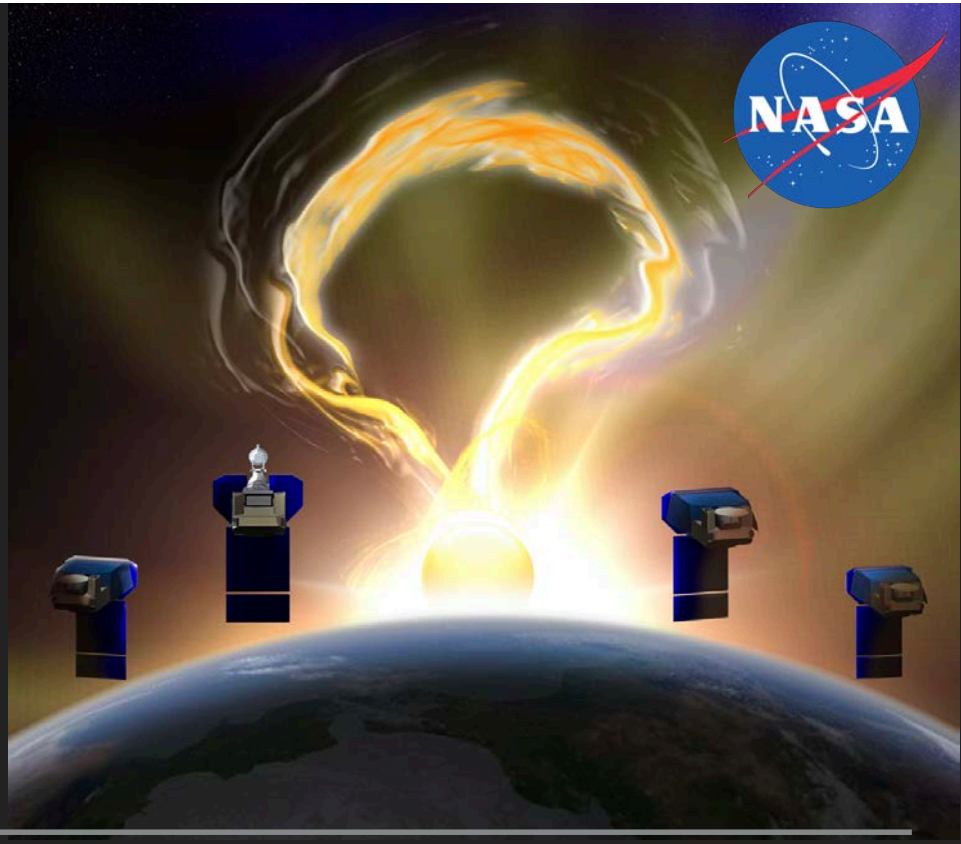
IMAGING THE CORONA AND SOLAR WIND AS A SINGLE SYSTEM



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AGU Fall Meeting 2019

U.S. NAVAL RESEARCH LABORATORY

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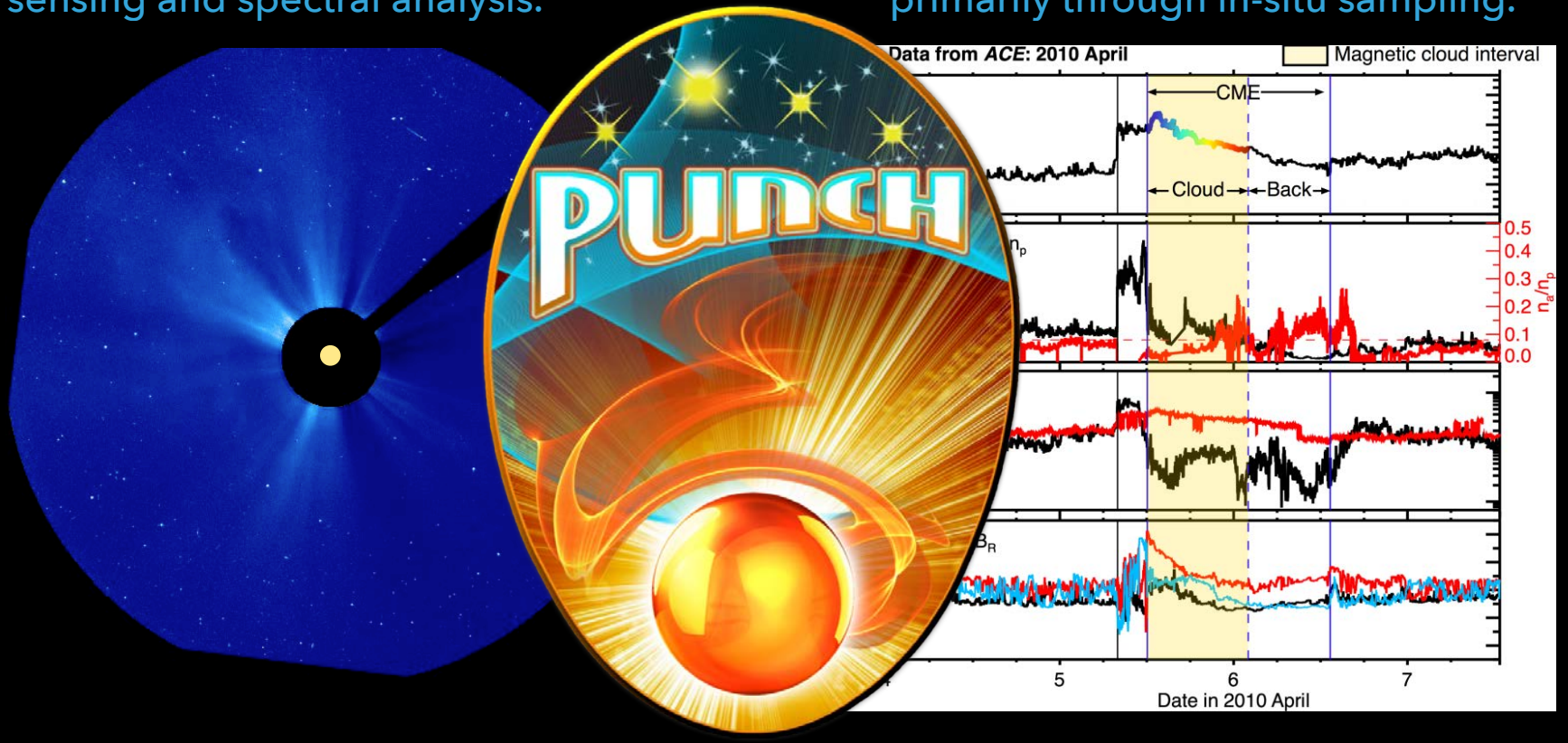
RAL Space

HELIOPHYSICS: ONE SCIENTIFIC FIELD, DIVIDED BY TECHNOLOGY

Solar physics studies the Sun and solar corona, primarily through remote sensing and spectral analysis.

Heliospheric physics studies the solar wind in interplanetary space, primarily through in-situ sampling.



WHAT IS THE PUNCH SMALL EXPLORER MISSION?

Scientific Driver: Understanding how the corona gives rise to the heliosphere and solar wind

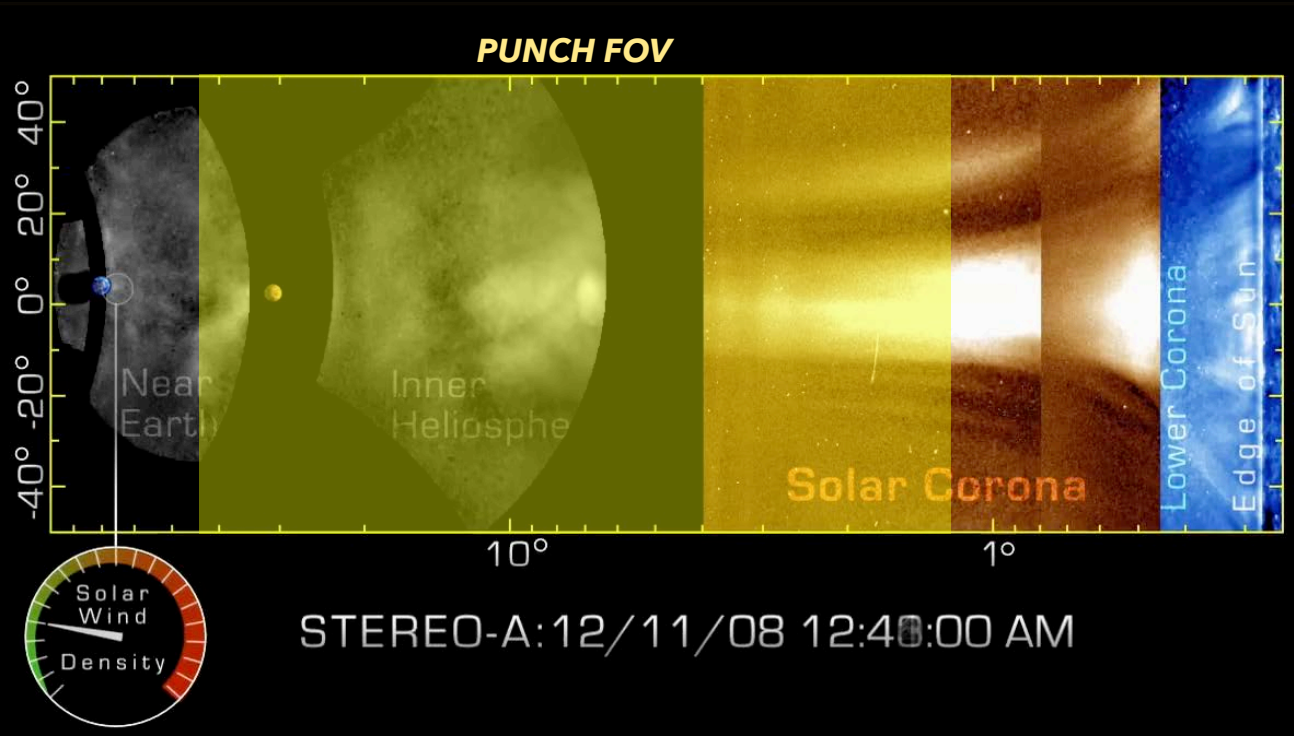
Approach: direct, continuous, 3D imaging of the entire outer corona and inner heliosphere

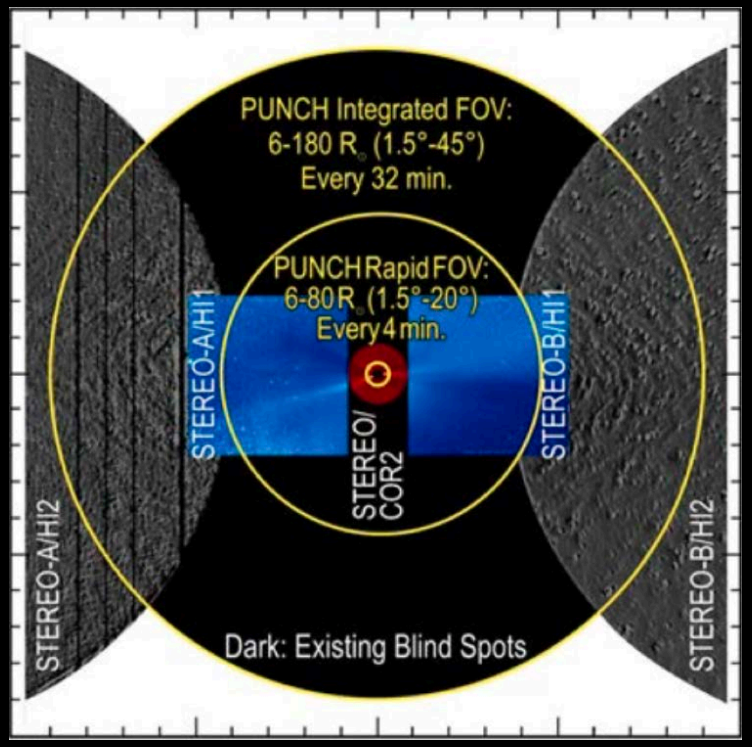
Measurement: polarized images of Thomson-scattered light, every 4 minutes

Mission structure:
- four synchronous smallsats
- 570km sun-synch LEO
- two year duration; launch early 2023

Status: Phase B (preliminary design)
- PDR: Scheduled for Sep 2020

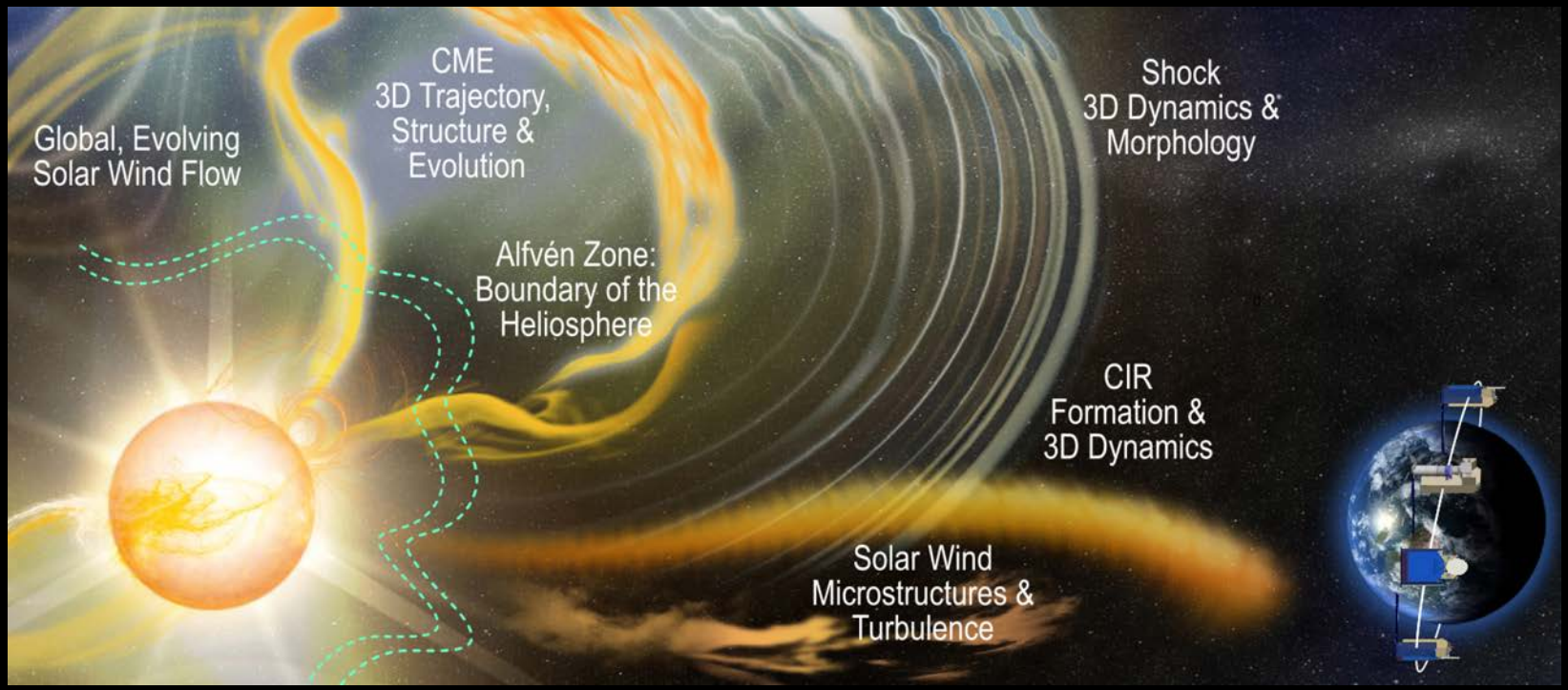
THE PUNCH FIELD OF VIEW: CONTINUOUS AND POLE-TO-POLE





PUNCH FOV: 1.25° to 45° from the Sun, full annulus; **observing cadence**: 4 minutes

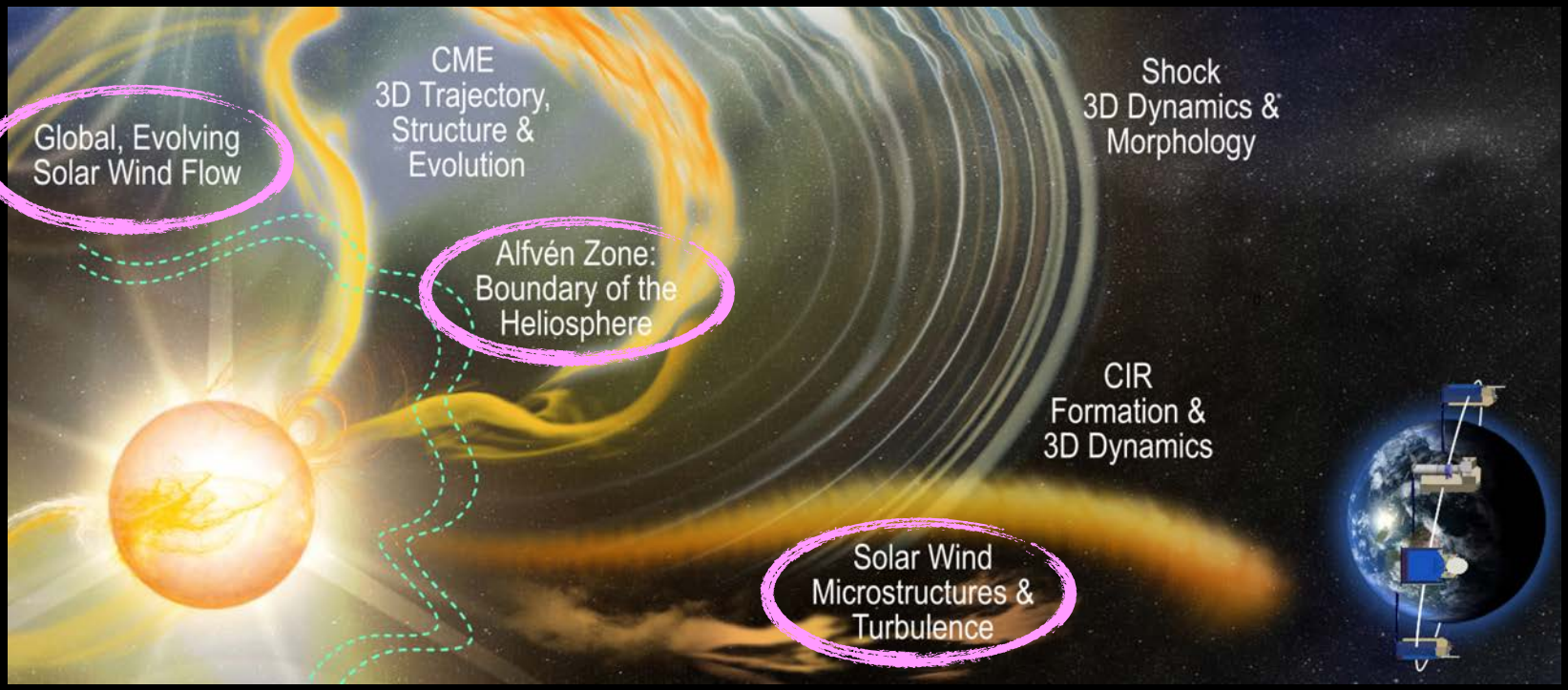
PUNCH SCIENCE: FOCUSED ON UNIFICATION



PUNCH's **Science Objectives:**

1. **Understand how coronal structures become the ambient solar wind.**
2. **Understand the dynamic evolution of transient structures in the young solar wind.**

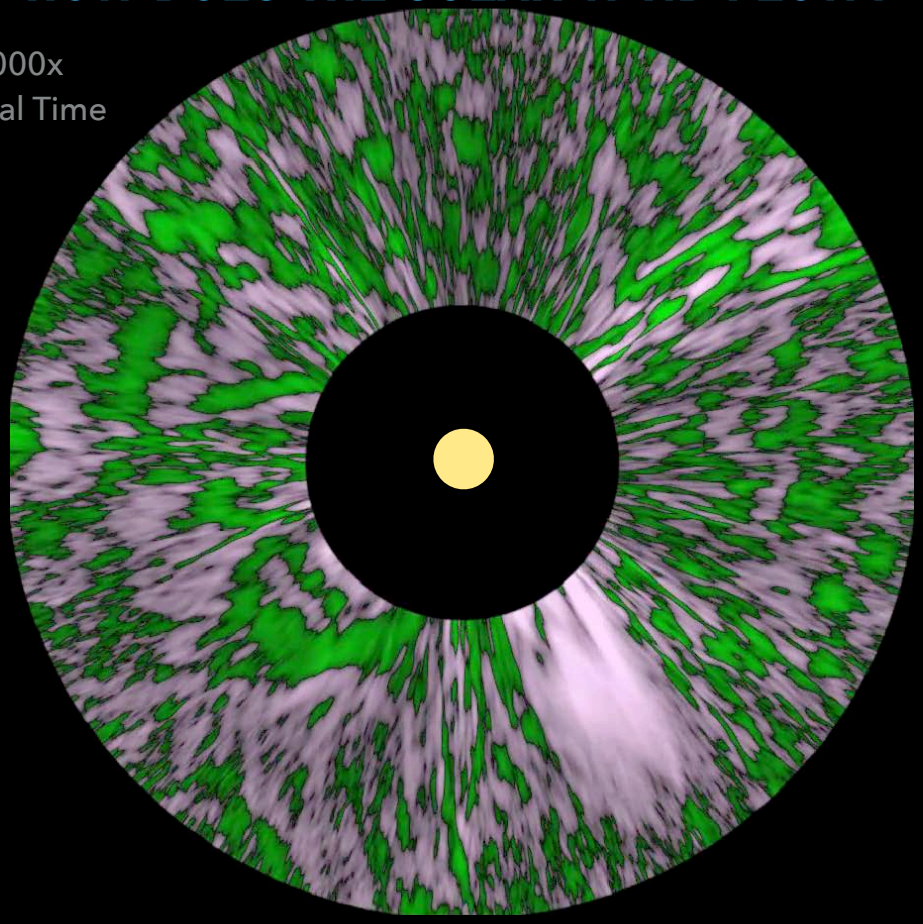
PUNCH SCIENCE OBJECTIVE 1: AMBIENT SOLAR WIND

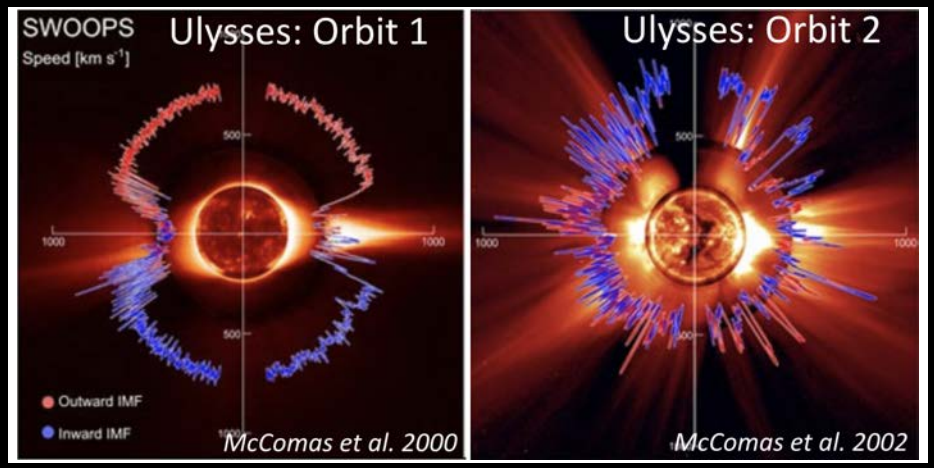


Objective 1: Understand how coronal structures become the ambient solar wind.

THE YOUNG SOLAR WIND REVEALED

HOW DOES THE SOLAR WIND FLOW?

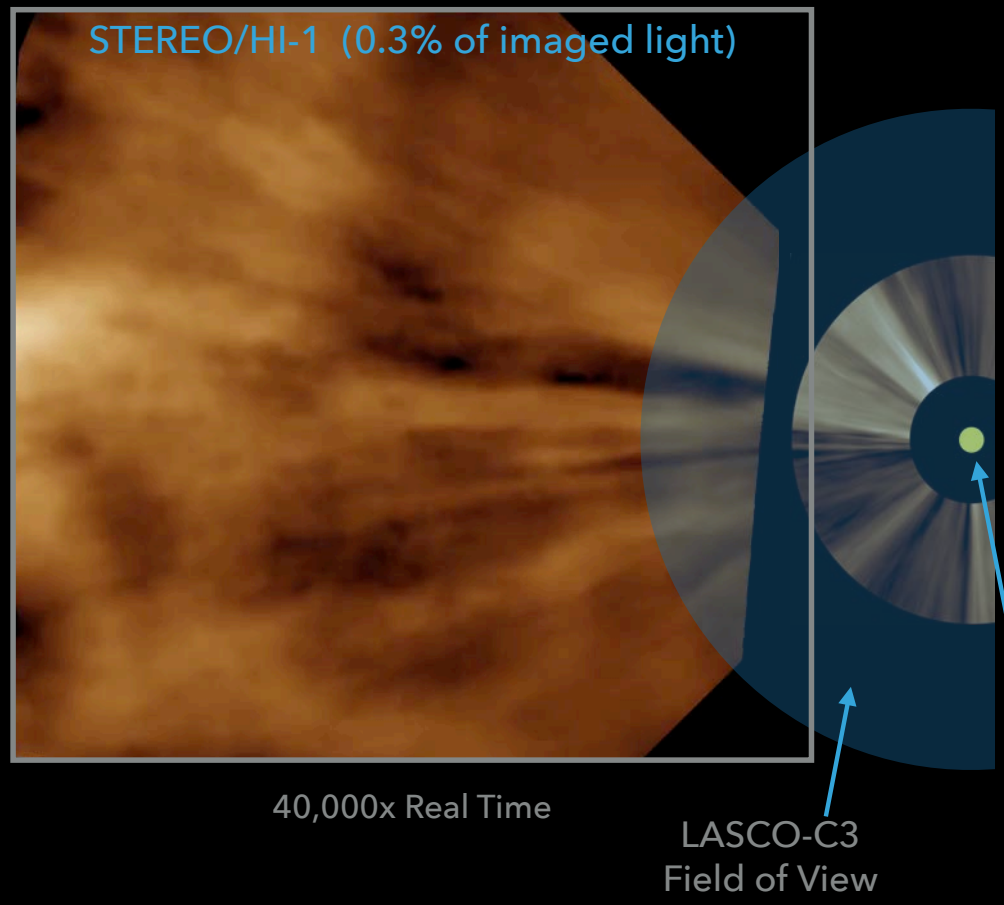




- Outflow is visible everywhere because of small moving features.
- PUNCH exploits these features to map the flow of the young solar wind every six hours.
  - Our best current data is from Ulysses … once every six years … at >1AU.

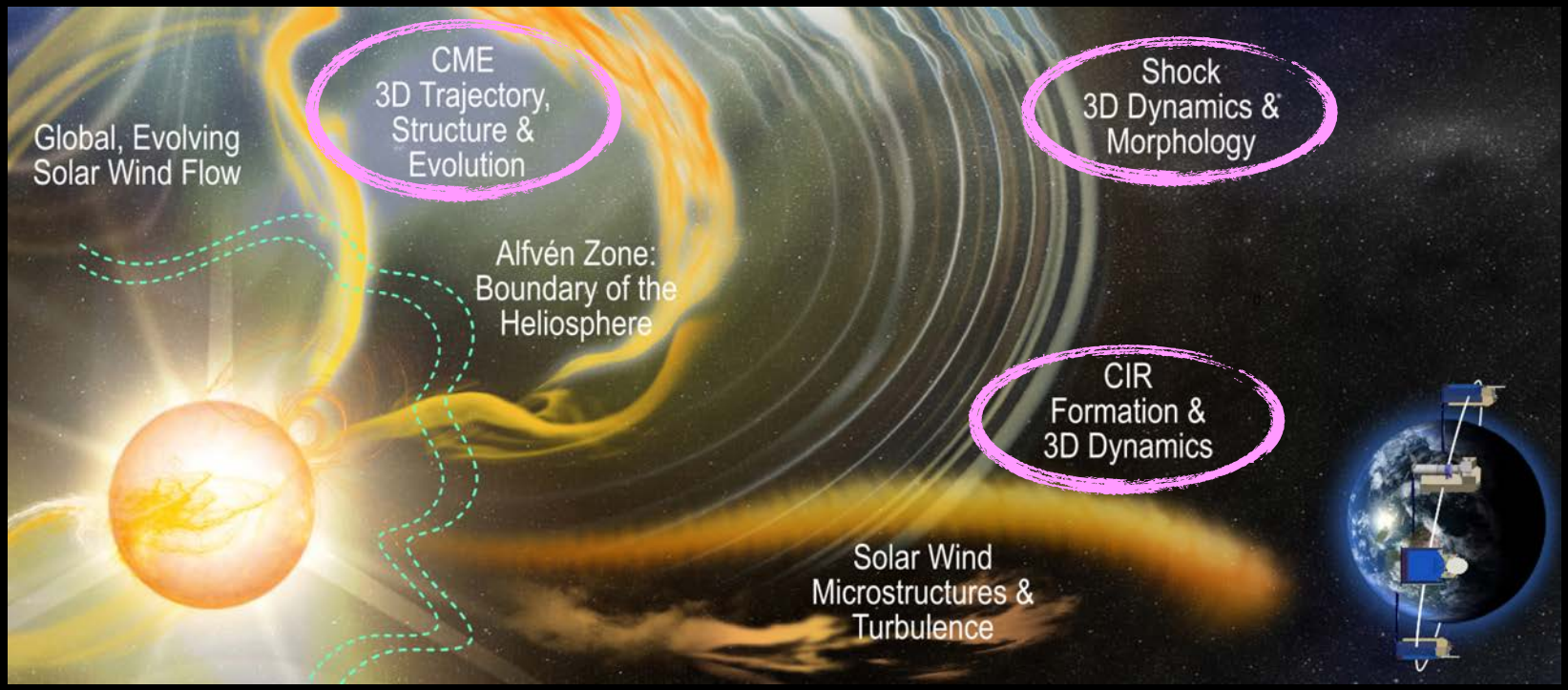
THE SOLAR CORONA BECOMES THE TURBULENT SOLAR WIND

WHERE DOES THE SOLAR WIND BEGIN?



- Current instruments can *just* identify the top of the solar corona.
- Bright radial structures fade into “fluffy" dense clouds, ~10° from the Sun.
- PUNCH will image this transition with 30x more sensitivity.

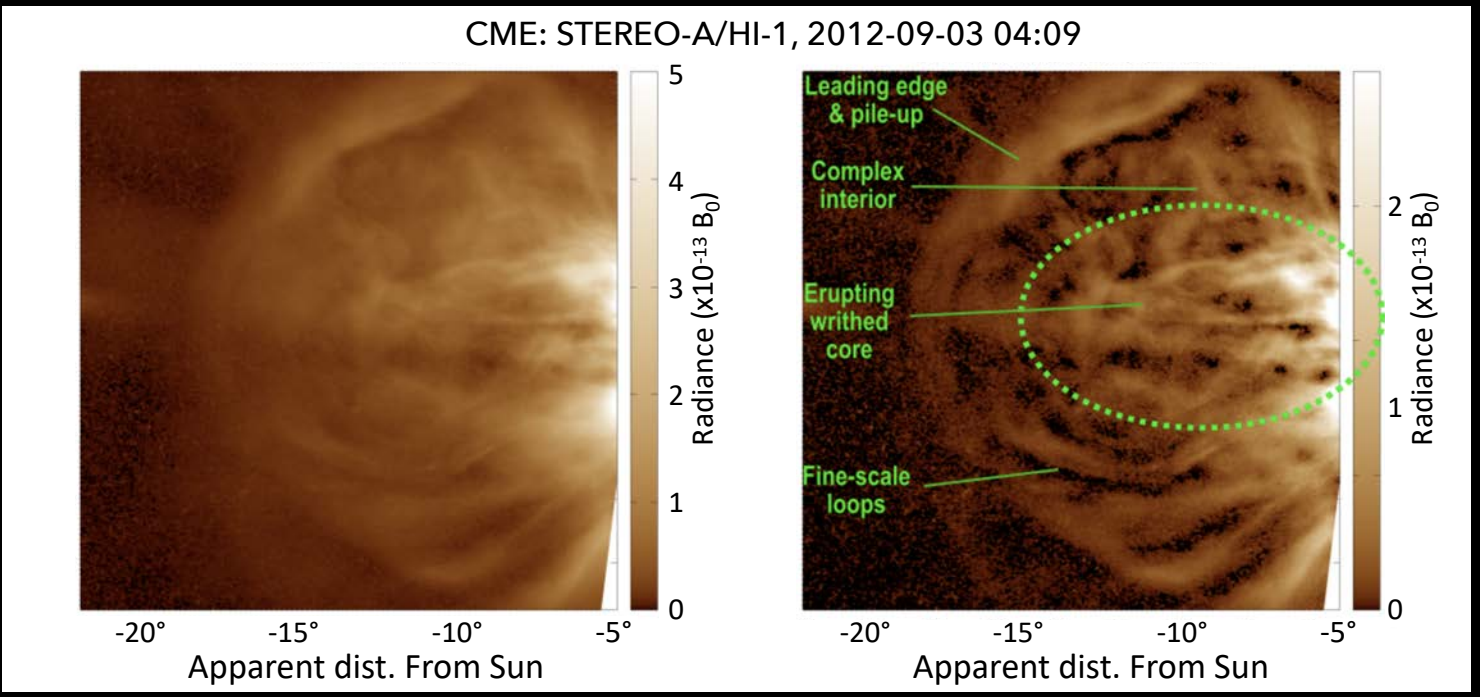
PUNCH SCIENCE OBJECTIVE 2: TRANSIENT STRUCTURES



Objective 2: Understand the dynamic evolution of transient structures in the young solar wind.

CME INTERIOR STRUCTURE

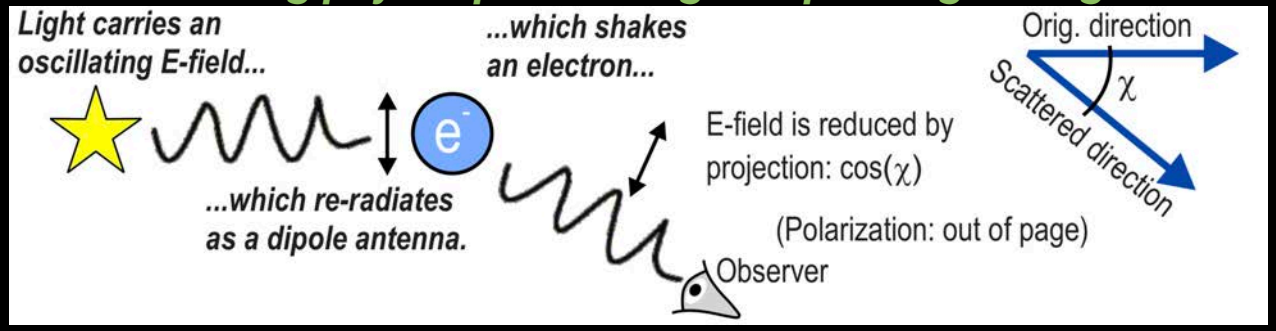
TRACKING CMES' EVOLVING STRUCTURE IN 3D



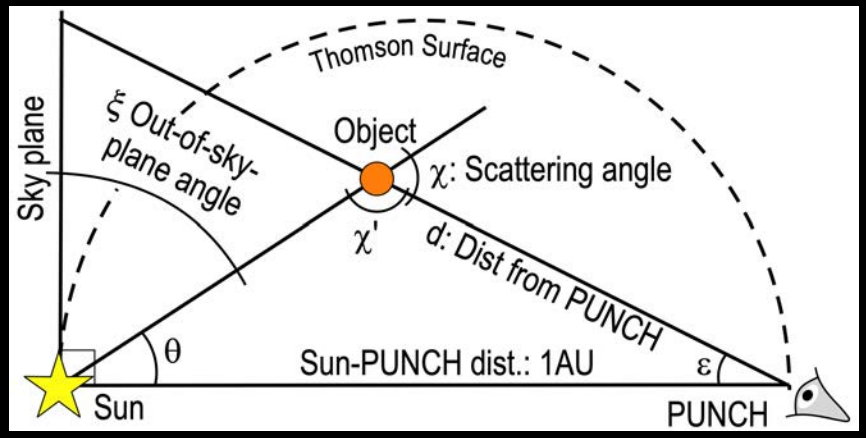
- CMEs are quite complex
- Interior structure evolves as the CME propagates
- Fine-scale structure is visible down to the noise limit in HI-1.
- PUNCH has 10x-30x lower noise

3D IMAGING WITH POLARIZATION

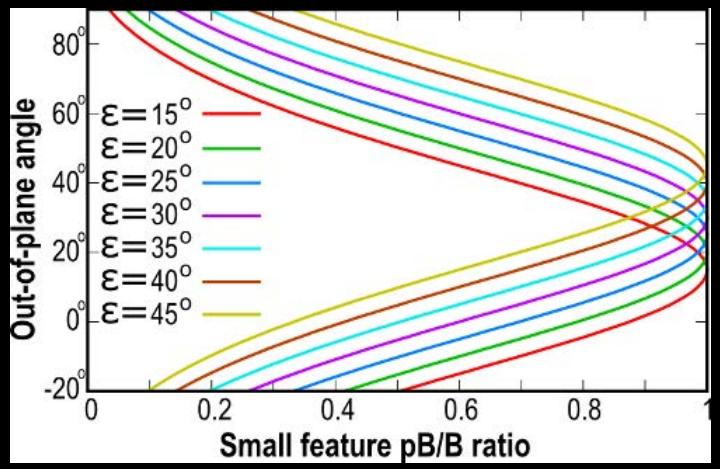
Scattering physics polarizes light depending on angle.



Other angles can be determined from geometry



The ratio of polarized brightness in each feature determines scattering angle.

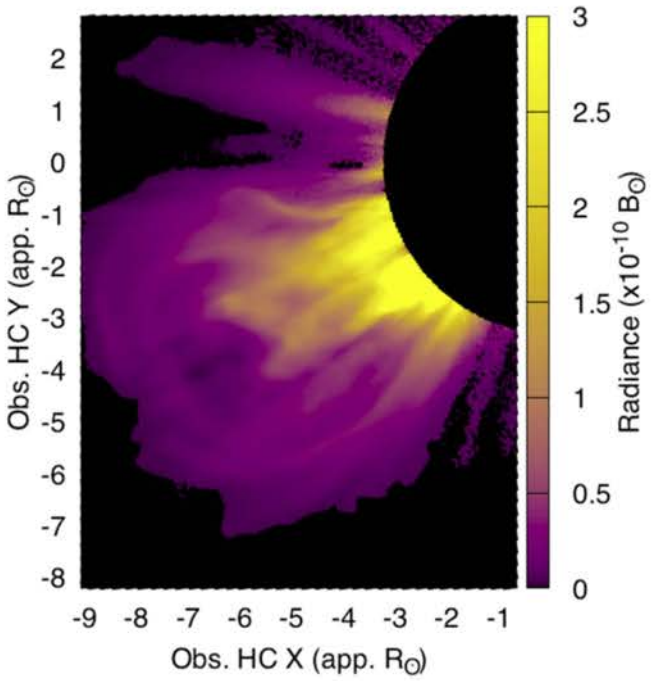


3D position is fully specified

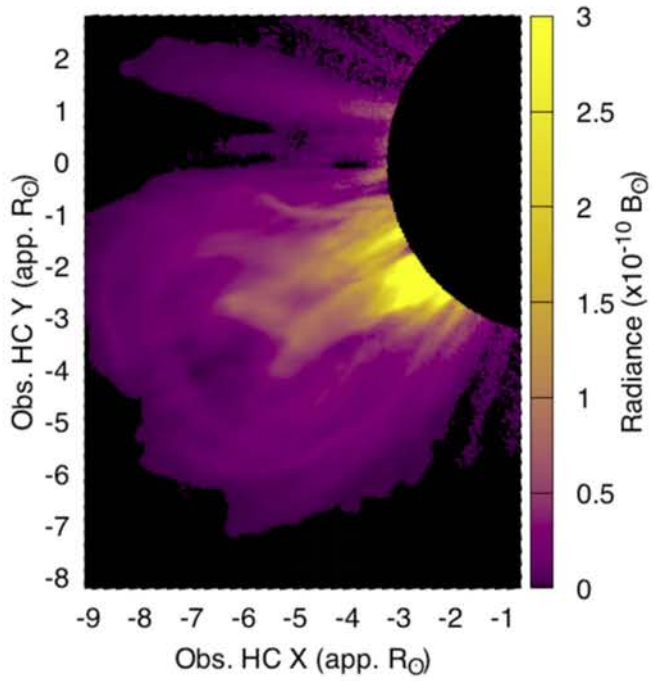
- Y, Z from sky-plane projection
- X = r cos θ

3D IMAGING WITH POLARIZATION: AN EXAMPLE WITH STEREO/COR2

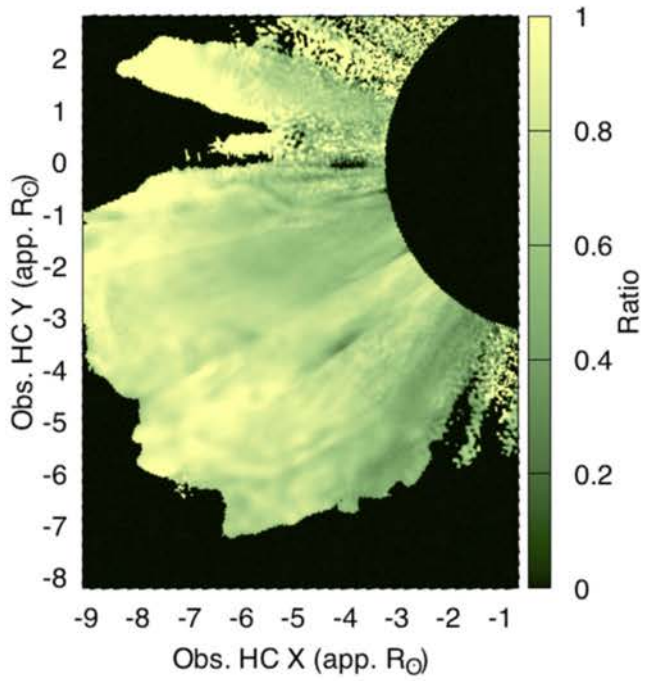
CME in unpolarized light



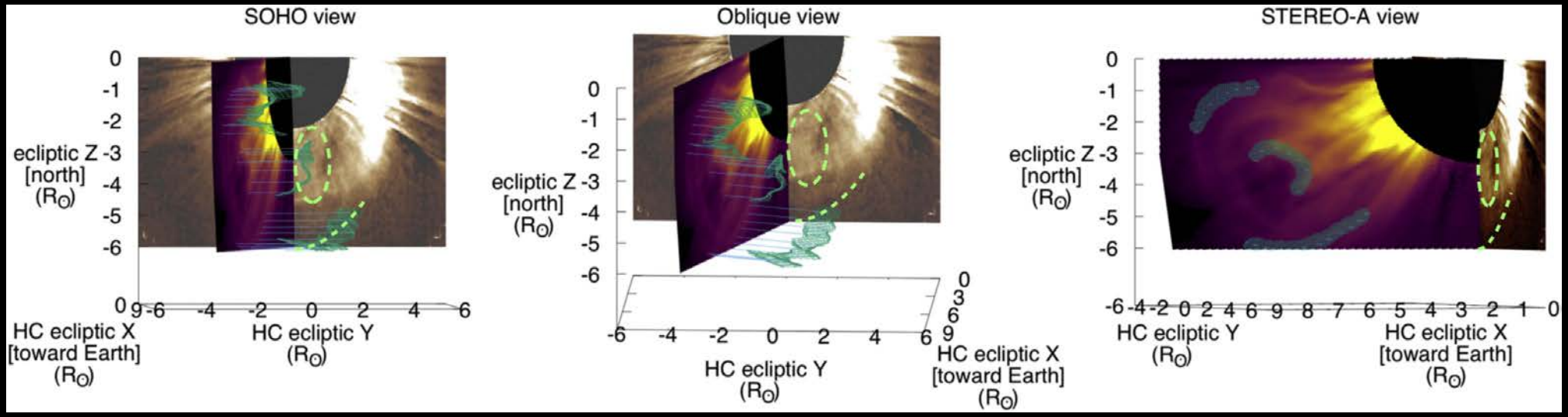
CME in "excess polarized" (pB) light



Polarization ratio



3D IMAGING WITH POLARIZATION: VALIDATED WITH STEREOSCOPY



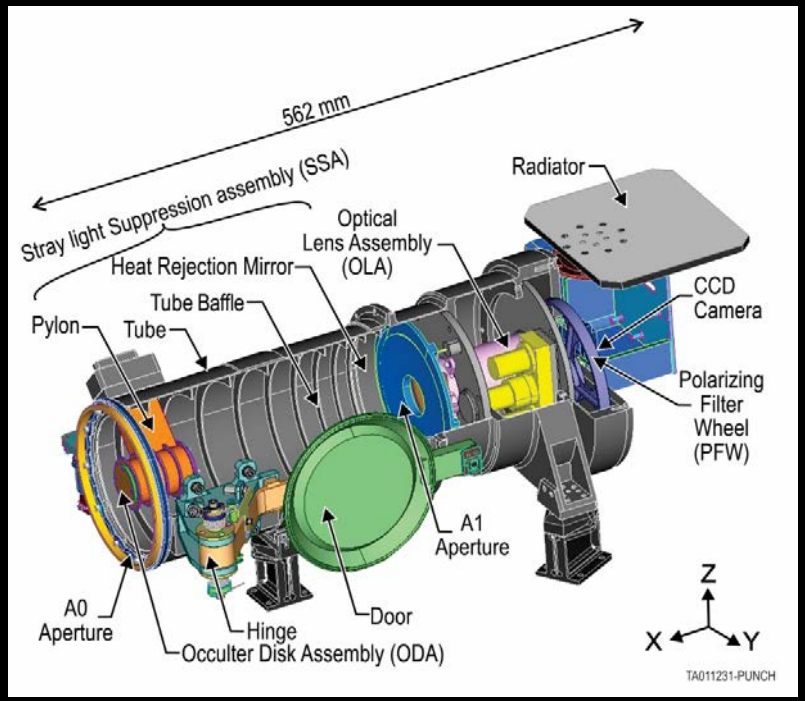
SOHO view shows that the CME core and edges line up with the STEREO 3D determination

Reprojected 3D view shows the SOHO image plane

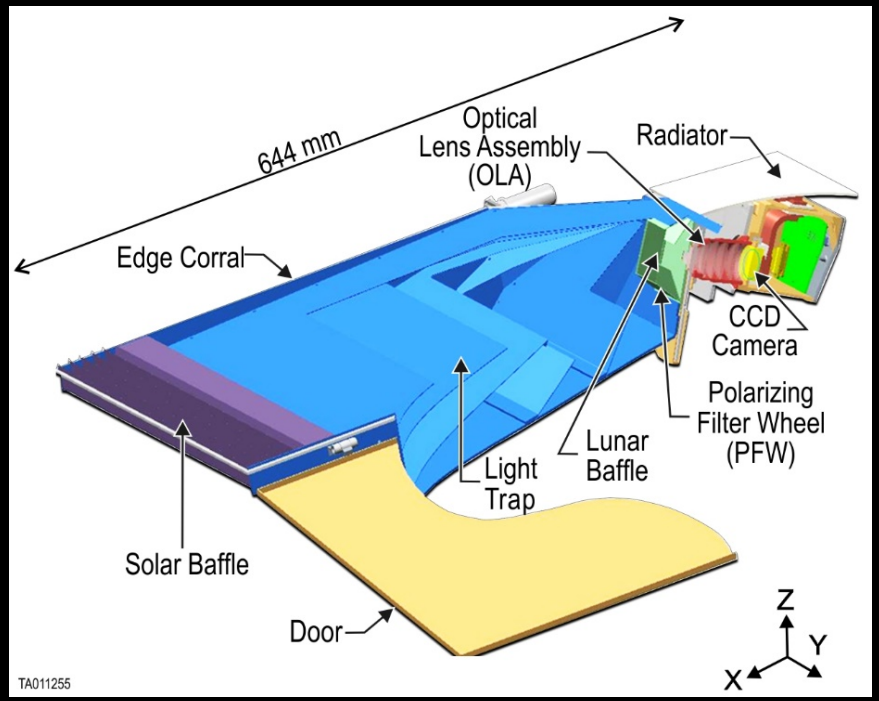
Original image from STEREO shows marked regions of interest

TWO TYPES OF POLARIZING CAMERA COVER THE PUNCH FOV

1x NFI: Compact Coronagraph design
Naval Research Laboratory

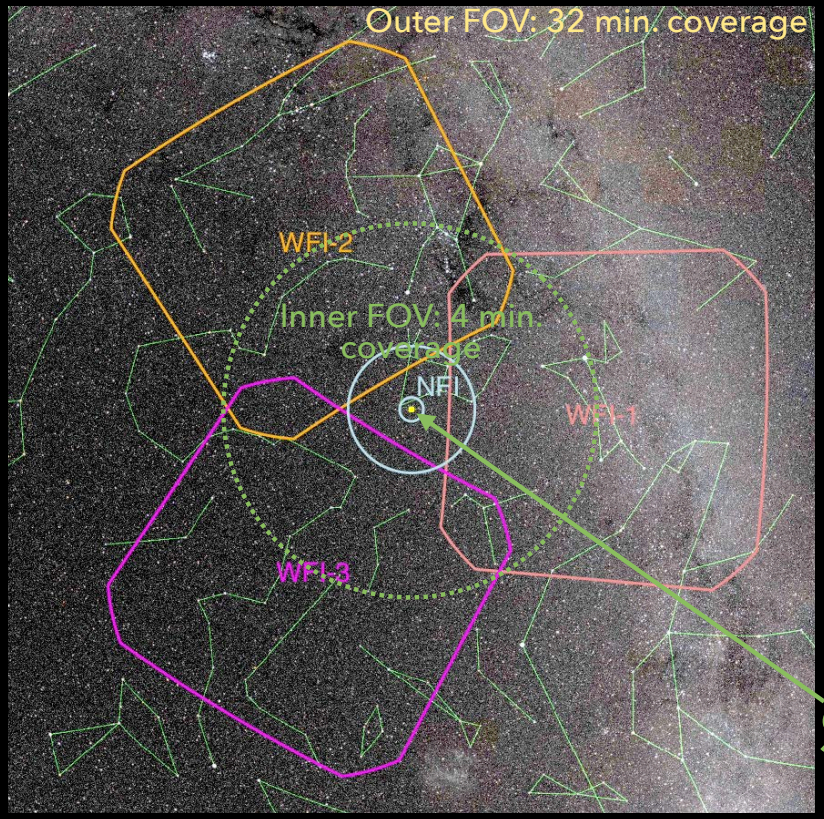


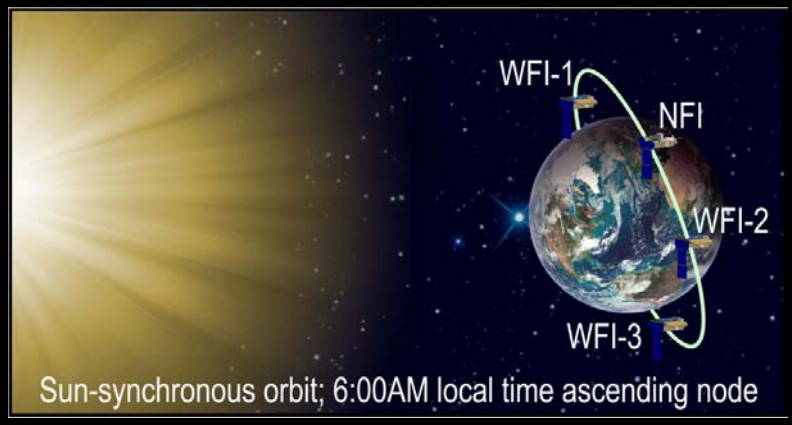
3x WFI: Heliospheric Imager design
Southwest Research Institute



HOW DOES PUNCH WORK?

MERGING IMAGES TO CREATE A SINGLE LARGE FOV





- The WFI cameras fly in formation 120° apart in orbit.
- Each spacecraft rotates every 8 minutes to match its orbital motion.
- Exposures are combined on the ground.
- Each flash: complete polarization sequence
- Green circle: 4-min cadence coverage inside ~80 Rs

SUMMING UP

- PUNCH will create and exploit low-noise images of the transition from corona to solar wind.
- Low-noise polarized imagery yields 3D structure in interplanetary space
- Primary novelty is not the instruments themselves
  - Novel mission design: single synchronized “virtual instrument”
  - Novel exploitation: integrated data products; 3D inversions

- PUNCH launches in 2023.
  - PUNCH has an open data policy.
  - Open science team meetings begin in 2021 – stay tuned!