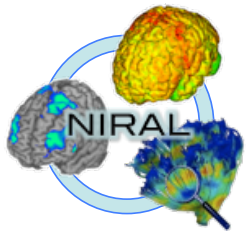
NA-MIC
National Alliance for Medical Image Computing
http://na-mic.org



DTI Atlas Registration via 3D Slicer and DTI-Reg

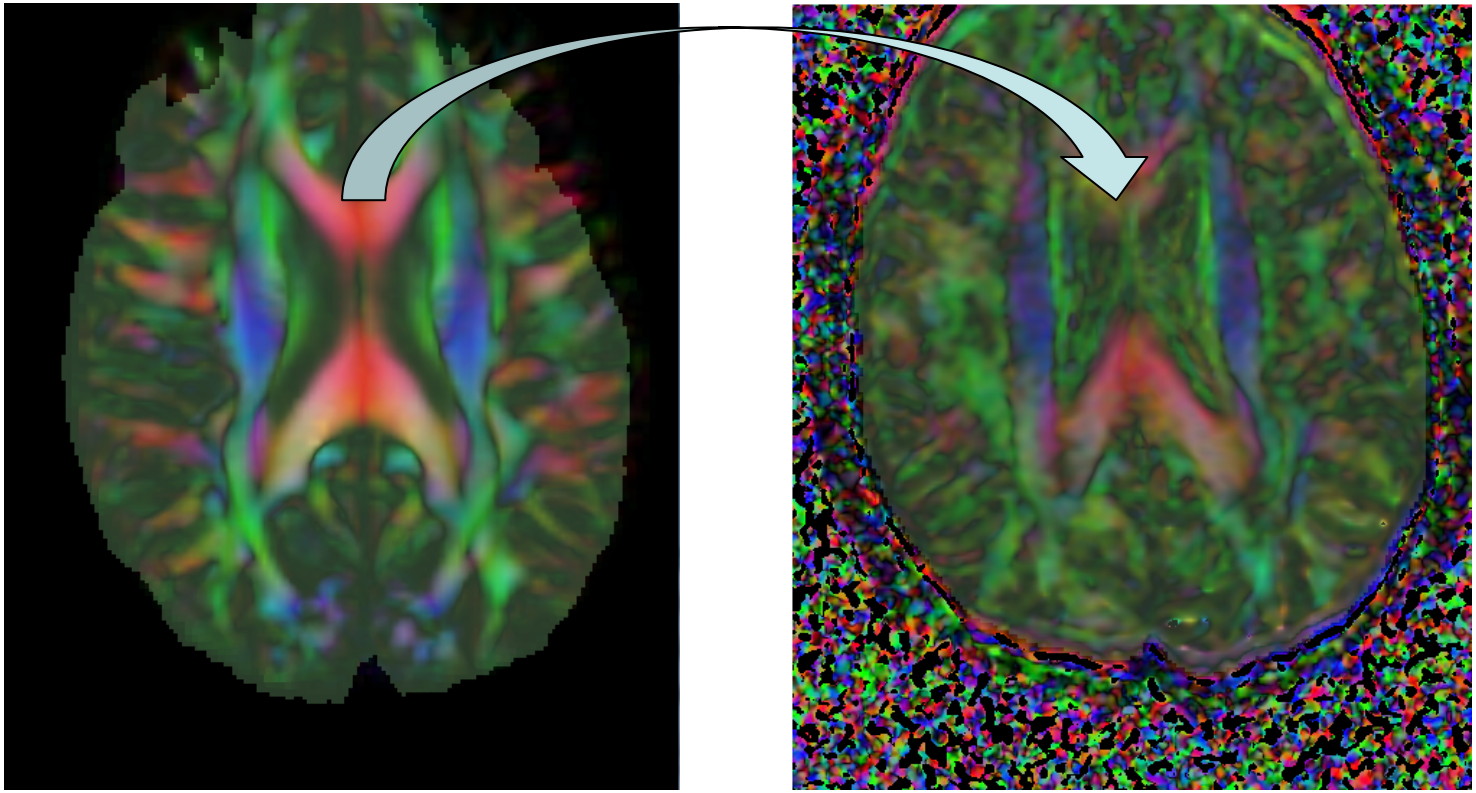
Martin Styner, UNC

Francois Budin, UNC

DTI Registration

- This tutorial teaches you how
  - Load DTI datasets & masks
  - Perform a pair-wise registration to a prior atlas via DTI-Reg
    - Affine transform and deformable transform
  - Save the transformed images and the deformable transform

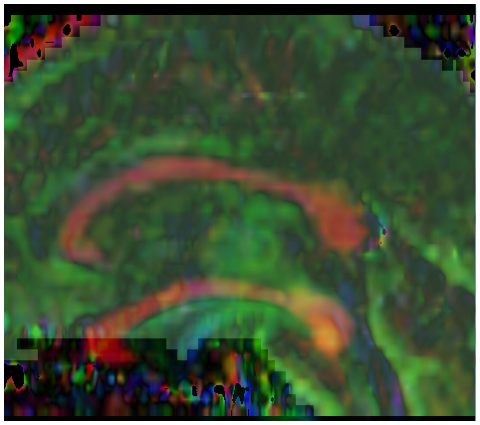
Concept of Registration



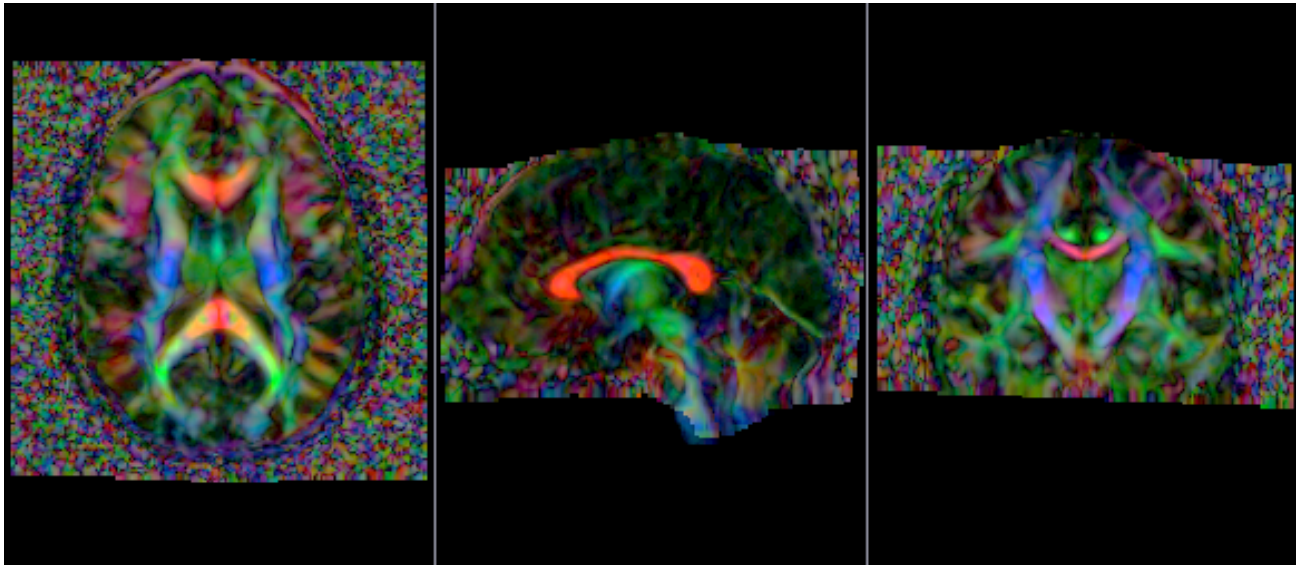
Combining information from multiple images requires the geometric relationship between them to be known...

Concept of Registration: Overlay of pair of images

misaligned

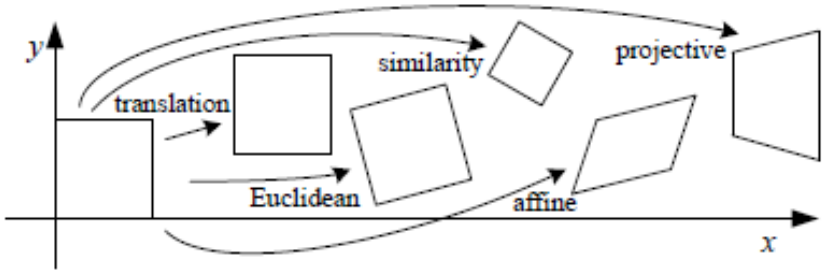


aligned



Transformation for Image Registration

Choice of transformations (complexity of transformation, #degrees of freedom depends on application).



Transformation	Matrix	# DoF	Preserves	Icon
translation	$\left[\begin{array}{c\|c} \boldsymbol{I} & \boldsymbol{t} \end{array}\right]_{3\times4}$	3	orientation	
rigid (Euclidean)	$\left[\begin{array}{c\|c} \boldsymbol{R} & \boldsymbol{t} \end{array}\right]_{3\times4}$	6	lengths	
similarity	$\left[\begin{array}{c\|c} s\boldsymbol{R} & \boldsymbol{t} \end{array}\right]_{3\times4}$	7	angles	
affine	$\left[\begin{array}{c} \boldsymbol{A} \end{array}\right]_{3\times4}$	12	parallelism	
projective	$\left[\begin{array}{c} \tilde{\boldsymbol{H}} \end{array}\right]_{4\times4}$	15	straight lines	

credit: R. Szelisky, Computer Vision

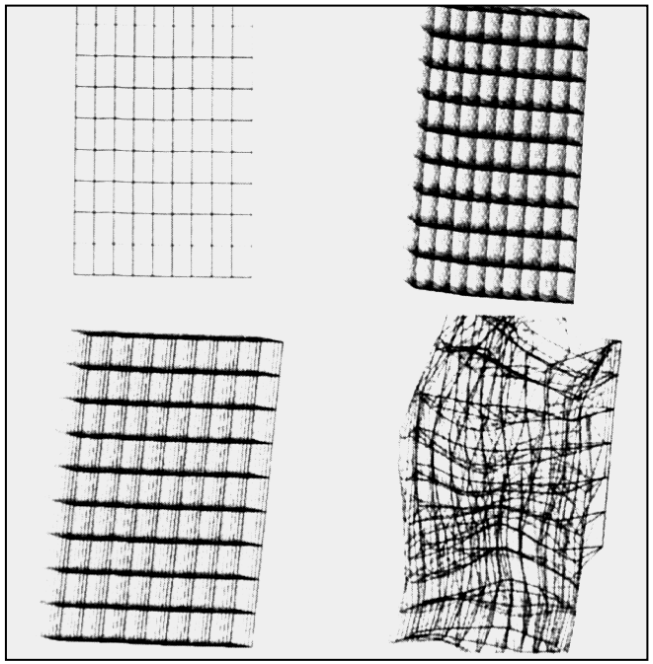
3D Transformations

Linear Transformations (invertible, low DOF):

Translation (3 DOF) $x' = \begin{bmatrix} I & t \end{bmatrix} \bar{x}$

Rigid:
Trans & Rot (6 DOF): $x' = \begin{bmatrix} R & t \end{bmatrix} \bar{x}$

Affine (12 DOF) $x' = \begin{bmatrix} a_{00} & a_{01} & a_{02} & a_{03} \\ a_{10} & a_{11} & a_{12} & a_{13} \\ a_{20} & a_{21} & a_{22} & a_{23} \end{bmatrix} \bar{x}$

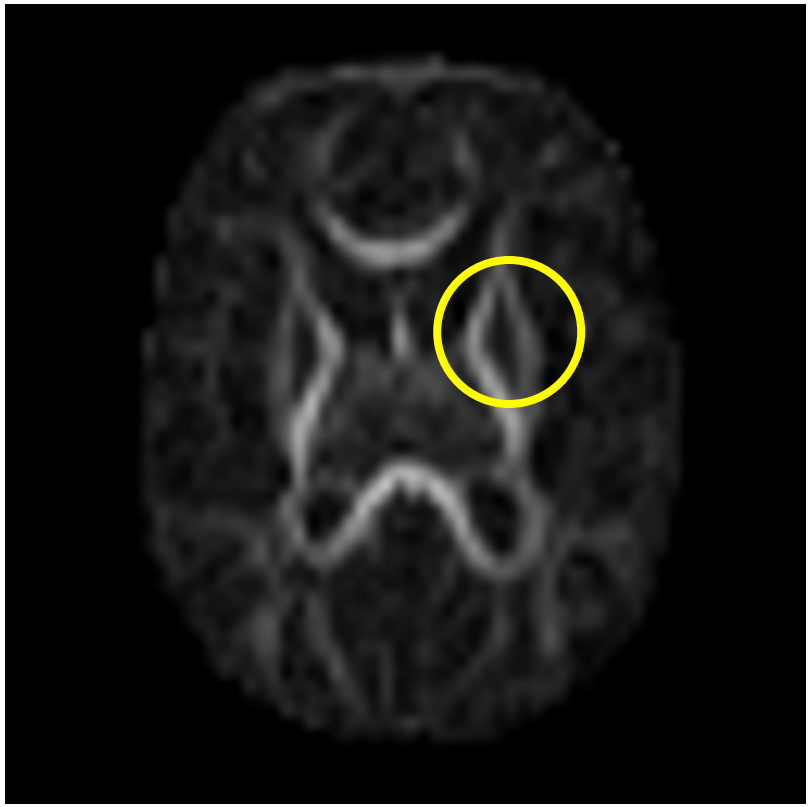


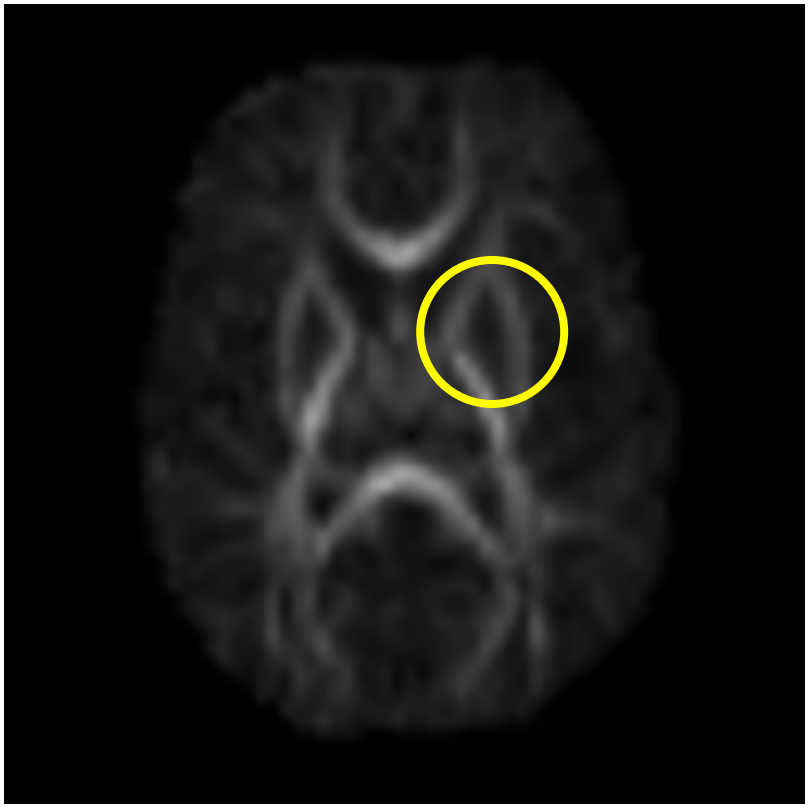
Nonlinear, deformable transformations (high DOF):

B-spline (deformable, grid of control points)

Diffeomorphic (highly deformable, smooth transformation, invertible)

Co-registration: From linear to nonlinear



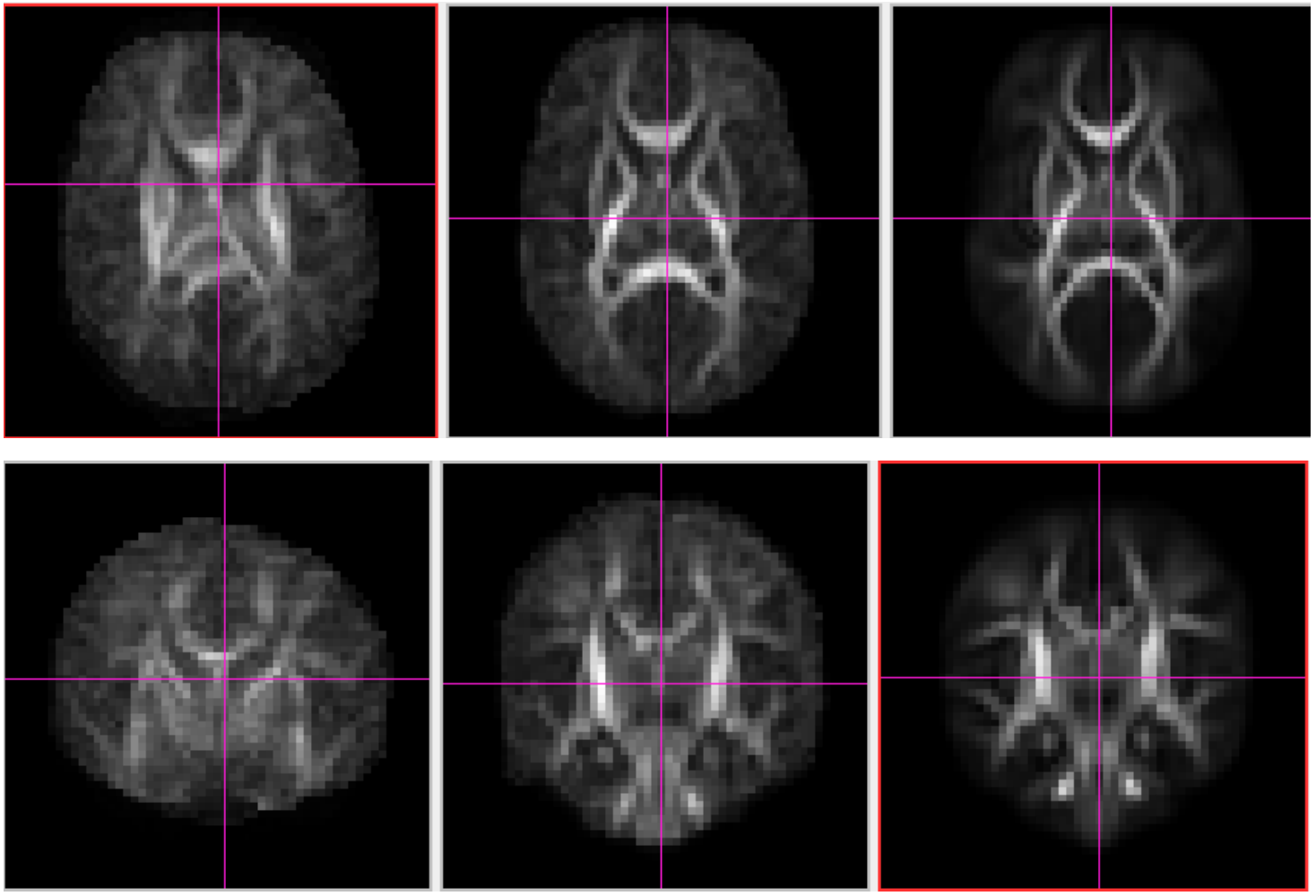


Linear registration (affine)

Nonlinear registration (diffeom.)

Example: Registration of DTI to atlas template

Atlas Building: Averaging registred FA images

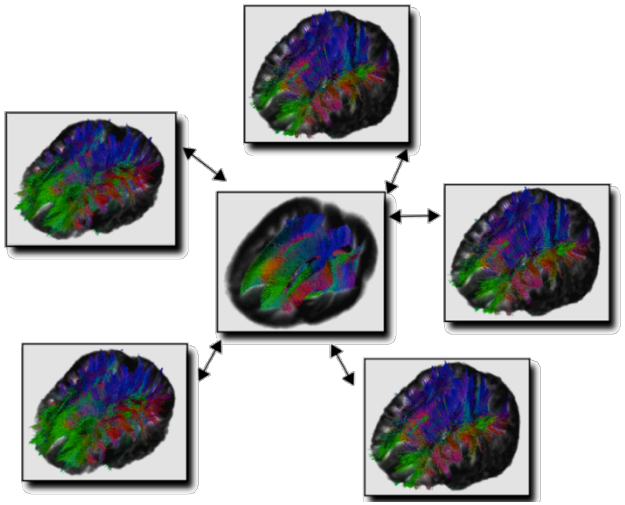


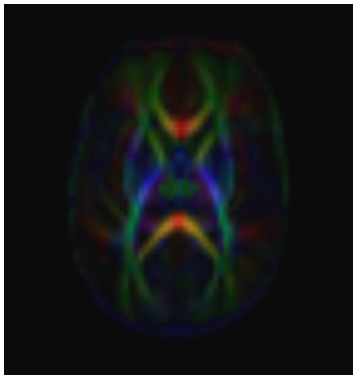
raw linear nonlinear

Quality (sharpness) of atlas improves with deformable transformations.

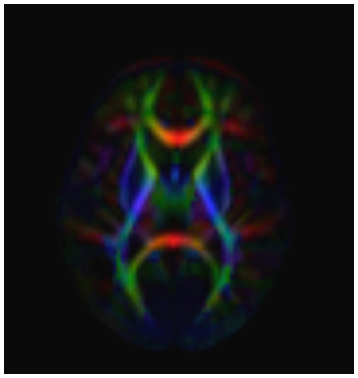
DTI Population Atlases

- Definition of standard, normative space
- Templates to become available to researchers

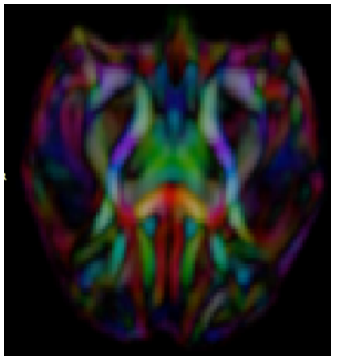




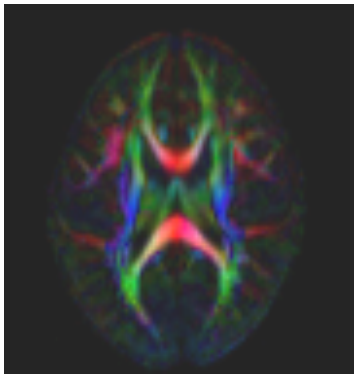
Neonate



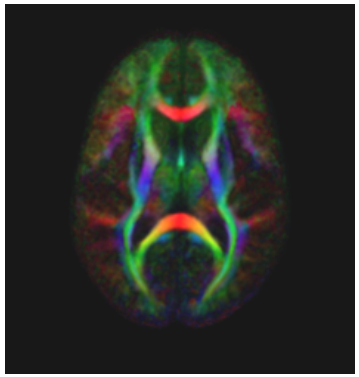
1 year



Rhesus (15mo)

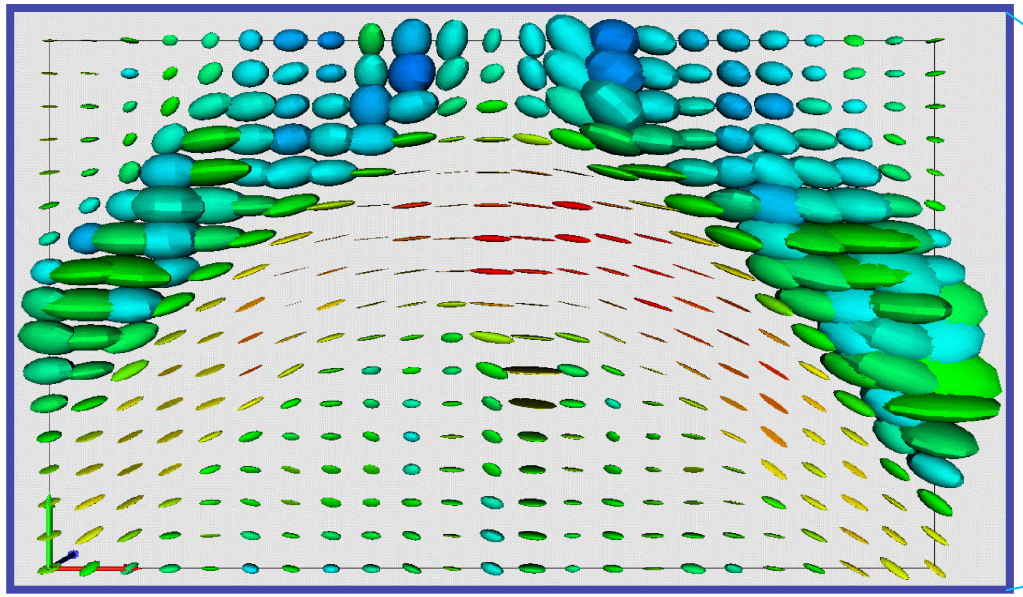


2 year



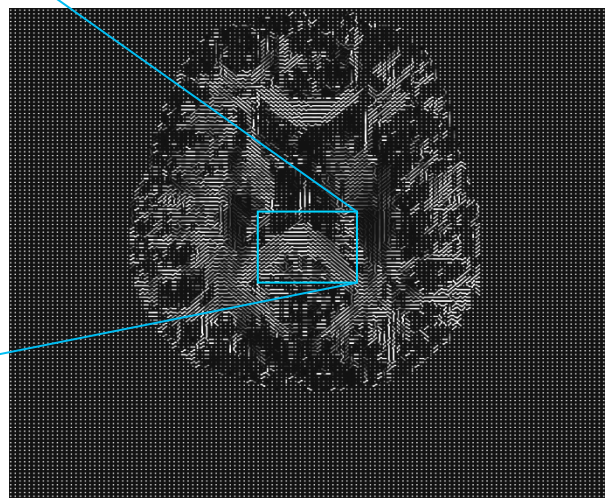
Adult

Spatial Transformations of Diffusion Tensors



Warmer colors indicate higher anisotropy

Principal diffusion directions in anisotropic regions of a DT-MR image slice



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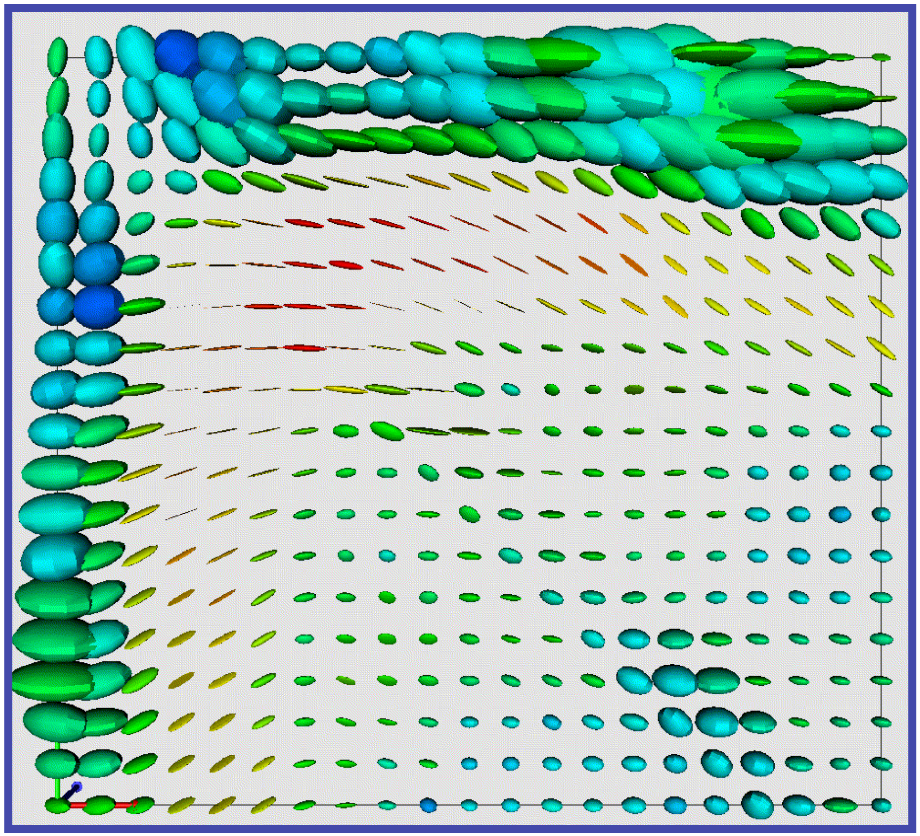
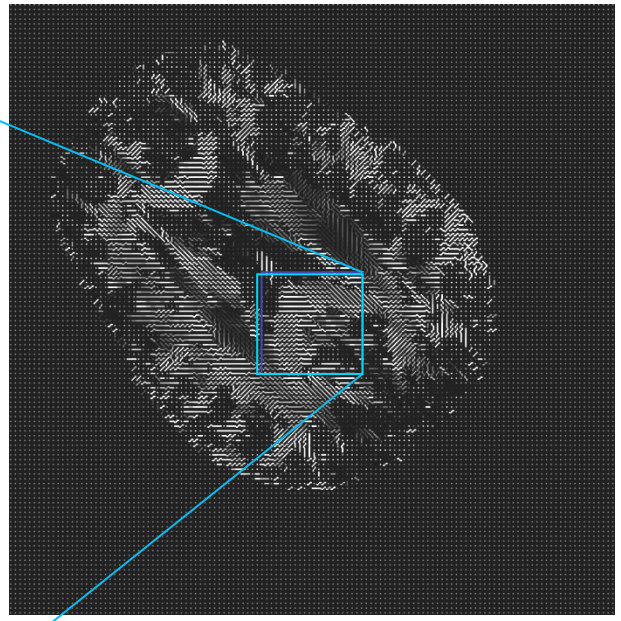
University of Pennsylvania

Rotation without DT Reorientation: Transform voxel grid, leave tensors





- Directional structure is lost.
- DTs orientations are no longer consistent with the anatomical structure of the image.

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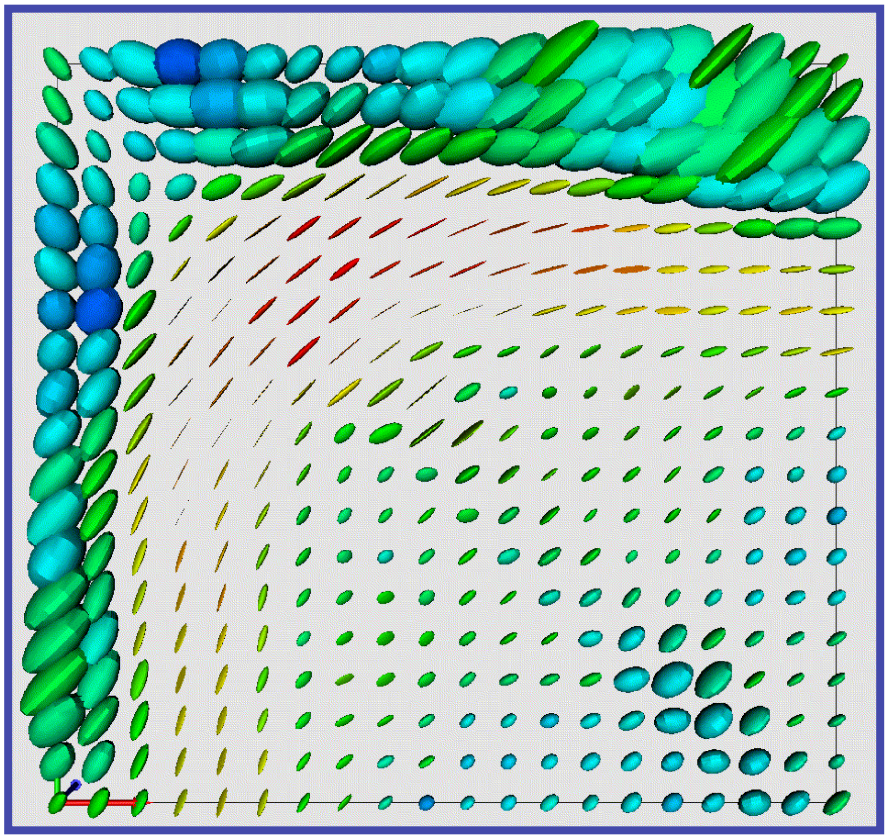
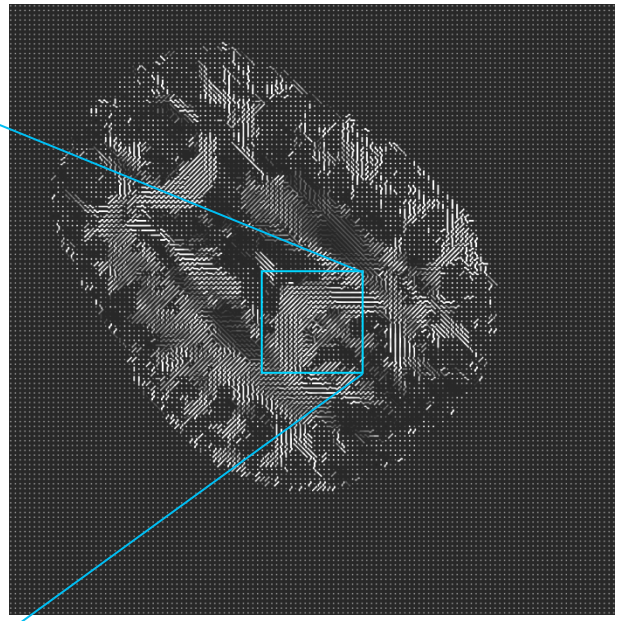
University of Pennsylvania

Rotation with DT Reorientation





- $D \rightarrow R \cdot D \cdot R^{T}$.
- Directional structure preserved.
- DTs orientations remain consistent with the anatomy.

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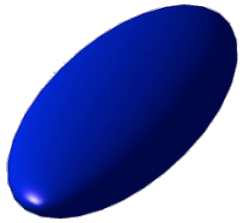
Affine Tensor Transformations
(*Alexander et al, MICCAI 1999)*

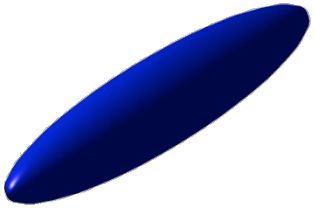
Original Tensor

Transformed Tensor



$D \rightarrow F \cdot D \cdot F^{T}$

- We wish to preserve the shape of the DTs.
- But we must reorient them appropriately.
- Require R that reflects reorientation due to F.



$D \rightarrow R \cdot D \cdot R^{T}$

- For an affine transformation, , $D \rightarrow F \cdot D \cdot F^{T}$?
- No...

Finite Strain Estimation

- Decompose F into:
  - Rigid rotation, R, and
  - Deformation, U:

$$F = R \cdot U$$

$$R = F \cdot (F^{T} \cdot F)^{-1/2}$$

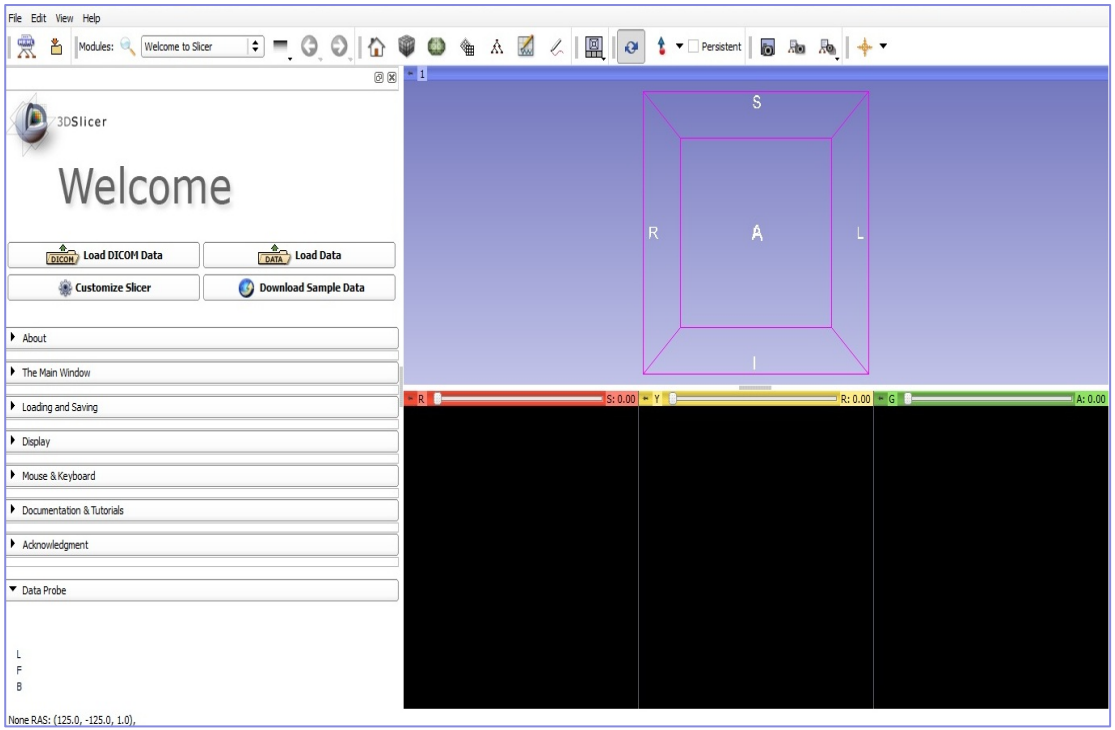
- Then reorient D using R:

$$D' = R \cdot D \cdot R^{T}$$

Dataset

For this tutorial you will need DTI data files that can be found following this link : http://hdl.handle.net/1926/1759

Start Slicer 4



Linux/Mac users :

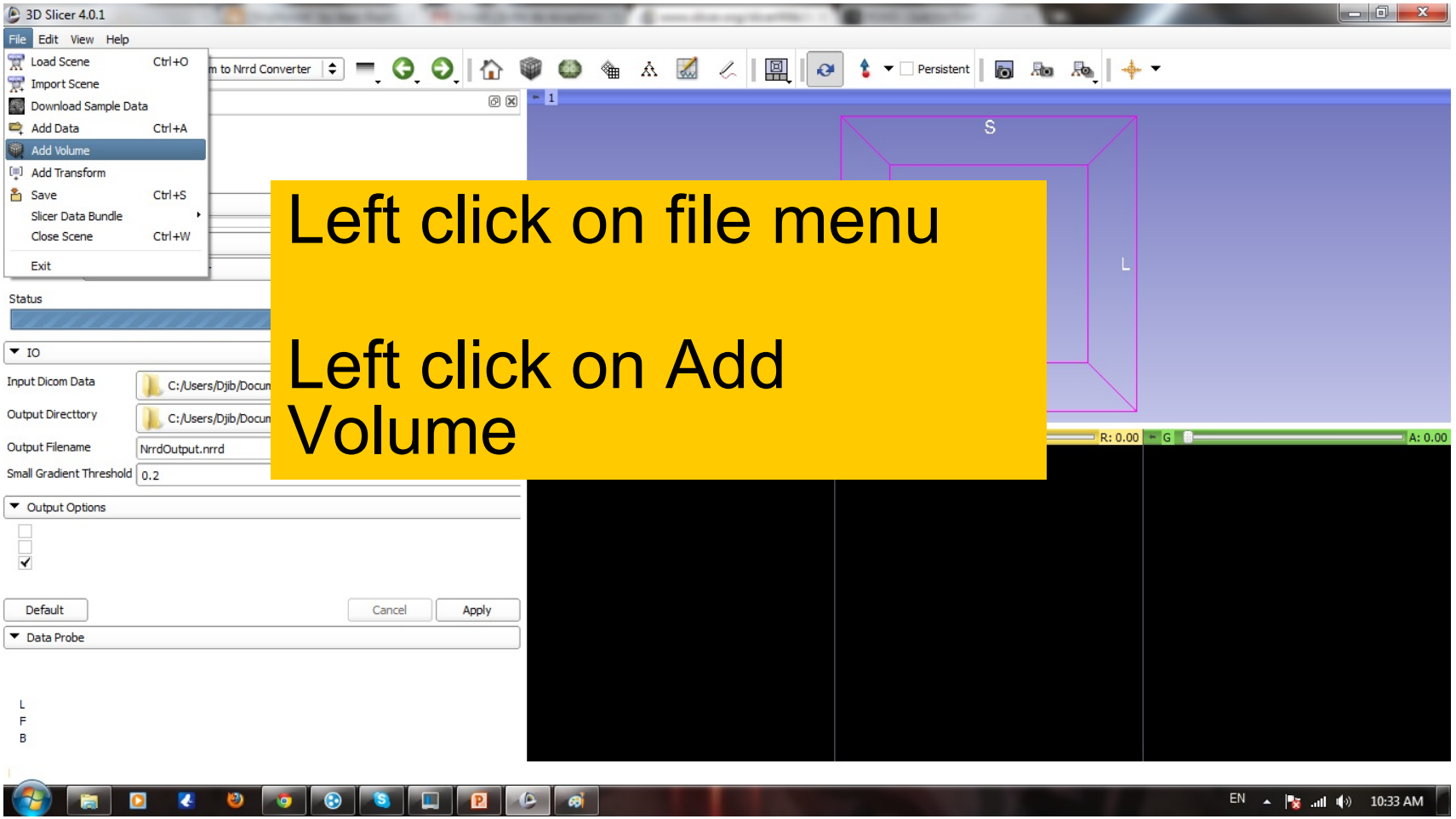
Launch the Slicer executable located in the Slicer4 directory

Windows users :

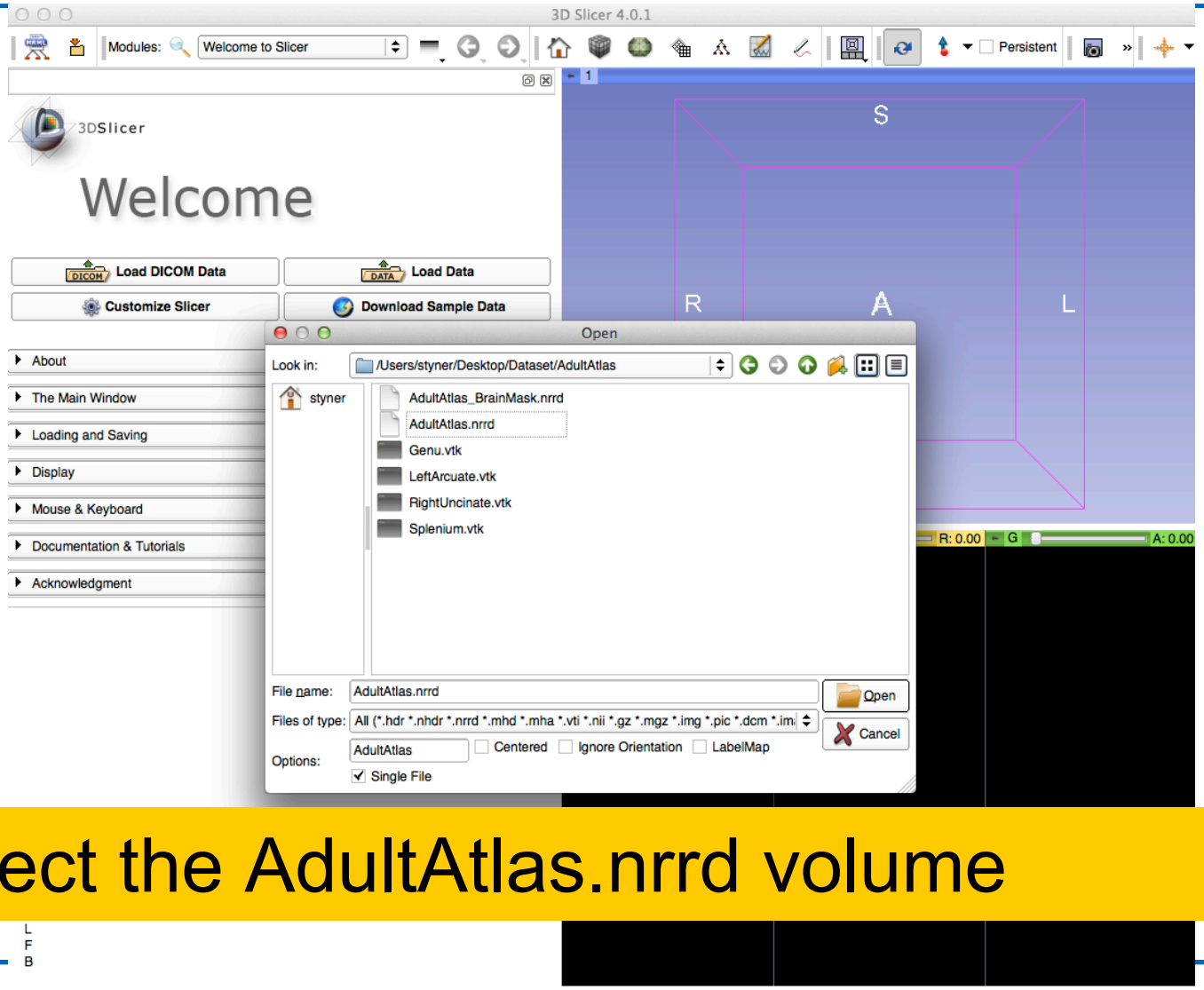
Select Start→All Programs→Slicer4.0.1→Slicer

Or launch the Slicer executable from Slicer4 directory

Loading DTI Atlas

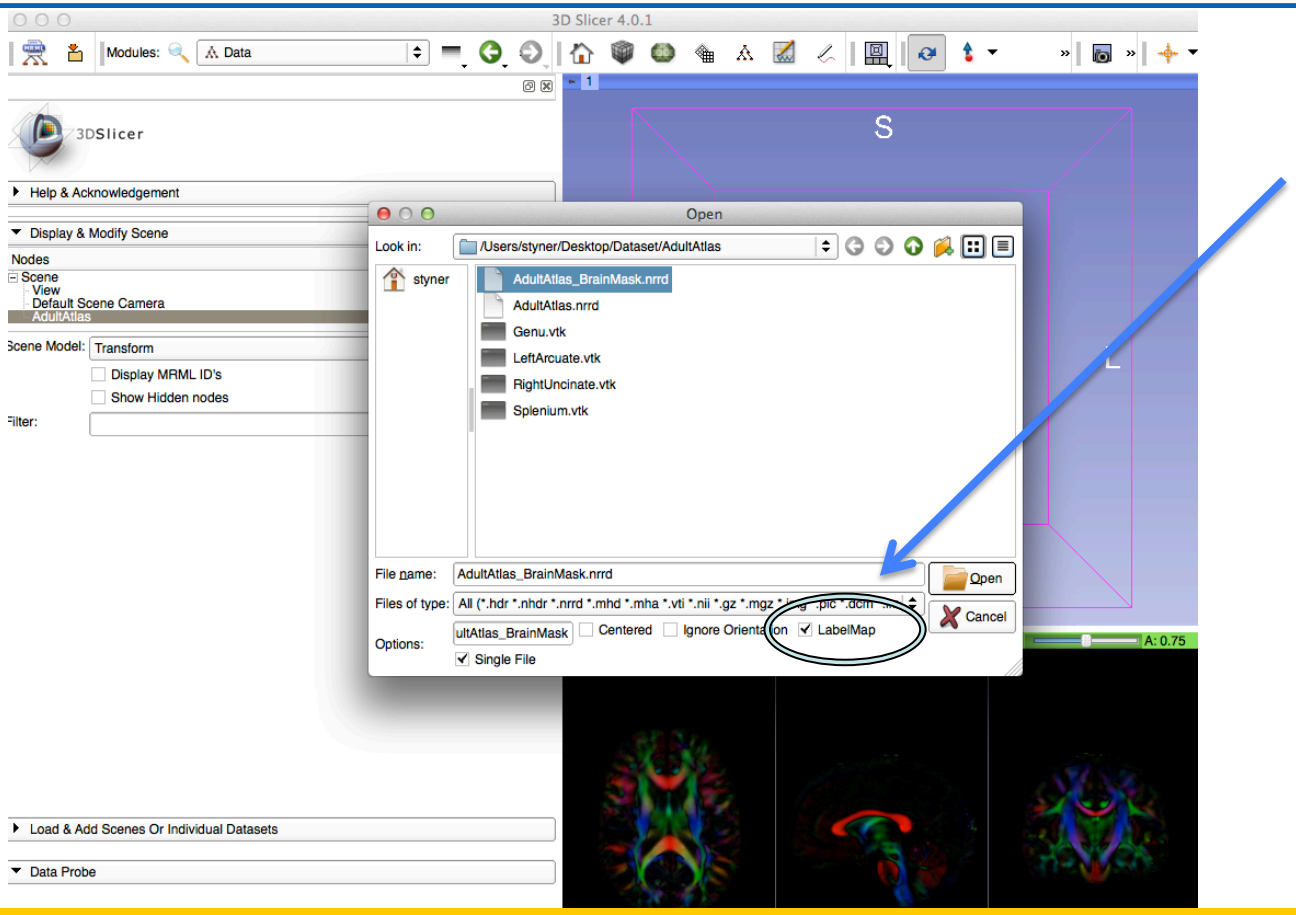


Loading DTI Atlas



Select the AdultAtlas.nrrd volume

Loading DTI Atlas Mask

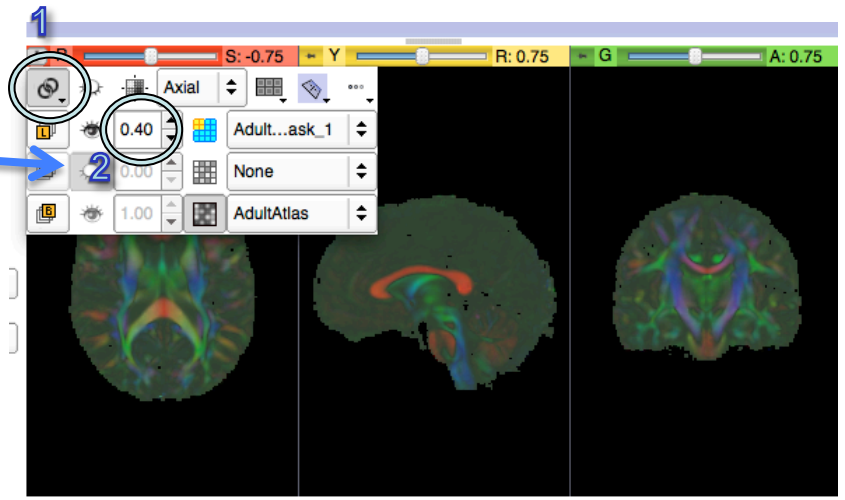


Load AdultAtlas_BrainMask.nrrd label map

Adjust View

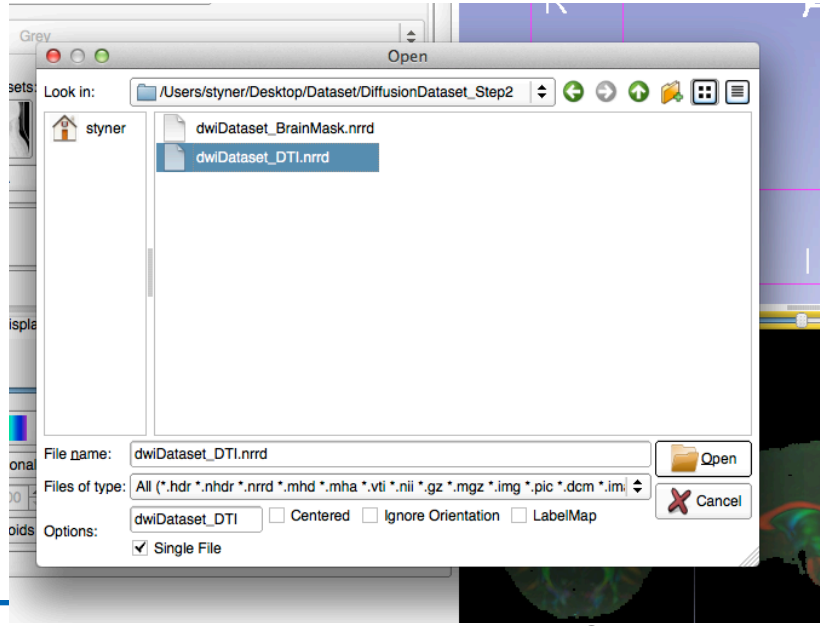
- Adjust view to see both mask and atlas

1. Link all 3 viewers
2. Opacity change



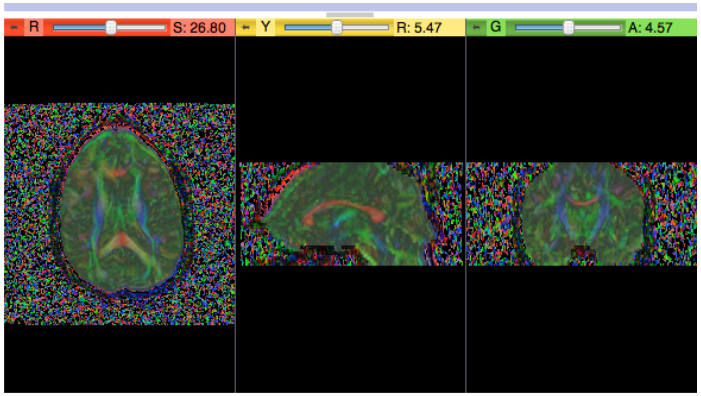
Loading 2nd DTI dataset

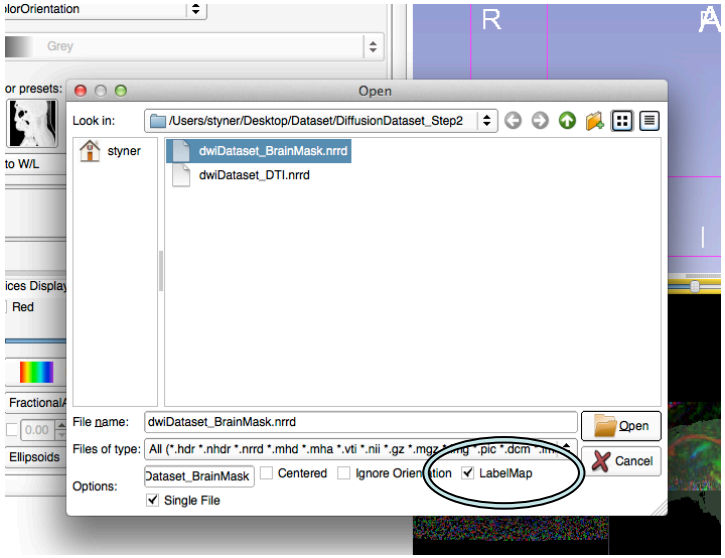
- File Menu =>Add Volume (or see previous tutorial)
- Directory: DiffusionDataset_Step2
- Load **dwiDataset_DTI.nrrd**



Loading DTI dataset mask

- File Menu =>Add Volume (or use from previous tutorial)
- DiffusionDataset_Step2
- Load BrainMask
- “LabelMap” checkbox

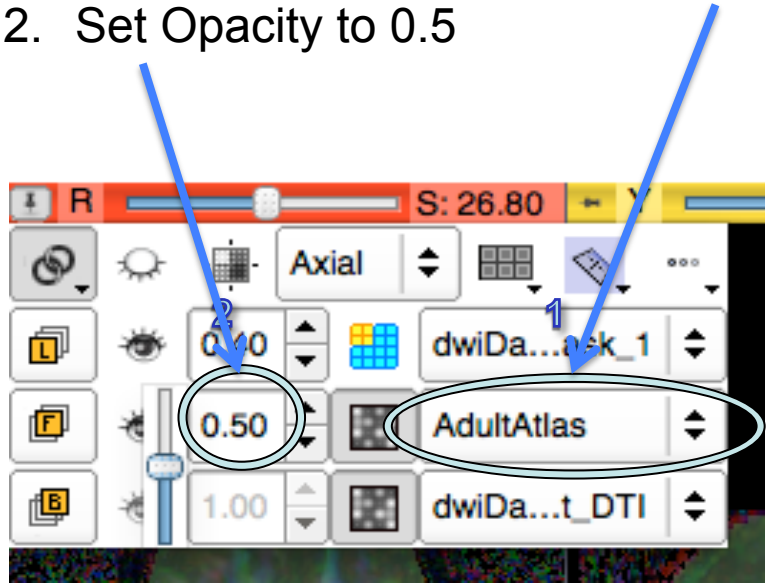




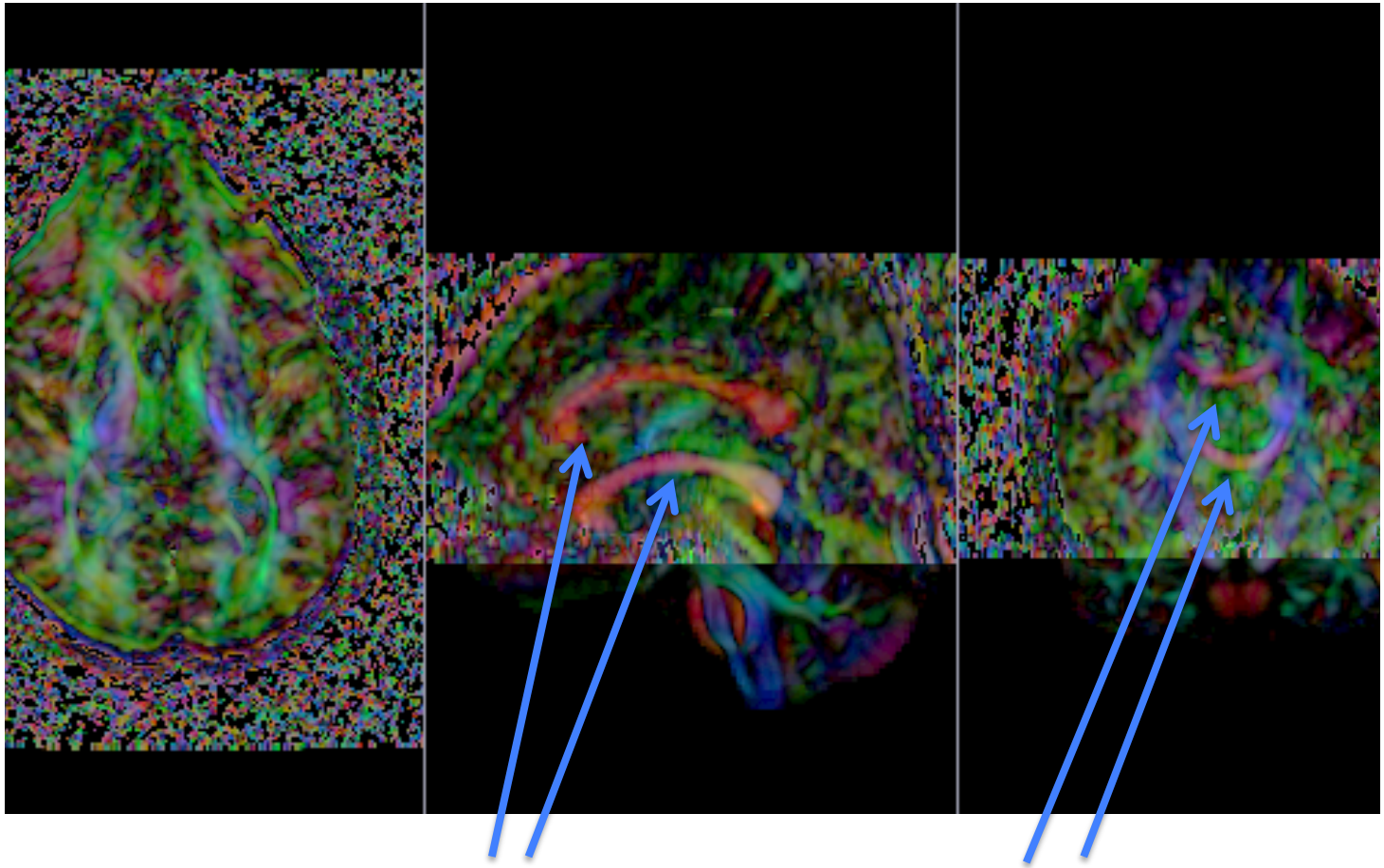
Overlay DTI datasets

- How can we check alignment?
- Overlay the DTI images!

1. Select AdultAtlas for Foreground
2. Set Opacity to 0.5



Overlay



Bad alignment: 2 separate corpus callosum

Select DTI-Reg Module

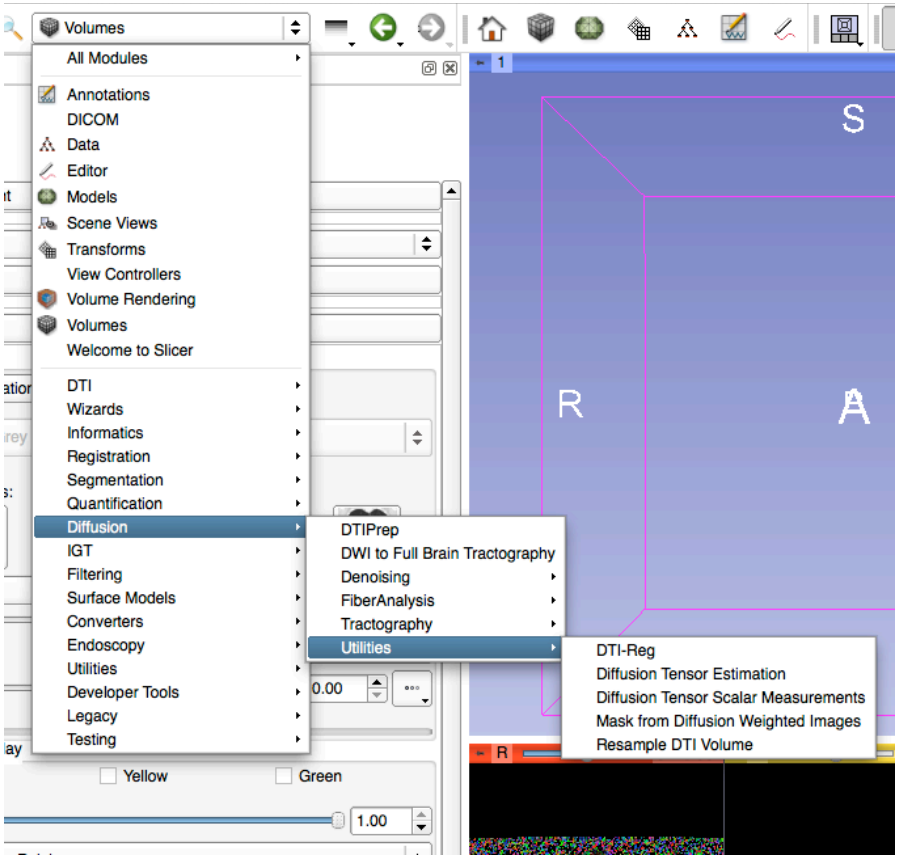
- Slicer modules

  Diffusion

  → Utilities

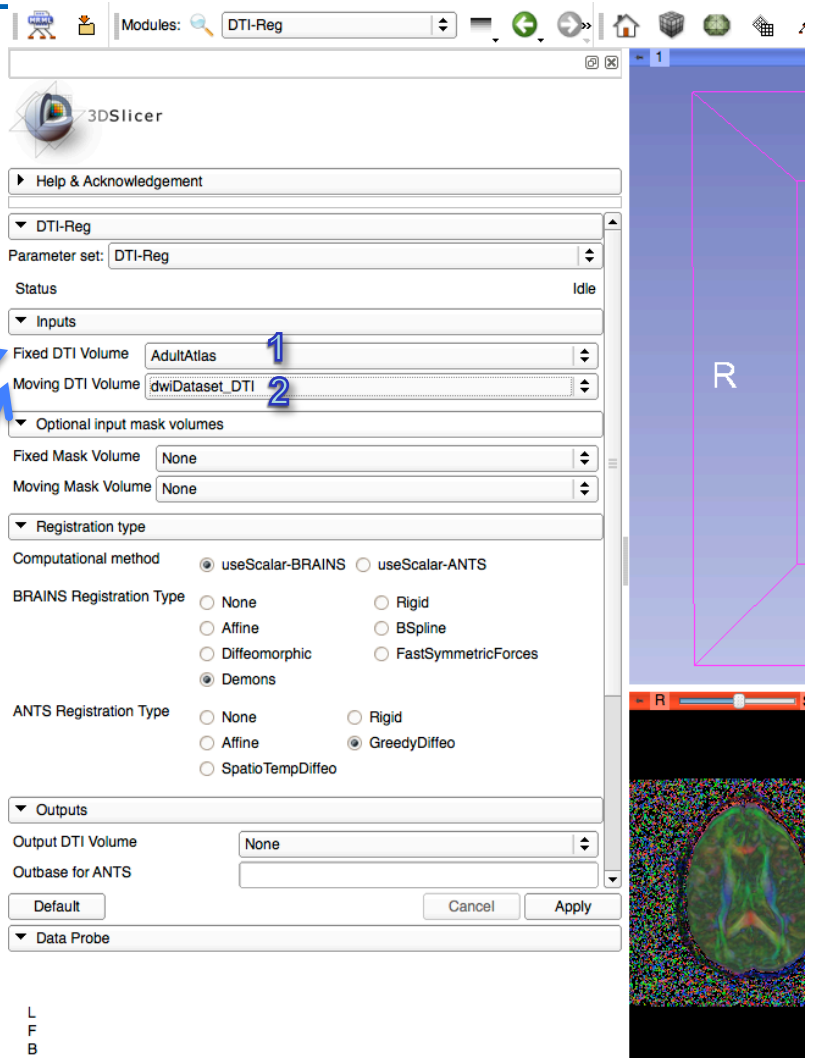
  → DTI-Reg

- DTI-Reg: Pairwise DTI registration module



Volumes for Registration

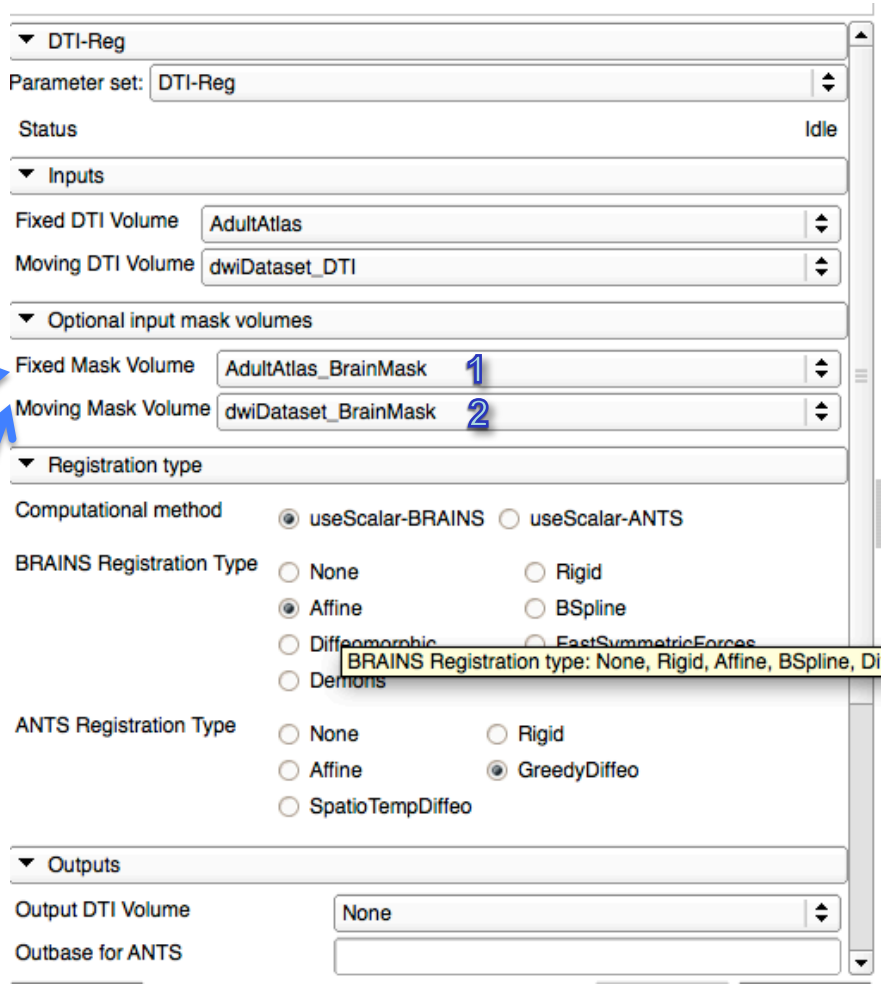
1. Fixed Volume: Target of registration = **AdultAtlas.nrrd**
2. Moving Volume: Image to be transformed: **dwiDataset_DTI**



Set Masks for Registration

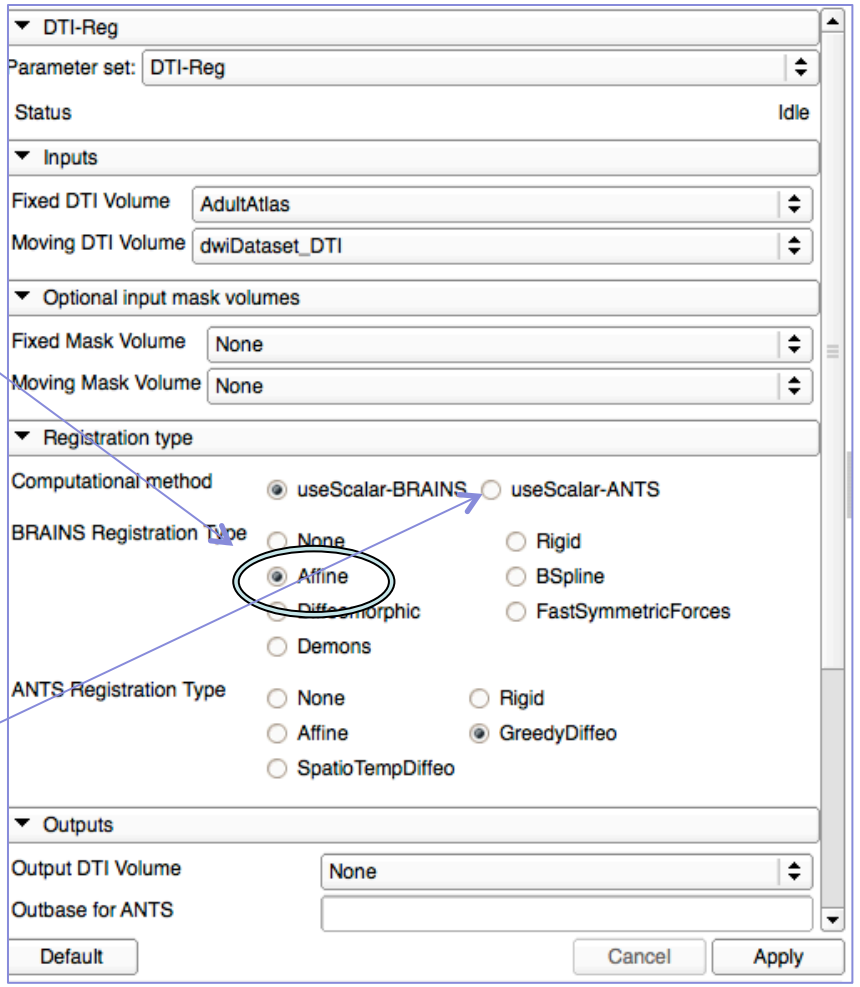
1. Set Fixed Mask to Atlas Mask:
   AdultAtlas_BrainMask.nrrd

2. Set Moving Mask to dwiDataset Mask:
   dwiDataset_BrainMask.nrrd



Set Transform to Affine

- Set registration transform to **Affine**
- Deformable Registration is performed in 2 steps: Affine followed by nonlinear.
- ANTS generally better but much slower

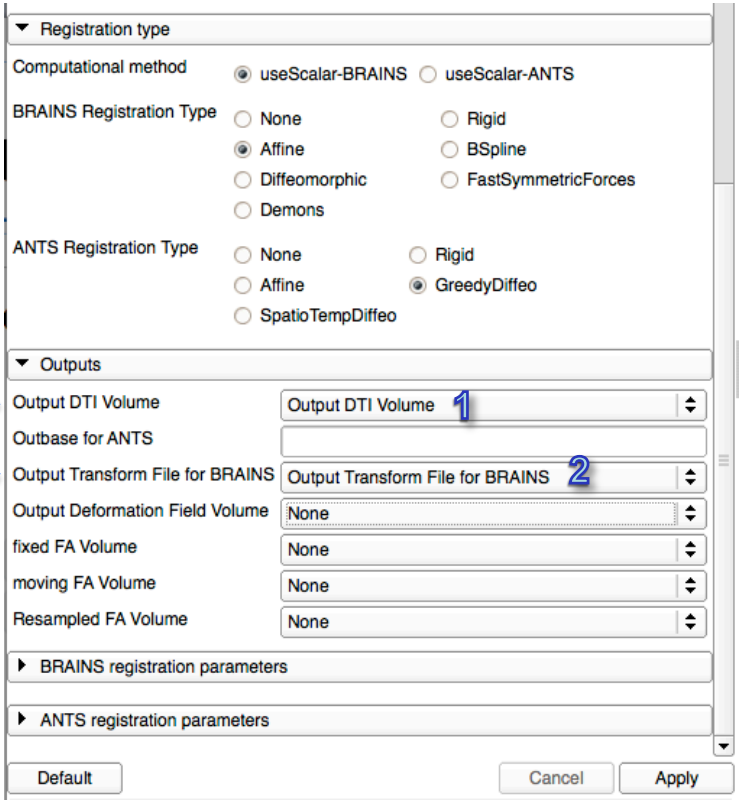


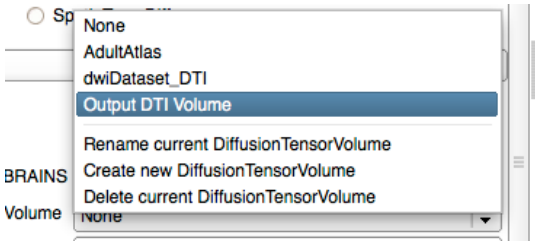
Select Outputs

- Create & rename volumes for output

1. Affinely registered DTI dataset
2. Affine transform

- Apply to run & wait



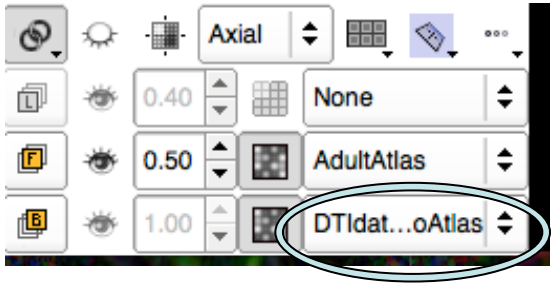


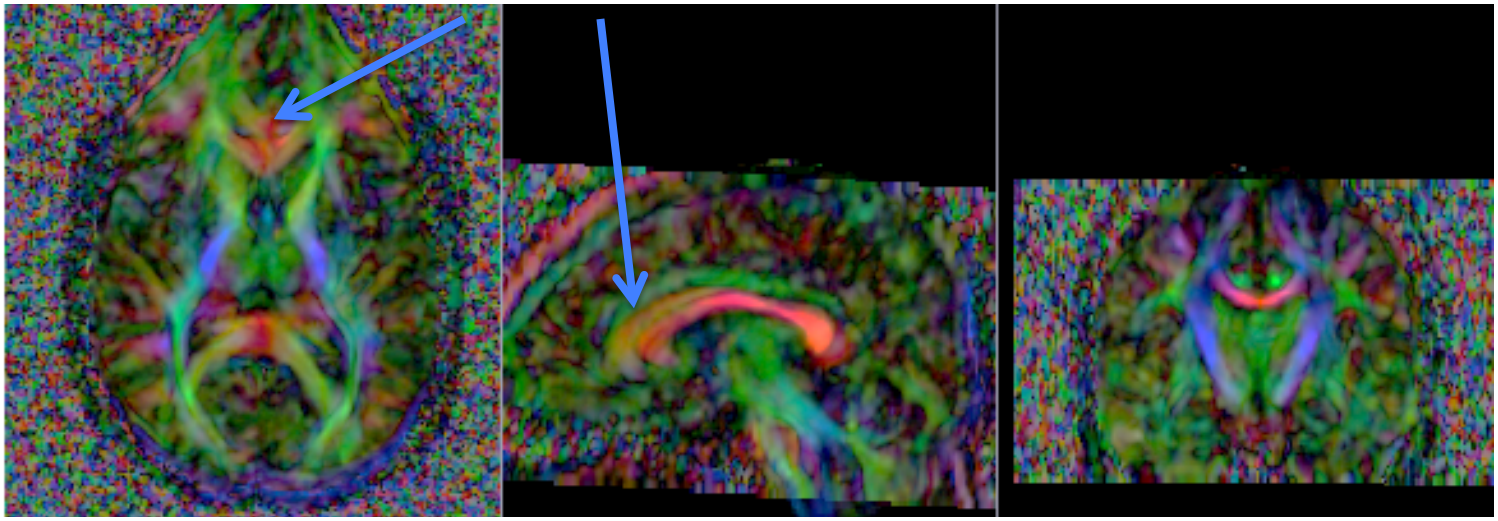
Registration

- Several pairwise registration methods available.
- **DTI-Reg** supports several registration methods based on normalized FA images:
  - Affine, B-spline, Demons-variants from within Slicer
  - ANTS as external call
- Plan: DTI-TK support
  - Registration based on full tensor.

Affine Results

- Select DTI-Reg result as background
- Result: single corpus callosum, but fuzzy, insufficient registration

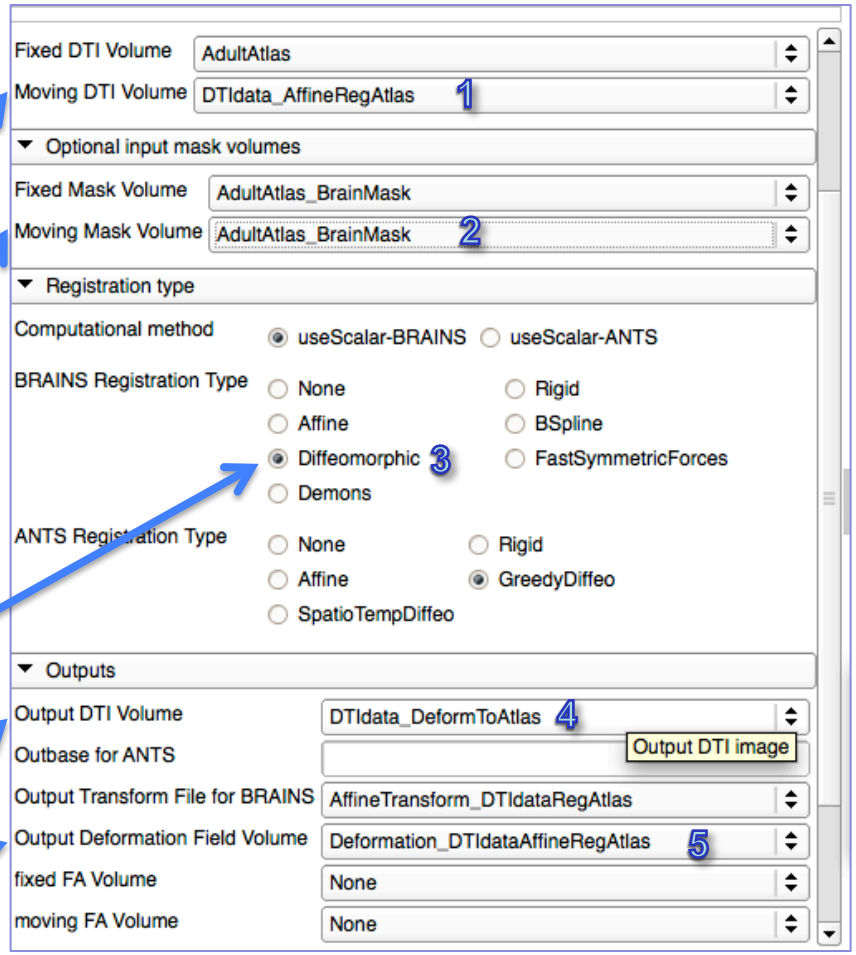




Deformable Registration

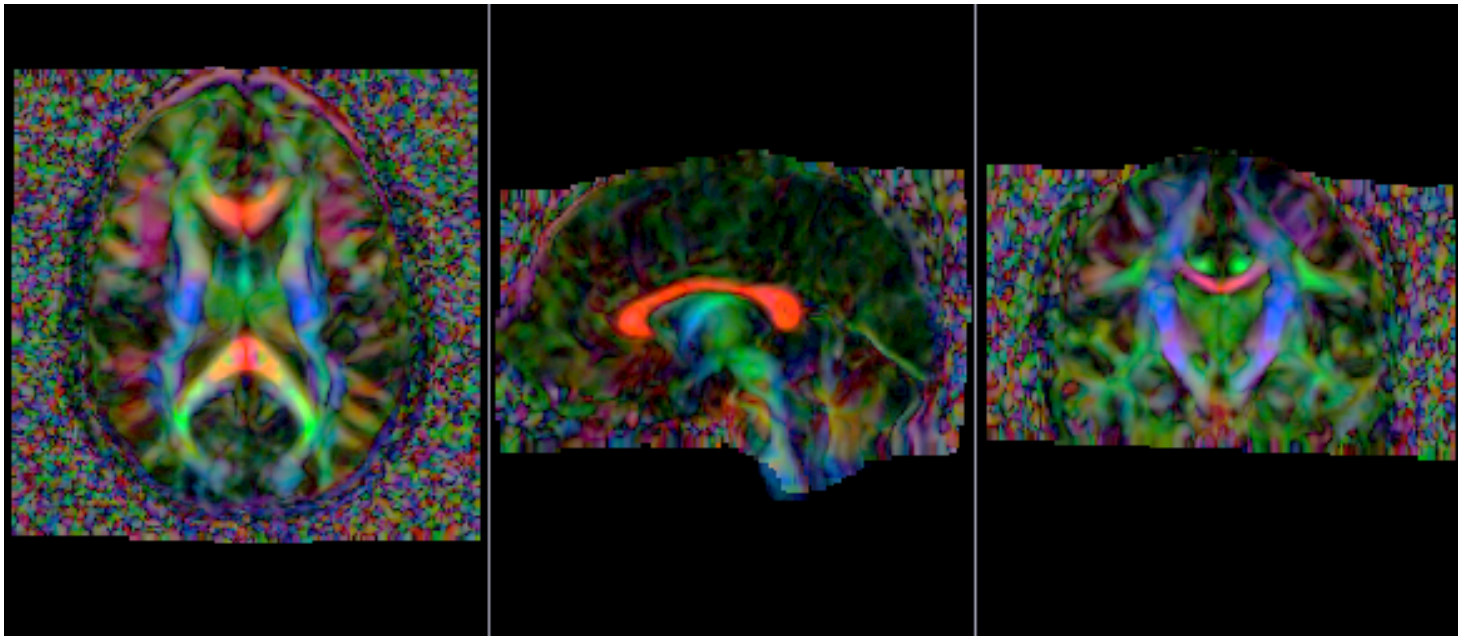
Concept: Use affine registration as initialization for deformable registration:

1. Change moving volume to affinely registered data
2. Change moving mask to atlas mask
3. Change registration to Diffeomorphic (Demons)
4. Create/rename output names for deformable transformation



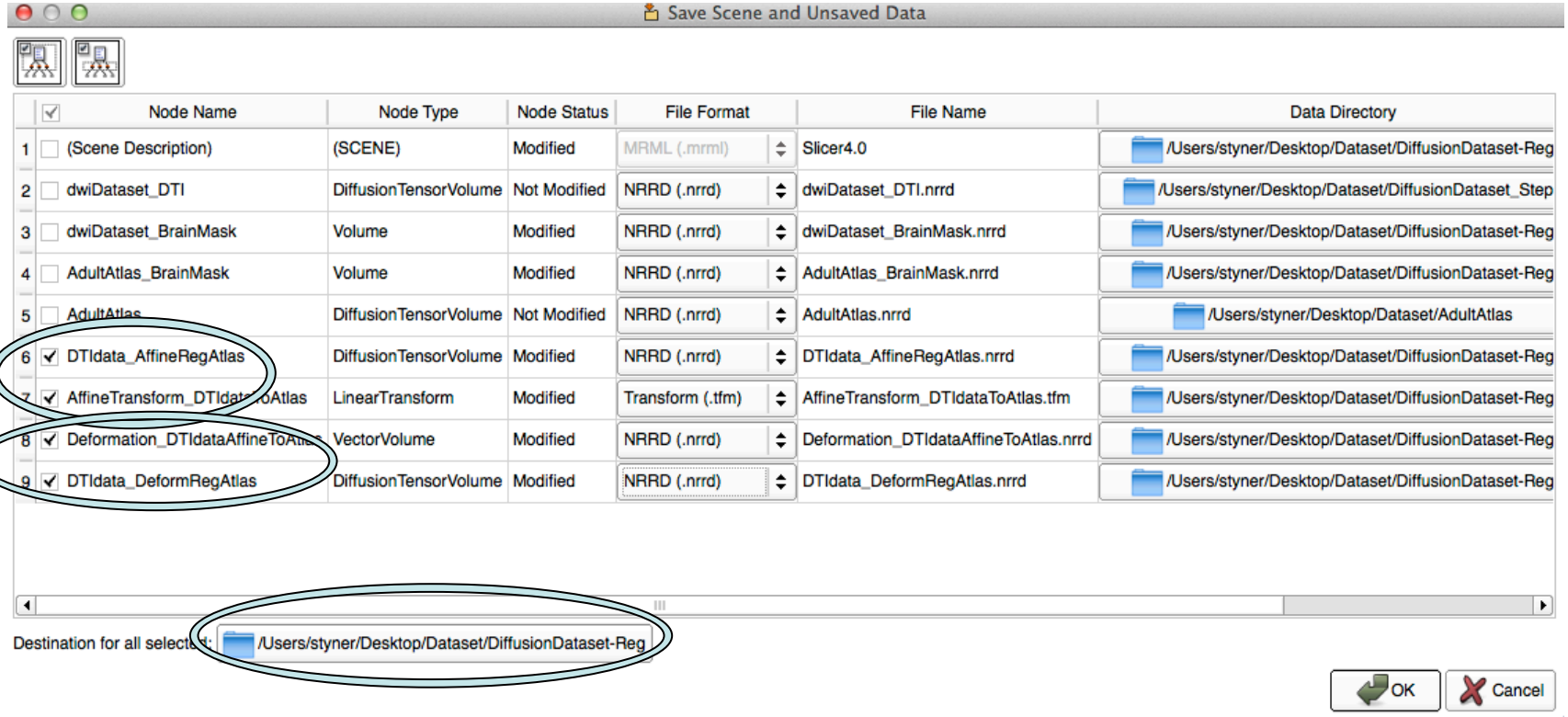
Deformable Results

- Select DTI-Reg deformable result as background
- Result: No longer fuzzy, significantly better registration



Save Outputs and Done

- Save selected volumes and transforms
- File → Save → (deselect/select checkboxes)
- Choose common directory: “destination for all selected”



Conclusions

- DTI registration is available in Slicer
- 2-step process currently, to be improved soon
- Brainmasks are needed (unless data is skull stripped already)
- This tutorial taught you how to register to an atlas
  - How to get atlas?
- Alternative: Build atlas from data

Acknowledgment

- **National Alliance for Medical Image Computing**
  NIH U54EB005149
- UNC: Jean-Baptiste Berger, Clement Vachet, Aditya Gupta
- Utah: Guido Gerig, Sylvain Gouttard
- Iowa: Hans Johnson, Joy Matsui