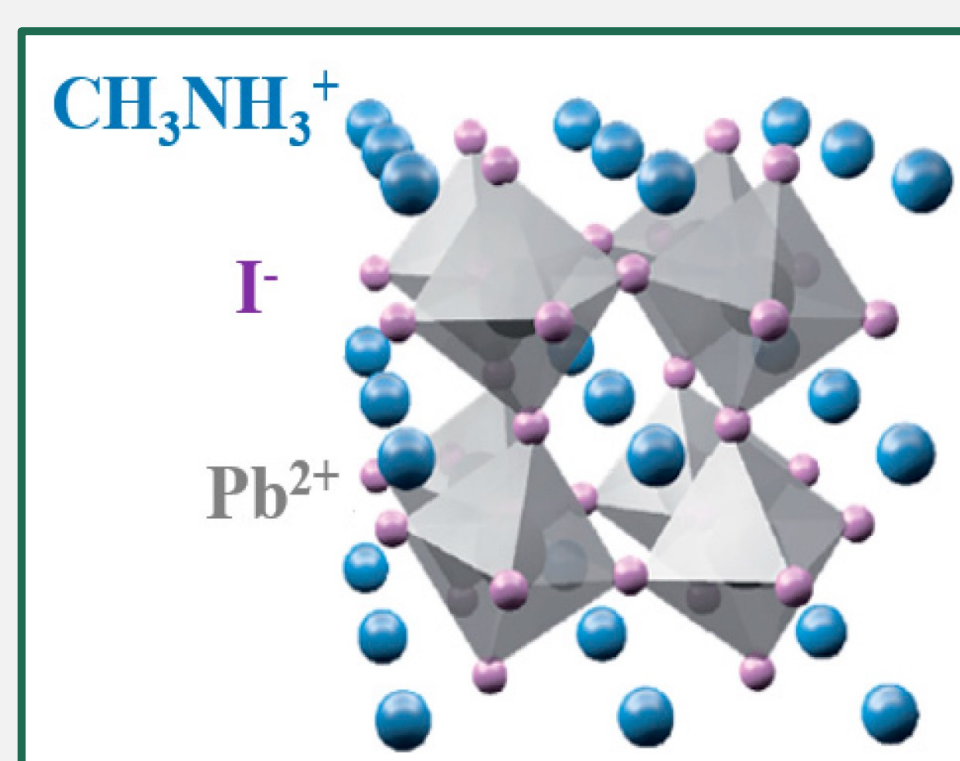


Jonathan Perkins¹, Ethan Taylor¹, Kannatassen Appavoo¹
Department of Physics, University of Alabama at Birmingham

MOTIVATION

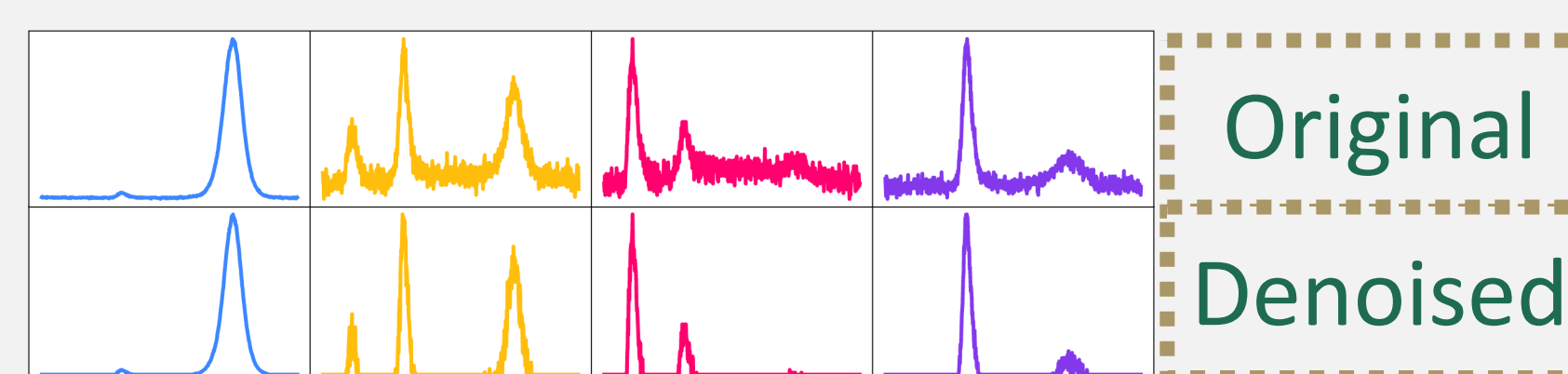
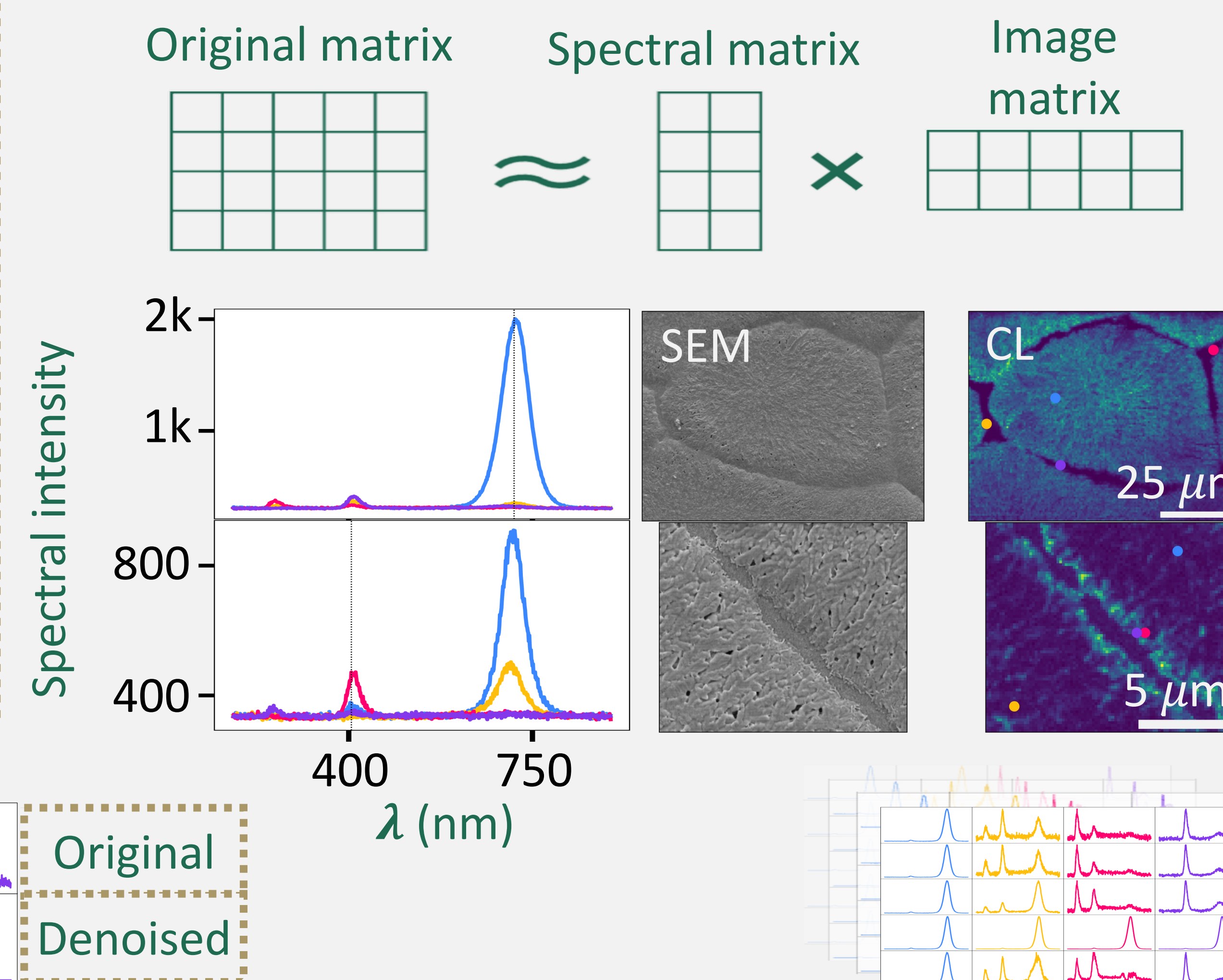
- **Hybrid perovskites (HP's)** have recently generated unprecedented growth in opto-electronic technologies.
- Used in photovoltaics (solar cells), light-emitting diodes, neuromorphic computing... etc.
- Deeper understanding of phase stabilization is critically needed



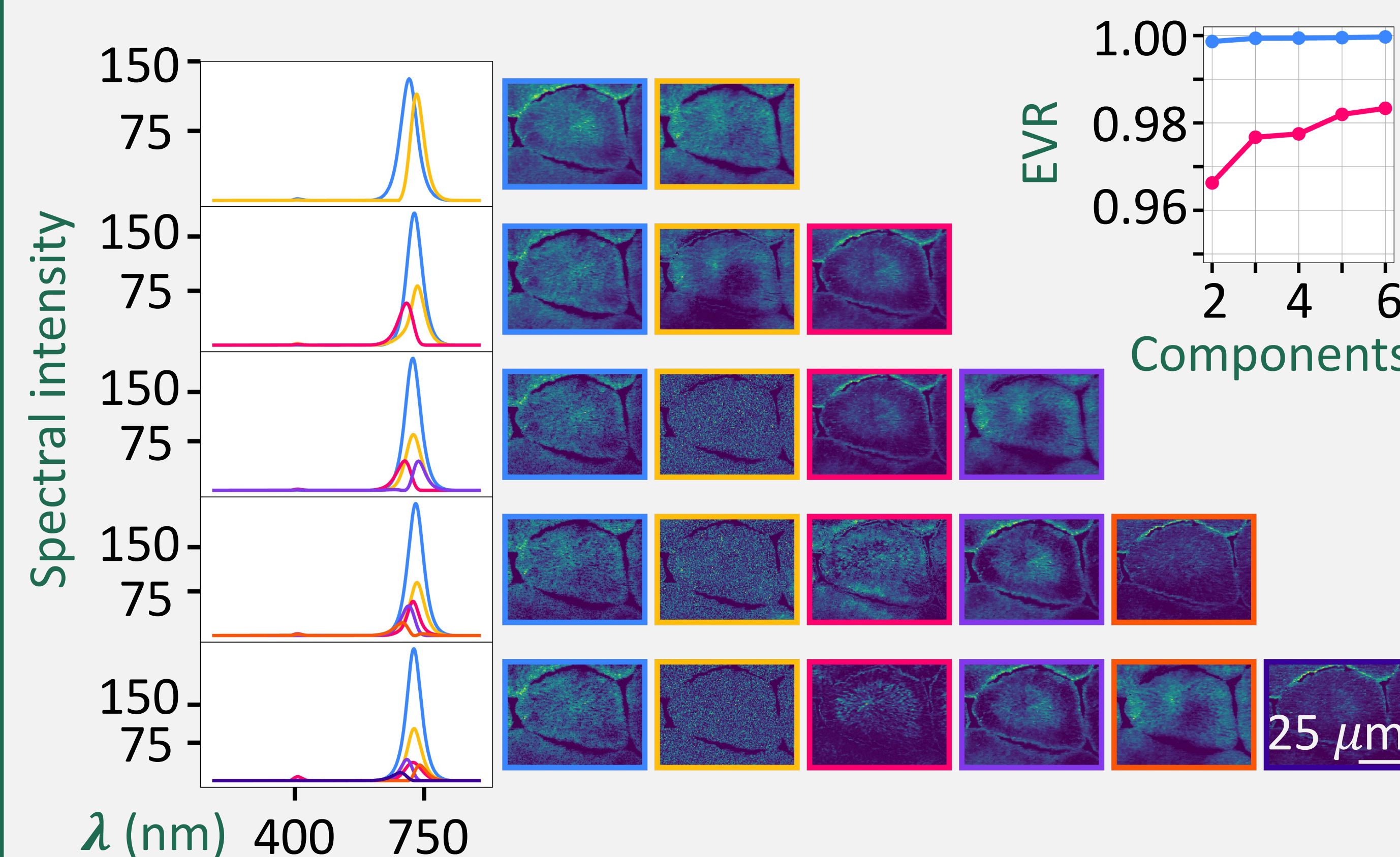
Machine learning is increasingly being used to understand complex data in novel ways beyond human perception.

METHODS

- **NMF** is a machine learning algorithm that produces a **parts-based** representation of data.¹
- 1 complex matrix is decomposed into 2 matrices of lower rank.
- Right: Wide-field HP cell (top), HP grain boundary (bottom)

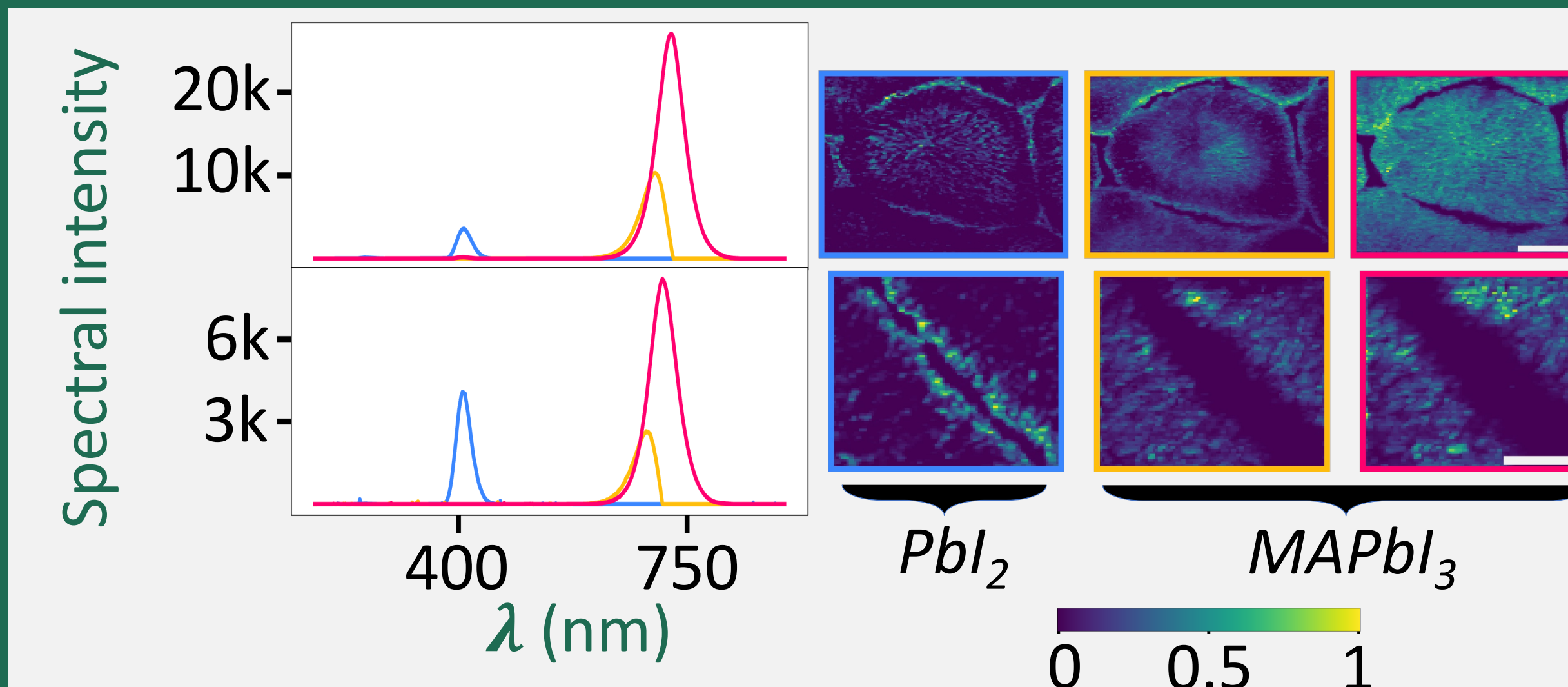


After testing 20+ filter combinations on various spectral signatures, subtracting background and applying a median filter best improved data quality



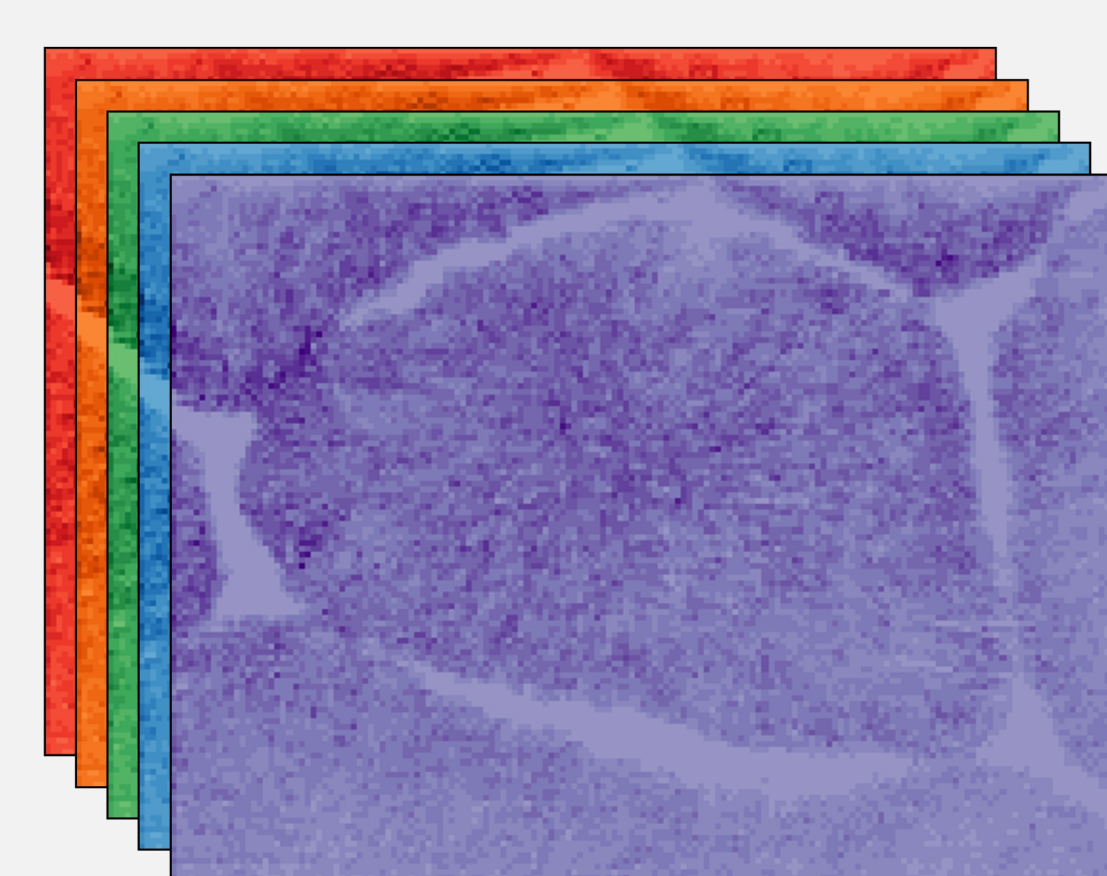
- Blind NMF with 2 to 6 components and explained variance (EVR) suggest 3 components are sufficient
- We enforced **sparseness** (degree to which a vector is populated by zeros) on the loss function to varying amounts

RESULTS AND DISCUSSION



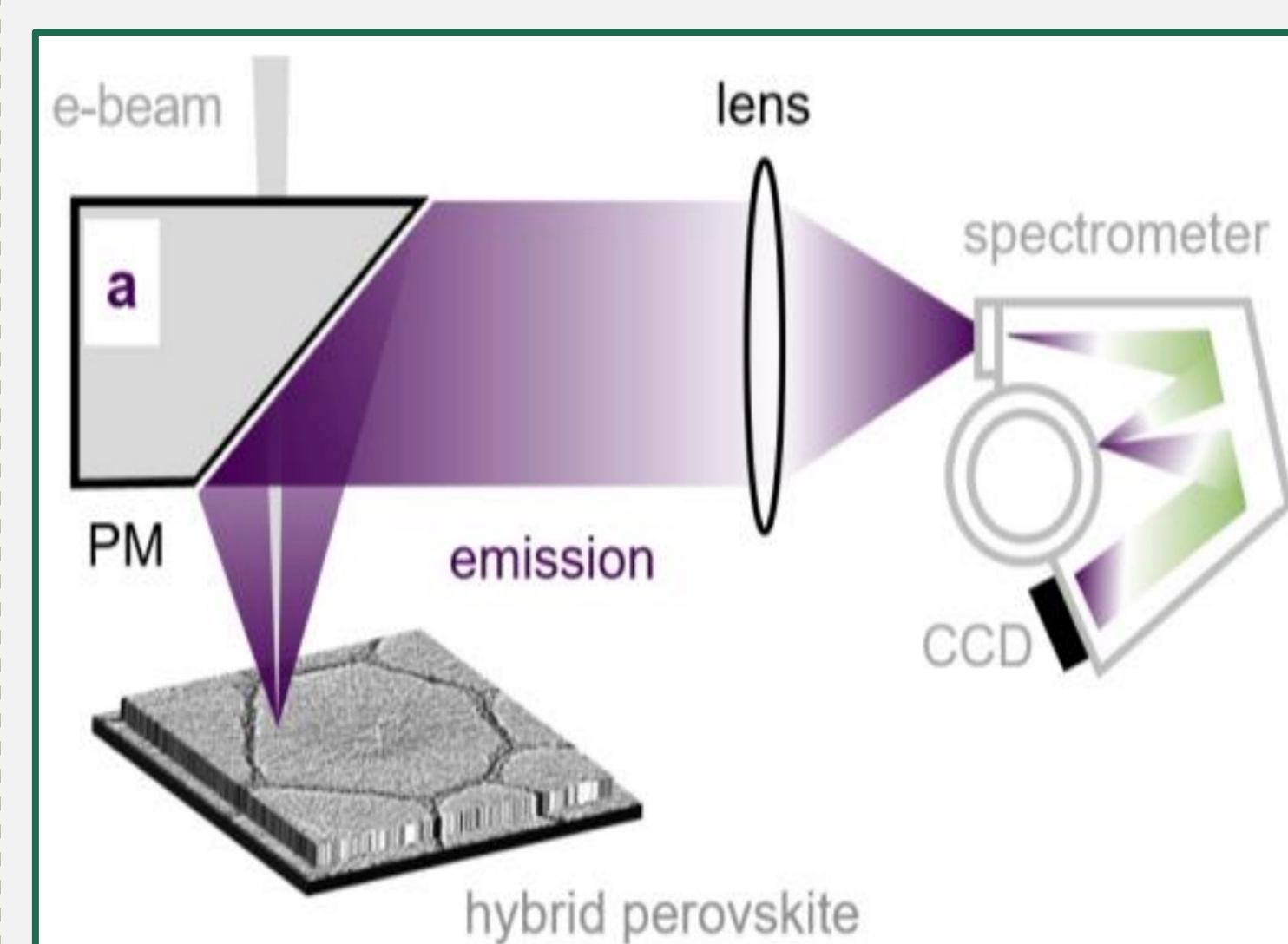
- 3-component NMF with high spectral sparseness at 200 iterations decomposes the perovskite and lead iodide signatures into separate components.
- HP degrades into lead iodide at grain boundaries where it has higher exposure to humidity.

BACKGROUND

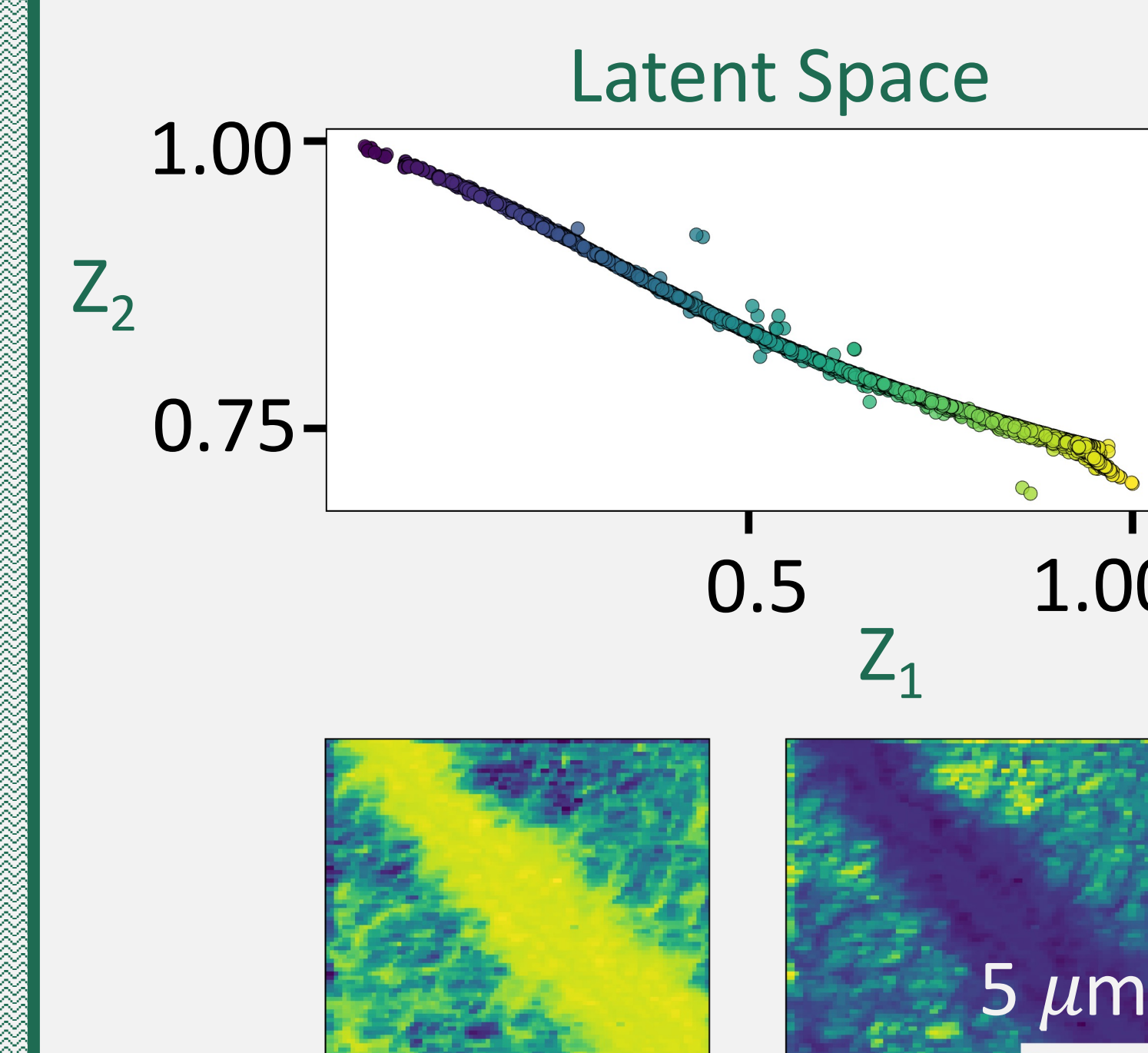


Hyperspectral datasets of HP were acquired via scanning electron microscopy (SEM) and **cathodoluminescence (CL) spectroscopy**, a powerful tool for mapping materials below the diffraction limit.

In CL, A beam of electrons excites the atoms in the HP which emits photons to be directed by a hyperbolic mirror into a charge-coupled device (CCD).



FURTHER STUDIES



Preliminary investigations using a **variational autoencoder** revealed inverse correlations between lead iodide presence (Z_1) and HP dominance (Z_2)

REFERENCES

- ¹Lee, Daniel D., and H. Sebastian Seung. "Learning the Parts of Objects by Non-Negative Matrix Factorization." *Nature* 401, no. 6755 (October 1999)

ACKNOWLEDGEMENTS

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