In Situ Observations of CMES in the Heliosphere

Focusing STEREO vision on internal and contextual HCME complexity

Internal complexity: Variability of HCME signatures

- Large-scale field rotation
- Strong magnetic field
- Temperature depression
- Low magnetic field variance

} *Magnetic cloud*

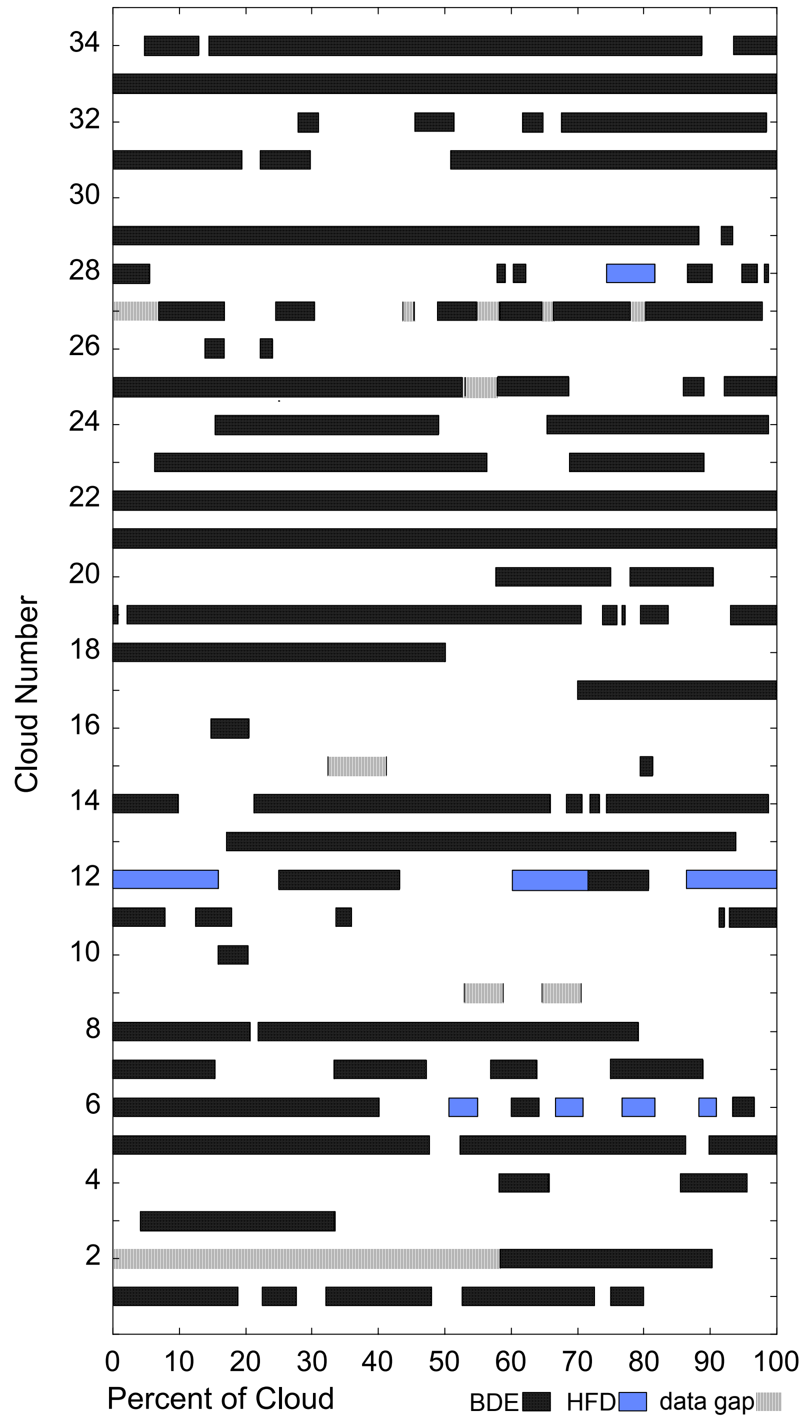
- Cosmic ray depression
- Mismatched sector boundary signatures **New**
- Charge state and composition anomalies
- Counterstreaming suprathermal electrons

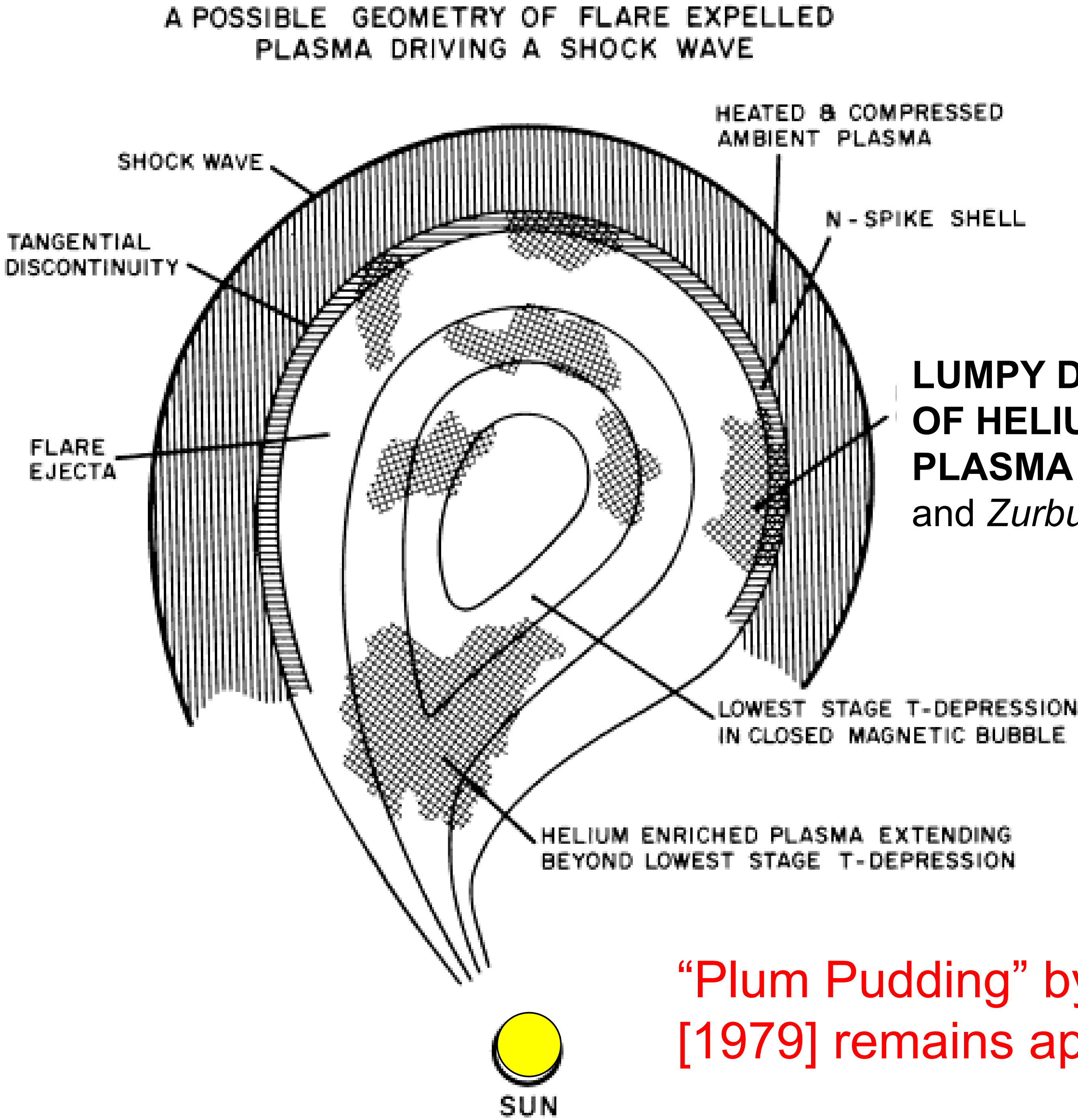
[e.g., *Gosling*, 1990; *Neugebauer and Goldstein*, 1997]

Variability in counter-streaming electrons

- Each line represents one magnetic cloud
- Shaded bars indicate intervals of closed fields
- Clouds range from completely open to completely closed

Shodhan et al. [1999]





LUMPY DISTRIBUTION OF HELIUM ENRICHED PLASMA [Cf. *Lepri et al.* and *Zurbuchen et al.*, 2001]

"Plum Pudding" by Bame et al. [1979] remains appropriate

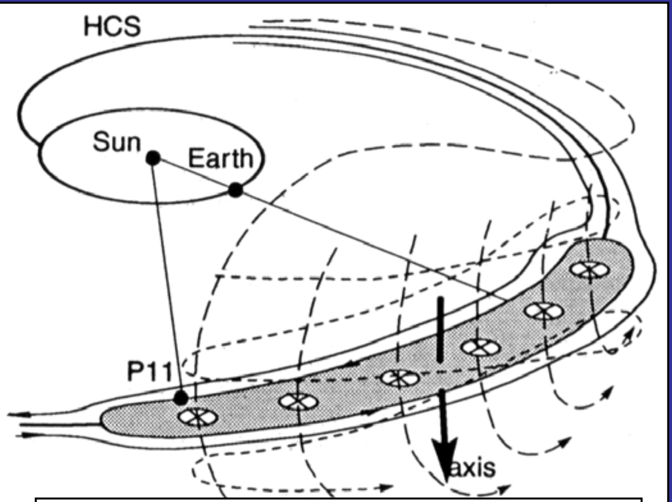
STEREO vision* focused on internal complexity can help determine

- shapes of
  - charge-state and composition regimes
  - magnetically open and closed regions
- solar counterparts to HCME types
  - e.g., do magnetic clouds correspond to CMEs with 3-part structure?

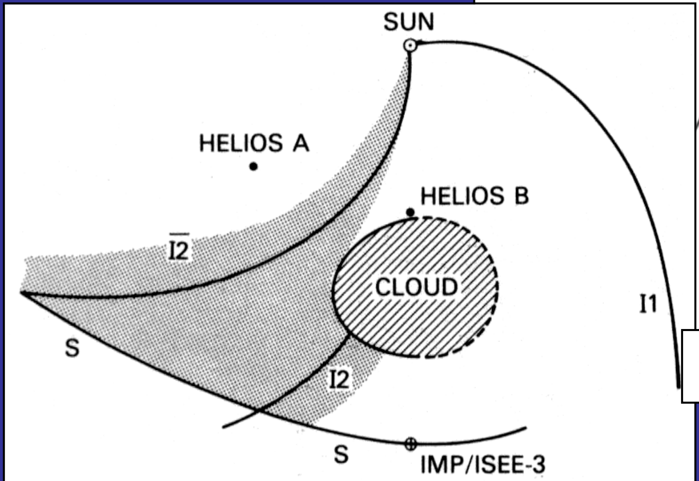
*two-point in situ measurements combined with heliospheric imaging

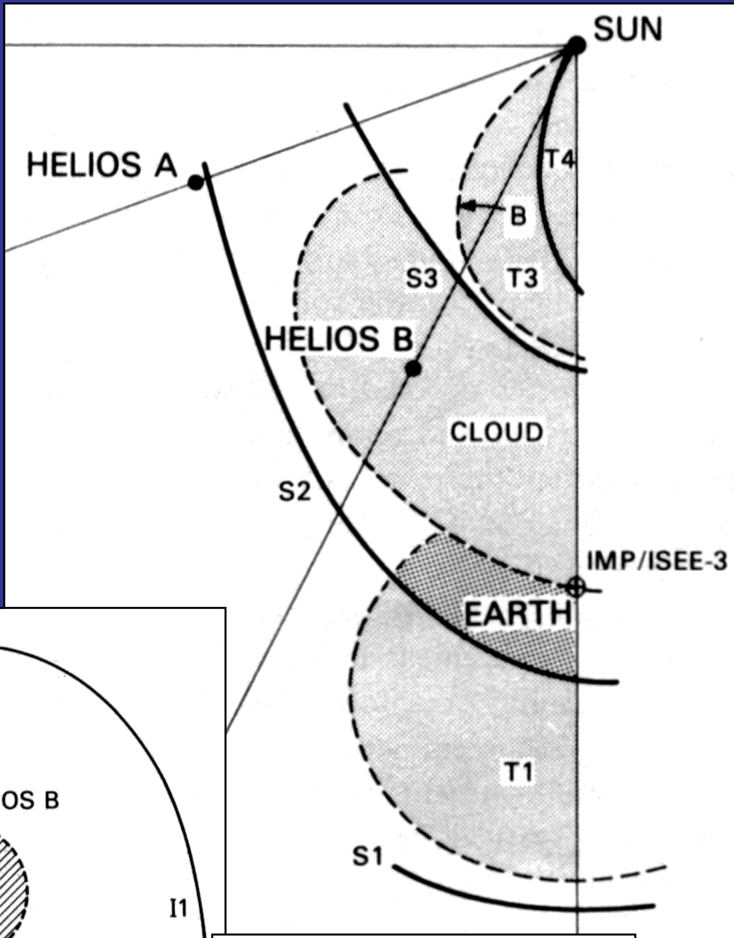
Contextual complexity: Evolution of shape and compound streams

- HCME distention
  - e.g., *Newkirk et al.*[1981], *Suess* [1988], *Odstrcil and Pizzo, Russell, Mulligan, et al.*
- Stream-HCME interactions
  - e.g., *Crooker and Cliver* [1994], *Fenrich and Luhmann* [1998], *Odstrcil and Pizzo*
- Multiple HCME interactions
  - e.g., *Gopalswamy et al., Cargill et al.*



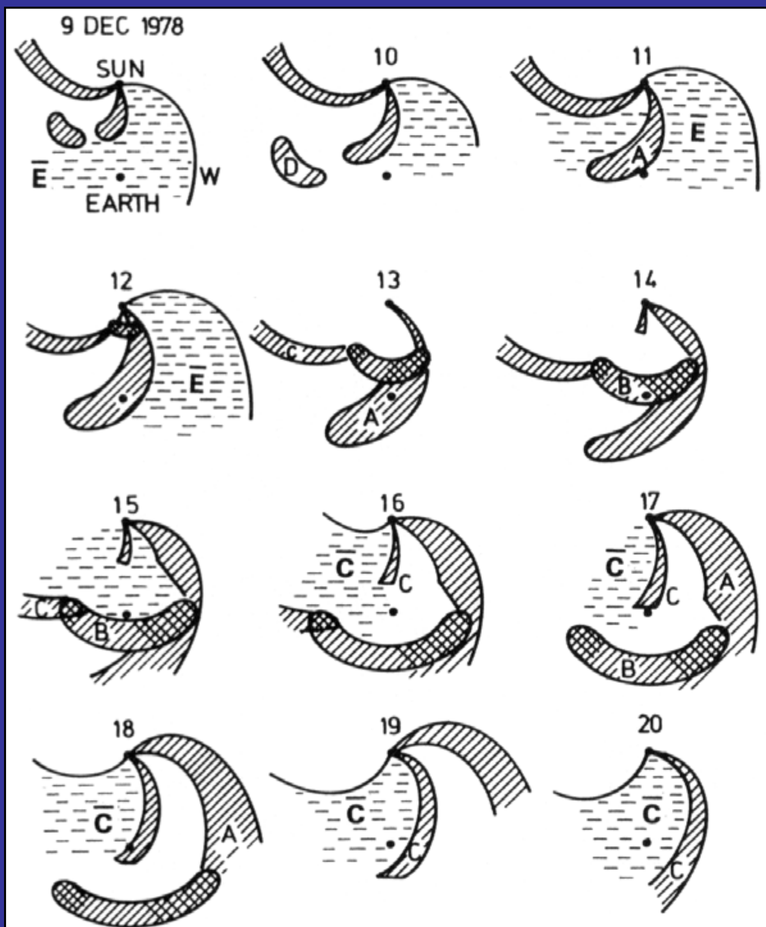
Crooker and Intriligator [1996]



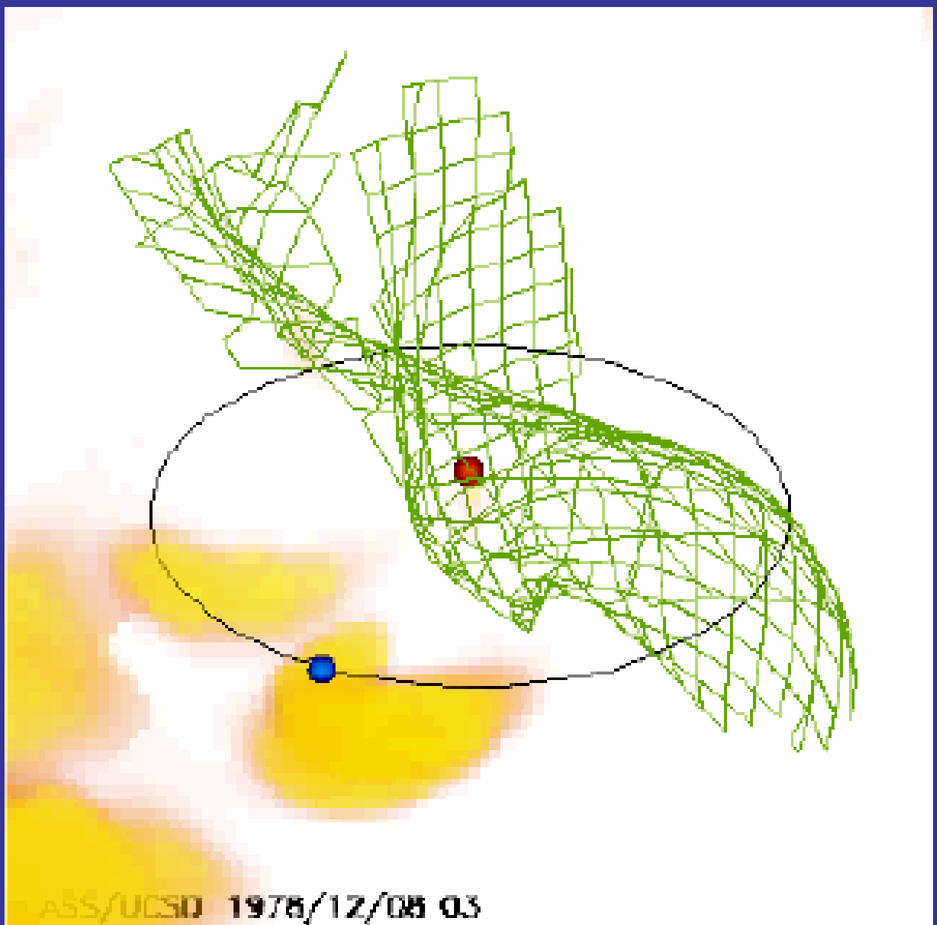


Burlaga et al. [1987]

Improving global views



IPS and multispacecraft analysis
[*Behannon et al.*, 1991]



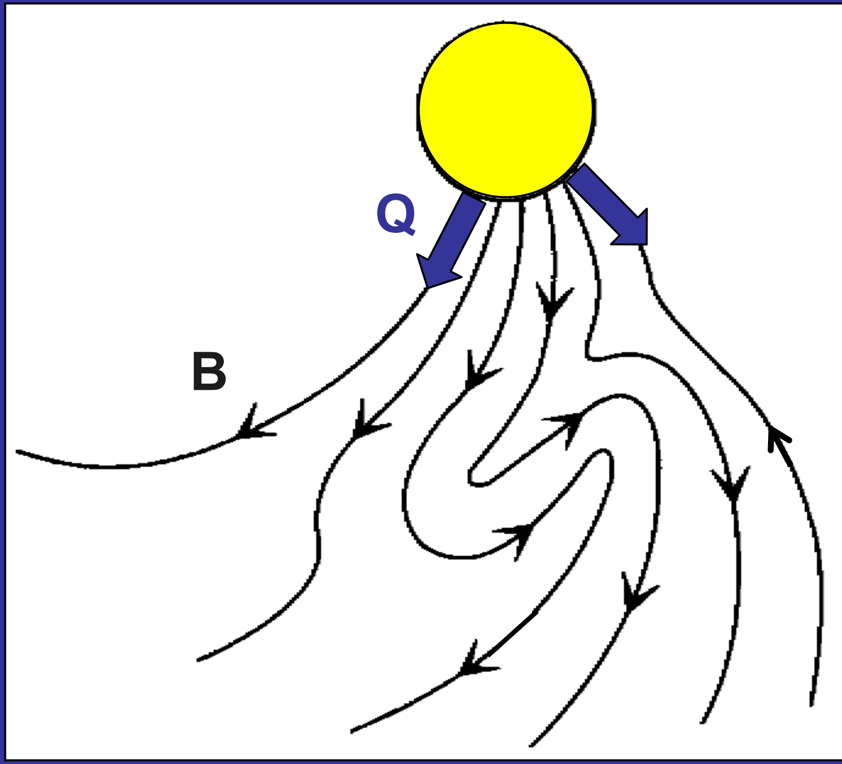
Helios photometer tomography
[*Jackson et al.*, 2002]

Contextual complexity: Outflows at sector boundaries

- HCMEs often bring or carry the polarity reversal marking a sector boundary [e.g.,*Crooker et al.*, 1998]
- Newly identified signature suggests large-scale transient outflows at sector boundaries may be more common than previously thought
  - Consists of mismatch between magnetic field reversals and polarity reversals incontrovertibly identified in electron data

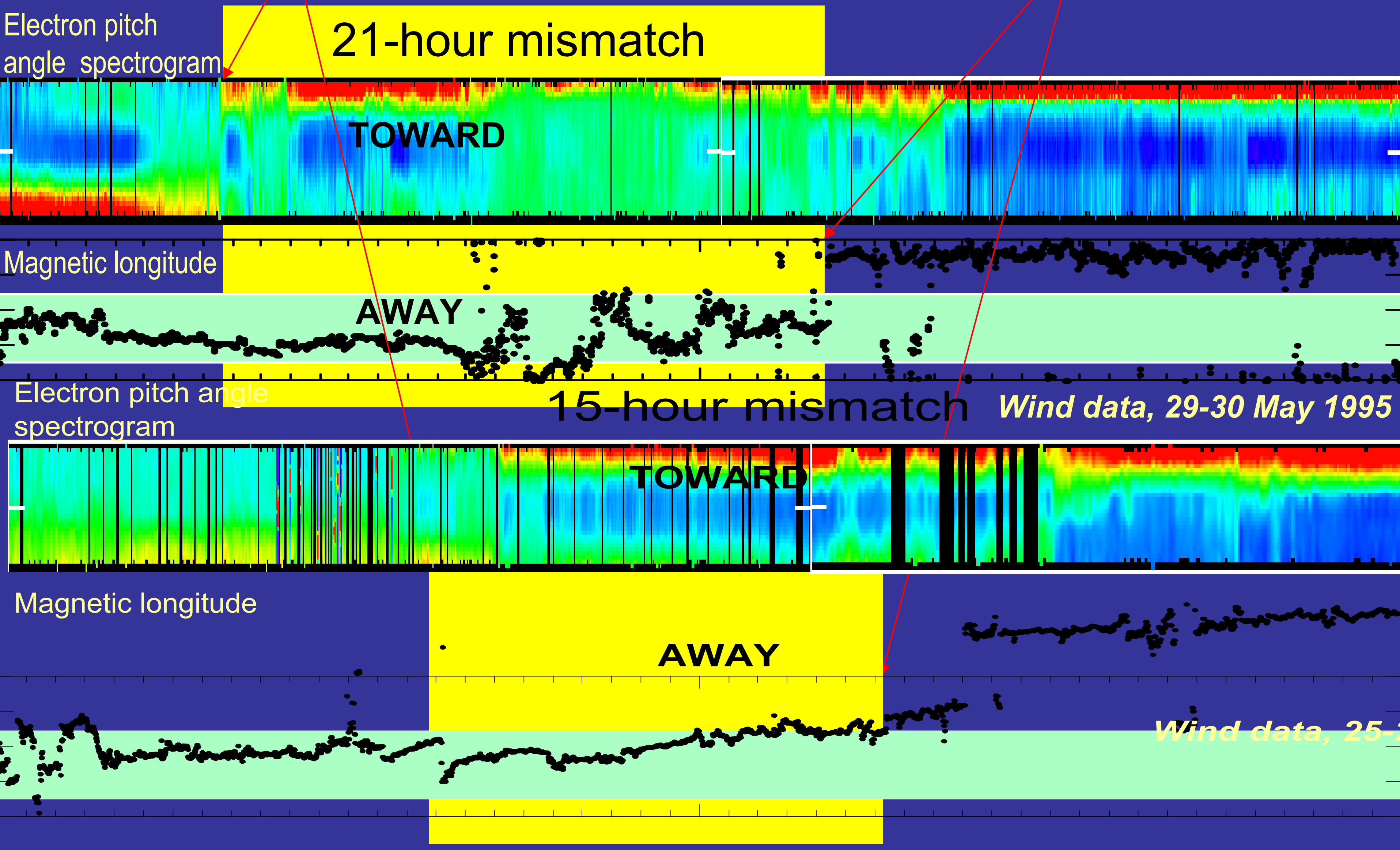
Suprathermal electrons as incontrovertible sensors of polarity

- Suprathermal electrons carry heat flux **Q** away from the Sun along magnetic field **B**
  - **Q** ll **B** ⇒ away polarity
  - **Q** anti-ll **B** ⇒ toward polarity
- **Q•B** always gives correct polarity, independent of local **B** orientation
- **Q•B** can distinguish fields turned back on themselves



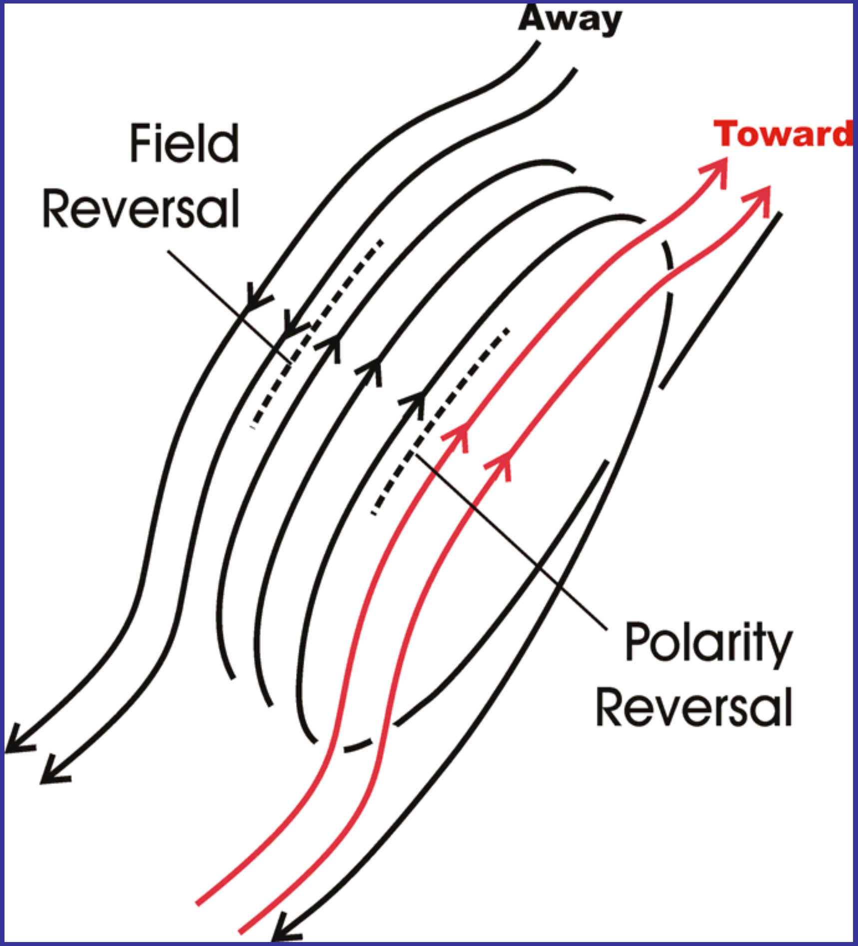
Kahler et al. [1996]

Polarity reversal precedes field reversal



Topology of mismatched reversals

- Magnetic field does not change at polarity reversal because away field line coils back on itself.
- Magnetic reversal occurs between coiled and straight field lines of same polarity.
- Signature found at 8 of 28 successive sector boundary crossings in 1995.
- One was caused by an open magnetic cloud.
- Remaining have few other HCME signatures.
- Mismatch may be signature of more general class of HCME [cf. *Howard et al.,* 1995].



STEREO vision focused on contextual complexity can help determine

- shapes of propagating HCMEs and dependence of shape on internal properties
- shapes and dynamics of multiple HCME and stream-HCME interaction regions
- characteristics of a more general class of HCMEs at sector boundaries

Discussion

- What do we know about the range of HCME forms from existing coronograph measurements?
- Will STEREO be able to identify
  - a range of forms in oncoming CMEs for correlation with in situ observations?
  - three-part structure in oncoming CMEs?
  - which forms give rise to
    - magnetic clouds?
    - magnetically closed HCMEs?
    - mismatched polarity and field reversals?