Looking for the heating function of solar coronal loops

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MSU Solar Physics REU – 2011

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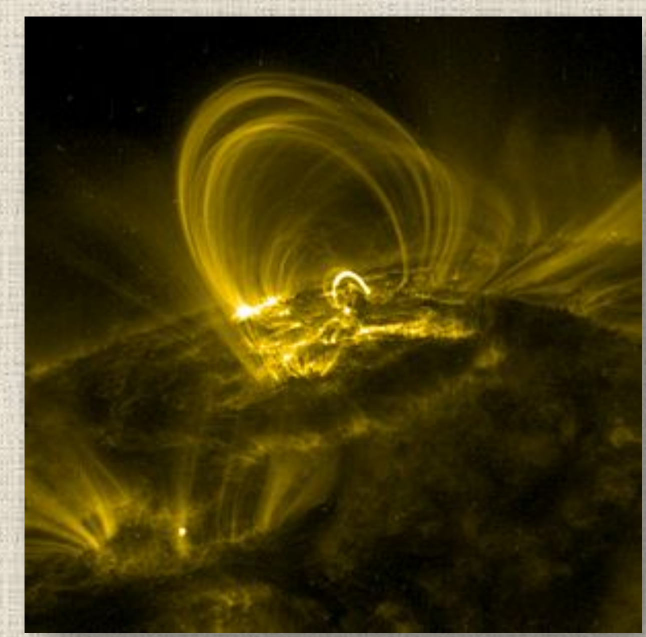
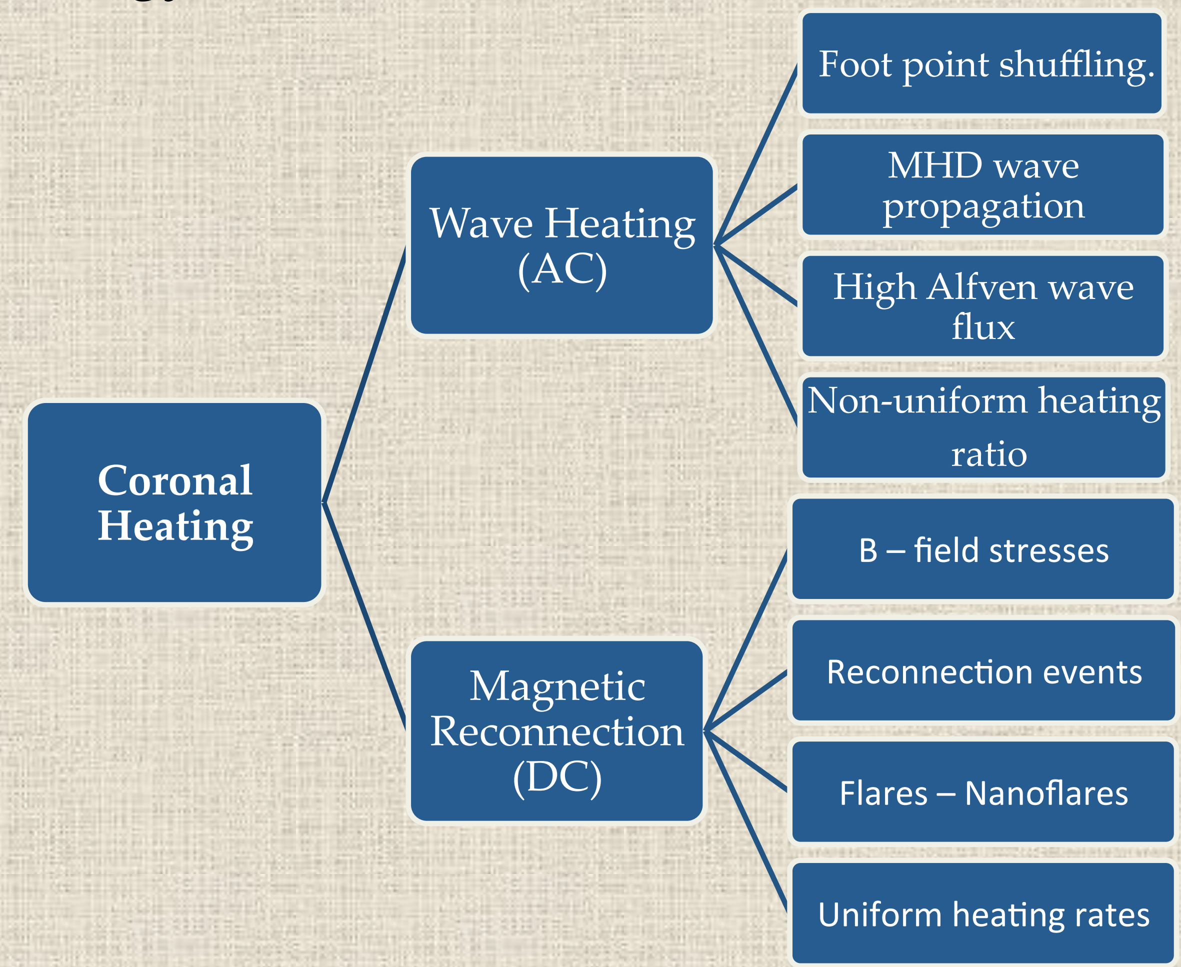
Outline

- ✧ Project background & theory.
- ✧ Data & Instruments.
- ✧ Analysis.
- ✧ Current project status.
- ✧ Next…
- ✧ Acknowledgments

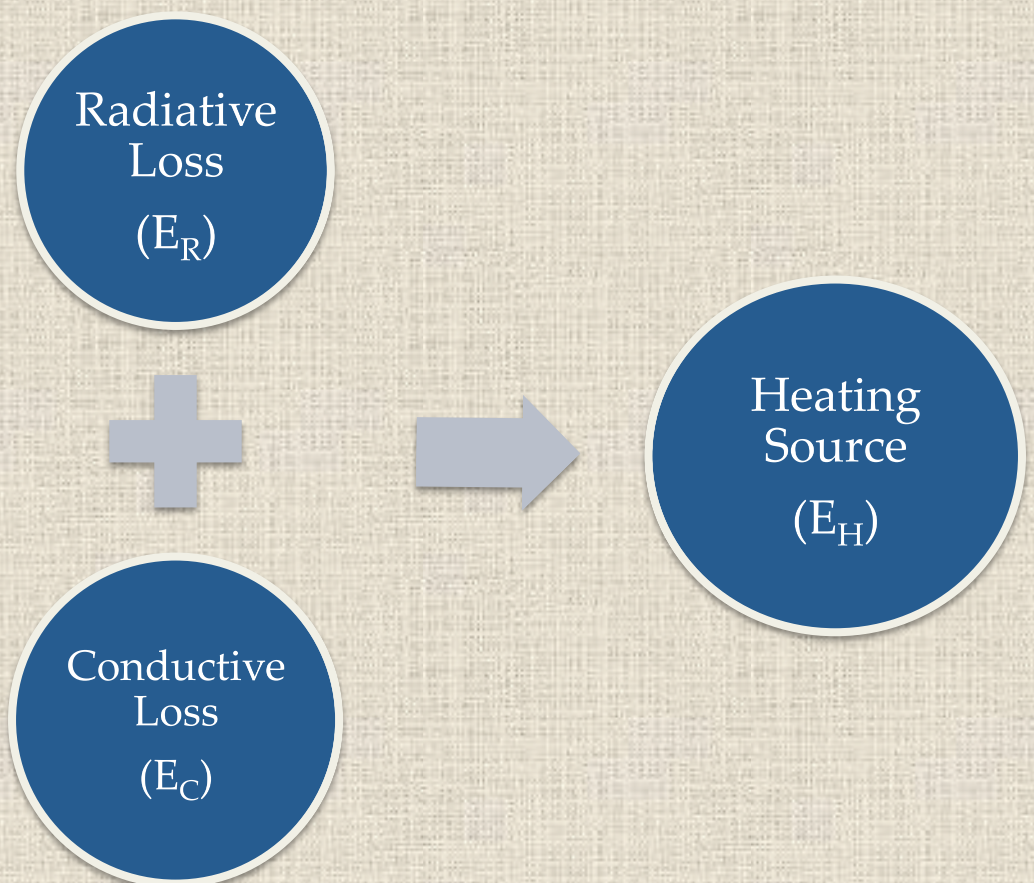


Project Background

Coronal Heating : Conversion of free magnetic energy into thermal energy.

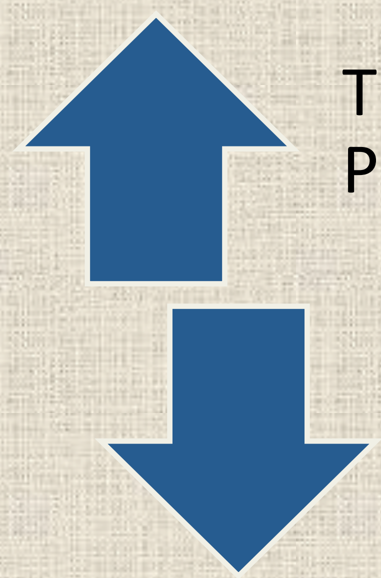


Coronal Heating Requirement



$$E_H(x) - E_R(x) - E_C(x) = 0$$

Hydrostatic Scale Height



Momentum eq;

$$\frac{dP(r)}{dr} = -\mu m_H n_e(r) g_e \left(\frac{R_e^2}{r^2}\right)$$

$$p(r) = 2 n_e(r) \kappa_B T_e(r)$$

Height ‘h’ above surface; $h = r - R_0$

Therefore, solution of energy balance eq. becomes

$$p(h) = p_0 \exp\left[-\frac{(h-h_0)}{\lambda_p(T_e)\left(1+\frac{h}{R_e}\right)}\right] \qquad \lambda_p(T_e) = \frac{2\kappa_B T_e}{\mu m_H g_e}$$

For a static coronal loop; energy eq. is:

$$\frac{d}{dz}\left(\kappa_0 T^{\frac{5}{2}} \frac{dT}{dz}\right) + E_H - p_0^2 \chi_0 T^{-(2+\gamma)} = 0$$

Rosner – Tucker – Vaiana (RTV) scaling laws,

$$P_0 L \sim T_{\max}^3$$

RTV's approx. of **constant pressure, no gravity and uniform heating**.

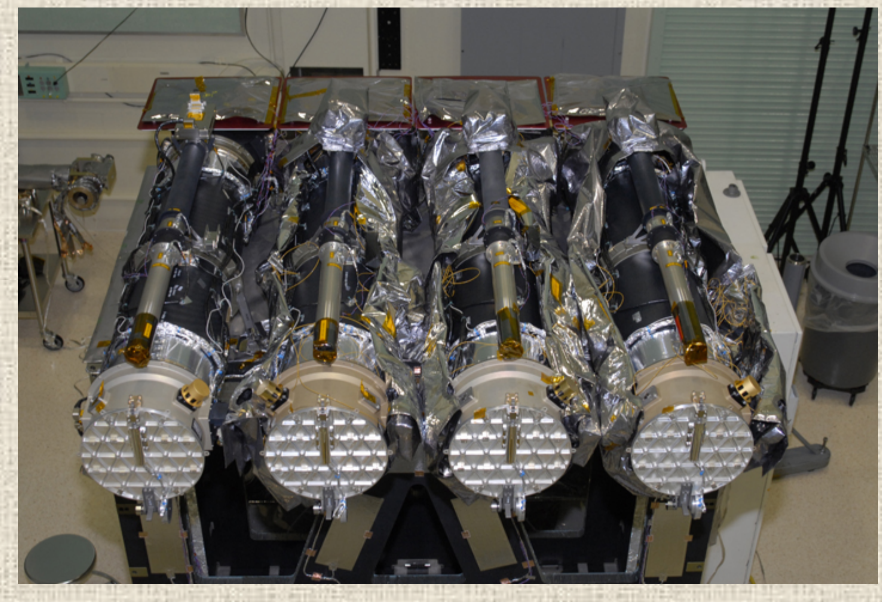
$$E_H = H P_0^{\beta} T^{\alpha}$$

$$T(z) = T_{\max}\left[\beta_r^{-1}\left(\frac{s}{L}; \lambda + 1, \frac{1}{2}\right)\right]^{\frac{1}{2+\gamma+\alpha}}$$

$$P_0 L = T_{\max}^{\frac{11+2\gamma}{4}} \left[\frac{\kappa_0}{\chi_0}\right]^{\frac{1}{2}} \frac{(3-2\gamma)^{\frac{1}{2}}}{4+2\gamma+2\alpha} B\left(\lambda + 1, \frac{1}{2}\right)$$

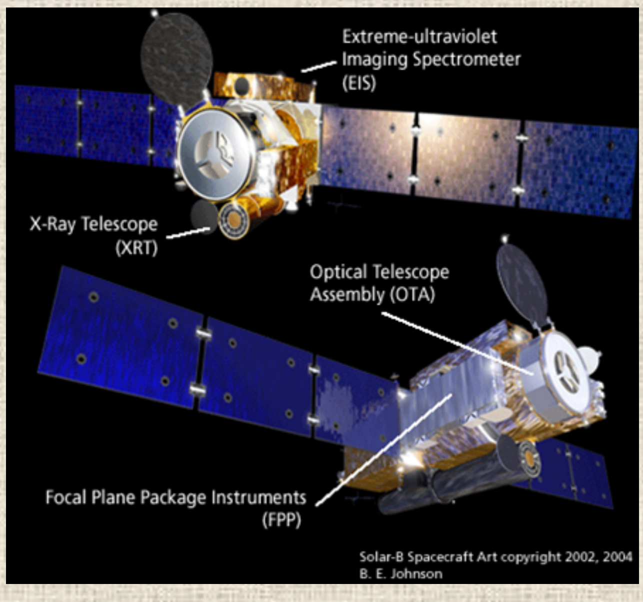
Instruments and Data Sources

Instruments



AIA/SDO

AIA:
High cadence, resolution
Full-disk
Low spectral resolution.

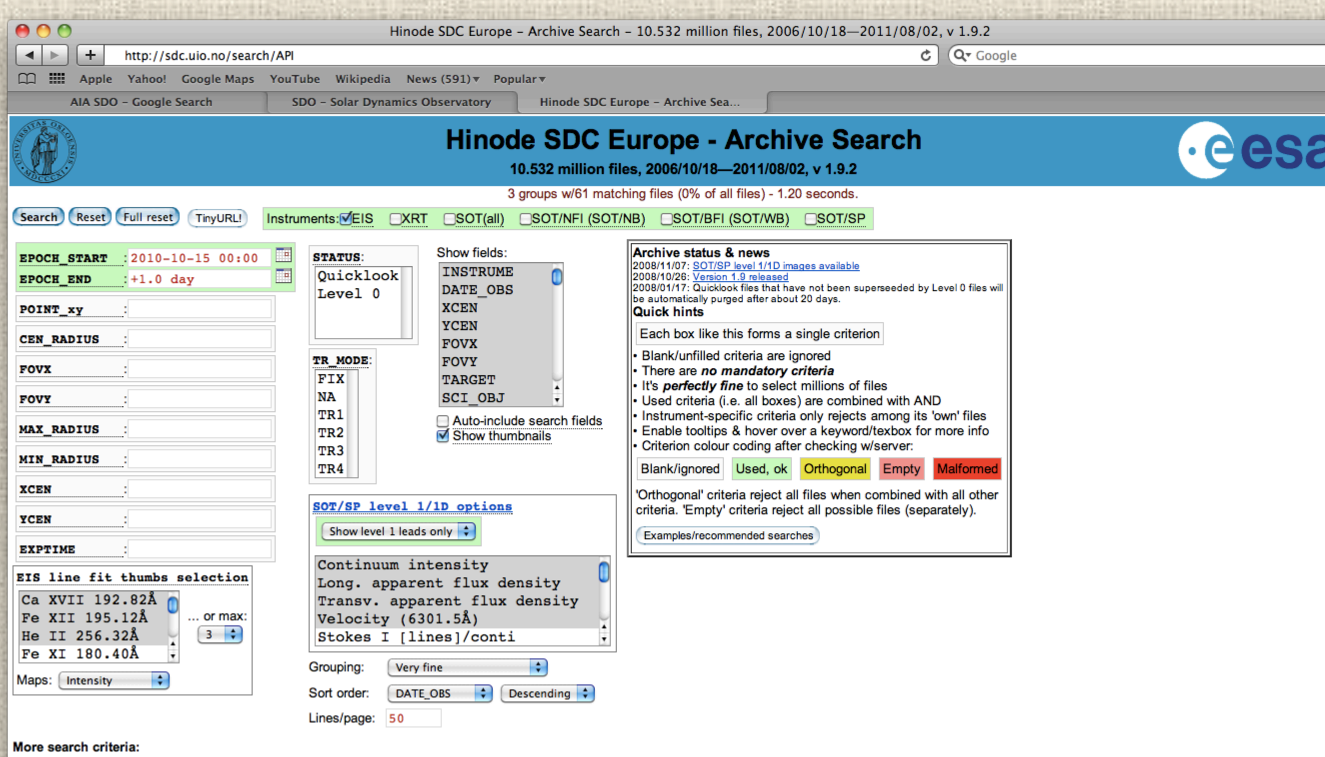


EIS/Hinode

EIS:
Scanning spectrograph
Limited cadence, field of view
High spectral resolution

Data Sources

Extreme-Ultraviolet Imaging Spectrometer (EIS)



http://msslxr.mssl.ucl.ac.uk:8080/SolarB/

Atmospheric Imaging Assembly (AIA)

Used IDL : vso_search & vso_get

Region Identification

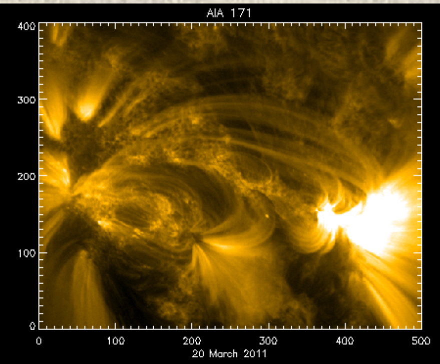
Criteria for selecting loops:

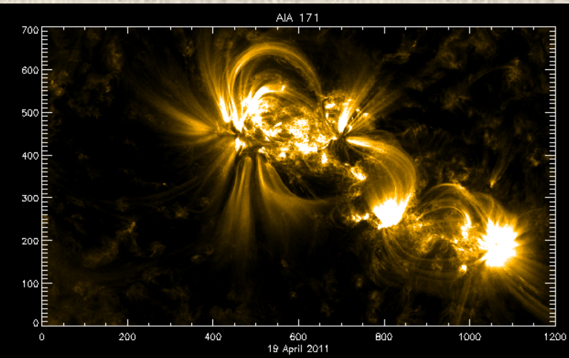
✧ Stable.

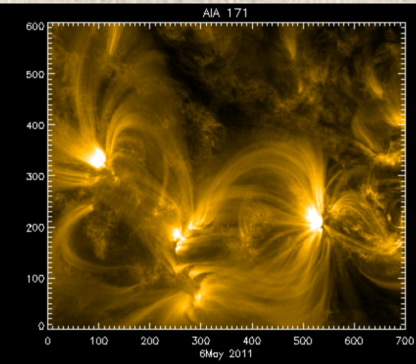
✧ Non Flaring.

✧ Away from limb.

✧ Observed in EIS with 1 arc-second slit ID.





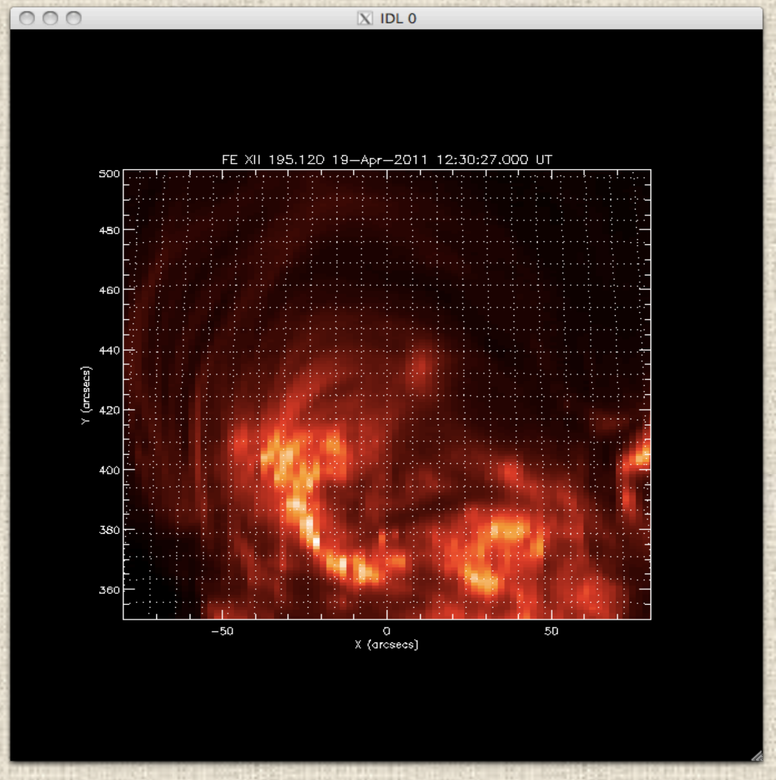


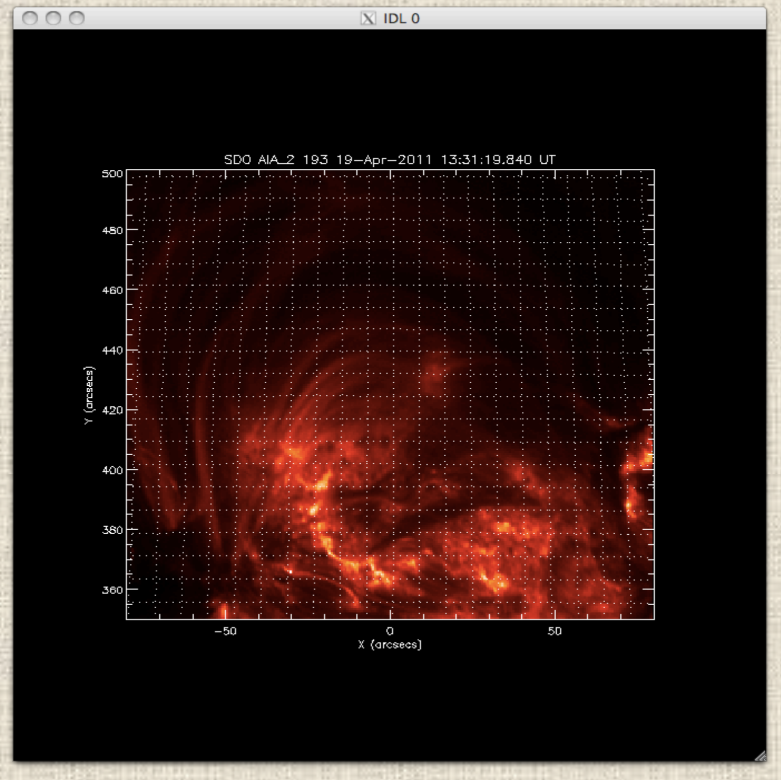
Data Processing:

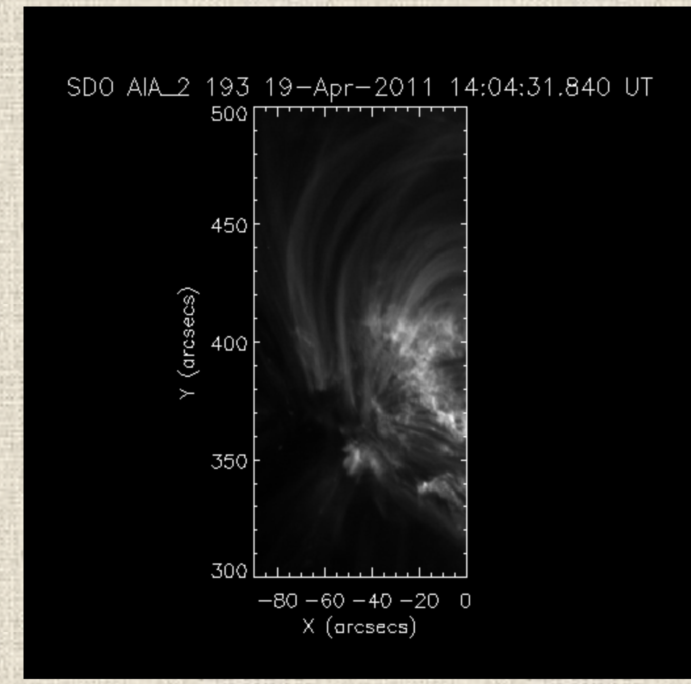
Converted EIS and AIA level – 1 .fits files into .map files.

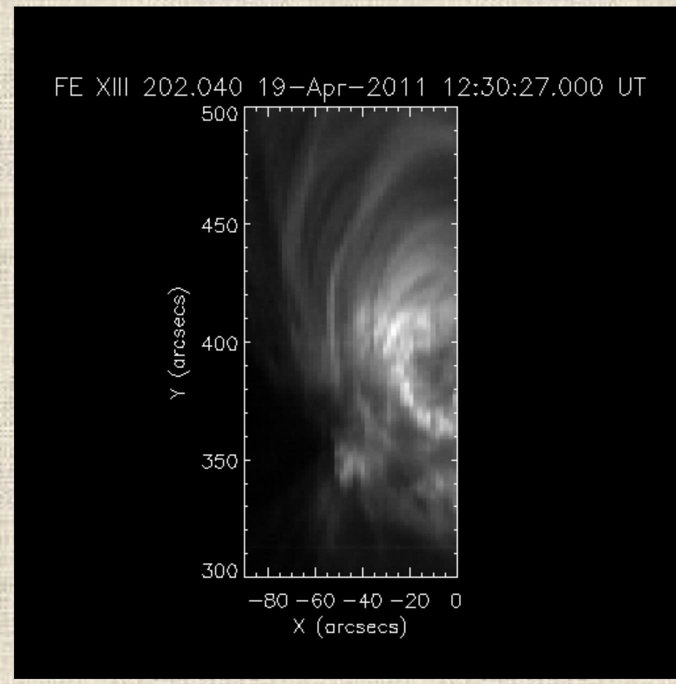
Co-Alignment

To ensure similar pixel locations on EIS and AIA datasets.






SDO AIA_2 193 19-Apr-2011 14:04:31.840 UT
Y (arcsecs)
500
450
400
350
300
−80 −60 −40 −20 0
X (arcsecs)


FE XIII 202.040 19-Apr-2011 12:30:27.000 UT
Y (arcsecs)
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450
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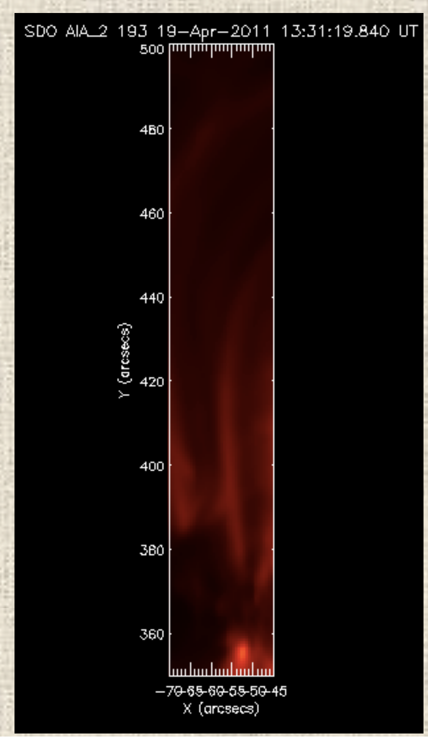
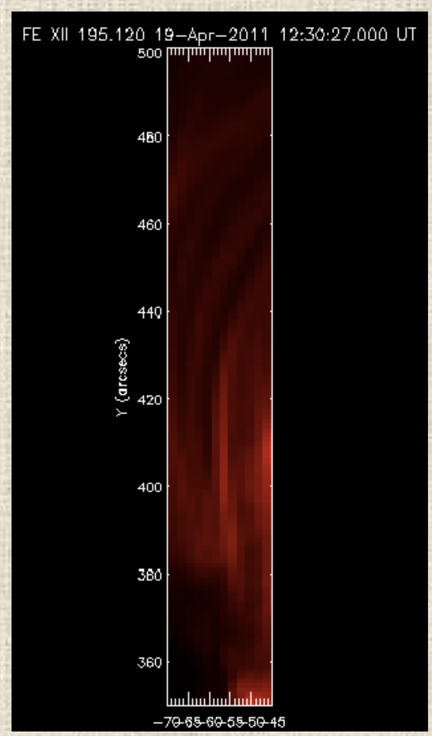
−80 −60 −40 −20 0
X (arcsecs)


SDO AIA_2 193 19-Apr-2011 13:31:19.840 UT
Y (arcsecs)
500
480
460
440
420
400
380
360
−70−65−60−55−50−45
X (arcsecs)


FE XII 195.120 19-Apr-2011 12:30:27.000 UT
Y (arcsecs)
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460
440
420
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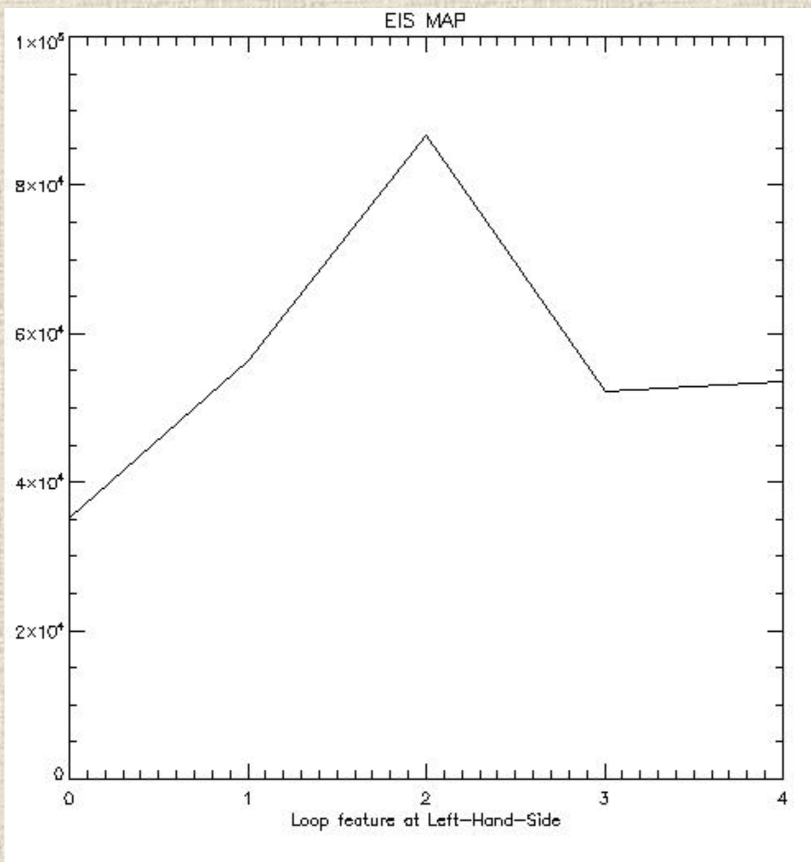
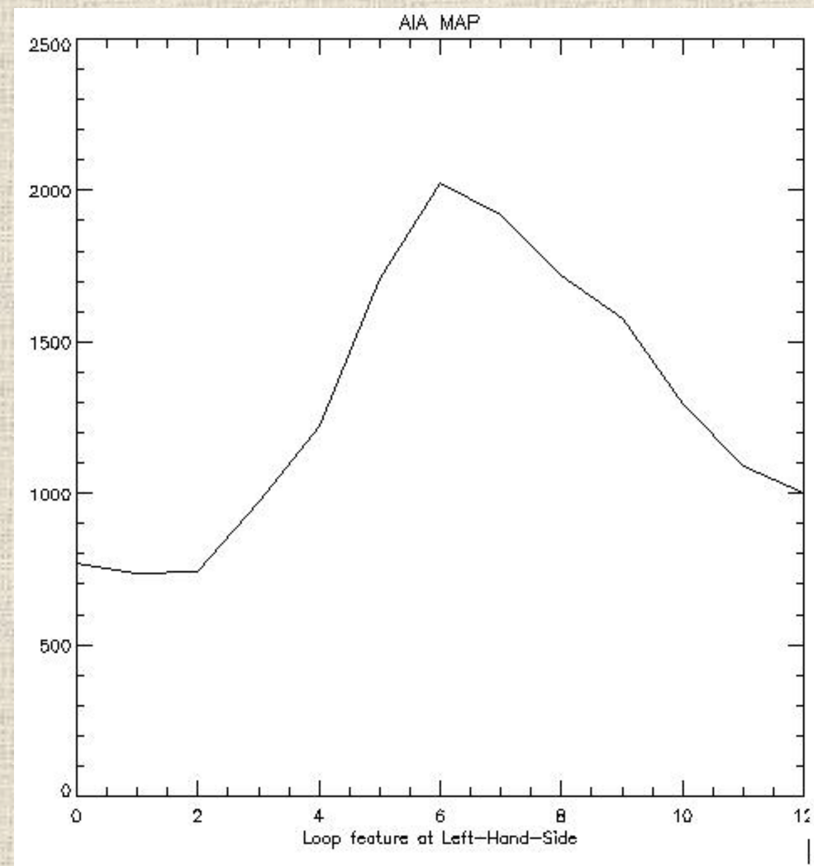
360
−70−65−60−55−50−45

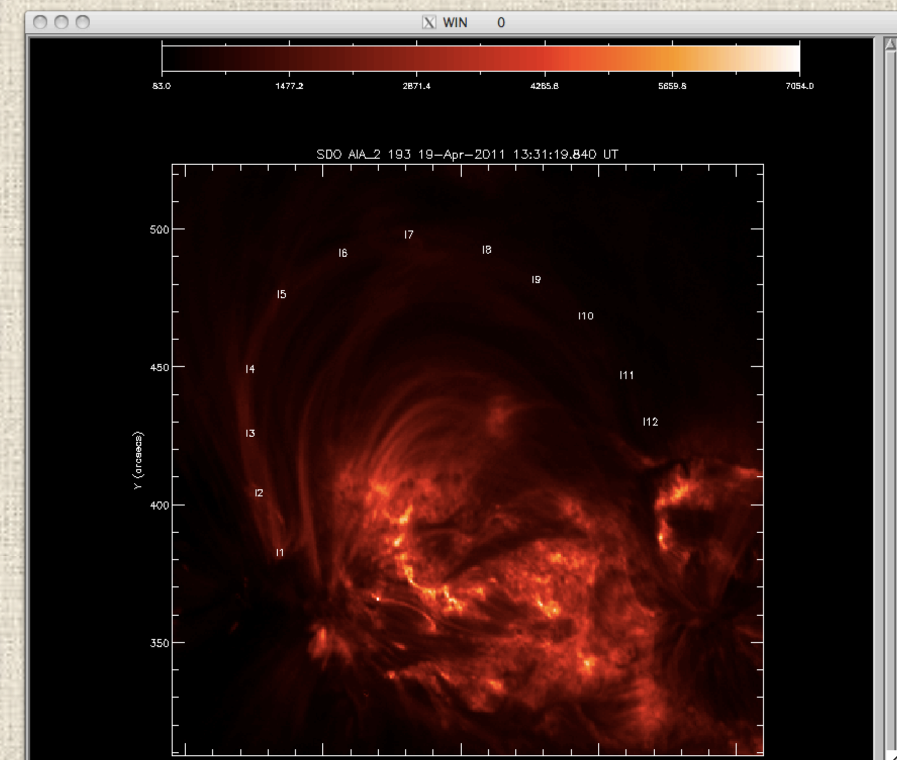
Co-alignment Check

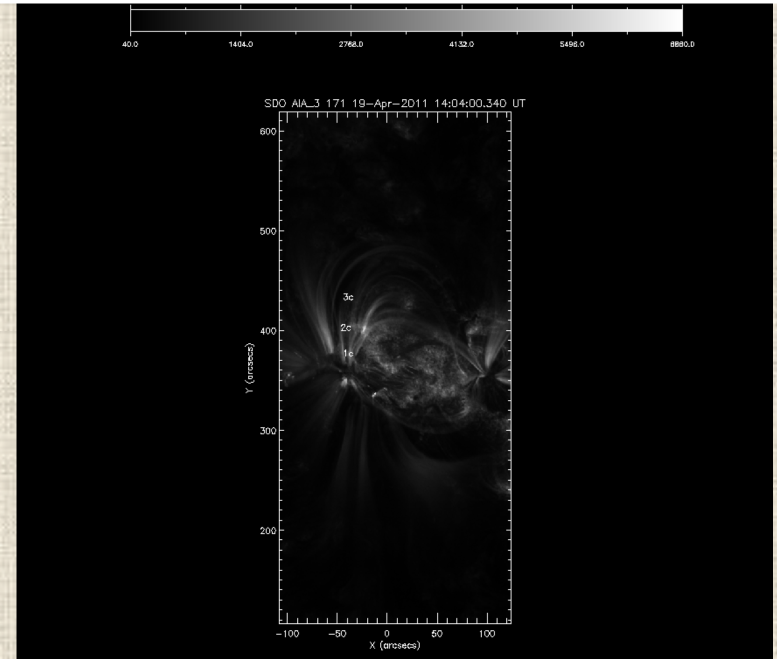


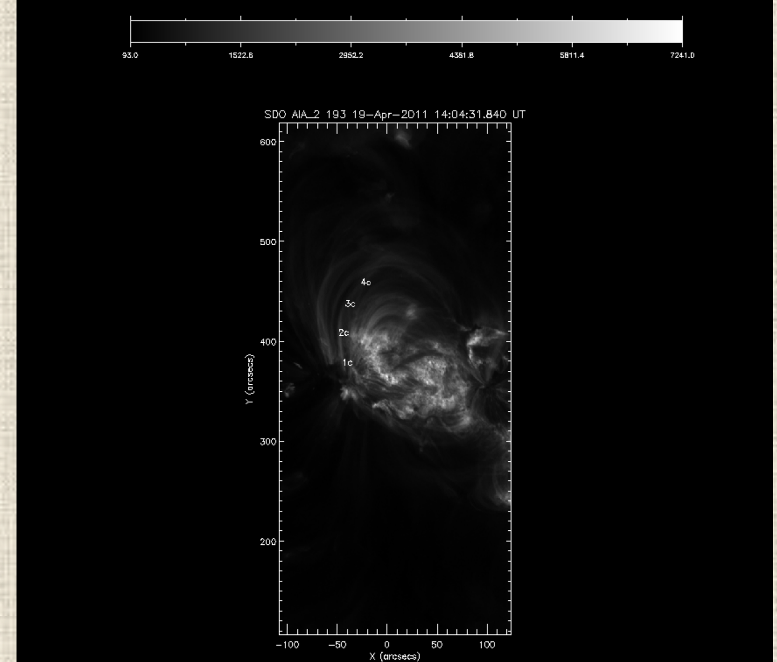


Widget Interface for Loading Map Applications WILMA,
a GUI written
by Trae Winter & Jason Scott used to select points for above.

Picking Points

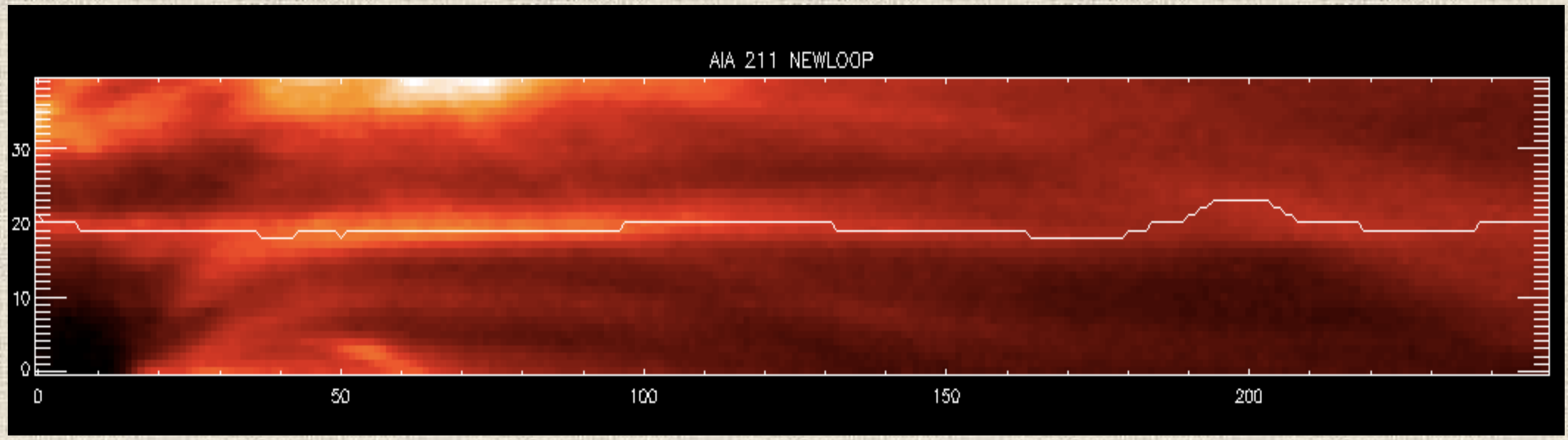




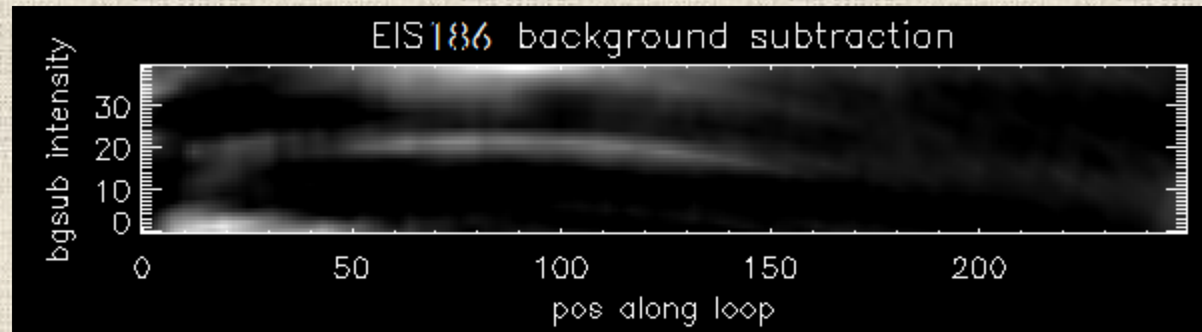


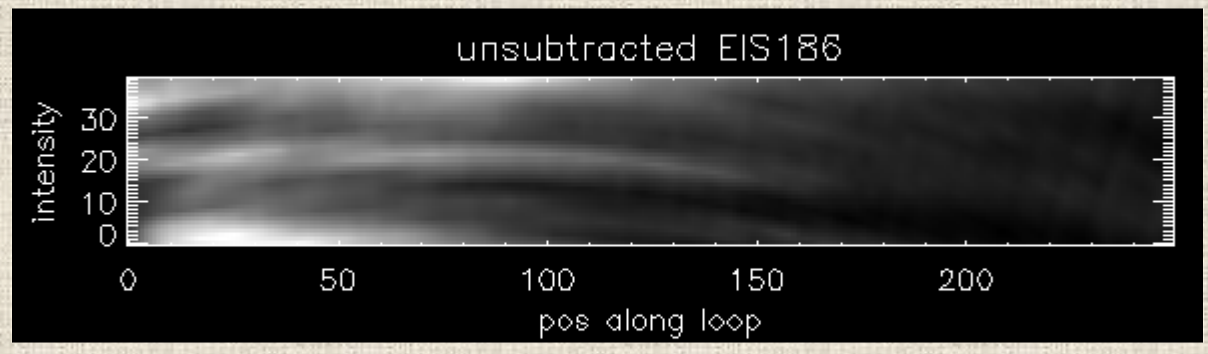
Loop straightening

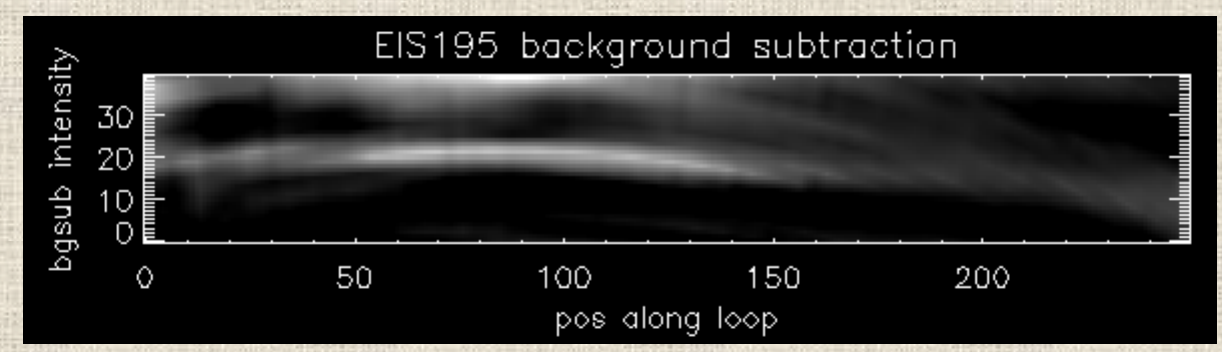
Using a loop straightening tool gave a better idea of the geometry of the loop.

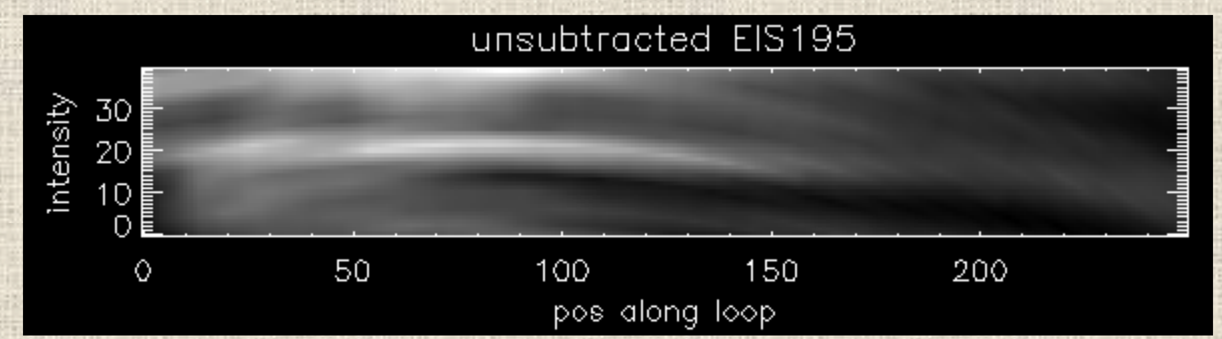


Background Subtraction



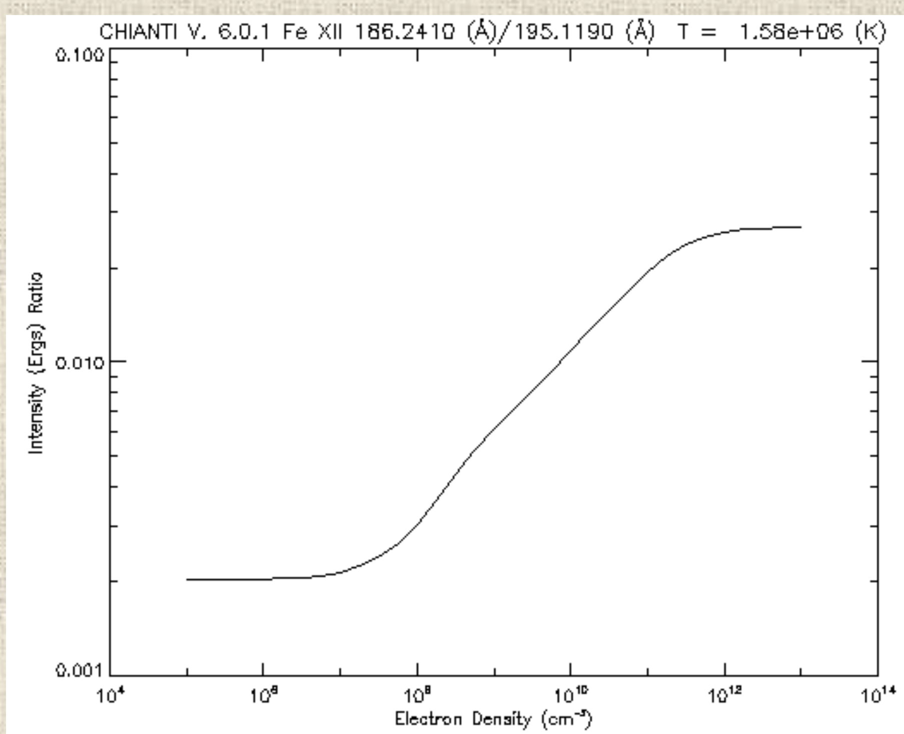


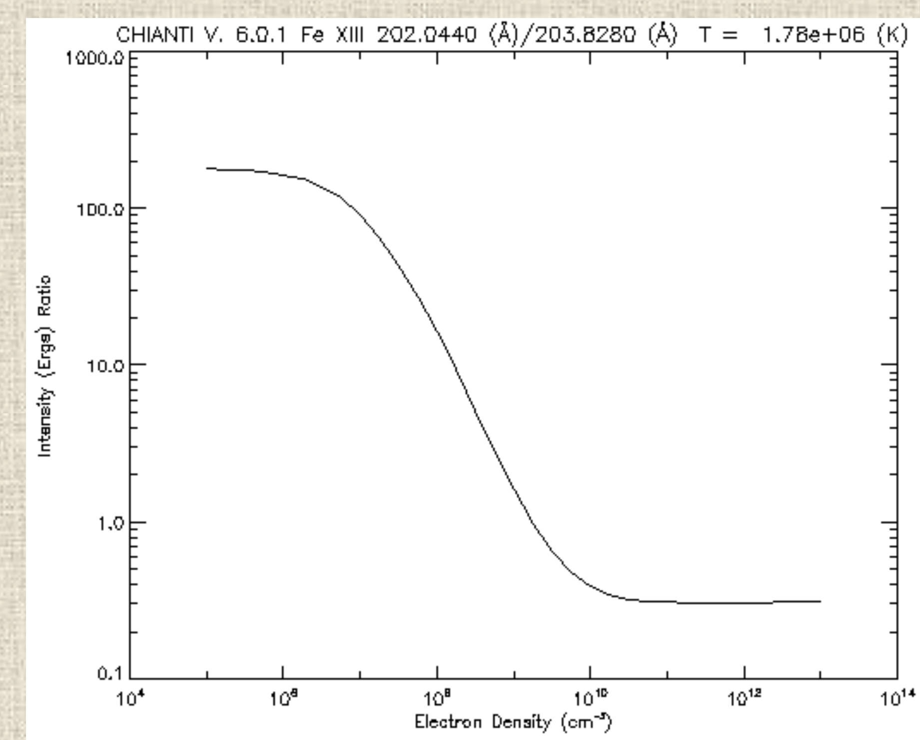




Density diagnostics

- ✧ Involved finding intensity ratio of density sensitive emission lines.
- ✧ Highly important for estimating pressure balance, energy and 'filling factor.'

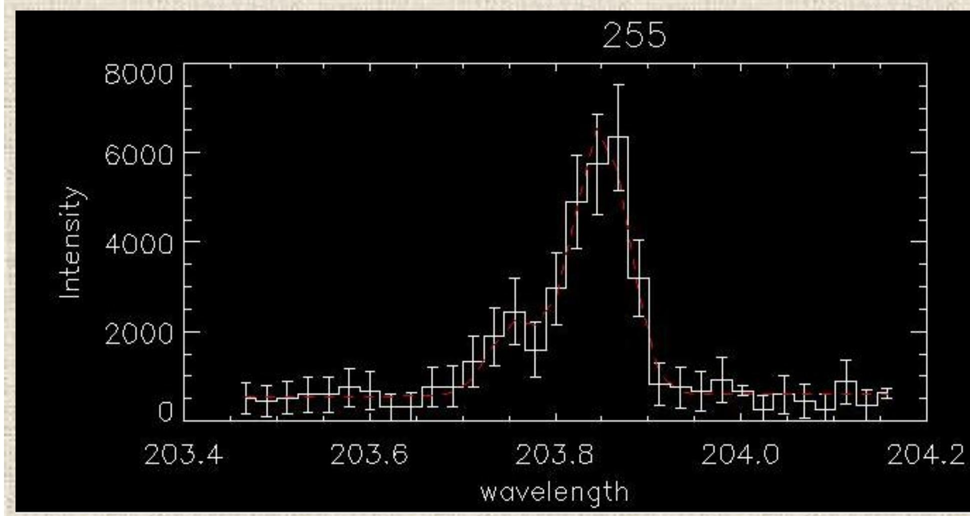


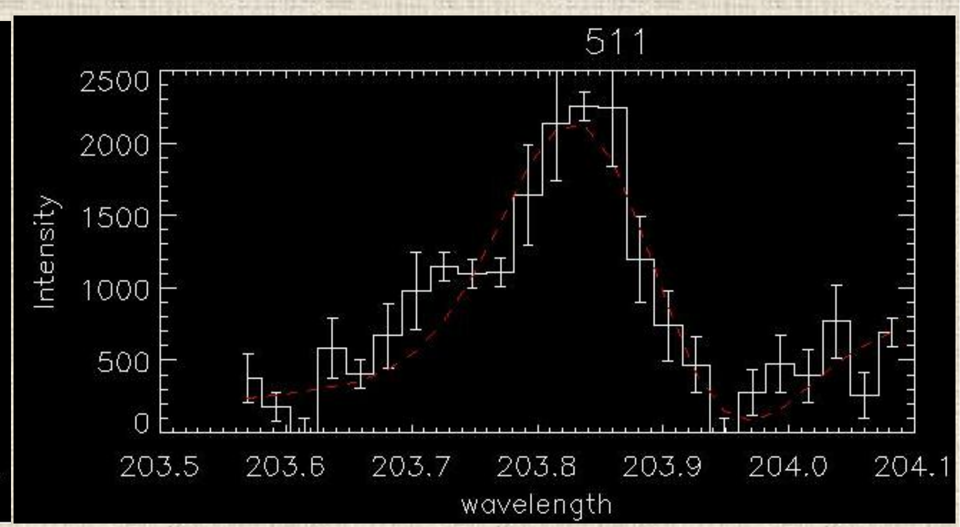


CHIANTI corresponding intensity ratios and density

Gaussian fitting for intensity profile

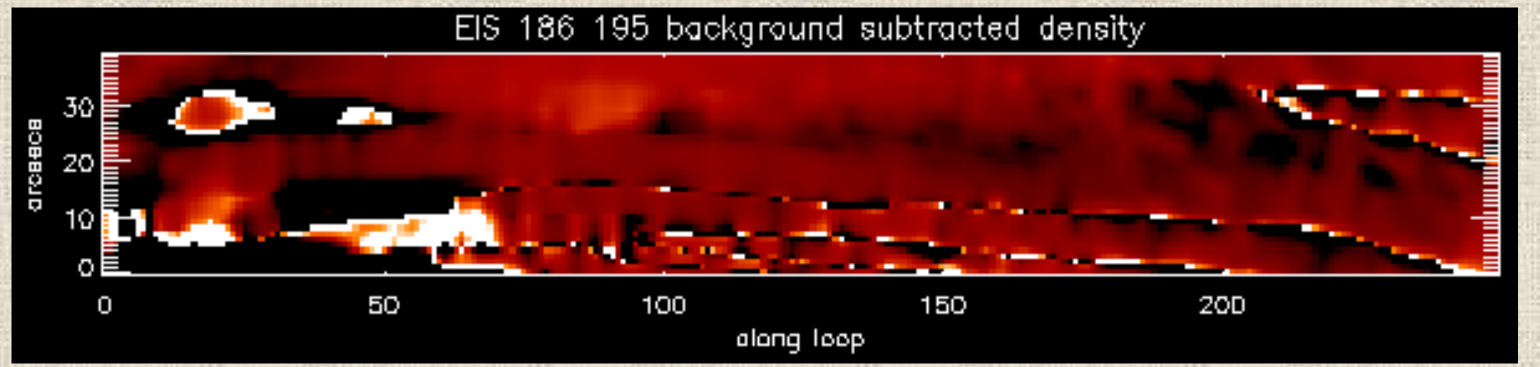
✧ The fitting of gaussians resolved wavelength blending;
✧ Gave us fit_struc files to work with.

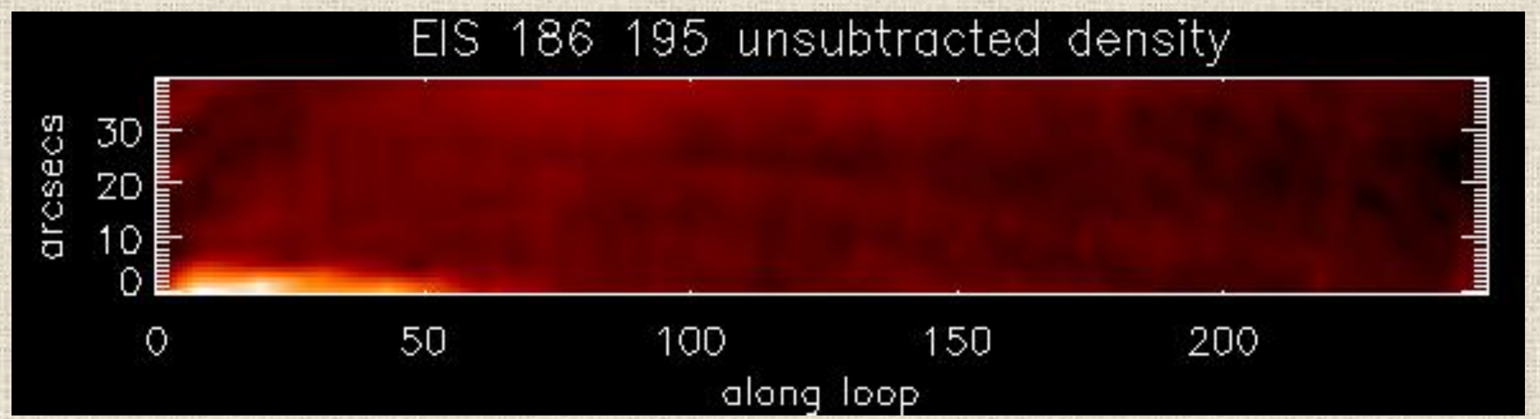




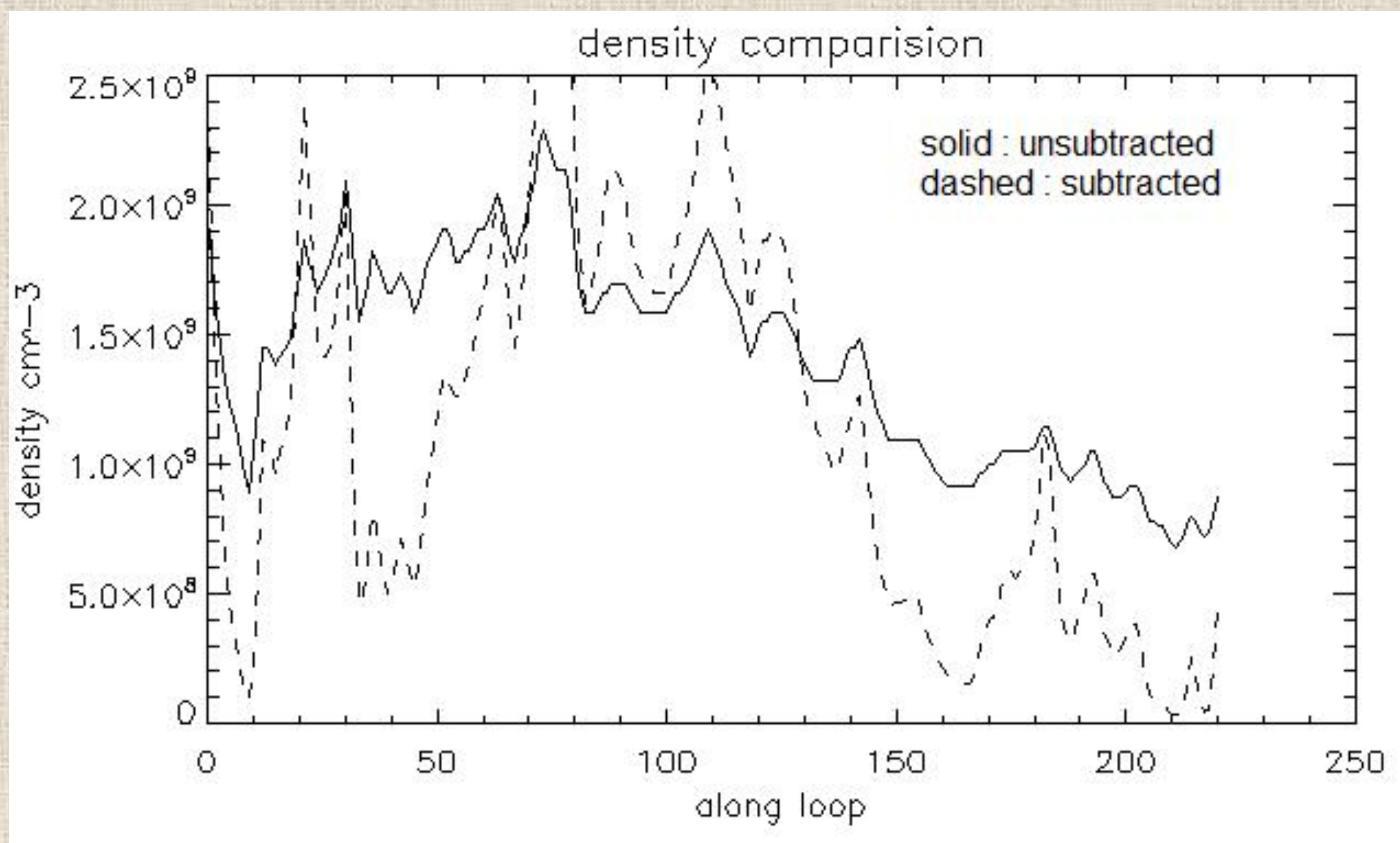
Density plots

- .fit_struc files were converted into .map file.
- Loops were straightened from these files.
- Background intensities were subtracted.
- A code "get_dens_195.pro" finds the corresponding densities





Density profile comparison



What next…

Temperature profile: By using EM Loci method for isothermal loops or by Differential Emission Measurements (DEMs) for multi-thermal loops.

Pressure: By ideal gas law, using temperature and densities found and loop length.

All these parameters can provide an estimate of heating function from scaling law.

$$E_H = H P_0^{\beta} T^{\alpha}$$

$$P_0 L = T_{\max}^{\frac{11+2\gamma}{4}} \left[\frac{\kappa_0}{\chi_0}\right]^{\frac{1}{2}} \frac{(3-2\gamma)^{\frac{1}{2}}}{4+2\gamma+2\alpha} B\left(\lambda+1, \frac{1}{2}\right)$$

Acknowledgements

We are grateful to our mentor Prof. Petrus (Piet) Martens, Joseph Plowman and Jason Scott for all their patience and help throughout the summer, and the Solar Physics group for the opportunity.

Thank you to the other REUs for a great summer.

Thank you Eric for everything.

To the Grad-Students for making us believe;

"Nullum magnum ingenium sine mixtura dementiae fuit"
"No great genius has existed without a mixture of madness"