Exploring the Potential of DEM Analysis Using Solar Orbiter/EUI and AI-Generated Data

Junmu Youn[1], Harim Lee[2], Hyun-Jin Jeong[3,1], Jin-Yi Lee[2], Eunsu Park[4] and Yong-Jae Moon[1,2]

[1] School of Space Research, Kyung Hee University, Yongin, 17104, Republic of Korea
[2] Department of Astronomy and Space Science, College of Applied Science, Kyung Hee University, Yongin, 17104, Republic of Korea
[3] Centre for mathematical Plasma Astrophysics, Department of Mathematics, KU Leuven, Celestijnenlaan 200B, 3001 Leuven, Belgium
[4] Space Science Division, Korea Astronomy and Space Science Institute, Daejeon, 34055, Republic of Korea

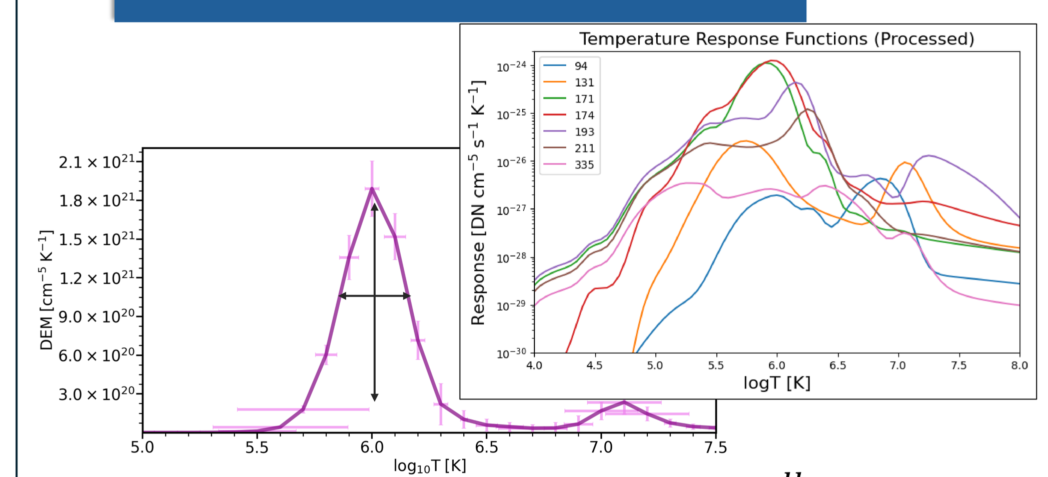
More Informations?

Contact: jmyoun@khu.ac.kr

Introduction

- Solar Orbiter / Extreme Ultraviolet Imager (EUI) / Full Sun Imager (FSI) observes only two full-disk extreme UV (EUV) channels, **174 and 304 Å.**
- To enhance scientific research techniques like **differential emission measure (DEM)**, additional EUV channels are needed.
- DEM is a technique used to **quantify the density and temperature** of emitting multi-thermal plasma **in the solar atmosphere.**
- DEM analysis is an **ill-posed mathematical problem** that requires data from **multiple channels to accurately determine the plasma characteristics.**
- Fortunately, both FSI and Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) share similar EUV wavelengths, such as **174 (171) and 304 Å**, offers an opportunity for image translation.
- In this poster, we aim to address whether we can properly **determine DEMs from Solar Orbiter/EUI/FSI with AI-generated data**.

What is DEM?



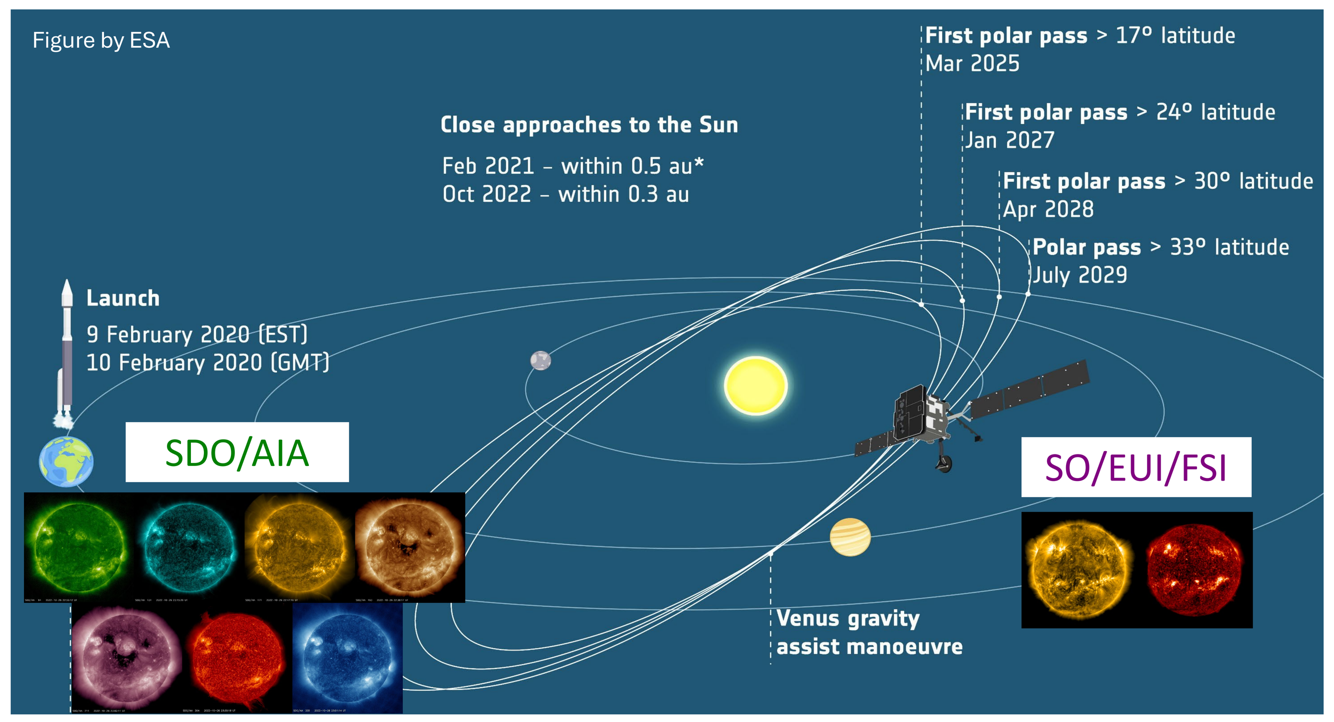
Key equations:

$$DEM(T) = n_e(T)^2 \frac{dh}{dT}$$

$$DN_i = \int_0^\infty K_i(T_{ij})\, DEM(T_j)\, dT$$

- ✓ **DEM** is a technique used to quantify the **density** $(\mathbf{n_e})$, **and temperature (T)** of emitting multi-thermal plasma within the line-of-sight solar atmosphere.
- ✓ The width of the DEM profile corresponds to whether the plasma is multi-thermal or iso-thermal, and the height corresponds to the electron density.
- ✓ We need **various wavelength observations** $(\mathbf{DN_i})$, as each wavelength has a different **temperature response function** $(\mathbf{K_i})$ depending on temperature to solve more accurate DEMs.

Instruments for our Research



✓SO/EUI/FSI

- SO/EUI launched in February 2020.
- The FSI consists of two EUV wavelengths channels (174 and 304Å).
- Mission provides close-up (0.28AU), **high-latitude (33°) observations** of the Sun.
- Solar Orbiter will look at its **uncharted polar regions** for the first time.

✓SDO/AIA

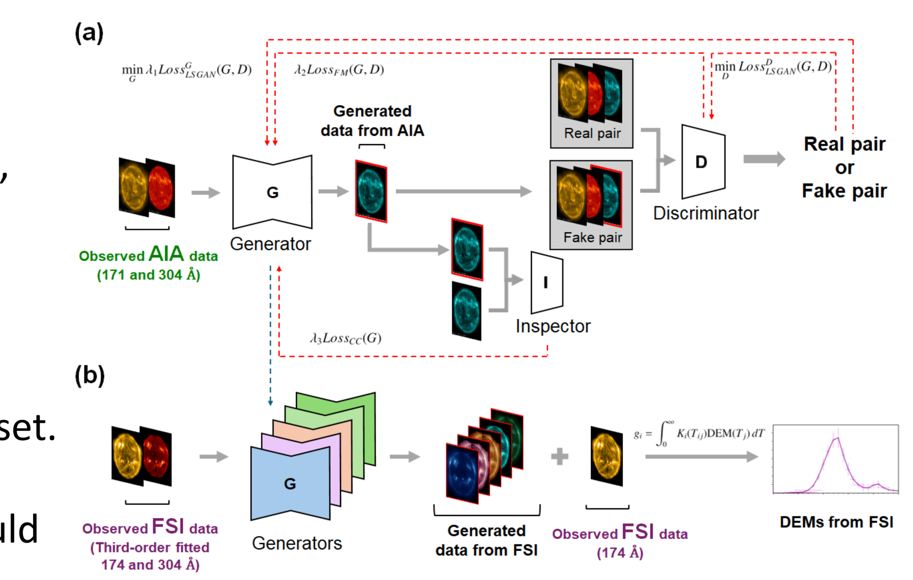
- SDO/AIA launched in February 11, 2010, and is still in operation.
- SDO is placed in a **geosynchronous orbit** around Earth.
- The AIA Consists of seven EUV channels (94, 131, 171, 193, 211, 304 ,and 335 Å) using four telescopes.
- The temperature diagnostics of the EUV emissions cover the range from $6{\times}10^4$ K to $2{\times}10^7$ K.

Method

(a) Training process :
We train a separate model for each channel (94, 131, 193, 211, and 335Å) using only the AIA-observed dataset.

(b) Applying process :
After we successfully train the models, we applied the generative models to the Solar Orbiter/FSI observed dataset.

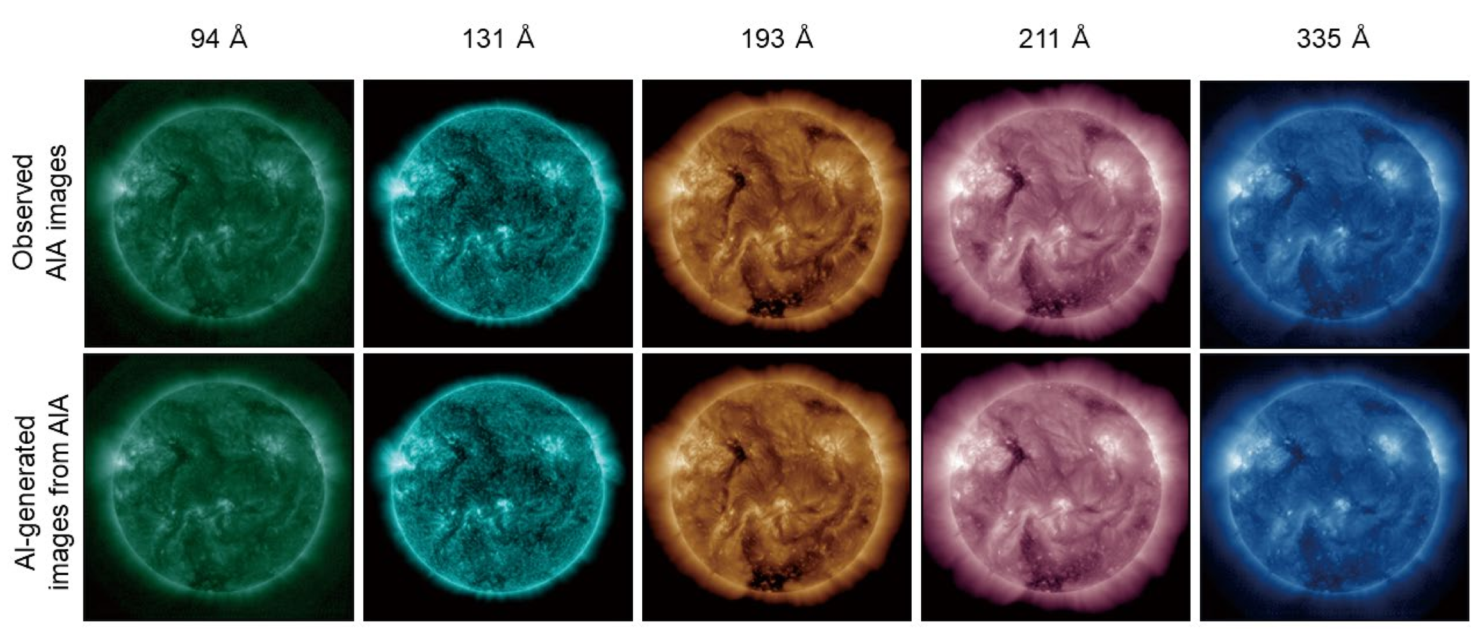
Finally, the observed FSI 174 Å with AI-generated sets could determine the DEMs.



❖ We use a model named Pix2PixCC developed by Jeong et al. (2022).

AI-generated AIA results

We apply the AIA images to the model.



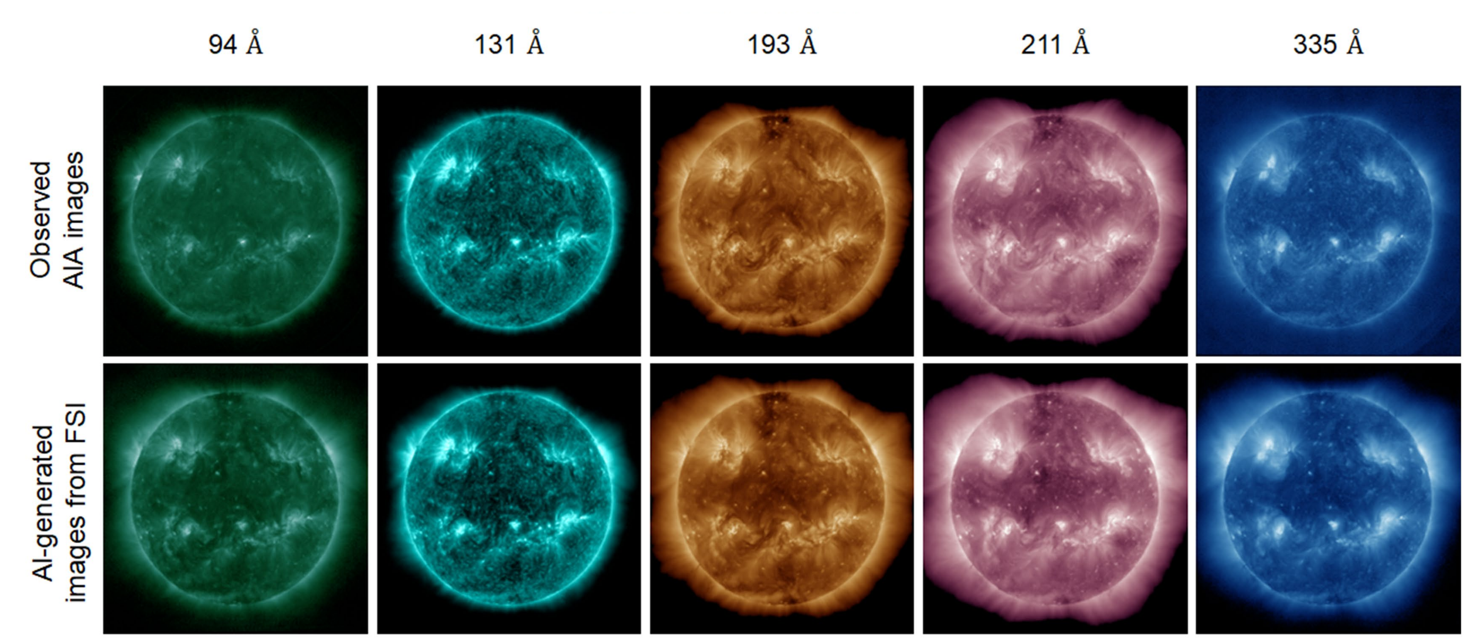
The averaged metric values of the SDO/AIA dataset.

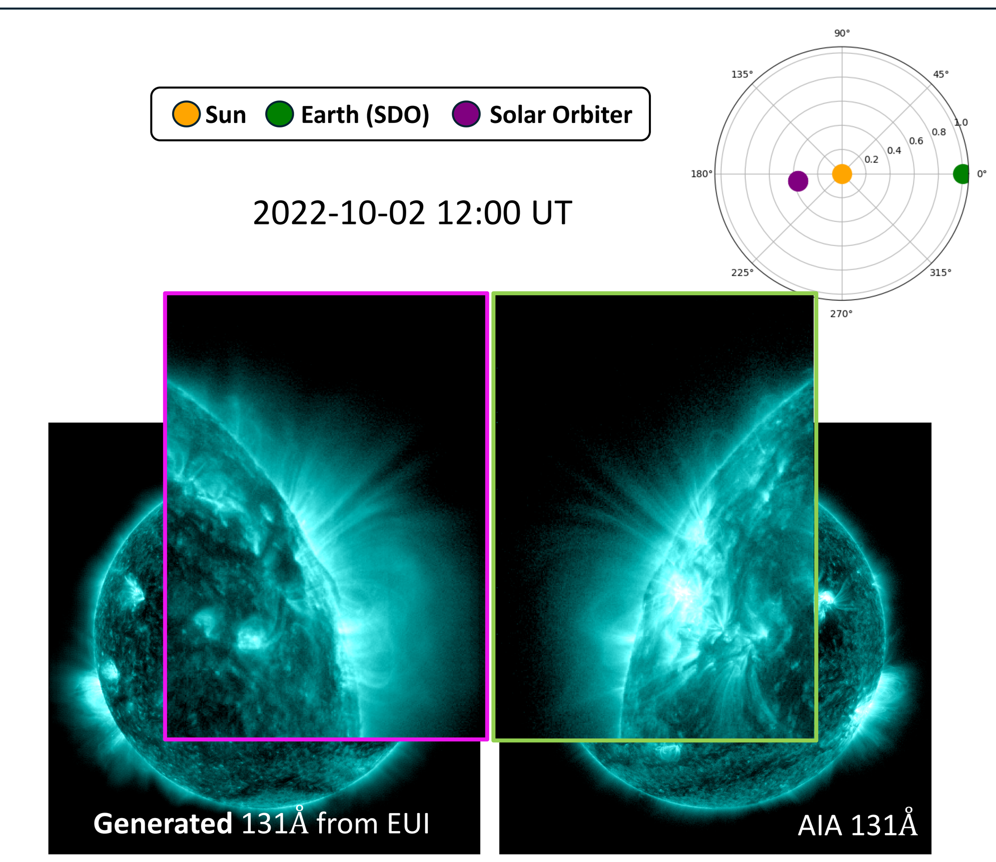
channel (Å)	CC	RMSE [DN/s]	NRMSE
94	0.87 ± 0.07	0.50 ± 0.66	0.012 ± 0.006
131	0.96 ± 0.03	1.26 ± 0.88	0.008 ± 0.003
193	0.95 ± 0.02	38.96 ± 5.59	0.012 ± 0.003
211	0.95 ± 0.02	13.55 ± 3.08	0.010 ± 0.003
335	0.93 ± 0.05	0.84 ± 0.46	0.011 ± 0.005

- The model that generates 131 Å yielded the best performance.
- The model generating 94 Å performed the lowest.
- It is because 94 Å observations are more temperature-sensitive at higher temperatures than the inputs.

AI-generated Solar Orbiter/FSI results

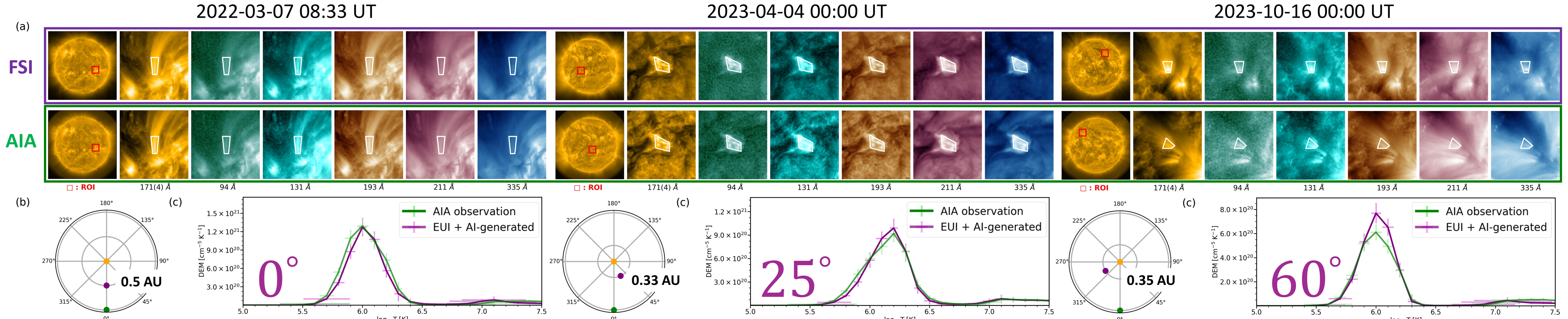
We apply the Solar Orbiter/FSI images to the model.





DEM Results / Conclusion

❖ We use the regularized inversion method Hannah & Kontar (2012) to determine the DEMs.



Takeaway message

1. We demonstrate **that we can properly determine the DEM from FSI data using deep learning** when two instruments **are in conjunction and separated by 25°.**
2. The **DEM peaks are well-fitted** at the same coronal structure, meaning that the **electron density and temperature are consistent** with observation and the deep learning model.
3. This reveals **that our method can effectively determine DEMs** even when the two observations are taken from **different vantage points.**

Further work

1. In the future, this approach could benefit missions at Lagrangian **points L4 and L5 (60° apart).**
2. We are currently developing a method that can apply not only FSI, but also **High Resolution Imagers (HRIs).**