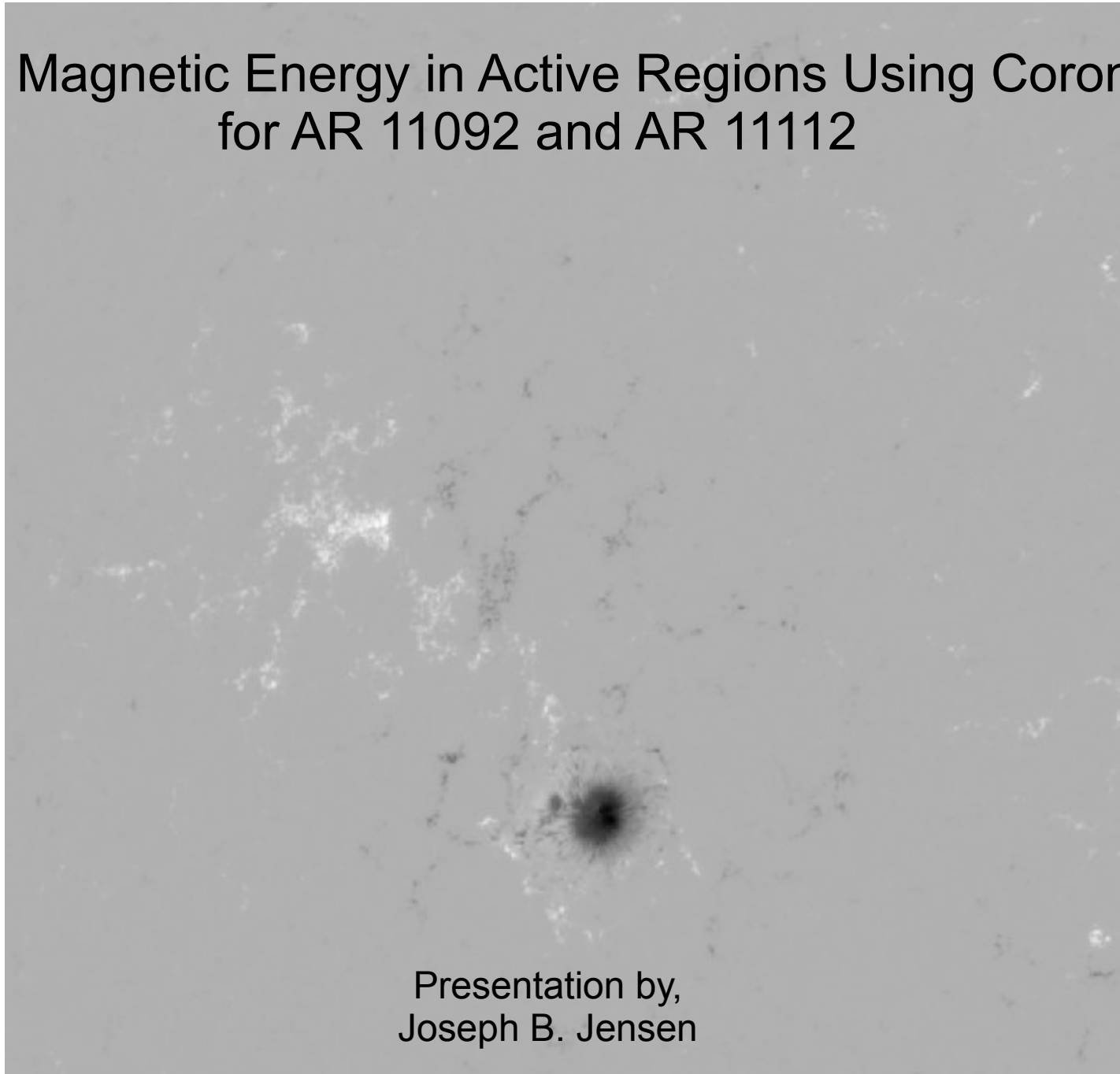


# Calculating Magnetic Energy in Active Regions Using Coronal Loops for AR 11092 and AR 11112



Presentation by,  
Joseph B. Jensen

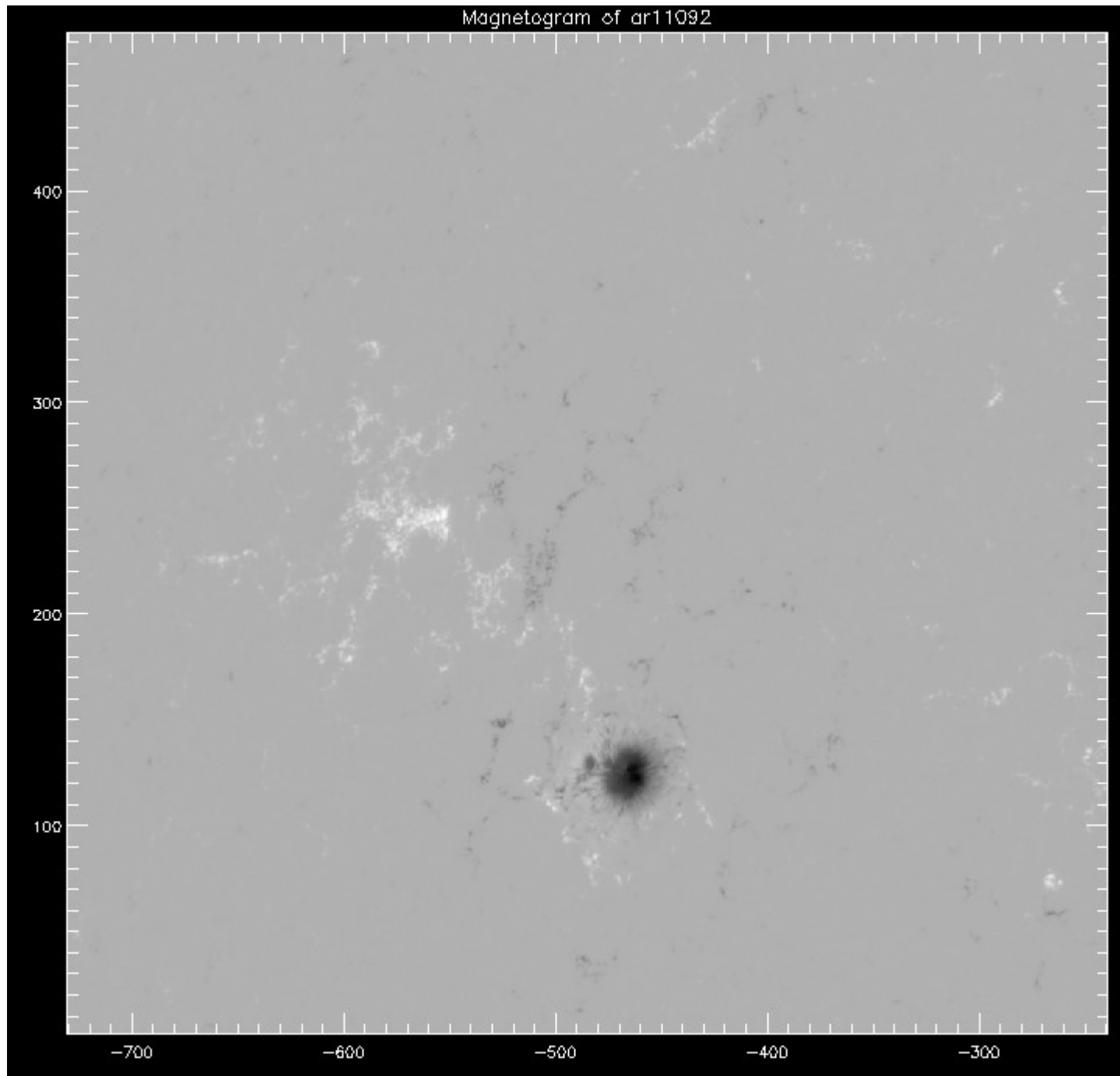
## Magnetic energy equation

$$W = 1/8 \pi \int |\mathbf{B}^2| d^3 x = 1/8 \pi \int d\Phi \int \mathbf{B} dl$$

$$\textit{Force} = \mathbf{J} \times \mathbf{B} + \nabla p + \rho \mathbf{g} = 0$$

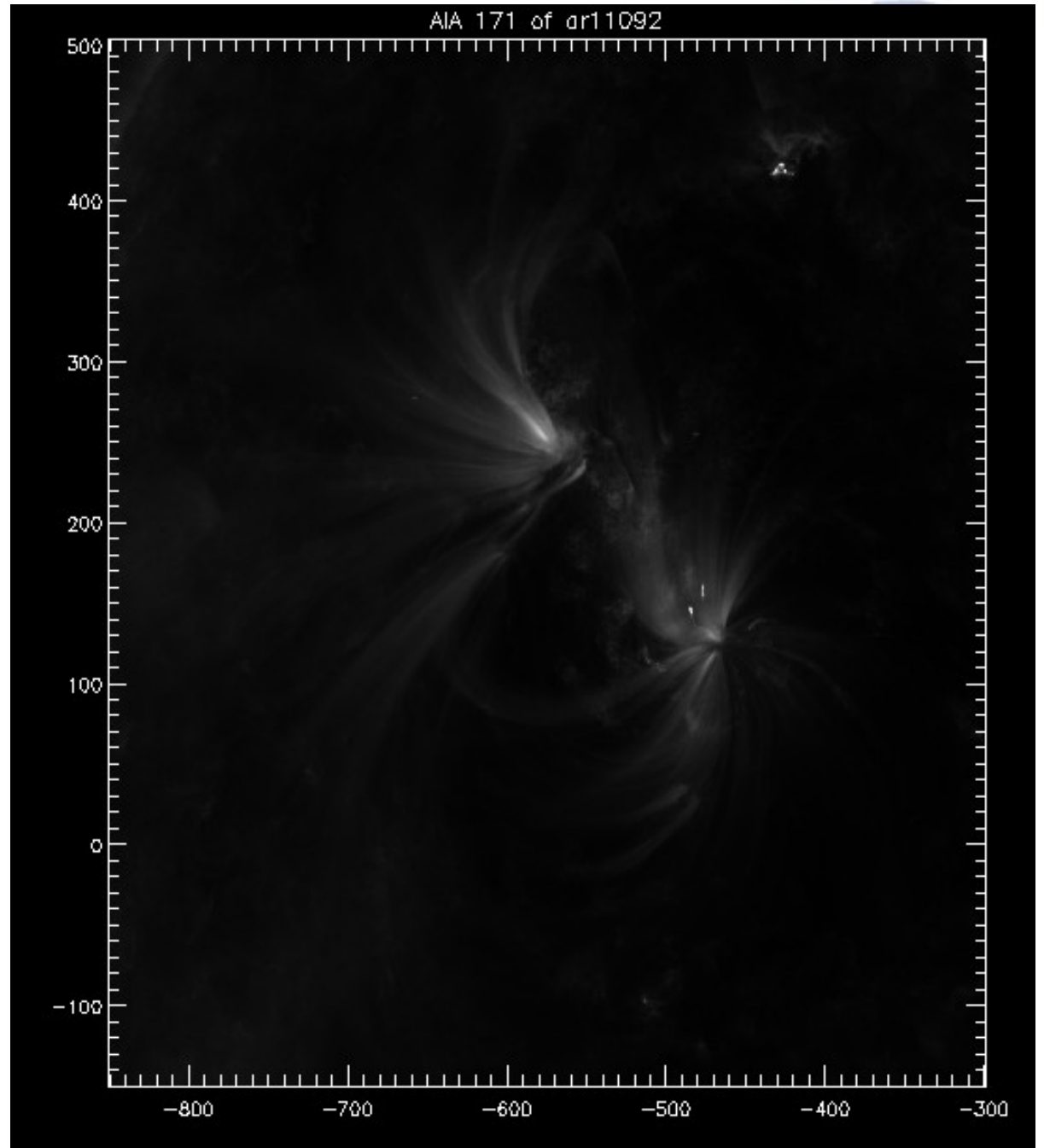
Non-linear force-free equilibrium for coronal field

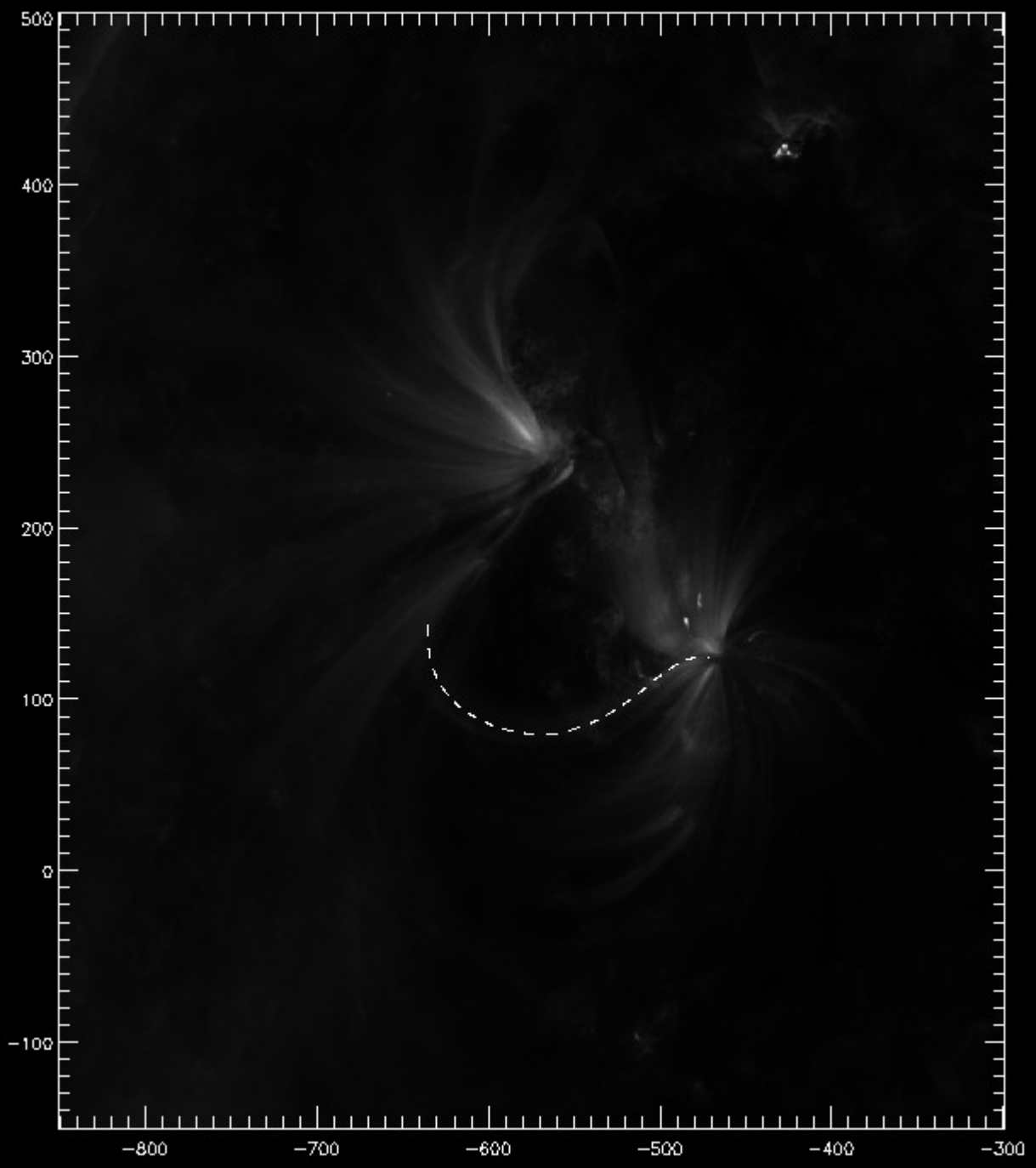
$$\nabla \times \mathbf{B} = \alpha(x) \mathbf{B}(x)$$



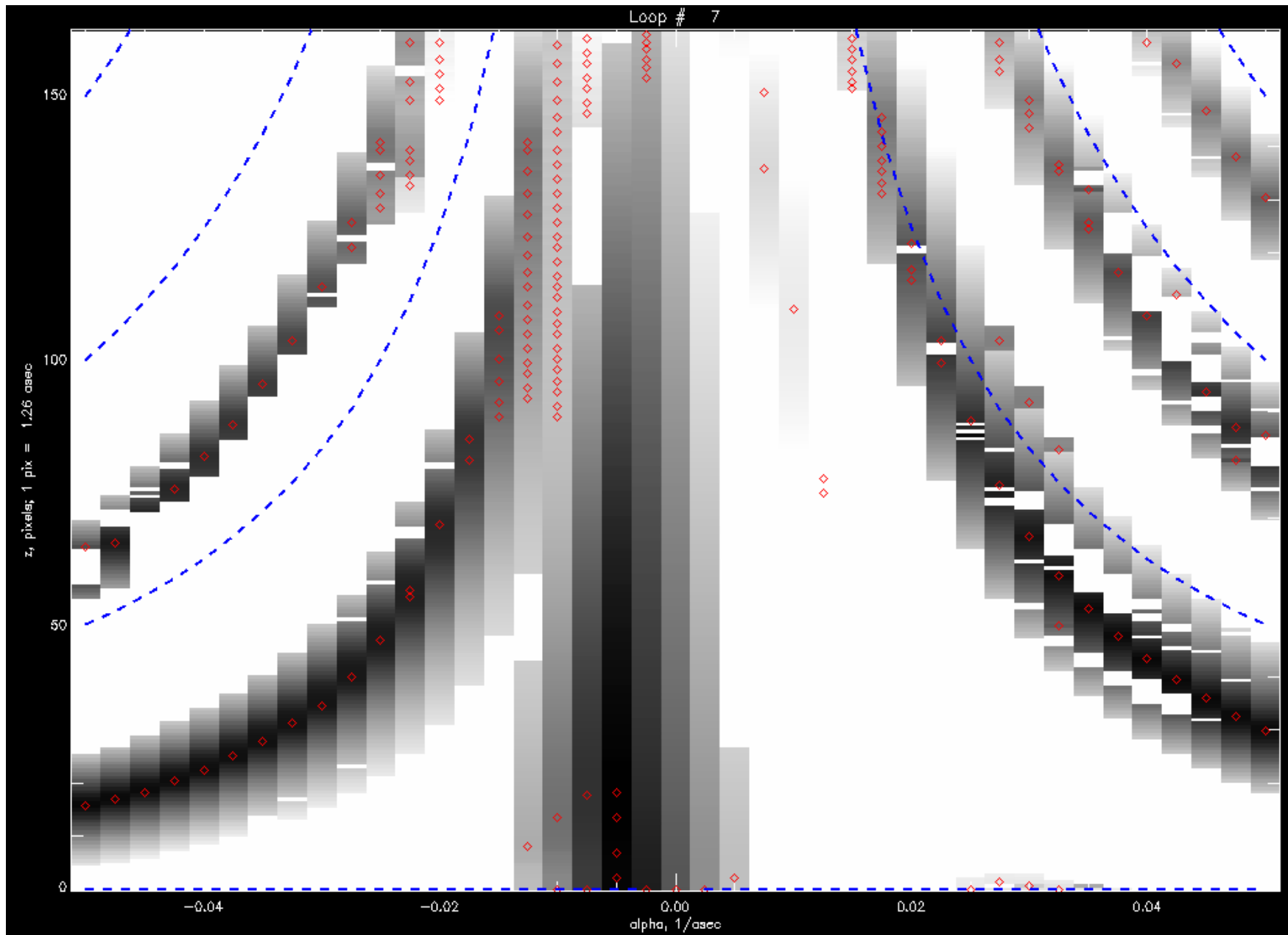
Magnetogram  
of active  
region 11092  
August 1, 2010  
at 5:00

Active region 11092  
in 171 angstrom  
wavelength

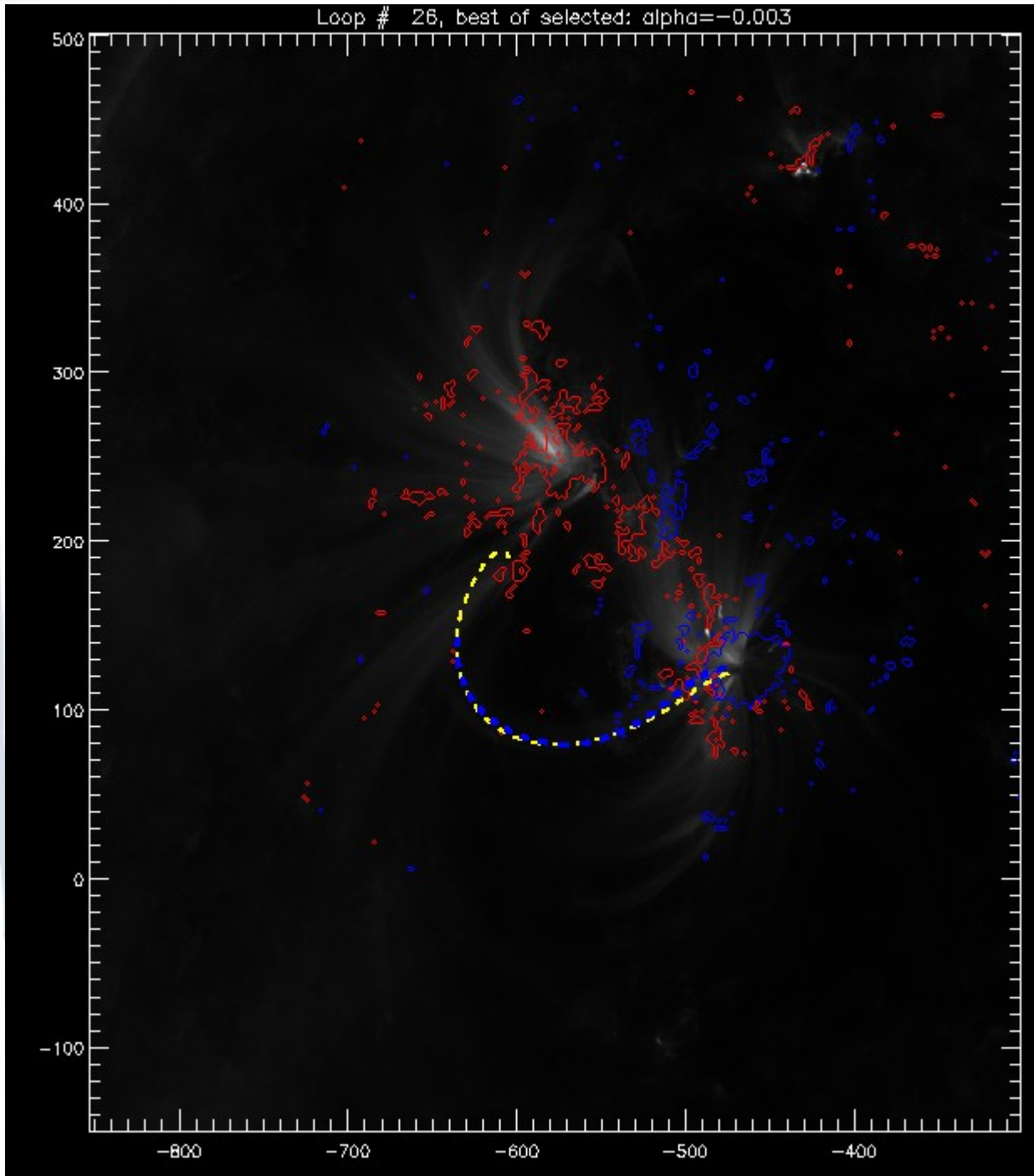




# The alpha and h parameter space of one coronal loop

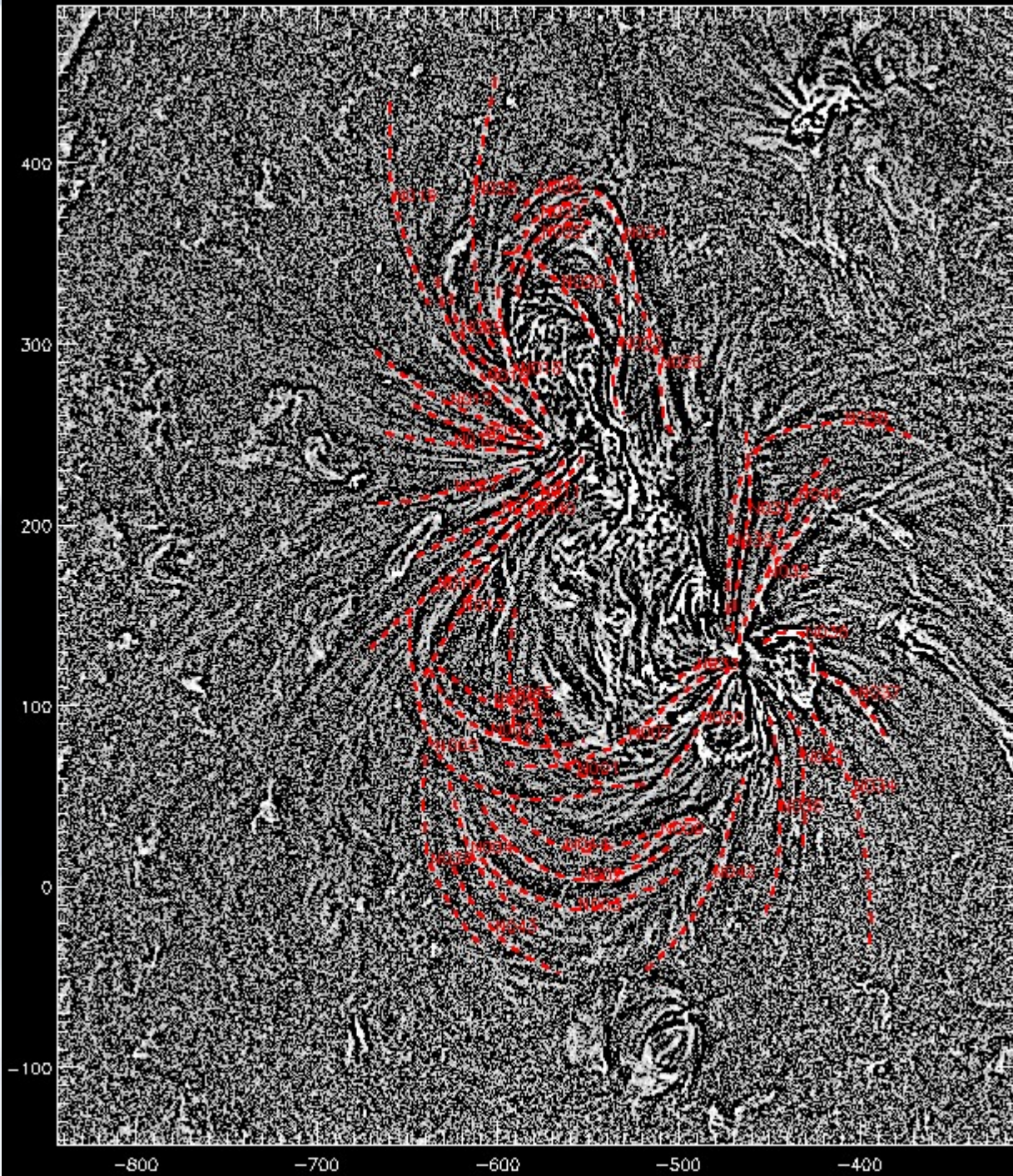


Loop # 26, best of selected: alpha=-0.003



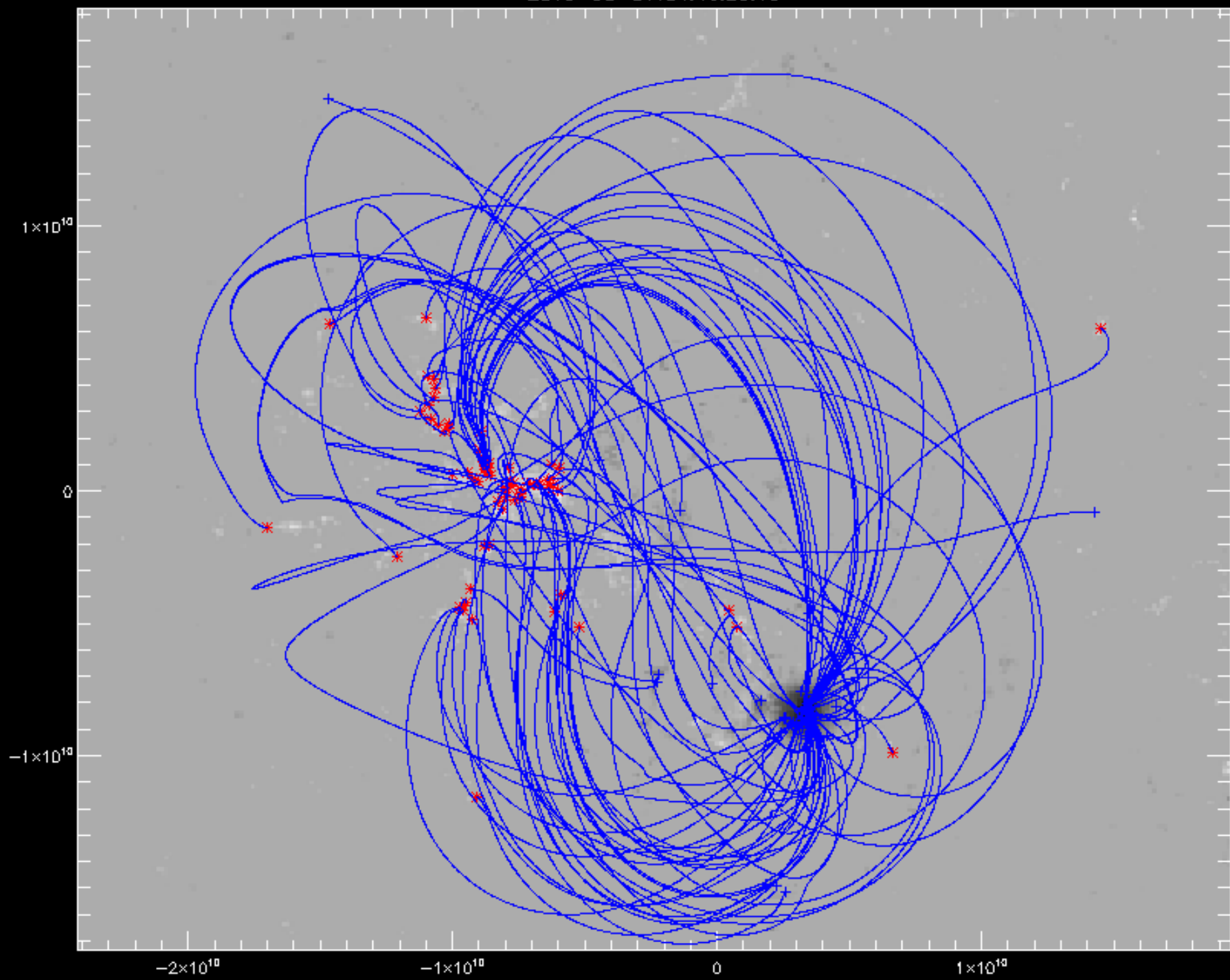
The blue line is user input, the yellow is the computed loop

select Bezier curve: reference



All loops identified  
on ar11092 at the  
171 wavelength

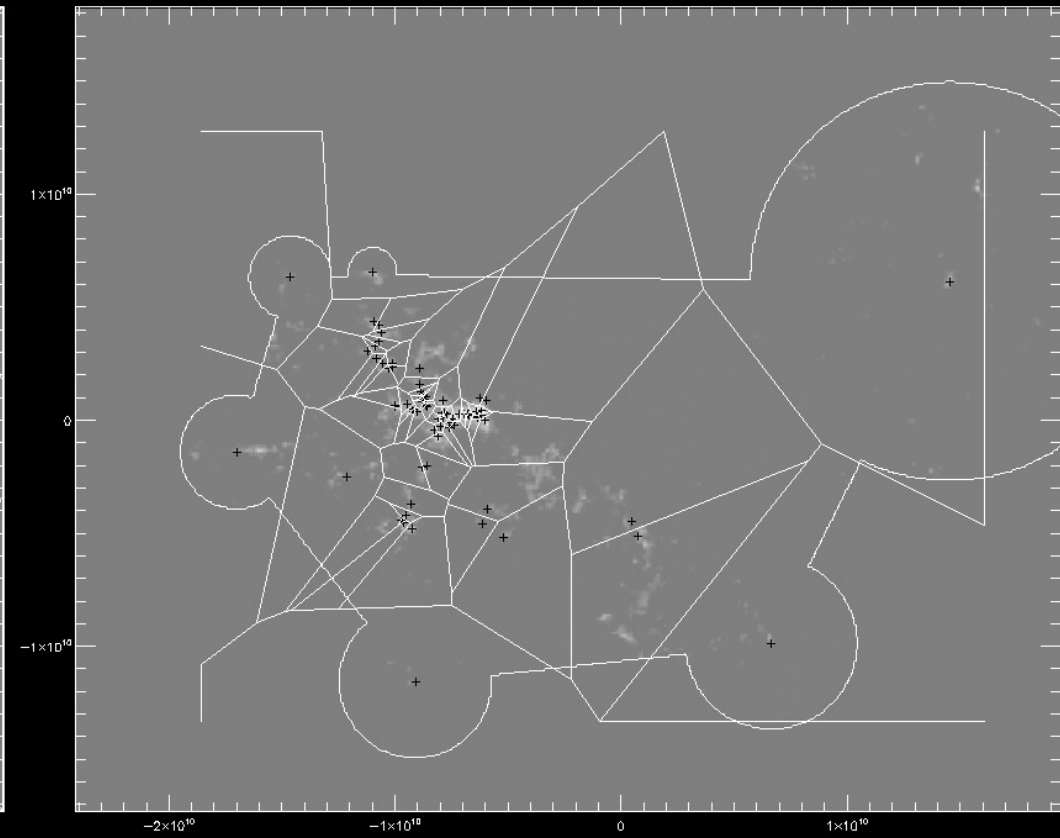
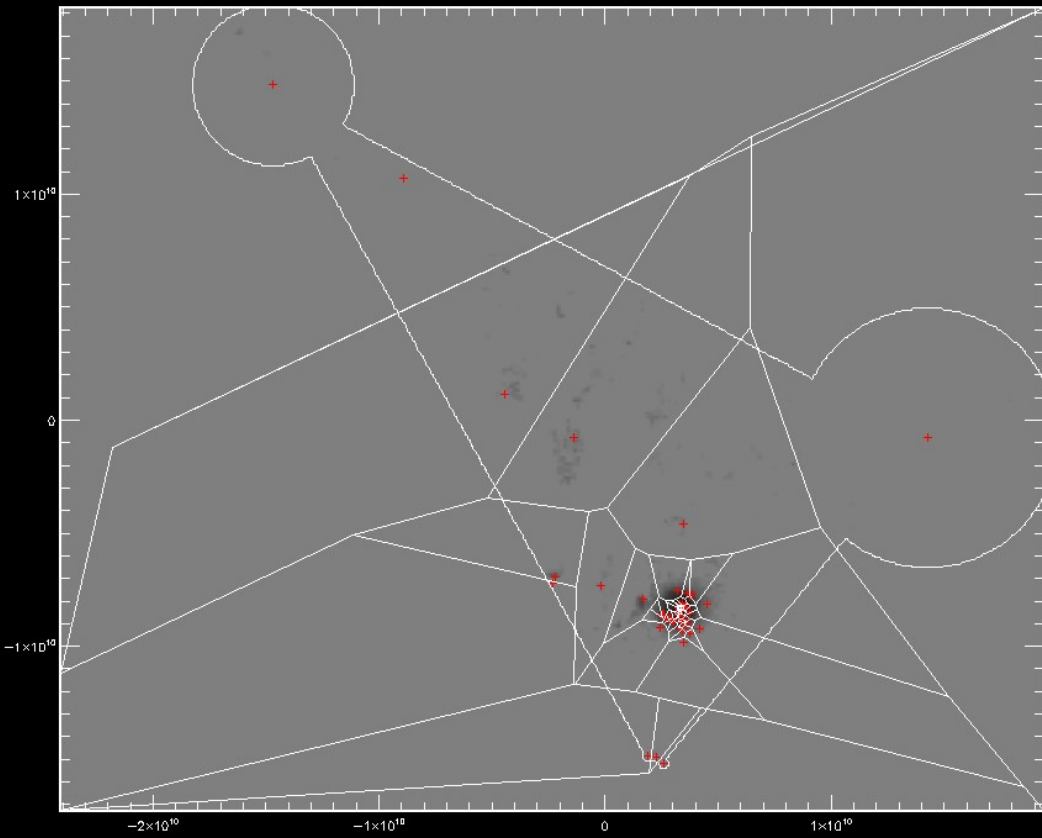
2010-08-01T04:46:26.10



# Voronoi Tessellation

Negative footpoints

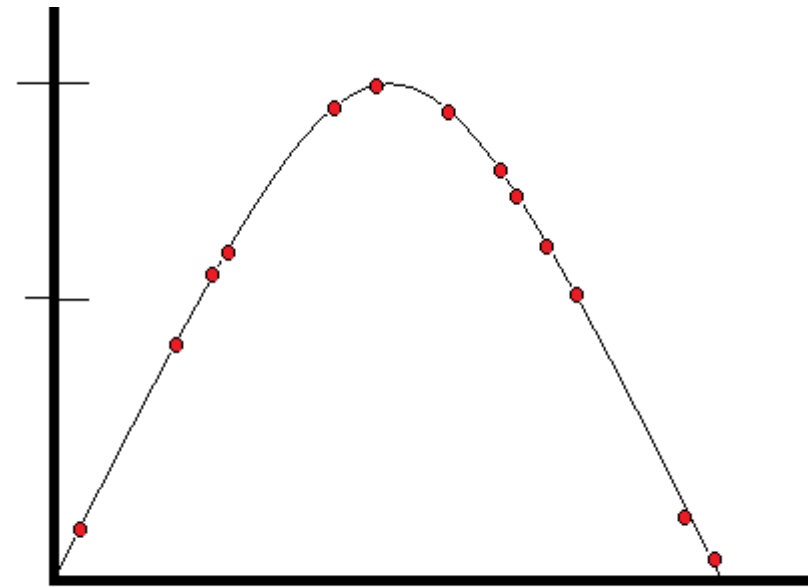
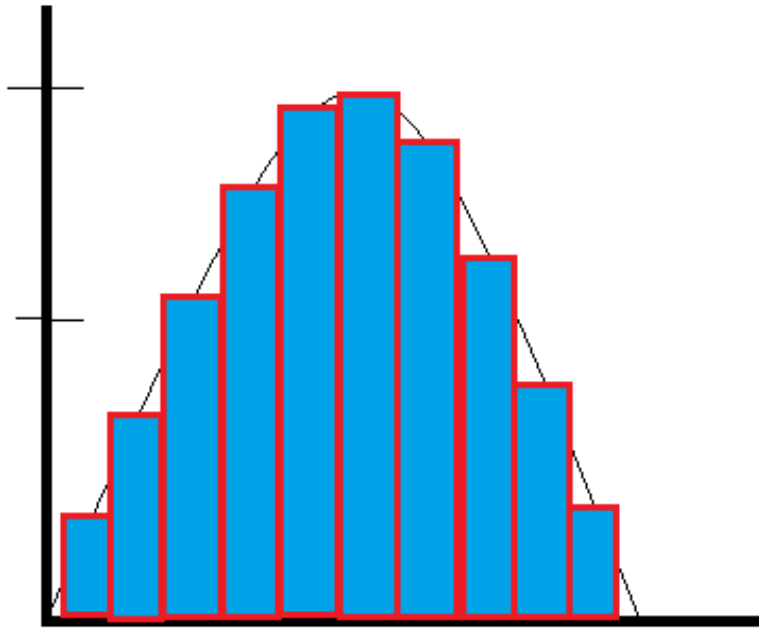
Positive footpoints



# Monte Carlo Method



# Monte Carlo Method



$$\int_a^b \sin(x) \approx (b-a)/N \sum_{i=1}^N \sin(x_i)$$

$$\int_a^b \sin(x) \approx (b-a)/N \sum_{i=1}^N \sin(x_i)/p(x_i)$$

## Calculating Total Magnetic Energy

$$\begin{aligned}W_N &= 1/N \sum_{i=1}^N |\mathbf{B}_z(x_i, y_i, 0)| C(x_i, y_i) / 8\pi p(x_i, y_i) \\ &= \sum_{i=1}^N \Phi_i C(x_i, y_i) / 8\pi\end{aligned}$$

where

$$C(x, y) = \int_{L(x, y)} B[x(l)] dl$$

and

$$\Phi_i = |\mathbf{B}_z(x_i, y_i, 0)| / N p(x_i, y_i)$$

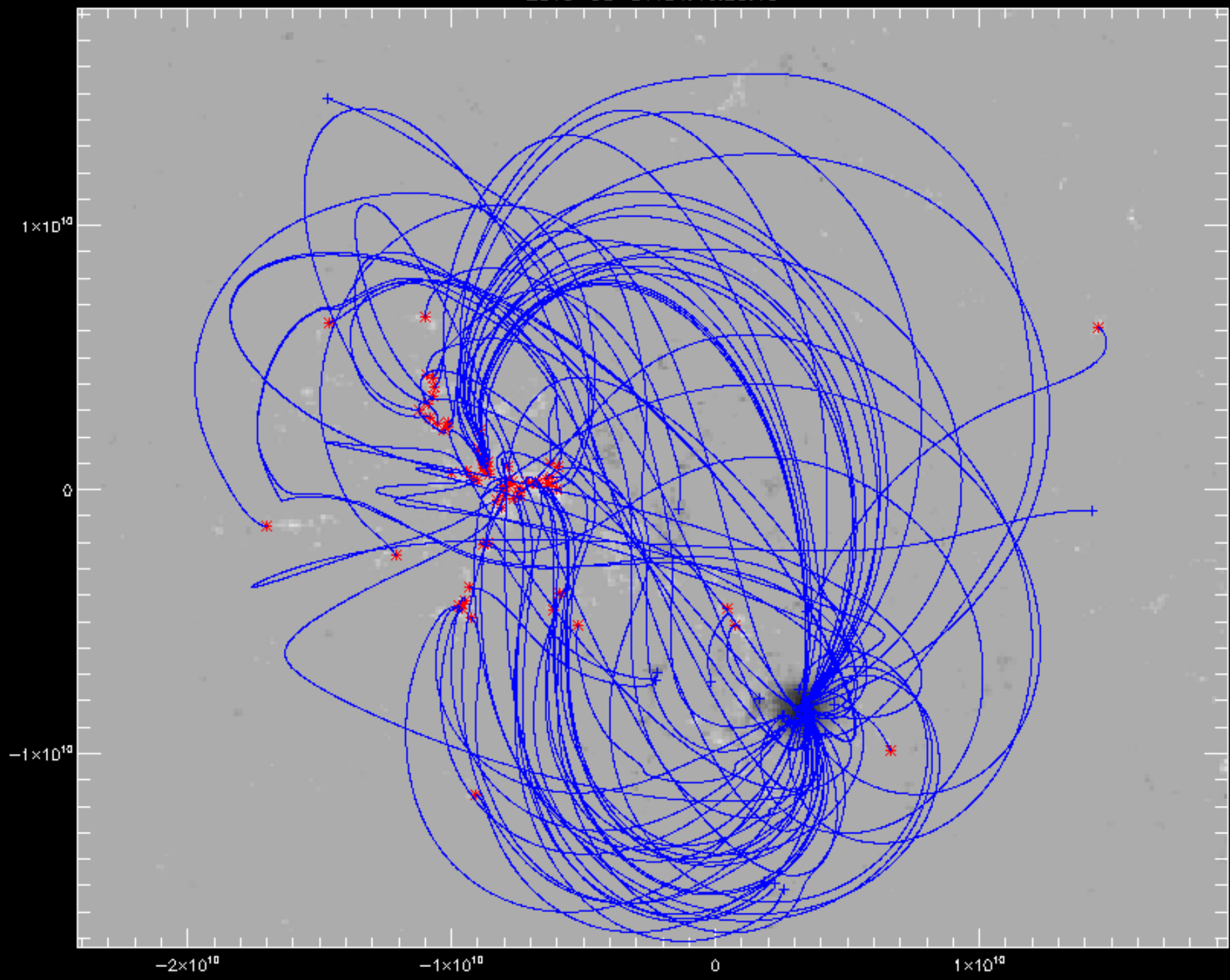
## Calculating the Free Energy

$$W_{free} = 1/8\pi \int d\Phi \int (\mathbf{B} - \mathbf{B}_P) \cdot d\mathbf{l} \approx \sum_{i=1}^N \Phi_i \Delta C_i / 8\pi$$

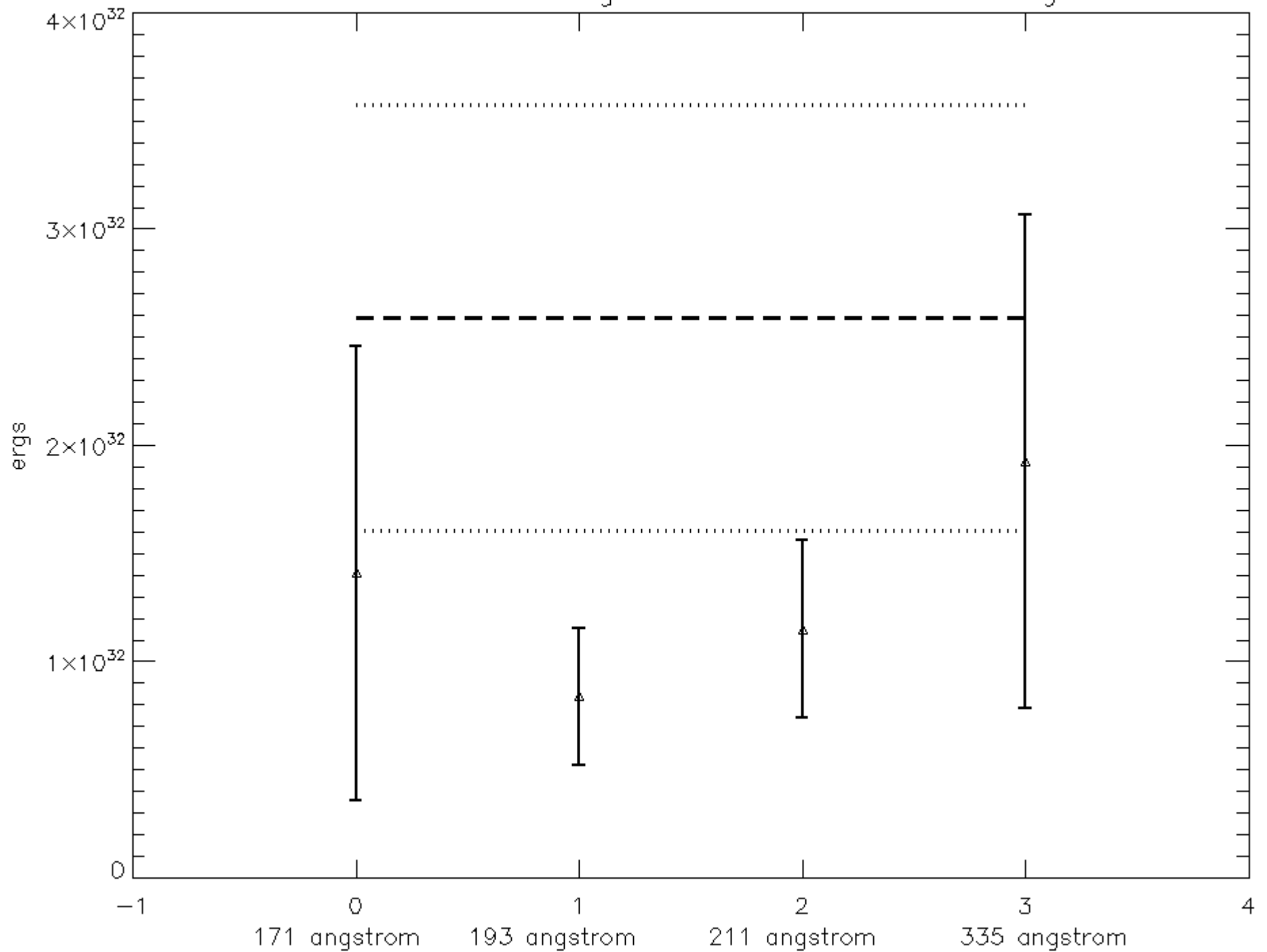
where

$$\Delta C_i(x, y) = \int_{L_i} (\mathbf{B} - \mathbf{B}_P) \cdot d\mathbf{l}$$

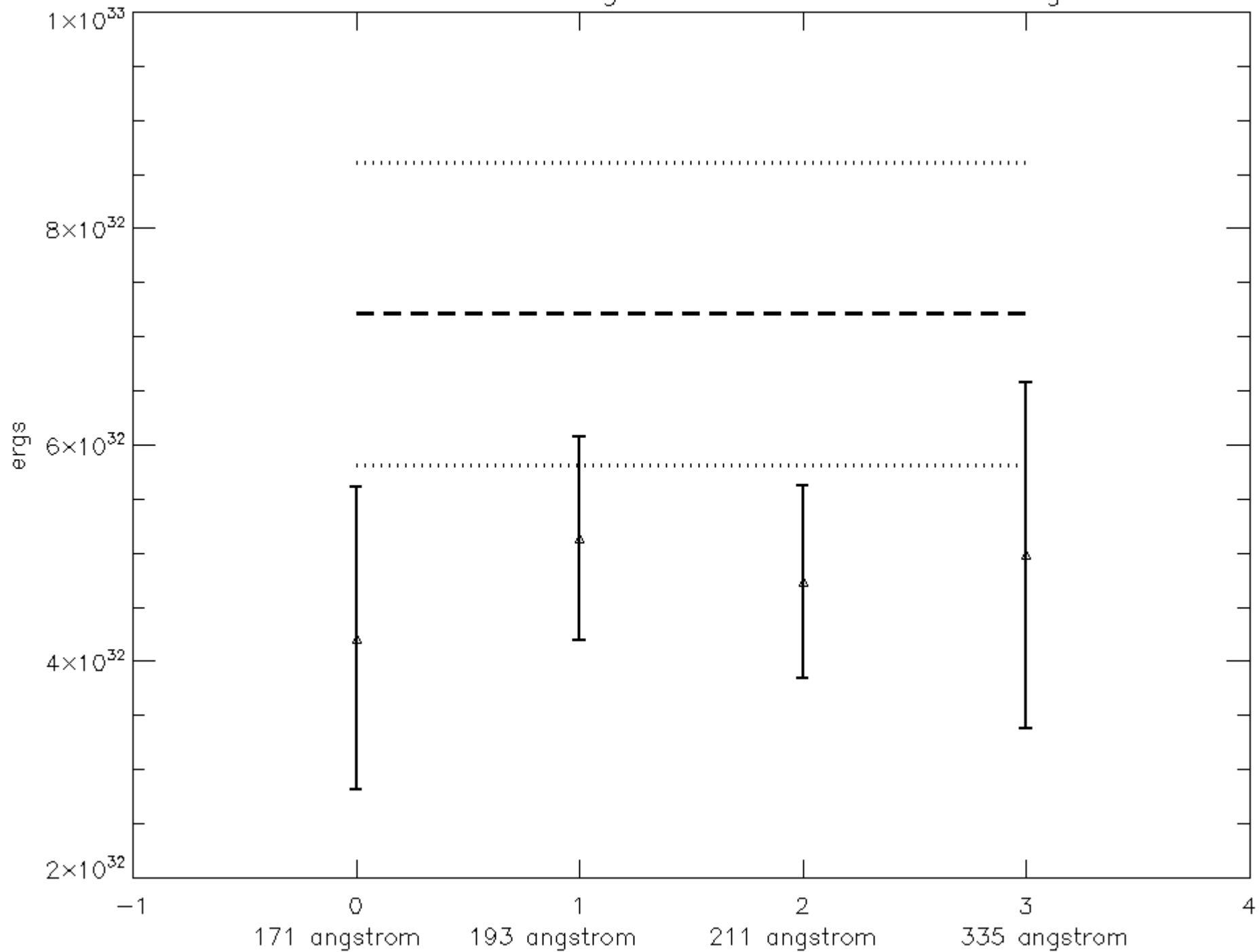
2010-08-01T04:46:26.10



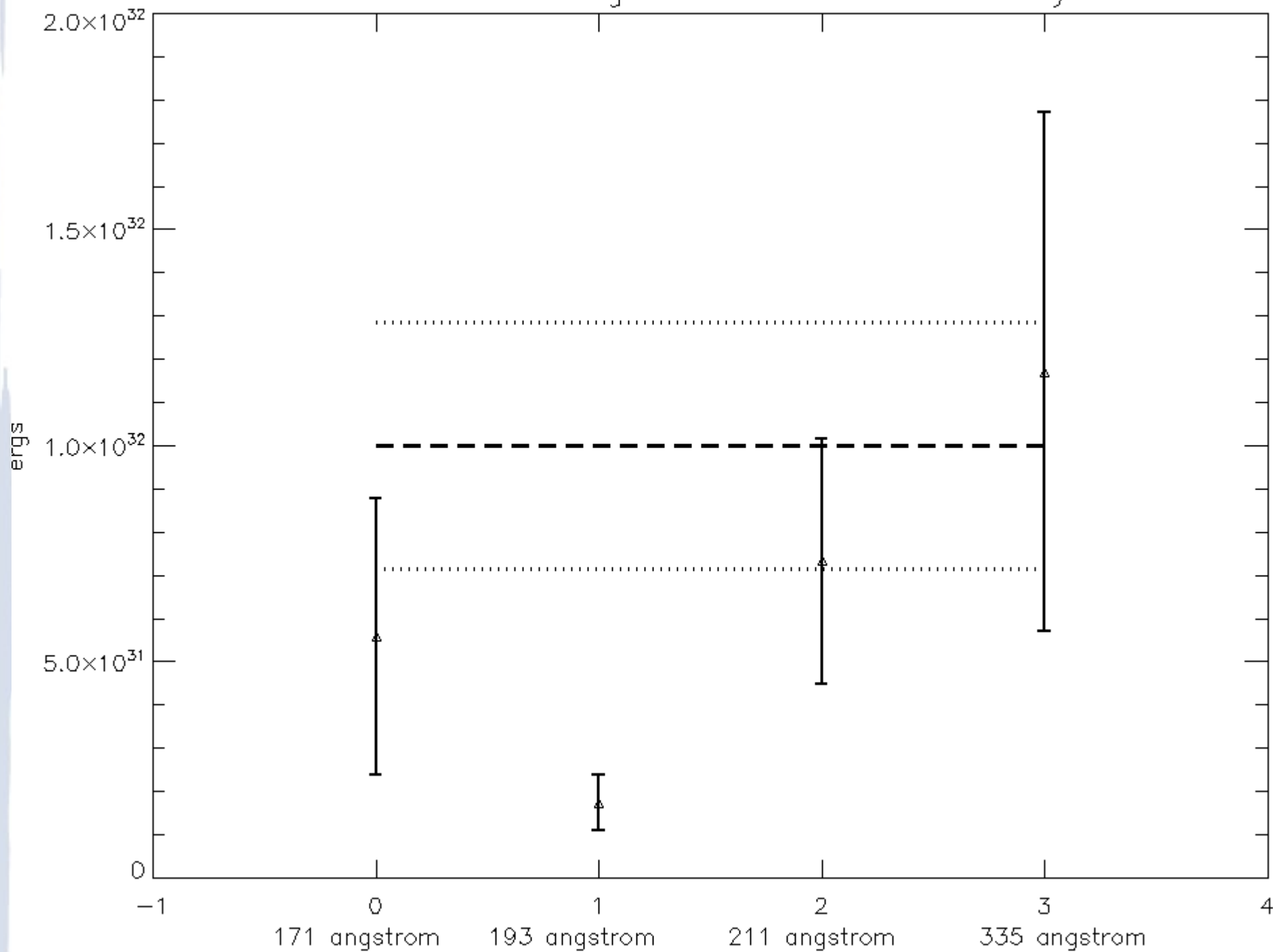
Calculated Free Energies for ar11092 0500 UT Aug 1



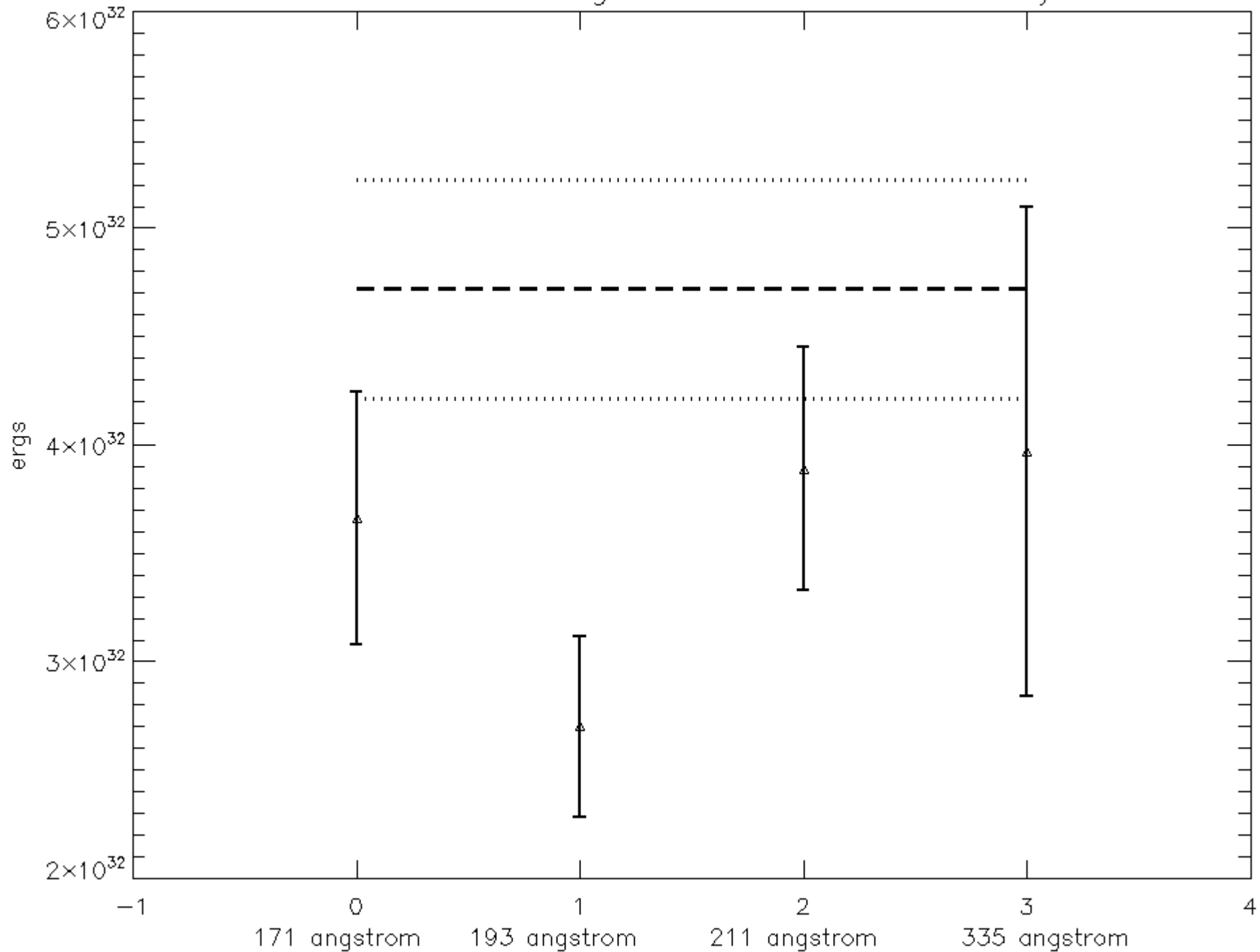
Calculated Total Energies for ar11092 0500 UT Aug 1



Calculated Free Energies for ar11092 1700 UT July 31



Calculated Total Energies for ar11092 1700 UT July 31



$$B_{total} - B_{free} = B_{potential}$$

Ar11092 at 0500 UT

$$7.2 \times 10^{32} \text{ ergs} - 2.6 \times 10^{32} \text{ ergs} = 4.6 \times 10^{32} \text{ ergs}$$

$$\underline{4.5 \times 10^{32} \text{ ergs}}$$

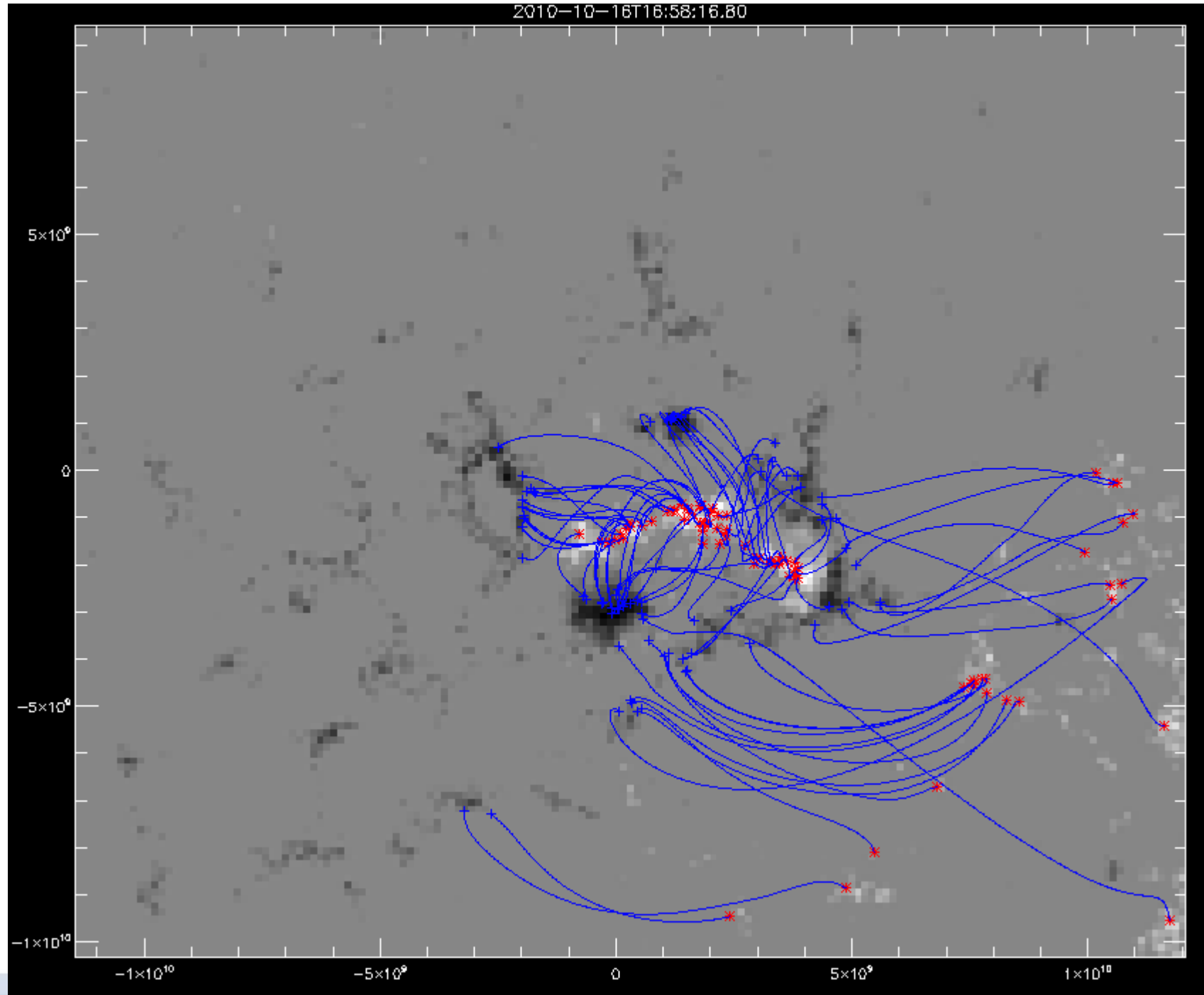
Ar11092 at 1700 UT

$$4.7 \times 10^{32} \text{ ergs} - 1.0 \times 10^{32} \text{ ergs} = 3.7 \times 10^{32} \text{ ergs}$$

$$\underline{3.8 \times 10^{32} \text{ ergs}}$$

ar11112

2010-10-16T16:58:16.80



$$B_{total} - B_{free} = B_{potential}$$

Ar11112 at 1650 UT

$$8.5 \times 10^{31} \text{ ergs} - 1.1 \times 10^{31} \text{ ergs} = 7.4 \times 10^{31} \text{ ergs}$$

$$\underline{8.7 \times 10^{31} \text{ ergs}}$$

Lower bound on the free energy of

$$8.25 \times 10^{30} \text{ ergs}$$

## Conclusion

- The four different wavelengths agree well with each other.
- This method is in good agreement with some other methods of energy calculation.

## Special Thanks to

Dr. Dana Longcope  
and  
Lucas Tarr for programming help

## References

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