Magnetic Fields and Intensity Changes in Coronal Dimming Regions

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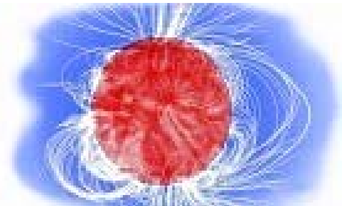
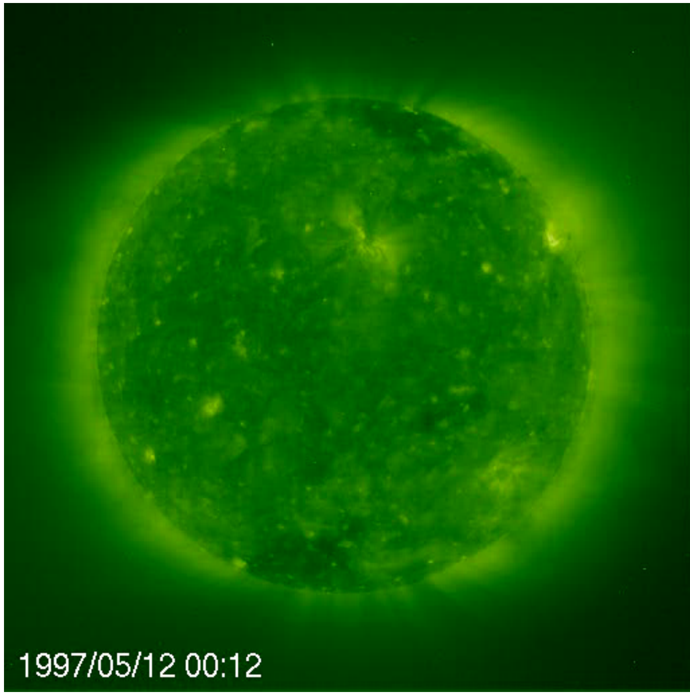


Background to dimming

- Observed as a decrease in intensity in both EUV and X-ray images
  – First observed in Skylab images & referred to as “transient coronal holes” (Rust 1983)



- Strong correlation with CMEs

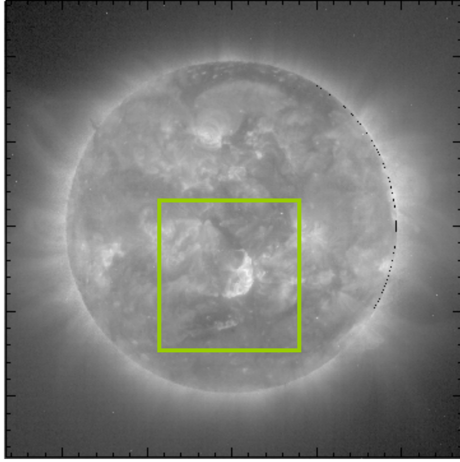
• Understanding the magnetic nature of CMEs requires investigation of the magnetic nature of dimmings

Cause of dimmings

- Plasma evacuation due to eruption of the local magnetic field
  - Mass outflow (Harra & Sterling, 2001)
  - Density depletion (Harrison & Lyons, 2000)
  - Multi-wavelength dimmings (Zarro et al, 1999)
  - Mass ejected as part of CME (Sterling & Hudson, 1997)
- Temperature variation
  - Differences between images observed in various emission lines (Chertok & Grechnev, 2003; Harrison & Lyons, 2000; Thompson et al 1998)

Generally accepted that coronal dimmings are primarily a result of plasma evacuation.

Defining dimming regions



EIT 195Å
10th April 2001
06:35 UT

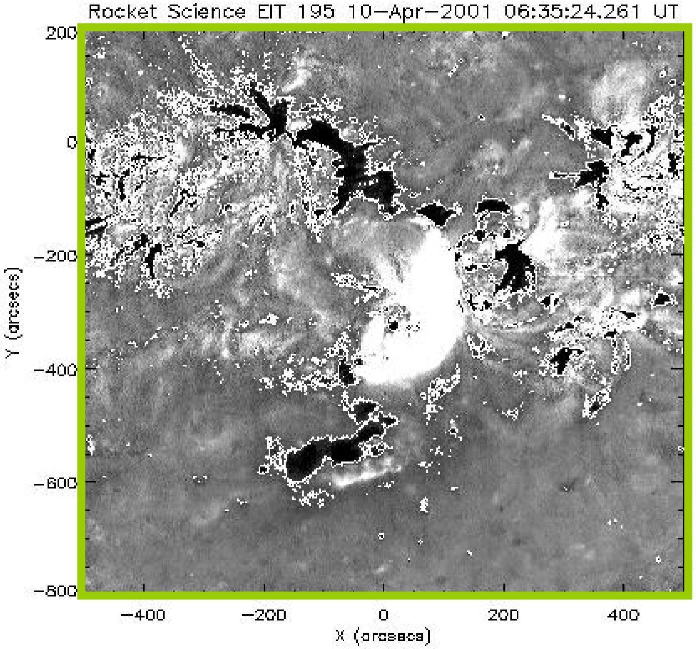
<u>10th April 2001</u>

Multi-wavelength analysis

- Used SOHO/EIT 195Å, 171Å, 284Å, 304Å, SOHO/MDI, Yohkoh Soft X-ray and Hida FMT H-alpha data

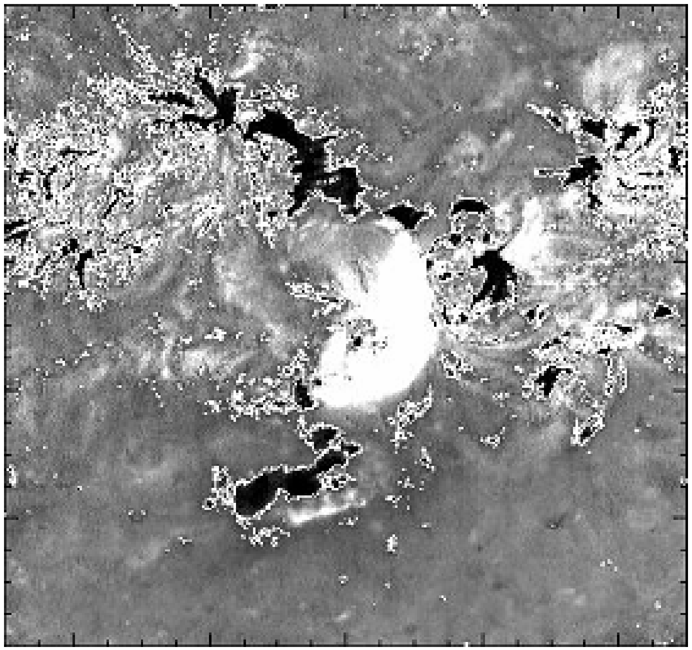
- Base Difference Images

- Contours used to define dimming regions



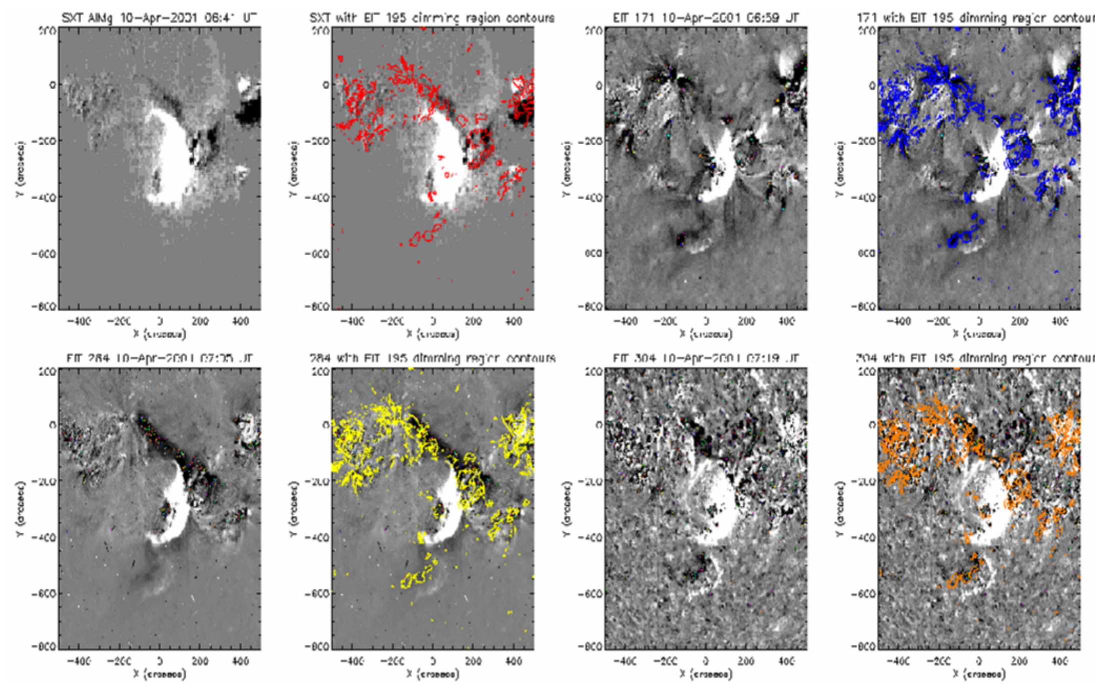
EIT 195Å base difference image with contour overlay at 06:35 UT, 10th April 2001

Multiwavelength analysis confirms dimming as density effect



EIT 195Å Dimmings

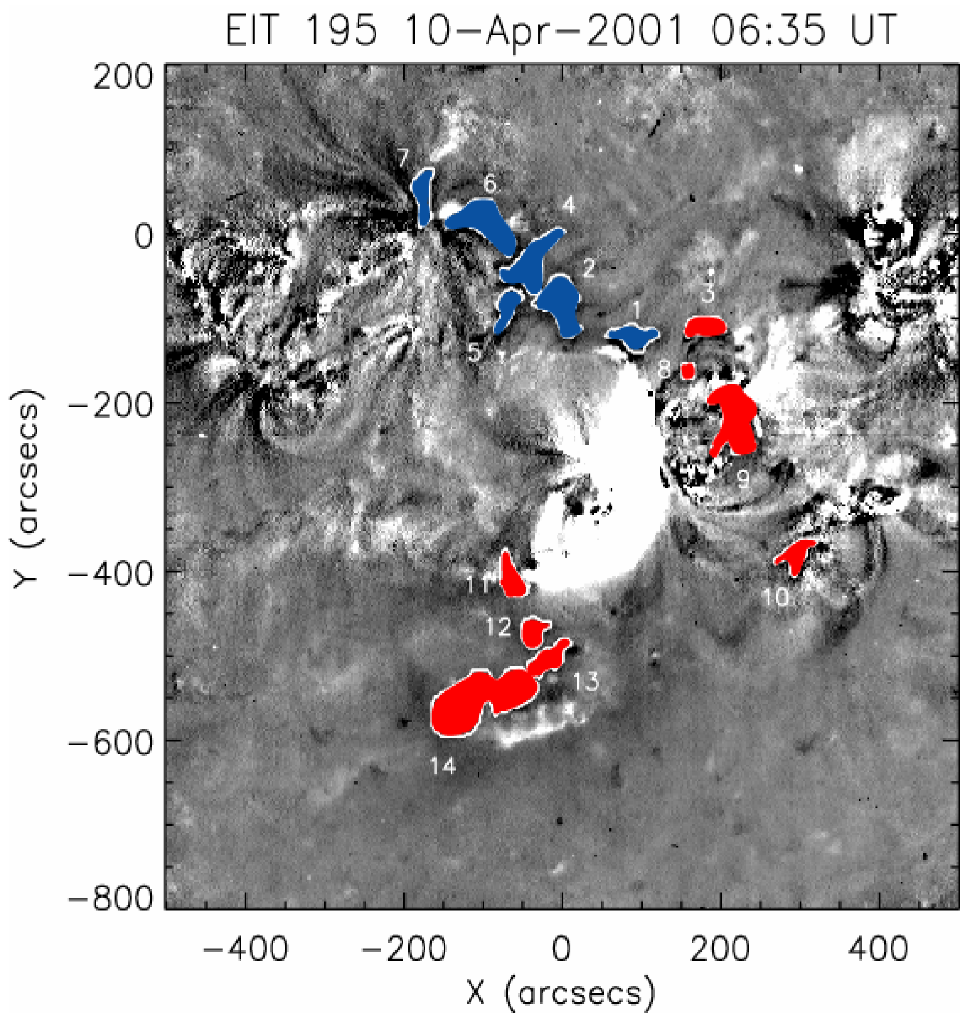
SXT AlMg   EIT 171Å



EIT 284Å   EIT 304Å

Dimmings at different wavelengths (temperature range: 50000 K to 3 MK) with EIT 195Å contours overlaid.

Measurement of magnetic flux



Red = Net Positive Flux

Blue = Net Negative Flux

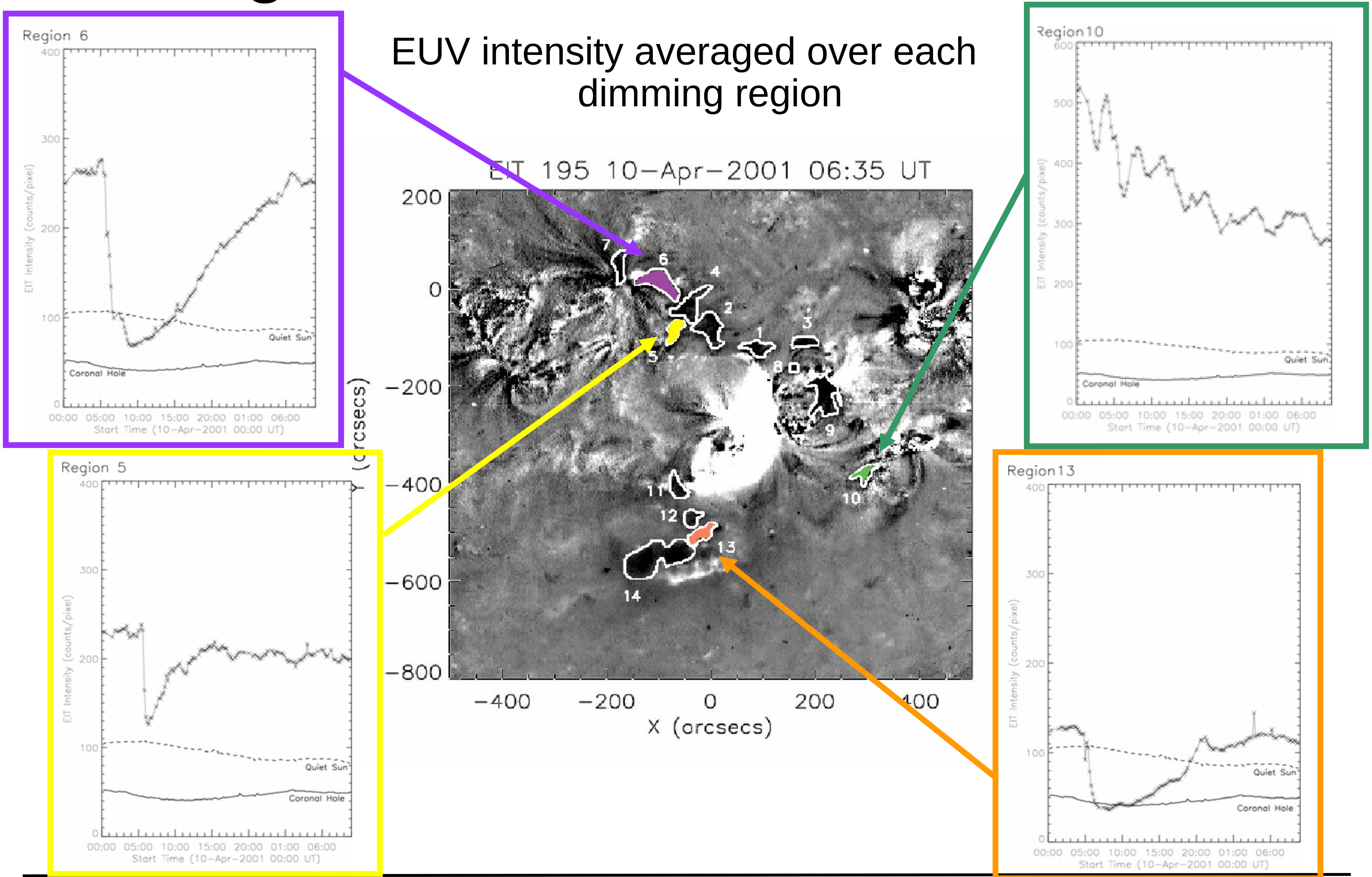
Through ALL regions

Total Positive Flux
1.83×10^{21} Mx

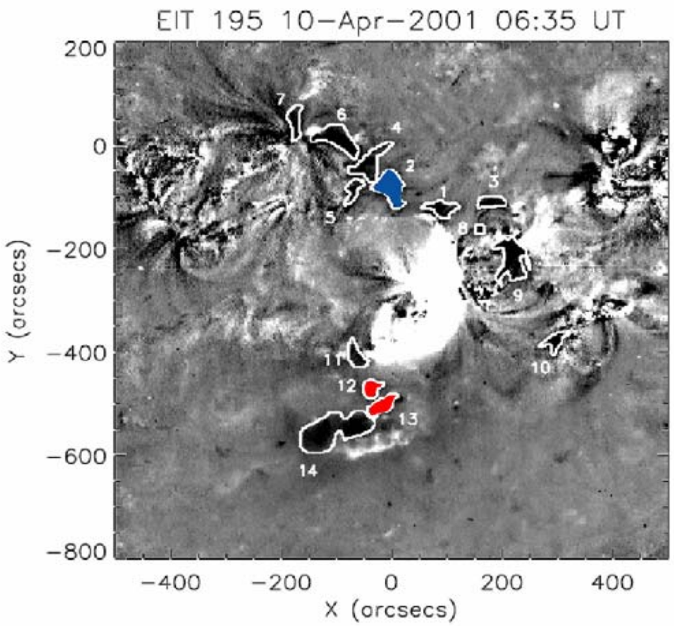
Total Negative Flux
-1.53×10^{21} Mx

Lightcurves of EIT 195Å data

EUV intensity averaged over each dimming region



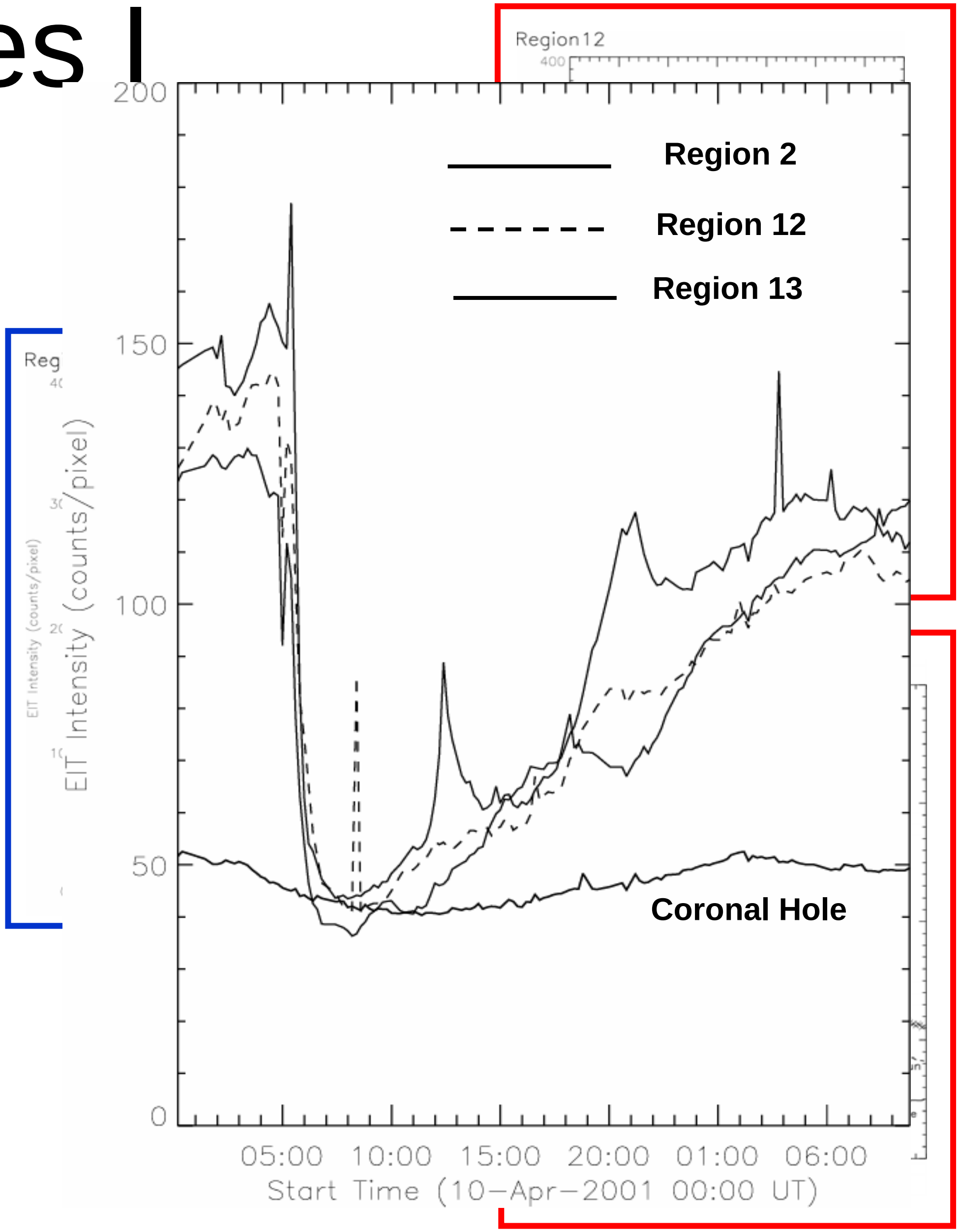
Interconnectivities I



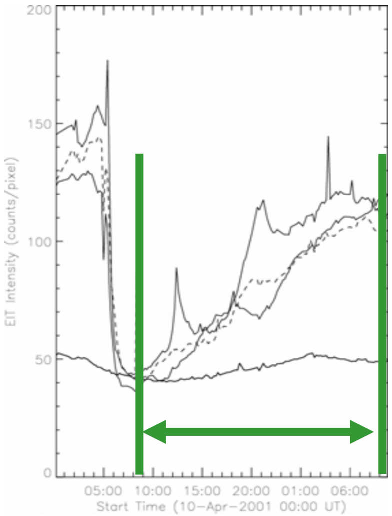
Total Positive Flux = $8x10^{19}$ Mx

Total Negative Flux = $-8x10^{19}$ Mx

Similar lightcurves may reveal magnetic connectivities



The speed of the recovery



Similar recovery gradients dI/dt

(Red indicates region of net positive flux & blue indicates negative)

Regions 1 and 14 have dI/dt = 0.0004 (counts per pixel/sec)

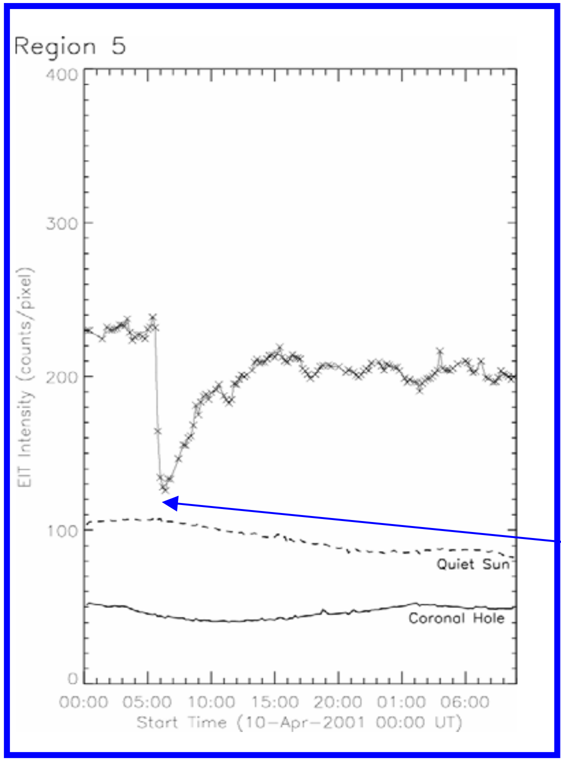
Regions 2, 12 and 13 have dI/dt = 0.0008, 0.0008 & 0.0010

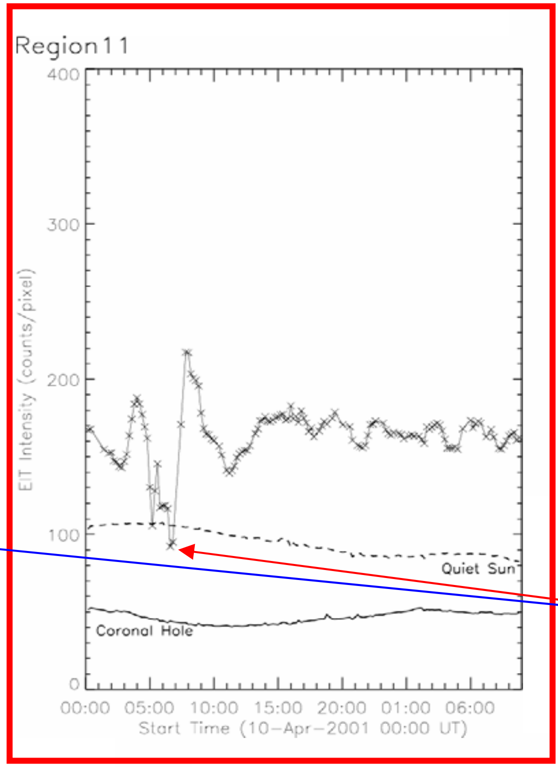
Regions 3 and 4 have dI/dt = 0.0016 & 0.0017

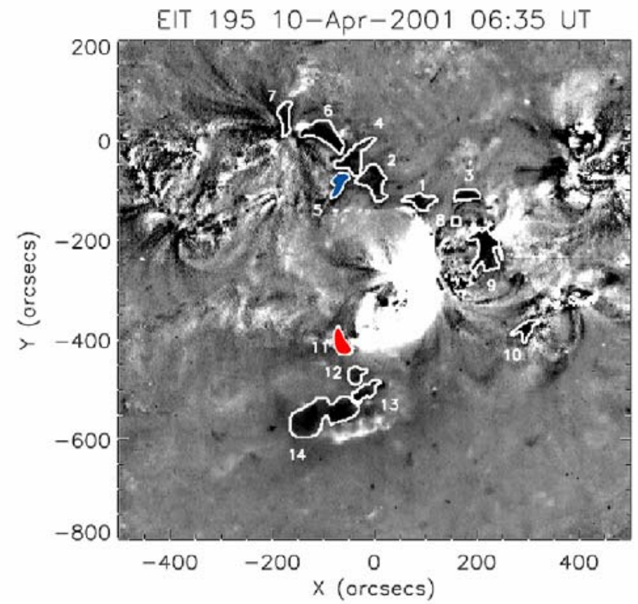
Regions 6, 8 and 9 have dI/dt = 0.0025, 0.0021 & 0.0024

Similar recovery evolution may reveal post-eruption magnetic loop structure

Interconnectivities II

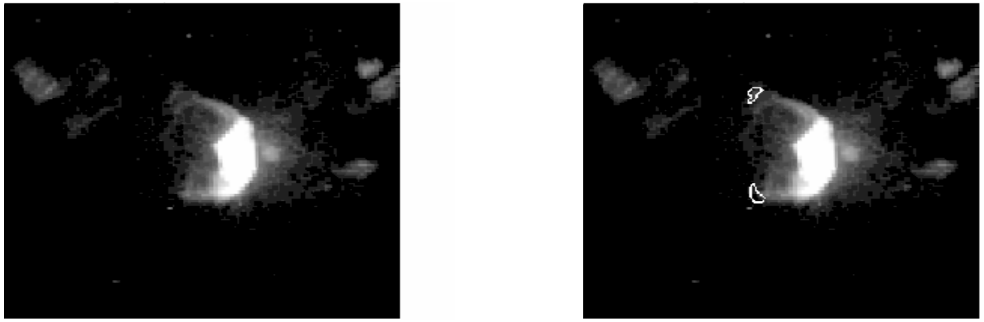






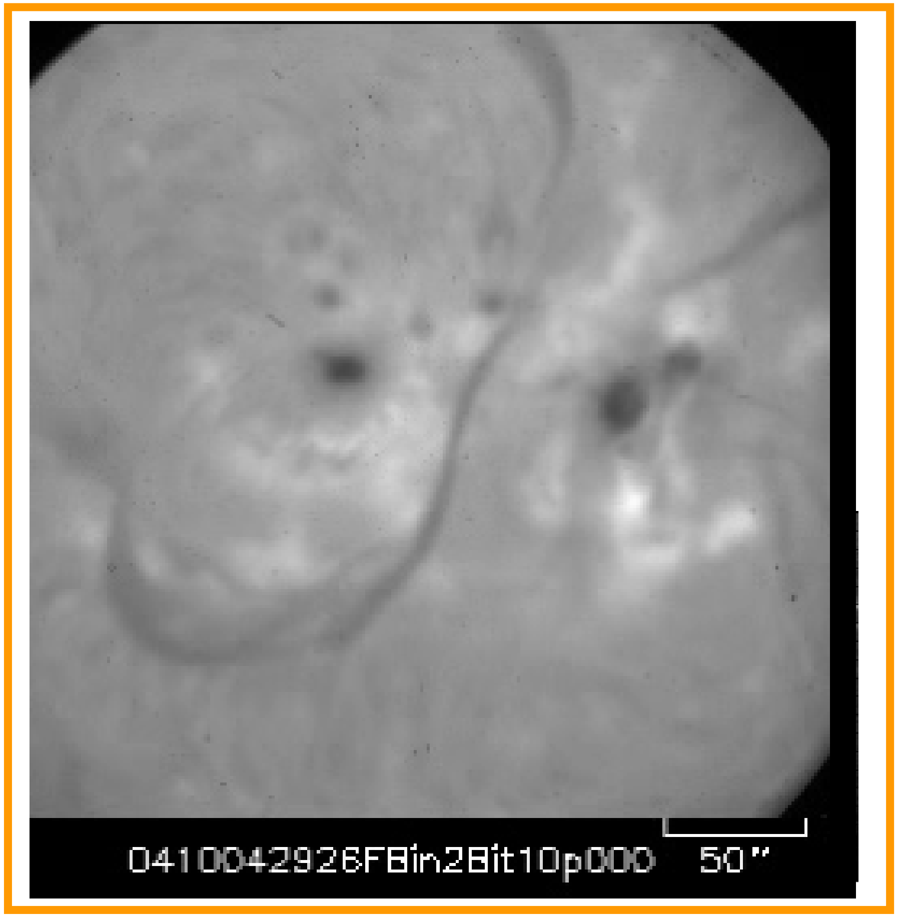
Maximum dimming @ 06:23 UT & 06:35 UT

Overlay of regions 5 and 11 shows that the apparent ends of the SXT feature terminate at the boundaries of the two EUV dimming regions.



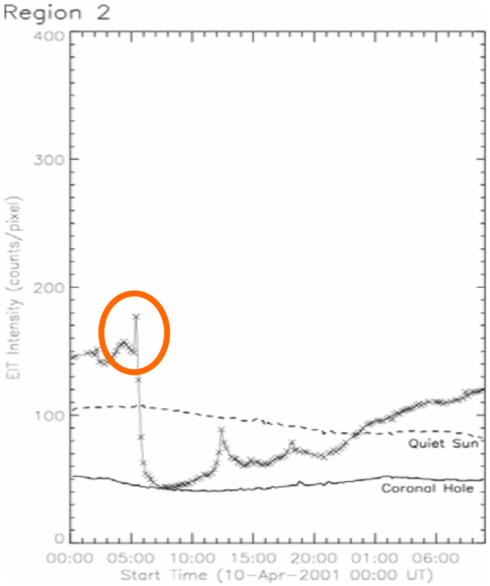
Yohkoh SXT AlMg at 06:32 UT

H-Alpha data - Courtesy of Hida FMT, Japan



Brightening reaches region 2 between 05:18 & 05:25 UT

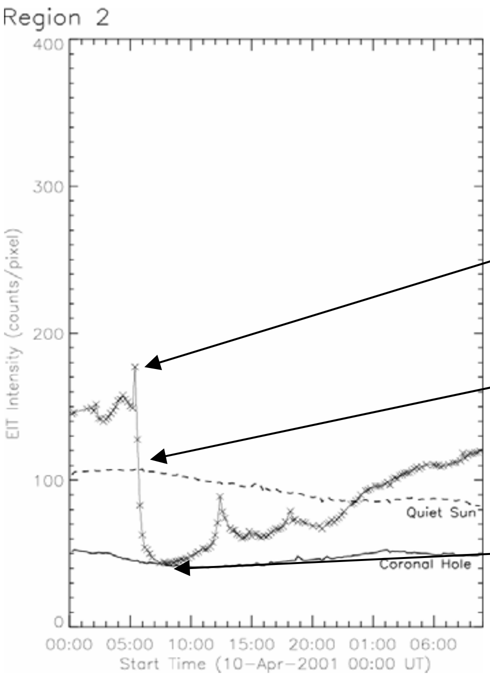
Sharp peak in EIT emission observed @ 05:23 UT



Brightening in H-alpha caused by heating, which is caused by reconnection.

Signature of reconnection also observed in EIT emission.

Signatures of magnetic reconnection



Sharp brightening observed.
Reconnection opens field.

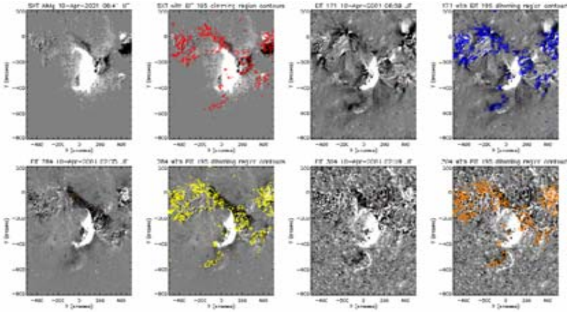
Dimming in progress.
Plasma evacuated along open field.

Dimming reaches a maximum.
Intensity starts to recover.
Field must now be closed.

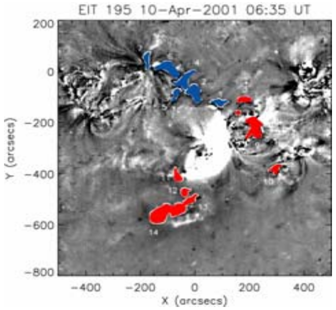
Diagnostic tool for determining the timescale over which the magnetic reconnection process takes place.

- Initial reconnection for opening takes place @ 05:23 UT
- Maximum dimming occurs @ 07:59 UT
- Maximum timescale for reconnection process = 2 hr 35 mins

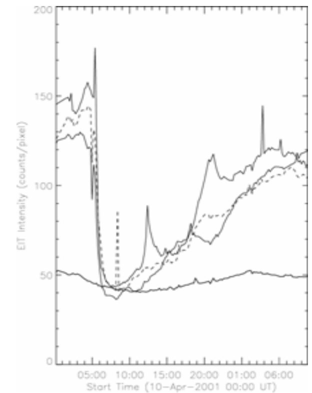
Conclusions



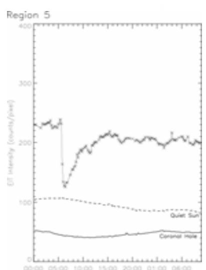
- Evidence that the strong dimmings identified for the 10th April 2001 are indeed due to a change in density, not in temperature.

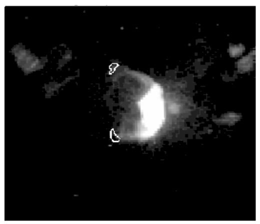


- An approximate flux balance is found between all the identified dimming regions.



- Similarities in recovery evolution of the EUV emission may reveal magnetic loop connectivities.





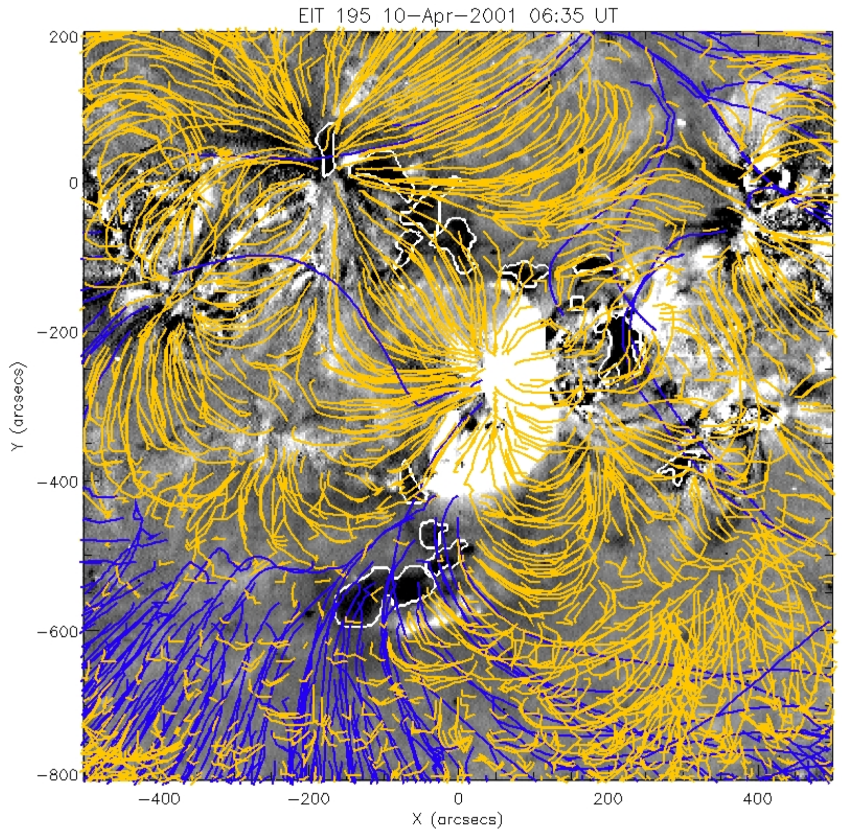
- Fast recovery signatures appear to be associated with the dimming regions at the termination points of the SXT feature.

• Diagnostic tool for determining the timescale over which the magnetic reconnection process takes place.

Magnetic field extrapolation

The reconstruction of 3-D magnetic field lines is made based on the method proposed by Hakamada 1995. This method uses the computation of spherical harmonic coefficients to calculate a potential model of the coronal magnetic field. We use a combination of a SoHO/MDI full disk magnetogram at the time nearest to the maximum dimming and a synoptic chart to infer the three dimensional structure of the magnetic field. The boundary condition on the solar surface is provided by the SoHO/MDI data and we assume that the magnetic scalar potential is zero on the surface so that only the radial component of the coronal magnetic field exists. A height limit of 2.5 solar radii is used for this calculation.

Model courtesy of N. Narukage, Kyoto University



Calculated |**B**| at the centre of each dimming region.