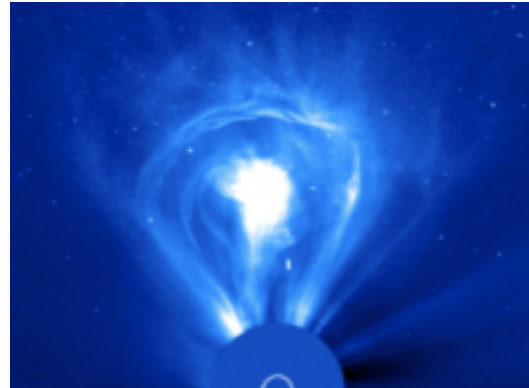


A “Lasso” Model for LDGRFs

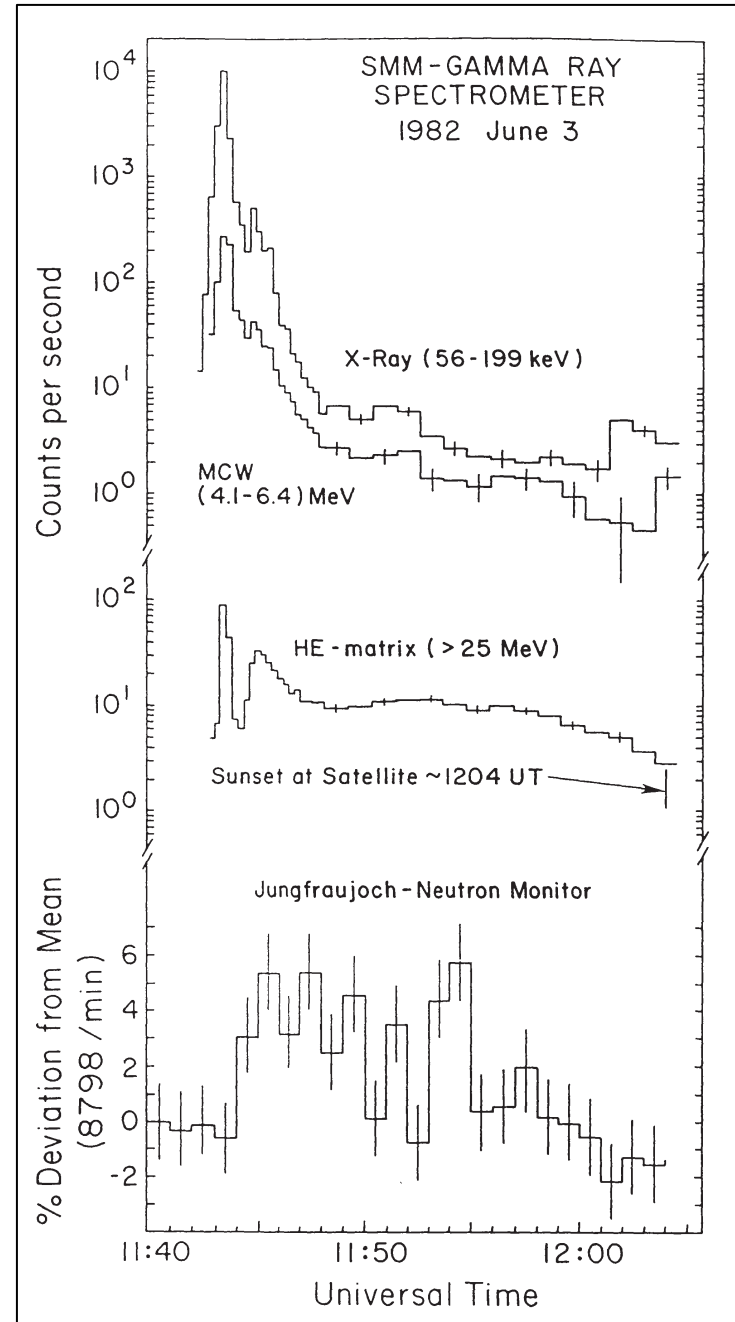
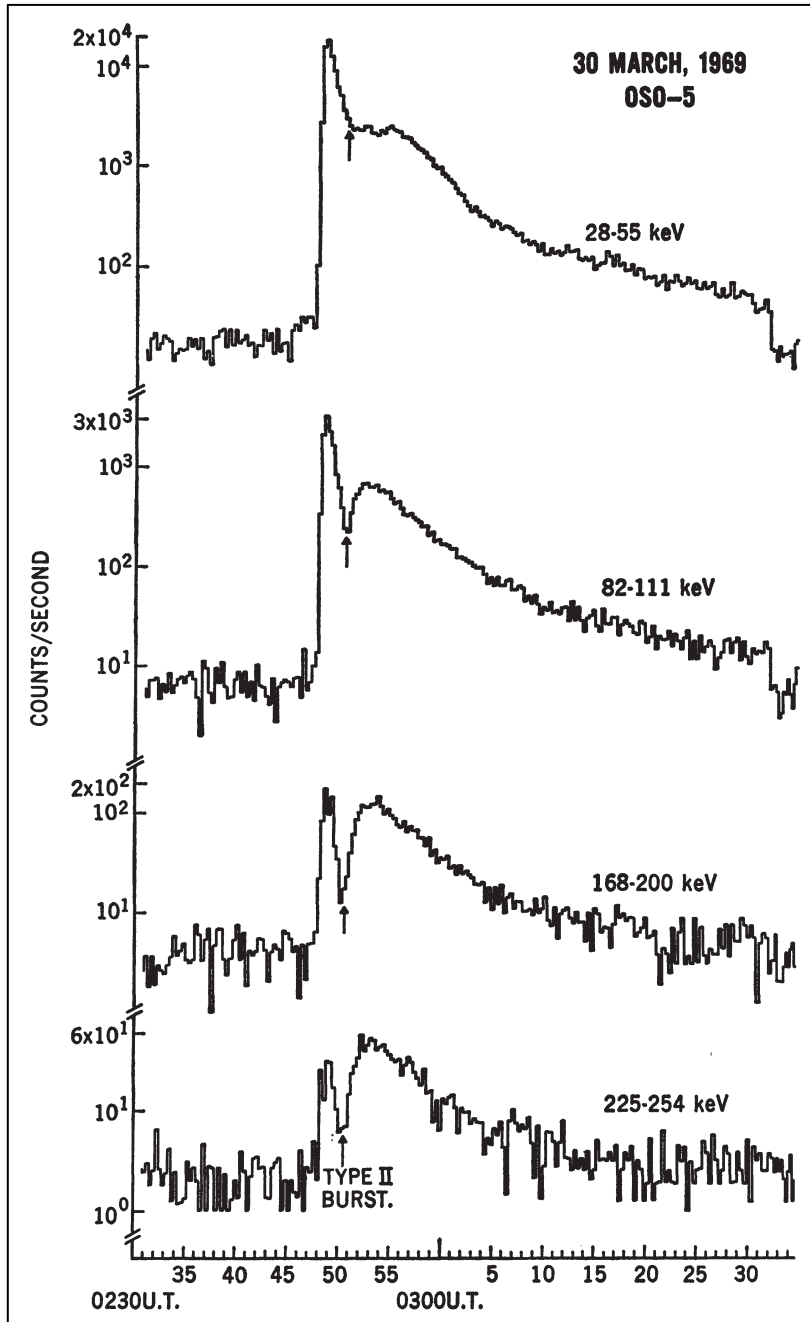


The lasso model just describes the LDGRF protons as those SEPS corralled by the coronal field

What is an LDGRF?

- Coronal HXR events, SOL1969-03-30 (Frost & Dennis, 1969)
- Long-Duration γ -ray events, SOL1982-06-03 (Forrest et al, 1985)

I think these phenomena belong together, and with a novel sort of loop structure we may be able to explain them



SOL1969-03-30 HXR

- Coronal origin (by occultation)
- Hard spectrum, $J_\nu \propto (h\nu)^{-2}$
- Low peak microwave frequency
- Association with type II/IV burst
- Drifting cm-wave source
- SEPs

- Un-imageable scale (*RHESSI*)
- CME association

SOL1982-06-03 γ -ray

- Very high energies (GeV)
- Pion decay radiation
- Long duration, up to hours
- Association with type II burst
- Neutrons
- SEPs

- Coronal origin (*Fermi*)
- CME association

Two big mysteries:

- What are these things? (Can't see them in AIA!)
- How can the GeV particles be related to the SEPs?

The SEPs loss-cone problem

The SEPs presumably come from CME-driven shock waves.

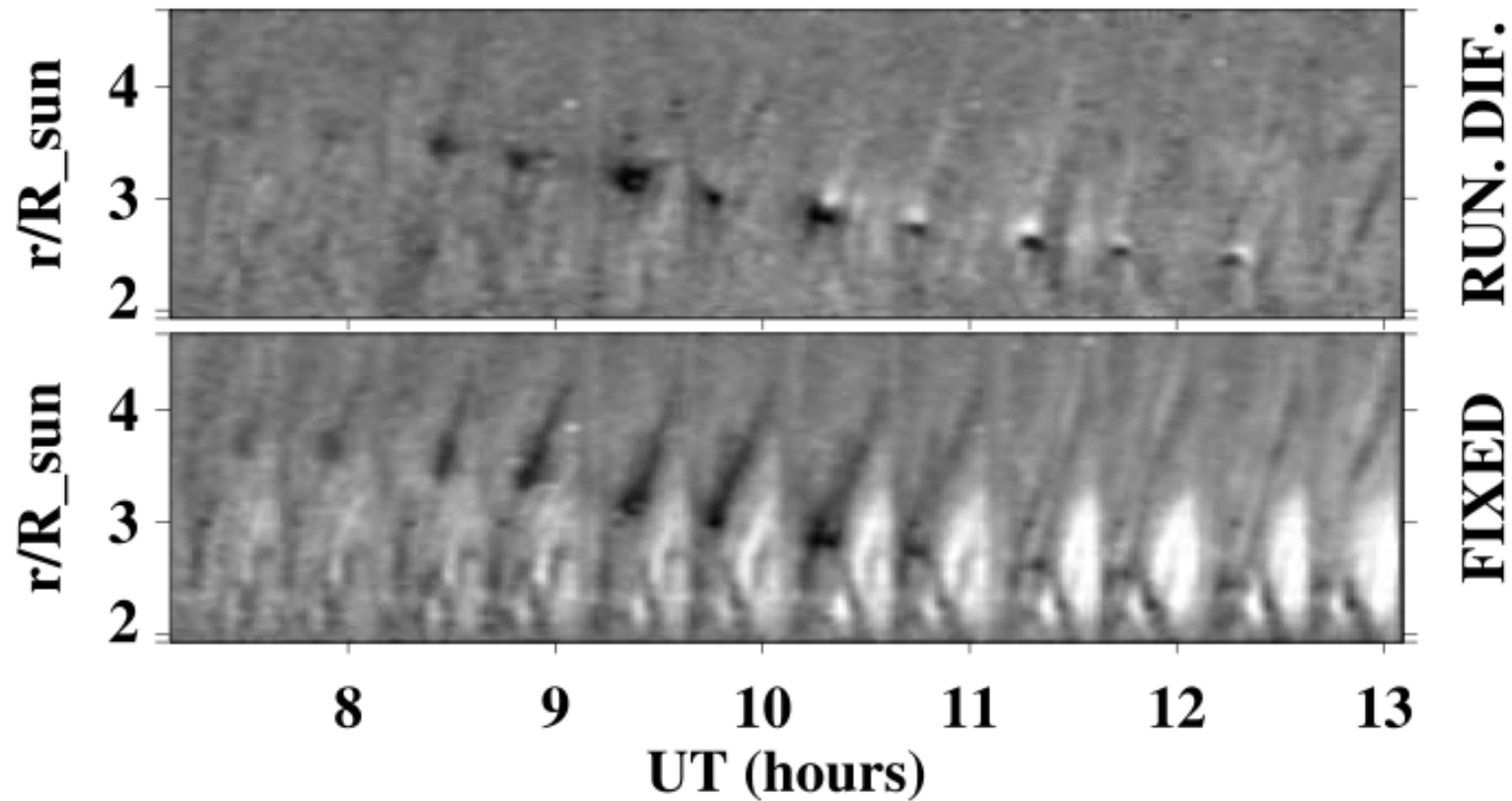
- On open fields, the particles would just go away and never interact to produce pions and γ -rays
- On closed fields, e.g. at $3 R_{\odot}$, the loss cone is negligible (of order 10^{-3} sr), so the 1st adiabatic invariant strongly prevents precipitation

The Lasso Model

- Shock acceleration takes place in large closed-field structures (“loops”)
- These then retract, leading to further (betatron) acceleration and trapping
- The retraction opens the loss cone, allowing particles to get access to high densities

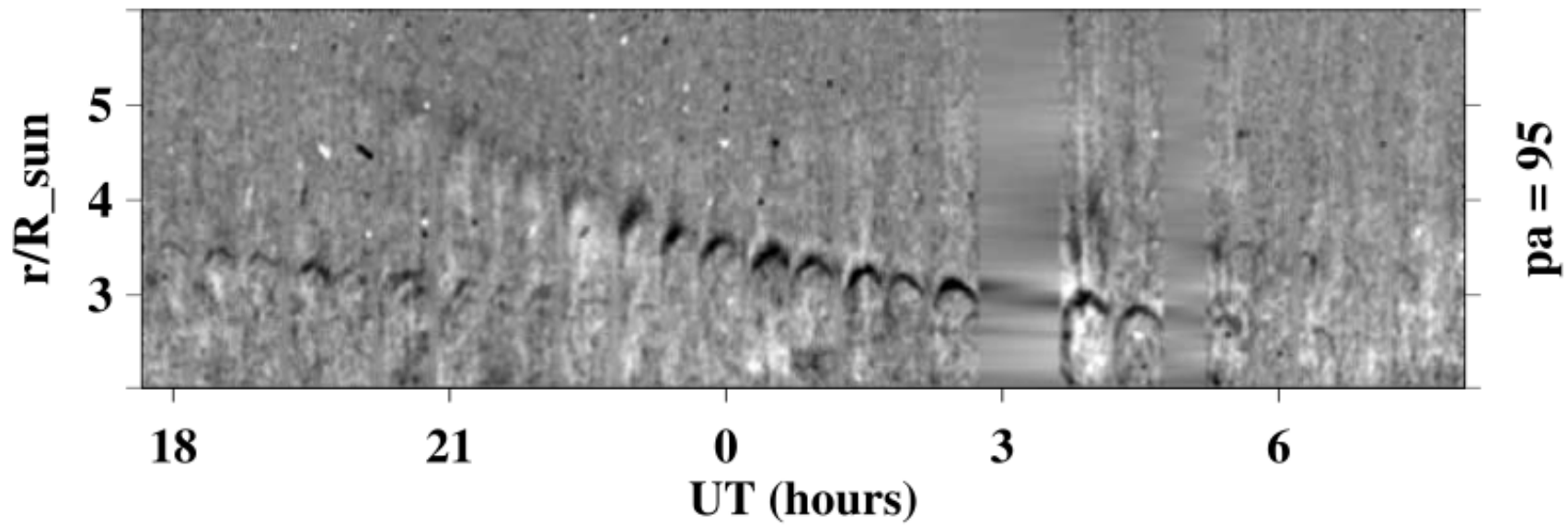
Large-scale coronal loop retractions

October 23, 2000 (pa = 258, w = 25)



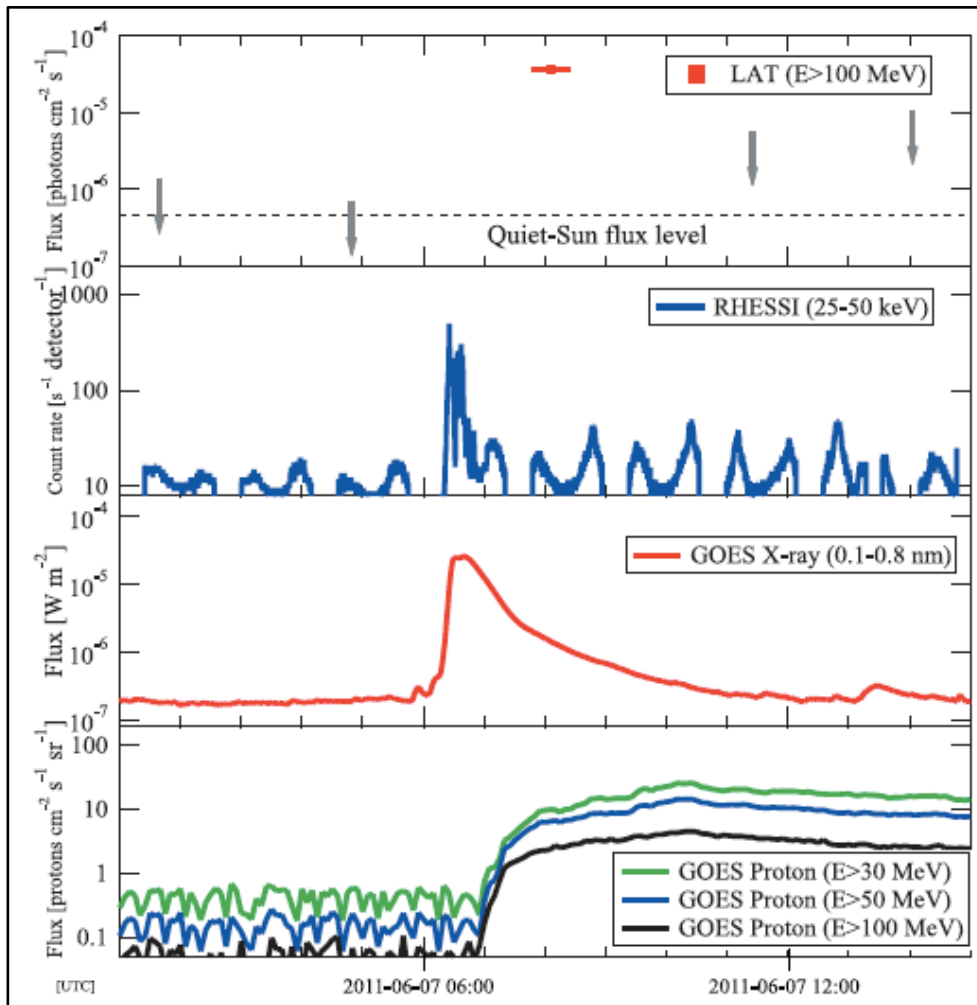
Large-scale coronal loop retractions

December 6 - 7, 2002

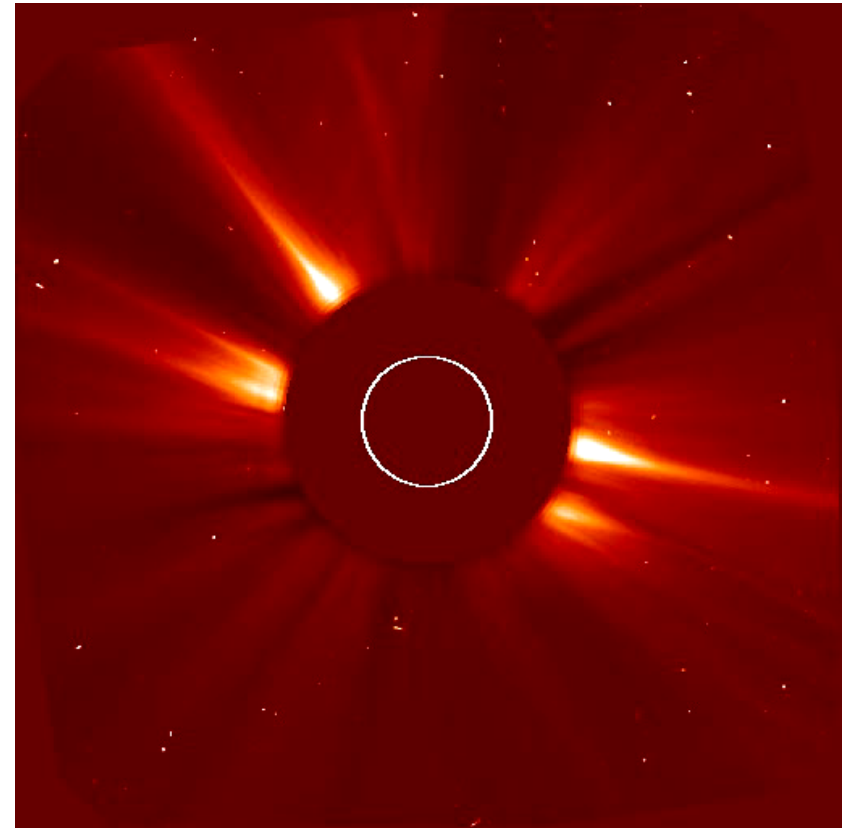


Sheeley et al. 2004

SOL2011-06-07 LDGRF



Ackermann et al. 2012



Note the image evidence for retracting fields following this LDGRF

Lasso model concerns

- Is the CME/shock geometry realistic?
- Are the trapping time scales OK?
- How in the world do we relate the electron signatures to the ions?
- Are the Lasso Model's "predictions" observable?
 - should spot the retracting structures
 - should find little γ -ray source motion
- Can somebody work out a quantitative theory?

A “Lasso” Model for LDGRFs

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SH 1.2-10

ION ENERGY STORAGE FOR POST-FLARE LOOPS

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ABSTRACT

Low-energy non-thermal protons may have long lifetimes in coronal loops with low density and high temperature. If energy were stored in such protons in the initial phases of a solar flare, it could be released slowly during the later phases. Within the present observational limits for post-flare loops, this mechanism should be considered in addition to a field-line reconnection theory of the Kopp and Pneuman type. The thin-target γ -ray emission from the trapped protons is below present limits, but more sensitive observations can test the hypothesis.

1985ICRC...4...58H

Plus... Heritage from Ryan, Lee, Kocharov...