Effect of Coronal Hole Obscuration on Open Flux Measurements

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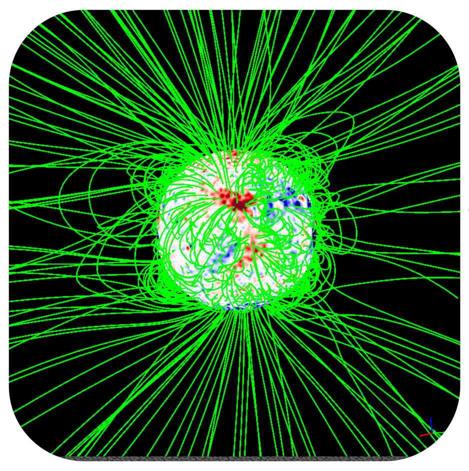
SHINE

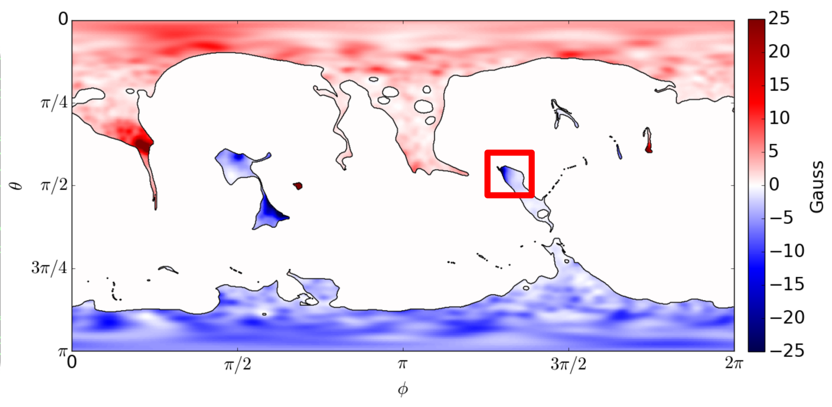
INTRODUCTION

Coronal holes (CH) are commonly associated with open field regions on the Sun. Full-sun maps of CHs detected in EUV images can be overlaid on photospheric magnetic field measurements to estimate the open magnetic flux in the heliosphere, but these estimates are typically smaller than averaged in-situ measurements at Earth. This could be due to many factors, including incomplete CH detection due to obscuration by nearby structures. Here we attempt to systematically test the effects of CH obscuration using diagnostics from a realistic thermodynamic MHD model of the global solar corona. The results give insight into how much the obscuration of CHs might influence CH-based open flux estimates.

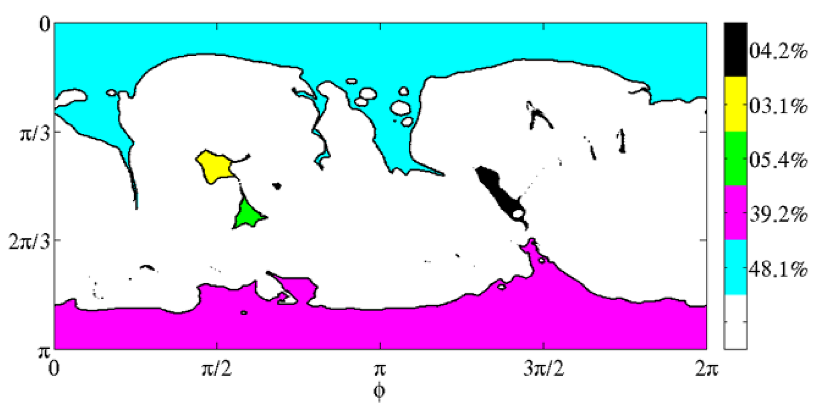
Global Thermodynamic MHD Model of Corona
Magnetogram based on HMI CR2192+CR2193

Obtain "True" Open Field Maps (OFM) through Field Line Tracing



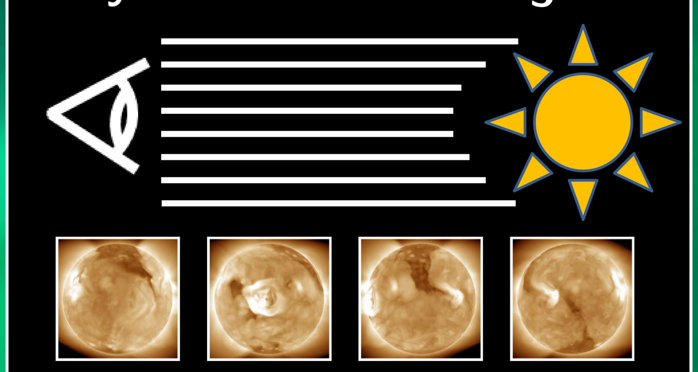


OFM over B_r $(r = 1.02R_\odot)$



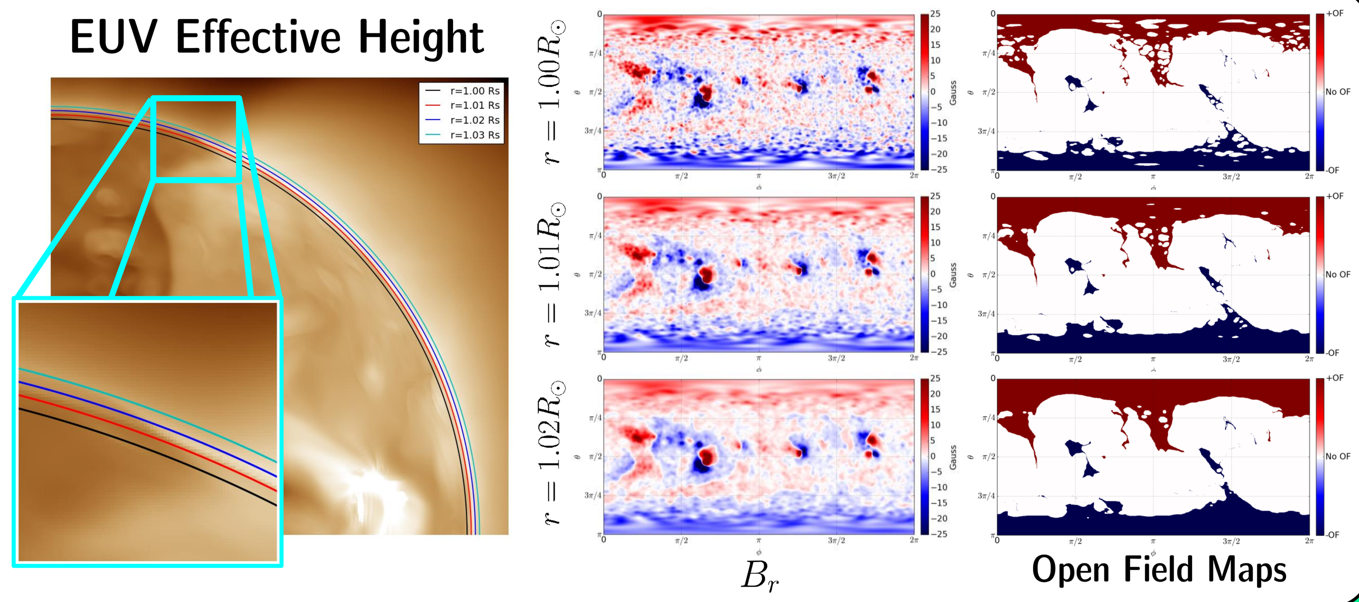
% Open Flux in each Open Field Region

Synthetic EUV images



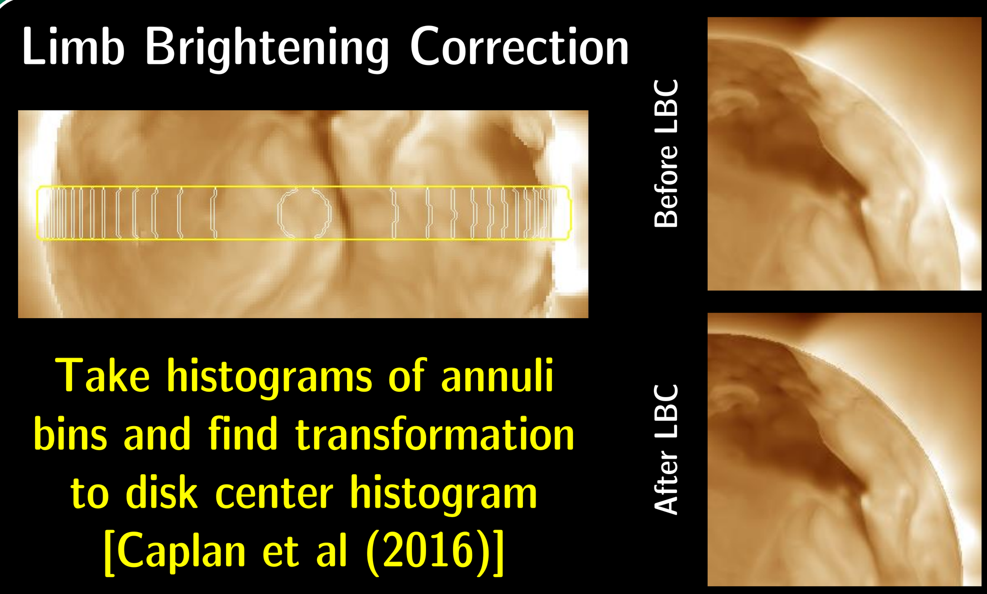
Integrated line-of-sight images using CHIANTI emissivities. Include continuum absorption by cold material [Mok et al (2016)]

EUV Effective Height



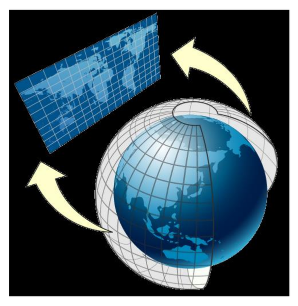
B_r Open Field Maps

Limb Brightening Correction



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

EUV Mapping Options



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

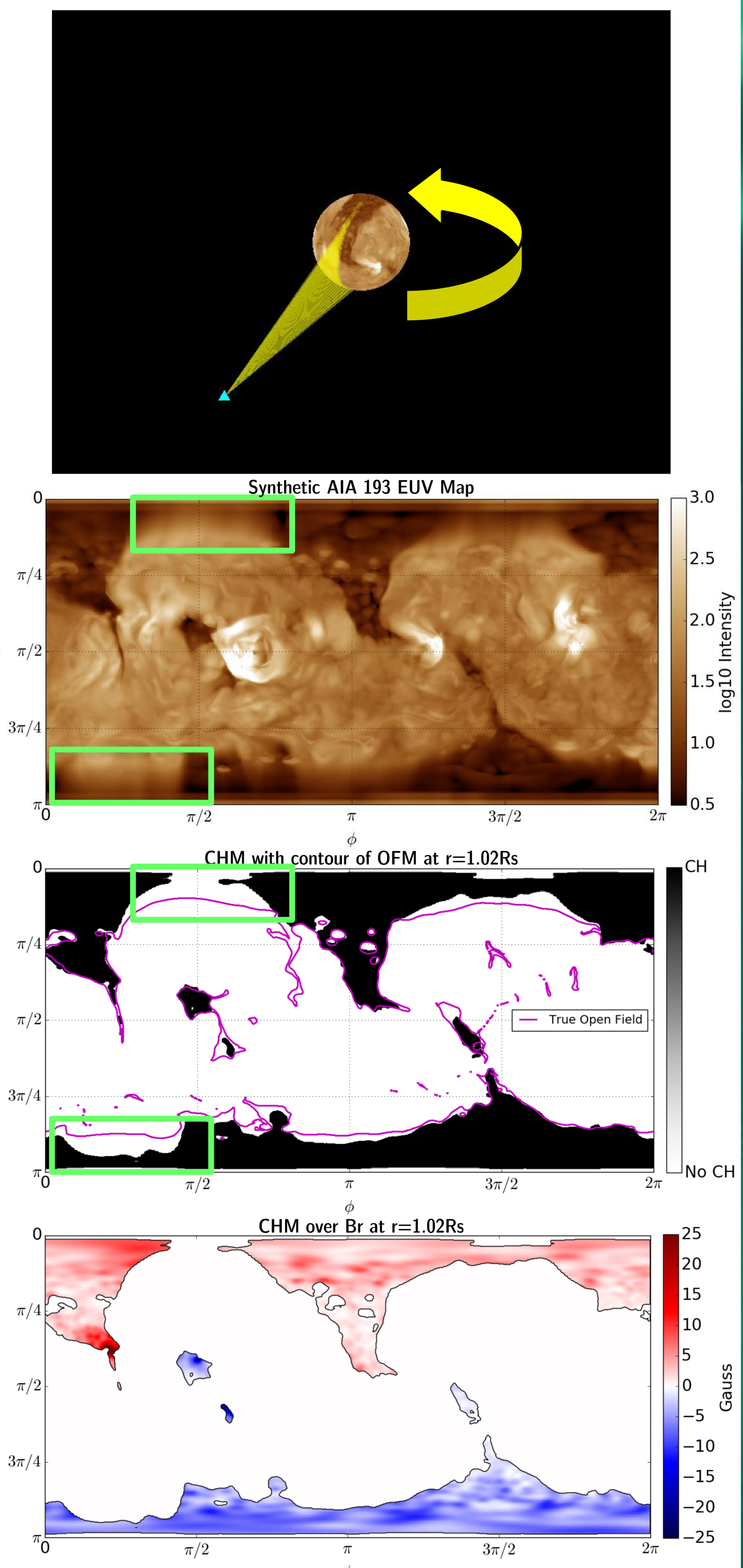
Five mapping options:

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)

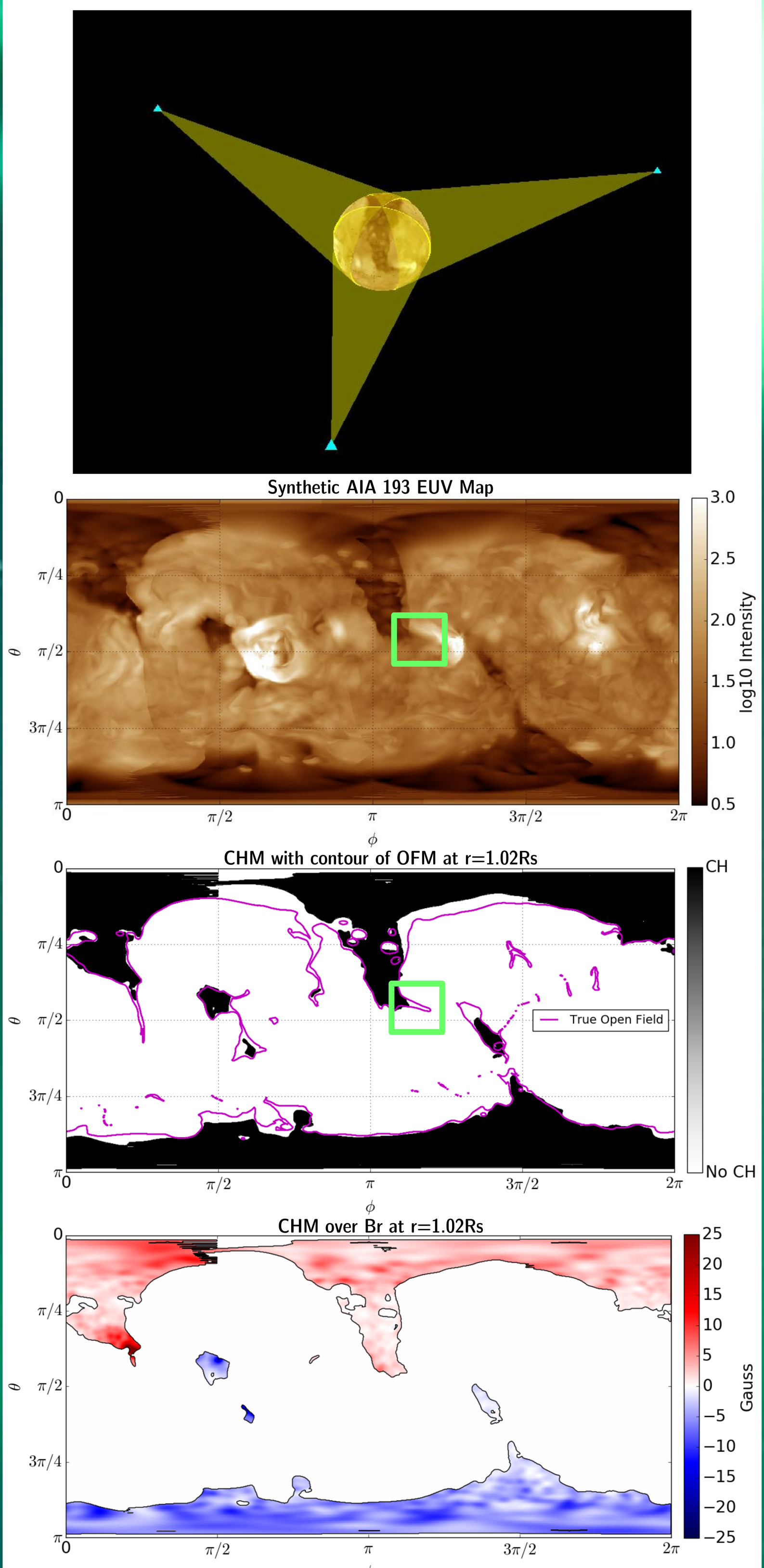
Coronal Hole Detection

Use EZSEG from [Caplan et al (2016)] with $t_1 = 1.025, t_2 = 1.125$

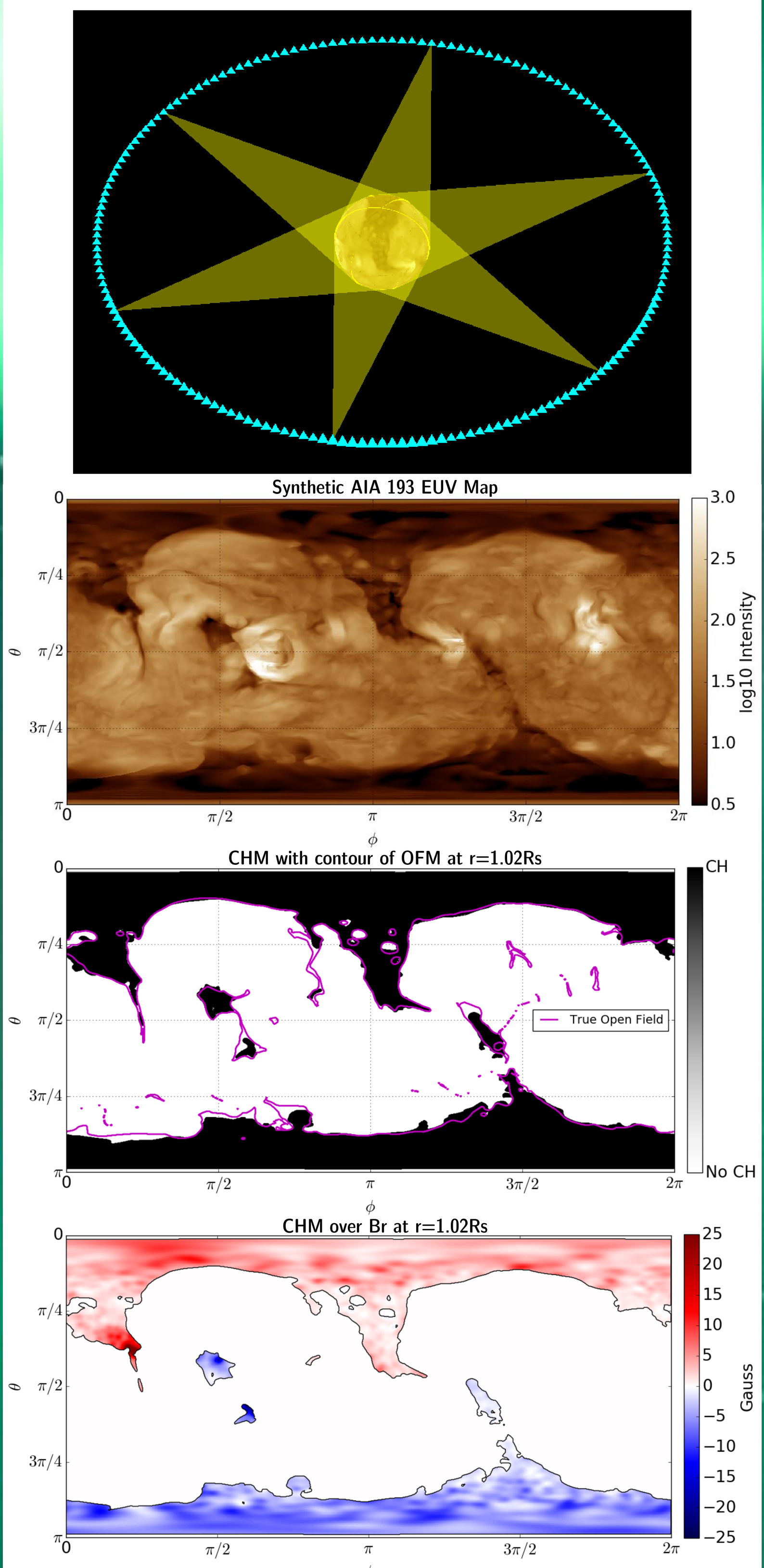
(a) Synoptic



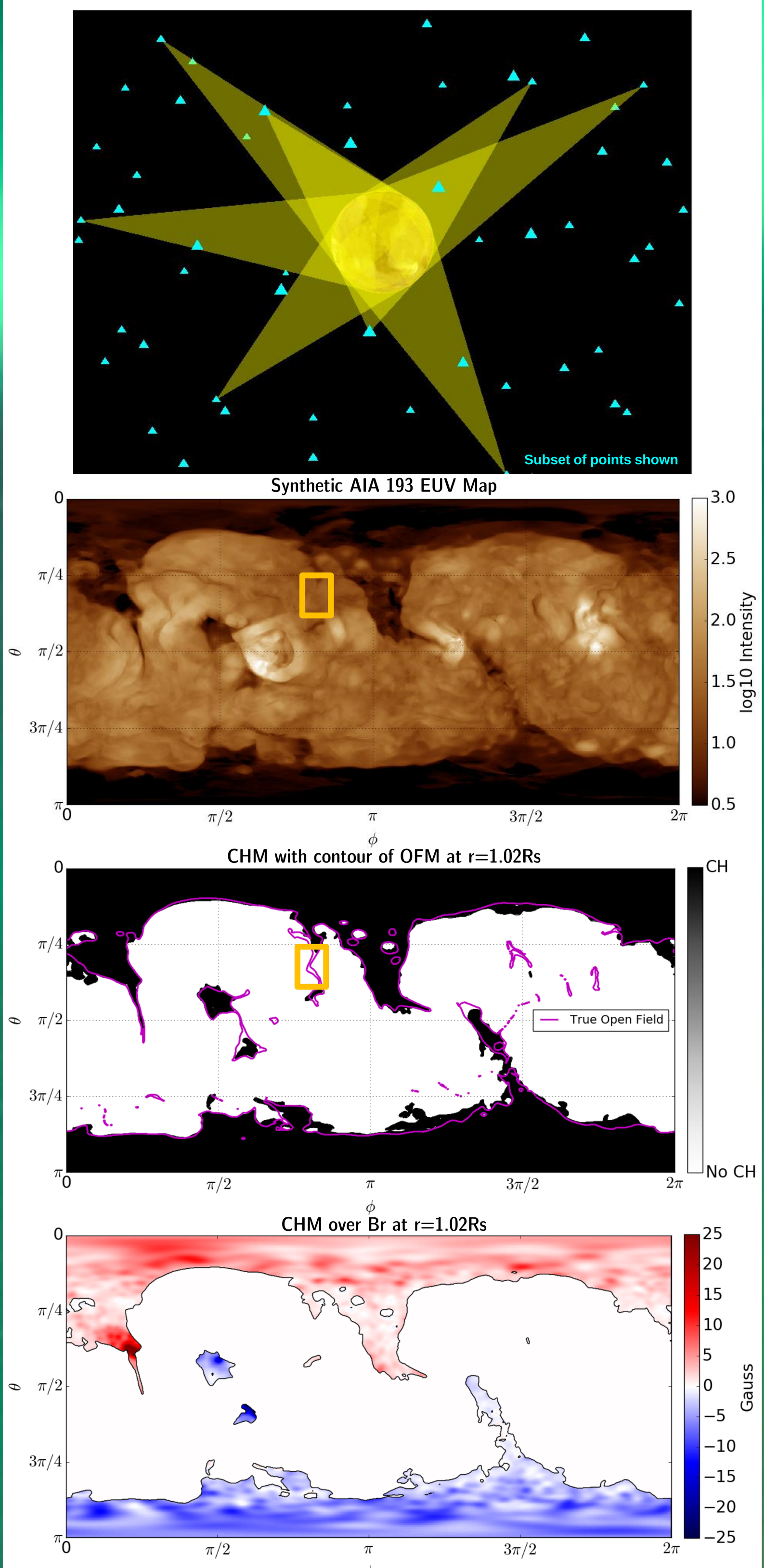
(b) MIDM 3 Eq Obs



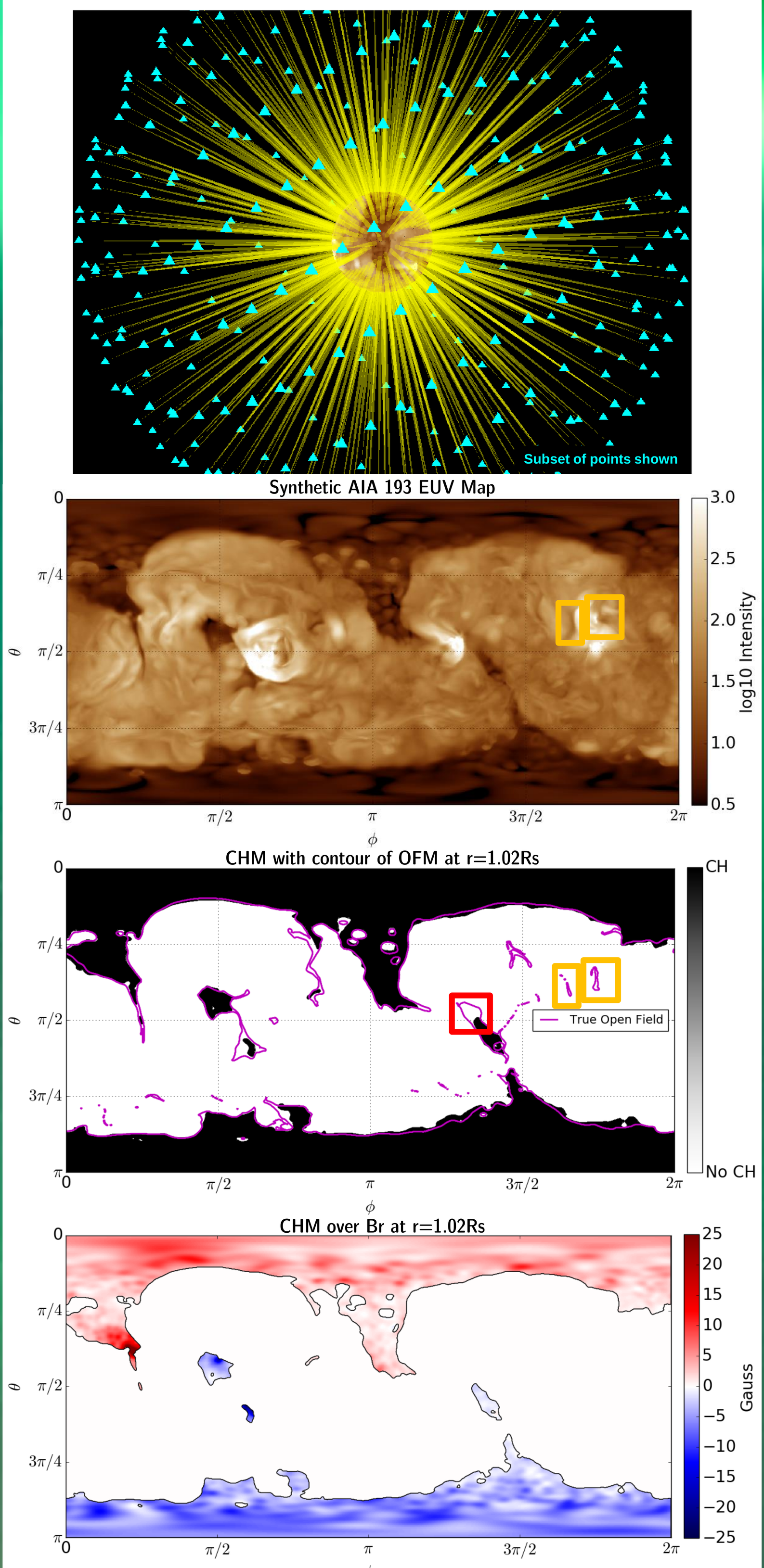
(c) MIDM 180 Eq Obs

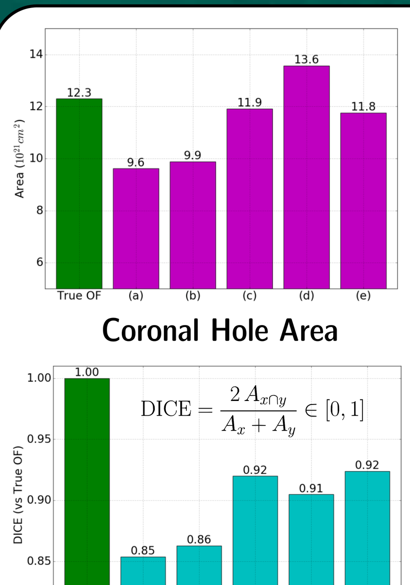


(d) MIDM 720 Obs



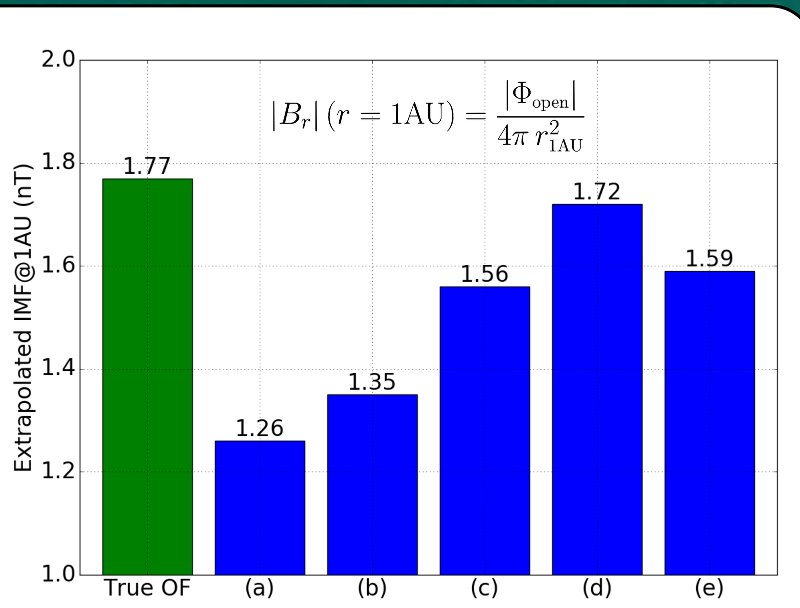
(e) Direct Center Line





Coronal Hole Area

Contour Match with OFM



Extrapolated $|B_r|$ @1AU

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

Effect of EUV Height

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

Br@1AU (nT)

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

DISCUSSION

- 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. This is promising because such maps can be generated from observations using MIDM of Earth-facing disk images over a solar rotation, which may improve open flux estimations.
- 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.