2D Solar Wind Propagation for HELIO

Paul A. Higgins[1], **David Perez-Suarez**[1], Caitriona Jackman[2], Peter T. Gallagher[1]

1. Trinity College Dublin
2. University College London

Goals

- Use **in situ** solar wind data to estimate **properties** of heliosphere in the **ecliptic plane**

See: Usmanov et al., 2000

- Use **multiple** spacecraft to analyse **HSSW** streams and **ICMEs** out to 1 AU (OMNI, STA, STB)

See: Opitz et al., 2009 & 2010

- Use **OMNI** and **Pioneer 10** data to analyse events at **Jupiter**

See: Prangé et al., 2004

Method

SHILLELAgh: Solarwind-Heliosperic Imaging in Latitude and Longitude by Estimating Large-scale Attributes

("shi-lay-lə")

Propagate **in situ** data from one or more spacecraft to a grid of points in **ecliptic plane**

Assumptions:

- Solar wind propagates perfectly **radially** in the **ecliptic plane**
- **Corona** is **static**

Method

1. **Radially** propagate in situ data (assume perfectly radial wind)

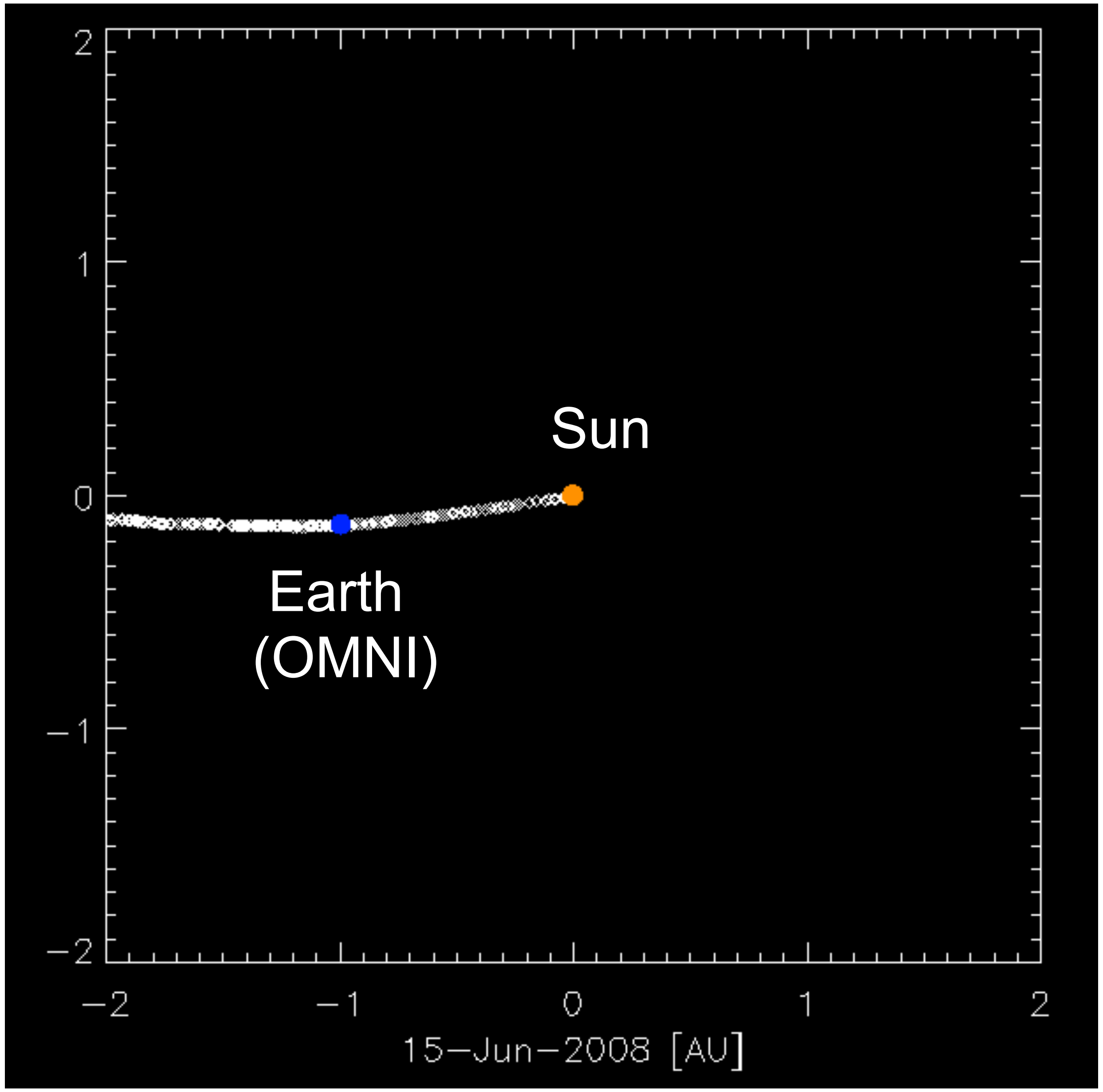
$$R_{\mathrm{pt}} = R_{\mathrm{sc}} + v_{\mathrm{pt}}(t_{\mathrm{now}} - t_{\mathrm{pt}})$$

R_{sc} = radius of spacecraft

t_{now} = "current" time for map

t_{pt} = time data point was recorded

v_{pt} = solar wind speed

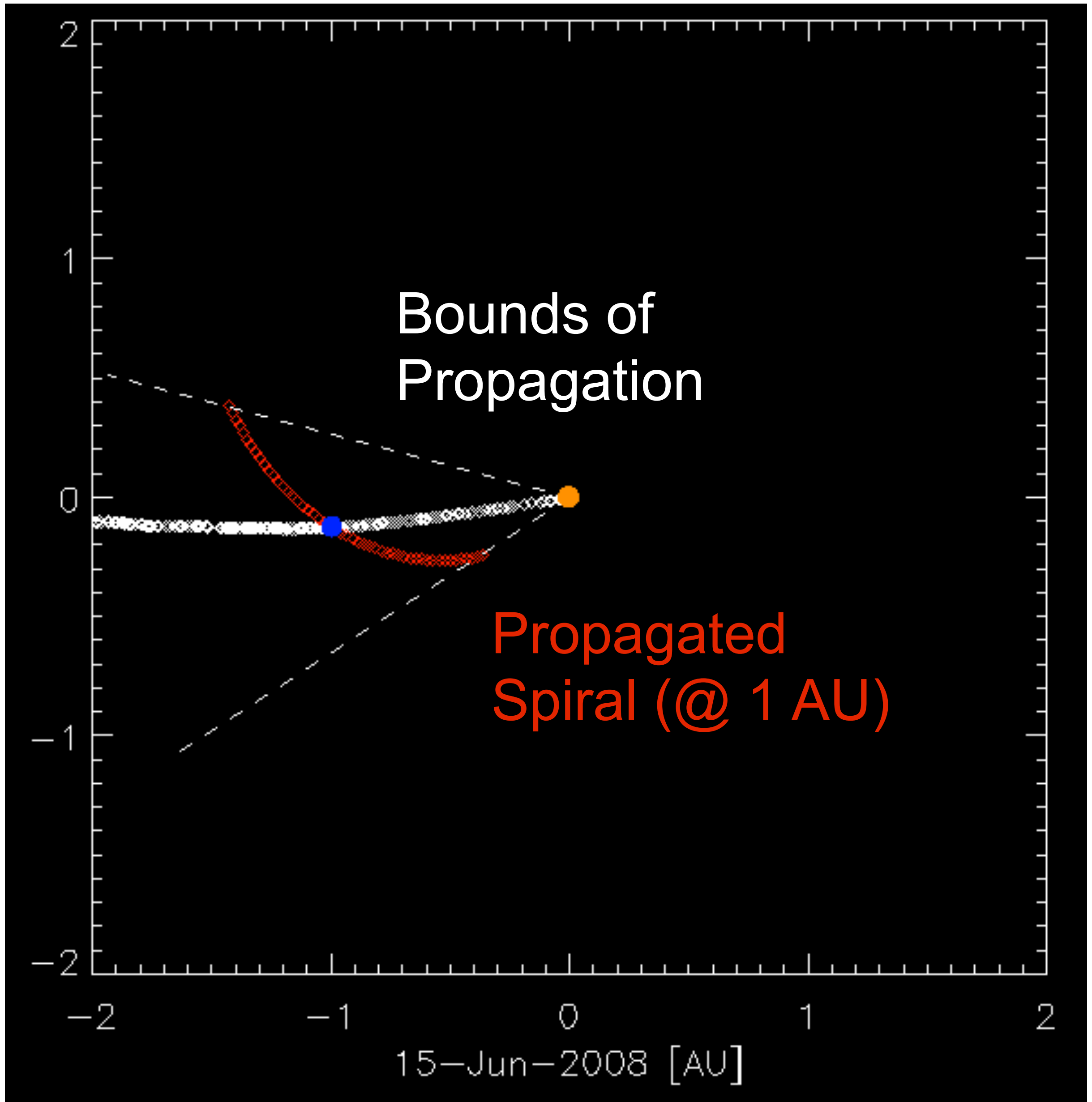


(Line is curved due to spacecraft motion)

Method

2. Propagate each data point **along** the **spiral** passing through it (assume static corona)

$$R(\theta) = R_{\mathrm{pt}} - v_{\mathrm{pt}}(\phi - \phi_{\mathrm{pt}})/\omega_{\odot}$$



R_{pt} = radius of data point

ϕ = Longitude of spiral

ϕ_{pt} = Longitude of data point

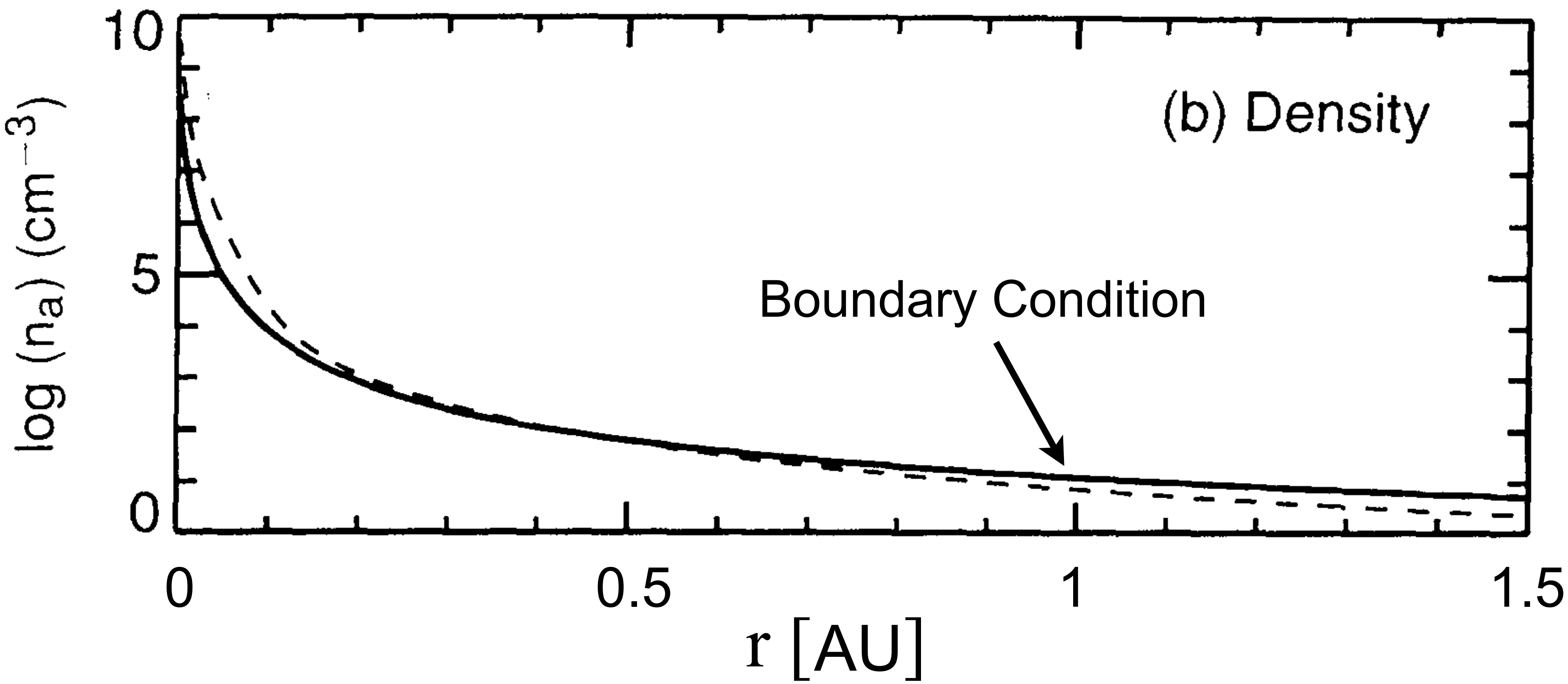
v_{pt} = radial speed of data point

$\omega_{\odot}$ = solar angular rot. speed (equator)

Method

3. Optionally assume model for radial dependence of properties (i.e. density, magnetic field, temperature)

Example: Chen, 1996

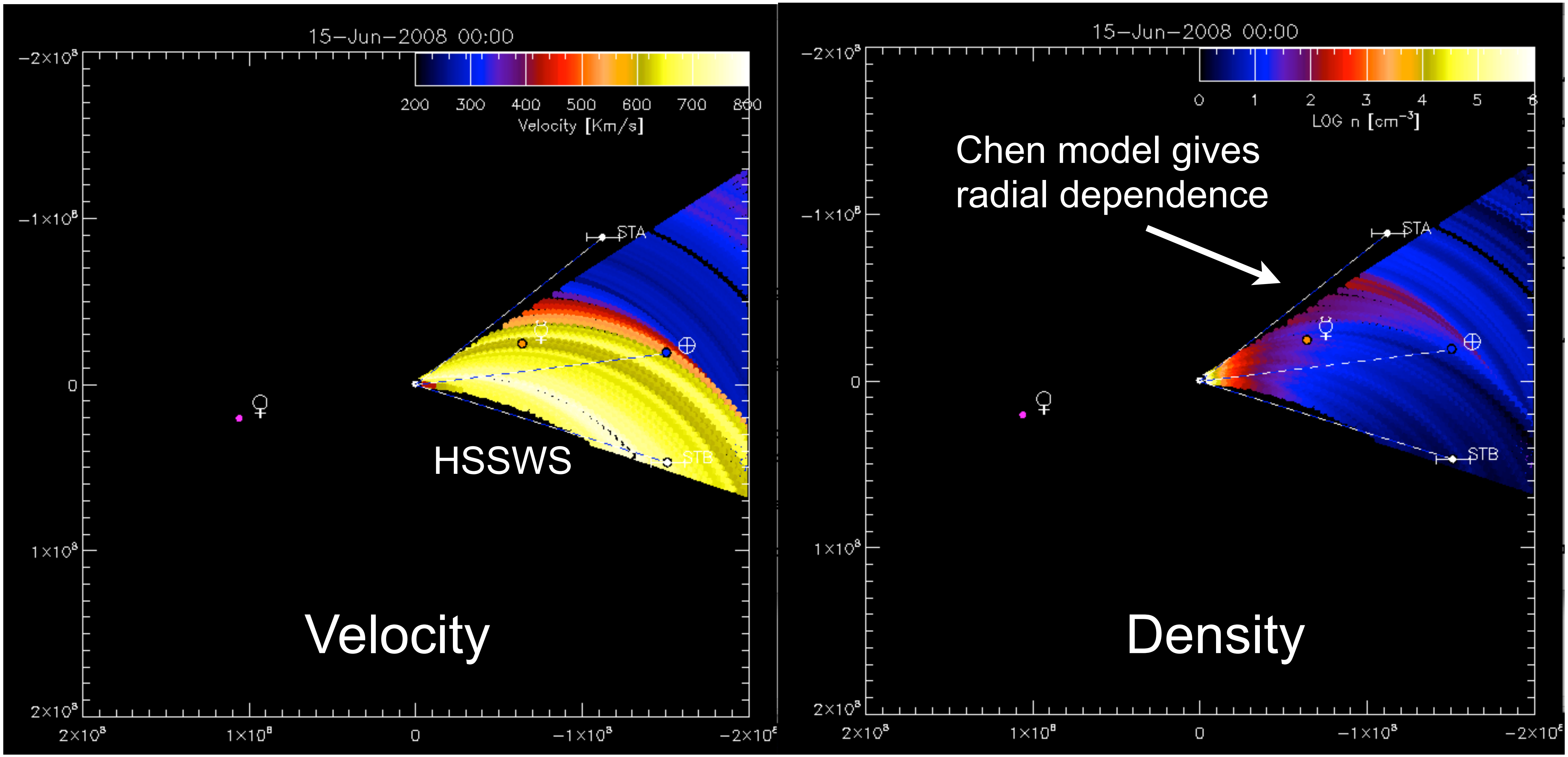


Chen density: $f(R) = 4(3R^{-12} + R^{-4}) \times 10^8 + 3.5 \times 10^5 R^{-2}$

Our model: $n(R) = n'(R)\left(\frac{f(R)}{f(R_{sc})}\right)$ $\quad n'(R) =$ in situ values

Method

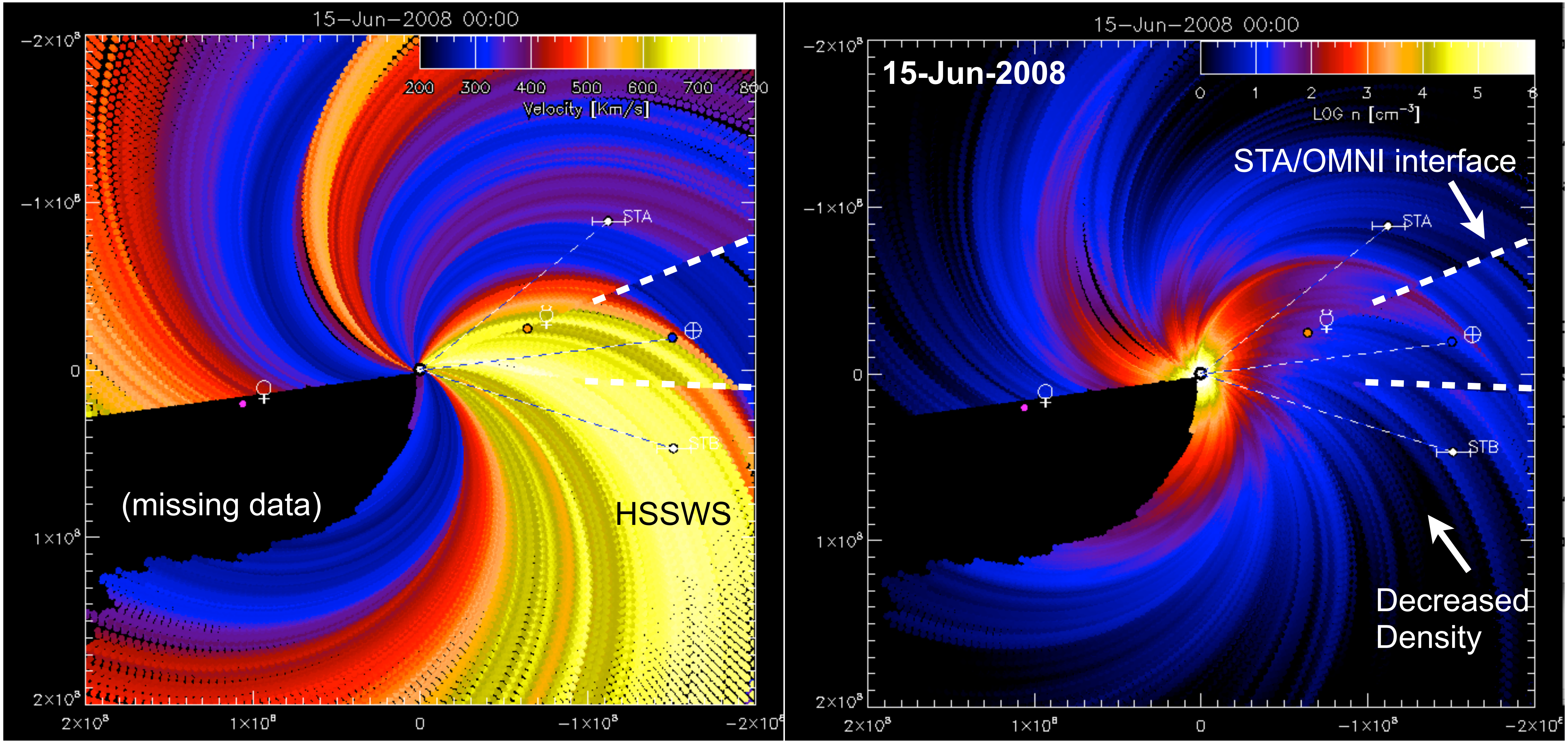
Completed propagation using **OMNI** data (1hr cadence)



15-Jun-2008

Example: High Speed Solar Wind Stream

Comparing STA, OMNI, STB

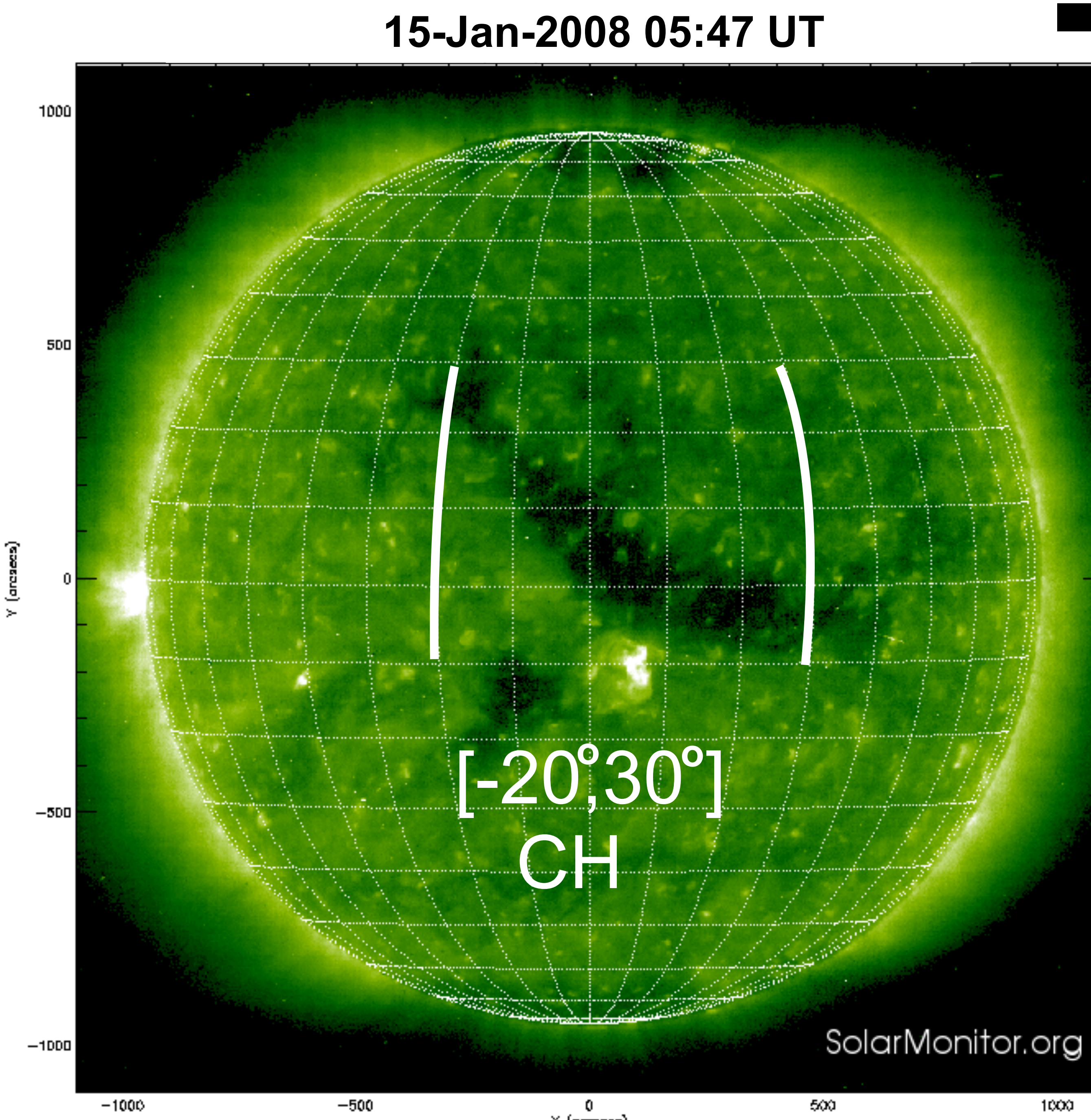


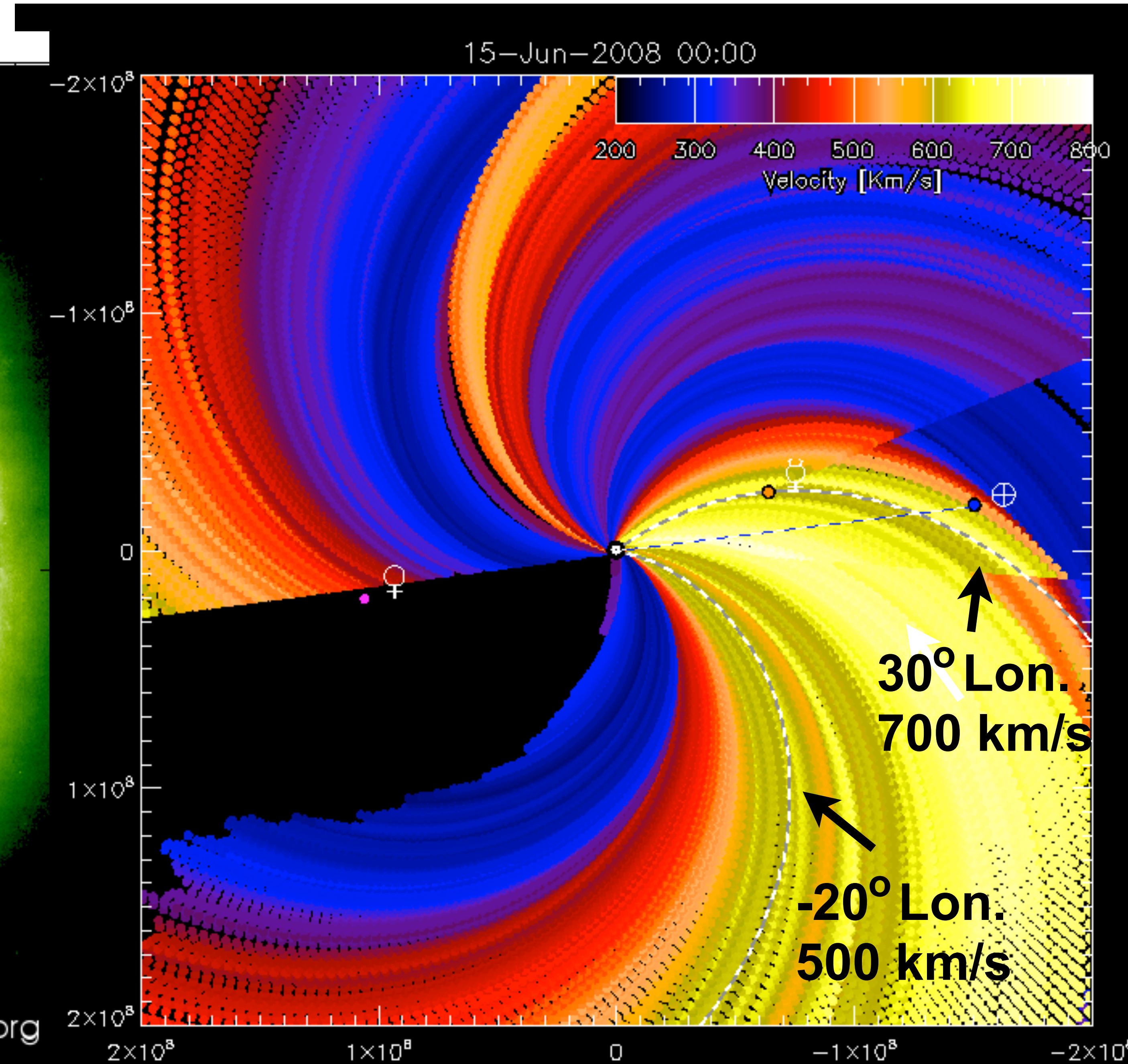
Interfaces provide information- spiral feature? non-spiral?
(**HSSW** stream?) (**CME**?)

Example: High Speed Solar Wind Stream

15-Jun-2008: In situ **HSSW** connected to **on-disk** coronal hole

Analysed in Krista & Gallagher, 2009



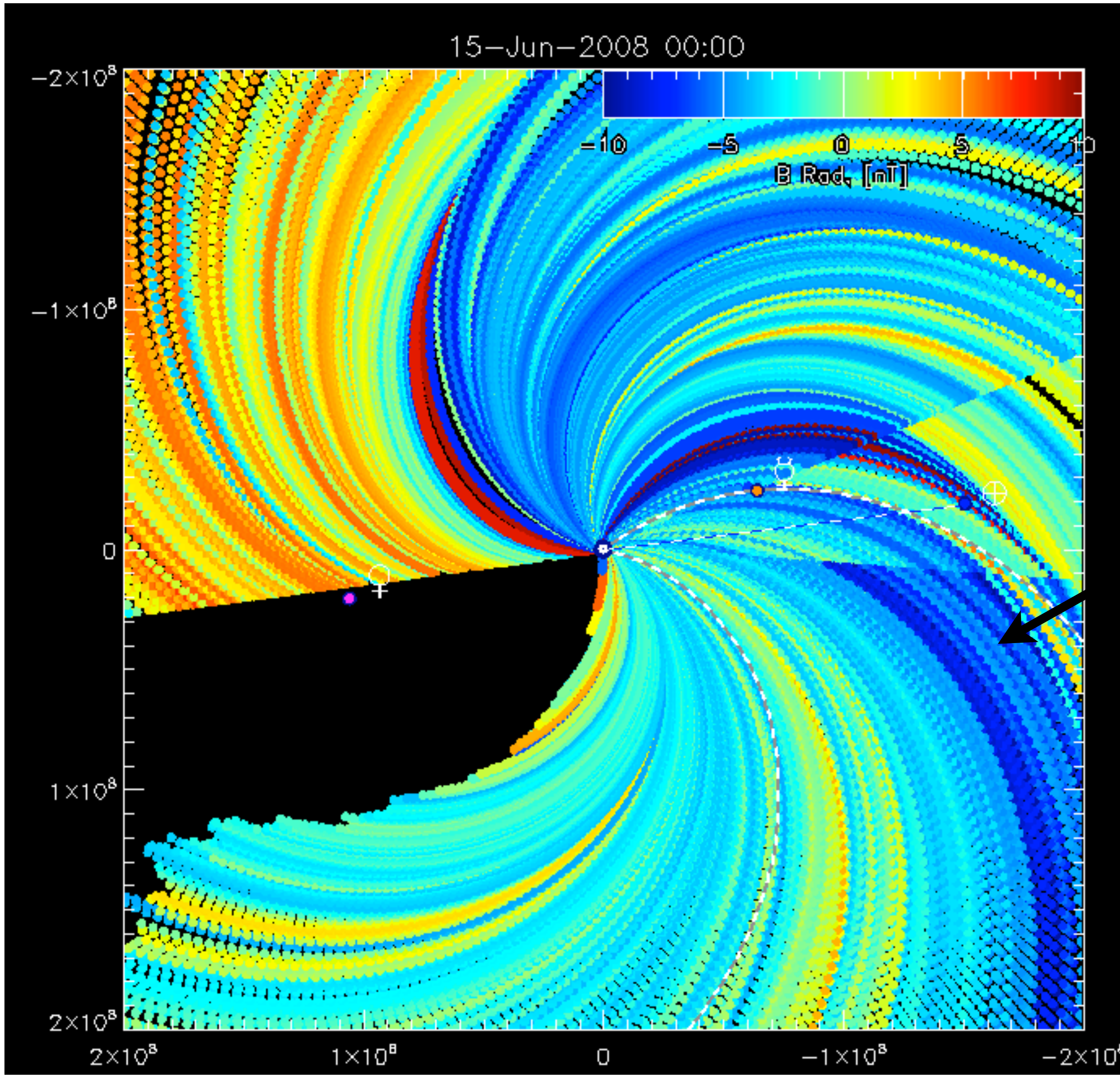


Foot-points are well matched to **HSSW**

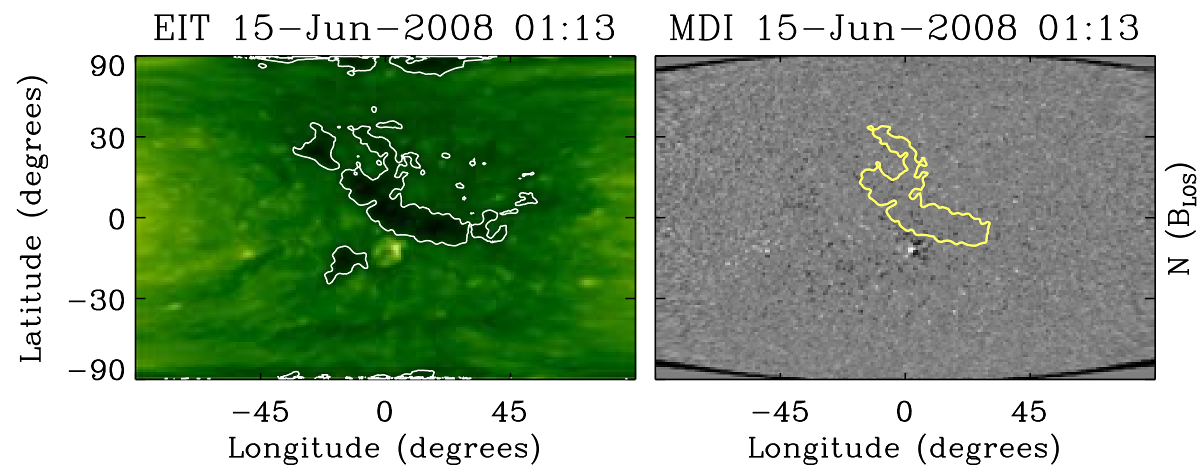
Example: High Speed Solar Wind Stream

Compare **polarity** of CH between **in situ** and **magnetogram**

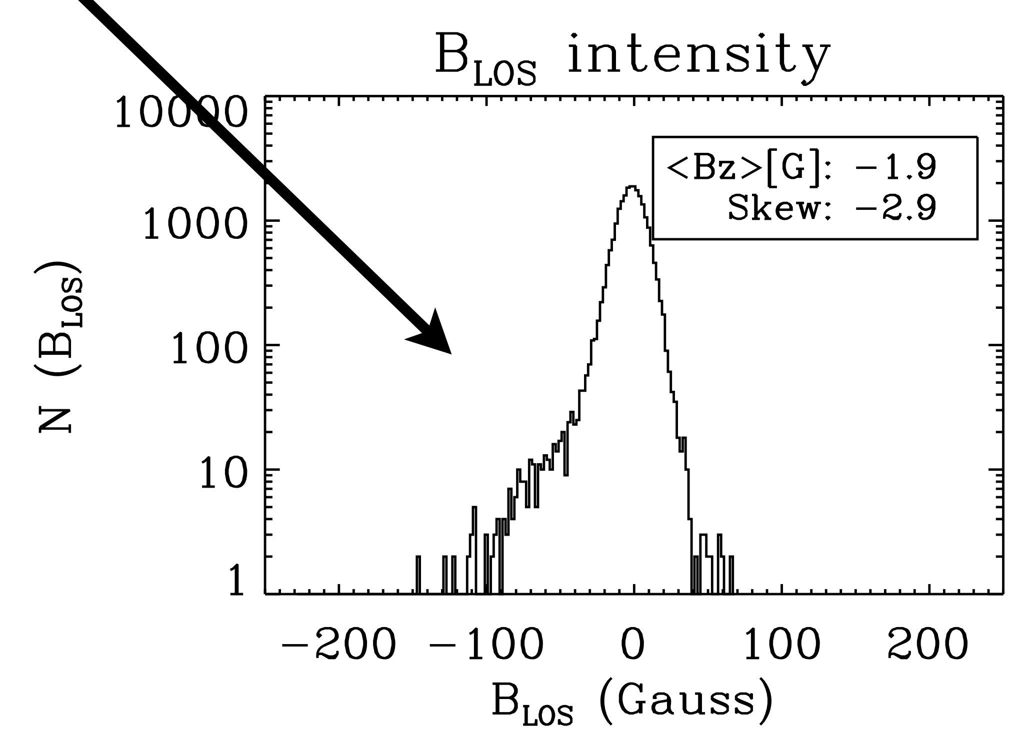
Radial Magnetic Field (B_{rad})



Krista & Gallagher, 2009



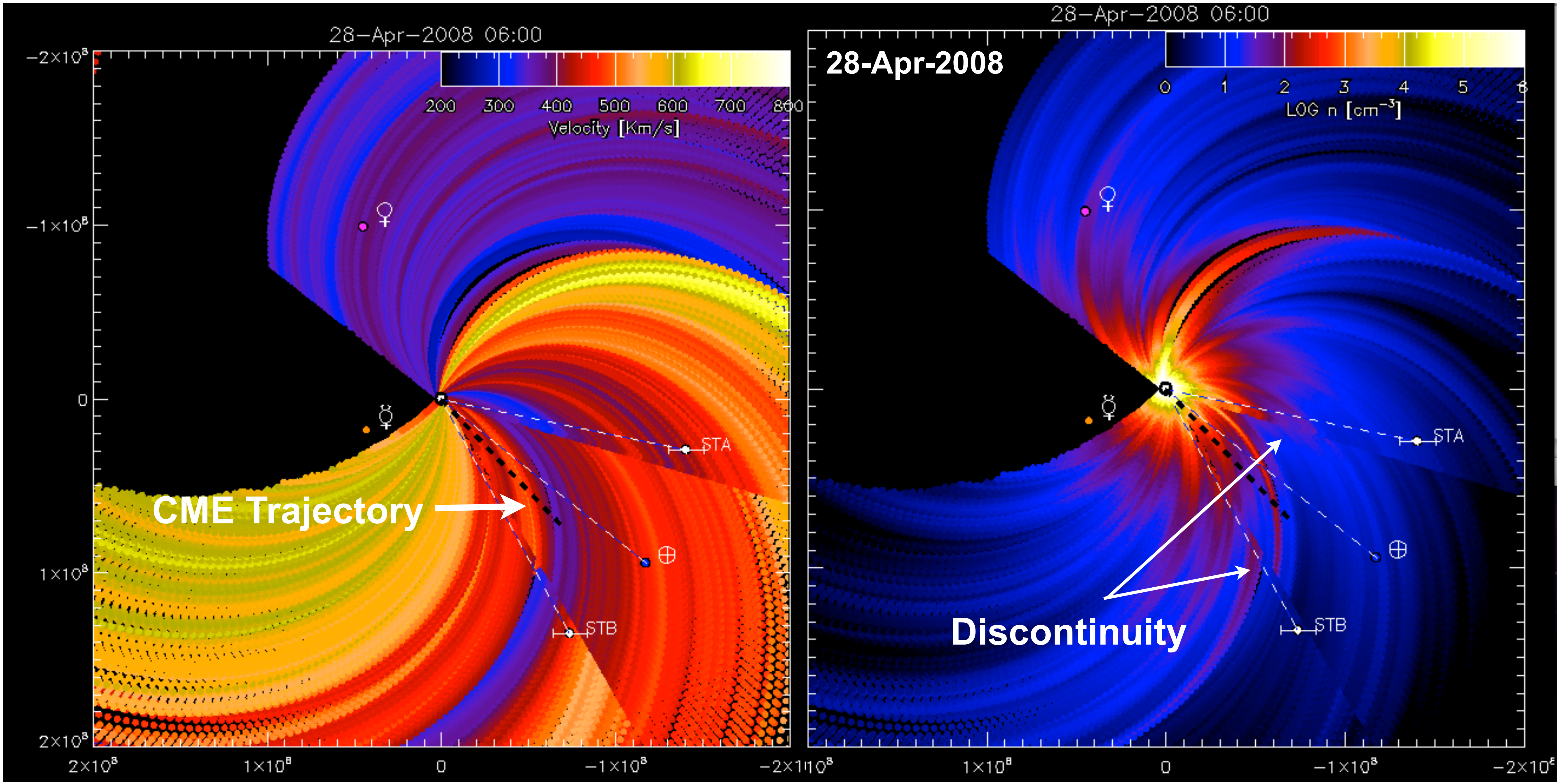
negative B_{rad} in situ and **negative** B_{los} in magnetogram



Example: In situ Coronal Mass Ejection

26-Apr-2008: **CME** erupts from ~N08,**E08** (partial halo in STA)

Analysed in Poomvises et al., 2010; Thernisien et al., 2009



Algorithm **breaks down** for CMEs (not spiral shaped...)

Discontinuities could be used to **detect** ICMEs!

Example: In situ Coronal Mass Ejection

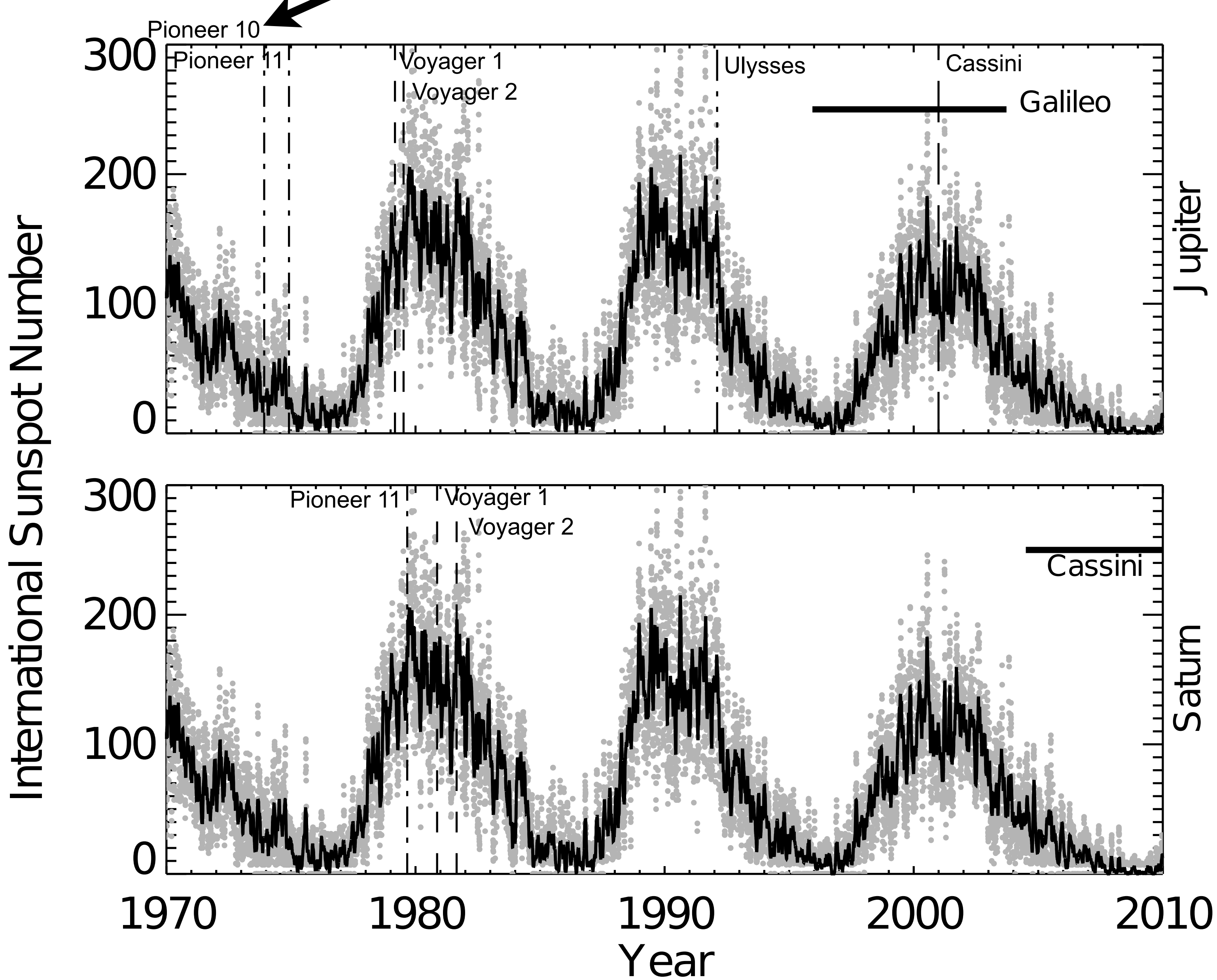
Movie of propagated data
at the time of the CME

Example: Propagating to the Outer Planets

Goal: Identify a **HSSW** stream from **Sun** to **Jupiter**

Pioneer 10 has **minimum** distance to **Jupiter** on 3-Dec-1973

From Jackman & Arridge, 2011

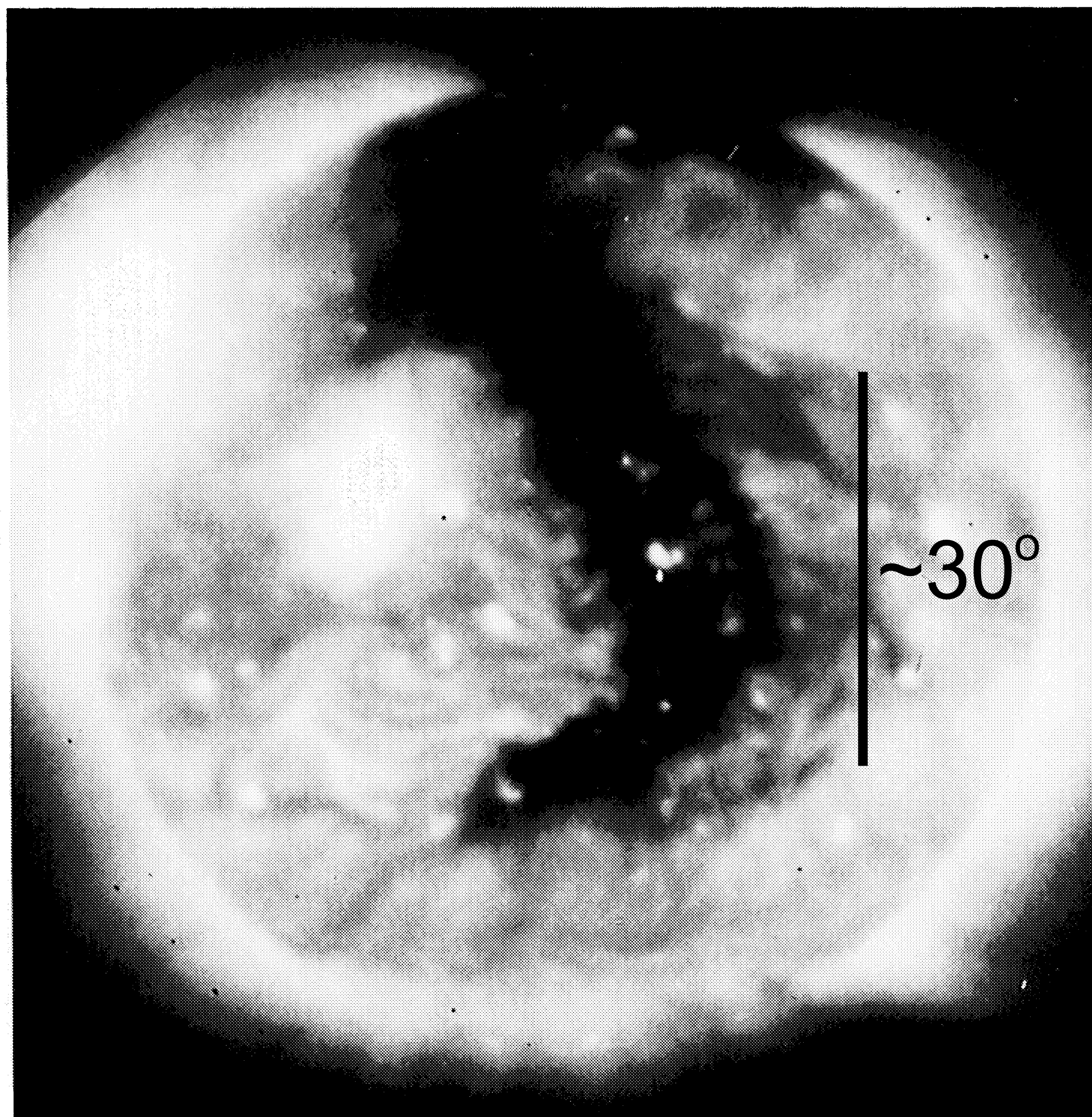


Example: Propagating to the Outer Planets

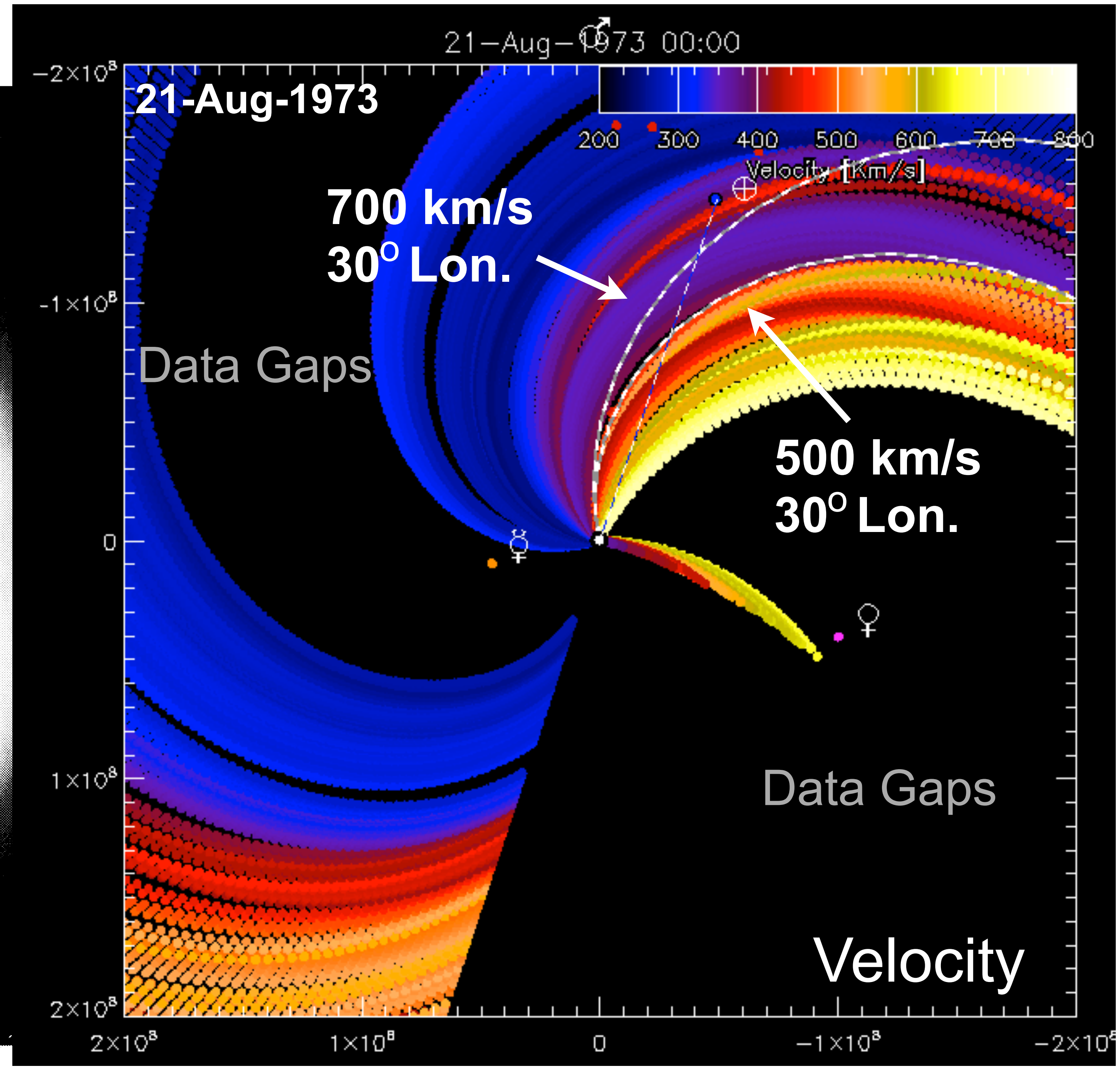
Disk-center **Coronal Hole**
From Maxson & Vaiana, 1977

In situ catches **leading edge** of the HSSWS

Sky Lab X-ray corona image
21-Aug-1973

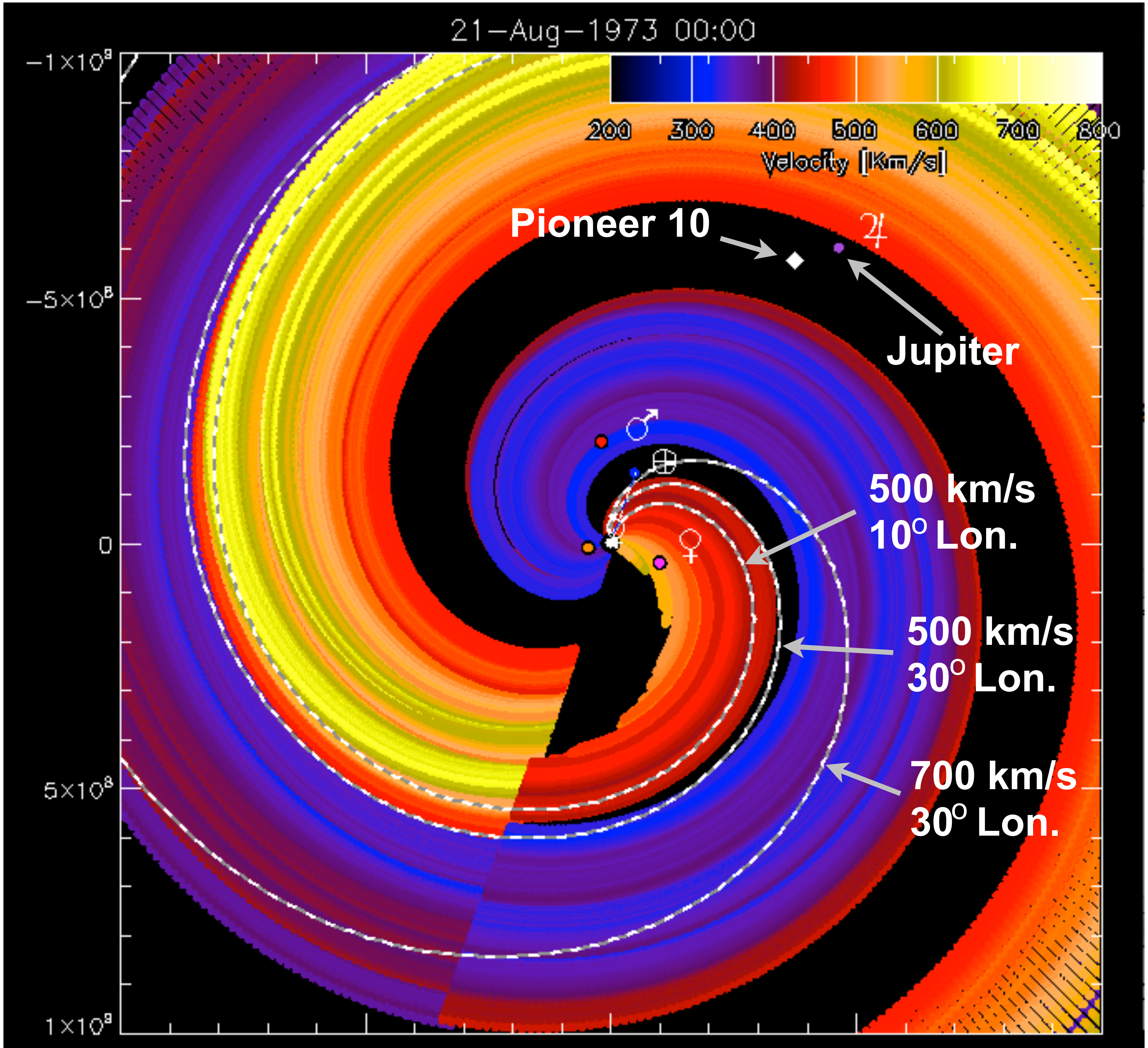


Using OMNI Data

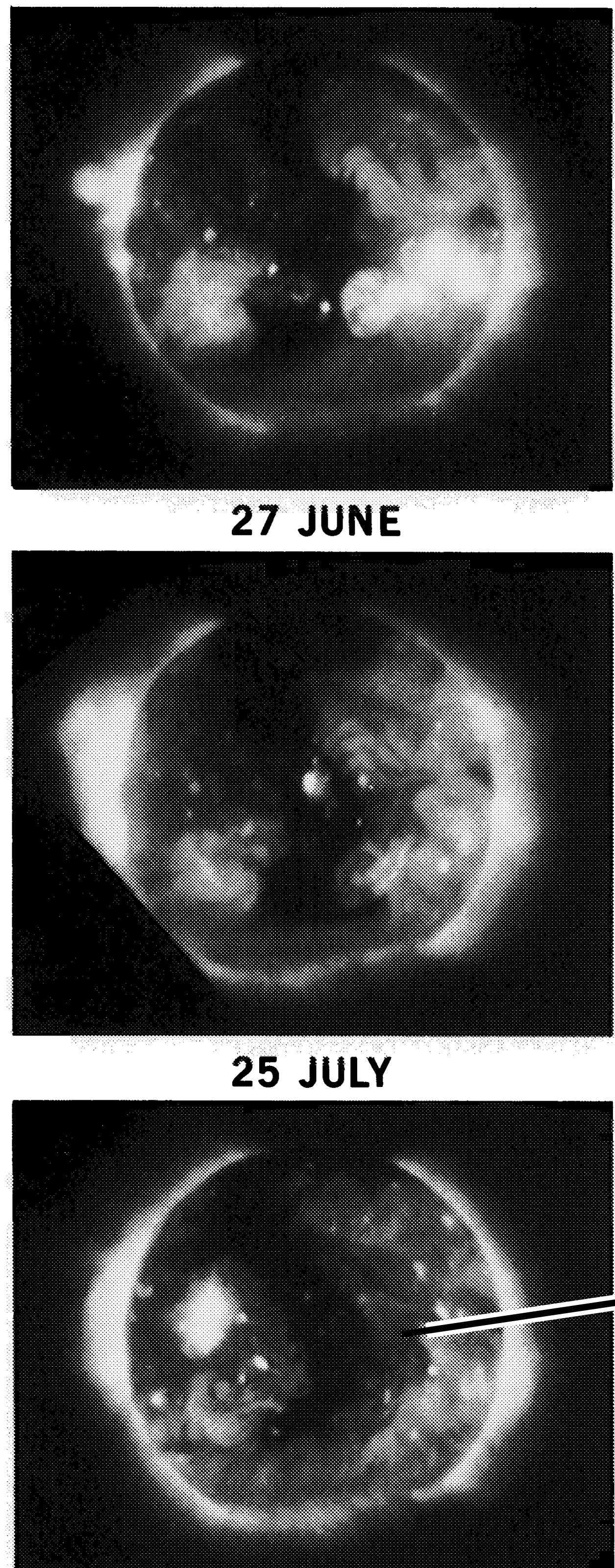


Example: Propagating to the Outer Planets

Using Pioneer Data



Example: Propagating to the Outer Planets



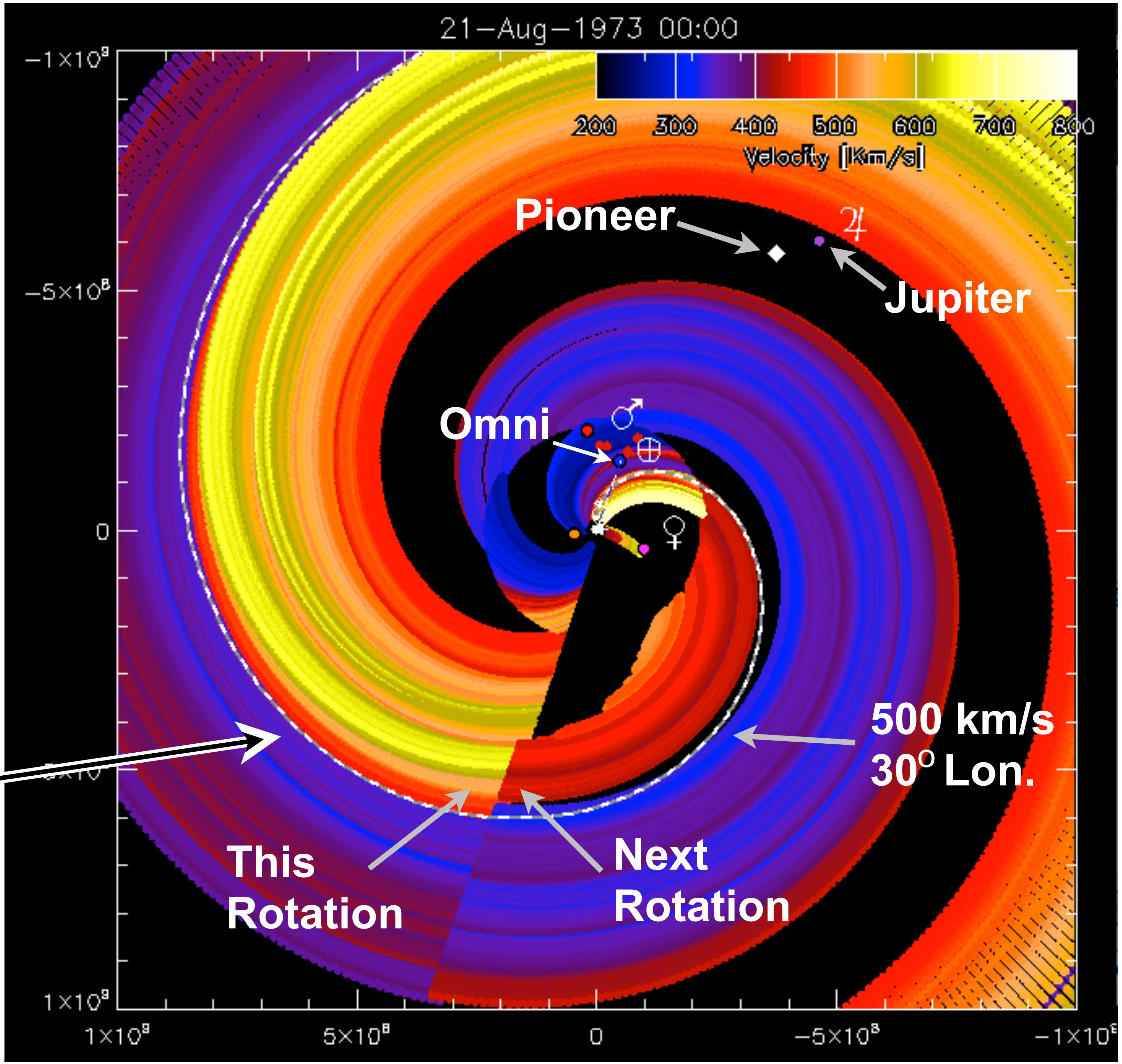
27 JUNE

25 JULY

21 AUGUST

Combined **OMNI** and **Pioneer** Plot

- **Decay** of HSSWS **velocity** observed



Conclusions

- **SHILLELAgh** is useful for quickly **identifying** SW features in large amounts of **in situ** data

- Provides good representation of **HSSW streams**

- Transients (e.g., **CMEs**) are identified by **discontinuities** between spacecraft (model breaks down)

- Allows **distant** observations to be **tied** back to the solar **surface**

    -This work shows **in situ** observation of CH **decay**

- **SHILLELAgh** useful to **HELIO** and other web services: provides **context** for large-scale **solar wind** attributes

.

Bonus slides

CME 2008-apr-26

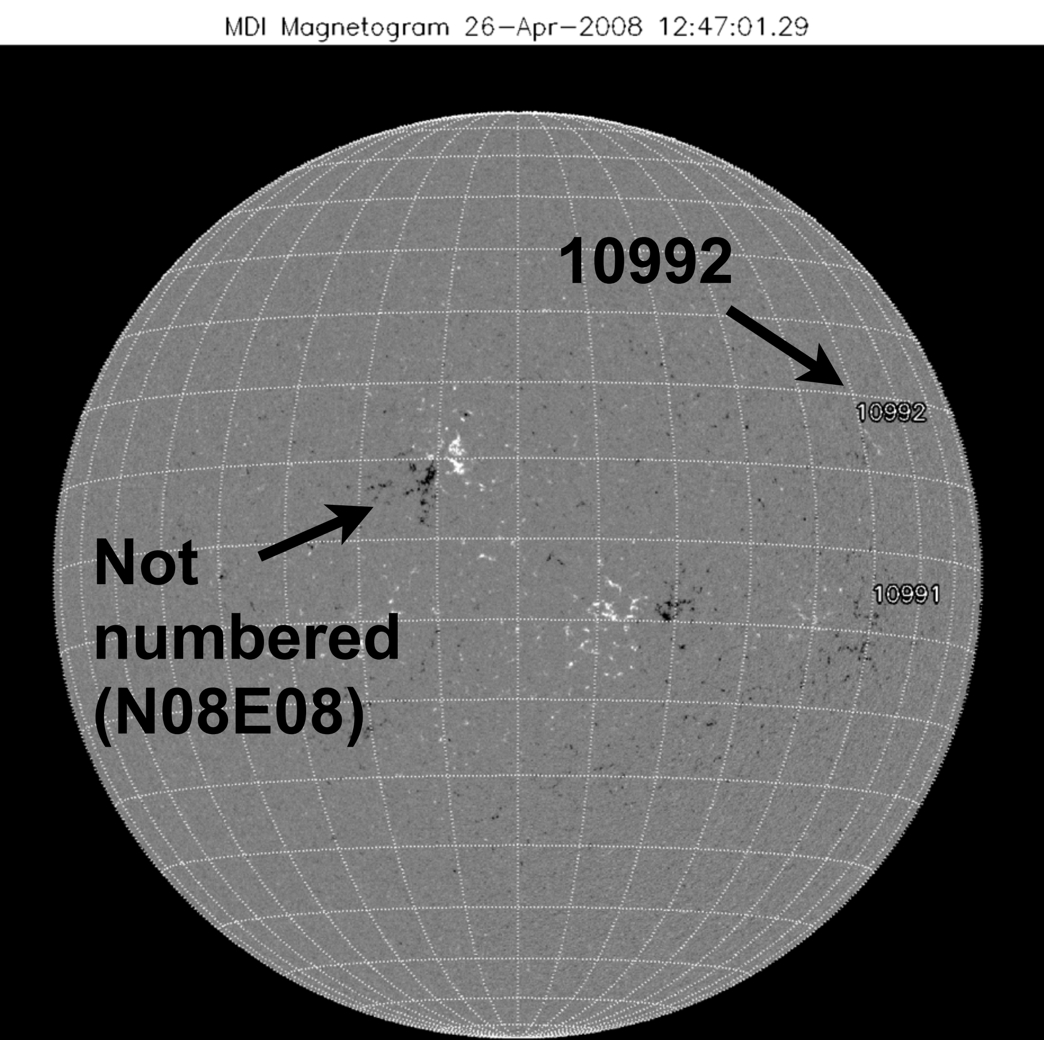
Thernisien et al., 2009

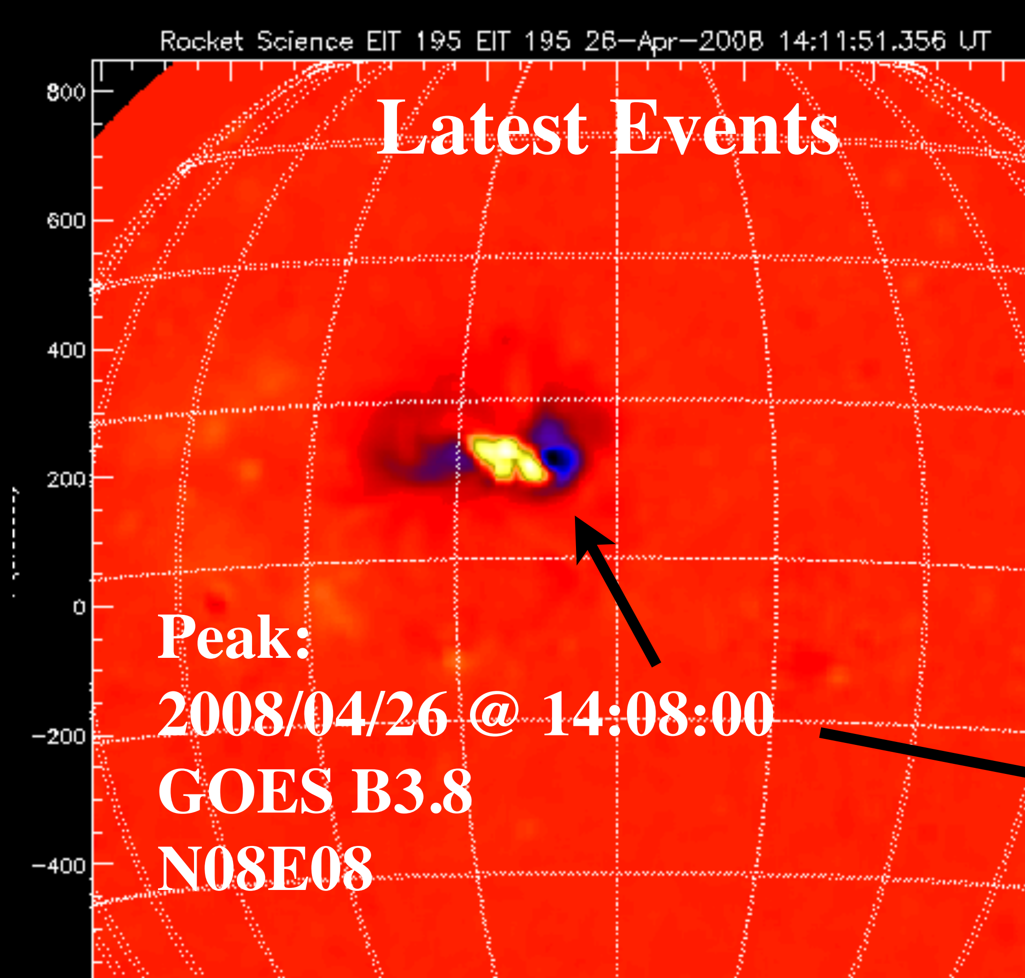
"CME of 26 April 2008
The pair of COR2 images for this CME are shown in the first row of Figure 4. We see that the CME travels toward the east in the FOV of A, and it appears as a halo in the FOV of B. "

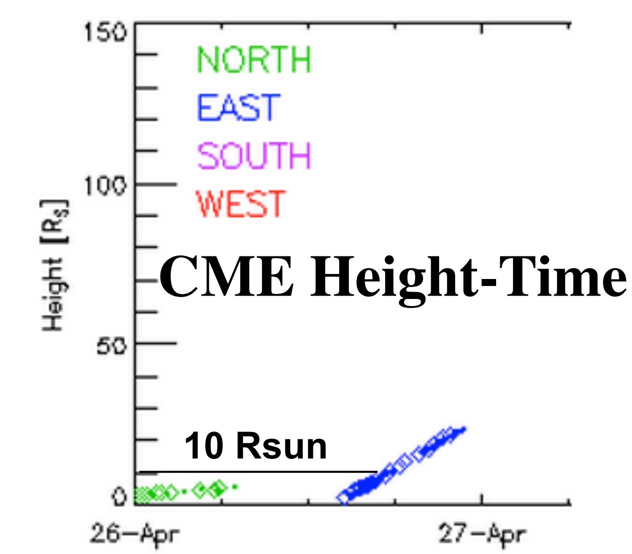
Poomvises et al., 2009

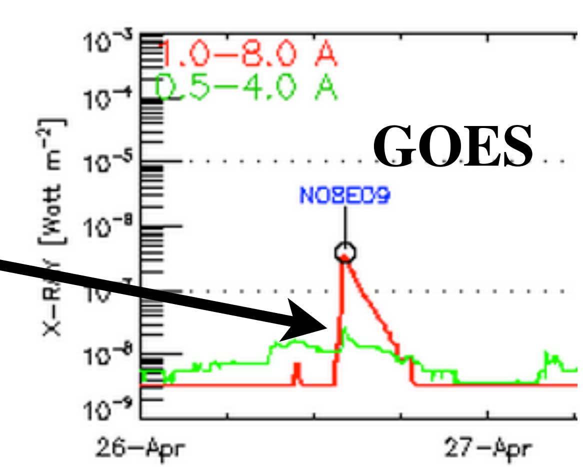
3.2. Event: 2008 April 26

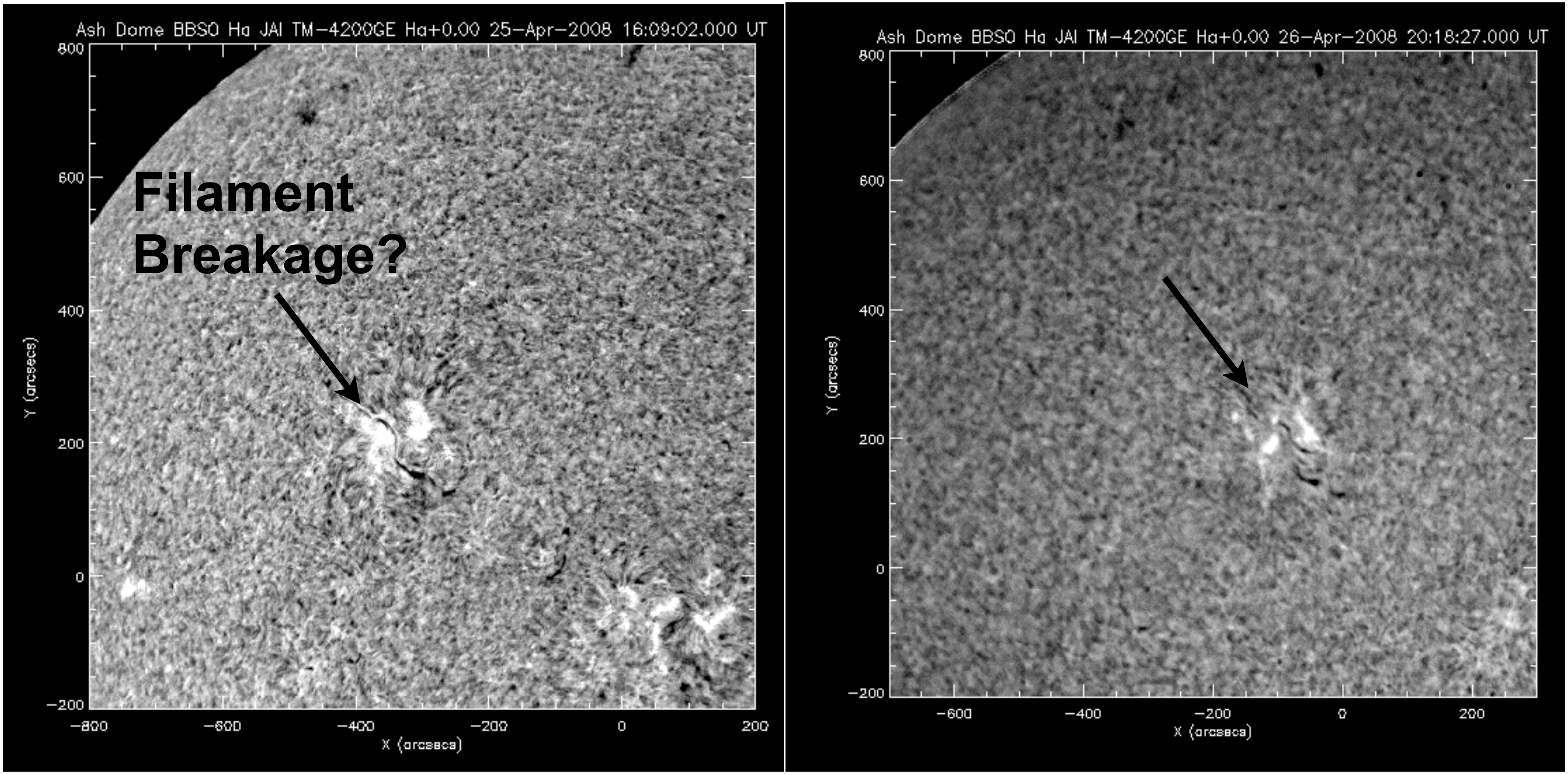
This event was originated at $\boxed{\text{NOAA AR 0992}}$ with heliographic coordinate $\boxed{\text{N13°W32°}}$ and Carrington longitude ~204° and latitude ~3°. This CME is a partial halo from the point of view of *STEREO A*. The evolution of the velocities of this CME is shown in Figure 3 (top panel). The LE velocity of this event at 13 $R_\odot$ is about 720 km s^{-1} and the velocity decreases to about 640 km s^{-1} at 40 $R_\odot$ and thereafter. Additionally, the minor radius expansion velocity converges to about 140 km s^{-1} and the bulk velocity to about $\boxed{500 \text{ km s}^{-1}}$ at large distances. The initial and final LE velocities that we obtain are consistent with those of previous studies of this event (Thernisien et al. 2009).

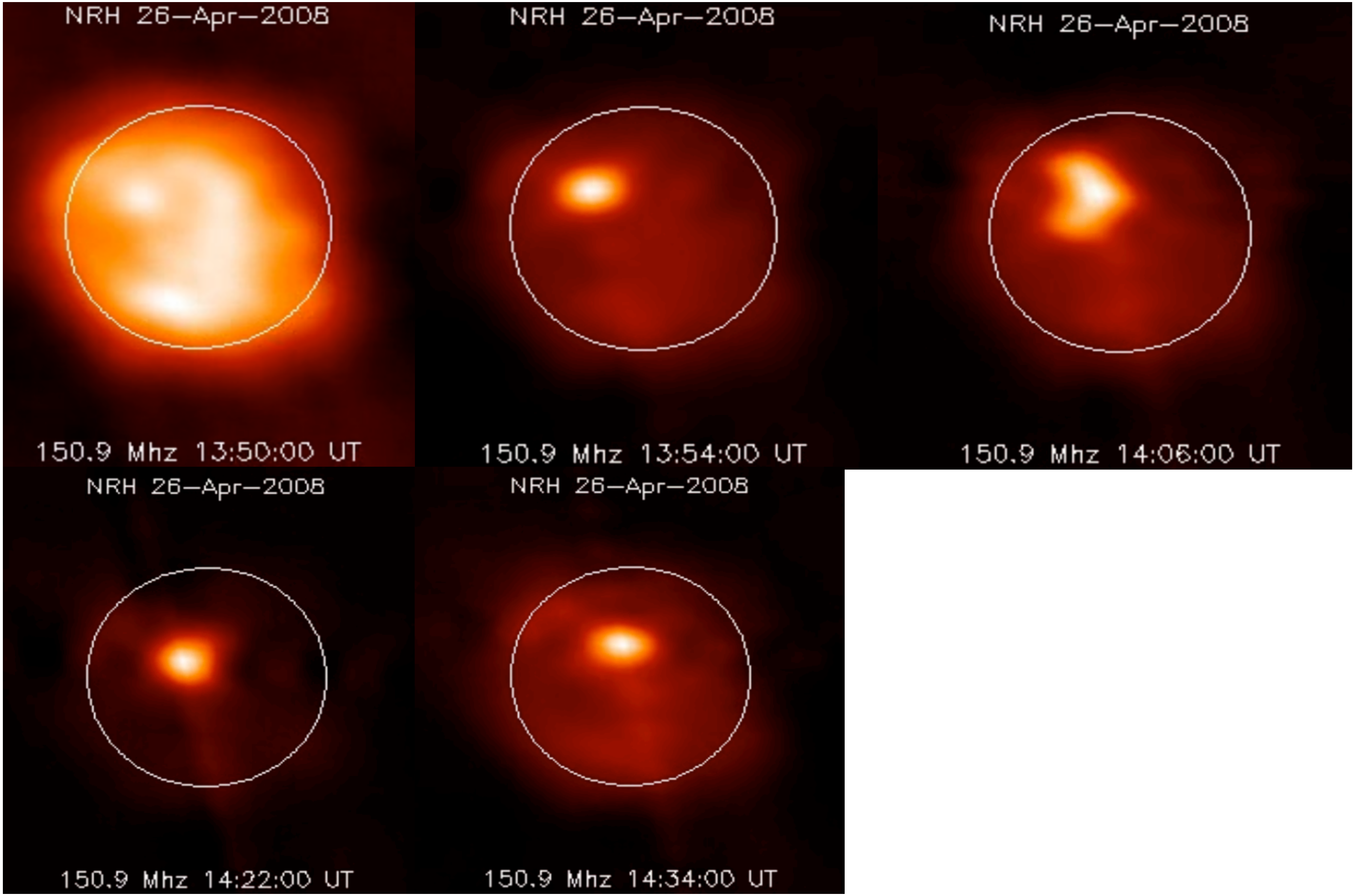









Ash Dome BBSO Hα JAI TM-4200GE Hα+0.00 25-Apr-2008 16:09:02.000 UT
Filament Breakage?
Y (arcsecs)
X (arcsecs)
Ash Dome BBSO Hα JAI TM-4200GE Hα+0.00 26-Apr-2008 20:18:27.000 UT
Y (arcsecs)
X (arcsecs)


NRH 26-Apr-2008
150.9 Mhz 13:50:00 UT
NRH 26-Apr-2008
150.9 Mhz 13:54:00 UT
NRH 26-Apr-2008
150.9 Mhz 14:06:00 UT
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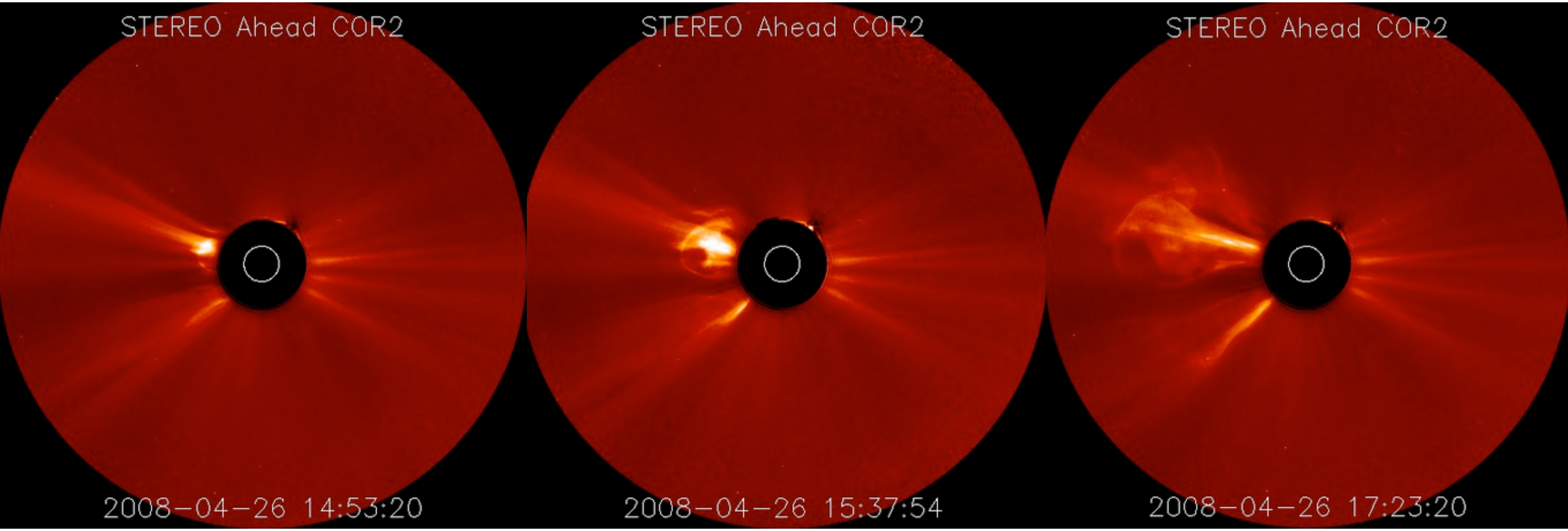
150.9 Mhz 14:34:00 UT


STEREO Ahead COR2
2008-04-26 14:53:20
STEREO Ahead COR2
2008-04-26 15:37:54
STEREO Ahead COR2
2008-04-26 17:23:20