Coronal magnetic field observations

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- Useful coronal field model constraints can be obtained from IR observations
- This is a vigorous activity, with three serious ongoing efforts (plus important solar radio measurements proposed)
Are images enough?

(from Chen et al., Low, Gibson, Roussev et al.)
Magnetic linear polarization sensitivity

Permitted ($A \approx \omega_L$) – Hanle
(eg. HeI 1083 nm, $A = 10^7 \text{ s}^{-1}$)

Forbidden ($A \ll \omega_L$)
(eg. FeXIII 1075 nm, $A = 10^2 \text{ s}^{-1}$)

$\omega_L \approx \frac{eB}{mc}$
($1 \text{G} \rightarrow \omega_L = 1.8 \times 10^7 \text{ s}^{-1}$)

$\frac{1}{\Gamma} = A$ \hspace{1cm} ($10^2 - 10^7 \text{ s}^{-1}$)

$Q, U \propto B$ (almost with $I$ profile)
$V \propto B$ \hspace{1cm} (almost $dl/d\lambda$ profile)

$|Q, U| \geq |V|$

polarization is $\parallel$ or $\perp$ to $B$
Coronal Hanle measurements

  - OVI 103.2nm polarization measurement using CDS in a coronal hole (9%, 9 degree from limb tangent)
  - Analysis: non-unique solution requires both B of a “few gauss” and velocity of “few 10’s km/s”
QU forbidden line observations
Coronal forbidden line Zeeman Observations

  - FeXIII V polarimetry
Why IR: Atmospheric backgrounds
IR expectations

- Judge, Casini, Tomczyk, Burkepile...
  (http://comp.hao.ucar.edu/how.html)*

<table>
<thead>
<tr>
<th>Ion</th>
<th>Wavelength</th>
<th>Temperature</th>
<th>Prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe XIV</td>
<td>530.3nm</td>
<td>2MK</td>
<td>ok</td>
</tr>
<tr>
<td>FeXIII</td>
<td>1075nm</td>
<td>1.7MK</td>
<td>excellent</td>
</tr>
<tr>
<td>Si X</td>
<td>1430nm</td>
<td>1.3MK</td>
<td>ok</td>
</tr>
<tr>
<td>Mg VIII</td>
<td>3027nm</td>
<td>0.8MK</td>
<td>?</td>
</tr>
<tr>
<td>Si IX</td>
<td>3932nm</td>
<td>1.1MK</td>
<td>good</td>
</tr>
<tr>
<td>Mg VII</td>
<td>9031nm</td>
<td>0.6MK</td>
<td>?</td>
</tr>
</tbody>
</table>
The IR corona

Infra-red imaging spectroscopy, using fixed and tunable (λ/Δλ = 500–600) filter elements, reveals evidence of a new Si IX emission line. This line is far into the infra-red and may allow direct measurements of coronal magnetic fields (heretofore impossible). The experiment was conducted from an open CL-30 aircraft (operated by NCAR). Scientists from NSO/SP, Rhodes College, MSU, Max Plank (Kiel), and EAO participated in a broad range of IR experiments. A new Kodak 7B40D high dynamic range infra-red array camera (sensitive between 1.5 μ and developed at MSU in collaboration with NSO/SP) was used to obtain these results. [This slide was prepared by J. R. Kuhn]

Fig. 1.—Intra-corona at λ = 1.10μ
Fig. 2.—Intra-corona at λ = 1.46μ

The upper figures show the K corona (continuum only) brightness at 1.1 μ and 1.43μ in a 7μm bandpass. A tunable liquid crystal Lyot filter was used to obtain these images.

Fig. 3.—Continuum + FeXXII λ = 1.07μ
Fig. 4.—Continuum + Si IX λ = 3.05μ

These figures show the continuum + line emission near Fe XXII and the predicted Si IX wavelengths. The bright region on the lower (west) limb of figure 4 is likely evidence of Si IX emission. Extensive intensity calibration suggests that this may be one of the brightest coronal emission lines worldwide. The long wave observations were obtained with a 7.5μm bandwidth interference filter centered at 3.03μ.

Kuhn et al. 1995, 1999

Also Judge et al., 2002
Ideal B measurement sensitivity

5 min observation, 10” pixel
Ongoing Coronal B efforts

- COMP, Ground-Based Coronal Research Project (HAO lead)
- ATST (NSO)
- SOLARC (IfA)

M1: 0.5m F/3.7

M2 Gregorian focus 8m f.l.

F/20, efl 8m, prim-sec 1.7m 0.5m, 1.5m fl primary 55mm, secondary l/10 p-v figure
diff. Limited @ 1 micron over 15' fov

10.4 deg tilt angle

SOLAR-C CoMP: Coronal Multichannel Polarimeter (HAO)

- FeXIII filtergraph polarimeter
- Sac Peak 20 cm “One Shot” Coronagraph

- 1024x1024 Rockwell IR detector
- ± 1.5 R field-of-view
- 5.6” pixels

Augment with spectroscopy at Evans

First measurements in 2003
SOLARC
Roy Coulter, Jeff Kuhn, Haosheng Lin, Don Mickey

3.93 micron

100nm spectrograph filter bandpass
Magnetic field measurements...

- ...will be achieved in the quiet corona with a sensitivity of better than 1 G
- ...from IR coronal observations obtained by several research groups using sensitive polarimetry techniques
- ...on a timescale of one year
Vector Inversions

• FF and potential model from Low (1993)
  – External potential field+FF at r<R + dipole

• Radon transform using Algebraic Reconstruction Technique

\[ B(y, z) = \mathcal{R}^{-1}(B_y(s, \theta) \cos \theta + B_z(s, \theta) \sin \theta) \]

\[ \mathcal{R}^{-1}(\cos \theta \sin \theta) = 0 \quad B_y \approx \mathcal{R}^{-1}(B_{\text{los}} \cos \theta) \quad B_z \approx \mathcal{R}^{-1}(B_{\text{los}} \sin \theta) \]
The projection problem
The inversion

10 iterations over 12 projections spaced 15 degrees...
Another inversion

6 projections, 0-90 degrees...
Potential field...
Long Wavelengths

- SOLARC
- Prime or Gregorian Focus
- chop
- Warm IR Spectrograph
- Fast 1-5mu IR Camera
- Cold Narrow-band filter

Graphs showing intensity over wavelength and pixel.