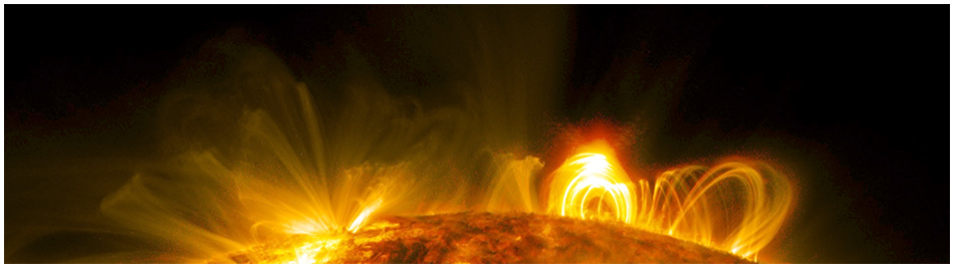

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# Hard X-ray upper limits of the quiet Sun with new FOXSI observations

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Solar nanoflares are small eruptive events releasing magnetic energy in the quiet corona. If nanoflares follow the same physics as their larger counterparts, they should emit hard X-rays (HXRs) but with a rather faint intensity. A copious and continuous presence of nanoflares would result in a sustained and persistent emission in HXRs, which in turn would deliver enormous amounts of energy into the solar corona, possibly accounting for its high temperatures. To date, there has not been any direct observation of such sustained and persistent HXRs from the quiescent Sun. However, Hannah et al. in 2010 constrained the quiet Sun HXR emission using almost 12 days of quiescent solar-off-pointing observations by RHESSI. These observations set $2\sigma$ upper limits at $3.4 \times 10^{-2}$ photons$^{-1}$ s$^{-1}$ cm$^{-2}$ keV$^{-1}$ and $9.5 \times 10^{-4}$ photons$^{-1}$ s$^{-1}$ cm$^{-2}$ keV$^{-1}$ for the 3-6 keV and 6-12 keV energy ranges, respectively. Observing feeble HXRs is challenging because it demands high sensitivity and dynamic range instruments in the HXR energy band. The Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket experiment excels in these two attributes when compared with RHESSI. Particularly, FOXSI completed its third successful flight (FOXSI-3) on September 7th, 2018. During FOXSI-3's flight, the Sun exhibited a fairly quiet configuration, displaying only one aged non-flaring active region. Using the entire $\sim$6.5 minutes of FOXSI-3 data, we constrained the quiet Sun emission in HXRs. We found $2\sigma$ upper limits in the order of $\sim 10^{-3}$ photons$^{-1}$ s$^{-1}$ cm$^{-2}$ keV$^{-1}$ for the 5-10 keV energy range. FOXSI-3's upper limit is consistent with what was reported by Hannah et al., 2010, but FOXSI-3 achieved this result using $\sim$1/2640 less time than RHESSI. A possible future spacecraft using FOXSI's concept would allow enough observation time to constrain the current HXR quiet Sun limits further or perhaps even make direct detections.

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