The BrainGlobe Initiative: An Open Source Neuroanatomy Platform for the 21st Century

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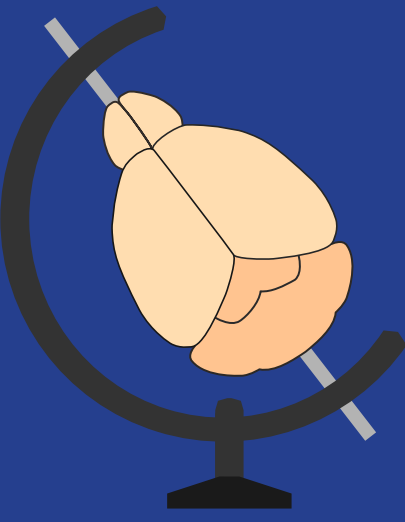
Introduction

Neuroanatomy is key for understanding the brain, but software to analyse the data are often single purpose, for one model species and suffer from lack of support following publication. We have established the BrainGlobe Initiative - an international, distributed team of users and developers working towards the goal of creating open-source, interoperable and easy to use tools for the analysis of all types of neuroanatomical data.

To analyze data from many samples, it is critical to map individual datasets onto a standard anatomical reference atlas, but neuroscience relies on many animal model species. The BrainGlobe toolkit is therefore not built around a specific brain atlas but rather a generalised atlas framework (the BrainGlobe Atlas API) which is regularly updated with new brain atlases from multiple species.

Claudi, F., Petrucco, L., Tyson, A. L. et al. (2020) "BrainGlobe Atlas API: a common interface for neuroanatomical atlases" Journal of Open Source Software, v5(54), 2668, doi.org/10.21105/joss.02668

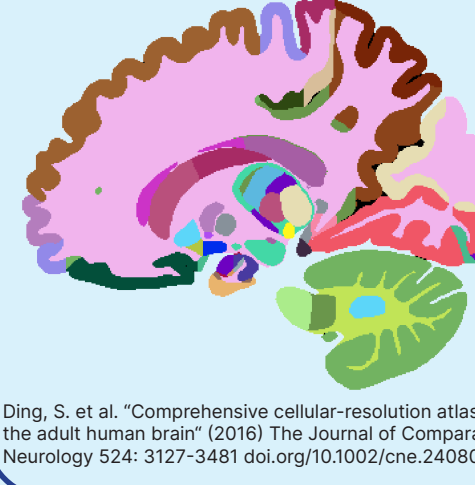## Atlases
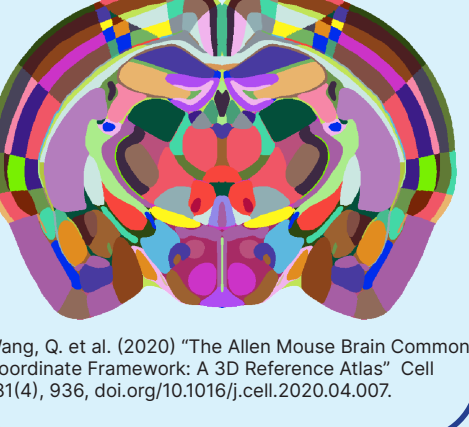
Allen Adult Mouse Brain Atlas
Wang, Q. et al. (2020) "The Allen Mouse Brain Common Coordinate Framework: A 3D Reference Atlas" Cell 181(4), 936, doi.org/10.1016/j.cell.2020.04.007.

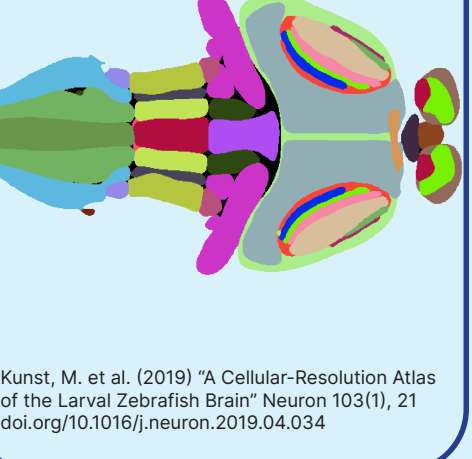Waxholm Space Atlas of the Sprague Dawley Rat brain
Papp et al. (2014) "Waxholm Space Atlas of the Sprague Dawley rat brain" Neuroimage 105, 561, doi.org/10.1016/j.neuroimage.2014.04.001
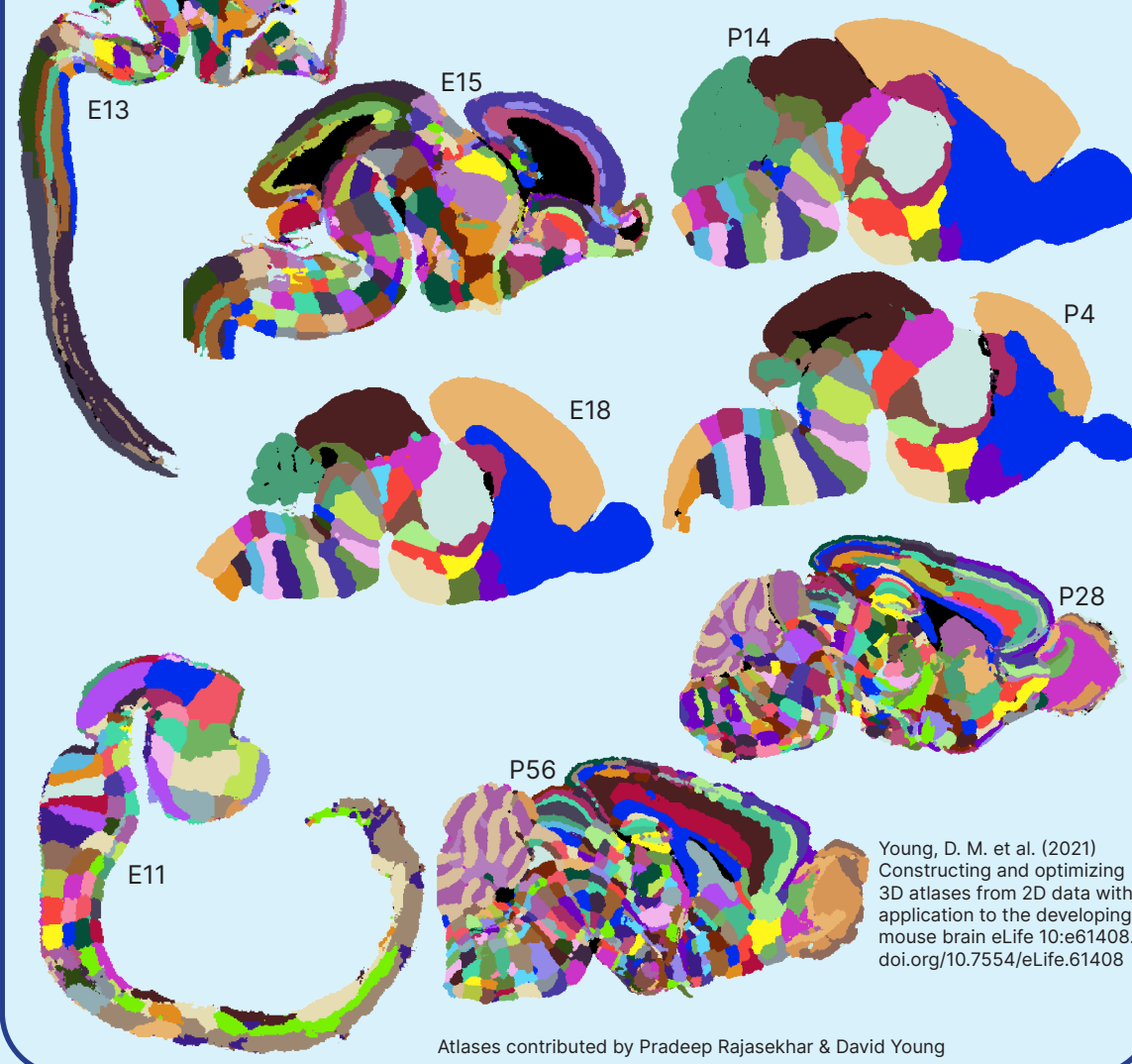Atlas contributed by Ben Kantor

Allen Adult Human Brain Atlas
Ding, S. et al. "Comprehensive cellular-resolution atlas of the adult human brain" (2016) The Journal of Comparative Neurology 524: 3127–3481 doi.org/10.1002/cne.24080
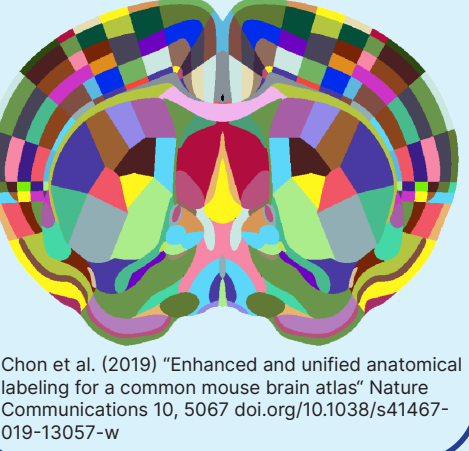

Max Planck Larval Zebrafish Brain Atlas
Kunst, M. et al. (2019) "A Cellular-Resolution Atlas of the Larval Zebrafish Brain" Neuron 103(1), 21 doi.org/10.1016/j.neuron.2019.04.034

3D Edge-Aware Refined Atlases Derived from the Allen Developing Mouse Brain Atlases
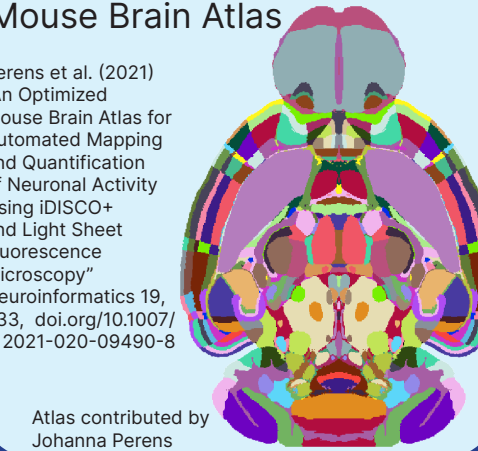Young, D. M. et al. (2021) Constructing and optimizing 3D atlases from 2D data with application to the developing mouse brain eLife 10:e61408, doi.org/10.7554/eLife.61408
Atlases contributed by Pradeep Rajasekhar & David Young

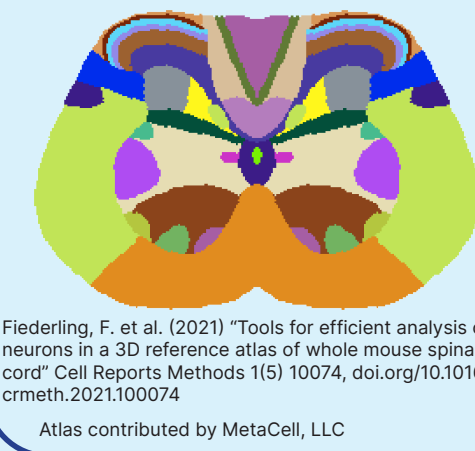
Enhanced and Unified Mouse Brain Atlas
Chon et al. (2019) "Enhanced and unified anatomical labeling for a common mouse brain atlas" Nature Communications 10, 5067 doi.org/10.1038/s41467-019-13057-w

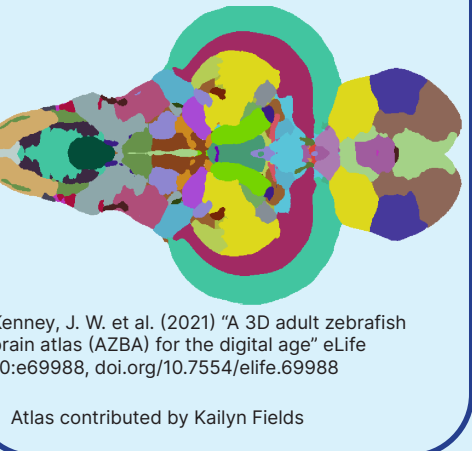Gubra's Lightsheet Fluorescence Microscopy Mouse Brain Atlas
Perens et al. (2021) "An Optimized Mouse Brain Atlas for Automated Mapping and Quantification of Neuronal Activity Using iDISCO+ and Light Sheet Fluorescence Microscopy" Neuroinformatics 19, 433, doi.org/10.1007/s12021-020-09490-8
Atlas contributed by Johanna Perens

3D Version of the Allen Mouse Spinal Cord Atlas
Fiederling, F. et al. (2021) "Tools for efficient analysis of neurons in a 3D reference atlas of whole mouse spinal cord" Cell Reports Methods 1(5) 10074, doi.org/10.1016/j.crmeth.2021.100074
Atlas contributed by MetaCell, LLC

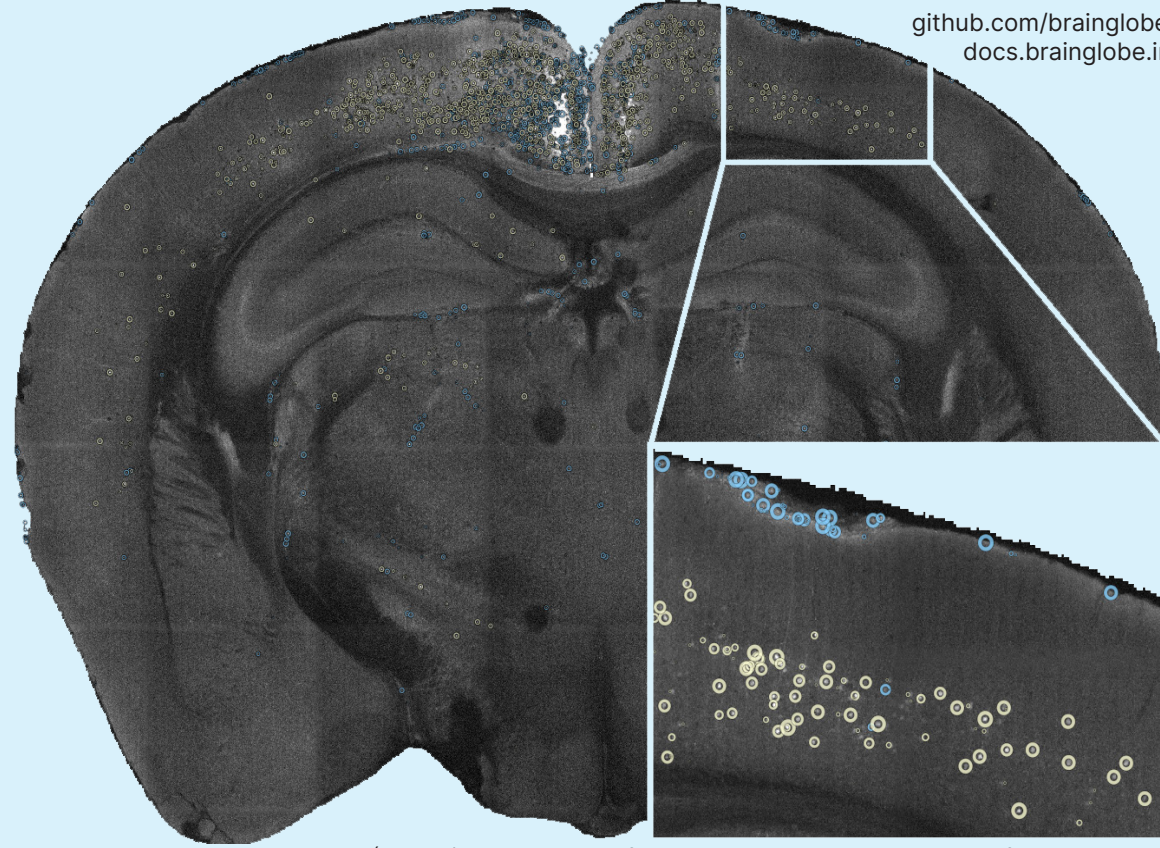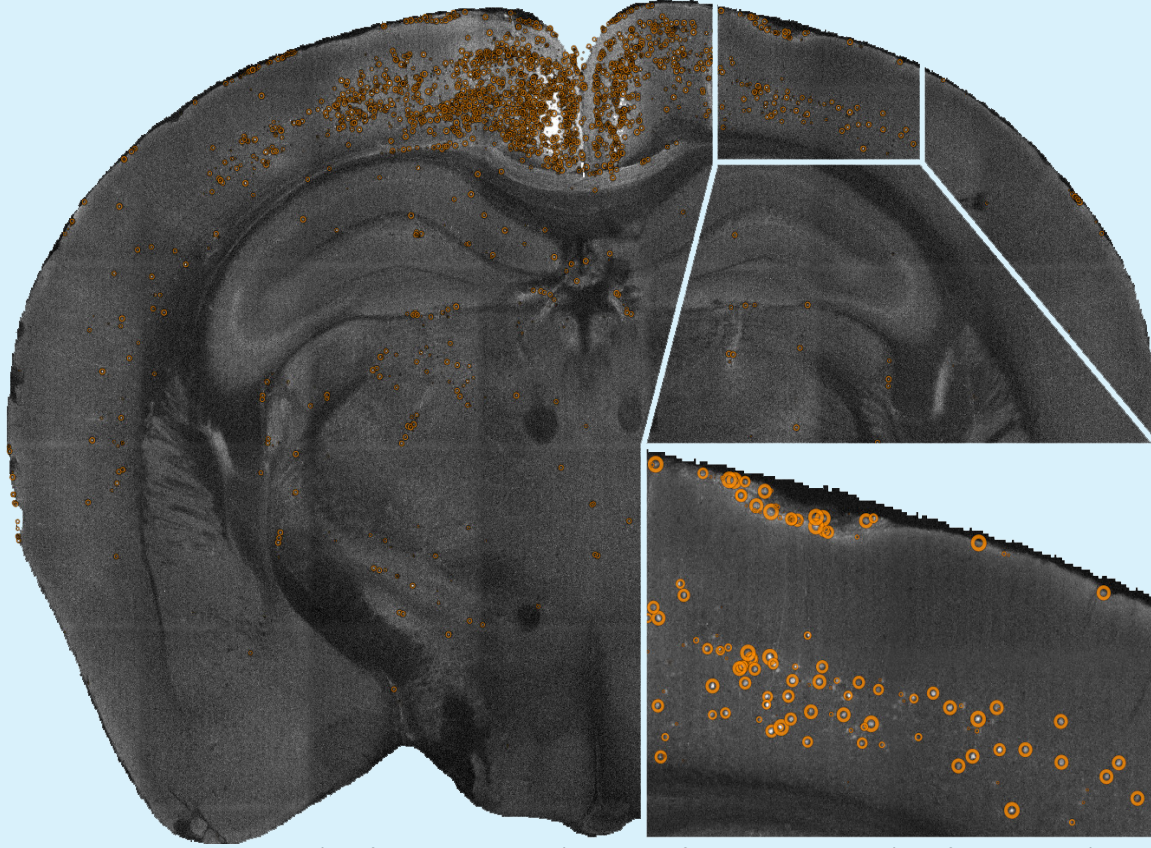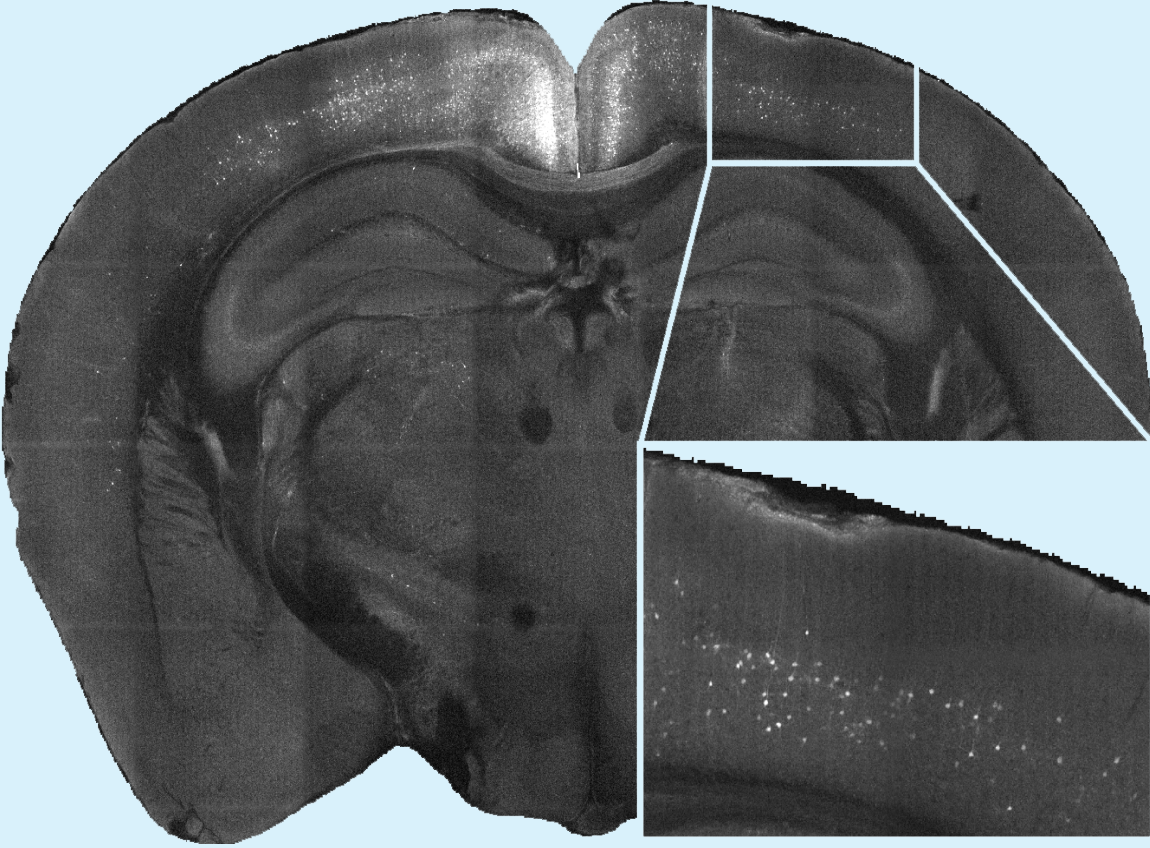AZBA: A 3D Adult Zebrafish Brain Atlas
Kenney, J. W. et al. (2021) "A 3D adult zebrafish brain atlas (AZBA) for the digital age" eLife 10:e69988, doi.org/10.7554/eLife.69988
Atlas contributed by Kailyn Fields

cellfinder

github.com/brainglobe/cellfinder
docs.brainglobe.info/cellfinder

Efficient 3D cell detection in large fluorescence microscopy images, e.g. cleared whole mouse brains imaged with lightsheet microscopy.

4000 cells can be detected in a 200GB image in ~90 mins on a laptop

Tyson, A. L., Rousseau, C. V., Niedworok, C. J. et al. (2021) "A deep learning algorithm for 3D cell detection in whole mouse brain image datasets" PLoS Comp Biol 17(5) e1009074, doi.org/10.1371/journal.pcbi.1009074
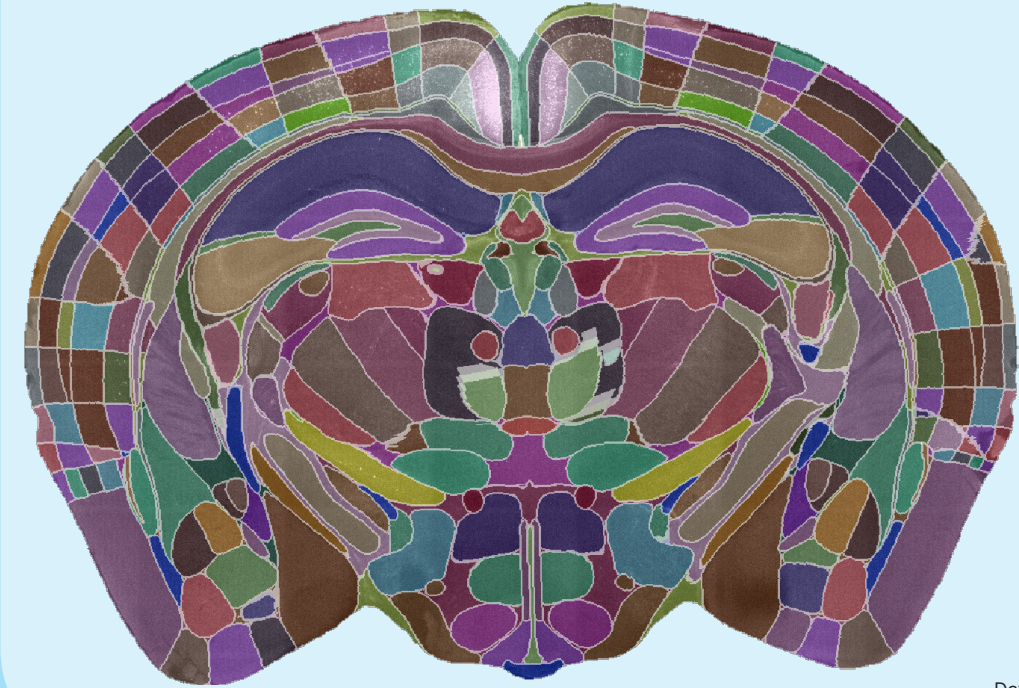
Data courtesy of Chryssanthi Tsitoura & Sepiedeh Keshavarzi

Raw coronal serial two-photon mouse brain image showing labelled cells

Classical image analysis (e.g. filters, thresholding) is used to find cell-like objects (with false positives)

A deep-learning network (ResNet) is used to classify cell candidates as true cells or artefacts

brainreg

github.com/brainglobe/brainreg
docs.brainglobe.info/brainreg

User friendly 3D whole-brain atlas registration software supporting:
- Registration to any BrainGlobe atlas
- Segmentation of brain regions in raw data
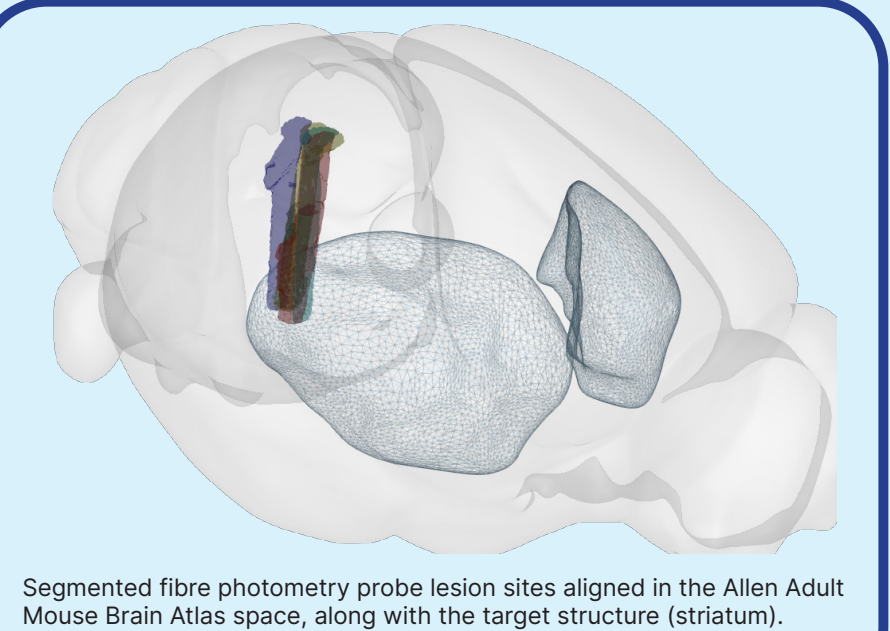- Transformation of features into a common coordinate (atlas) space

Tyson, A. L., Vélez-Fort, M., Rousseau, C. V. et al. (2022) "Accurate determination of marker location within whole-brain microscopy images" Scientific Reports 12, 867, doi.org/10.1038/s41598-021-04676-9

Data courtesy of Chryssanthi Tsitoura & Sepiedeh Keshavarzi

Brain region boundaries from the Allen Adult Mouse Brain Atlas overlaid upon a coronal cross-section of a serial two-photon image.

brainreg-segment

github.com/brainglobe/brainreg-segment
docs.brainglobe.info/brainreg-segment

Companion to brainreg allowing segmentation and analysis of brain structures in a common anatomical space

Segmented fibre photometry probe lesion sites aligned in the Allen Adult Mouse Brain Atlas space, along with the target structure (striatum).

Data courtesy of Stephen Lenzi

VISp   VISp
RF elevation (deg) 0 to -25
RF azimuth (deg) 10 to 40

Localisation of GCaMP7f labelled cells in the primary visual cortex following two-photon calcium imaging. Left: rendering of recorded cells color-coded according to their elevation in visual space. Right: color-coded according to their azimuth position in visual space.

Data courtesy of Chryssanthi Tsitoura

Trajectories of 7 traced Neuropixels probes segmented and visualised in the Allen Adult Mouse Brain Atlas along with the target structure (primary visual cortex).

Data courtesy of Mateo Vélez-Fort

Tyson, A. L., Vélez-Fort, M., Rousseau, C. V. et al. (2022) "Accurate determination of marker location within whole-brain microscopy images" Scientific Reports 12, 867, doi.org/10.1038/s41598-021-04676-9
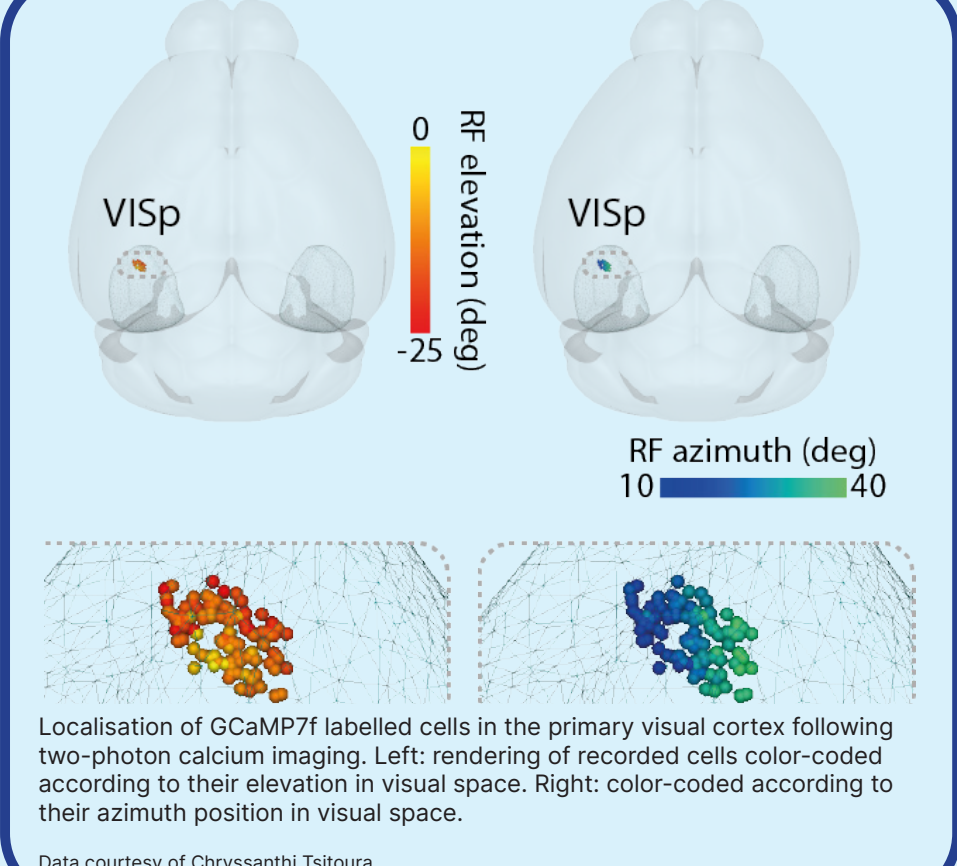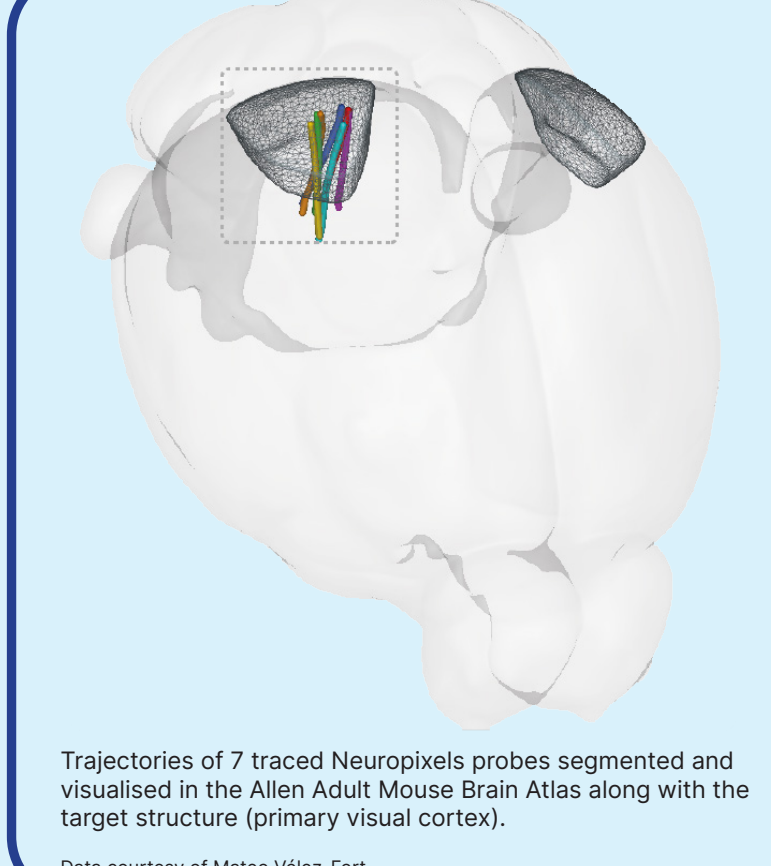
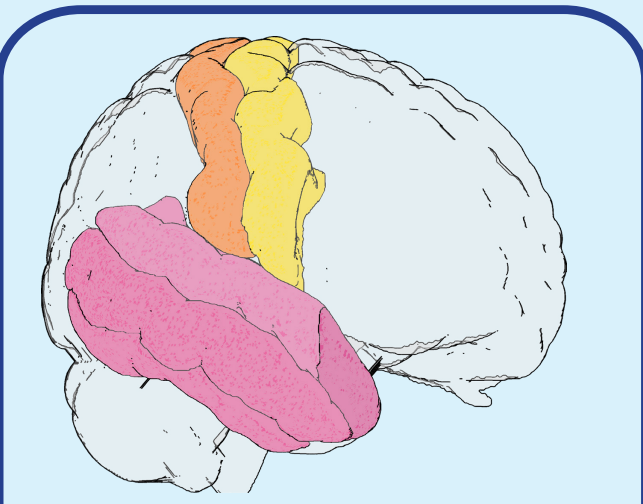## brainrender

Python package for interactive visualisation of multidimensional datasets registered to BrainGlobe atlases.

github.com/brainglobe/brainrender
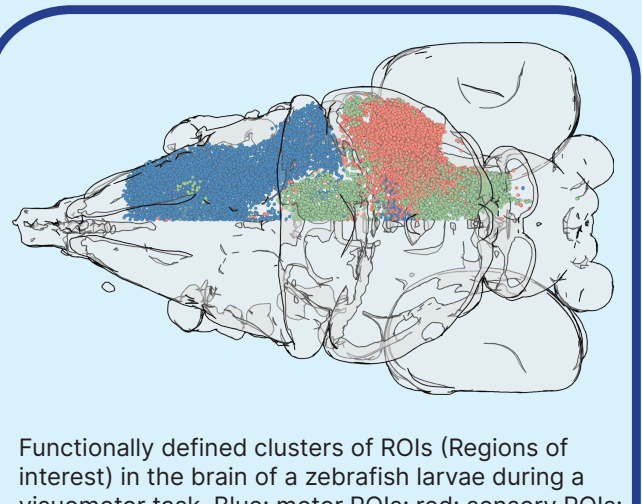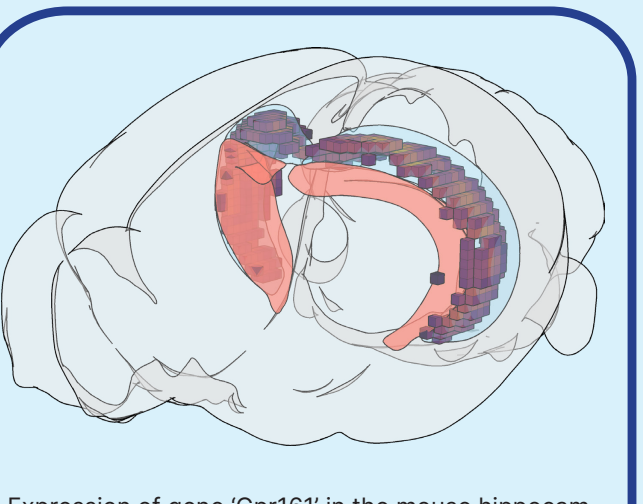docs.brainrender.info

Visualisation of several cortical areas in the human brain (data from Ding et al. 2016).
Ding, S. et al. (2016) The Journal of Comparative Neurology 524: 3127–3481

Functionally defined clusters of ROIs (Regions of interest) in the brain of a zebrafish larvae during a visuomotor task. Blue: motor ROIs; red: sensory ROIs; green: sensory ROIs (data from Markov et al. 2021).
Markov et al. (2021) Nature Communications doi.org/10.1038/s41467-021-26988-0

Expression of gene 'Gpr161' in the mouse hippocampus (gene expression data from Wang et al. 2020).
Wang, Q. et al. (2020) Cell 181(4), 936, doi.org/10.1016/j.cell.2020.04.007

Labelled cells (salmon) identified using cellfinder. In blue are efferent projections from the Allen Mouse Connectome project targeting the same region (data from Tyson et al. 2021 & Oh et al. 2014).
Tyson, A. L., Rousseau, C. V., Niedworok, C. J. et al. (2021) PLoS Comp Biol 17(5) e1009074, doi.org/10.1371/journal.pcbi.1009074
Oh et al. (2014) Nature doi.org/10.1038/nature13186

Two secondary motor cortex neurons (gray) projecting to the mouse thalamus (data from Winnubst et al. 2019, downloaded with morphapi from neuromorpho.org). Secondary motor cortex and thalamus are shown in green and red. respectively.
Winnubst, J. et al. (2019) Cell doi.org/10.1016/j.cell.2019.07.042

Efferent projections (green) from the mouse primary motor cortex (MOp, green) following injection of an anterogradely transported virus expressing fluorescent proteins (data from Oh et al. 2014).
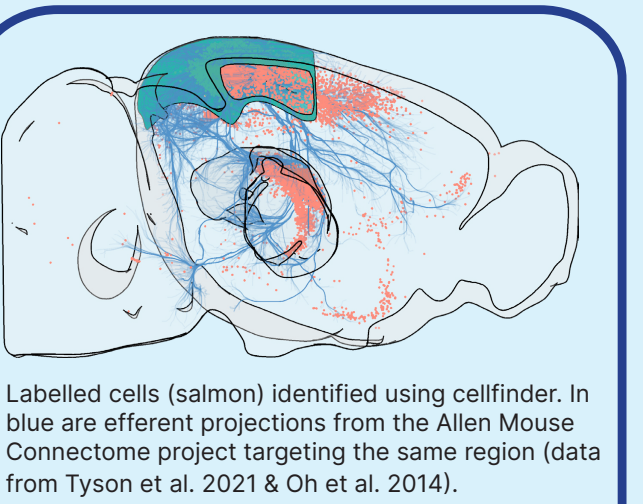Oh et al. (2014) Nature doi.org/10.1038/nature13186

Claudi, F. et al. (2021) "Visualizing anatomically registered data with Brainrender" eLife 10:e65751, doi.org/10.7554/eLife.65751
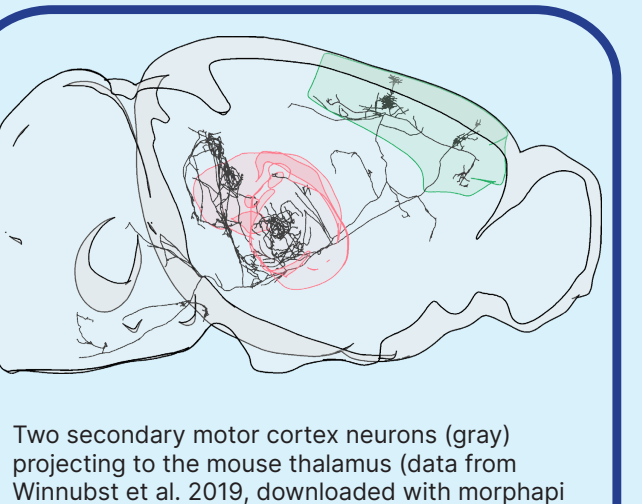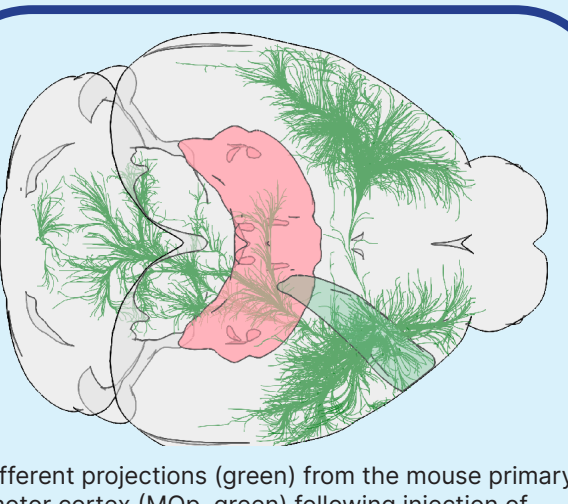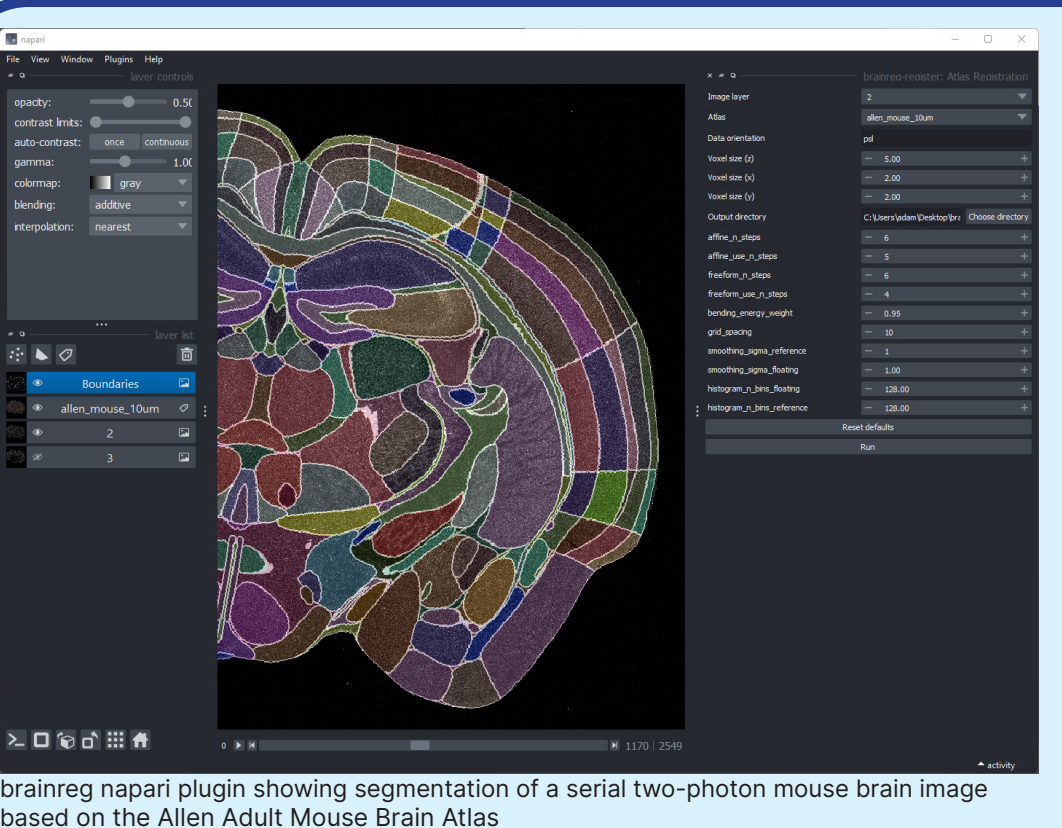
napari plugins

BrainGlobe image analysis tools are released as napari plugins for ease of use, and integration with the wider open-source bioimage analysis community.
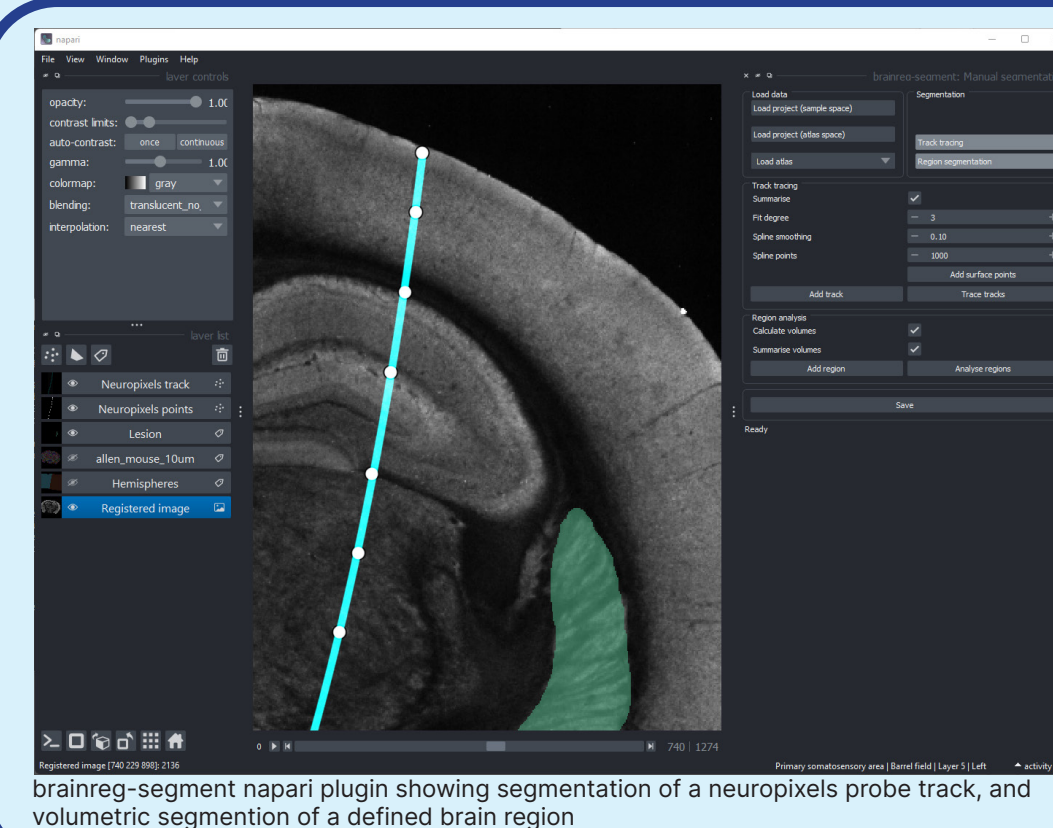
napari.org
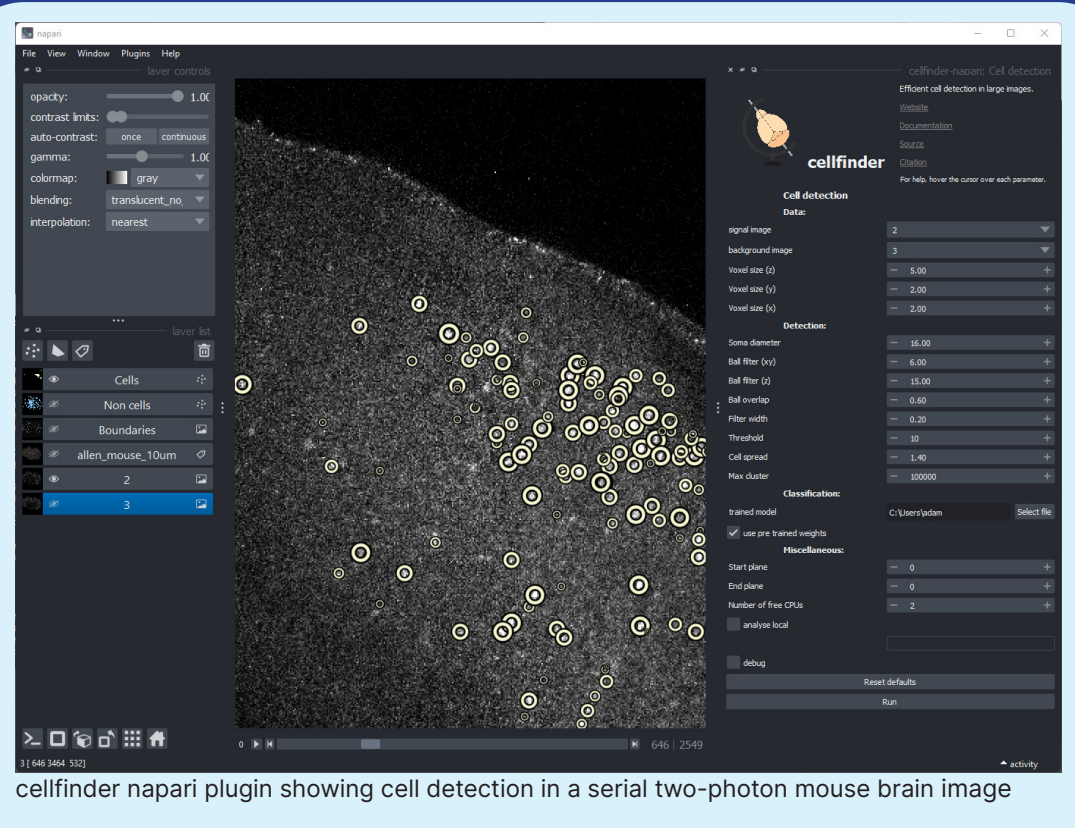
cellfinder napari plugin showing cell detection in a serial two-photon mouse brain image

brainreg napari plugin showing segmentation of a serial two-photon mouse brain image based on the Allen Adult Mouse Brain Atlas

brainreg-segment napari plugin showing segmentation of a neuropixels probe track, and volumetric segmention of a defined brain region

Supported by

Sainsbury Wellcome Centre
UCL
GATSBY
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Get involved

We always welcome new contributors. Please get in touch to:
- Use BrainGlobe software
- Develop new software leveraging the Atlas API
- Contribute to existing software
- Contribute a new atlas to the API
- Develop training materials (e.g. documentation, tutorials etc.)

More information

brainglobe (GitHub)
brain_globe (Twitter)

Website: brainglobe.info
Documentation: docs.brainglobe.info
Help forum: forum.image.sc/tag/brainglobe