Handling Covariances in the MUSE Pipeline

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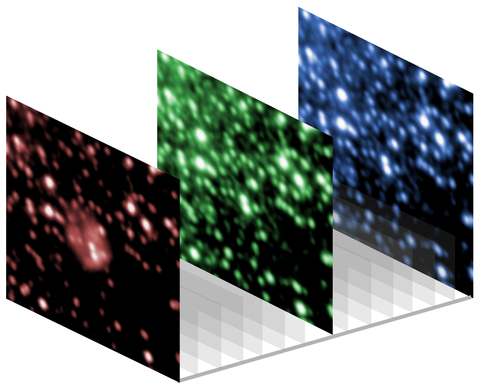
Introduction

- Resampling of MUSE/BlueMUSE data introduces covariances.
- The size of MUSE datacubes with N ≃ 300 × 300 × 3600 pixels makes handling of the full covariance matrix infeasible.
- Not carrying covariances causes underestimation of uncertainties.



Covariance Table

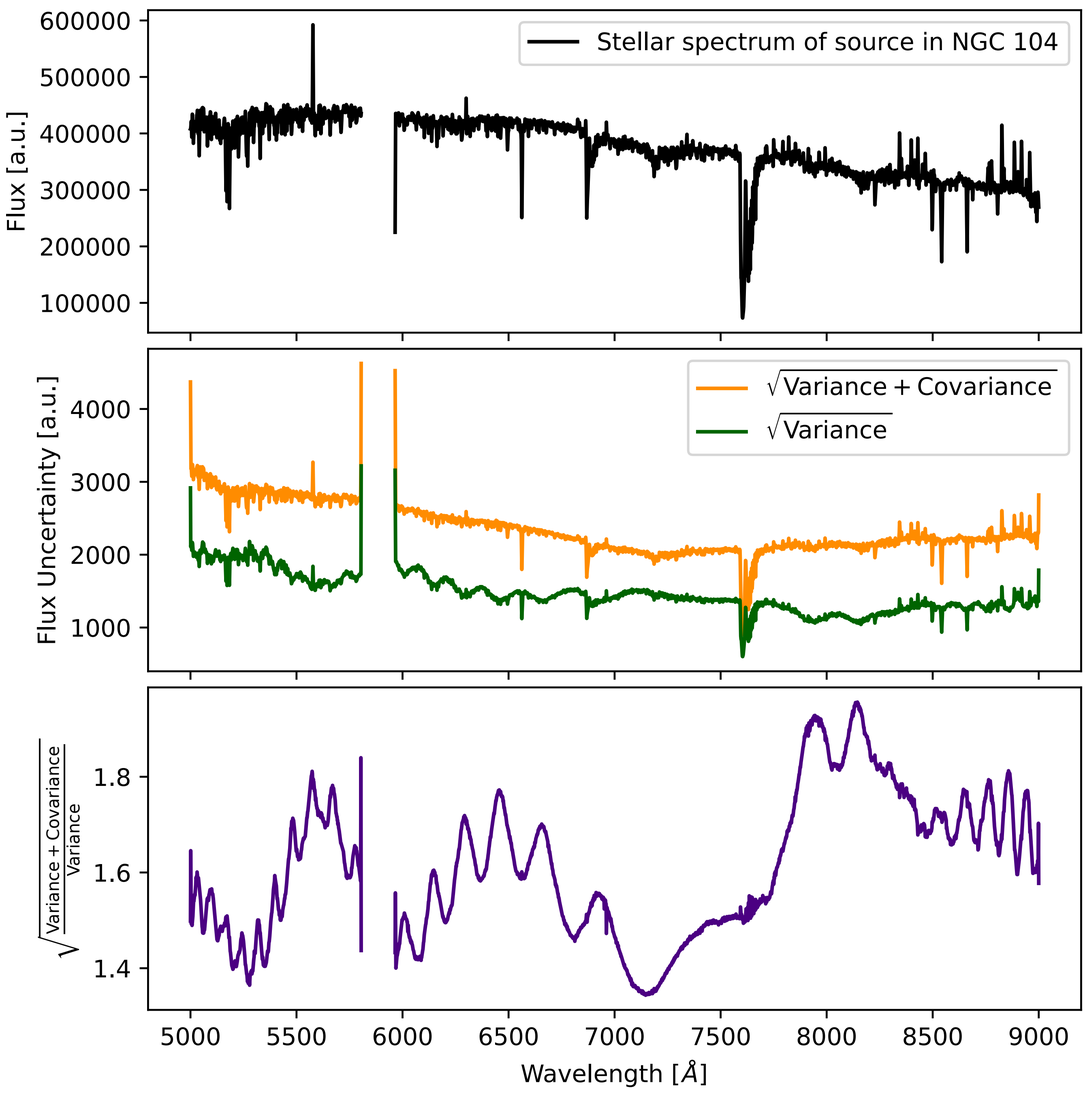
- Resampling usually only considers nearest neighbors, so most entries in the covariance matrix are zero.
- We implement the approach presented by Law et al. (2016):

$$\mathrm{Cov}_{ij} = \sum_{n=m} w_{i,m} \cdot \sigma_{n,m} \cdot w_{j,n}$$

w : resampling weight σ : voxel variance

- The resulting covariance table contains ~27 × N entries.

Effect on Flux Uncertainties



- Extract spectra from a MUSE datacube of globular cluster NGC 104
- Derive flux uncertainties with and without covariances:

$$\sigma_{\mathrm{flux}} = \sqrt{\sum_i \mathrm{Var}_i + 2 \cdot \sum_i \sum_{j<i} \mathrm{Cov}_{ij}}$$

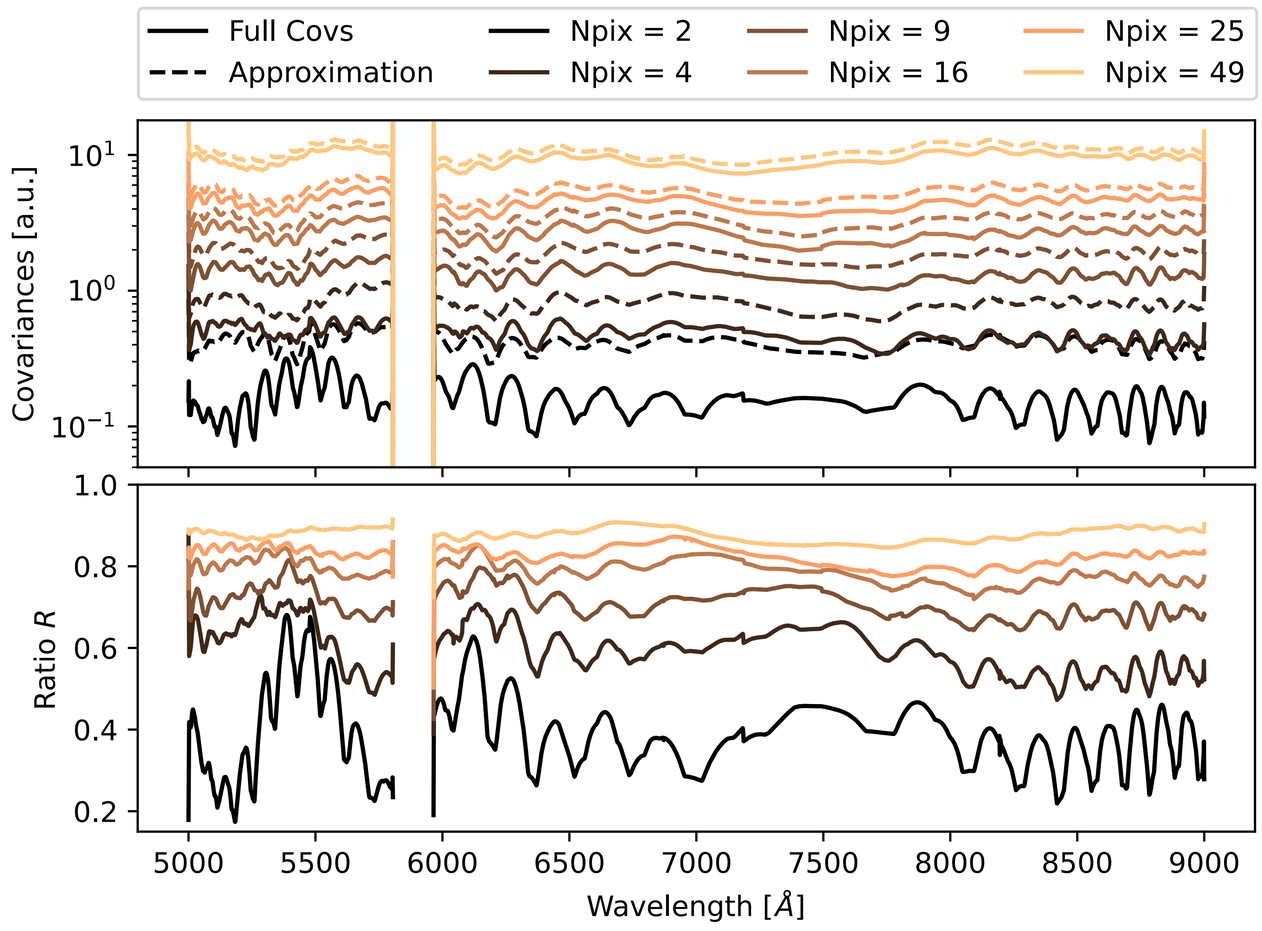
- Uncertainties are underestimated by ≳ 40% without covariances.
- Contribution of covariances varies with wavelength and position.

Approximation of Flux Uncertainties

- Deriving uncertainties based on the covariance table is computationally complex due to its size, so we try to approximate uncertainties for each voxel:

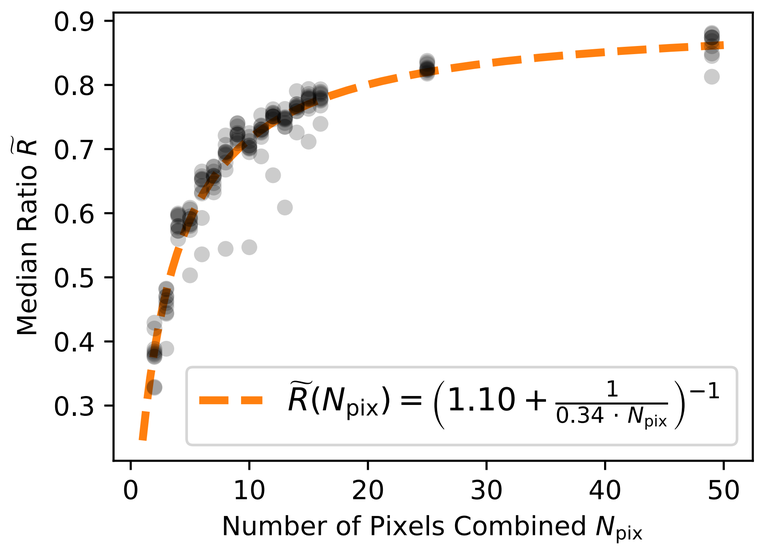
$$\sigma_{\mathrm{flux,i}} = \sqrt{\mathrm{Var}_i + 2 \cdot \sum_{j<i} \mathrm{Cov}_{ij}}$$

- The resulting uncertainty cube can replace the existing variance cube, which makes handling this information in post-data reduction trivial.



- Create datacube with noise and extract sources of different size.

→ The approximation apporach overestimates the covariance contribution.



- The ratio scales with the number of spaxels included in the extraction.
- When all voxels in a cube are included, the ratio is one.

→ Rescale the approximated uncertainties.

Conclusion & Outlook

- We are able to derive exact covariances for MUSE datacubes during resampling.
- Covariances contribute significantly to the flux uncertainties.
- To make covariances easier to handle in post-data reduction, we approximate the flux uncertainties.

→ Apply this approach to MUSE science data to test this approximation.

→ Analyze the effect of covariances on the extraction and fits of MUSE spectra.