A Study of Particle Energisation in Kinematic MHD Models of CMTs in The Relativistic Regime.

Solmaz Eradat Oskoui & Thomas Neukirch & Keith Grady
School of Mathematics and Statistics,
University of St Andrews, St Andrews, Scotland

Introduction

Reconnecting coronal loops can form collapsing magnetic traps (CMTs) (see Fig. 1).

CMTs have been suggested to take part in flare particle acceleration (e.g. Somov & Kosugi, 1997; Karlicky & Kosugi, 2004; Giuliani et al., 2005; Grady & Neukirch,2009; Grady & et al., 2012).

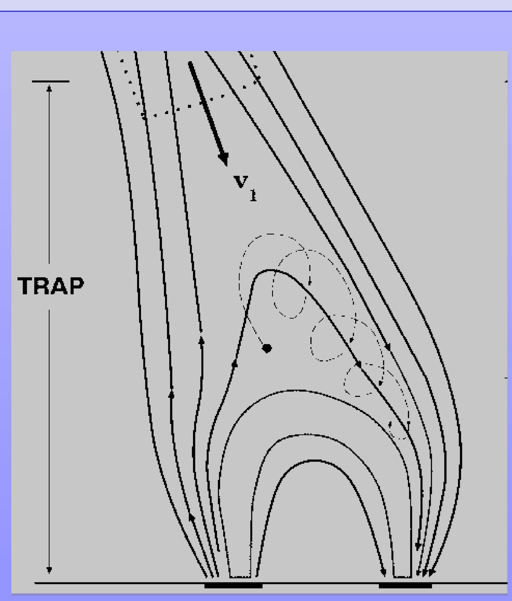

Fig. 1: Cartoon of CMT (adapted from Somov & Kosugi, 1997)

Studies of particle acceleration in CMTs have been carried out for the Earth's magnetotail (e.g. Birn et al., 1997, 1998).

Example Collapsing Magnetic Trap

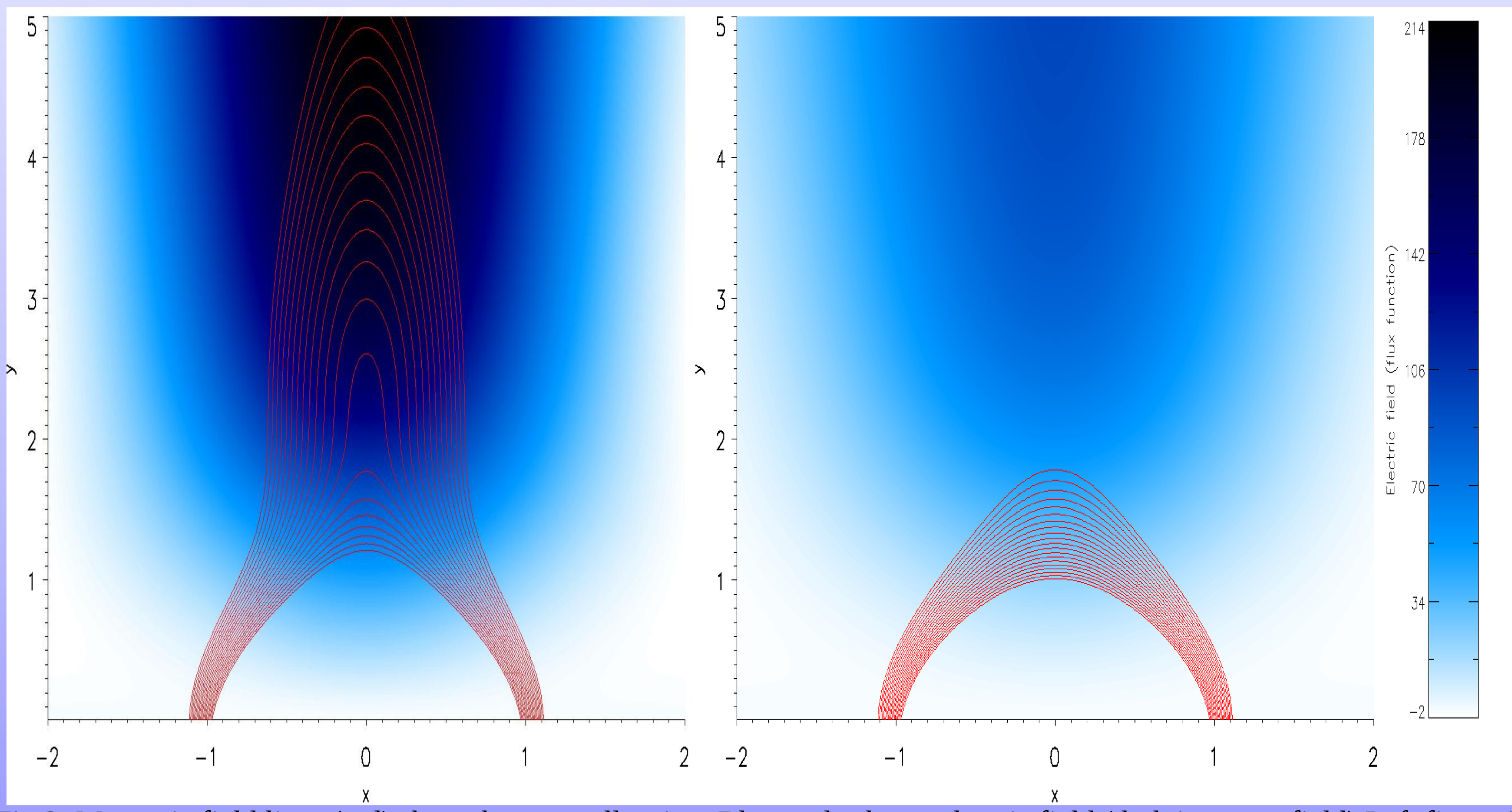

Fig 2: Magnetic field lines (red) show the trap collapsing. Blue scale shows electric field (dark is strong field) Left figure is trap before collapsing, right after an arbitrary time (95 seconds). Lengths are normalized to 10Mm.

Background Work by Giuliani et al. (2005)

Downflow generates strong electric field in central parts of CMT (see Fig. 2).

Results below are based on a 2.5D ideal kinematic MHD model (Giuliani et al., 2005).

Time evolution of E and Guiding Centre Motion

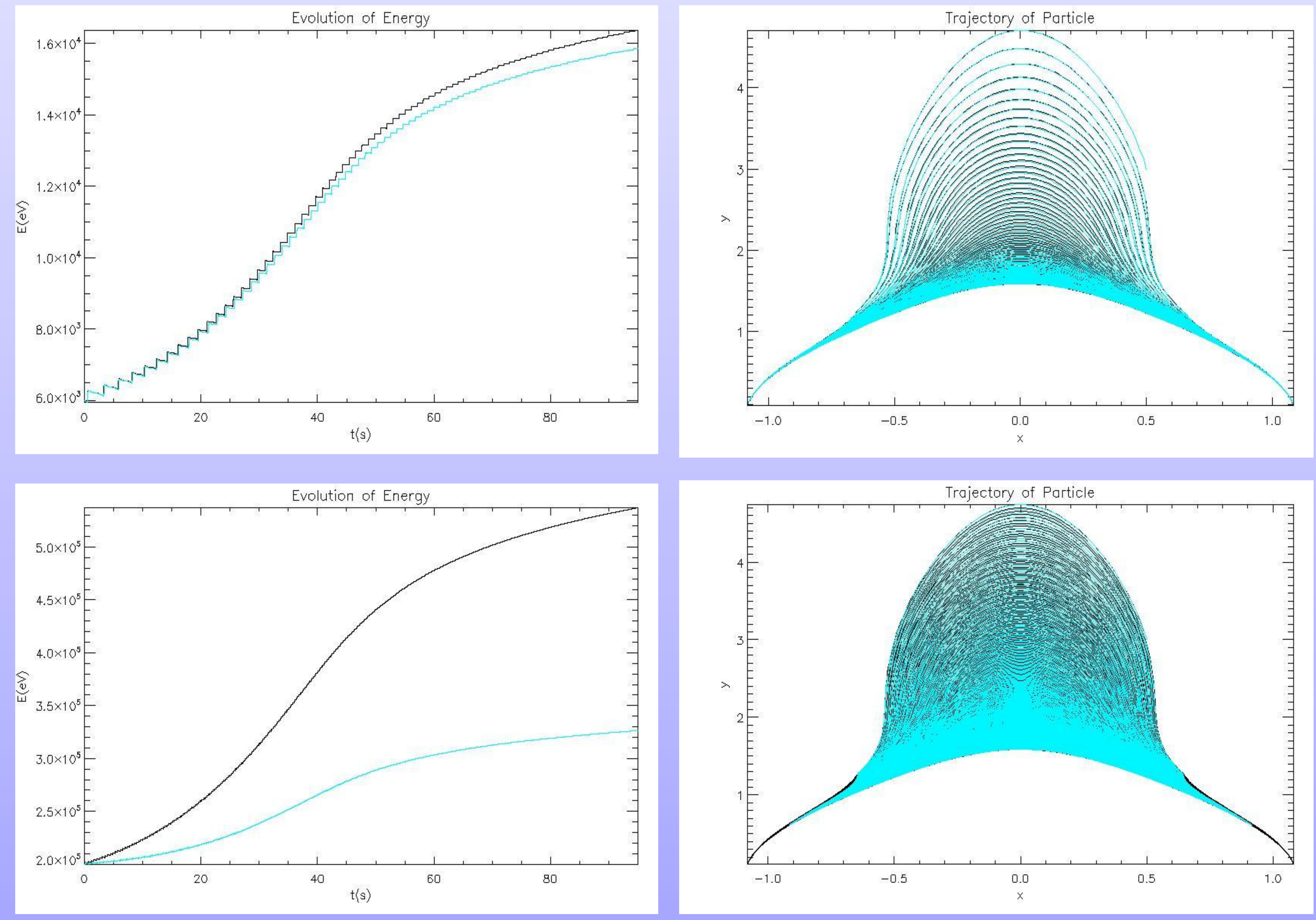

Fig 3: Top two figures are the energy evolution and guiding centre motion for a particle starting at a non-relativistic energy (6 keV). The bottom two figures are the same for a particle starting at a mildly relativistic energy (200 keV). The discrepancy in energy evolution and guiding centre motion are much clearer for the highly relativistic case. γ= 1.03, v=0.24c for the top figure and γ=1.63, v=0.79c for the bottom figure.

Effects of particle initial conditions on energy gains

Use the relativistic guiding centre approximation (Northrop, 1963) to calculate particle orbits.

As shown in Fig. 4, injection position, energy and pitch angle have an effect on the trapping time, mirror points and thus the energy of the particles once they escape from the trap.

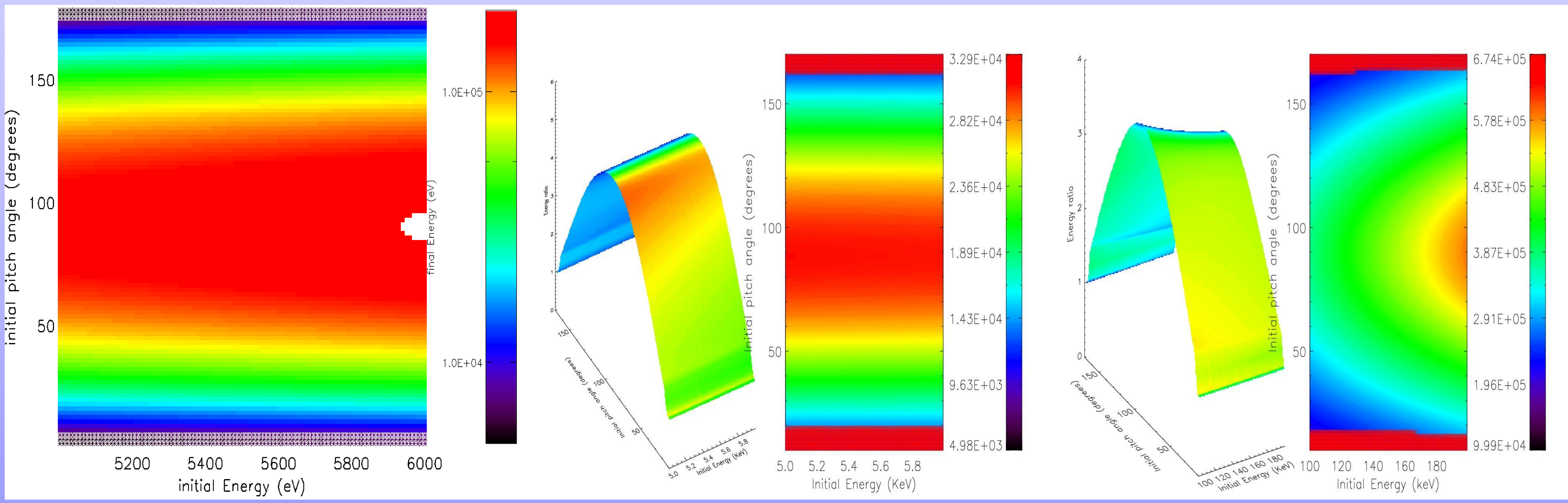

Fig 4: Graphs showing effect of initial energy and pitch angle on escape energy (shown as colour). Each frame shows particles starting at x=0, y = 4.2. Left graph (non relativistic) is to be compared to the centre and right graph which use the relativistic guiding centre approximation. Particles that escape are indicated with hatching.

Positions at later times

Trapped particles are accelerated by the betatron effect and due to the curvature terms in the parallel equation of motion.

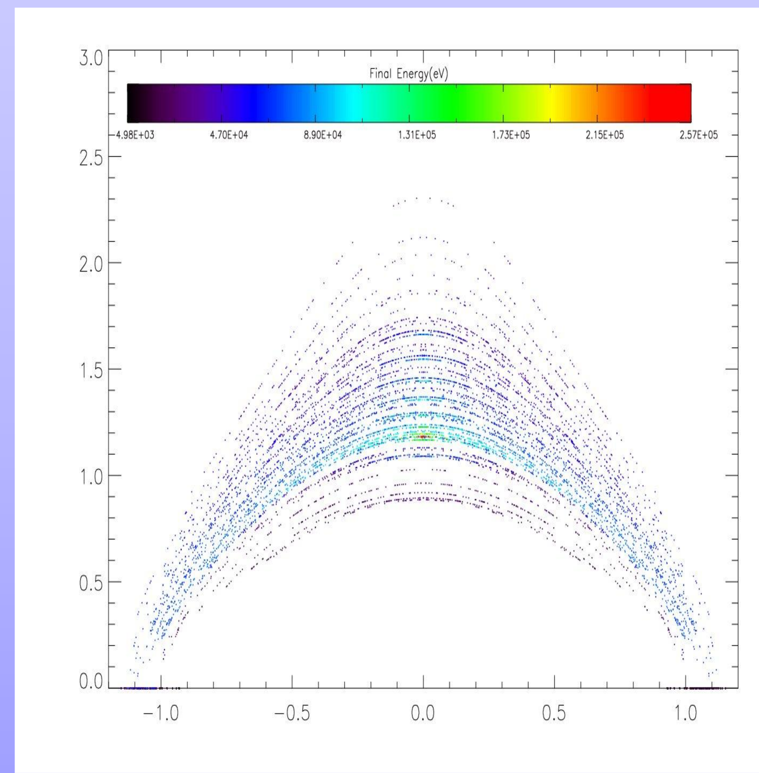

Fig 5: Particles with initial energies of 5keV-6keV that gain most energy are trapped at the loop top and have an initial pitch angle close to 90°.

Discussion and Conclusions

The non-relativistic guiding centre approximation is no longer valid in cases where the initial energy becomes mildly relativistic.

Particles gain more energy if they have initial pitch angles close to 90° and start in the middle of the trap in weaker field regions. Therefore particles with highest energies are trapped at the top of the field lines with the largest ratio B_{final} /$B_{initial}$.

Future work: more realistic CMT models, e.g; calculation of particle orbits including Coulomb collisions; calculations of distribution functions.

References

•J. Birn et al. 1997, JGR 102, 2325
•J. Birn et al. 1998, JGR 103, 9235
•P. Giuliani, T. Neukirch & P. Wood 2005, ApJ 635, 636
•M. Karlický & T. Kosugi 2004, A&A 419, 1159
•T. G. Northrop 1963, *The Adiabatic Motion of Charged Particles*, Interscience Publishers
•B. V. Somov & T. Kosugi 1997, ApJ 485, 859
•D. P. Stern 1987, JGR 92, 4437
•K.J. Grady & T. Neukirch, 2009, A&A.
•K.J. Grady, T. Neukirch & P. Giuliani 2012, A&A, submitted.