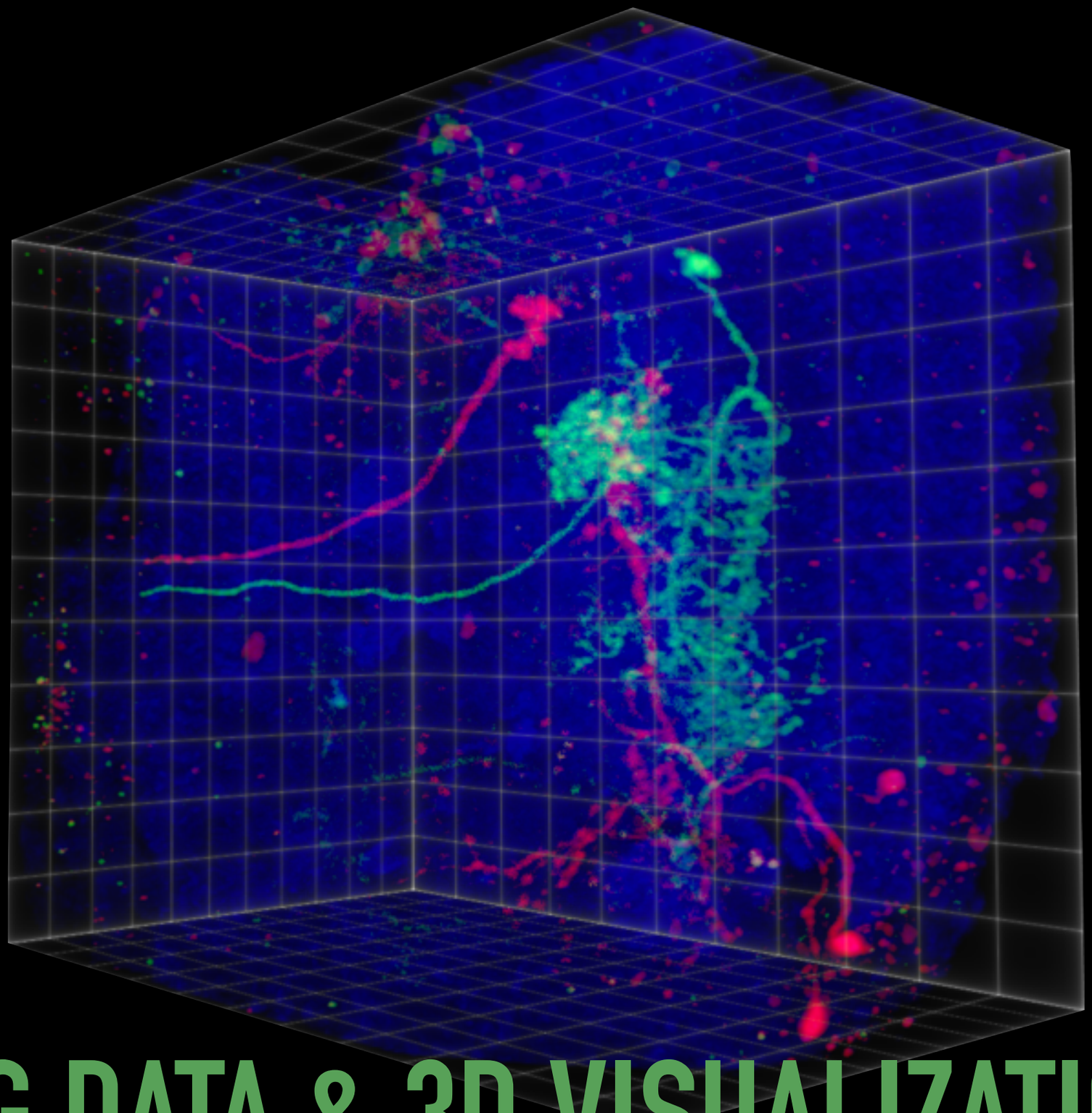


BIG DATA & 3D VISUALIZATION

FLORIAN JUG (TOBIAS PIETZSCH)

CSBD / MPI-CBG

Big Data?

Clarification:

- Big **<u>Image</u>** Data.

- Reasonable number of relatively large images. (i.e. meta-data is not a big problem.)

Big Image Data

Examples - Modern Light-sheet Microscopes

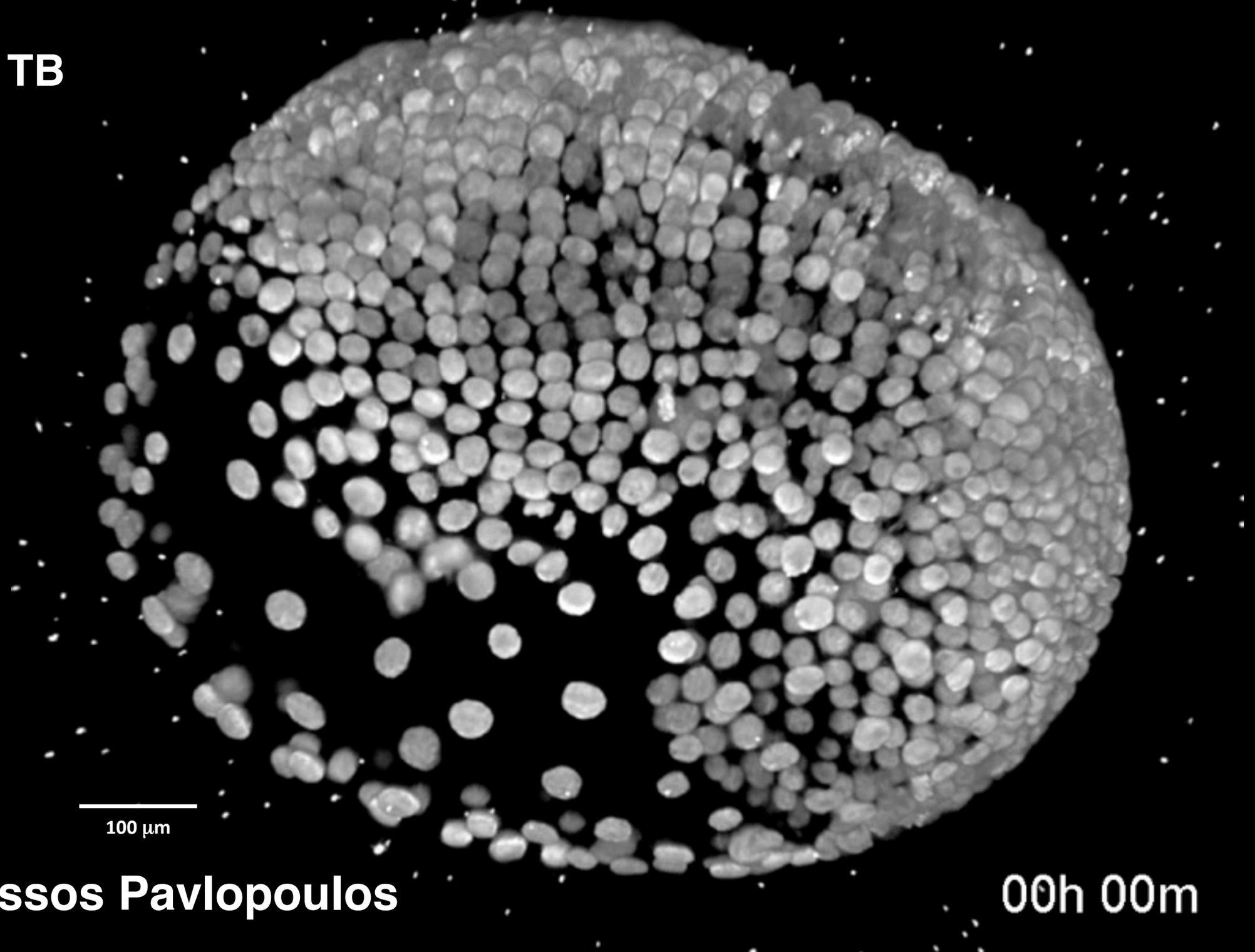
- realistic time-lapse datasets:
  single experiments of ~5 TB

- theoretical max much higher
  e.g. 800 MB/s ⟶ 66 TB/d

Parhyale hawaiensis

888 time-points (every 7.5 min for 5 days)
3-5 views per time-point

~8 TB



Tassos Pavlopoulos

Big Image Data

Examples - Electron Microscopy Data

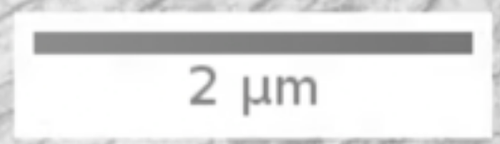
Entire adult brain of *drosophila*

- 21 million tiles in 7000 sections

- 106TB on disk

- stitched in 12 iterations, where each iteration
  - occupied half of Janelia's cluster for 10 days
  - cost ~$15K in CPU time

Janelia FlyTEM team project



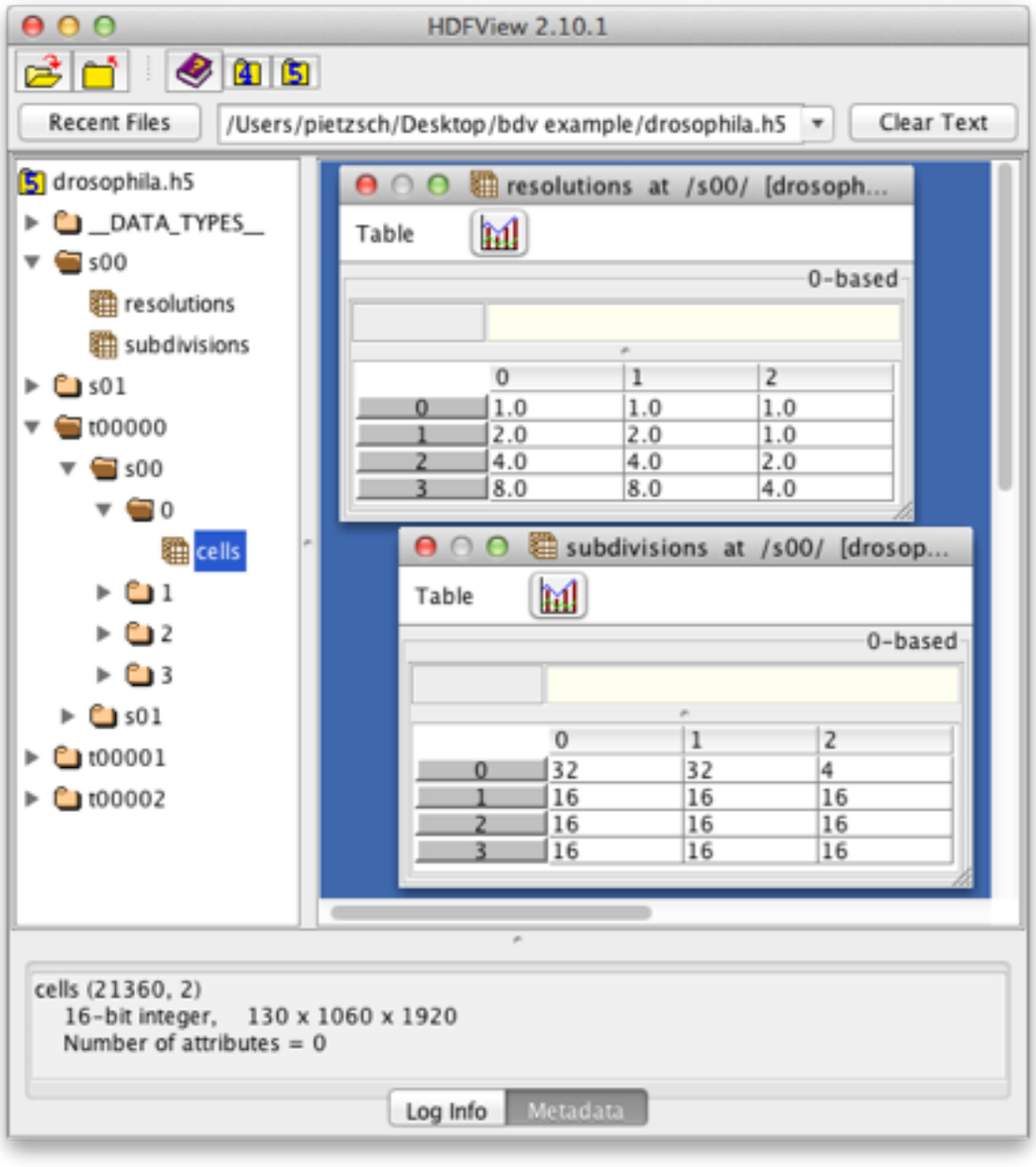
- You cannot have your data on your laptop.
- Copying is expensive.
- Difficult to share with collaborators.
  (sending HDD by mail…)
- Very basic processing takes a lot of time
  (unless you can use a compute cluster).
- *Everything* takes a lot of time.
  (just reading 8TB at 1GB/s takes ~2.5h)

Storage formats

- TIFF stacks
- HDF5-based (BigDataViewer, Luxendo, Imaris, …)
- other open-source (KLB, Vaa3D raw, …)
- proprietary (arivis SIS, Amira LDA, …)

Bad news: You will need more than one.

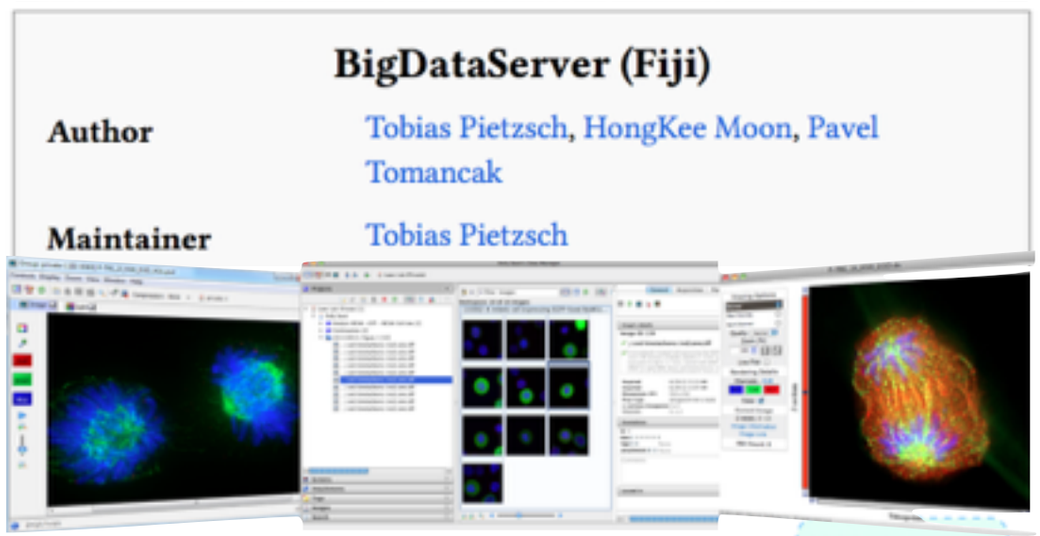
HDF5

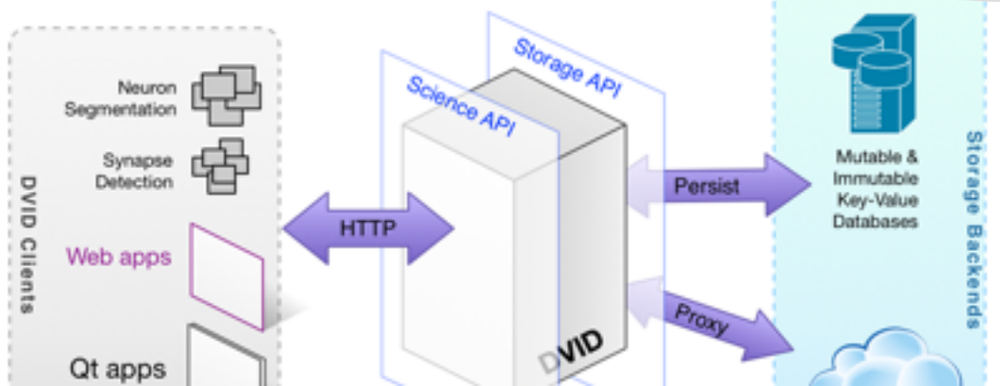


- “File system in a file”
- standard API and datatypes for multidimensional arrays (a.k.a. images)

Storage “in the Cloud”

- CATMAID (png/jpg tiles)
- OpenConnectome (blocks)
- BigDataServer (blocks)
- OMERO (OME)
- DVID (Janelia)
  "github for large image-oriented data”

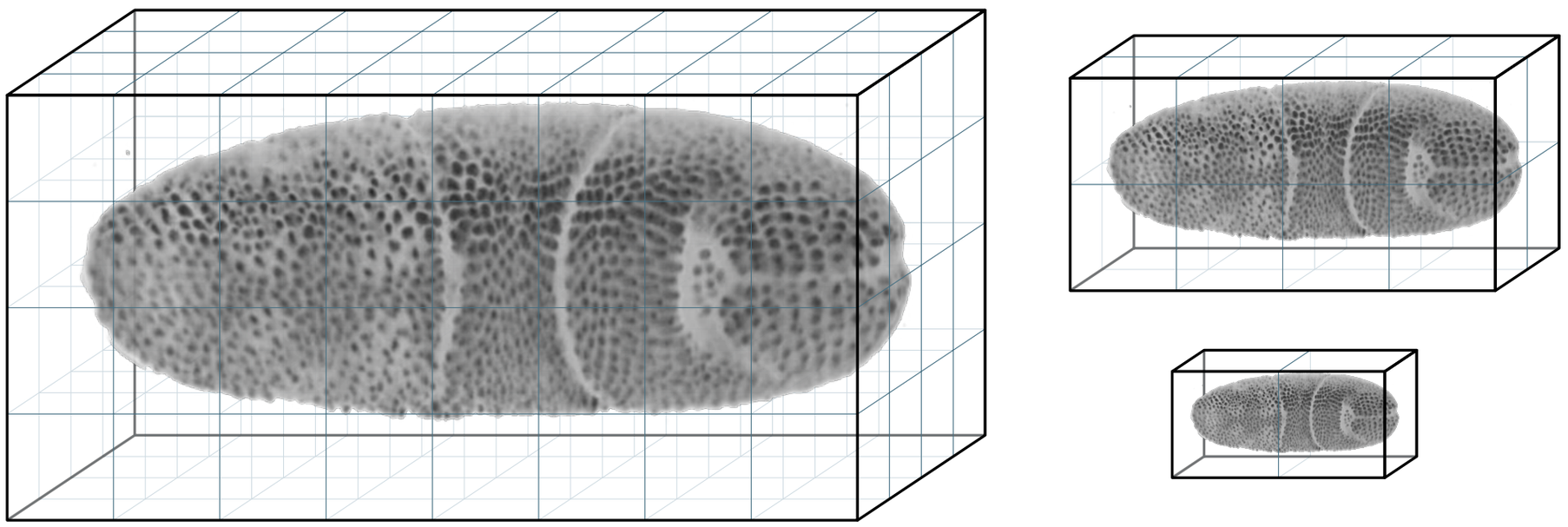




Why does everybody convert to their own file format?

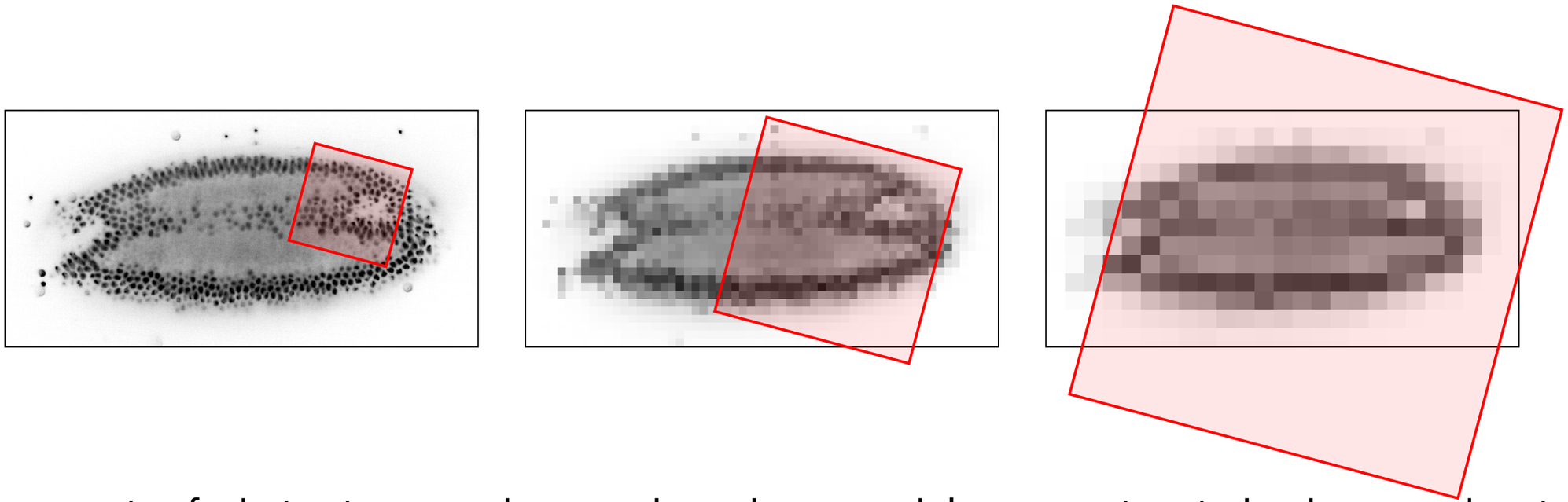
Storage Strategies for Interactive Visualization

- Multi-Resolution
- Tiling (chunking, blocking, …)



Multi-Resolution

Region to render.

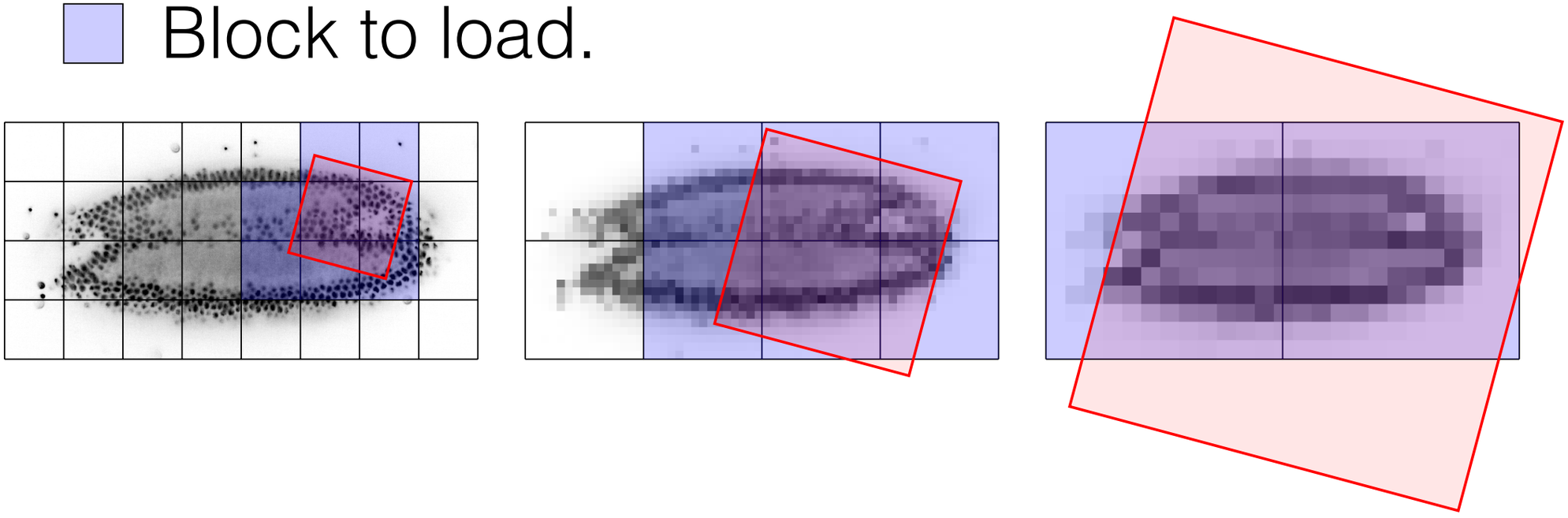


- Amount of data to render a view is roughly constant, independent of region size.
- Aliasing artifacts are reduced.
- Load low-resolution first for rapid browsing.

Tiling

Region to render.

Block to load.



- Trade-off between reading only the required voxels and reading contiguous data.

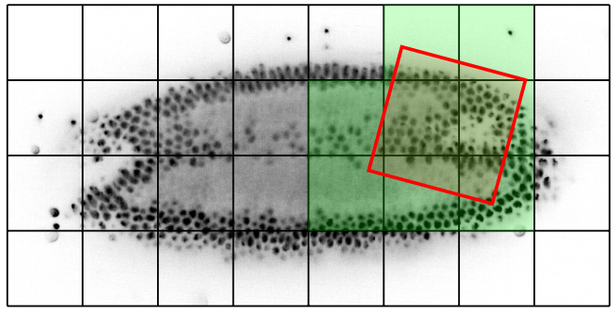
- Blocks can be individually compressed.

Tiling

Region to render.

Cached block.

Block to load.

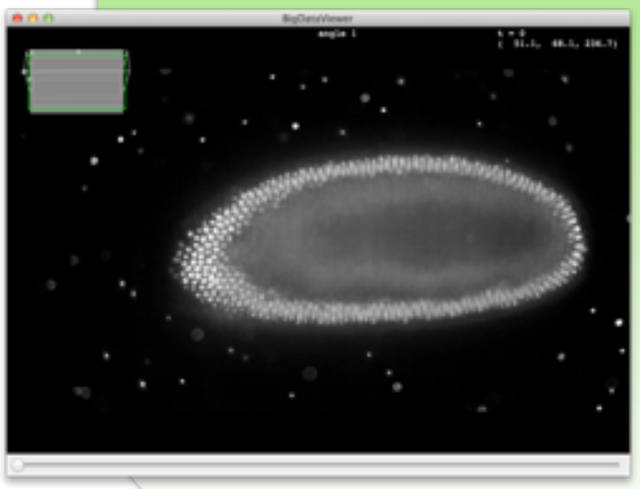


- Facilitates caching.

Big Data & 3D Visualization

BigDataViewer

CATMAID



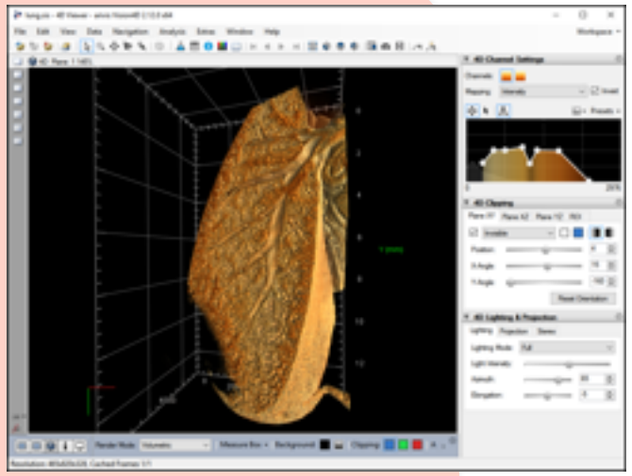
100TB

>10TB Arivis

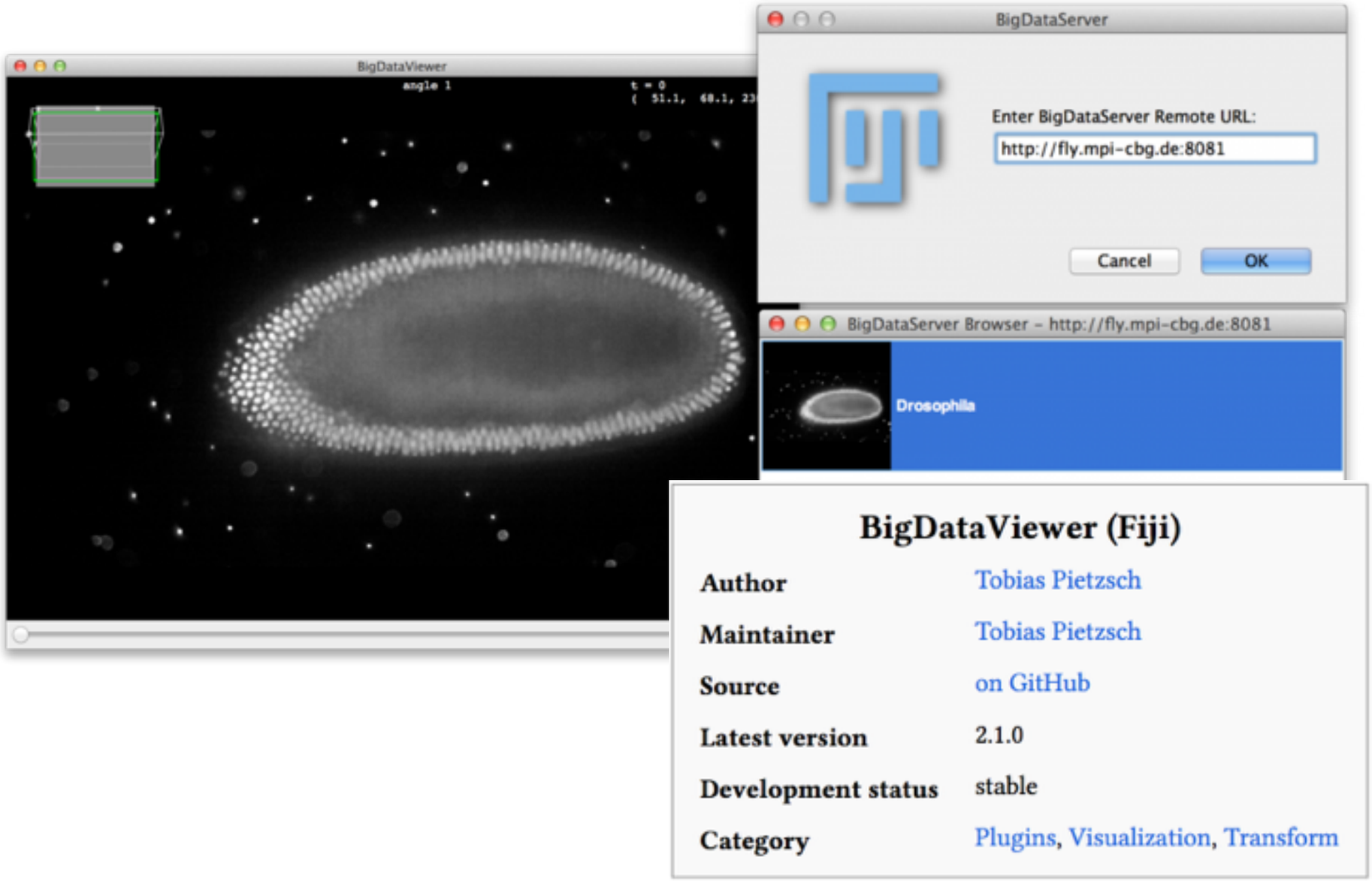
2.5TB Terafly

Imaris

12GB ClearVolume

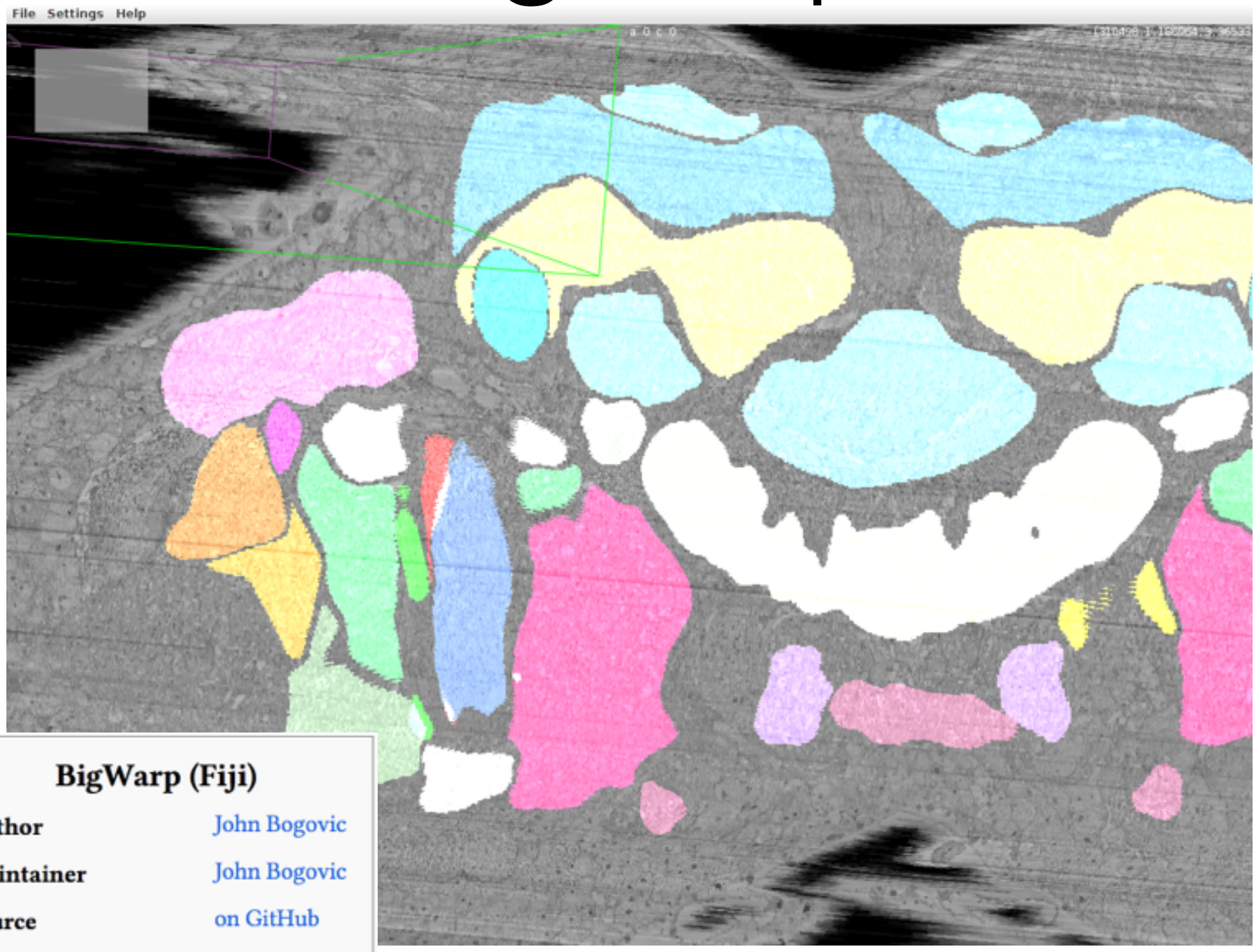


BigDataViewer



Pietzsch T., Saalfeld S., Preibisch S., and Tomancak P. (2015) *Nature Methods*, 12(6): 481–483
BigDataViewer: visualization and processing for large image data sets.

BigWarp



BigWarp (Fiji)

Author	John Bogovic
Maintainer	John Bogovic
Source	on GitHub
Latest version	2.1.5
Development status	stable

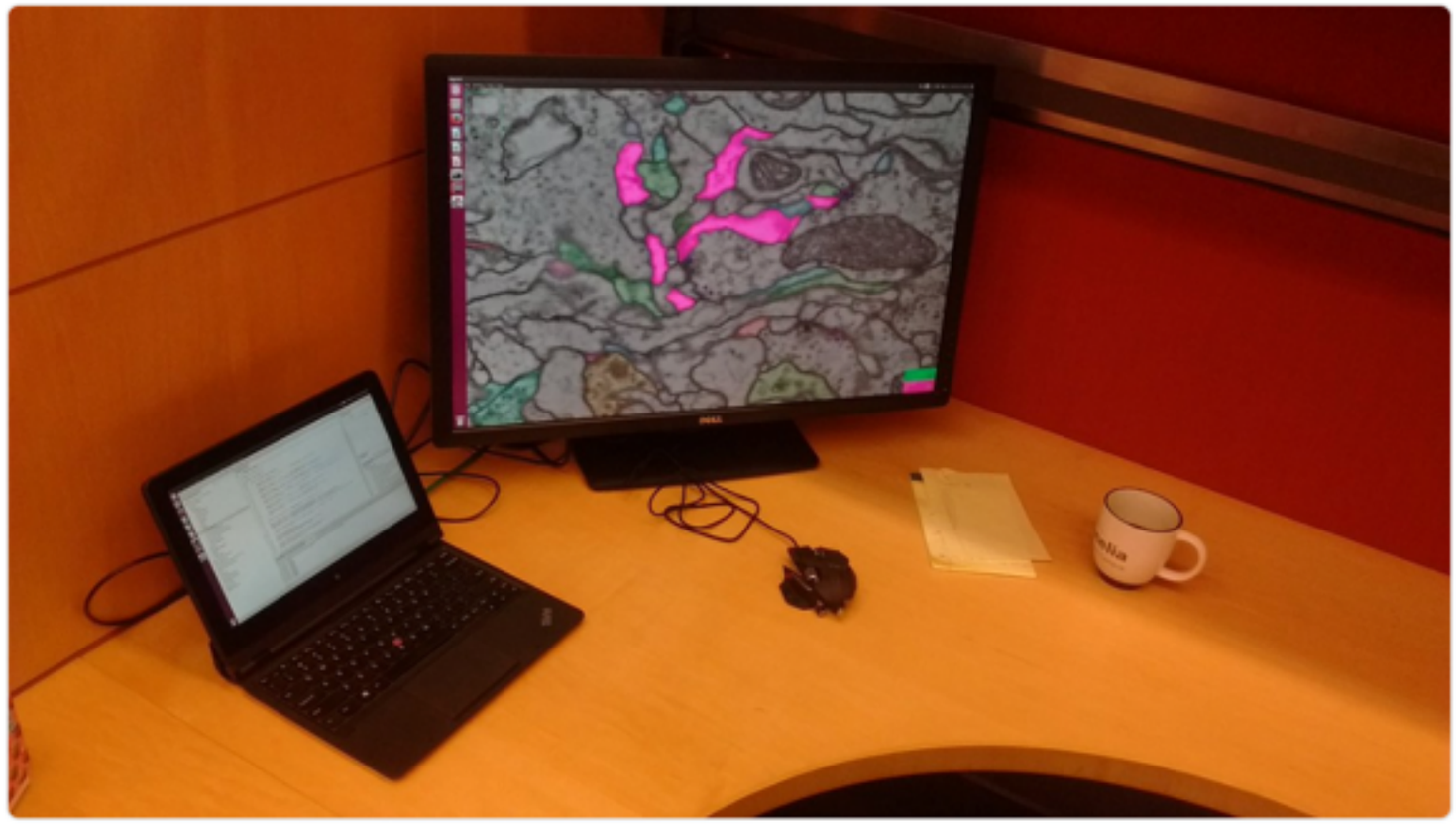
http://imagej.net/BigWarp

BigCAT

Stephan Saalfeld
@herrsaalfeld

Following

Our #CREMIChallenge proofreading station is a Helix tablet powered by #Ubuntu and #BigDataViewer



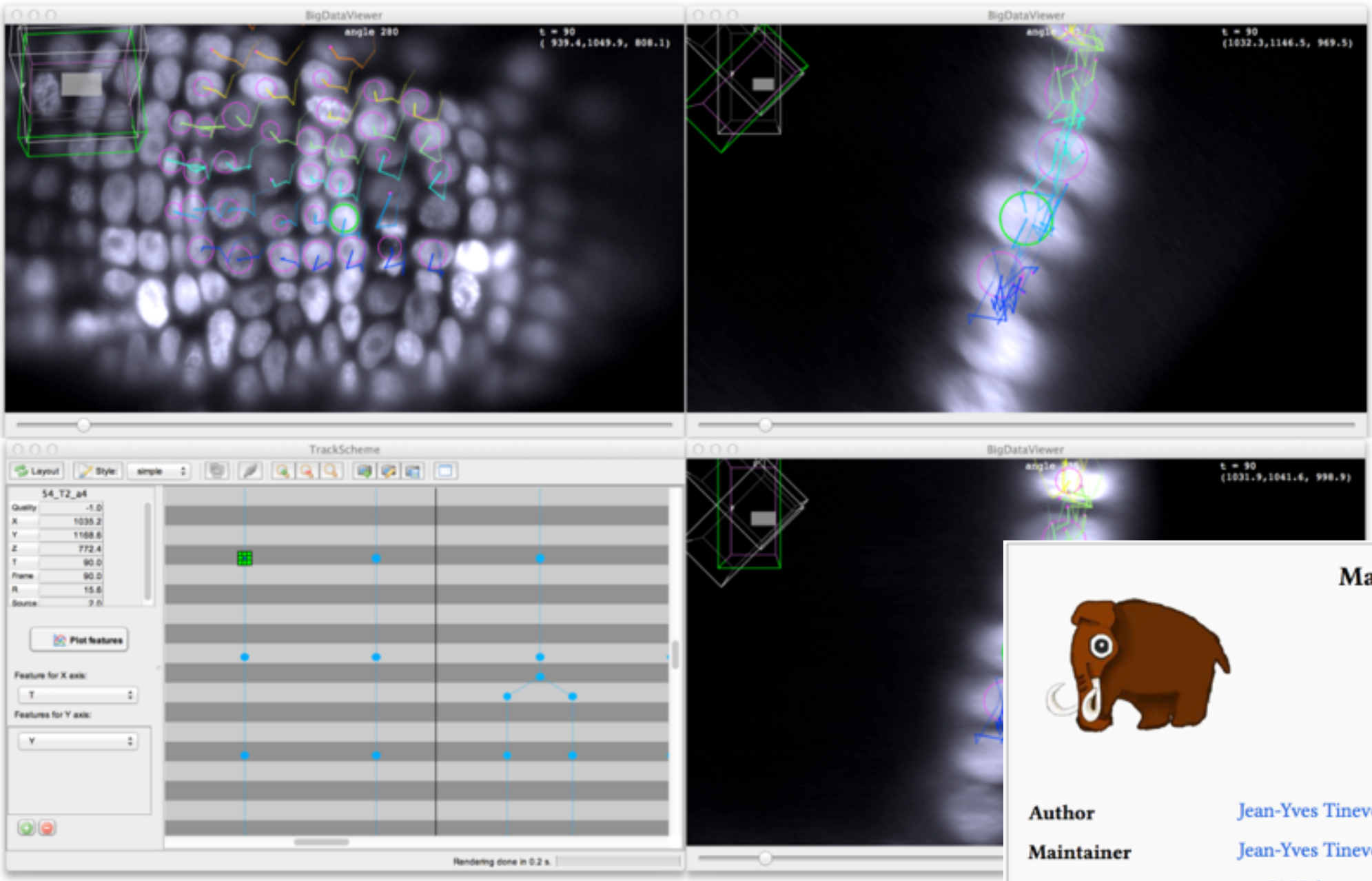
RETWEETS 3 LIKES 9

Stephan Saalfeld
Philipp Hanslovsky
Jan Funke

https://github.com/saalfeldlab/bigcat

MaMuT

tracking in multiview datasets



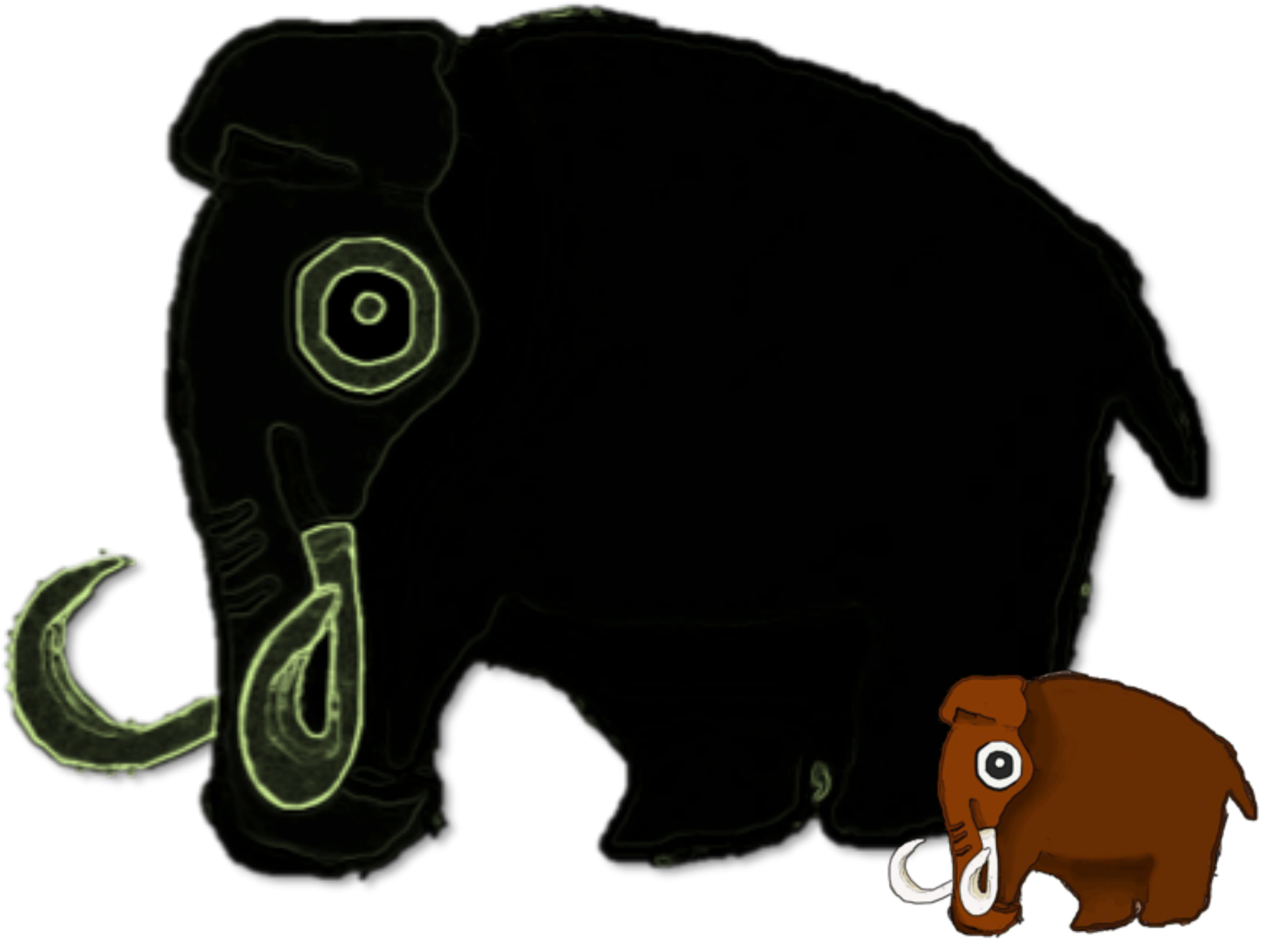
Jean-Yves Tinevez
Tassos Pavlopoulos

MaMuT (Fiji)

Author	Jean-Yves Tinevez, Tobias Pietzsch
Maintainer	Jean-Yves Tinevez
Source	on GitHub
Initial release	06/01/2015
Development status	v0.27.0, active
Category	Segmentation, Tracking, Category:Plugins

Mastodon

tracking in multiview datasets



VisTools

bigdataviewer / **bigdataviewer-vistools**

Watch 6 | Unstar 3 | Fork 2

Code | Issues 0 | Pull requests 0 | Projects 0 | Wiki | Pulse | Graphs

Helpers to use BigDataViewer as a quick visualization tool in other projects.

54 commits | **4** branches | **4** releases | **2** contributors

Branch: **master** | New pull request | Create new file | Upload files | Find file | Clone or download

tpietzsch committed with Jenkins Bump to next development cycle ... Latest commit `22cd3a1` on Oct 27, 2016

src	expose list of SourceAndConverter underlying a BdvStackSource	4 months ago
.gitignore	new project bigdataviewer-vistools for quickly displaying stuff in BD...	11 months ago
README.md	Update README.md	10 months ago
pom.xml	Bump to next development cycle	4 months ago
screenshot.png	add screenshot	10 months ago

README.md

bigdataviewer-vistools

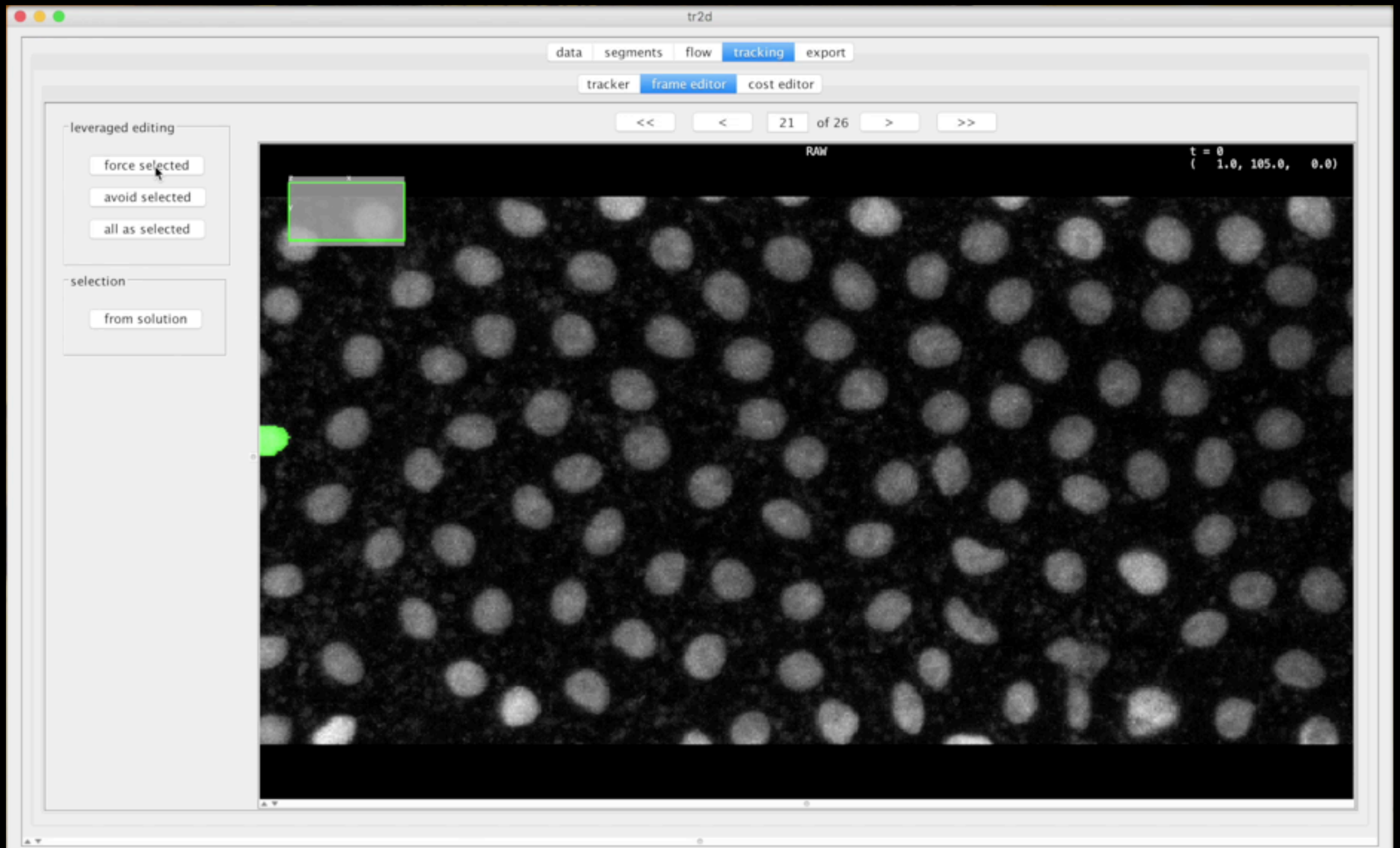
Helpers to use BigDataViewer as a quick visualization tool in other projects. This is intented to replace/augment

Usage

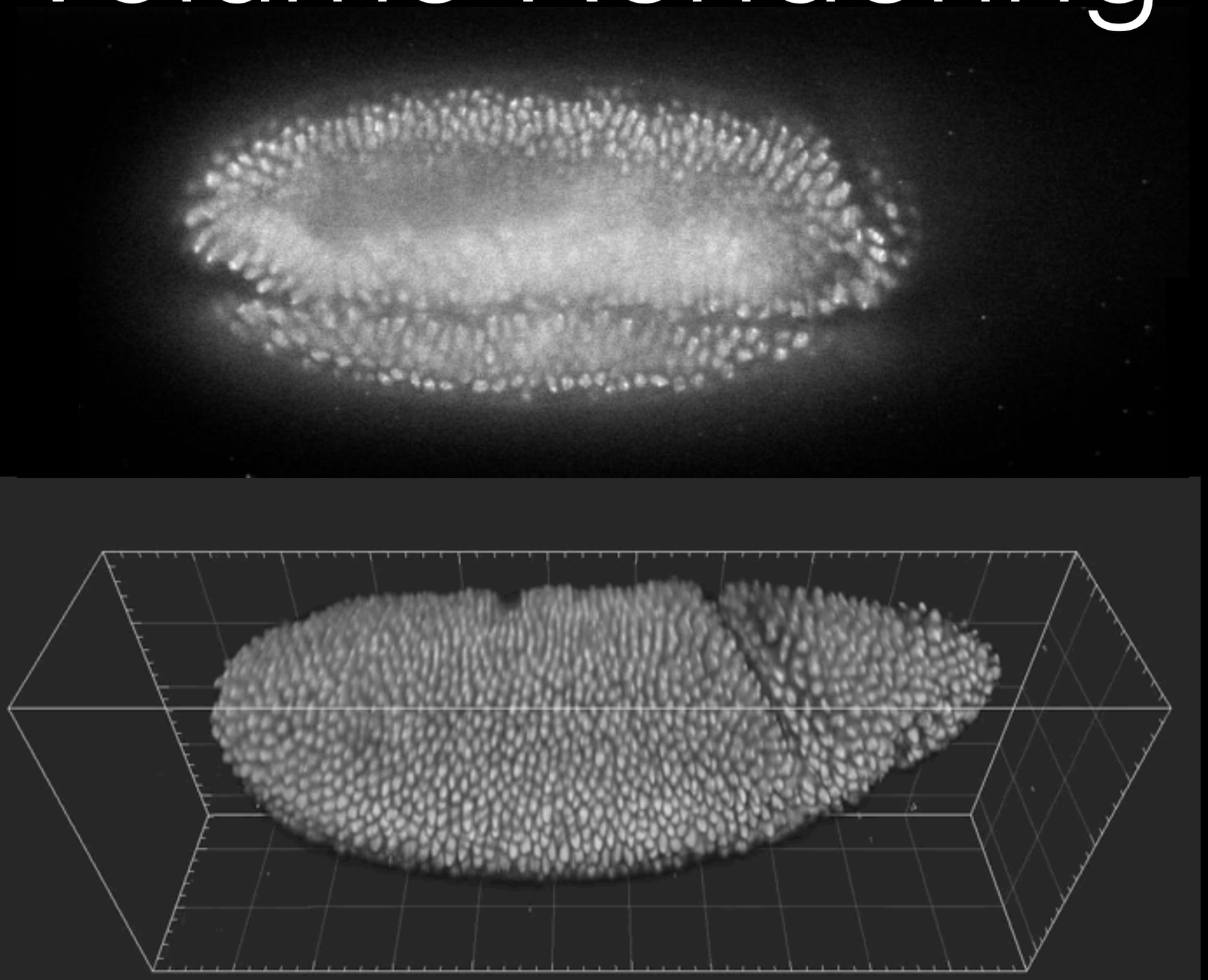
```
Random random = new Random();
Img<ARGBType> img = ArrayImgs.argbs(100, 100, 100);
img.forEach(t -> t.set(random.nextInt()));
Bdv bdv = BdvFunctions.show(img, "img");
```

VisTools

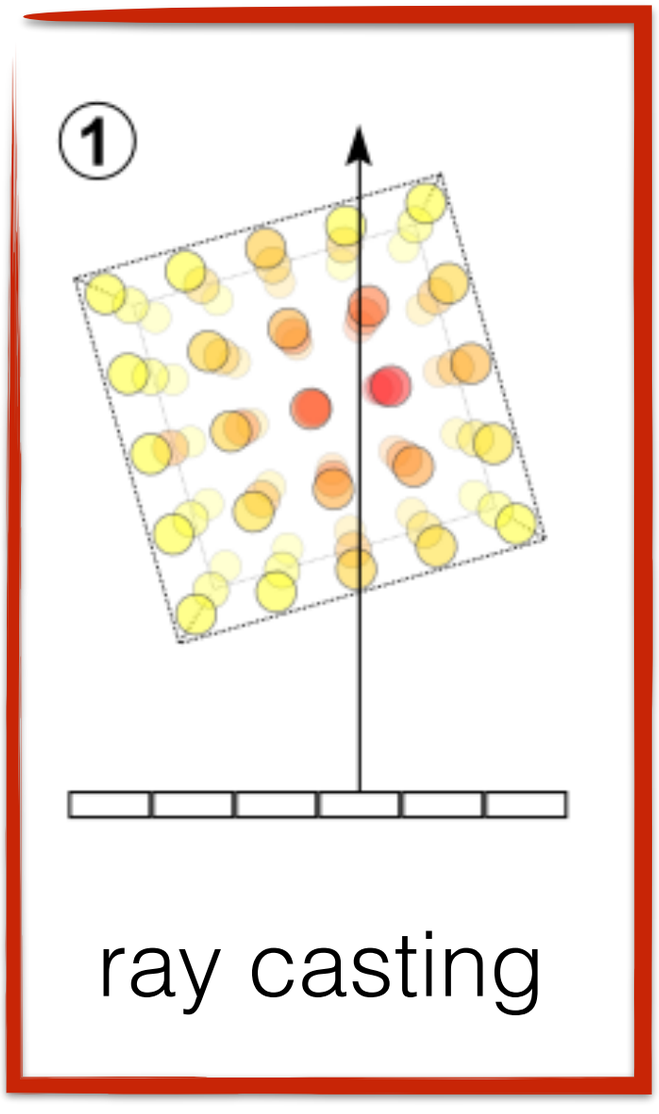
https://github.com/fjug/tr2d



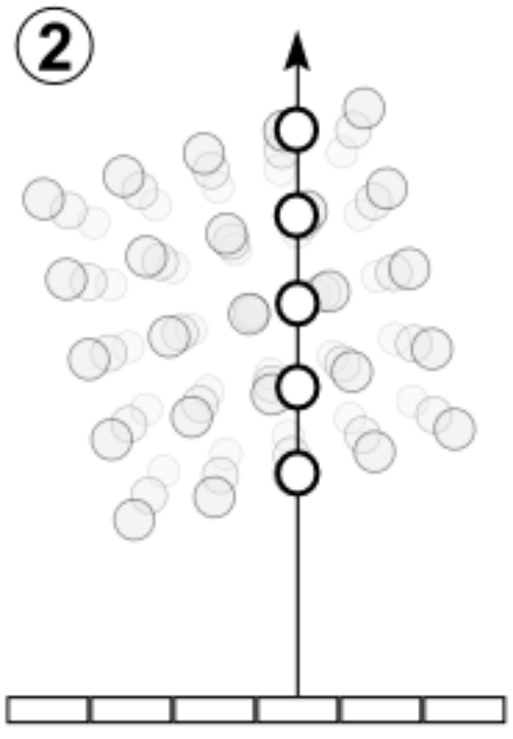
Volume Rendering



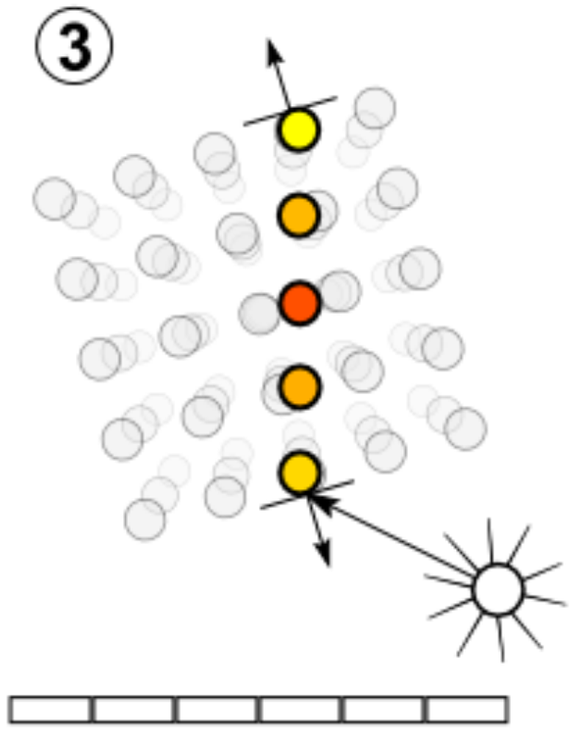
Volume Ray Casting



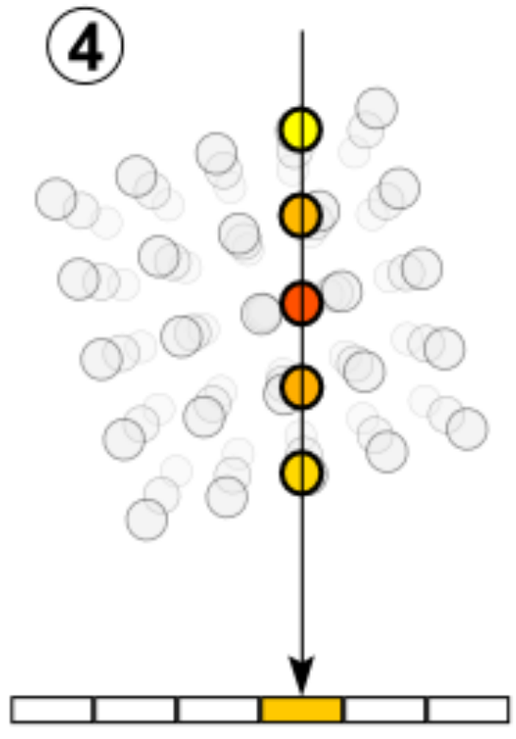
ray casting



sampling



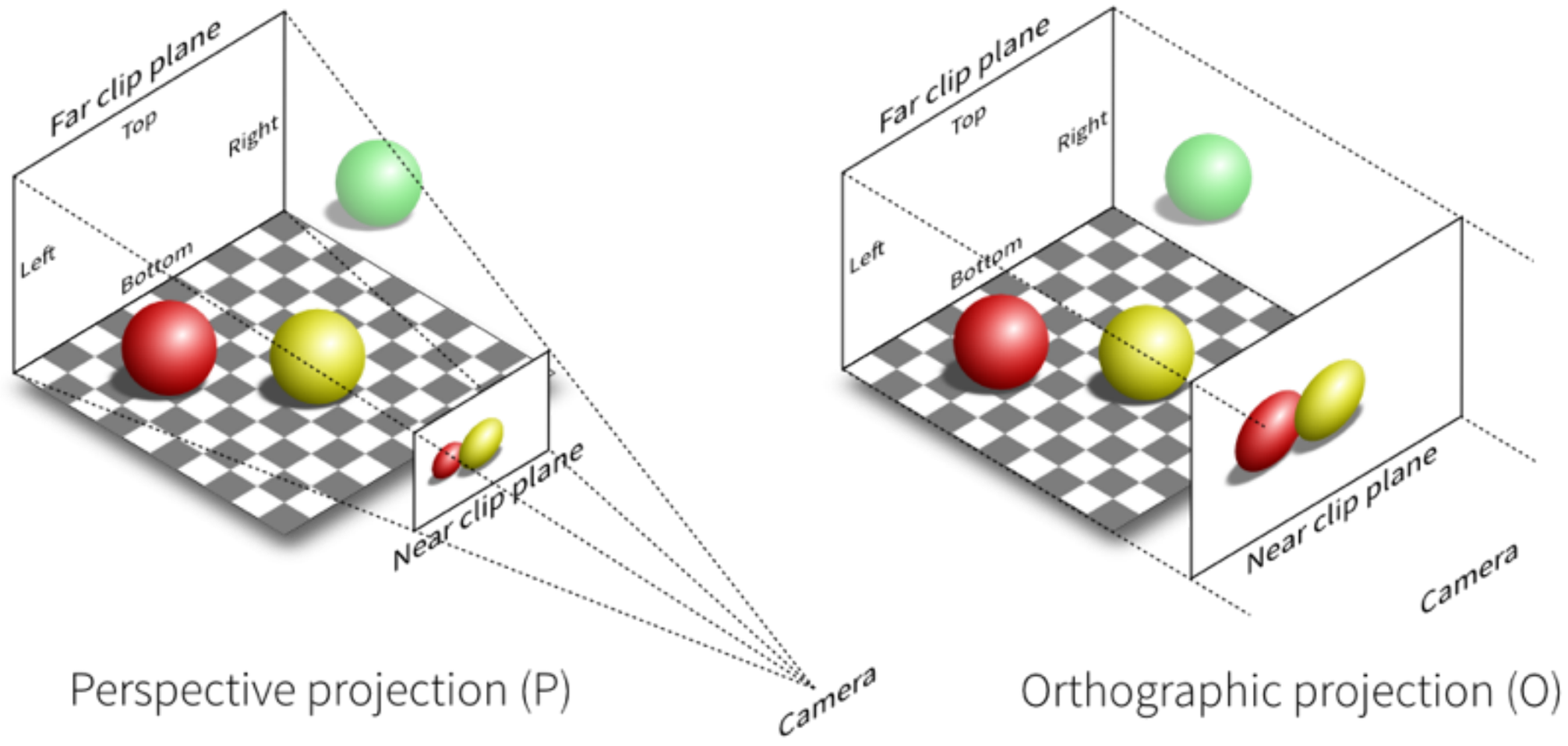
shading



compositing

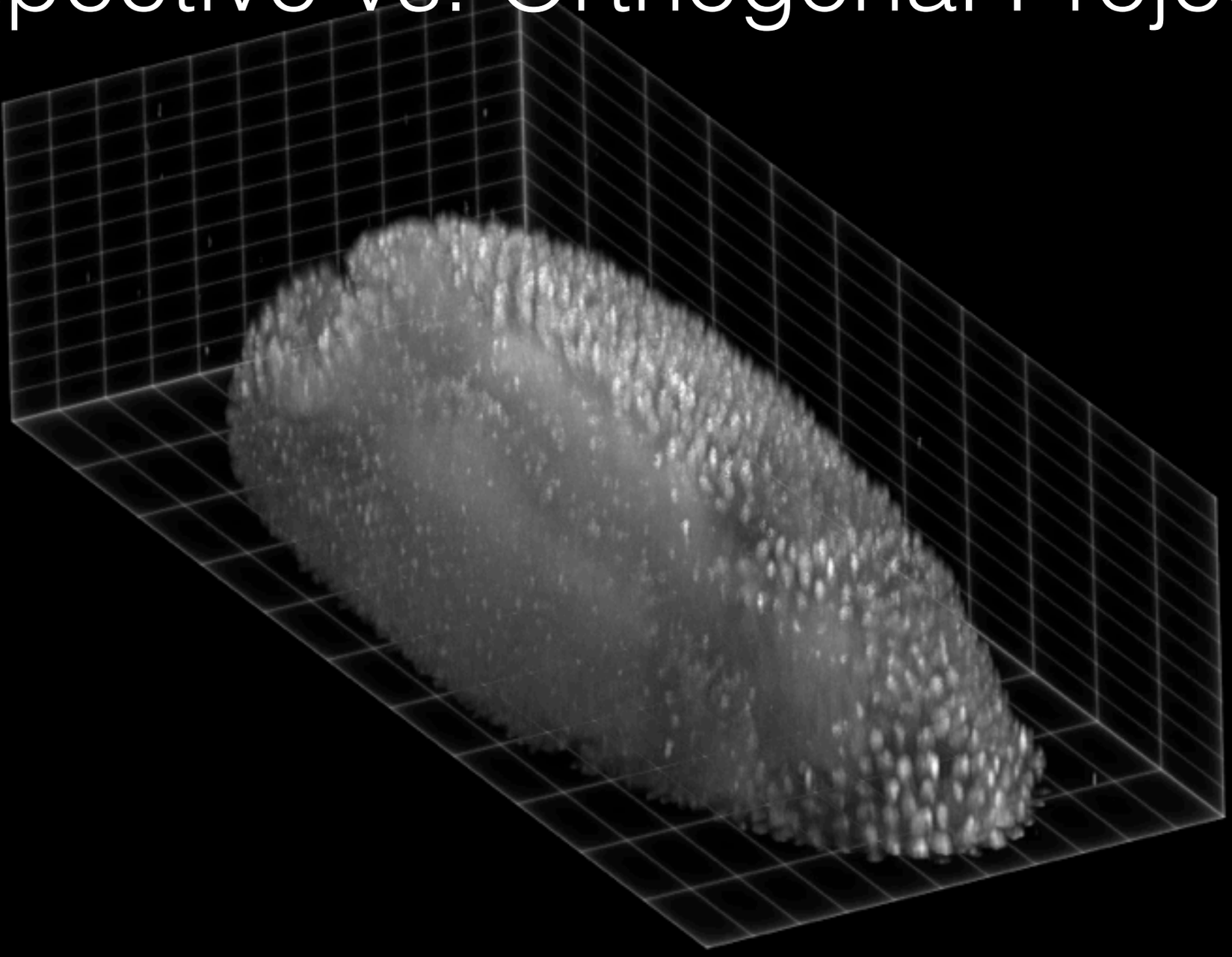
(image: wikipedia)

Ray Casting
Perspective vs. Orthogonal Projection



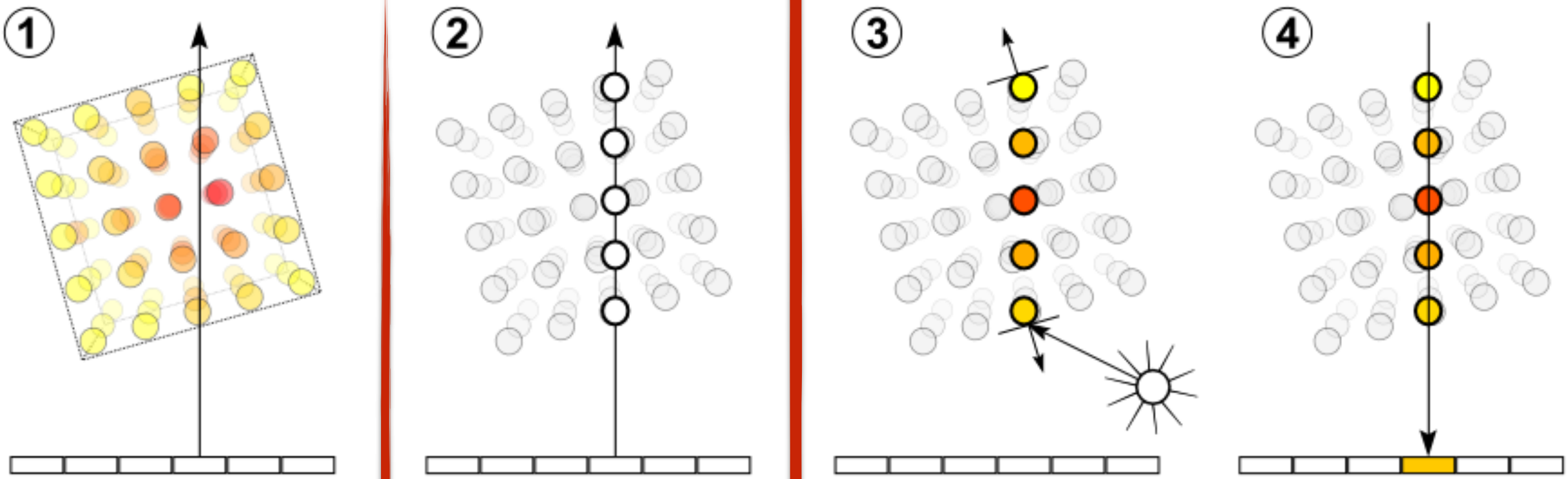
(image: https://glumpy.github.io/modern-gl.html)

Ray Casting
Perspective vs. Orthogonal Projection



ClearVolume

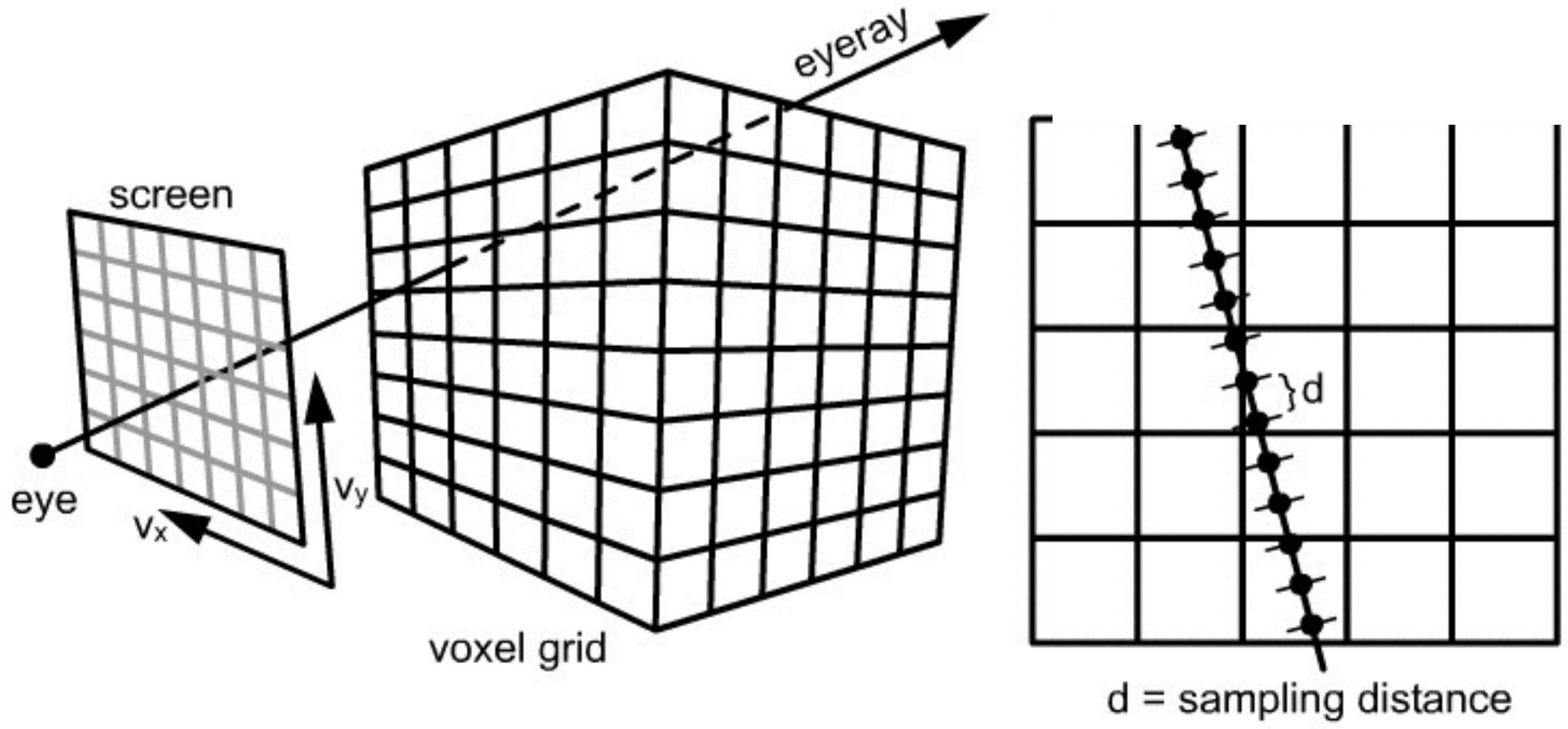
Volume Ray Casting



ray casting | sampling | shading | compositing

(image: wikipedia)

Sampling

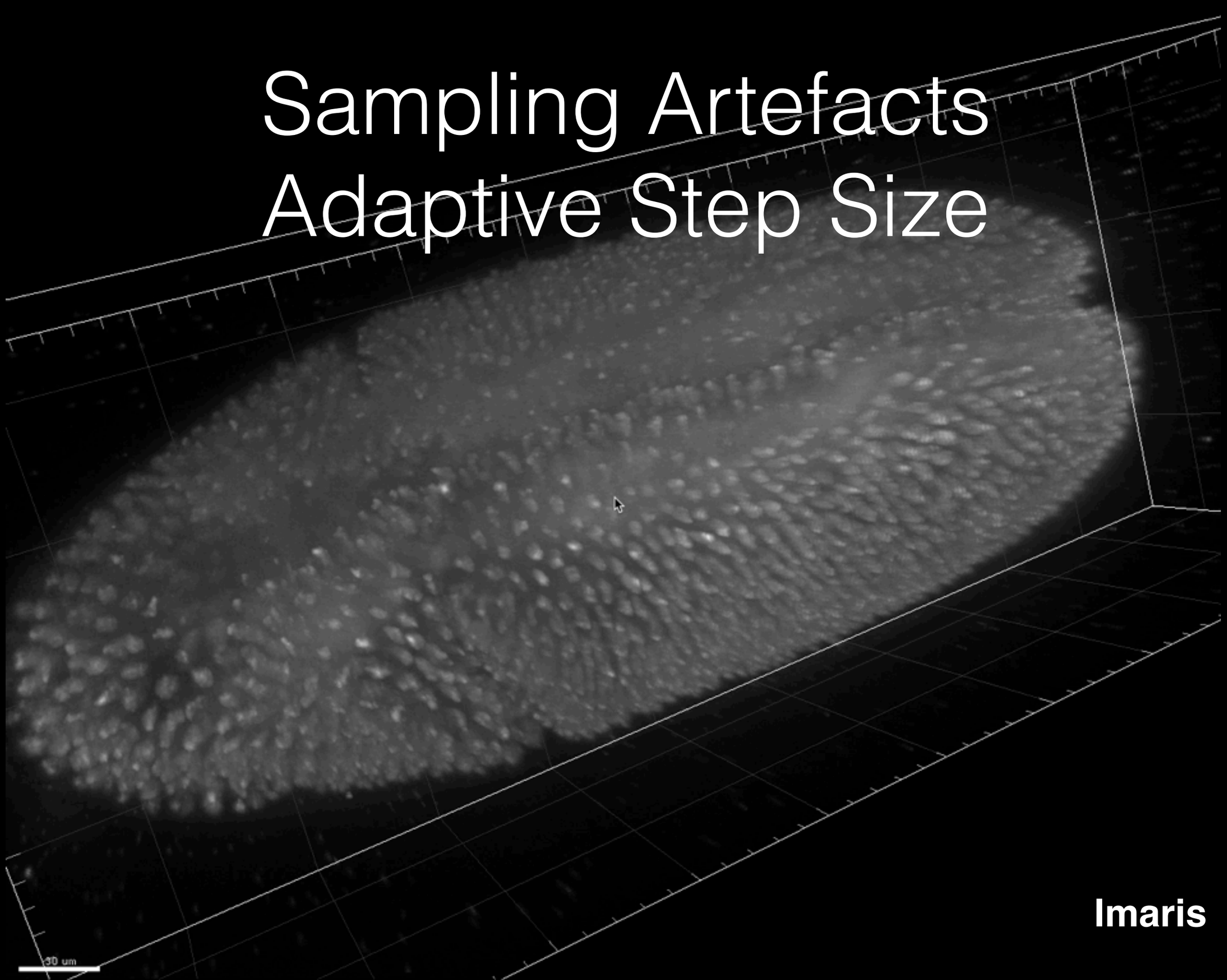


- Step size.

- Interpolation method,
  usually Nearest-Neighbor or Bi-/Tri-Linear

(image: http://johnrichie.com/V2/richie/isosurface/volume.html)

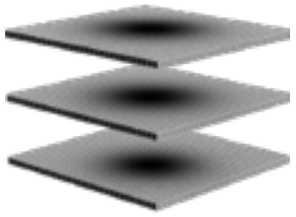
Sampling Artefacts
Adaptive Step Size



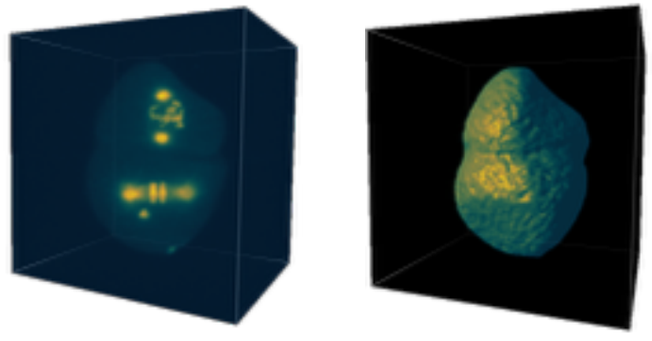
Imaris

Sampling in ClearVolume

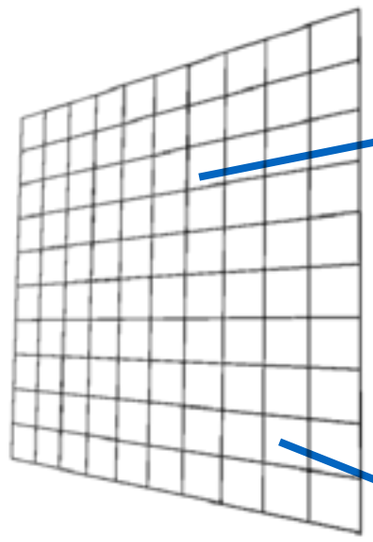
Volumetric Data

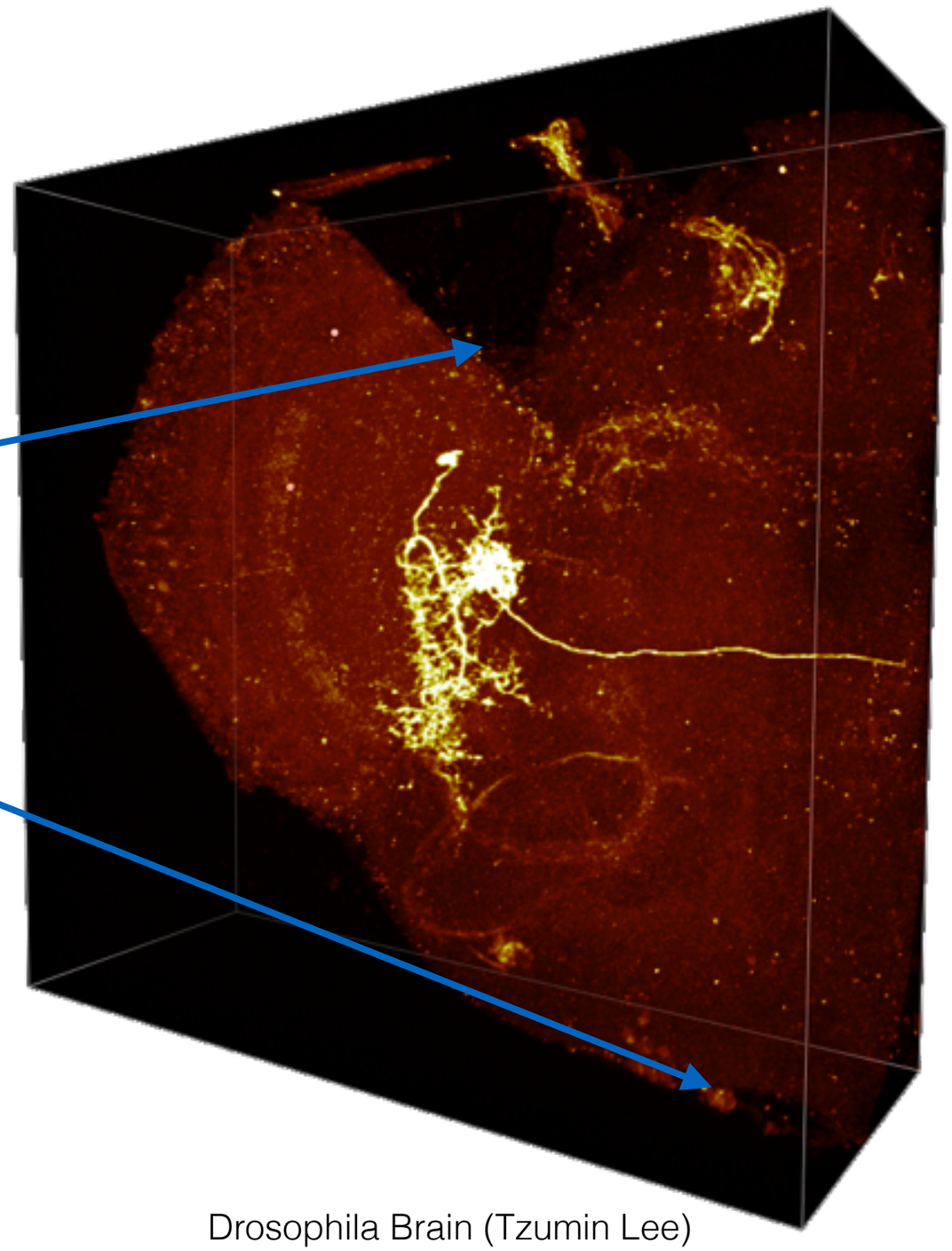


GPU
OpenCL, CUDA



Volume Rendering
Isosurfaces





Drosophila Brain (Tzumin Lee)

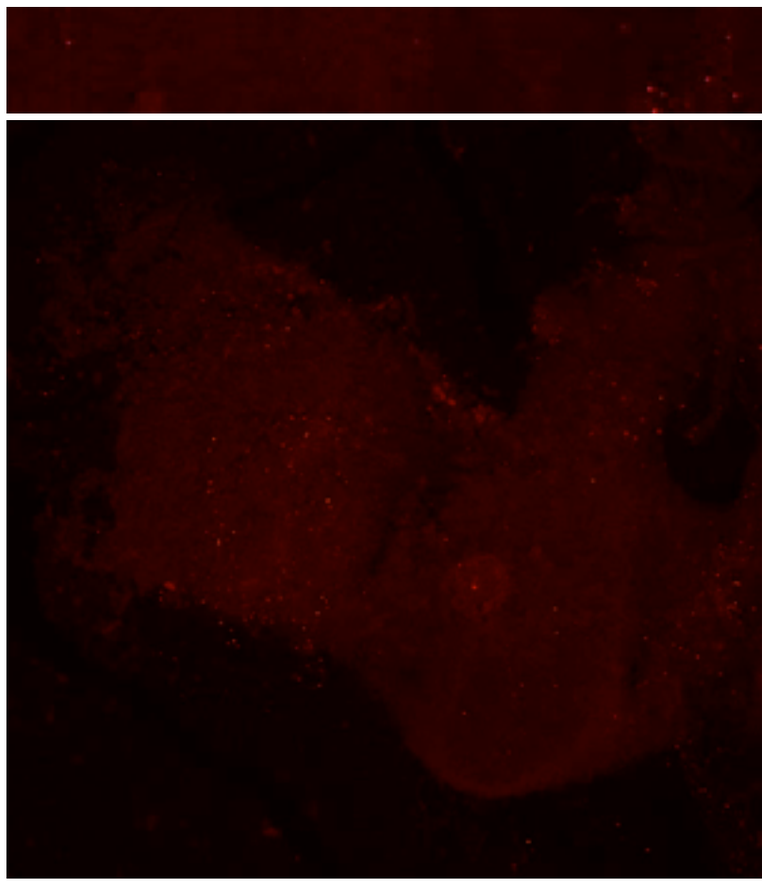
e.g. ~ 50ms for 400MB Dataset on a modest card

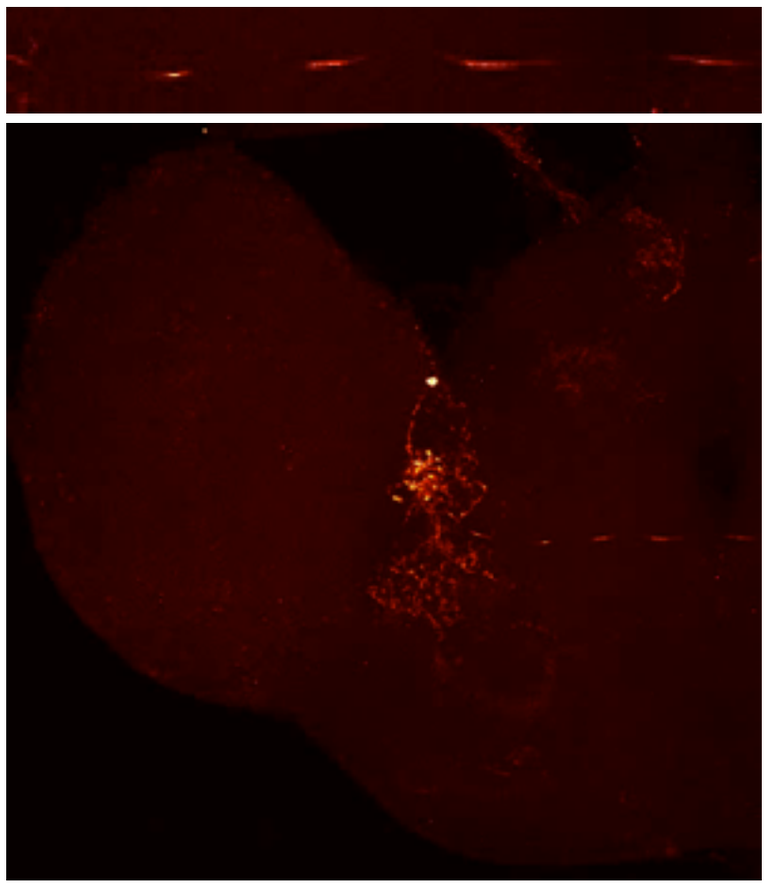
Fibonacci multi pass for big volumes

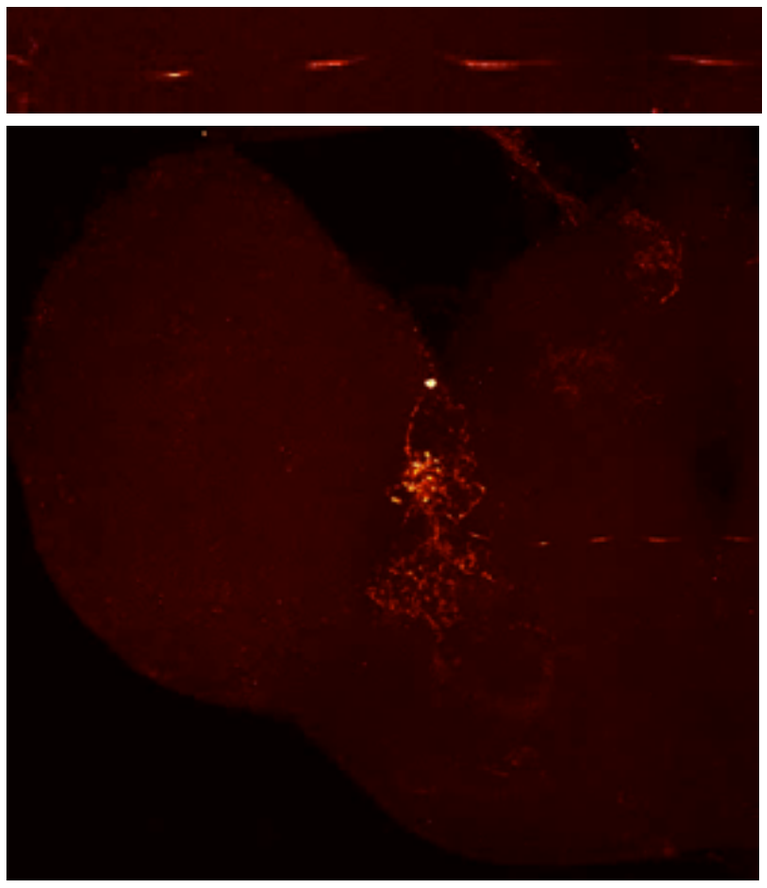
naive

successive

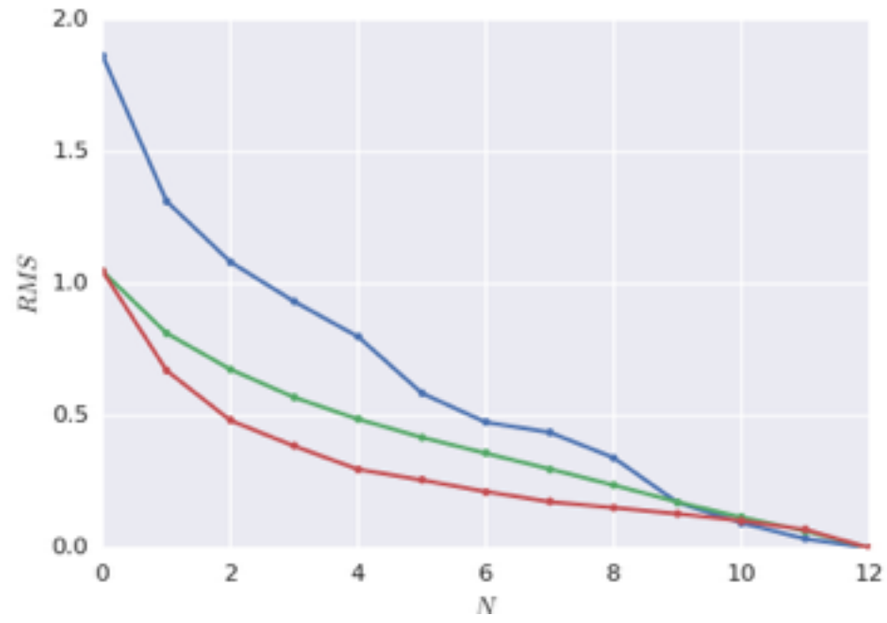
Fibonacci



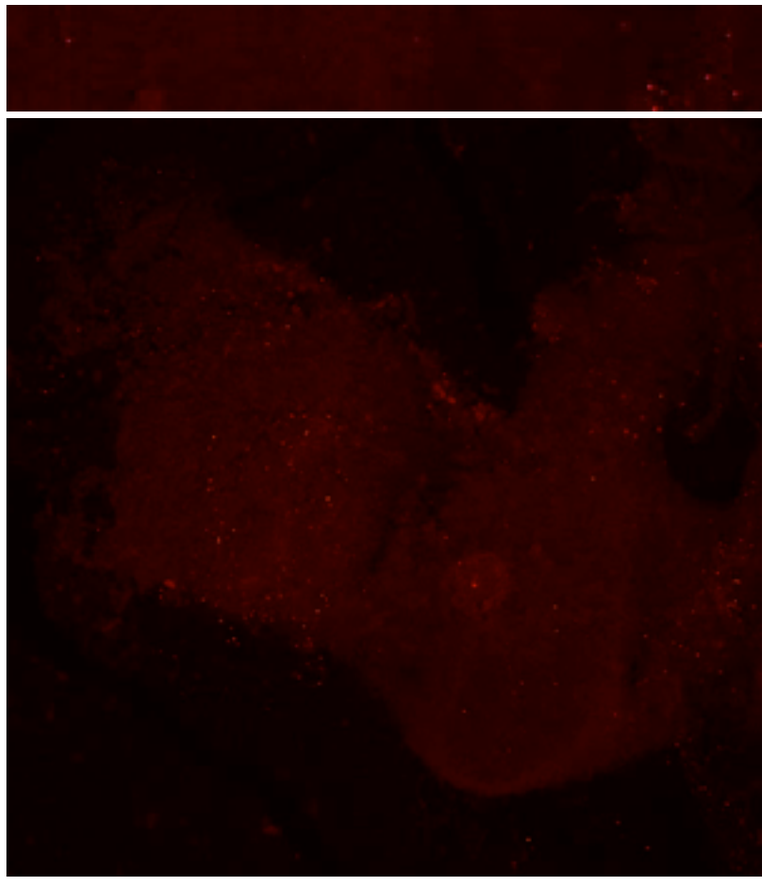




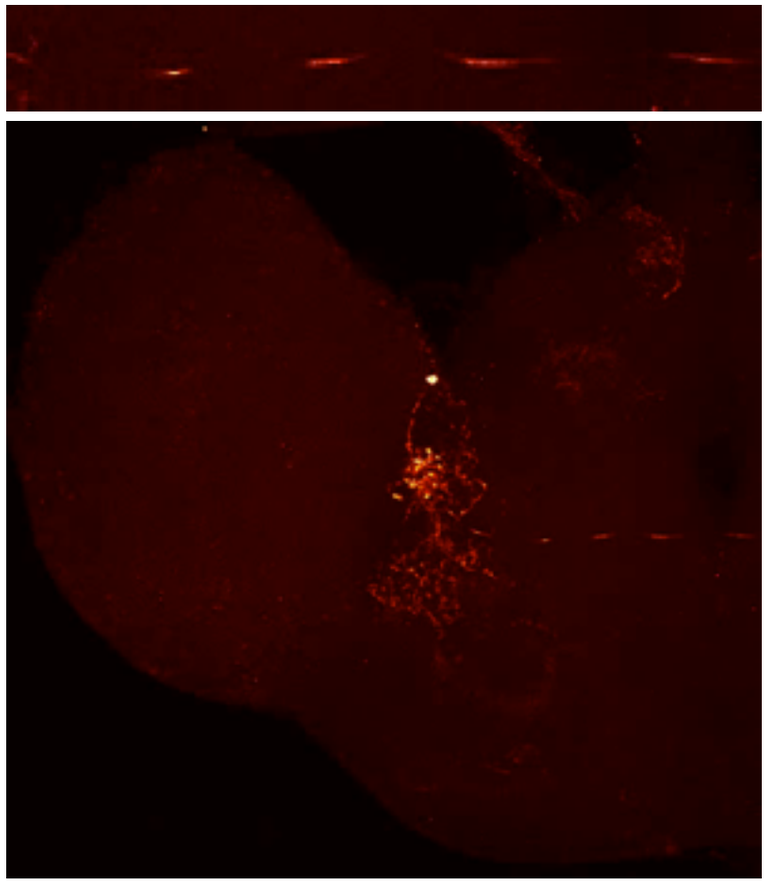
Fibonacci multi pass for big volumes



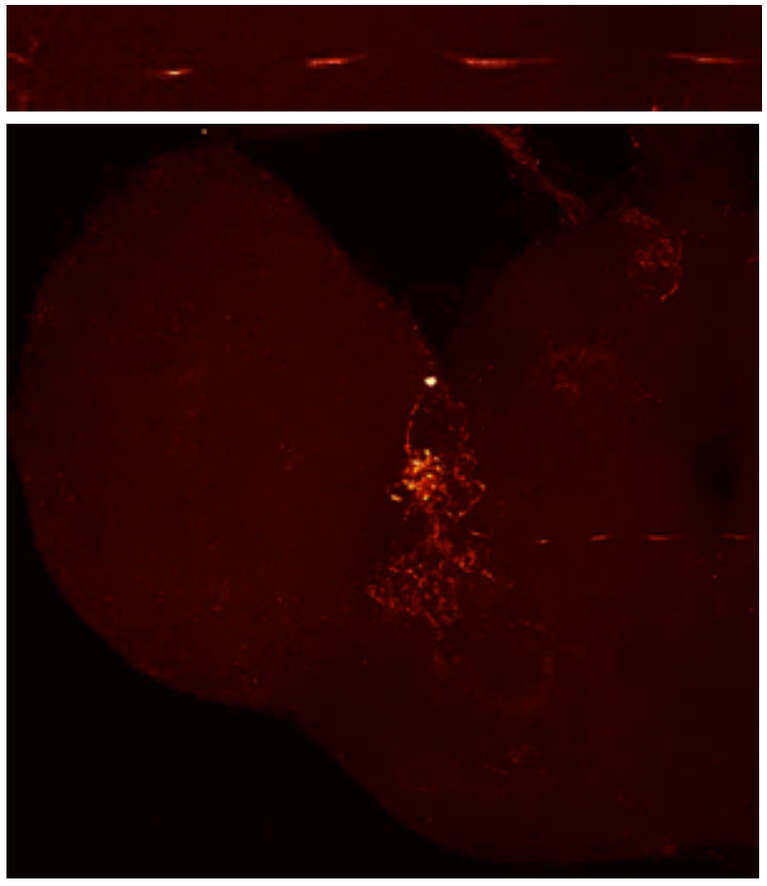
naive



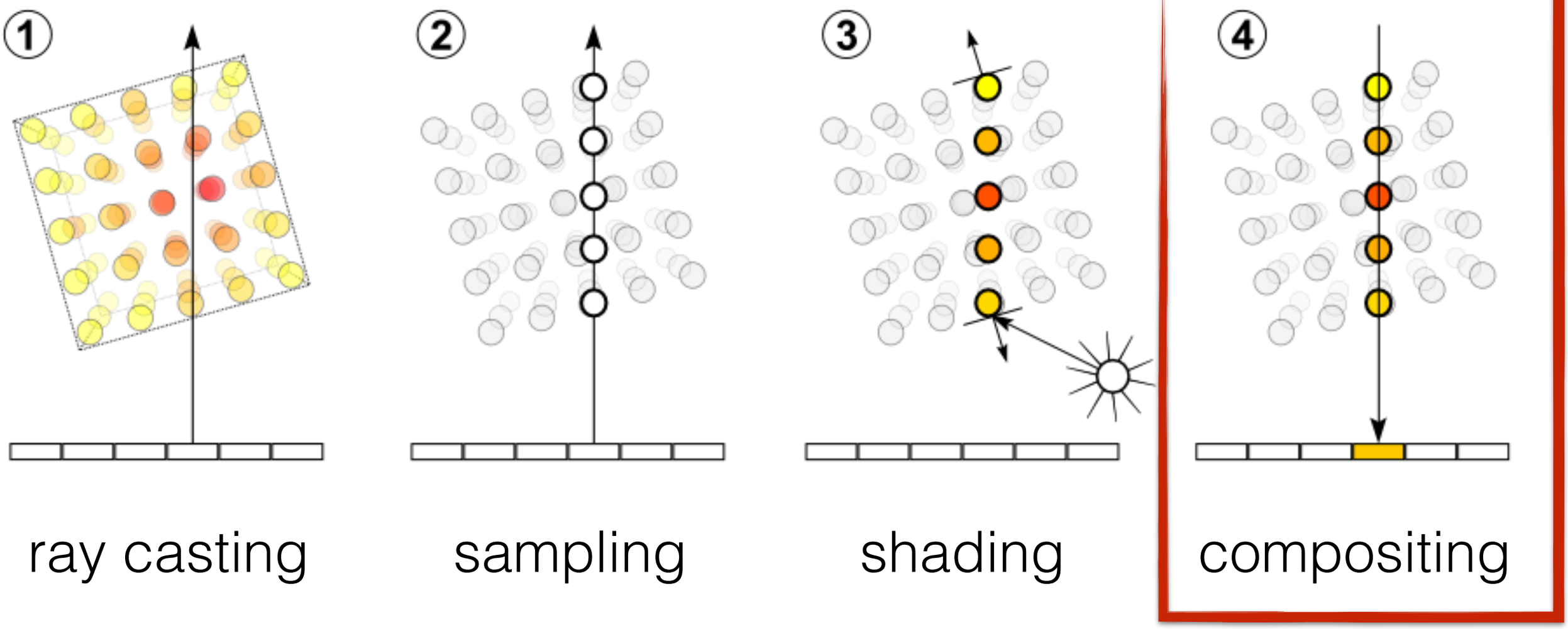
successive



Fibonacci



Volume Ray Casting



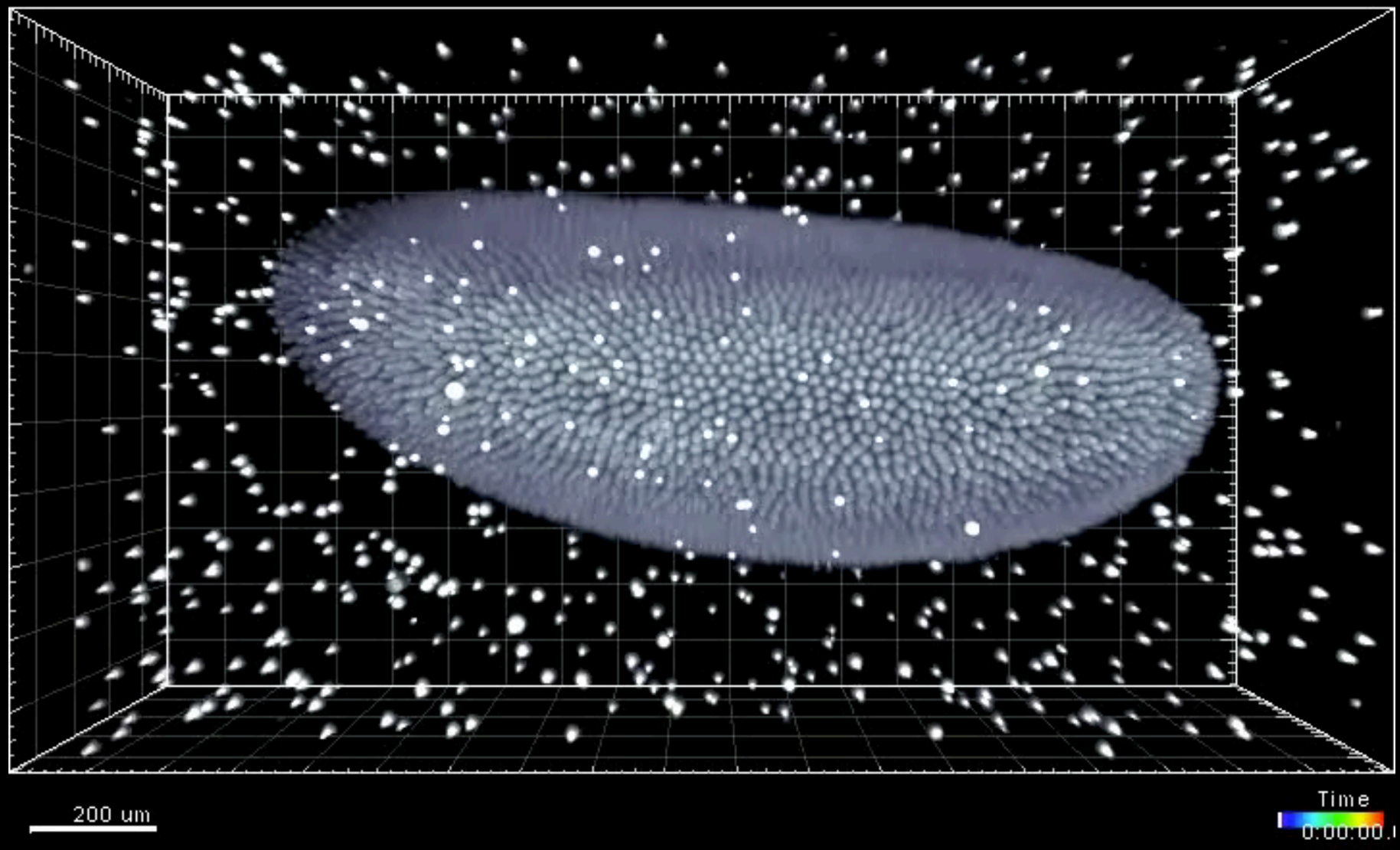
ray casting | sampling | shading | compositing

(image: wikipedia)

Compositing Methods

- Maximum Intensity Projection
- Alpha-Blending (Emission-Absorption Model)
- Iso-Surface(s)

Maximum Intensity Projection



Imaris

Alpha-Blending

- Optical model describes how particles in the volume interact with light.

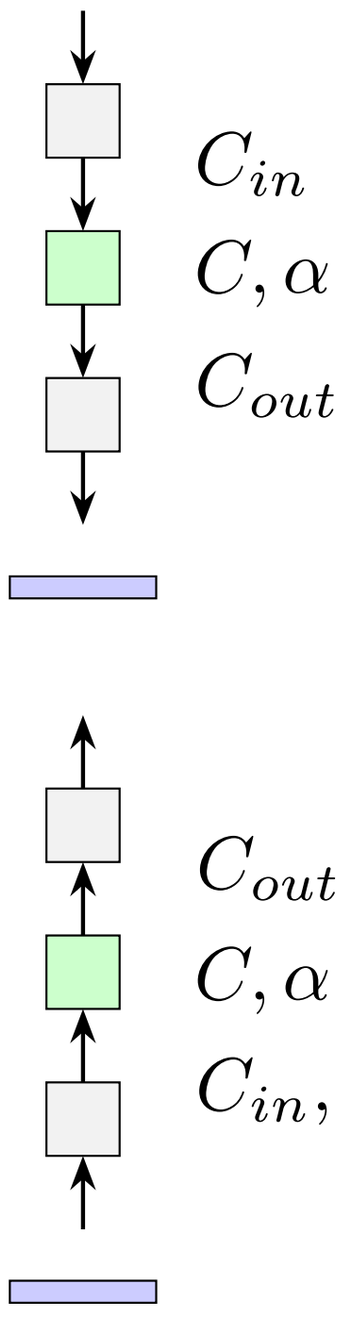
- Emission-Absorption model assumes that the volume consists of particles that simultaneously emit and absorb light.

- ARGB samples (pre-multiplied alpha)
  RGB — emitted color
  Alpha — opacity

Alpha-Blending

Back-to-Front Compositing

$$C_{out} = (1 - \alpha)C_{in} + C$$

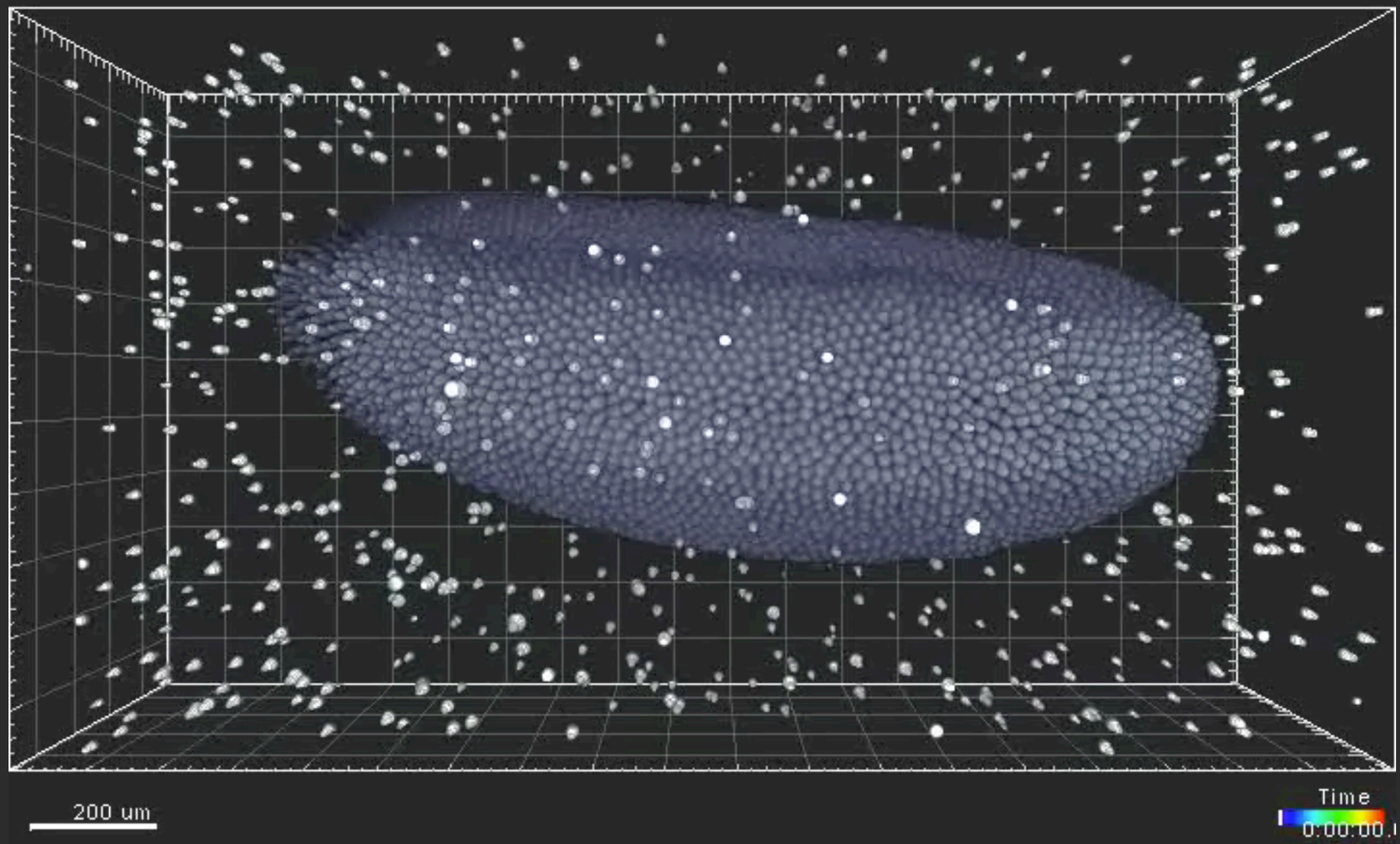


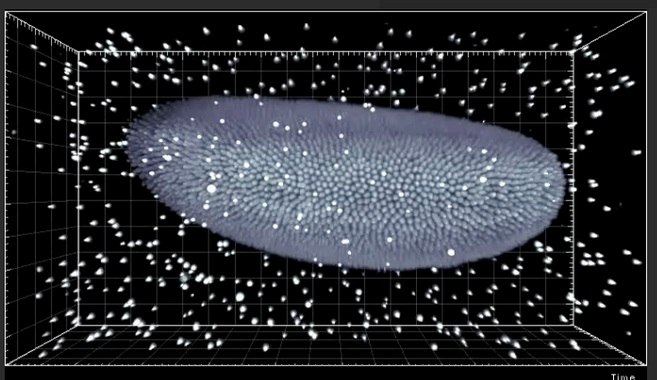
Front-to-Back Compositing

$$C_{out} = (1 - \alpha_{in})C + C_{in}$$

$$\alpha_{out} = (1 - \alpha_{in})\alpha + \alpha_{in}$$

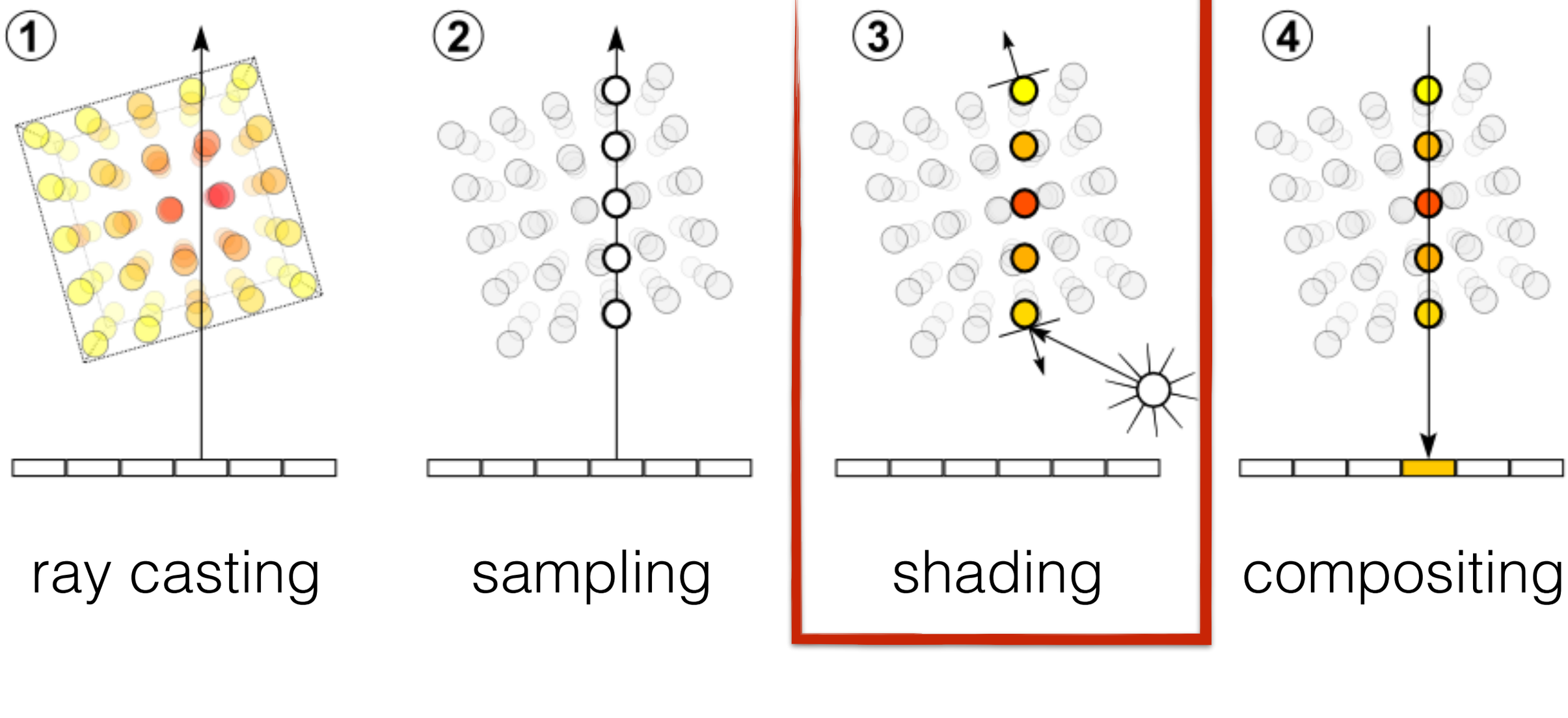
Alpha Blending





Imaris

Volume Ray Casting



ray casting | sampling | shading | compositing

(image: wikipedia)

Shading

How do intensities in the volume map to ARGB values?

$$I \longrightarrow ARGB$$

Arbitrary function in general.

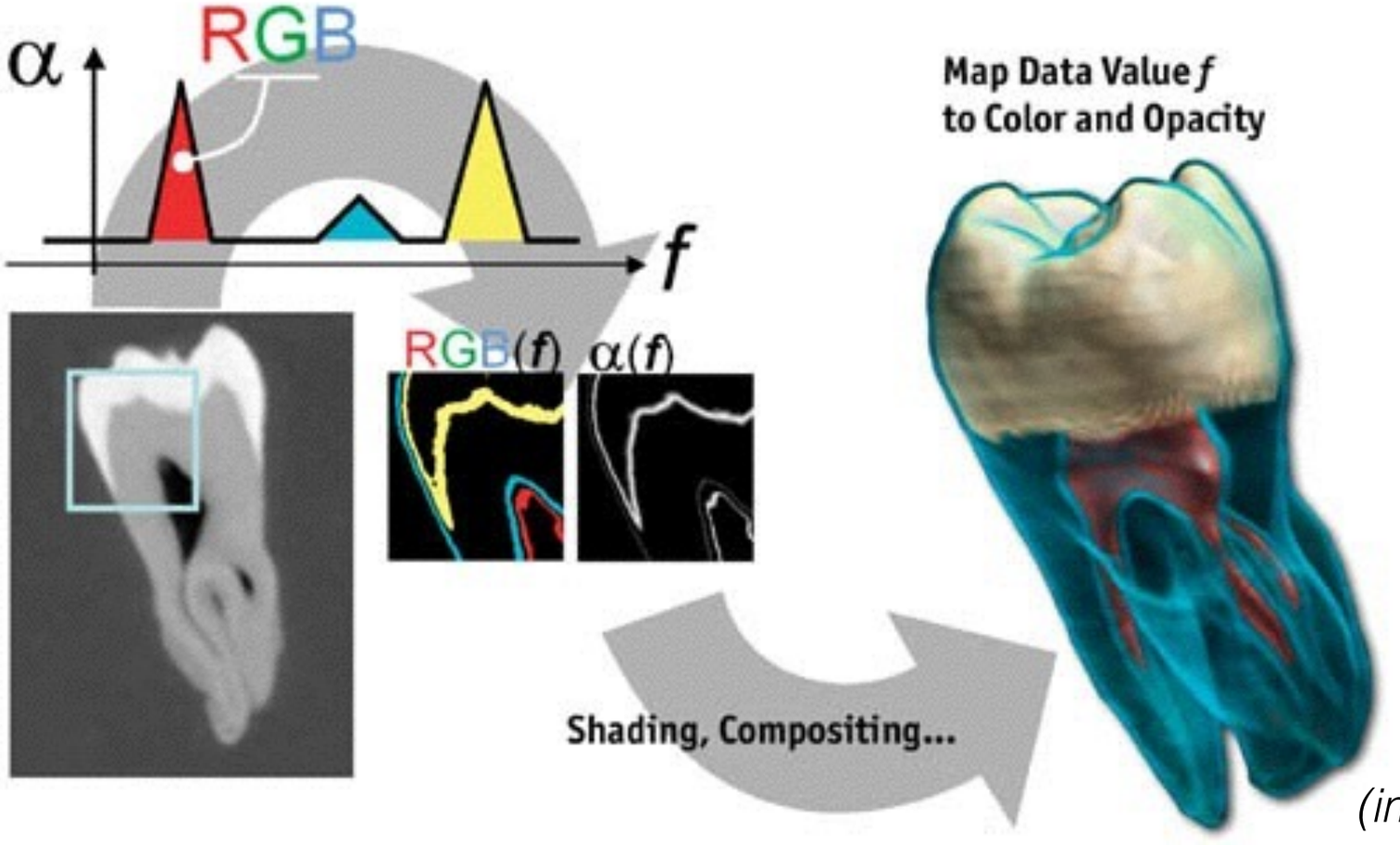
But restricted by UI parameterization:

- brightness, contrast, gamma
- color LUTs
- A is often tied to RGB

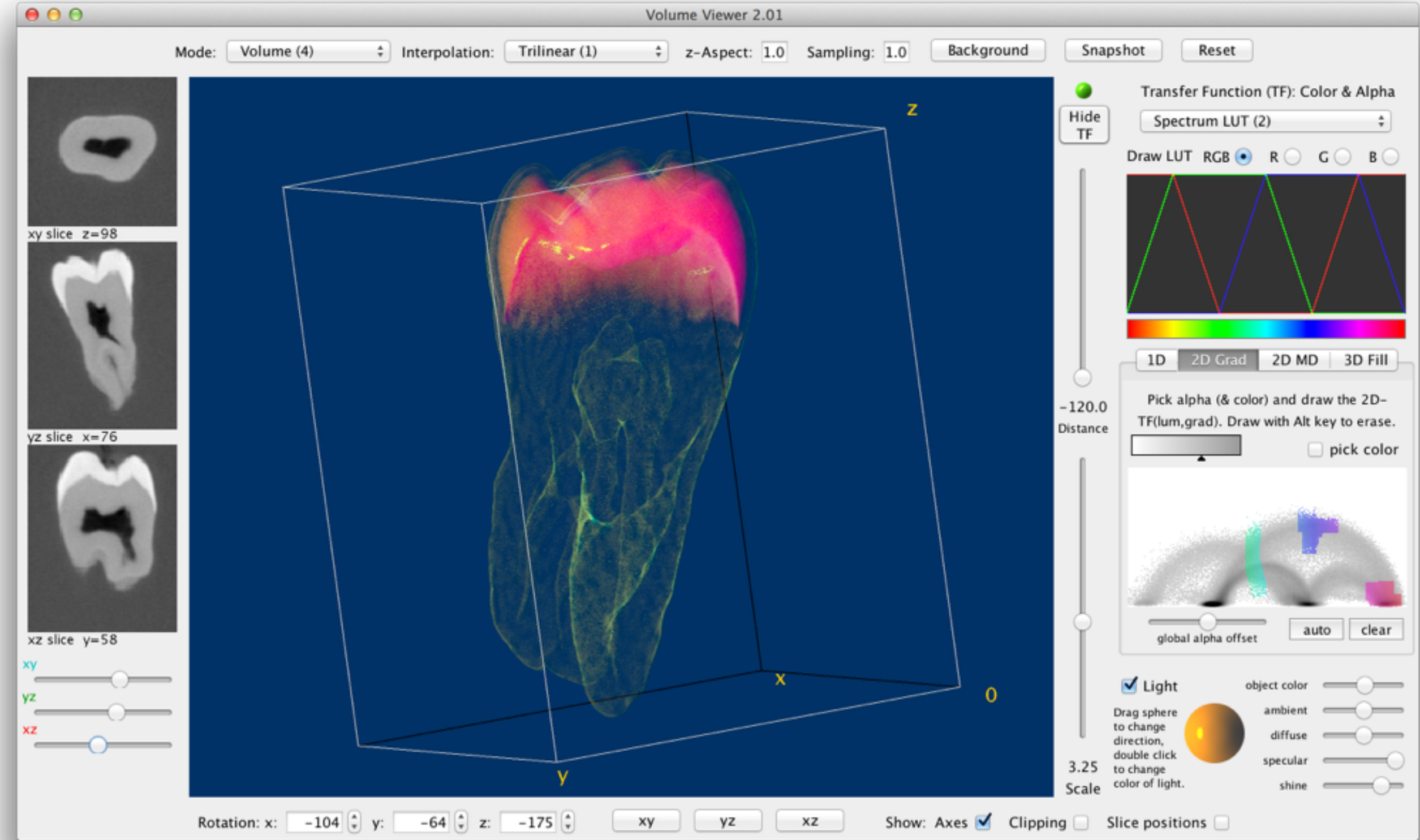
Shading

How do intensities in the volume map to ARGB values?

$$(I, \nabla) \longrightarrow ARGB$$



(image: GPU Gems)

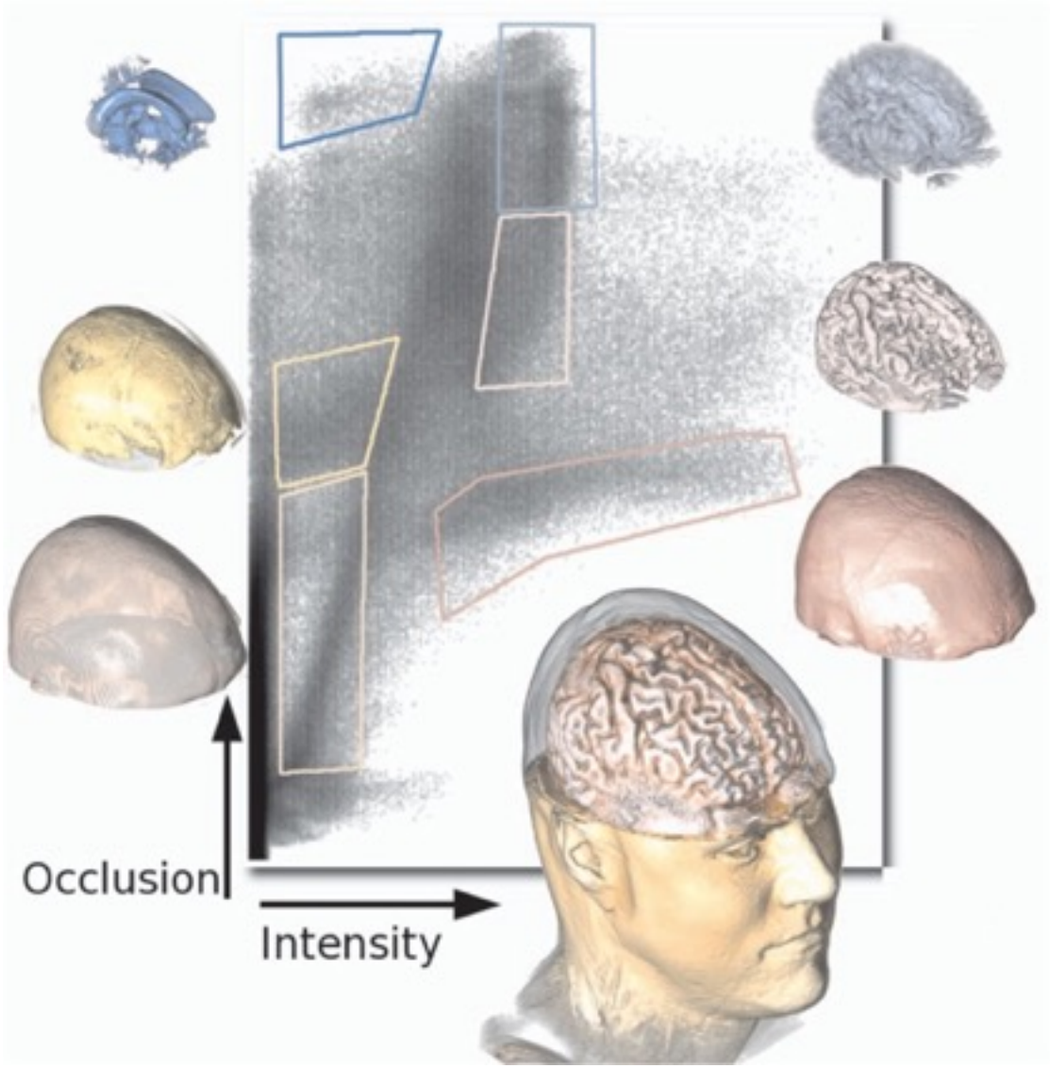


ImageJ Volume Viewer

Shading

How do intensities in the volume map to ARGB values?

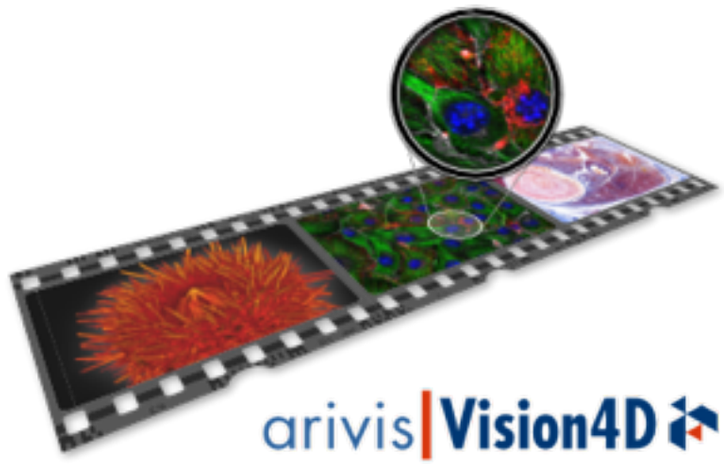
- Multi-Channel
- other local properties
  e.g. ambient occlusion, …



(image: Correa & Ma, 2009)

Practical Considerations

- Defining transfer functions, composition modes, …
- Defining region of interest, clipping planes, …
- Showing segmentations, annotations, …
- Creating Time-lapse movies and keyframe animation.

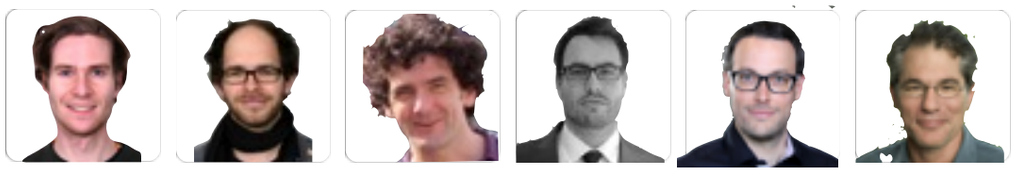


ClearVolume

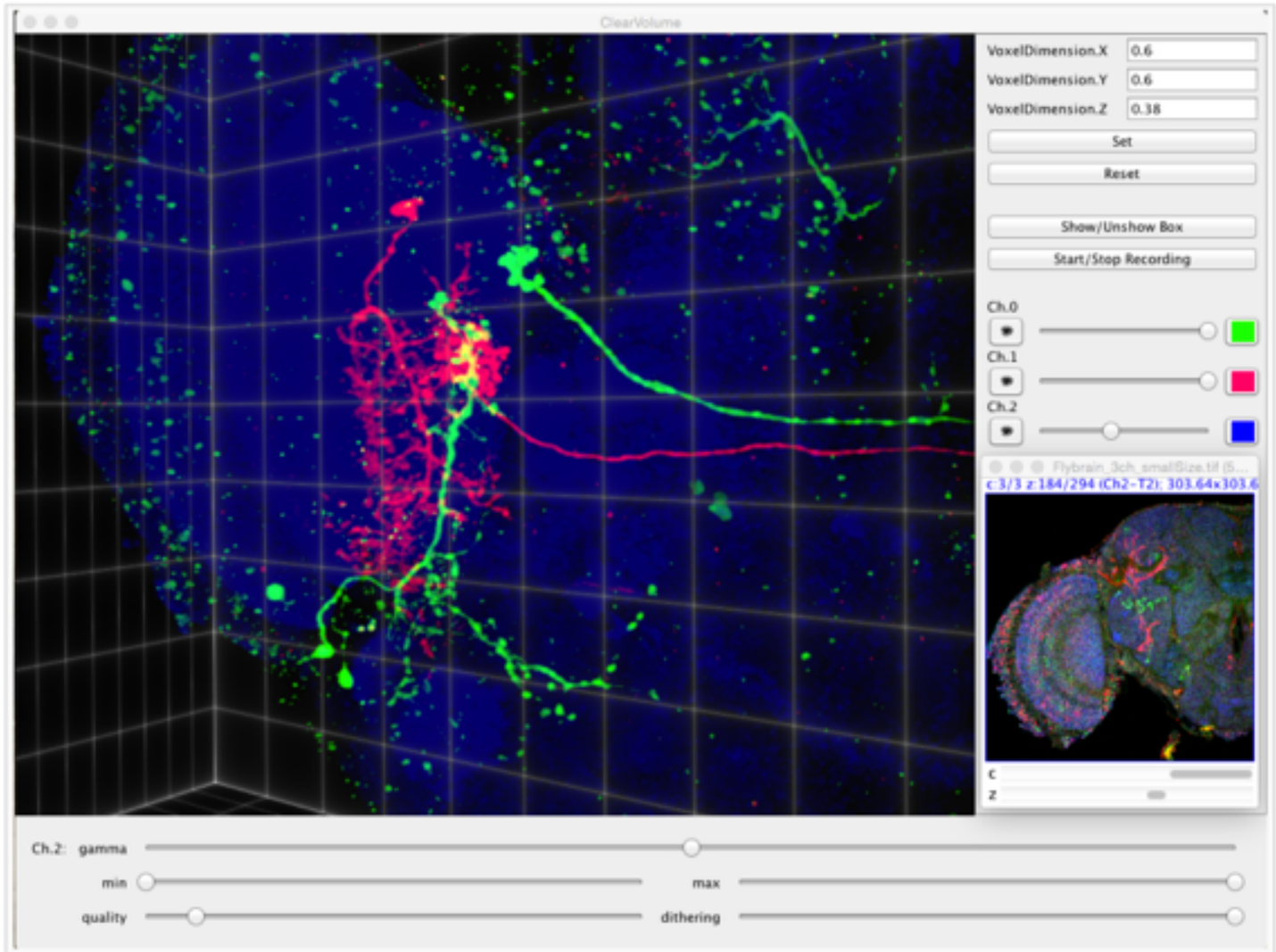


ClearVolume (Fiji)

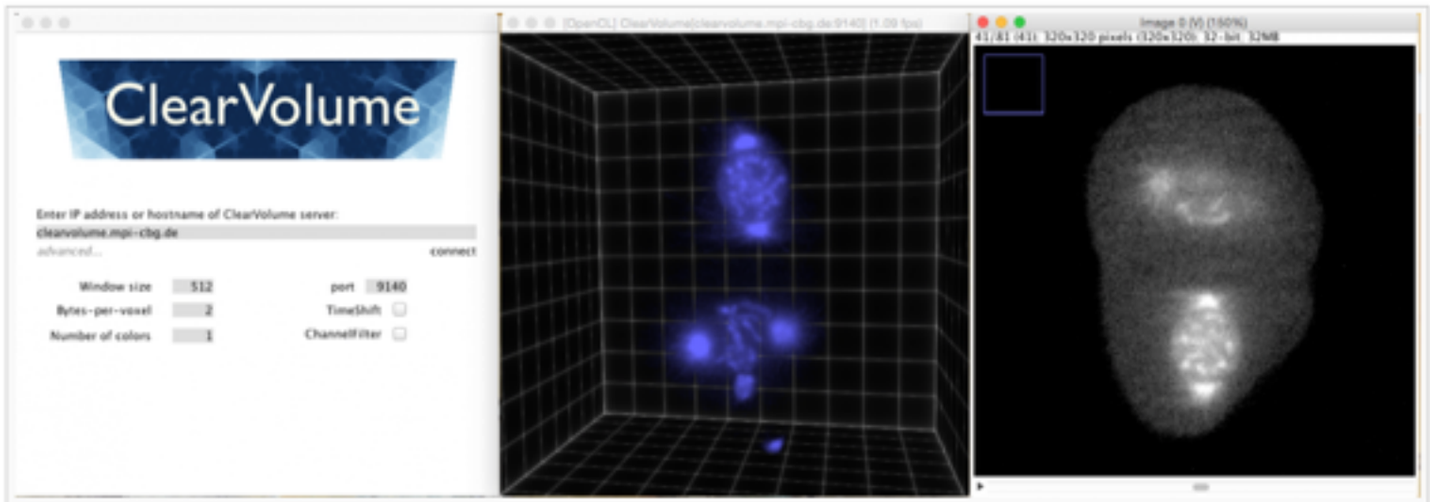
Author	Florian Jug, Loic Royer, Martin Weigert, Ulrik Günther
Maintainer	Florian Jug
Source	on GitHub
Development status	active
Category	Visualization
Website	https://clearvolume.github.io/



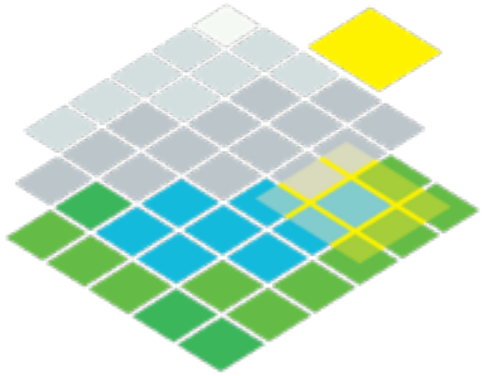
Loic A. Royer, Martin Weigert, Ulrik Günther, Nicola Maghelli, Florian Jug, Ivo F. Sbalzarini, Eugene W. Myers , Nature Methods 12, 480–481 (2015) doi:10.1038/nmeth.3372



The main ClearVolume plugin can render volumetric multi-channel data. Channel LUTs, transparency, rendering quality, etc. can easily be set in the plugins user interface. We thank Tzumin Lee's group at Janelia for being allowed to use their twin-spot MARCM (Yu et al., Nature Neuroscience, 2009) labeled neurons.

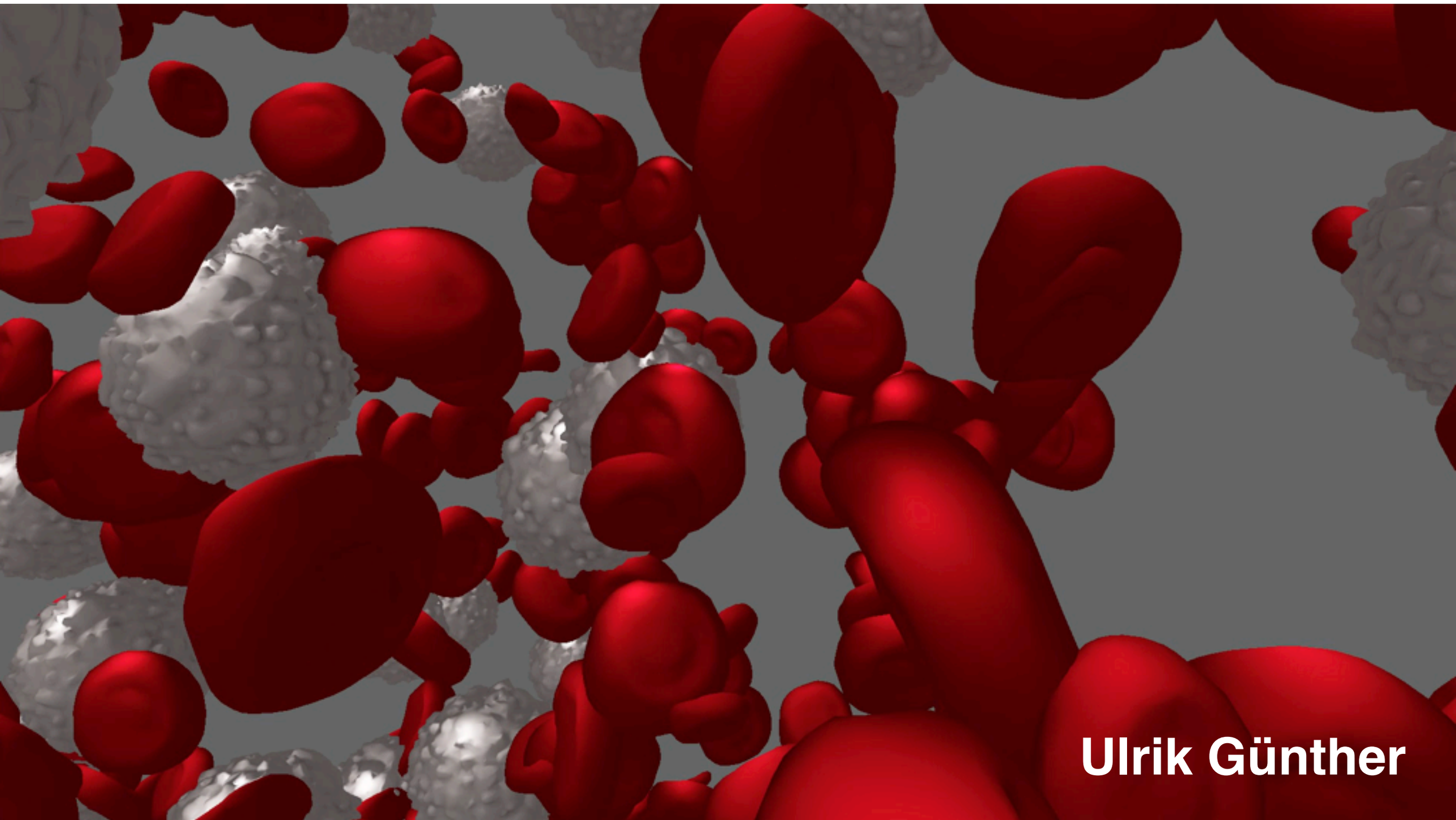


The ClearVolume network client can be started from Fiji/ImageJ2 and enables users to receive volumetric data from a remote source, e.g. live from a microscope in the basement of your collaborators institute.



scenery

https://github.com/ClearVolume/scenery



Ulrik Günther

ThreeDViewer

ThreeDViewer (ImageJ)	
Author	Kyle Harrington, Ulrik Günther, Robert Haase
Maintainer	
Source	ThreeDViewer
Initial release	in development
Latest version	in development
Development status	alpha
Category	Visualization
Website	https://github.com/kephale/ThreeDViewer

Purpose

This plugin provides 3D visualization capabilities for images and meshes using the Scenery and ClearVolume infrastructure. An ambition of this plugin is to serve as a modern replacement to 3D Viewer. ThreeDViewer also integrates ImageJ2 functionality, including ImageJ Ops.

Thanks!

- **Tobias Pietzsch** &
  Pavel Tomancak

- Ulrik Günther (Sbalzarini lab)

- Loic Royer and the Myers lab

- ***ImgLib2***
  Stephan Saalfeld
  Stephan Preibisch

- ***ImageJ2 / Fiji / KNIME ...***
  Curtis Rueden
  Christian Dietz