Coronal signatures of flares and CMEs

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Large scale structures in the corona
Large Scale Structures Near the Solar Surface

two kinds of measurement to collect information about the Sun:

Remote Sensing and In-situ Measurement
Key for remote sensing of the sun (and stars): Solar Spectrum

complete solar spectrum and EUV part of solar spectrum
Key for remote sensing of the sun (and stars): Solar Spectrum
Key for understanding solar activity: the solar magnetic field: active regions

Global magnetic field (extrapolation): 3d structure
Line-of-sight full disk magnetogram: 2d cut at photosphere
Key for understanding solar activity: the solar magnetic field: active regions

Full disk white light image (SDO), full disk line-of-sight magnetogram (SDO)
Key for understanding solar activity: the solar magnetic field: active regions

Active Region evolution in white light and magnetogram (SDO).
Key for understanding solar activity: the solar magnetic field: active regions

If we just have white light images and magnetograms:
Q: How are the polarities connected?
Key for understanding solar activity: 
the solar magnetic field: active regions

If we just have white light images and magnetograms:
Q: How are the polarities connected?

A1: extrapolation
A2: corona images: outline (some) of the magnetic field connectivity!
Key for understanding solar activity: the solar magnetic field: active regions

Full disk magnetogram and 171 image (SDO)
Key for understanding solar activity: the solar magnetic field: filaments

Full disk image in H alpha (BBSO): filaments seen as dark absorption structures
Key for understanding solar activity: the solar magnetic field: filaments

High resolution image in H alpha (Dutch Open Telescope) filaments seen as dark absorption structures.
Key for understanding solar activity: the solar magnetic field: filaments

Example of filaments:

- Quiescent filament in high spatial resolution (Hinode SOT)

- Filament eruption (SDO, composite)
SIMPLE (!!) cartoon of active region magnetic field

positive polarity

negative polarity

polarity inversion line

magnetic field lines almost perpendicular to PIL
SIMPLE (!!) cartoon of filament magnetic field

magnetic field lines almost parallel to PIL
Key for understanding solar activity: the solar magnetic field: filaments

Notes on filaments:

• Filament: on-disk structure (seen in absorption)
  Prominence: same structure off limb (seen in emission)
• Best wavelengths: H alpha, He II 304, Fe XII 195 A (AIA, STEREO)
• All filaments have a PIL
• But not all PILs are filaments!

• Caution: full disk magnetograms give only the line-of-sight magnetic field – projection effects near the solar limb!
Solar Eruptions: Flares and CMEs

- Energy is stored in the solar magnetic field (active regions and filaments): accumulated over a long period of time – days, weeks, months

- Energy is released in eruptions (flares, CMEs): in a short time scale (minutes, hours)

Magnetic energy is converted to thermal energy (and radiative energy) and kinetic energy (e.g. mass motion in CMEs and SEPs)
Solar Eruptions: Flares and CMEs

Solar Flares: Event that releases X-rays
X-ray monitor on-board GOES spacecraft (in Earth orbit), full disk monitor (no spatial information of location of flare on the sun)
larger events radiate also in other wavelengths especially in UV, EUV (and radio) → use SDO/AIA images to determine location!
one possible scenario for an eruption:

- reconnection at the x-point (energy release)
- CME escapes upward, field-lines open up
- Post-eruptive loops appear below x-point (additional heating)
Solar Eruptions: Flares and CMEs

**Caution:** the real sun is more complicated compared to the cartoon – e.g. magnetic field is a 3d structure

- some eruptions show no/very little X-ray signature (particularly filament eruptions)
- some flares have no CMEs
Large scale structures in the corona

- Images: SDO AIA 193 A, STEREO EUVI 195 A (filter contains Fe XII 195 A line, T~1.5 MK)
- Line-of-sight magnetograms: polarity inversion line (PIL)

- **Active Regions**: bi-polar, bright (emission), closed magnetic field (field lines perpendicular to PIL)
- **Filaments**: bi-polar, dark (absorption), closed magnetic field (field lines parallel to PIL)
- **Coronal hole**: uni-polar, dark (less dense), open magnetic field
Coronal signatures of CMEs

- **Data to use:** SDO AIA, STEREO EUVI (A & B)

- **Brightenings:** flares, post-eruptive arcade (193), arcade footpoints (304, 193)

- **Darkenings:** dimmings (transient coronal holes), dark/absorbing/cool material rising (filament eruption)

- **Off-limb:** opening of closed coronal field lines, AIA 304 emission structure

- Not a signature of eruption: active region loop brightenings, (small) flares
Coronal signatures of CMEs

Good period to study: SDO 2014-02-18 - 21
(use AIA 211, 193, 304)