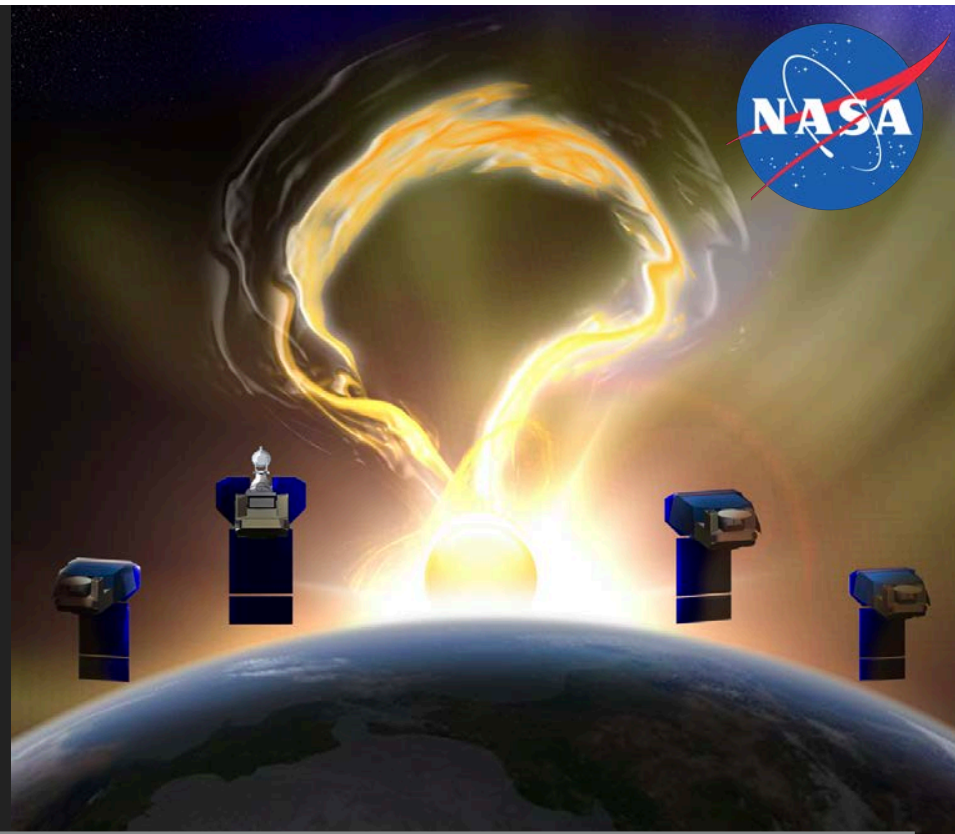C. DeForest, R. Colaninno, S. Gibson, R. Killough, W. Kosmann, G. Laurent, and the PUNCH team

BIG SCIENCE
WITH
SMALL SATELLITES

POLARIMETER TO UNIFY THE CORONA AND HELIOSPHERE

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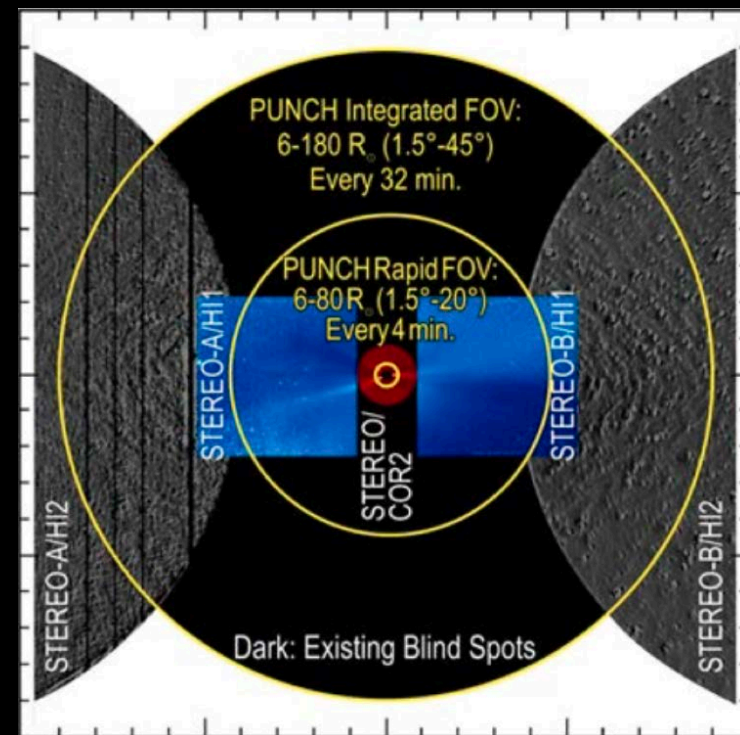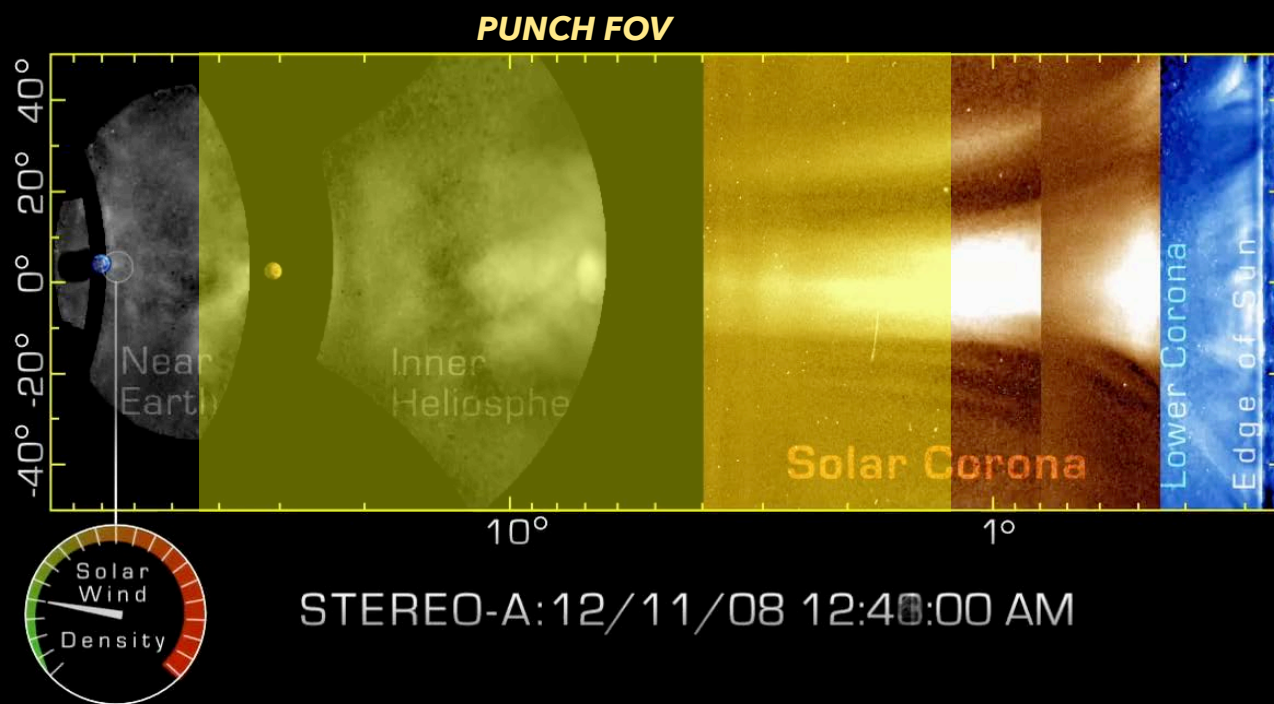
Mission structure:
 - four synchronous smallsats
 - 570km sun-synch LEO
 - two year duration; launch early 2023

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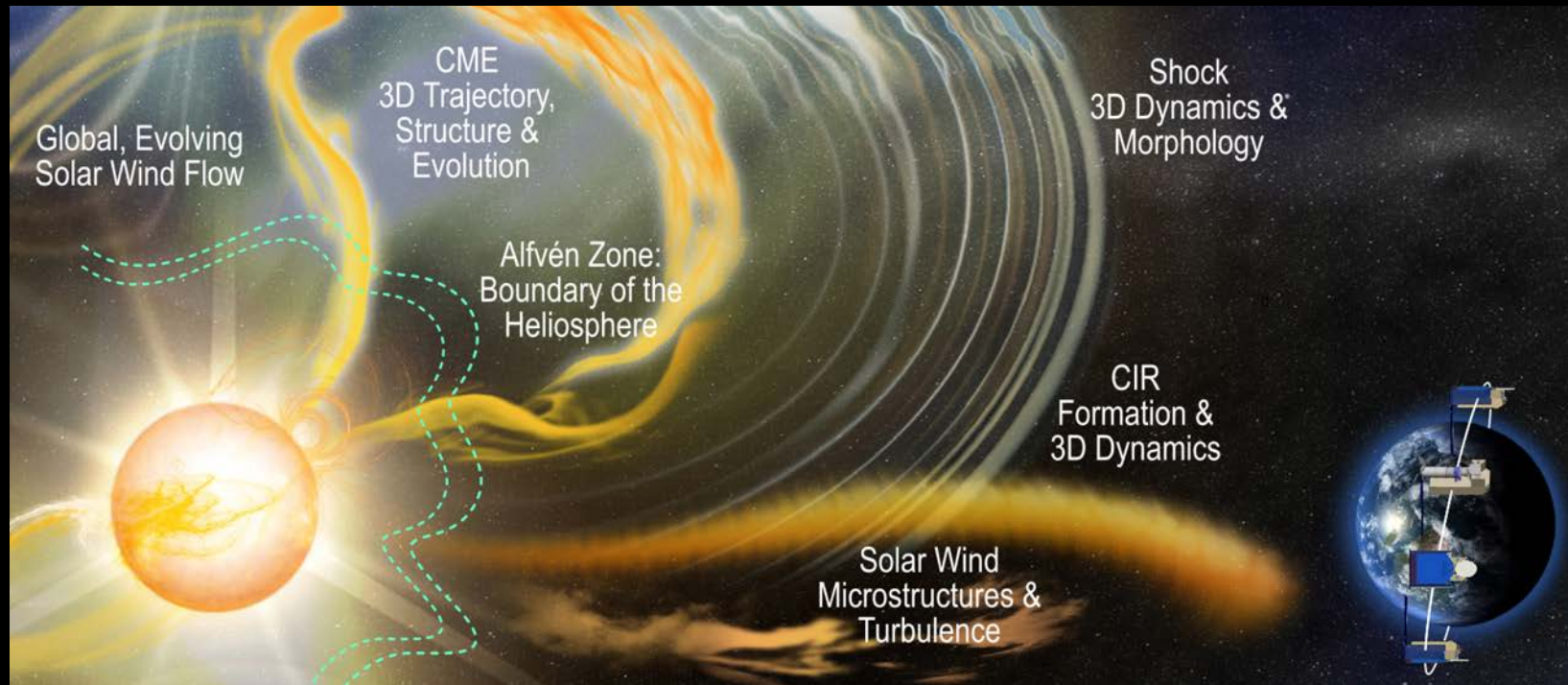 - PDR: Scheduled for Sep 2020

EXPLORING THE YOUNG SOLAR WIND: FOV IS CONTINUOUS AND POLE-TO-POLE

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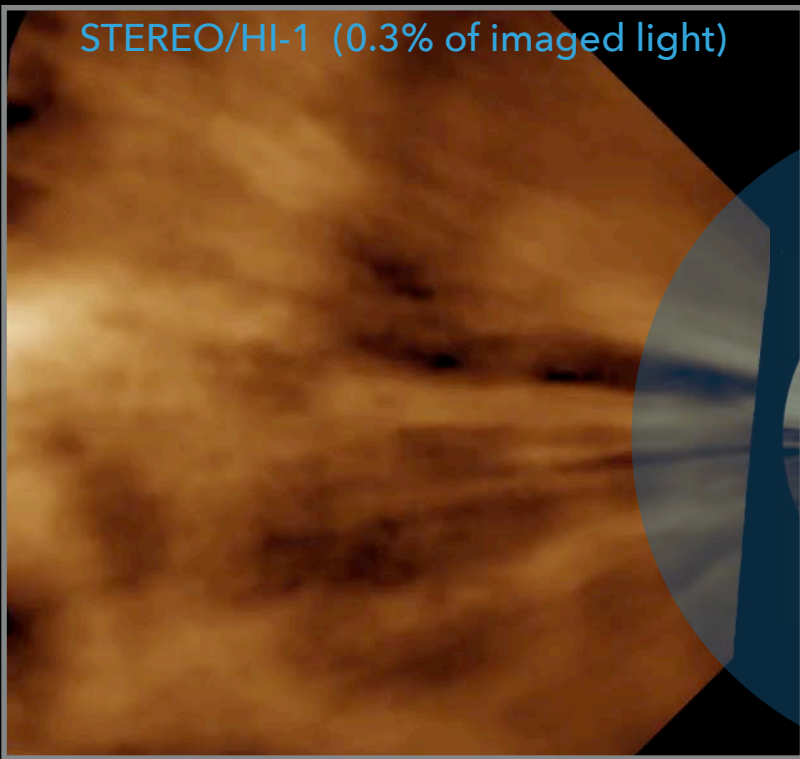
PUNCH's **Science Objectives:**

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

WHERE DOES THE SOLAR WIND BEGIN?

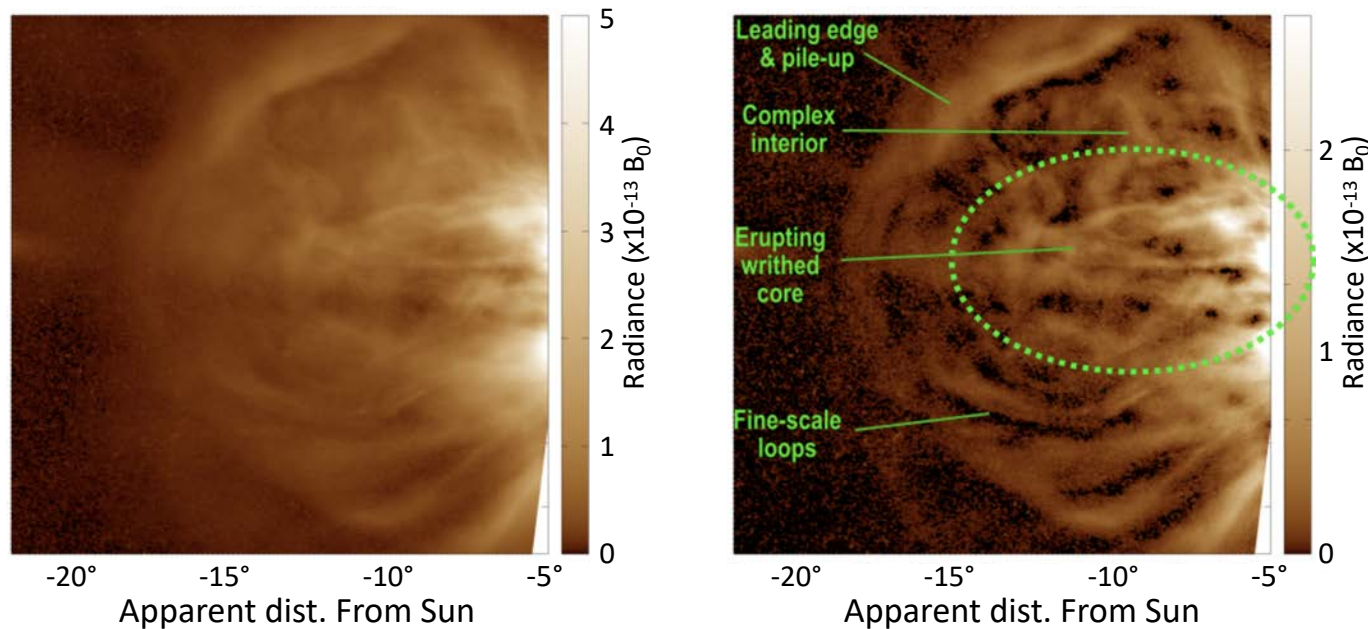STEREO/HI-1 (0.3% of imaged light)

40,000x Real Time

LASCO-C3
Field of View

Sun

- 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.

TRACKING CMES' EVOLVING STRUCTURE IN 3D

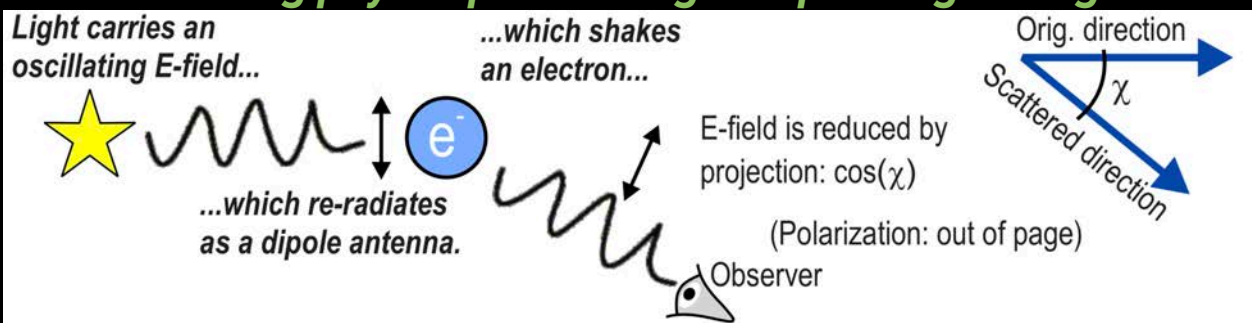CME: STEREO-A/HI-1, 2012-09-03 04:09

- CMEs are quite complex

- Interior structure evolves as the CME propagates

- Fine-scale structure is visible down to the noise limit in HI-1.
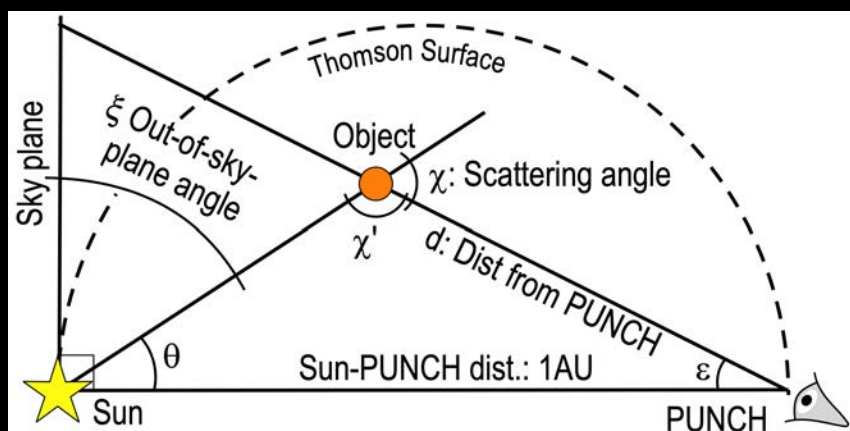
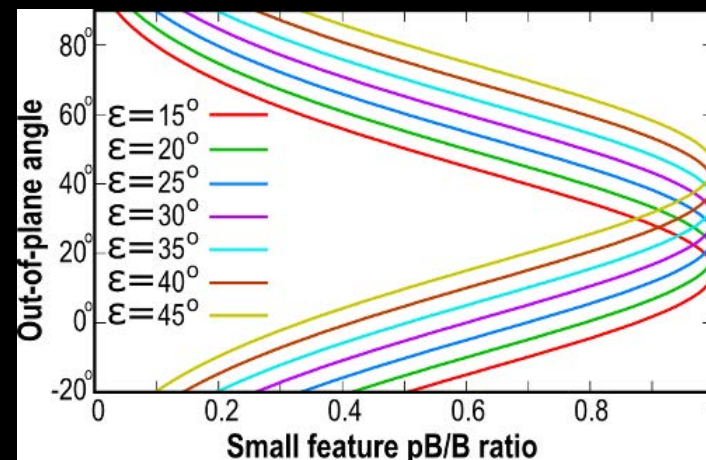- PUNCH has 10x-30x lower noise

3D IMAGING WITH POLARIZATION

Scattering physics polarizes light depending on angle.

Other angles can be determined from geometry

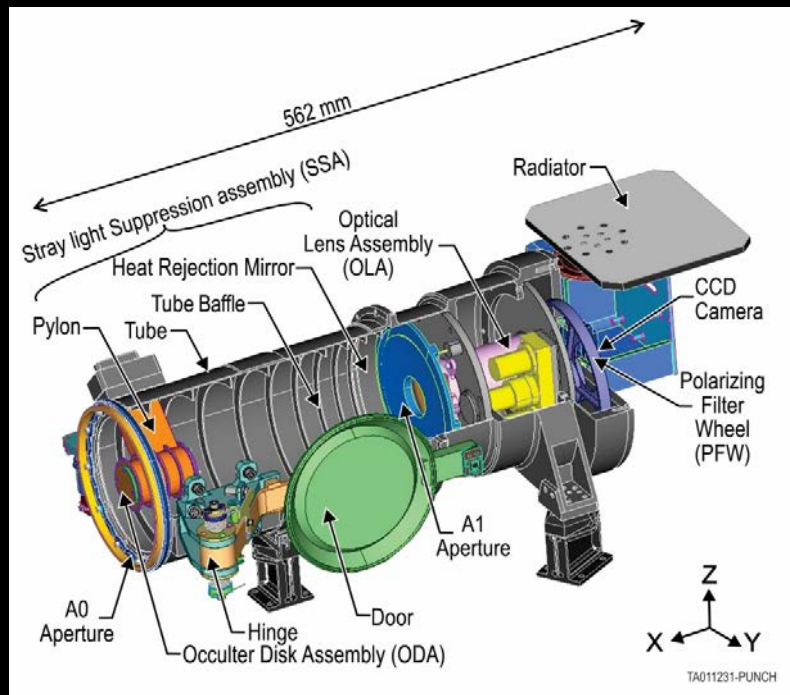*The ratio of polarized brightness in each feature determines scattering angle.*

3D position is fully specified

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

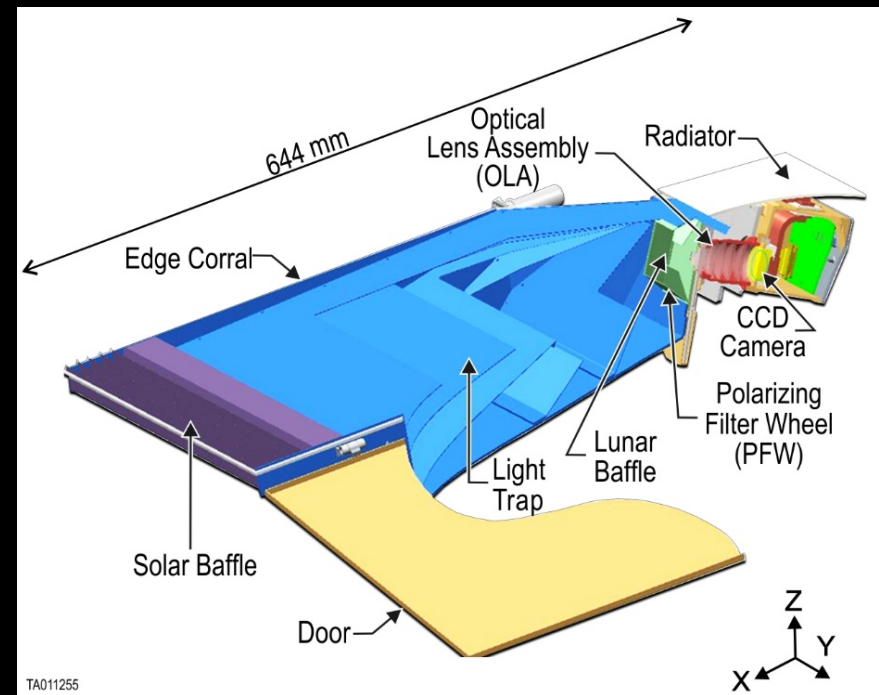# TWO TYPES OF POLARIZING CAMERA COVER THE PUNCH FOV

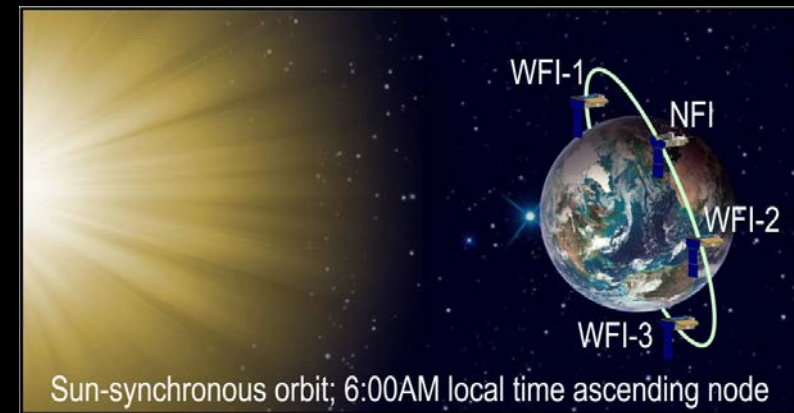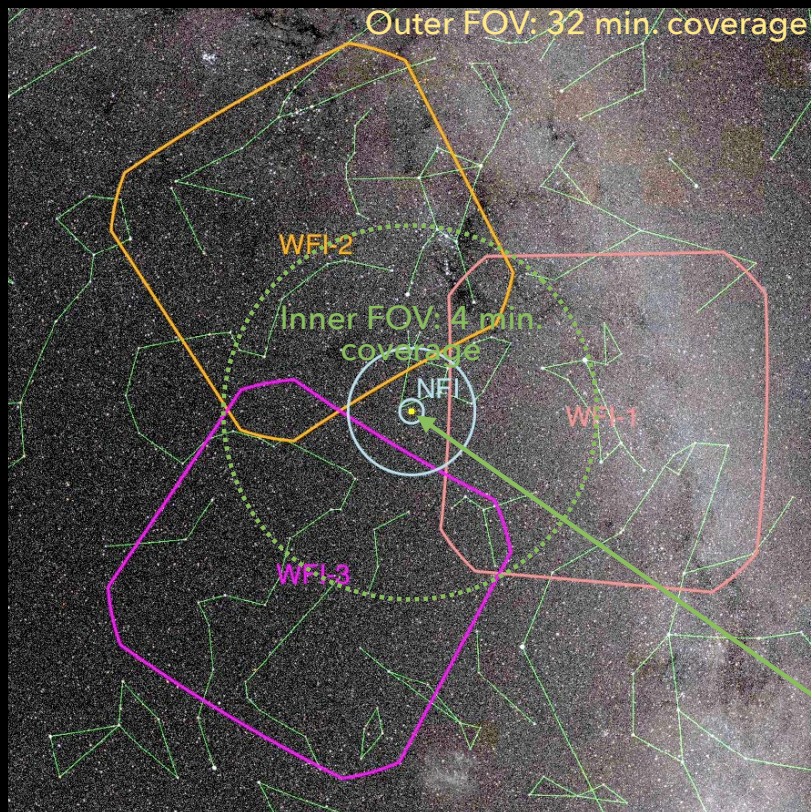### 1x NFI: Compact Coronagraph design
Naval Research Laboratory

3x WFI: Heliospheric Imager design
Southwest Research Institute

MERGING IMAGES TO CREATE A SINGLE LARGE FOV

Outer FOV: 32 min. coverage

WFI-2

Inner FOV: 4 min. coverage

NFI

WFI-1

WFI-3

Sun

WFI-1

NFI

WFI-2

WFI-3

Sun-synchronous orbit; 6:00AM local time ascending node

- 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

THE SMALLSAT COMMERCIAL ECOSYSTEM ENABLES PUNCH
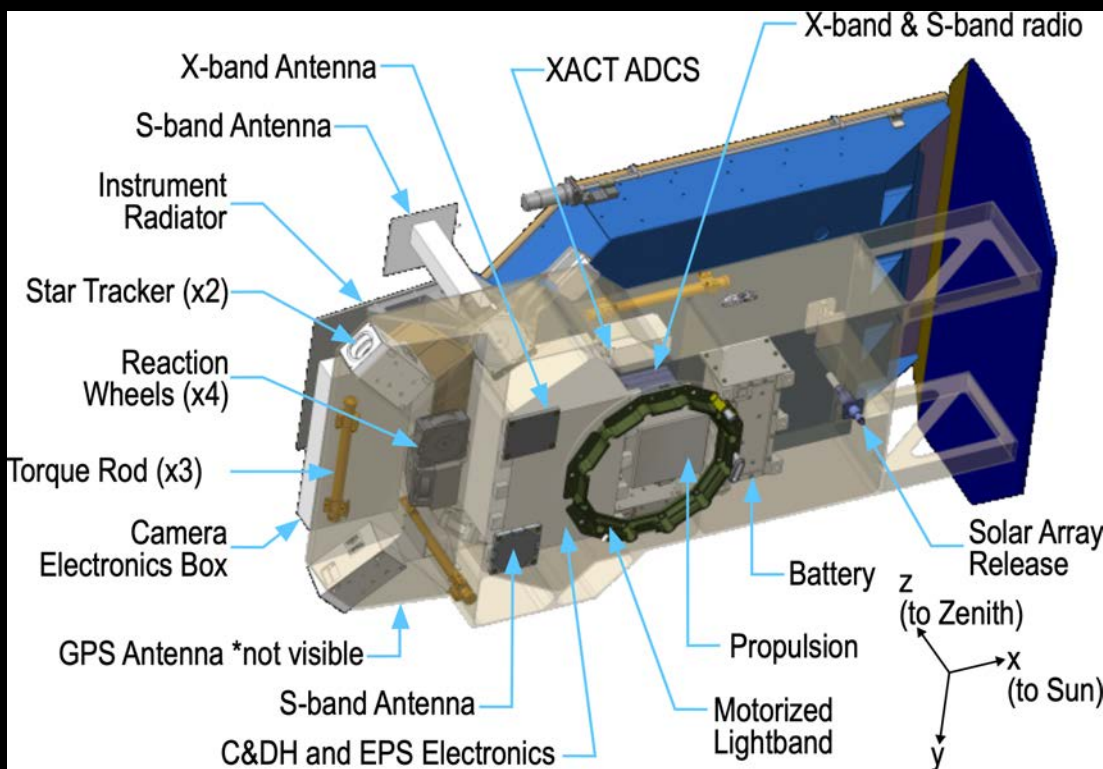
- PUNCH spacecraft use modular COTS subsystems:
  - ADCS
  - S/X dual-band radio
  - mini propulsion unit
  - power management

- Simplifies system design
- Greatly reduces cost
- Enables a constellation mission within SMEX

SUMMING UP

- PUNCH will create and exploit low-noise images of the transition from corona to solar wind.

- The PUNCH science requires either a deep space mission or a LEO constellation.

- Available COTS subsystems reduce cost and enable a constellation within SMEX scope.

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