EM Maps of a Two-Ribbon Flare

Iain Hannah and Lyndsay Fletcher

SUPA School of Physics & Astronomy, University of Glasgow

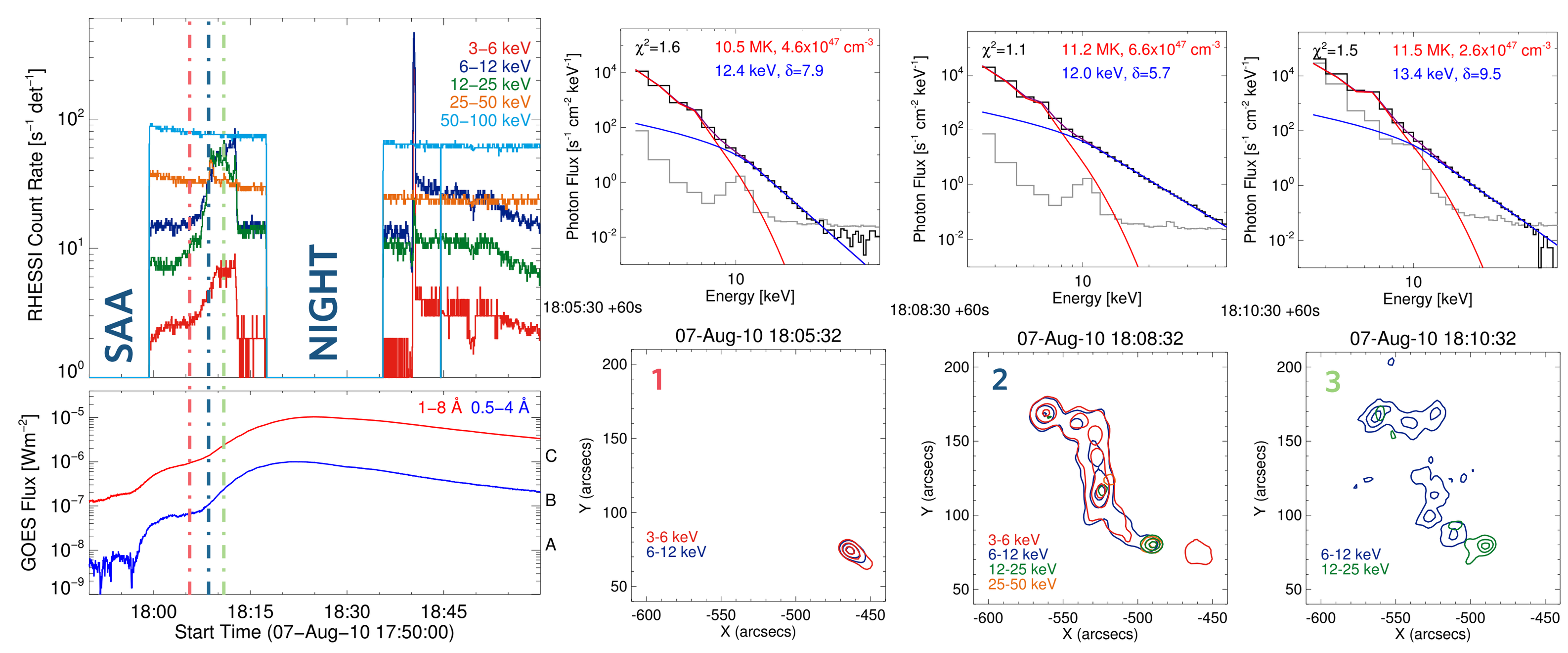
University of Glasgow

Overview:

The current wealth of solar observations presents a unique opportunity to study energy release in solar flares, particularly particle acceleration and plasma heating. The spatial and temporal resolution of SDO/AIA EUV data give an unprecedented view of dynamical response of the solar atmosphere to flares yet to fully exploit this resource the underlying thermal properties of the emitting plasma needs to be recovered. This is difficult as it is an ill-posed inverse problem and there is copious data. Our recently implemented regularized inversion method (Hannah & Kontar 2013) can quickly and robustly find the Differential Emission Measure (DEM) solution (and its uncertainties), with the resulting EM maps allowing the temperature and density evolution to be studied both spatially and temporally. Combing this with the hard X-ray imaging and spectroscopy of RHESSI, we present a study of the energetics in the early stages of a two-ribbon M-class flare SOL2010-08-07T18:24, some of which was recently published (Fletcher et al. 2013). We also look at the relationship between the heating and the underlying magnetic field configurations.

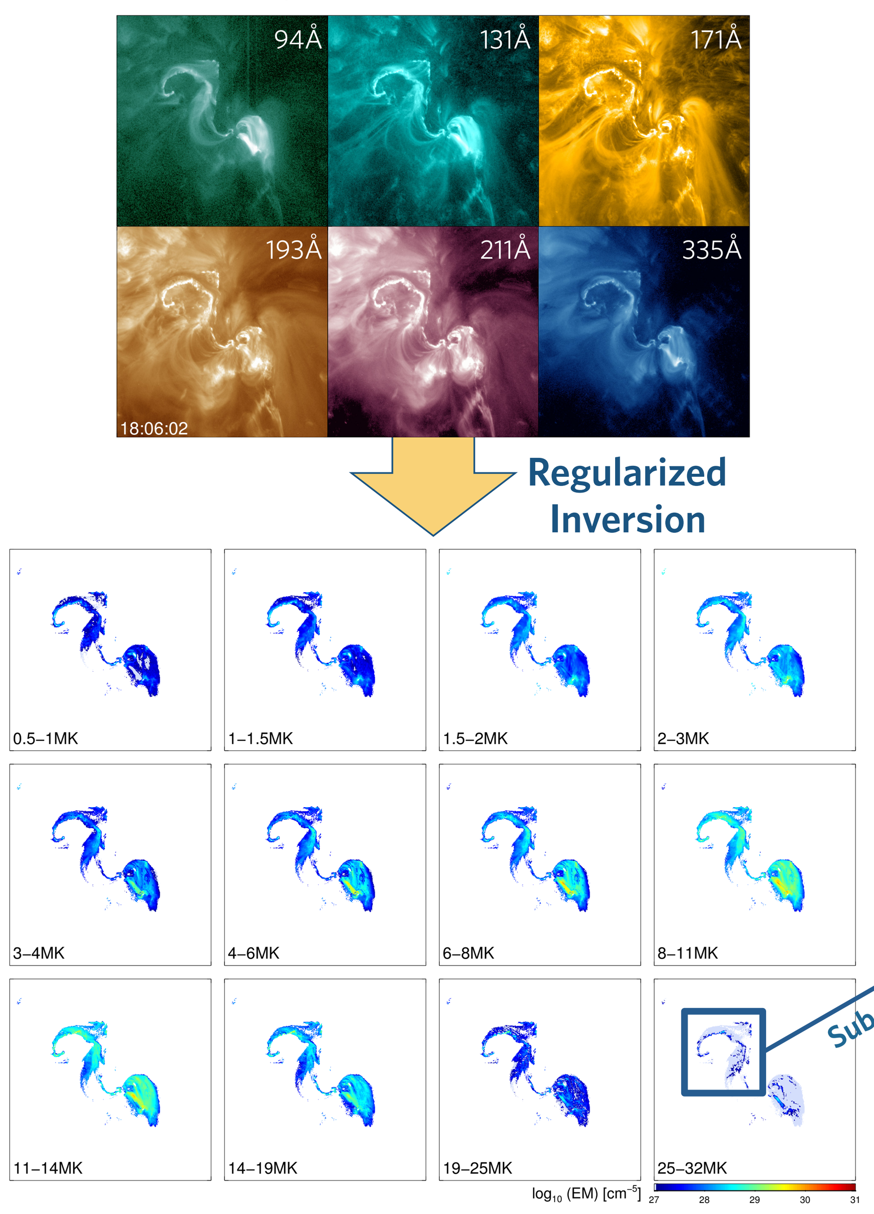
X-rays from RHESSI & GOES:

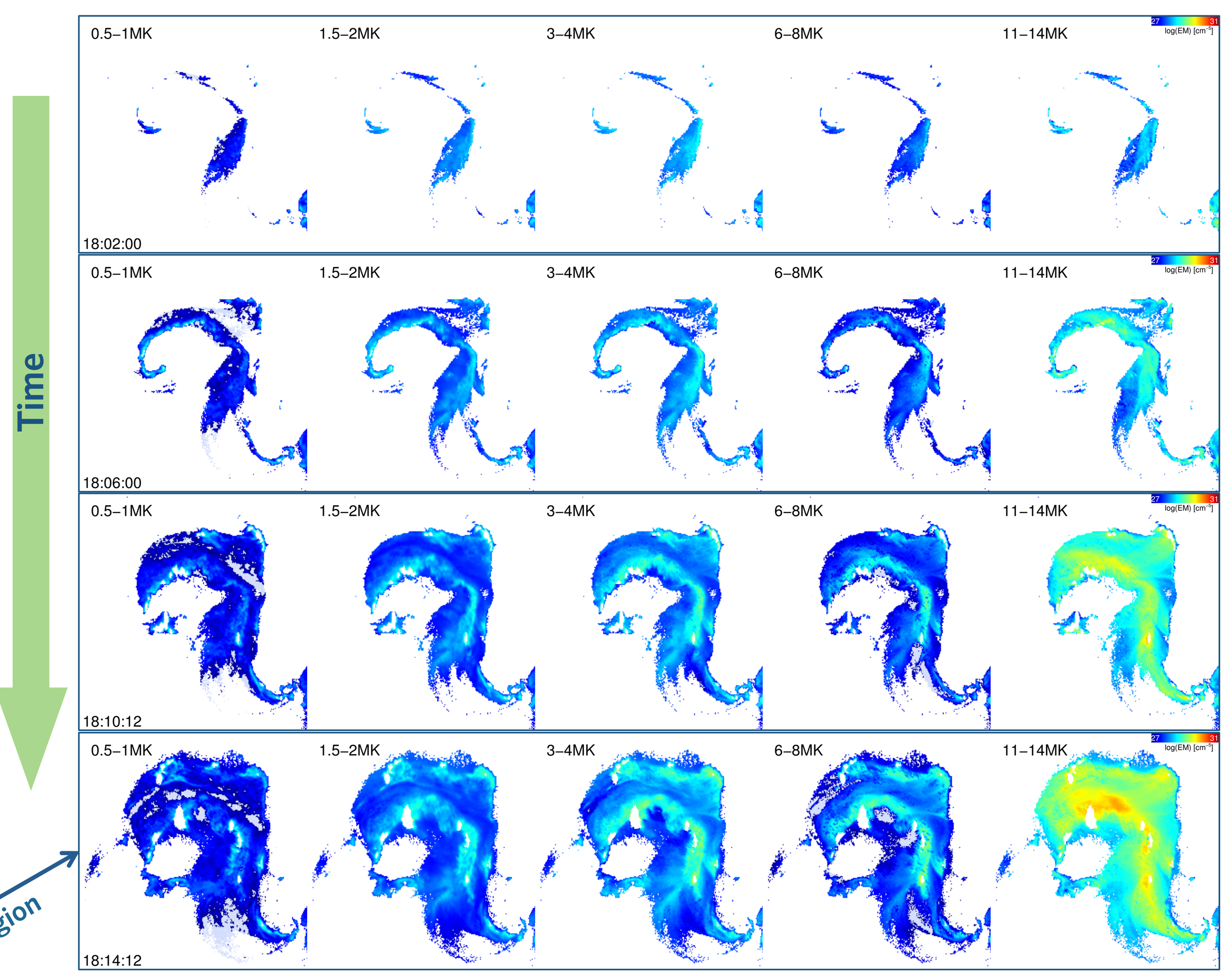
At the start of the flare the RHESSI X-ray emission is concentrated at the lower right (-460,75) before developing a bright region to the left (-490,80) as well as an extended ribbon which is visible until RHESSI enters eclipse. From fitting the RHESSI spectra we find thermal emission of around 11 MK and 10^{47}cm^{-3} and non-thermal power of about 10^{27} to 10^{28} erg s^{-1}.



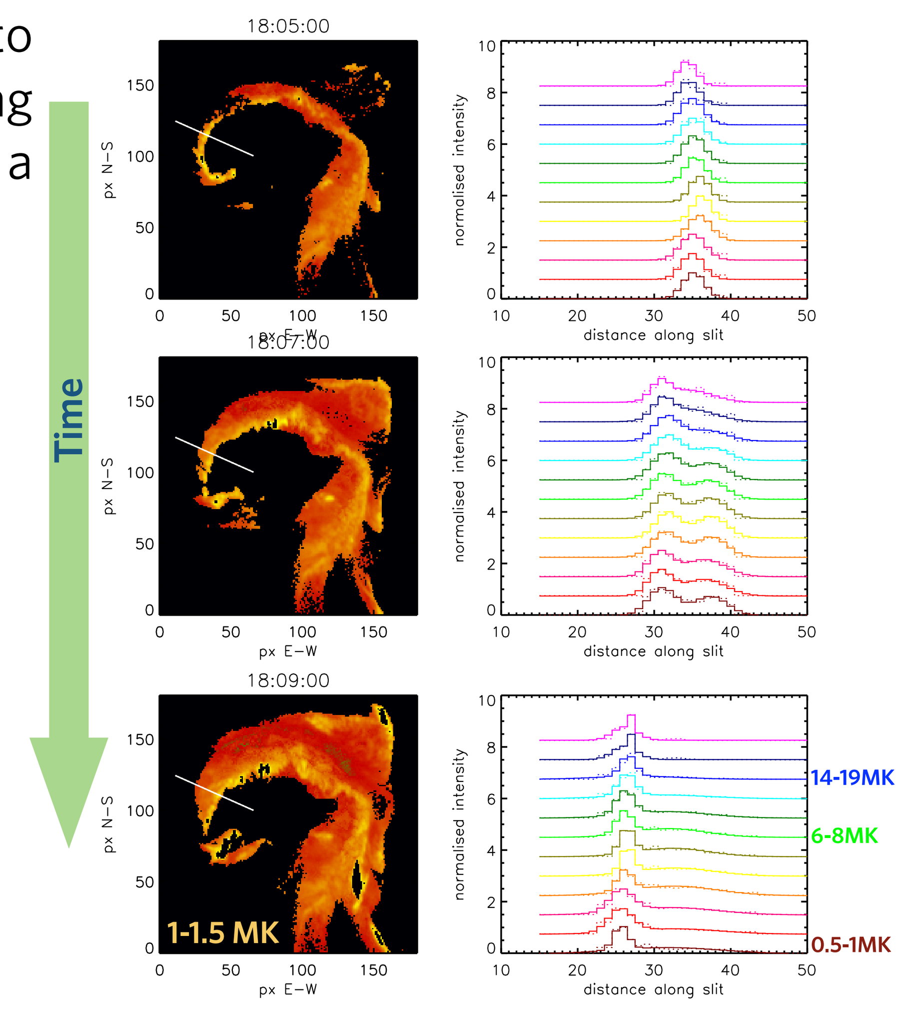
EM Maps from SDO/AIA:

To study the heating of the ribbons, and taking advantage of SDO/AIA's multi-filter EUV images, we want to produce Emission Measure EM(T) distributions for each pixel location and time. We solve the resulting inverse problem using a regularized approach (Hannah & Kontar 2013, code available online$^{\$}$) as it provides a fast method, requires no EM model form and provides uncertainties on the regularized EM.





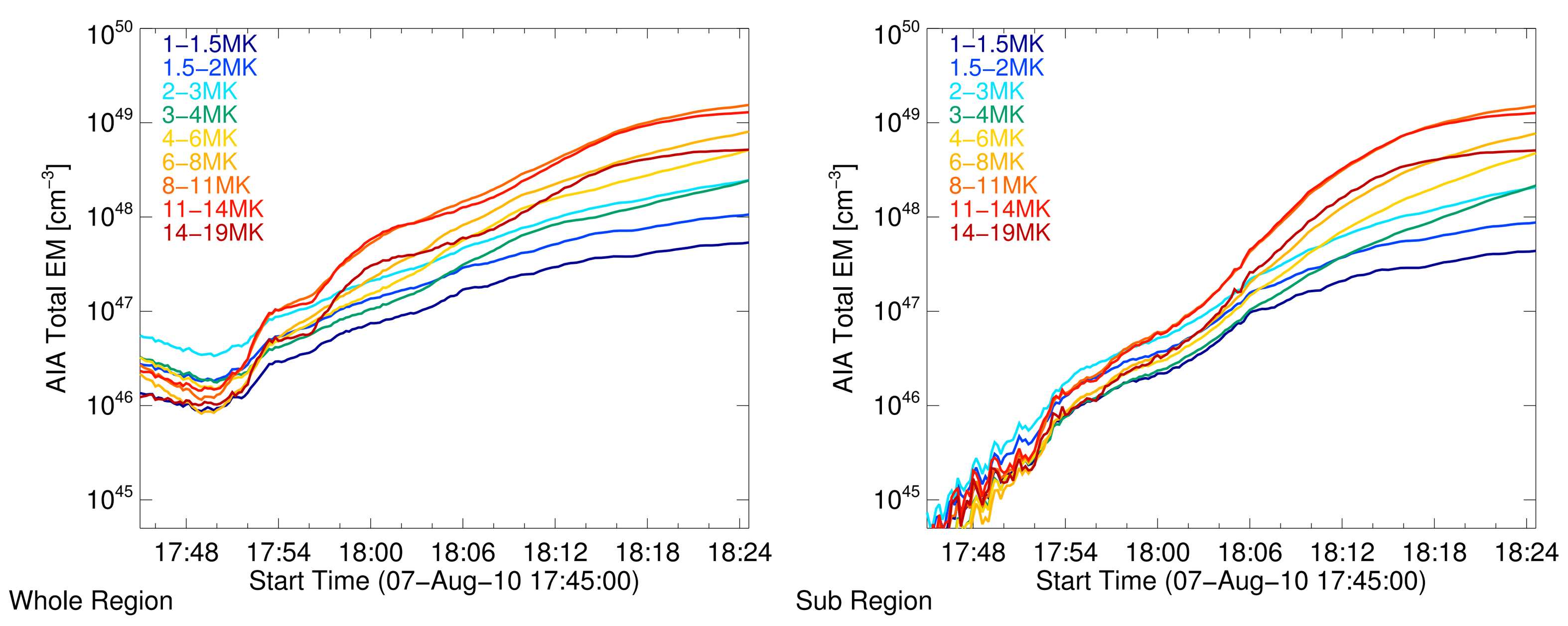
Time evolution of the top-left ribbons in five of the twelve EM temperature bins. (White is no EM calculated as either saturated or poor SNR, grey/blue is below range)



The EM profile through the ribbon for different temperatures and times, showing the motion and spread of the ribbon. (*Right* 1-1.5 MK EM map; *Left* EM profile for each T from bottom coolest to top hottest)

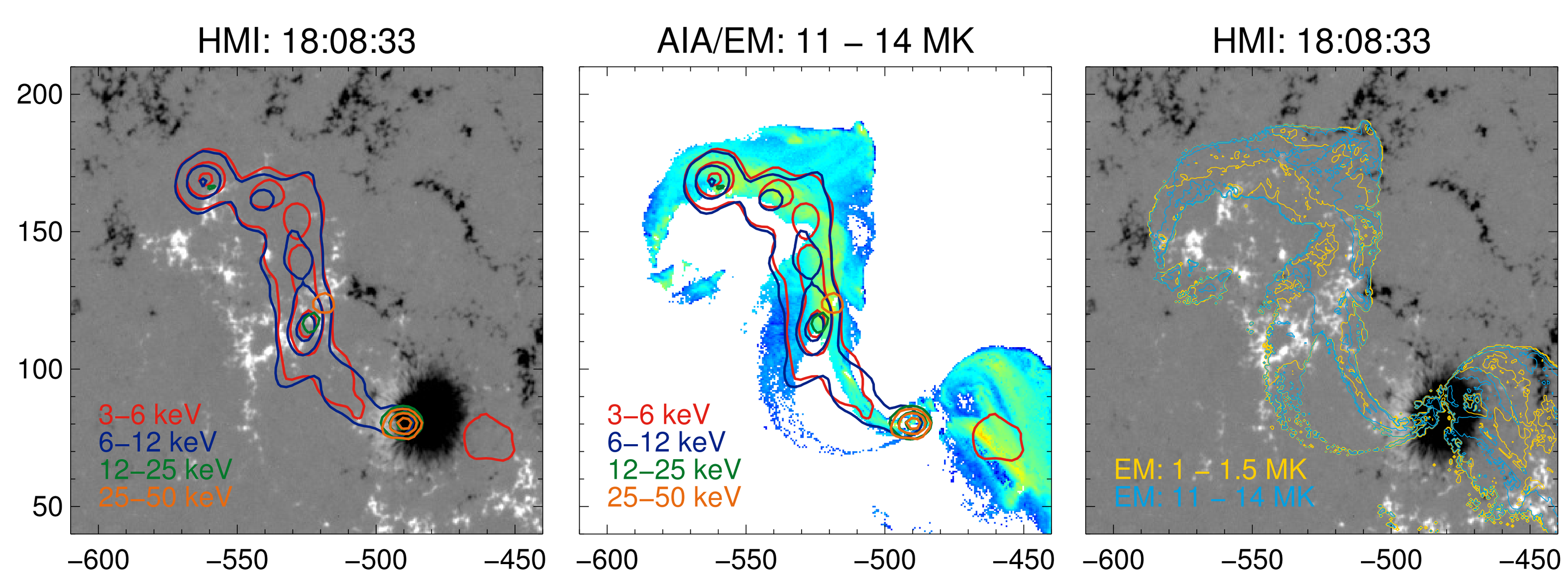
EM Time Profiles:

We can produce the time profile of the EM as a function of temperature for both the whole region of the flare as well as the sub-region of the top-left ribbons (as shown in the middle panels above). As expected the hottest emission rises first and peaks before the cooler emission, showing the ribbons heating up first the cooling down. (NB: the profiles do not include EM from saturated pixels)



Comparison of EM, X-rays & Magnetic Field:

The strongest HXR and EM emission is located at the bottom right near a strong field region, however the emission from the extended ribbon does not seem to be correlated to the photospheric line-of-sight magnetic field (from SDO/HMI).



Refs: Hannah & Kontar A&A 553 2013, Fletcher et al. ApJ 771 2013

This work is support by the Royal Society and STFC.

$^{\$}$The EM map code: http://www.astro.gla.ac.uk/~iain/demreg/map

Contact: iain.hannah@glasgow.ac.uk