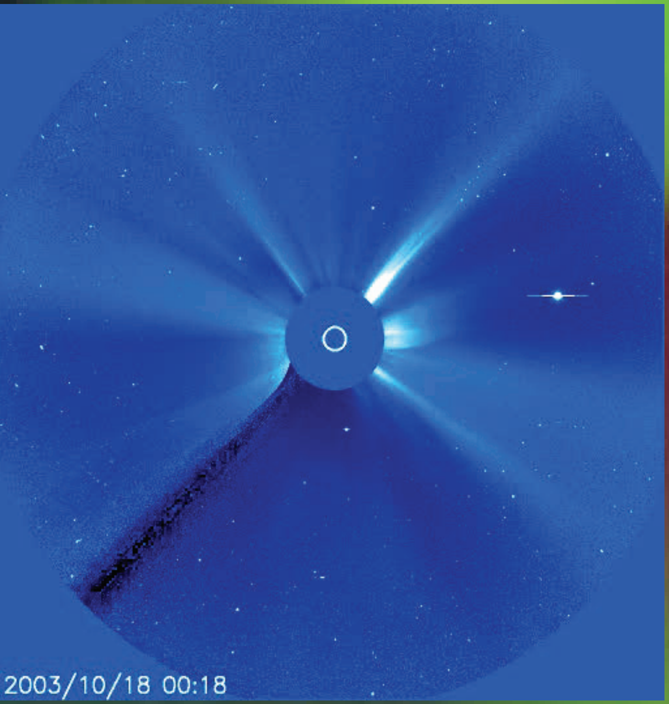
IMPRS Retreat 2011



Lecture on June 21,
by Rainer Schwenn

a) Coronal mass ejections (CMEs)

- History, examples, definition of terms
- Balloon type CMEs and halos
- Typical CME properties during the activity cycle
- The relationship between CMEs and flares
- Where is the shock in coronagraph data?
- CMEs, shocks, ejecta clouds: a strange metamorphosis!

b) Rainer's catalog of ignorance

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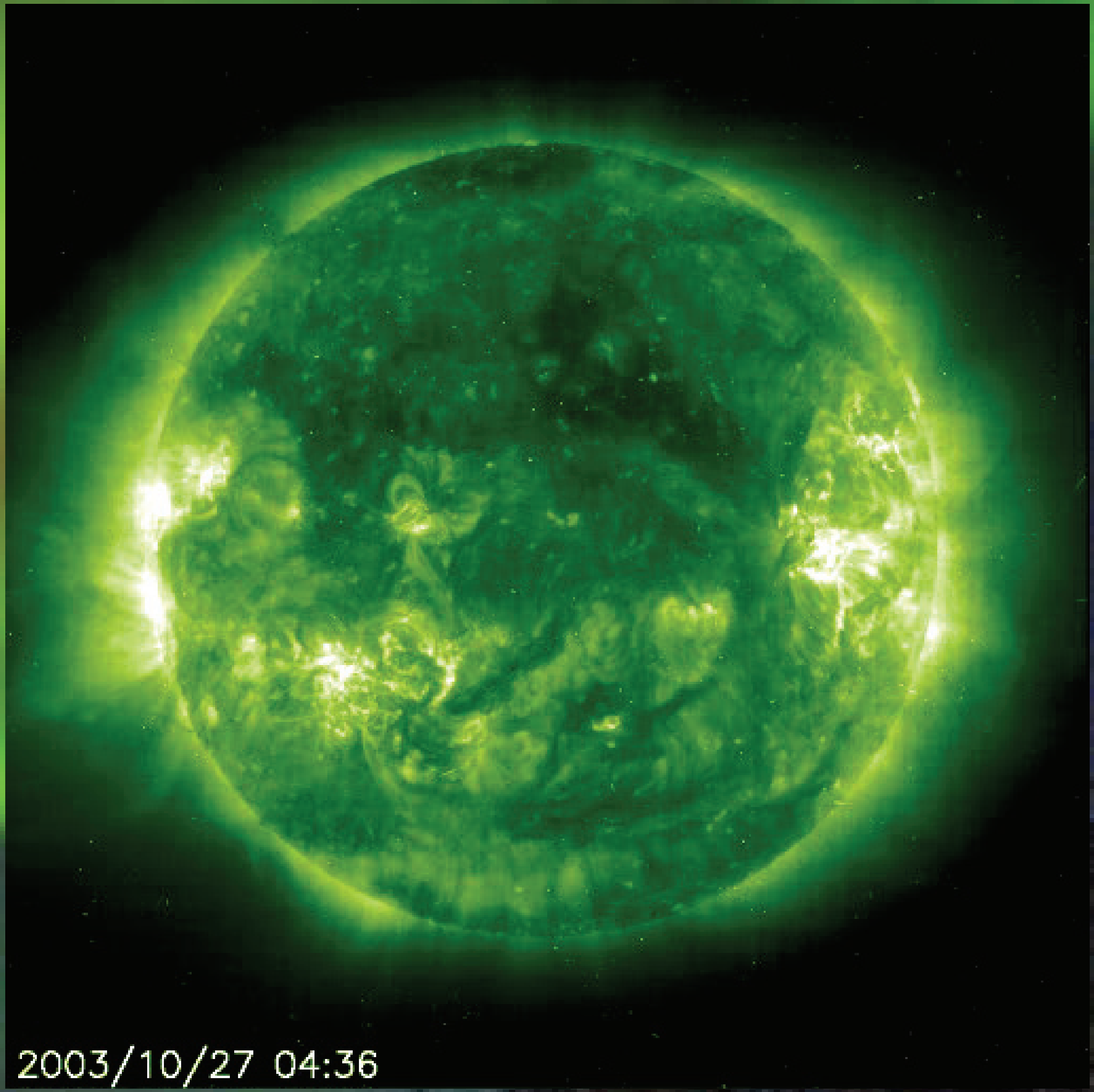
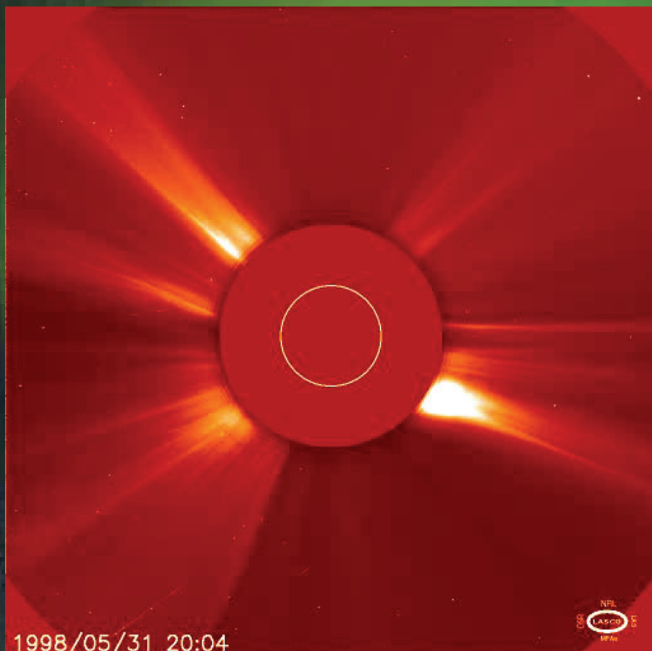
1. The onset of coronal mass ejections

1.1. Which pre-event signature signals an impending CME ?

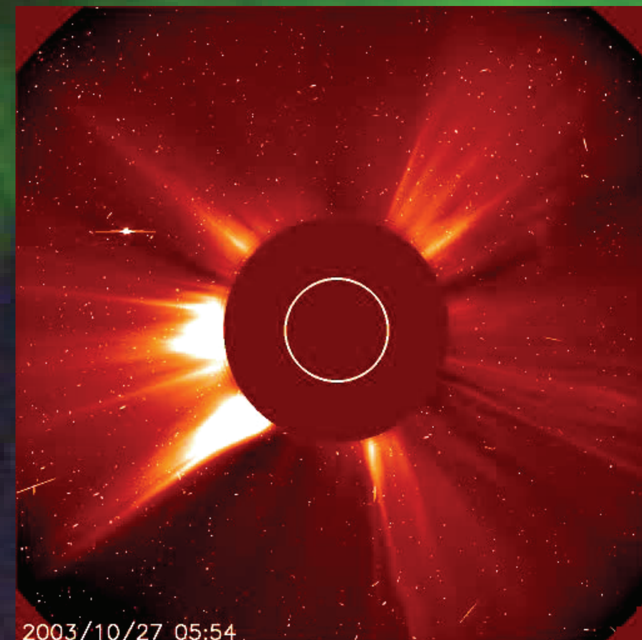


1. The onset of coronal mass ejections

1.2. What is the actual trigger of a CME?



Two small comets were evaporating near the Sun. A few hours later a huge ejection occurred. Coincidence?



On October 28, 2003, in conjunction with a X13 flare, there occurred a gigantic CME . 8 hours earlier a little comet had evaporated! **Coincidence?**

By the way: In 15 years mission time, SOHO has seen more than 2000 little comets and some 15,000 CMEs…

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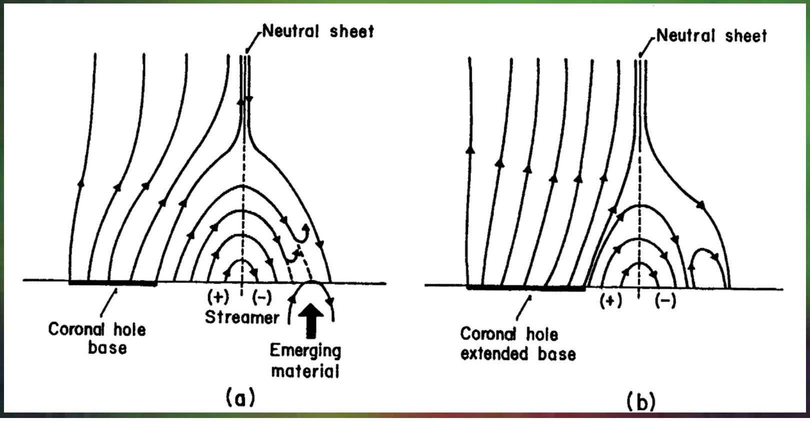
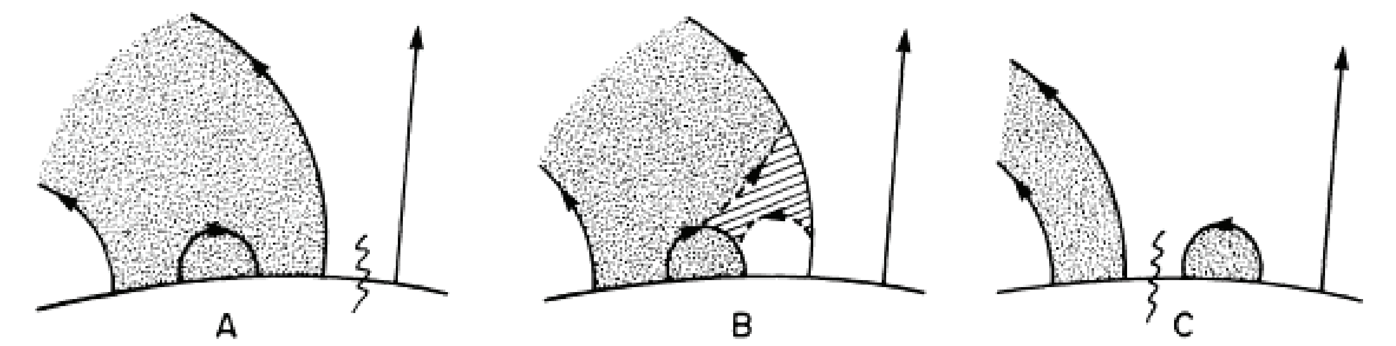
1. The onset of coronal mass ejections

1.3. Is proximity of coronal hole boundary stimulating CME?



The idea:
Emerging loop near CH boundary reconnects with CH open field line and thus shifts CH boundary.

(Remnant of Hewish's idea:
CHs -> „eruptive streams" -> CMEs)



1.4. Which role do flares play for CMEs' onset and further fate?

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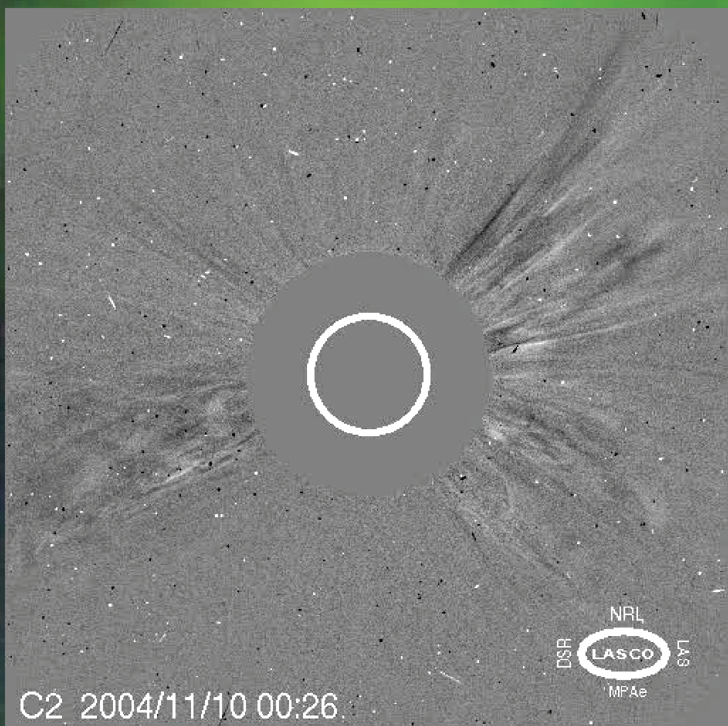
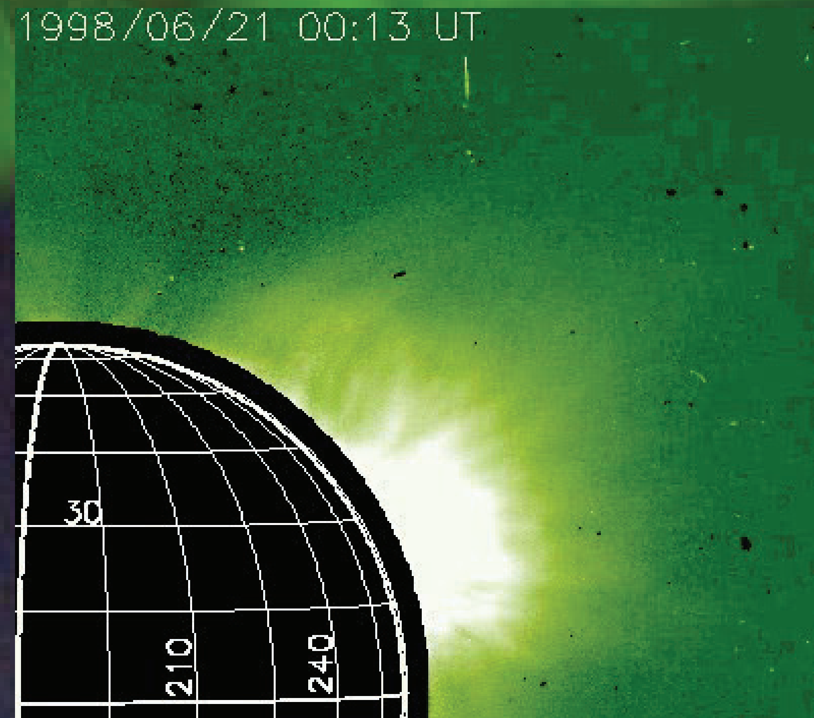
2. Are there different types of CMEs?

The bandwidth of CME properties (speed, acceleration profiles, sizes, event associations, etc) is enormous. It is hard to conceive that they are all due to the same release and acceleration mechanisms.



This extremely fast limb CME of Nov. 10, 2004, went to 30 Rs in 2 hours!



This balloon took some 30 hours to finally take off! It was the offspring of an eruptive prominence.

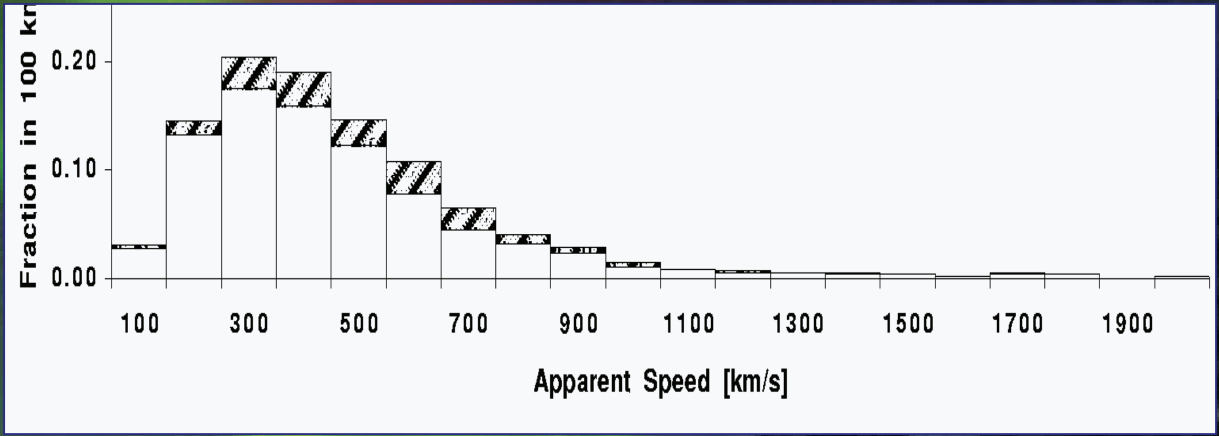
2. Are there different types of CMEs?

2.1. Are there different acceleration mechanisms at work?

The bandwidth of CME properties (speed, acceleration profiles, sizes, event associations, etc) is enormous. It is hard to conceive that they are all due to the same release and acceleration mechanisms.

2.2. How small are the smallest CMEs?

2.3. How are the ejected plasma clouds integrated into the solar wind?

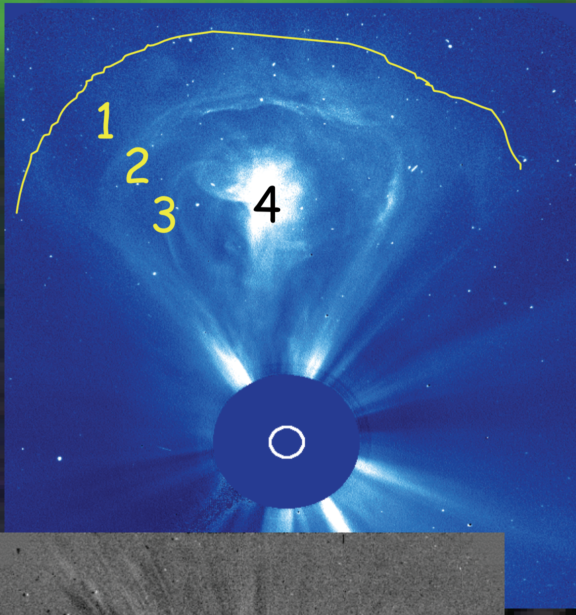


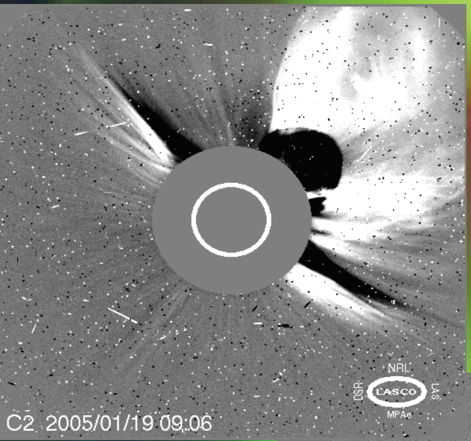
3. What is the topology of CMEs?

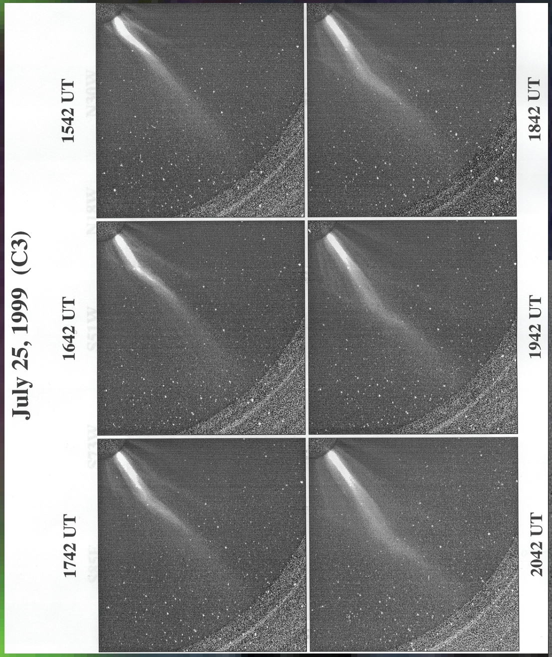
3.1. How to interpret the various commonly observed features of CMEs?

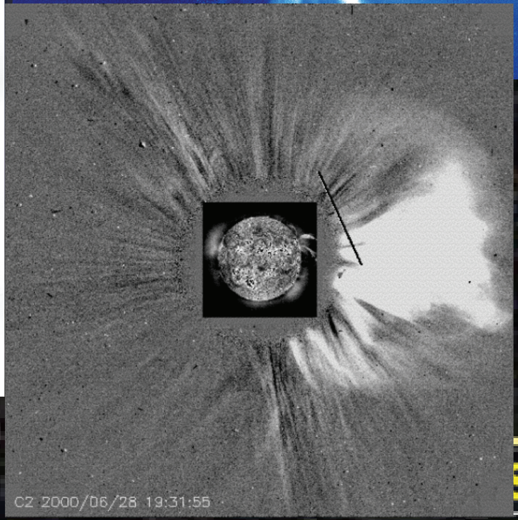
3.2. Where would a shock front be in coronagraph images? How far ahead of the bright loop and how far extended?

The majority of CMEs has a clearly discernible 4-part structure. Str.1 and the shock itself remain invisible, but...



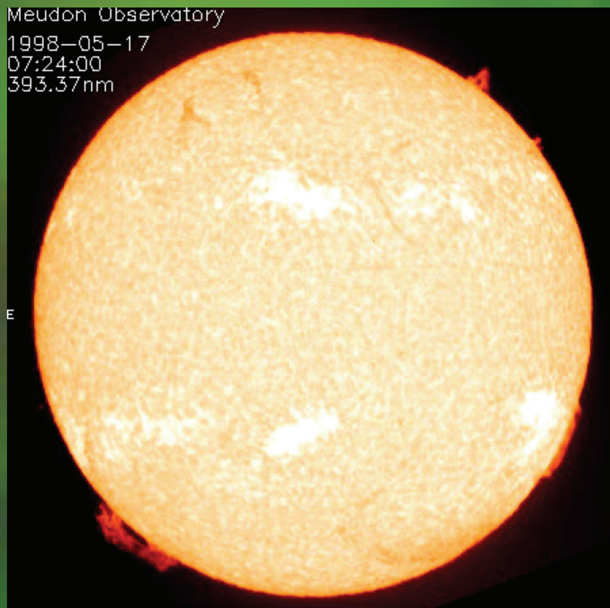






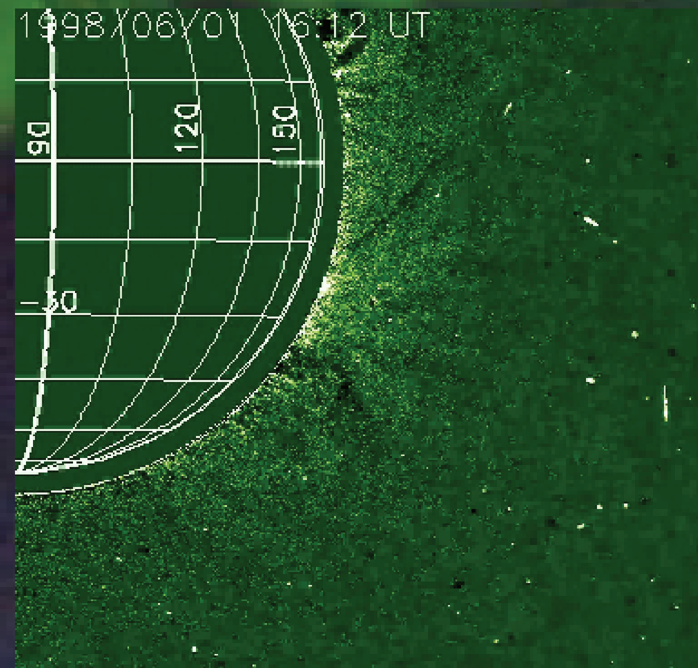
3. What is the topology of CMEs?

3.3. How long before a CME eruption is the big loop formed? Does it hold the stuff down until it erupts or is it formed as part of the eruption process?



The filament has been sitting there for severel day, before it suddenly erupted!

Why?



A CME with an erupting prominence, observed on June 2nd, 1998.

3. What is the topology of CMEs?

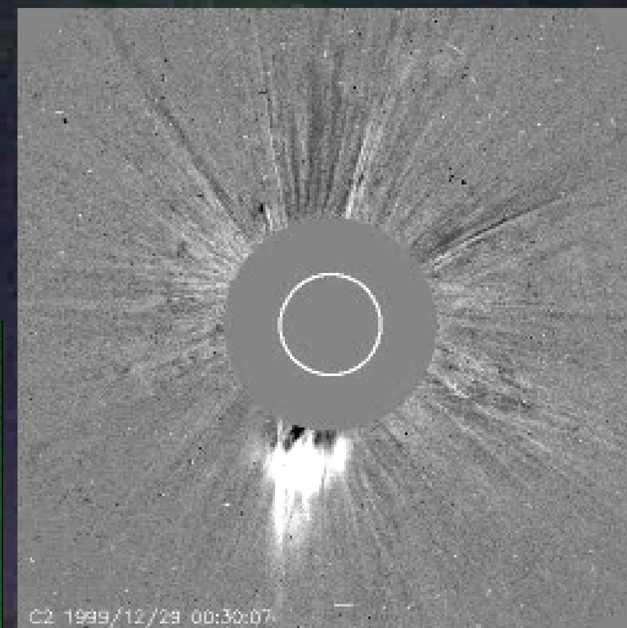
3.4. Is the bright white loop part of the ejecta, i.e., does it act as driver or is it driven itself?

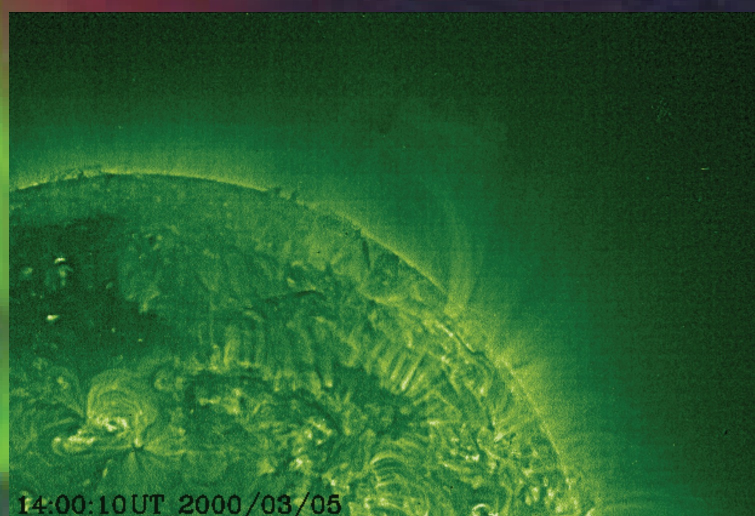
3.5. Where and when are the loop legs ever disconnected?

3.6. Are the cavity and the bright kernel separate entities or are they both parts of one big flux rope?

3.7. Do all erupting streamers have cavities?

3.8. What do the downflow events and collapsing loops mean?





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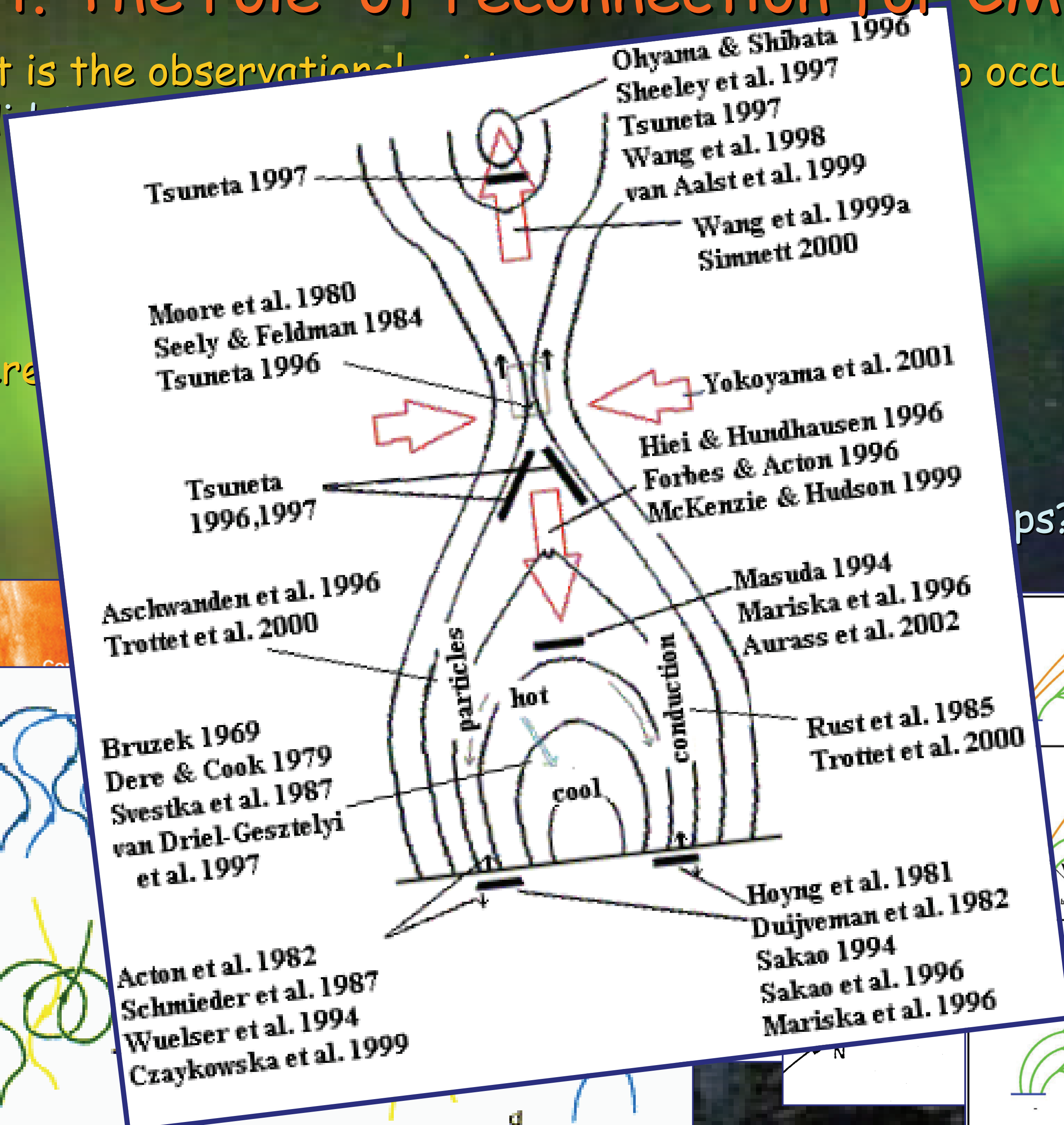
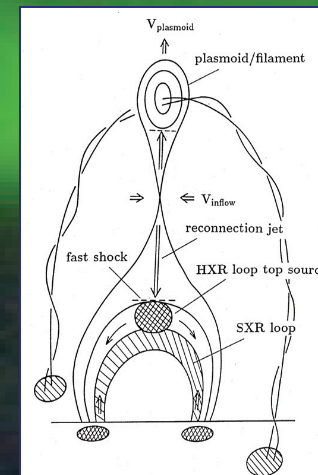
4. The role of reconnection for CMEs

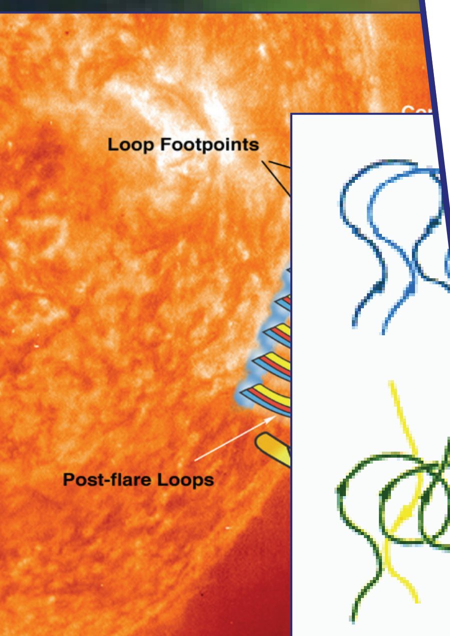
4.1. What is the observational ... occur?
Candi...

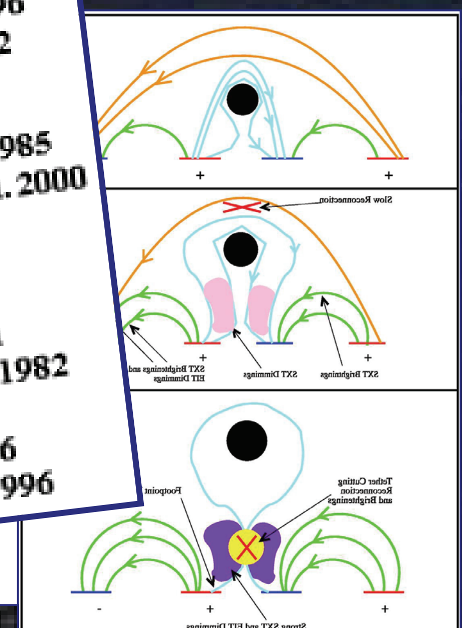
4.2. Where...

...ps?







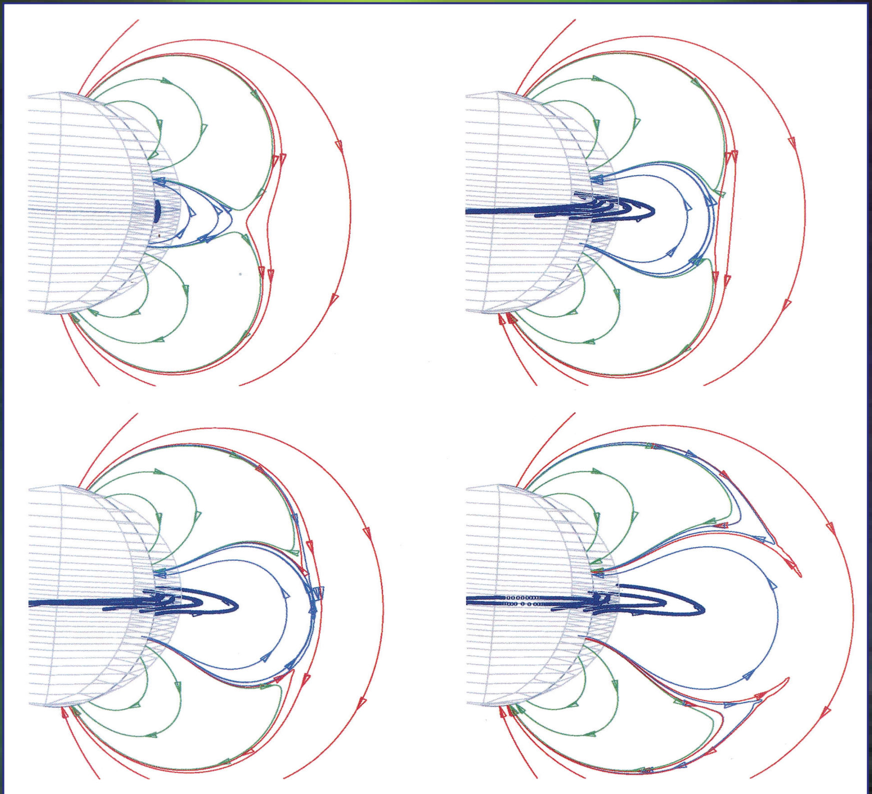


4. The role of reconnection for CMEs

4.3. When does reconnection occur in the CME process?

4.4. What exactly is the role of reconnection: trigger, driver, or mere sequel?

4.5. How, where and on which time scales is the new flux opened by a CME compensated by appropriate reconnection?



The „breakout model" for CMEs

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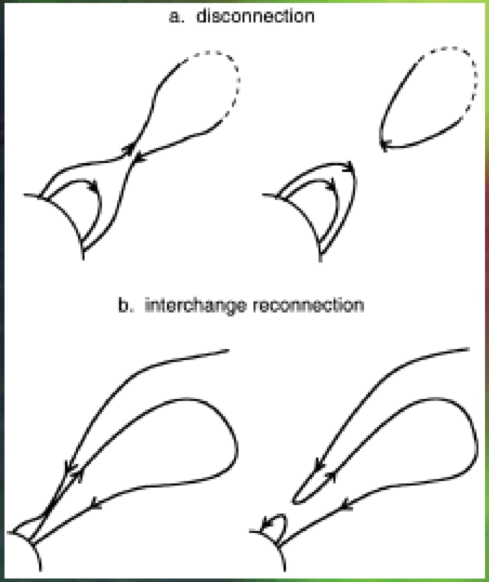
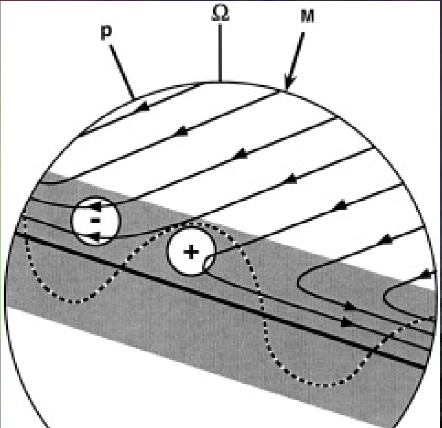
4. The role of reconnection for CMEs

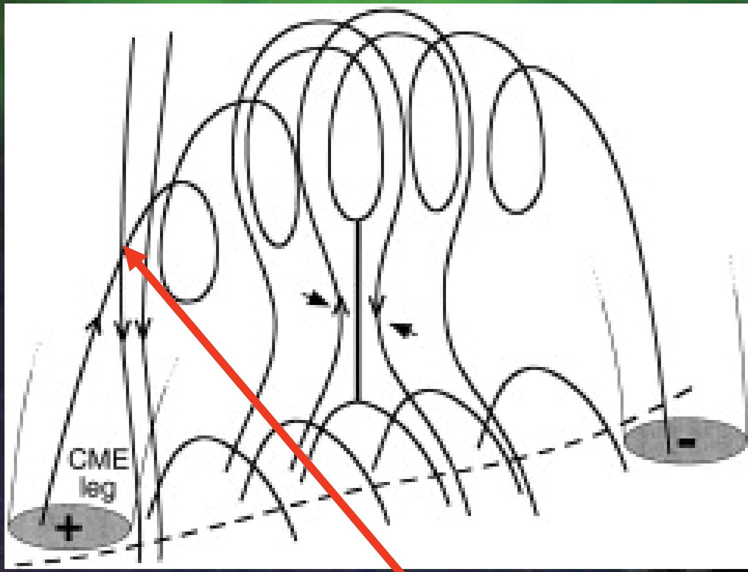
4.6. How is the „flux catastrophy“ avoided?

The problem: Emerging bipolar loops break open in CMEs and keep adding flux to the IMF. How is that ever compensated?



Interchange reconnection might help to maintain CH rigid rotation above the differentially rotating photosphere

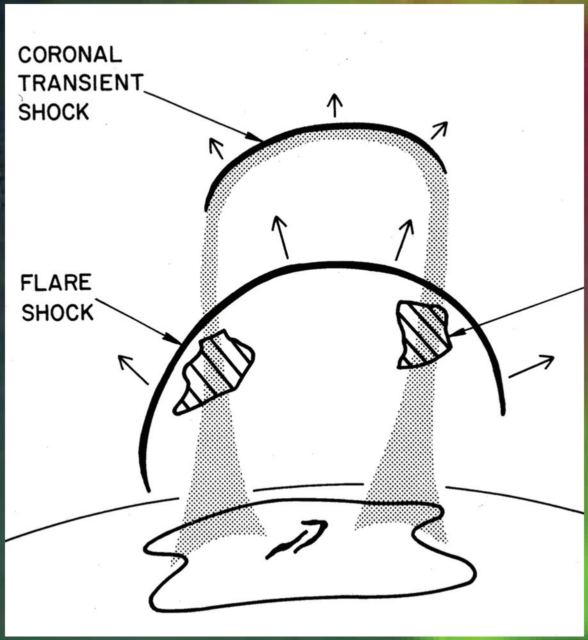


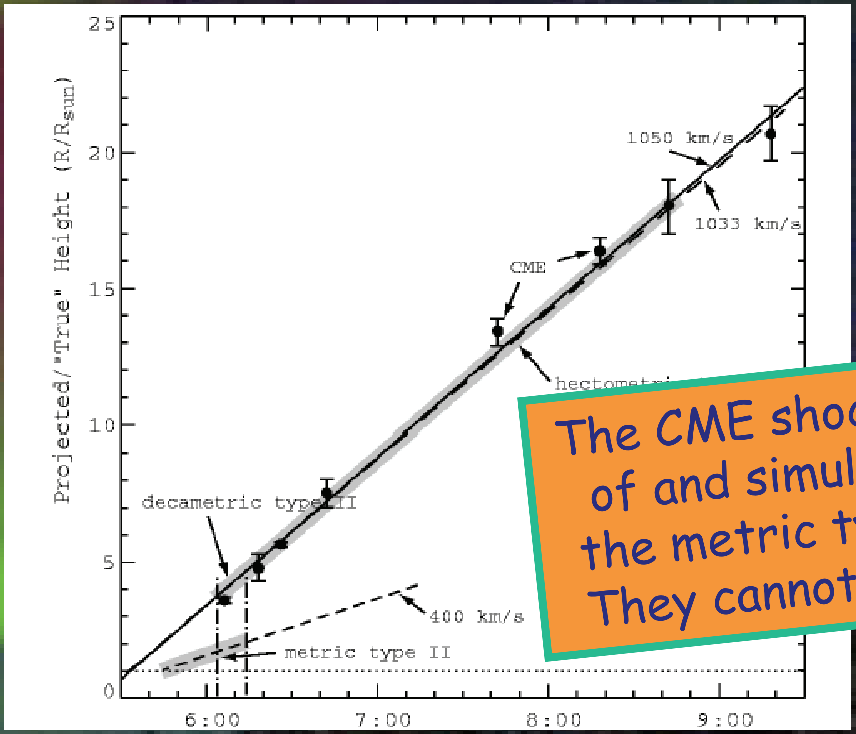


Interchange reconnection might happen here!

5. Shock waves from flares and CMEs

5.1. Where are shock waves actually being formed?
5.2. Are shocks from flares blast waves, qualitatively different from driven CME shocks?
5.3. Do flare shocks eventually die out, and where?
5.4. Do flare shocks catch up with ejecta and CME shocks?
5.5. Moreton- and EIT waves, coronal dimmings, radio type II&III bursts, energetic particles – is there a consistent scenario? ^

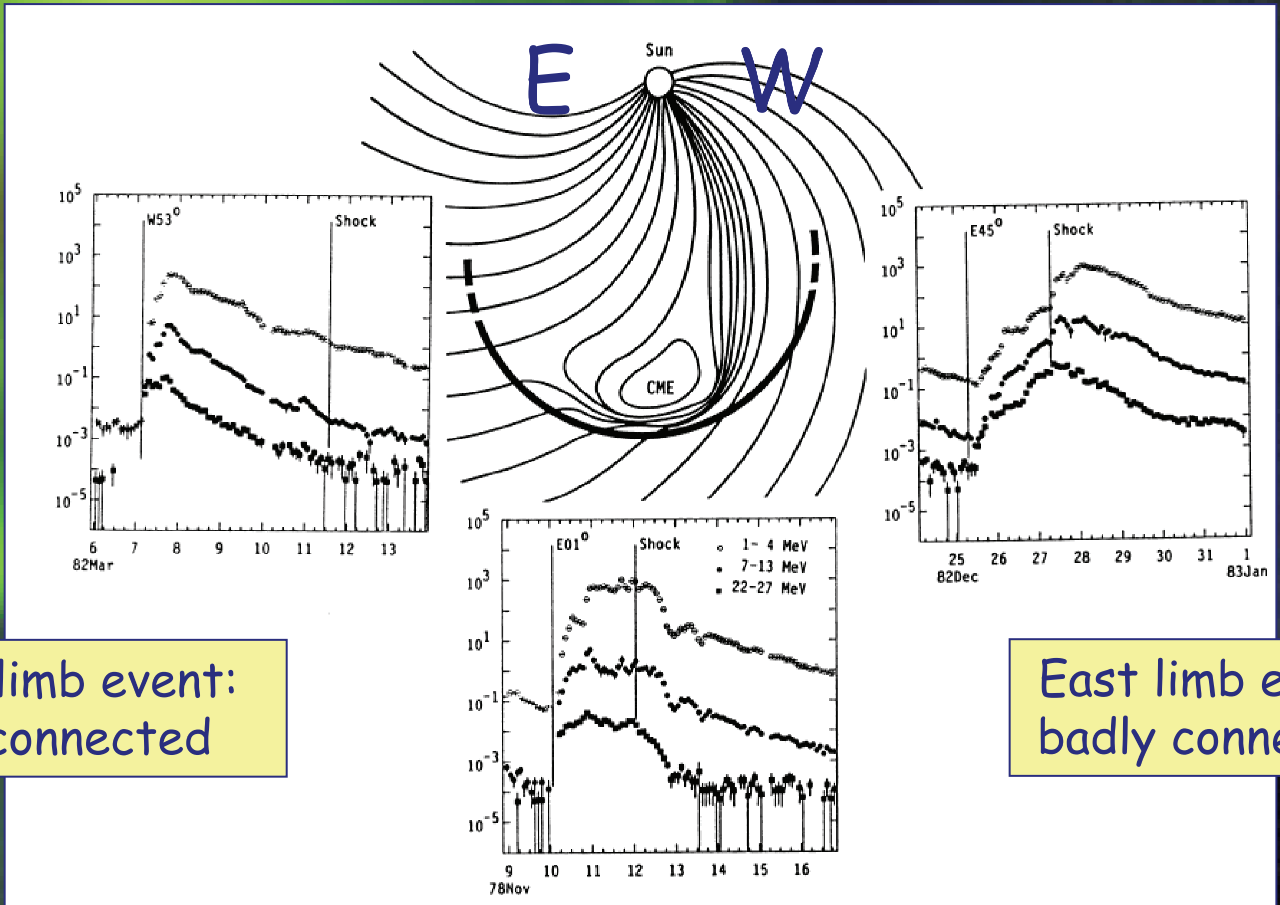




The CME shock runs ahead of and simultaneously to the metric type II shock. They cannot be the same!

6. Particle acceleration (SEPs)

6.1. Where, when and how are particles accelerated?
6.2. Are there two (or even more) classes of SEPs?
6.3. Injection of SEPs on far distant field lines: transport or local acceleration?
6.4. What is the seed population for SEPs?



West limb event: well connected

East limb event: badly connected

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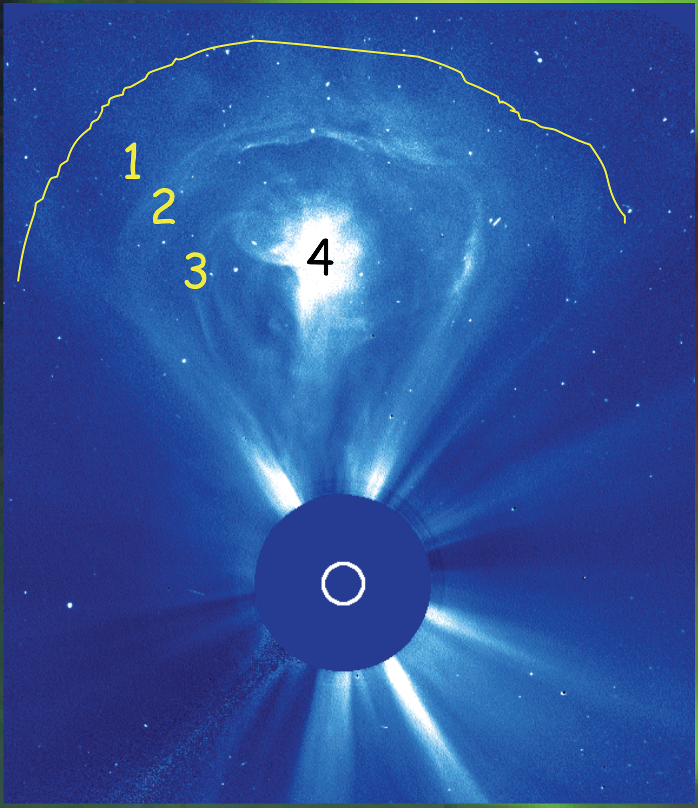
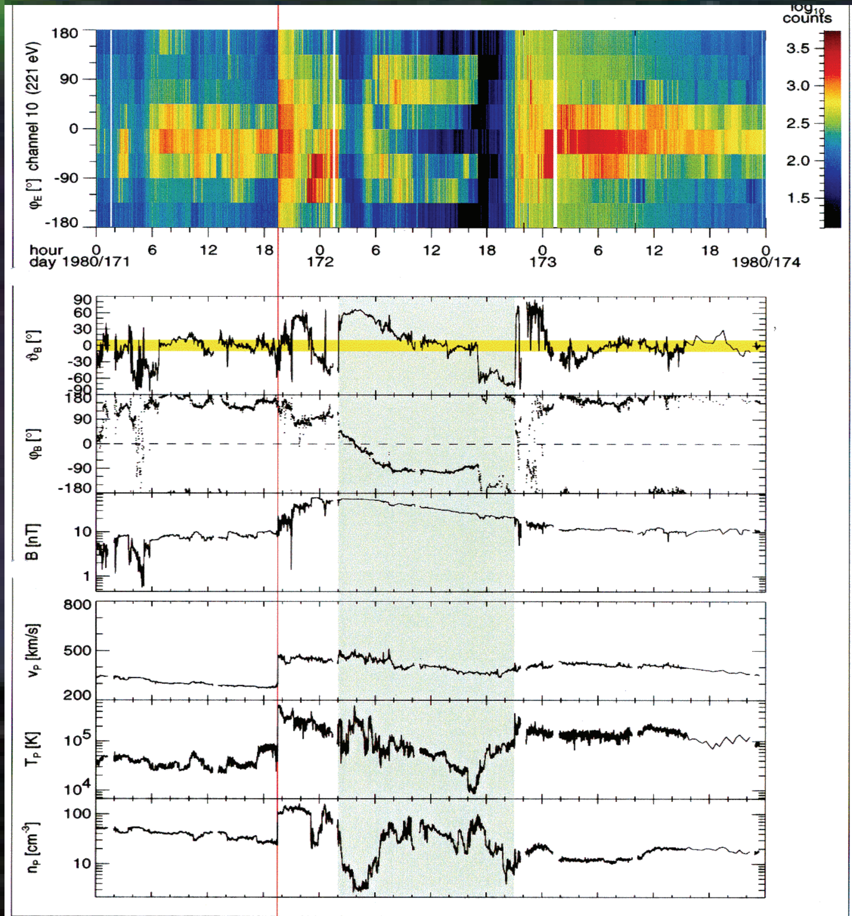
7. The transformation of CMEs into ICMEs

The majority of CMEs has a clearly discernible multi-part structure. But most ICMEs exhibit a very different two-part structure: a shock-compressed sheath layer followed by a rather homogeneous low beta plasma, with several other characteristic signatures („driver gas", „piston").

7.1. How is the CME structure transformed into the ICME structure?





7. The transformation of CMEs into ICMEs

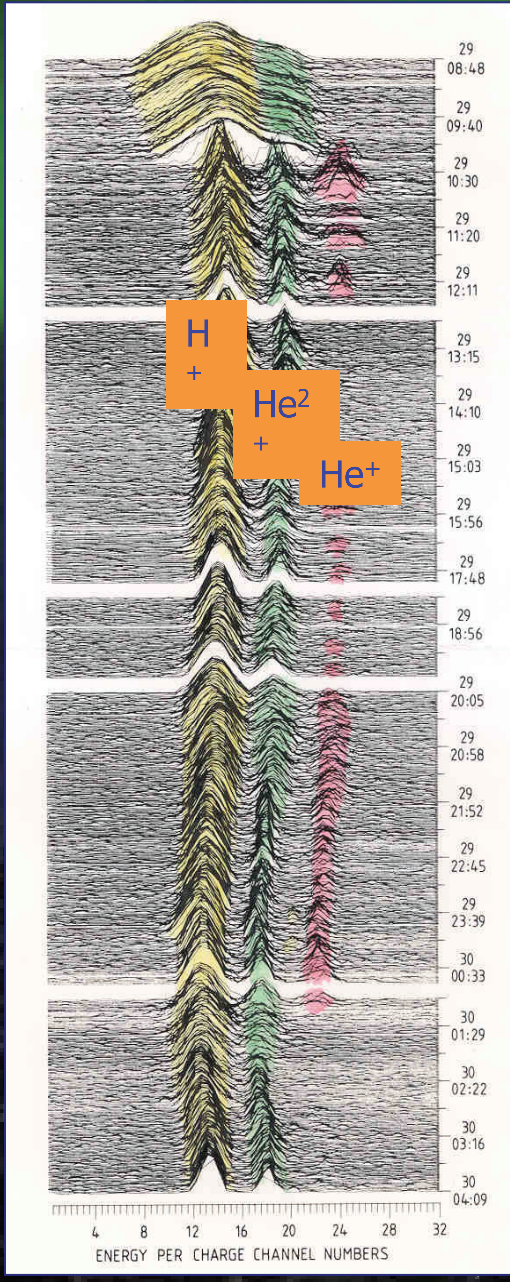
7.1 Why are not all ejecta clouds also magnetic clouds?

7.2. Where and how long do ICMEs act as shock drivers?

7.3 Why do we find He+ so rarely in ICMEs?

7.4. What do abundance and ionization state mesurements tell us about the ICMEs' origin?

7.5. What does bi-directional streaming really mean?



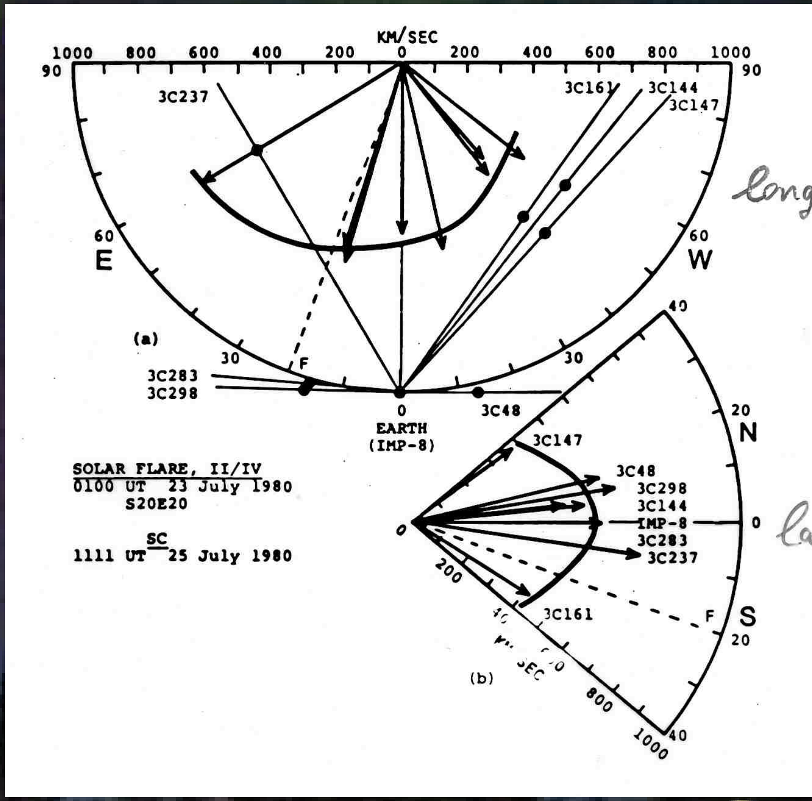
8. The extent of shock fronts, ejecta, and SEP fluxes

8.1. How far around the Sun do ICMEs and SEP fluxes extend?

8.2. How irregular are the shockfronts due to local shock speed differences?

8.3. Are shock fronts continuous surfaces all around?

8.4. Acceleration & deceleration processes throughout the heliosphere?



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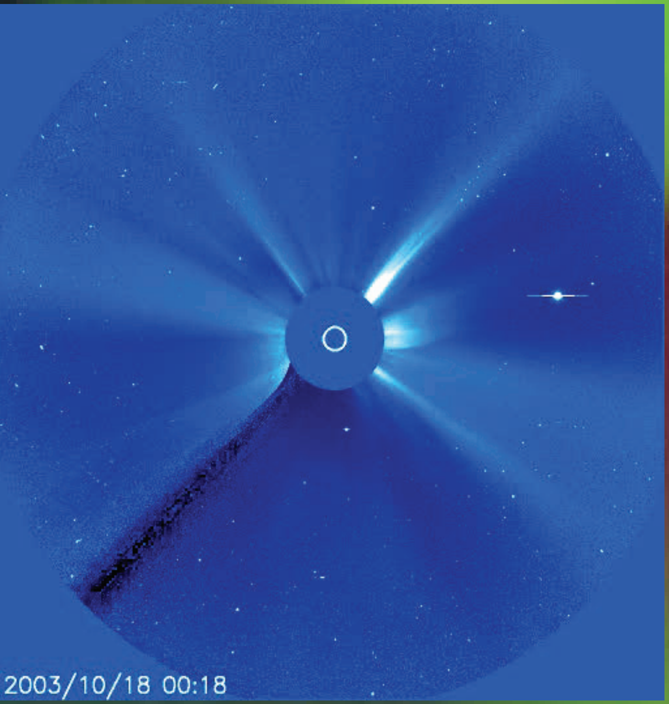

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