



Solar Sounding Rockets Past, Present, and Future!

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MSFC - ST13 Heliophysics

Astronomy Day 2023

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Overview

- The Sun
- Sounding Rockets
 - Introduction
 - Early Sounding rocket successes
 - Integrating and launching sounding rockets
 - Marshall Solar Sounding Rocket Missions
 - CLASP
 - Hi-C
 - MaGIXS
- Looking Ahead
 - Flare campaign
 - Eclipses!
- Final Thoughts
 - Summary
 - Public Participation



Sun

Internal Structure:

inner core
radiative zone
convection zone

photosphere
sunspot

plage

coronal mass ejection

corona

Earth

magnetosphere

polar cusp

incoming
solar wind
particles

plasmasphere

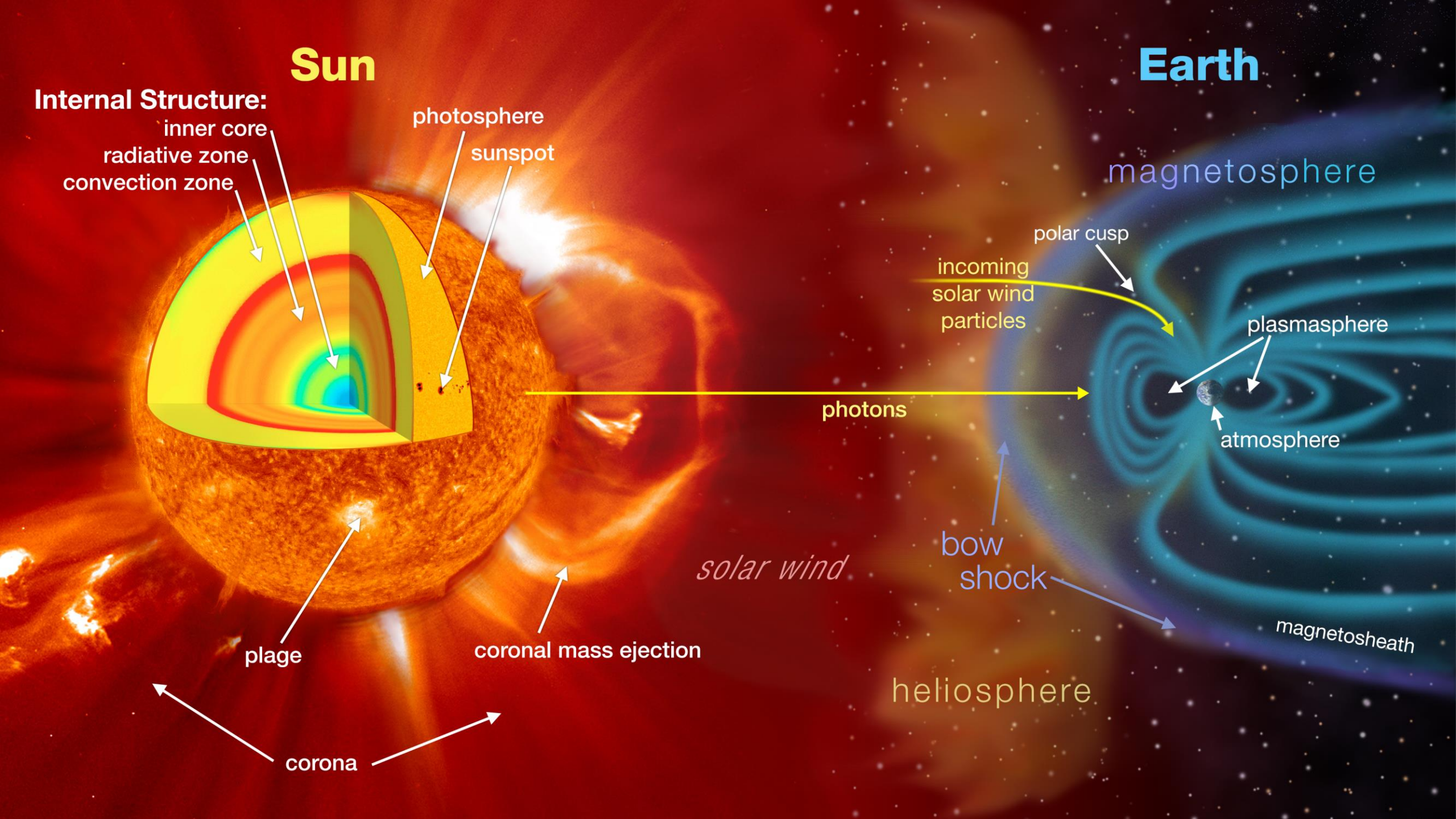
atmosphere

photons

bow
shock

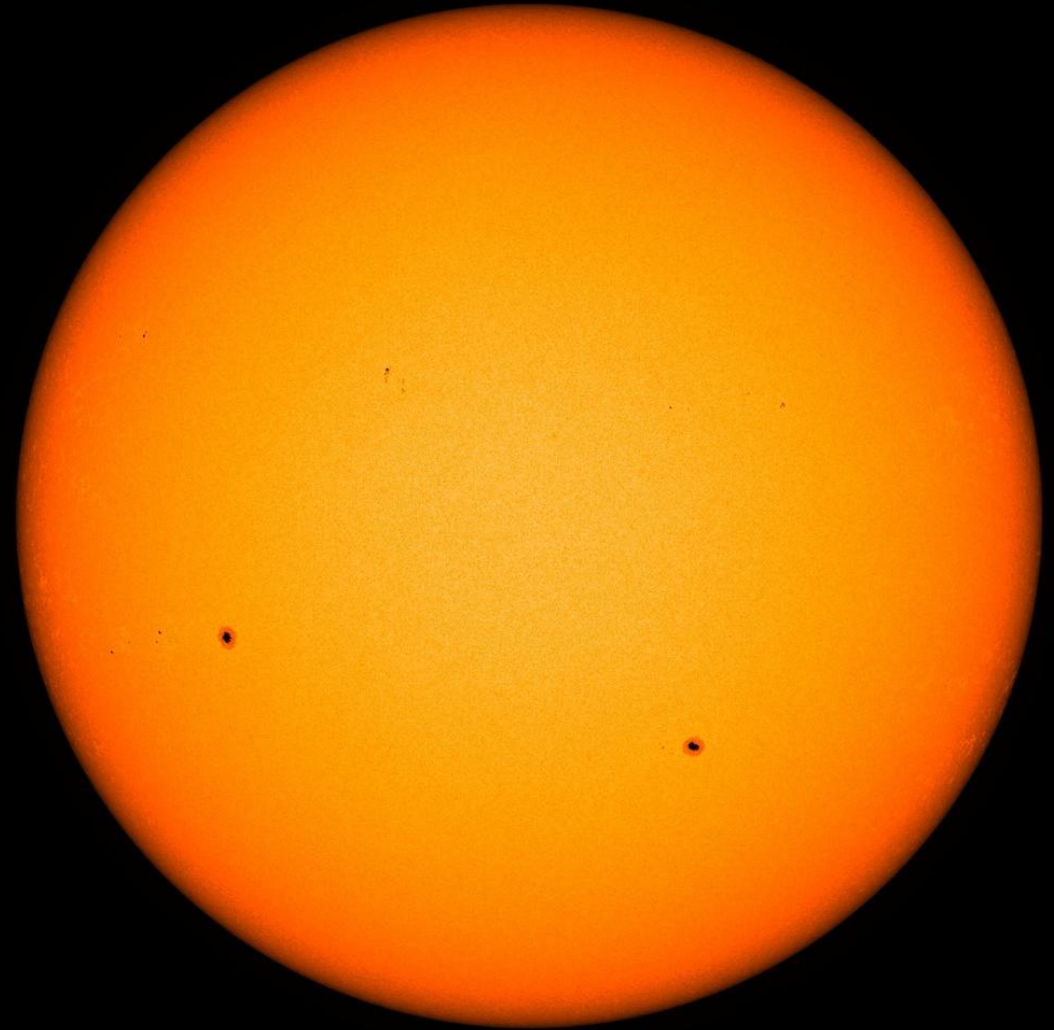
magnetosheath

heliosphere



Dynamic Sun

AIA 171 movie of 3 solar rotations

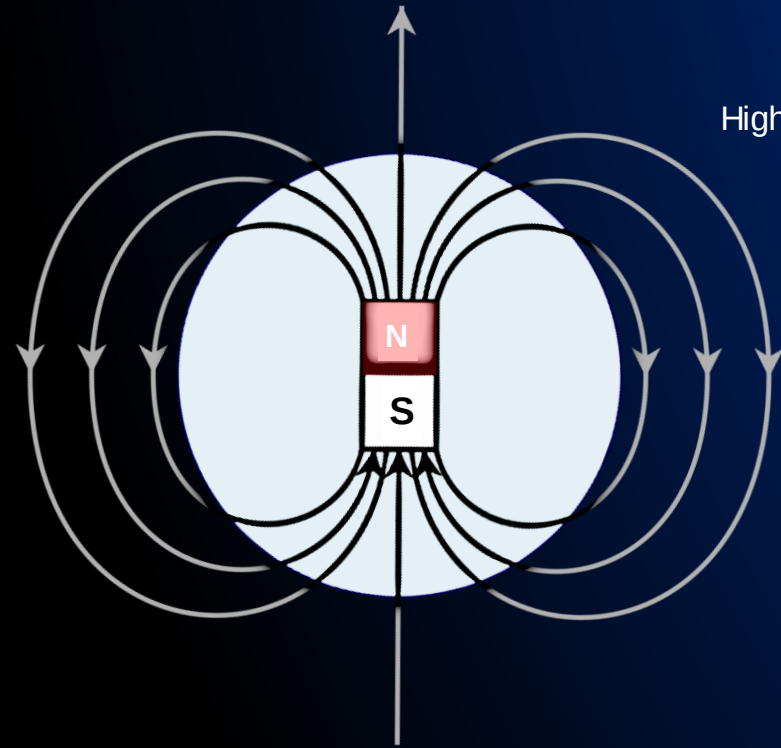


SDO/HMI Quick-Look Continuum: 20141015_050000

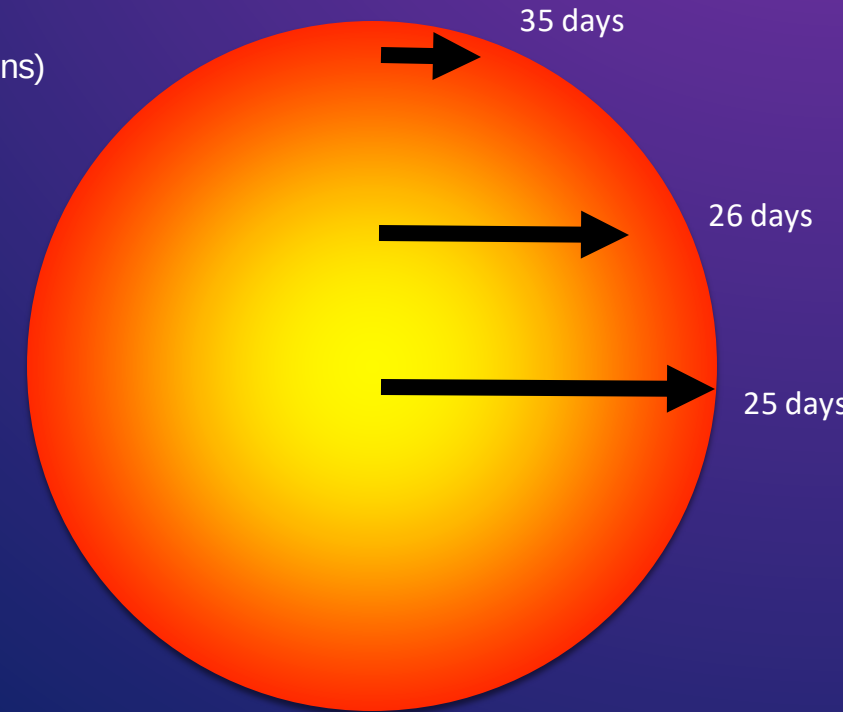
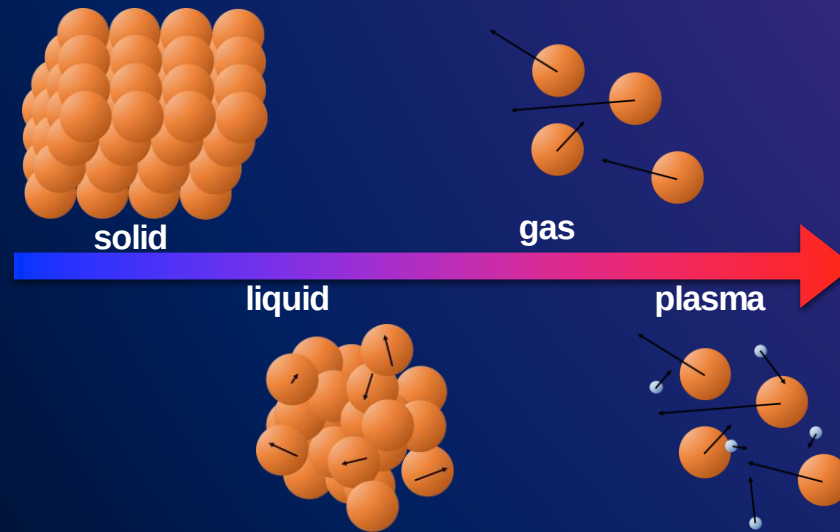
Magnetic Field and Plasma Dynamics

The Sun, like the Earth, has a global magnetic field.

The equator spins faster than the poles: *differential rotation*.



Highly ionized gas composed of charged particles (ions and electrons)



Solar Dynamo

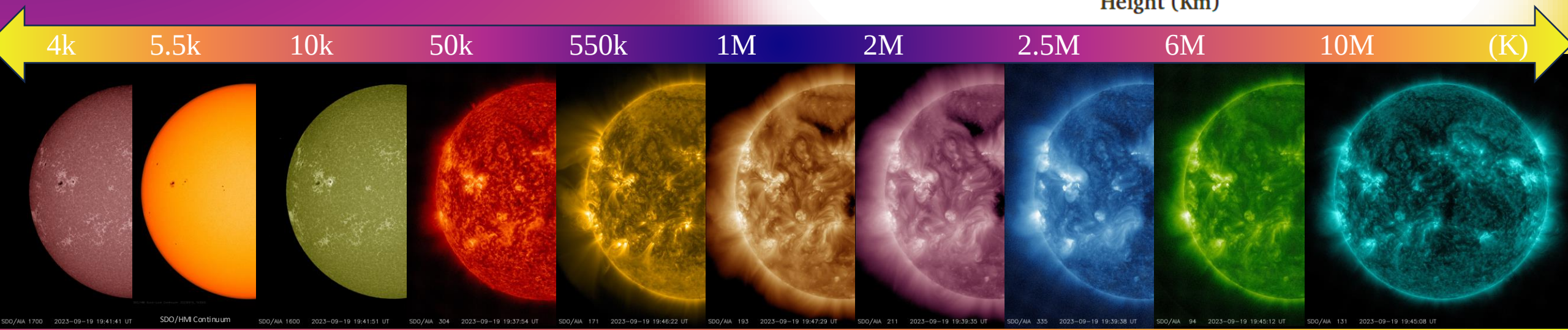
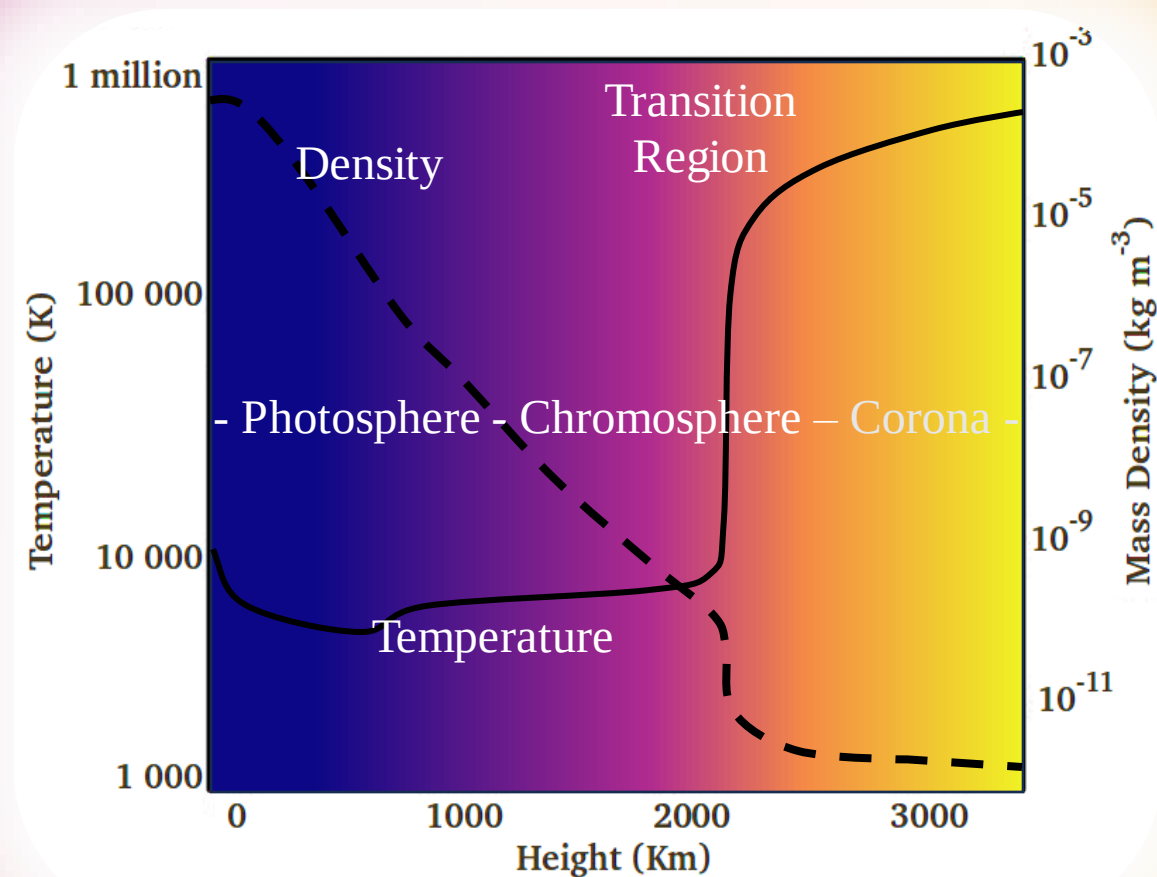
- Spinning plasma drags the magnetic field
- Generating complex structure
- How is this linked to the solar cycle? Evolution of structure of the Solar atmosphere? Transfer of energy? Impact on Solar Wind?



Source:SOHO (ESA/NASA)

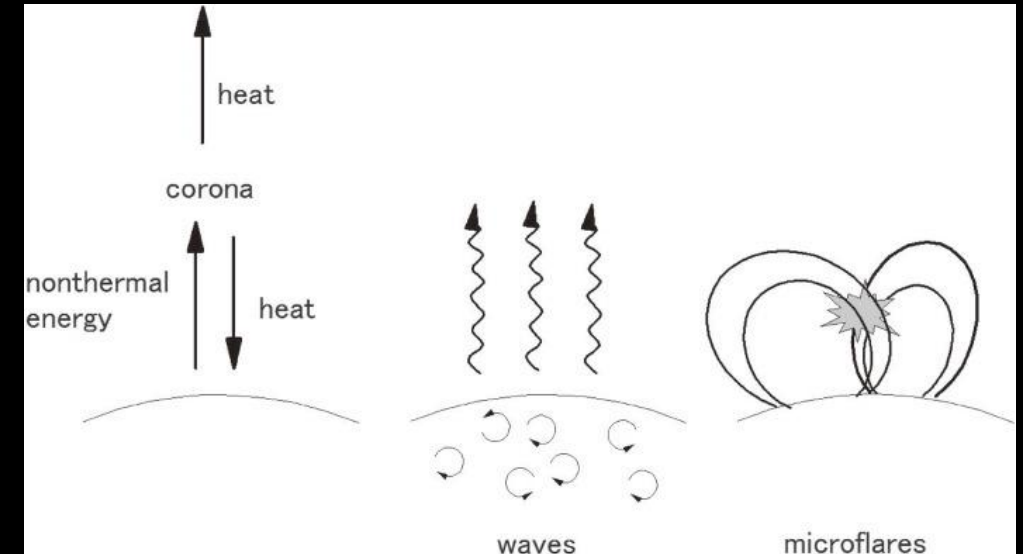
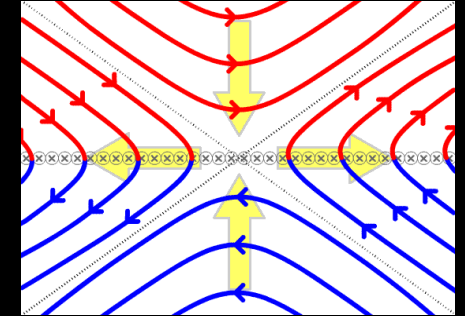
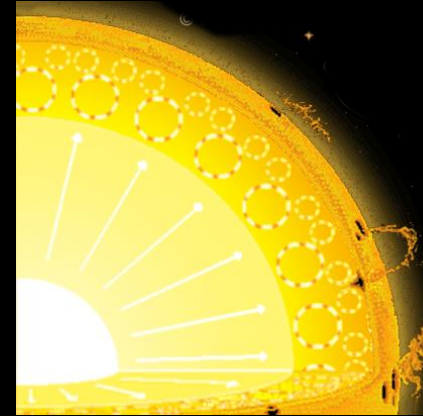
The Solar Atmosphere

- Solar heating mystery
 - Surface of Sun is cooler than hot atmosphere
 - As density drops off, temperatures climbs radically from a few thousand degrees to millions of degrees Kelvin
 - Mechanism of how all this energy gets there is unknown



Heating Mechanisms

- High Frequency (Wave dissipation)
 - Waves generated in deeper layers of Sun constantly emanate outward and deposit energy in the corona
- Low Frequency (magnetic reconnection)
 - Sporadic 'nanoflare' or reconnection events too small to be observed by current telescopes cause heating
- Which mechanism is dominant and in what regions of the Sun?
 - Some consensus that high frequency may heat coronal holes and quiet sun while nanoflares may dominate in active regions



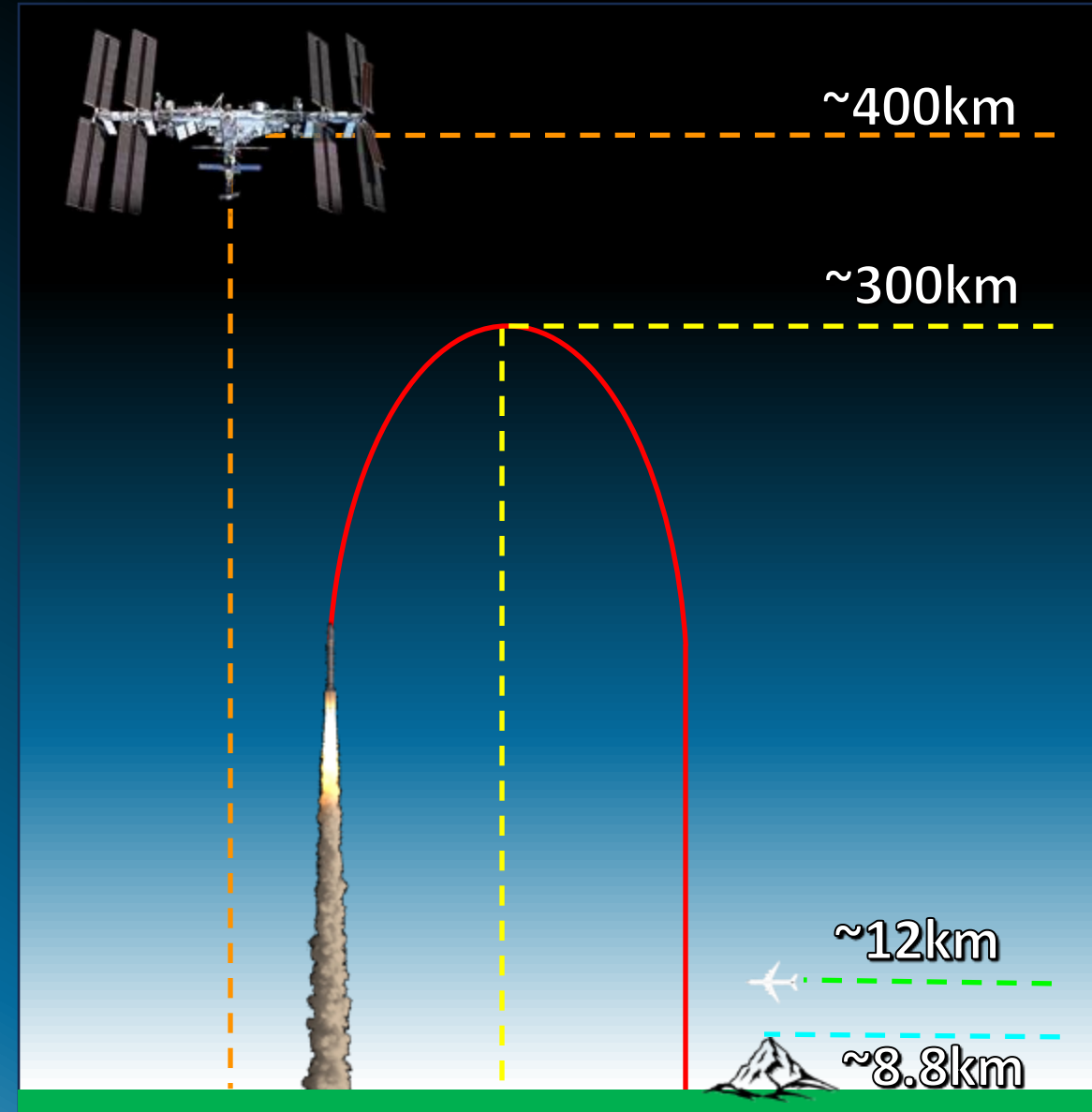
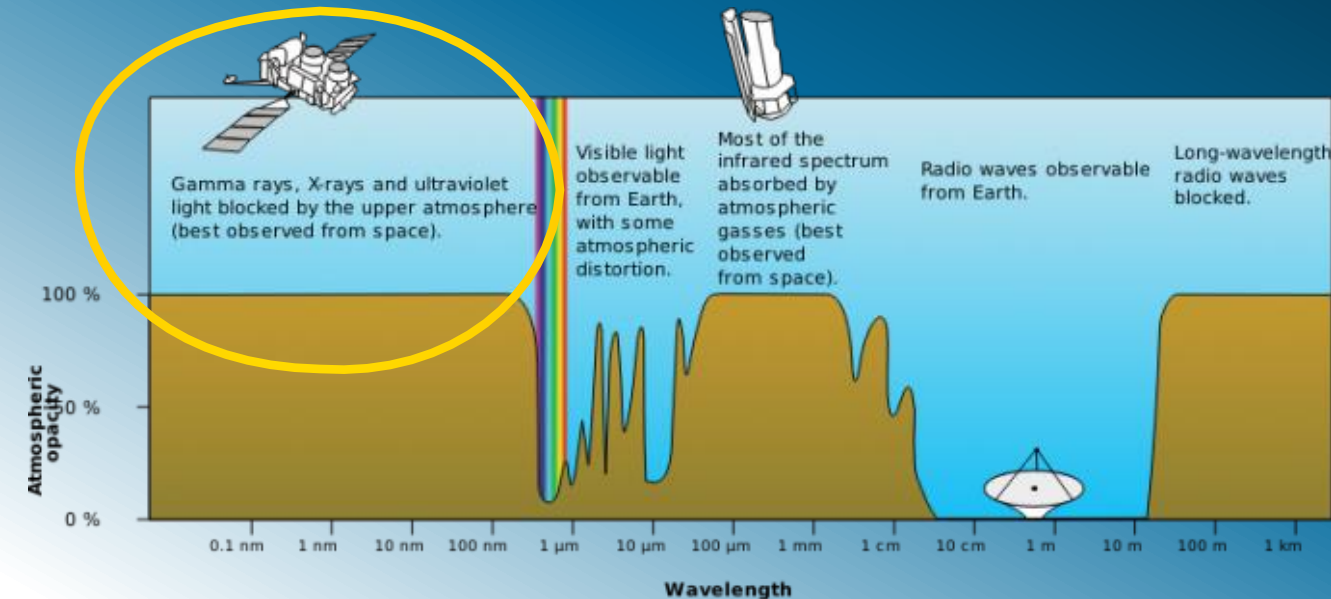
Sakurai T. Heating mechanisms of the solar corona. Proc Jpn Acad Ser B Phys Biol Sci. 2017;93(2):87-97. doi: 10.2183/pjab.93.006. PMID: 28190871; PMCID: PMC5422629.



Sounding Rockets

Sounding rocket in brief

- What is a sounding rocket?
 - Sub-orbital vehicle that can carry a payload to several hundred km altitude.
- Why use sounding rockets?
 - Glimpse above Earth's Atmosphere –See Gamma, X-ray, UV
 - Inexpensive – Few Million \$ vs Billion \$\$\$ Budgets
 - Quick - ~1-5 years of dev. Typically 3 years
 - Larger payloads than CubeSats possible
 - Recoverable! Re-fly!
 - Great way to test out novel instrument
 - Applications for Astronomy, Heliophysics, Meteorology, Atmospheric Science, Biology, ect...



Early Sounding Rockets Missions

- Solar EUV and X-ray emission is theorized in the 1930s, not observed until the adoption of German rocket program after WWII
- 1948: Extra-terrestrial X-rays observed using photographic film filtered 3-111 Å on a captured V-2 Rocket
- 1960: First X-ray photograph of sun pinhole camera 8-50 Å on Aerobee Hi Rocket
- Lead the way for numerous sounding rocket missions for Heliophysics



Historic Burnnight 1948
Observations of X-rays on Film [1]



First X-ray Photograph of the
Sun Pinhole Camera 1960

German V-2
Rocket [2]



Aerobee Hi
Rocket



[1] Boyd, R. L. F. (1965). Techniques for the Measurement of Extra-Terrestrial Soft X-radiation. *Space Science Reviews*, 35–90.

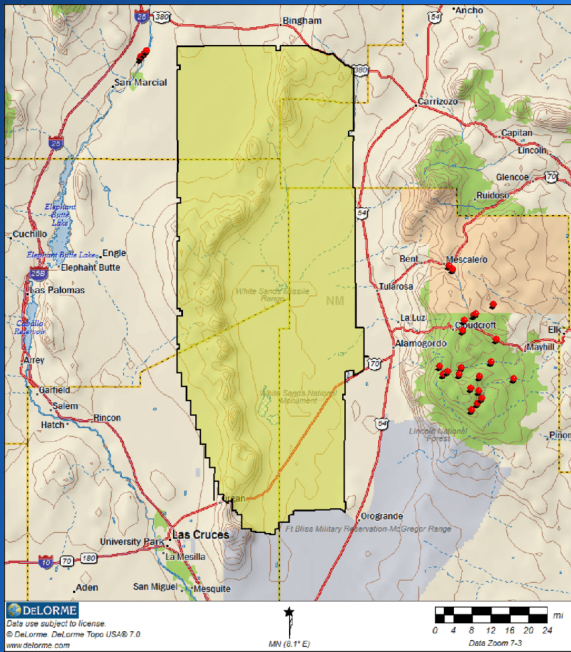
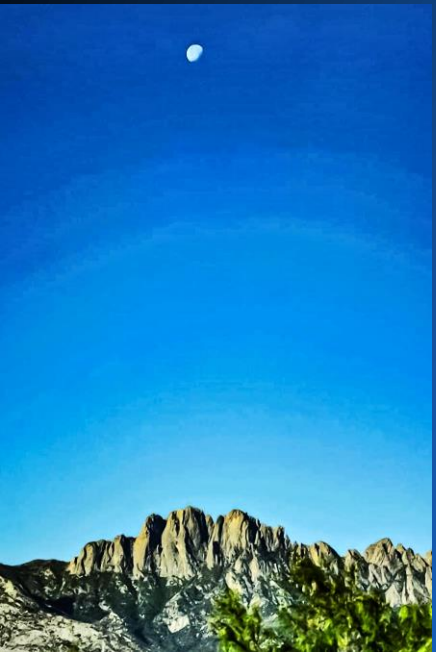
[2] Christe, S., Zeiger, B., Pfaff, R., & Garcia, M. (2016). *Introduction to the Special Issue on Sounding Rockets and Instrumentation*. <http://arxiv.org/abs/1602.02333>

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SF 710 (1-87)

Launch site operations



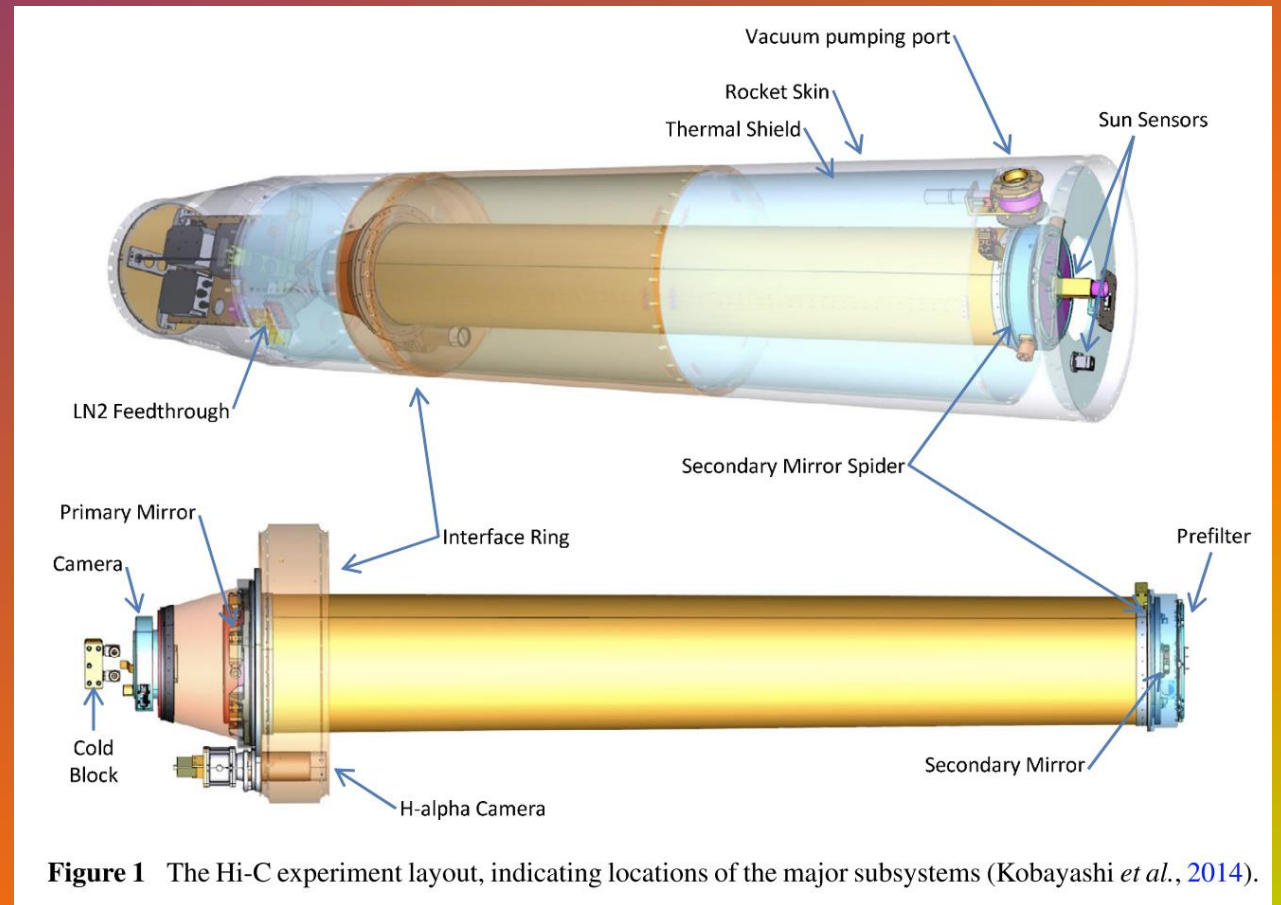
Recovery

- Benefit of sounding rockets (land based launch sites)
- Perks of the job: Members of our team get to ride a helicopter out to recover payload

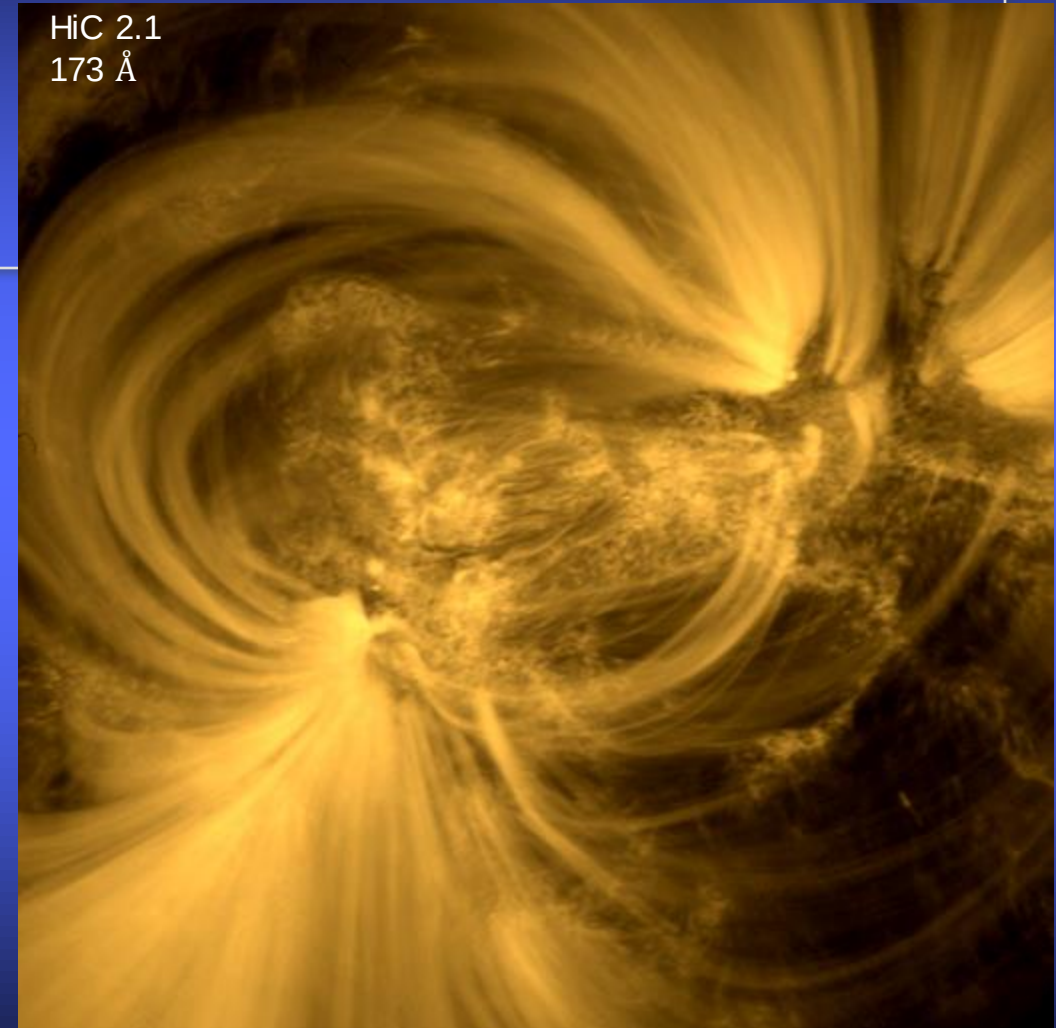
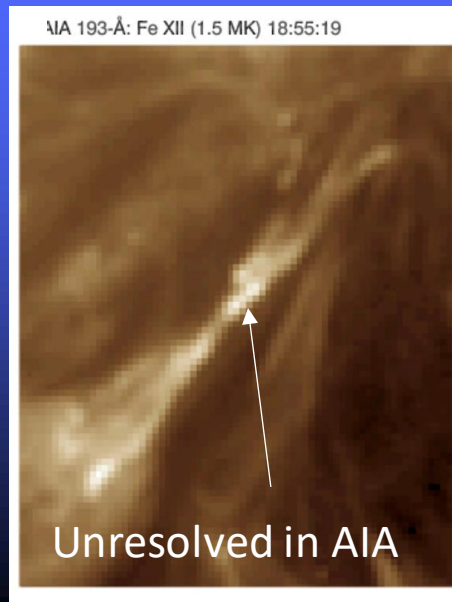
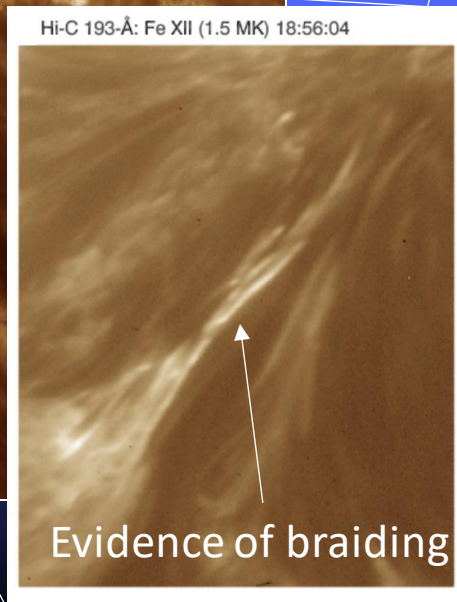
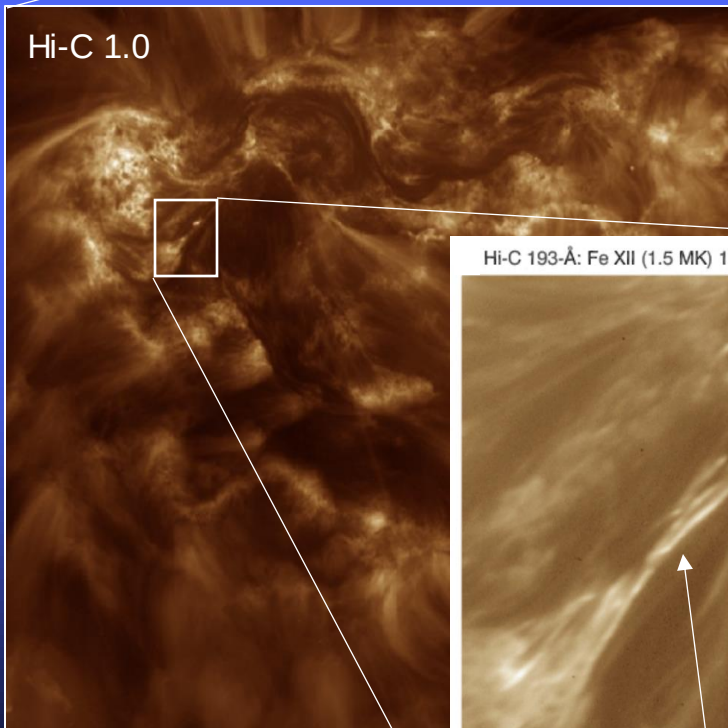
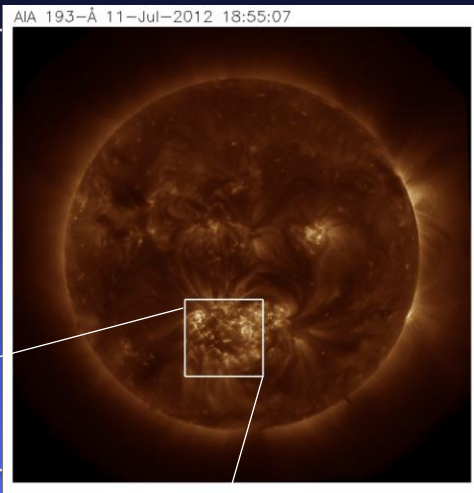


High-Resolution Coronal Imager

- Collaboration with Smithsonian Astrophysical Observatory (SAO)
- Questions
 - Is there substructure current instruments are not able to resolve?
 - What are the typical size and time scales of those structures?
 - What do these substructures reveal about coronal heating, energy flow, solar dynamics?
- Narrow band EUV Telescope
 - Specialized multiplayer coatings reflecting $193\text{\AA}$ ($172\text{\AA}$ Hi-C 2.1)
 - Two-mirror system optimized for spatial resolution
 - Low noise CCD camera developed at Marshall (Hi-C 2.1)



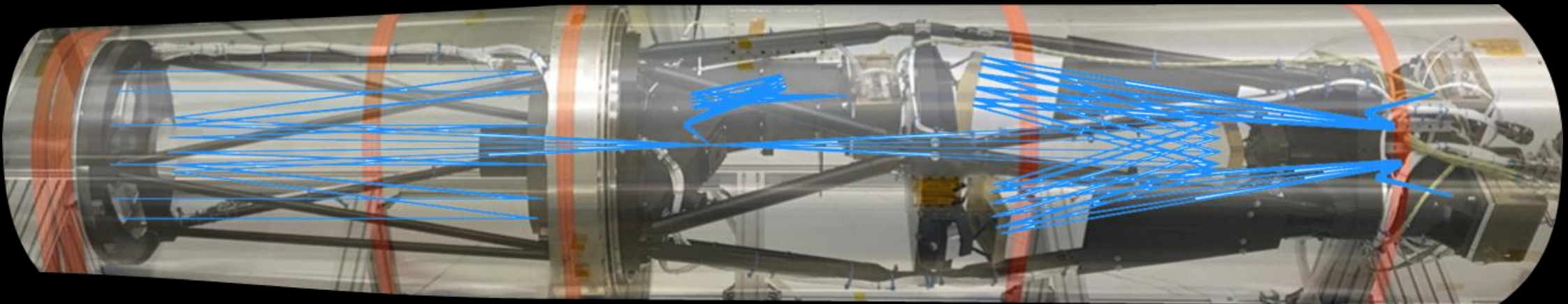
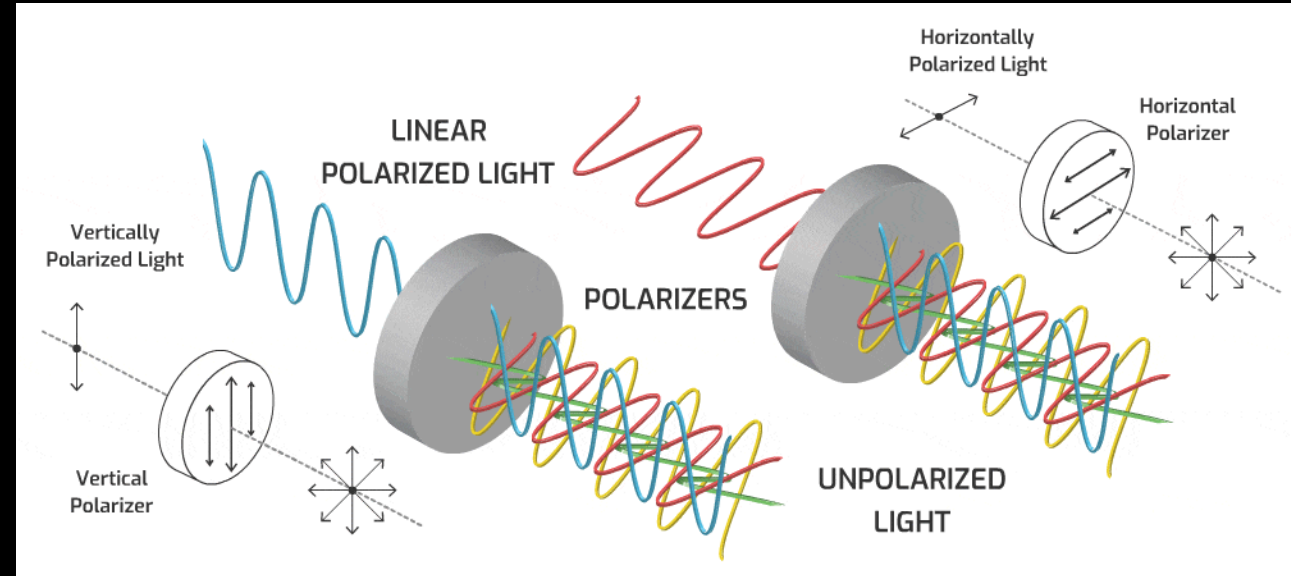
Hi-C Results



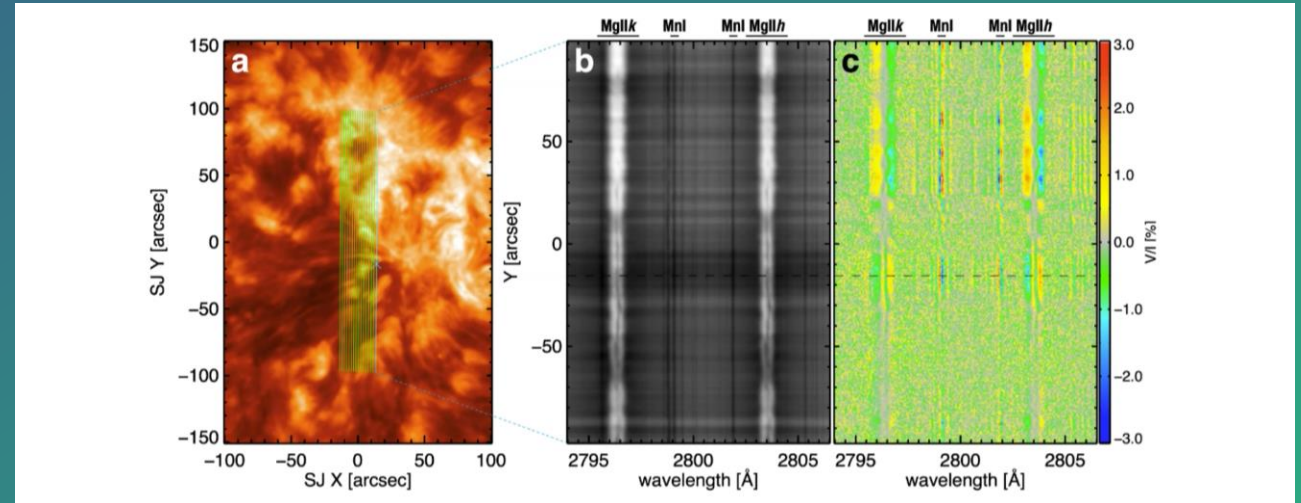
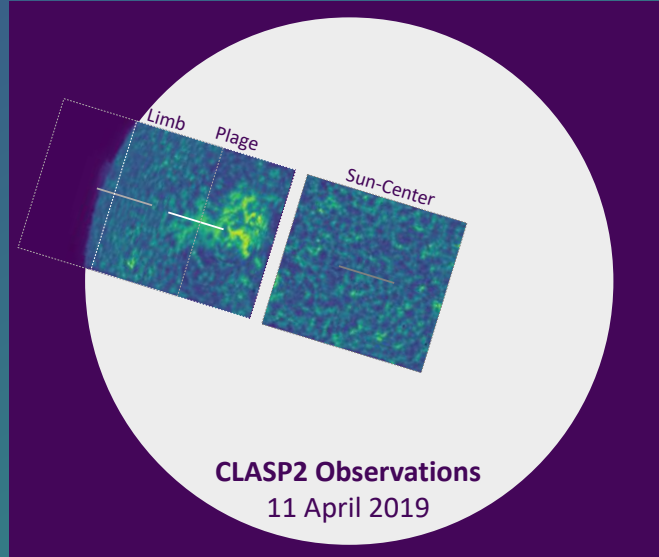
Highest Resolution of Solar Corona!

Chromospheric Layer SpectroPolarimeter

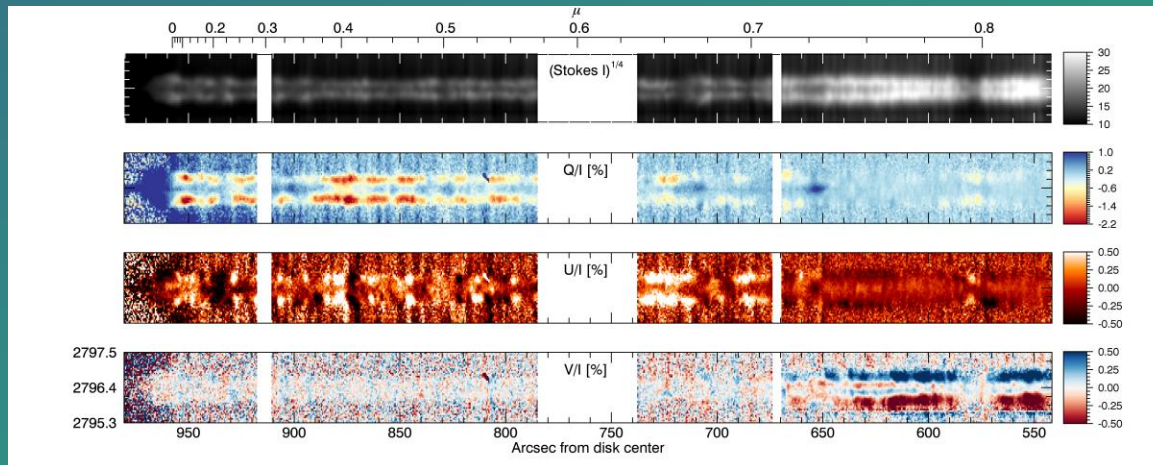
- Collaboration with National Astronomical Observatory of Japan (NAOJ)
- Questions:
 - What is the magnetic structure of the chromosphere?
 - Better understanding of boundary conditions?
 - Better understanding of chromosphere role in energizing upper solar atmosphere?
- Polarization of light gives us a clue about the local magnetic field since unpolarized light is modified in the presence of magnetic fields of varying strength
- CLASP consists of a Cassagrain telescope, 2-arm perpendicular polarimeter system to measure full Stokes parameters



Recent Missions: CLASP Launch and Results

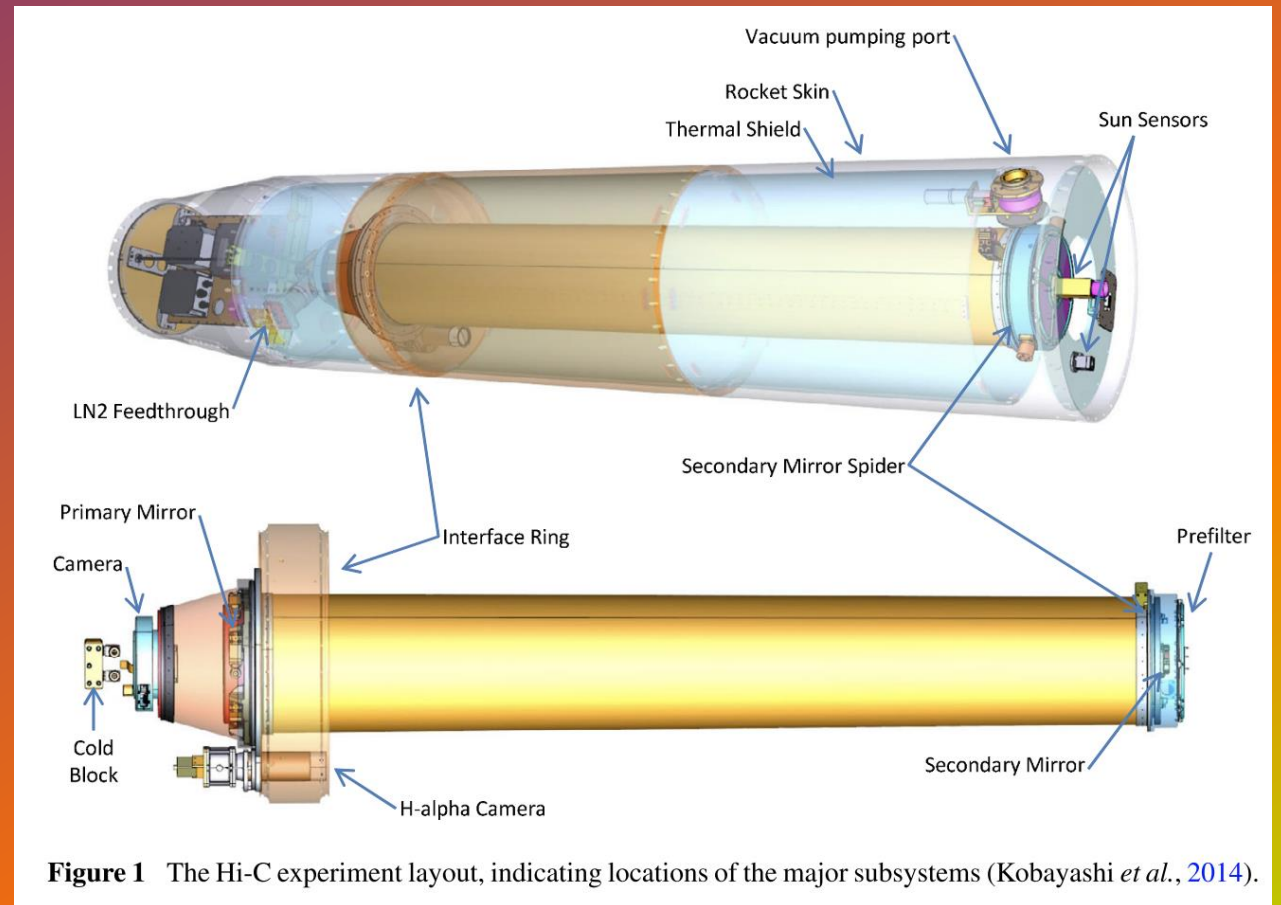


- Different wavelengths and polarization parameters are sensitive to different magnetic field strengths and mechanisms
- CLASP 1 :
 - Ly-alpha (~ 121 nm)
 - Sun center and single slit location
- CLASP 2 :
 - Mg h and k (~ 280 nm)
 - Sun center and 2 slit locations across plage and to limb
- CLASP 2.1
 - Mg h and k (~ 280 nm)
 - Scan of 16 slit pointings to generate 2D map



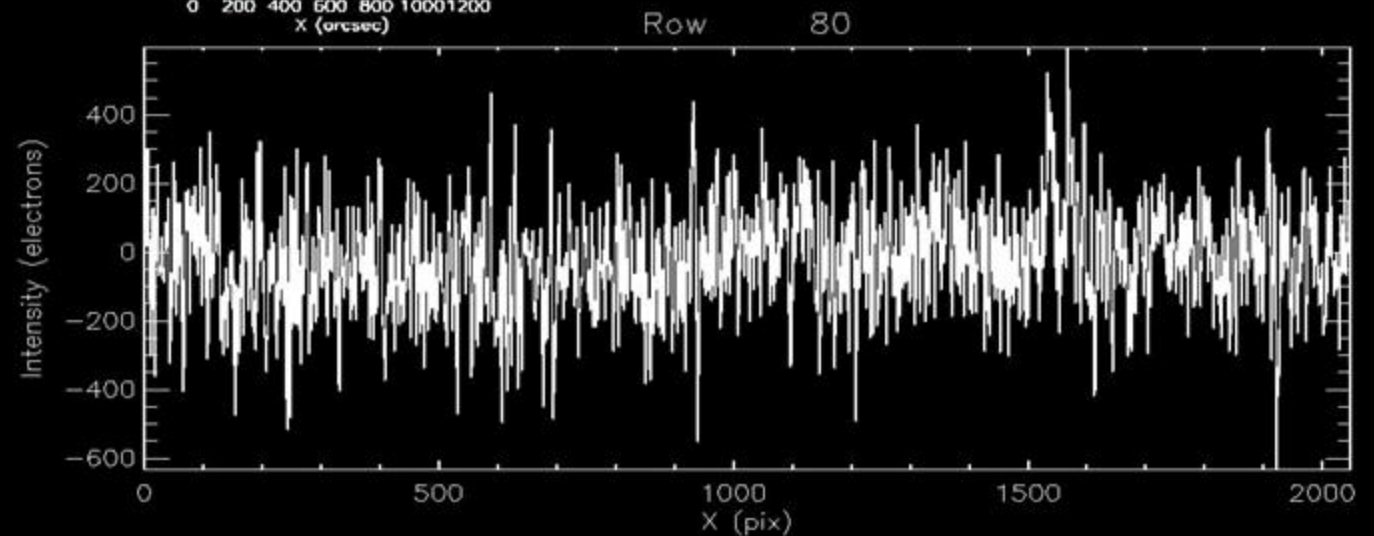
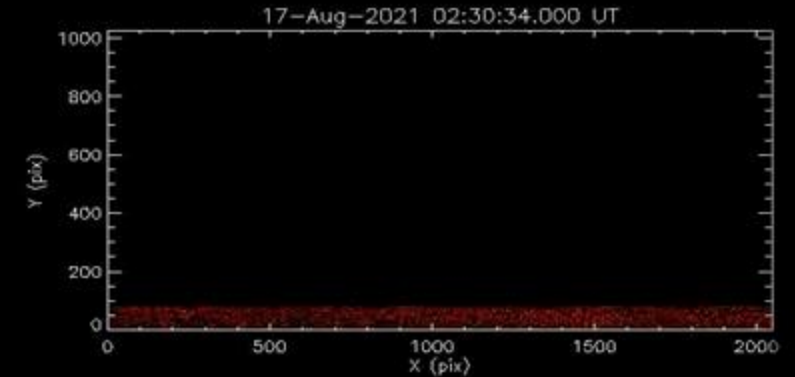
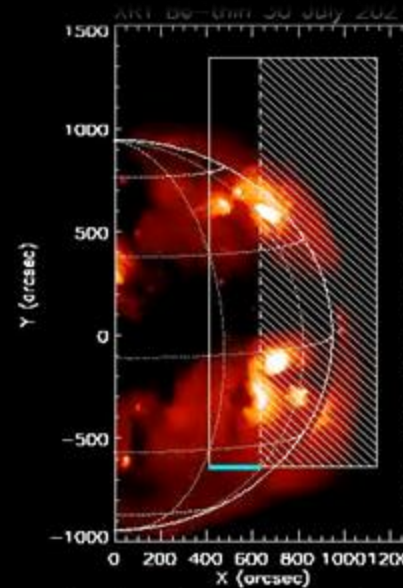
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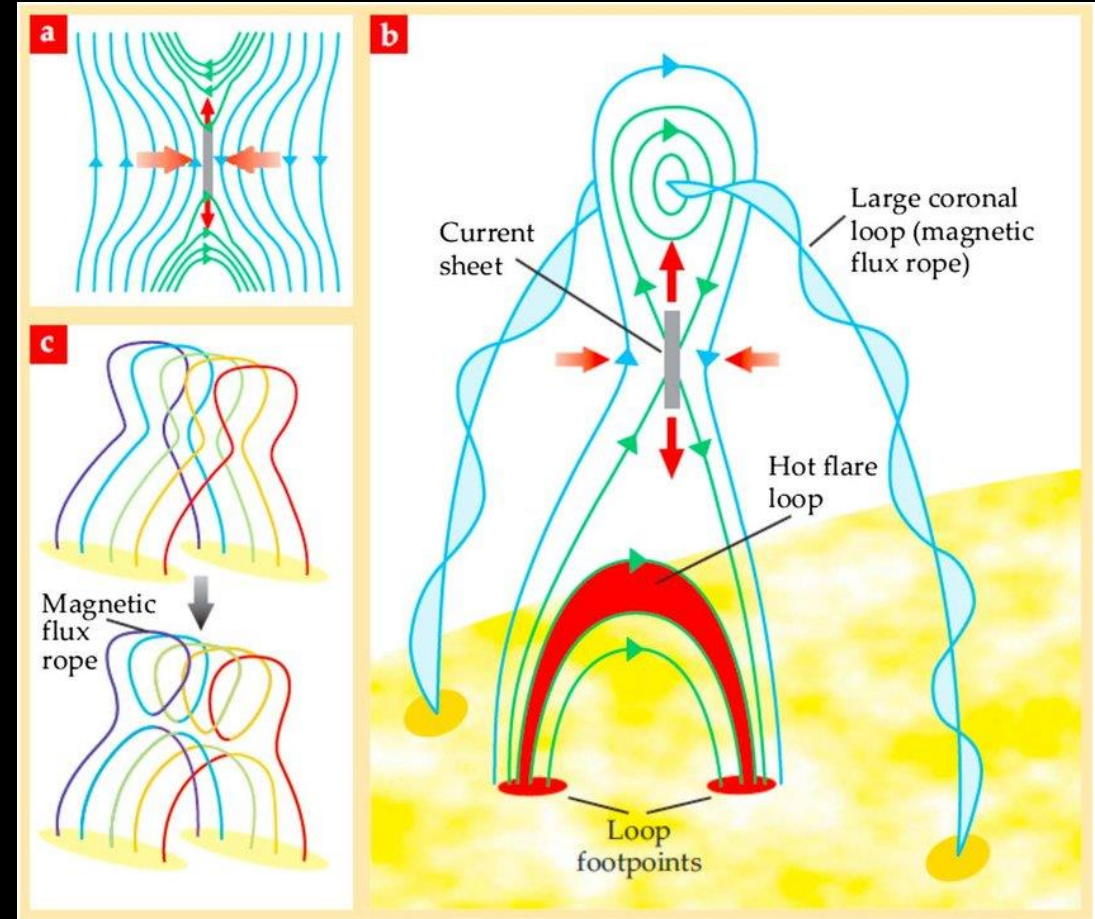
MaGIXS Data

- Marshall Grating Incidence X-ray Spectrometer
- MaGIXS 1 Successfully measured soft X-ray Overlappogram
- MaGIXS 2 scheduled for July 2024
 - Reduced instrument complexity
- Science Question: Heating mechanism – high vs low frequency



Future Missions: Hi-C FLARE

- What are flares?
- What are we trying to do?
- Real time Flare Monitoring
- Launch for Spring 2024 !



Holman, G. D. (2016). Scientific considerations for future spectroscopic measurements from space of activity on the Sun. *Journal of Geophysical Research: Space Physics*, 121(12), 11,667-11,697. <https://doi.org/10.1002/2016JA022651>

Future Solar Eclipses

- Annular Oct 14 2023
- Total April 2024
- Eclipse Map Info:

<https://solarsystem.nasa.gov/resources/2917/nasas-2023-and-2024-solar-eclipse-map/>



ECLIPSE



2023 THROUGH THE EYES OF NASA

SATURDAY, OCTOBER 14, 2023

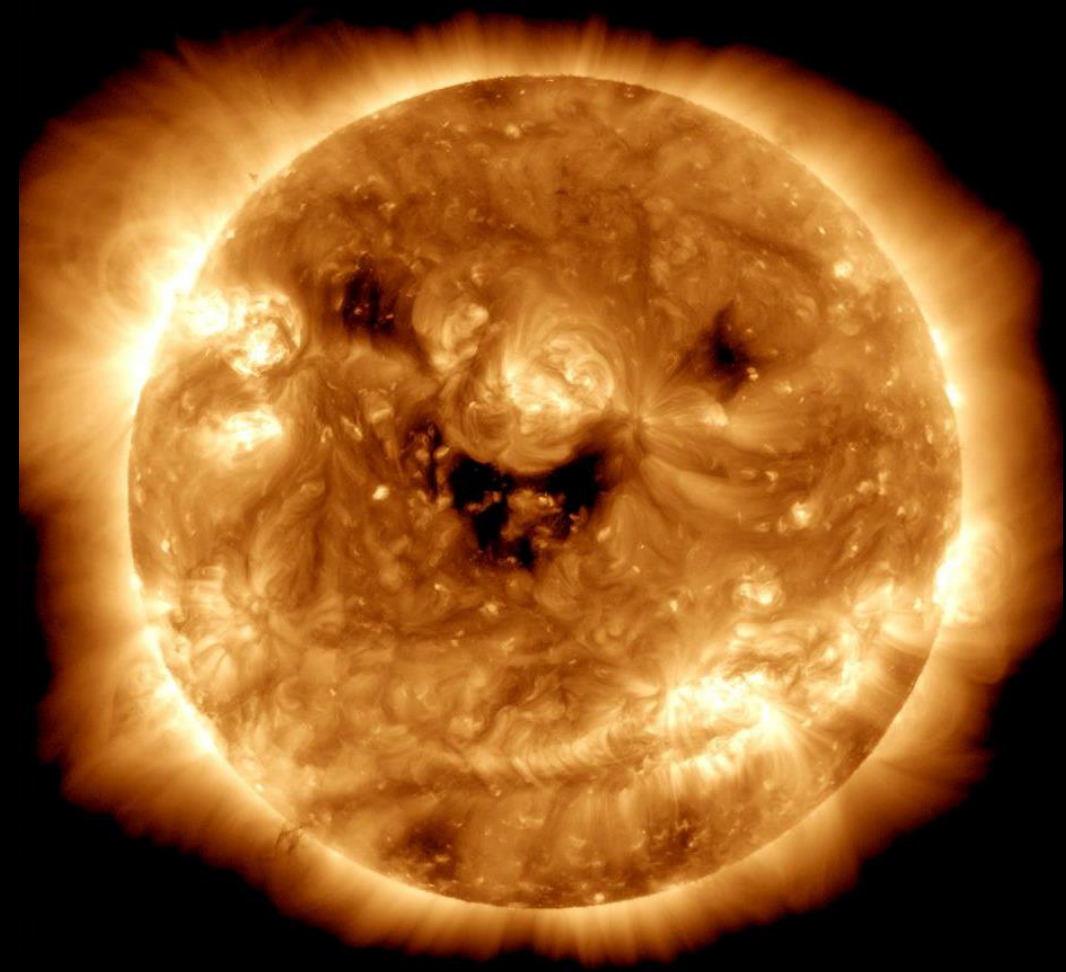
**Make your plans and get your
eyewear!**

ANNUAL ECLIPSE THROUGH THE EYES OF NASA

SATURDAY, OCTOBER 14, 2023

Summary

- Intro to the Sun and solar atmosphere
- Intro to sounding rockets
- Early solar sounding rocket missions and results
- Sounding rocket integration and launch
- Recent MSFC missions
- Future MSFC missions and Solar Events!

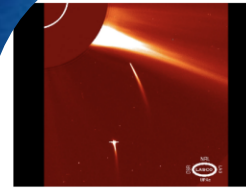


SDO/AIA 193 2022-10-26 21:37:29 UT

How can you learn more and
get involved?!

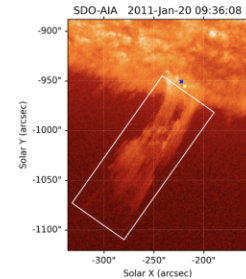
Resources and Citizen Science

- The Sun Today !
 - <https://www.thesuntoday.org/sun/current-observations/>
- Citizen science resources
 - <https://solarsystem.nasa.gov/eclipses/resources/citizen-science/>
- Eclipse! Get you glasses!
Make your plans!



The Sungrazer Project

Discover and report previously unknown comets.



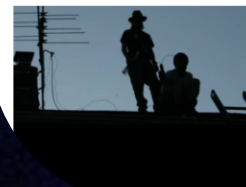
Solar Jet Hunter

Join the hunt for solar jets — enigmatic bursts of energy from our own star, the Sun.



Aurorasaurus

Did you see the aurora? Join a worldwide reporting system to help us understand how the Sun affects Earth.



HamSCI

Are you a Ham radio operator? Help us better understand Earth's ionosphere.

1600 Å

304 Å

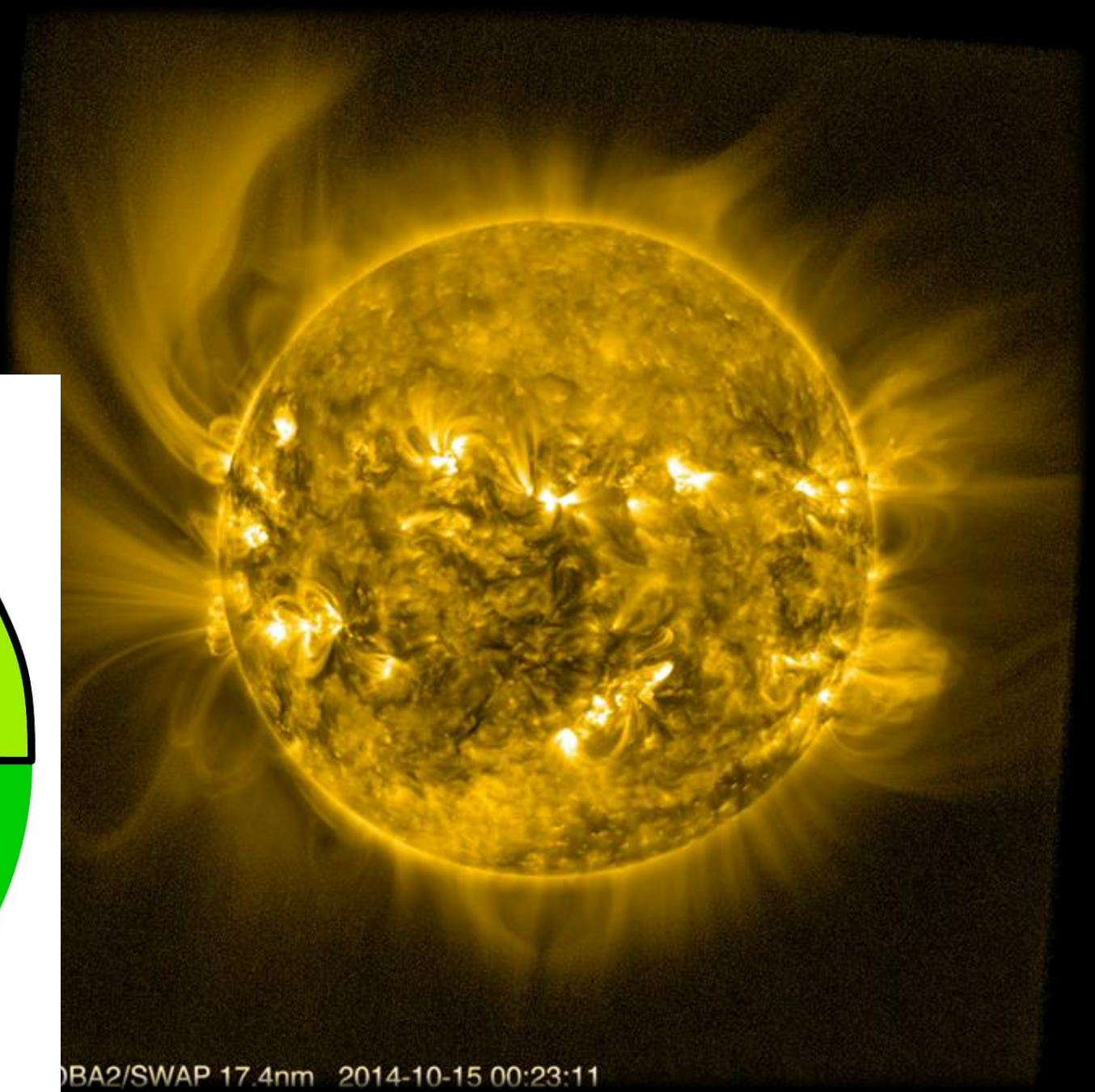
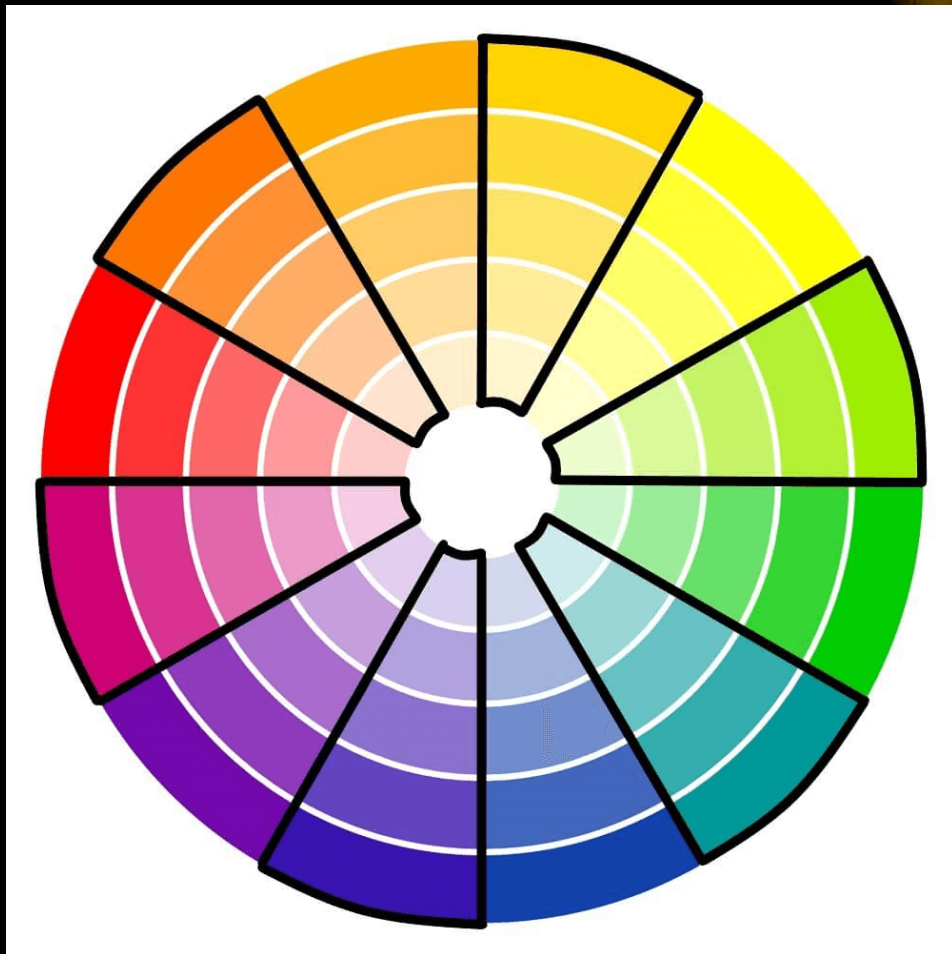
171 Å

335 Å

94 Å

131 Å

Extra Slides



SOBA2/SWAP 17.4nm 2014-10-15 00:23:11