Midterm Presentation

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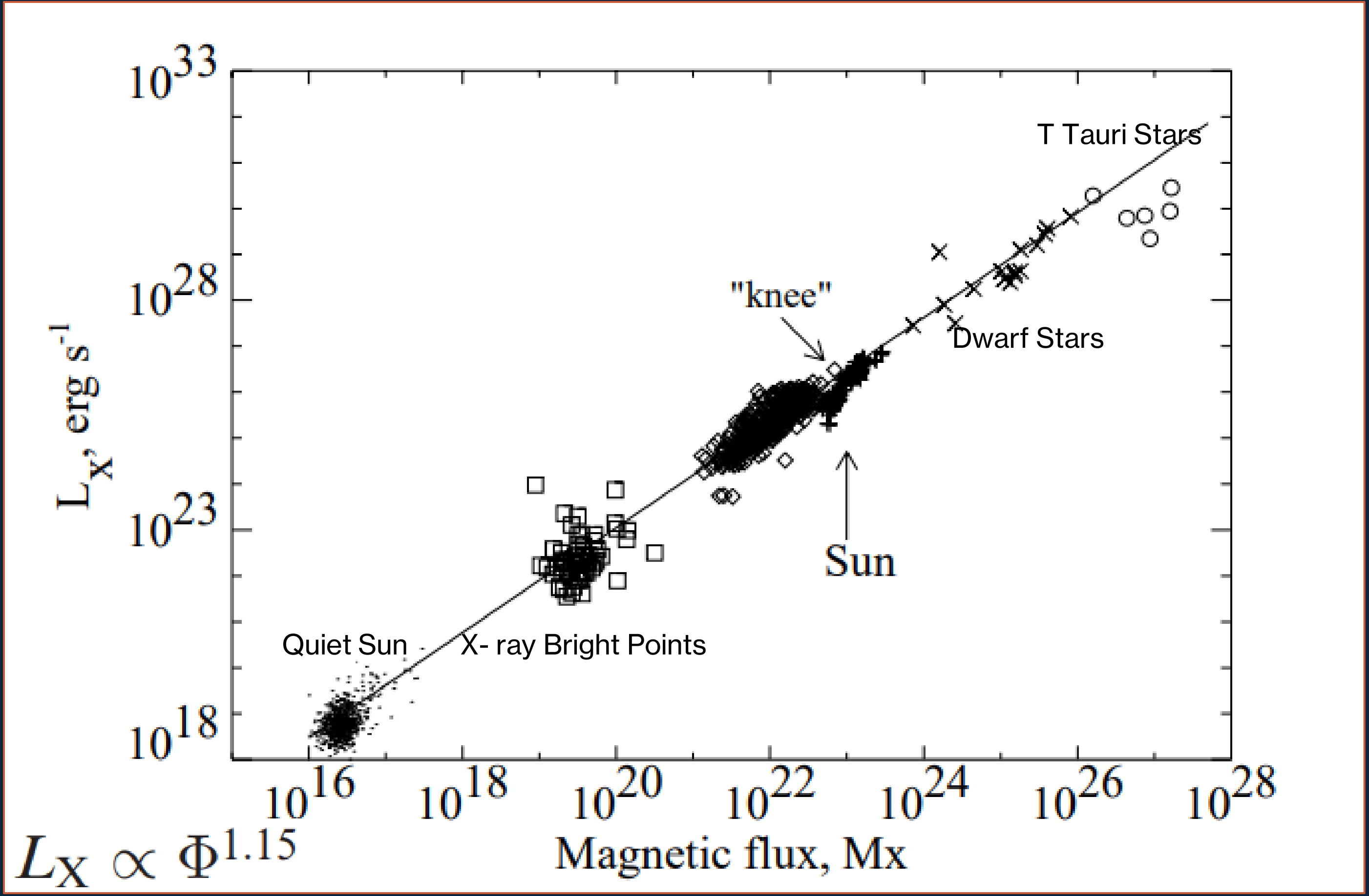
Project's Purpose



- The overarching goal of the project is to better understand the heating mechanism of the sun's corona.
- The particular method is to closely compare the *coronal X-ray luminosity* with the *photospheric line-of-sight magnetic field*.
- The graph to the left shows that magnetic flux and X-ray luminosity follow a (nearly) linear power-law relationship with an exponent of 1.15.
  - The increase in X-ray luminosity correlates to an increase in magnetic flux when plotted on a logarithmic scale.
  - This is from a paper by Pevtsov, published in 2003, using data from the old Yohkoh satellite, which was the precursor to the Hinode satellite.
- In this project, we are focused on the quiet sun, whilst Keiji is researching the full sun & active regions.

Abbreviations

Abbreviations:

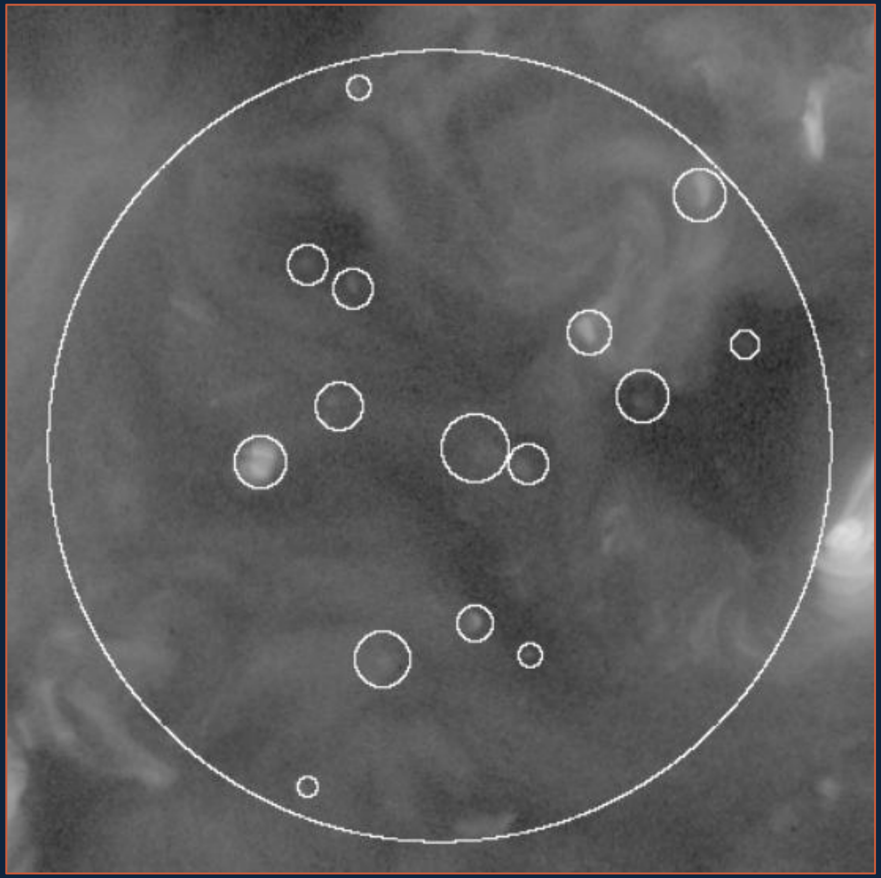
- XRT – X-Ray Telescope
- HMI – Helioseismic & Magnetic Imager
- SDO – Solar Dynamics Observatory
- FITS – Flexible Image Transport System
- Al Poly – Aluminium-Polyimide Filter
- Al Mesh – Aluminium-Mesh Filter
- BP – Bright Point

Data Sources

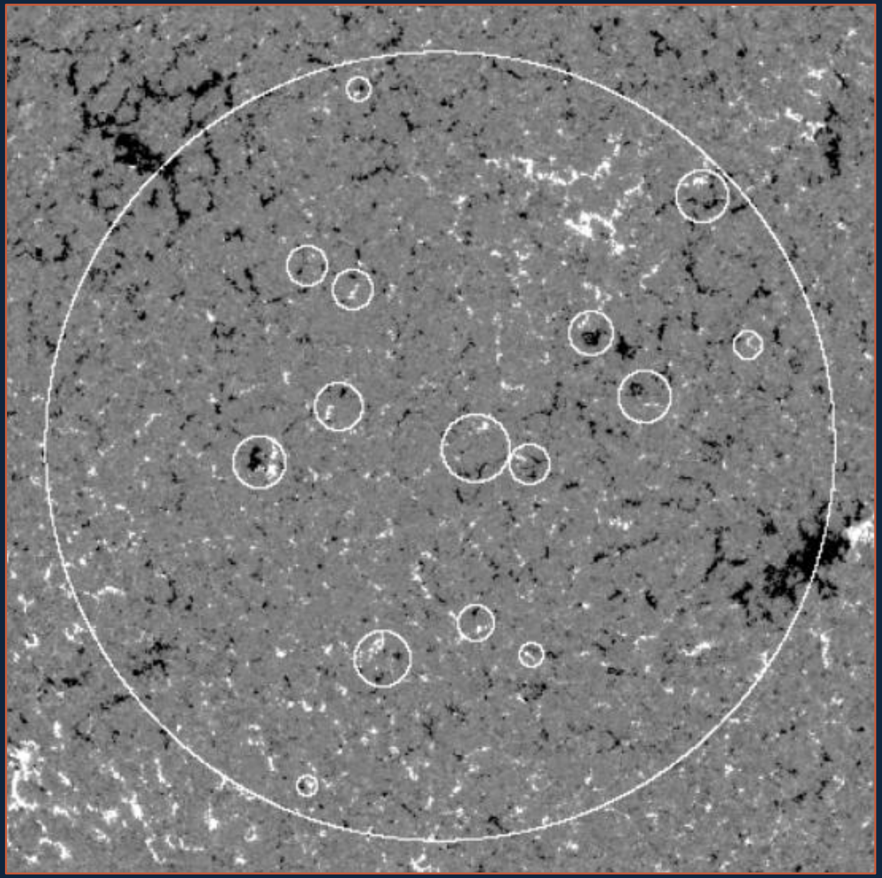
- Hinode XRT Satellite
  - Al Poly & Al Mesh
  - Luminosity & irradiance
- SDO HMI
  - Magnetograms
  - Magnetic flux

Bright Points

XRT



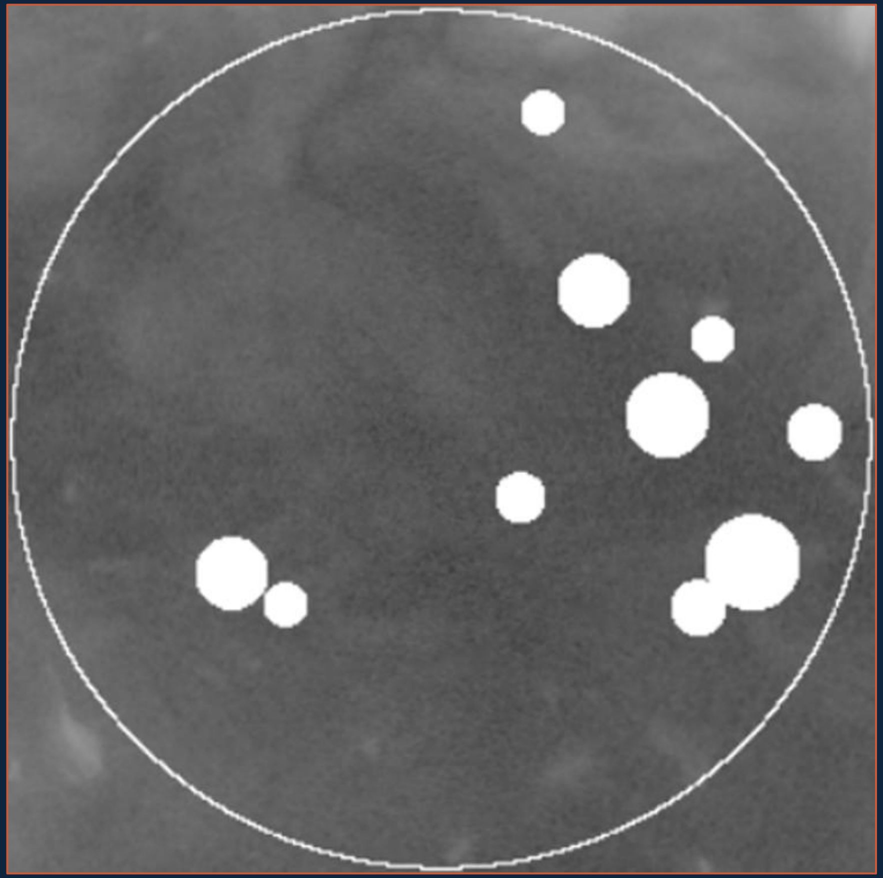
HMI

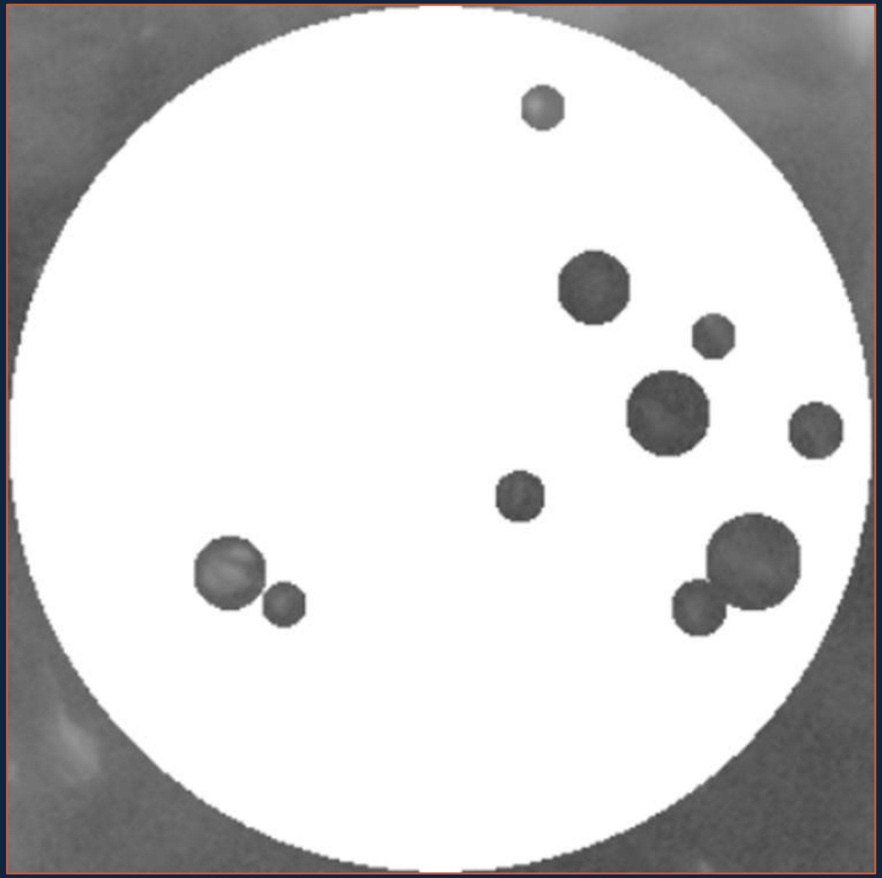


Masks

Masks are cast over each individual Bright Point as well as the part of the solar disk within the chosen that excludes each Bright Point. These make up the Bright Point masks as well as the Quiet Sun mask. This process is done with both XRT and HMI, and for XRT specifically, it is done for both Al Mesh and Al Poly filters. More on why later.

Bright Points





Bright Points

XRT

The masking program measures how much X-ray brightness is inside each selected region for each XRT filter.

HMI

The masking program measures how much unsigned magnetic field is inside each selected region.

These are not quite what we are looking for, as we need to find:

Luminosity

Magnetic Flux

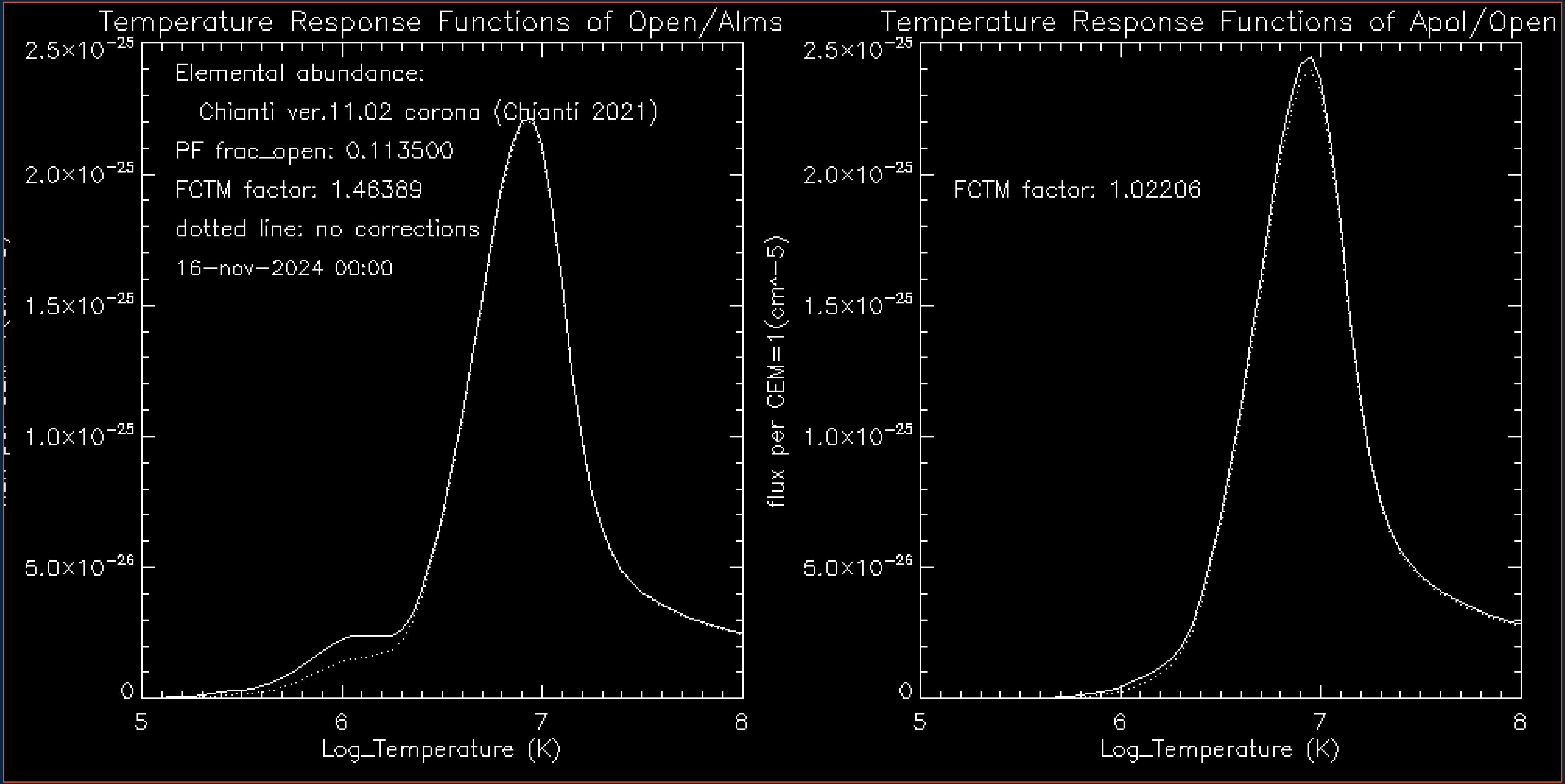
But, using measured X-ray brightness and unsigned magnetic field, we can determine the luminosity and magnetic flux.

The Filter Ratio Method

For XRT

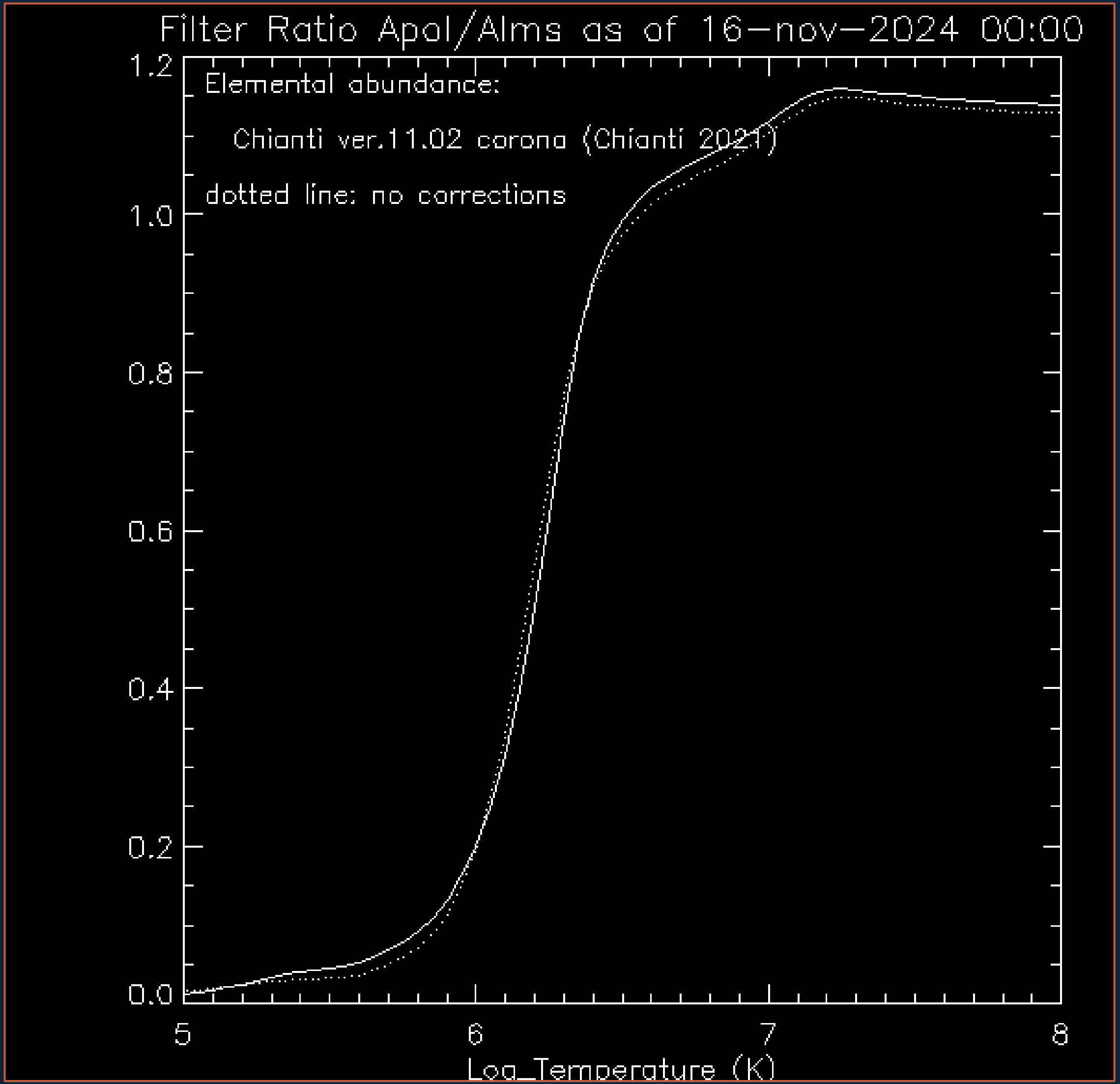
Filter Ratio Method

- XRT does not directly measure plasma temperature, it measures direct X-ray intensity through filters.
- In order to convert the measured XRT signal to physical units, we need build the temperature response function.
    - The temperature response function predicts how strongly XRT should detect plasma at each temperature.
    - For this to work, we must assume that the plasma is isothermal.
- In essence, the temperature response function informs us how strongly XRT would respond to plasmas at each temperature per a specific filter, since each filter responds differently to different plasma temperatures.
- Once the response functions are known, a ratio between them can be used to approximate temperature.

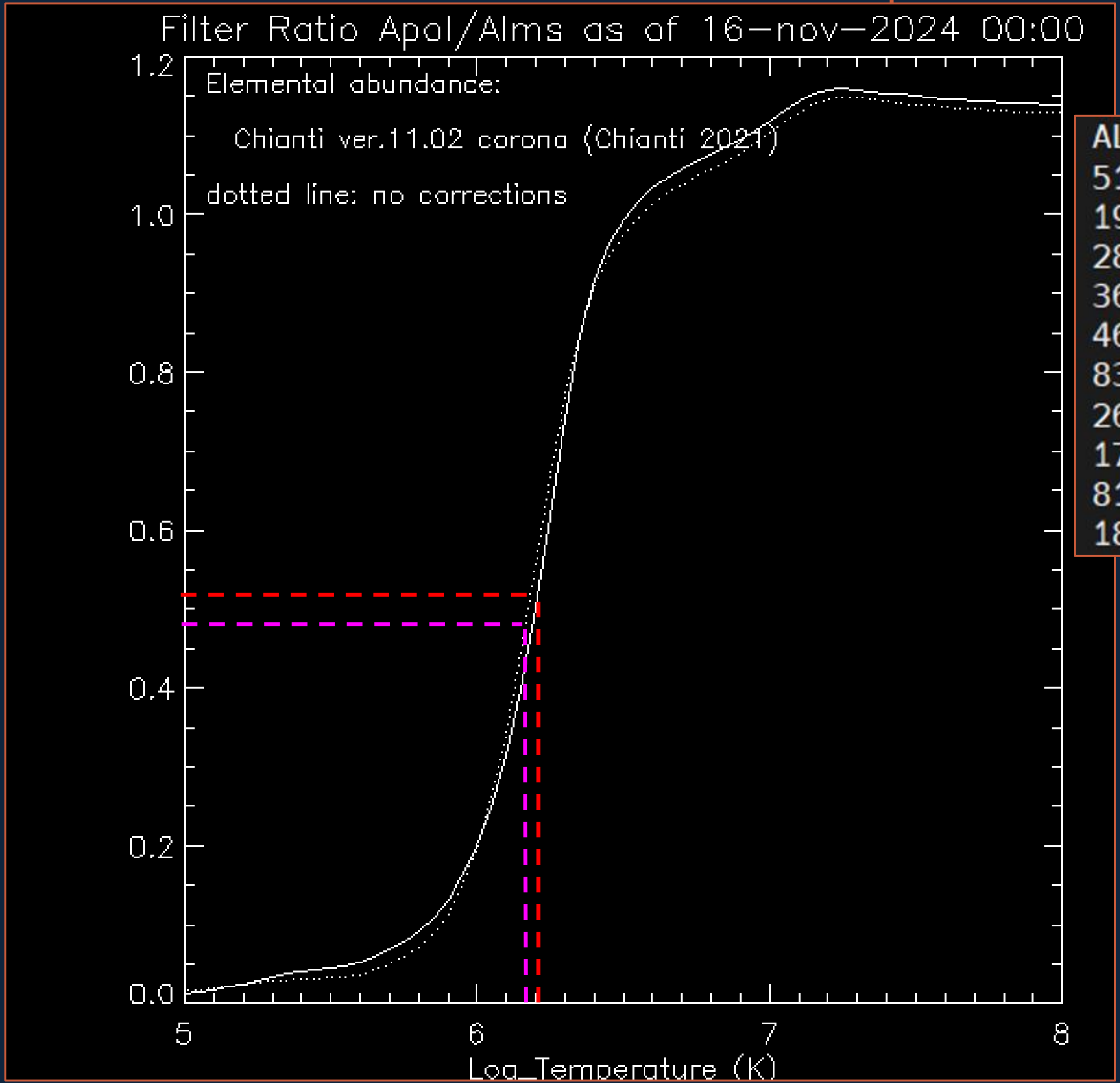

Temperature Response Functions of Open/Alms
Elemental abundance:
Chianti ver.11.02 corona (Chianti 2021)
PF frac_open: 0.113500
FCTM factor: 1.46389
dotted line: no corrections
16-nov-2024 00:00
Log_Temperature (K)
Temperature Response Functions of Apol/Open
FCTM factor: 1.02206
flux per CEM=1(cm^-5)
Log_Temperature (K)

Ratio Time!

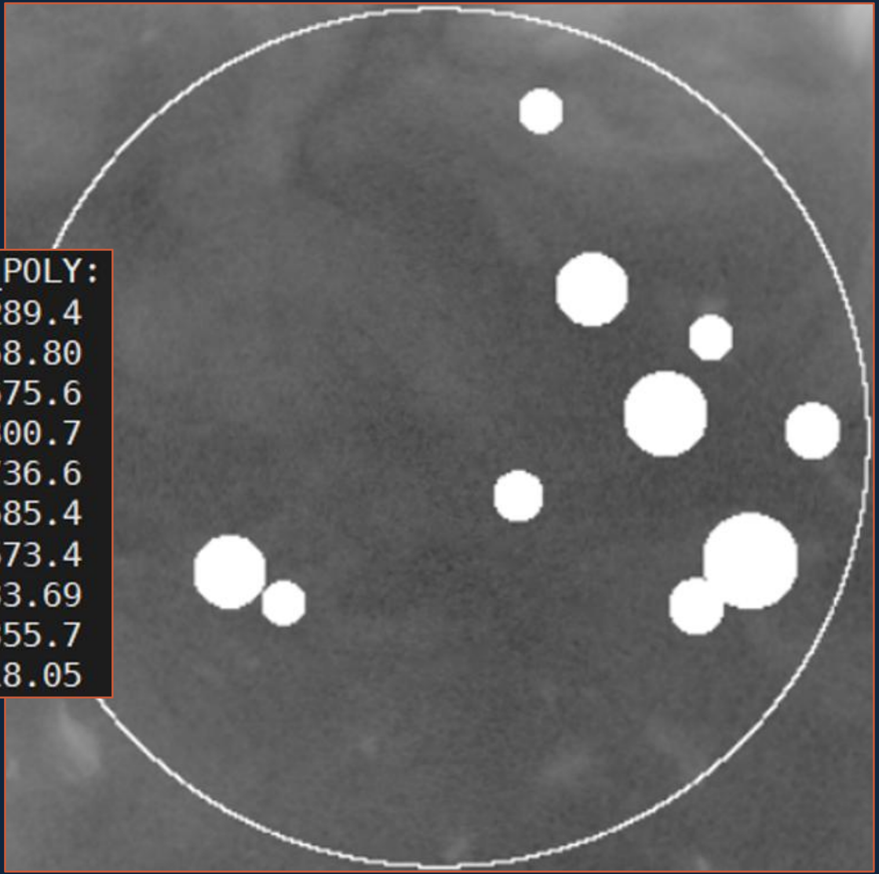
- For those who have not guessed it yet, we are using the Al Mesh and Al Poly filters for the ratio.
- Previously, I made it known that it was necessary that our chosen dates would include data for both Al Poly and Al Mesh filters, specifically for this.
- The x-axis is log-temperature, and the y-axis is the modeled filter ratio between the two filters.
- For this, the elemental abundance model from CHIANTI is used.



More simply…



AL_MESH:	AL_POLY:
51700.8	27289.4
19678.1	9168.80
28070.3	11675.6
36389.9	16800.7
46029.3	19736.6
83430.8	36585.4
26125.1	11573.4
17754.9	8733.69
81205.7	47355.7
18662.4	9918.05



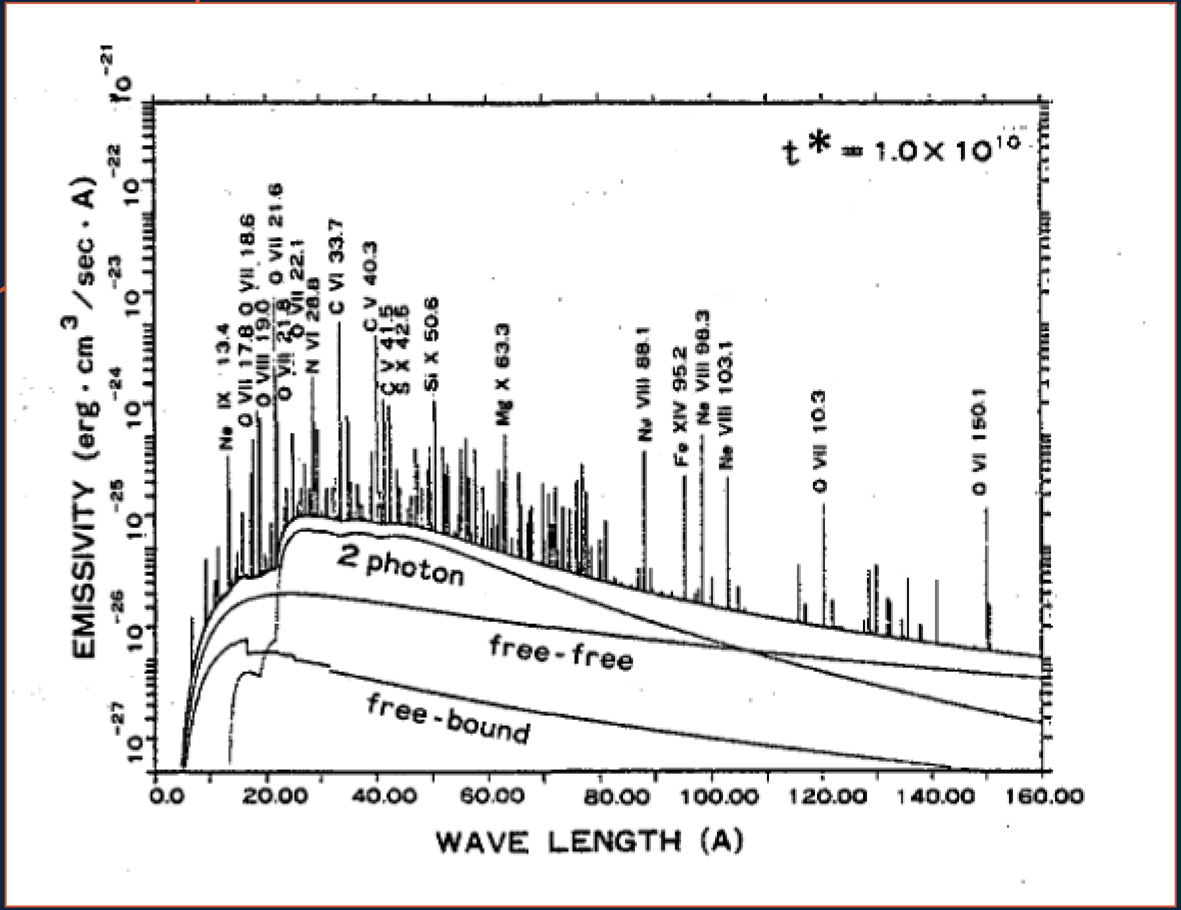
Al Poly/Al Mesh:

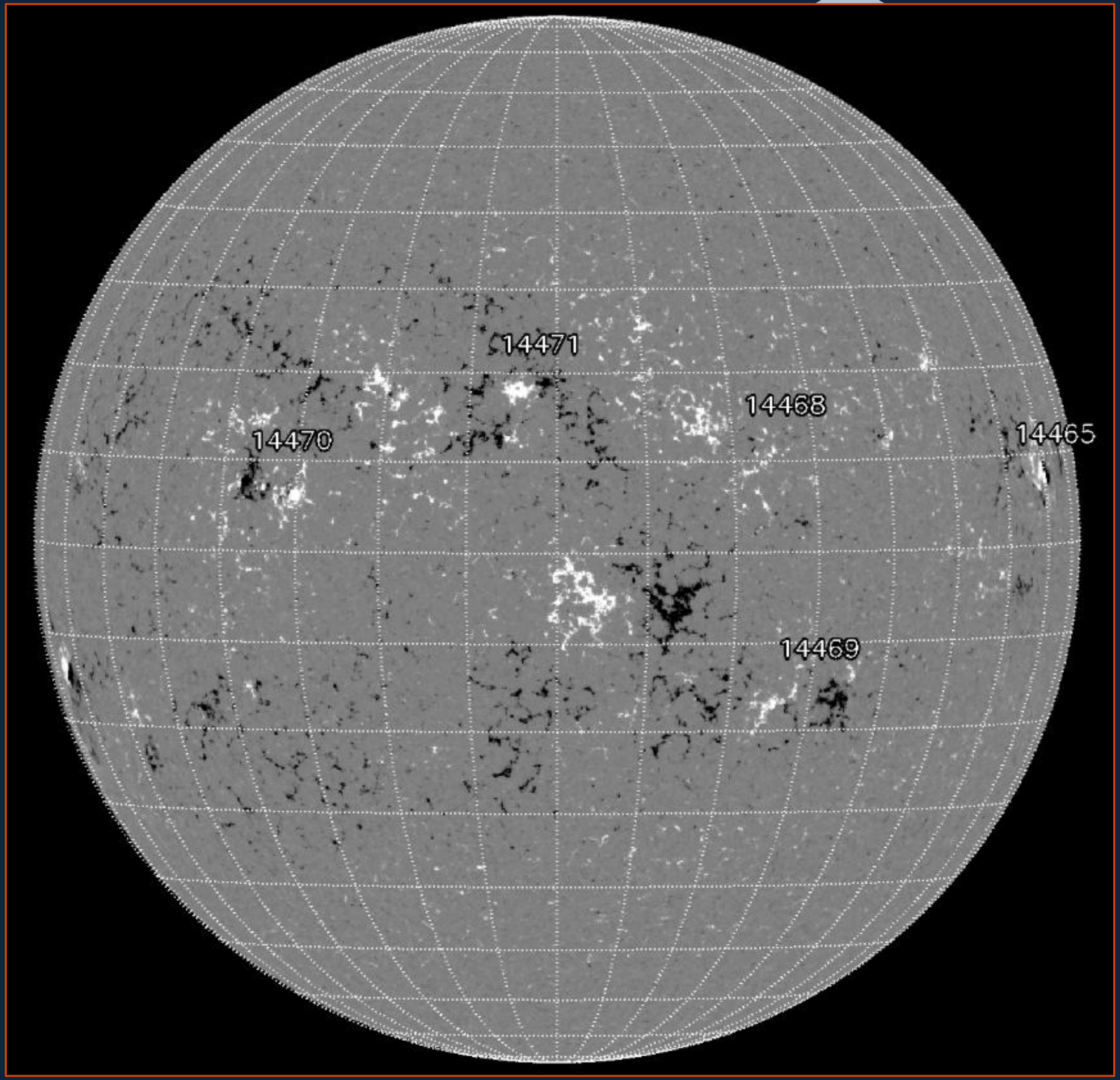
27289.4/51700.8 ≈ 0.5278

9168.80/19678.1 ≈ 0.4659

X-Ray Luminosity

- So now, we have the temperature (K) and emission measure.
    - We use the actual XRT brightness to figure out how much plasma is producing that emission; that amount is the emission measure.
- With these two quantities, we are able to model the X-ray spectrum, an example of which can be seen to the right.
- The graph essentially shows emitted energy as a function of wavelength.
- In our case, we sum the modeled emissions from 2.8 to 36.6 Å, which gives us the X-ray luminosity, or total emitted energy per second.





Magnetic Flux

- Repeating the masking process for HMI gives the magnetic field strength for each pixel.
- We then sum the absolute magnetic field values within the masked region.
- We then multiply by the physical area of one HMI pixel.
    - The caveat to this is that area encompassed by one pixel depends on the position of the pixel.
    - Since the Sun is a sphere and our images are flat, pixels that are further from the center of the solar disk actually cover a larger area.
- Another correction is necessary to compensate for the Sun's tilt/viewing geometry, so that the HMI pixels are mapped correctly before we extract magnetic flux values under our masks.

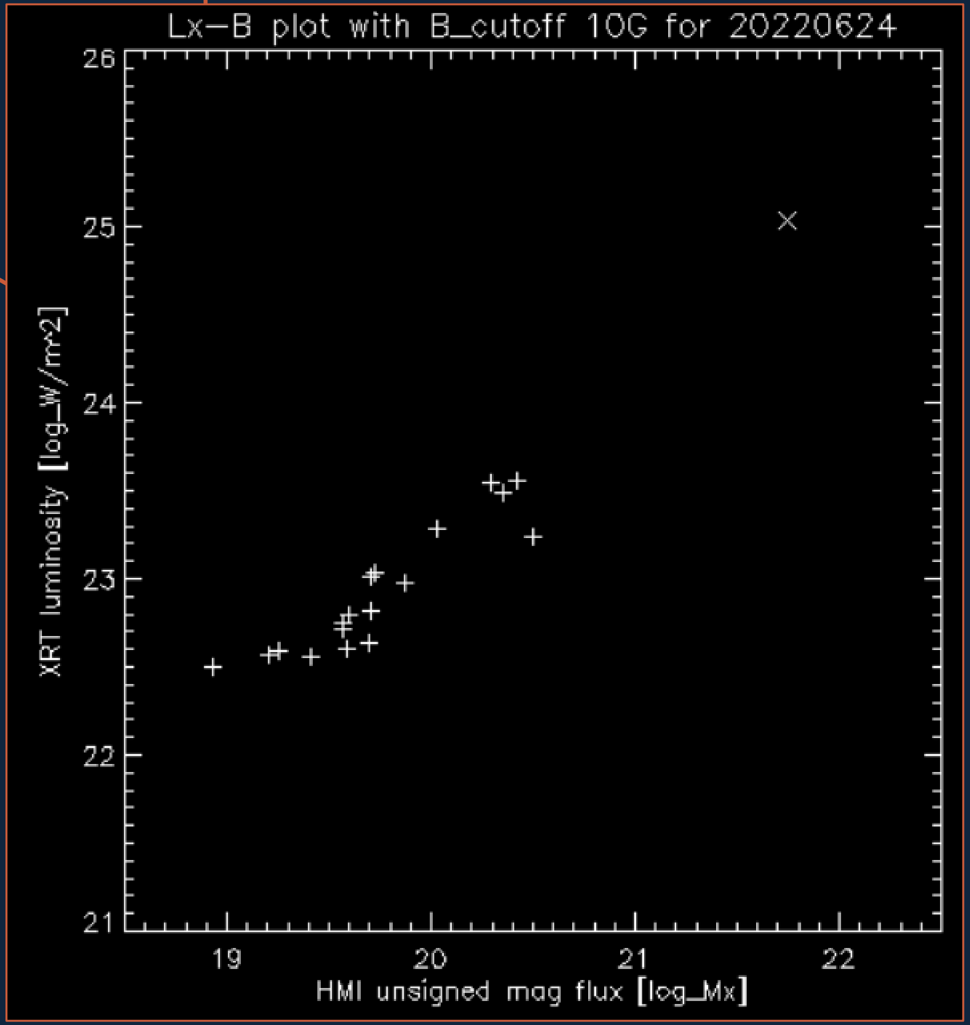
Contaminant Buildup & Stray Light Correction

- An additional factor we must account for is contaminant buildup on the actual Hinode satellite, as it affects our data.
- Buildup blocks a certain amount of X-ray signal from reaching the CCD detectors.
    - The effect varies from filter-to-filter, so there's separate corrections done for Al Mesh and Al Poly

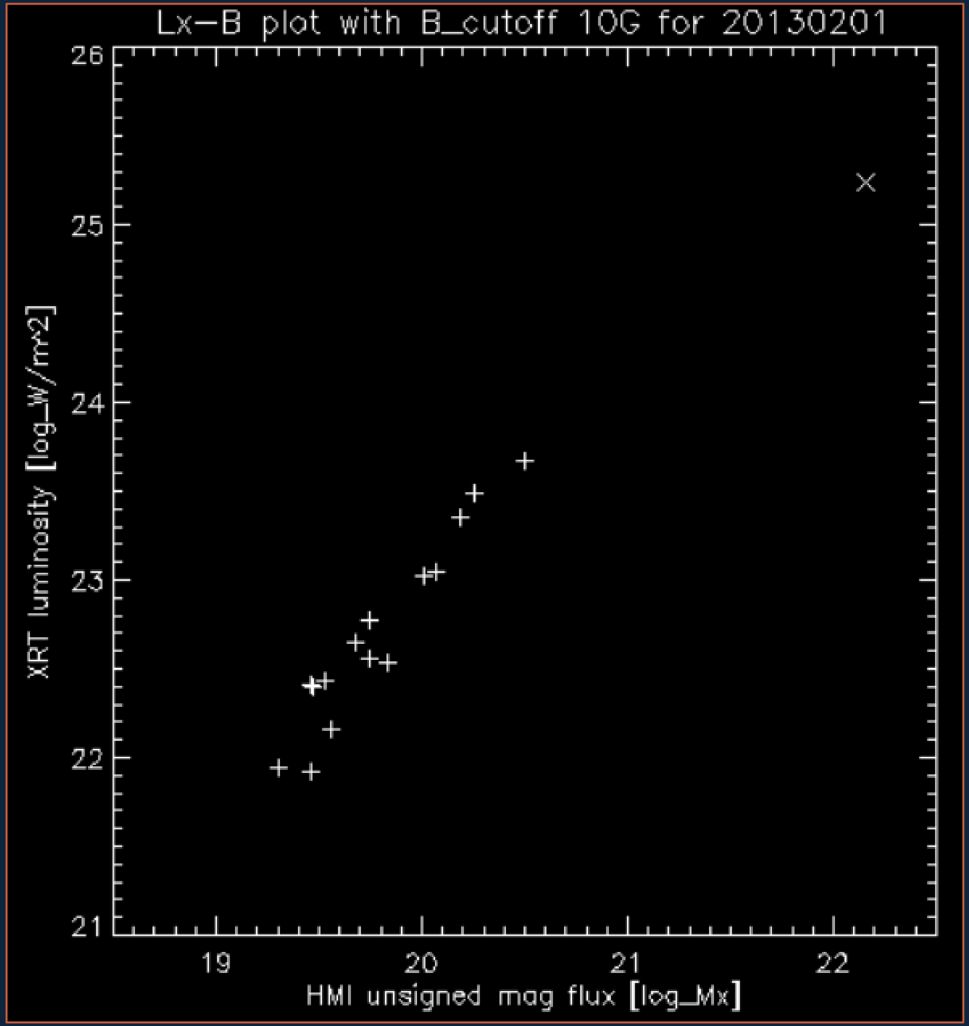
- This correction is done before the filter ratio method, but including this slide earlier breaks the nice rhythm, so it is here.
- To deal with the contaminant buildup, we apply filter-specific correction factors to the XRT signal to counteract the blocked X-rays.
- Another issue is stray light that seeps its way in.
- Stray light adds extra background signal to our data and image, which we do not want.
- To correct for stray light, an amount is estimated based on the image and calibration.
    - That estimated value is subtracted from the measured image to produce the corrected solar signal.

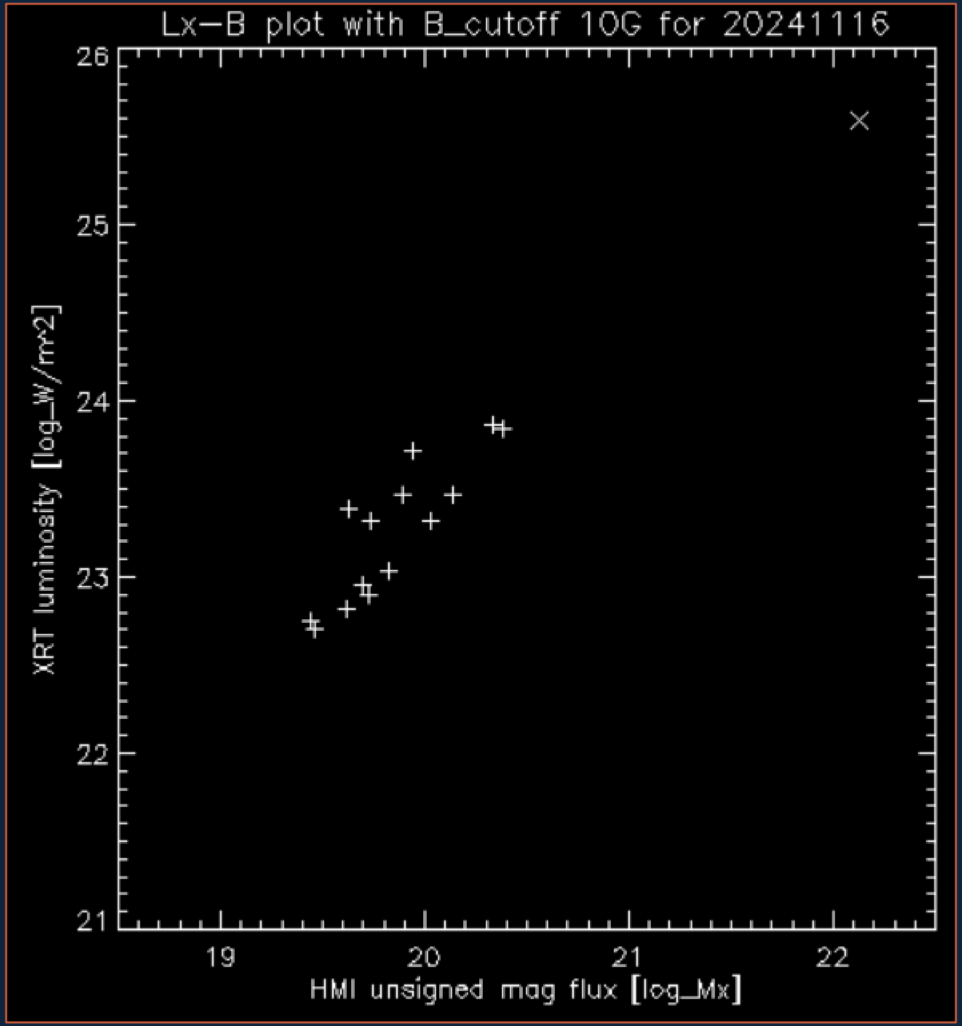
Resultant Plots

- Each point represents a single measured region.
- The cluster of points to the bottom-left are all Bright Points.
- The lone point to the top-right is the Quiet Sun.
- The x-axis is HMI unsigned magnetic flux, logarithmically.
- The y-axis XRT luminosity. logarithmically.



Resultant Plots





What’s next?

- Much more data.
- Overplotting the bright point data with Keiji’s full sun analysis.

References

- https://solar.physics.montana.edu/HINODE/XRT/SCIA/
- https://solarmonitor.org/index.php
- https://solar.physics.montana.edu/takeda/REUproj2026/papers/Pevtsov2003.pdf