

The background is a dark blue gradient with a subtle pattern of white dots. Overlaid on the left side are several concentric circles and arcs, some solid and some dashed, with small arrows indicating a clockwise direction. A scale is visible along one of the larger arcs, with numerical labels ranging from 140 to 260 in increments of 10.

# SOLAR SOFT X-RAY IRRADIANCE WITH Hinode/XRT

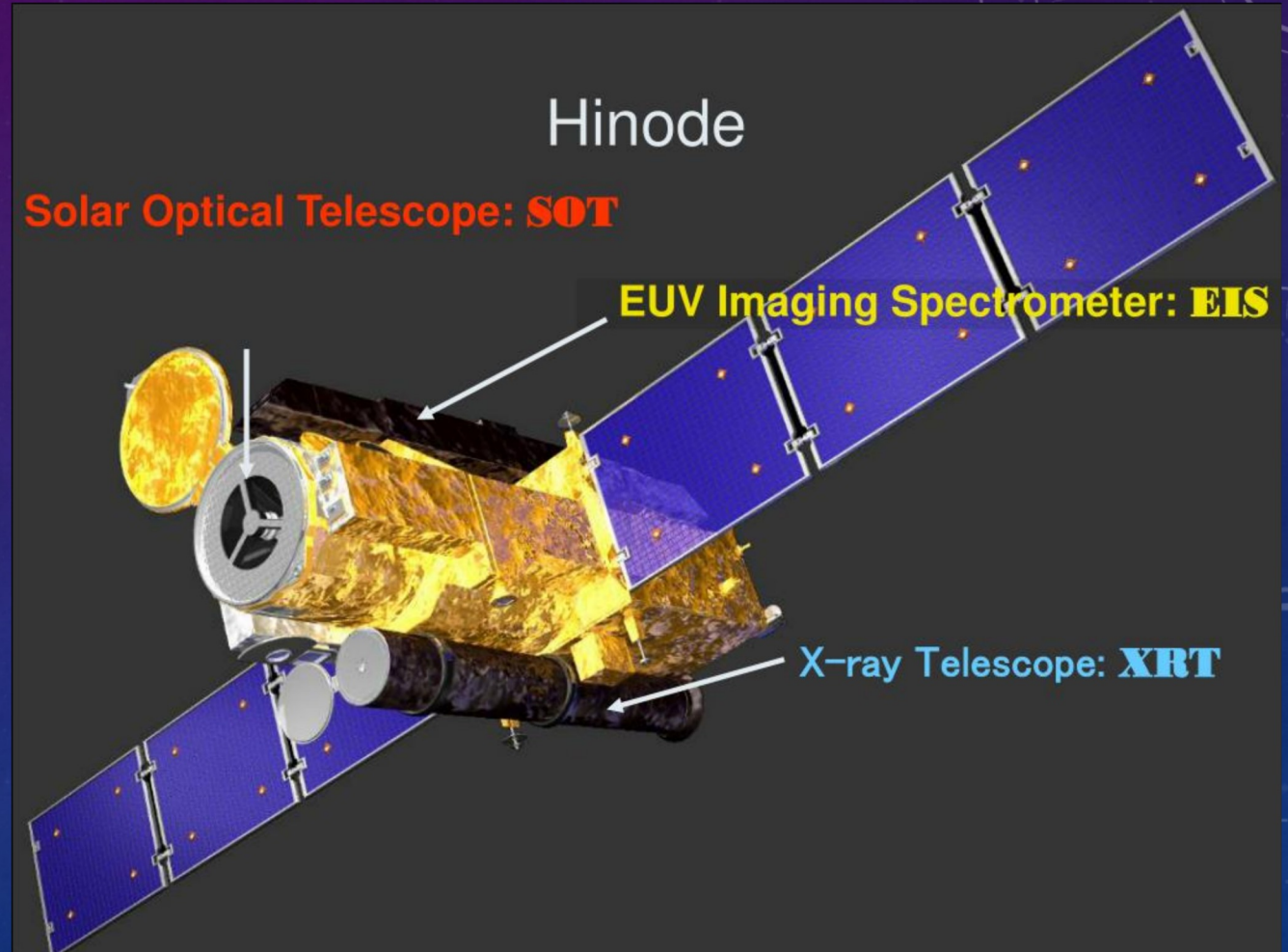
BY: STEFANIE DAVIS

MENTOR: AKI TAKEDA



# THE HINODE SATELLITE

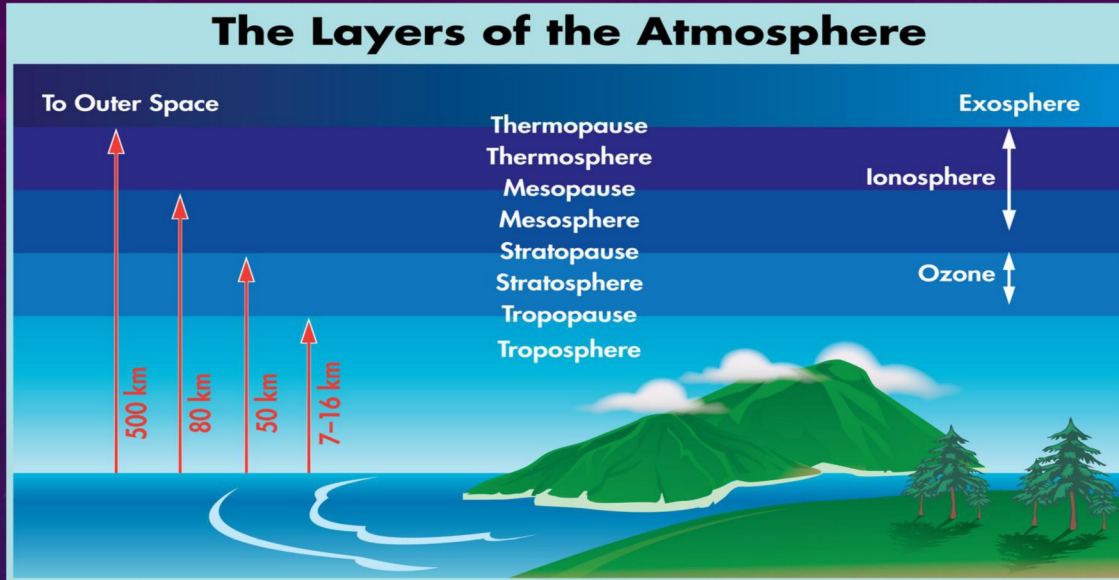
- Orbits at about 500-600km above the Earth.
- Launched in September, 2006
- Hinode has a polar orbit
- Hinode has the ability to observe the full sun or just a partial region.





# THE IMPORTANCE OF OUR PROJECT

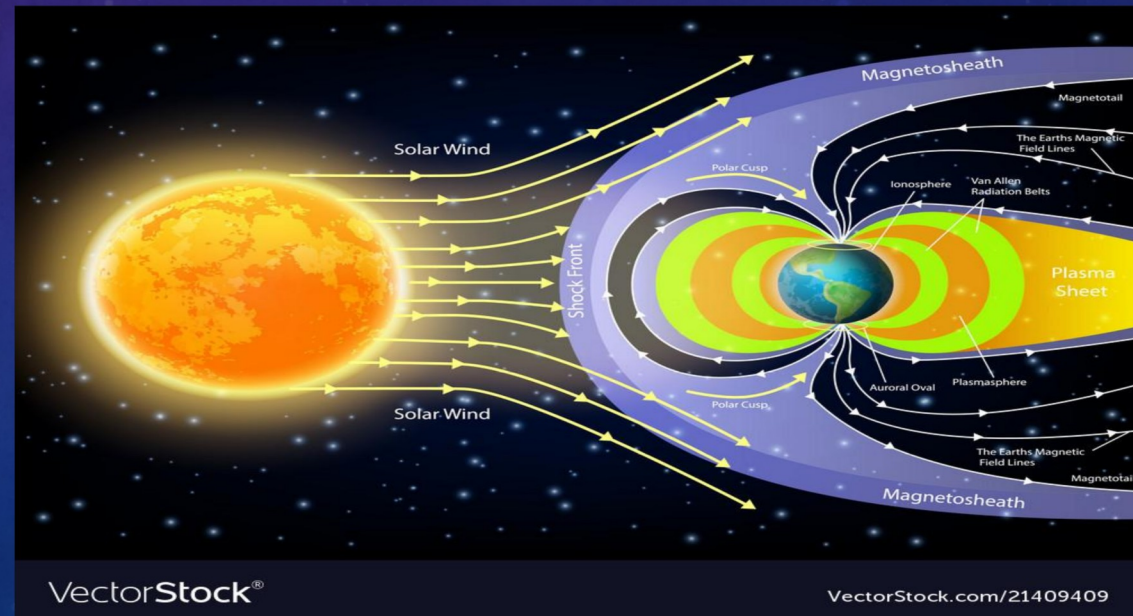
## The Layers of the Atmosphere



[http://data.allenai.org/tqa/layers\\_of\\_the\\_atmosphere\\_L\\_0023/](http://data.allenai.org/tqa/layers_of_the_atmosphere_L_0023/)

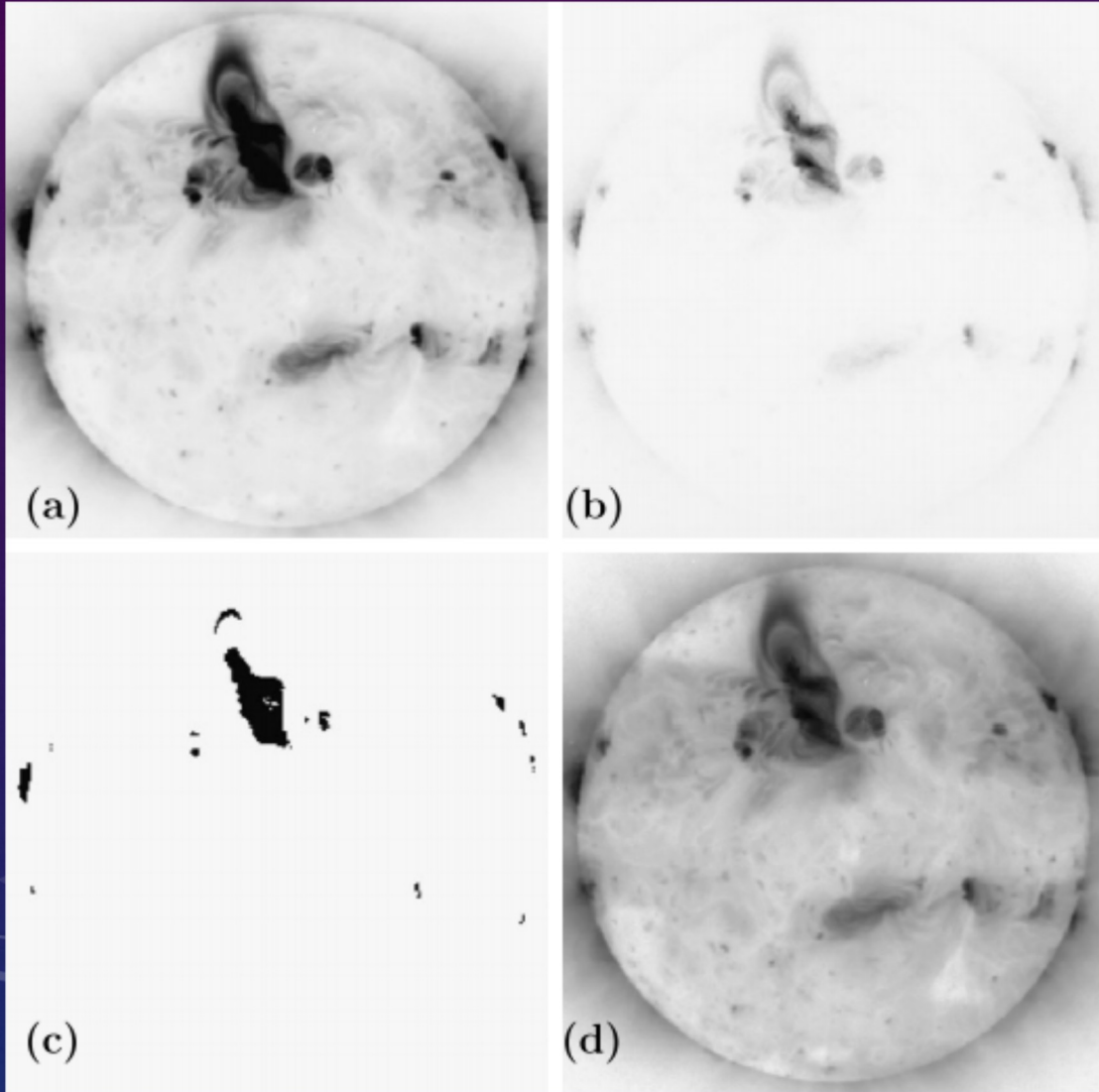
- Soft x-rays are important because they show many magnetic field configurations and have a wide temperature coverage.
- Soft x-rays are absorbed in the ionosphere.

- Solar irradiance is the amount of light energy from the sun that is measured on Earth.
- Space Weather can interfere with Earth communications, overload power grids, and cause geomagnetic storms.





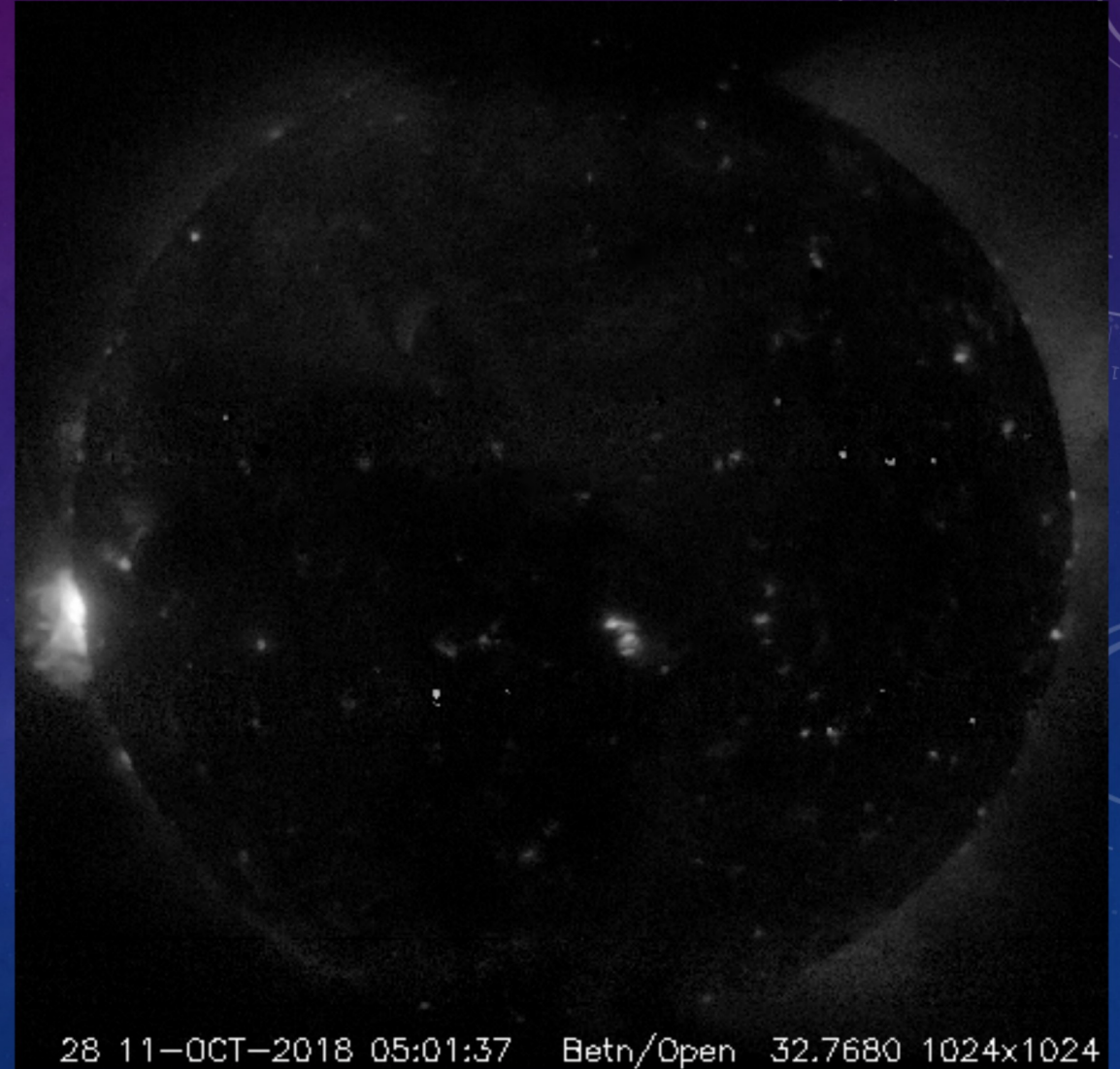
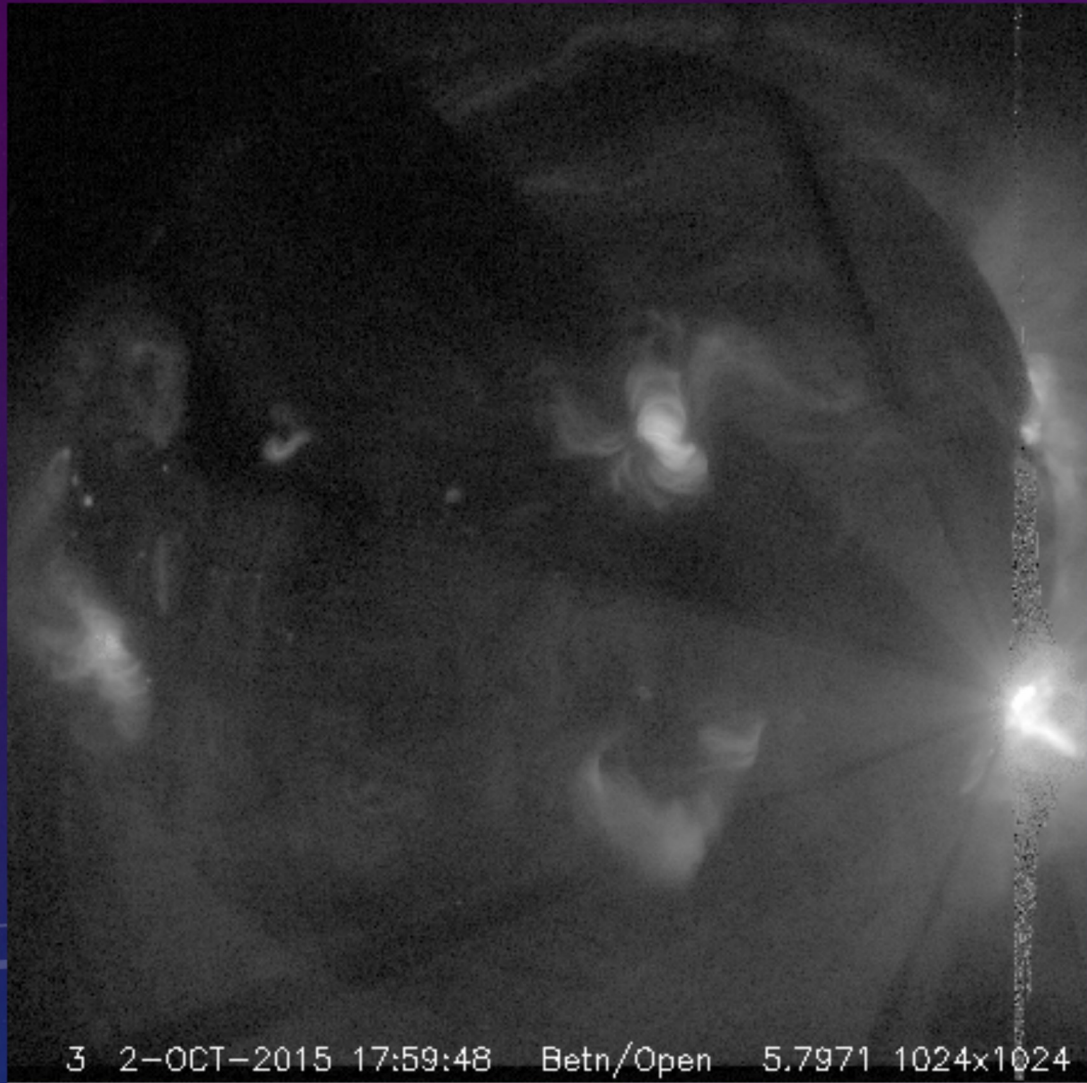
# PROJECT OVERVIEW



- Our project was focused on using soft x-rays from the XRT.
- We used the XRT Synoptic Composite Image Archive created by MSU.
- 2008-present day
- Thin-Be filter: measure higher temperatures
- Al-mesh filter: measure lower temperatures
- Our goal was to measure the average temperature and emission measure of the sun and calculate irradiance.



# STEP 1: DATA SELECTION





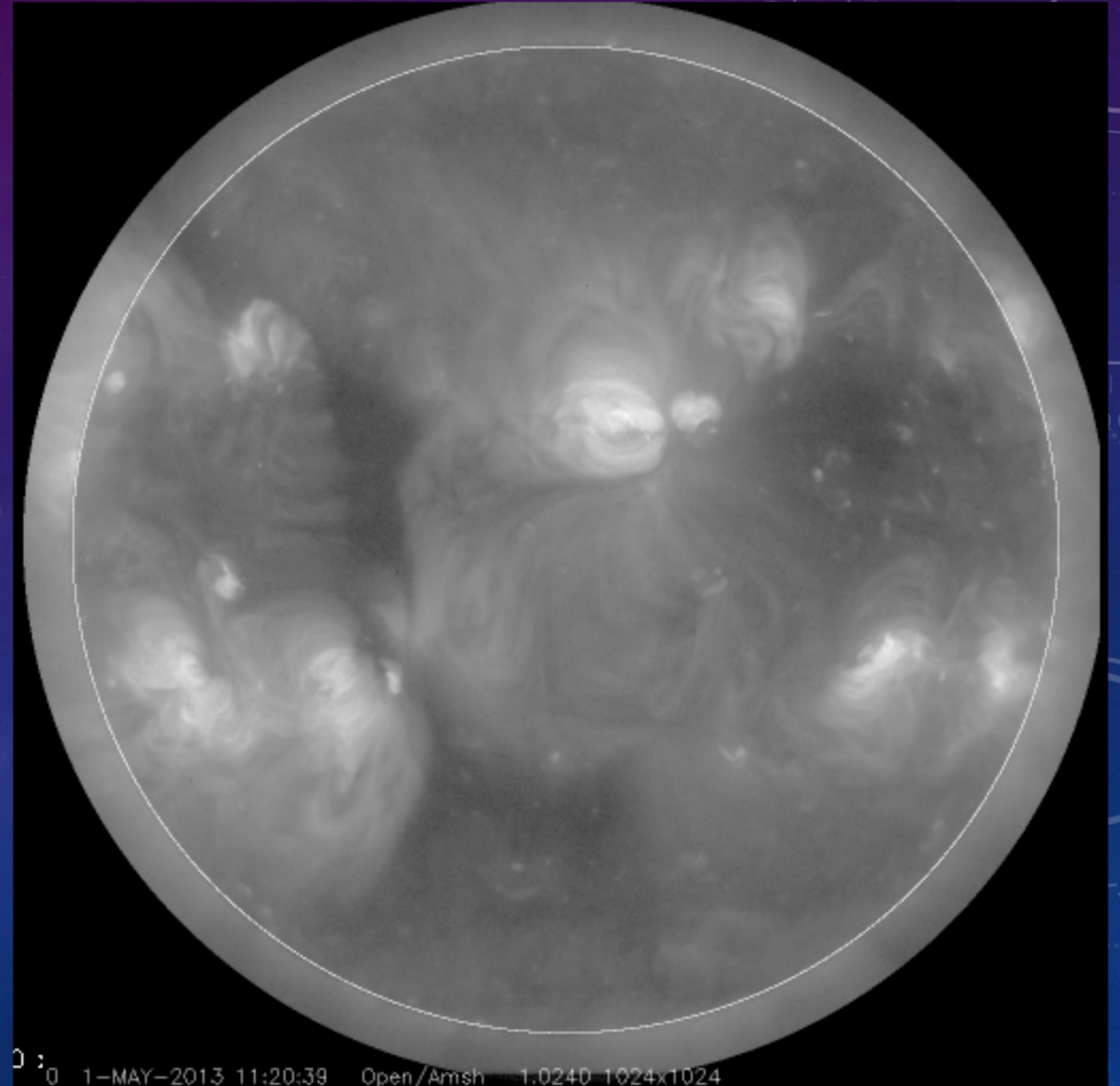
# SAVED DATA

Year	# of data
2008	22
2009	43
2010	0
2011	117
2012	108
2013	135
2014	107
2015	351
2016	213
2017	154
2018	557
2019	1287
2020	1054
2021	398
Total	4572



## STEP 2: SIGNAL COLLECTION

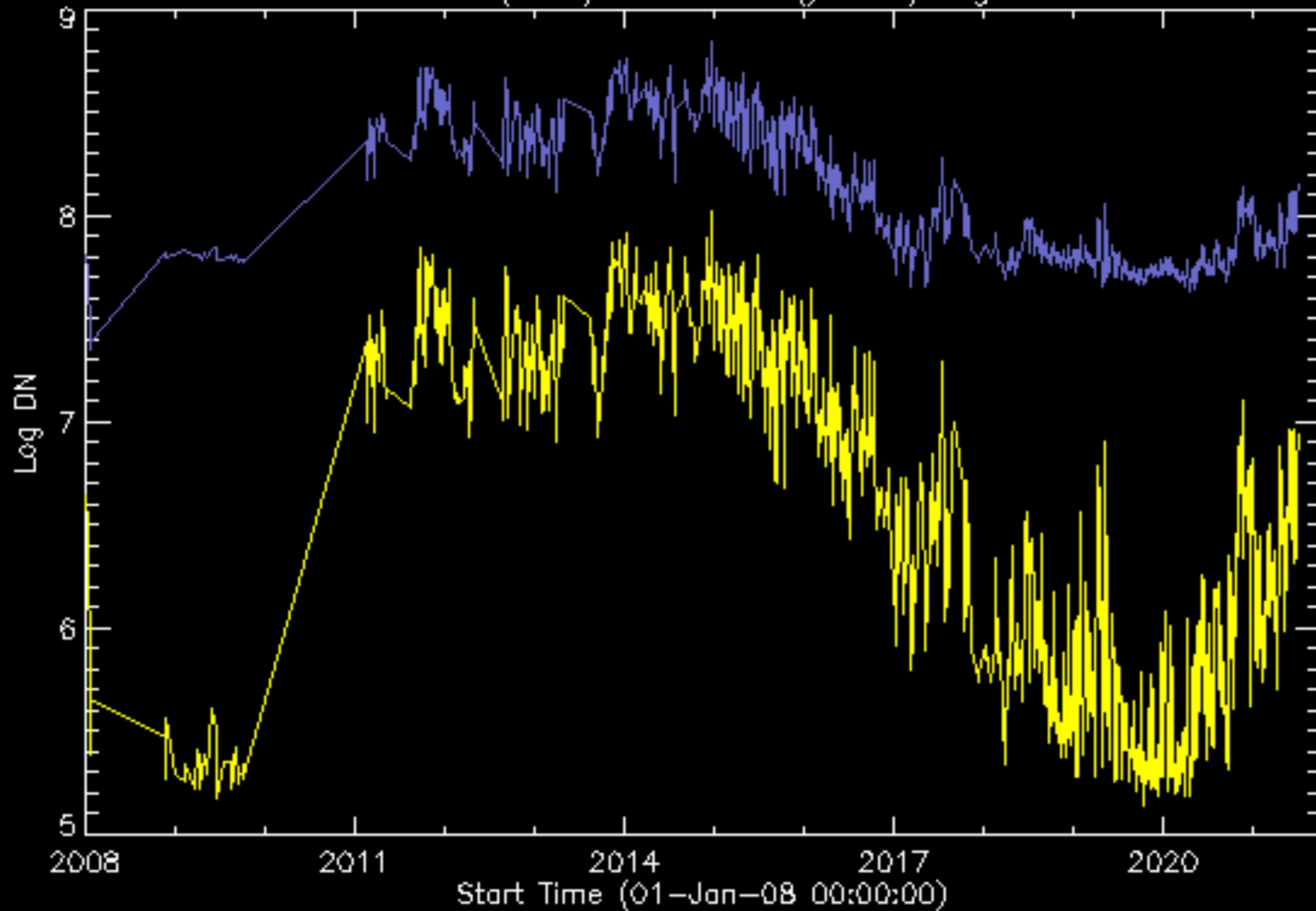
- My next step was to put masks around the images.
- 1.1 radii of the sun
- Then modified a program to plot the intensities.





# FINDING INTENSITY

Al-mesh(blue) & thin\_Be(yellow) signals





# STEP 3: FINDING TEMPERATURE AND EMISSION MEASURE

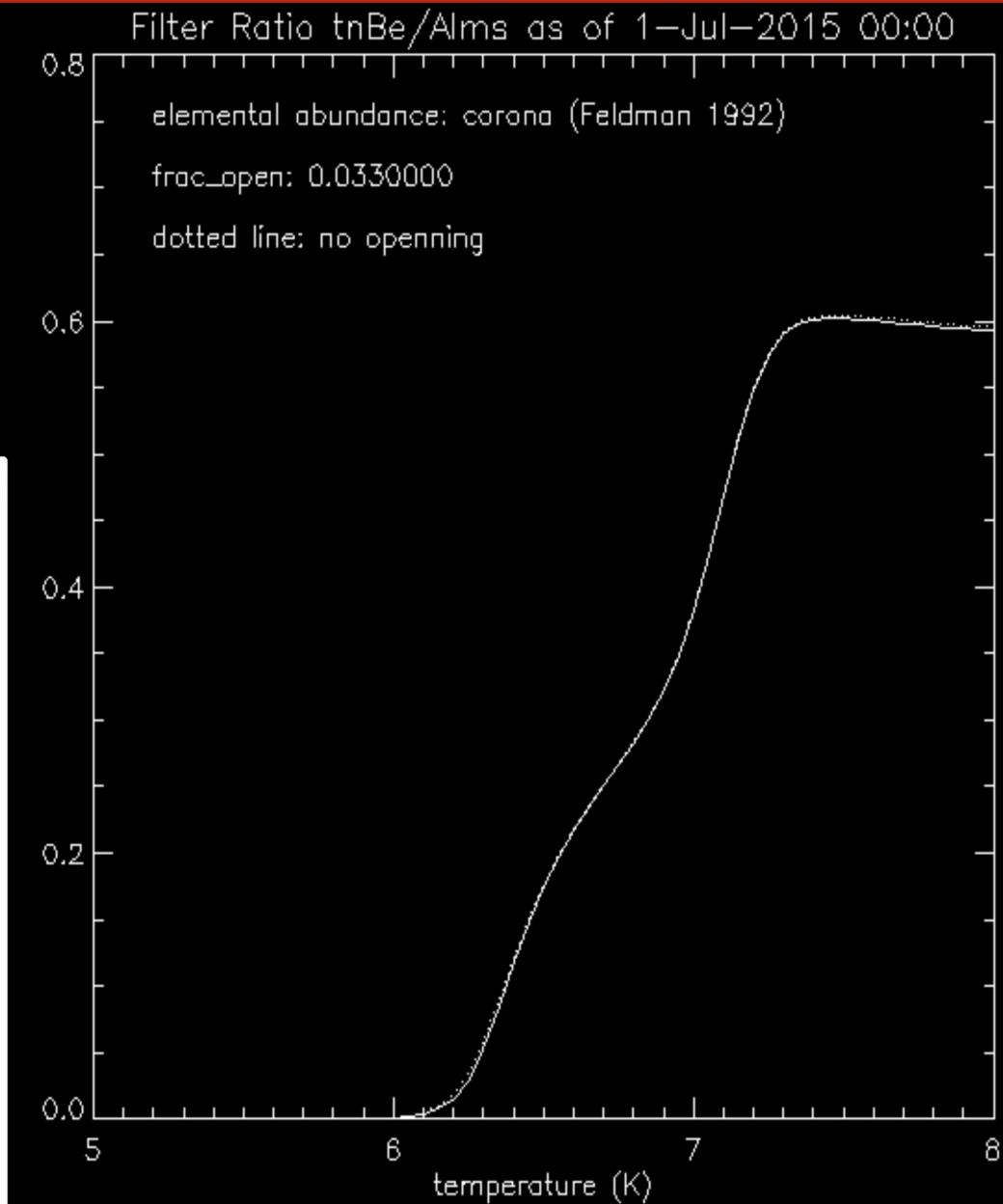
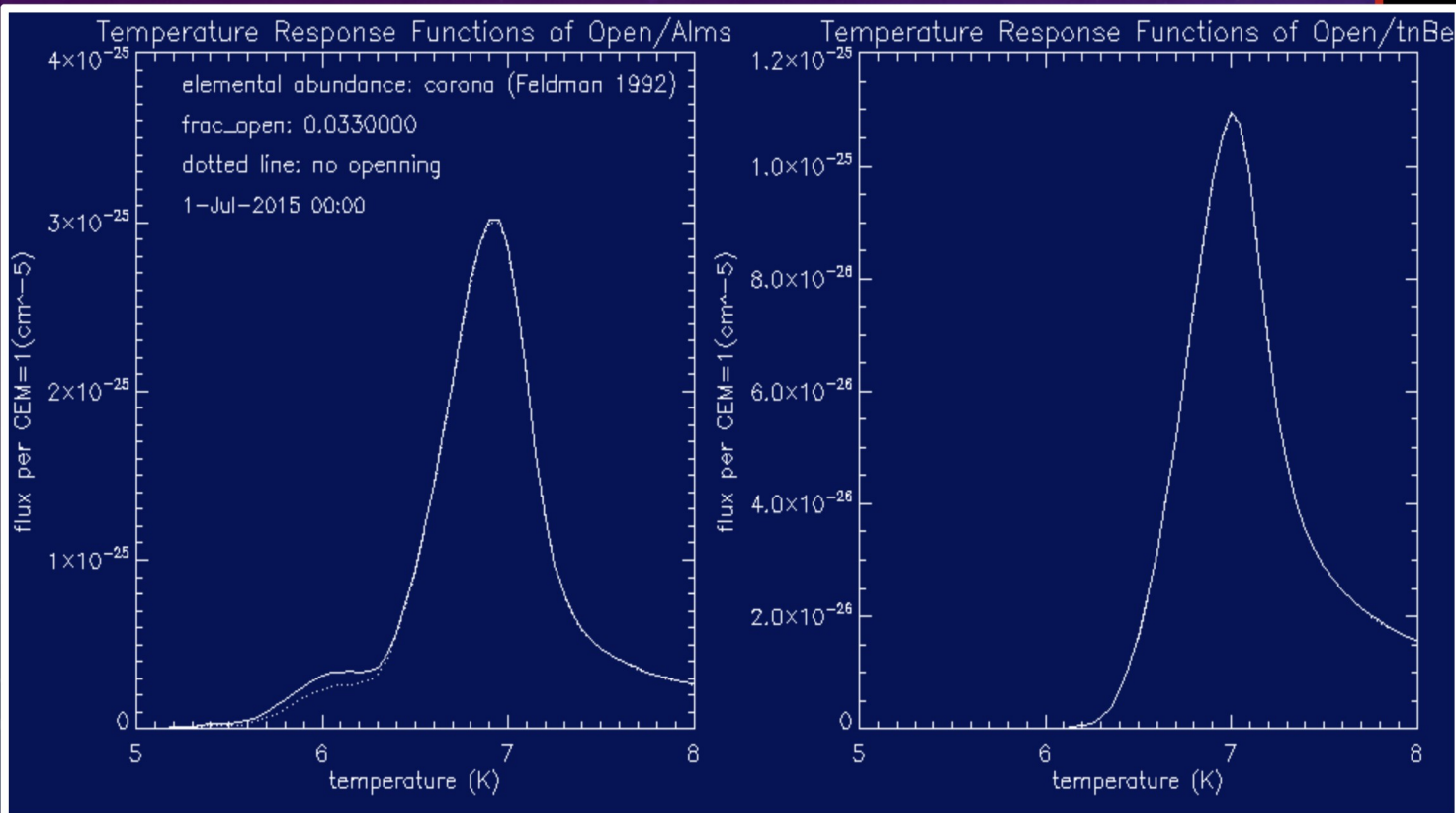
- The filter-ratio method is the key to finding the average coronal temperature and the average emission measure.
- Using the ratio of two different filters, we are left with the function of temperature. With that we can also go back and find the emission measure.
- I ran a program that used the filter-ratio method to find the temperature and emission measures of the Al-mesh and thin-Be filters.

$$R_{ij} \equiv \frac{DN_i/\delta t_i}{DN_j/\delta t_j} = \frac{F_i(T)}{F_j(T)}.$$

$$\varepsilon = \int_0^\infty N_e^2(l) dl \cdot d\sigma. \quad (4)$$



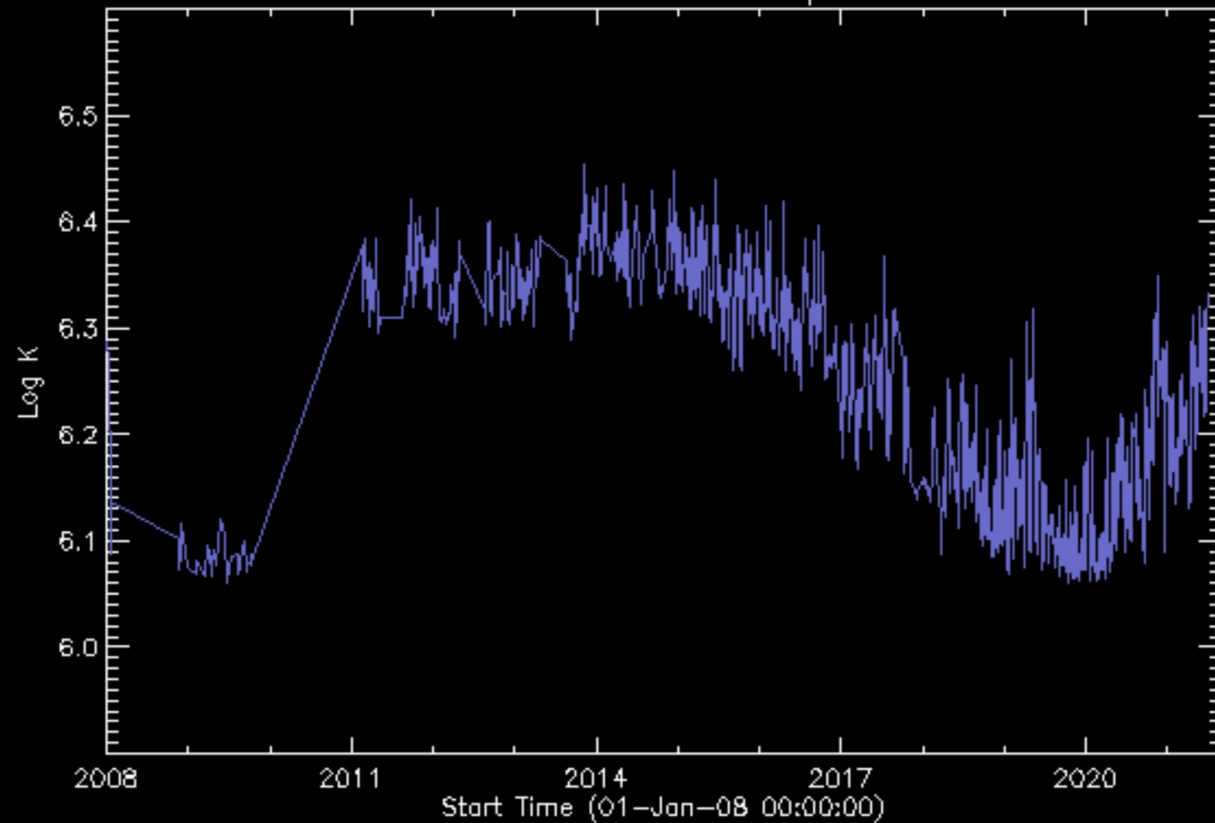
# TEMPERATURE RESPONSE FUNCTIONS AND FILTER RATIO



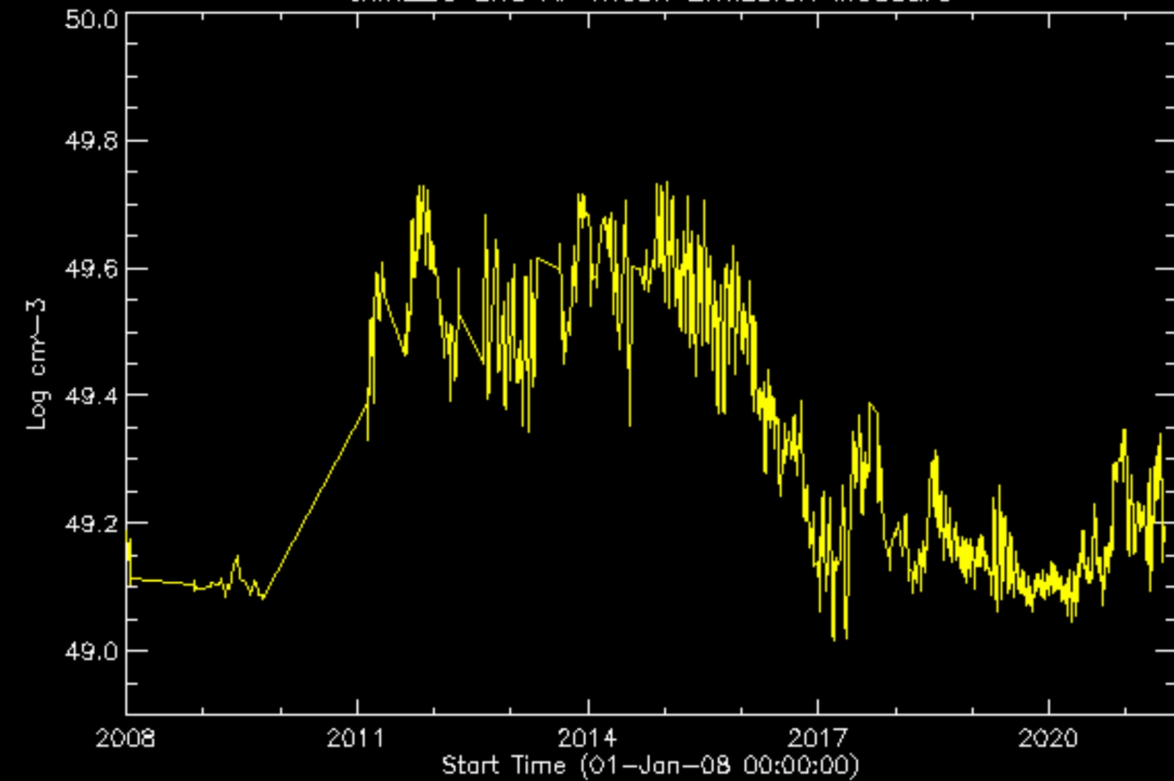


# TEMPERATURE AND EMISSION MEASURE

Al\_mesh and thin\_Be Temperature

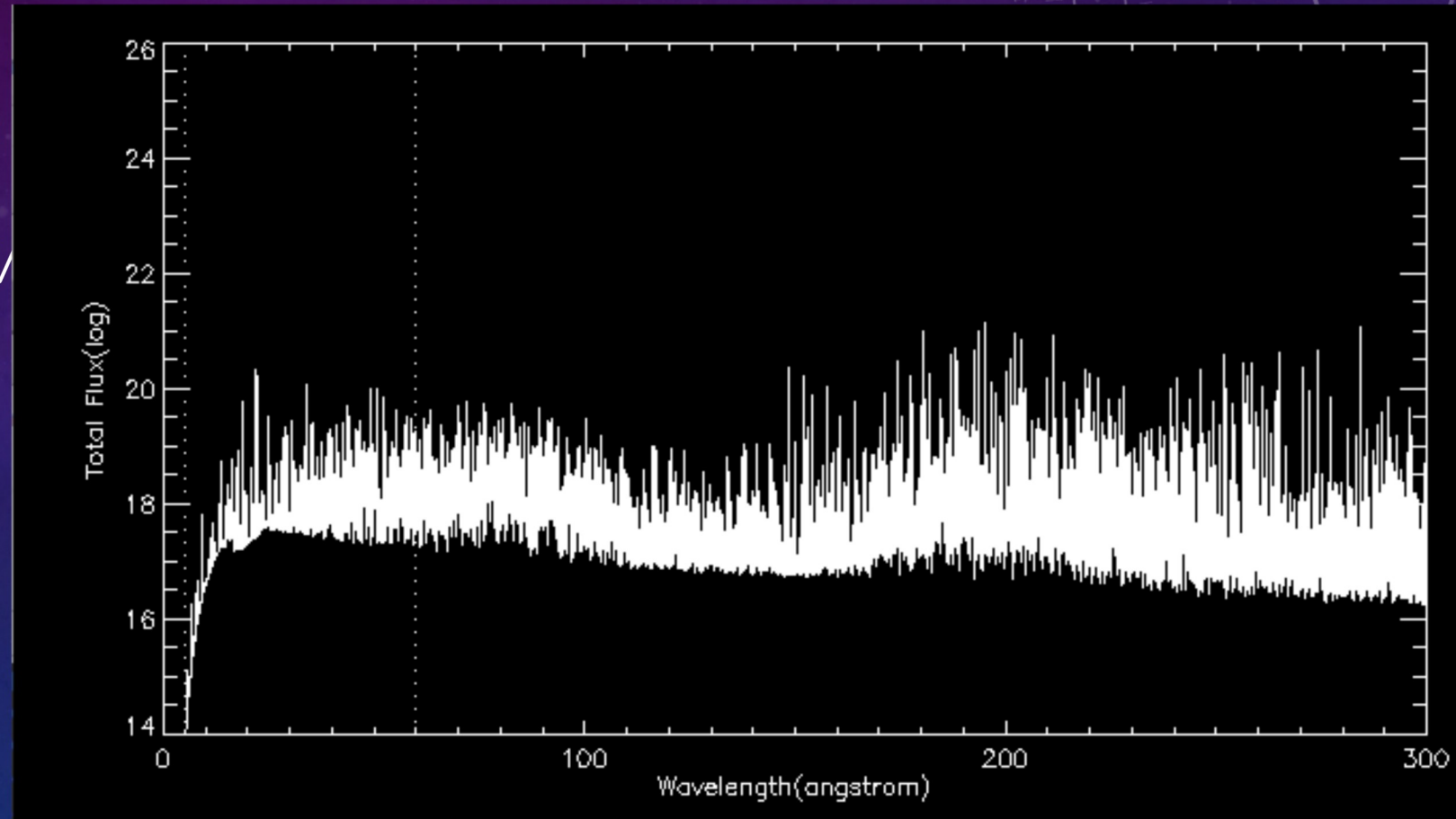


thin\_Be and Al-mesh Emission Measure



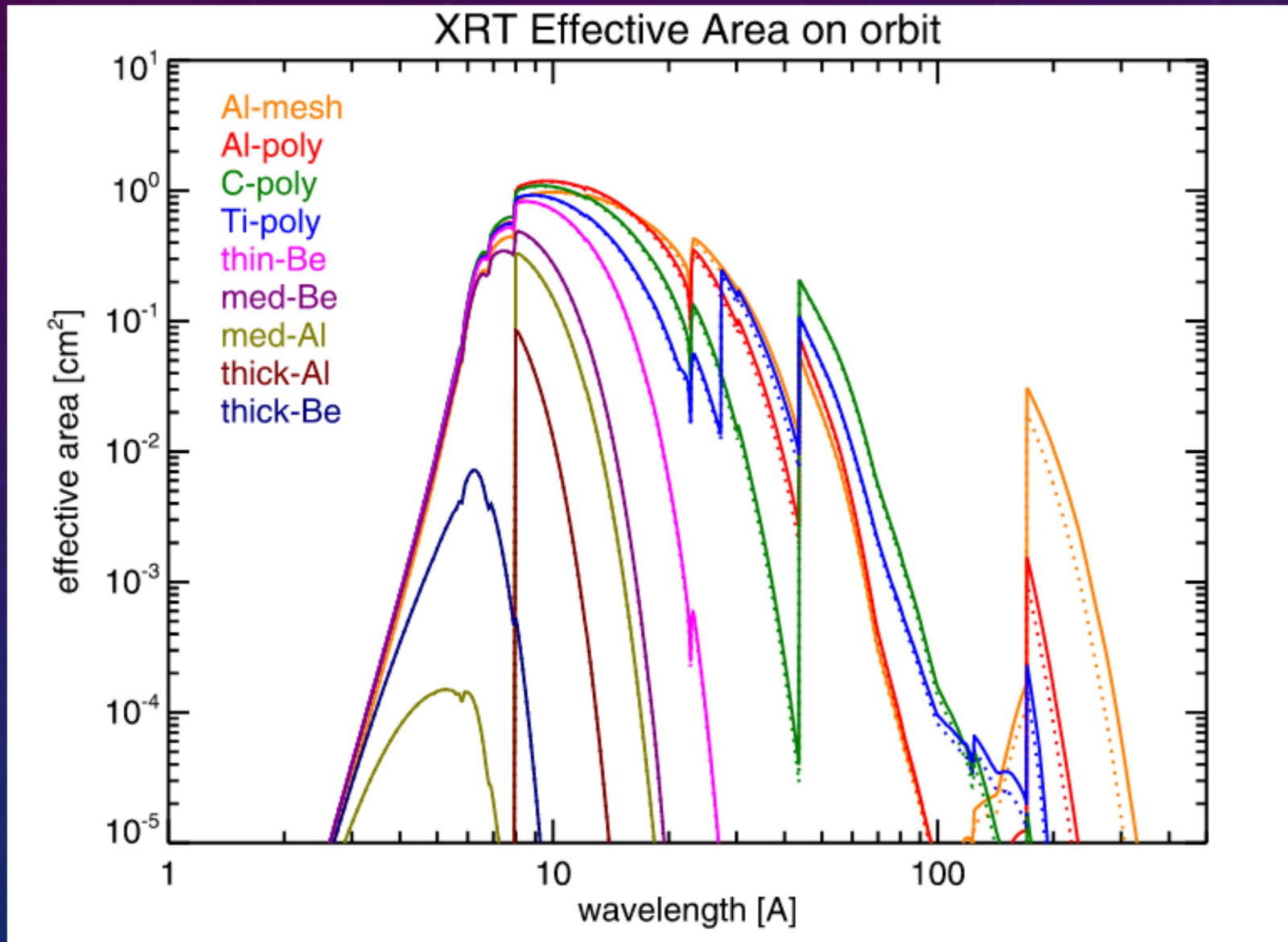
# STEP4:FINDING IRRADIANCE

- We converted the temperature and emission measure to solar irradiance in the unit of  $\text{W}/\text{m}^2$  by using the isothermal double spectral model plotted by Chiari et al. CHIANTI database.
- We then integrated over the wavelengths range of 5-60 (Å) XRT spectral response

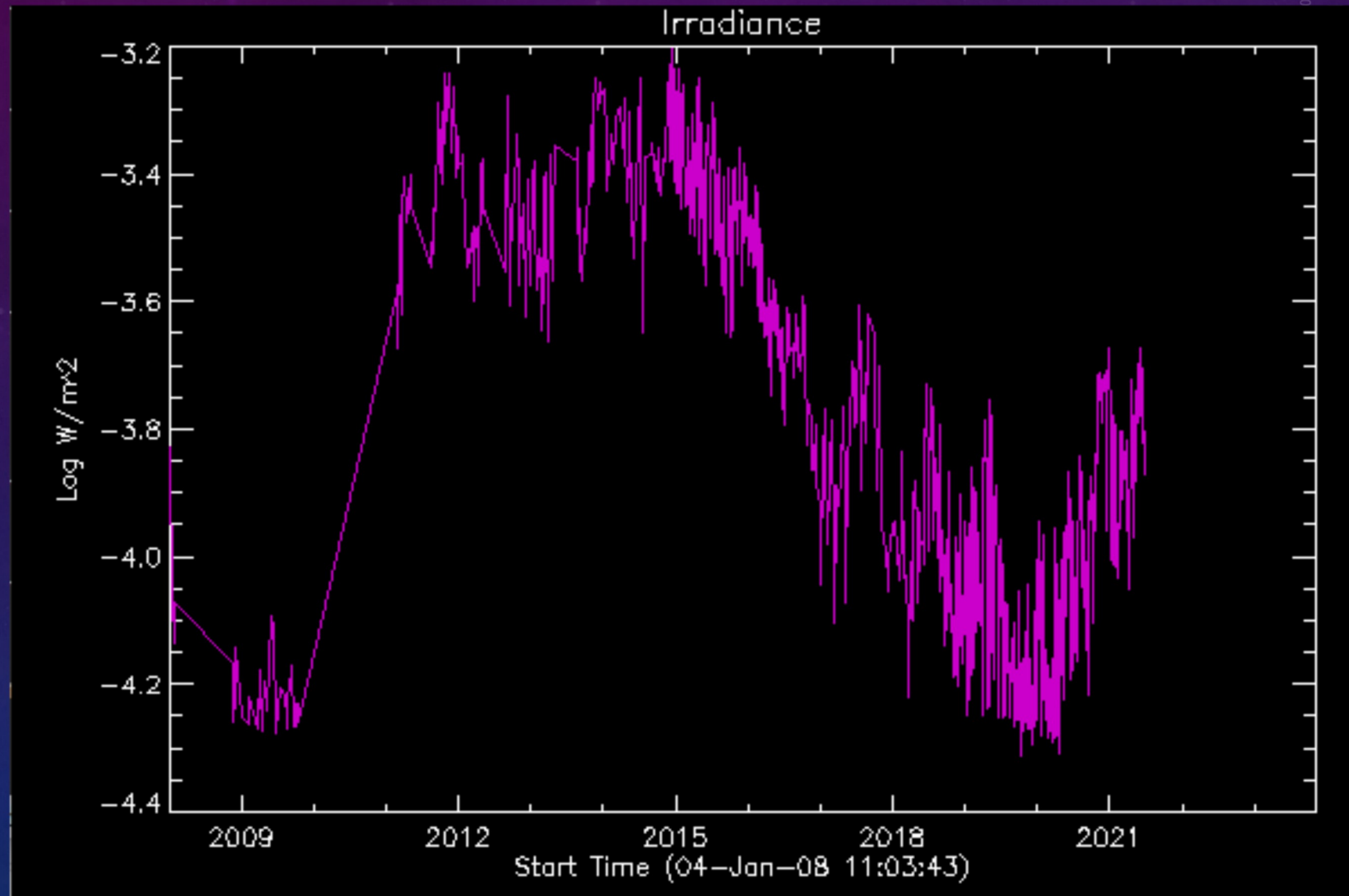




# XRT SPECTRAL RESPONSE

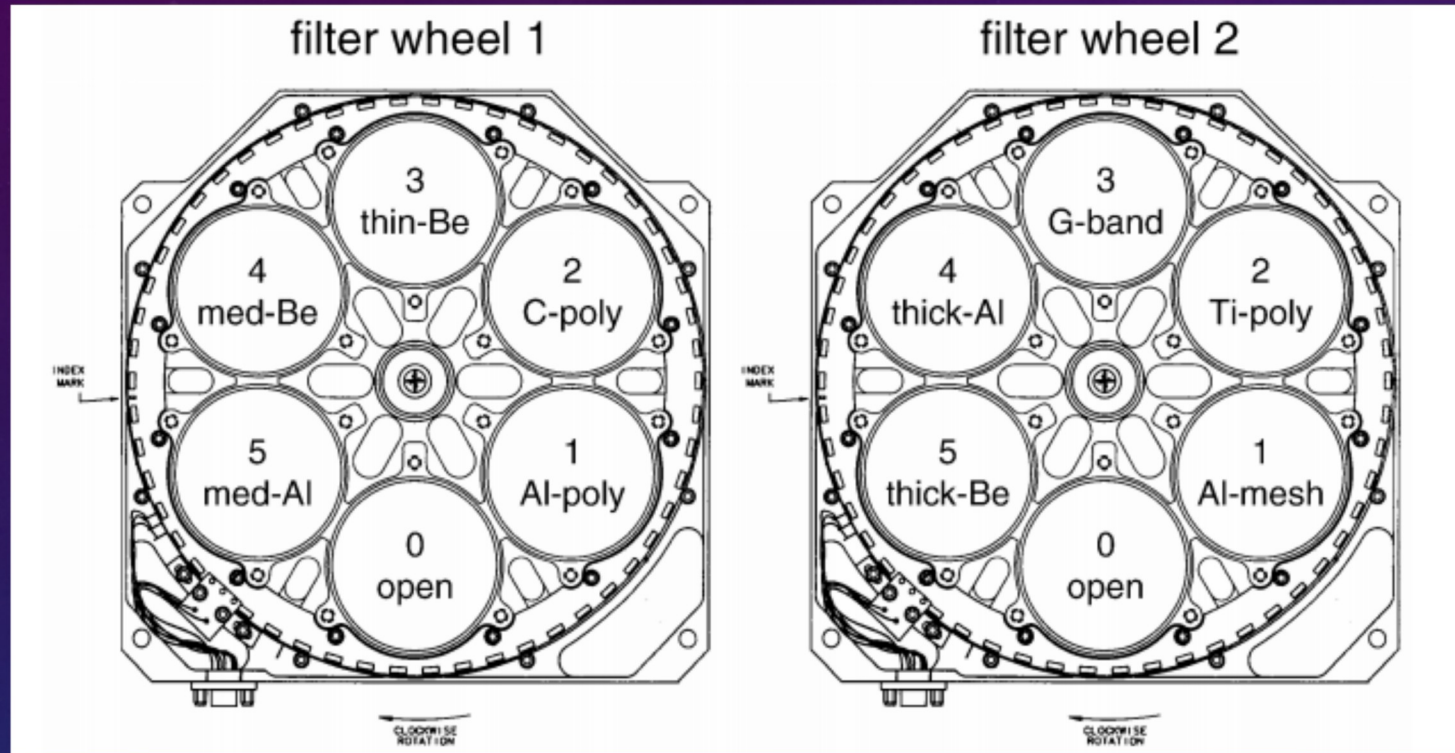


# IRRADIANCE OF AM/TB





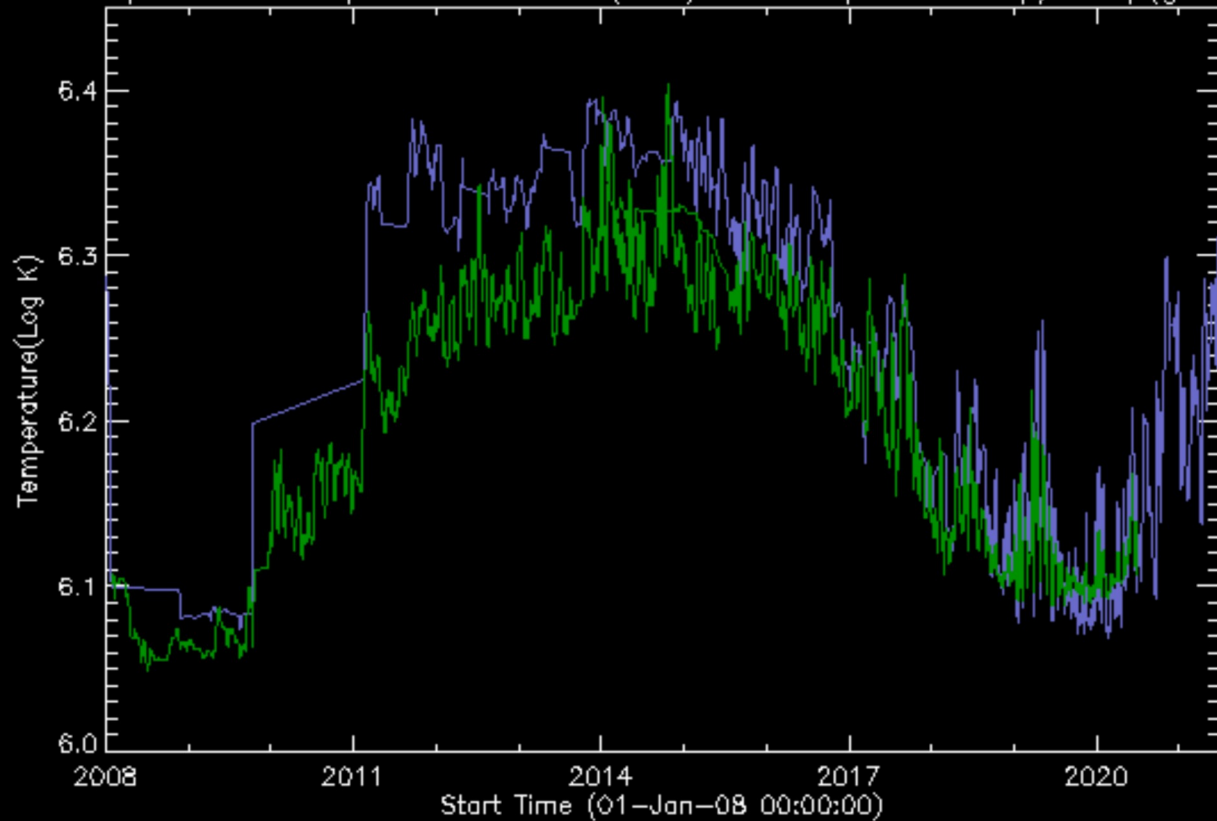
# STEP5:COMPARISON



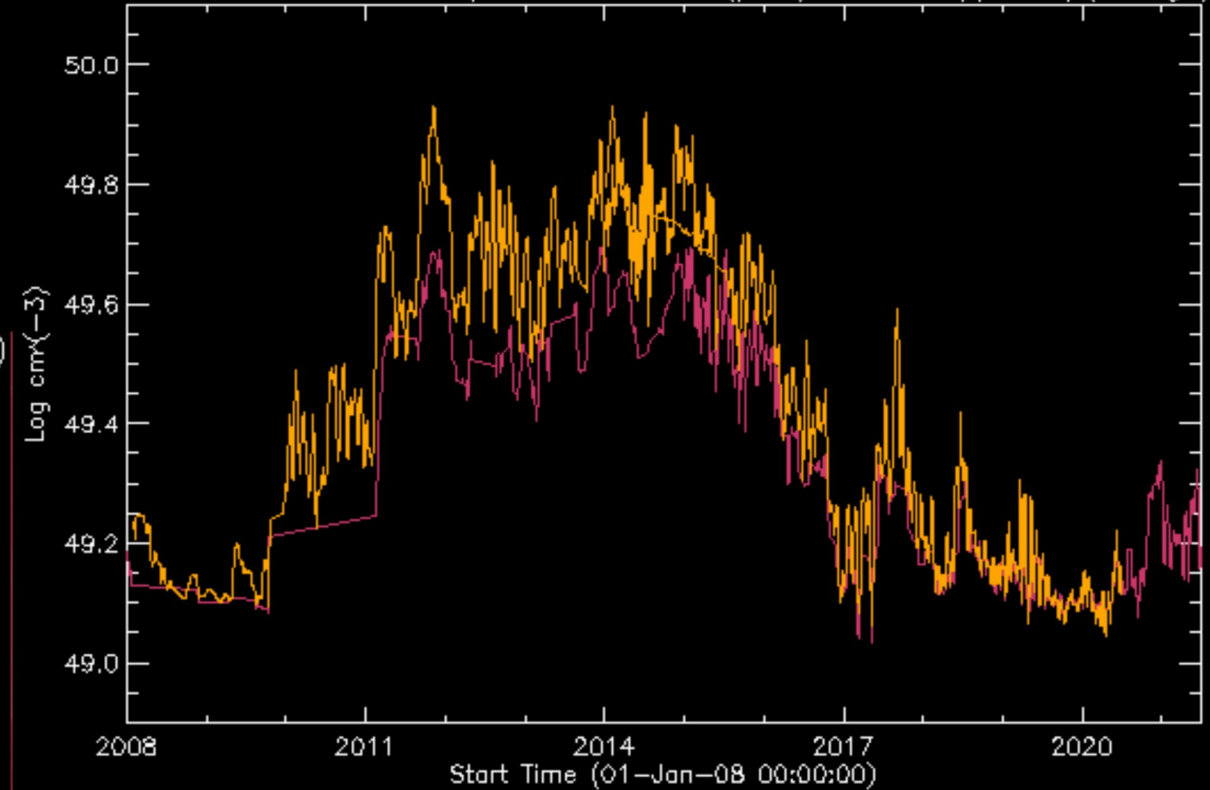
- Previous Study
  - Al-mesh/Ti-poly (2006-2015)
  - Al-mesh/Al-poly (2015-2020)
- Sunspot Numbers
  - Silso
  - <https://wwwbis.sidc.be/silso/>
- The following plots have smoothed data points for easier comparison

# TEMPERATURE AND EMISSION MEASURE COMPARISON

Temperature Comparison of AmTb(blue)and Composite AmTp/AmAp(green)

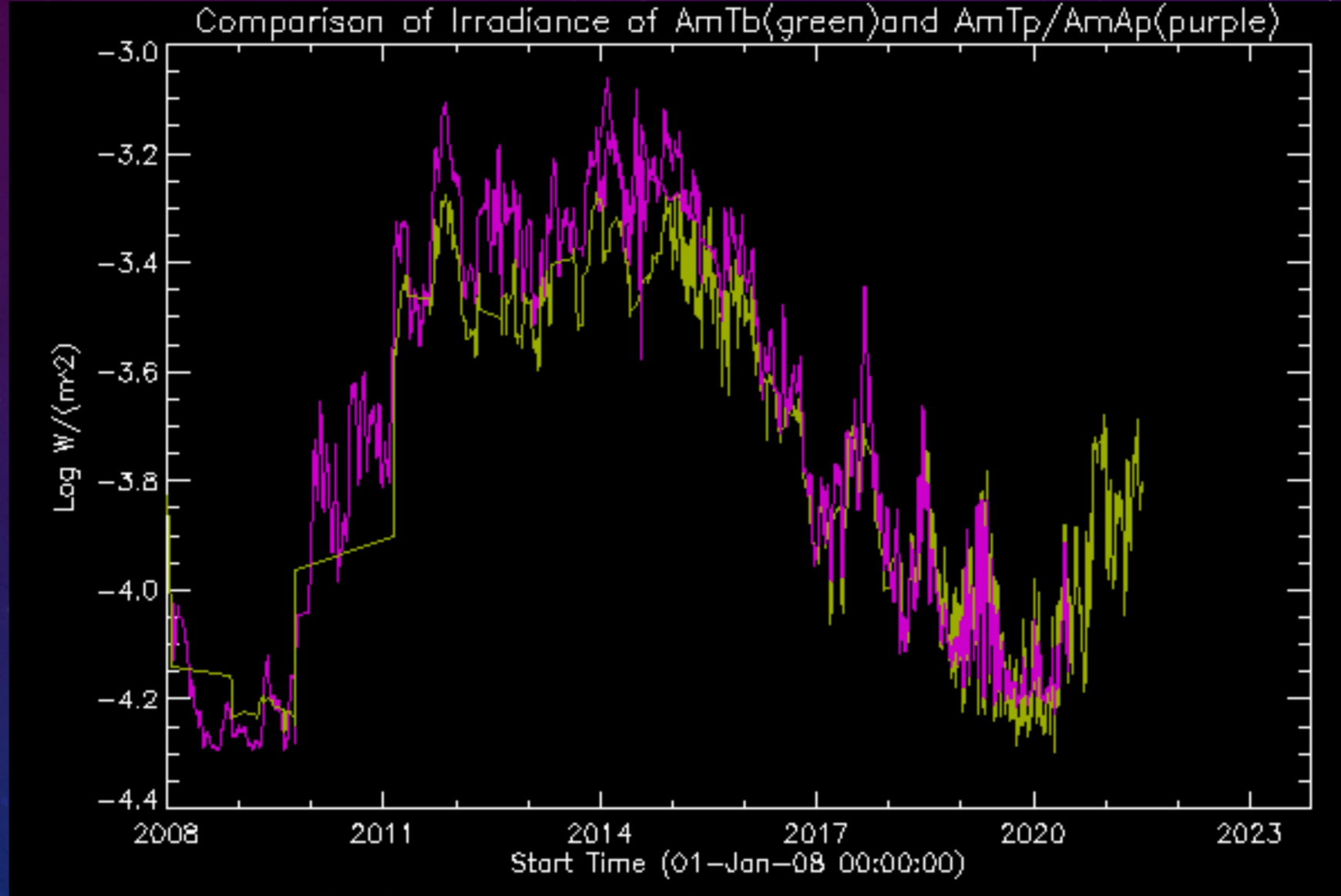


Emission Measure Comparison of AmTb(pink) and AmTp/AmAp(orange)

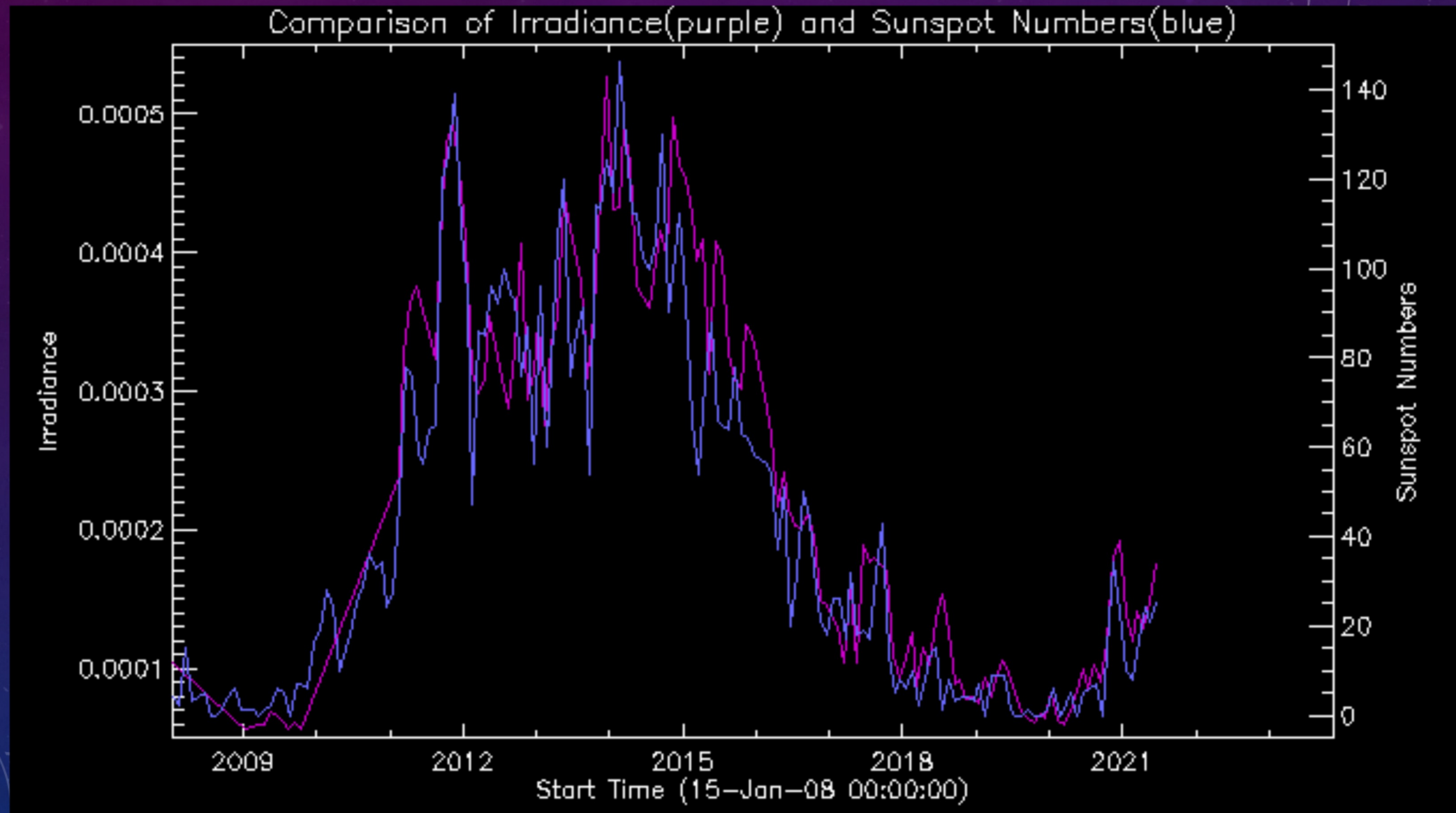




# IRRADIANCE COMPARISON



# COMPARISON OF SUNSPOT NUMBER AND XRT IRRADIANCE





# SUMMARY

- We successfully found the temperature, emission measure, and irradiance of the thin-be and al-mesh filter pair.
- The plots follow the 11 year cycle
- During the comparison with the previous study, we found that our study had a higher temp, but lower emission measure than the other study. We also see the direct correlation between the emission measure and the irradiance.
- Finally, the sunspot number is very similar to the irradiance.



# REFERENCES

- Hara, H., Tsuneta, S., Lemen, J.R., Acton, L.W., and McTiernan, J.M.: 1992, *Publications of the Astronomical Society of Japan* **44**, L135.
- Lang, Kenneth R., et al. *The Cambridge Encyclopedia of the Sun*. Cambridge University Press, 2001.
- Narukage, N., et al. “Coronal-Temperature-Diagnostic Capability of the Hinode/x-Ray Telescope Based on Self-Consistent Calibration.” *Solar Physics*, vol. 269, no. 1, 2011, pp. 169–236., doi:10.1007/s11207-010-9685-2.
- Takeda, Aki, et al. “The Hinode/Xrt Full-Sun Image Corrections and the Improved SYNOPTIC Composite Image Archive.” *Solar Physics*, vol. 291, no. 1, 2015, pp. 317–333., doi:10.1007/s11207-015-0823-8.
- “XRT (SAO, NASA, Jaxa, NAOJ).” The X-Ray Telescope on Solar-B, [xrt.cfa.harvard.edu/index.php](http://xrt.cfa.harvard.edu/index.php).



# THANK YOU

- Special Thanks to Aki Takeda, Suman Panda, and all the mentors for guiding me on this journey.
- Thank you to all my fellow students who supported me along the way.



# FILTER RATIO METHOD

$$E_i = \frac{1}{4\pi D^2} \int_0^\infty \int_\lambda N_e^2(l) P[\lambda, T(l)] \eta_i(\lambda) d\lambda dl \cdot d\sigma, \quad (1)$$

$$E_i = \frac{1}{4\pi D^2} F_i(T) \varepsilon, \quad (2)$$

$$F_i = \int_\lambda P(\lambda, T) \eta_i(\lambda) d\lambda \quad (3)$$

$$\varepsilon = \int_0^\infty N_e^2(l) dl \cdot d\sigma. \quad (4)$$

$$DN_i = f_i(T) \varepsilon \delta t_i. \quad (5)$$

$$R_{ij} \equiv \frac{DN_i / \delta t_i}{DN_j / \delta t_j} = \frac{F_i(T)}{F_j(T)}. \quad (6)$$

$$N_i = E_i / 3.65 k_e,$$

$$DN_i = N_i \delta t_i / 100,$$

Equations used from Hara et al (1992)