Global Coronal Plasma Diagnostics Based on Multi-slit EUV Spectroscopy

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Full-disk spectroscopic observations of the solar corona are highly desired to forecast solar eruptions and their impact on planets and to uncover the origin of solar wind. In this paper, we introduce a new multi-slit design (5 slits) to obtain extreme ultraviolet (EUV) spectra simultaneously. The selected spectrometer wavelength range (184-197 Å) contains several bright EUV lines that can be used for spectral diagnostics. The multi-slit approach offers an unprecedented way to efficiently obtain the global spectral data but the ambiguity from different slits should be resolved. Using a numerical simulation of the global corona, we primarily concentrate on the optimization of the disambiguation process, with the objective of extracting decomposed spectral information of six primary lines. This subsequently facilitates a comprehensive series of plasma diagnostics, including density (Fe XII 195.12/186.89 Å), Doppler velocity (Fe XII 193.51 Å), line width (Fe XII 193.51 Å) and temperature diagnostics (Fe VIII 185.21 Å, Fe X 184.54 Å, Fe XI 188.22 Å, Fe XII 193.51 Å). We find a good agreement between the forward modeling parameters and the inverted results at the initial eruption stage of a coronal mass ejection, indicating the robustness of the decomposition method and its immense potential for global monitoring of the solar corona.

1. Schematic of multi-slit design. Primary lines and plasma diagnostics. Wavelength range (184~197 Å)

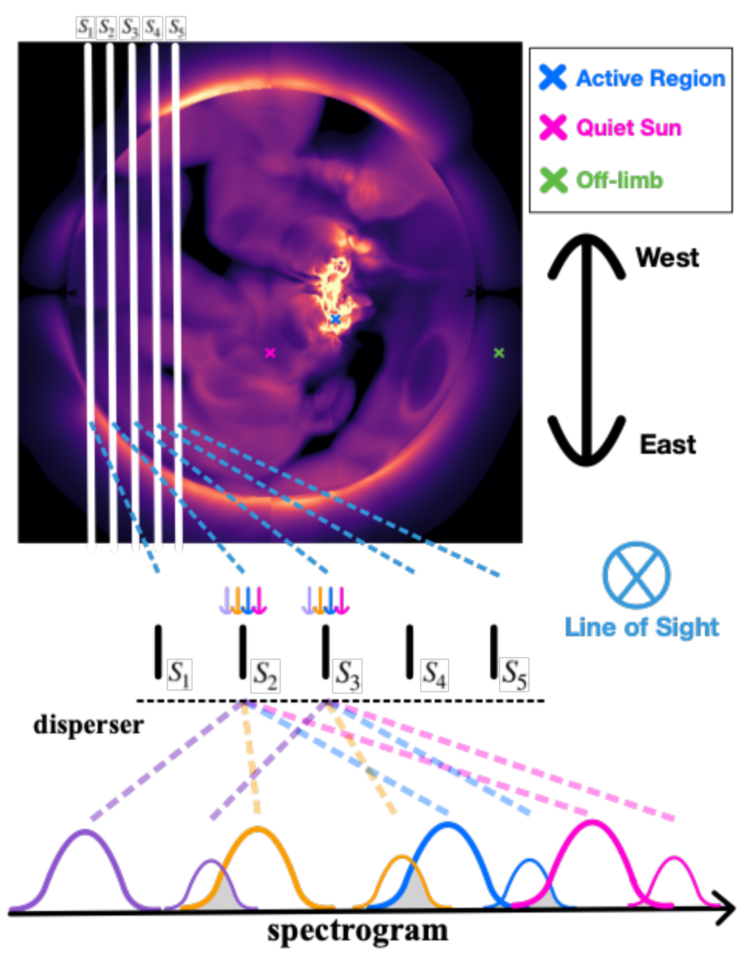

Fig. 1. Schematic of spectrum using a five-slit design, resulting in the multi-slit ambiguity (indicated by grey shadow)

- To achieve **rapid** spectroscopic **global** observations of the solar **corona**, a single-slit spectrometer is insufficient due to its low cadence and limited field of view.
- Therefore, we adopted a **five-slit** design in the EUV band. However, this introduced **spectral confusion** (Fig. 1).
- Spectral confusion: The spectrum from each of the five slits is recorded with a slight **displacement** on the detector. With an **inter-slit spacing** of 1.02 Å (separation on the spectrogram), the spectra from each slit blend into each other (indicated by the grey shadow in Fig. 1).
- We selected **six primary lines** (Table 1) to obtain a series of plasma diagnostics.
- Example spectrum (Fig. 2) coupled with an effective area with a peak value of $\sim 1.61\ \mathrm{cm}^2$ and these six primary lines are all bright and relatively isolated.

Table 1. Six primary lines used for different plasma diagnostics

	Ion and formation temperature (log T/K)	Wavelength (Å)		
T Diagnostic (DEM)	Fe VIII (5.65)	185.21		
	Fe X (6.00)	184.54		
	Fe XI (6.10)	188.22		
	Fe XII (6.20)	195.21	186.887	193.51
		Density diagnostic		Doppler velocity and line width

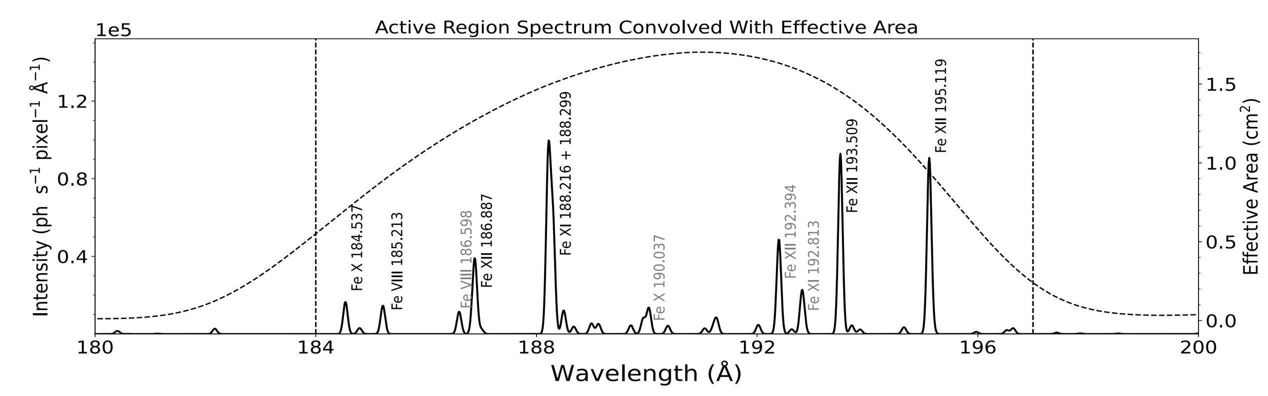

Fig. 2. Example spectrum from CHIANTI convolved with an effective area

2. Decomposition and inverted results

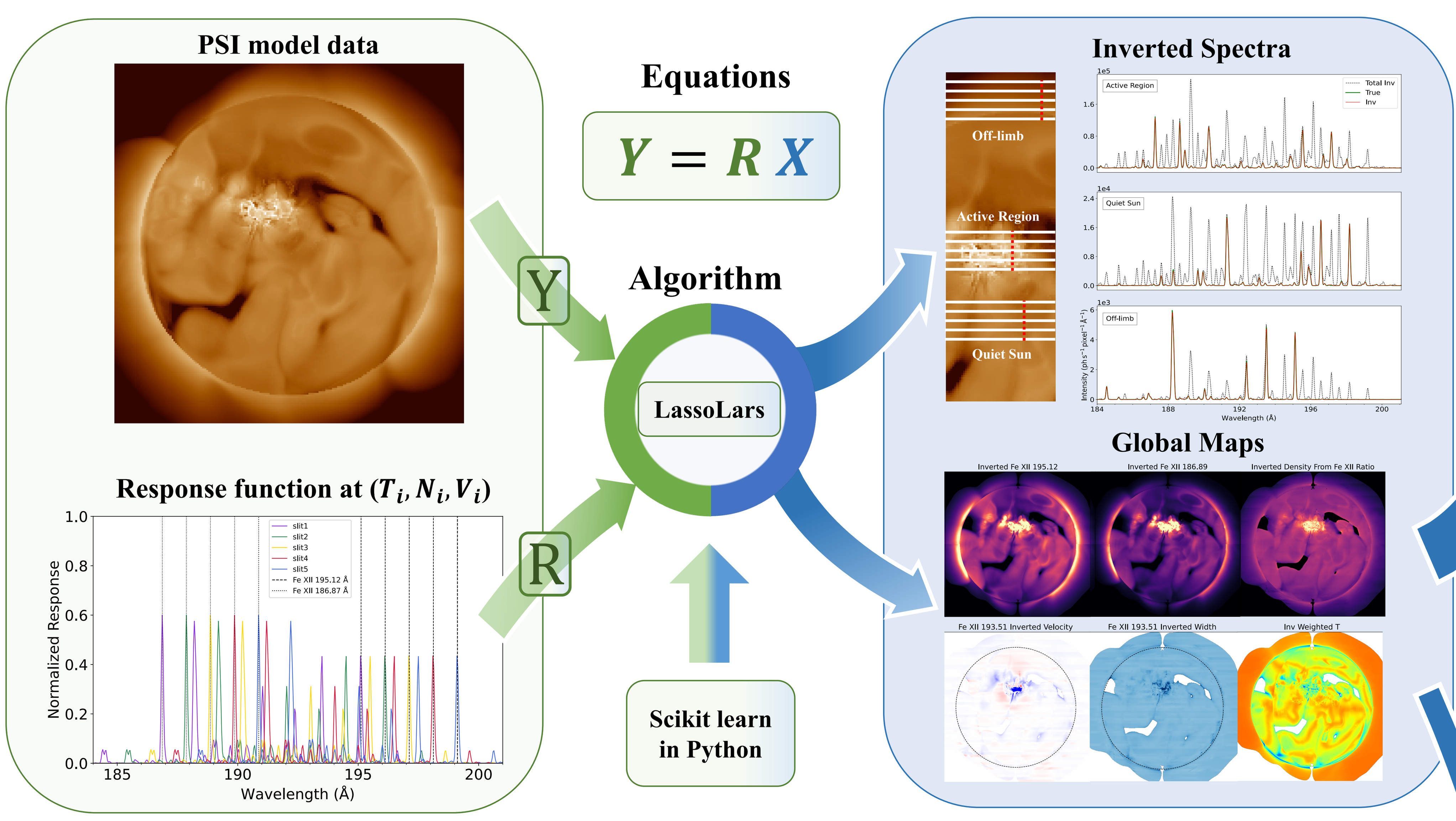

Fig. 3. Schematic of decomposition process, including input (left side), output (right side) and algorithm (LassoLars)

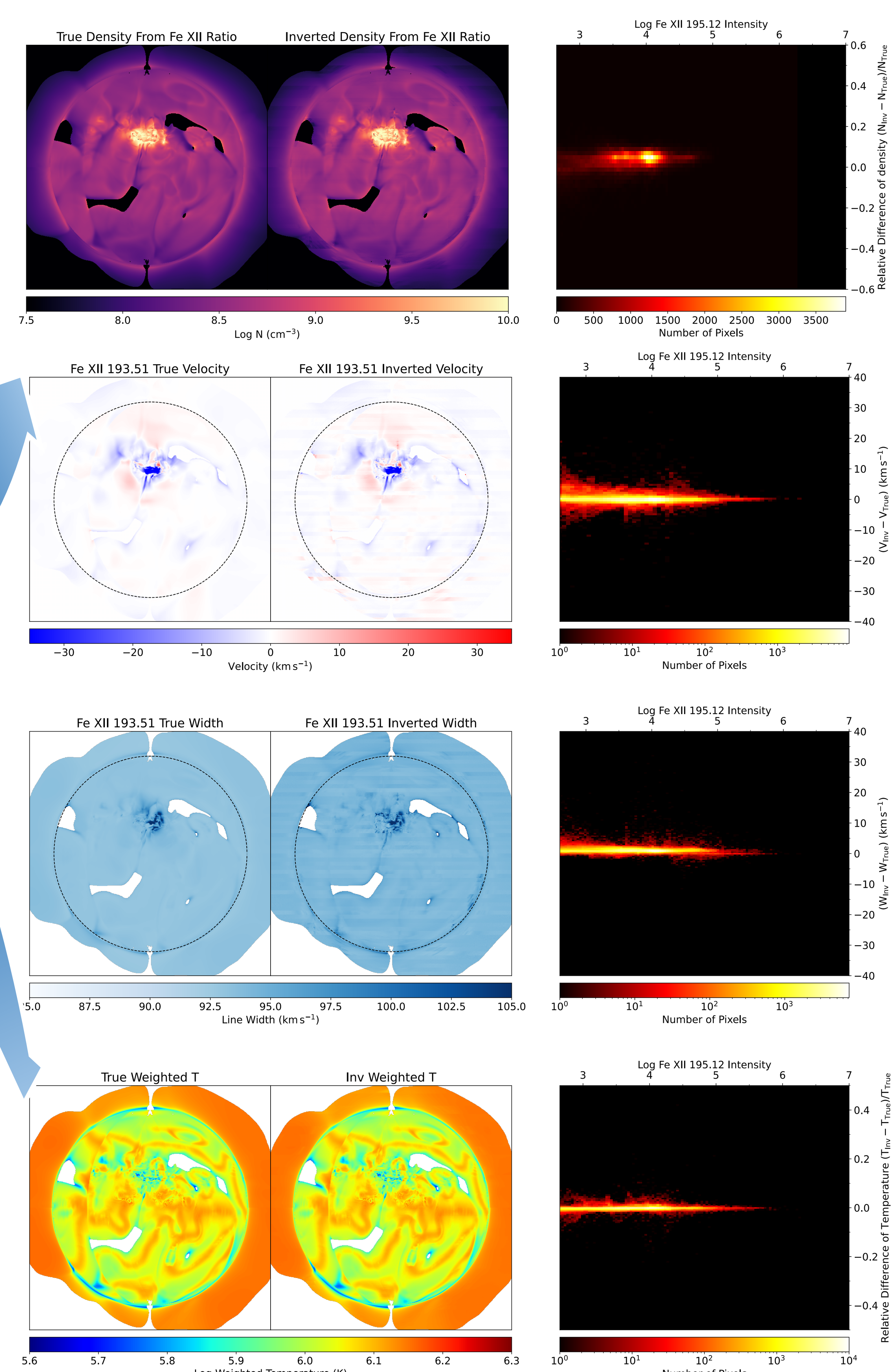

Fig. 4. Comparison of the ground truth (left column) and inversion (middle column) for different parameters by using the statistical results (the JPDFs in the right column)

- To solve the multi-slit confusion, we utilized a recently advanced **decomposition technique** to **separate the lines** from different slits.
- The decomposition problem can be simplified by solving a **linear system** $\mathbf{Y} = \mathbf{RX}$, which is usually underdetermined.
- Input 1: **PSI model**, a numerical model of the global corona, is utilized for synthesizing observation spectra $\mathbf{Y}$.
- Input 2: **Response matrix (R)**, generated based on CHIANTI, coupled with instrument parameters (e.g., effective area). It represents the **detector response of the spectrograph** across all spectral pixels at a certain slit, density, velocity and temperature (shown in the left bottom panel of Fig.2)
- Algorithm: **LassoLars**, optimizes solutions with **sparsity** by introducing L_1 norm.
- Output: **Inverted spectra**. We decomposed each 5-slit spectrum to extract the contributions from individual slits and combined them to create **global maps**.

3. Summary

We present an **efficient** scheme for providing spectral diagnostics of the **full disk**, including density, velocity, line width, and temperature with **high accuracy**. To minimize **multi-slit confusion**, we employ a **decomposition** method.

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