Fast Inversion of $\textit{MOSES}$ Data

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Abstract

The Multi-Order Solar Extreme Ultraviolet Spectrograph (MOSES) is a snapshot imaging spectrometer payload planned for launch from White Sands Missile Range in July, 2005. We describe the Smooth Multiplicative Algebraic Reconstruction Technique (SMART), a new algorithm for near real time reconstruction of line profile parameters from MOSES data. Though the technique was developed for generating a quick look data product, the results have high fidelity. In simulations, doppler shifts are reconstructed with $< 0.25$ pixel accuracy (RMS).
Multi-order concept

Concave multilayer grating

Imaging detectors

n = +1

n = 0

n = −1
Inversion = Tomography

\[ I(x) = I_0(x) + (x - \lambda) I_\infty(\lambda) \]

Images at \( n = -1, 0, +1 \)
Motivation

**MOSES** Allows us to take spectra simultaneously over a large field. Because there is no slit, the exposure can be very short. Since the **MOSES** field of view is $2048 \times 1024$ pixels, this amounts to a 1000-fold speed advantage over a slit spectrograph of comparable aperture and resolution.

Disentangling spatial and spectral information Can we turn the four projections $I_+(x + \lambda)$, $I_0(x)$, $I_-(x - \lambda)$ and $I_\infty(\lambda)$ back into $I(x, \lambda)$? And if so, how?
1. $G(x, \lambda) = I_0(x) I_\infty(\lambda)/N$  \hspace{1cm} \text{Initial guess.}

2. $[I'_0, I'_+, I'_-, I'_\infty] = TG$ \hspace{1cm} \text{Projection.}

3. $G = G \left[ \frac{I_0(x)}{I'_0(x)} \right]^\gamma \cdot \left[ \frac{I_+(x+\lambda)}{I'_+(x+\lambda)} \right]^\gamma \cdot \left[ \frac{I_-(x-\lambda)}{I'_-(x-\lambda)} \right]^\gamma \cdot \left[ \frac{I_\infty(\lambda)}{I'_\infty(\lambda)} \right]^\gamma$ \hspace{1cm} \text{Correction.}

4. $G = G \otimes \frac{1}{1+2a+2b} \begin{bmatrix} 0 & a & 0 \\ b & 1 & b \\ 0 & a & 0 \end{bmatrix}$ \hspace{1cm} \text{Smoothing.}

5. $[I'_0, I'_+, I'_-, I'_\infty] = TG$ \hspace{1cm} \text{Projection.}

6. Evaluate goodness of fit, $\chi_0^2, \chi_+^2, \chi_-^2$.

7. Adjust smoothing parameters, $a = a/(\chi_+^2 \chi_-^2); b = b/\chi_0^2$.

8. Loop to (3).
Reconstruction Simulations

We used a single SUMER raster containing O III λ 703.87 and Mg IX λ 706.02 as our “true” Sun. These lines resemble the He II λ 303.8 and Si XI λ 303.3 that will be observed by MOSES. The data cube was rescaled to 300 counts per (x, y) pixel.

1. Velocities were measured by centroiding the SUMER O III line.
2. Added shot noise and re-measured the line centers.
3. Projection of MOSES orders \( m = -1, 0, +1 \) plus noise.
4. Reconstructed data cube using SMART.
5. Measured velocities from the reconstructed spectra.
SMART example

True velocity (SUMER data)

Data resampled with shot noise (0.12 pixel RMS)

Reconstruction from *MOSES* projections (0.20 pixel RMS)
RMS error 0.12 pixels. This represents response of an idealized slit spectrograph.
RMS error 0.20 pixels. Reconstruction from multi-order data systematically underestimates velocity.
Each bar is a bin of 281 pixels. The reconstruction (black) has $\chi_R^2$ trending upward with brightness.
Line separation

It is challenging to isolate the coronal line, which is nearly an order of magnitude weaker than the TR line.

The recovered coronal image is distinctly recognizable, though some of the transition region fine structure “shows through”.

O III

Mg IX

True

SMART
Conclusions

- Reconstruction of velocities by fast inversion of \textit{MOSES} data has been demonstrated with $< 0.25$ pixel (RMS) accuracy.

- Velocities are systematically underestimated. Artifacts generally are systematic, not noise induced.

- Regions with strong signal are underfitted, while regions with weak signal are overfitted. We plan to attack this problem by varying the smoothing parameters over the image.

- It is possible to recover a weak coronal line adjacent to a strong transition region line.
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