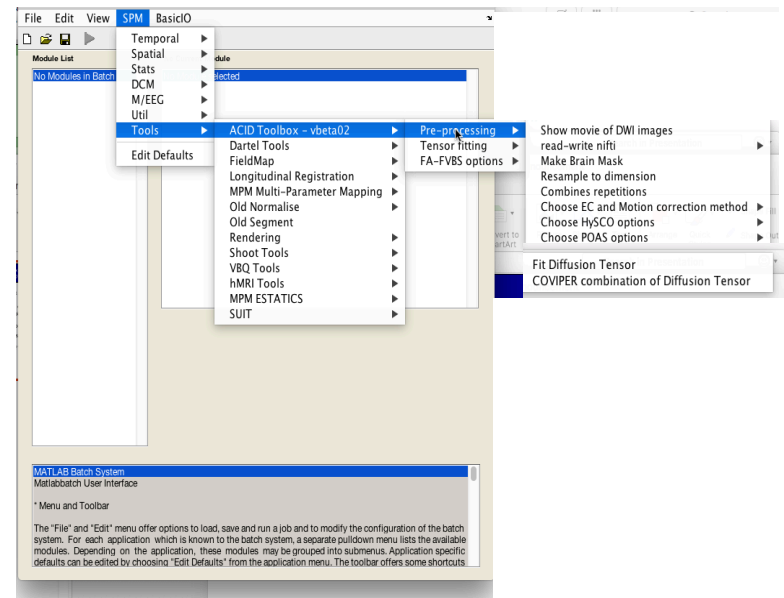


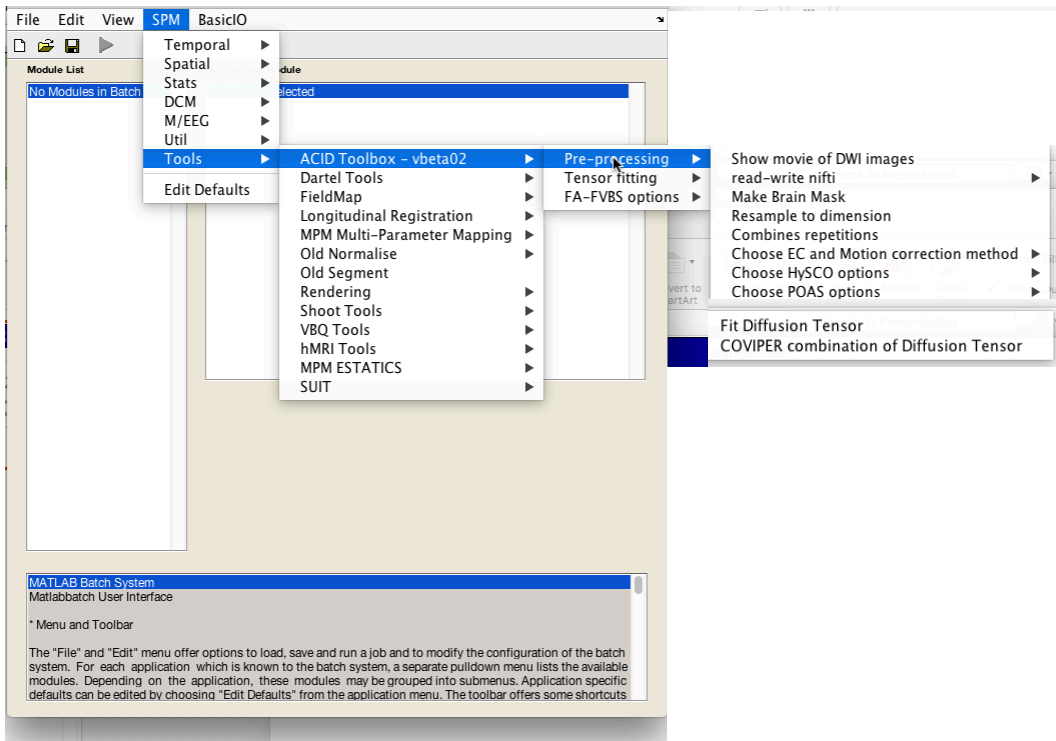
Artefact Correction In Diffusion MRI

ACID SPM toolbox

Siawoosh Mohammadi

Department of Systems Neuroscience
University Medical Center Eppendorf
Hamburg, Germany
s.mohammadi@uke.de





Preprocessing:

- Eddy current and motion
- HySCO (EPI distortions)
- msPOAS (adaptive smoothing)
- Vibration Artifacts (DTI model)

Signal Models:

- DTI (ols, wols, robust fitting)
- Diffusion Kurtosis Imaging
- NODDI-DTI (Tba)

Open-Access: www.diffusiointools.com

Questions/queries to Siawoosh Mohammadi
s.mohammadi@uke.de



Universitätsklinikum
Hamburg-Eppendorf

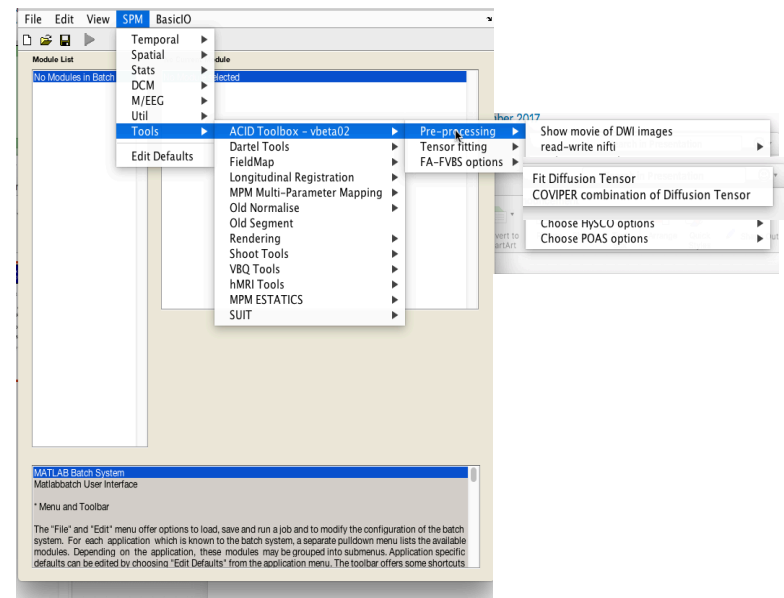
Artefact Correction In Diffusion MRI

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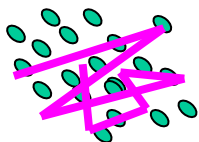
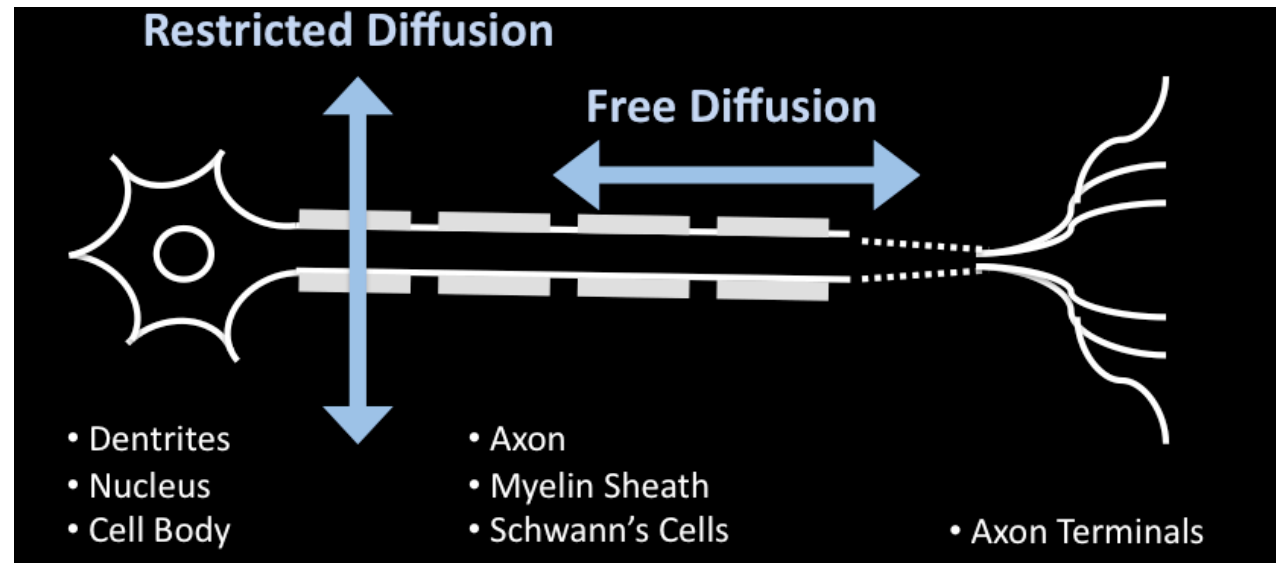
- Diffusion MRI: why, how, and what does it mean?
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- Diffusion MRI: why, how, and what does it mean?
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 - Susceptibility artefacts correction (in development)
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 - Position-orientation adaptive smoothing (in development)
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Introduction into diffusion MRI and Diffusion Tensor Imaging

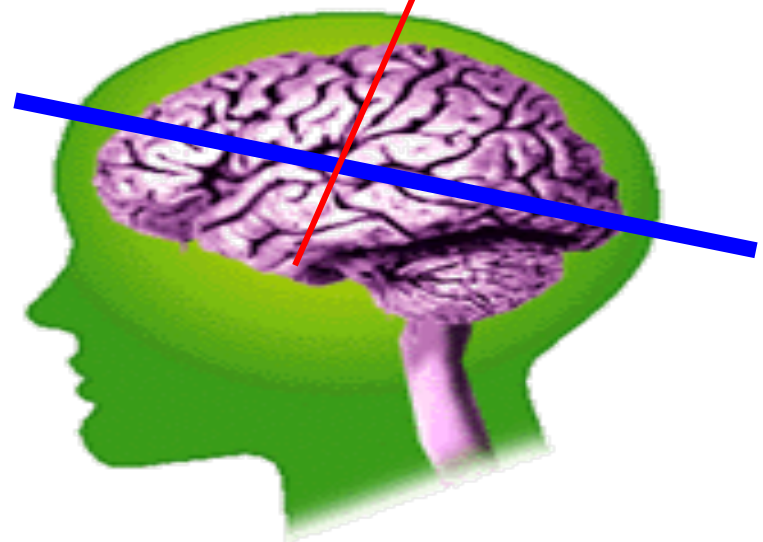
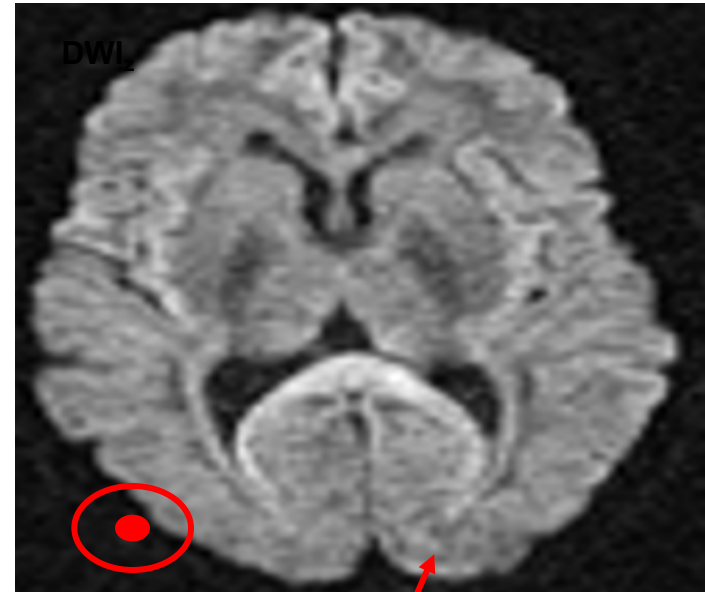
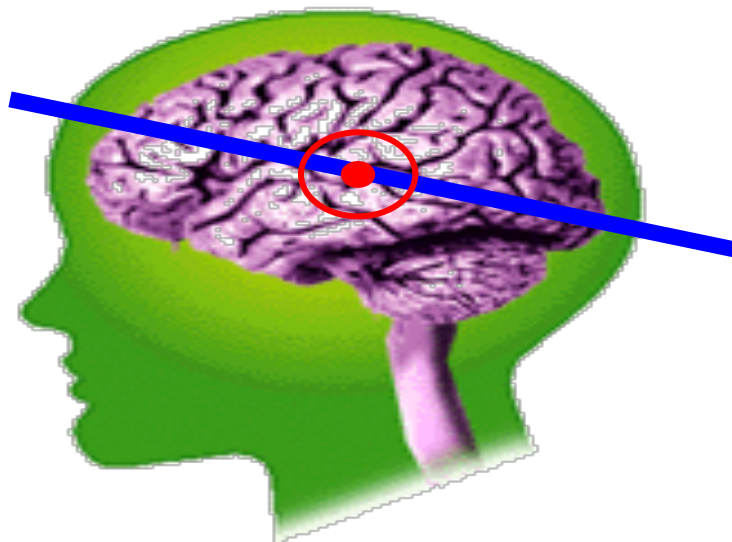
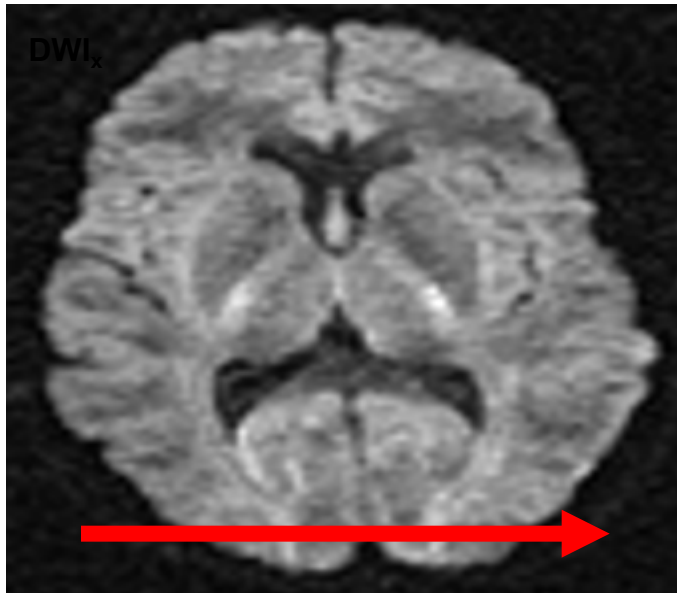


Schematic Neuron

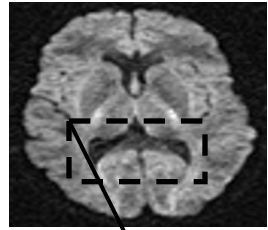


water diffusion

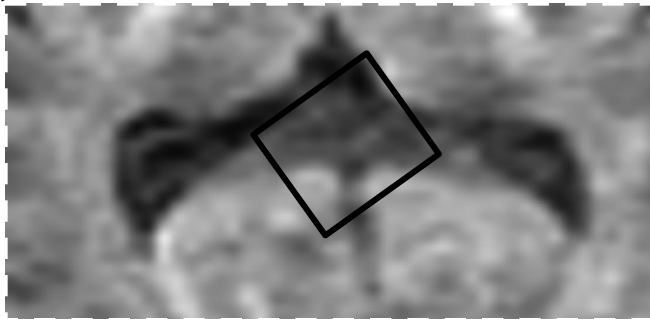
Diffusion weighted images



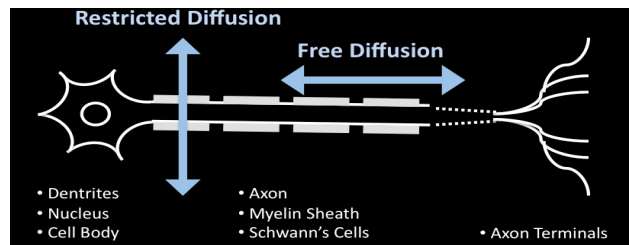
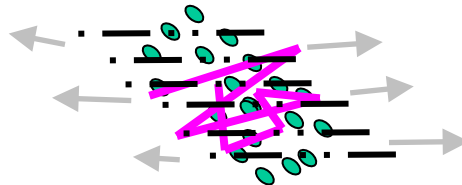
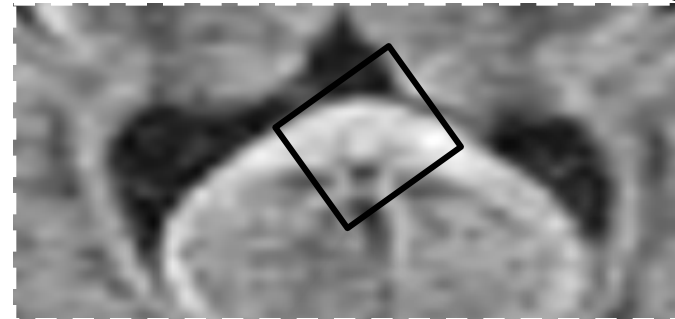
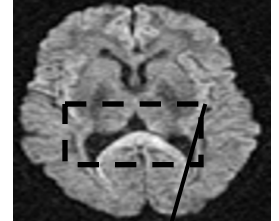
Diffusion weighted images



$$\vec{G}^D = (G_x \quad 0 \quad 0)$$

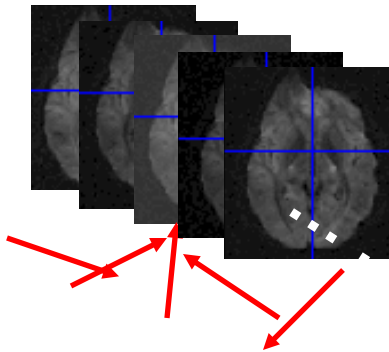


$$\vec{G}^D = (0 \quad 0 \quad G_z)$$



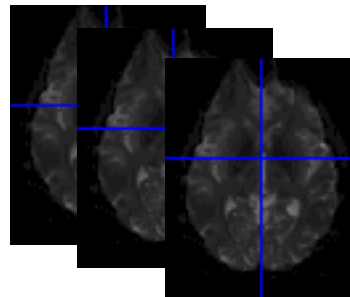
What do we need for diffusion MRI?

n DW images



+

m $b=0$ images



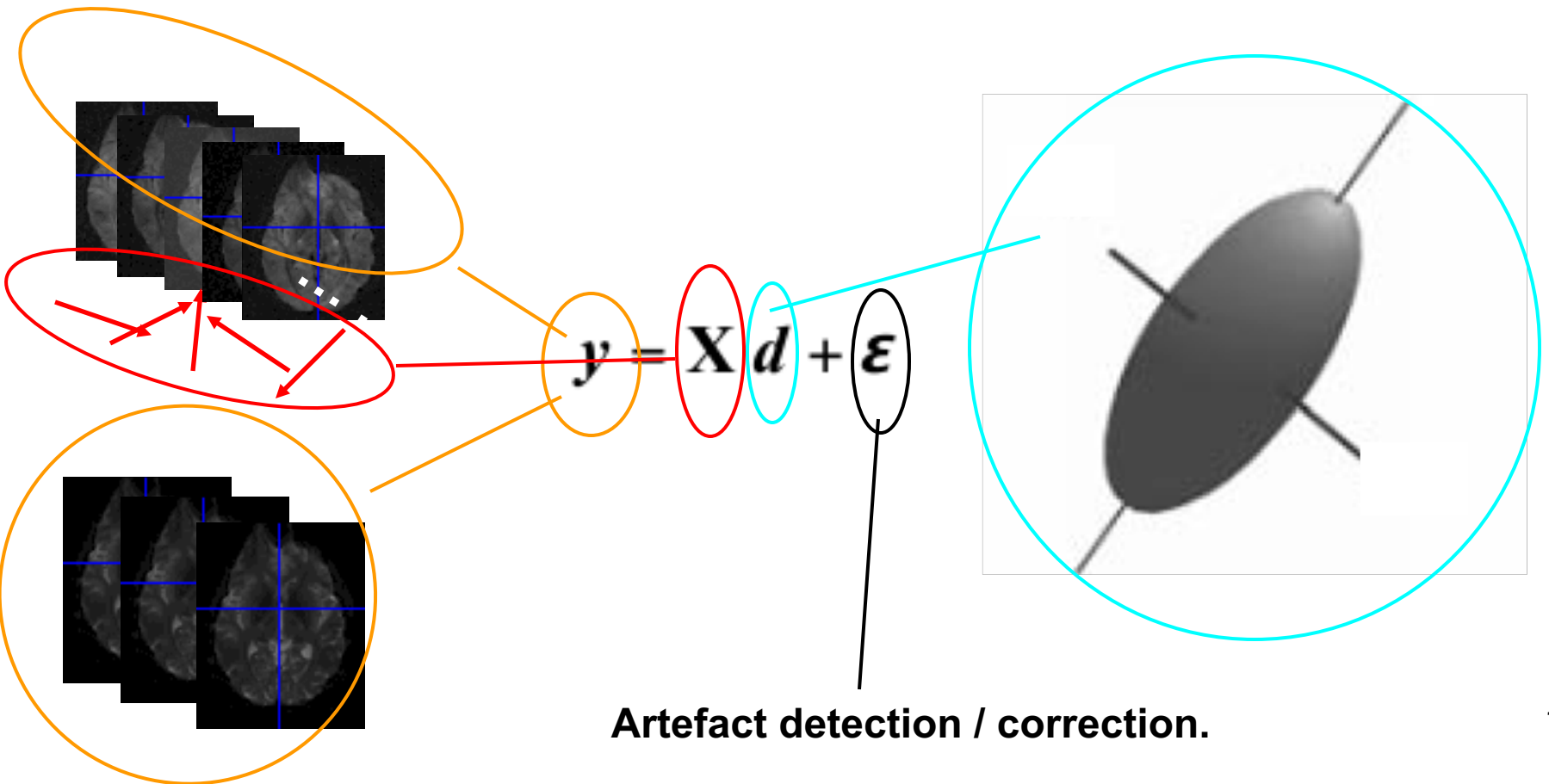
+

Model

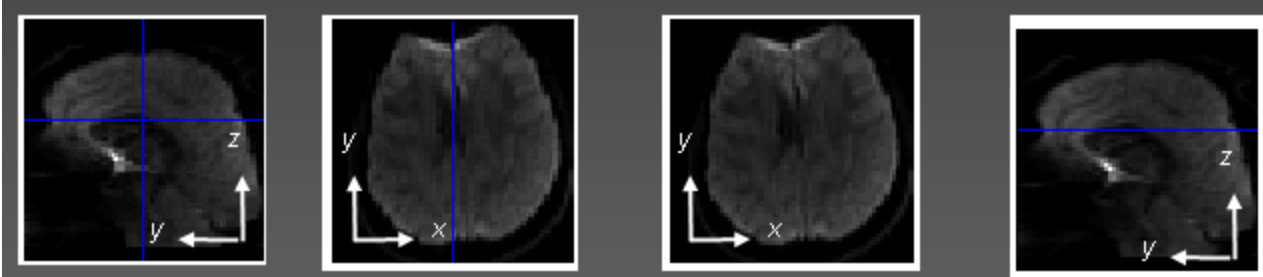
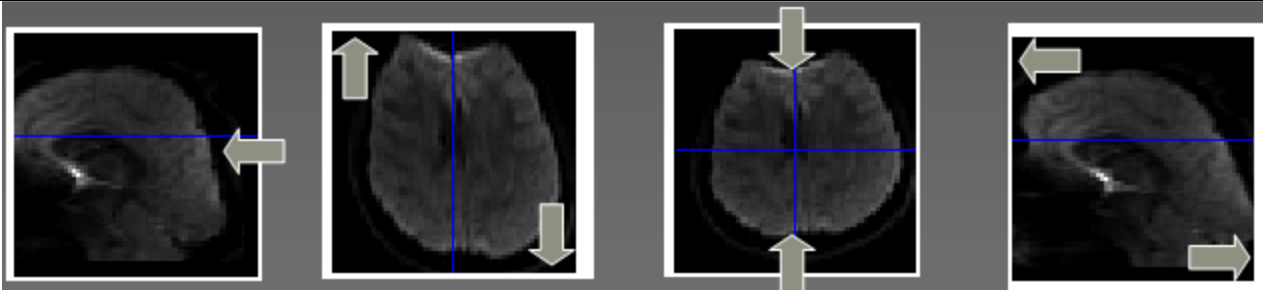
Single spin echo



The general linear model framework for diffusion MRI



- Diffusion MRI: why, how, and what does it mean?
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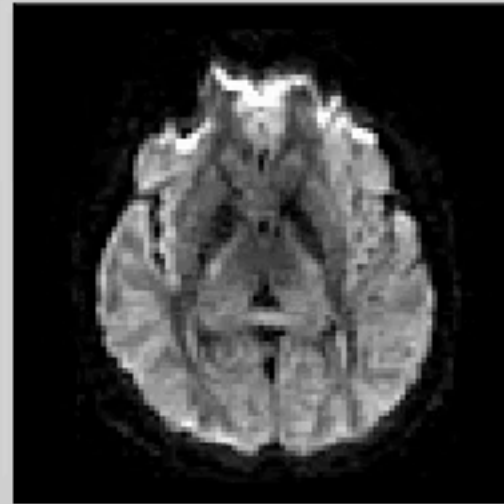
original image				
distorted image				
	translation	in-plane shearing	scaling	through-plane shearing
eddy current field components	B_0^{EC} 			

Single spin echo



Stejskal & Tanner, JCP, 1965

Double spin echo



Reese et al., MRM, 2003



Eddy current and motion correction toolbox

The screenshot displays the MATLAB Batch Editor interface. The 'Tools' menu is open, showing a list of toolboxes. The 'ACID Toolbox - vbeta02' is selected, and its 'Pre-processing' submenu is also open. Within the 'Pre-processing' submenu, the 'EC and Motion Correction multi targets' option is highlighted. The 'MATLAB Batch System' window at the bottom provides additional context about the batch system's functionality.

Batch Editor

File Edit View SPM BasicIO

Module List

No Modules in Batch

Temporal

Spatial

Stats

DCM

M/EEG

Util

Tools

Edit Defaults

ACID Toolbox - vbeta02

Dartel Tools

FieldMap

Longitudinal Registration

MPM Multi-Parameter Mapping

Old Normalisation

Old Segment

Rendering

Shoot Tools

VBQ Tools

hMRI Tools

MPM ESTATICS

SUIT

Pre-processing

Tensor fitting

FA-FVBS options

EC and Motion Correction

EC and Motion Correction multi targets

Write EC and Motion corrected Images

Show movie of DWI images

read-write nifti

Make Brain Mask

Resample to dimension

Combines repetitions

Choose EC and Motion correction method

Choose HySCO options

Choose POAS options

18:04:08 - 26/09/2017

.....done

PMSK=spm_se

AMSK=ACID_r

figure;imag

figure;imag

mSb0=mean(Al

mSb0=mean(Al

mSb0=mean(Al

mSb0=mean(Al

mSb0*0.05

mSb0*0.14

%-- 26.09.17,

spm12 mispl

MATLAB Batch System

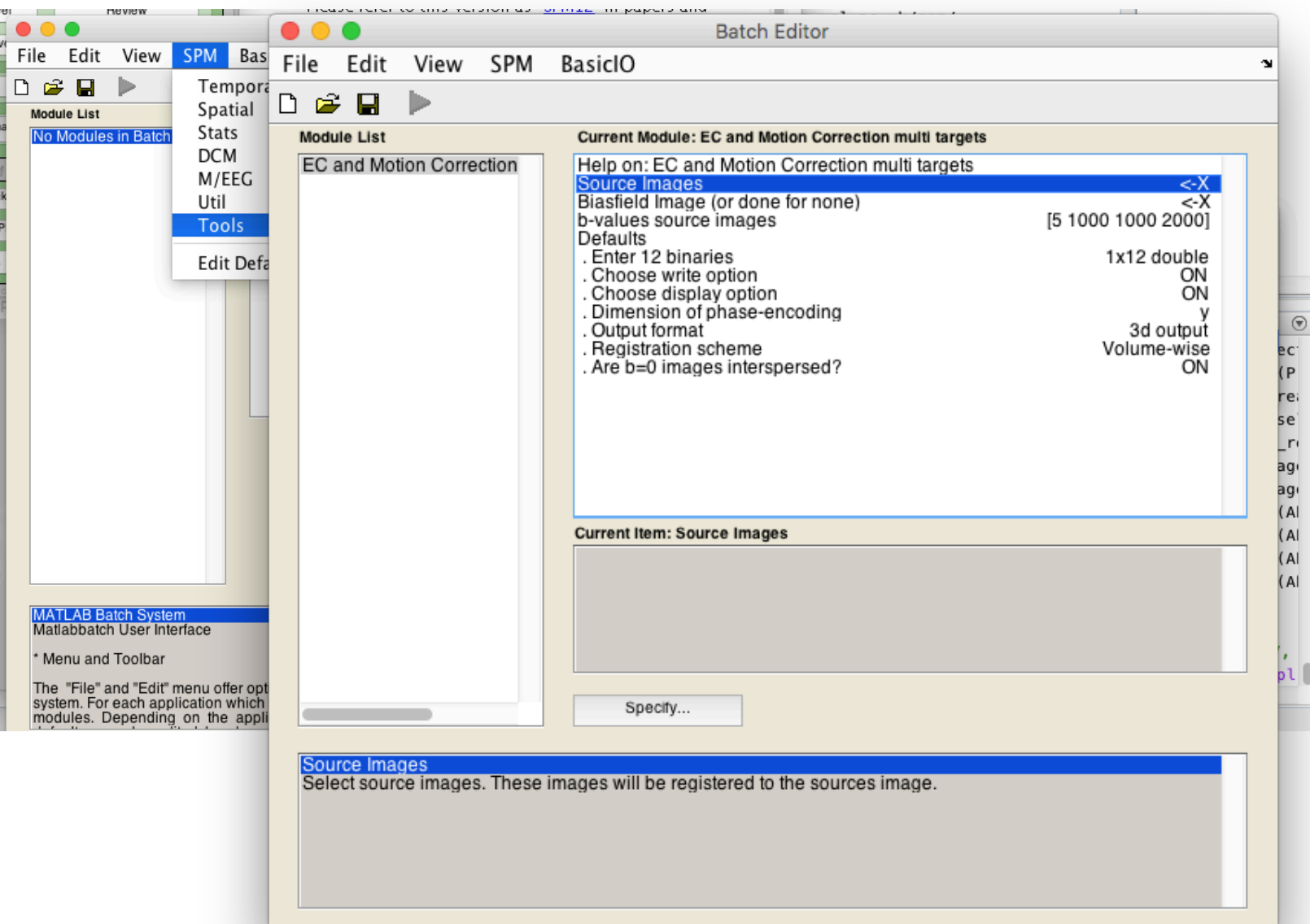
Matlabbatch User Interface

* Menu and Toolbar

The "File" and "Edit" menu offer options to load, save and run a job and to modify the configuration of the batch system. For each application which is known to the batch system, a separate pulldown menu lists the available modules. Depending on the application, these modules may be grouped into submenus. Application specific



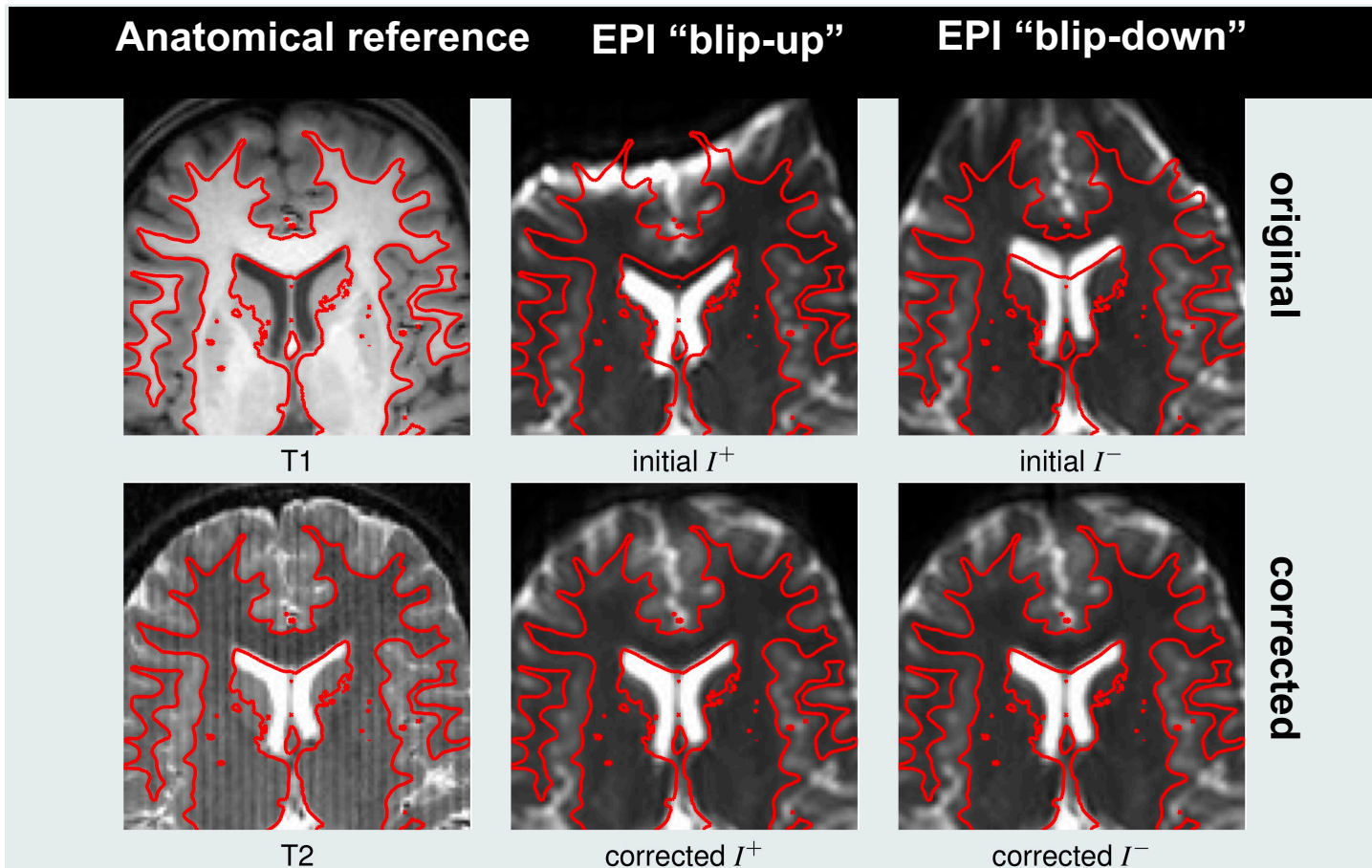
Eddy current and motion correction toolbox



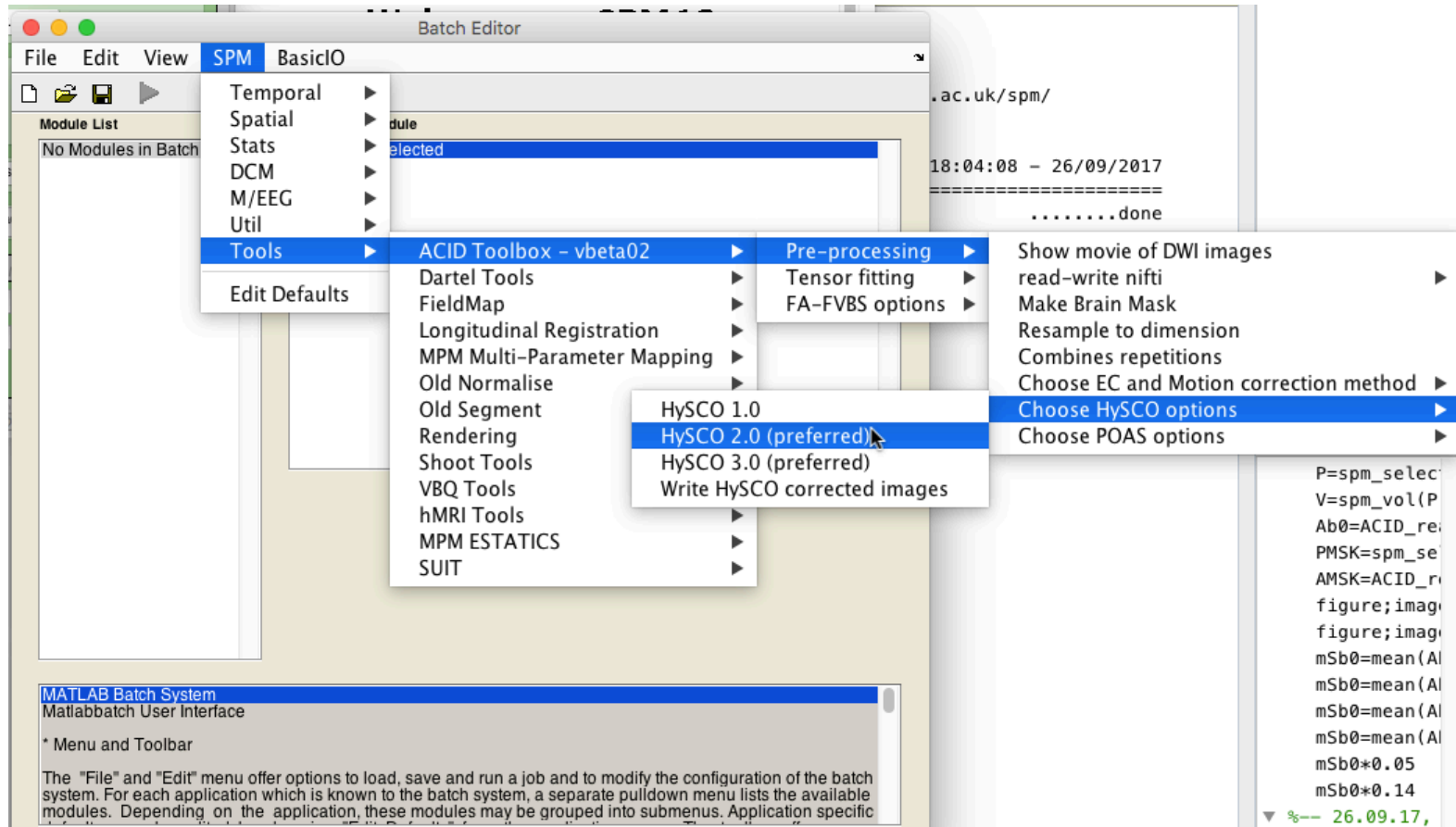
- Diffusion MRI: why, how, and what does it mean?
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ACID - HYSCO

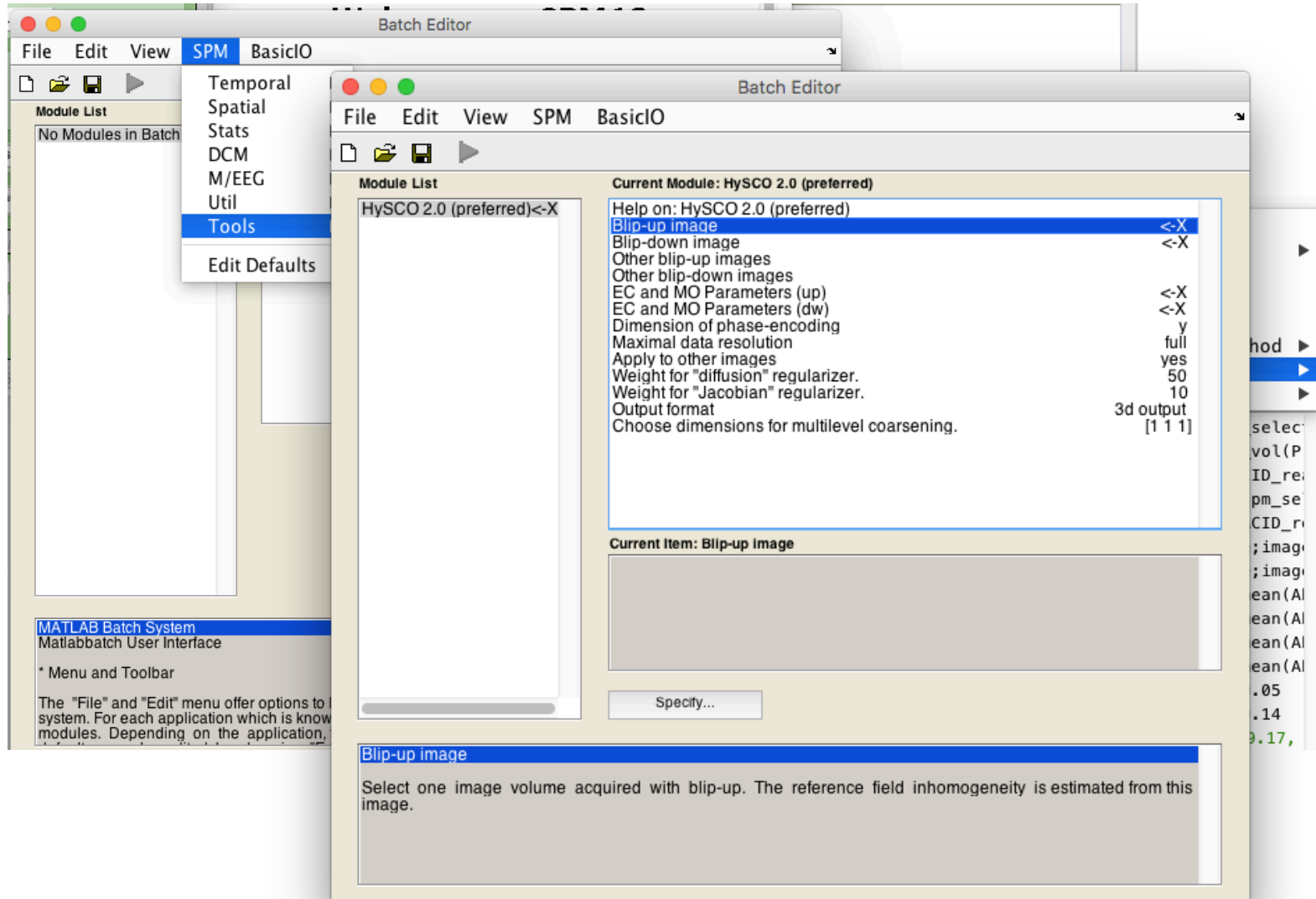
EPI distortion correction



ACID - HYSCO EPI distortion correction



ACID - HYSCO EPI distortion correction



The screenshot displays the MATLAB Batch Editor interface for the HySCO 2.0 module. The interface is divided into several sections:

- File Edit View SPM BasicIO**: The top menu bar.
- Module List**: A list of modules available for the batch, currently showing "HySCO 2.0 (preferred)<-X".
- Current Module: HySCO 2.0 (preferred)**: The configuration panel for the selected module.
 - Help on: HySCO 2.0 (preferred)**: A list of parameters and their values:
 - Blip-up image: <-X
 - Blip-down image: <-X
 - Other blip-up images: <-X
 - Other blip-down images: <-X
 - EC and MO Parameters (up): <-X
 - EC and MO Parameters (dw): <-X
 - Dimension of phase-encoding: y
 - Maximal data resolution: full
 - Apply to other images: yes
 - Weight for "diffusion" regularizer: 50
 - Weight for "Jacobian" regularizer: 10
 - Output format: 3d output
 - Choose dimensions for multilevel coarsening: [1 1 1]
 - Current Item: Blip-up image**: A text area for additional configuration or notes.
 - Specify...**: A button to specify the input image.
- Blip-up image**: A section with a description: "Select one image volume acquired with blip-up. The reference field inhomogeneity is estimated from this image."

On the right side of the image, a portion of a MATLAB script is visible, showing commands related to image selection and processing:

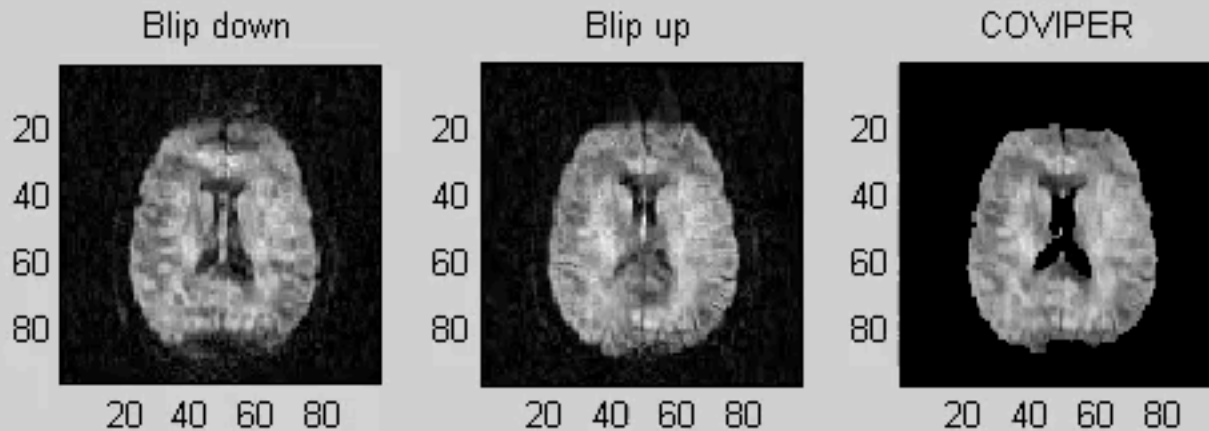
```

select
vol(P
ID_re
pm_se
CID_r
;imag
;imag
ean(Al
ean(Al
ean(Al
.05
.14
9.17,
  
```



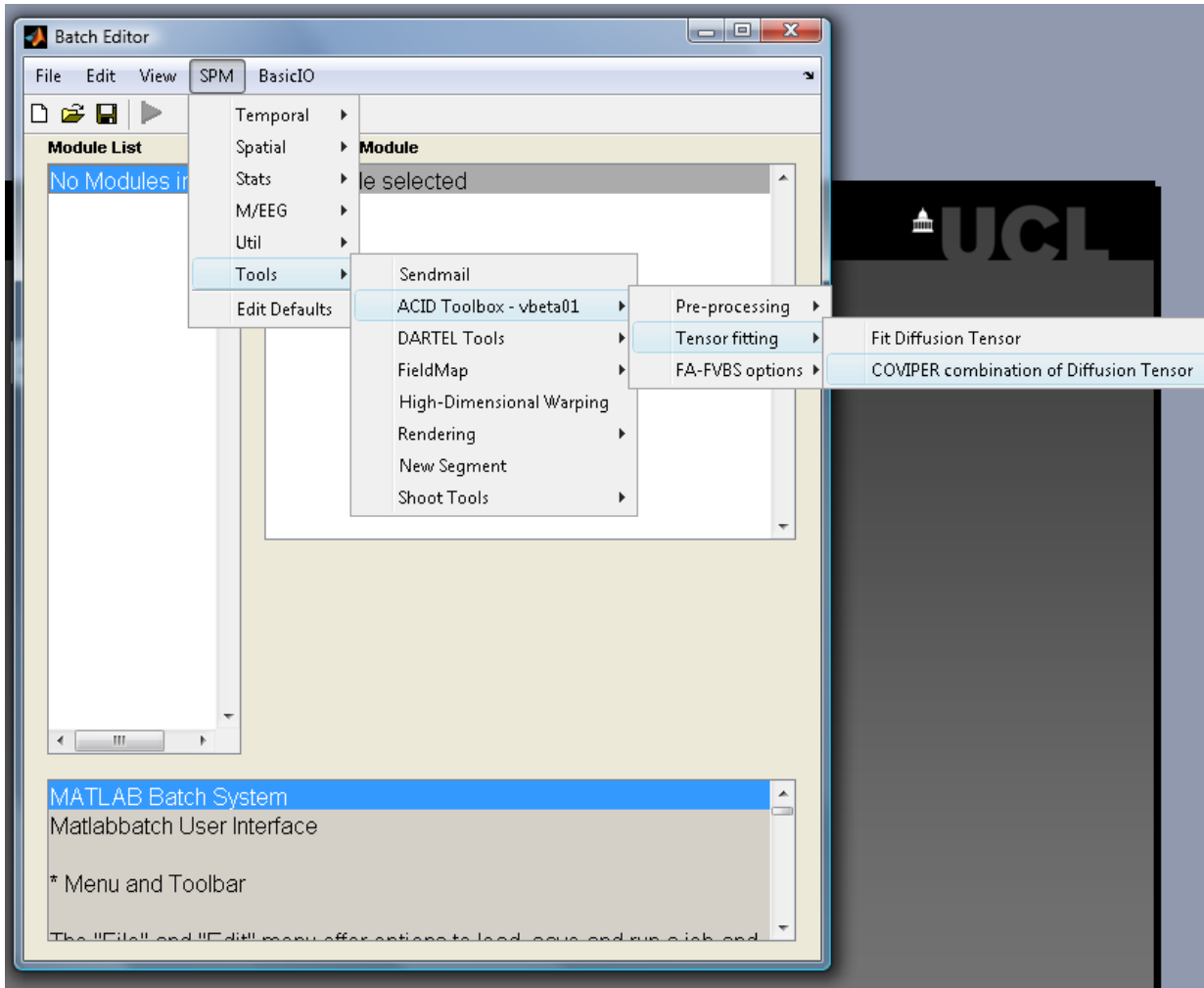
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Vibration artifacts and its correction



**Correction of Vibration Artifacts in DTI
Using Phase-Encoding Reversal
(COVIPER)**

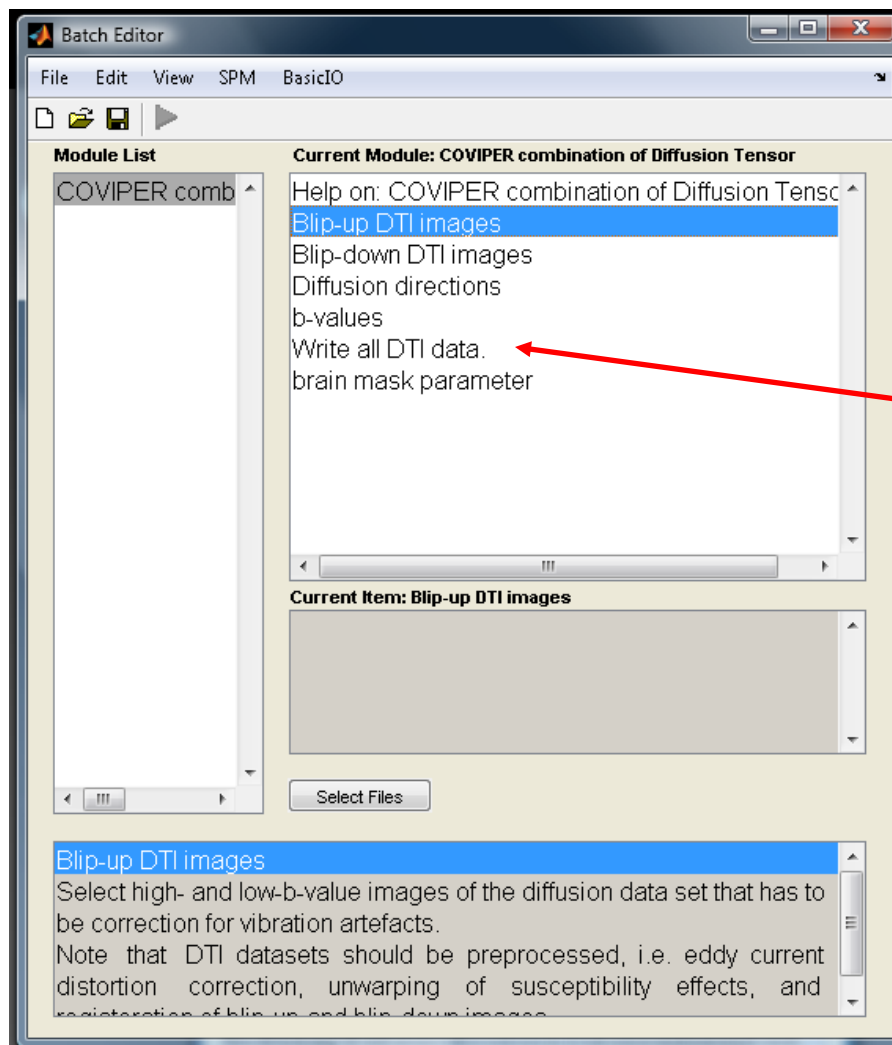
Mohammadi et al., MRM, 2012





ACID-COVIPER tool

Vibration artefacts

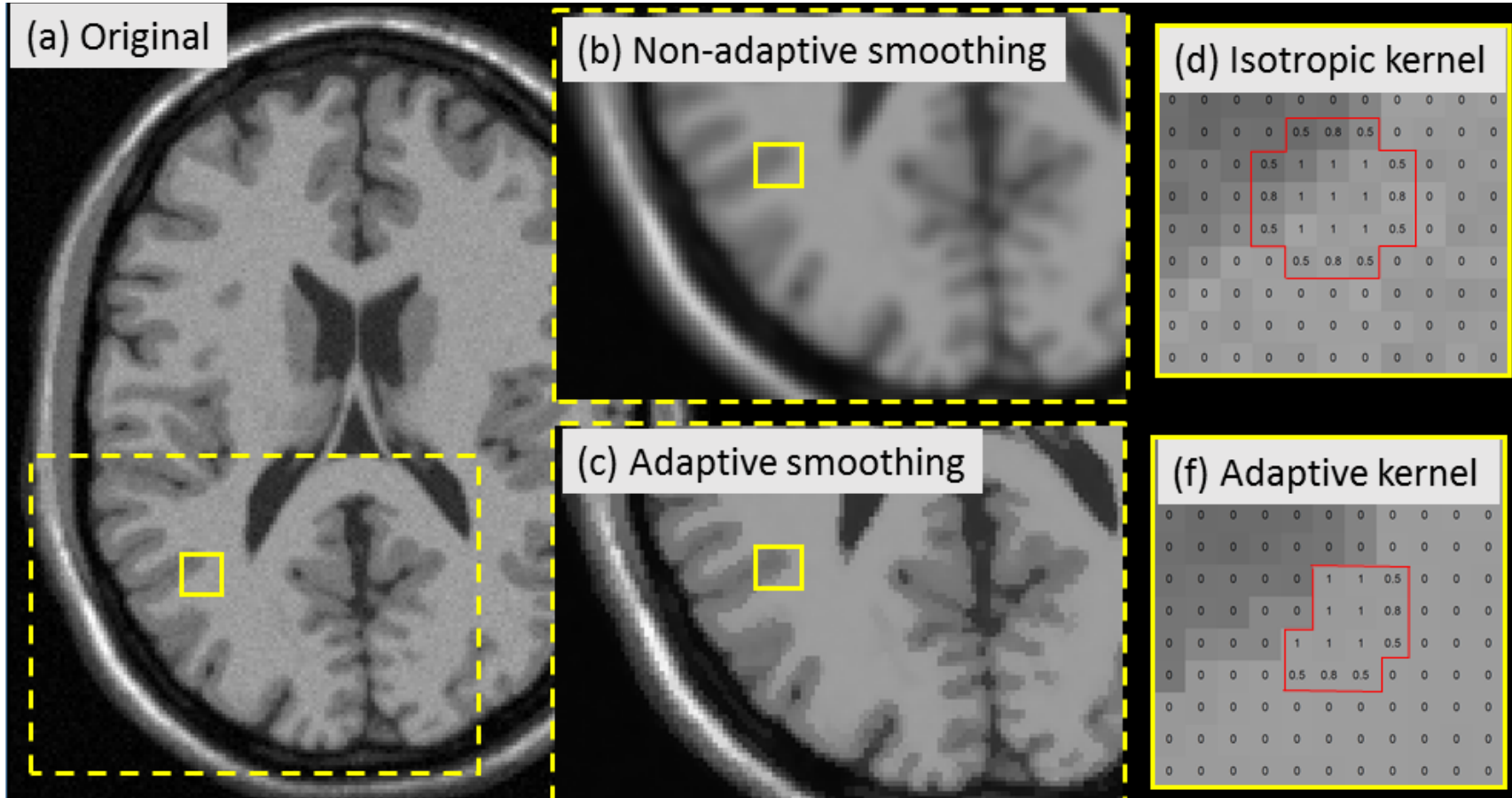


**Corrected DTI
dataset**

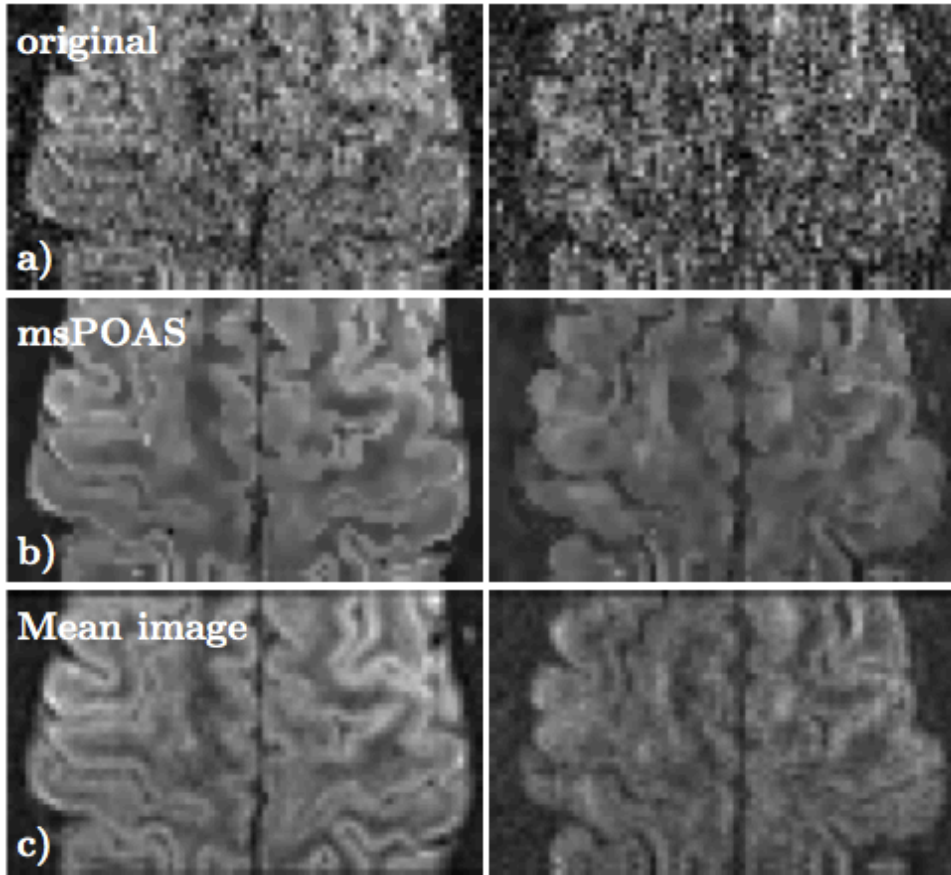


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What is adaptive denoising?

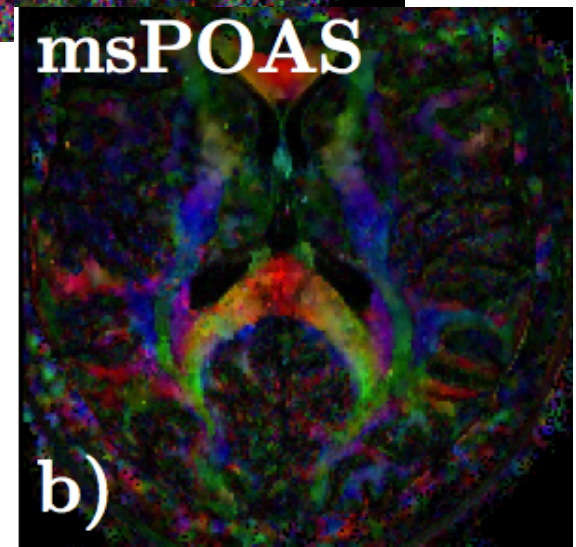
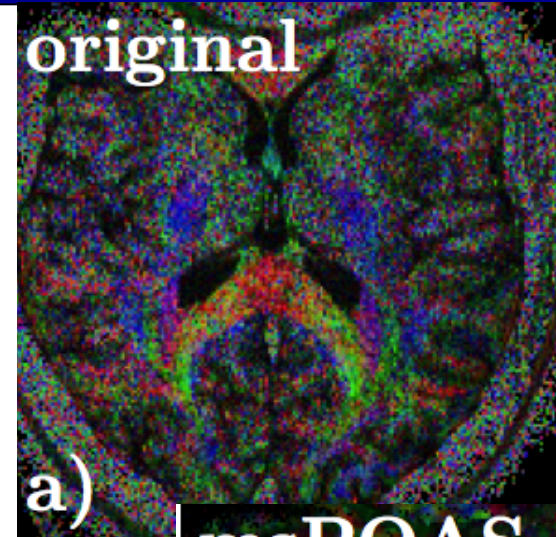
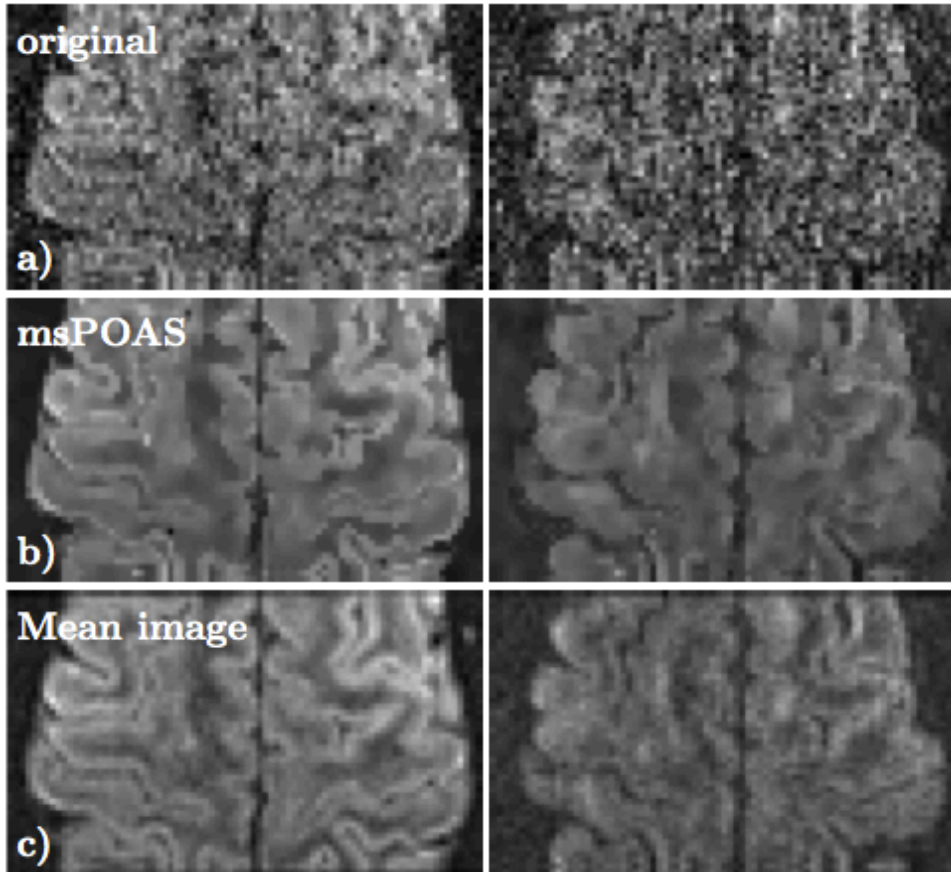


Denoising: multi-shell orientation-position adaptive smoothing (msPOAS)

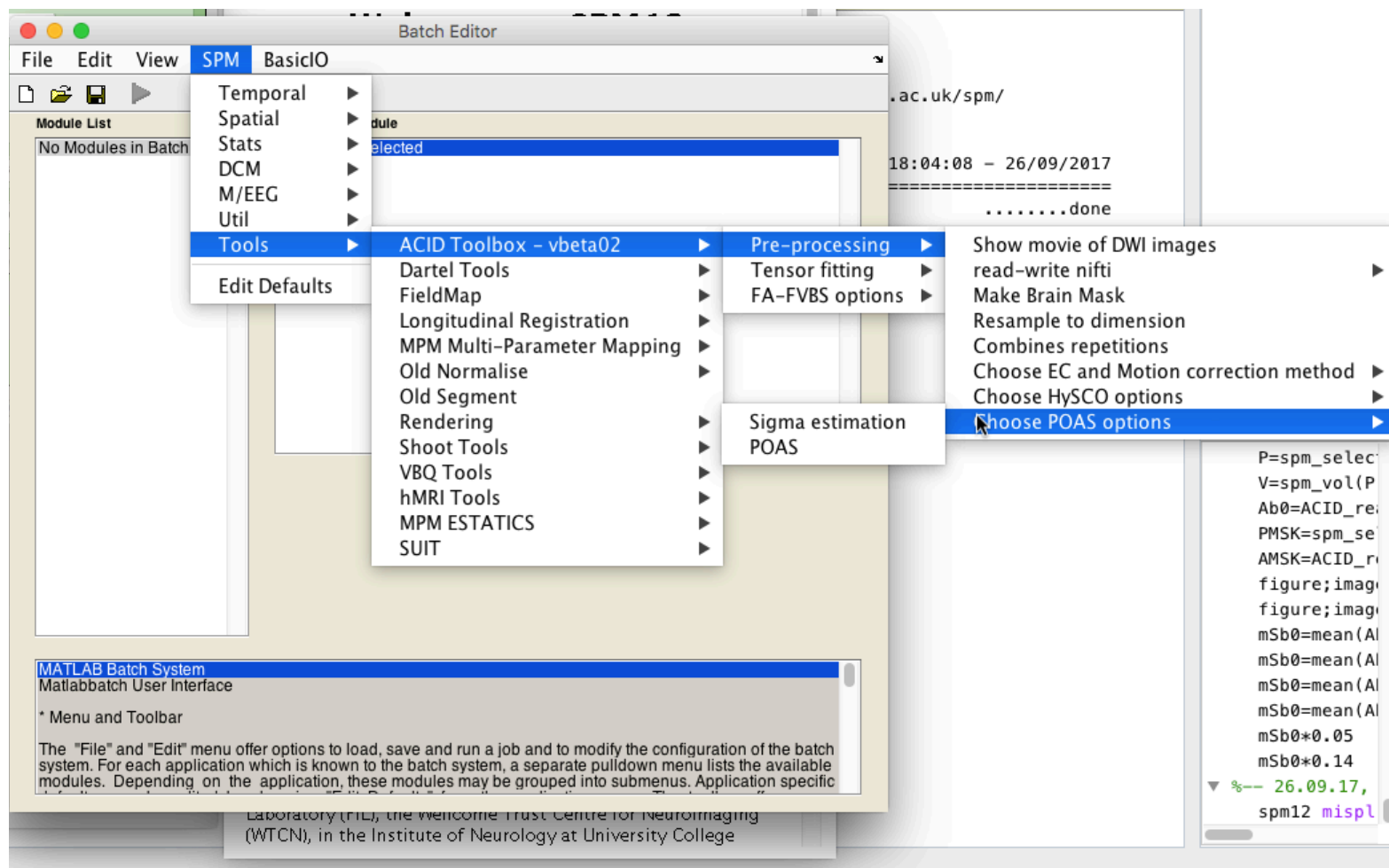


- **Multi-shell dMRI**
- **@1.2 x 1.2 x 1.2 mm³**
- **@ 3T clinical scanner**

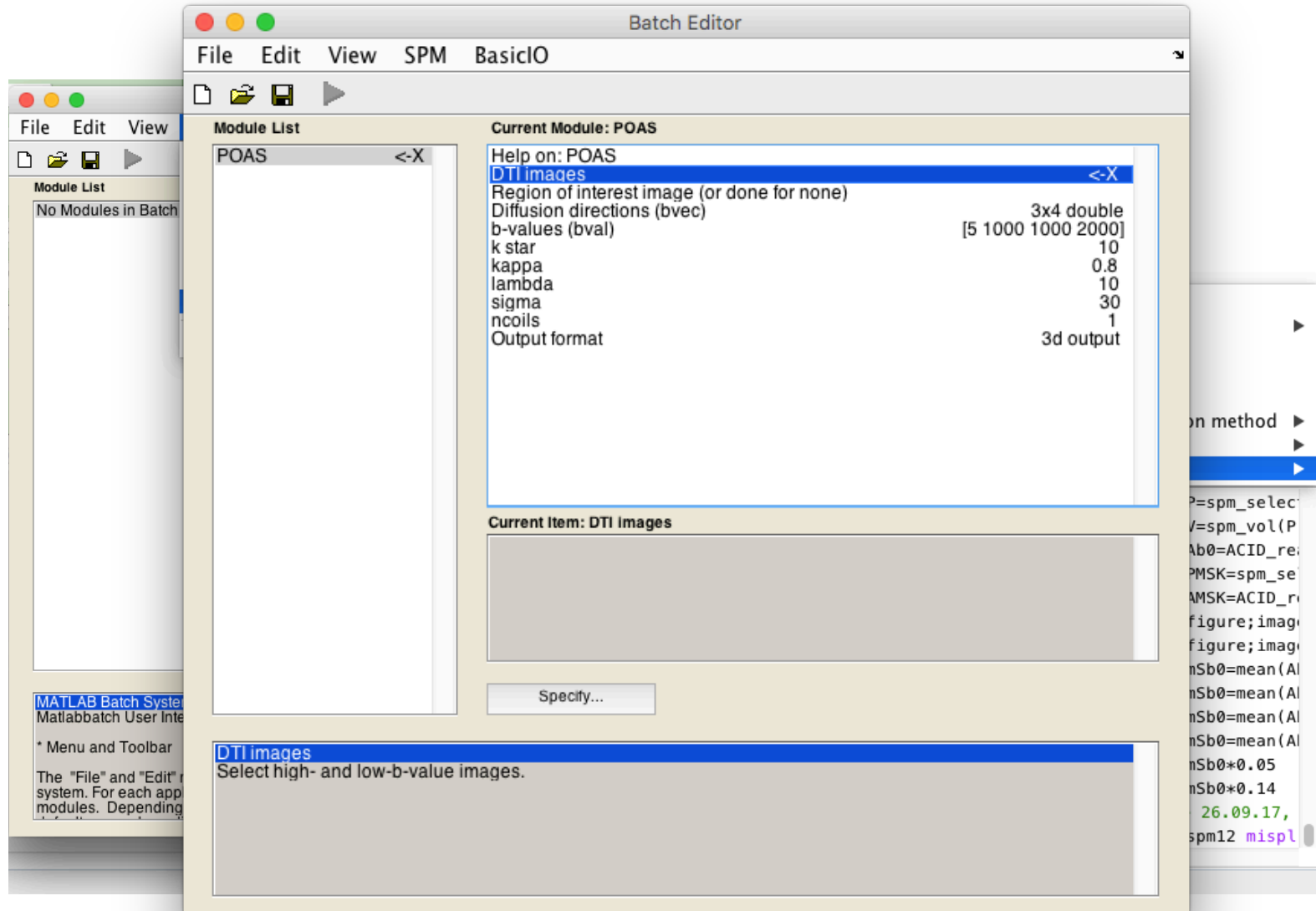
Denoising: multi-shell orientation- position adaptive smoothing (msPOAS)



Denoising: multi-shell orientation- position adaptive smoothing (msPOAS)

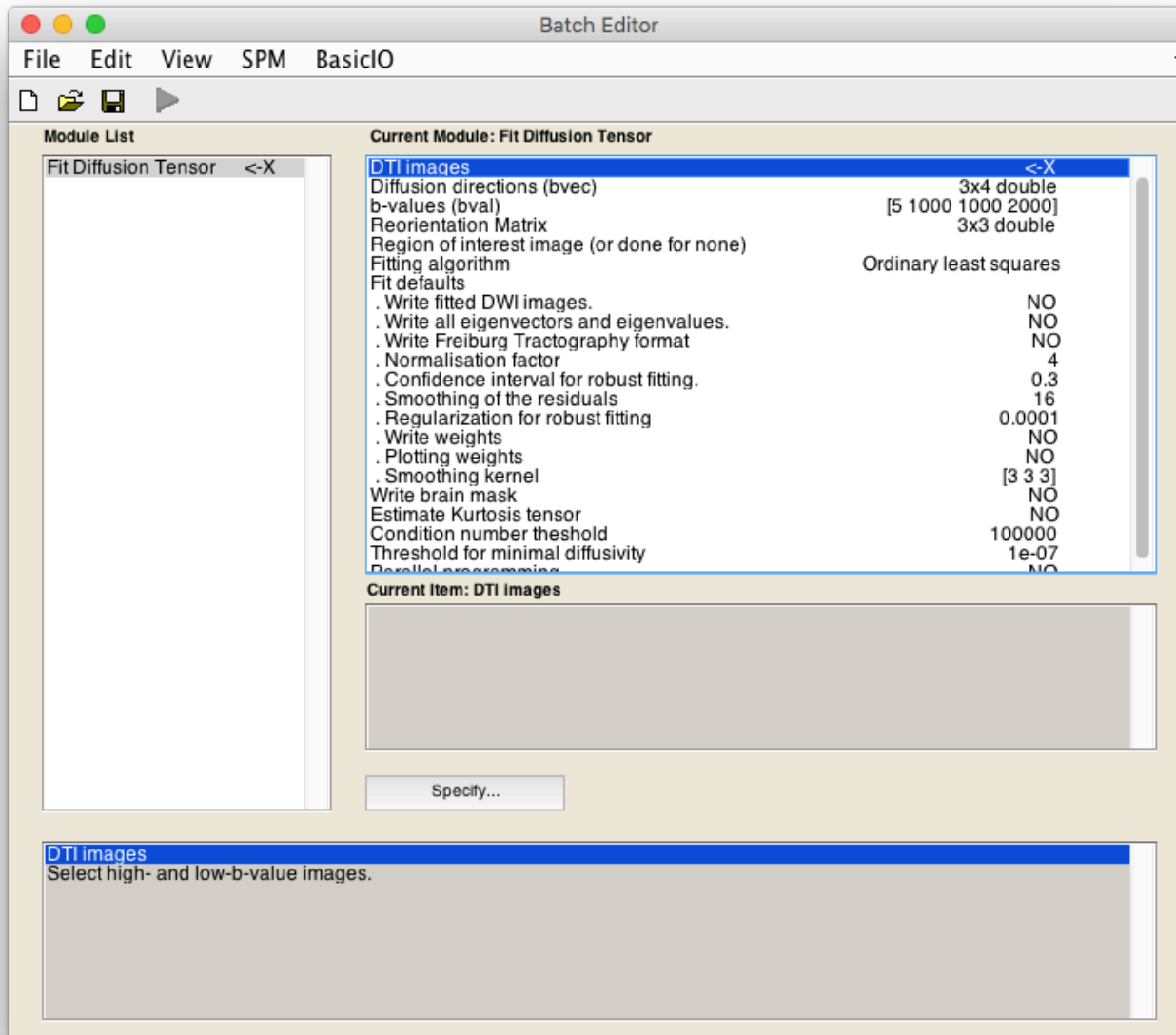


Denoising: multi-shell orientation- position adaptive smoothing (msPOAS)



- The diffusion tensor model in the SPM language
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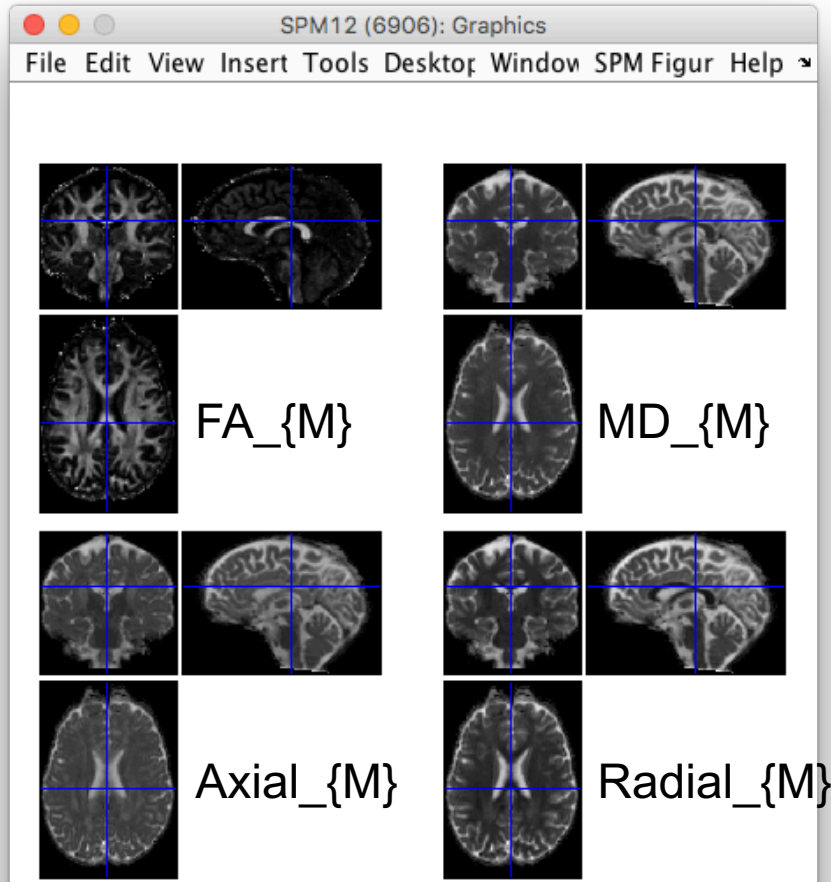
What are the inputs?



Most important

- Diffusoin Data
- b-values
- b-vectors

What are the outputs?



{M} = method:

- ols: ordinary least square
- wls: weighted ordinary least square
- robust: robust fitting
- see *Mohammadi et al., 2012, 2013*

More advanced:

- Tensor fit error: RES_{M}
- Eigenvalues and Eigenvectors
- Output for Freiburg Fibertools (Tractography – contact Marco Reisert / Volkmar Glauche)

Learn more about the DTI metrics:

Basser et al. 1996; Diffusion MRI..., Ed: H Johansen-Berg & TEJ Behrens, 200?

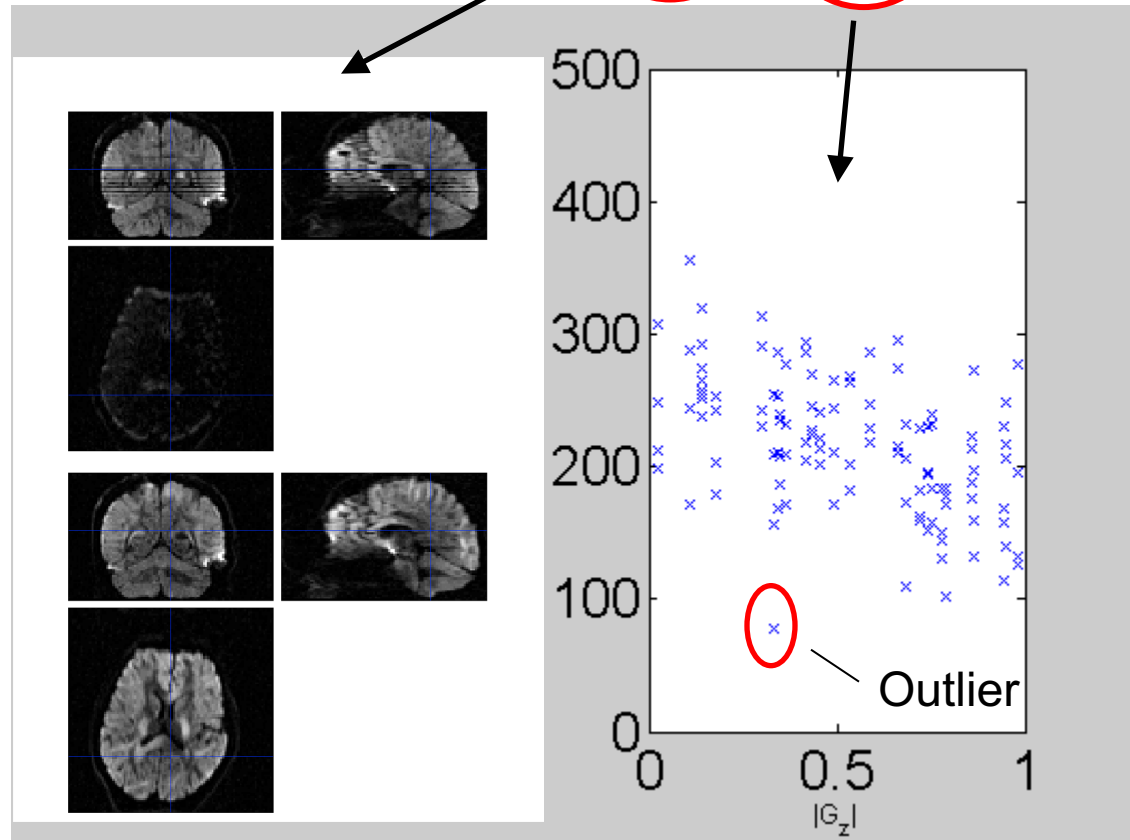
Robust tensor fitting for spinal cord DTI

*Based on Zwiers,
NI, 2010*

$$y = Xd + \varepsilon$$

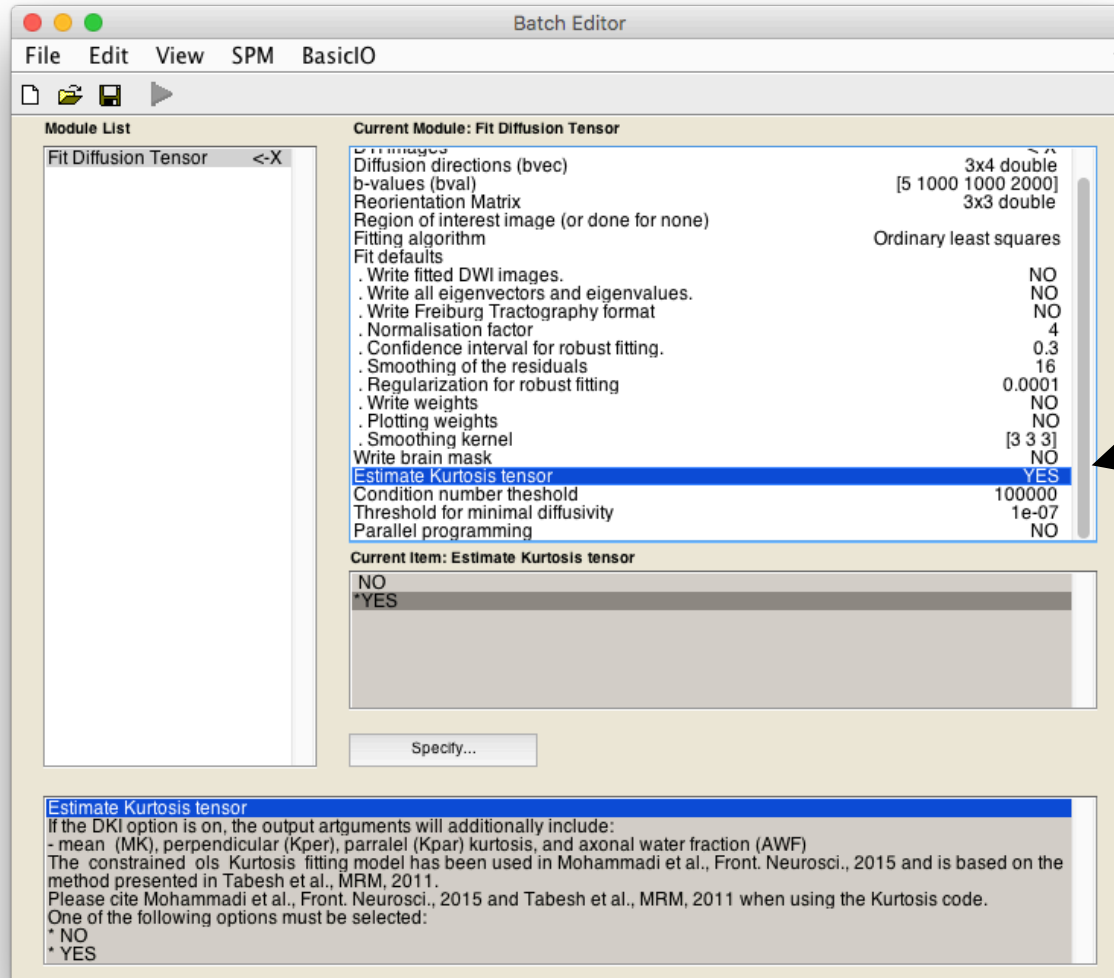
*Mohammadi et al.,
MRM, early view*

$$\omega = \omega_{\text{DWI}} \times \omega_s \times \omega_v$$



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What is the DKI switch?

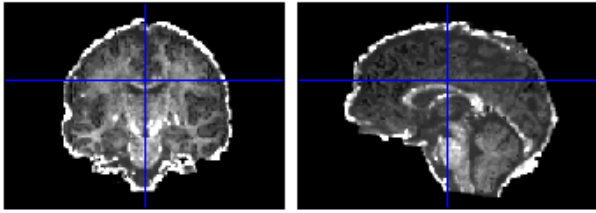


Most important

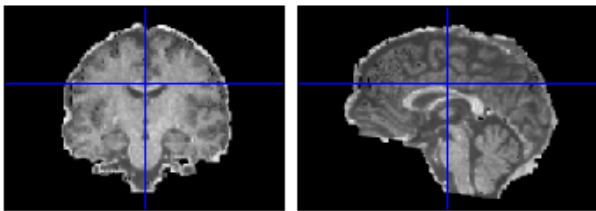
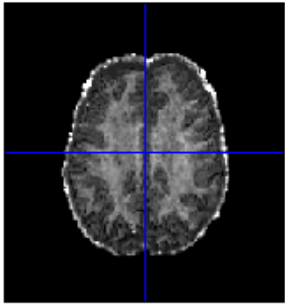
- Diffusion Data
- b-values (multi-shell)
- b-vectors

DKI switch

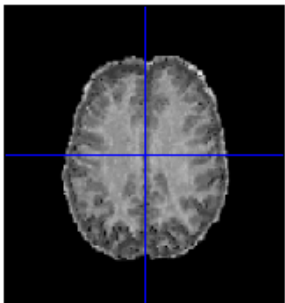
What are the outputs?



MK_ols



AWF_ols



Maps

- MK – mean kurtosis
- AWF – axonal water fraction

Learn more about them:

*Jensen et al., 2010 (review about DKI);
Fieremans et al., 2011 (biophysical
model of AWF)*

*Jelescu et al., 2015 (comparison to
NODDI)*

Learn more about these DKI metrics:
Fieremans et al., NI, 2011