The Automatic Detection and Tracking of Interplanetary Coronal Mass Ejections (ICMEs)

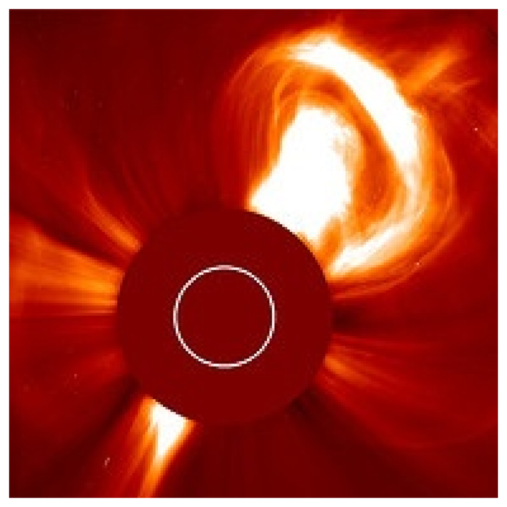
Robin N. Thompson

Supervisor: Dr T.A. Howard[1]

[1]Southwest Research Institute, 1050 Walnut St, Boulder, CO 80302, USA

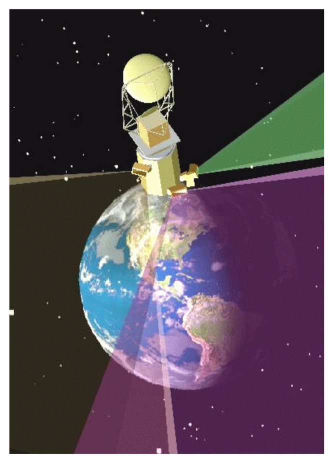
Introduction

Motivation:



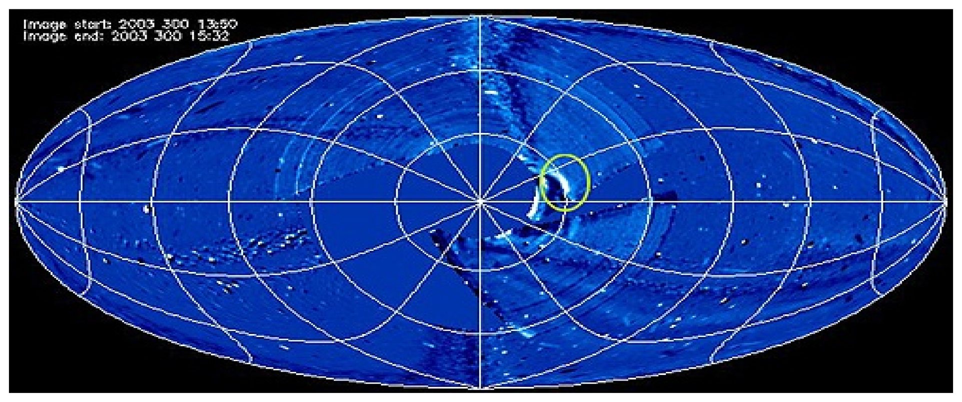
- A **CME** is an eruption of **plasma** and **magnetic field** from the sun, travelling roughly radially outwards.
- Upon impact with the Earth, CMEs can be responsible for **severe space weather effects**. In particular, they can disrupt telecommunication facilities and spacecraft. As we develop more sensitive electronics here on Earth, an ability to predict both the arrival times of CMEs at Earth and their affects is of great importance.

Where my images come from:

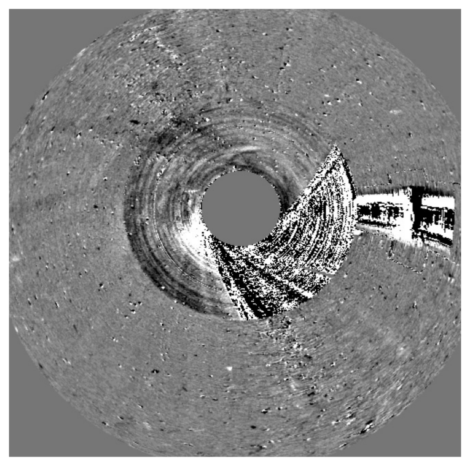


- Onboard Coriolis, the Solar Mass Ejection Imager (SMEI) captures an image of (almost) the entire sky every 101 minute orbit. We can project this image into 2-d.

Types of projection:



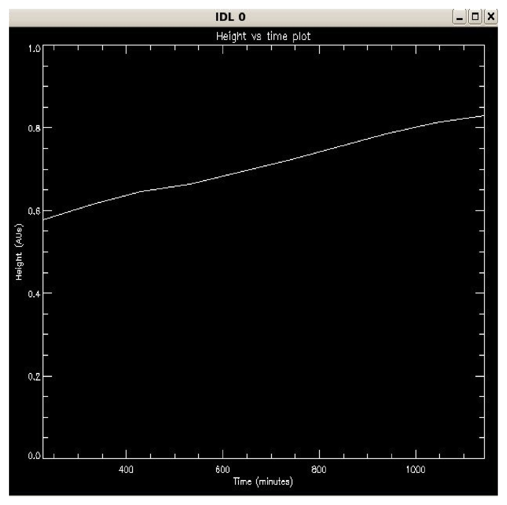
- Hammer-Aitoff: The third gridline out from the centre represents the plane of the observer. The far left and right of the image are directly behind the observer.



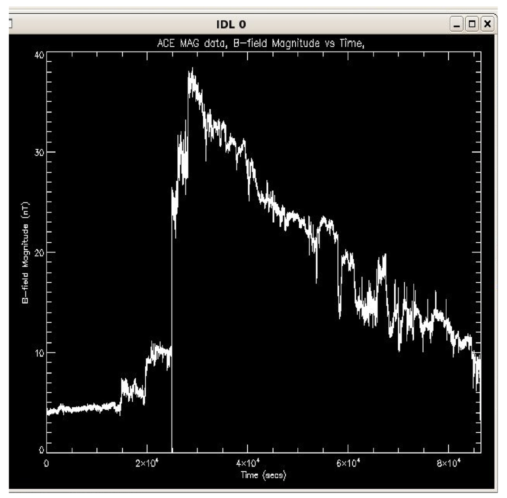
- 'Fisheye': The image is projected such that the locus of points at a given elongation angle from the sun forms a perfect circle in the projection. As in the other images, the sun is blocked out in the centre.

Problems

Initial Predictions:



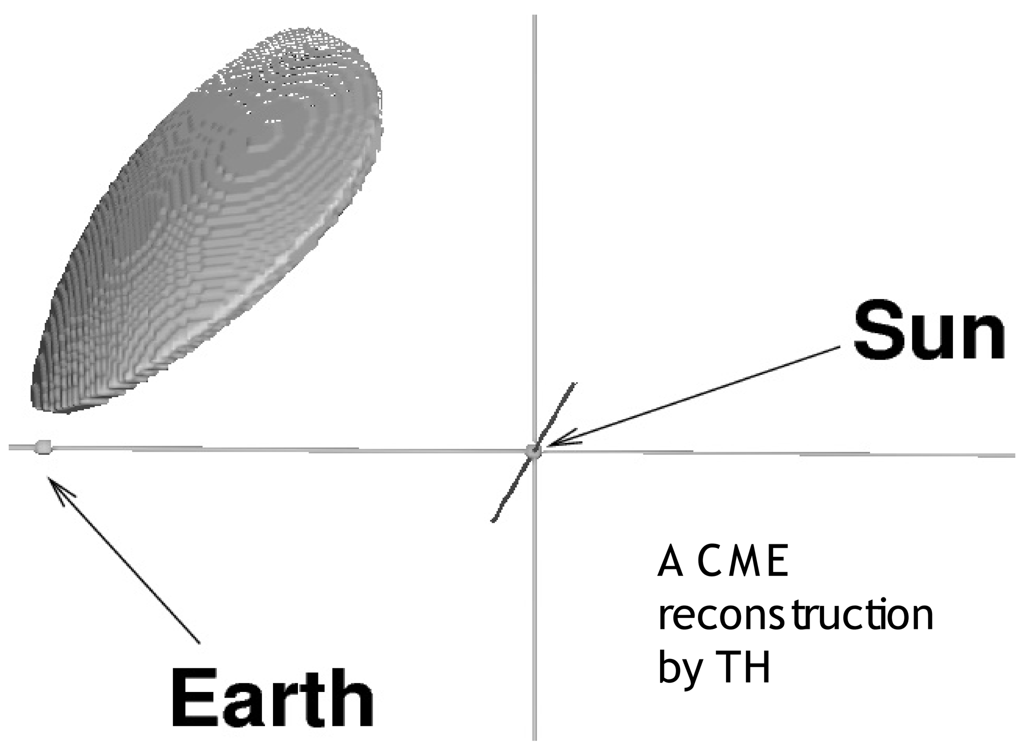
- Predicting (by hand) the arrival of the December 2nd 2004 CME at Earth (assuming constant speed)
- **Prediction:** 4th December 2004, 4am



- Looking at magnetic field data from the ACE magnetometer tells us the actual arrival time.
- **Actual time:** 5th December 2004, 7am
- **Difference:** 27 hours – in total the CME took just 55 hours to reach the Earth.
- Measure the CME leading edge by hand takes **time** (and deciding whether it really is a CME is **subjective**).

Solutions

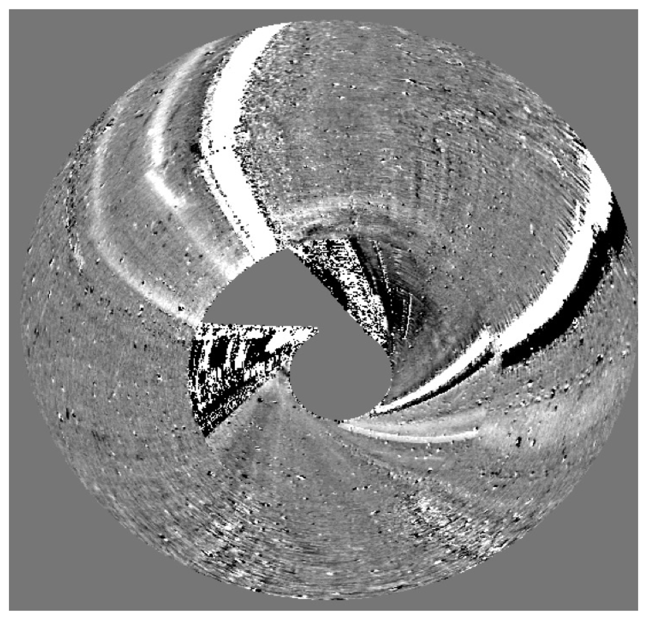
- Instead of assuming the CME travels at a constant speed, use the **Tappin-Howard (TH) model** (Tappin and Howard, 2009).
- **Automate** the picking out of the leading edge of CMEs from SMEI image data.

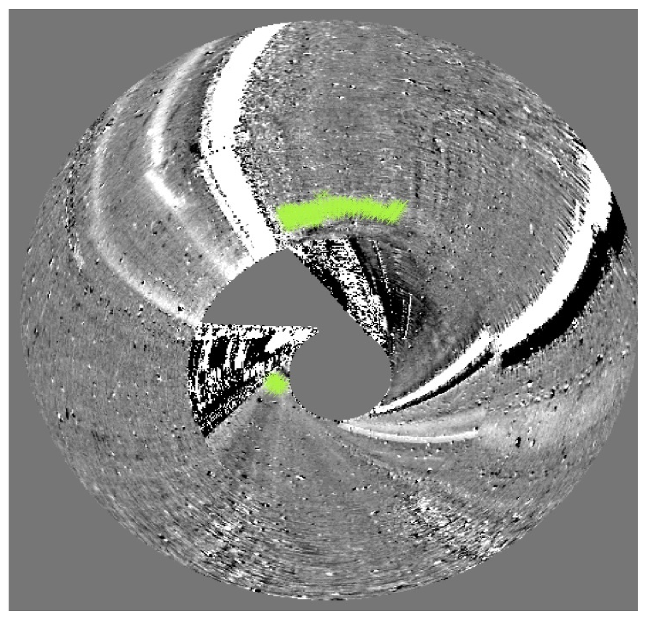


A CME reconstruction by TH

Automatic CME Detection

Raw SMEI image (May 2003)

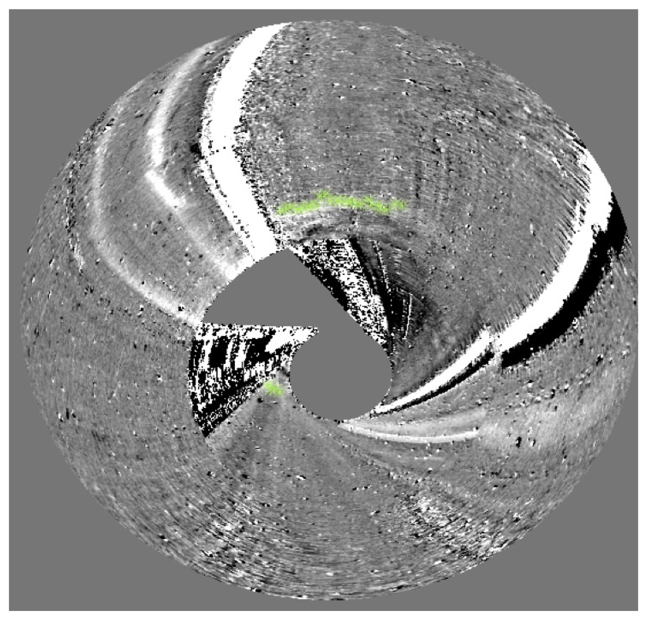


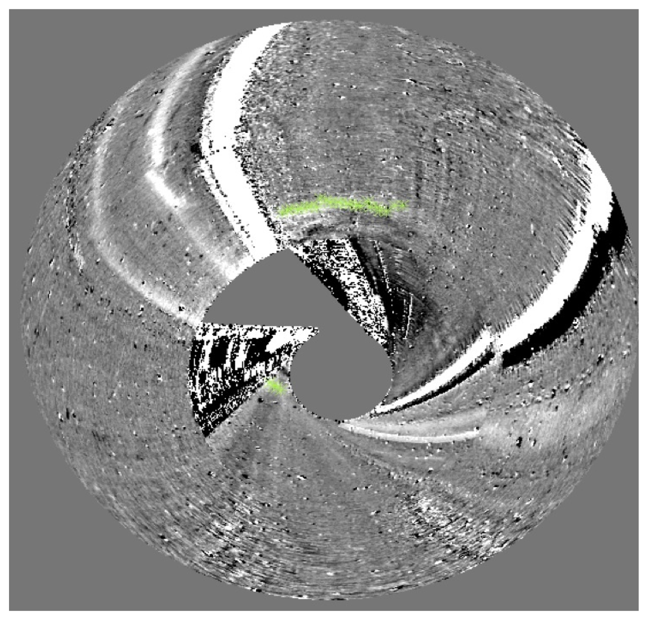


Plot of **entire CME** by AiCMEDs CME detection program (Max Hampson[2], adapted by Robin Thompson)

Which leading edge detection method?

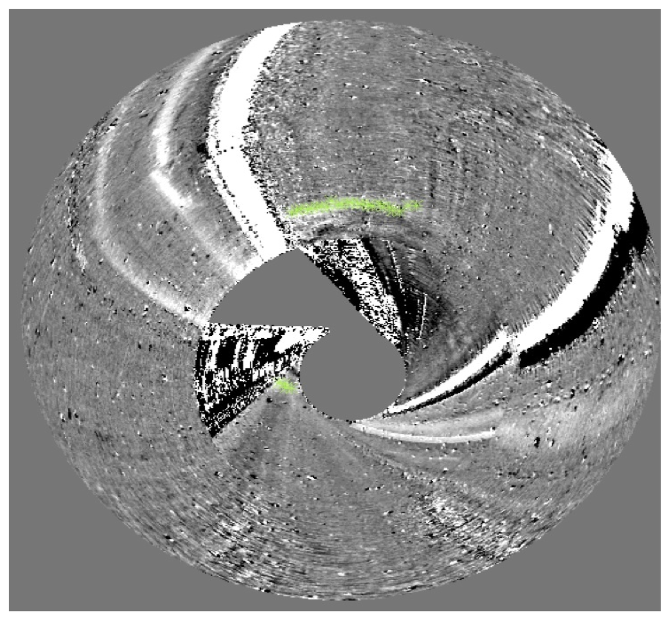
Plot of **extreme leading edge of CME** (outermost point at each P.A.)





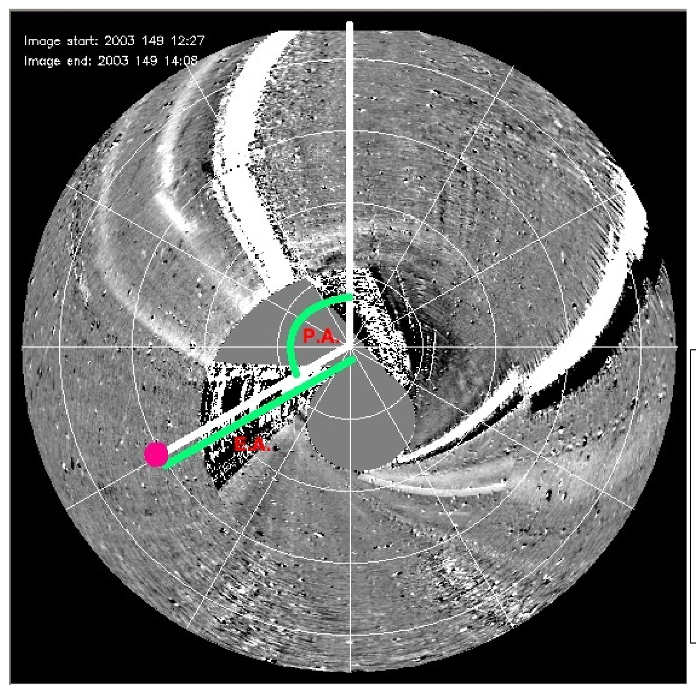
Mean plot (mean of outermost two points at each P.A.)

Median plot (median of outermost three points at each P.A.)



Co-ordinate Systems

Standard 'Fisheye' Co-ordinates



(E.A. , P.A.) corresponding to (r,θ) in polar co-ordinates.

E.A. -elongation angle- the angle between the sun-observer line and the CME-observer line

P.A. - position angle

To plot, use pixel co-ordinates (x,y)

Split into quadrants

Convert P.A.s into radians

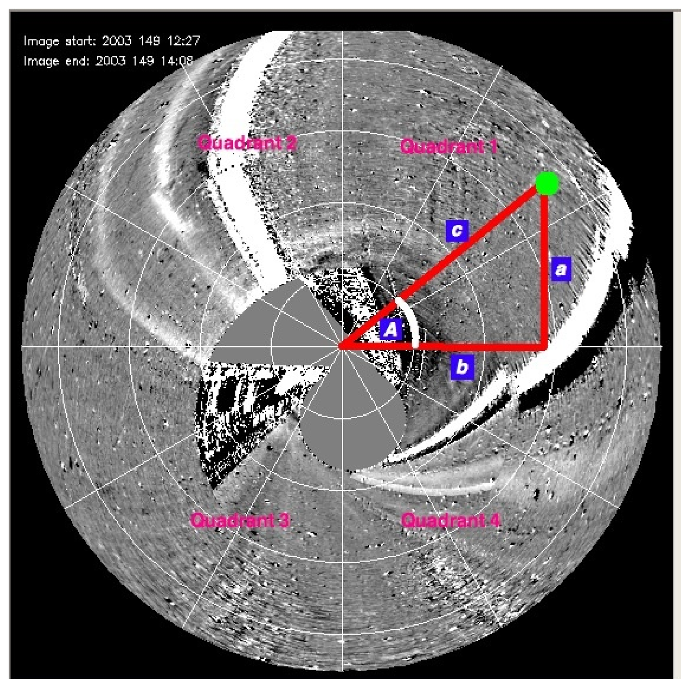
Note 1 degree elongation = 2 pixels, c = 2*E.A.

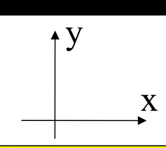
Use trig, e.g. in quadrant 1:

A = P.A. - 3*Pi/2

x= 280 + c*cos(A)

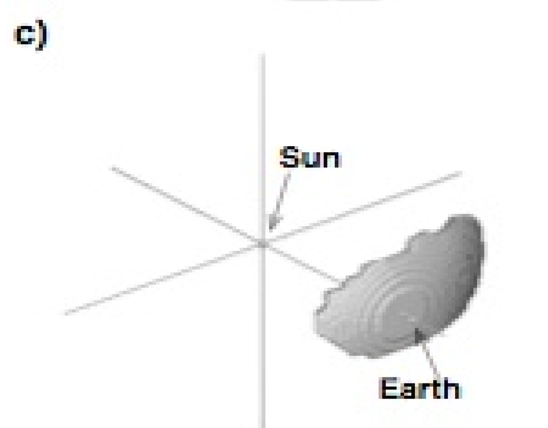
y= 280 + c*sin(A)



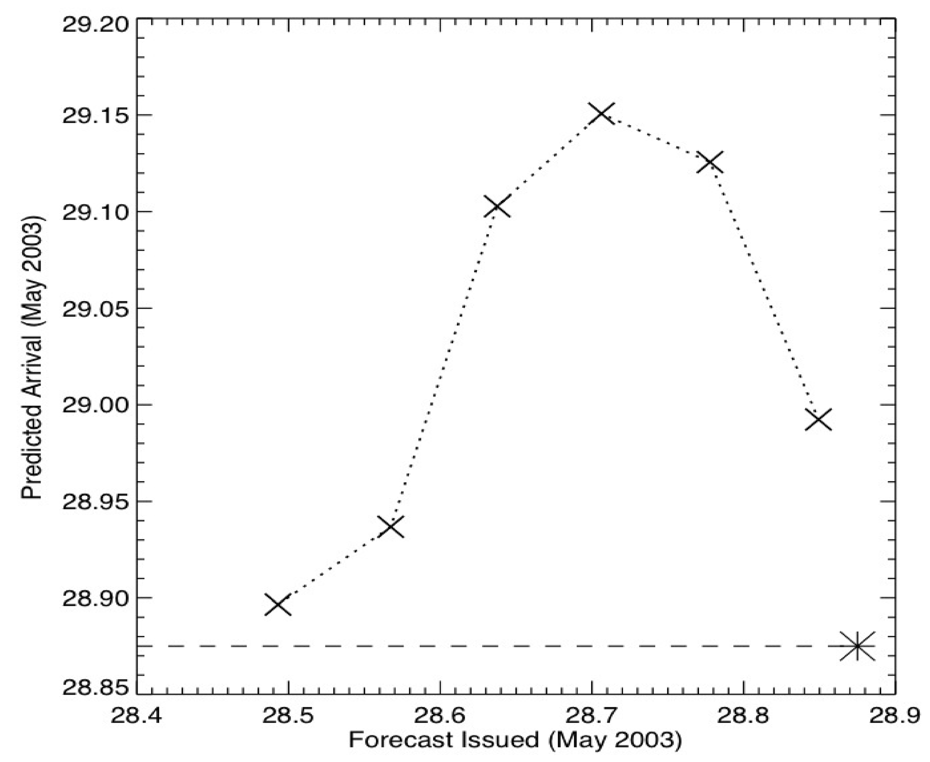


$x,y \in [0,560]$

Feed Leading Edges into TH



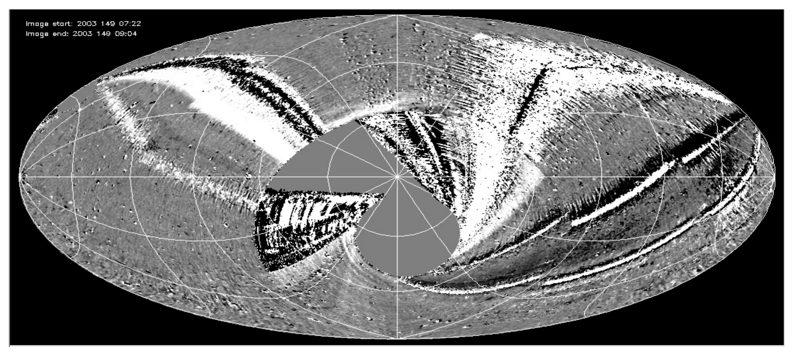
3-d reconstruction of CME leading edge by Tappin-Howard model



Prediction of arrival of CME at Earth by TH model

This is me. If I'm not standing here then please come and find me at any time! Or email me at: robin.thompson@worc.ox.ac.uk

HOW MANY CMES CAN YOU SEE IN THIS HAMMER-AITOFF PROJECTION?



[2]**Acknowledgements:**

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