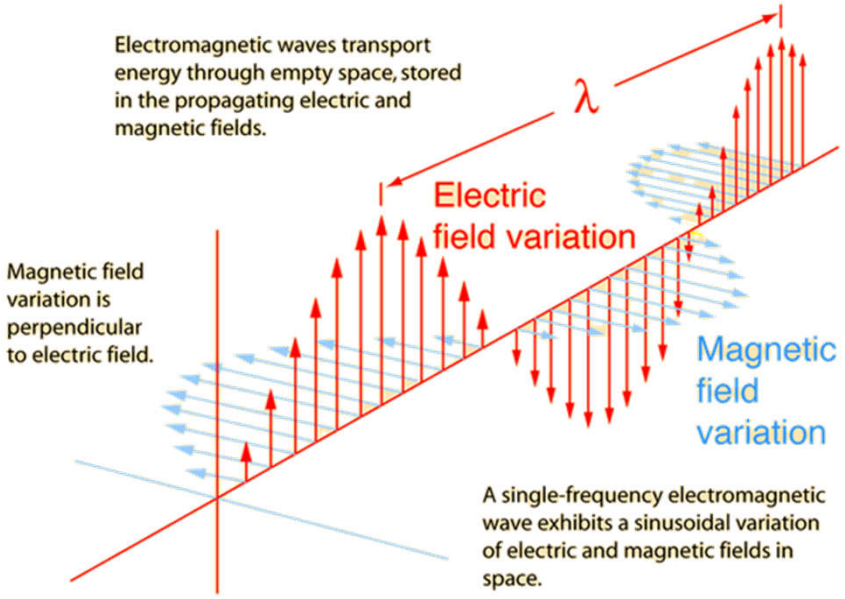

Part II
SOLAR IRRADIANCE

Electromagnetic radiation

- Result of oscillating electric and magnetic fields

How does the Sun generate these oscillations?

- → Nuclear fusion generates extreme temperatures
- Constituents move around, collide, and oscillate violently
- Constituents are charged → bunch of oscillating charges sending out light



Generation of EM radiation

- Mass = Energy (Einstein): $E=mc^2$
- Nuclear fusion: **Proton-Proton-reaction**
- Resulting energy mainly transmitted as light

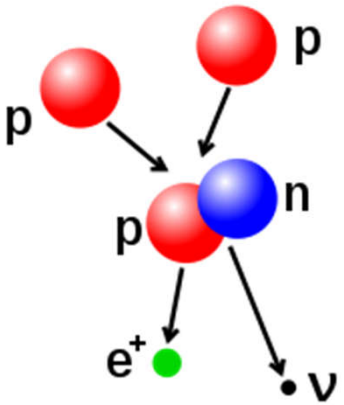
p: Proton

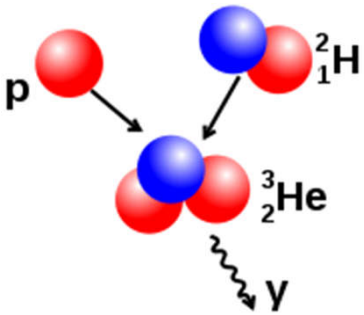
n: Neutron

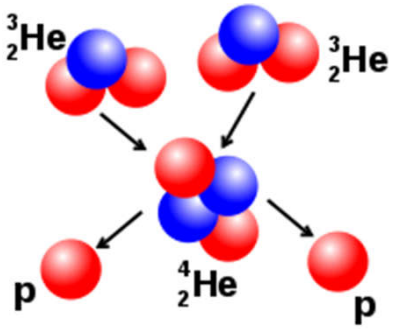
e^+: Positron

ν: Elektronneutrino

y: Gammaquant

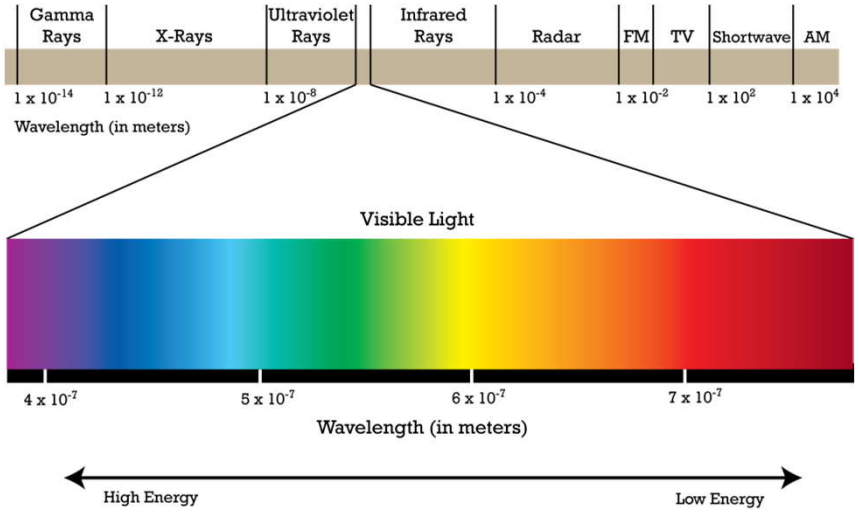






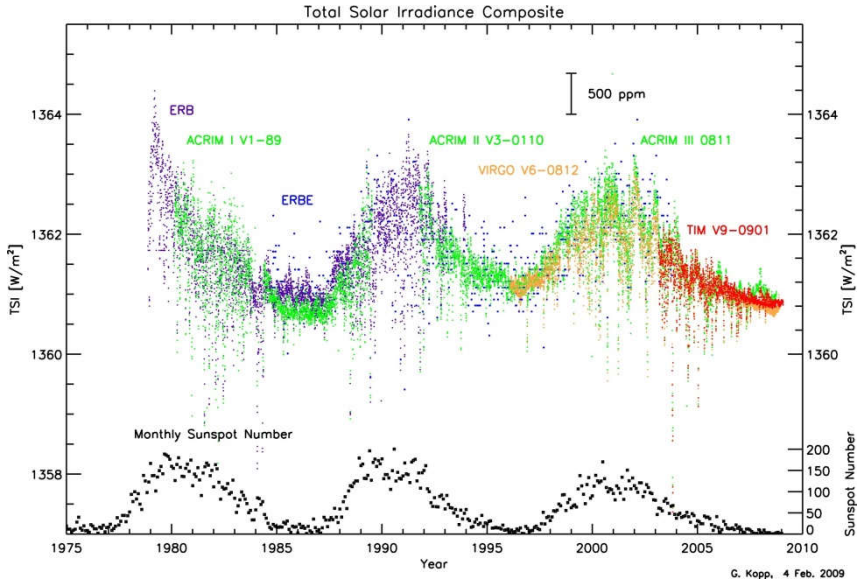
EM spectrum

- EM waves transmitted as photons
- Travelling with speed of light
- From radiowaves to X-ray and gamma waves
- Energy varies intensively with wavelength
- Most of the solar radiation comes from the *photosphere*
- At wavelengths below a few hundred nm the radiation comes from the *chromosphere* and the *corona* and it can vary in intensively



Solar irradiance

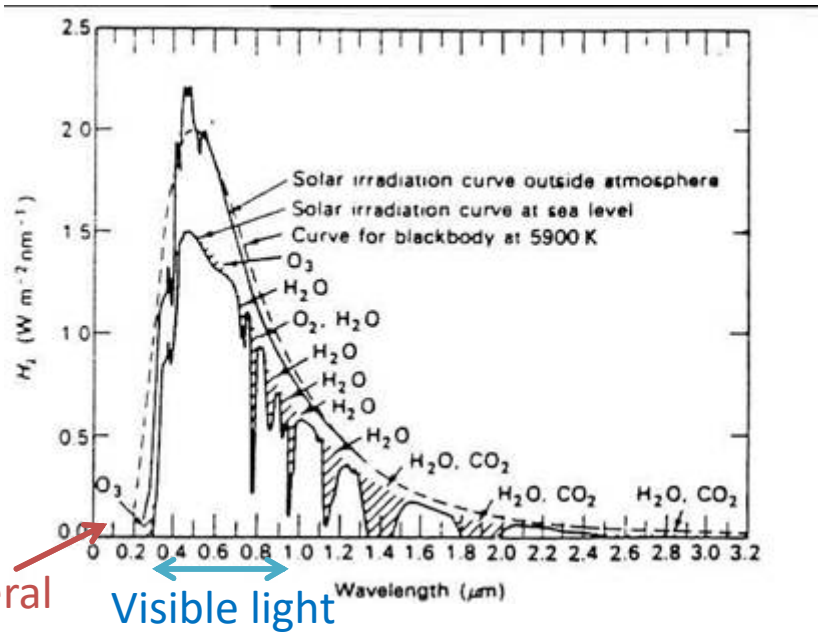
- Amount of energy that strikes Earth's atmosphere
- Total solar irradiance (TSI): all of the radiation
- Spectral irradiance: measured as function of wavelength
- Variability with:
  - Solar cycle
  - Solar rotation
  - flares



Three-decade record of TSI compiled by patching together data from U.S. and European satellites. Credit: Greg Kopp, LASP

Spectral flux

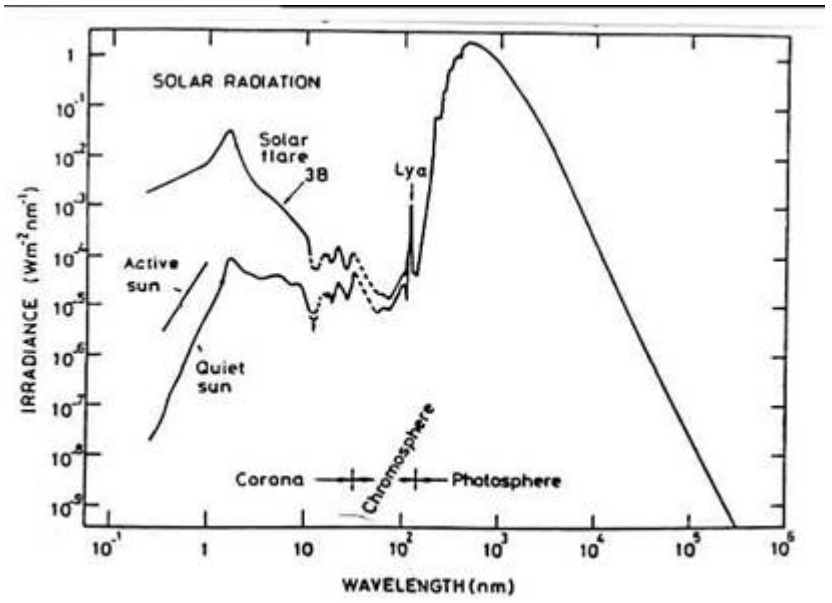
- Maximum of radiant energy flux is in the visible region
- Radiation can be approximated by a blackbody curve with the temperature of Sun's photosphere
- Attenuation by scattering and absorption
- Attenuation is much greater at certain wavelengths
- General reduction at shorter wavelengths, less than 320 nm



The solar irradiance at the top of the atmosphere and at sea level.

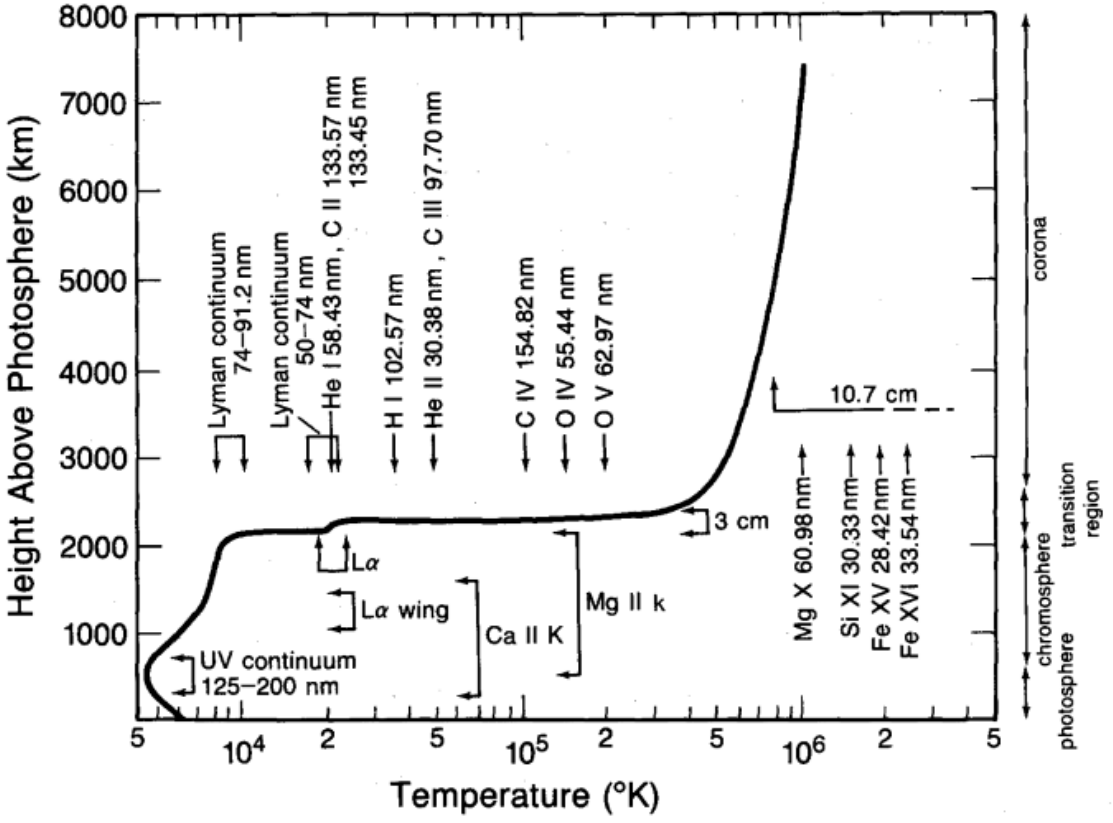
Spectral flux

- The logarithmic representation emphasizes the contribution of X-rays and extreme ultraviolet radiation.
- Vary in intensity by several orders of magnitude over a solar cycle
- Short-wave radiation is absorbed in the thermosphere

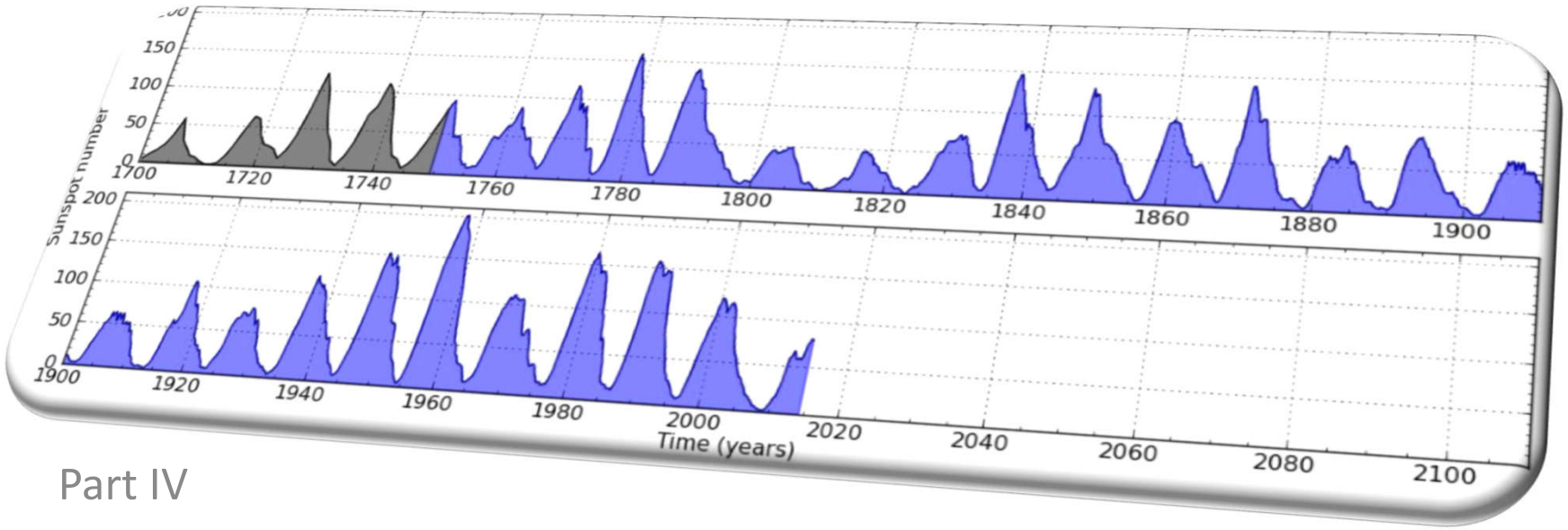


Logarithmic representation of spectral distribution of the solar irradiance and it variation with solar activity. After Smith and Gottlieb (1974)

Temperature emission



- Schematic of the average temperature distribution
- Peak temperatures of emissions of various atoms and ions
- Lean (1988)

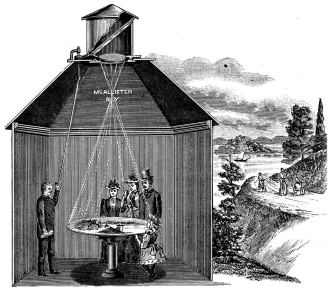


Part IV

SOLAR INDICES AND MEASUREMENTS

Sunspot number

- Observe by eye
- Camera obscura in the 16th and early 17th century
- telescopic instrumentation starting during the early 17th century



Sunspot number

Wolf Sunspot Number R_Z

- Wolf defined the sunspot number, R_Z, as

$$R_Z = k(10g + f)$$

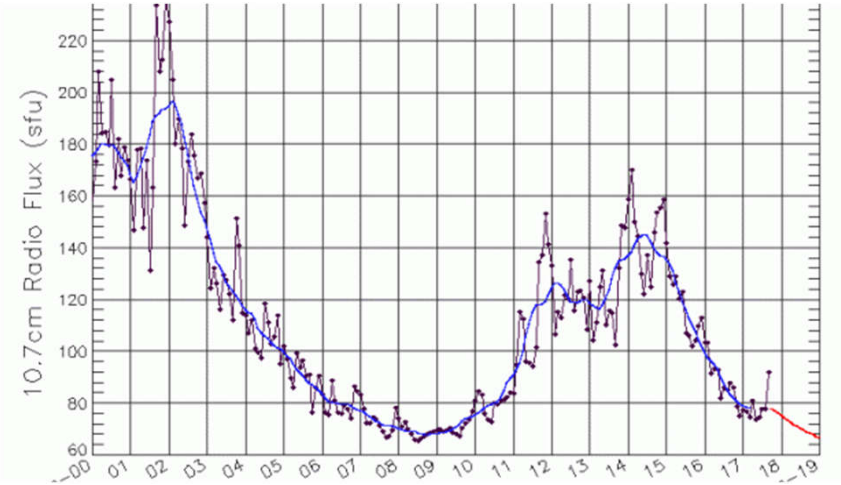
- g: number of sunspot groups
- f: the number of individual sunspots
- k: a correction factor for each observer

Group Sunspot Number, R_G

- Hoyt and Schatten (1998)
- $R_G = \frac{12.08}{N} \sum k'_i G_i$
- i: number of observer
- Gi is the number of sunspot groups recorded by I
- ki is the i-th observer's correction factor
- N the number of observers used to form the daily value

10.7 cm radio flux

- solar radio flux at 10.7 cm (2800 MHz) → F10.7 index
- excellent indicator of solar activity
- one of the longest running records of solar activity
- F10.7 radio emissions originates high in the chromosphere and low in the corona of the solar atmosphere
- F10.7 correlates well with the sunspot number as well as a number of UltraViolet (UV) and visible solar irradiance records
- 1 record per day, reported in “solar flux units”, (s.f.u.)

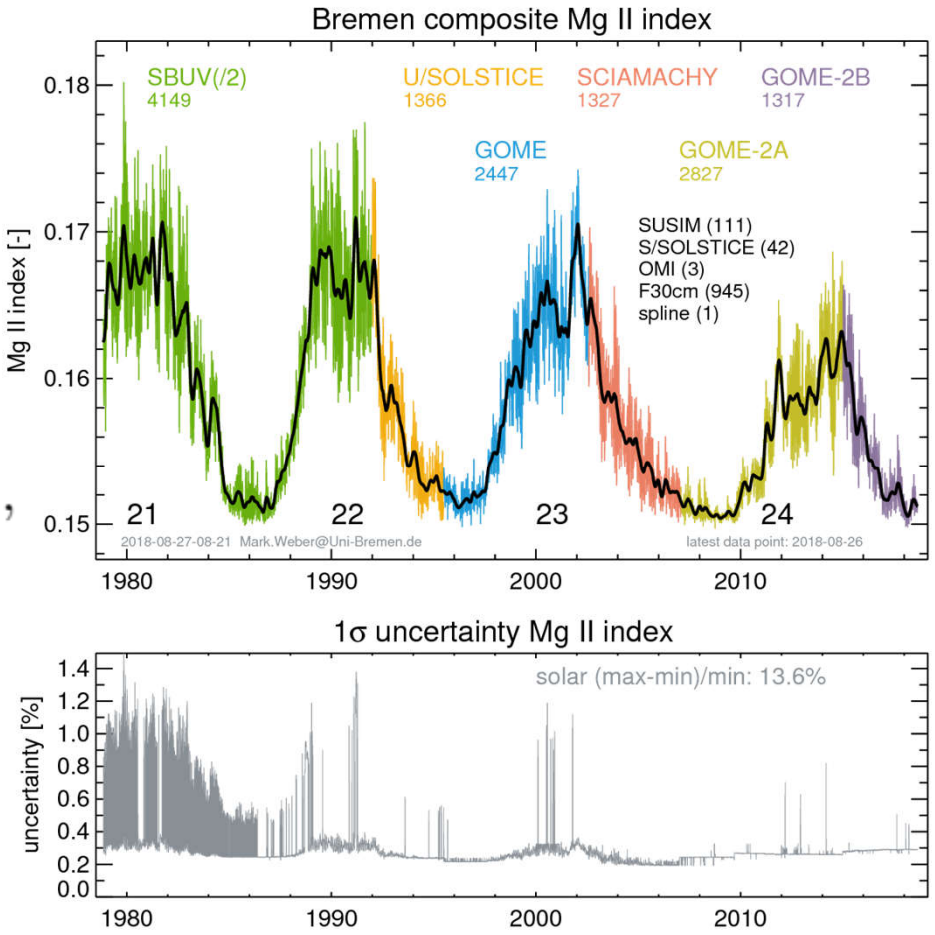


Mg II index

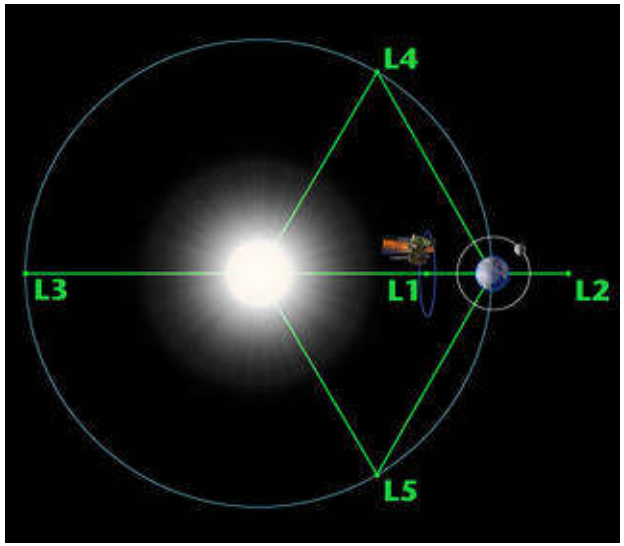
- Heath & Schlesinger (1986)
- useful proxy for the solar EUV irradiance.

$$I = \frac{4[E_{279.8} + E_{280.0} + E_{280.2}]}{3[E_{276.6} + E_{276.8} + E_{283.2} + E_{283.4}]},$$

- fairly easy to measure and is relatively insensitive to instrumental artifacts
- challenge to turn those qualitative statements into quantitative data-sets



Heliospheric fleet



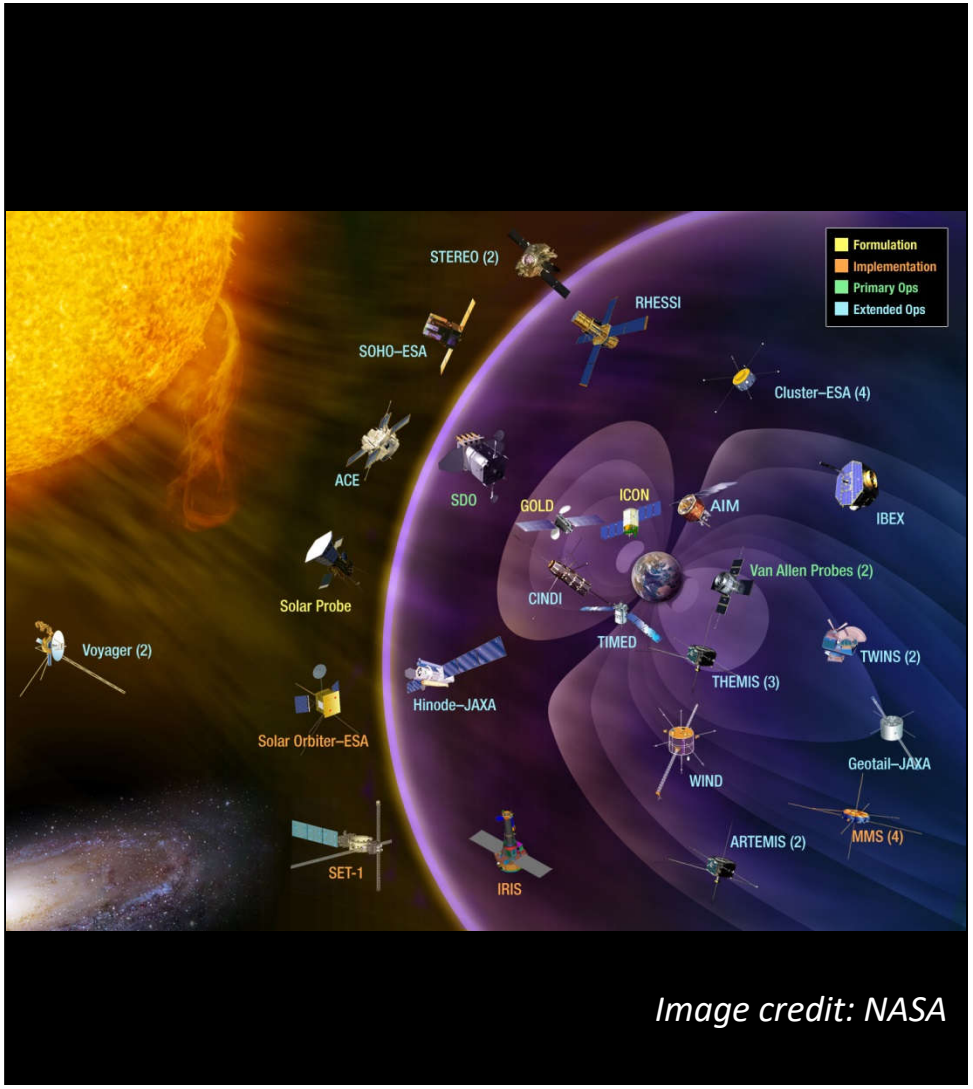
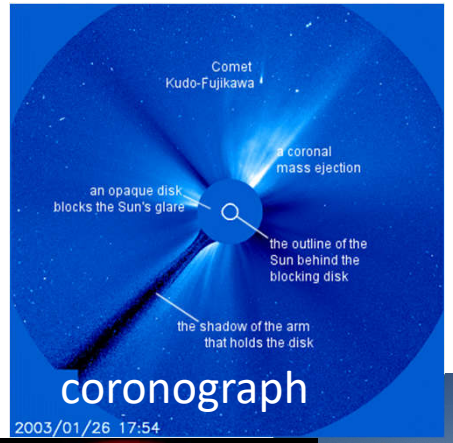


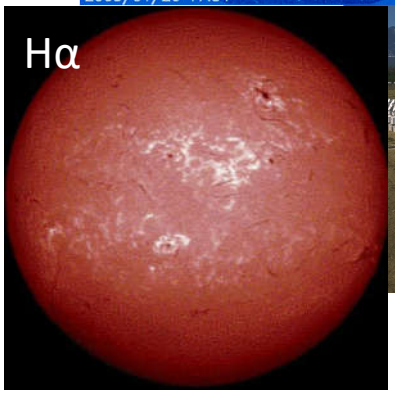
Image credit: NASA

Measurements

Region	Measurement
Photosphere	White light Sunspot drawings
Chromosphere	Calcium Magnetograms H-Alpha
Corona	Radio Heliographs Coronographs Coronal holes



coronograph




Nobeyama Radioheliograph