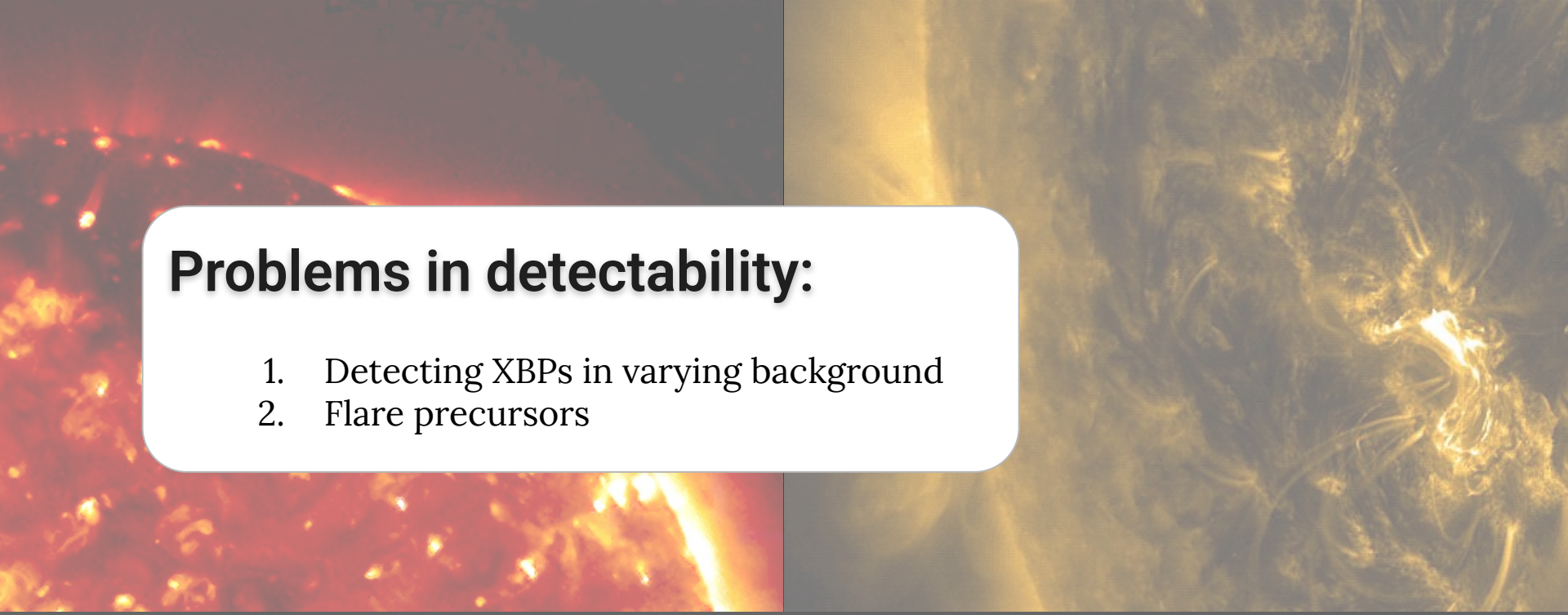

Problems in detectability:

1. Detecting XBPs in varying background
2. Flare precursors

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PhD thesis:
A study on solar flare triggers
Thesis supervisor:
Dr. Sreejith Padinhatteeri

Previous works:
Hinode XRT image segmentation and irradiance variability

At CfA Hosted by:
Vinay Kashyap

Outline

1. Detecting XBPs in varying background
    a. What are XBPs
    b. Detection method
    c. Problem
    d. Summary

2. Flare precursor
    a. What are solar flares
    b. Light curve of the flares
    c. Magnetic flux emergence
    d. Problem
    e. Summary

Problem: 1

X-ray bright points

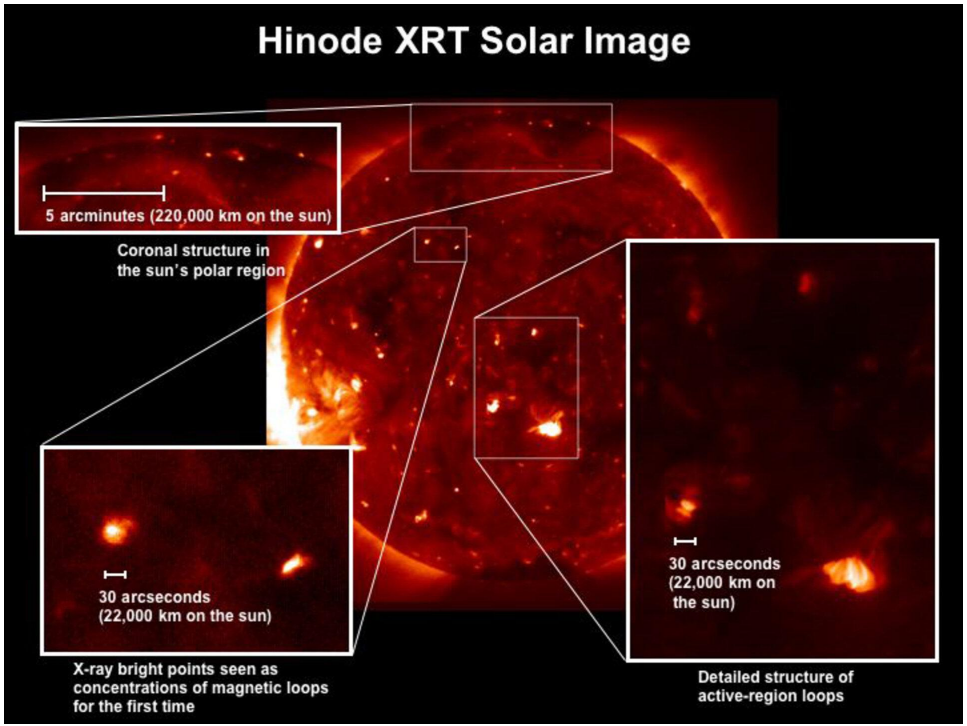
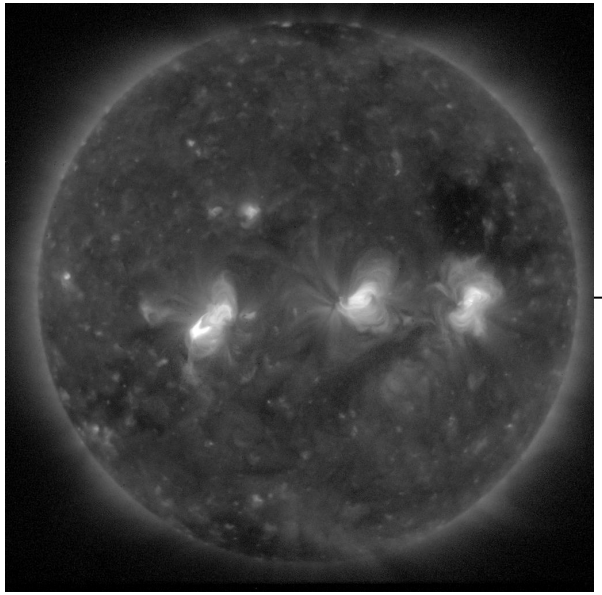


Image credit: JAXA

- X-ray bright points (Coronal bright points) are small unresolved feature on the solar corona.
- Size varies from 5” to 30”.
- We can find them all over disc unlike active region they are not restricted to -40 to 40 degree latitude region.

X-ray bright points detection method

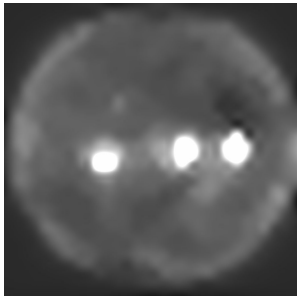


Hinode XRT composite image
(Exposure normalized, DN/s)

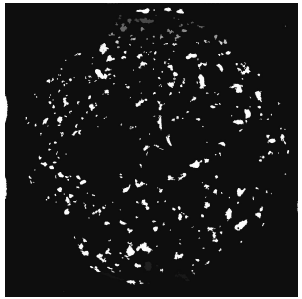
Source detection using SExtractor

Further refinement of source selection

XBP detection using Source-Extractor



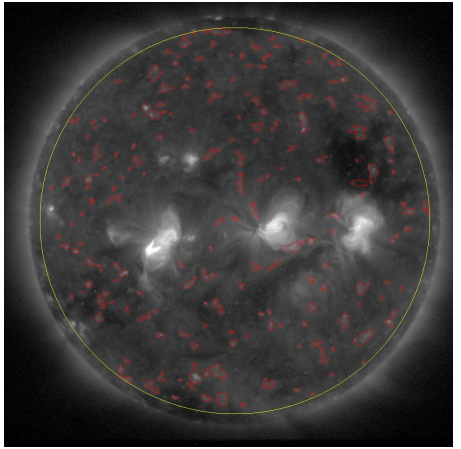
Smoothed background image



Segmentation map

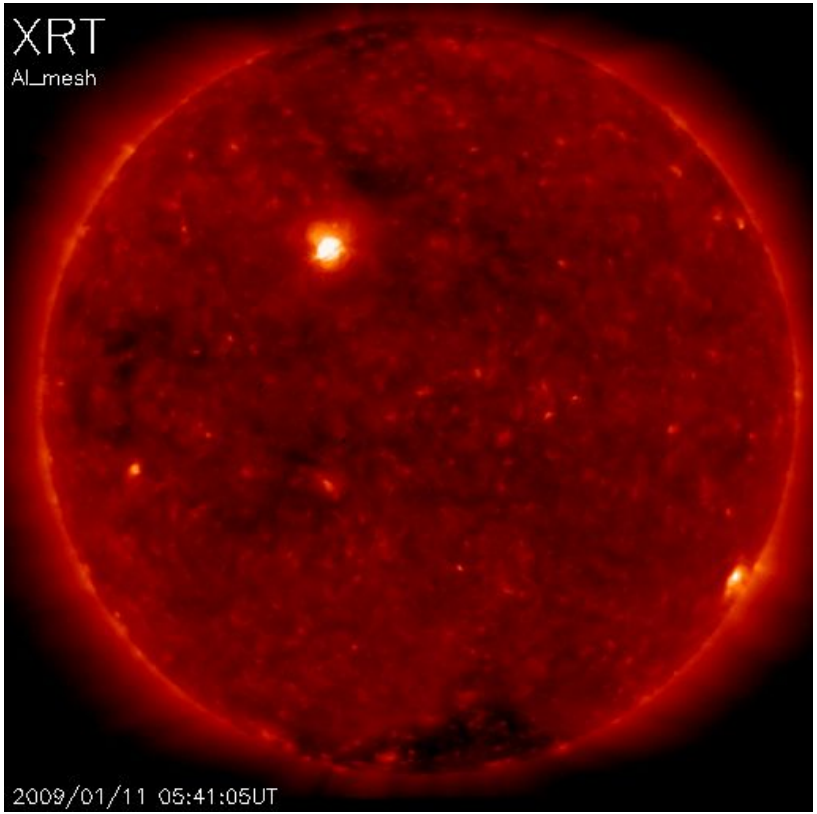
- **Background is estimation:** The image is divided into a grid of small "meshes." Within each mesh, pixels belonging to objects are identified and removed (sigma-clipping).
- **Smoothening:** 3x3 median filter is applied to smoothen the background
- **Source detection:** Pixels brighter than the local background +2*sigma are identified as a source.
- Generated segmentation file is used for further refinement

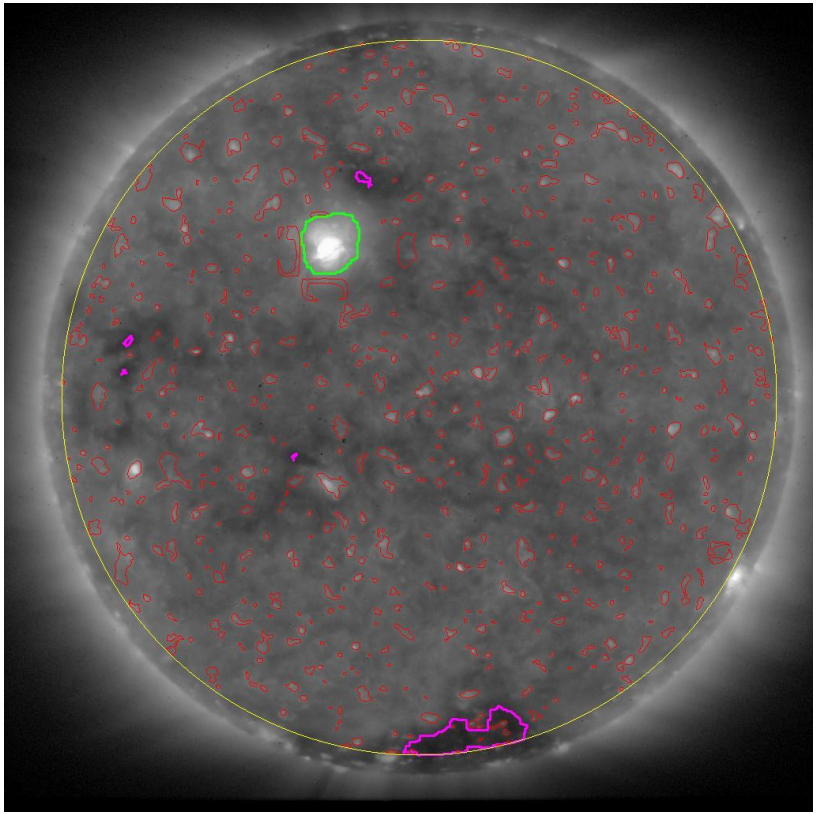
Further refinement of sources selection



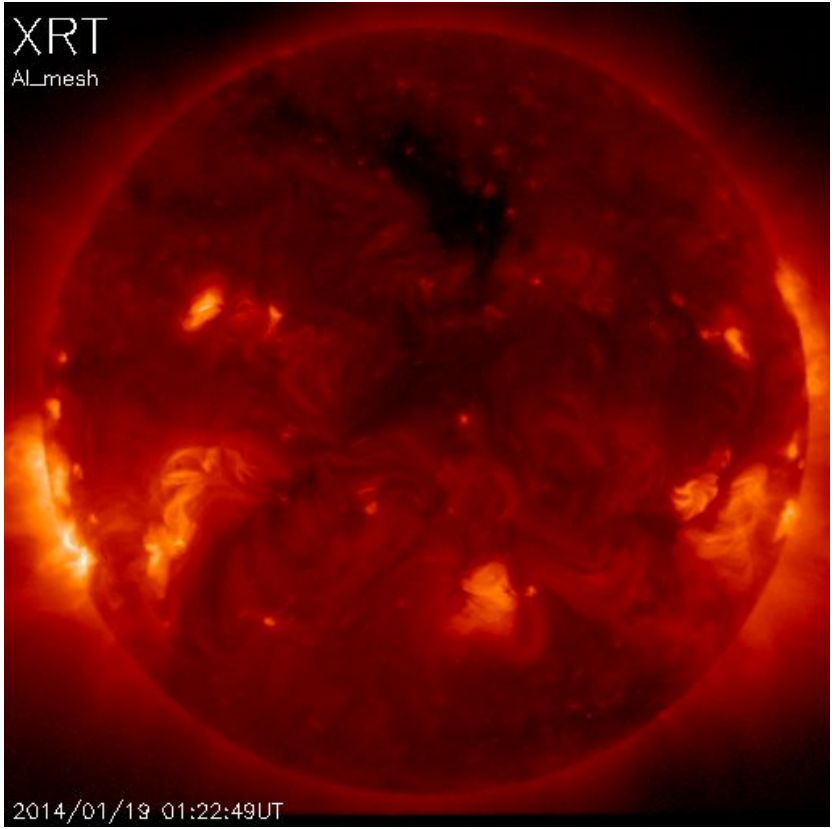
- Sources inside 0.95% solar radius are considered.
- Features detected less than PSF size are removed.
- To eliminate elongated structures (part of active region loops) , we fit the ellipse, the detected regions having semi major axis more than 150 pixels are eliminated (still fine tuning required)

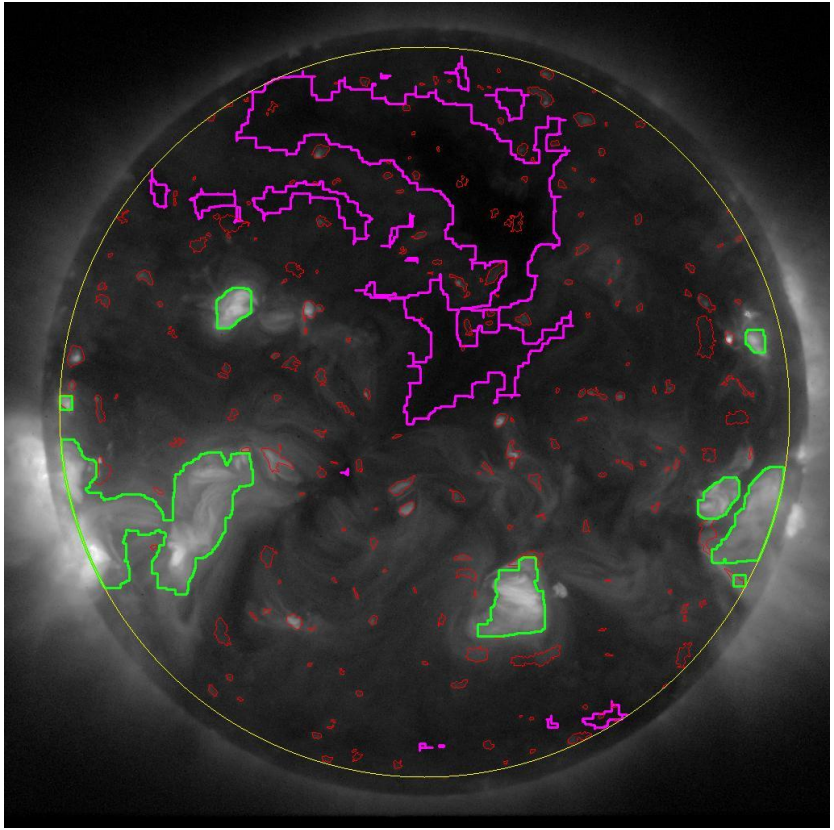
Images during solar minima



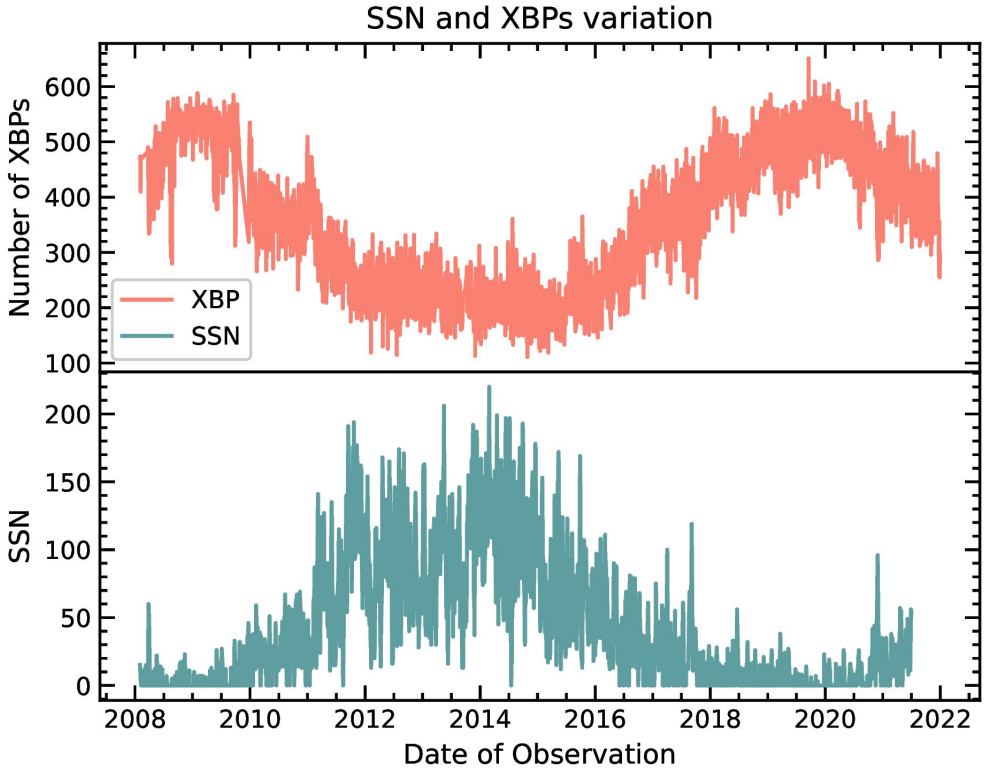


Images during solar maxima





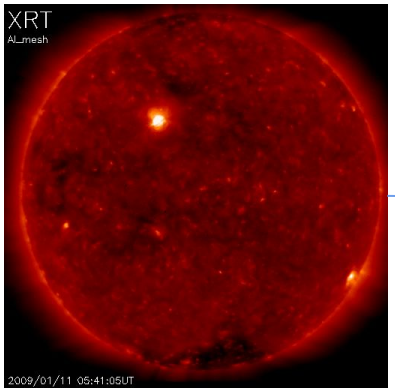
Total number of XBPs over solar cycle

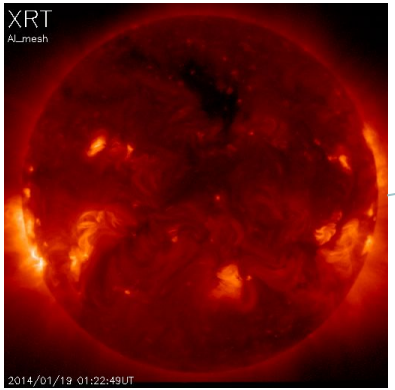


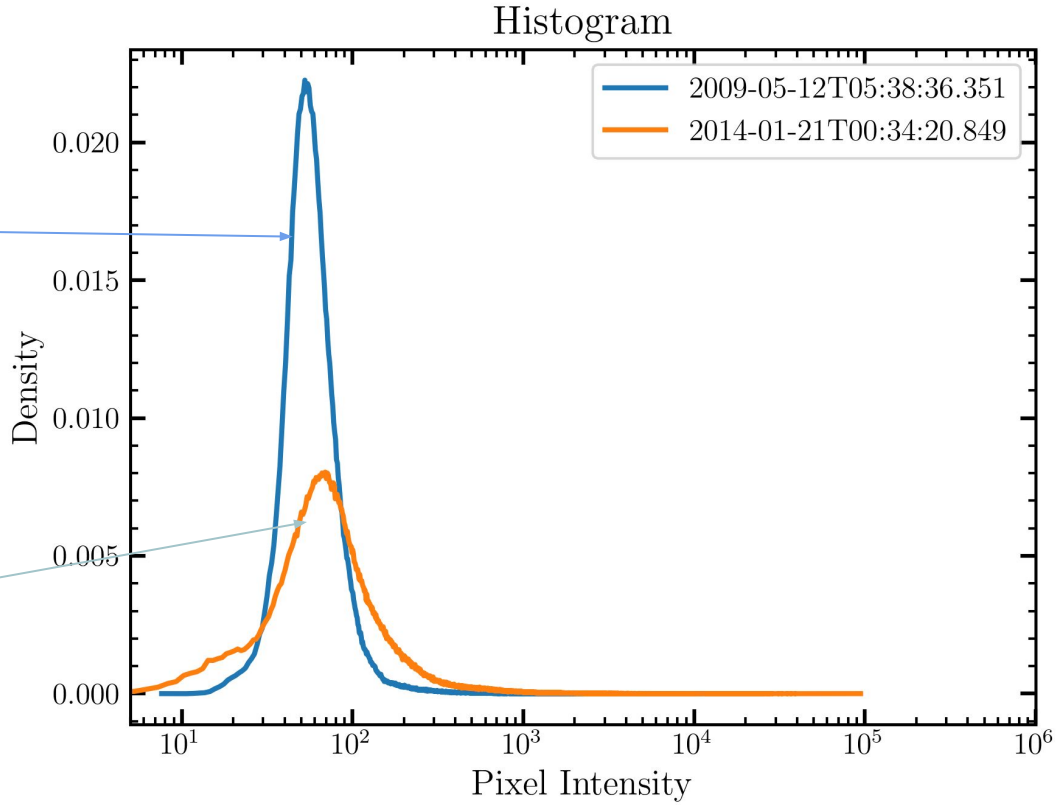
- Large number of XBPs detected during solar minima.
- Small number of XBPs detected during solar maxima.

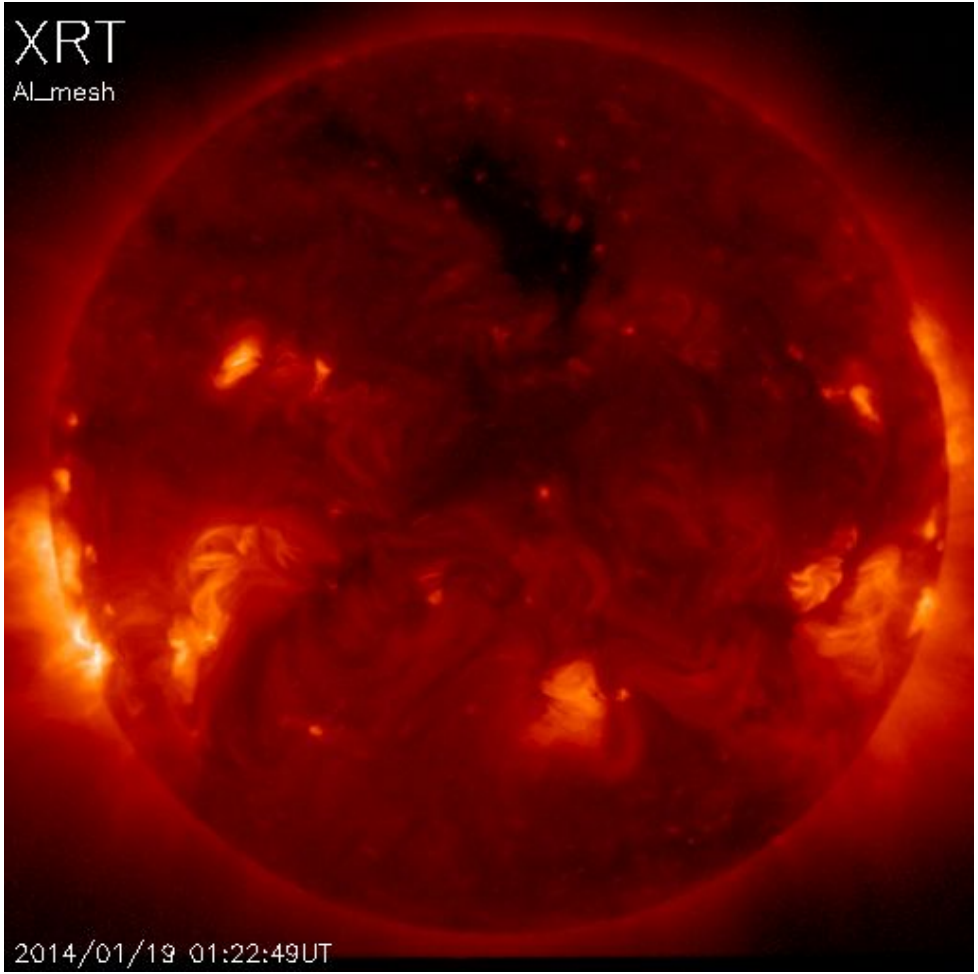
- During solar maxima, significant portion is occupied by Active regions and its loops.
- Overall background intensity is increased during solar maxima

Variation of background









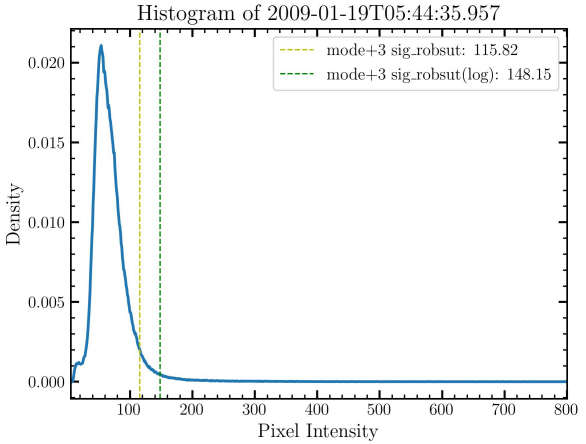
Addressing background variation issue in XBPs counting

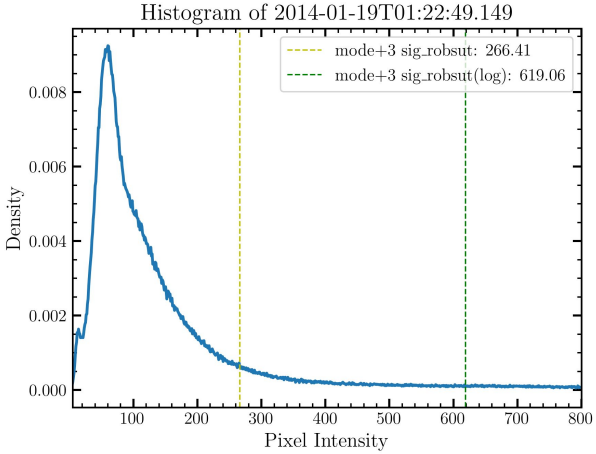
1. Counting XBPs density in one specific location

2. Counting XBPs density only in quiet region

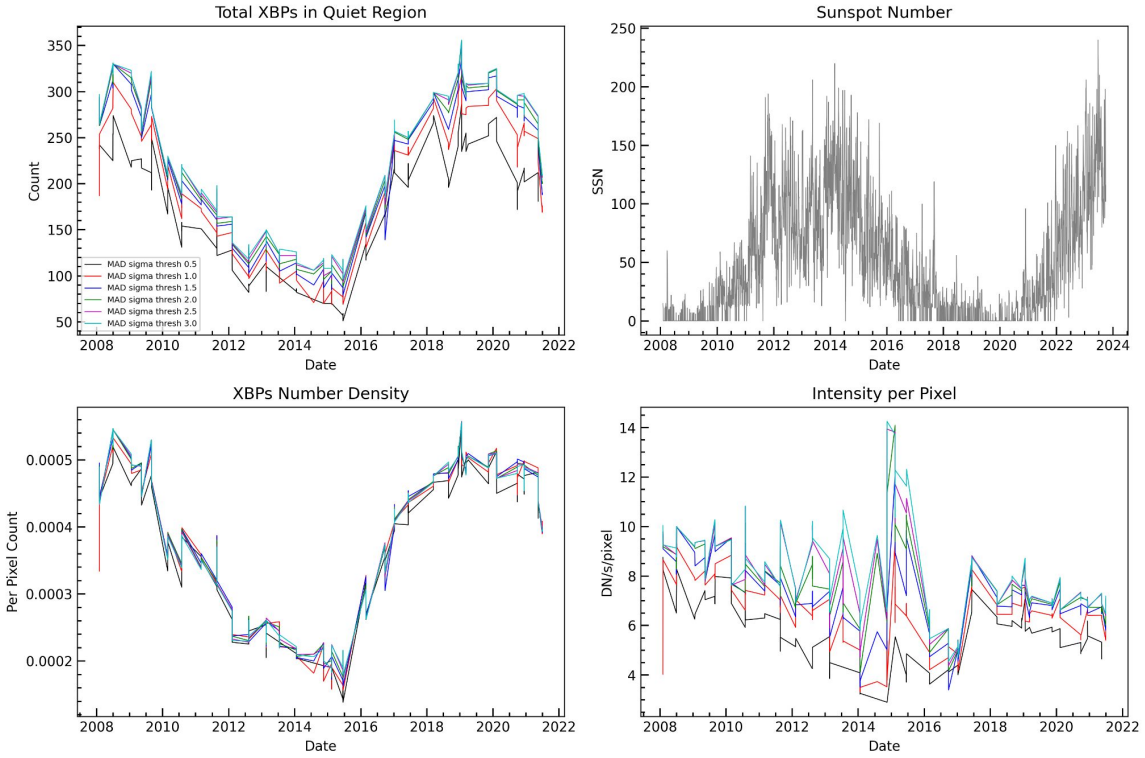
MAD sigma

$$\sigma_{\mathrm{MAD}} = \frac{\mathrm{median}\left(|x_i - \mathrm{median}(x)|\right)}{\Phi^{-1}(0.75)}$$

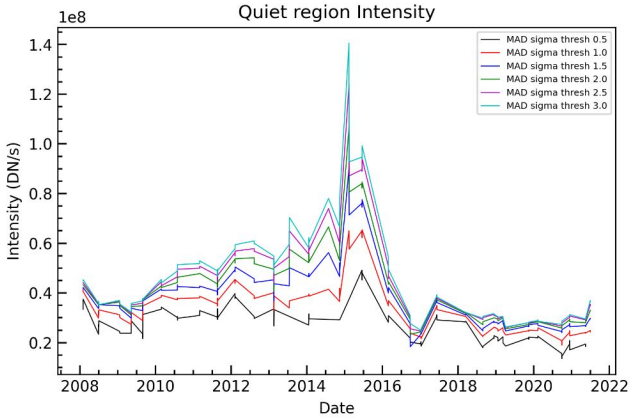


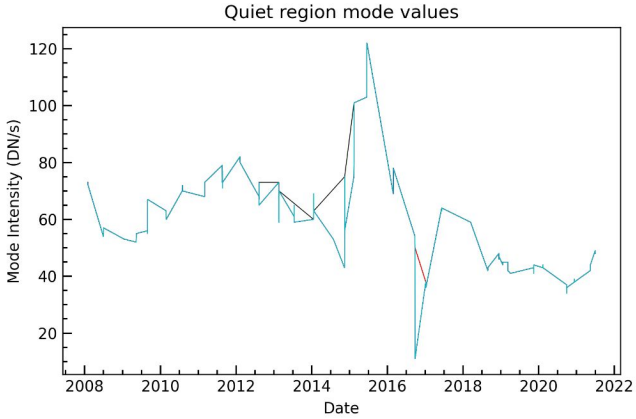


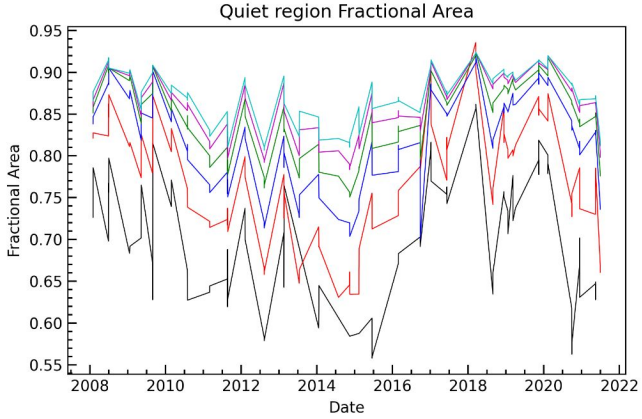
MAD sigma levels and number of XBP detected

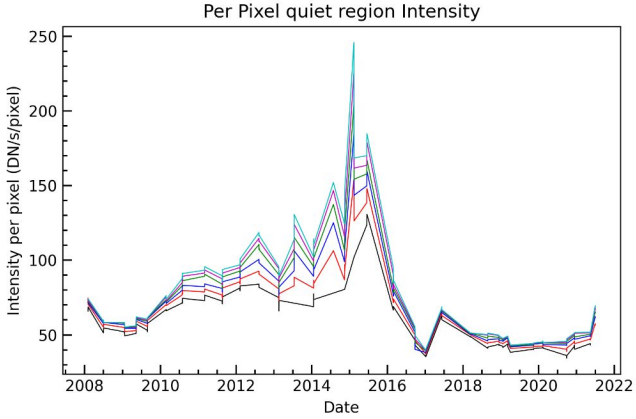


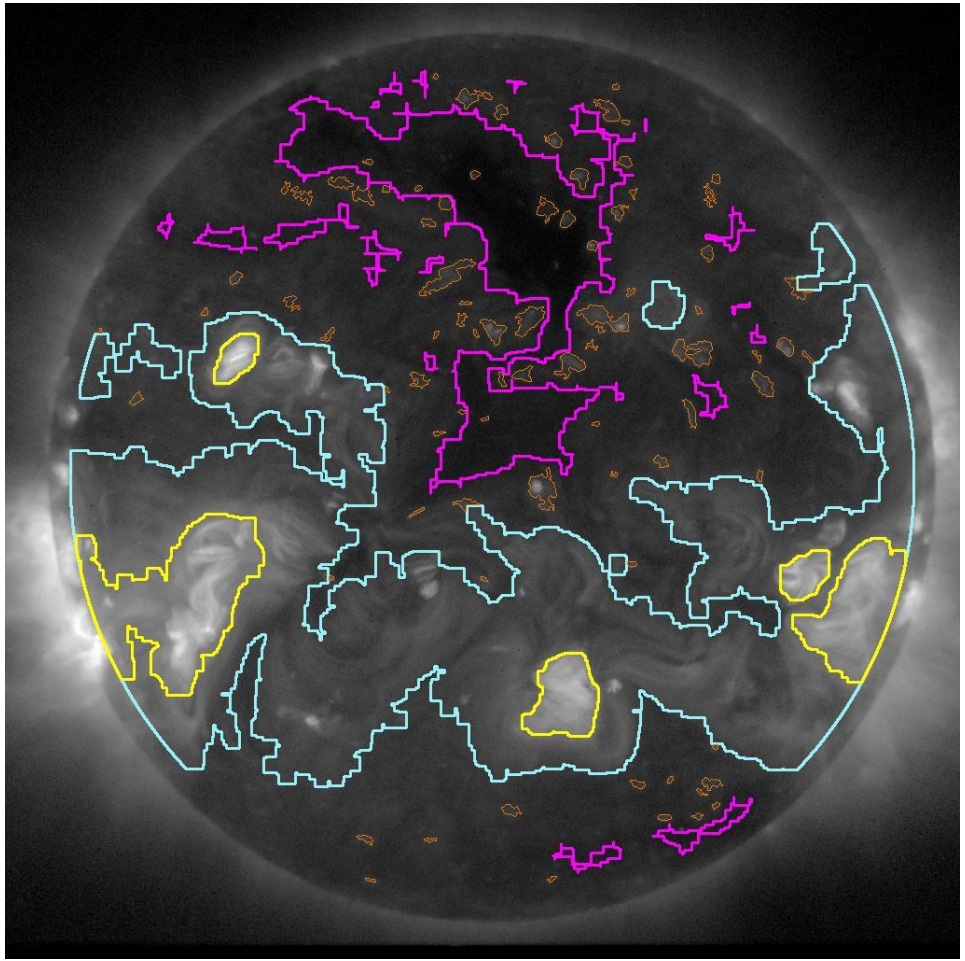
- Considered 100 image from full data set (representing different phase of solar cycle)
- Counted XBPs for different quiet region thresholds


Quiet region Intensity
1e8
Intensity (DN/s)
Date
MAD sigma thresh 0.5
MAD sigma thresh 1.0
MAD sigma thresh 1.5
MAD sigma thresh 2.0
MAD sigma thresh 2.5
MAD sigma thresh 3.0


Quiet region mode values
Mode Intensity (DN/s)
Date


Quiet region Fractional Area
Fractional Area
Date

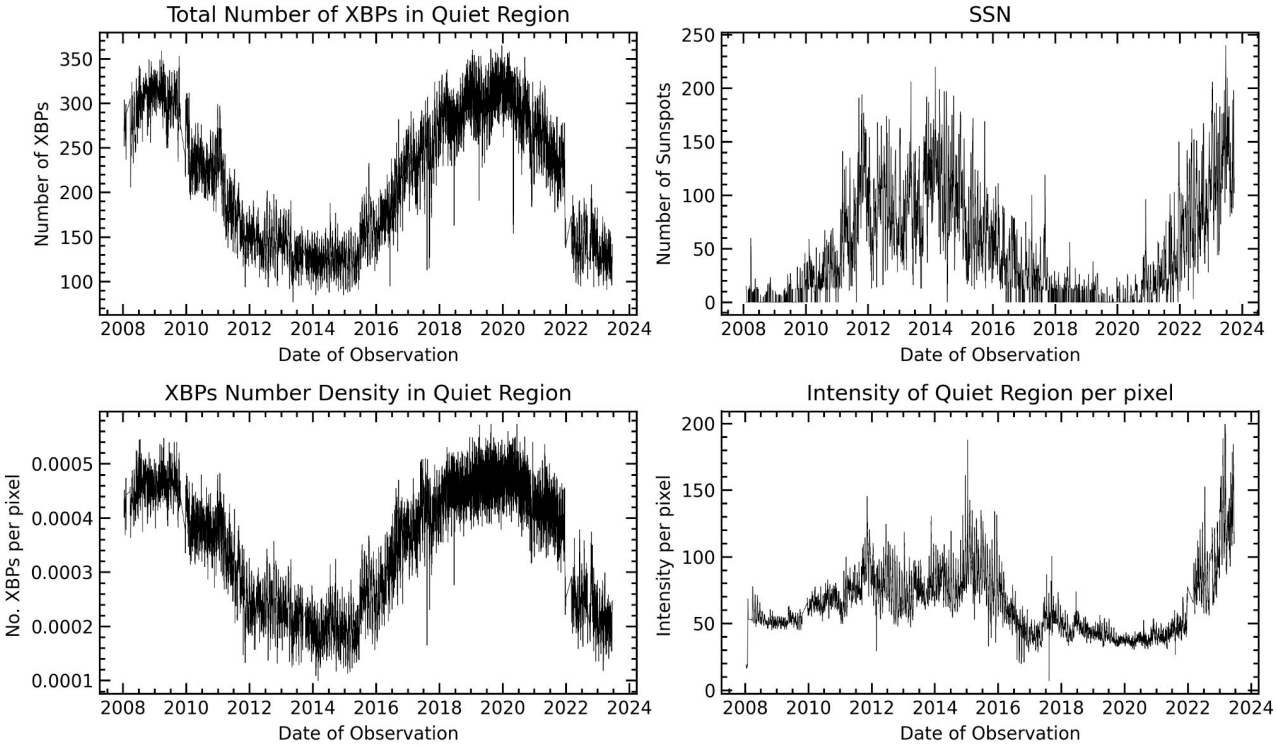

Per Pixel quiet region Intensity
Intensity per pixel (DN/s/pixel)
Date



Cyan color contour is for mode +0.5 sigma value

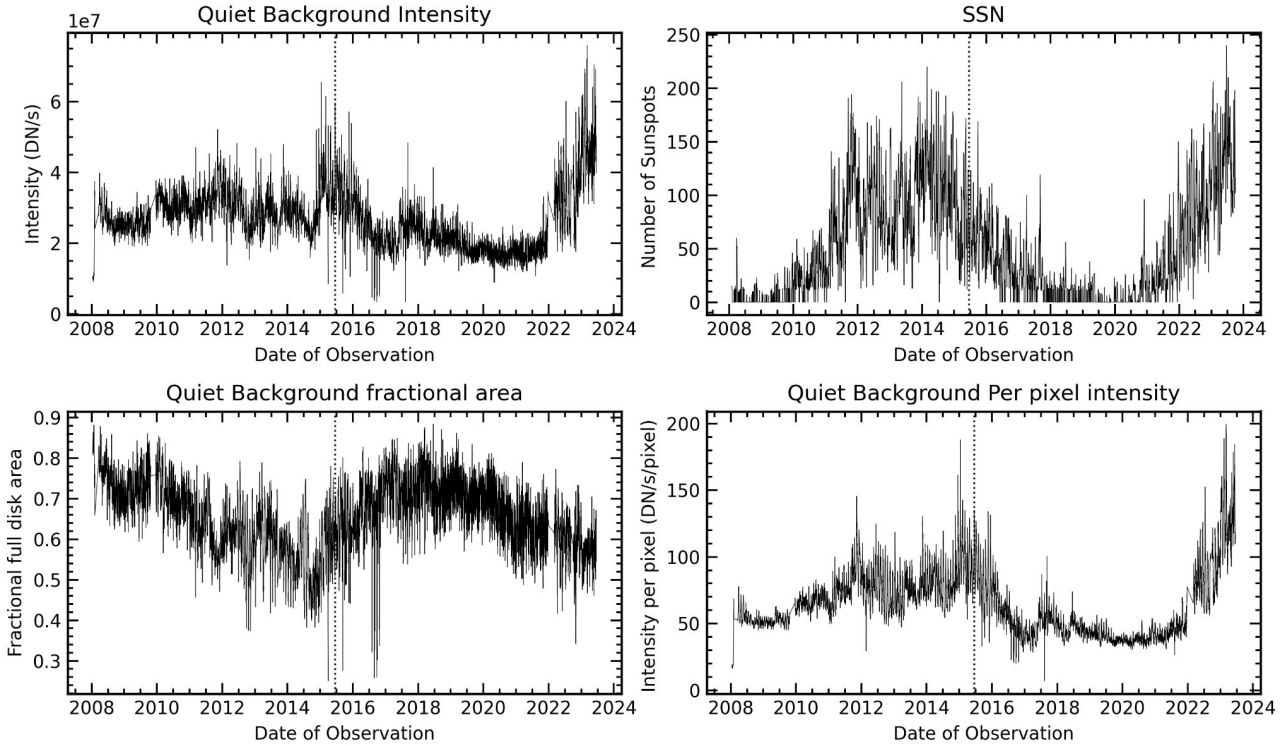
Quiet region= Regions having counts less than mode +0.5 x sigma

XBP numbers in quiet sun region



- We still see the anticorrelation trend

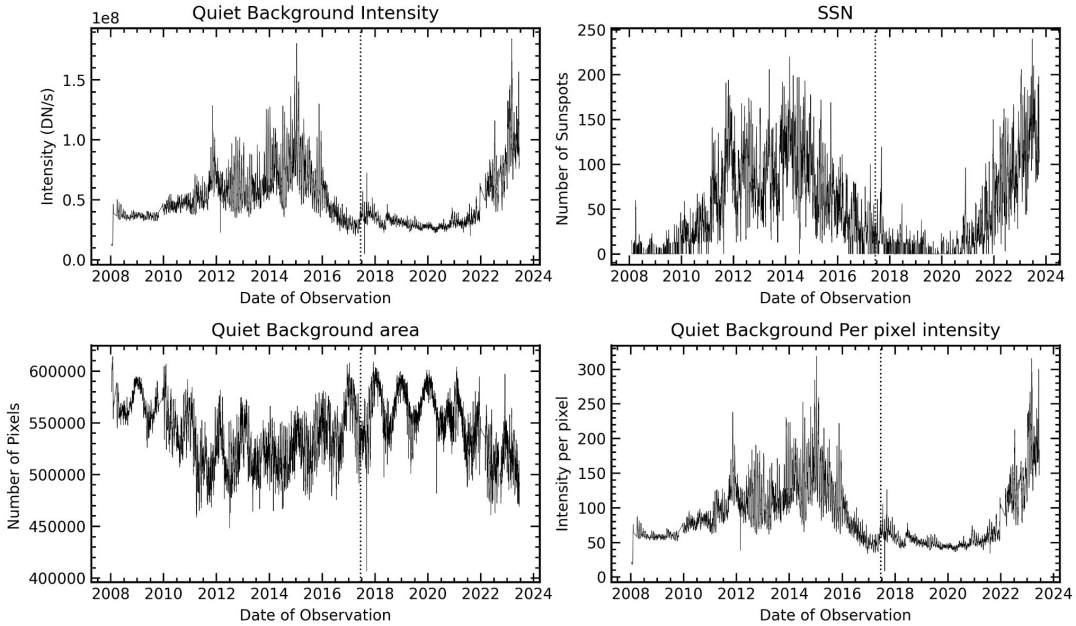
Quiet sun intensity



- Stray light leak level increased after 2015 June

Issues with detection

- Quiet sun level is increasing with solar cycle.
- Exposure time is changing with the solar cycle (approximately 2 -8 sec)



- Quiet background= Regions having counts less than mode +3 x sigma
- Stray light leak level increased after 2015 June

Problem:

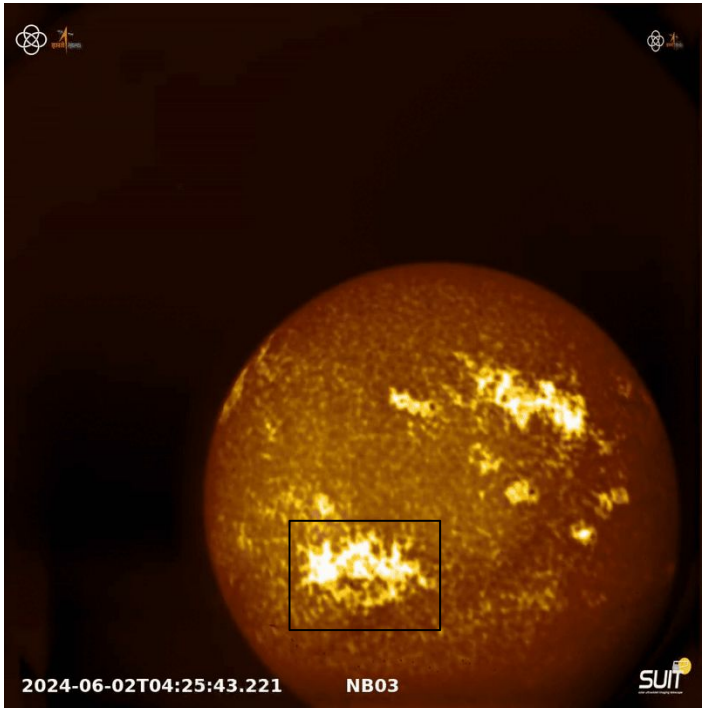
- How to study the variation of XBPs in varying quiet sun level ?

Summary

- Understanding number variability is important part of XBPs understanding
- Better understanding of number variability helps account proper irradiance due to XBPs hence total solar irradiance modelling can be improved.
- Small scale closed magnetic field structure has the role in shaping gamma ray emission from sun (Puzzoni et al 2024,Li et al 2024)

Problem: 2

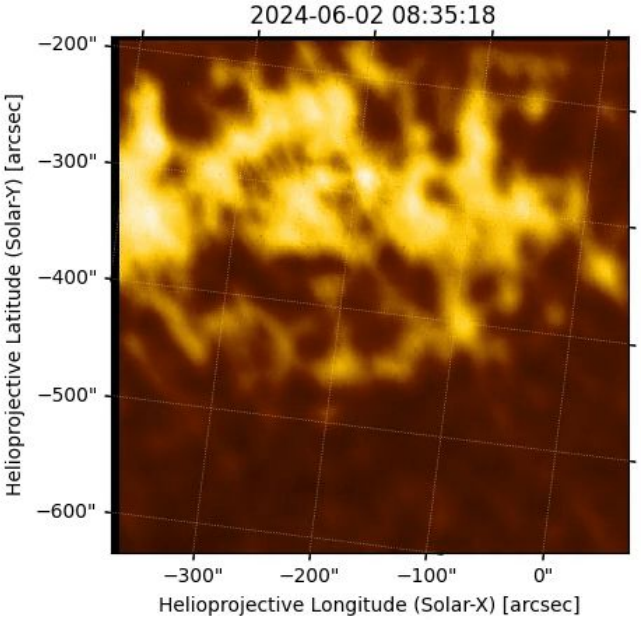
Flare precursors



Flare observed in Solar Ultraviolet Imaging Telescope/Aditya L1 in Mg II k filter

A solar flare is a sudden, intense burst of electromagnetic radiation originating from the solar atmosphere.

We are trying to explore flare precursors in chromosphere data (NUV observations) from recently launched solar mission Aditya-L1

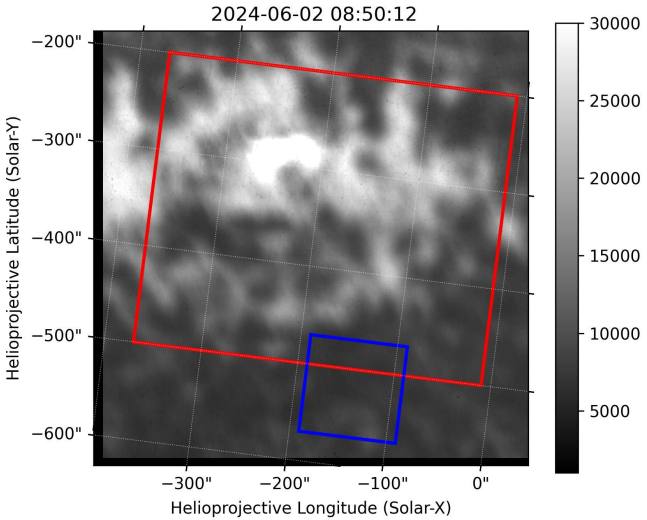


Flare observed in Solar Ultraviolet Imaging Telescope/Aditya L1 in Mg II k filter

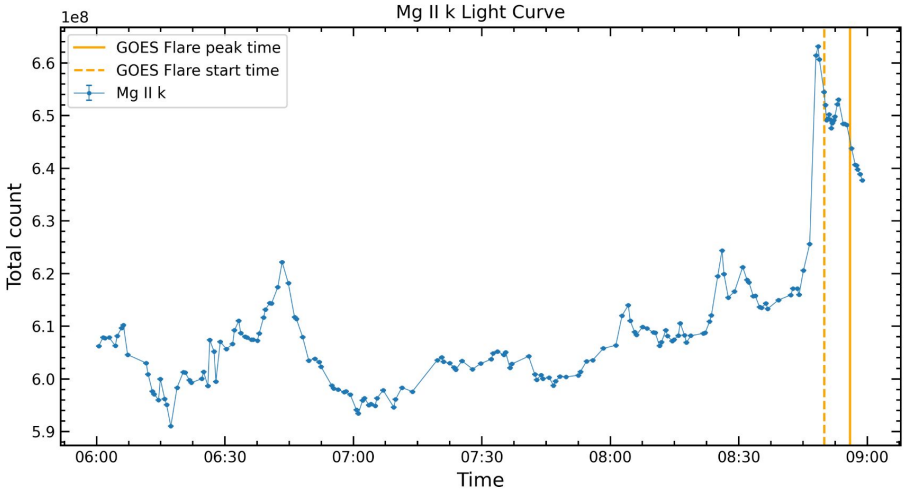
For high cadence observation data we use the Region of Interest (ROI) images.

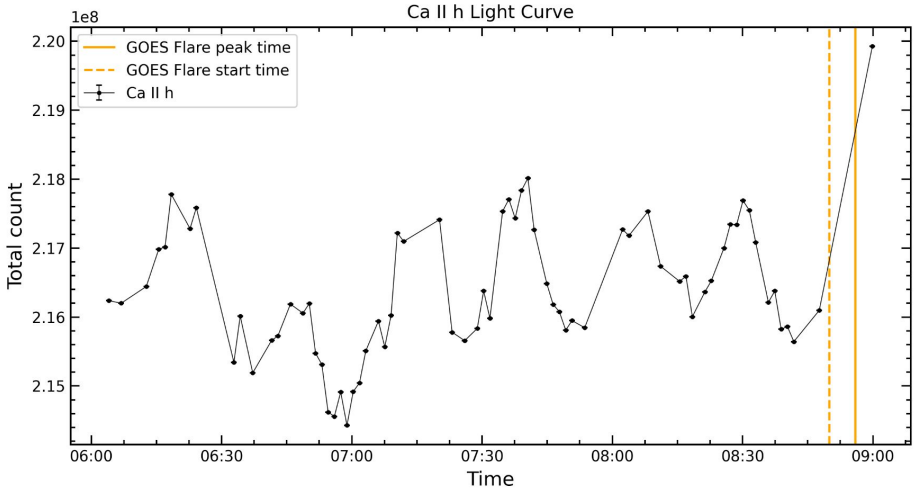
We are studying the flaring region before the flare time to find the causal connection between flare and chromosphere.

Light curves of flaring region from different filters

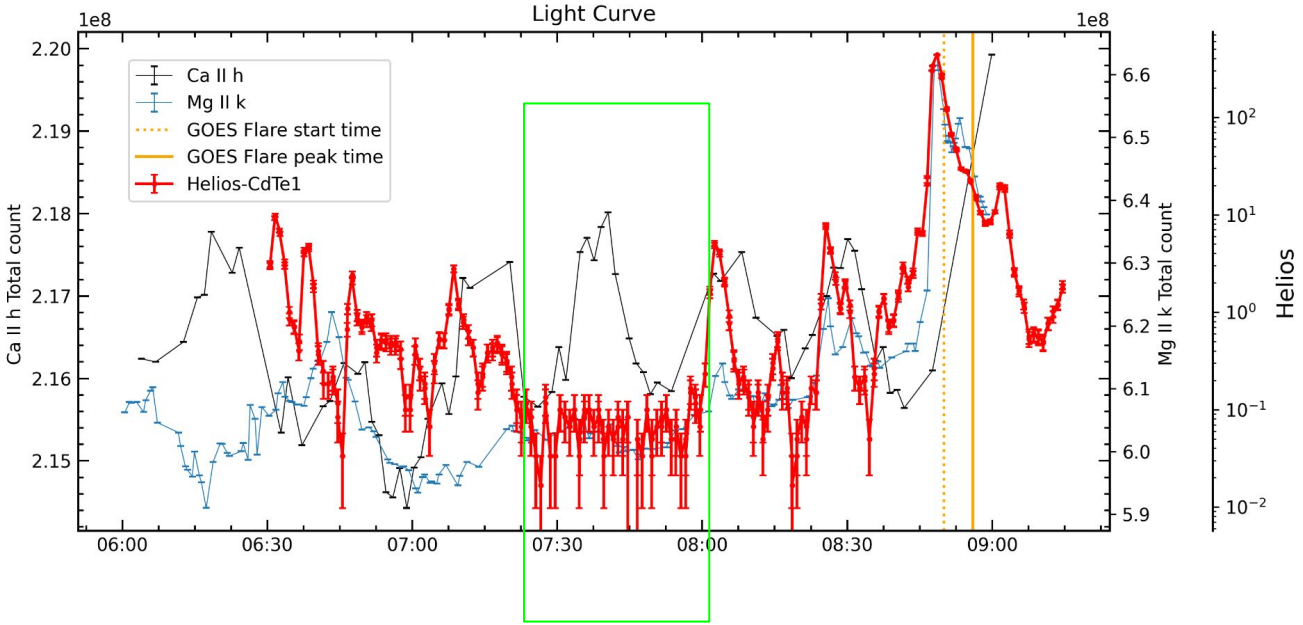


The red box here represents the flaring region considered for the light curve plotting.



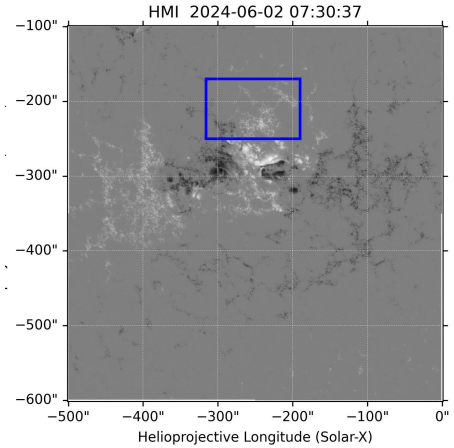


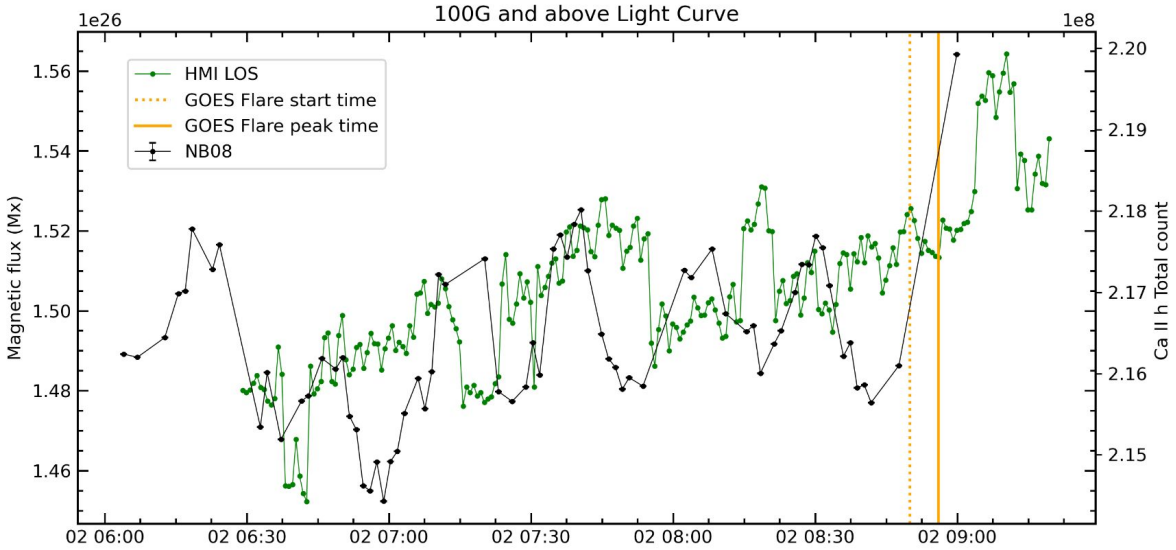
Comparing with hard x-ray data



- Only Ca II h showed enhancement at 7:30 -8:00
- No hard x-ray enhancement was observed around that time

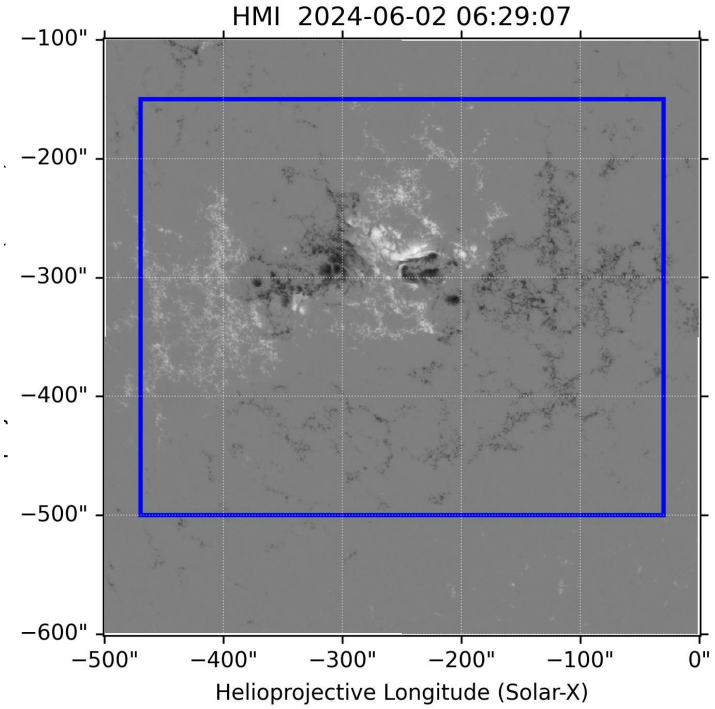
Light curve of the event

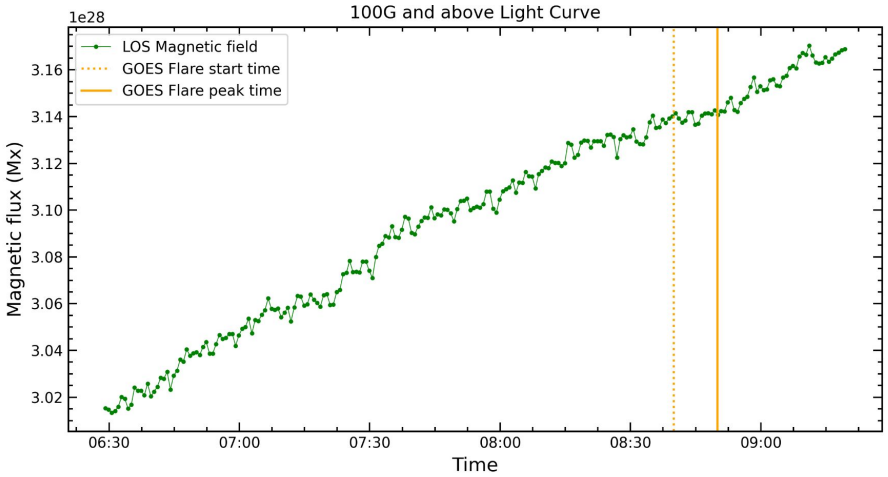




Magnetic field image, (blue box; region considered for light curve)

Magnetic field of full region





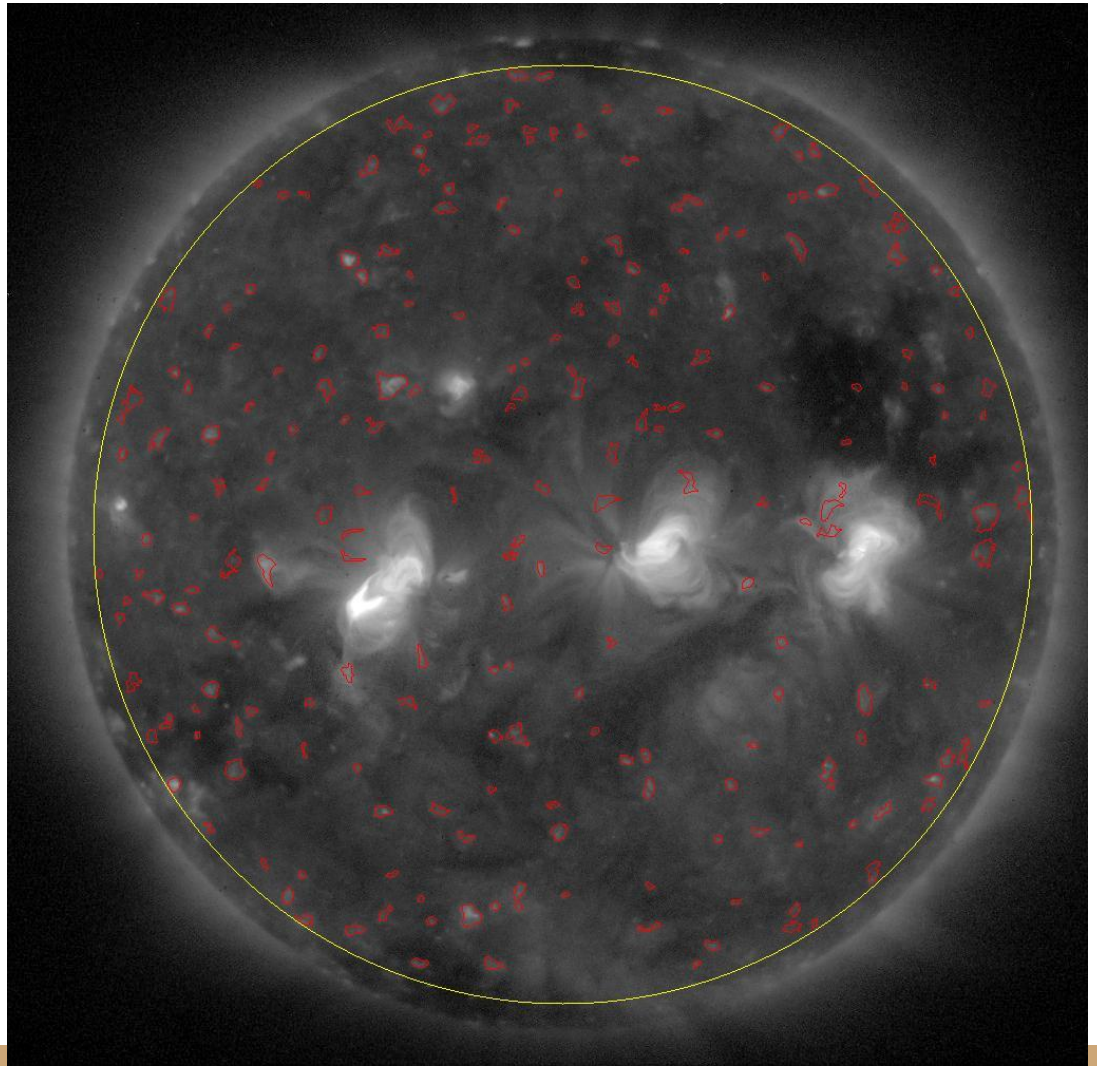
Problem

- How to quantify this enhancement is significant.
- How to establish, if there is causal connection between flux enhancement and flare.

Summary

- Identifying flare precursors is key to understanding the flare process and improving flare prediction.
- Solar data often has a good signal-to-noise ratio, so identifying significant fluctuations helps narrow down important regions for focused analysis.
- Techniques for establishing causal connections between events are crucial.

Thank you.!



- For bright XBPs we can see photosphere counter points.

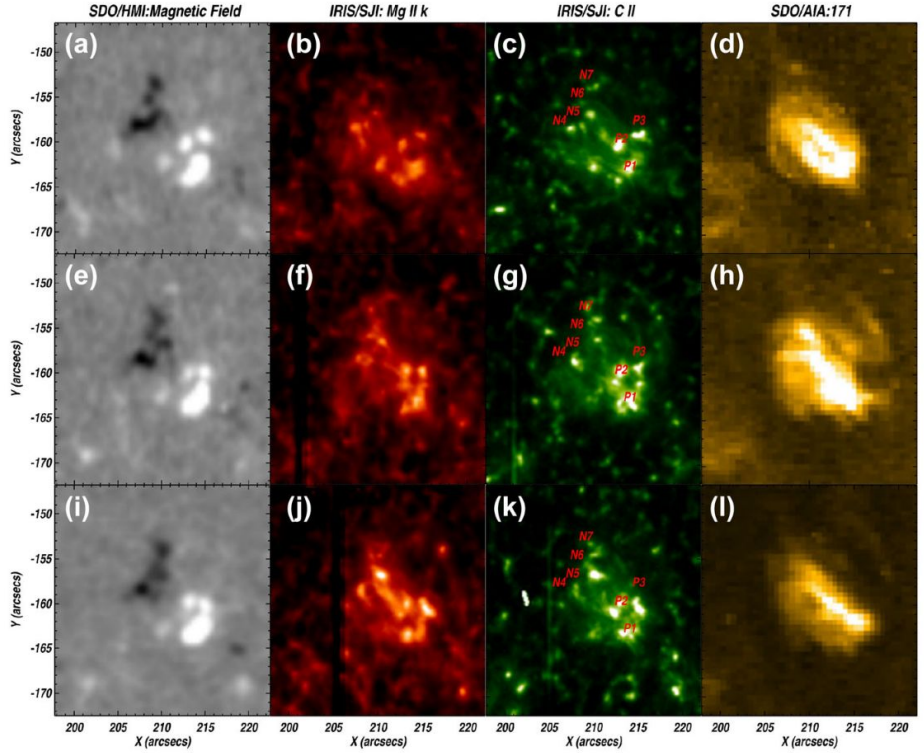
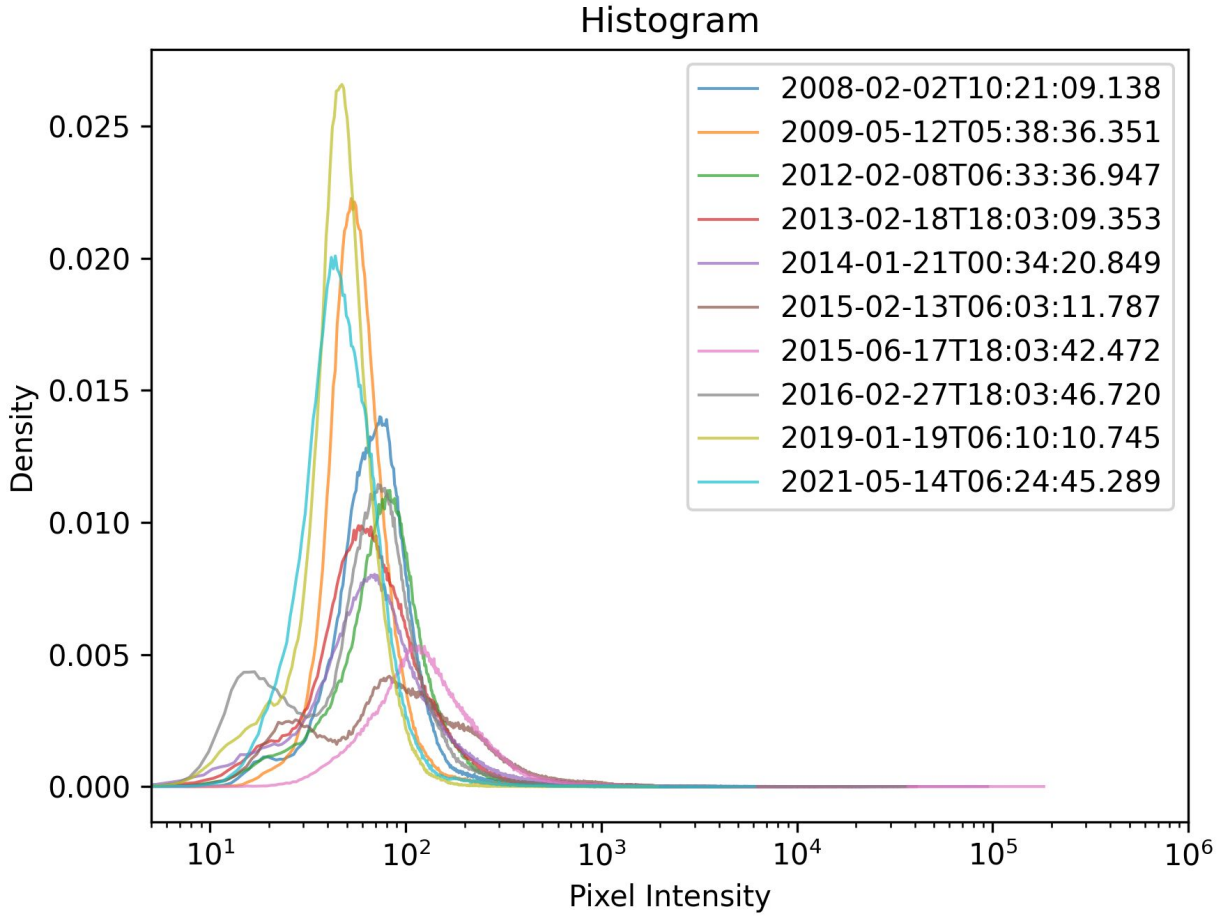
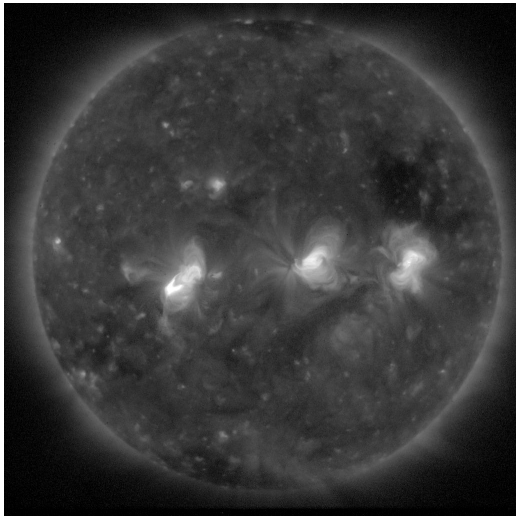


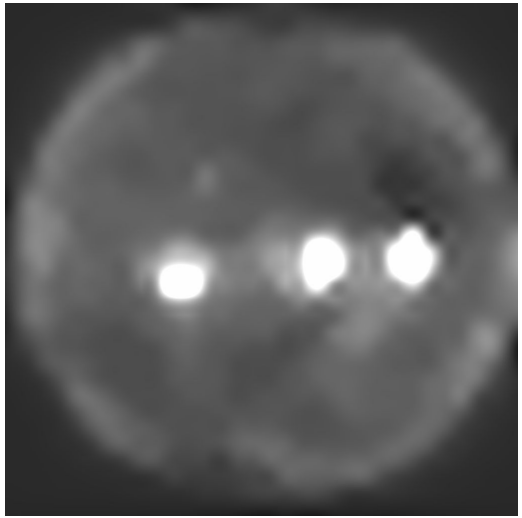
Fig. 4 Temporal evolution of a CBP. From left to right: SDO/HMI longitudinal magnetograms showing the bipole associated with the CBP. IRIS SJ images in the Mg II k 2796 Å passband, SJ images in the C II 1330 Å passband, and SDO/AIA 171 Å images. The top row images are taken at 11:33:51 UT, the middle row at 11:43:19 UT, and the bottom row at 12:03:18 UT. Image reproduced with permission from Kayshap and Dwivedi (2017), copyright by Springer


Histogram
Density
0.025
0.020
0.015
0.010
0.005
0.000
10^1
10^2
10^3
10^4
10^5
10^6
Pixel Intensity
2008-02-02T10:21:09.138
2009-05-12T05:38:36.351
2012-02-08T06:33:36.947
2013-02-18T18:03:09.353
2014-01-21T00:34:20.849
2015-02-13T06:03:11.787
2015-06-17T18:03:42.472
2016-02-27T18:03:46.720
2019-01-19T06:10:10.745
2021-05-14T06:24:45.289

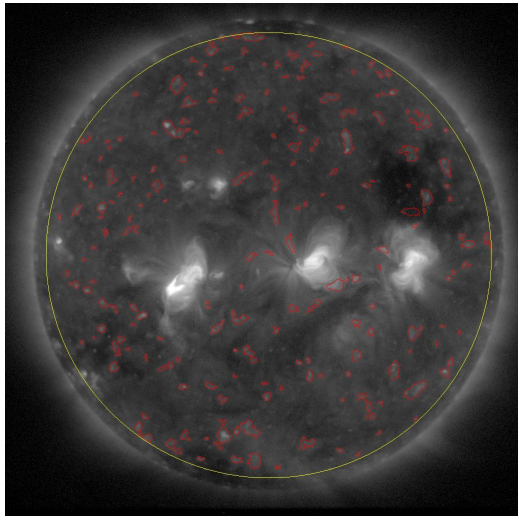
X-ray bright point detection method



XRT Image



Smoothed background image



Detected XBPs (red contours)

Using SExtractor (Source-Extractor))

- Smoothed the background
- Picked the source above 2 sigma