Coronal signatures of flares and CMEs

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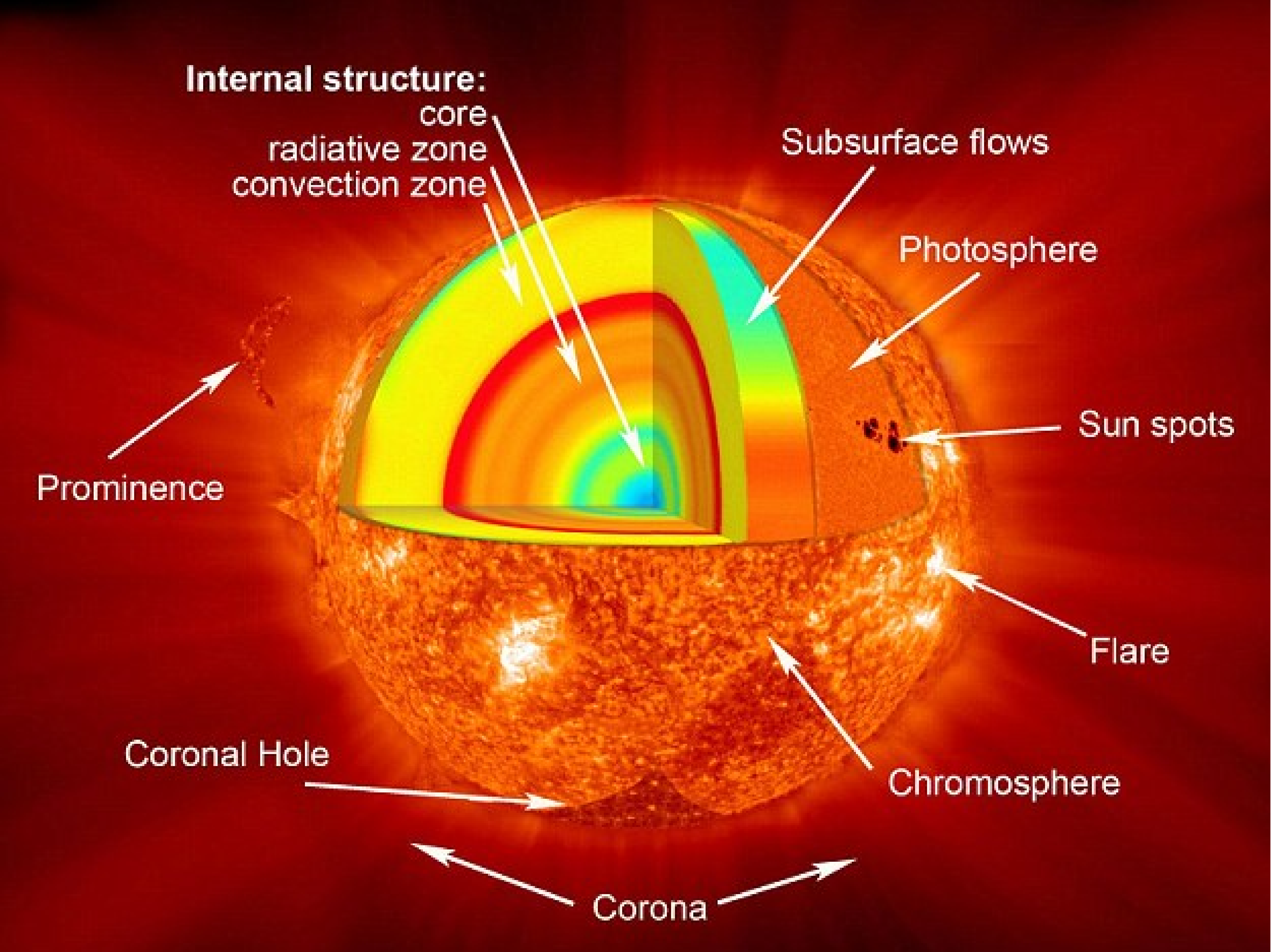
Space weather training at KSC, 2016

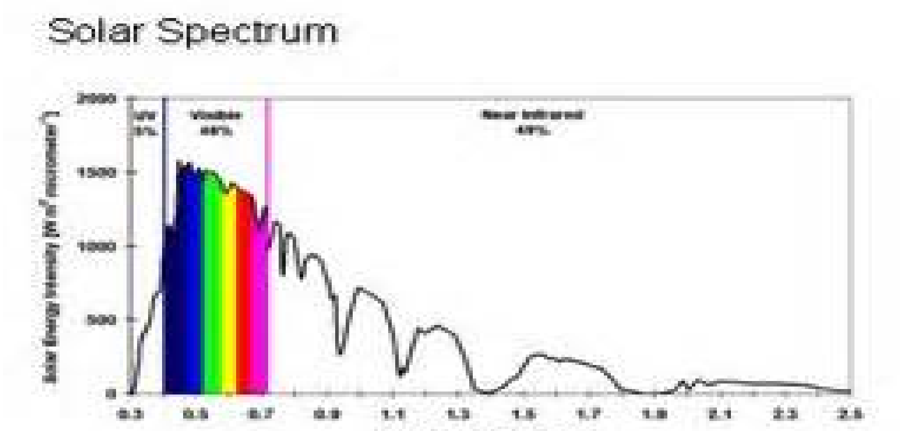

Internal structure:
core
radiative zone
convection zone
Subsurface flows
Photosphere
Sun spots
Prominence
Flare
Coronal Hole
Chromosphere
Corona

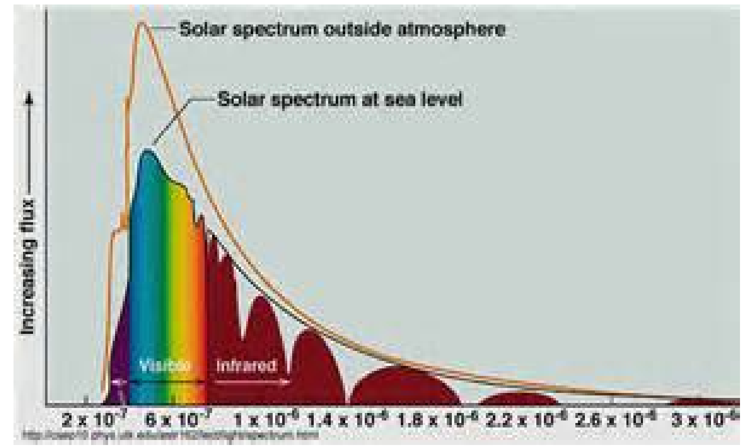
Large Scale Structures Near the Solar Surface

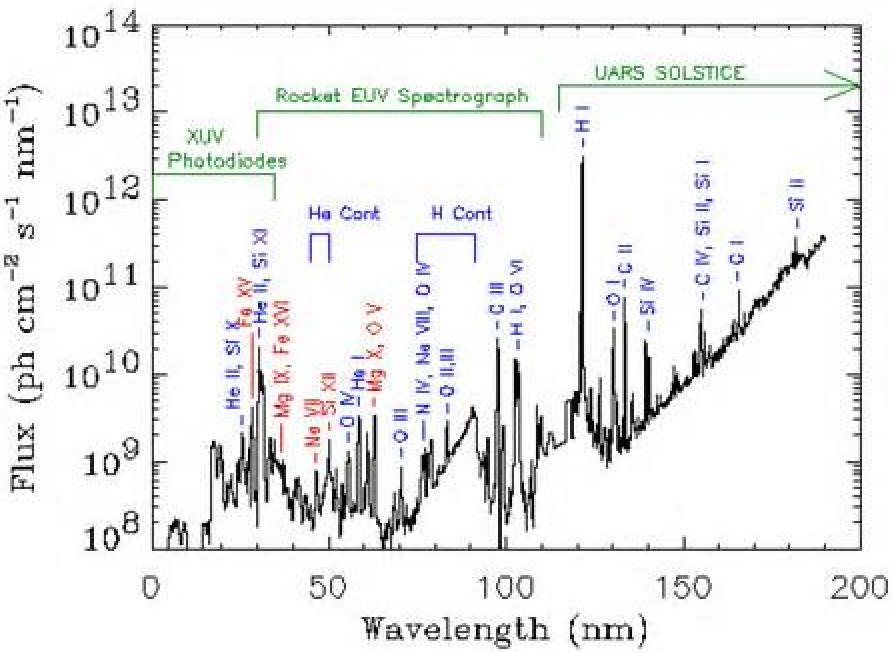
two kinds of measurement to collect information about the Sun:

Remote Sensing and In-situ Measurement

Key for remote sensing of the sun (and stars): Solar Spectrum





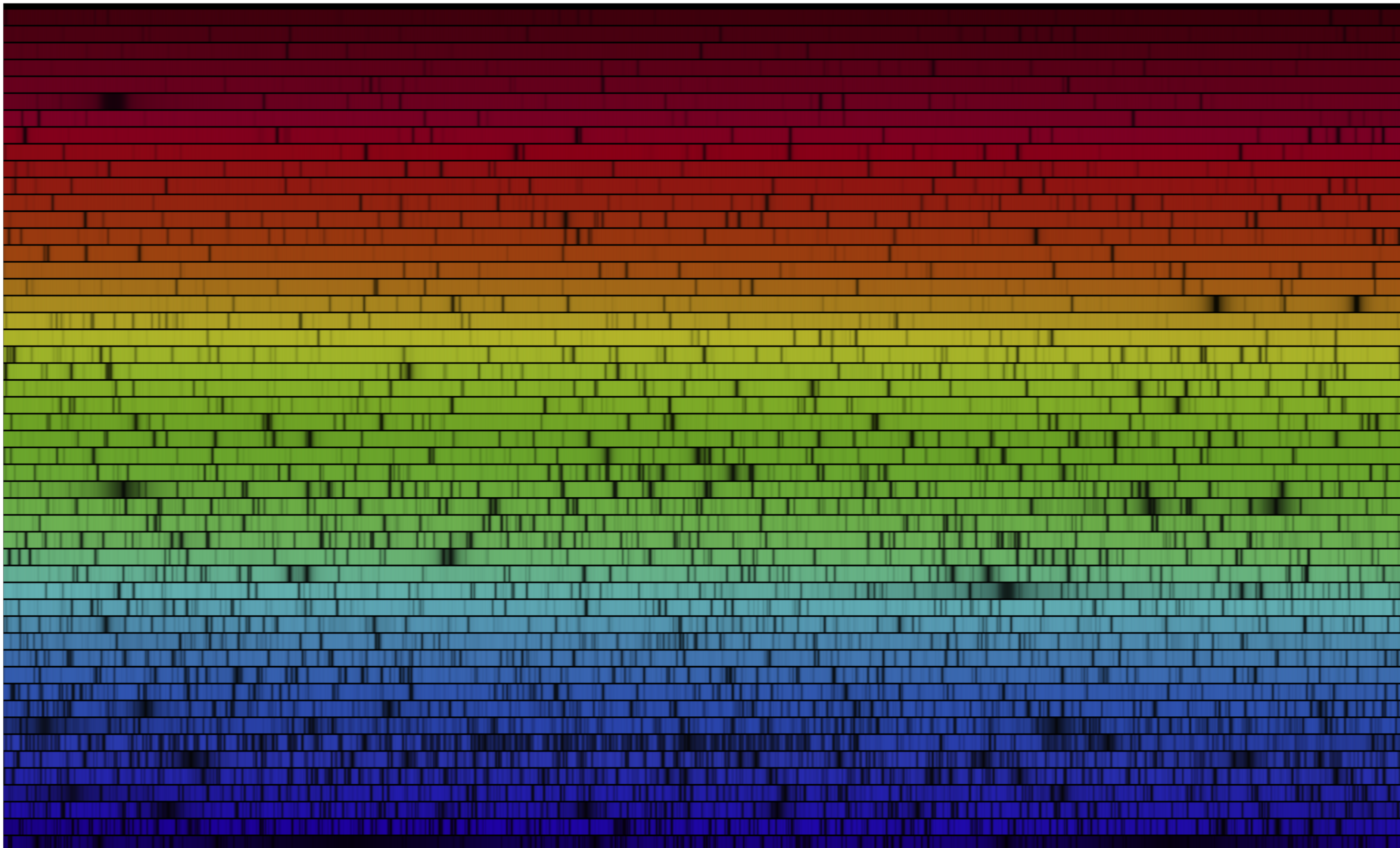


complete solar spectrum

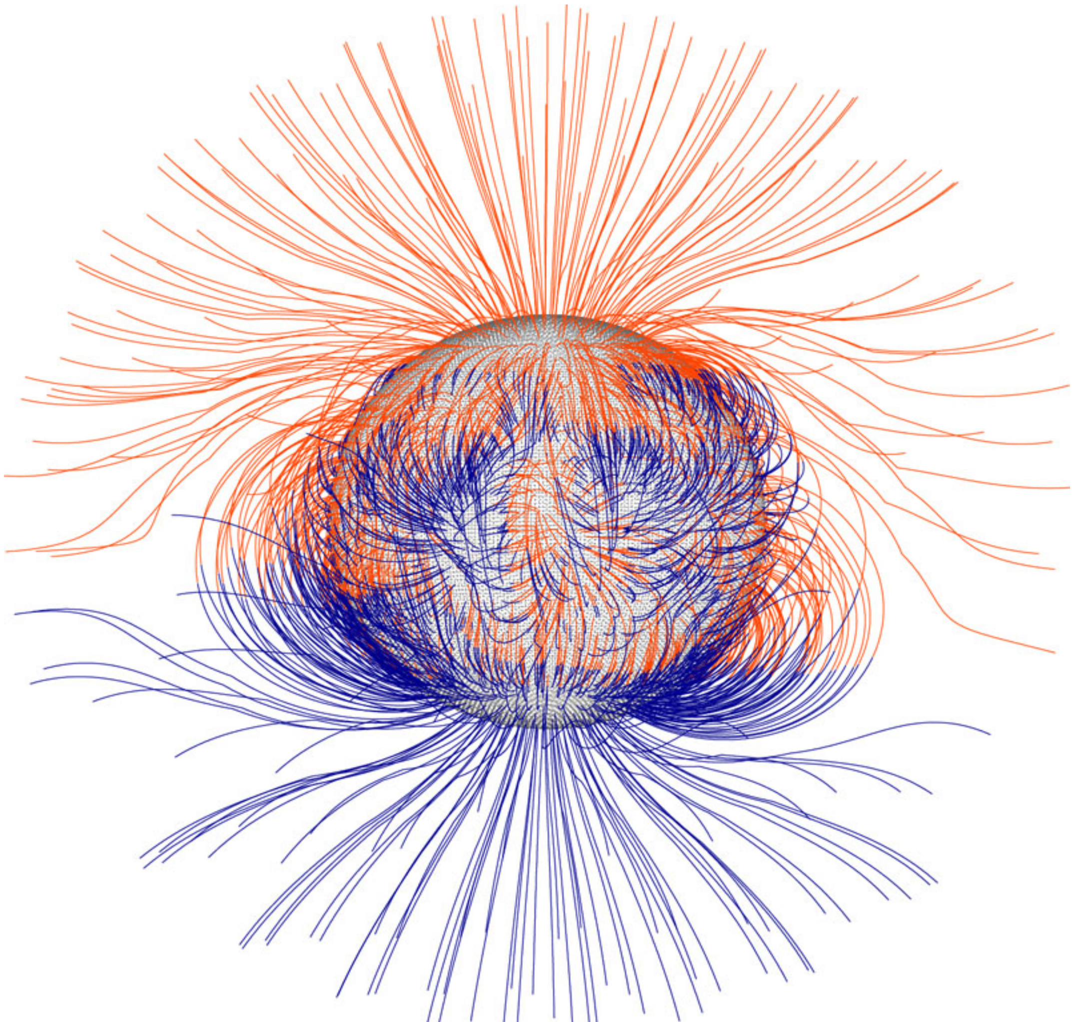
and

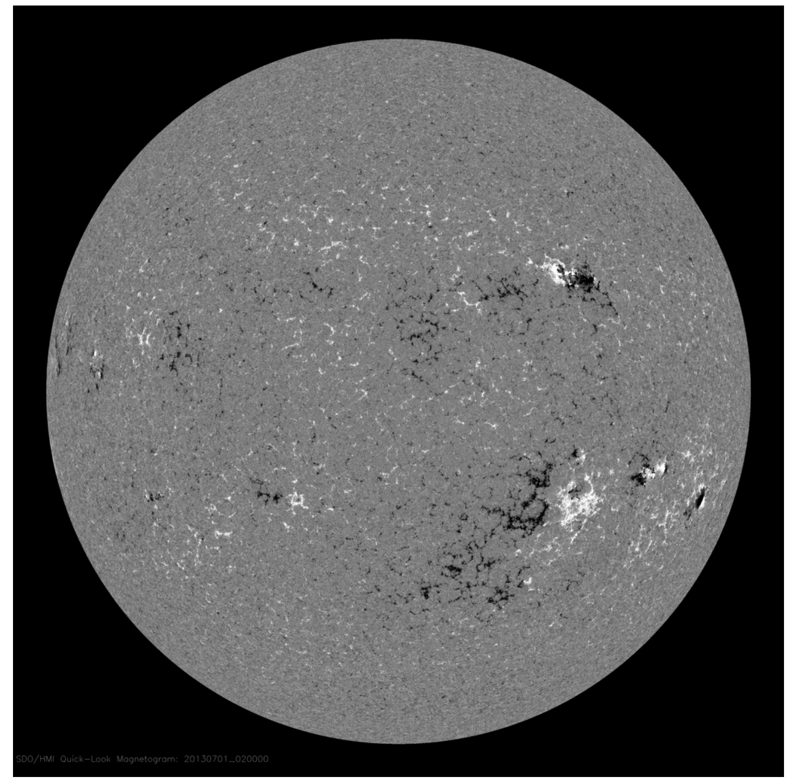
EUV part of solar spectrum

Key for remote sensing of the sun (and stars): Solar Spectrum



Key for understanding solar activity: the solar magnetic field: active regions

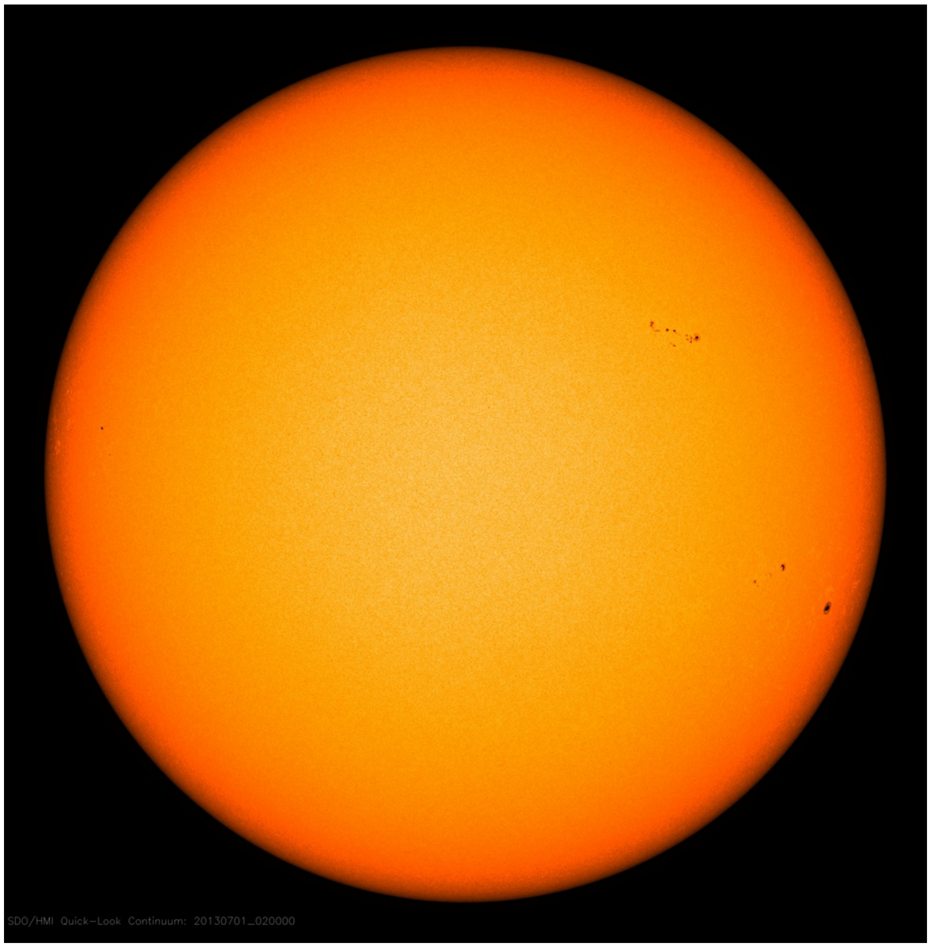


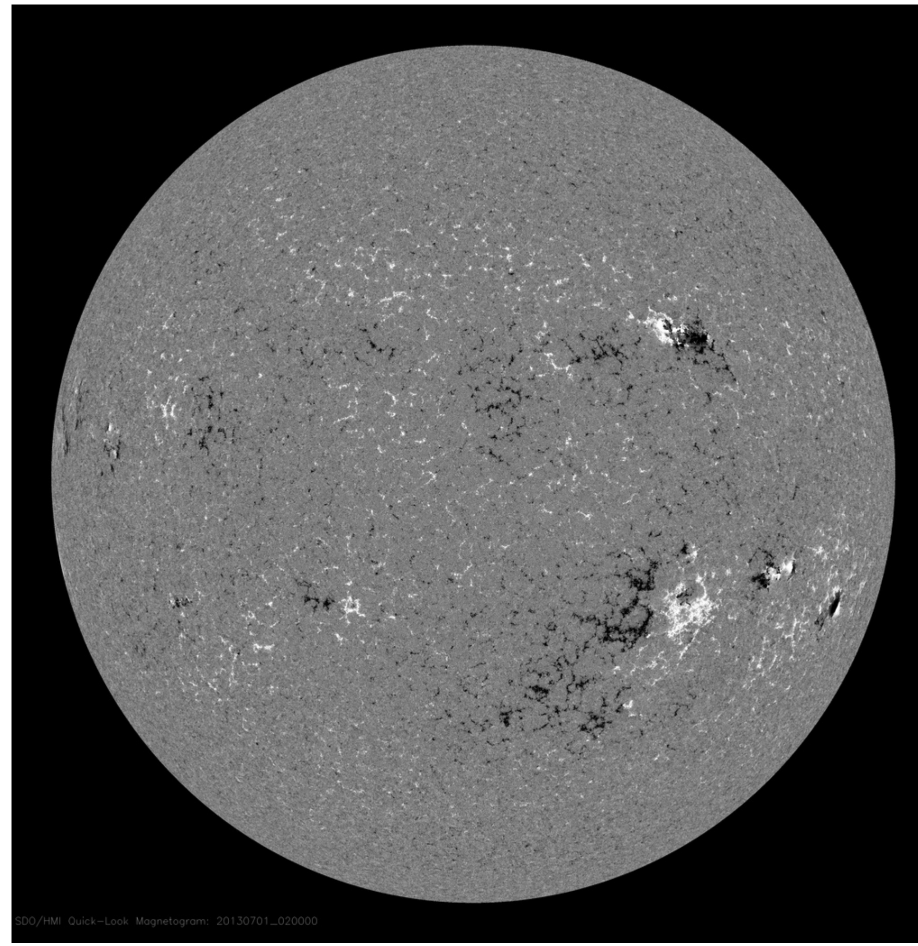


Global magnetic field (extrapolation): 3d structure

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

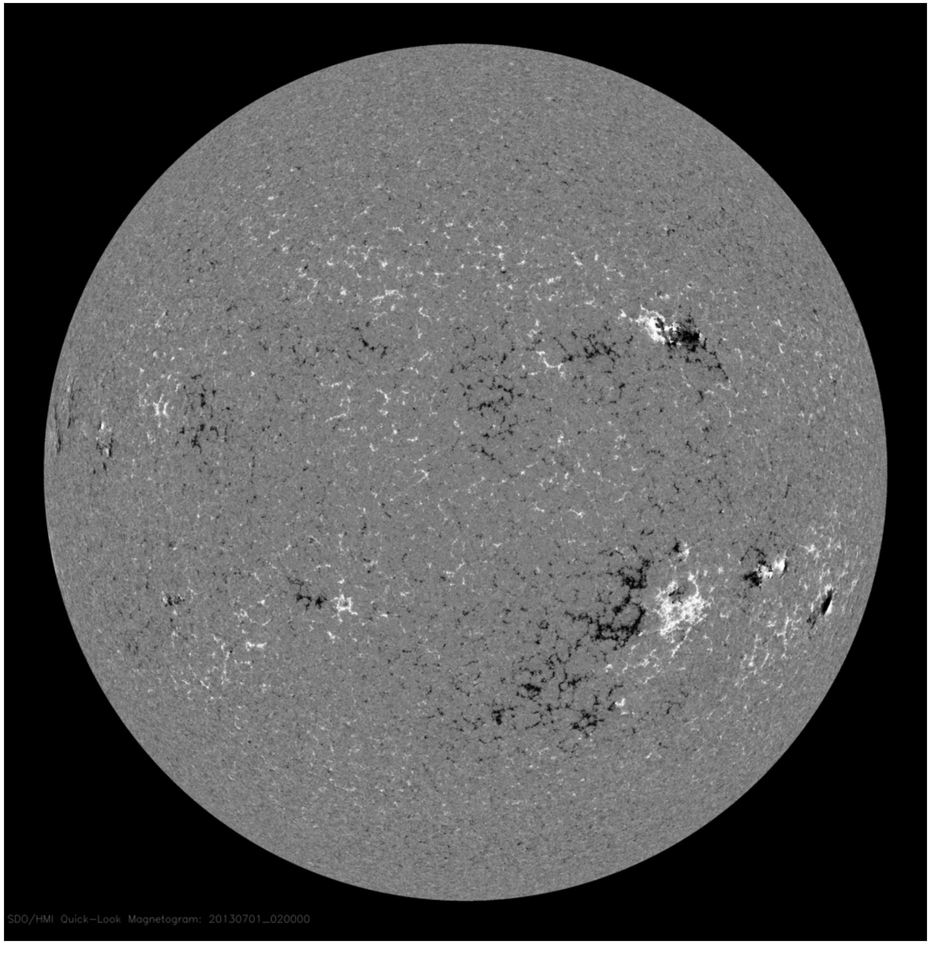
If we just have white light images and magnetograms:

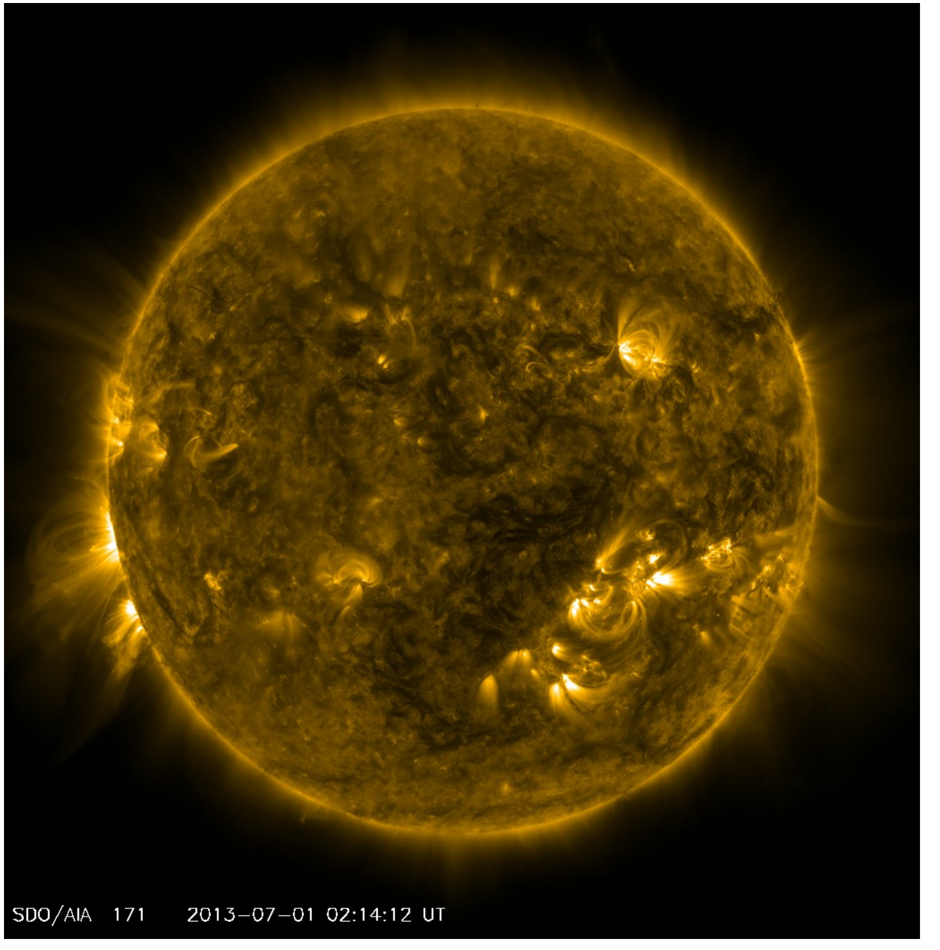
Q: How are the polarities connected?

A1: extrapolation

A2: corona images: outline (some) of the magnetic field connectivity!

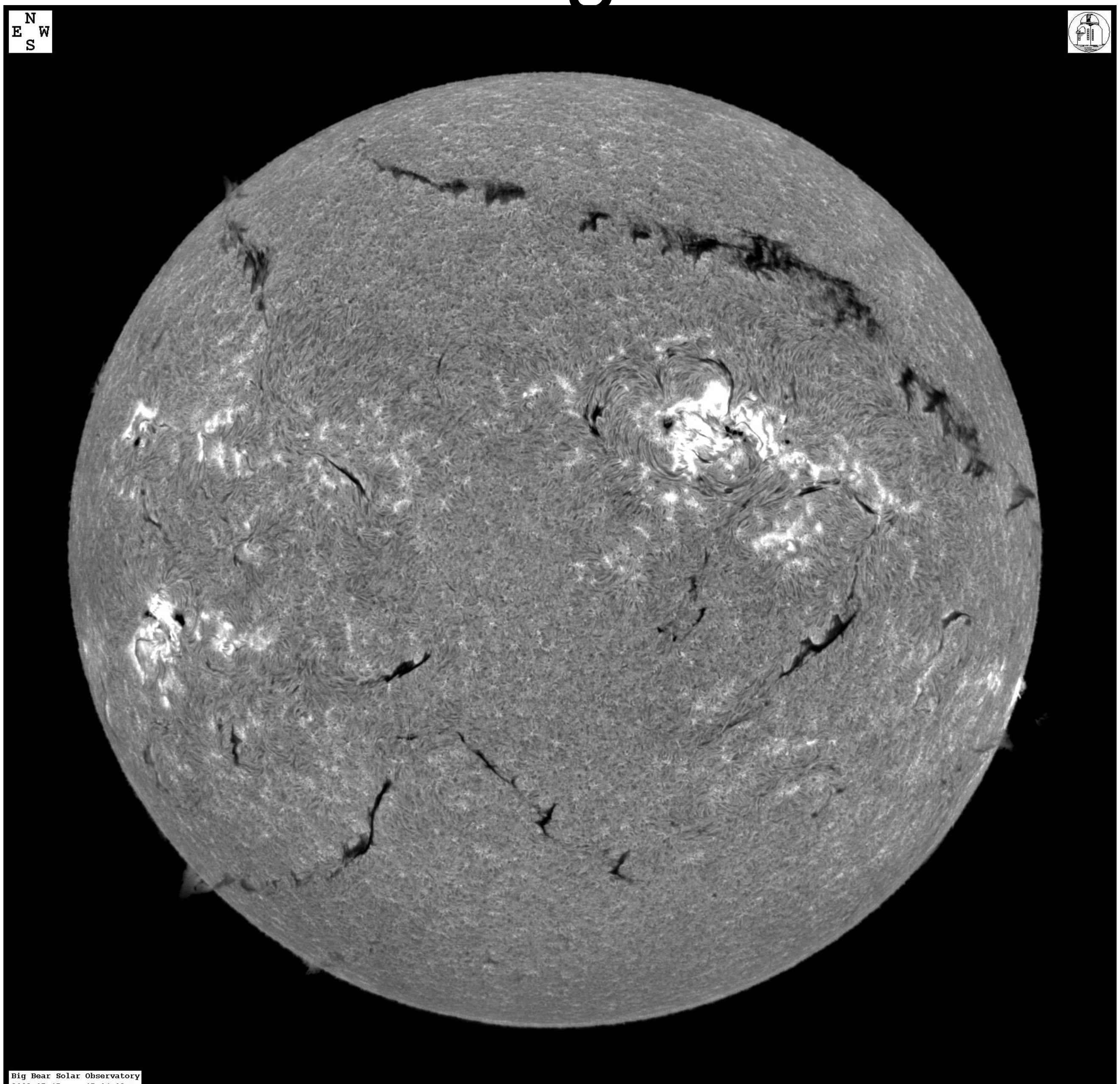
Key for understanding solar activity: the solar magnetic field: active regions





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

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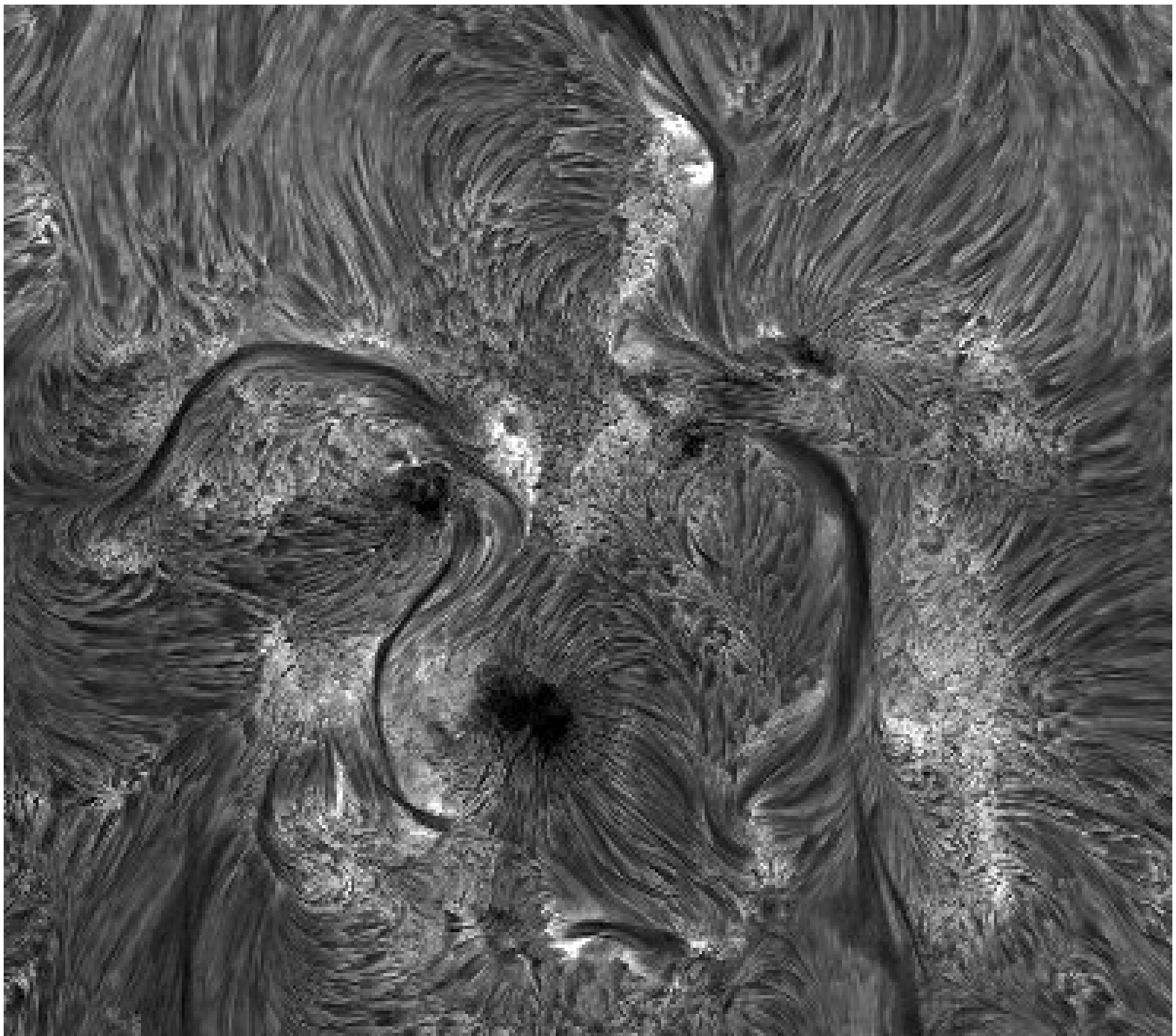


High resolution image in H alpha (Dutch Open Telescope)

filaments seen as dark absorption structures

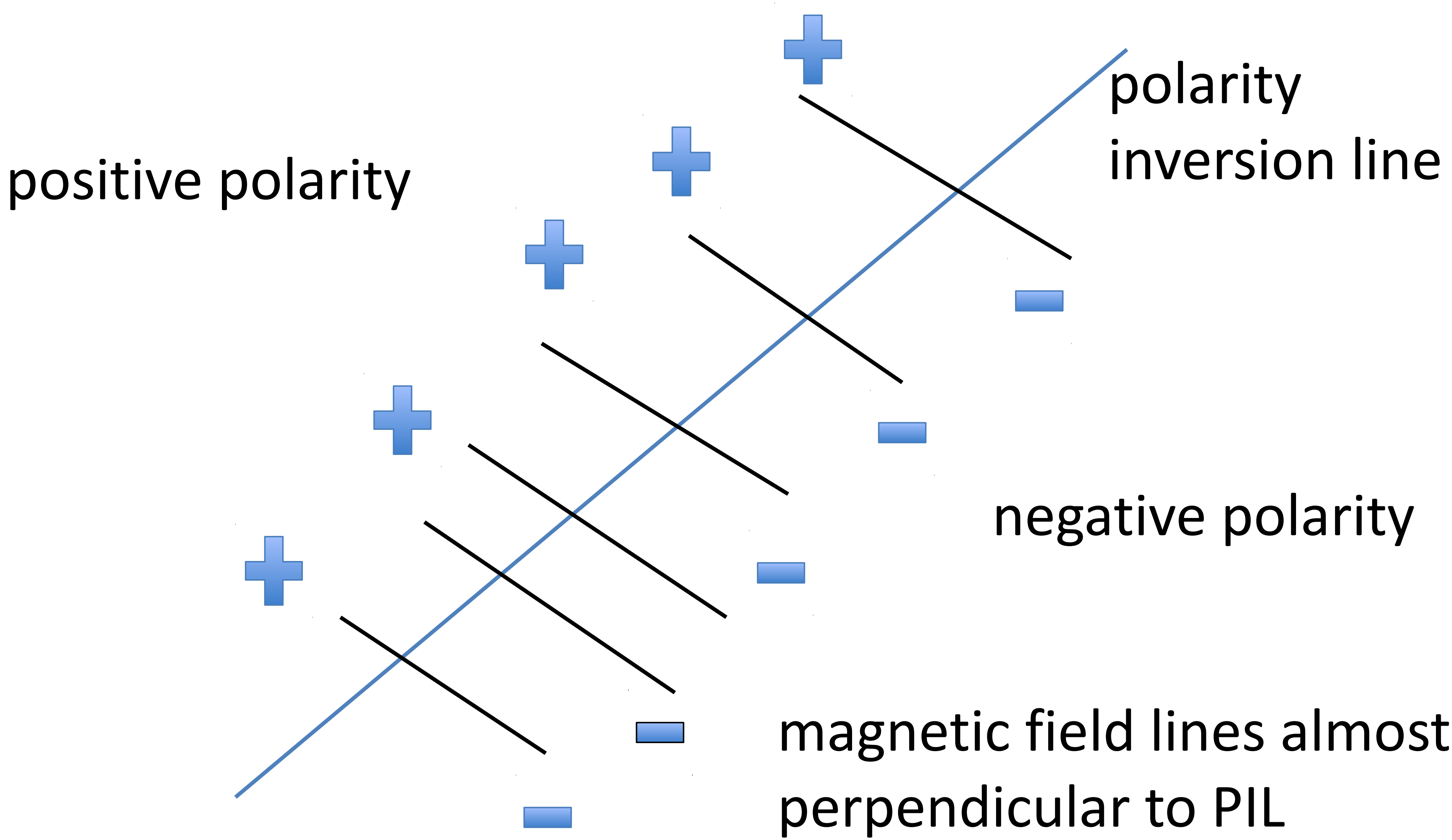
Key for understanding solar activity: the solar magnetic field: filaments

Example of filaments:

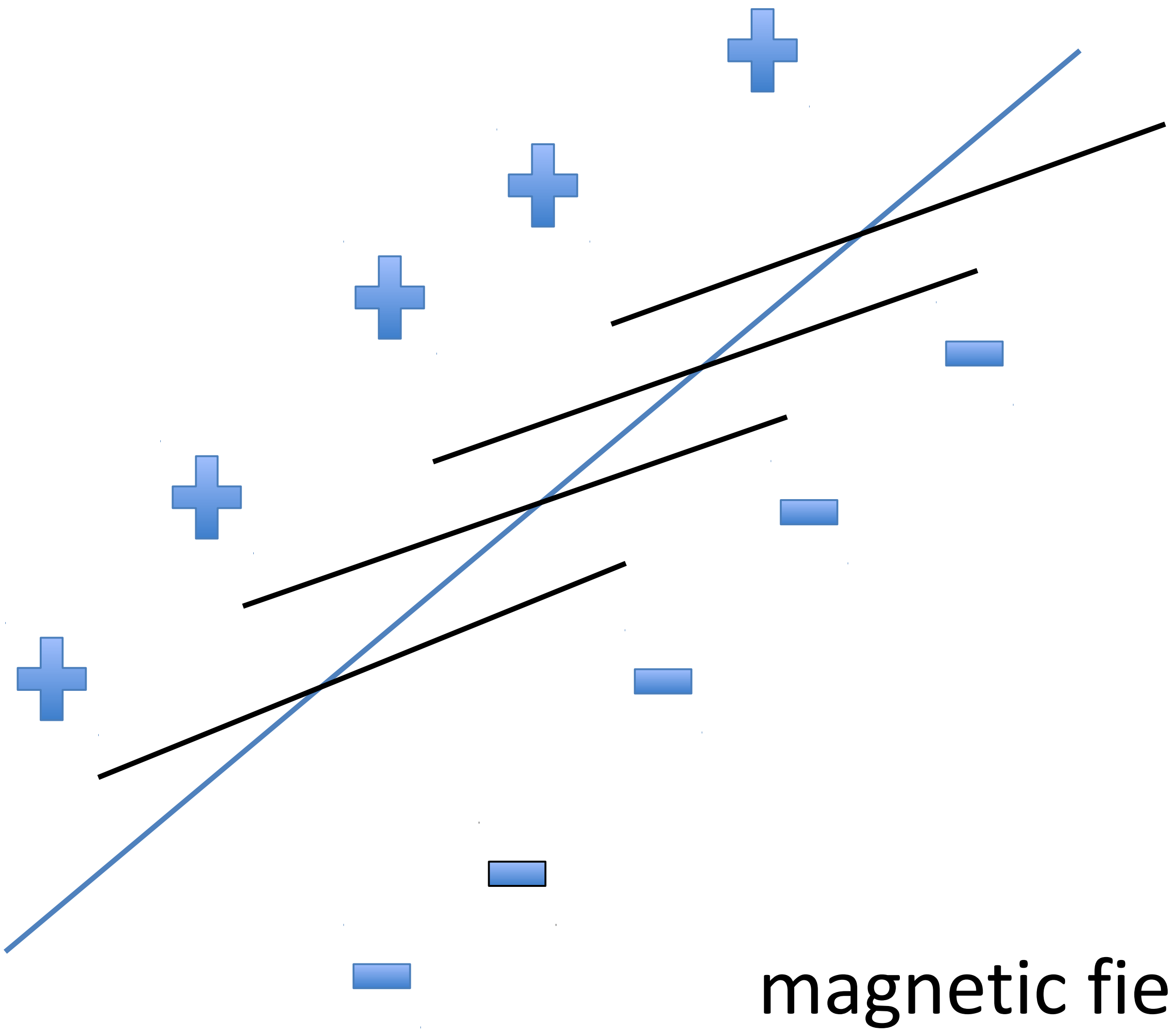
- Quiescent filament in high spatial resolution
  (Hinode SOT)

- Filament eruption (SDO, composite)

SIMPLE (!!) cartoon of active region magnetic field



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)

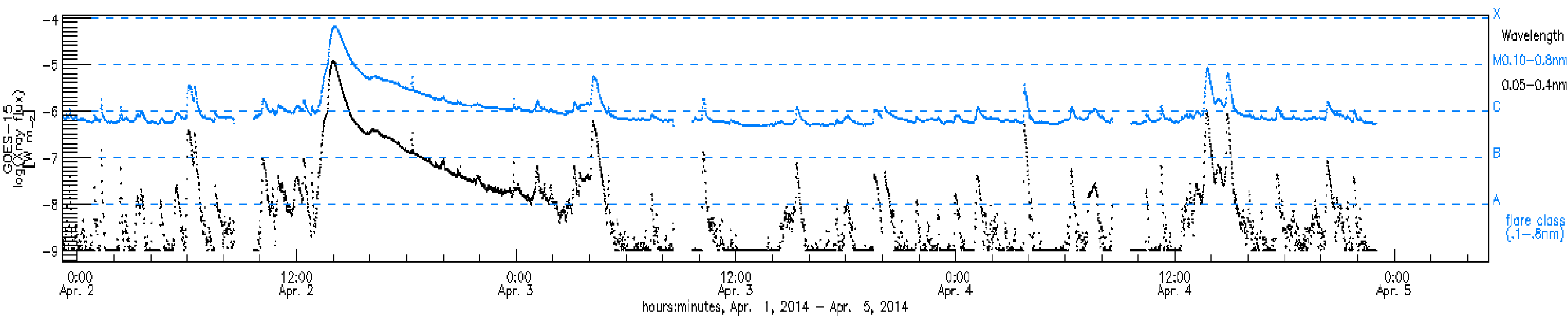
  Magnetic energy is converted to thermal energy (and radiative energy) and kinetic energy (e.g. mass motion in CMEs and SEPs)

Solar Eruptions: Flares and CMEs

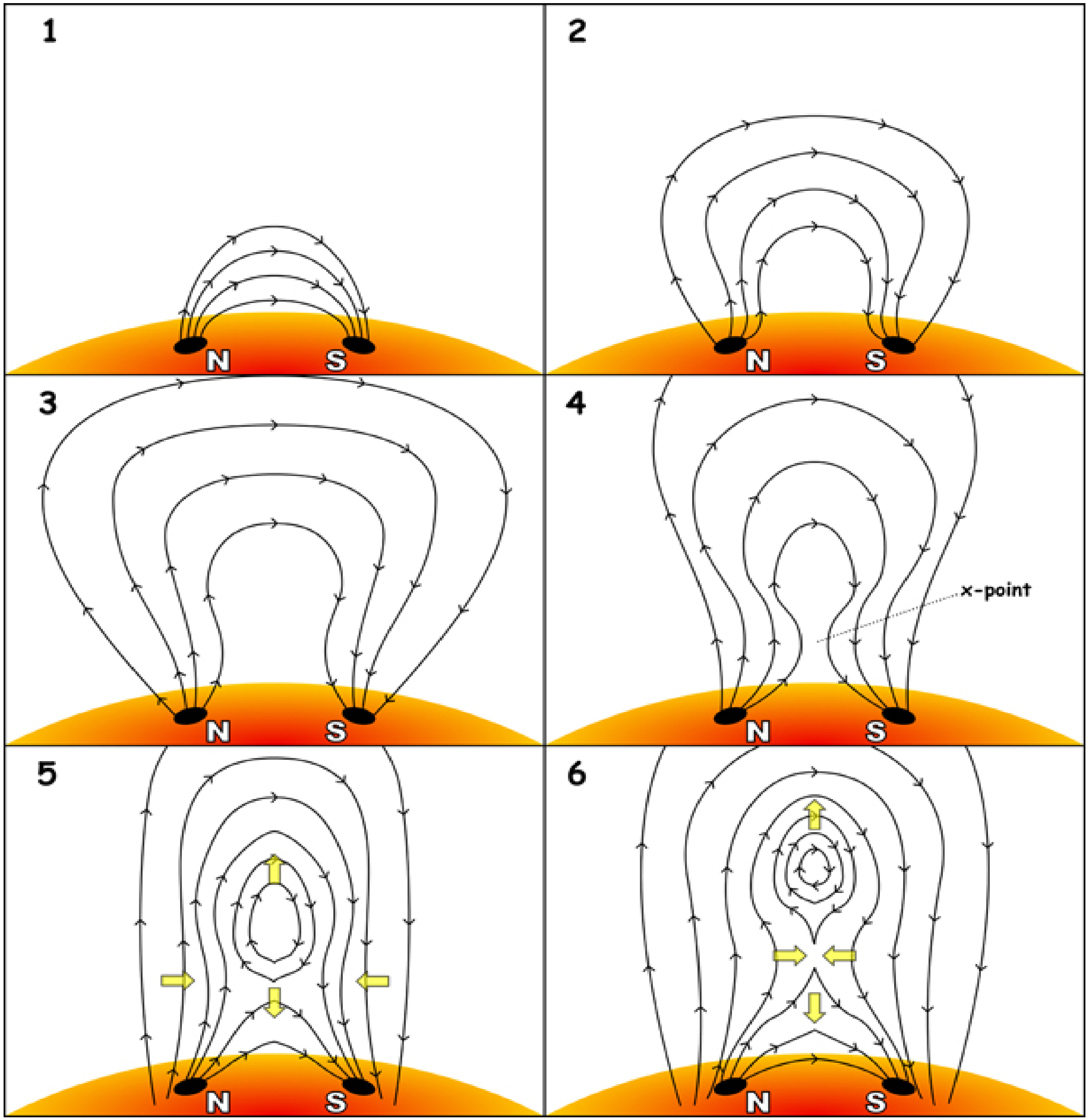
Solar Flares: Event that releases X-rays

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!



Solar Eruptions: Flares and CMEs



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)