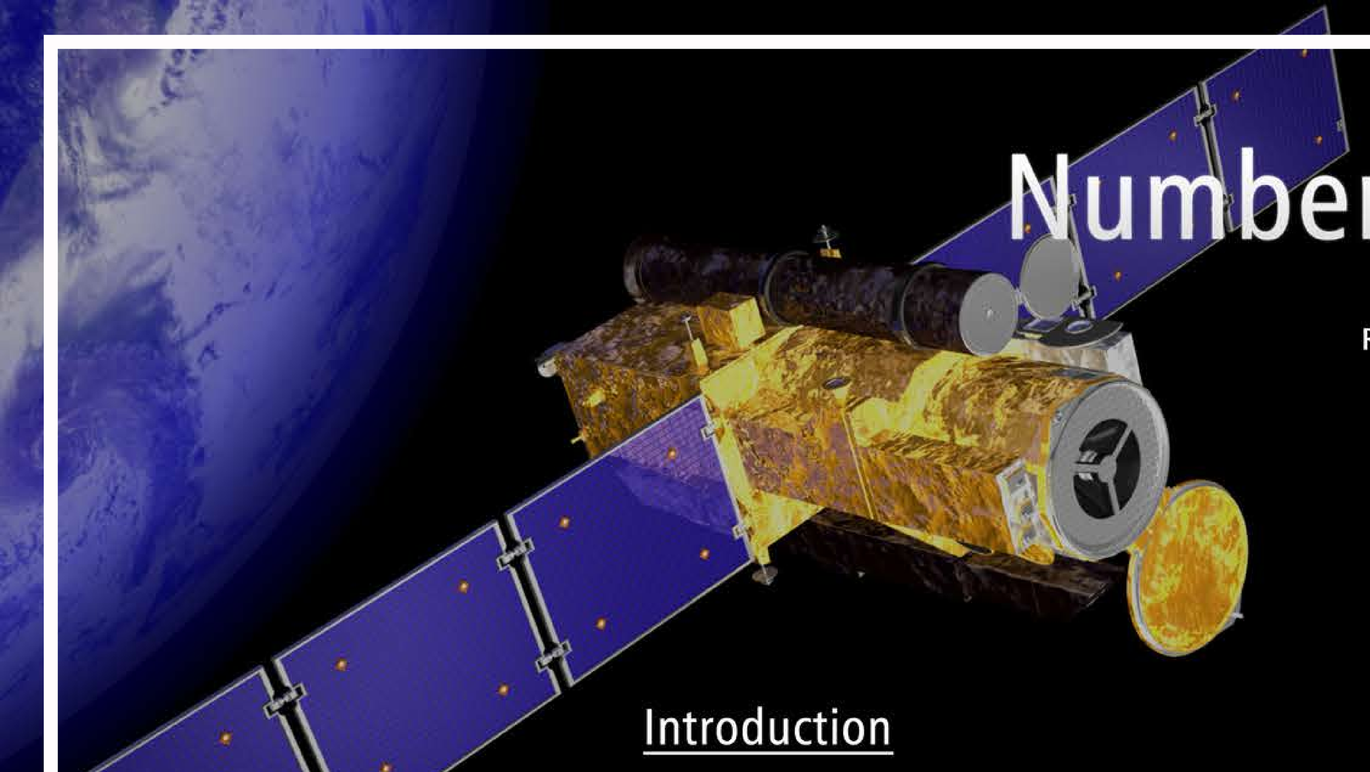

Number Variation of XBPs with Solar Cycle 24

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Introduction

XBPs are relatively small in size and bright magnetic features of the solar corona
Variation of XBPs number is different from other features like Active region and Coronal Holes. It is important to understand the variation of the XBPs number to understand the physics of the solar corona.
Important applications of XBPs to understand the various aspects of physics of the solar corona:

- Intensity oscillations in XBPs --- a period of intensity oscillations ranges from a few minutes to hours – Kariyappa & Varghese, A&A (2008)
- Temperature oscillations in XBPs --- 1.1 MK to 3.4 MK – Kariyappa, et al. A&A (2010)
- Coronal rotation determined by XBPs as tracers --- shows differential rotation – Kariyappa, A&A (2008)
- Heating at the sites of XBPs --- XBP heating rate can be highly variable on short timescales, suggesting that it has a reconnection origin --- Kariyappa, et al., A&A (2010)
- XBPs contribution to X-ray irradiance --- large numbers, numbers are varying, intense magnetic regions – Adithya, Kariyappa et al., Solar Physics (2021)
- Extensive studies on UV and EUV band images called them Coronal bright points (Sattarov et al., 2005a, 2005b; McIntosh and Gurman, 2005; Karachik, Pevtsov, and Sattarov, 2006, Rens et al. 2021).
- A detailed study of XBPs was done using Yohkoh data (Hara and Nakakubo - Morimoto, 2003)

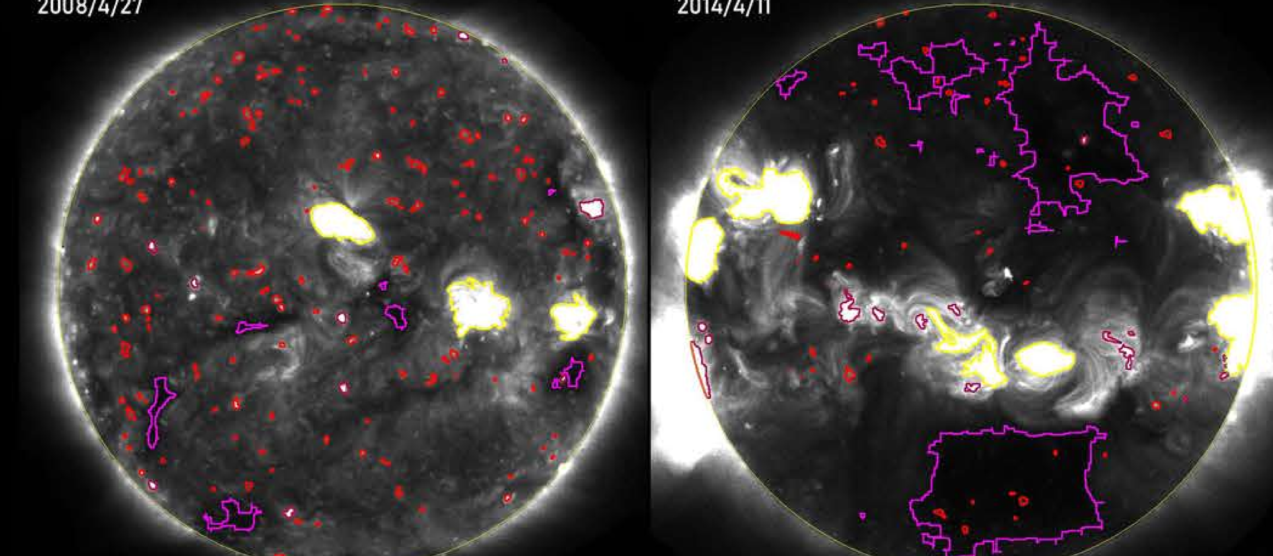
But some uncertainties in the analysis like extracting very dim XBPs, visibility effect during solar maximum and influence of ARs on XBPs detection still remained unsolved.
Our study, for the first time, uses multiple approaches to understand the XBPs number variability using Hinode/XRT images.

Abstract

Coronal X-ray bright points (XBPs) are one of the most interesting features of the Sun in soft X-ray wavelengths. They are bright, very large in number but small scale features. XBPs have many important applications to understand the Physics of the Solar Corona. XBP number is a measure of magnetic activity.
The number variability of XBPs will be very helpful in understanding the dynamics of XBPs over the solar cycle and its role in the solar variability.
To study the number of variations of XBPs for the solar cycle 24, we have used X-ray images of the Sun obtained from Hinode/XRT for the period 2008-2021. We developed a sophisticated python algorithm to detect all XBPs, and derived the number of XBPs, integrated intensity and area of all XBPs.
It has been reported by previous studies that the number of XBPs are anti-correlated with SSN. To confirm this anti-correlation and their behavior over the solar cycle, we further investigated the number variability of XBPs in different approaches:

- Variation of XBPs per unit area (XBPs number density)
- Variation of number density in a quiet corona, to avoid AR influence
- Number variation of strong and weak XBPs
- Number variation with respect to different latitudes

We found from this analysis that both the total number of XBPs and XBPs number density are strongly anti-correlated with SSN but the total intensity of XBPs is well correlated with SSN. There is an indication of XBPs number variation independent of latitude.



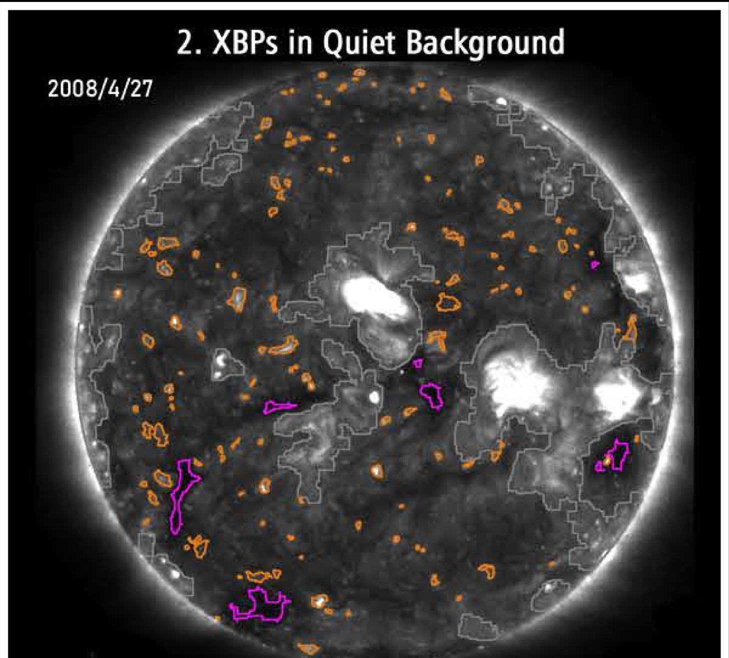
XBPs at Solar Minima | XBPs at Solar Maxima

Red:- X-ray Bright Points , Yellow:- Active Region, Violet:- Coronal Hole, Remaining is Background

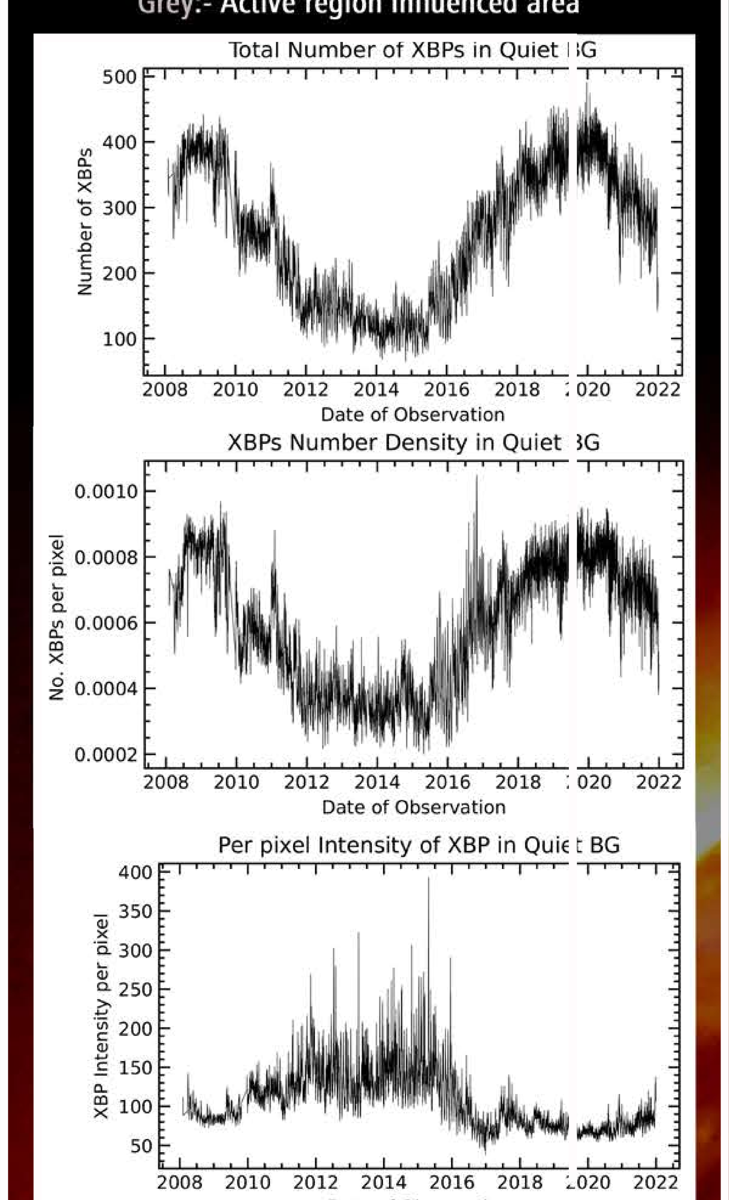
Observations and analysis

- To study the number variations of XBPs for the solar cycle 24, we have used Al_mesh, full-disk, composite, level-2, 1024x1024 size X-ray images of the corona obtained from Hinode/XRT for the period 2008-2021 (Solar cycle 24). Stray light corrections are done for the images after 14th June 2015.
- We developed a sophisticated python algorithm to detect all XBPs, and derived the number of XBPs, integrated intensity and area of all the XBPs.
- We used the 'Source Extractor' package to detect the XBPs. The algorithm detects local maxima and checks the intensity of bright region whether it is gaussian in nature or not, if it is gaussian, pick it as XBP.
- To look in to regions where active region's influence is less (Quiet background), regions having intensity more than the median of full disk and more than 1000 pixels in area are neglected for XBPs detection.
- Heliographic coordinates are fixed to max of each XBPs to check the variation of XBPs as a function of latitude.
- XBPs are classified as bright and dim based on their intensity, XBPs have max intensity (at least 10 pixels) more than 5 times median of the

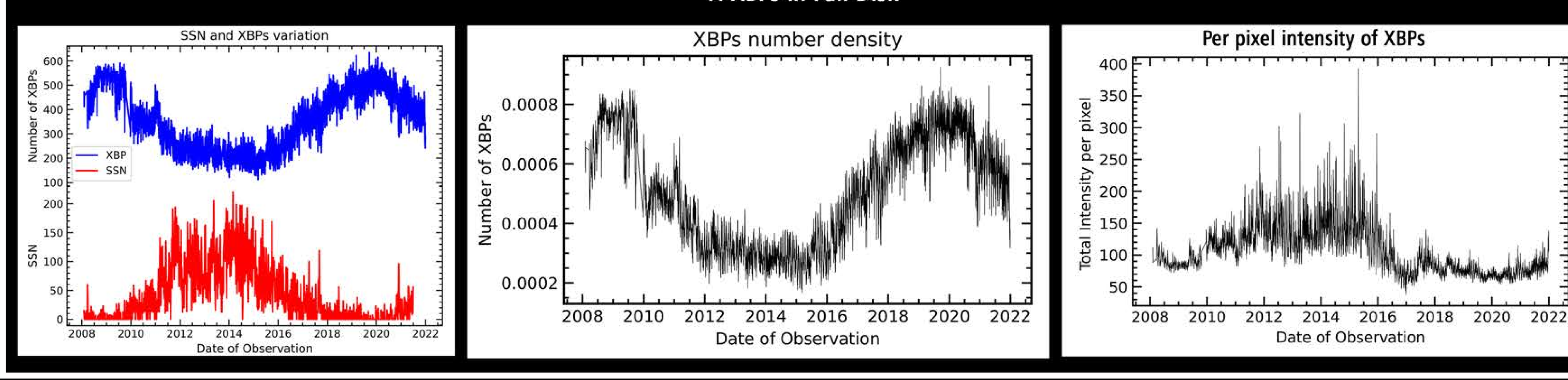
2. XBPs in Quiet Background



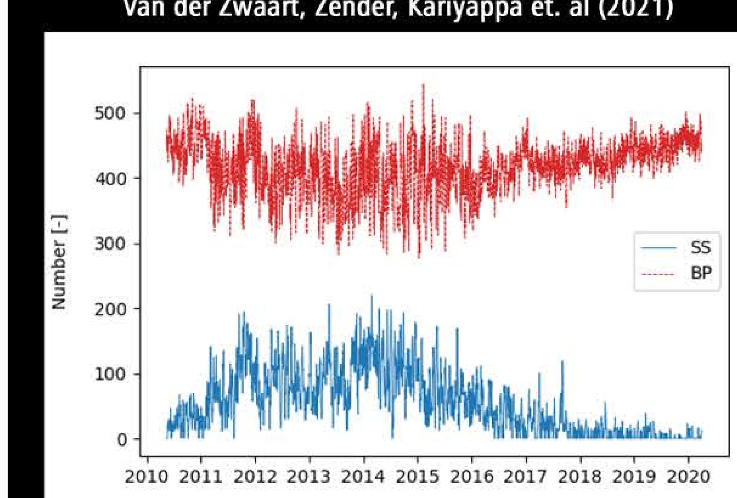
Orange:- XBPs in quiet background,
Grey:- Active region influenced area



1. XBPs in Full Disk

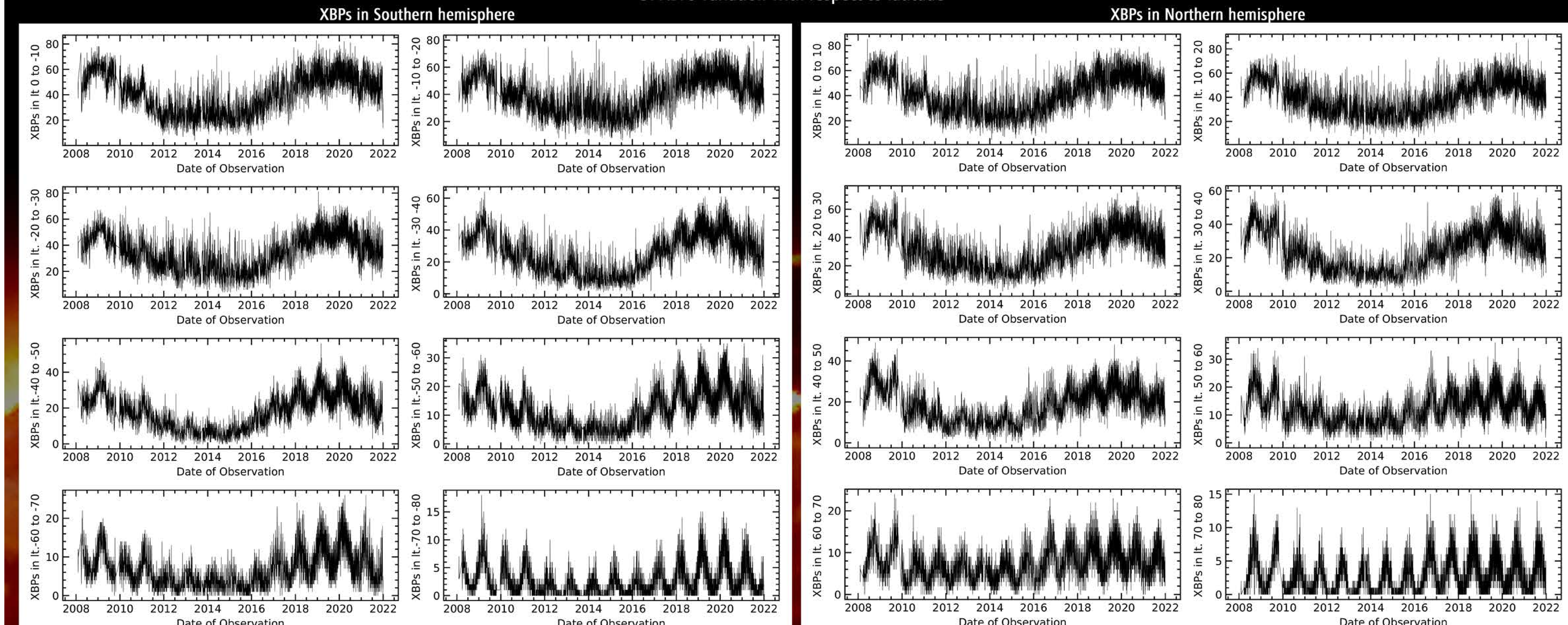


AIA 171 CBPs vs SSN
Van der Zwaart, Zender, Kariyappa et. al (2021)

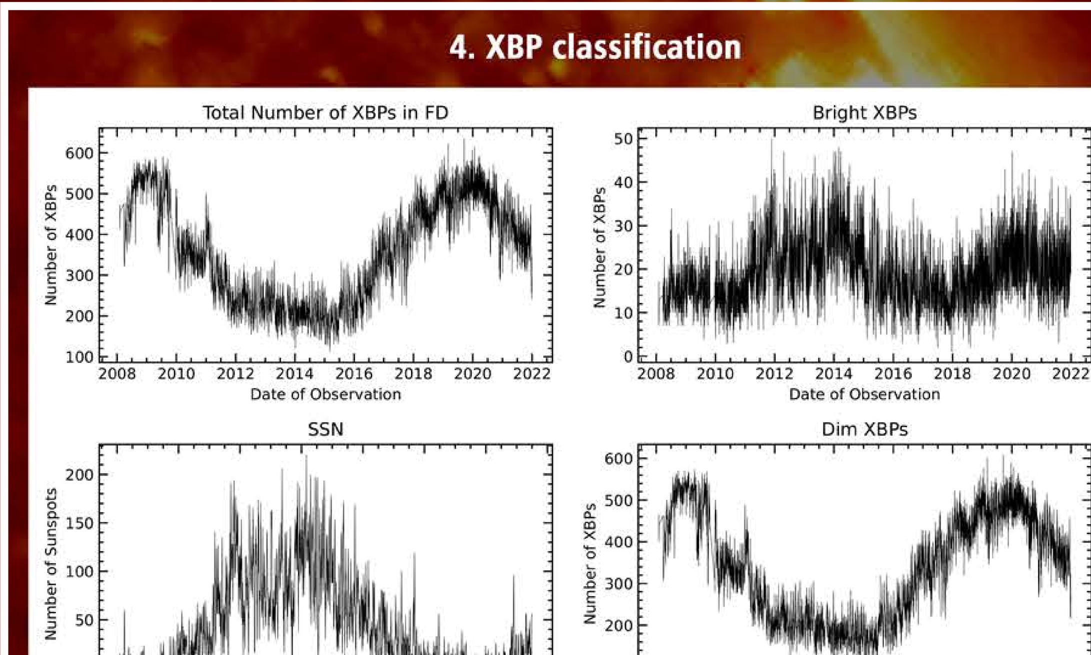


3. XBPs variation with respect to latitude

XBPs in Southern hemisphere | XBPs in Northern hemisphere



4. XBP classification



Results and Discussion

- Improved XBPs detection confirms that the number of XBPs are anticorrelated with SSN (R= -0.79) and the number density (XBPs per pixel) is also anticorrelated with SSN. Intensity of XBPs vary in phase with the SSN.
- XBPs number in the quiet background and the number density also showed an anticorrelation of XBPs with SSN (R=-0.83).
- XBPs number in all the latitudes show anticorrelation, there is no dependency of XBPs number to the latitude.
- Based on the intensity of XBPs, the XBPs are classified as Bright and dim XBPs. Dim XBPs are anticorrelated with SSN (R=-0.85) whereas bright XBPs appear to correlate with SSN (R=+0.28).

Related references

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Van der Zwaart, Zender, Kariyappa et. al 2021, Sol. Phy. 296, 138
Hara H & Nakakubo-Morimoto K, 2003 ApJ 589, 1062
Sattarov et. al 2010, Sol. Phy. 262, 321-335

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