

# Only you can save planet Earth!

Improving the space weather forecast with Solar Stormwatch

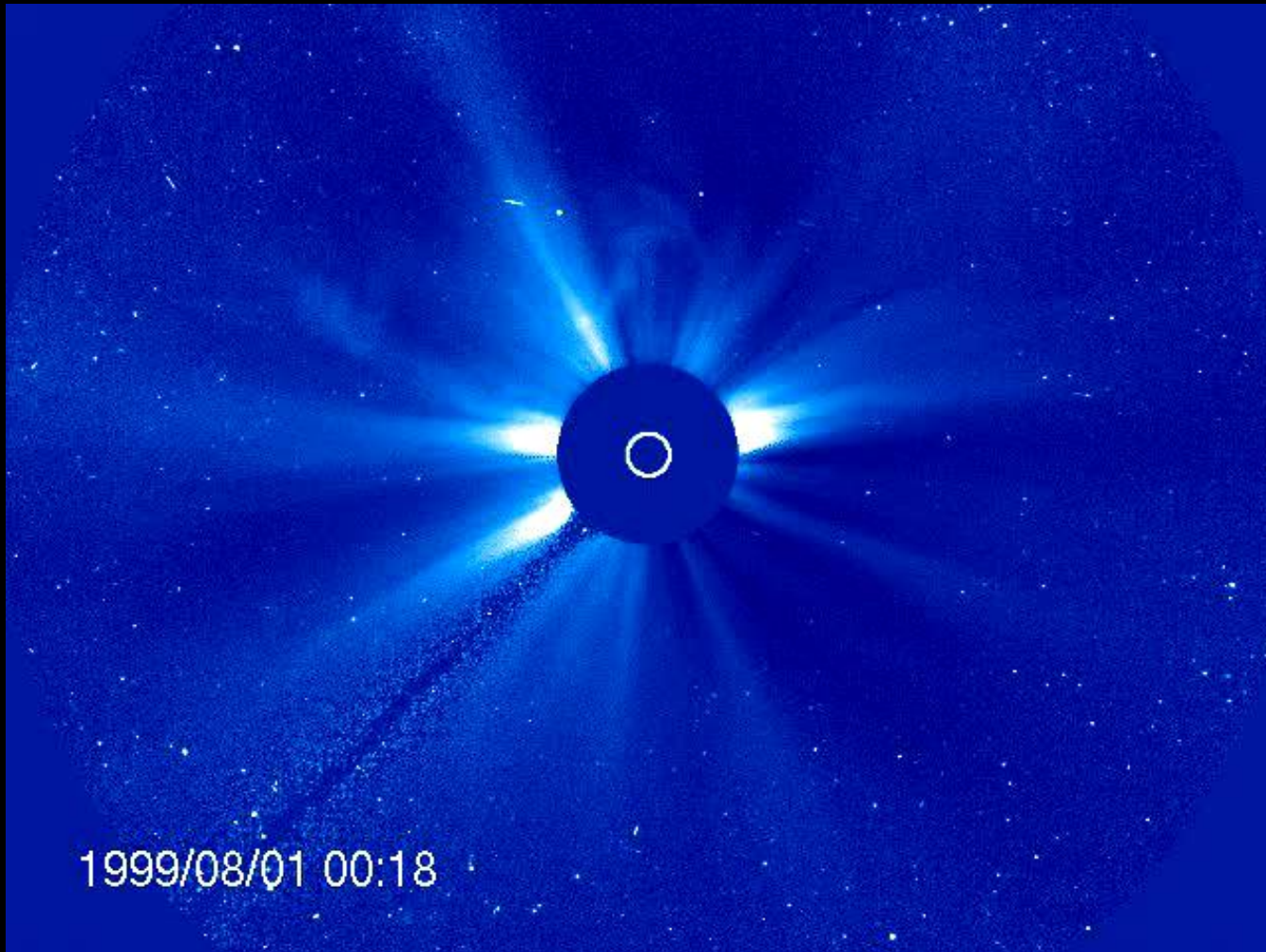
Chris Scott

February 2015

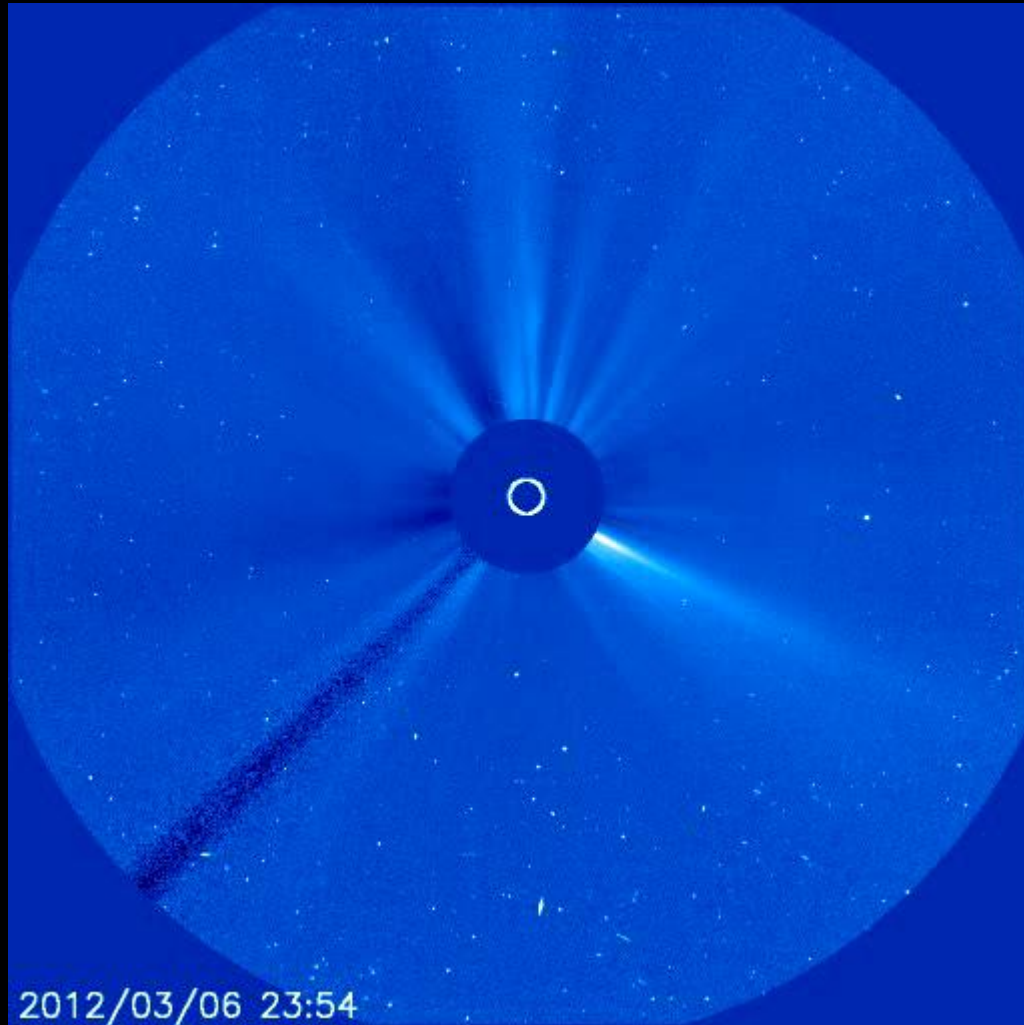
With thanks to Luke Barnard, Kim Tucker-Hood, Amy Skelt and to all the Stormwatchers



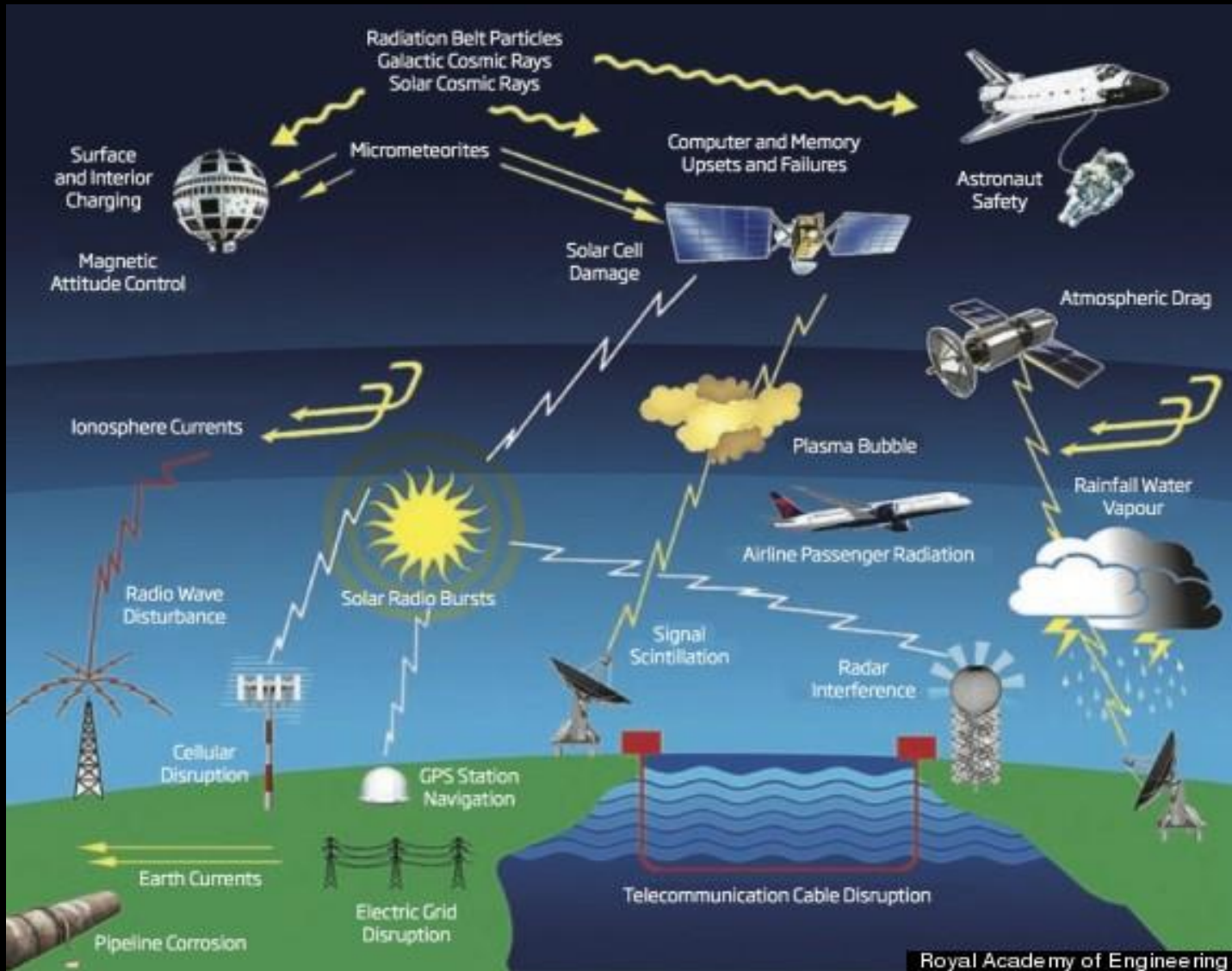
# Solar wind and solar storms observed by SOHO



Earth-directed solar storms observed from near the Earth appear as diffuse 'halos'



# The effects of Space Weather at Earth – a handy (if confusing!) summary





BRIEFING

**SPACE WEATHER**

Its impact on Earth and implications for business



RAL Space

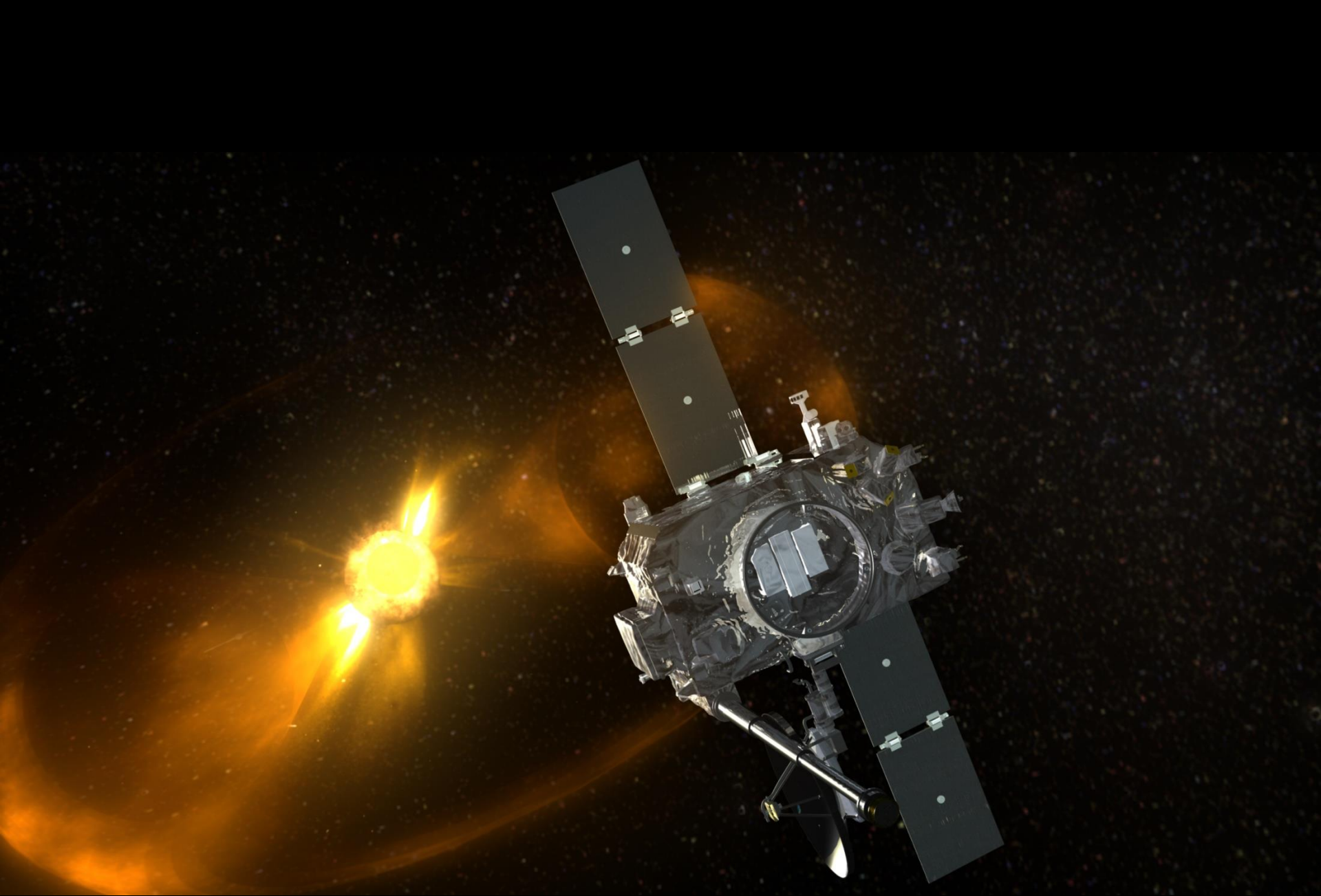
# EXECUTIVE SUMMARY

- 1. SPACE WEATHER DESCRIBES EVENTS THAT HAPPEN IN SPACE, WHICH CAN DISRUPT MODERN TECHNOLOGIES**
- 2. THE GROWTH OF TECHNOLOGIES HAS LEFT SOCIETY MORE AT RISK FROM SPACE WEATHER**
- 3. SPACE WEATHER COULD POTENTIALLY CREATE HUGE DISTURBANCES IN THE TRANSPORT, AVIATION AND POWER SECTORS**
- 4. ALL GPS SIGNALS ARE VULNERABLE TO SPACE WEATHER, WHICH IMPACTS ON, FOR EXAMPLE AVIATION NAVIGATION SYSTEMS**
- 5. SPACE WEATHER CAN ALSO DISRUPT PIPELINES AND RAILWAY SIGNALS**
- 6. A VERY SEVERE OUTBREAK OF SPACE WEATHER COULD CREATE A SYSTEMIC RISK TO SOCIETY**
- 7. BUSINESSES AT RISK FROM SPACE WEATHER NEED ACCESS TO RELEVANT EXPERTISE**
- 8. FINDING DEFENCES AGAINST SPACE WEATHER MAY ALSO PROVIDE BUSINESS OPPORTUNITIES**

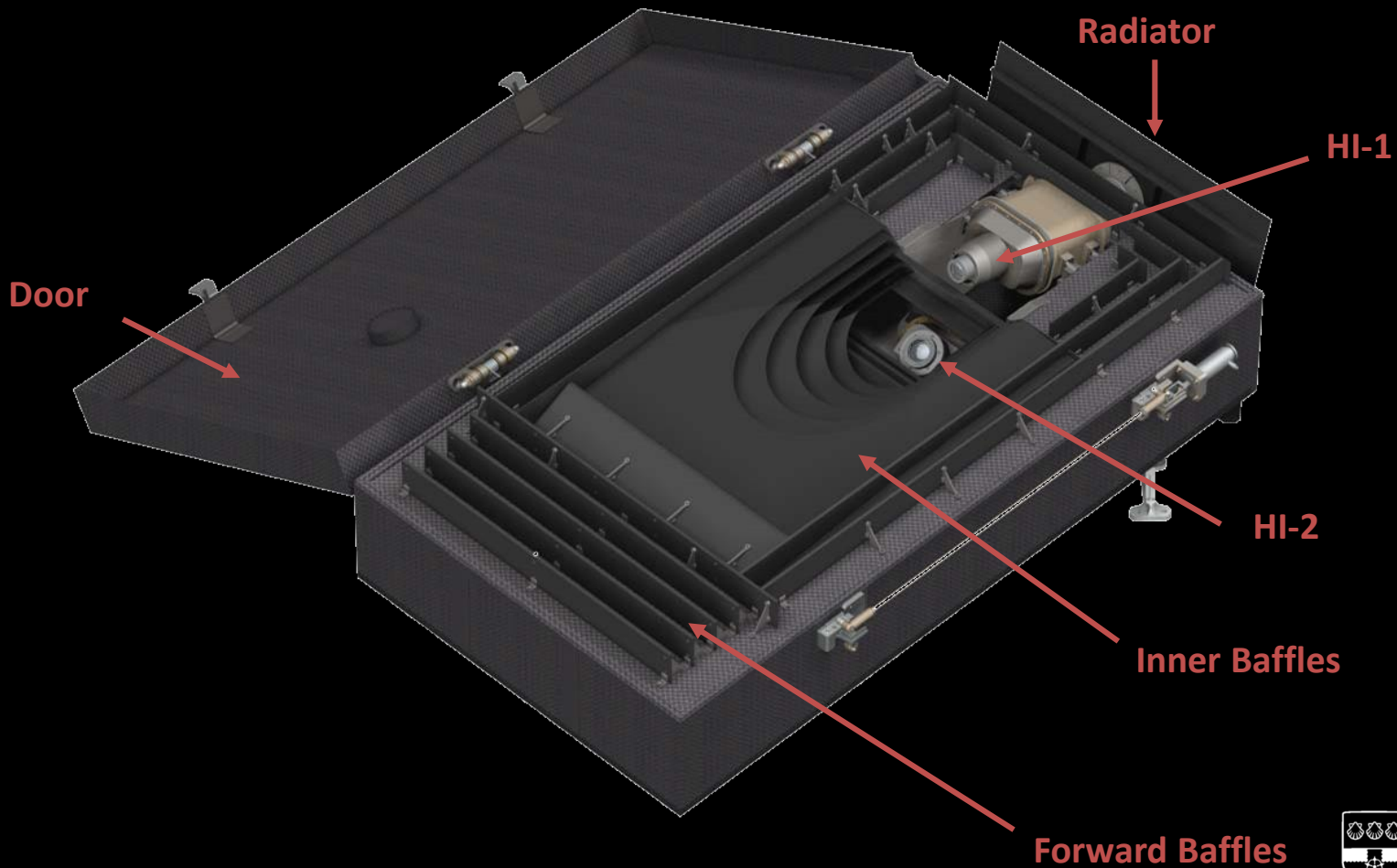


# Introducing STEREO





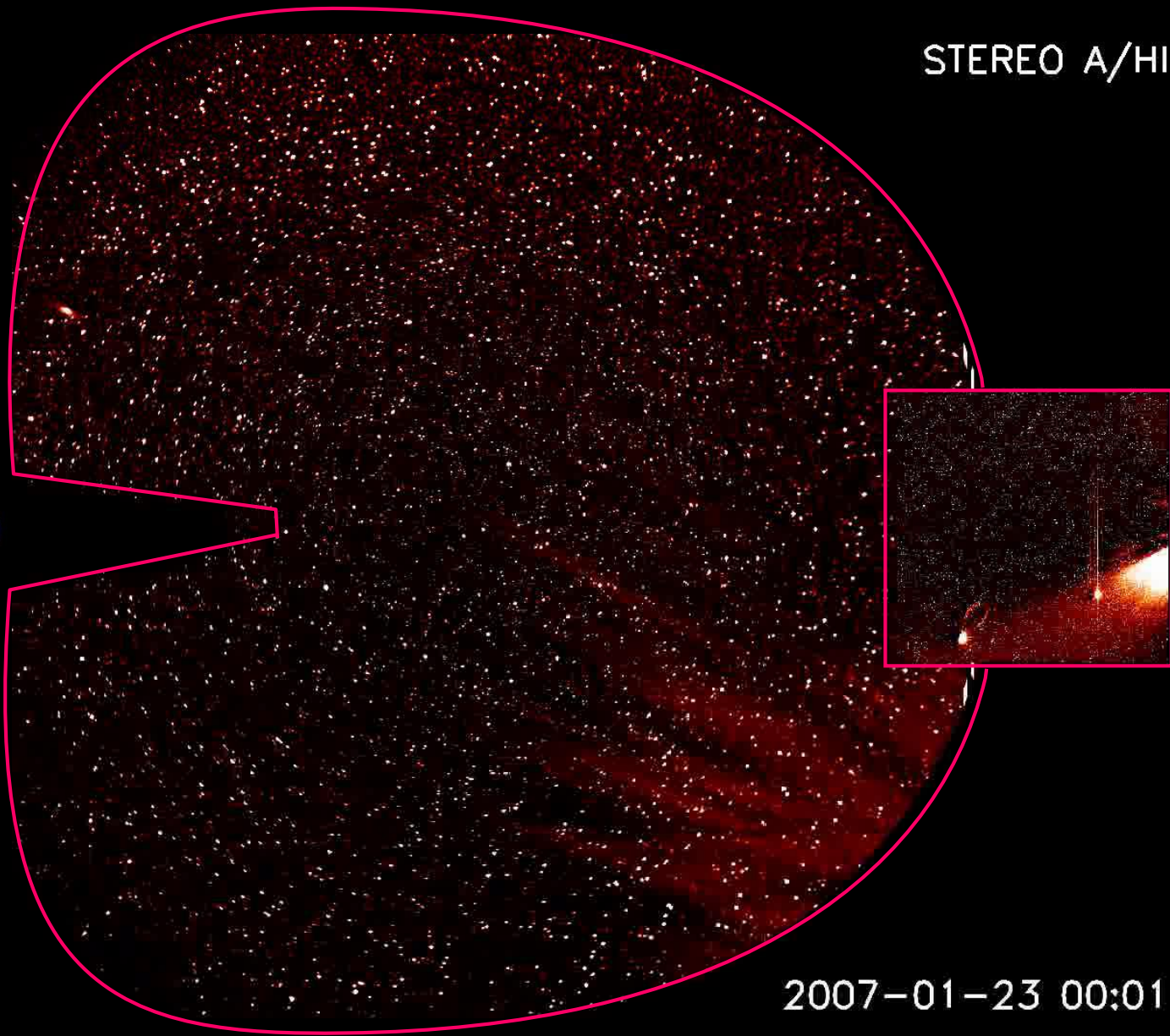
# Heliospheric Imager





THE combined field of view of the HI cameras

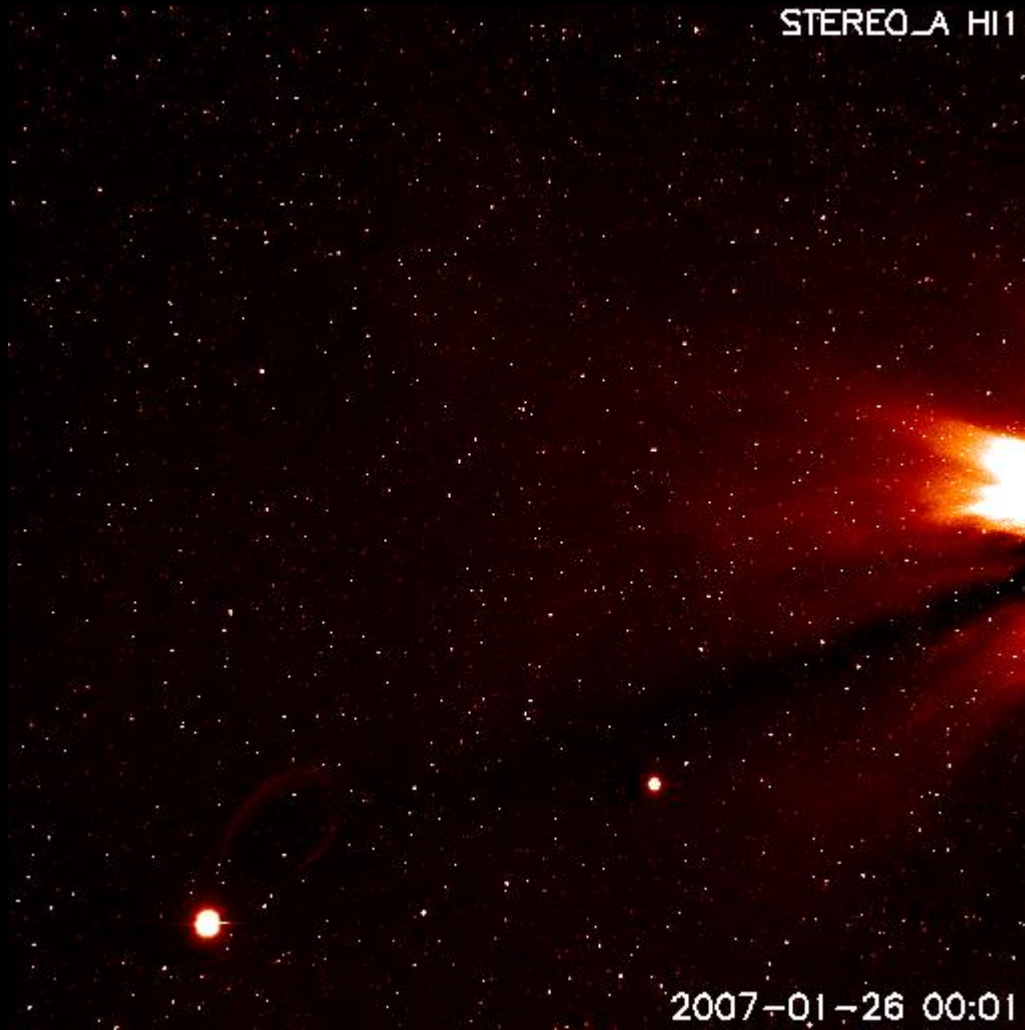
STEREO A/HI



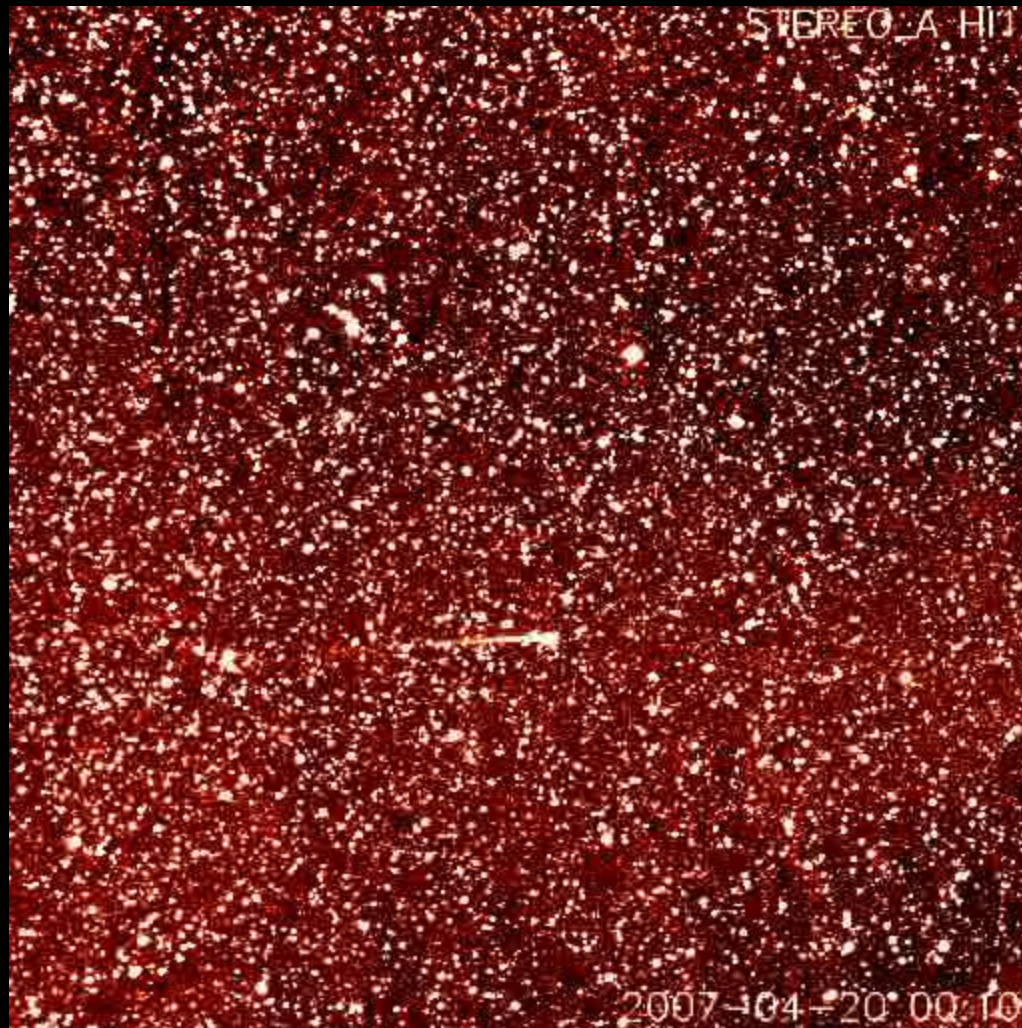
2007-01-23 00:01

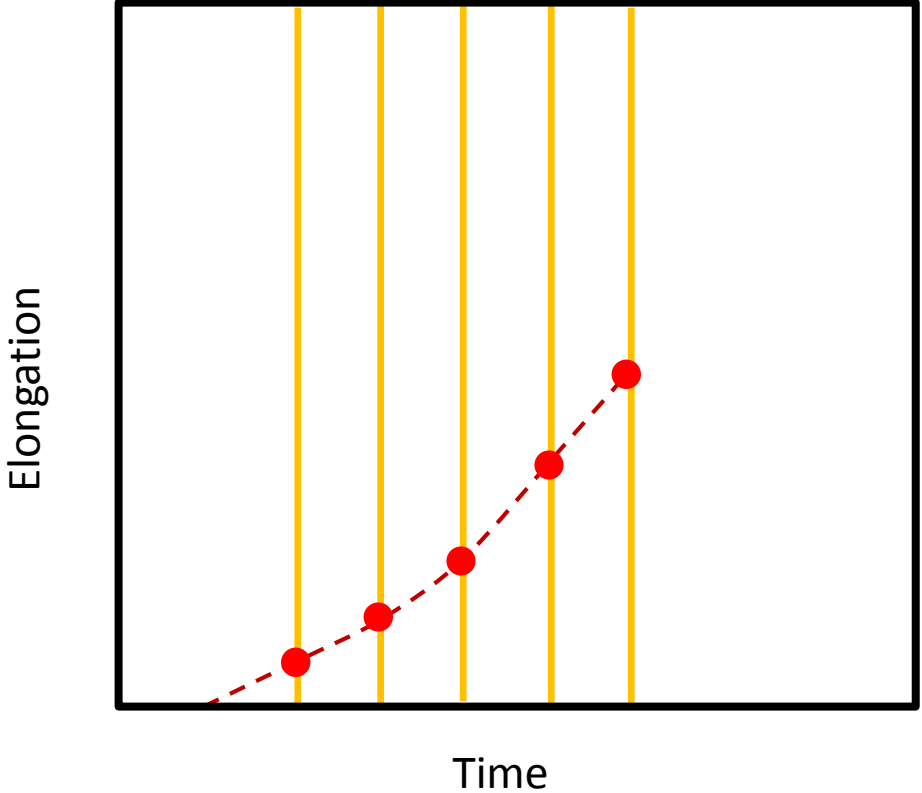
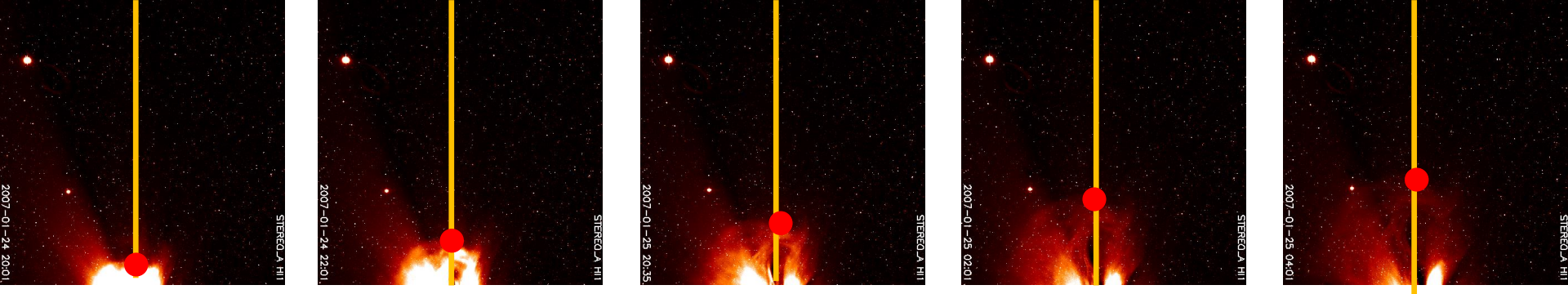
Earth and Sun not to scale!

STEREO\_A HI1



2007-01-26 00:01



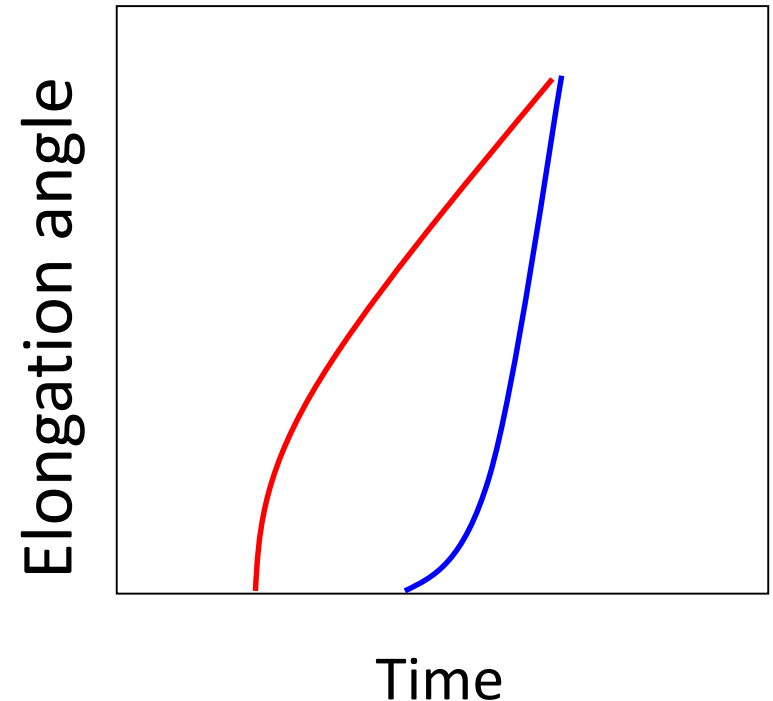
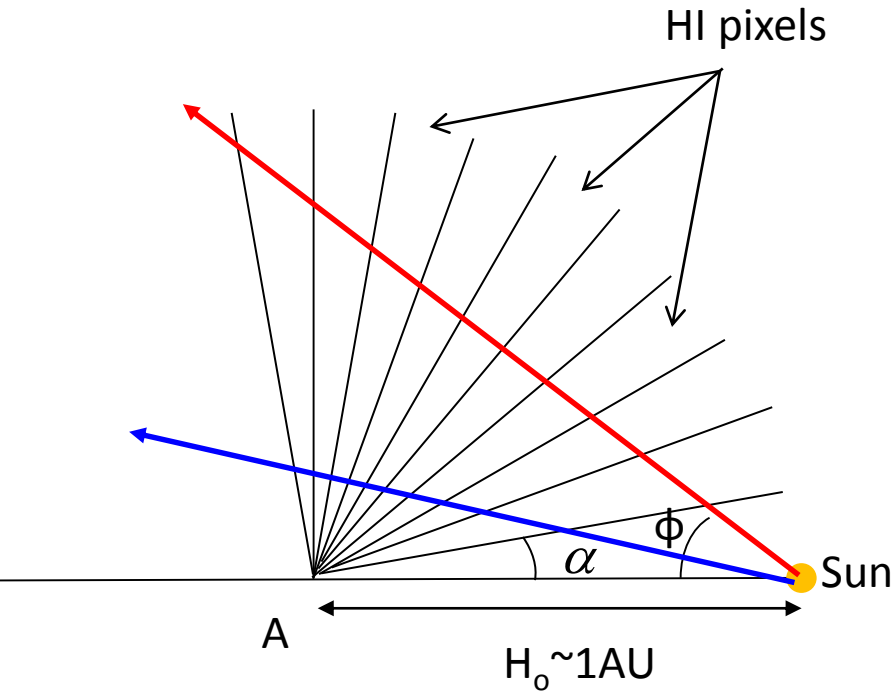


The ecliptic lies approximately along the central line of the HI images.

Tracking the rate at which the CME expands along this line generates a 'J-map'.

The gradient is a function of speed and direction of the CME

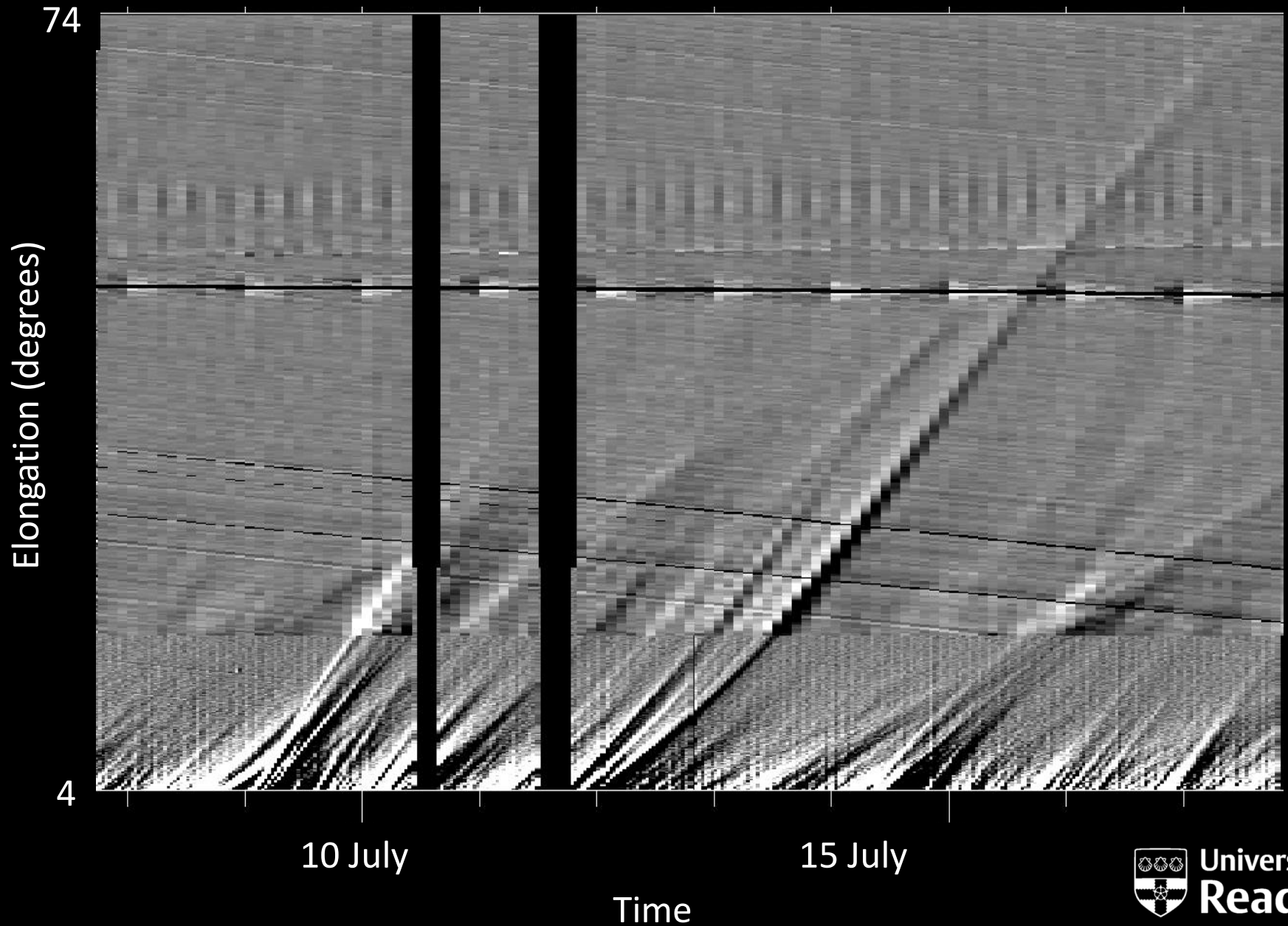
# Apparent acceleration at large elongations – the ‘Fixed Phi’ approximation



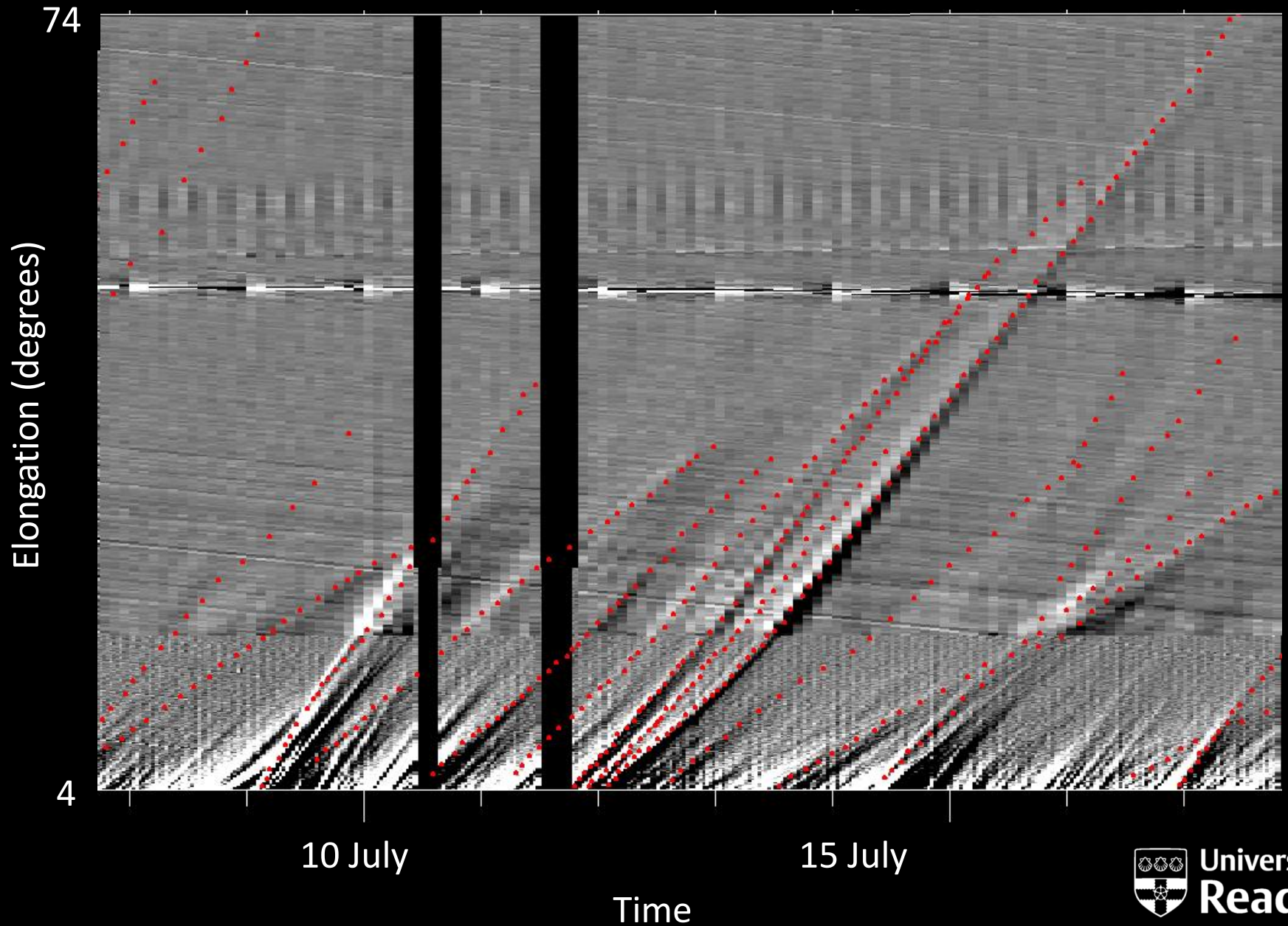
Assuming the solar storm propagates radially ( $\phi$  constant) and at a constant speed;

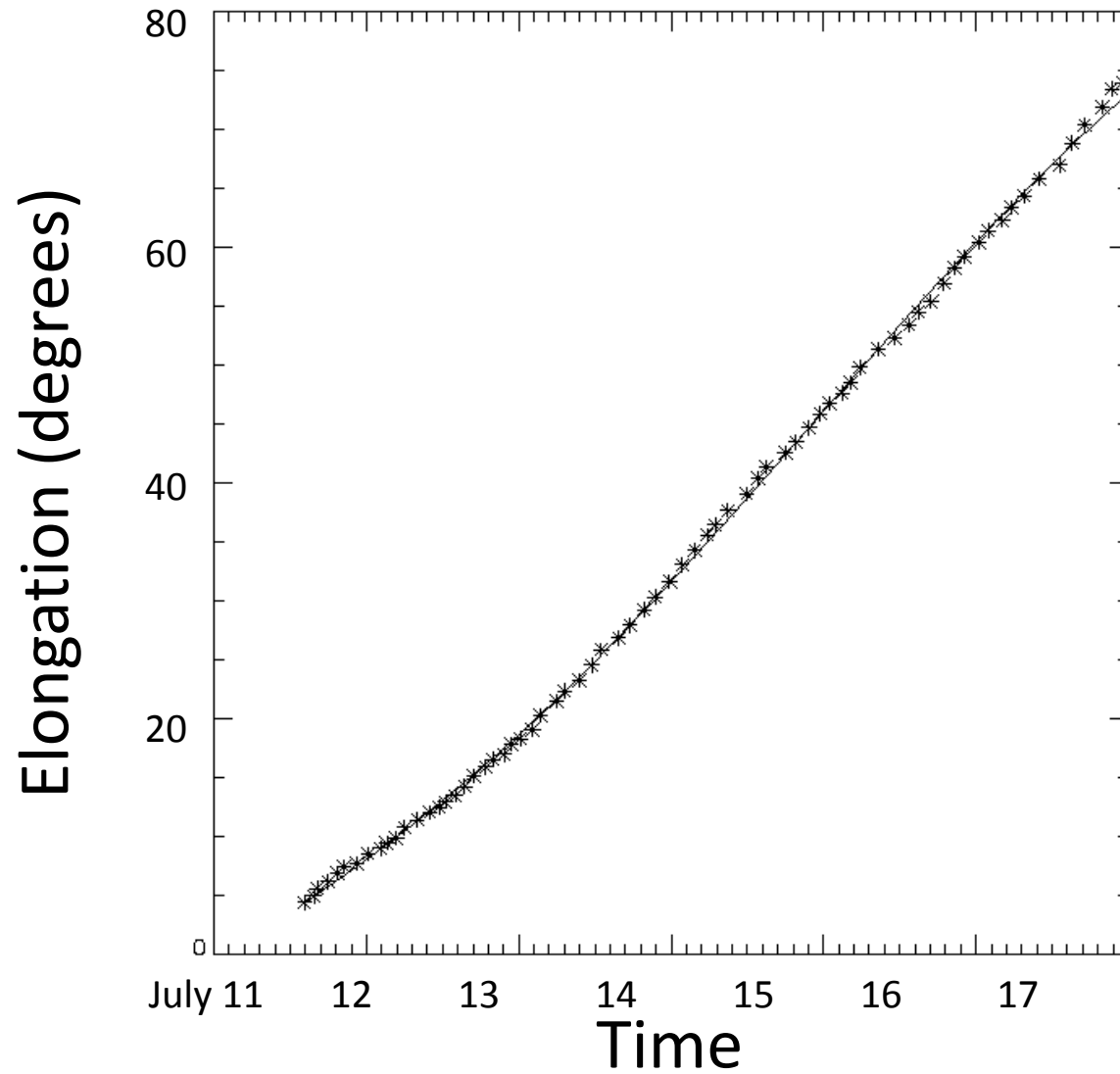
$$\alpha(t) = \arctan \left[ \frac{vt \sin(\phi)}{H_0 - vt \cos(\phi)} \right] \quad (\text{Sheeley et al., JGR, 1999})$$

# Obtaining speeds and direction of CMEs in HI



# Obtaining speeds and direction of solar storms in HI







## Event 123

Launch date 2007-07-11

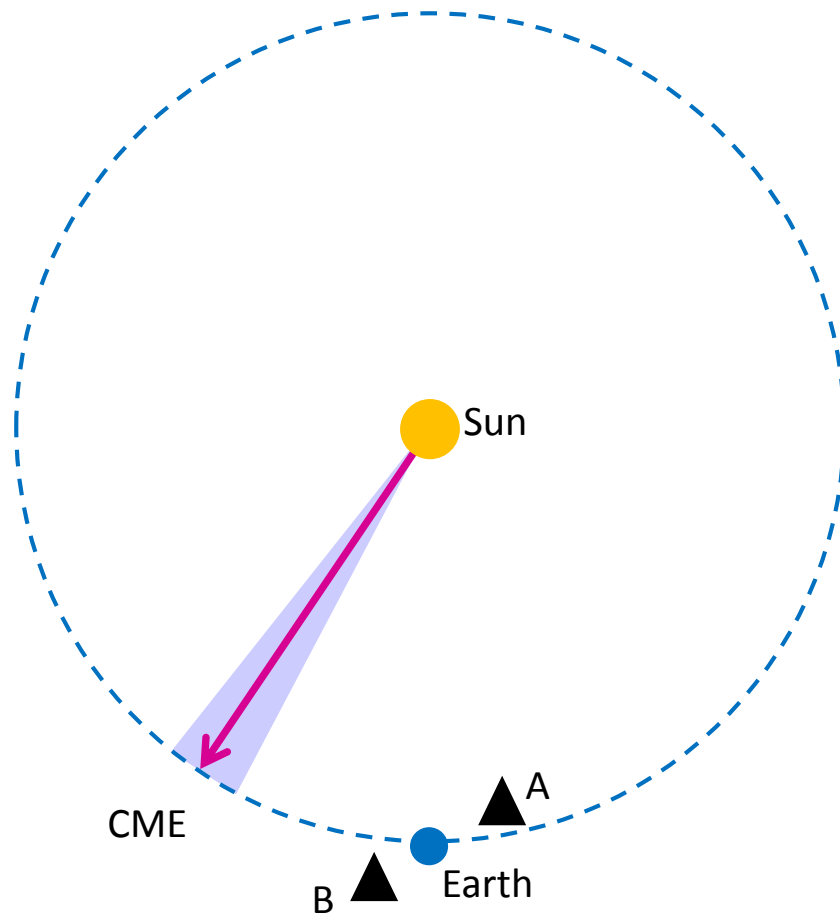
Launch time 12:47 UT

Speed:  $301 \text{ km s}^{-1}$

Angle from Earth  $-34^\circ$

Predicted arrival at 1 AU

2007-07-17 at 09:09 UT



# SOLAR STORMWATCH

|      |   |
|------|---|
| HOME | <a href="#">WHY SCIENTISTS NEED YOU</a> |
|      | <a href="#">MISSION BRIEFING</a>        |
|      | <a href="#">SPOT &amp; TRACK STORMS</a> |
|      | <a href="#">TALK ABOUT IT</a>           |

## Solar scientists need you!

Help them spot explosions on the Sun and track them across space to Earth. Your work will give astronauts an early warning if dangerous solar radiation is headed their way. And you could make a new scientific discovery.



[GET STARTED](#)

Photo by JMA SA

### WHY SCIENTISTS NEED YOU

Watch our solar scientists explain why your contributions are vital, and find out what they're doing with your results behind the scenes.

#### WATCH VIDEOS



### MISSION BRIEFING

Explore our interactive mission briefing to get up to speed with solar science, zoom in on the STEREO spacecraft and meet our science team.

#### VISIT MISSION BRIEFING



### Featured member

**Jo Echo Syan**



**Member since:** February 2009

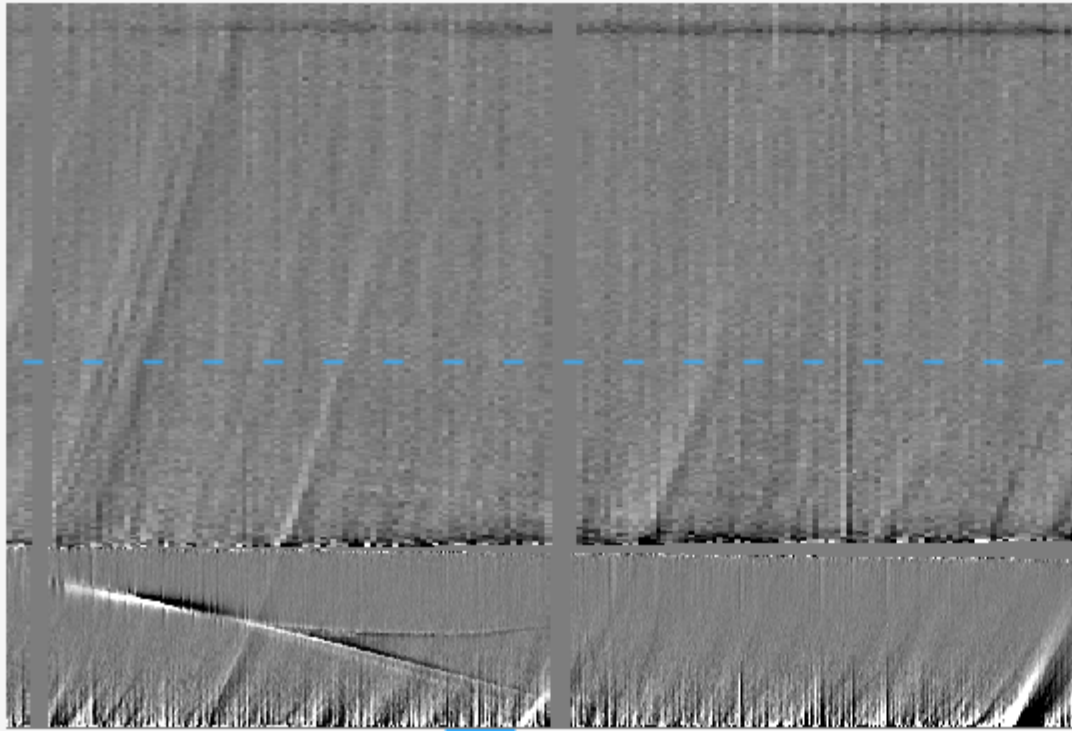
The cool thing is, I am welcome, allowed to ponder, be amazed and explore not only a subject previously inaccessible to me, but it has also enabled me to respond and take a new approach to my work as an Artist.

**Achievements**

Log in

# Trace it

## J-MAP FROM HELIOSPHERIC IMAGERS 1 AND 2



MARKS

00/20

MARK



DELETE



SIZE



SHOW/HIDE



RESET



★ ADD CLIP TO FAVOURITES

### YOUR ANSWER

Make sure you mark as much of the storm as you can. Then press **SEND ANSWERS**. If you can't see any feature that goes at least half way up the image from the start point, press **NOTHING TO SEE** [HERE](#).

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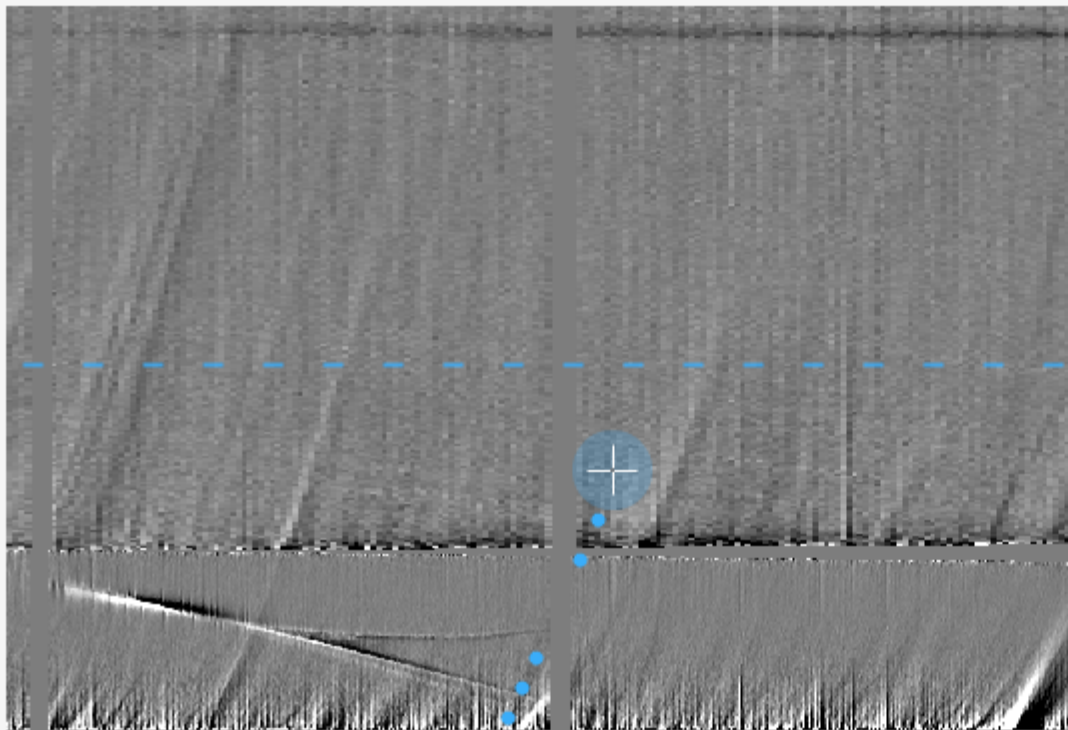
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# Trace it

## J-MAP FROM HELIOSPHERIC IMAGERS 1 AND 2



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SHOW/HIDE



RESET



★ ADD CLIP TO FAVOURITES

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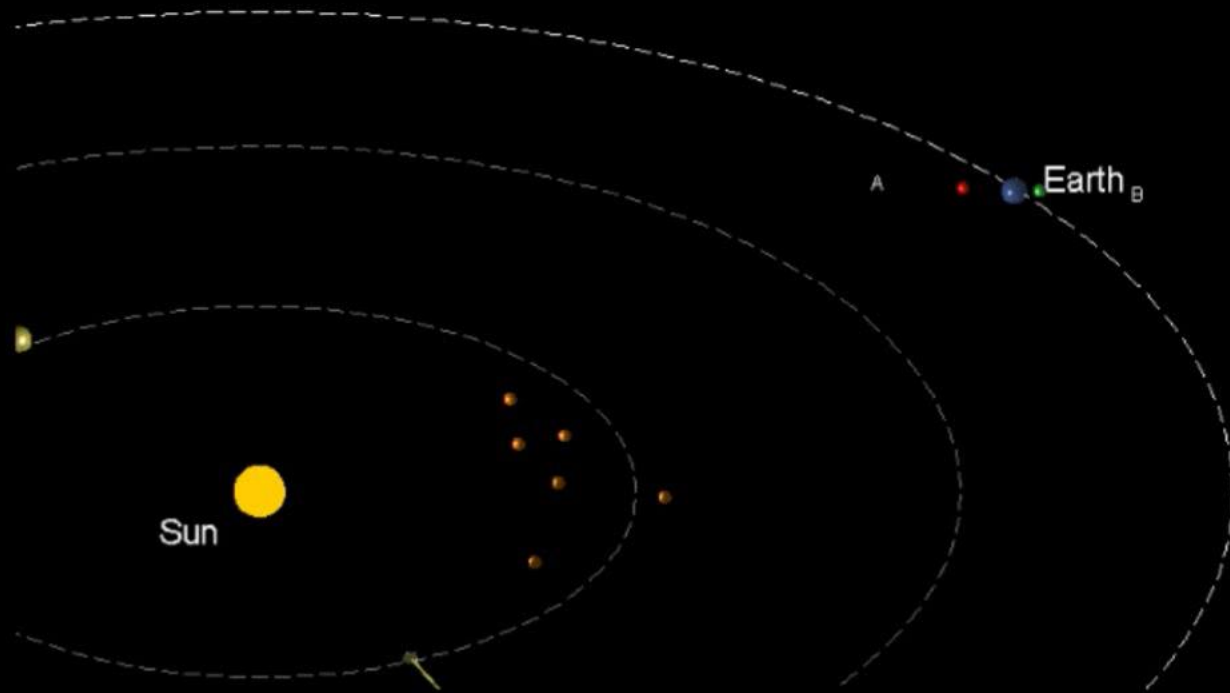
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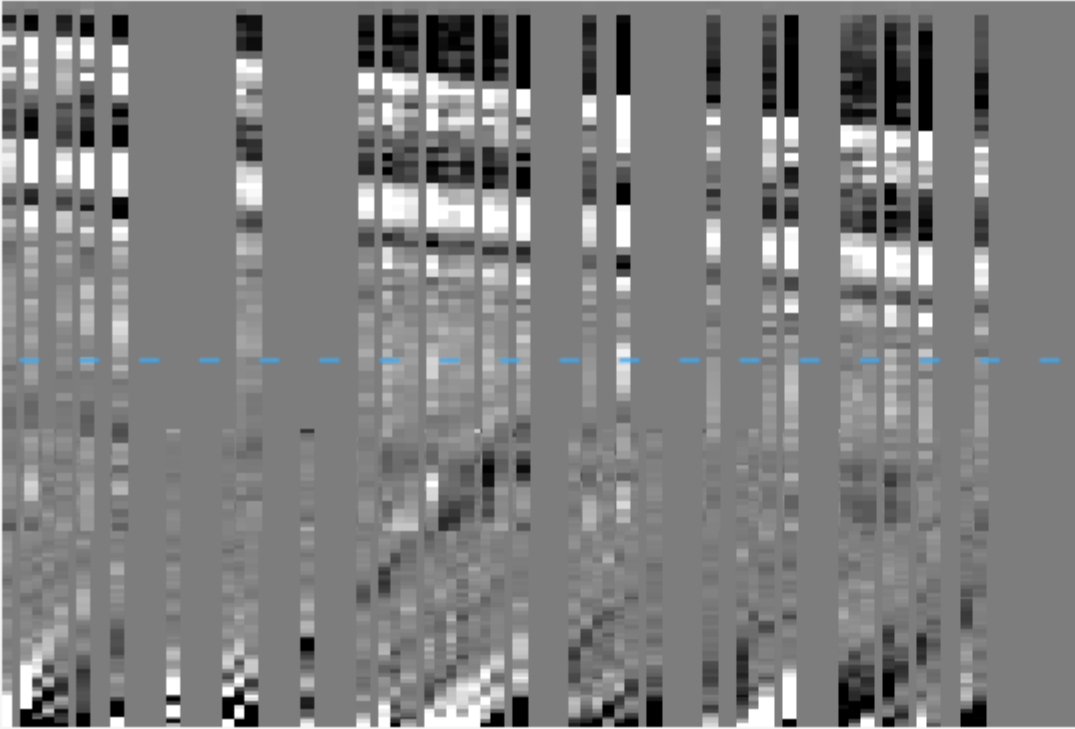
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2007/04/01 01:00

# Incoming Trace it

J-MAP FROM HELIOSPHERIC IMAGERS 1 AND 2



MARKS  
00/20

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DELETE

SIZE

SHOW/HIDE

RESET

★ ADD CLIP TO FAVOURITES

## YOUR ANSWER

Make sure you mark as much of the storm as you can. Then press **SEND ANSWERS**. If you can't see any feature near the right hand side of the image press **NOTHING TO SEE HERE**

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SEND ANSWERS >

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Started by [Qualiss](#)

811 Views

by [Qualiss](#)



## Planet Hunting new

Started by [Qualiss](#) < 1 2 >

28 Replies  
5668 Views

April 21, 2011,  
03:49:35 am  
by [Qualiss](#)



## WHAT'S THAT?

Started by [jules](#)

0 Replies  
3204 Views

March 01, 2010,  
12:25:24 am  
by [jules](#)



## New Prediction new

Started by [srcrothers](#) < 1 2 3 ... 26 >

387 Replies  
20507 Views

June 19, 2013,  
08:51:10 am  
by [srcrothers](#)



## Creating educational Solar Filters new

Started by [mystarrymessenger](#)

3 Replies  
111 Views

June 10, 2013,  
04:37:19 pm  
by [jules](#)



## Want to attend the Zooniverse Project Workshop in Chicago? new

Started by [jules](#)

2 Replies  
186 Views

May 16, 2013,  
06:03:13 pm  
by [Qualiss](#)



## soho alert new

Started by [srcrothers](#) < 1 2 3 >

34 Replies  
3413 Views

May 16, 2013,  
01:37:49 pm  
by [srcrothers1](#)



## Solar storm achievements

Started by [Chocstar](#)

7 Replies  
259 Views

May 07, 2013,  
10:18:19 pm  
by [jules](#)



## New predictions of the cometary kind new

Started by [srcrothers1](#) < 1 2 >

26 Replies  
788 Views

April 19, 2013,  
09:16:45 am  
by [srcrothers1](#)



## Incoming new

14 Replies

March 26, 2013,



## srcrothers

Science Team  
Sr. Member



Posts: 310



### Re: New Prediction

« **Reply #384 on:** June 07, 2013,  
11:00:23 am »




Quote

This one should give Venus a nudge but misses us...

<http://www.solarstormwatch.com/storms/320>

Steve

Report to moderator  Logged

## srcrothers

Science Team  
Sr. Member



Posts: 310



### Re: New Prediction

« **Reply #385 on:** June 13, 2013,  
01:31:55 pm »



Quote

Do you know where your tin hats are? Probably a glancing blow...

<http://www.solarstormwatch.com/storms/321>

Steve 😊

Report to moderator  Logged



# SOLAR STORMWATCH

HOME

WHY SCIENTISTS NEED YOU

MISSION BRIEFING

SPOT & TRACK STORMS

TALK ABOUT IT

## INCOMING SOLAR STORM: 11 JUNE 2013

- **Time & Date:** Solar storm expected at Earth 10:00 14 June 2013 GMT
- **Estimated speed:** 540 kilometres per second
- **Proximity to Earth:** Glancing Blow



### THIS PREDICTION OF EARTH-BOUND SOLAR STORMS USES CLASSIFICATIONS MADE BY THESE SOLAR STORMWATCH MEMBERS

- gwnashjr
- pinkfiddler
- MingMing
- lspieler
- PADDLO
- watersnake
- Bkesm605
- patfinney

### Forum

Want to discuss this discovery? Head on over to the forum.

SOLAR STORMWATCH FORUM

### Share this alert

+ Share |   

### Generate next alert

PLAY INCOMING!

### Official prediction

Visit NASA's <http://spaceweather.com> website to see how this forecast compares with the professionals'

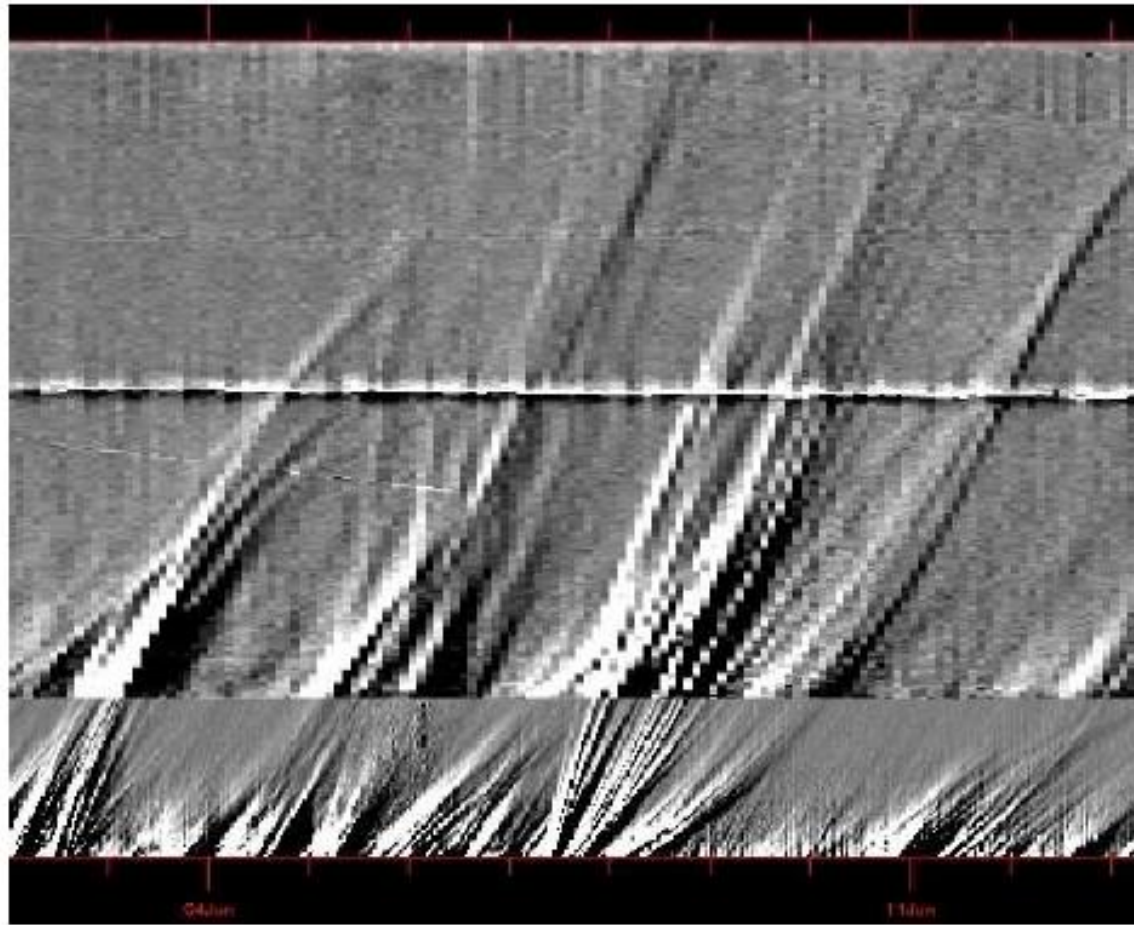
### Other results for this storm

SPOT ANALYSIS

TRACE IT ANALYSIS

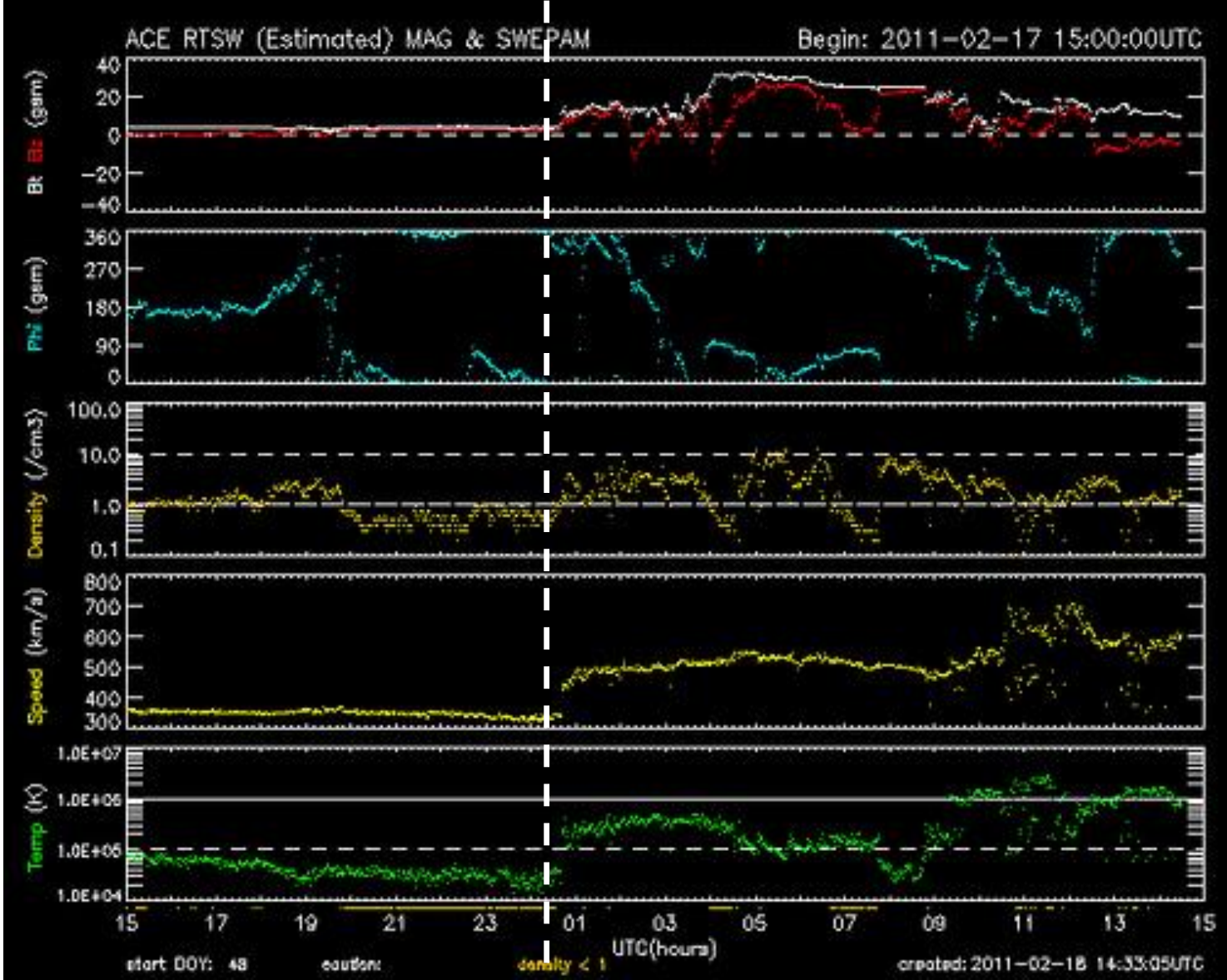
TRACK IT BACK ANALYSIS

# The challenge of forecasting: Science data versus real-time data



What are the scientists getting to see (in real time) after

# How do we know when the storm has reached Earth?



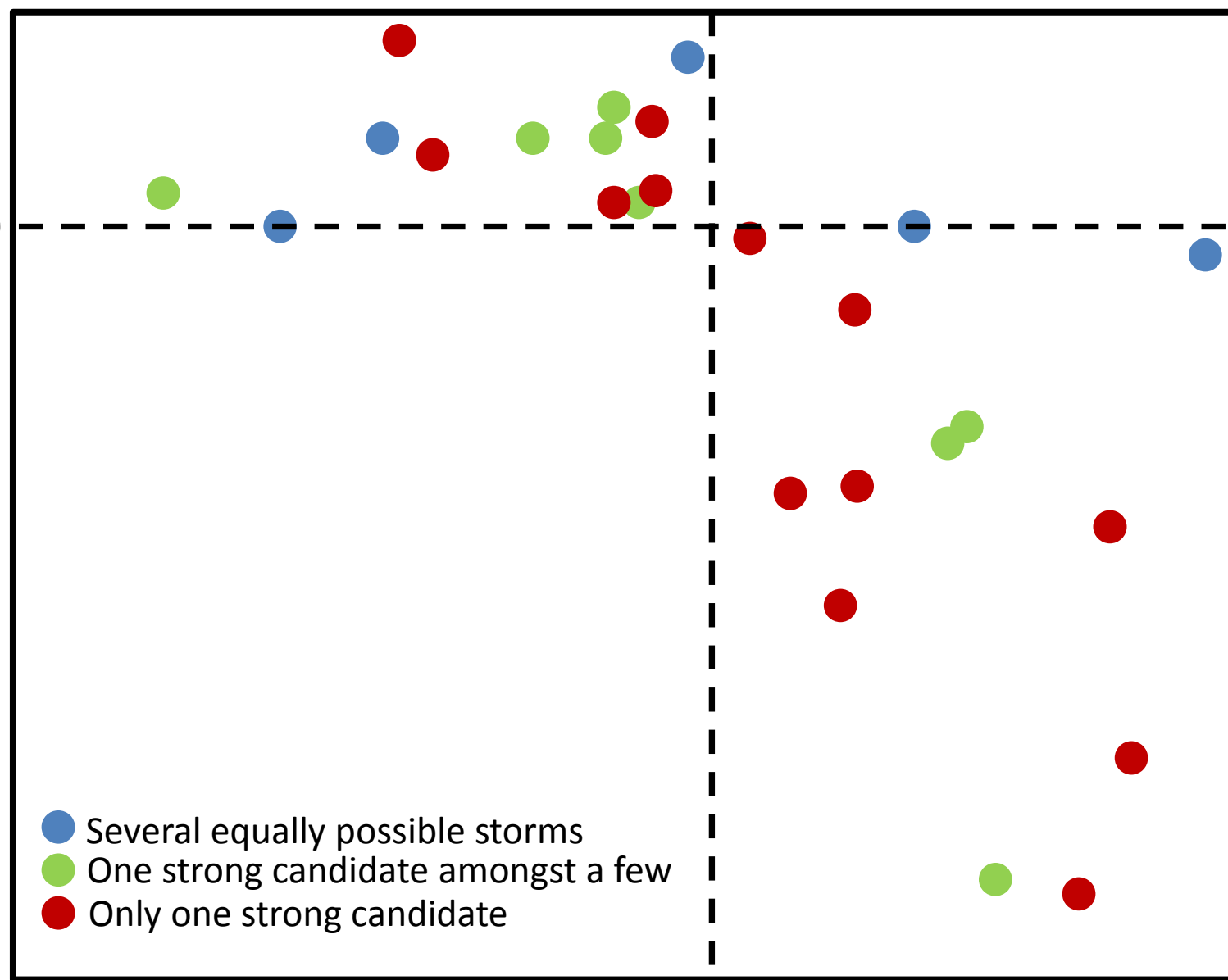
[Predicted-Observed] solar wind speed (km/s)

0

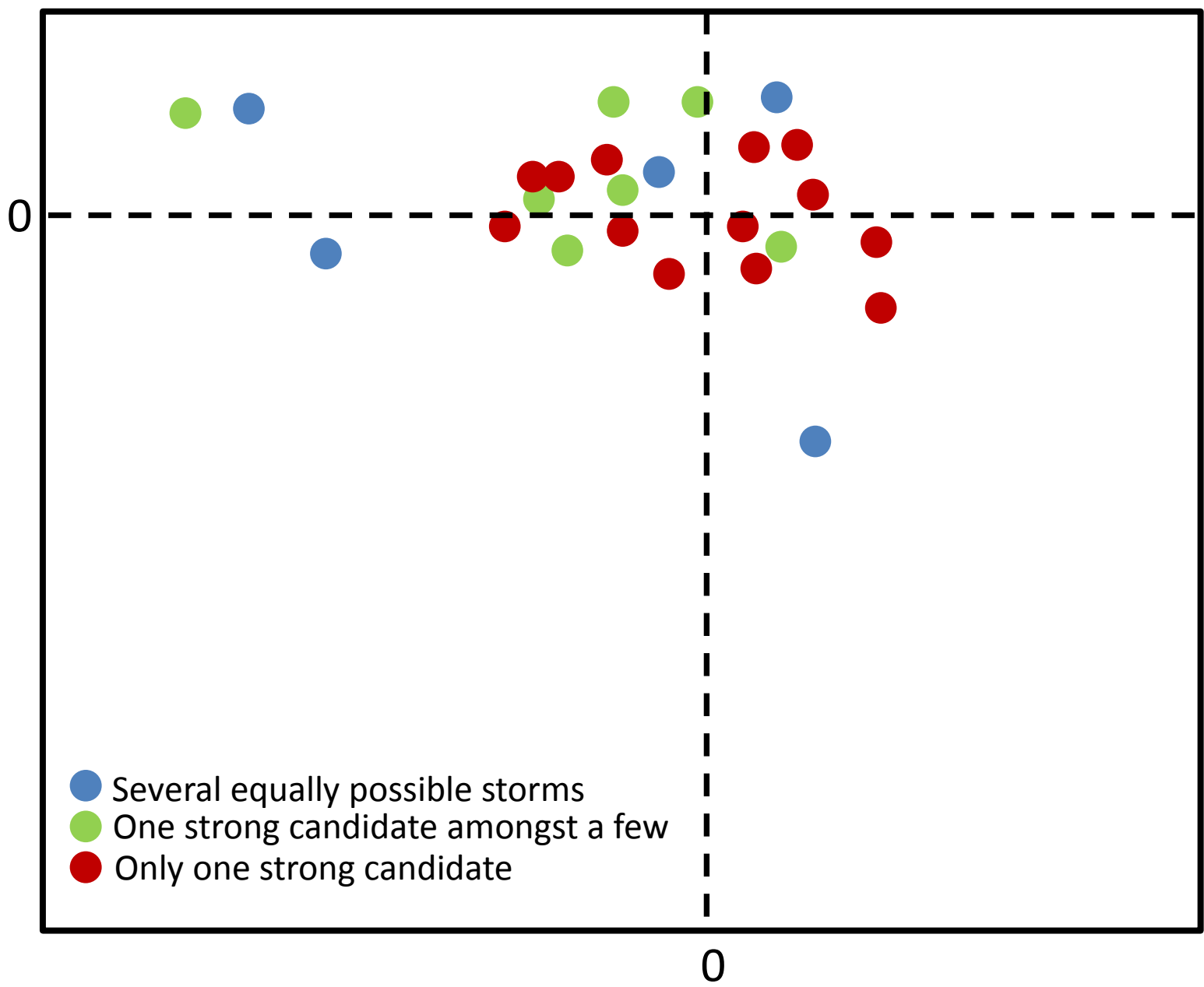
- Several equally possible storms
- One strong candidate amongst a few
- Only one strong candidate

0

[Predicted - Observed] arrival time (hours)



[Predicted-Observed] solar wind speed (km/s)



[Predicted - Observed] arrival time (hours)

Solar Stormwatch volunteers have enabled us to make genuine real-time predictions of space weather events at Earth

By comparing these with in-situ spacecraft data near Earth we can assess the accuracy of our predictions of solar wind speed and arrival times

The Stormwatch results have enabled us to investigate ways of improving the 'space weather forecast' by using genuine real-time predictions made without the benefit of hindsight

By far the greatest motivation for volunteers is that they are contributing to genuine science problems

Over 16,000 volunteers (1/3 UK, 1/3 USA) have contributed to five scientific papers so far...