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Constant cross section of loops in the solar corona

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More information in Bingert & Peter (2012) A&A 548, A1: Click here for link to ADS.

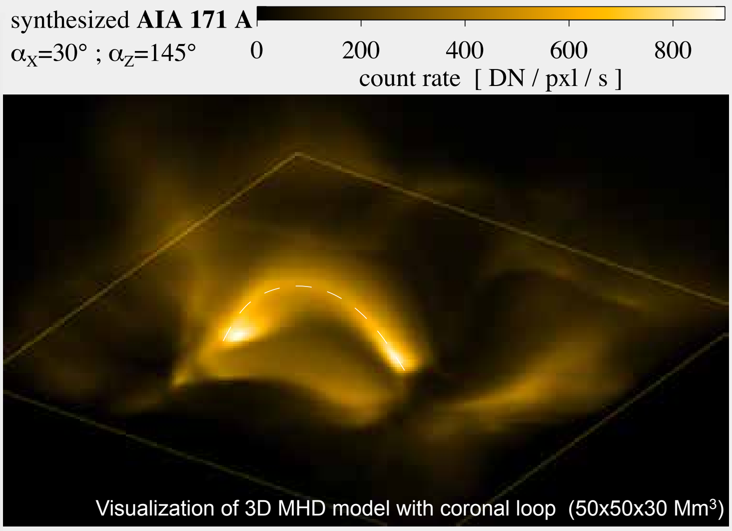
The corona of the Sun is dominated by emission from loop-like structures. When observed in X-ray or extreme ultraviolet emission, these million K hot coronal loops show a more or less constant cross section.

In this study we show how the interplay of heating, radiative cooling, and heat conduction in an expanding magnetic structure can explain the observed constant cross section.

We employ a three-dimensional magnetohydrodynamics (3D MHD) model of the corona. The heating of the coronal plasma is the result of braiding of the magnetic field lines through footpoint motions and subsequent dissipation of the induced currents. From the model we synthesize the coronal emission, which is directly comparable to observations from, e.g., the Atmospheric Imaging Assembly on the Solar Dynamics Observatory (AIA/SDO).

We find that the synthesized observation of a coronal loop seen in the 3D data cube does match actually observed loops in count rate and that the cross section is roughly constant, as observed. The magnetic field in the loop is expanding and the plasma density is concentrated in this expanding loop; however, the temperature is not constant perpendicular to the plasma loop. The higher temperature in the upper outer parts of the loop is so high that this part of the loop is outside the contribution function of the respective emission line(s). In effect, the upper part of the plasma loop is not bright and thus the loop actually seen in coronal emission appears to have a constant width.

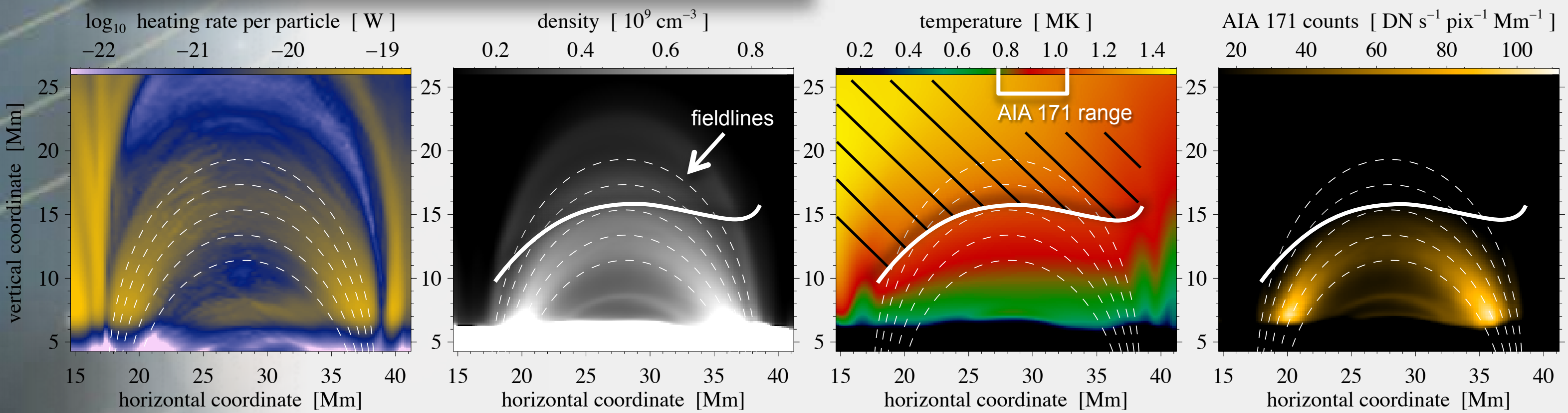
From this we can conclude that the underlying field-line-braiding heating mechanism provides the proper spatial and temporal distribution of the energy input into the corona – at least on the observable scales.



Visualization of 3D MHD model with coronal loop (50x50x30 Mm³)

We solve the time-dependent 3D MHD problem, i.e. the induction equation along with the mass conservation, momentum, and energy balance from the cool solar surface into the hot corona above an active region. The energy equation includes Spitzer heat conduction along the magnetic field, optically thin radiative losses and Ohmic heating. Only this ensures a proper description of the coronal pressure, which is prerequisite to synthesizing EUV emission as would be expected for, say, AIA observations.

Details of our model are found in Bingert & Peter (2012) A&A 548, A1.



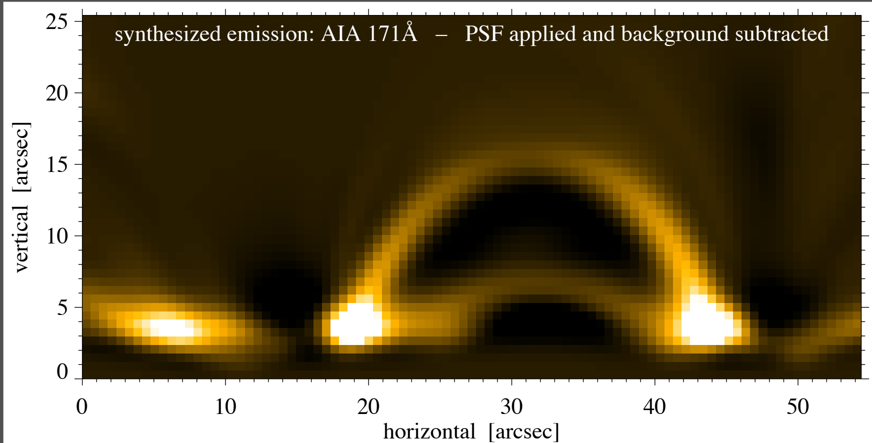
Cuts through the loop plane

The magnetic field expands by about a factor of 5.

The density structure also expands along the loop.

The peak temperature of longer fieldlines is smaller
→ cuts off top part of density structure !

The resulting 171 Å emission has constant cross section.



Synthetic AIA 171 Å observation of the constant-cross section loop

View of the synthesized coronal loop in AIA 171 Å (top right of poster) when horizontally integrating through the box along a line-of-sight perpendicular to the loop plane. The AIA 171 Å point spread function (PSF) was applied and the image is shown with the same pixel size as AIA (0.6” corresponding to 435 km on the Sun). As in observations, a background sub- traction was applied to enhance the contrast.

Further reading:

The constant cross section of loops is a long-standing problem. A comprehensive discussion of the observational findings can be found in *Klimchuk (2000) Solar Phys. 193, 53* and *Watko & Klimchuk (2000) Solar Phys. 193, 77.*

The first to point to the non-trivial relation of magnetic and thermal structure in 3D MHD getting a basic reasoning for constant cross section were *Mok, Mikic, Lionello & Linker, 2008, ApJ 679, L161.*

A model to show the role of the non-isotropic expansion of the magnetic field is found in *Malanushenko & Schrijver (2013) ApJ 775, 120.*