Statistically Identifying Systematics from Far-side Acoustic Images

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Outline

- **Why are Far-Side Acoustic Images important?**
- **Project Overview:** (HSWO2R)

  "Reliably Inferring the Sun's Far-Side Magnetic Flux for Operations Using Time-Distance Helioseismology"

  - Far-Side Acoustic Maps
  - Establishing a Relationship between EUV and Magnetic Field Images
  - Calibrating using a Flux Transport Model

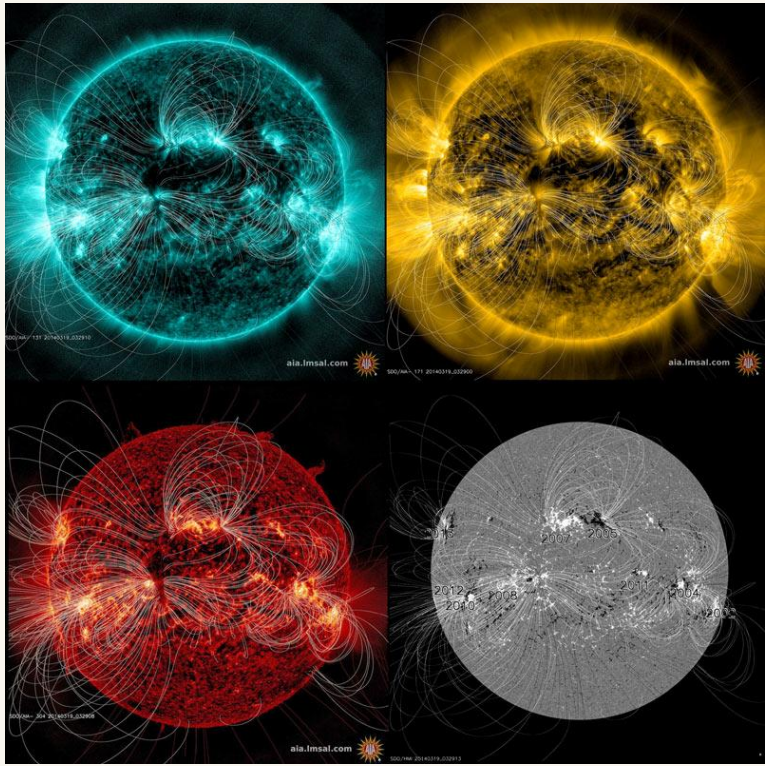
- **Statistical Analysis So Far**
  - Annual Variation
  - Average Background
  - Success Rate:

    Acoustic Far-Side AR Detections Compared to *STEREO* 304 Å Far-Side AR Observations

Why are Far-Side Acoustic Images Important?

Current Far-Side Solutions:

- Flux Transport Models
  - Signed Flux
  - Effectively progress observed near-side flux around to far side
  - Incapable of incorporating:
    - Growth of existing AR
    - New flux emergence
- *STEREO/EUVI* Observations
  - Quantitative relationship btw 304 Å emission and magnetic flux → proxy (Ugarte-Urra et al. 2015)
  - No guarantee of future observations
- Current Helioseismic Imaging
  - Acoustic Holography (Lindsey & Braun 2000; Braun & Lindsey 2001)
  - Time-Distance (Zhao 2007)
  - Often give spurious signals
  - Not calibrated into magnetic flux



Courtesy of the SDO Gallery

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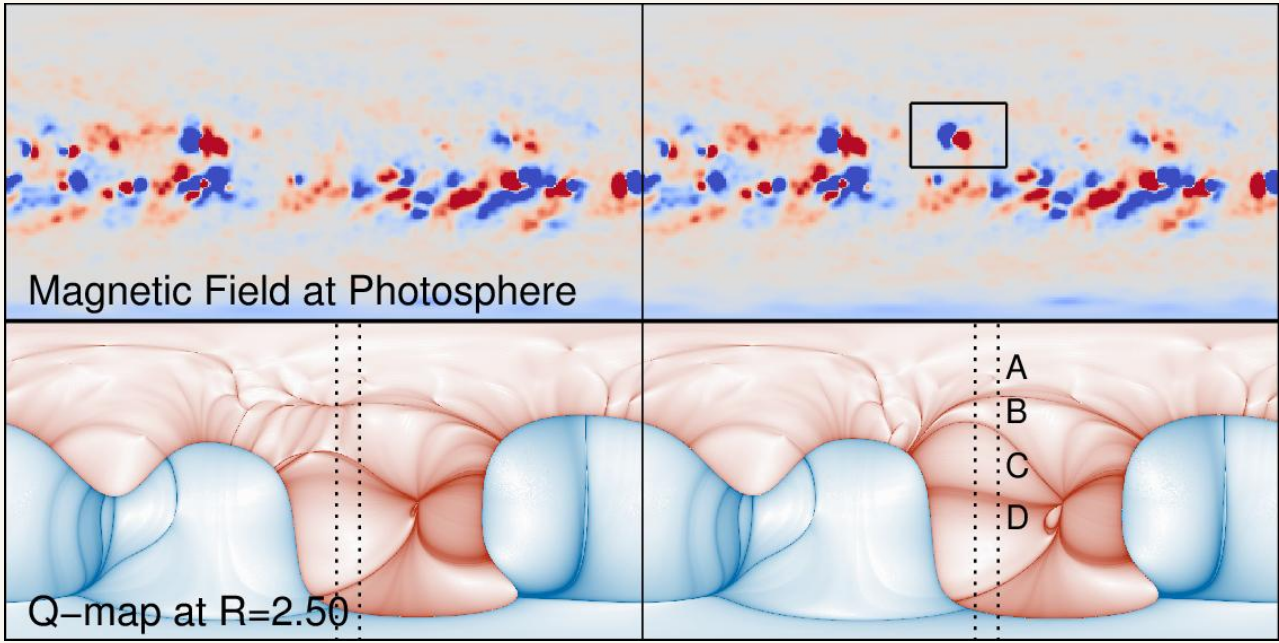

Top: FTM data-assimilation model for 17-Feb-2014 12:00 UT (left) with an artificial far-side "emerged" AR (right)
Bottom: Q-maps calculated using above synchronic flux maps
Courtesy of M. Derosa and Y. Liu

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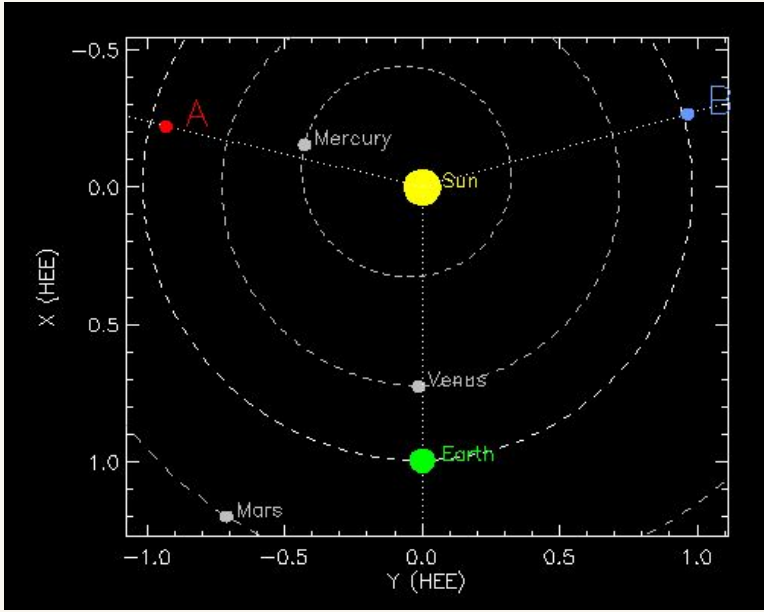

Positions of STEREO A and B for 24-Oct-2018 23:00 UT
Courtesy of the STEREO Science Center

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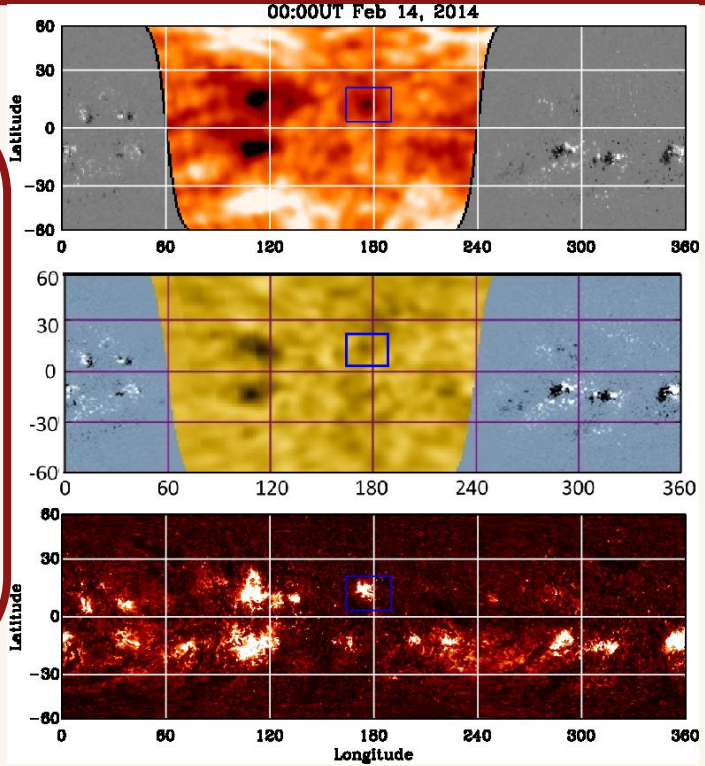
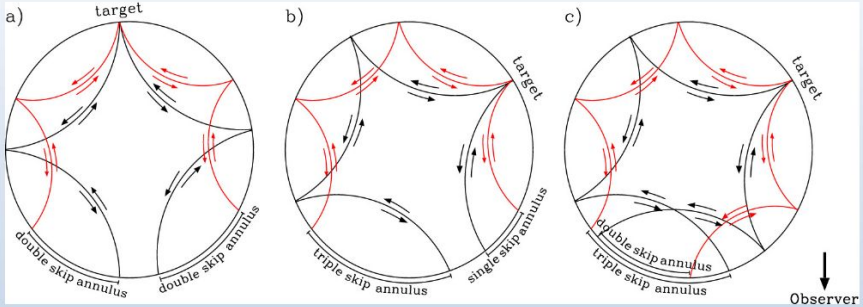


Top: Far-side travel-time acoustic map with near-side HMI magnetic field
Middle: Far-side holography acoustic map with near-side HMI magnetic field
Bottom: Synoptic map using *SDO/AIA* and *STEREO/EUVI* 304 Å observations
Courtesy of J. Zhao

Project Overview: *Far-Side Acoustic Maps*



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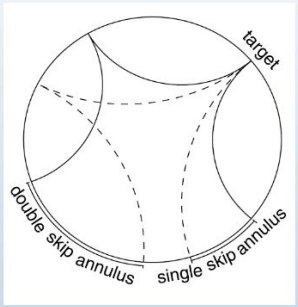
6-skip: 3x3
8-skip: 4x4

4-skip: 1x3
8-skip: 2x6

5-skip: 2x3



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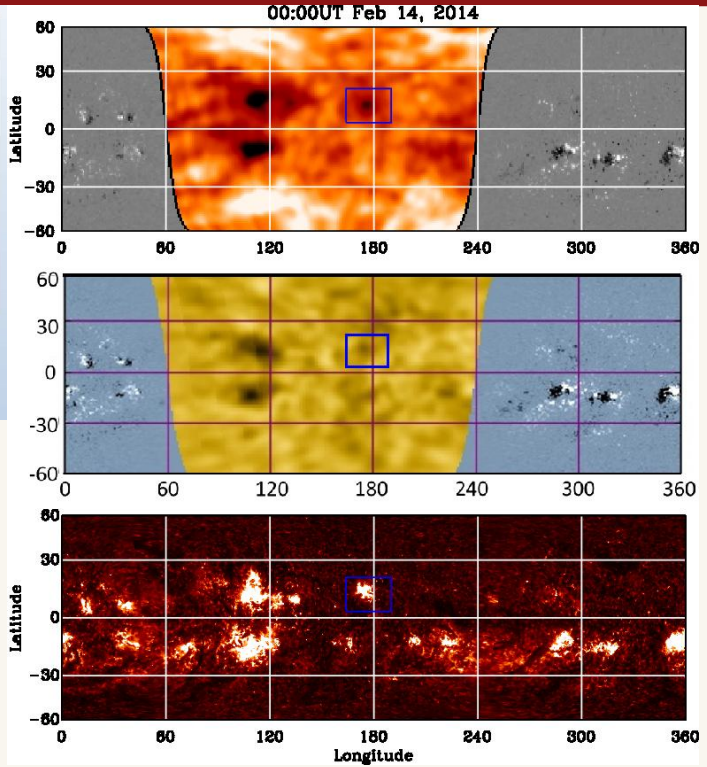

- New Far-Side Time-Distance Technique
  - Takes advantage of helioseismic geometry for different “skip” waves
  - 14 total sets of individual calculations
  - Expanded total wave-travel distances beyond 360°

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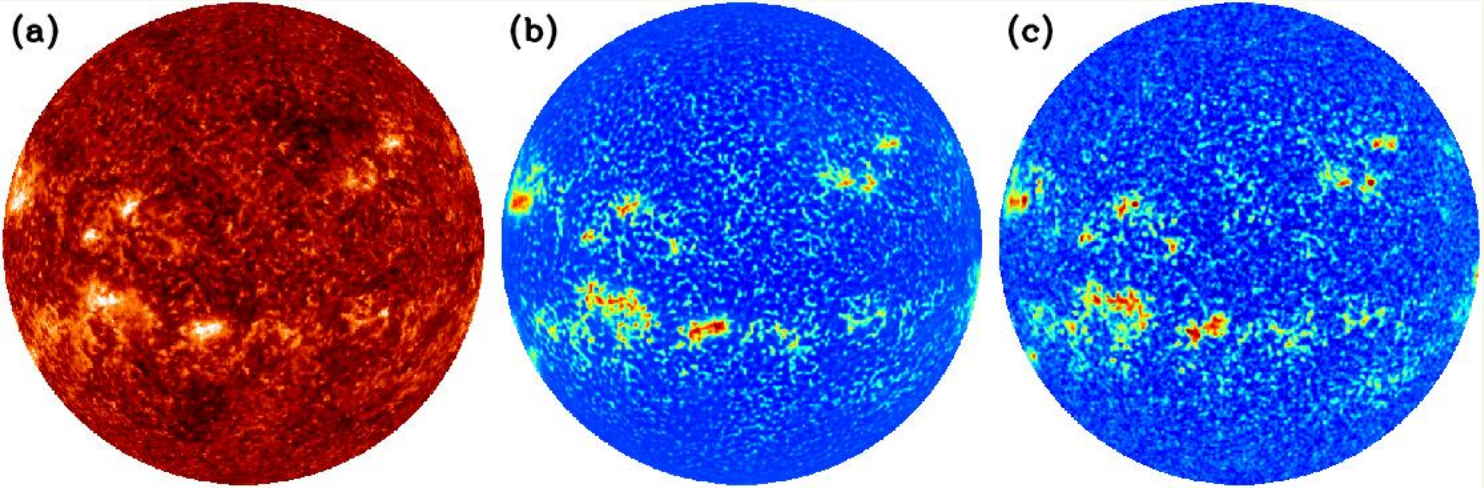
Project Overview: *Deep-Learning*



For 1-Aug-2013 00:00 UT

(a) AIA 304Å image

(b-c) HMI magnetic flux data & approximated DNN result

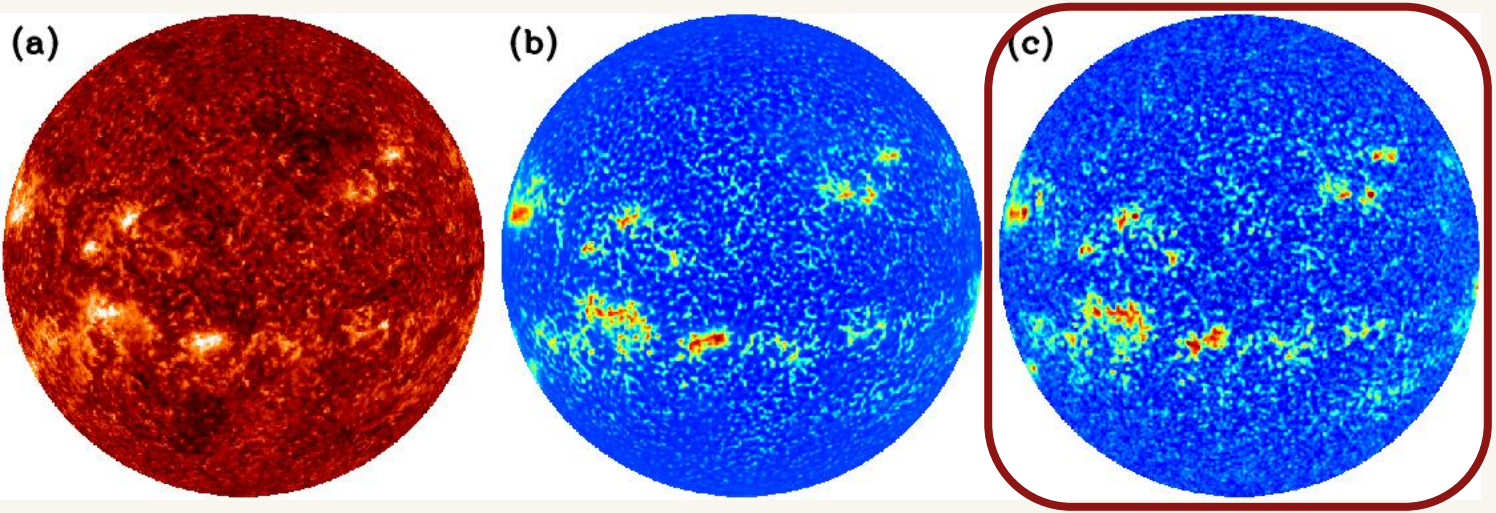
Courtesy of R. Chen

- Deep Neural Network
- 3 sets of kernels
- 8 years of training/test data
- Train on 2700 pairs of AIA 304 Å and HMI unsigned magnetic flux images

BETWEEN (b) AND (c)
WHICH IS THE REAL HMI DATA
AND WHICH IS PRODUCED BY THE DNN?

See e-Poster by R. Chen today (Thursday)

Project Overview: *Deep-Learning*



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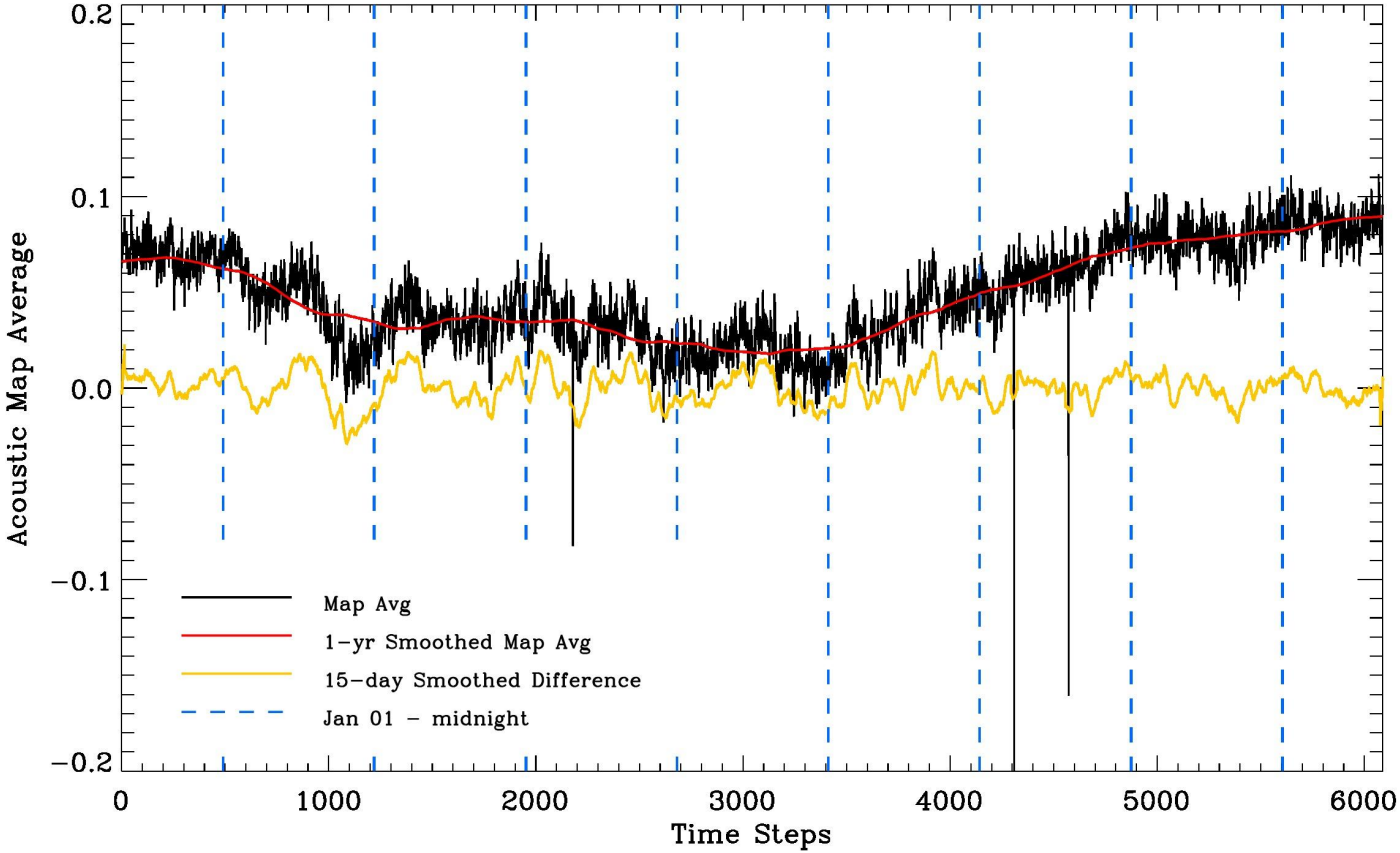
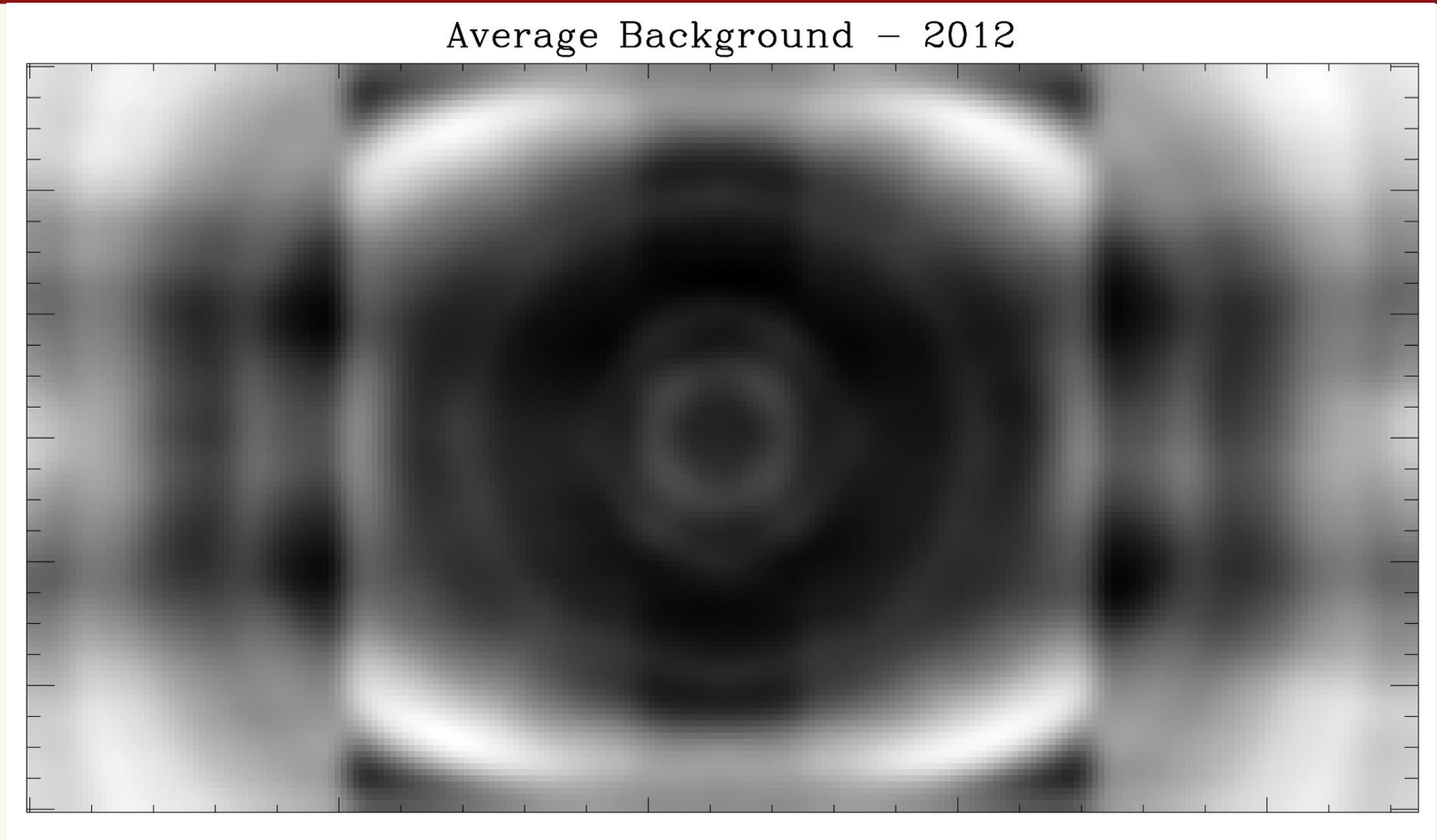
Project Overview: *Calibrating with FTM*

- Data-Assimilated Flux Transport Model (Schrijver & DeRosa 2003)
- Pro: Retains magnetic field polarity
- Con: Cannot model growth of existing AR or emergence of new AR
- Select at least 10 “perfectly modeled” ARs
  - Selection based on predicted total flux and position compared to region reappearance on the eastern limb
  - For selected regions, fit modeled total flux VS total acoustic travel-time shifts
  - Establish empirical relation
  - Useful for determining some uncertainty measures

Statistical Analysis: *Annual Variation*



Statistical Analysis: *Average Background*



Statistical Analysis: *Success Rate*

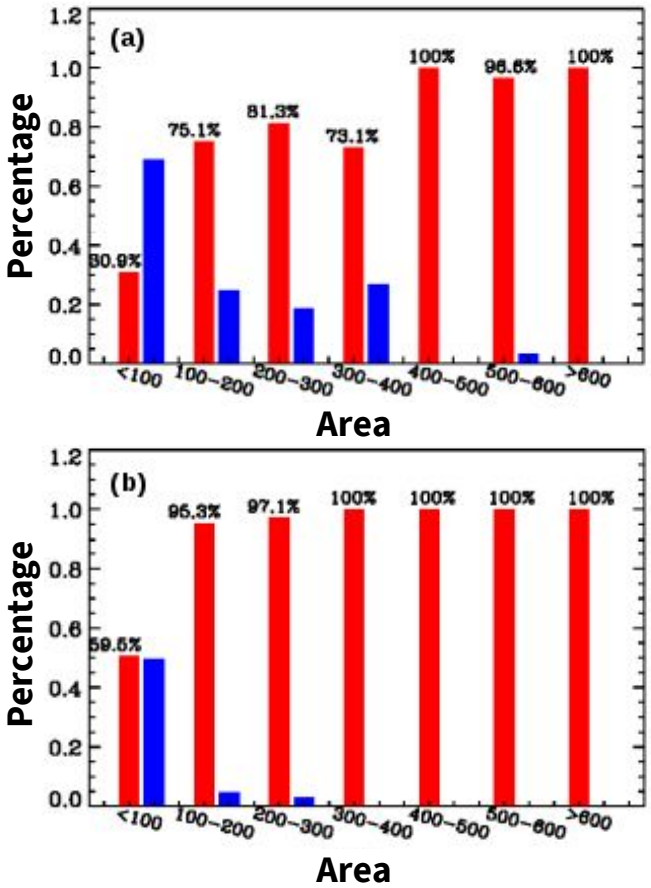
Based on 3 months of statistics (Jan - Mar, 2014)

(a) For far-side ARs observed in *STEREO* 304 Å :

- ARs >400 units (1 unit = 1.4 μhemispheres): nearly 100% detectable in acoustic images
- For ARs between 100 and 400 units: 75% are detectable in acoustic images

(b) For ARs detected in far-side acoustic images:

- ARs >100 units: nearly 100% correspond to observed *STEREO* 304 Å AR



Red: true positive (top and bottom
Blue: false negative (top) and false positive (bottom)
Courtesy of J. Zhao

Summary

- Far-side magnetic flux maps are important for improved coronal and space weather modeling
- We are working on a new far-side magnetic flux product that uses machine learning and statistical analysis:
  - Link magnetic flux → EUV 304 Å → acoustic maps
  - Calibrate with a data-assimilated flux transport model
- Currently: Using statistical analysis to prepare far-side acoustic maps for use with machine learning method
- Statistical Results so far:
  - Negligible annual variation!!
  - Cannot subtract an average background without biasing data
  - For ARs ≥ 100 pixels, excellent agreement between acoustic map detections and EUV 304 Å images
- Next: Statistical study of hemispheric differences and progress on machine learning