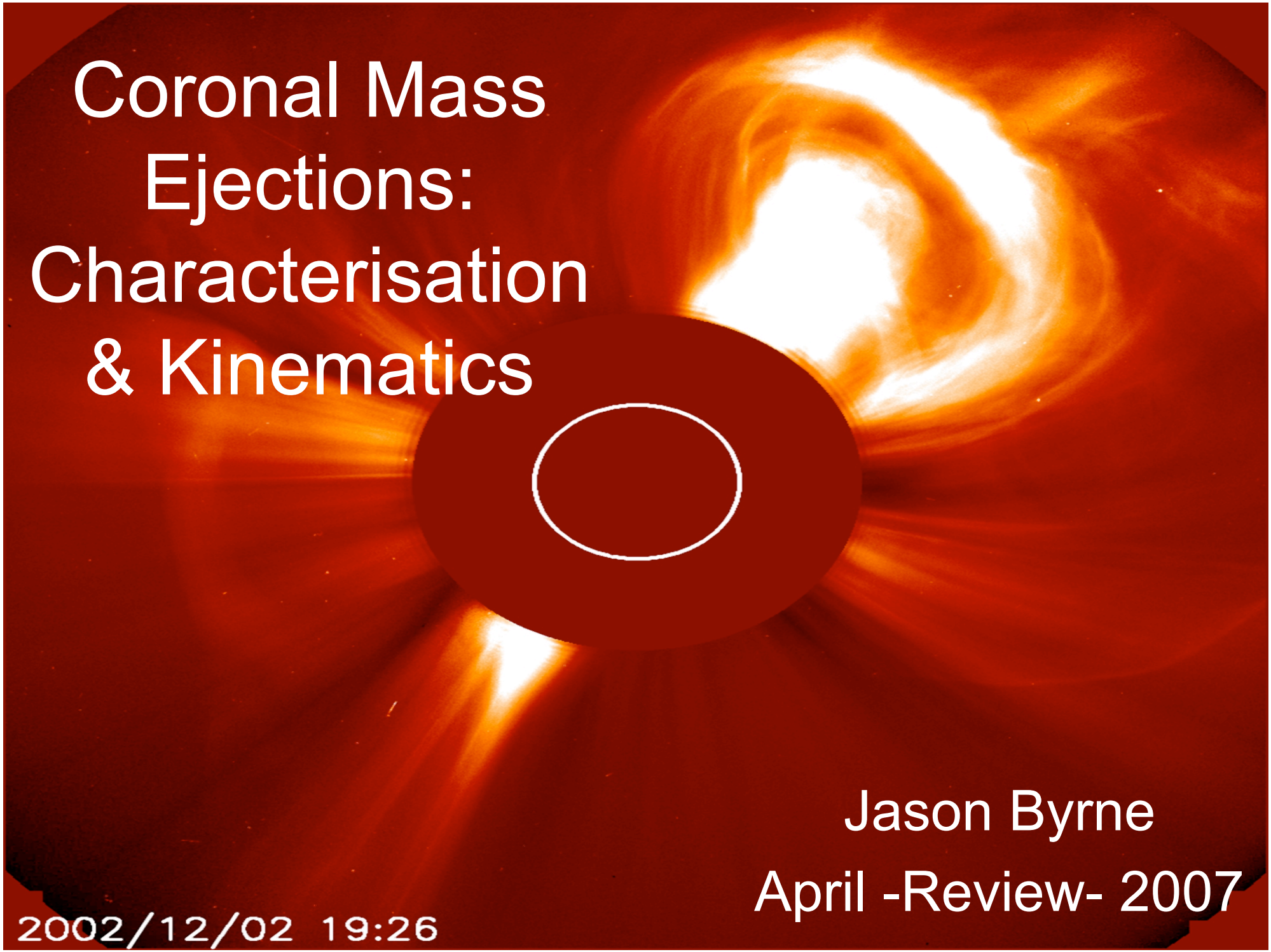

Coronal Mass Ejections: Characterisation & Kinematics
Jason Byrne
April -Review- 2007
2002/12/02 19:26

CME Study

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

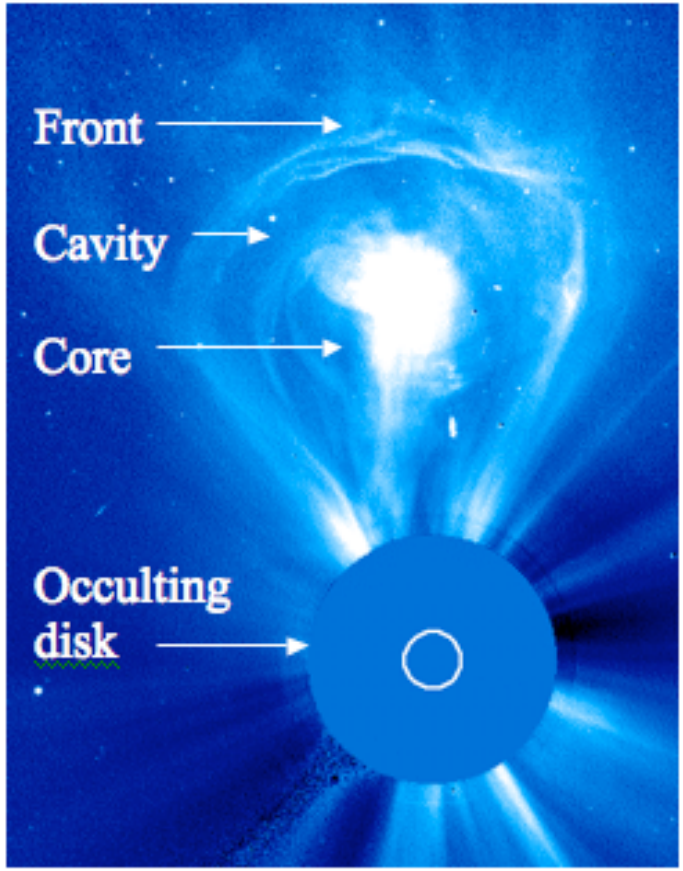
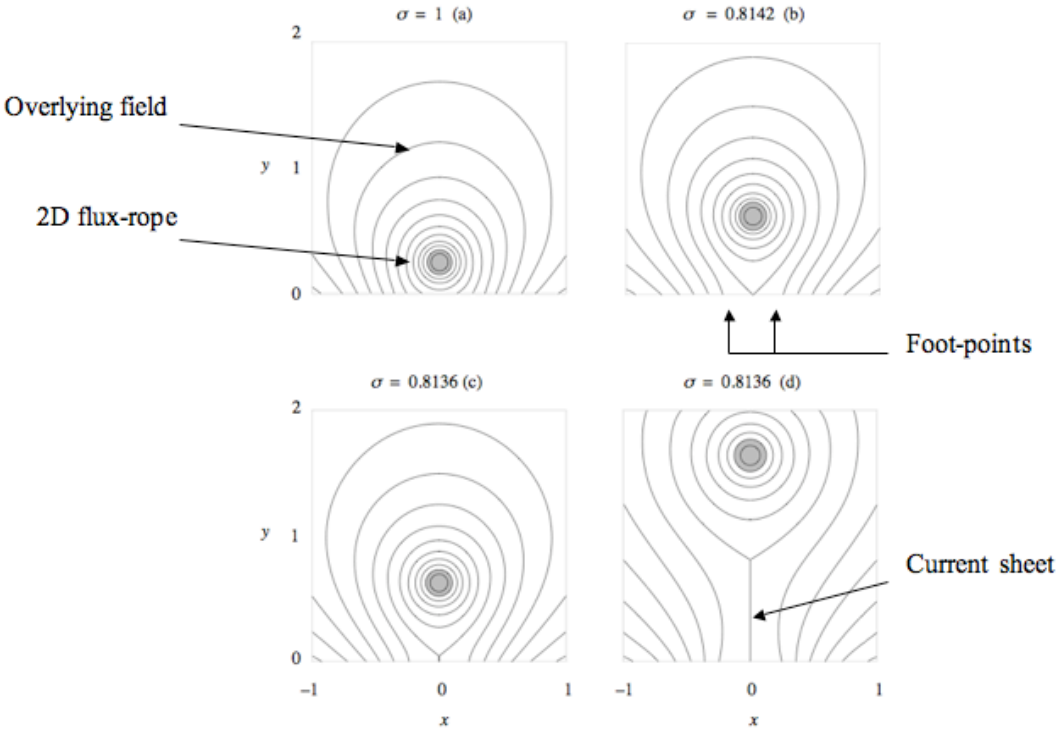


Figure 1: *The fundamental components of a CME observed by the LASCO coronagraph on the SOHO spacecraft.*

CME Models

- Magnetic Flux-Rope:



- Magnetic Break-out:

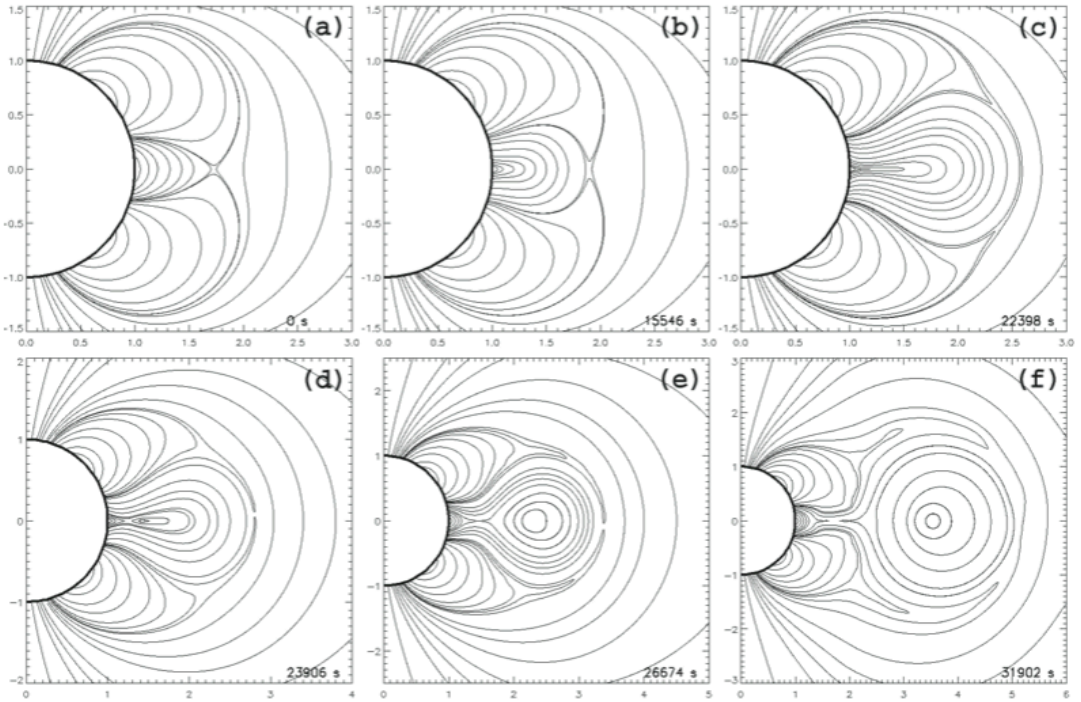
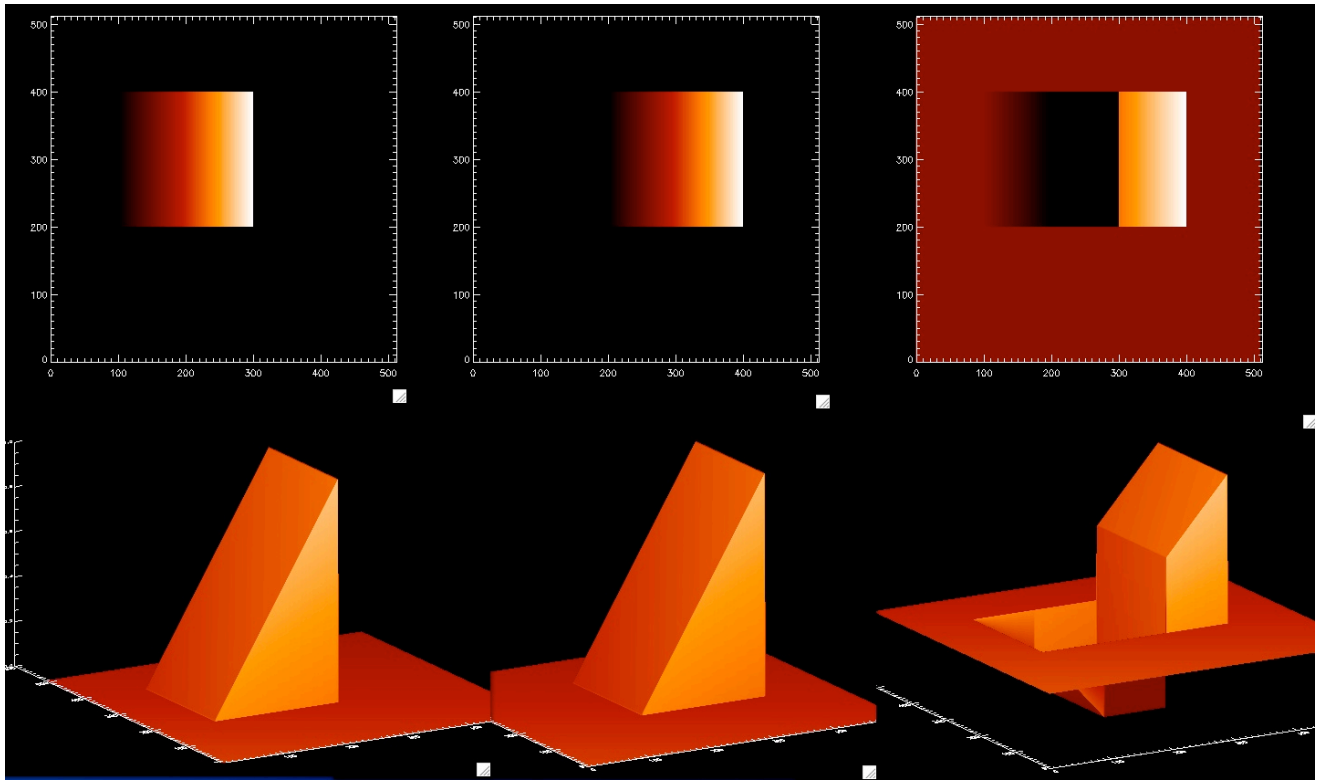


Image Processing

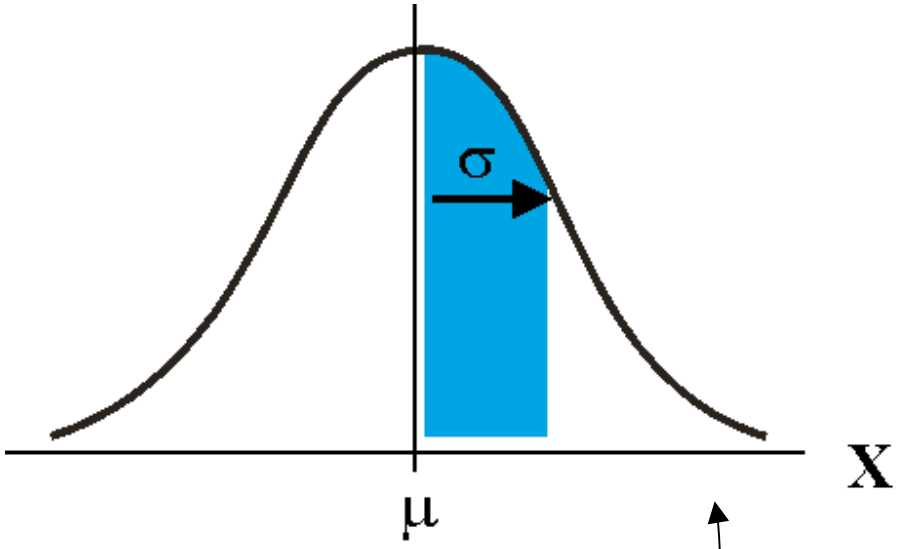
Running Difference

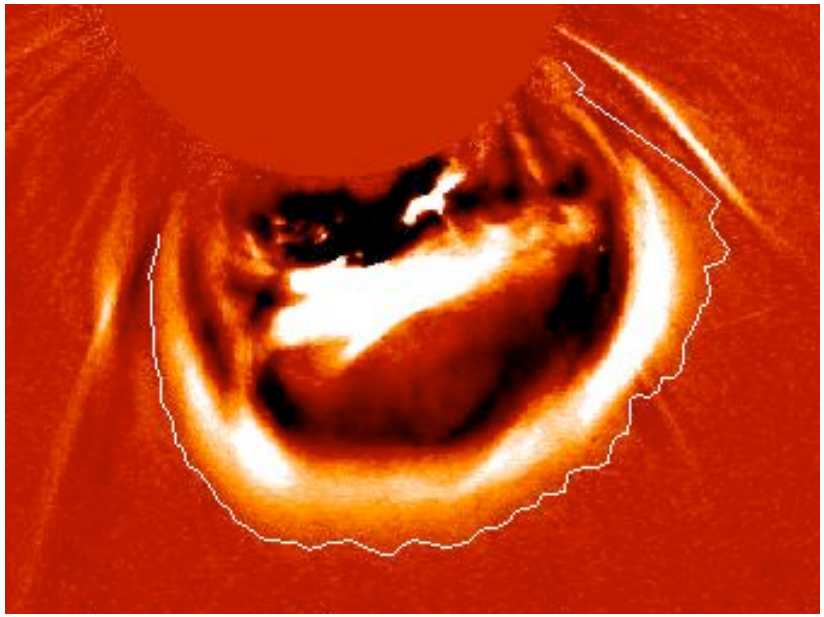


Diff(*,*,j) = Data(*,*,j+1) - Data(*,*,j)

Running Difference

- Intensity thresholding
- Front identification
- Contouring





3 sigma

CME Front Characterisation

- Ellipse fit
- Height, Width, Curvature, Orientation

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

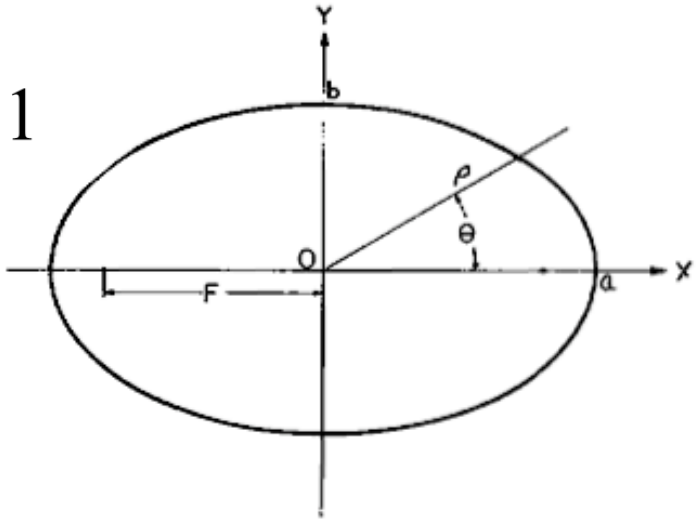
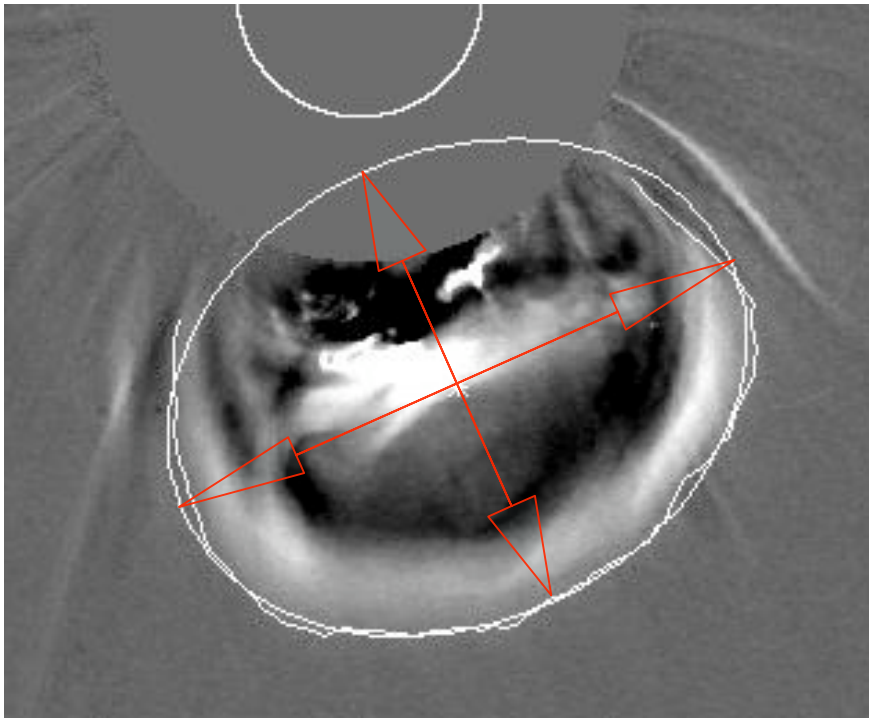


Fig. 3—Ellipse in rectangular coordinates.



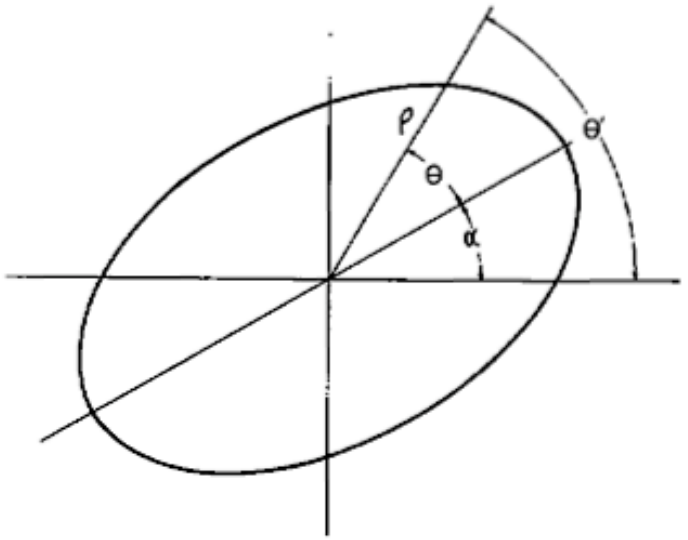
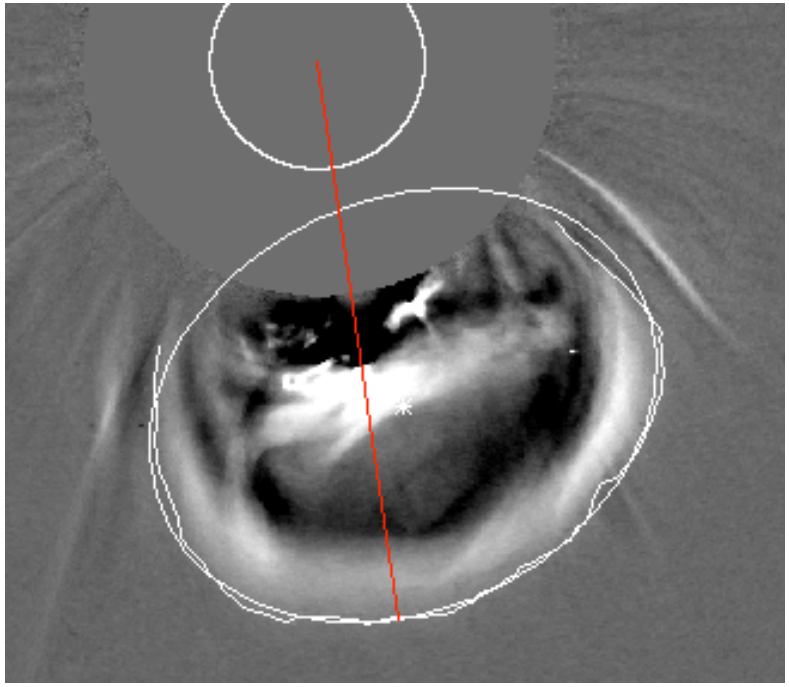
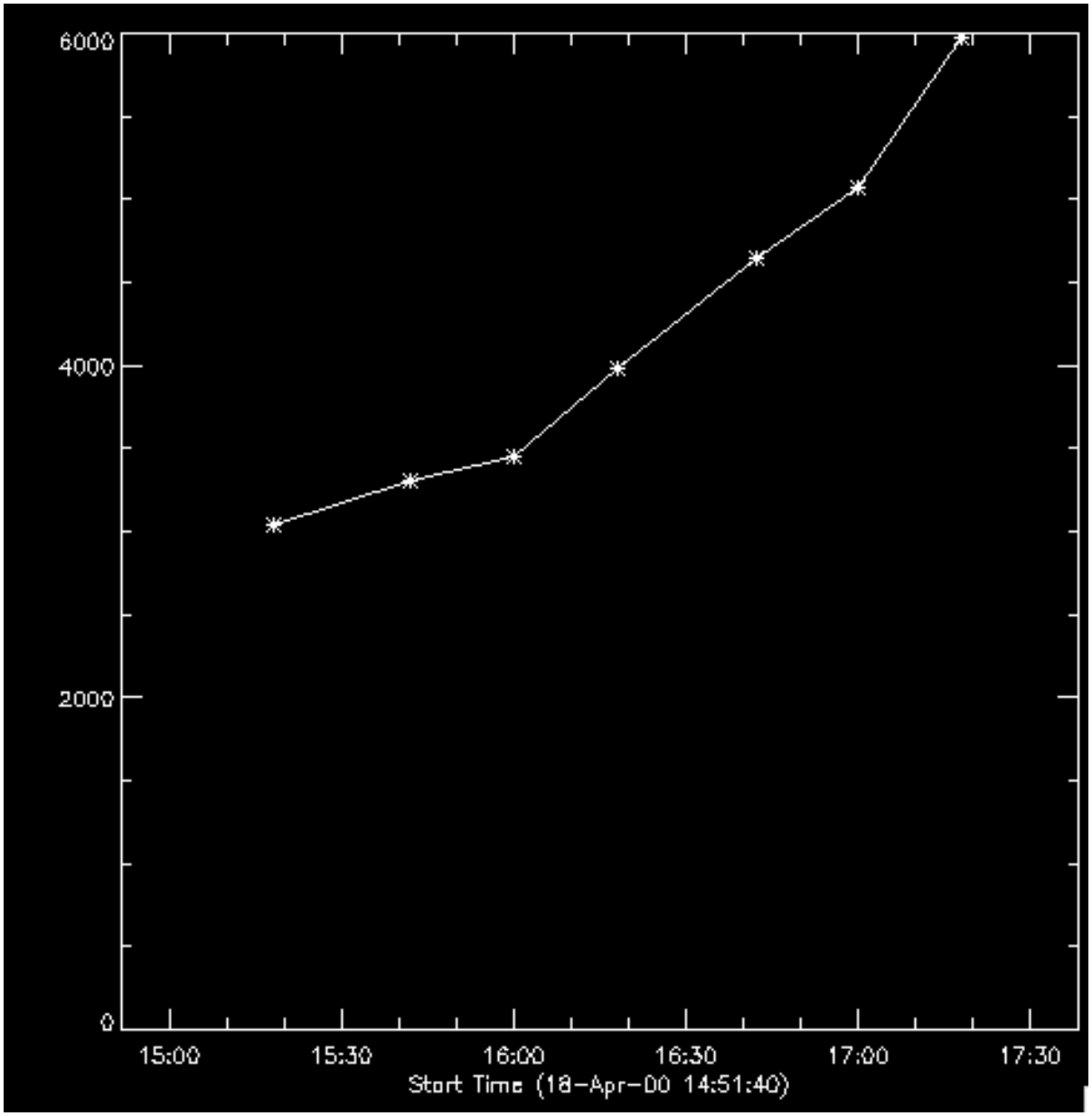


Fig. 4—Inclined ellipse.

CME Kinematics

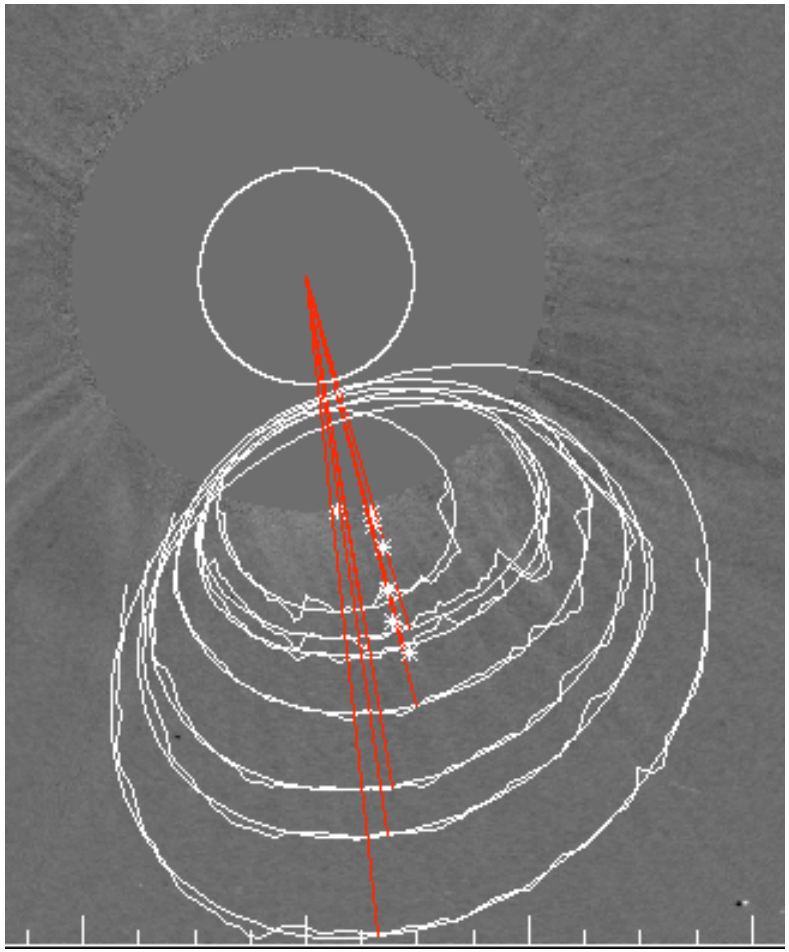
- Height-time profile

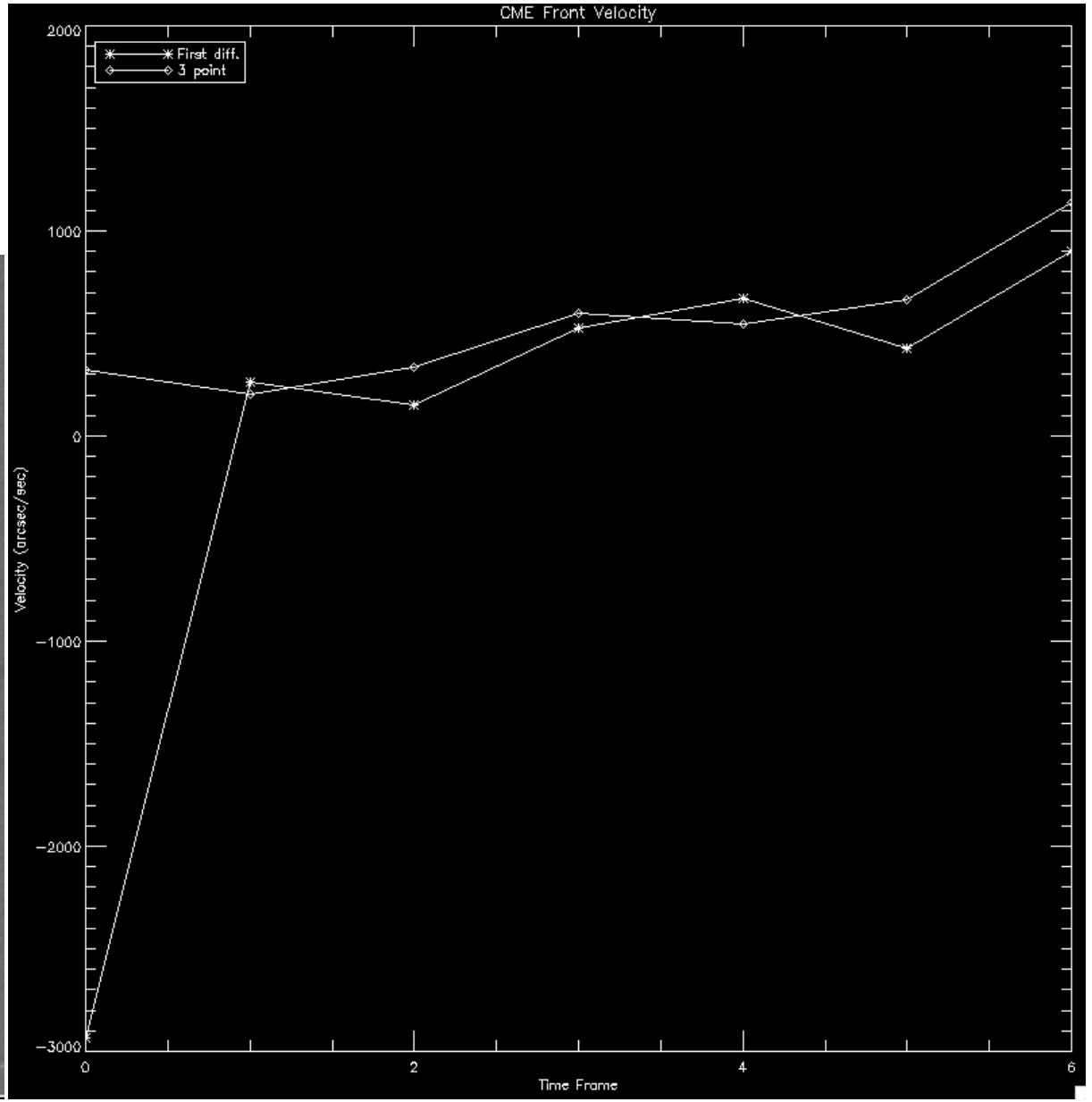




CME Kinematics

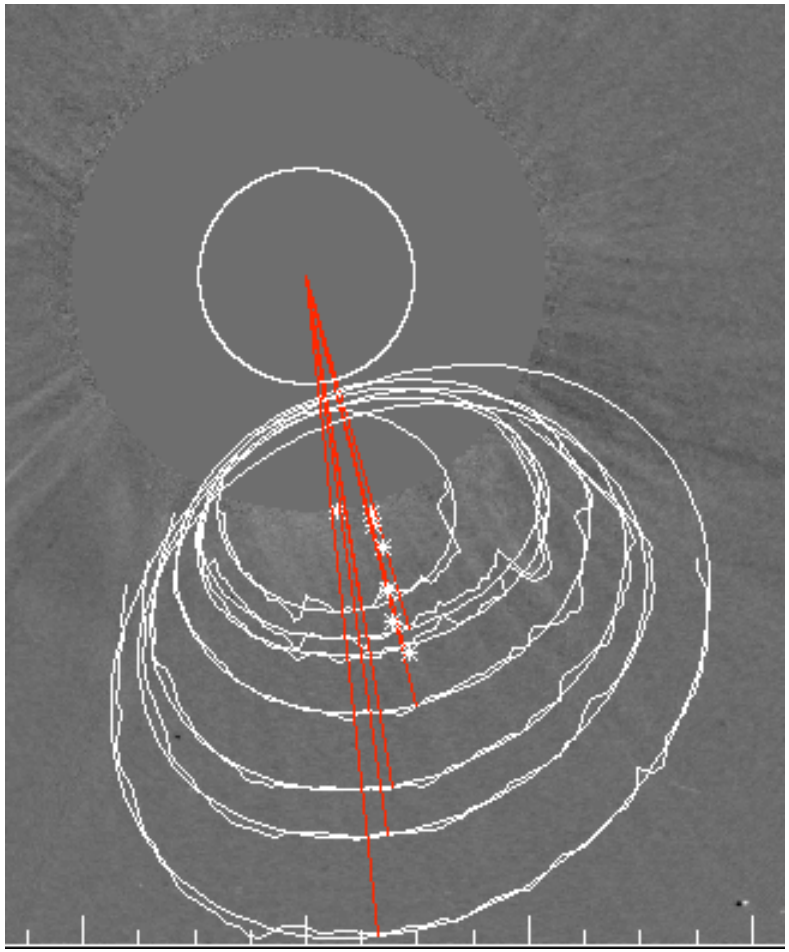
- Velocity profile

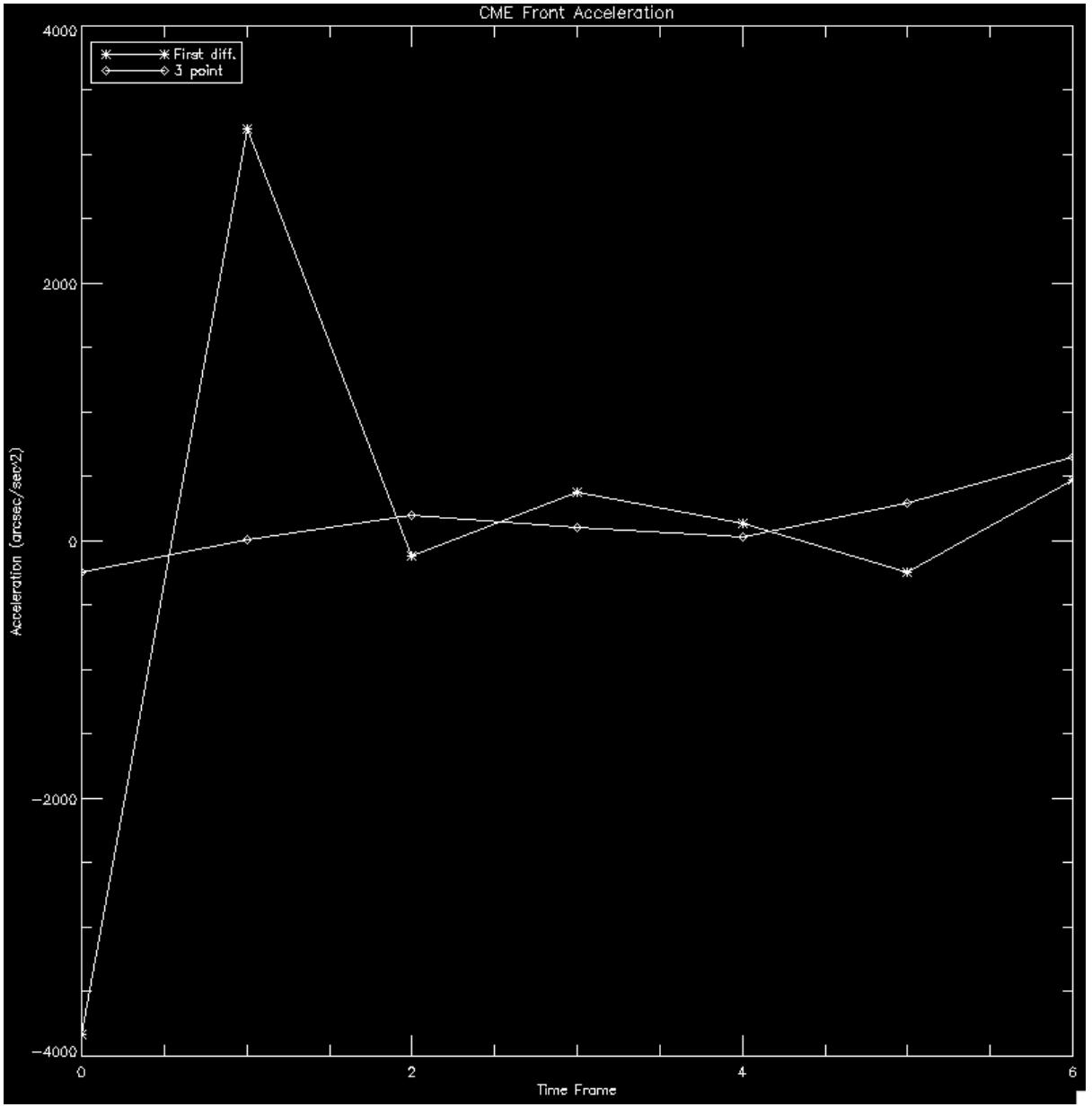




CME Kinematics

- Acceleration profile





Multiscale Analysis

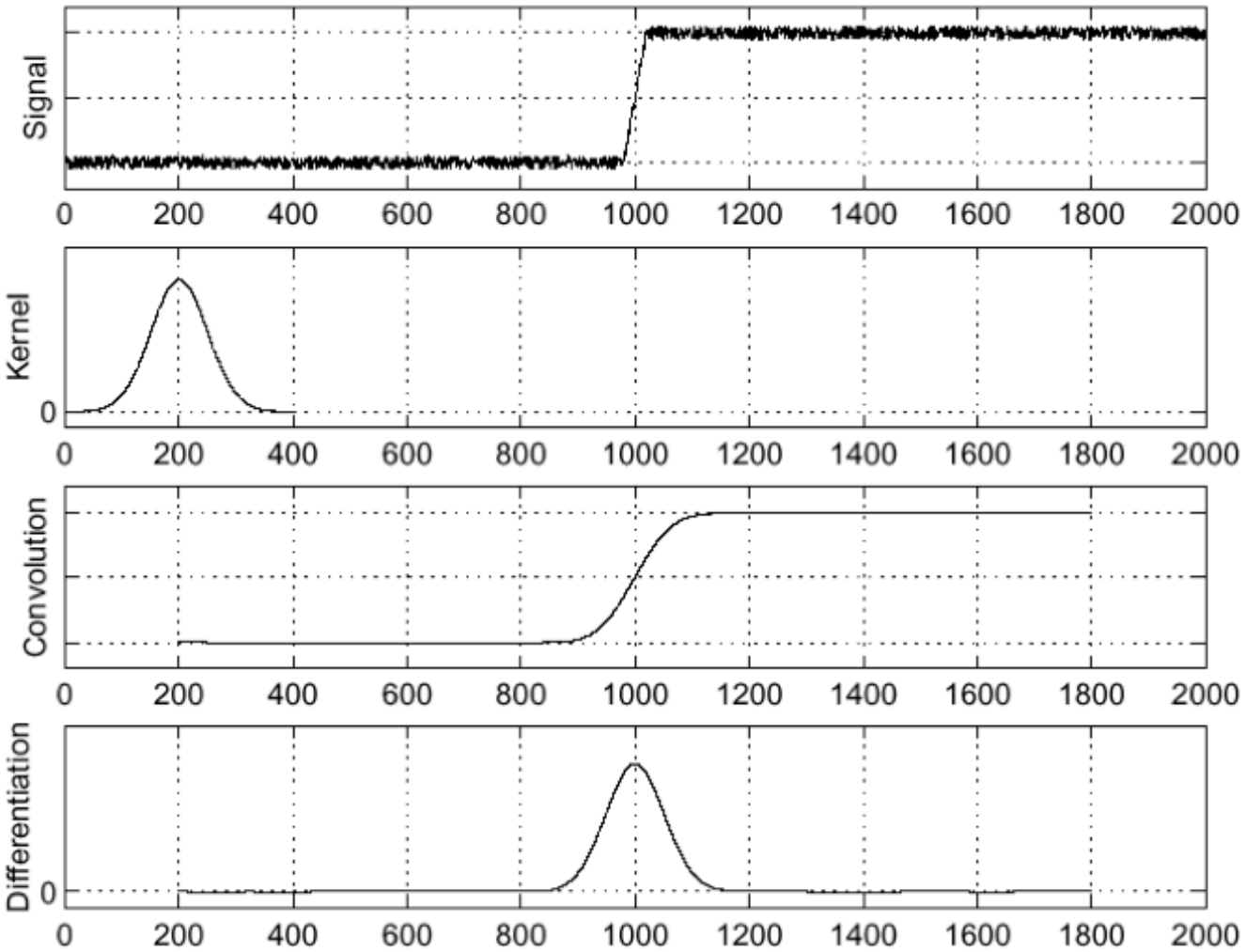
- Edge Detection:

f

h

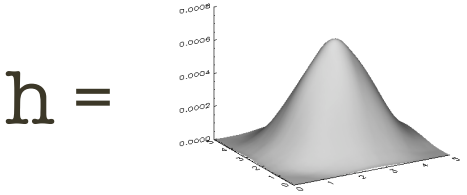
$h \star f$

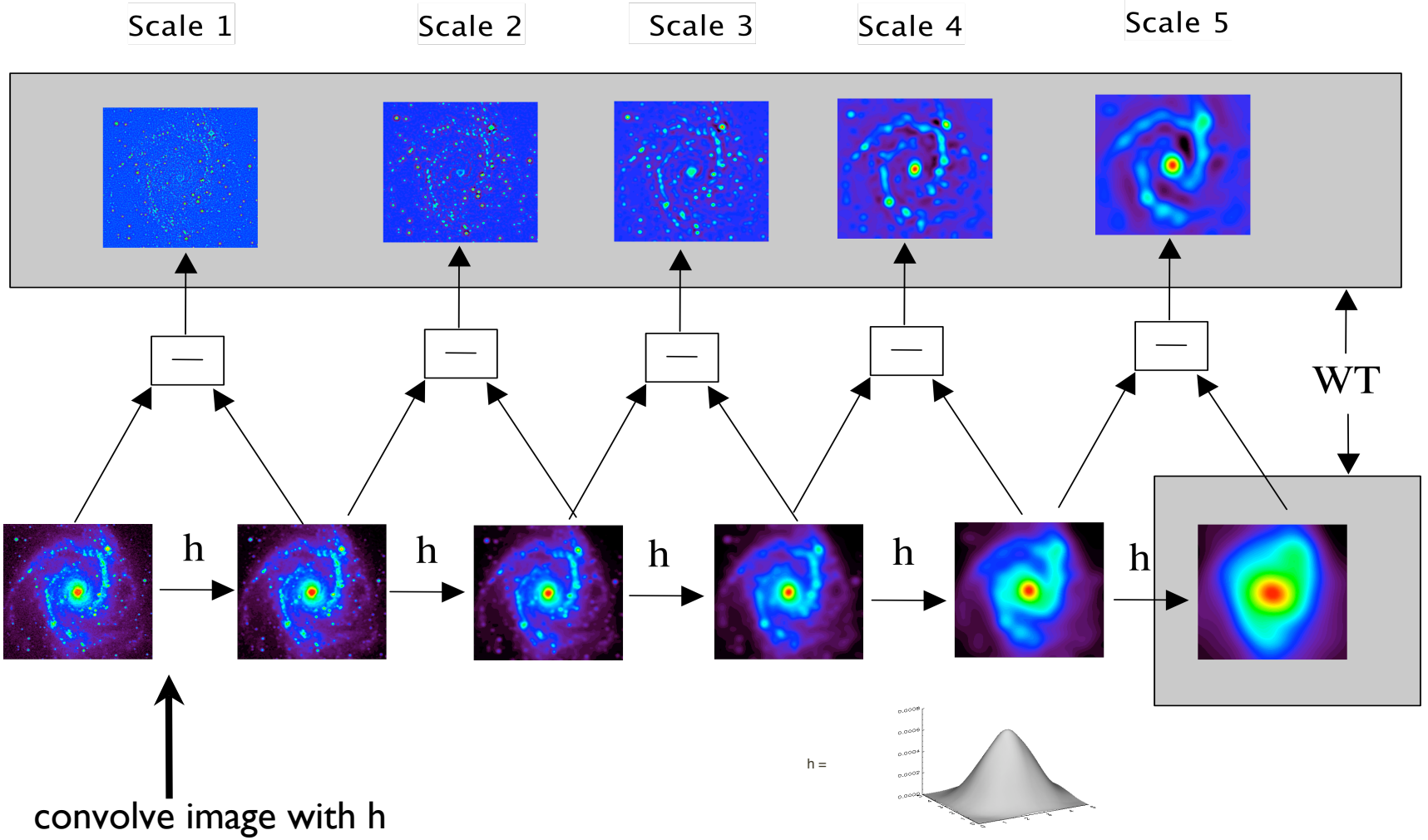
$\frac{\partial}{\partial x}(h \star f)$



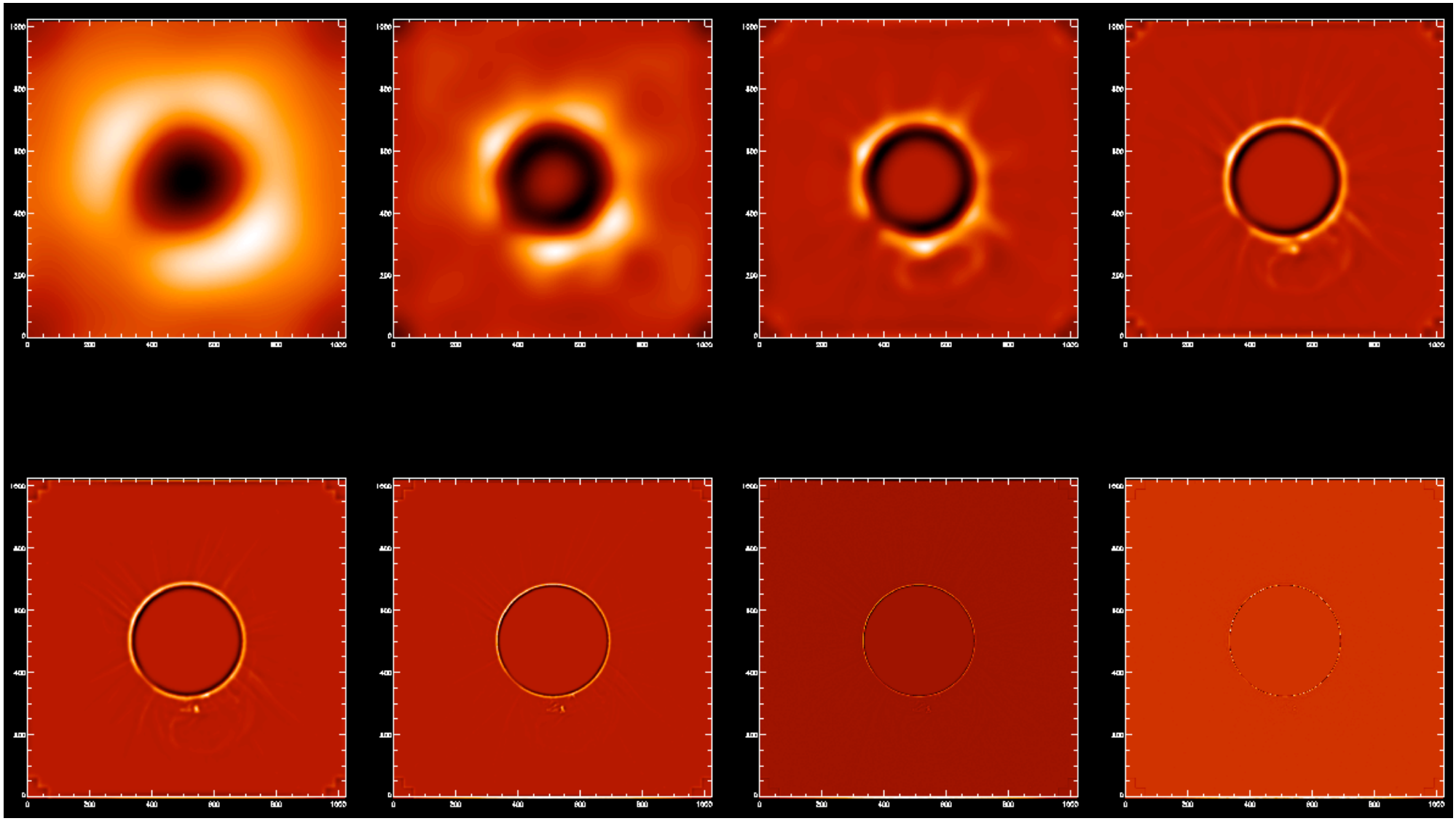
Multiscale Analysis

- ‘a trous’ wavelet

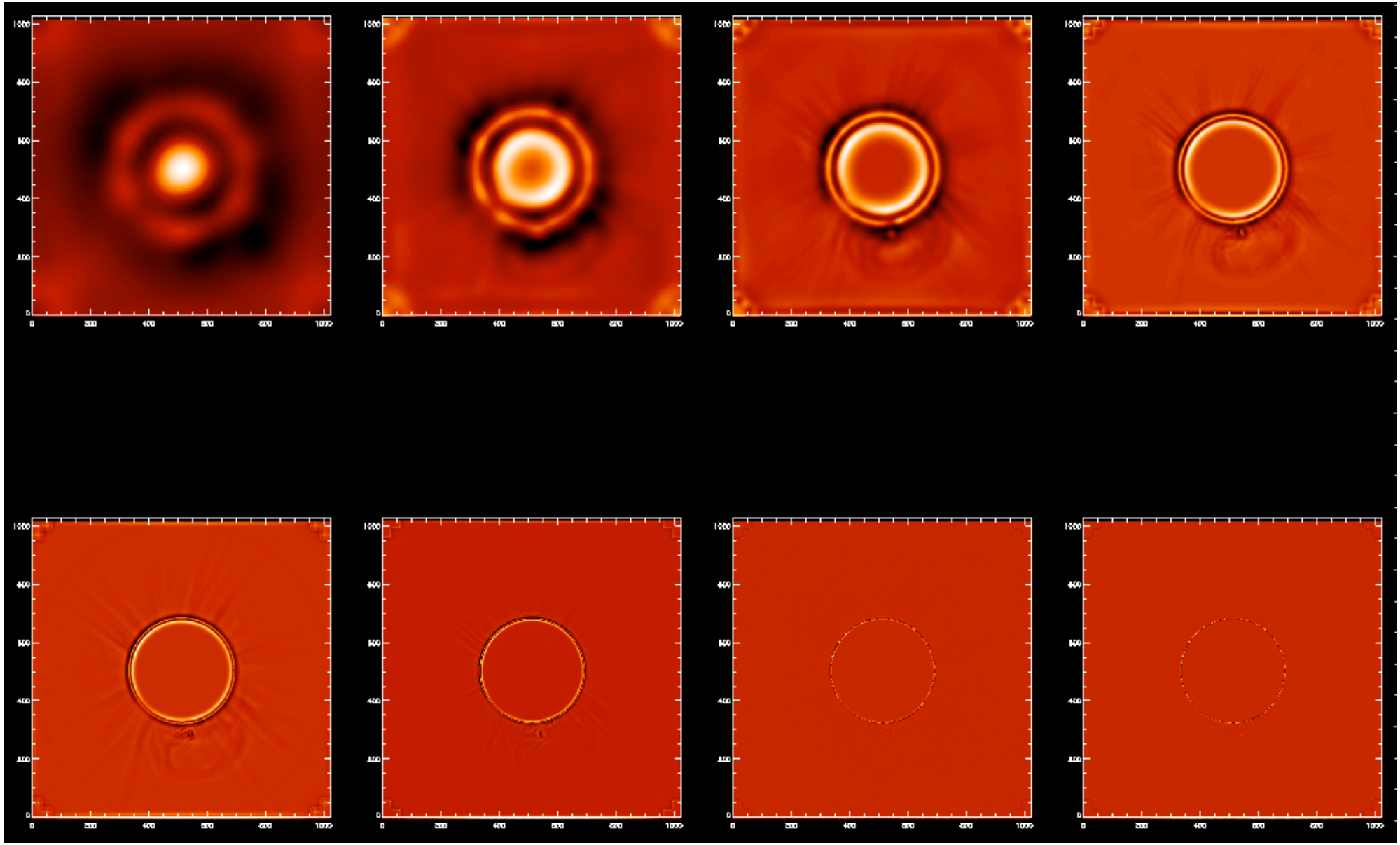




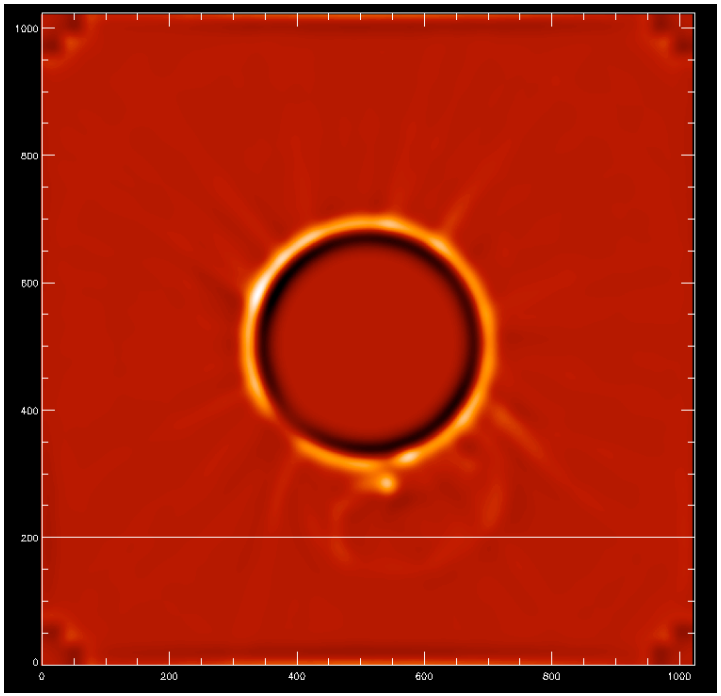
Multiscales of CME



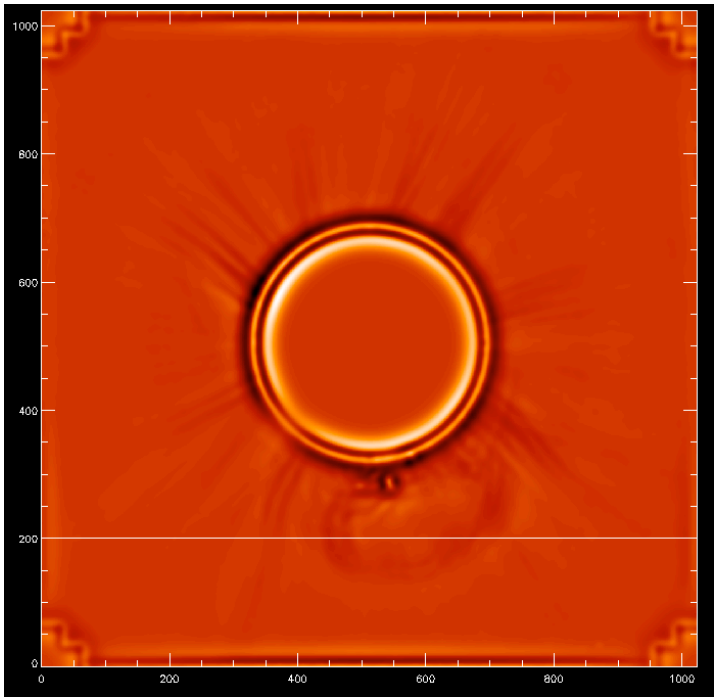
‘a trous’ wavelets

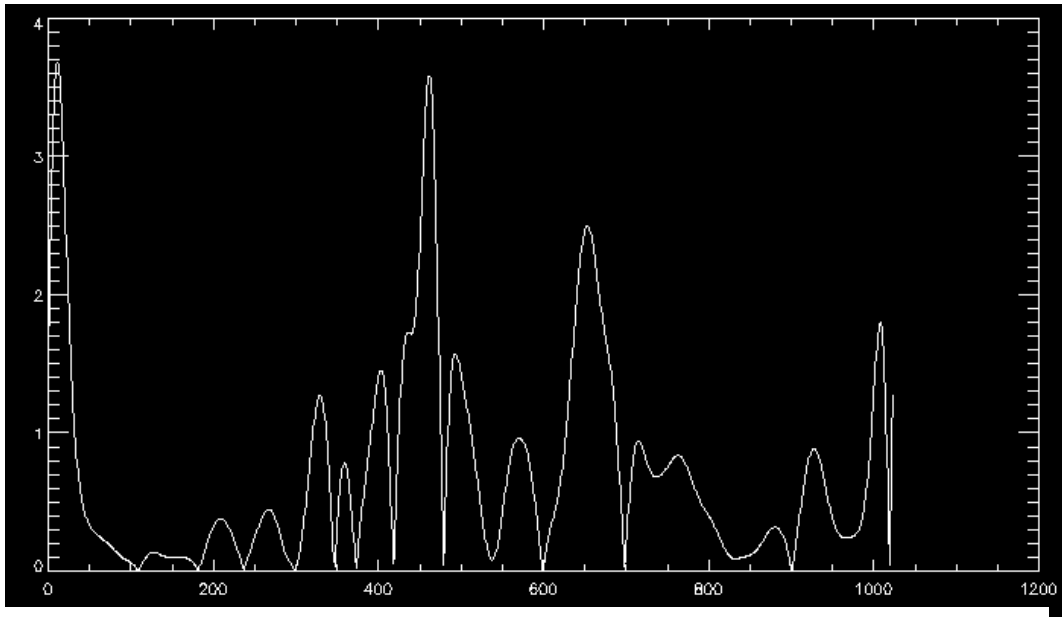


Scale 5



Scale 5-4





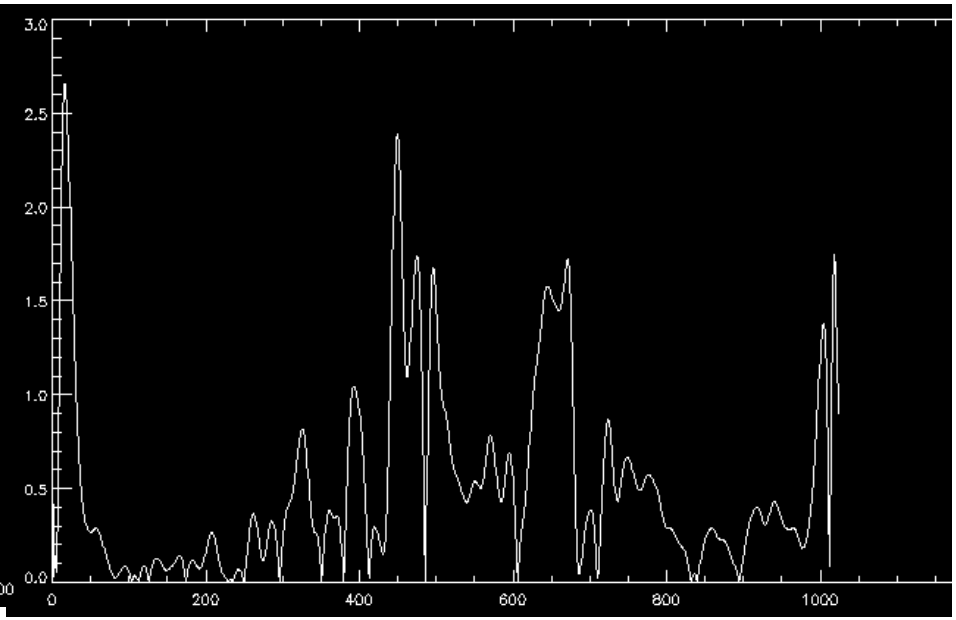
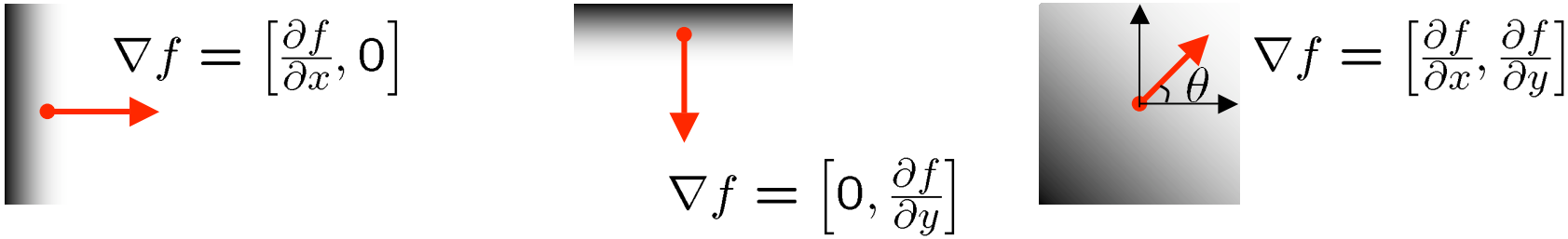


Image gradient

- 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?

…Max$\left| \frac{d}{dx}(f * \theta_s)(x) \right|$

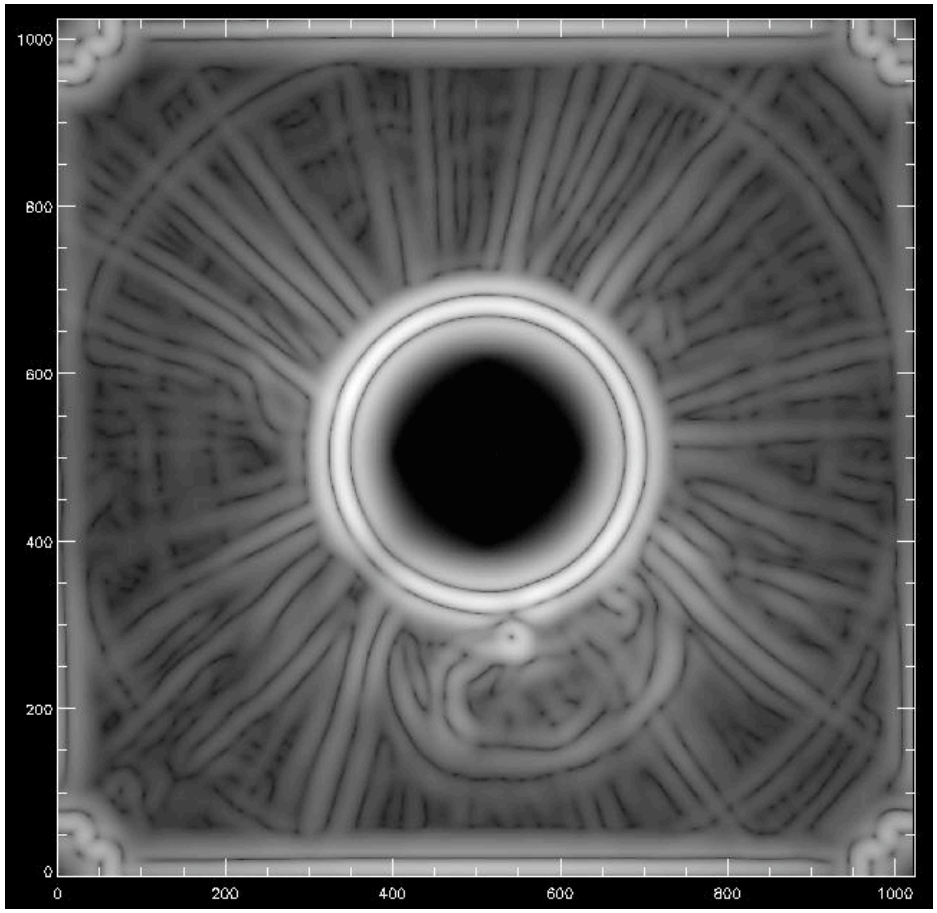
- Canny: $\begin{pmatrix} W_s^1 f(x,y) \\ W_s^2 f(x,y) \end{pmatrix} = s \begin{pmatrix} \frac{\partial}{\partial x}(f * \theta_s)(x,y) \\ \frac{\partial}{\partial y}(f * \theta_s)(x,y) \end{pmatrix} = s\nabla(f * \theta_s)(x,y).$

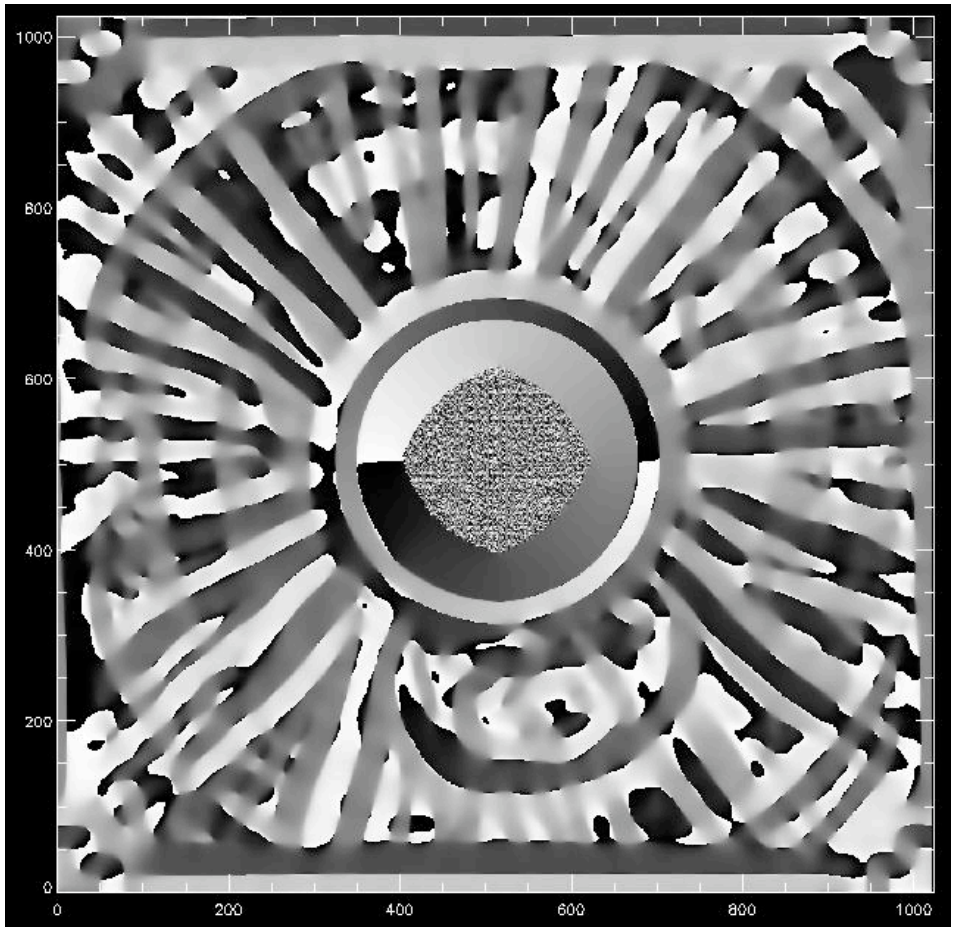
  => WTMM twice smoothed!

- a trous: $W_s^a f(x) = (f * \psi_s^a)(x) = s\frac{d}{dx}(f * \theta_s)(x)$

  => WTMM twice differentiated!

‘a trous’ image gradient





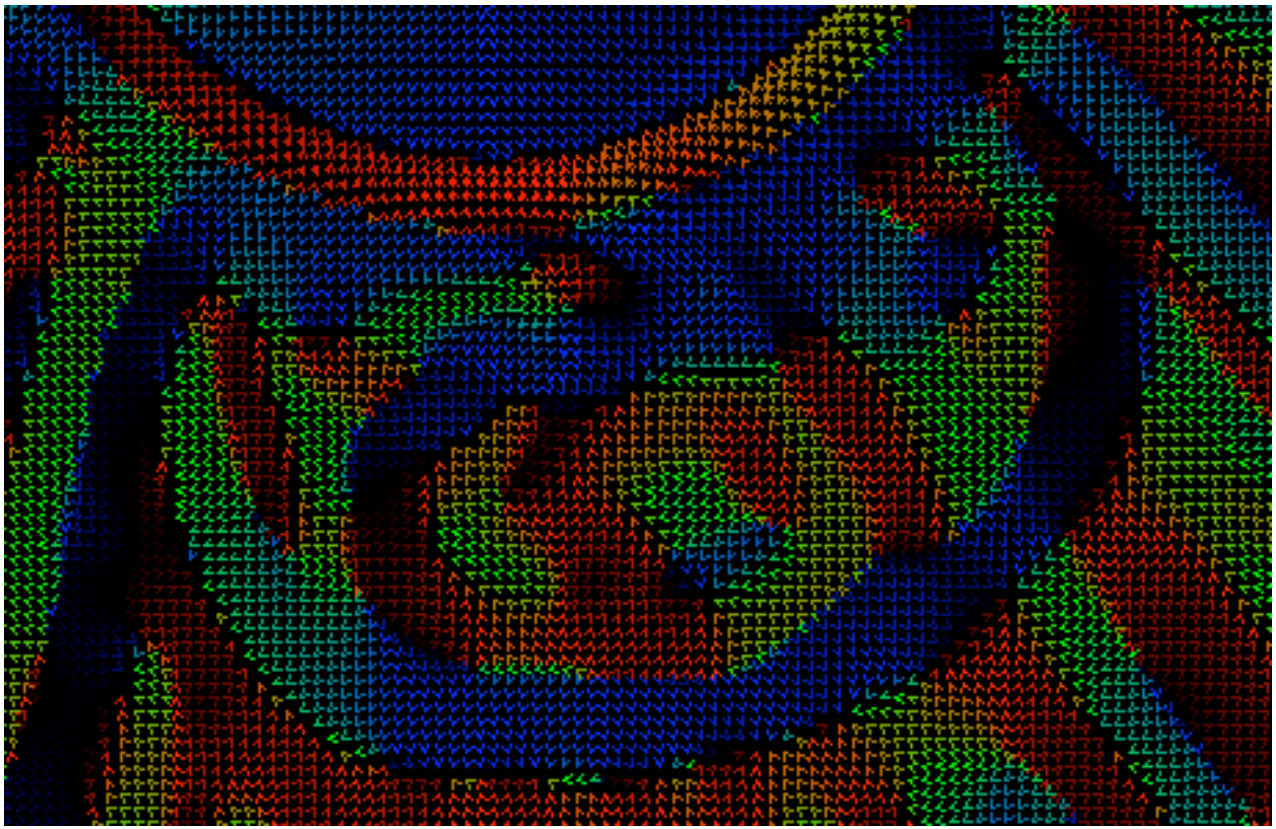
$$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$$

$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$

Next Steps…

- Front only

-further wavelet analysis



- More data + C3

- STEREO

STEREO: Early / Initial Analysis