Microflares in active region cores

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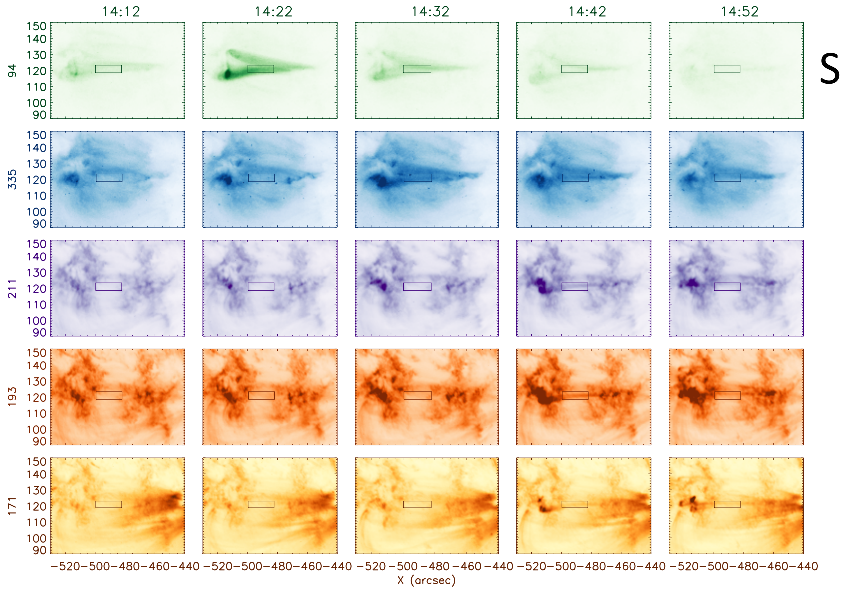
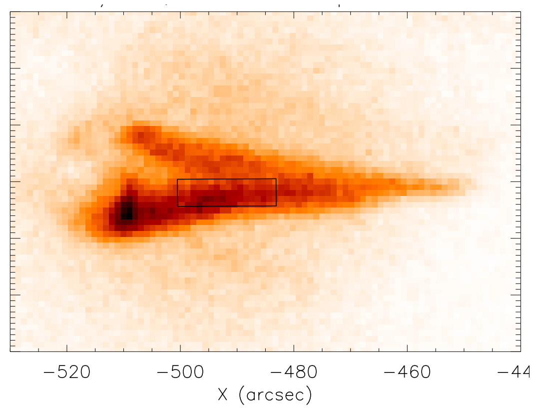
Microflares (GOES class A or below) mostly occur in active region cores and are recurrent. What is their contribution to AR heating? Are they scaled-down versions of larger flares? What are the maximum temperatures? Is there non-thermal emission?
Few spectroscopic observations are available. Hinode XRT and EIS indicate that flare loops have low isothermal temperatures (4—8 MK) and drain quickly (10 min), **see Mitra-Kraev & Del Zanna (2019, A&A, 628, A134).**
However**,** EIS lacks spectral lines at 5-10 MK, so we need X-ray or soft X-ray observations.

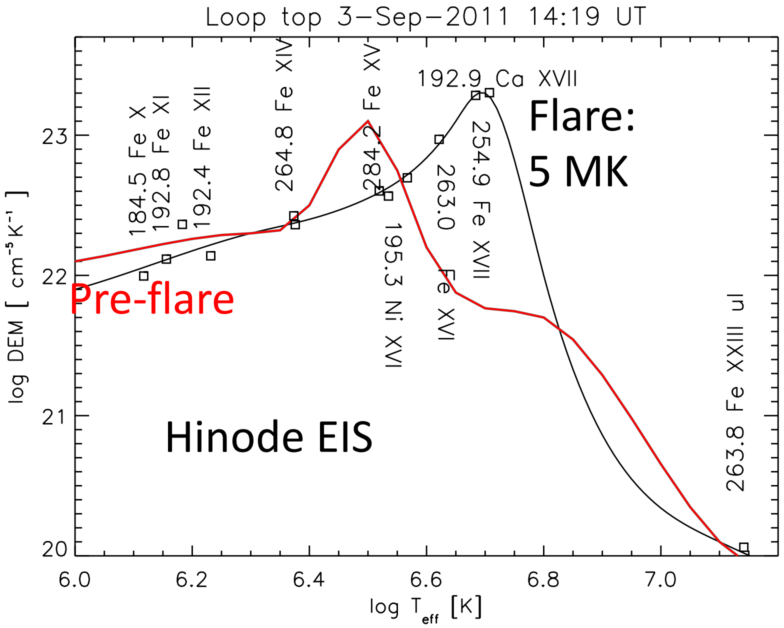
- Little info from earlier full-sun X-ray spectra (SPHYNX)
- NuSTAR has provided some info (on a few cases) on EM, T (in the range 4-10 MK) and non–thermal emission only in some cases (cf. Hannah+2019, Cooper+2020, Duncan+2021)



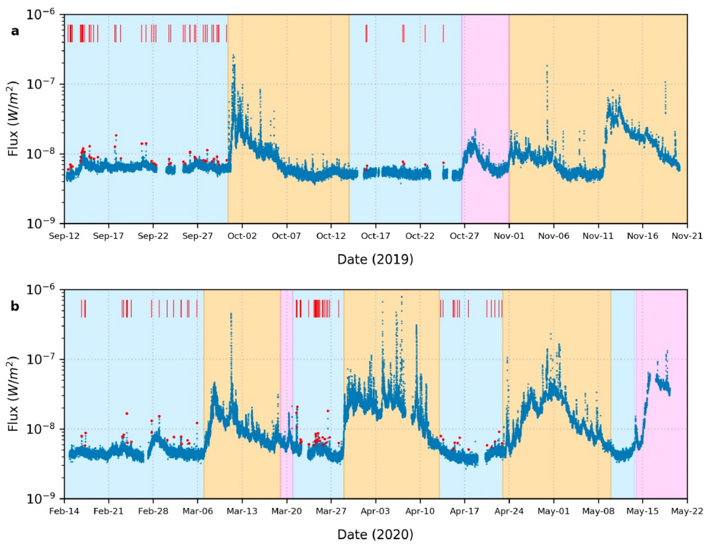
SDO AIA

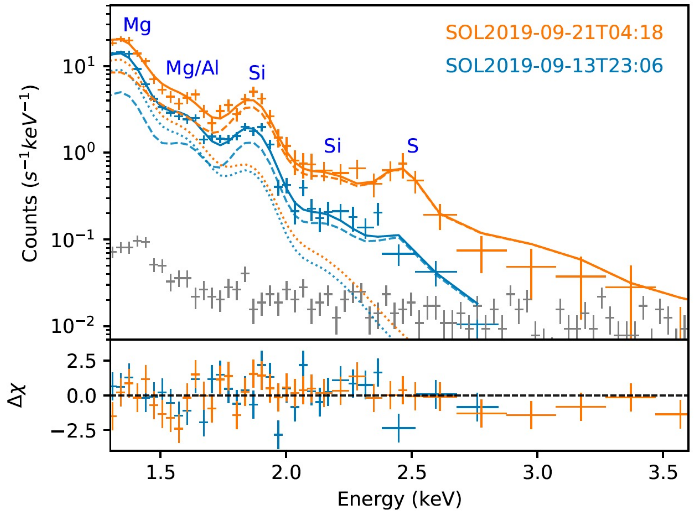


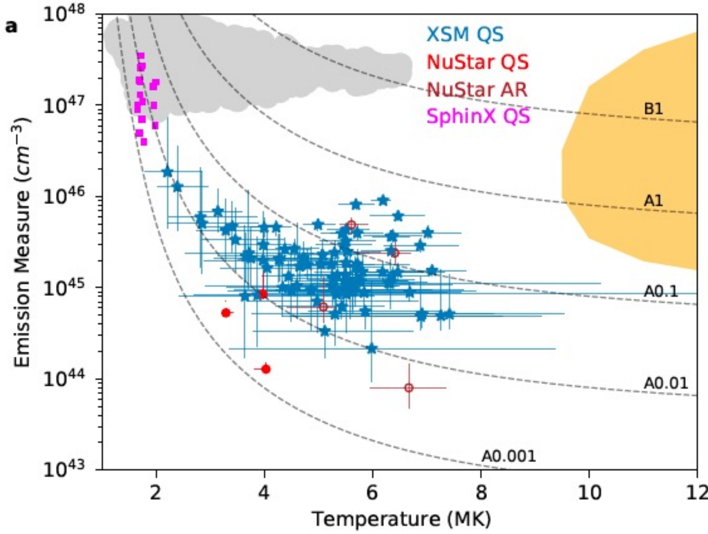
Hinode XRT



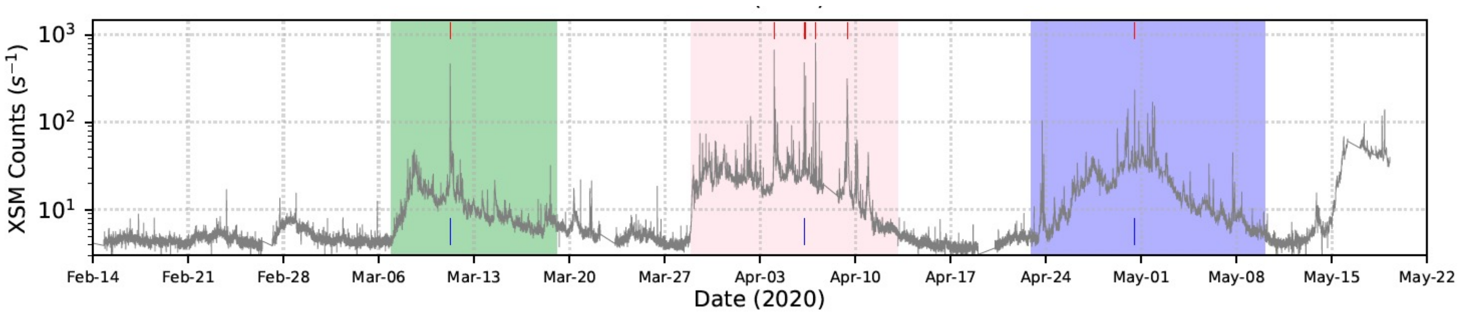
The X-ray Solar Monitor (XSM) on Chandrayaan-2 has been providing spectra with a sensitivity higher than GOES (similar to SPHYNX and NuSTAR), and has enough spectral resolution to allow absolute measurements of chemical abundances of Si, S, Mg, Al. XSM discovered many sub A-class flares in the quiet Sun (outside ARs) during the 2019-2020 solar minimum. **See Vadawale+2021, ApJ,912,1,L13 and https://www.prl.res.in/ch2xsm/ (lightcurves)**



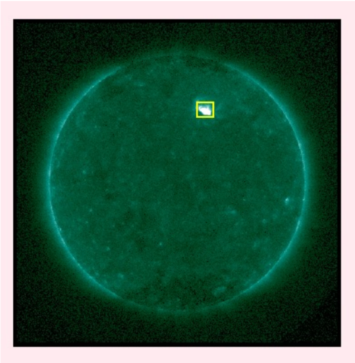




We have analysed several AR B-class flares (**Mondal+2021, ApJ, in press**). We focus here on the microflares in Apr 2020, during the disk passage of AR 12759, an isolated AR.

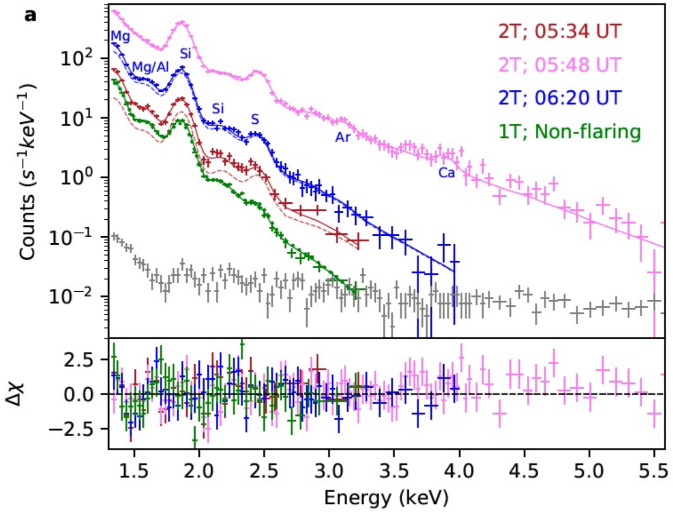


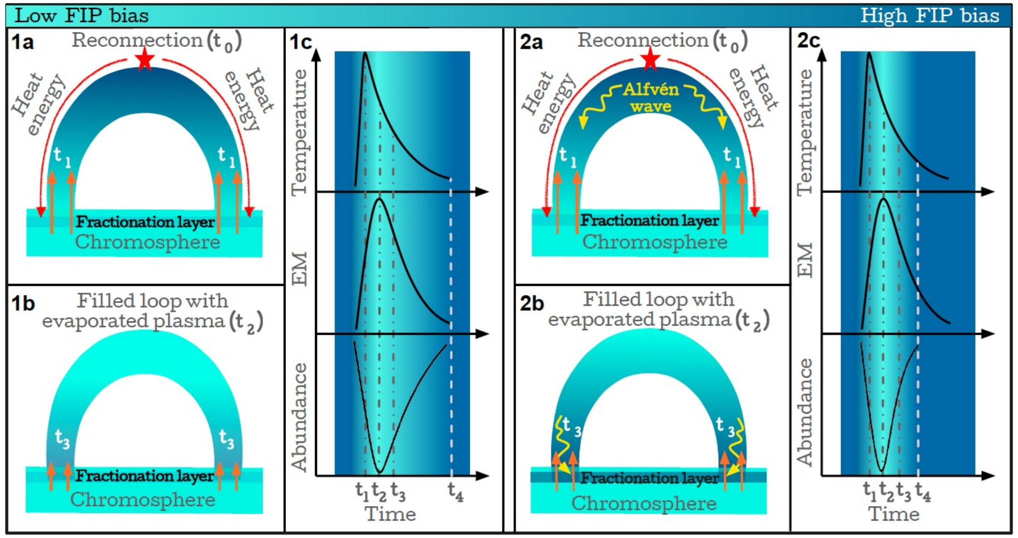
AIA 94 Å - AR 12759

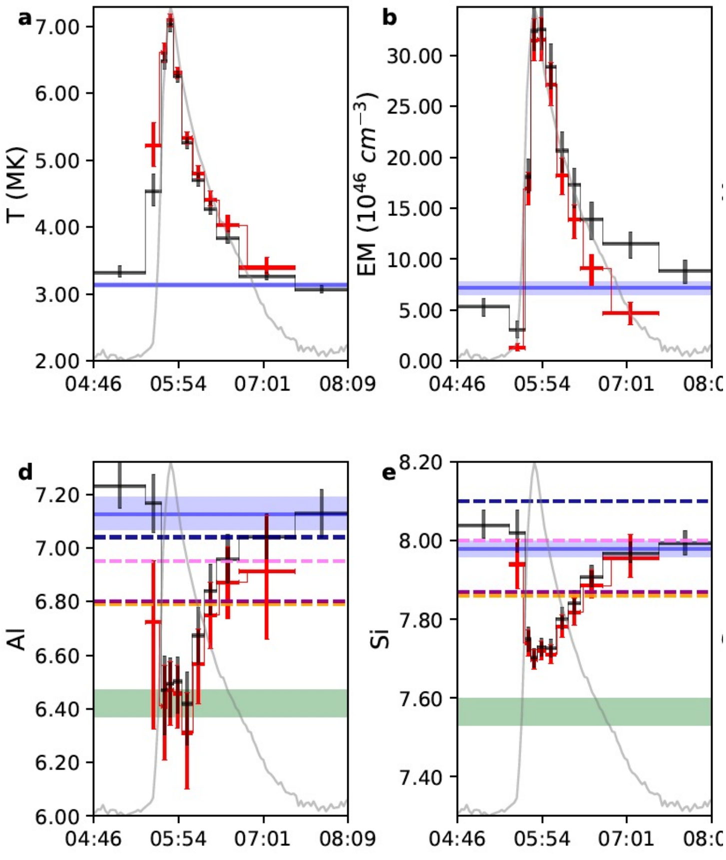


Hinode EIS observations show that the AR 12759 core had stable temperatures (~3 MK) and chemical abundances of low-FIP elements (Fe, Si) increased by a factor of 3.2, compared to photospheric values (and relative to the abundances of high-FIP Ar, S) (**Del Zanna+2021, in prep**). These results are consistent with those of Del Zanna+ 2014,A&A, 573, A104, and Del Zanna (2013,A&A,558,A73), see also Del Zanna & Mason, 2018, Living Reviews 15,5. All the AR 12759 B-class flares showed peak temperatures around 6—9 MK (**Mondal+2021**).
No EIS data were available. XRT and AIA did not provide reliable results because of various issues.

For the first time, variations in chemical abundances were seen in all the flares by XSM, varying from coronal values to nearly photospheric during the peak X-ray emission, to then return to coronal values. This provides new constraints for models of the FIP effect such as those of M. Laming (S.P. Living Reviews, 2015,12,2). Two possible scenarios are proposed, although further studies are needed.







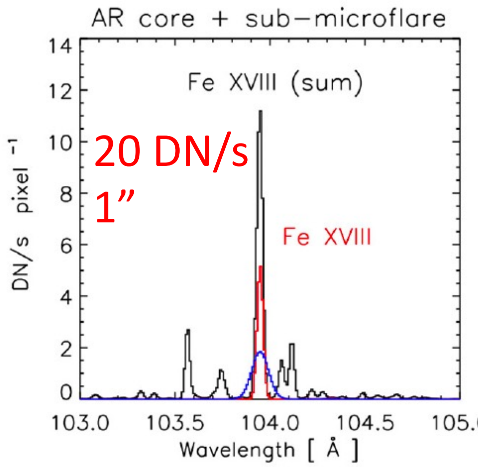
To study heating in ARs and microflares, we need high-resolution spectroscopy of lines in the 5—10 MK range (hotter than Fe XVIII) with at least 1” spatial resolution. **See the review by Del Zanna+2021 (Frontiers in Astronomy and Space Sci. 8,33).**

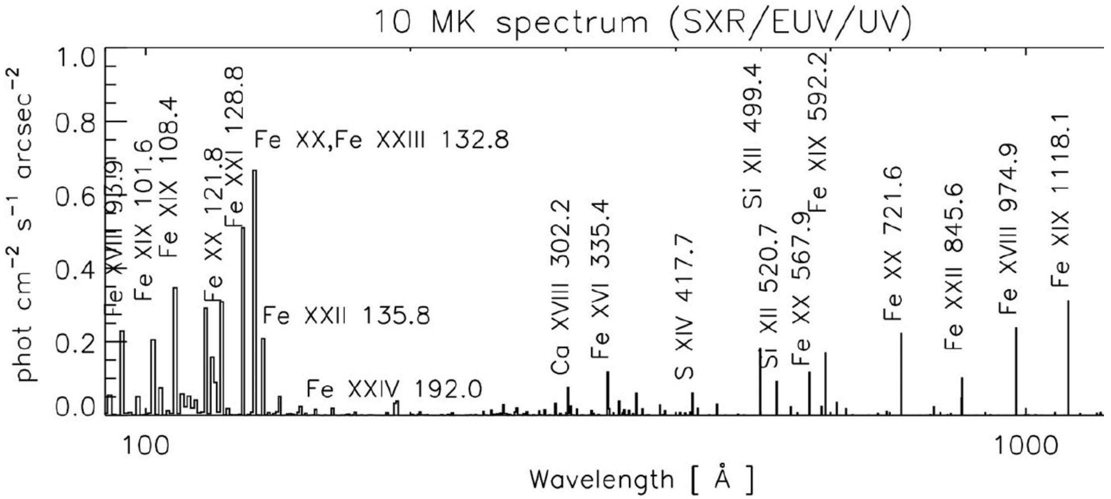
- MaGIXS (launch 30 July 2021) : first imaging spectrometer in the X-rays
- EUNIS (May 2021): first imaging spectrometer in the soft X-rays.
- MUSE: limited to Fe XIX 108.36 Å and Fe XXI 108.12 Å
- SOLAR-C/EUVST: great for lots of science, with strong hot lines from Fe XIX, Fe XX but no density in hot lines.

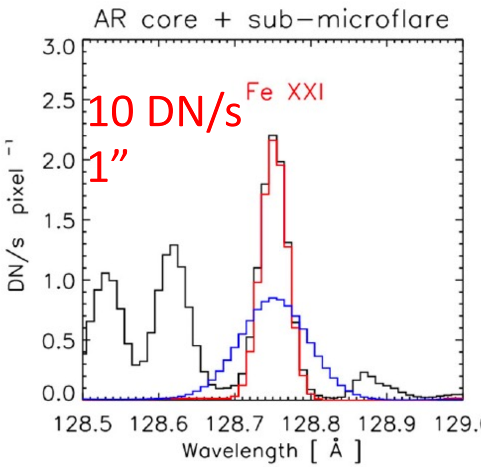
All the above have some limitations in their diagnostics or sensitivity, and a new instrument is proposed with the following characteristics:

- A compact 20-cm soft X-ray (100-150 Å) spectrometer with newly designed multilayers can
  * measure at 1” hot line profiles with 10 s exposures even for a 0.005 A-class microflare !
  * measure densities of high-T plasma from line ratios;
  * observe six ionisation stages of Iron (Fe XVIII-Fe XXIII) to study time-dependent ionisation.
  Is much less affected by EUV absorption, significant below 912 Å

0.005 A-class microflare







Acknowledgements:
The XSM was mainly developed at PRL, while Chandrayaan-2 is funded by ISRO.
Research at PRL is supported by the Department of Space, Govt. of India.
We acknowledge funding from STFC (UK) and the Royal Society (international exchanges grant).