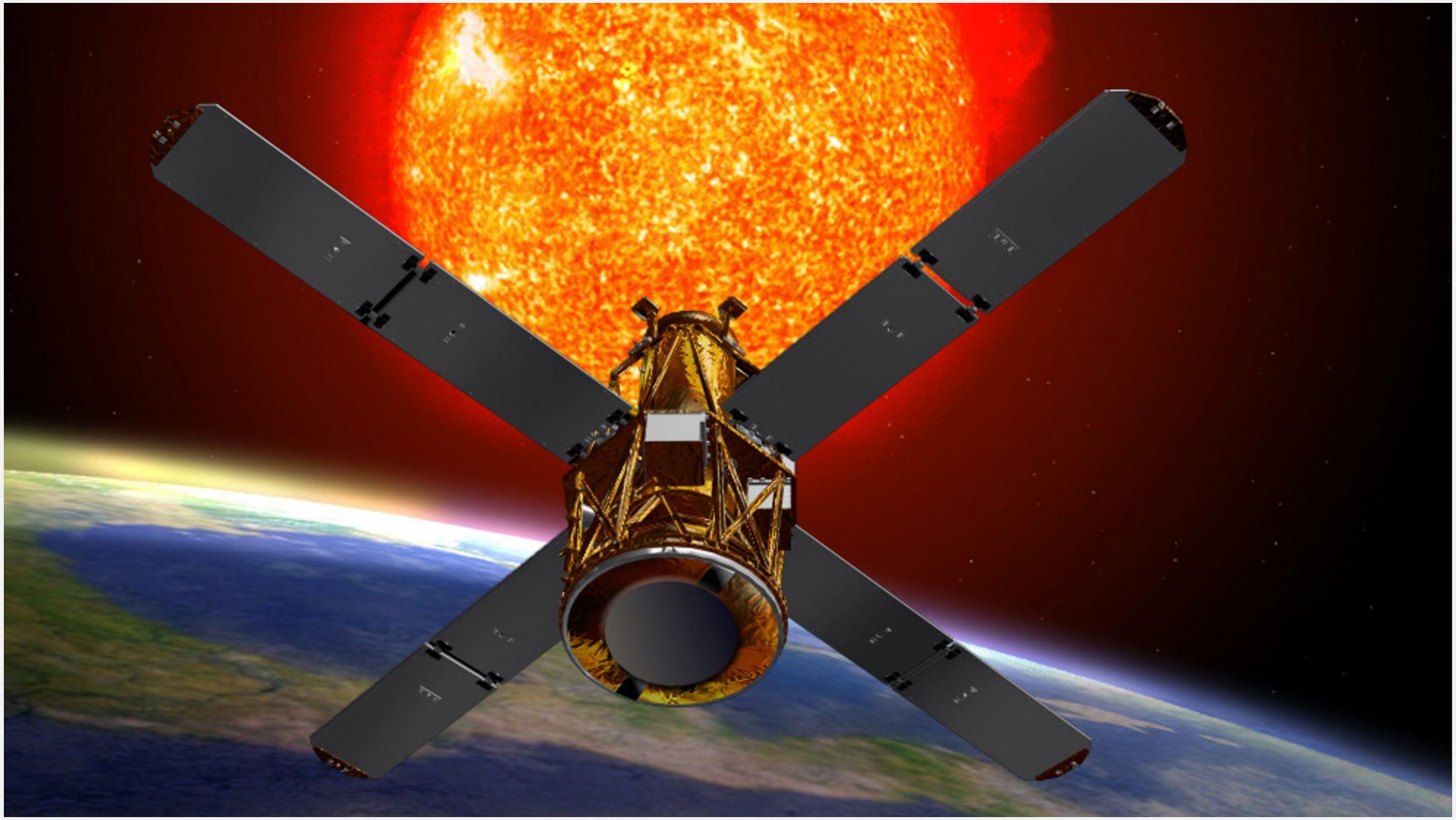
Group Project Task: Helios



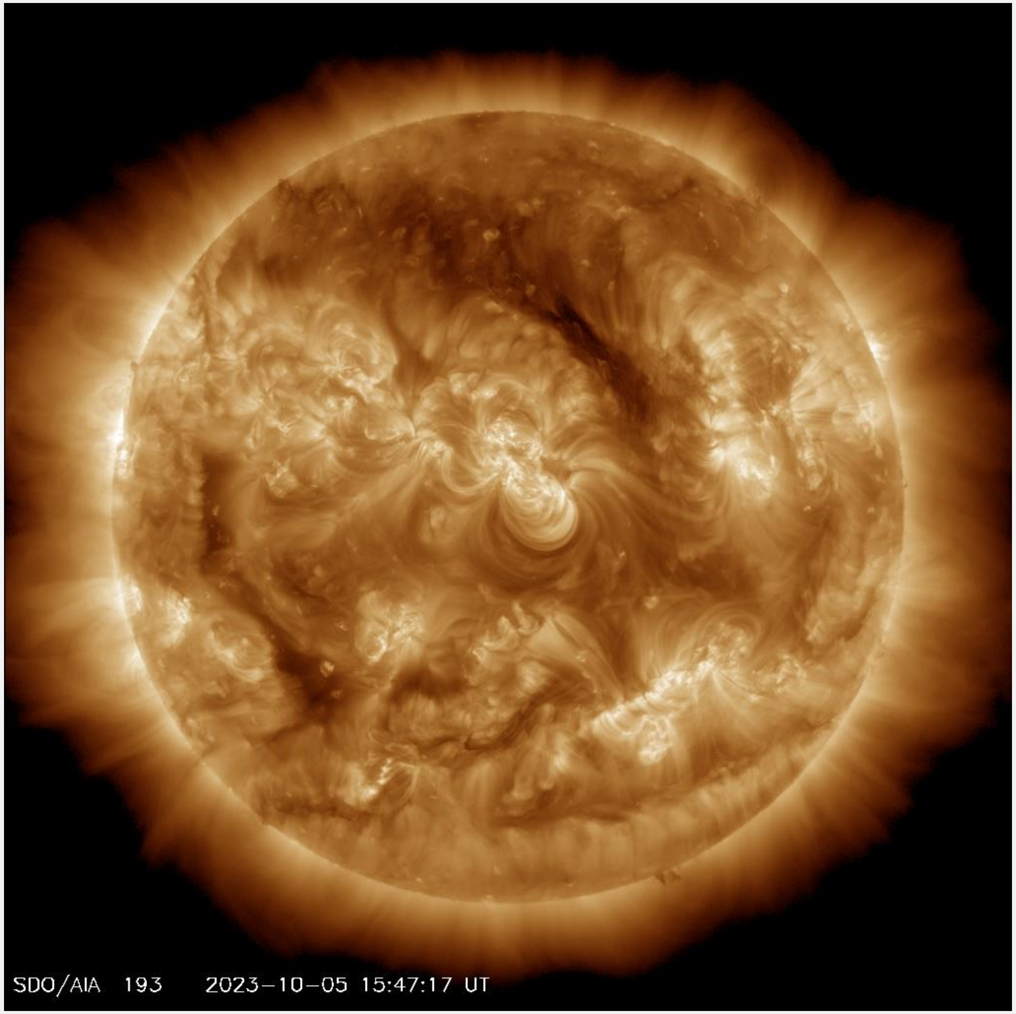
Reuven Ramaty High Energy Solar Spectroscopic Imager
NASA solar flare observatory

RHESSI

- RHESSI observed the Sun from orbit around the earth, and during its observing lifetime measured dangerous high energy X-ray and gamma-ray emission from more than 100,000 solar flares.
- The imaging data from RHESSI provided key information on the location and energetics of solar flares, and clues to how these flares fire cosmic rays into the solar system.
- RHESSI documented the enormous range of solar storms, from tiny "nano-flares" to extreme superflares tens of thousands of times more explosive. Data from RHESSI was even used by scientists to better determine the Sun's geometric shape.
- After about 16 years in orbit, communication issues with RHESSI caused NASA to decommission the satellite in 2018. The satellite remained in orbit for another 5 years, until atmospheric drag caused the orbit to decay. Its job well done, RHESSI fell harmlessly to earth over the Sahara desert on Wednesday, April 19, 2023.

Existing Research

- Combined STEREO/RHESSI study of coronal mass ejection acceleration and particle acceleration in solar flares
  - M. Temmer *et al*
- Gamma-Ray Burst Polarization: Limits from RHESSI Measurements
  - C. Wigger *et al*
- RHESSI Data Analysis Software
  - Schwartz *et al*



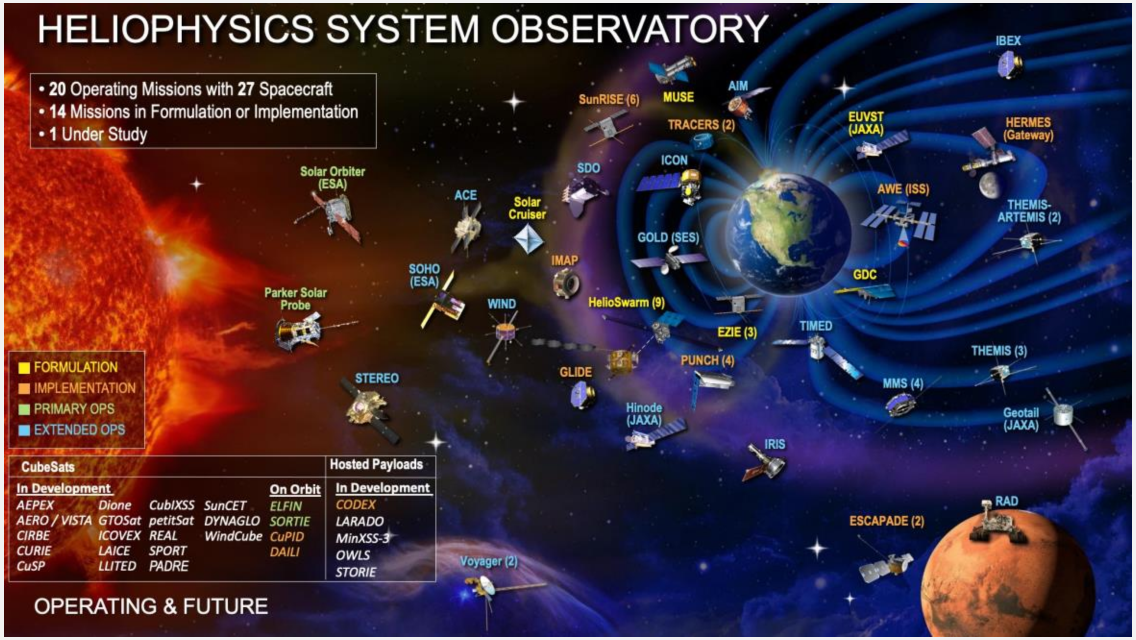
Latest SDO HMI / AIA 171 Composite

Learning Objectives

1. Summarizing complex spatio-temporal data
2. Density Estimation
3. Hotspot Discovery
4. Change Analysis

- Design and implement a system called *Helios*, which is capable of:
    - summary generation,
    - mapping,
    - hotspot discovery,
    - change analysis

of high-intensity solar flares events.

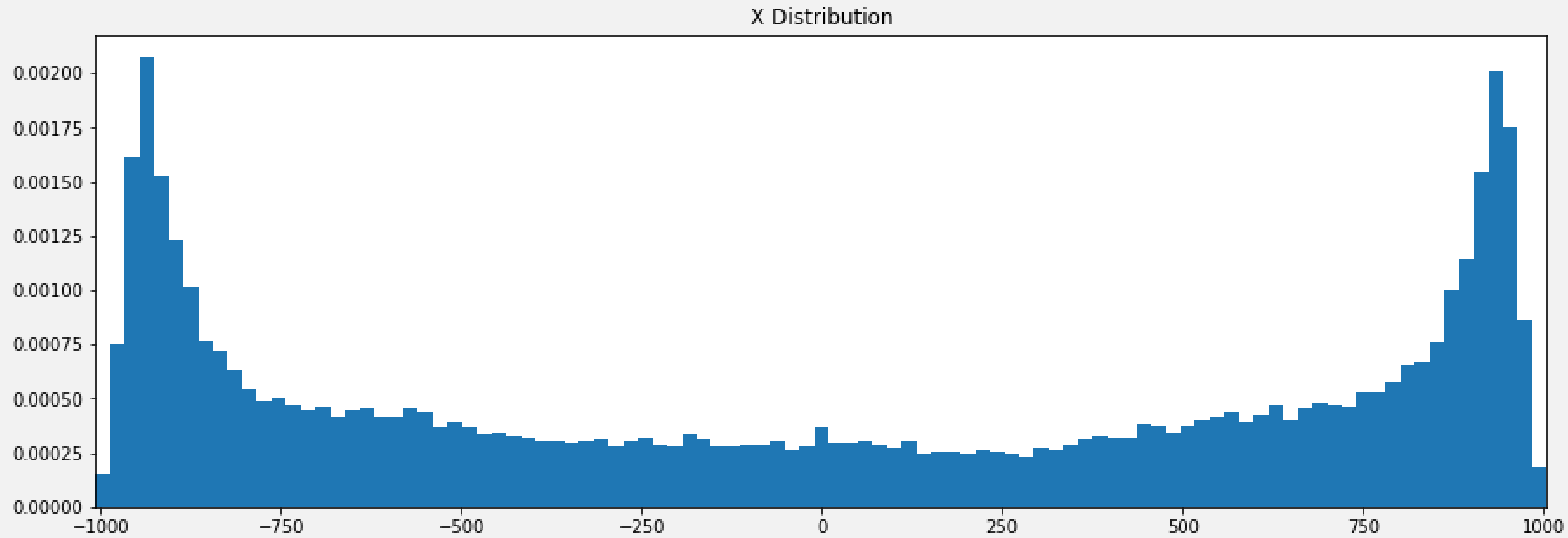


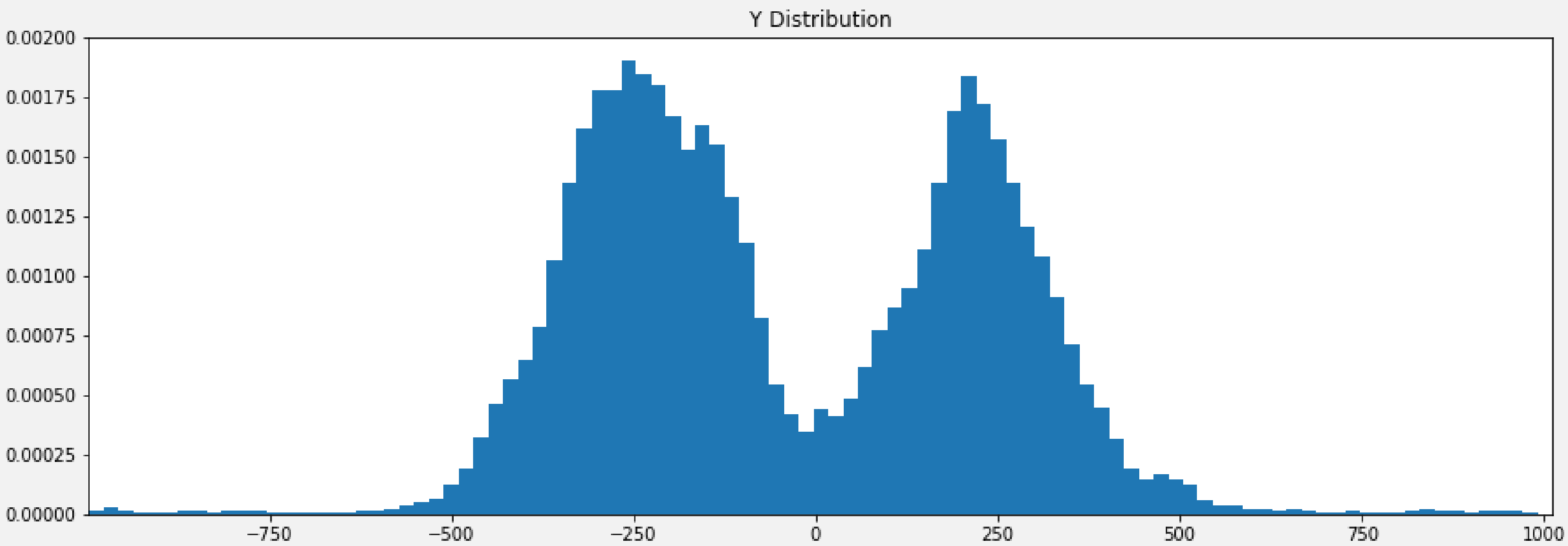
This graphic represents NASA’s Heliophysics Fleet as of March 2022. **Credit: NASA**

Data Structure

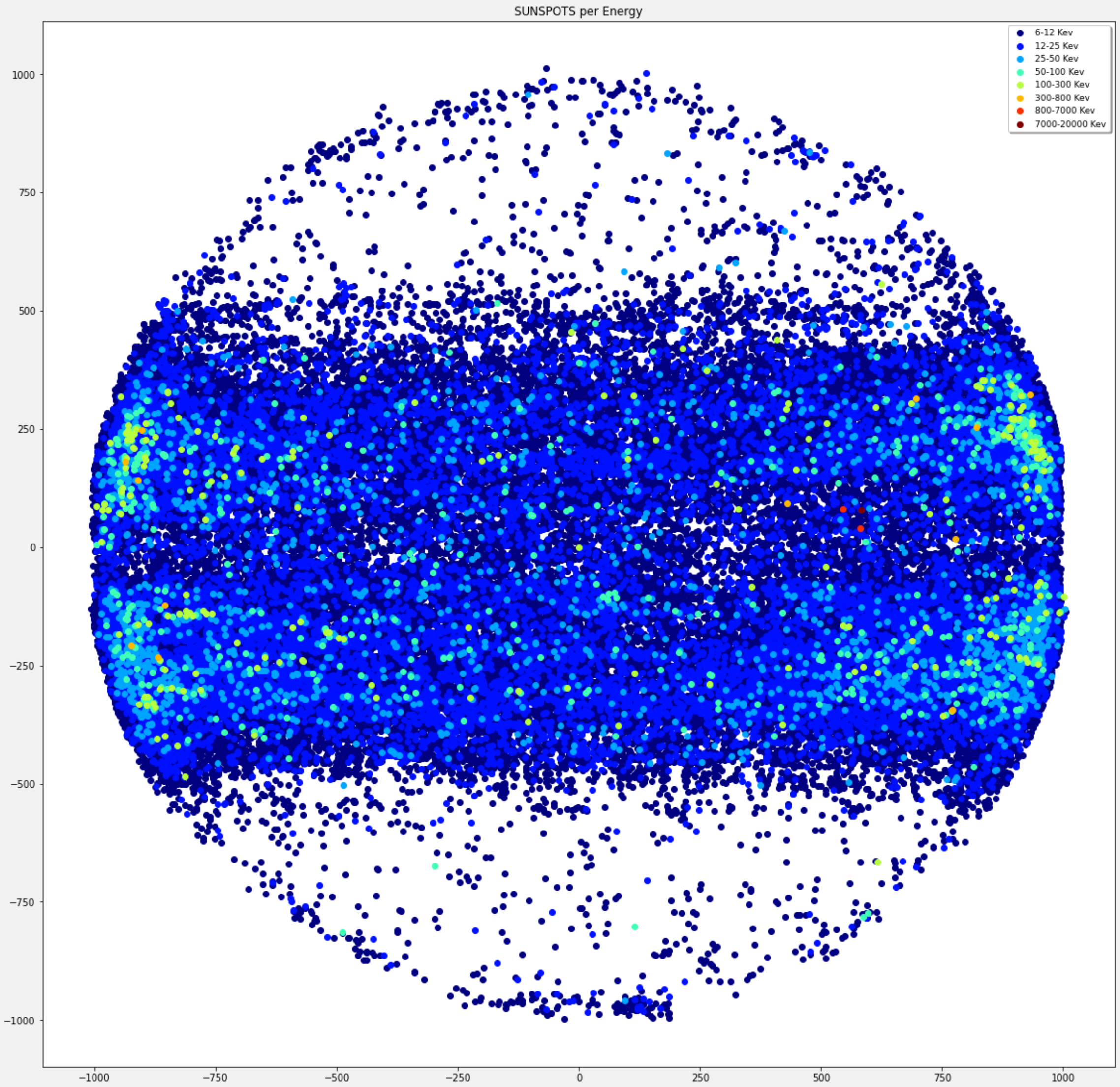
• Flare	- An ID number, ymmddnn, e.g., 2042101 is the first flare found for 21-Apr-2002. These numbers are not time ordered.
• **Date**	**- The date when the flare occurred**
• Start	- Flare start time
• Peak	- Flare peak time
• End	- Flare end time
• Dur[s]	- Duration of flare in seconds
• Peak[c/s]	- Peak count rate in corrected counts, peak counts/second
• **Total Counts**	**- Total of counts in corrected counts, counts in energy range**
• **Energy [keV]**	**- The highest energy band in which the flare was observed.** **['3-6', '6-12', '12-25', '25-50', '50-100', '100-300', '300-800', '800-7000', '7000-20000']**
• **X pos [asec]**	**- Flare position in arcsec from Sun center**
• **Y pos [asec]**	**- Flare position in arcsec from Sun center**
• Radial [asec]	- Radial distance in arcsec from Sun center
• Flags	- Quality Codes

Coordinate Density Plot



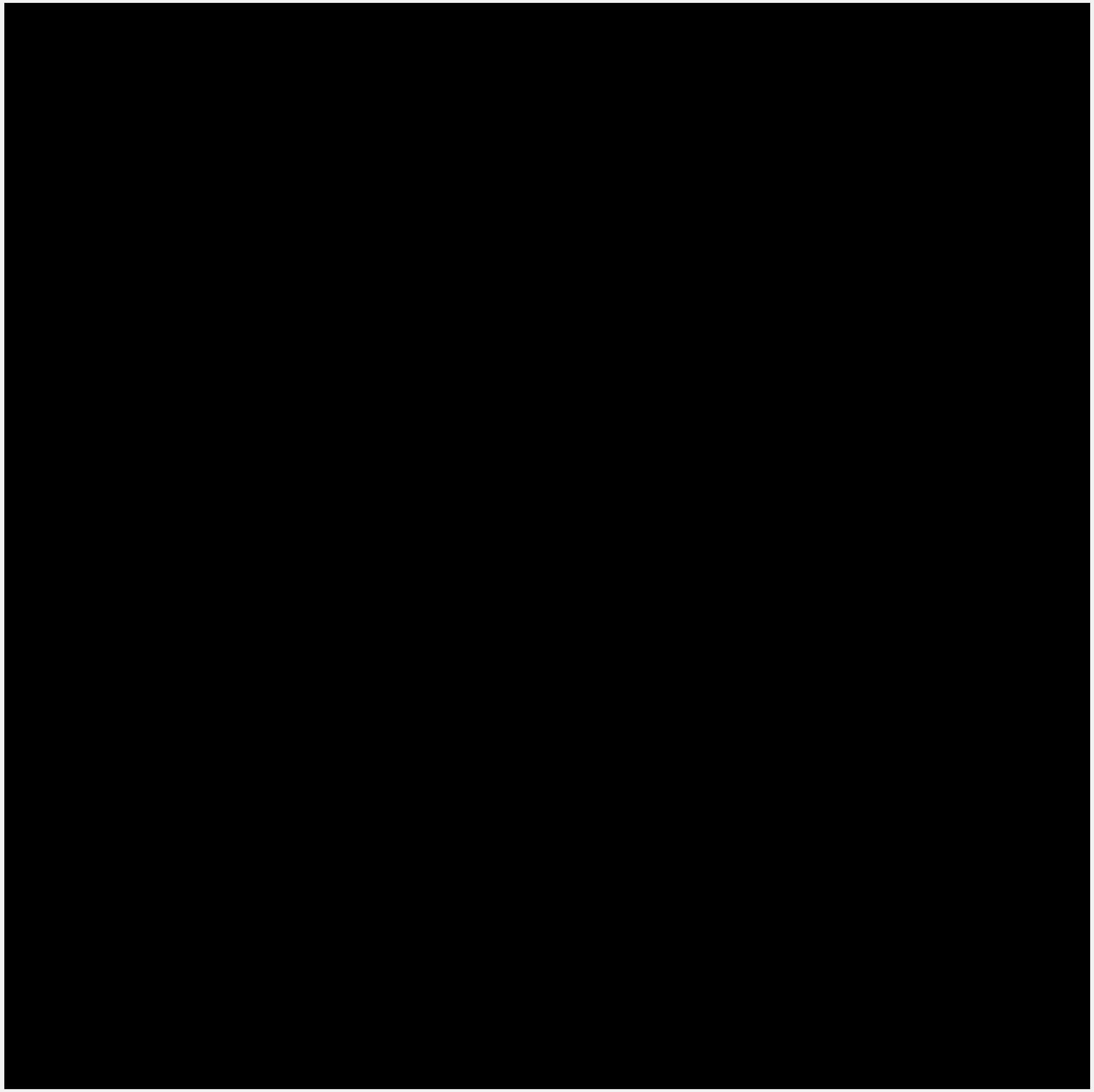


Sunspots

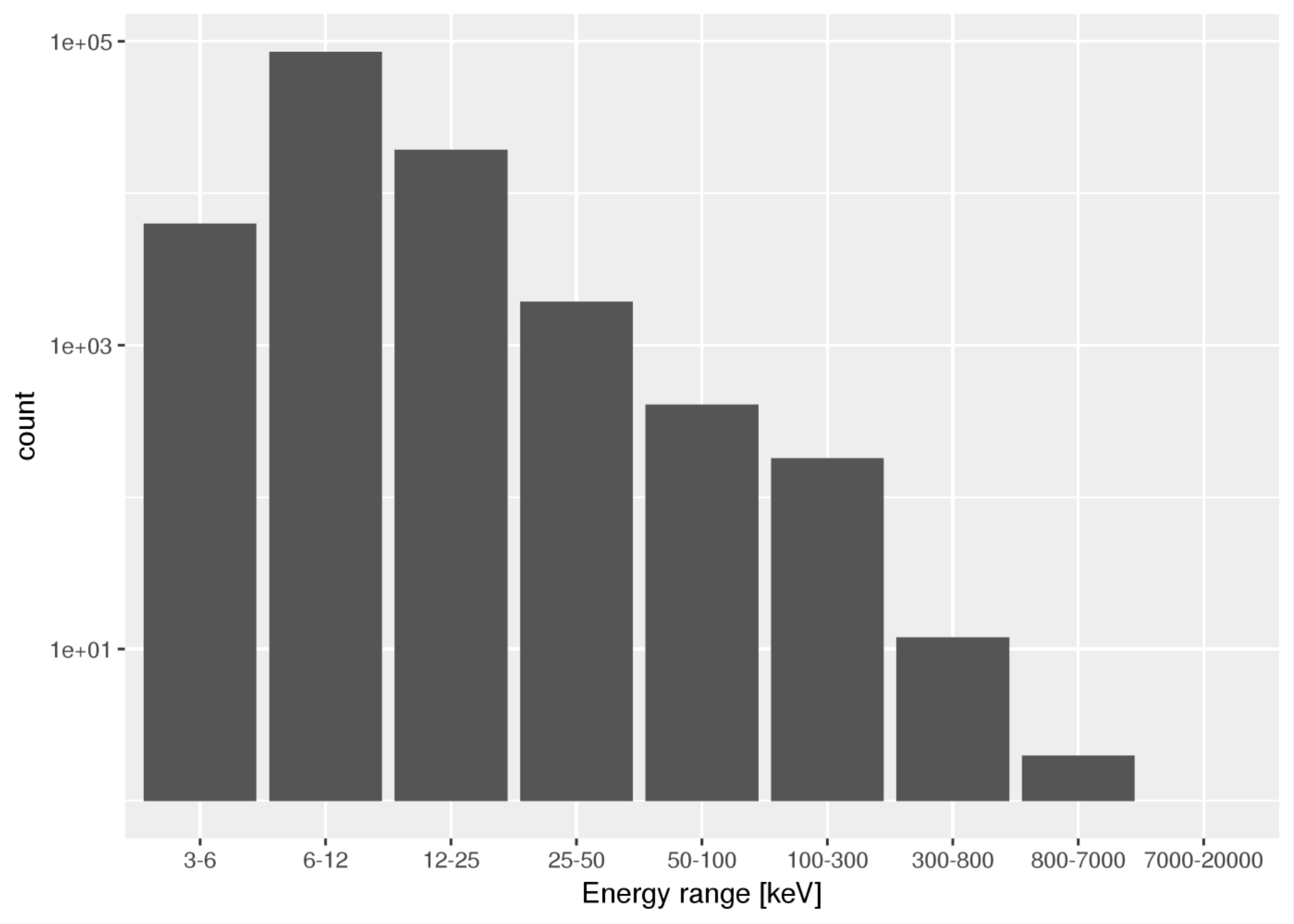


SUNSPOTS per Energy
6-12 Kev
12-25 Kev
25-50 Kev
50-100 Kev
100-300 Kev
300-800 Kev
800-7000 Kev
7000-20000 Kev
1000
750
500
250
0
−250
−500
−750
−1000
−1000
−750
−500
−250
0
250
500
750
1000

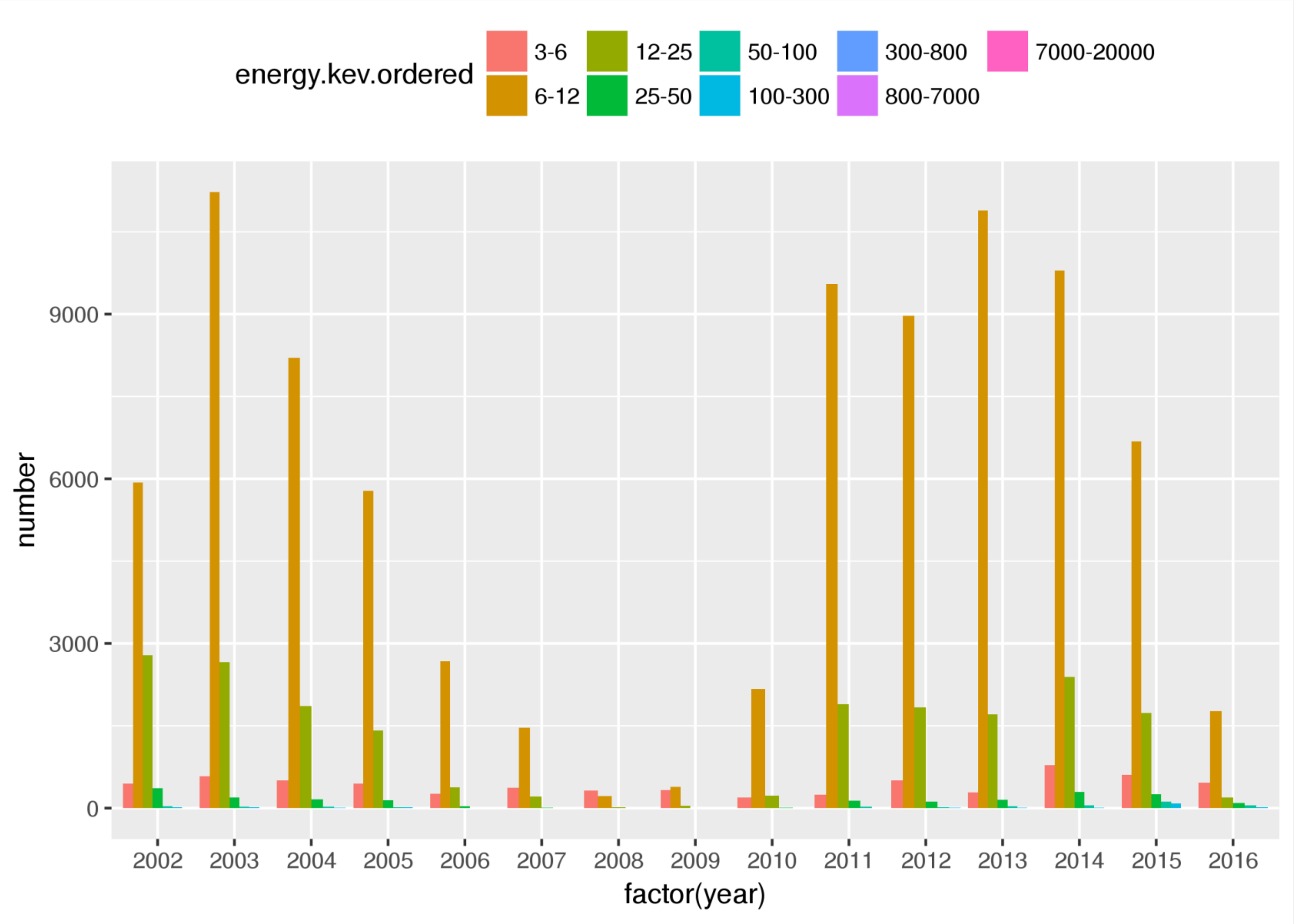
Visualization



Energy Bands



Sunspot Energy Structure by Year



Task 1: Solar Flare Intensity Estimation

- Subdivide data into smaller batches:
  - Assuming a batch size of 4 months and 2 months overlap between consecutive batches; that is, there will be batches for months 1+2+3+4, months 3+4+5+6, …, months 33+34+35+36 (17 batches).
- Develop two methods of flare intensity estimation; intensity estimation techniques measure the flare intensity in a location ((X,Y)) based on a set of flare events:
  - Method 1 measures the intensity based on the **total.counts** attribute.
  - Method 2 measures the intensity based on the **duration.s** and **energy.kev** attributes.

Task 2: Hotspot Discovery and Analysis

- Develop hotspot discovery techniques for the intensity maps you generated in Task1.
- We assume a hotspot is a contiguous polygon in a 2D X-Y space for which the event intensity of points inside the polygon is above a user-defined intensity threshold. Your system should create two kinds of hotspots:
  a. Small, very hot spots whose density is above a “high” intensity threshold d1
  b. Large, more regional hotspots whose intensity if a above a “medium high” intensity threshold d2; d1>d2.

However, you might create hotspots of “simpler” shapes, instead of polygons; e.g. rectangular hotspots or hotspots which are contiguous regions of grid cells.

Task 3: Change Analysis for Solar Flares

- Compare the solar flare data from Set 1 (2004 to 2006) with those from Set 2 (2015 to 2017)
- Summarize the major differences between the two datasets.
  - Compare the two kind of intensity we introduced hotspots and flare durations and analyze spatial variation.
  - You can use methods you developed in Task 1 and Task 2 for your comparison.

Helpful Links

1. Detailed Explanation of the Solar Cycle:
   - http://solarcellcentral.com/sun_page.html

2. NASA's Parker Solar Probe spacecraft flies right through sun explosion, captures footage:
   - https://mashable.com/article/sun-solar-ejection-nasa-footage

3. Reuven Ramaty High Energy Solar Spectroscopic Imager was a NASA solar flare observatory. After more than 16 years of successful operations since its launch in 2002, RHESSI was decommissioned on 16 August, 2018.
   - https://en.wikipedia.org/wiki/Reuven_Ramaty_High_Energy_Solar_Spectroscopic_Imager