MOSES Instrument and Data Inversion

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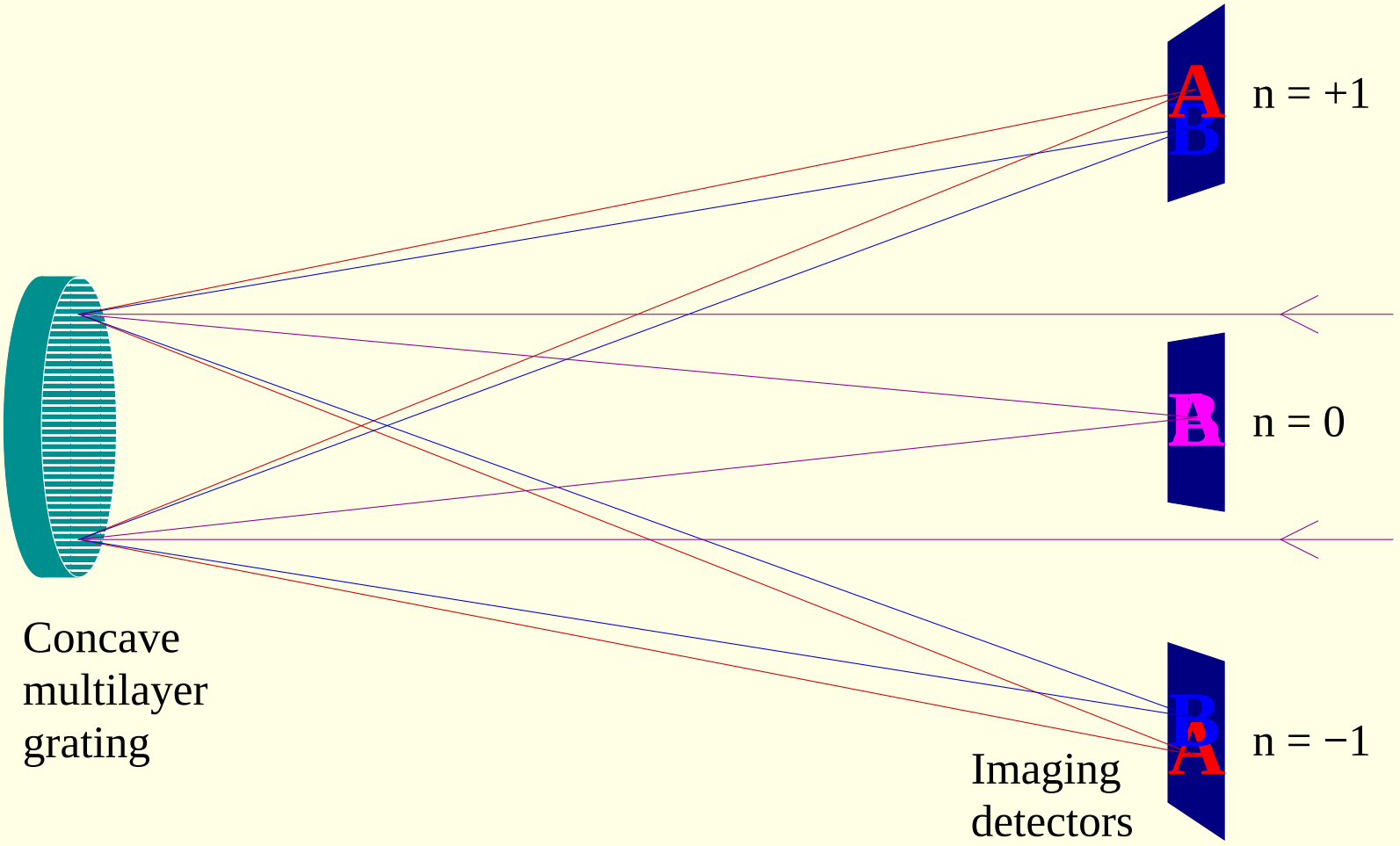
MSSL *Solar Orbiter* Imager — 2003 Oct 16

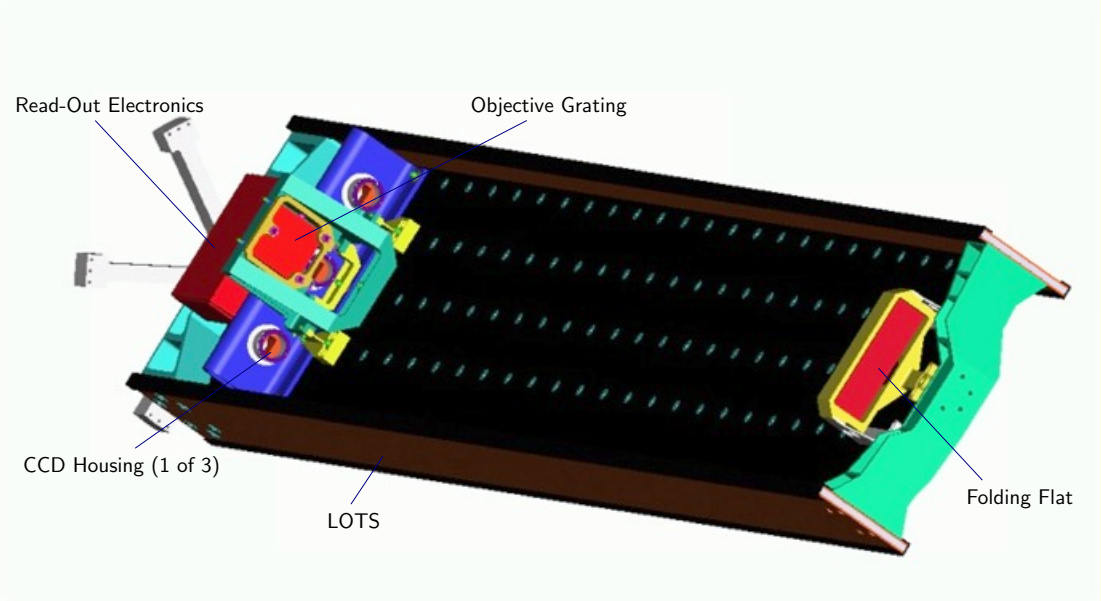
Outline — Instrument

- *MOSES* instrument concept
- Rocket instrument
- Benefits and costs
- Design approach for *Solar Orbiter*
- Specific design possibilities
- Conclusions

MOSES—Multi-Order Solar EUV Spectrograph



Rocket Instrument



1. Flight hardware complete—February, 2004
2. Calibration, I&T—Spring, 2004
3. Flight—Summer, 2004

Benefits and Costs

Benefits:

- Speed ($100 - 1000\times$ comparable slit spectrograph)
- Simultaneity (no scanning in space or spectrum)

Costs:

- Detector real estate
- Inversion

Design Approach for Orbiter

1. Establish constraints (telemetry, volume, mass)
2. Choose lines and parameters to measure
3. Choose orders and dispersion
4. Verify inversion
5. Iterate & optimize

Design Possibilities

- Gregorian layout
  - Magnification (compactness)
  - Field stop (edge effects, spectral selectivity)
  - TVLS gratings (Poletto & Thomas 2003)
- Multiple orders per detector
  - More spectral parameters, less ambiguity
  - Trade off: more detectors, or multiple orders per detector
    Example: $4\,\mathrm{k} \times 4\,\mathrm{k}$ detector, 75 km pixels, 4 orders, 150,000 km FOV (leaving 96 pixel margin between orders).

Conclusions

- New capability: simultaneous measurement of spectral parameters in a narrow band, over a large 2D field of view.
- Propose specific observables as a starting point for design (Thanks Ben!)

Inversion—Outline

- Inversion problems in solar physics
- Tomography in hybrid space (x, λ)
- Fourier backprojection
- Pixon reconstruction
- Discussion
- Conclusions
- Next Steps

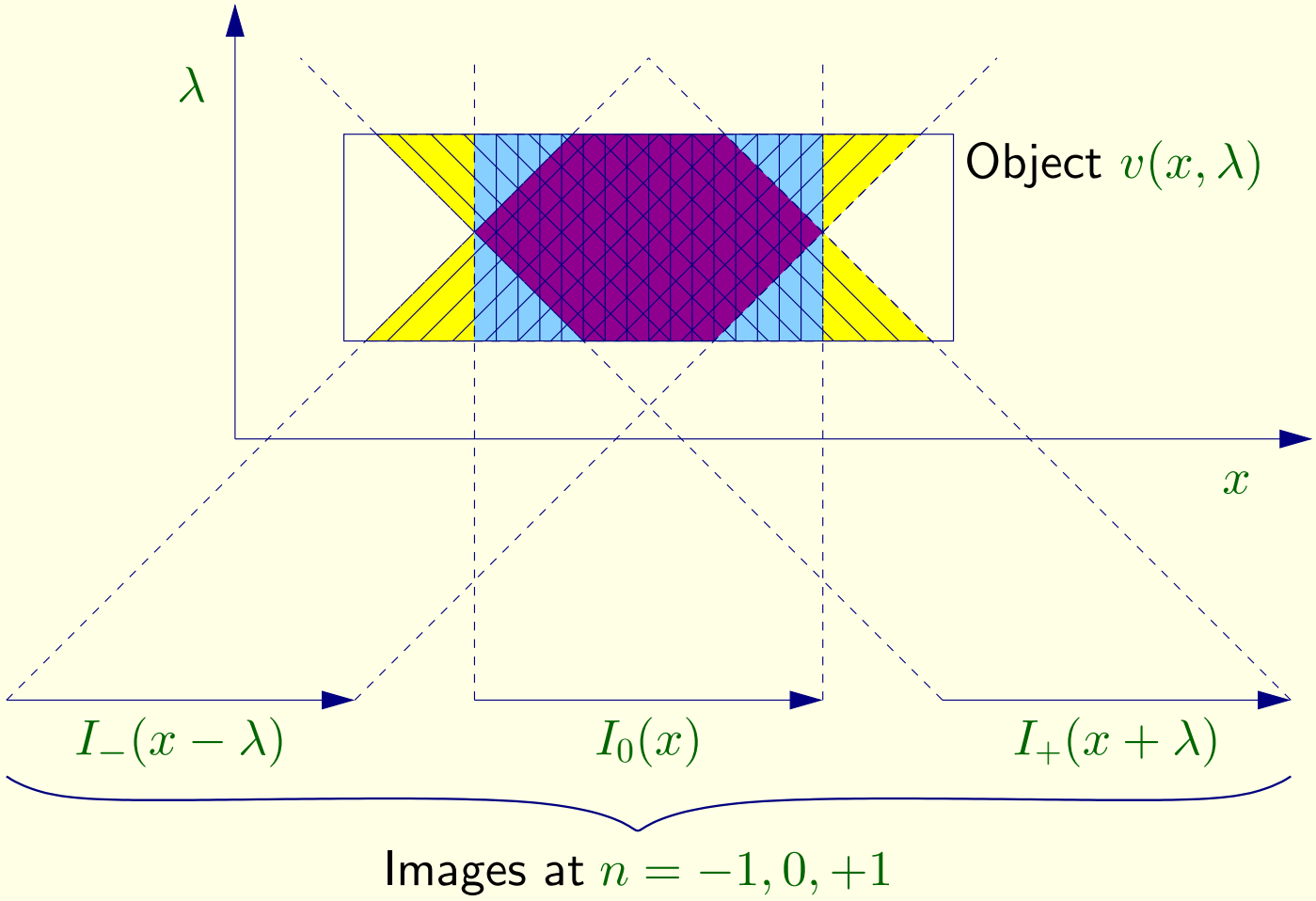
Inversion

Inversion problems are endemic to remote sensing, and to solar physics in particular:

- *MOSES*
- Differential emission measure
- Coded-aperture imagers (HXT, RHESSI)
- Magnetography

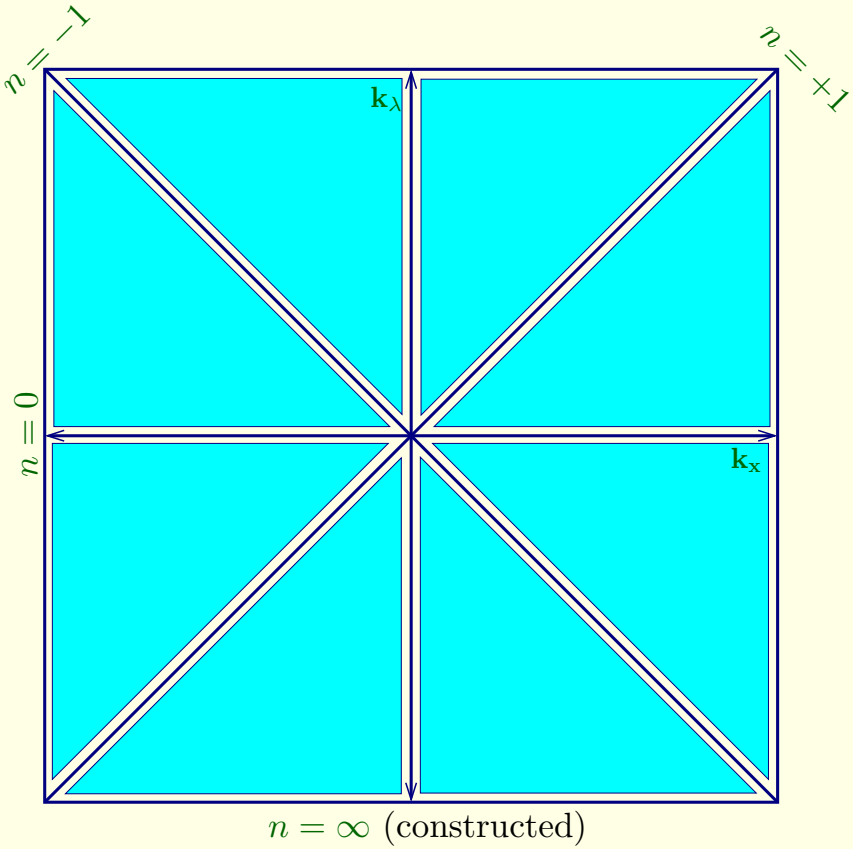
For example, magnetography requires simplifying assumptions about the spectrum in a pixel.

Inversion = Tomography



Fourier Backprojection

- Each projection corresponds to a slice in the Fourier transform of $I(x, \lambda)$.
- Include horizonal projection, $I_\infty(\lambda) = \int I(x, \lambda)\, dx$
- Iterate to enforce $I(x, \lambda) > 0$.

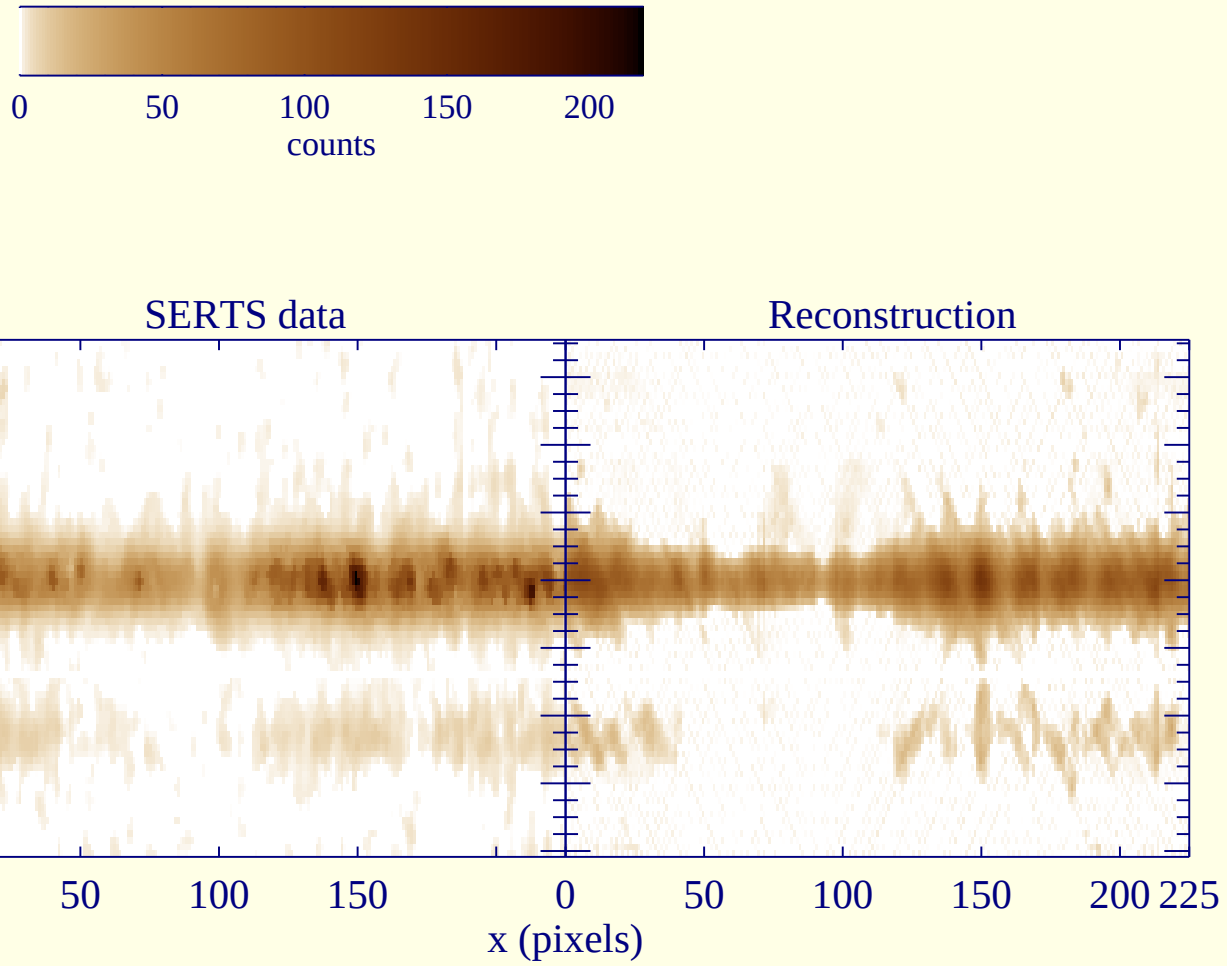


Characterizing $I_\infty(\lambda)$

The inversion relies on knowing $I_\infty(\lambda)$, which is not measured directly.

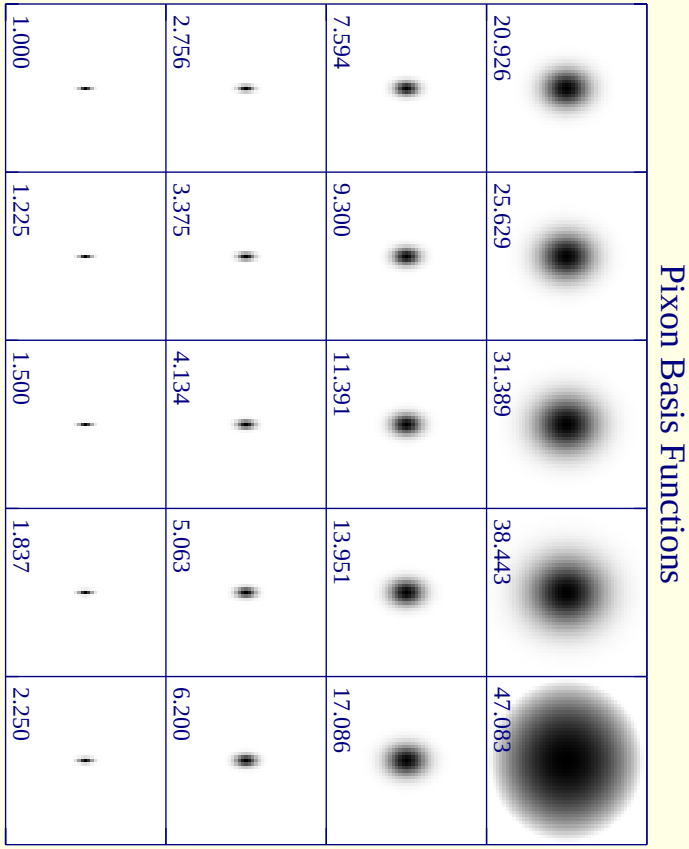
- He II line center can be derived from the data (and the 3 orders co-aligned) by cross-correlation.
- He II line width can be inferred in at least two ways:
  - Knowledge of typical solar values plus instrumental linewidth.
  - Convergence of iteration for non-negativity.
- Si XI contribution does not significantly influence results for He II profile.

Fourier Results

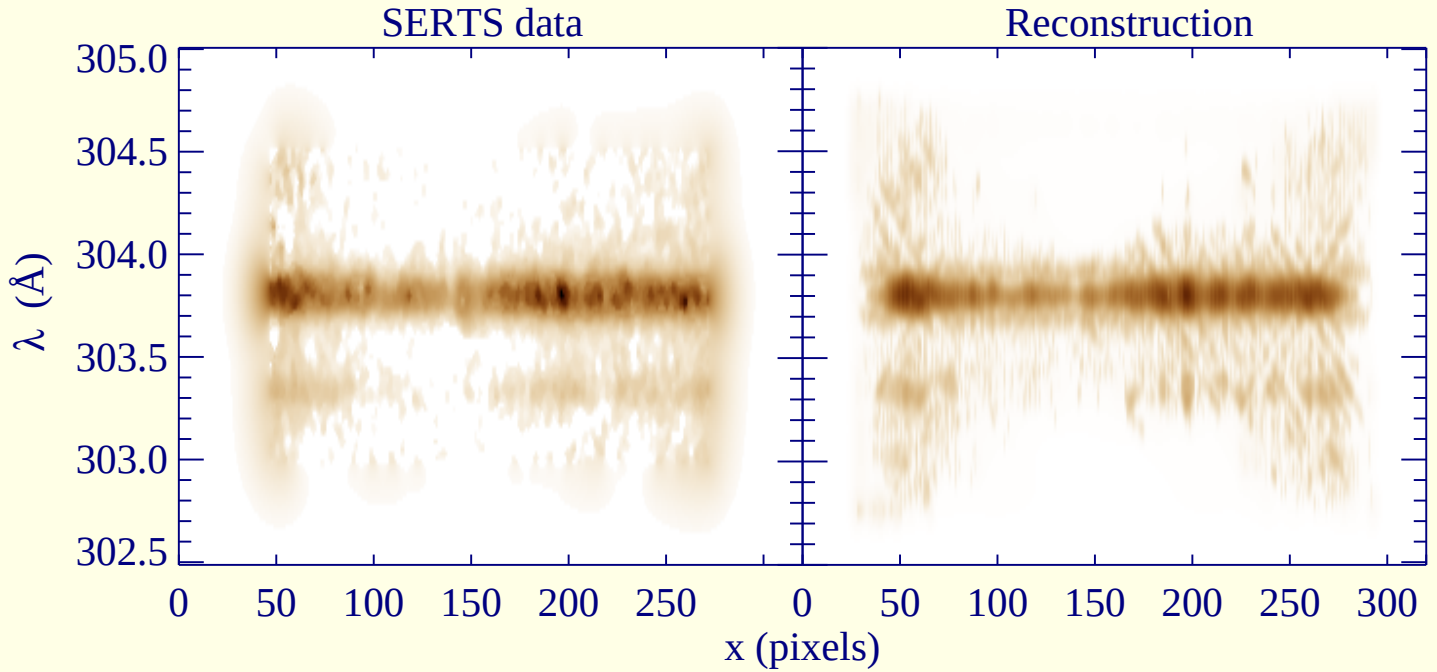


Pixon Reconstruction

- Incomplete fuzzy Pixon basis
- χ^2 goodness of fit
- Fit the data using the least information.
- Include horizonal projection $I_\infty(\lambda)$



Pixon Results

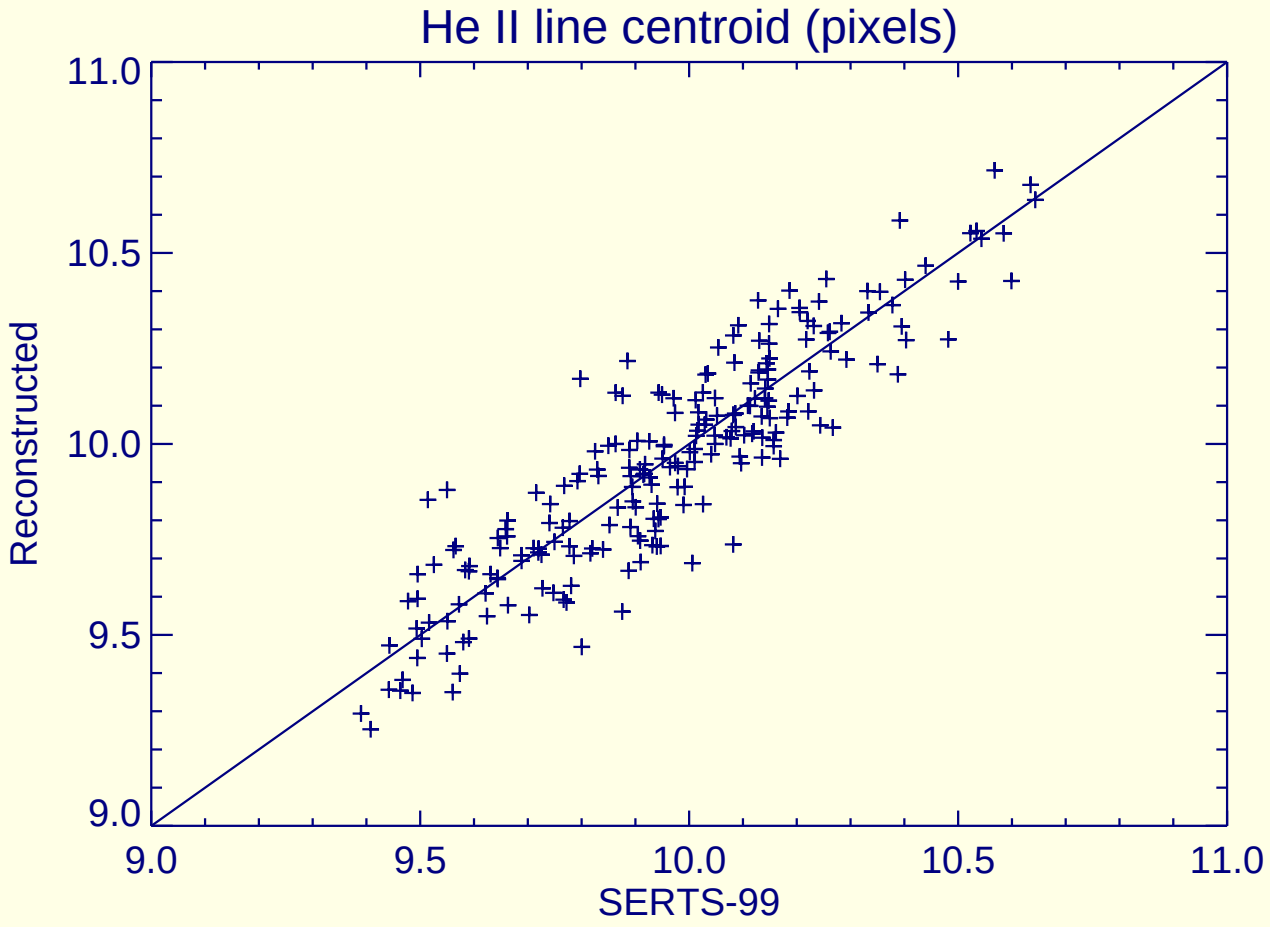


Comparison of results

Differences between true and reconstructed line profile parameters. Line center and linewidth errors are in pixels. For each parameter, a mean offset and RMS error are given. One *MOSES* pixel is approximately 20 mÅ (20 km/s at 304 Å).

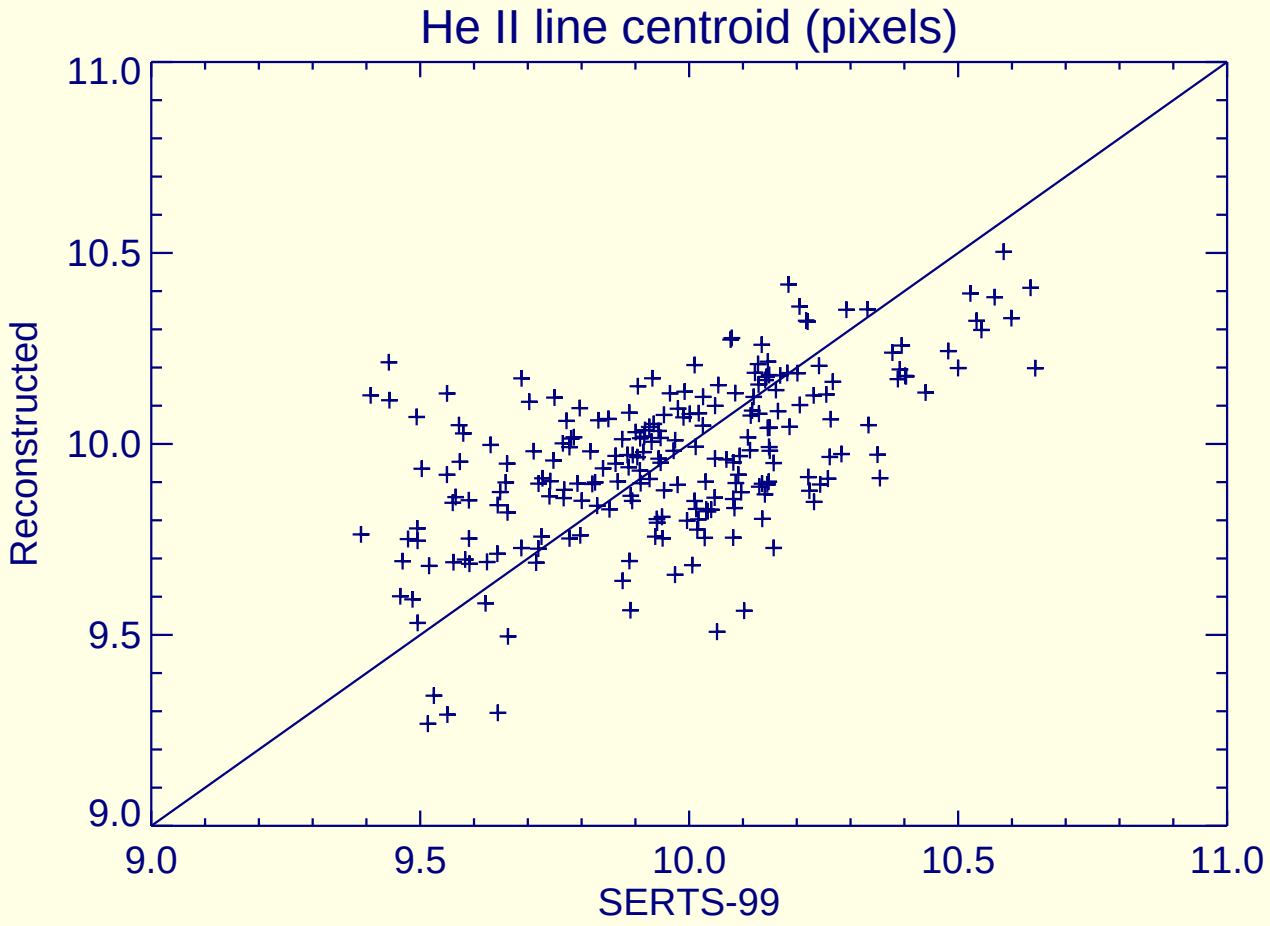
Algorithm	center (median) mean	RMS	width (quartiles 1-3) mean	RMS
Fourier	-0.01	0.32	-0.19	0.97
Pixon	-0.04	0.36	-0.04	0.59

Slit spectrograph



Centroiding error due to Poisson noise only.

MOSES backprojection



The glass is half full: if error is systematic, perhaps it can be corrected.

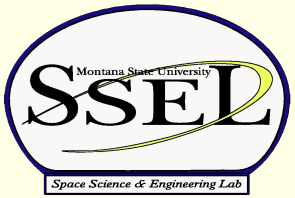
Conclusions

- Inversion demonstrated by both Fourier and Pixon methods.
- He II is recovered, but not the weaker Si XI.
- Doppler shift reconstructed to $\frac{1}{3}$-pixel accuracy.
- Linewidth is reconstructed best by pixons (0.6 pixel).
- Exploring several avenues to improve performance.

A paper is in press for *Proc. SPIE*. Preprints available upon request.

Next Steps

- Complete the Pixon algorithm (Fox & Metcalf).
- Parametric forward modeling (Fox).
- Understand and correct systematic errors in reconstruction.
- Quantify benefits of adding more orders (Theissen).
- Simulation/validation of specific wavelength options for *Orbiter* (Dobke).



Acknowledgments

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