Data-Optimized Coronal Magnetic Field Model (DOC-FM): Recent results and progress

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Coronal polarimetry

Polarization (Zeeman, saturated Hanle)

MAS model —> FORWARD

Gibson et al. 2016
CoMP Observations

Linear polarization (percent and direction)

Gibson et al. 2016
Linear polarization (percent and direction)

Gibson et al. 2016
Stokes parameters used in loss function (generalization of e.g. chi-squared, a.k.a likelihood)

Dalmasse et al. 2016
Quantify non-potentiality?

Linear polarization (percent and direction)
How to use this new polarimetric diagnostic

Identify **how/where measurements are sensitive** to coronal magnetic fields

Establish **quantitative measures** of that sensitivity

Use these measures to help **optimize coronal magnetic models**

Test **robustness** to different models

Determine usefulness for **prediction** using **observations**
CoMP linear polarization: Sensitivity to magnetic fields

- Magnetic flux ropes
- Pseudostreamers
- Non-radial expansion
Cavities and flux ropes
Diagnostic of magnetic flux rope

Van Vleck inversion in flux rope
Van Vleck inversion in arcade
Flux rope axis

Bak-Steslicka et al., 2013
Lagomorphs, cavities and flux ropes

EUV coronal cavities = CoMP lagomorphs
Lagomorphs, cavities and flux ropes

EUV coronal cavities = CoMP lagomorphs

EUV cavity
Prominence
CoMP Doppler Vlos

Lagomorph vs. EUV cavity widths

Bak-Steslicka et al., 2014; 2016, Gibson, 2015; Fan, 2012
Free energy of evolving magnetic flux rope

- Twisted magnetic flux emerges (free energy increases)
- Flux rope equilibrium (energy declines a little - num. diffusion)
- Eruption (energy released)

Fan, 2017
Linear polarization: measuring non-potentiality

Evolution during emergence phase

Simulation

Potential field - same boundary

Difference

Summer project: SOARS undergraduate Marcel Corchado Albelo
Circular polarization: measuring non-potentiality

Evolution during emergence phase

Simulation
Potential field - same boundary
Difference

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Circular polarization: measuring non-potentiality

Evolution during emergence phase

Free energy

Summer project: SOARS undergraduate Marcel Corchado Albelo
Evolu'on	of	a	polar
crown

Pseudostreamers

Evolution of a polar crown

Guennou et al 2016
Pseudostreamers in linear polarization

Expected topology

Rachmeler et al 2014
Pseudostreamers in linear polarization

CoMP observations vs models

Gibson et al. 2017; Rachmeler et al. in preparation
Pseudostreamers in linear polarization

Gibson et al., 2017
Potential field model null is lower than observed by CoMP.
Non-radial expansion

diverging fields

converging fields

CoMP Azimuth -
black=radial;
blue=clockwise tilt;
red=counterclock tilt
Non-radial expansion

Expansion factor associated with pseudo streamers is underestimated
Significant for solar wind acceleration models
(Wang et al. 2007; Riley & Luhmann, 2012; Wang et al. 2012)
Data-optimized coronal field model (DOCFM)

Coronal-model based approach to forward-fitting the global solar magnetic field (NCAR-CfA collaboration)

Parameterized model of the solar coronal physical state (magnetic field, density, temperature... Use priors!)

Forward operation of magnetically-sensitive physical processes on the physical state, resulting in synthetic polarimetric observations

Maximize posterior

Modify model

Calculation of likelihood comparing synthetic vs. measured observations – efficient statistical methods
ROAM: Radial-basis-function Optimization Approximation Method

Using parameterized model, seek to regain “ground truth”

Efficient, radial-basis-function interpolant to speed up grid search

Dalmasse et al., 2016
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Flux-rope insertion: grid of solutions

CMS model

Parameters: axial and poloidal flux

13 X 13 grid

van Ballegooijen, Savcheva

Fan simulation
Applying ROAM

V/I

Dalmasse et al., in preparation

CMS models

Fan simulation
Applying ROAM

Initial results:
Axial flux better constrained than poloidal by polarimetric data

CMS requires density model:
• hydrostatic
• current-dependent
• “true” density

Dalmasse et al., in preparation
New capability in FORWARD: open vs. closed topology density weighting

Working to apply it to Mackay global models

Tassev
Complex test bed: CME, flares

Rempel; Chen et al., 2017
Sensitivity to polarimetric data

Kenzie Nimmo; REU summer project
Exposes sensitivities of polarimetric data to high densities, temperatures, and velocities

Kenzie Nimmo; REU summer project
Coronal base boundary condition

Machine learning — statistical regression model

Blos photosphere

Blos coronal base (statistical)

Blos coronal base (full model)

Relative error (~10%)

Nathaniel Mathews - CU graduate student
Identify **how/where measurements are sensitive** to coronal magnetic fields:

- cavities — linear-polarization lagomorphs
  - expect clear signature in circular polarization (DKIST, COSMO...)
- pseudostreamers — linear-polarization lobes and nulls
- streamer/coronal hole interface — non-radial expansion in azimuth
Establish **quantitative indices** of that sensitivity:

- non-potentiality index from cavity circular polarization - tracks free energy
  - how do we use the information in the linear polarization lagomorphs?
- magnetic null heights from linear polarization in pseudostreamers
- non-radial expansion from azimuth at streamer/coronal hole interface
How to use this new polarimetric diagnostic

Use these indices to help optimize coronal magnetic models

- Finish flux-rope fit to Fan simulation (*Dalmasse et al.*)
  - Iterative ROAM
  - Test robustness to density model
  - Consider other contributions to loss function (magnetic skeleton — *Malanushenko*)

- Create optimized model of pseudostreamer (4/15/2015) (*Karna et al.*)
  - Incorporate height of null, polarization expansion factor in loss function

- Sensitivities to noise, measurement uncertainties (*Fan et al.*)
Photon noise estimated using:
Aperture: 150 cm
Resolution: 12 arcsec
Integration: 300 sec
Efficiency: 0.05
Modeff: $1/\sqrt{3}$
Test **robustness** of polarization sensitivities with respect to different models:

- correlation of polarimetric data to free energy (*Corchado Albelo et al.*)
- sensitivities to density, temperature, velocity (*Nimmo et al.*)
- develop generalized solver (*Mathew et al.*)
Determine usefulness of non-potentiality index for prediction using observations:

- CoMP observations of erupting vs. non-erupting cavities
- Calculate non-potentiality index; analyze trends
Connections to other teams

Bastille-day event
flux rope insertion -
collaboration with PSI

Savcheva et al., in preparation
Connections to other teams

McCauley et al. submitted

MWA vs. FORWARD-modeled MAS
CORONAL MAGNETOMETRY

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