

# 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**

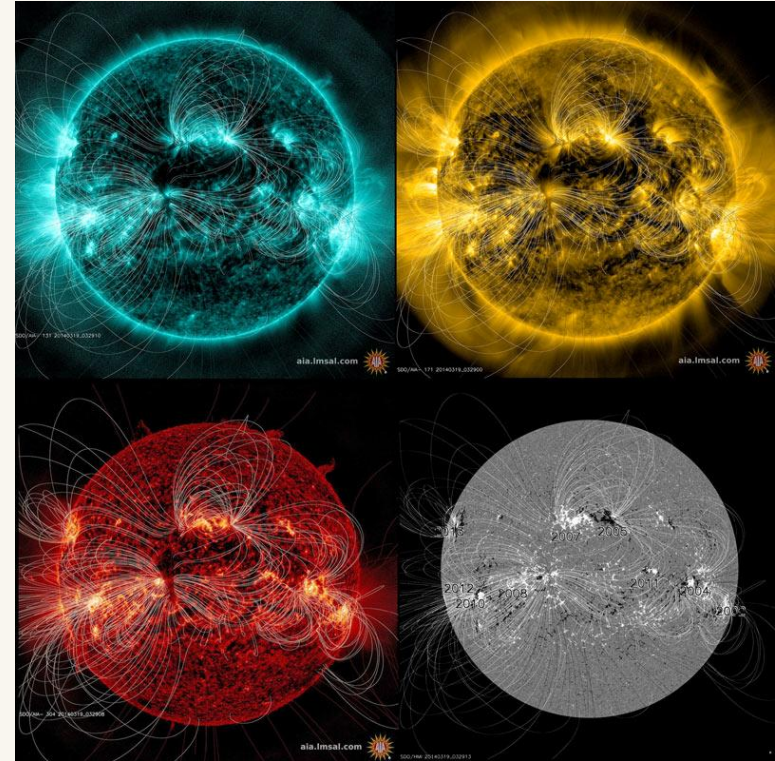
- ◆ Annual Variation
- ◆ Average Background
- ◆ Success Rate:

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

# Why are Far-Side Acoustic Images Important?

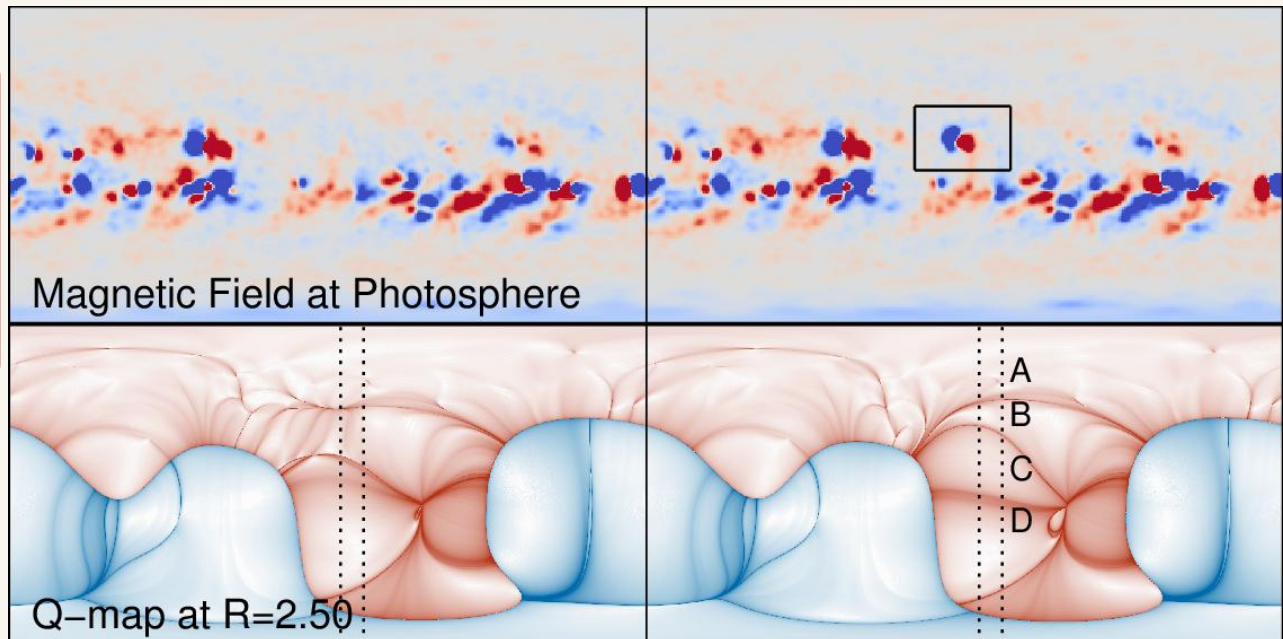
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Top: FTM data-assimilation model for 17-Feb-2014 12:00 UT (left) with an artificial far-side “emerged” AR (right)

Bottom: Q-maps calculated using above synchronic flux maps

Courtesy of M. Derosa and Y. Liu

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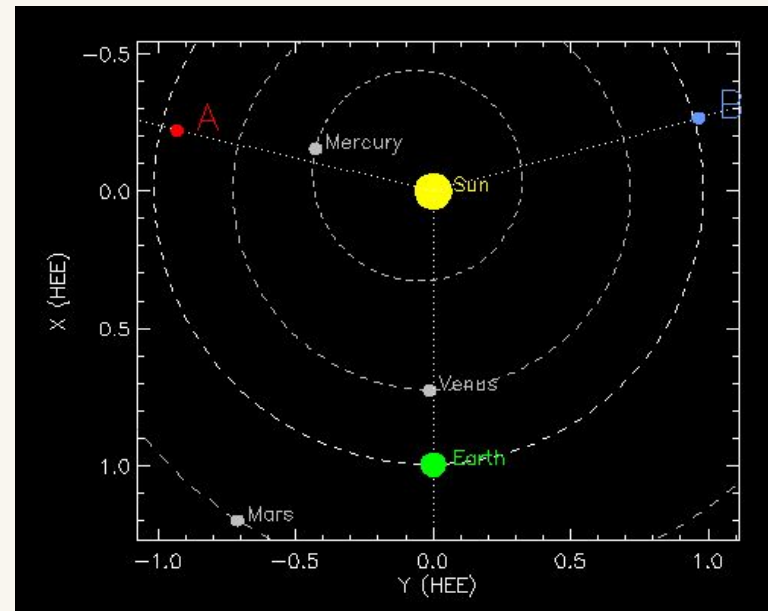
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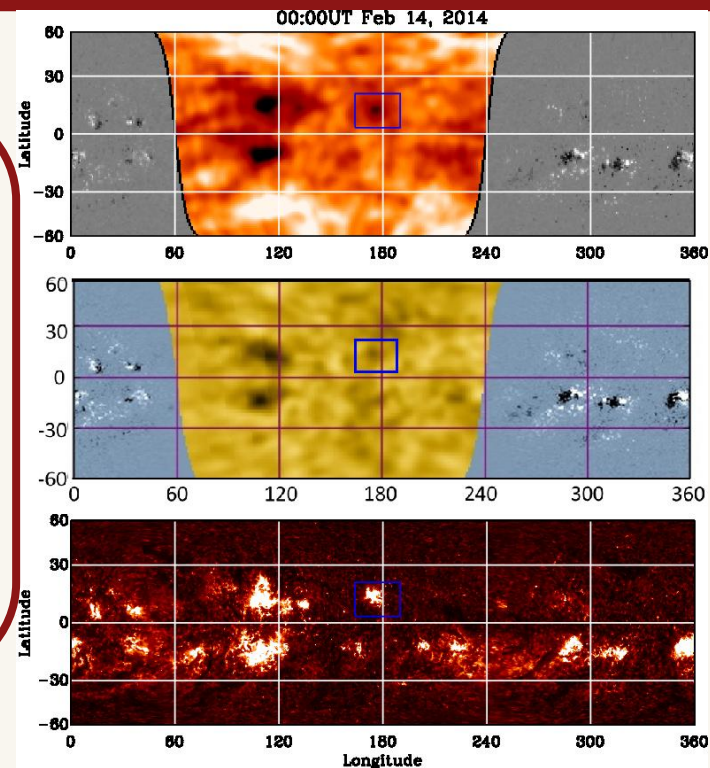
Positions of STEREO A and B for 24-Oct-2018 23:00 UT  
Courtesy of the STEREO Science Center

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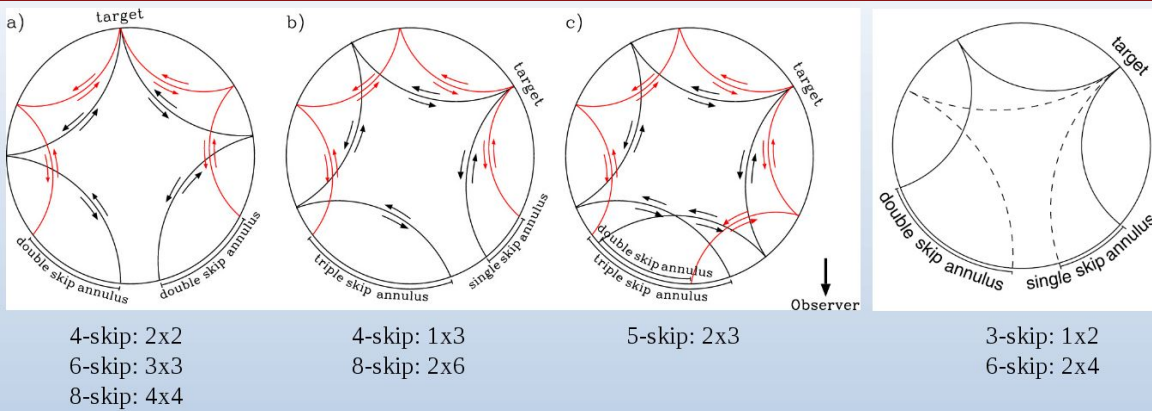
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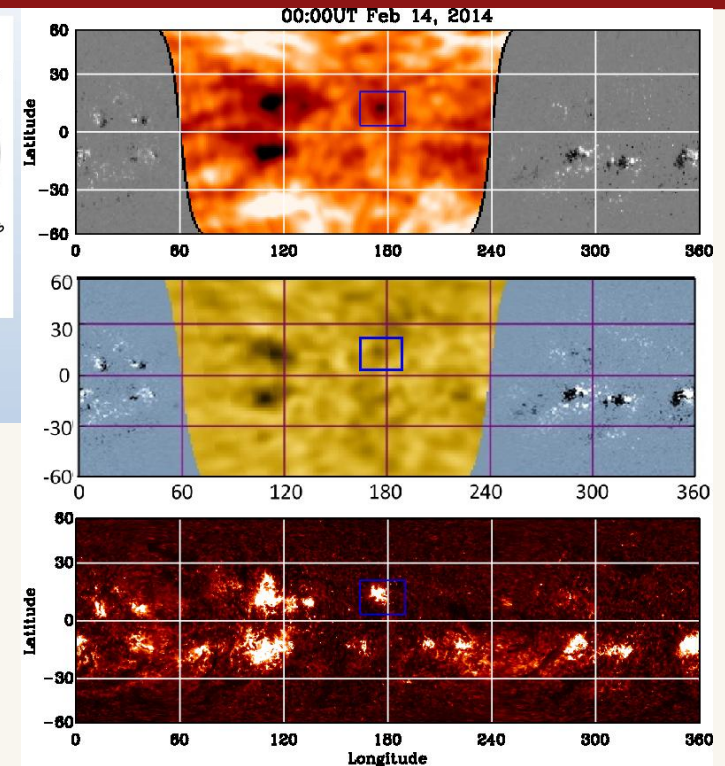
Top: Far-side travel-time acoustic map with near-side HMI magnetic field  
Middle: Far-side holography acoustic map with near-side HMI magnetic field  
Bottom: Synoptic map using *SDO/AIA* and *STEREO/EUVI*  $304 \text{ \AA}$  observations  
Courtesy of J. Zhao

# Project Overview: *Far-Side Acoustic Maps*



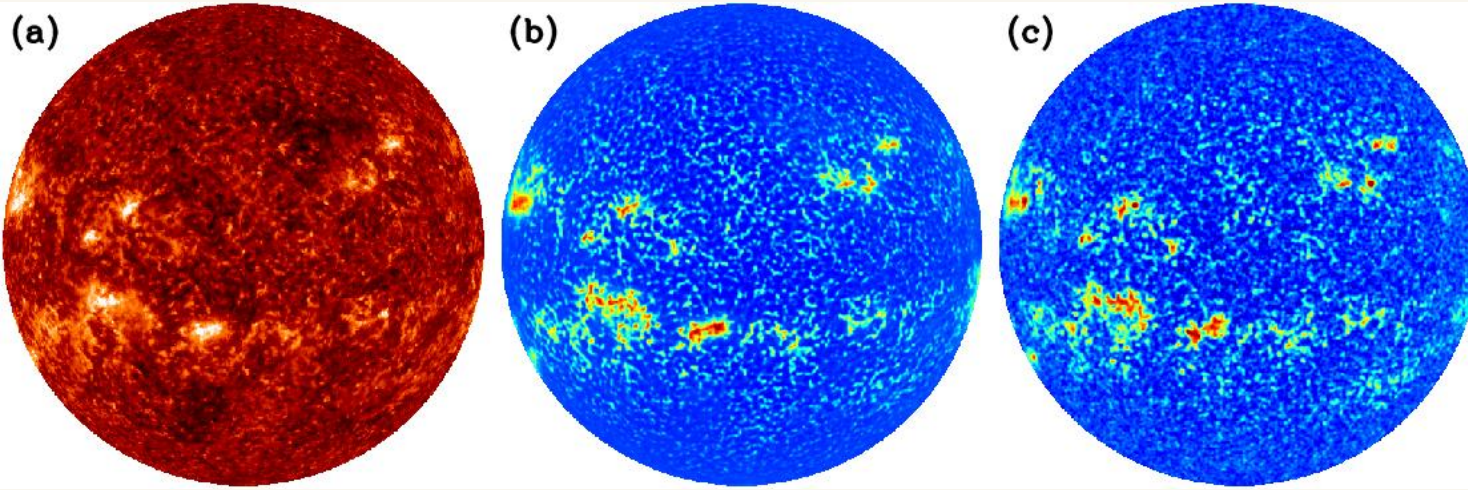
Courtesy of J. Zhao

- 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°



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: *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

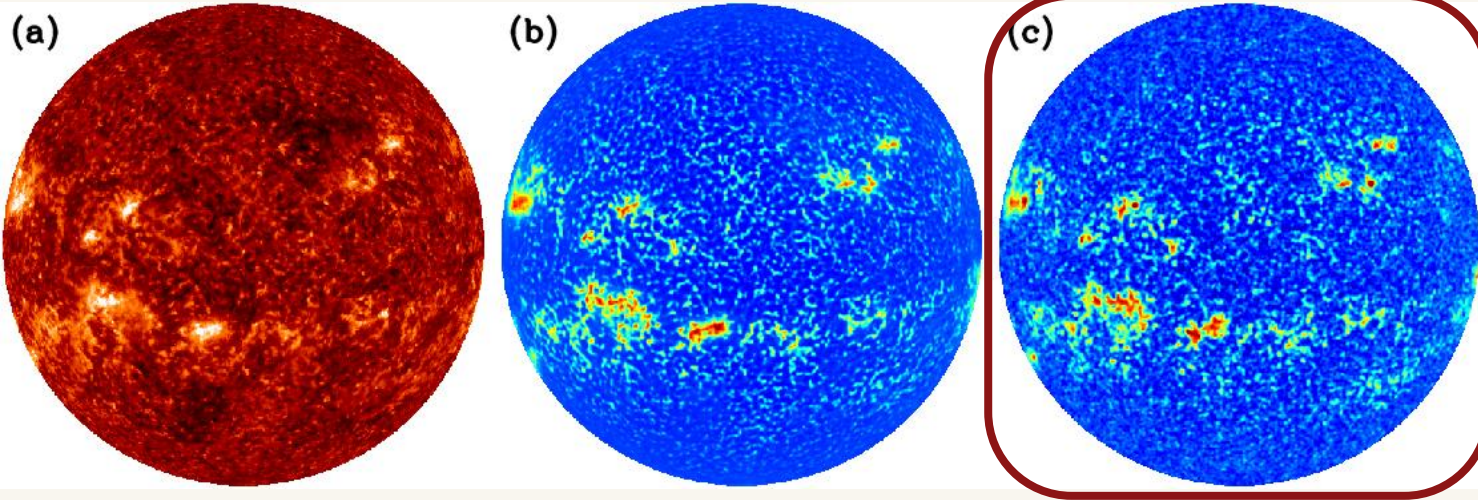
- Deep Neural Network
- 3 sets of kernels
- 8 years of training/test data
- Train on 2700 pairs of AIA 304 Å and HMI unsigned magnetic flux images

**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)



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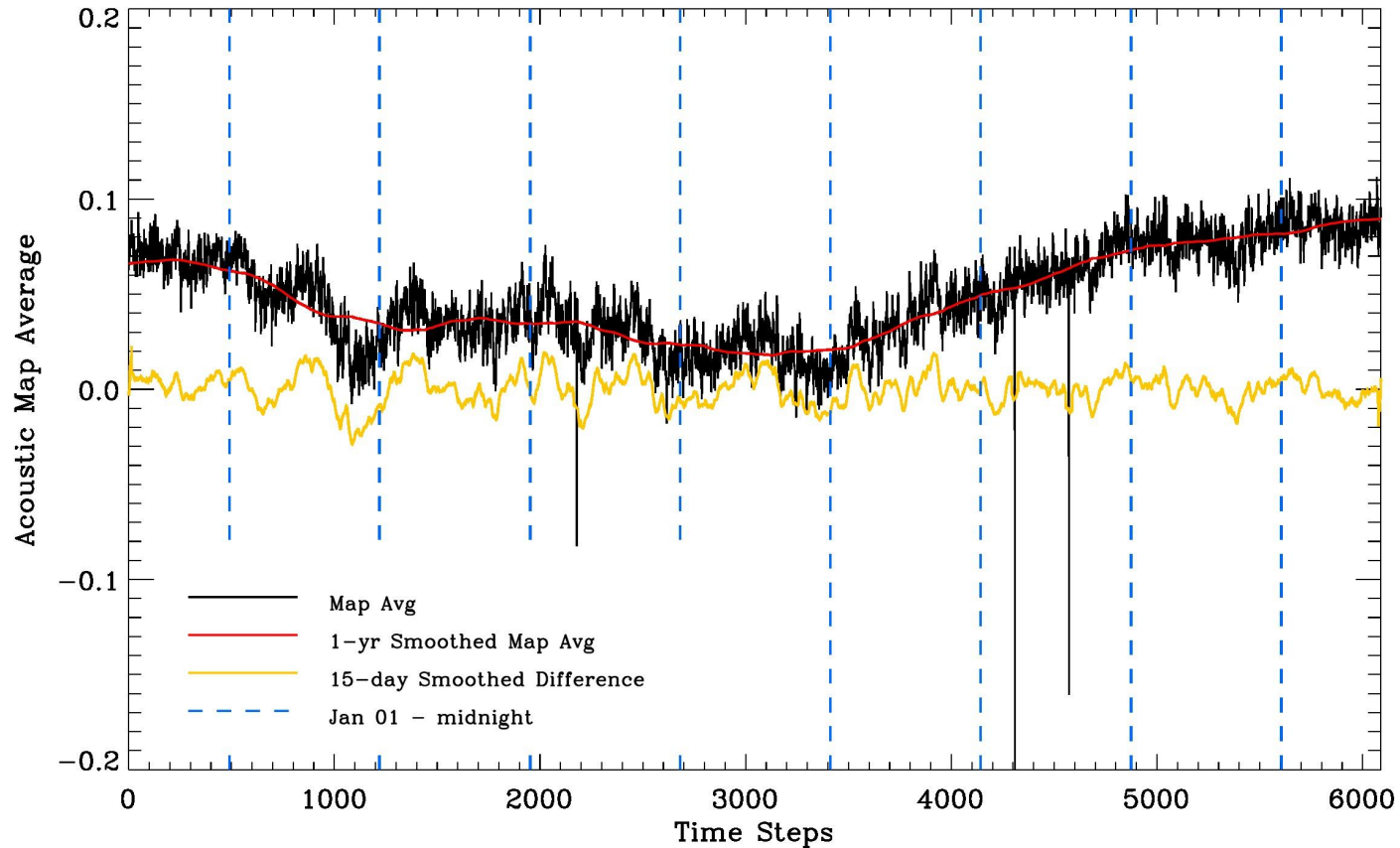
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# Project Overview: *Calibrating with FTM*

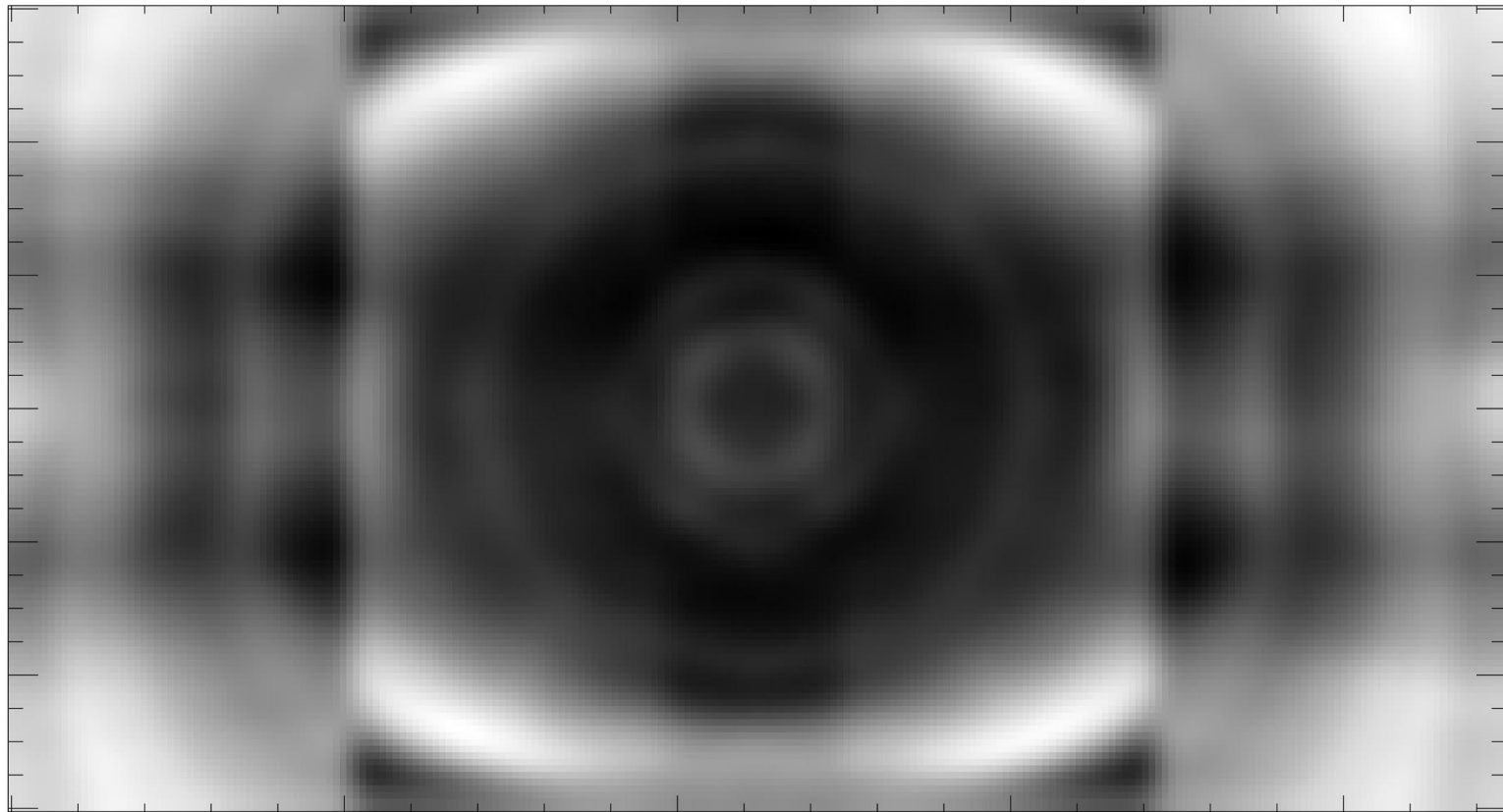
- Data-Assimilated Flux Transport Model (Schrijver & DeRosa 2003)
- Pro: Retains magnetic field polarity
- Con: Cannot model growth of existing AR or emergence of new AR
- Select at least 10 “perfectly modeled” ARs
  - ◆ Selection based on predicted total flux and position compared to region reappearance 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*

Average Background – 2012



# Statistical Analysis: Success Rate

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

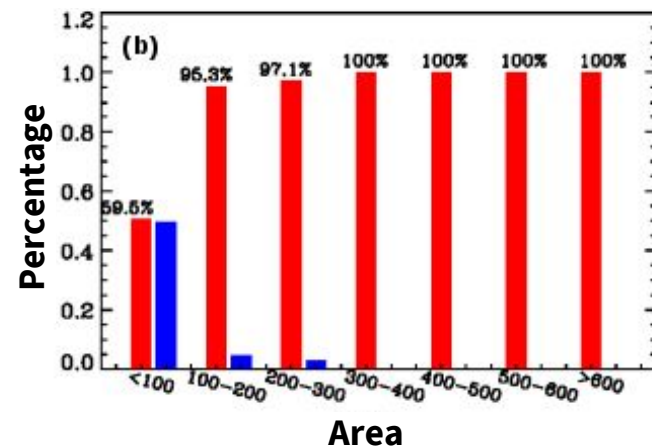
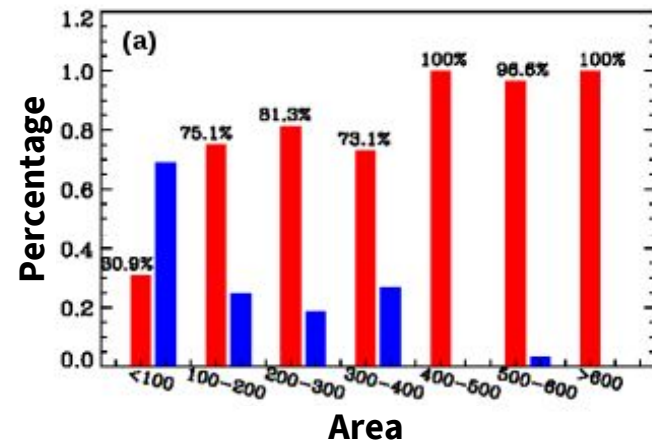
(a) For far-side ARs observed in *STEREO* 304 Å:

- ARs >400 units (1 unit = 1.4  $\mu$ hemispheres): 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  $\rightarrow$  EUV 304 Å  $\rightarrow$  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  $\geq$  100 pixels, excellent agreement between acoustic map detections and EUV 304 Å images
- Next: Statistical study of hemispheric differences and progress on machine learning