# SIMULATING SECCHI/EUVI OBSERVATIONS OF ACTIVE REGION CORONAE

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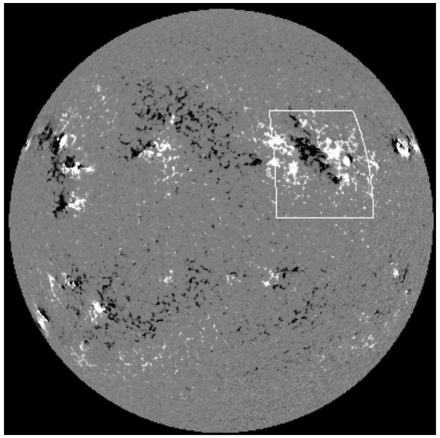
**Using potential field extrapolations of active region magnetic fields, observed by SOHO/MDI, as a representation of a real active region, we apply hydrostatic and hydrodynamic coronal loop models to the derived magnetic structures and generate realistic distributions of temperature and density throughout the simulated corona. These distributions are then folded through the EUVI instrument responses and projected onto the plane of the sky to yield simulated EUVI images. The simulated images will also incorporate the EUVI point-spread-function, EUVI pixel size, background emission and noise. These simulations can provide a set of test data for future 3D STEREO reconstruction methods.**

# Introduction

**To simulate the expected observations of the SECCHI/EUVI we have utilized an approach which provides a realistic set of temperature and density distributions throughout an active region. These simulations are based upon a combination of real data (magnetograms), observational results from SOHO/EIT, TRACE and Yohkoh (heating rates and heating scale heights), representations of the coronal field (potential field extrapolations), calculation of temperature and density distributions (hydrostatic loop models), expected EUVI characteristics (pixel size, PSF, temperature response), and 3D simulation (volume rendering).**

**These simulated data provide an appropriate representation of the expected observations and as such provide a useful input to image reconstruction techniques currently being developed for the STEREO mission.**

# Generation of Active Region Field

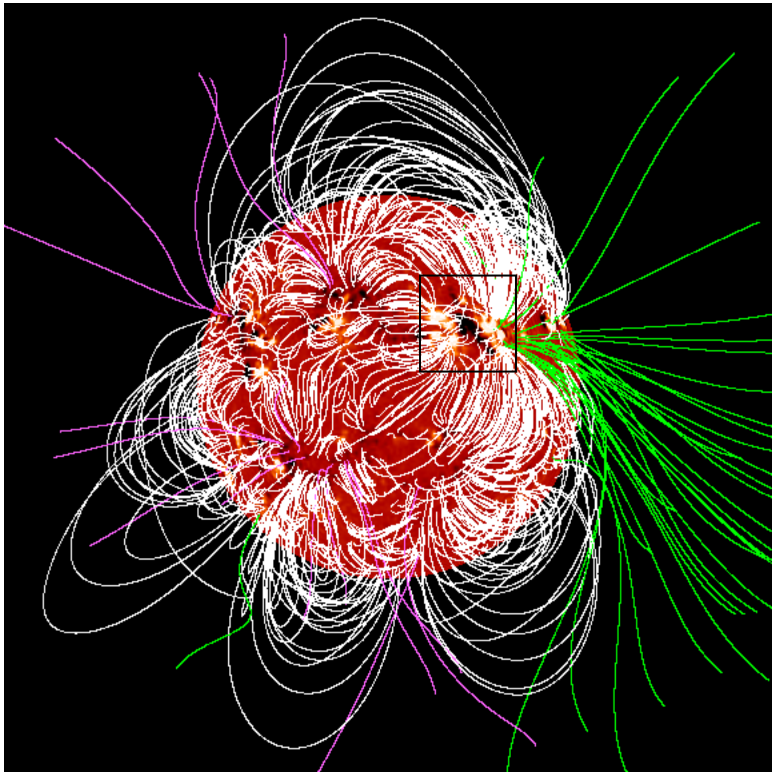


We use a potential field, $\nabla \times B=0$, solving Laplace's Equation $\nabla^2\Phi=0$ within the coronal volume, where $\nabla\Phi=-B$.

In spherical polar coordinates, $\nabla^2\Phi=0$ is solved by

$$\Phi(r,\theta,\varphi)=\sum_{l,m}\left[A_{lm}r^{l}+B_{lm}r^{-(l+1)}\right]Y_{lm}(\theta,\varphi)$$

where the coefficients $A_{lm}$ and $B_{lm}$ are determined by the imposed boundary conditions in radius. At $r=R_{sun}$, we set the radial component of B equal to the field observed in an MDI magnetogram $M(\theta,\phi)$:



$$\frac{\partial\Phi}{\partial r}=-M(\theta,\varphi) \qquad \text{at } r=R_{sun}$$

We also force the field to become radial at a spherical source surface: $\Phi=0$ at $r=2.5R_{sun}$. Once $\Phi$ is known, B can then be calculated and the field lines can be traced through the volume using

$$\frac{dr}{B_r}=\frac{r d\theta}{B_\theta}=\frac{r\sin\theta d\varphi}{B_\varphi}$$

# Hydrostatic Solutions

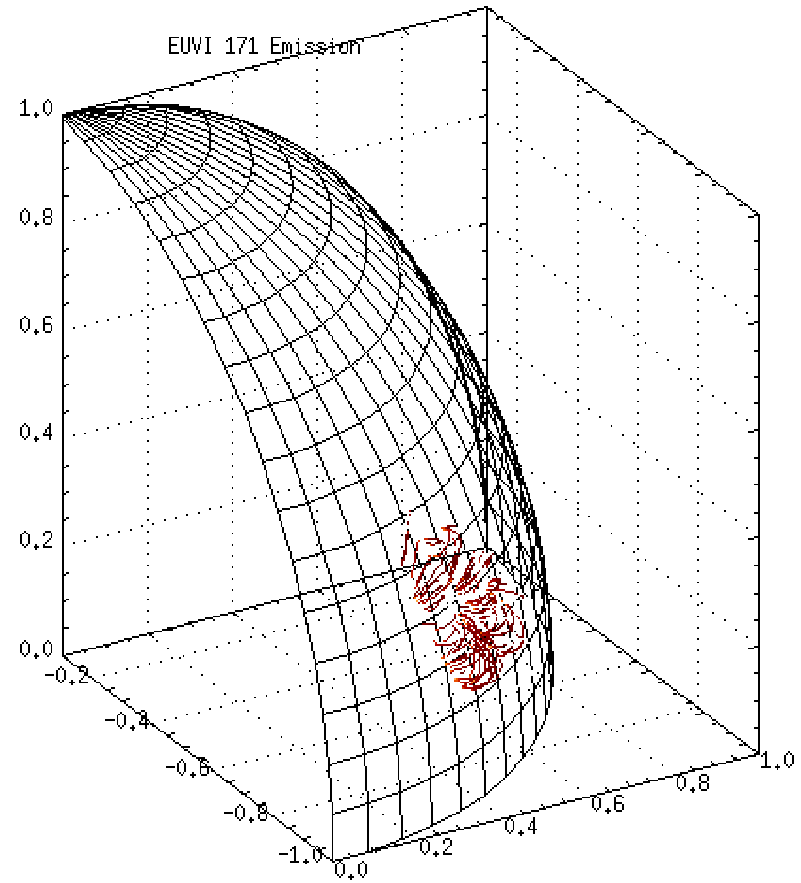
**The solutions used to determine the distributions of temperature and density along the extrapolated field lines satisfy the usual hydrostatic equations.**

**The heating rate is assumed to be of the form:**

$$E_h(s) = E_{h0} e^{-s/s_h}$$

**where $E_{h0}$ is the base heating rate, s is the loop coordinate, and $s_h$ is the heating scale height.**

**In what follows we will adopt different forms for $E_{h0}$ but $s_h$ will be fixed at $s_h$ =10 Mm.**



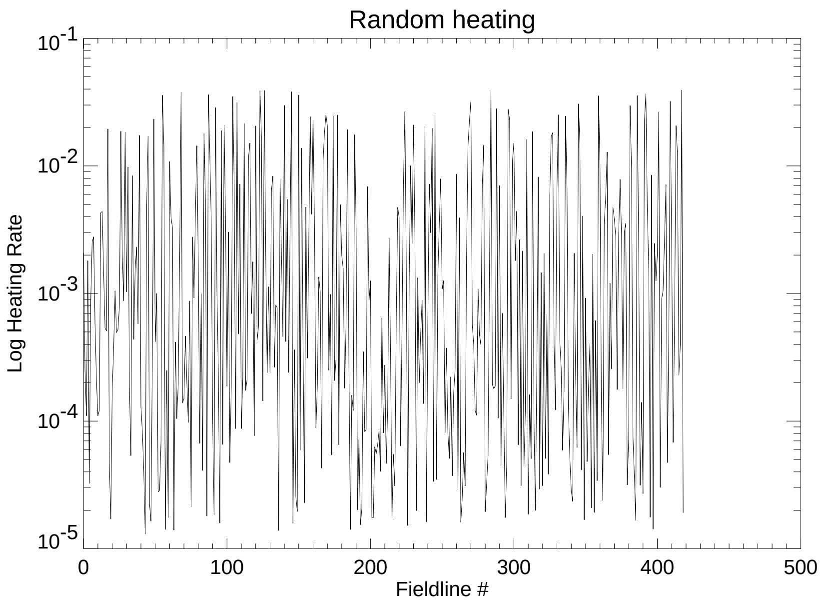

**Note that for loop lengths >3$s_h$ the loop top temperatures are fixed by the base heating rate**

# Random vs. Uniform Heating

We apply two different assumptions about the spatial distribution of the heating function throughout the active region.

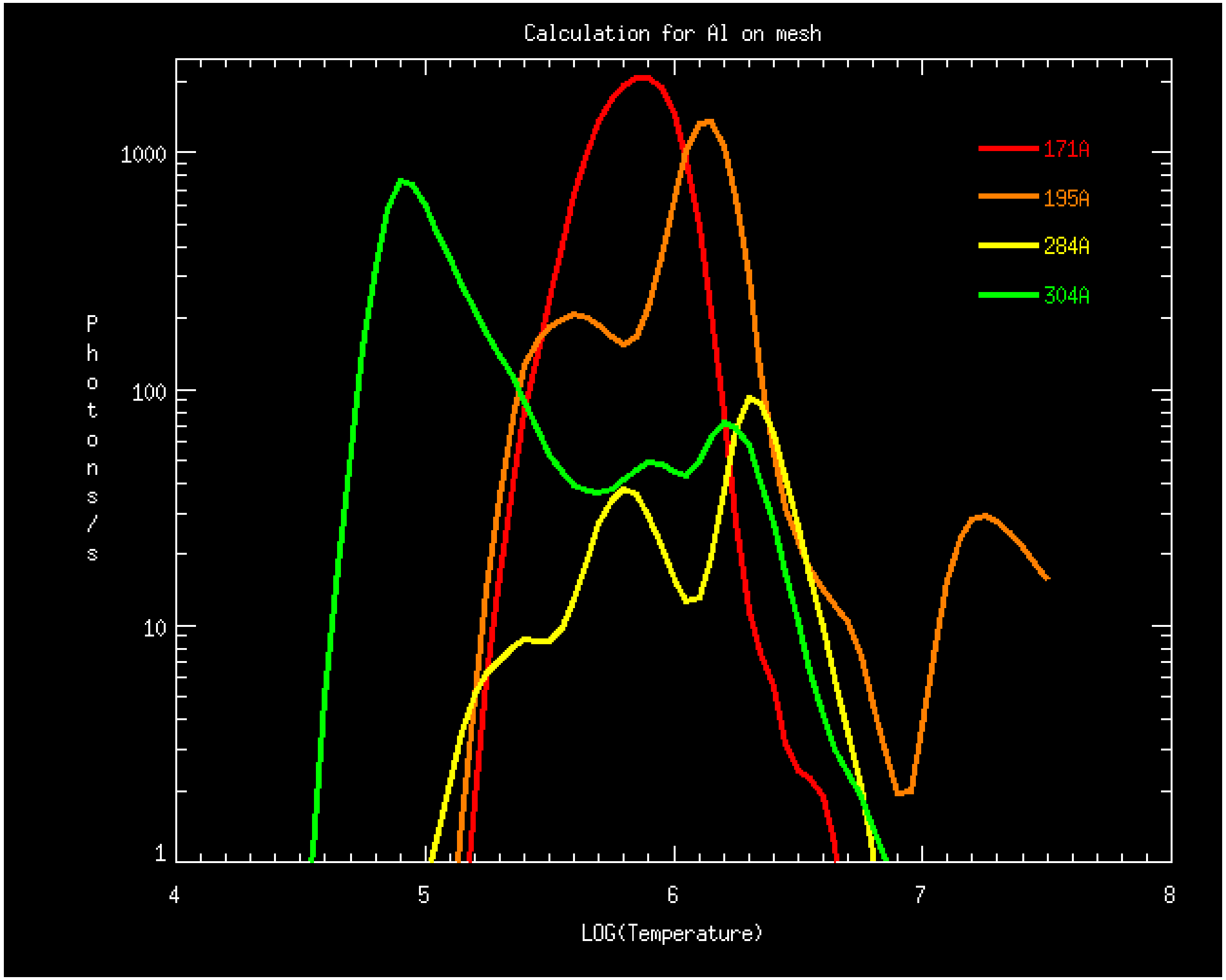
The first is uniform heating where each field line "sees" the same base heating rate: $E_{h0}=5\times10^{-4}$ ergs cm$^{-3}$ s$^{-1}$. This ensures maximum loop temperatures *for all loops* of around 1 MK.

To provide for a range of maximum loop temperatures we adopt a random distribution of heating rates with each field line being heated by a differently. The figure to the left shows the distribution of heating rates. We constrained the range to $1\times10^{-5}<E_{h0}<5\times10^{-2}$ ergs cm$^{-3}$ s$^{-1}$ which yields $T_{max}$~0.5-2.5 MK for these hydrostatic solutions.



# EUVI Response Function

**In calculating the expected photon rates in our simulations we have adopted the the EUVI response shown below.  The photon rates here assume an emission measure of $10^{44}$ $cm^{-3}$.**



# Noise and Background

**In addition to folding the temperature and density distributions through the instrument response, we have also incorporated the instrument pixel size and point spread function (PSF), and added a background signal and random noise.**

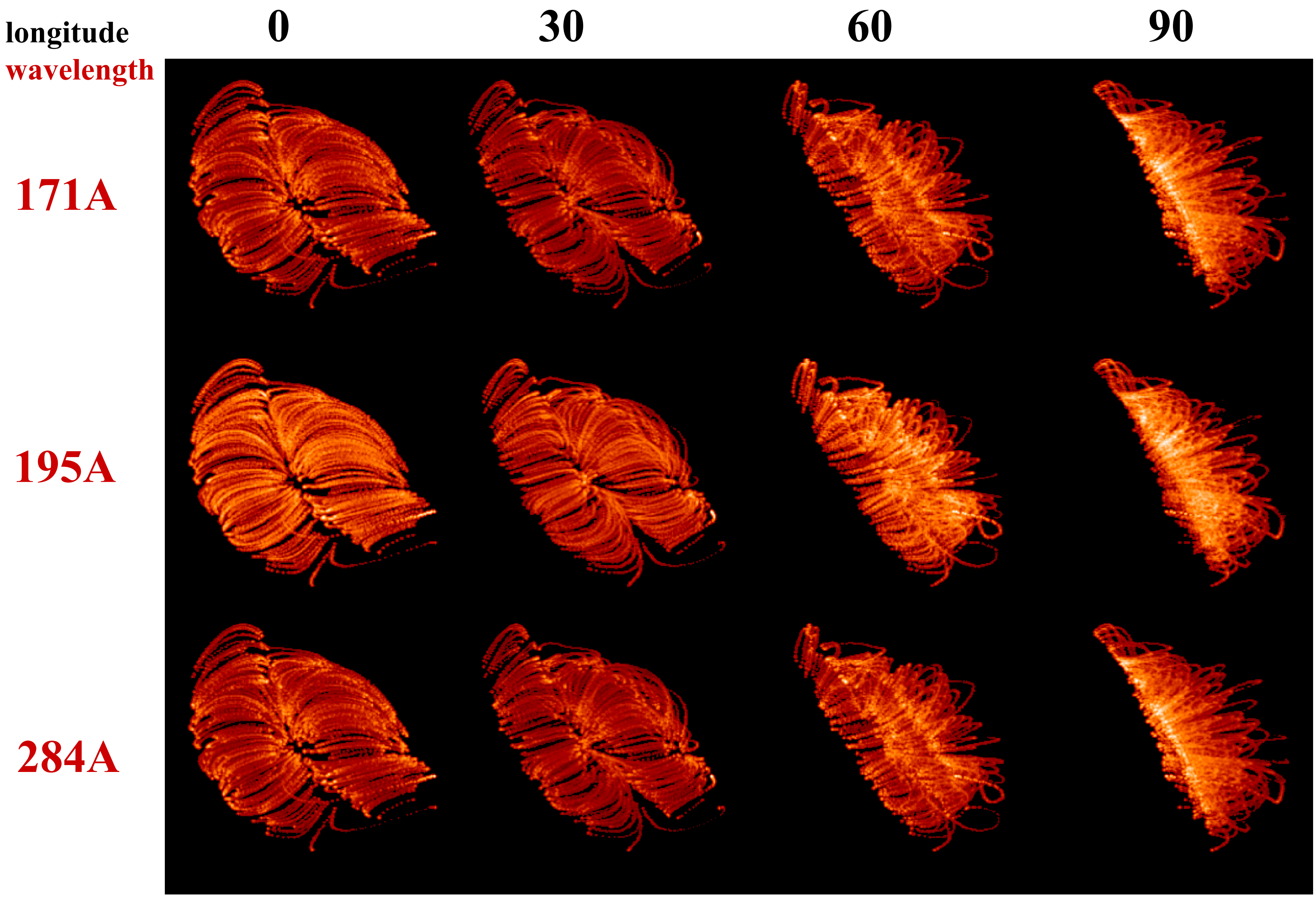
**Pixel Size: 1.7 arcsec** **PSF: 2D Gaussian with ($\sigma_x$, $\sigma_y$) = 0.5 pixels**

**Background:**

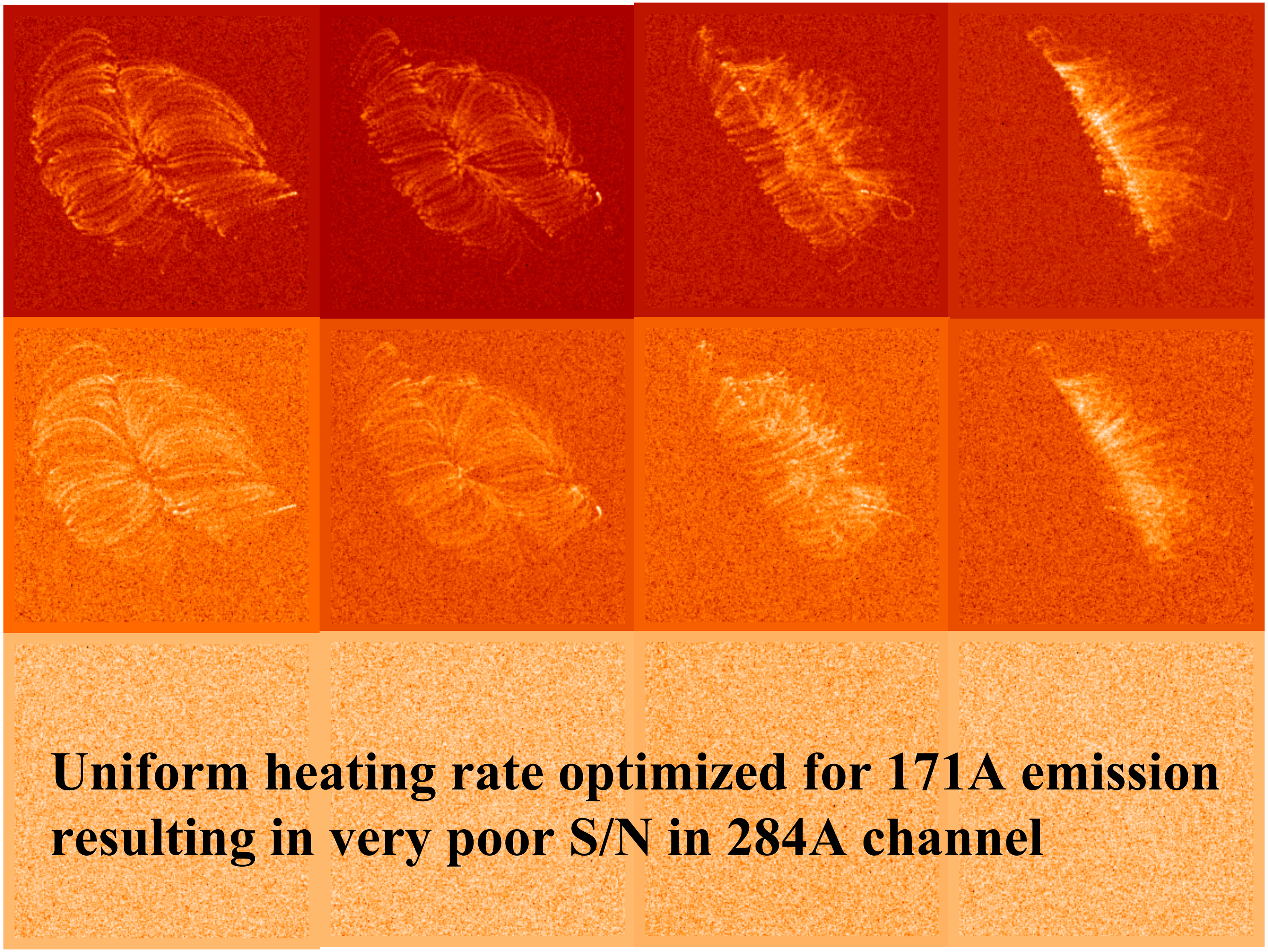
**We define a background on macro-pixel scales, where a macro-pixel is 9x9 EUVI pixels (~15"x15"), and choose, for the examples presented here. $B(i,j)=b_0 I(i,j)$ where $b_0$=10% and $I(i,j)$ is the average emission in the macro-pixel.**

**Noise: Poisson noise acting on signal + background**

# DATA SET 1: Uniform Heating - No Noise – No Background

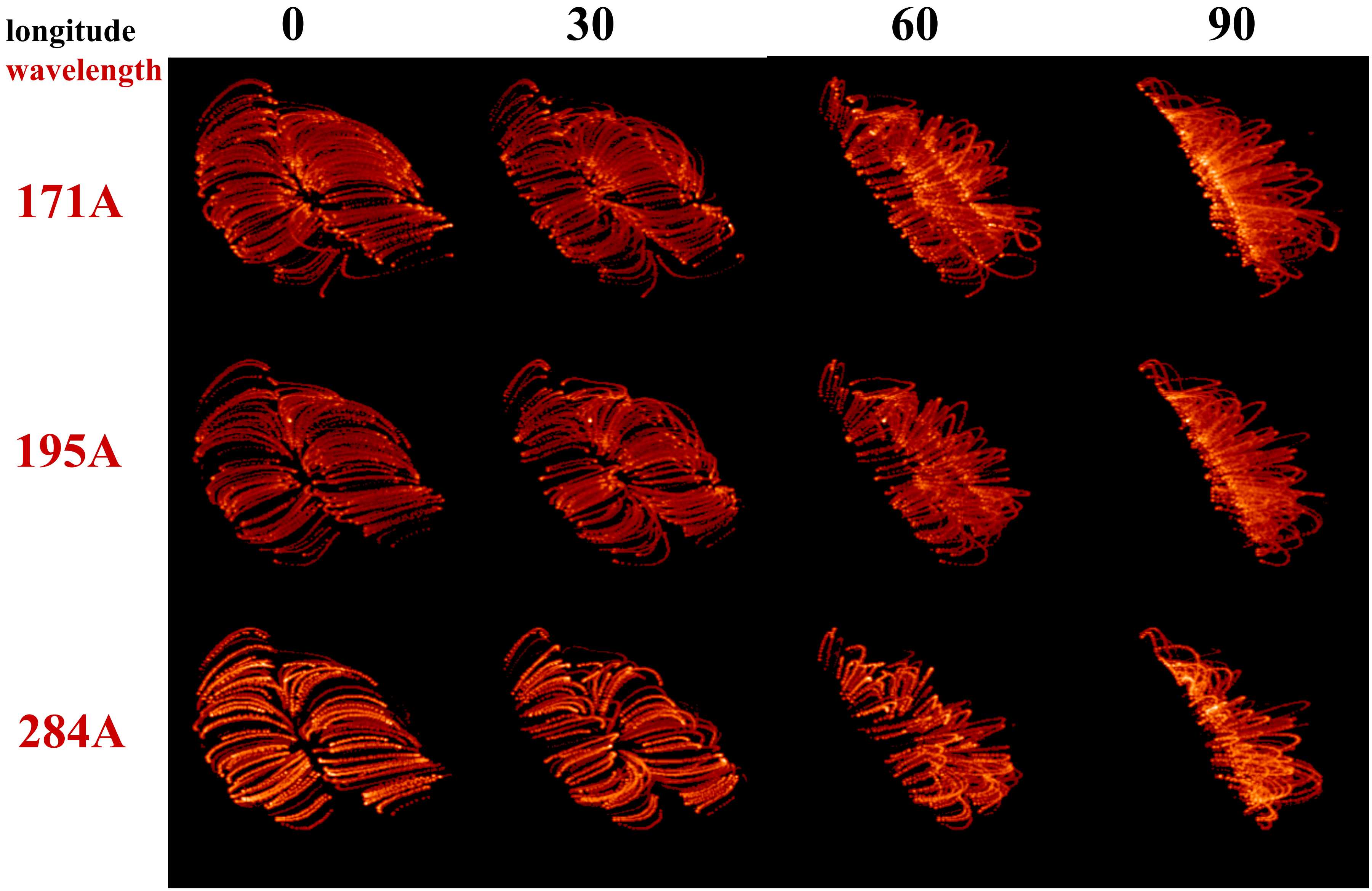


# DATA SET 2: Uniform Heating - Noise + Background

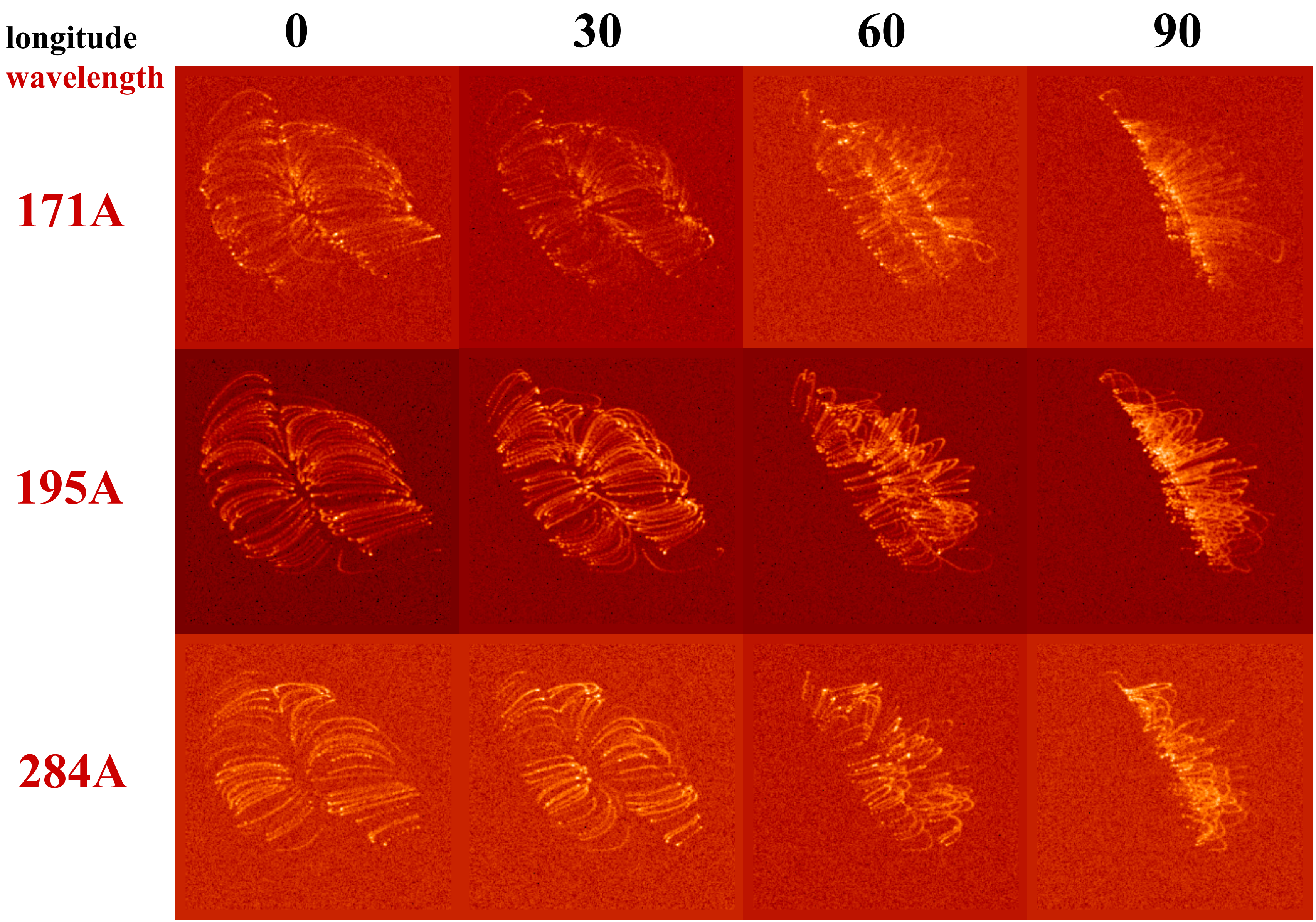



**Uniform heating rate optimized for 171A emission resulting in very poor S/N in 284A channel**

# DATA SET 3: Random Heating - No Noise – No Background



# DATA SET 4: Random Heating - Noise + Background



# Discussion

The simulated SECCHI/EUVI images presented here provide a series of pre-launch test data suitable as input to the 3D reconstruction algorithms being developed for the STEREO mission.

To be effective we have to iterate these simulations with the reconstruction teams and develop a consistent set of test data which best represents the expected observations from the SECCHI EUVI. The data presented here provide a first step towards this.  However, a number of immediate improvements need to be made:

- Simulated data needs to be converted to FITS formats with STEREO or SECCHI adopted headers.
- Simulations in DN/s rather than photons/s.
- More realistic modeling of the background should be performed.  Values consistent with observations should be used and an allowance for  center-to-limb effects in the projected images should also be included.
- Extension to hydrodynamic models and time variability will also provide more “realism”.