The Relationship Between Solar Surface Magnetic Field and Coronal Soft X-Ray Filter Images

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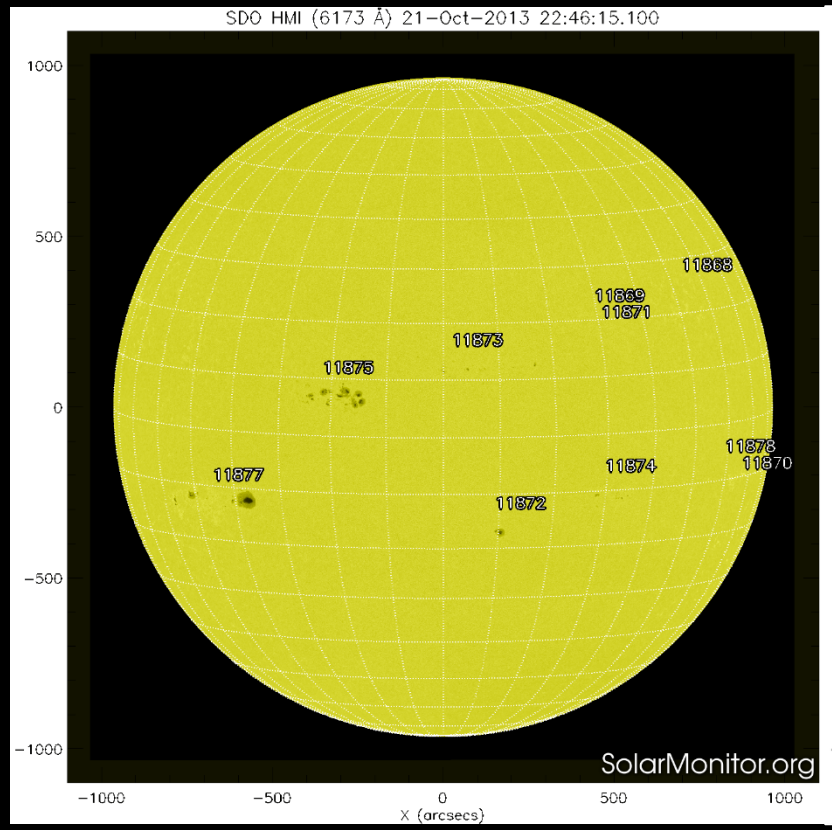
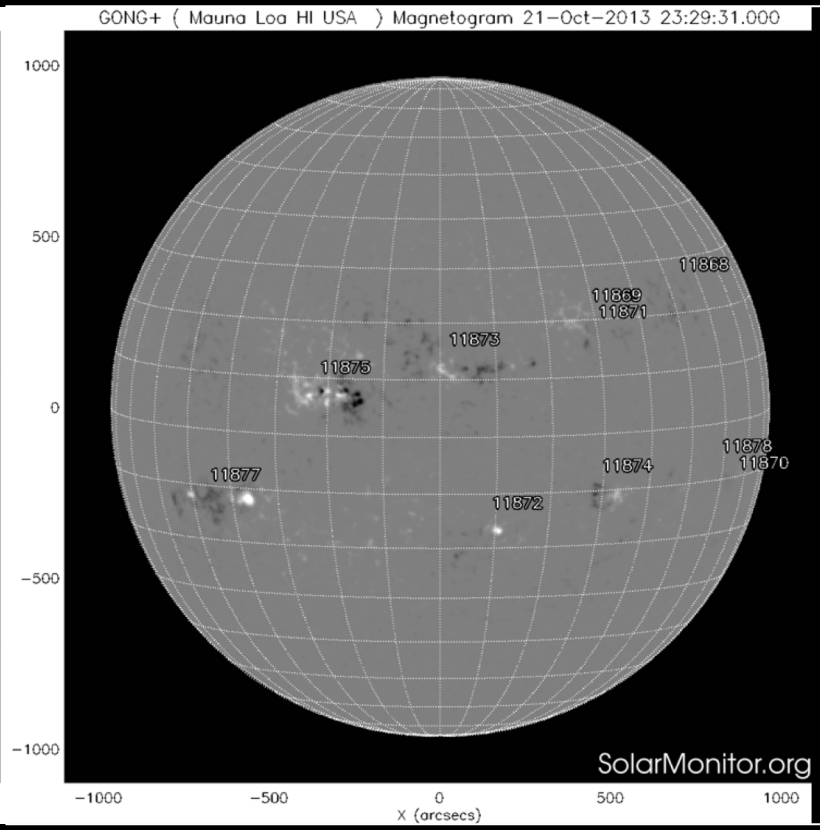
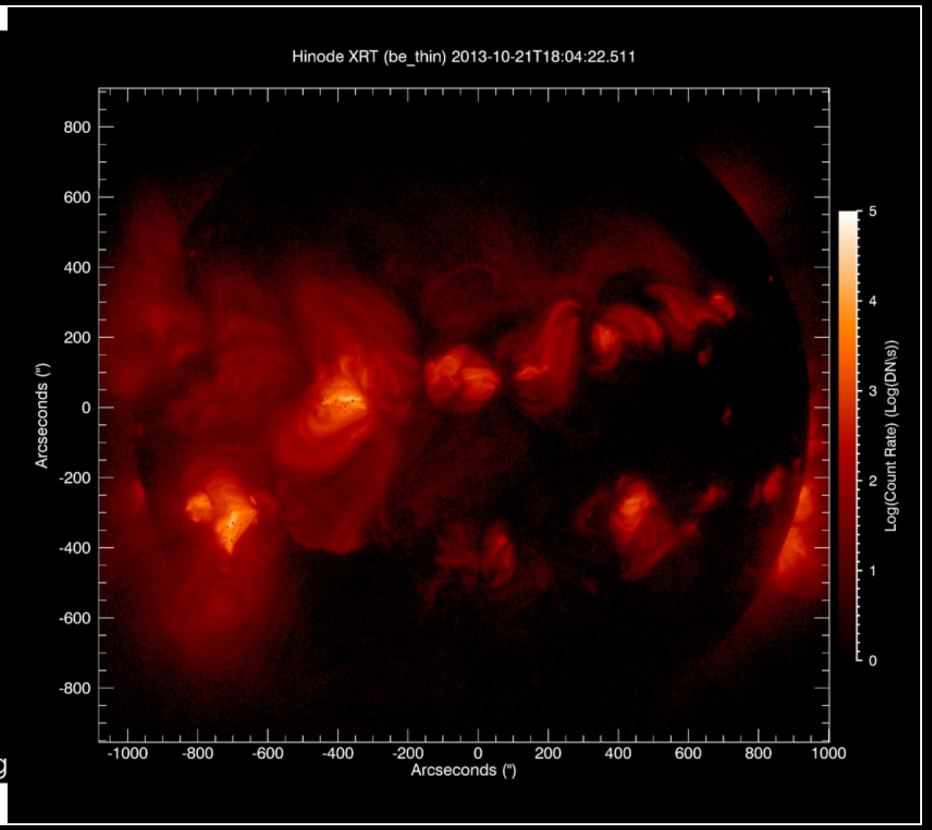
Sunspots ↔ Active Regions

Slide courtesy of Chris Moore

Visible Light | **Magnetic Field** (line-of-sight) | **X-rays**







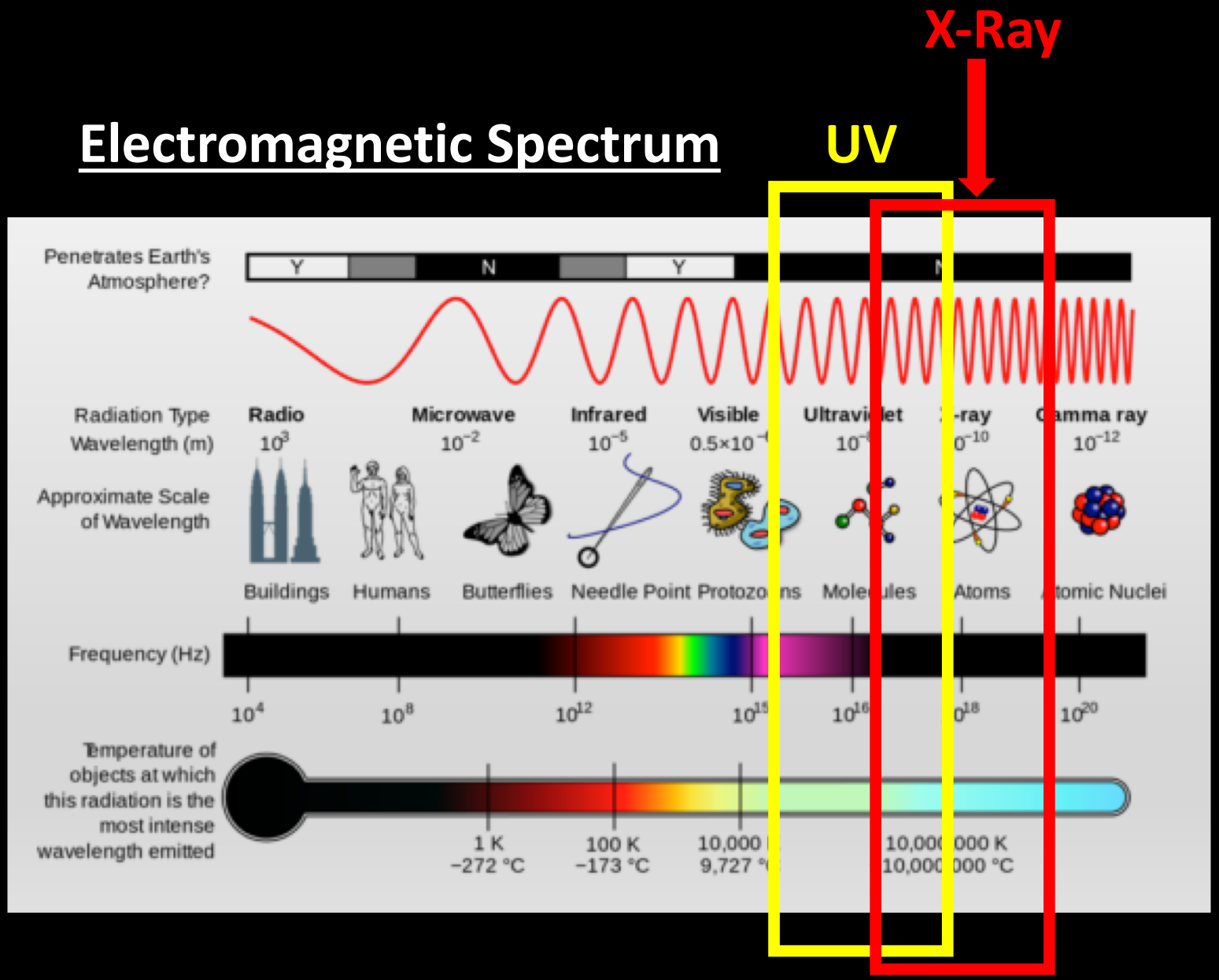
Hot plasma (~10^6 K) → Confined by Magnetic Fields → Cools via X-rays + EUV

(heating sources in debate) (enhances local density) (particle collisions/interactions)

Instruments used:

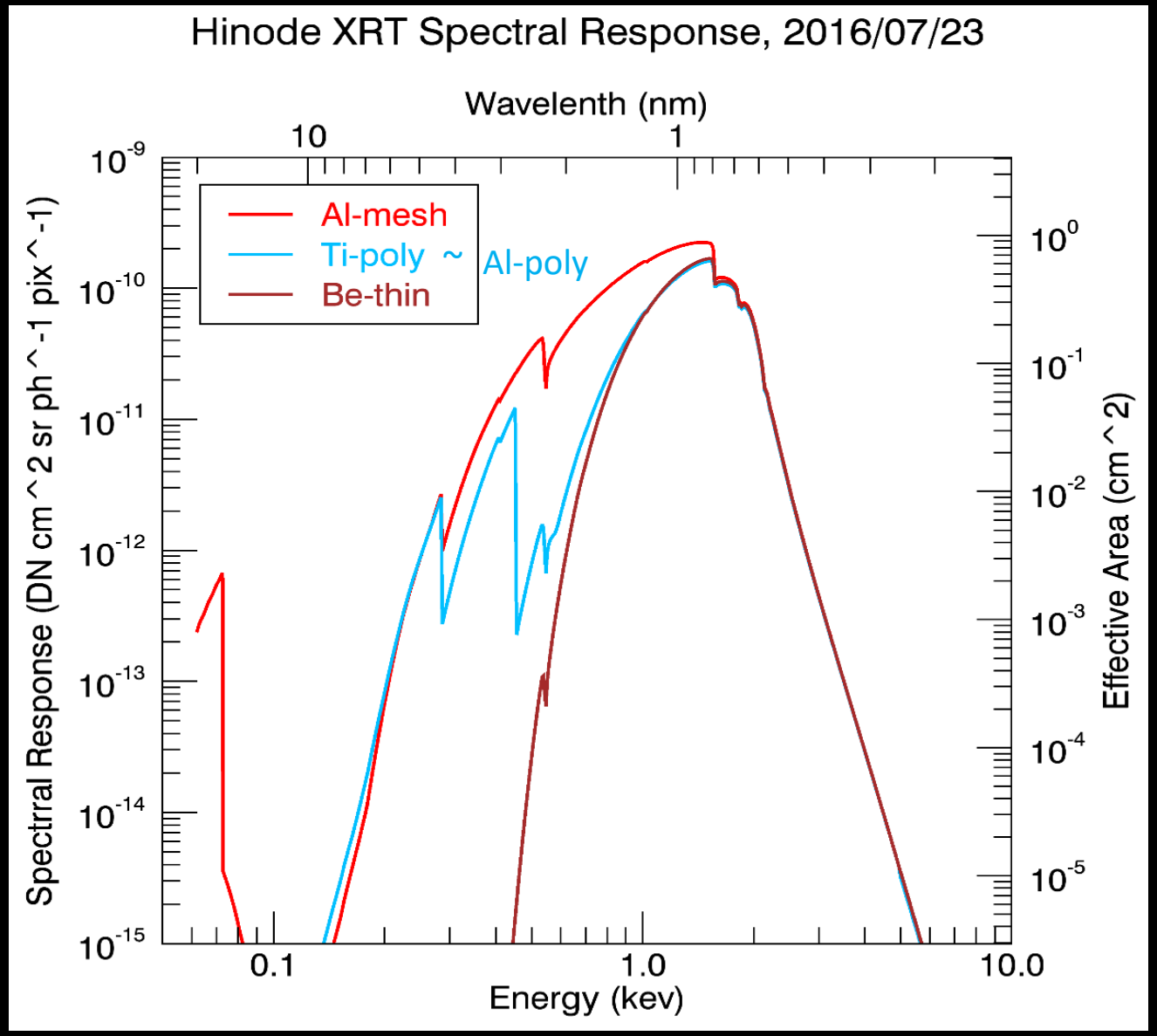
- Hinode/XRT (X-Ray)
  - Be-Thin
  - Al-Mesh
  - Al-Poly
- SDO/AIA (EUV)
  - 94Å
  - FeXVIII
- SDO/HMI
  - Line-of-sight (los)
- MinXSS cubesat
  - X123 (spectrometer)

Electromagnetic Spectrum



Hinode / XRT Filters

- Al-Mesh
- Al-Poly
- Be-Thin

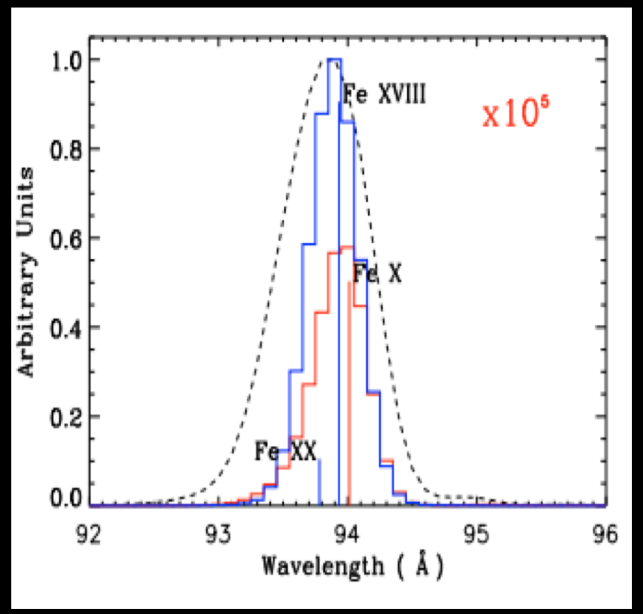


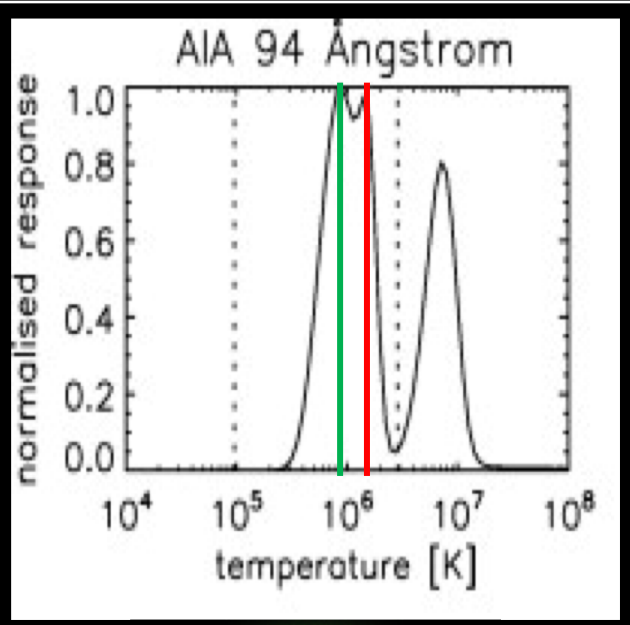
Slide courtesy of Chris Moore

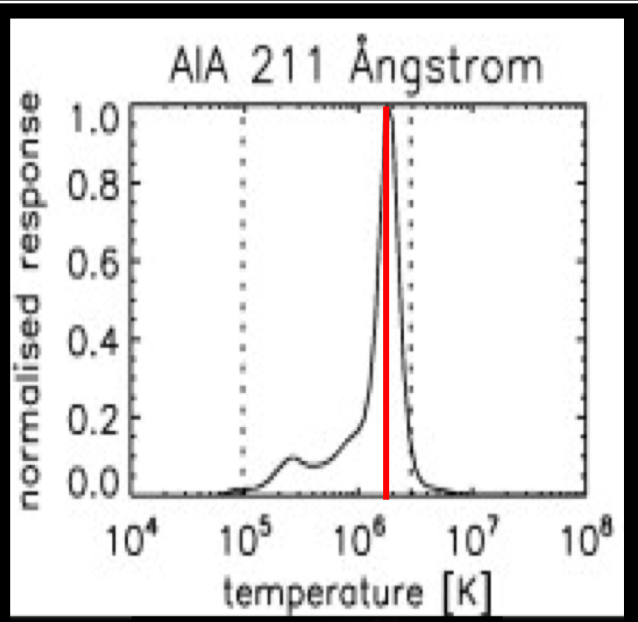
SDO / AIA passbands

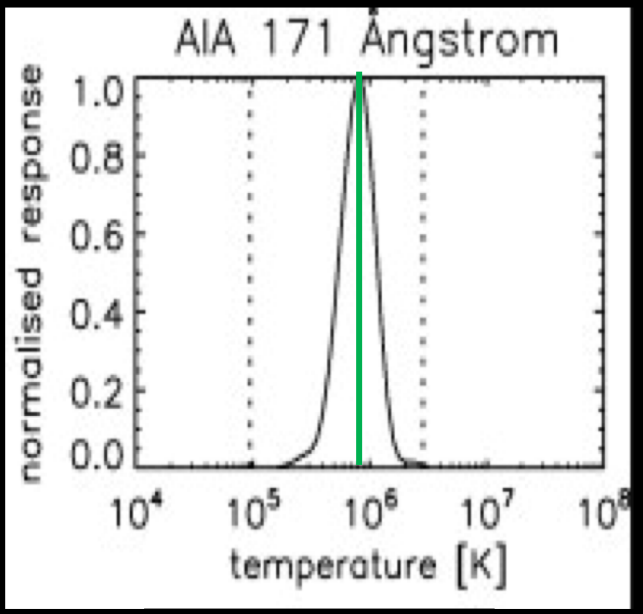
- **94Å**
- **Fe XVIII**

Fe XVIII = $I_{94Å}$ − $aI_{211Å}$ − $bI_{171Å}$

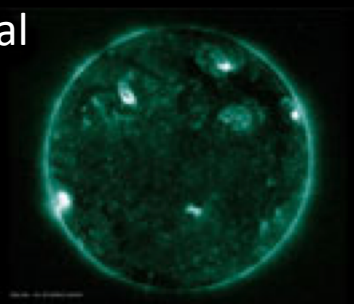




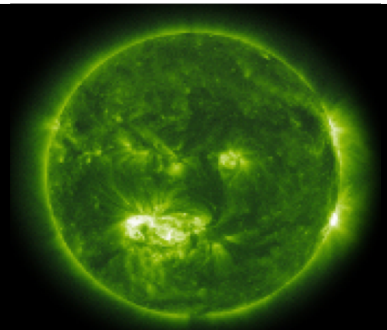




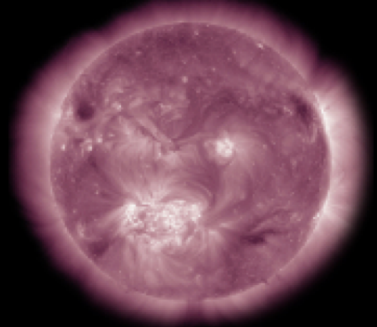
O'Dwyer et al



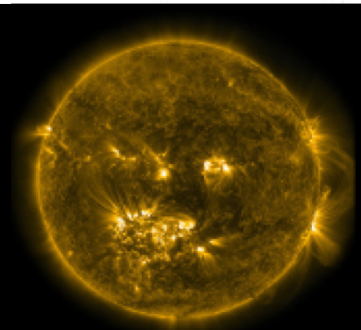
Fe XVIII from 94Å



AIA 094 Å



AIA 211 Å

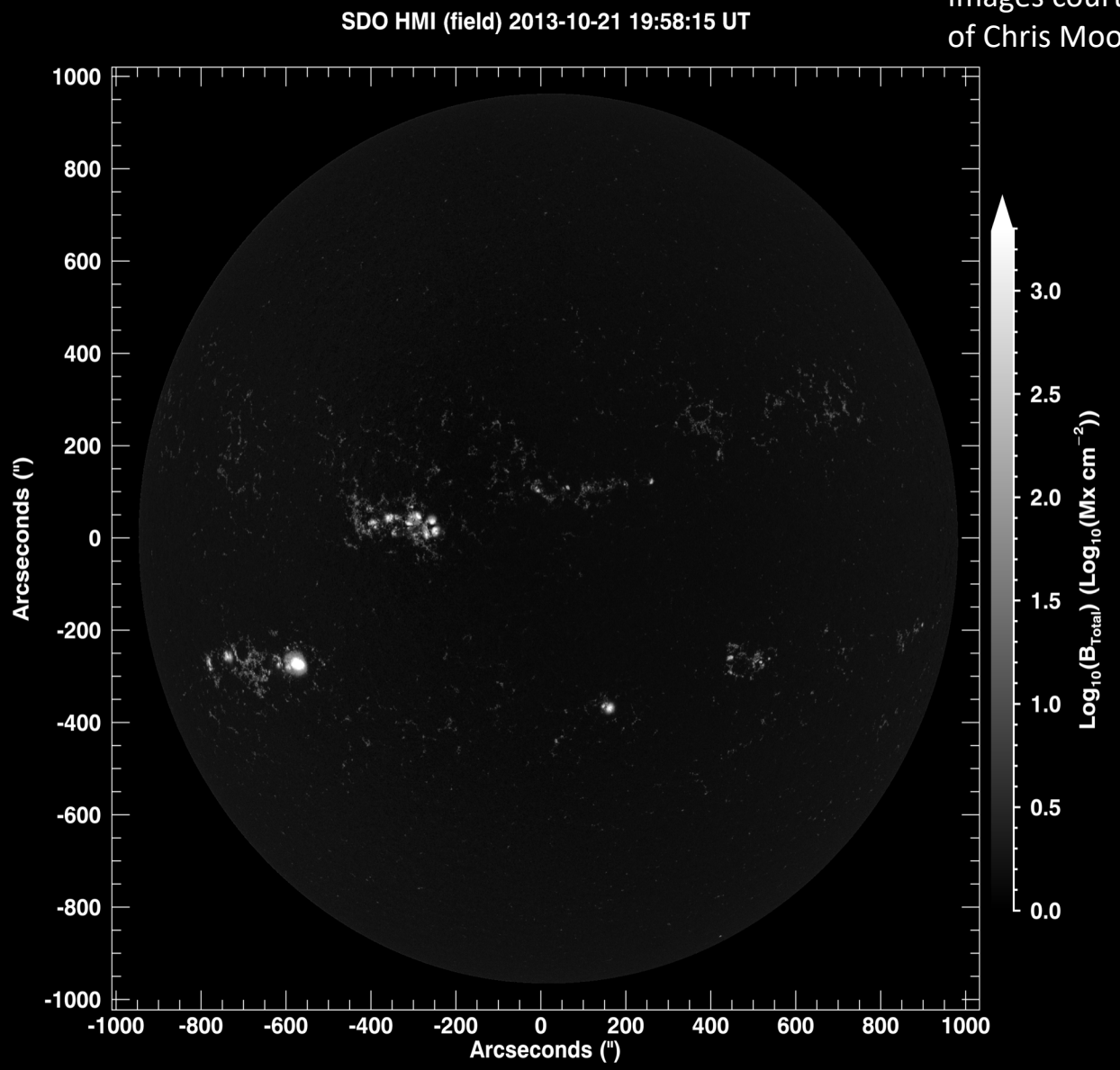


AIA 171 Å

What type of relationship do we expect?

$$F_{Xray} \propto \iint |\vec{B}_{los}| d\vec{A}$$

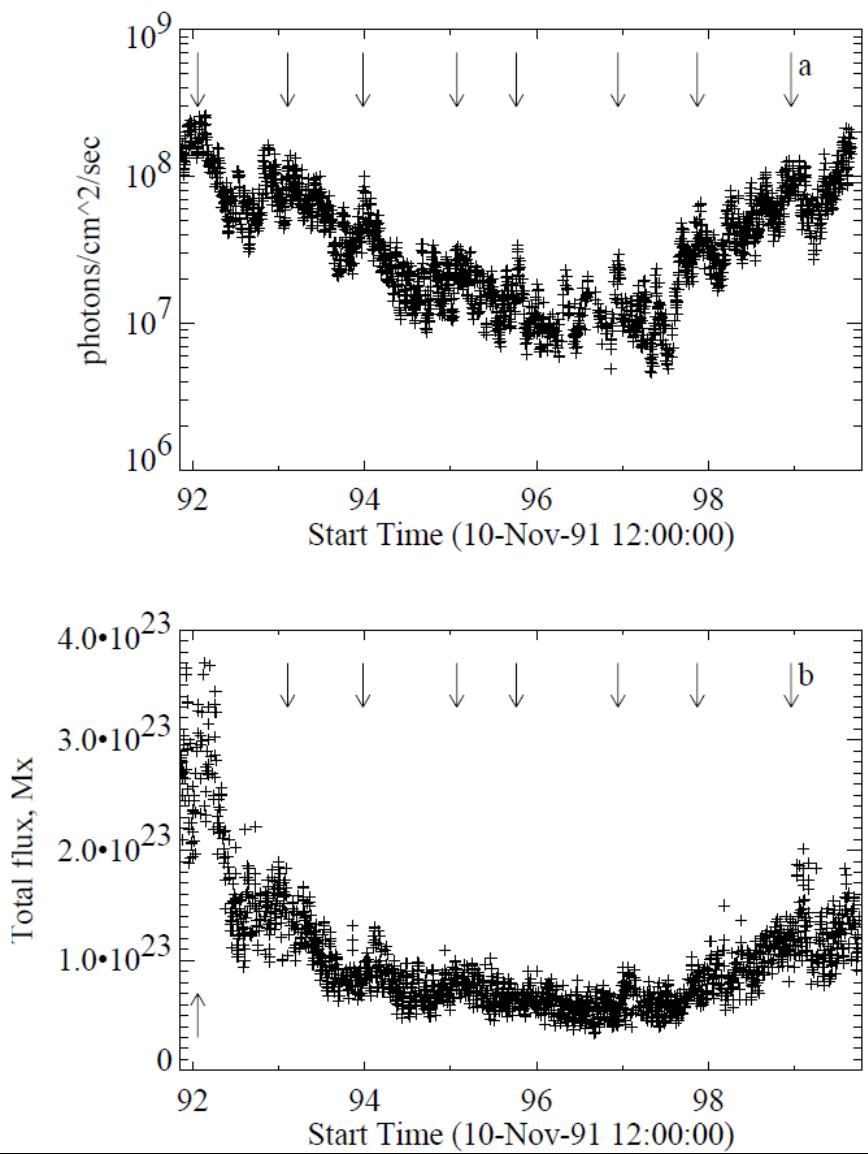
Images courtesy of Chris Moore



Previous Studies: X-ray Flux vs. Magnetic Flux

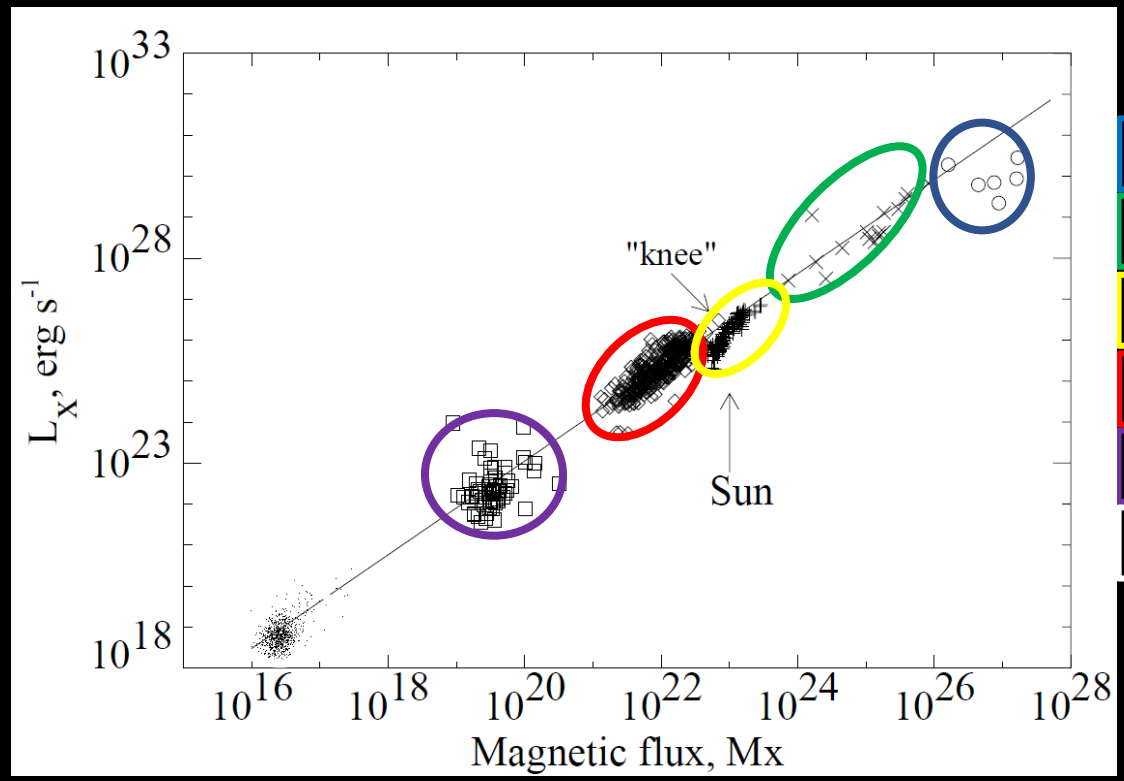
Slide courtesy of Chris Moore

Solar Disk Average



- X-ray images - Yohkoh
- Magnetic Flux – Big Bear
- Temperatures – filter ratios

Solar Features



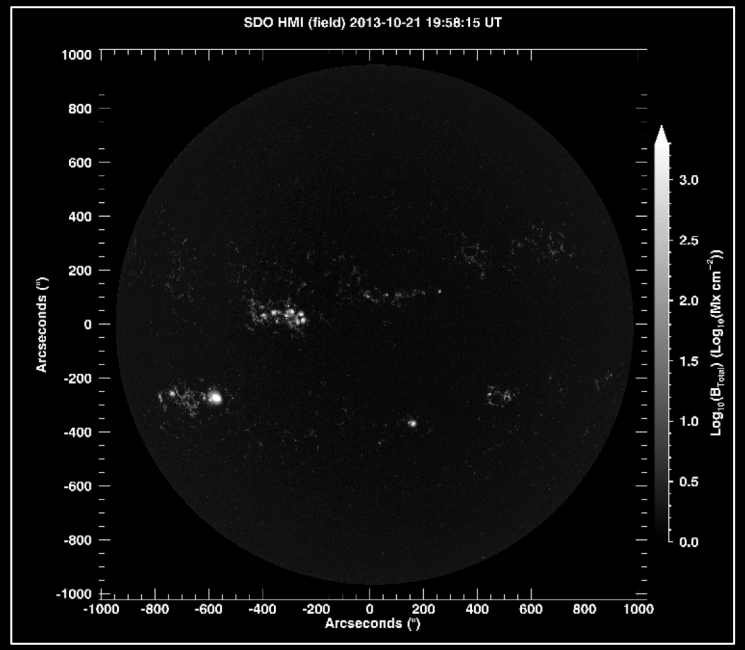
T Tauri Stars
G, K, M Dwarfs
Disk Average
Active Regions
Bright Points
Quiet Sun

PEVTSOV & ACTON The Astrophysical Journal, 554:416–423, 2001 June 10
PEVTSOV ET AL. The Astrophysical Journal, 598:1387–1391, 2003 December 1

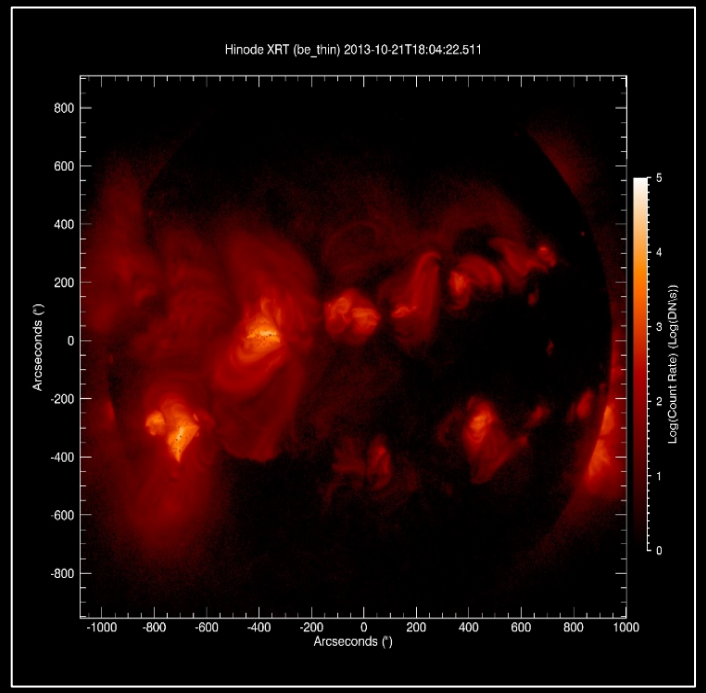
Our Research: *Spectral* X-ray Flux ↔ Unsigned Magnetic Flux

Slide courtesy of Chris Moore

Magnetograms

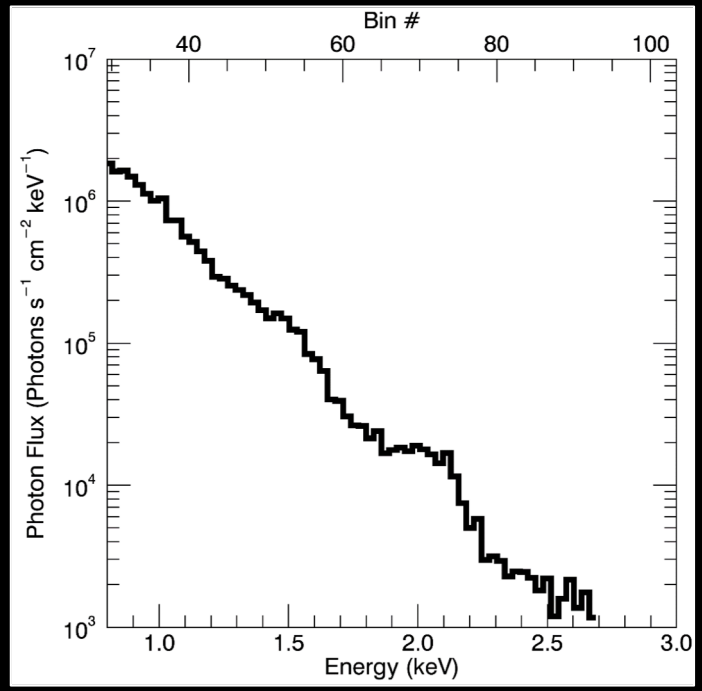


X-ray Images



$$F_{Xray} \propto \iint \|\vec{B}\| dA$$

X-ray Spectra



Challenges with Programming

IDL →

```
;nested for loop to extract the specified date of observation
for t = 0, N_XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter - 1 do begin
  ;filter
  date_month = strmid(XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter[t].INDEX_NORM.DATE_OBS, 5, 2)
  date_day = strmid(XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter[t].INDEX_NORM.DATE_OBS, 8, 2)
  date_year = strmid(XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter[t].INDEX_NORM.DATE_OBS, 0, 4)
  date_hour = strmid(XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter[t].INDEX_NORM.DATE_OBS, 11, 2)
  date_minute = strmid(XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter[t].INDEX_NORM.DATE_OBS, 14, 2)
  date_second = strmid(XRT_COMPOSITE_STRUCTURE_DN_RATE_Filter[t].INDEX_NORM.DATE_OBS, 17, 2)
  XRT_COMPOSITE_STRUCTURE_all_Filter_JD_OBSERVATION_DATE[t] = julday(date_month, date_day, date_year, date_hour,
endfor ;end on nested for loop
```

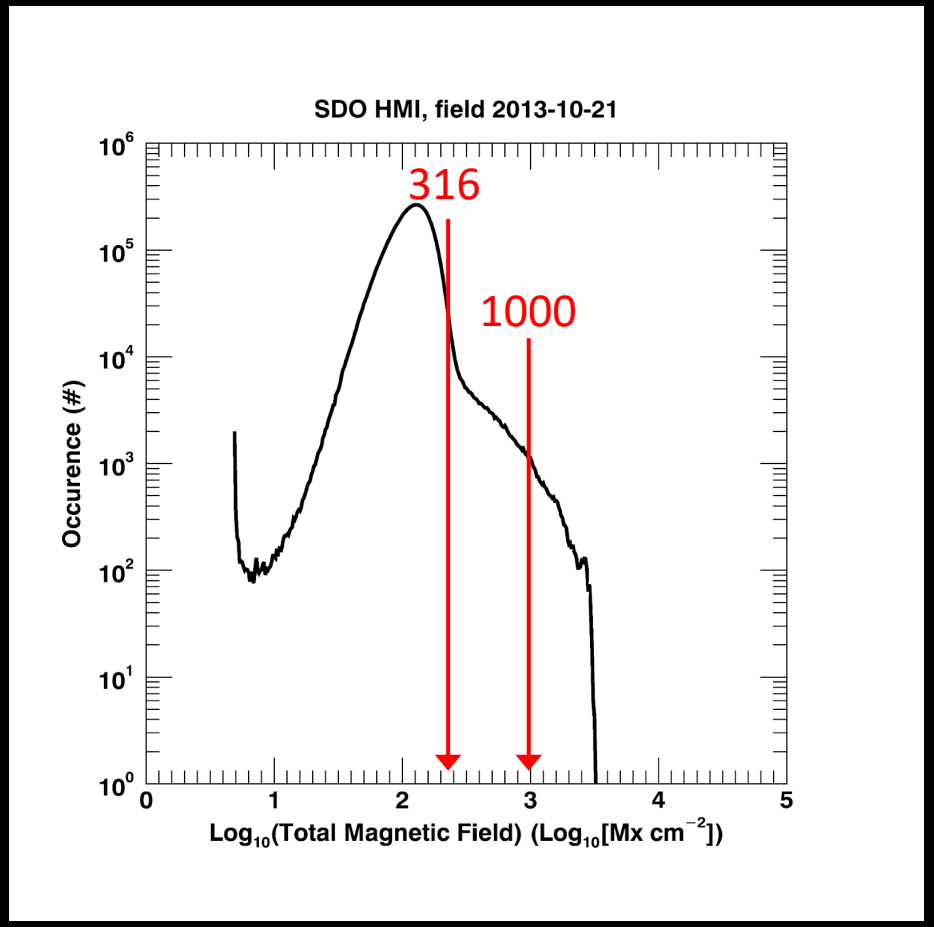
Python →

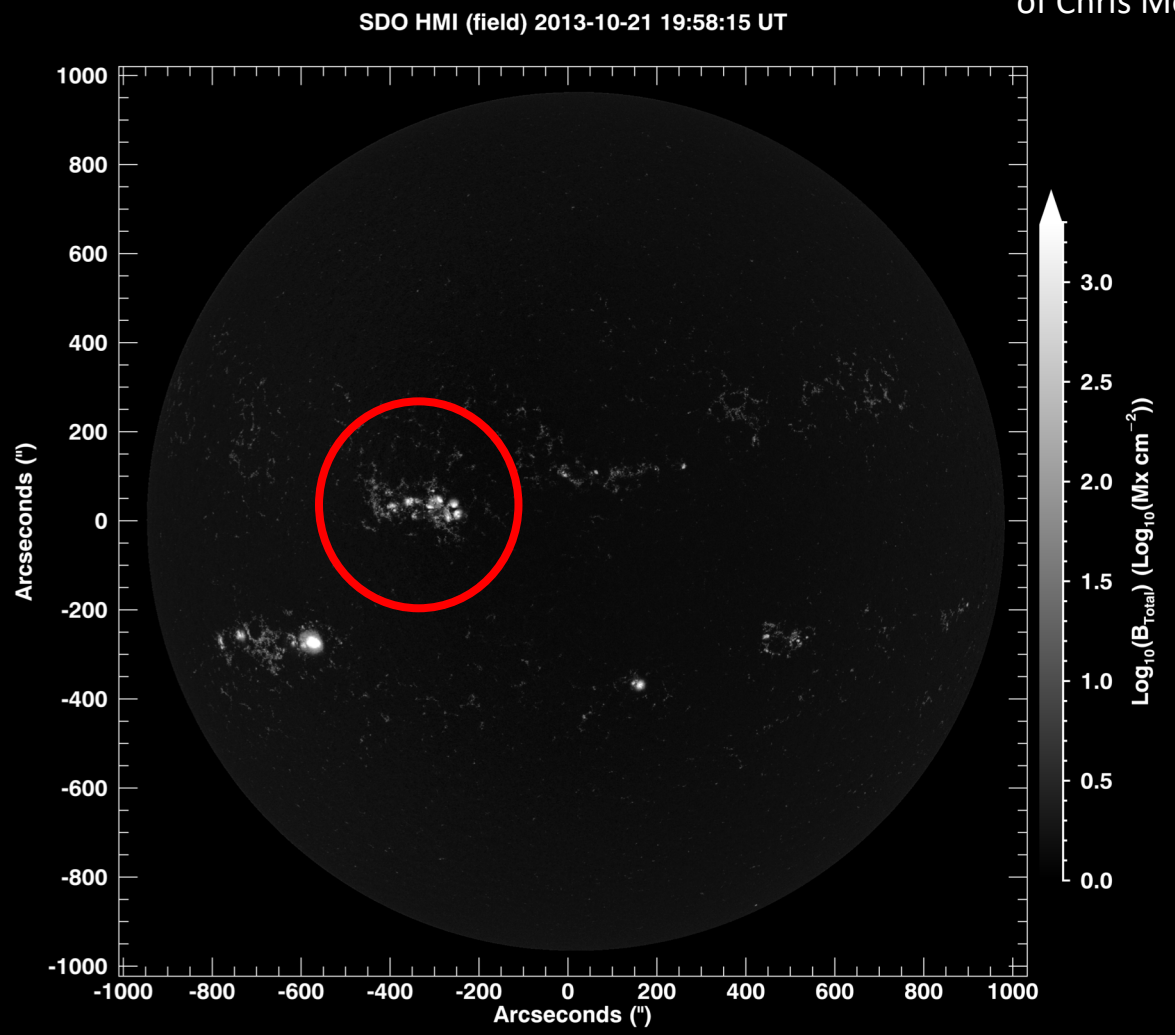
```
# Al_Mesh extract Obs Dates and Format to Year-Month-Day
Al_Mesh_timerange = []
for t in range(N_XRT_Al_Mesh_Filter):
    Al_Mesh_timerange.append(XRT_Al_Mesh_Filter[t]['INDEX_NORM']['DATE_OBS'][0].decode("utf-8"))

Al_Mesh_daterange = []
for t in range(N_XRT_Al_Mesh_Filter):
    Al_Mesh_datesubstring = Al_Mesh_timerange[t][0:10]
    Al_Mesh_datetimes = [datetime.strptime(Al_Mesh_datesubstring, "%Y-%m-%d")]
    Al_Mesh_daterange.append(Al_Mesh_datetimes)
```

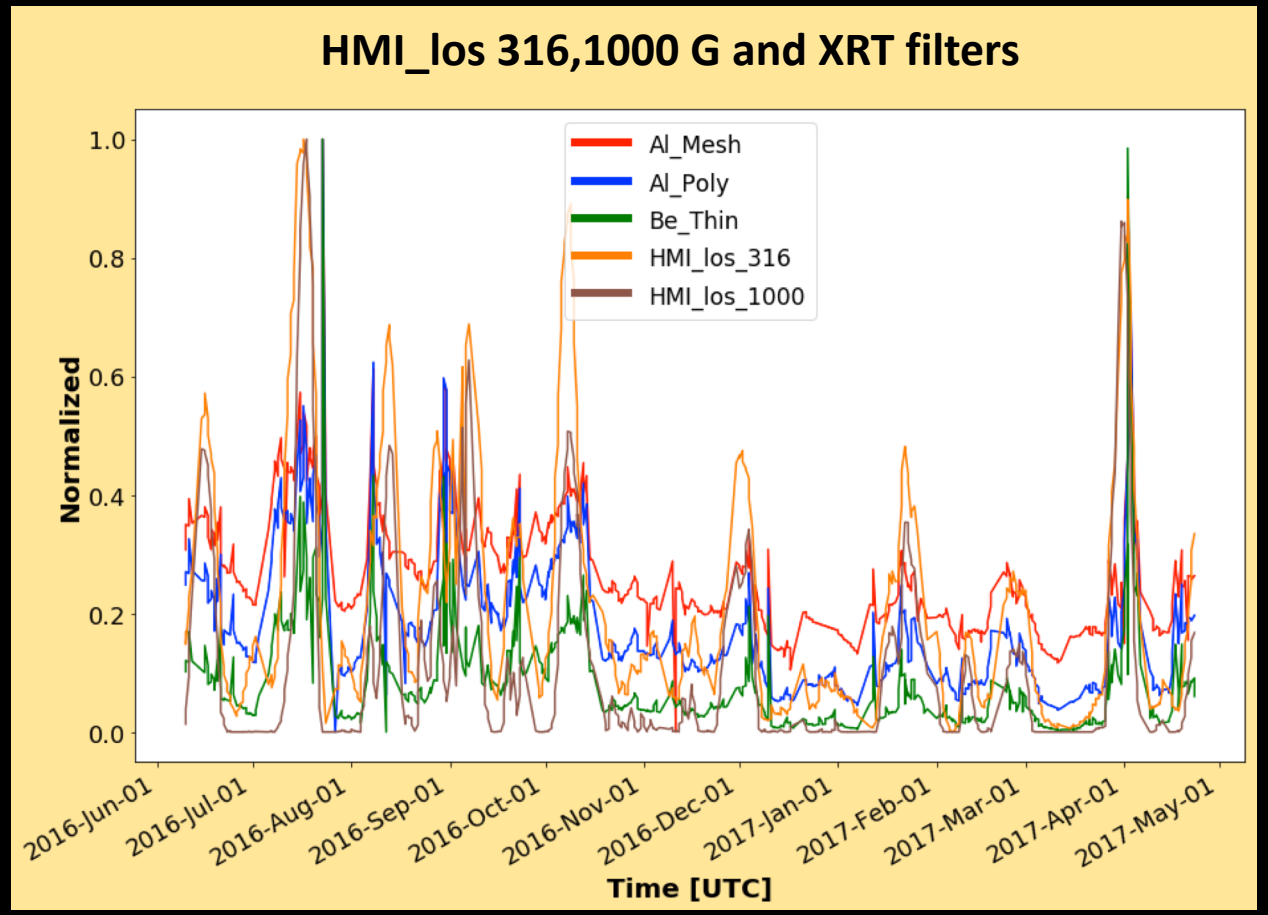
Thresholding HMI_los values above 316/1000 G

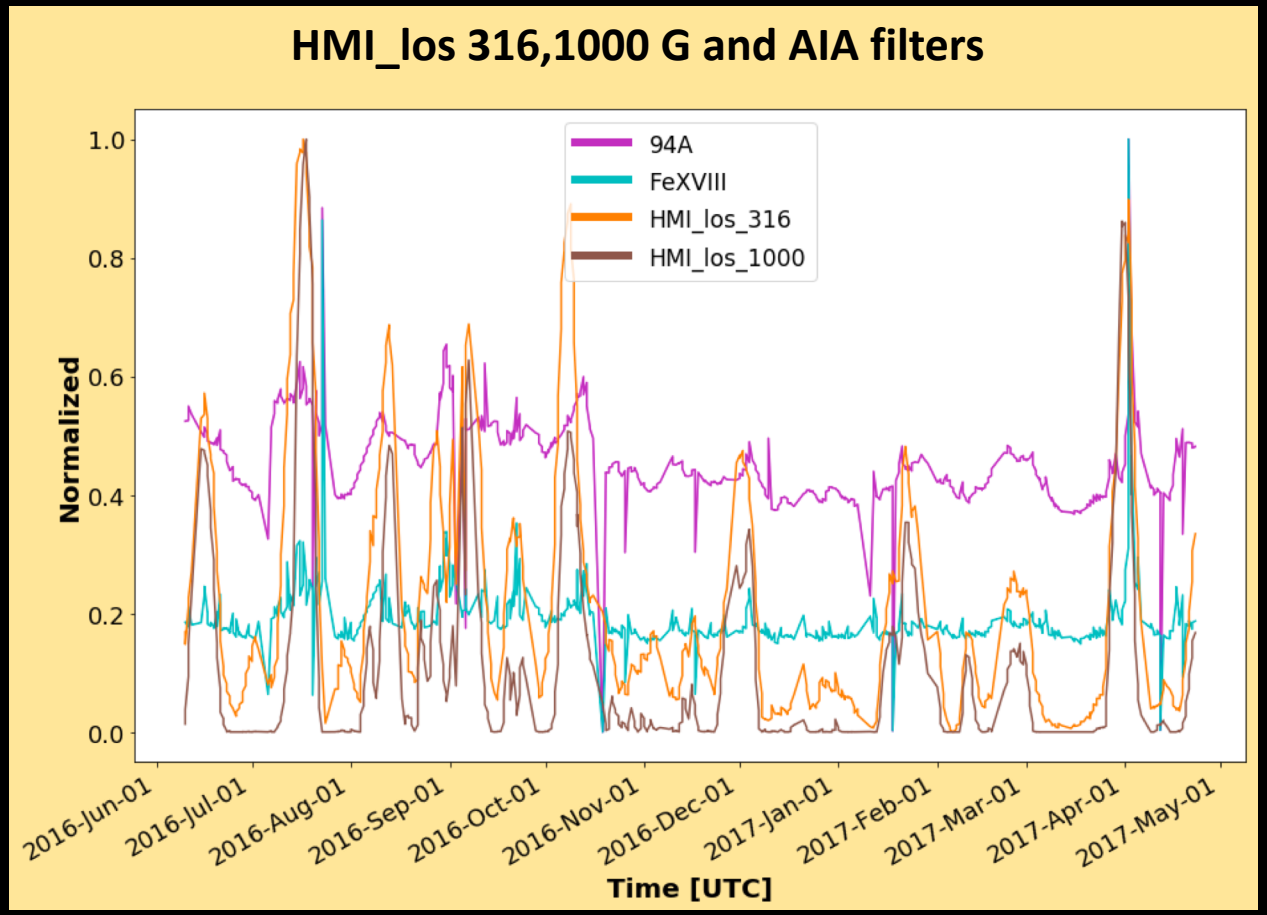
Images courtesy of Chris Moore



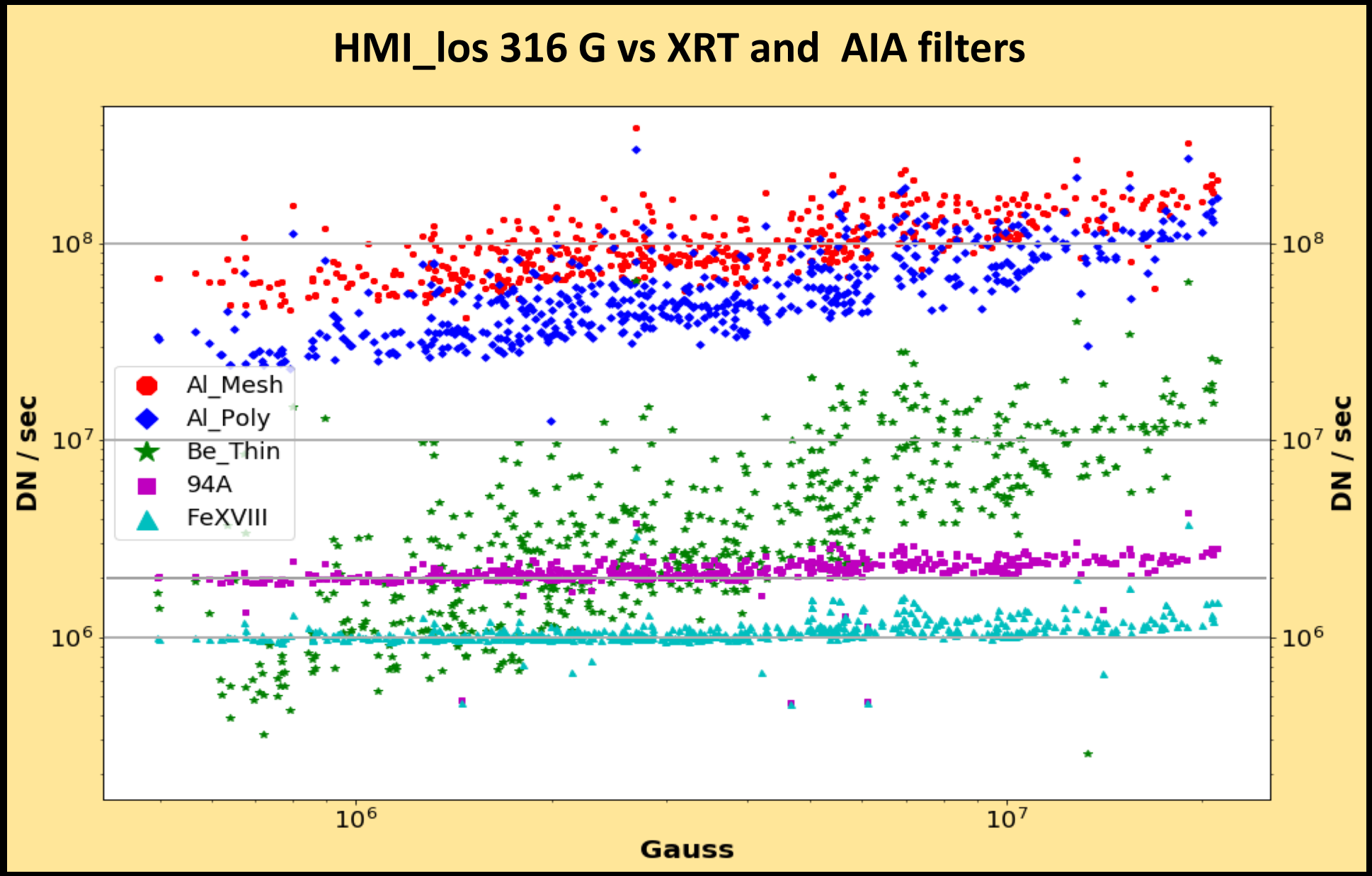


Time Series Plots



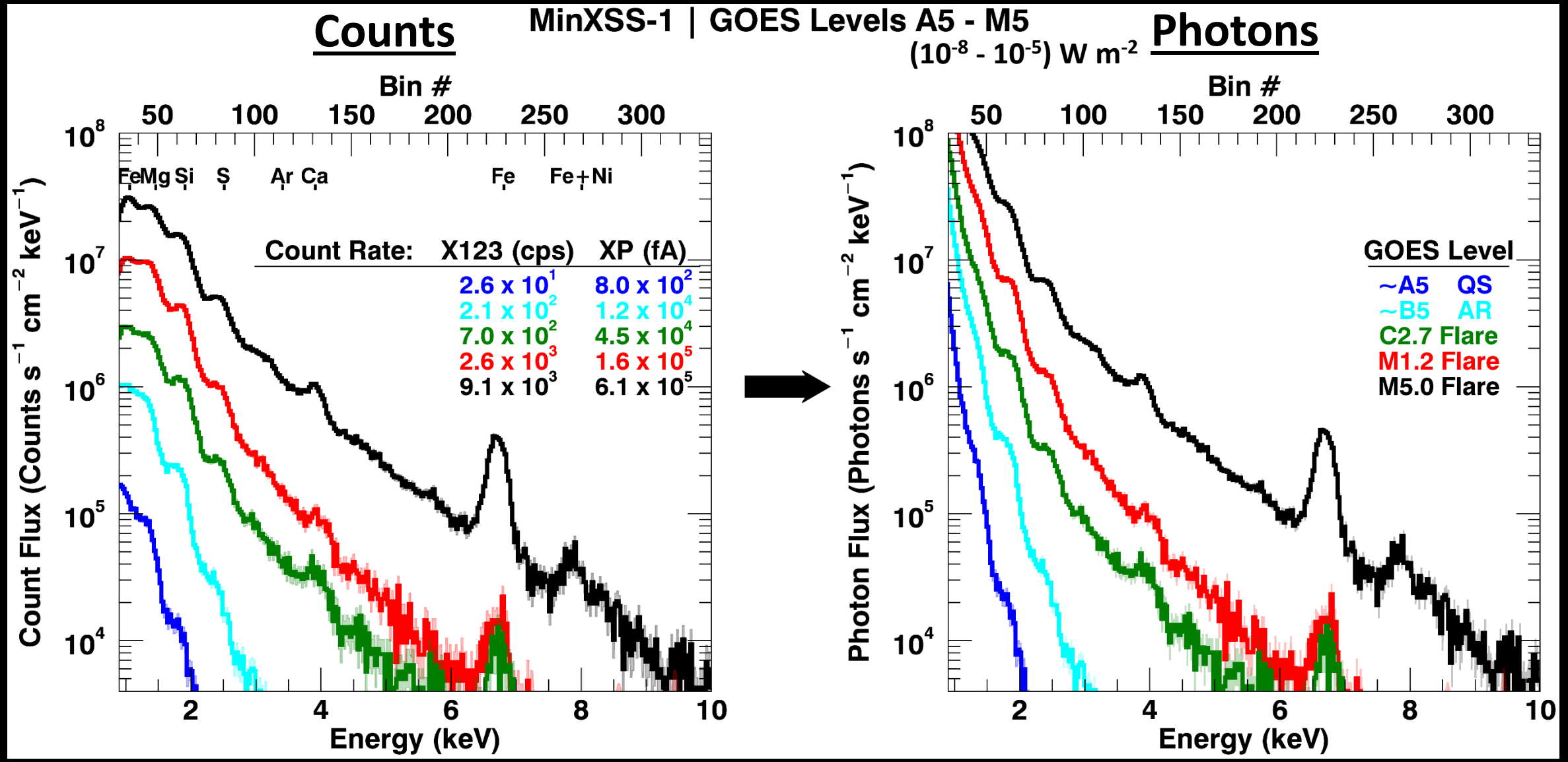


Scatter Plot



What is next?

Slide courtesy of Chris Moore



Moore et al. 2018 (published in Solar Physics)

Summary

- We were able to verify the connection of unsigned magnetic field to coronal soft x-ray flux

$$F_{Xray} \propto \left|\vec{B}_{los}\right|$$

- Identified a strong correlation between the XRT filters and magnetic field
- AIA 94A and Fe XVIII emission may not be as strongly correlated to magnetic field
- Spatial (HMI and XRT) and Spectral (MinXSS) information can help understand connection to plasma temperature and elemental abundance

Acknowledgements!

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