Heating Features of Interesting Supra-arcade Downflows

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Abstract

Supra-arcade downflows (SADs) have been observed above flare loops during the decay phase of flare. They appear as tadpole-like dark plasma voids traveling towards the Sun. In areas surrounding where they appear, temperatures are often high. We aim to investigate temperature and heating mechanism of SADs. We apply our analysis to the M1.7 flare that occurred on 2012 July 12 and was observed by the Atmospheric Imaging Assembly (AIA) on the *Solar Dynamics Observatory*. There are many obvious SADs above the arcade during this event in the AIA 131 Å channel. We calculate the differential emission measure and emission measure weighted temperature with AIA data in the region where SADs are concentrated. We find that the temperature in SADs region tends to be lower than the surrounding plasma. We also calculate velocities of SADs using the Fourier Local Correlation Tracking (FLCT, Fisher & Welsch, 2008) method to derive velocities in the supra-arcade region. Using corks to track the calculated velocities, we find our velocity results are consistent with the SAD motions in the AIA 131 Å intensity movie. We use the velocities to derive the adiabatic heating caused by the compression of plasma. Preliminary results indicate that there is adiabatic heating in front of the SADs.

Background

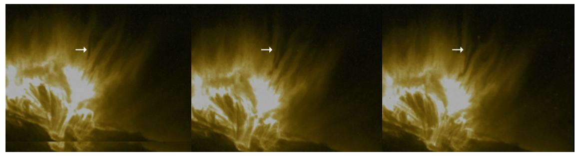

Figure1: Supra-arcade Downflows (SADs) are dark plasma voids flowing towards the Sun during the decay phase of flare. SAD (TRACE 195 Å on 2002 April 21) is pointed out with white arrow in this figure.

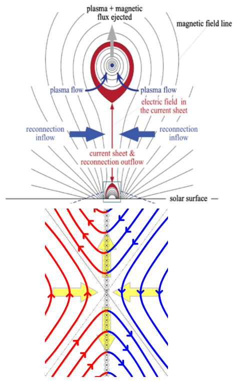

Figure2: Upper: Sketch of the flux rope/CME model of Lin and Forbes (2000) (Lin et al., Space Sci Rev, 2015). Lower: Magnetic Reconnection.

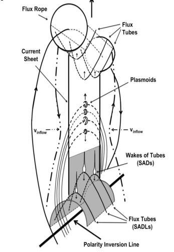

Figure3: A model for SADs (Savage et al., ApJ, 2012).

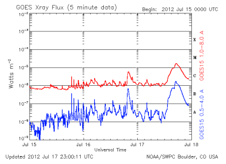

Figure4: Goes X-Ray Flux. The decay phase of flare lasts for few hours.

We calculate the adiabatic heating of SADs. Adiabatic heating is caused by the compression of plasma and is determined by the following equation: $H_a = -(\gamma - 1)T\,\nabla \cdot v$ (Reeves et al., ApJ, 2017).

Event

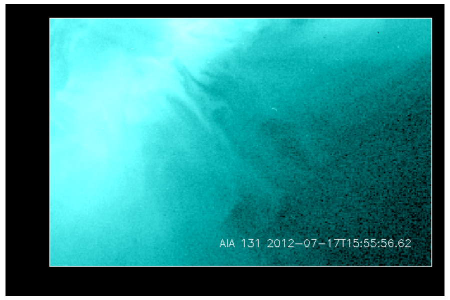

Figure5: Subregion of M1.7 flare on July 17 2012. At the moment shown in this figure, there are many SADs and good contrast.

Velocity

We use Fourier Local Correlation Tracking (FLCT, Fisher & Welsch, 2008) method to derive velocities. FLCT calculates cross-correlation of two images to find the most similar points in order to get displacement. There are three parameters in this process: σ, threshold and low-pass filter (k value). σ is Gaussian width. Threshold is set to exclude dim pixels. And k value is to remove high spatial frequency noise.

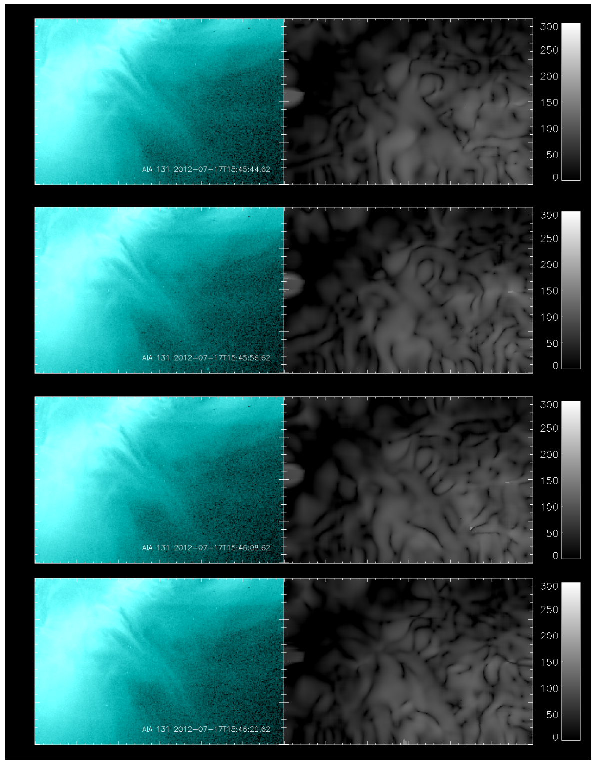

Figure6: Velocity Movie. From these panels, we can see that the flows in the velocity movie match the flow in the intensity movie.

Smooth

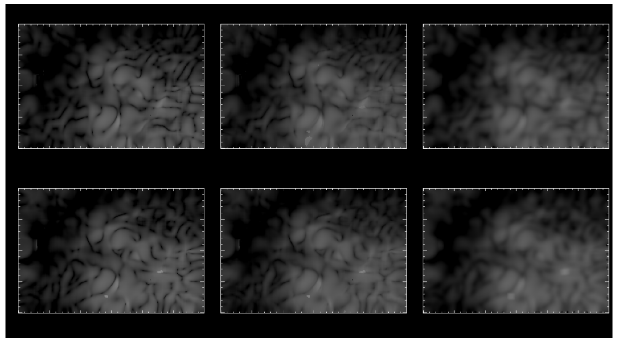

Figure7: Left Panel: Original velocity data. Middle Panel: Temporal Smooth. Right Panel: Boxcar Smooth. We use different ways to smooth the velocity data in order to get rid of noise. Unfortunately, there is not much enhancement.

Cork

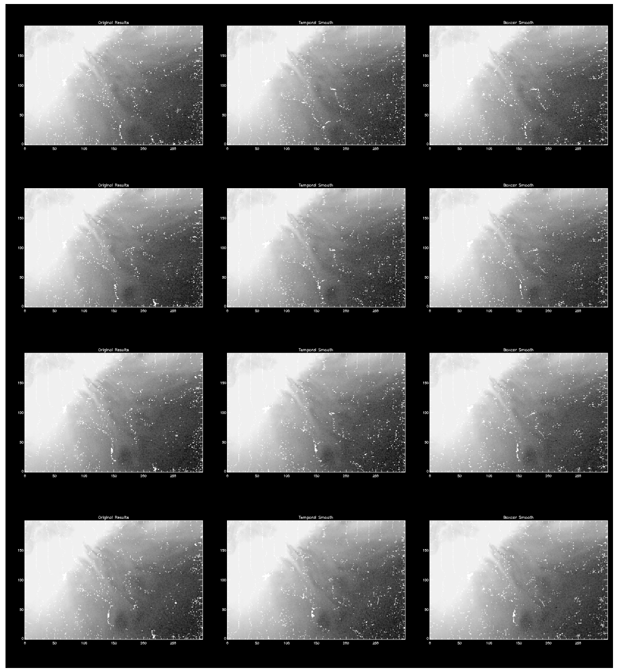

Figure8: "Corks" track the calculated velocities. The background images are intensity images. When we see a downflow on intensity image, "corks" also move with the downflow, which means the calculated velocities are correct. The distribution of the three panels are the same as Figure7. There isn't much difference between these three smoothed data sets, so we use the original calculated velocities in the following.

Heating

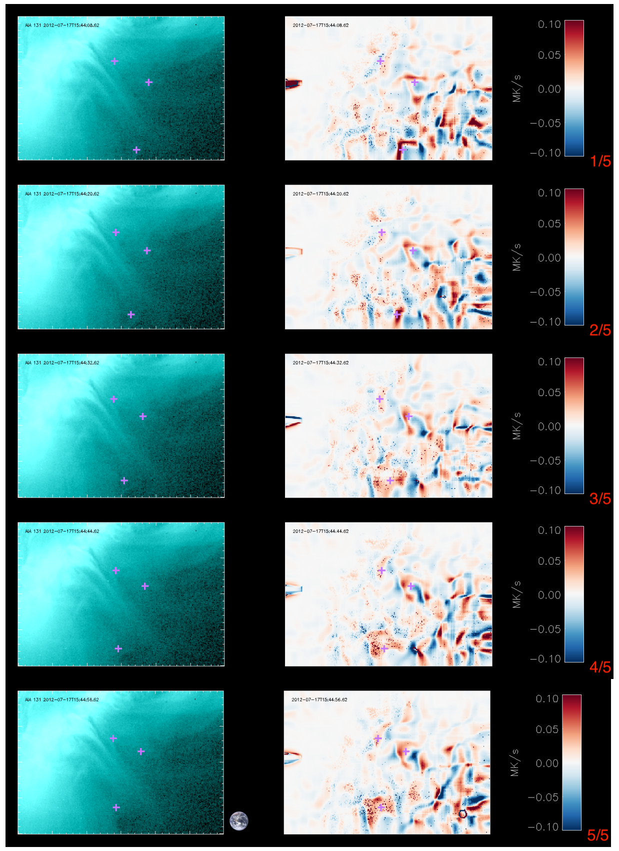

Figure9: Left Panel: Intensity. Right Panel: Adiabatic heating. The temperature was calculated from the AIA data using a differential emission measure (DEM) technique. There is a purple plus symbol in front of each SAD. In heating figures, red represents heating and blue represents cooling. From these figures, we can conclude that there is always heating in front of SADs. The order of heating rate is about 0.1MK, which is enough to overcome cooling. And from the last figure, the size of SAD is about the same size as the Earth.

Conclusions

1. There is heating in front of SADs and cooling behind them.
2. Adiabatic heating is on the order of about 0.05MK/s.
3. Heating is enough to overcome conductive cooling.
4. SADs help heating plasma.

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