

Inversion of *MOSES* Data

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2004 June

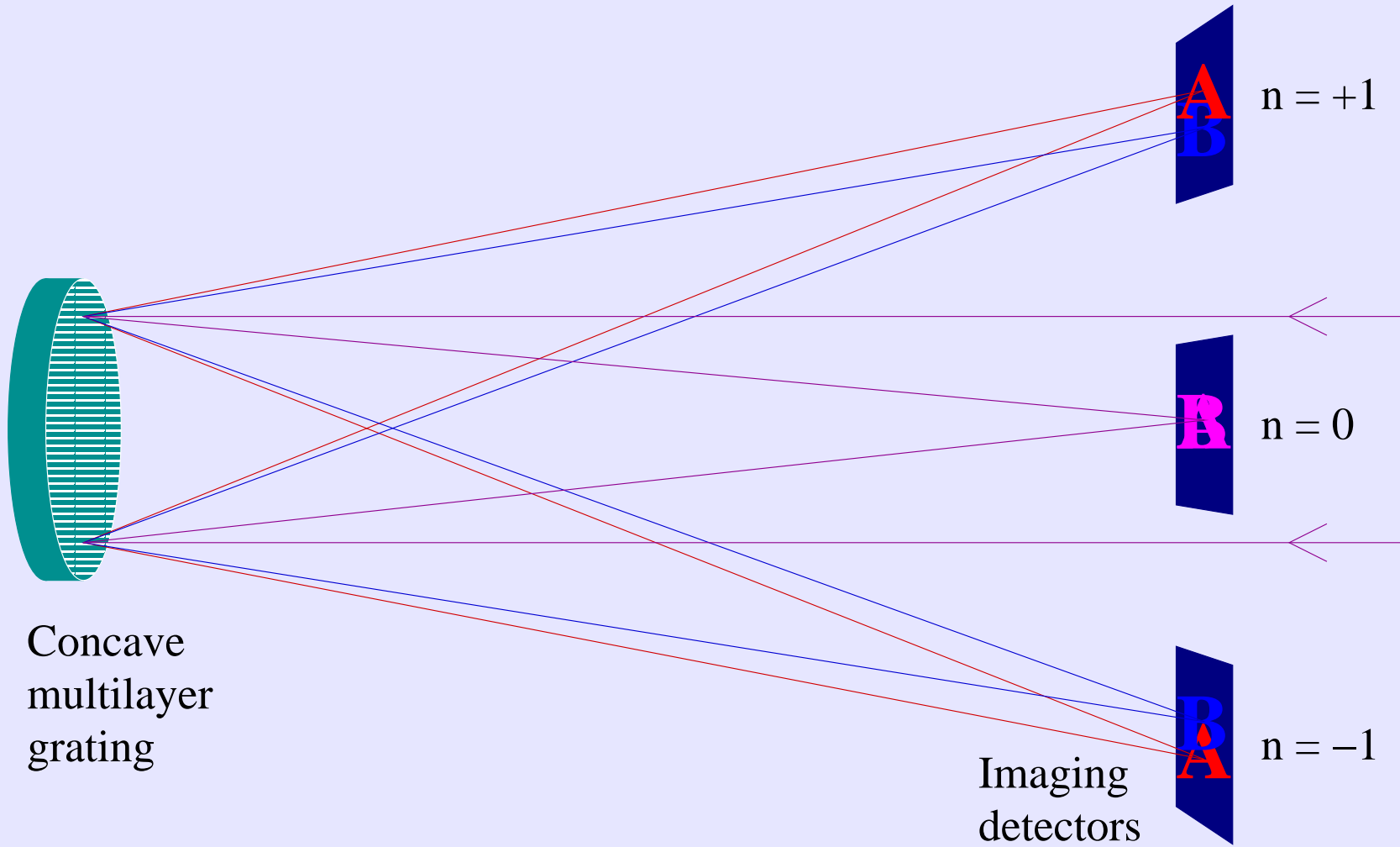


Abstract

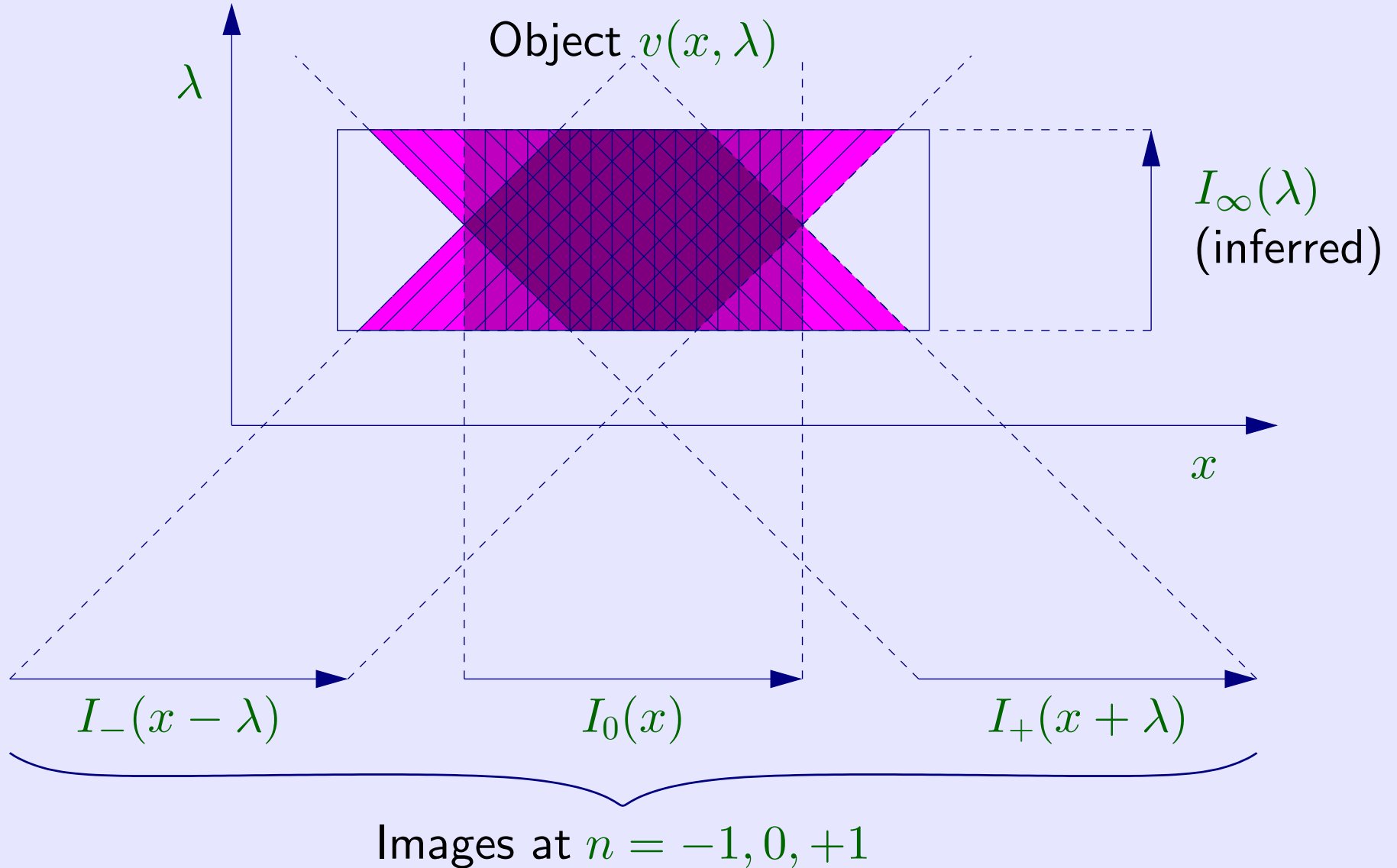


The *Multi-Order Solar Extreme Ultraviolet Spectrograph (MOSES)* is a snapshot imaging spectrometer payload planned for launch from White Sands Missile Range in July, 2005. We describe the Smooth Multiplicative Algebraic Reconstruction Technique (SMART), a new algorithm for near real time reconstruction 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



Inversion = Tomography





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 2048×1024 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?

Smooth Multiplicative Algebraic Reconstruction Technique

1. $G(x, \lambda) = I_0(x) I_\infty(\lambda) / N$ Initial guess.
2. $[I'_0, I'_+, I'_-, I'_\infty] = T G$ Projection.
3. $G = G \left[\frac{I_0(x)}{I'_0(x)} \right]^\gamma \cdot \left[\frac{I_+(x+\lambda)}{I'_+(x+\lambda)} \right]^\gamma \cdot \left[\frac{I_-(x-\lambda)}{I'_-(x-\lambda)} \right]^\gamma \cdot \left[\frac{I_\infty(\lambda)}{I'_\infty(\lambda)} \right]^\gamma$ Correction.
4. $G = G \otimes \frac{1}{1+2a+2b} \begin{bmatrix} 0 & a & 0 \\ b & 1 & b \\ 0 & a & 0 \end{bmatrix}$ Smoothing.
5. $[I'_0, I'_+, I'_-, I'_\infty] = T G$ 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).



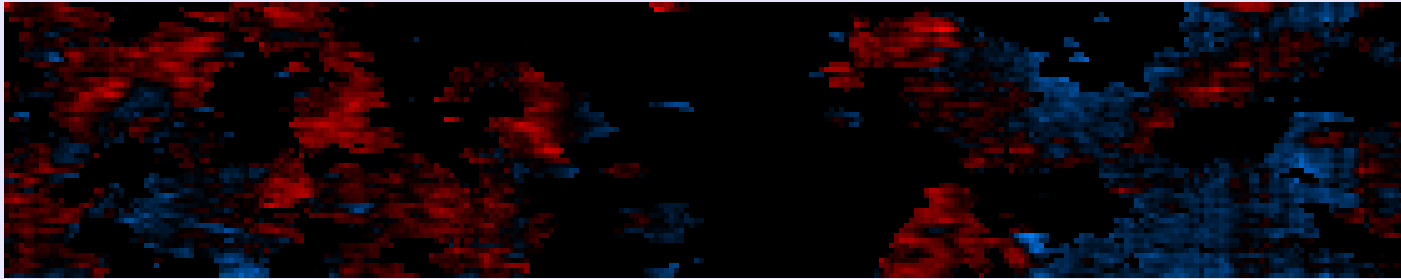
Reconstruction Simulations



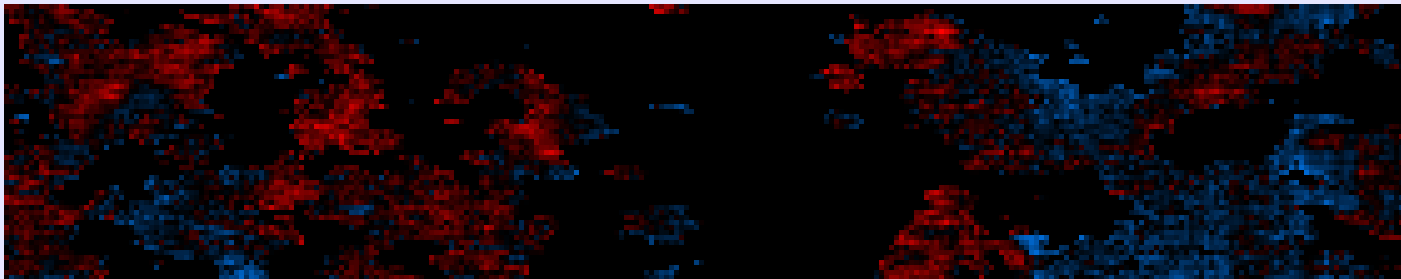
We used a single SUMER raster containing O III $\lambda 703.87$ and Mg IX $\lambda 706.02$ as our “true” Sun. These lines resemble the He II $\lambda 303.8$ and Si XI $\lambda 303.3$ that will be observed by *MOSES*. The data cube was rescaled to 300 counts per (x, y) pixel.

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.

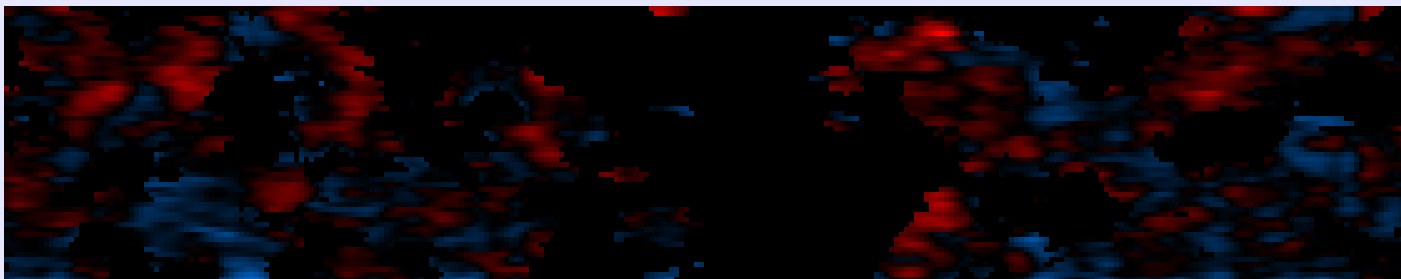
SMART example



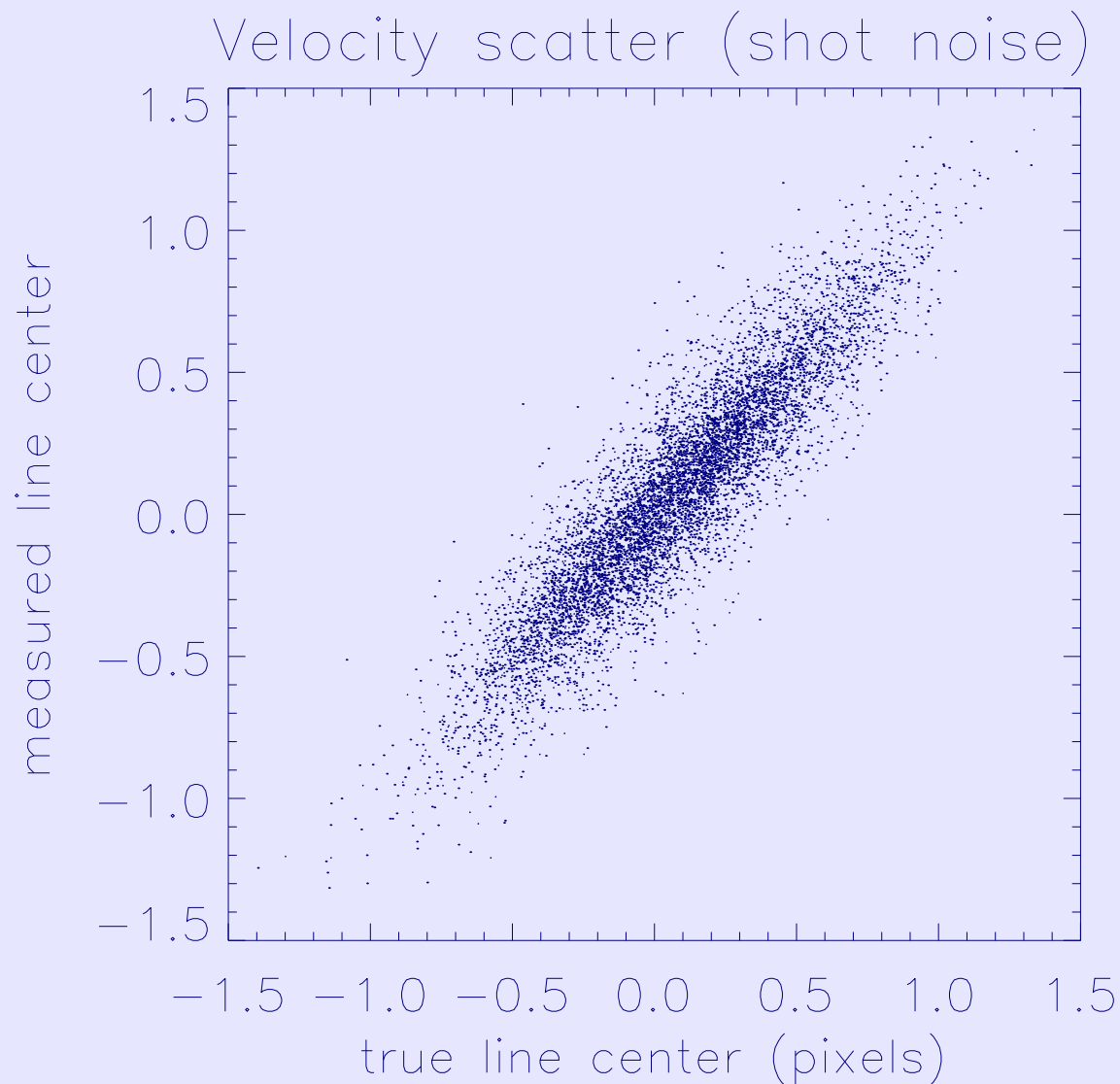
True velocity (SUMER data)



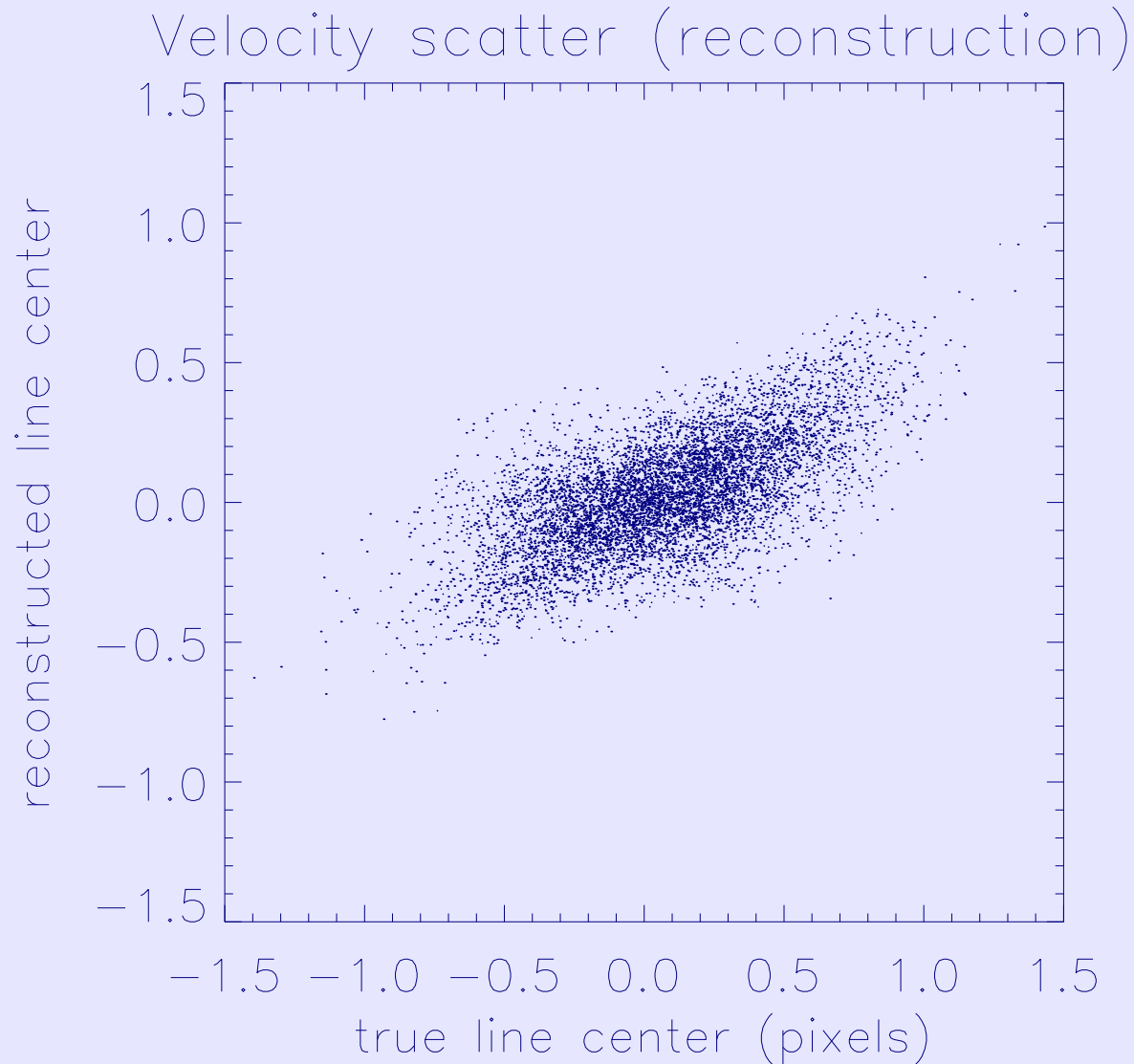
Data resampled with shot noise (0.12 pixel RMS)



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.

Line separation

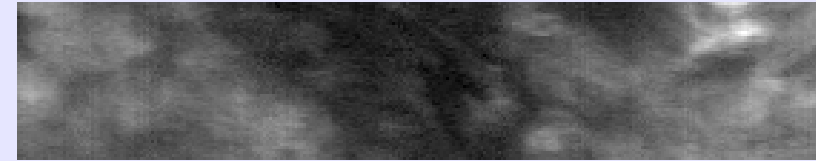
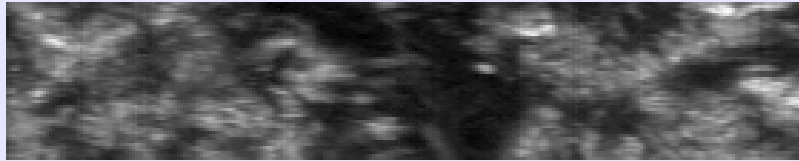


It is challenging to isolate the coronal line, which is nearly an order of magnitude weaker than the TR line.

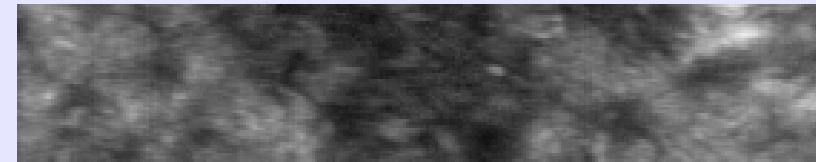
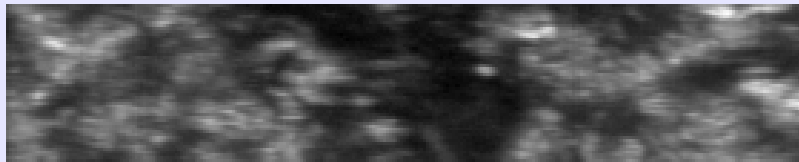
O III

Mg IX

True



SMART



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



Algorithm Speed



Approximate time for inversion of a 280×1 pixel FOV (on a slow laptop).

<i>Algorithm</i>	<i>Time</i>
Simulated annealing	10 hr
Fourier	2 min
SMART	1 sec



Summary



- Problems solved:
 - Speed: SMART converges in 15 iterations. Inversion of (~ 1 GB) *MOSES* data in 1 day.
 - Regularization. Global $\chi_R^2 = 1$.
 - Sub-pixel (~ 0.2 pixel RMS) velocity measurement in He II.
 - Separation of weak coronal line (Si XI).
- Remaining issues:
 - Velocities are systematically underestimated.
 - Bright pixels are underfitted, dim pixels are overfitted. Probably because my χ_R^2 has the wrong form for dim pixels.
 - $I_\infty(\lambda)$: How to infer integrated line ratios?



Acknowledgments



Thanks to Louise Harra for providing the reduced SUMER data cube.

MOSES is a collaboration of Montana State University, Goddard Space Flight Center, Mullard Space Science Laboratory and Lockheed-Martin Solar and Astrophysics Laboratory.

The *MOSES* rocket project is sponsored by NASA grant NAG5-10997.