Non-Thermal Motions in the Hot Cores of Solar Active Regions

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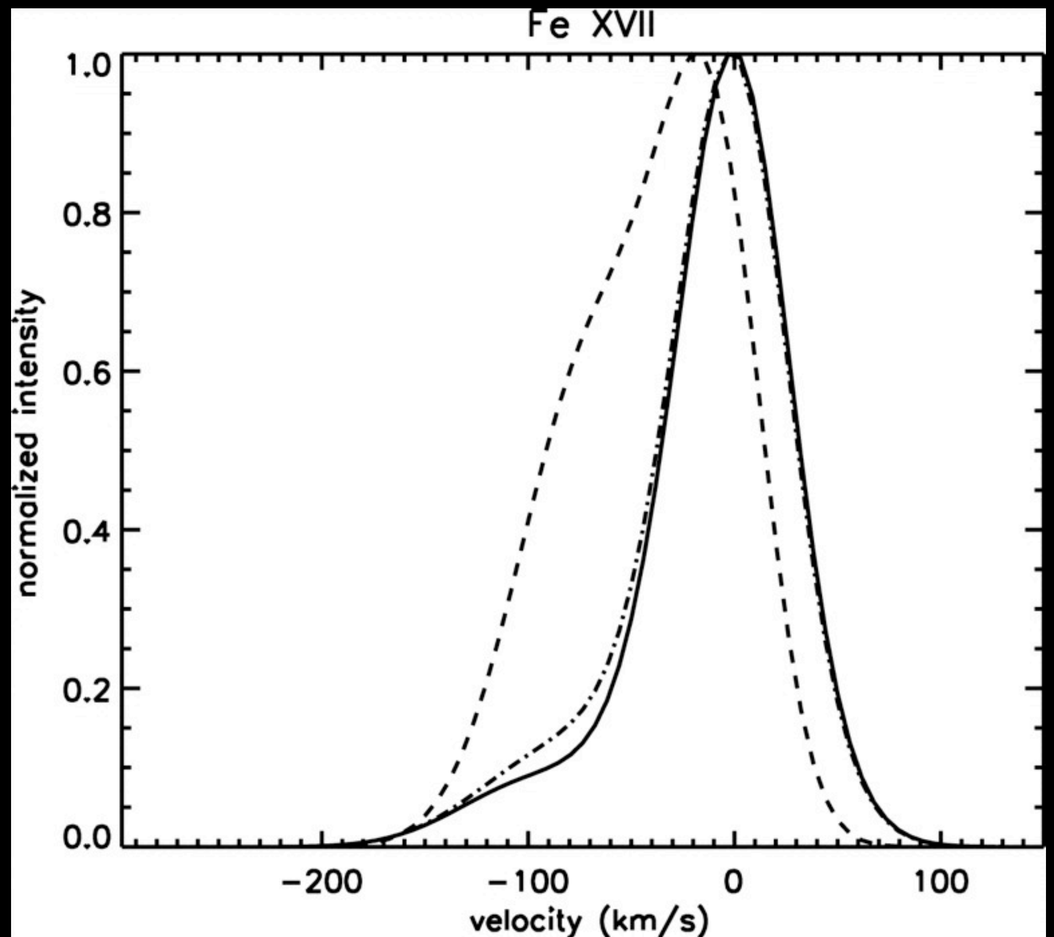
  -- Chromospheric evaporation in response to coronal nanoflares:
  ~ 20-36km/s @ 1.1-5.6MK @ loop tops
  (Patsourakos & Klimchuk 2006)
  [Increasing trend with temperature]



Simulated Profile: Patsourakos & Klimchuk

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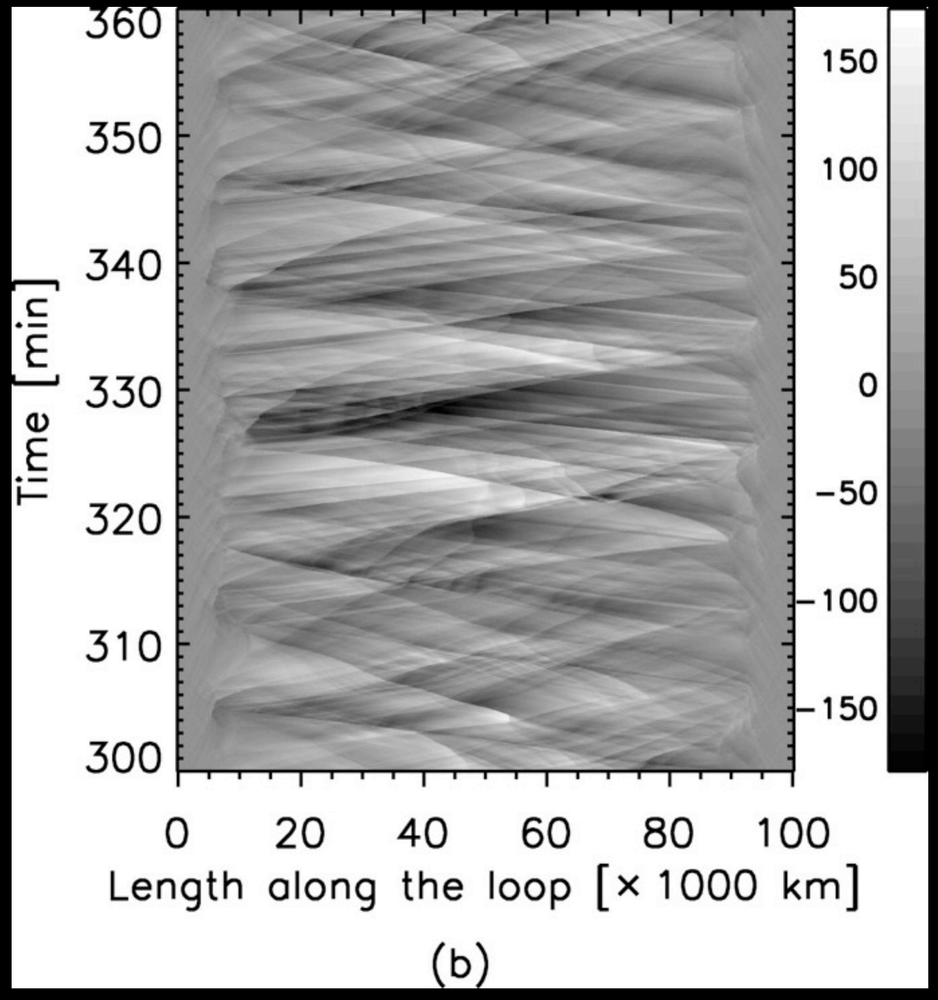

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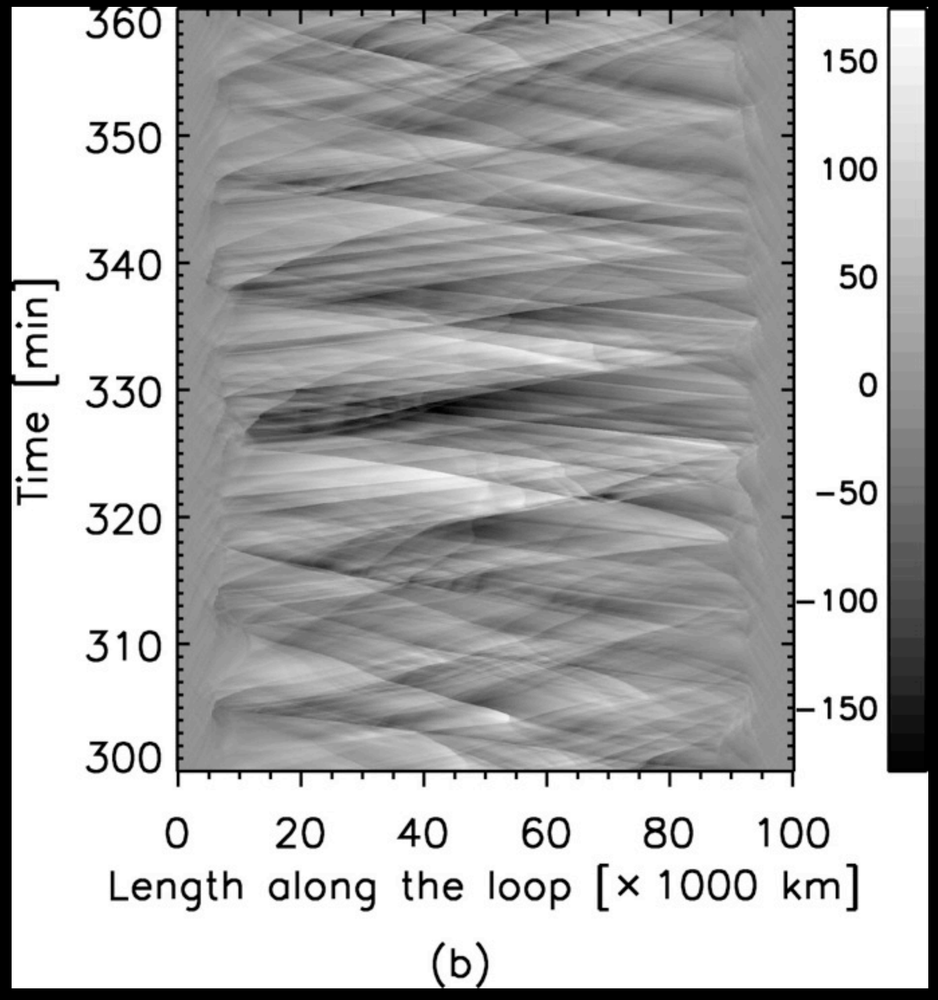
  - -- First Ionization Potential Effect:
    ~ 50-80km/s (Laming 2004 2012)



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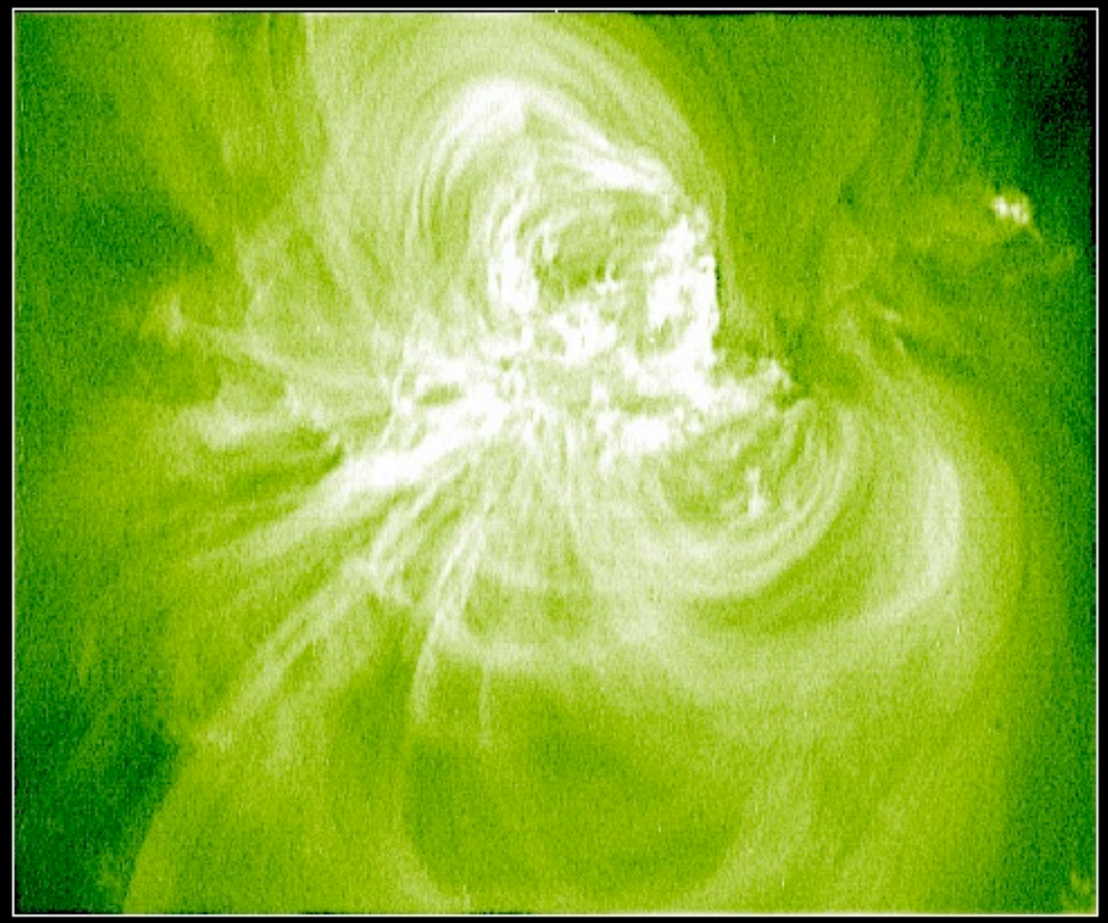
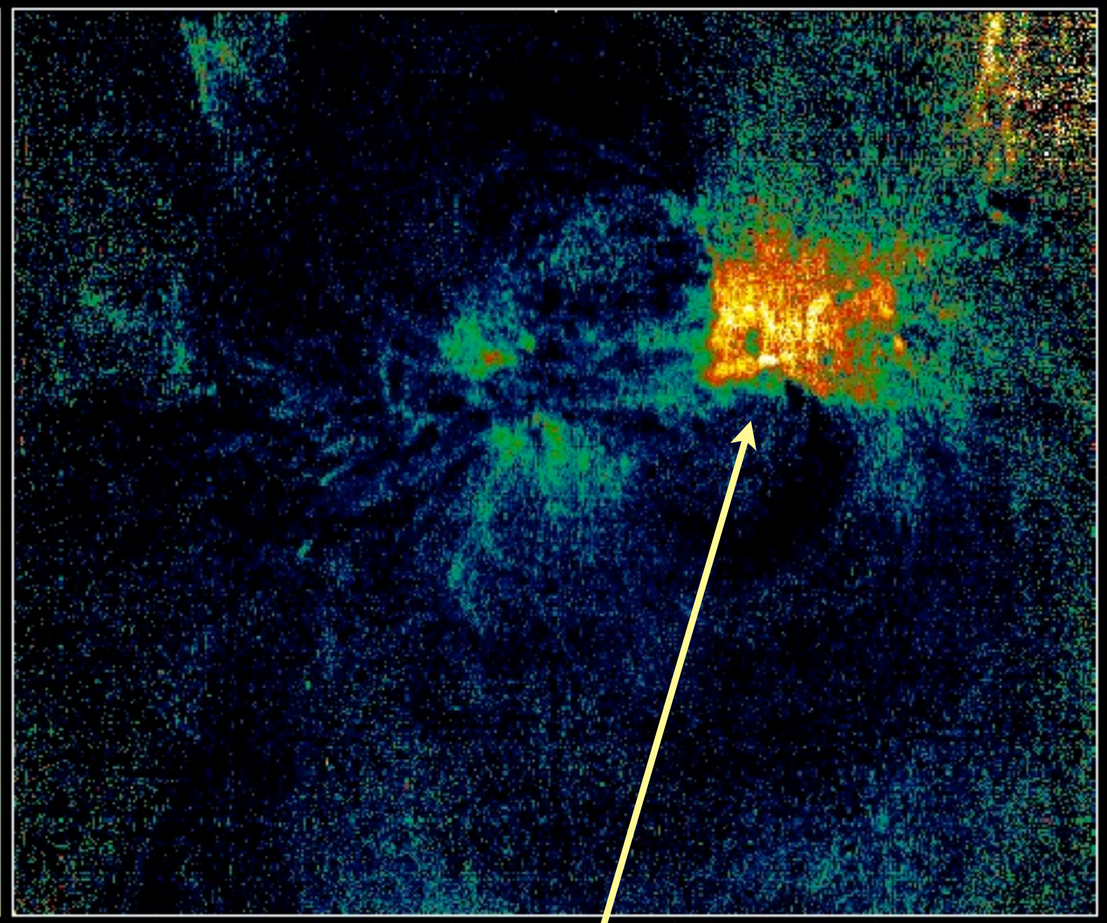
- A systematic survey to see if the models and observations can be reconciled.

AR 10978 Intensity and Non-thermal Velocity Maps

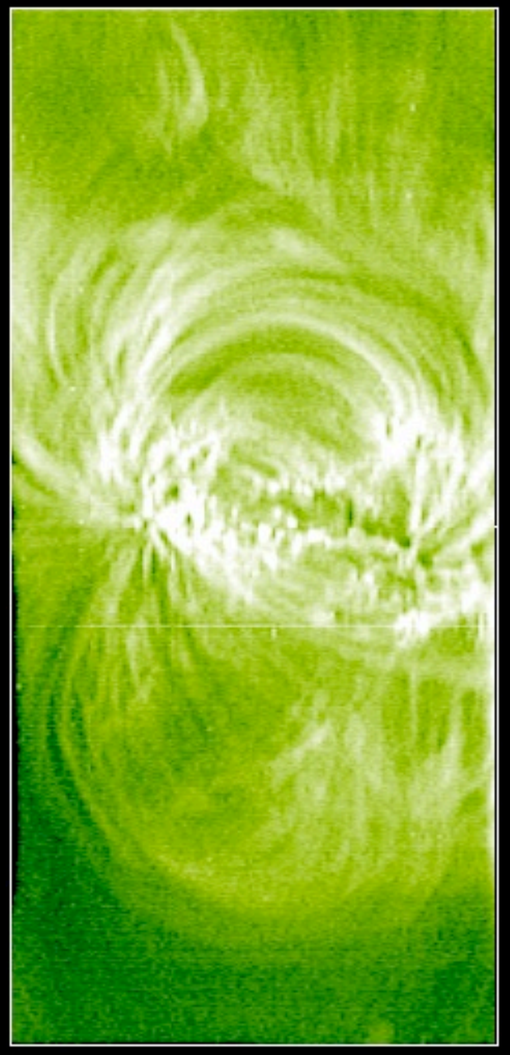


Fe XIII 202Å



Largest widths at AR boundary
(Doschek et al. 2008)

AR 11190 Intensity and Non-thermal Velocity Maps



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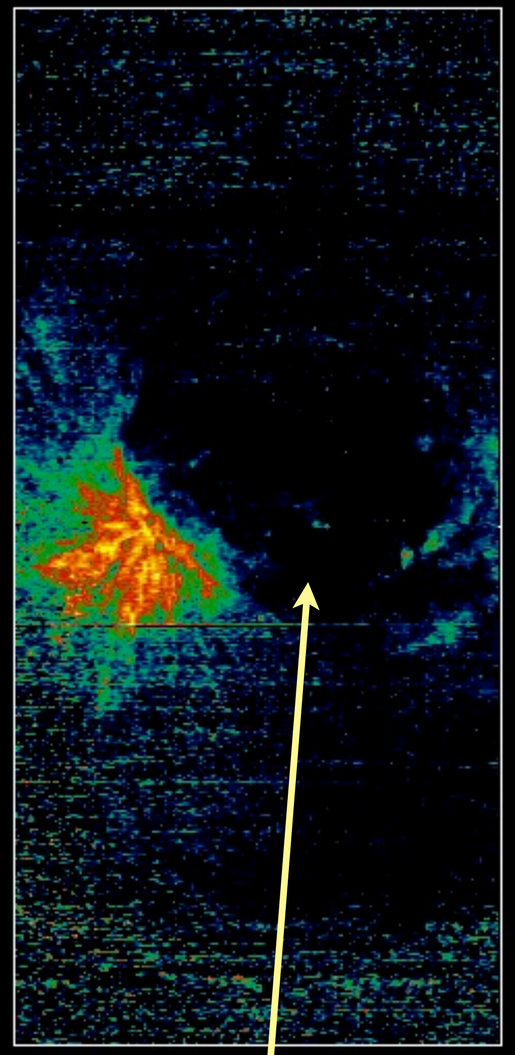

Narrow widths in AR core

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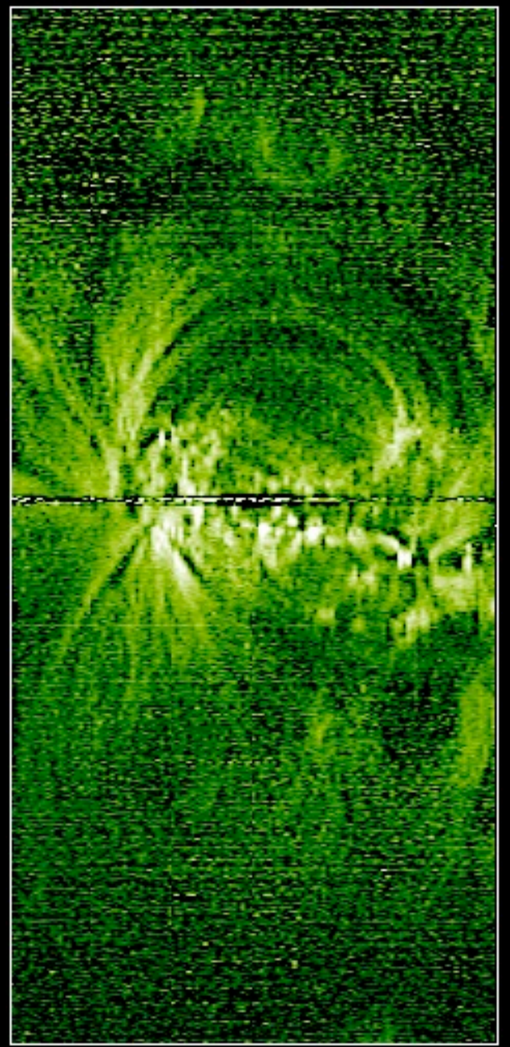
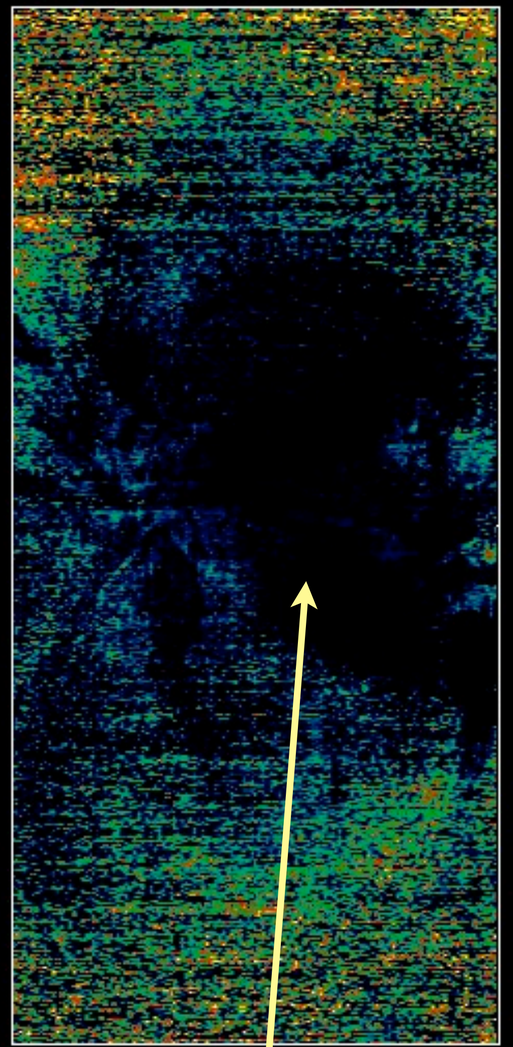
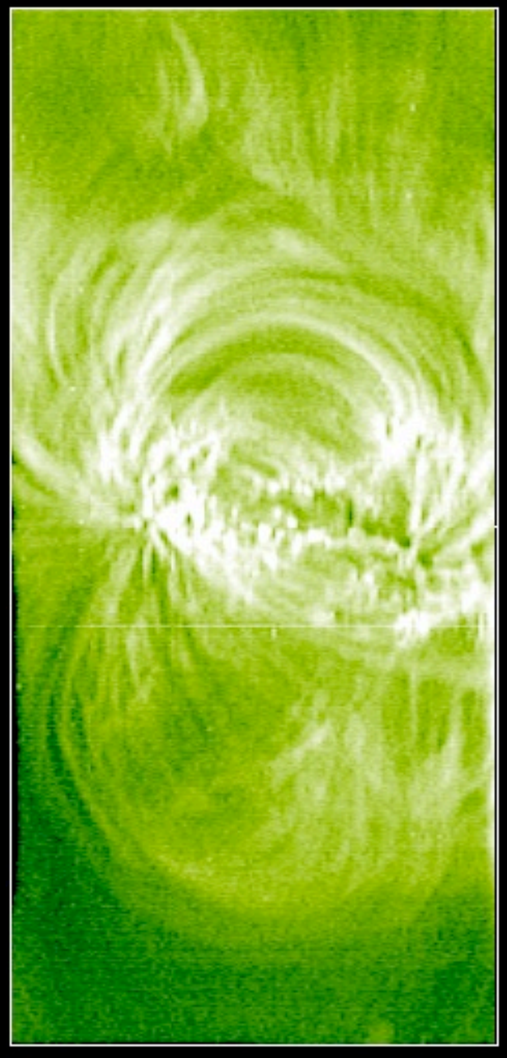


Ca XIV 194Å



Narrow widths in AR core

Instrumental Issues: Y-variation of instrumental width



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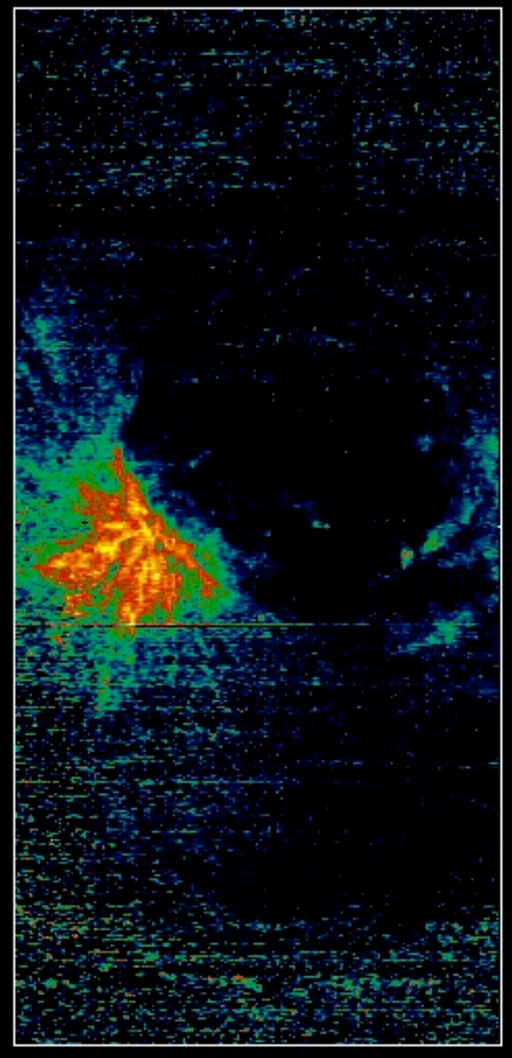

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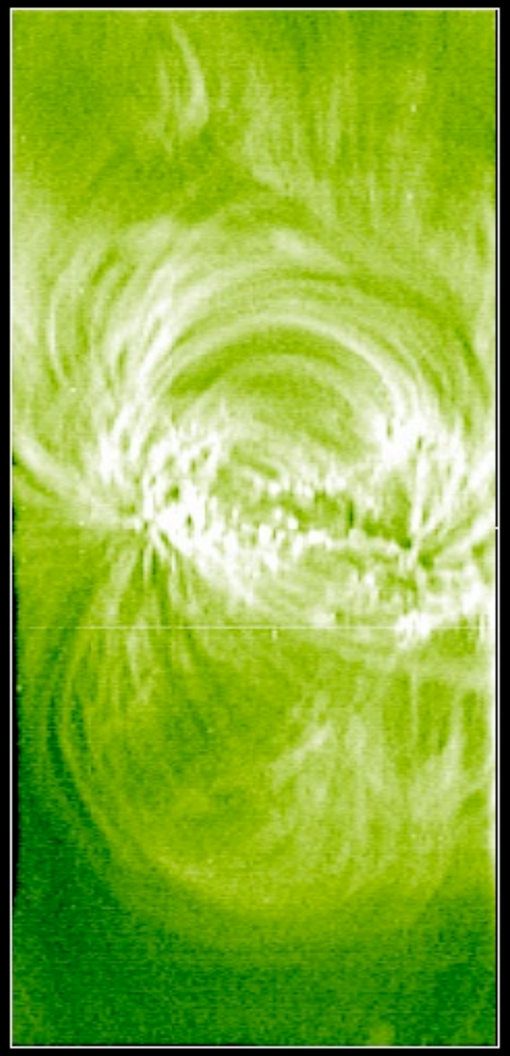

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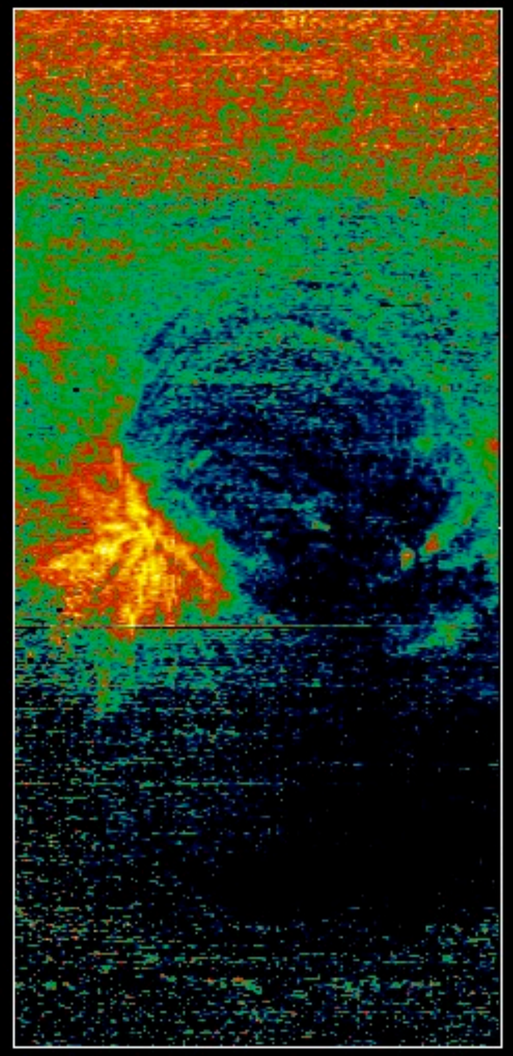
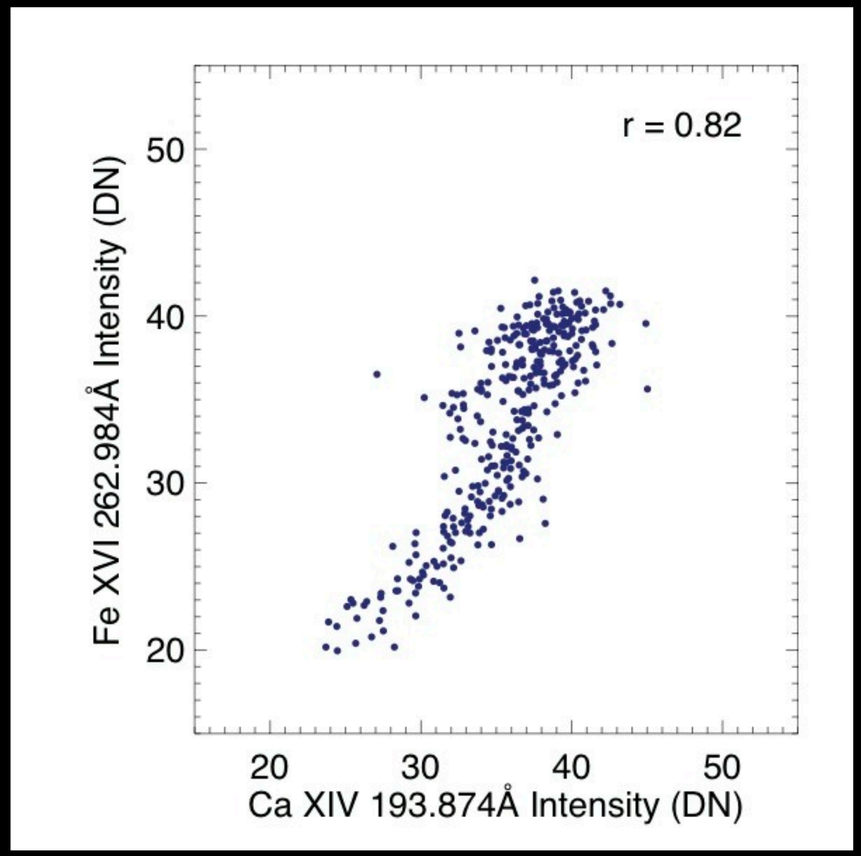


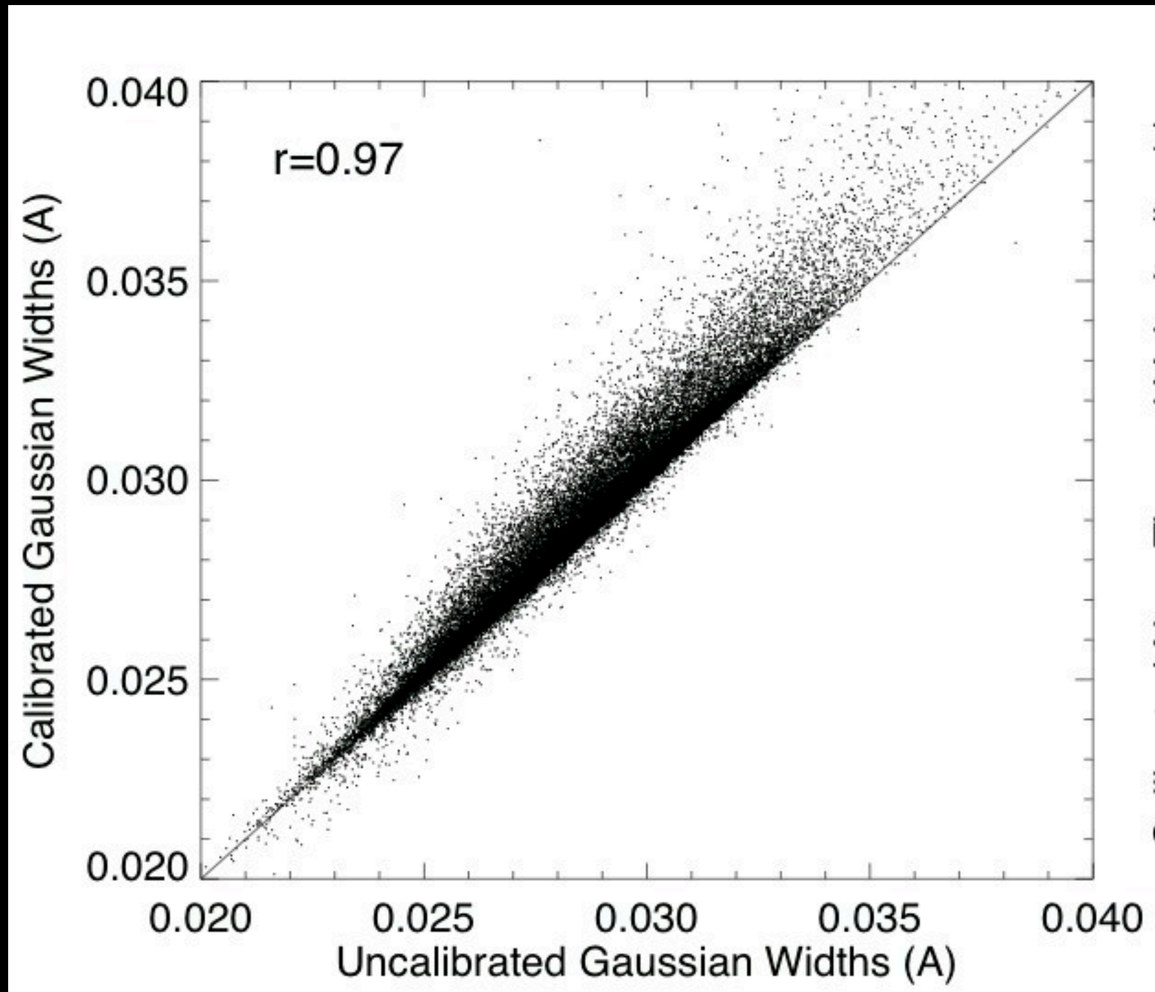
Data Analysis Strategy

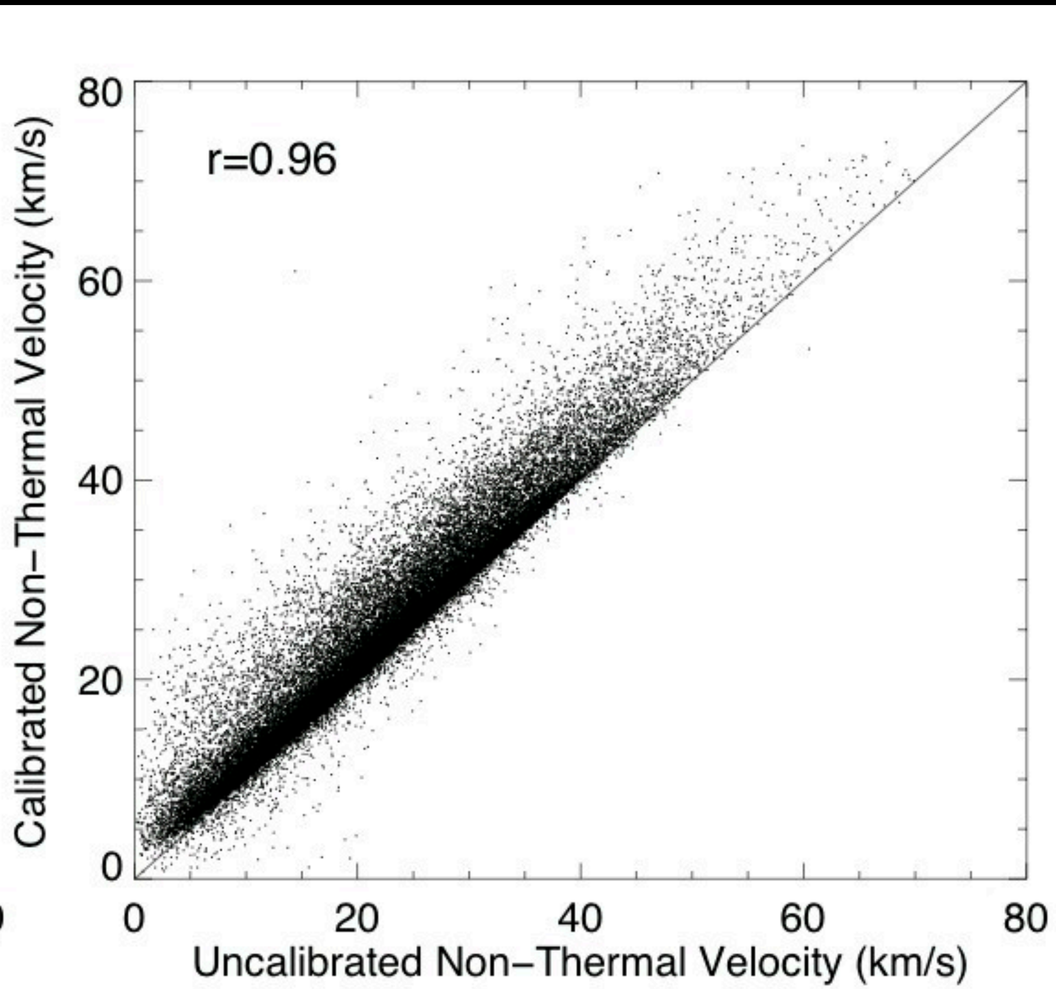
- Inter-moss regions between hot loop footpoints in 15 AR cores (2010-2011):

  - bright loops in AIA Fe XVIII (isolated using Warren et al. 2012).
  - no significant moss emission in AIA 171Å.
  - relatively narrow spectral windows.
  - only clean, unblended lines.
  - Gaussian profiles.
  - intensities must be correlated with Ca XIV.
  - no absolute intensity calibration.



Instrumental issues: absolute calibration





Warm Pixels: Widths from 2007 and recent data are similar.

Calculation of non-thermal velocities

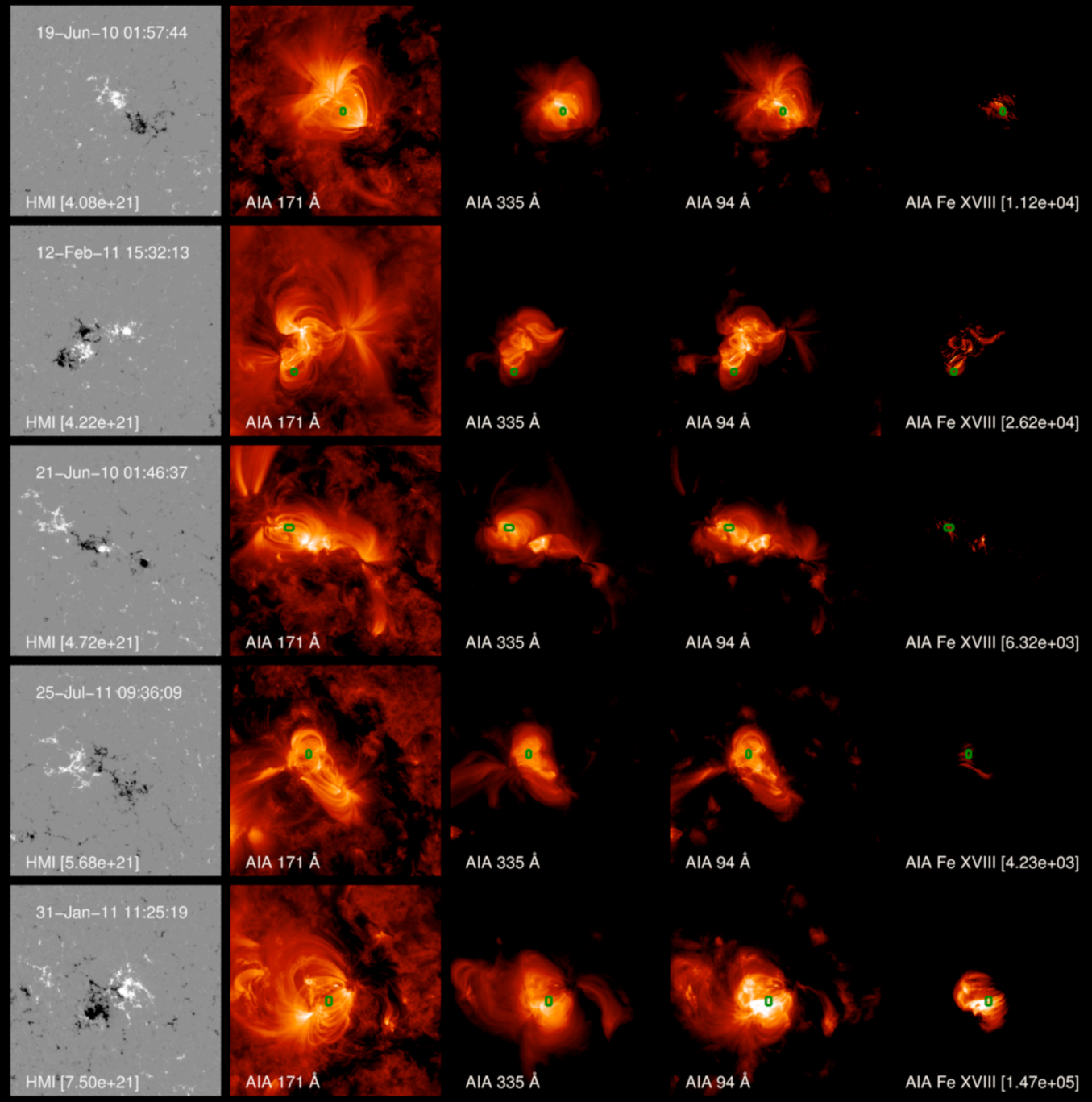
- Method 1:

- Method 2 (Imada et al. 2009):
  - Use S XIII 257Å & Fe XVI 263Å
  - Assume ion temperatures & non-thermal velocities are the same

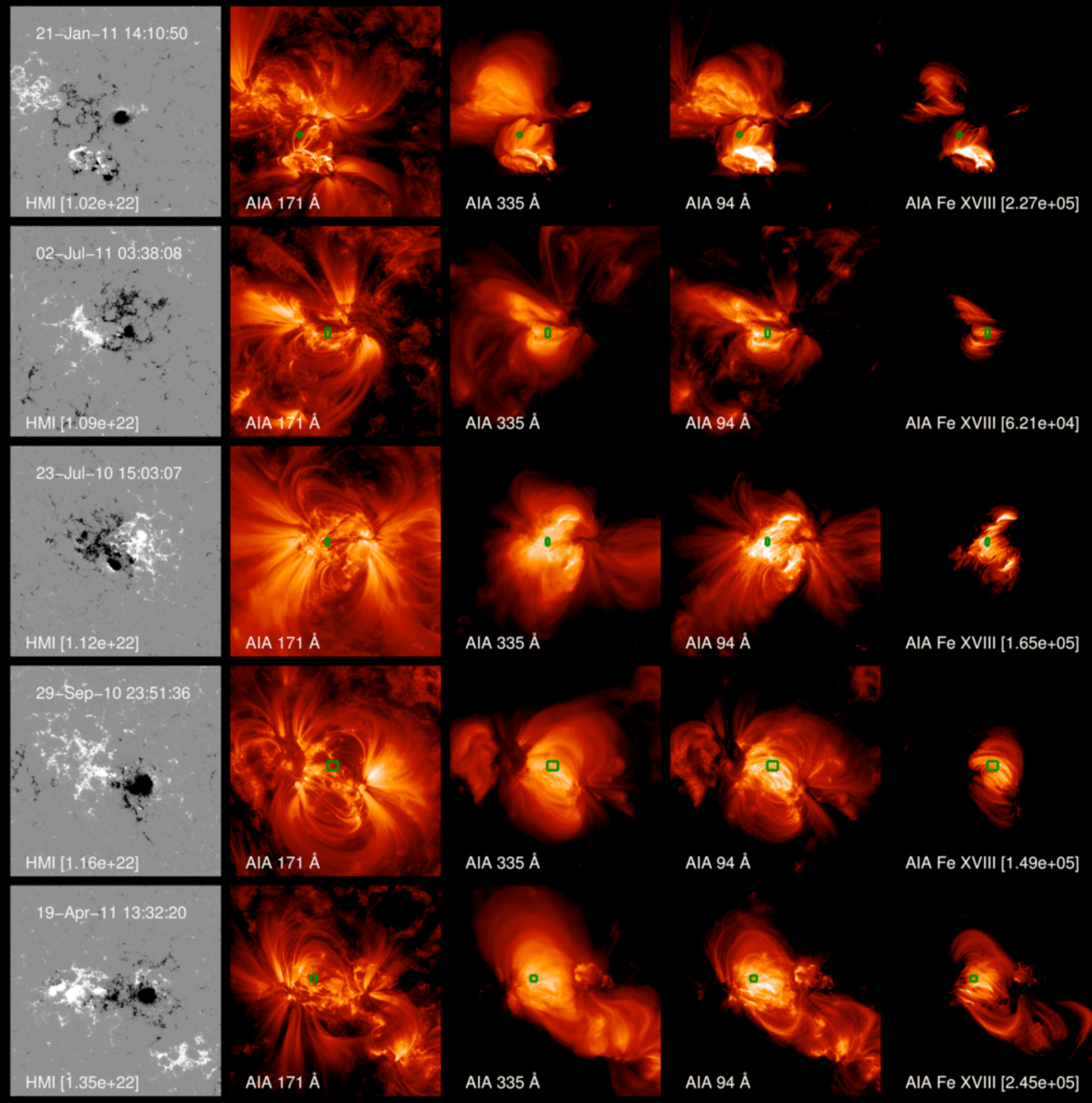
$$\delta\lambda = \frac{\lambda_0}{c}\sqrt{4\ln 2\left(\frac{2k_B T_i}{m} + \xi^2\right) + \sigma_I^2} \qquad (1)$$

$$\xi^2 = \frac{m_2 W_2^2 - m_1 W_1^2}{4\log 2(m_2 - m_1)} \qquad (2)$$

$$T_{ion} = \frac{W_1^2 - W_2^2}{8k_B \log 2}\frac{m_1 m_2}{m_2 - m_1} \qquad (3)$$



Warren et al (2011,2012)



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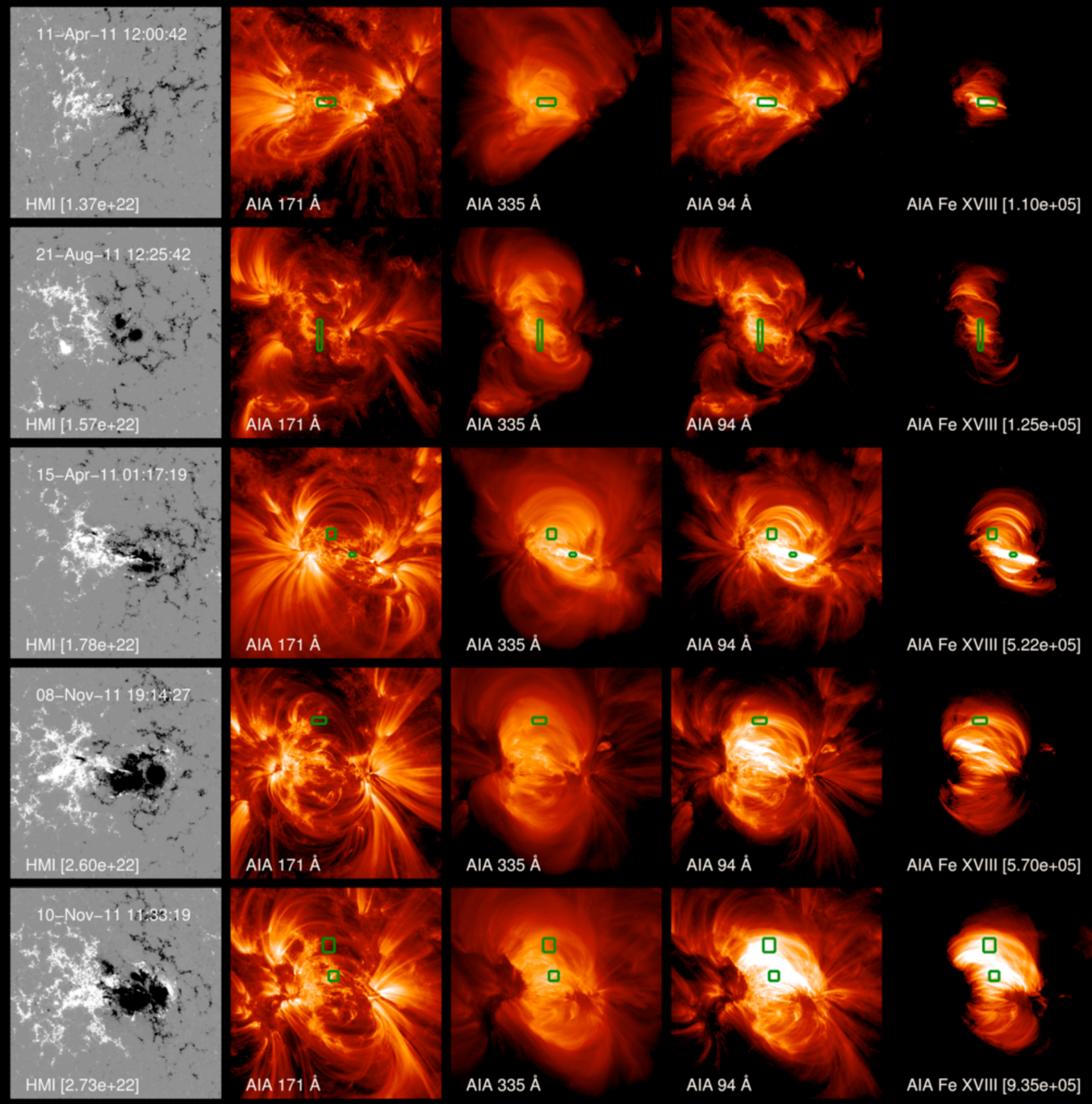

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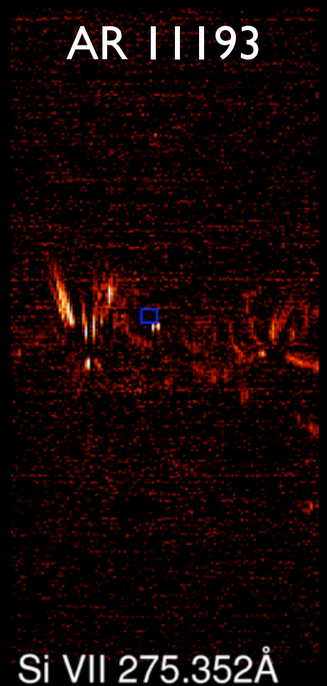
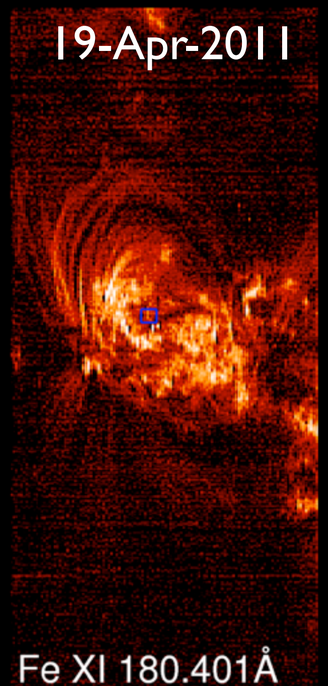
AR 11193

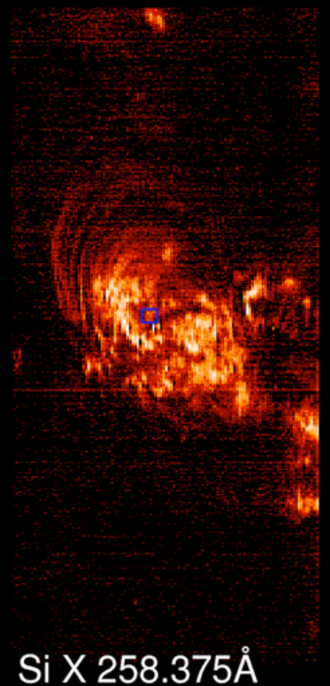
19-Apr-2011



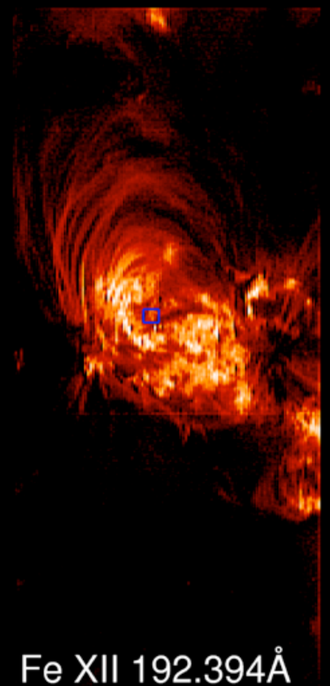
Si VII 275.352Å



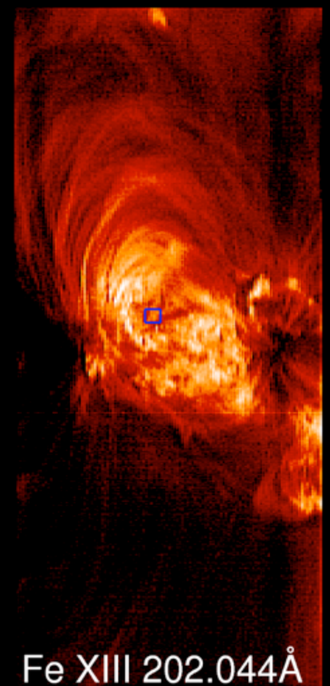
Fe XI 180.401Å



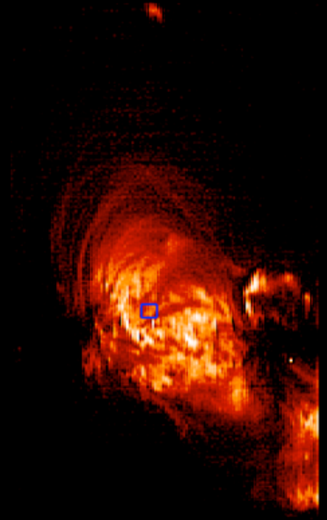
Si X 258.375Å



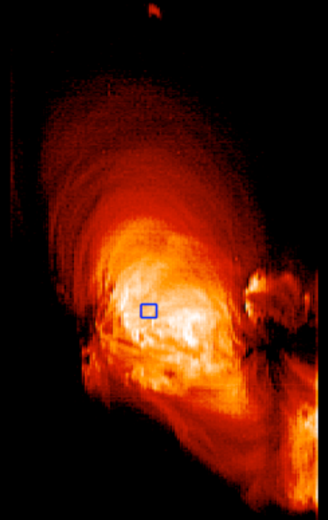
Fe XII 192.394Å



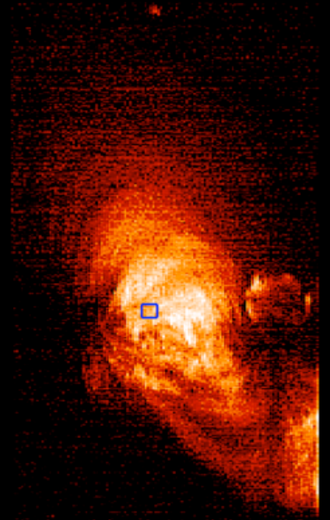
Fe XIII 202.044Å



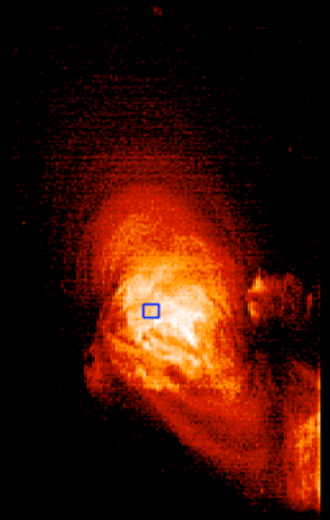
Fe XIV 264.787Å



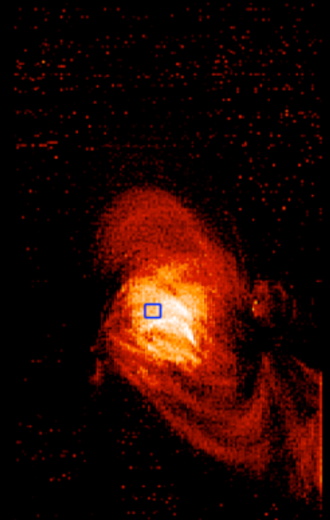
Fe XV 284.160Å



S XIII 256.686Å

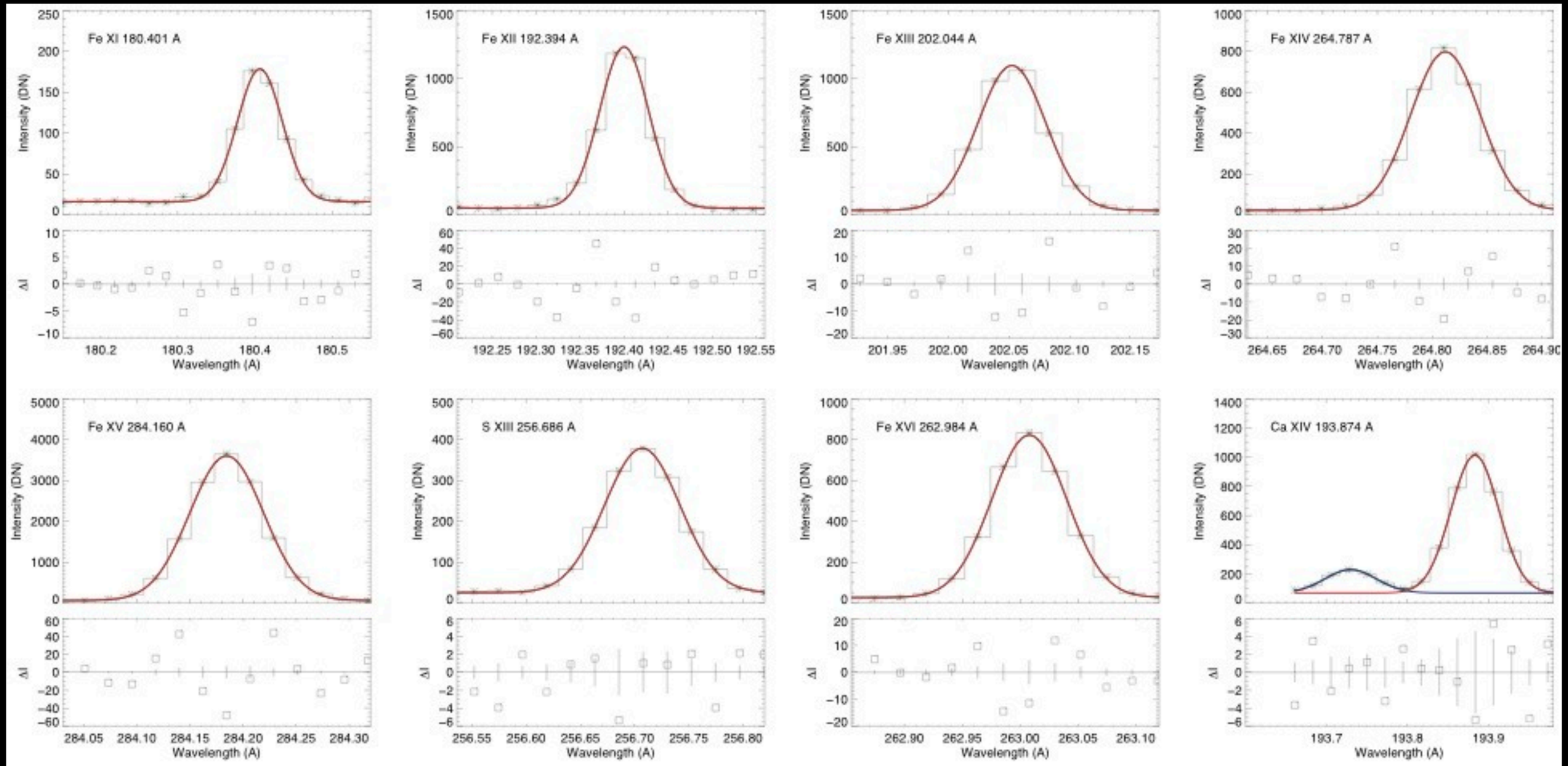


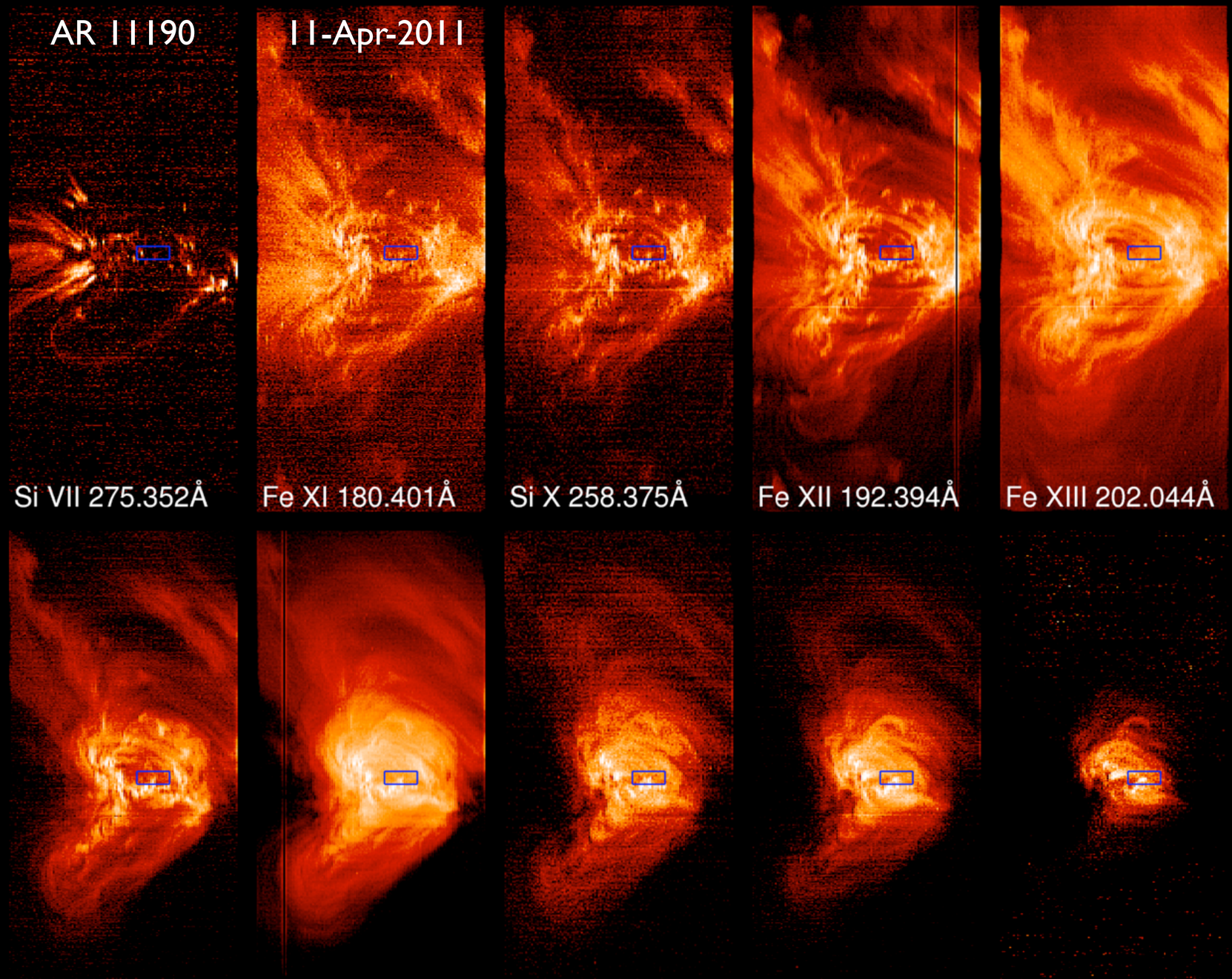
Fe XVI 262.984Å



Ca XIV 193.874Å

AR 11193 19-Apr-2011




AR 11190
11-Apr-2011
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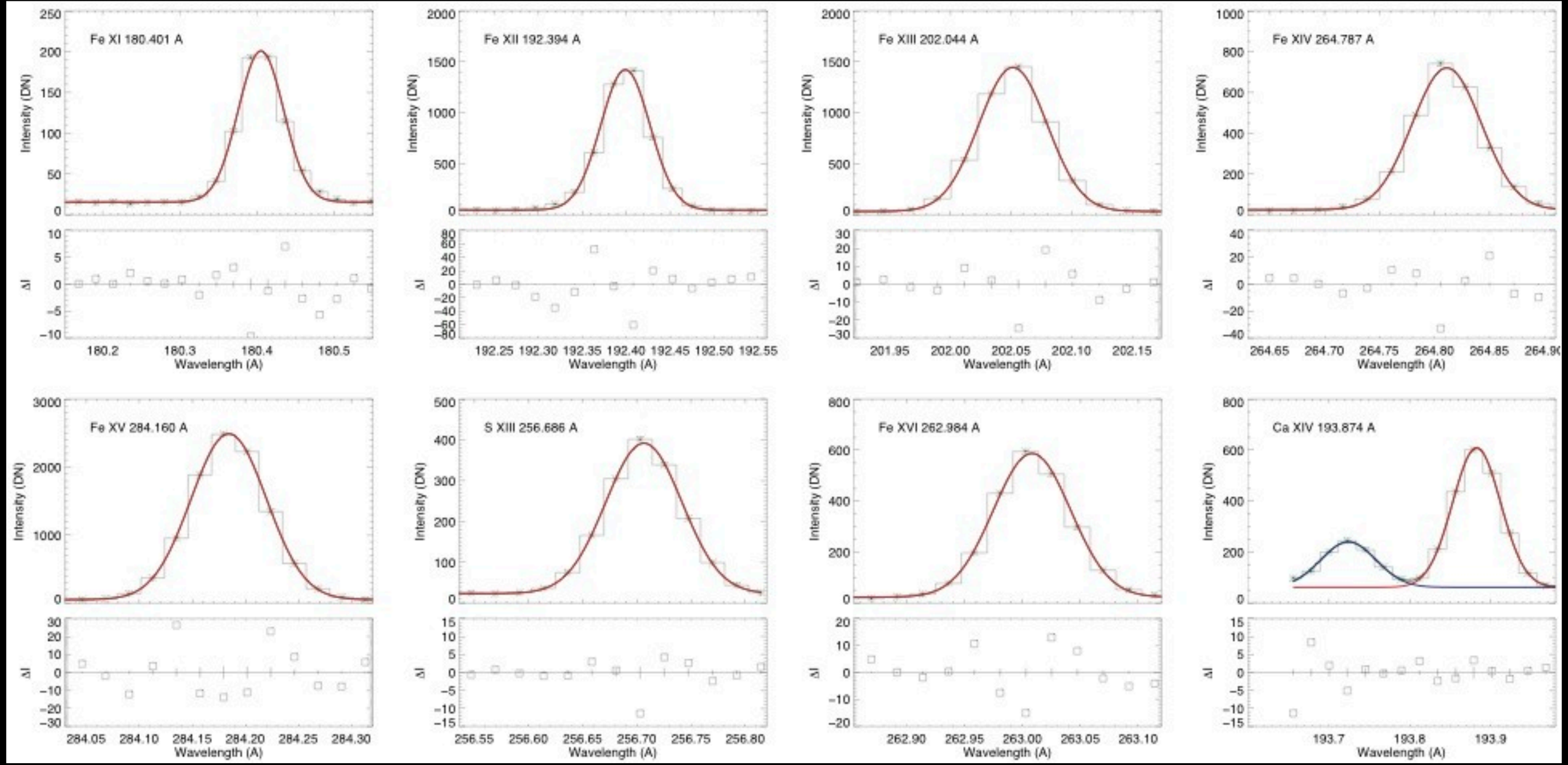
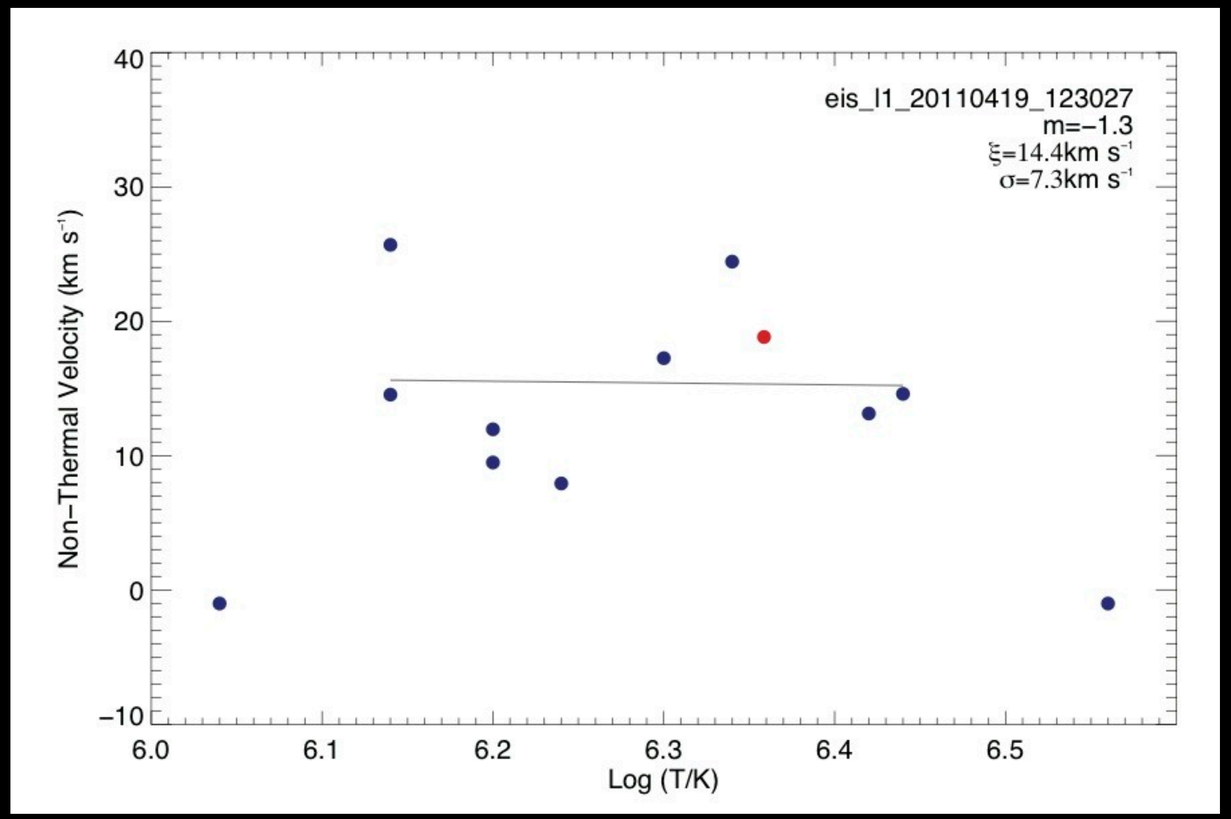
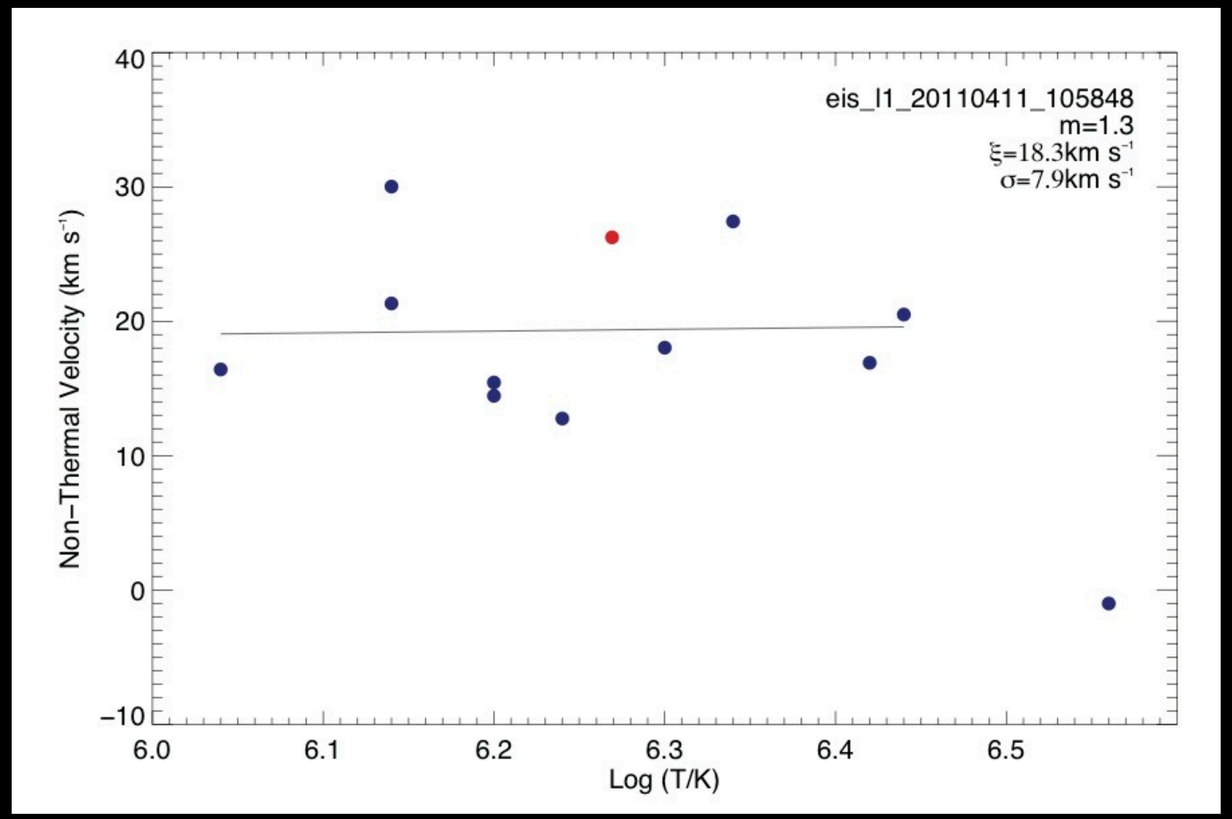


Non-thermal velocity as a function of temperature





Blue dots are Method 1. Plotted against the temperature of the peak of the contribution function.
Red dots are Method 2 (Imada et al. 2009). Plotted against the calculated ion temperature.

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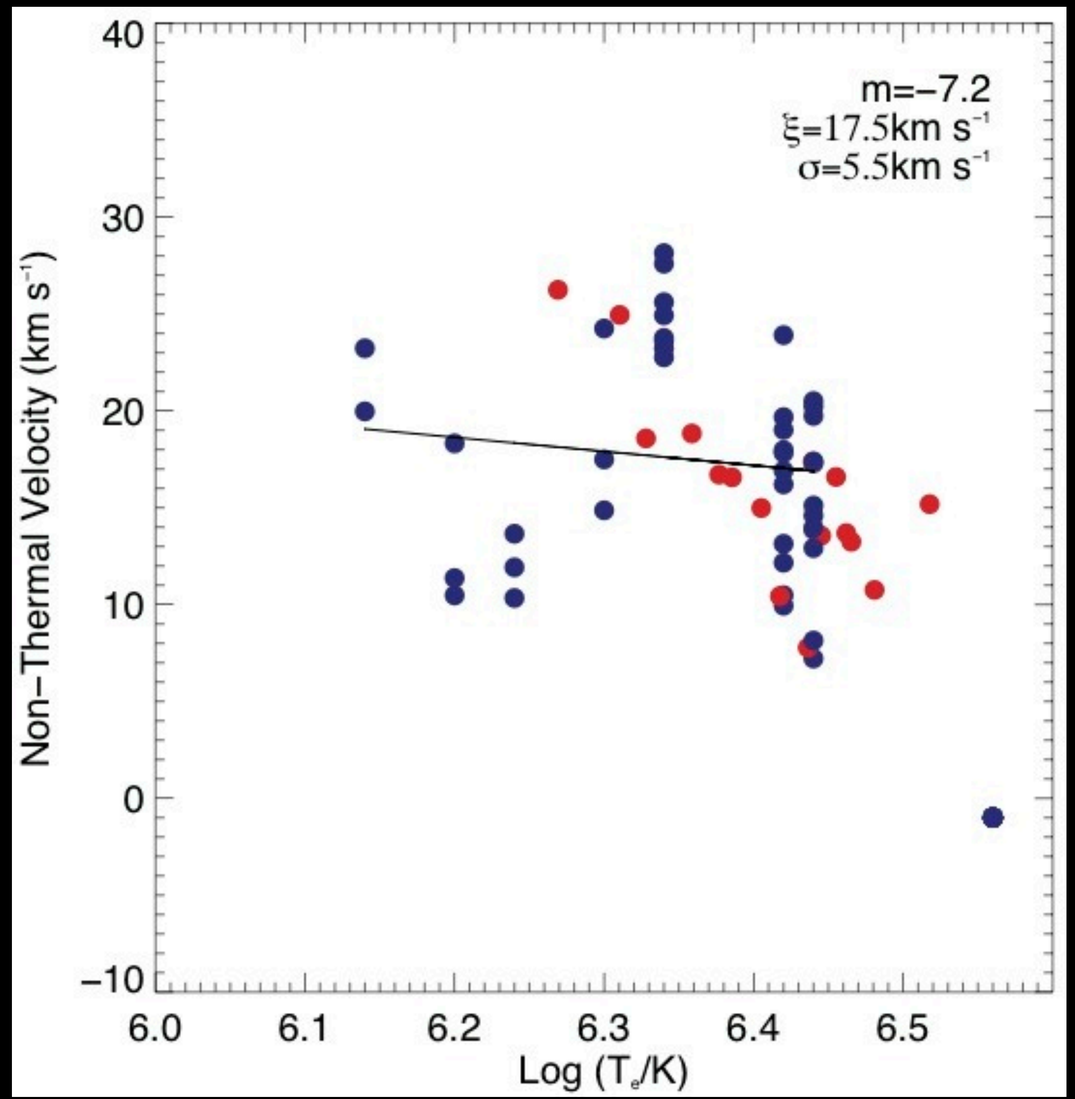
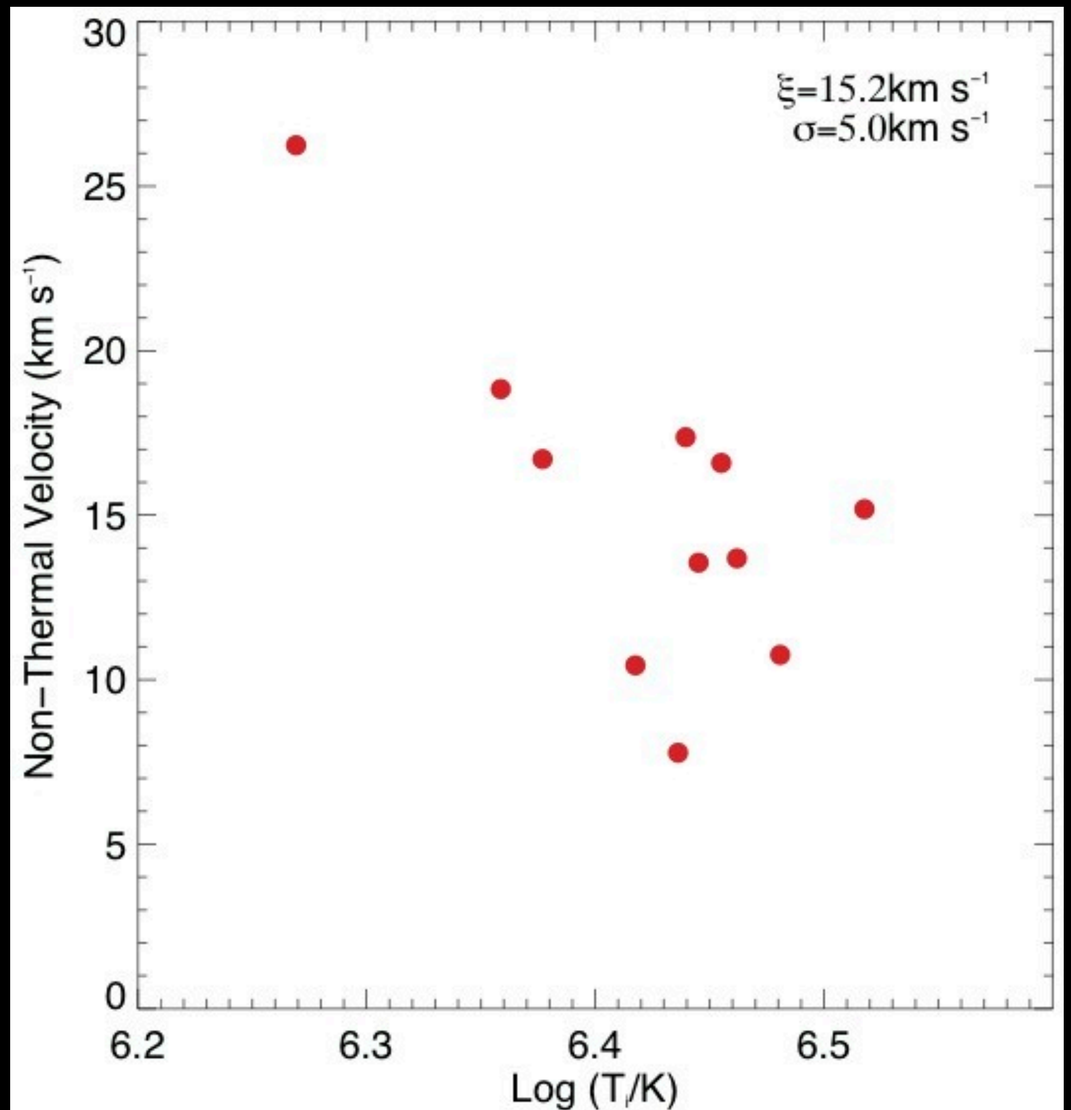
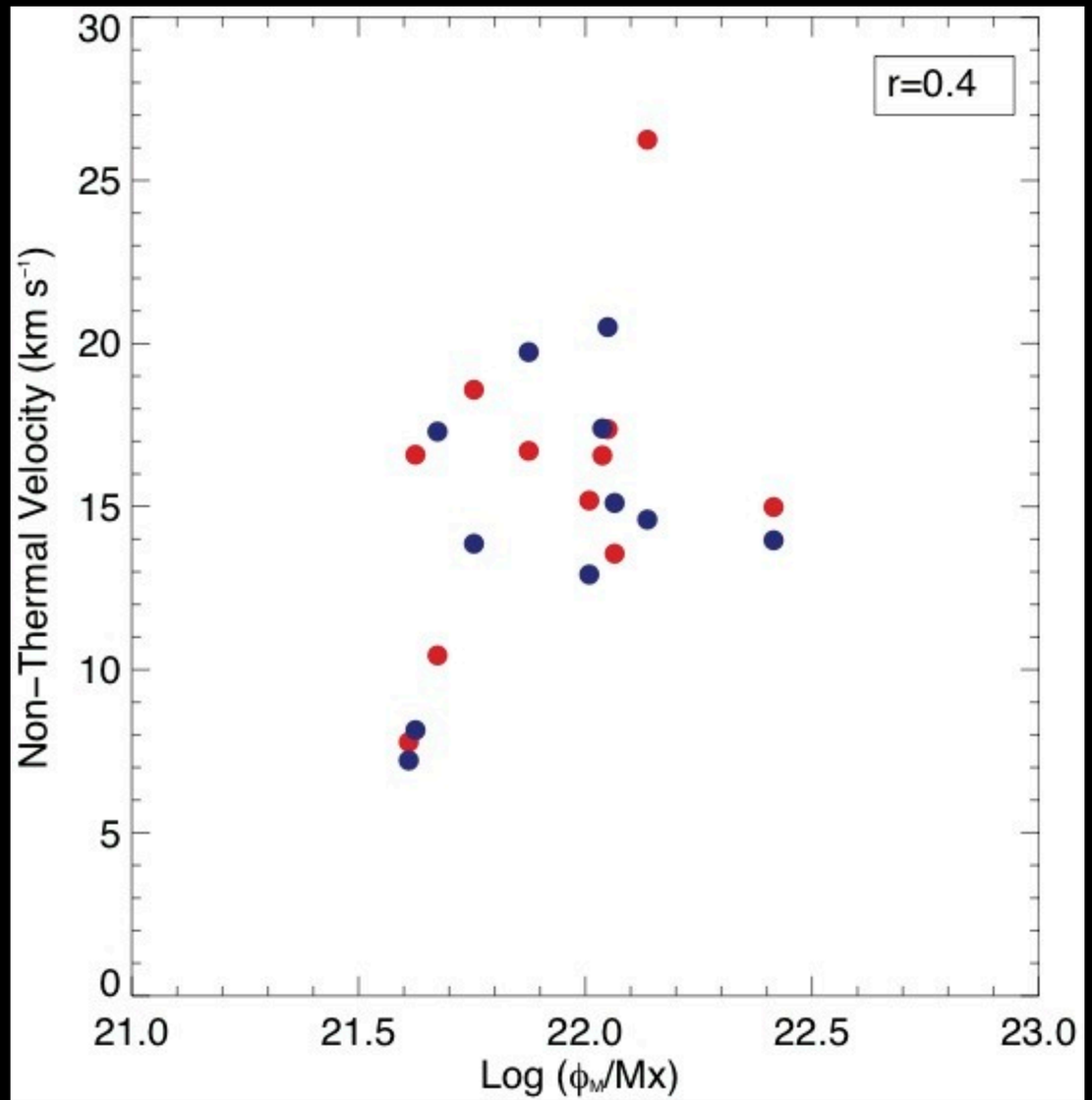


Non-thermal velocity for different AR cores



Ion Temperature

Non-thermal velocity as a function of AR magnetic flux



Total Unsigned Magnetic Flux

Results and Implications

- Only modest (18+/-6 km/s) non-thermal broadening at 1-5MK in the active region core.
- Hinode/EIS measurements show no significant trend with temperature in hot core loops (T > 1MK).
- Ca XIV 193.874Å (3.5MK) is always zero!
- Weak trend suggesting higher non-thermal velocities with larger magnetic flux!
- Inconsistent with nanoflare and Alfven wave heating models?