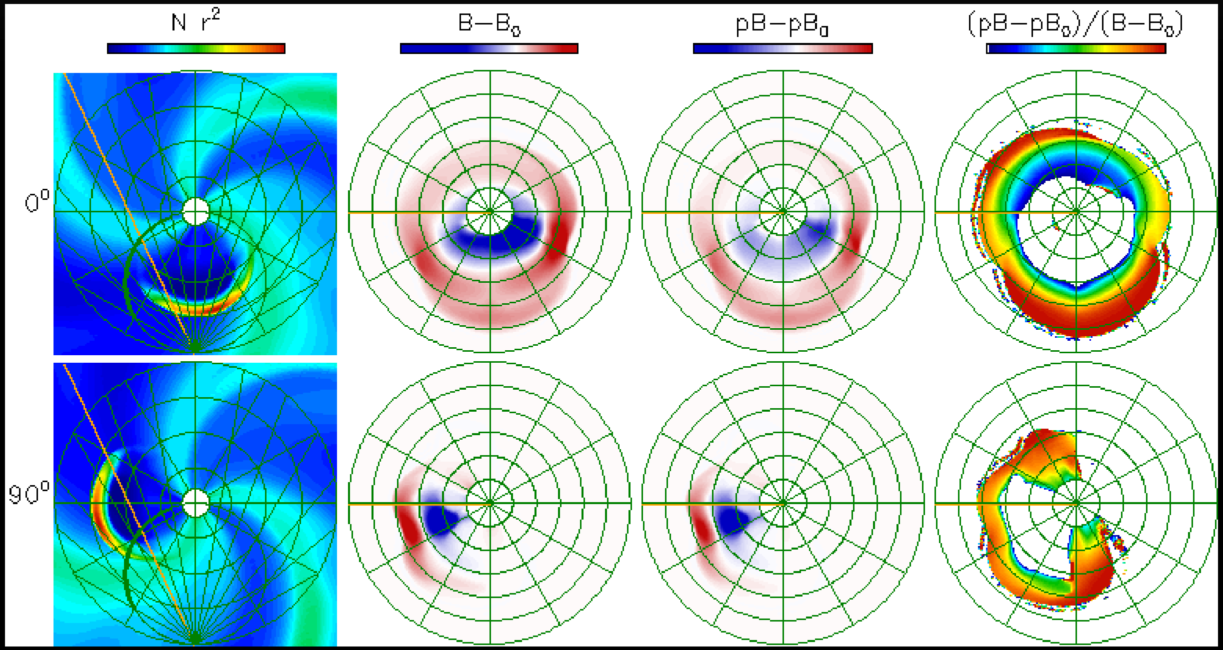
Heliospheric Imaging

The Status Quo and Future

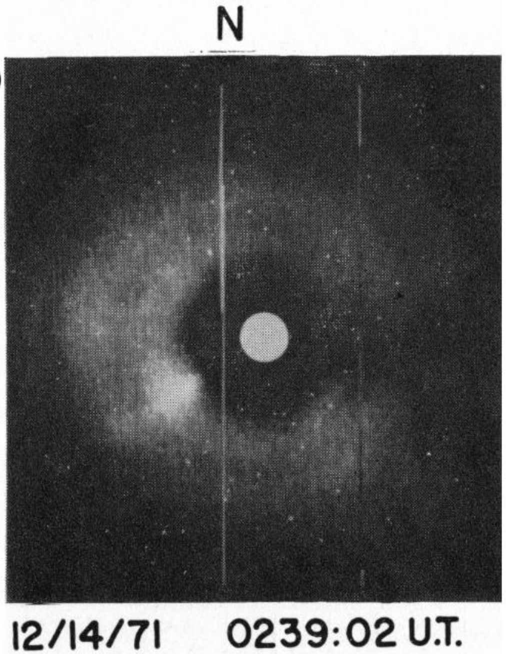


T.A. Howard & C.E. DeForest
Southwest Research Institute, Boulder, CO, USA

White Light Imaging

Traditionally Done with Coronagraphs

OSO-7

a)


Skylab

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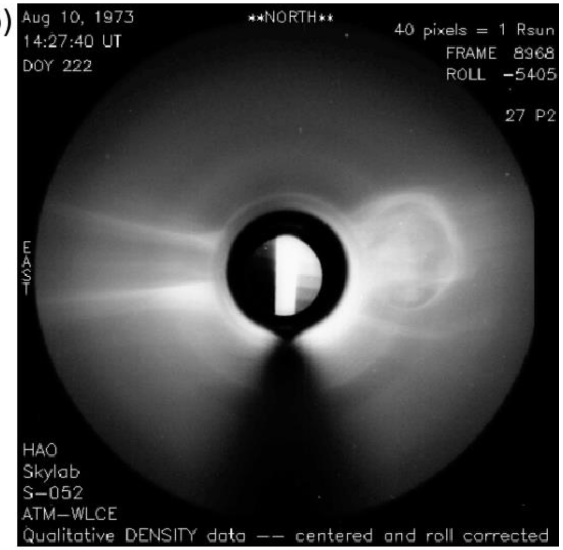
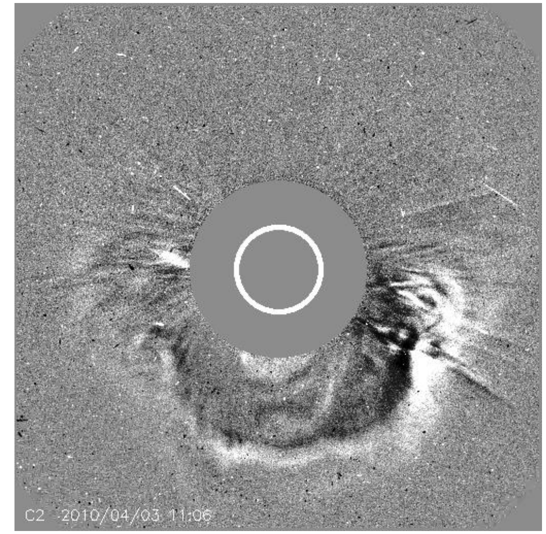
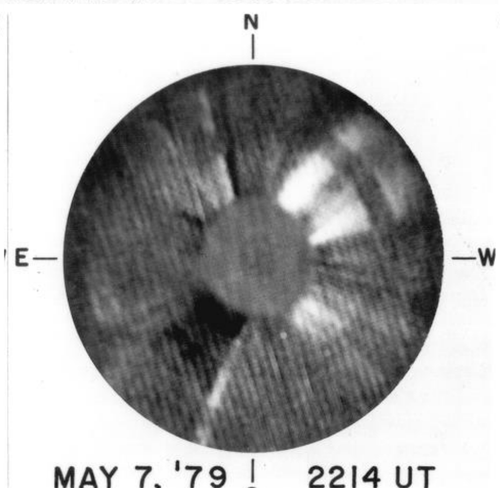
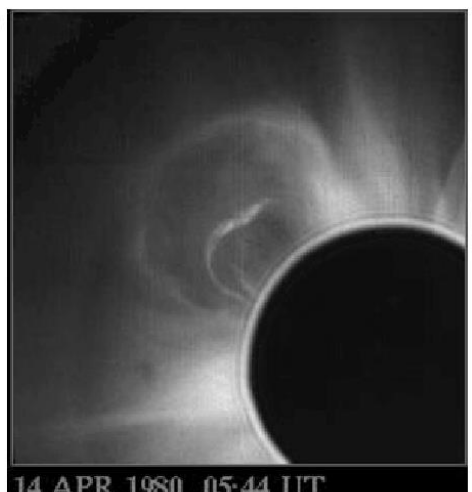
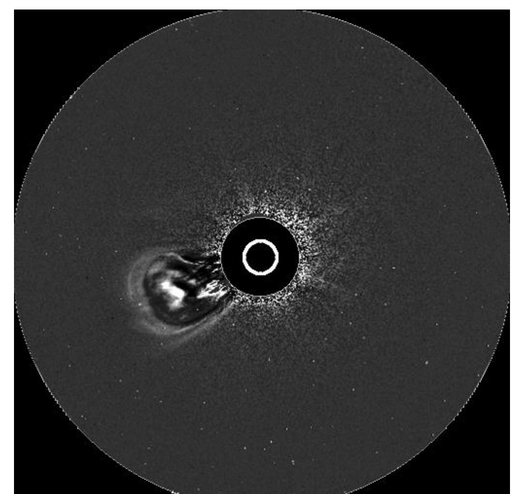


LASCO



c)


d)




Solwind

SMM

STEREO

White Light Imaging

Problems with Using Coronagraphs

Background removal / calibration

Observing range close to the Sun

Observed medium is optically thin

Nature of Thomson scattering – broad sensitivity across LOS

Leading to

Uncertainty in photometry

Cannot track features across the sky

No 3-D information

Solution: Heliospheric Imaging

Heliospheric Imaging Enables

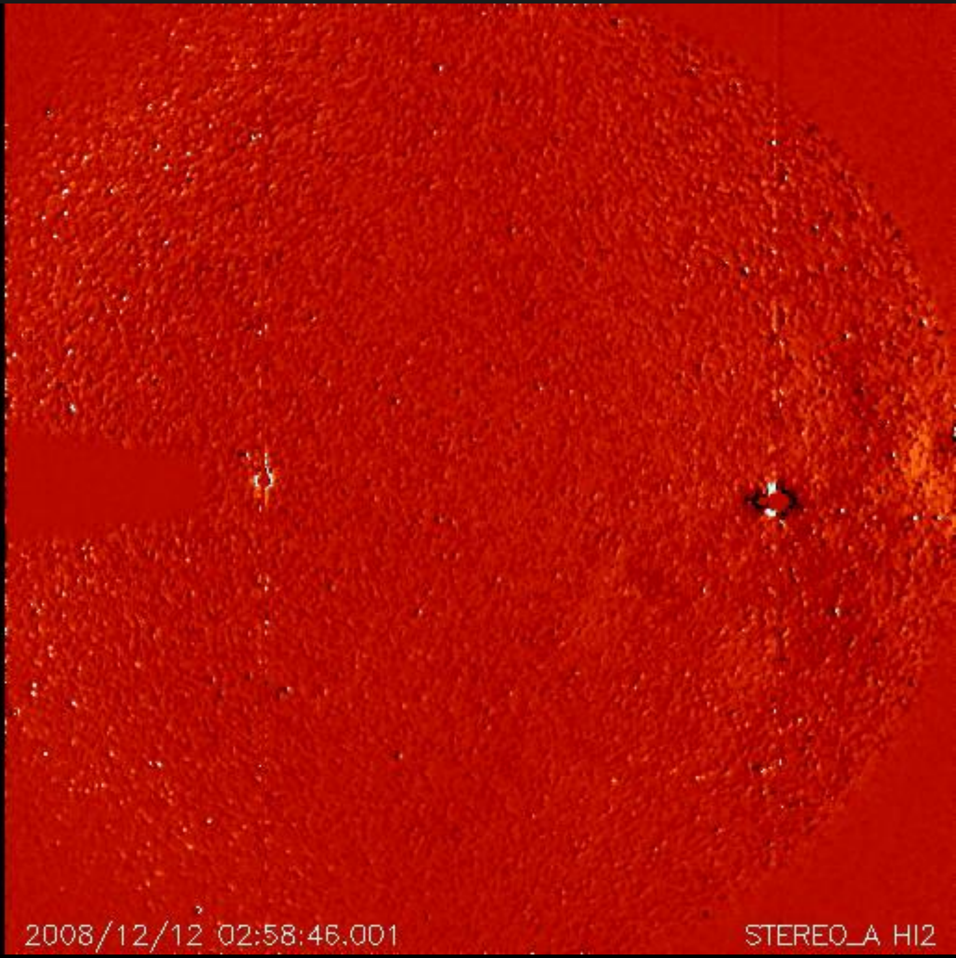
Accurate photometric measurements

Continuous tracking of features across large distances in the sky

3-D information to be extracted from the images

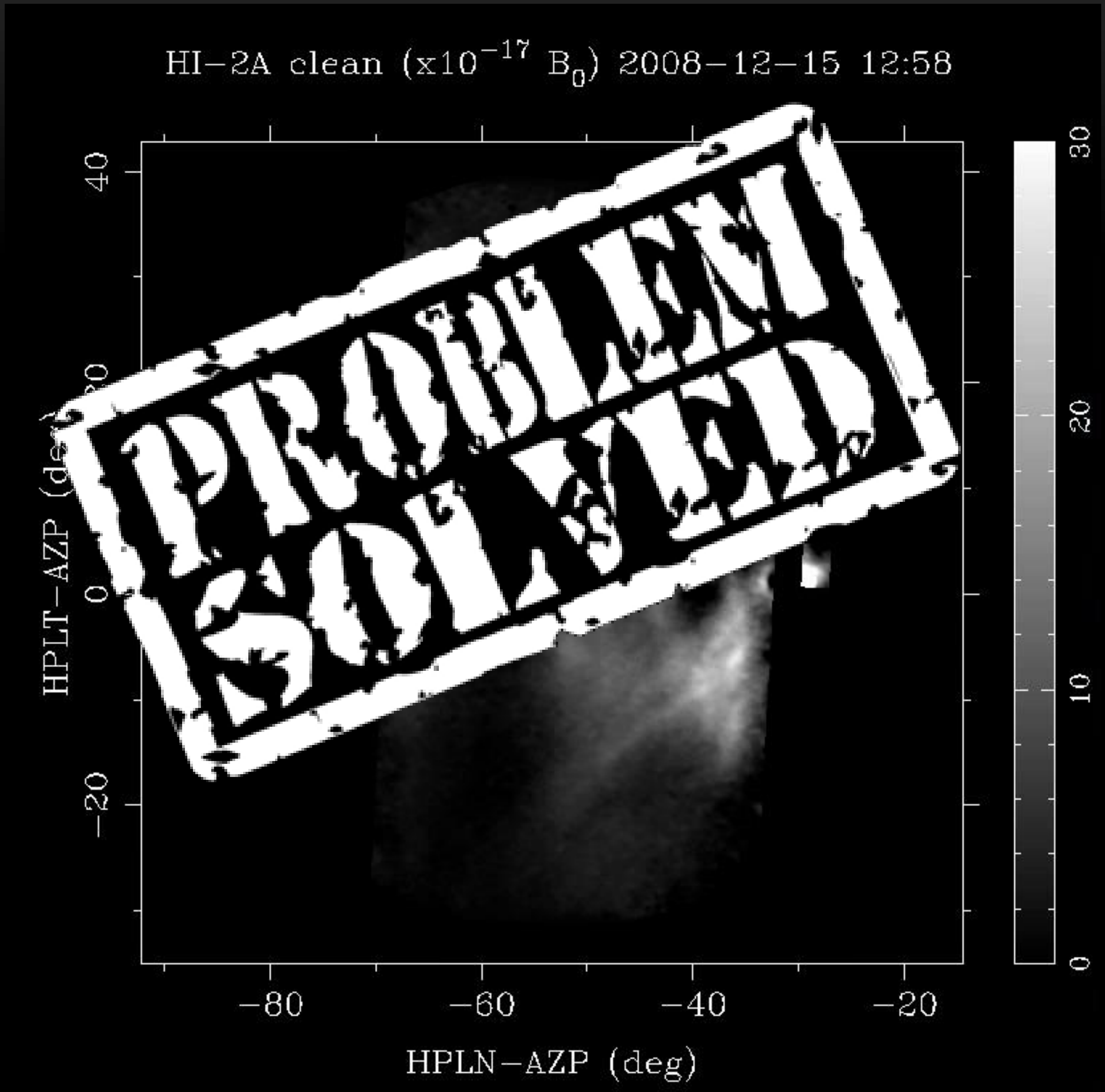
1. Accurate Photometric Measurements

Prior to 2011



1. Accurate Photometric Measurements

Post-2011



*DeForest et al., ApJ, **738**, 103, 2011*

1. Accurate Photometric Measurements

$$m_{ev} = (\rho d)wh = \mu_{av}\frac{B}{B_\odot}\Omega_\odot^{-1}(r)\sigma_e^{-1}\left(1+cos^2\varepsilon'\right)^{-1}\Omega_{ev}$$

Distance to feature

Apparent size of feature

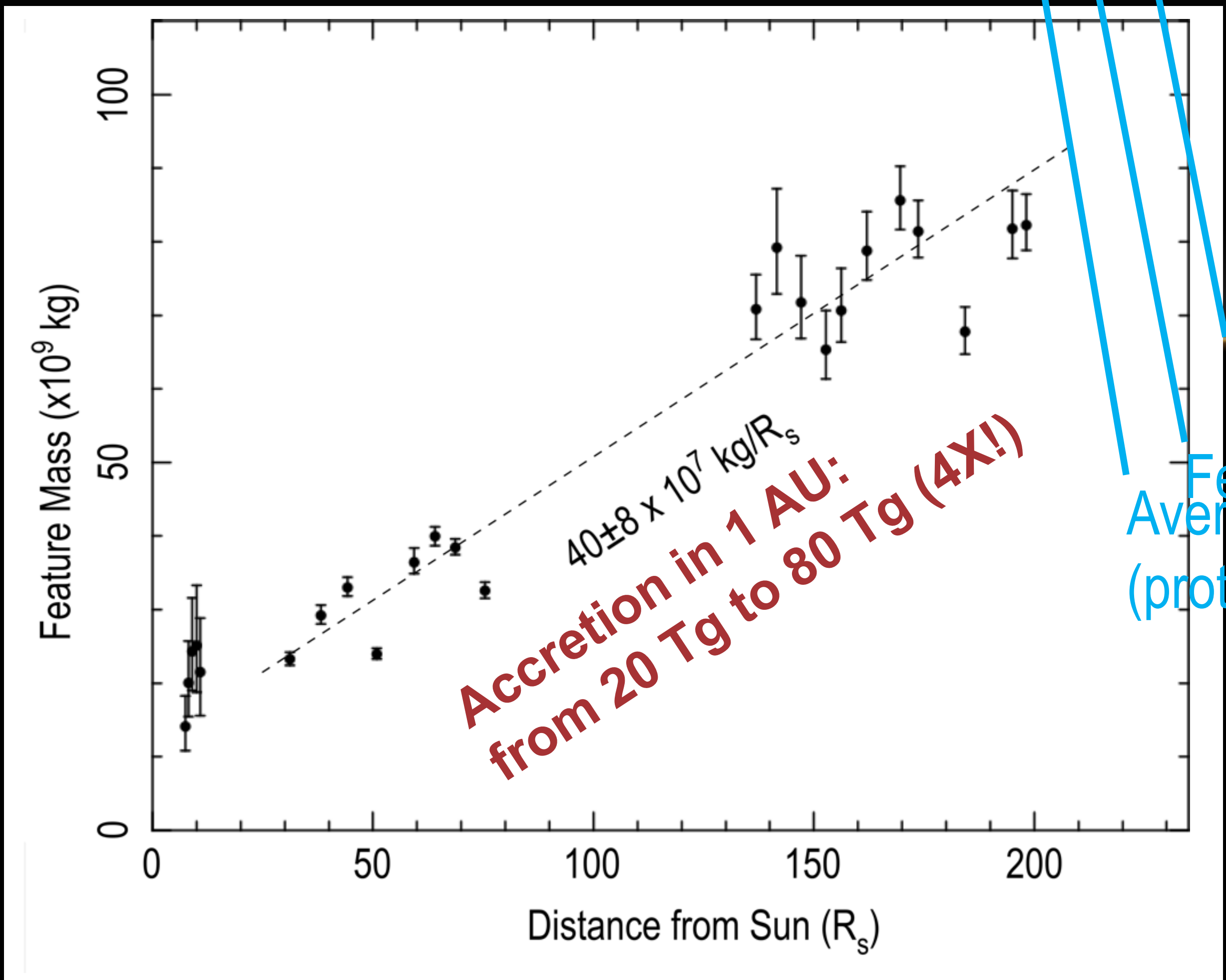
Thomson geometric factor

Thomson cross section

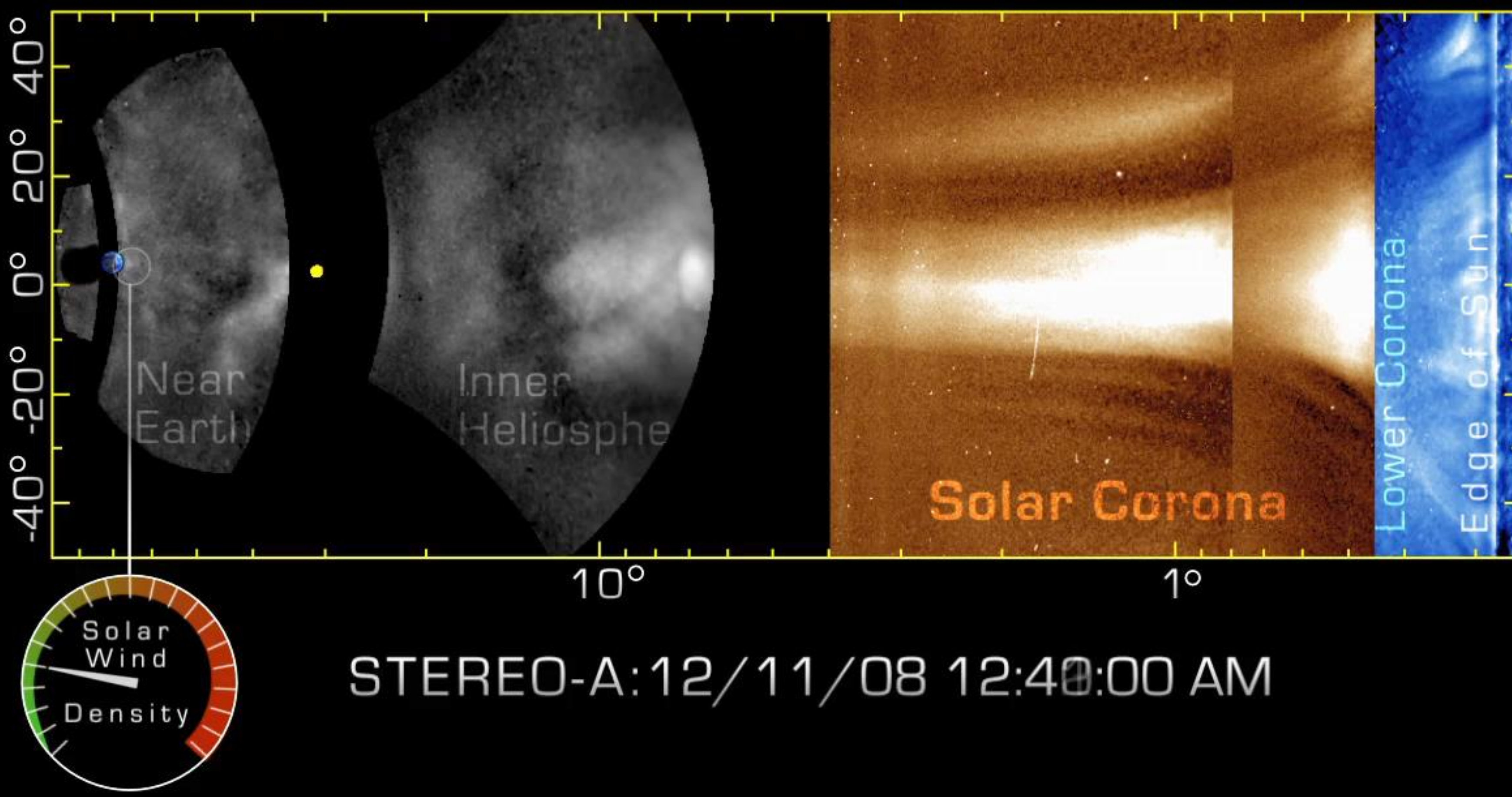
Solar solid angle from feature's vantage

Feature brightness

Average mass per electron (proton mass * 1.1)



2. Continuous Tracking of Features Across the Sky



2. Continuous Tracking of Features Across the Sky

*Howard & DeForest, ApJ, **746**, 64, 2012.*

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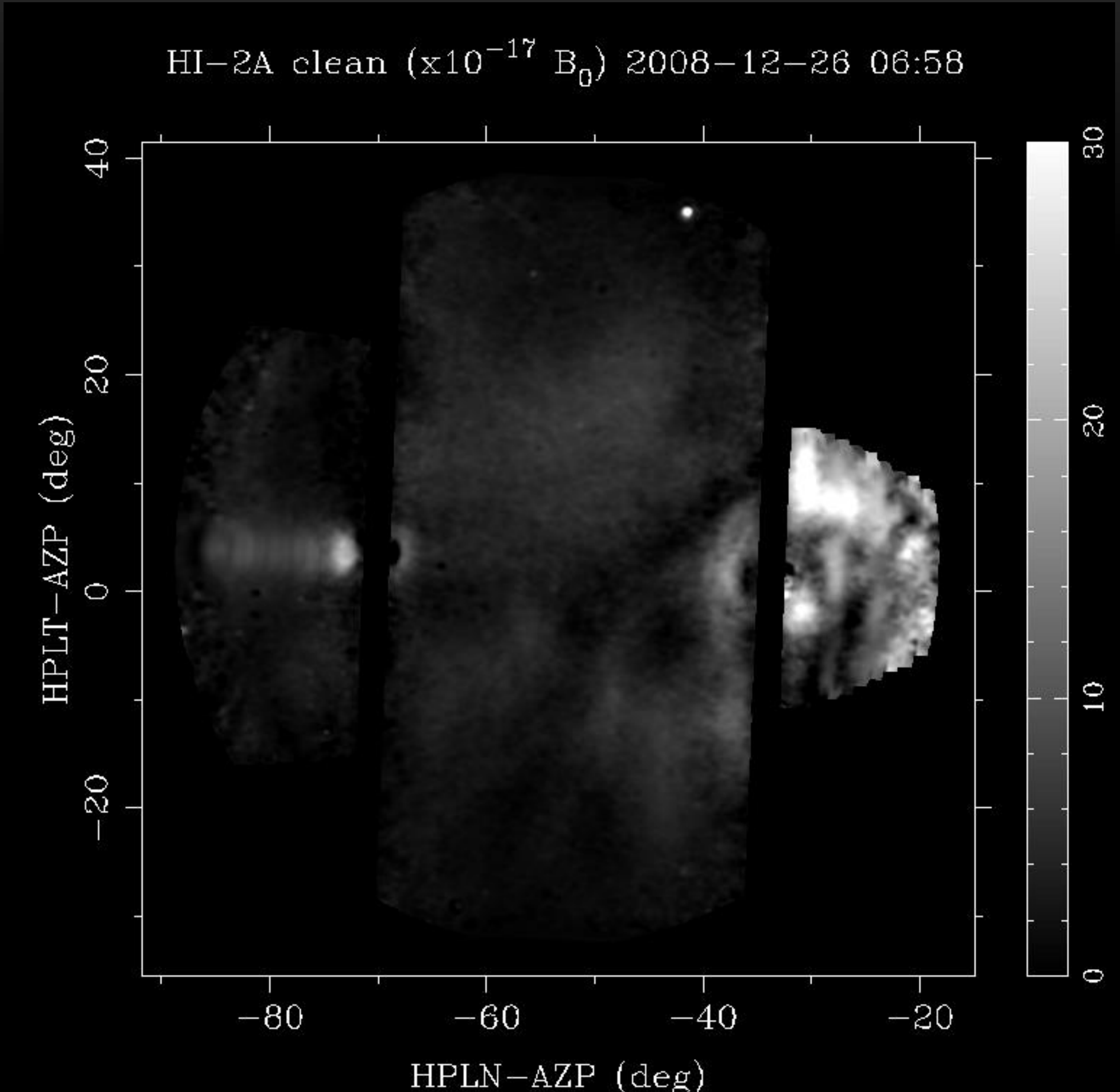
CIRs



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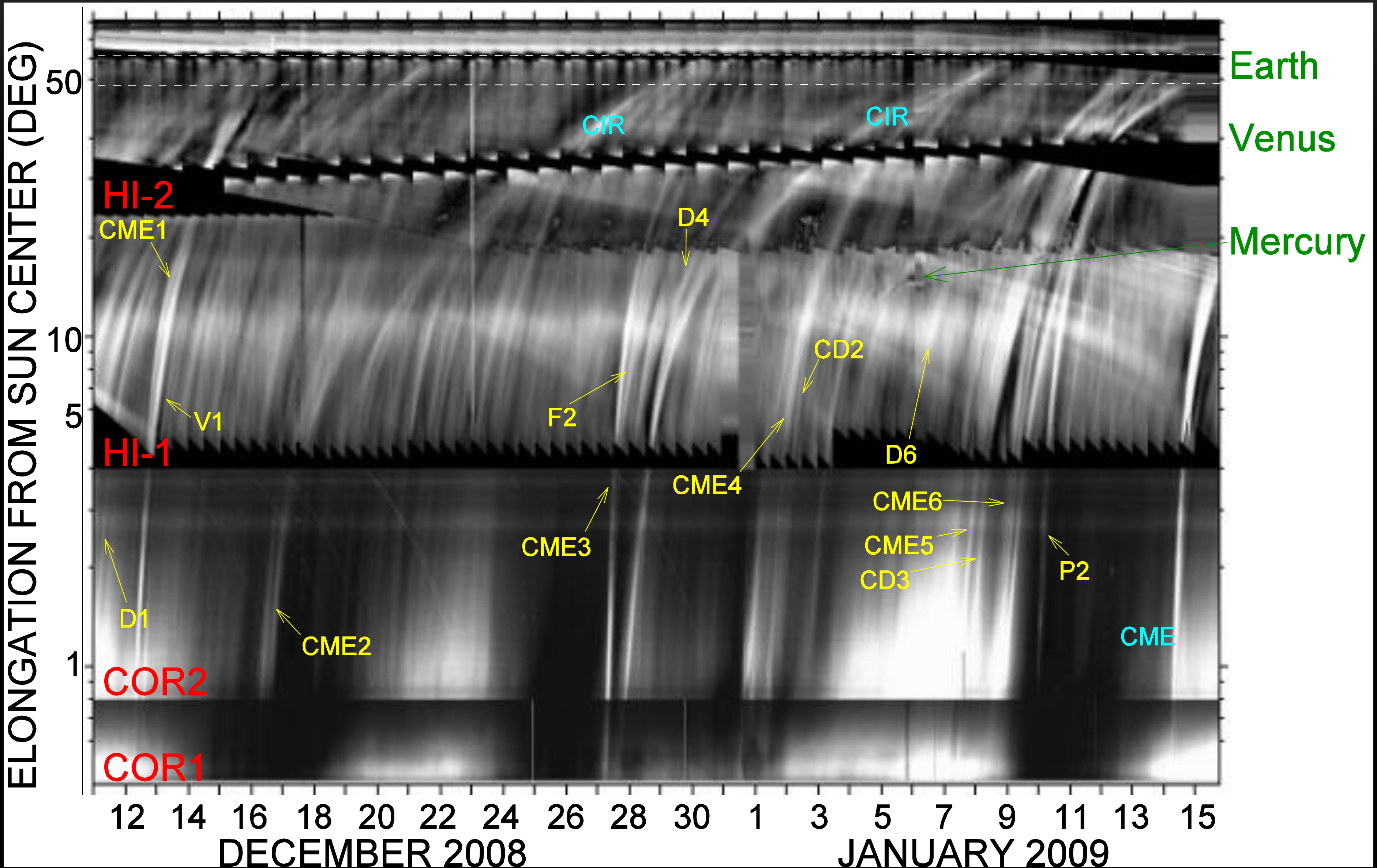
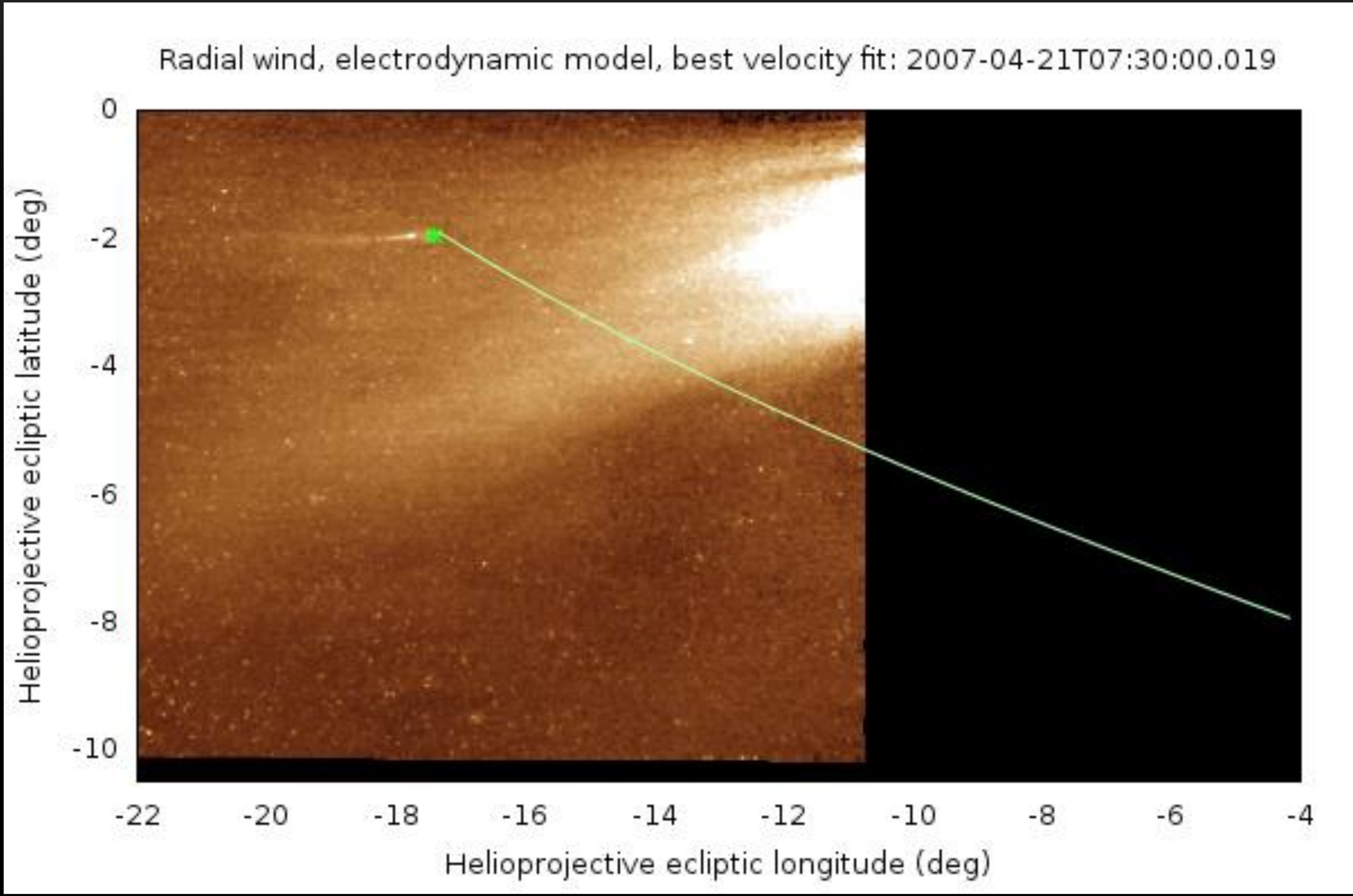
CIRs



2. Continuous Tracking of Features Across the Sky

Turbulence



It's not radiation pressure

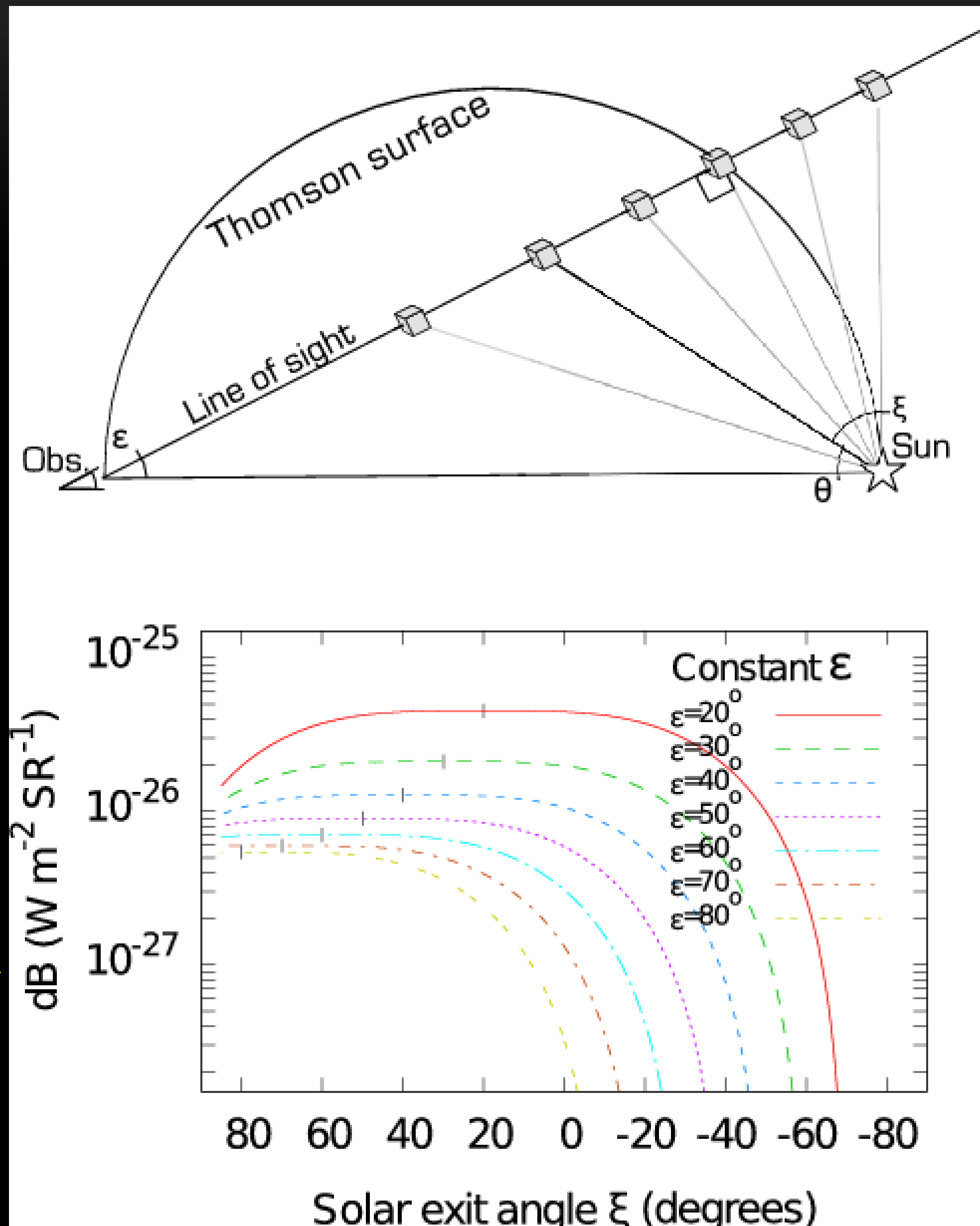
Hydrodynamic drag fits best: Drag ~ Δv^2

3. Extracting 3-D Information

Thomson Scattering + Optical Thinness of the Corona & Solar Wind

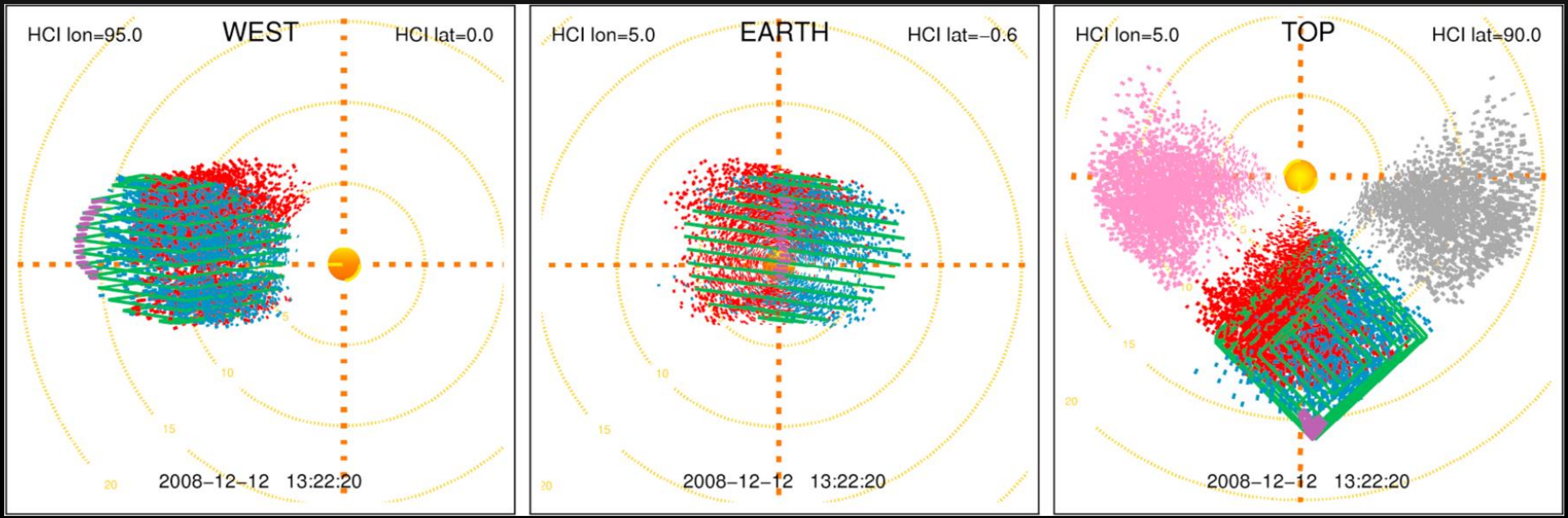
Recall:
What an imager measures is the brightness per solid angle

Radiance dB is the average pixel response within a feature.



*Howard & DeForest, ApJ, **752**, 130, 2012*

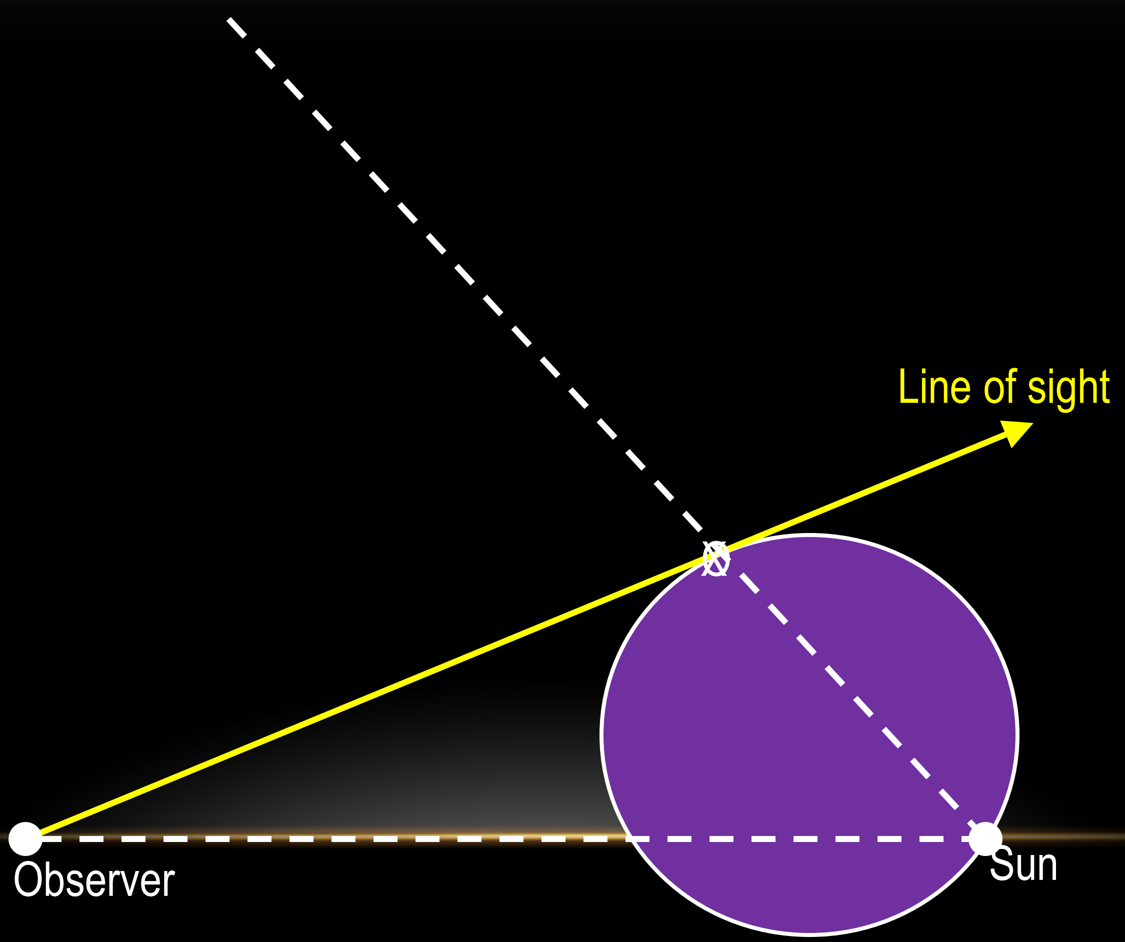
3. Extracting 3-D Information



de Koning and Pizzo,
Space Weather, 9, S03001, 2011

3. Extracting 3-D Information

Getting Distance from the angular measurements: e.g. Fixed-Φ



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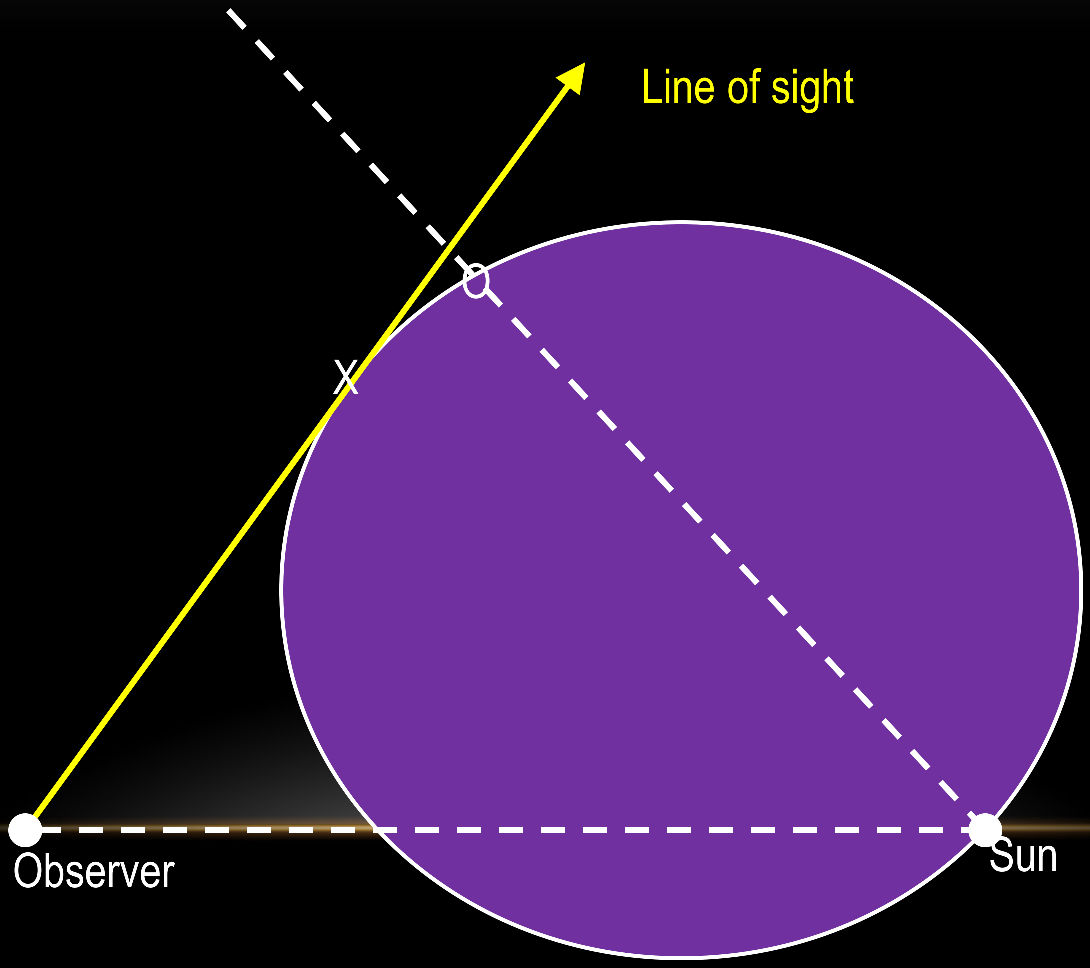

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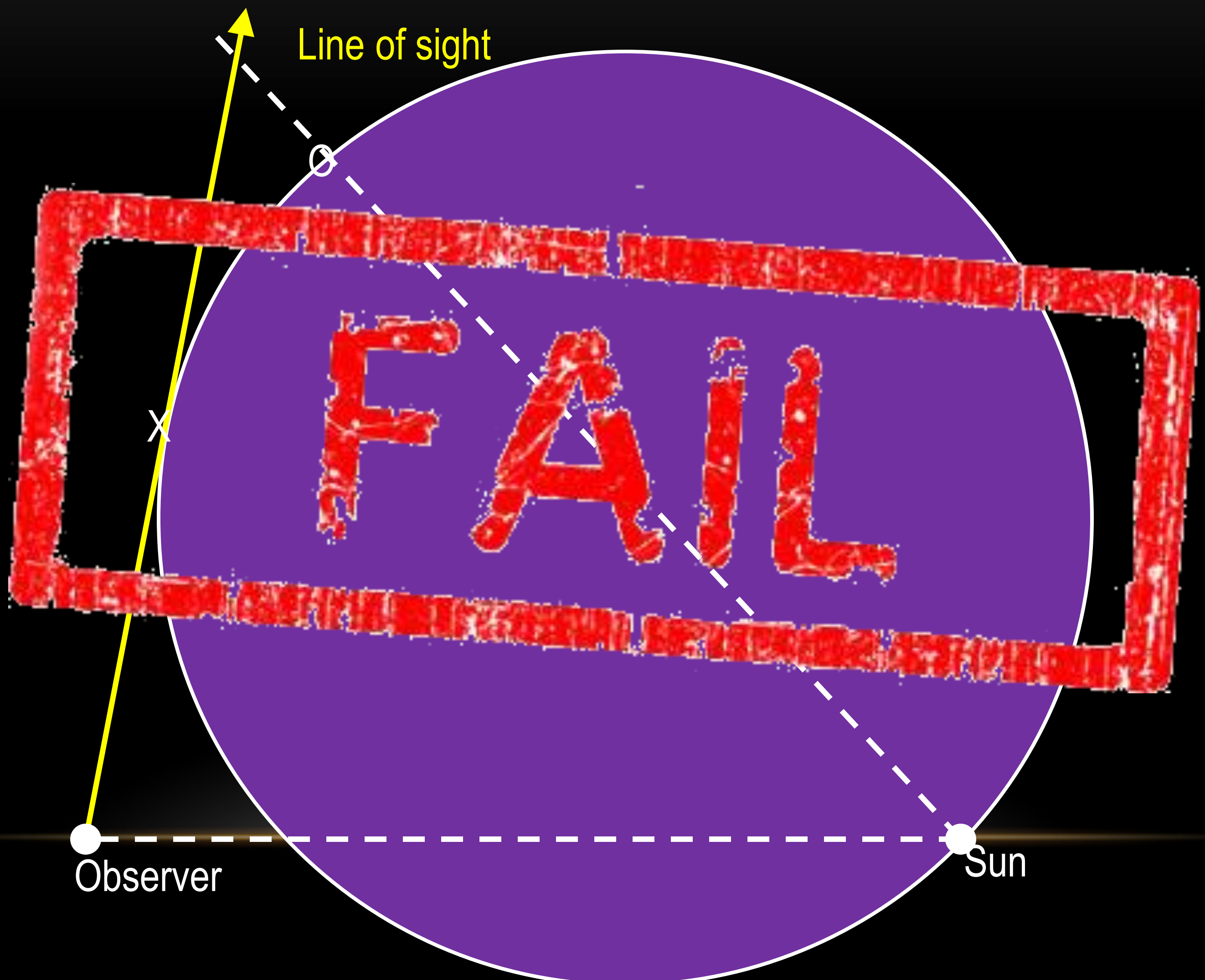

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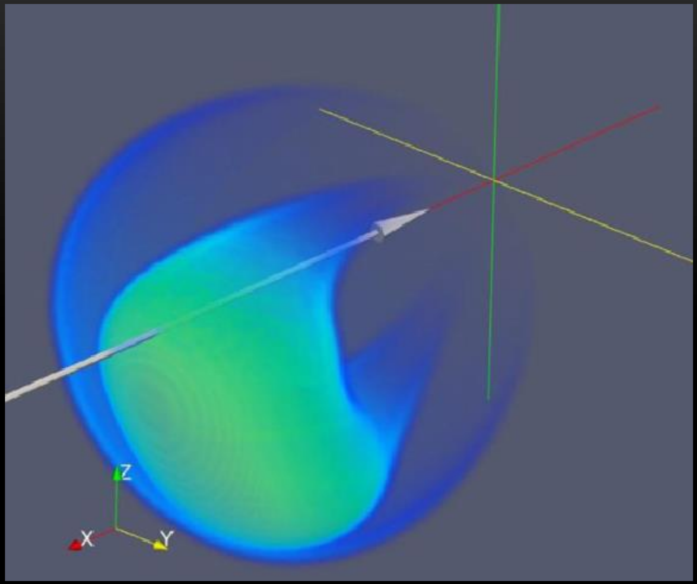
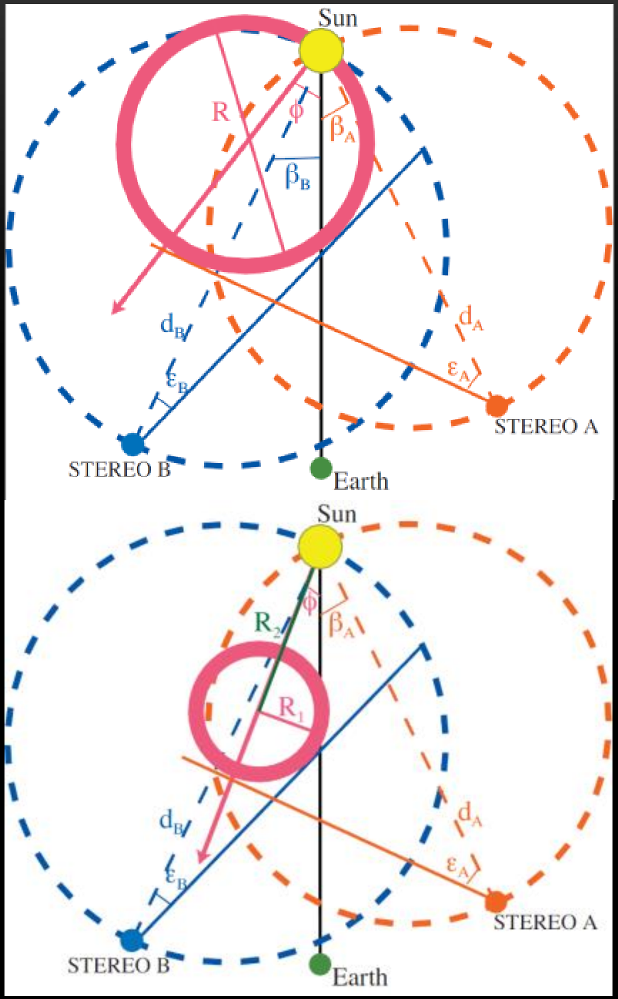
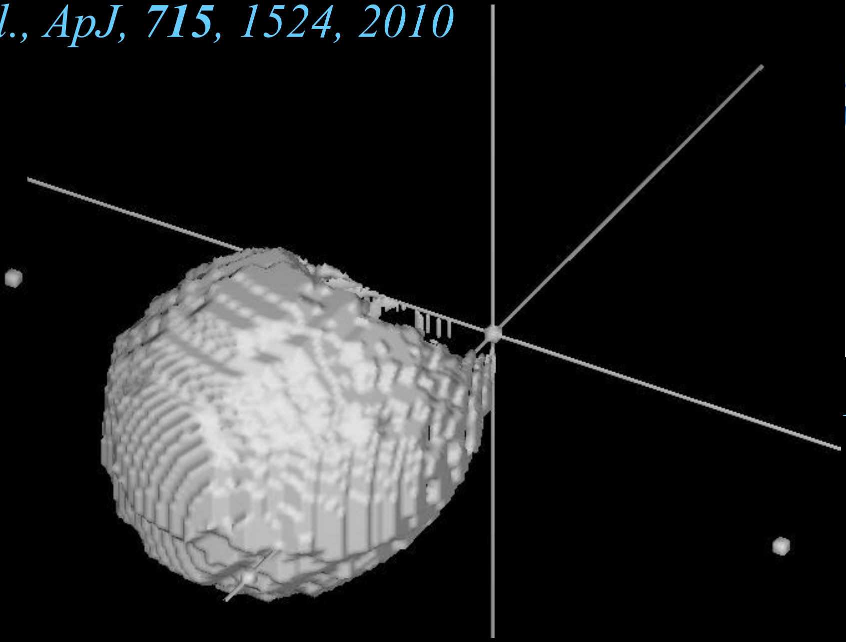


*Wood et al., ApJ, **715**, 1524, 2010*



*Lugaz et al., ApJ, **715**, 493, 2010*



*Howard & Tappin, Space Weather, **8**, S07004, 2010*

The Future

The Future

Remaining Challenges

Resolving smaller features

Operational capabilities

3-D reconstruction

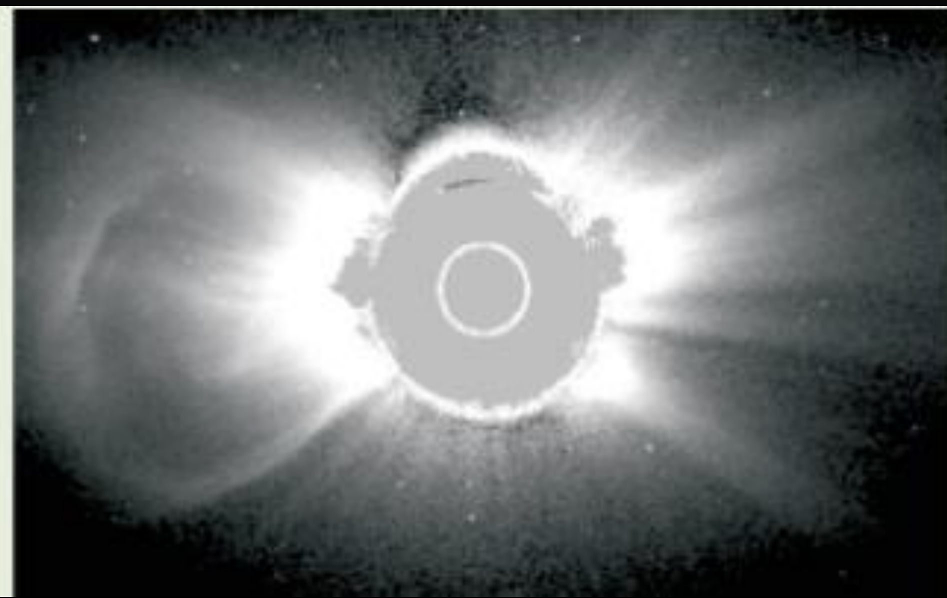
Modeling comparison

Big picture narrative

The Future

The Benefits of Polarimetry

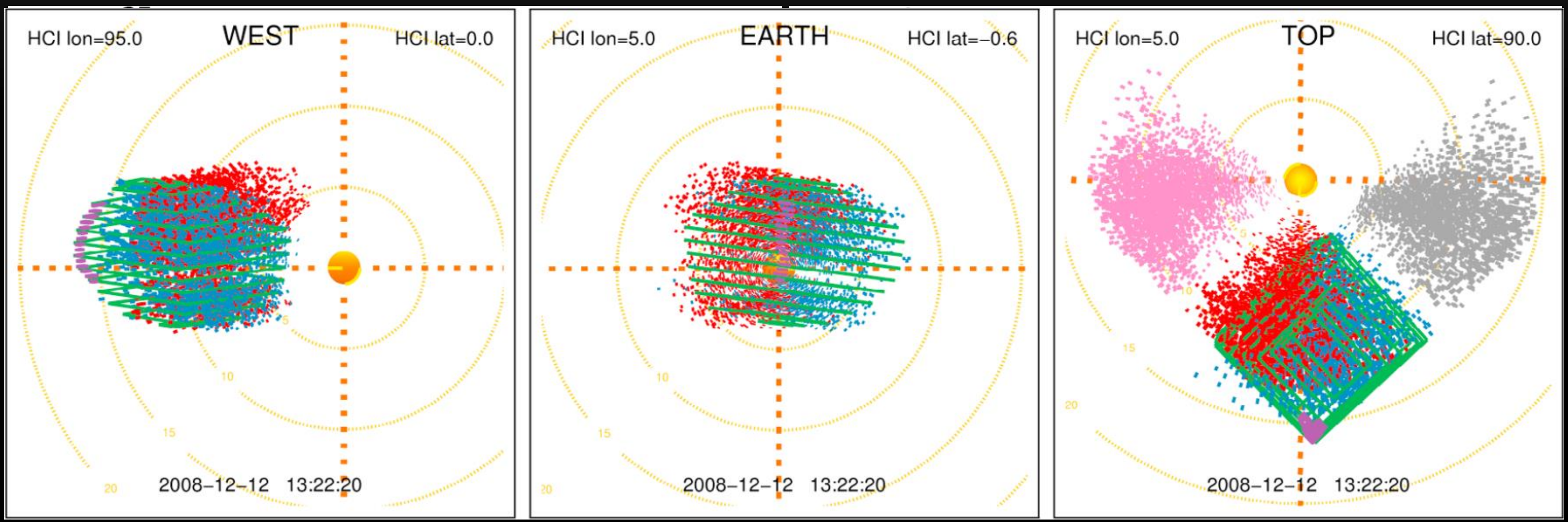
Unpolarized



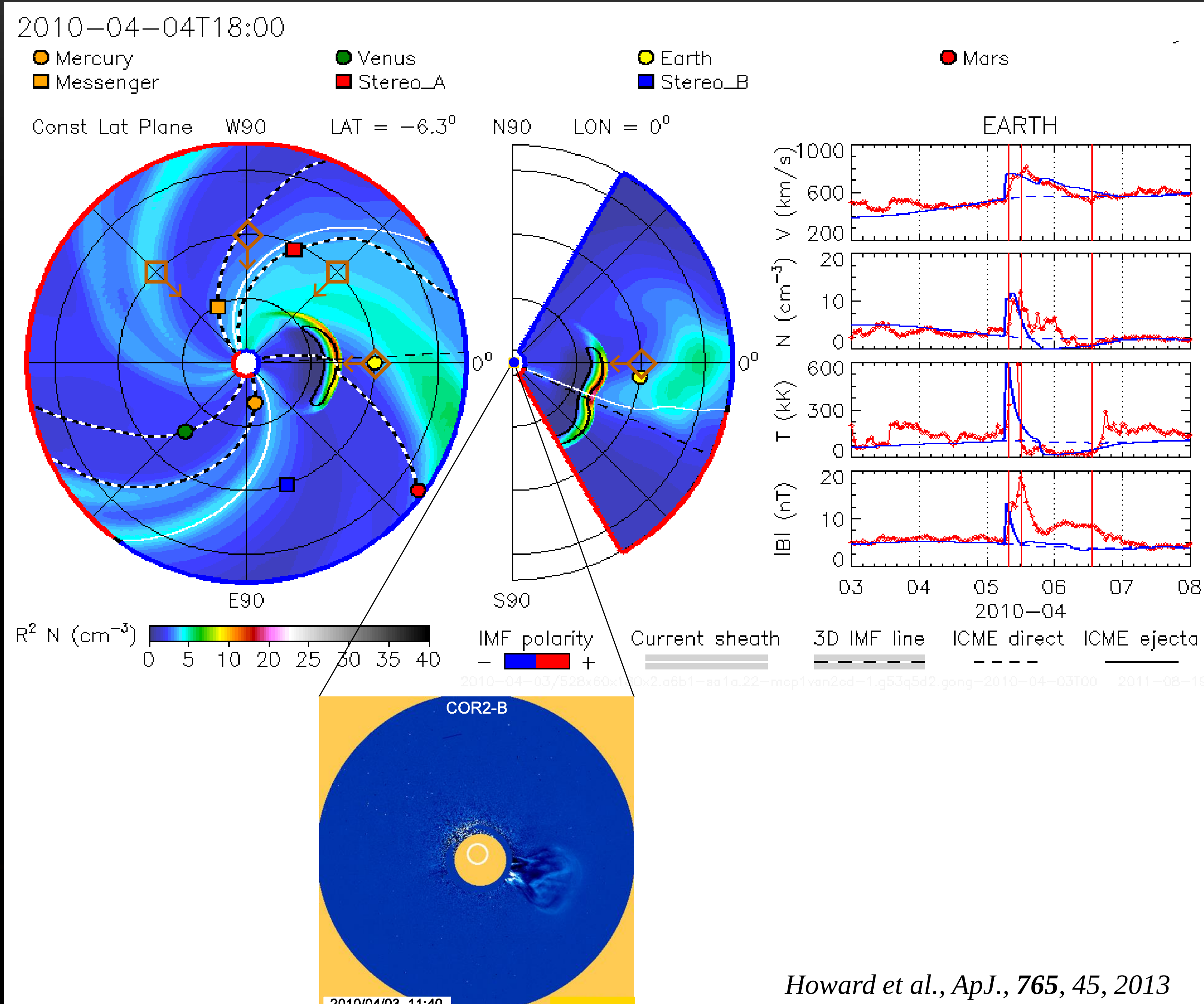
Polarized

The Future

The Benefits of Polarimetry

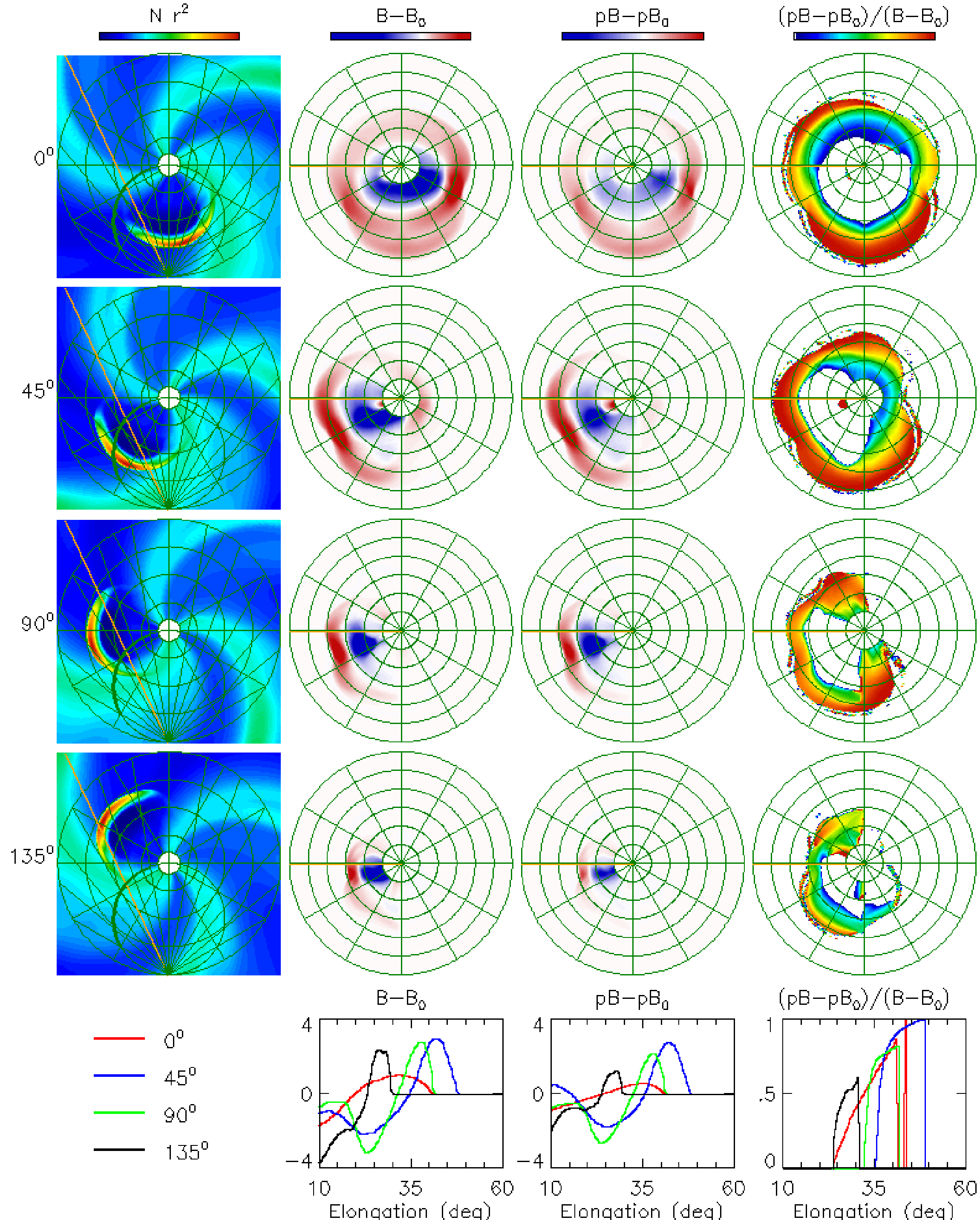


The Future



Howard et al., ApJ., ***765***, *45, 2013*

Example Event: April 2010

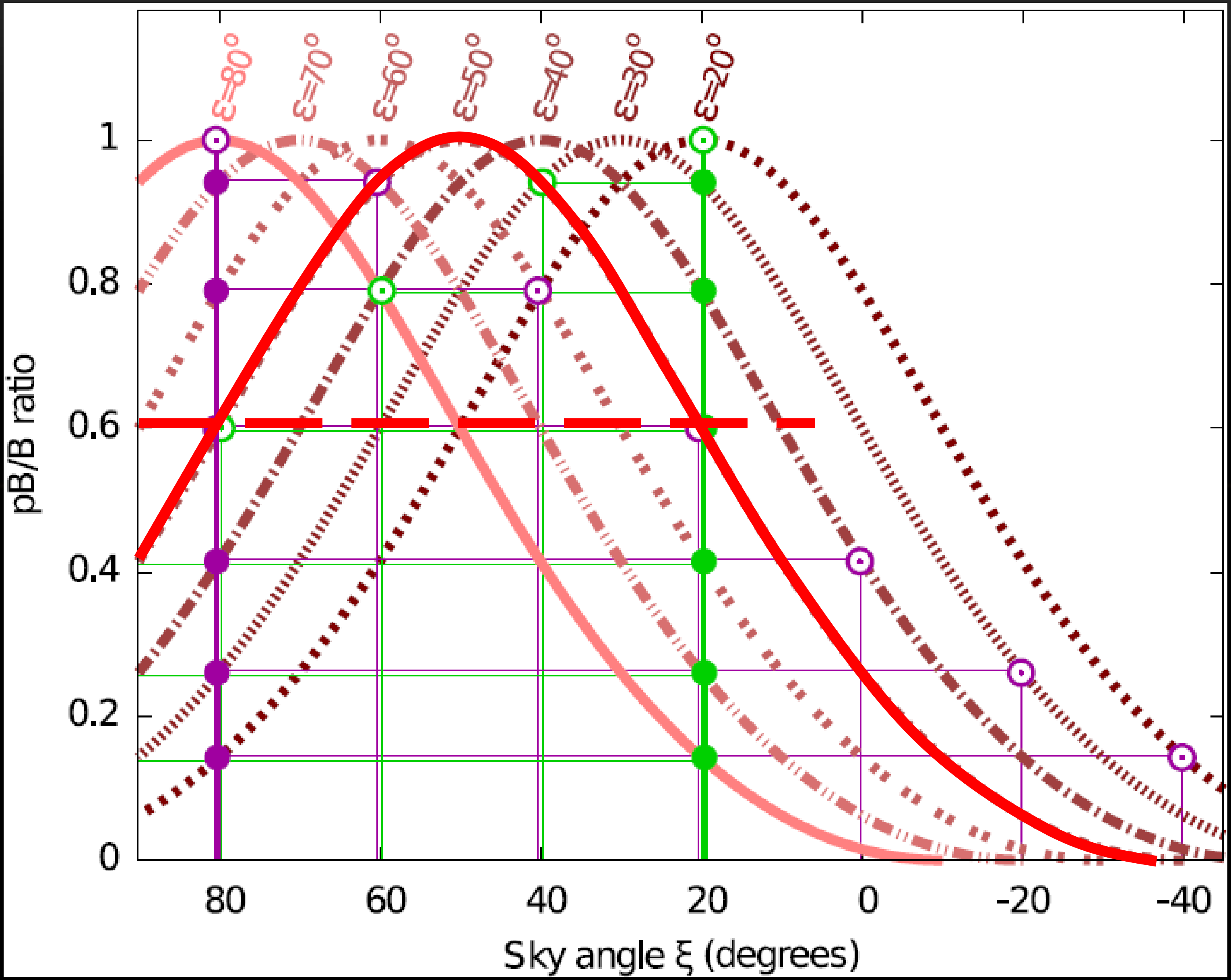


*Howard et al., ApJ., **765**, 45, 2013*

The Future

3-D Identification

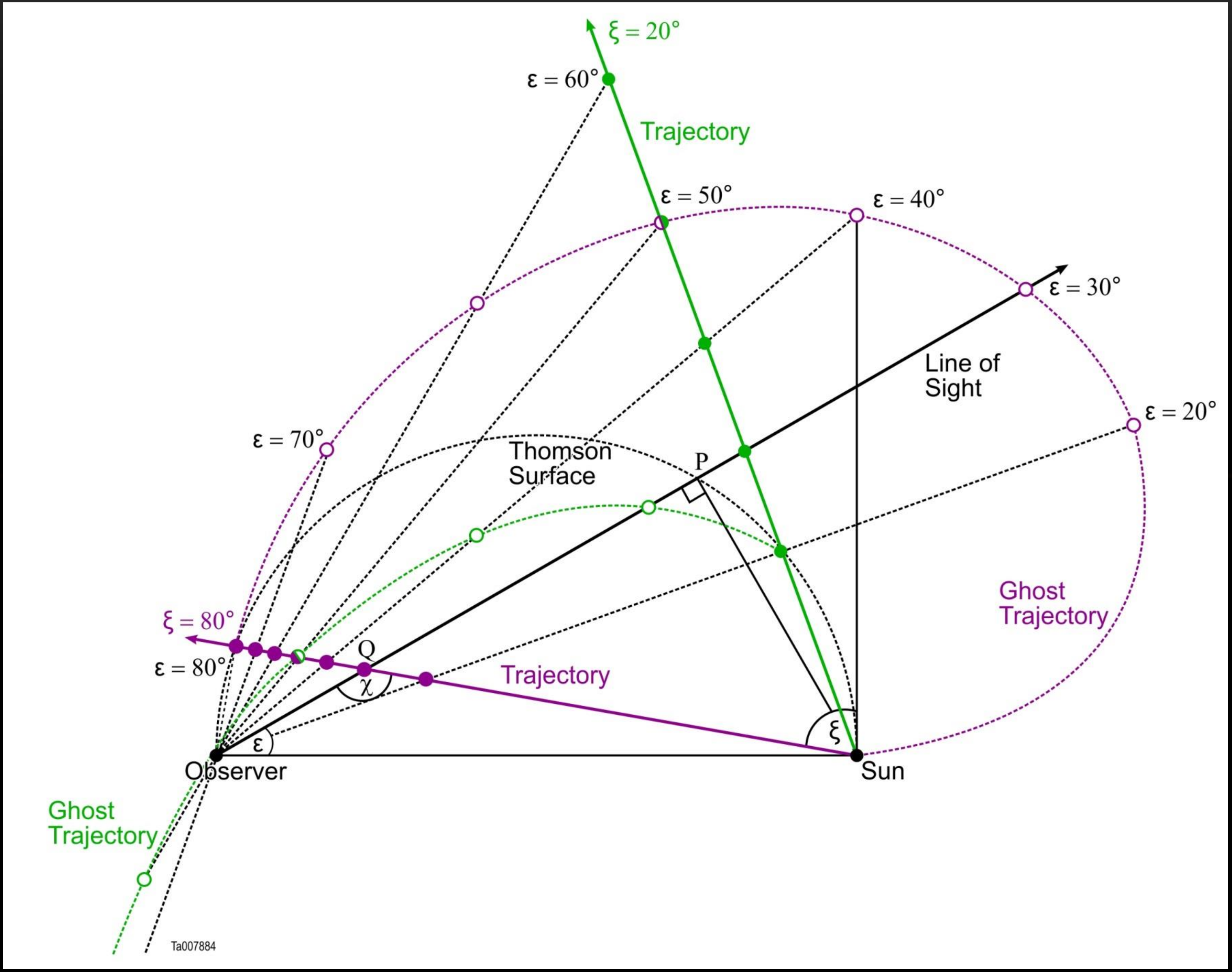
*DeForest et al., ApJ., **765**, 44, 2013*



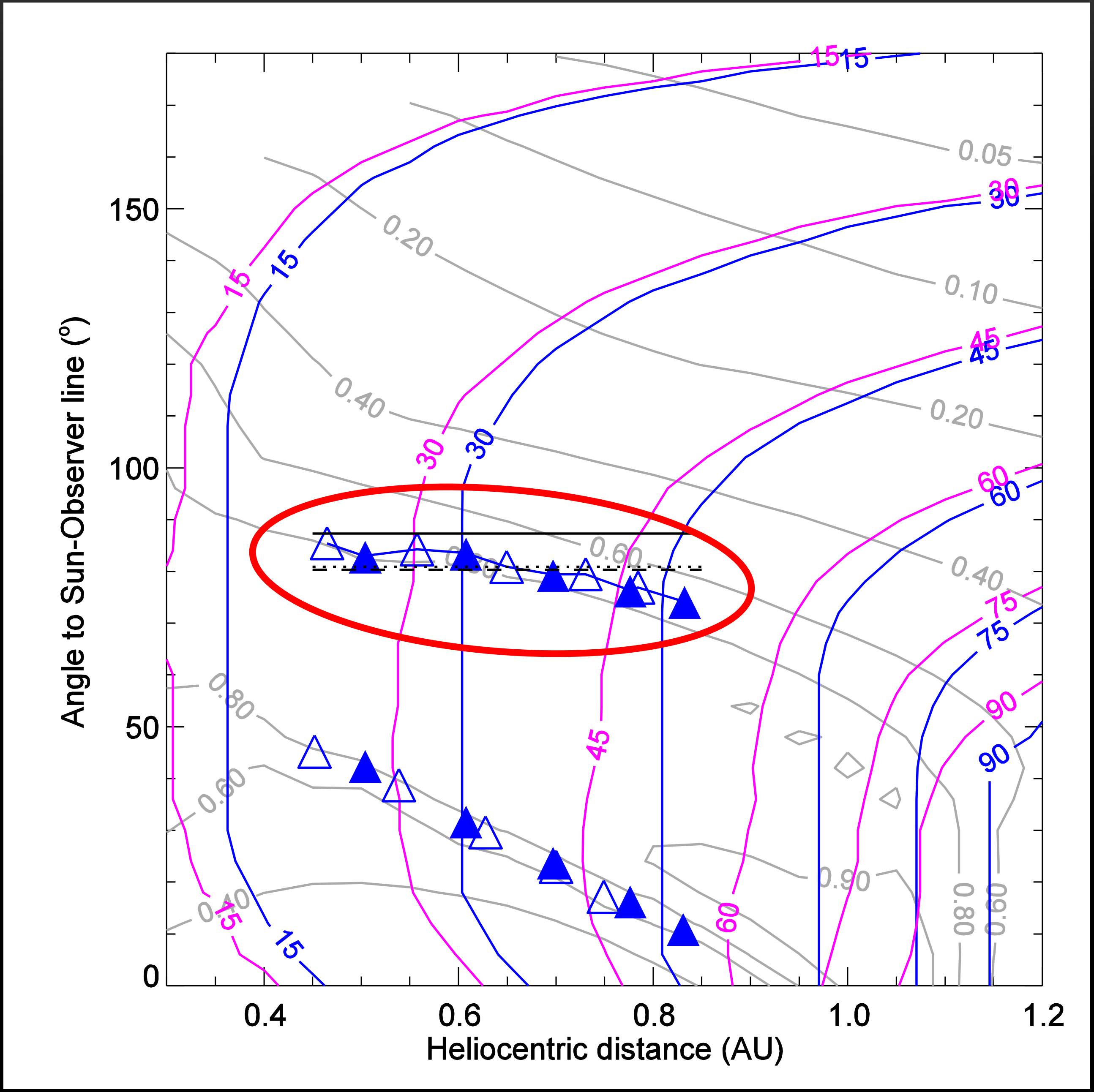
The Future

3-D Identification

*DeForest et al., ApJ., **765**, 44, 2013*



60° Wide CME



*Howard et al., ApJ., **765**, 45, 2013*

ENDE