Coronal active region modeling based on SDO data

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The heating of the solar corona, which has a temperature of order of 10^6K compared to 5000K in the photosphere, is yet a puzzling problem. Several models to describe the physical parameters, e.g. temperature or density, along coronal loops with different assumptions for the relevant physical processes (like wave damping) were suggested in the past, for example the RTV78 model by Rosner, Tucker and Vaiana. With these models and the knowledge of the 3D configuration of the magnetic field above an active region it is possible to calculate the radiation emitted by the coronal loops above this region. This 3D field configuration is provided for an active region with the help of a nonlinear force free field optimization code from photospheric SDO/HMI vector magnetograms as boundary conditions. We use this field to model the plasma along these loops with the RTV78 model and create artificial coronal images in different wavelength, which we compare with images obtained with the multispectral imager SDO/AIA. Such comparisons allow us to evaluate the quality of our model approach.

The basic idea is to use a reconstructed field above an active region and different loop models to create artificial images:

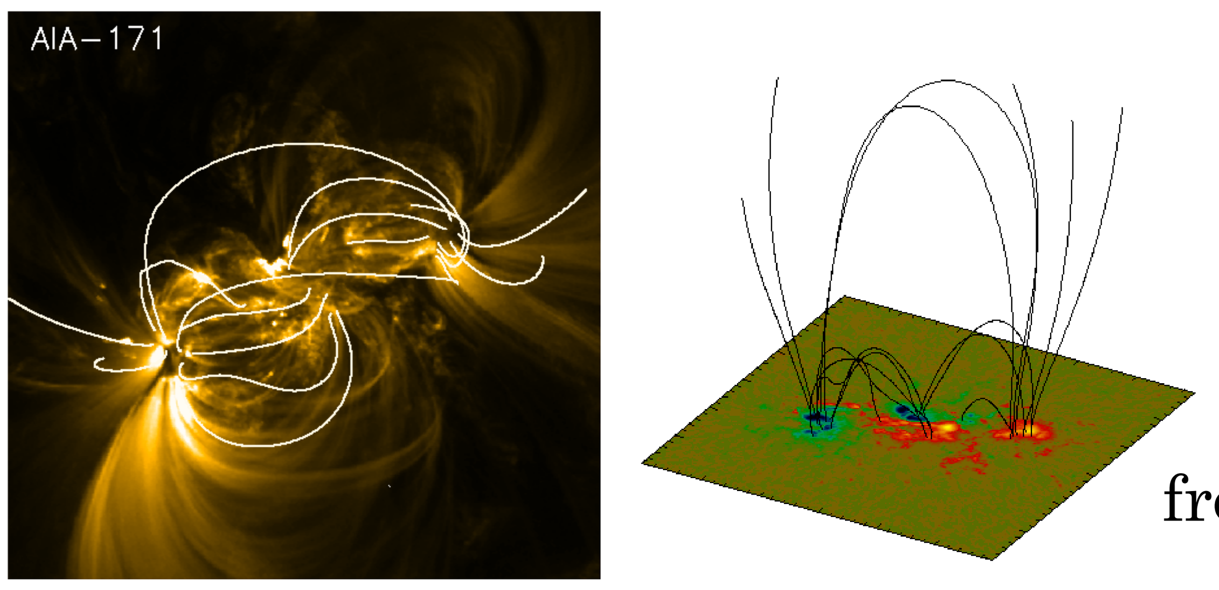
field geometry + loop model + filter
=> artificial image in various wavelengthes

Comparison with images from satellites will give us a hint which models, and thus the underlying heating processes, are able to explain the observations.

To recover the 3D geometry of the magnetic field of an active region, a code based on an optimization approach [1] was used by Wiegelmann et al. [2], with SDO/HMI data as boundary conditions. Hence it is a nonlinear force free field it fulfils the equations

$$\nabla \times \vec{B} = \alpha \vec{B} \qquad \nabla \cdot \vec{B} = 0$$

with a spatially varying α.



from [2]

As loop model we took the basic RTV78 model [3], which uses the energy balance

$$E_{heating} + E_{cooling} - \nabla \cdot \vec{F}_{heat} = 0$$

with constant pressure along the loop. The loop temperature can be expressed then as a function of the loop coordinate, the maximum temperature and the pressure. To close the set of equations, we use both a model by Golub et al. [4]:

$$\underset{\text{pressure}}{p} = 63\underset{\text{z component of field}}{B_z^{3/2}}\underset{\text{loop length}}{L^{-1/4}}$$

and one by Schrijver et al. [5]:

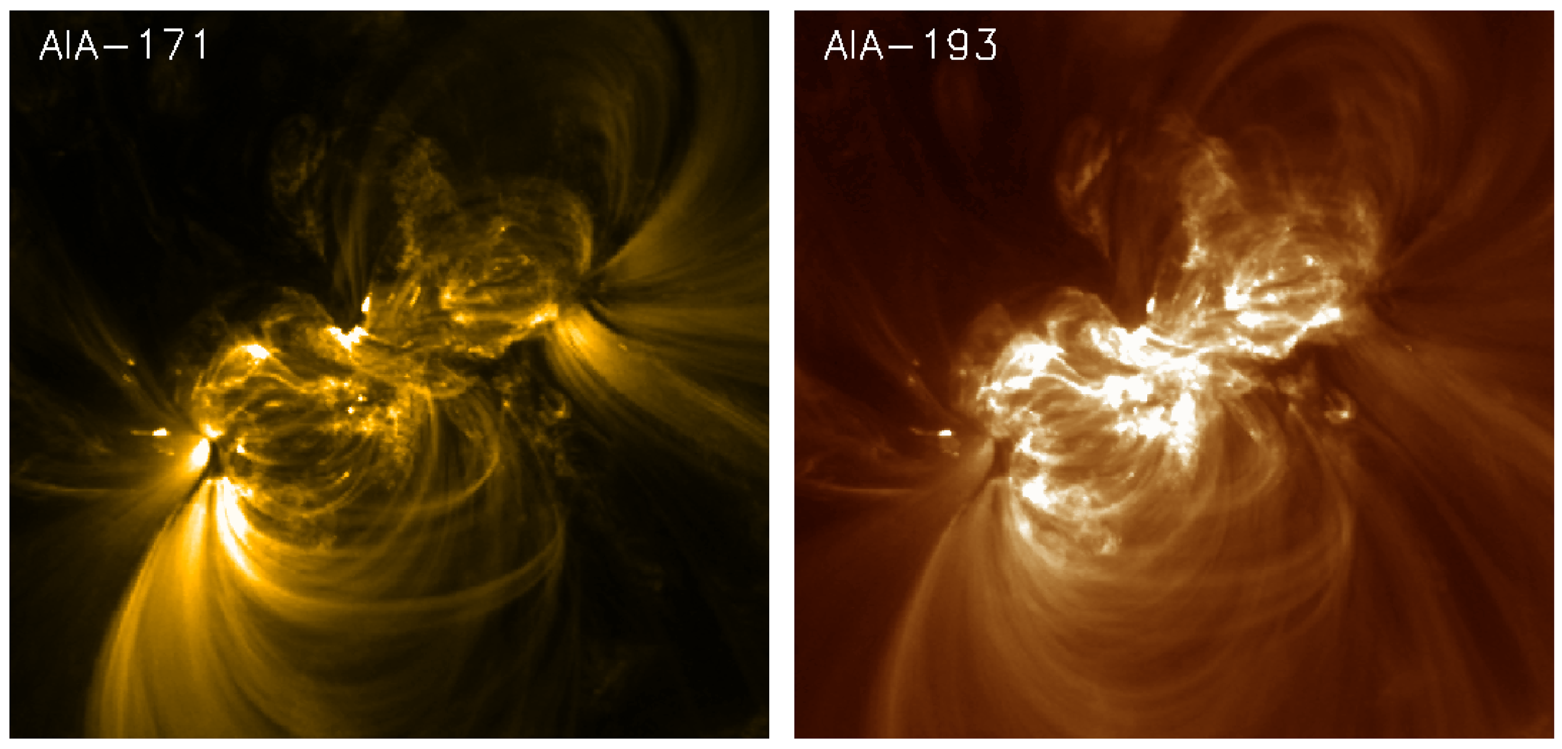
$$\underset{\text{max. temp.}}{T_m} \approx \sqrt[3]{1400 \cdot \underset{\text{field strength}}{B} e^{-(B/500)^2}}\, e^{L/10\underset{\text{pressure scale height}}{s_p}}$$

together with the ideal gas equation.

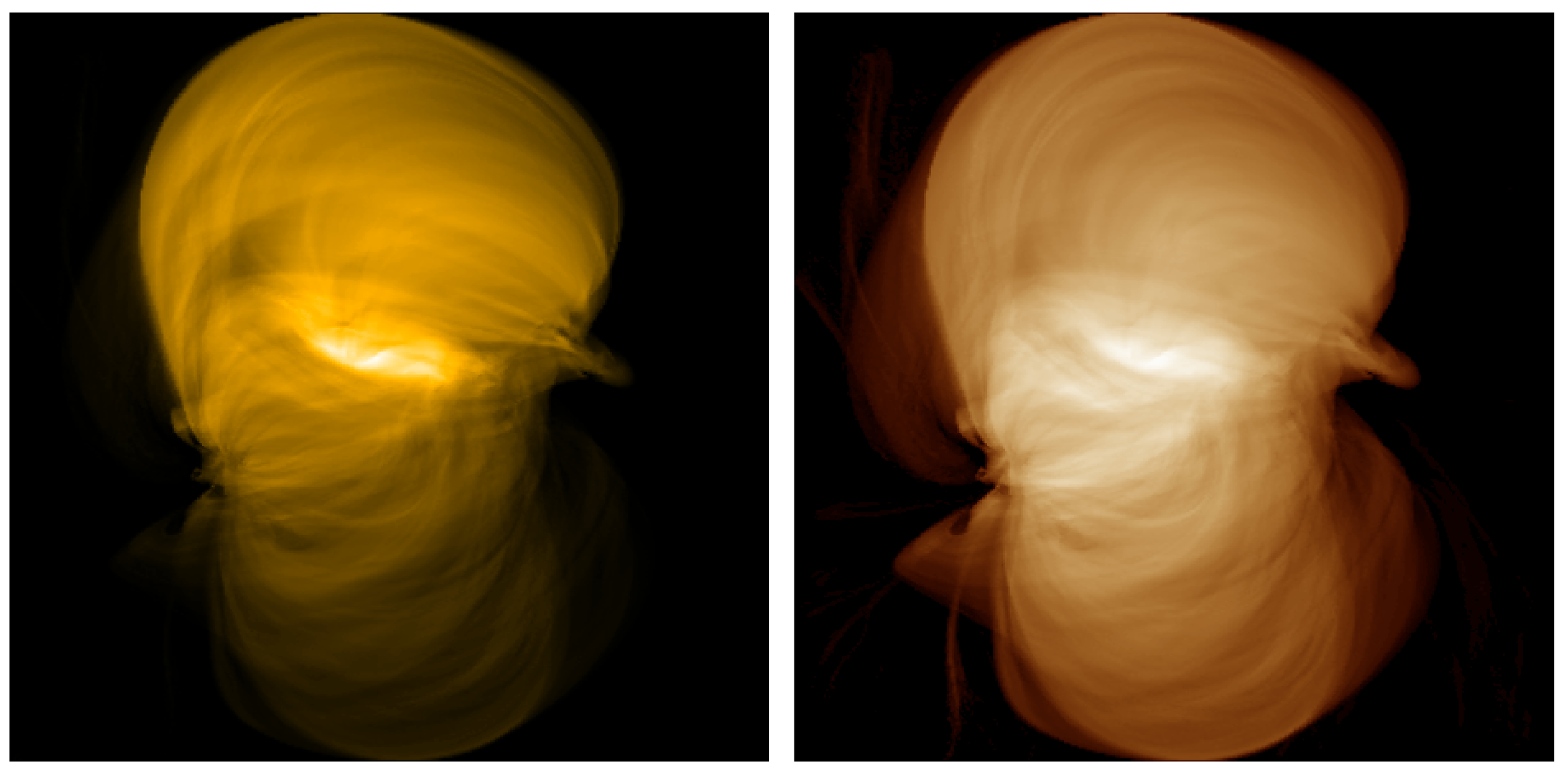
After computing temperature density and pressure in a grid of 300x300x160 cells à 720 km we computed the differential emmission measure of each cell and folded it with the response functions of SDO/AIA [6] in seven EUV channels.

Qualitative results (color scalings not the same):

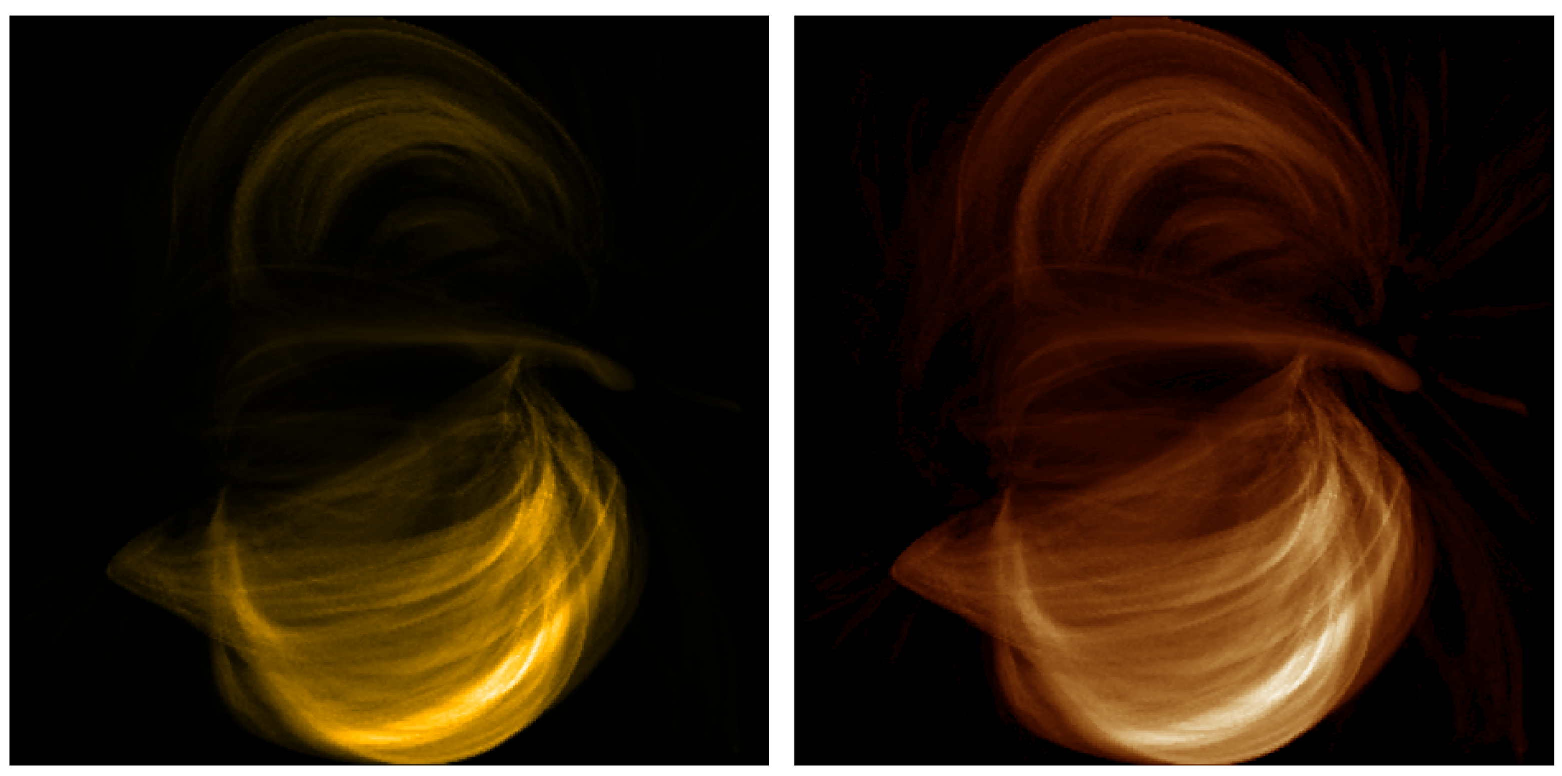
AIA images [7]



Model RTV78 + Golub et al. 82



Model RTV78 + Schrijver et al. 04



The basic features of the loops above an active region were recovered successfully. However, there are still discrepancies. The comparison between RTV+Golub et al. and RTV+Schrijver et al. also shows that the results are very sensitive to the method which is used to get the physical parameters of a loop.

[1] Wheatland et al; ApJ, 540, 1150 (2000) [2] Wiegelmann et al; SoPh, 67W (2012) [3] Rosner et al; ApJ, 220, 643 (1978)
[4] Golub et al; ApJ, 259, 359 (1982) [5] Schrijver et al; ApJ, 615, 512 (2004) [6] Boerner et. al.; Solar Phys, 275, 41 (2012) [7] NASA