Coronal Hard X-ray emission in a partially occulted solar flare

Laura Bone, John C. Brown, Lyndsay Fletcher

Department of Physics and Astronomy, University of Glasgow, University of Glasgow, Glasgow G12 8QQ.

1. Introduction.

On 20th July 2002 an X3.3 flare occurred in active region 0039 then behind the Suns east limb. The occultation height was estimated to be 11000km (Kane et al.). The flare was observed simultaneously by RHESSI and Ulysses, which was behind the east limb. From these observations we can infer that the coronal component of the hard x-ray flux is a significant fraction of the total hard x-ray flux between 25-150KeV. The flare was also observed by Owens Valley Solar Array

2.Observations.

Both imaging and spectral information were available. The RHESSI images show what appears to be an arcade of flaring loops on the east limb. In this event the footpoints are occulted but we still see emission to >100keV from the looptops. When the RHESSI counts from 25-150keV are compared to those from Ulysses we see that the >25keV emission from the unocculted portion of the flaring loop accounts for on average 15% of the emission.

The emission observed by OVSA is mostly linearly polarised indicating gyrosychrotron emission, with a peak frequency, at the maximum of the flare of 10.6GHZ. The maximum flux at this temperature is ~10^4 SFU. Complementary multiwavelength data was also available in Hα and EUV. From these Hα observations we can clearly see an arcade of loops rising over the solar limb (fig.2).

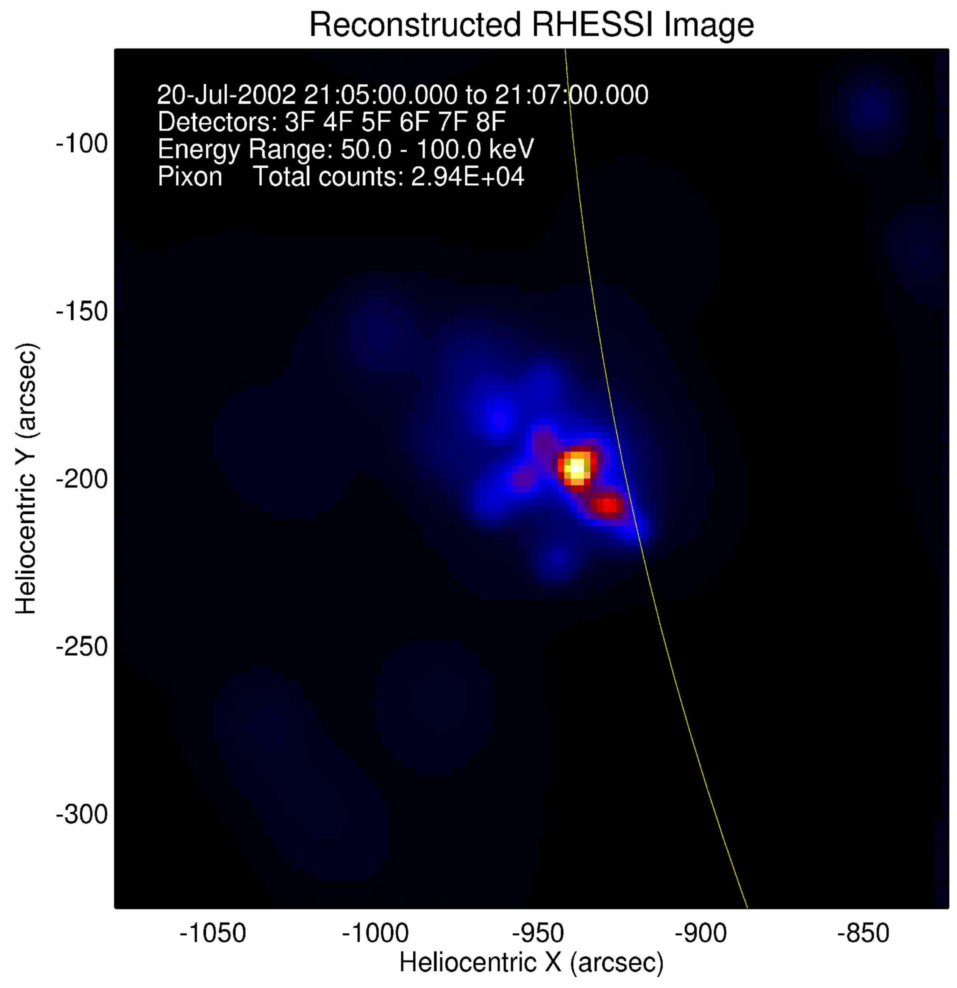

Fig. 1 looptop emission imaged by RHESSI at 50-100KeV

3. Modelling

We approximated the volume of flaring plasma to a cuboid of sides ~2.0e9 cm, which we estimated from the RHESSI images, we can estimate a plasma density from the GOES differential measure (n^2V=2.8e50cm^{-3}). This gives us a value for the plasma density of 1.8e11cm^{-3}. Densities are already rather high at the onset of flaring (0.5e11cm^{-3}).

We assume that the same population of electrons gives both the hard X-ray and radio emission. We use a model for an inhomogeneous non -thermal radio source (Dulk and Dennis, 1982, Dulk & Marsh 1982) to analyse the gyrosychrotron emission. Using the spectral index obtained from the radio spectrum δ=3.13 (fig.4) , this gives us a rather high ~500G magnetic field, and we derive an ambient density of 8.0e11cm^{-3}, assuming E_0 >10keV . The amount of material that can be evaporated by direct beam driven evaporation is given by;

$$N_{\rm beam}\ ({\rm cm}^{-2}) \simeq 8.2\times10^{19}\left[7.7\times10^{-12}B\left(\frac{\delta}{2},\frac{1}{3}\right)(\delta-2)\frac{P_{(25)}}{A}p\right]^{\frac{2}{\delta+2}}$$

Kontar et al. (2003) and conductive evaporation is given by a Rosner, Viana and Tucker scaling law (1978);

$$N_{\rm cond}\ ({\rm cm}^{-2}) \simeq 1.4\times10^{20}T_7^2\,.$$

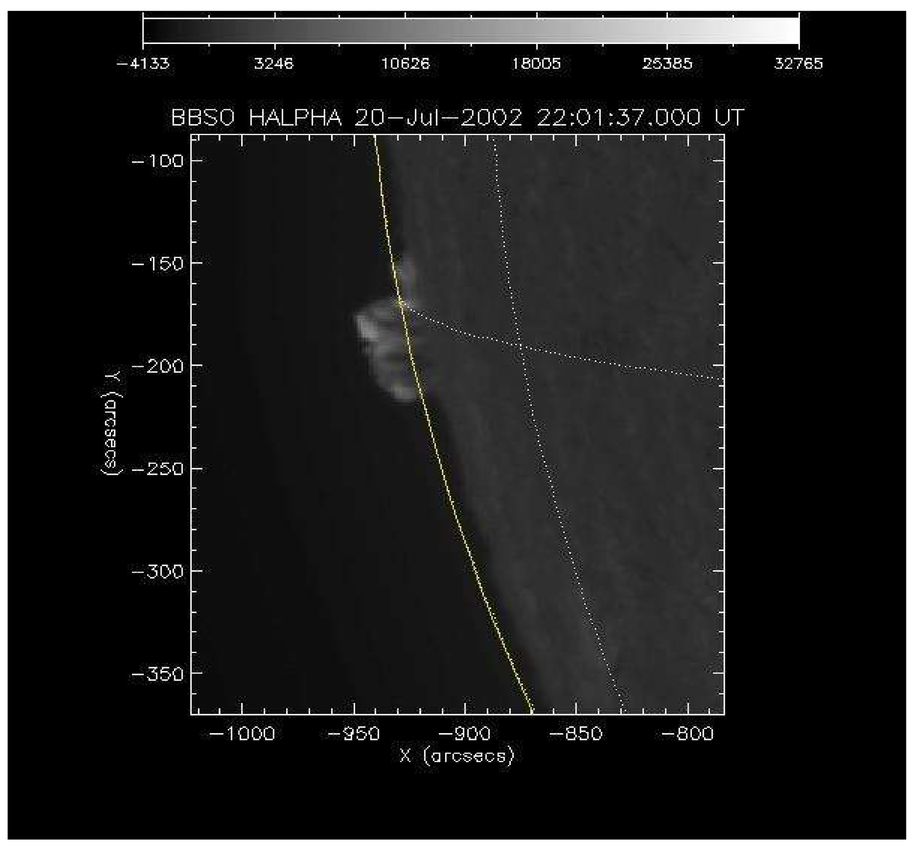

Fig.2. H alpha loop observations from BBSO

The amount of material evaporated from the chromosphere is consistent with conductive evaporation. When we calculate the amount of material that it is possible for the beam to evaporate directly we see that it is at least an order of magnitude to small, whereas conductive evaporation gives good agreement. This is consistent with a scenario in which large numbers of electrons deposit their energy in the corona leading to efficient heating of the nearby plasma and conductive evaporation of the chromosphere, rather than direction deposition of beam energy at footpoints. From these densities we can estimate that electrons of energies between 35keV (from hard x-ray bremsstrahlung) and 80keV (from gyrosychrotron) are stopped fully in the corona.

4. Conclusions

These observations are consistent with a coronal thick target model (Veronig and Brown, 2004), a scenario where anomalous density is sustained in the corona leading to electrons of 10's of keV being stopped in the corona before impacting the chromosphere. The coronal plasma is heated very efficiently to high temperatures by the energy deposition of the electrons. Leading to efficient conductive evaporation from the chromosphere. These events typically have a rather high magnetic field, which consistent with pressure balance and energy balance arguments.

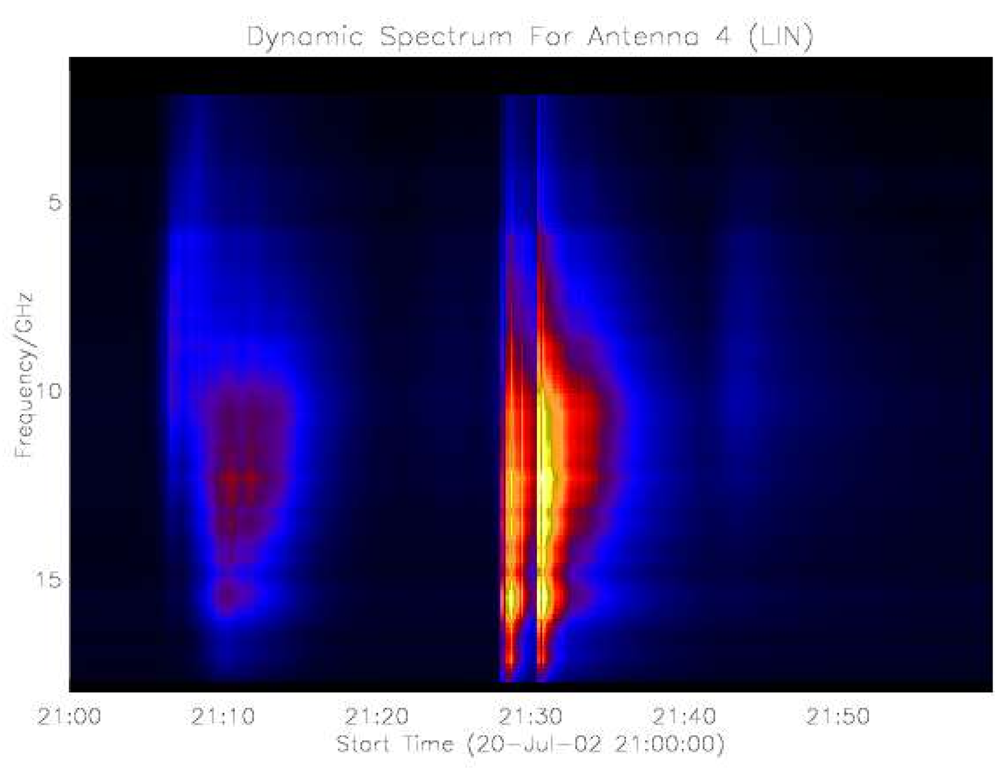

Fig.3 Dynamic spectrum of the radio emission associated with the 20th July 2002 flare.

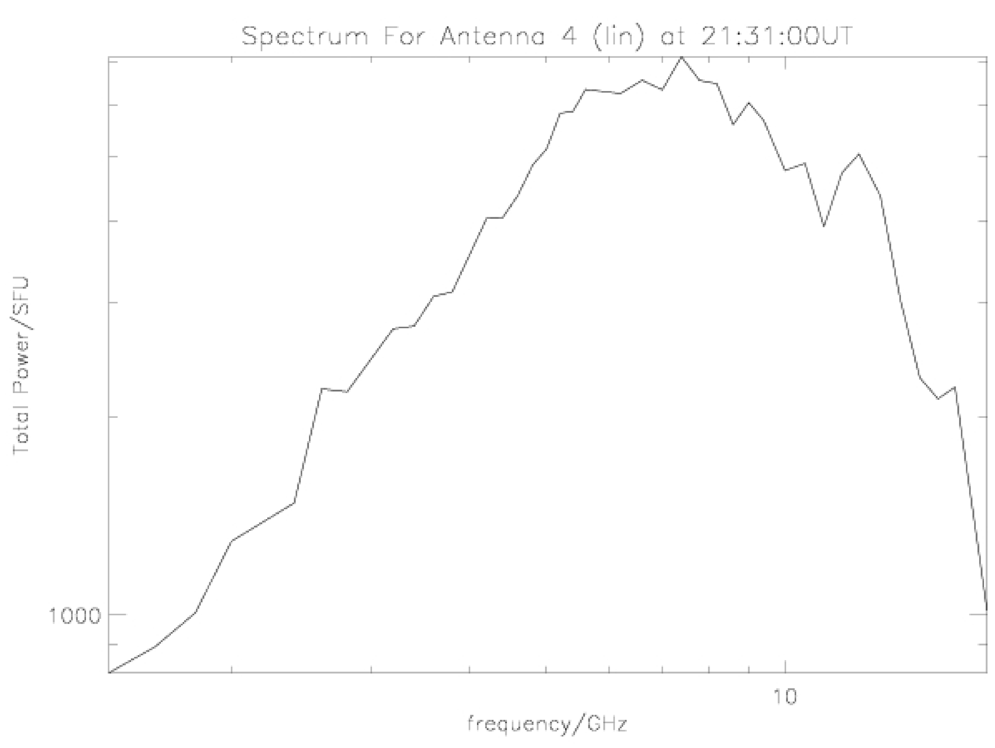

Fig 4. Radio spectrum at peak of flare from OVSA.

5. References.

2. Dulk & Dennis , 1982, ApJ 260, 875

3. Dulk & Marsh, 1982, ApJ 259, 350

4. Kane et al. 2004, private comm.

5. Kontar et al. 2003, ApJ 595, L123

6. Rosner et al. 1978, ApJ 220, 643

7. Veronig & Brown, 2004, ApJL 117, 603