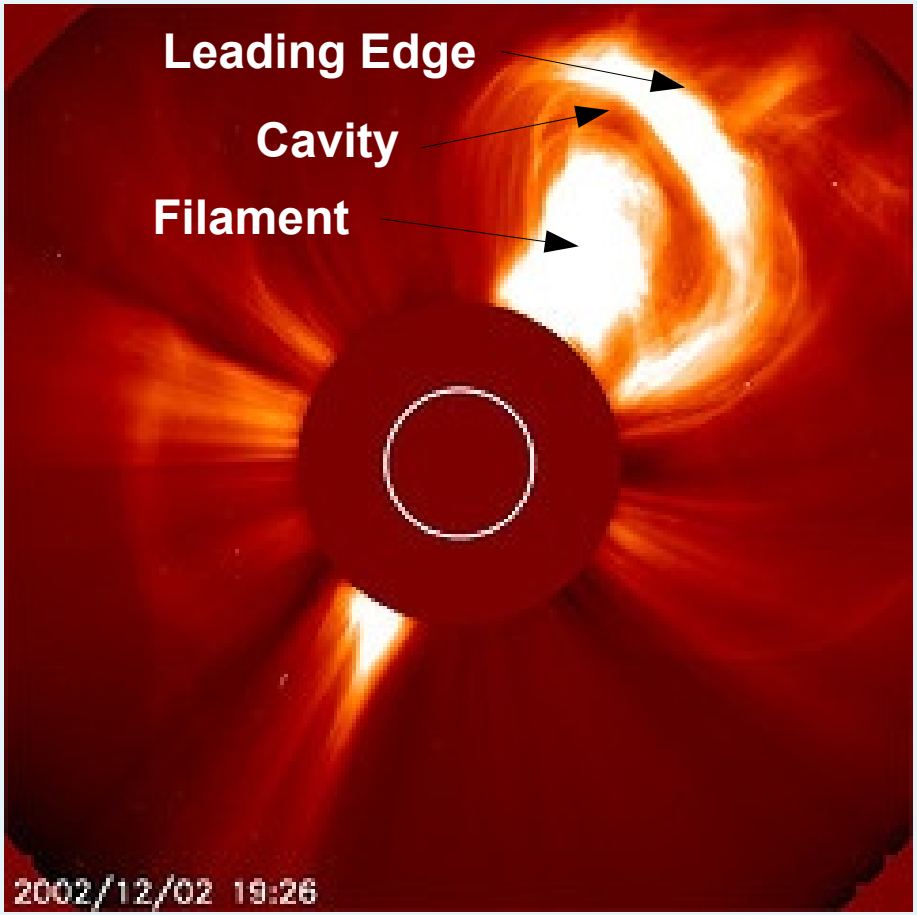
The Automatic Detection and Tracking of Interplanetary Coronal Mass Ejections (ICMEs)

By Robin Thompson

Supervised by Dr Tim Howard, SwRI

What is a CME?

- An eruption of plasma and magnetic field from the sun, travelling roughly radially outward.
- Typical mass 10^{12} kg, typical speed 500-1000 km/s.



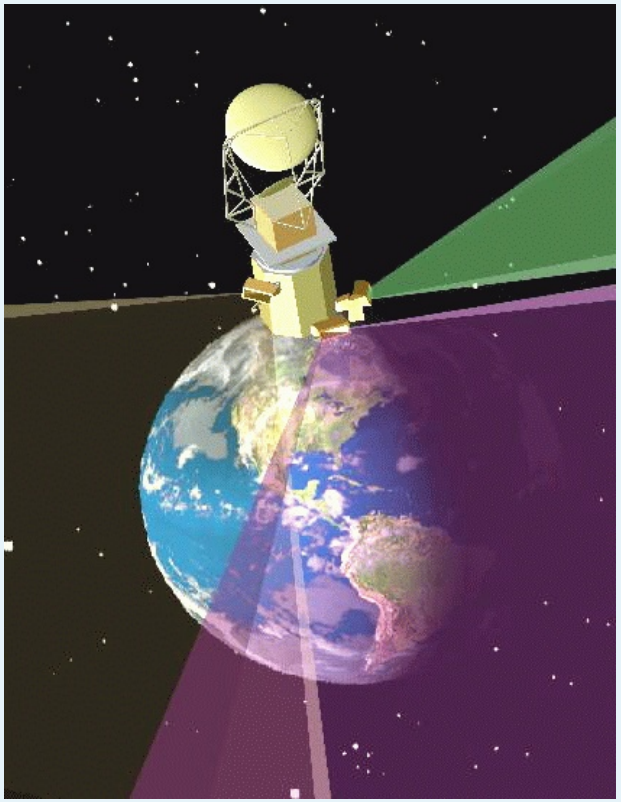
WHY BOTHER?

Upon impact with Earth, interplanetary coronal mass ejections (ICMEs) can be responsible for severe space weather effects, e.g.

- **Aurora enhancement**
- **Disruption of telecommunications facilities, power grids and spacecraft**

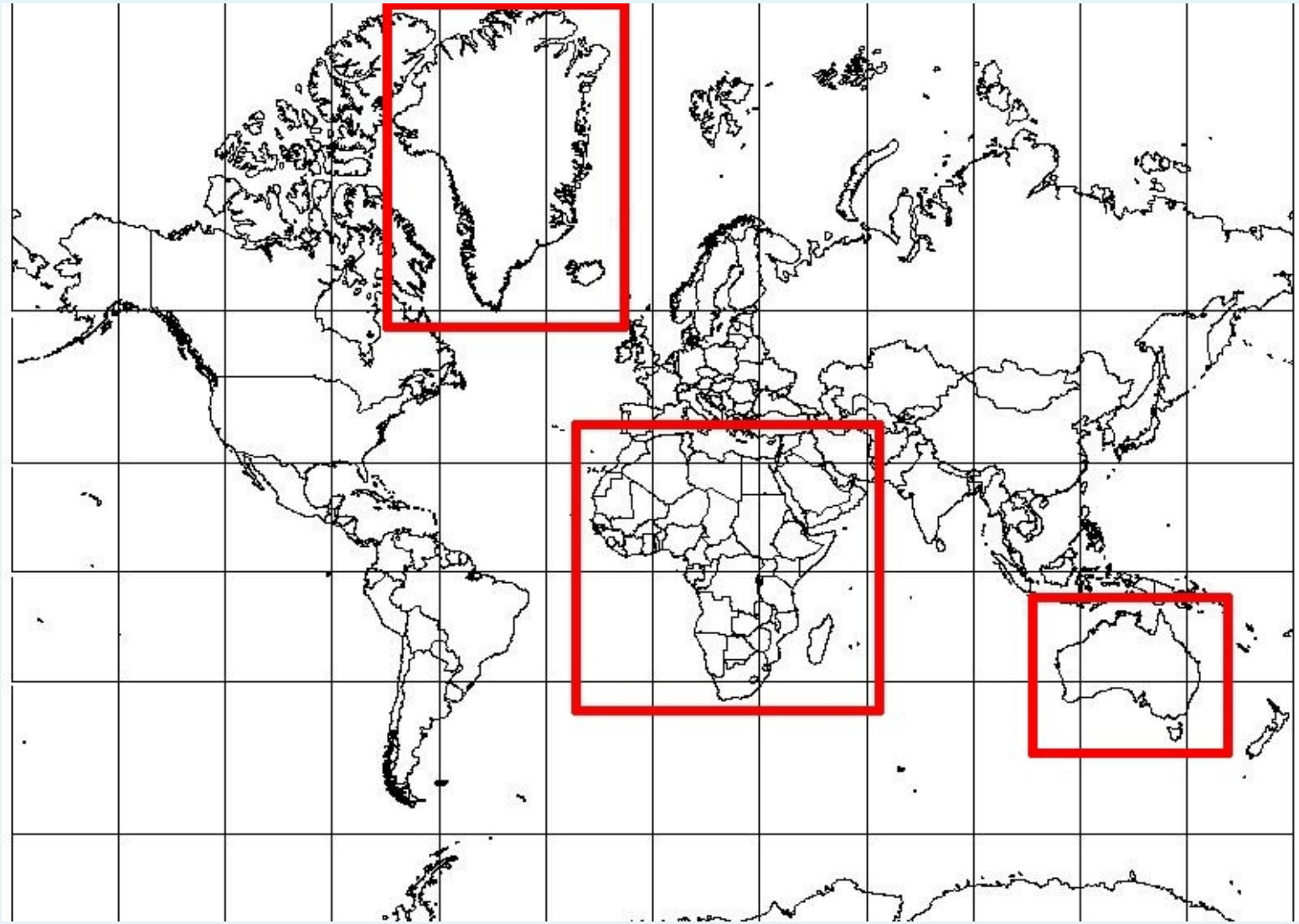
The development of more sensitive electronics means we now need greater understanding of CMEs, including predicting both their arrival and the consequences of their impact with Earth.

SMEI (Solar Mass Ejection Imager)



- Onboard Coriolis spacecraft
- 3 cameras, each with 60° FOV
- Every 101 minute orbit we get image of (almost) whole sky
- Can produce a 'Fisheye' or a Hammer-Aitoff projection to show a pieced-together view of the entire sky

Problems with projections...



BUT how big are these places really...?

Resolved Question

Show me another »

How big is the continent of Africa?

xinnybux...

4 years ago

Report Abuse

Best Answer - Chosen by Voters

its pretty big and it is the 3.r 4th largest continent

Source(s):

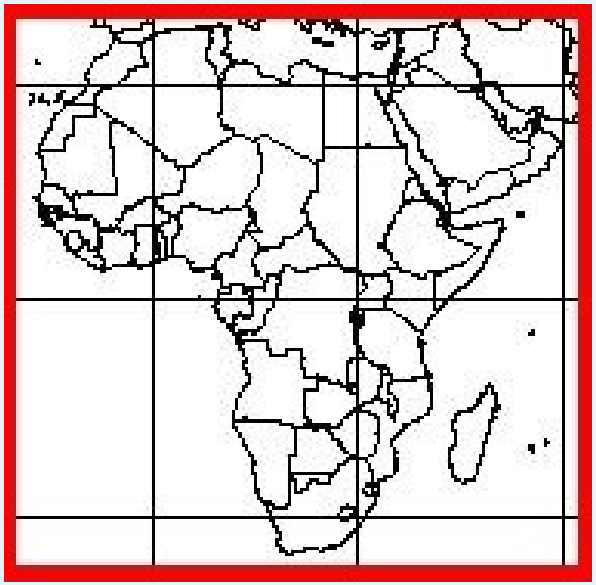
me

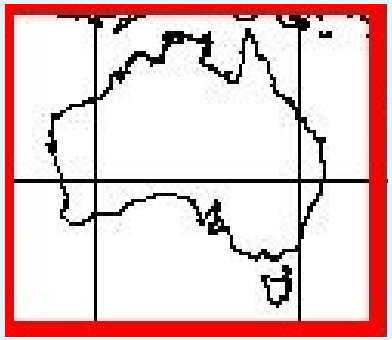
michelle...

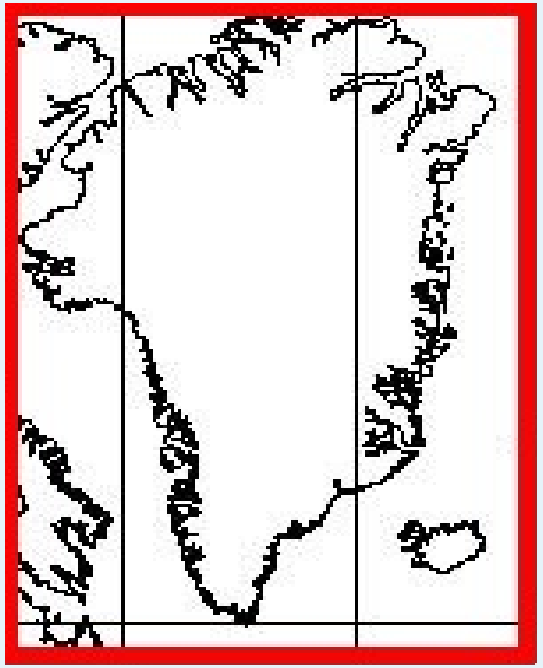
4 years ago

100% 1 Vote

Report Abuse







Africa:

- Lat. ~ 30°S – 30°N
- 30,065,000 km^2

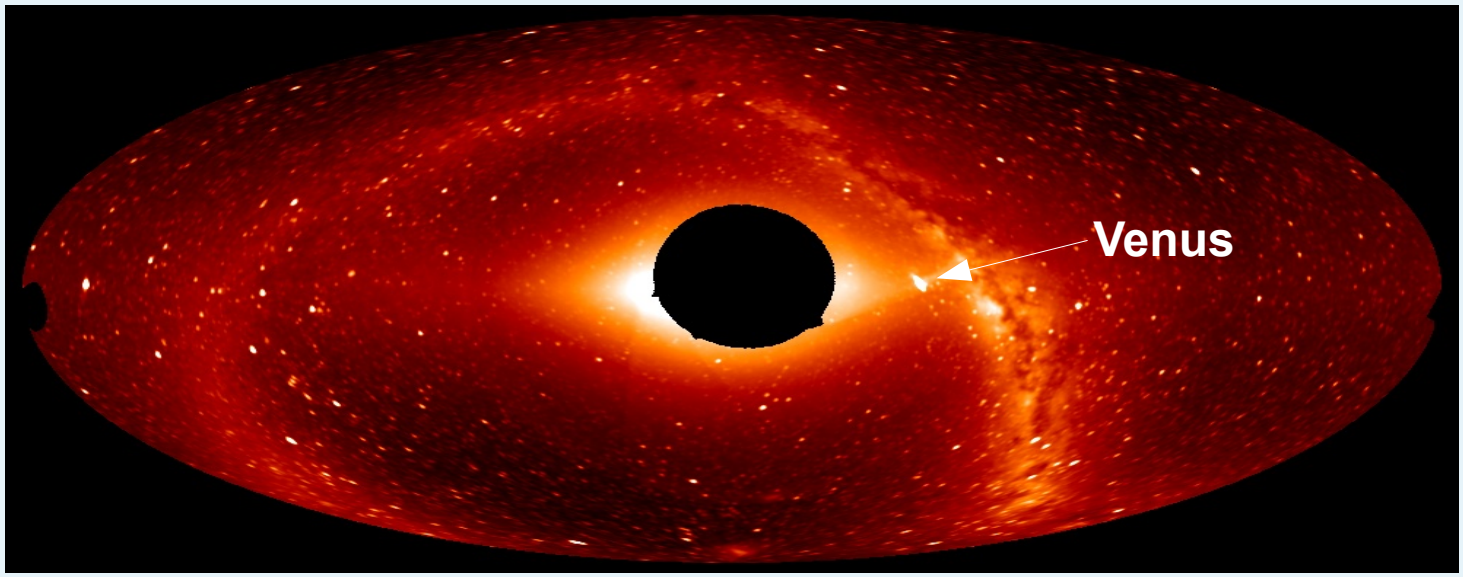
Australia:

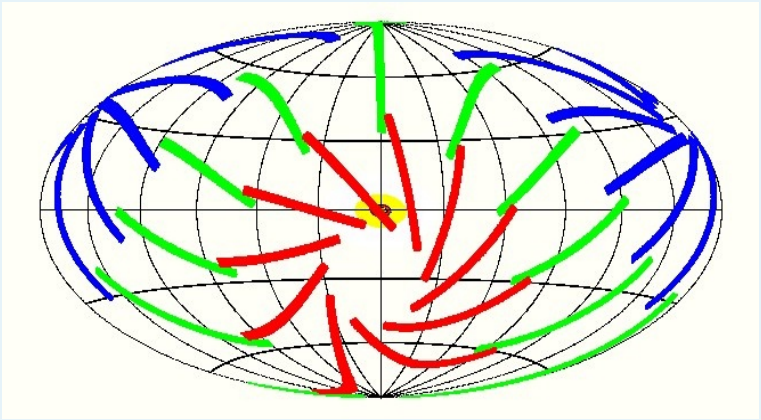
- Lat. ~ 30°S
- 7,686,850 km^2

Greenland:

- Lat. ~ 70°N
- 2,166,086 km^2

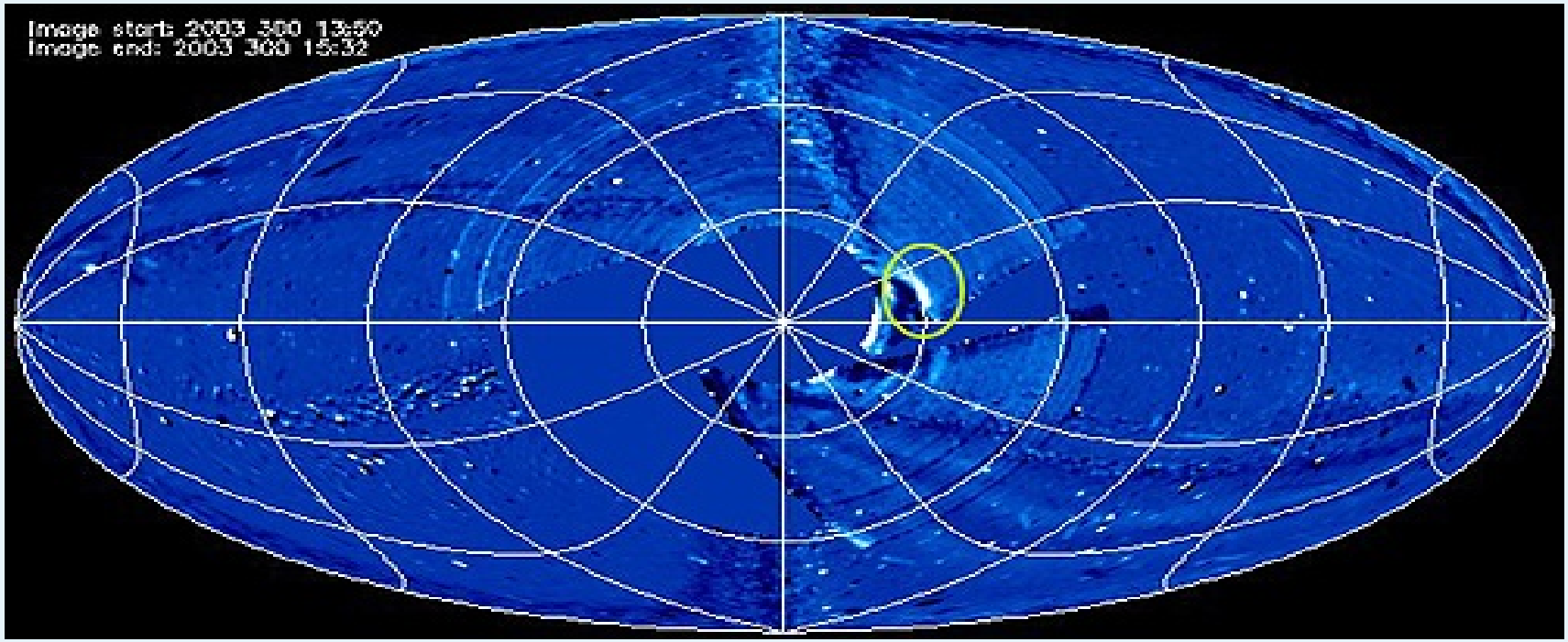
SMEI Composite all sky image (Hammer-Aitoff Projection, March 2003)





Sky mapped out by:
Blue- Camera 1
Green- Camera 2
Red- Camera 3

October 2003 Image



- CME in yellow circle

- The darkened areas at centre and to the left are where SMEI does not take data because the Sun and Moon are in this area.

- The grid overlay indicates 60-degree increments in the field of view. When the CME extends to the third ring - 180 degrees - it has reached the plane of the Earth. The far left and right points correspond with the anti-Sun direction into deep space.

- If we look at lots of these images over time, we can see CMEs move.
- We can subtract any constant/slow-moving known sources of light (e.g. stars/planets) from our images.

LET'S PLAY... Spot the CME

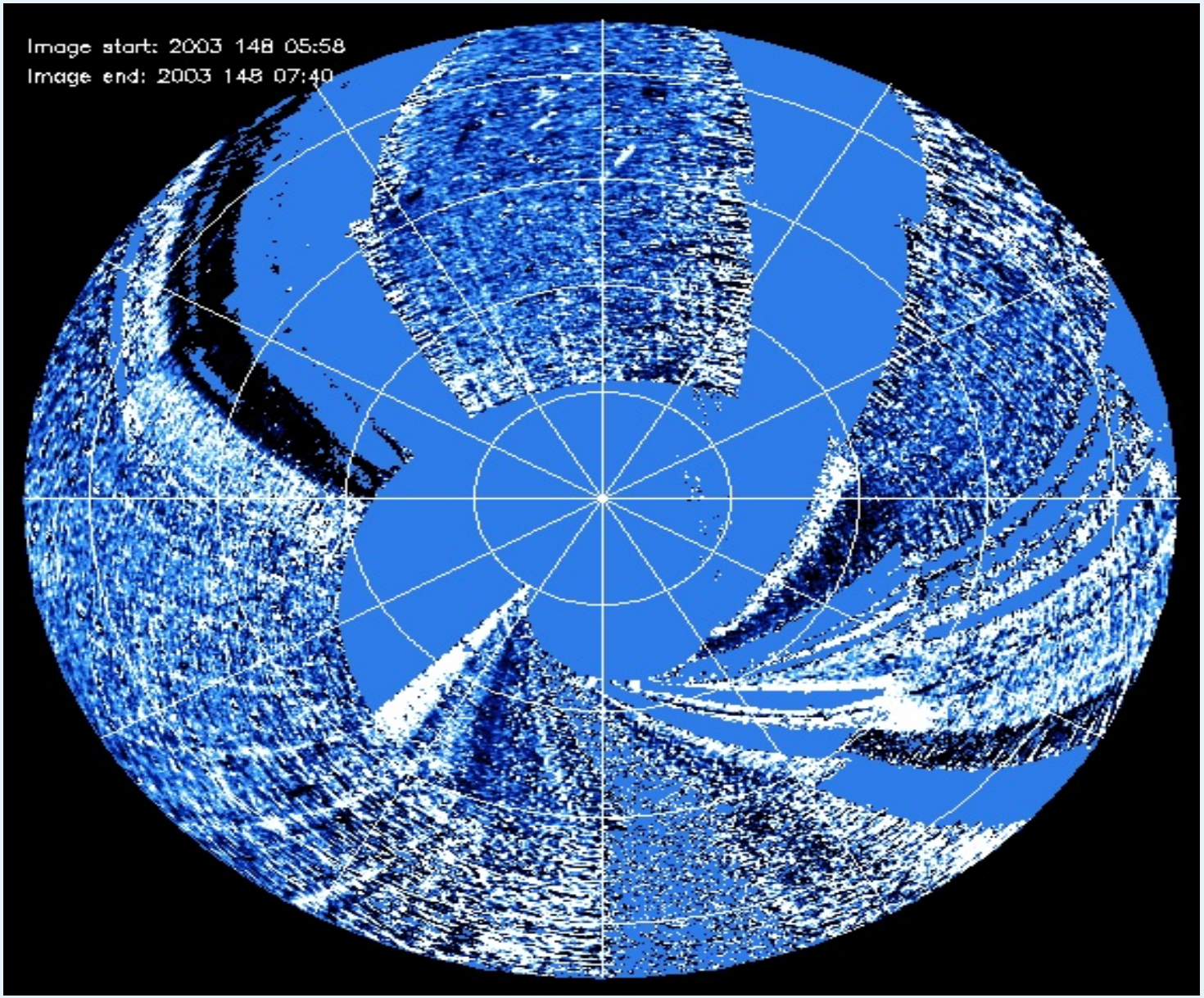
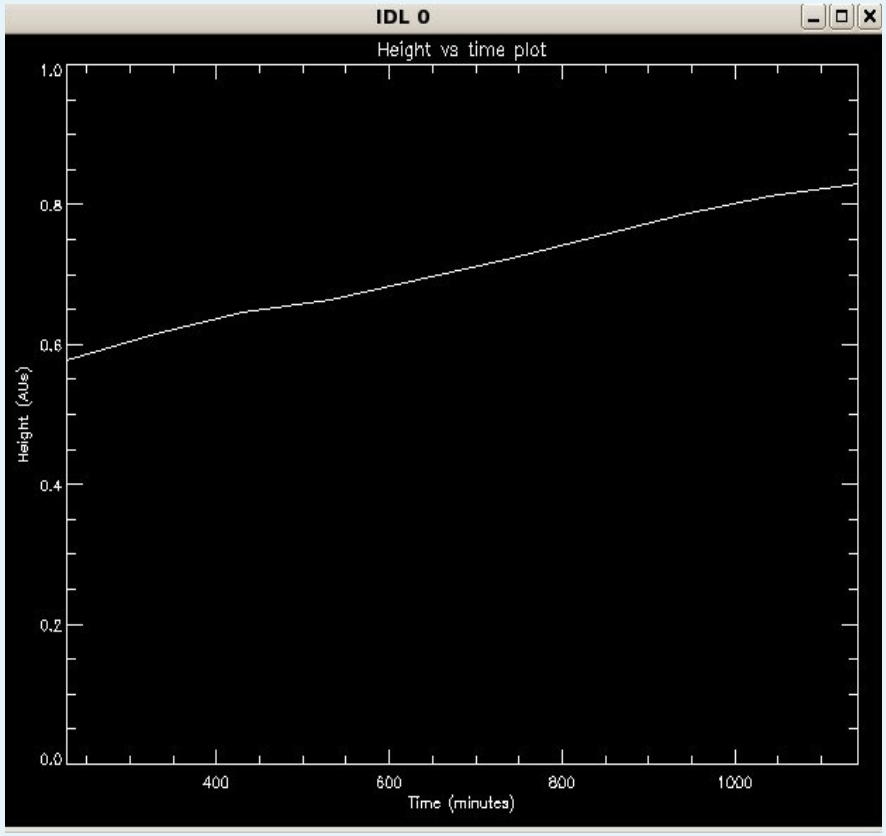


Image start: 2003 148 05:58
Image end: 2003 148 07:40

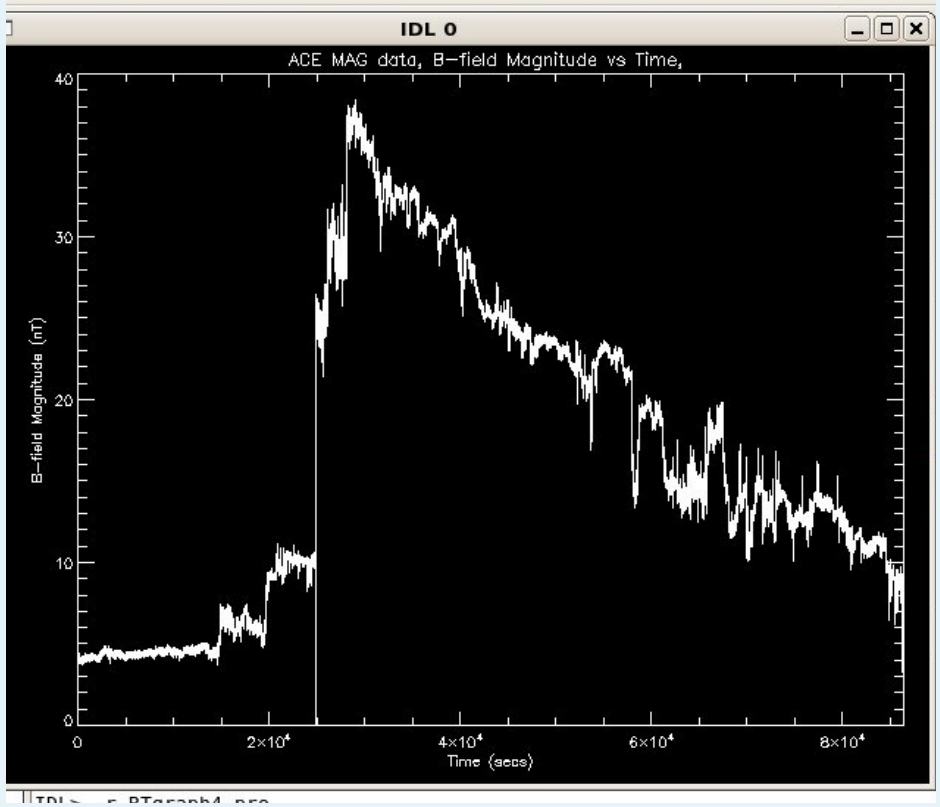
Initial Attempts (2nd December 2004 event)



- Measuring CME leading edge by hand, and estimating it's arrival time at the Earth assuming CME travels at constant speed...

ESTIMATED ARRIVAL TIME:
5am on 4th December 2004

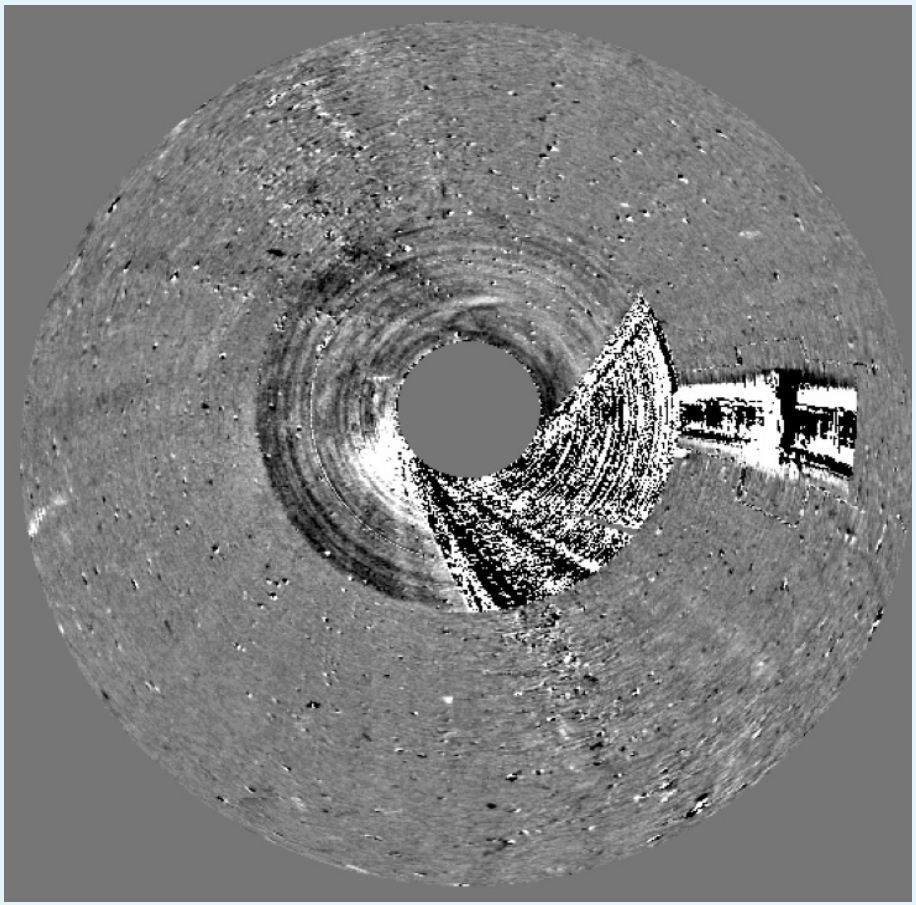
ACE Magnometer data



- By looking at variations in the near-Earth magnetic field, we can get a close approximation to the actual time of arrival of the CME

ACTUAL ARRIVAL TIME:
6.56am on 5th December 2004

2 big problems...



SMEI 'Fisheye' image: December 2004

- Need a better predictor of when the CME will reach the Earth...
- Need a quicker, less subjective way to pick CMEs out of SMEI image data...

Solutions!

- SOLUTION I:

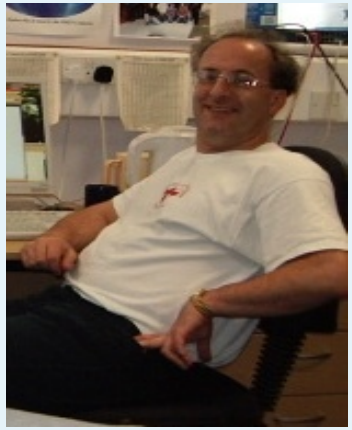
  Use the Tappin-Howard (TH) model

- SOLUTION II:

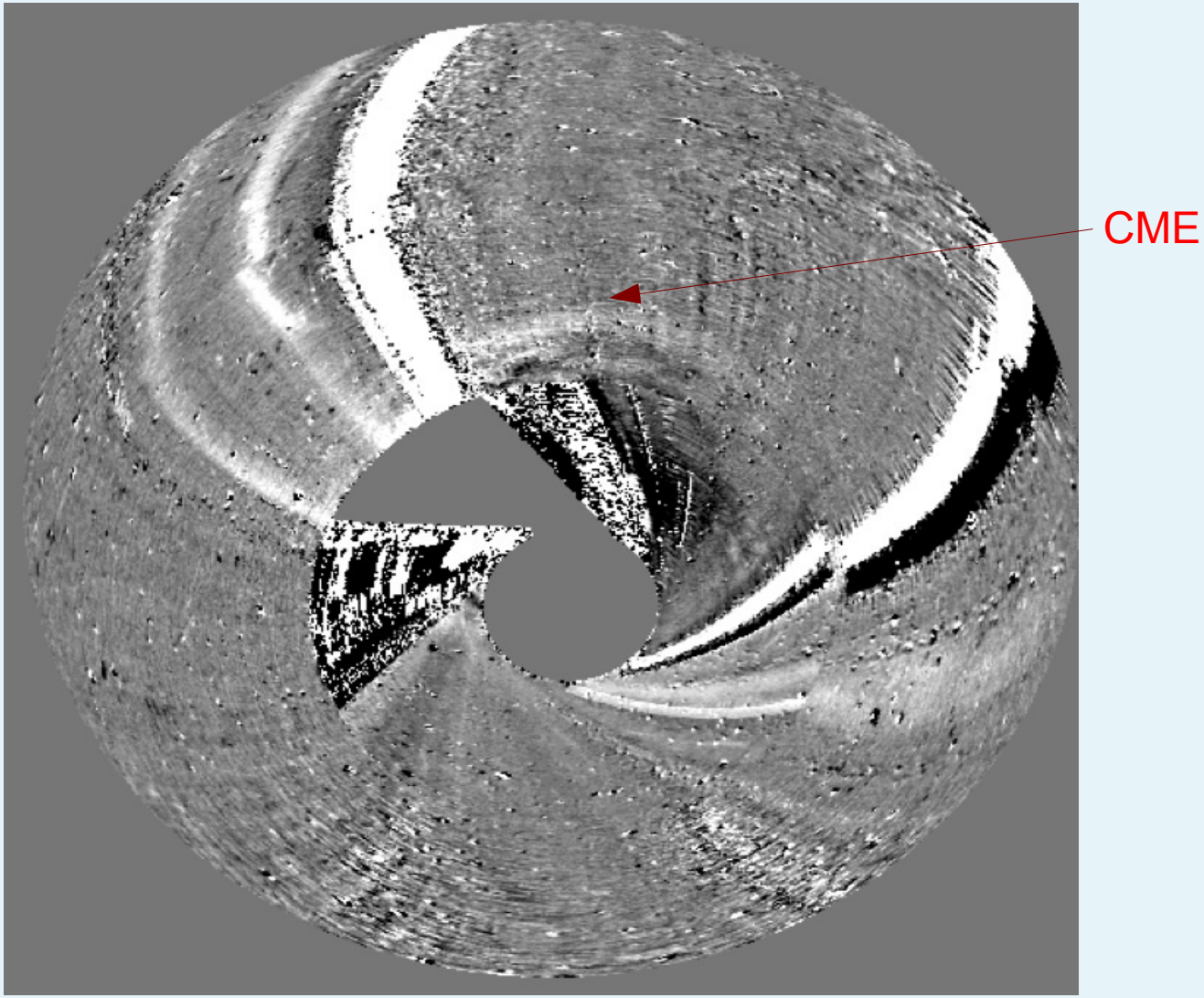
  Automate the detection of CMEs in the SMEI data

GOAL:

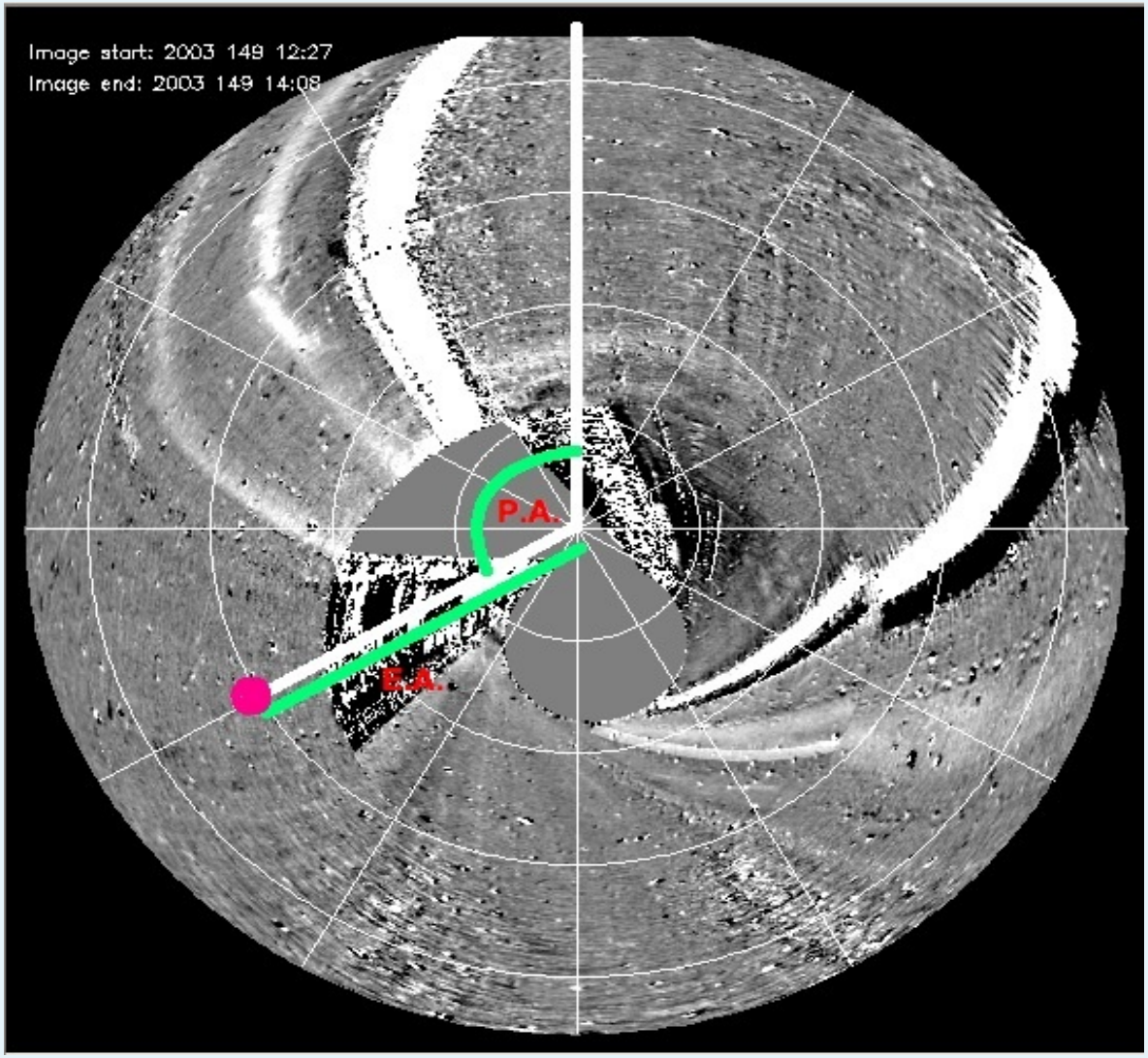
Automate the feeding of co-ordinates of the leading edge into the Tappin-Howard model.



RAW SMEI image, May 2003

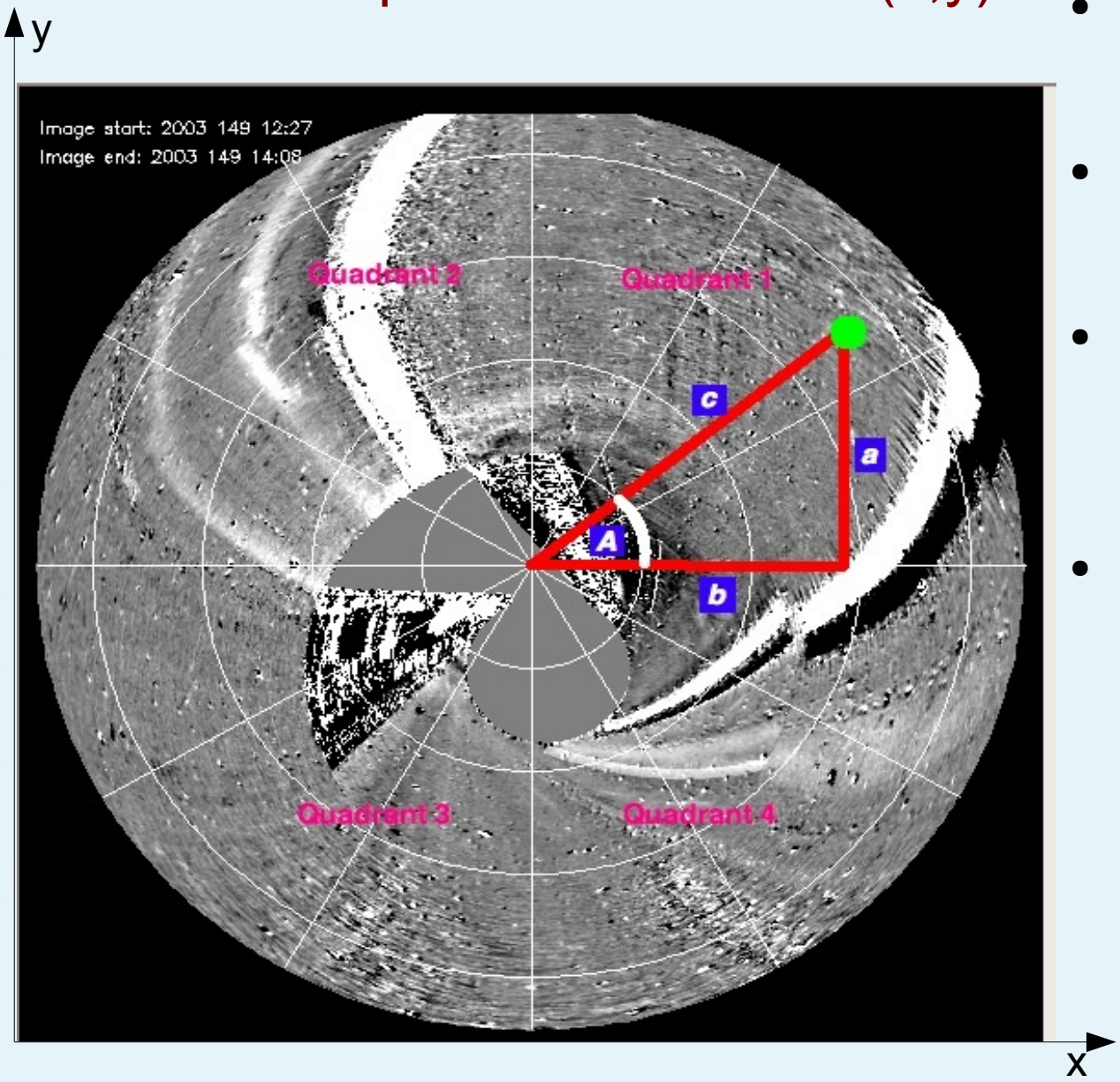


Co-ordinate System



Marked point Is at (E.A.,P.A.) = (90,120)

Transform to 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:

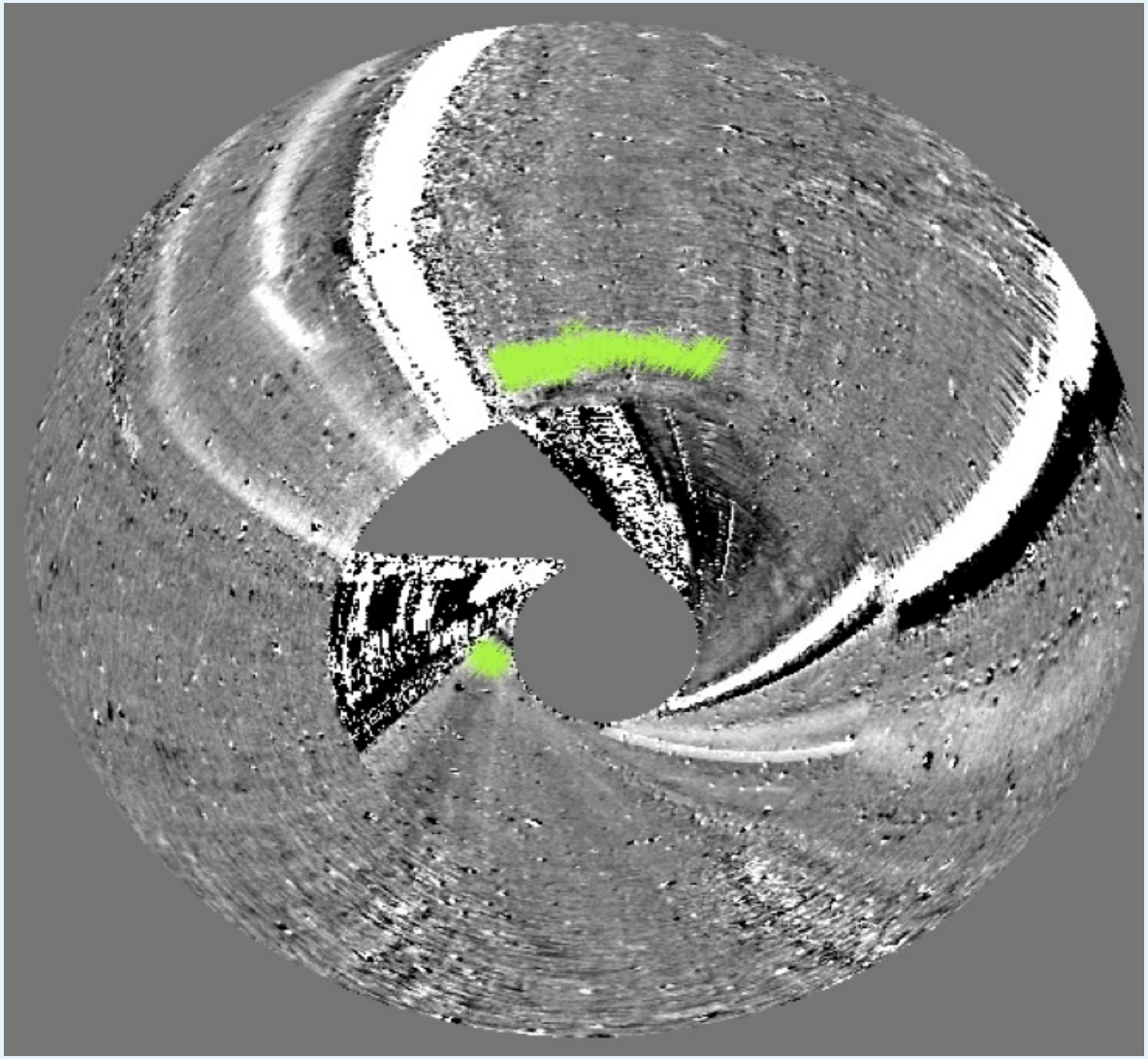
  A = P.A. - 3*Pi/2

  x= 280 + c*cos(A)

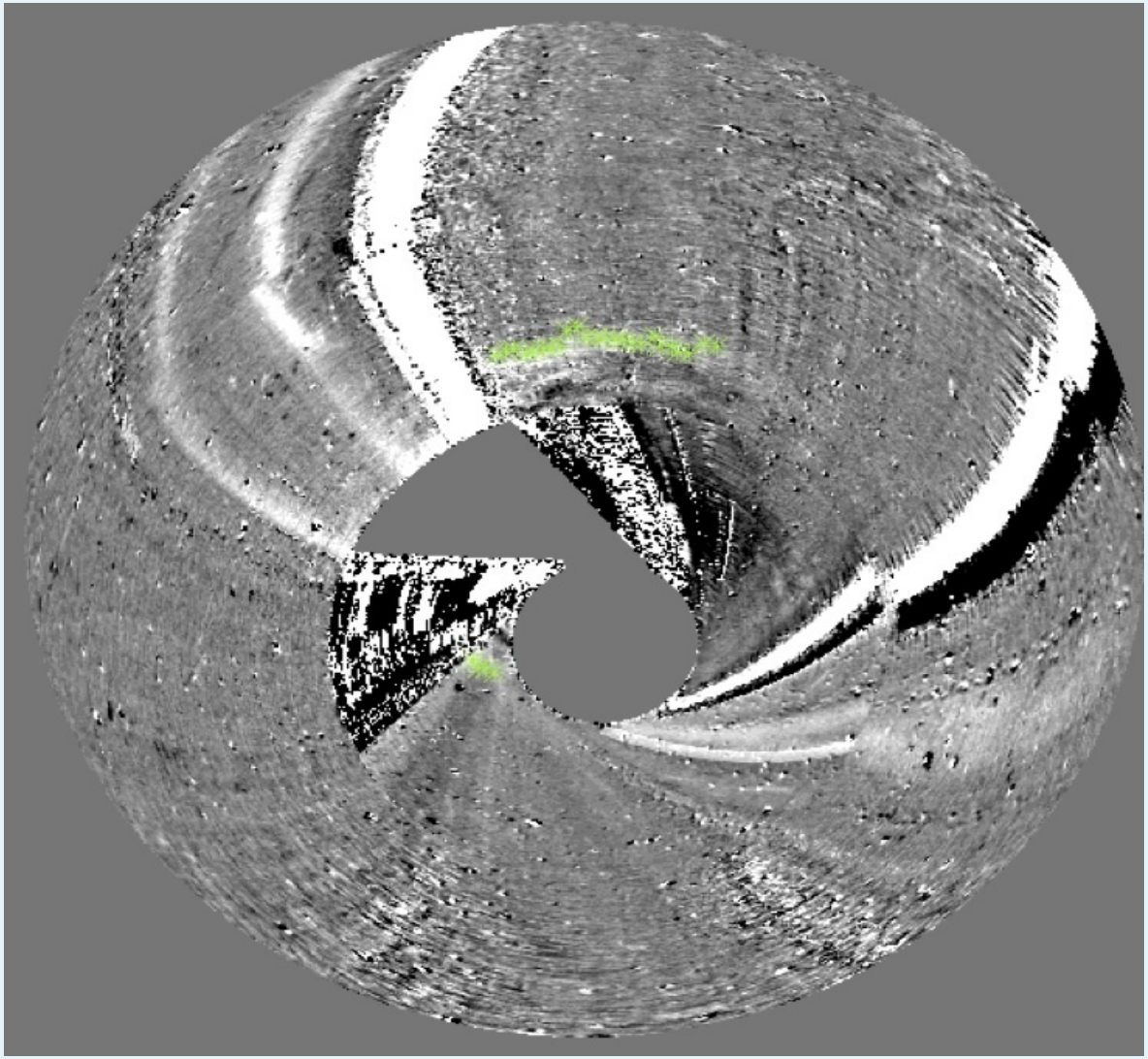
  y= 280 + c*sin(A)

Entire CME (fixed!)

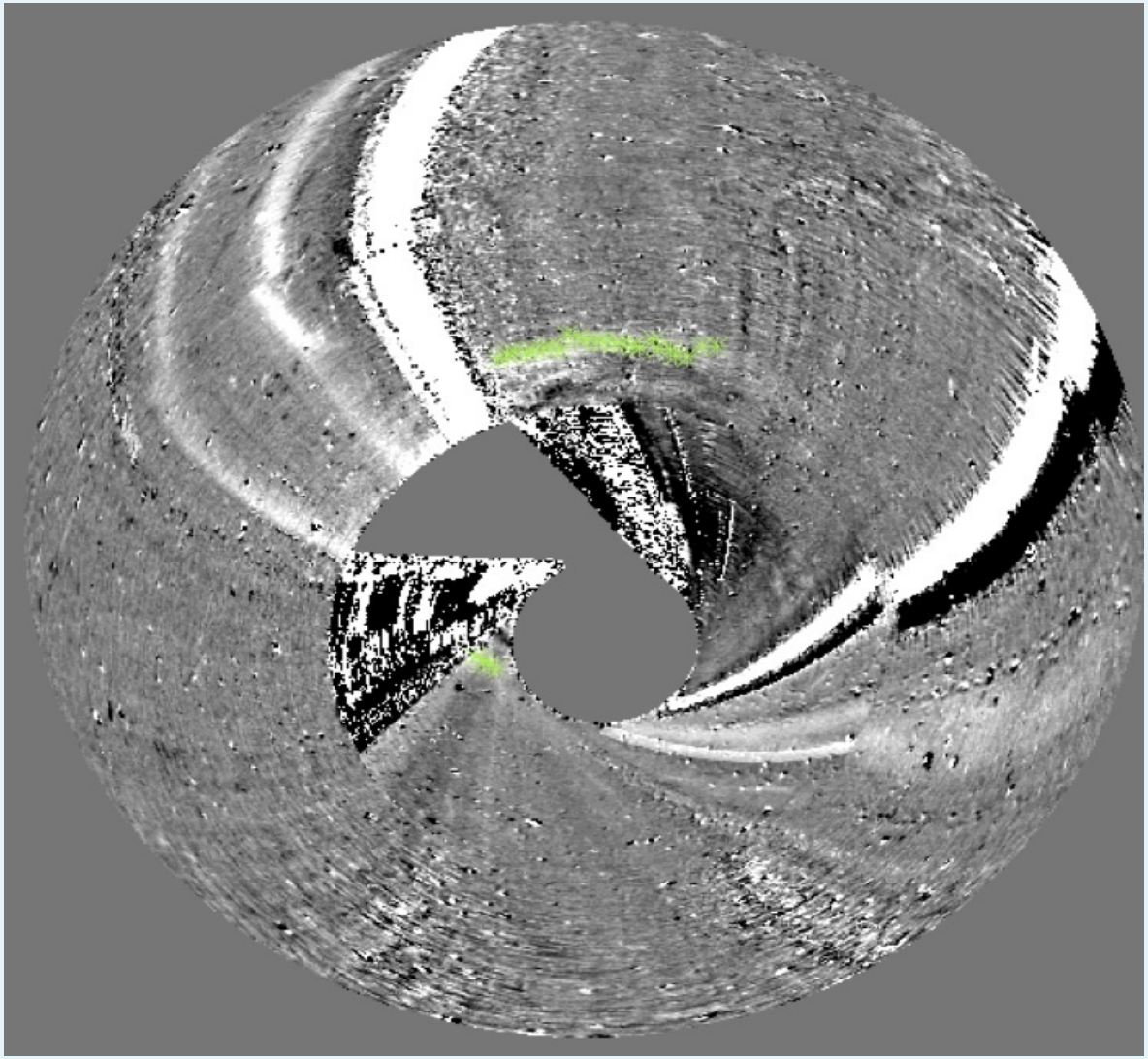
Green points are a plot of the CME detected by AiCMEDs – a CME detection program by Max Hampson (LASP)



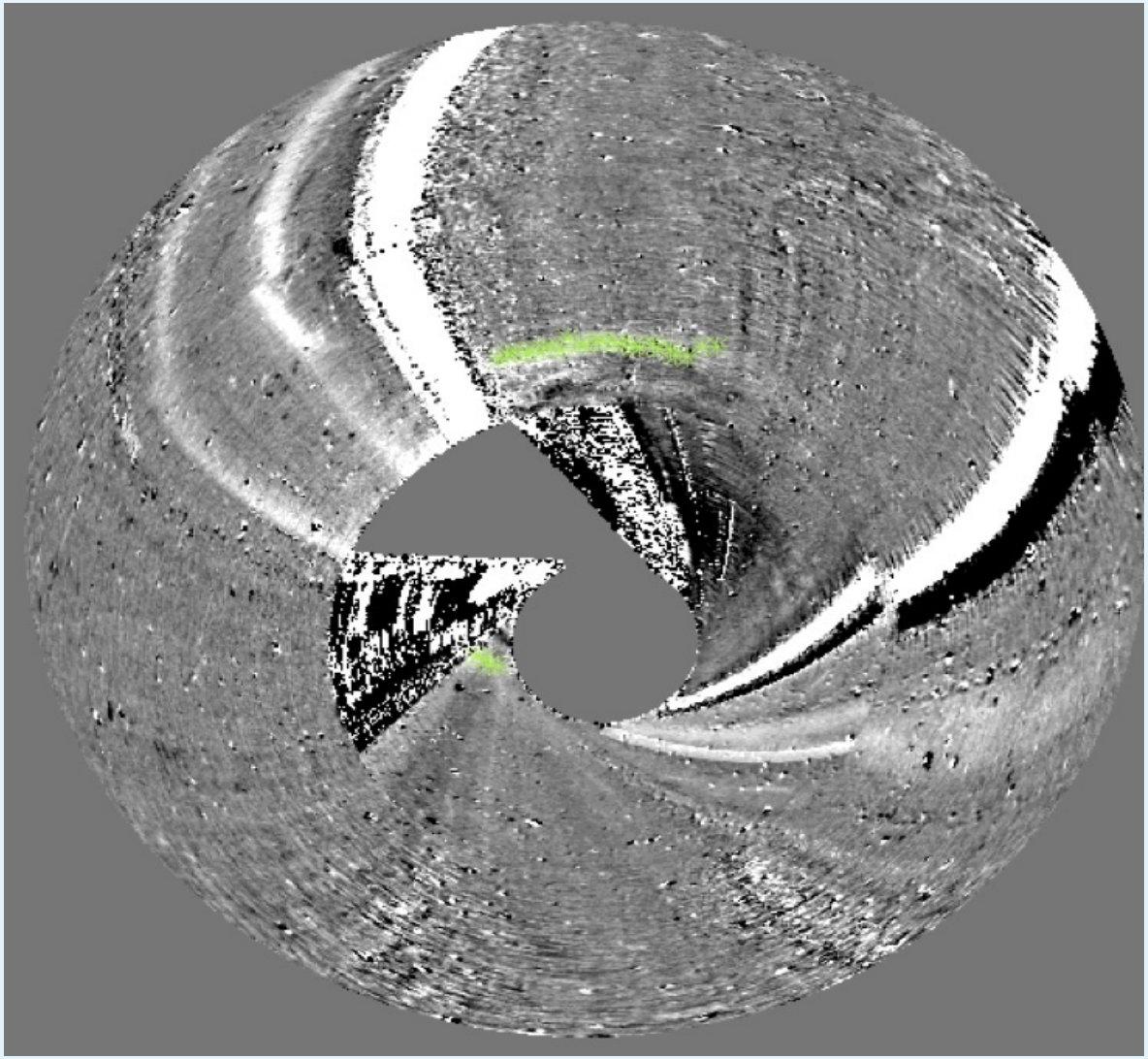
Automatic Detection: Extreme Leading Edge



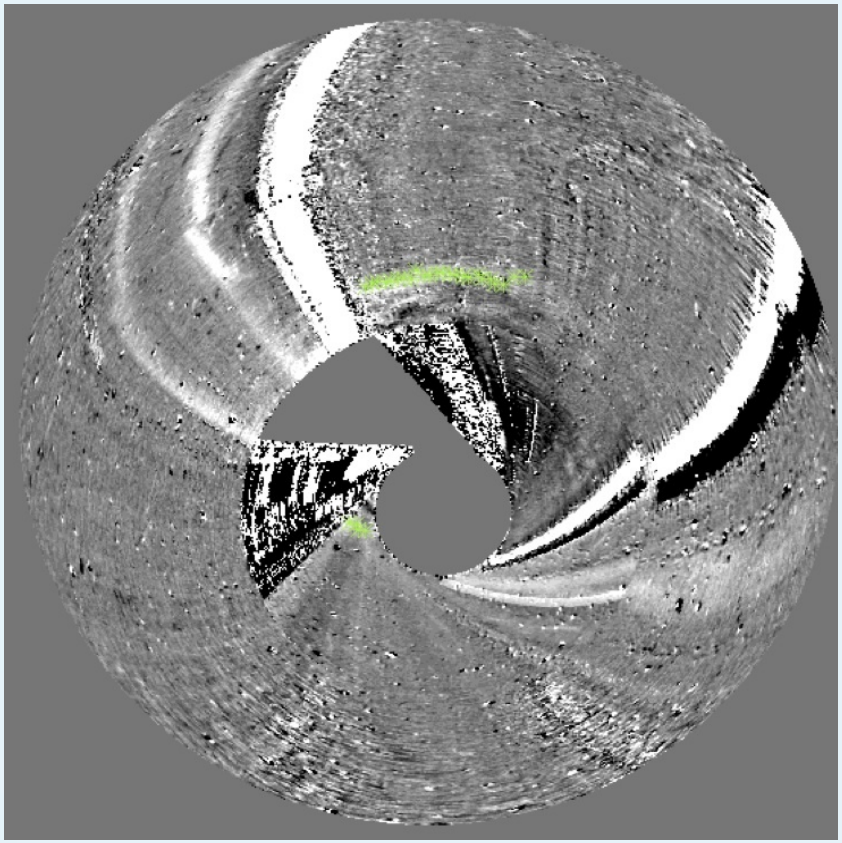
Automatic Detection: Mean



Automatic Detection: Median



My choice: Median



- Very little difference between LE detection methods (because so few points at each PA, and so tightly clustered)
- If any outliers do occur at different PAs, taking the median of the outermost 3 points will eliminate these

Put CME LE points into a format understandable by TH...

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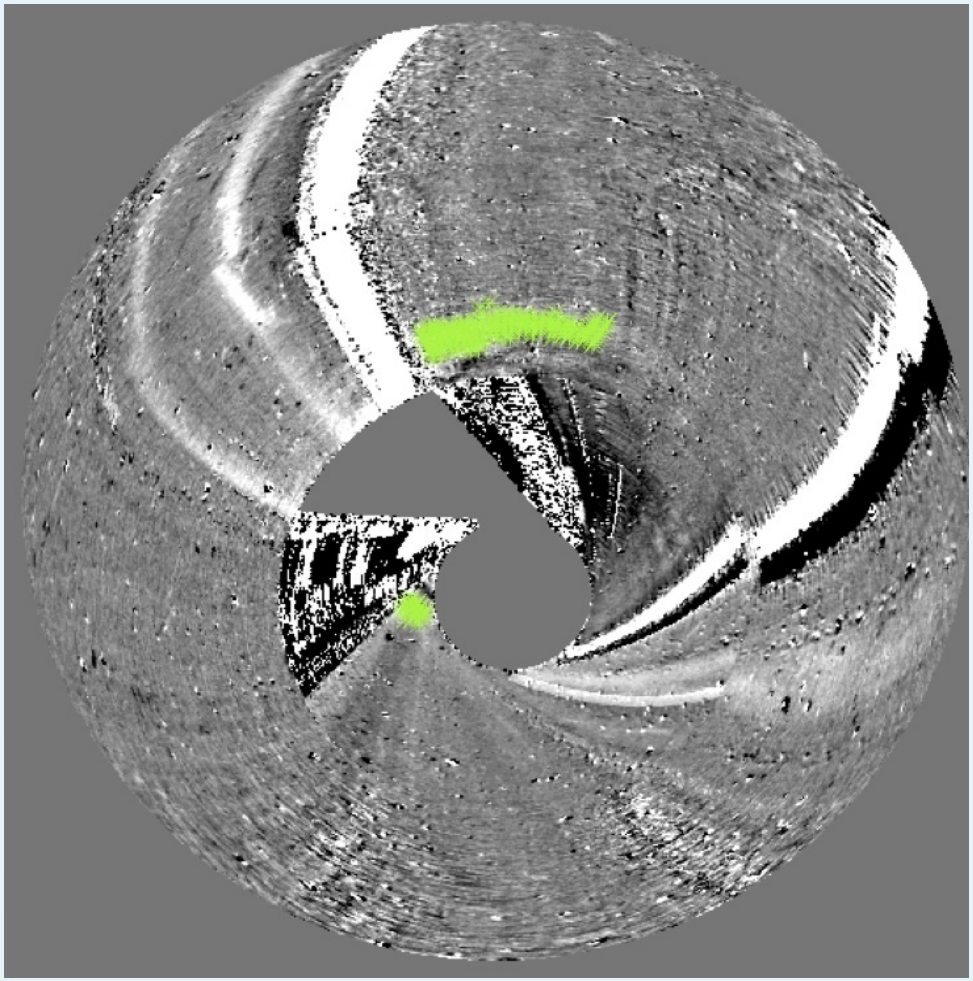
2003_149_1227_1_MED.txt*

Start	Stop	Long	Lat	RA	Dec	Value	P	Elong	PA	Flag	UT	SClong	SClat	X	Y
2452789.019005	2452789.089560	0.18	0.33	4.41	21.96	2.136	0.006	0.37	28.81	0	0.538466	71.98	27.19	227	212
2452789.019005	2452789.089560	0.18	0.32	4.41	21.96	1.316	0.006	0.37	29.44	0	0.537365	73.40	21.62	231	211
2452789.019005	2452789.089560	0.18	0.32	4.41	21.95	0.919	0.006	0.37	29.97	0	0.536318	74.68	16.33	233	207
2452789.019005	2452789.089560	0.19	0.32	4.41	21.95	1.160	0.006	0.37	30.56	0	0.534549	76.75	7.36	238	207

- n.b. U.T. times correspond to PIXEL TIMES
- Split up different CMEs

Splitting up different CMEs

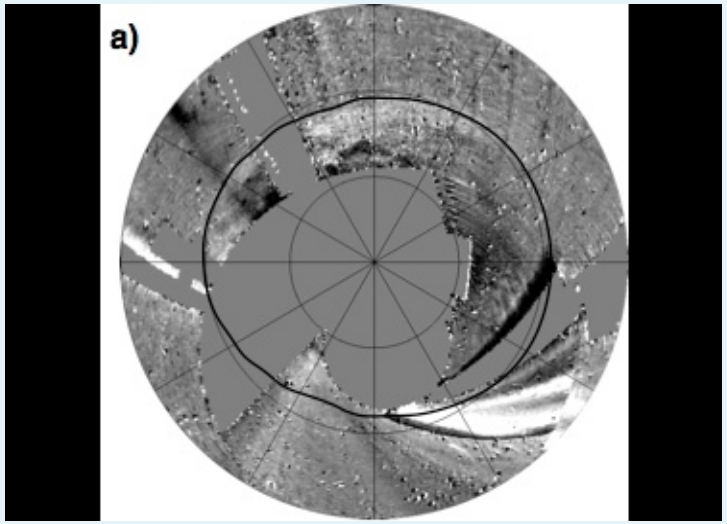


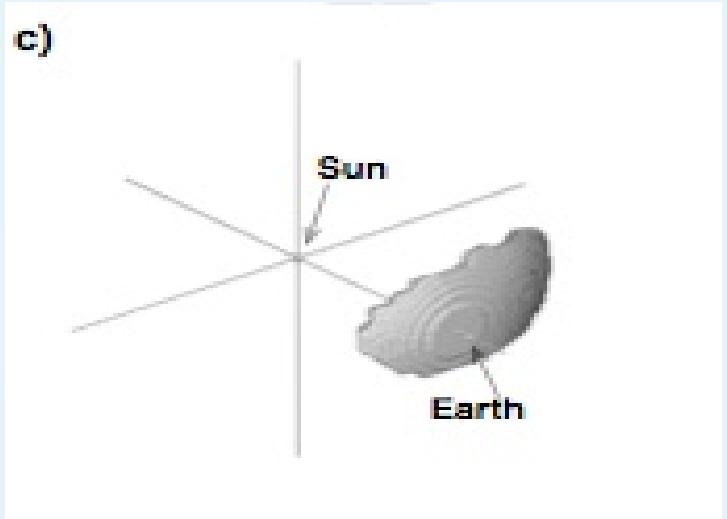
- If a group of points isn't within both 15 degrees elongation and position angle of another group, then we consider it to be a 'complete CME' (and these are split up by my program)
- In the case where we see multiple fragments of same CME, these are treated as different CMEs

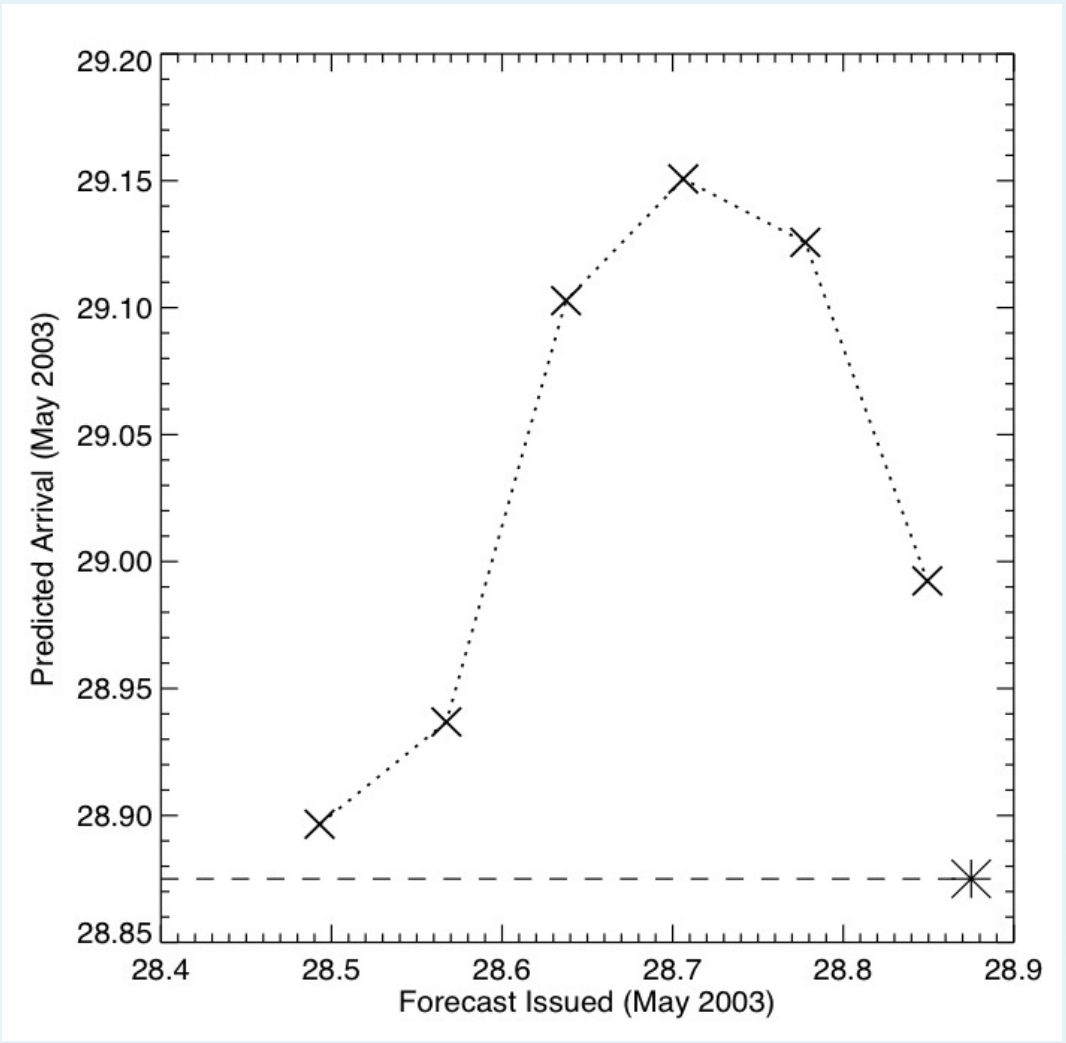
Procedure summary (up 'til now)

- Read in SMEI image sequence
- 'Fisheye' project into the plane
- Take running difference image and remove known light sources
- Use AiCMEDs to identify CMEs
- Transform to pixel co-ordinates to plot
- Pick out leading edge (using 'median' method)
- Put leading edge into form understandable by TH model

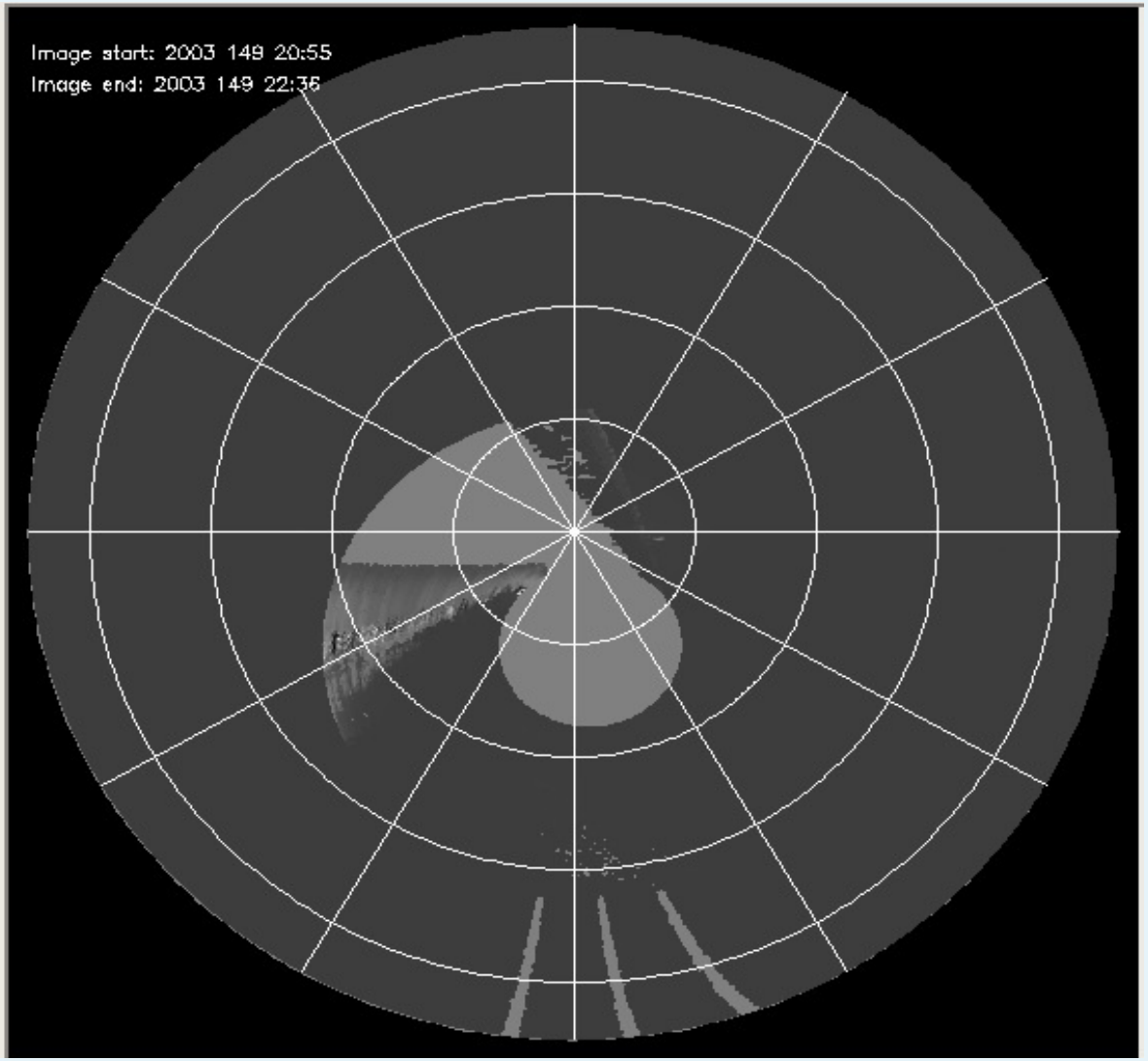
Putting May 2003 CME into TH





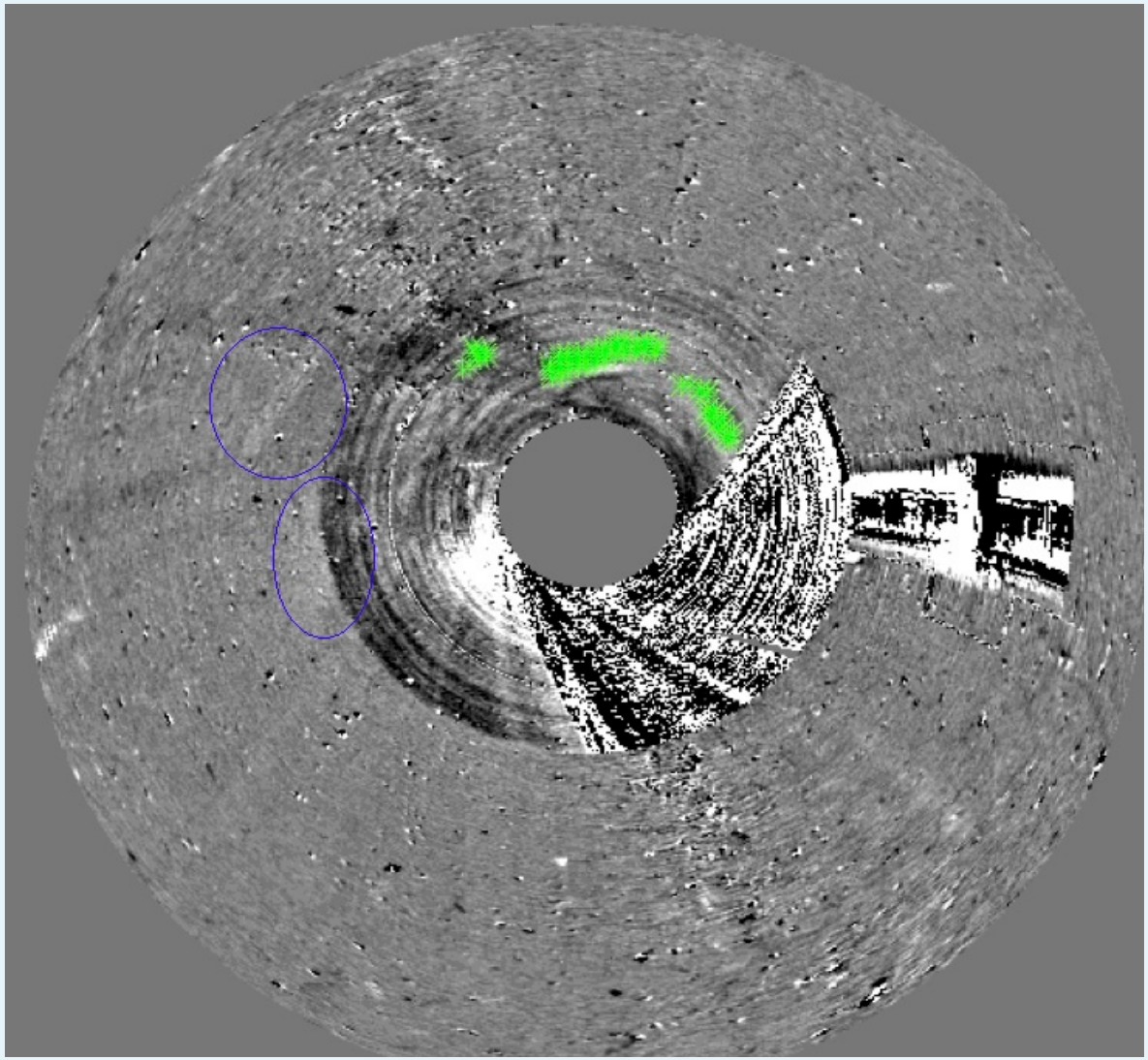


Next Steps...



- TH also requires measurements of the masked regions (obviously CMEs could extend into masked regions)- we want to automate this process

Missed CMEs!



- Some accepted CMEs are missed by the program...
- Need to quantify this, and seek optimal parameters to find all CMEs without any 'false positives'

Future work

- Automate the feeding of noisy regions into TH
- Try my program (and the TH model) on many CMEs and ascertain the reliability of both (compare with when the CMEs actually arrived at the Earth)

Thanks...

- Dr T.A. Howard
- Dr Marty Snow and Erin Wood
- The Research Experience for Undergraduates (funded by the National Science Foundation)
- Dr James Tappin (National Solar Observatory)
- Max Hampson (LASP)
- Everyone else in the REU!