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Particle Motion and Energy Gains in 2½D Collapsing Magnetic Trap Models

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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).

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

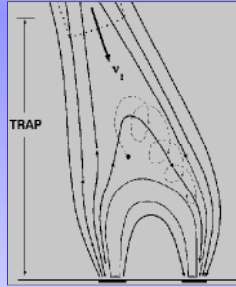


Fig. 1: Cartoon of CMT (adapted from Somov & Kosugi, 1997)

Background Work

Downflow generates strong electric field in central parts of CMT – this is expected to help trap and accelerate particles – fields that enhance this effect will be looked into in further work.

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

Calculate particle orbits with guiding centre approximation (Northrop, 1963; Giuliani et al., 2005)

Model also works with fully 3D fields (Grady & Neukirch, 2009)

Magnetic Trap Fields

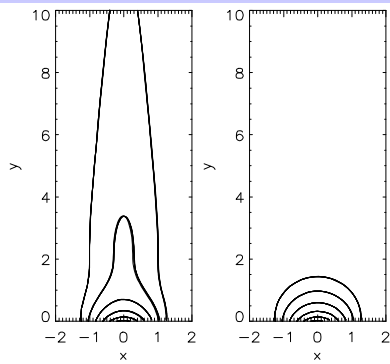


Fig 2: Magnetic field lines show the trap collapsing. Left figure is trap before collapsing, right after an arbitrary time (95 seconds). Lengths are normalized to 10Mm.

Final field is given by loops between two line currents.

Transformation from Lagrange to Eulerian coordinates stretches field initially, then allowed to relax to potential field.

Electric fields can be calculated from $\mathbf{E} = -\mathbf{v} \times \mathbf{B}$

Dependence of final energy on initial energy

Changes in particle initial energy do not greatly effect final energy.

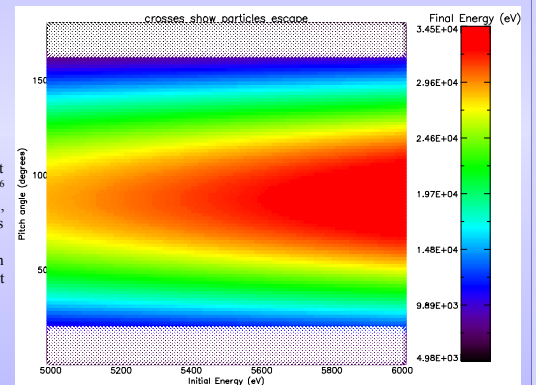


Fig 3: Particles injected at $x=0.1, y=2.0, z=1.25 \times 10^{-6}$ in normalised coordinates, with different pitch angles and initial energies as show. Particles with pitch angle 90° have the highest final energy for this position. Particles with very high or low pitch angle escape before the trap has collapsed.

Effect of initial position and pitch angle

Highest energy gains are for particles starting close to the trap centre, where magnetic field is strongest, with pitch angle close to 90° .

For positions further from the trap centre, the pitch angle of particles with the highest energy gain moves further away from 90° .

Particles with pitch angle close to 0° or 180° escape the trap; the exact loss cone depends on position.

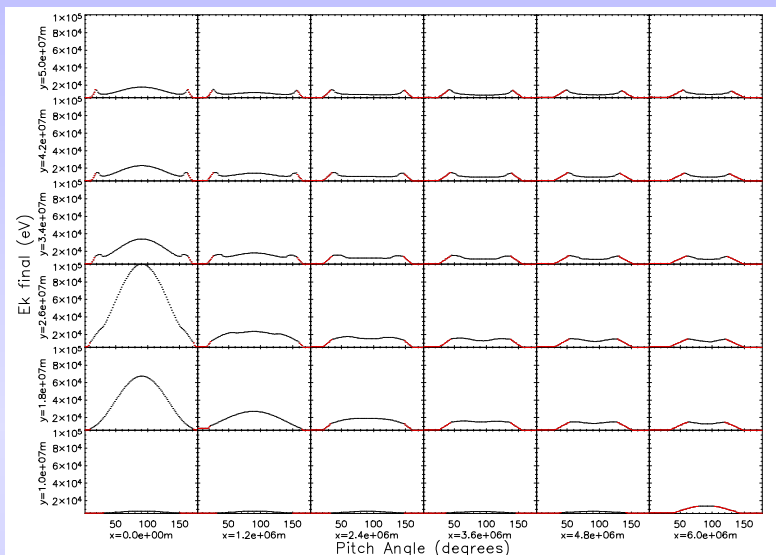


Fig 4: Particles with energy 5.5keV. Each plot shows final energy vs pitch angle for a different initial position. Red dots indicate particles that escape.

Discussion and Conclusions

Particles can gain up to ~ 50 times their initial energy in the CMT.

Energy gain depends on initial position and pitch angle and less so on initial energy.

Highest energy particles in final configuration are trapped at the loop top.

Betatron acceleration most important for particles with pitch angle close to 90° ; Fermi acceleration can be important for particles with smaller pitch angles.

Higher order terms in the guiding centre approximation (e.g. Grad-B drift) are found to influence the particle acceleration process.

Future work: more realistic CMT models, e.g. 3D, localised electric field; calculation of particle orbits including Coulomb collisions; calculations of distribution functions.

References

- J. Birm et al. 1997, JGR 102, 2325
- J. Birm et al. 1998, JGR 103, 9235
- P. Giuliani, T. Neukirch & P. Wood 2005, ApJ 635, 636
- K. Grady & T. Neukirch 2009, A&A 508, 1461
- 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