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February 25, 2014 solar flare data analysis in SunPy

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Solar flares are strong radiation bursts, whereas large clouds of solar material and magnetic fields that erupt at high speeds from the Sun are coronal mass ejections. Harmful radiation from a flare does not pass through the atmosphere of the Earth to physically impact humans on the ground, but can disrupt the atmosphere in the layer where GPS and communication signals travel. Flares generate results across the entire electromagnetic spectrum. They emit x-rays and ultraviolet radiation, which means extremely high temperatures during a flash. Radio waves mean that tiny fractions of particles are accelerated to high levels of energy. Most of the radiation is synchrotron radiation produced along magnetic field lines by electrons traveling along spiral paths. In this paper was monitored solar flare registered on February 25, 2015. This flare, which peaked at 00:49 am EDT from a sunspot called Active Region 1990 (AR1990), is classified as an X4.9-class flare. We have performed solar data analysis using the Python/SunPy tool. SunPy was chosen as the principle data analysis environment since it provides easy to use interfaces to the Virtual Solar Observatory (VSO).

Key words: solar flares, emission measure, reconnection rate, SunPy.
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Introduction

Solar-based flares are one of the most impressive energetic events in the solar atmosphere. Given their part of job in the solar corona's energy balance and their function playing important role in the space weather, numerous observations researched the release of energy and induction of solar flares, focusing on the solar active. National solar observatories are providing the overall network with a wealth of data, covering extensive time ranges (e.g. Solar and Heliospheric Observatory, SOHO), numerous perspectives (Solar Terrestrial Relations Observatory, STEREO), and returning a lot of information (Solar Dynamics Observatory, SDO) [1].

Solar and stellar flares have been studied using both ground and space-based investigation [2-3]. Currently, using GOES and soft X-ray data of *Yohkoh* Bragg crystal spectrometer, by [4] proposed between's the peak temperature of solar flares and their volume emission measure a exceptional correlation, where n is the electron number density and V is the volume. Shimizu [5] found a comparative connection in microflares observed by the *Yohkoh* soft X-ray telescope. Feldman, Laming, & Doschek [4] show that this relationship can also be effectively extrapolated to the instanse of stellar X-ray flares.

X-ray flare databases are used in our analysis. A dataset provided by the Geostationary Operational Environmental Satellite (GOES) [6] was used to collect the solar activity processes. According to their peak flux (W m−2) observed in the 0.1 to 0.8 nm wavelength range, GOES flares are classified as A, B, C, M, and X-class, corresponding to their peak flux. We selected the X-class flares corresponding to a flux in excess of 10−4 W m−2 at Earth, respectively. The GOES flare lists are available at NGDC/NOAA [7].

SunPy, an open-source and free community-developed solar data analysis package written in Python [8], was used in this research. Python/SunPy was chosen as the key data analysis framework because it provides the Virtual Solar Observatory with easy to use interfaces (VSO). SunPy is a toolkit for data analysis that provides the requisite tools for Python's analysis of solar and heliospheric datasets. SunPy aims to provide the current standard, an IDL based solar data analysis environment known as SolarSoft (SSW) [9-13], with a free and open-source alternative.

In this work, we have observed solar flare occurred on Feb. 25, 2014. This flare, which peaked at 00:49 am EDT on Feb. 25, 2014from a sunspot called Active Region 1990 (AR1990), is classified as an X4.9-class flare.

2. Solar data visualization

To find and overplot the location of the brightest pixel, we first created the Map using the FITS data and imported the coordinate functionality. In the Figure 1 shown the brightest pixel location in different wavelengths obtained by Python/SunPy.

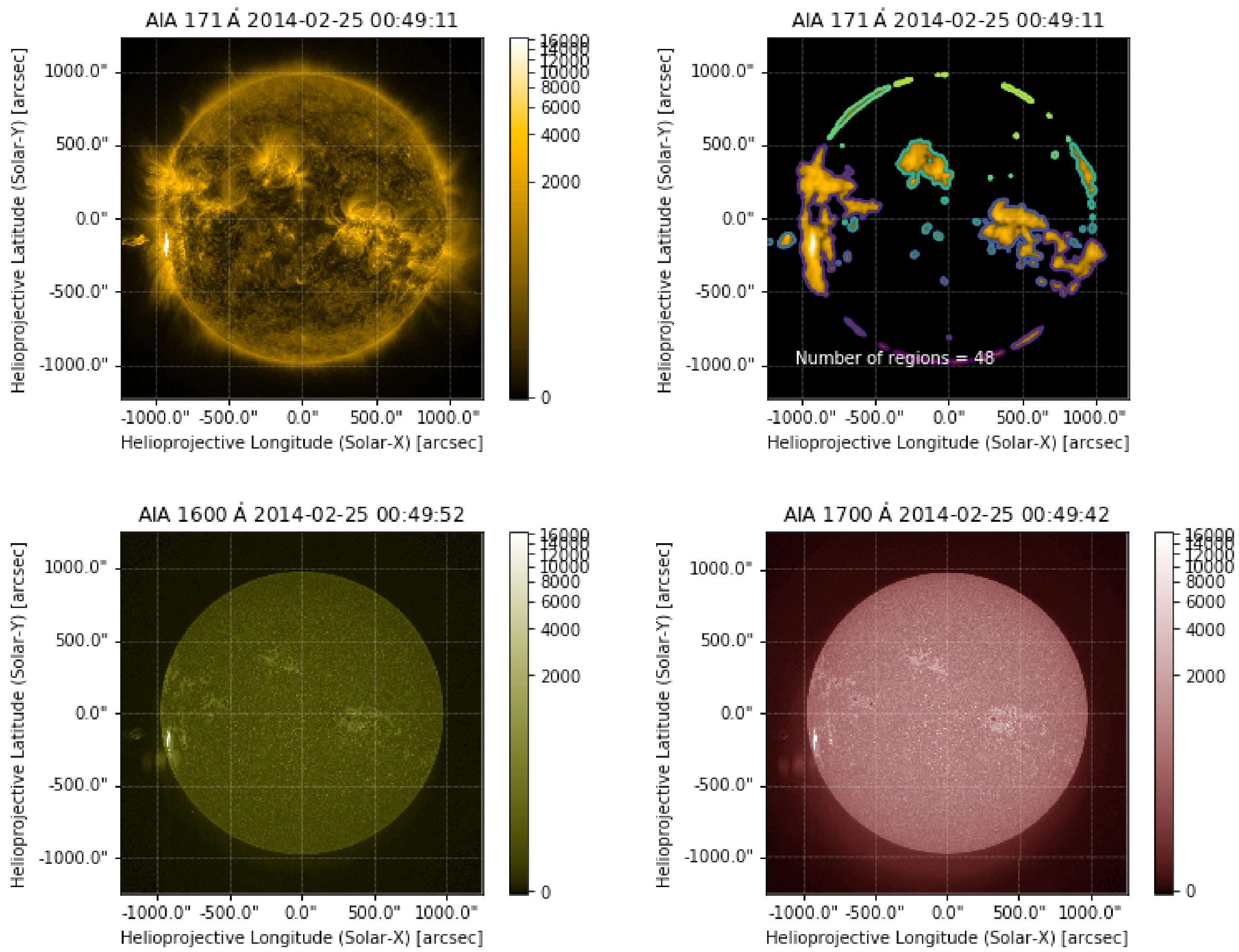

Figure 1 – The brightest pixel location (AR 1990 in AIA 171 Å, AIA 1600 Å and AIA 1700 Å)

To obtain the GOES flare intensity, we first grab GOES XRS data for a particular time of interest that is Feb. 25, 2014. Then the data loaded into a TimeSeries. Next we grab the HEK data for this time from the NOAA Space Weather Prediction Center (SWPC). The Figure 2 shows the Daily Synoptic Maps produced by the HMI on Feb. 25, 2014.

To enhance emission above the limb, we first created the Map using the FITS data. Next, we build two arrays, which include the entire x and y pixel indices. Then we converted this to helioprojective coordinates and created a new array, which contains the normalized radial position for each pixel. Next, we plot it along with a fit to the data. We fit the logarithm of the intensity since the intensity drops of very quickly as a function of distance from the limb [14-15].

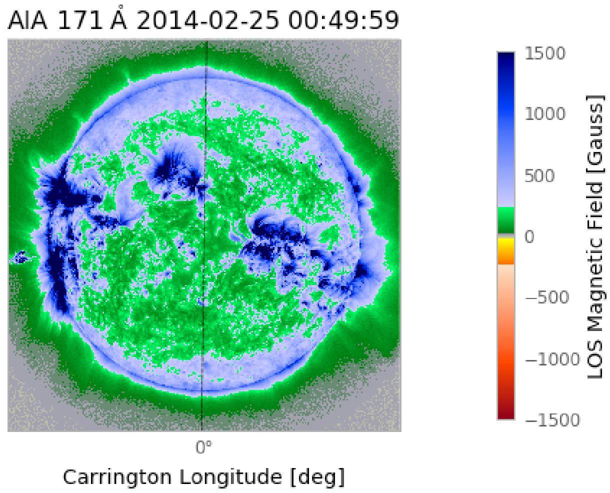

Figure 2 – Daily Synoptic Maps produced by the HMI

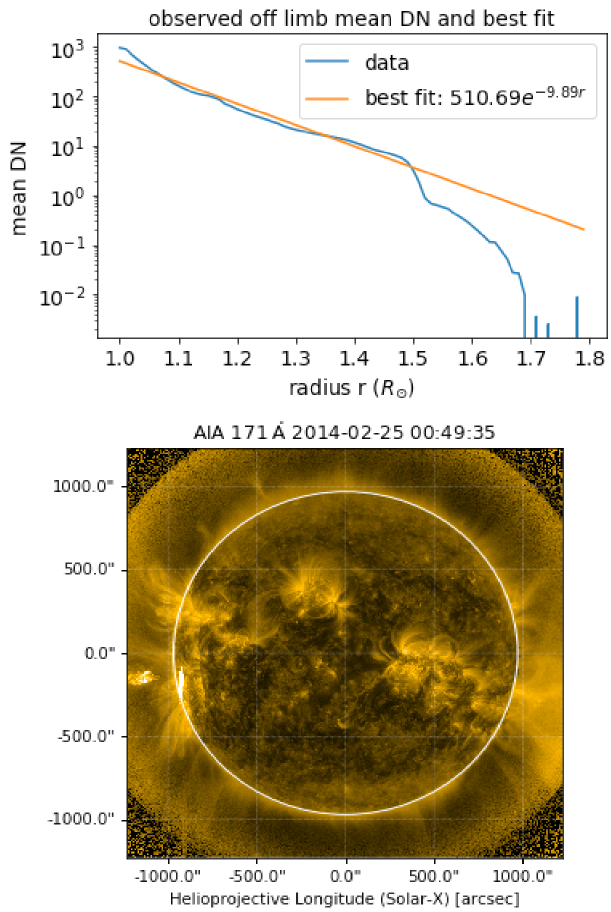

Figure 3 – Observed off limb mean DN and best fit

The National Oceanic and Atmospheric Administration (NOAA) is launching and maintaining a collection of satellites called Geostationary Operational Environmental Satellites with weather forecasting services (GOES). Each GOES satellite also includes a solar X-ray package (the «X-ray sensor» or XRS) consisting of a collimator that feeds a pair of ion chambers. Those ion chambers measure the Sun's spatially incorporated soft X-ray flux in two wavelength bands, 0.5-4 and 1-8Å, with a 3-s cadence. For 30 years, the GOES soft X-ray detectors have provided an essentially uninterrupted track of the activity of the Sun and are a valuable resource for the study of previous solar activity and space weather prediction [16-19].

The X-ray fluxes themselves are of little use for quantitative physical understanding of processes in the Sun's atmosphere. However, the temperature and emission measurements of the plasma produced by soft X-rays are mirrored, and these physical quantities are of great importance: the energy of solar flares and other energy releases can be deduced from them.

Corresponding volume emission measure of the solar soft X-ray emitting plasma observed by the GOES/XRS. The volume emission measure were obtained in SunPY using the methods of White et al. [20] who used the CHIANTI atomic physics database to model the response of the ratio of the short (0.5-4 angstrom) to long (1-8 angstrom) channels of the XRSs onboard various GOES satellites. Obtained histogram of the data of a map is shown in Figure 4.

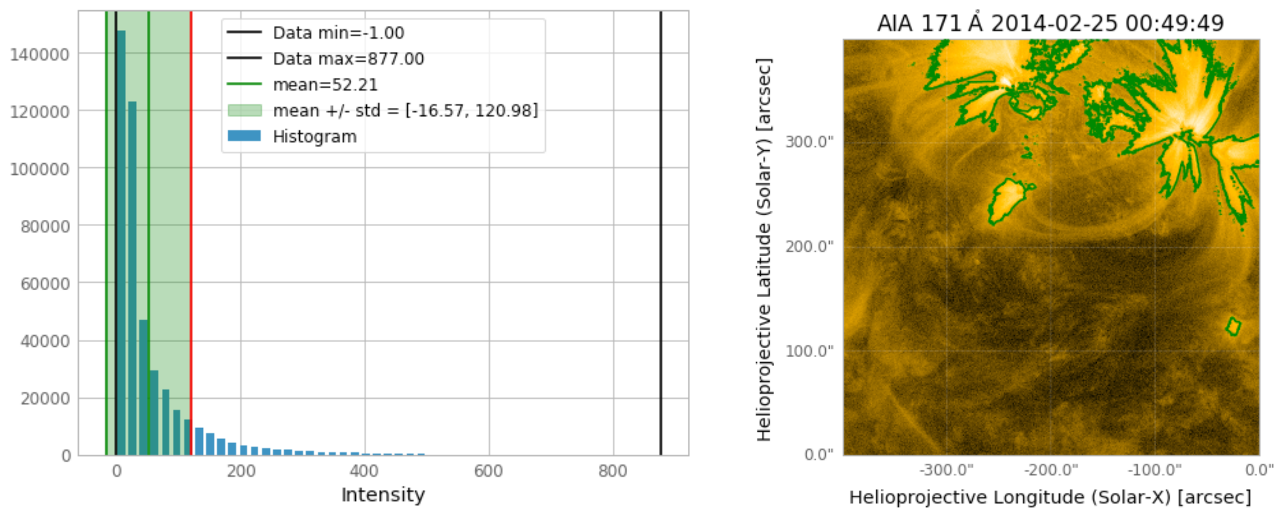

Figure 4 – Obtained histogram of the data of a map.

3. Conclusions

In other disciplines, the scientific python culture is much more developed than in solar physics. SunPy is making use of existing scientific python projects, with potential future deeper integration with projects such as Astropy and sci-kit image. Using SunPy package we have obtained the values of temperature and emission measure from a GOES Light Curve. This function calculates the isothermal temperature and corresponding volume emission measure of the solar soft X-ray emitting plasma observed by the GOES/XRS.

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References

1 Gyenge N., Ballai I., Baranyi T. Statistical study of spatio-temporal distribution of precursor solar flares associated with major flares // Monthly Notices of the Royal Astronomical Society. – 2016. – Vol. 459. –No.4. – P. 3532 – 3539.

2 Svestka, Z., Cliver, E.W. Eruptive sol. Flares // Lecture Notes in Physics. -1992. – Vol. 399. -P. 1.

3 Haisch, B., Strong, K.T., Rodono, M. Flares on the Sun and other stars // Ann. Revs. Astron. Astrophys. – 1991. – Vol. 29. – P. 275.

4 Feldman, U., Laming, J.M., Doschek, G.A. The correlation of Sol. flare temp. and EM extrapolated to the case of stellar flares // Astrophys. J. Lett. – 1995. –Vol. 451. – P.79.

5 Shimizu T. Energetics and occurrence rate of active-region transient brightenings and implications for the heating of the active-region Cor. // Publ. Astron. Soc. Japan. – 1995. – Vol.47. – P. 251–263.

6 http://www.ngdc.noaa.gov/stp/satellite/goes/

7 ftp://ftp.ngdc.noaa.gov/STP/space-weather/solar-data/solar-features/solar-flares/x-rays/goes/

8 Mumford S.J., Christe S. SunPy-Python for solar physics //Comput. Sci. Disc. – 2015. –Vol.8. – P. 014009.

9 Garcia H.A. Reconstructing the thermal and spatial form of a solar flare from scaling laws and soft X-Ray measurements // ApJ. – 1998. – Vol.504. – P.1051.

10 Tsuneta S., Masuda S., Kosugi T., Sato J. Hot and superhot plasmas above an impulsive flare loop // ApJ. – 1997. – Vol.478. – P.787.

11 Isobe H., Yokoyama T., Shimojo M., Morimoto T., Kozu H., Eto S., Narukage N., Shibata K. Reconnection rate in the decay phase of a long duration event flare on 1997 May 12 // ApJ. – 2002. – Vol.566. – P.528.

12 Isobe H., Takasaki H., Shibata K. Measurement of the energy release rate and the reconnection rate in solar flares // ApJ. – 2005. – Vol.632. – P.1184.

13 Sweet P.A. Electromagnetic phenomena in cosmical physics // Cambridge Univ. Press. – 1958. – 123 p.

14 Spitzer L. Physics of Fully Ionized Gases //Interscience. – 1956.

15 Sarsembayeva, A. T., Sarsembay, A. T. Solar activity monitoring for the period April 10-20, 2017 // News of the National Academy of Sciences of the Republic of Kazakhstan-series Physico-Mathematical. – 2018. – Vol.2 . –No.318. – P.9-11.

16 Aschwanden M. J., Alexander D. Solar flare and CME observations with STEREO/EUVI // Solar Phys. – 2001. – Vol.204. – P.91.

17 Bornmann P.L. Limits to derived flare properties using estimates for the background fluxes-Examples from GOES // Astrophys. – 1990. – Vol. J356. – P.733.

18 Phillips K. J.H., Feldman U. Properties of cool flare with GOES class B5 to C2 // Astron. Astrophys. – 1995. – Vol.304. – P.563.

19 Garcia H. A. Forecasting methods for occurrence and magnitude of proton storms with solar hard X rays // Space Weather. – 2004. – Vol.2. – P.S06003.

20 White S.M., Thomas R.J., Schwartz R.A. Updated expressions for determining temperatures and emission measures from goes soft X-Ray measurements // Solar Physics. – 2005. Vol.227. – P.231.