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Tracking Solar Flares Using the Super SID Monitor

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Abstract

Sudden Ionospheric Disturbances are the immediate effects of solar flares, which impact the earth, and affect the upper atmospheric layers used for telecommunications. The aim of this project was to research, design and build a super sudden Ionospheric Disturbance Monitor for amplitude and phase perturbations occurring in the D-layer of the Ionosphere. For the design and implementation of this monitor Stanford University (NASA) and Society for Amateur Radio Astronomers (SARA) provided the SuperSID distribution pre-Amp, antenna wire and a RG 58 Coax Cable. During the design phase of the super SID Monitor a vertical loop antenna with dimension was constructed as a means to transfer energy from free space into a guided wave into the receiver; a VLF receiver from SARA was attached with the kit, which would incorporate all the signal processing and finally a data-logging device/software to act as an interface between the analogue natural events and the digital interface to record data to a PC. At the implementation stage the constructed balanced loop antenna was tested for its applicability with VLF receiver to process the signals from distant transmitters as a means to observe the propagation of the transmitted VLF signals received by the system. Observations were made through graphical representations of the VLF signatures on the computer by using the data-logging interface. Summary of the global data from GOES-13 which the local data generated by the receiver used for this project revealed an unusual spikes in the region of a low Solar flares on 23rd May, 19th and 21st June, 2015. Solar scientists classified it as an M-flare, in this case an M5.6-class flare. The flare peaked at about 6pm. The flare was identified to come from Sunspot AR2257. A continuous system for long term monitoring is strongly recommended for this work.

Keywords: Sudden Ionospheric Disturbance; Solar Flares; SuperSID Monitor.

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1. Introduction

A sudden ionospheric disturbance (SID) is an abnormally high ionization/ plasma density in the D region of the ionosphere caused by a solar flare [8, 1, 45]. The SID results in a sudden increase in radio-wave absorption that is most severe in the upper medium frequency (MF) and lower high frequency (HF) ranges, and as a result often interrupts or interferes with telecommunications systems. The Dellinger effect, or sometimes Mögel–Dellinger effect, is another name for a sudden ionospheric disturbance. According to the report of [35], the effect was discovered by John Howard Dellinger around 1935 and also described by the German physicist Hans Mögel (1900-1944) in 1930. The fadeouts are characterized by sudden onset and a recovery that takes minutes or hours.

When a solar flare occurs on the Sun according to [8], a blast of intense ultraviolet and x-ray radiation hits the dayside of the Earth after a propagation time of about 8 minutes. This high energy radiation is absorbed by atmospheric particles, raising them to excited states and knocking electrons free in the process of photo ionization. The low altitude Ionospheric layers (D region and E region) immediately increase in density over the entire dayside. The Ionospheric disturbance enhances VLF radio propagation. Scientists on the ground can use this enhancement to detect solar flares; by monitoring the signal strength of a distant VLF transmitter, Sudden Ionospheric Disturbances (SIDs) are recorded and indicate when solar flares have taken place.

Short wave radio waves (in the HF range) are absorbed by the increased particles in the low altitude ionosphere causing a complete blackout of radio communications. This is called a short wave fading. These fadeouts last for a few minutes to a few hours and are most severe in the equatorial regions where the Sun is most directly overhead. The ionospheric disturbance enhances long wave (VLF) radio propagation [29, 32, 33]. SIDs are observed and recorded by monitoring the signal strength of a distant VLF transmitter. A whole array of sub-classes of SIDs exist, detectable by different techniques at various wavelengths [10]: the SPA (Sudden Phase Anomaly), SFD (Sudden Frequency Deviation), SCNA (Sudden Cosmic Noise Absorption), SEA (Sudden Enhancement of Atmospherics),etc.

For the purpose of this research, sudden Ionospheric disturbances were tracked for about seven months from February 2015 to September, 2015 using the Super SID receiver donated by the Society of Amateur Radio Astronomer and stationed at the Physics Laboratory of the department of Science Technology, Federal Polytechnic, Ado-Ekiti, Nigeria. The observatory is in place providing continuous data generation, logging and routine transmission to GOES-13 Global Observatory.

2. Materials and Methods

2.1. The Requirement to Host the SuperSID Monitor

- Access to power
- A SuperSID monitor (preamp) plus instructions on how to install it
- A PC computer with the following minimal specifications:

✓ MS Windows operating system (Windows 2000 or more recent)

- ✓ A CD reader
- ✓ Standard keyboard, mouse, monitor, etc.

- 1 GHz CPU with 128mb RAM
- Ethernet connection & internet browser *(desirable, but only necessary for accessing centralized data)*
- An inexpensive antenna

2.2. Instrument used for Installation of Antenna

- ➢ Power strip (otherwise known as plug board, power board, power bar, distribution board, or multi-box), extension cords, and other electrical support
- ➢ An assortment of basic tools such as screwdrivers, hammer, knife, pliers, etc.
- ➢ PVC pipes to build the antenna

The primary parts of the SuperSID instrument are an antenna, a preamplifier, and a computer with a sound card. SuperSID needs a loop antenna to pick up radio signals reflected from the ionosphere. These signals typically are very small, only ~0.1 milli-volts3, so a preamplifier is needed to boost or amplify the signal about a thousand times, to the level that can be captured with a PC sound card. The sound card converts the signal from analog to digital. Then, a program provided by SARA, running on the PC, tracks the VLF transmission signal strengths and processes the data. Since the reflected radio signals are strongly influenced by the Sun's radiation, plotting the signal strengths over time tells us when there is a solar flare on the Sun.

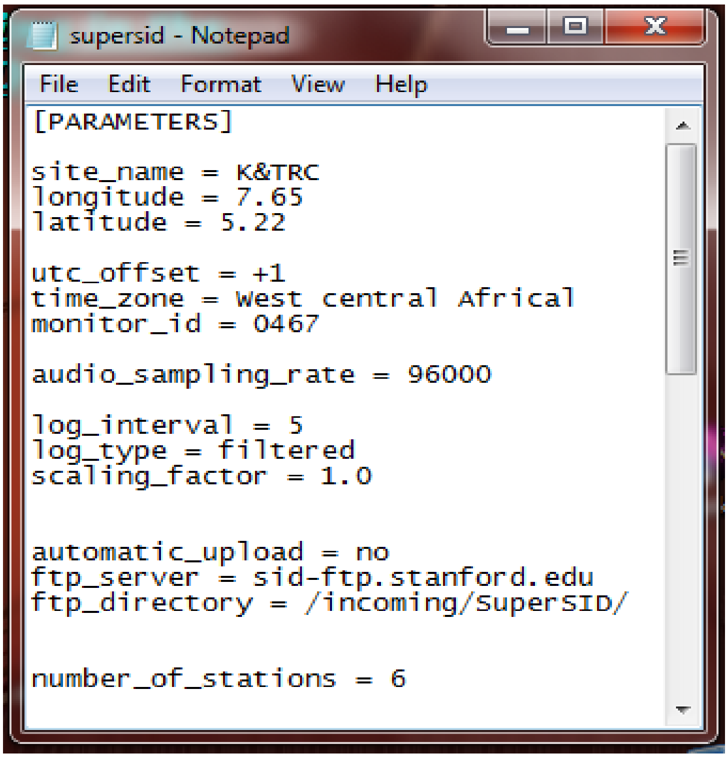
2.3. Installation Steps

- Familiarization with the concepts, collection of materials, determination of suitable site for antenna and computer & SuperSID
- Construction of antenna
- Installation and connection of hardware, including a new sound card
- Installation of software
- Testing the system; collection of data, and debugging
- Sending data back to Stanford for sharing with colleagues

2.4. Adjusted configuration of the site-The Sc

2.5. Installation of Solar Panel.

The necessary materials involved are: cable, 24V battery, solar charge controller, converter and solar panel. The cable was connected to the already existing cable at the back of the solar panel. On one end of the cable about a few inches away, the coated wire was removed. The red wire (the live) was connected to the positive cable of the panel, already indicated by the manufacturer. One end of the brown wire was connected to the negative cable of the panel, and then the panel was carried to a height and mounted. The opposite end of the wire was connected to the solar charge controller inside the house. The controller had three points of connections; one point was for the battery, the second was for panel, and the third was for the load (computer).



3. Results

3.1. Report of Solar Geographical Activity

:Product: Report of Solar-Geophysical Activity

:Issued: 2015 Jun 18 2200 UTC

: Period: March 1 – June 19

Prepared jointly by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center and the U.S. Air Force., KTRC....

Joint USAF/NOAA Solar Geophysical Activity Report and Forecast

SDF Number 169 Issued at 2200Z on 18 Jun 2015

3.1.1. Analysis of Solar Active Regions and Activity from 17/2100Z to18/2100Z

Solar activity has been at moderate levels for the past 24 hours. The largest solar event of the period was a M3 event observed at 18/1736Z from Region 2371 (N12E39). There are currently 3 numbered sunspot regions on the disk.

3.1.2. Solar Activity Forecast

Solar activity is likely to be moderate with a slight chance for an X-class flare on days one, two, and three

(19 Jun, 20 Jun, 21 Jun).

3.1.3. Geophysical Activity Summary 17/2100Z to 18/2100Z

The geomagnetic field has been at quiet to unsettled levels for the past 24 hours. Solar wind speed, as measured by the ACE spacecraft, reached a peak speed of 605 km/s at 18/0301Z. Total IMF reached 6 nT at 18/0912Z. The maximum southward component of Bz reached -4 nT at 18/1136Z. Protons greater than 10 MeV at geosynchronous orbit reached a peak level of 16 pfu at 18/1445Z. Electrons greater than 2 MeV at geosynchronous orbit reached a peak level of 1198 pfu.

3.1.4. Geophysical Activity Forecast

The geomagnetic field is expected to be at quiet levels on days one, two, and three (19 Jun, 20 Jun, 21 Jun). Protons are expected to cross threshold on days one and two (19 Jun, 20 Jun) and are likely to cross threshold on day three (21 Jun).

3.1.5. Event probabilities 19 Jun-21 Jun

Class M 70/70/60

Class X 15/15/10

Proton 80/80/60

PCAF yellow

3.1.6. Penticton 10.7 cm Flux

Observed 18 Jun 151

Predicted 19 Jun-21 Jun 145/147/148

90 Day Mean 18 Jun 127

3.1.7. Geomagnetic A Indices

Observed Afr/Ap 17 Jun 014/014

Estimated Afr/Ap 18 Jun 005/005

Predicted Afr/Ap 19 Jun-21 Jun 006/006-006/005-006/005

3.1.8. Geomagnetic Activity Probabilities 19 Jun-21 Jun

A. Middle Latitudes

Active 10/05/05

Minor Storm 01/01/01

Major-severe storm 01/01/01

B. High Latitudes

Active 15/15/15

Minor Storm 25/15/15

Major-severe storm 1

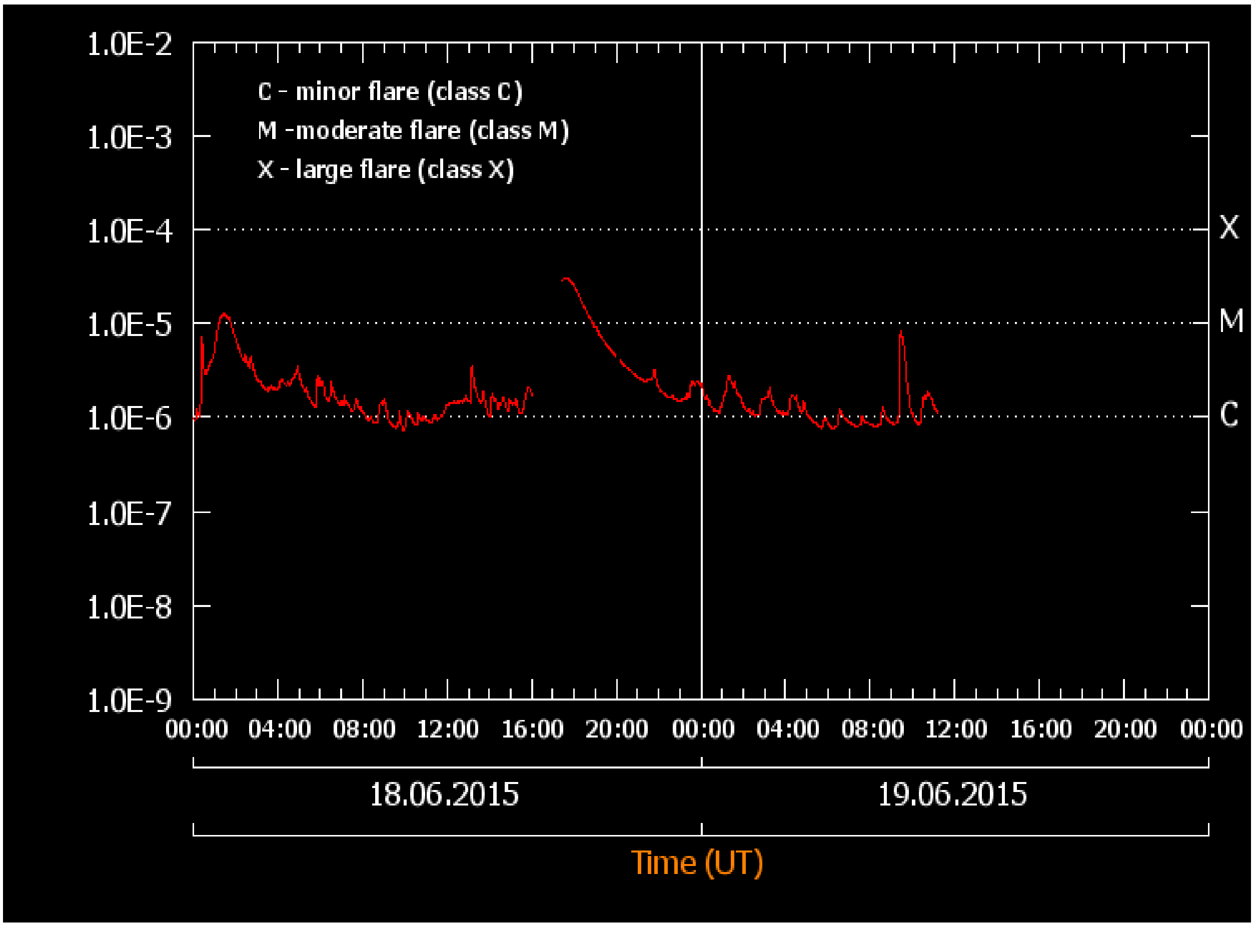


Figure 1: SID data Graph of signals strength against time noting the solar flares

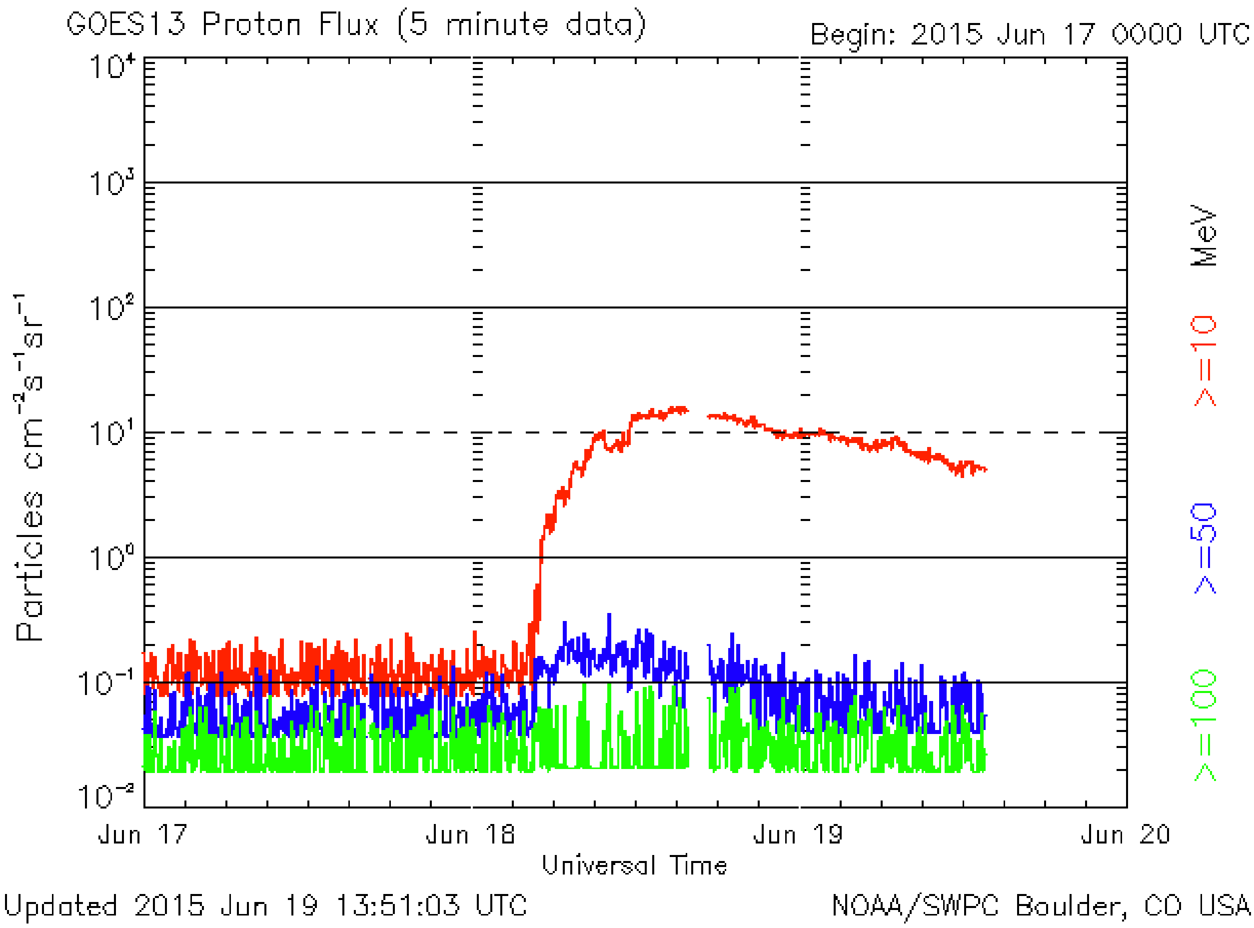


Figure 2: SID data Graph of signals strength against time noting sunrise, sunset and the solar flares

3.2. Joint USAF/NOAA Solar and Geophysical Activity Summary

SGAS Number 170 Issued at 0245Z on 20 Jun 2015. This report is compiled from data received at SWO on 20 June, 2015.

3.2.1. Proton Events: The greater than 10 MeV proton flux reached; event threshold at 18/1135 UTC and remains above threshold.

3.2.2. Geomagnetic Activity Summary: The geomagnetic field was quiet to unsettled with an isolated period of active conditions.

The sun emitted a mid-level solar flare on the 19th June, 2015. Solar scientists classified it as an M-flare, in this case an M5.6-class flare. The flare peaked at about 6pm. The flare came from Sunspot AR2257.

The strength of the VLF signals changes depending on the ionization of the Earth's ionosphere. Solar flares show up on SID data graph as spikes above the normal signal strength level. This spike shows Ionospheric response to solar flares, however, spikes can occur due to some other interference like electrical interferences, noise e.t.c.

Solar flares are powerful bursts of radiation from the sun, which release potentially harmful radiation. In this case, there was no significant coronal mass ejection (CME) emerging from the site of the flare. That means there will be no increased sun-Earth interaction with this event, and no geomagnetic storms as a result, and thus no possibility of intense auroras caused by this flare (although the auroral displays over the past few days have been pretty good, anyway) (19, 29, 33, 34). Radiation from a solar flare, by the way, cannot pass through Earth's atmosphere to affect humans on the ground, but an extremely intense flare can disturb Earth's atmosphere in the layer where GPS and communications signals travel.

Table 1: Energetic Events

Begin	Max	End	Rgn	Loc	Xray	Op	245MHz	10cm	Sweep
0032	0032	0032					100		
0033	0127	0155	2365		M1.2				
0147	0147	0147					100		
0238	0238	0238					110		
0332	0332	0332					150		
0357	0357	0357					280		
0426	0426	0426					110		
1630	1736	1825	2371	N15E50	M3.0	1n	250	2200	IV

Mariners and ham radio operators may have noticed a brief communications blackout at frequencies below about 10 MHz, on the night of January 12, 2015, over Australia and the Indian Ocean. The map below from NOAA shows the affected region. Image via Spaceweather.com via NOAA.

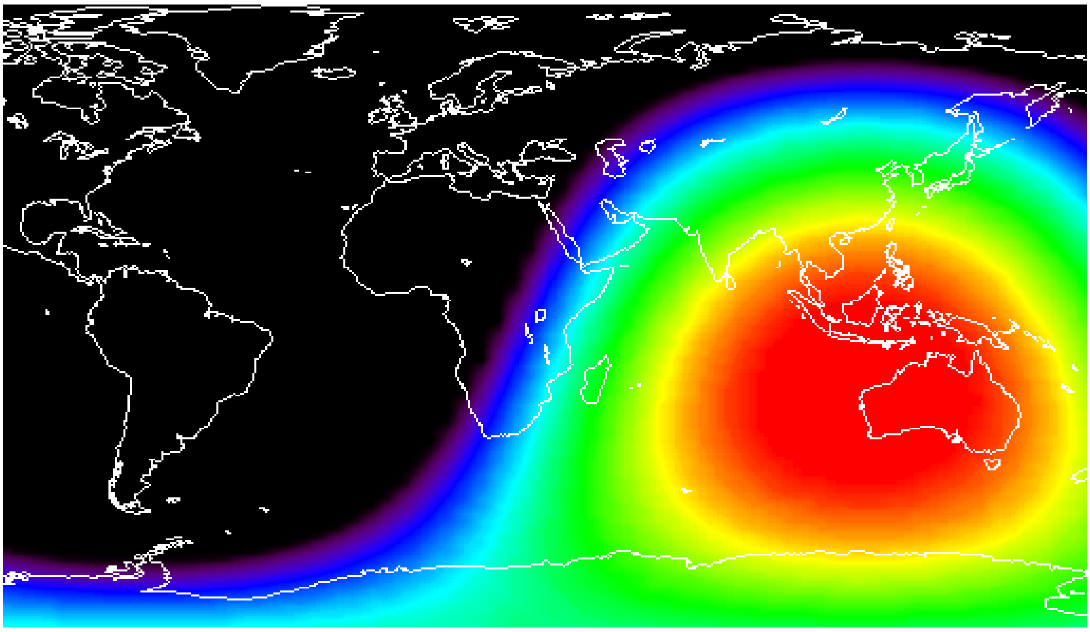


Figure 3: Global map showing regions of communications blackout on 12th January, 2015

4. Conclusion and Recommendation

The Super SID monitor installed and the antenna constructed have been confirmed to be working accurately as confirmed by comparisons with results from satellite data and other ground base observatories. The data collected showed sunrise and sunset signatures which are indications that the monitor is sensitive to changes in Ionospheric electron density. Hence, the installation of the Super SID monitor at the Federal Polytechnic, Ado-Ekiti was successful.

It is recommended that further work should be carried out with the equipment by other researchers to cover a longer period of time as well as provide a more robust data to improve the global response. It is also recommended that the solar power option should be upgraded to enable the monitor to be online always. Finally, it is recommended that the monitor be relocated to a more secluded environment to minimize interference.

Acknowledgements

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References

[1] Andriets E. S., Kondrashova N. N. Semiempirical Photospheric Models Of A Solar Flare On May 28, 2012..vol 55. Pp 871-878, doi 10.1016/j.asr.2014.07.026

[2] Arregui I., Asensio Ramos A.. Determination Of The Cross-field Density Structuring In Coronal Waveguides Using The Damping Of Transverse Waves. Astronomy And Astrophysics. vol 565. pp A78, 2014. doi 10.1051/0004-6361/201423536. **URL:** http://adsabs.harvard.edu/abs/2014A&A...565A..78A

[3] Aschwanden M. J., A Macroscopic Description Of A Generalized Self-organized Criticality System: Astrophysical Applications. Astrophysical Journal. vol 782. pp 54. doi 10.1088/0004-637X/782/1/54. **URL:** http://adsabs.harvard.edu/abs/2014ApJ...782...54A

[4] Aschwanden M. J., Boerner P. And Ryan D. And Caspi A. And McTiernan J. M. And Warren H. P. Global Energetics Of Solar Flares: II. Thermal Energies. Astrophysical Journal. vol 802. pp 53., 2015. doi 10.1088/0004-637X/802/1/53 **URL:**http://adsabs.harvard.edu/abs/2015ApJ...802...53A

[5] Asensio Ramos A., Arregui I.. Coronal Loop Physical Parameters From The Analysis Of Multiple Observed Transverse Oscillations. Astronomy And Astrophysics. vol 554. pp A7, 2013 doi 10.1051/0004-6361/201321428.**URL:** http://adsabs.harvard.edu/abs/2013A&A...554A...7A

[6] Asgari Targhi M., Van Ballegooijen A. A. And Cranmer S. R. And DeLuca E. E. The Spatial And Temporal Dependence Of Coronal Heating By Alfvén Wave Turbulence. Astrophysical Journal. vol 773. pp

111, 2013. doi 10.1088/0004-637X/773/2/111. **URL:** http://adsabs.harvard.edu/abs/2013ApJ...773..111A

[7] B. O'Dwyer, G. Del Zanna, H. E. Mason. Response Of Hinode XRT To Quiet Sun, Active Region And Flare Plasma. Astronomy And Astrophysics. vol 561. pp A20, 2014. doi 10.1051/0004-6361/201016346. **URL:** http://adsabs.harvard.edu/abs/2014A&A...561A..20O

[8] Babu A., Coronal Mass Ejections From The Sun - Propagation And Near Earth Effects. . vol . pp 25. 2014. doi. **URL:** http://adsabs.harvard.edu/abs/2014arXiv1407.4258B

[9] Baker D., Brooks D. H. And Demoulin P. And Yardley S. L. And Van Driel Gesztelyi L. And Long D. M. And Green L. M.. FIP Bias Evolution In A Decaying Active Region. Astrophysical Journal. vol 802. pp 104, 2015. doi 10.1088/0004-637X/802/2/104. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...802..104B

[10] Bobra M. G., Couvidat S.. Solar Flare Prediction Using SDO/HMI Vector Magnetic Field Data With A Machine-learning Algorithm. Astrophysical Journal. vol 798. pp 135, 2015. doi 10.1088/0004-637X/798/2/135

[11] Bogod V. M., Alissandrakis C. E. And Kaltman T. I. And Tokhchukova S. K.. RATAN-600 Observations Of Small-Scale Structures With High Spectral Resolution. Solar Physics. vol 290. pp 7-20, 2015. doi 10.1007/s11207-014-0526-6. **URL:** http://adsabs.harvard.edu/abs/2015SoPh..290....7B

[12] Bougher S. W., Pawlowski D. And Bell J. M. And Nelli S. And McDunn T. And Murphy J. R. And Chizek M. And Ridley A. Mars Global Ionosphere-Thermosphere Model: Solar Cycle, Seasonal, And Diurnal Variations Of The Mars Upper Atmosphere. . vol 120. pp 311-342, 2015. doi 10.1002/2014JE004715. **URL:** http://adsabs.harvard.edu/abs/2015JGRE..120..311B

[13] Brasser R., Wang J. H.. An Updated Estimate Of The Number Of Jupiter-family Comets Using A Simple Fading Law. Astronomy And Astrophysics. vol 573. pp A102, 2015. doi 10.1051/0004-6361/201423687. **URL:** http://adsabs.harvard.edu/abs/2015A&A...573A.102B

[14] Cargill P., . From Flares To Nanoflares: Magnetic Reconnection On The Sun. Astronomy & Geophysics. vol 54. pp 030003-3, 2013 doi 10.1093/astrogeo/att078. **URL:** http://adsabs.harvard.edu/abs/2013A&G....54c3.16C

[15] Caspi A., Woods T. N. And Warren H. P. New Observations Of The Solar 0.5-5 KeV Soft X-Ray Spectrum. Astrophysical Journal, Letters. vol 802. pp L2., 2015 doi 10.1088/2041-8205/802/1/L2. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...802L...2C

[16] Chandra R., Gupta G. R. And Mulay S. And Tripathi D. Sunspot Waves And Triggering Of Homologous Active Region Jets. Monthly Notices Of The RAS. vol 446. pp 3741-3748., 2015. doi 10.1093/mnras/stu2305. **URL:** http://adsabs.harvard.edu/abs/2015MNRAS.446.3741C

[17] Chen N., Ip W. H. And Innes D.. Flare-Associated Type III Radio Bursts And Dynamics Of The EUV

Jet From SDO/AIA And RHESSI Observations. Astrophysical Journal. vol 769. pp 96., 2013. doi 10.1088/0004-637X/769/2/96. **URL:** http://adsabs.harvard.edu/abs/2013ApJ...769...96C

[18] Chen R., Yang Z. L. And Deng Y. Y.. The Induced Electric Field Distribution In The Solar Atmosphere. Research In Astronomy And Astrophysics. vol 13. pp 729-738, 2013. doi 10.1088/1674-4527/13/6/012. **URL:** http://adsabs.harvard.edu/abs/2013RAA....13..729C

[19] Chernov G., Fomichev V. And Tan B. And Yan Y. And Tan C. And Fu Q. Dynamics Of Flare Processes And Variety Of The Fine Structure Of Solar Radio Emission Over A Wide Frequency Range Of 30 - 7000 MHz. Solar Physics. vol 290. pp 95-114, 2015 doi 10.1007/s11207-014-0598-3. **URL:** http://adsabs.harvard.edu/abs/2015SoPh..290...95C

[20] Cheung M. C. M., De Pontieu B. And Tarbell T. D. And Fu Y. And Tian H. And Testa P. And Reeves K. K. And Martinez Sykora J. And Boerner P. And Wulser J. P. And Lemen J. And Title A. M. And Hurlburt N. And Kleint L. And Kankelborg C. And Jaeggli S. And Golub L. And McKillop S. And Saar S. And Carlsson M. And Hansteen V. Homologous Helical Jets: Observations By IRIS, SDO, And Hinode And Magnetic Modeling With Data-Driven Simulations. Astrophysical Journal. vol 801. pp 83. doi 10.1088/0004-637X/801/2/83, 2015. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...801...83C

[23] Collins, R. E., . Antenna and Radio wave propagation. Mc Graw-Hill Inc. New York., pp 185, 1985

[24] D. F. Ryan, P. C. Chamberlin, R. O. Milligan, P. T. Gallagher. Decay-phase Cooling And Inferred Heating Of M- And X-class Solar Flares. Astrophysical Journal. vol 778. pp 68, 2013 doi 10.1088/0004-637X/778/1/68. **URL:** http://adsabs.harvard.edu/abs/2013ApJ...778...68R

[25] Dai X., Wang H. And Huang X. And Du Z. And He H. An Improvement On Mass Calculations Of Solar Coronal Mass Ejections Via Polarimetric Reconstruction. Astrophysical Journal. vol 801. pp 39, 2015. doi 10.1088/0004-637X/801/1/39. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...801...39D

[26] Dalmasse K., Chandra R. And Schmieder B. And Aulanier G. Can We Explain Atypical Solar Flares?. Astronomy And Astrophysics. vol 574. pp A37, 2015. doi 10.1051/0004-6361/201323206. **URL:** http://adsabs.harvard.edu/abs/2015A&A...574A..37D

[27] Dalmasse K., Chandra R. And Schmieder B. And Aulanier G.. VizieR Online Data Catalog: Solar Flares Movies (Dalmasse+, 2015). . vol 357. pp 49037. Doi. **URL:** http://adsabs.harvard.edu/abs/2015yCat..35749037D

[28] De La Cruz Rodriguez J., Lofdahl M. G. And Sutterlin P. And Hillberg T. And Rouppe Van Der Voort L.. CRISPRED: A Data Pipeline For The CRISP Imaging Spectropolarimeter. Astronomy And Astrophysics. vol 573. pp A40, 2015 doi 10.1051/0004-6361/201424319. **URL:** http://adsabs.harvard.edu/abs/2015A&A...573A..40D.

[29] Deborah, S., Research with Space Weather Monitor Data. An unpublished project work presented to Stanford University for International Heliophysical Year (IHY) program, 2007.

[30] Del Zanna G., Tripathi D. And Mason H. And Subramanian S. And O'Dwyer B.. The Evolution Of The Emission Measure Distribution In The Core Of An Active Region. Astronomy And Astrophysics. vol 573. pp A104, 2015 doi 10.1051/0004-6361/201424561. **URL:** http://adsabs.harvard.edu/abs/2015A&A...573A.104D

[31] Efremov V. I., Parfinenko L. D. And Solov'ev A. A. Identification Of Large-scale Cellular Structures On The Sun Based On The SDO And PSPT Data. Astrophysics And Space Science. vol 356. pp 1-6, 2015 doi 10.1007/s10509-014-2195-1. **URL:** http://adsabs.harvard.edu/abs/2015Ap&SS.356....1E

[32] Emilio M., Couvidat S. And Bush R. I. And Kuhn J. R. And Scholl I. F. Measuring The Solar Radius From Space During The 2012 Venus Transit. Astrophysical Journal. vol 798. pp 48, 2015. doi 10.1088/0004-637X/798/1/48. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...798...48E

[33] Fainshtein V. G., Egorov Y. I.. Initiation Of CMEs Associated With Filament Eruption, And The Nature Of CME Related Shocks. . vol 55. pp 798-807, 2015. doi 10.1016/j.asr.2014.05.019. **URL:** http://adsabs.harvard.edu/abs/2015AdSpR..55..798F

[34] Fainshtein V. G., Zagainova Y. S. On The Occurrence And The Motion Of Fast Impulsive Coronal Mass Ejections Associated With Powerful Flares And Unassociated With Eruptive Filaments. . vol 53. pp 31-46, 2015. doi 10.1134/S0010952515010050. **URL:** http://adsabs.harvard.edu/abs/2015CosRe..53...31F

[35] Gold, T. and Hoyle, F. Origin of solar flares. Royal Astronomical Society 120, 89, 1960.

[36] Guglielmino S. L., Zuccarello F. And Romano P.. (2014) Penumbral-like Filaments In The Solar Photosphere As A Manifestation Of Flux Emergence. Astrophysical Journal, Letters. vol 786. pp L22. doi 10.1088/2041-8205/786/2/L22.**URL:** http://adsabs.harvard.edu/abs/2014ApJ...786L..22G

[37] Hudson, H. S. Solar flares, Microflare, Nanoflares and Coronal heating, 133, 357, 2004

[38] Kopp, Lawrence and Rottman, “The total Irradiance Monitor (TIM) Science Results”. Solar Physics 230, 139, 2005.

[39] Mewaldt, R. A., Space Weather Implications of the 20th January, 2005 solar energetic particle event, 410, 50, 2005.

[40] Michael, Z. and John, G. Astronomy. The Cosmic Perspective, John Wily & Son, Inc, New York, 1990.

[41] Okeke, P. N. and Soon, Introductory to Astronomy. SAN Press ltd, Nigeria, 2004.

[42] Onel, H., Mann, G. and Sedimayr, E.. "Propagation of energetic electrons through the Solar Corona and Interplanetary Medium" 463, 1143, 2007.

[43] Otto, S., Beverly, L. and Helen, P. Elementary Astronomy, Oxford University Press, Inc. New York, 1961.

[44] Pam, S., Sun Observer's guide, Firefly Books U.S.A., 2004.

[45] Space Weather Monitor from http://sid.stanford.edu/databasebrowser/monitors.jsp SWPC Anonymous FTP Server, Indices, Events and Region Data, Solar Event reports-last 90 days from http://www.sec.noaa.gov/ftpmenu/indices/events.html **URL:** http://adsabs.harvard.edu/abs/2015ApJ...798..135B

[46] Willian, K. H., Astronomy. The Cosmic Journey, Wadsworth Publishing Company Belmont, California, 1987.

[47] Zhang J., Zhang B. And Li T. And Yang S. And Zhang Y. And Li L. And Chen F. And Peter H.. (2015) Coronal Heating By The Interaction Between Emerging Active Regions And The Quiet Sun Observed By The Solar Dynamics Observatory. Astrophysical Journal, Letters. vol 799. pp L27, 2015. doi 10.1088/2041-8205/799/2/L27. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...799L..27Z

[48] Zhang Y., Tan B. And Karlicky M. And Meszarosova H. And Huang J. And Tan C. And Sim Oes P. J. A.. Solar Radio Bursts With Spectral Fine Structures In Preflares. Astrophysical Journal. vol 799. pp 30, 2015. doi 10.1088/0004-637X/799/1/30. **URL:** http://adsabs.harvard.edu/abs/2015ApJ...799...30Z

[49] Zheleznyakov, V.V., (1970)."Radio Emission of the Sun and Planets", Pergamon, Press ltd, London, 1970 Edition.