Active Region Simulation with EBTEL

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ABSTRACT

The temperature of the solar atmosphere counterintuitively increases from a few thousand Kelvin to well over one million Kelvin while moving away from the photosphere to the corona. This currently unexplained phenomenon is known as the Coronal Heating Problem. Since its discovery, multiple theories have been proposed to explain the strangely drastic heating. One of them is the nanoflare theory, and it was proposed on the basis of observed solar flares. Nanoflares are small-scale, impulsive heating events thought to be happening constantly in the corona. Here, we examine nanoflares as a possible heating mechanism in the bright EUV and X-ray structures of the corona, known as active regions (AR). We utilize the Enthalpy-Based Thermal Evolution of Loops code to simulate the emission of the coronal loops within AR NOAA 12846. The results are tested for varying heating parameters of the nanoflare events. Then, we compare the simulated results with the observed emissions from different passbands of XRT and AIA images.

GOAL

Simulate NOAA 12846 with EBTEL

- Study the nanoflare heating scenario in AR.
- Simulate EUV and X-ray emissions of the AR loops heated by random nanoflare events
- Compare simulated emissions with observations to understand the possibility of nanoflare heating.

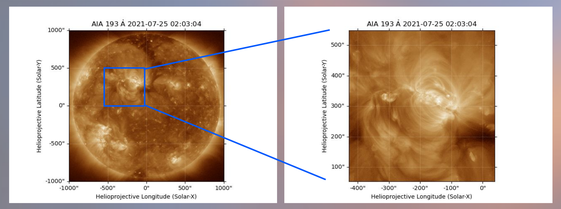


Figure 1: left - Full disk image of the sun in AIA 193 Å; right - cropped section of full disk to show AR NOAA 12846

BACKGROUND

- The sun's outermost layer is significantly hotter than the surface...Why?
- Heating mechanism for this sharp increase is not completely understood - known as the Coronal Heating Problem
- Many theories, including nanoflares
  - Nanoflares: small-scale, impulsive heating events, possibly contributing to the heating of the corona

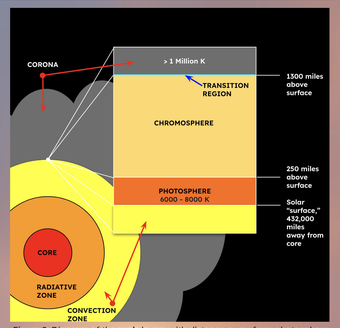


Figure 2: Diagram of the sun's layers with distance away from photosphere

QUESTION

- Can we predict heating scenarios as to simulate previously observed data?
- How do differing heating parameters change what we see in simulations?

METHODS

- Create magnetic skeleton through extrapolation
- Each loop heated by sequence of nanoflares dependent on loop lengths and magnetic-field strength
- Create simulated images using stored DEM, loop coordinates, and instrument response functions
- Compare sims with observations - create graphs showing predicted vs observed data and ratios between predicted/observed values

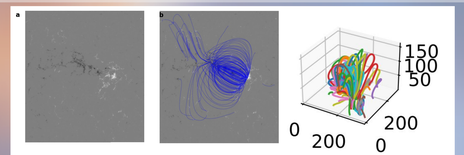


Figure 3: left - HMI LOS Magnetogram; middle - extrapolated loops over magnetogram; right - 3D skeleton

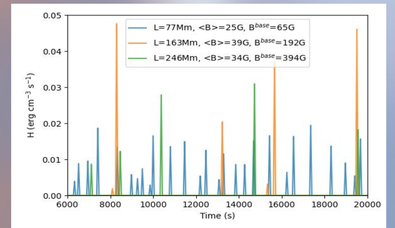


Figure 4: example of EBTEL output for differing loop lengths and magnetic field strengths

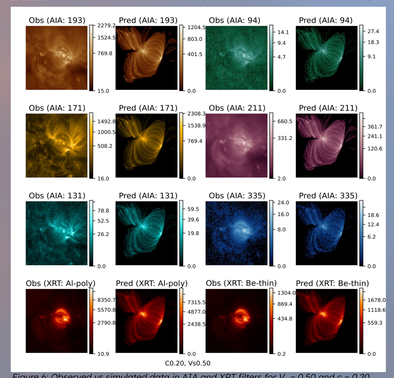


Figure 6: Observed vs simulated data in AIA and XRT filters for V_s = 0.50 and c = 0.20

EBTEL:

Input: Heating profile obtained from loop parameters such as **length, magnetic field strength, velocity** of horizontal flow (V_s), and line **tangent to loop's Parker angle** (**c**) (Diagram of V_s and c shown below)
Output: DEM (e^-, ion, and combined)

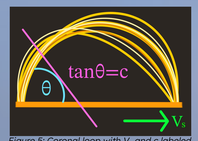


Figure 5: Coronal loop with V_s and c labeled

Credit: NASA (2021)

Credit: JAXA/ISAS (2005)

RESULTS

- Simulated AIA 94, 131, 171, 211, 355 Å; XRT Be-Thin and Al-poly using the instruments' temperature response functions
- Ratio graphs show that observed/predicted values do not match well - more work is needed to improve predictions
- **Simulated what MaGIXS would have seen of the same AR**

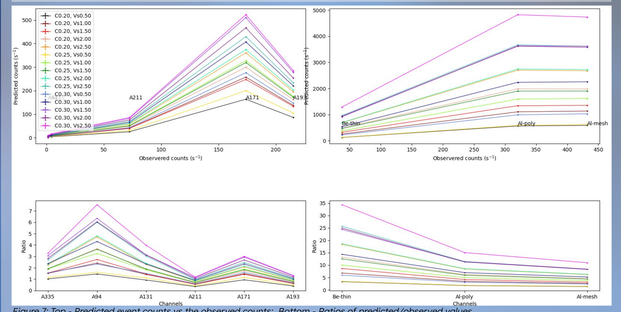
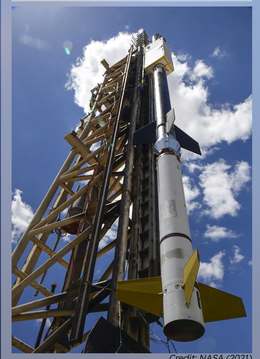


Figure 7: Top - Predicted event counts vs the observed counts; Bottom - Ratios of predicted/observed values

- MaGIXS observed different AR in various spectral lines as represented in the figure
- We simulated NOAA 12846 in those wavelengths with the MaGIXS temperature response function similar to the AIA and XRT simulations



Credit: NASA (2021)

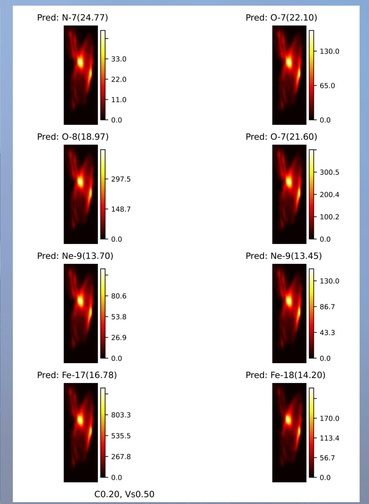


Figure 8: AR 12846 simulated with MaGIXS response

DISCUSSION

- Work done: Heating events generated randomly at varying values Parker angles and horizontal drive velocity
- Frequency of heating events vs heating velocity - same negative trend as large scale solar flares (*Figure 9*)
- Results and future results will help determine which technologies need to be incorporated in future observation instruments

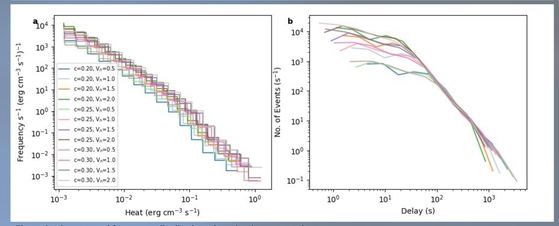


Figure 9: Histogram of frequency distribution of randomly generated events

FUTURE WORKS

- Can our current instruments resolve data with specific frequencies of heating? Do we need better technology to do so? Which frequencies show the most accurate or the brightest DEM?
- Simulate upcoming instruments' functions with differing heating frequencies - assess if instruments can diagnose nanoflare heating frequencies based on their temperature responses
- Simulate AR over a set period of time to observe how evolution of the AR affects heating scenario

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RESOURCES

For a full list of references, full sized images and graphs, and more, please scan the QR code below to visit my linktree.