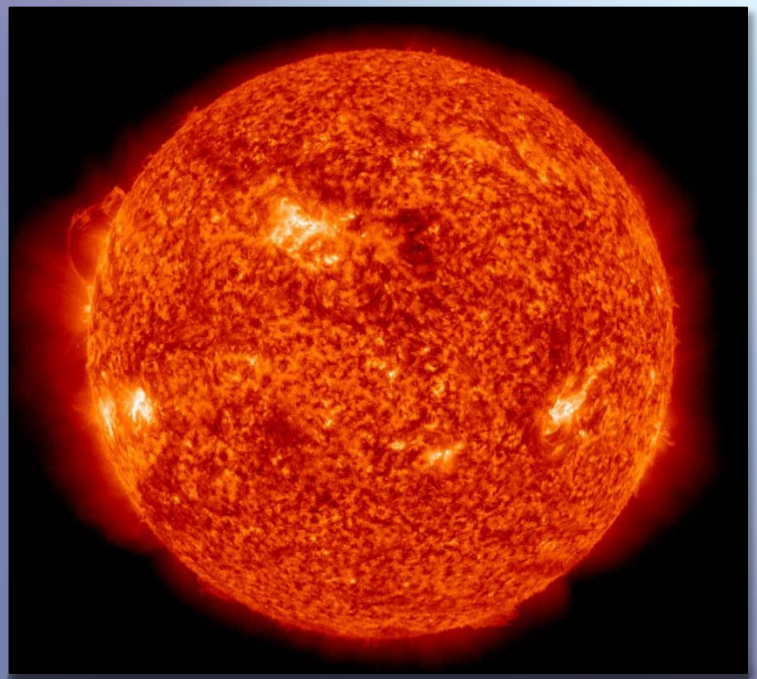
Exploring Far-side Active Regions



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Committee on Solar and Space Physics

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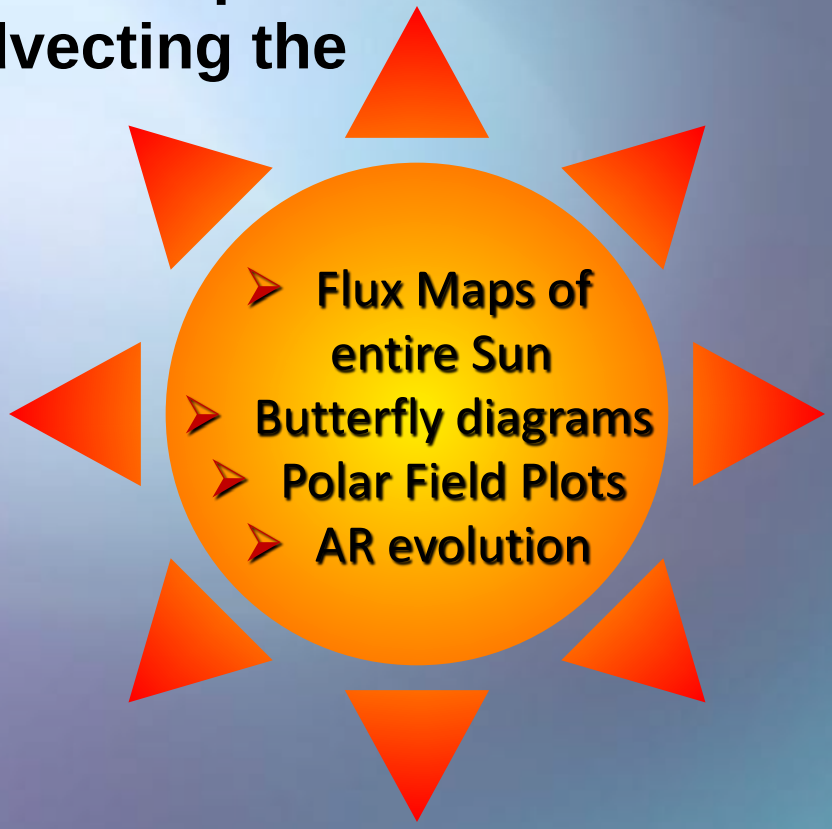
***In collaboration with David Hathaway (NASA/ARC), Ignacio Ugarte-Urra (NRL), and Harry Warren (NRL)**

Advective Flux Transport

David Hathaway and I have developed a new surface flux transport model, the Advective Flux Transport (AFT) model (2014b,a). This model reproduces magnetic field evolution by advecting the flux with the observed flows

- Observed Surface Flows
- Observed Magnetic Field



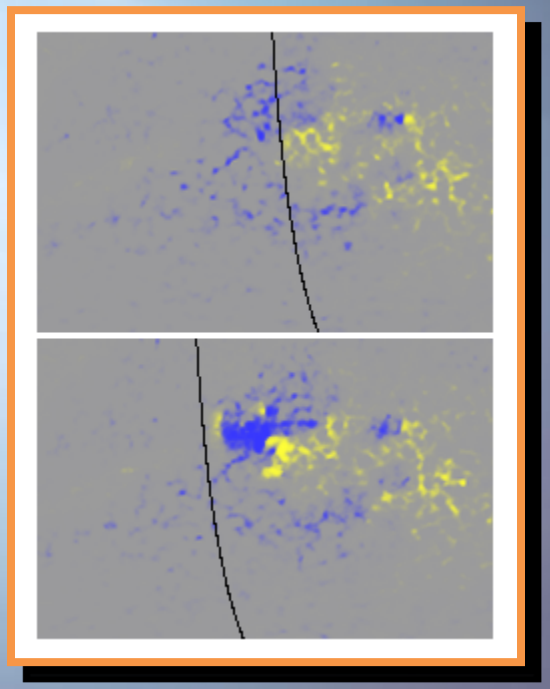
Upton, L., & Hathaway, D. H. 2014a, ApJ, 792, 142
Upton, L., & Hathaway, D. H. 2014b, ApJ, 780, 5

Flux Transport Movie

Looping video showing 1 year (2011) of Flux Transport

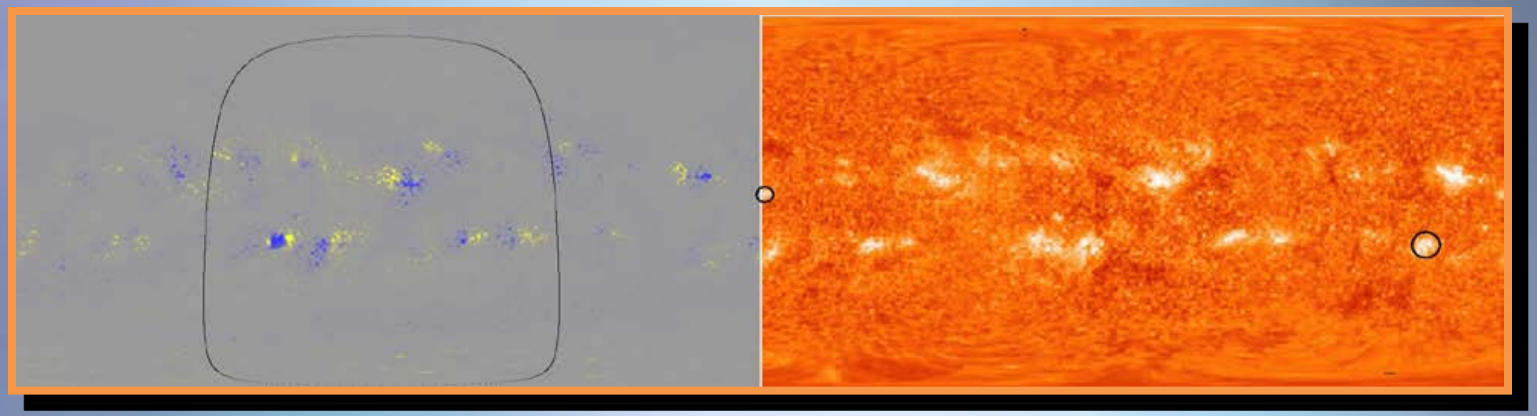
Far-side Emergence

- One of the biggest limitations for determining the global state of the solar atmosphere and inner heliosphere is the absence of reliable magnetic data for the far-side of the Sun.
- While AFT can transport ARs that emerge on the near-side, far-side ARs are neglected until they rotate onto the near-side.
- We began developing a method for including far-side active regions in the AFT model.



A far-side AR rotates into view.

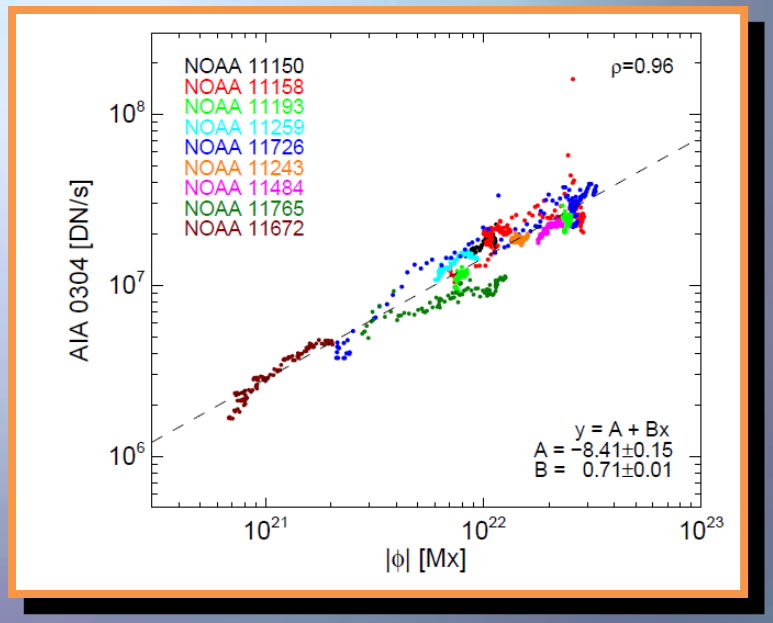
Far-side Imaging Method



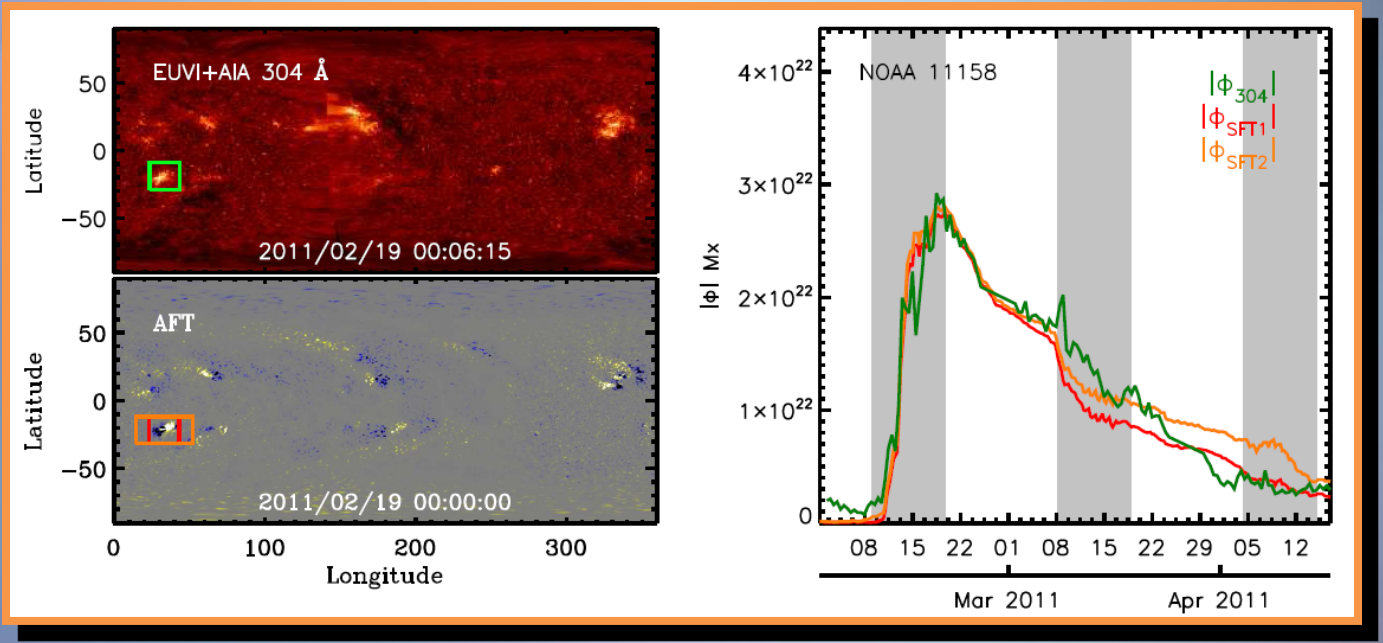
- A synchronic map (left) and a map of the He II 304°A coronal emission from SDO/AIA and STEREO A/B EUVI.
- Two missing far side active regions are circled in the coronal emission image.
- Other far side active regions may have experienced additional growth.
- Can STEREO 304°A be used as a proxy for far-side fields?

Flux-Luminosity

- Ignacio Ugarte-Urra (NRL) and Harry Warren (NRL) were also interested in far-side Active Regions and had the same idea.
- Ignacio characterized the relationship between the He 304°A luminosity and the total unsigned flux in an Active Region.
- We began a collaboration to investigate the long term evolution of active regions and see if we could use this knowledge to improve far-side magnetic observations.



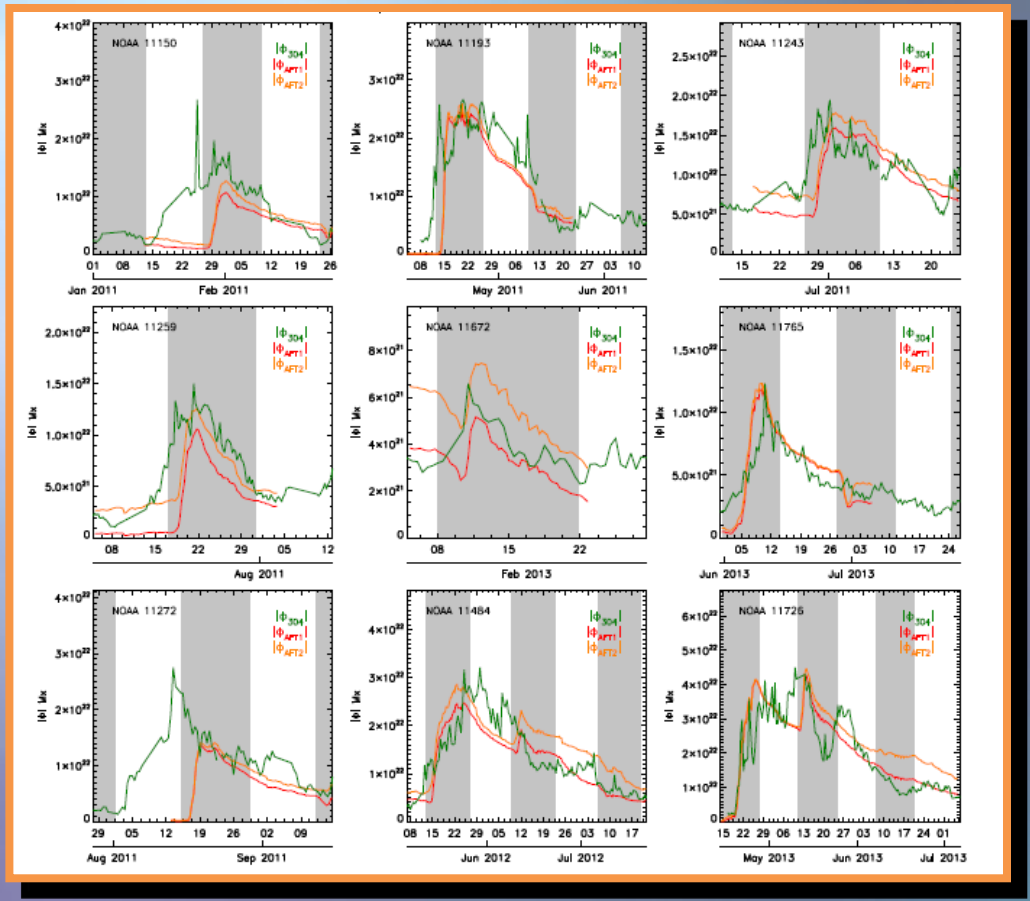
Long Term AR Evolution



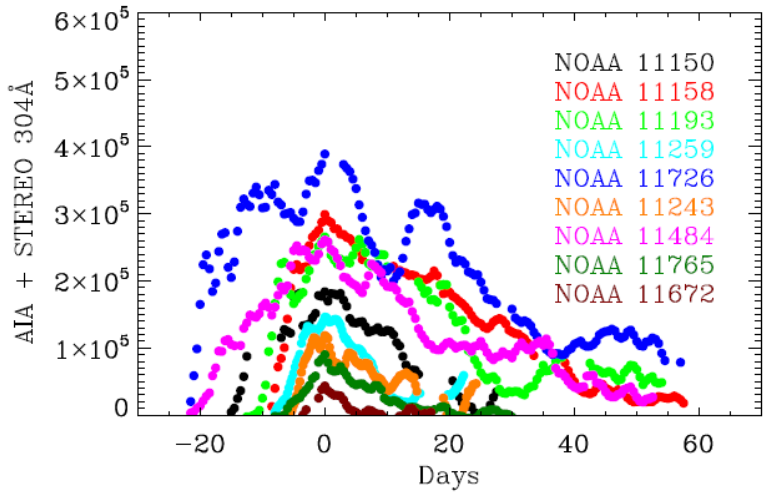
- We compared EUVI+AIA 304°A and AFT model maps for NOAA 11158.
- The plot show the total unsigned magnetic flux for the 304°A proxy (green) and for two area integrations of the AFT model (red and orange).
- Grey areas mark the times when the active region is on the Earth side, when data from HMI magnetograms is being assimilated.
- The two are in good agreement for several rotations of the AR.

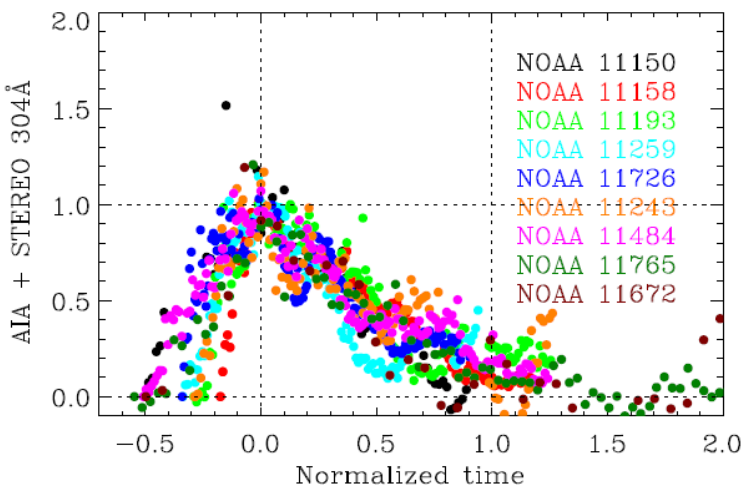
More Examples

- This was repeated for several simple Active Regions with similar results.
- The close match of the curves during times of assimilation serves as an assurance that our 304°A proxy approach works
- The close match elsewhere shows that the AFT model can accurately reproduce the active region evolution when the active region is not being observed by HMI.



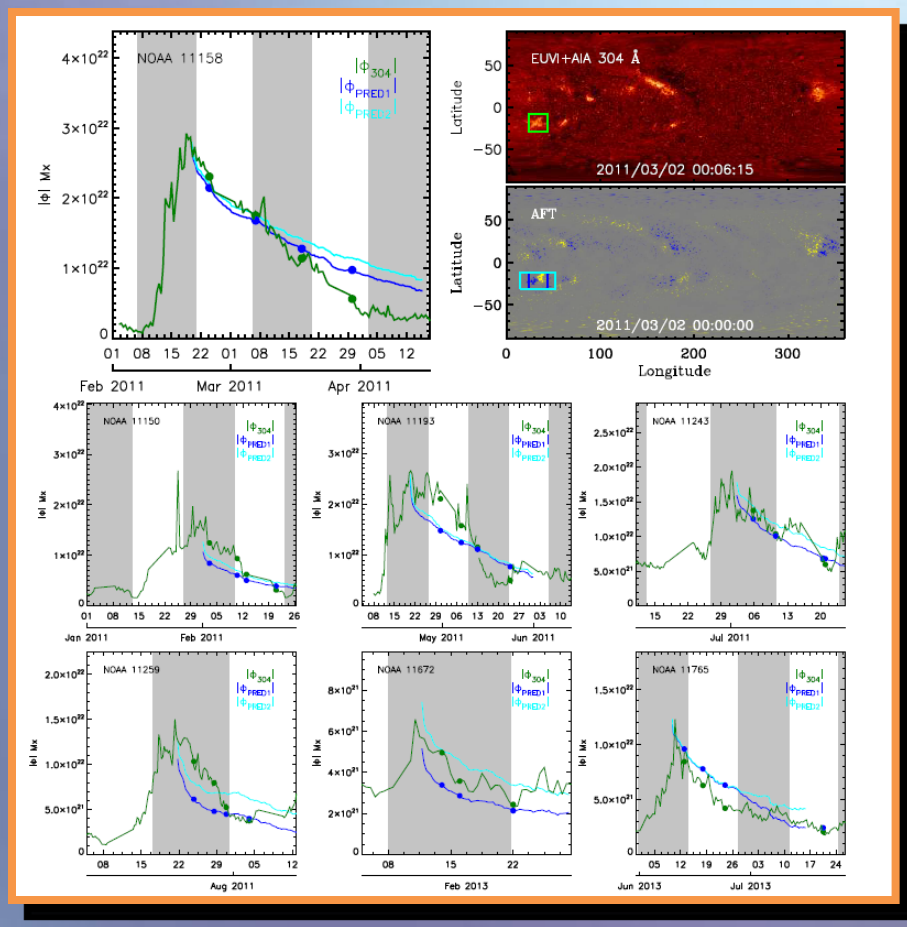
304°A Light Curves





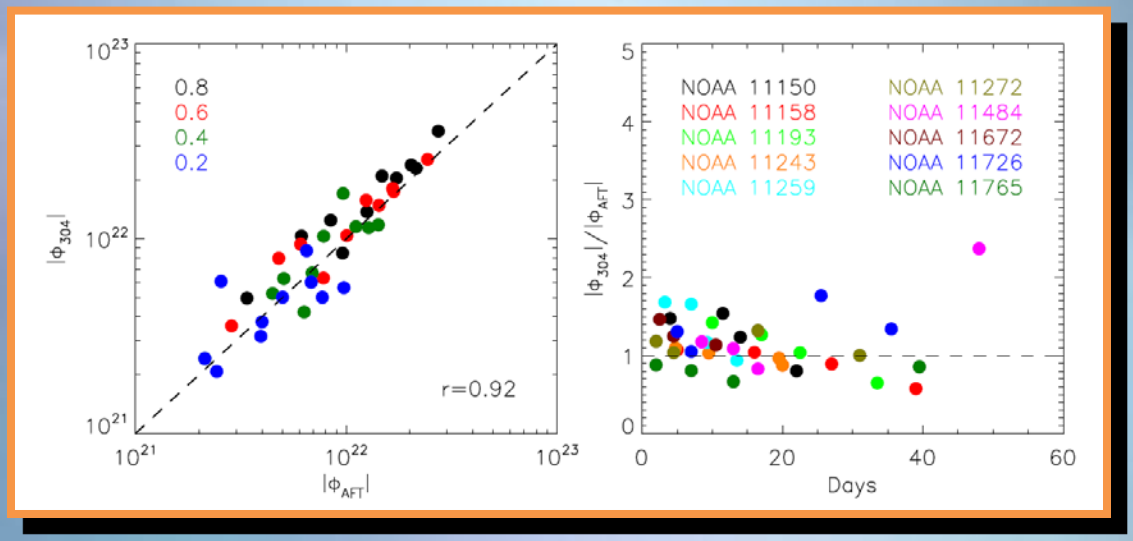
- The curves show emergence leading to a rapid rising phase followed by a longer decay period, which in most regions in our sample is close to monotonic.
- The evolution light curves are scalable by peak intensity – on the right we show all the light curves scaled to the active region 11158 peak intensity.
- That same scaling factor is used to scale the time, meaning that an active region twice as bright at peak, will live twice as long.
- By knowing the peak intensity of a region in 304°A, we can estimate the lifetime of the active region.

More Examples



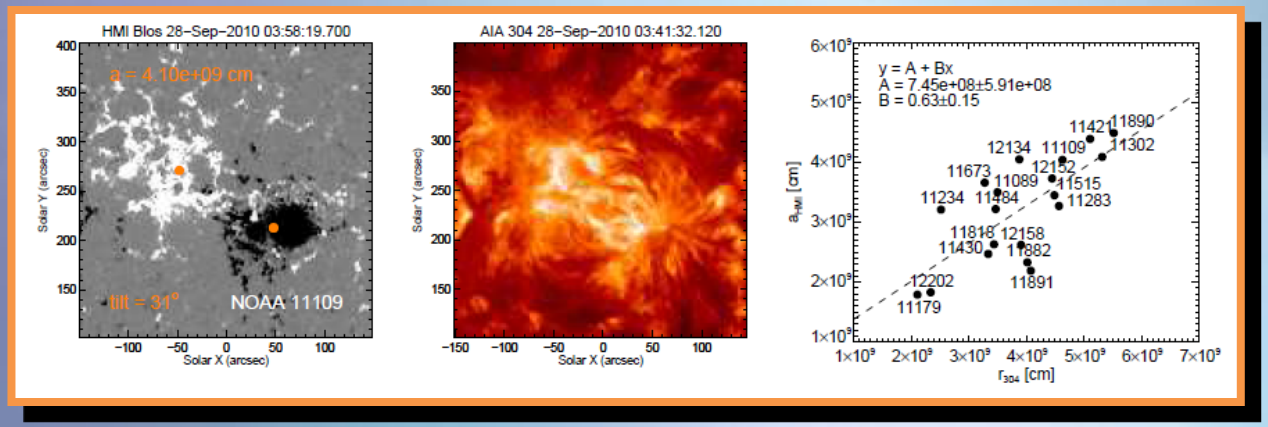
- In these examples, the data assimilation was halted at the time of peak 304°A intensity so that the AR evolution is produced by AFT alone.
- The plots show that the AFT model does very well over multiple solar rotations.
- In cases like 11158, observations and model diverge as the region leaves the Earth view for a second rotation.

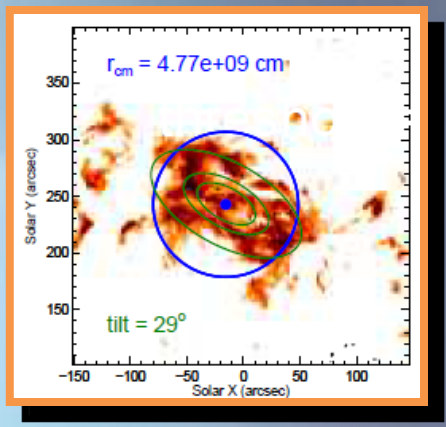
AR Evolution by AFT



- To quantify the accuracy of the AR decay in AFT, we compared the total unsigned flux for the 304°A and AFT curves for times when the 304°A intensity reaches a fraction of the peak flux.
- We also show a ratio of both fluxes as a function of time for the same instances. (Dashed lines indicate expected values for the same flux.)
- AFT consistently predicts the flux to within about a factor of 2 for the AR lifetime.
- While a few point worsen with time, this is attributed to an increased chance of other contributions not considered in the model, such as new emergences.

Simulating Far Side ARs

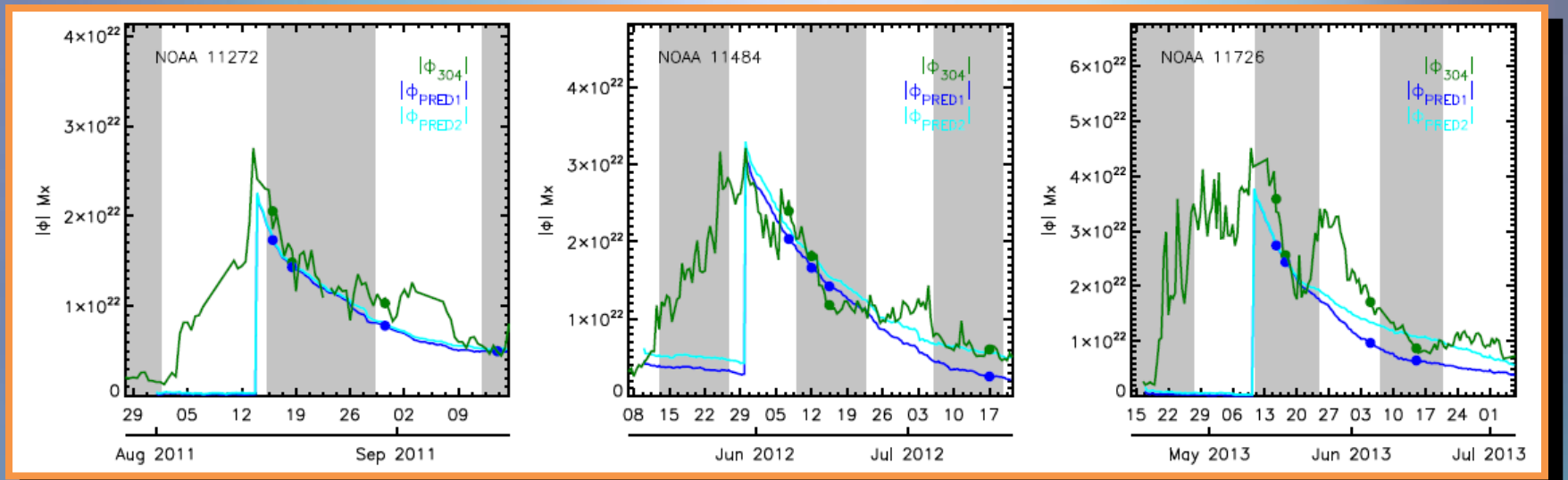




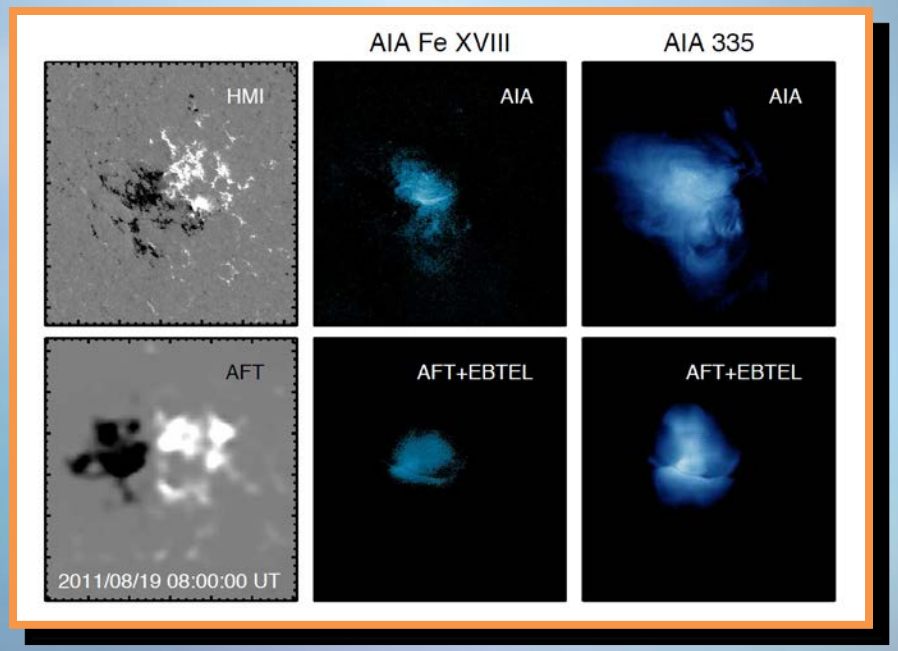
- Magnetic field strength is well described by 304°A, but what can it tell us about the field distribution (e.g., polarity centroids, separation , and tilt angle)?
- The plot (third panel) shows a separation distance relationship as measured for 19 active regions near central meridian.
- The blue circle (far right) uses this relationship to calculate the separation distance from the 304°A intensity centroid.
- The green elipses (far right) correspond to a 2D gaussian fit, which we used to attempt to estimate the tilt.
- Unfortunately, the tilt method proved unreliable without further constraints for some active regions.

AR Predictions by AFT

- Here the far-side 304°A data is used as the single source of information to introduce the ARs into AFT while on the back side of the Sun.
- The AR is manually placed into AFT at the time of peak 304°A intensity.
- The bipolar strength is chosen from the total unsigned magnetic flux inferred from 304 °A, split between the two polarities.
- The 304 °A centroid, separation relationship, and Joy's law tilt are used to determine the bipole placement.



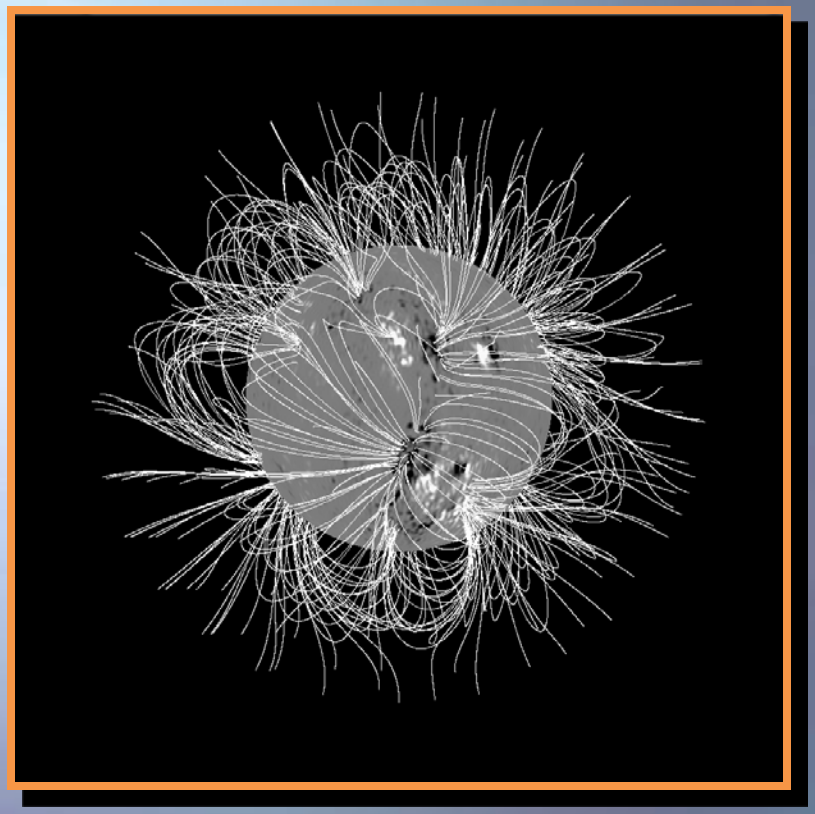
Back to the Corona



- Comparison of SDO observations (HMI magnetogram and EUV images) to synthetic images of NOAA 11272.
- Ignacio computed synthetic images from hydrodynamic steady state solutions where heating is scaled as B/L (EBTEL).
- The geometry is given by potential extrapolations of the line-of-sight magnetic field given by the AFT model in predictive mode.

Global Field

- 304 shows great promise for improving our knowledge of far-side magnetic field.
- Combining AFT with far side data from 304 measurements should be able to provide a more complete picture of the magnetic field configuration of the entire Sun.
- Using AFT in global models may be able to improve space weather predictions, such as solar irradiance, solar wind, and coronal field models.

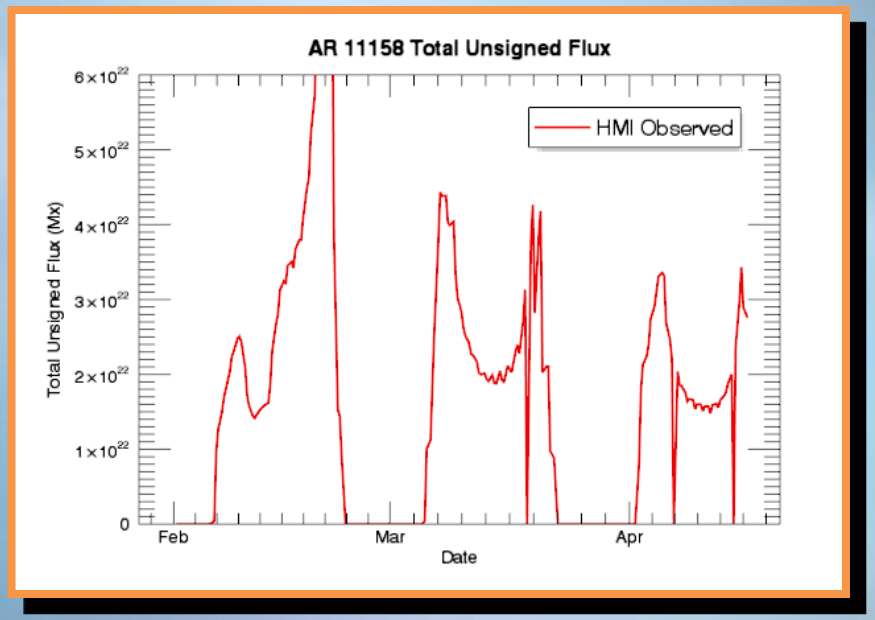


PFSS of AFT from July 2012

QUESTIONS and COMMENTS

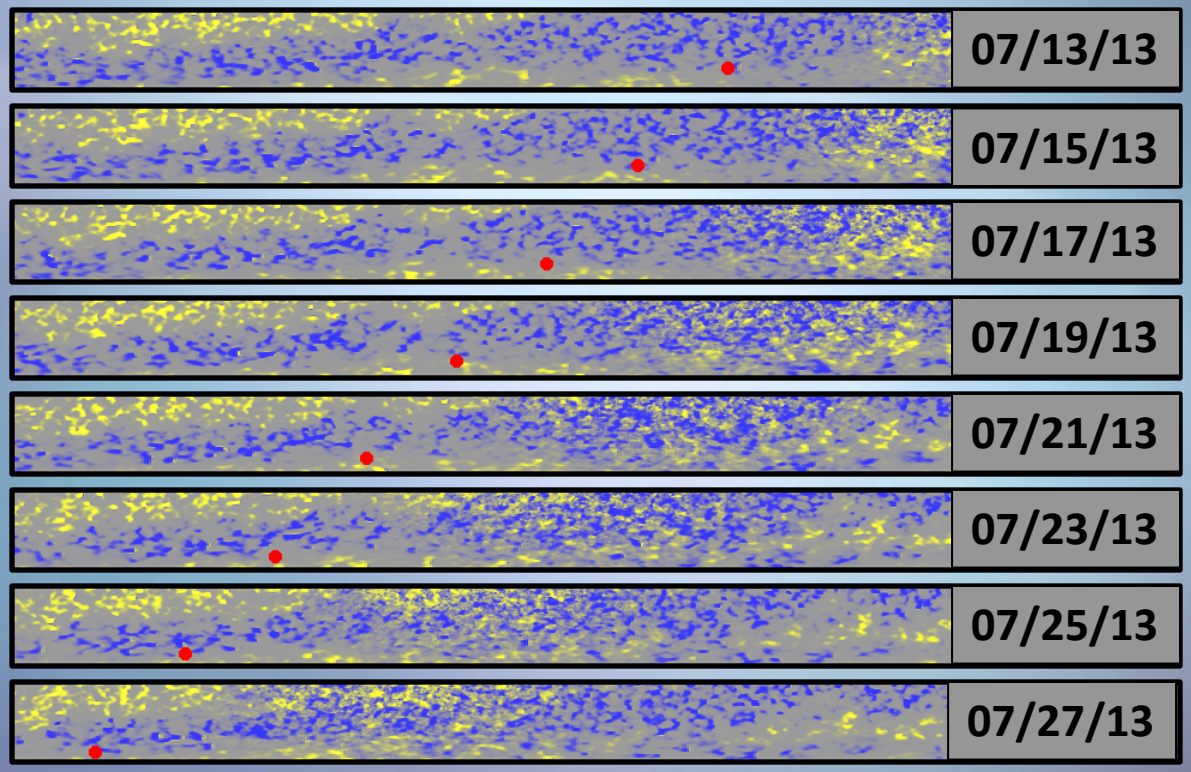
AFT+304° vs GONG

Near Side AR Evolution



- Until the launch of STEREO, the study of active regions was limited to the time window it takes the regions to transit from limb to limb.
- Furthermore, magnetic data is plagued by limb effects that further limit this time window for magnetic observations.
- In the case of long lived active regions, this resulted in large data gaps in the majority of their histories.

Coronal Cavities



- Nishu Karna tracked the position of a coronal cavity over time.
- This location (red dot) was superimposed onto saturated AFT maps.
- The location of this cavity tracks nicely with the polar PIL line.

Conclusions

- AFT is a state of the art SFT model capable of producing the most realistic magnetic maps of the entire Sun
- 304 measurements can be coupled with a SFT model to establish how the total unsigned flux of an active region changes over long time scales.
- 304 shows great promise for improving our knowledge of far-side magnetic field.
- Combining AFT with far side data from 304 measurements should be able to provide a more complete picture of the magnetic field configuration of the entire Sun.