The image features a large, textured orange sphere, possibly representing a filament or a celestial body, with a dark, irregular shape on its left side. The sphere has a granular, porous appearance. The background is black, and the entire scene is framed by a thin black border.

FILAMENT EVOLUTION IN CMES AND IMPLICATIONS FOR ICMES

PURPOSE

- To stimulate discussion on the standard but unconvincing answers to two questions regarding the fate of erupting filament plasma

MOTIVATION

- Morphology of 12 Sept 2000 CME analyzed by *Suleiman et al.* [2004]

LONGSTANDING QUESTIONS AND STANDARD ANSWERS

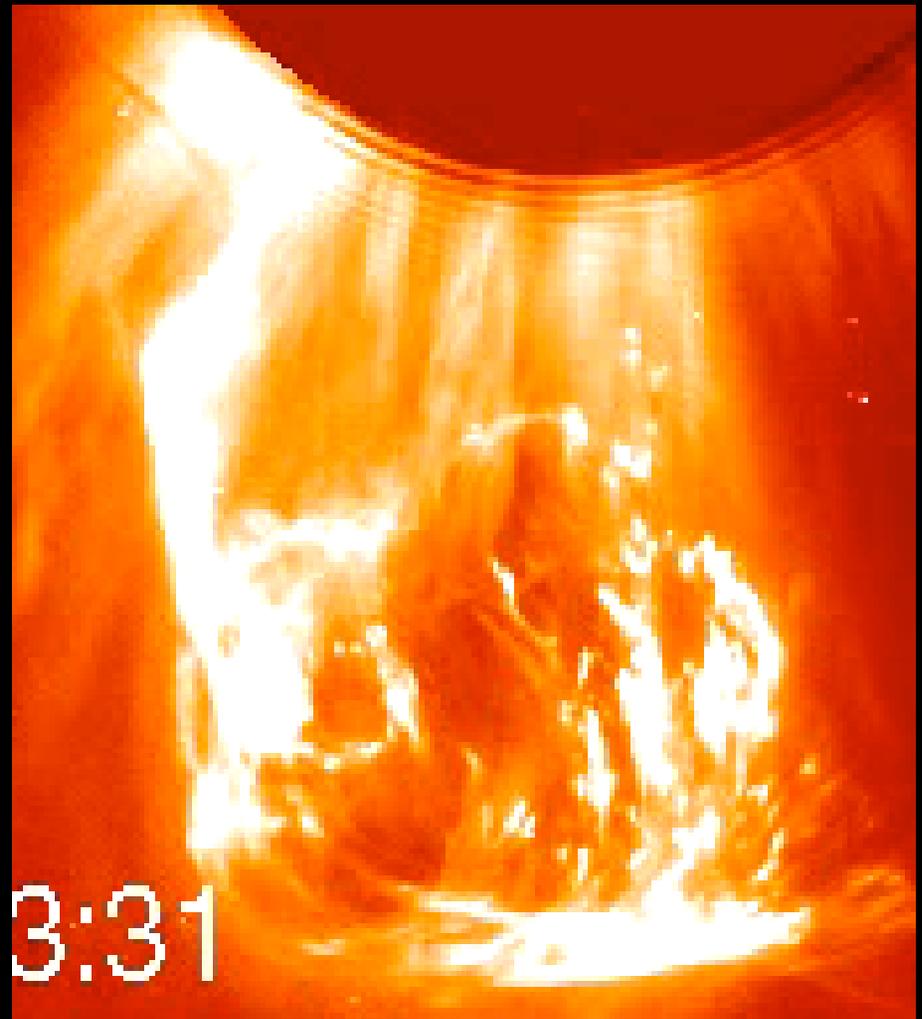
- What structures constitute the dark cavity and bright core of a 3-part CME?
 - Dark cavity is a flux rope.
 - Bright inner core is the filament.
- Why are so few filament signatures detected in ICMEs?
 - Filaments are very small compared to CMEs.

ALTERNATIVE ANSWERS

- What structures constitute the dark cavity and bright core of a 3-part CME?
 - The bright core is filament plasma that has lost its magnetic coherence and resides on flux rope field lines that form during CME liftoff.
- Why are so few filament signatures detected in ICMEs?
 - Filament plasma can fill substantial volumes of CMEs but heats and thereby loses its expected low-charge-state signature.

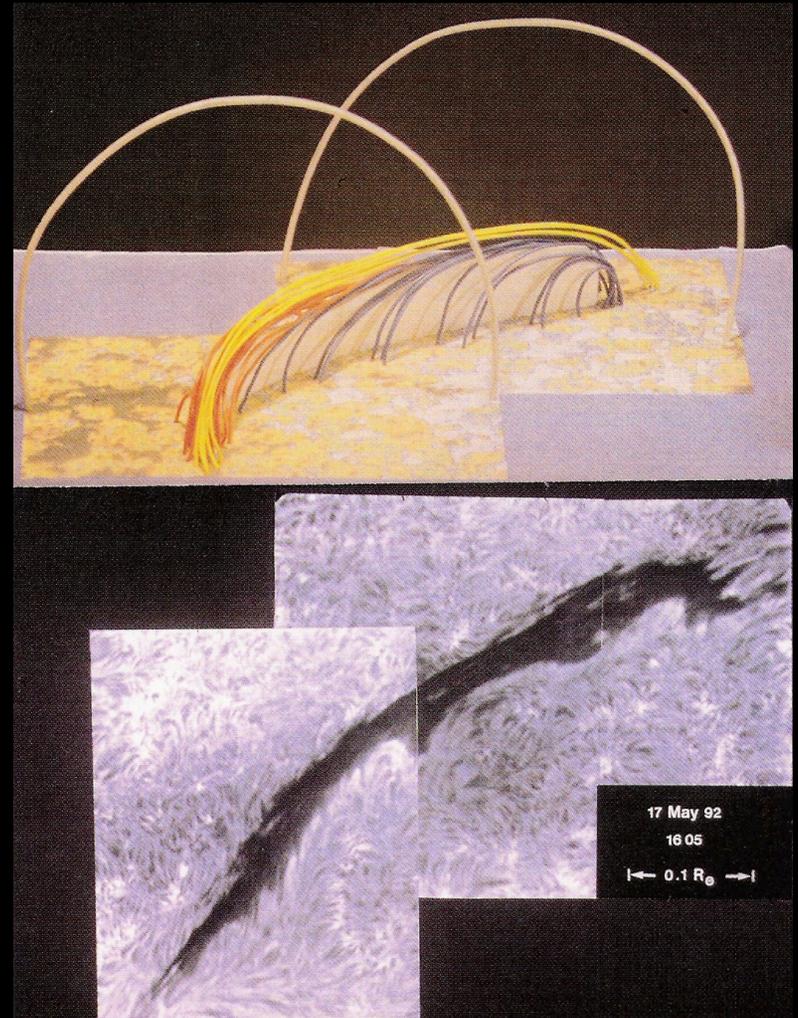
The bright core is filament plasma that has lost its magnetic coherence and resides on flux rope field lines that form during CME liftoff.

- Evidence on 9/12/00
 - EIT arcade event implies
 - partial disconnection
 - creation of tightly wound flux rope
 - Bright core is filament plasma on tightly wound flux rope coincident with X-ray arcade event
 - Filament plasma may gain access to flux rope in dark cavity through reconnection



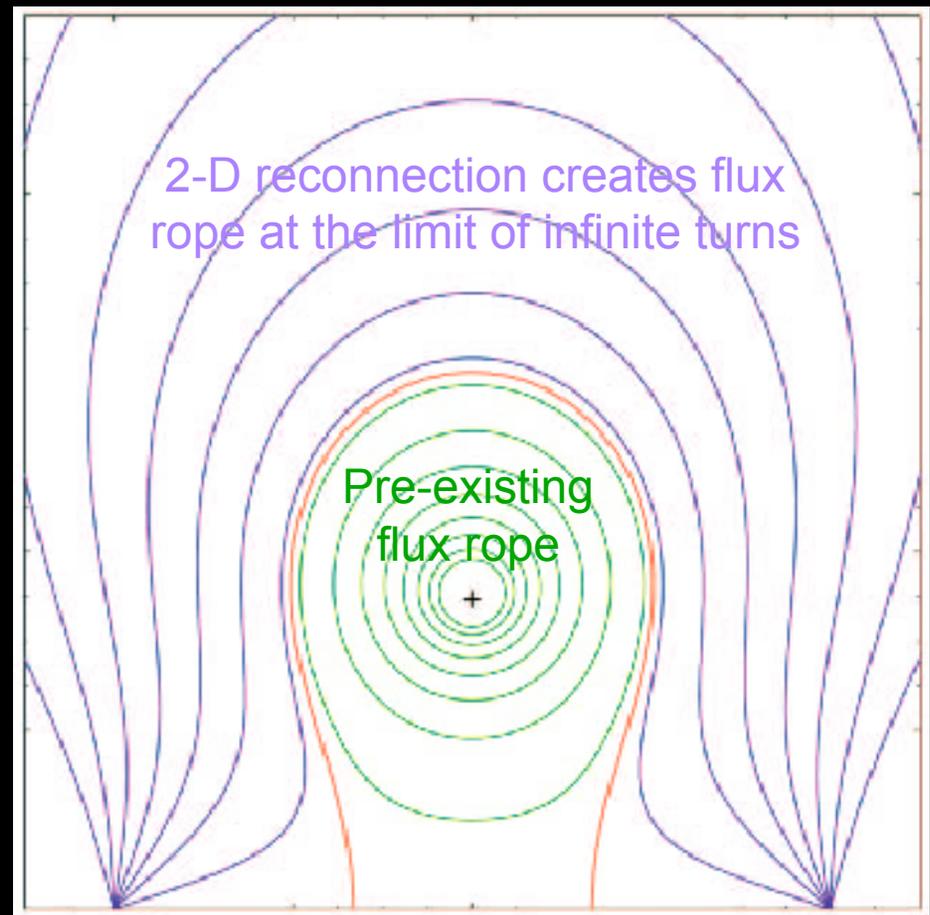
TIGHTLY-WOUND FLUX ROPE IS NOT PRE-EXISTING FILAMENT

- Based upon observations, Martin argues that filaments have little if any twist
- On Monday, van Ballegooijen argued likewise
- CME models with pre-existing filament flux ropes require only a few turns (?)



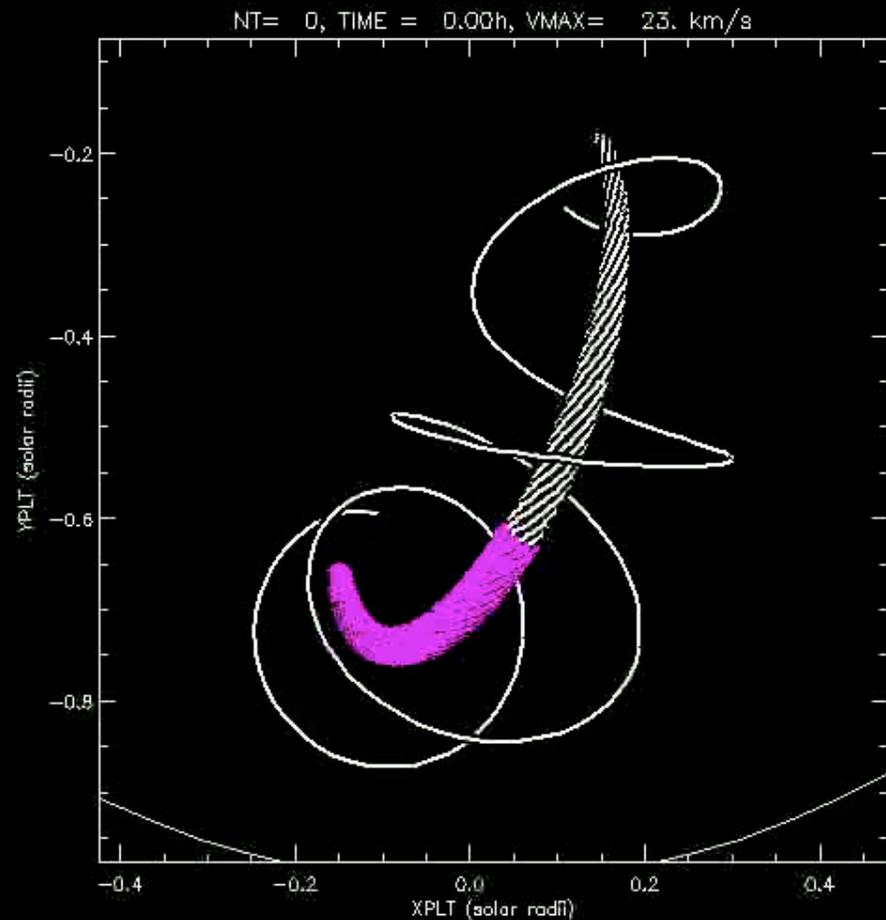
MODEL RECONNECTION CREATES TIGHTLY-WOUND FLUX ROPE

- Lin, Forbes et al. model incorporates
 - Pre-existing filament flux rope
 - 2-D partial disconnection at liftoff to create encompassing flux rope “bubble” with infinite turns



ALTERNATIVE TO LOSS OF MAGNETIC COHERENCE

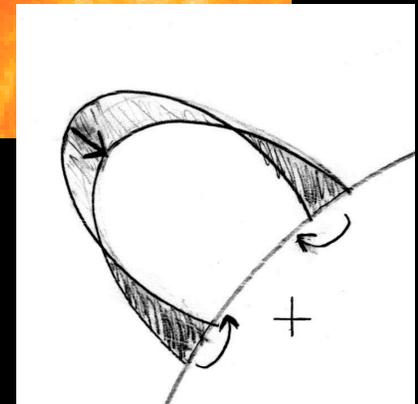
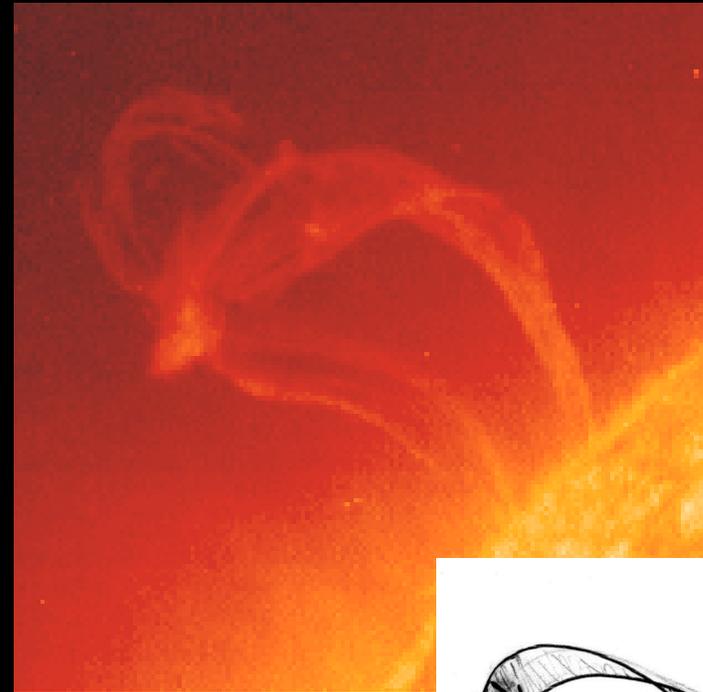
- Tightly-wound flux rope is pre-existing filament transformed by kink instability
- This option avoids problem of filament plasma transport to top of loops against force of gravity

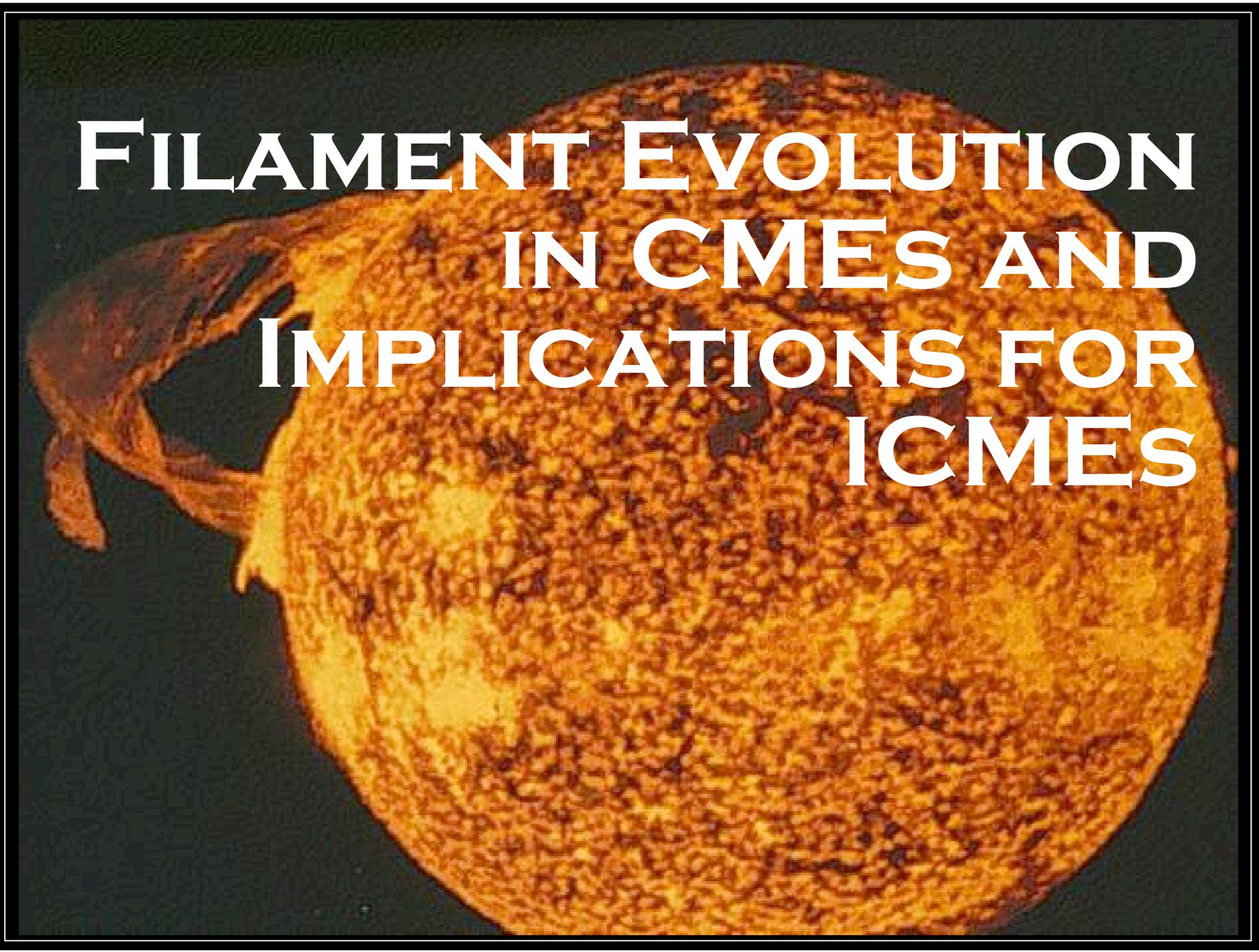


A. van Ballegooijen [last week]

ANOTHER WAY TO TWIST FILAMENT FIELDS

- Martin's Roll Effect
 - Filaments are sheets
 - Tension forces of overlying fields cause apex of sheet to curl during eruption
 - Rolling twists feet in opposite directions
 - Resulting flux rope will have both chiralities but not many turns

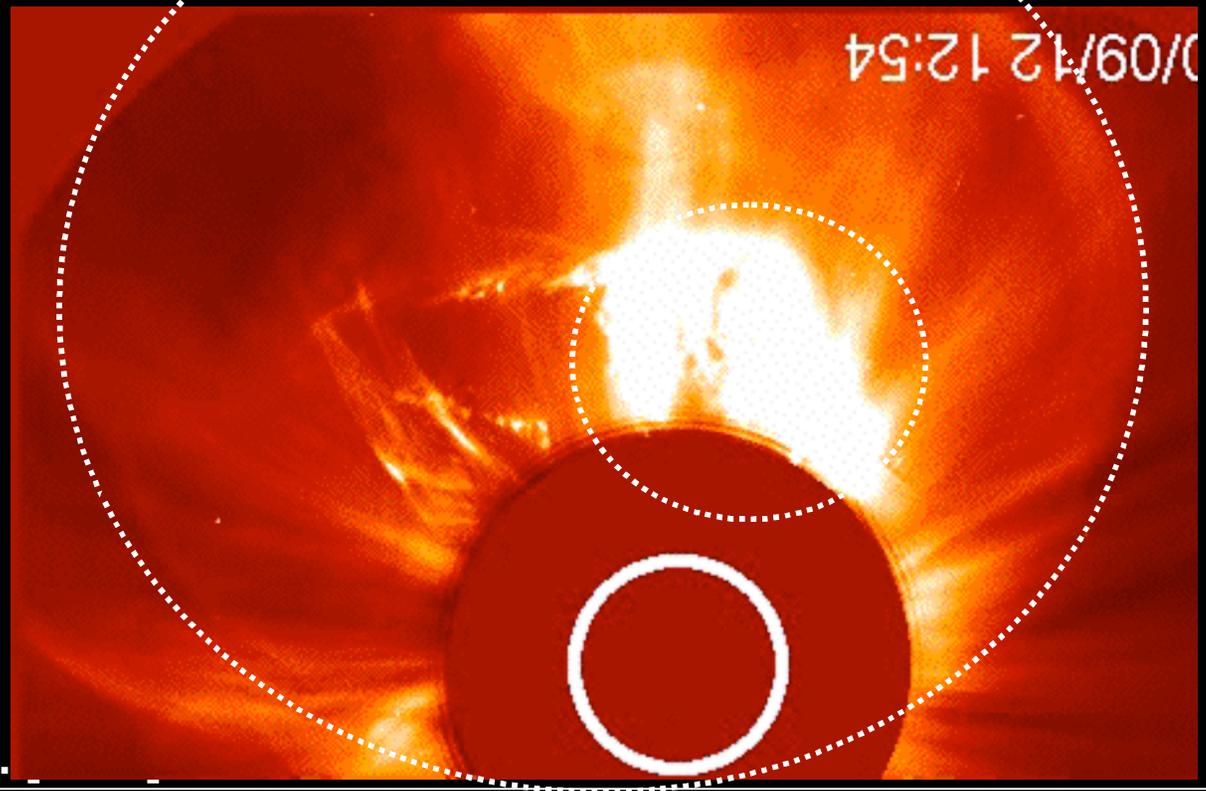
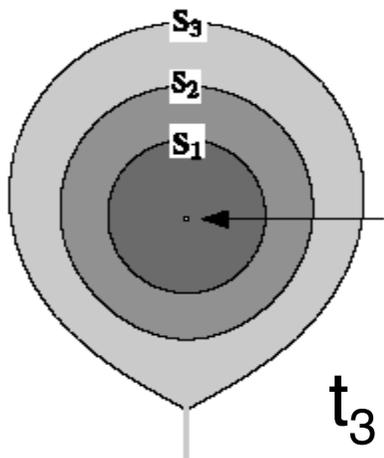
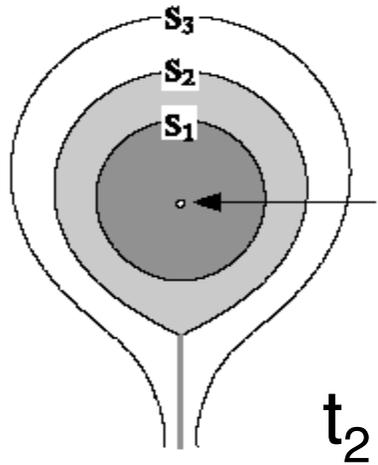
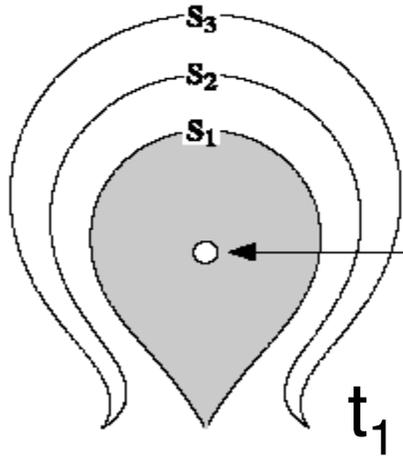


The image features a large, textured orange sphere, possibly representing a filament or a celestial body, with a dark, fibrous tail extending from its left side. The sphere has a granular, porous appearance with varying shades of orange and yellow. The background is solid black, and the entire scene is enclosed in a thin black border.

FILAMENT EVOLUTION IN CMES AND IMPLICATIONS FOR ICMES

FILAMENT SIZE

- Model filament small compared to CME
- Bright core much larger



J. Lin et al.

QUESTION ONE SUMMARY

- While the bright core is filament plasma, it has not passively risen with the CME
 - volume too large
 - tightly-wound flux rope implies formation at liftoff
 - concurrent arcade event
 - pre-existing filament flux ropes have few if any turns
- Filament plasma can gain access to flux rope in dark cavity through reconnection and thus no longer reside on original filament field lines

WHY ARE SO FEW FILAMENT SIGNATURES DETECTED IN ICMEs?

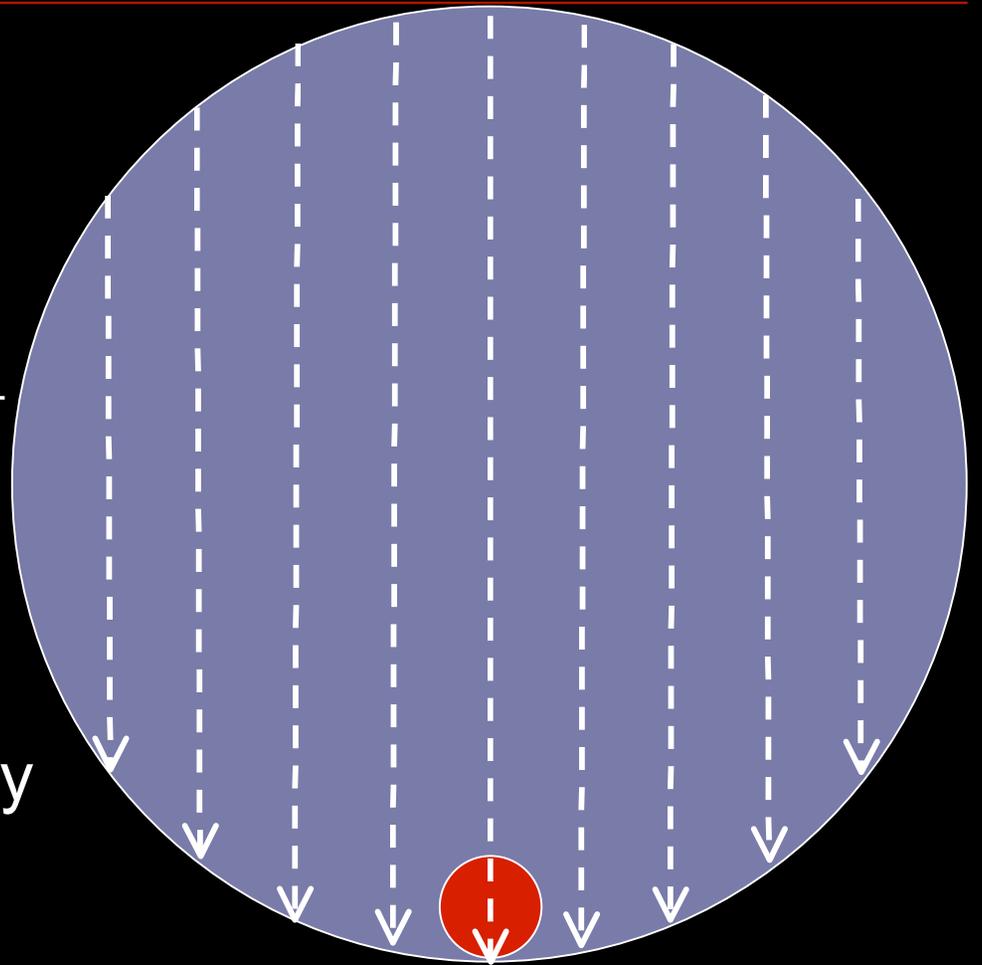
- Filaments commonly accompany CMEs.
- Filament plasma in bright cores occupy larger volume than original filament.
- Smoking-gun signature in heliosphere has been He^+ , but it is rarely observed.

9 HE⁺ EVENTS IN 33 YEARS

Date	Spacecraft	Author	Publication
22 Oct 2001	Genesis	Steinberg	
3 May 1998	ACE	Skoug, Gloeckler, et al.	1999
11 Jan 1997	Wind	Burlaga et al.	1998
10 Dec 1981	ISEE 3	Bochsler	1983
9 May 1979	Helios 1	Schwenn	1983
1 Dec 1977	IMP 7	Zwickl et al.	1982
4 Dec 1977	IMP 7	Zwickl et al.	1982
29 Jul 1977	IMP 7	Gosling et al.	1980
29 Jan 1977	Helios 1	Schwenn et al.	1980
Small events prior to 1972 (poor spacecraft coverage)			
7 in 1969-1975	Vela	Bame	1980
13 Jan 1967	Vela	Bame	1980
8 Oct 1965	Vela	Bame et al.	1968

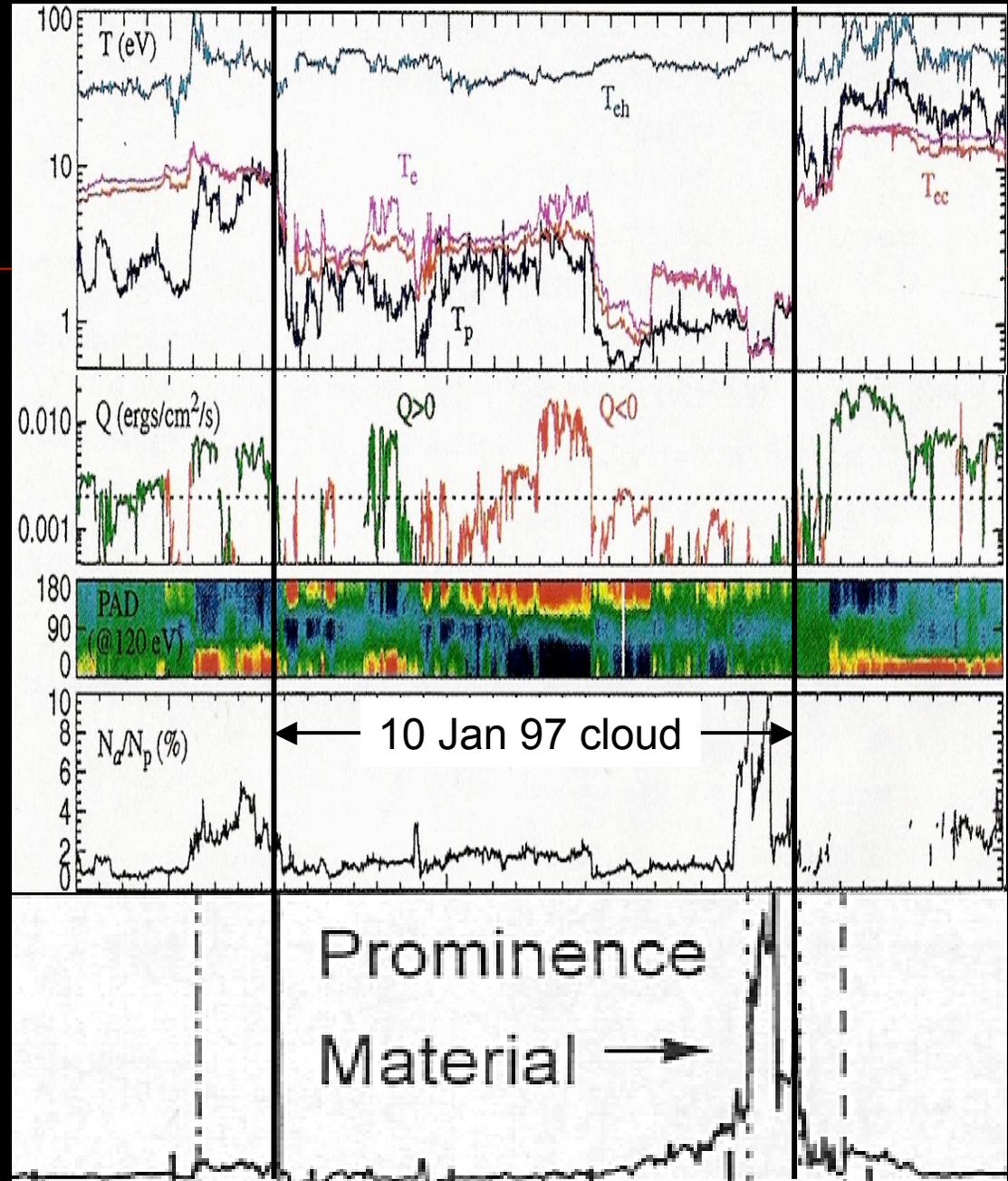
PROBABILITY OF ENCOUNTERING FILAMENT PLASMA

- During 1996-2002, *Cane and Richardson [2003]* found 214 ICMEs in near-Earth data
- Only 1%(2) contained He^+
- Factor of 10 too small for core radius 1/10 ICME radius
- Factor of 5 too small if only half of CMEs contain filament material



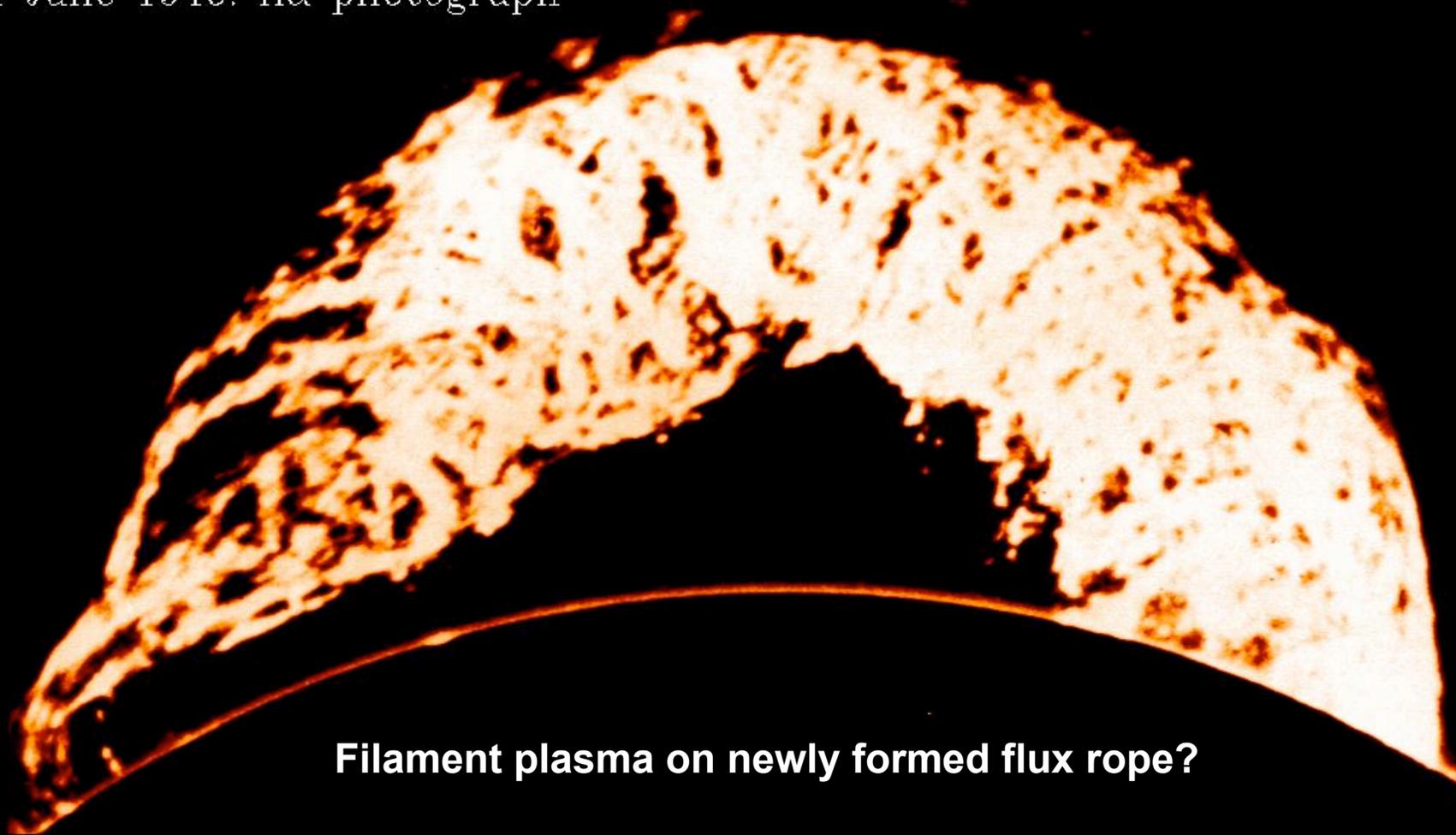
HE⁺ EVENT

- No consistent place in magnetic cloud flux ropes
 - Supports loss of magnetic coherence
 - In situ electron temperature coldest reported—no heat flux
 - Supports magnetic isolation
- [Larson et al., 2000]



RECORD He^+ EVENT?

4 June 1946: $\text{H}\alpha$ photograph



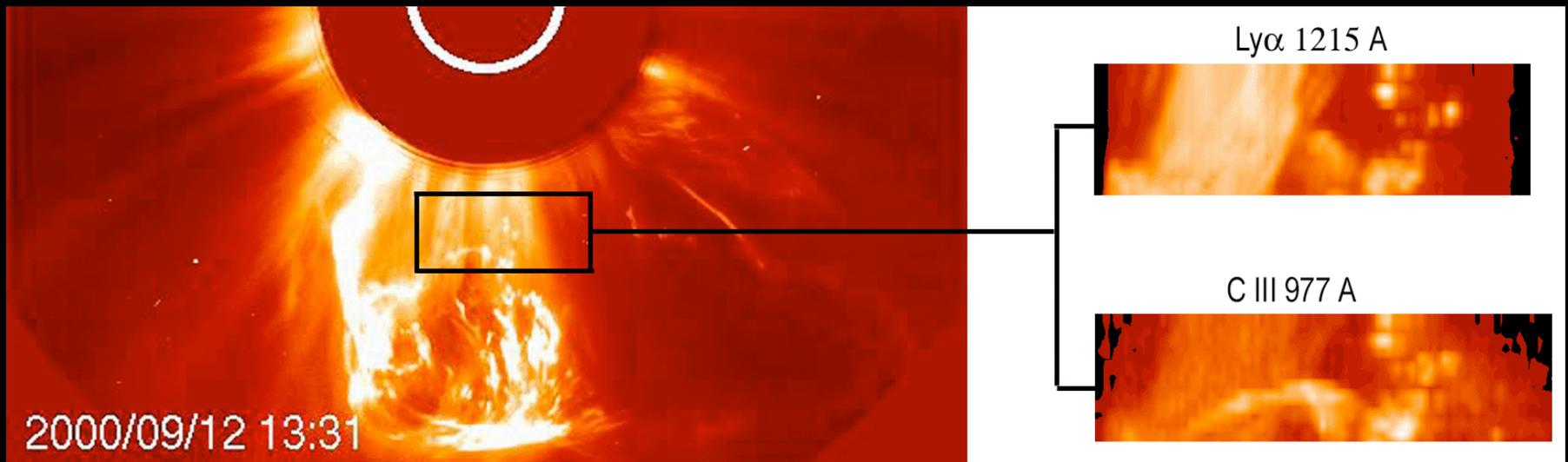
Filament plasma on newly formed flux rope?

Source: High Altitude Observatory Archives

HAO A-007

UVCS SHOWS COOL PLASMA

- Helical structure passed slit on 12 Sept 2000
- C III emission indicates cool filament plasma
- Ratios of line intensities give ionization temperature range $<25,000$ °K to $>150,000$ °K implying some heating
- No high-temperature emission (e.g., Mg X)
- He⁺ event?



MORE QUESTIONS RAISED THAN ANSWERED

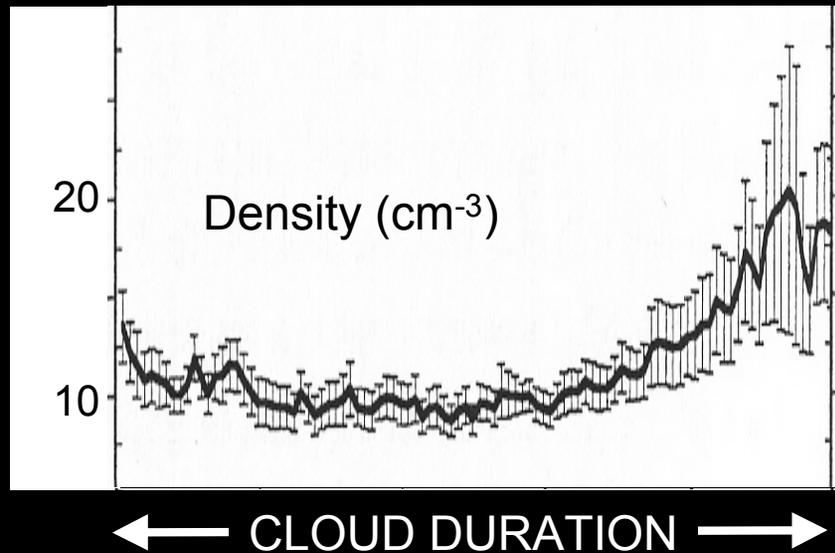
- Are He⁺ events rare because they are magnetically isolated?
 - They occur on disconnected and doubly-connected field lines
 - While disconnection is rare, and may signal magnetic isolation, double connection is not
- Are He⁺ events those that show filament plasma on tightly wound flux ropes?
- Does interchange reconnection low in corona place filament plasma on open field lines where low-charge states are not retained?
- Does retention of low charge states on filament plasma have anything to do with magnetic topology?

WHY ARE SO FEW FILAMENT SIGNATURES DETECTED IN ICMES?

- While the question of why He⁺ events are rare remains unanswered, the alternative answer to our question remains viable
 - Much of the plasma from filaments heats and thereby loses its expected low-charge-state signature
- *Skoug et al.* [1999] conclude, “It is...possible that prominence material is regularly observed in CMEs at 1 AU but is not recognized as such because it is no longer distinguishable as ionizationally cold.”
- Observations of rising filaments indicate plasma heating [*T. Forbes*, private communication].

INCREASING CLOUD DENSITY MAY SIGNAL FILAMENT PLASMA

- Averages of 19 magnetic clouds [*Lepping et al.*, 2003]
- Half show density rise
- Partly dynamic effect?
- Mix of open (~40%) and closed fields



CONCLUSIONS

- Filament plasma may gain access to tightly wound flux ropes through
 - magnetic reconfiguration at CME liftoff
 - kink instability
- While model filaments are dwarfed by CMEs, filament plasma in bright cores is not, implying some kind of transformation
- Filament plasma may lose both its magnetic coherence and its low-charge-state signature