Semi-supervised segmentation of neurons from brainbow images

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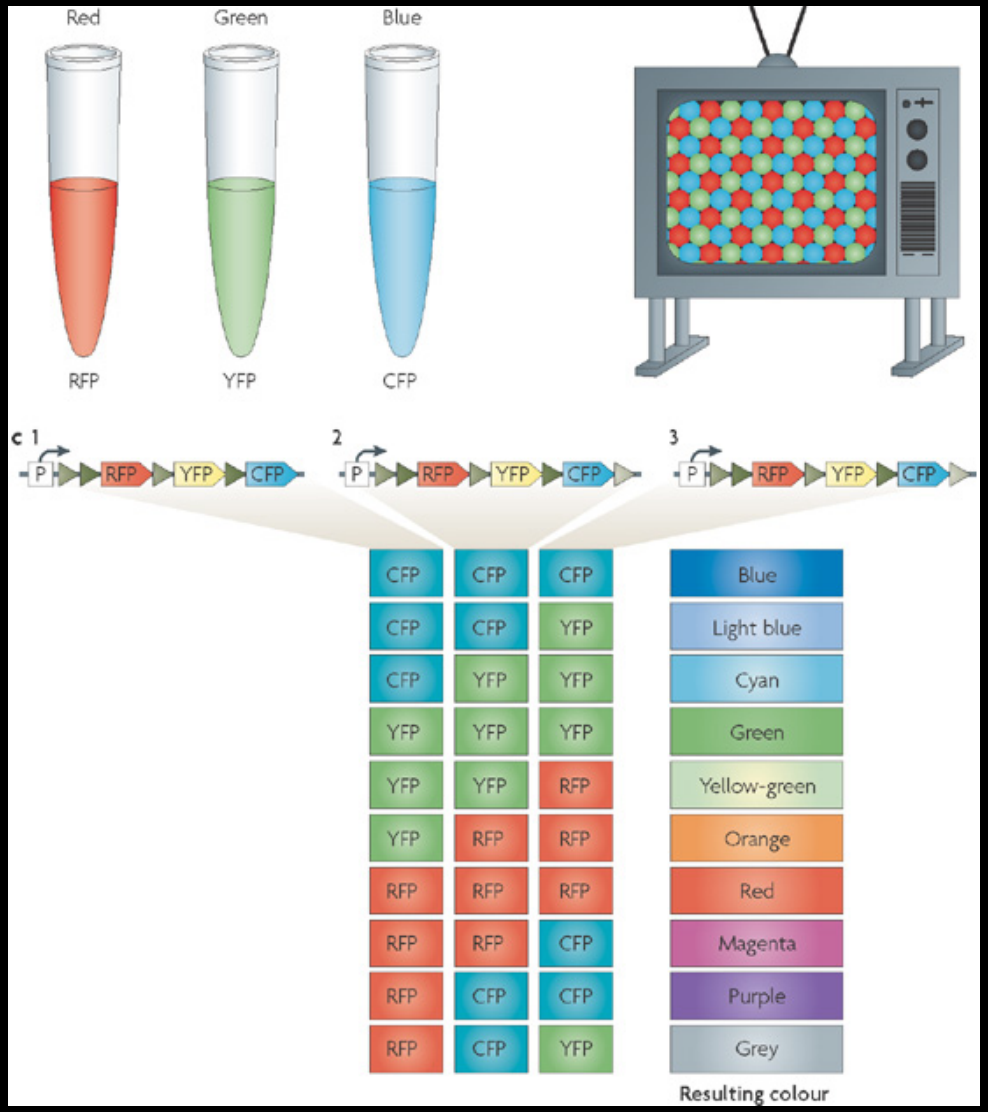
Dawen Cai, John Cunningham, Liam Paninski

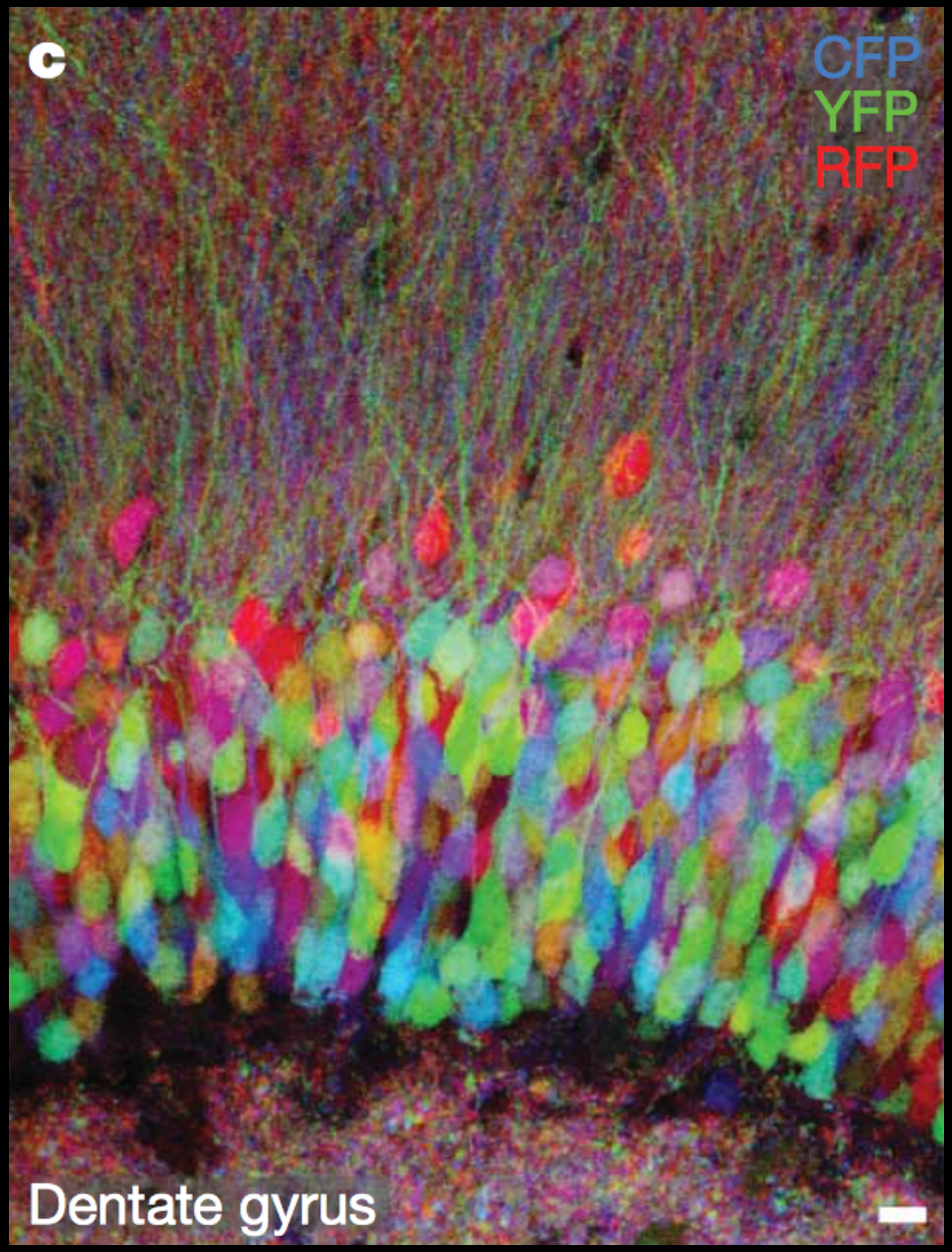
The Brainbow construct



Lichtman et al.

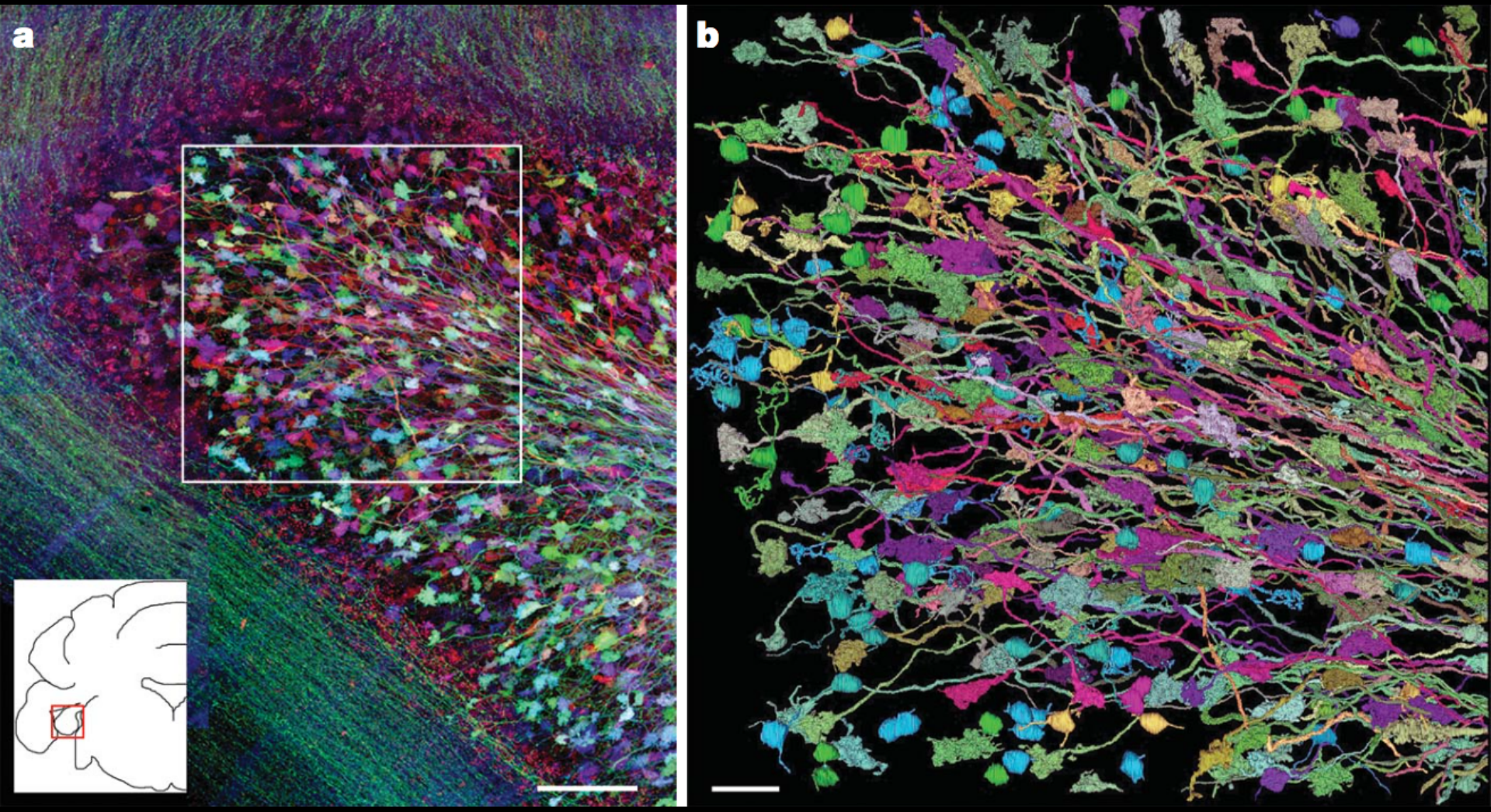
- A tool to identify individual neurons by color

The structural substrate beneath



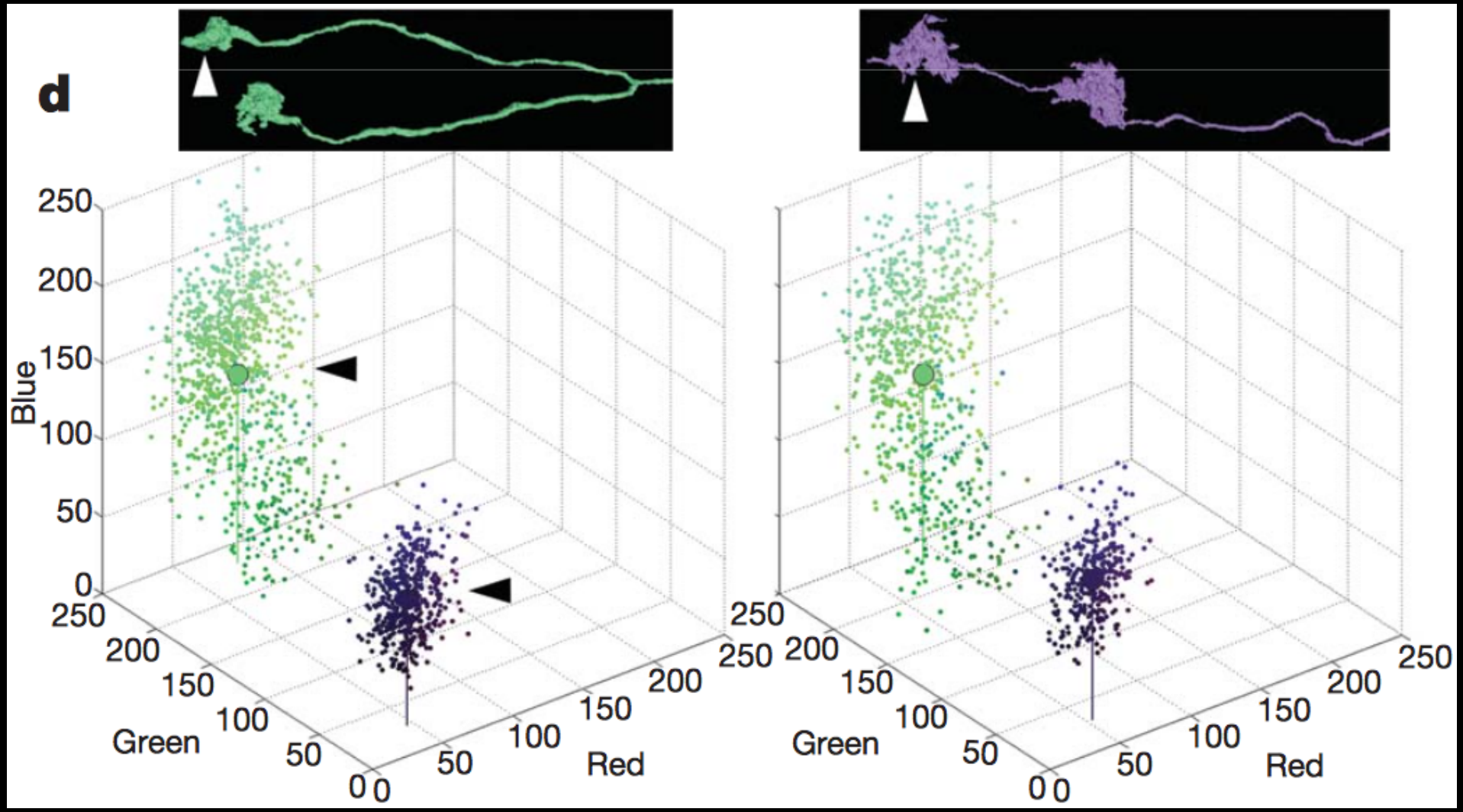
Livet et al, 2007

The structural substrate beneath



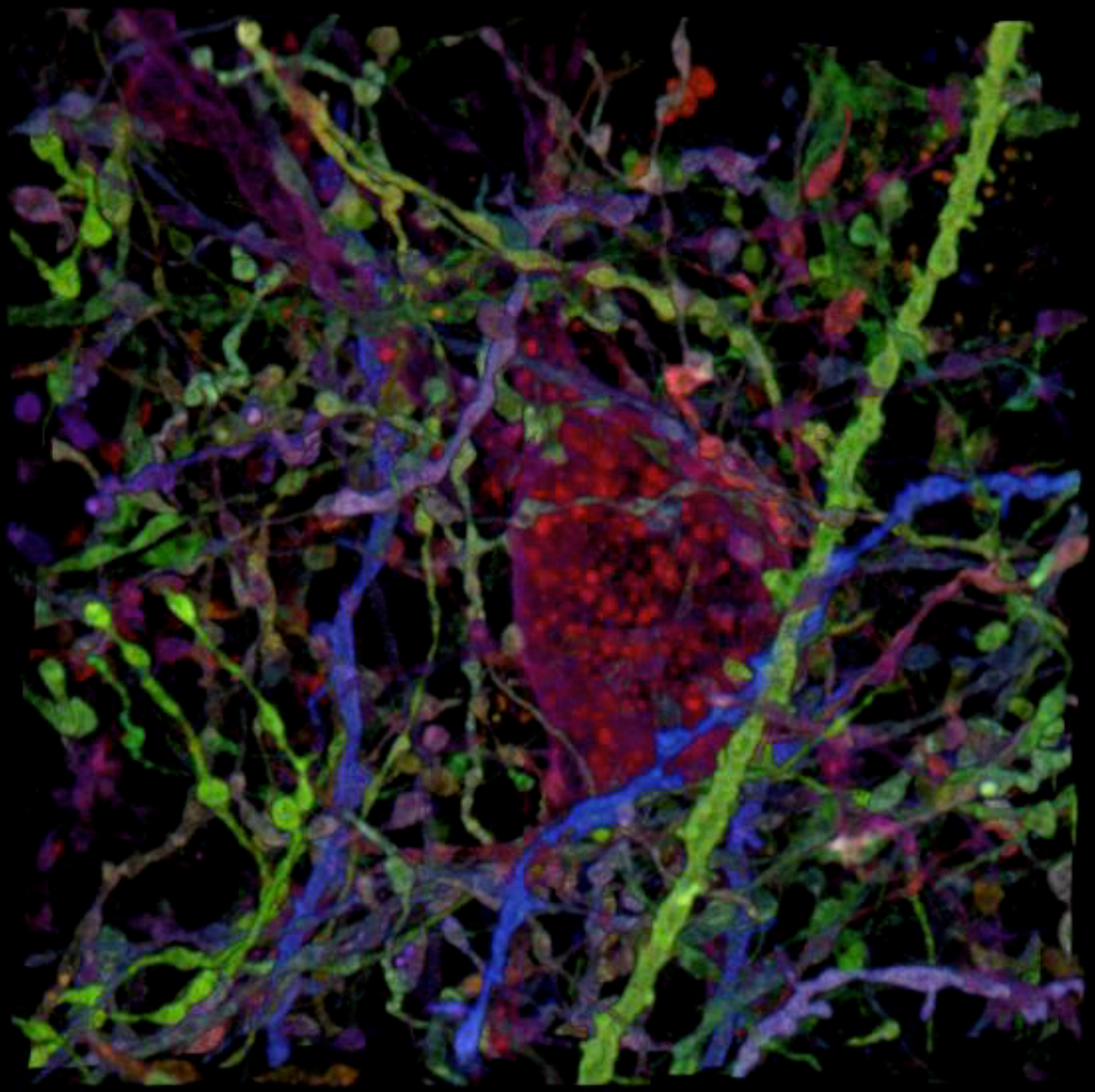
Livet et al, 2007

Noise sources



Livet et al, 2007

3D image stacks of neuronal tissues



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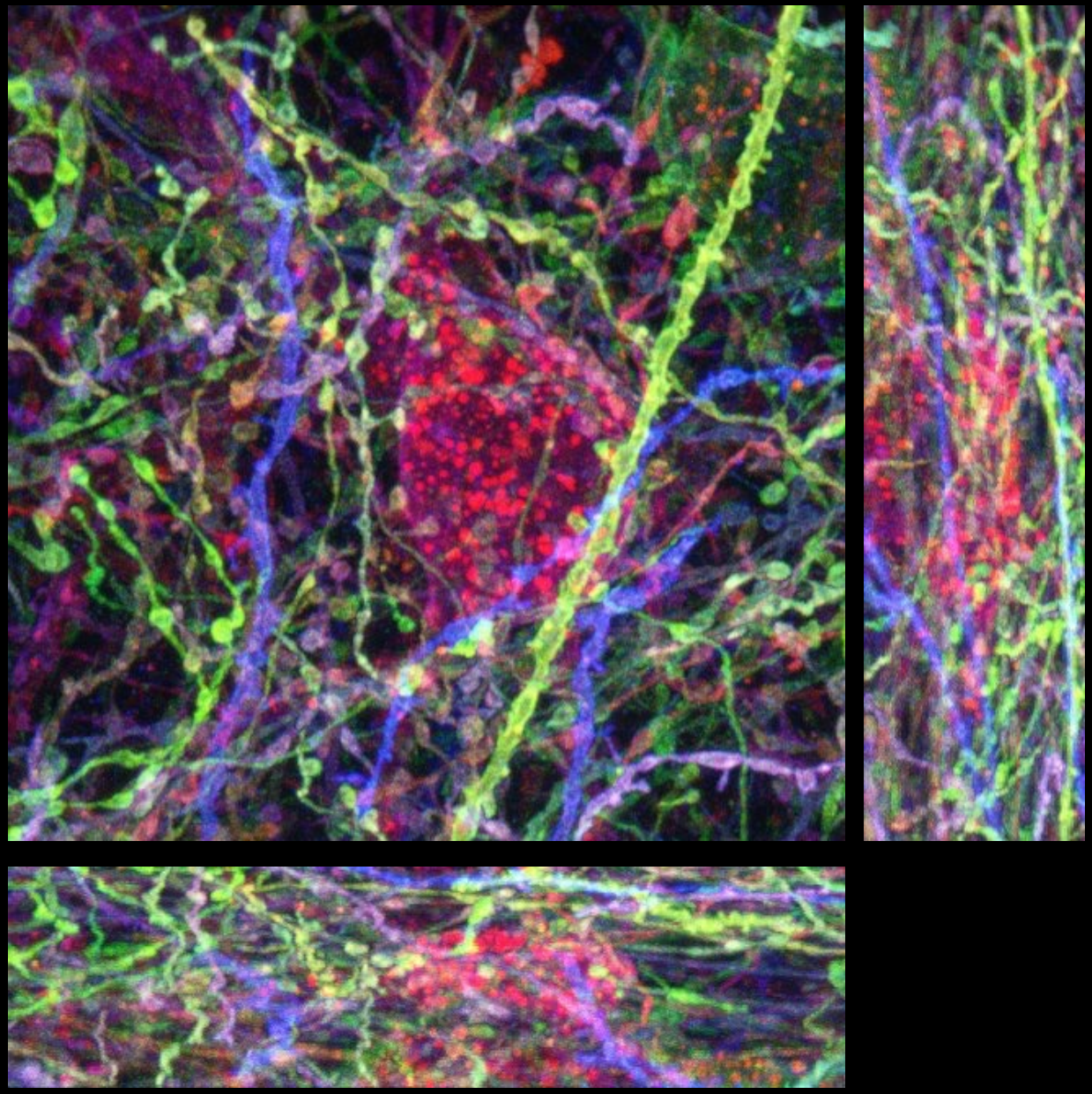
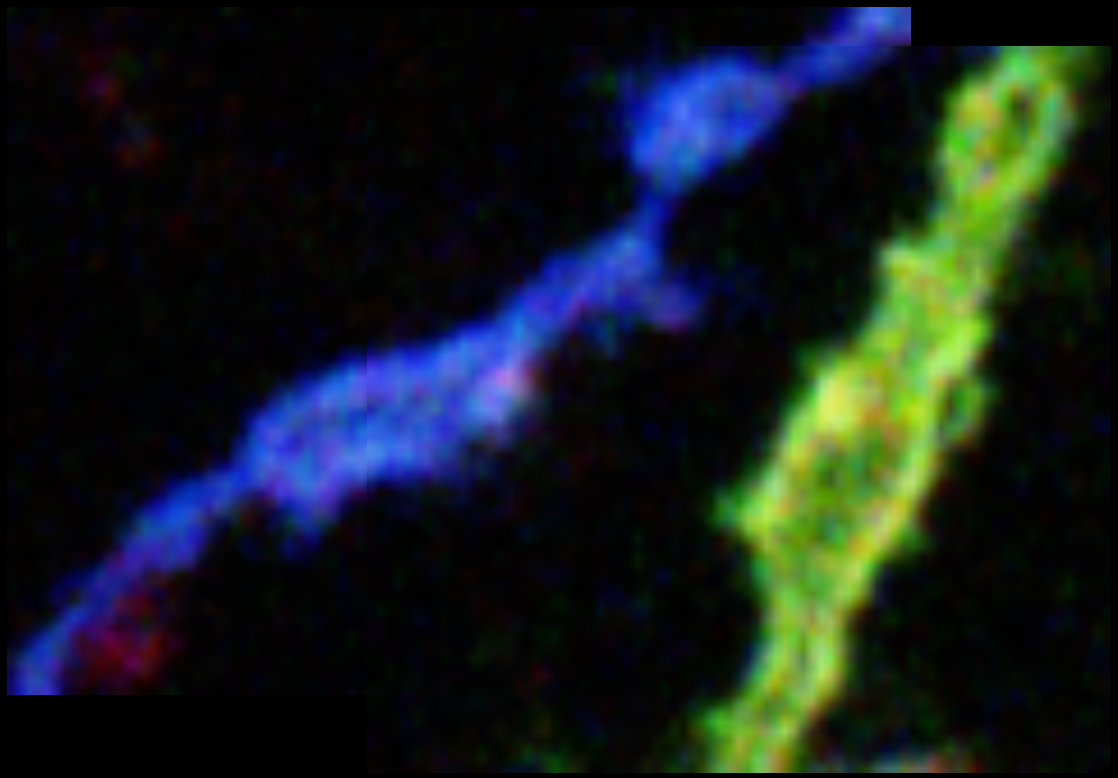
Maximum intensity projections



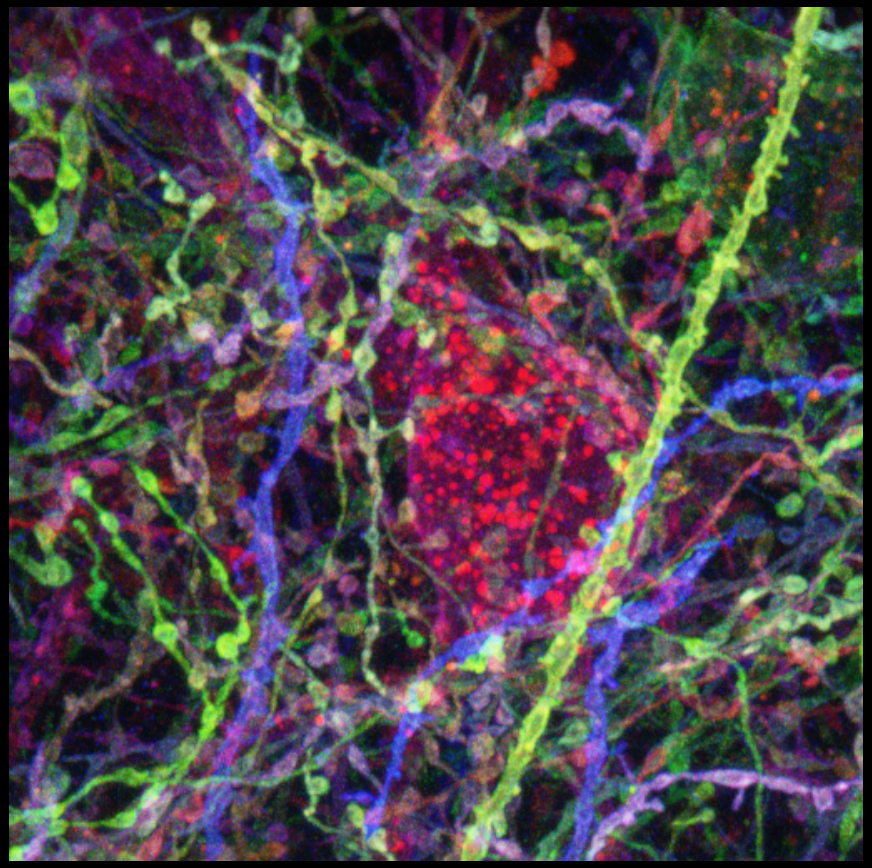
Noise in the Improved Brainbow



The task: segment individual neurons

- Partition the set of foreground voxels

$$S = \{ [x_v\ y_v\ z_v\ r_v\ g_v\ b_v] \}_v$$



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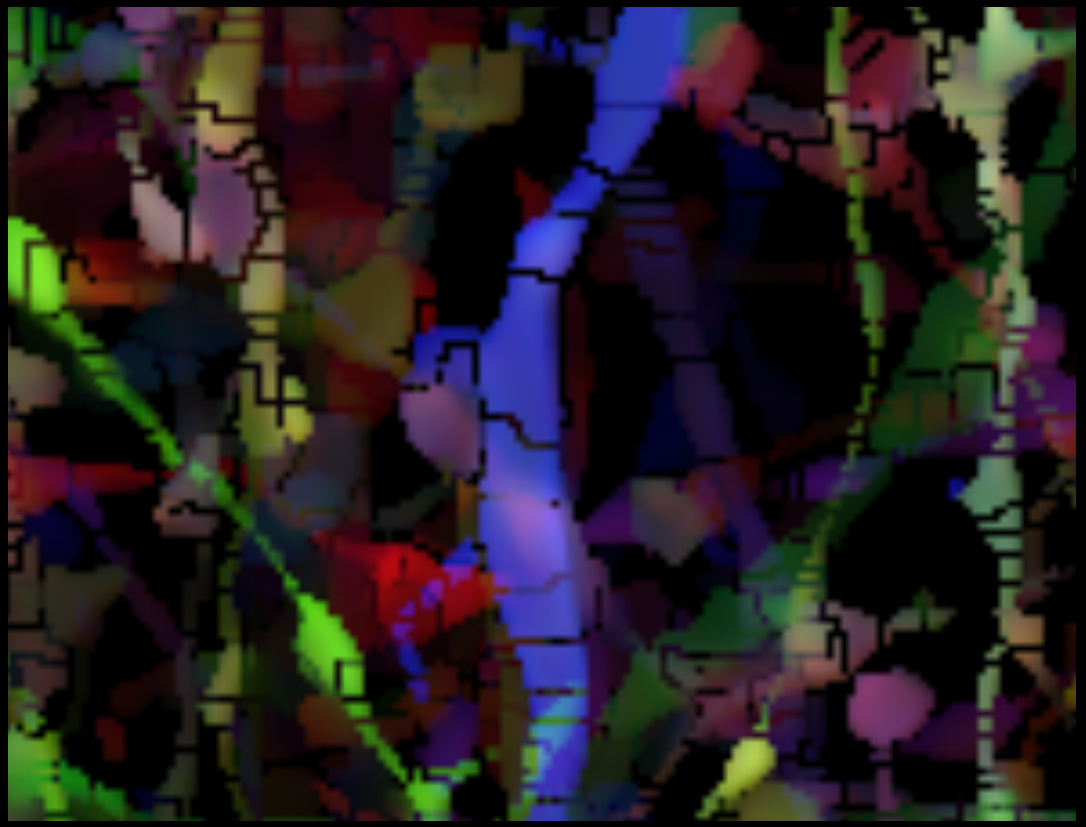
- Very large apparent size

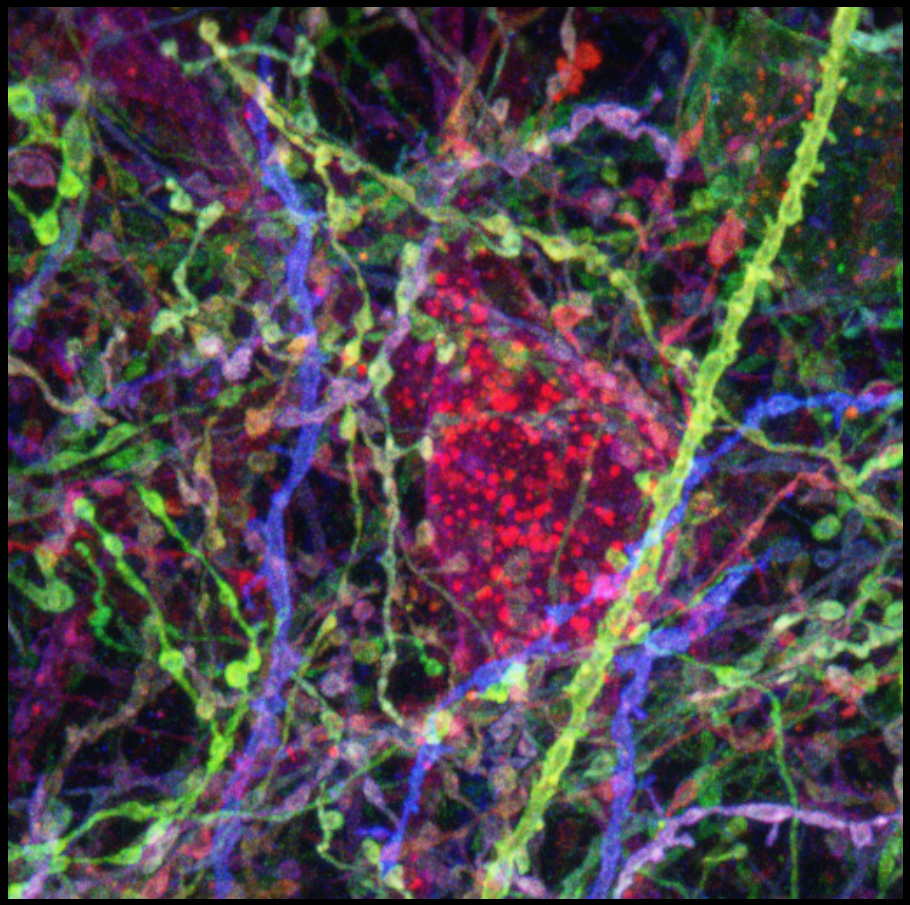
Supervoxels: connected voxels with similar colors

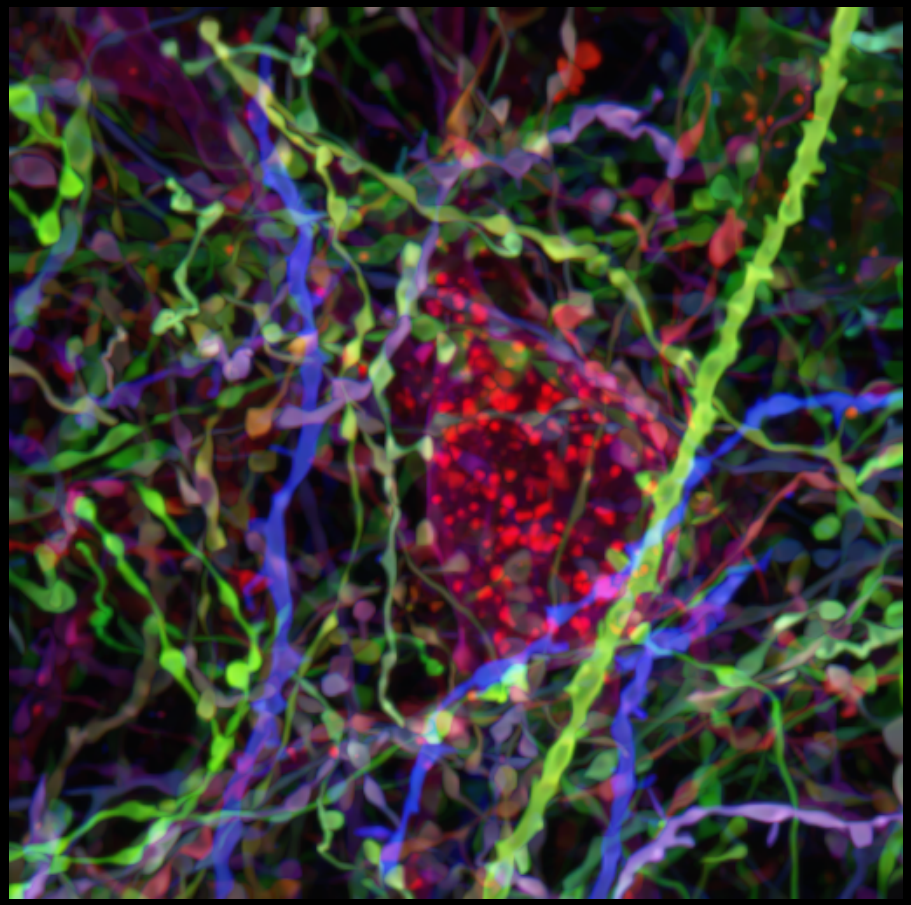
- Identify the foreground
- Obtain an oversegmentation



- Summarize each supervoxel's color with the mean:
- # voxels / # supervoxels ~ 100

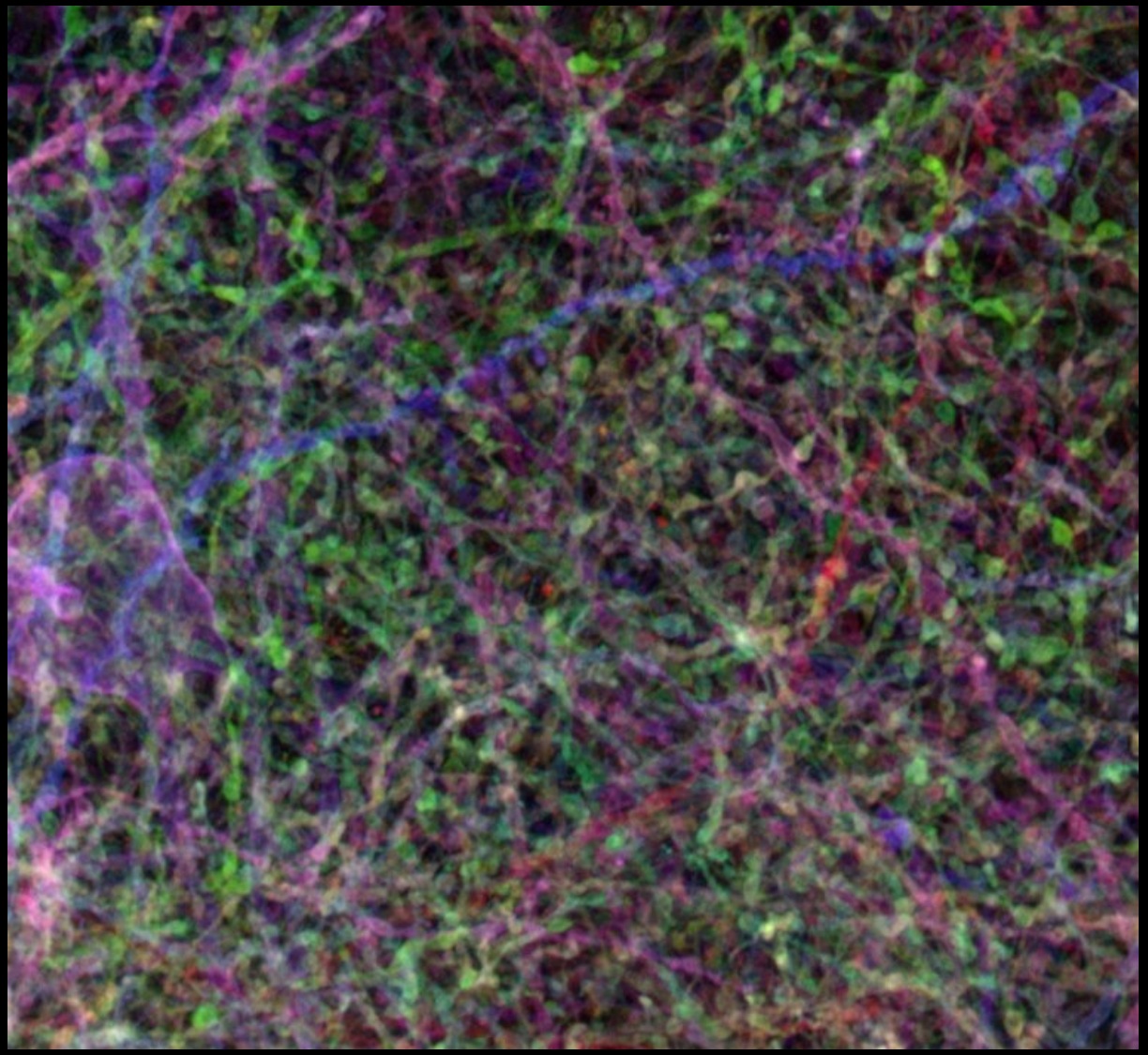
Collaborative filtering and watershed transformation





BM4D

STD projection of 3d stack to be segmented



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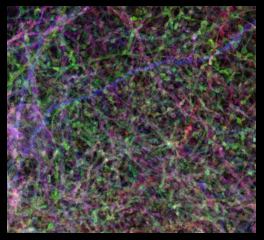
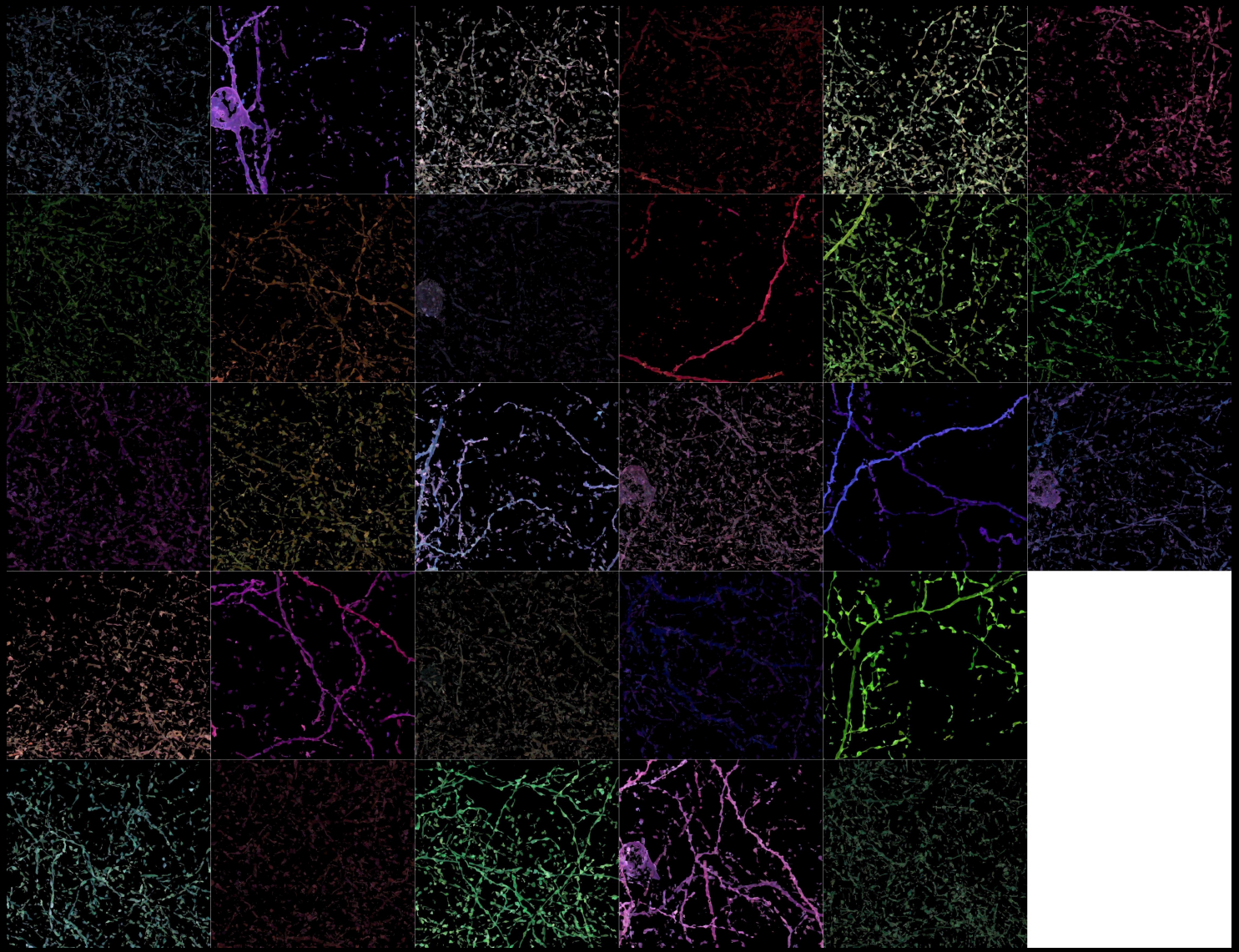
- 764 x 704 x 223 voxels ~ 76μ x 70μ x67μ
- 125K supervoxels

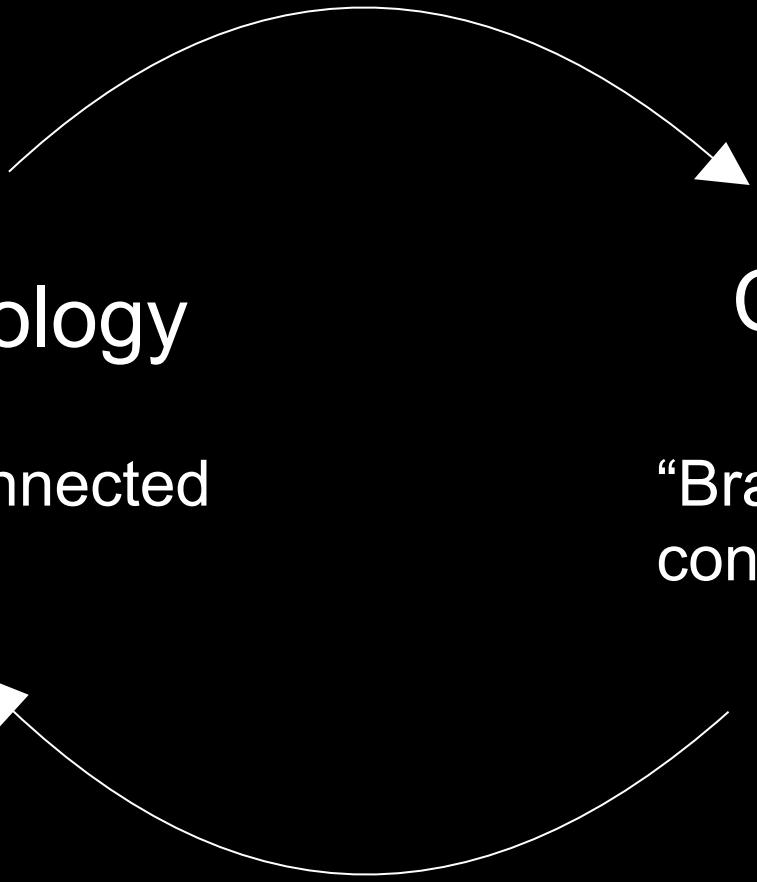


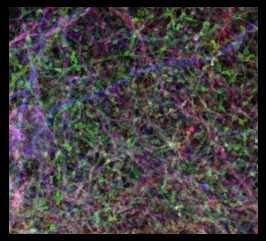
A first approach: weighted k-means

- Transform to LUV color space
- Weights: Color SNR α $\sqrt{\text{voxel count}}$

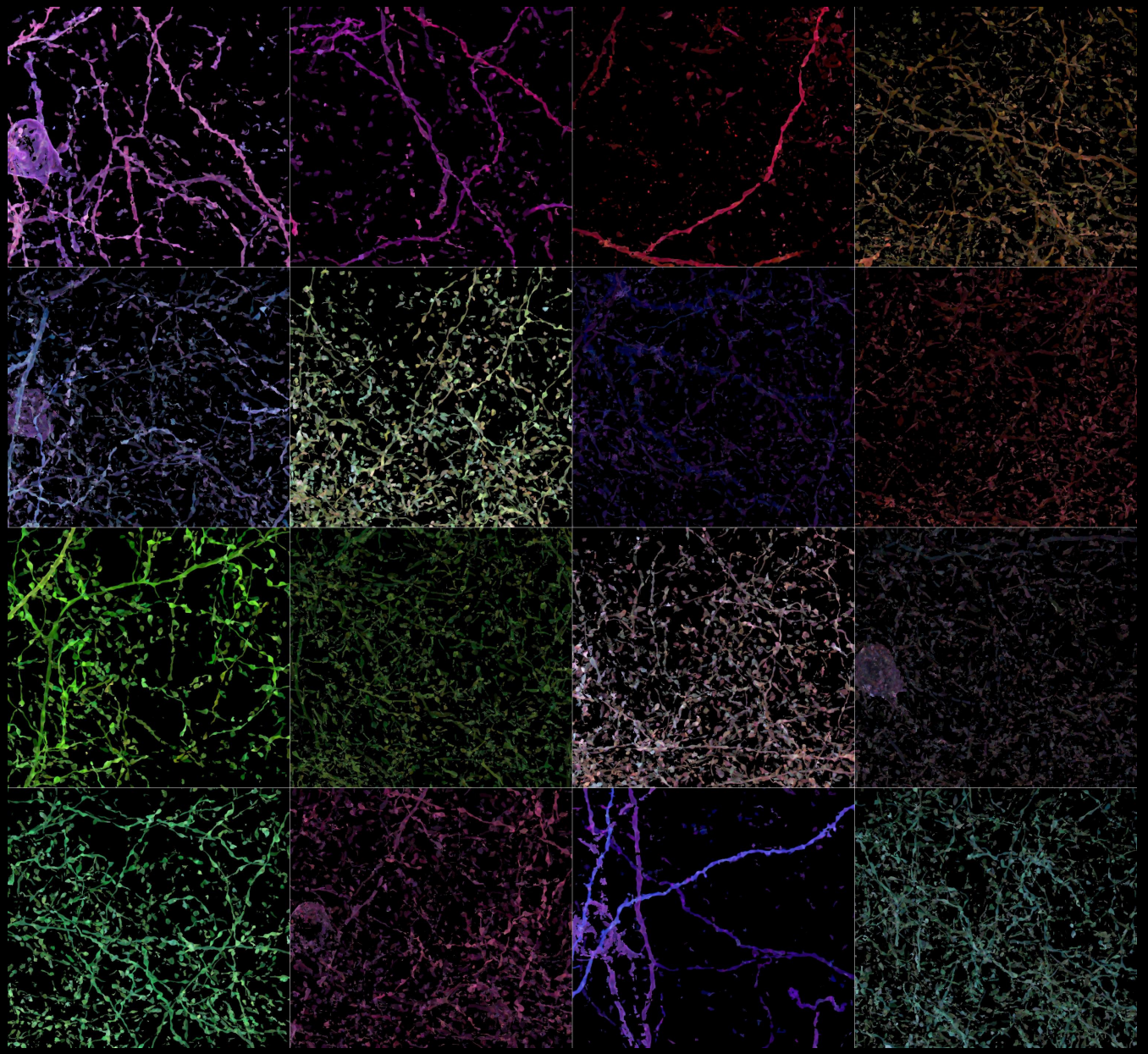


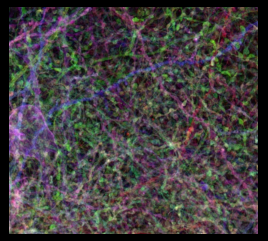
Utilize both space and color



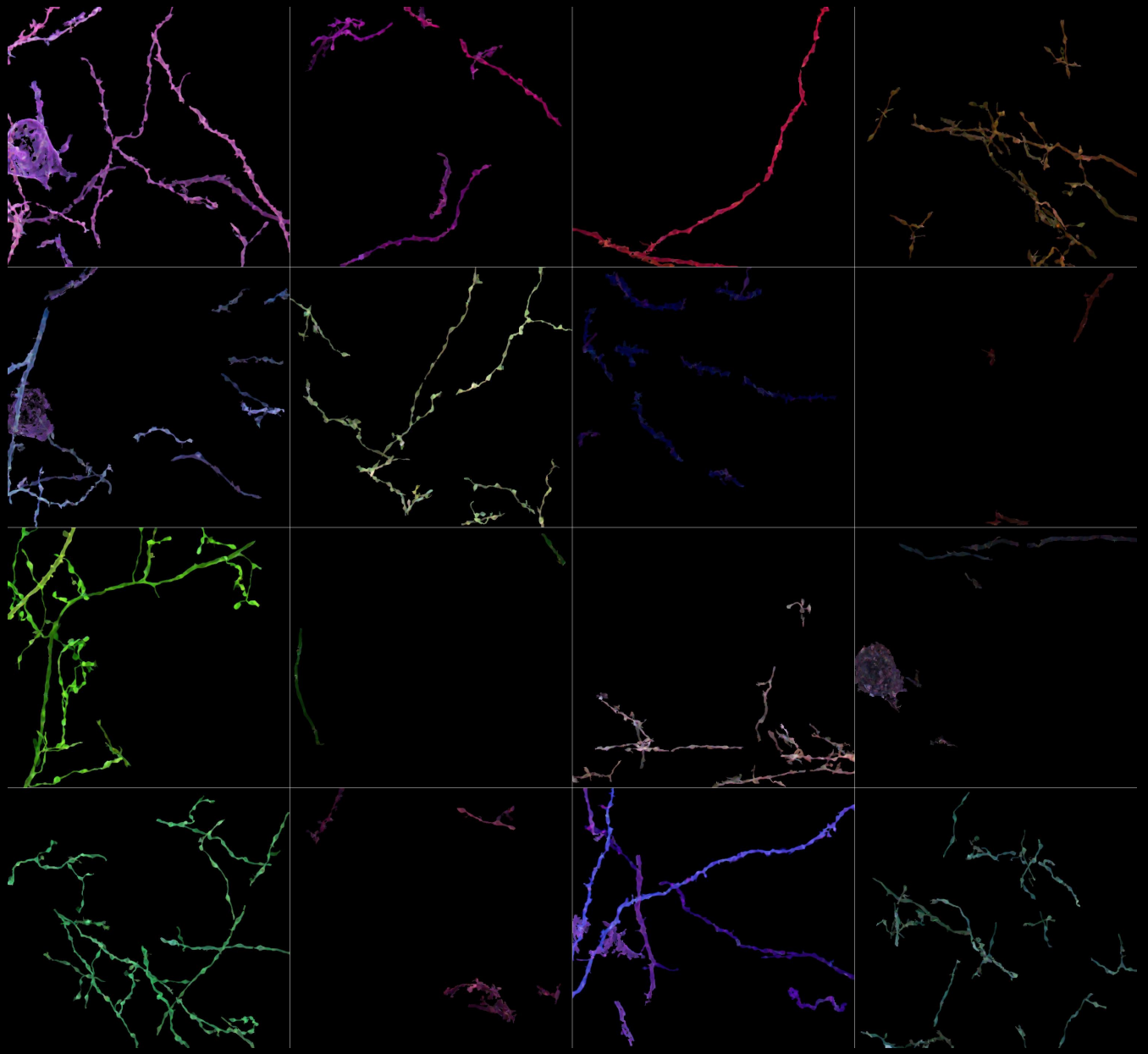


1. Undersegment with weighted k-means

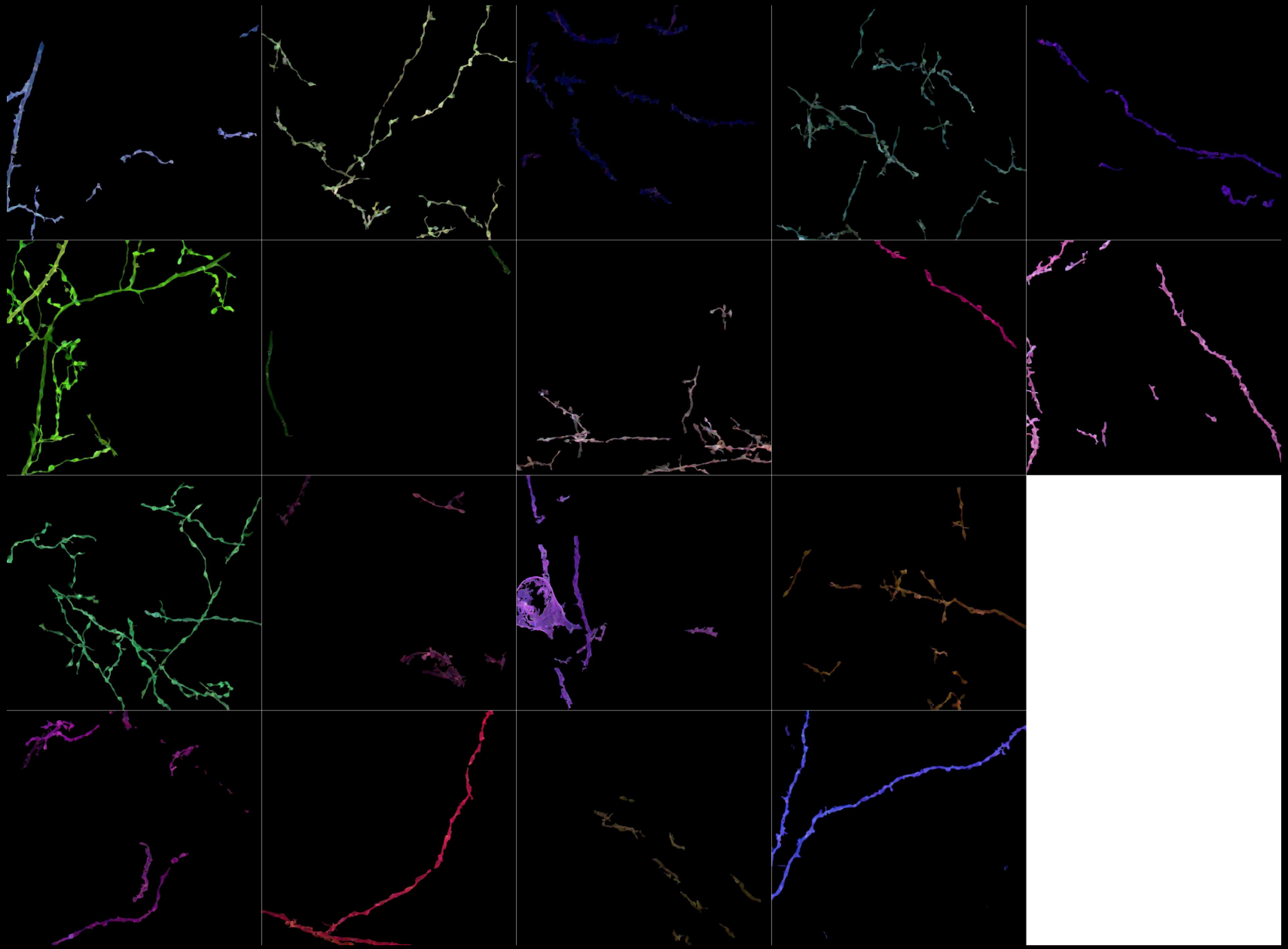




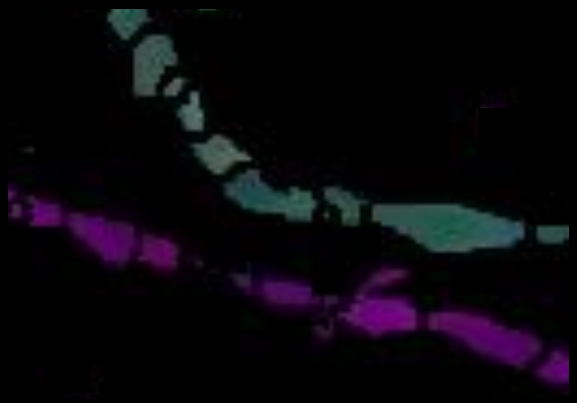
2. Retain big connected components

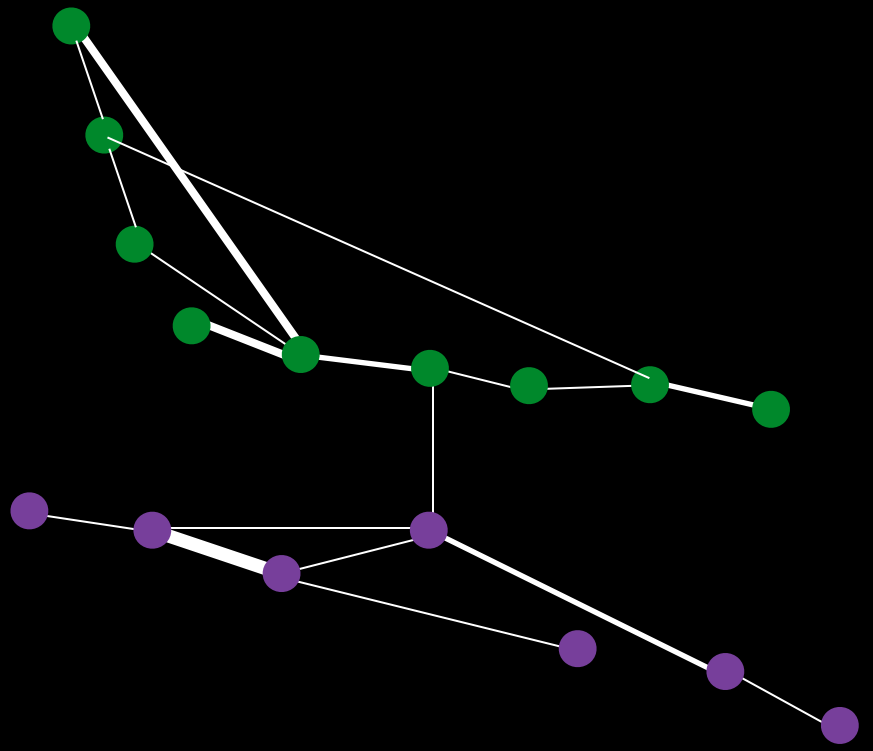


3. Cluster-level user manipulation



Supervoxels are the nodes of a graph





- Edge weights decay with color (and spatial) distance
- Small supervoxels can have local edges only
- Need sparse connectivity due to size
- The task: cluster the nodes of the graph

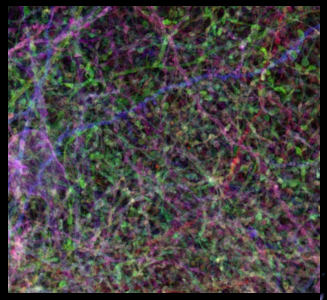
Semi-supervised spectral clustering

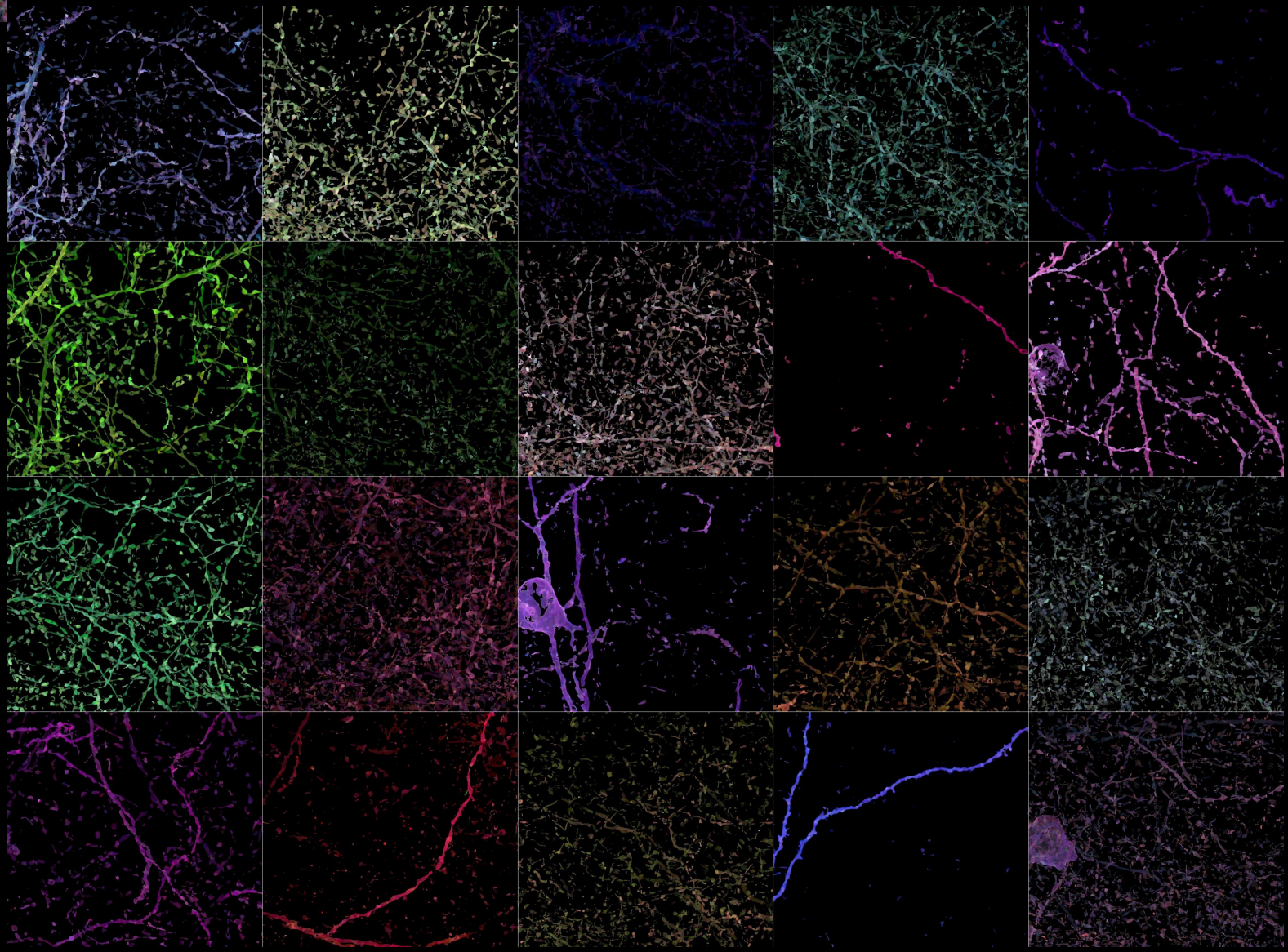
Kamvar et al, 2003
Kulis et al, 2005

- Calculate affinity matrix (<2% dense)
- Impose edge weights from user input
- Calculate normalized eigenvectors of Laplacian

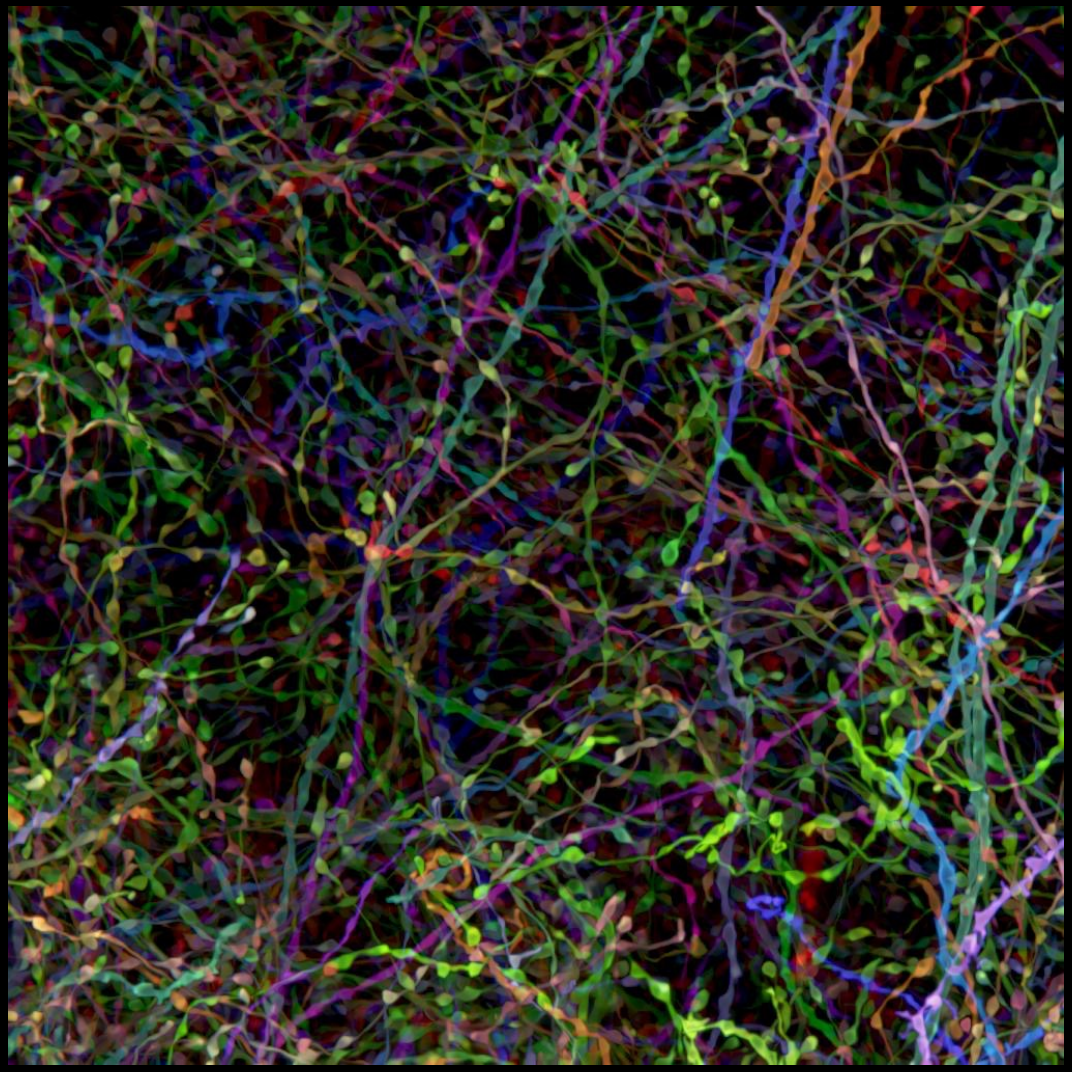
- Weighted k-means on the feature vectors
- Impose cluster memberships from user input

4. Spectral clustering





Another image stack (BM4d filtered)



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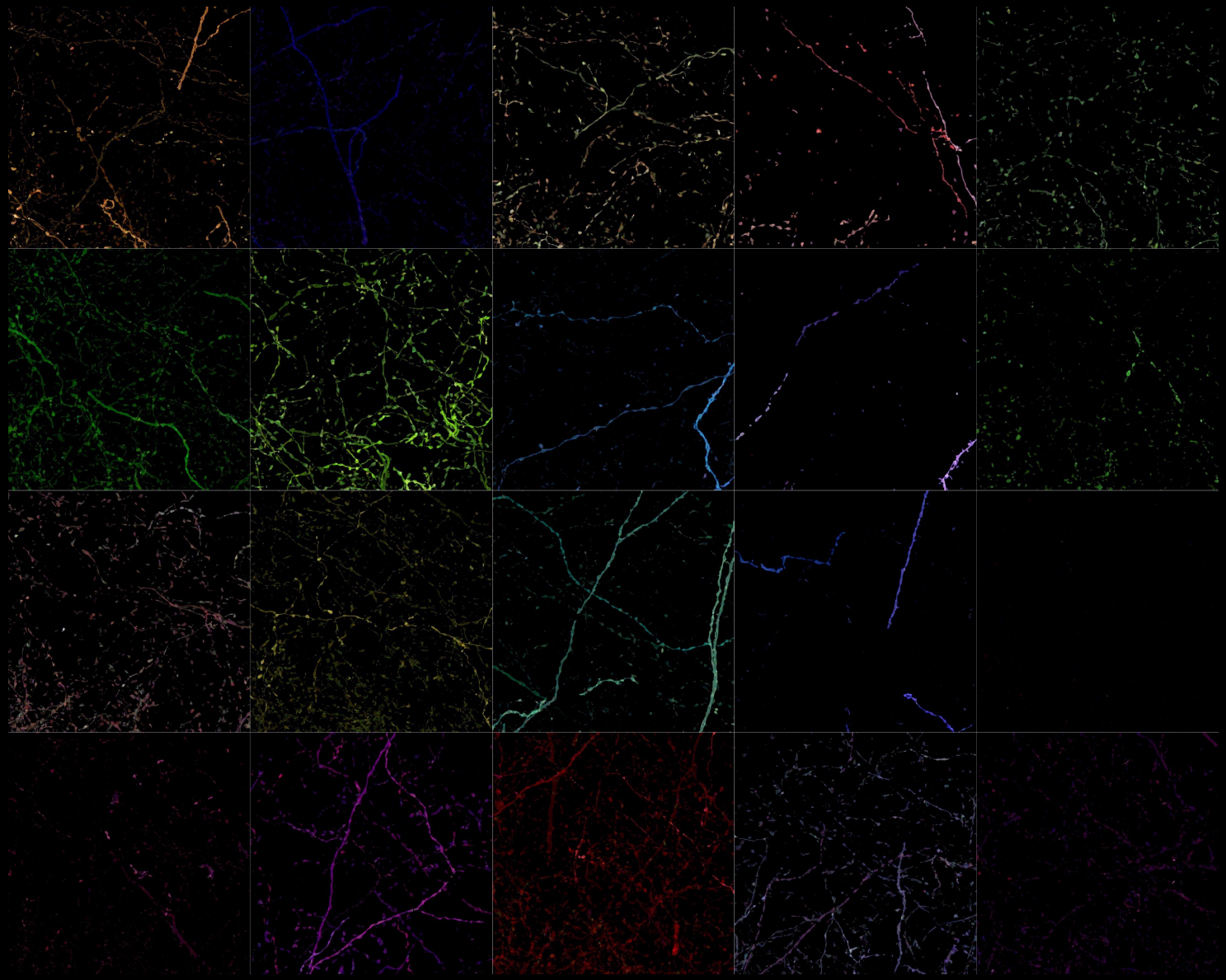
- 1020 x 1020 x 225 voxels ~ 102μ x 102μ x67μ
- 86K supervoxels

4. Spectral clustering



Challenges

- Number of neurons
- Edge weights (spatio-color)
- Warmer starts for more user interaction