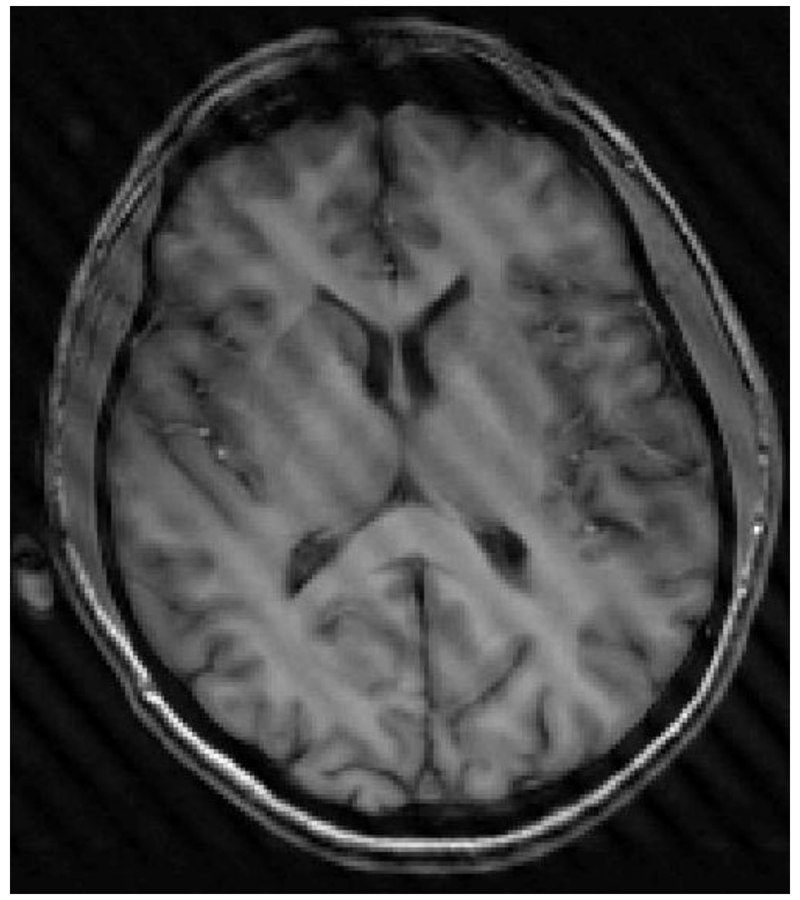
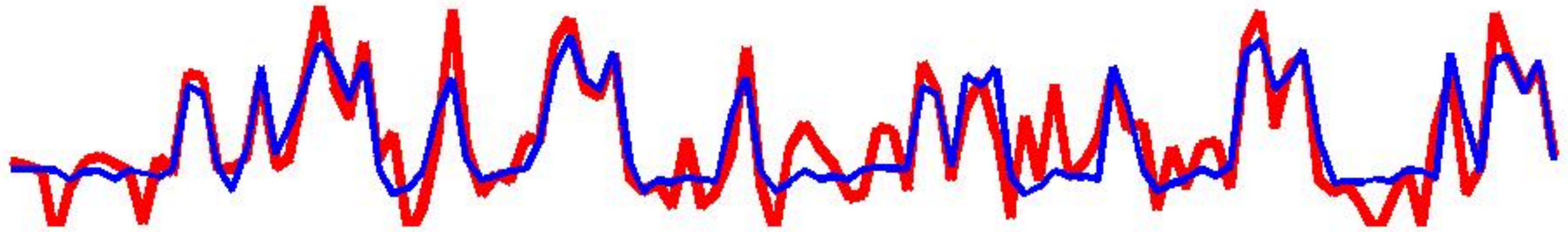
FMRI single subject analysis

- Overview
- fMRI experiment basics
- Preprocessing
  - motion correction
  - slice timing
  - temporal filtering
  - smoothing





Generic study blueprint

1. Data acquisition

2. Data preprocessing

3. Single-subject analysis

This morning

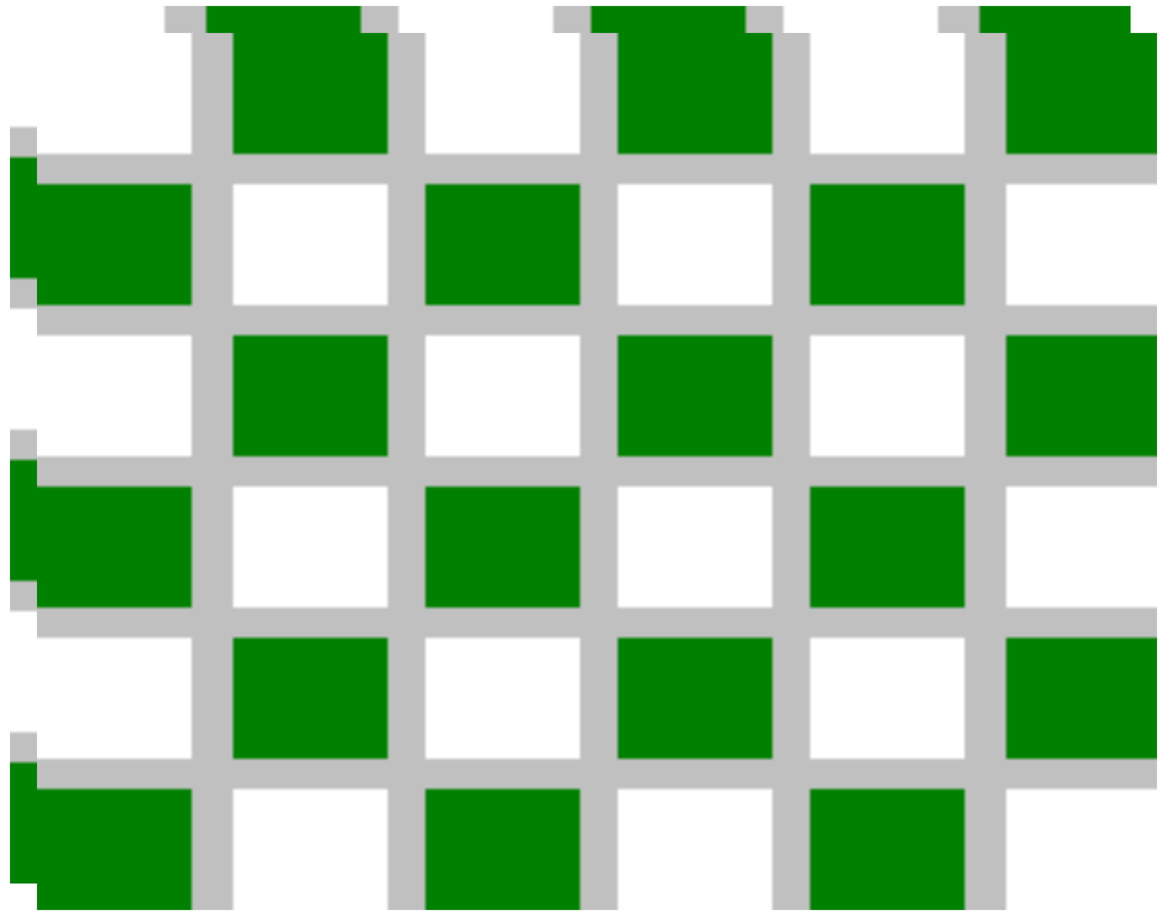
4. Group-level analysis

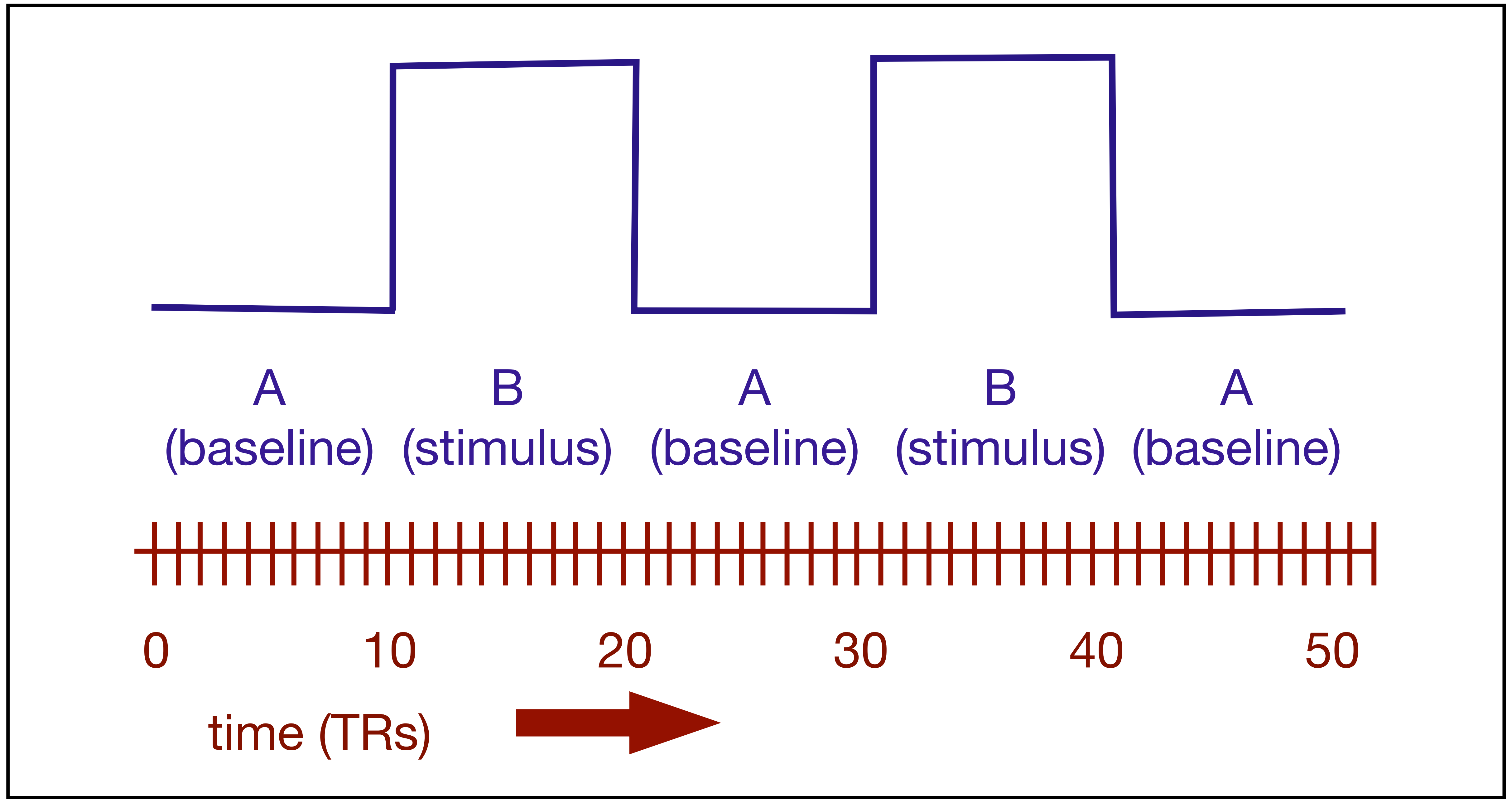
5. Statistical inference

This afternoon

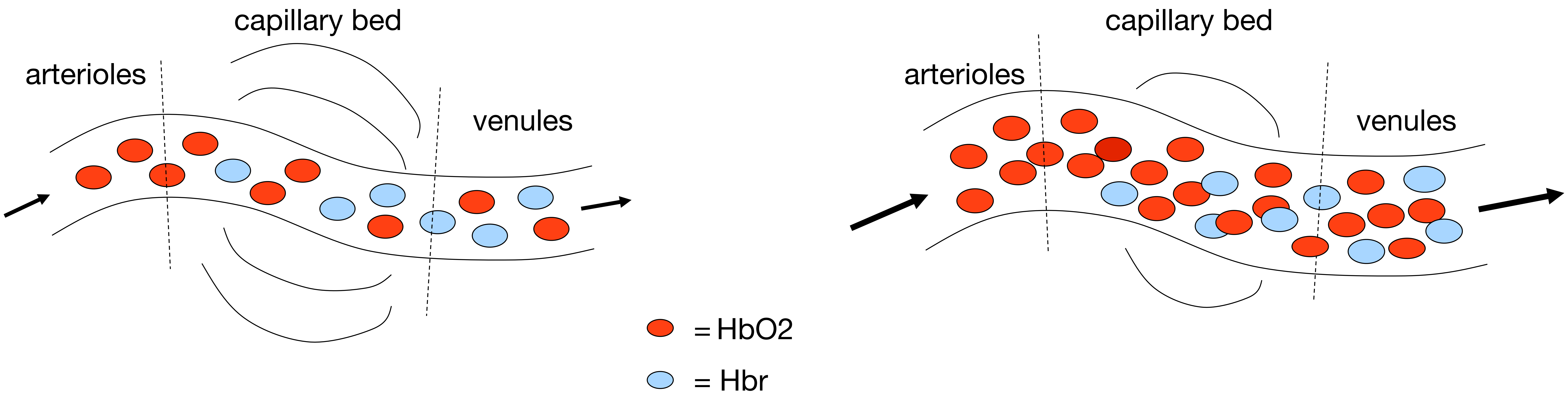
Functional MRI experiments

- Measuring change > need baseline condition
- Simple example design
  - Include a stimulus and baseline
  - Constant stimulus "intensity"
  - Keep block length the same
  - Many repetitions (ABABAB)





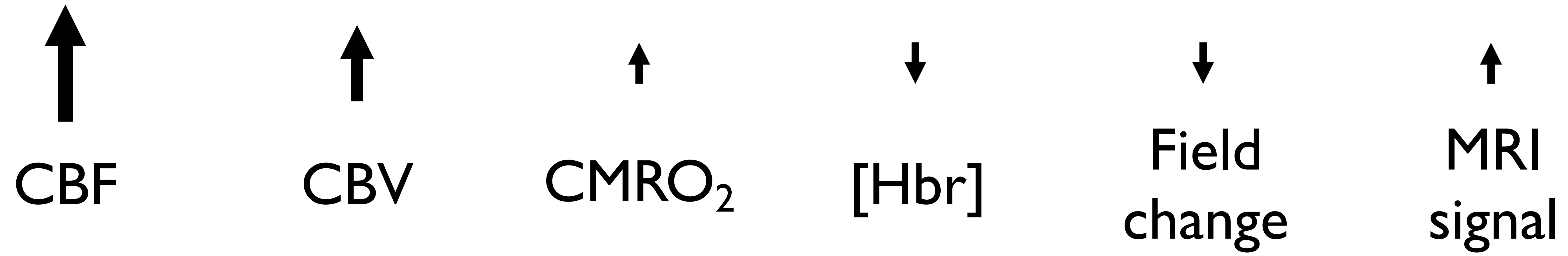
The Hemodynamic Response



Basal State

Activated State

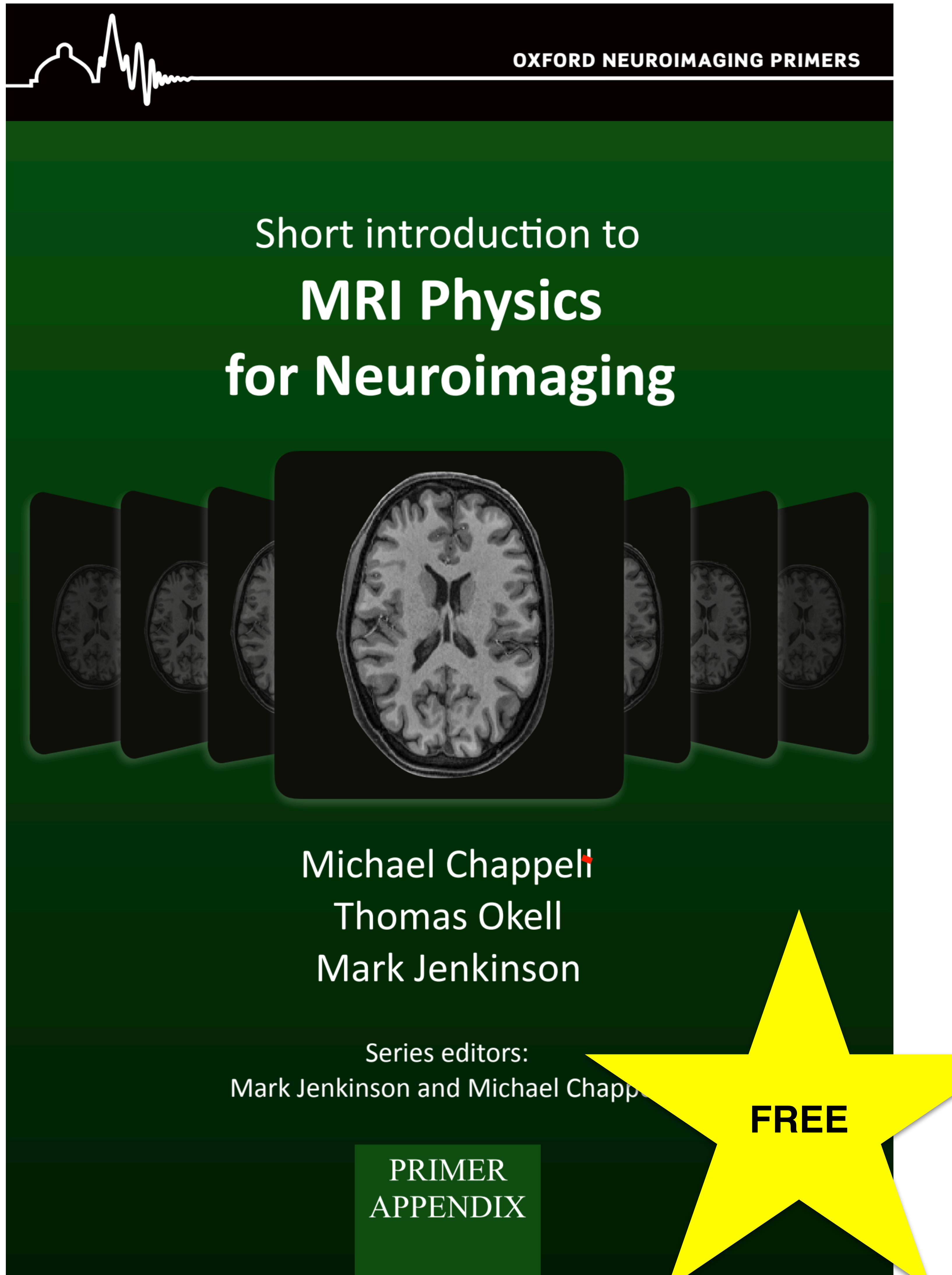
Activation leads to:

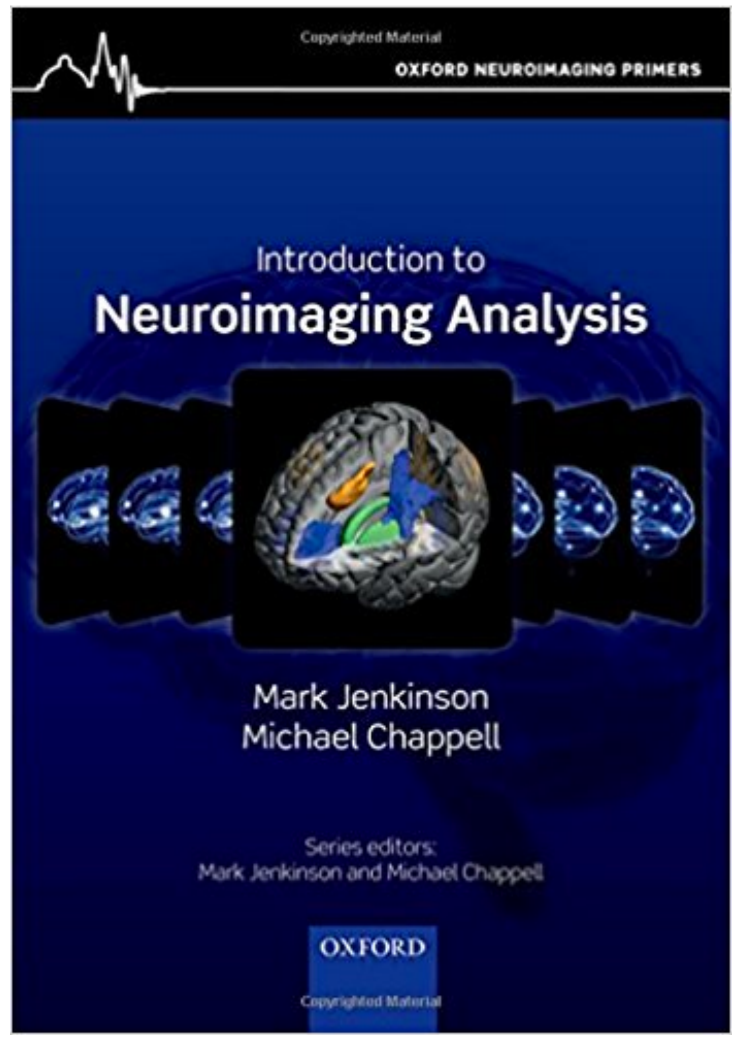


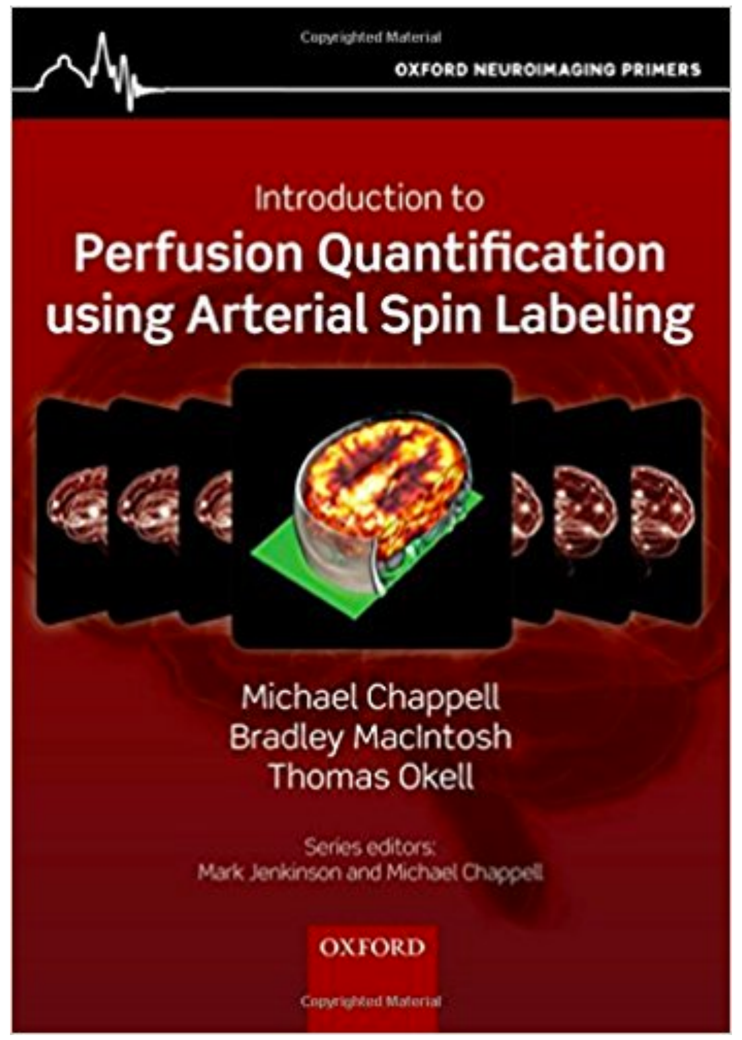
BOLD MRI = T_2^*-weighted

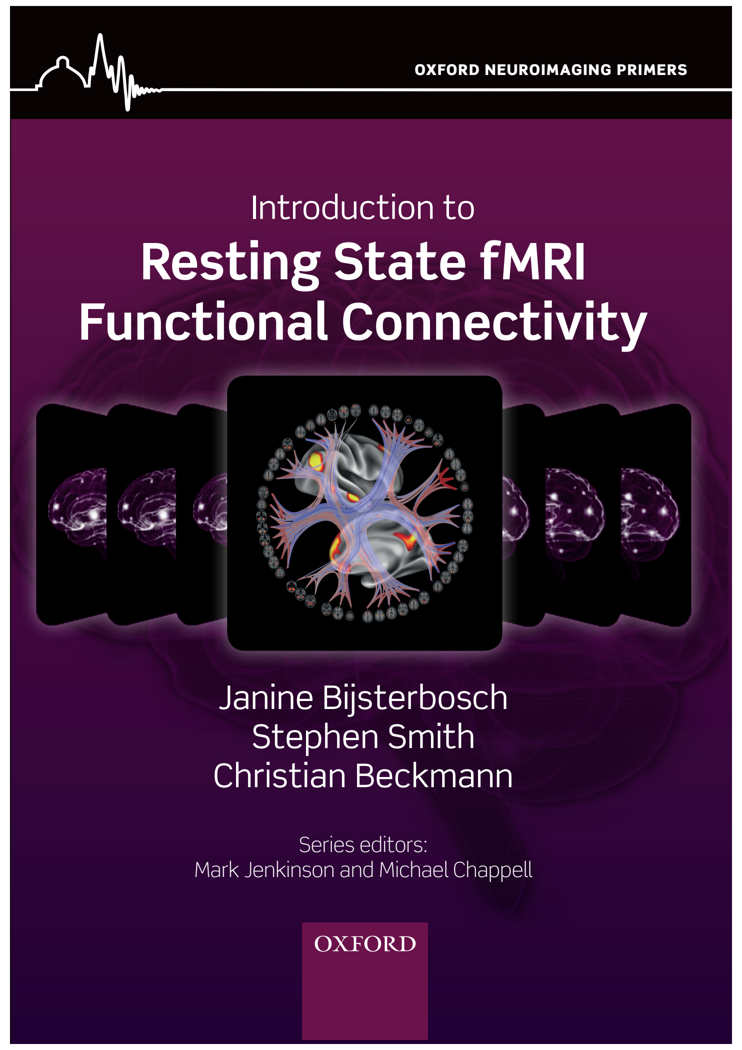
The free online appendix

- Part of a series of Oxford Neuroimaging Primers
- https://www.fmrib.ox.ac.uk/primers/appendices/mri_physics.pdf

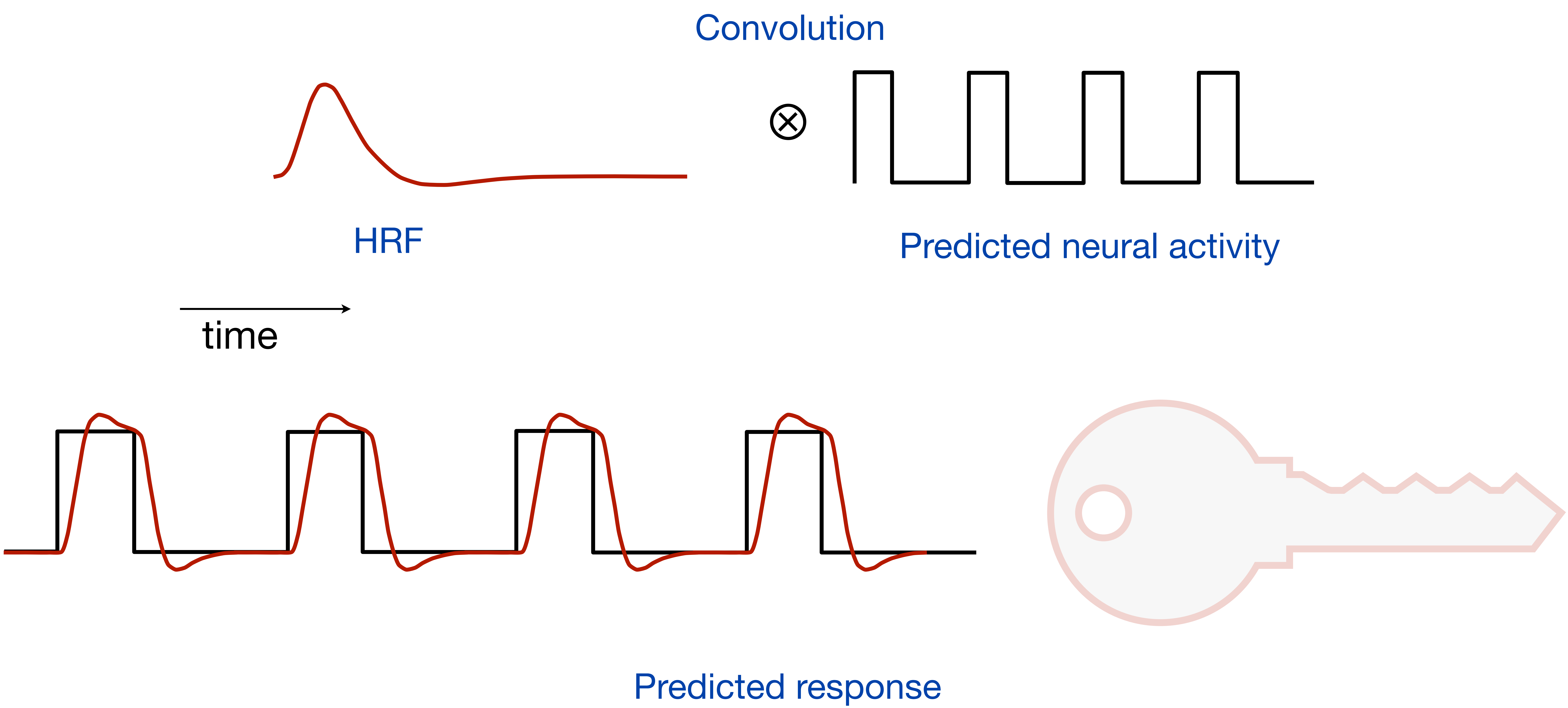






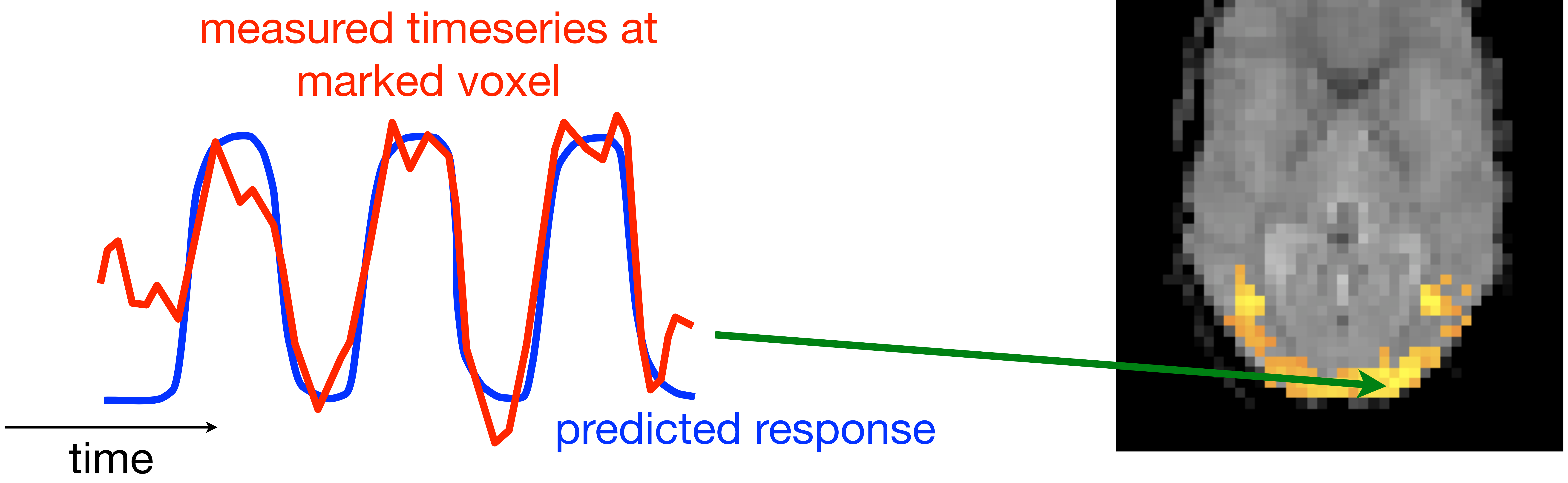


Model


Convolution
HRF
⊗
Predicted neural activity
time
Predicted response

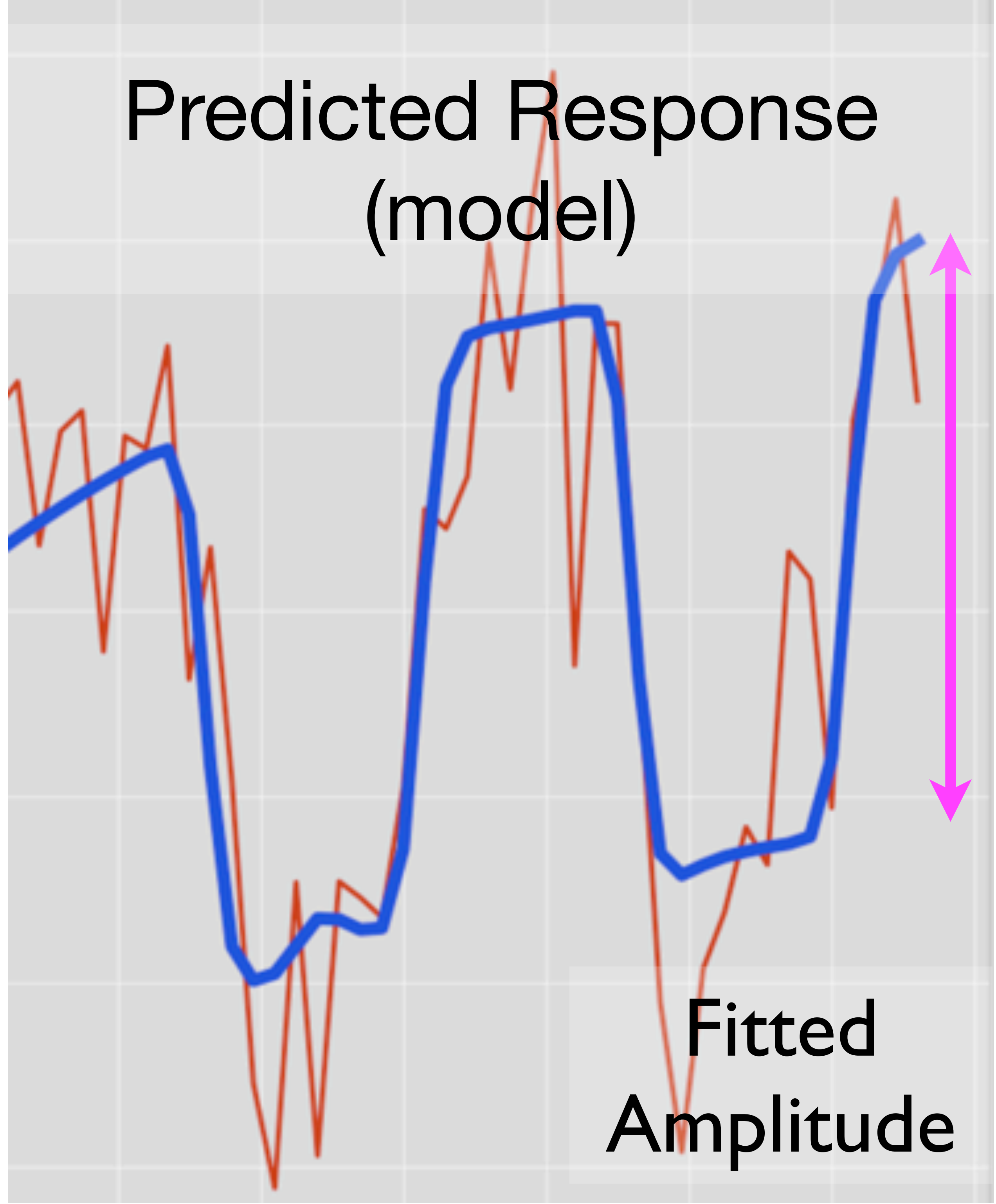
Fit model to data

- Look for voxels that have a BOLD timeseries similar to the model



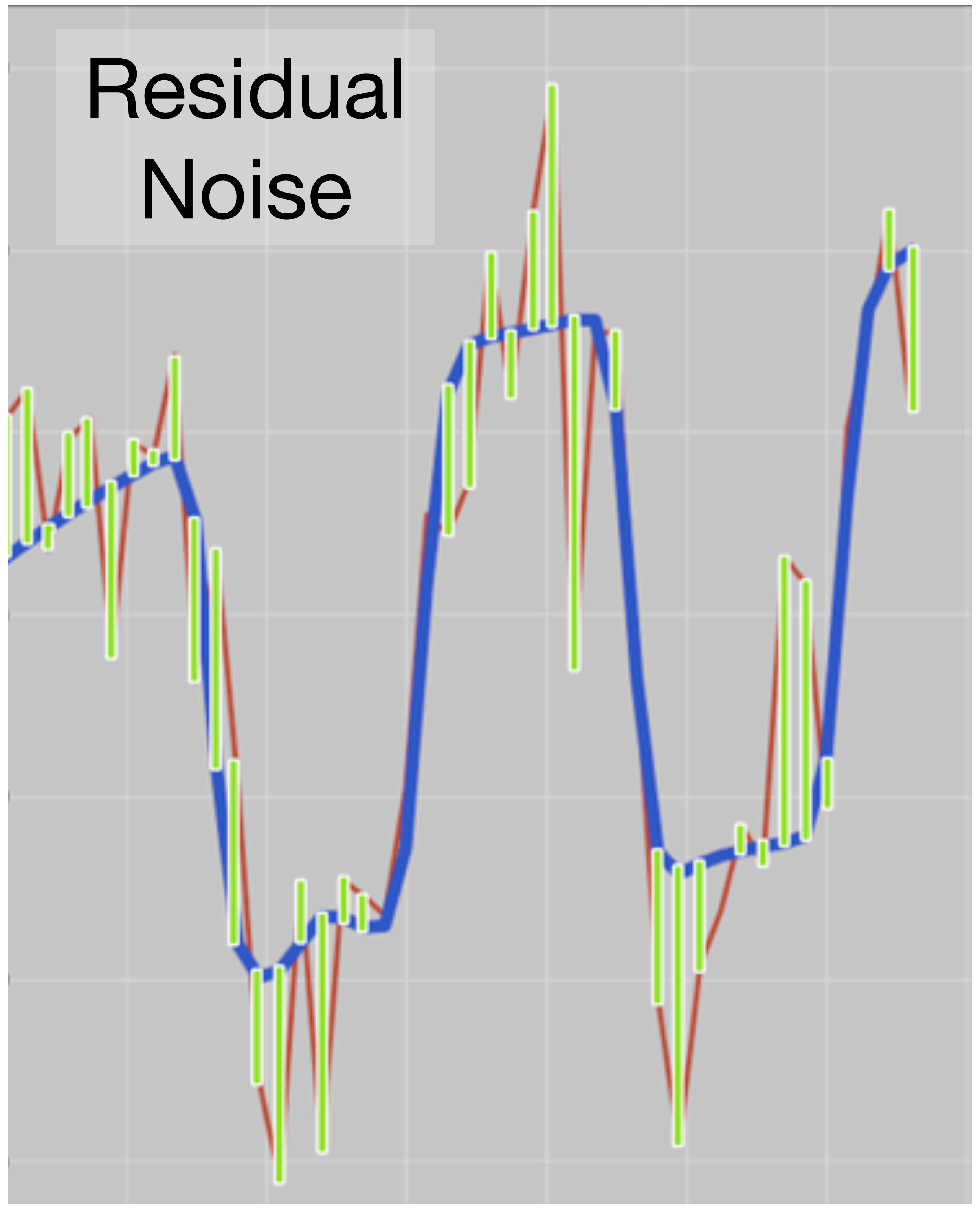
Standard GLM statistics

- Fit model to each voxel separately



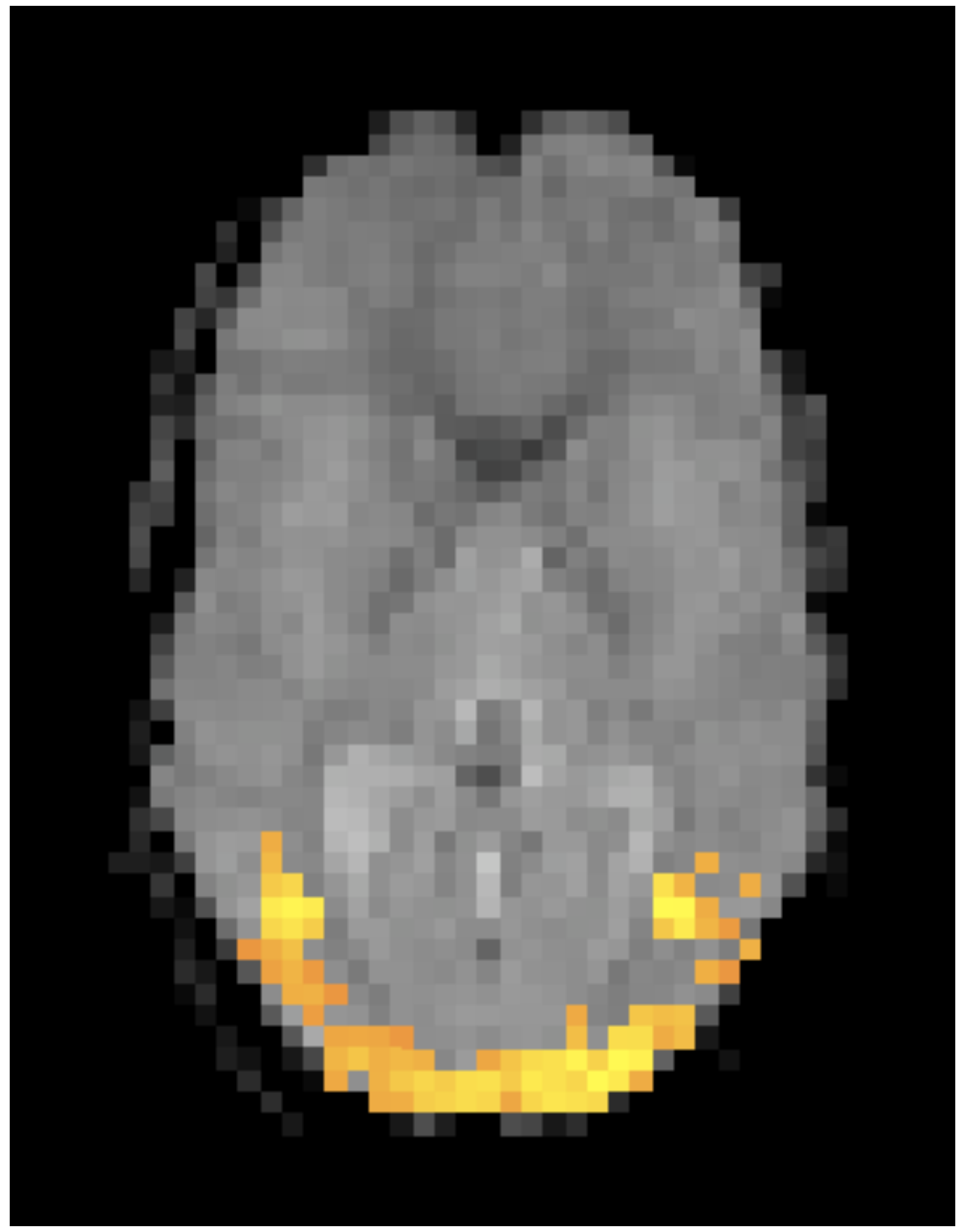
Standard GLM statistics

- Fit model to each voxel separately
- Measure residual noise variance



Standard GLM statistics

- Fit model to each voxel separately
- Measure residual noise variance
- Voxel t-statistic = model fit / noise amplitude
- Threshold t-statics and display map



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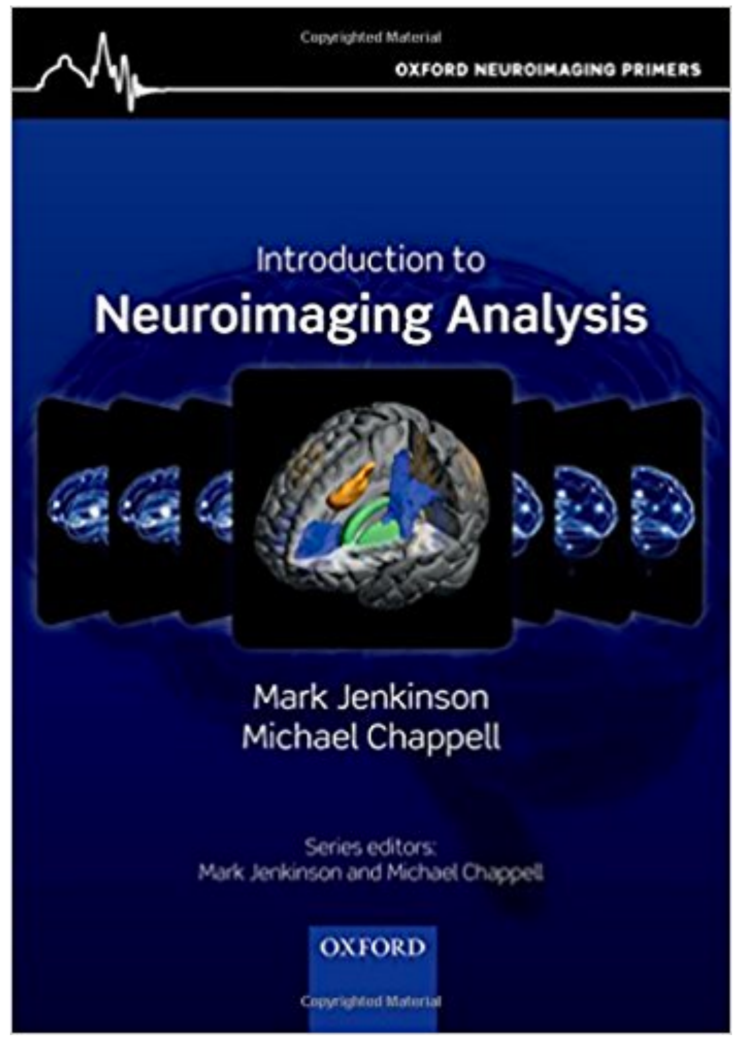

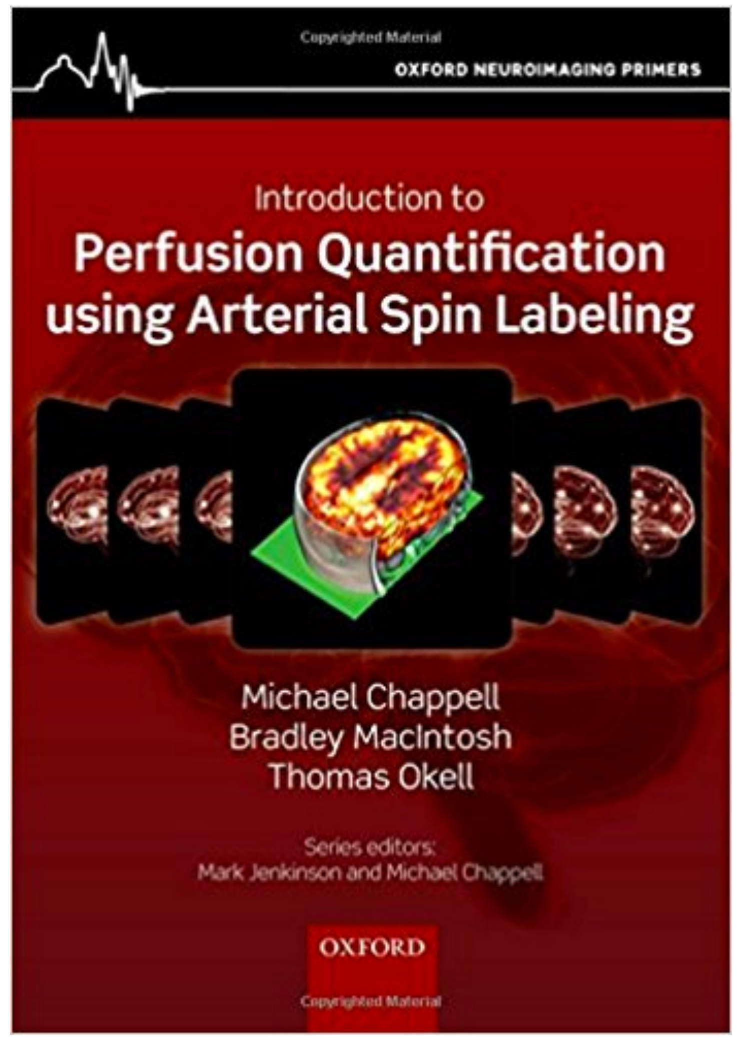

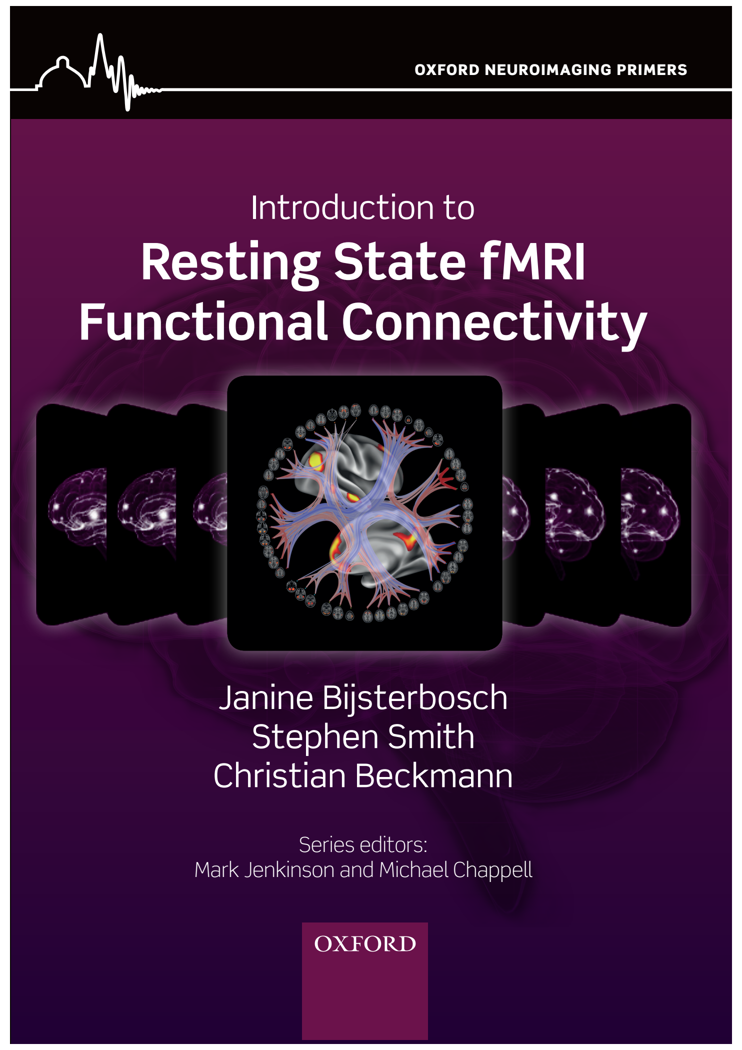

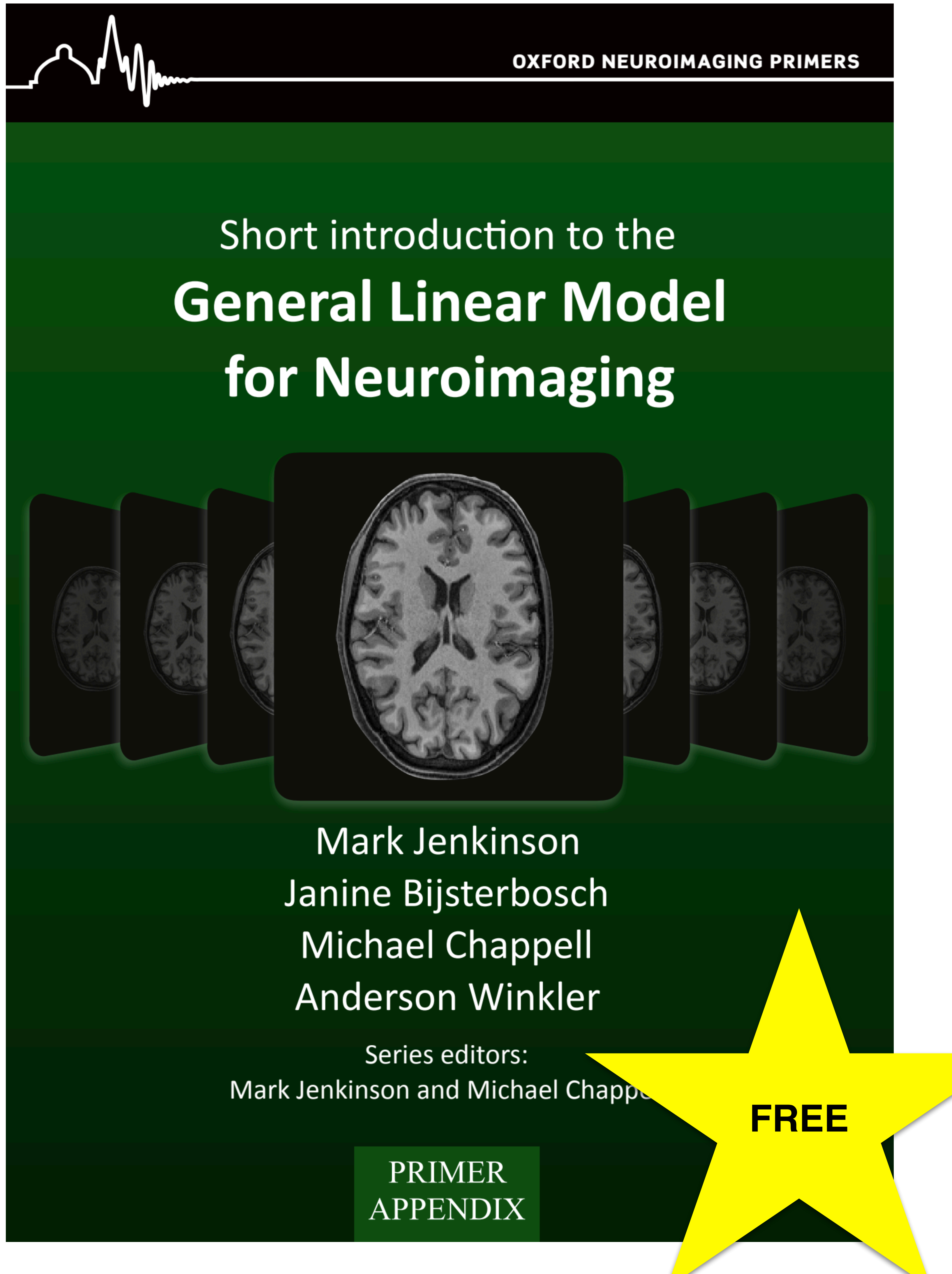

Standard GLM statistics

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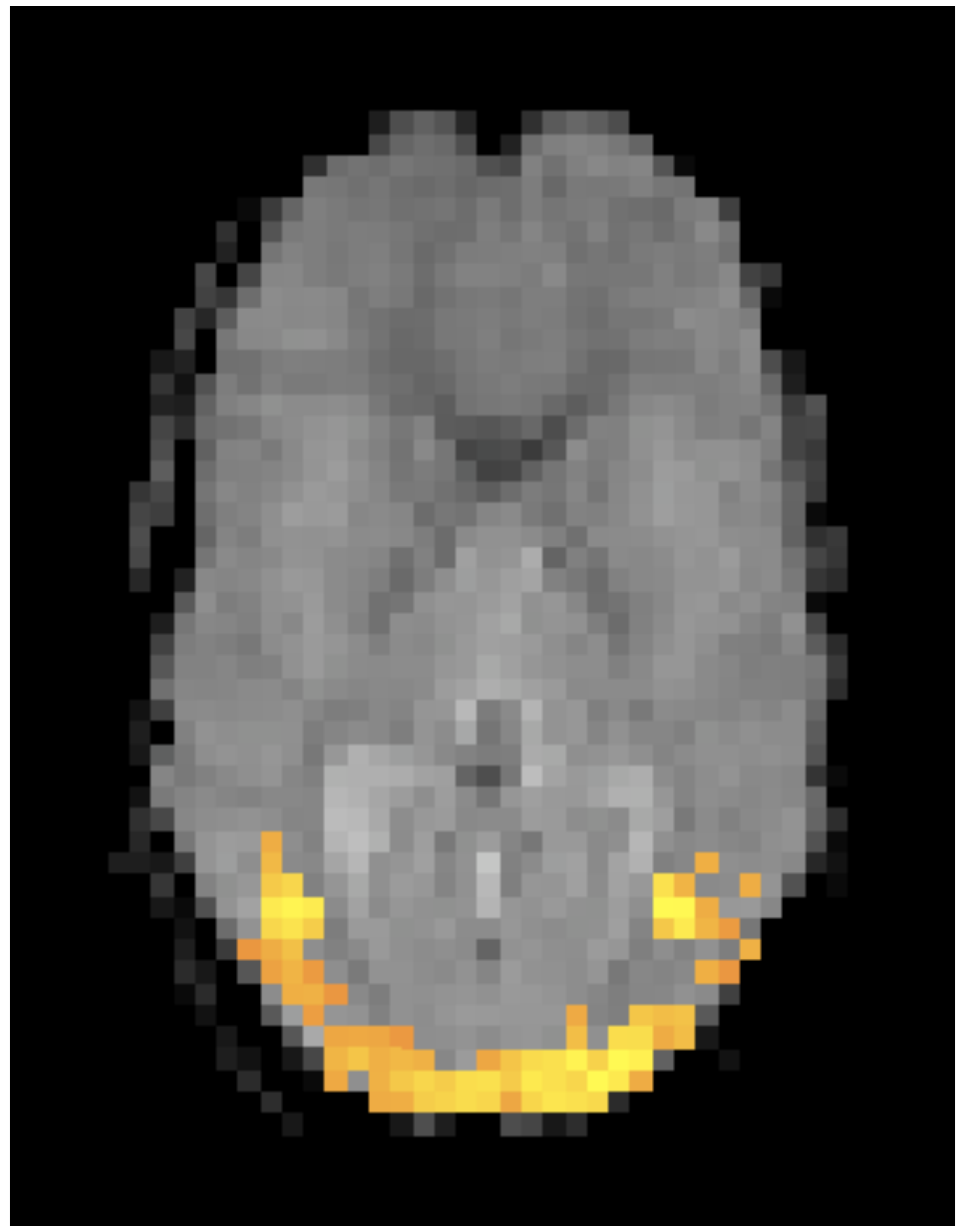


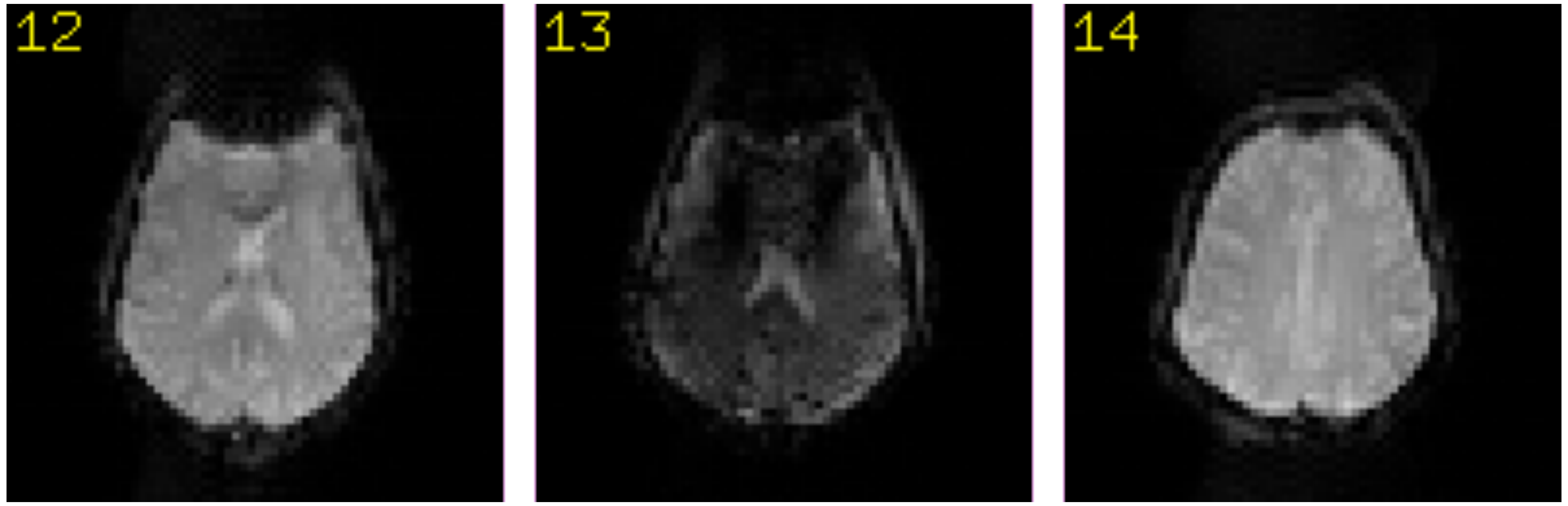
BUT artifacts can affect model fit and noise amplitude

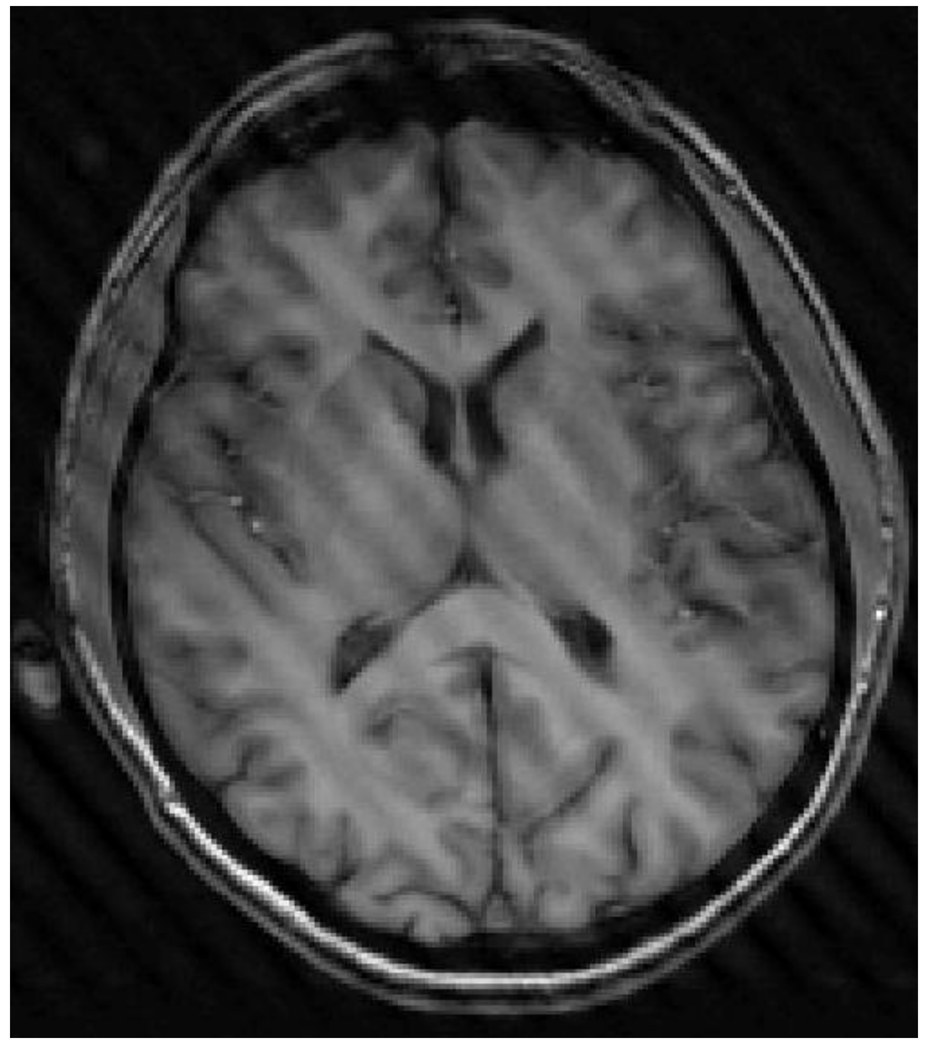
NEED preprocessing to reduce artifacts

Preprocessing

Image reconstruction

- Convert k-space data to images using reconstruction algorithm
- Problematic data due to e.g., slice timing errors, RF spikes or RF interference





Scanner artifact detection

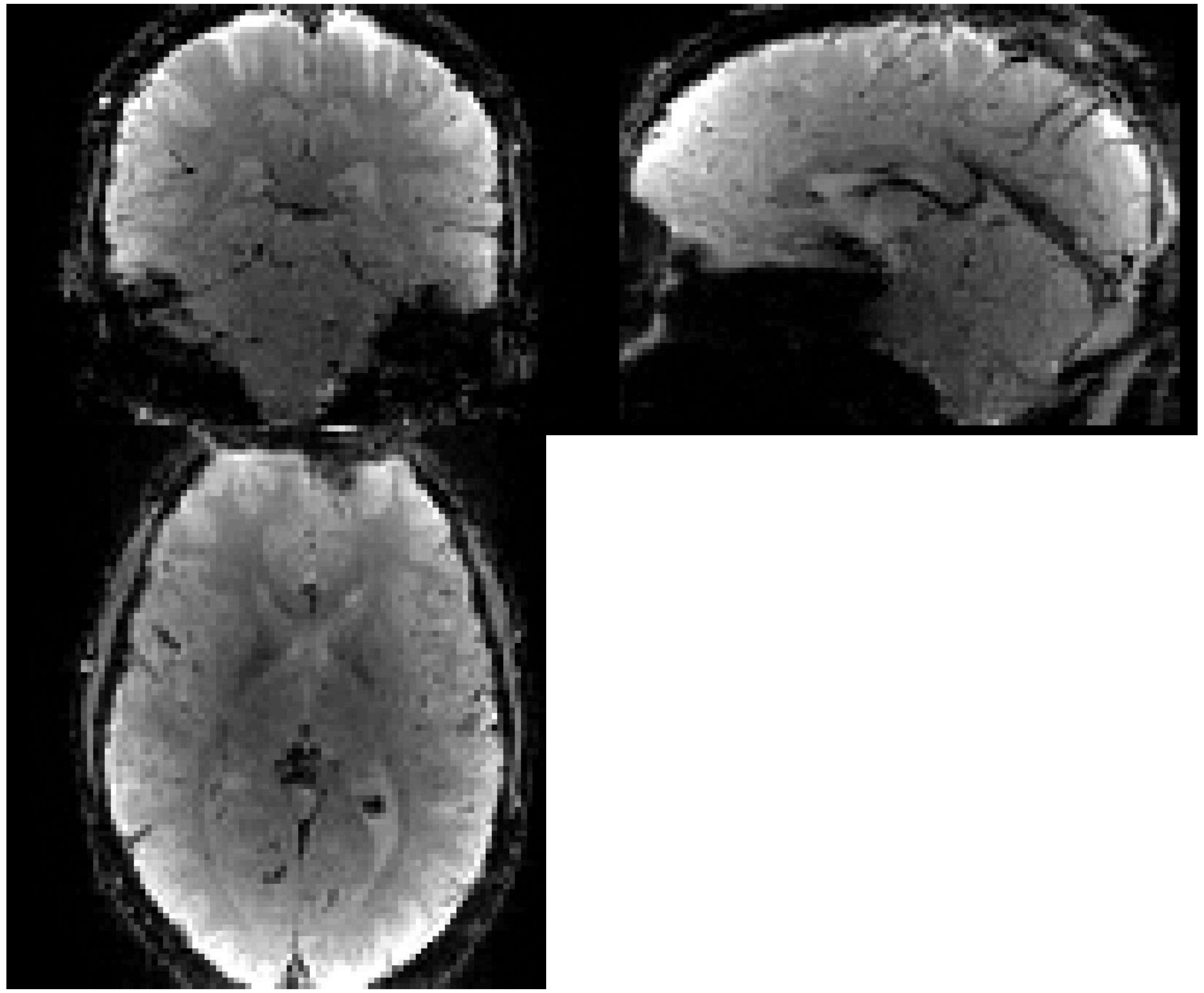
Preprocessing overview

Conventional preprocessing steps

- Motion & distortion correction
- Slice timing correction
- High pass temporal filtering
- Spatial smoothing
- Registration

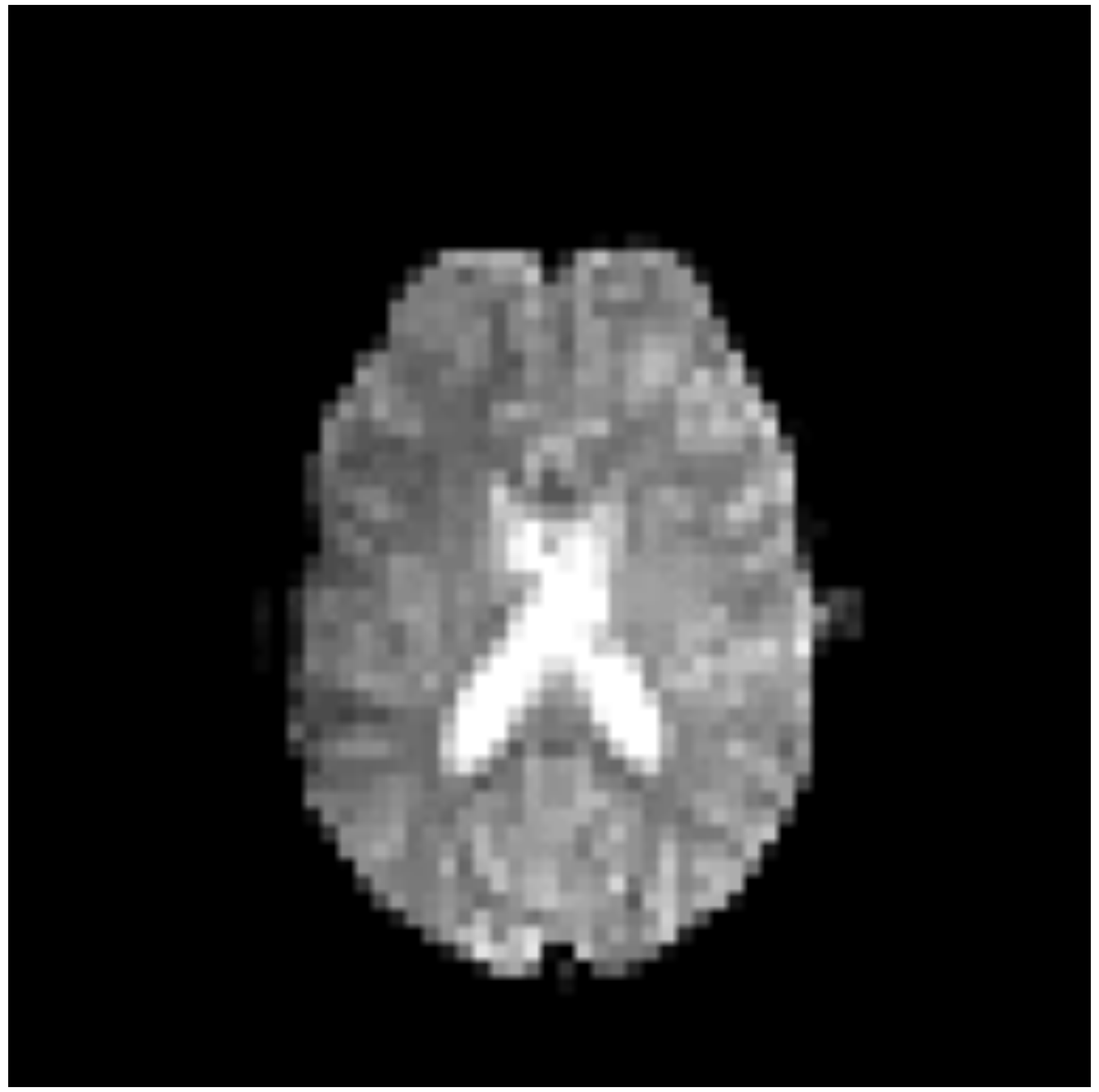
These same concepts are applied across all imaging modalities (task, rest, diffusion, ASL etc)

Motion correction



- Biggest source of noise
- Correction is always necessary
- Linear correction may leave motion effects in data (e.g. partial volume)
  - Additional motion correction methods will be discussed later in the course

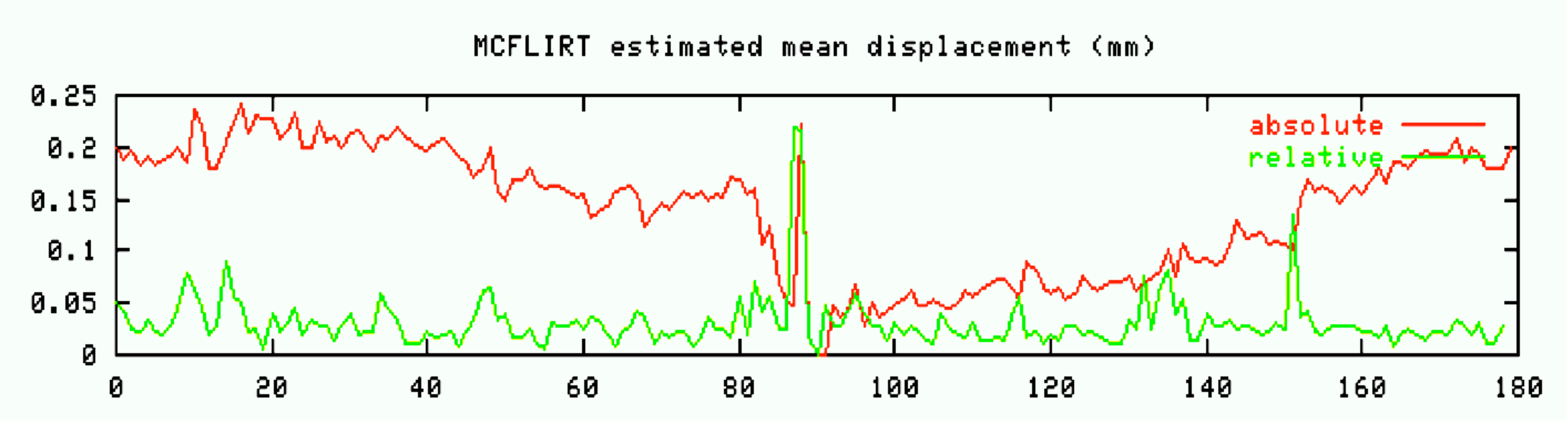
Motion correction



- Uses rigid body registration
- Select reference timepoint = target
- Register each fMRI volume to target separately
- Use rigid body (6 DOF)

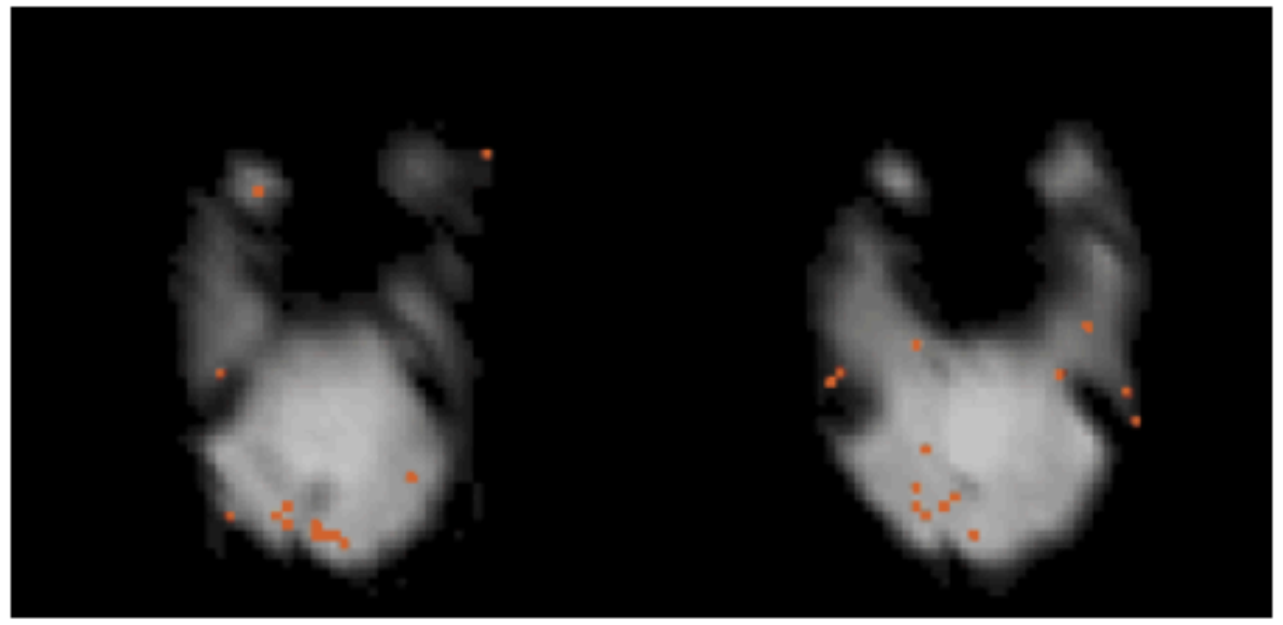
Motion correction

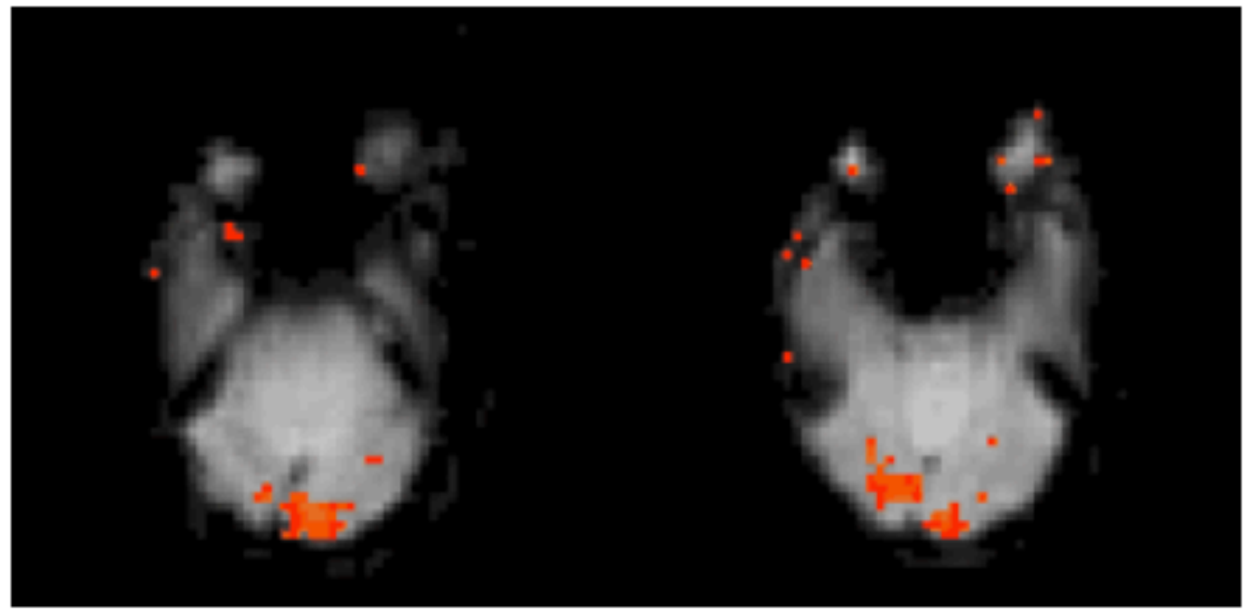
- Results in 6 summary measures (rotations and translations)
  - Absolute = timepoint to target (shows jumps & drifts)
  - Relative = timepoint to next timepoints (shows jumps)
- Large jumps are more important than slow drifts (especially in relative motion plot)



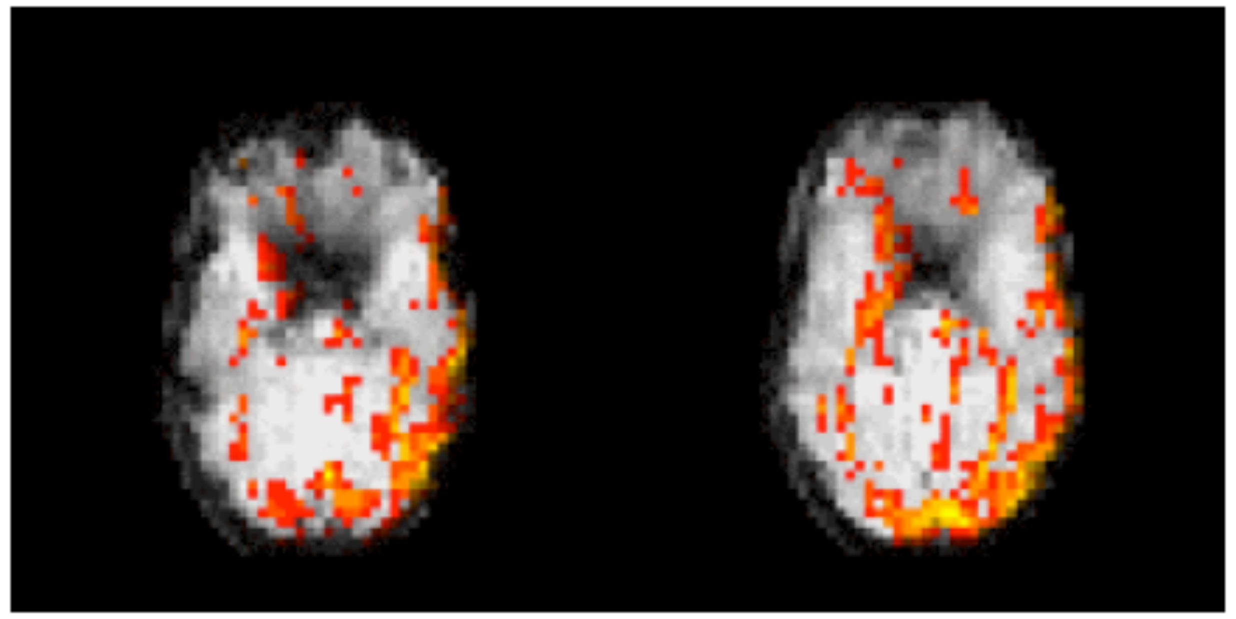
Effect of motion correction

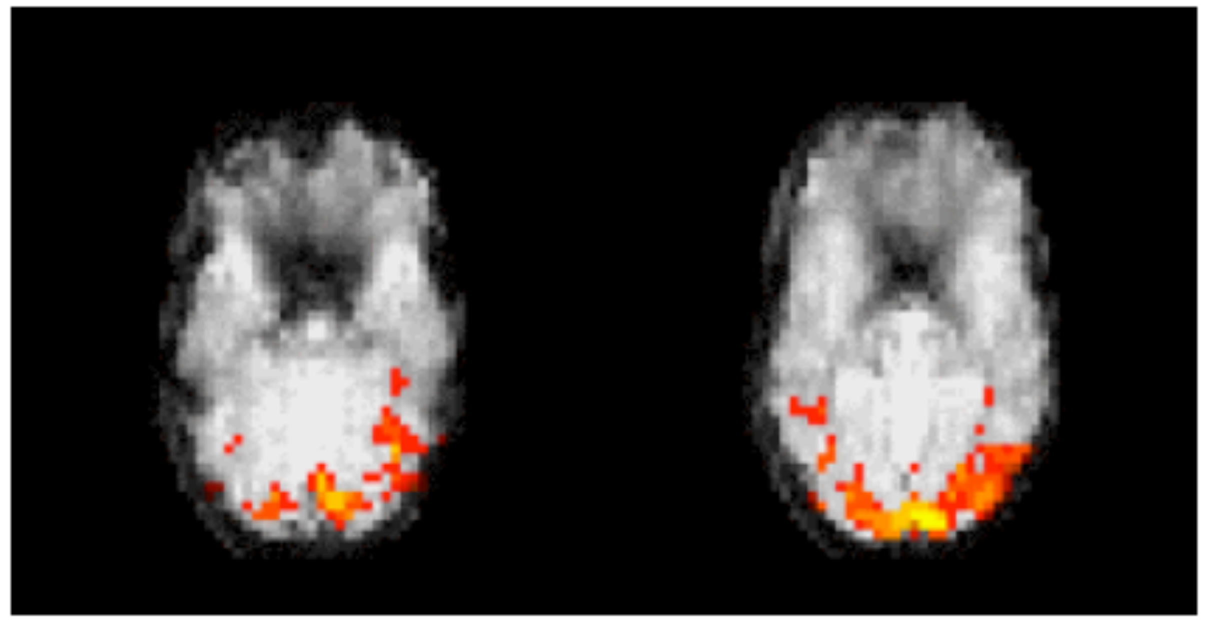
Uncorrelated Motion





Stimulus Correlated Motion

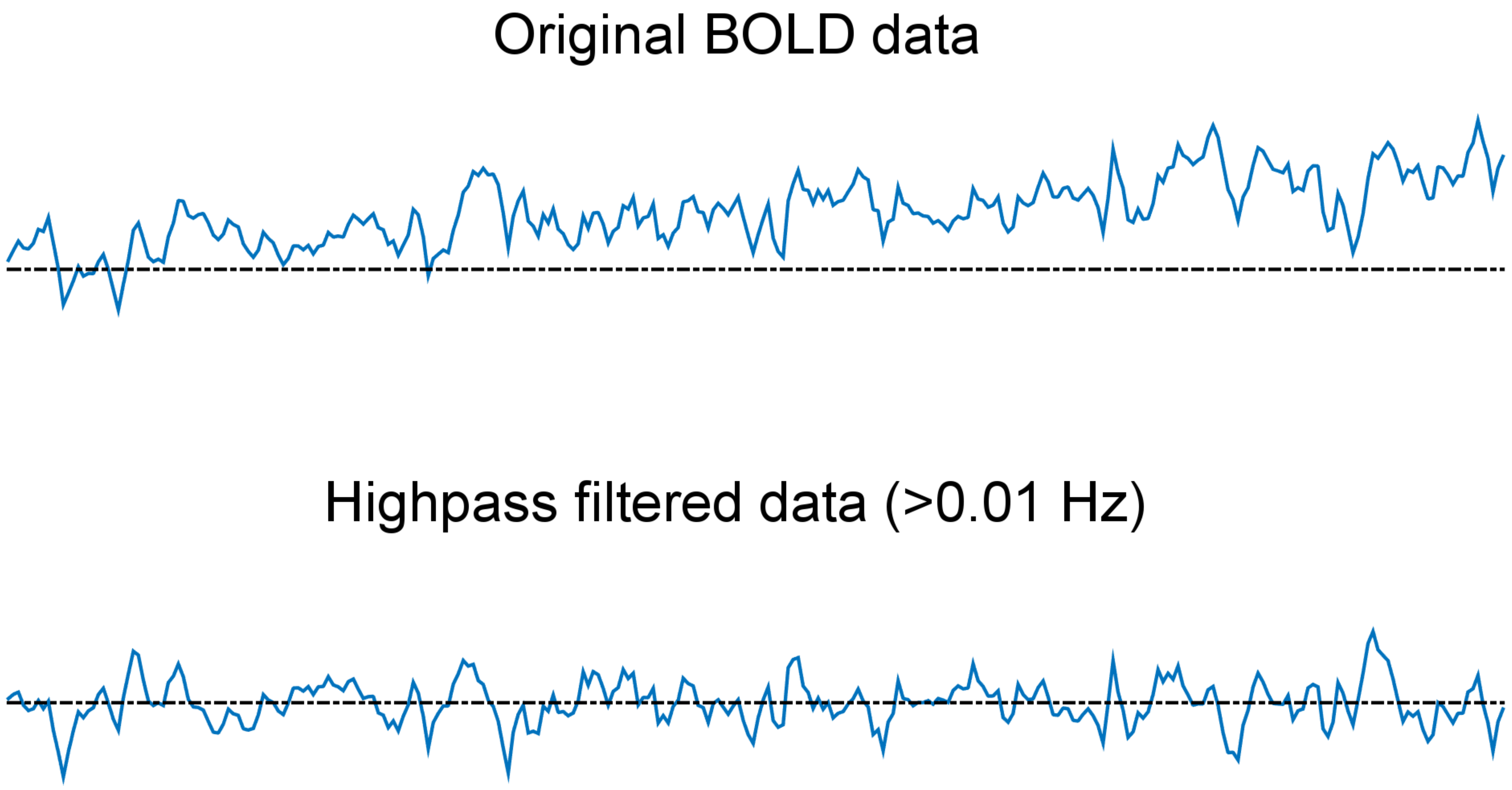




Without MC

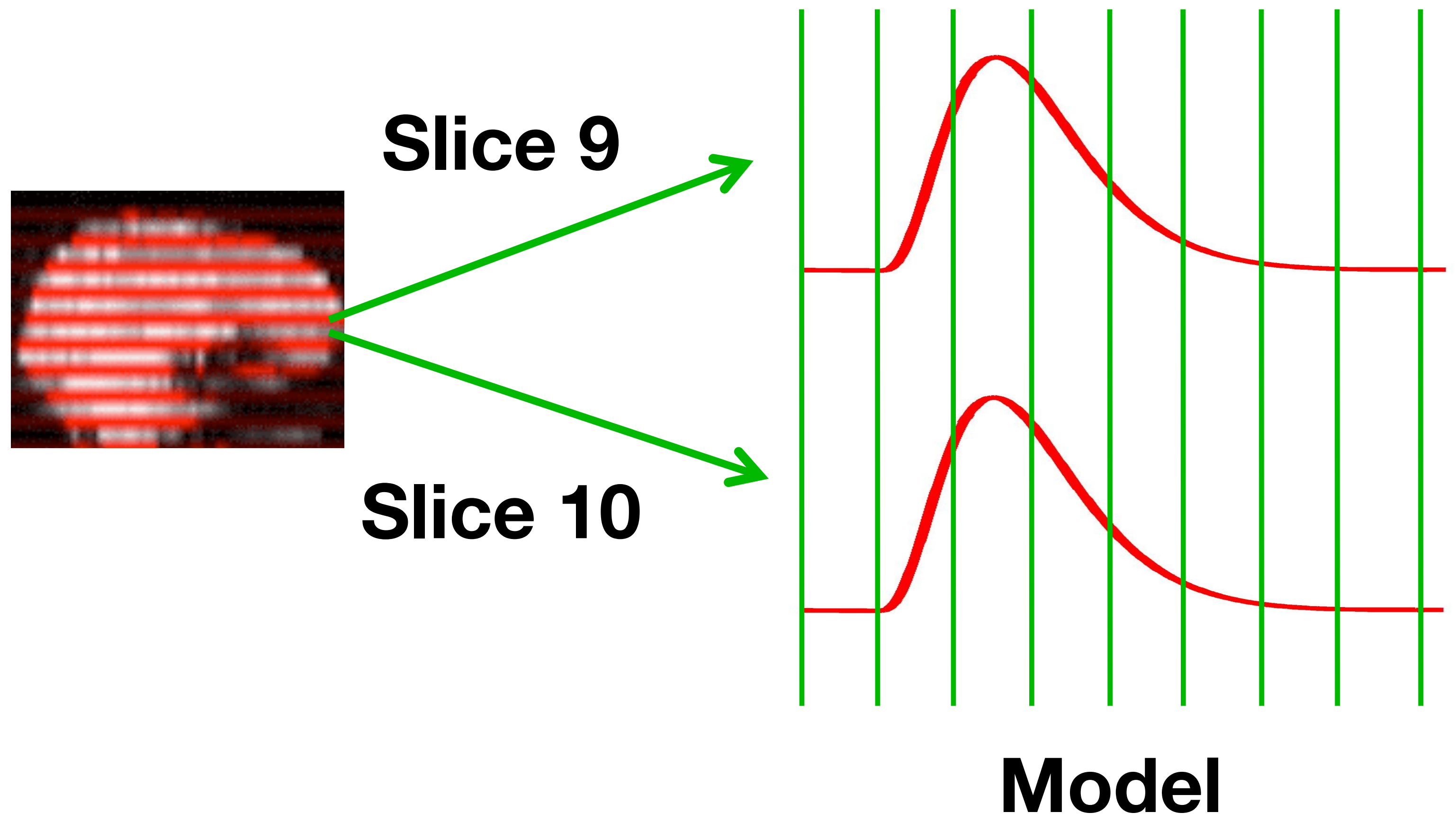
With MC

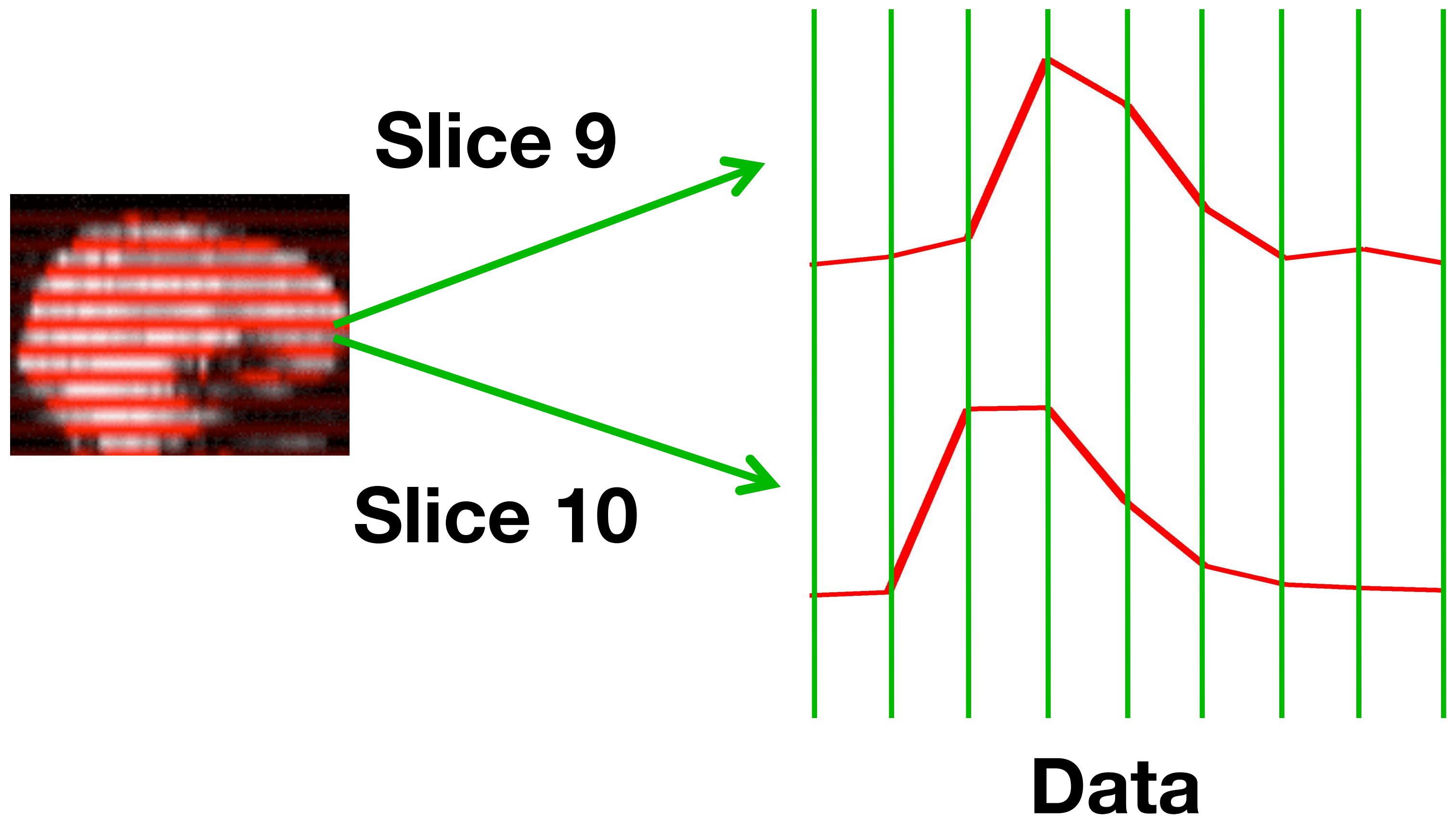
Temporal filtering



- Correct for gradual drift in the data
- High-pass filtering recommended
- Need to choose cutoff frequency carefully
    - Lower frequency (i.e. longer period) than task frequencies of interest
    - Should be >90 seconds for autocorrelation estimation

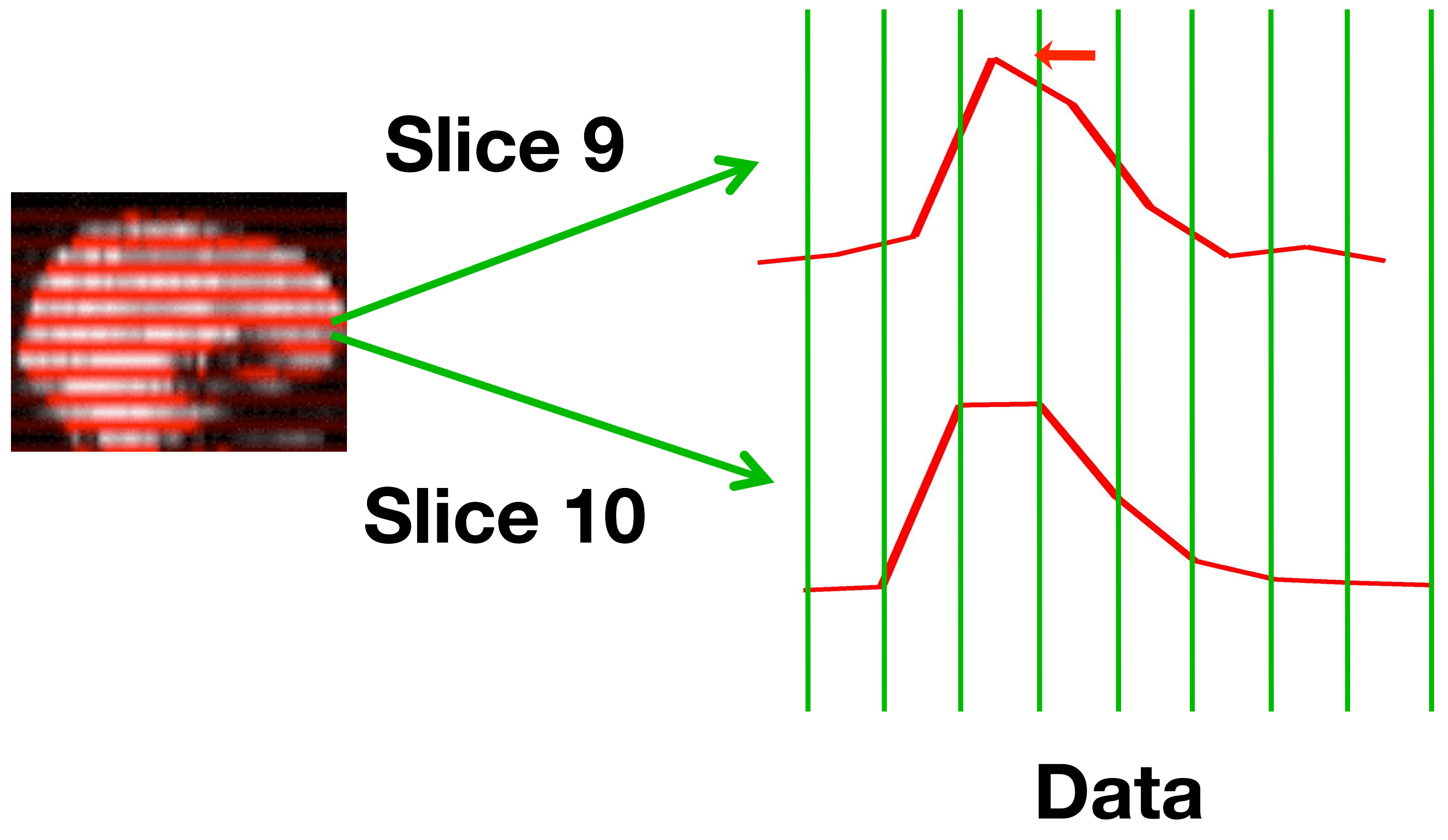
Slice timing correction

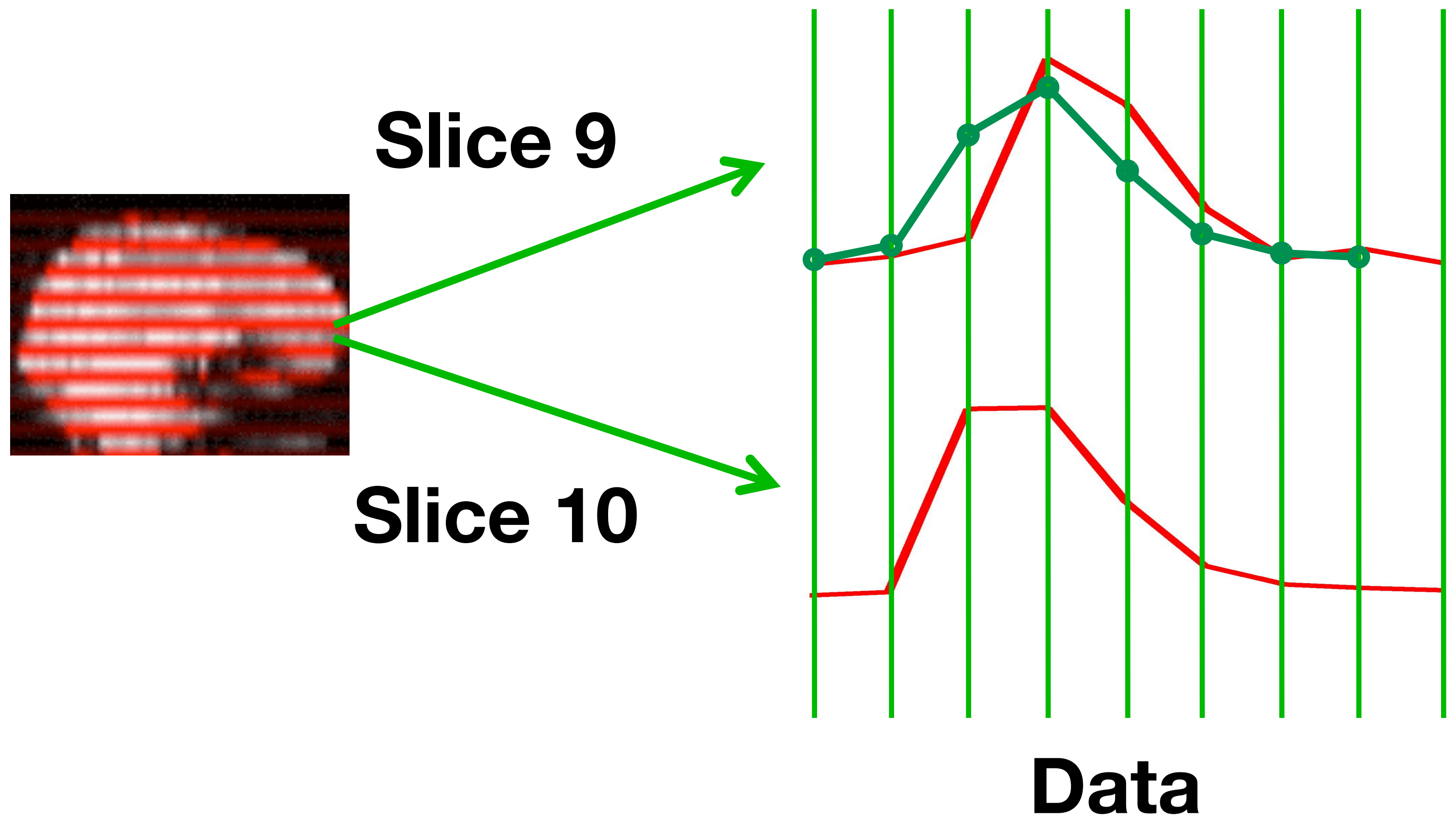




- Need to adjust for differences in acquisition time between different slices

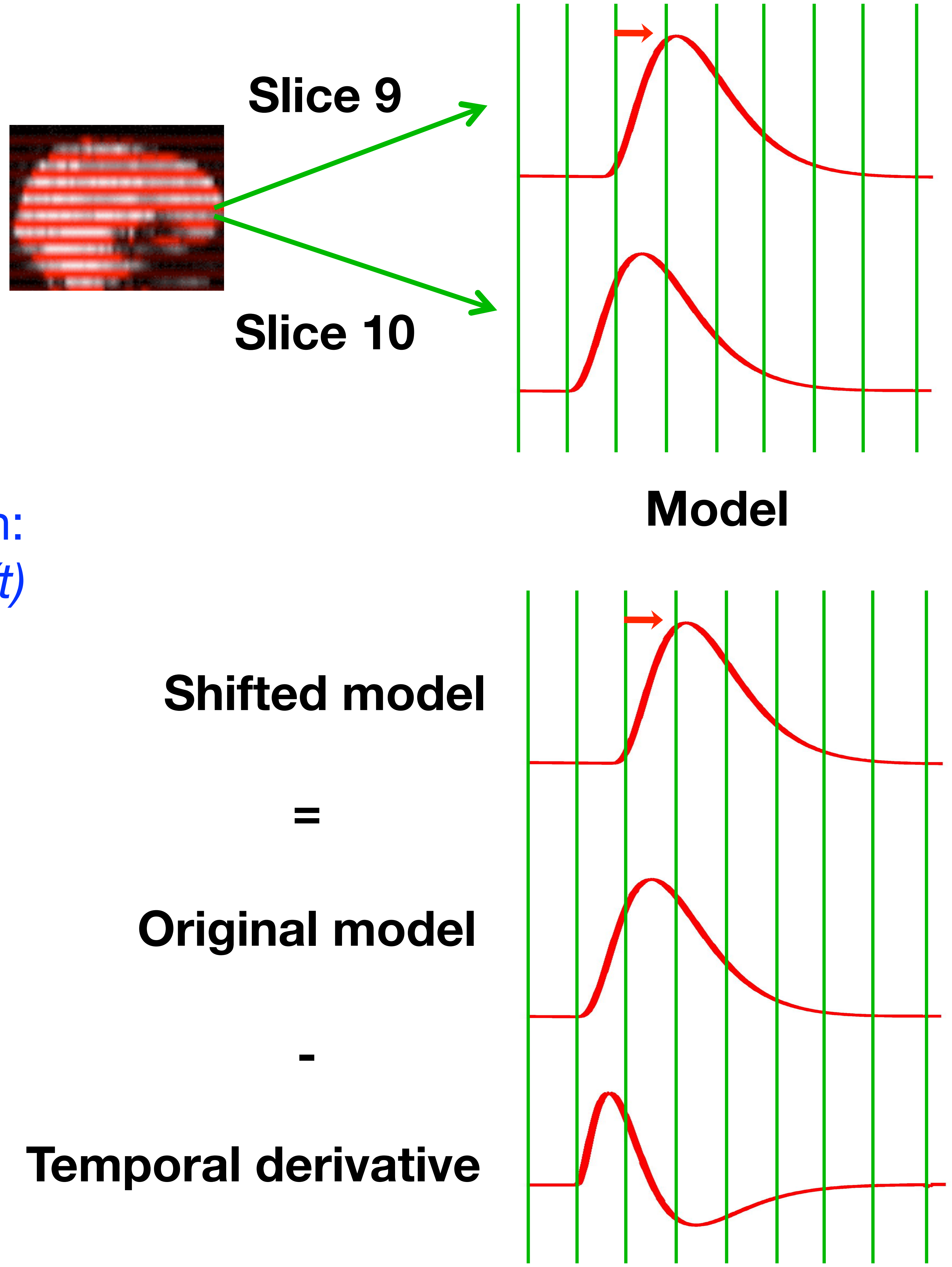
Slice timing correction





- Need to adjust for differences in acquisition time between different slices
- Can de with slice timing correction (i.e. shifting the data), but interpolation leads to degraded data

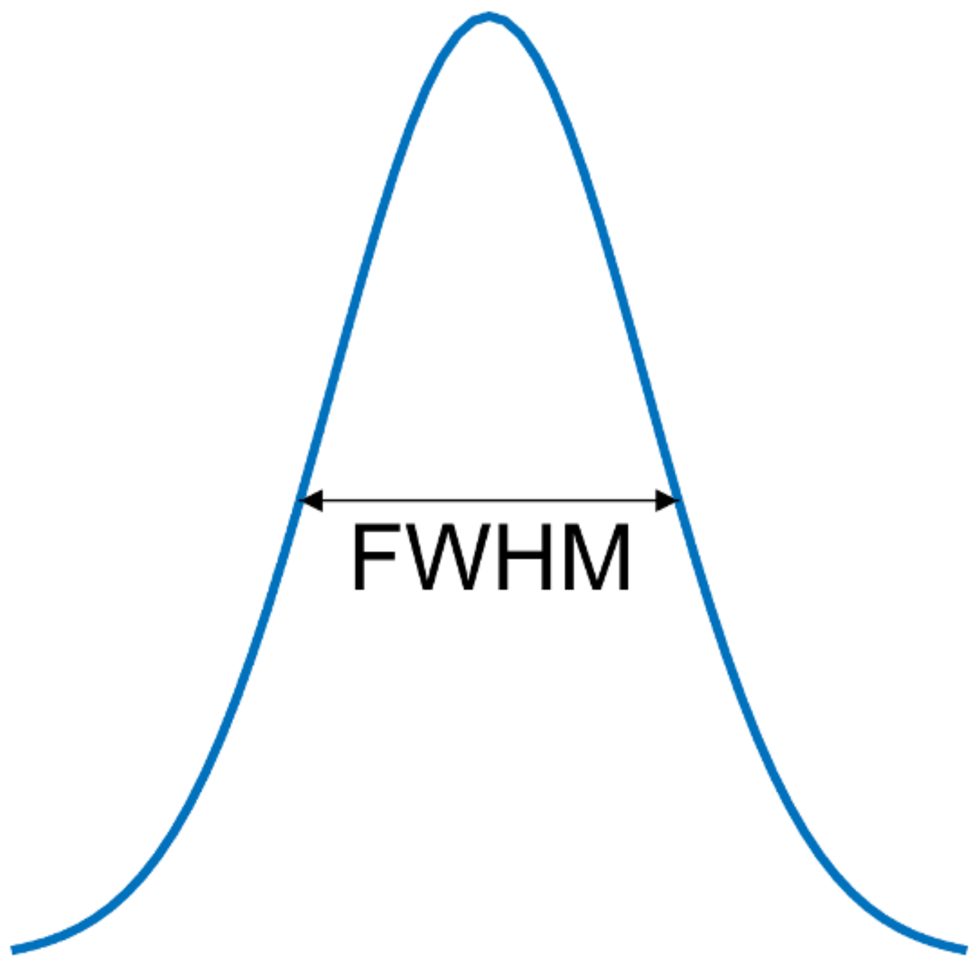
Slice timing correction



Based on
Taylor approximation:
$m(t+a) = m(t) + a.m'(t)$

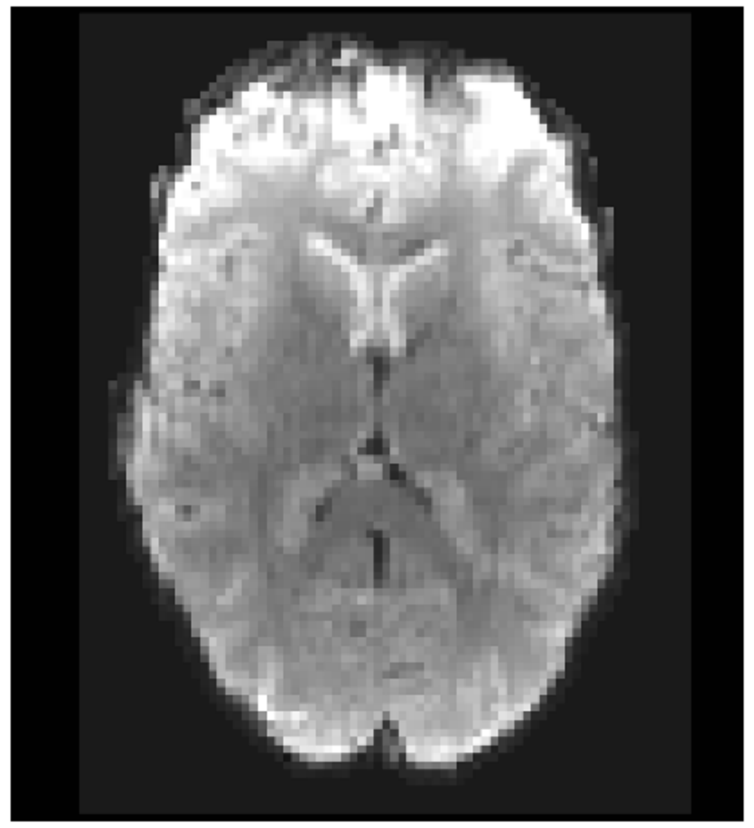
- Need to adjust for differences in acquisition time between different slices
- Can de with slice timing correction (i.e. shifting the data), but interpolation leads to degraded data
- Better to shift the model, which we can do by including the temporal derivatives of EVs

Smoothing (spatial filtering)

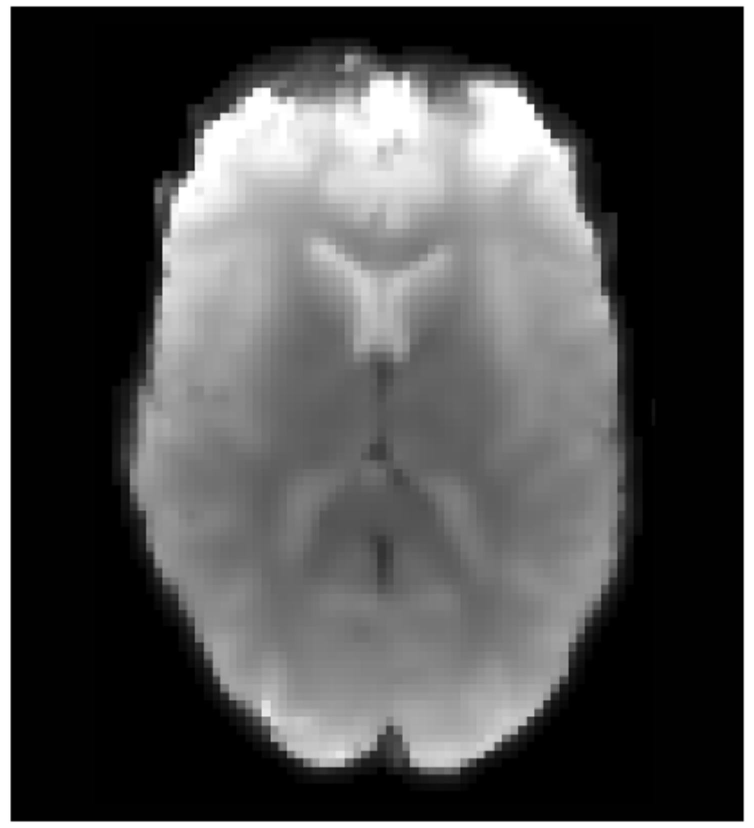


0.1	0.3	0.4	0.3	0.1
0.3	0.6	0.8	0.6	0.3
0.4	0.8	1.0	0.8	0.4
0.3	0.6	0.8	0.6	0.3
0.1	0.3	0.4	0.3	0.1

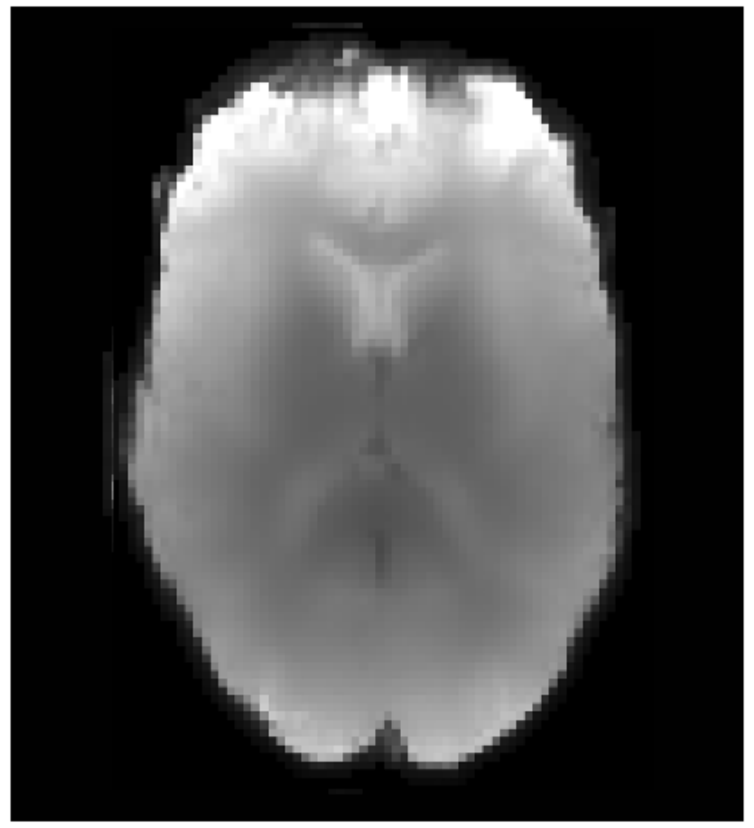
FWHM



No smoothing



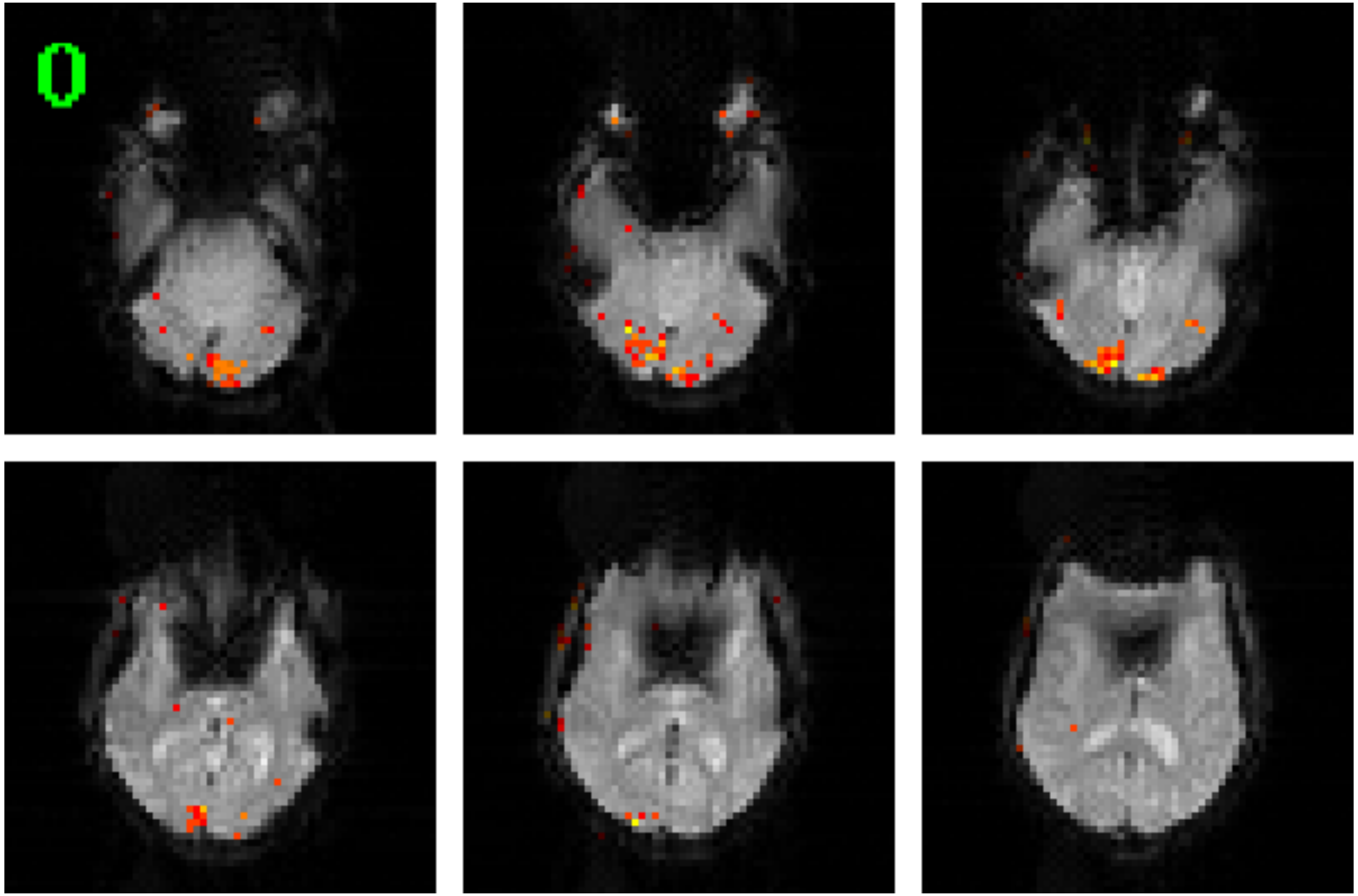
5 mm smoothing



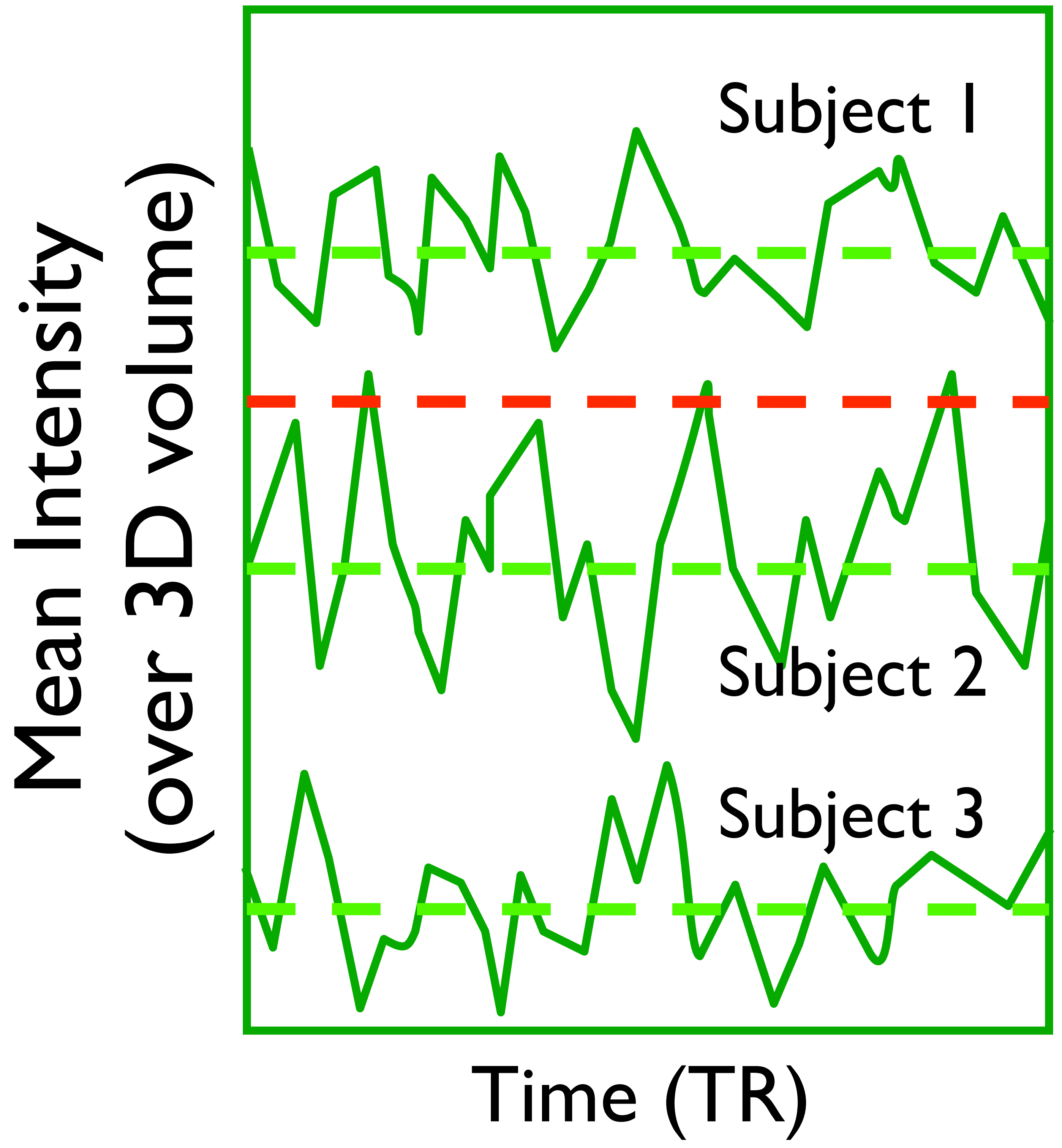
10 mm smoothing

- Increase signal to noise ratio by blurring the image
  - Averaging leads to less noisy voxel values
  - Needed for some stats (GRF)
- Keep in mind:
  - Size of expected activation
  - Desired spatial specificity
  - May not need to do any

Effect of smoothing



Global Intensity Normalisation



- Need to remove uninterested offsets between subjects and sessions
- Scale (i.e. multiply) each 4D dataset by a single value
- Automatically done in all software packages
- Not the same as global signal regression!

Summary of preprocessing

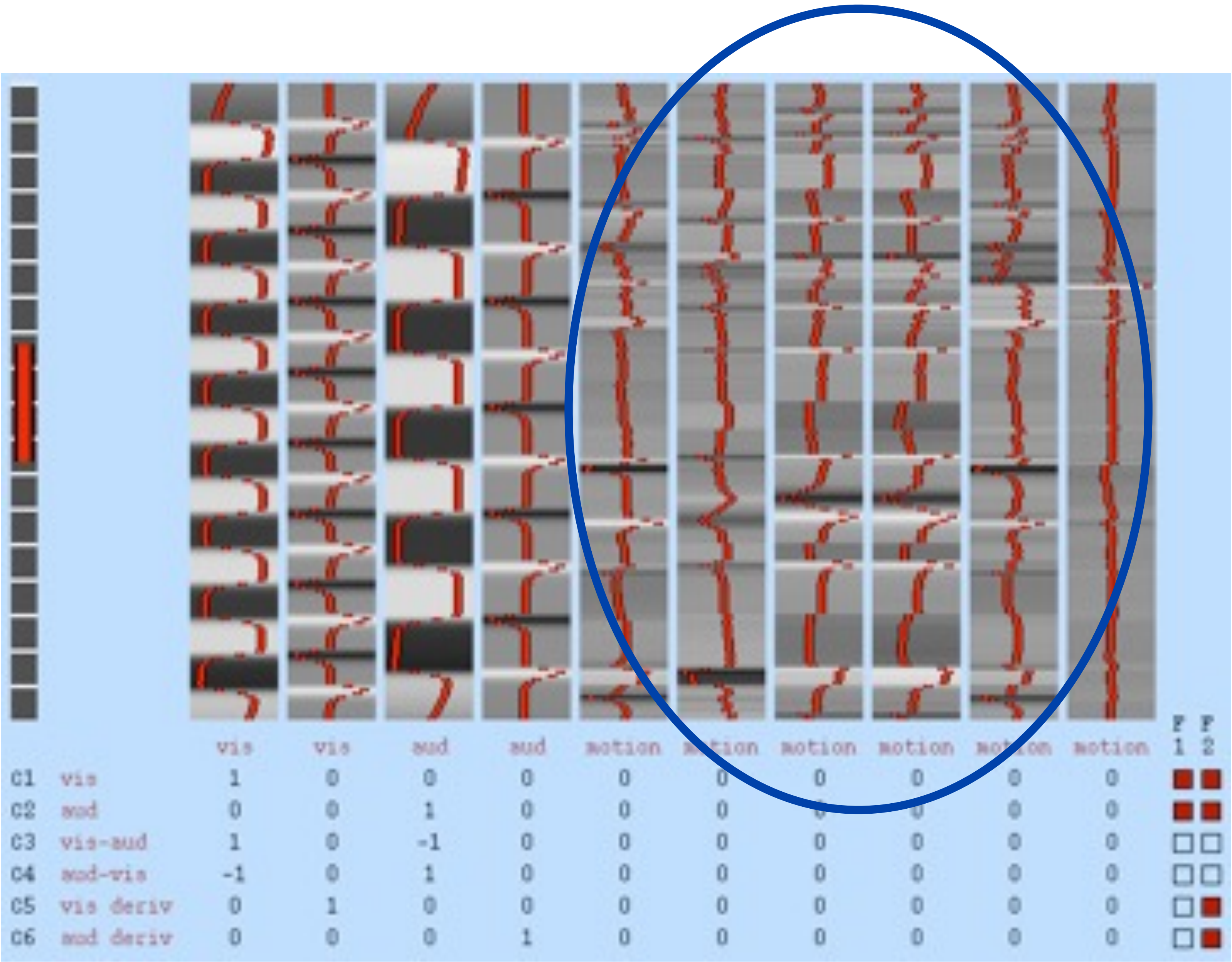
Reconstruction	Create image and remove gross artefacts
Motion Correction	Get consistent anatomical coordinates (always do this)
Slice Timing	Get consistent acquisition timing (use temporal derivative instead)
Spatial Smoothing	Improve SNR & validate GRF
Temporal Filtering	Highpass: Remove *slow* drifts Lowpass: Avoid for autocorr est.
Intensity Normalisation	4D: Keeps overall signal mean constant across sessions

Break Time!

Motion Parameter Confounds

Add the 6 parameters (rotations and translations) as measured by MCFLIRT to the GLM as *confounds* - simple button in FEAT

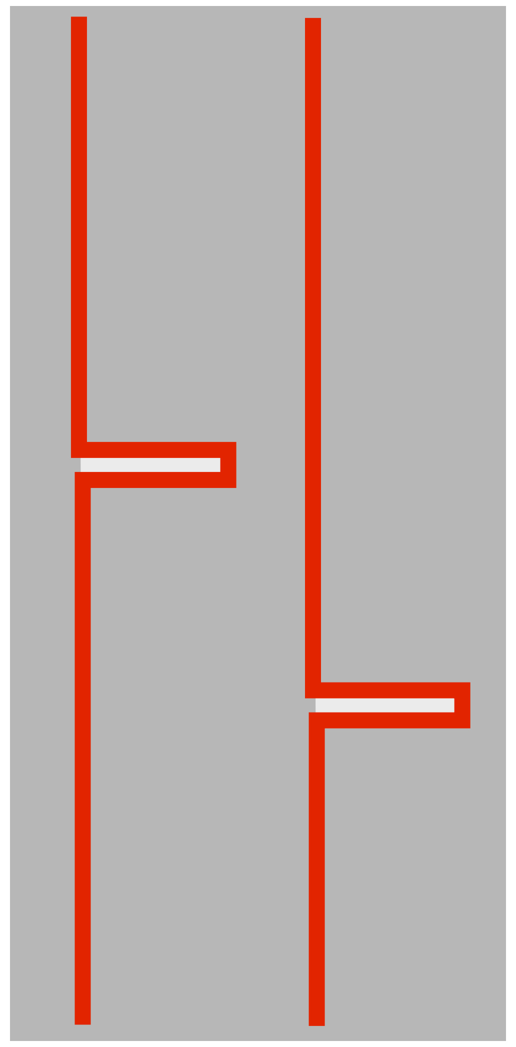
- Removes any correlated signals (since they are confounds)
- Assumes a linear relationship between motion parameters and intensity of motion artefact
- Assumes that MCFLIRT estimation is accurate
- Problematic if motion parameters and EVs of interest are highly correlated (stimulus-correlated motion)



Outlier Timepoint Detection

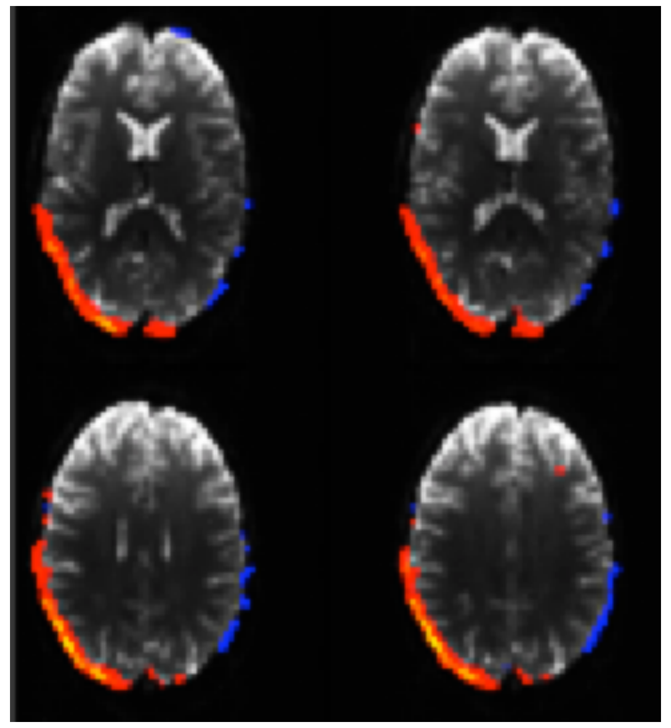
- Also known as scrubbing or volume censoring
- Removes ***all*** influence of the timepoints
- Uses one extra confound regressor per outlier timepoint
- fsl_motion_outliers creates confound matrix for GLM
- Can cope with very extreme motion effects
- But leaves other timepoints uncorrected

Confound matrix with 2 outlier timepoints

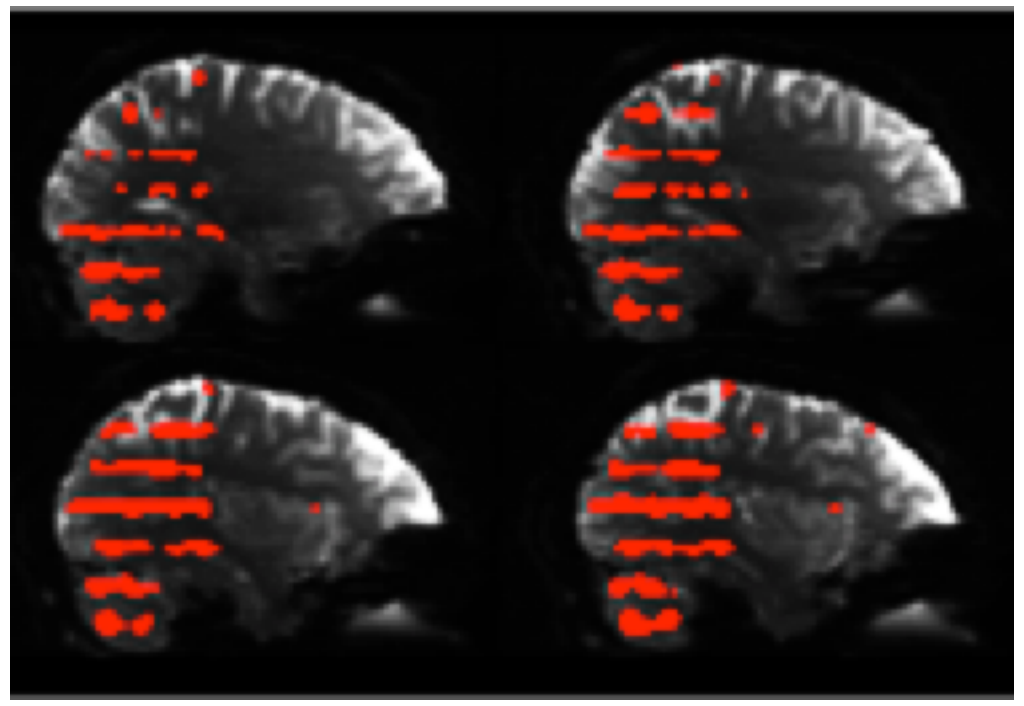


ICA denoising

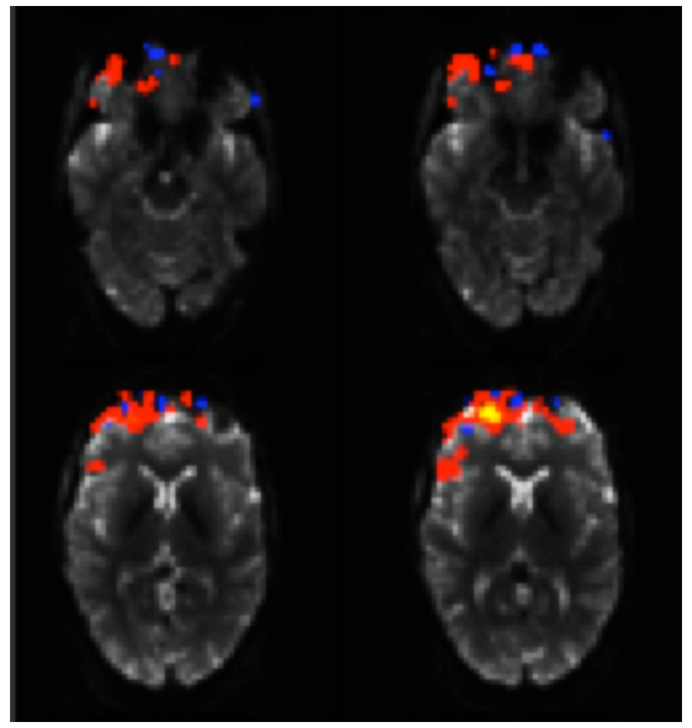
- Use ICA to identify noise comports
- More on this during the ICA lecture



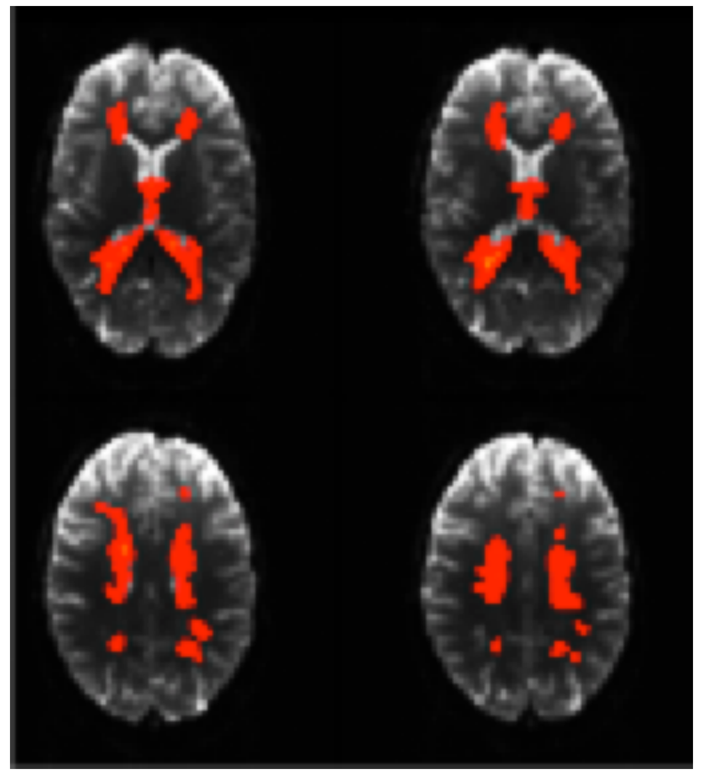
Classic motion



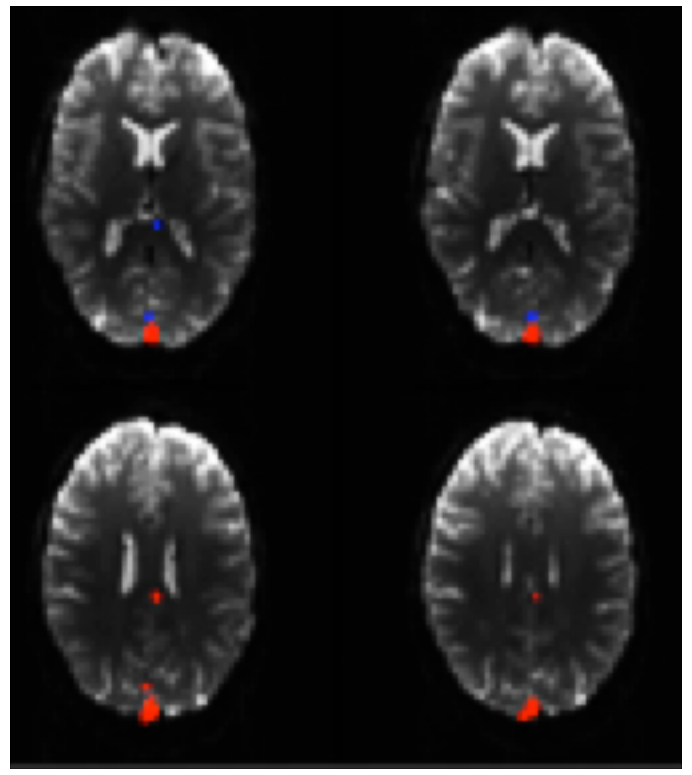
Multiband motion



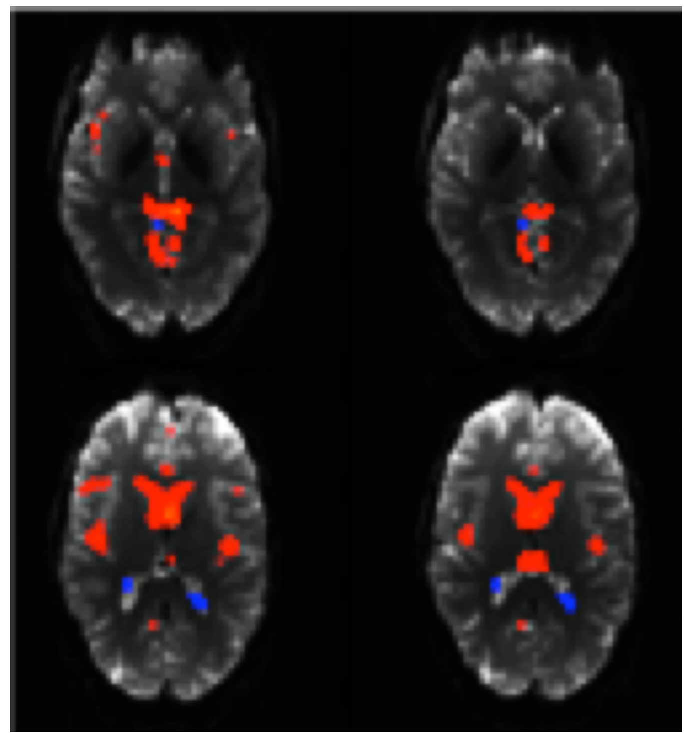
Susceptibility motion



White matter



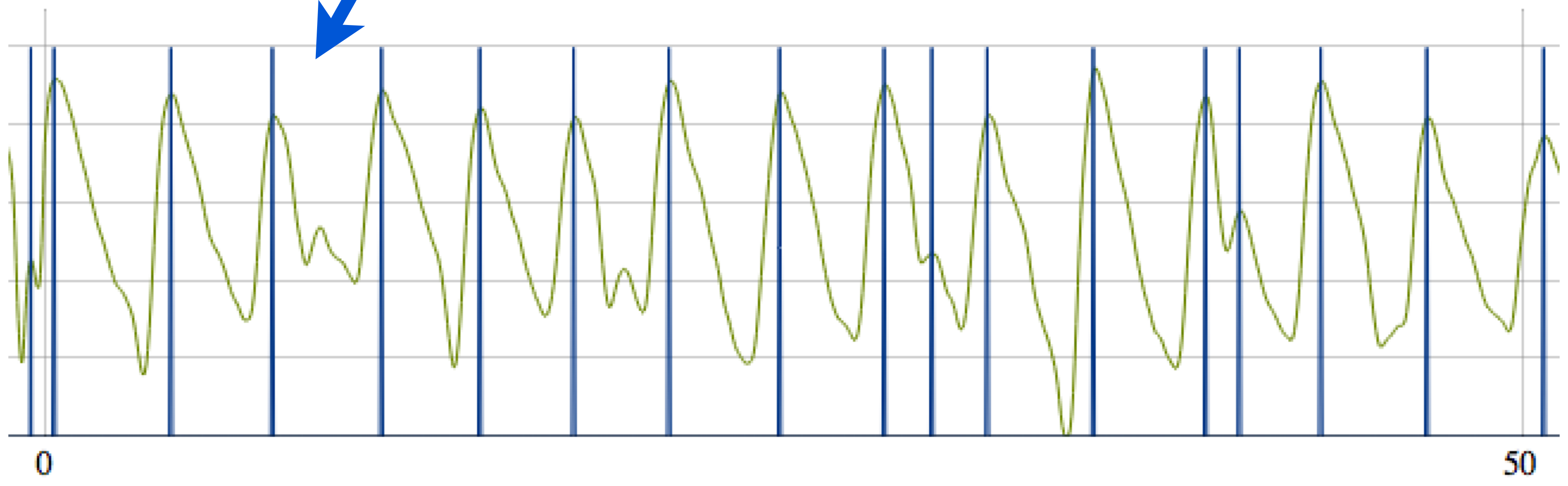
Sagittal sinus



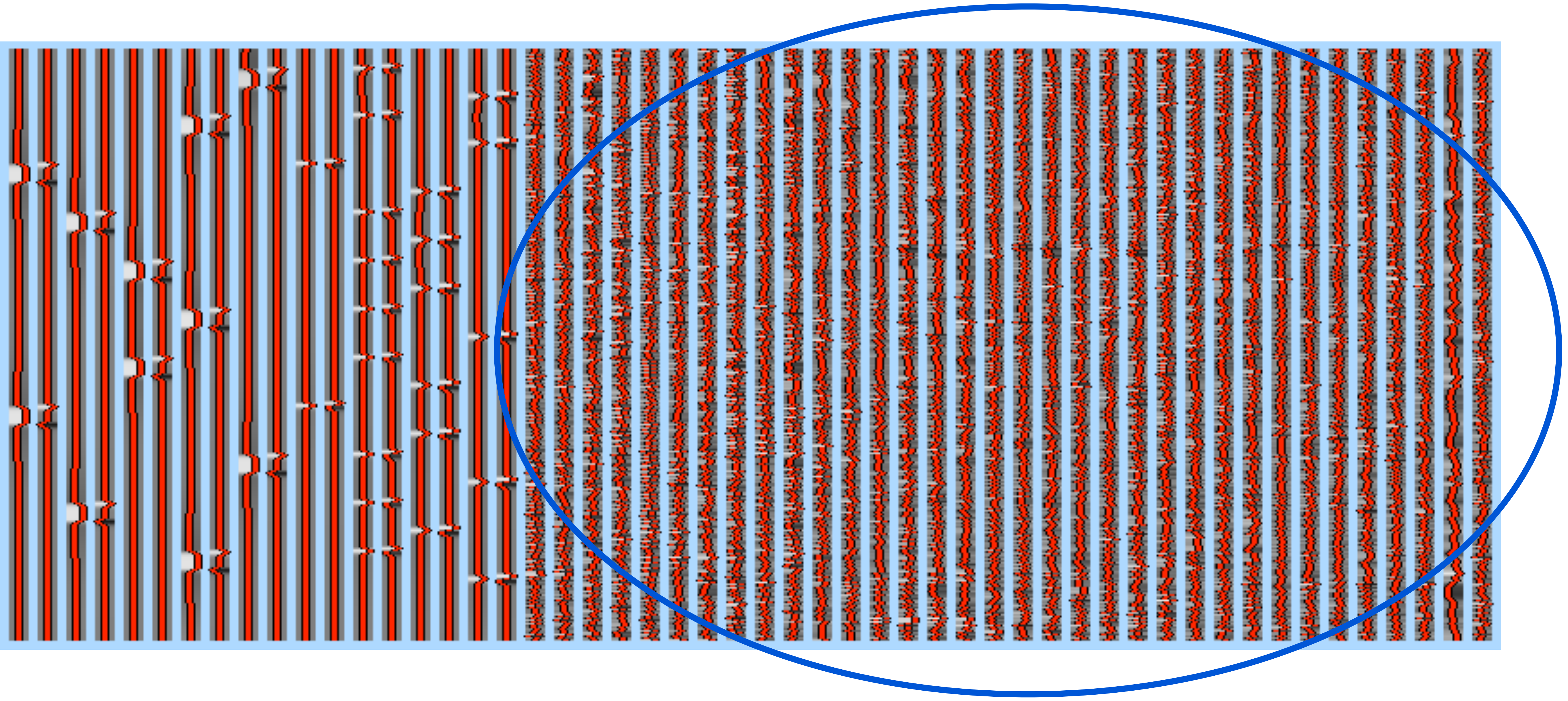
Cardiac/CSF

Physiological Noise Regression

Peak detection in physiological trace



PNM GUI creates a set of files suitable for use as *Voxelwise Confounds* in FEAT



Very important for high-risk brain regions such as the brainstem