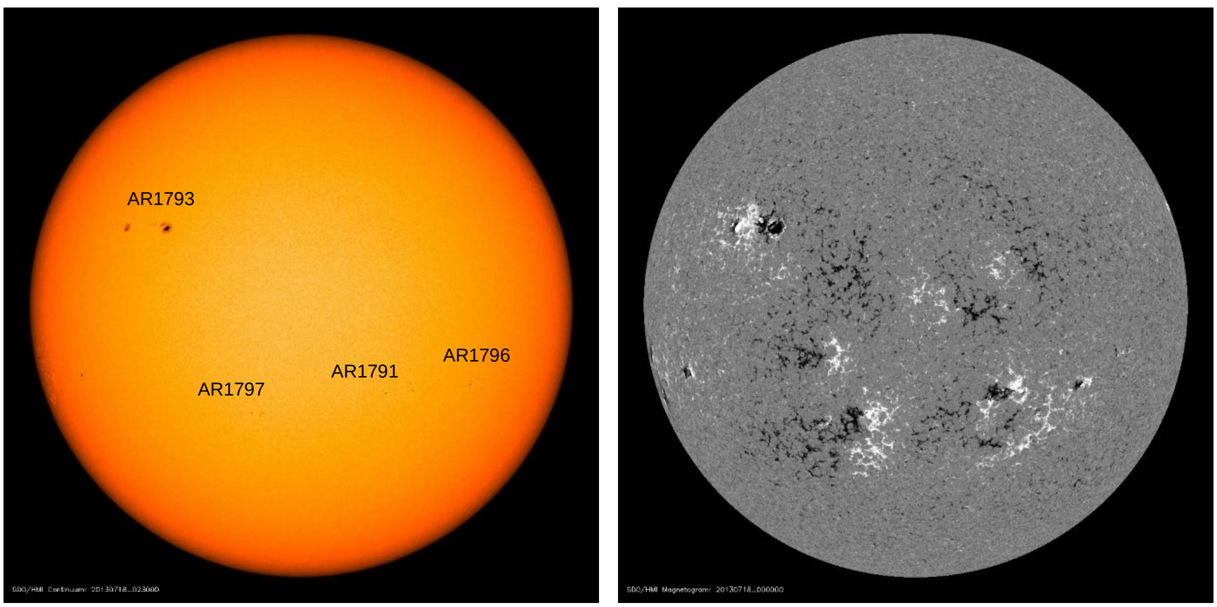
Introduction

Active regions on the Sun are areas of strong magnetic field. Sunspots are used to visually identify these regions. Thus, an active region may contain one or more sunspots. The National Oceanic and Atmospheric Administration (NOAA) provides the numbers to identify these active regions. They are numbered according to which region appeared in the solar disk chronologically. The current number system started on January 5, 1972. Figure 1 shows the six (6) identified active regions, named as AR1791, AR1793, AR1796, and AR1797, on July 18, 2013. Figure 1a is an Intensitygram of the solar disk is obtained from the Helioseismic and Magnetic Imager (HMI) of the Solar Dynamics Observatory (SDO). This intensitygram is a continuum filtergrams that shows a broad-wavelength photograph of the solar protosphere[1]. On the other hand, figure 1b shows the magnetogram of the same solar disk using the same instrument. Magnetograms are visual representations of the spatial variations of the magnetic field of the solar surface. Here, the north polarities are displayed as white while south polarities are shown as black. And as you can see, active regions that appear to be faint in the intensitygram became noticeable in the magnetogram.



(a) (b)

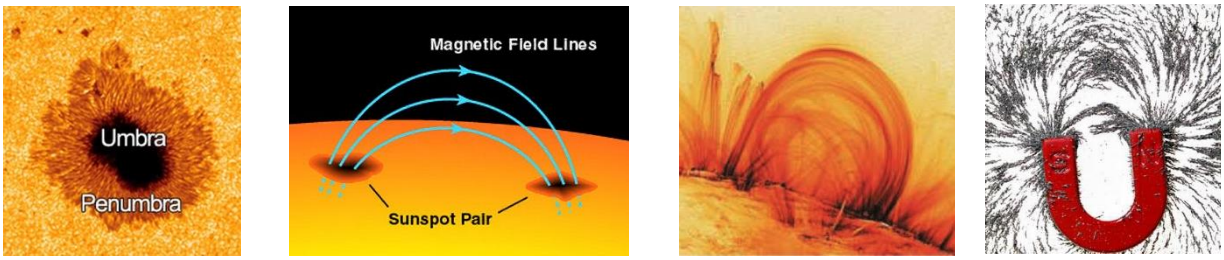
Figure 1. The (a) Intensitygram and (b) magnetogram from the SDO/HMI of the solar disk on July 18, 2013. The six (6) identified active regions, AR1791, AR1793, AR1796, and AR1797, were labeled.

Recall that active regions typically form magnetically linked bipolar groups where each corresponds to the north and south poles of a magnet typical of a horseshoe magnet (Figure 2). Thus, these active regions can also categorize based on the complexity of their magnetic structure. Today, the Mount Wilson magnetic classification system[2] is used. Developed by Smith and Howard in 1968, this system uses magnetograms where active regions are classified as unipolar, bipolar, complex bipolar, and a combination of these. The description and examples of the major classes,

[1] Joint Science Operations Center (JSOC) Science Data Processing (SDP). Available online: http://jsoc.stanford.edu/

[2] Smith S.F., Howard R. (1968) Magnetic Classification of Active Regions. In: Kiepenheuer K.O. (eds) Structure and Development of Solar Active Regions. International Astronomical Union / Union Astronomique Internationale (Symposium No. 35 held in Budapest, Hungary, 4–8 September 1967), vol 35. Springer, Dordrecht. https://doi.org/10.1007/978-94-011-6815-1_5

α, β, and γ, are shown in Table 1. Table 2, on the other hand, shows the evolution of active region 1791.



(a) (b) (c) (b)

Figure 2. (a) The umbra and penumbra of a sunspot. (b) Sketch of the Sun's magnetic field lines that develop from pairs of sunspots in an active region (sunspot pair). (c) A image of a solar surface where ionized gas flow though the magnetic field lines between sunspots (NASA/TRACE). (d) Iron filings aligned along the magnetic field produced by a horseshoe magnet.

Table 1. Mount Wilson magnetic classification system and an example of each designation.

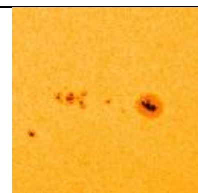
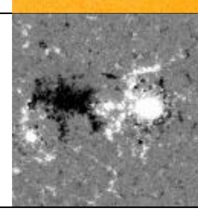
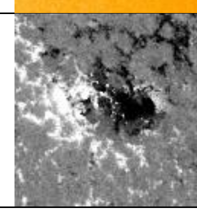
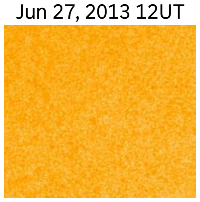
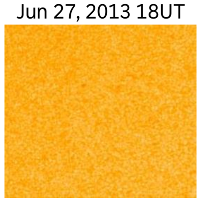
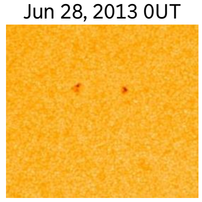
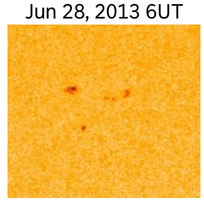
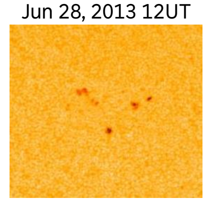
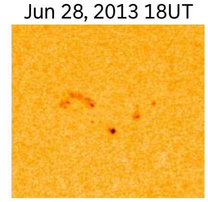
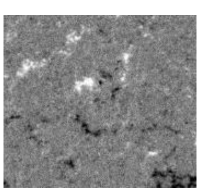
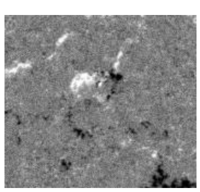
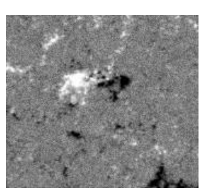
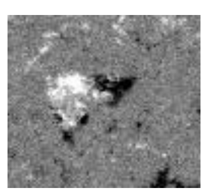
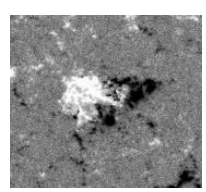
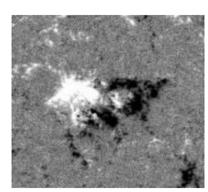
Major class designations	α	β	γ
Description	A group having only one polarity, i.e, unipolar.	A group of magnetic polarities, with a simple division between them.	A complex active region not classifiable as a bipolar group.
Sample Active Region	**AR1658**	**AR1721**	**AR1660**
Intensitygram			
Magnetogram			
Date	Jan 23, 2013	Apr 14, 2013	Jan 23, 2013

Table 2. Intensitygram and Magnetogram of AR 1781 from June 27, 2013, 12 UT to June 28, 2013, 18 UT.

Jun 27, 2013 12UT	Jun 27, 2013 18UT	Jun 28, 2013 0UT	Jun 28, 2013 6UT	Jun 28, 2013 12UT	Jun 28, 2013 18UT
					
					

In this activity you will identify active regions and characterize them based on their magnetic configuration (α, β, and γ) using sunspot drawings, Intensitygrams and magnetograms. Of course, there can be a combination of these classes, which are difficult to distinguish by non-professionals.

Materials:

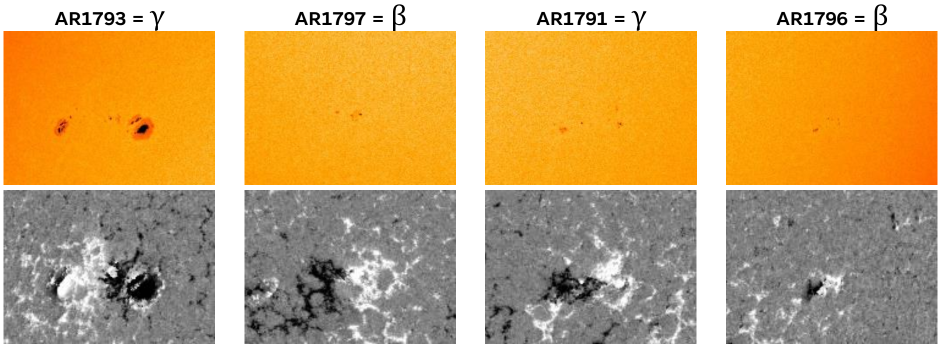
- Computer
- Internet
- Photo Editing software
- Word Processor Software

Instructions:

1. Download the Sunspot drawing and Intensitygram for the dates given in Table 1, from the following links:
    a. Sunspot drawing: https://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-imagery/photosphere/sunspot-drawings/
        i. Select archive site (e.g, *boulder*, *charles-schott*, *soon, etc.*). Each site includes certain years of observation.
        ii. Navigate through the directory by choosing the desired year and month.
        iii. Choose any available file (based on the date) that suits your requirement. Use any observatory code (e.g., *khmn*, *liss*, *aplm*, etc.) whichever is available.
    b. Intensitygram: http://jsoc.stanford.edu/data/hmi/images/
        i. Navigate the directory by choosing the desired year, month, and day.
        ii. Choose any available "**Ic**" file (regular or flat) that suits your requirement with at least 1K resolution.
    c. Magnetogram: http://jsoc.stanford.edu/data/hmi/images/
        i. From the same directory as your intensitygram, choose any available "**M**" file that suits your requirement with at least 1K resolution.
        ii. For our purposes, use the black-and-white version. Colored magnetograms are for more advanced users and you can explore these in your own time.

    Note: You can also browse the intensitygram and magnetogram at: http://jsoc.stanford.edu/HMI/hmiimage.html
2. From the sunspot drawing identify the active region in the Intensitygram. Crop each active region separately.
3. Do the same for its magnetogram. Identify the class where the active region belongs. Below is an example for July 18, 2013:

AR1793 = γ **AR1797 = β** **AR1791 = γ** **AR1796 = β**



4. Document your results in a word processor software (e.g., *Microsoft Word*, *Google Doc*, *Libre Office Writer*, *Apple Pages*, etc.)
5. Verify your results with official classification from USAF/NOAA solar region report:
   https://tinyurl.com/usaf-solar-region-report
   See USAF/NOAA solar region report format:
   https://tinyurl.com/solar-region-report-format
   Note: For more complicated classes such as δ, β-γ, β-δ, β-γ-δ, and γ-δ, you should have at least identified the basic class α, β, and γ. For example, the class β-γ can be considered as β or γ.

CHALLENGE 1:

1. Extend your data using intensitygram and magnetogram for the year 2013.
2. For each day starting from January 1, 2013, count the number of each class, α, β, and γ, visible within the solar disk. Increment for one solar rotation (27 days). (e.g, January 1, January 28, February 24, etc.)
3. Plot a histogram showing the distribution of the number of major classes for this data set.
4. Animate the collected intensitygram and magnetogram in video or animated GIF format.
5. Which active regions survived more than one solar rotation? Describe how its class and size evolved.

CHALLENGE 2:

1. Using the official USA/NOAA solar region report, plot the frequency distribution of the number of class α, β, γ, δ, β-γ, β-δ, β-γ-δ, and γ-δ observed in one station only (LEAR, SVTO, HOLL, etc.) in 2013.
2. Record the Area of the region in millionths of solar hemisphere and plot a histogram showing the distribution of size of active regions
3. Correlate the class and size of the active regions.

Last update: June 4, 2021