Coronal Hole Obscuration and Open Flux

Predictive Science Inc.

Ronald M. Caplan, Cooper Downs, Jon A. Linker, and Zoran Mikić

Predictive Science Inc. 9990 Mesa Rim Rd San Diego, CA 92121 www.predsci.com

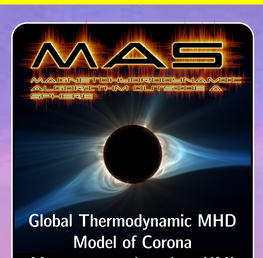
Funding provided by NASA NSF

AGU 100 FALL MEETING Washington, D.C. | 10–14 Dec 2018

INTRODUCTION

Coronal holes (CH) are dark areas in EUV images that are generally associated with open magnetic field regions on the Sun. They can be used to estimate the open magnetic flux in the heliosphere by overlaying them on magnetic field measurements. Accurately measuring the CH boundaries over the whole Sun remains challenging due to many factors, including limited instrument coverage, obstruction by nearby bright structures, and the assumptions of a given detection algorithm.

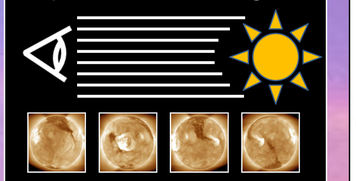
Here we explore the effects of CH obscuration using a global thermodynamic MHD model of the corona. We generate synthetic EUV images for several sets of observer locations, and combine them into maps using current and new obscuration-mitigating strategies. CH maps are generated from each resulting EUV map (using an established CH detection algorithm) and used to estimate the open flux. The importance of synchronizing the effective EUV image height to the height of the magnetic field values is demonstrated. Comparisons of the CH contours and open flux results with the known open field in the simulation gives insight into how much CH obscuration might influence observationally detected CH maps and open flux estimates. Application of the obscuration-mitigating mapping techniques to observations during an active part of the solar cycle is shown.



Global Thermodynamic MHD Model of Corona
Magnetogram based on HMI CR2192+CR2193

[Mikic et al (2018)]

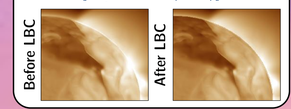
Synthetic EUV images



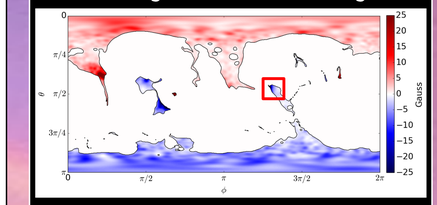
Integrated line-of-sight images using CHIANTI emissivities. Include continuum absorption by cold material [Mok et al (2016)]

Limb Brightening Correction

Take histograms of annuli bins and find transformation to disk center histogram [Caplan et al (2016)]



"True" Open Field Map (OFM) through Field Line Tracing



OFM over $B_r\ (r = 1.02R_\odot)$

EUV Mapping Options

Minimum Intensity Disk Merge (MIDM): Select minimum intensity from all disk images (within 75°) for each map grid point

Mapping options:

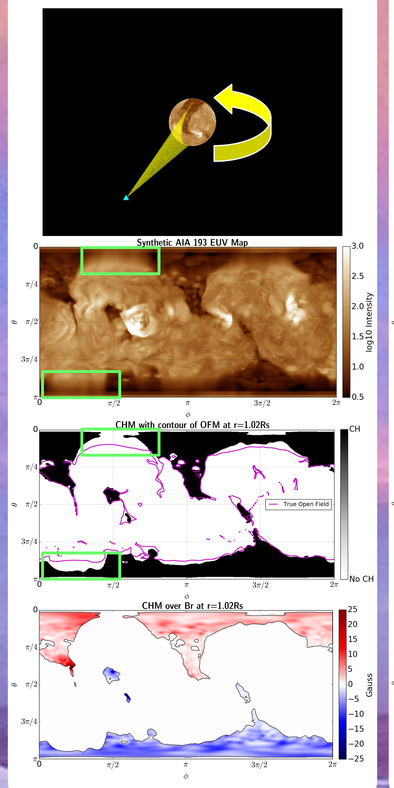
a) Synoptic (using 180 images, 2° width)
b) MIDM with 3 equatorial observers
c) MIDM with 180 equatorial observers (2° spacing)
d) MIDM with 720 observers (over full range of θ/ϕ)
e) Direct Center Line (DCL) Integration (no disk images used)

Coronal Hole Detection

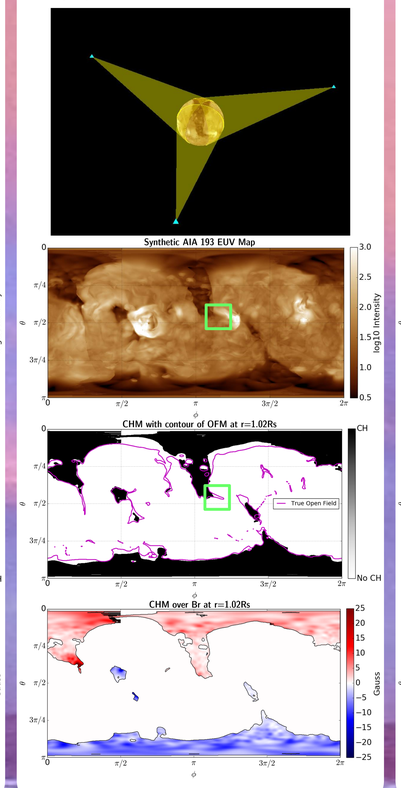
Use EZSEG from [Caplan et al (2016)] with selected thresholds

MHD Model (CR2192+CR2193)

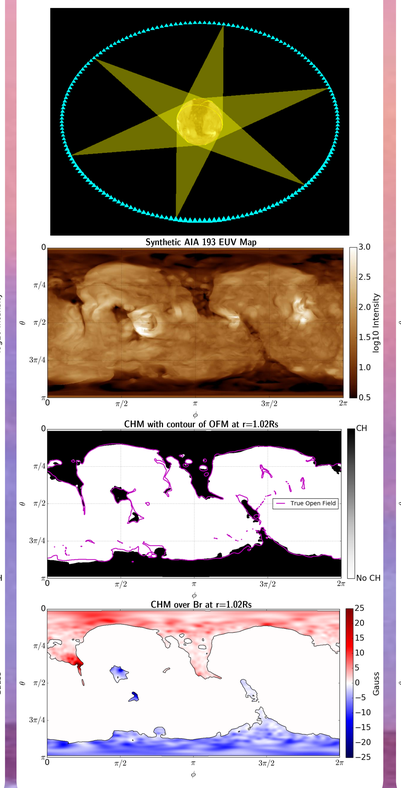
(a) Synoptic



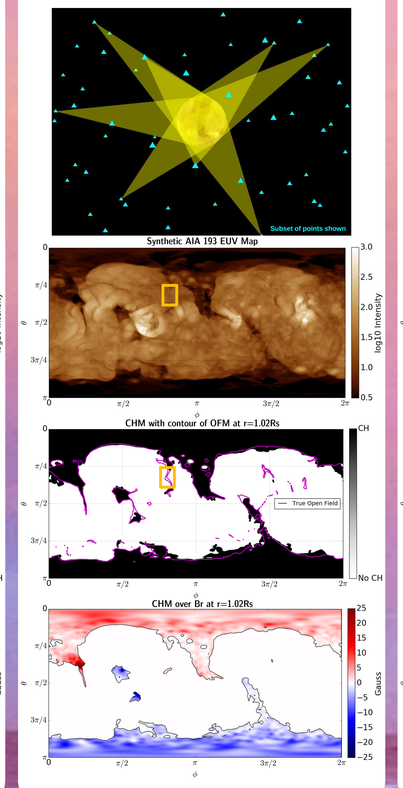
(b) MIDM 3 Eq Obs



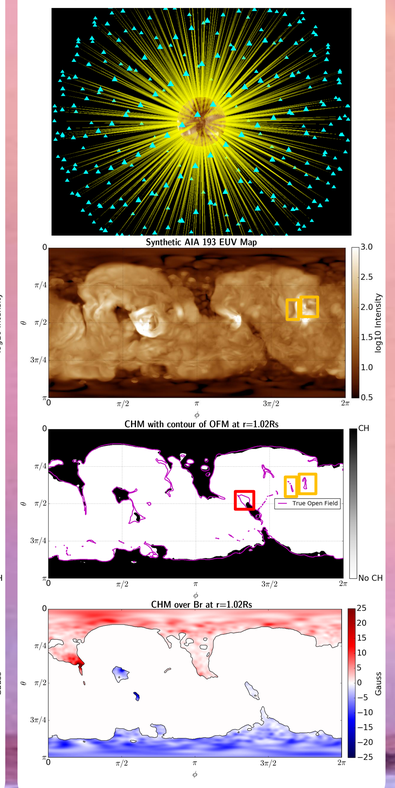
(c) MIDM 180 Eq Obs



(d) MIDM 720 Obs

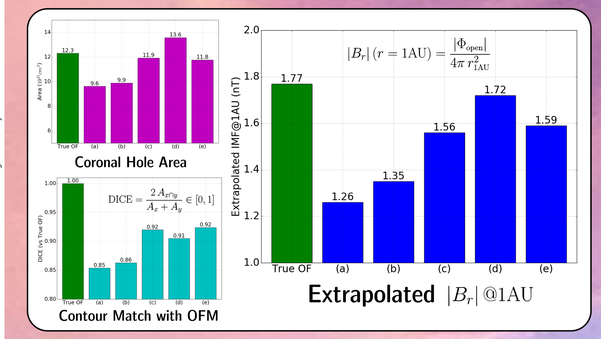


(e) Direct Center Line

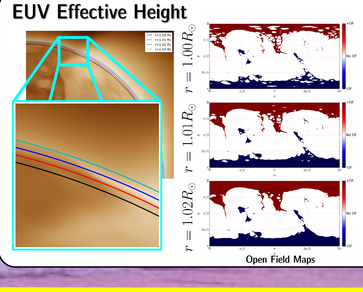


Highlights

- Examples of CH obscuration avoided by more observers
- Examples of CHs too bright to detect even unobstructed
- Example of undetected CH with non-trivial flux contribution



EUV Effective Height



What if one uses surface Br instead of the Br at true effective height of the EUV disk images?

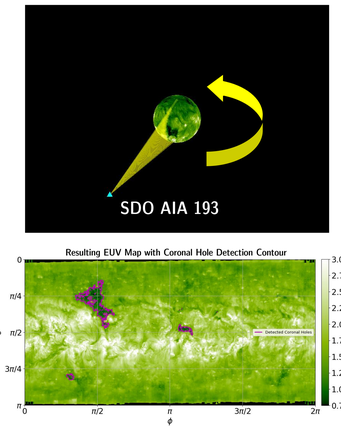
MAP	r=1.02Rs	r=1.00Rs
OFM	1.77	1.90
(a)	1.26	1.32
(b)	1.35	1.43
(c)	1.56	1.65
(d)	1.72	1.78
(e)	1.59	1.67

Br@1AU (nT)

Observations (CR2144)

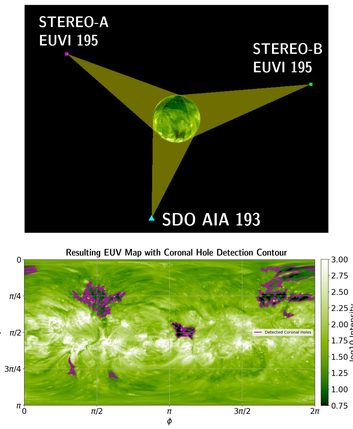
(i) Synoptic

Single Instrument
All times over whole CR



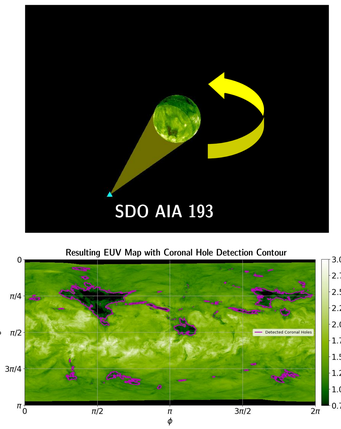
(ii) MIDM 3 Eq Obs

Multi-Instrument
One time at Middle of CR



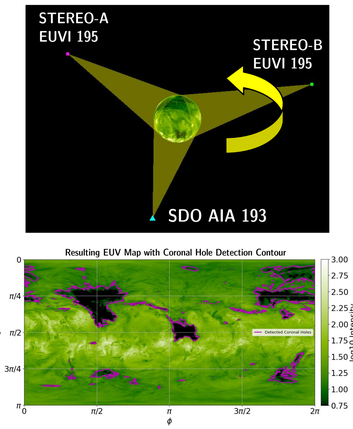
(iii) MIDM 115 Eq Obs

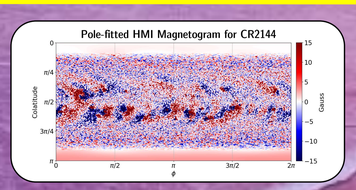
Single Instrument
All times over whole CR

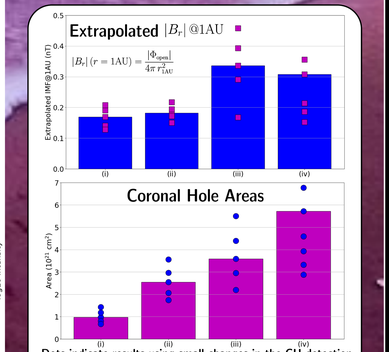


(iv) MIDM 111 Eq Obs

Multi-Instrument
All times over whole CR







Dots indicate results using small changes in the CH detection algorithm parameters (all yielding reasonable detections by eye)
Bar values correspond to displayed CH contours (left)

DISCUSSION

MHD Model

- Using Coronal Holes (CH) from EUV images as proxies for open fields has systematic problems, including detection ability and obscuration effects.
- Obscuration of CHs by bright structures can have significant impact on derived open flux measurements.
- Synoptic and 3-observer minimum intensity disk merge (MIDM) maps exhibit noticeable CH obscuration.
- Using MIDM with 180 equatorial disk images avoids much of the obscuration and yields open flux results similar to having hundreds of observers all over the Sun.
- The difference between the effective height of EUV images versus that of the photospheric magnetogram can cause flux calculation errors. Using Br slices from PFSS models may help mitigate this problem.

Observations

- MIDM methods (especially multi-instrument) bring out CHs not observed and/or obscured in classic synoptic map.
- MIDM maps over whole CR over-estimate CHs due to temporal evolution.
- Synoptic magnetogram is inherently mismatched with any EUV map.
- MIDM methods provide upper-bound on CH boundaries, but higher CH areas do not always increase open flux.
- Small changes in the CH detection algorithm parameters yield large variations in open flux and area.