# Verification of the “Standard” Model of Flare-CME Connection

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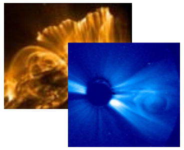
**NRL**

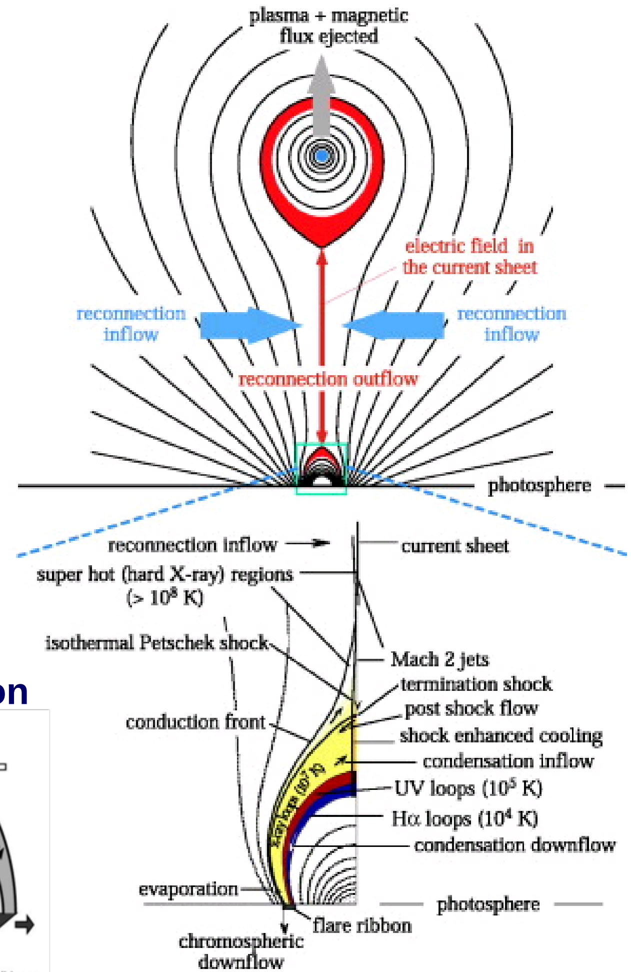
**Based on work from Patsourakos, Vourlidas & Kliem (2010)**



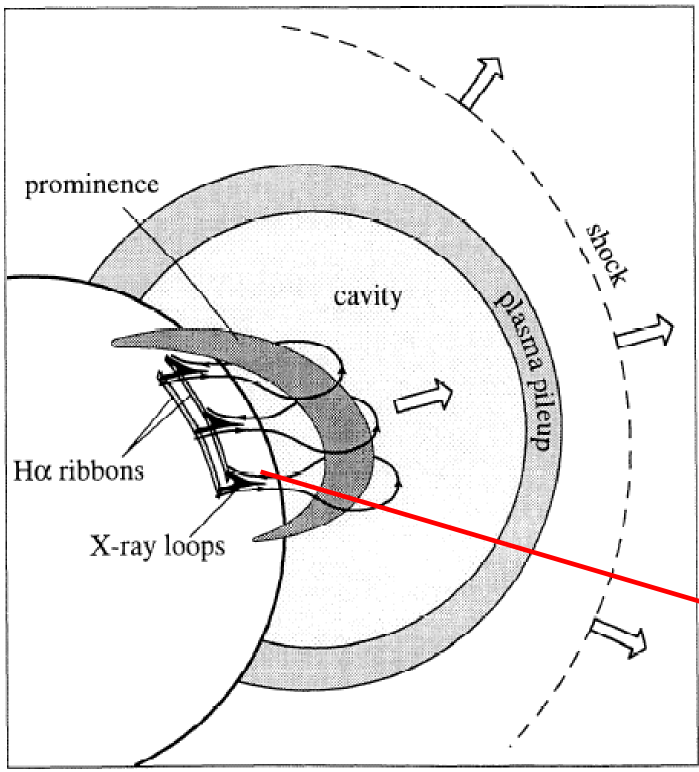
# The “Standard” Flare-CME Concept

(from Vourlidas’ Review at NAPA 2008 workshop)

Still at cartoon level (pick your favorite from *solarmuri.ssl.berkeley.edu/~hhudson/cartoons*)

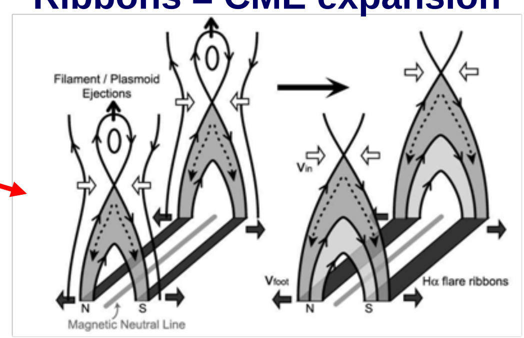



Lin & Forbes 2002




Forbes 2000

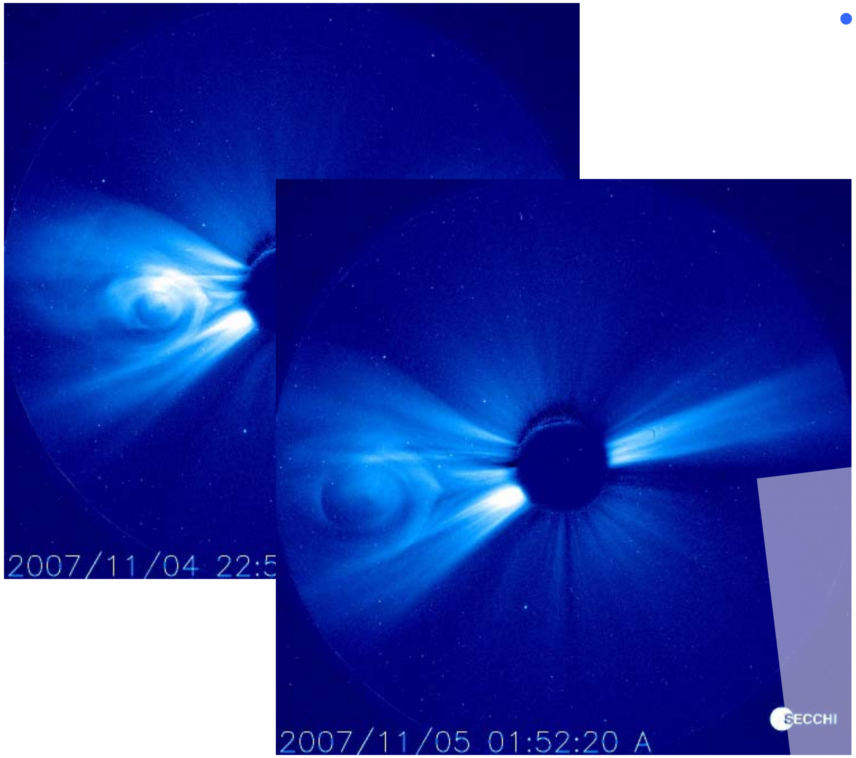
## Ribbons = CME expansion

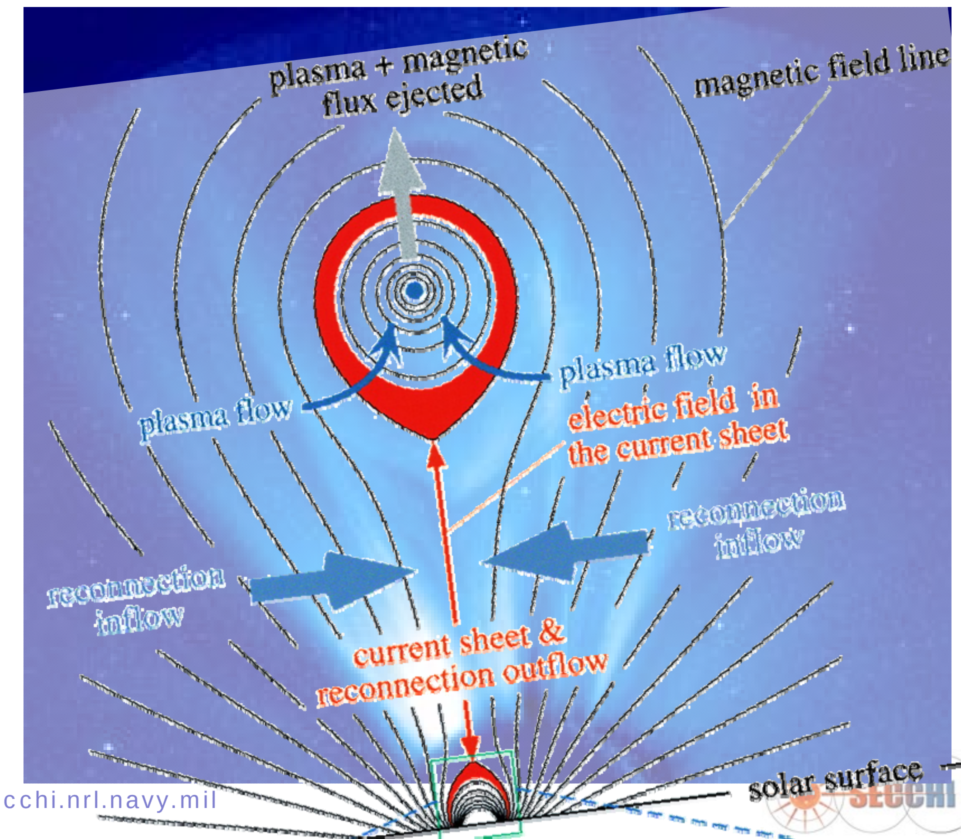


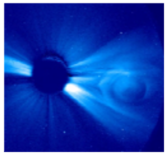

Asai et al 2006

# CME Internal Structure

- **The tip of the post-CME current sheet is visible.**
  - **The current sheet should be visible in the low corona.**



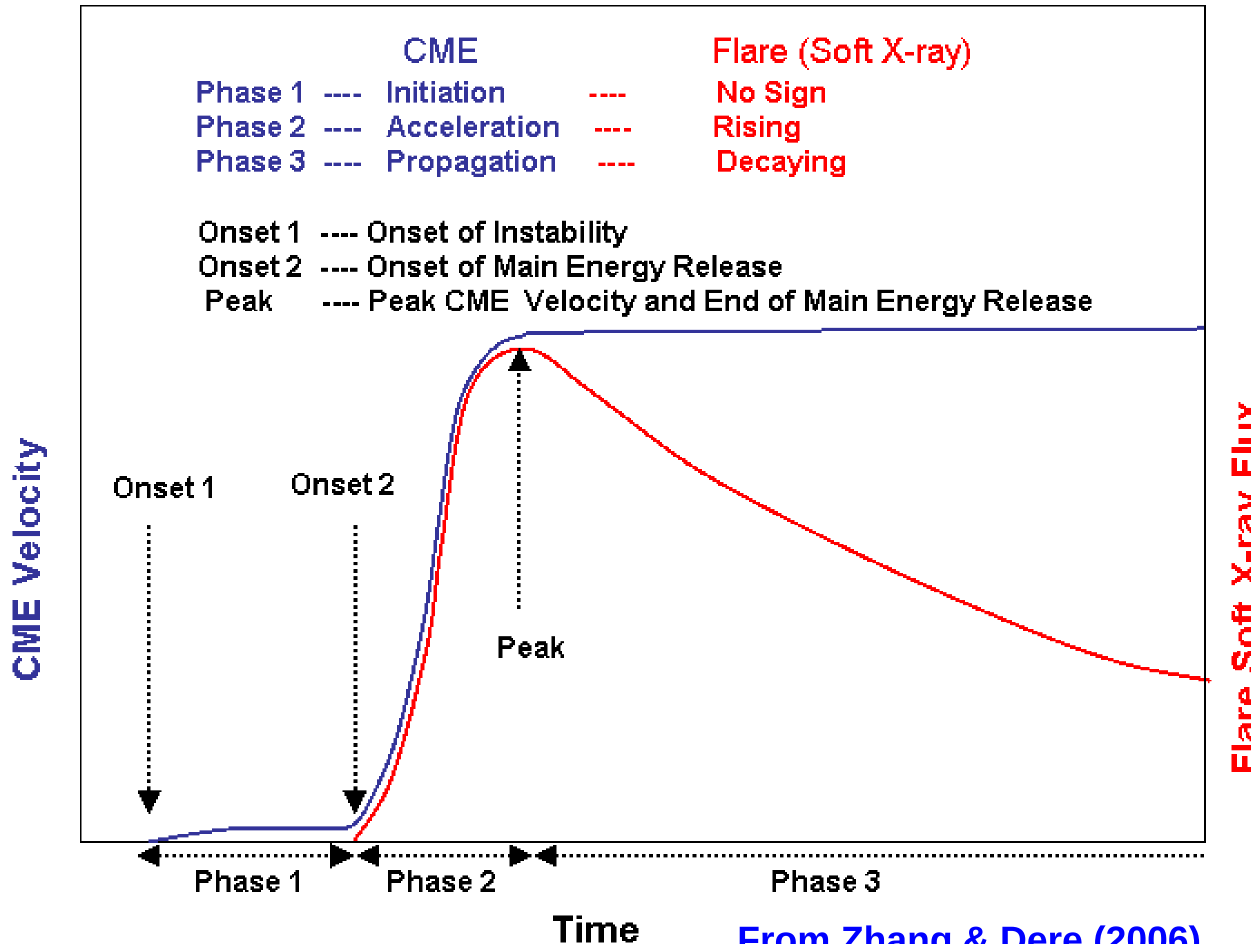


# Flare-CME Connection: CME Acceleration

(from J. Zhang's SHINE 2007 presentation)

**CME main acceleration coincides with flare energy release phase**

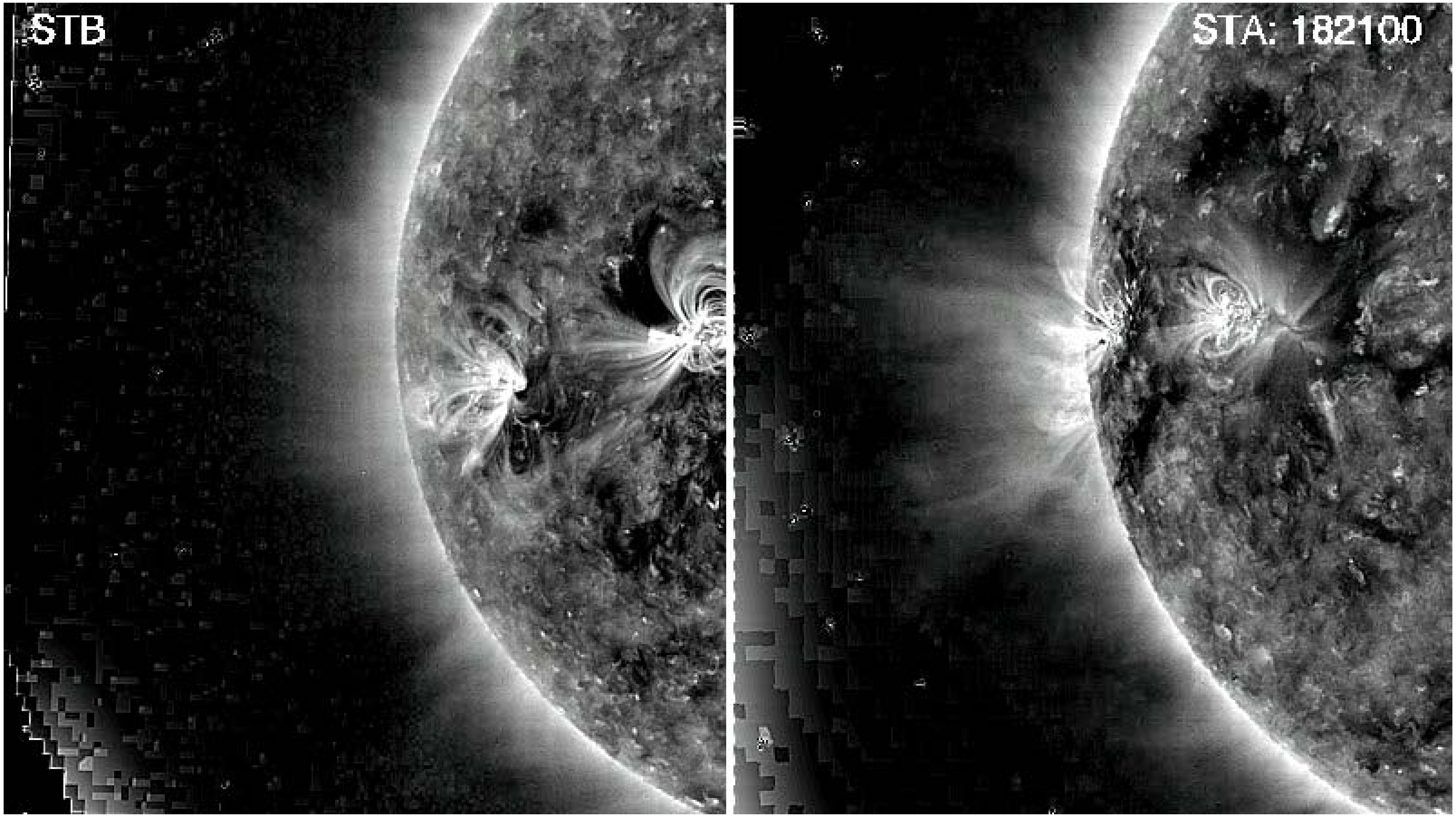
**CME Kinematic Evolution and Timing with Associated Flare**




**From Zhang & Dere (2006)**

# Observing the Genesis of Impulsive CMEs

Patsourakos et al (2010)

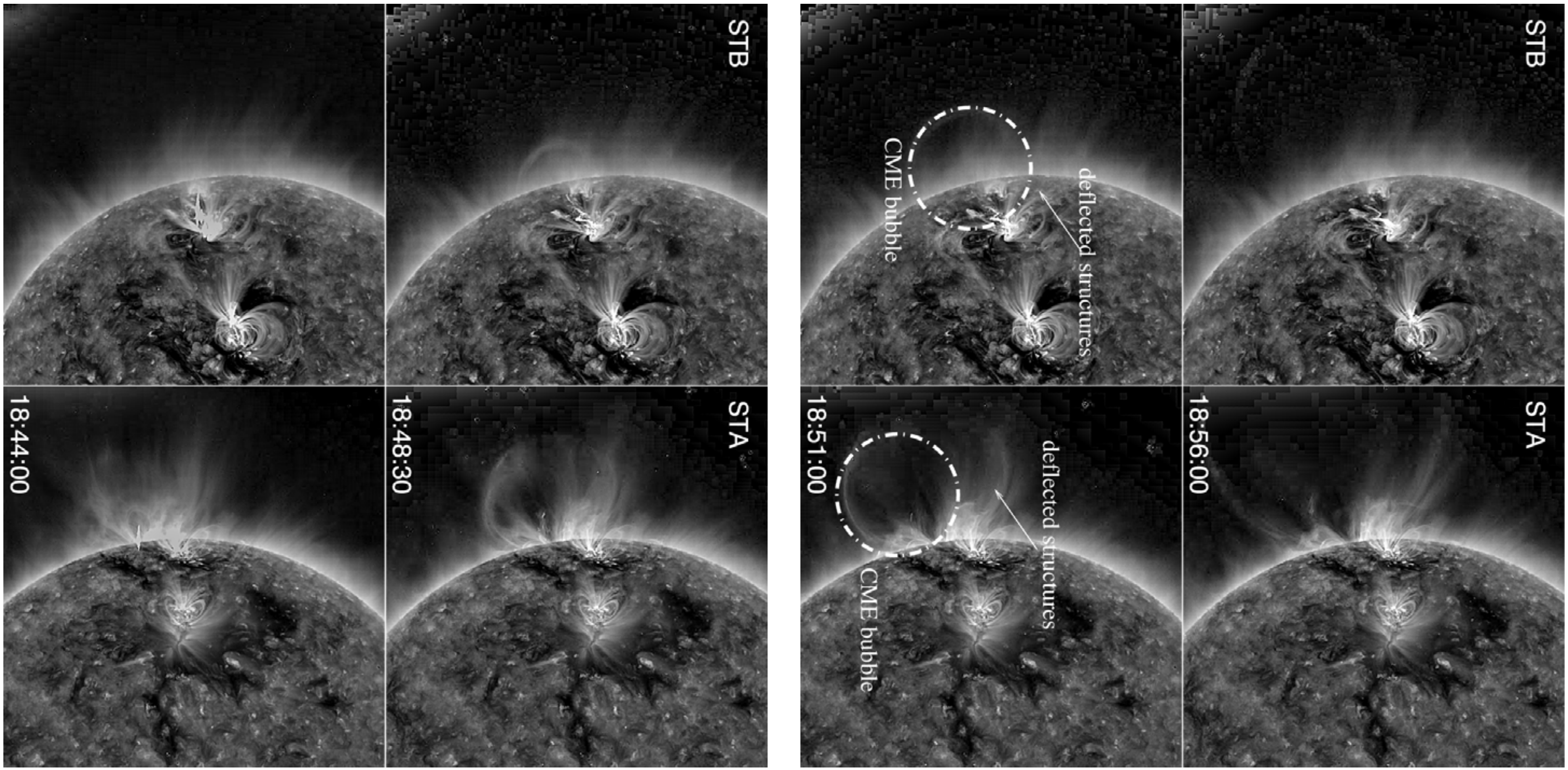



25 March 2008 – 47 deg separation

huge bubble forms in 10 min
typical of impulsive CMEs;
12-31-07, 1-2-08, 2-13-09, …

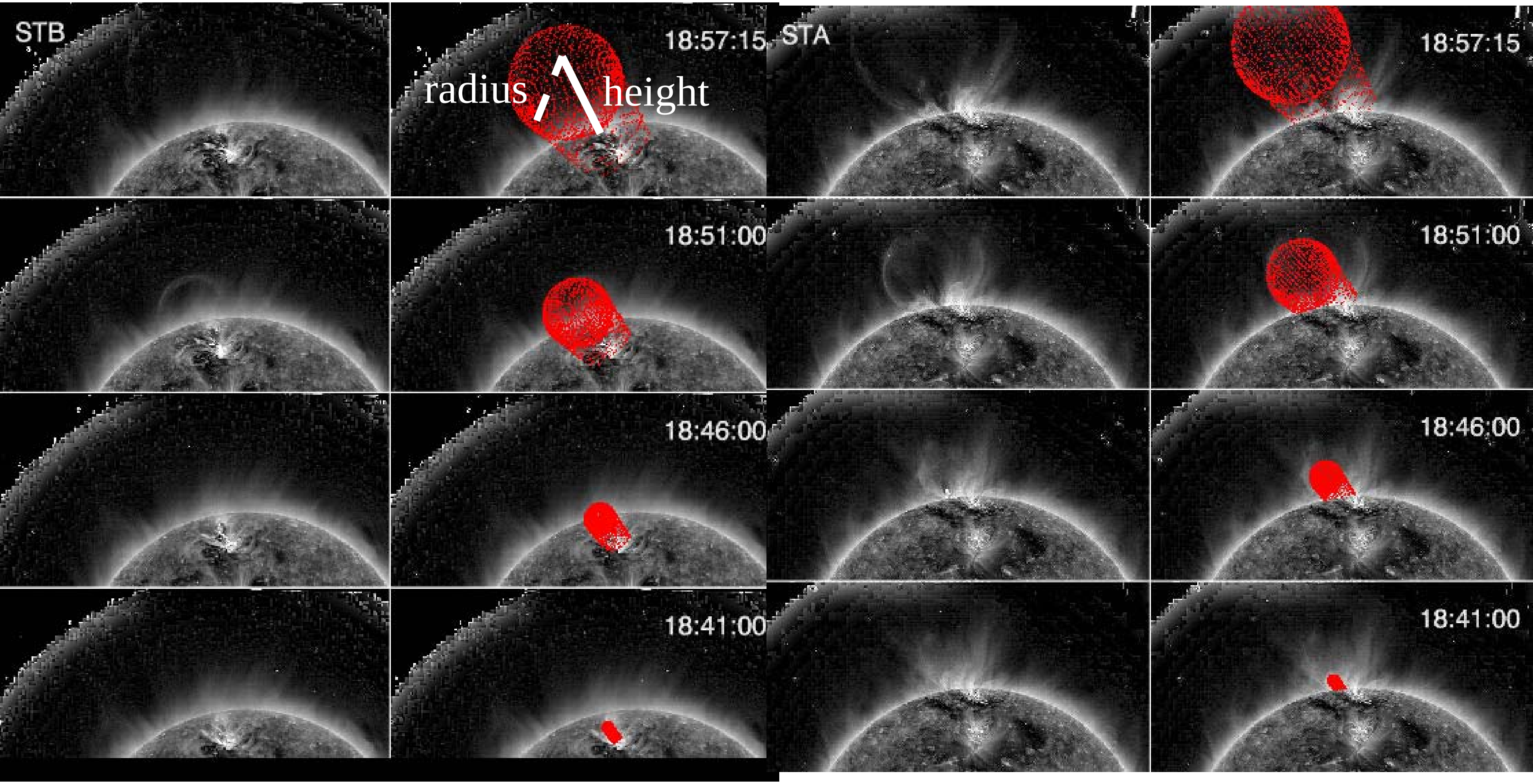
# Two Views Determine the 'Real' Bubble

Patsourakos et al (2010)



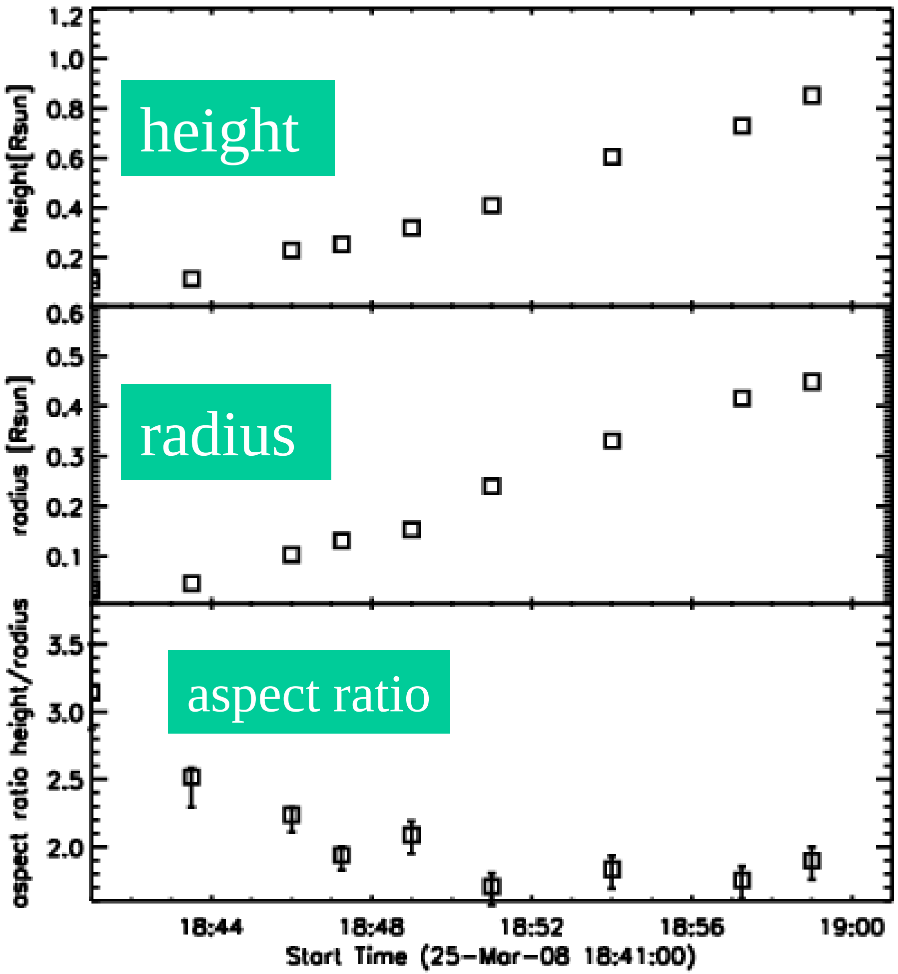

Transformation of a set of loops into a bubble
'real' bubble induces deflections which could confuse analysis …

# 3D Modeling of the Bubble




Use parameterized geometric 3D model of Thernisien et al.
to simultaneously fit the bubble in A+B

# Bubble Evolution



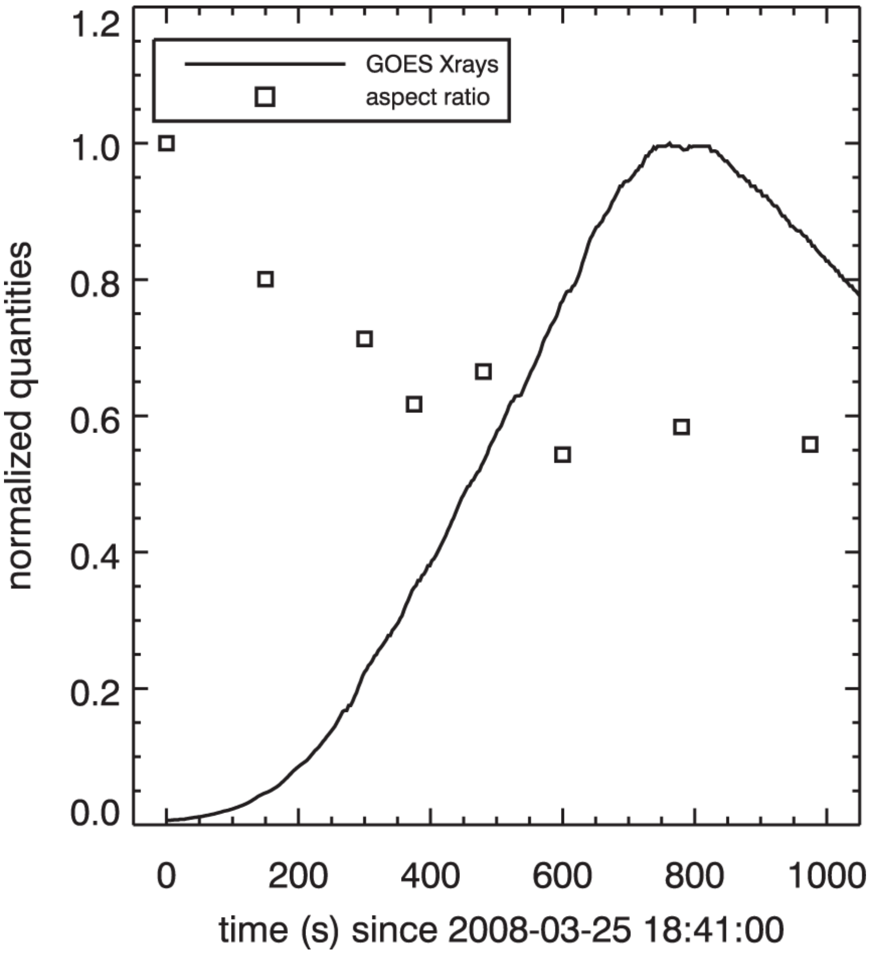

**CONCLUSIONS:**

- **Expansion speed ~1000 km/s**
- **Aspect ratio decreases with time**
- **Conversion of arcade → flux rope**

**→ Part of the flux rope forms on-the-fly**

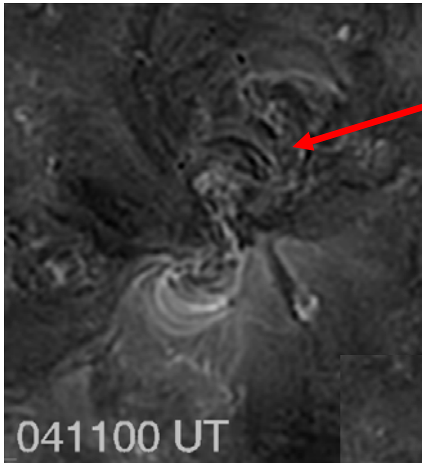
# Flare-CME Synchronization

**Non-linear expansion of flux rope coincides with impulsive phase of flare!**

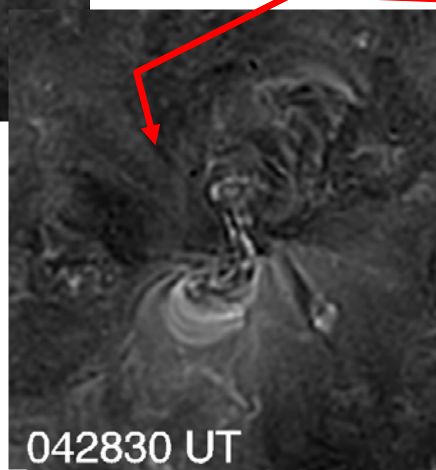


# Implications from a STEREO/EUV Wave

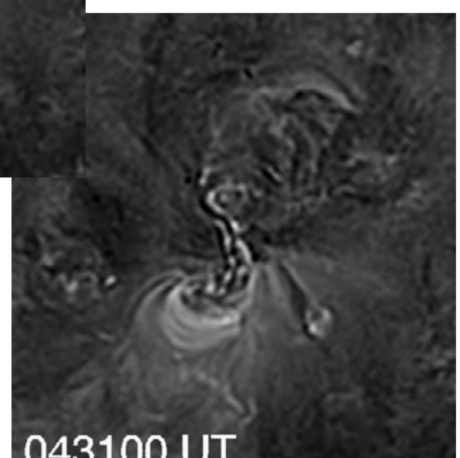
EUVI 171A, 12/7/07 Event from Patsourakos et al 09




- Loops start to rise
  - 10 min BEFORE wave

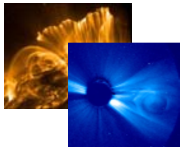



- Wave appears
  - No flare!
  - Connection between wave & rising loops?



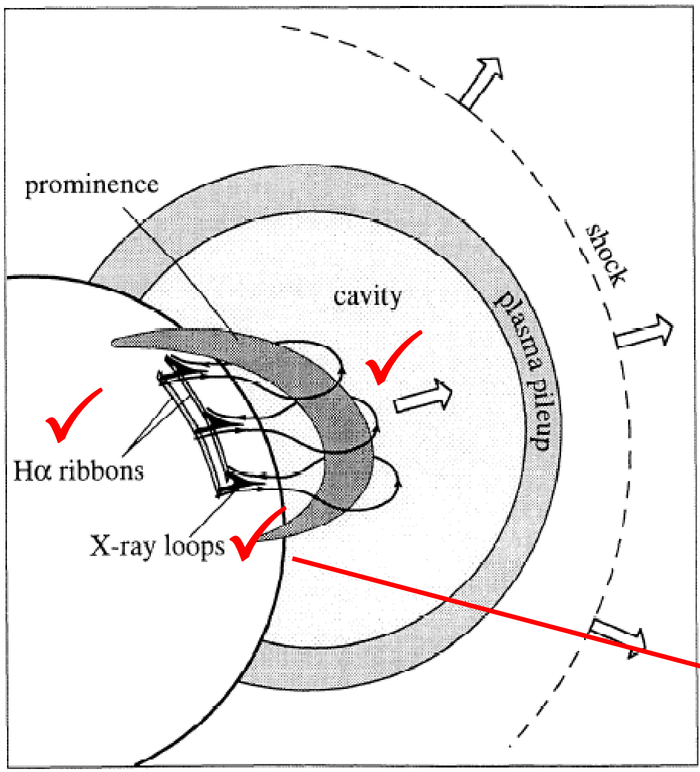

- Flare ribbons appear
  - Rising loops disappear
  - Wave accelerates or forms?

**Phase transition in 90 sec!!**



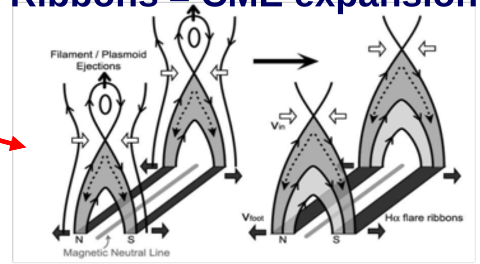
# The “Standard” Flare-CME Concept

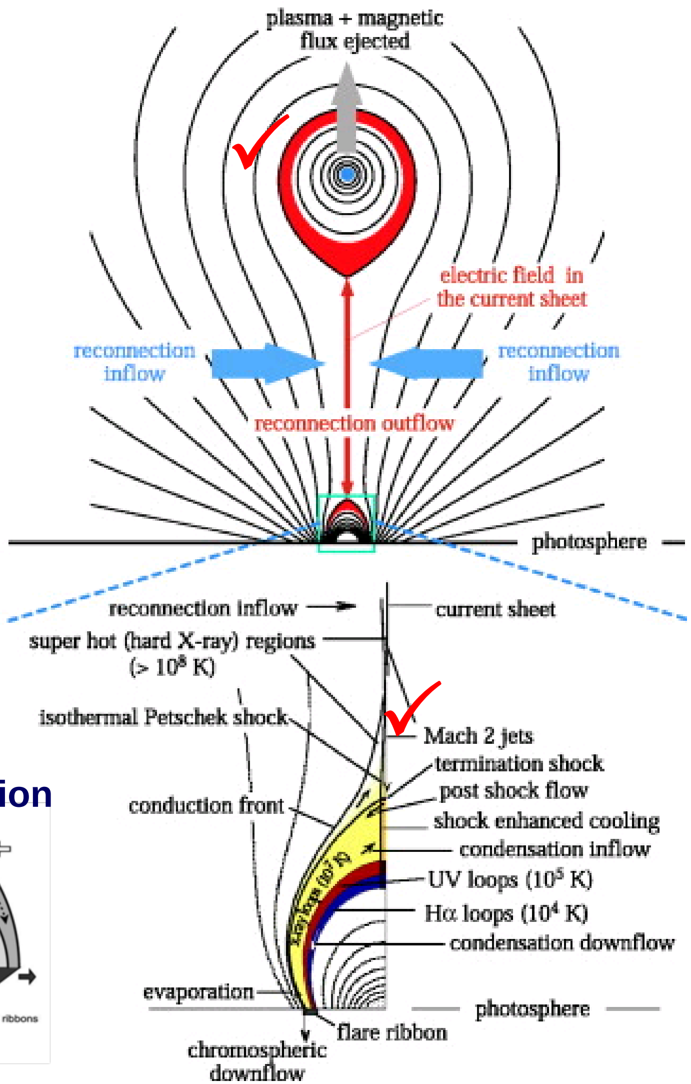
**Where is the direct physical connection betwe
CME and Flare?**




Forbes 2000

**Ribbons = CME expansion**




Lin & Forbes 2002

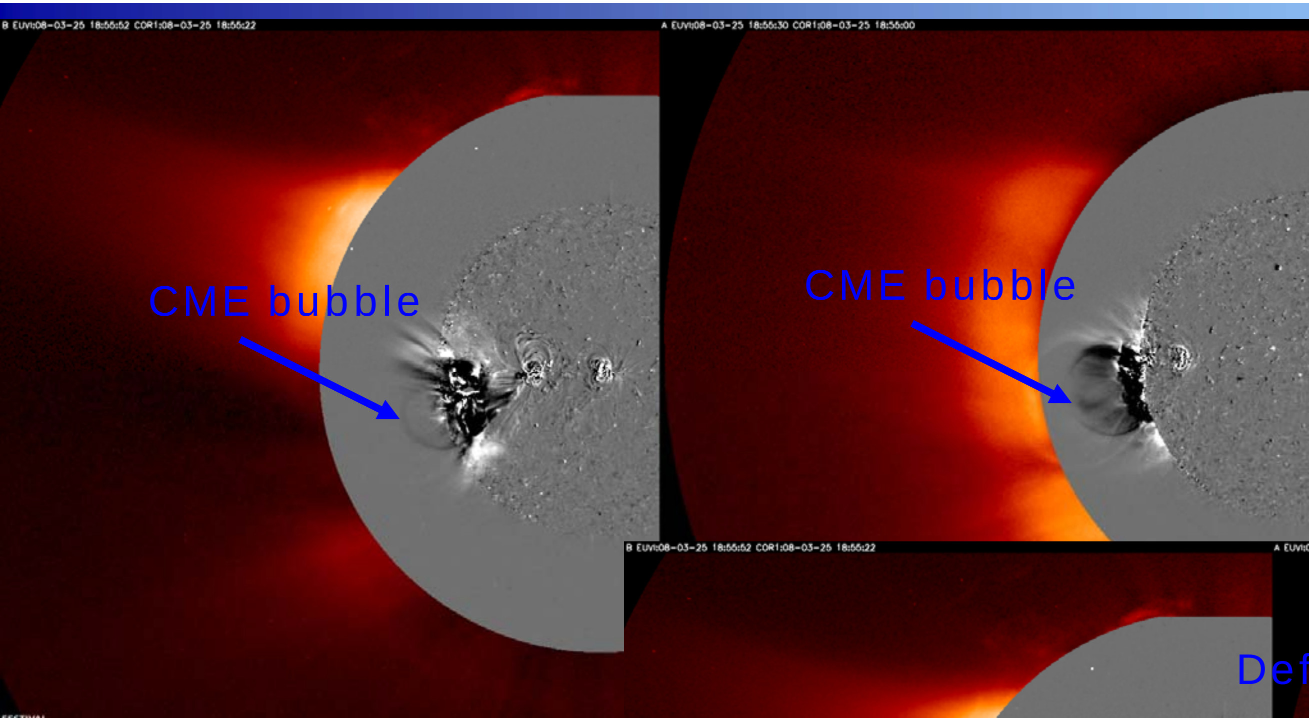
# Conclusions

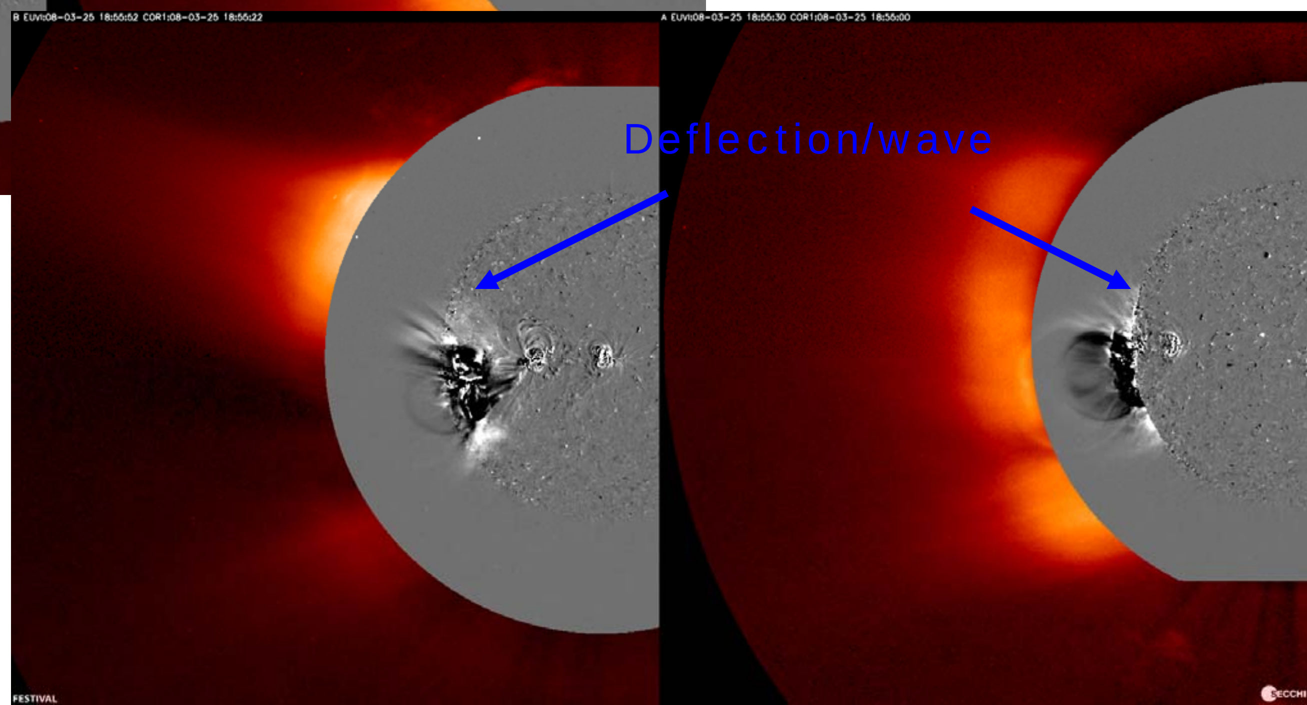
- CME starts as a set of rising loops at AR core (speed ~ 50 km/s)
- Extremely sharp transition (< 75 sec) from loops → erupting bubble
- Bubble = CME fluxrope
- Two phases in formation of fluxrope
  - Non-linear expansion along neutral line followed by
  - Self-similar expansion → CME
- Non-linear expansion coincides with flare impulsive phase
- Expansion speed of ~1000km/s drives the EUV wave.
  - When expansion ceases, EUV wave becomes blast wave (hence deceleration)?
- The above event sequence seems to be common to impulsive EUVI events!

- "Standard" model of solar eruptions consistent with observations!

# Backup Slides

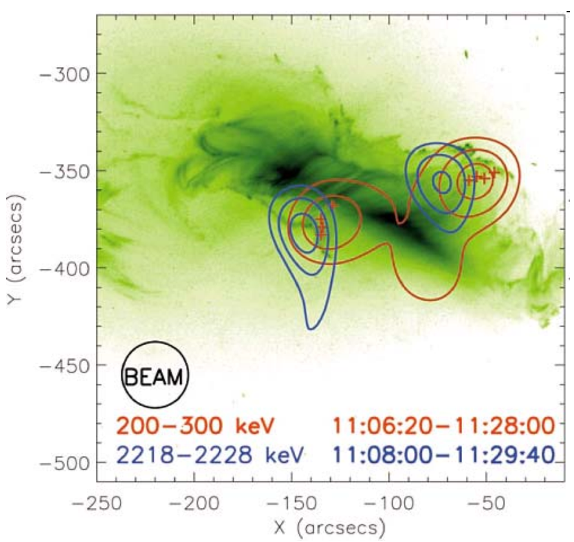
# EUV Wave and Bubble are Different Entities



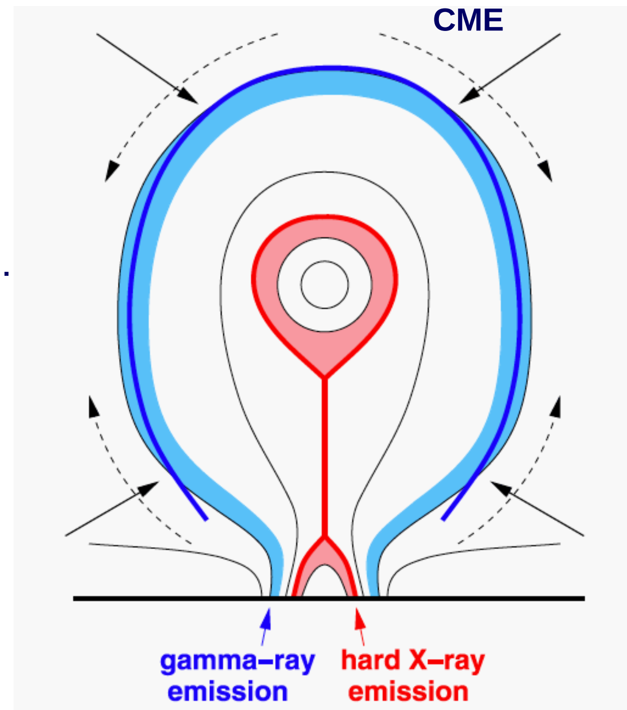
# Flare-CME Connection: Ions don't like Electrons?

- **Ions & electrons seem to be accelerated at different sites**
  - **Different loop sizes? (Emslie et al 2004)**




Hurford et al (2006)

But if we look at the big picture….

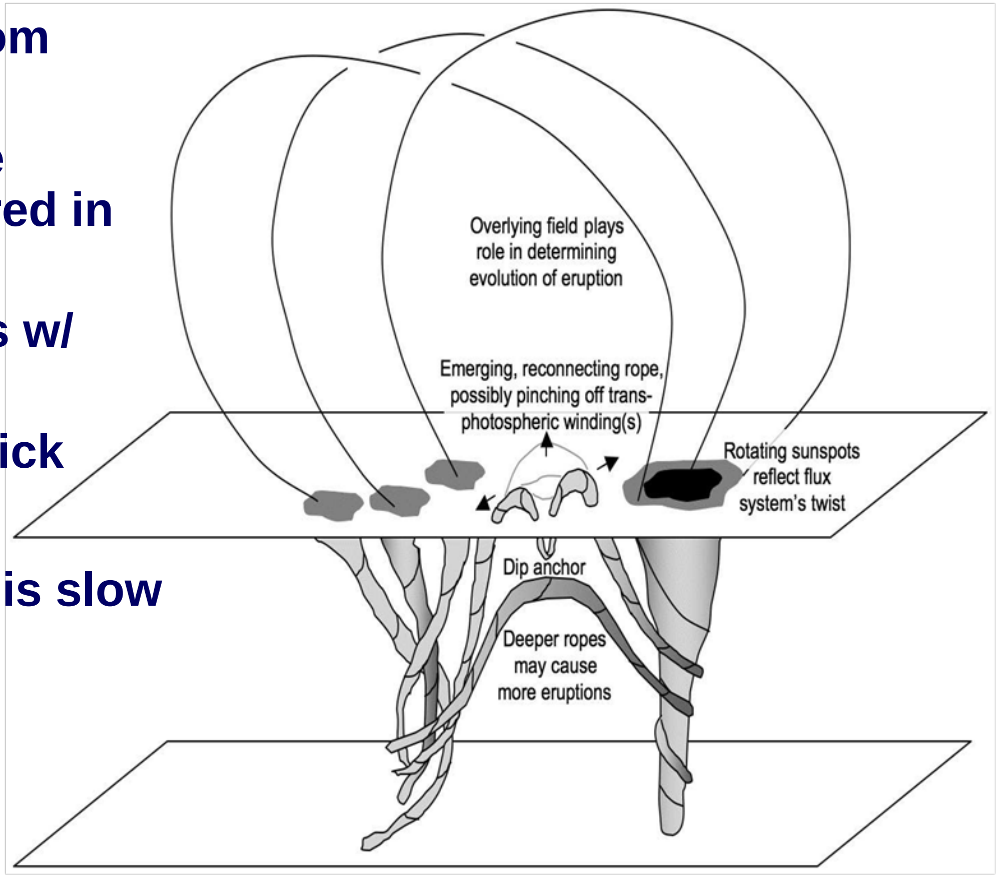



Pomoell et al (2008)

# Putting it all together

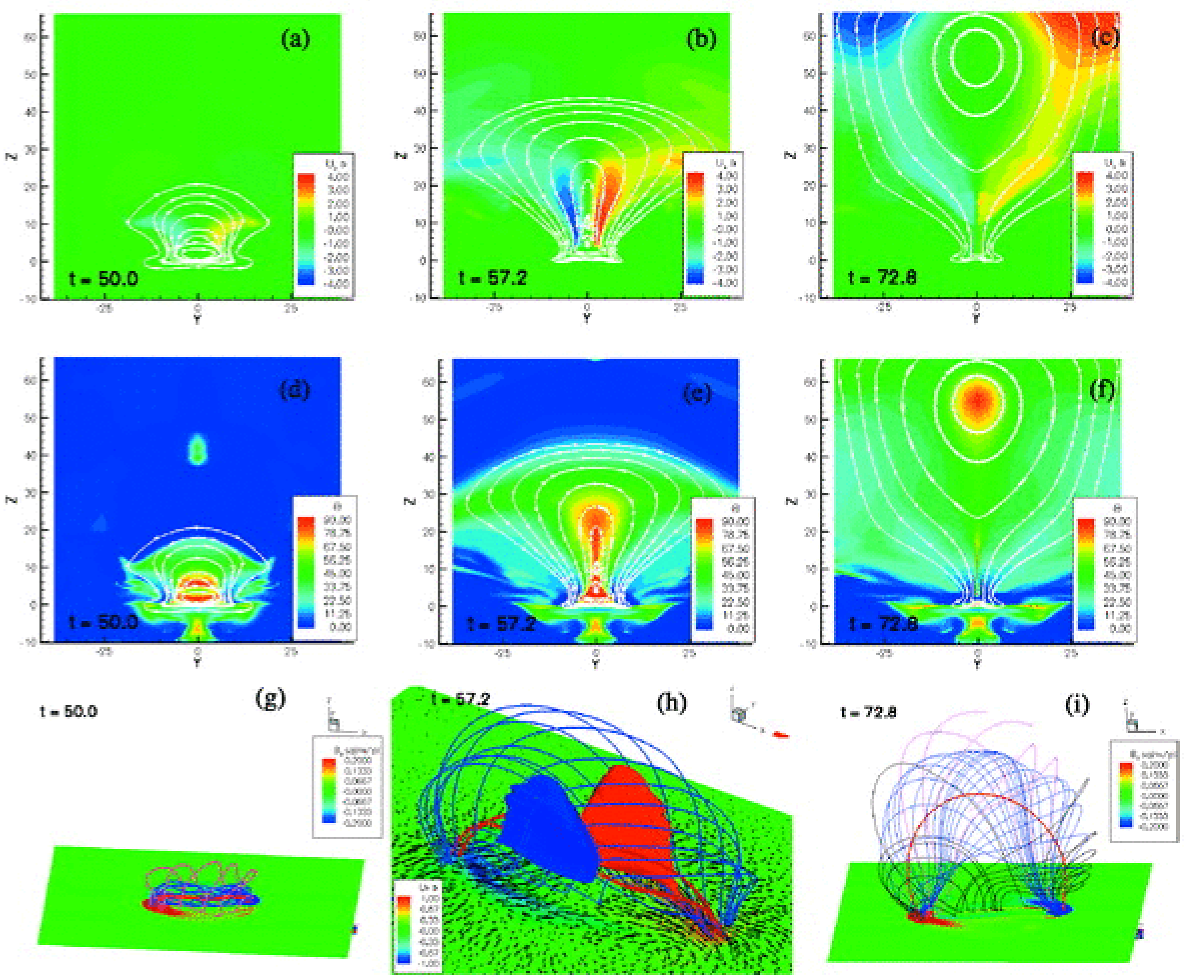
**A possible scenario (see Schrijver 2009):**

1. **Magnetic field rises as fluxrope from convection zone**
2. **Top of fluxrope bursts through the chromosphere; rests stays anchored in photosphere**
3. **The new coronal fluxrope interacts w/ background:**
    1. **Flare only if reconnection is quick**
    2. **Flare+CME if enough $E_{mag}$**
    3. **Eruption only if energy release is slow**



# Putting it all together

**MHD models support such scenario**




From Manchester et al 2004

# Nugget 2: EUV Wave Structure/Evolution

- A-B separation = 42 deg
- Cadence = 2.5 min
- Mild wavelet enhancement

- First EUV wave with
  - High cadence (< 2.5 min)
  - Multi-temperature (4 wavelengths within minute)
  - Stereoscopic (EUVI-A, -B, EIT)