STRIDE-CH: Sub-Transition Region Identification of Ensemble Coronal Holes

Jaime Landeros[1], Michael S Kirk[1], Charles Nickolos Arge[1], Laura Boucheron[1], Jie Zhang[1], Vadim M Uritsky[1], Matthew Dupertuis[1], and Jeremy Grajeda[1]

[1]Affiliation not available

April 12, 2024

Abstract

Coronal Holes (CH) are large-scale, low-density regions in the solar atmosphere which may expel high-speed solar wind streams that incite hazardous, geomagnetic storms. Segmentation of CH boundaries may aid in validating predictive coronal and solar wind models but has proved difficult due to similar appearances as filaments and the tendency for dense coronal plasmas to block underlying CHs in Extreme Ultraviolet (EUV) imagery. We propose an automated detection algorithm of CHs which revisits ground-observed, chromospheric He I 10830 Å line imagery and underlying photospheric magnetograms as drivers to circumvent these issues and provide a complementary method to the space-observed, coronal EUV emission-driven methods that have been widely adopted in the community. Classical computer vision techniques are applied to imbue the routine with design variables based in radiative and magnetic properties of CHs, as well as produce an ensemble of boundaries with quantified intra-algorithm uncertainty. This method is science-enabling towards future studies of coronal hole formation and variability from a mid-atmospheric perspective.Abstract content goes here

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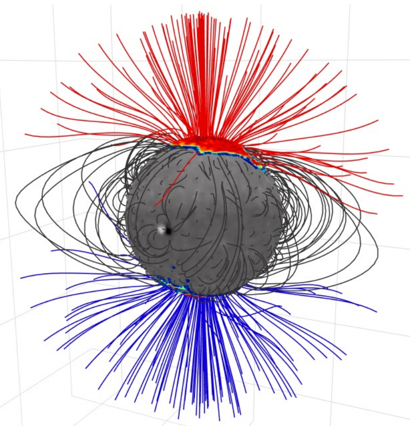
Jaime A. Landeros[1,2,3], Michael S. Kirk[1], C. Nick Arge[1], Laura E. Boucheron[4], Jie Zhang[5], Vadim M. Uritsky[1,6], Jeremy A. Grajeda[4], Matthew Dupertuis[5]

[1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[2]California State Polytechnic University Pomona, Pomona, CA 91768, USA
[3]ADNET Systems Inc, Bethesda, MD 20817, USA
[4]Klipsch School of Electrical & Computer Engineering, New Mexico State University, Las Cruces, NM 88003, USA
[5]School of Physics, Astronomy and Computational Sciences, George Mason University, Fairfax, VA 22030, USA
[6]Catholic University of America, Washington, DC, 20064, USA

Motivation

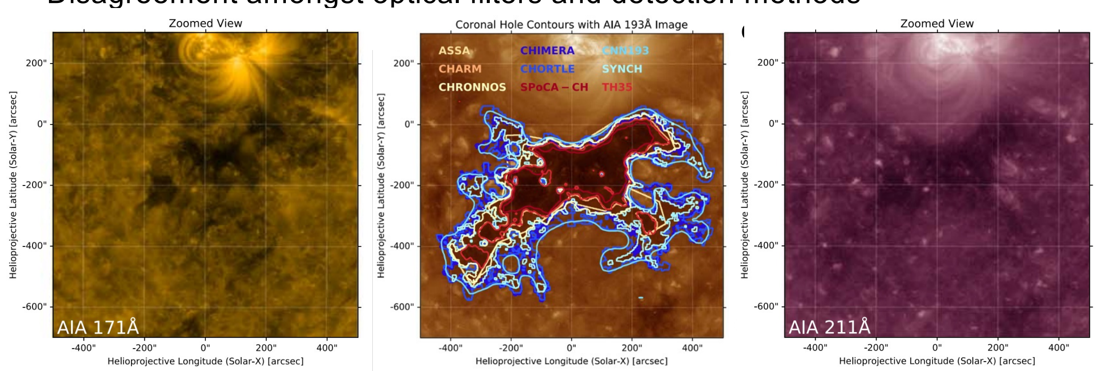
Steady solar wind is fundamental to space weather, but predictive models need to be validated

- Ambient steady solar wind originates primarily from Coronal Holes (CHs)
- CHs host magnetic field lines that are "open" to the heliosphere
- Quantitative validation of modeled CHs requires CH boundary detection in solar imagery



Advances have been made in CH detection using Extreme UV (EUV) imagery observed from space, but observational challenges remain

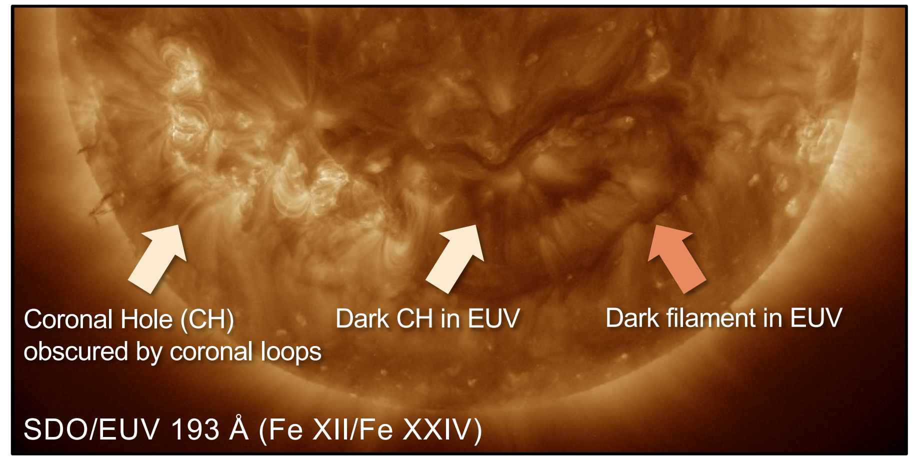
1) Bright coronal loops extrude from the solar disk and obscure CHs regions
   - Coronal Loops: Hot plasma in closed magnetic field regions
2) Filaments have a similar dark appearance to CHs
   - Filaments: Cool plasma in closed magnetic field regions
3) Lack of ground truth in boundary location
   - Disagreement amongst optical filters and detection methods

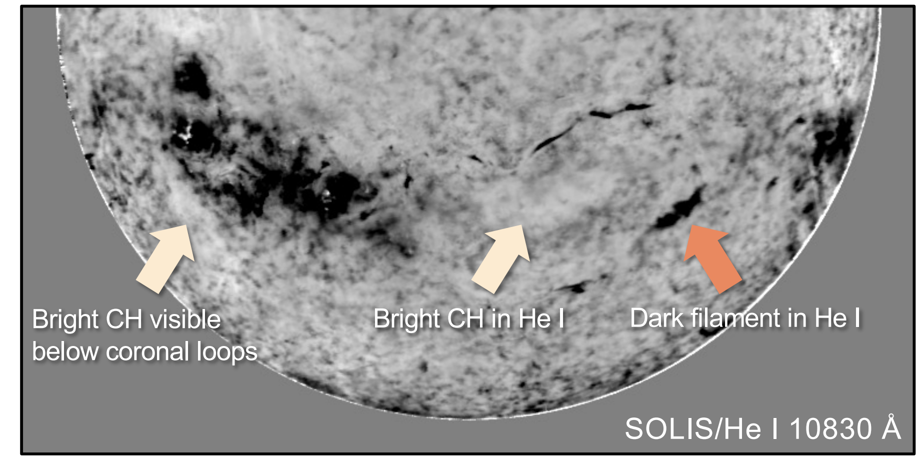


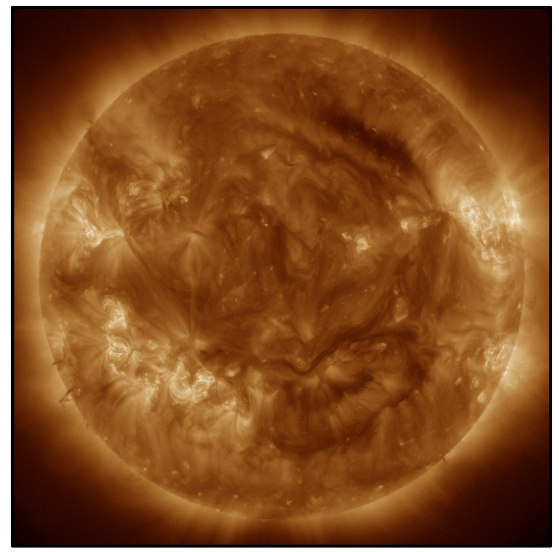
Reiss et al., 2021

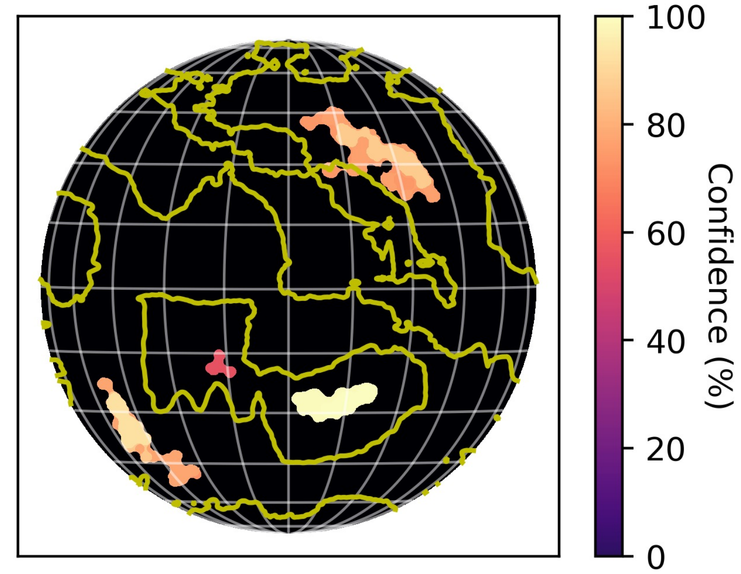
Methods

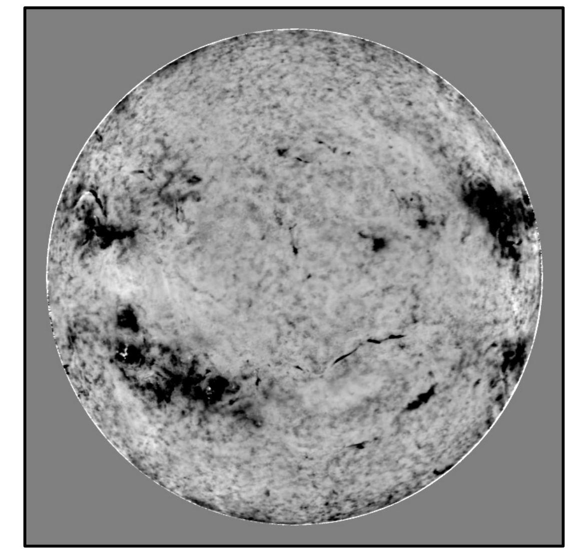
1) Use a He I 10830 Å image of the upper chromosphere captured by ground-based observatories
   - CHs now appear bright and **unobscured by active regions**
2) Apply a threshold and morphological operations to retain bright, coherently-shaped candidate regions
3) Assign greater confidence to candidates with high unipolarity in the magnetic field map of the underlying photosphere
   - CHs are now **disambiguated from filaments**
4) Create an ensemble of CH boundaries by varying threshold level and kernel size for morphological operations, then threshold away predominantly bipolar regions
   - Distinct CH boundaries **confront the lack of ground truth** with physically motivated confidence

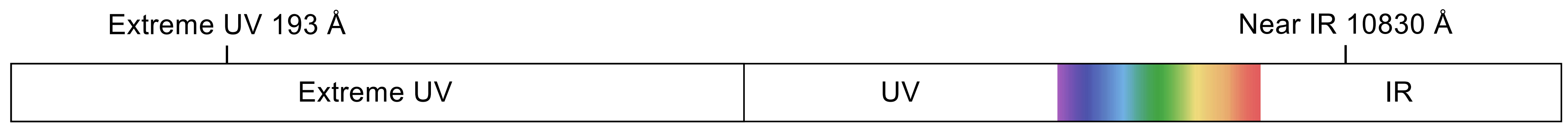












A new detection method provides a unique, **multi-physics constraint** for solar space weather models with **quantified confidence**

Weaknesses

1) Boundary location uncertainty is enhanced due to poor contrast in He I relative to EUV
2) While STRIDE-CH detects CHs obscured by active regions in EUV, it fails to detect CHs near the limb from VSM observations
   - VSM instrumental effect of noise in He I near limb adds to challenging off-line of sight view
3) Lack of availability in full-disk He I observations since 2015

Future Work

1) Quantitative validation of STRIDE-CH against state-of-the-art CH detection methods
2) Fuse CHs detected in He I 10830 Å with complementary EUV-derived CHs to construct a global CH map for model validation
3) Advocate for reinstatement of full-disk He I observations in future ground-based observatories

Please contact me at the email below if you have any questions or ideas towards better quantifying uncertainties and optimally fusing with EUV-derived CHs!

Ensemble Image Segmentation of Coronal Holes in Sub-Transition Region Observations (J. Landeros, in prep) | jalanderos@ucsd.edu