Characteristics of the *Roman* Prism

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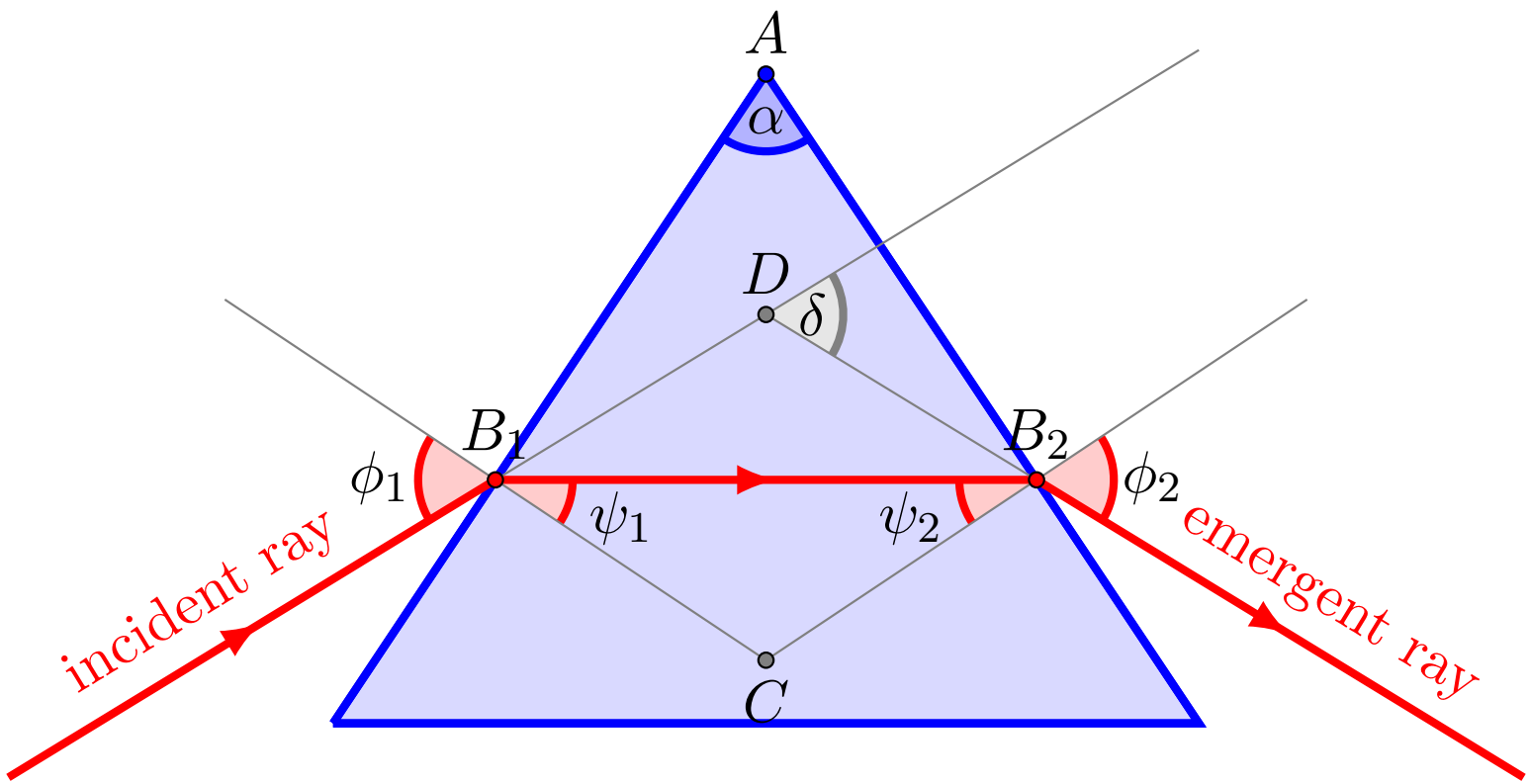
How prism works

- Refraction: light bends when it passes from one medium to another.
- The bending (non-linearly) depends on the wavelength of the light:

$$n^2 = 1 + \sum_{i=1}^{3} \frac{B_i \lambda^2}{\lambda^2 - C_i}, \tag{1}$$



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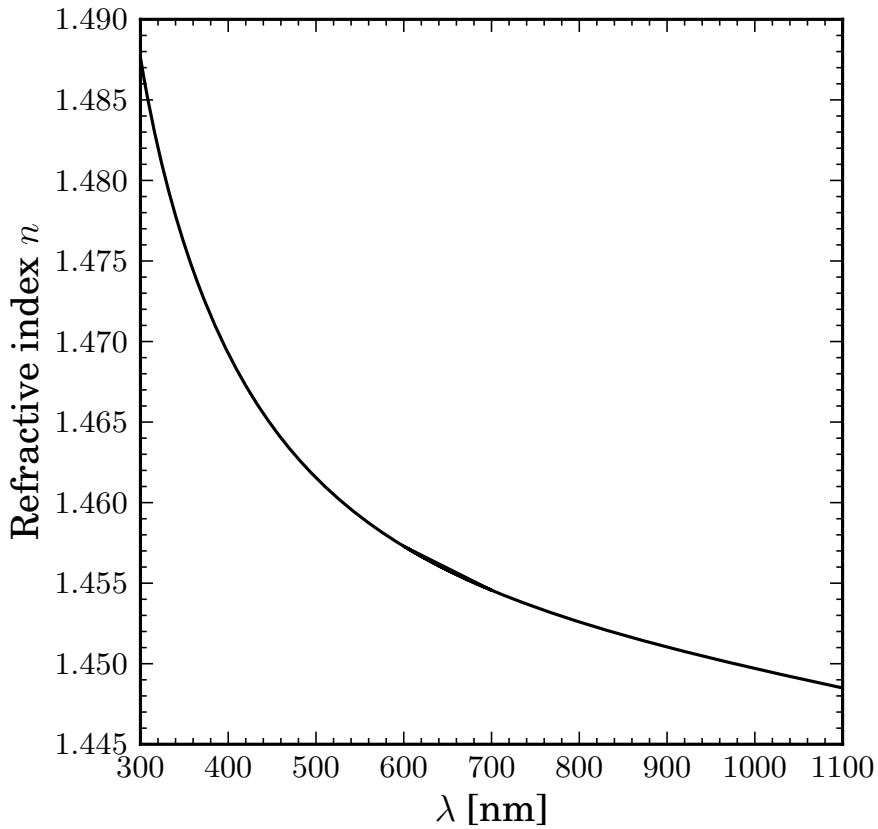
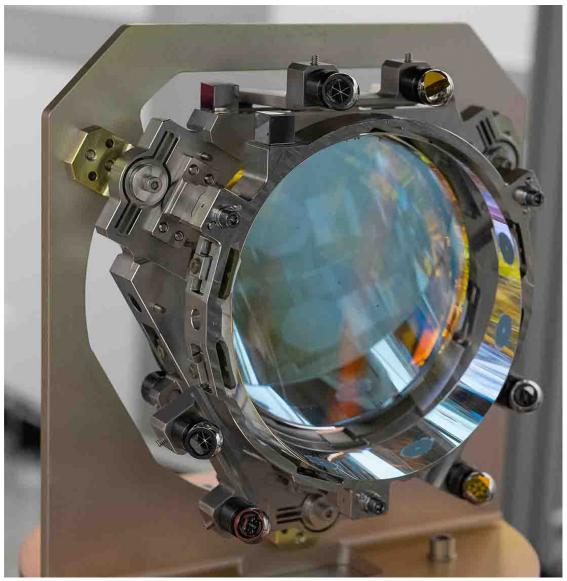
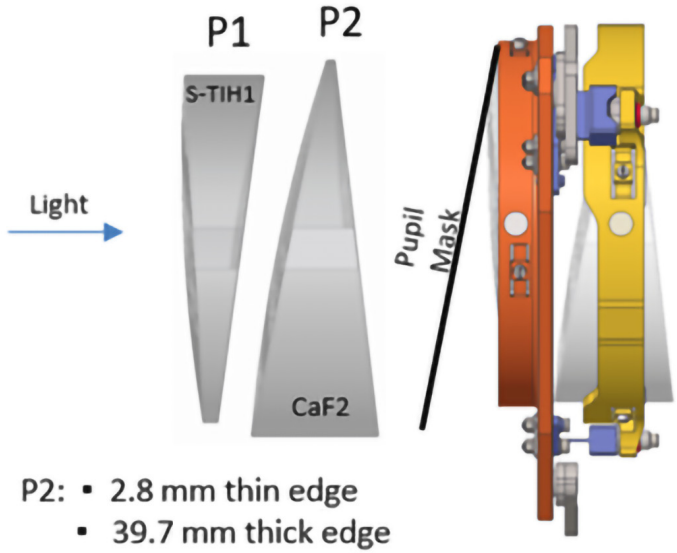
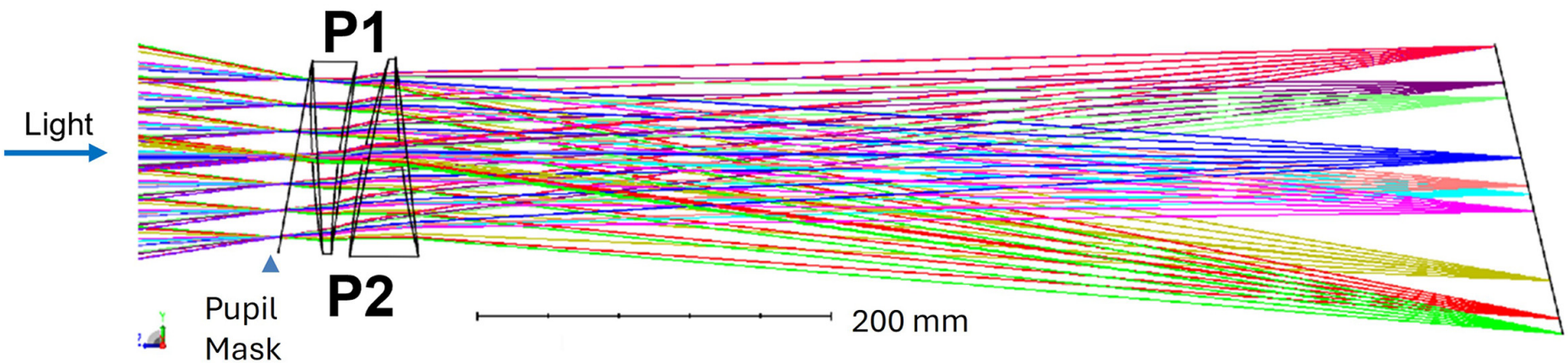


Introducing *Roman* prism

Of course real life is not as simple as textbook...

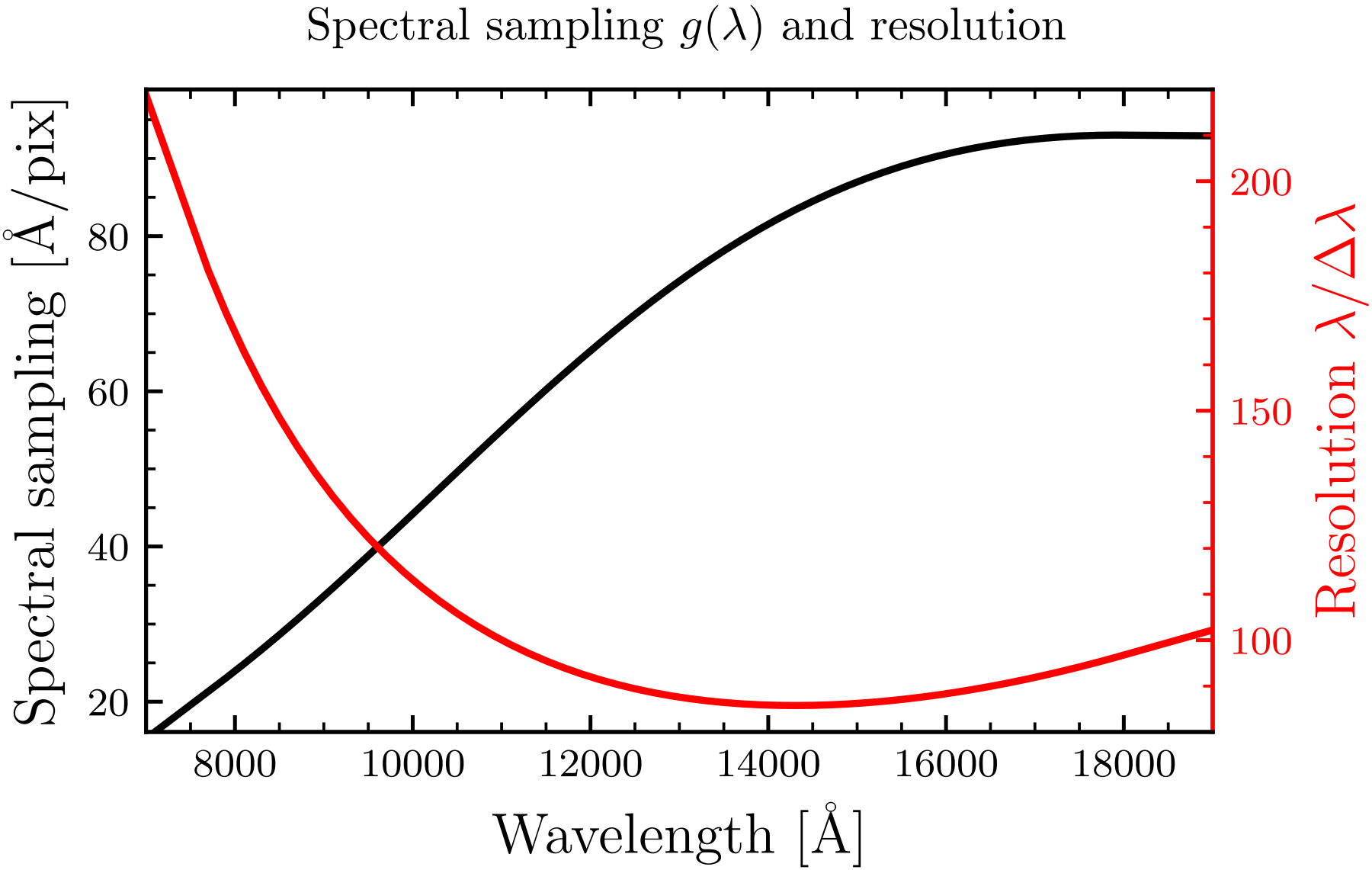






Eegholm et al. 2025

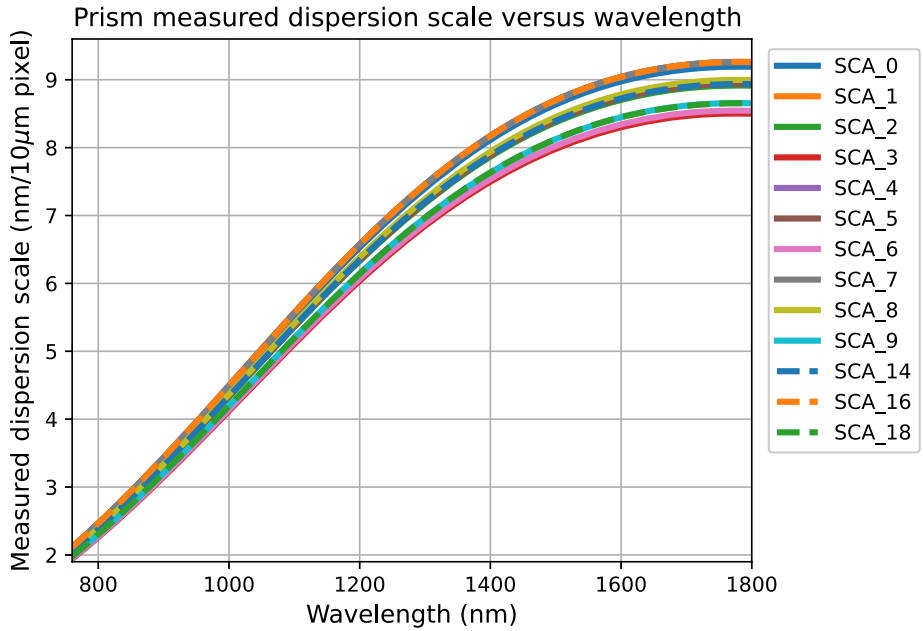
Introducing *Roman* prism



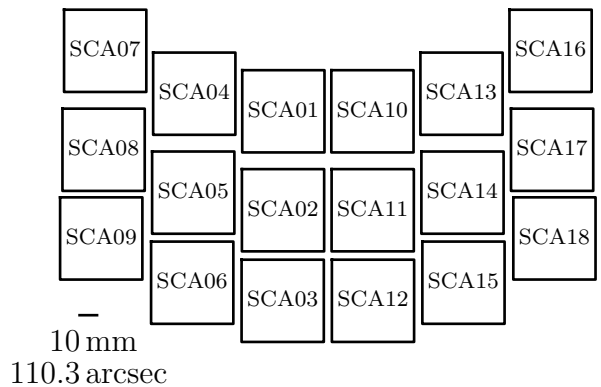
Source: *Roman* Space Telescope Reference Information, `roman.gsfc.nasa.gov`

Introducing *Roman* prism

More complications: Spectral sampling changes with detectors.



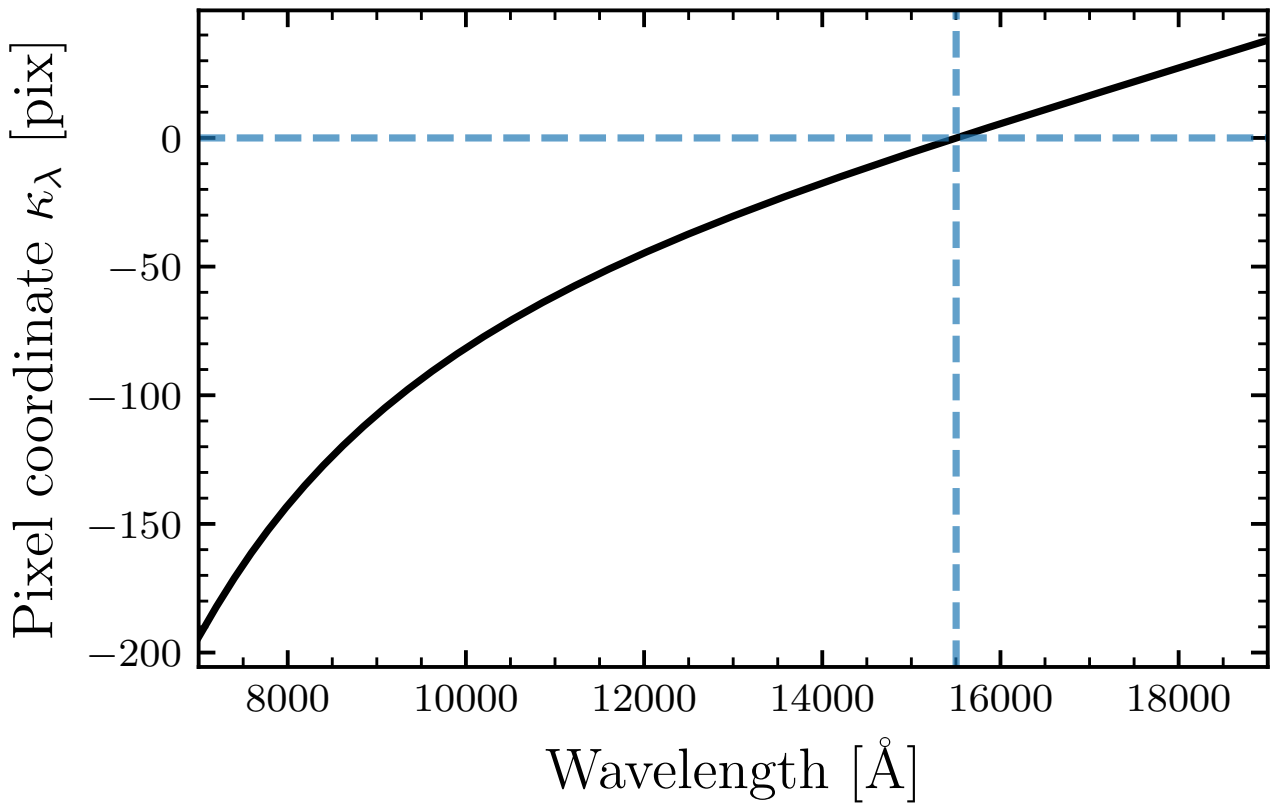
Eegholm et al. 2025



Introducing *Roman* prism

Dispersion curve

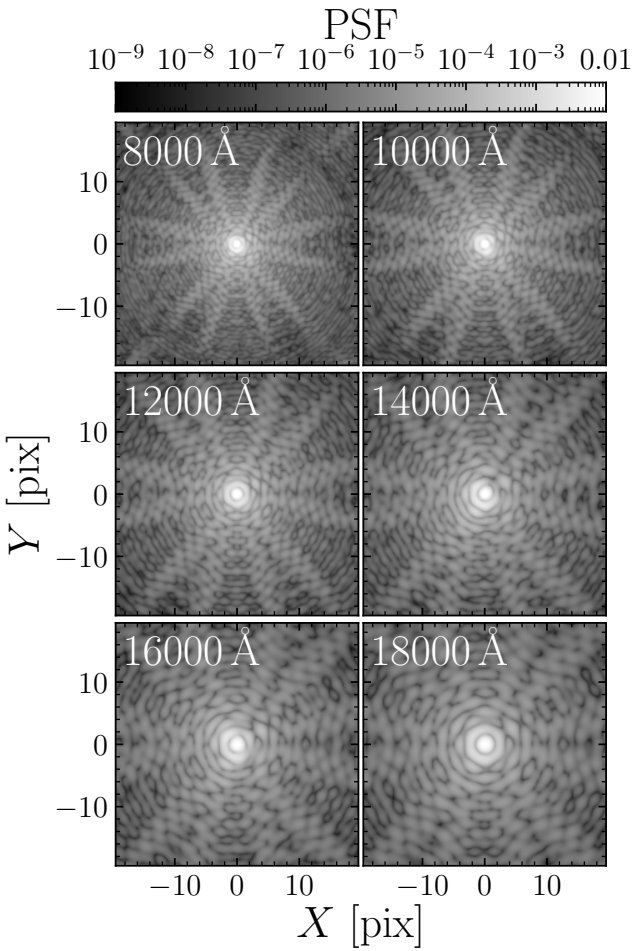
$$\kappa_\lambda(\lambda;\lambda_0,\kappa_0) = \kappa_0 + \int_{\lambda_0}^{\lambda} \frac{\mathrm{d}\lambda}{g(\lambda)}. \tag{2}$$

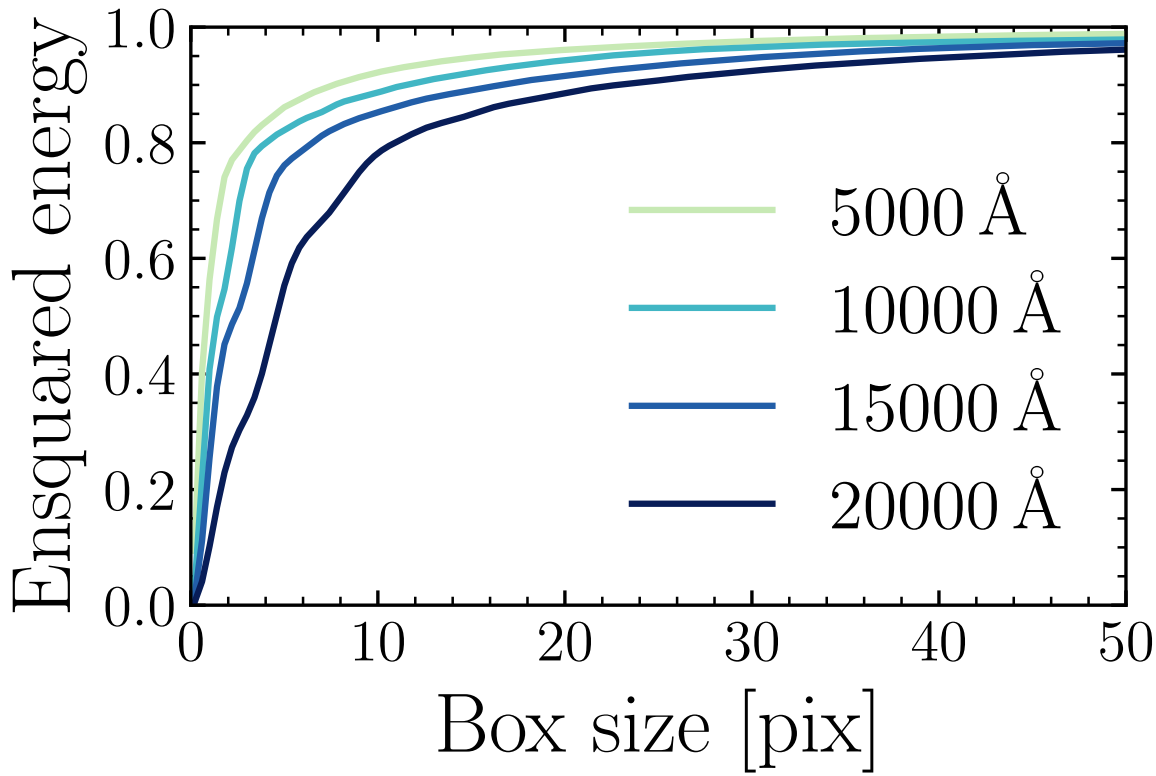


At $\kappa_\lambda = 0$, $\lambda_0 = 1.55\,\mu$m.

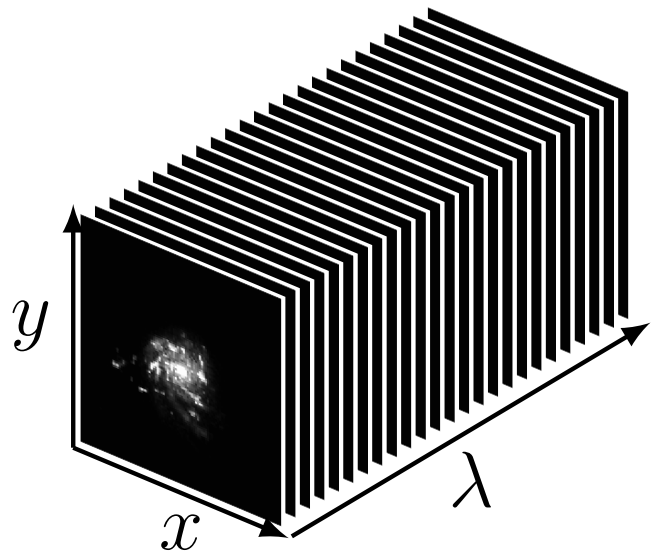
Roman PSF

Using `stpsf`, simulations of *Roman* PSF exhibit a dependence with wavelength (among other things).





2d spectral image formation: From scene to pixel



Datacube

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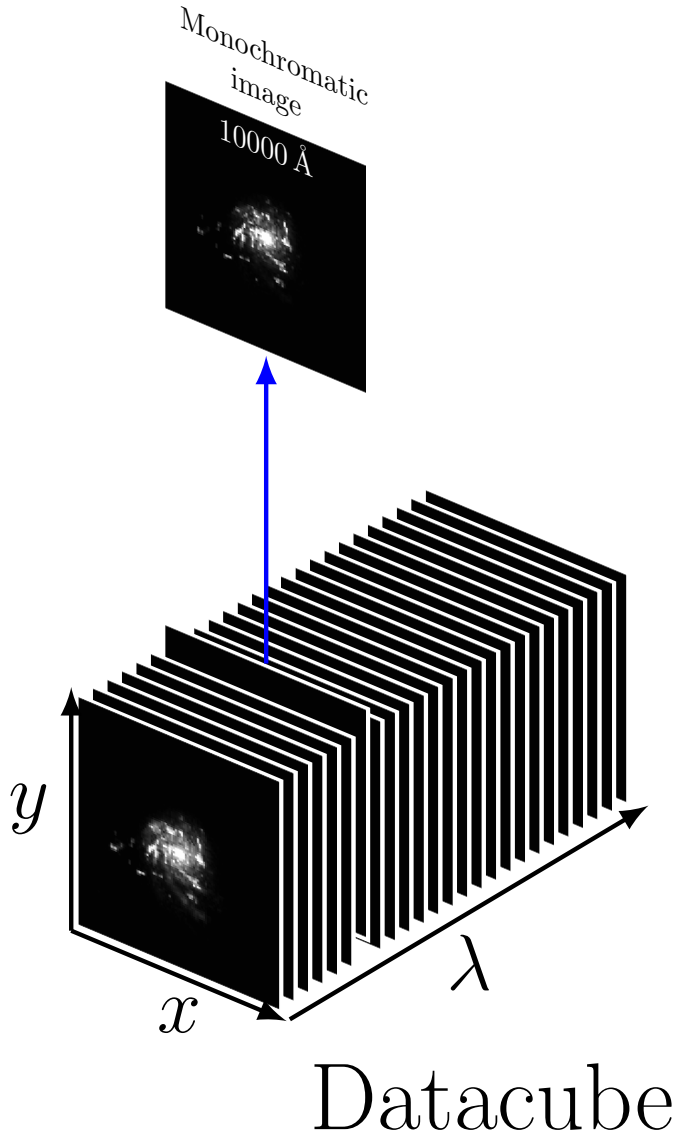

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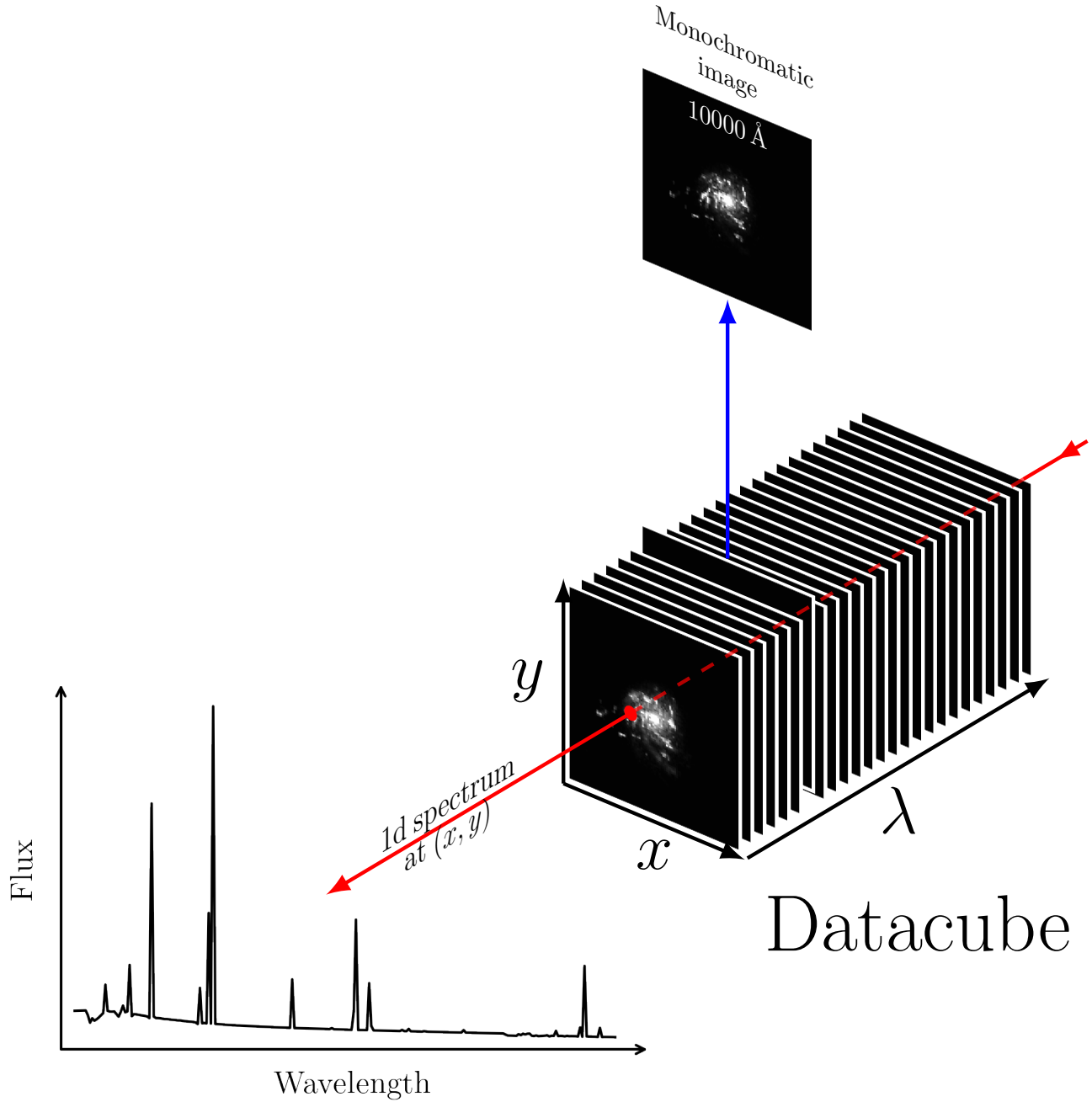

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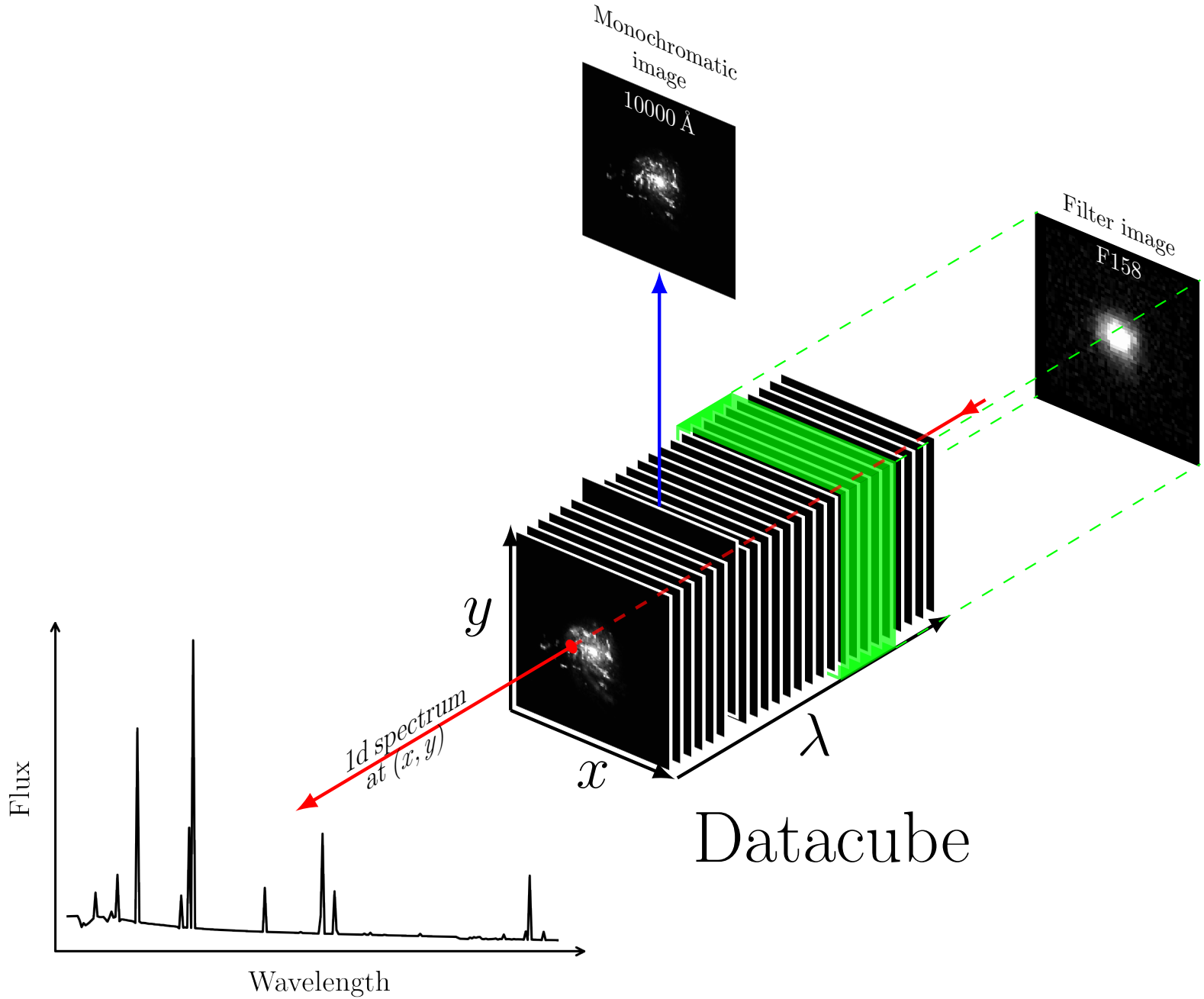

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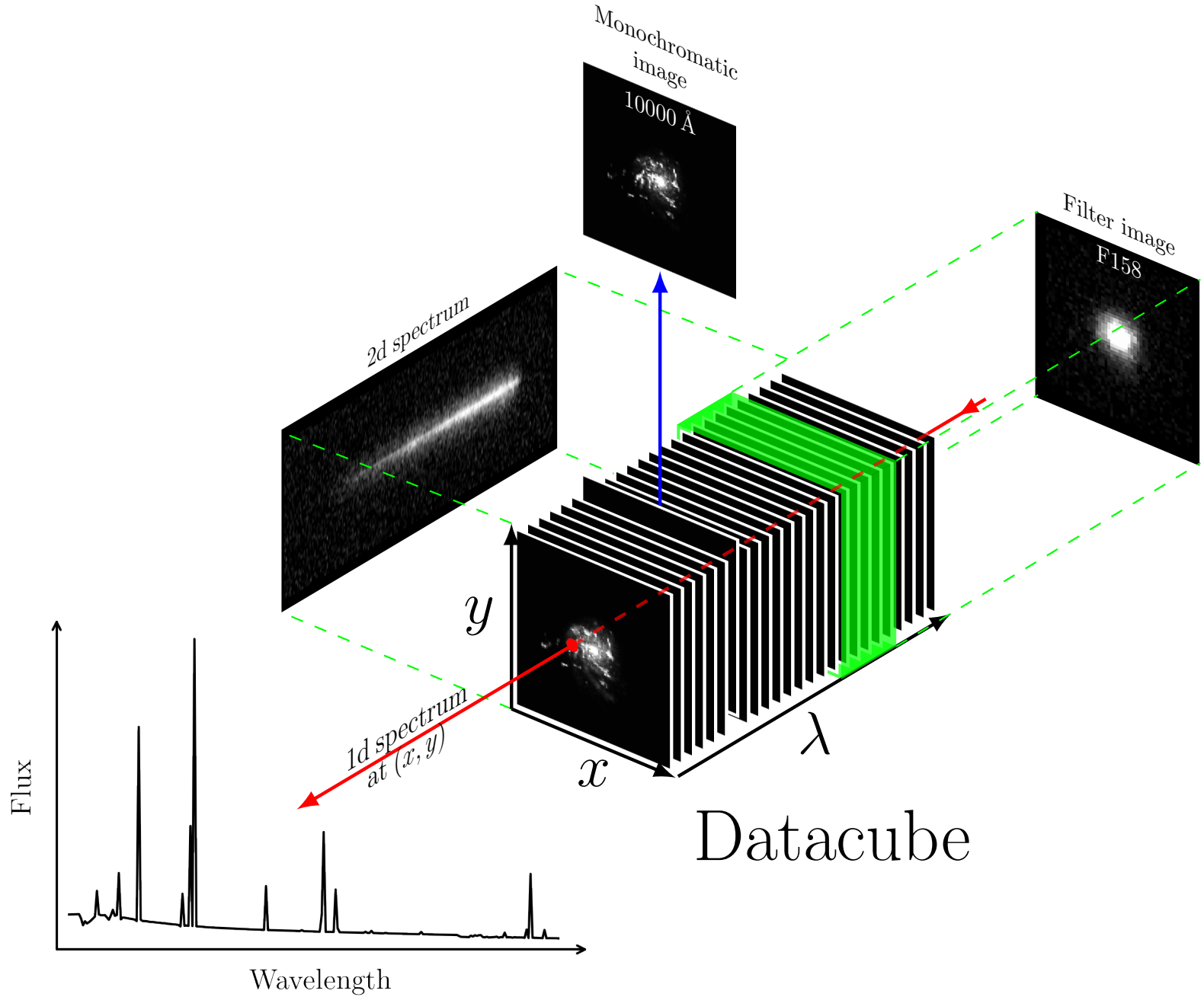
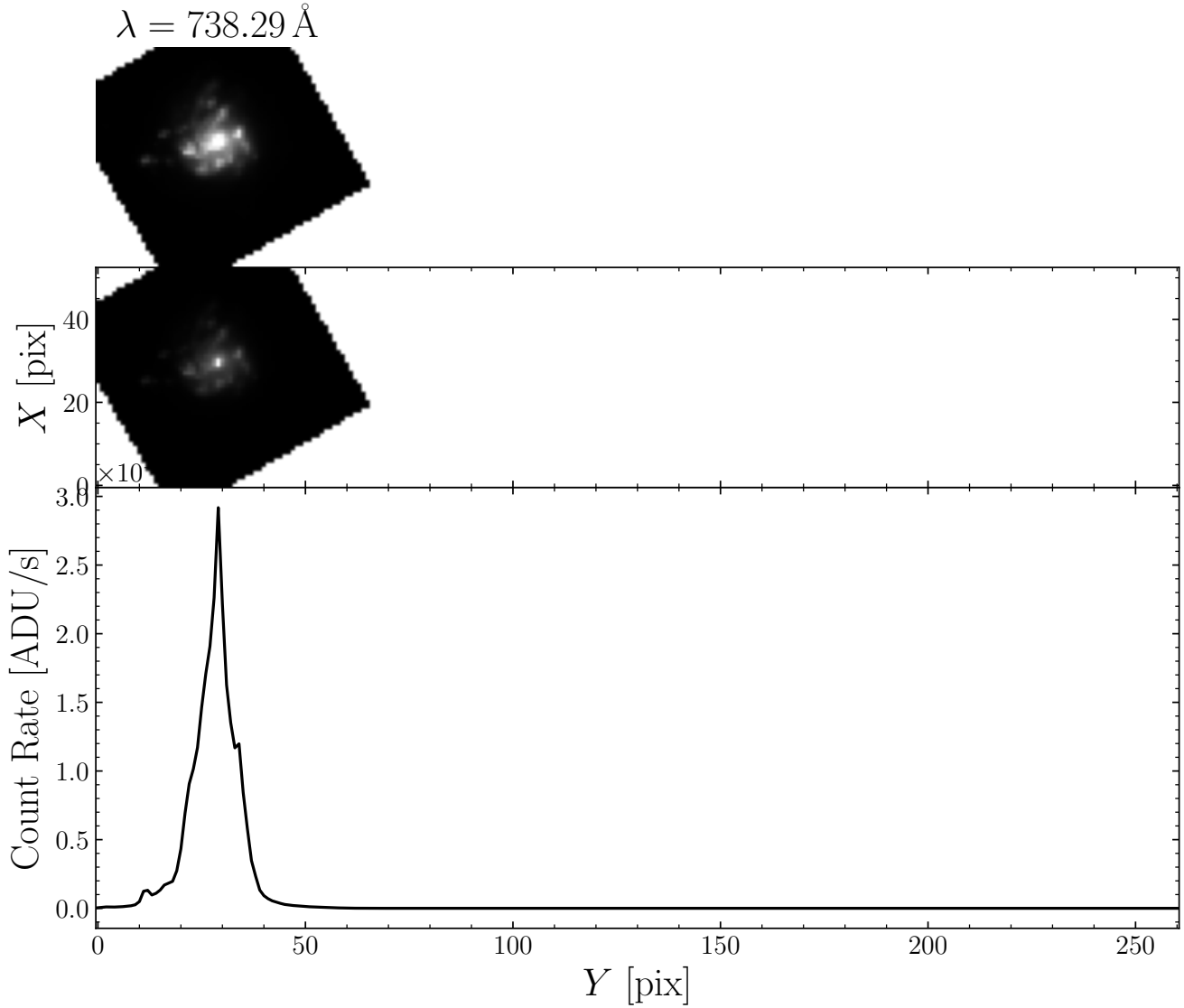


Two-dimensional spectral image formation

After rotation and convolution, all the monochromatic images are dispersed along the trace.



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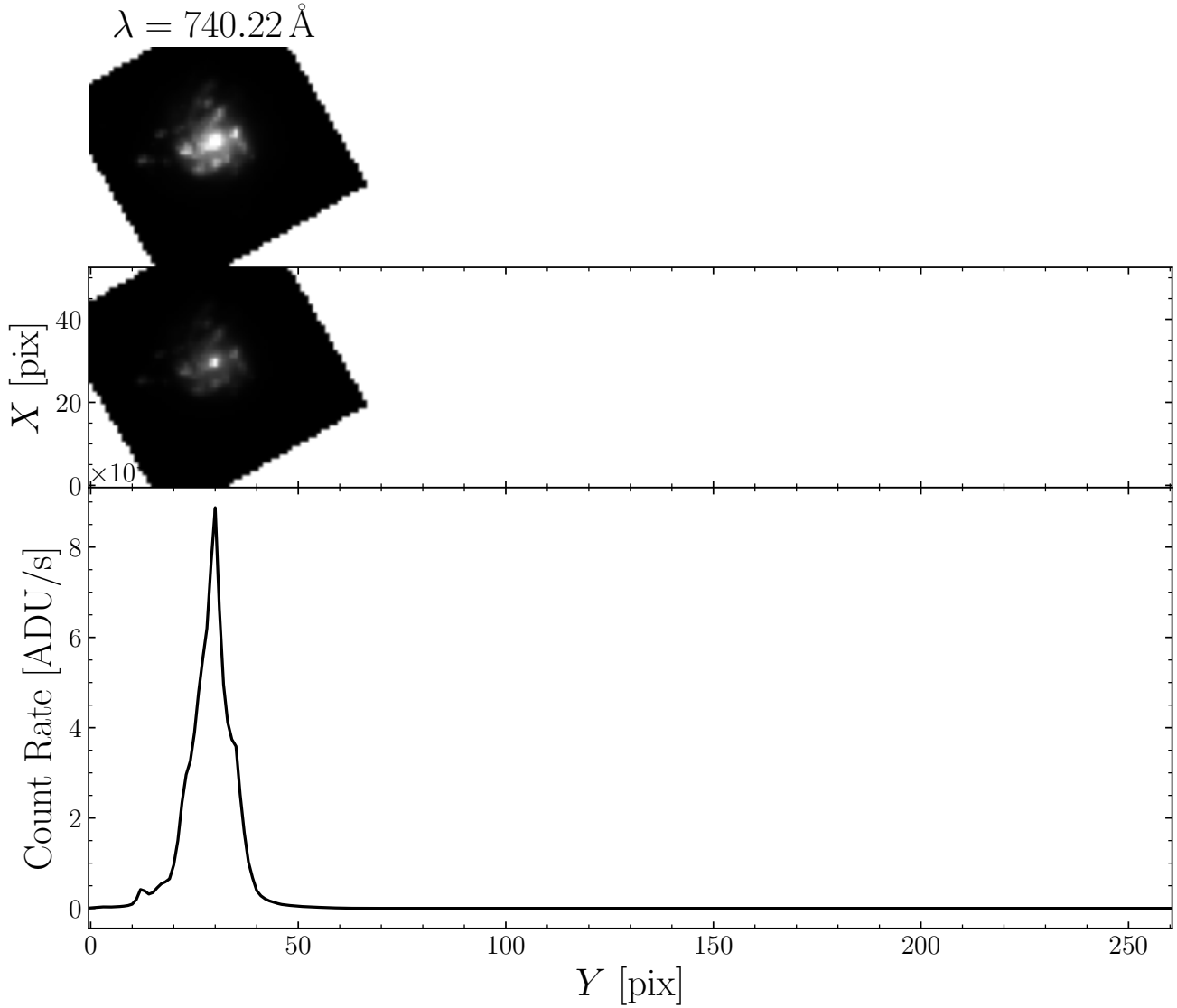

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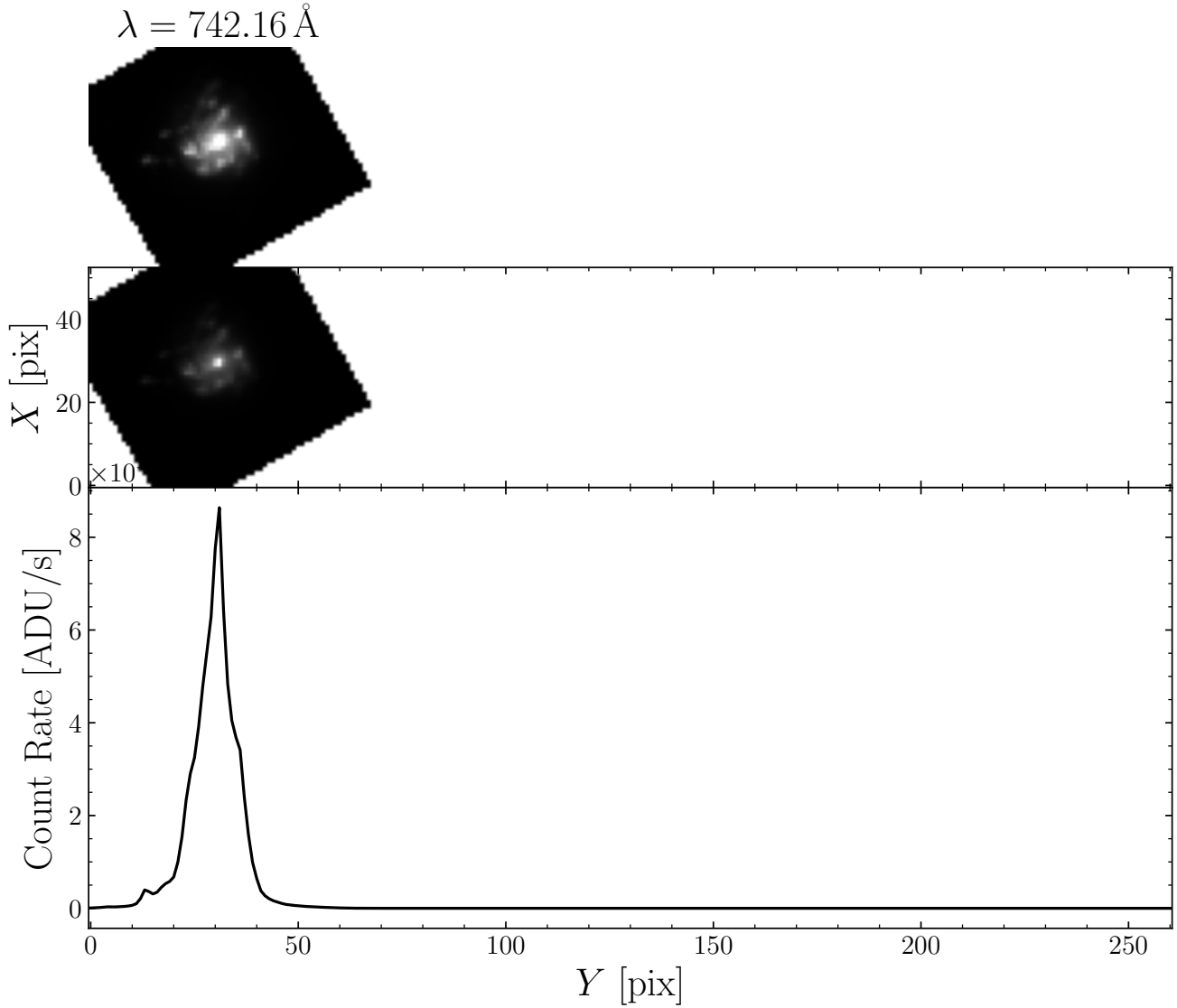

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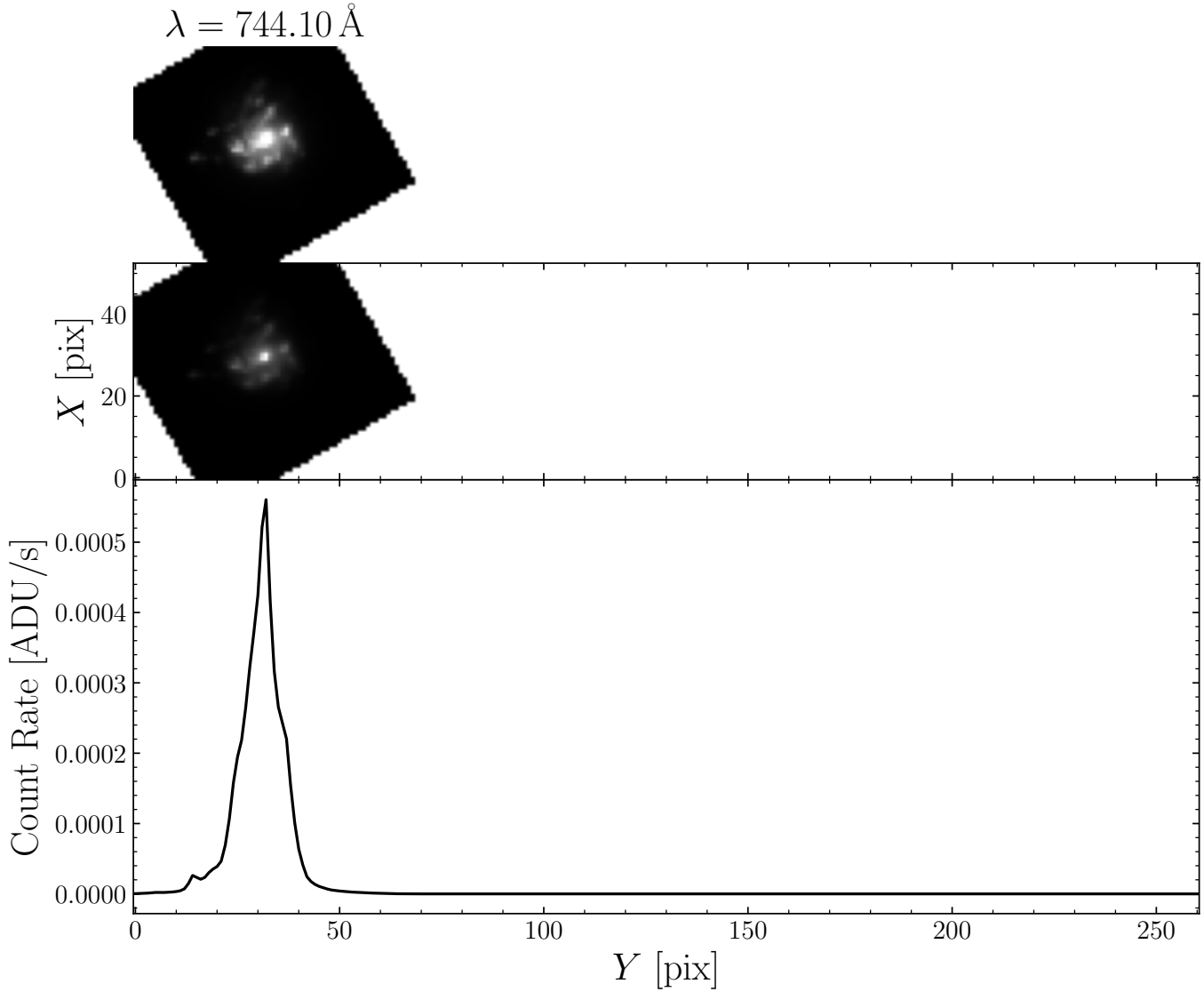

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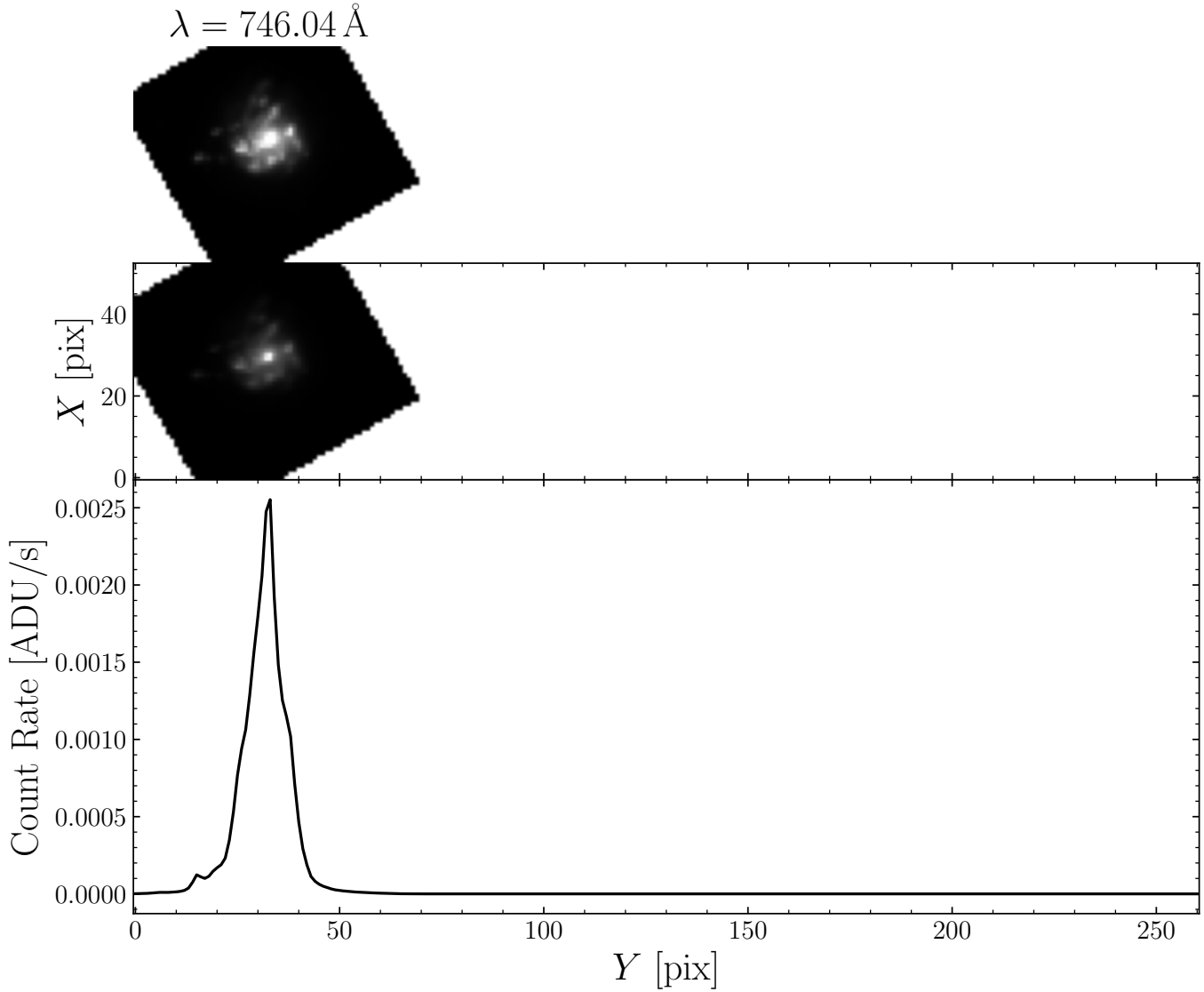

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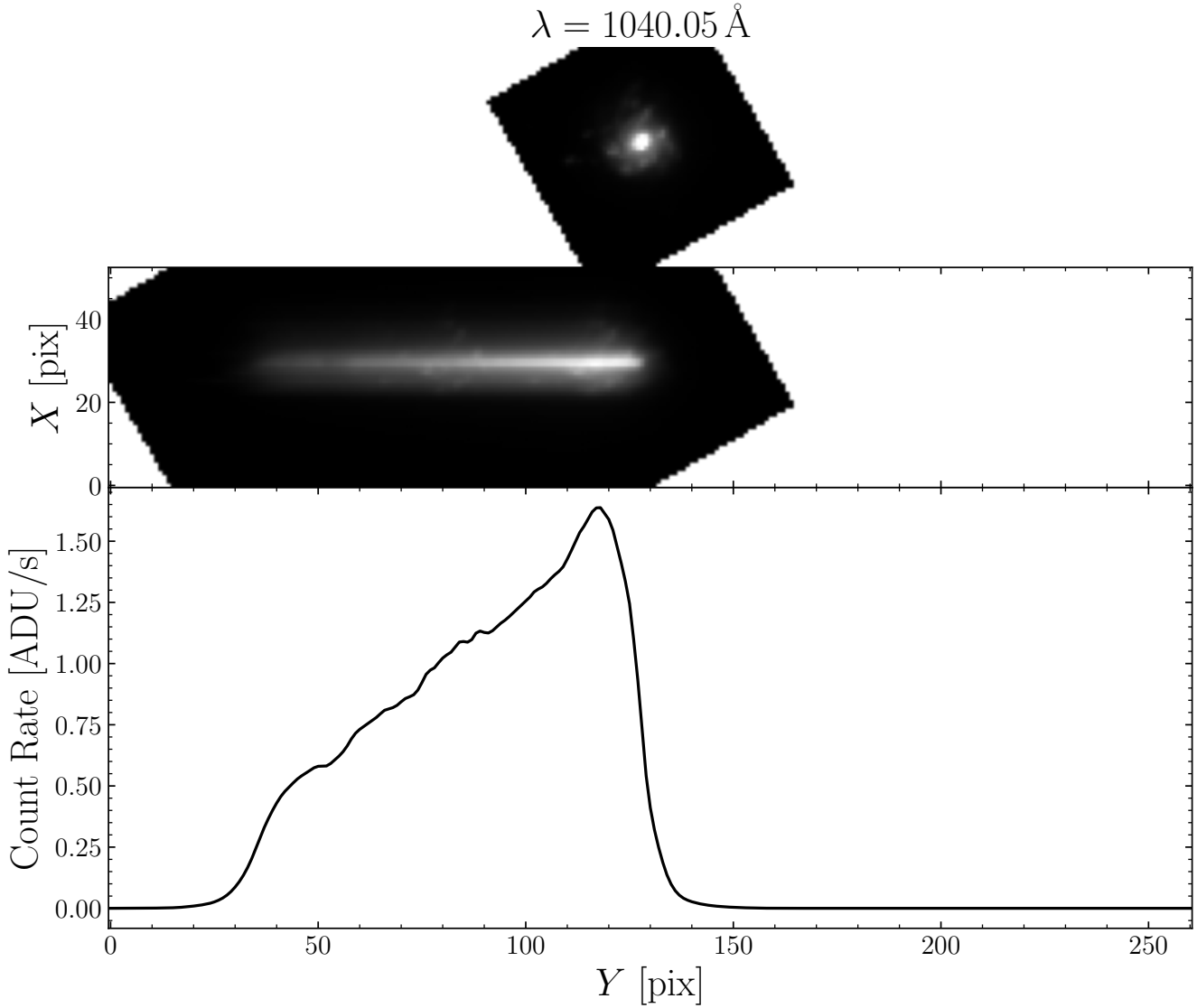

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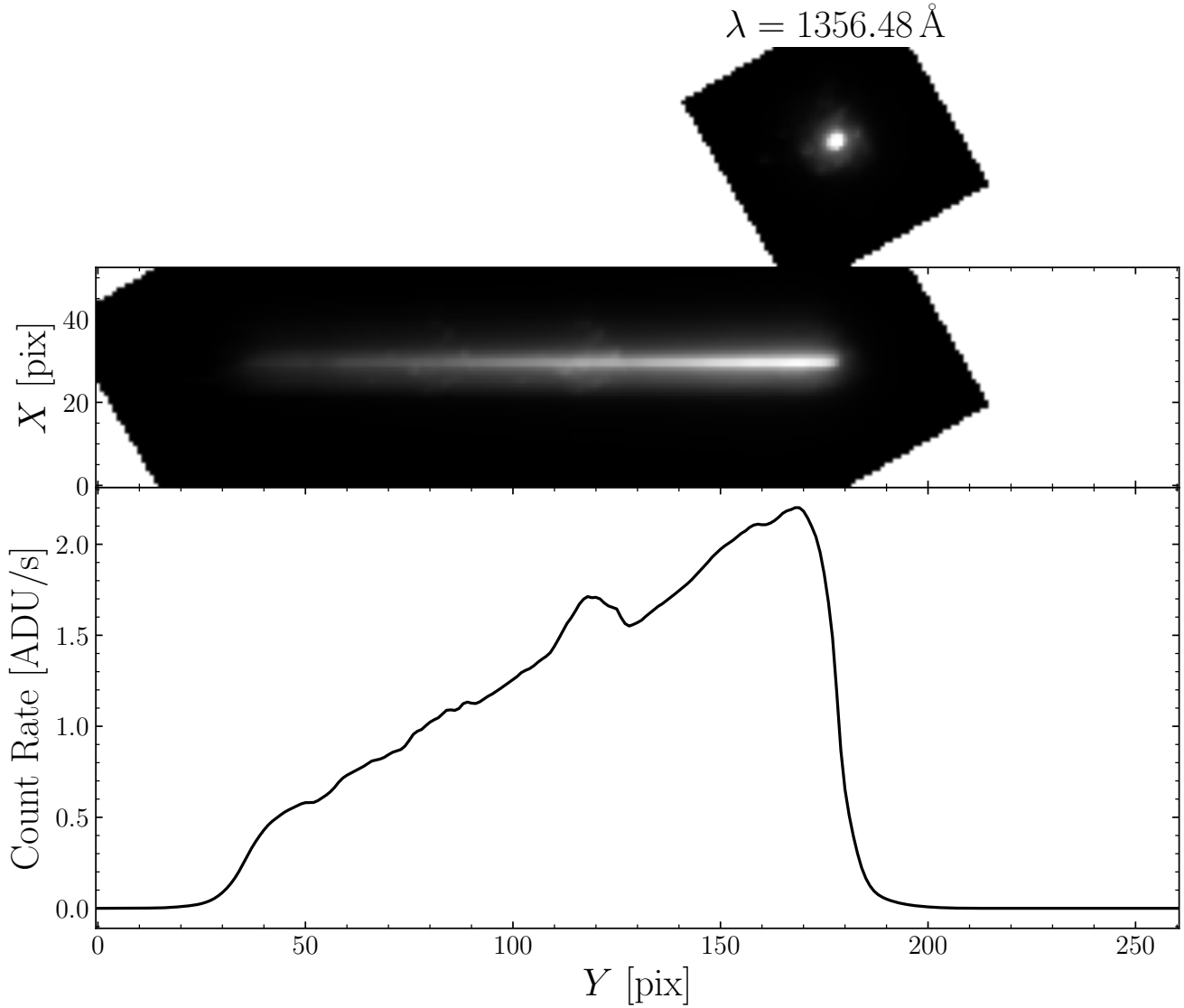

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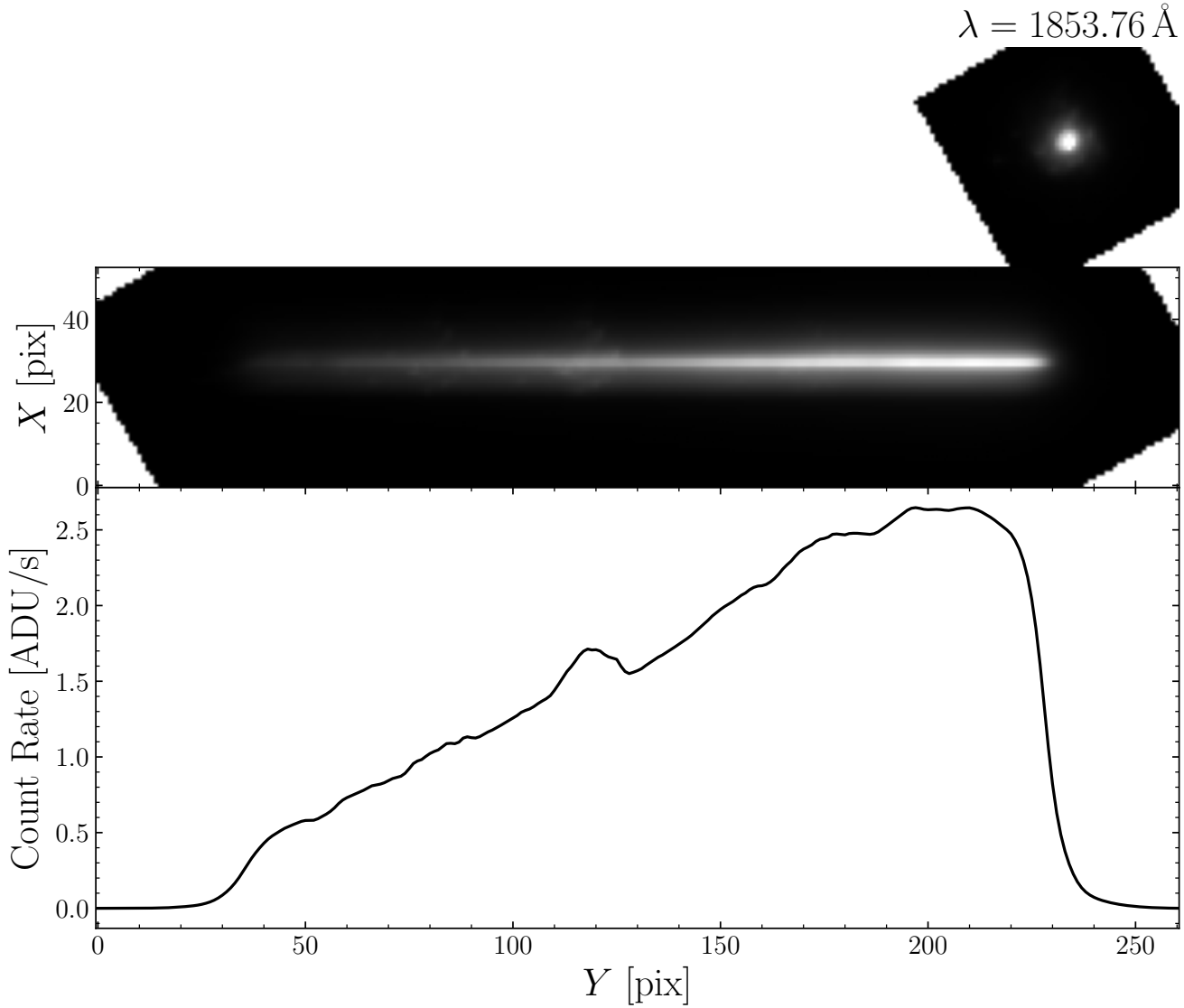

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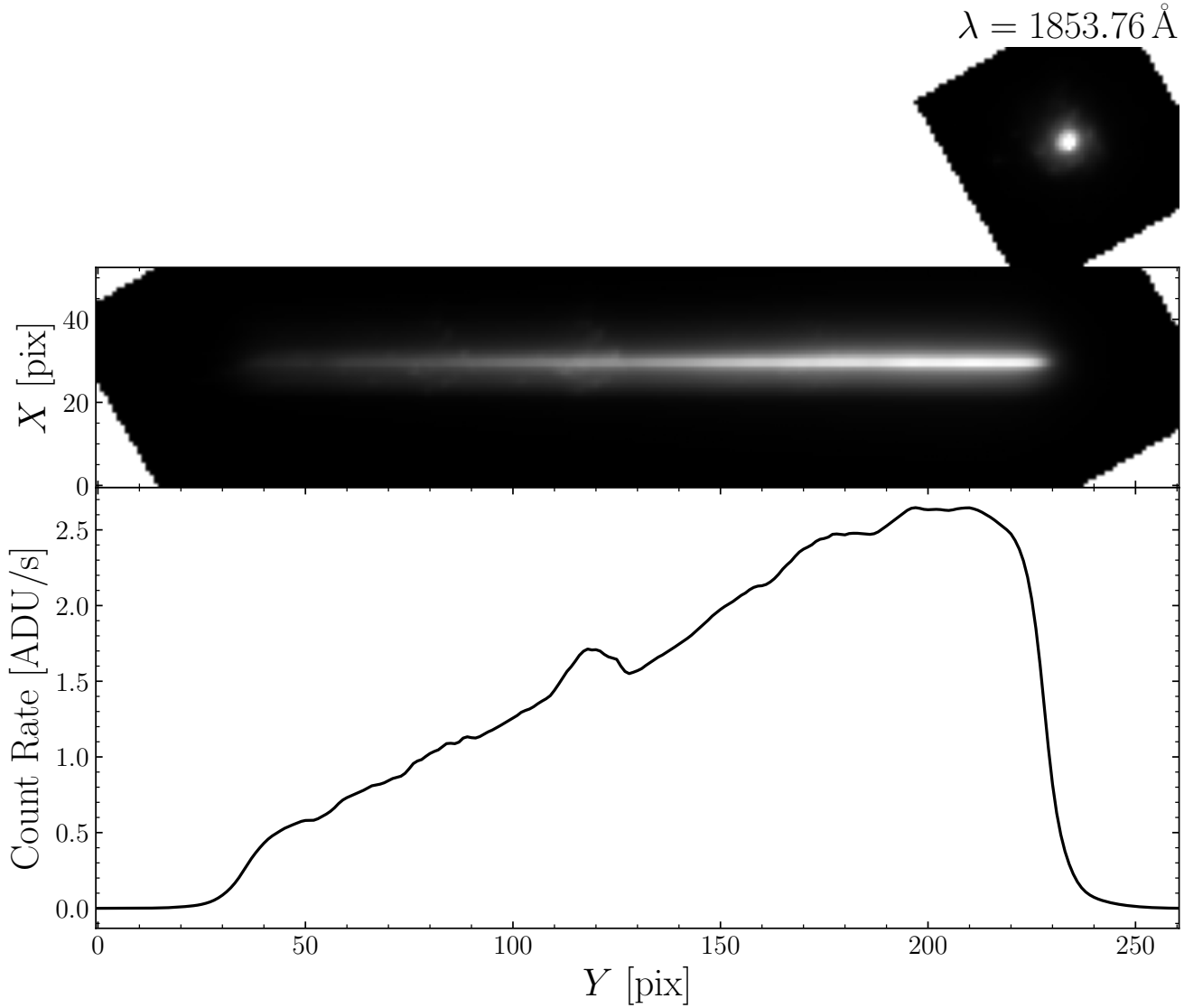
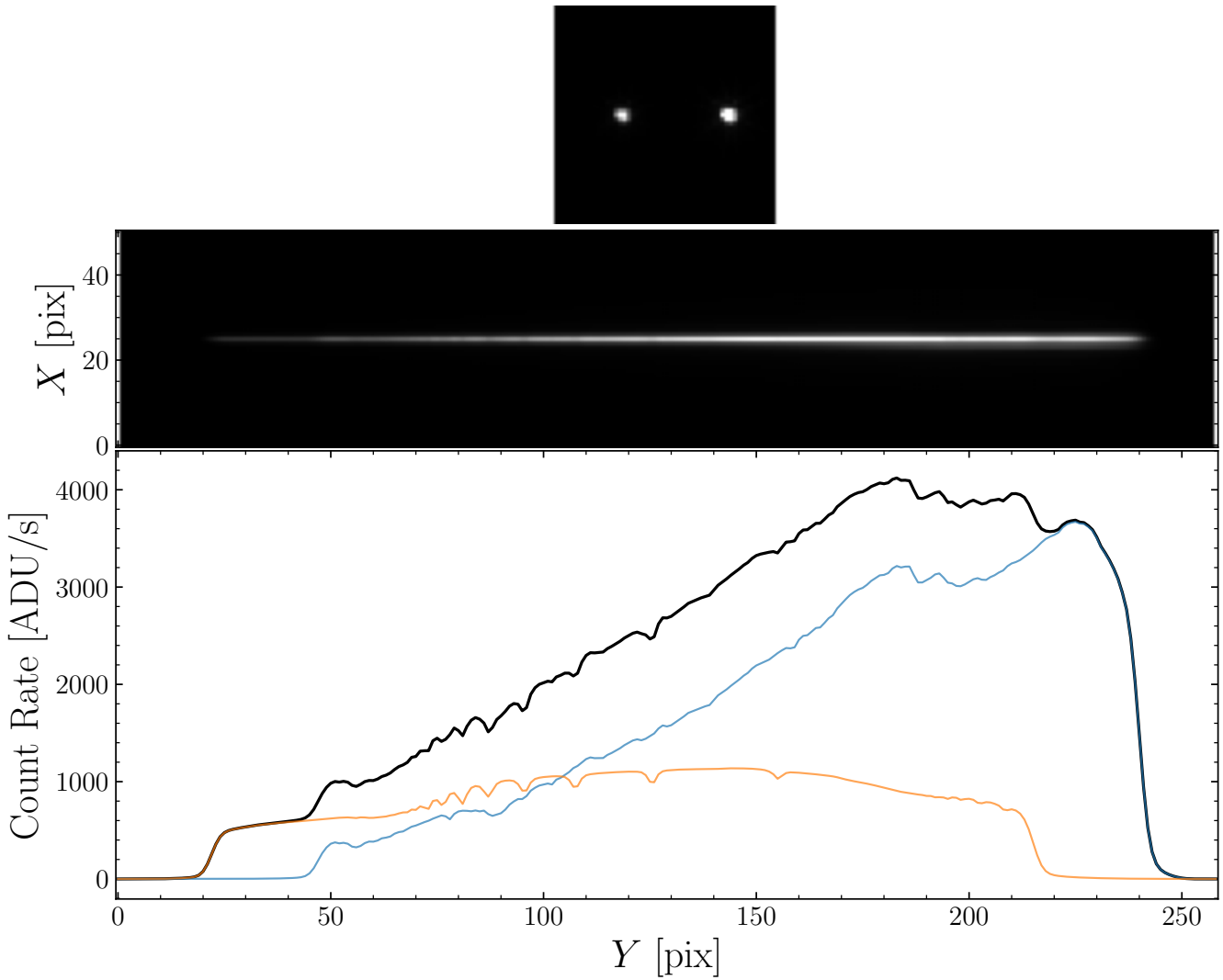


Overlapping spectra in slitless spectroscopy

In slitless spectroscopy, depending on the dispersion direction, multiple spectra of close objects can overlap.



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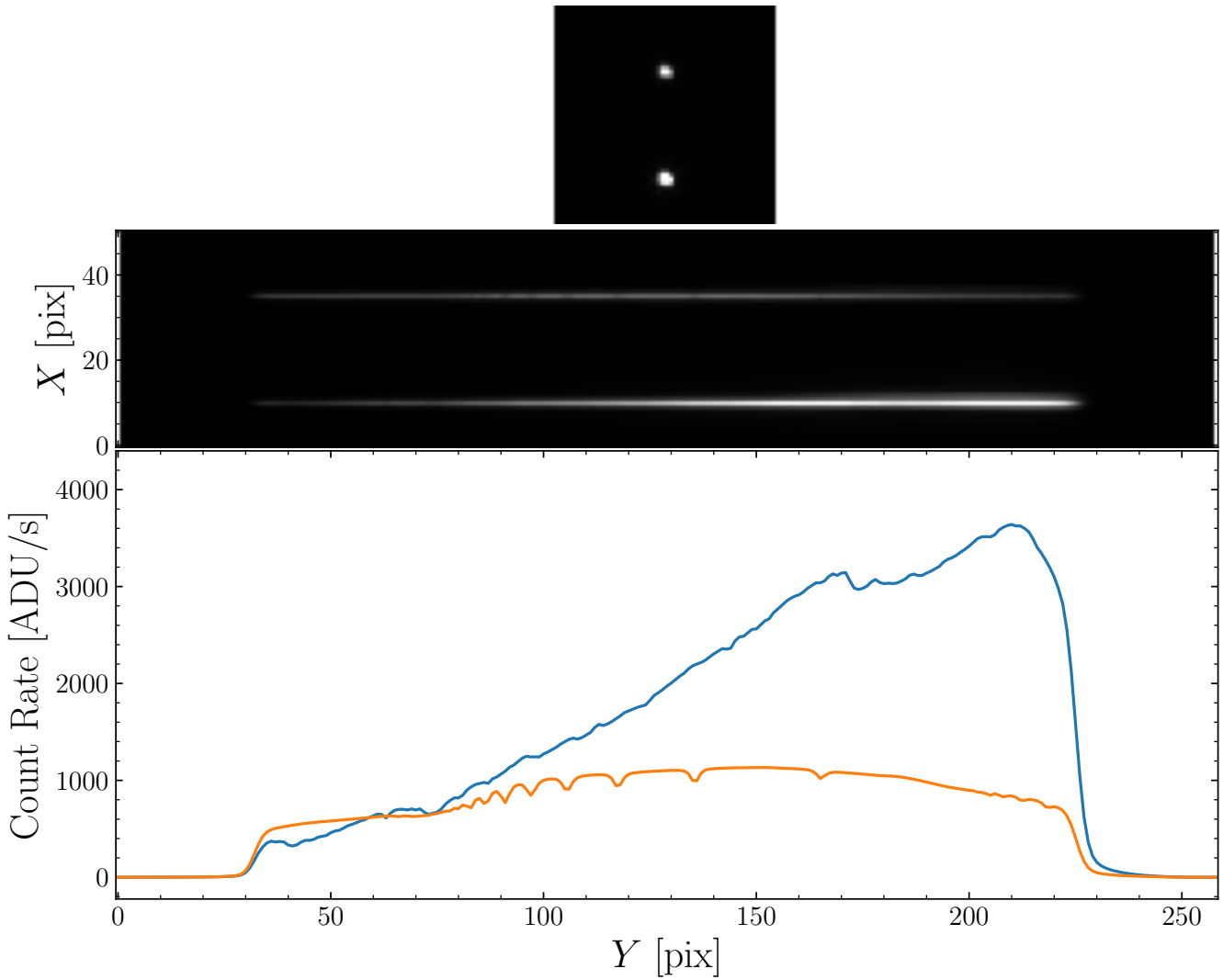
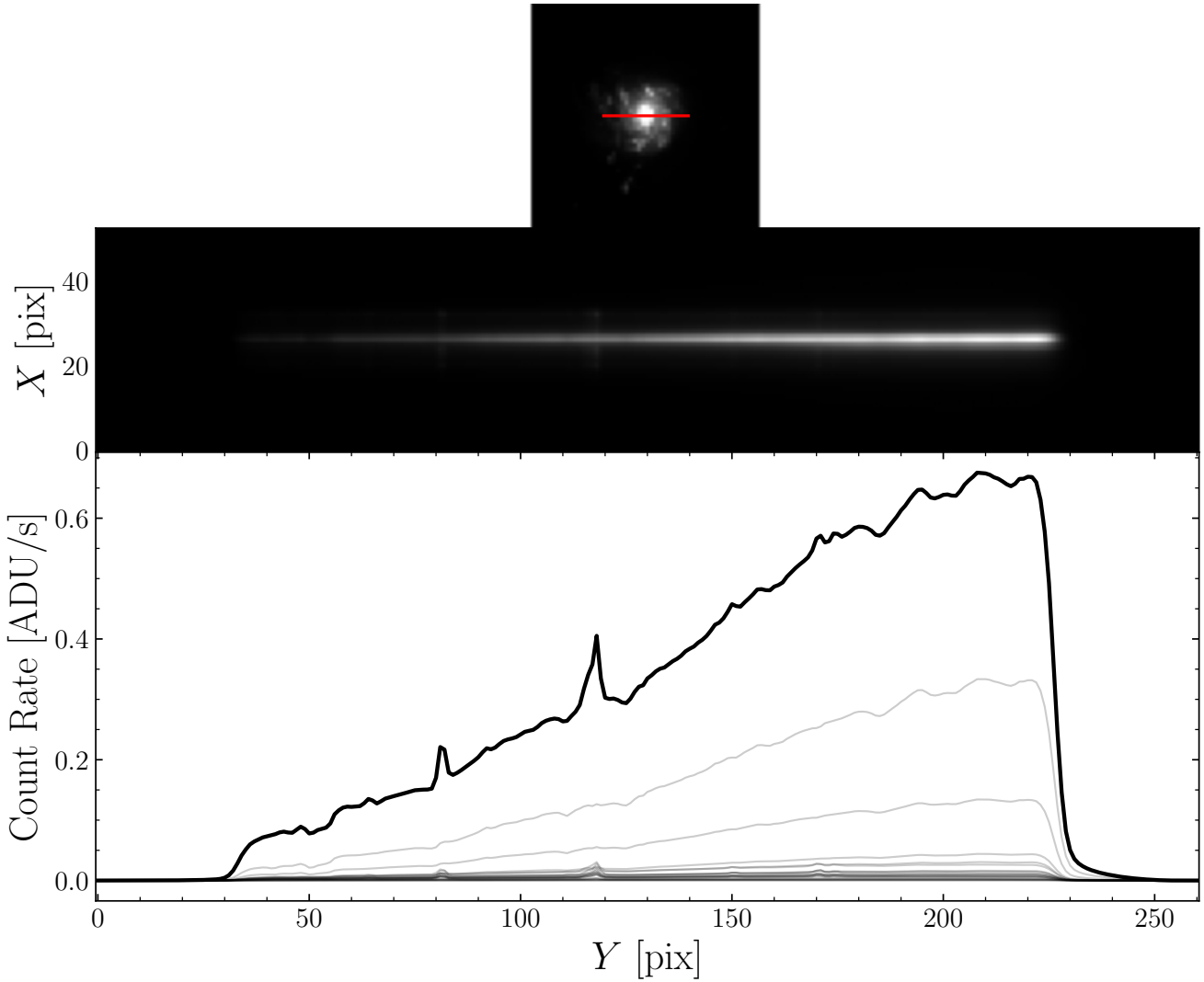


Extended objects in slitless spectroscopy

The spectrum of an extended object is a hot mess of overlapping spectra of individual points.



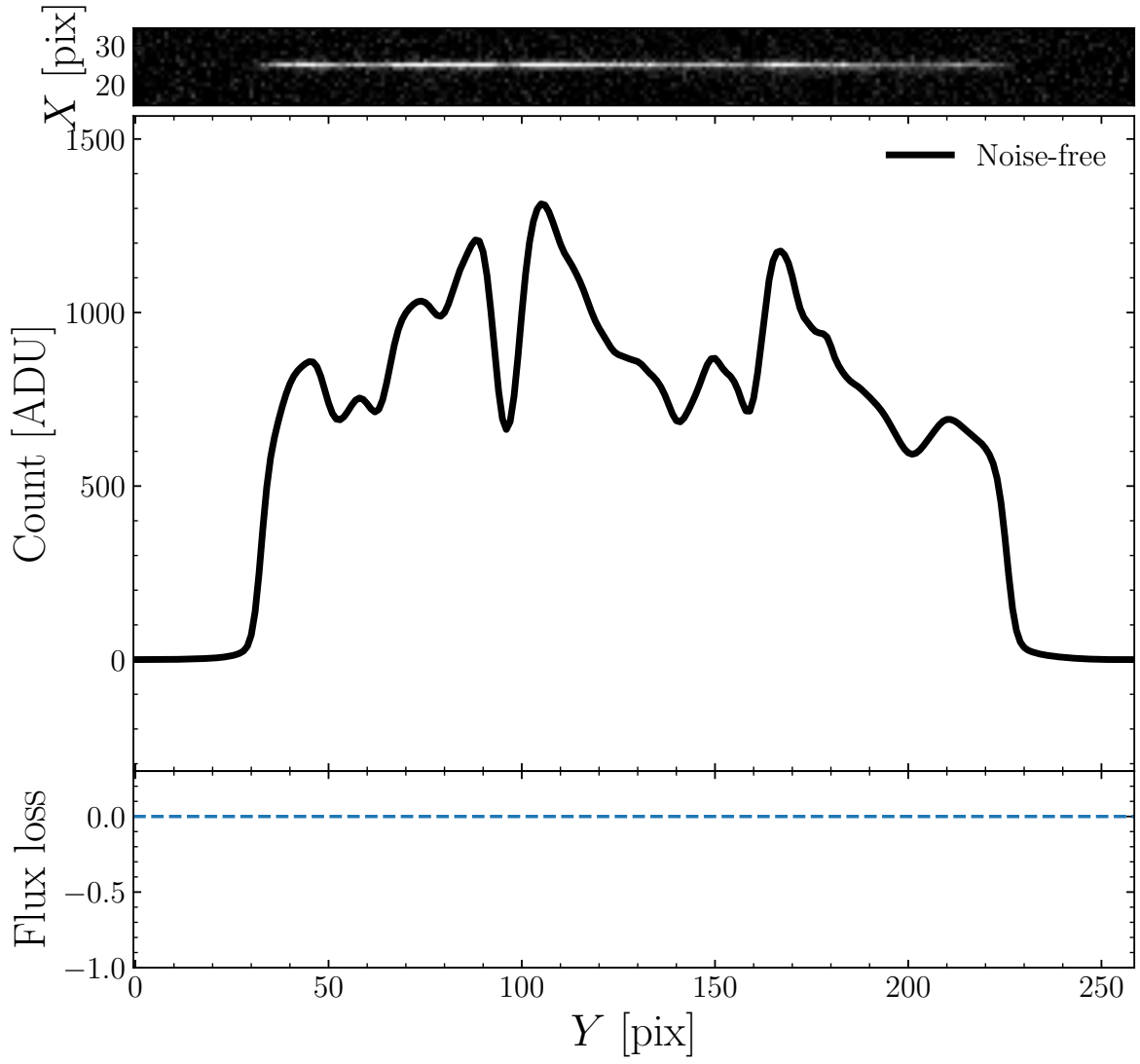
Summary

- We can view 2d spectral formation as a mathematical projection of a 3d datacube into a 2d image space.
- Along the dispersion axis, spatial position and wavelength information are entangled.
- Techniques exist to recover the underlying 3d datacube by making use of multiple observations of a scene.

APPENDIX

Extracting 1d spectrum using simple summation

Choosing the appropriate aperture width is a balancing act between flux loss and noise-admission.



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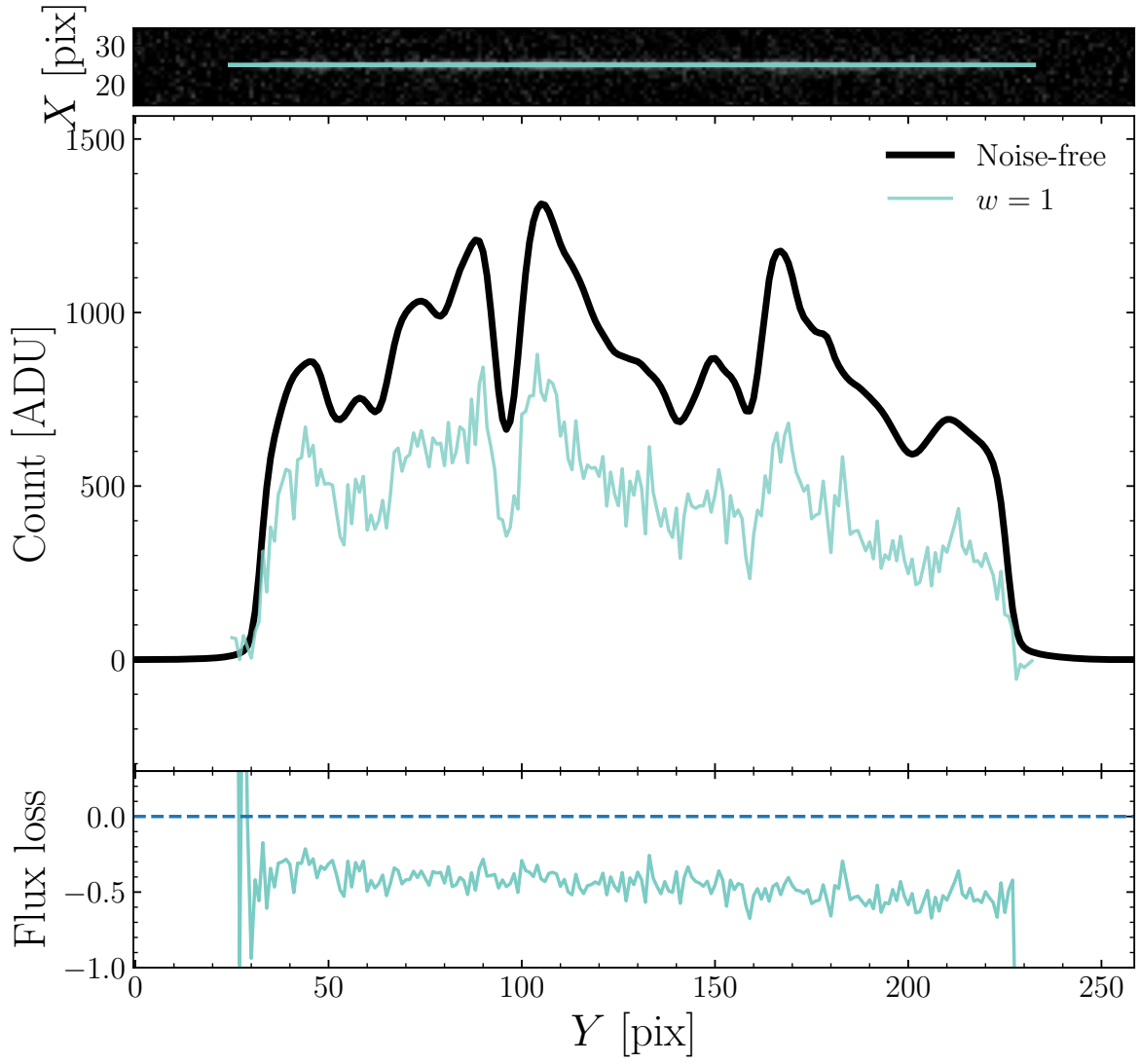

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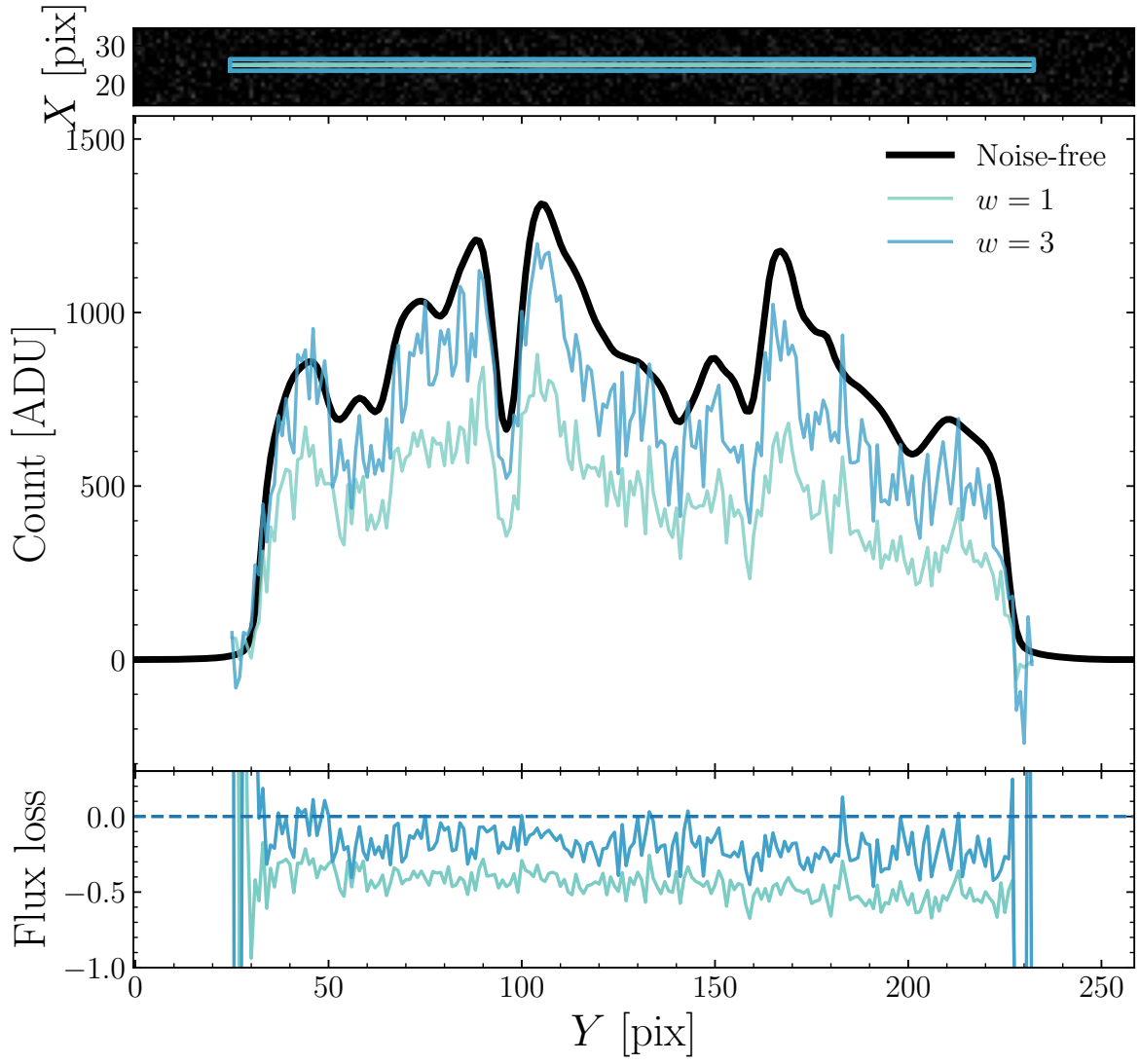

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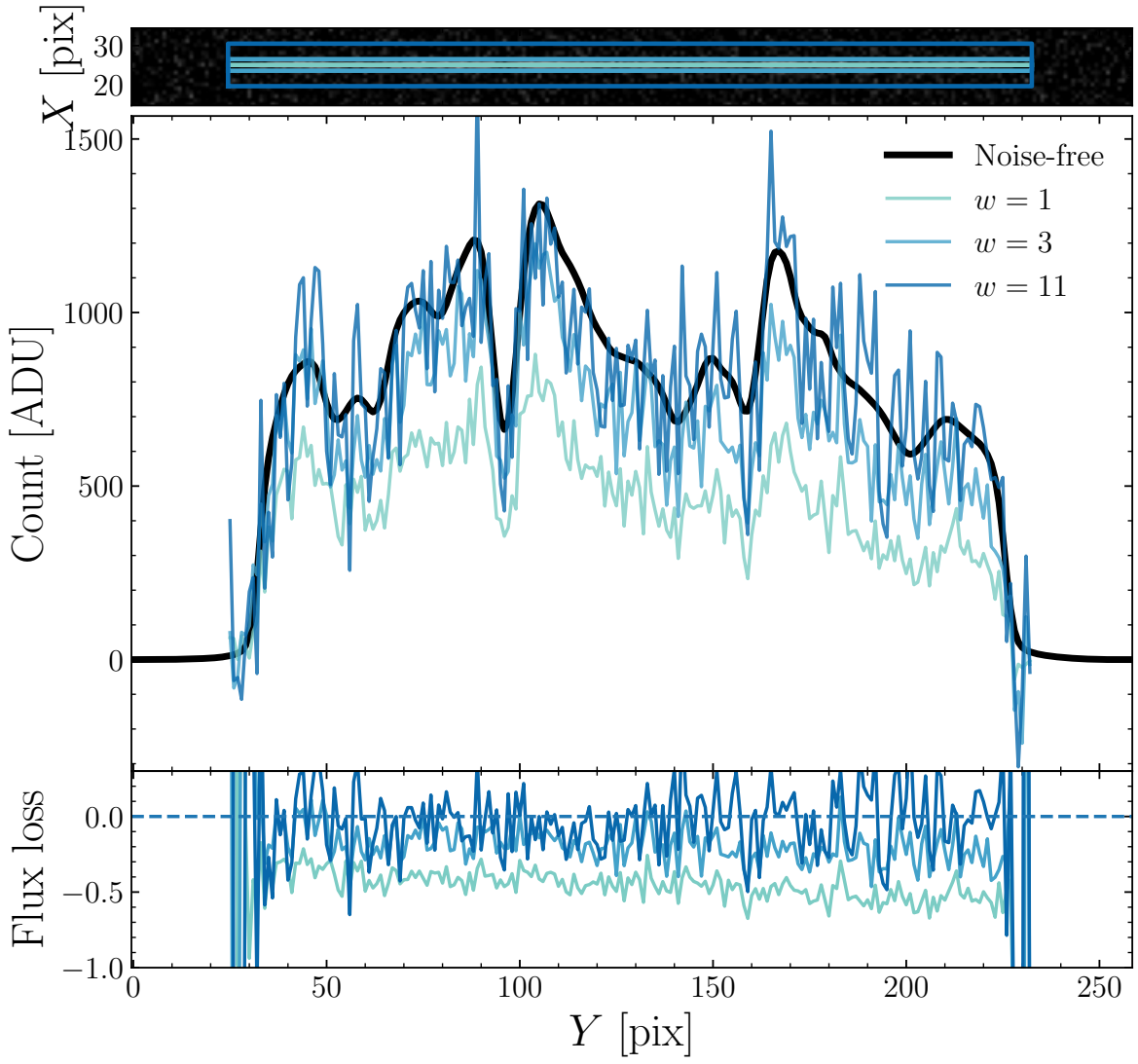
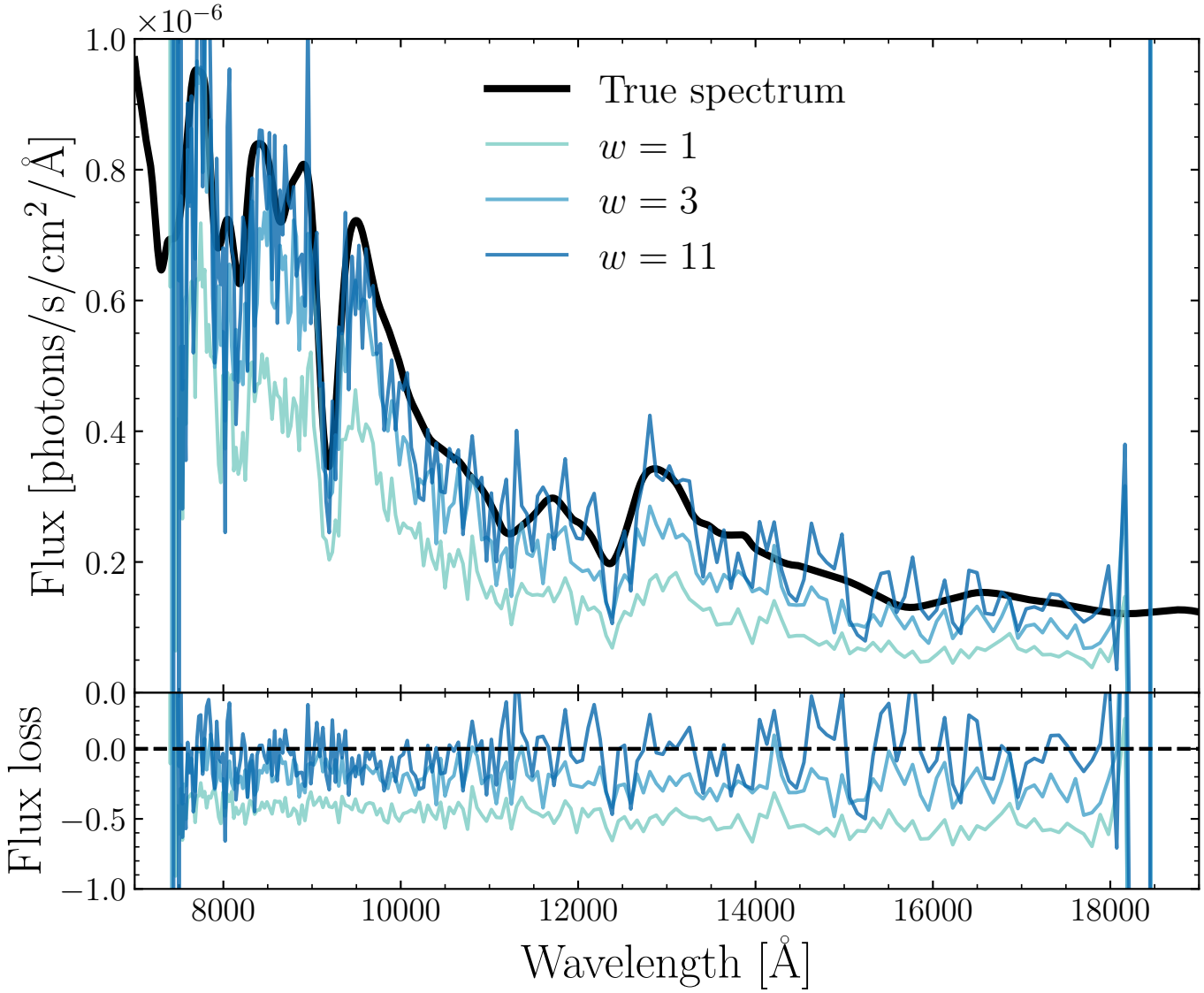


Extracting 1d spectrum using simple summation

Calibrated 1d spectrum: $f(\lambda_i) = \dfrac{I_i}{t_{\rm exp} A_{\rm eff}(\lambda_i) \left.\frac{d\lambda}{d\kappa_i}\right|_{\lambda_i}}$



Optimum spectral extraction (Horne 1986)

Using optimum spectral extraction, noise and flux loss can be minimized