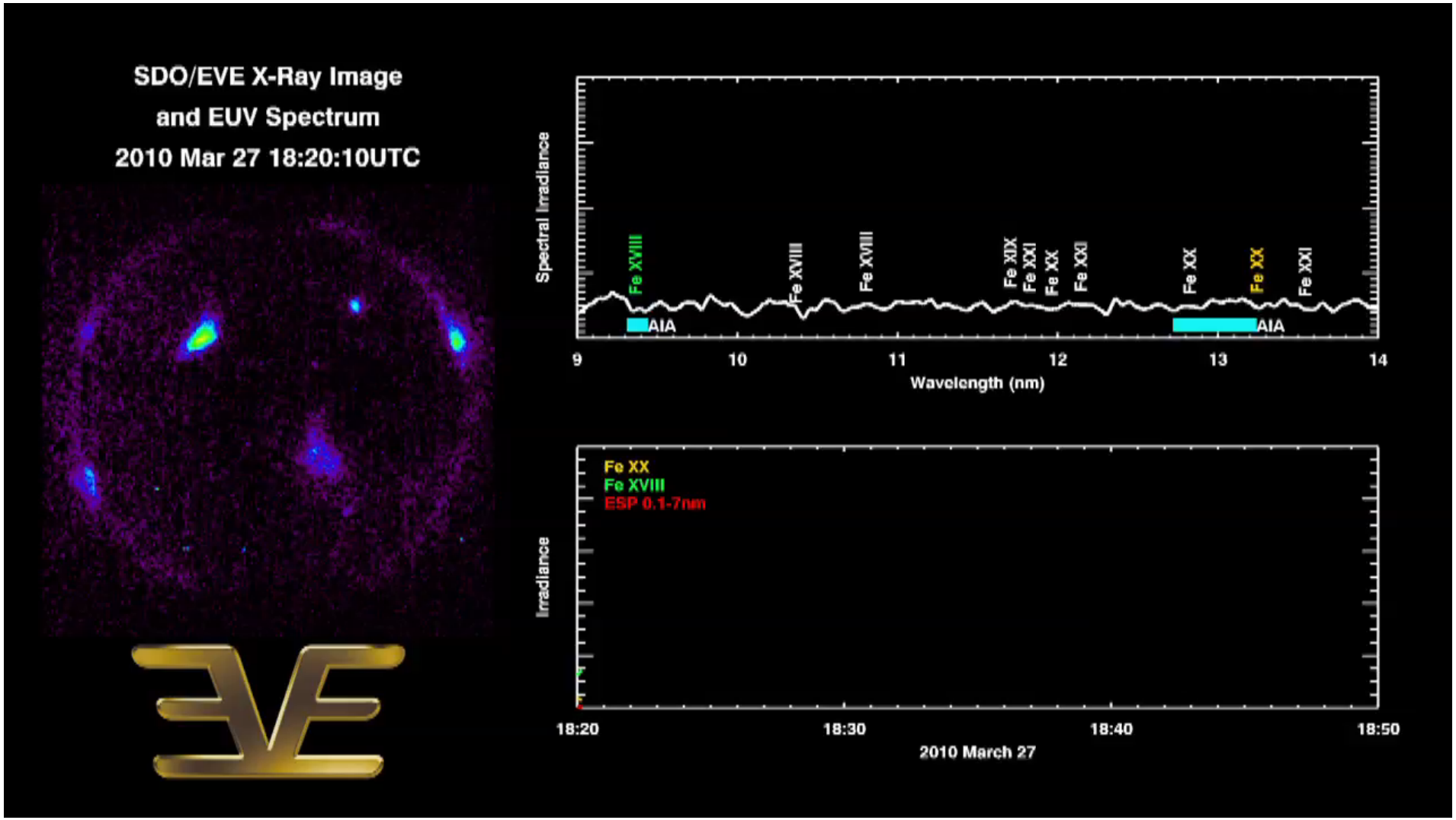
EUV:The Heartbeat of SpWx



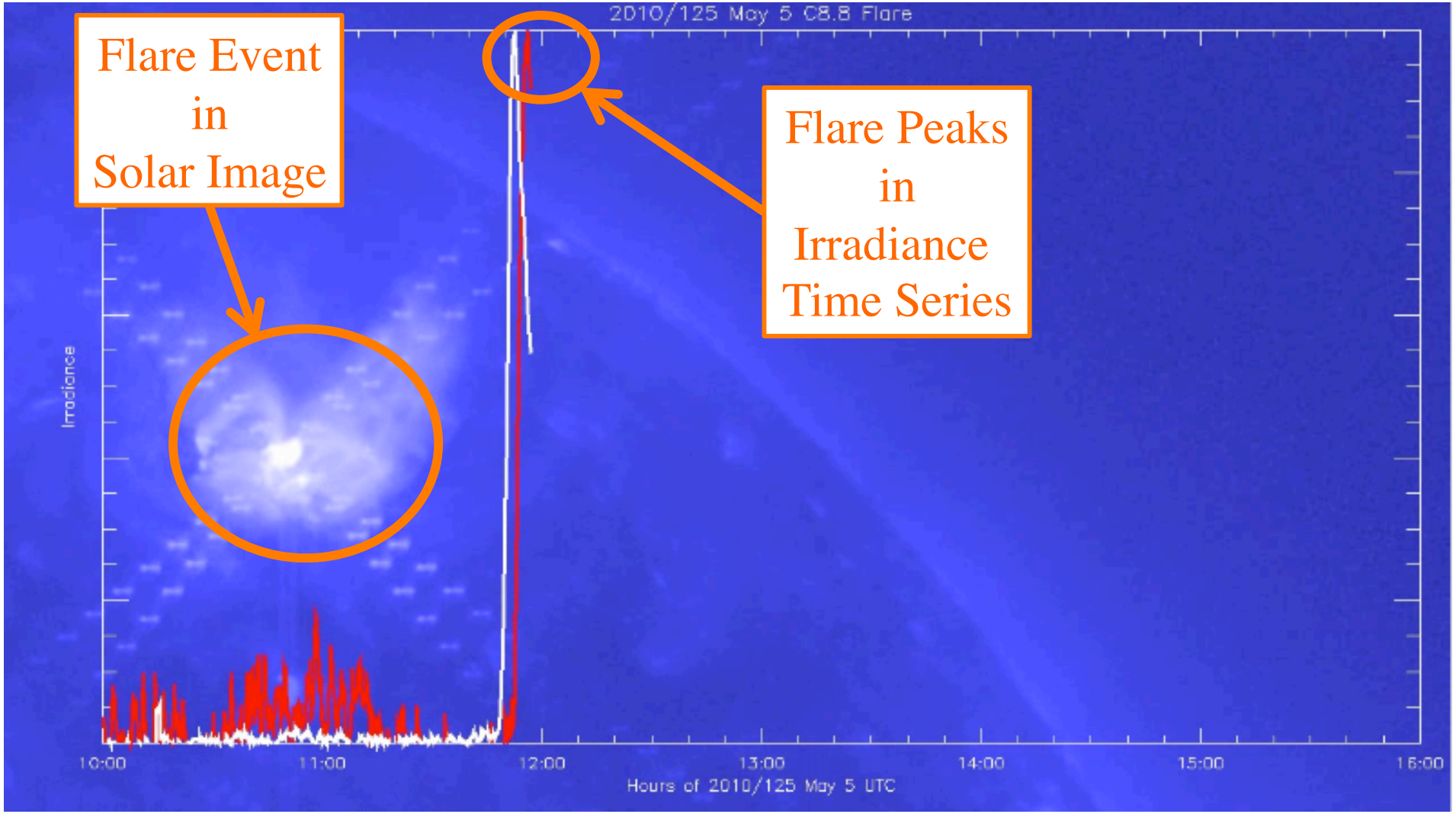
EVE's First Flare



EVE's First Flare



Surprise Result from EVE is Secondary Peak after X-ray Flare



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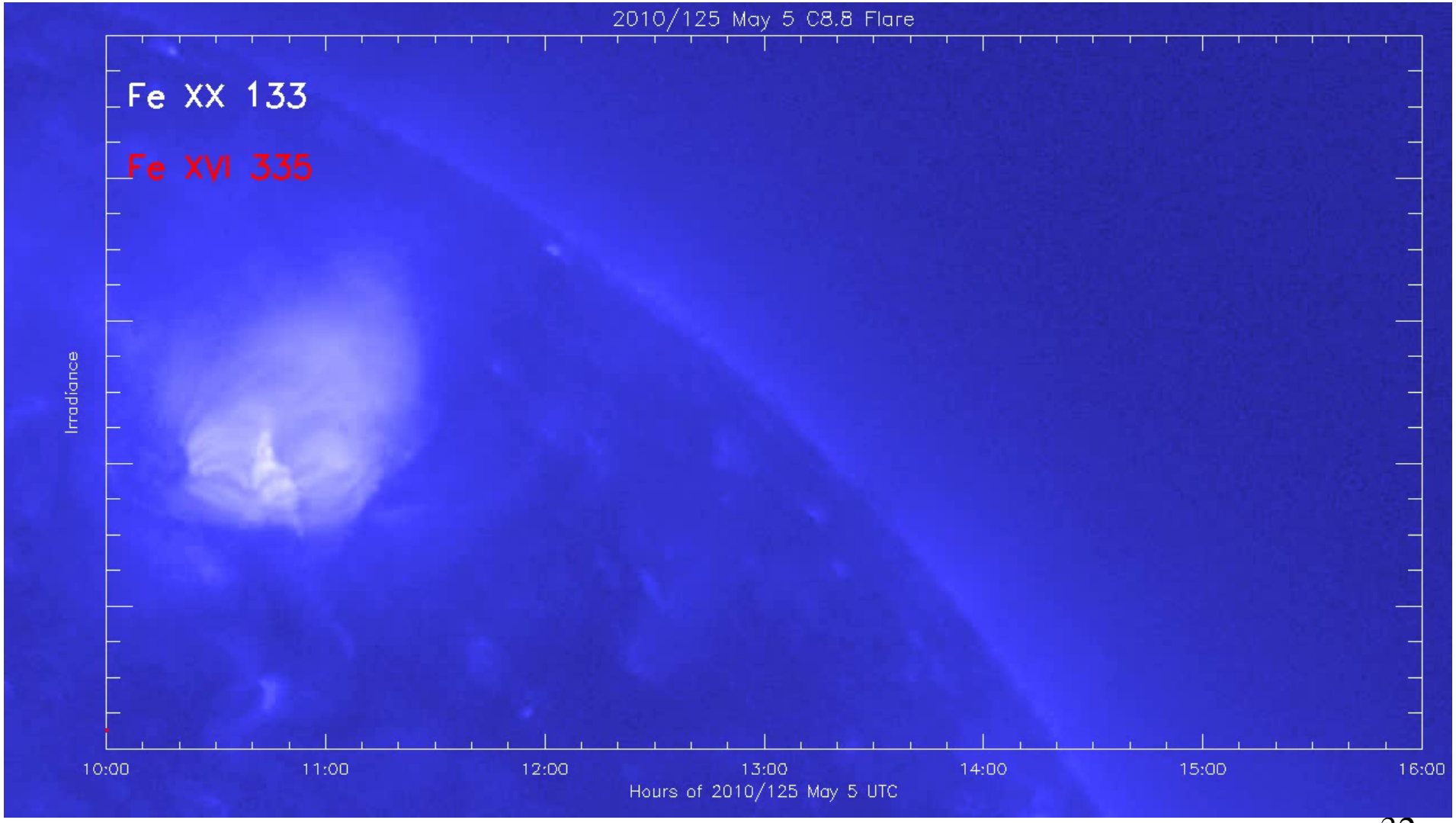
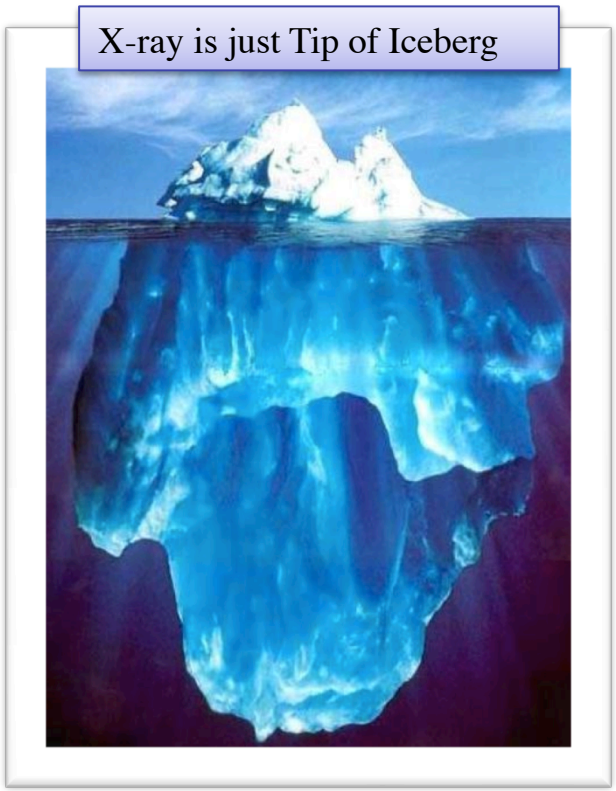
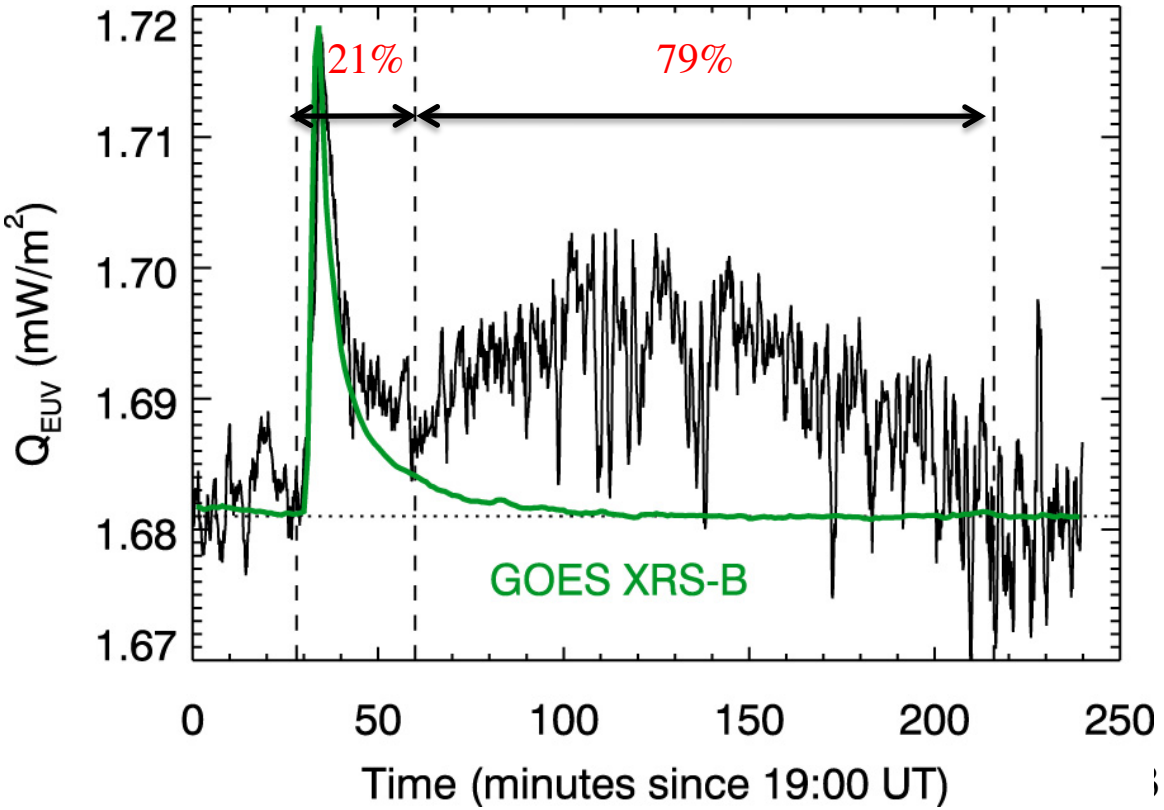


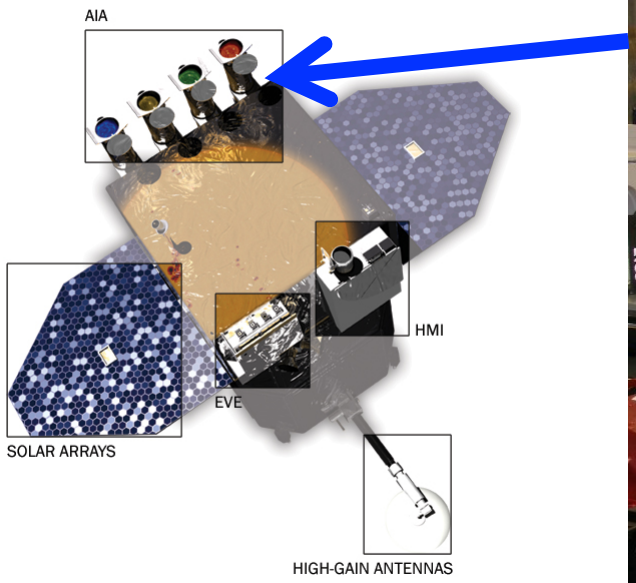
Secondary Peak is Very Important for Space Weather Applications at Earth

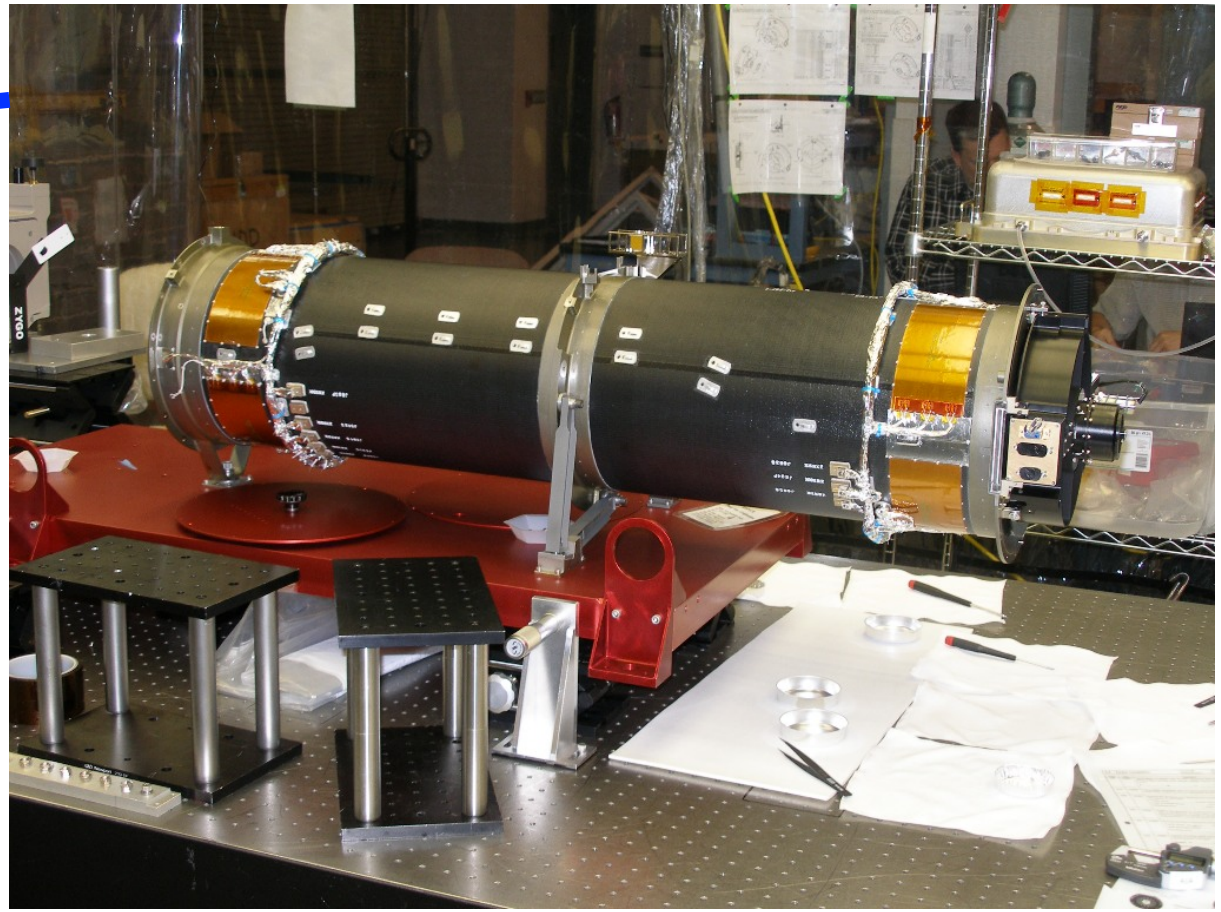
- All flares observed by EVE show that secondary peak contribution is 70-90% of total flare energy
  - Secondary peak is weaker but longer life
  - GOES X-ray flare proxy underestimates flare energy by factor of ~3



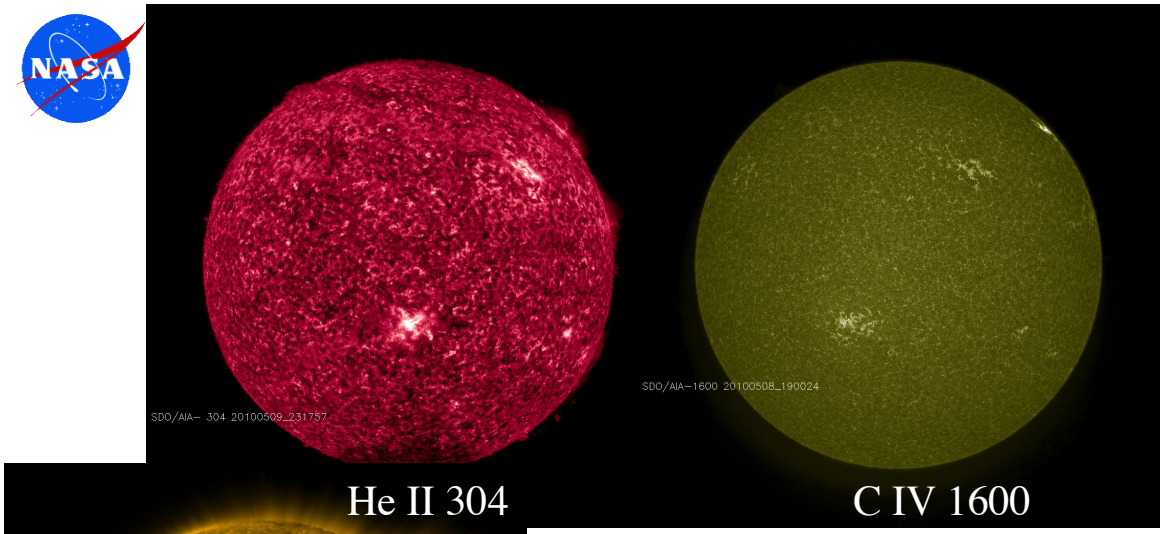


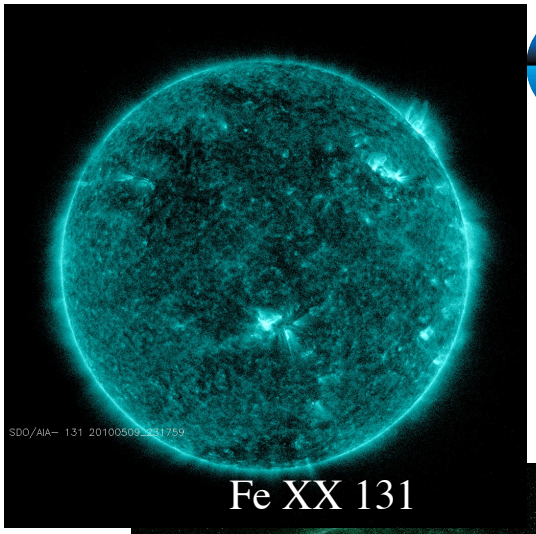
AIA
Atmospheric Imaging Assembly

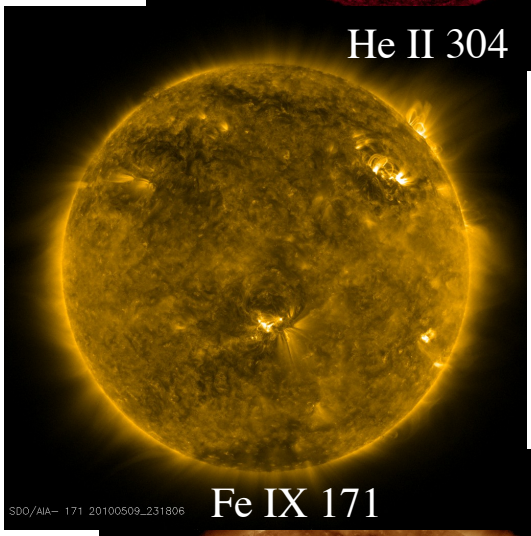




- Built at Lockheed Martin Solar and Astrophysics Laboratory in Palo Alto, CA
- AIA has four telescopes with multiple ultraviolet filters
  - Images solar activity over the full solar disk (with four 4096 x 4096 CCDs)

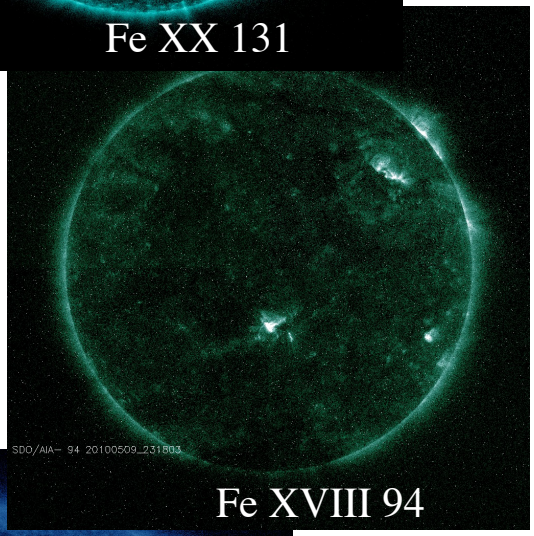


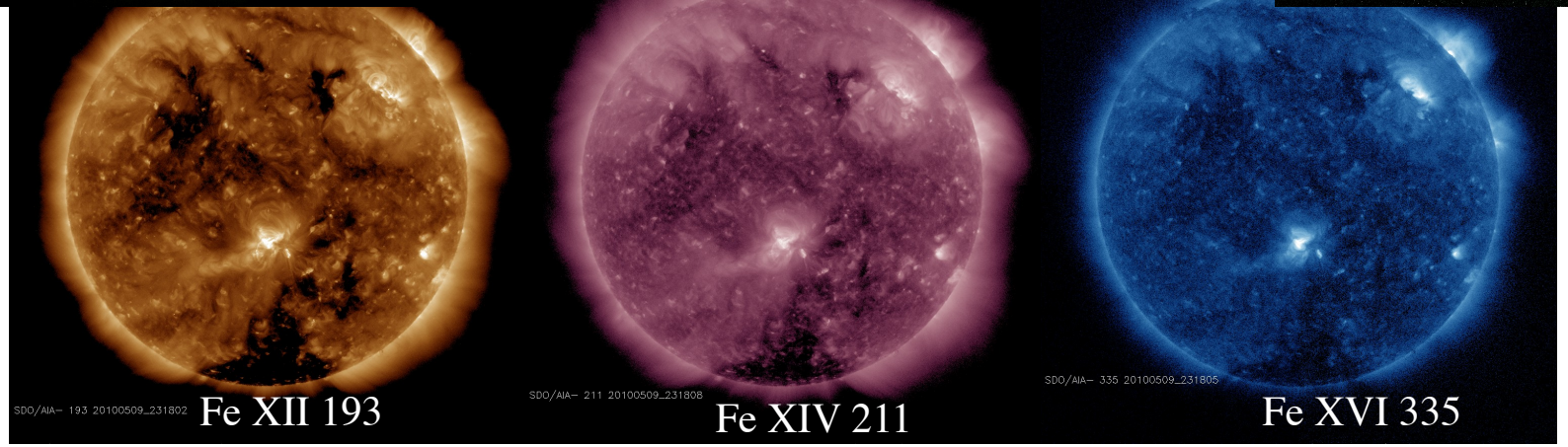


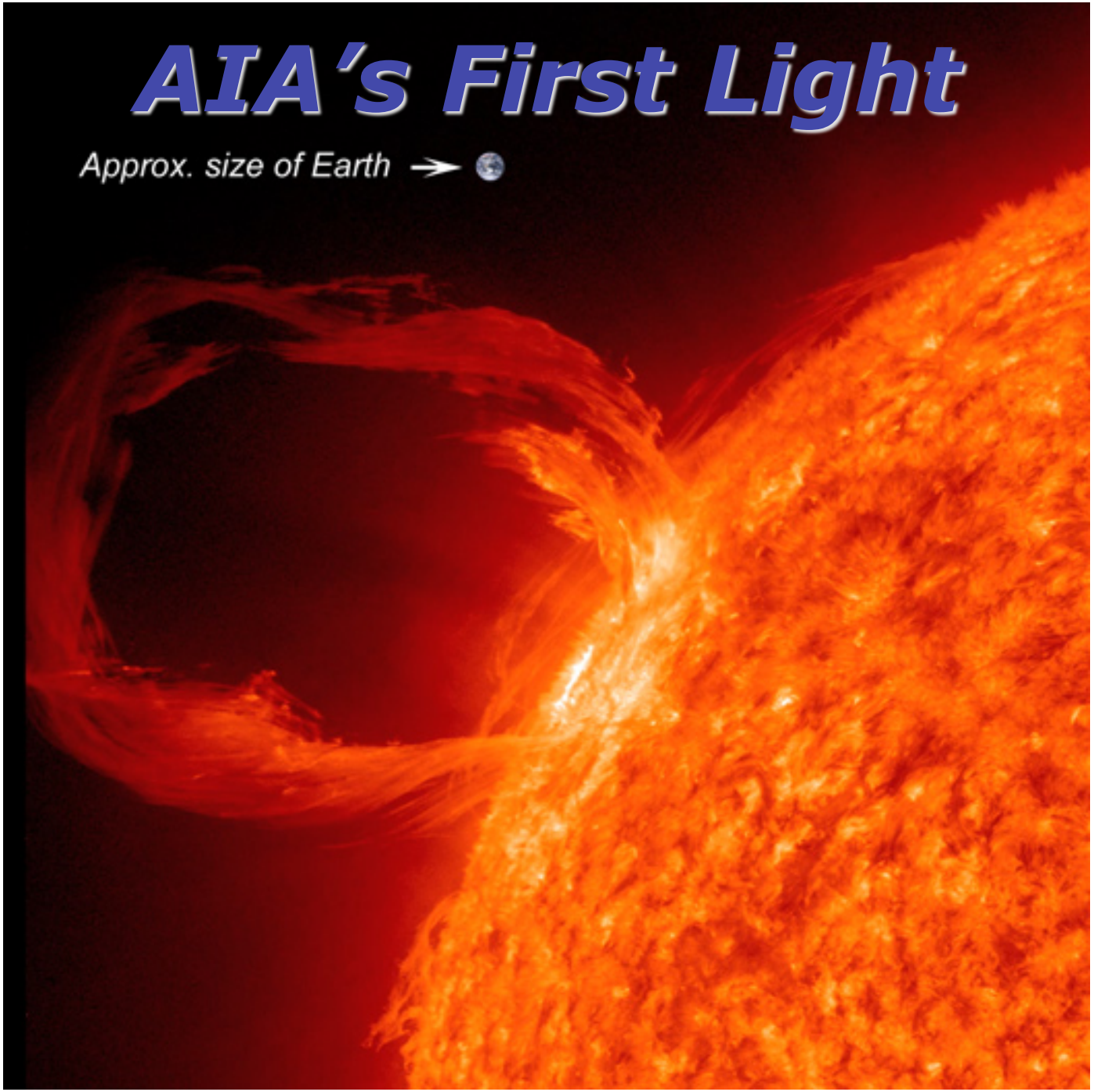


AIA Data

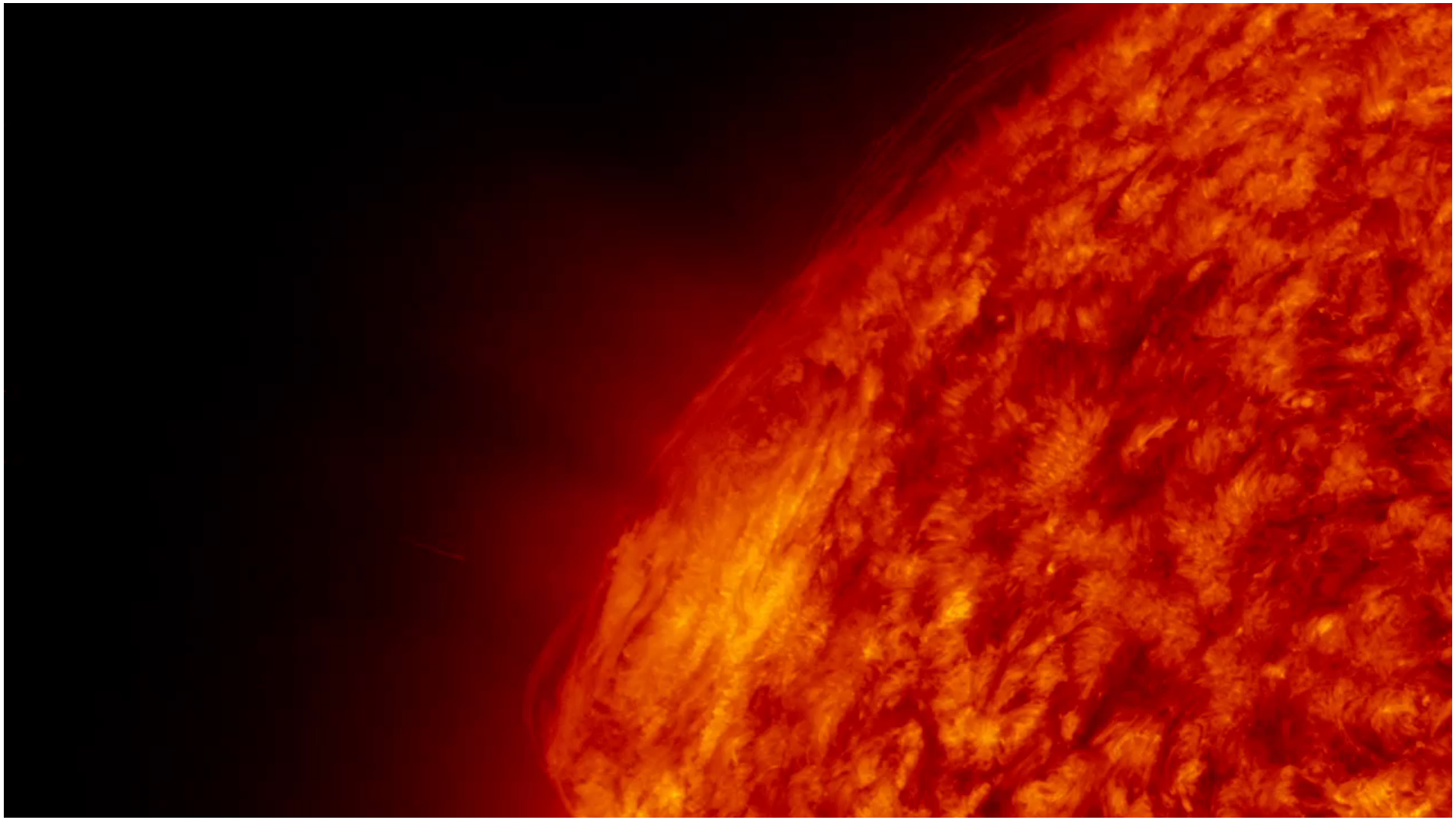
8 solar images every 12 seconds





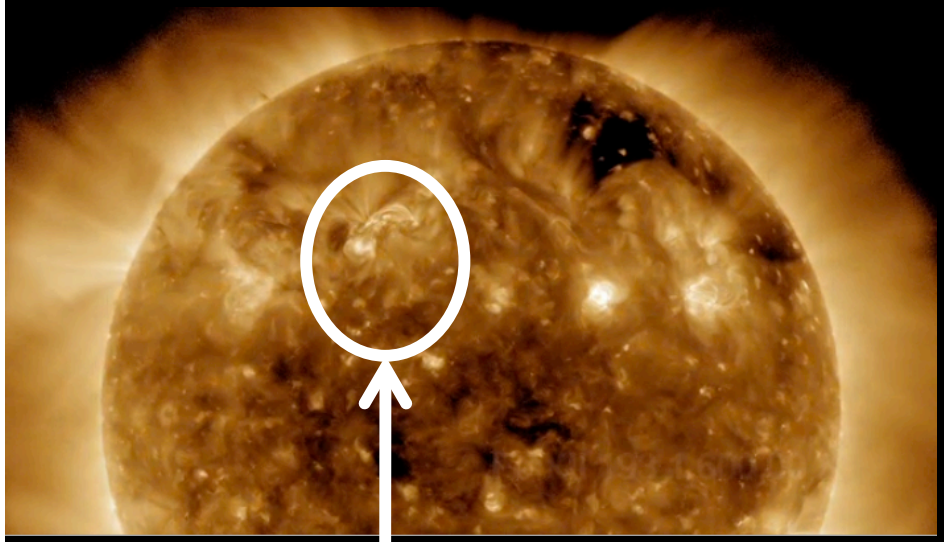

AIA's First Light
Approx. size of Earth

AIA's First Light

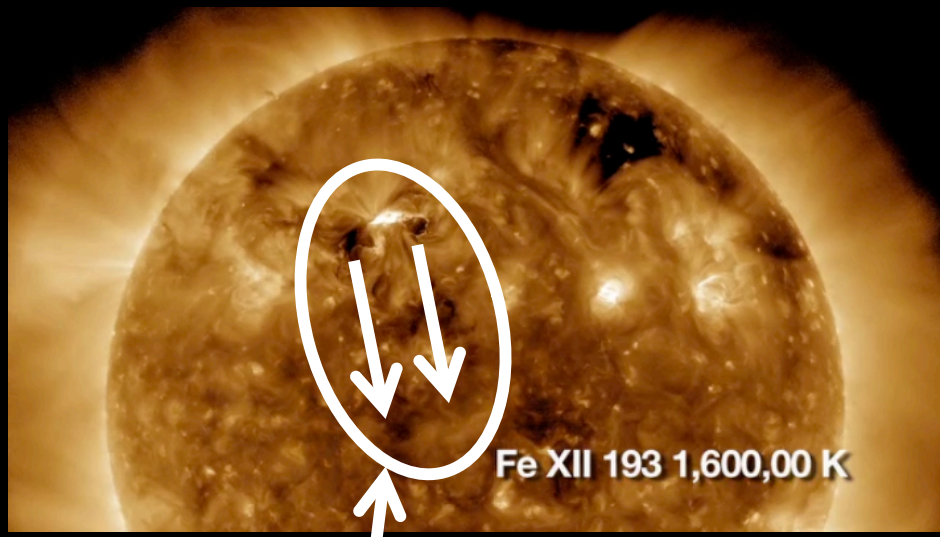


AIA's First Flare / CME

movie of same event using different telescopes

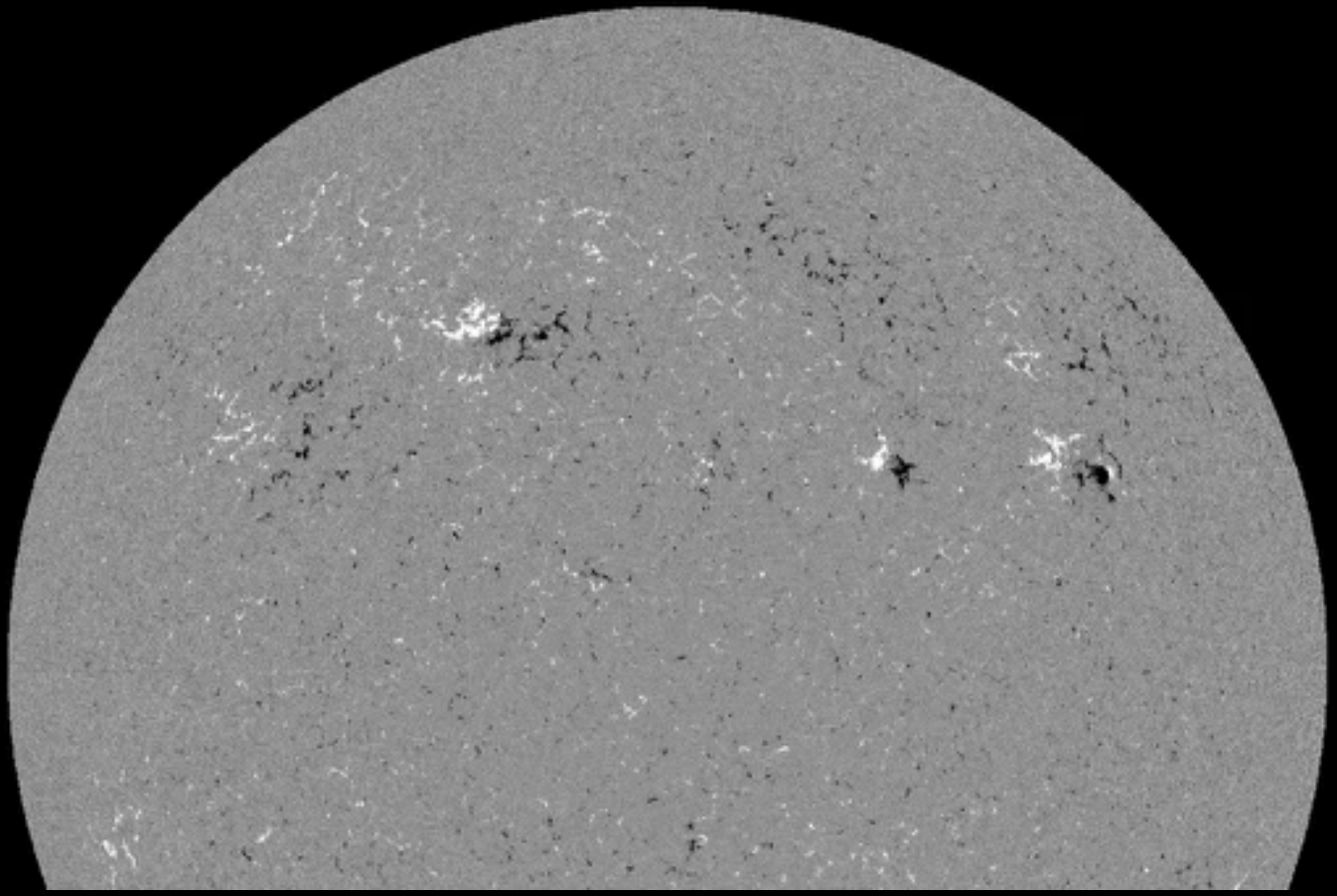


watch this area for the flare / CME event

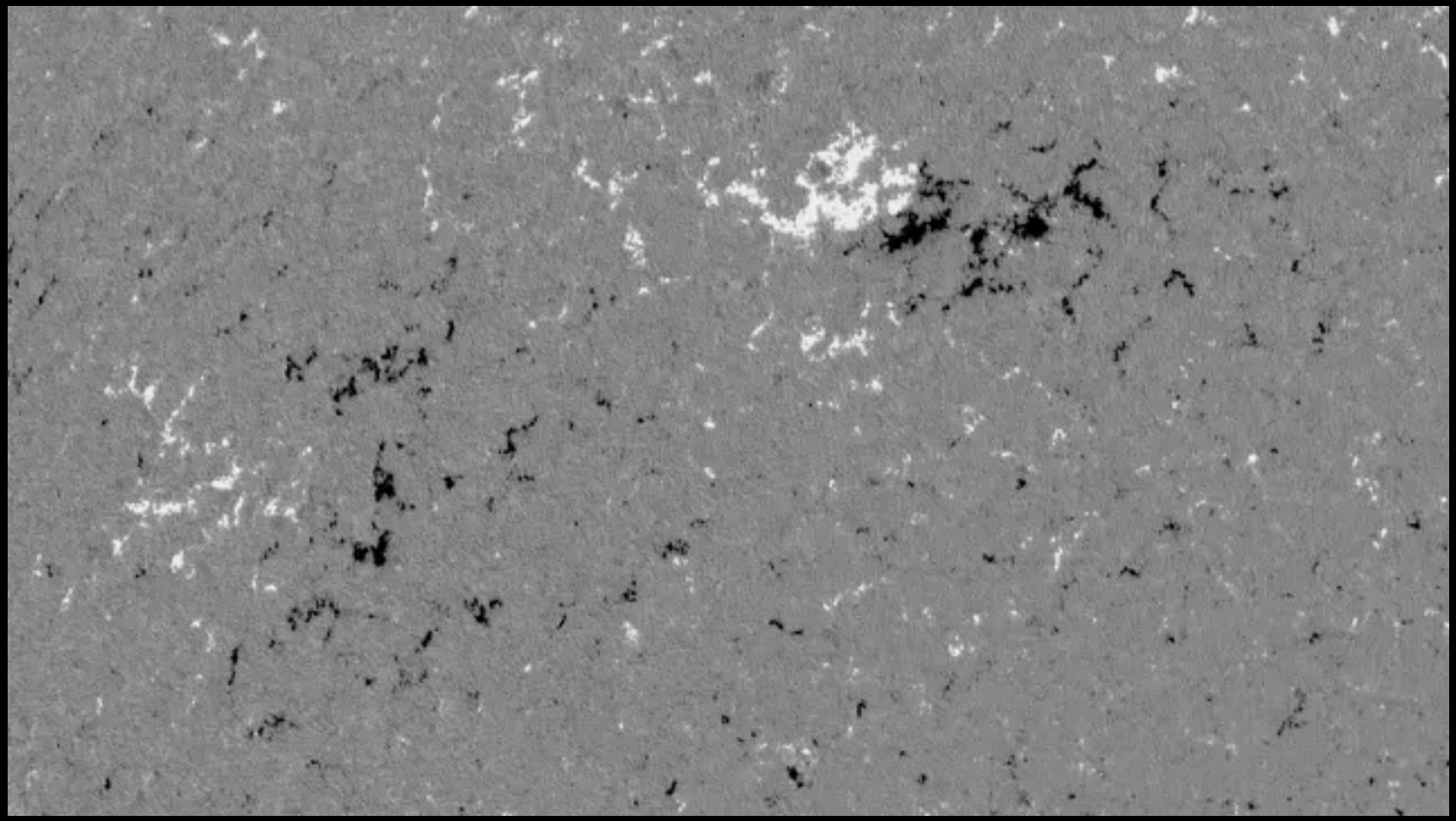


note the large wave that moves downward

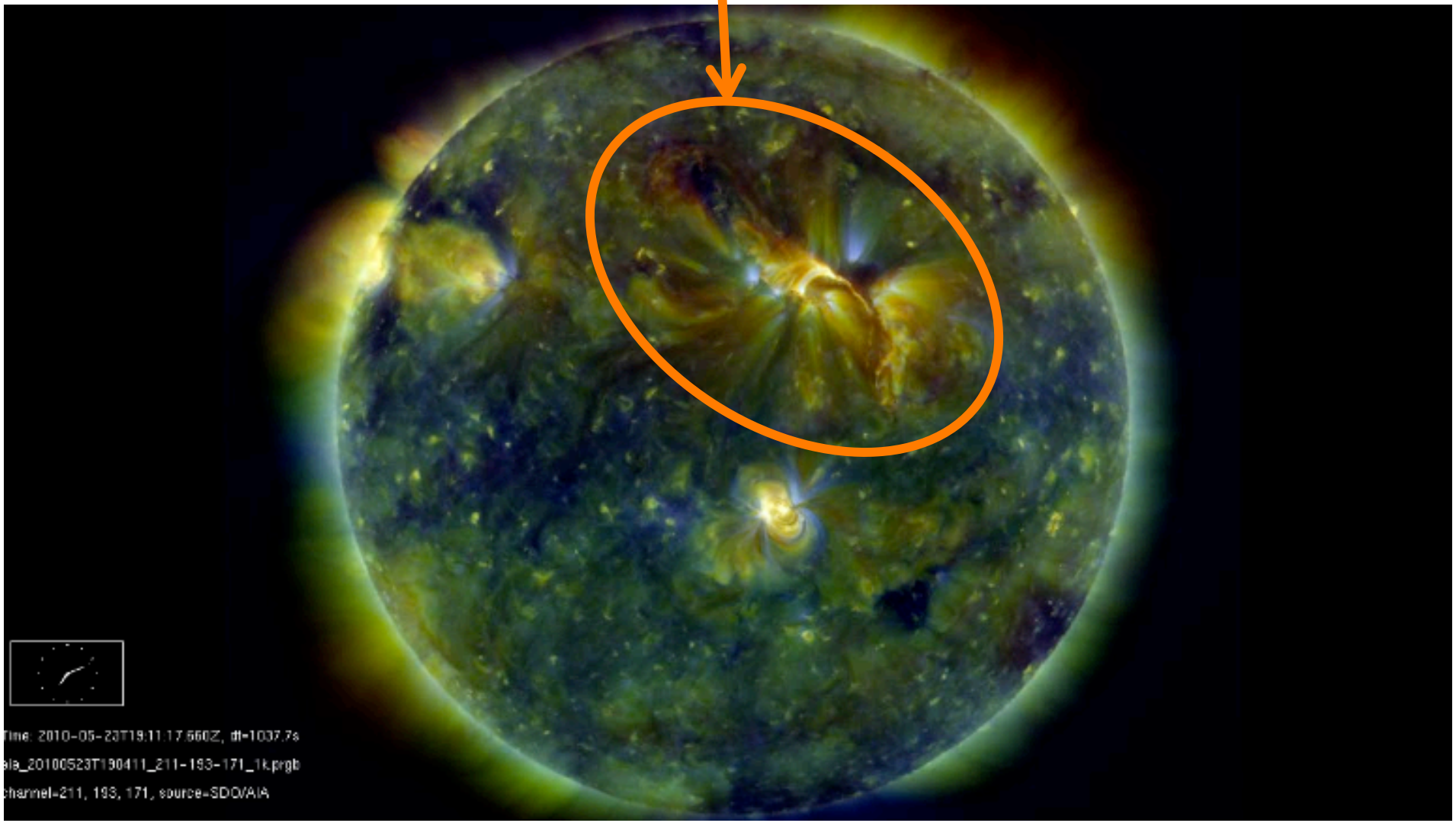
AIA's First Flare / CME



AIA's First Flare / CME

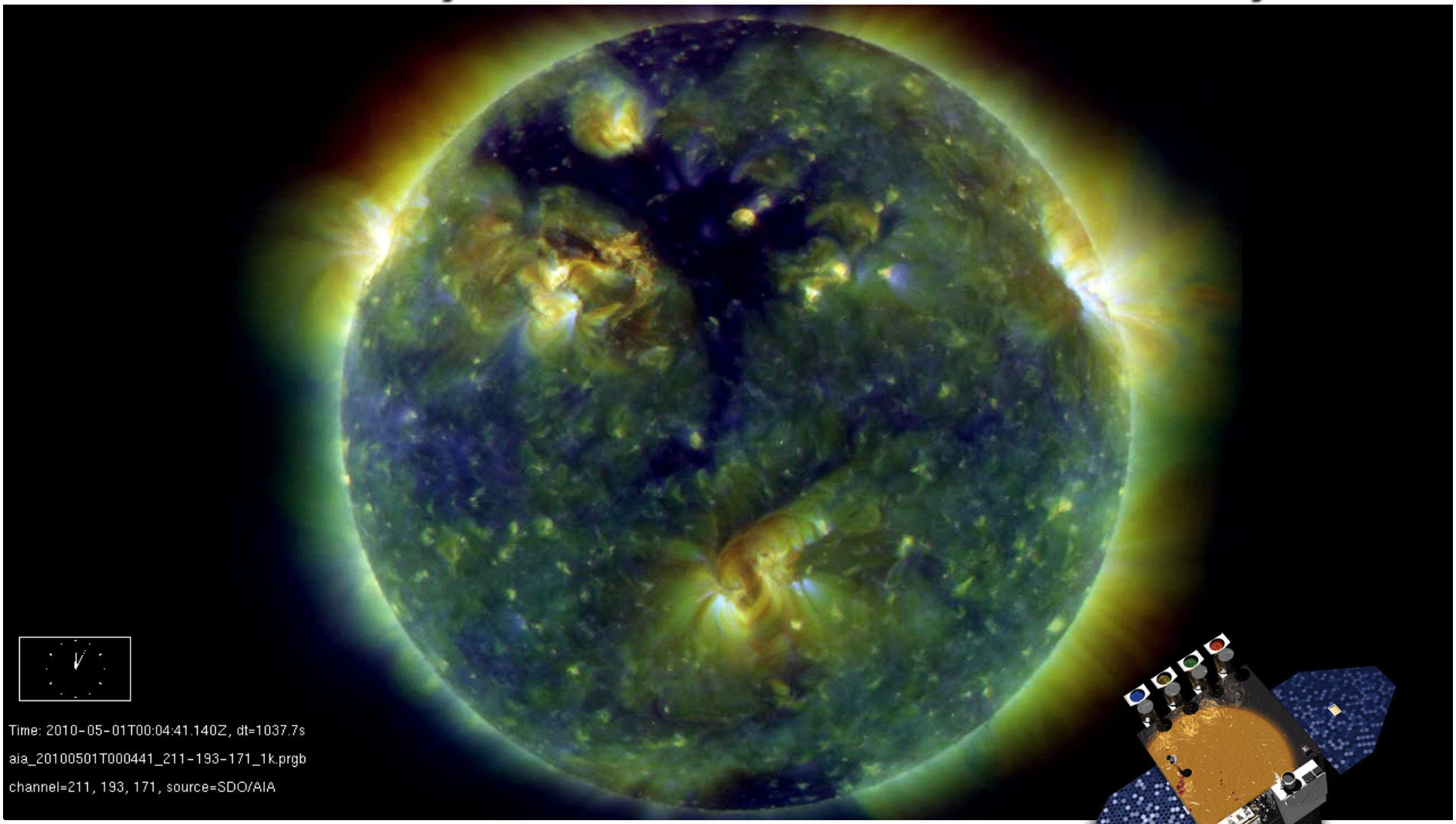


Large Scale Fields & Interactions



Credit: AIA Team

Solar Dynamics Observatory



Credit: AIA Team