Resolving the unresolved background emission in the corona: ubiquitous, low-emission coronal threads observed by the High Resolution Coronal Imager

Professor Robert Walsh and Dr Tom Williams, Jeremiah Horrocks Institute, University of Central Lancashire, Preston, UK

Dr Amy Winebarger, NASA Marshall Space Flight Centre, Huntsville, Alabama

With the HiC Science and Operations Teams
Presentation outline

- The fundamental nature of coronal strands.
- High resolution coronal imager refight, HiC 2.1, May 2018
- Multi-scale Gaussian normalisation of resulting data
- Analysis of AIA vs HiC 2.1 for the low emission corona
- Comparison of resolved structure widths – unique from HiC 2.1
The fundamental nature of a coronal plasma strands

*Peter et al., 2013*

- no visible substructure across HiC 1 observed loops.

Thus either

- temperature and density varies smoothly across the loop or...
- loops are resolved in HiC.

- Argues that strand diameter $d$ would need to be $20 \text{ m} < d < 15 \text{ km}$

- Argues that HiC loop could have 7500 strands with 10% (750) “bright” at any one time.
Brooks et al, 2016
- IRIS observations, transition region temperatures
- Unresolved fine structure = 133km
- Can be modelled with a single strand approach.

Aschwanden & Peter 2017
- Coronal loop widths fully resolved by HiC
- 100-550 km, monolithic structures
High Resolution Coronal Imager 2.1

- Launch: 29th May 2018 at ~1850 UT.
- Fe IX 17.2 nm EUV emission.
- 2k x 2k resolution at 0.13 x 0.13 arcsec^2/pixel compared to AIA: 0.6 arcsec.
- ~329 s of data captured at ~5.5s cadence for a total of 78 images.
The method normalises an image via the local mean and standard deviation using a Gaussian-weighted sample of local pixels.

Normalised image is transformed by arctan function and applied over several spatial scales.

Final image is a weighted combination of the normalised components.

Morgan & Druckmüller (2014), SoPh, 289, 8, pp 2945-2955
Low emission corona – HiC 2.1 and SDO AIA

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Field of view (pixels)</th>
<th>Low emission region of interest (pixels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDO AIA</td>
<td>450 x 450</td>
<td>114 x 115</td>
</tr>
<tr>
<td>HiC 2.1</td>
<td>2064 x 2048</td>
<td>540 x 540</td>
</tr>
</tbody>
</table>
SDO AIA 17.1 nm

HiC 2.1 17.2 nm
HiC 2.1 “jitter images” removed (35 images considered).

HiC every 4\textsuperscript{th} error bar.
AIA every 2\textsuperscript{nd} error bar.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>No of pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>HiC 2.1</td>
<td>109</td>
</tr>
<tr>
<td>SDO AIA</td>
<td>25</td>
</tr>
</tbody>
</table>

Mean, normalised intensity along slices (south to north)
Normalised intensity along slice 3 (south to north)

HiC 2.1 -------- SDO AIA

Single snapshot -> Time averaged -> Remove interpolation through minima

AGU 2018, SH23A: Breakthrough Observations of the Sun on Suborbital-Class Platforms I
Walsh, Williams, Winebarger
Normalised intensity along slice 5 (south to north)

HiC 2.1  ------  SDO AIA  ------

Single snapshot  Time averaged  Remove interpolation through minima

2018-05-29 18:58:34 Slice 5

2018-05-29 18:58:34 Slice 5

Mean Plot Slice 5

Slice 5 Variations
SDO AIA 17.1 nm

HiC 2.1 17.2 nm

Slice 5

Normalized intensity vs. slice position (arcseconds)

South North
Full width half maximum of resolved structures

Slice 3

Slice 5
HiC 2.1 - Full width half maximum of resolved structures

For HiC 2.1 we have:
- Total No widths identified over 8 slices = 101
- Single resolved strands = 64 (63%)
- Minimum width = 108 km
- Maximum width = 976 km
- Mean width = 435 km

In comparison, for AIA 17.1nm;
- Total No widths identified over 8 slices = 39
- Single resolved strands = 24 (62%)
- Minimum width = 555 km
- Maximum width = 4252 km
- Mean width = 1515 km
Conclusions: resolving the low emission corona

- At 17.2 nm, low emission corona filled with fine-scale structures.
- SDO AIA does not resolve the basic spatial scale of low emission features.
- HiC 2.1 reveals significant sub-structure where AIA does detect emission.
- HiC 2.1 detects and determines structure in AIA 17.1nm “noise”.
- Single resolved strands with a mean width of ~434km.

<table>
<thead>
<tr>
<th>Author</th>
<th>Instrument</th>
<th>Loop type</th>
<th>Mean width (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter <em>et al.</em>, 2013</td>
<td>HiC</td>
<td>Long, bright</td>
<td>1500km (?)</td>
</tr>
<tr>
<td>Brooks <em>et al.</em>, 2016</td>
<td>IRIS</td>
<td>Short, cool, bright</td>
<td>133 km (?)</td>
</tr>
<tr>
<td>Ashwanden &amp; Peter, 2017</td>
<td>HiC</td>
<td>All types, bright</td>
<td>550 km (?)</td>
</tr>
<tr>
<td>Walsh, Williams,</td>
<td>HiC 2.1</td>
<td>Long, low</td>
<td>434 km (?)</td>
</tr>
<tr>
<td>Winebarger, 2018</td>
<td></td>
<td>low emission</td>
<td></td>
</tr>
</tbody>
</table>
Further work on HiC 2.1

- Fitted Gaussians to the “double-peak” structures – reduce widths?
- Angle across the structures.

- What does this mean for determining coronal heating?
- Modelling observed strand widths.

- With HiC science team, determine coronal structures properties with HiC 2.1 field of view.