The solar orbiter imager (SoloHI) instrument for the Solar Orbiter mission

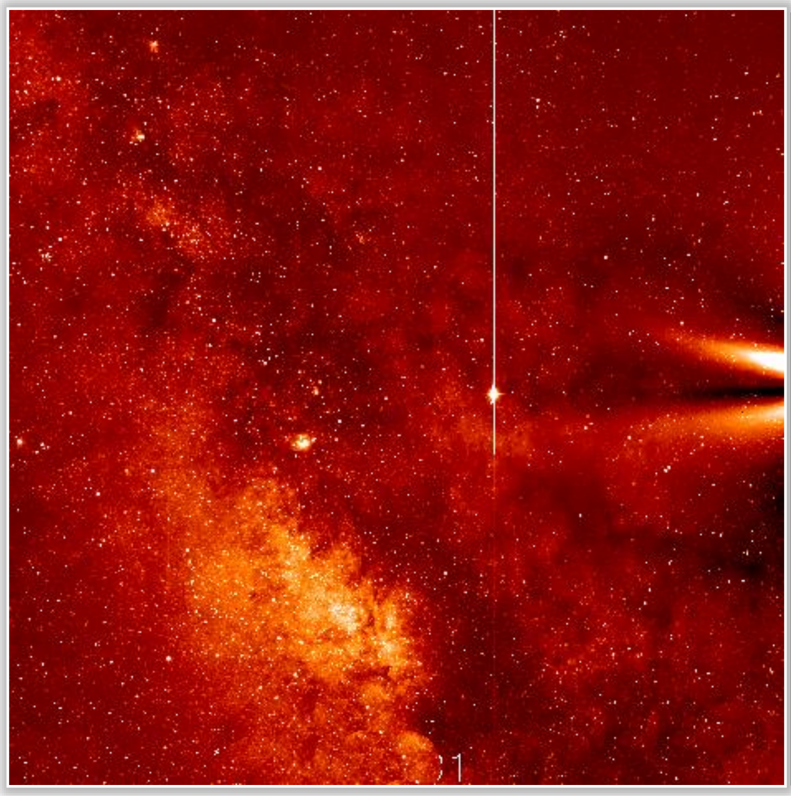
Russell A. Howard,
Naval Research Laboratory
russ.howard@nrl.navy.mil

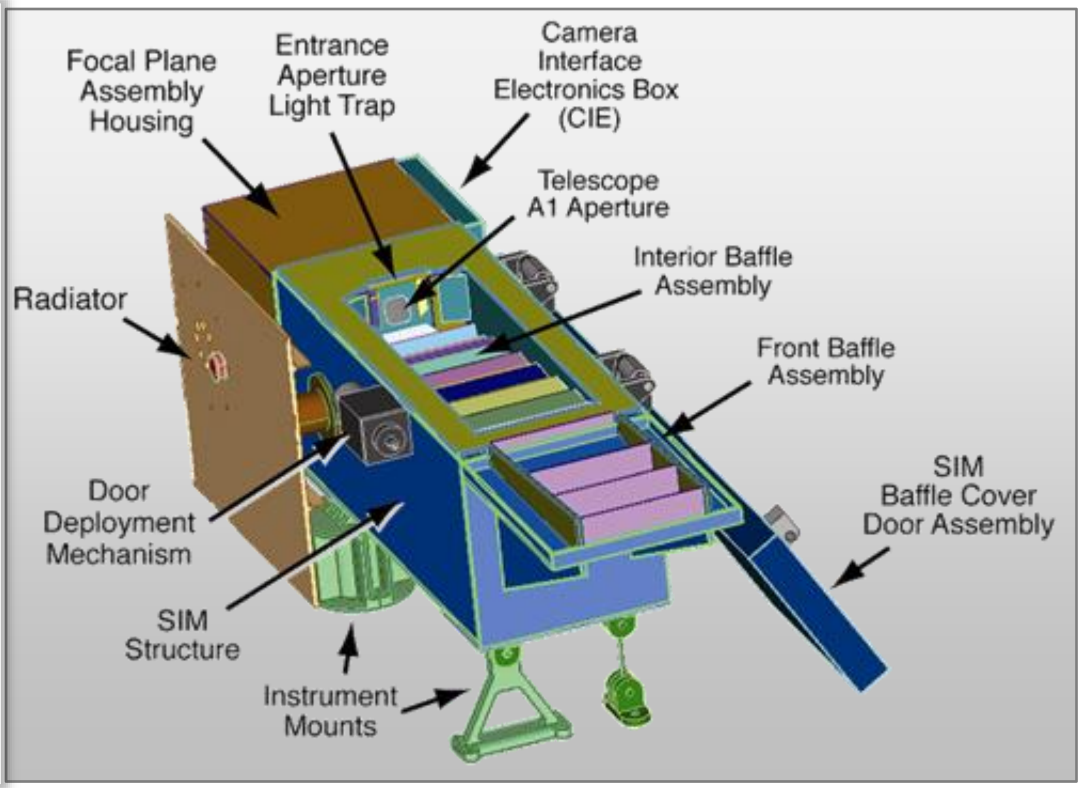
Outline

- What is SoloHI
- Science Objectives
- Instrument Concept
- Unique Science
- Interpreting Heliospheric Images
- Modeling CMEs & Their Propagation
- Observations of the Dust Corona

What Is SoloHI?

- Wide-Field Imager of the Heliosphere From 5 to 45 deg From the Sun.
- Visible Light Observations.
- Simple Telescope: No Mechanisms Other Than One-Shot Door.
- Next-Generation 4Kx4K APS Sensor.





Solar Orbiter Level-1 Science Objectives/Questions

- How and Where Do the Solar Wind Plasma and Magnetic Field Originate in the Corona?
  - What Are the Source Regions of the Solar Wind and Heliospheric Magnetic Field?
  - What Mechanisms Heat and Accelerate the Solar Wind?
  - What Are the Sources of Solar Wind Turbulence and How Does It Evolve?
- How Do Solar Transients Drive Heliospheric Variability?
  - How Do CMEs Evolve Through the Corona and Inner Heliosphere?
  - How Do CMEs Contribute to Solar Magnetic Flux and Helicity Balance?
  - How and Where Do Shocks Form in the Corona?
- How Do Solar Eruptions Produce Energetic Particle Radiation?
  - How and Where Are Energetic Particles Accelerated at the Sun?
- How Does the Solar Dynamo Work and Drive Connections Between the Sun and the Heliosphere?
  - How Are Variations in the Solar Wind Linked to the Sun at All Latitudes?
  - What Is the 3-Dimensional Structure and Extent of Streamers and CMEs?
- Additional SoloHI Goals/Questions
  - What Are the Sources and Properties of Dust in the Inner Heliosphere, and Do Sun-Grazing Comets Contribute to the Dust?

SoloHI Science Requirement Traceability Matrix (1 of 3)

Science Objective	2.1 How and where does the solar wind plasma and magnetic field originate in the corona?					2.2 How do solar transients drive heliospheric variability?		
Science Question #	2.1.1	2.1.2	2.1.3			2.2.1		
Science Question	What are the source regions of the solar wind and heliospheric magnetic field?	What mechanisms heat and accelerate the solar wind?	What are the sources of solar wind turbulence and how does it evolve?			How do CMEs evolve through the corona and inner heliosphere?		
Science Product ID	2.1.1a	2.1.2a	2.1.3a			2.2.1a		
Derived Science Products	Global maps of H and He flow velocities and He fractions (METIS, SoloHI)	Velocities and mass density of evolving structures (SoloHI, METIS)	Link evolution of CME properties in the corona to those measured *in-situ* (SoloHI, METIS)			Link evolution of CME properties in the corona to those measured *in-situ* (SoloHI, METIS)		
Science Measurements	Images of coronal and heliospheric solar wind structures in visible	Height-time plot and mass measurements of solar wind features	High cadence images of coronal and heliospheric structures in visible			Height-time plot and mass measurements of CMEs		
Type and Number of Events Captured Over Baseline Science Mission	• Quiescent wind for 3 days • Active wind for 3 days • Pseudo streamers for 3 days	• Quiescent wind for 3 days • Active wind for 3 days • Pseudo streamers for 3 days	Density power spectrum centered at 7 Rsun, 15 Rsun, 20 Rsun at the 0.28 a.u. perihelion			≥ 2 ICMEs		
Type and Number of Events Captured Over Threshold Science Mission	• Quiescent wind for 3 days • Active wind for 3 days	• Quiescent wind for 3 days • Active wind for 3 days	Density power spectrum centered at 7 Rsun at the 0.28 a.u. perihelion			≥ 1 ICME		
Required (R) or Supporting (S) Measurement	S	R	R			R		
Observation Requirements								
Instrument Distance From Sun (a.u.)	0.28 to 0.36	0.28 to 0.36	0.28 to 0.36			0.28 to 0.36	0.36 to 0.5	0.5 to 0.7
Spacecraft Solar Latitude	N/A	N/A	N/A			N/A		
Image Type	Visible broadband	Visible broadband	Visible broadband			Visible broadband		
Scene Radial Coverage	5.5 to 25º	5.5 to 40.5º	5.8 to 7.675º	13.5 to 15.375º	18.5 to 20.375º	5.5 to 44.5º	5.5 to 40.5º	5.5 to 30.5º
Scene Transverse Coverage	26º	5º	5º	5º	5º	26º		
Image Spatial Resolution	≤ 3.0 arcmin	≤ 2.7 arcmin	≤ 2.3 arcmin	≤ 2.6 arcmin	≤ 2.6 arcmin	≤ 3.0 arcmin		
Photometric Accuracy	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 16	≥ 16	≥ 16 [a] ≥ 12 [b]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [3] ≥ 5 [4]
Cadence	≤ 30 min	≤ 15 min	≤ 10 sec [a] ≤ 15 sec [b]	≤ 1 min	≤ 2 min	≤ 30 min [a, 5b] ≤ 60 min [6b]	≤ 40 min [5] ≤ 80 min [7] ≤ 120 min [8]	≤ 40 min [5] ≤ 80 min [9] ≤ 140 min [10]
Science Observation Period Per Day	24 hrs	24 hrs	≥ 4 hrs	≥ 4 hrs	≥ 4hrs	24 hrs		
Science Observation Days Per Orbit	≥ 14	≥ 6	≥ 4	≥ 4	≥ 4	≥ 14	≥ 12	≥ 1
Science Observation Days for Baseline Science Mission	≥ 98	≥ 42	8 [a], 24 [b]	8 [a], 24 [b]	8 [a], 24 [b]	≥ 98	≥ 92	≥ 16
Science Observation Days for Threshold Science Mission	≥ 14	≥ 6	2 [a], 3 [b]	2 [a], 3 [b]	2 [a], 3 [b]	≥ 14	≥ 14	≥ 1

SoloHI Science Requirement Traceability Matrix (2 of 3)

Science Objective	2.2 How do solar transients drive heliospheric variability?								
Science Question #	2.2.2			2.2.3					
Science Question	How do CMEs contribute to solar magnetic flux and helicity balance?			How and where do shocks form in the corona?					
Science Product ID	2.2.2a			2.2.3a		2.2.3b		2.2.3c	
Derived Science Products	Map source regions to *in-situ* properties: magnetic connectivity, polarity and helicity (EUI, METIS, SPICE, SoloHI, SWA, MAG, EPD)			Timing of eruptions and coronal manifestations (EUI, SoloHI)		Location, intensity, thermal/non-thermal distribution of erupting regions (SoloHI, RPW)		Position and speed of shocks (SPICE, METIS, SoloHI, RPW, EUI)	
Science Measurements	Height-time plot and mass measurements of CMEs			High cadence height-time plots and mass measurements of CME fronts					
Type and Number of Events Captured Over Baseline Science Mission	≥ 2 ICMEs			≥ 2 ICMEs with an accompanying shock		≥ 2 ICMEs		≥ 2 ICMEs with an accompanying shock	
Type and Number of Events Captured Over Threshold Science Mission	≥ 1 ICME			≥ 1 ICME		≥ 1 ICME		≥ 1 ICME	
Required (R) or Supporting (S) Measurement	S			R		S		R	
Observation Requirements									
Instrument Distance From Sun (a.u.)	0.28 to 0.36	0.36 to 0.5	0.5 to 0.7	0.28 to 0.36	0.36 to 0.5	0.28 to 0.36	0.36 to 0.5	0.28 to 0.36	0.36 to 0.5
Spacecraft Solar Latitude	N/A			N/A					
Image Type	Visible broadband			Visible broadband					
Scene Radial Coverage	5.5 to 44.5º	5.5 to 40.5º	5.5 to 30.5º	5.5 to 40.5º	5.5 to 30.5º	5.5 to 40.5º	5.5 to 30.5º	5.5 to 40.5º	5.5 to 30.5º
Scene Transverse Coverage	26º			5º					
Image Spatial Resolution	≤ 3.0 arcmin			≤ 2.7 arcmin					
Photometric Accuracy	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [3] ≥ 5 [4]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]
Cadence	≤ 30 min[a, 5b] ≤ 60 min[6b]	≤ 40 min [5] ≤ 80 min [7] ≤ 120 min [8]	≤ 40 min [5] ≤ 80 min [9] ≤ 140 min [10]	≤ 6 min[a, 5b] ≤ 15 min[6b]	≤ 6 min [5] ≤ 15 min [12c] ≤ 18 min [11d]	≤ 6 min[a, 5b] ≤ 15 min[6b]	≤ 6 min [5] ≤ 15 min [12c] ≤ 18 min [11d]	≤ 6 min[a, 5b] ≤ 15 min[6b]	≤ 6 min [5] ≤ 15 min [12c] ≤ 18 min [11d]
Science Observation Period Per Day	24 hrs			24 hrs	≥ 16 hrs	24 hrs	≥ 16 hrs	24 hrs	≥ 16 hrs
Science Observation Days Per Orbit	≥ 14	≥ 12	≥ 1	≥ 6	≥ 1	≥ 6	≥ 1	≥ 6	≥ 1
Science Observation Days for Baseline Science Mission	≥ 98	≥ 92	≥ 16	≥ 42	≥ 13	≥ 42	≥ 13	≥ 42	≥ 13
Science Observation Days for Threshold Science Mission	≥ 14	≥ 14	≥ 1	≥ 6	≥ 1	≥ 6	≥ 1	≥ 6	≥ 1

SoloHI Science Requirement Traceability Matrix (3 of 3)

Science Objective	2.3 How do solar eruptions produce energetic particle radiation that fills the heliosphere?						2.4 How does the solar dynamo work and drive connections between the Sun and the heliosphere?					
Science Question #	2.3.1						2.4.1		2.4.2		2.4.3	
Science Question	How and where are energetic particles accelerated at the Sun?						What is the three-dimensional structure and extent of streamers and CMEs?		How are variations in the solar wind linked to the Sun at all latitudes?		What are the sources and properties of dust in the inner heliosphere, and do Sun-grazing comets contribute to this dust?	
Science Product ID	2.3.1a		2.3.1b		2.3.1c		2.4.G1a		2.4.G2a		2.4.G3a	
Derived Science Products	UV and X-ray imaging of loops, flares, and CMEs (EUI, SPICE, STIX, METIS, SoloHI)		Location, timing, and motion of CMEs and shocks (EUI, SoloHI)		Images of longitudinal extent of CMEs in visible, UV, and hard X-rays (SoloHI, METIS, EUI, SPICE, STIX)		Measure the dynamic three-dimensional structures of streamers and CMEs at all latitudes (SoloHI, METIS*)		Observe morphology and dynamics of boundaries between streamers and coronal holes (SoloHI, EUI*, METIS*)		Measure F-corona brightness, morphology, and variability as a function of ecliptic latitude (SoloHI)	
Science Measurements	High cadence height-time plots and mass measurements of CME fronts						Images of coronal and heliopheric solar wind structures in visible		Images of coronal and heliospheric solar wind structures in visible		Images of coronal dust in visible	
Type and Number of Events Captured Over Baseline Science Mission	≥ 2 ICMEs		≥ 2 ICMEs		≥ 2 ICMEs		• Quiescent, active wind and pseudo streamers for 2 days • ≥ 1 CME at each latitudinal extreme		Quiescent, active wind and pseudo streamers for 2 days at each latitudinal extreme		≥ 1 Sun-grazing comet with a tail	
Type and Number of Events Captured Over Threshold Science Mission	≥ 1 ICME		≥ 1 ICME		≥ 1 ICME		N/A		N/A		N/A	
Required (R) or Supporting (S) Measurement	S		R		R		R		R		R	
Observation Requirements												
Instrument Distance From Sun (a.u.)	0.28 to 0.36	0.36 to 0.5	0.28 to 0.36	0.36 to 0.5	0.28 to 0.36	0.36 to 0.5	0.36 to 0.50	0.5 to 0.70	0.36 to 0.50	0.5 to 0.70	0.36 to 0.50	0.5 to 0.70
Spacecraft Solar Latitude	N/A						≥ 15°	≤ -15°	≥ 15°	≤ -15°	≥ 15°	≤ -15°
Image Type	Visible broadband						Visible broadband		Visible broadband		Visible broadband	
Scene Radial Coverage	5.5 to 40.5°	5.5 to 30.5°	5.5 to 40.5°	5.5 to 30.5°	5.5 to 40.5°	5.5 to 30.5°	5.5 to 40.5°	5.5 to 30.5°	5.5 to 40.5°	5.5 to 30.5°	5.5 to 40.5°	5.5 to 30.5°
Scene Transverse Coverage	5°						26°		26°		26°	
Image Spatial Resolution	≤ 2.7 arcmin						≤ 3.0 arcmin		≤ 3.0 arcmin		≤ 6.0 arcmin	
Photometric Accuracy	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [1] ≥ 5 [2]	≥ 20 [3] ≥ 5 [4]	≥ 20 [1] ≥ 5 [2]	≥ 20 [3] ≥ 5 [4]	≥ 20	
Cadence	≤ 30 min		≤ 6 min [a, 5b] ≤ 15 min [6b]	≤ 6 min [5] ≤ 15 min [12c] ≤ 18 min [11d]	≤ 30 min		≤ 40 min [5] ≤ 80 min [7] ≤ 120 min [8]	≤ 40 min [5] ≤ 80 min [9] ≤ 140 min [10]	≤ 120 min	≤ 120 min [5,9] ≤ 150 min [10]	≤ 120 min	
Science Observation Period Per Day	24 hrs	≥ 16 hrs	24 hrs	≥ 16 hrs	24 hrs	≥ 16 hrs	24 hrs		24 hrs		24 hrs	
Science Observation Days Per Orbit	≥ 6	≥ 1	≥ 6	≥ 1	≥ 6	≥ 1	≥ 4	≥ 4	≥ 4	≥ 4	≥ 4	≥ 4
Science Observation Days for Baseline Science Mission	≥ 42	≥ 13	≥ 42	≥ 13	≥ 42	≥ 13	≥ 12	≥ 12	≥ 12	≥ 12	≥ 12	≥ 12
Science Observation Days for Threshold Science Mission	≥ 6	≥ 1	≥ 6	≥ 1	≥ 6	≥ 1	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2

* Science data products from other Solar Orbiter instruments will address the science question better, but is not required

The Role of SoloHI on Solar Orbiter

- SoloHI Will Image
  - The Solar Wind Structures and Fluctuations Directly.
  - The Solar Wind Environment Around Planets and Other Missions.
  - CME and Shock Propagation and Evolution and Their Connection to the Site of Production of SEPs.

- SoloHI Will Measure Electron Density Turbulence
  - Fast Cadence Readout Mode To Generate Power Spectral Density to Compare to In-Situ Observations of Density and Magnetic Field Spectral Density.

- SoloHI Provides The Links Between the
  - Solar Orbiter Remote Sensing and in-situ Instruments.
  - Solar Orbiter and Solar Probe+ Missions.

The Physics of SoloHI Observations

$$B_{obs} = K + F + E + G + P + S$$

Where:

K = Photospheric Light Thomson Scattered from Free Electrons

F = Photospheric Light Scattered from Dust

E = Emission Line from the Plasma – usually zero in SoloHI

G = Galactic and Stellar Emissions – useful for calibration

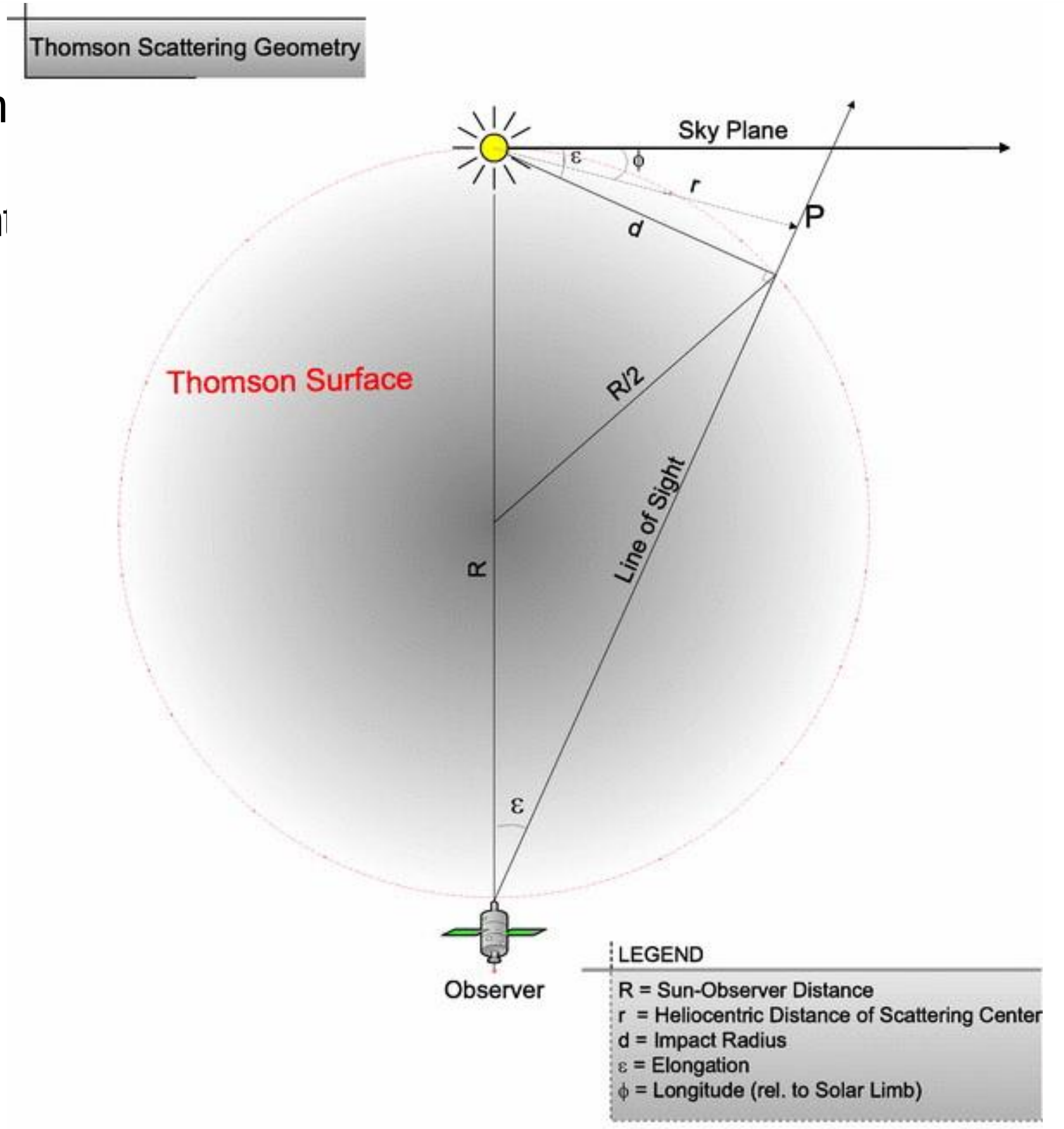
P = Planets and Comets

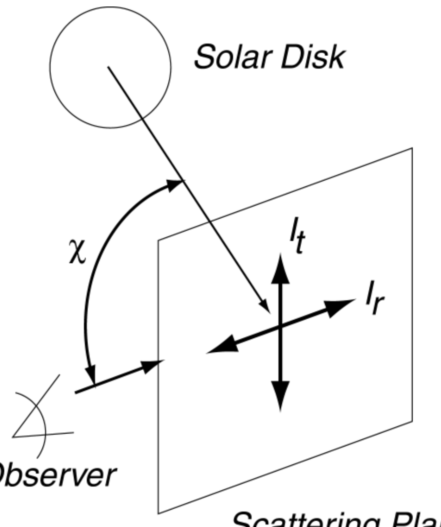
S = Stray light

Thomson Scattering Geometry

An electron scatters photons such that the electric vector lies in a plane perpendicular to the inciden[t] photon.

At a constant distance from the source, the intensity at 90º to the observer will be ½ the intensity observed directly on the plane.





Thomson Scattering Equations

The intensity of the tangential component:

$$I_t = I_o \frac{N_e \pi \sigma}{2} [(1-u)C+uD]$$

The intensity of the tangential - radial component (pB):

$$I_t - I_r = I_o \frac{N_e \pi \sigma}{2} \sin^2\chi [(1-u)A+uB]$$

A, B, C, and D are the “Van de Hulst Coefficients”
U is the limb darkening coefficient
σ is the electron scattering cross section
χ is an angle
Io is the mean brightness of the solar disk
Ne is the electron density

Thomson Scattering Equations

The intensity of the tangential component:

$$I_t = I_o \frac{N_e \pi \sigma}{2} [(1-u)C+uD]$$

The intensity of the tangential - radial component (pB):

$$I_t - I_r = I_o \frac{N_e \pi \sigma}{2} \sin^2\chi [(1-u)A+uB]$$

The only variable is Ne – the volume electron density distribution along the line of sight

Thomson Scattering Equations

The intensity of the tangential component:

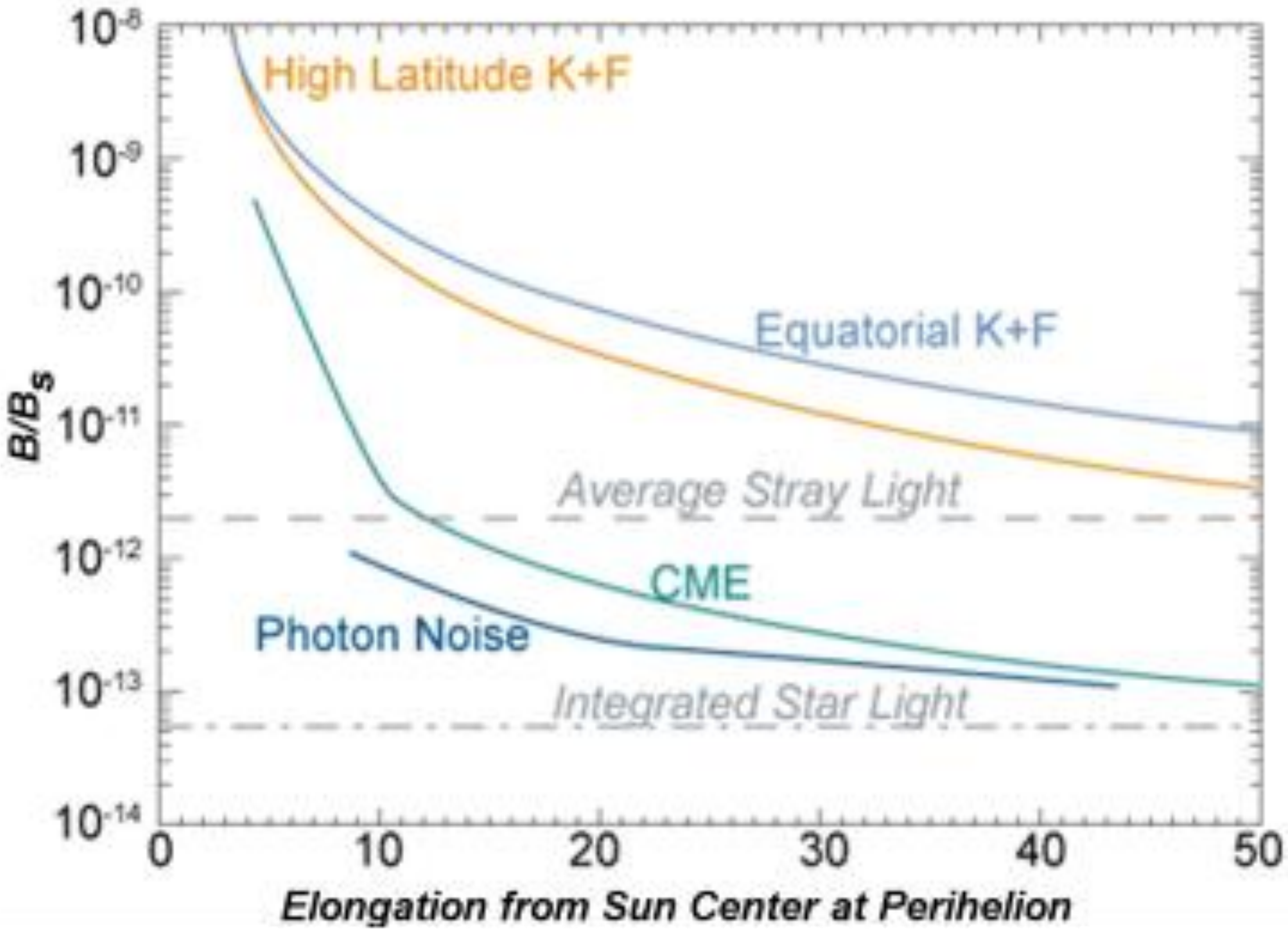
$$I_t = I_o \frac{N_e \pi \sigma}{2} [(1-u)C+uD]$$

The intensity of the tangential - radial component (pB):

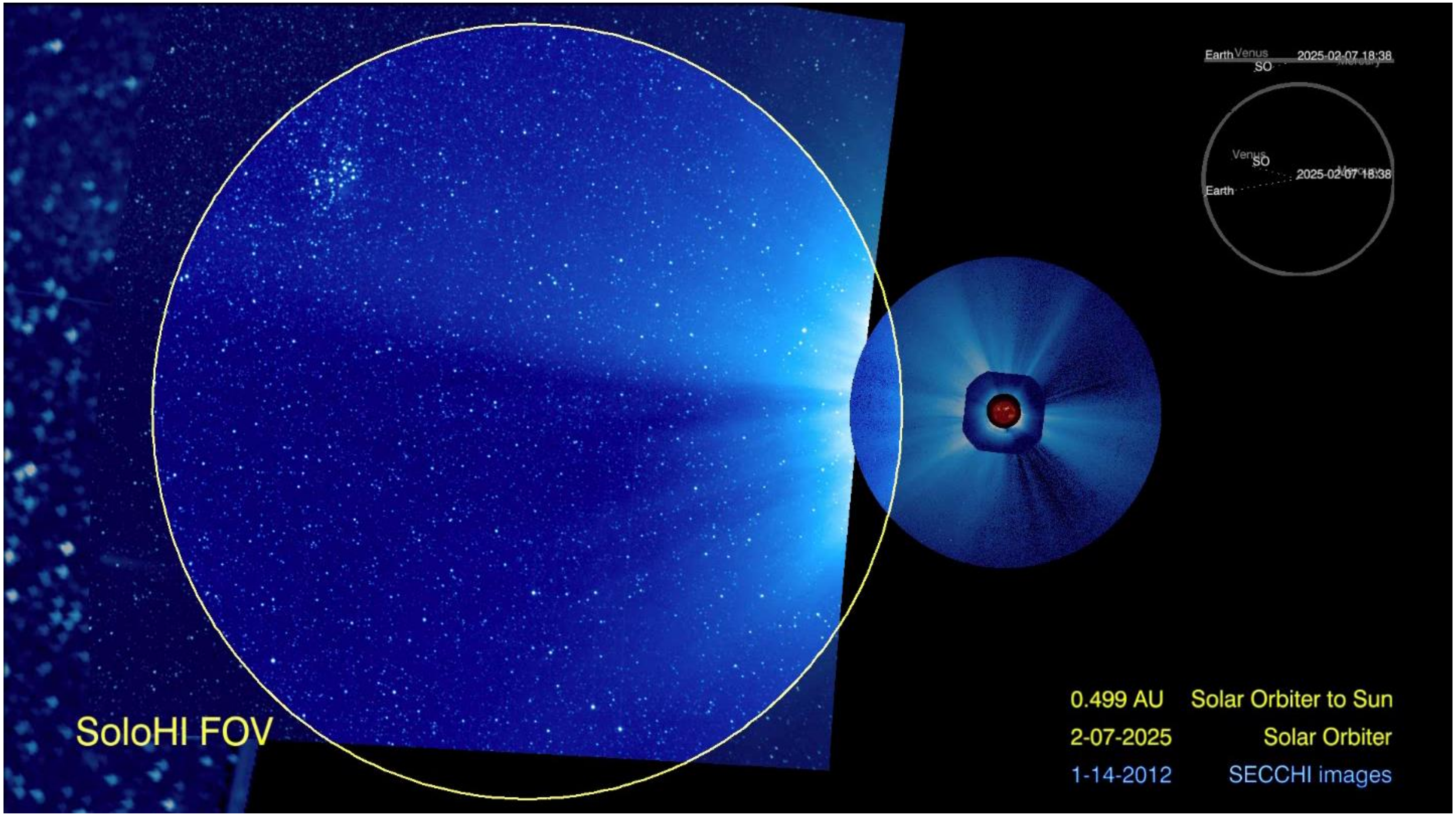
$$I_t - I_r = I_o \frac{N_e \pi \sigma}{2} \sin^2\chi [(1-u)A+uB]$$

But also I_0 has been assumed to be a constant, but in fact varies as the Total Solar Irradiance.

Scene Brightnesses and Stray Light Requirements



SoloHI Observing FOVs During 0.28 AU Perihelion



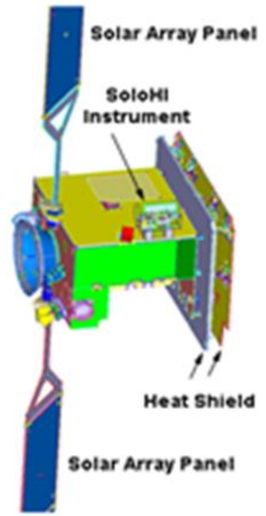
- Simulation of a SoloHI Observing Program During 0.28 AU Perihelion Passage Using a STEREO/SECCHI Composite
- Full-Frame (Large Circle), Shock Formation (Rectangular Box), and Turbulence Subframes (3 Small Boxes)

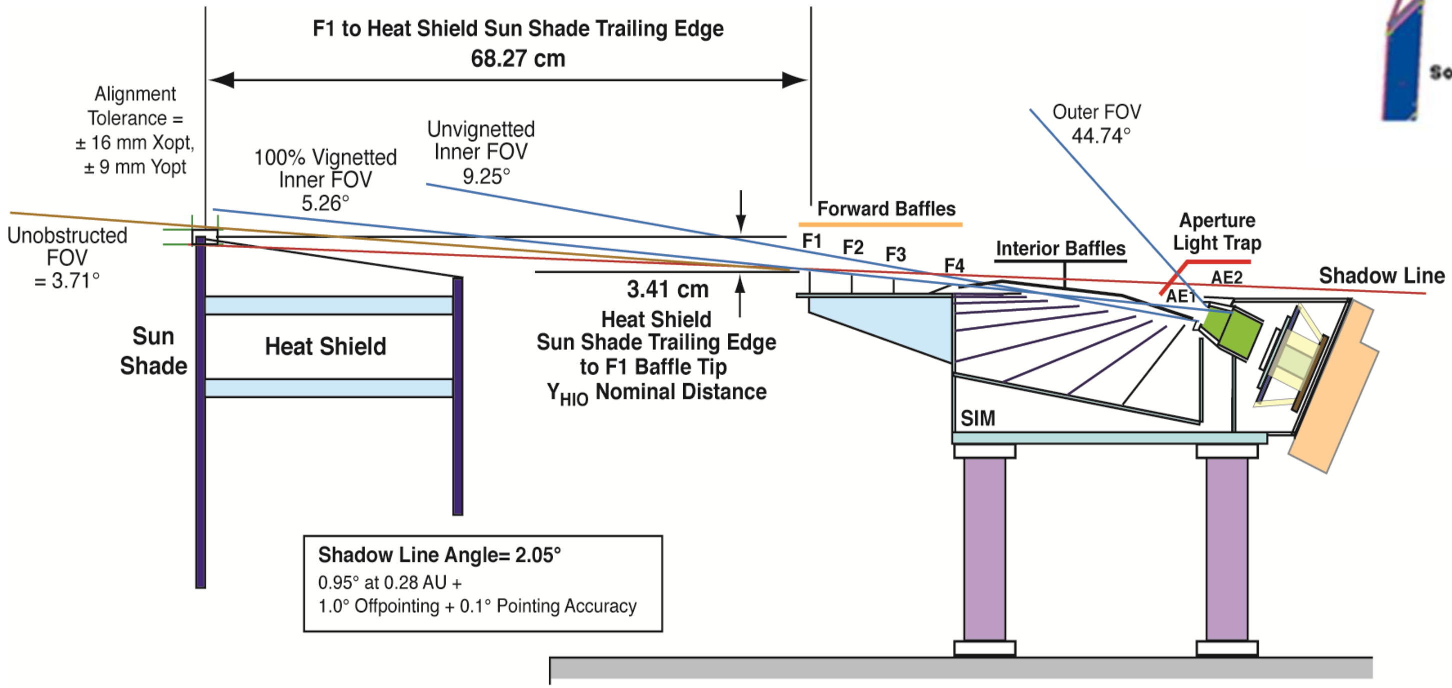
Significant Challenges to the Design of SoloHI

- Reduction of Stray Light
  - The usual reduction of diffracted light from the Sun
  - The reflected light from the solar array which is directly behind SoloHI
- Low Mass and Power
  - Development of a low mass/power camera
    - Use an APS/CMOS detector rather than CCD detector reduces the mass from ~6 kg to 1 kg
  - Minimizing mass was inconsistent with the high loads that the instrument would experience
- Low electromagnetic emissions
  - To be compatible with the MAG & RPW sensors

SoloHI Baffle Design Concept

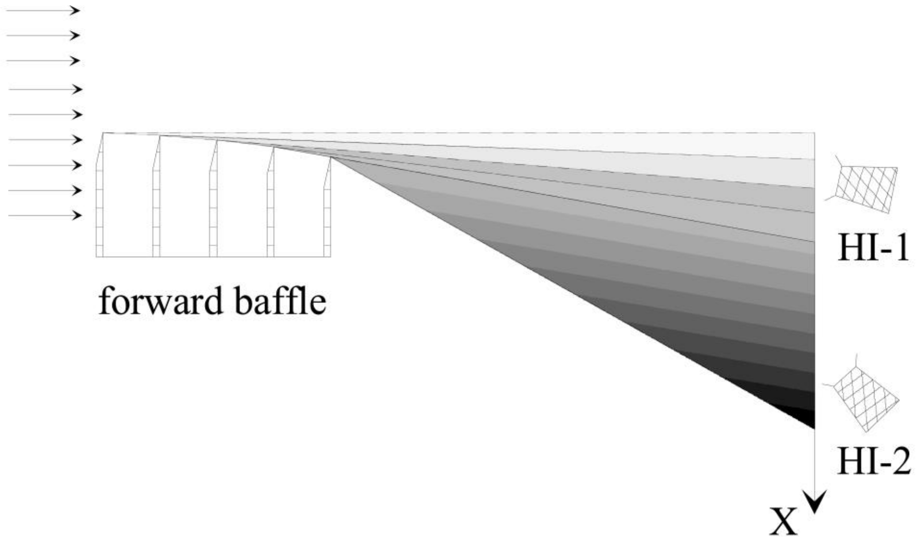
- There are 3 types of baffles:
  - Forward Baffles to reject the solar disk illumination
  - Interior Baffles to reject reflections from the solar array bright celestial/heliospheric reflections
  - Peripheral Baffles to reject reflections from spacecraft

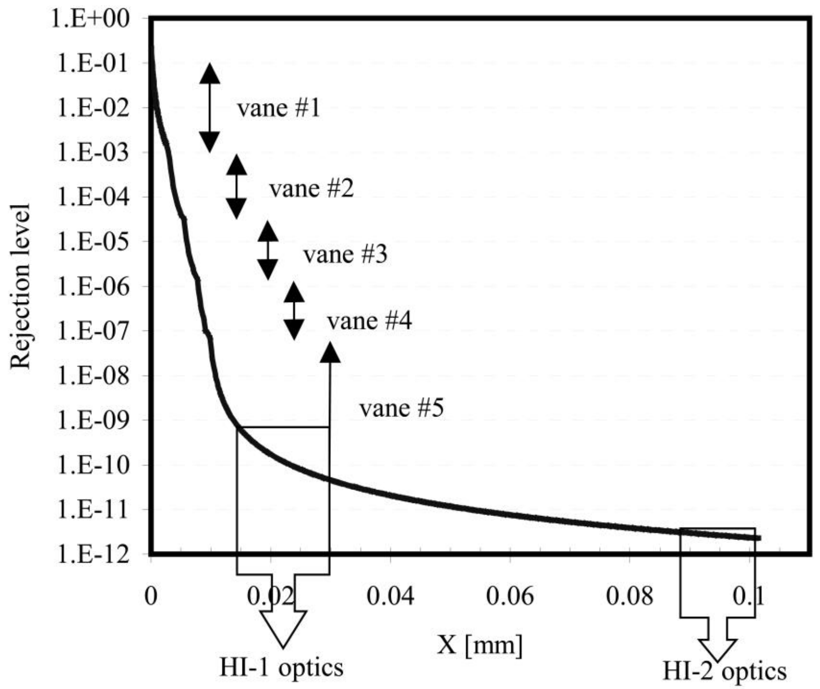




Solar Disk Stray Light Rejection

- The SL Suppression Concept Is Built Upon the Many Successful White Light Coronagraphs (e.g., SOHO/LASCO) and the Heliospheric Imager (HI) Component of SECCHI on the STEREO Mission.
- Forward Baffles of Heliospheric Imagers achieve 9-10 orders of solar disk rejection by using multiple edges.
- Performance measured for STEREO H1/H2 matches theory.
- SoloHI uses the edge of the SolO Heat Shield as the first baffle

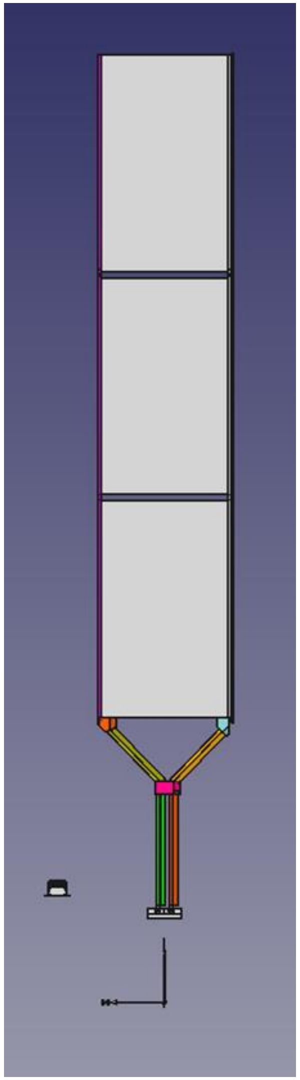


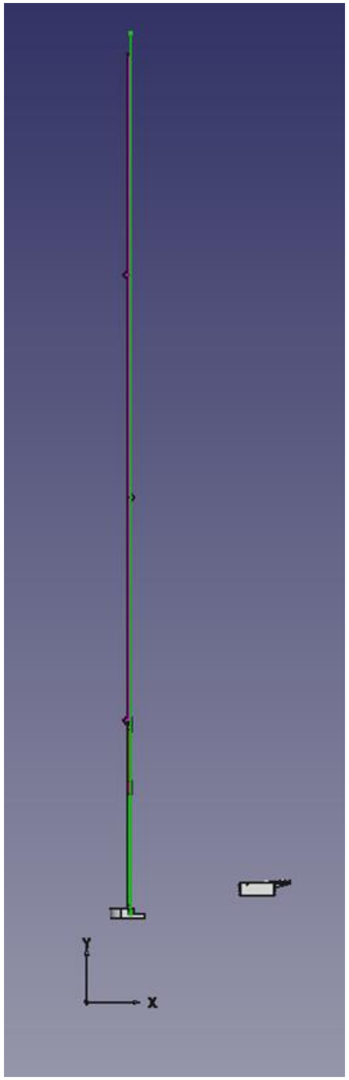


Rejection of Solar Array Reflections

- A significant source of stray light is the diffuse, reflected sunlight from the solar array which is behind the instrument and is reflecting onto the backs (anti-sunward side) of the baffles.
  - The figures to the right show the front and side views of the array and the SoloHI instrument

- To minimize the impact of reflected light from the solar array reaching the entrance aperture, the coatings of each of the baffles are individually specified to either be a reflective or diffuse scatterer.
  - The interior baffles are slanted backward to intercept the reflected light from the solar array, such that the lens does not look at a baffle that is directly illuminated by the solar array



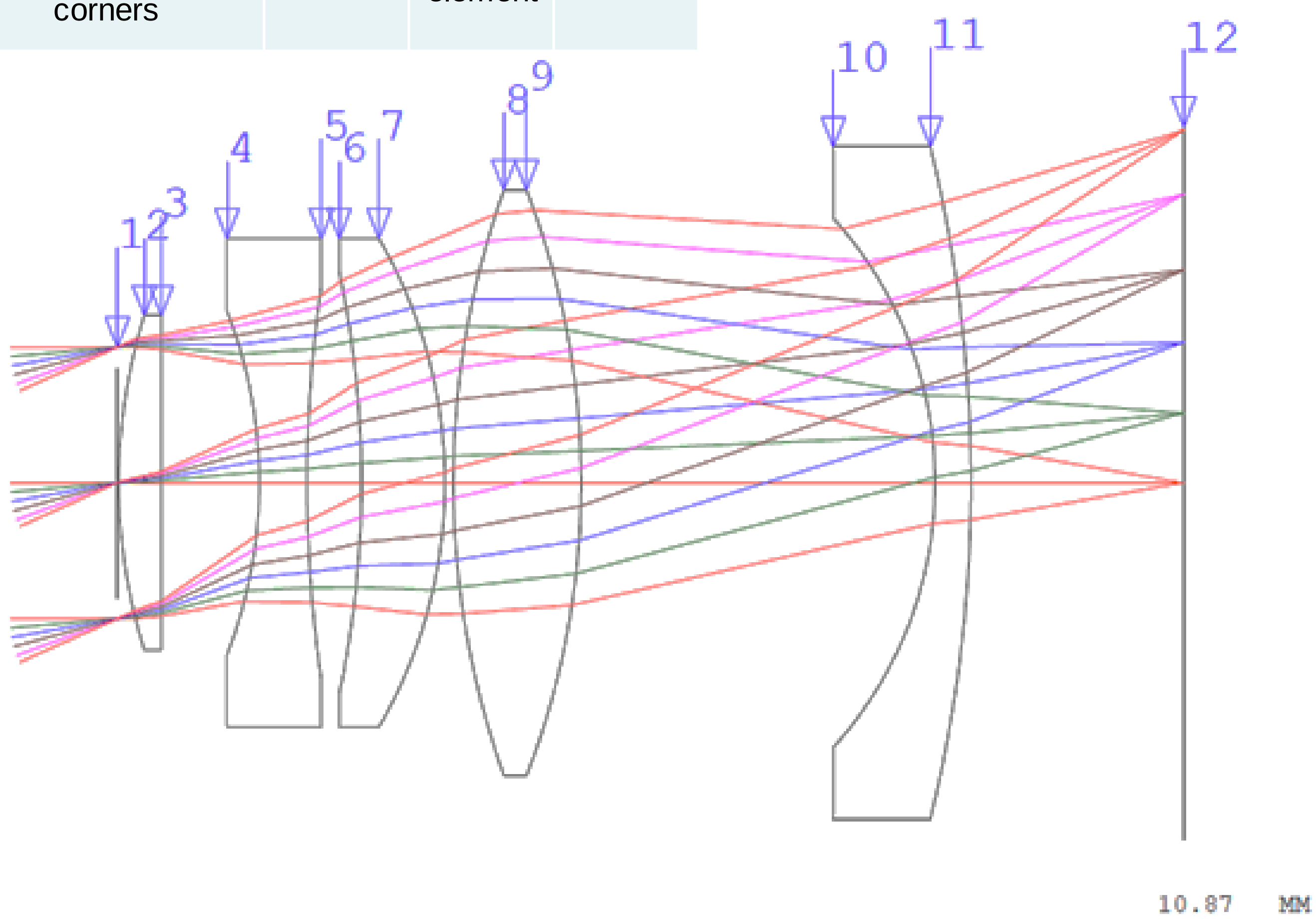


Optical Design

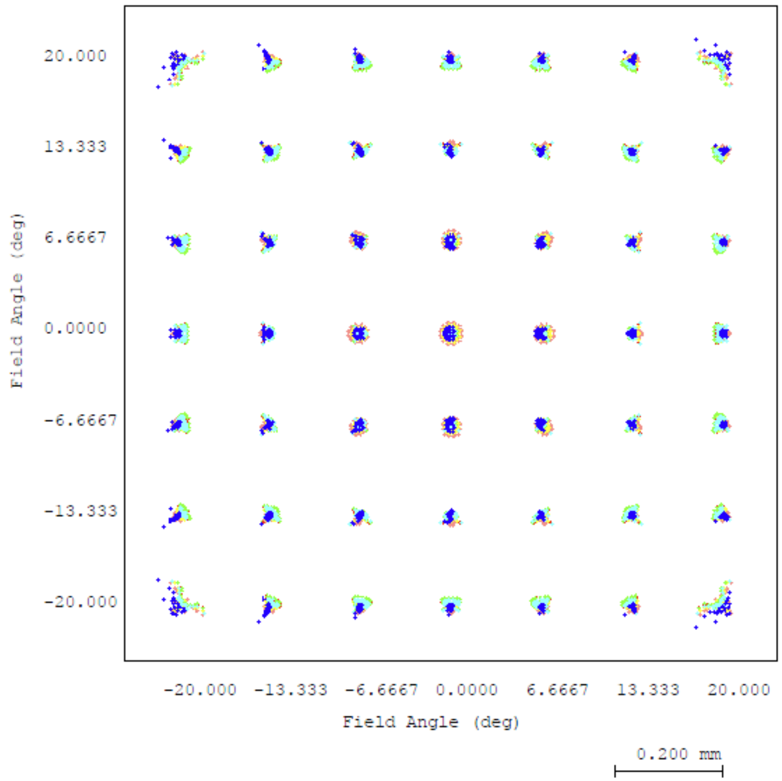
Telescope FOV	Detector FOV	Spectral Range (nm)	Entrance Pupil (mm)	F#	# of lenses	RMS Spot Size (µm)
Φ 48º	40º x 40º	500-700	16 x 16 llimited to 19 mm diameter in the corners	3.4	5-element	19-23

Low Pass Filter S9

High Pass Filter S7

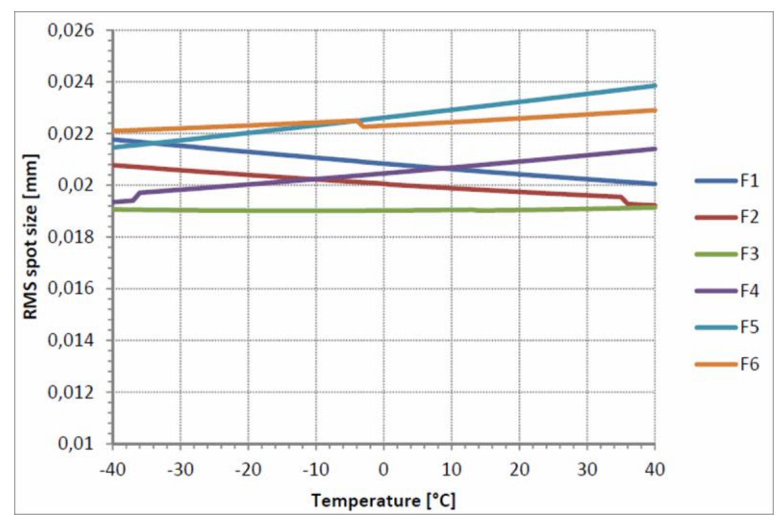


Spot Diagram



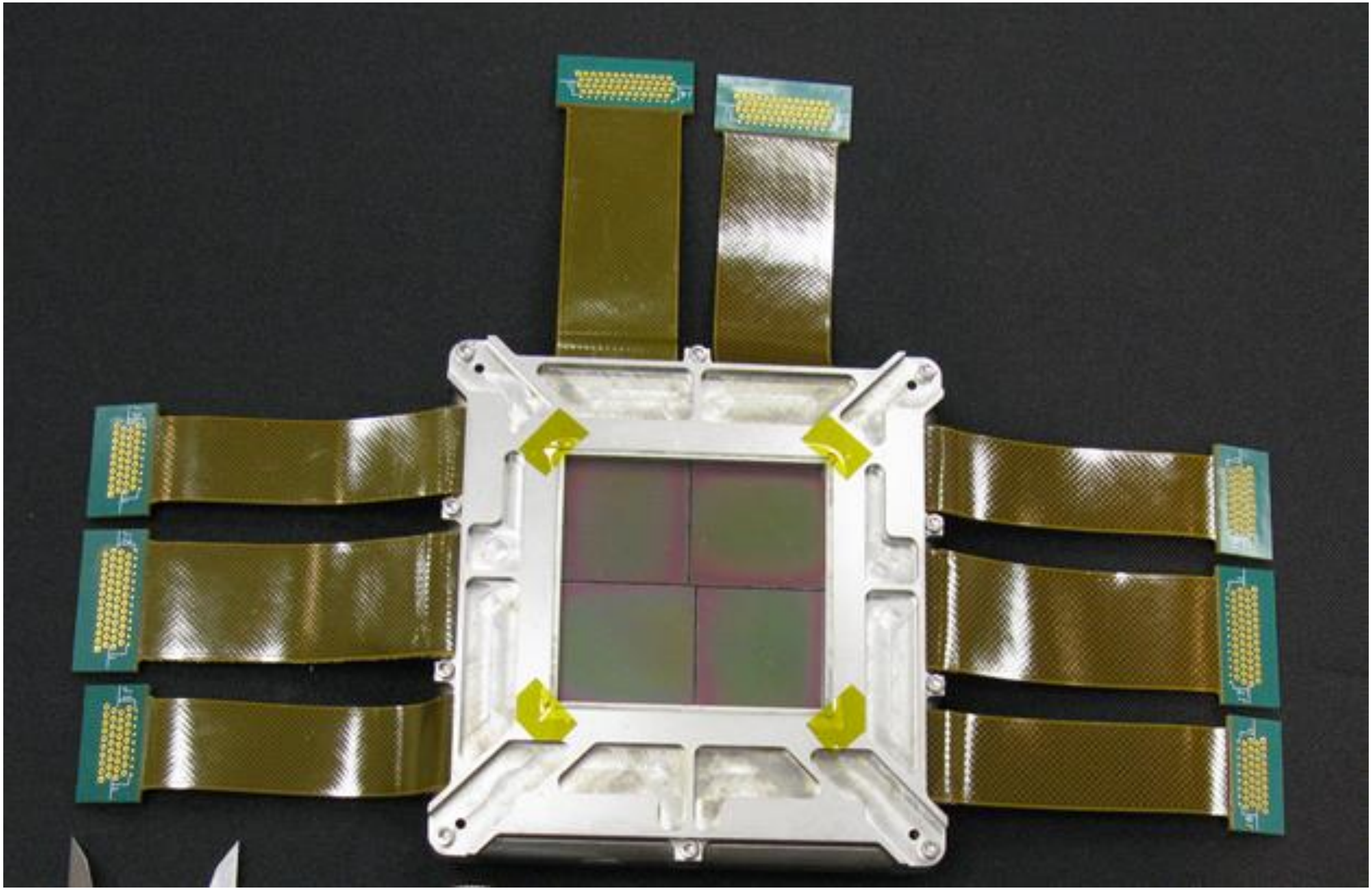
#	RMS spot [mm]
1	0.0213
2	0.0204
3	0.0189
4	0.0196
5	0.0214
6	0.0225

RMS spot diameter in nominal conditions.



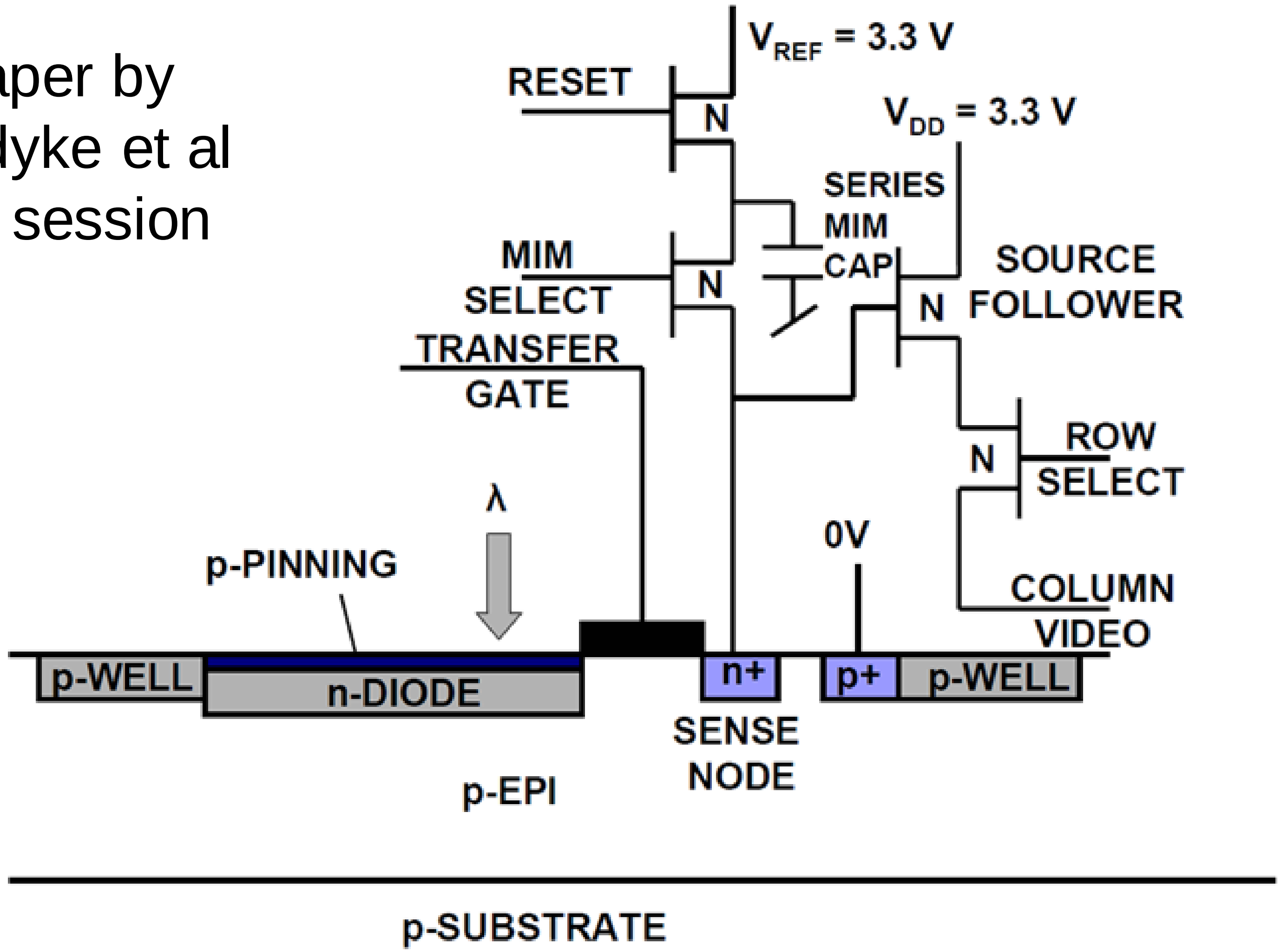
Spot Size vs Temperature

Structural Model of Quad-Tiled APS in Flight Package

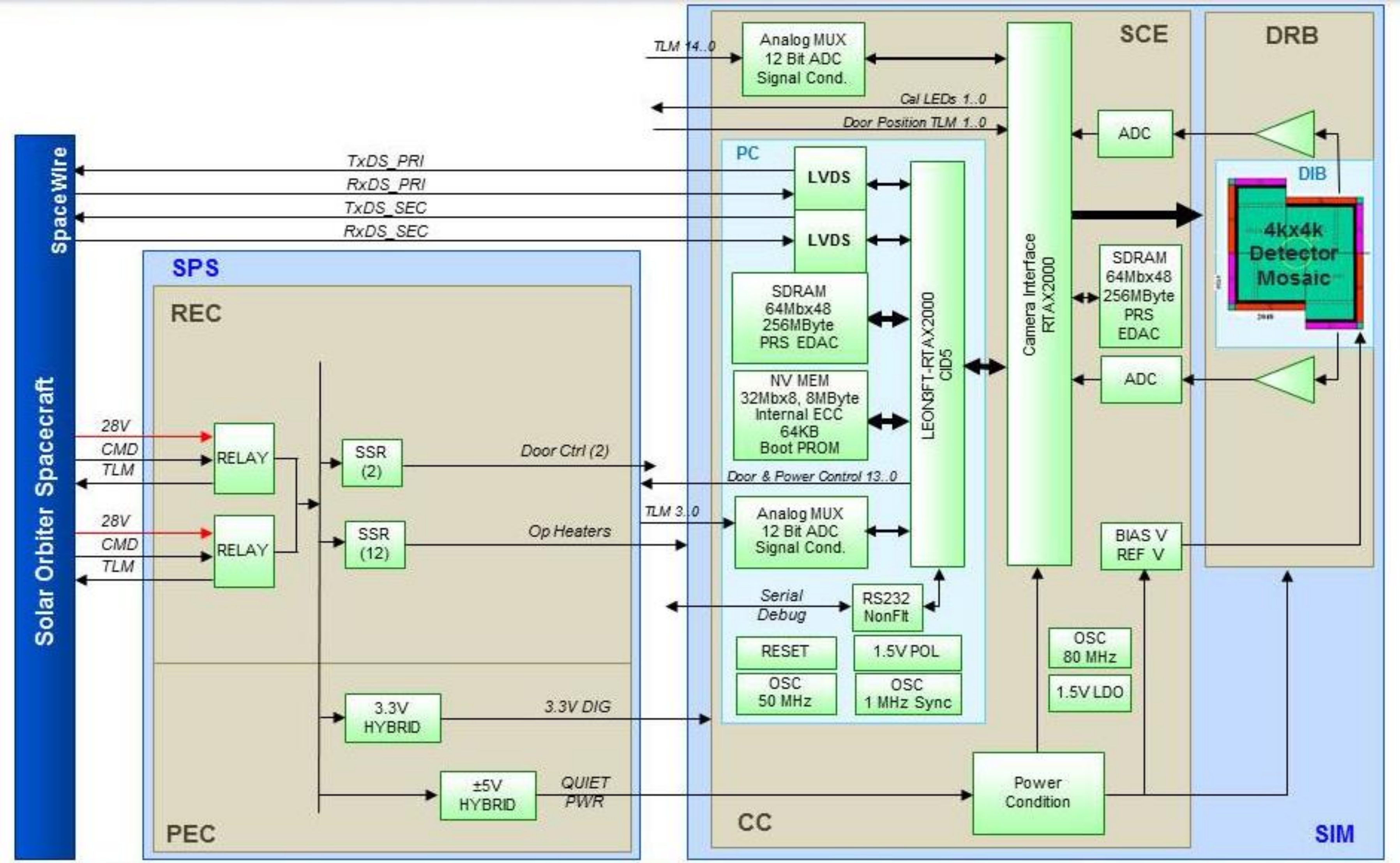


APS Pixel Design

See paper by Korendyke et al in next session

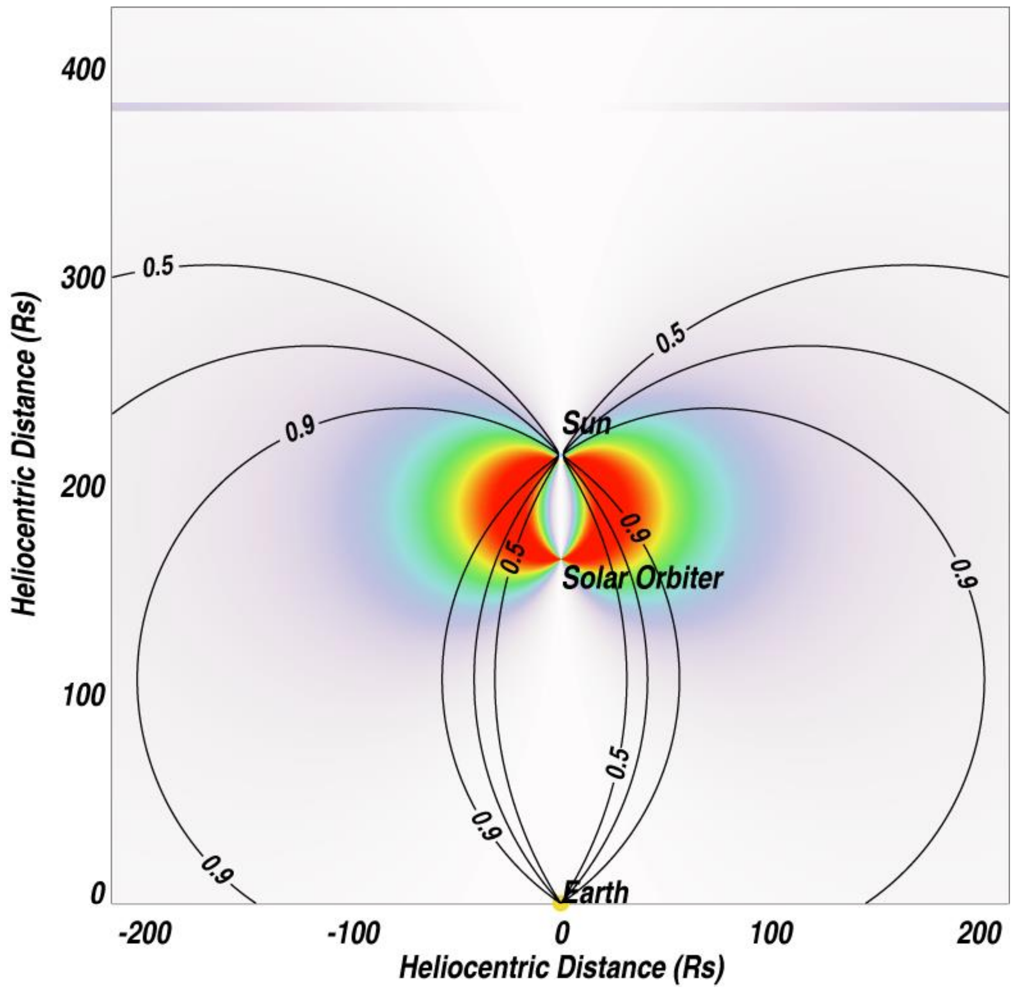


Electronics Block Diagram



SoloHI Will Lead to Unique Science

- The Varying Heliocentric Distance Transforms SoloHI From a Remote (at Aphelia) to a Local (at Perihelia) Imager
- SoloHI Is the First Imager to Provide Density Power Spectra at Rates Similar to in-situ Instruments (~1min) but at Multiple Locations at Once
- SoloHI Is the Only Instrument to Image Shocks and Connect the SEP Sources to the in-situ Measurements
- SoloHI Will Provide the First Measurements of the Dust 3D Distribution in the Inner Heliosphere
- SoloHI Only Possibility for Flyby Studies of Sungrazing Comets



Baseline Observing Programs for Perihelion Period

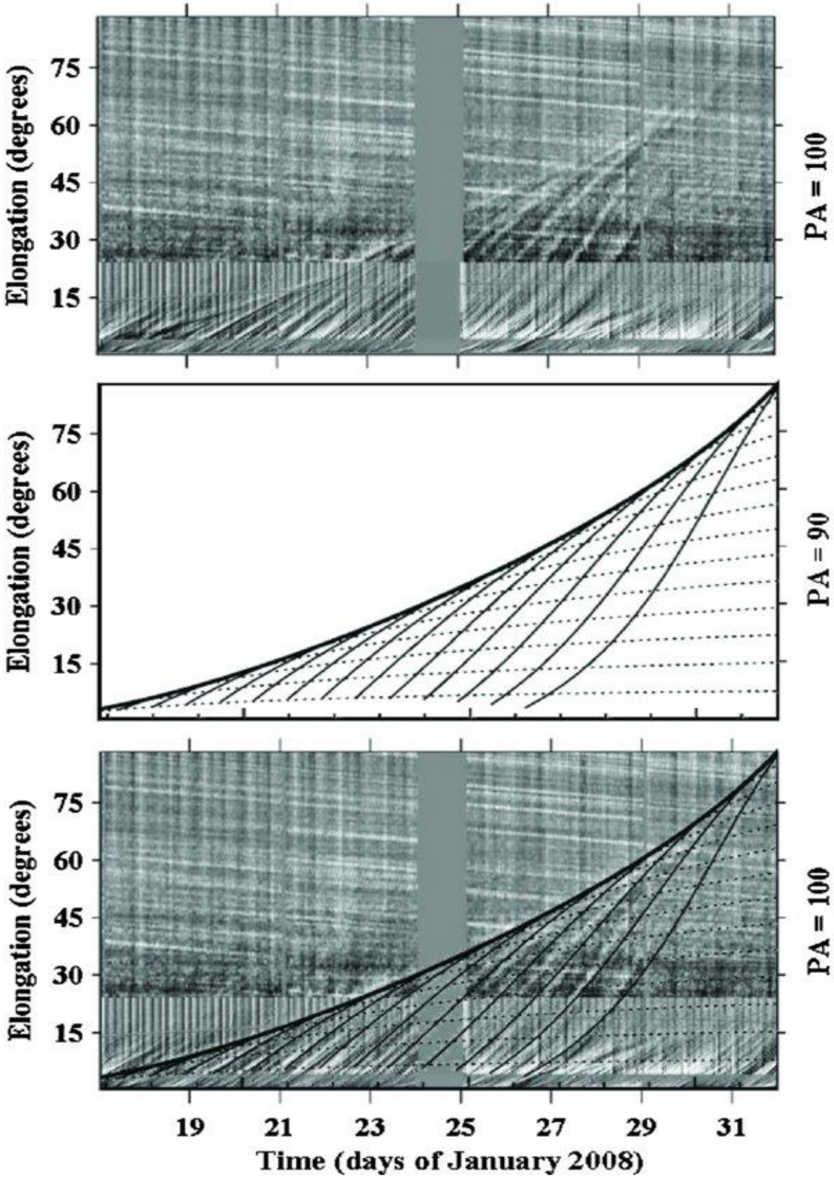
	Perihelion Region						
Observing Program ID	**A1.1**	**A1.2**	**B1.1**	**B1.2**	**B1.3**	**C1.1**	**C1.2**
Program Description	Synoptic		Wave Turbulence			Shock Formation	
Image Type	Full Frame		Inner FOV Subframe			Radial Swath Subframe	
Radial FOV	[5°, 25°]	[25°, 45°]	[5.80°, 7.68°]	[13.5°, 15.375°]	[18.5°, 20.375°]	[5°, 25°]	[25°, 45°]
Transverse FOV	40°		5°			5°	
Binning	2 x 2		1 x 1	2 x 2	2 x 2	2 x 2	
Image Size w/Binning	1024 x 2048	1024 x 2048	192 x 512	96 x 256	96 x 256	1024 x 256	1024 x 256
Maximum # of Images in Summed Image	4	32	8	12	16	4	32
Compression Type	H-Compress	Rice	H-Compress	Rice	Rice	H-Compress	Rice
Compressed Image Size (MB)	1.3	3.0	0.06	0.03	0.03	0.16	0.37
Image Cadence	30.0 min		0.13 min	0.77 min	1.54 min	5.54 min	
Images per Day	**48**		**1872**	**312**	**156**	**260**	
Observing Period per Day	24 hrs		4 hrs each			24 hrs	
Observing Days per Orbit	4		2			2	

Interpreting Heliospheric Images

Case studies of Streamer Blobs and Corotating Interaction Regions

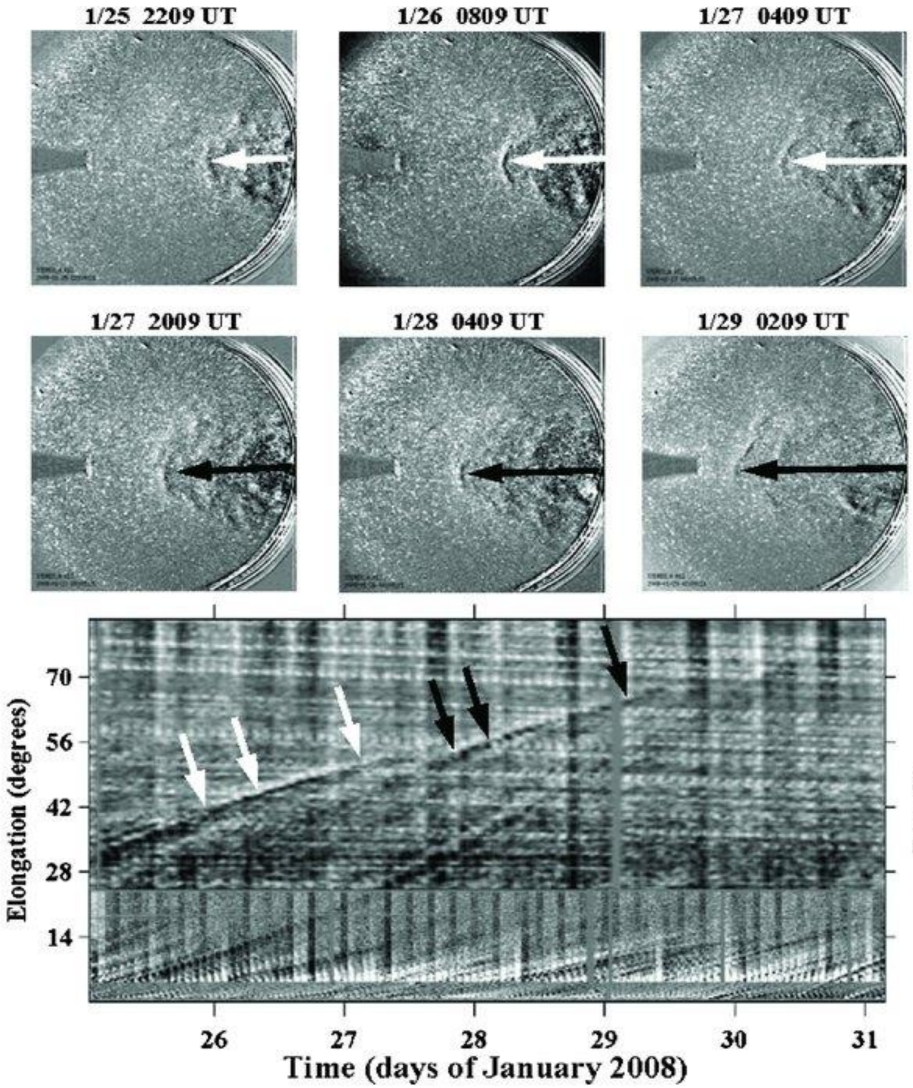
Height – Time Maps (J-Maps)

- The combination of coronal rotation, the solar wind outflow and the optically thin nature of the scattering, makes the interpretation of the heliospheric images challenging.
- We found that the construction of J-Maps facilitate the tracking of features from the sun to earth.
- The middle plot is a track of density blobs moving at 330 km/s and rotating with the solar rotation (.233 rad/day). The top & bottom plots are observations from SECCHI exactly matching those plots.



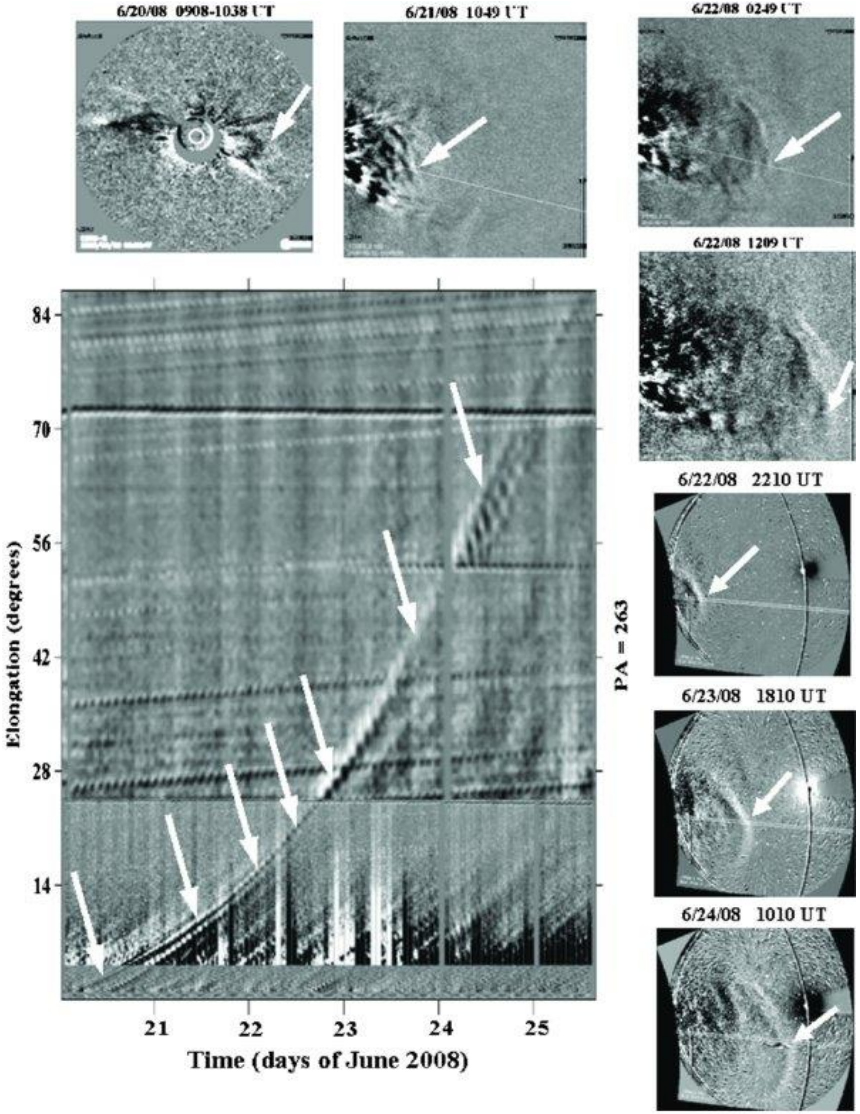
Example of the utility of J-Maps in Tracking Streamer Blobs

- The figures in the top 2 rows to the right show several streamer blobs, indicated by the white and black arrows.
- It isn't obvious from the images whether they are the same structure.
- The bottom J-Map drawn at a Position Angle of 91º shows the height-time tracks. The white and black arrows point to the two tracks. It is clear that these are two separate structures, which merge (in projection) onto the same track.



A Track of a Co-rotating Interaction Region

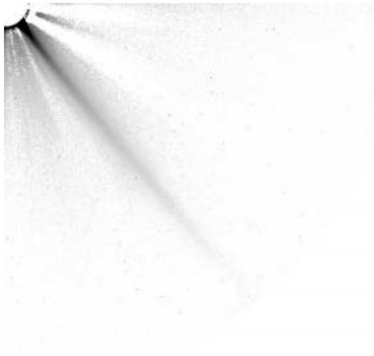
- Direct images and corresponding track of a streamer blob being swept up in the compressed region ahead of a high speed stream, forming the CIR

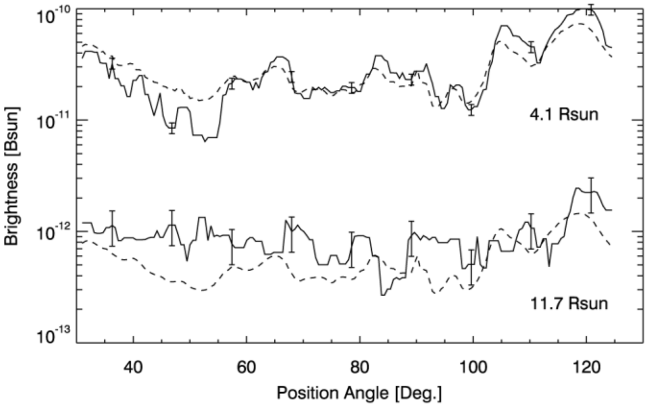


What is a “Streamer”

Streamer Observation

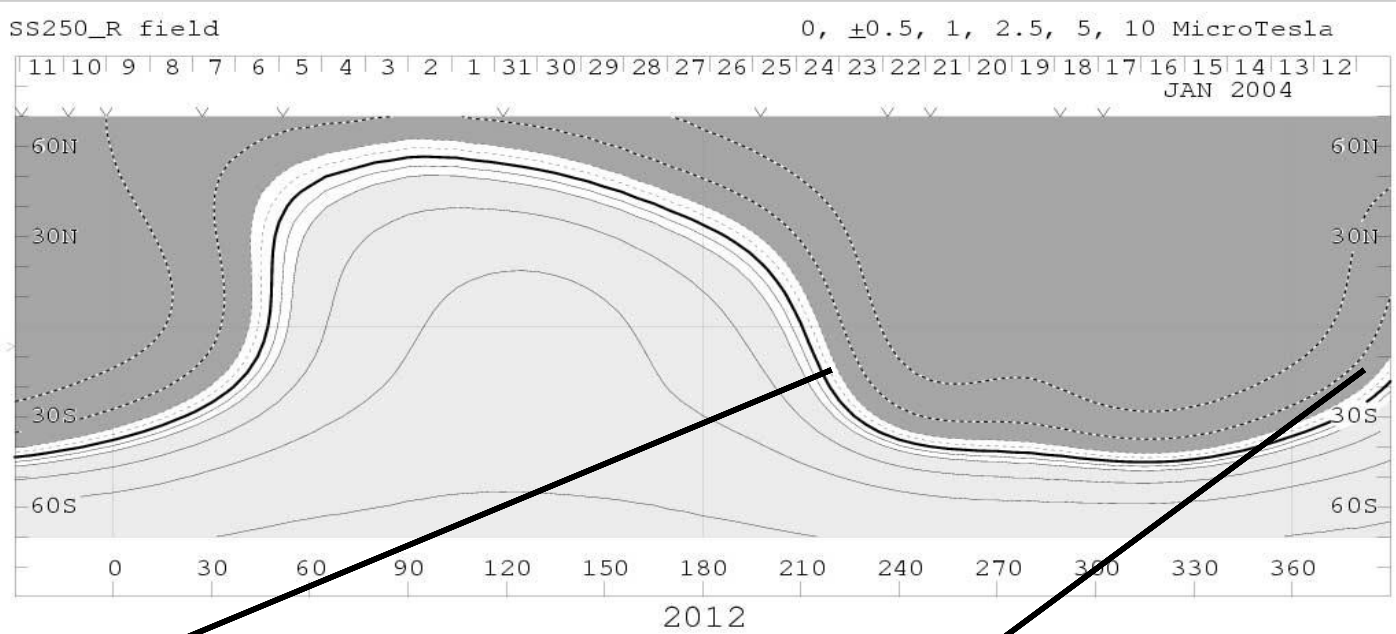
- In 2004 a very stable high-latitude streamer was observed from SOHO. An analysis (Thernisien & Howard, ApJ 2006) was able to determine the 3D density distribution along the axis (in longitude).
- The two figures on the right are showing the “same” streamer first seen edge-on at the limb and then seen face-on over the pole as the region was transiting behind the sun.
- The edge-on view defined the width of the streamer and used in the face-on view to define the depth.



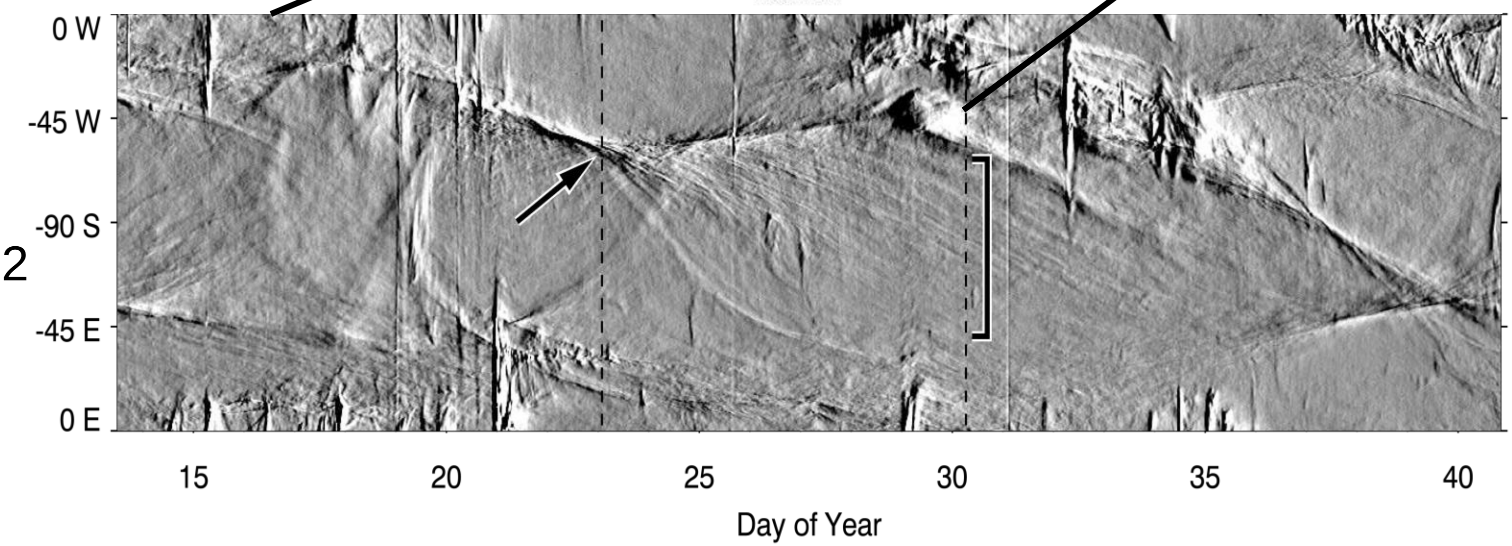


Synoptic Maps (July, 2004)

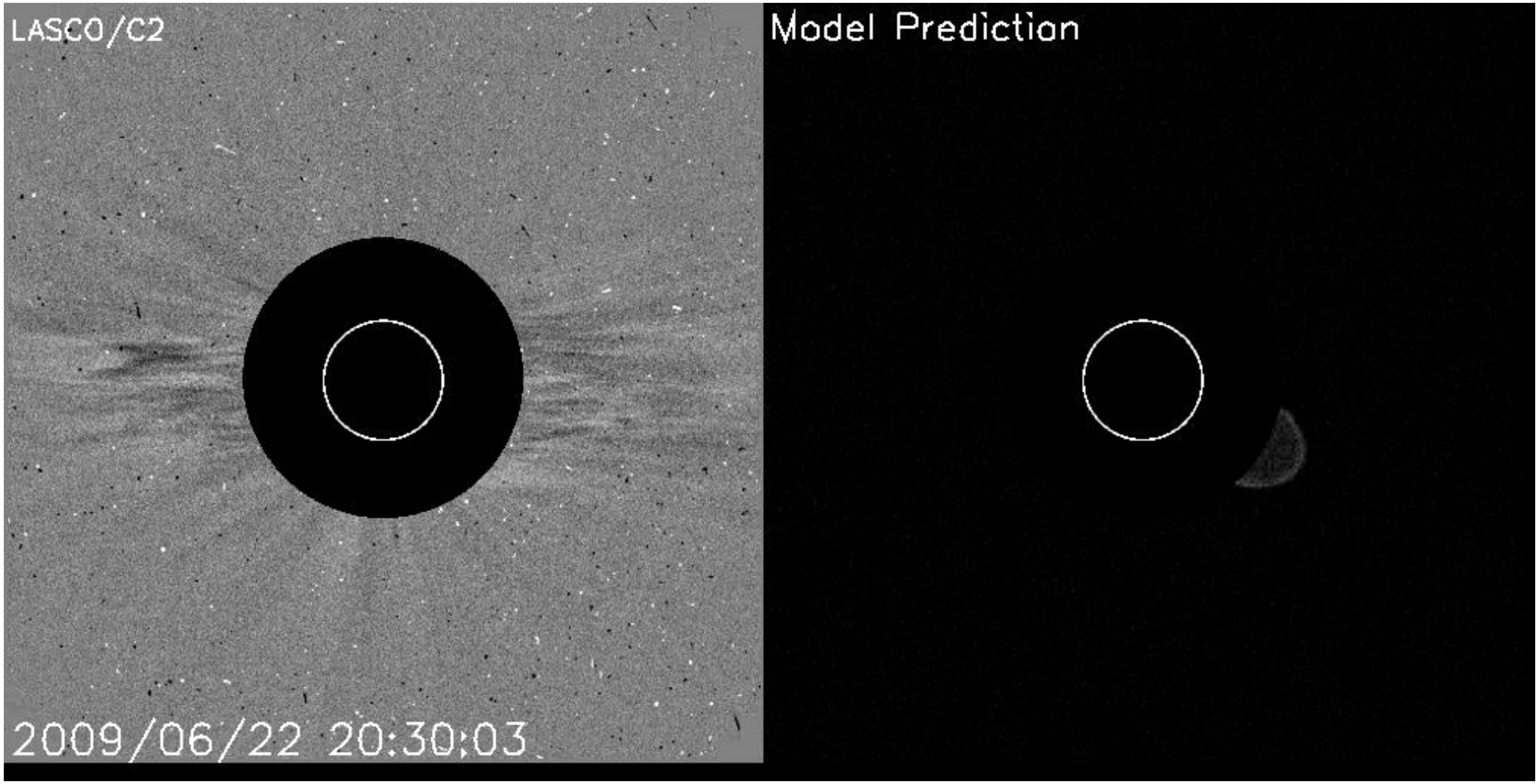
Photospheric Magnetic Field



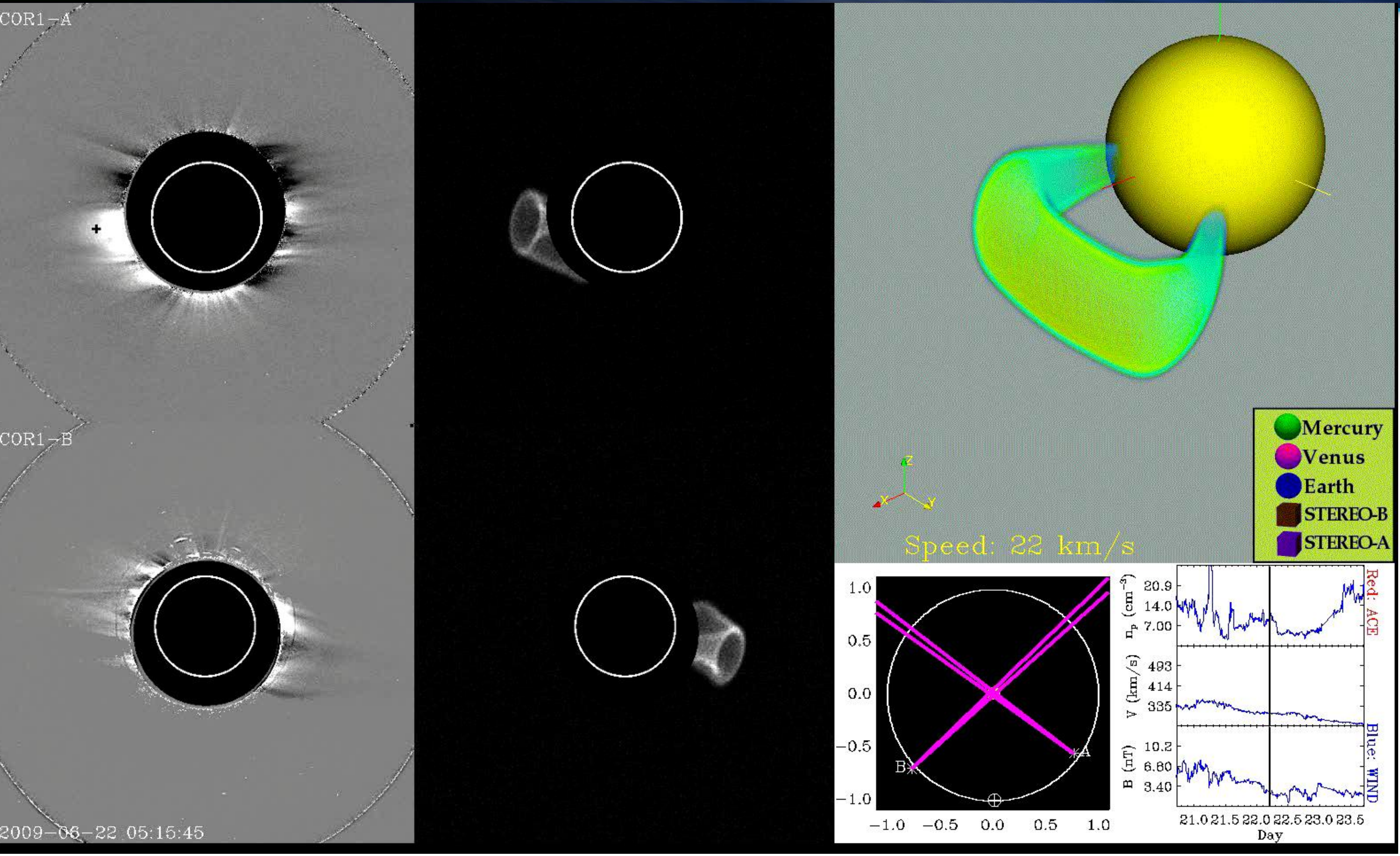
White Light LASCO-C2



Modeling a Coronal Mass Ejection



Wood et al, 2013)



Wood et al, 2013)

Observations of the Dust Corona

(F-Corona)

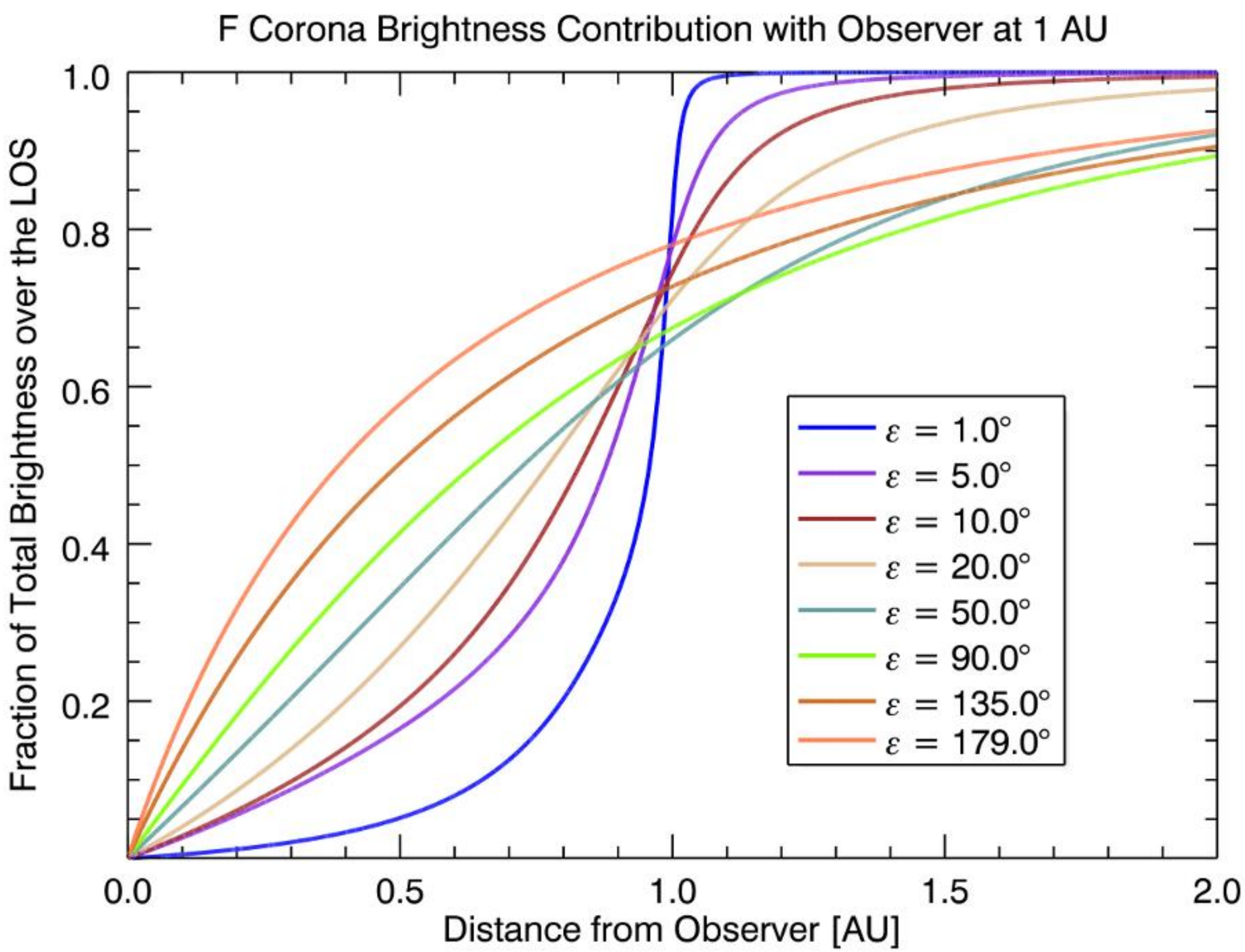
Observations of Dust Distribution

- SoloHI will observe the near-Sun dust environment – i.e. the F-corona from 0.28AU.
- As dust particles get close to the Sun they will evaporate and then not contribute to the scattering. The radial distance of this evaporation depends on the material composition
- A dust free zone at about 4-5 Rsun has been postulated (Russell, 1929), but has never been observed.

Questions:

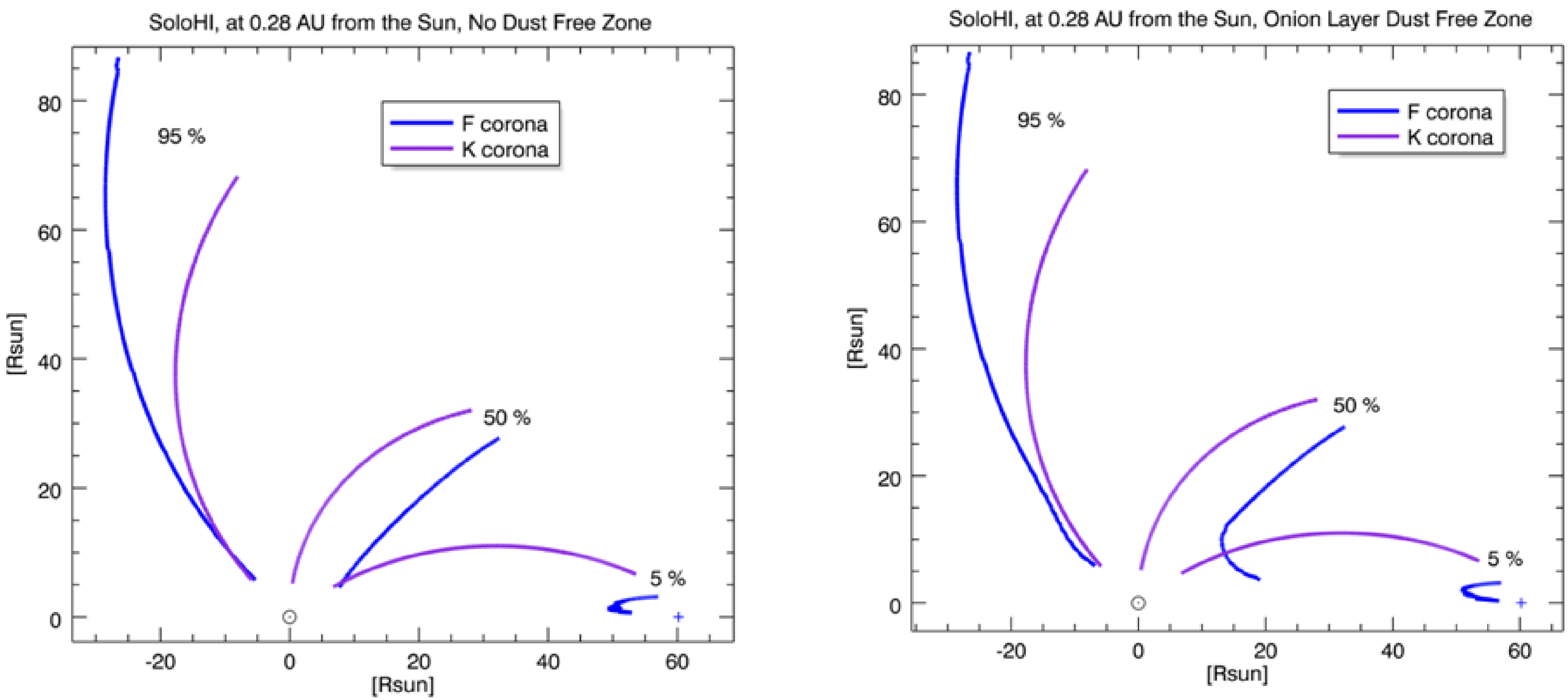
- What will the background F-Corona look like from SoloHI
- What inferences might we be able to make about the near-sun dust environment.

LOS Brightness Contribution from Dust Scattering with Observer at 1 AU



Even at ε =1º , 90% of the emission isn't achieved until about 0.2-0.3 AU from the sun. At ε=20º the contribution is almost linear from the sun to 1 AU.

Depth Contribution for SoloHI at Perihelion



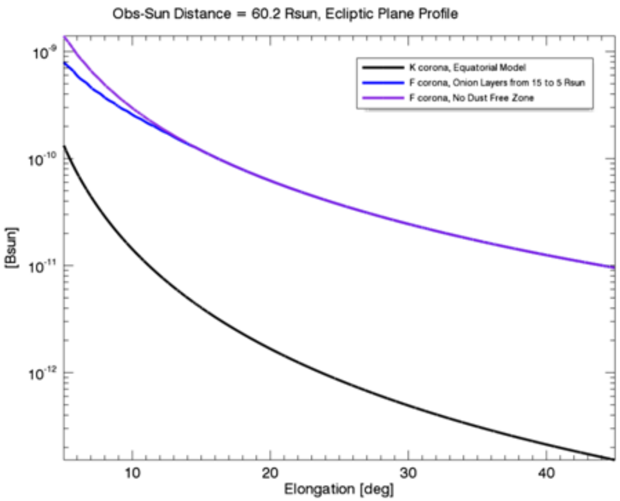
K and F corona depth contribution.

Left panel: no dust free zone.

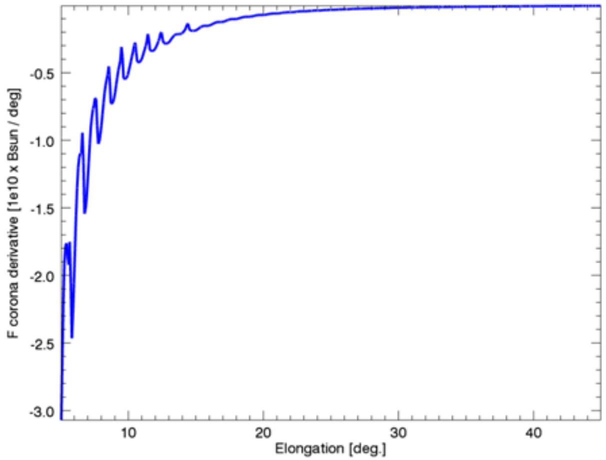
Right panel: onion layer dust free zone starting at 15 R_{sun}.

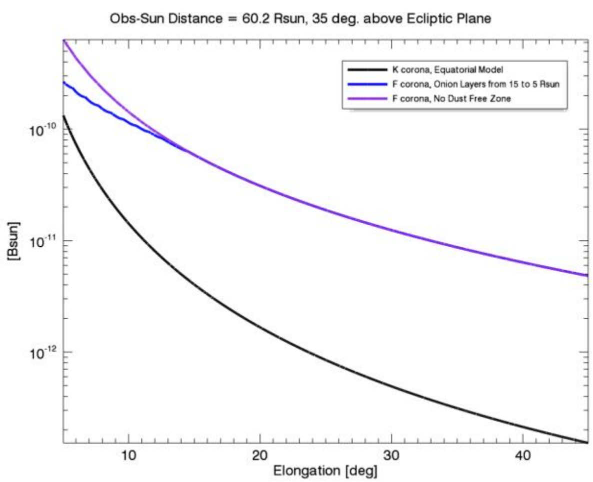
Onion Layers Dust Free Model, SoloHI FOV, from 0.28 AU

K and F coronal profiles	Spacecraft Location	Derivative of the Total Brightness Curve

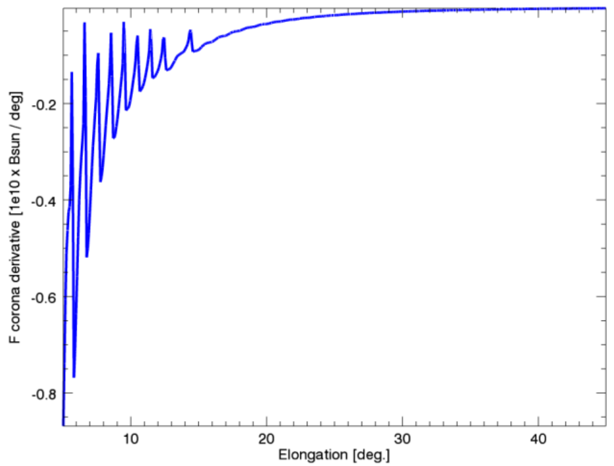


In the Ecliptic Plane





35^0 Above the Ecliptic Plane



Sublimation Zones For Different Materials

Material	Sphere	Fluffy	Ref.
Quartz	1.5–4 $R_\odot$	—	1,2,3
FeO-poor obsidian	1.9–7 $R_\odot$	2.5–3 $R_\odot$	4,5,6,7,8,9,10
FeO-rich obsidian	2.9–6 $R_\odot$	—	5,8
Glassy carbon	4 $R_\odot$	4 $R_\odot$	9,10
Graphite	≤ 5 $R_\odot$	≤ 2 $R_\odot$	2,5,7,8,11
Crystalline Mg-rich pyroxene	5 $R_\odot$	5 $R_\odot$	12
Amorphous Mg-rich pyroxene	5.5–6.5 $R_\odot$	5–6.5 $R_\odot$	12
Basalt	6 $R_\odot$	—	8
Andesite	9–10.5 $R_\odot$	—	3,4,11
Crystalline Mg-rich olivine	10 $R_\odot$	9.5–11 $R_\odot$	12
Amorphous Mg-rich olivine	13.5–15.5 $R_\odot$	12–15 $R_\odot$	12
Astronomical silicate	14 $R_\odot$	—	8
Iron	11–24.3 $R_\odot$	—	3,4
Magnetite	10–40 $R_\odot$	—	6
Water ice	1–2.8 AU	—	2,3,6

References. — (1) Over (1958); (2) Mukai and Mukai (1973); (3) Lamy (1974b); (4) Lamy (1974a); (5) Mukai and Yamamoto (1979); (6) Mukai and Schwehm (1981); (7) Mann *et al.* (1994); (8) Shestakova and Tambovtseva (1995); (9) Kimura, Ishimoto, and Mukai (1997); (10) Krivov, Kimura, and Mann (1998); (11) Mukai *et al.* (1974); (12) Kimura *et al.* (2002).

Mann et al (2004)

Summary

- SoloHI is poised to contribute to the exciting Solar Orbiter science observations and analyses
- We all depend on the next generation(s) of scientists

- With the Solar Orbiter mission joining SOHO, SDO, STEREO, SPP, BEPI-COLUMBO, Messenger and other interplanetary missions, we are in a “golden-age” of solar observations – these observations are necessary to provide the validation of the various models.

- I wish to gratefully acknowledge the contributions of the SoloHI team and the support of NASA.