# Software tools motivated by analysis of fMRI data

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http://cvnlab.net

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# Introduction

- **Where I am**
  - Center for Magnetic Resonance Research, University of Minnesota

http://www.cmrr.umn.edu

- **What I work on**
  - Computational models of visual processing
  - Object and form vision

- **Approach**
  - Cognitive neuroscience (experiments, fMRI)
  - Theoretical neuroscience (modeling)
  - Data analysis (stats, programming)

- **Resources**
  - http://cvnlab.net

# Computing approach

- Pull bits and pieces from:
  - FreeSurfer
  - SPM
  - FSL

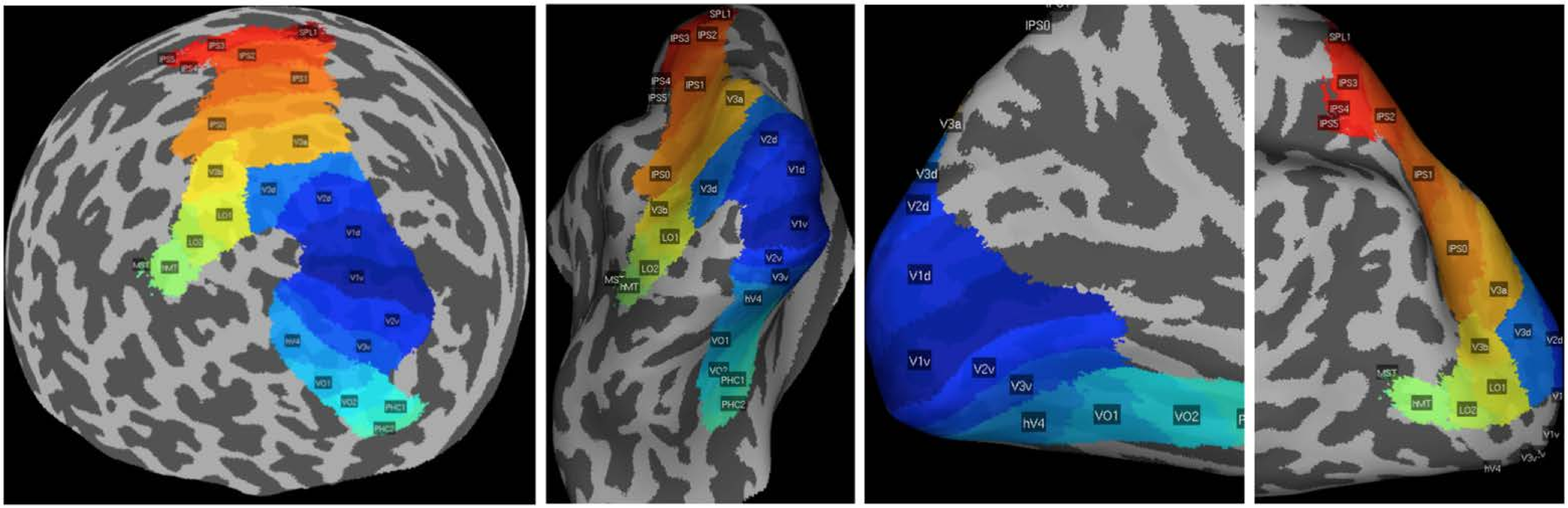
http://github.com/kendrickkay/

- Integrate into MATLAB pipelines
  - Some standalone MATLAB toolboxes (GLMdenoise, analyzePRF, etc.)
- Analysis is done mostly on a large workstation, using cluster computing for parallel analysis of individual voxels

# Automated surface visualizations (1/7)

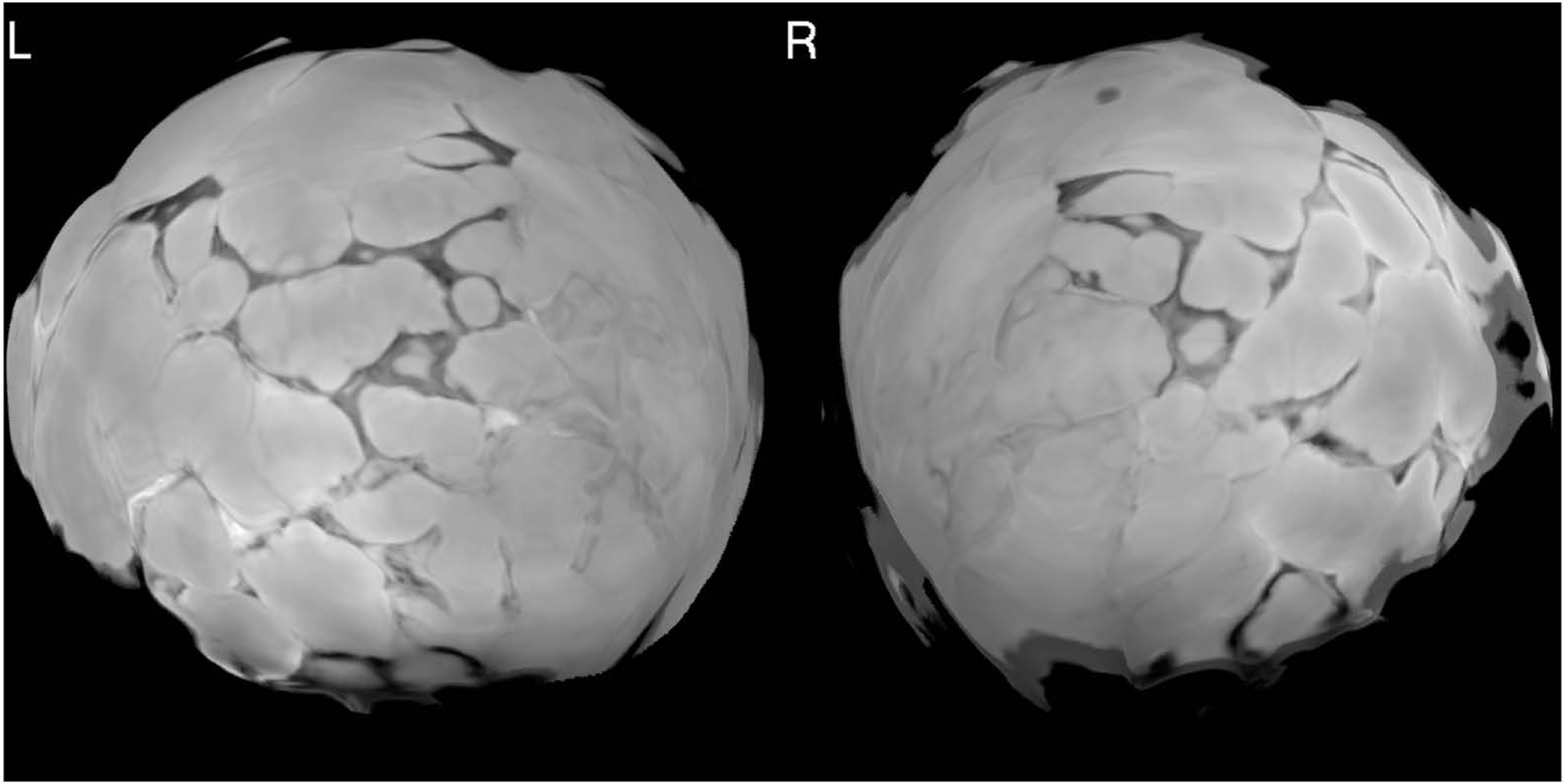
- High-throughput (avoid GUI, automated)
- Customizable (colormap, overlays, etc.)
- FreeSurfer-oriented but could be generalized
- Support for high-resolution surfaces
- Method: map pixels to vertices using nearest-neighbor interpolation, use caching mechanism for speed

# Automated surface visualizations (1/7)




sphere | occipital | medial | lateral

# Automated surface visualizations (1/7)



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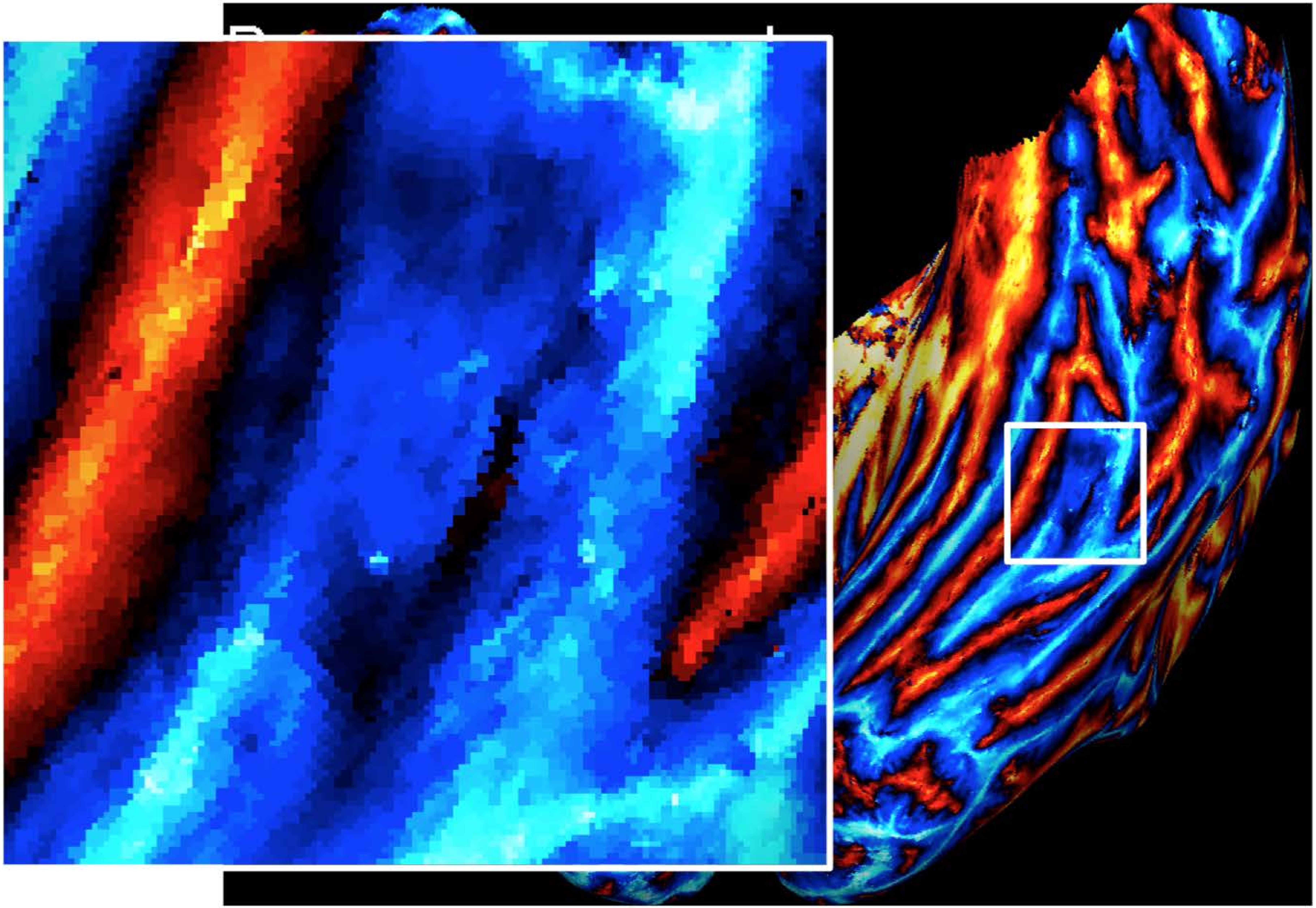

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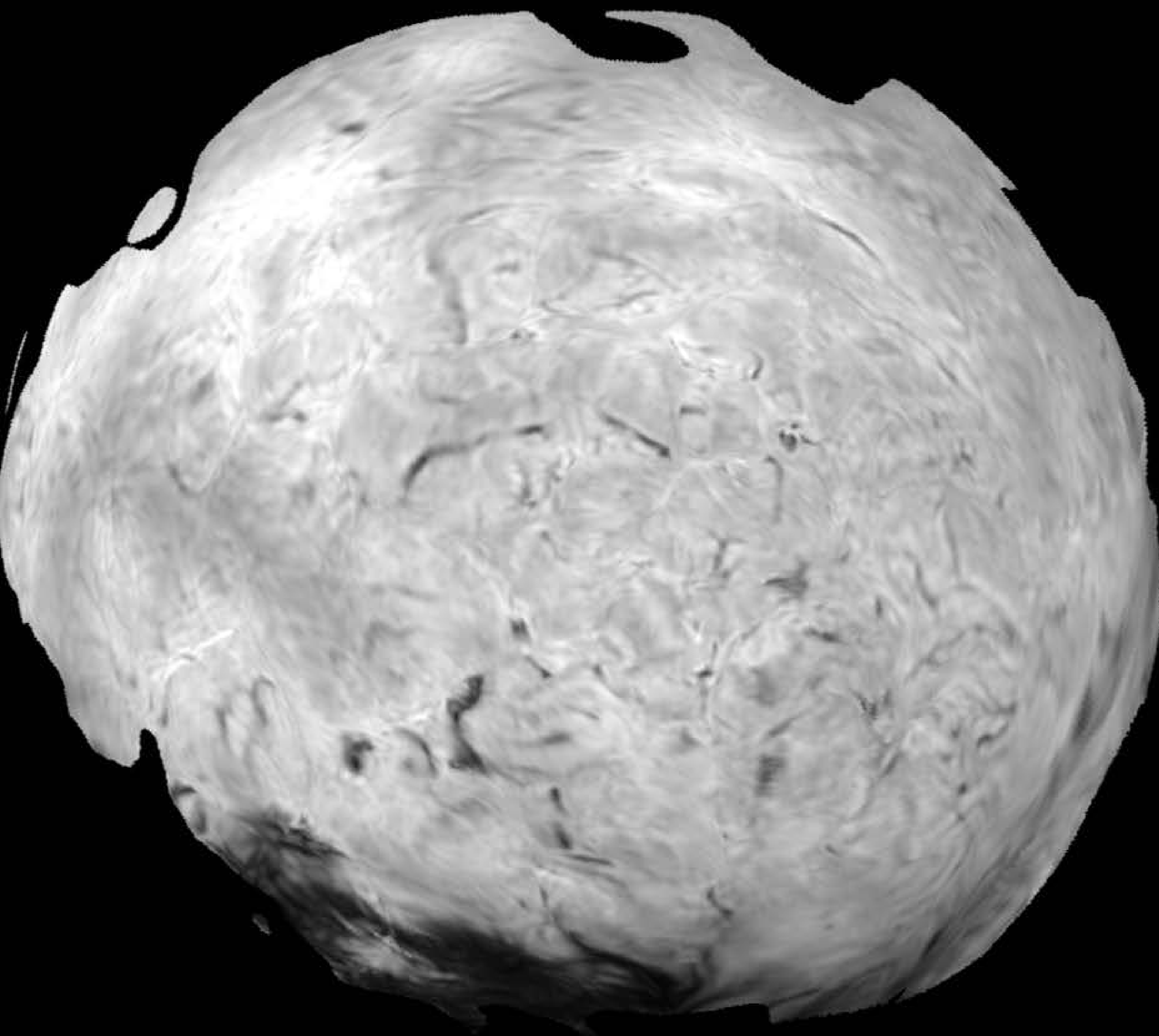

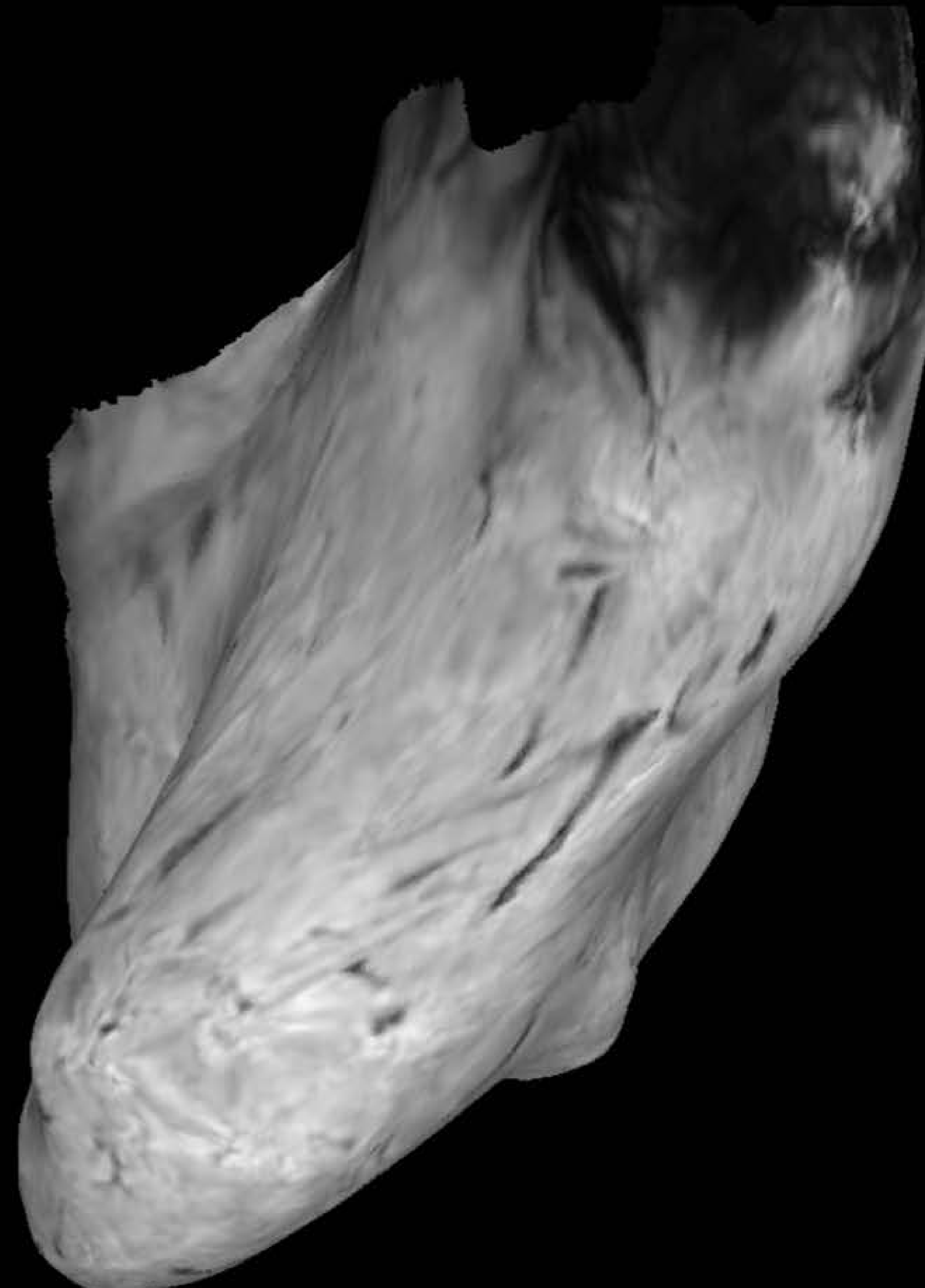

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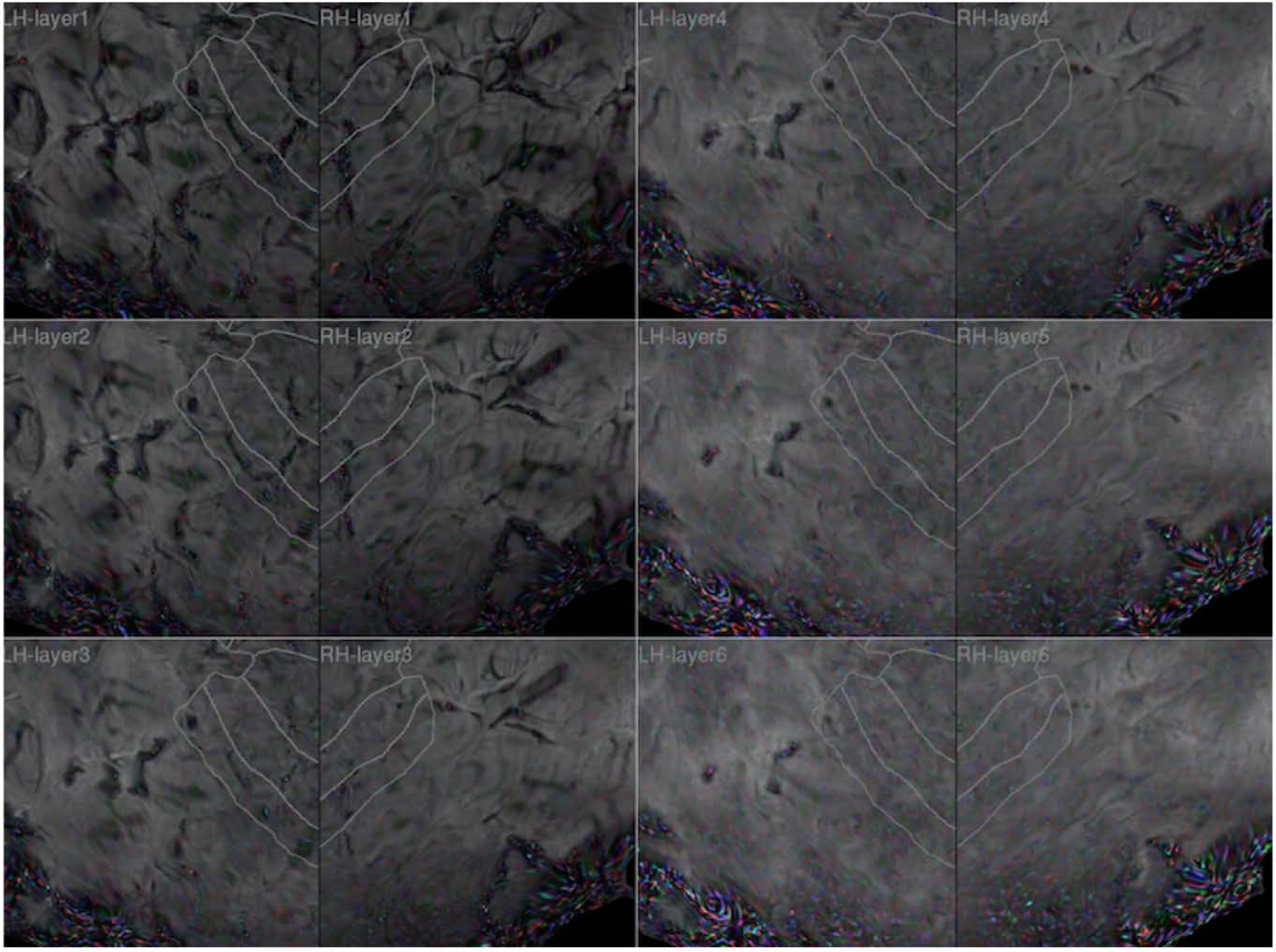
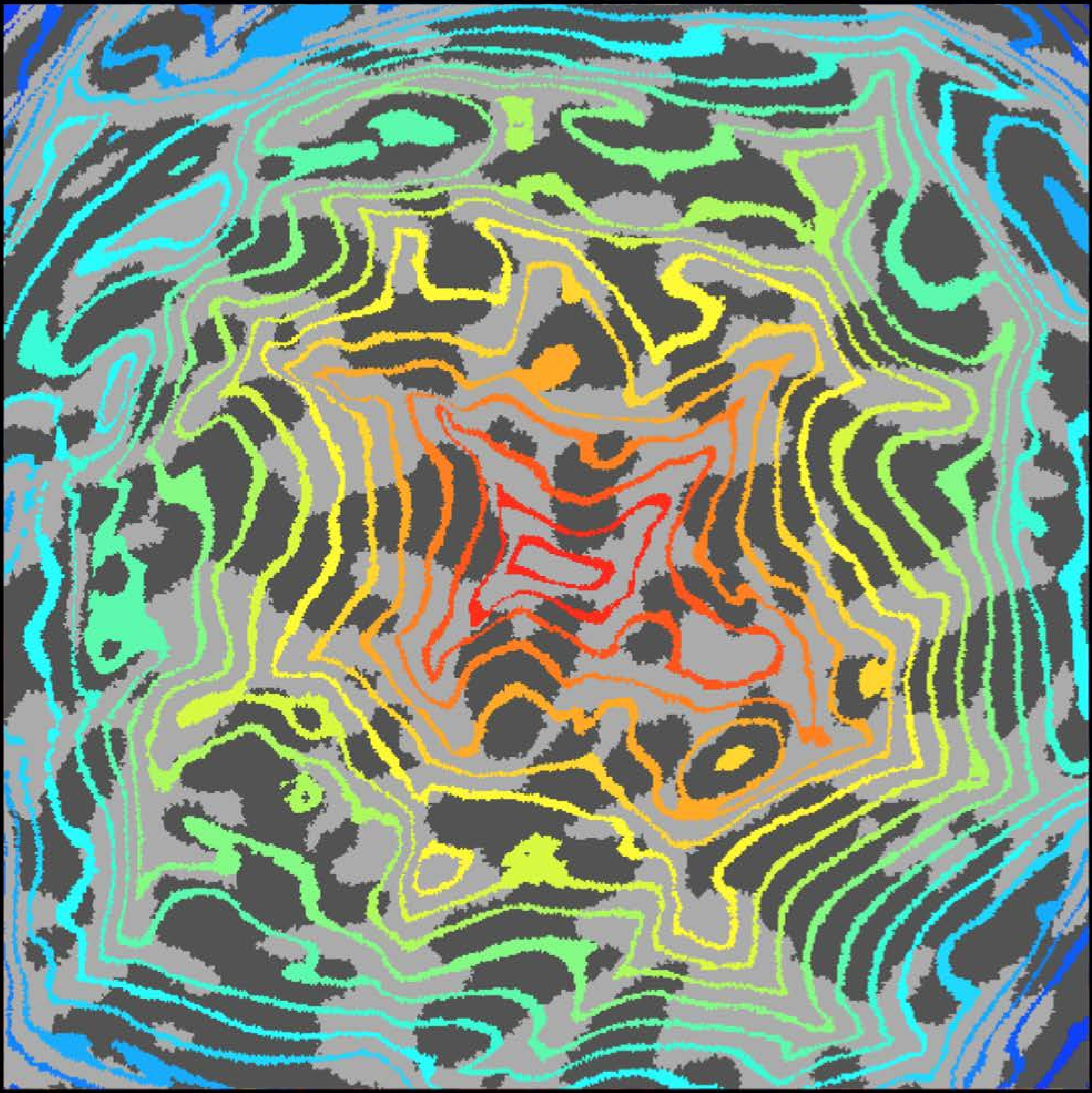


# Brain art (2/7)

- Real data masquerading as art!

# Brain art (2/7)



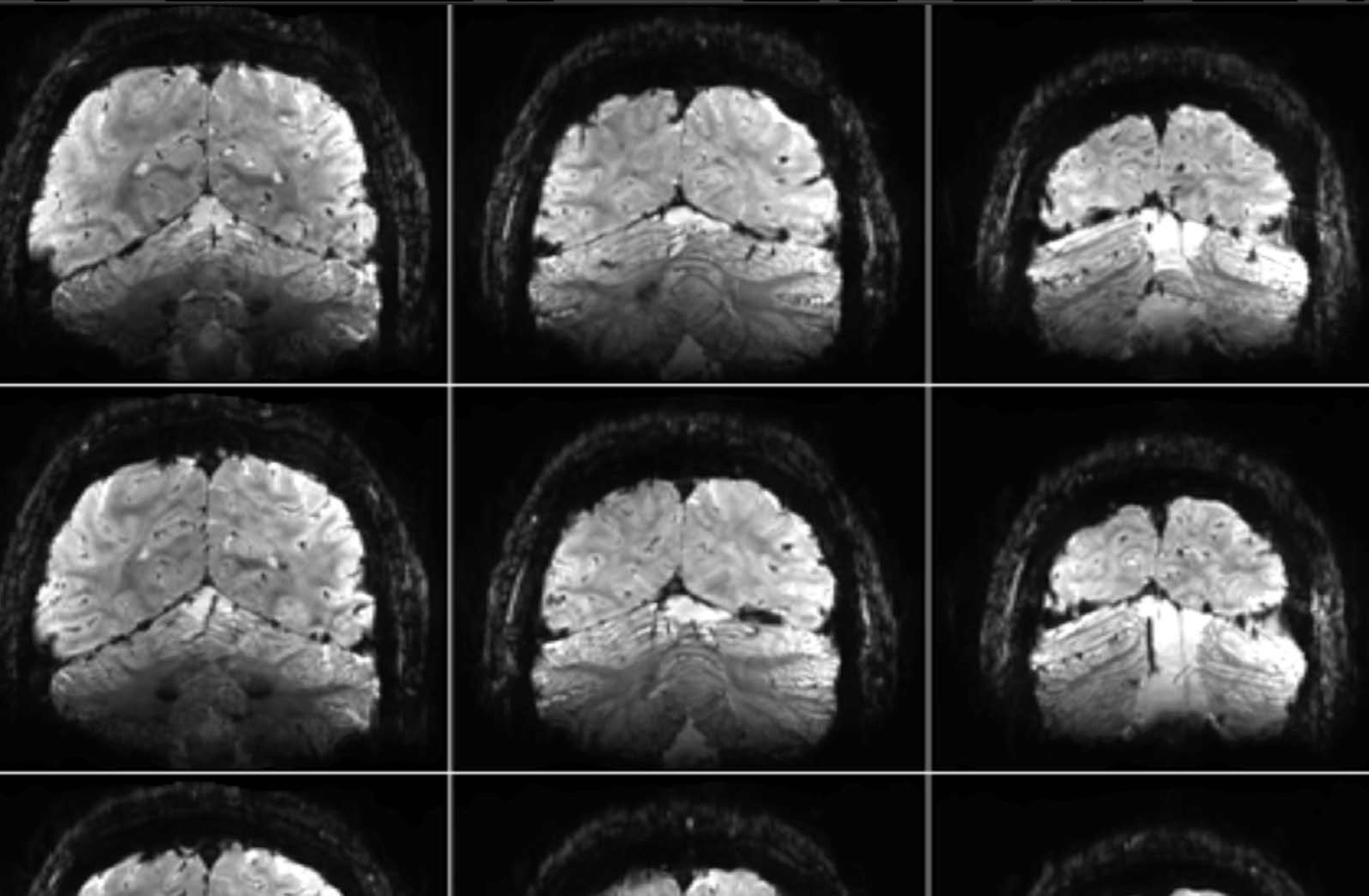
# Brain art (2/7)

# High-res fMRI pre-processing (3/7)

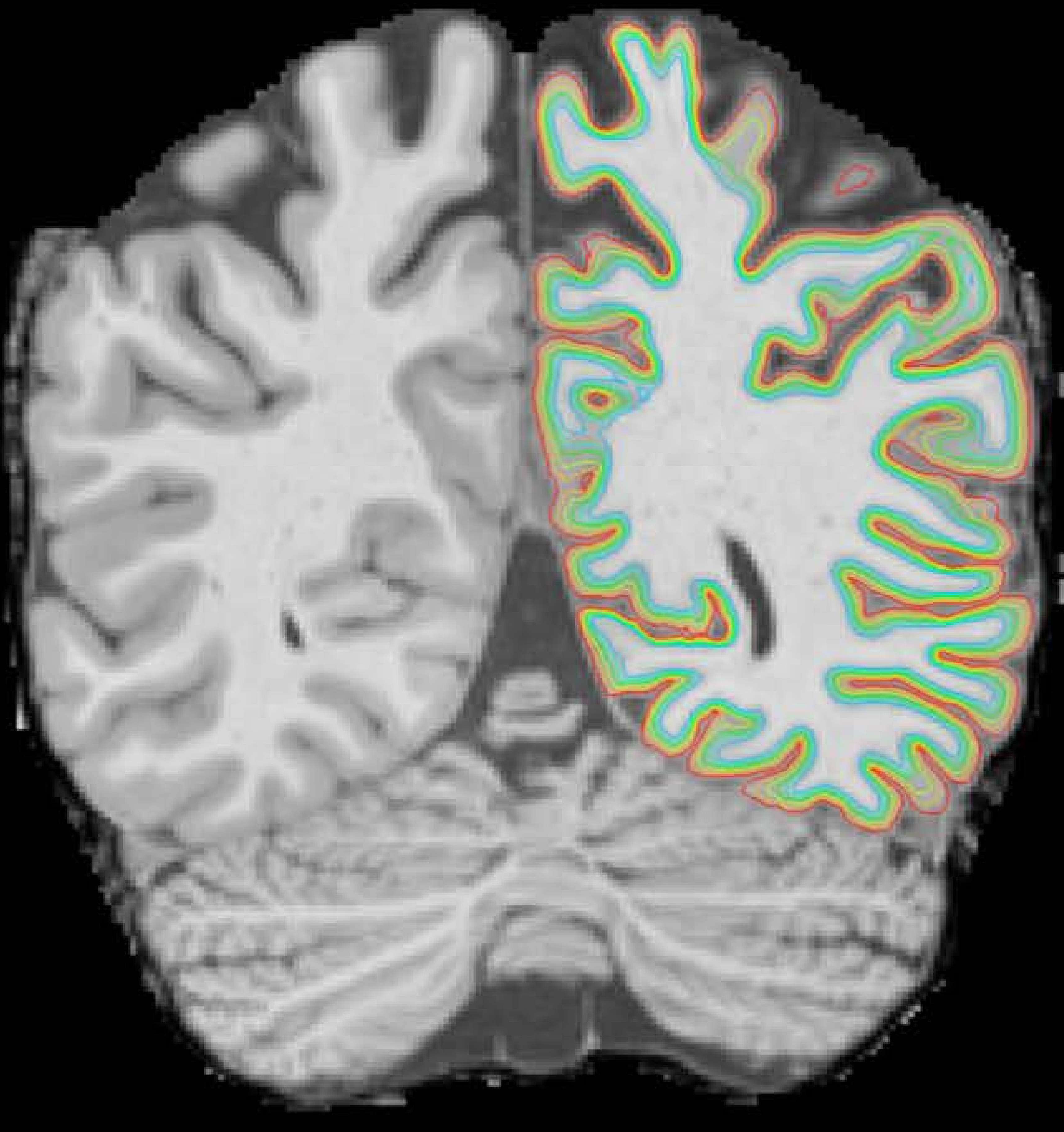
http://github.com/kendrickkay/cvncode/

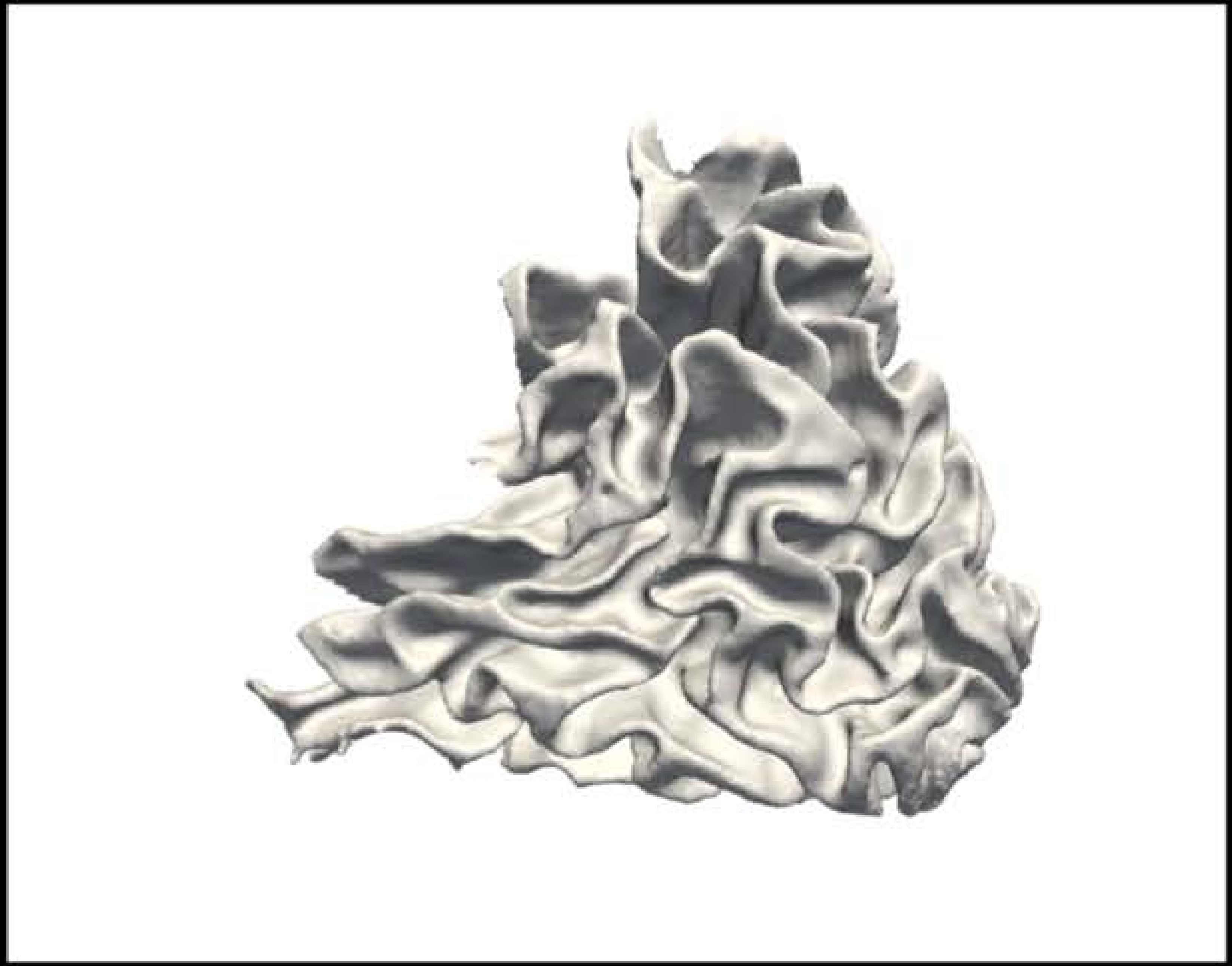
- Average T1s to improve SNR
- Co-registration: T1 to T1, T2 to T2, T2 to T1, EPI to T2
- Generate FreeSurfer cortical surfaces
  (dense, equidistant layers, truncated)
- Fieldmaps:
  - Regularize using local linear smoothing
  - Interpolate over time
- EPI:
  - Slice time correction
  - Motion correction
  - Fieldmap undistortion
  - Interpolation onto cortical surfaces
  - Total: 1 temporal resampling, 1 spatial resampling
- Homogenization of EPI intensities
  (polynomial basis functions, surface-based)

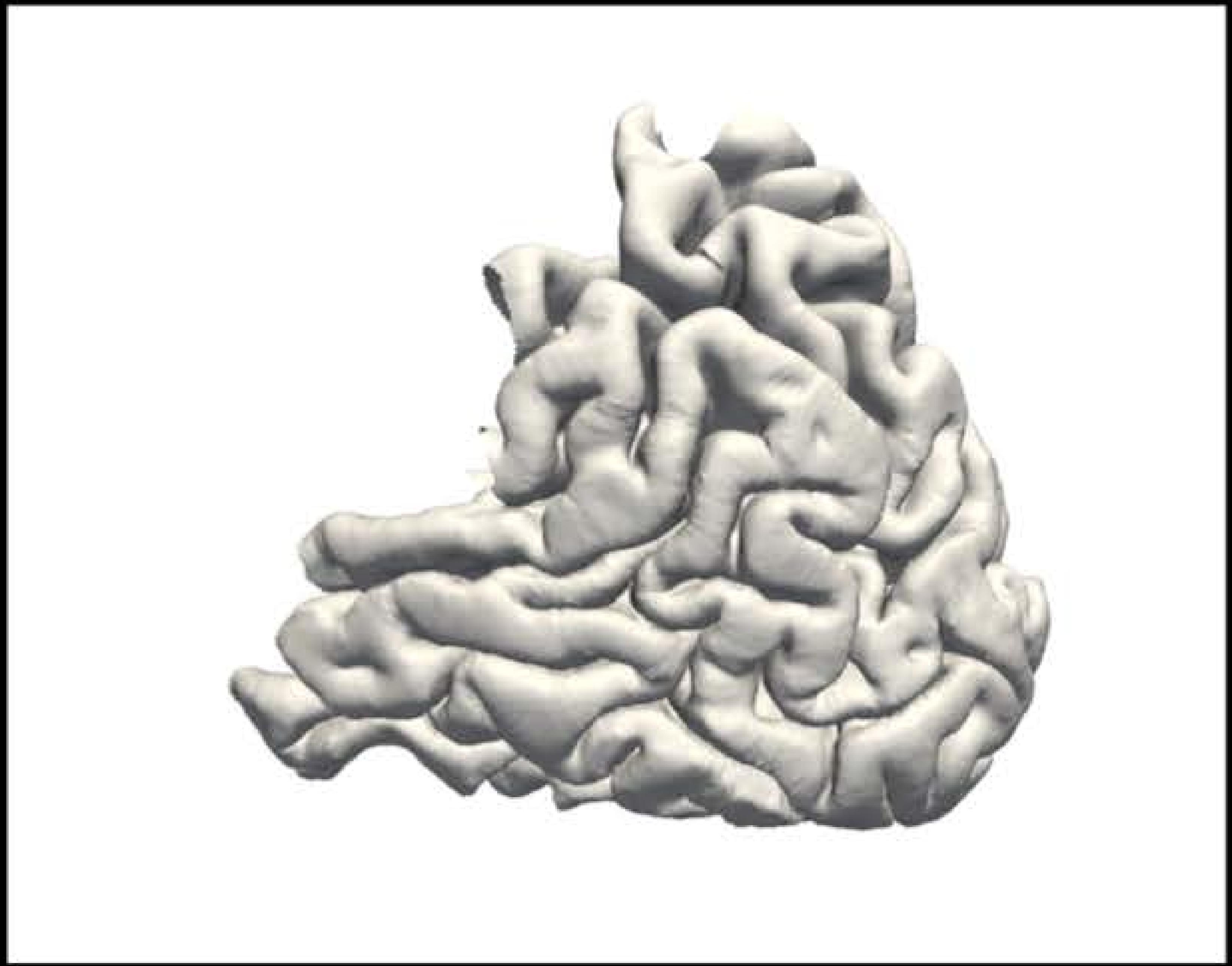
# High-res fMRI pre-processing (3/7)



# High-res fMRI pre-processing (3/7)







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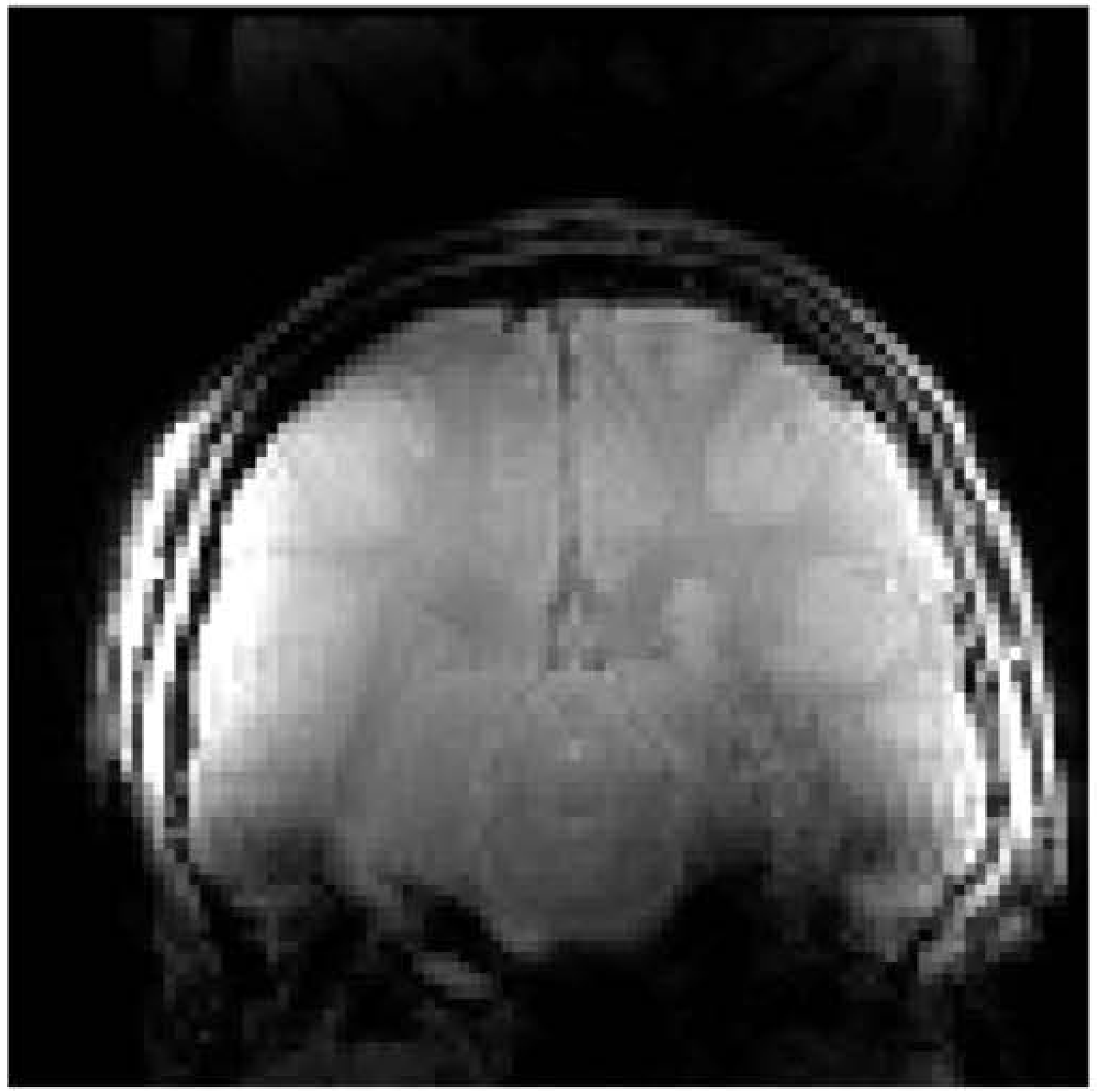
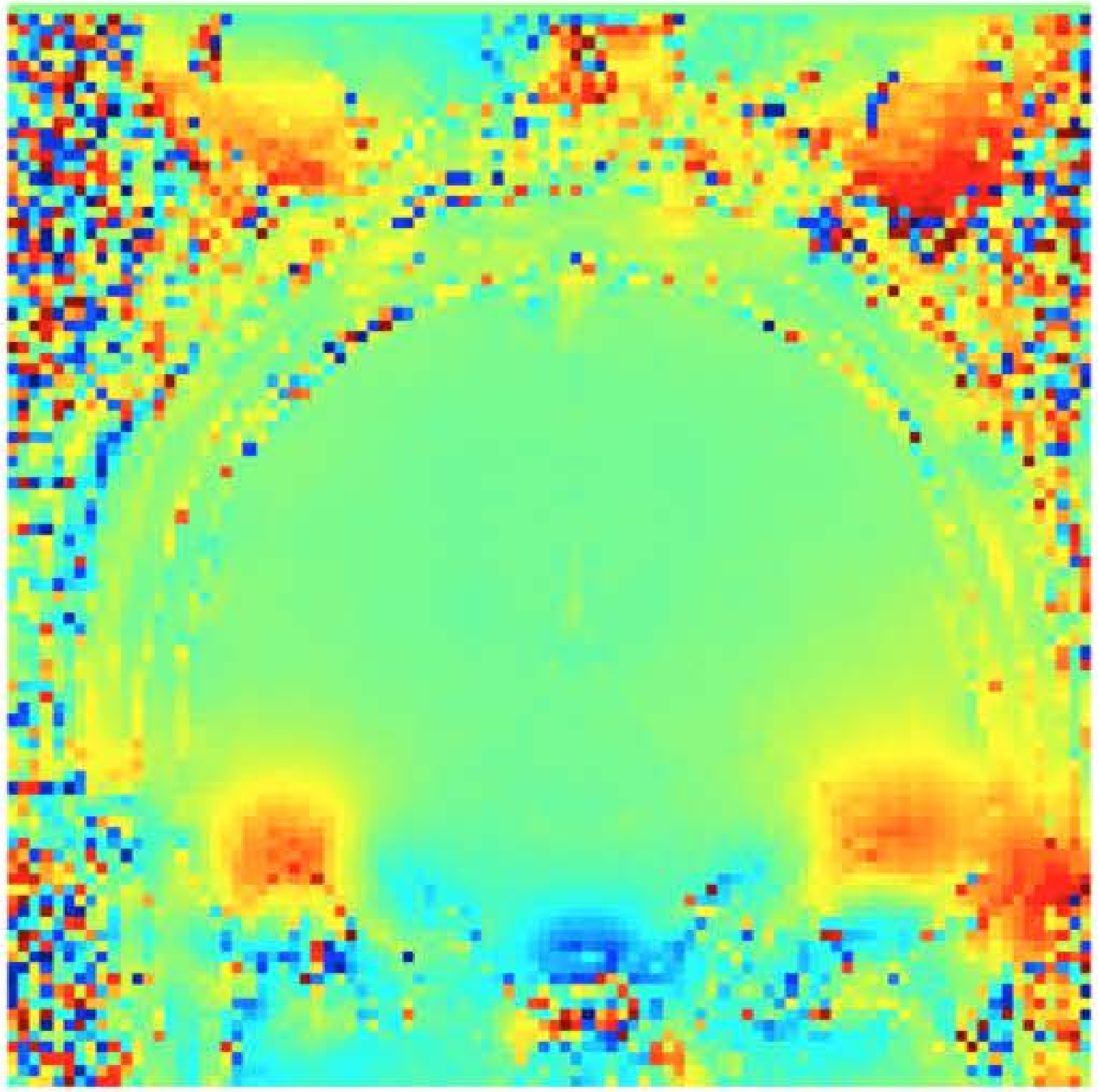
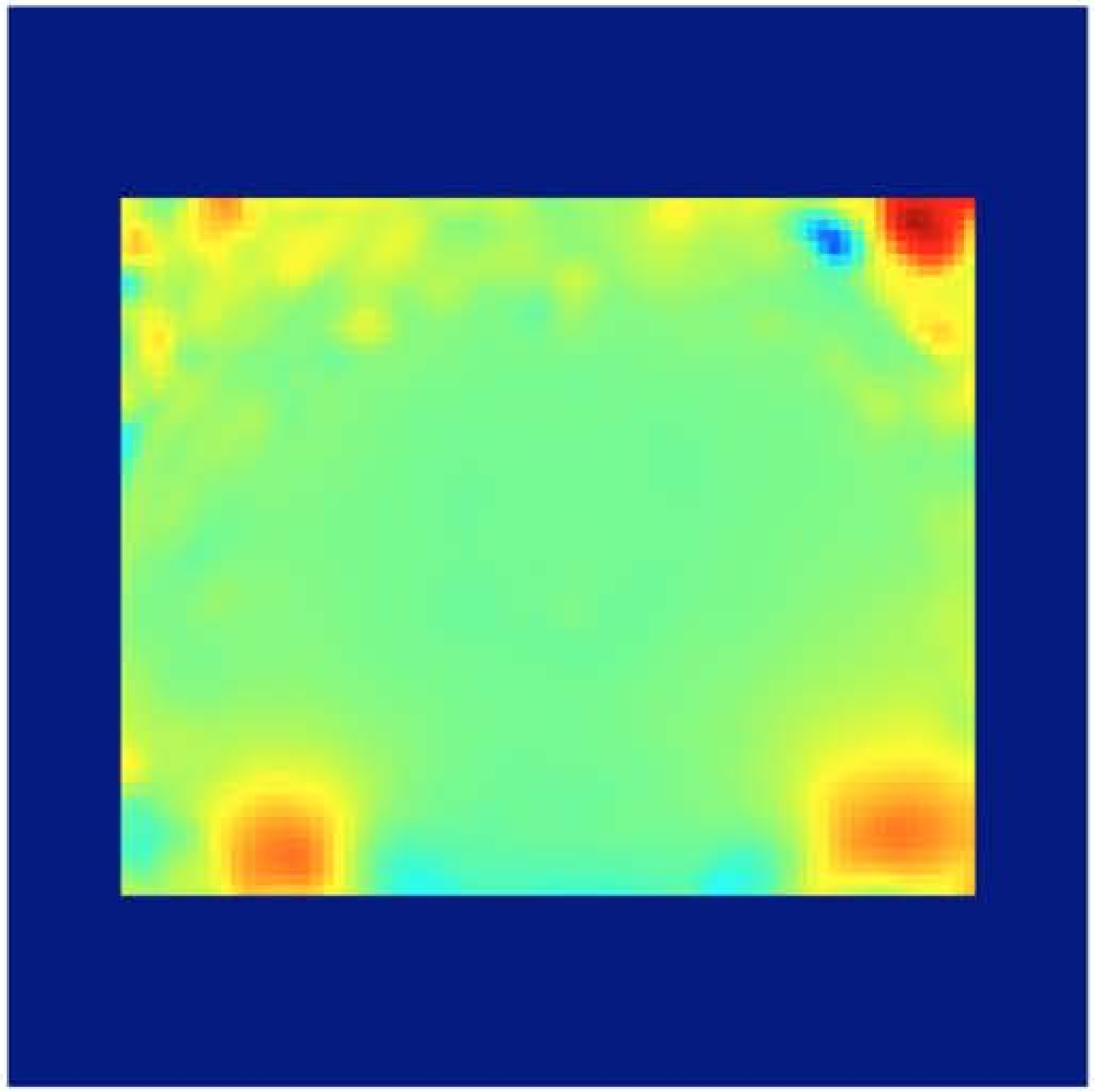


Fieldmap magnitude

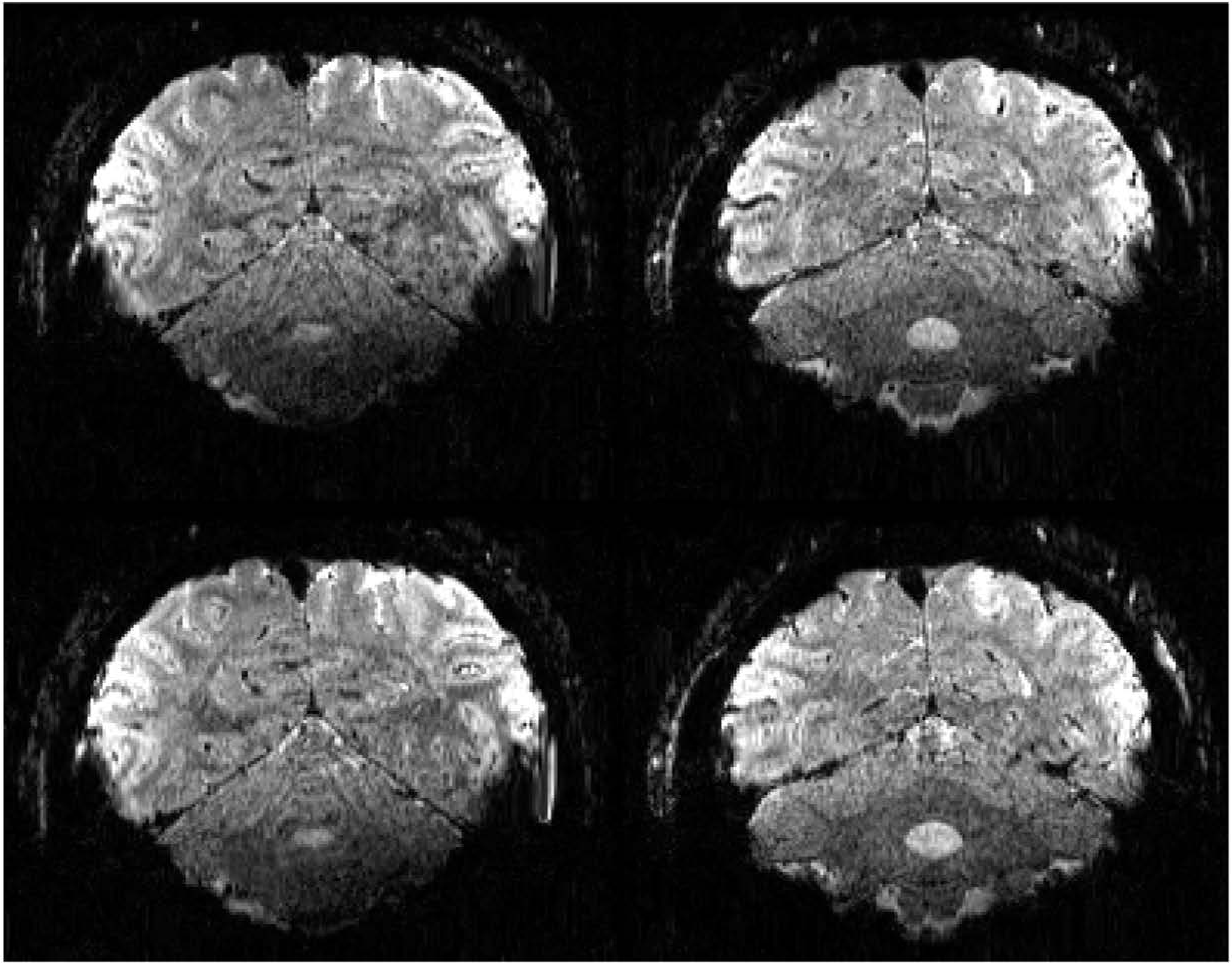


Fieldmap phase



Fieldmap phase (regularized)

# High-res fMRI pre-processing (3/7)



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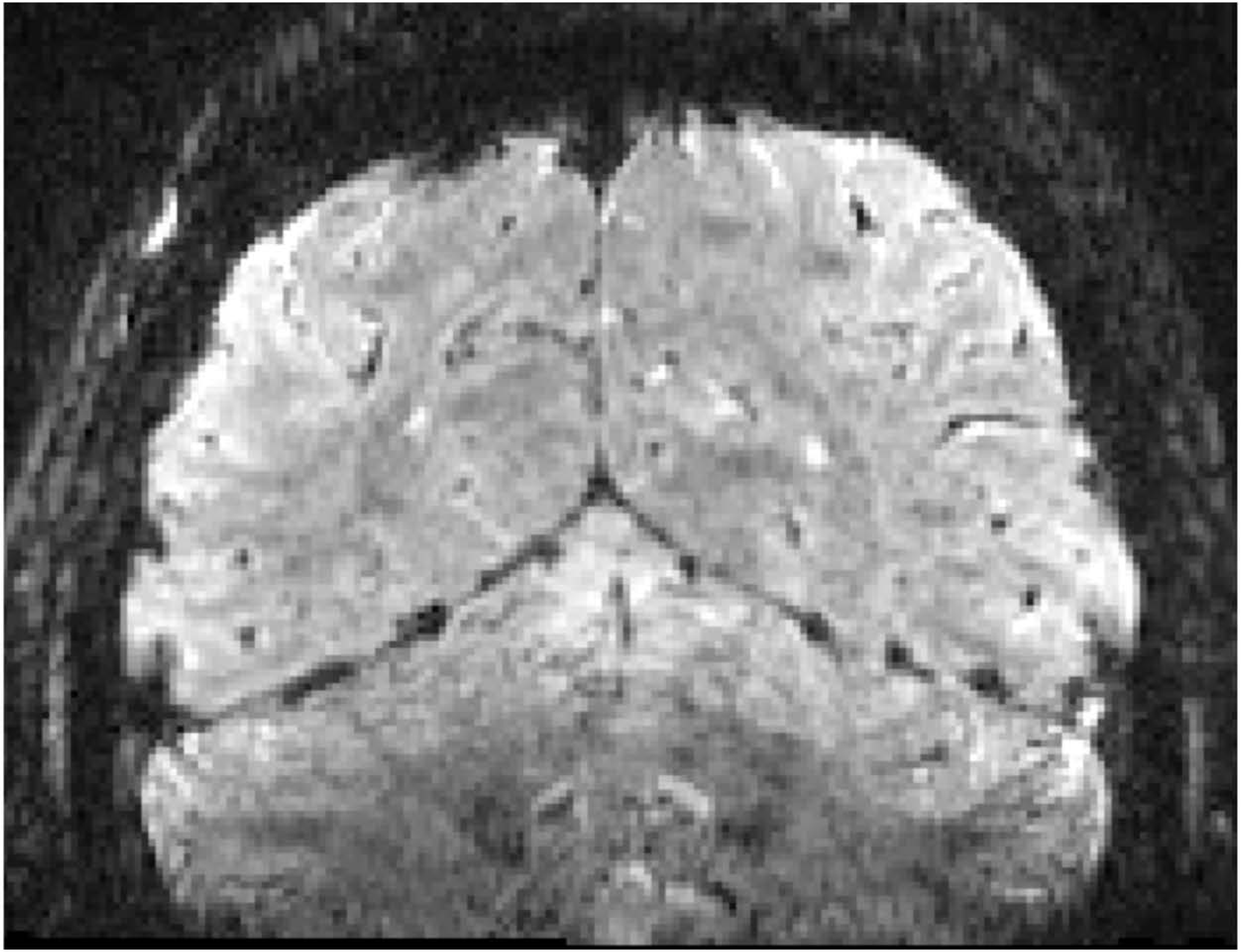

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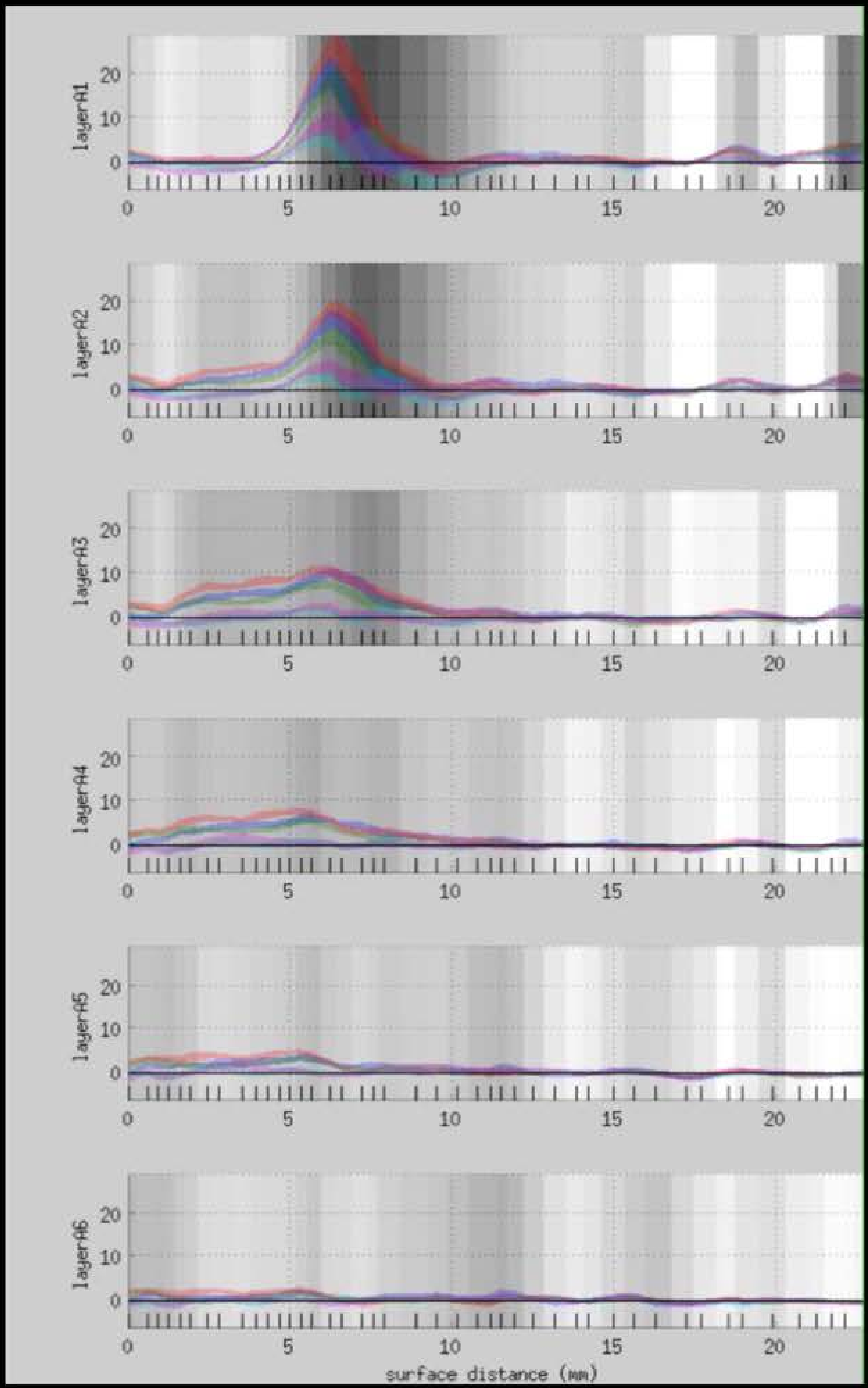
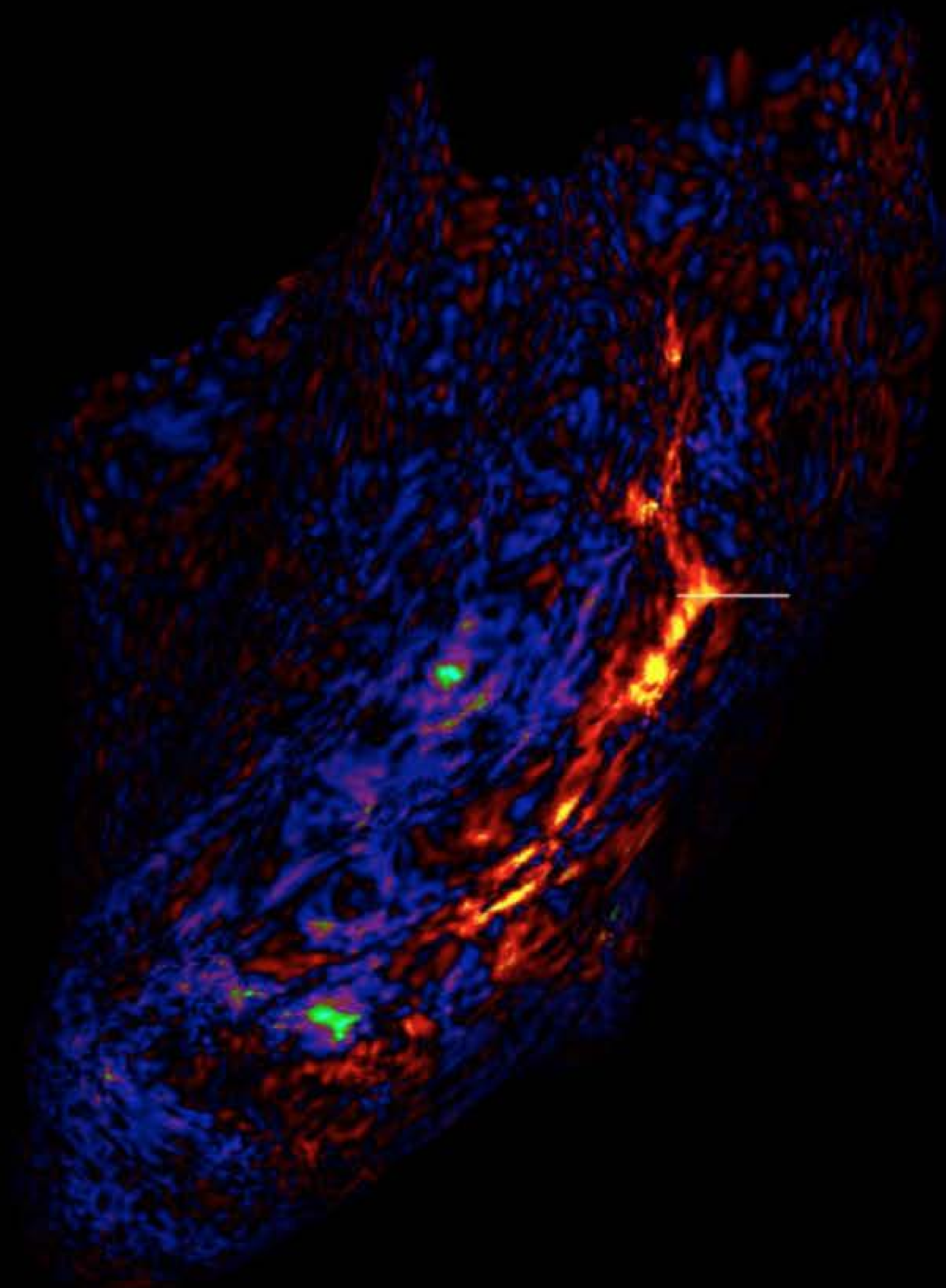


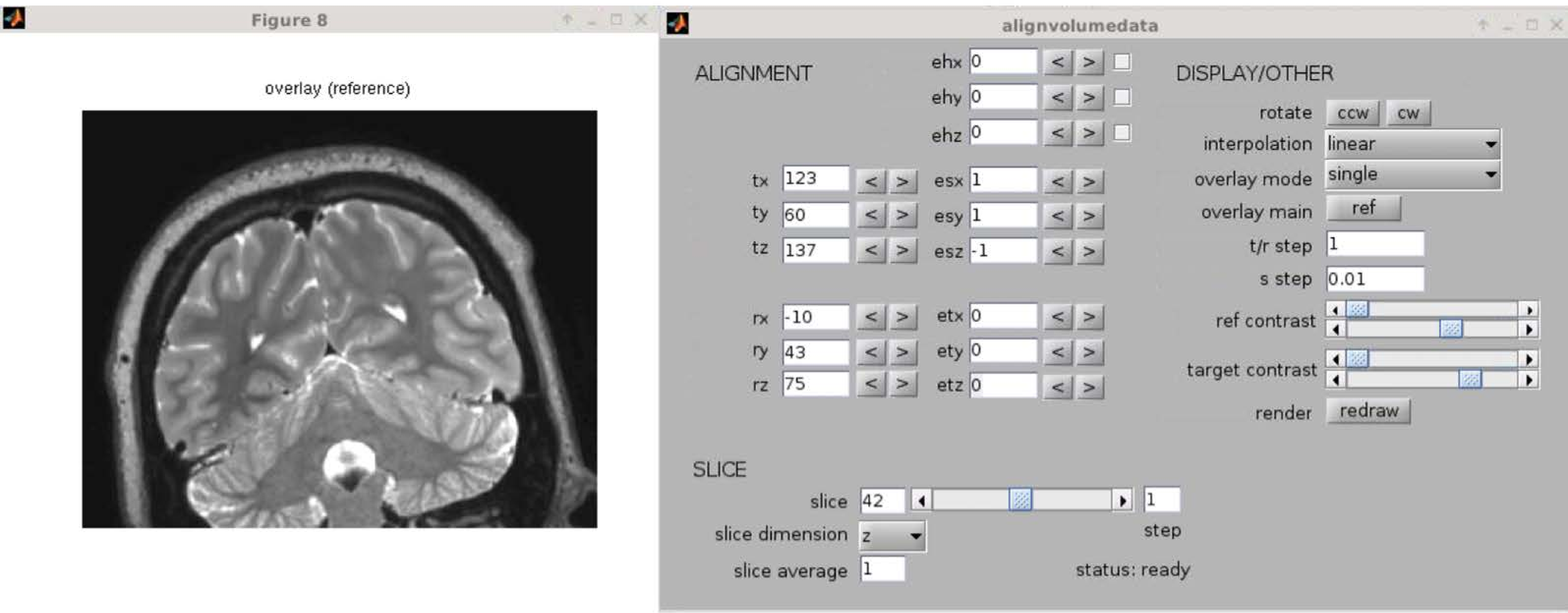
# Volume co-registration (4/7)

http://github.com/kendrickkay/alignvolumedata/

- Flexible inputs (any two volumes)
- Manual adjustment or automatic optimization
- Can use spatial mask
- Rigid-body or affine transformation

# Volume co-registration (4/7)

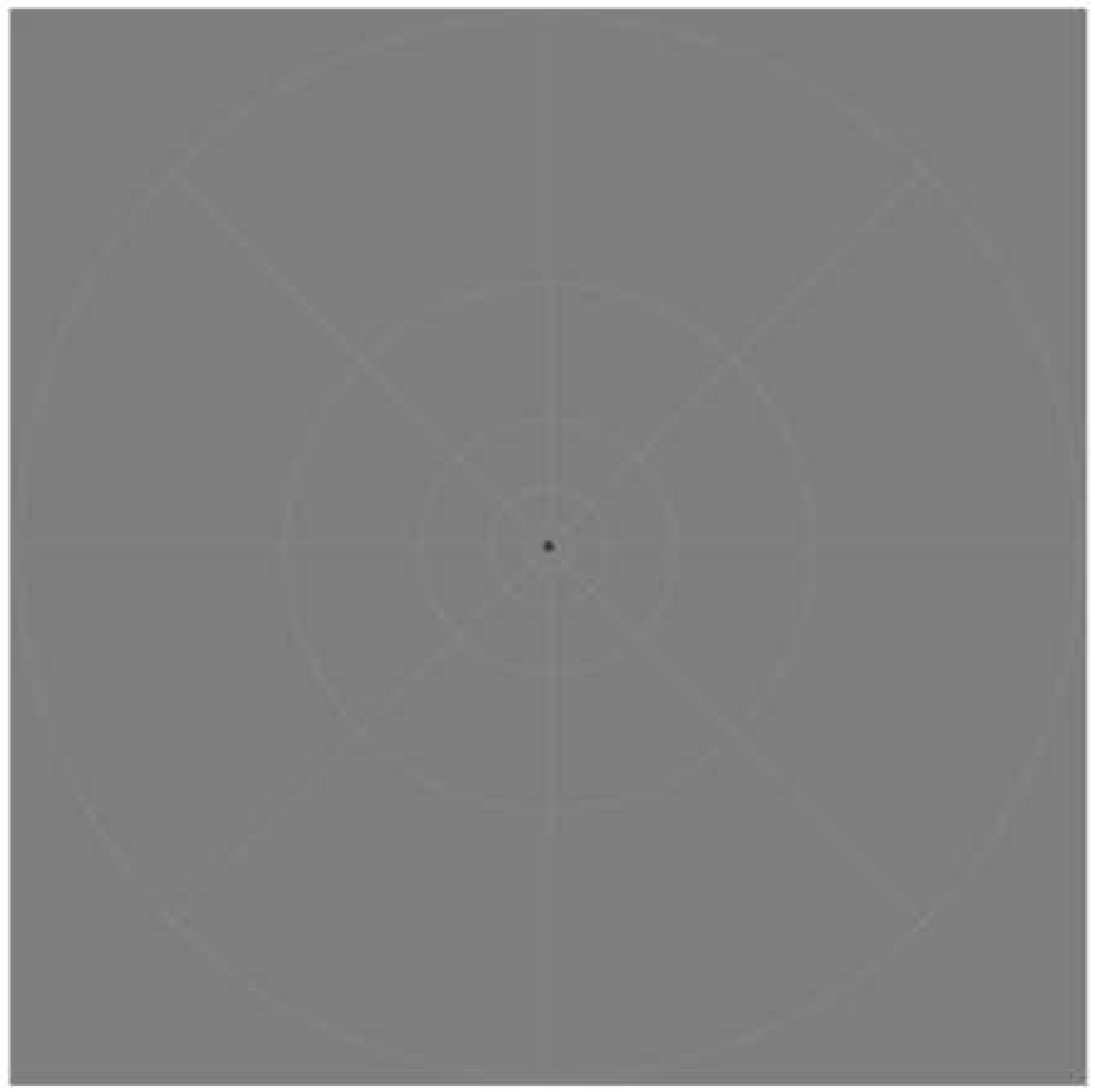
http://github.com/kendrickkay/alignvolumedata/

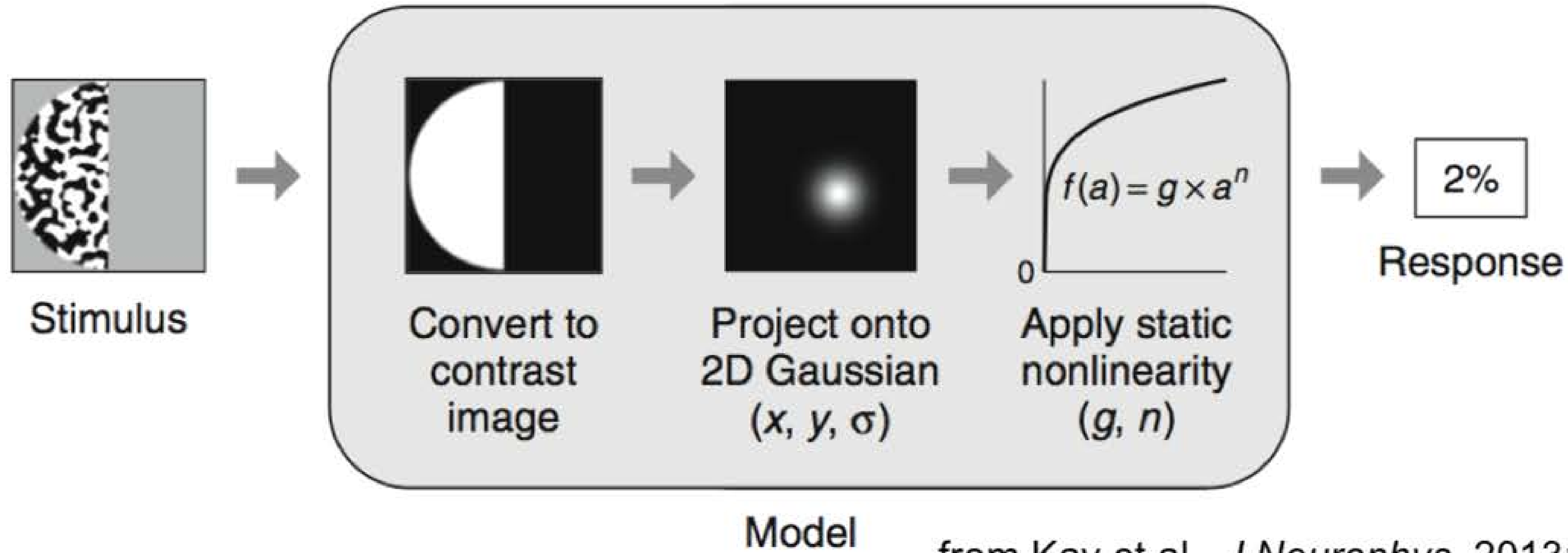


# analyzePRF (5/7)

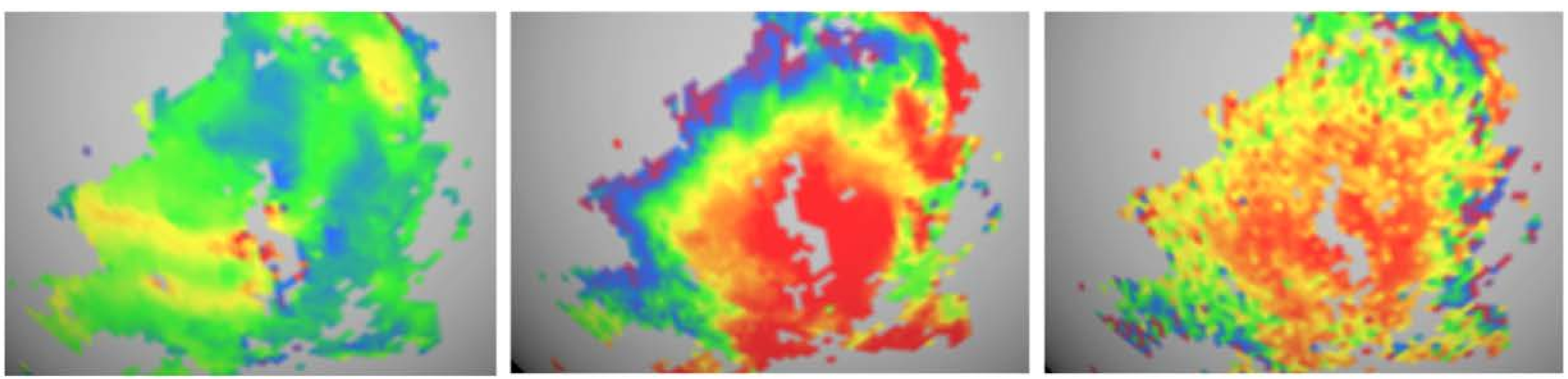
http://kendrickkay.net/analyzePRF/

- Fit a parametric model that characterizes stimulus-response mapping






from Kay et al., *J Neurophys*, 2013;
also see Dumoulin & Wandell 2008



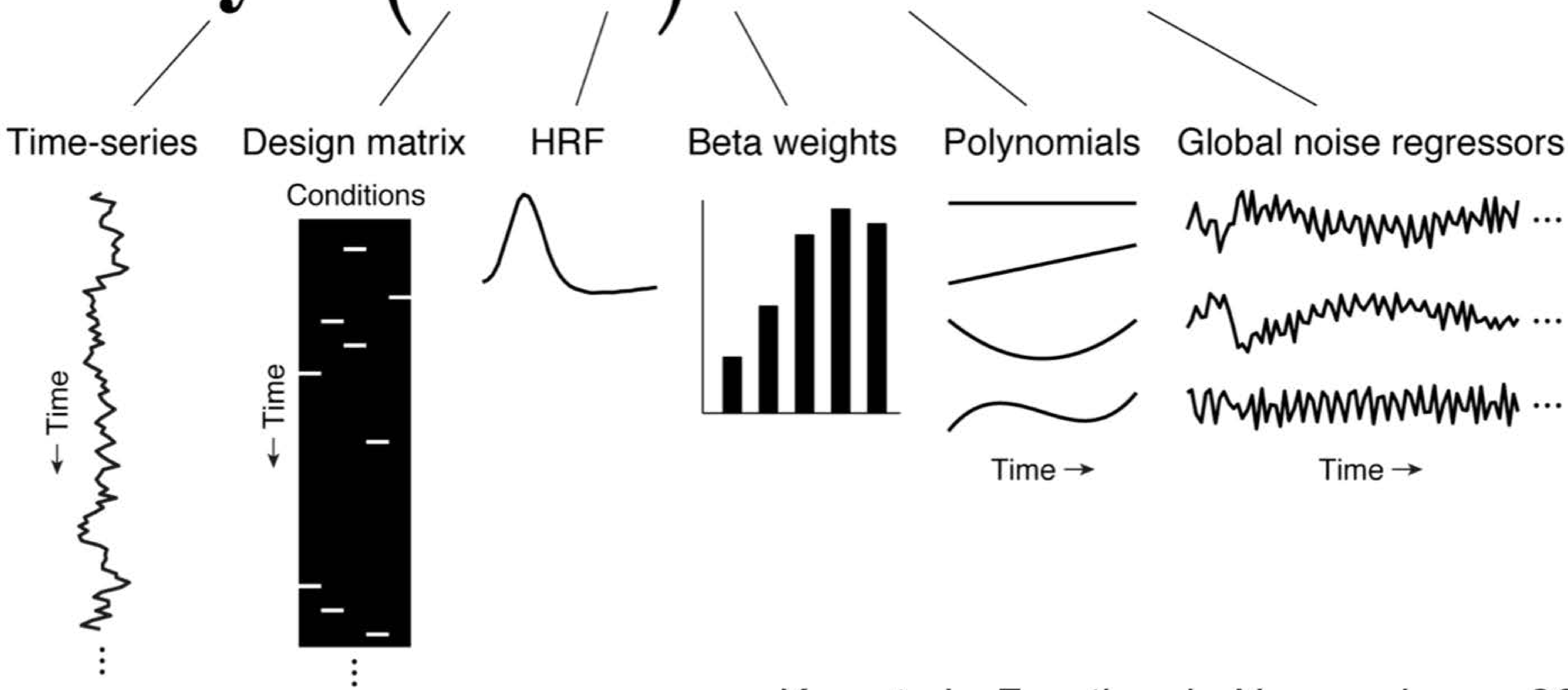
Angle Eccentricity RF size

# GLMdenoise (6/7)

http://kendrickkay.net/GLMdenoise/

- Fit a GLM that derives noise regressors and produces denoised beta weights

$$\mathbf{y} = \left(\mathbf{X} * \mathbf{k}\right)\mathbf{h} + \mathbf{P}\mathbf{u} + \mathbf{G}\mathbf{v} + \mathbf{n}$$




Kay et al., *Frontiers in Neuroscience*, 2013

# GLMdenoise (6/7)

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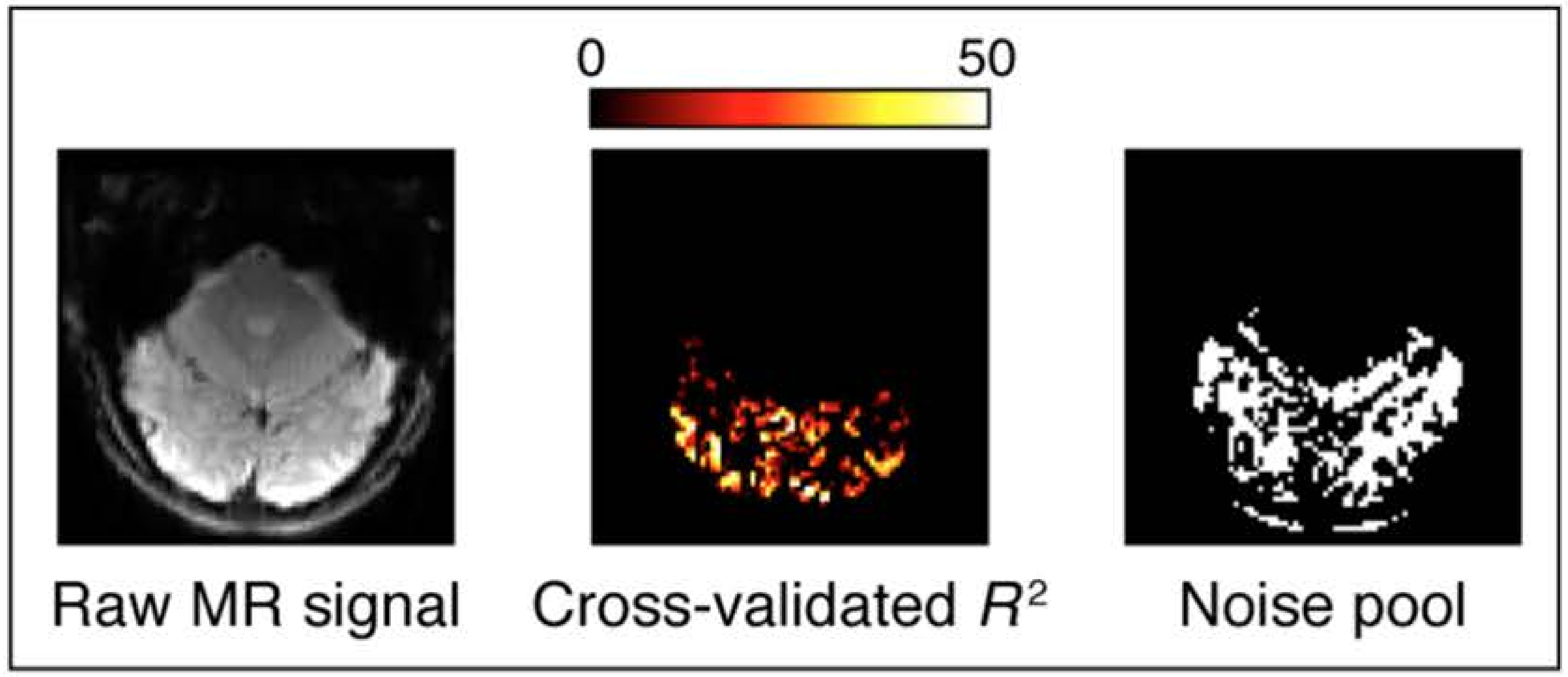
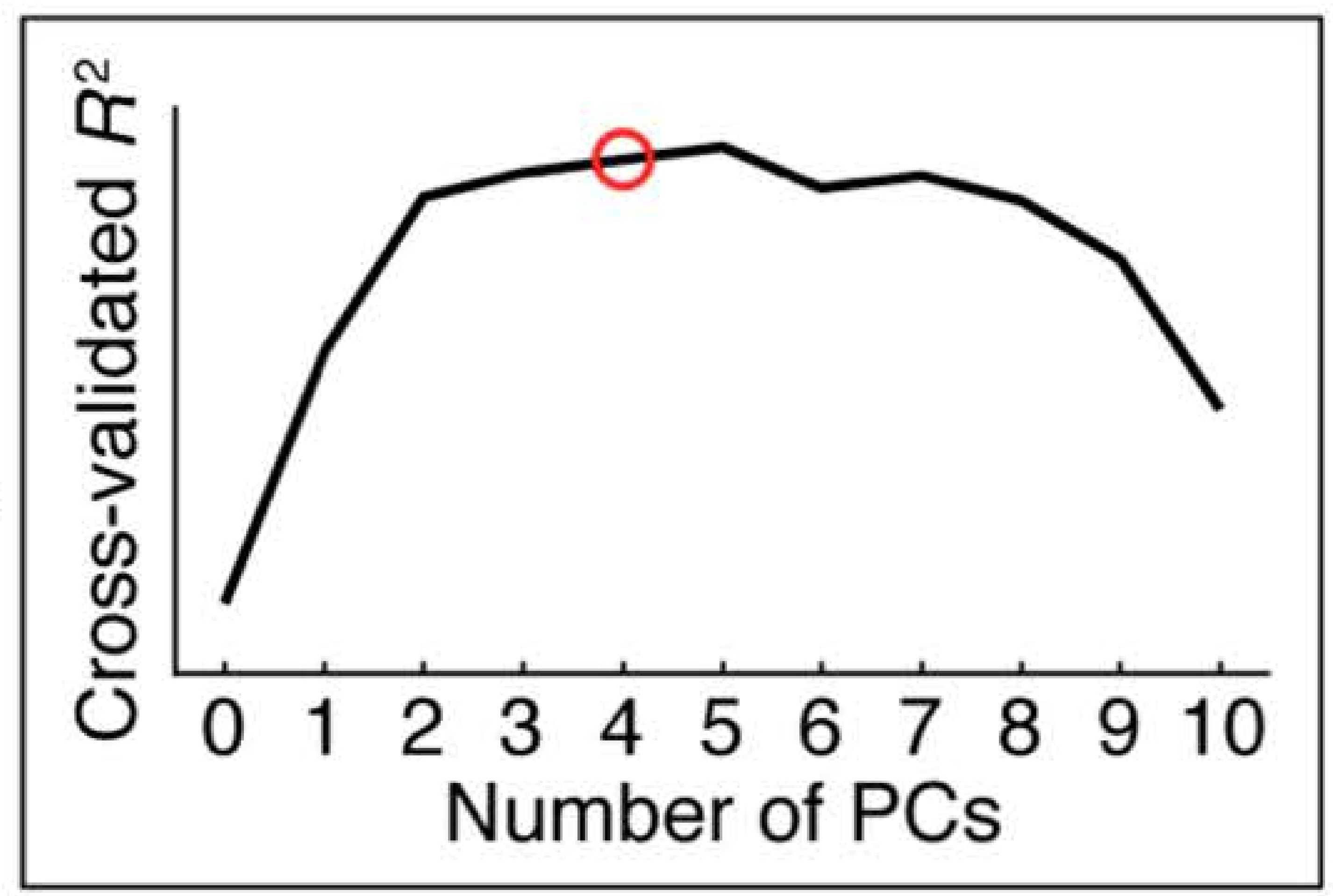



1. Perform initial model fit
2. Determine noise pool (cross-validated $R^2 < 0\%$)
3. Perform PCA on noise pool
4. Add PCs into the model, one at a time
5. Select number of PCs using cross-validation →
6. Fit final model to the full dataset

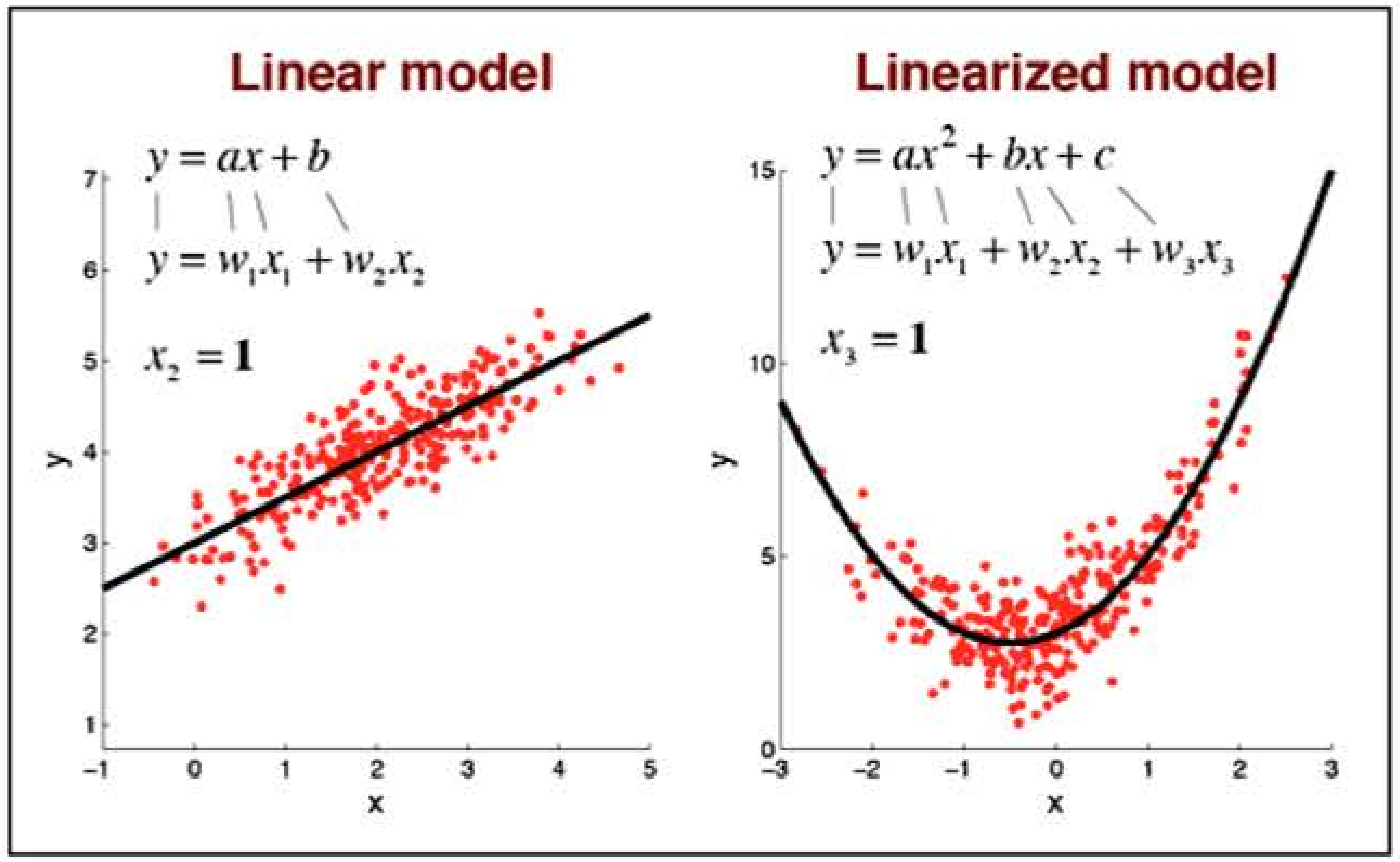


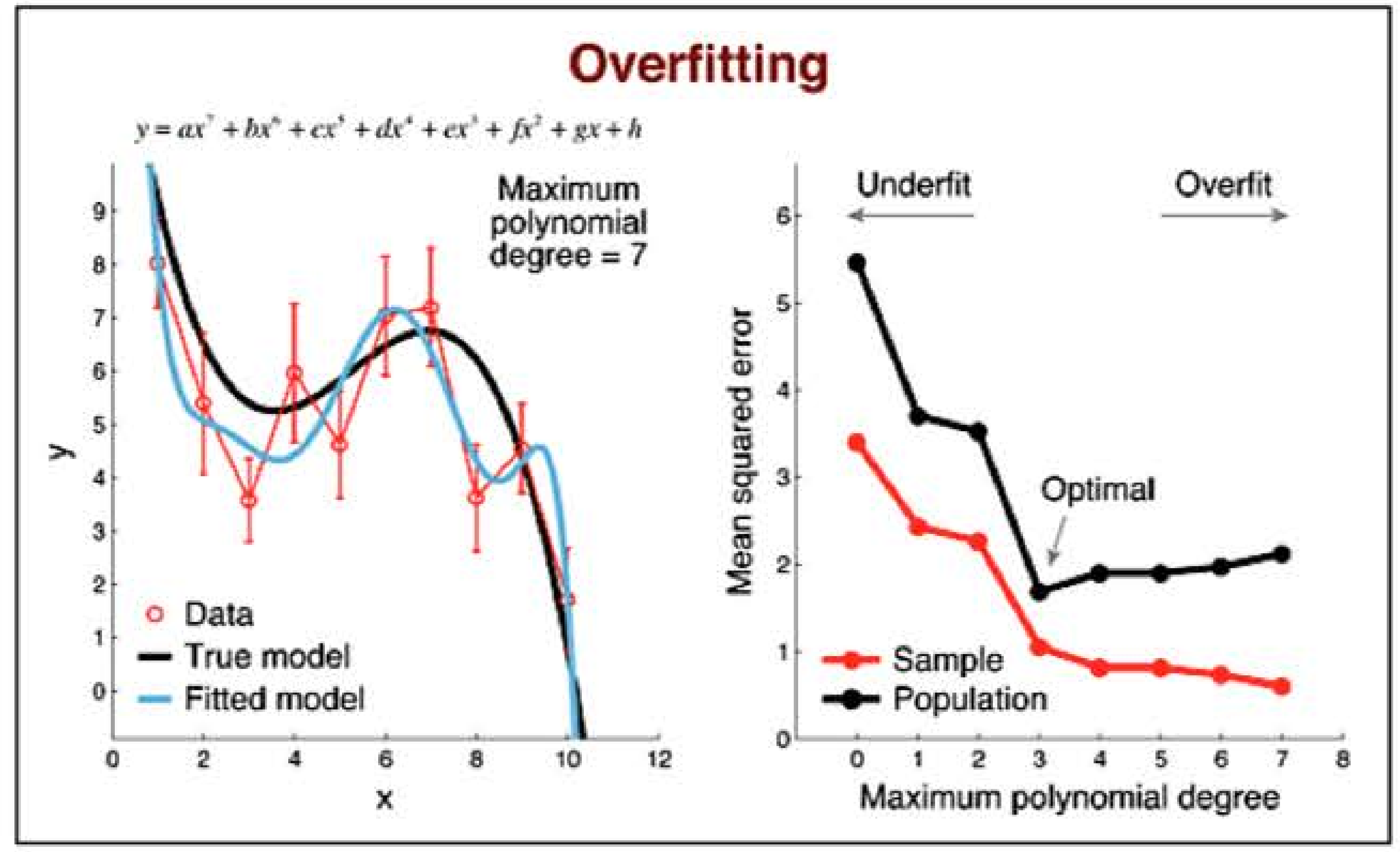

Kay et al., *Frontiers in Neuroscience*, 2013

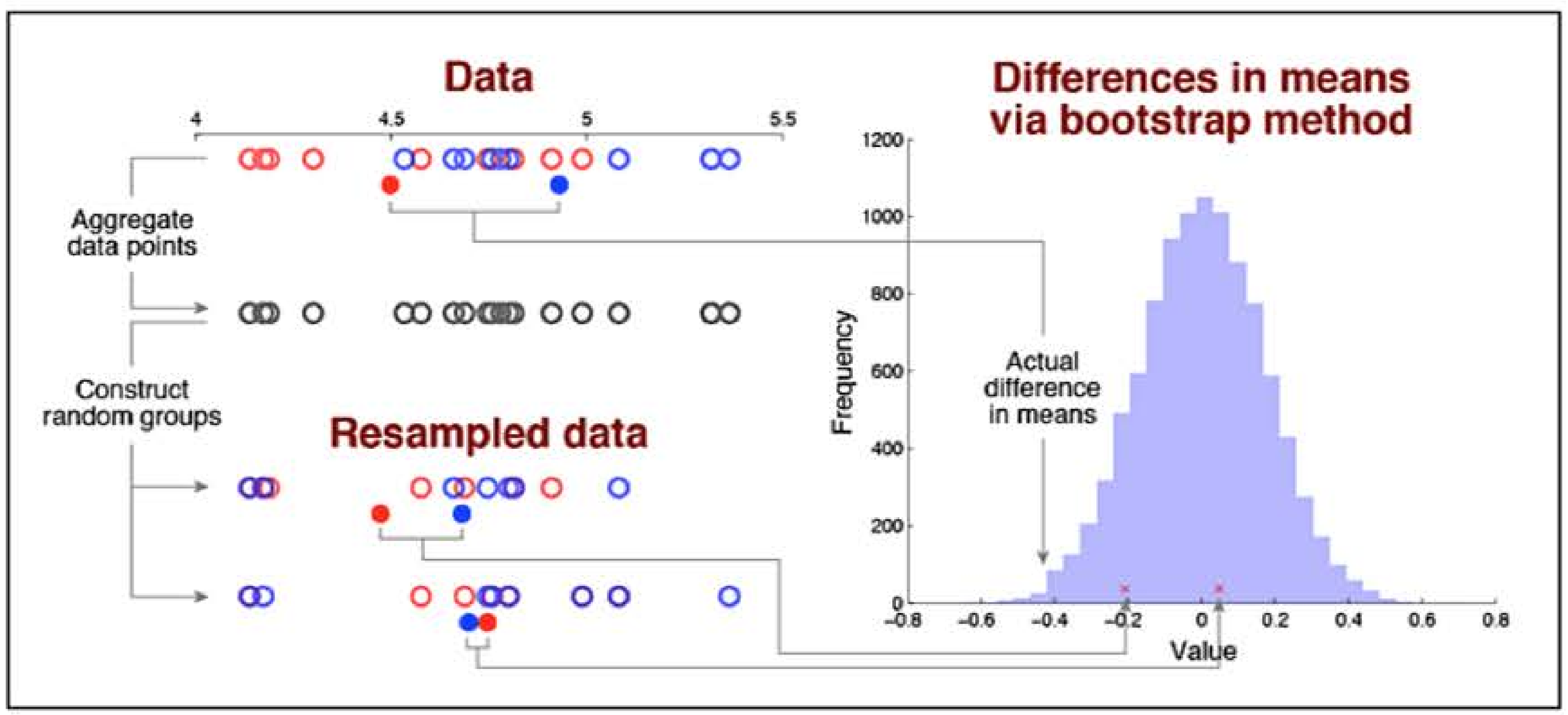
# Statistics, model fitting (7/7)

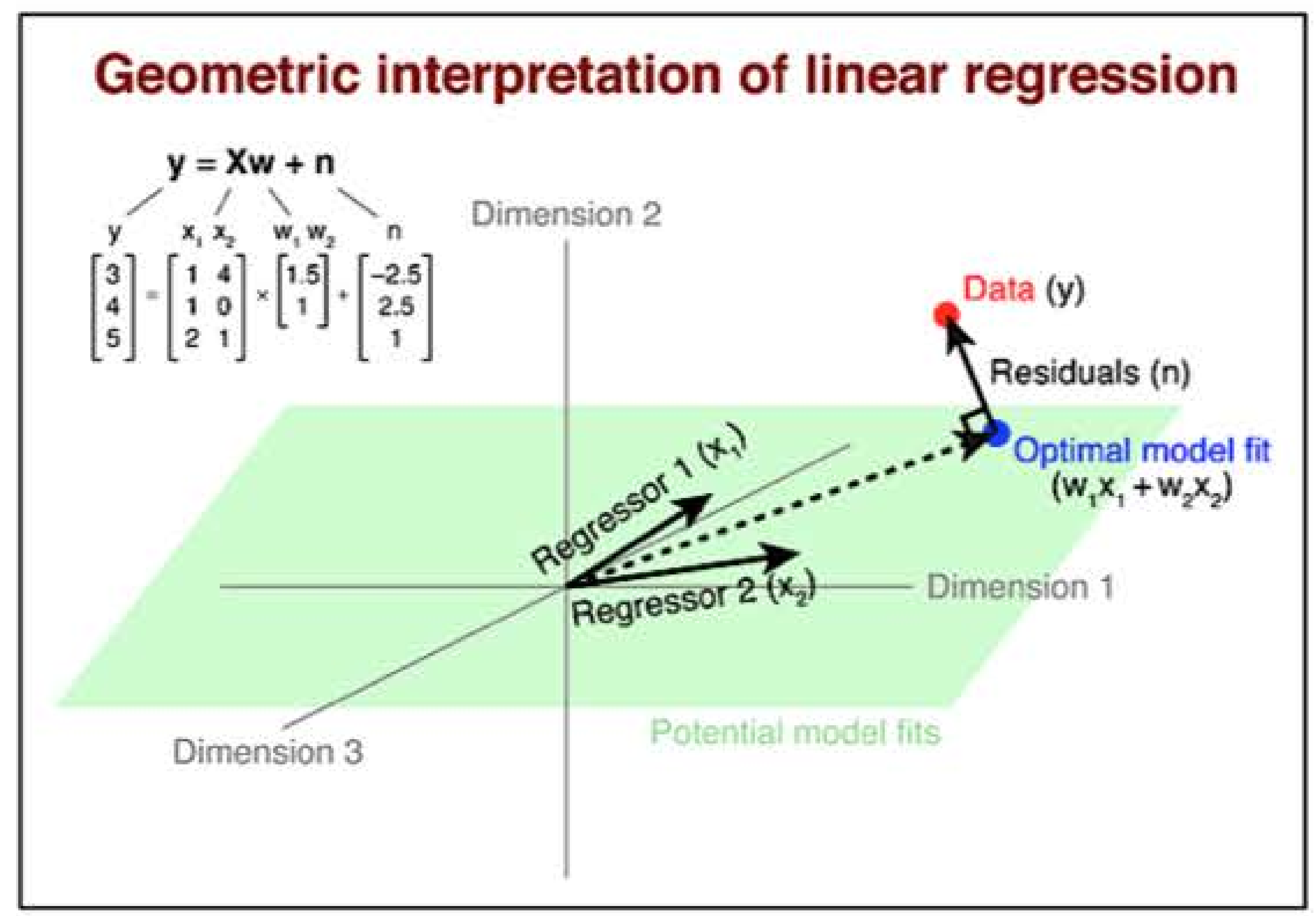
- Why statistical simulations?
  - They help teach concepts
  - They help check code correctness

# Statistics, model fitting (7/7)



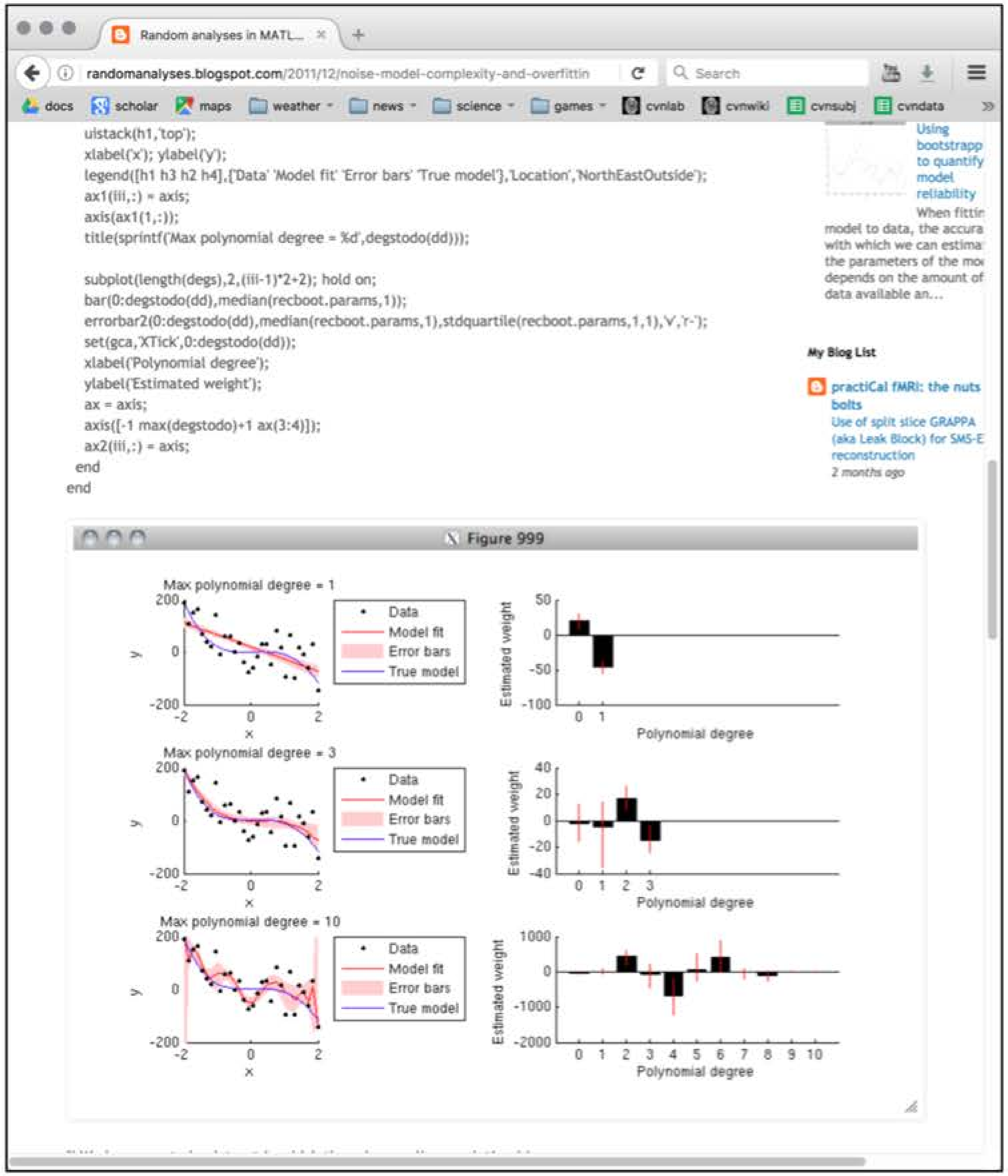




Materials at http://kendrickkay.net/psych5007/

Kendrick Kay, CMRR, University of Minnesota

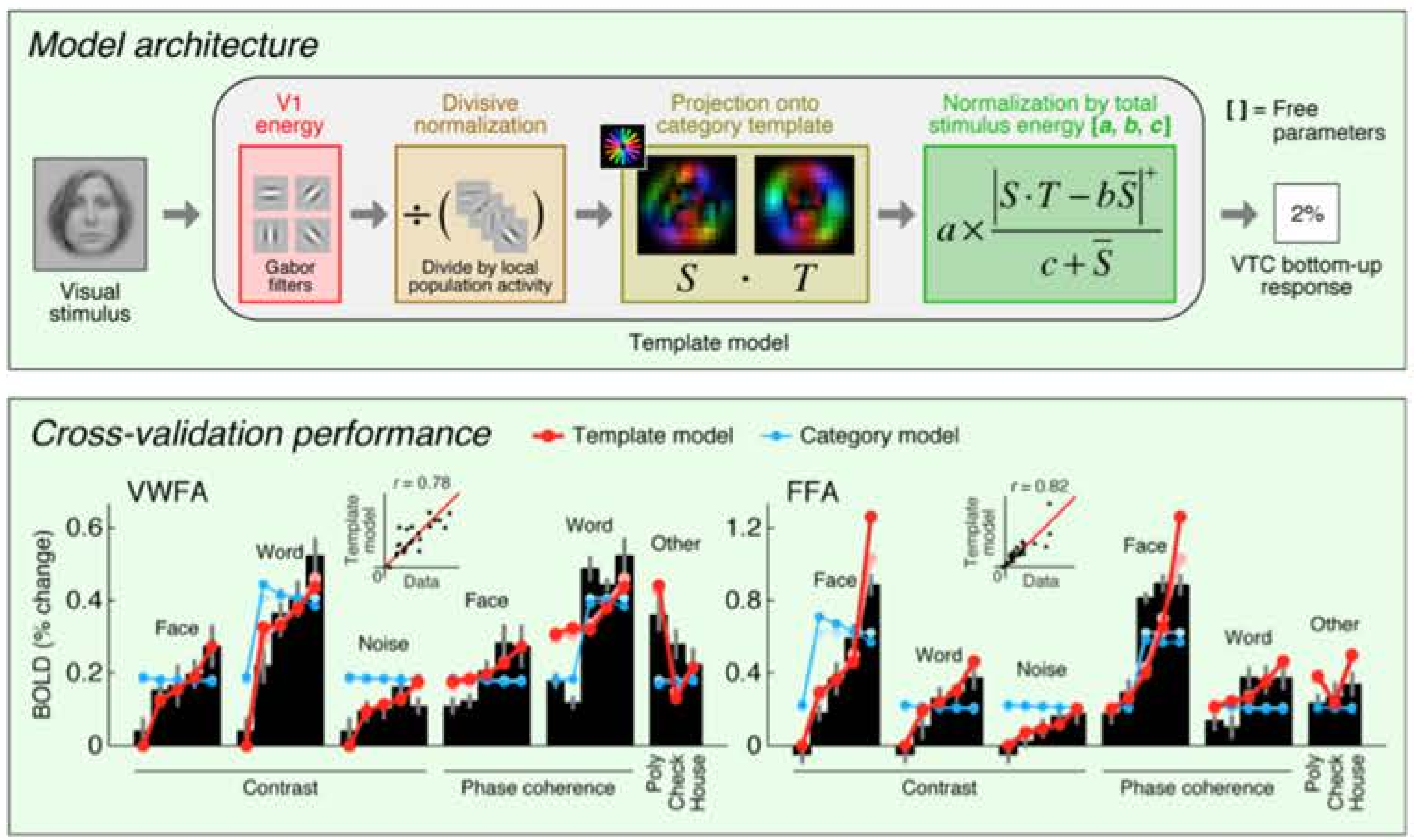
# Statistics, model fitting (7/7)

http://randomanalyses.blogspot.com

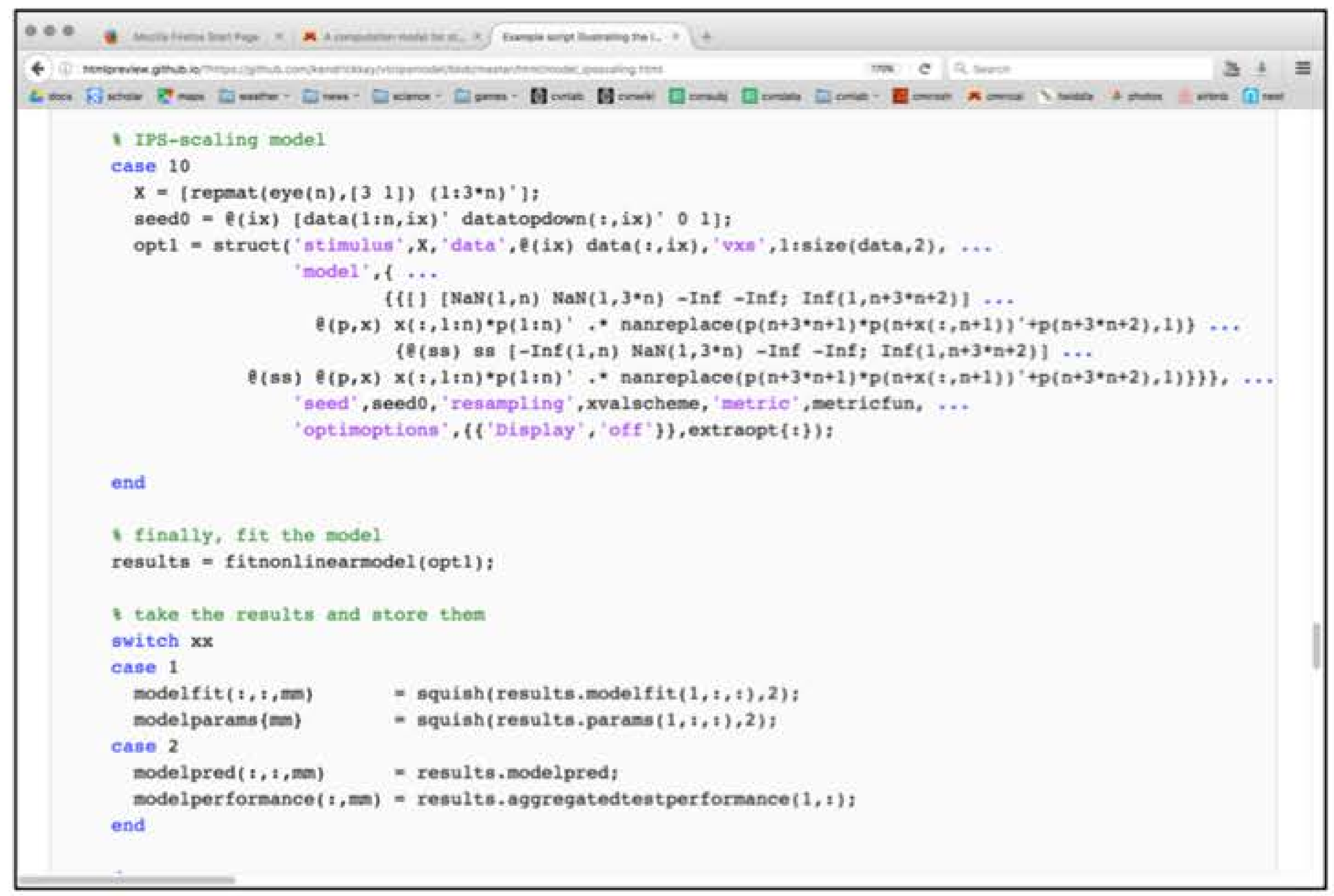


# Statistics, model fitting (7/7)

Kay & Yeatman, *eLife*, 2017




http://cvnlab.net/vtcipsmodel/



# Summary

1. Automated surface visualizations
2. Brain art
3. High-res fMRI pre-processing
4. Volume co-registration
5. analyzePRF
6. GLMdenoise
7. Statistics, model fitting

→ http://cvnlab.net

# Acknowledgments

- Keith Jamison (UMN)

- Eshed Margalit (Stanford)