Exploring the Sun's Active Regions in the Moments Before Flares

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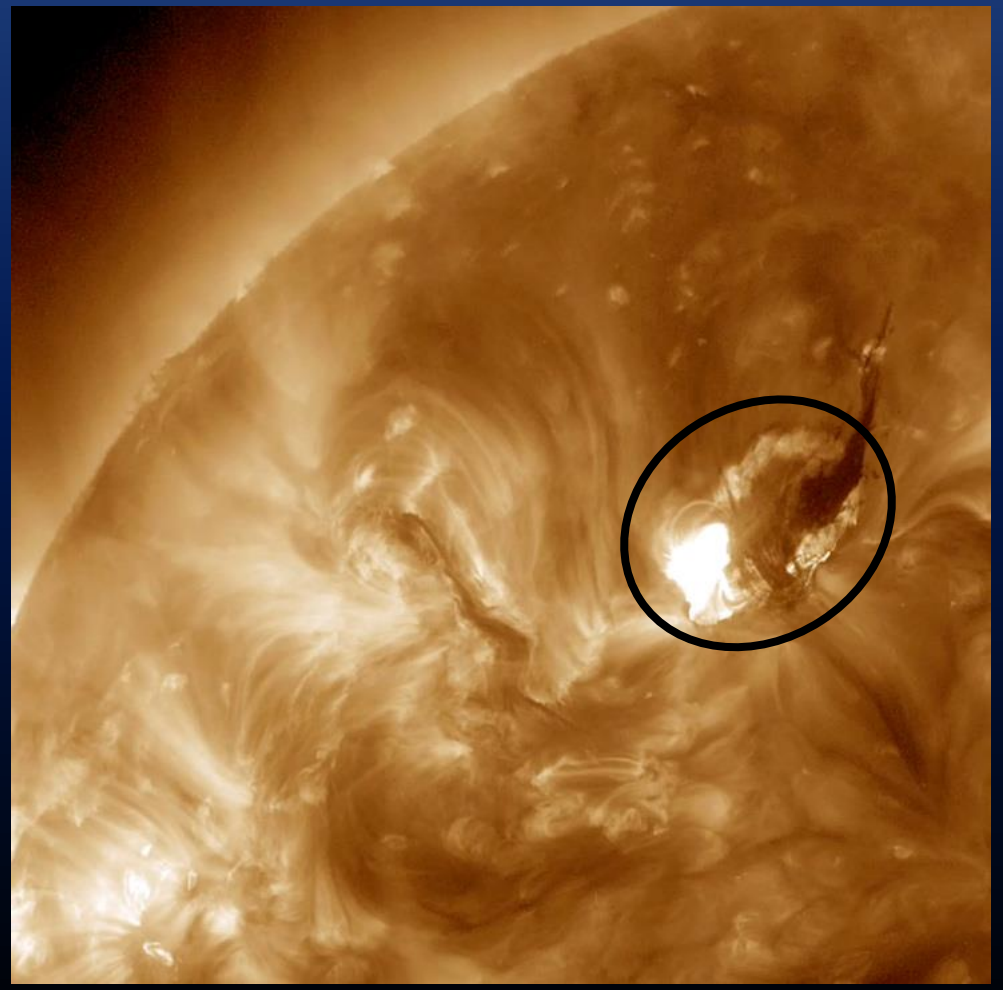
Solar Flares are Powerful

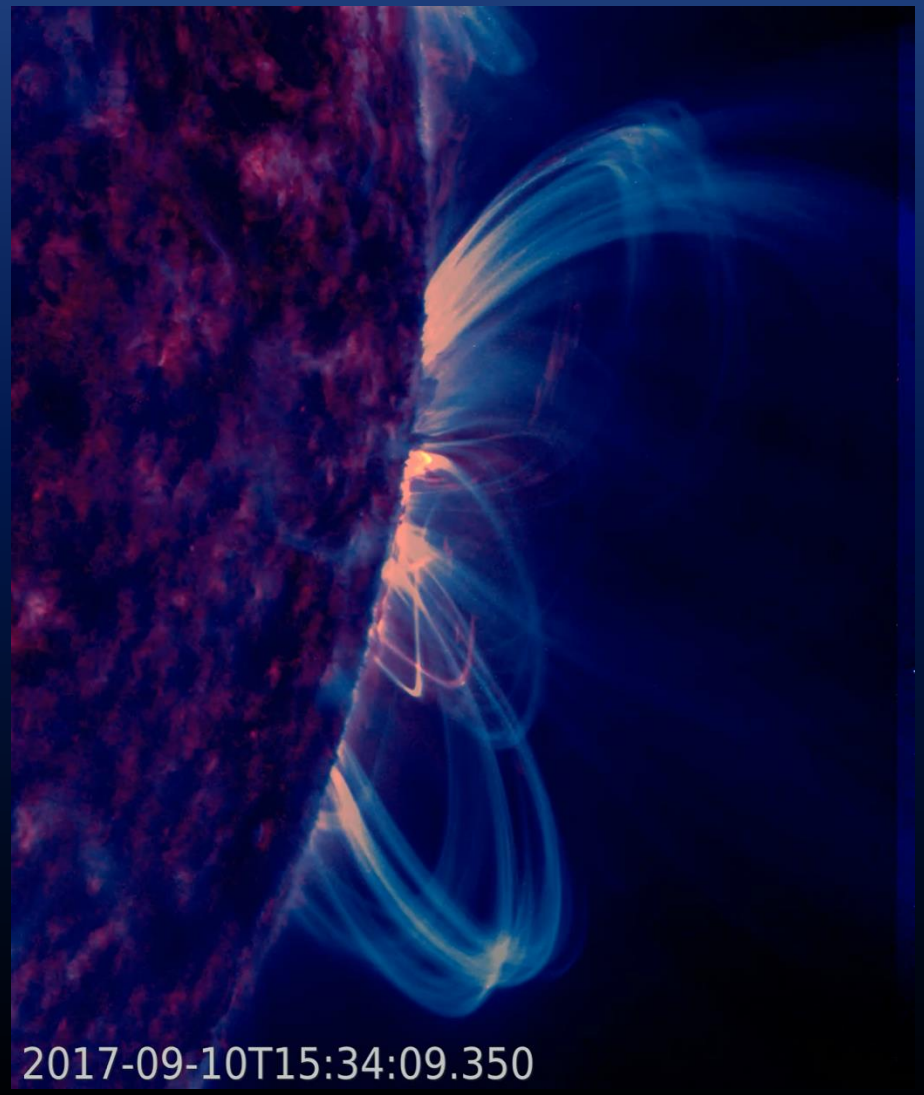
- Solar flares are what we observe when the Sun converts magnetic energy into light and motion

- We're talking about **a lot** of energy: an average flare releases enough energy in 1 second to power the US for 1 year

- They occur in large regions of very strong magnetic field, known as active regions (we're not creative with names)



…and Hard to Predict



- Flares can cause disruptions to the power grid, GPS, satellites, cellular systems, etc.
- Pinpointing when and where a flare is going to happen is extraordinarily difficult
- This is in large part because we don't yet understand what triggers the beginning of a solar flare

Our study is a promising step in the right direction

Solar Dynamics Observatory

- Observes the Sun 24/7/365
- 7 extreme ultraviolet wavelengths, magnetic fields, and visible "channels"
- Each channel focuses on plasma (superheated gas) at a specific temperature; together they give us a picture of what's happening on the Sun

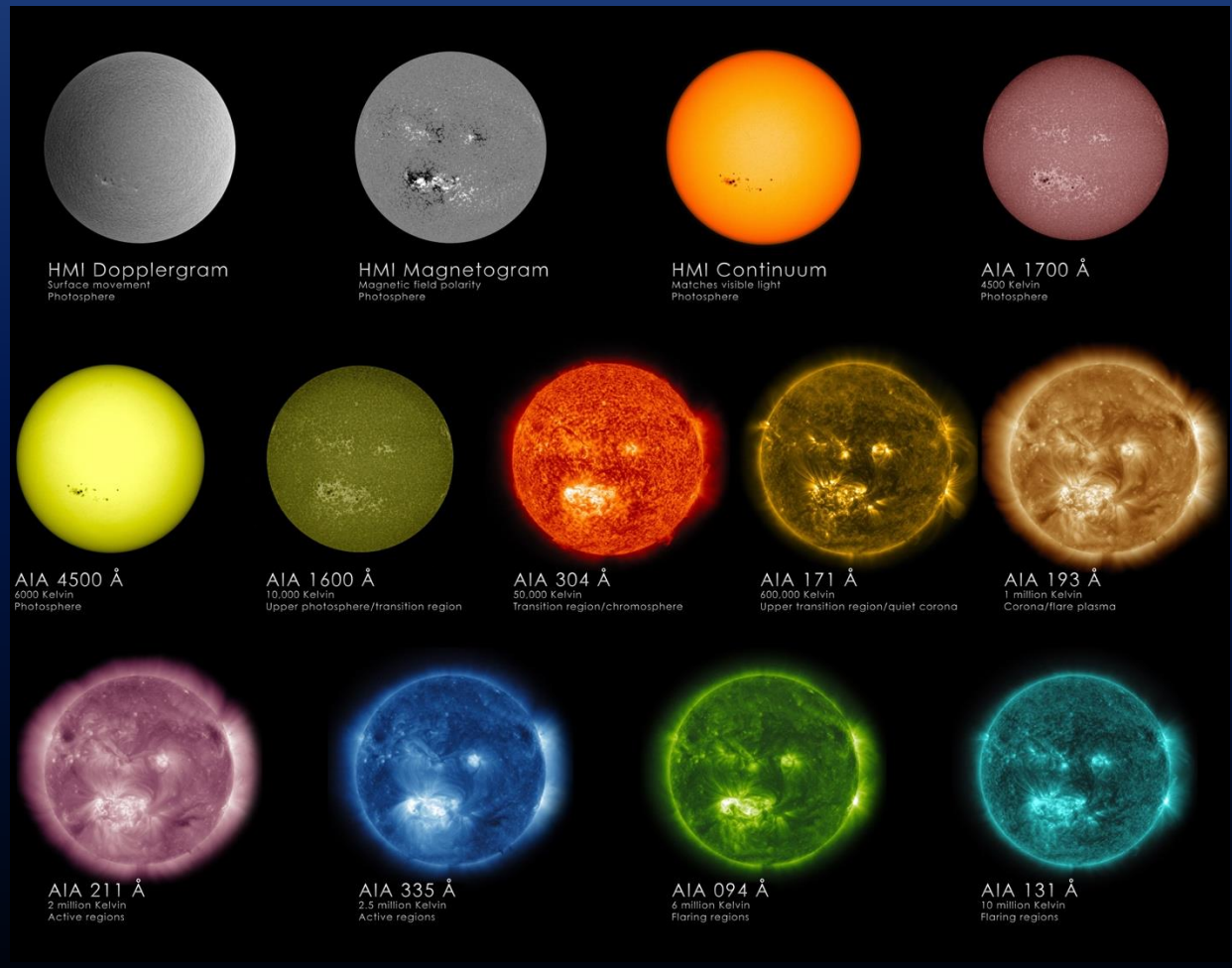


Image Credit: NASA/SDO/Goddard Space Flight Center

Our Study

- We used the 131, 171, 193, and 304 Å channels
- This gave us a wide range of temperatures to investigate (about 50,000 – 10 million degrees)
- Focusing on the brightening/dimming of coronal loops
- Coronal loops are exactly like the field lines you'd see from the classic iron filings/magnet science demo (just with hot gas, not iron)

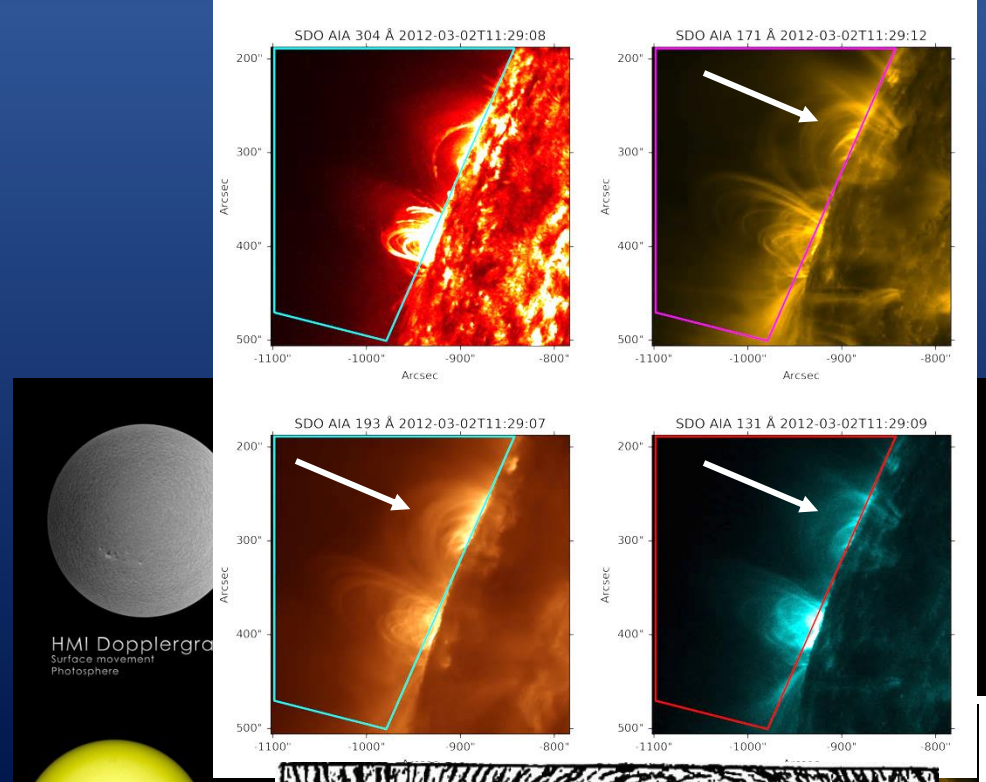


Image Credit:

Image credit: *The Principles of Physics*, 1895

Looking for Flare "Tells"

Like trying to read a poker player, we wanted to see if changes in the brightness of the loops above an active region foretell a flare

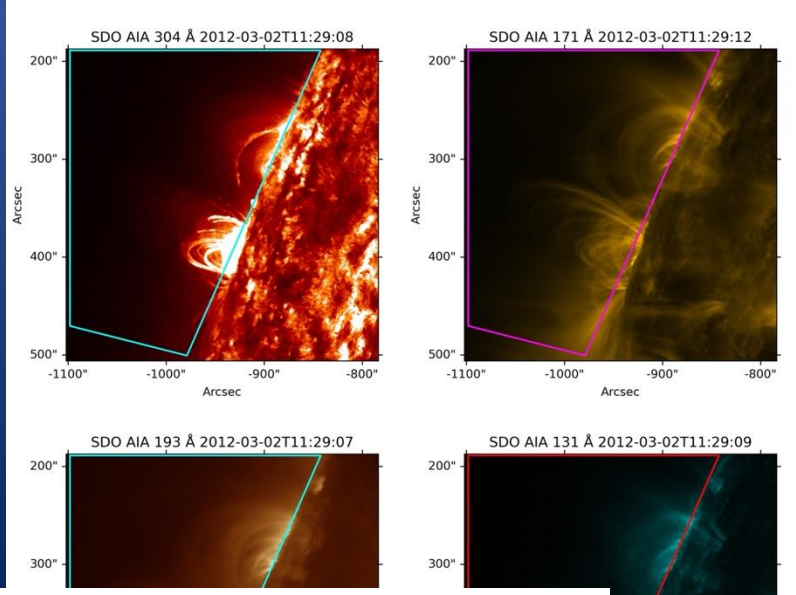
- Selected 50 flares from C, M, and X classes (X-ray classification, from fairly common to extreme)
- Used flares that SDO observed on the edge (or limb) of the Sun, to be able to see the loops clearly
- Also had to ensure no other active regions were overlapping with the flaring one, *and* that no major flares occurred for 6 hours prior

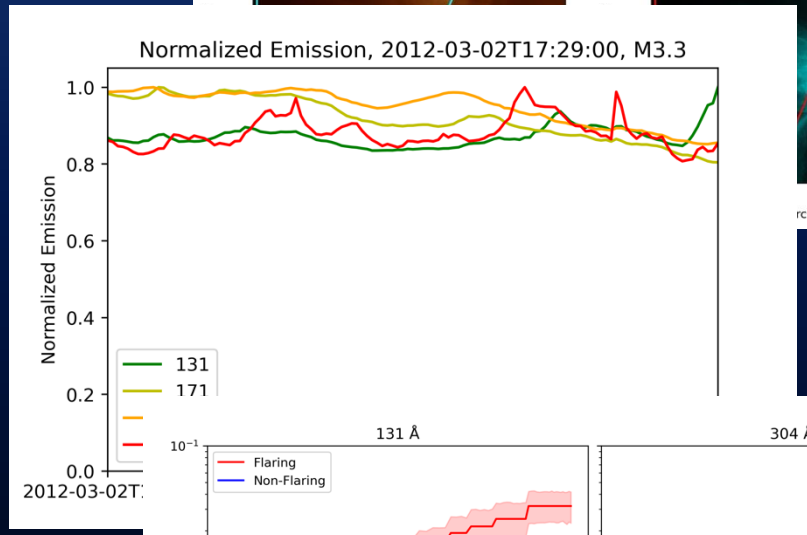
Crunching the Numbers

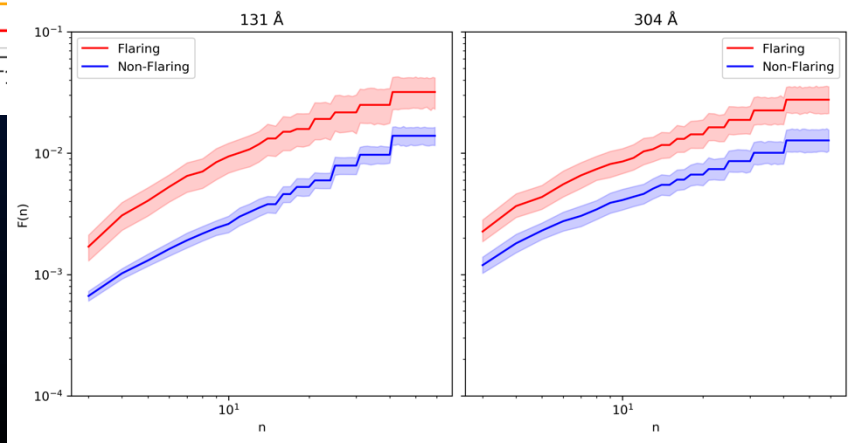
1. We drew boxes around the loops and summed up the light captured within each box for 6 hours before each flare

2. Then we graphed the totals over the 6 hours

3. We compared the variability of the flaring cases to a set of 30 non-flaring observations (selected and analyzed the same way)







What Did We Learn?

- Loops above flaring active regions were more variable than non-flaring cases 60-80% of the time *in all wavelengths studied*, with 131 and 304 Å (the coolest plasma) showing the strongest correlation

- This variability generally peaks 1-2 hours before a flare, possibly with stronger flares providing more warning*

- The variability is dominated by rapid changes in brightness, which hints at small-scale heating events within the loops

- Spikes in 131 Å brightness were a precursor more often for confined flares (flares without a coronal mass ejection)

* Our pool of X class flares was very small, so we need to do more work to confirm this relationship.

Next Steps

- Testing the method with more complex cases (flares not on the limb, active regions with overlap, etc.)
- Testing the method on blind cases (looking at 6 hours of data and predicting flaring without knowing if there was a flare *a priori*)
- Investigating the cause of the small-scale brightenings that drive the variability

Most of this work will be Kara's PhD thesis