

# Fast Inversion of *MOSES* Data

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# Abstract



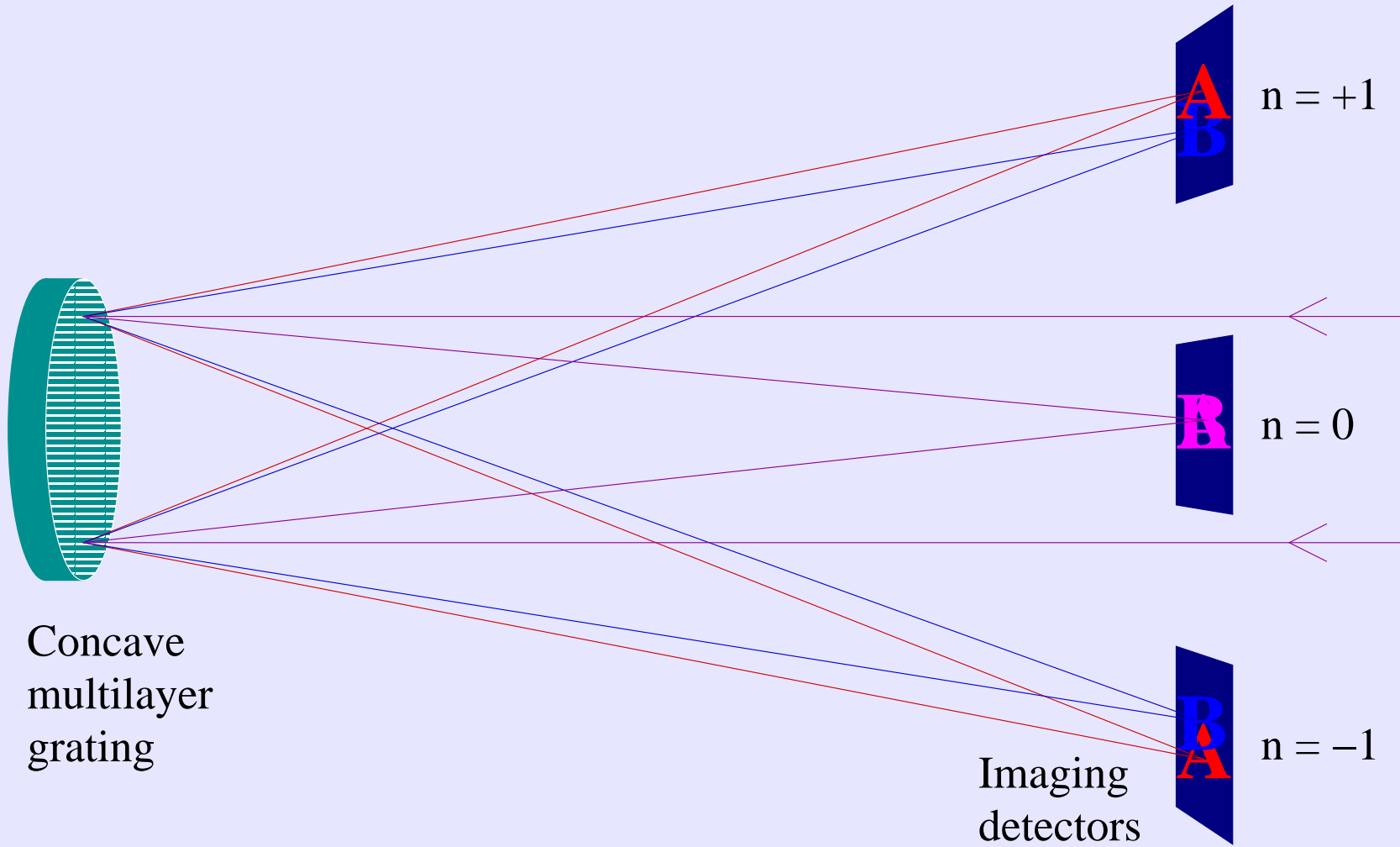
The *Multi-Order Solar Extreme Ultraviolet Spectrograph (MOSES)* is a snapshot imaging spectrometer payload planned for launch from White Sands Missile Range in July, 2005. We describe the Smooth Multiplicative Algebraic Reconstruction Technique (SMART), a new algorithm for near real time reconstruction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

# *MOSES* Optical I&T

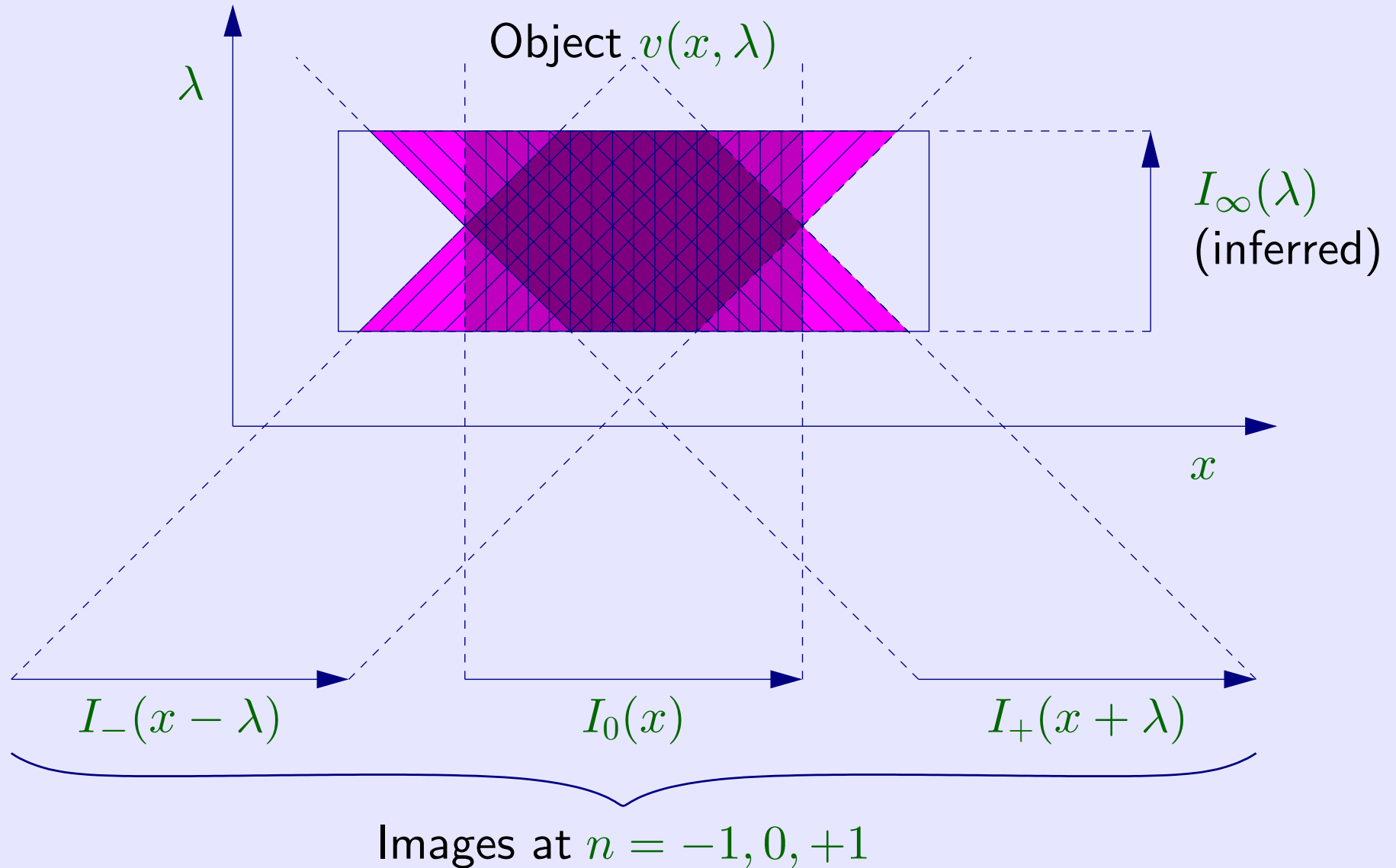


May 27, 2004

# 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  $2048 \times 1024$  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?

# 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

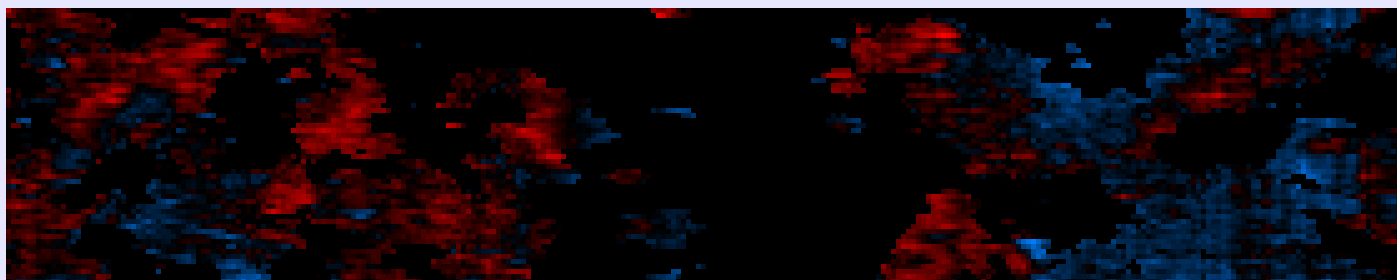


We used a single SUMER raster containing O III  $\lambda 703.87$  and Mg IX  $\lambda 706.02$  as our “true” Sun. These lines resemble the He II  $\lambda 303.8$  and Si XI  $\lambda 303.3$  that will be observed by *MOSES*. The data cube was rescaled to 300 counts per  $(x, y)$  pixel.

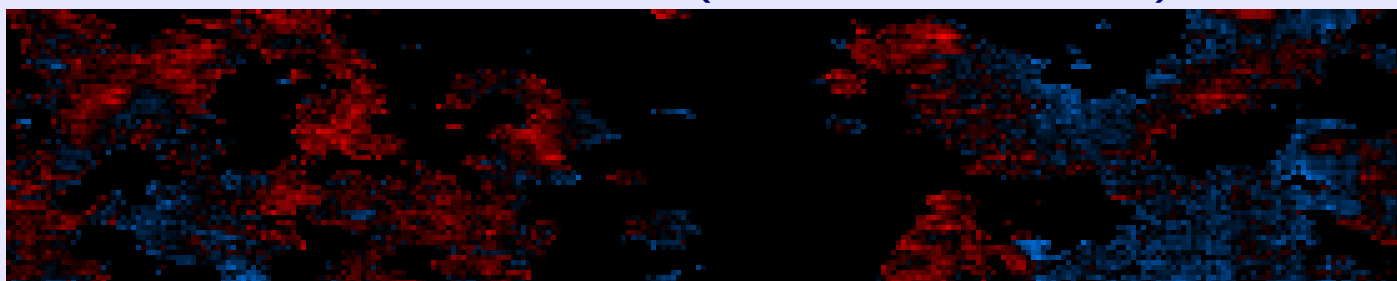
1. Velocities were measured by centroiding the SUMER O III line.
2. Added shot noise and re-measured the line centers.
3. Projection of *MOSES* orders  $m = -1, 0, +1$  plus noise.
4. Reconstructed data cube using SMART.
5. Measured velocities from the reconstructed spectra.



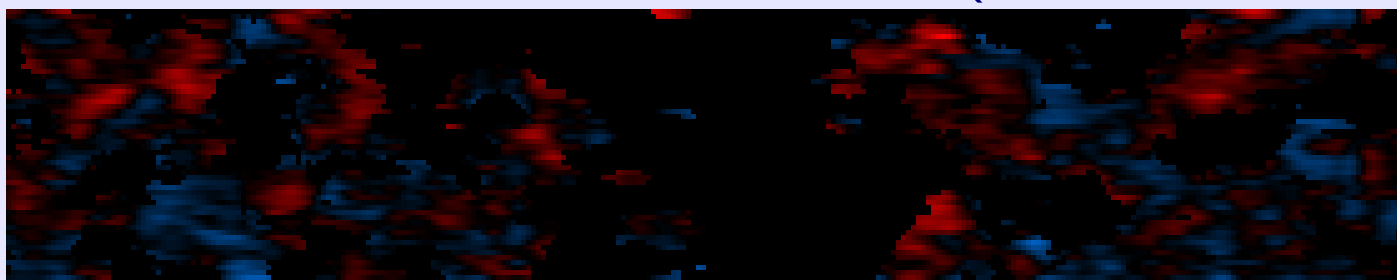
# SMART example



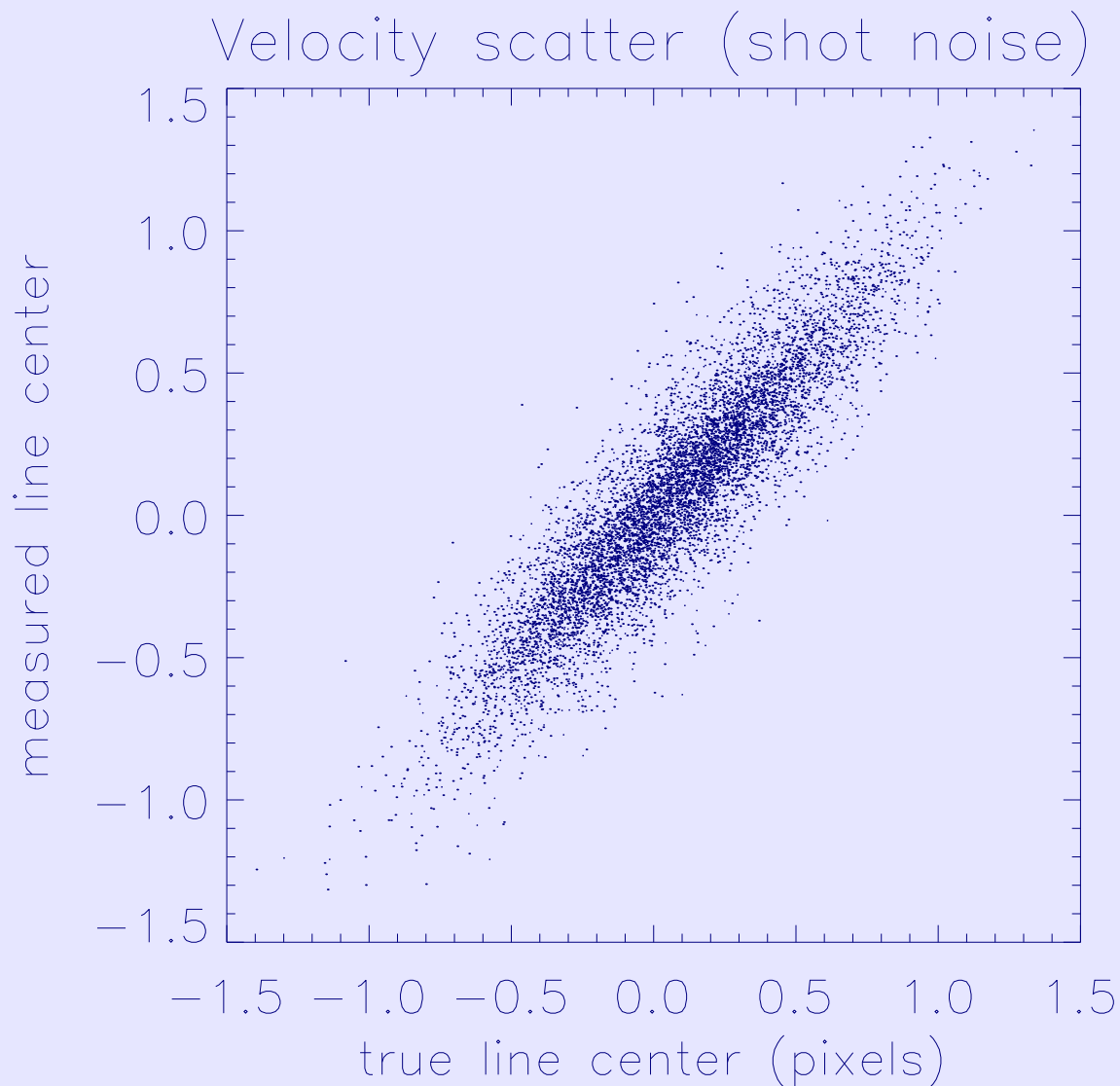
True velocity (SUMER data)



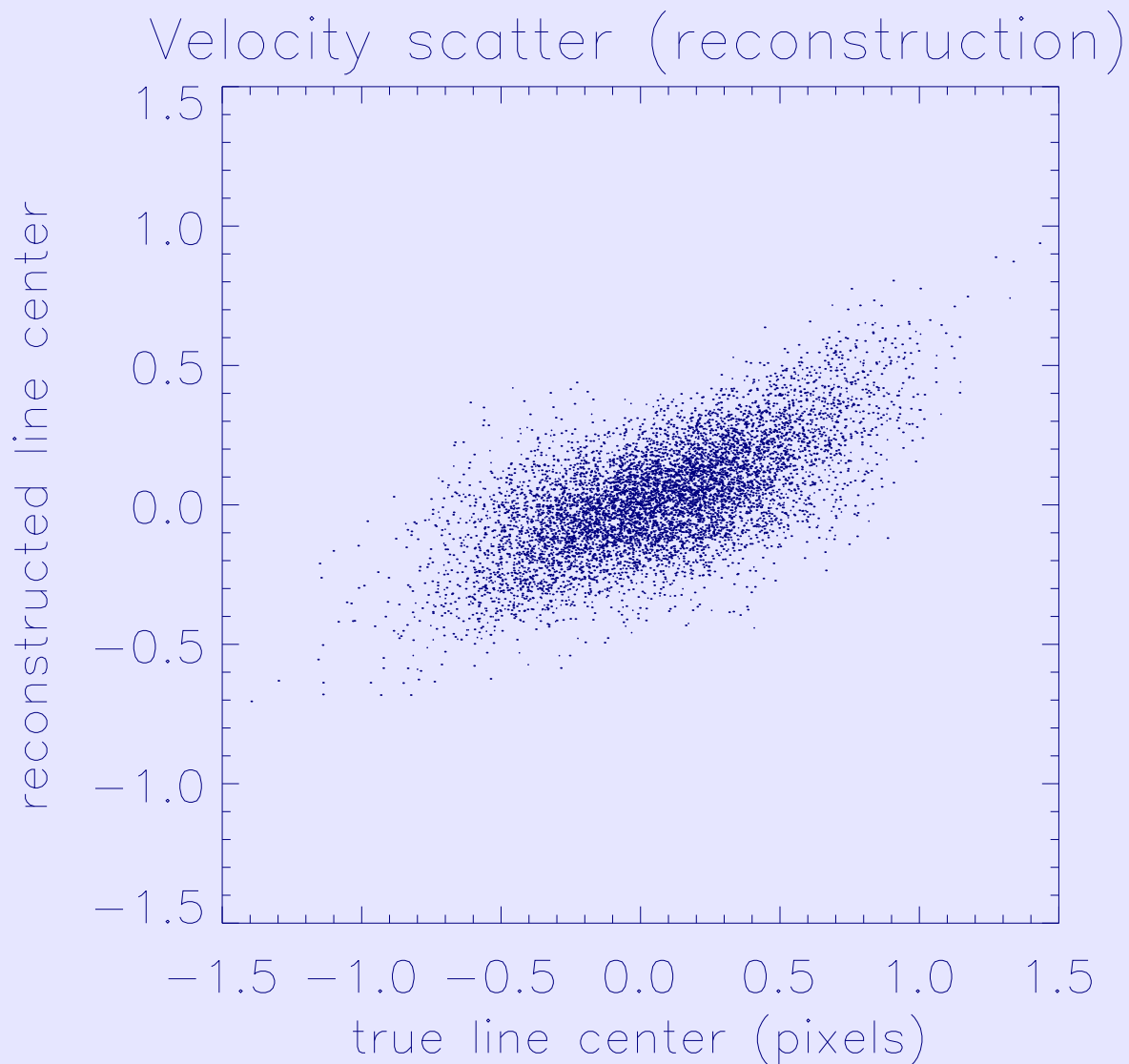
Data resampled with shot noise (0.12 pixel RMS)



Reconstruction from *MOSES* projections (0.20 pixel RMS)

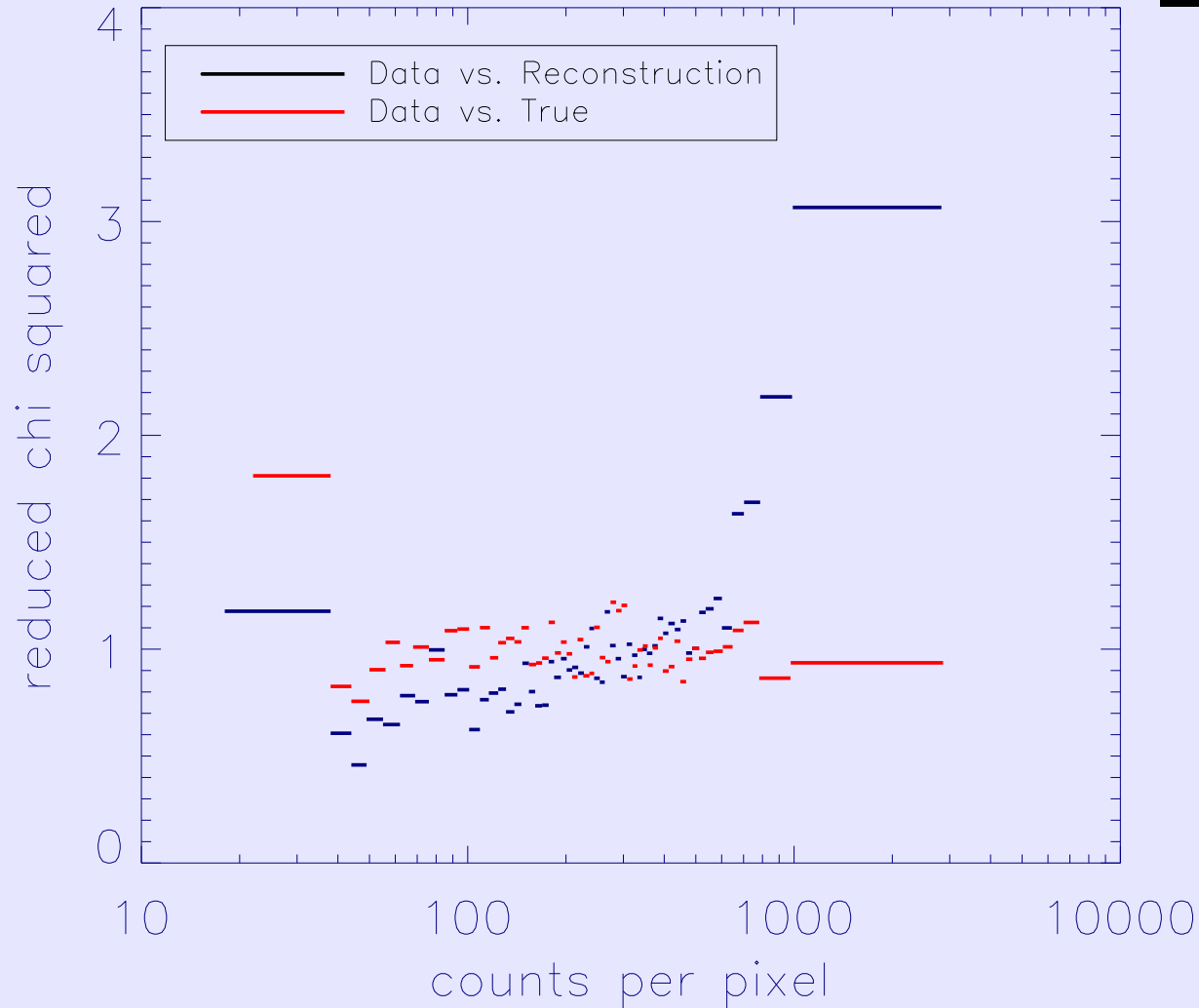


RMS error 0.12 pixels. This represents response of an idealized slit spectrograph.



RMS error 0.20 pixels. Reconstruction from multi-order data systematically underestimates velocity.

## An Uneven Fit



Each bar is a bin of 281 pixels. The reconstruction (black) has  $\chi_R^2$  trending upward with brightness.

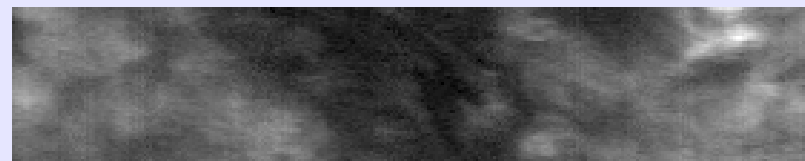
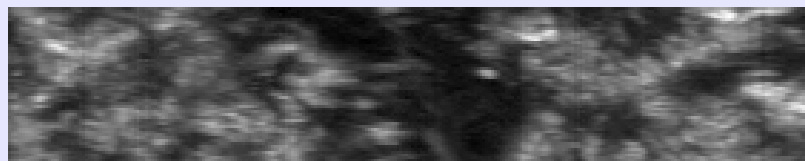
# Line separation

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

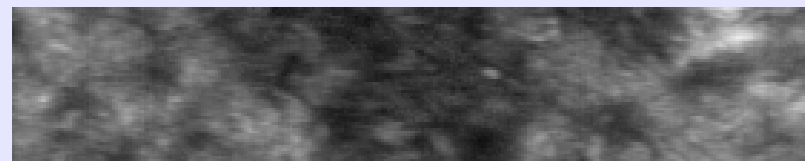
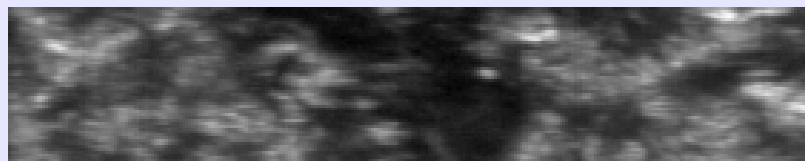
O III

Mg IX

True



SMART



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



# Conclusions



- Reconstruction of velocities by fast inversion of *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.



# Acknowledgments



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