<u>Week 1 2018- Tuesday</u>

Solar Photospheric and Coronal Observations

1. Which large-scale structures on the Sun are important for Space Weather?
Active regions, filaments/prominences, coronal holes.

2. What does a solar magnetogram show and in what layer in the atmosphere is it usually observed?
It shows the line-of-sight magnetic field at the photosphere, distribution of the solar magnetic field, 2d cut of the 3d magnetic field at the photospheric level.

3. What is the difference between the magnetic field structure of an active region and a filament?
In an active region magnetic field lines connecting opposite polarities are mostly perpendicular to the polarity inversion line, and in a filament they are mostly parallel to the polarity inversion line.

4. What are the signatures of a flare in SDO data and which SDO images are the best to use to identify flares?
Enhanced electromagnetic radiation in X-Ray, EUV and UV, AIA 131 (others can also be used like 211 or 193 and 171).

5. What are the coronal signatures of a CME and which SDO data products are the best to use to identify these signatures?

- Post-eruptive loop system after lift-off of CME (171, 193)
- Bright footpoints of post-eruptive loops (304, 193, 171)
- Darkenings (dimmings and waves, 193, cool filament material erupting, 304)
- Opening of coronal loops off limb (193, 171)
- Cool filament material in emission off limb (304)

Flares and Space Weather

1. How are solar flares classified? List each of the classes?
Flares are classified by the X-ray flux intensity in the 0.1 – 0.8 nm wavelength range. A strong flare usually manifests itself by a sudden jump of the X-ray intensity. Flares are classified according to their X-ray Flux intensity in the 0.1 – 0.8 nm wavelength range:

- Flux[Wm^(-2)] > 10^(-4) X - (eXtreme), strong
- Flux[Wm^(-2)] > 10^(-5) M – (Moderate)
- Flux[Wm^(-2)] > 10^(-6) C – (Common)
- Flux[Wm^(-2)] > 10^(-7) B – (Background)
- Flux[Wm^(-2)] > 10^(-8) A

2. What is the class of a flare if it's Flux is 2.5*10^(-4)?
X2.5

3. What is the correlation between solar flares and solar activity?
The flares happen more often during and close to a solar maximum, but strong X-class flares can occur anytime sunspots are present.

4. What can be the space weather effects from a solar flare?

- The flares can cause radio blackouts. The increased level of X-ray and extreme ultraviolet (EUV) radiation results in ionization in the lower layers of the ionosphere on the sunlit side of Earth. This can cause High Frequency radio signals to become degraded or completely absorbed.
- Solar flares can be an acceleration site for solar energetic particles (SEP) - proton radiation, with can have damaging effects on satellites and human.

CMEs and Their Impacts

1. What is a coronal mass ejection?
An eruption of a huge mass of solar plasma from the solar atmosphere occurring from time to time. If CME is directed towards Earth, depending on it's speed and size, it can reach the Earth in 1-3 days. CMEs usually cause the strongest geomagnetic storms. Statistics shows that during the solar activity maximum there are about 5 CMEs per day, and during the solar minimum a few CMEs a week (the ratio is of the order of 10).
Most of the CMEs originate from active regions, areas with an especially strong magnetic field.

2. What is the typical CME mass (kg and creative units)
~10^14 kg or about the weight of Mount Everest.

3. What is a typical CME speed?
Typical speed is 500 km/s, but it ranges from a few hundred to 3000 km/s.

4. What is a typical space weather effect from a CME?
Contributes to solar energetic particle (SEP) radiation. Can result in a geomagnetic storm. This can affect spacecraft electronics, radio communications, navigation (GPS), power grids.

5. What is the physical mechanism behind the flares and CMEs?
Magnetic reconnection. It is believed that the magnetic field can change its configuration in a constantly varying solar atmosphere and during this reconfiguration it releases energy accelerating solar plasma causing flares and CMEs. The scientists are still debating on the details of the mechanisms, but the fact that the magnetic field is involved somehow is accepted by everybody.

A CME has just erupted from the Sun with a latitude of zero and with a cruising speed of 500 km/s. Assuming the speed does not change, how many days does it take for this CME to reach:

Mercury (0.3 AU)	~1 day 1 hr
1 AU (Earth, Stereo A,B or Spitzer)	~3 days 11 hrs
1.5 AU (Mars)	~5 days 5 hrs
3 AU	~10 days 9 hrs
5.5 AU	~19 days

Assume the CME is moving at 1500 km/s (instead of 500 km/s) - how does the the timing change at each location?
Arrives 3x as fast.

6. Check the coronagraphs for the CME starting on 2013-04-11T07:36Z. Next check SDO/AIA on 2013-04-11 (before the CME start time of 2013-04-11T07:36Z) and list the coronal signatures of this CME.

- Flare
- Eruption from AR just north of disk center
- Dimming below AR
- Post-eruption arcade

Coronal holes and Space Weather

1. Coronal holes can be defined in three different ways, list them:

1) Low emission in x-ray or EUV images
2) Low off limb emission observed with coronagraphs
3) Open magnetic field lines extending from the photosphere into heliosphere

2. Describe the scenario in which a coronal hole can cause space weather effects here on Earth.
Two major factors contribute: The location of the coronal hole needs to be near the equator in the western hemisphere of the sun. In addition, the sources of the slow solar wind and the heliospheric current sheet need to be aligned such that the high-speed stream isn't diverted away from the Earth.

3. What is a high speed stream, and how is it related to a coronal hole?
A high speed stream is high speed solar wind originating from a coronal hole. Coronal holes correspond to regions of open magnetic fields. The plasma density of a coronal hole is lower when compared to the rest of the corona.

4. List at least three things you learned from the web module.
Sample answer:
Plasma and magnetic field spiral in the same direction (recall that plasma follows magnetic field).
If the Sun rotated at a faster rate, the Parker Spiral would be tighter.
If the solar wind is slower, the Parker Spiral is tighter.

5. What is the solar equatorial rotation period (average) in degrees per day?
~14.7 degrees per day.

6. Using your rotation period, consider a coronal hole at disk center with a speed of 400 km/s. How many degrees does the Sun travel through by the time the parcel of 400 km/s wind reaches Earth at 1AU?
(1 AU) / (400 km/s) = ~4 days 8 hours (4 days 8 hours)*(14.7 degrees)= ~63.7 degrees
What if the speed was 500?
(1 AU) / (00 km/s) = ~3 days 1 hours (3 days 11 hours)*(14.7 degrees)= ~50.8 degrees
What if the speed was 800?
(1 AU) / (800 km/s) = ~2 days 4 hours (2 days 4 hours)*(14.7 degrees)= ~31.8 degrees

7. Since the solar wind magnetic field is frozen into the solar wind flow, what does this tell you about the Earth's magnetic connection to which parts of the Sun?
Since the Sun is rotating, by the time the solar wind arrives at Earth, the part of the Sun that was center is now the west of the Sun (recall "west" is the right side when looking at SDO imagery), thus Earth is magnetically connected to the west. The solar wind flow carries with it the Sun's magnetic field (interplanetary magnetic field). The magnetic connectivity of the Earth to the Sun changes with solar wind speed. If the solar wind is faster, the Parker Spiral is less tight and the Earth is connected about 30 degrees west of disk central meridian. If the solar wind is slower, the Parker Spiral tightens and the Earth is connect to a point about 60 degrees west of disk central meridian.