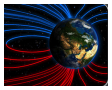


Sun Series: Supplemental Materials - 2014/2015

Solar and Space-Weather Vocabulary

Alpha Class - A sunspot group that contains only one polarity (+ or -); these often only have one spot in the group.

Beta Class - A sunspot group that contains both + and - sunspots.

Corona - The solar atmosphere.

Coronagraph - A device that images the outer corona and near-sun space. It is very sensitive, and allows the user to see charged particle ejections, as well as planets and comets, without the glare of the sun washing out the image.

Coronal Hole - An area of the corona with fewer magnetic fields, and which allows solar wind to stream out at a faster rate. Alfvén waves emanate from the centers of coronal holes.

Coronal Mass Ejection (CME) - An erupting cloud of plasma and charged particles from the sun that goes out into space; CMEs can be produced from Solar Flares or Filament Eruption/Collapse.

Delta Class - A sunspot group where both a + and - sunspot umbra co-exist in close proximity within a penumbral surrounding; this requires both polarities, or a Beta Class sunspot, and is the most likely class to produce solar flares.

Ejecta - The particles of a CME; the material that leaves the sun during a solar flare or filament release.

Filament (Plasma Filament, Solar Prominence) - A tight line of plasma and charged particles suspended above the solar surface by the sun's magnetism.

Flux Transfer Event (FTE) - The flood of charged particles that streams in earth's electromagnetic system every 8 minutes via Magnetic Portals in near-earth space.

Gamma Class - A sunspot group where + and - sunspots are spread out and dispersed such that they cannot be grouped together by a continuous line; this requires both polarities, or a Beta Class sunspot.

Geomagnetic Storm - The disruption to earth's magnetosphere due to space-weather.

(Solar) Grand Cycle - The ~400 year cycle of higher-activity solar cycles and lower-activity solar cycles.

(Solar) Grand Maximum - The highest activity period (multiple sunspot cycles) of a grand cycle; lots of sunspots/solar flares/geomagnetic activity.

(Solar) Grand Minimum - The lowest activity period (multiple sunspot cycles) of a grand cycle; fewer sunspots/solar activity.

Halo Eruption - A CME on SOHO LASCO that appears to be coming out of all sides of the central disk that blocks solar glare, and is indicative of an earth-directed CME. NOTE: A CME on the exact opposite side of the sun from earth may produce a Halo as well, so we need to confirm that the Solar Flare or Filament Eruption is on the earth-facing side of the sun before we declare and eruption is heading our way.

Heliosphere - The magnetic shield of the sun, extending up past all the planets; the sun's version of a Magnetosphere, encompassing the entire solar system.

Interplanetary Magnetic Field - The magnetic fields connecting the planets to the sun, to their moons, and to each other; likely a key factor in the strength of FTEs and Radiation Storms.

Magnetic Portals - The vortex-shaped hole that forms where earth's magnetic field pushes against the sun's magnetic field, allowing charged particles to stream into earth's systems in an FTE.

Magnetosphere (Earth's magnetic shield/field) - A magnetic shell that surrounds the earth and protects the planet from space energy.

Penumbra - The area surrounding the dark sunspot core.

Polar Cycle (Solar Polar Cycle) - The ~11 year cycle of fluctuating polar force of the sun, including the reversal of the sun's magnetic poles, which runs opposite to the sunspot cycle; maximum polar force on the sun correspond to Sunspot Minimum, while the weaker times of polar force occur as the solar fields prepare to reverse, occurring during Sunspot Maximum.

Radiation Storm (Space/Solar Radiation Storm, Polar Radiation Storm, Solar Energetic Particle Event) - A surge of charged particles that bombard the upper atmosphere at earth's polar regions; often caused by a solar flare.

Solar Flare - A burst of X-ray/Extreme ultraviolet energy released when umbral magnetic fields interact, surging charged particles and plasma in the corona to near the speed of light.

Solar Pole/Magnetic Reversal - The flip or reversal of the sun's magnetic poles; the north and south poles reverse polarity (+ and -) every ~11years.

Solar Wind - The constant flow of charged particles and neutral elements away from the sun in every direction; the solar wind blows out to distances past pluto.

Space-Weather - Forces that act upon earth, which are external to the earth; solar events, comets, meteors, galactic cosmic rays, etc.

Sunspot - A highly magnetic region of the sun where magnetic fields emerge from inside the sun.

Sunspot Classification - The characterization of sunspots in terms of likelihood to create solar flares, based on the magnetic structure of a sunspot or group of sunspots.

Sunspot Cycle - The ~11 year cycle of increased/decreased sunspot activity on the sun.

Sunspot Maximum - The period of the sunspot cycle with more sunspots/solar flares/geomagnetic activity.

Sunspot Minimum - The period of the sunspot cycle with fewer sunspots/solar flares/geomagnetic activity.

Umbra - The dark inner core of the sunspot.

Umbral Magnetic Field (Umbral field) - The magnetic fields (loops) that connect sunspots.

Solar Satellites and Observatories

Solar Dynamic Observatory (SDO) - The best all-around way to watch the sun. See flares, coronal holes, sunspots, magnetic fields, filaments, and CMEs.
SDO Image/Video Access: http://sdo.gsfc.nasa.gov/data/

GOES Solar X-Ray Imager (SXI) - A good secondary resource for seeing solar flares, coronal holes, and CMEs.
GOES SXI Video Access: http://www.swpc.noaa.gov/sxi/goes15/index.html

Solar and Heliospheric Observatory (SOHO EIT/LASCO) - The EIT images are the predecessors of the SDO imagers, and are less useful. HOWEVER, the LASCO images are the only coronagraph images available from earth's vantage point - allowing us to track CMEs.
SOHO Movie Maker: http://sohodata.nascom.nasa.gov/cgi-bin/soho_movie_theater

GONG H-Alpha Network - This global ground-based network provides near-real-time images of the sun with an H-Alpha filter, which can show filaments, flares, CMEs, etc.
H-Alpha Image/Video Access http://halpha.nso.edu

STEREO secchi - The STEREO A and B are positioned on the other side of the sun from earth, giving us views of the solar surface we cannot see, and also offering coronagraphs from the backside of the sun.
STEREO Image/Video Access: http://stereo-ssc.nascom.nasa.gov/beacon/

Interface Region Imaging Spectrograph (IRIS) - The close-up camera. The IRIS offers zoomed-in views of selected segments of the earth-facing side of the sun. The images require processing and are not usually close to real-time, but can offer windows into areas of the sun that no other satellite/observatory can provide.
Lockheed Martin IRIS Image/Video Access: http://iris.lmsal.com

GOES-R - The Next Generation Solar Satellite - Set to Launch in 2016.

Video on Using the Solar Observation Resources: http://youtu.be/M_rJdQzhoZU

Space-Weather Analysis

Monitor Solar Flares with the GOES X-Ray Flux:
Last 6 Hours: http://www.swpc.noaa.gov/rt_plots/xray_1m.html
Last 3 Days: http://www.swpc.noaa.gov/rt_plots/xray_5m.html

Monitor Solar Wind Telemetry with ACE:
Last 3 Days: http://www.swpc.noaa.gov/ace/MAG_SWEPAM_24h.html

Monitor Geomagnetic Disruptions:
KP Index (3 Days): http://www.swpc.noaa.gov/rt_plots/kp_3d.html
GOES Magnetomater: http://www.swpc.noaa.gov/rt_plots/GOEShp.gif
Monitor Charge Particle for Radiation Storms:
GOES Electron Flux: http://www.swpc.noaa.gov/rt_plots/Electron.gif
GOES Proton Flux: http://www.swpc.noaa.gov/rt_plots/Proton.gif
NOAA D-Region Absorption: http://www.swpc.noaa.gov/drap/global.html

Track CMEs with the ENLIL Spirals:
NOAA: http://www.swpc.noaa.gov/wsa-enlil/
NASA: http://iswa.gsfc.nasa.gov:8080/IswaSystemWebApp/iSWACygnetStreamer?timestamp=2038-01-23+00%3A44%3A00&window=-1&cygnetId=261

ISWA - Monitor Dozens of Indices: http://iswa.gsfc.nasa.gov/iswa/iSWA.html

SUGGESTED CLASS QUESTIONS:

Solar Wind (1)

The solar wind contains _____.

a) Heavy/Large particles
b) electrically charged particles
c) complex Molecules

In which direction does the solar wind flow from the sun?

a) Outward in All Directions
b) North to South
c) Inward Towards the Sun

Does the solar wind make it out to Jupiter? _____ Neptune? _____ Pluto? _____

Write Yes or No in the blanks.

What is the most abundant element in the solar wind?

a) Hydrogen
b) Helium
c) Nitrogen
d) Oxygen

How many different elements have been detected in the solar wind?

a) 2
b) 7
c) 23
d) Nearly all of them

When solar wind particles strike Oxygen and Nitrogen in the upper atmosphere, they create:

a) Lightning Storms
b) The Ozone Layer
c) Auroras (Northern Lights)

Fill in the blank: The density, _____, and temperature of the solar wind particles are the most important/most basic data points we measure.

Layers of the Sun (2)

What do we call the atmosphere of the sun?

a) corona
b) sunspot
c) photosphere
d) iris

Name two of the ionized elements visualized by the SDO [Solar Dynamics Observatory]

_____

The energy detected by the SDO/AIA 193 is…

a) Gamma
b) X-rays
c) EUV [Extreme Ultra Violet]

The magnetic imager uses the visible spectrum, and can see sunspots; what neutral element is seen by this imager?

a) Iron
b) Hydrogen
c) Carbon
d) Helium

Helioviewer Challenge: Make two movies; one showing the corona and another showing the surface of the sun.

Sunspots (3)

The yellow SDO images [AIA 171] show magnetic fields [loops] coming in and out of the sun; where do they connect to the solar surface? _____

Fill in the blanks: The dark center of the sunspot is the _____ and the area surrounding the center is called the _____.

How long is the duration of the sunspot pulse? [How long between the 'heartbeats' of the sun?]
_____

Circle one: The magnetic fields [loops] contain **charged/neutral** particles.

The magnetic fields associated with sunspots often interact and entangle, which can cause:

a) a sunquake
b) a solar flare
c) sunlight production
d) sunspots to grow

Helioviewer Challenge: Overlay the SDO/HMI continuum with the SDO/AIA 171 and see how the magnetic fields connect the sunspots.

Solar Flares and CMEs (4)

Fill in the blanks: A solar flare can excite the atmosphere and cause a communications disruption known as a _____ blackout.

List the classes of solar flares, from lowest energy to highest energy (5 of them):

_____

Which generally comes first, the solar flare or the CME? _____

What can cause CMEs besides solar flares? _____

Why is the sun covered with a central disk on SOHO Lasco?

_____

SEP and CME Impact (5)

What is the name of the sun's magnetic shield?

a) Magnetosphere
b) Heliosphere
c) Magnetoshield
d) Solarsphere

What happens during a Flux Transfer Event?

_____

How often do Flux Transfer Events occur? _____

Solar Energetic Particle Events affect what part of the globe? _____

Name one thing we do to protect people during Solar Energetic Particle Events:

_____

What level Solar Energetic Particle Events (Space radiation storm) is worse:

S2 or S4 [Circle One]

Geomagnetic Storms (7)

What is the space-weather event that comes to earth and causes the a Geomagnetic Storm

a) Sunspot
b) Solar Flare
c) CME (Coronal Mass Ejection)

What is a Halo Eruption?

_____

What are the two most important characteristics of a CME for guessing its strength? [Circle Two]

a) speed
b) color
c) density

Name one potential effect of a LOW LEVEL geomagnetic storm:

_____

Name a different potential effect of a HIGH LEVEL geomagnetic storm:

_____

Coronal Holes (8)

Are there more or fewer solar magnetic fields in coronal holes? _____

Do the magnetic field lines in coronal holes connect to the sun in two places or extend out into space?

_____

Do coronal holes have faster or slower solar wind than normal solar wind? _____

What rises first during coronal hole impact at earth, density or speed? _____

Can coronal holes cause geomagnetic storms? _____

Helioviewer Challenge: Use the SDO AIA 211 to make a 1-week movie from April of 2012, and identify the coronal holes.

Sunspot Classifications (9)

Matching

a) Alpha	___ Where both + and - sunspots are found in a group of sunspots
b) Beta	___ Where + and - sunspots cannot be separated by a continuous line
c) Beta-Gamma	___ + and - sunspots close together within one penumbral region
d) Delta Class	___ Only one polarity (+ or -) can be found in the sunspot group

Which of these sunspot classifications is not possible to see? And why?

a) Beta-Delta
b) Alpha-Gamma
c) Beta-Gamma-Delta

Why? _____

Solar Cycles (10)

Which is the closest to the rotation speed of the sun?

a) 1 day
b) 28 days
c) 2 months
d) 1 year

How long is the sunspot cycle? _____

Are there more solar flares in sunspot maximum in sunspot minimum? _____

The Solar Polar Cycle maximum/minimum are at the _____ as the sunspot maximum/minimum.

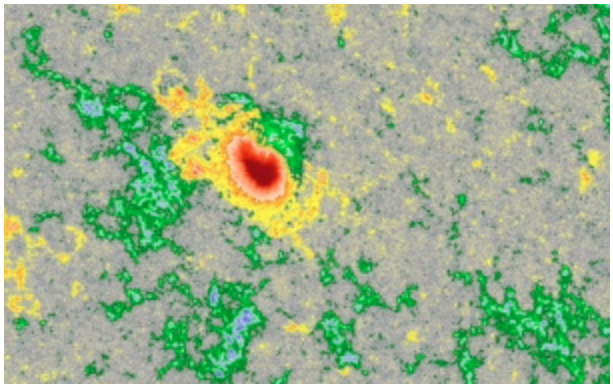
a) same time (direct relationship)
b) opposite time (indirect relationship)

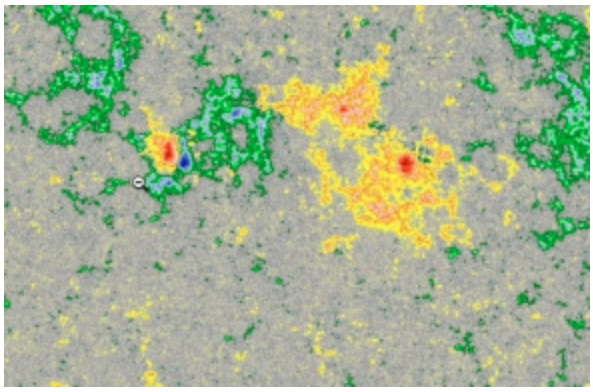
How often does the sun's magnetic pole flip (reverse)? _____

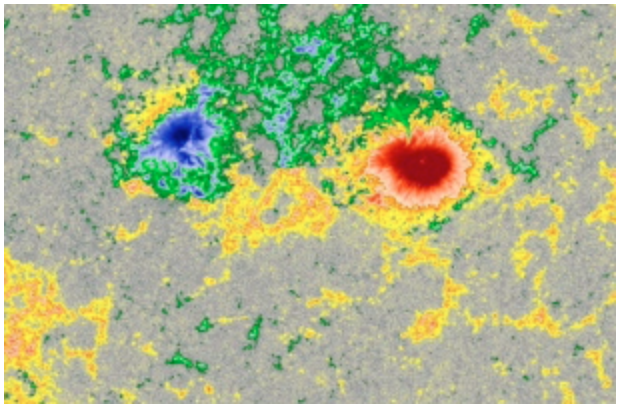
Answers. Bracketed sections denote the possibilities for one answer.

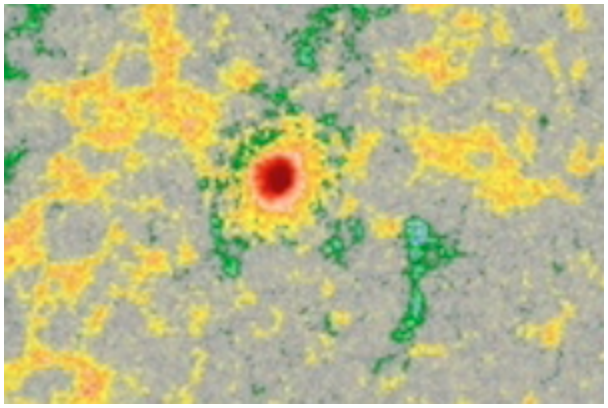
(1) b, a, Yes, Yes, Yes, a, d, c, speed/velocity
(2) a, [helium, carbon, iron, 'continuum'], c, a
(3) sunspots, umbra, penumbra, 2-3 minutes, charged, b
(4) radio, A-B-C-M-X, Solar flare, filament eruptions, to block glare
(5) b, [see vocabulary], ~ every 8 minutes, the poles, [re-route polar flights, send astronauts to safe zones], S4
(7) c, [see vocabulary], a/c, [animal phenomenon, auroras], [satellite damage, electrical grid damage, blackouts]
(8) fewer, extend out into space, faster, density, yes
(9) b, c, d, a, b, gamma requires both polarities
(10) b, ~11 years, sunspot maximum, b, ~11 years

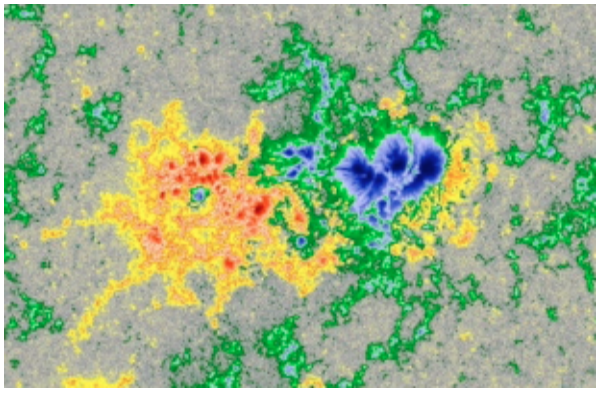
Sunspot Classification Exercise: To the right of each image, note the sunspot class, and give a reason for your answer. Remember not to confuse surface magnetics around a sunspot with an actual sunspot region - only the umbral magnetism is a factor in sunspot classification.
[Blue - Positive, Red - Negative]

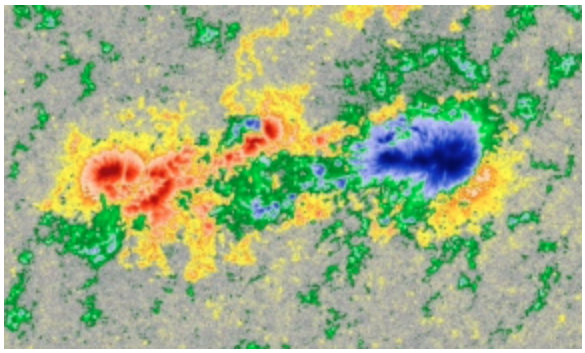


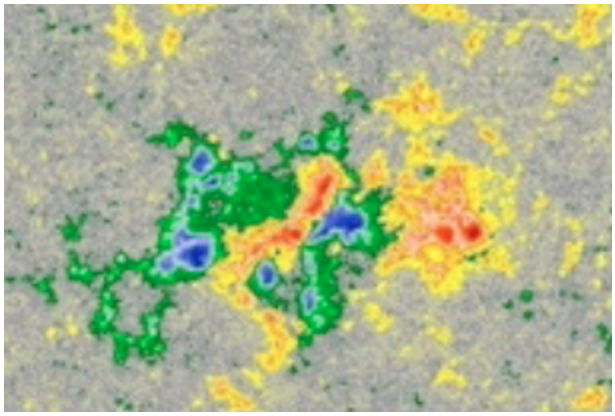


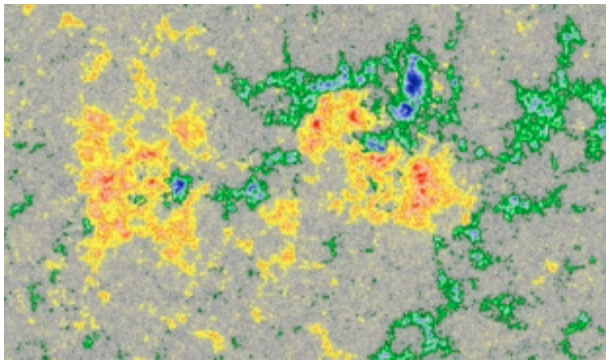


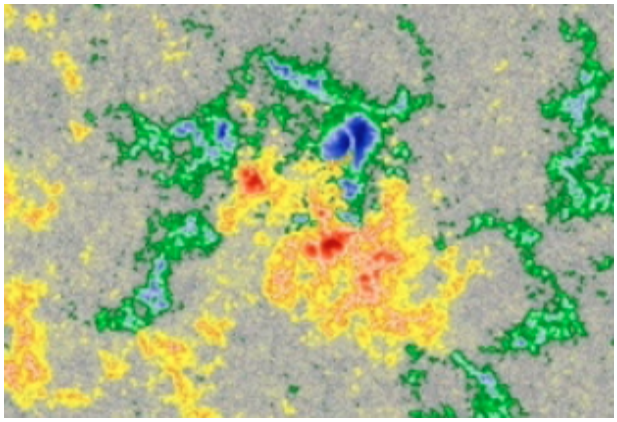


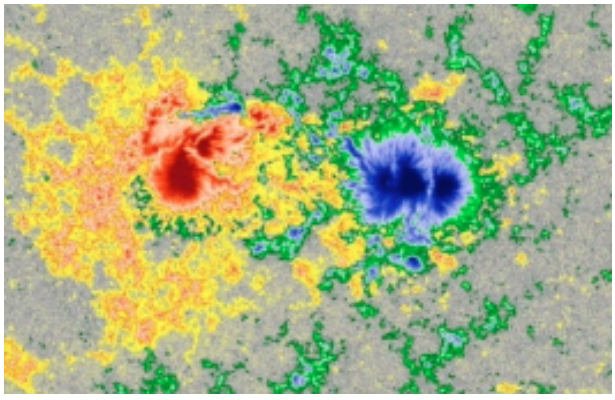


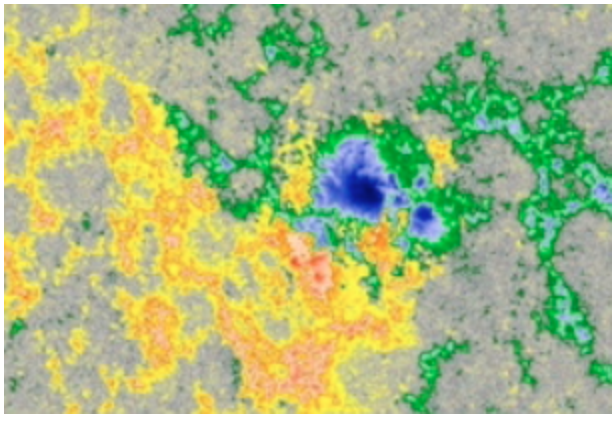


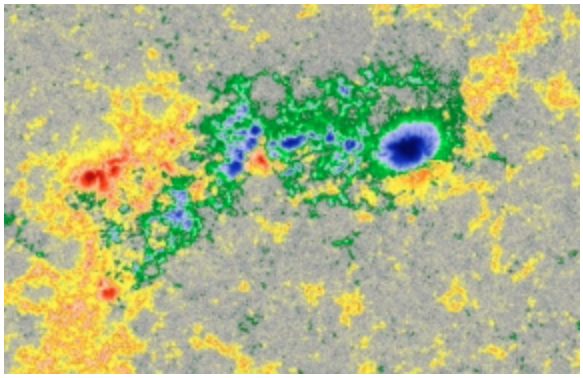


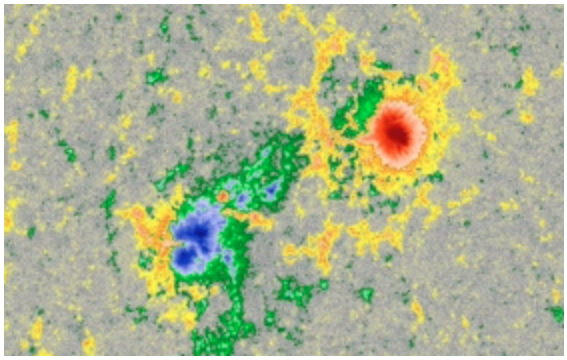


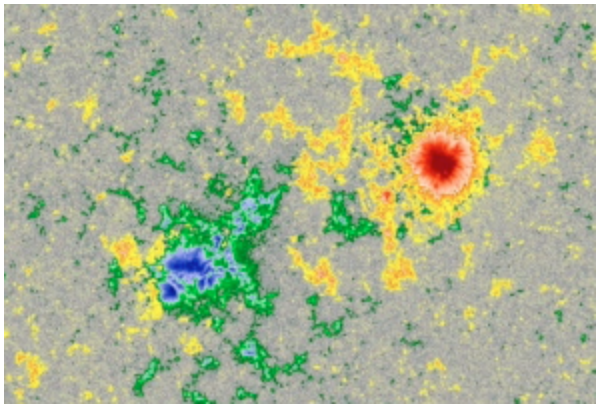












Sunspot Classification Exercise Answers

Page 1

Alpha Class - We have one negative spot. The blue positive areas surrounding it are surface magnetism.

Beta-Gamma Class - We see positive and negative spots, but the negative spots are split, front and back, and cannot be segregated with one continuous line.

Beta Class - Negative on the right, positive on the left.

Page 2

Alpha Class - We have one negative spot.

Beta-Gamma Class - We see positive and negative spots, interlaced between each other. If you said it was Delta Class as well, that is a good guess, especially because the positive spot furthest to the left looks to be interacting with the negative spots around it. In-fact, it is a lone spot with it's own penumbra. [Challenging]

Beta-Gamma-Delta Class - We have positive and negative spots, the positive spots are split on opposite sides of the negative central zone, and the northern-most portion in the center has a positive and negative sunspot within the same penumbra.

Beta-Gamma-Delta Class - We have positive and negative spots, the positive spots are split around the central negative zone, and the positive spot furthest to the right is within the same penumbra as the negative spot to its left.

Page 3

Beta-Gamma Class - The positive and negative spots are very spread out across the active region. If you said Delta Class you are pretty darn close, as there are two areas here that are what we call "Delta candidates".

Beta Class - Positive and negative spots. Do not let the odd shape and number of spots fool you into thinking it is something more complex.

Beta-Gamma-Delta Class - We have positive and negative spots, and the positive spot at the top left is separated (gamma) and within the same penumbra as the negative spots below (delta)

Beta Class - Positive and negative spots. If you said Beta-Delta you are not only very close, as the meeting place of positive and negative appears very-close to being within the same penumbral region, but you recognized the lack of a gamma classification, which is not needed in order to have a delta class. In fact, the bottom-left positive spots are tiny and have their own penumbras.

Page 4

Beta-Gamma-Delta Class - Positive and negative spots. The positive spots on the left are separated (gamma) and the negative spot in the center is within the same penumbra as the positive spot to its right (delta).

Beta Class - This one is tricky; it appears that a negative spot is at the 1-oclock position of the positive spot to the left, but that is actually surface magnetism. [Challenging]

Beta Class - Positive and negative spots.