Three Dimensional Reconstruction of an Earth-directed CME Front

Jason P. Byrne, Shane A. Maloney, R. T. James McAteer, Jose M. Refojo & Peter T. Gallagher

STEREO Science Working Group

Trinity College Dublin

March 2010

Funded by SFI's Research Frontiers Programme.

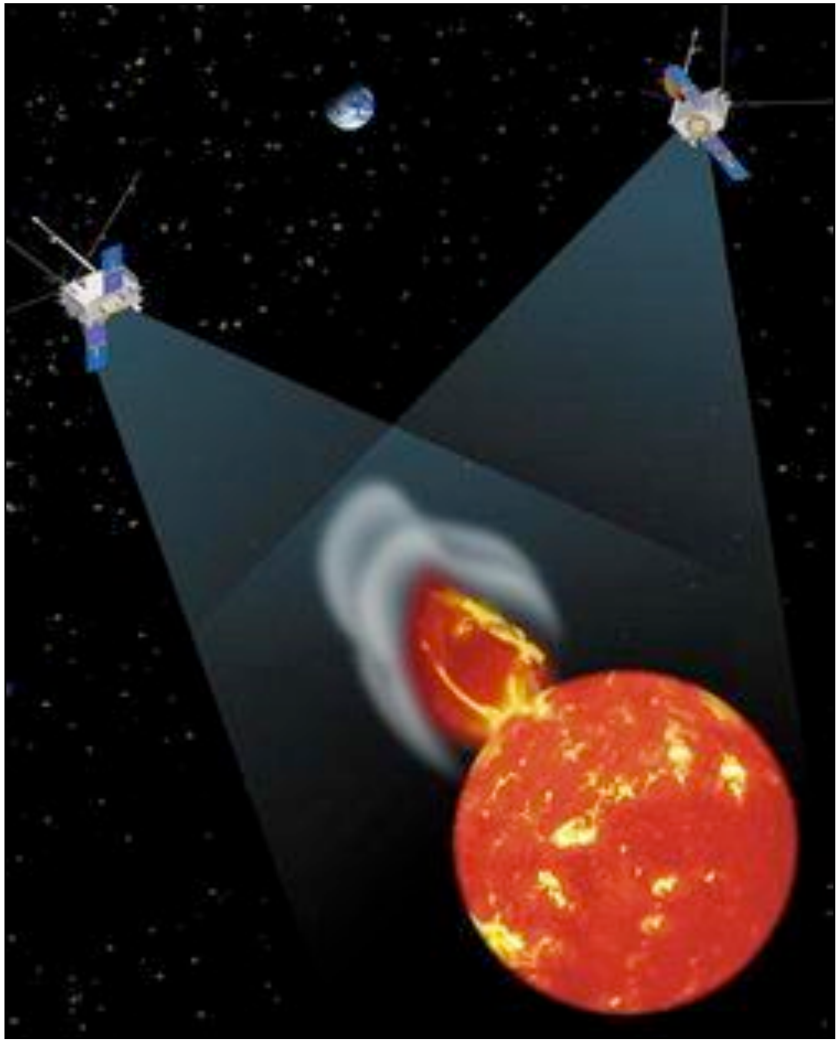
Motivation

What influences the trajectory of a CME in the magnetised solar atmosphere?

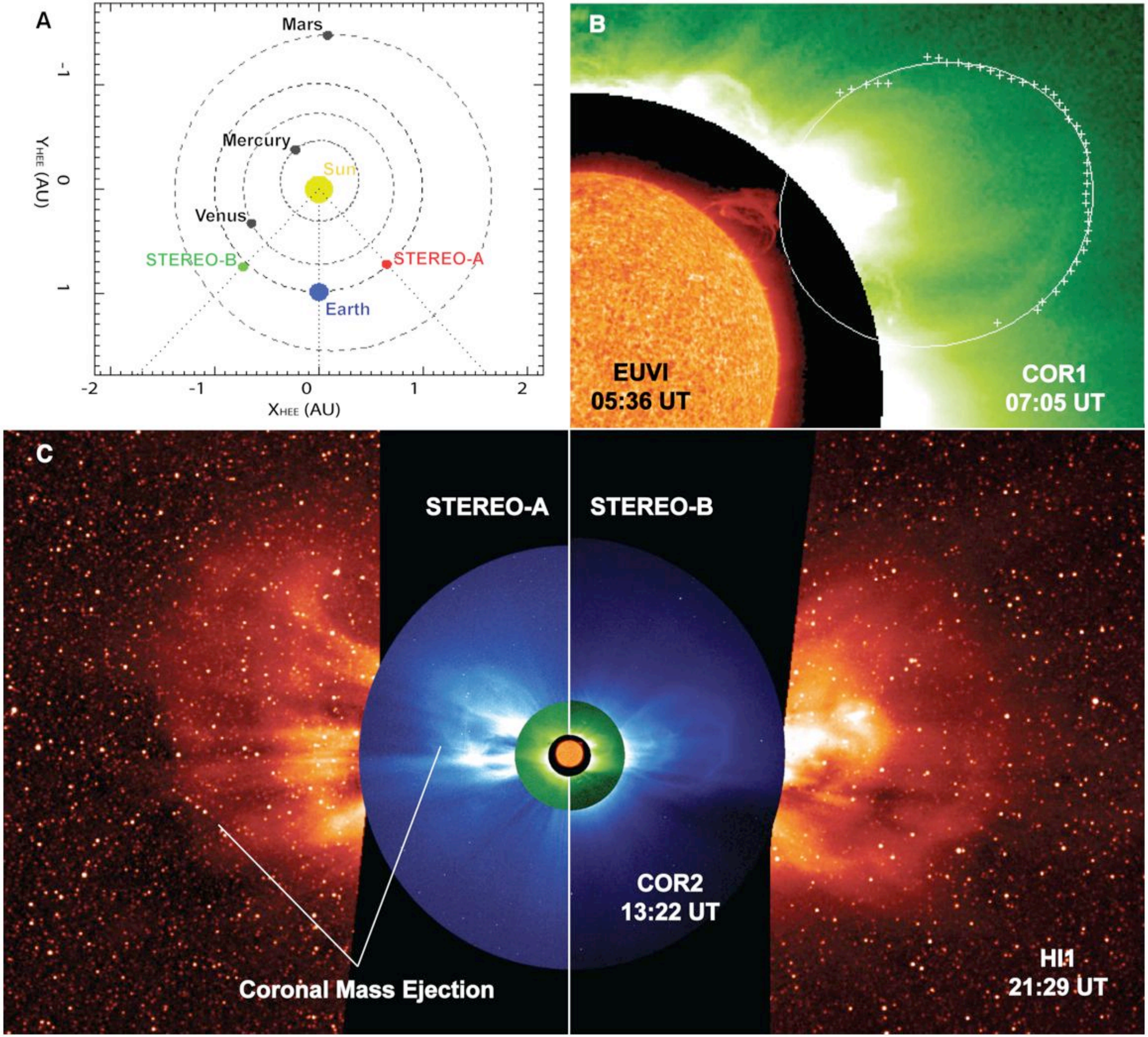
How do erupting magnetic flux-ropes expand in the solar atmosphere?

What mechanisms govern the motion of CMEs in the Heliosphere?

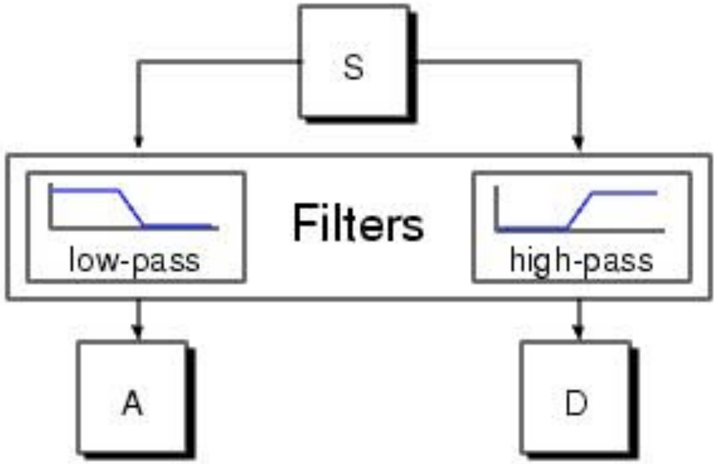
$$\rho \frac{D\vec{v}}{Dt} = \vec{j} \times \vec{B} - \nabla P - \rho \vec{g} - \frac{1}{2} \rho \vec{v}^{2}$$



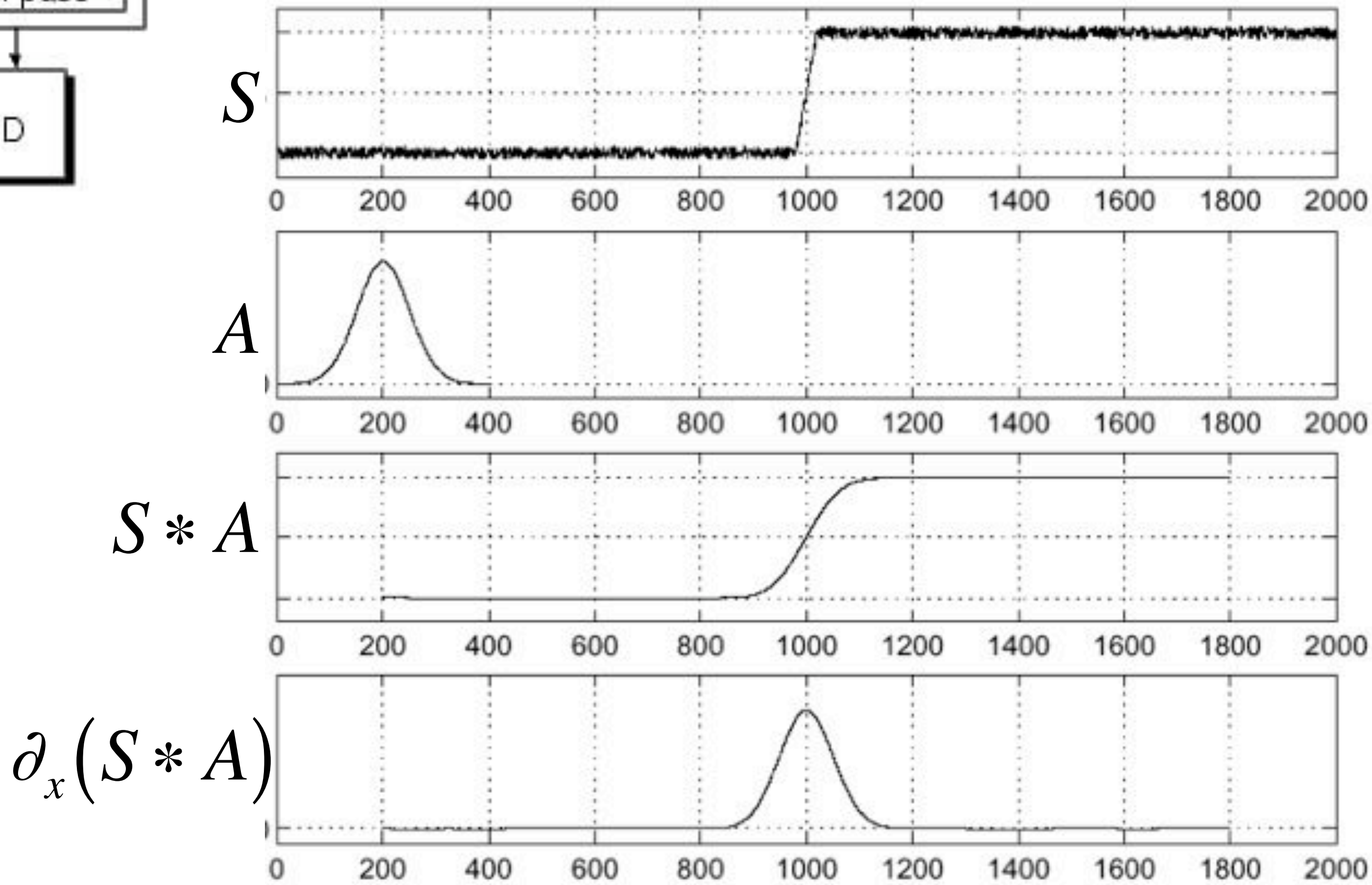
STEREO illustration


A
Mars
Mercury
Sun
Venus
STEREO-B
STEREO-A
Earth
Y_{HEE} (AU)
X_{HEE} (AU)
-1
0
1
-2
-1
0
1
2
B
EUVI
05:36 UT
COR1
07:05 UT
C
STEREO-A
STEREO-B
COR2
13:22 UT
HI1
21:29 UT
Coronal Mass Ejection

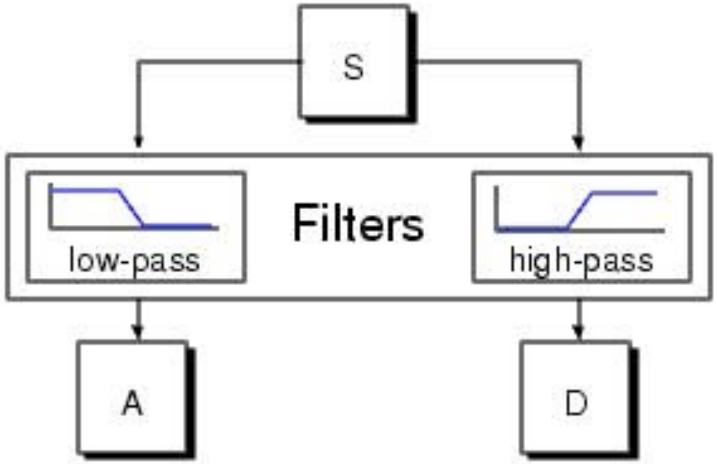
Finding the CME Front



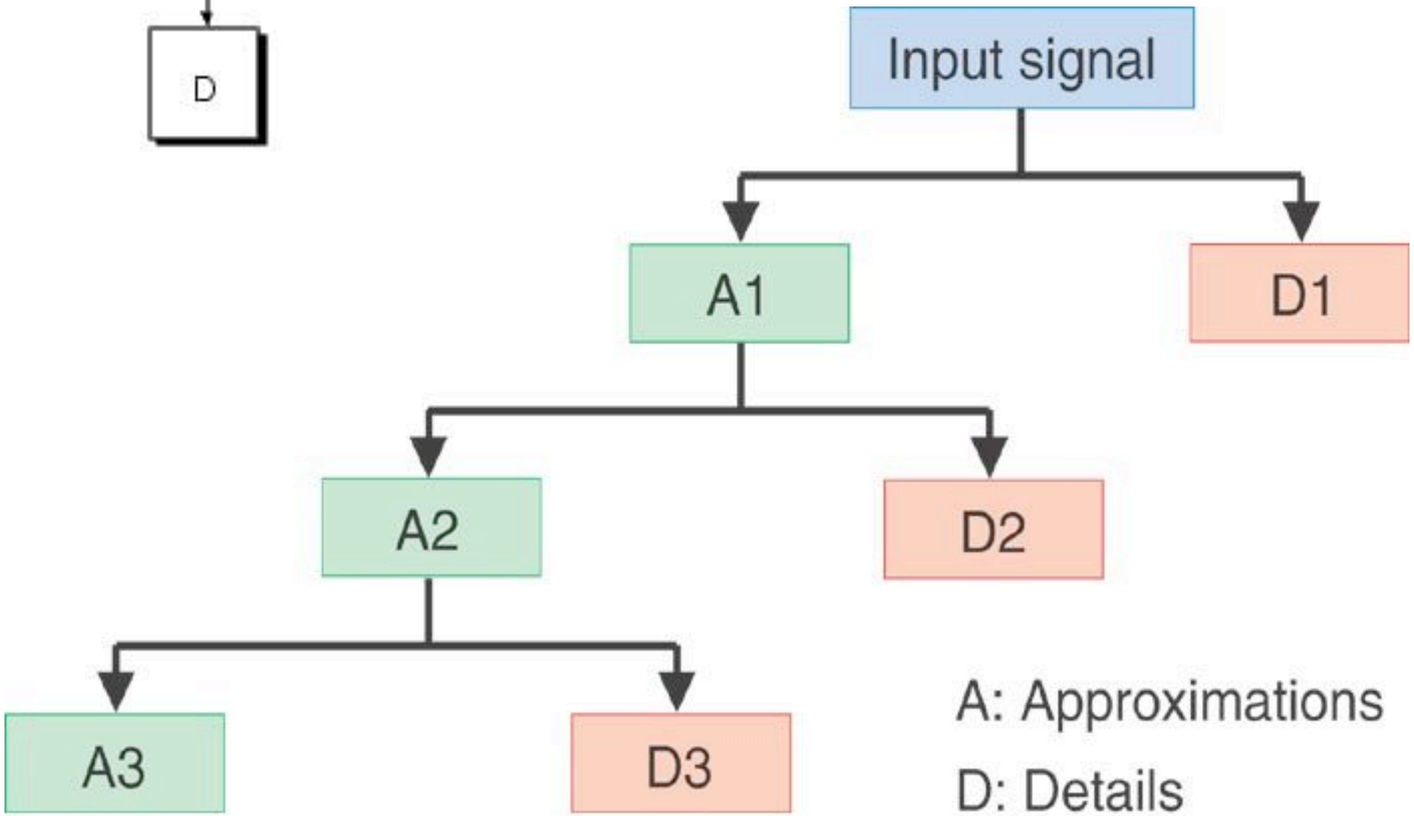
Edge Detection



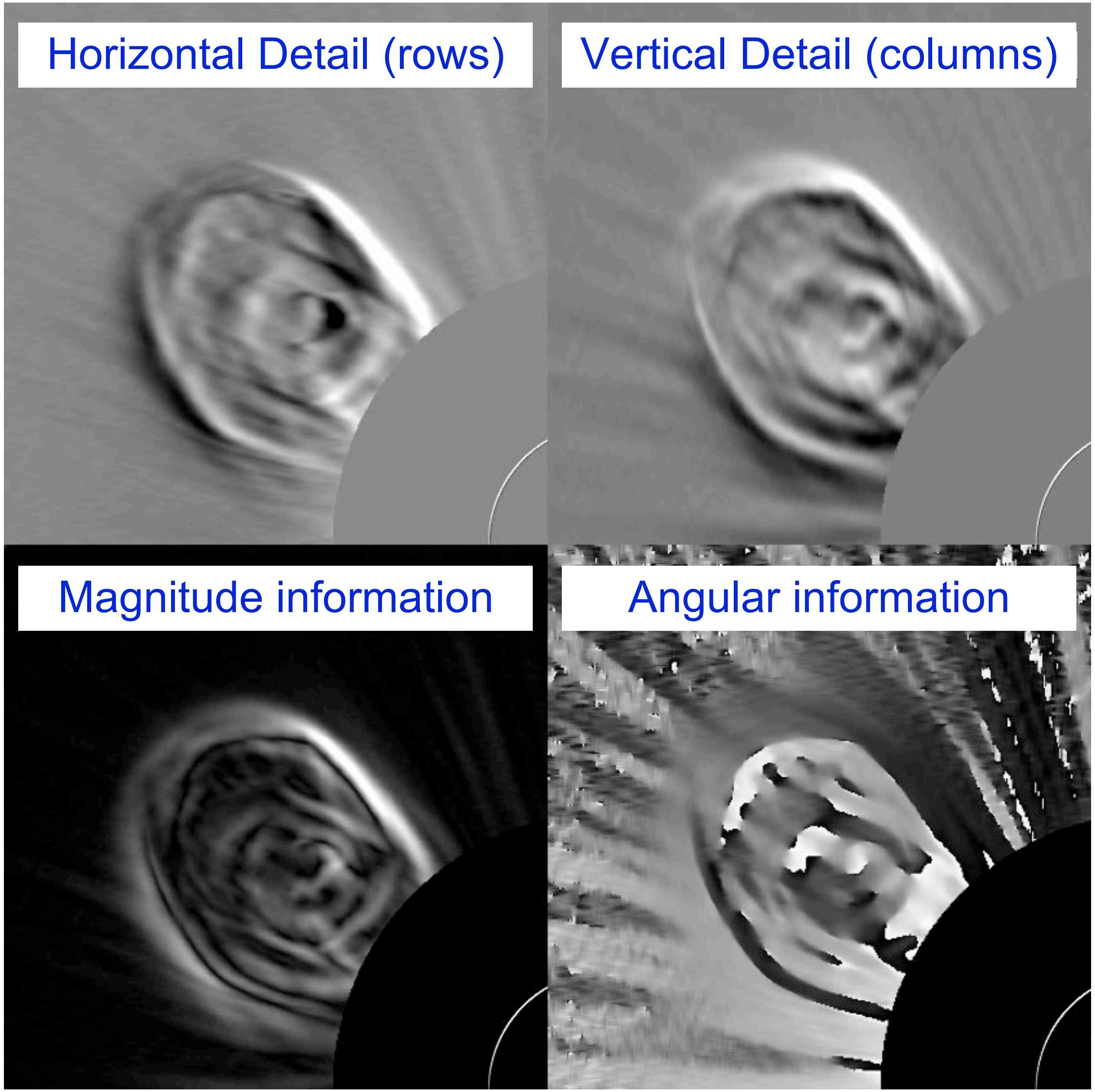
Finding the CME Front



Multiscale Analysis



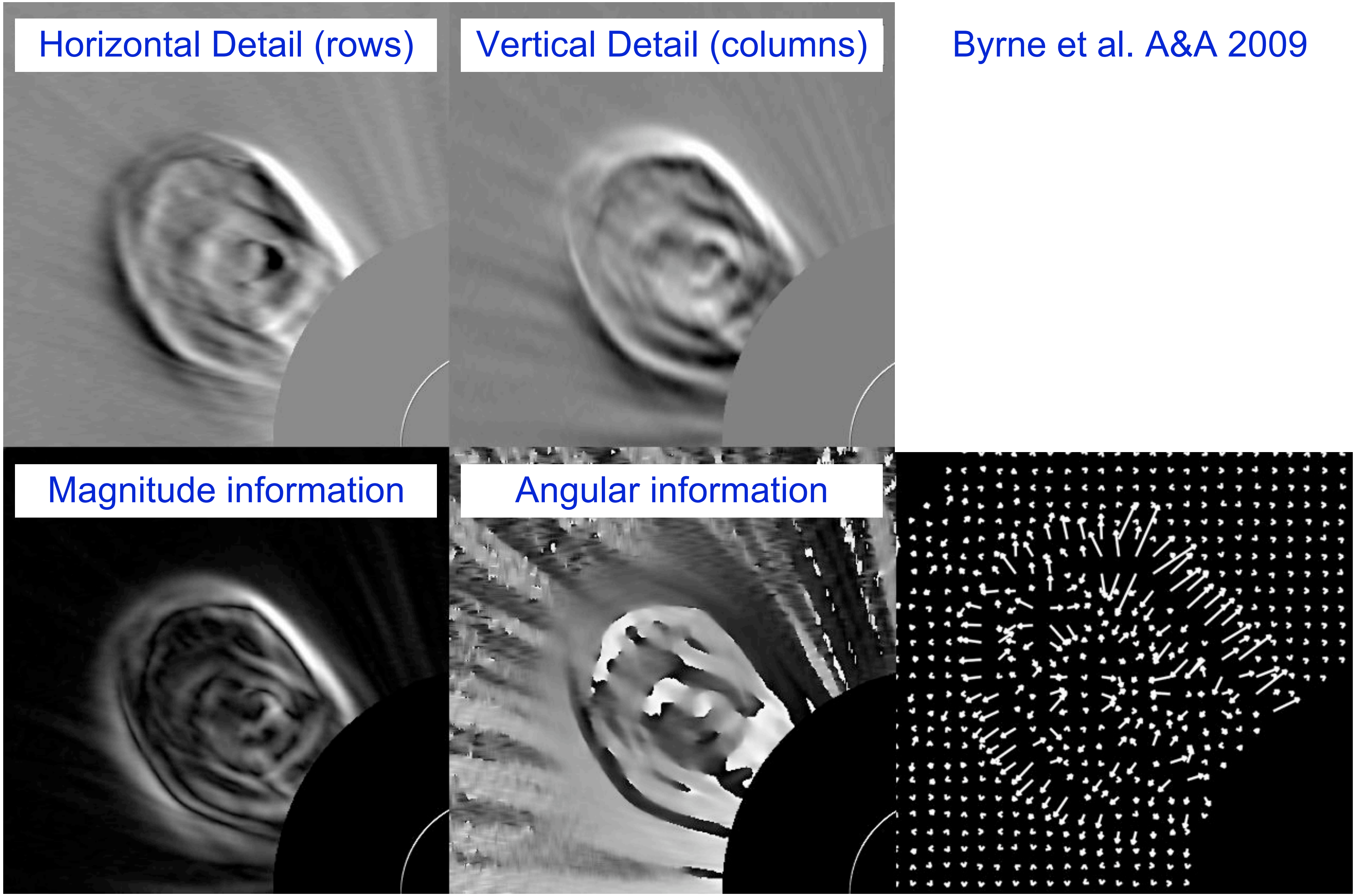
Finding the CME Front



Byrne et al. A&A 2009

Finding the CME Front

Byrne et al. A&A 2009



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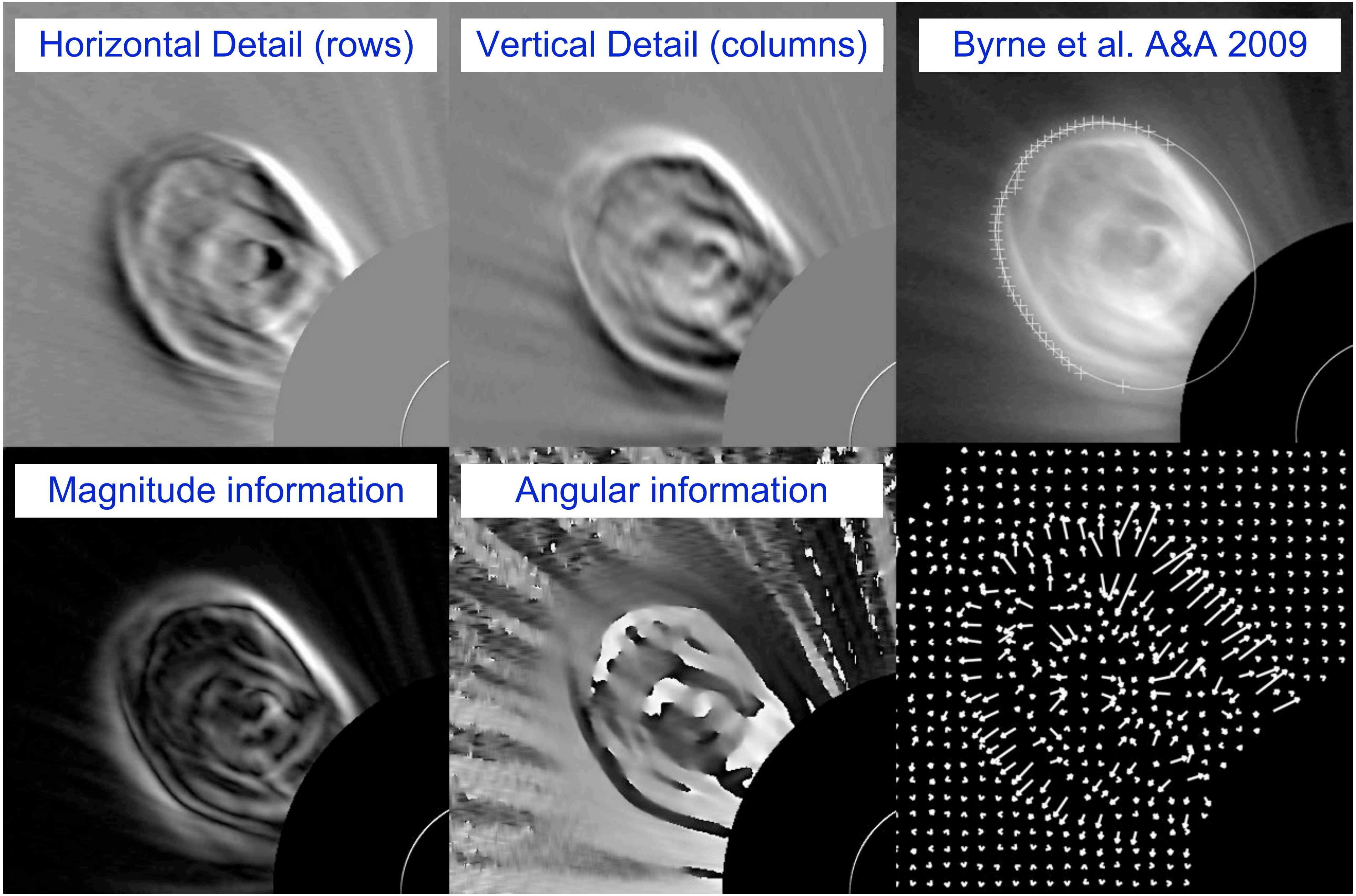
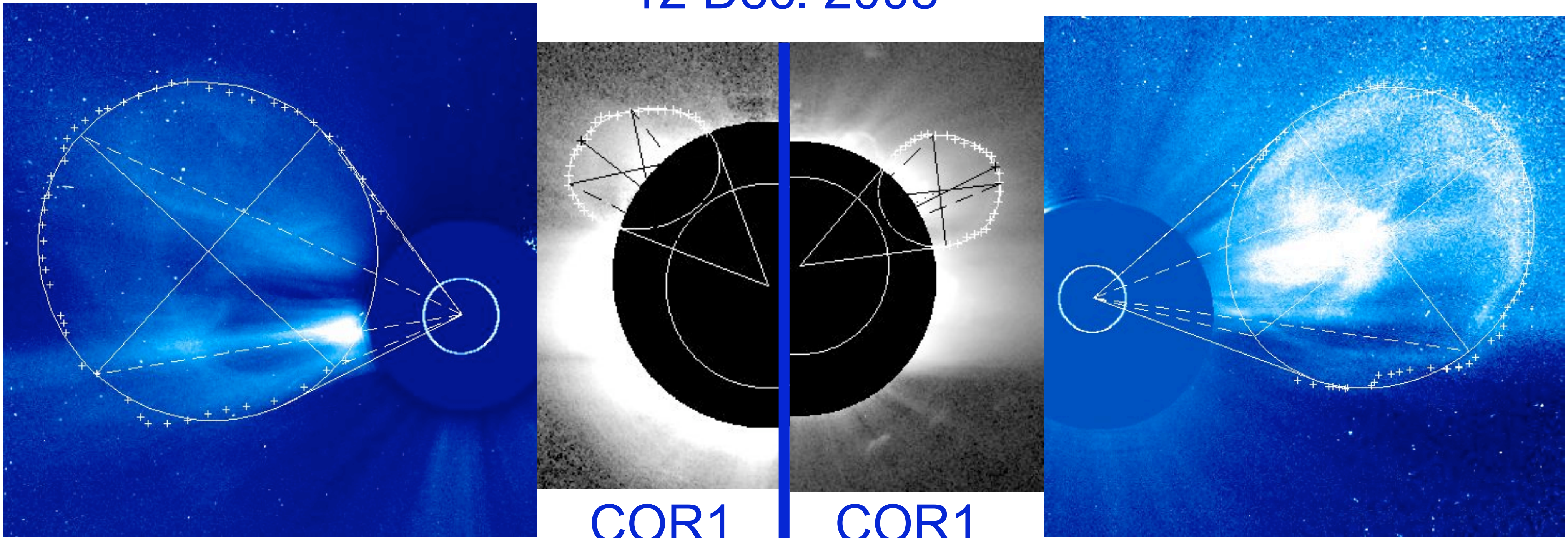


Finding the CME Front

12 Dec. 2008

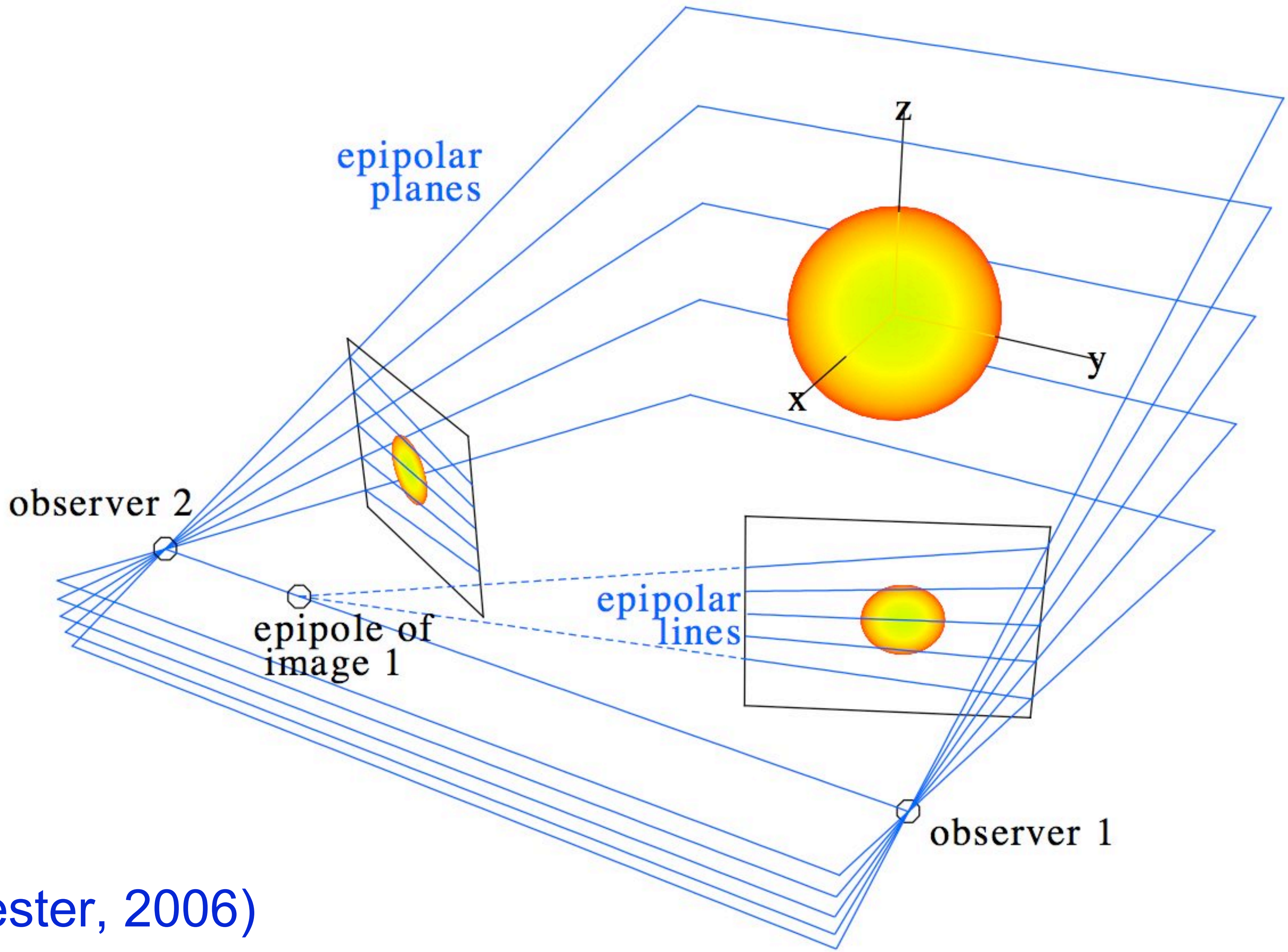


COR1 COR1

COR2 COR2

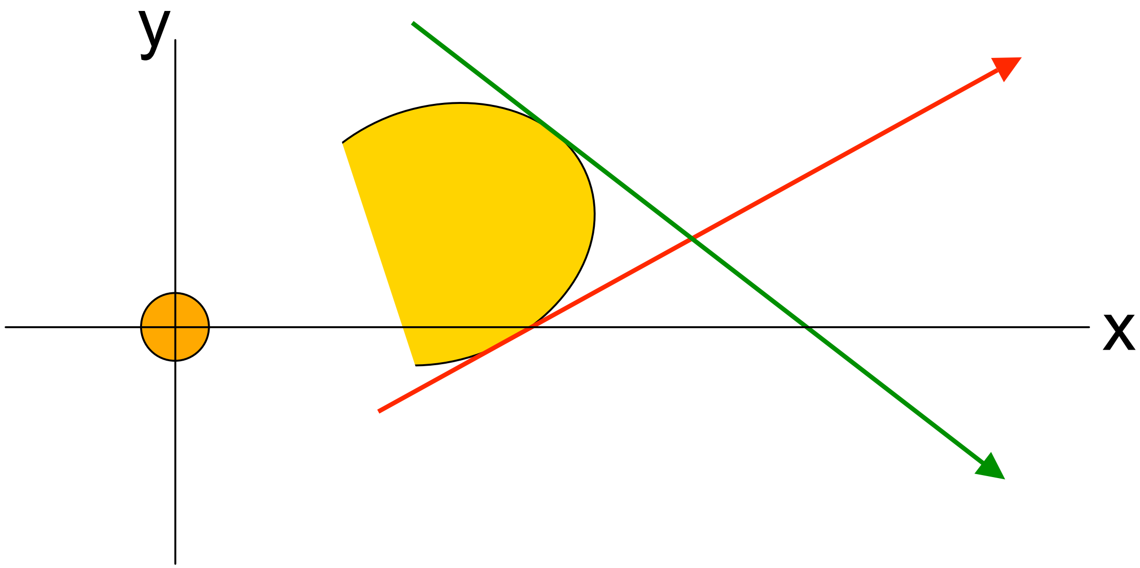
STEREO-Ahead STEREO-Behind

Stereoscopic Analysis



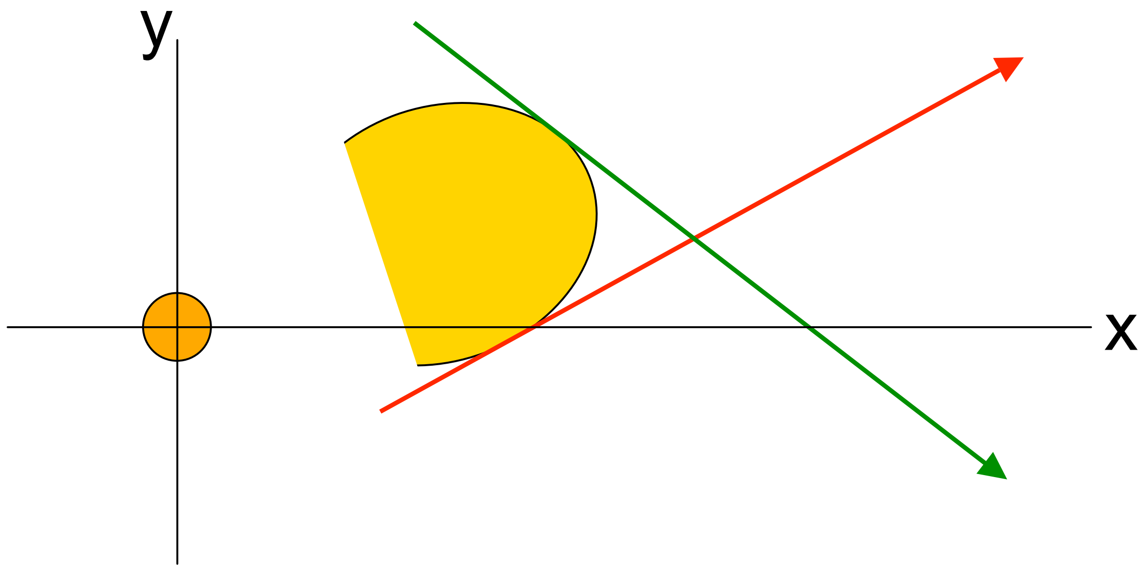
(Inhester, 2006)

Stereoscopic Analysis



Geometric Localization
(Pizzo & Biesecker, 2004)

Stereoscopic Analysis



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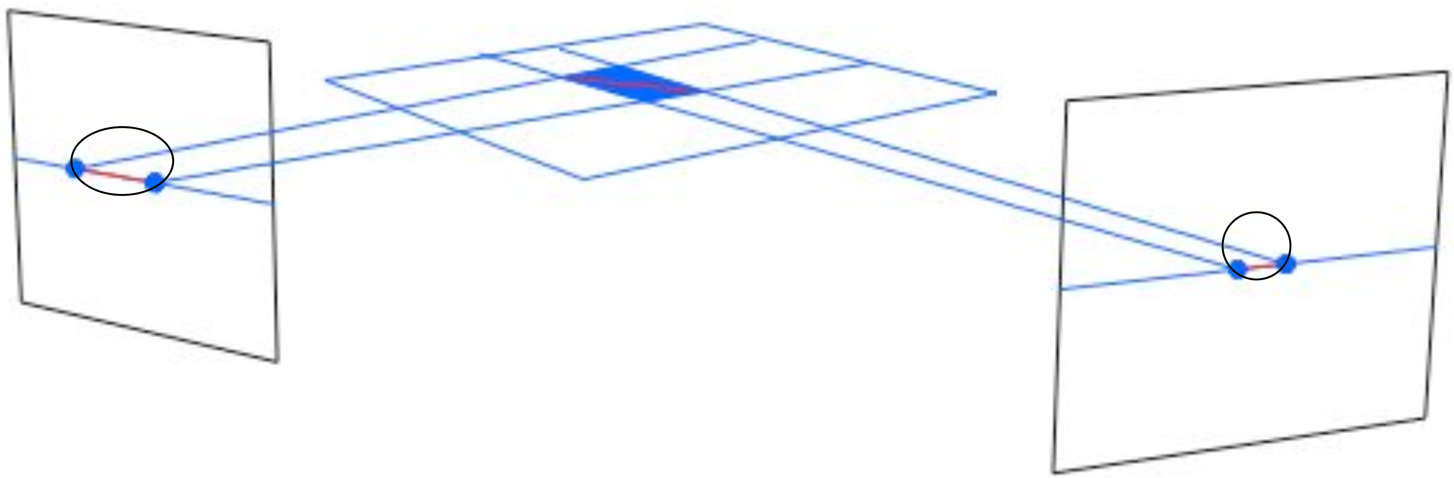
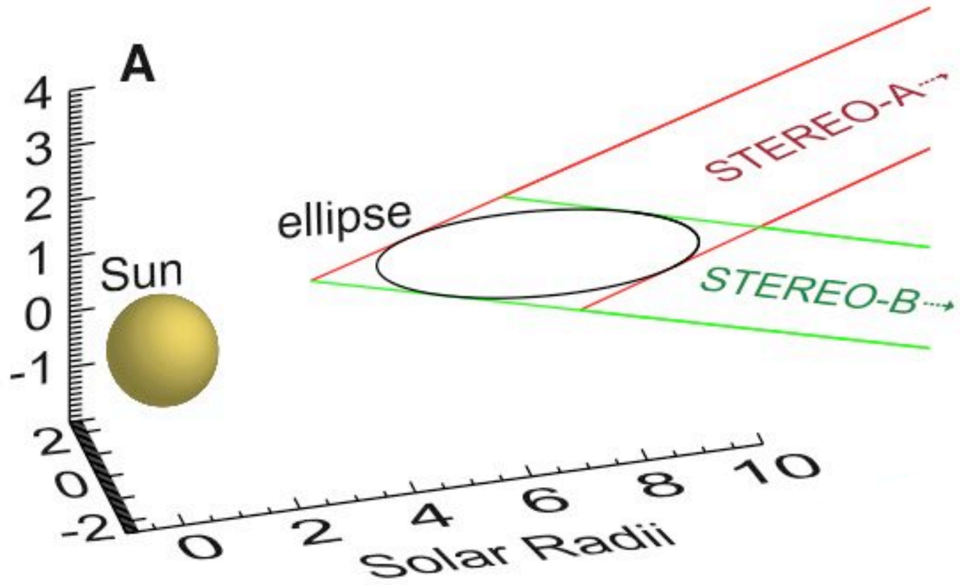


Stereoscopic Analysis

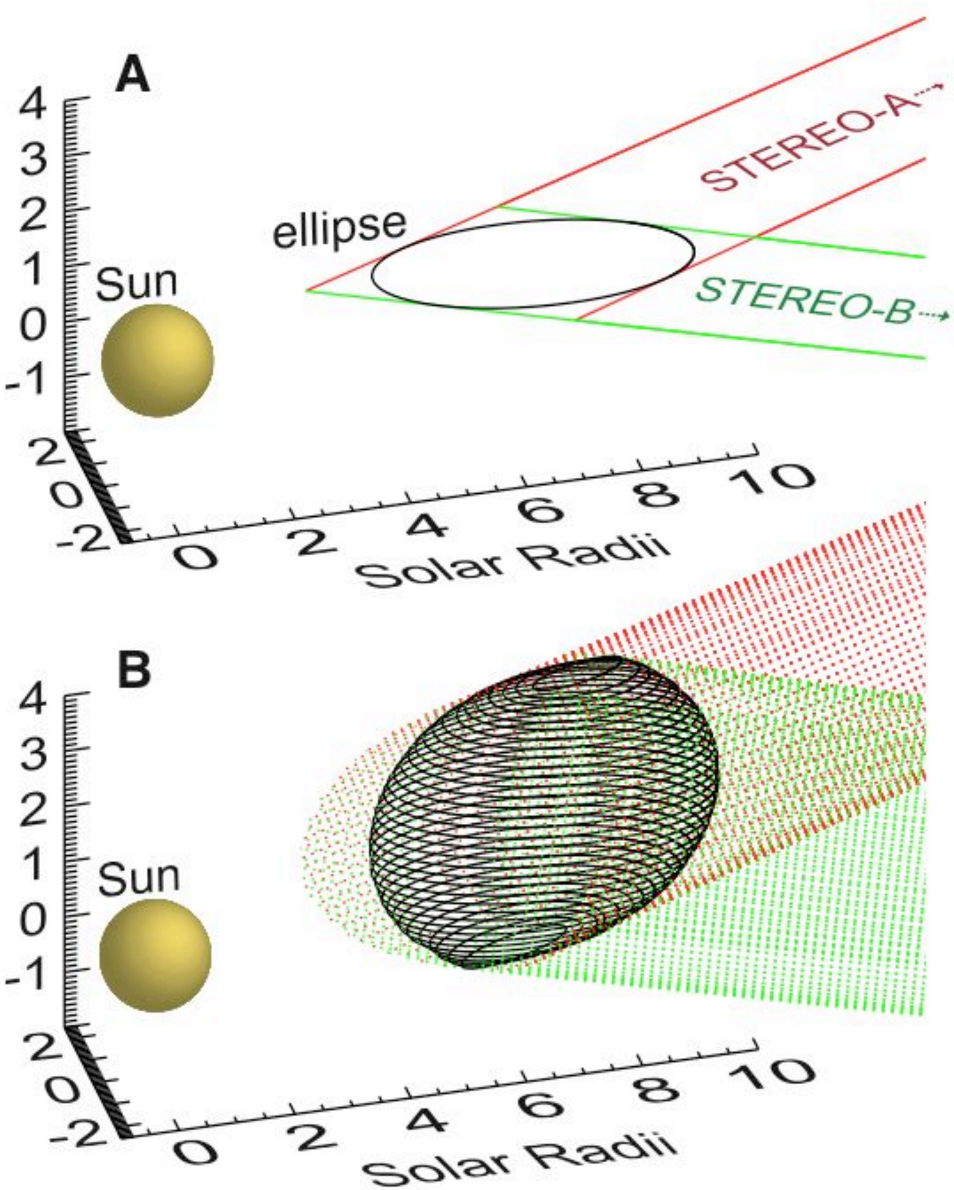


Theorem:

Let T_1, T_2, T_3, T_4 be four given lines in the plane, such that no three of the T_j are parallel or have a common intersection point. Then there is an ellipse E which is tangent to each of the T_j.

(Horwitz, 1999)

Stereoscopic Analysis



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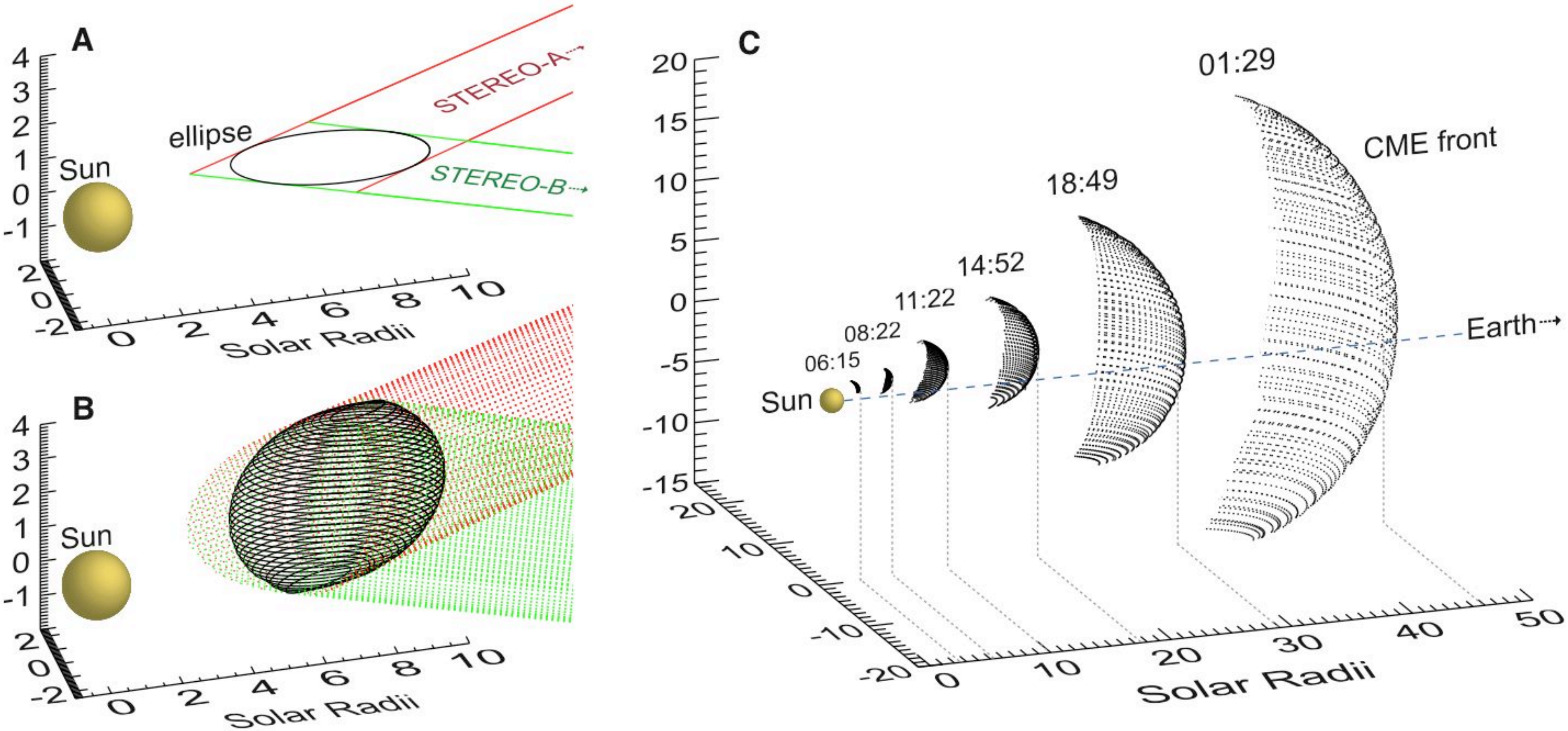
Stereoscopic Analysis

12 Dec. 2008 CME



Three dimensional reconstruction of an Earth-directed CME front

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12 December 2008 08:05 UT
Instrument: COR1

STEREO-A

Three dimensional reconstruction of an Earth-directed CME front

Earth

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Sun

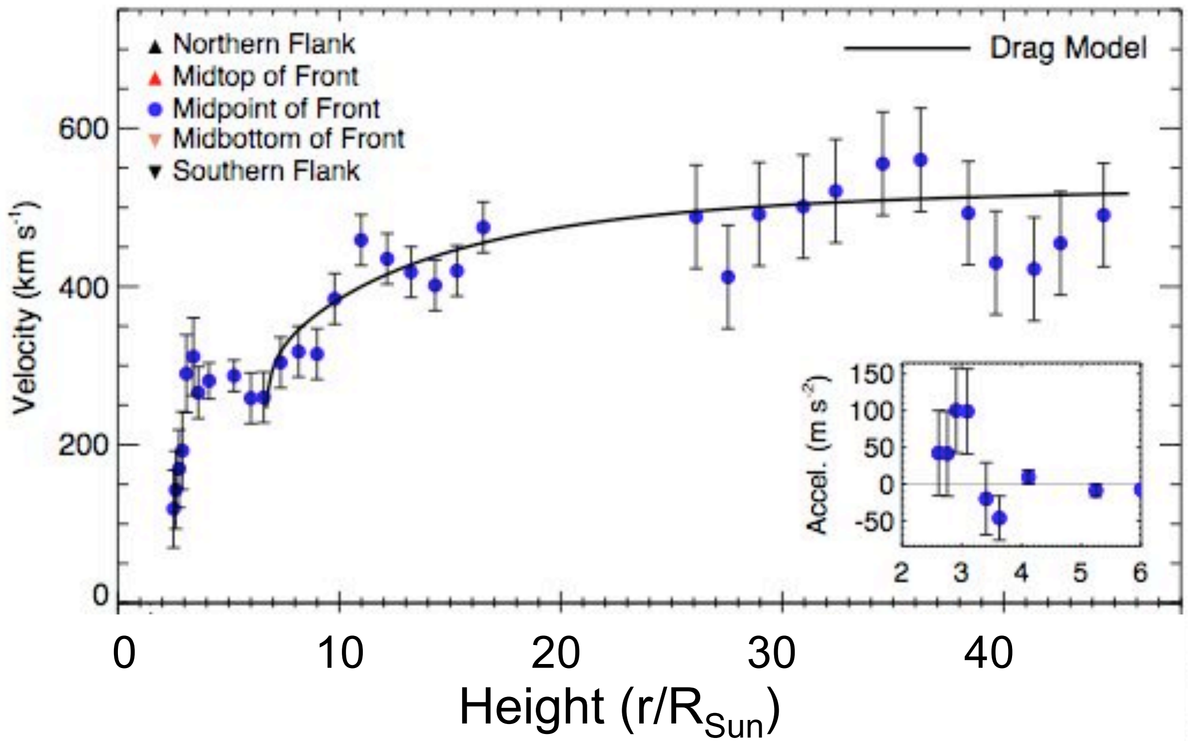
5

TCHPC

SECCHI

sfi

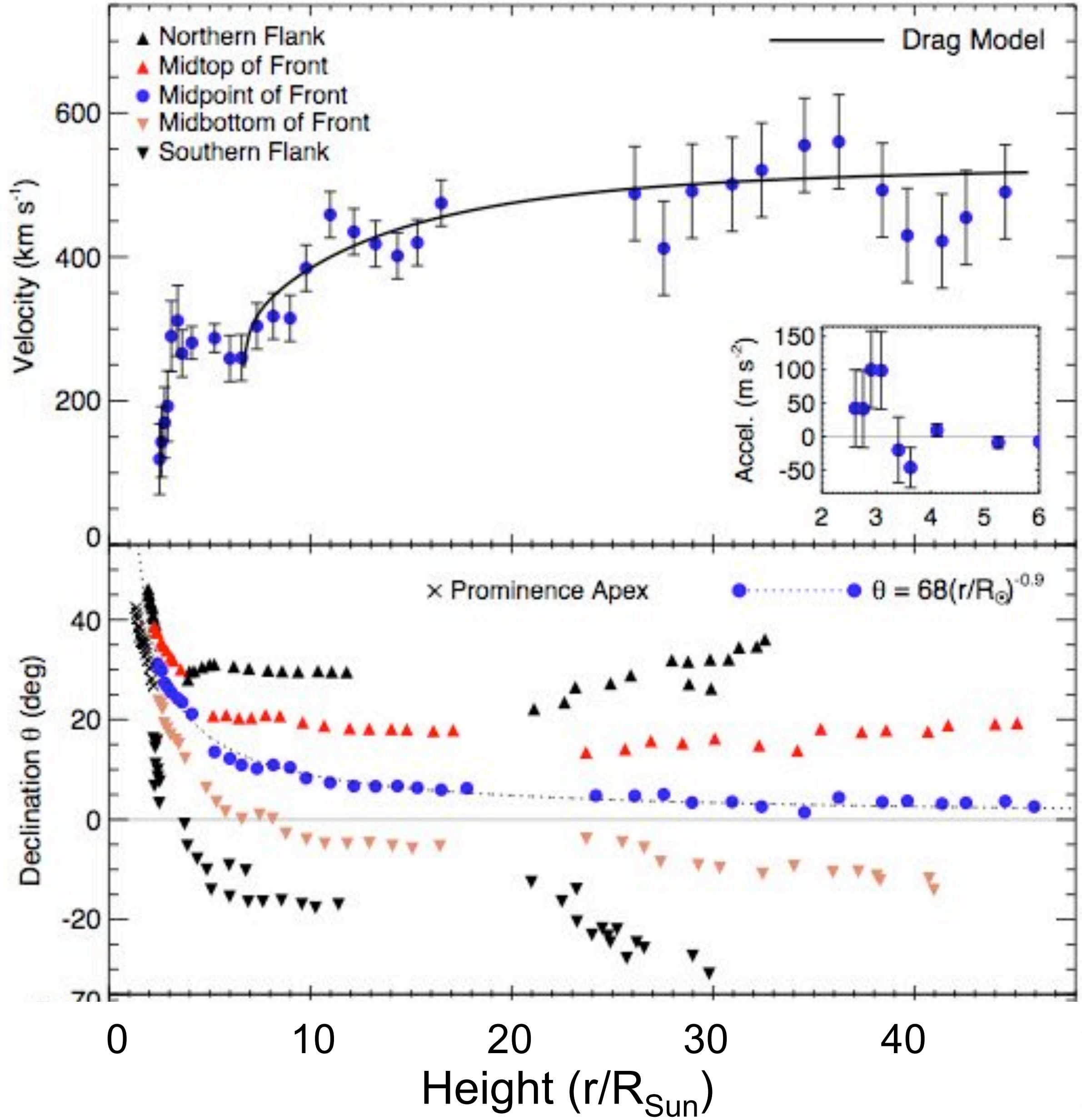
20 Solar Radii



CME propagation:

Early acceleration phase.

Subsequent drag phase in the solar wind.



CME propagation:

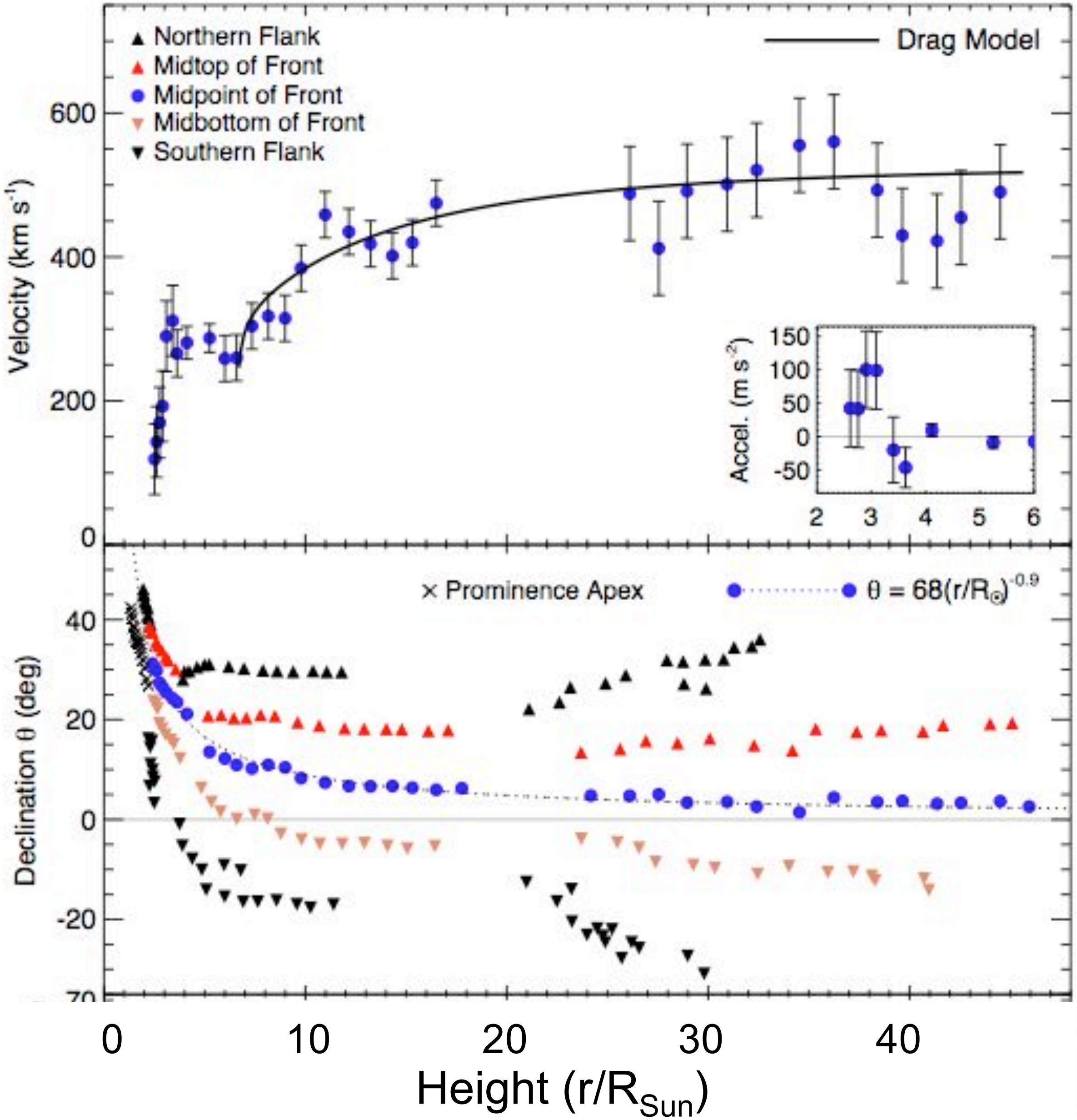
Early acceleration phase.

Subsequent drag phase in the solar wind.

CME deflection:

$$\theta(R) = 68R^{-0.9}$$

Source region ~ 55˚N
Tends toward the ecliptic.



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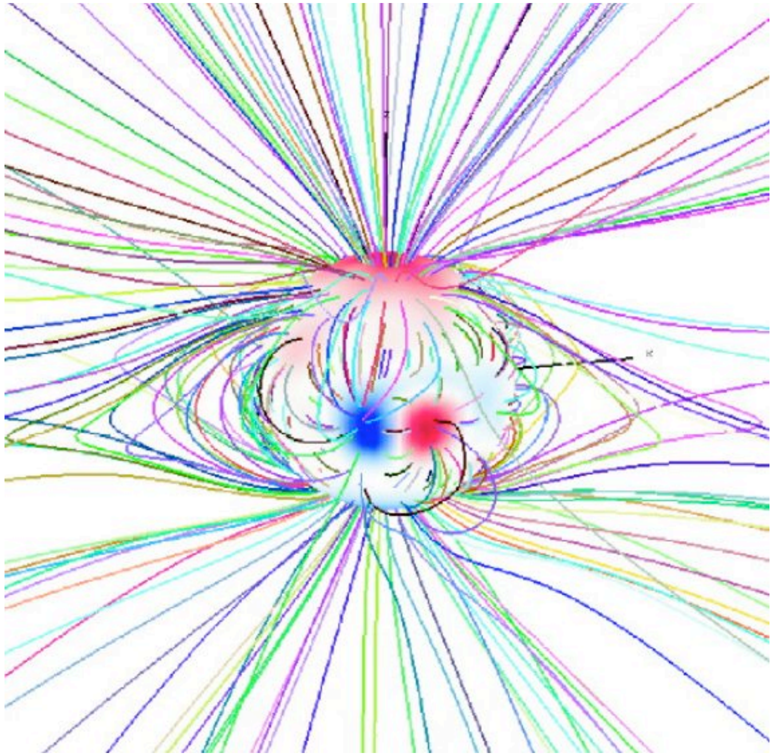
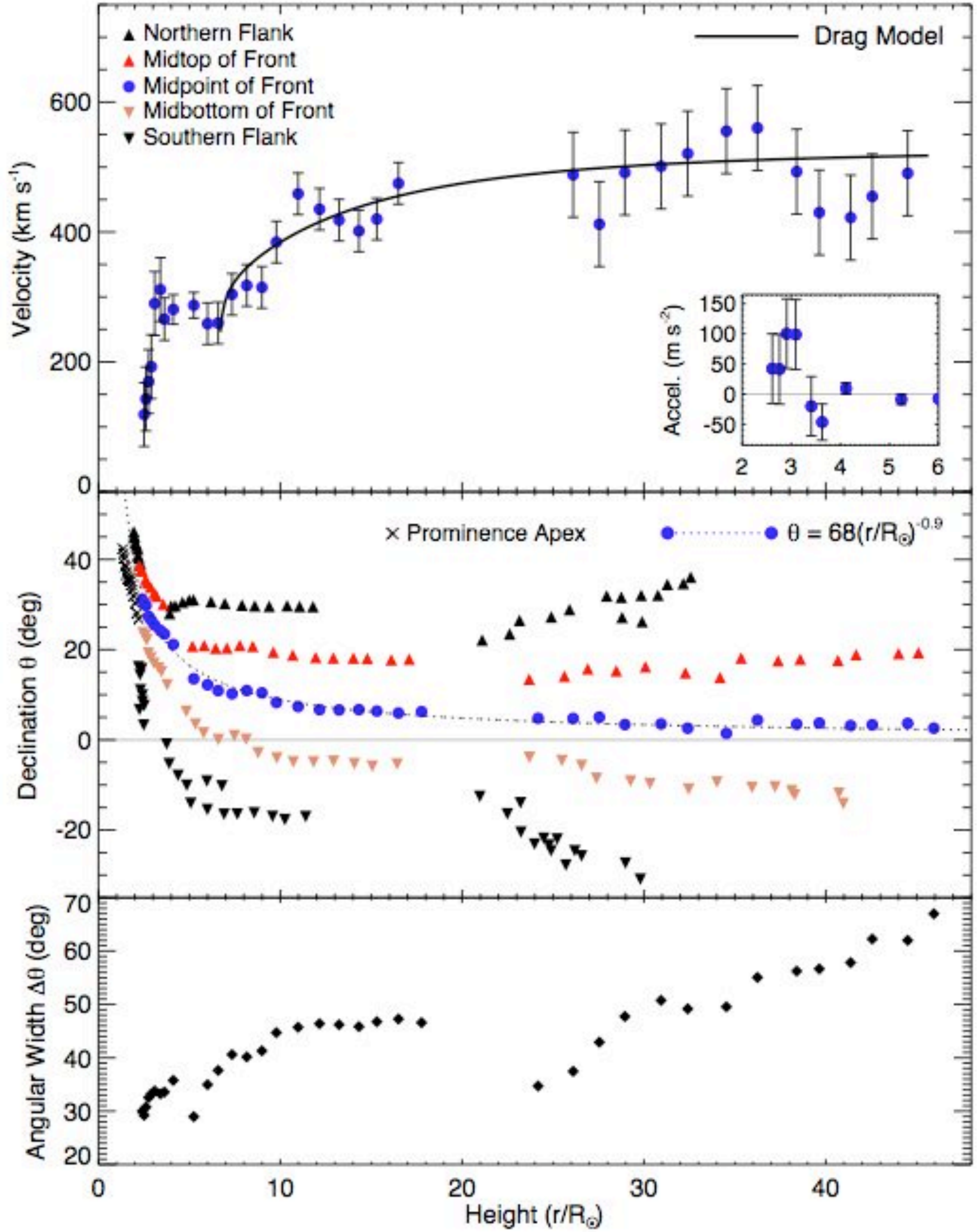


(Riley et al. ApJ 2006)



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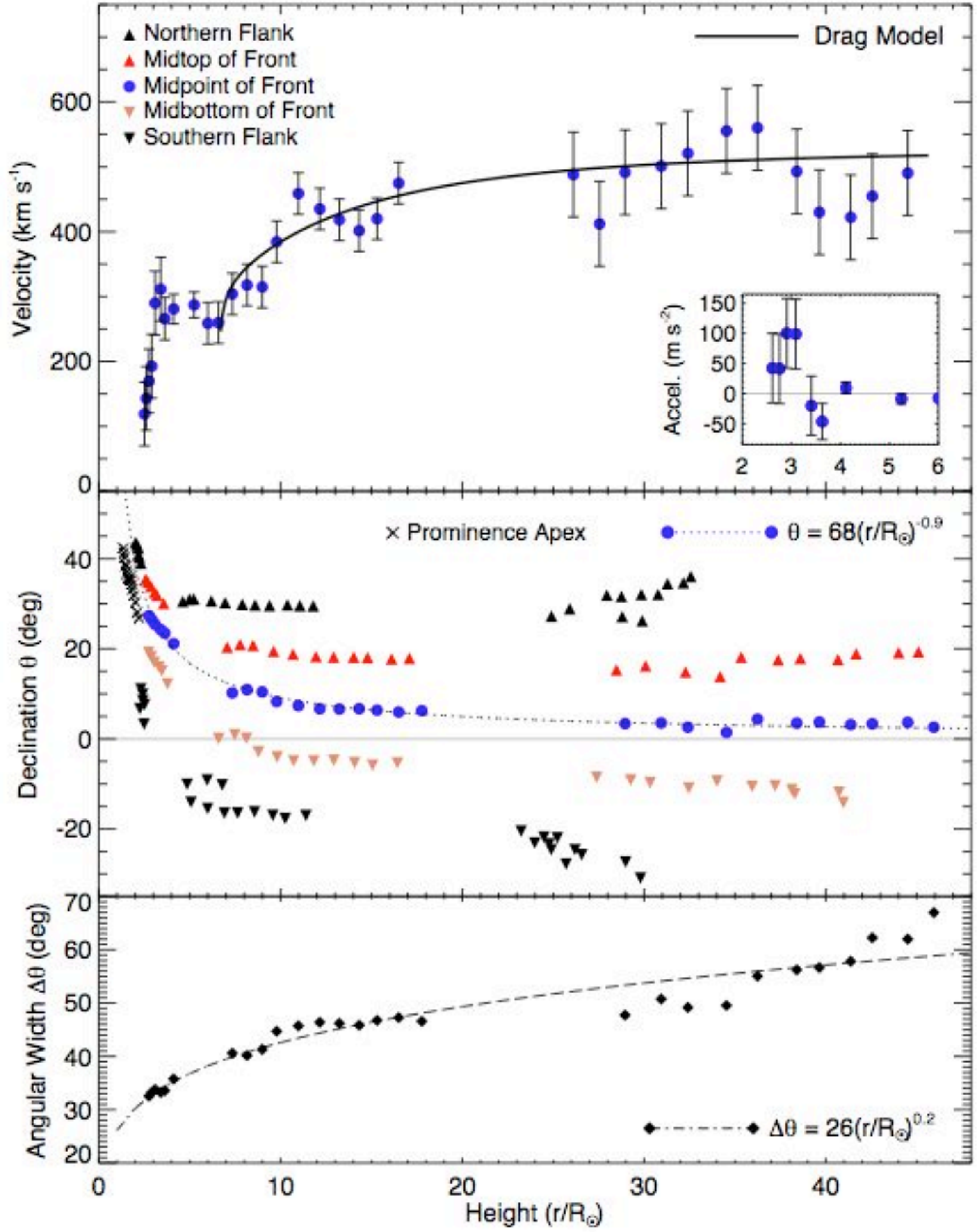
CME expansion:

Occulter effects are apparent.



CME propagation:

Early acceleration phase.

Subsequent drag phase in the solar wind.

CME deflection:

$$\theta(R) = 68R^{-0.9}$$

Source region ~ 55°

Tends toward the ecliptic.

CME expansion:

$$\Delta\theta(R) = 26R^{0.2}$$

Initial overpressure.

Tends toward a constant.

Conclusions

1. **Acceleration** in the low corona ~ $100ms^{-2} \pm 50ms^{-2}$

2. **Deflection** of CME front from high latitude into ecliptic.

$$\theta(R) = 68R^{-0.9}$$

Travels non-radially along the non-potential magnetic field of the corona.

3. Angular width **expansion**.

$$\Delta\theta(R) = 26R^{0.2}$$

Initial overpressure of the CME relative to the surrounding corona.

4. **Drag** dominated propagation in the solar wind $> 7\ R_{Sun}$