Study Of The Quiet Solar Extreme Ultraviolet Emission and its Flaring Properties

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Solar flare and other extreme ultraviolet (EUV) emission research predominantly focuses on large scale events due to their potentially catastrophic effects on our modern technology. This study focuses instead on the contributions of the quiet sun. We examined the correlation between the EUV emissions from small scale events, and fluctuations in the radio spectra and flux detected by the FIELDS instrument onboard Parker Solar Probe (PSP). We processed data from the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO) through TrackPy, a software package that can identify points of maximum EUV emission and track their evolution across the solar disk over time. We used a rolling windowed time lagged cross correlation to account for the time delay between the two instruments. We found several strong correlations between the AIA and PSP data. These correlations suggest the injection of high energy electrons in the interplanetary magnetic field by small reconnection events, which are later observed by PSP as type III radio emissions. Future research is needed to investigate the anticorrelation periods found using these methods.

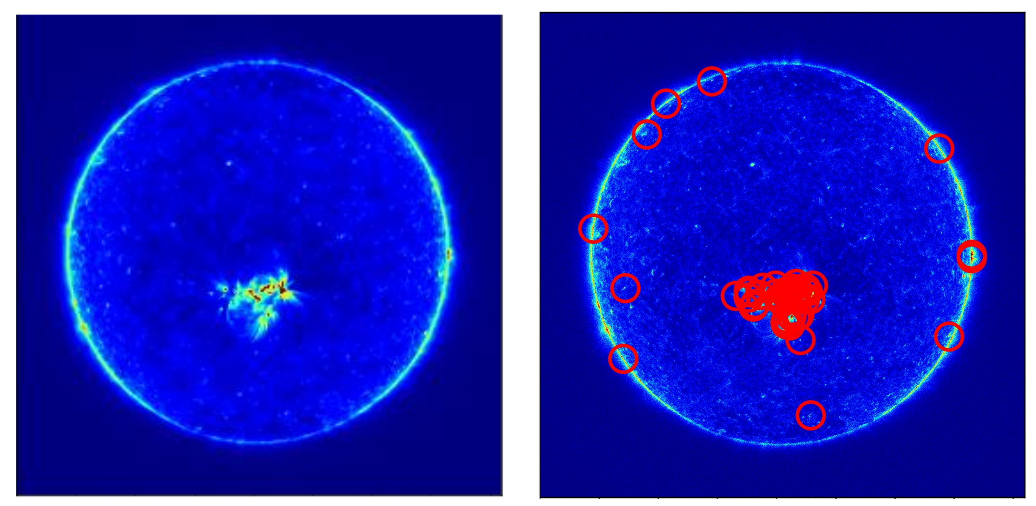
INTRODUCTION

- The data for our analysis was collected by the Parker Solar Probe's FIELDS instrument suite and Solar Dynamics Observatory's Atmospheric Imaging Assembly. This data was collected from April 14th, 2019 during the quiet part of the solar cycle. We analyzed radio flux data between 16 and 10 MHz from PSP/FIELDS. From SDO/AIA, we analyzed AIA 131 A wavelength, emitted by iron-20 (Fe XX) and iron-23 (Fe XXIII) at temperatures greater than 18 million °F.
- During solar flares, a major fraction of the flare accelerated electrons and ions propagate into the solar wind, guided by the magnetic field following a magnetic reconnection event. It is widely accepted that electrons with energies in the keV range are responsible for observed radio emissions from MHz to kHz. These radio emissions are called type III radio bursts.
- Recently, Harra et al. investigated the source of a type III radio burst storm during Encounter 2 of PSP. They analyzed data from the Hinode, PSP/FIELDS, and SDO/AIA, finding that although the active region on the disc produces no significant flares, its evolution indicates it is a source of the electron beams causing the radio storm. This demonstrates that small scale explosive phenomena have been detected by PSP/FIELDS.
- We explore the observations of SDO/AIA in the context of PSP to study small scale explosive events, analyzing the temporal and spatial correlation between the corresponding coronal and chromospheric signatures in AIA and observations from the PSP/FIELDS instrument.

METHODS AND RESULTS

TrackPy

- Tracking software designed for tracking particles in a solution
- The algorithm was originally implemented by John Crocker and Eric Weeks in IDL
- Used as seen below to select the brightest points on the solar disk and track their development over time for further analysis



Figures above:
Solar disk annotated by TrackPy

Rolling Windowed Time Lagged Cross Correlation

- OFFSET is the amount of time lag between the PSP and AIA data, TIME is measured in epochs from 2019-04-14 07:06:16 to 2019-04-14 20:03:31
- This is a Pearson correlation done over a small part of the signal, repeated in a rolling window over time, and then repeated over a time lag (offset). This type of correlation accounts for the distance between the two instruments and creates a dynamic visualization of the relationship between the two sets of data
- The two figures were generated using two different viewing windows. While the bottom figure includes more of the whole dataset, it also includes edge cases where there is not enough data to make a valid correlation analysis. Due to this, we examined correlations that had an offset between -15 and 15. We also ignored the blank horizontal lines that appear due to gaps in the data
- The figures show regions of clear correlation between the AIA data and the averaged radio flux from PSP. We analyzed dark red sections where the correlation was greater than 0.50

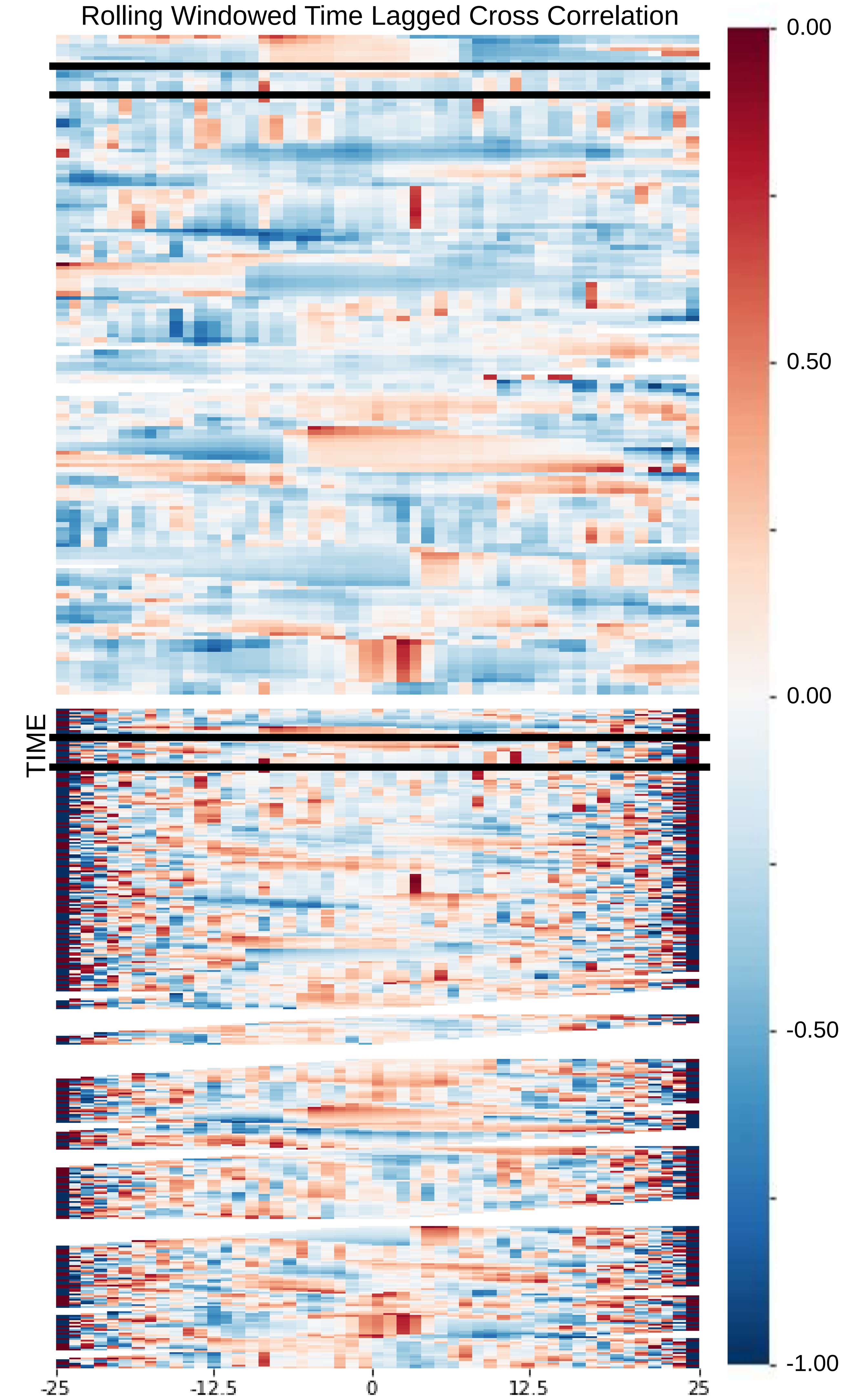
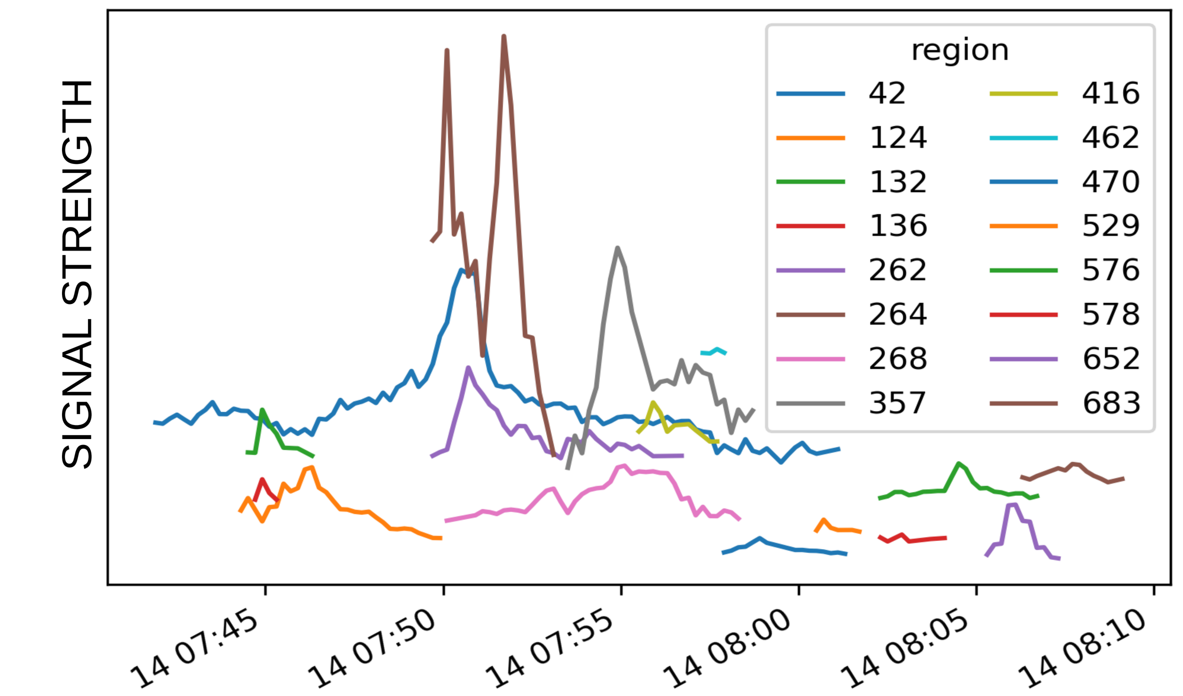


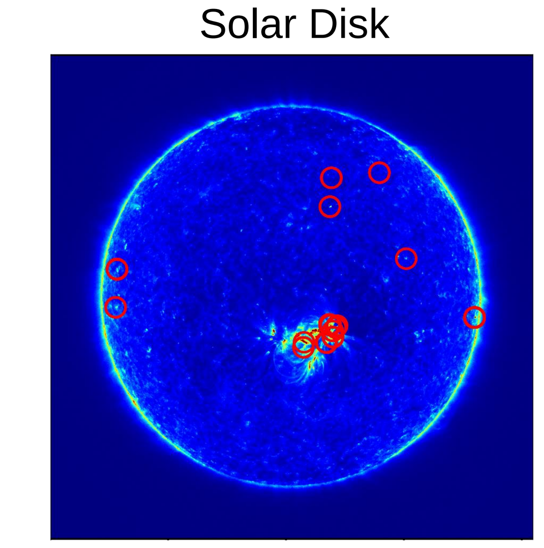
Figure above:
OFFSET: time lag between the PSP and AIA data
TIME: measured from 2019-04-14 07:06:16 to 20:03:31

RESULTS AND CONCLUSIONS

Individual Light Curves from Strong Correlations



Regions of Strong Correlation From Above Mapped onto Solar Disk



- Extracting the regions during the correlation epochs we found evidence of flaring activity in the AIA data, dominated by emission in the active region that was crossing the solar disk during the period of observation
- Some other small scale activity might be related to small scale emission from the quiescence regions of the solar disk.
- Future work: examine the regions of strong anticorrelation

REFERENCES

[1] G. Del Zanna. The multi-thermal emission in solar active regions. , 558:A73,October 2013.

[2] W. D. Pesnell, B. J. Thompson, and P. C. Chamberlin. The Solar Dynamics Observatory (SDO). , 275:3–15, January 2012.

[3] S. D. Bale, K. Goetz, P. R. Harvey, et al. The FIELDS Instrument Suite for Solar Probe Plus. Measuring the Coronal Plasma and Magnetic Field, Plasma Waves and Turbulence, and Radio Signatures of Solar Transients. , 204:49–82, December 2016.

[4] N. J. Fox, M. C. Velli, S. D. Bale, et al. The Solar Probe Plus Mission: Humanity's First Visit to Our Star. , 204:7–48, December 2016.

[5] James R. Lemen, Alan M. Title, David J. Akin, et al. The atmospheric imaging assembly (aia) on the solar dynamics observatory (sdo). Solar Physics, 275(1):17–40, Jan 2012.

[6] D. B. Allan, T. Caswell, N. C. Keim, et al. Trackpy V0.5.0. 2021.

[7] J. H. Cheong. Four ways to quantify synchrony between time series data. Medium, 2021.

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WORKFLOW