

# Effects of Spatial Resolution of Boundary Data on Coronal Magnetic Field Extrapolations

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# Effects of Spatial Resolution of Boundary Data on Coronal Magnetic Field Extrapolations

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# Motivation – I

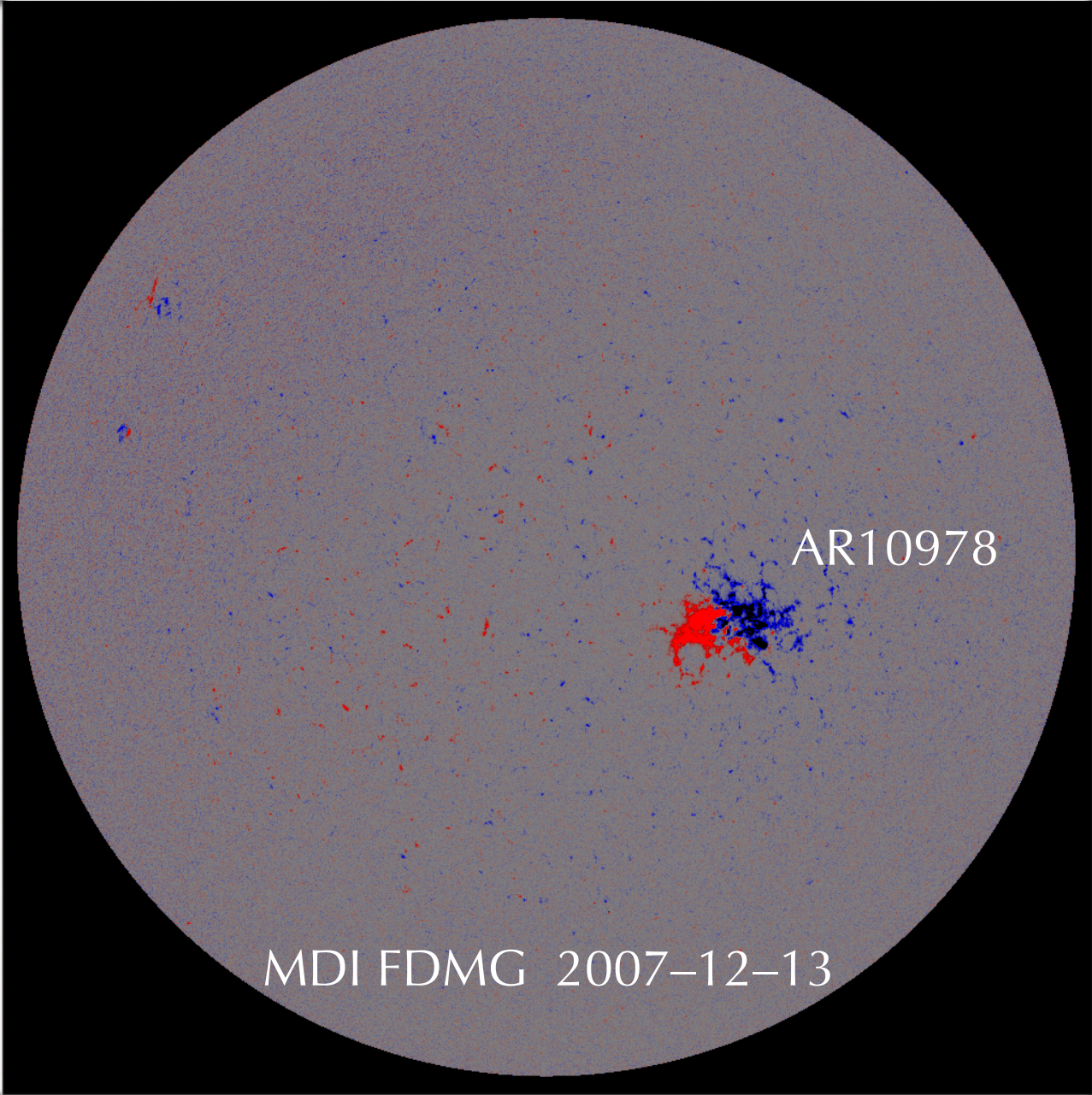
- Previous work into the determination of nonlinear force-free field (NLFFF) models of the solar coronal magnetic field had uncovered several factors that affected the ability to obtain reliable results.
- Of these factors, the effects due to the spatial resolution of the photospheric vector magnetogram boundary data were hypothesized to be significant.
  - *Why? It is presumed that the apparent fine-scale nature of vertical currents present in high-resolution vector data is important to capture.*

# Motivation – II

- In recent years, the NLFFF methods have improved. As an example, most methods now include techniques that account for uncertainties in the photospheric field data.
- Instrumentation that provide the data that are later used to create vector magnetograms possess different spatial resolutions.
  - *In particular, SDO/HMI are now producing full-disk vector magnetograms, but these have a lower spatial resolution than Hinode/SOT-SP.*

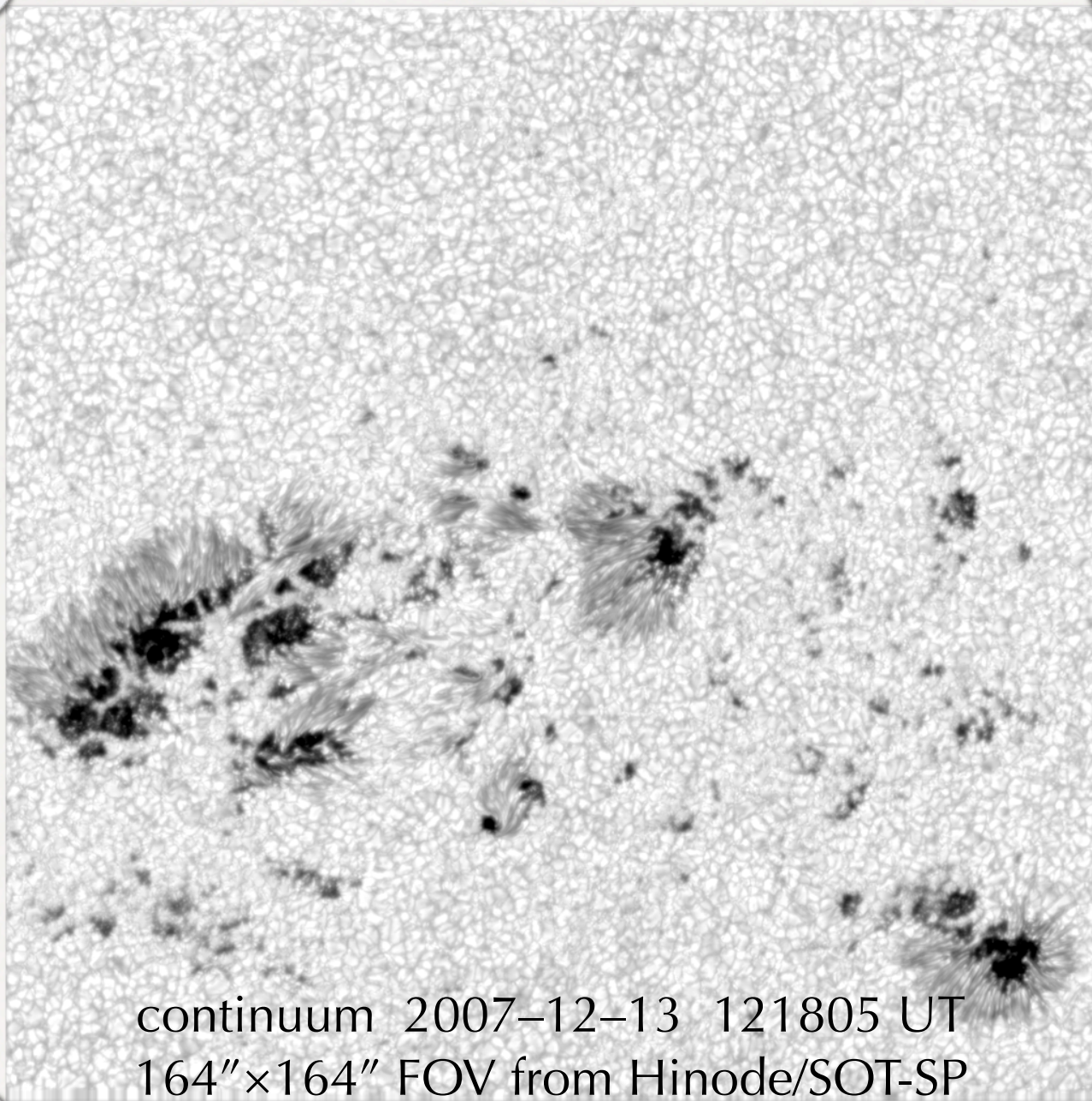
# The Experiment

- To test the effects of spatial resolution, we perform extrapolations of the coronal field above AR10978 (December 2007) at variable spatial resolutions.
- High-resolution (normal-map) polarization spectra from the Hinode/SOT-SP are used (0.16" pixels).
- These spectra have been rebinned by various factors (1, 2, 4, 8, 12, and 16) prior to being inverted into vector magnetograms, which are then in turn used as lower boundary conditions for the modeling after remapping onto a Cartesian coordinate system.

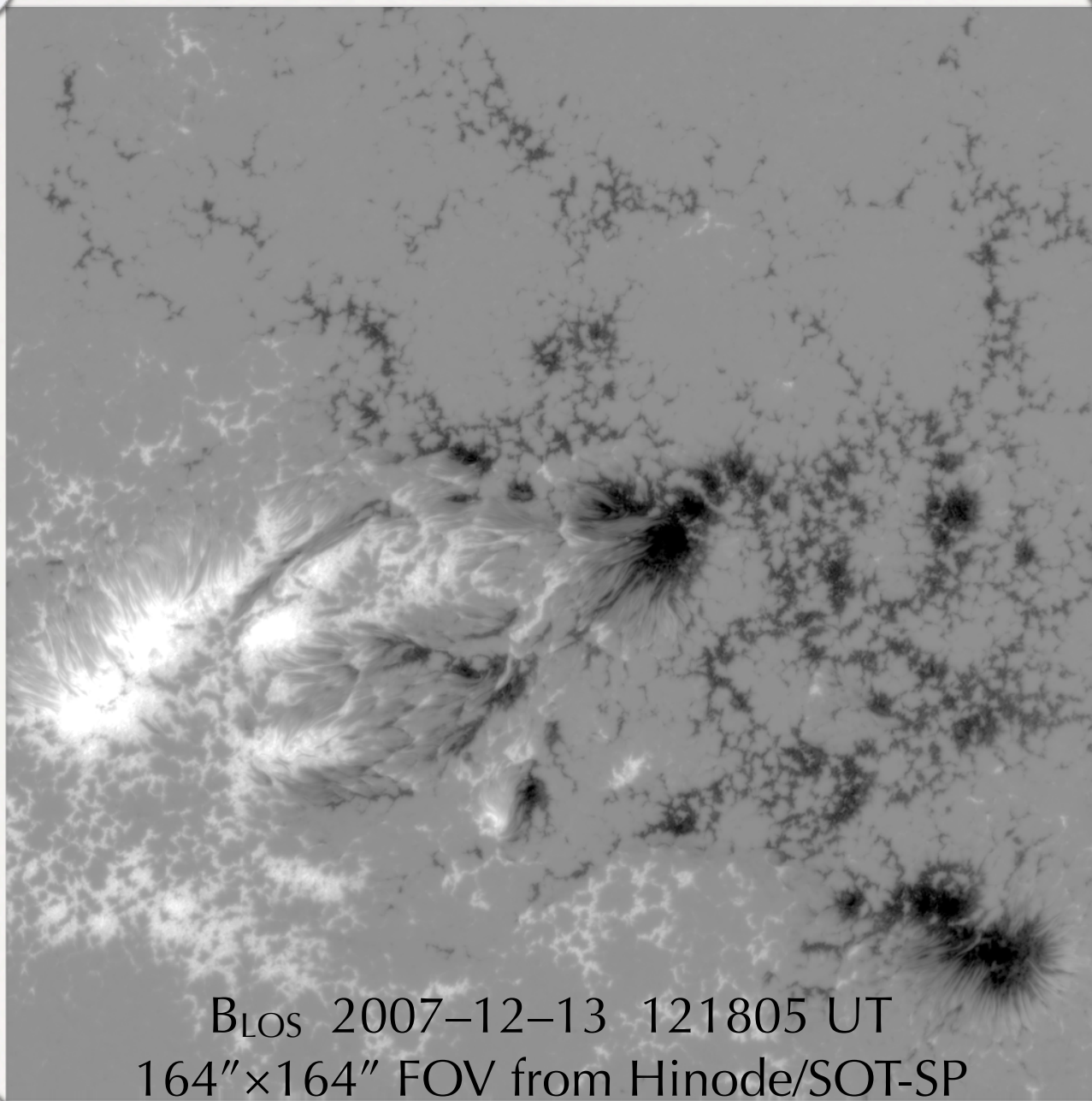


AR10978

MDI FDMG 2007-12-13

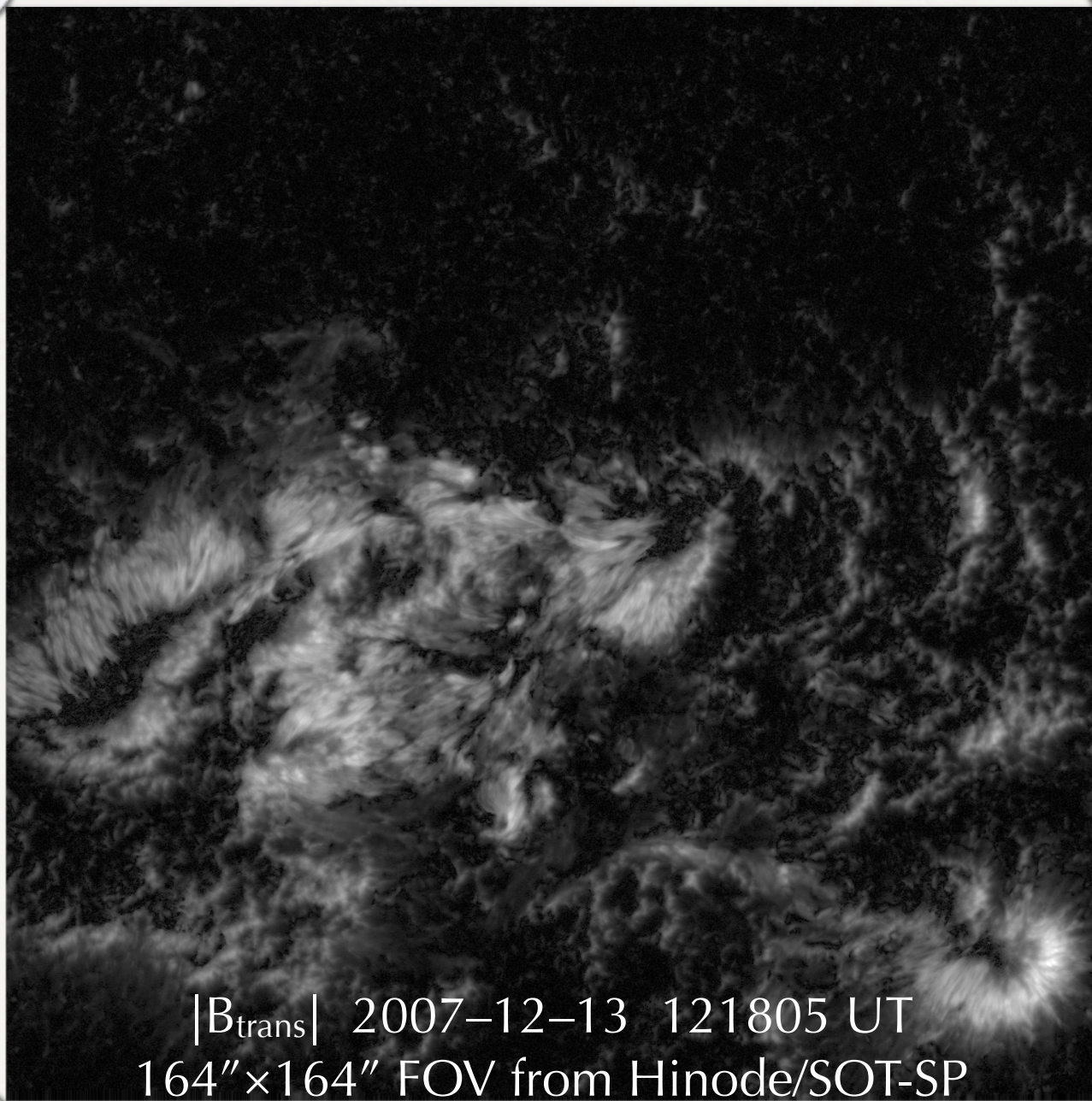


continuum 2007-12-13 121805 UT  
164"×164" FOV from Hinode/SOT-SP

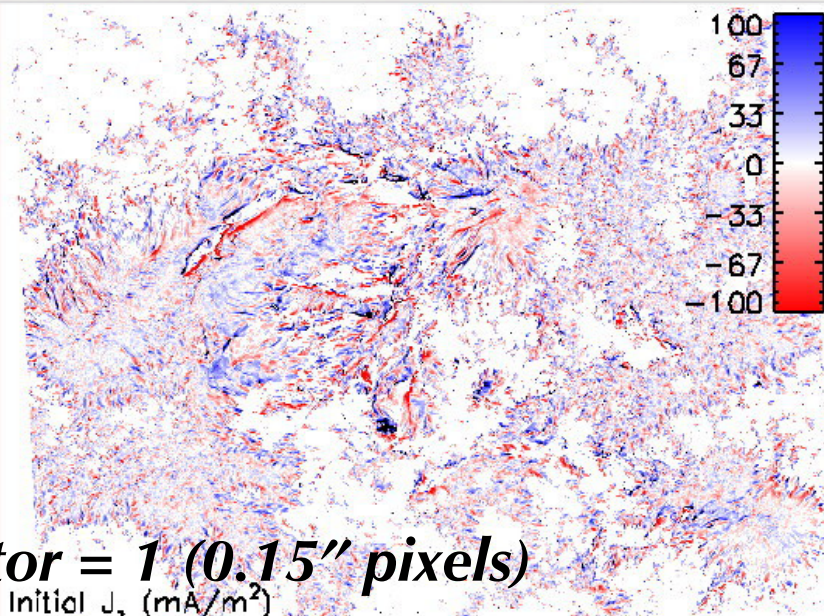
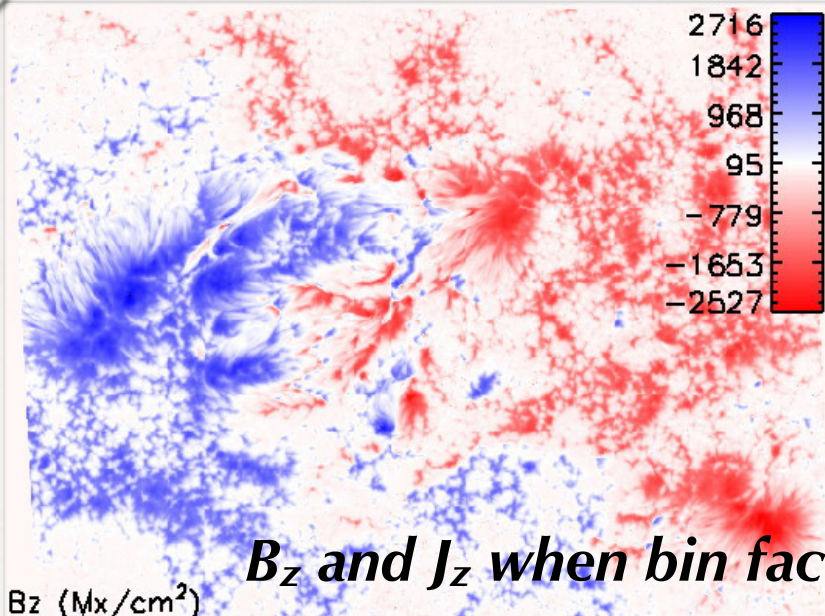


$B_{LOS}$  2007-12-13 121805 UT  
164"×164" FOV from Hinode/SOT-SP

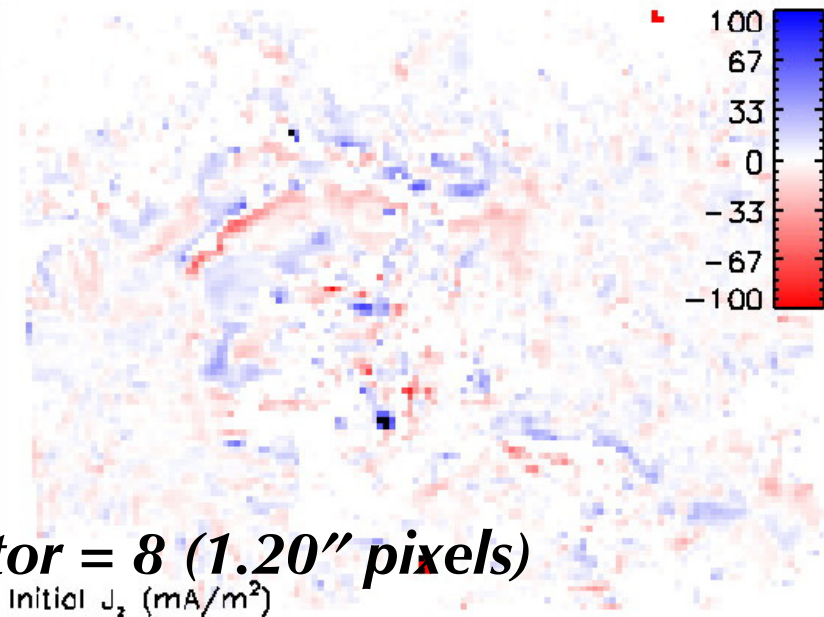
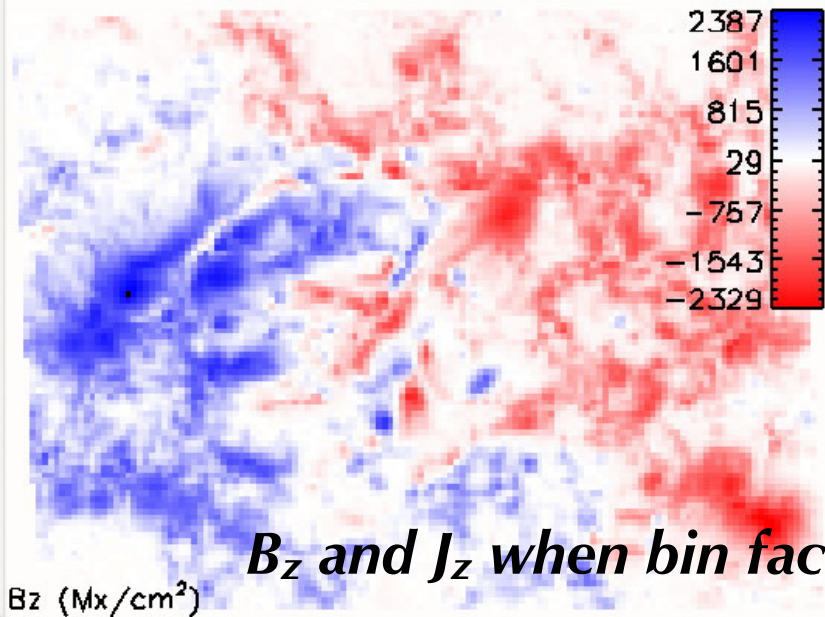




$|B_{\text{trans}}|$  2007-12-13 121805 UT  
164"  $\times$  164" FOV from Hinode/SOT-SP



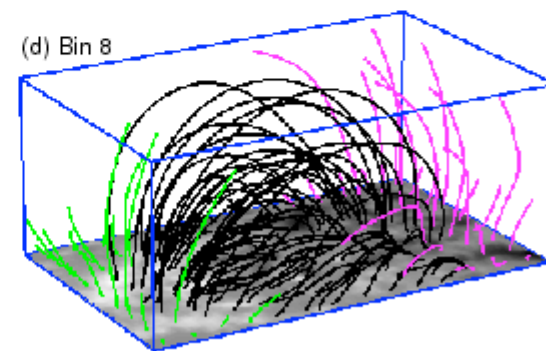
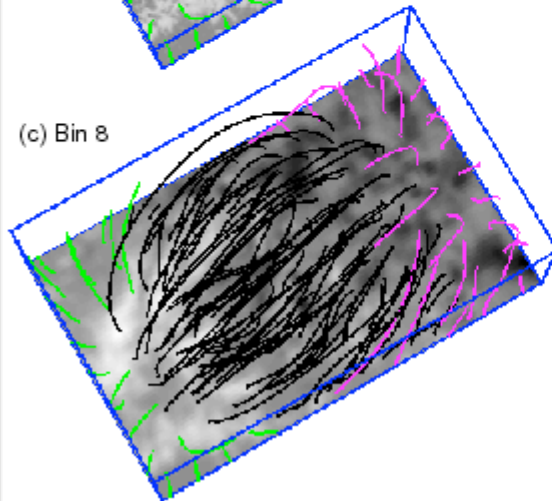
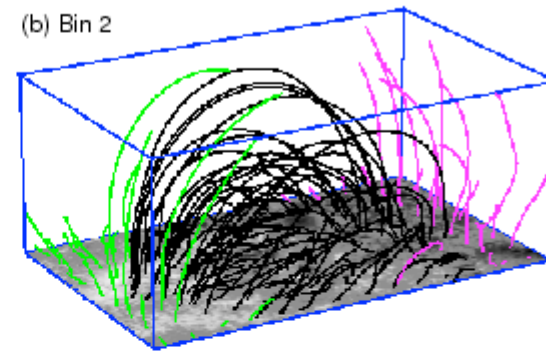
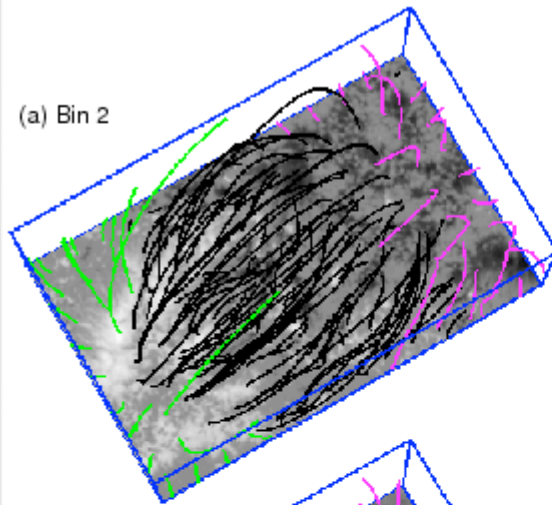
***$B_z$  and  $J_z$  when bin factor = 1 (0.15'' pixels)***



***$B_z$  and  $J_z$  when bin factor = 8 (1.20'' pixels)***

# Results – I

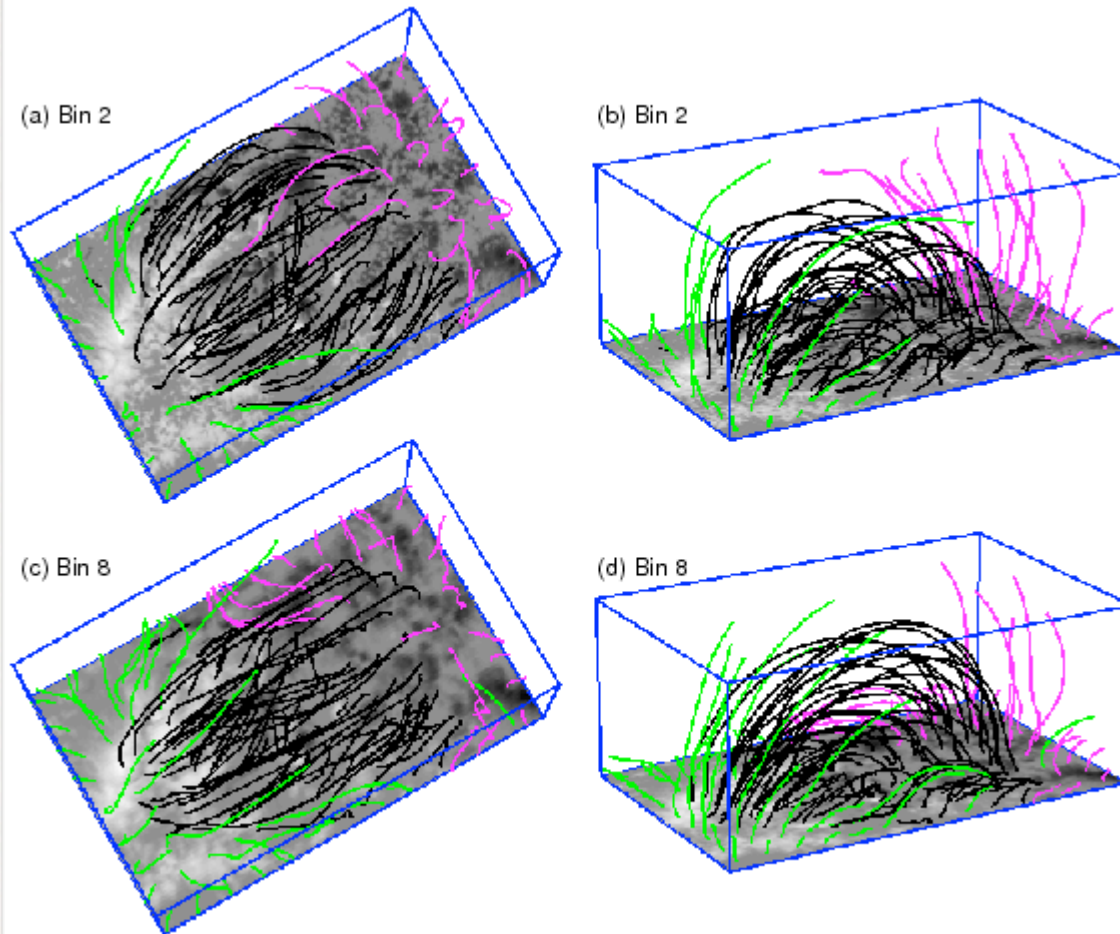
optimization method



courtesy: Julia Thalmann

# Results – I

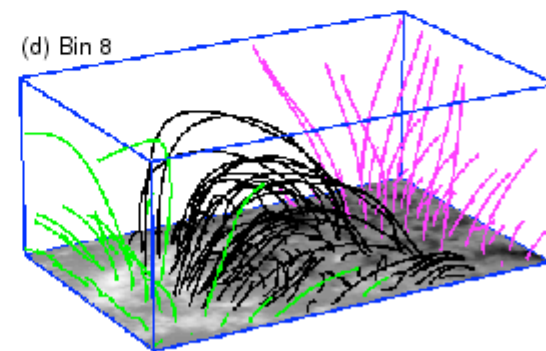
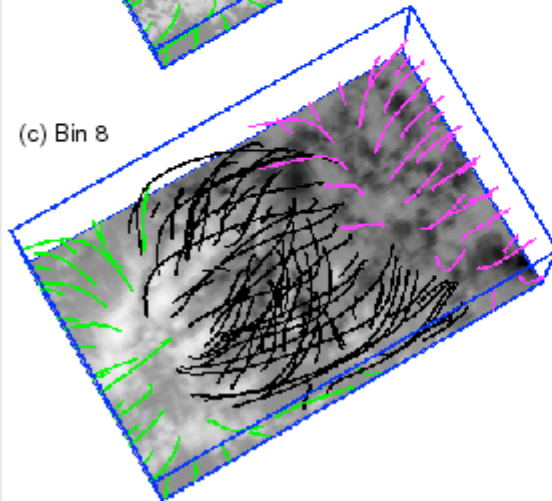
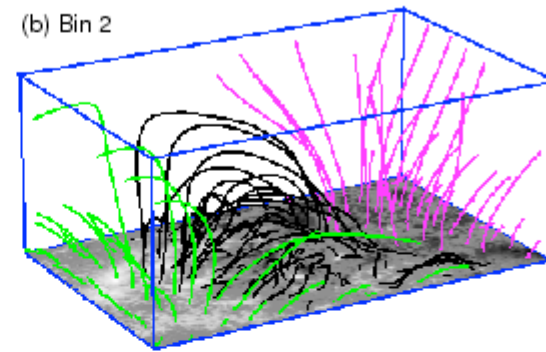
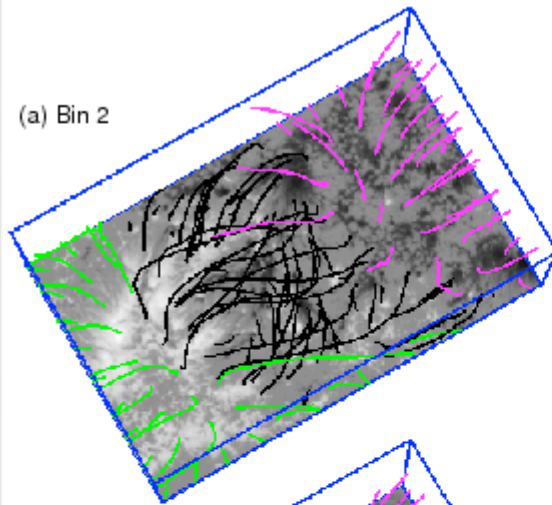
magnetofrictional relaxation method



courtesy: Gherardo Valori

# Results – I

Grad-Rubin method



courtesy: Mike Wheatland

# Results – II

bin factor = 2

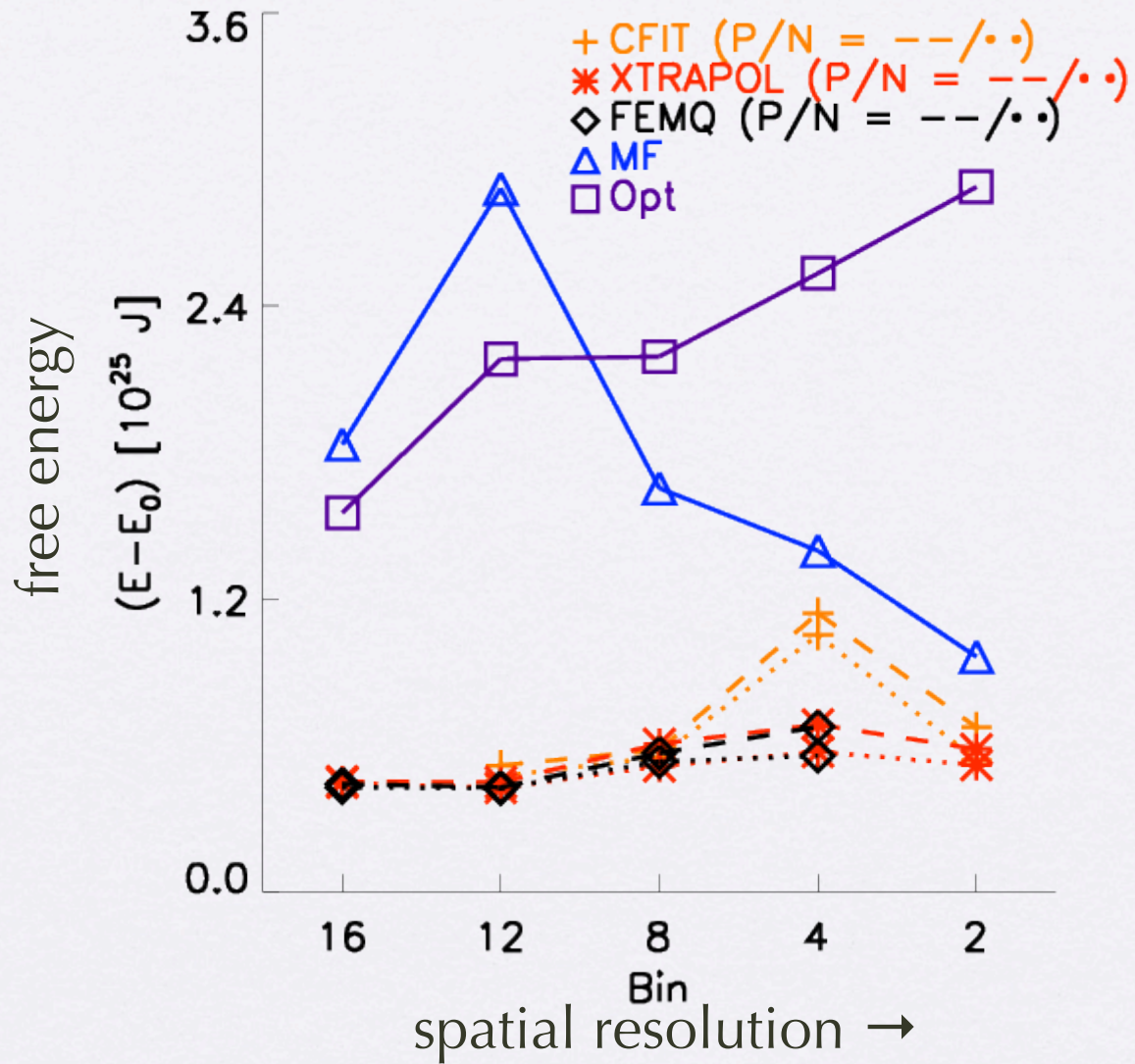
<b>Code</b>	<b>Author(s)</b>	<b><math>E</math> [<math>10^{26}</math> J]</b>	<b><math>E/E_0</math></b>	<b><math>H_m</math> [<math>10^{26}</math> Wb<sup>2</sup>]</b>
<i>CFIT -</i>	<i>Wheatland, Gilchrist</i>	<i>1.10</i>	<i>1.05</i>	<i>2.42</i>
<i>CFIT +</i>		<i>1.12</i>	<i>1.06</i>	<i>4.54</i>
<i>XTRAPOL -</i>	<i>Amari, Canou</i>	<i>1.27</i>	<i>1.04</i>	<i>3.19</i>
<i>XTRAPOL +</i>		<i>1.27</i>	<i>1.05</i>	<i>3.21</i>
<i>Optimization</i>	<i>Wiegelmann, Thalmann</i>	<i>1.50</i>	<i>1.24</i>	<i>-0.04</i>
<i>Magneto- frictional</i>	<i>Valori</i>	<i>1.08</i>	<i>1.10</i>	<i>1.88</i>

# Results – II

bin factor = 8

<b>Code</b>	<b>Author(s)</b>	<b><math>E</math> [<math>10^{26}</math> J]</b>	<b><math>E/E_0</math></b>	<b><math>H_m</math> [<math>10^{26}</math> Wb<sup>2</sup>]</b>
<i>CFIT -</i>	<i>Wheatland, Gilchrist</i>	<i>1.12</i>	<i>1.05</i>	<i>4.66</i>
<i>CFIT +</i>		<i>1.12</i>	<i>1.05</i>	<i>3.35</i>
<i>XTRAPOL -</i>	<i>Amari, Canou</i>	<i>1.28</i>	<i>1.04</i>	<i>3.55</i>
<i>XTRAPOL +</i>		<i>1.28</i>	<i>1.05</i>	<i>3.81</i>
<i>Optimization</i>	<i>Wiegelmann, Thalmann</i>	<i>1.46</i>	<i>1.18</i>	<i>0.43</i>
<i>Magneto- frictional</i>	<i>Valori</i>	<i>1.28</i>	<i>1.15</i>	<i>5.17</i>

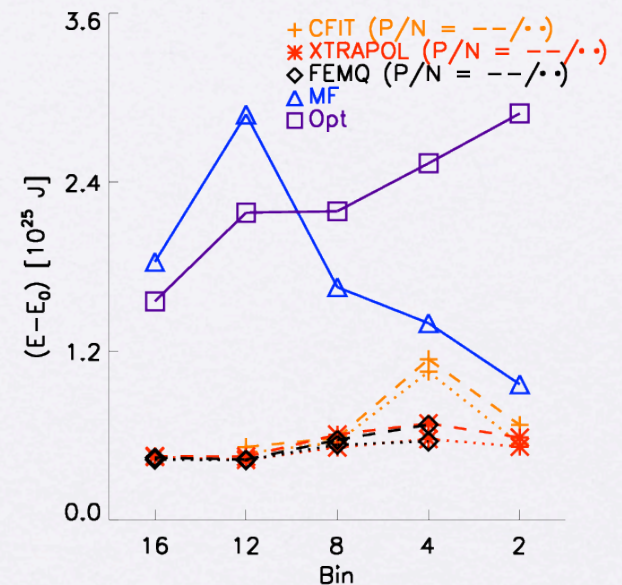
# Results – III





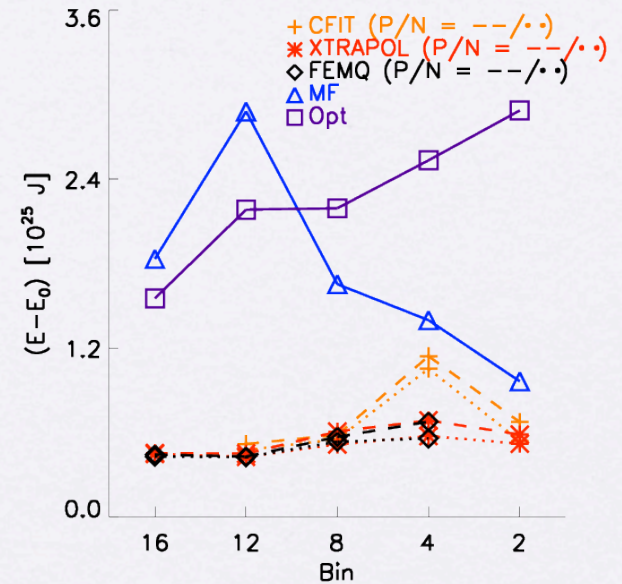
# Interpretation – I

- Considering all models and bin factors in the sample, the mean energy of the ensemble is  $1.3 \times 10^{26}$  J.
- The ensemble of models include highly nonlinear cases with a lot of energy in currents and cases that are not too different than the potential field. The  $E/E_0$  metrics energies thus range from 1.03 to 1.24.



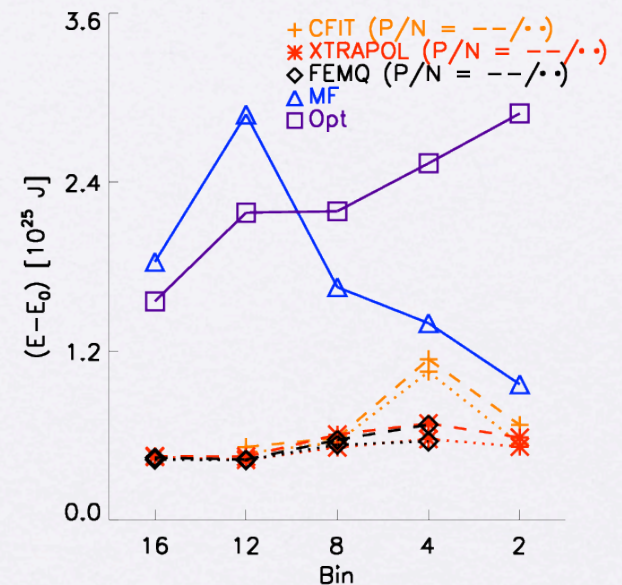
# Interpretation – II

- The trends of free energy vs. spatial resolution are mixed, with the MF code showing a decreasing trend and the others an increasing trend.
- Details of the implementation of the Grad-Rubin methods seem to matter less than the spatial resolution in determining free energy.



# Interpretation – III

- It is known from previous experiments that methods that apply preprocessing to the lower boundary data tend to produce results having greater free energies, and this accounts for some of the discrepancy between the Grad-Rubin methods and the others.



# Summary

- We performed NLFFF extrapolations of the coronal field above AR10978 (December 2007) at varied spatial resolutions.
- Resulting energy metrics depend a lot on the method used. The most obvious trend seems to be that energy  $E$  and free energy  $E - E_0$  increases with spatial resolution (in line with expectations).
- We need to better understand the exceptions to this trend before drawing firm conclusions.

*FIN*