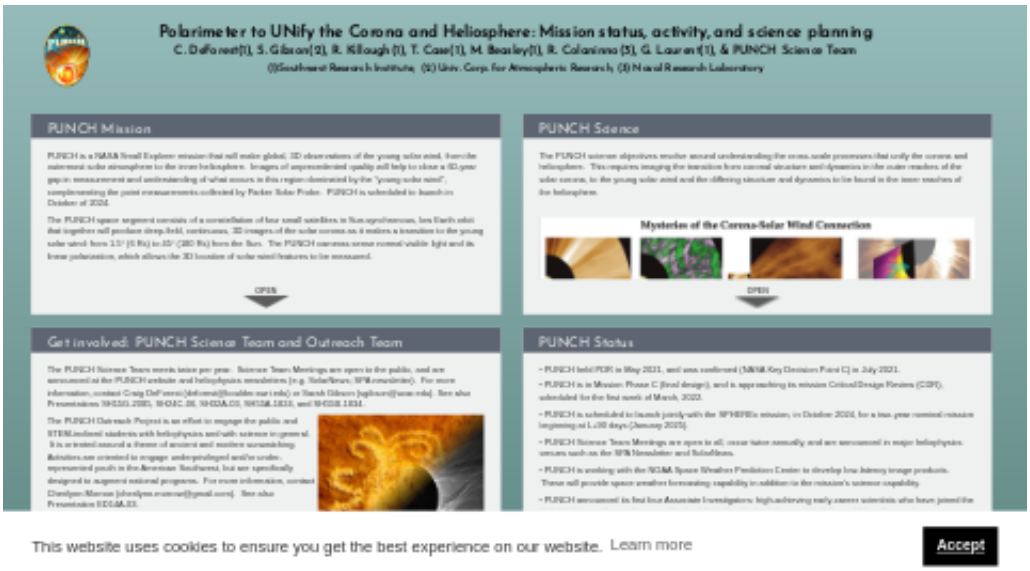
Polarimeter to UNify the Corona and Heliosphere: Mission status, activity, and science planning



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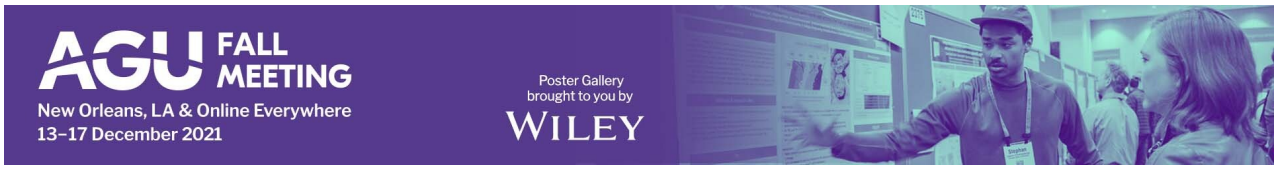


PUNCH MISSION

PUNCH is a NASA Small Explorer mission that will make global, 3D observations of the young solar wind, from the outermost solar atmosphere to the inner heliosphere. Images of unprecedented quality will help to close a 60-year gap in measurement and understanding of what occurs in this region dominated by the "young solar wind", complementing the point measurements collected by Parker Solar Probe. PUNCH is scheduled to launch in October of 2024.

The PUNCH space segment consists of a constellation of four small satellites in Sun-synchronous, low Earth orbit that together will produce deep-field, continuous, 3D images of the solar corona as it makes a transition to the young solar wind: from 1.5° (6 Rs) to 45° (180 Rs) from the Sun. The PUNCH cameras sense normal visible light and its linear polarization, which allows the 3D location of solar wind features to be measured.

For more information, visit https://punch.space.swri.edu (https://punch.space.swri.edu).

GET INVOLVED: PUNCH SCIENCE TEAM AND OUTREACH TEAM

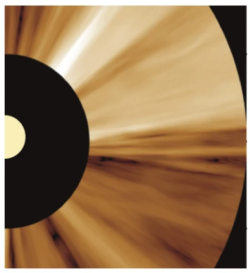
The PUNCH Science Team meets twice per year. Science Team Meetings are open to the public, and are announced at the PUNCH website and heliophysics newsletters (e.g. SolarNews; SPA newsletter). For more information, contact Craig DeForest (deforest@boulder.swri.edu) or Sarah Gibson (sgibson@ucar.edu). See also Presentations SH15G-2085, SH24C-06, SH32A-03, SH55A-1824, and SH55B-1834.

The PUNCH Outreach Project is an effort to engage the public and STEM-inclined students with heliophysics and with science in general. It is oriented around a theme of ancient and modern sunwatching. Activities are oriented to engage underprivileged and/or under-represented youth in the American Southwest, but are specifically designed to augment national programs. For more information, contact Cherilynn Morrow (cherilynn.morrow@gmail.com). See also Presentation ED14A-03.

PUNCH SCIENCE

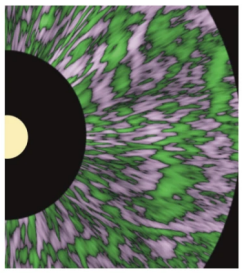
The PUNCH science objectives revolve around understanding the cross-scale processes that unify the corona and heliosphere. This requires imaging the transition from coronal structure and dynamics in the outer reaches of the solar corona, to the young solar wind and the differing structure and dynamics to be found in the inner reaches of the heliosphere.

Mysteries of the Corona-Solar Wind Connection



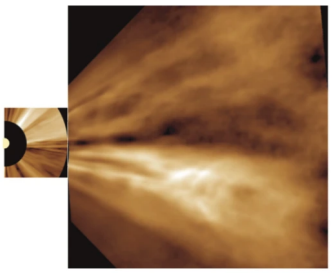
Detailed structure shapes the outer corona and young solar wind:

Recent results from STEREO/COR2 show that the transition to the solar wind is highly structured at all optically resolvable scales. This contrasts with current solar wind models that treat the flow as smooth. With 10x higher sensitivity than COR2, PUNCH reveals how this structure imprints on the solar wind.



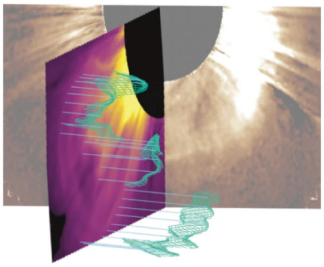
Intermittent structure traces solar wind flow & causes variability at Earth:

Flow in the outer corona is highly variable. Intermittent ejecta may comprise up to 100% of the outflowing plasma. PUNCH is uniquely able to routinely track all of these features in 3D, to trace the origin of the solar wind, identify late-stage acceleration, and determine the role of ejecta in the solar wind as a whole.



The Alfven zone and onset of turbulence mark the elusive base of the heliosphere:

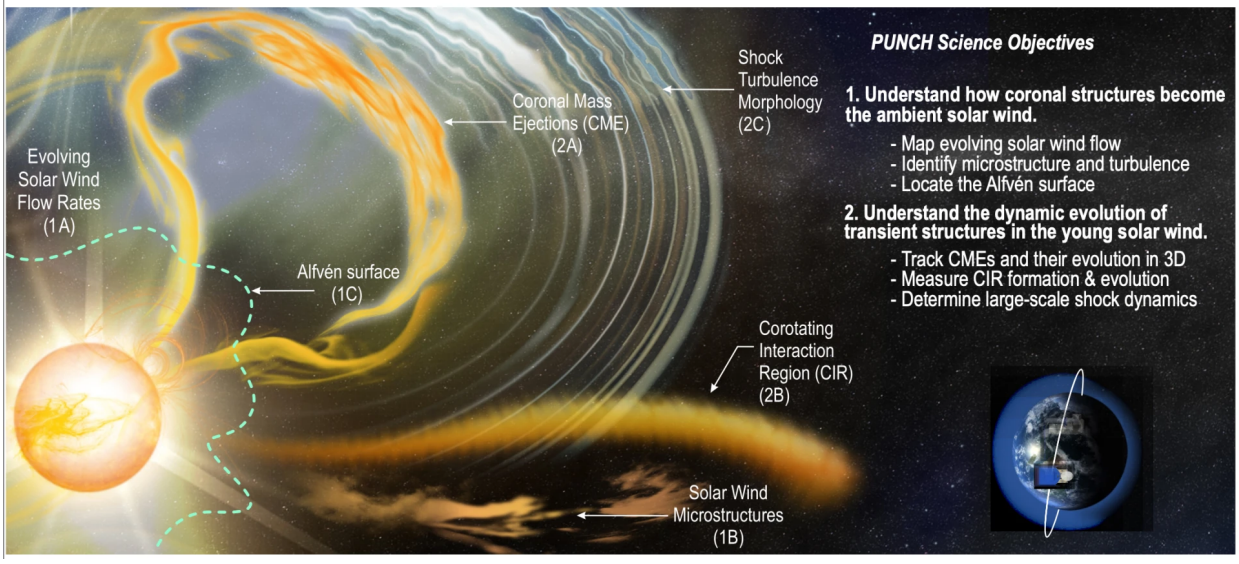
The transition from structured coronal flow to isotropic turbulent flow marks the outer boundary of the corona and the inner boundary of the solar wind. The newly-discovered Alfven zone determines the Sun's open flux budget and shapes the solar wind. PUNCH explores the otherwise inaccessible cross-scale physics of this "discovery space" and the plasma's journey from corona to solar wind.



Polarized imaging reveals how CMEs and solar wind structures move and evolve in 3D

CMEs and other ejecta are fundamentally 3D objects. Deep-field polarized imaging with PUNCH reveals the 3D details of these structures for the first time, revealing: interior evolution; flux rope chirality (tied to leading-edge Bz); 3D propagation, acceleration and possible deflection; and solar wind interaction of CMEs and ejecta.

PUNCH 3D results have immediate and obvious application (R2O) to space weather forecasting.



PUNCH STATUS

• PUNCH held PDR in May 2021, and was confirmed (NASA Key Decision Point C) in July 2021.

• PUNCH is in Mission Phase C (final design), and is approaching its mission Critical Design Review (CDR), scheduled for the first week of March, 2022.

• PUNCH is scheduled to launch jointly with the SPHEREx mission, in October 2024, for a two-year nominal mission beginning at L+90 days (January 2025).

• PUNCH Science Team Meetings are open to all, occur twice annually, and are announced in major heliophysics venues such as the SPA Newsletter and SolarNews.

• PUNCH is working with the NOAA Space Weather Prediction Center to develop low-latency image products. These will provide space weather forecasting capability in addition to the mission's science capability.

• PUNCH announced its first four Associate Investigators: high-achieving early-career scientists who have joined the PUNCH Science Team. They are: Raphael Attié, Bea Gallardo-Lacourt, C. Gilly, and Elena Provornikova.

• The PUNCH WFI engineering model instrument passed stray light tests and collected its first starfield images, in Q3 and Q4 of 2021.

• For more information, visit the PUNCH website: https://punch.space.swri.edu (https://punch.space.swri.edu).

ABSTRACT

The Polarimeter to UNify the Corona and Heliosphere (PUNCH) is an in-development mission, now in a combined Phase C/D in the NASA mission lifecycle, to image the outer solar corona and inner heliosphere as a unified system. The flight assets comprise four spacecraft to be launched to 6am/6pm Sun-synchronous Low-Earth Orbit; one spacecraft carries a Narrow Field Imager (NFI) coronagraph, and three carry copies of a Wide Field Imager (WFI) heliospheric imager. These prime instruments are specifically designed to work together as a seamless "virtual instrument" with a 90° FOV, centered on the Sun. PUNCH will produce polarized (pB) and unpolarized (B) images of the young solar wind as it forms and departs the Sun, allowing 3D analysis of solar wind and CME structure and trajectory. Aa student-contributed instrument, STEAM, comprises two solid-state X-ray spectrometers to study coronal heating and flare physics. PUNCH has an open data policy and all data products will be made available to everyone at the same time as the mission team. PUNCH is working to a launch readiness date of 3-Oct-2023.

The PUNCH science team comprises PI Craig DeForest, PS Sarah Gibson, and project Co-Investigators and Associate Investigators. Organized into six working groups, we are actively preparing for the 2-year prime mission starting 90 days after launch. Science team meetings are open to all, and are announced in the usual venues and the PUNCH web page (https://punch.space.swri.edu). Current preparations include forward modeling, derivation of predicted image characteristics from existing data, and development of a suite of analysis tools in the vigorous open-source Python/NumPy/SunPy millieu.

The mission is complemented by the groundbreaking PUNCH Outreach Program (POP) centered around a theme of ancient and modern sunwatching, and concentrated in the American Southwest. POP is specifically designed to support national, as well as regional, educational and outreach efforts and to stimulate interest in science by engaging under-represented populations in the focus region and around the nation.

We will present the current technical status of PUNCH, the primary science objectives and observing plan, current preparation activity and working group structure, and pathways to coordinate and/or get involved with the mission.

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