Modeling Solar Spectral Irradiance (SSI) from Iron lines using the COronal DEnsity and Temperature (CODET) model v1.1

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COronal DEnsity and Temperature (CODET) model

CODET is a physics-based model. It provides coronal density estimations and emission (SSI) in the EUV wavelengths.

$$B = \sqrt{B_r^2 + B_\theta^2 + B_\phi^2}$$

LMSAL(Schrijver)-PFSS

The density and temperature distribution are described as a function of the magnetic field using scaling laws (Emslie, 1985)

$$N(B) = N_o \left(\frac{B}{B_s}\right)^{\gamma} \quad [cm^{-3}]$$

$$T(B) = T_o \left(\frac{B}{B_s}\right)^{\alpha} \quad [K]$$

γ and α are power-law indices, $\left(\frac{B}{B_s}\right)$ is the factor related to the flux amount in each pixel, $B_s[G]$ is a constant value of magnetic field, $N_o\ [cm^{-3}]$ and $T_o[K]$ are background density and temperature

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More details see Rodríguez-Gómez et al. 2018

COronal DEnsity and Temperature (CODET) model

The function $B_f(R) = b_{fo} \times e^{-\left(\frac{R}{\tau_{bf}}\right)^2}$ is used to describe two different temperature regimes related to regions with strong and weak magnetic field

If $B < B_f(R)$ $\quad T(B) = T_o \quad [K]$

If $B > B_f(R)$ $\quad T(B) = T_o \left(\frac{B}{B_s}\right)^{\alpha} \quad [K]$

b_{fo} and τ_{bf} are constant values and R is the height from $1R_\odot$ to $2.5R_\odot$
γ and α are power-law indices, $\left(\frac{B}{B_s}\right)$ is the factor related to the flux amount in each pixel, $B_s[G]$ is a constant value of magnetic field, N_o $[cm^{-3}]$ and $T_o[K]$ are background density and temperature

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More details see Rodríguez-Gómez et al. 2018

COronal DEnsity and Temperature (CODET) model

- This model provide coronal density estimations, emission maps and SSI time series in the EUV wavelengths (**mean full-disc intensity**)

- The main purpose of the CODET model is to retrieve and analyze the SSI irradiance variability in **long time scales** days to Solar Cycles

- Because of the relationship between magnetic field and emission, it is possible to obtain SSI estimations from July 1996 to July 2024, where SOHO/MDI and SDO/HMI photospheric magnetic field data are available.

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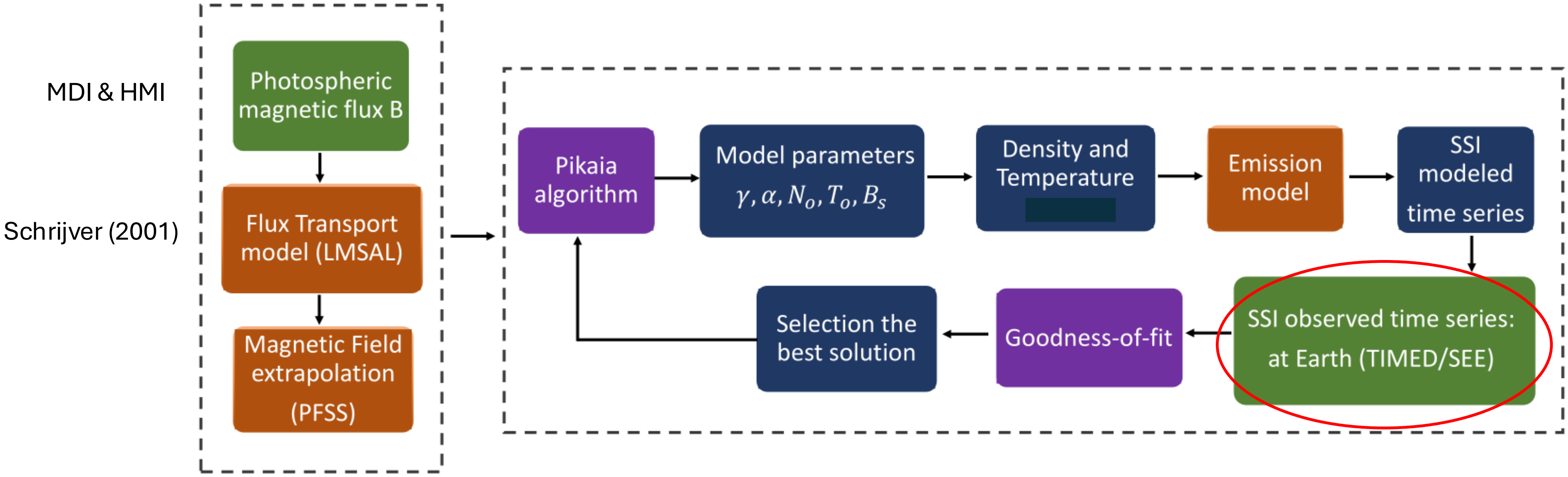
More details see Rodríguez-Gómez et al. 2018

COronal DEnsity and Temperature (CODET) model



The observational datasets are shown in green rectangles. Models, algorithms and test are depicted in orange and purple.

Density and temperature profiles are input for $\boldsymbol{G(\lambda, T)}$

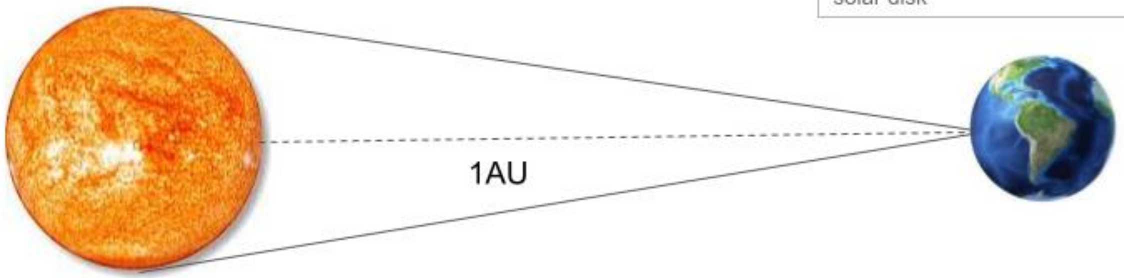
Emission model

Assuming that the emission lines are optically thin, it is possible to measure the integrated emission along the line of sight, but it necessary to consider the **contribution function $\boldsymbol{G(\lambda, T)}$** to obtain the solar spectra for a specific wavelength. This is obtained from the CHIANTI atomic database.

$$I_o(\lambda) = \iint R(\lambda)G(\lambda, T)d\lambda N^2 ds$$

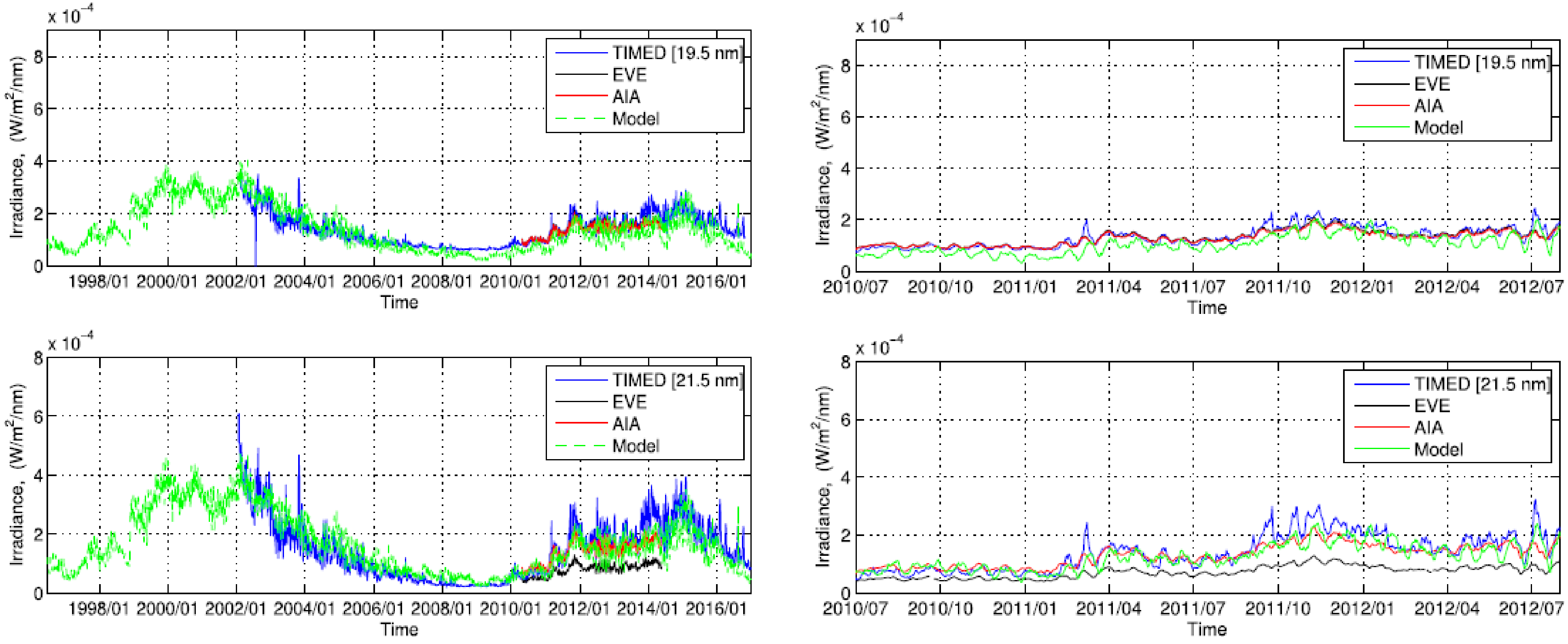
Where $R(\lambda)$ is the instrumental response, $d\lambda$ is the differential element in wavelength and ds is the differential distance along the line of sight. The intensity (I) corresponds to SSI. It is the intensity full-disk average measured at D=1 AU. $I = I_O/D^2$

I_o each pixel, I integrated over the visible solar disk



Assumptions: Line-of-sight, the emission lines depends of the atomic transitions and conditions of the solar atmosphere, instrumental response R(λ)=1

COronal DEnsity and Temperature (CODET) model



(a) SSI at 19.3nm and 21.1nm

(b) Close-up/detail of SSI interval at 19.3 nm and 21.1 nm

Figure 3. Solar Spectral Irradiance (SSI) using the CODET model (green line) and Solar Spectral Irradiance from TIMED/SEE (blue line), *SDO*/EVE (black line), and *SDO*/AIA (red line). (a) SSI at 19.3 and 21.1 nm during solar cycles 23 and 24. (b) The best-fit interval of Solar Spectral Irradiance (SSI) from the CODET model from 2010 July 01 to 2012 July 31.

TIMED version 12 is calibrated through Jan 2017. The wavelengths shorter than 27 nm and from 115-120 and 122-129 nm are populated using models driven by SEE measurements*.
*https://lasp.colorado.edu/lisird/data/

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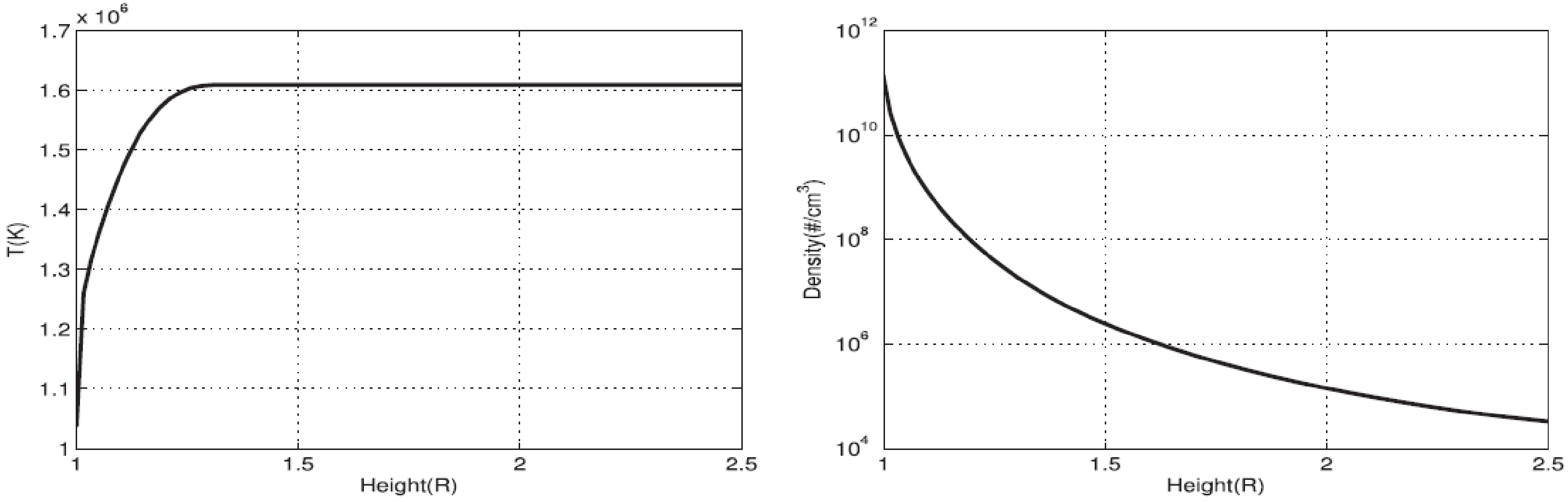
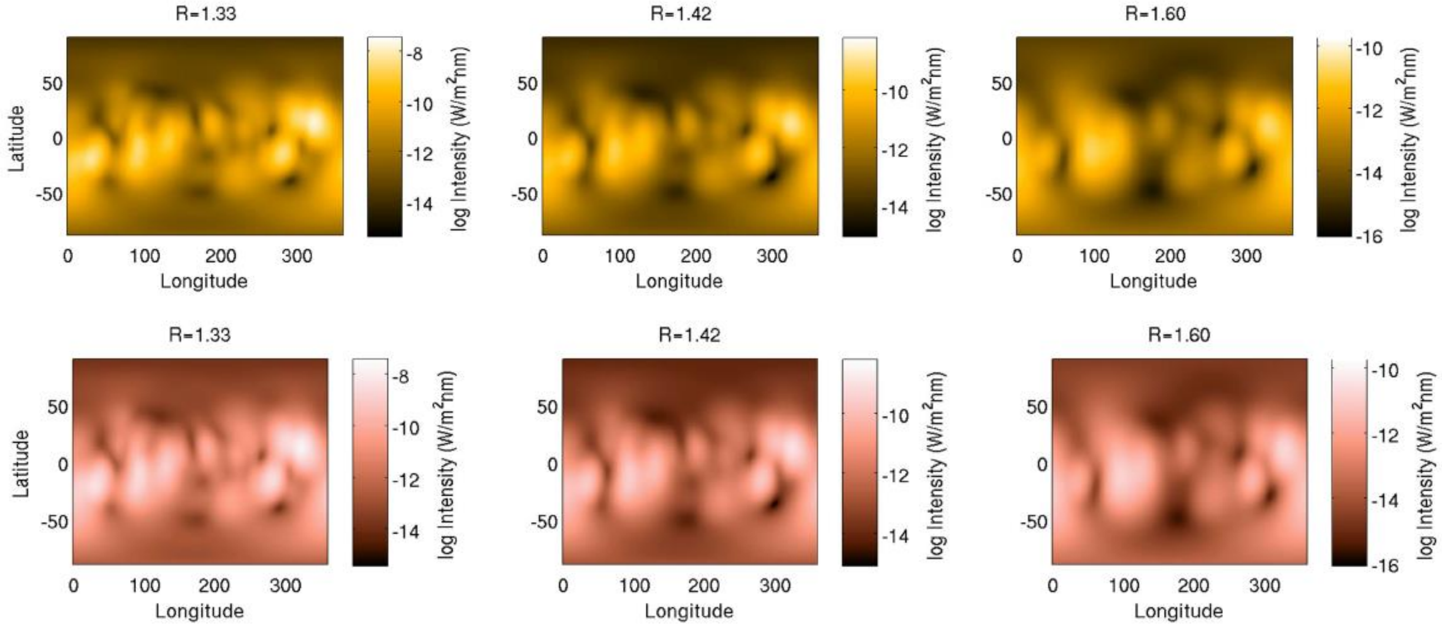
COronal DEnsity and Temperature (CODET) model



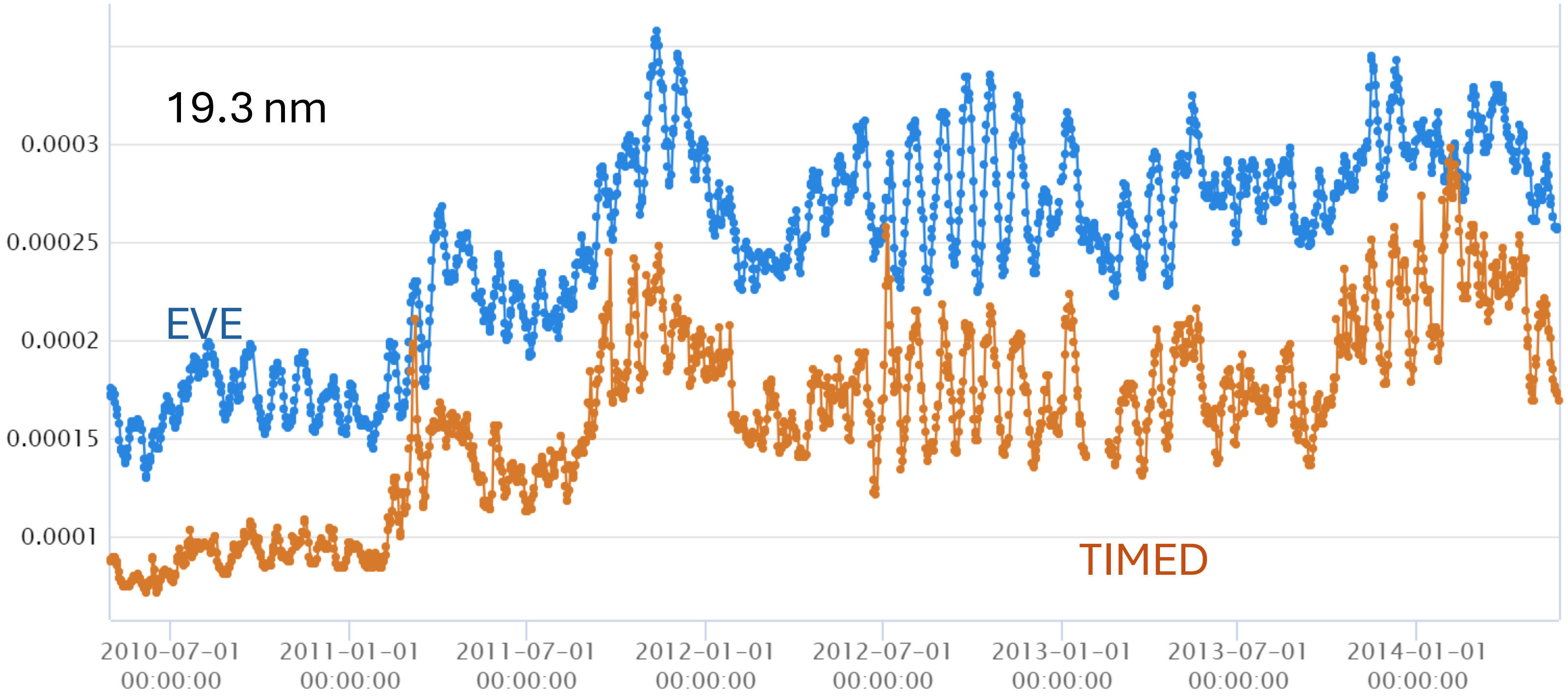
(a) Temperature profile (b) Density profile

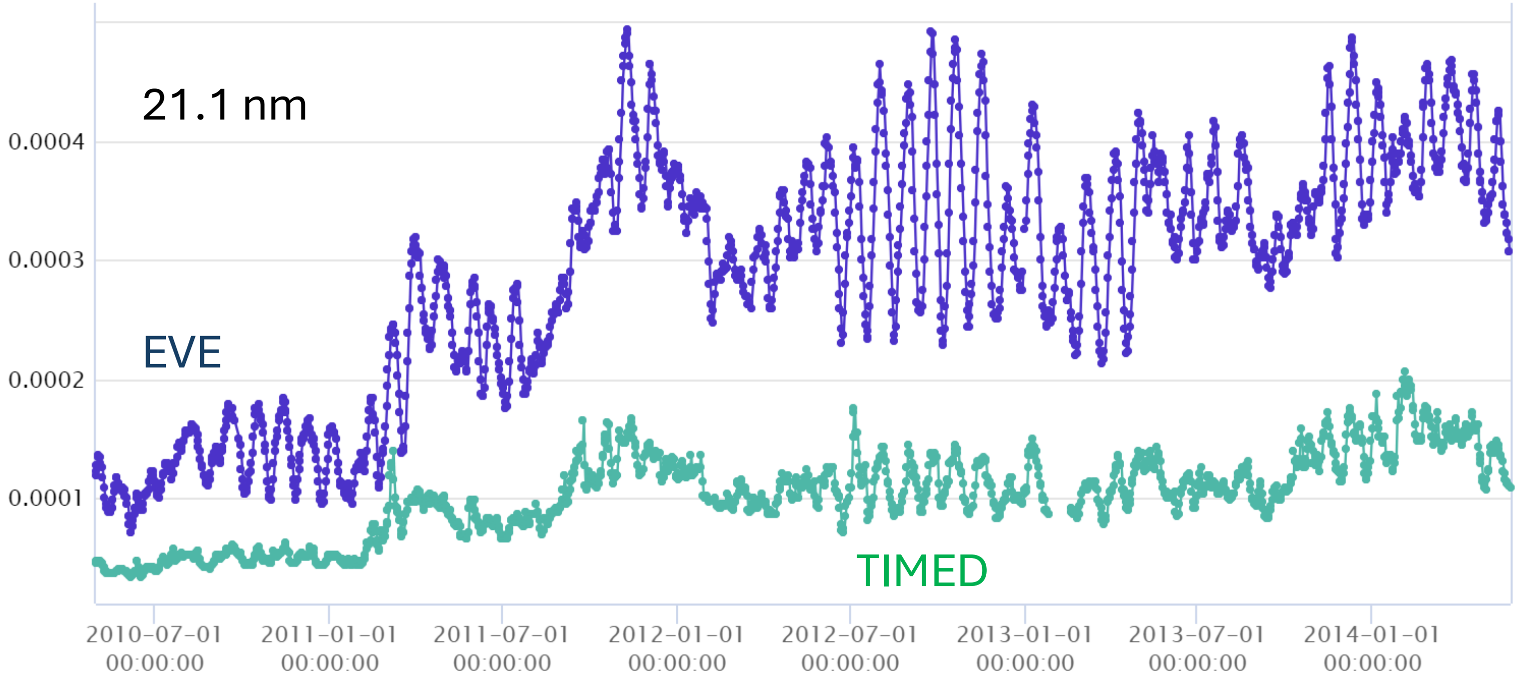
Figure 4. Temperature profile (left panel) and density profile (right panel) through the solar atmosphere on 2001 December 15; specifically from $R = 1\ R_\odot$ to $R = 2.5\ R_\odot$, for the parameter combinations shown in Table 1.



(a) Dec. 15 (2001)

More details see Rodríguez-Gómez et al. 2018





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COronal Density and Temperature (CODET) model V1.1

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COronal Density and Temperature (CODET) model V1.1

HMI photospheric maps +magnetic flux transport model (SFT-LMSAL) + observational datasets EVE/SDO level 3 v.7 to constrain model outputs*.
Include more wavelengths, e.g., 19.5 nm, 21.1 nm, 28.4 nm, 17.1 nm and 9.4 nm
Time interval from **April 30, 2010, to May 26, 2014 (SDO/EVE MEGS-A)**

*a new version of EVE/SDO level 3 v8. is now available (June 14, 2024).

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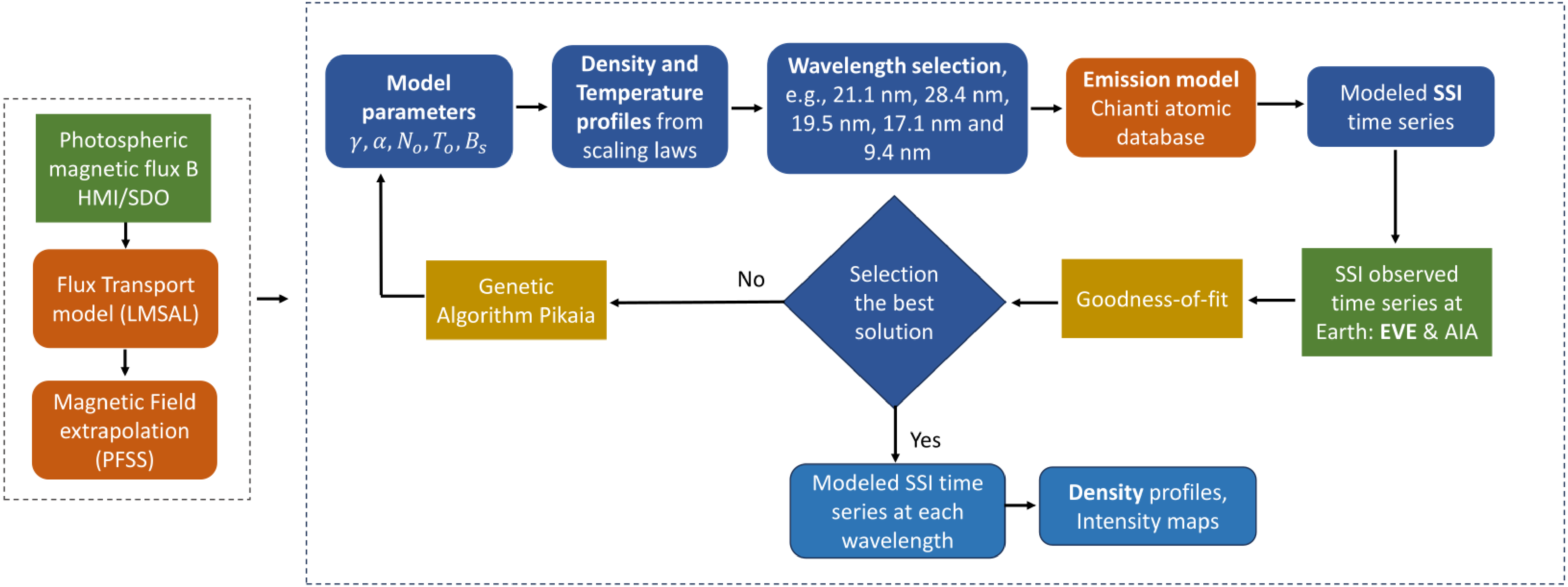
COronal Density and Temperature (CODET) model V1.1



The Observational datasets are shown in green rectangles. Orange rectangles correspond to models, algorithms and tests are depicted as yellow rectangles. The CODET model routines and outputs are described with blue rectangles.

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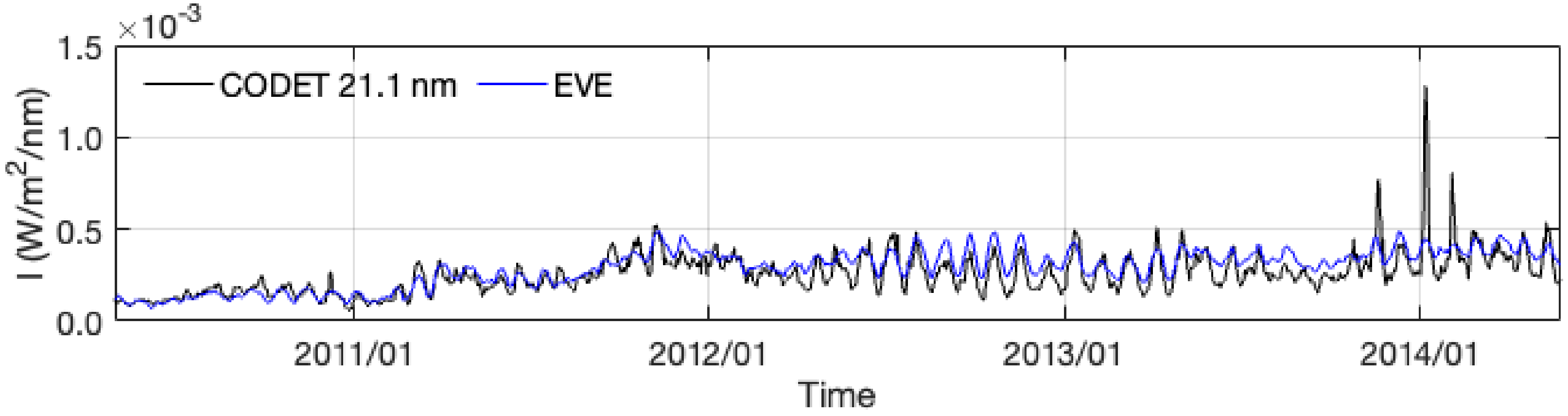
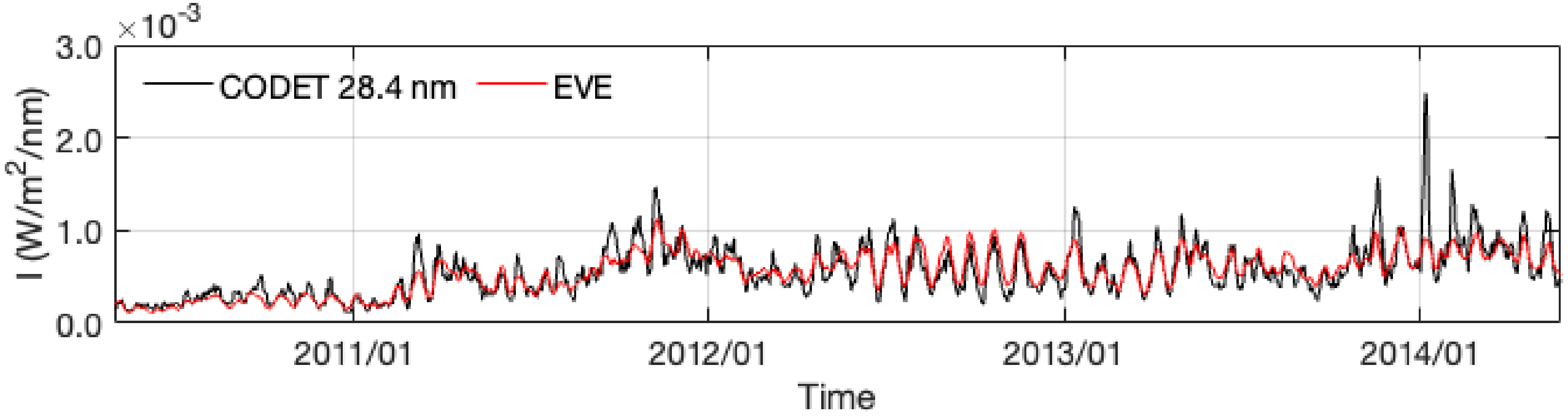
COronal DEnsity and Temperature (CODET) model v.1.1

- 54 days (~ 2 days per month – Forecast capability CODET)
- April 30, 2010, to May 26, 2014, period (SDO/EVE MEGS-A)
- Scott a, b, 2015 ionization model-Contribution function from Chianti atomic database

Preliminary results





COronal DEnsity and Temperature (CODET) model v.1.1

April 30, 2010, to May 26, 2014 (SDO/EVE MEGS-A)

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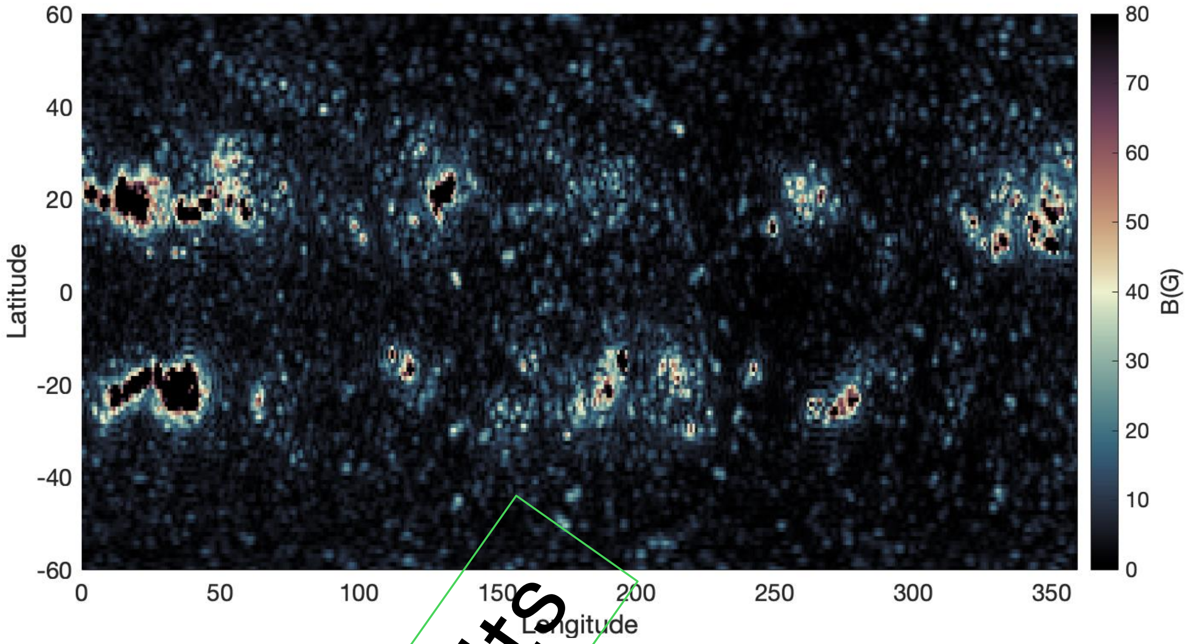
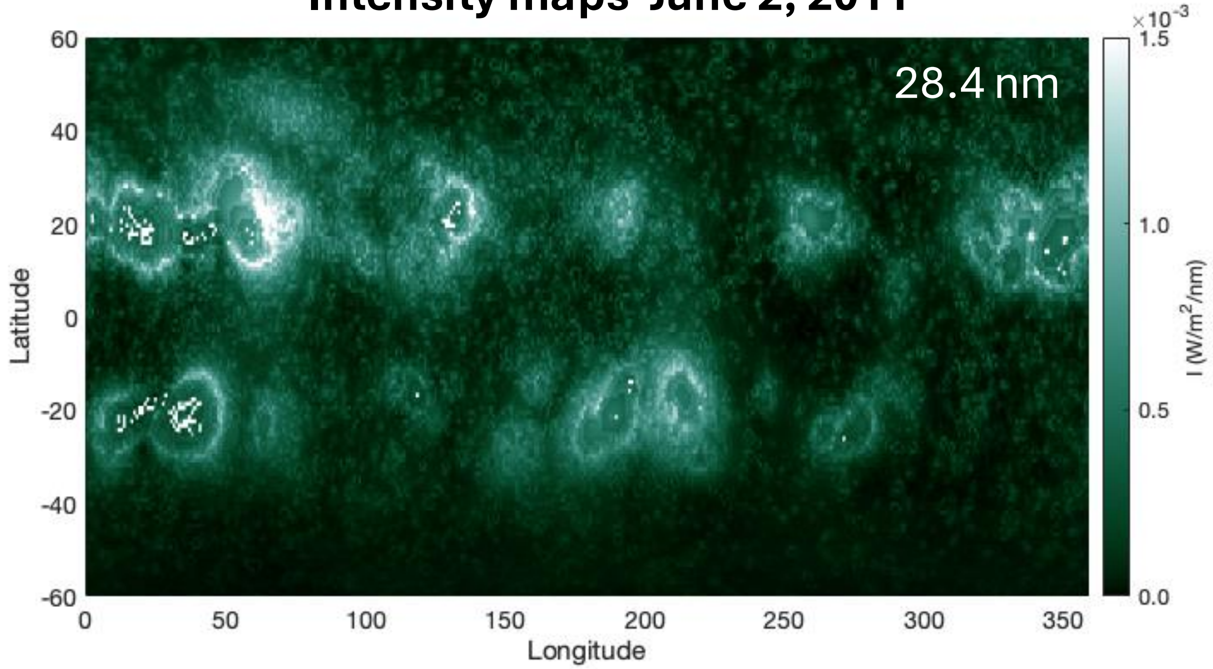
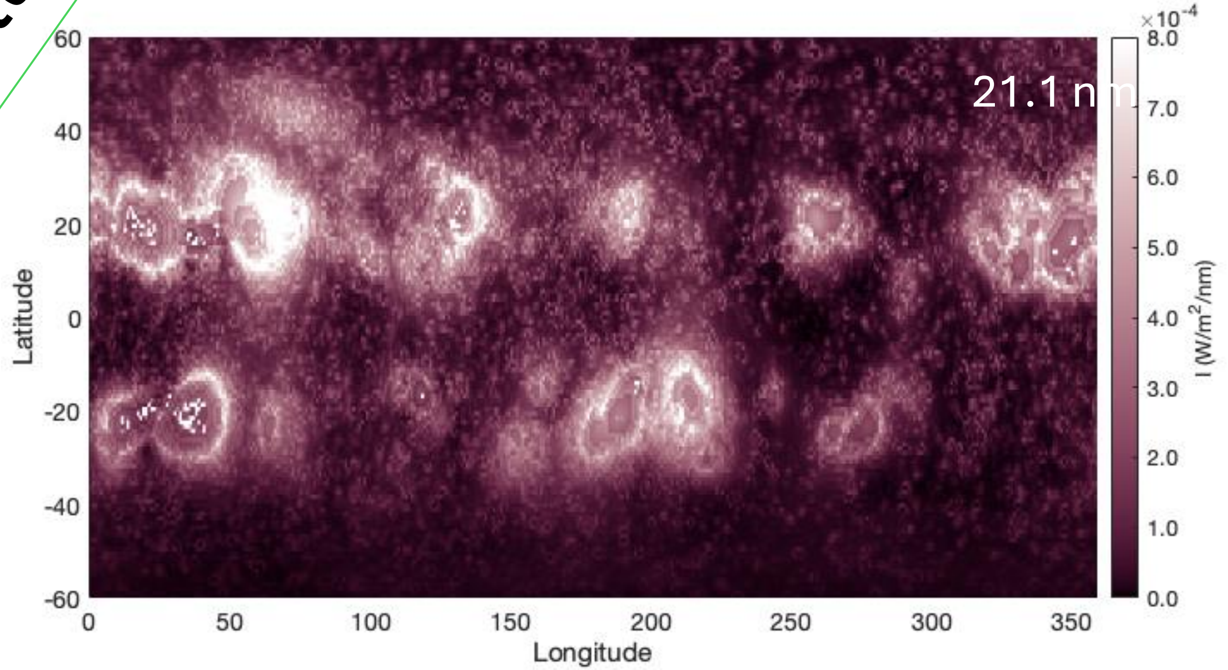
Photospheric Magnetic Flux



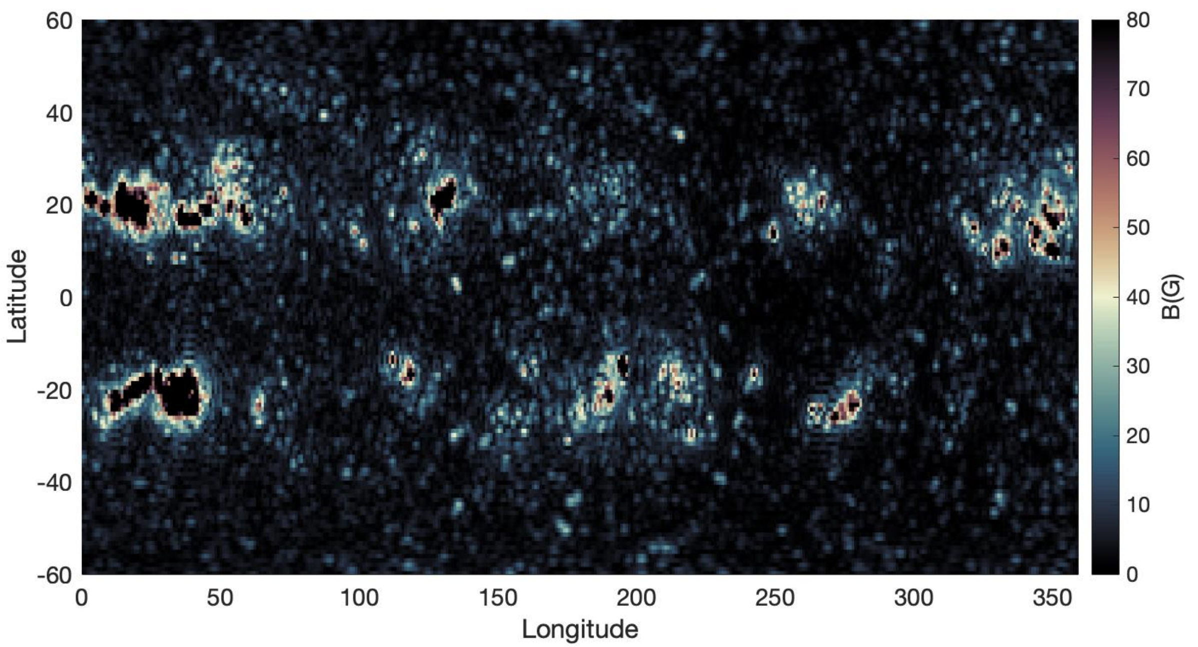
Intensity maps June 2, 2011

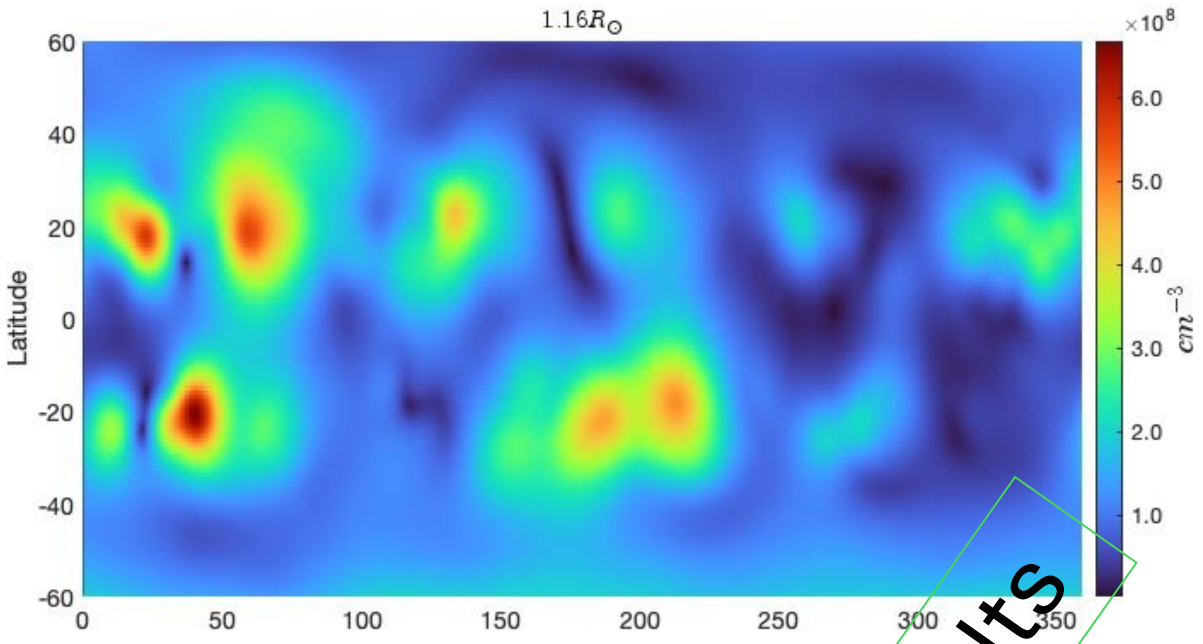


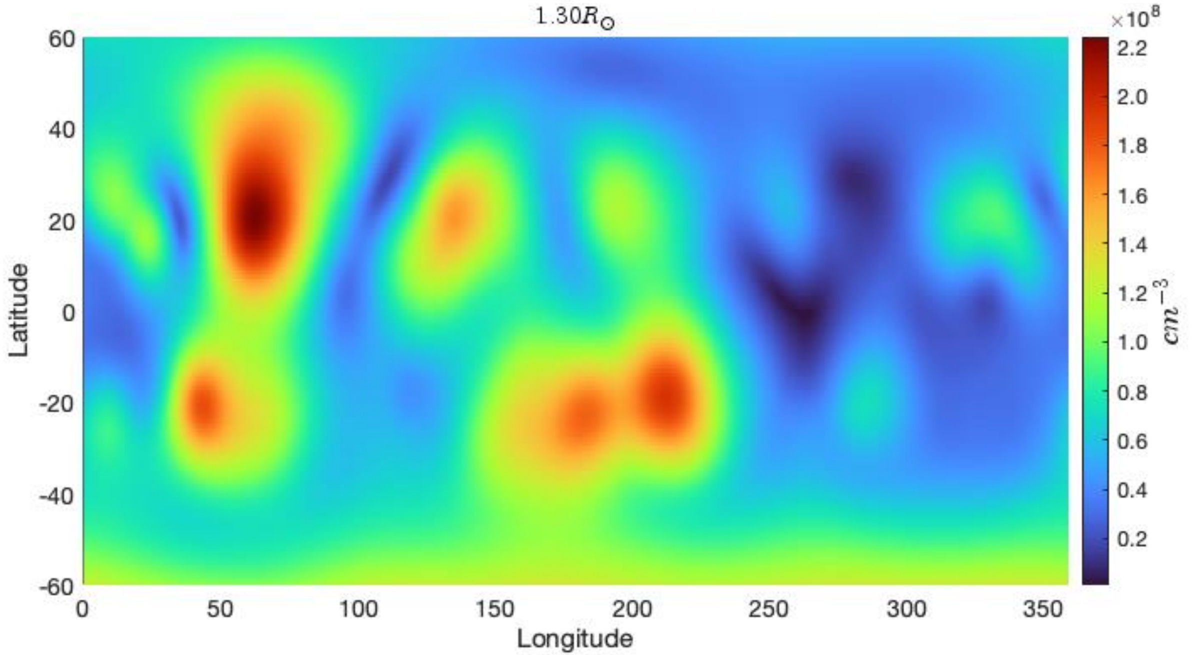


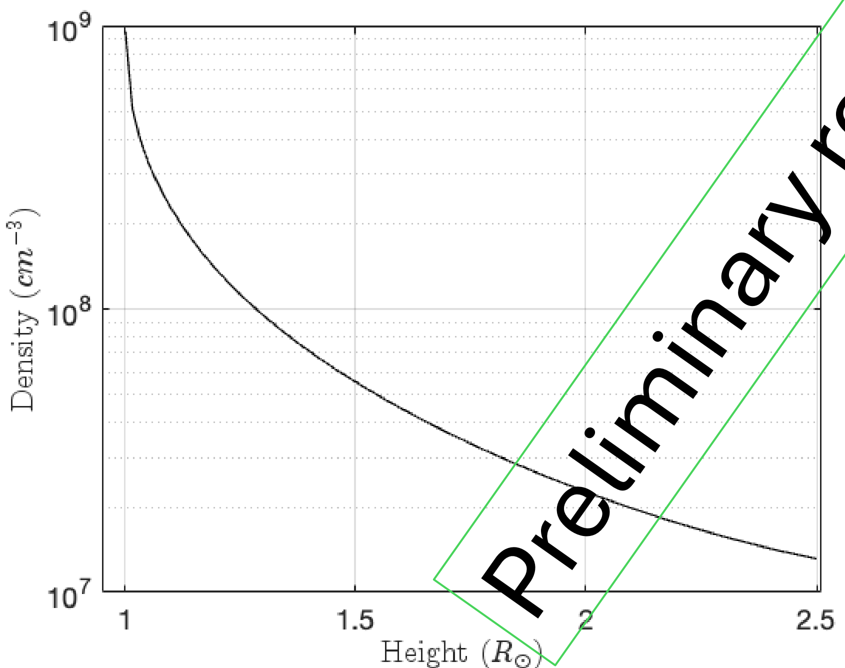
Preliminary results

COronal DEnsity and Temperature (CODET) model v.1.1





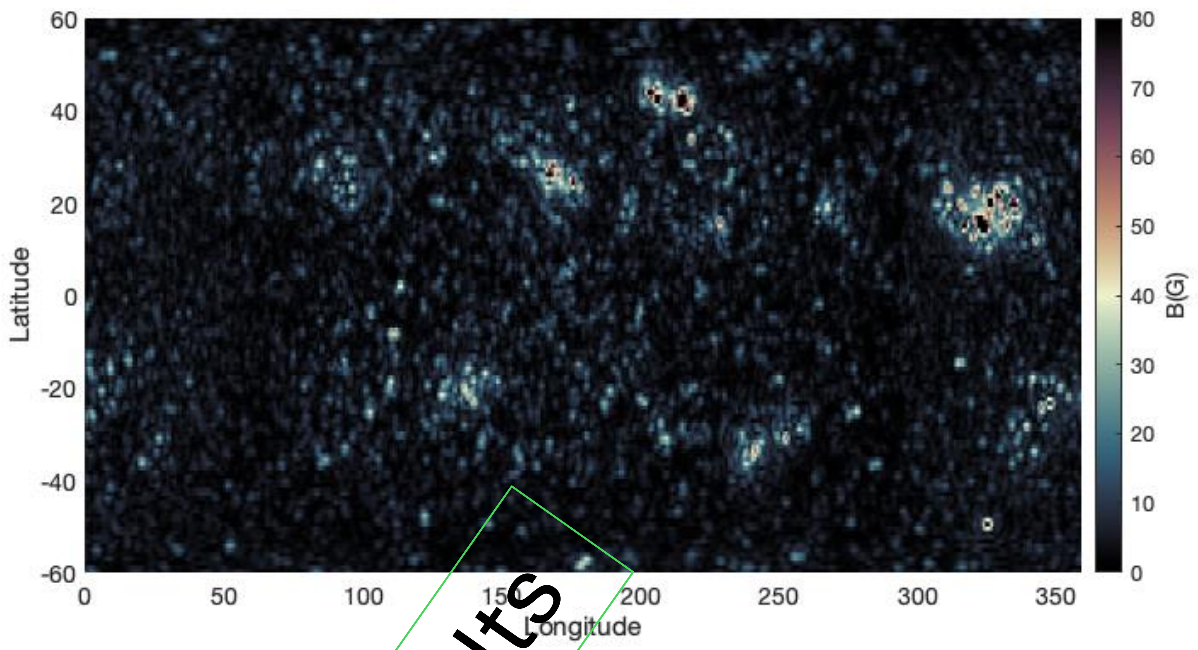


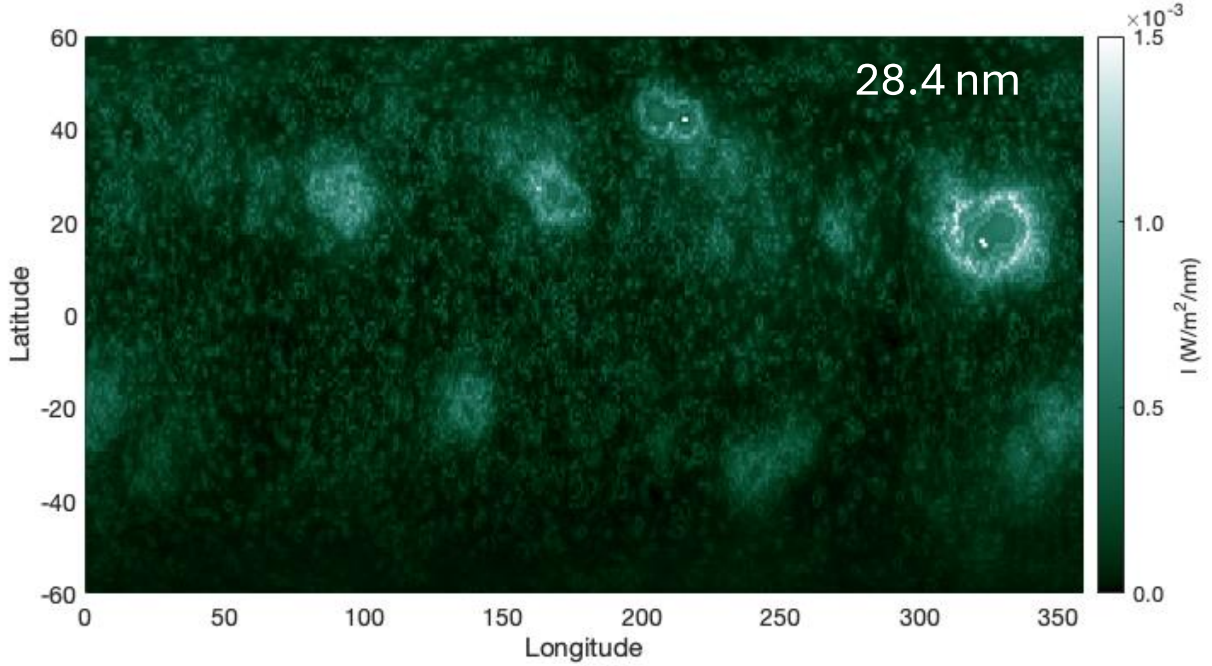


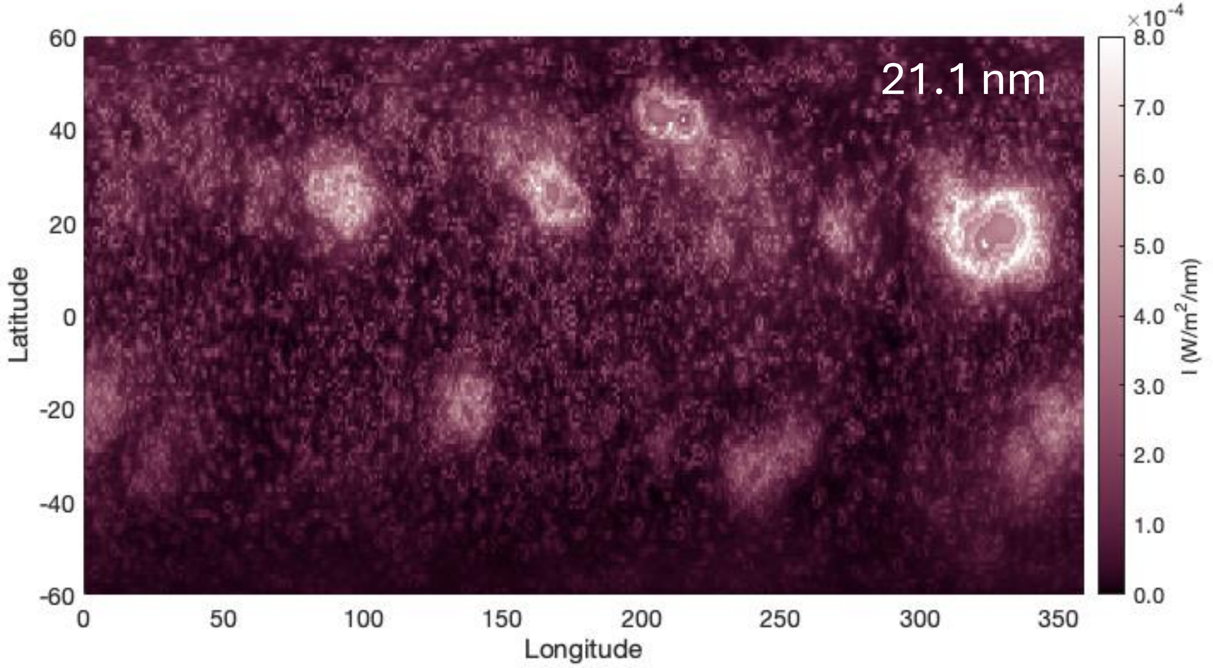
Preliminary results

Mean density profile June 2, 2011

Photospheric Magnetic Flux **Intensity maps May 2, 2010**







Preliminary results

Comparing Density profiles obtained from the COronal DEnsity and Temperature (CODET) model v.1.0 with METIS/SolO data

Rodríguez-Gómez, J. M. (NASA/CUA), Liberatore A. (JPL).

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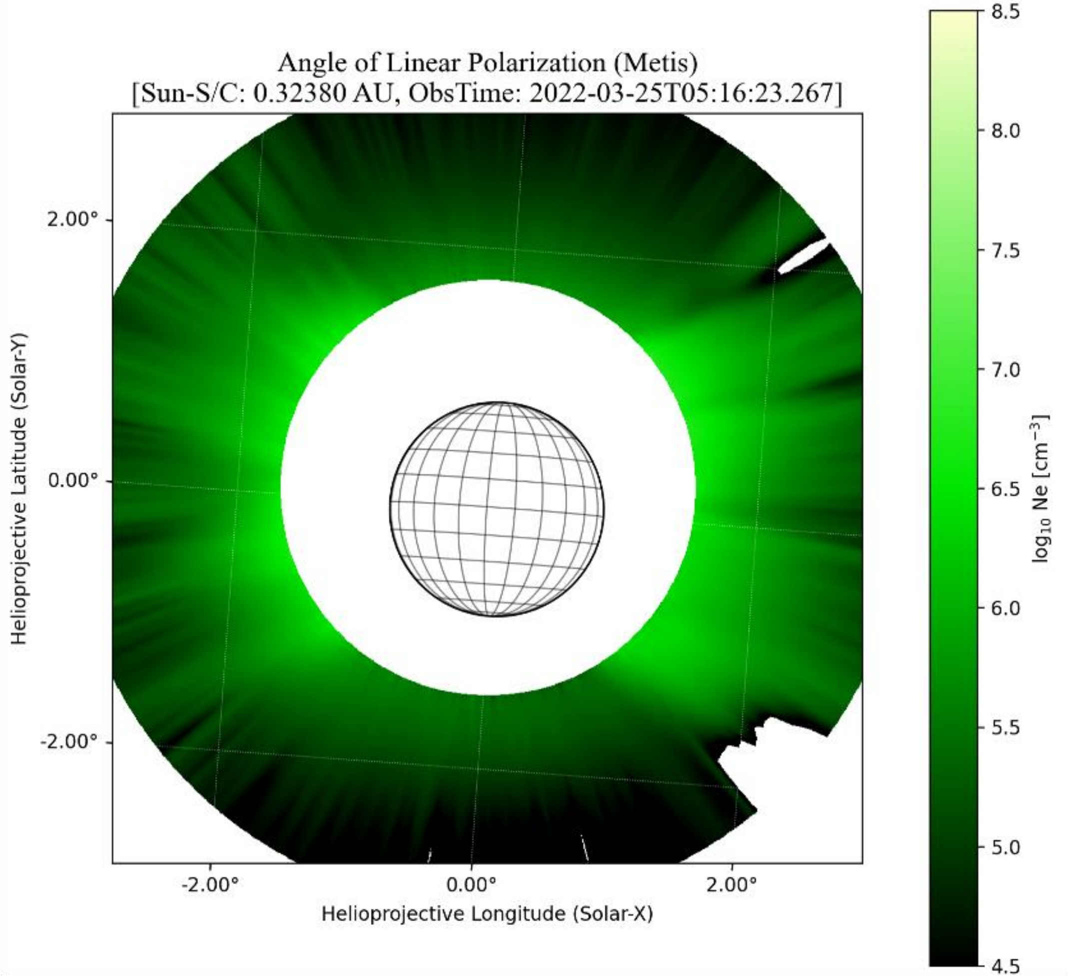
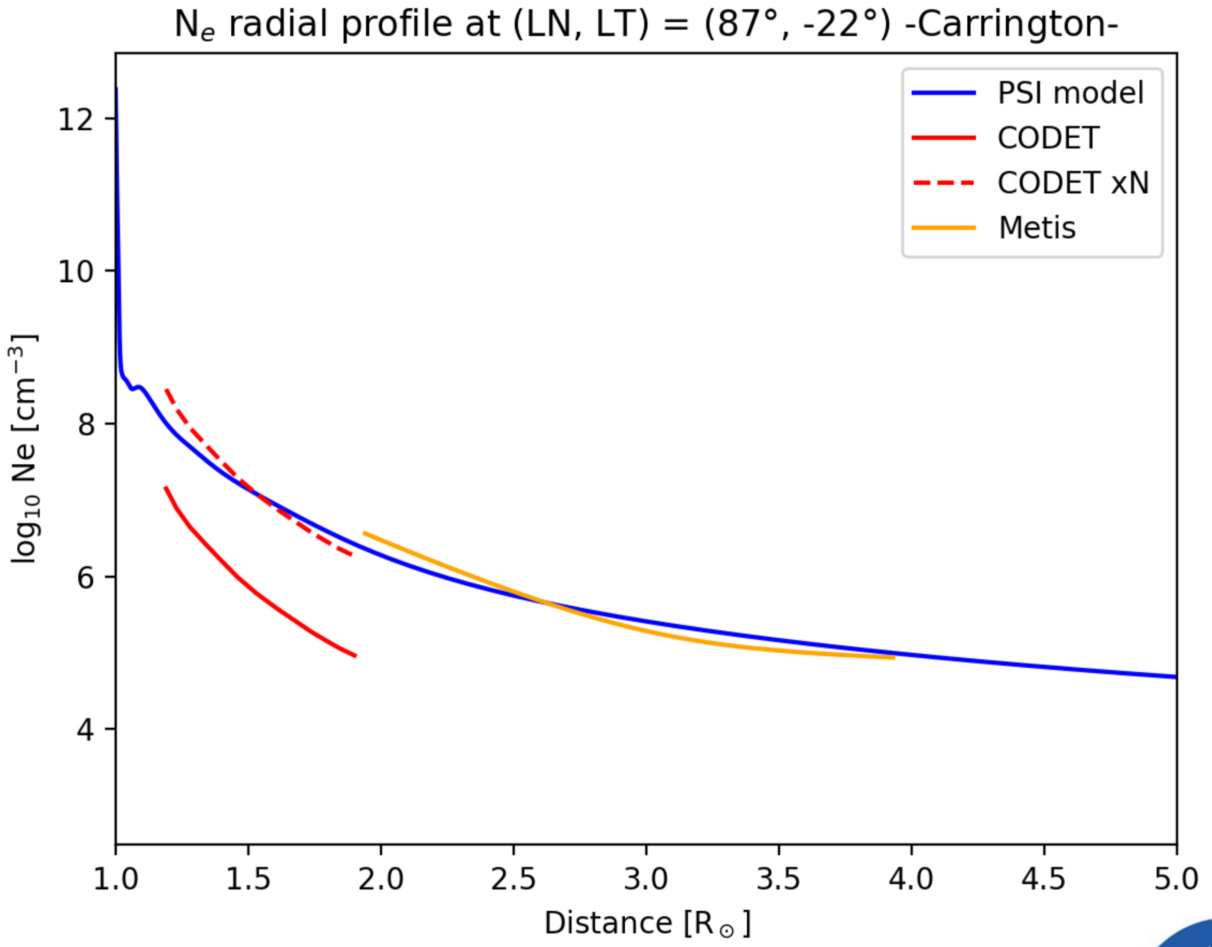
Density profiles from CODET model v.1.0 (19.3 nm +21.1 nm TIMED) and METIS/SolO





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Rodríguez-Gómez, J. M., Liberatore A.

Next Steps

- Including more EUV wavelengths e.g., EVE MEGS-B (33.33 nm to 105 nm), to compare density profiles from CODET model and METIS Solar Orbiter data.

Ion	Wavelength [nm]	Log(T) [K]
Fe XVI	33.54	6.43
Fe XX	56.78	6.96
Fe XIX	59.22	6.89
Fe XX	72.15	6.96

Ion	Wavelength [nm]	Log(T) [K]
Si XII	49.94	6.29
Si XII	52.10	6.28

Ion	Wavelength [nm]	Log(T) [K]
Mg X	60.98	6.10
Mg X	62.49	6.05

COronal DEnsity and Temperature (CODET) model v.2.0

Rodríguez-Gómez, J. M. (NASA/CUA), Balmaceda, L. (GMU),
Arge, N. (NASA) and Farrish, A. (NASA)

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COronal DEnsity and Temperature (CODET) model v.2.0

- ADAPT-WSA from $1R_{\odot}$ to $2.48R_{\odot}$ May 2010 using GONG photospheric magnetic field maps

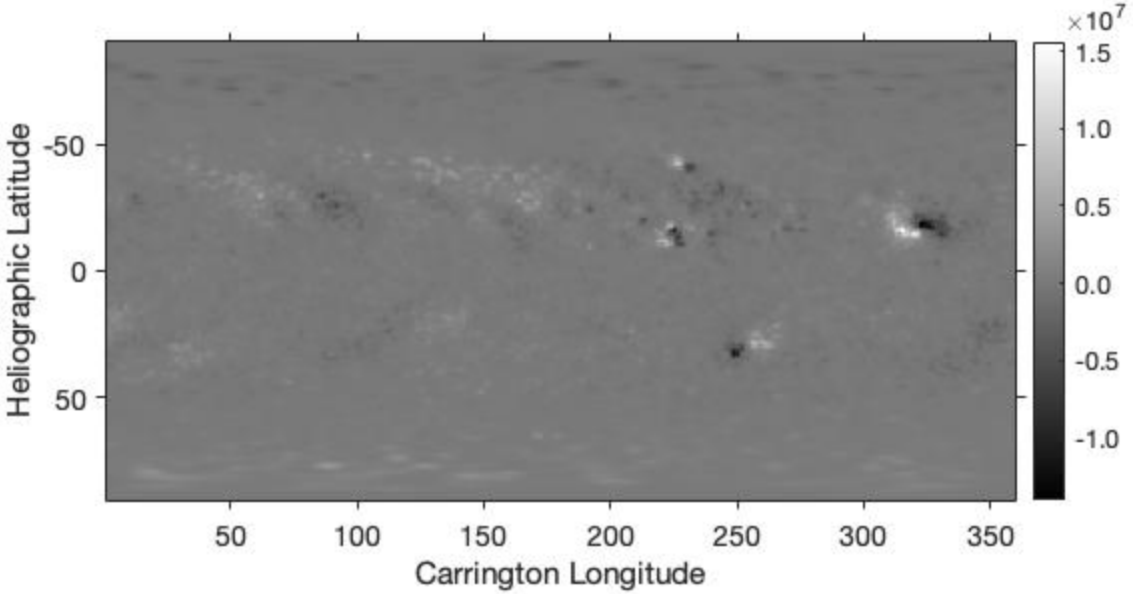
- Implement the ADAPT-WSA: CODET model v2.0

Air Force Data Assimilative Photospheric Flux Transport (ADAPT)

↓

Wang-Sheeley-Arge (WSA) model

ADAPT-WSA map May 01, 2010



ADAPT-WSA has 11 realizations per day

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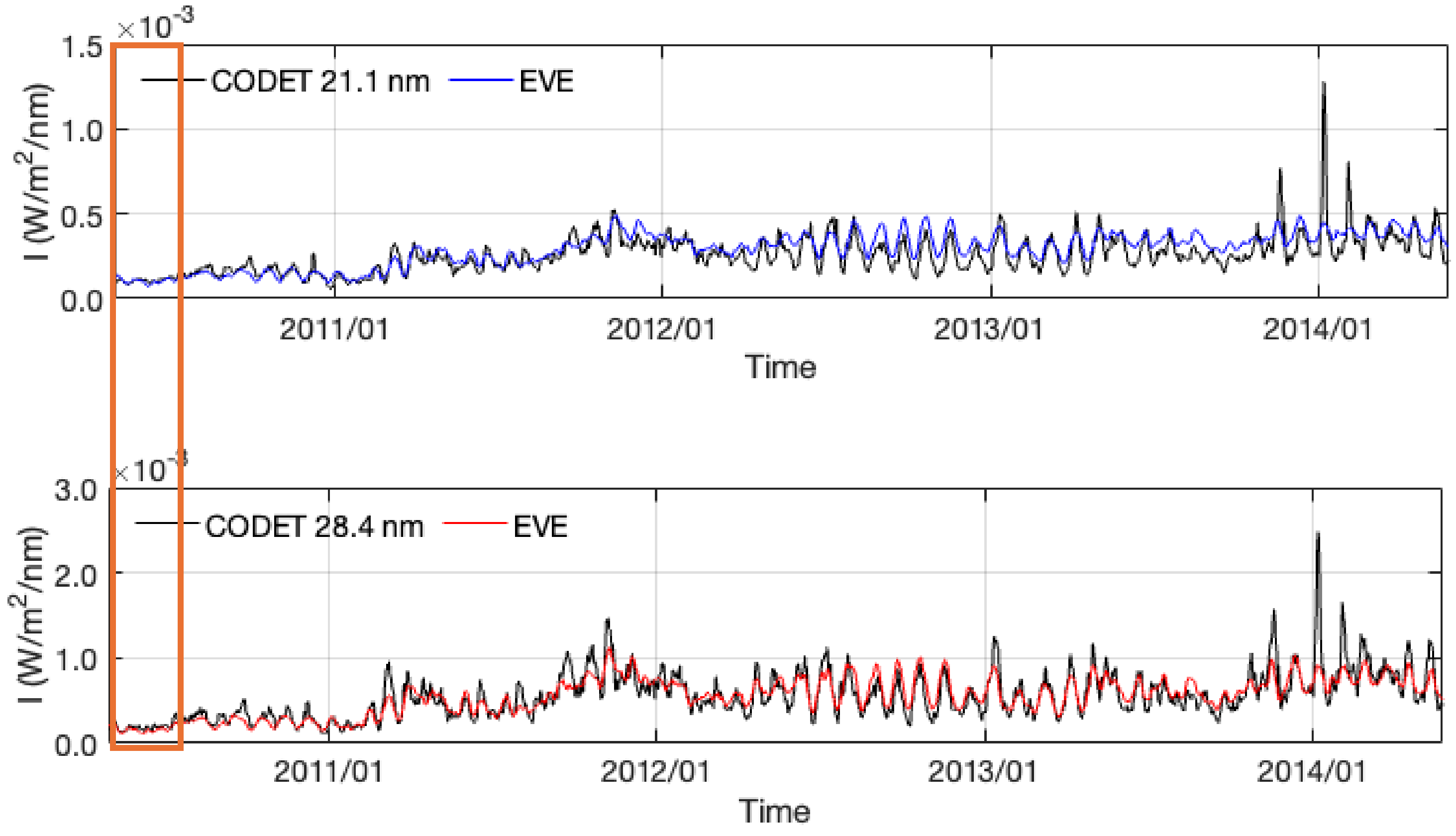
COronal DEnsity and Temperature (CODET) model v.2.0



$$Skill = 1 - \frac{MSE\ (model)}{MSE(reference)}$$

$MSE(model)$ is CODET model V2.0 using ADAPT-WSA

$MSE(reference)$ is CODET model V1.1 using LMSAL-PFSS

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COronal DEnsity and Temperature (CODET) model v.2.0

Next Steps

Periods of Interest

April 30, 2010, to August 31, 2011

ADAPT WSA – HMI compare with STEREO metrics

Dataset to compare SSI model outputs
- SDO/EVE-MEGS-A
- SDO/AIA from May 20, 2010
- STEREO A & B

August 1 to September 30, 2014

ADAPT WSA – HMI compare with STEREO metrics

Dataset to compare SSI model outputs
- SDO/EVE-MEGS-B
- SDO/AIA
- STEREO A & B

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Acknowledgments

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Project: **Investigating the Forecast Capabilities of Modeling of the Solar Spectral Irradiance from the Solar Surface Magnetic Flux.**
Award No. 80NSSC23K0900

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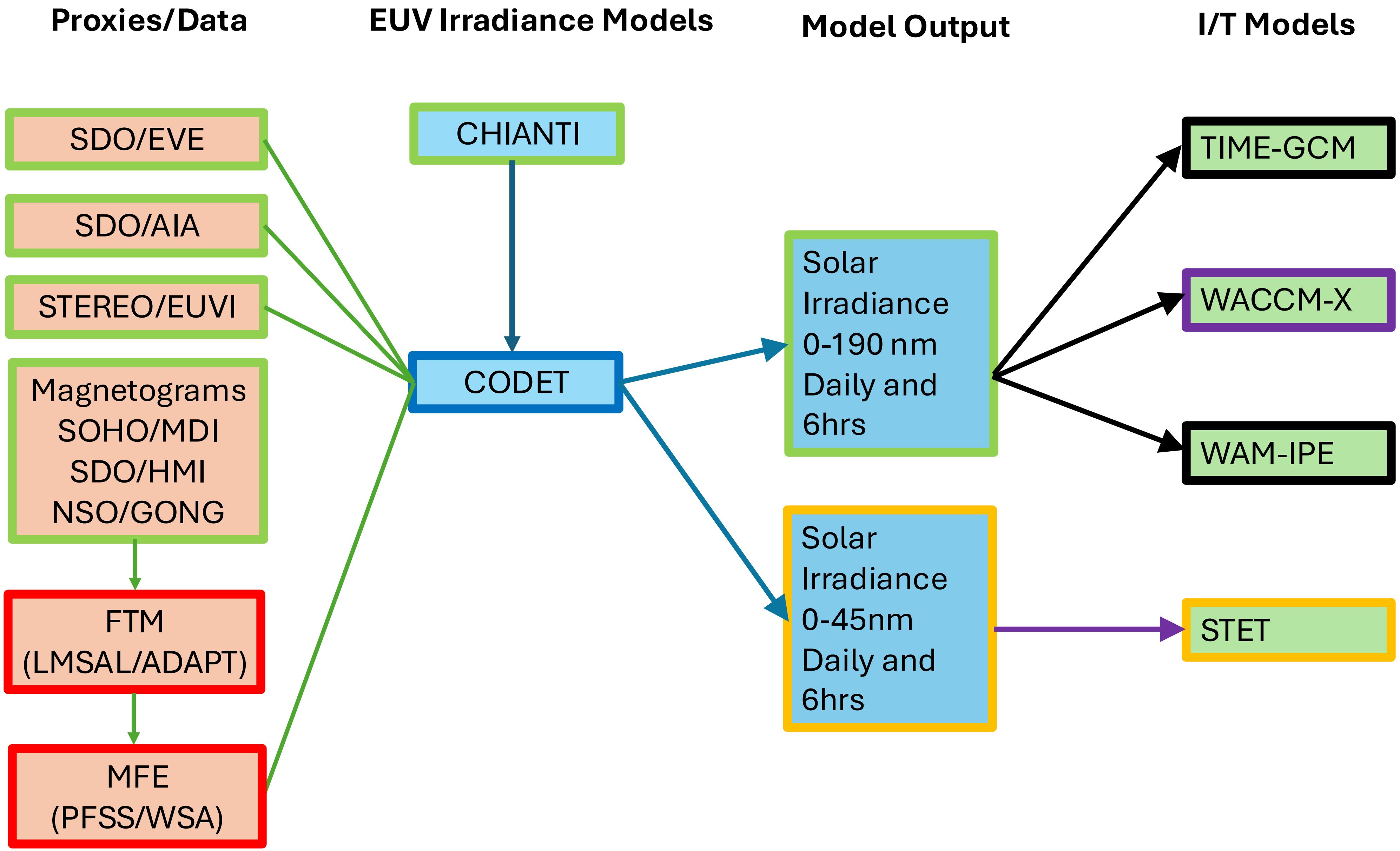

Flux Transport Model (FTM)
Magnetic Field Extrapolation (MFE)

Rodríguez-Gómez, J. M., Balmaceda L., Arge, N.

Modeling EUV Intensity at the top of the Transition Region using CODET model, SPICE-SolO and SDO/EVE data

Rodríguez-Gómez, J. M. (NASA/CUA), Kucera, T. (NASA) and
Young, P. (NASA).

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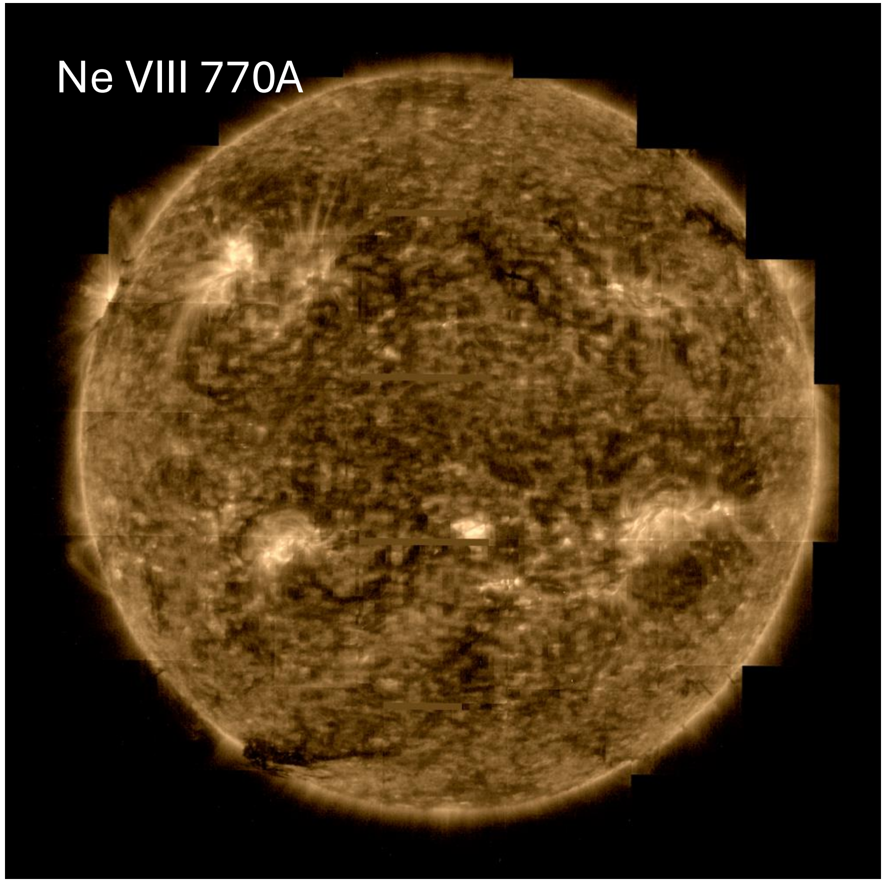
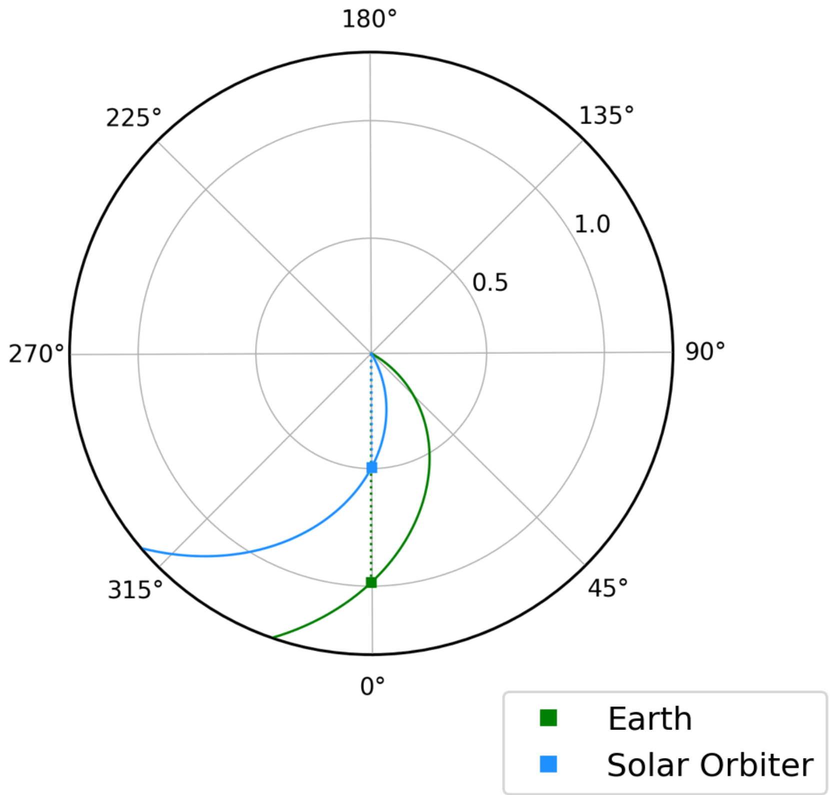
SPICE Full Disc Mosaic

March-07, 2022 from 07:00:30 to 11:24:31 UT



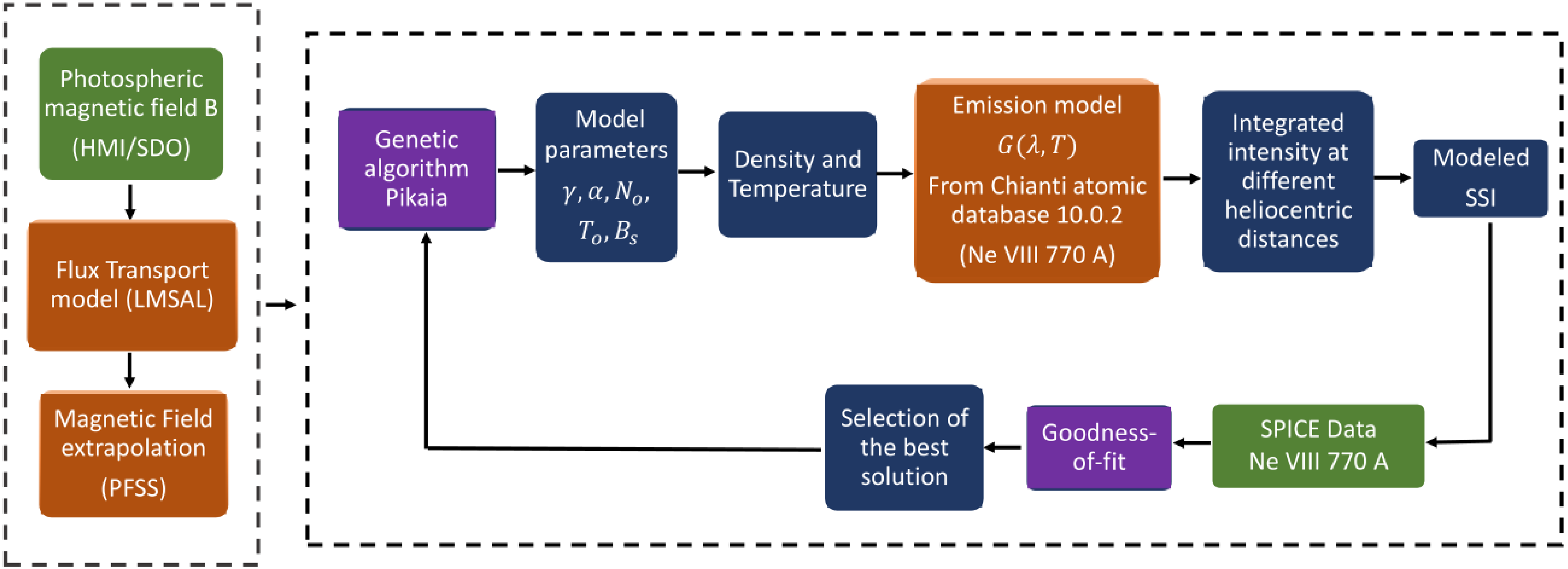
D=0.4977 AU



https://solar-mach.github.io/

- 30” slit
- TR line
- $log_{10}(T) = 5.8\ K$
- Use SDO/EVE data to constrain model outputs

SPICE – EVE Comparison



The observational datasets are shown in green rectangles. Models, algorithms and test are depicted in orange and purple.

EVE DOY 66 2022

Wide slit 30” [W/m^2/sr]

SPICE intensity at 1AU

The CODET model - EUV SPICE data in TR

The hypothesis is that the emission coming from TR can be described using the magnetic field at the coronal base at $1.014R_{\odot}$ (from PFSS)

↓

Ne VIII 770 A from SPICE is located at the top of TR ($log_{10}T = 5.8\ K$)

↓

A different approach is necessary to modeling the emission through chromosphere, e.g., C III and Lyβ

Acknowledgments

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Thank you!