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Modeling Coronal Response in Decaying Active Regions with Magnetic Flux Transport and Steady Heating

Ignacio Ugarte-Urra

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MODELING CORONAL RESPONSE IN DECAYING ACTIVE REGIONS WITH MAGNETIC FLUX TRANSPORT AND STEADY HEATING

Ignacio Ugarte-Urra,[1] Harry P. Warren,[1] Lisa A. Upton,[2] and Peter R. Young[3,4,5]

Abstract

We present new measurements of the dependence of the EUV radiance on the total magnetic flux in active regions as obtained from the AIA and HMI on board the Solar Dynamics Observatory (SDO). Using observations of nine active regions tracked along different stages of evolution, we extend the well known radiance - magnetic flux power-law relationship to the AIA 335 A passband, and the Fe XVIII 93.93 A spectral line in the 94 A passband. We find that the total unsigned magnetic flux divided by the polarity separation is a better indicator of radiance for the Fe XVIII line. We then use these results to test our current understanding of magnetic flux evolution and coronal heating. We use magnetograms from the simulated decay of these active regions produced by the Advective Flux Transport (AFT) model as boundary conditions for potential extrapolations of the magnetic field in the corona. We then model the hydrodynamics of each individual field line with EBTEL model with steady heating scaled as the ratio of the average field strength and the length. We find that steady heating is able to partially reproduce the magnitudes and slopes of the EUV radiance - magnetic flux relationships and discuss how impulsive heating can help reconcile the discrepancies.

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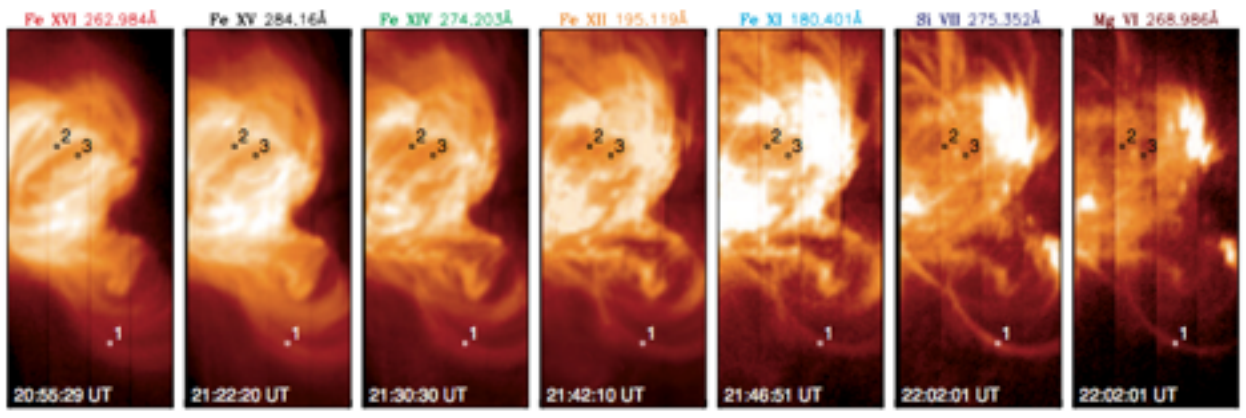
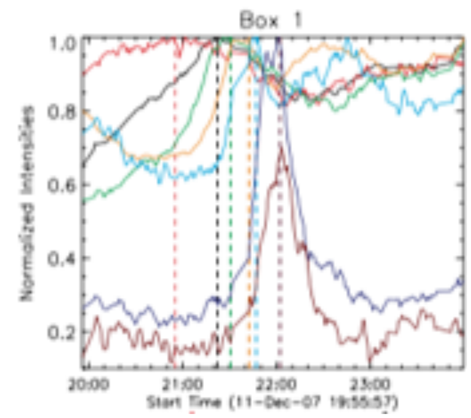
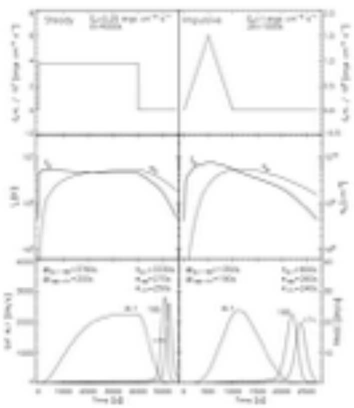
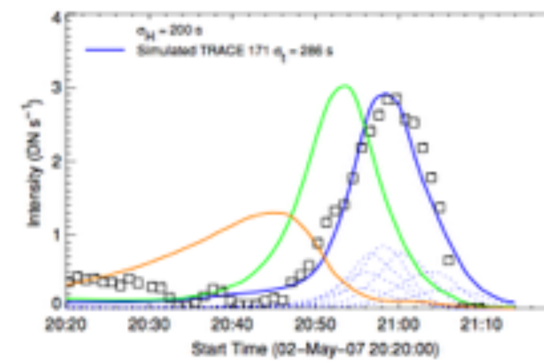
Studying coronal heating

Loop scales:1D Hydro evolution vs X-ray/EUV measurements (Ugarte-Urra et. al 2006, 2009, Warren el al. 2010)









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Active region spatial scales and **active region evolutionary time scales**:

Magnetic flux transport + Field extrapolation + 0D-Hydro

Surface flows:

differential rotation, meridional circulation, convection

Advective Flux Transport Model
Upton & Hathaway (2014a,b)

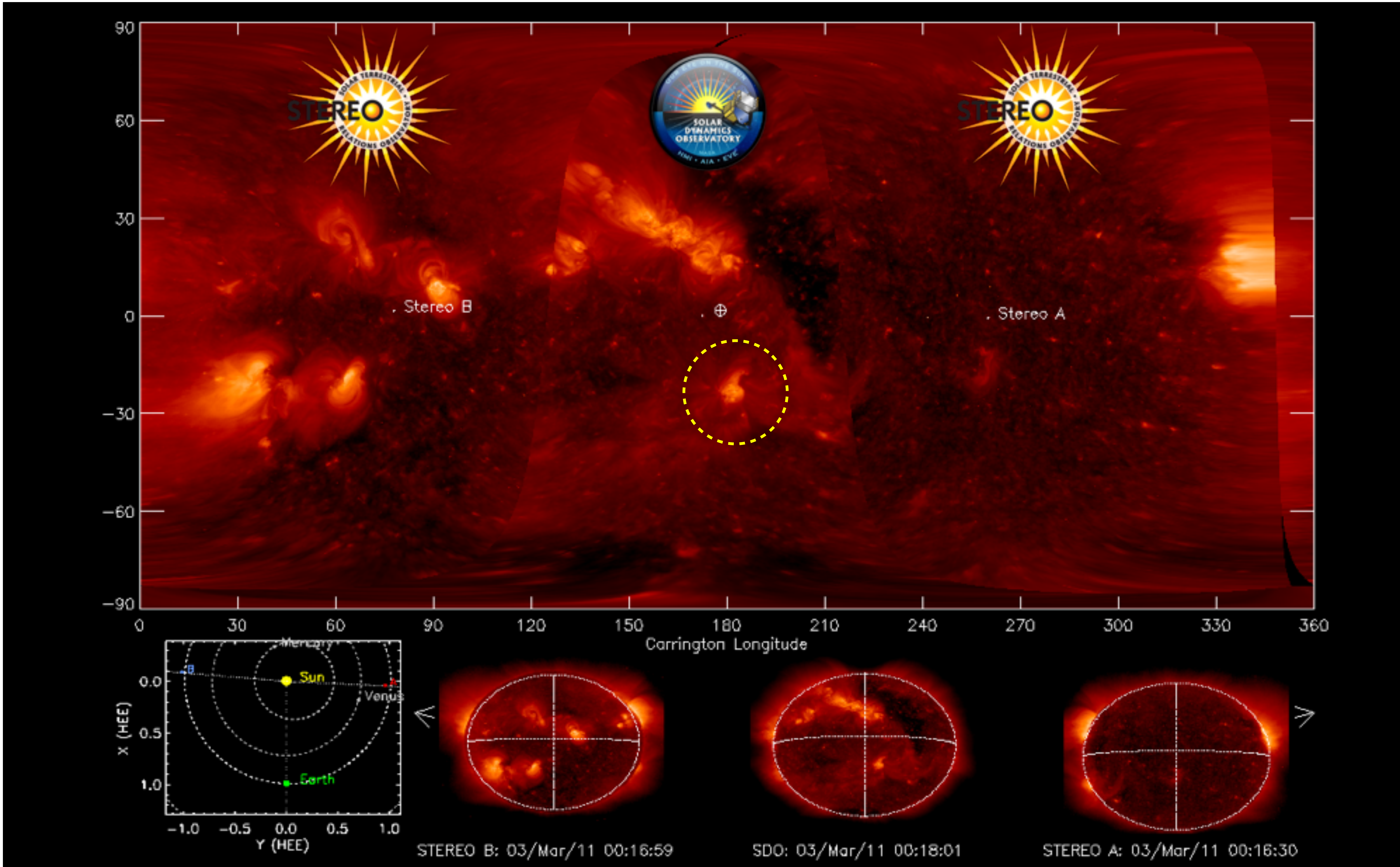
Loop geometry

Potential Field Extrapolation

Plasma Response
Forward Modeling

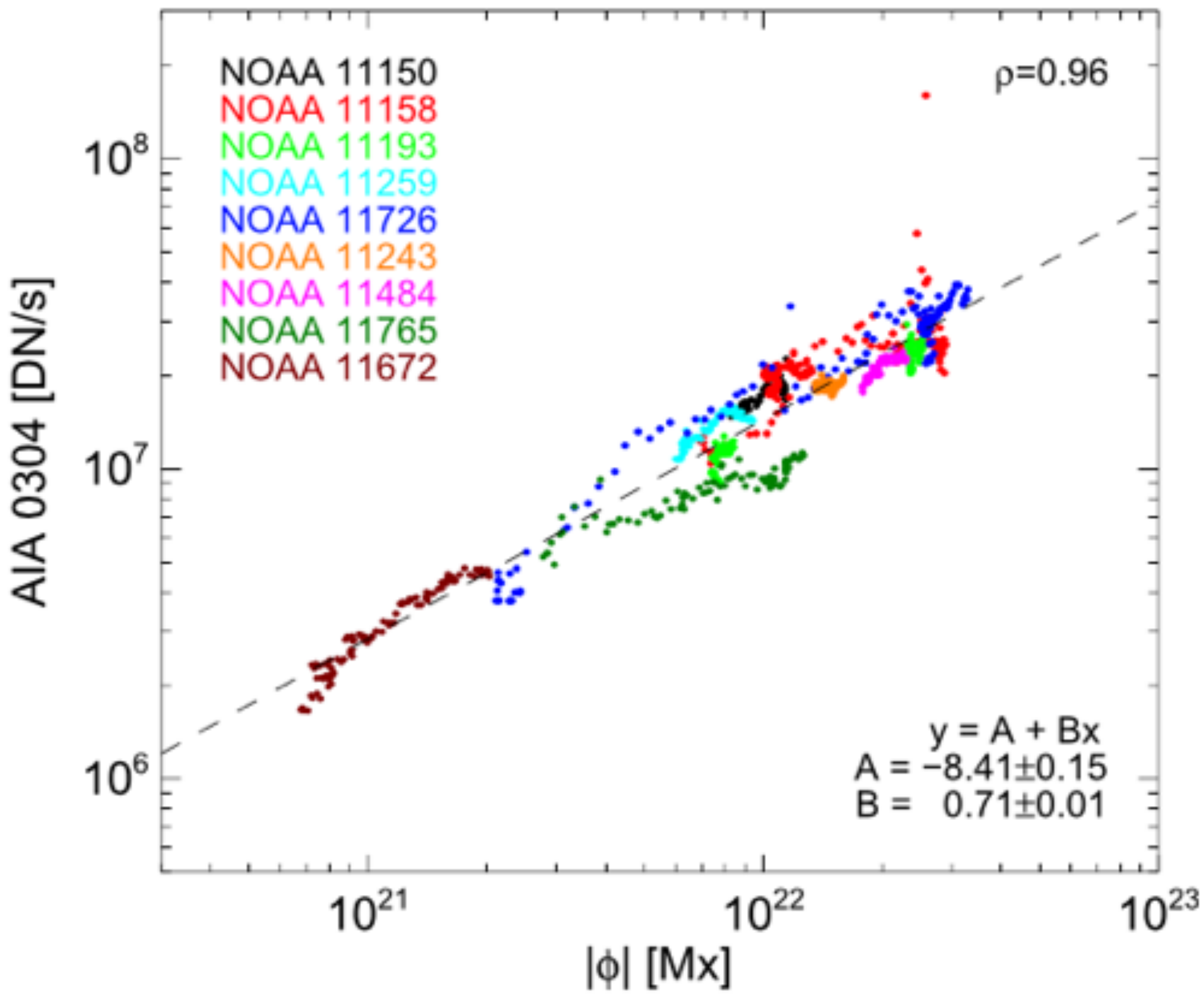
EBTEL
Klimchuk et al. (2008)
Cargill et al. (2012)

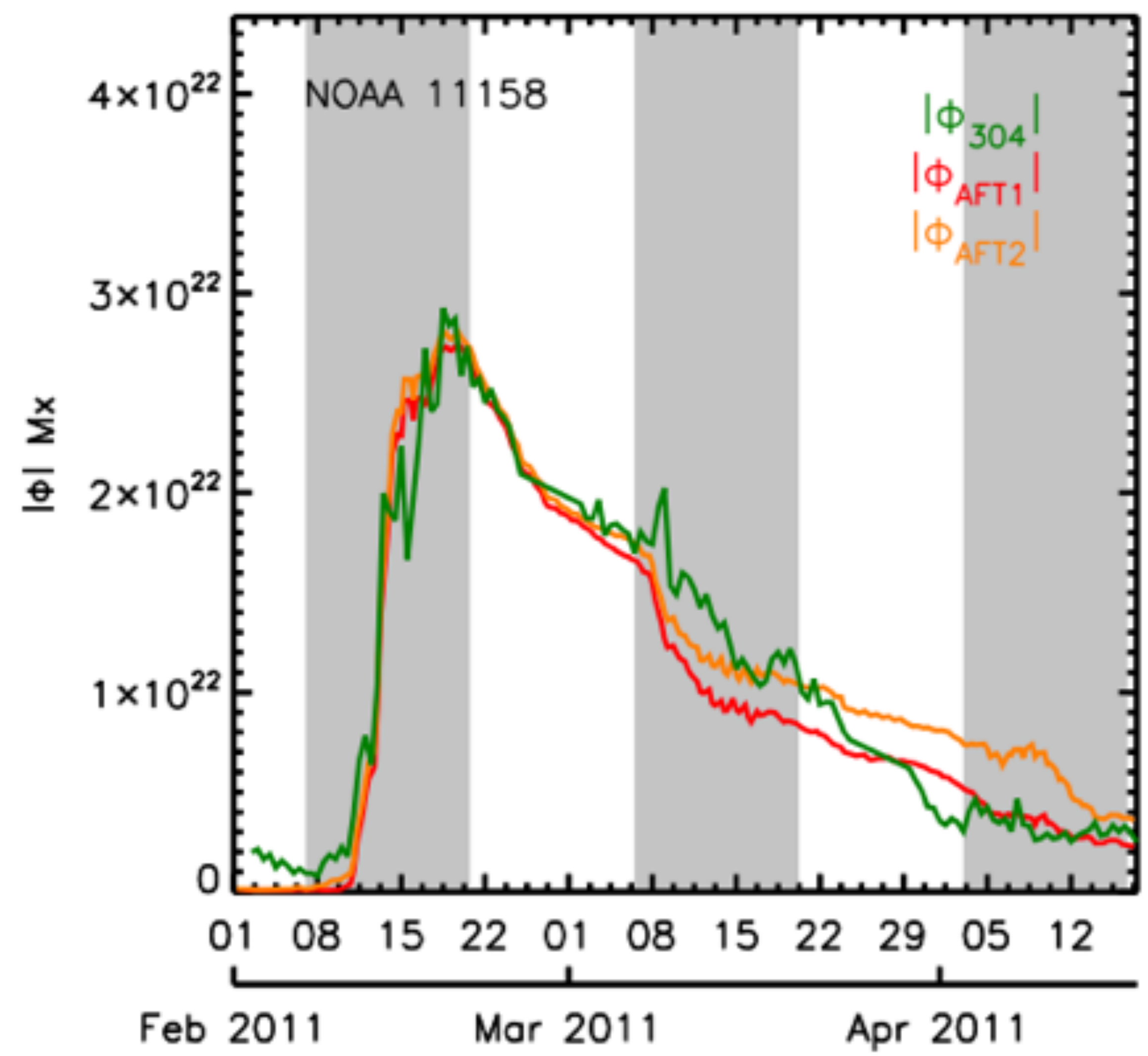
CHIANTI
Dere et al. (1997)
Del Zanna et al. (2015)



STEREO
STEREO
SOLAR DYNAMICS OBSERVATORY
Stereo B
Stereo A
90
60
30
0
−30
−60
−90
0
30
60
90
120
150
180
210
240
270
300
330
360
Carrington Longitude
Mercury
Sun
Venus
Earth
X (HEE)
Y (HEE)
0.0
0.5
1.0
−1.0
−0.5
0.0
0.5
1.0
STEREO B: 03/Mar/11 00:16:59
SDO: 03/Mar/11 00:18:01
STEREO A: 03/Mar/11 00:16:30

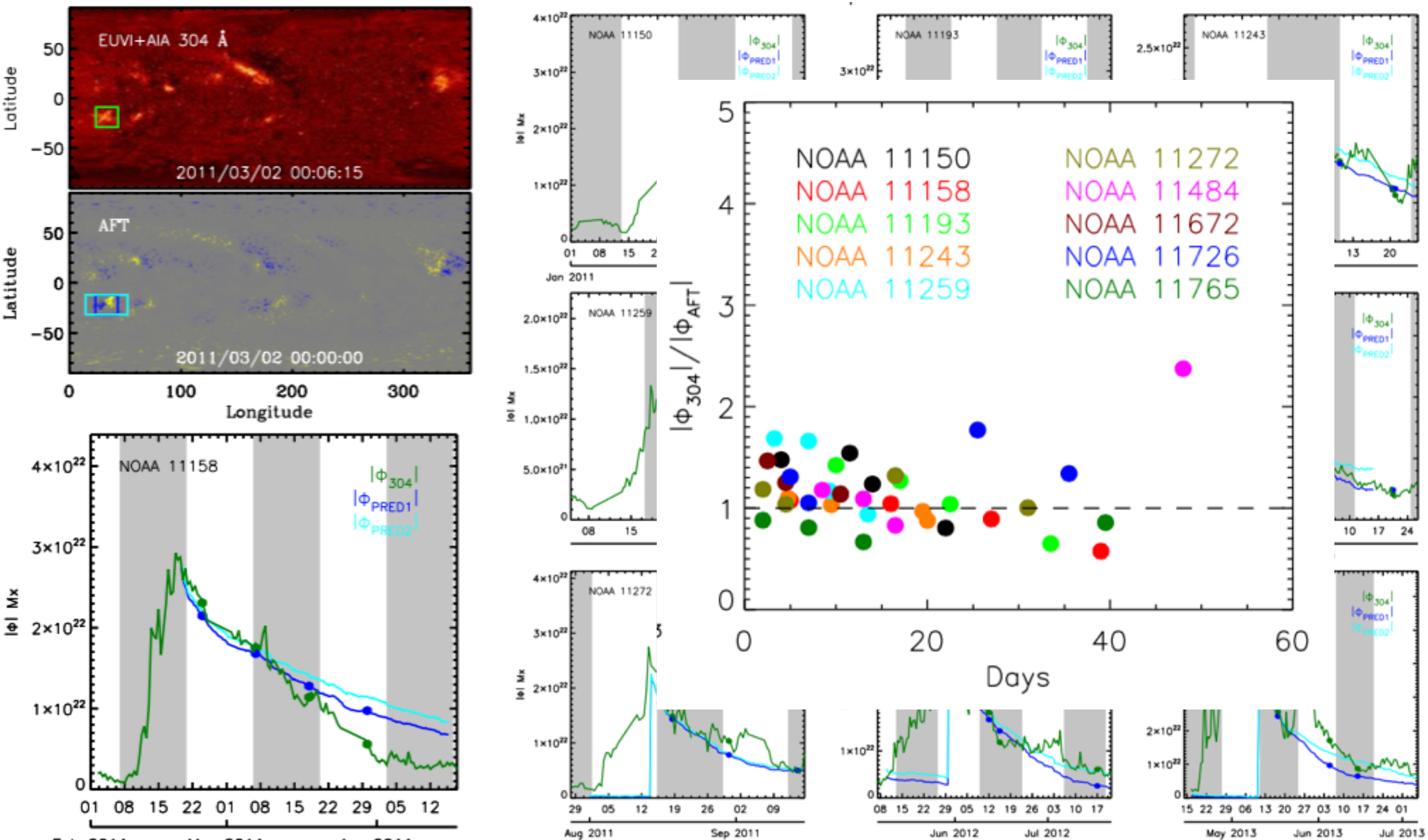
Far side 304Å: proxy of Total Magnetic Flux





Ugarte-Urra, Upton, Warren & Hathaway (2015)

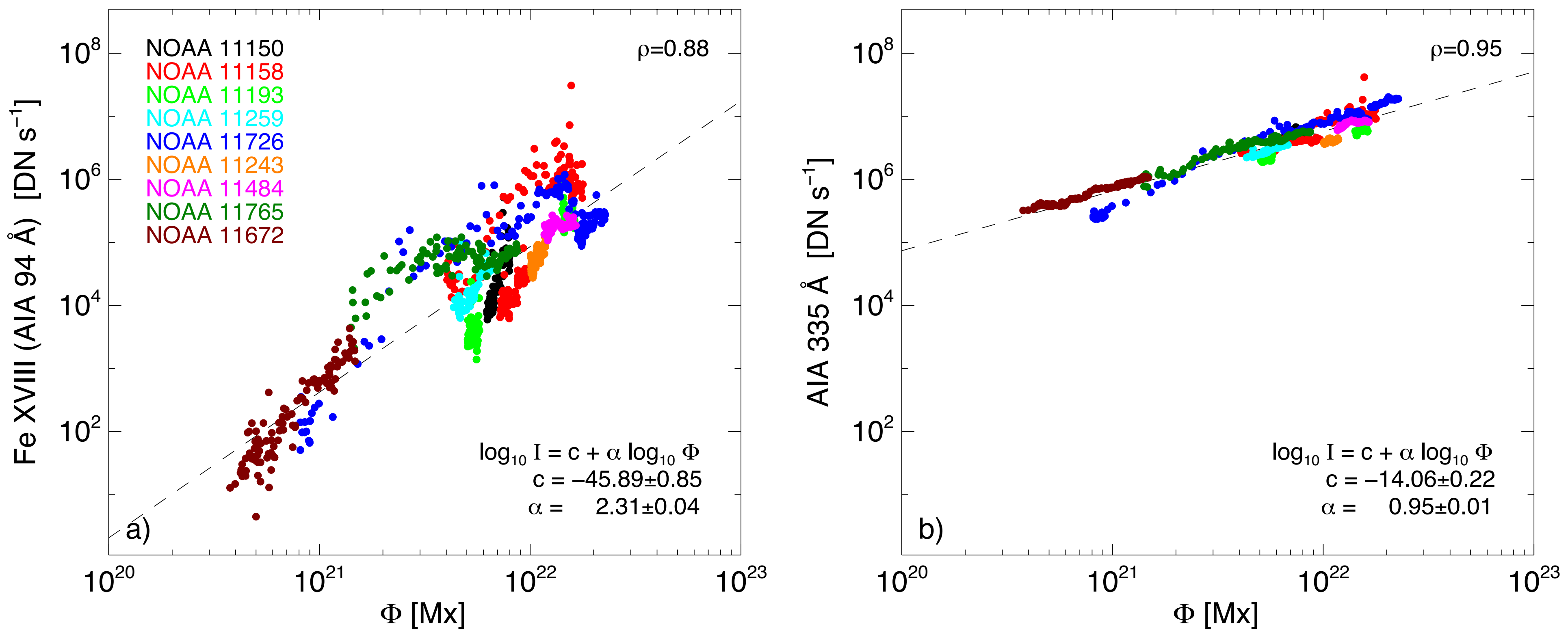
Magnetic flux transport: magnetic flux forecast



Ugarte-Urra, Upton, Warren & Hathaway (2015)

Total magnetic flux vs EUV radiance

$$I \propto \Phi^{\alpha}$$



Can we use our understanding of
flux evolution, **topology** and **heating** to
model the coronal response of active regions over evolutionary timescales?

Active region spatial scales and **active region evolutionary time scales**:

Magnetic flux transport + Field extrapolation + 0D-Hydro

Surface flows:

differential rotation, meridional circulation, convection

Advective Flux Transport Model
Upton & Hathaway (2014a,b)

Loop geometry

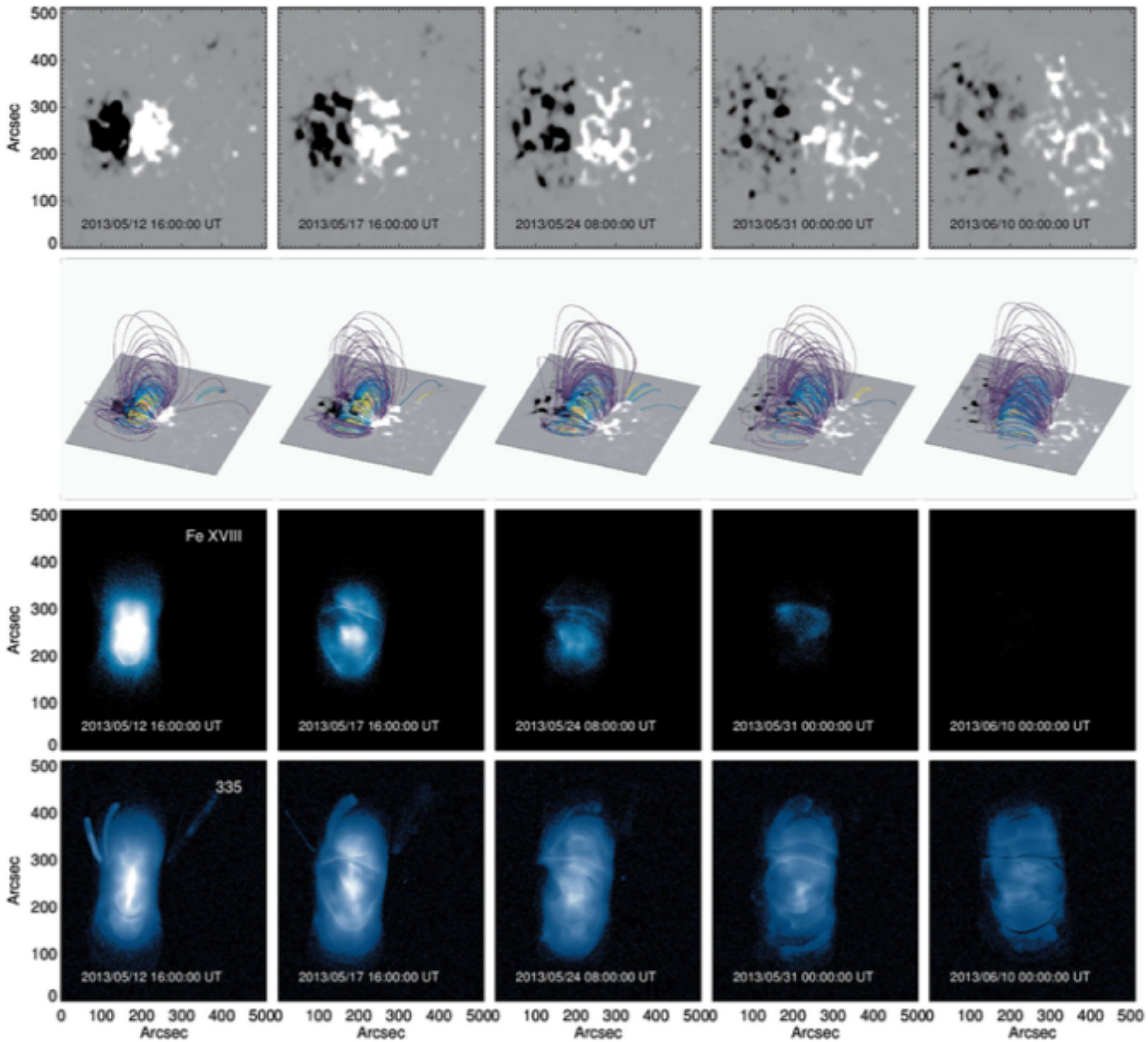
Potential Field Extrapolation

Plasma Response
Forward Modeling

EBTEL
Klimchuk et al. (2008)
Cargill et al. (2012)

CHIANTI
Dere et al. (1997)
Del Zanna et al. (2015)

Workflow



Simulated flux decay
$\Phi_{304}(t=0)$ + AFT model

Potential extrapolation
1 loop per 1” pixel

Forward model
EBTEL + CHIANTI

$$\epsilon_H = \epsilon_0 \frac{\bar{B}}{\bar{B}_0} \frac{L_0}{L}$$

r_{loop}=350km

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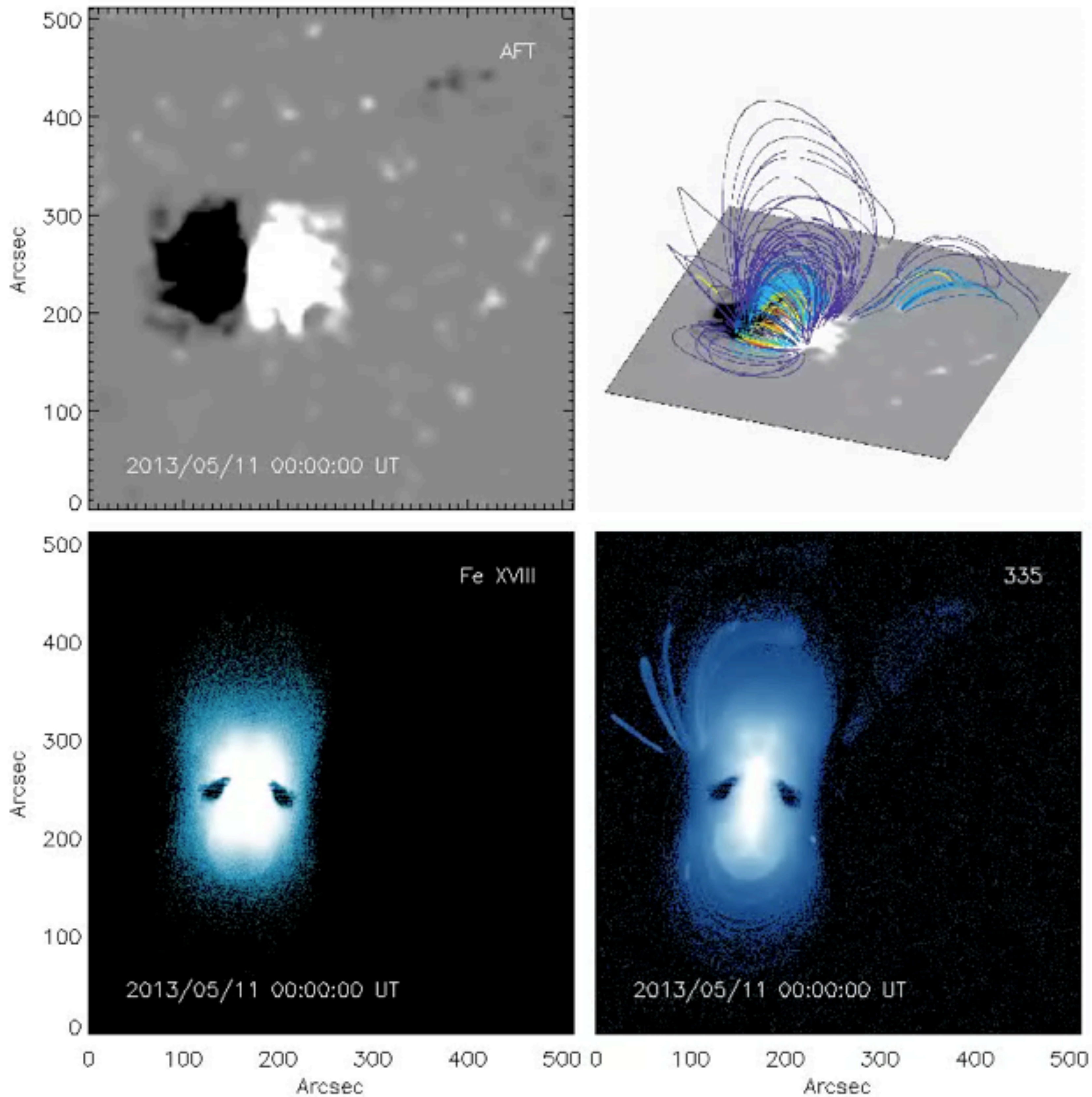
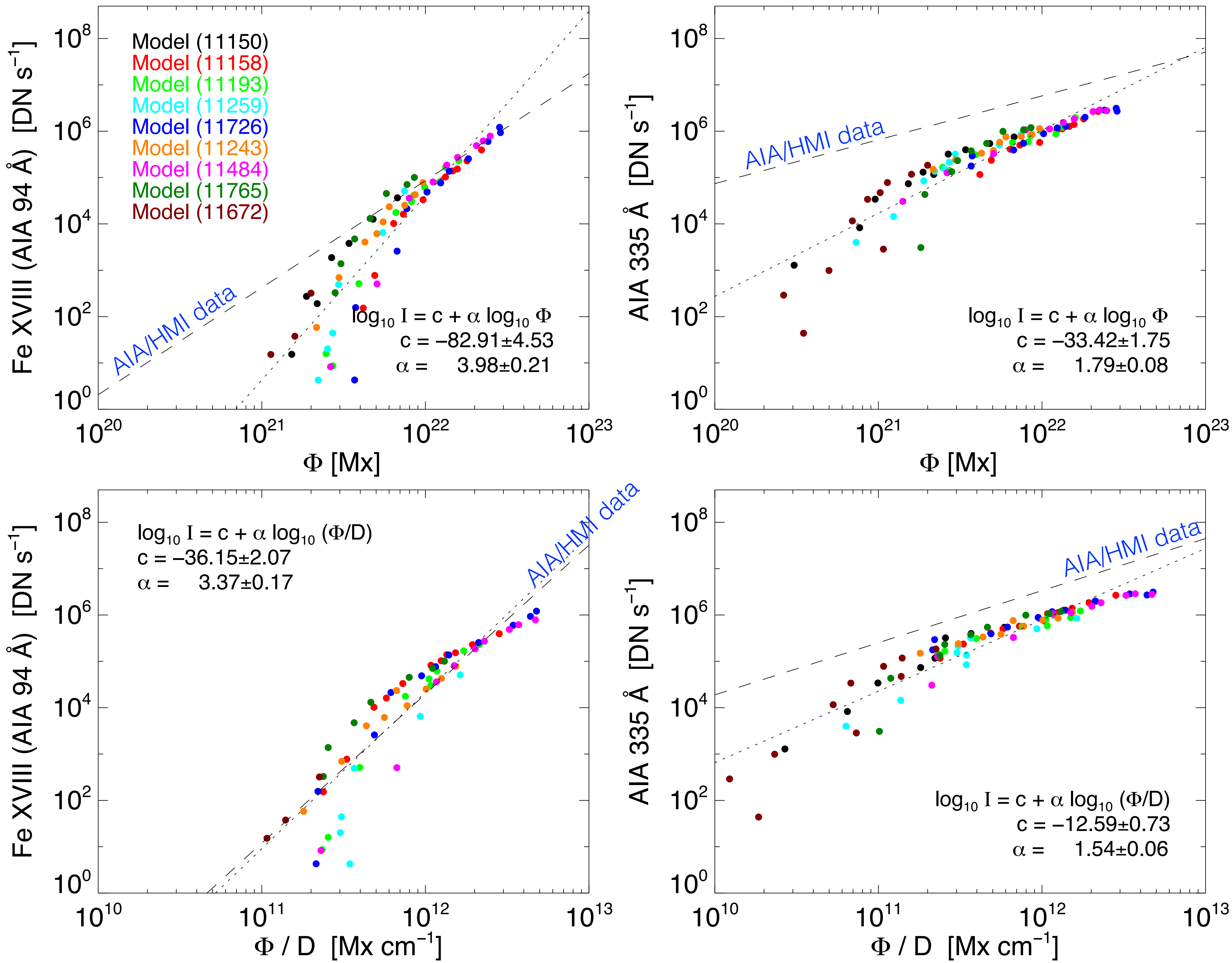
Modeled active region

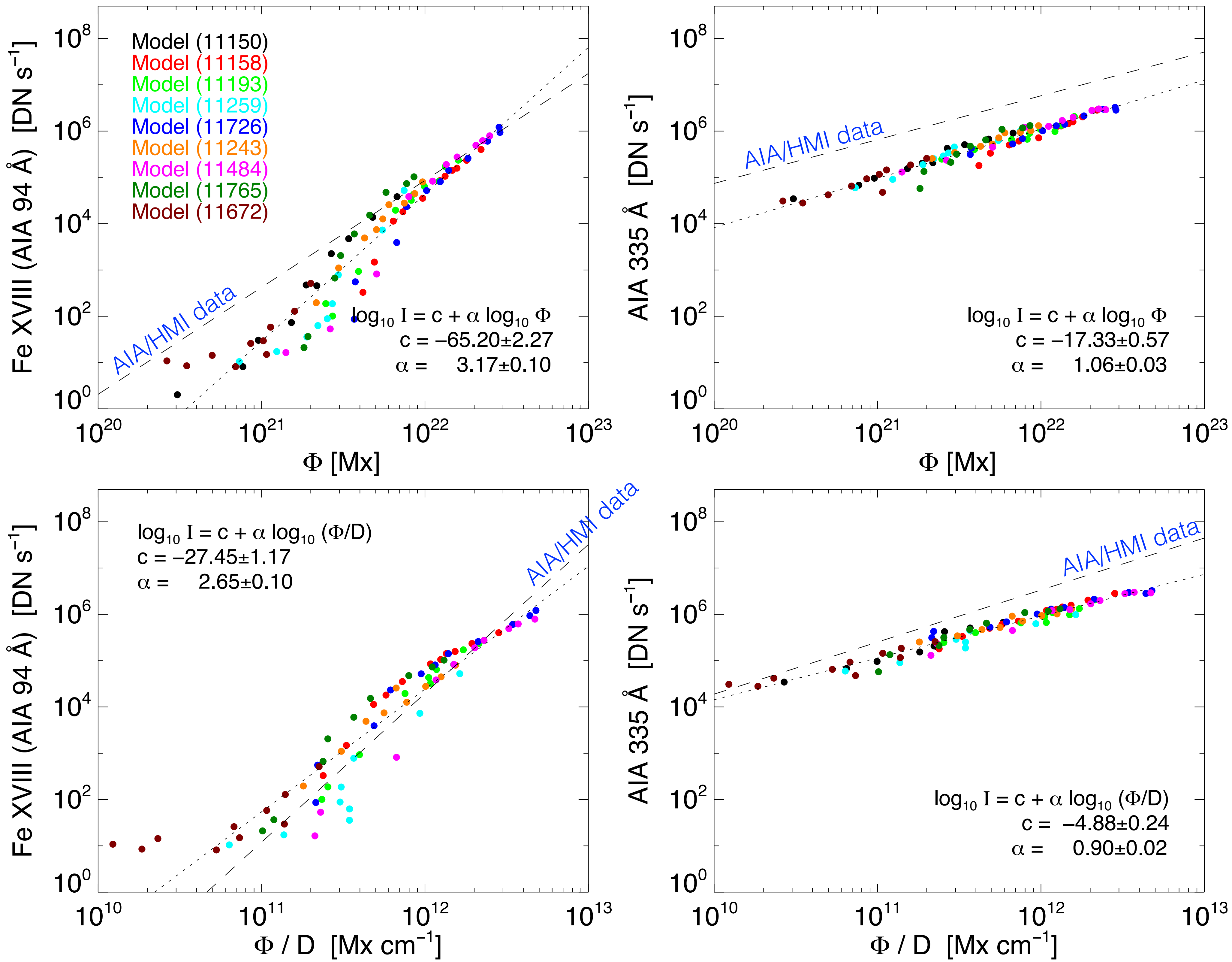


Results

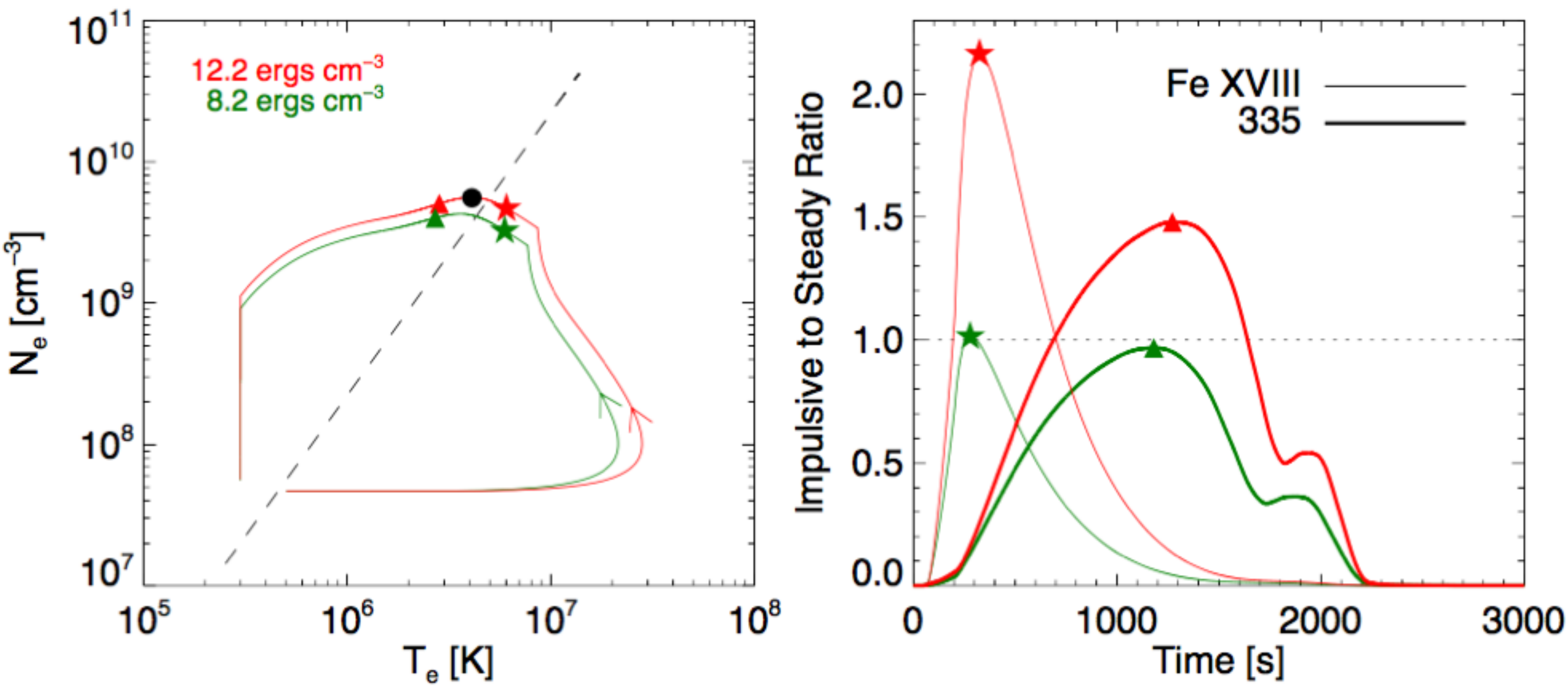


Model (11150)
Model (11158)
Model (11193)
Model (11259)
Model (11726)
Model (11243)
Model (11484)
Model (11765)
Model (11672)
AIA/HMI data
$\log_{10} I = c + \alpha \log_{10} \Phi$
$c = -82.91 \pm 4.53$
$\alpha = 3.98 \pm 0.21$
Fe XVIII (AIA 94 Å) [DN s^{-1}]
Φ [Mx]
AIA/HMI data
$\log_{10} I = c + \alpha \log_{10} \Phi$
$c = -33.42 \pm 1.75$
$\alpha = 1.79 \pm 0.08$
AIA 335 Å [DN s^{-1}]
Φ [Mx]
$\log_{10} I = c + \alpha \log_{10} (\Phi/D)$
$c = -36.15 \pm 2.07$
$\alpha = 3.37 \pm 0.17$
AIA/HMI data
Fe XVIII (AIA 94 Å) [DN s^{-1}]
Φ / D [Mx cm^{-1}]
AIA/HMI data
$\log_{10} I = c + \alpha \log_{10} (\Phi/D)$
$c = -12.59 \pm 0.73$
$\alpha = 1.54 \pm 0.06$
AIA 335 Å [DN s^{-1}]
Φ / D [Mx cm^{-1}]

Results (adding background)



Impulsive heating?



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Conclusions

- Total unsigned magnetic flux divided by the polarity separation (**Φ/D**) is a **better indicator of radiance** for the Fe XVIII line with a slope of $\alpha = 3.22 \pm 0.03$.

- **Steady heating** is able to partially reproduce the magnitudes and slopes of the EUV radiance - magnetic flux relationships.

- **Combined models** of magnetic flux transport, magnetic topology and heating can yield **realistic** estimates for the **decay of active region radiances** with time.