Active Region Simulation with EBTEL

Hayden Dauphin[1], Biswajit Mondal[2], Amy Winebarger[2], Subramania Athiray Panchapakesan[2,3]

[1]Old Dominion University; [2]NASA Marshall Space Flight Center; [3]Center for Space Plasma and Aeronomic Research, University of Alabama in Huntsville

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 using different AIA and XRT filters to determine which parameters best align with the data.

GOAL

Simulate NOAA 12846 with EBTEL

- Compare simulations with observed data
- Test different values to alter the simulations
- Determine if the instruments we have now are resolving the DEMs they should be

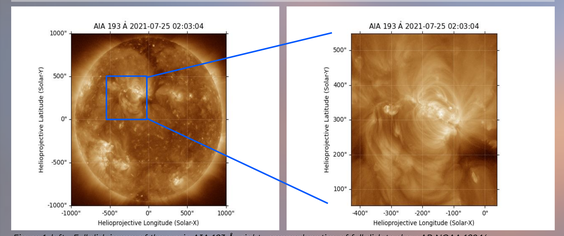


Figure 1: left - Full disk image of the sun in AIA 193 Å; right - cropped section of full disk to show AR NOAA 12846

BACKGROUND

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

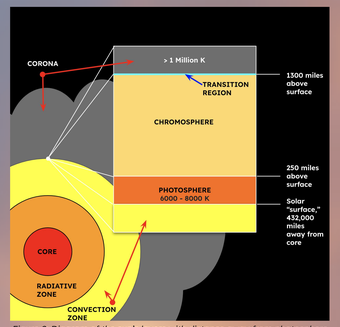


Figure 2: Diagram of the sun's layers with distance away from photosphere

QUESTION

- How do heating parameters change what we see in simulations?
- Can we see what we need to see with what we have?

METHODS

- Magnetic skeleton - extrapolation
- Run EBTEL, store DEM
- Create simulated images using stored DEM and loop coordinates from HMI magnetogram
- Compare sims with observations; ratio graphs and frequency distributions

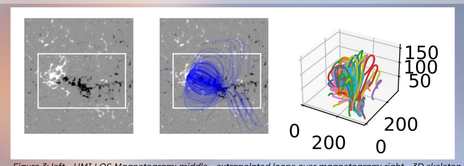


Figure 3: left - HMI LOS Magnetogram; middle - extrapolated loops over magnetogram; right - 3D skeleton

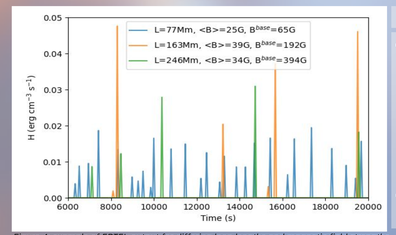
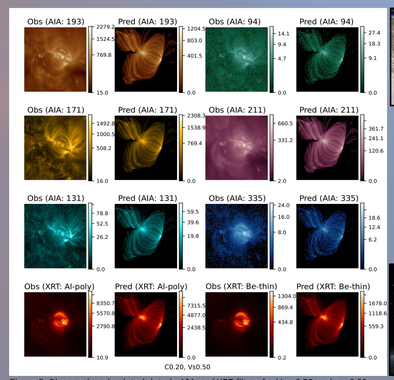
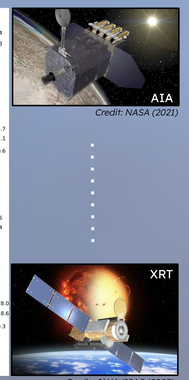


Figure 4: example of EBTEL output for differing loop lengths and magnetic field strengths

EBTEL:

- Input: Loop parameters such as length and magnetic field strength obtained from extrapolation (shown above), nanoflare heating profile
- Output: DEM; e^-, ion, and combined





Credit: NASA (2021)

Credit: JAXA/ISAS (2005)

Figure 5: Observed vs simulated data in AIA and XRT filters for V_s = 0.50 and c = 0.20

RESULTS

- Simulated AIA 94, 131, 171, 211, 355 Å; XRT Be-Thin and Al-poly using the instruments' temperature response functions
- Constant trend in observed/simulated match ratio
- Lower values of V_s and c tend to match better
- **Simulated what MaGIXS would have seen of the same AR**

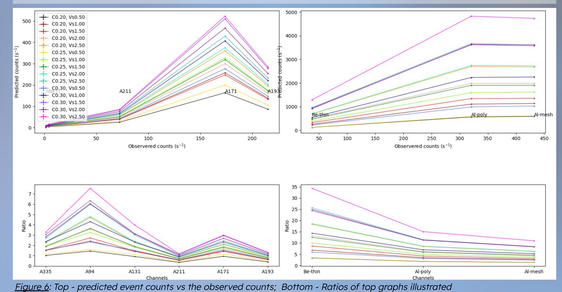
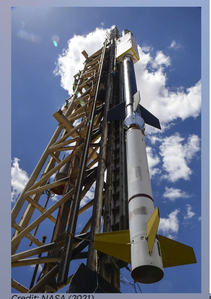


Figure 6: Top - predicted event counts vs the observed counts; Bottom - Ratios of top graphs illustrated

- MaGIXS observed 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)

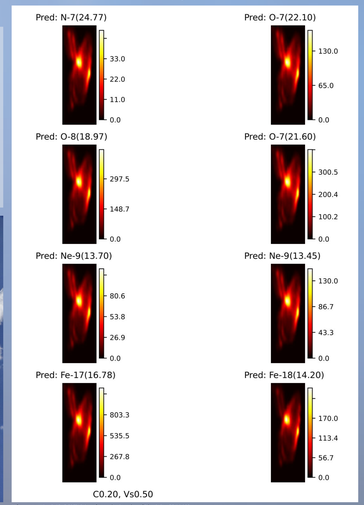


Figure 7: AR 12846 simulated with MaGIXS response

DISCUSSION

- This project: heating events generated *randomly* at varying values Parker angles and horizontal drive velocity

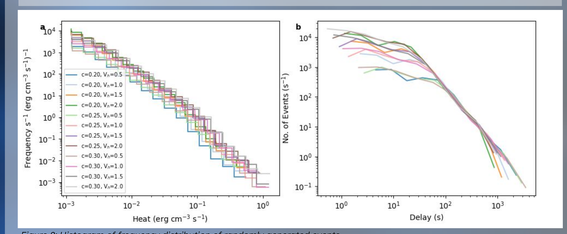


Figure 8: Histogram of frequency distribution of randomly generated events

- Next: simulate just high or low frequency events where

$$\varepsilon = \frac{\langle t_{wait} \rangle}{\tau_{cool}} \begin{cases} <1\,, \text{high frequency,} \\ >1\,, \text{low frequency} \end{cases}$$

with t_{wait} as the time between the end of one event and the beginning of the next and τ_{cool} as the heating frequency in terms of ratio between fundamental cooling timescale *(Barnes, 2019)*

  - 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 MaGIXS, CubIXSS, and upcoming instruments' functions with differing heating frequencies - assess if instruments can diagnose nanoflare heating frequencies based on their temperature responses

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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.