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Pixon Reconstruction and the Masuda Event of 1992 January 13

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Abstract. An important set of observations in the search for signatures of magnetic reconnection in the solar corona has been that of localised hard X-ray sources observed by the *Yohkoh*/HXT. These data have been analysed using Maximum Entropy Methods (MEM) to reconstruct HXT images. Recently, an alternative method, that of Fractal Pixon Reconstruction, has been developed for use with the HXT. In particular, we have reanalysed the event of 13 Jan 1992 (*the Masuda event*), comparing the MEM and pixon methods. Our results are presented here. There are distinct differences in the two sets of results. The pixon method, which we favour, indicates a less impulsive coronal source than the MEM reconstruction and also a relatively weaker coronal/footpoint emission ratio.

1. Introduction

Reconstructing images from data collected by the bi-grid modulation collimators of HXT (Kosugi et al., 1991) is particularly difficult and requires the use of non-linear methods to obtain the best results. A method using a Maximum Entropy technique has been successfully applied to HXT solar flare data (Sakao, 1994) while a pixon based reconstruction approach has been developed by Metcalf et al. (1996). The results from these two approaches are significantly different and a careful comparison is necessary.

Both the PIXON and the MEM approaches apply the Bayesian method of logical inference (see Loredo, 1989) to reconstruct an image from the noisy and sparse HXT data. These non-linear techniques share much in common. However, the key difference between them lies in how they deal with the number of degrees of freedom. This is particularly important when the data are sparse. While MEM assumes no correlation between the individual pixels and therefore has 64 x 64 degrees of freedom (the typical size of an image), PIXONS minimises the degrees of freedom by creating a *pixon map* where the individual pixon sizes vary to accommodate the information content in the data (the more information at a given location, the smaller the pixon size there). For a typical HXT image the number of degrees of freedom in the PIXON approach is around 100, comparable to the number of data points.

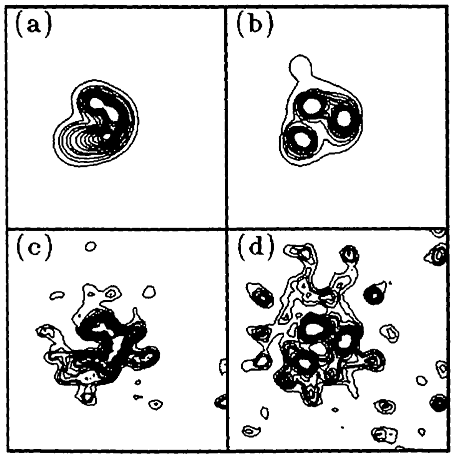

Figure 1. Comparison of PIXON and MEM calculations for the LO and M1 channels. Contour maps for the LO and M1 channels produced with PIXONS are shown in (a) and (b) while the corresponding MEM maps are shown in (c) and (d).

Figure 1 shows a comparison between the PIXON and the MEM approach for the event of 13 Jan 92. This event has been well studied by Masuda and colleagues using MEM (Masuda et al., 1994) and Gaussian methods (Masuda et al. this proceedings). The PIXON approach has some advantages over these methods but there is still considerable debate over the best way to analyse HXT data. In comparing the PIXON and MEM techniques we have tried to keep as many parameters in common as possible.

It is clear from Figure 1 that better photometry is achieved using PIXONS; most of the emission is concentrated in the strongest sources. In each case the emission shown is regarded as statistically significant by the method used. We regard the lack of spurious sources in the PIXON approach to be a distinct advantage over MEM. The result of this is that the coronal component of this event is considerably weaker relative to the footpoint emission than has been previously claimed.

2. Temporal Variation of the Hard X-Ray Emission

To study the dynamical nature of the hard X-ray emission in the event of 13 Jan 92, we considered three separate spatial regions of the flaring structure. The three regions chosen include the north footpoint, the south footpoint, best observed in the higher energy channels, and a coronal region which incorporates the coronal source emission. These were analysed using the PIXON approach. The light curves for each of the chosen regions show several interesting features:

1. The impulsive nature of the footpoint emission is very clear in all channels.

2. The gradual thermal rise of the loop top is evident in the LO channel and at late times in the M1 channel (see below).

3. There is little evidence for impulsive behaviour in the coronal emission during the peak of the event.

4. Early in the event (around 17:27) the coronal emission in M1 and M2 appears to be impulsive in nature mirroring the impulsive signal of the north footpoint.

5. Late in the event (around 17:29) the coronal emission in M1 appears to be thermal in nature, behaving similarly to the LO channel emission

3. Relative Strength of Coronal Emission

One important difference between the PIXON approach and that of MEM is in the relative importance given to weak sources. The nature of the MEM approach, viz. the assumption of a flat image, means that it takes no account of the spatial association of the individual sources present. In maximising the entropy, within the constraints of the data, MEM will tend to overemphasise weak sources at the expense of the stronger sources. With PIXONS, on the other hand, this contamination is largely avoided since the relative spatial locations of the individual sources are considered.

For HXT M1 channel observations of the 13 Jan 92 flare, there is a very bright source and a very faint source in the same field of view (footpoint vs. coronal emission). Although the two sources are spatially distinct, the entropy term in MEM will tend to drive the two sources to have the same intensity. The data, on the other hand, will tend to drive the sources to have different intensities. The compromise reached between these two competing mechanisms will be determined by the level of noise in the data. This problem is circumvented to some degree in the PIXON approach because the pixon map allows for the spatial location of the emission to be considered. The result is that the relative strengths of faint to bright sources are significantly different in the two methods.

Figure 2 shows a comparison of the footpoint to coronal emission in the M1 channel for both the PIXON and MEM approaches. At the peak of the event, MEM would suggest that the coronal emission is very strong, some 13% of the total footpoint emission, while the PIXON approach would suggest a much lower figure, around 3%. The extent to which the contamination of faint sources by strong sources is avoided in the PIXON approach is still under investigation.

4. Conclusions

1. The nature of the PIXON approach makes it a more appropriate technique for reconstructing images from the HXT data than MEM.

2. The coronal source seen in the M1 channel is significantly weaker than previously thought and does not appear to be impulsive.

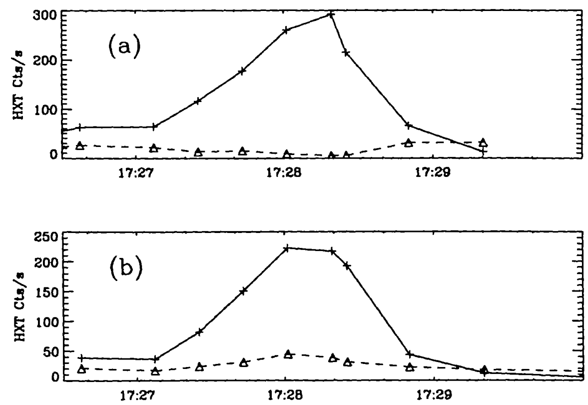

Figure 2. Comparison of footpoint to coronal emission in the M1 channel using both (a) PIXON and (b) MEM approaches.

3. The non-impulsive nature of the coronal source and the existence of coronal emission early in the event suggest a model more akin to that of Takakura et al. (1993) than that presented by Masuda et al. (1994).

Events like the one studied here are important for investigating the role of reconnection in energising the solar corona. The presence of hard X-ray emission in the low density corona in the early stages of the energy release severely constrains any model of the flaring corona. The nature of the HXT makes image reconstruction a major issue in the analysis and interpretation of the data. It is clear from this work that the results are method dependent and currently tests are underway to determine which technique is most effective.

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Flare Theory