

Multiscale Characterisation of CMEs

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CME Study

- Eruptions of Plasma & Magnetic Field
- Theoretical Models
- Image Processing
- Morphology & Kinematics
- STEREO Analysis

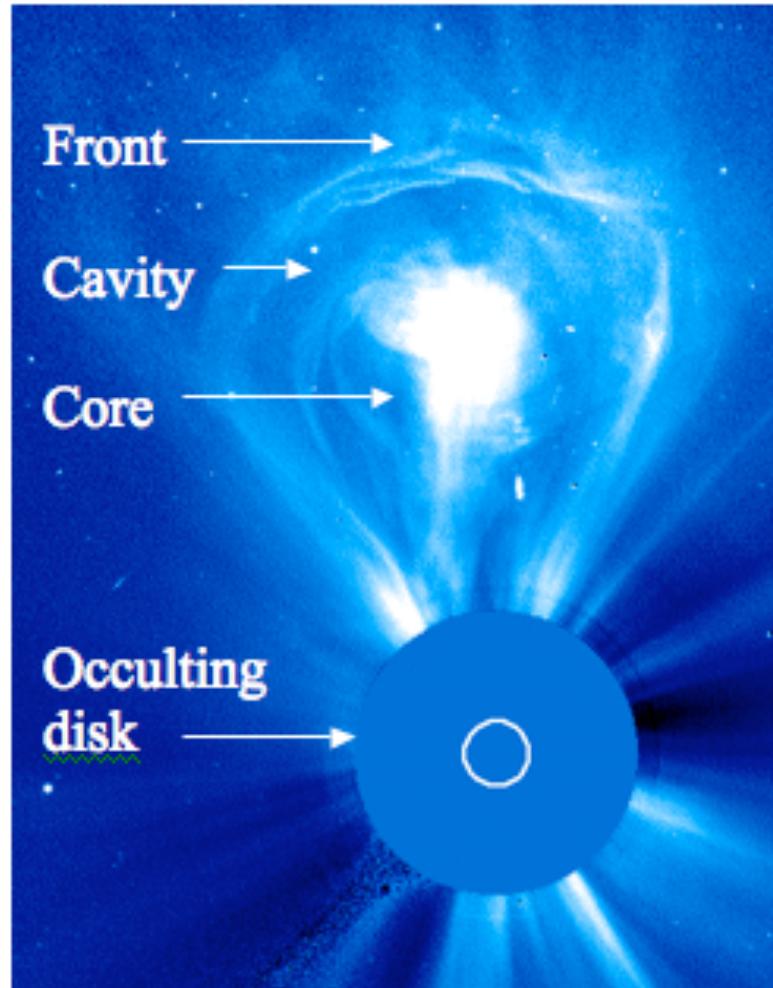
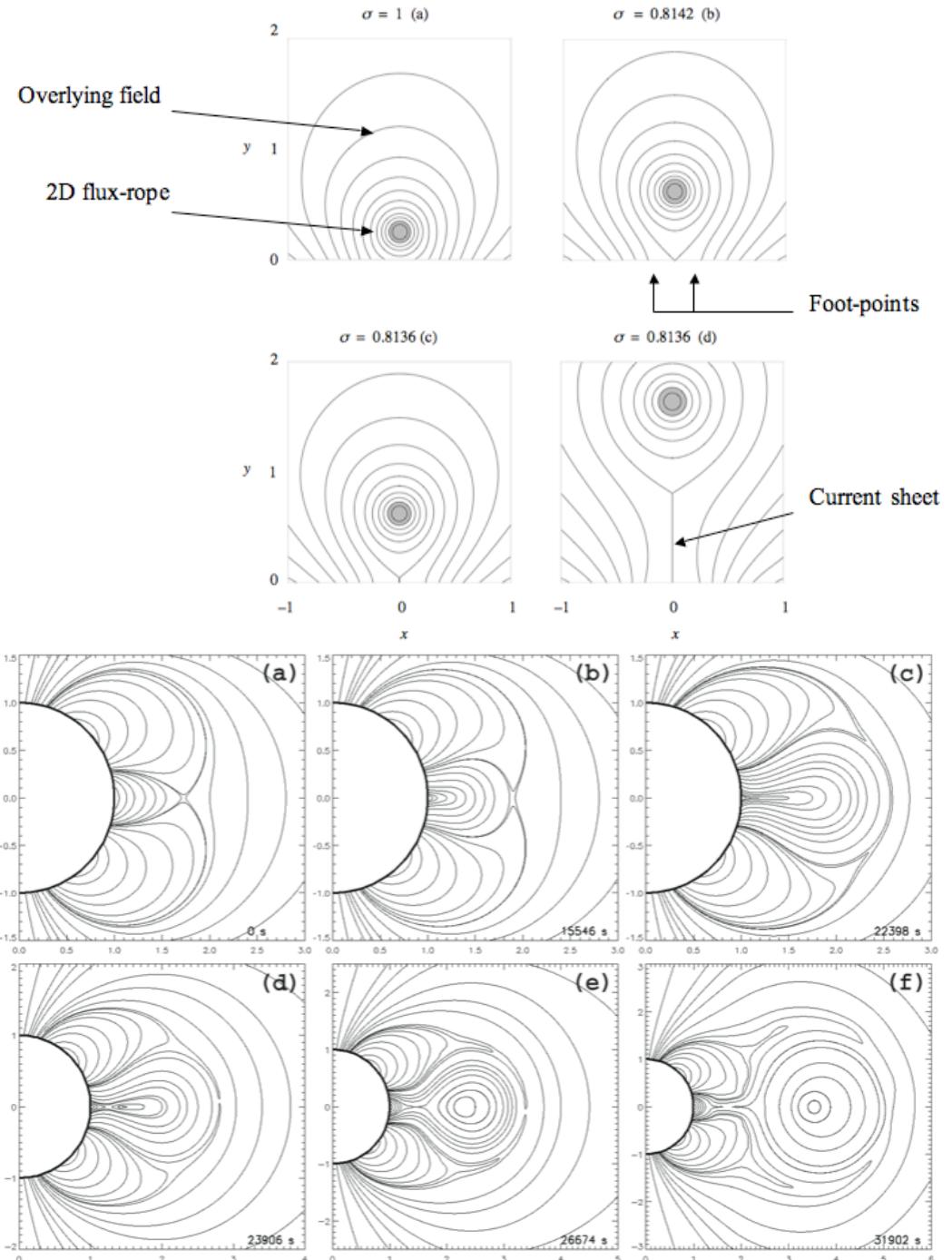


Figure 1: The fundamental components of a CME observed by the LASCO coronagraph on the SOHO spacecraft.

CME Models

- Magnetic Flux-Rope:
- Magnetic Break-out:



Observing CMEs

- White Light Coronagraphs
- Occulting disk
- CCD detectors
- Pixel Information

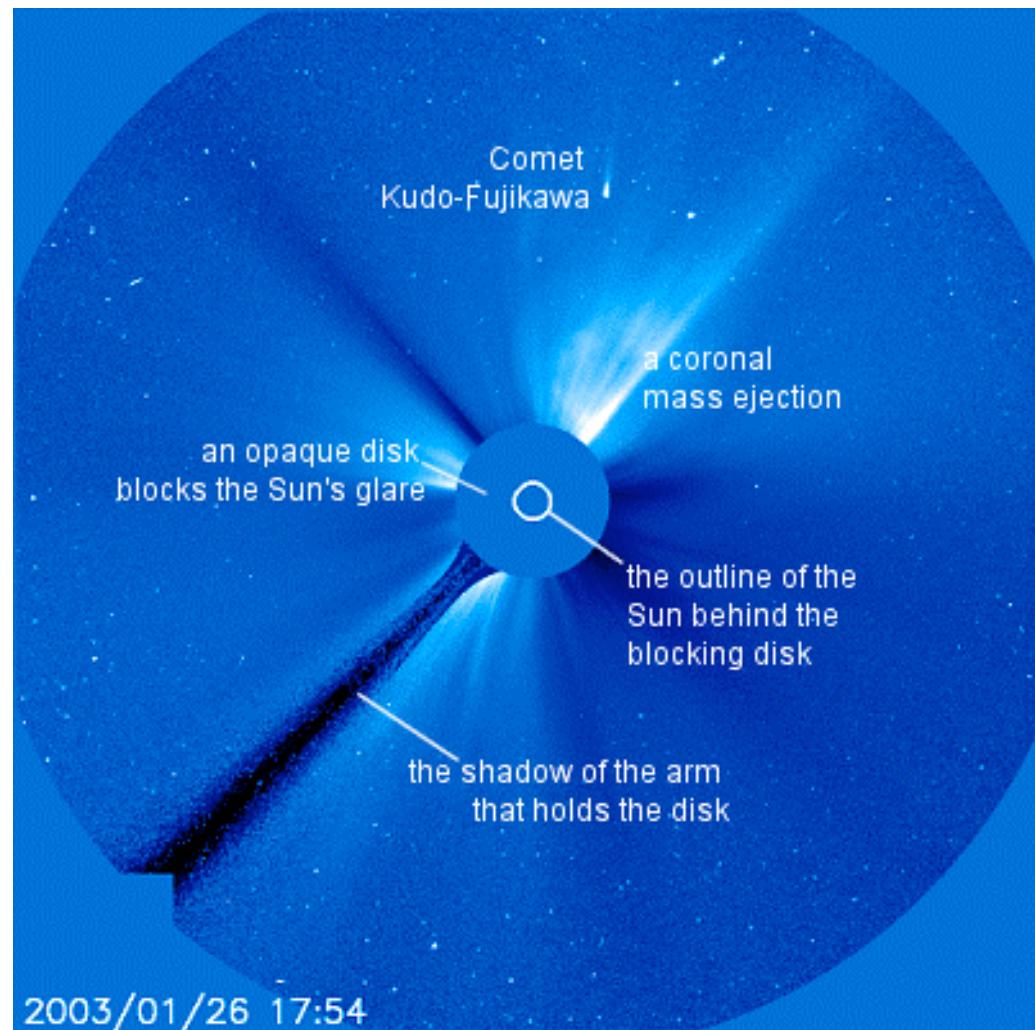
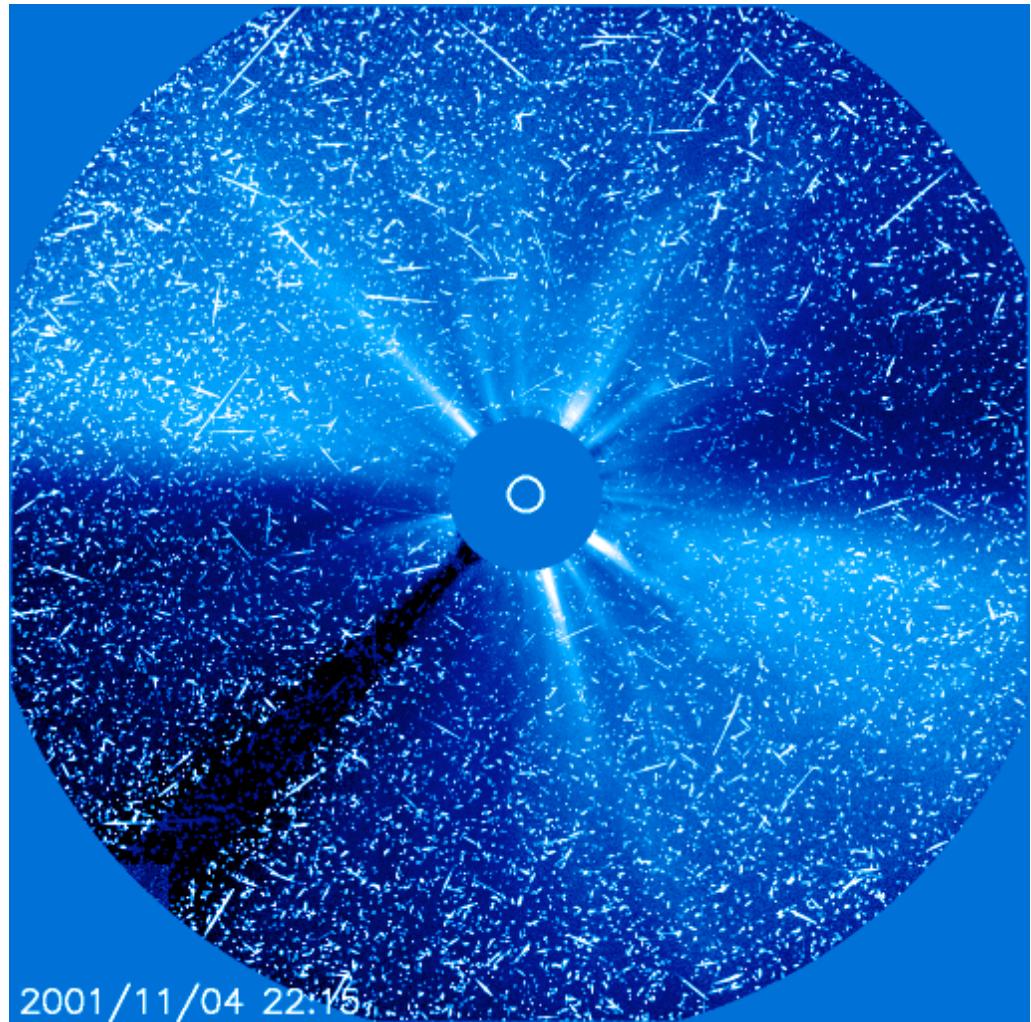


Image from Lasco/C3 onboard SOHO

Image Pre-processing

- Normalisation
 - exposure time
 - CCD bias
 - data dropouts
- Background subtraction
- Median filtering
(de-noising)

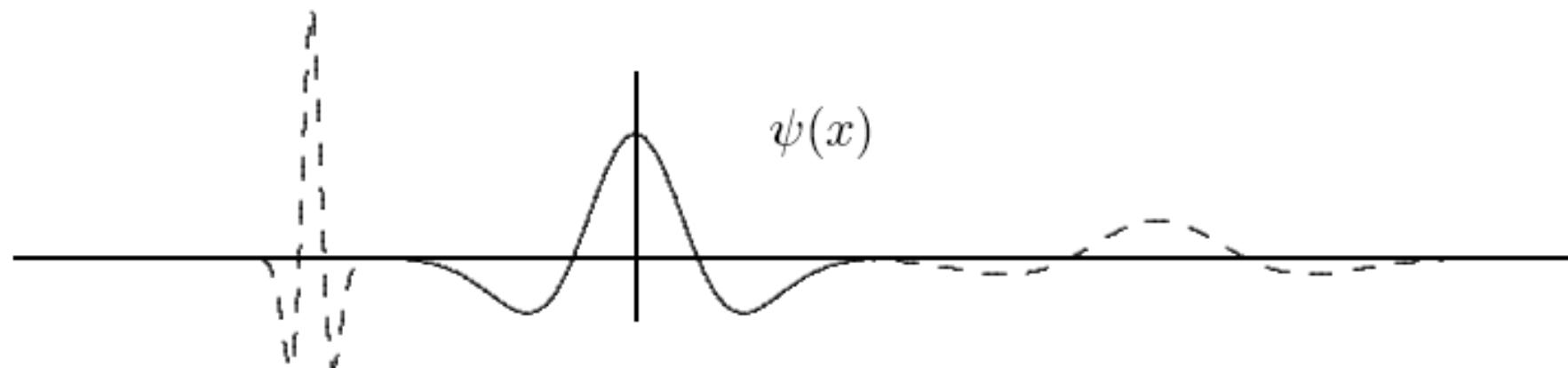


Lasco/C3 ‘snow-storm’: cosmic rays / SEPs

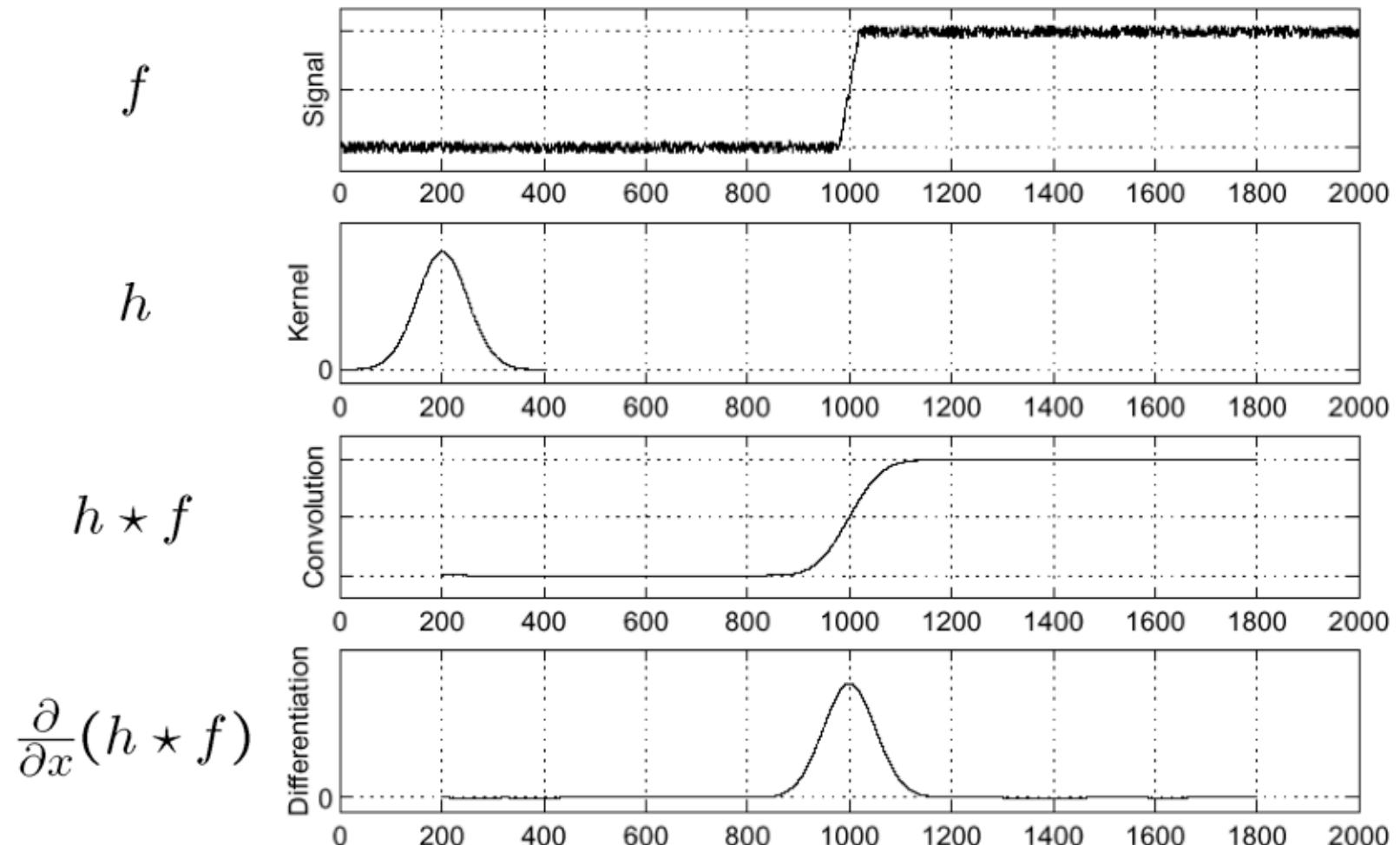
Multiscale Analysis

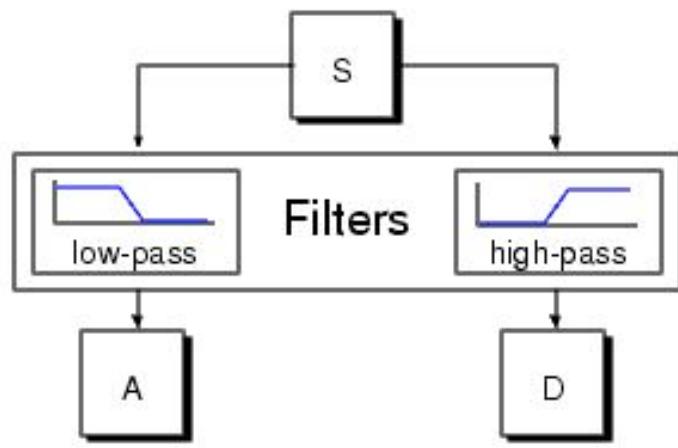
- Wavelets:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{b}} \psi\left(\frac{t-a}{b}\right)$$

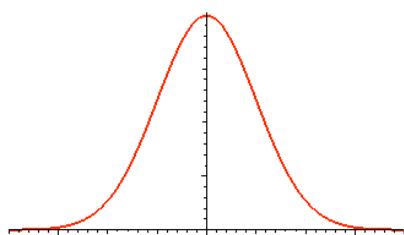


- Edge Detection:

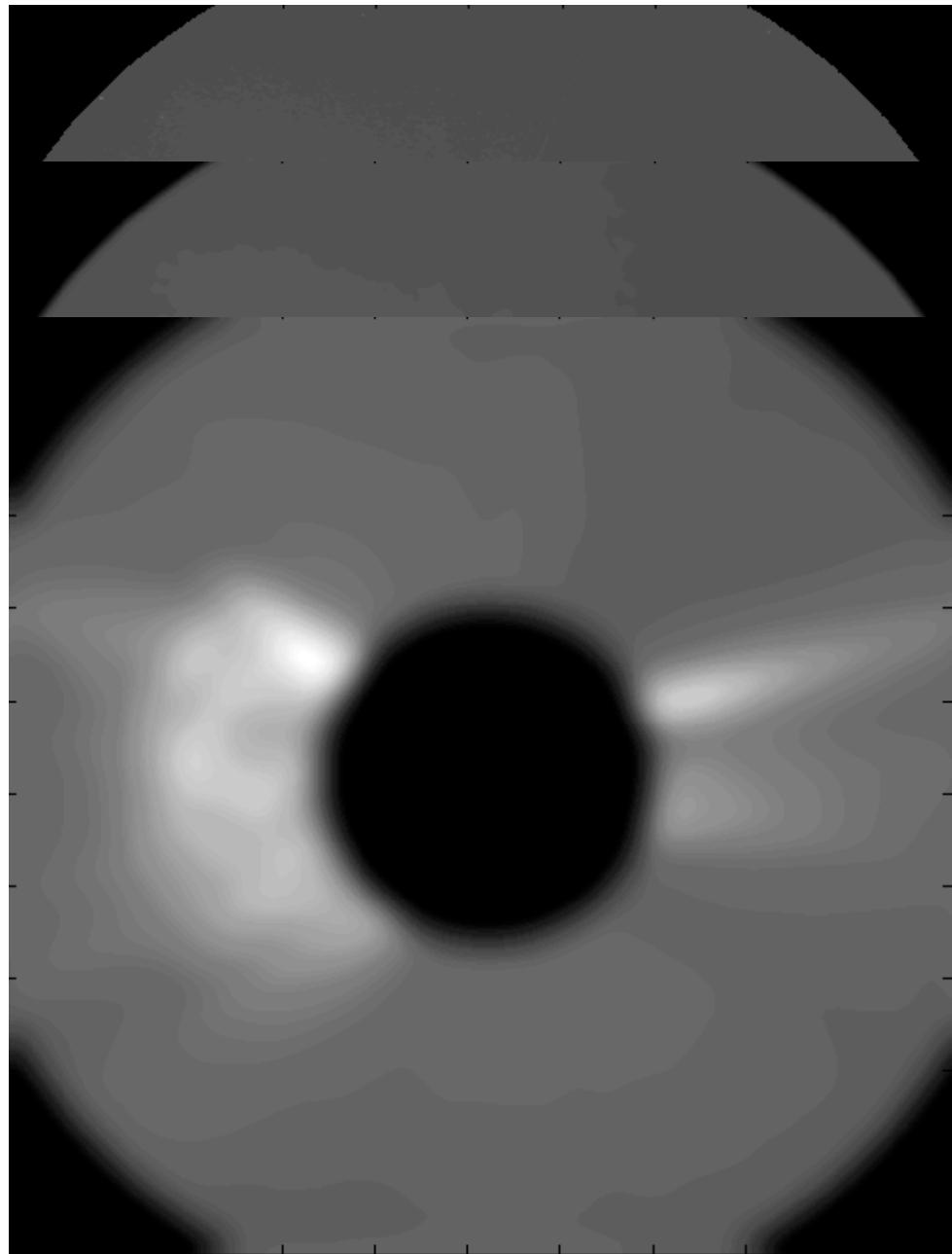
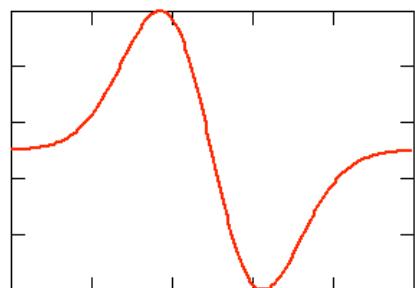




Low pass: Approximation



High pass: Detail



Vertical Direction:



Horizontal Direction:

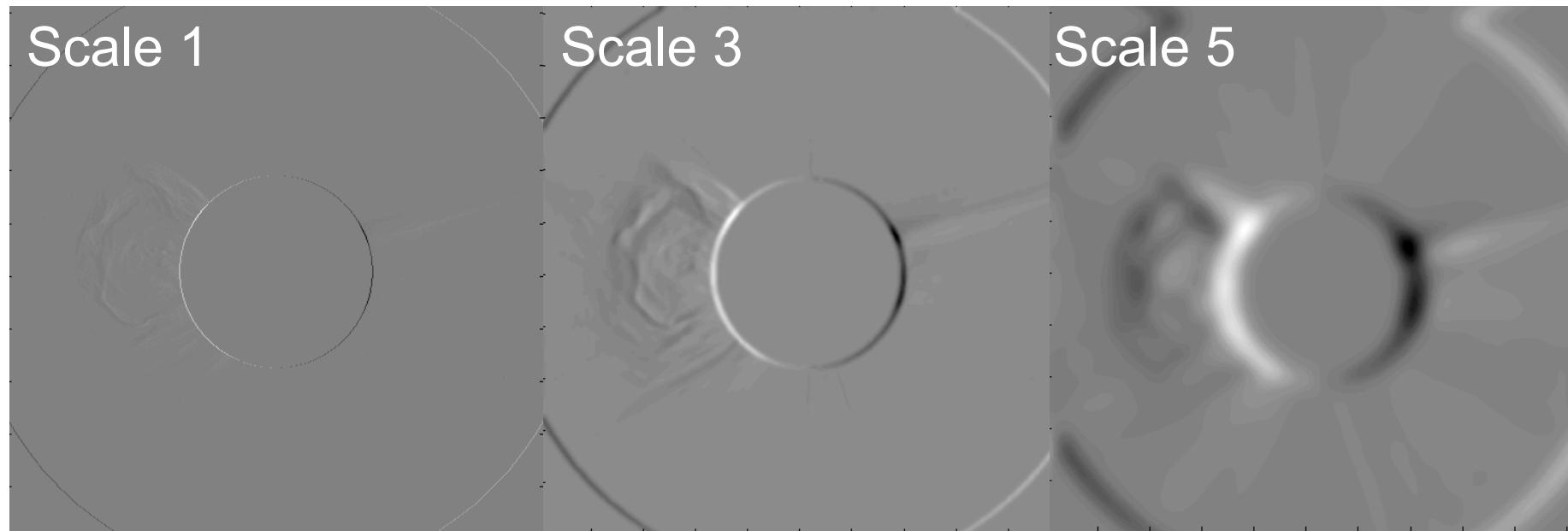
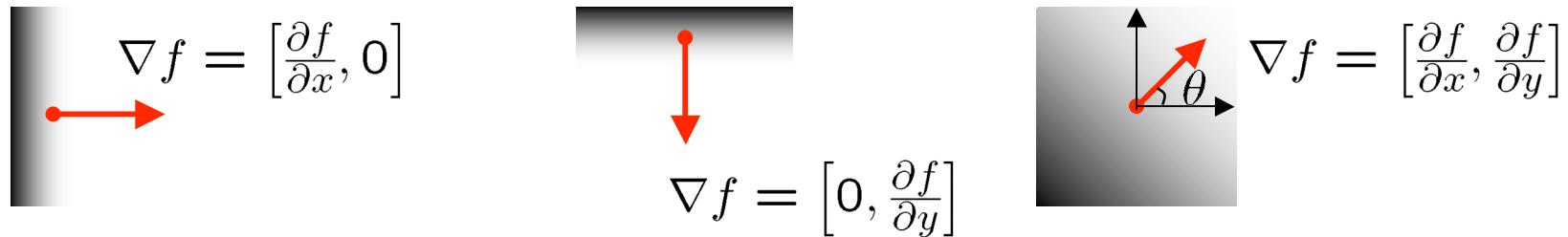


Image gradient

- The gradient of an image: $\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y} \right]$
- The gradient points in the direction of most rapid change in intensity



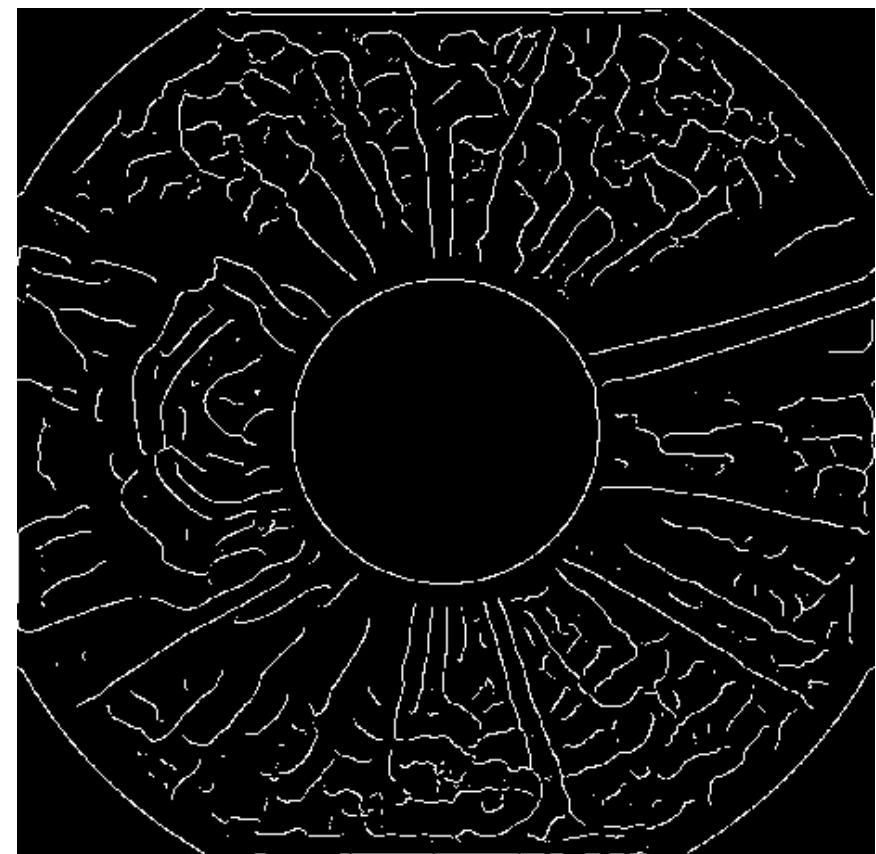
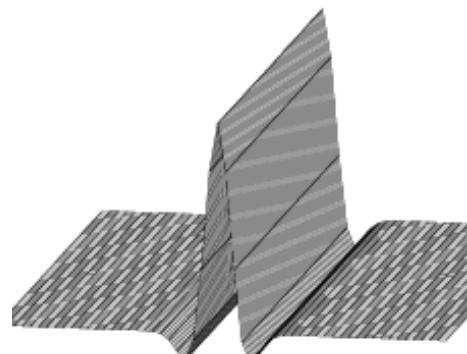
- The gradient direction is given by:
$$\theta = \tan^{-1} \left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x} \right)$$
- The *edge strength* is given by the gradient magnitude

$$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2}$$

WTMM: Non-maxima suppression

Pixel chaining highlights edges:

- 1) An individual pixel is chosen
- 2) Neighbouring pixels are compared
- 3) If specific criteria is satisfied, the pixels are chained.



CME Front Characterisation

- Ellipse fit
- Height, Width, Curvature, Orientation

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

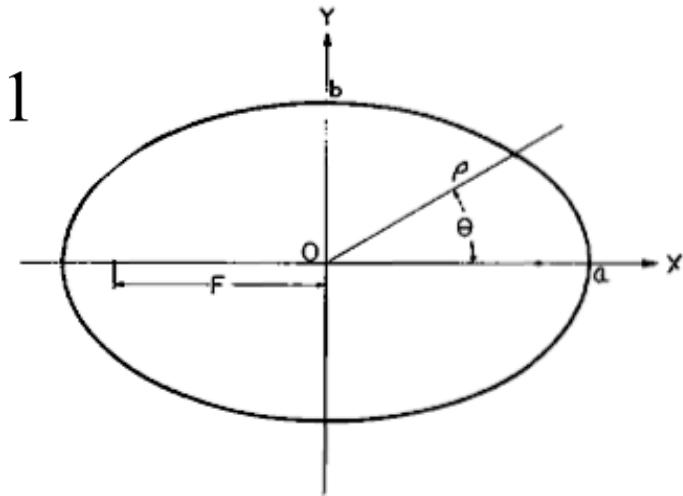
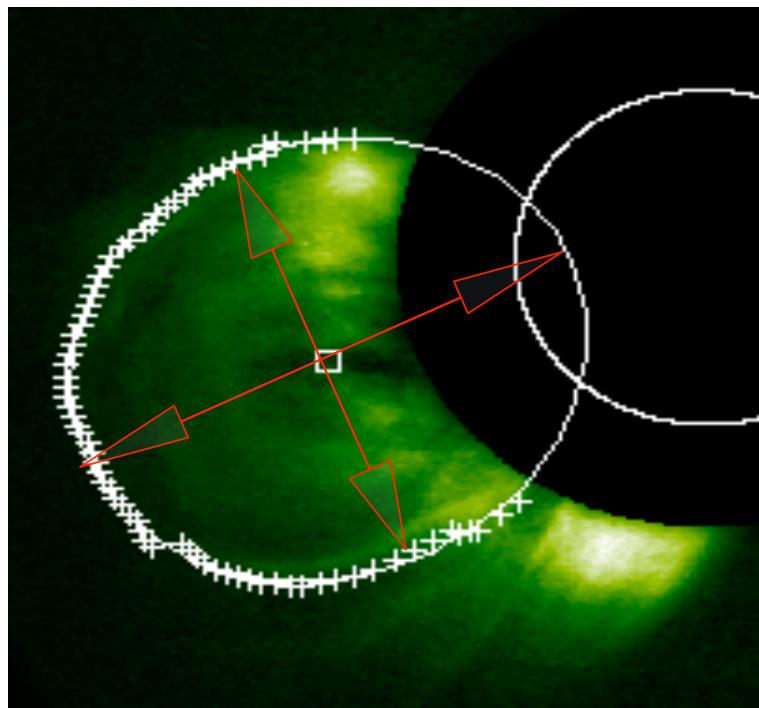


Fig. 3—Ellipse in rectangular coordinates.



Secchi/Cor1 24Jan07

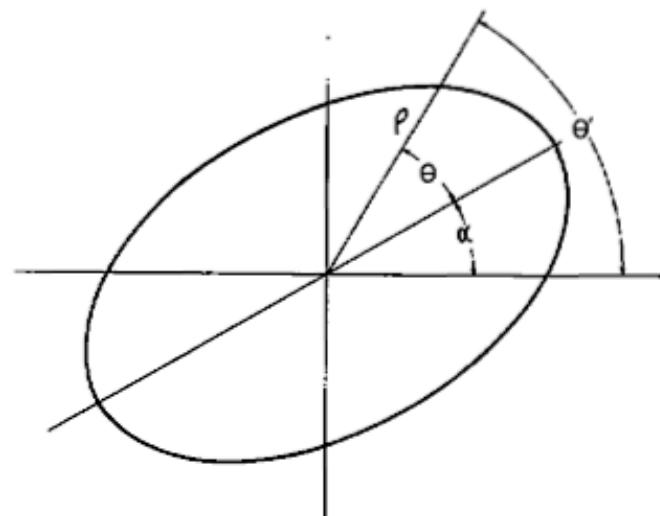
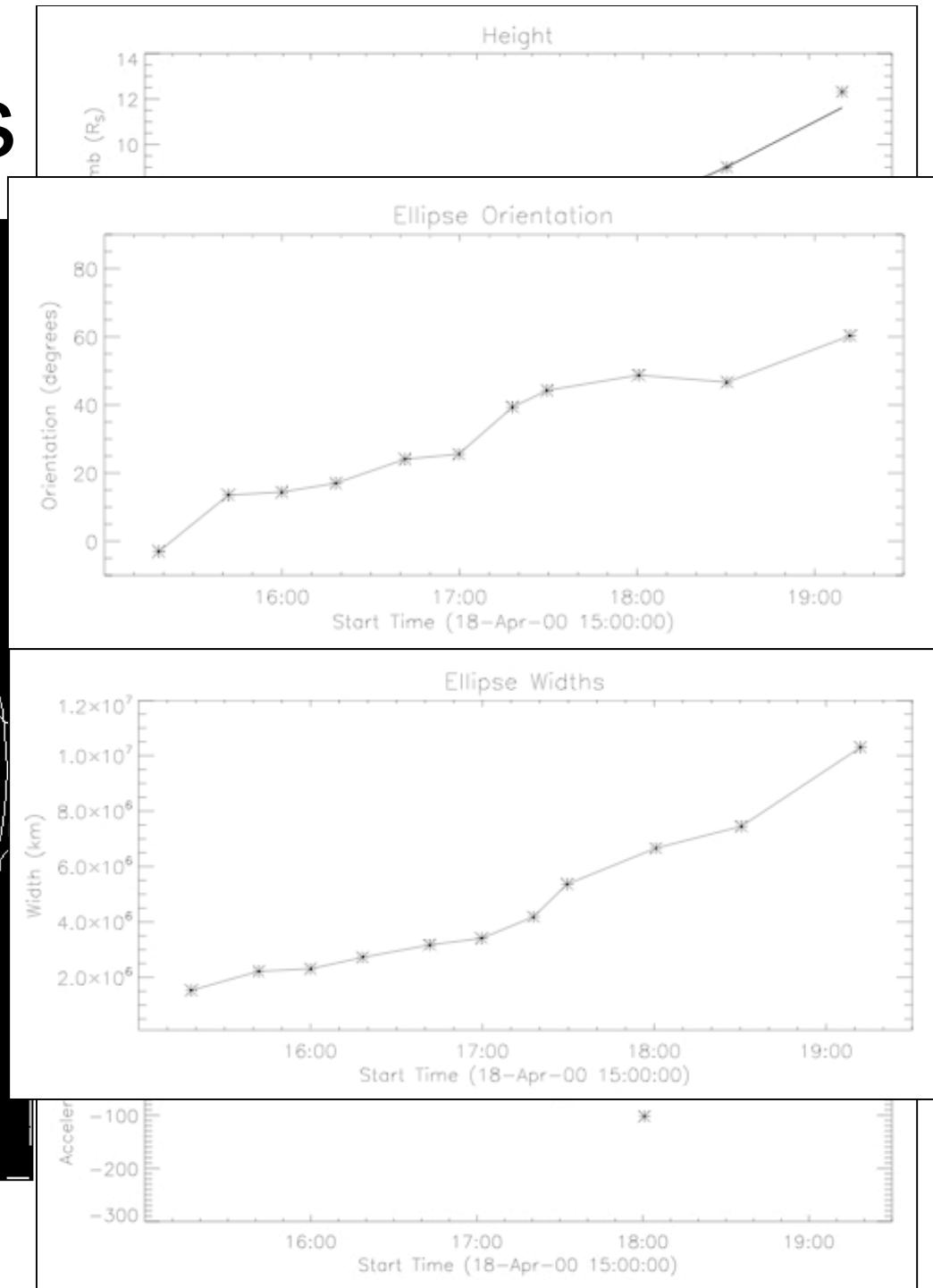
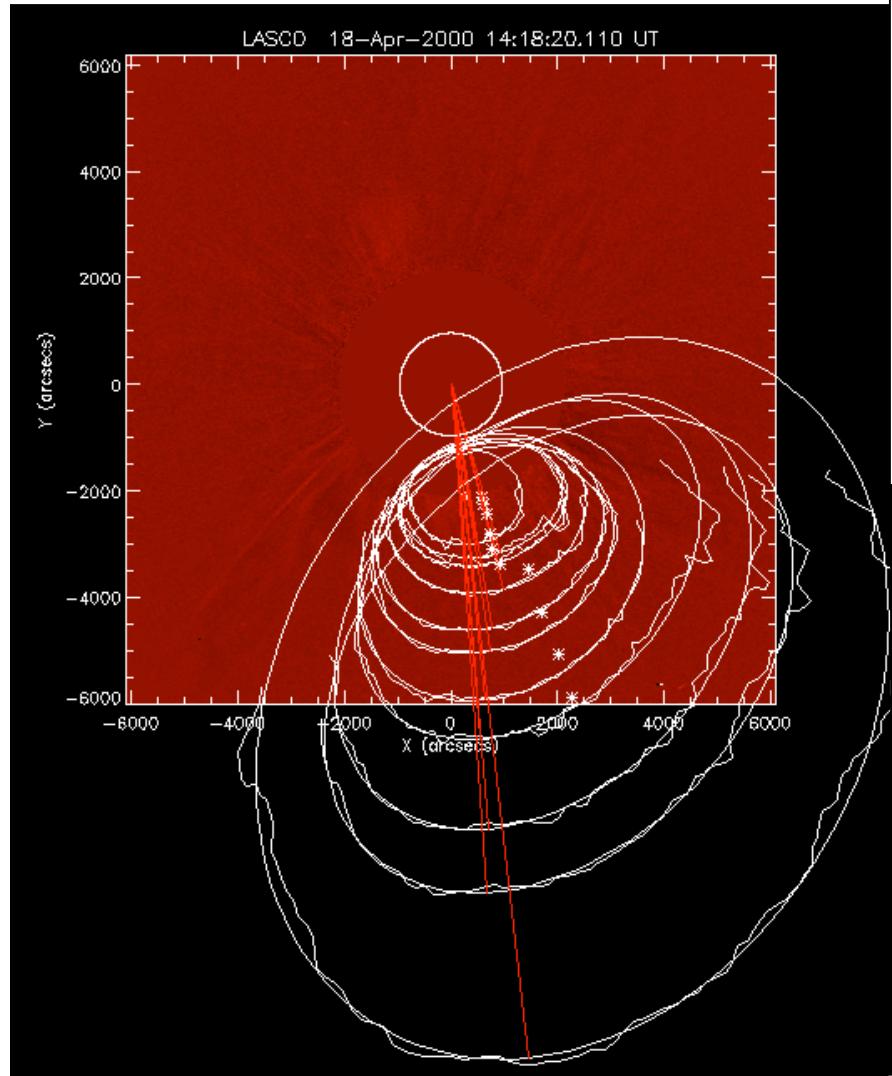


Fig. 4—Inclined ellipse.

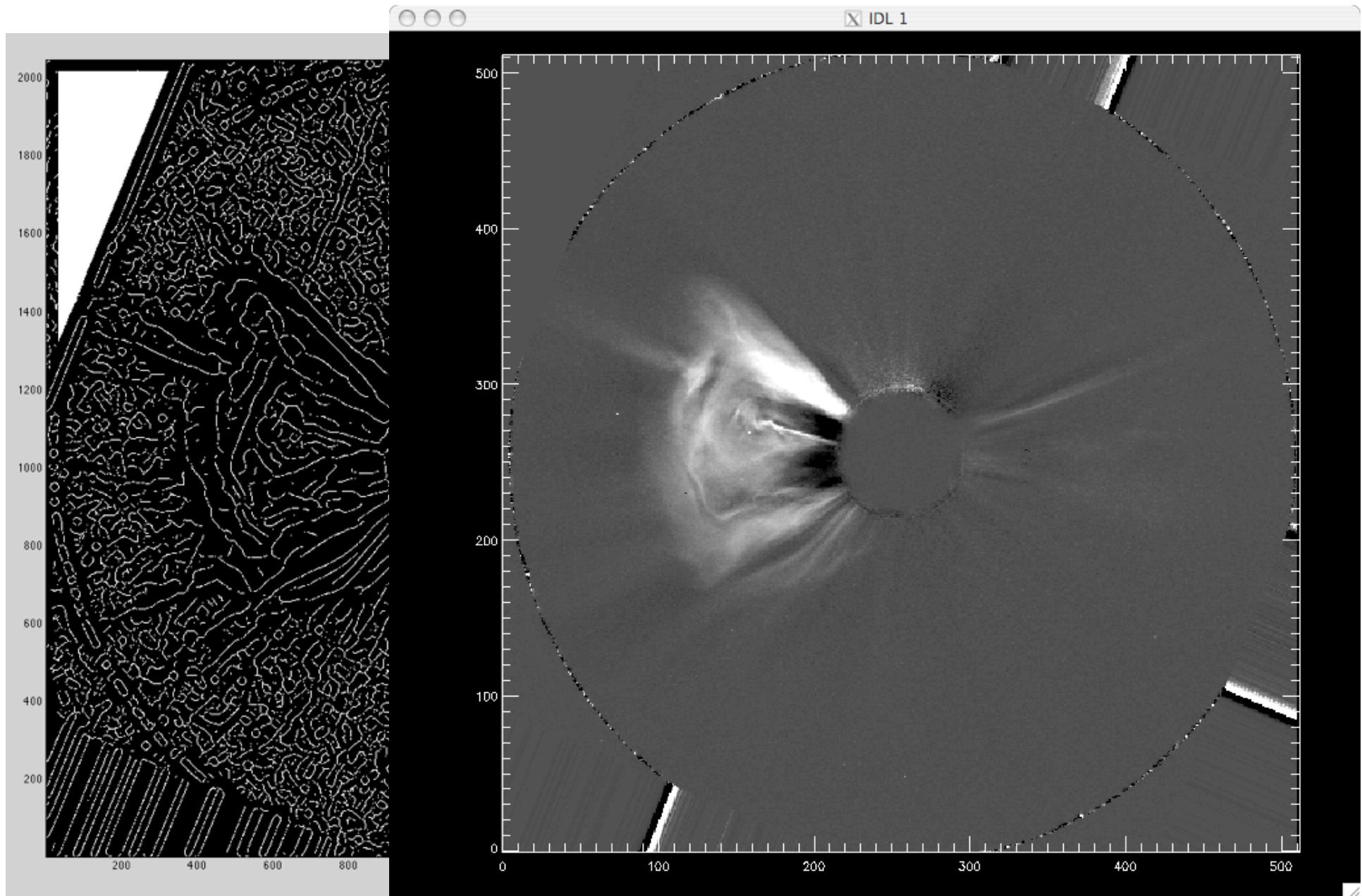
CME Kinematics



Movie Scripts

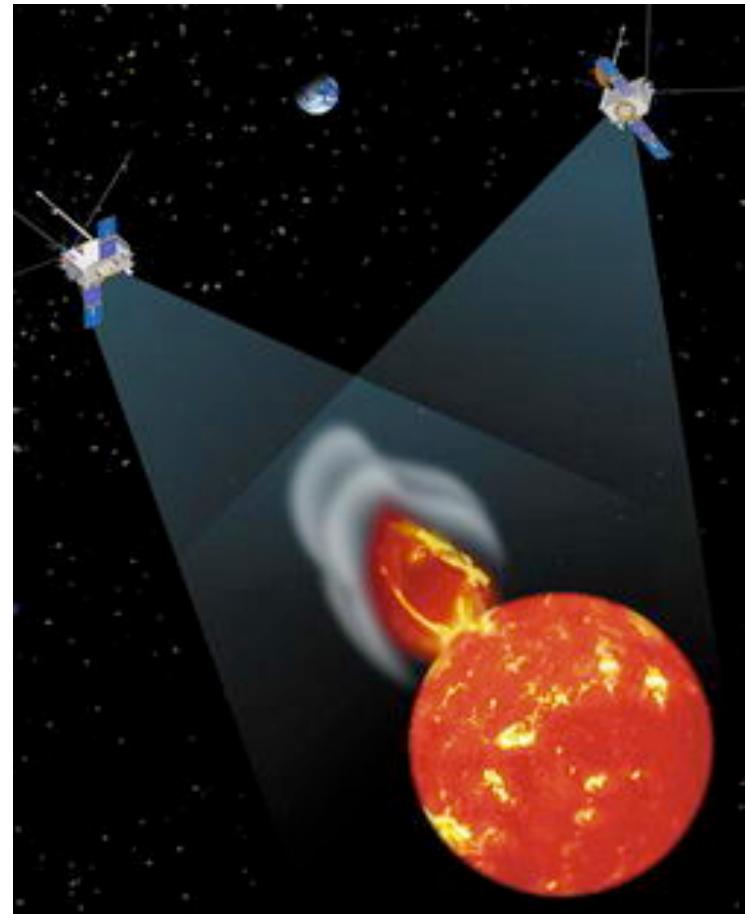
- www.maths.tcd.ie/~jaydog/Solar/CME_ellipse_movies/24jan07/C2_movie_ell.html
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- www.maths.tcd.ie/~jaydog/Solar/CME_ellipse_movies/24jan07/Graphs_plots_lasco.html
- www.maths.tcd.ie/~jaydog/Solar/STEREO/pb/24jan07/Graphs_plots.html

SECCHI Cor2



Next Steps...

- More data; distribution of CME kinematics.
- Multiple view points (Stereo); triangulation / projection effects.
- Automated front detection; space weather forecasting.



Thank You

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