NuSTAR Observations of the Quiet Sun

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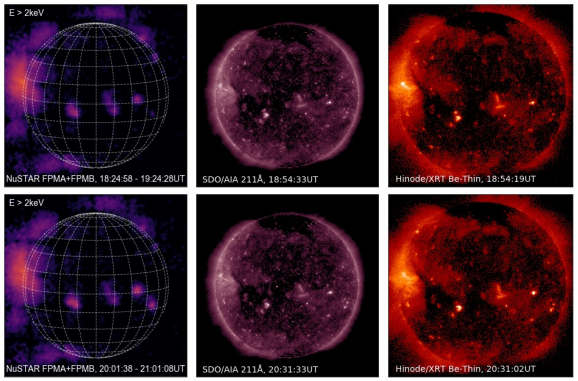
Summary

NuSTAR is a hard X-ray focusing telescope which, though designed as an astrophysics mission, can observe the Sun (Grefenstette et al., 2016). Using direct imaging, NuSTAR has a greater sensitivity in the HXR range than previous dedicated solar instruments. This sensitivity combined with the recent solar minimum has presented a unique opportunity to observe faint HXR emission from the quiet Sun. These observations allow for the properties of quiet Sun features to be determined, and their contribution to heating the solar atmosphere to be investigated.

In this poster, we present analysis from the 28 September 2018 NuSTAR full disk mosaics, including an overview of this observation (right), and detailed analysis of some of the features present. These include XBPs and bright emission from the limb (bottom left) and an emerging flux region (bottom right). Analysis of this and the other NuSTAR QS campaigns from the recent solar minimum is ongoing – see http://ianan.github.io/nsovr for overview summaries of all NuSTAR solar data.



The Sep 2018 NuSTAR Quiet Sun Mosaics

On 28 September 2018, NuSTAR observed the quiet Sun for 2 orbits (~1 hour each) to produce 2 full disk mosaics, each comprised of 25 pointings. The pointings overlap such that each feature can be observed up to 4 times in an orbit. The times of the orbits were 18:25-19:25UT and 20:01-21:01UT. Full disk data is also available from SDO/AIA and Hinode/XRT for this observation, with a comparison between the three instruments shown on the left.

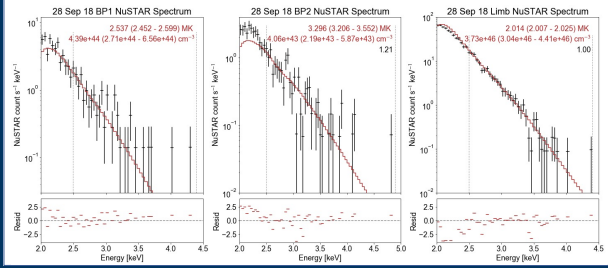
There are several bright features present in NuSTAR in each orbit, including X-ray bright points (XBPs) and bright emission from the limb. There is also an emerging flux region (EFR), which went on to become an active region (AR 12723β) a few days later. Several of the features change brightness over the course of the observation.

XBPs and Bright Limb Emission

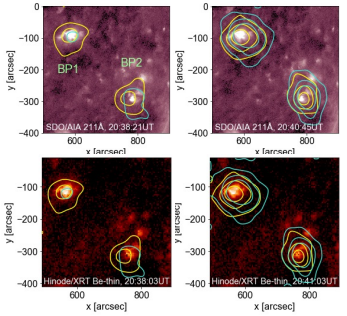
There are several features present in the September 2018 mosaics, including XBPs and bright emission from the limb. Two bright points are seen clearly in two pointings in orbit 2 (right). Both bright points appear brighter in the second NuSTAR orbit than in the first and, in both cases, this brightening is also observed in Hinode/XRT and SDO/AIA 211Å. The bright emission on the limb is observed by NuSTAR in both orbits (right).

With NuSTAR, the features' X-ray spectra can be fit to determine temperature and emission measure. XSPEC, an X-ray spectral fitting program, is used for the fitting, and these quiet Sun features' spectra are fit with a single APEC thermal model. For these faint QS features, the fits can be improved by fitting the spectra for multiple pointings simultaneously, assuming that the source does not change significantly between the pointings being used. Below, we present the spectral fits for these three features.

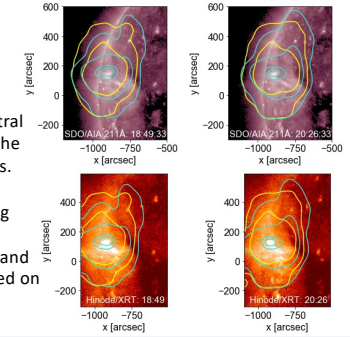
The fits give temperatures of 2.5 and 3.3 MK for BP1 and BP2 respectively, and 2MK for the emission from the limb.



NuSTAR spectral fits (left) for the three features. Dotted lines indicate fitting range and temperature and EM are marked on plots.



SDO/AIA 211Å and Hinode/XRT Be-thin images of the XBPs (above) and the bright limb emission (below), with NuSTAR FPMA (yellow) and FPMB (blue) contours

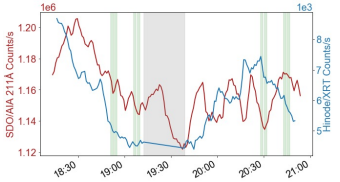


Emerging Flux Region

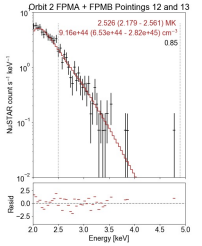
The EFR was captured 4 times by NuSTAR in both orbits, allowing its temporal evolution to be studied. The NuSTAR emission mainly originates from the central region in the Hinode/XRT images. The EFR is brighter in NuSTAR's second orbit, in agreement with the Hinode/XRT lightcurve for the central region (right).

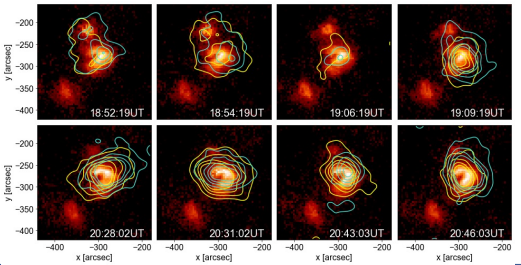
An example of a fitted spectrum from the EFR is presented on the right. This spectrum is from ~20:28UT, corresponding to a peak in the XRT lightcurve. The fit for this spectrum (also a single thermal model) gives a temperature of 2.5MK. From the fitted NuSTAR spectra for all of the NuSTAR pointing times, no significant change in temperature was found throughout.

Data from NuSTAR, Hinode/XRT and SDO/AIA are combined to recover the differential emission measure for this time, shown below.

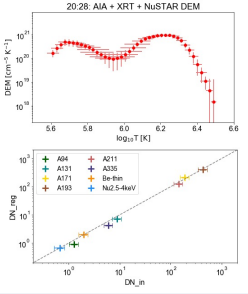


Hinode/XRT and SDO/AIA lightcurves, with NuSTAR pointings in green (above), and EFR NuSTAR spectrum (right)





NuSTAR FPMA (yellow) and FPMB (blue) contours on Hinode/XRT Be-thin (left)



EFR DEM (right)

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