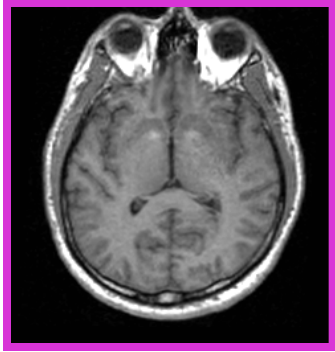


Image Registration Tutorial

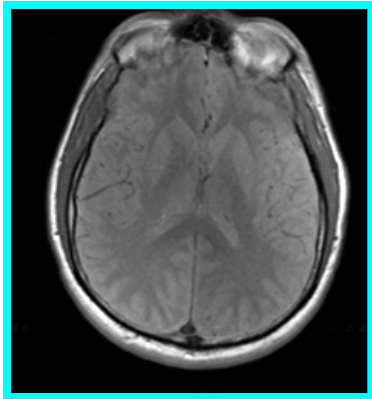
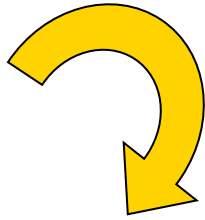
**Sonia Pujol, Ph.D. Dominik Meier, Ph.D.,
Ron Kikinis, M.D.**

Surgical Planning Laboratory
Brigham and Women's Hospital
Harvard Medical School

Motivation



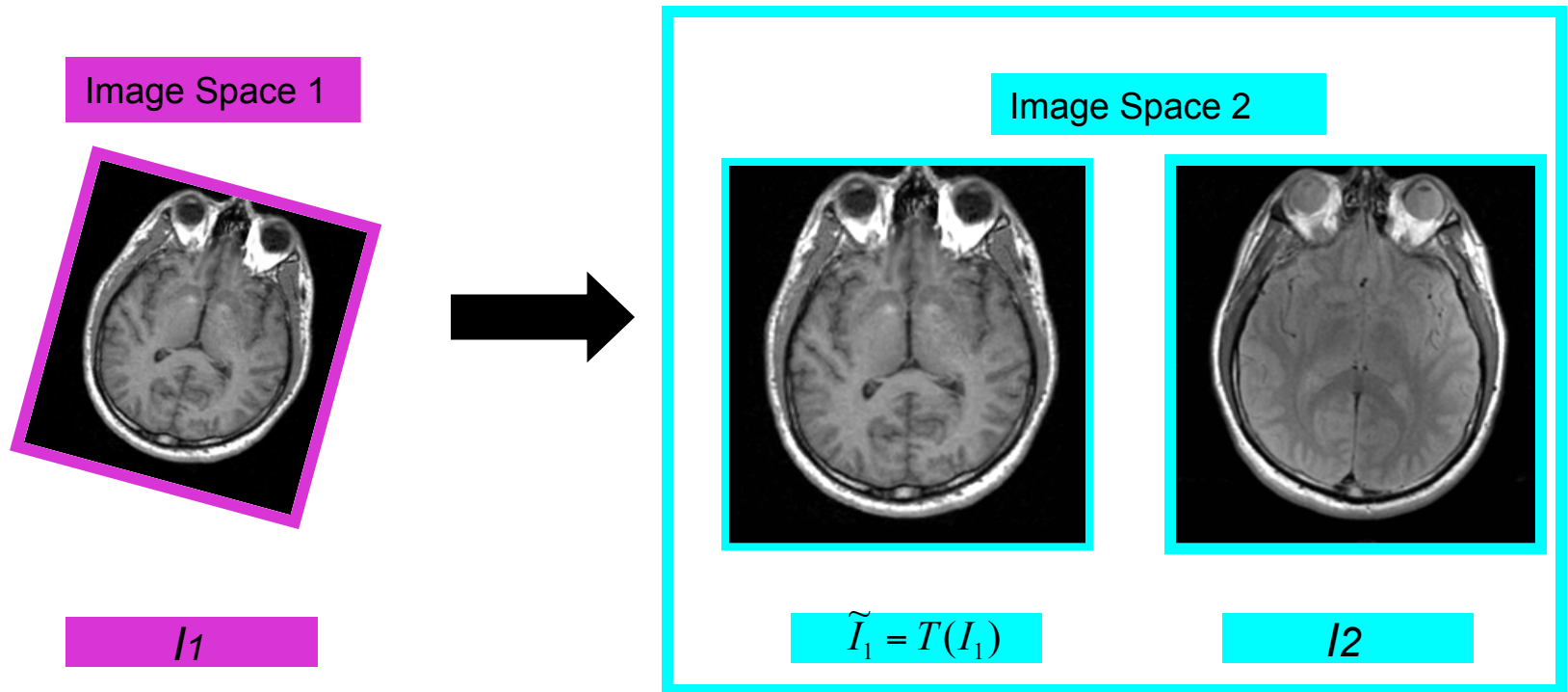
Dataset 1



Dataset 2

Registration algorithms bring multiple image data sets into spatial alignment, in order to achieve **anatomical agreement**.

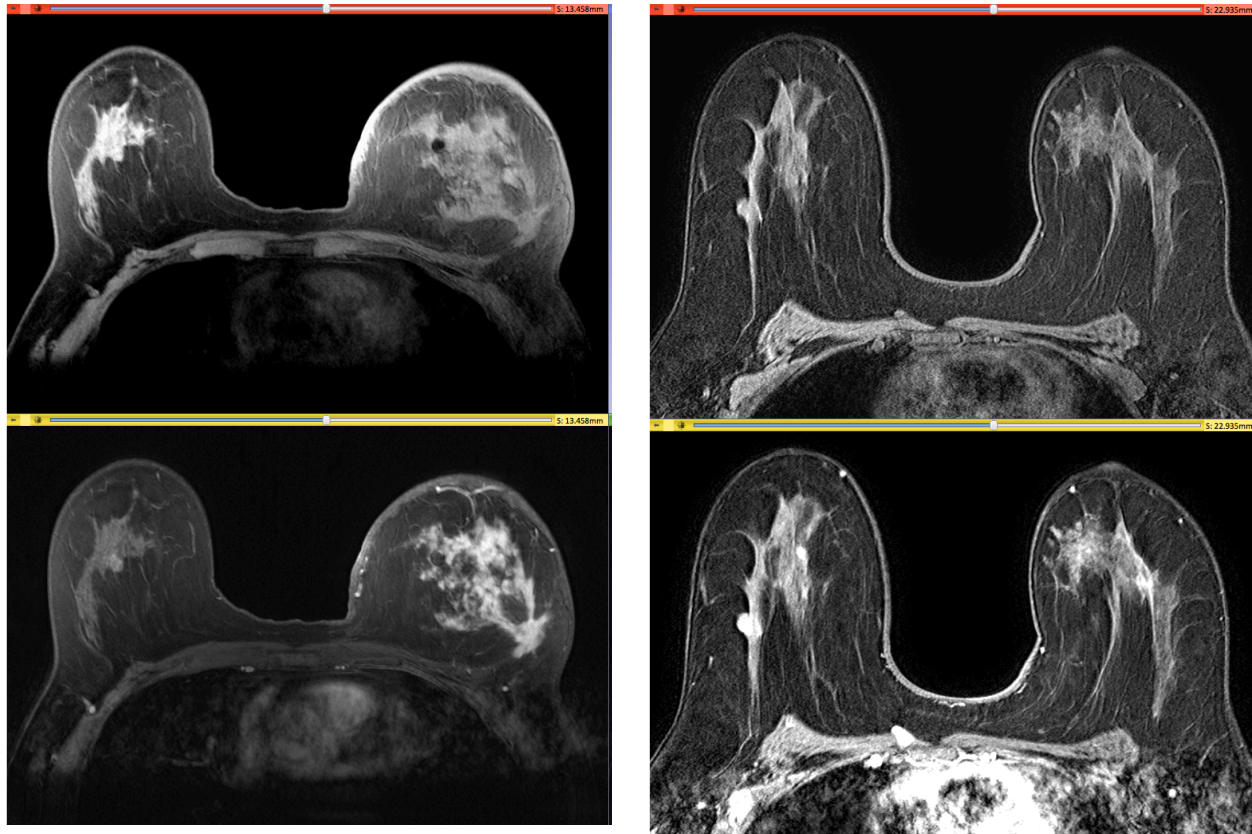
Apply the registration transform



By applying the registration transform to the initial volume I_1 , we can generate a new volume $T(I_1)$ spatially aligned with the volume I_2 .

This allows the extraction of quantitative information from the two volumes.

Example 1: Large volumetric change between two time points

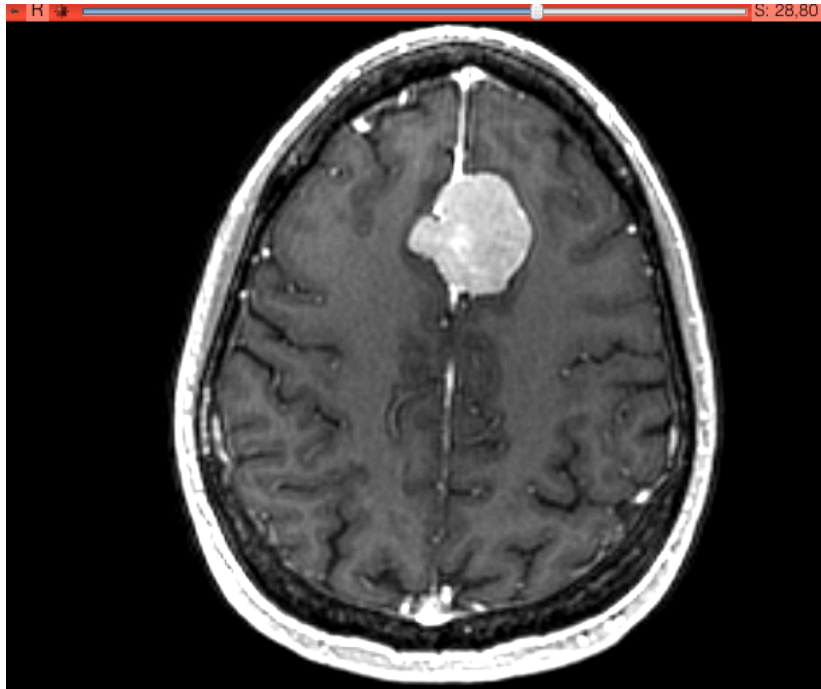


Pre-therapy

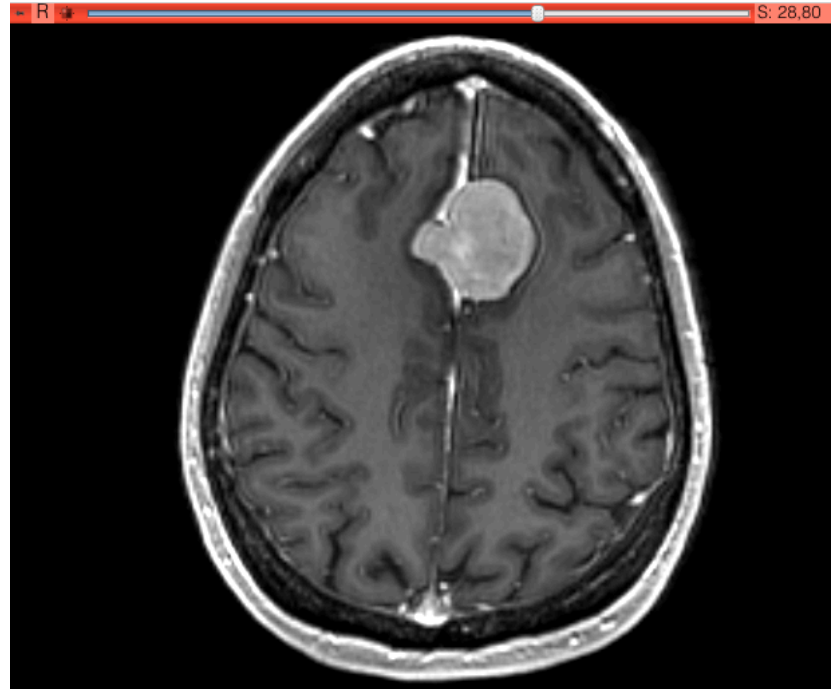
Post-therapy

Infiltrating ductal carcinoma

Example 2: Small volumetric change



MR Scan1 June 2006



MR Scan2 June 2007

Meningioma

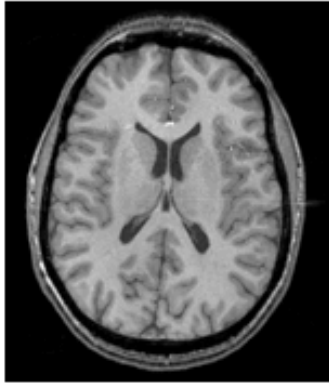
Objective of the tutorial

- Guiding you step-by-step through the process of automatically registering two structural MR datasets acquired on two different subjects using rigid and non-rigid registration
- This tutorial is built upon the Registration Case Libray 31 tutorial available at http://www.na-mic.org/Wiki/index.php/Projects:RegistrationLibrary:RegLib_C19

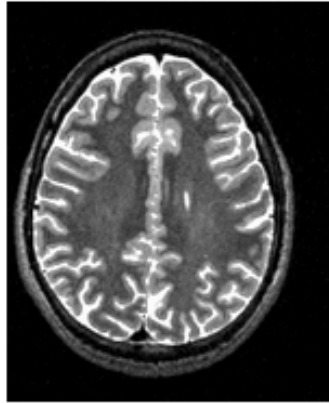
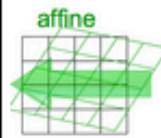
Tutorial Dataset

- The dataset includes two T1-weighted and T2-weighted MR scans acquired on two healthy subjects.
- The dataset is Registration Case 19 of the NAMIC registration case library (P.I. Dr. Dominik Meier, Ph.D.)

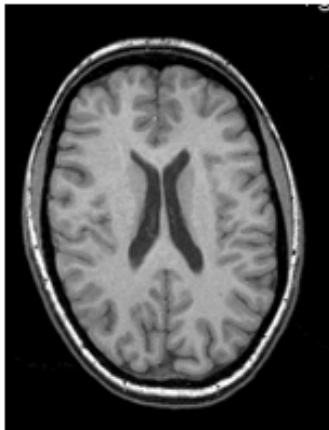
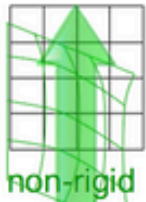
Registration pipeline



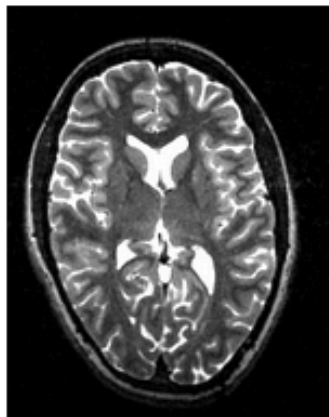
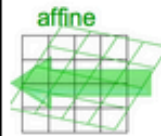
subj 1: T1



subj 1: T2



subj 2: T1



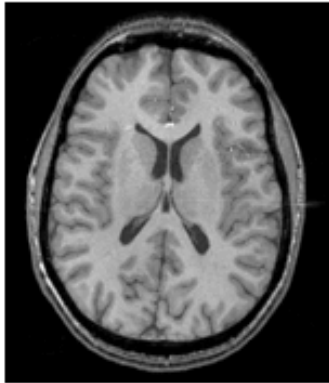
subj 2: T2

Step 1:

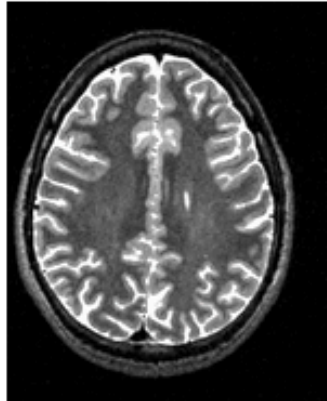
Subject A, T2 to T1 registration

Image courtesy
of Dominik
Meier, Ph.D.

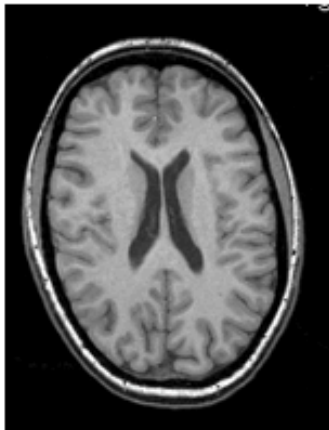
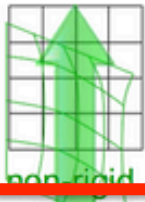
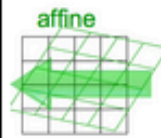
Registration pipeline



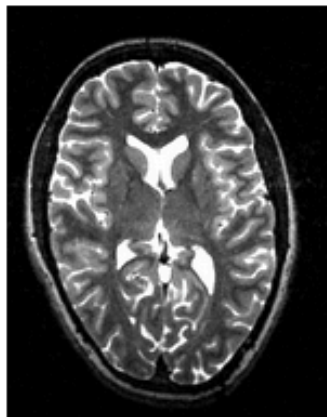
subj 1: T1



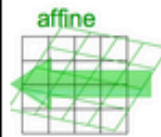
subj 1: T2



subj 2: T1



subj 2: T2



Step 1:

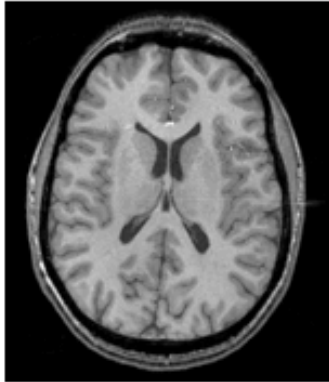
Subject A, T2 to T1 registration

Step 2:

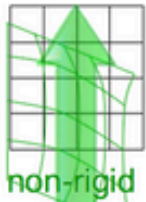
Subject B, T2 to T1 registration

Image courtesy
of Dominik
Meier, Ph.D.

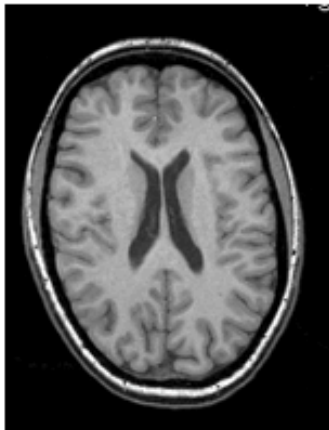
Registration pipeline



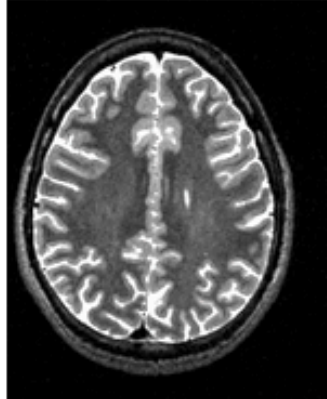
subj 1: T1



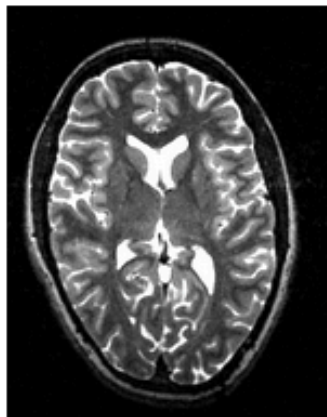
non-rigid



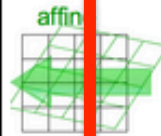
subj 2: T1



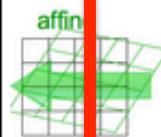
subj 1: T2



subj 2: T2



affin



affin

Step 1:

Subject A, T2 to T1 registration

Step 2:

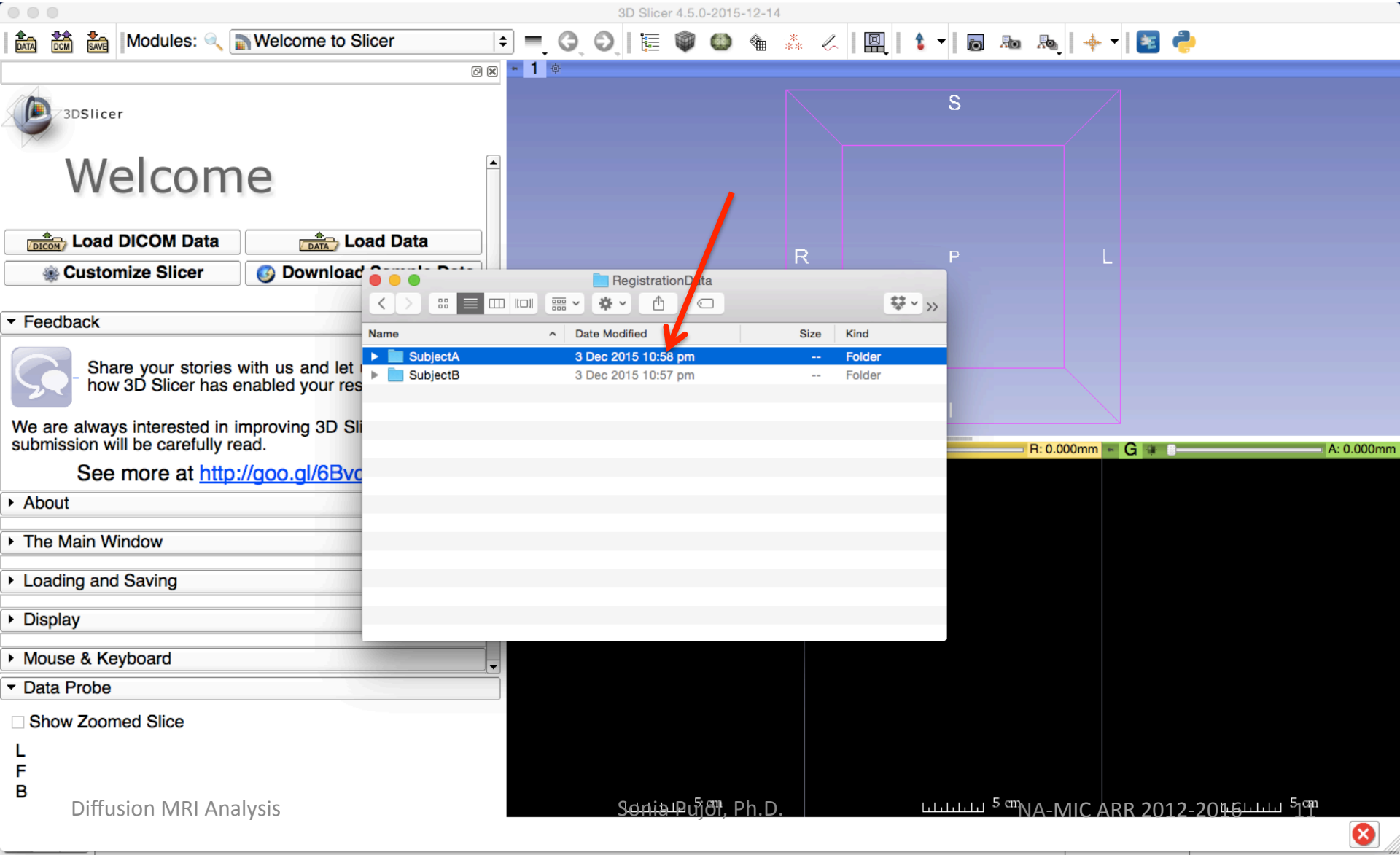
Subject B, T2 to T1 registration

Step 3:

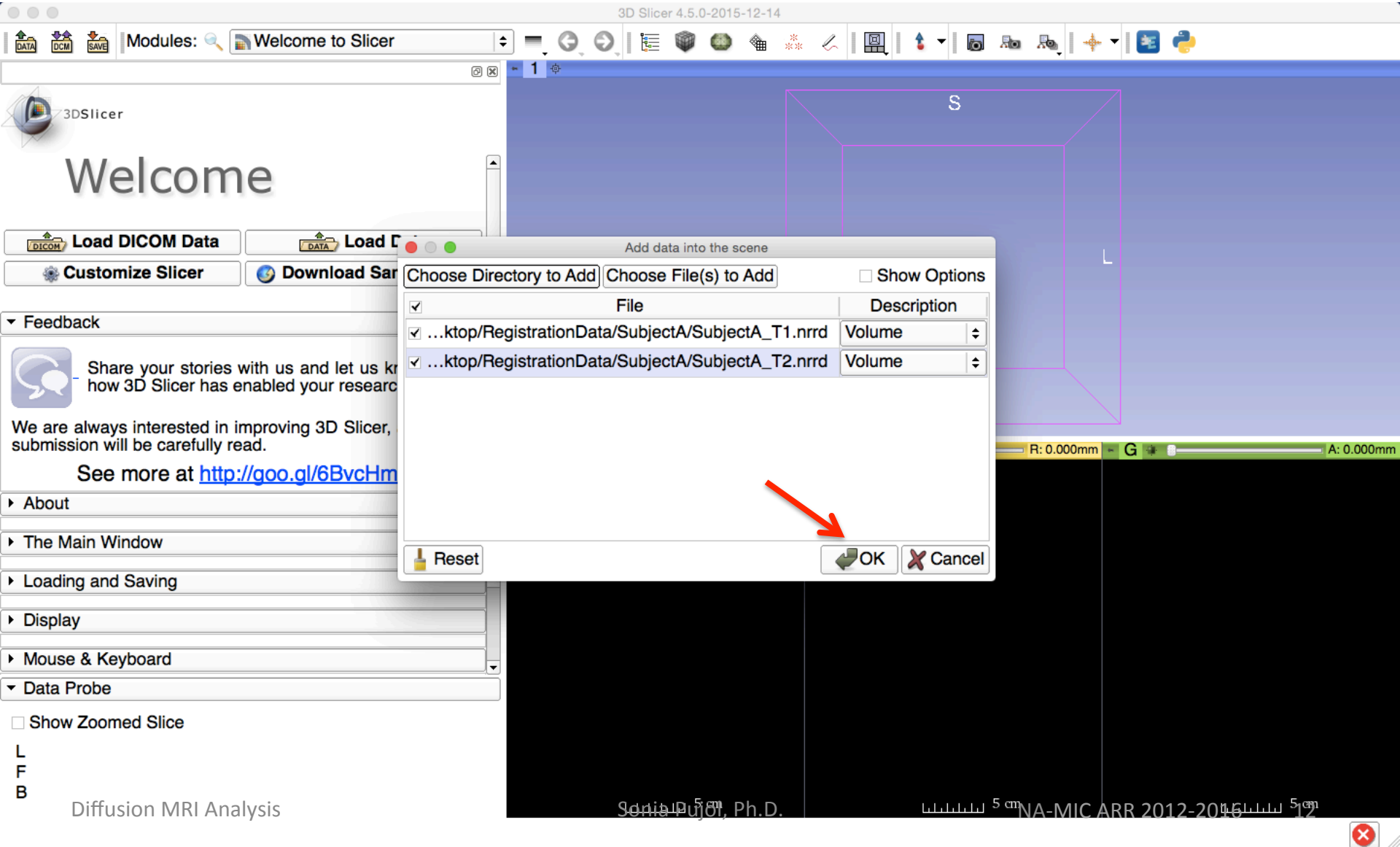
Subject B, T1 to Subject A, T1 registration

Image courtesy
of Dominik
Meier, Ph.D.

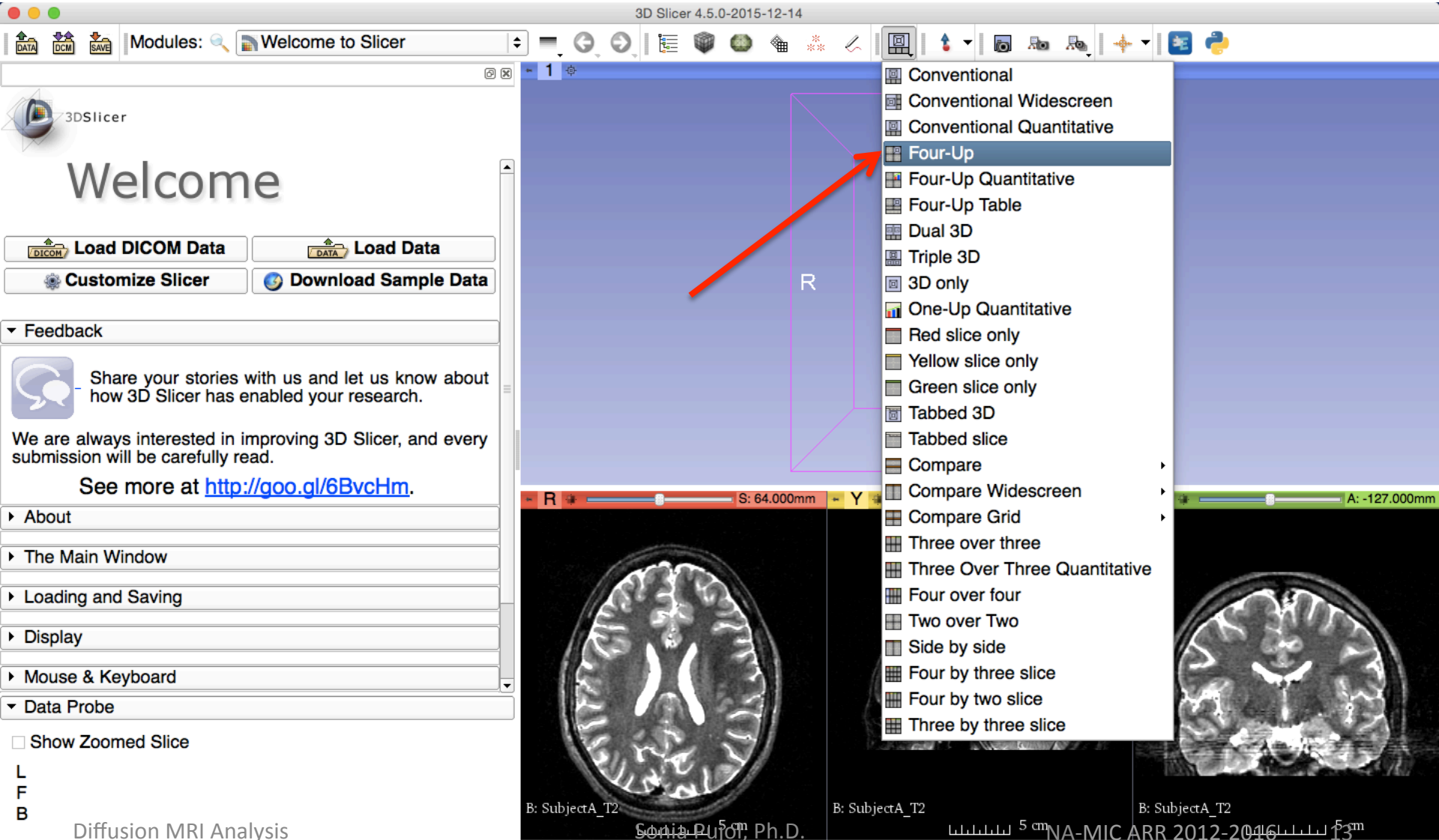
Subject A: Data loading



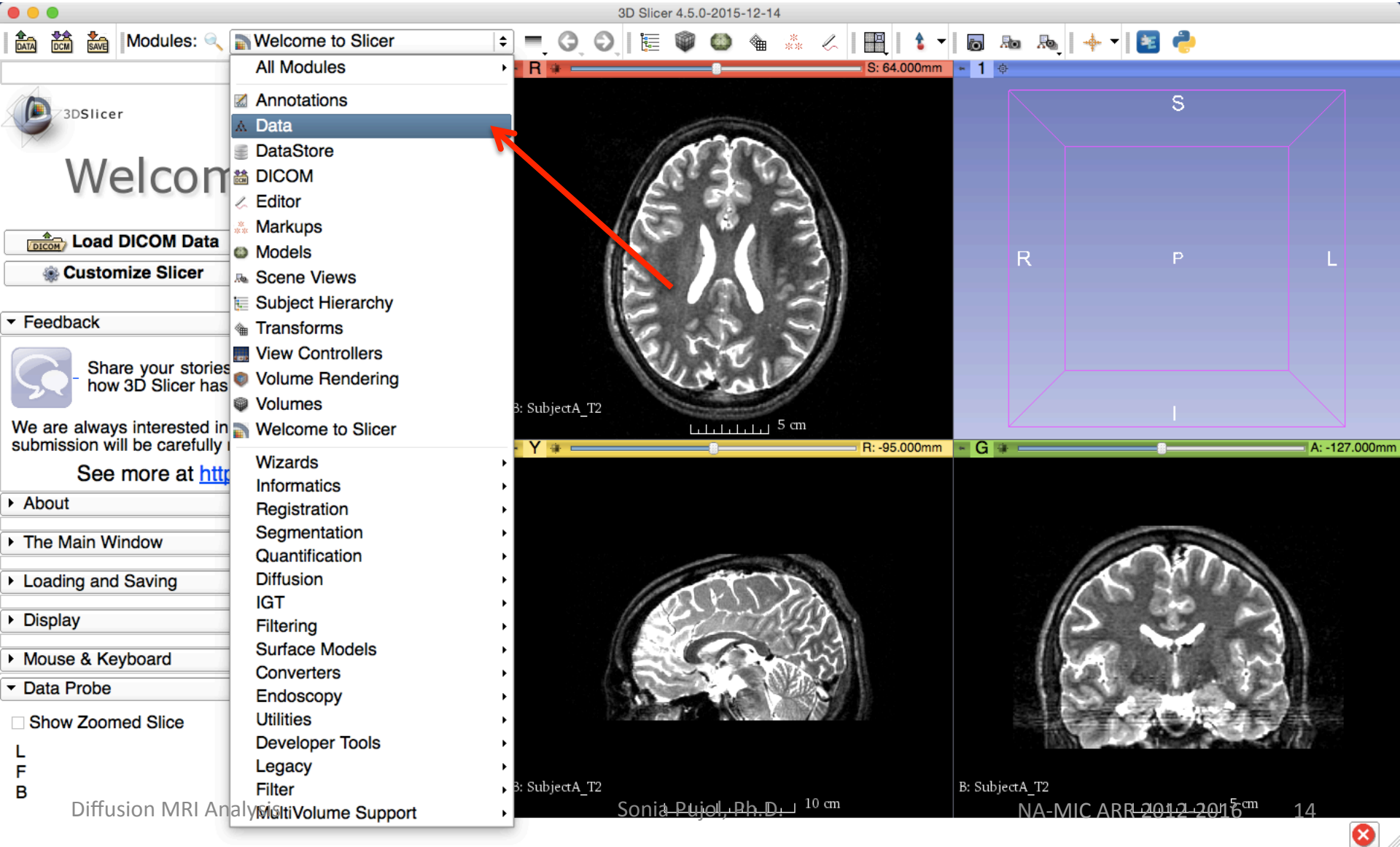
Subject A: Data loading



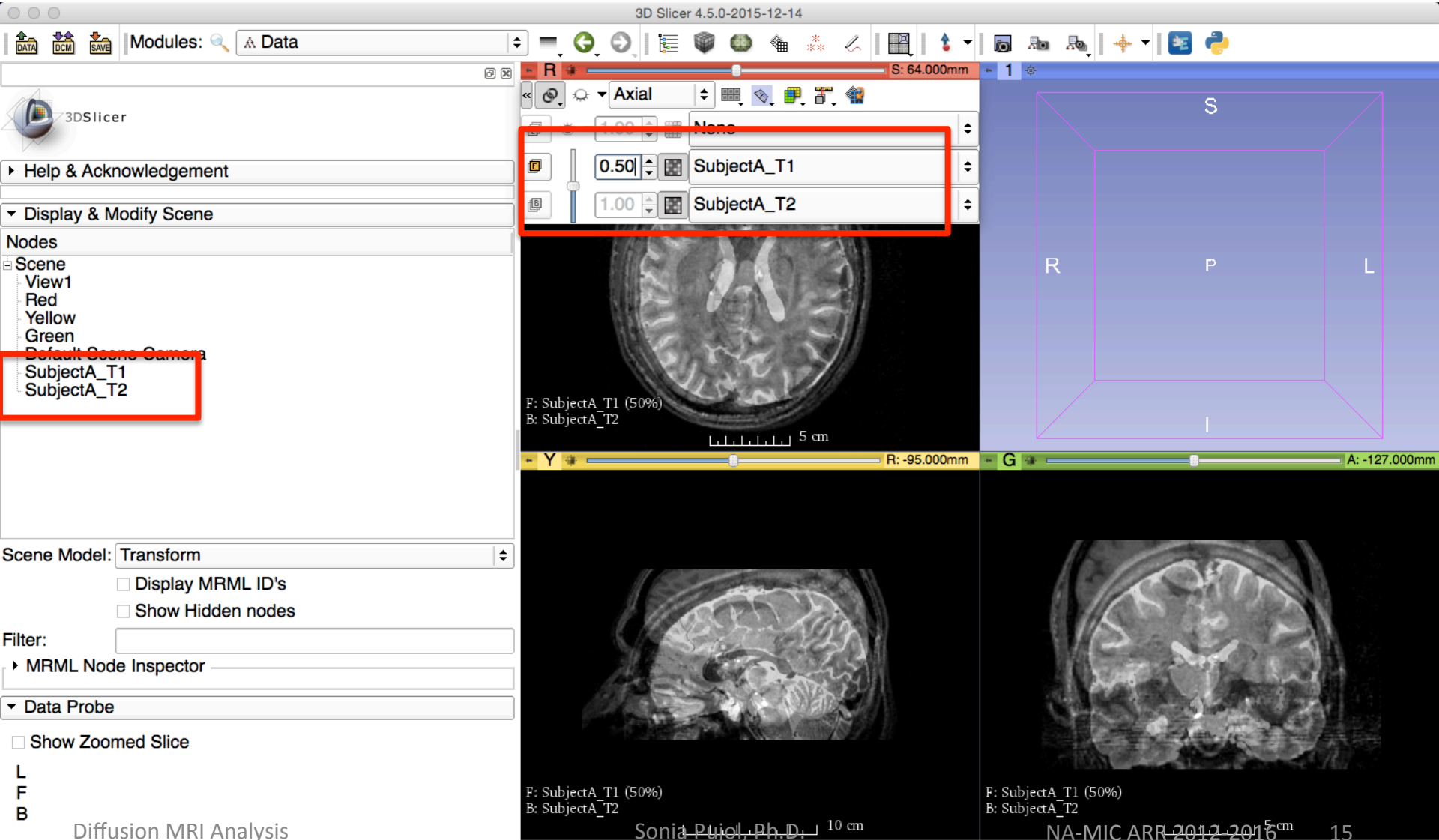
Subject A: Data loading



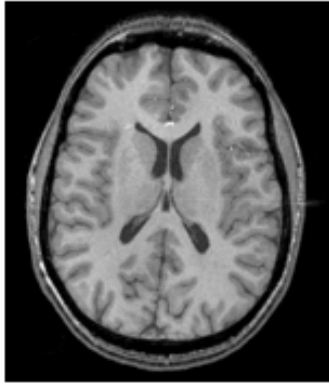
Subject A: Initial mis-registration



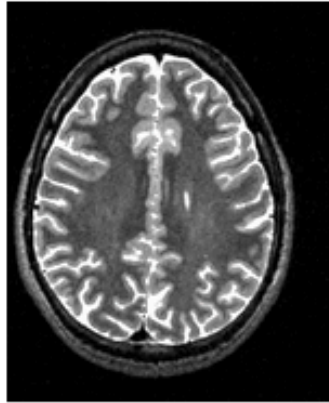
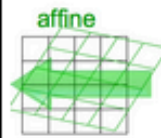
Subject A: Initial mis-registration



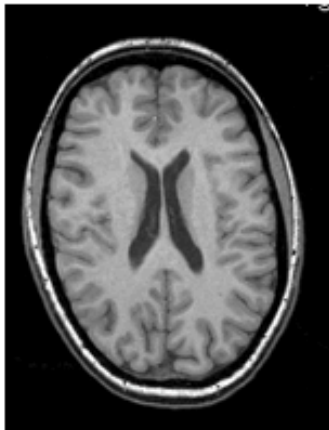
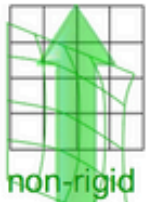
Registration pipeline



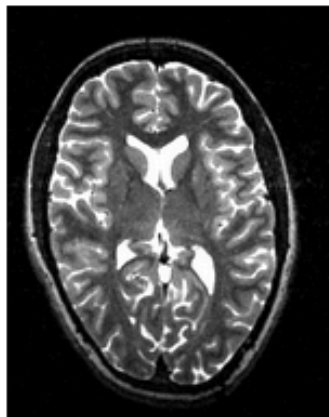
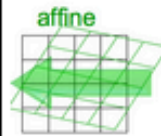
subj 1: T1



subj 1: T2



subj 2: T1



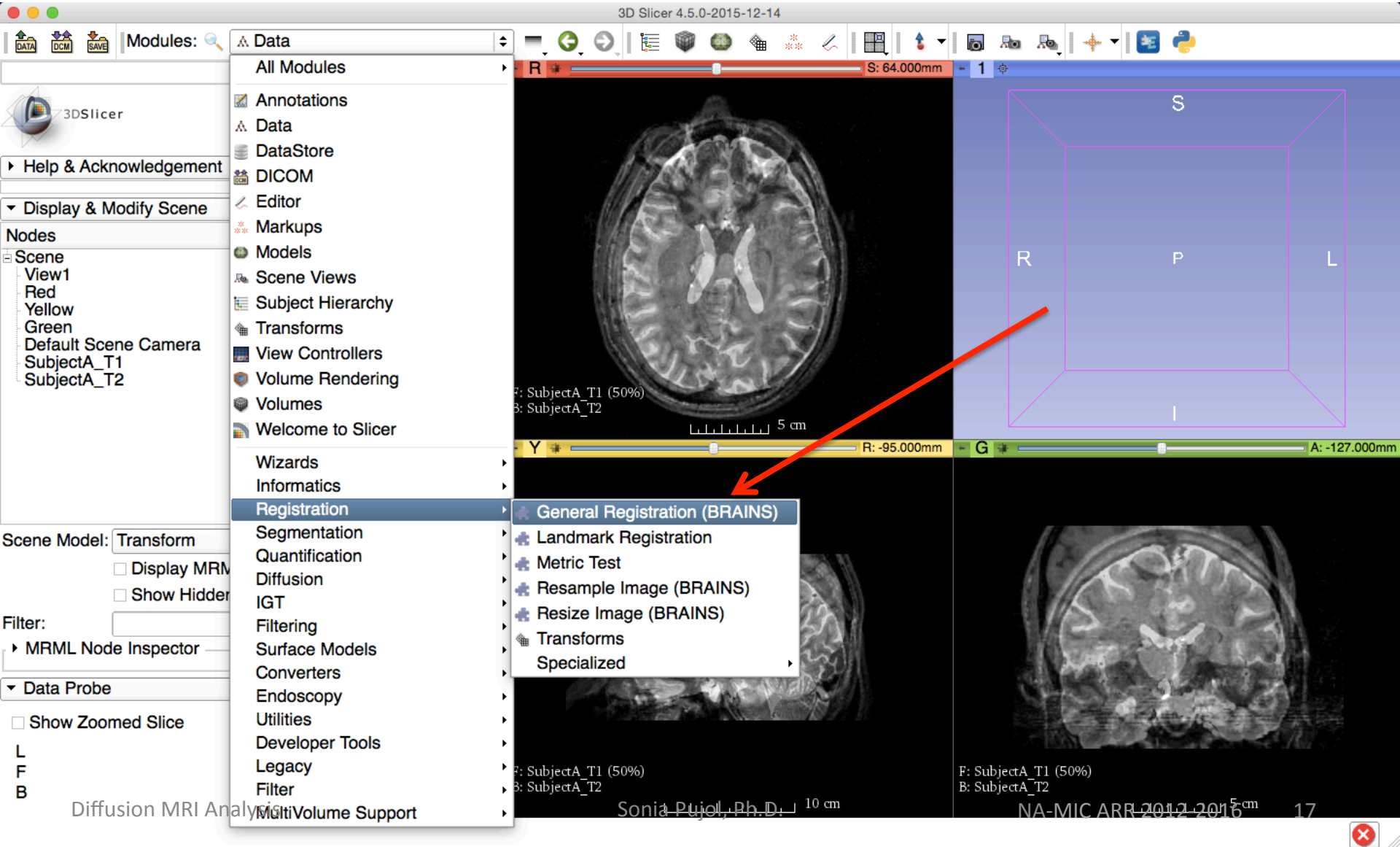
subj 2: T2

Step 1:

Subject A, T2 to T1 registration

Image courtesy
of Dominik
Meier, Ph.D.

Subject A: Data registration



Subject A: Data registration

3D Slicer 4.5.0-2015-12-14

Modules: General Registration (BRAINS)

3DSlicer

Help & Acknowledgement

General Registration (BRAINS)

Parameter set: General Registration (BRAINS)

Input Images

Fixed Image Volume: SubjectA_T1

Moving Image Volume: SubjectA_T2

Percentage Of Samples: 0.002

B-Spline Grid Size: 14,10,12

Output Settings (At least one output must be specified)

Slicer Linear Transform: Xf2_SubjectA_T2_to_T1

Slicer B-Spline Transform: None

Output Image Volume: None

Transform Initialization Settings

Initialization transform: None

Initialize Transform Mode: ☒ Off ☐ Use Moments Align

Status: Idle

Restore Defaults AutoRun Cancel Apply

Data Probe

Yellow RAS: (-95.0, -124.5, 112.3) Sagittal Sp: 1.0

L None

F SubjectA_T1 (95, 124, 112) 87

B SubjectA_T2 (95, 124, 112) 302

Diffusion MRI Analysis

3D Slicer 4.5.0-2015-12-14

R S: 64.000mm 1

F: SubjectA_T1 (50%)
B: SubjectA_T2

5 cm

Y R: -95.000mm G A: -127.000mm

F: SubjectA_T1 (50%)
B: SubjectA_T2

10 cm

Sonia Pujol, Ph.D. NA-MIC ARR 2012-2016 18

Subject A: Data registration

3D Slicer 4.5.0-2015-12-14

Modules: General Registration (BRAINS)

3DSlicer

Help & Acknowledgement

Transform Initialization Settings

Initialization transform: None

Initialize Transform Mode:

- ☐ Off
- ☐ useMomentsAlign
- ☒ useCenterOfHeadAlign
- ☐ useGeometryAlign
- ☐ useCenterOfROIAlign

Registration Phases (Check one or more, executed in order listed)

- ☒ Rigid (6 DOF)
- ☐ Rigid+Scale(7 DOF)
- ☒ Rigid+Scale+Skew(10 DOF)
- ☐ Affine(12 DOF)
- ☐ BSpline (>27 DOF)
- ☐ SyN
- ☐ Composite (many DOF)

Image Mask and Pre-Processing

Advanced Output Settings

Status: Idle

Restore Defaults AutoRun

Cancel Apply

Data Probe

☐ Show Zoomed Slice

L
F
B

Diffusion MRI Analysis

Set Initialization mode to UseCenterOfHeadAlign

Set Registration Phases to Rigid and Affine

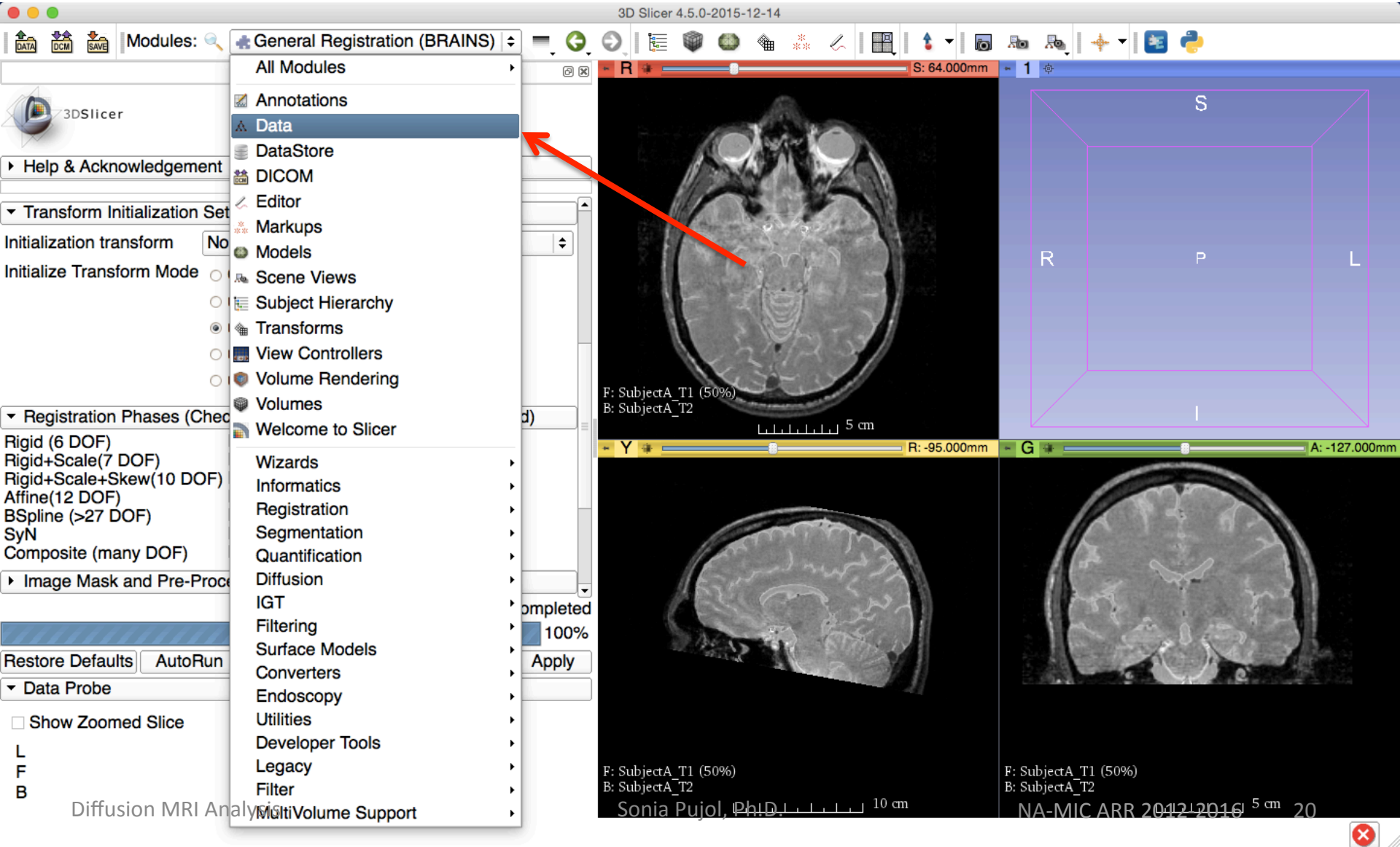
F: SubjectA_T1 (50%)
B: SubjectA_T2

10 cm

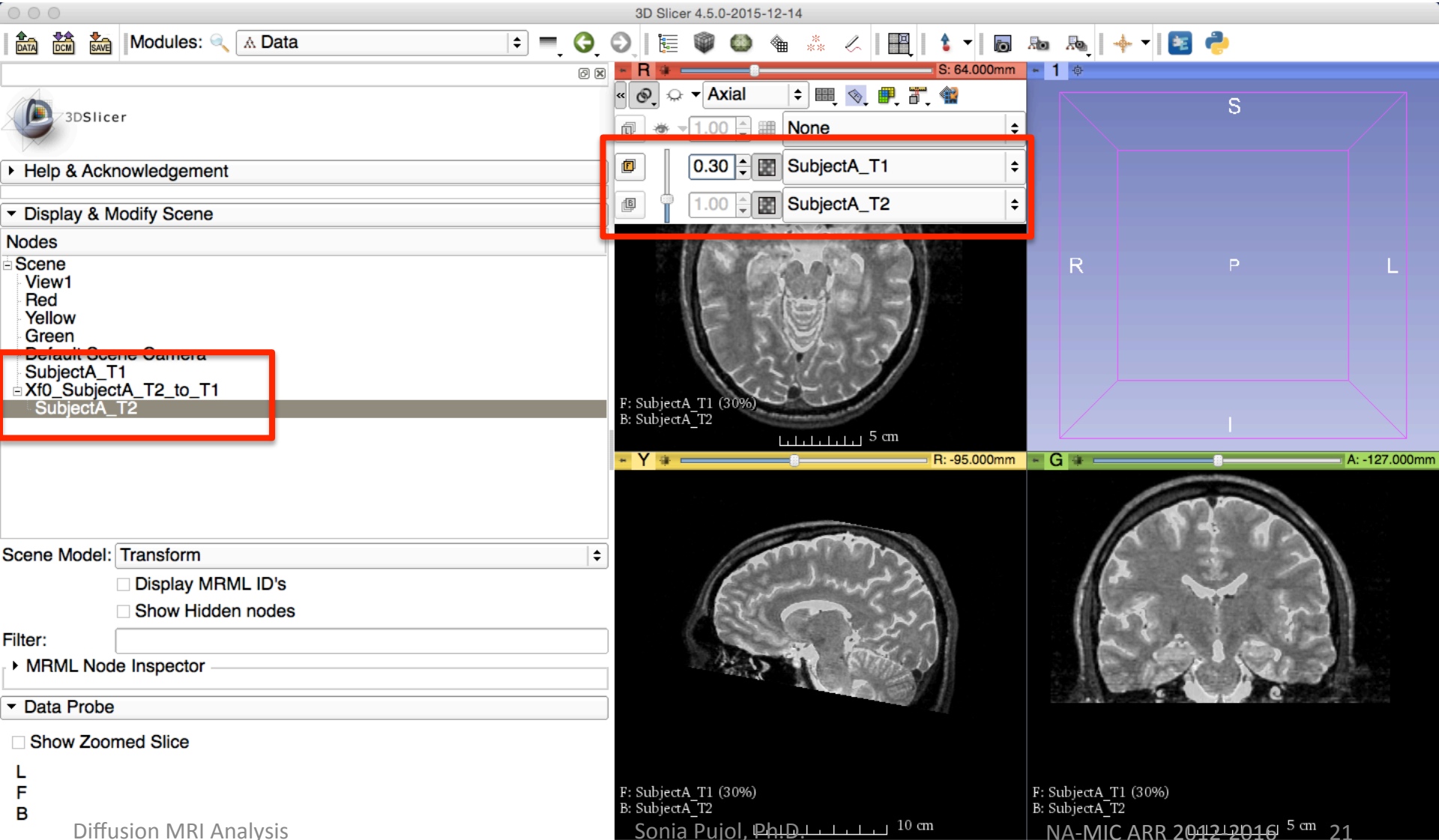
5 cm

NA-MIC ARR 2012-2016

Subject A: Data registration



Rigid Affine Transformation



Subject B: Data Loading

3D Slicer 4.5.0-2015-12-14

Modules: Data

Nodes

- Scene
- View1
- Red
- Yellow
- Green
- Default Scene Camera
- SubjectA_T1
- Xf0_SubjectA_T2_to_T1
- SubjectA_T2

Scene Model: Transform

- ☐ Display MRML ID's
- ☐ Show Hidden nodes

Filter:

MRML Node Inspector

Data Probe

- ☐ Show Zoomed Slice

RegistrationData

Name	Date Modified	Size	Kind
SubjectA	3 Dec 2015 10:58 pm	--	Folder
SubjectB	3 Dec 2015 10:57 pm	--	Folder

Diffusion MRI Analysis

10 cm

5 cm

NA-MIC ARR 2012-2016

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Subject B: Data Loading

3D Slicer 4.5.0-2015-12-14

Modules: **Data**

3DSlicer

► Help & Acknowledgement

▼ Display & Modify Scene

Nodes

- Scene
 - View1
 - Red
 - Yellow
 - Green
 - Default Scene Camera
 - SubjectA_T1
 - Xf0_SubjectA_T2_to_T1
 - SubjectA_T2

Scene Model: Transform

- ☐ Display MRML ID's
- ☐ Show Hidden nodes

Filter:

► MRML Node Inspector

▼ Data Probe

Red RAS: (-14.8, -220.3, 64.0) Axial Sp: 1.2

L None

F SubjectA_T1 (15, 220, 64) 1

B SubjectA_T2 (23, 224, 44) 41

Diffusion MRI Analysis

Add data into the scene

Choose Directory to Add Choose File(s) to Add ☐ Show Options

<input checked="" type="checkbox"/>	File	Description
<input checked="" type="checkbox"/>	...ktop/RegistrationData/SubjectB/SubjectB_T1.nrrd	Volume
<input checked="" type="checkbox"/>	...ktop/RegistrationData/SubjectB/SubjectB_T2.nrrd	Volume

Reset OK Cancel

R S: 64.000mm 1

R S P L

G A: -127.000mm

F: SubjectA_T1 (30%)
B: SubjectA_T2

10 cm

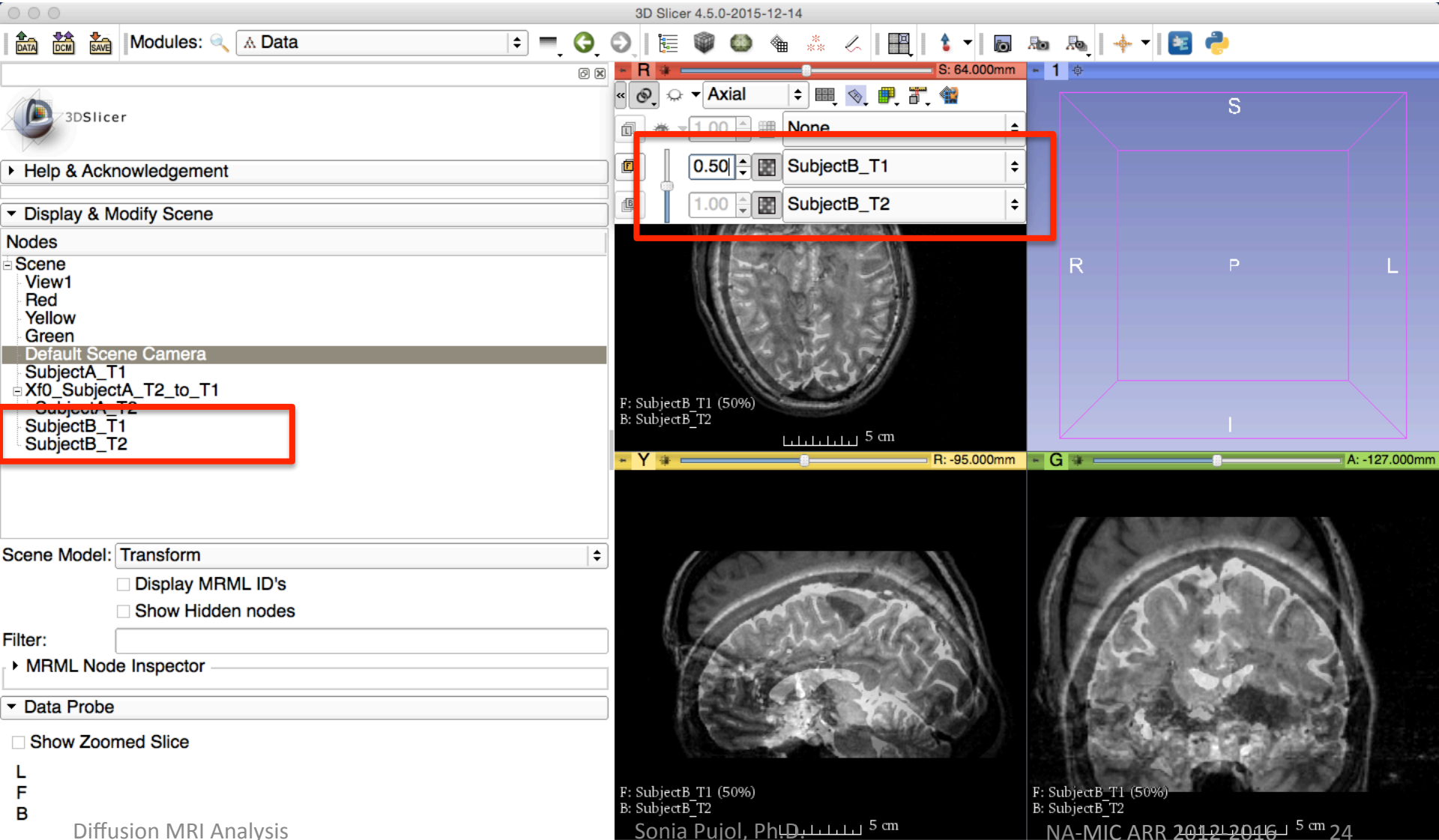
F: SubjectA_T1 (30%)
B: SubjectA_T2

5 cm

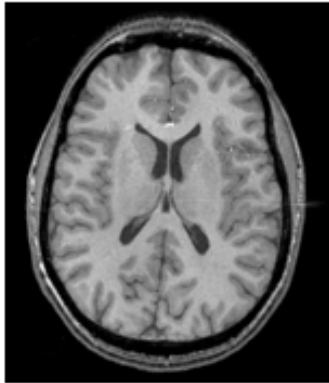
NA-MIC ARR 2012-2016

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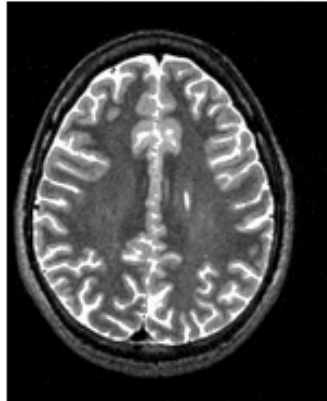
Subject B: Initial mis-registration



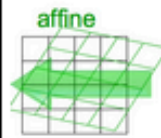
Registration pipeline



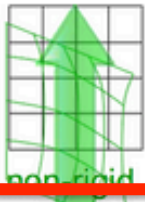
subj 1: T1



subj 1: T2



affine



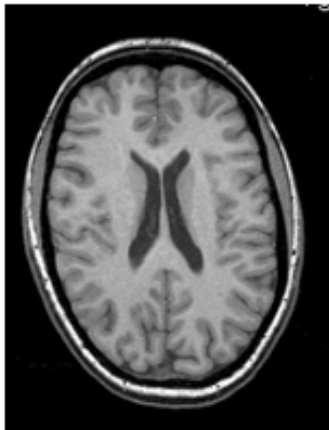
non-rigid

Step 1:

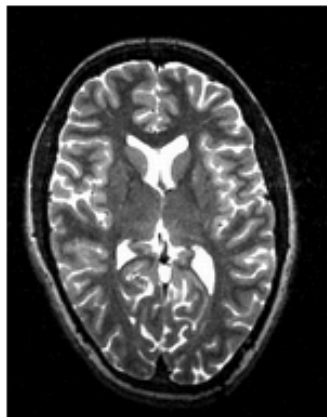
Subject A, T2 to T1 registration

Step 2:

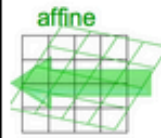
Subject B, T2 to T1 registration



subj 2: T1



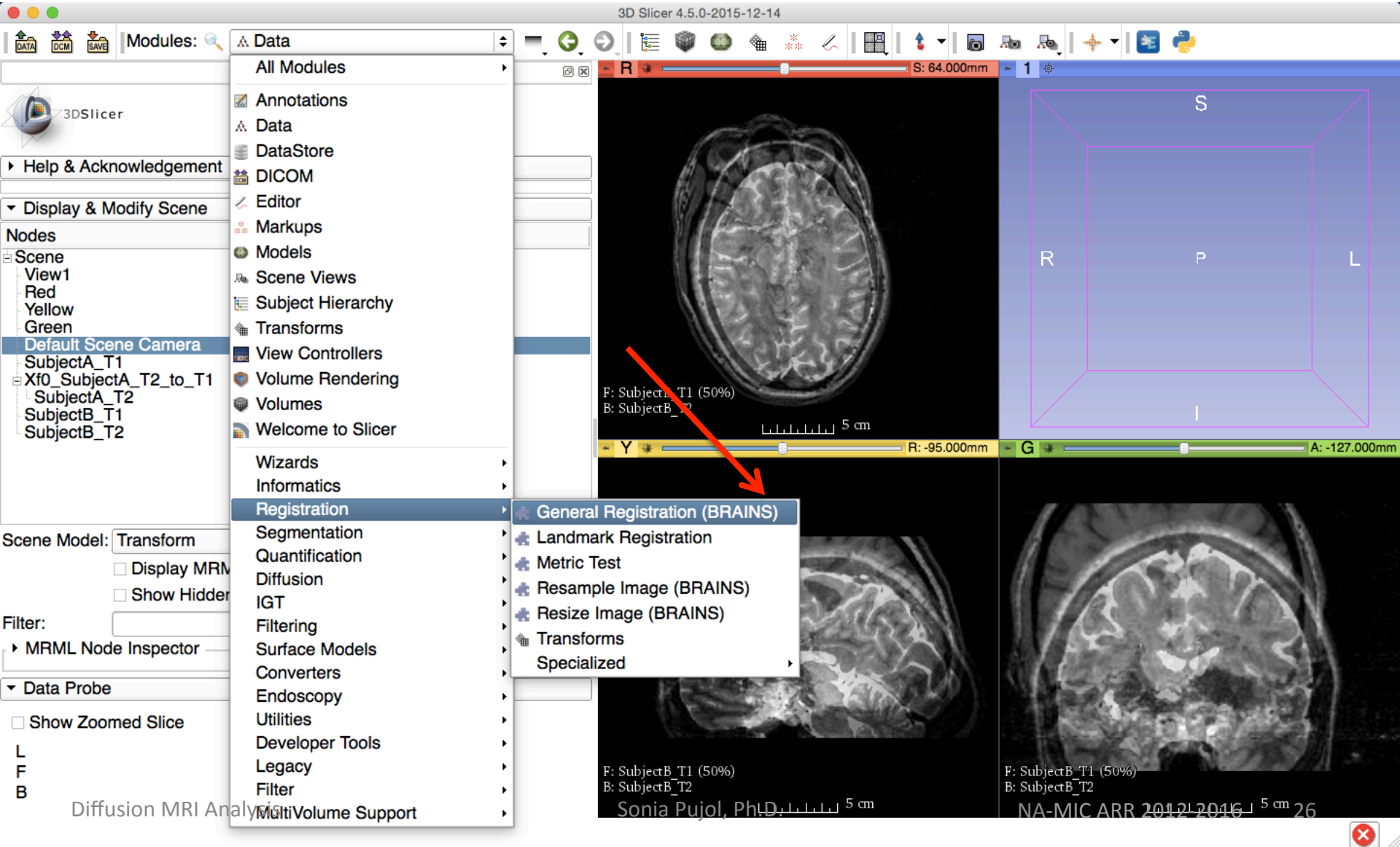
subj 2: T2



affine

Image courtesy
of Dominik
Meier, Ph.D.

Data Registration



3D Slicer 4.5.0-2015-12-14

Modules: General Registration (BRAINS)

3DSlicer

Help & Acknowledgement

General Registration (BRAINS)

Parameter set: General Registration (BRAINS)

Input Images

Fixed Image Volume: SubjectB_T1

Moving Image Volume: SubjectB_T2

Percentage Of Samples: 0.002

B-Spline Grid Size: 14,10,12

Output Settings (At least one output must be specified)

Slicer Linear Transform: Xf1_SubjectB_T2_to_T1

Slicer B-Spline Transform: None

Output Image Volume: None

Transform Initialization Settings

Initialization transform: None

Initialize Transform Mode: Off

Status: Completed

100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L

F

B

Diffusion MRI Analysis

axial view: F: SubjectB_T1 (50%) B: SubjectB_T2 5 cm

sagittal view: F: SubjectB_T1 (50%) B: SubjectB_T2 5 cm

coronal view: F: SubjectB_T1 (50%) B: SubjectB_T2 5 cm

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Subject B: Data Registration

3D Slicer 4.5.0-2015-12-14

Modules: General Registration (BRAINS)

Transformation Initialization Settings

Initialization transform: None

Initialize Transform Mode: ☐ Off
☐ useMomentsAlign
☒ useCenterOfHeadAlign
☐ useGeometryAlign
☐ useCenterOfROIAlign

Registration Phases (Check one or more, executed in order listed)

☒ Rigid (6 DOF)
☐ Rigid+Scale(7 DOF)
☒ Rigid+Scale+Skew(10 DOF)
☐ Affine(12 DOF)
☐ BSpline (>27 DOF)
☐ SyN
☐ Composite (many DOF)

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

☐ Show Zoomed Slice

L
F
B

Diffusion MRI Analysis

Set Initialization mode to UseCenterOfHeadAlign

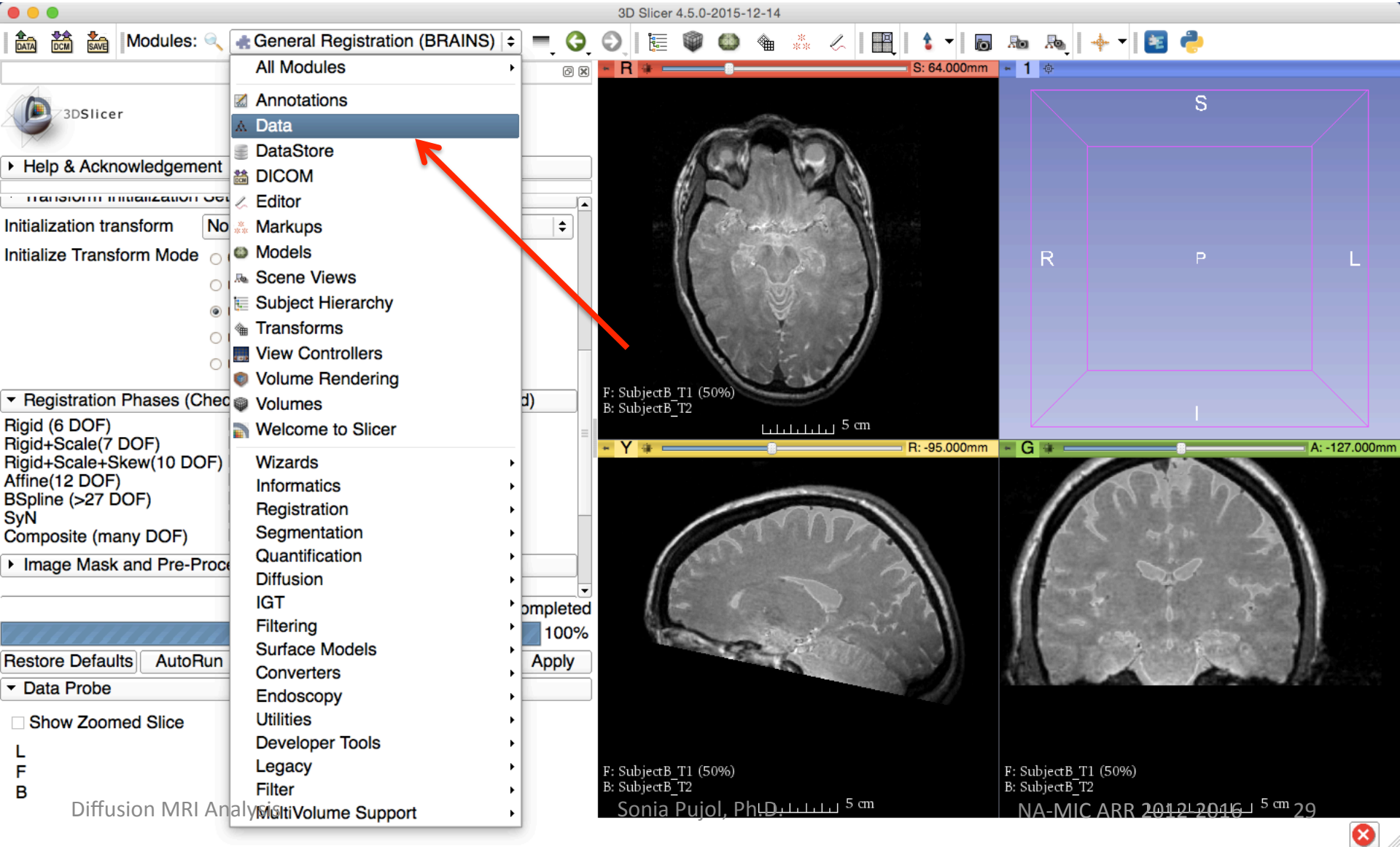
Set Registration Phases to Rigid and Affine

F: SubjectB_T1 (50%)
B: SubjectB_T2

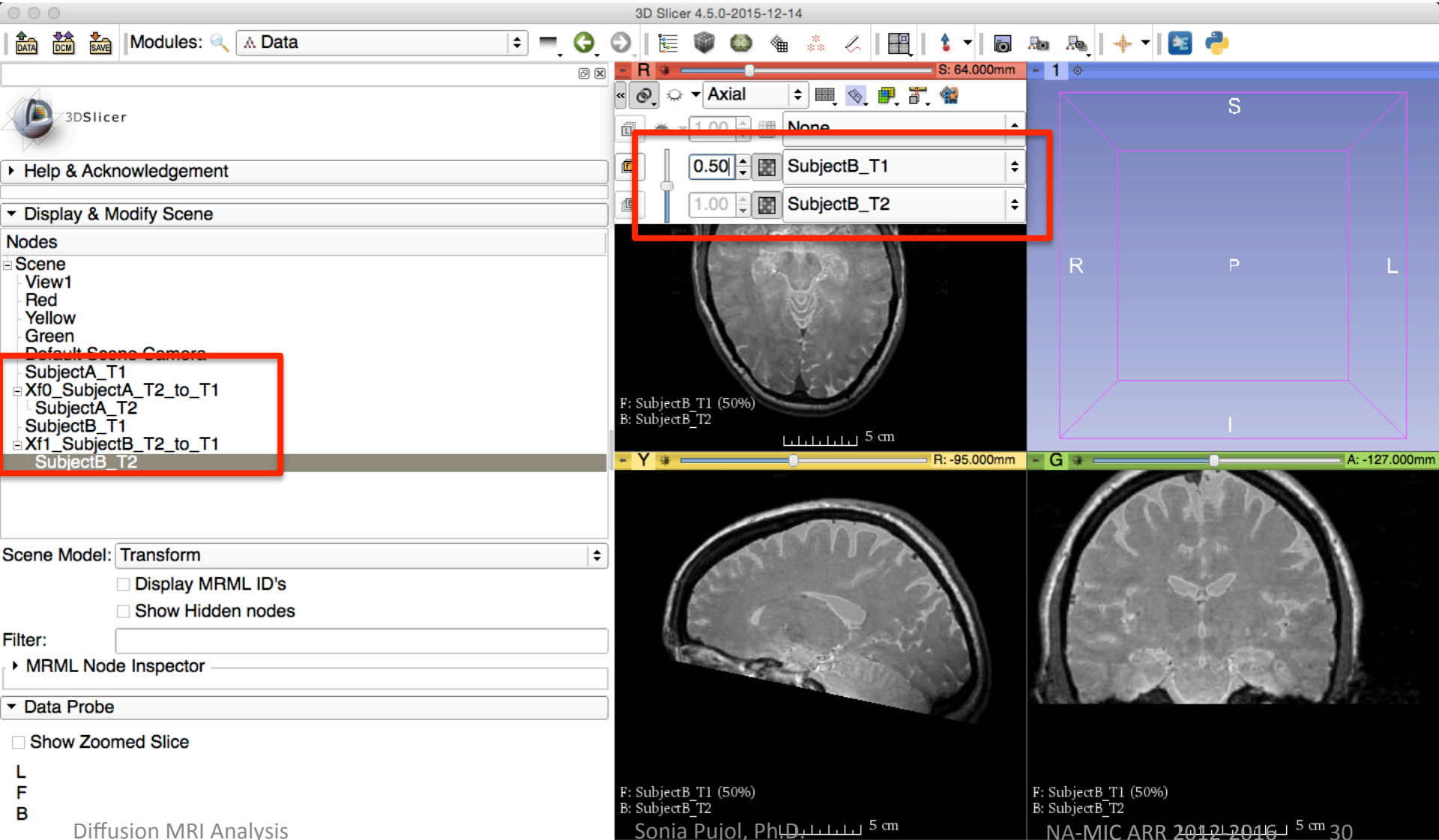
5 cm

NA-MIC ARR 2012-2016 28

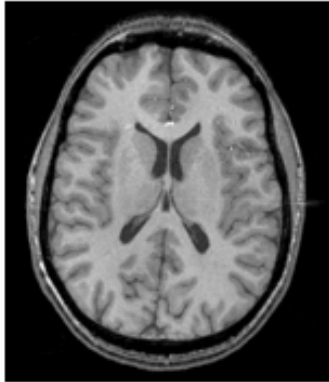
Subject B: Data Registration



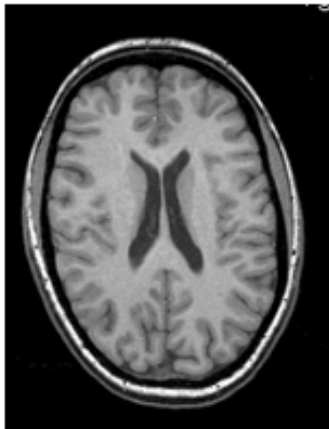
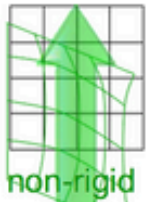
Subject B: Data Registration



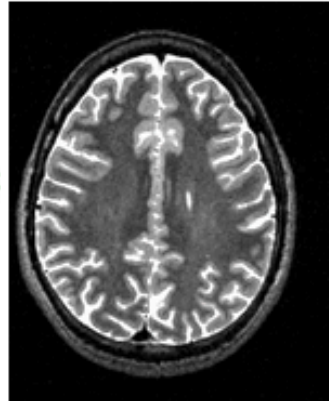
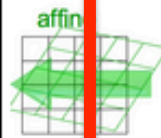
Registration pipeline



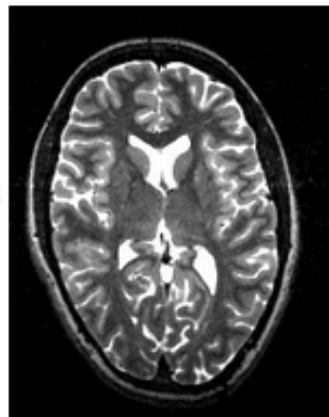
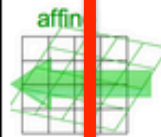
subj 1: T1



subj 2: T1



subj 1: T2



subj 2: T2

Step 1:

Subject A, T2 to T1 registration

Step 2:

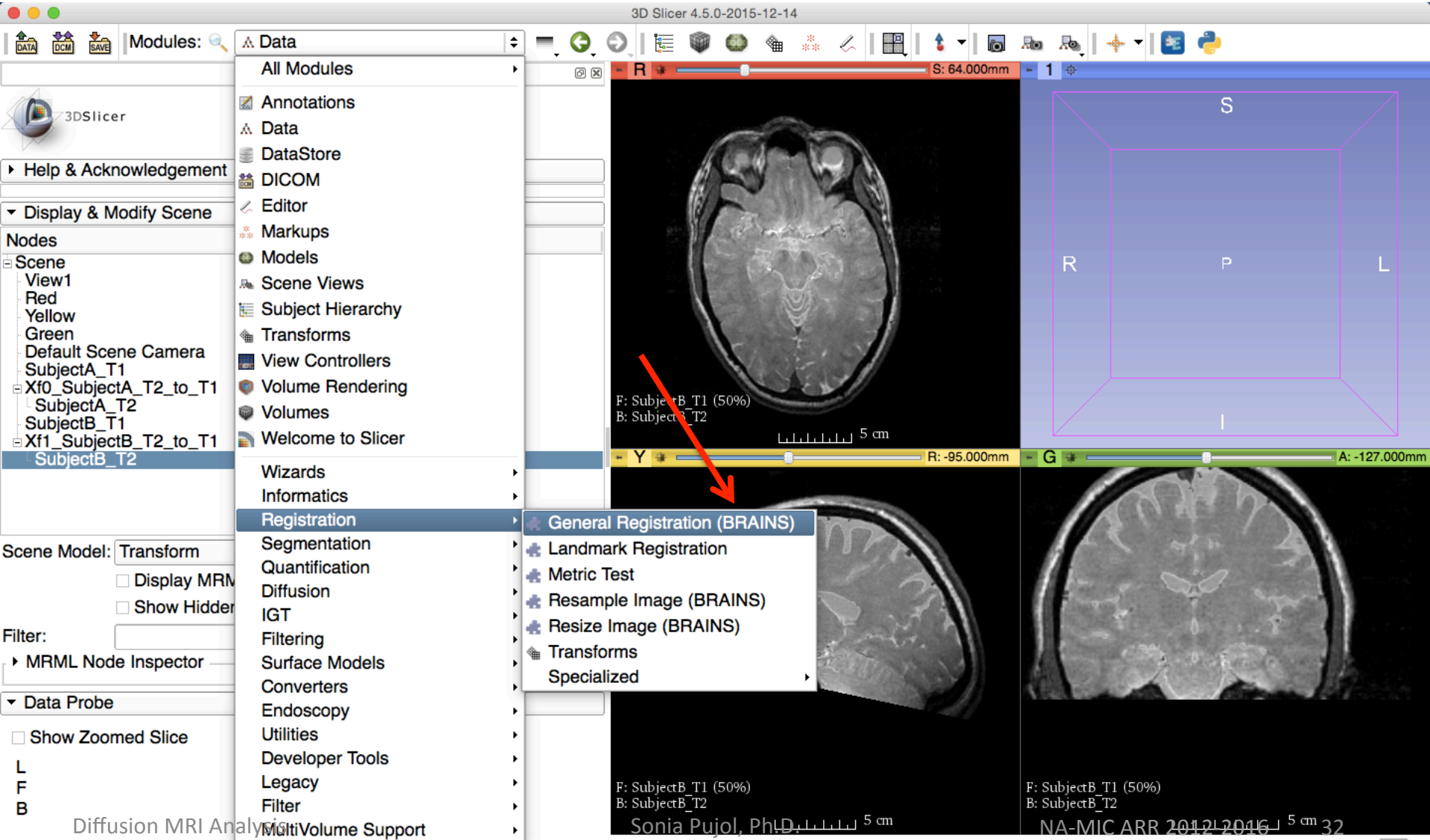
Subject B, T2 to T1 registration

Step 3:

Subject B, T1 to Subject A, T1 registration

Image courtesy
of Dominik
Meier, Ph.D.

Co-registration of Subject B to Subject A



Non rigid registration of Subject B to Subject A

3D Slicer 4.5.0-2015-12-14

Modules: General Registration (BRAINS)

Parameter set: General Registration (BRAINS)

Input Images

Fixed Image Volume	SubjectA_T1
Moving Image Volume	SubjectB_T1
Percentage Of Samples	0.02
B-Spline Grid Size	3,3,3

Output Settings (At least one output must be specified)

Slicer Linear Transform	None
Slicer BSpline Transform	Xf2_SubjectB_T1_to_SubjectA_T1
Output Image Volume	SubjectB_T1_Xf2_transformed

Transform Initialization Settings

Initialization transform	None
Initialize Transform Mode	Off

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

Show Zoomed Slice

L
F
B

Diffusion MRI Analysis

Set the Percentage of Samples to 0.02

Set the B-Spline Grid size to 3,3,3

F: SubjectB_T1 (50%)
B: SubjectB_T2

5 cm

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Non rigid registration of Subject B to Subject A

3D Slicer 4.5.0-2015-12-14

Modules: General Registration (BRAINS)

3DSlicer

Help & Acknowledgement

Transform Initialization Settings

Initialization transform: None

Initialize Transform Mode: ☒ Off

- ☐ useMomentsAlign
- ☐ useCenterOfHeadAlign
- ☐ useGeometryAlign
- ☐ useCenterOfROIAAlign

Registration Phases (Check one or more, executed in order listed)

- ☐ Rigid (6 DOF)
- ☐ Rigid+Scale(7 DOF)
- ☐ Rigid+Scale+Skew(10 DOF)
- ☐ Affine(12 DOF)
- ☒ BSpline (>27 DOF)
- ☐ SyN
- ☐ Composite (many DOF)

Image Mask and Pre-Processing

Status: Completed 100%

Restore Defaults AutoRun Cancel Apply

Data Probe

☐ Show Zoomed Slice

L
F
B

Diffusion MRI Analysis

Set Initialization mode **Off**

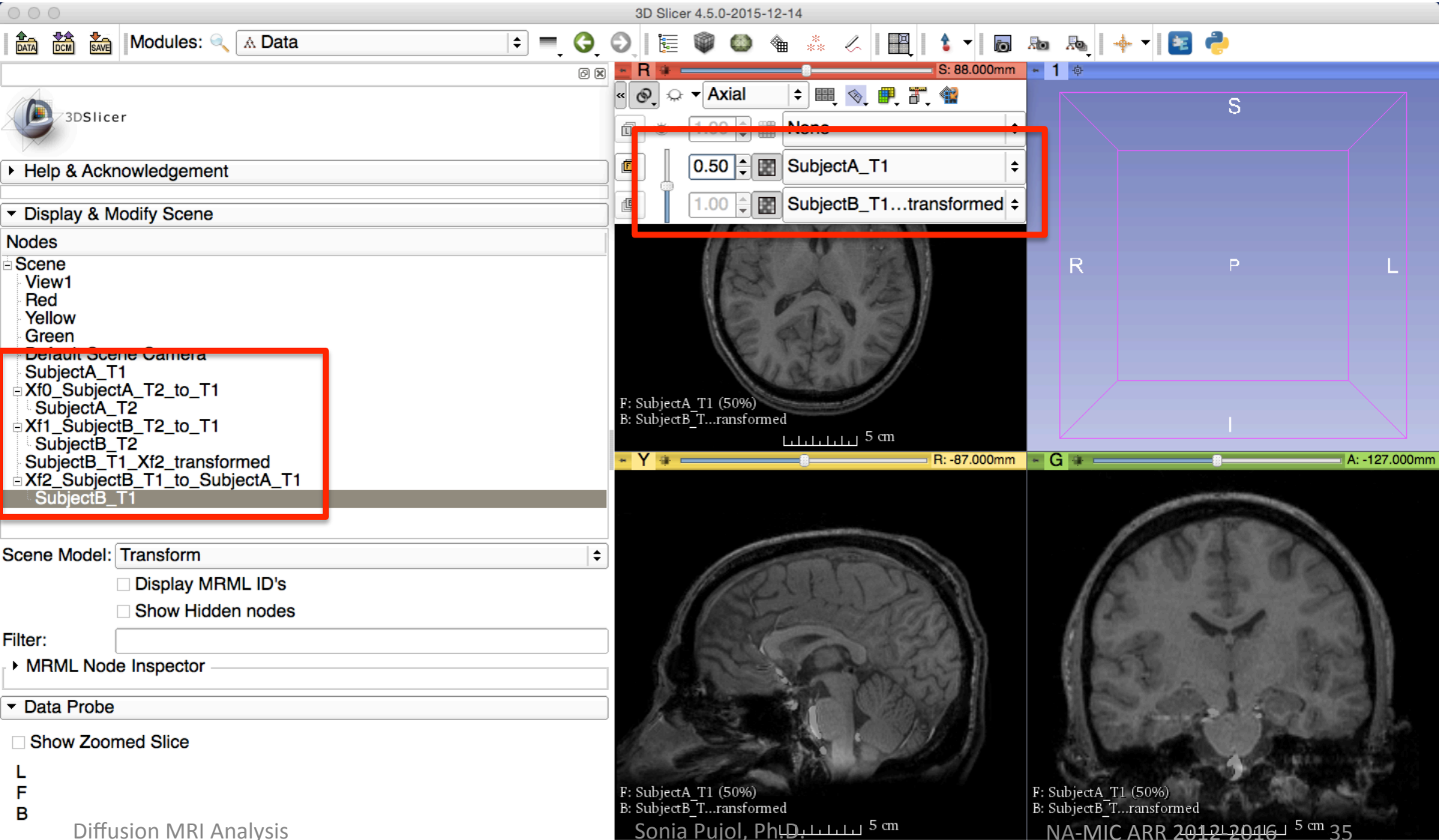
Set Registration Phases to **BSpline**

F: SubjectB_T1 (50%)
B: SubjectB_T2

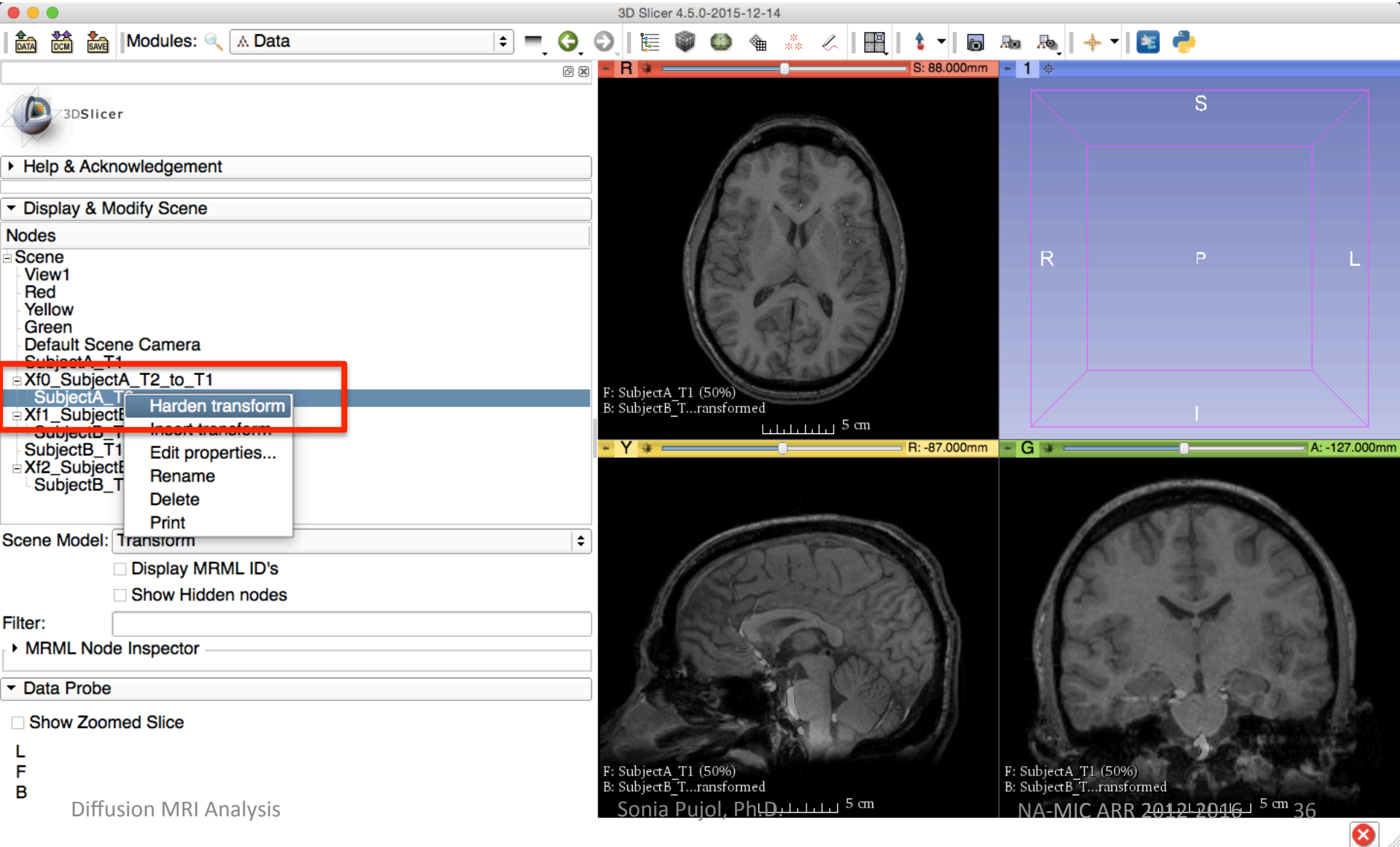
5 cm

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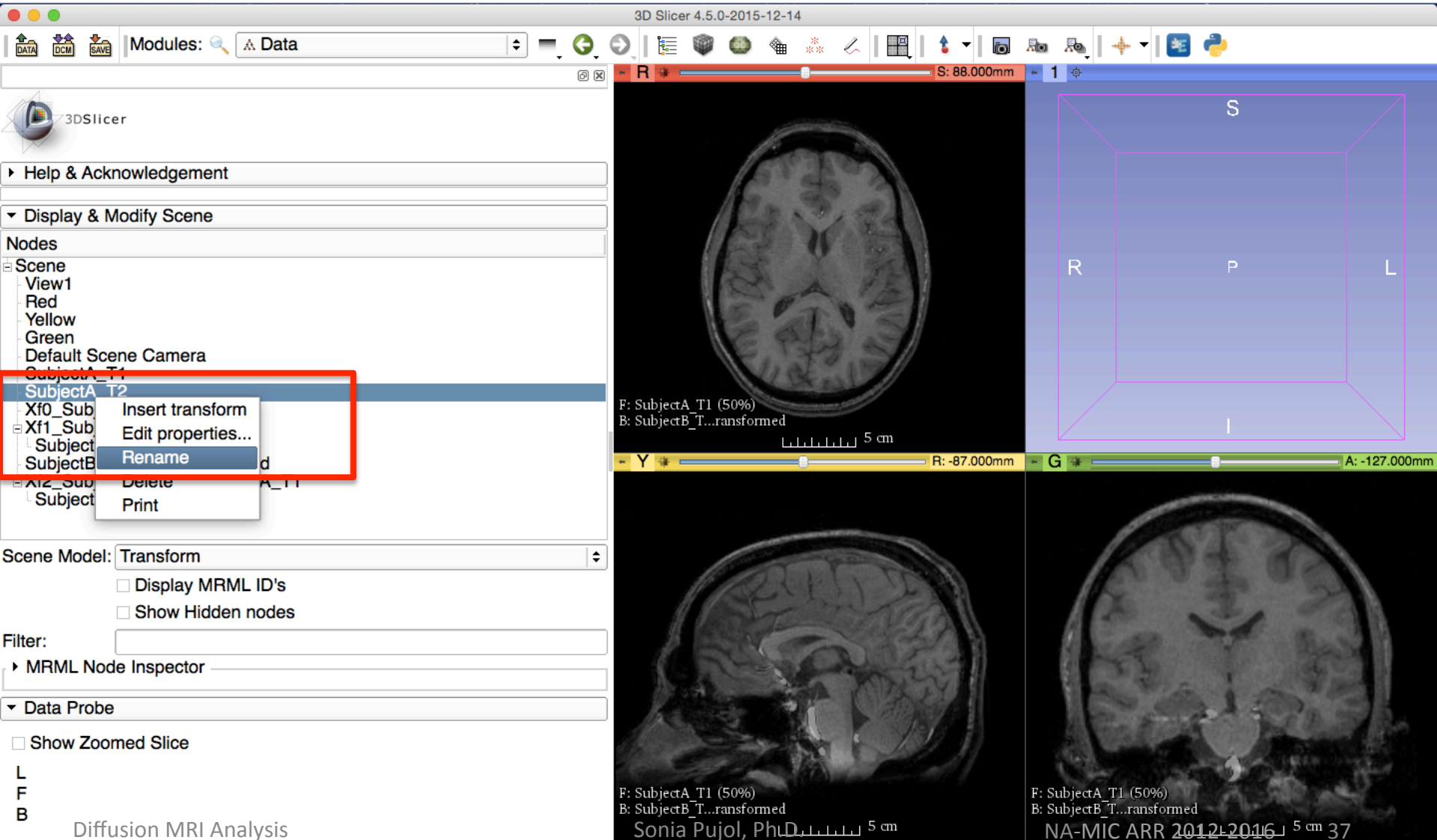
Co-registration of Subject B to Subject A



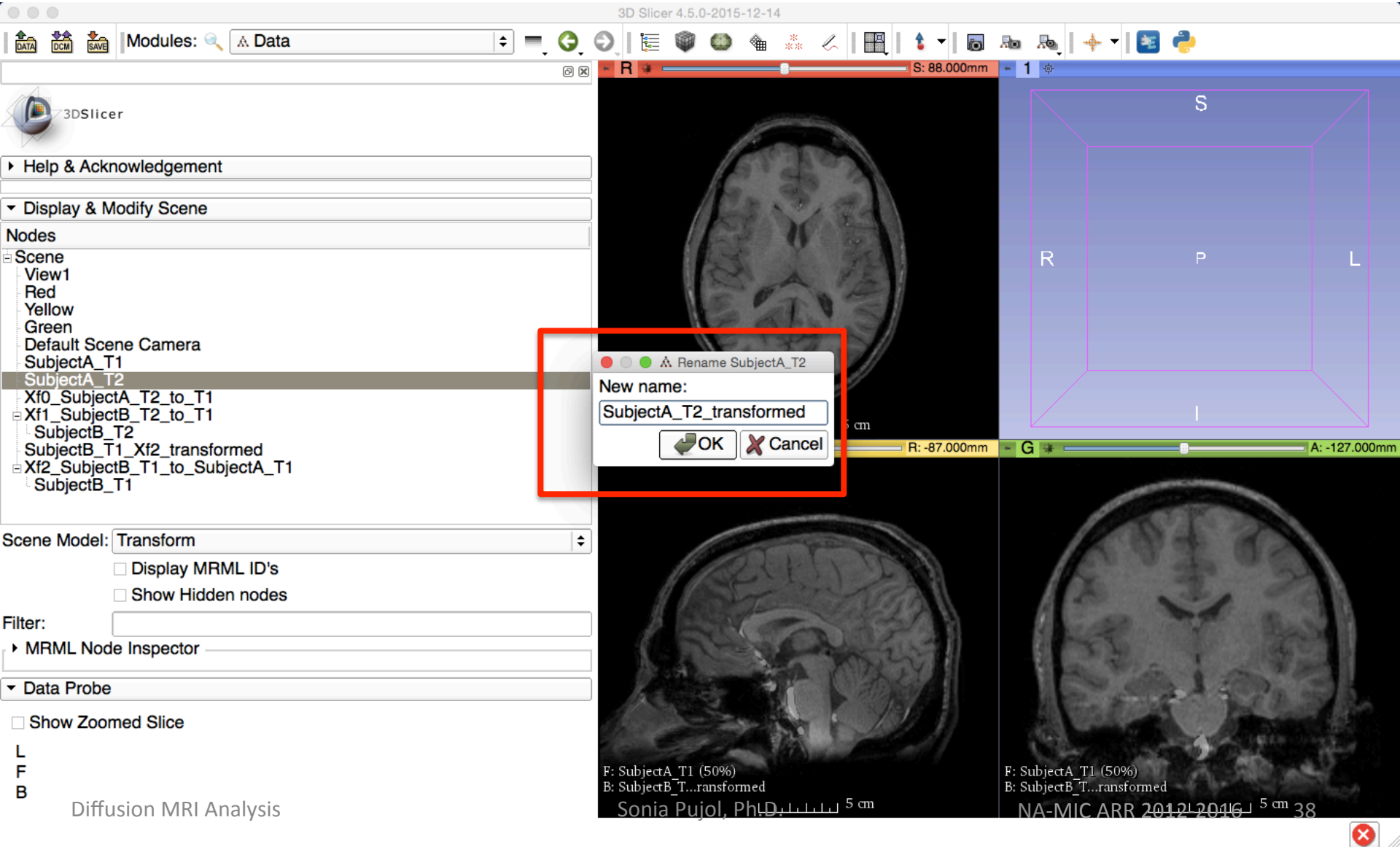
Harden Transform Xf0 (Subject A: T2 to T1)



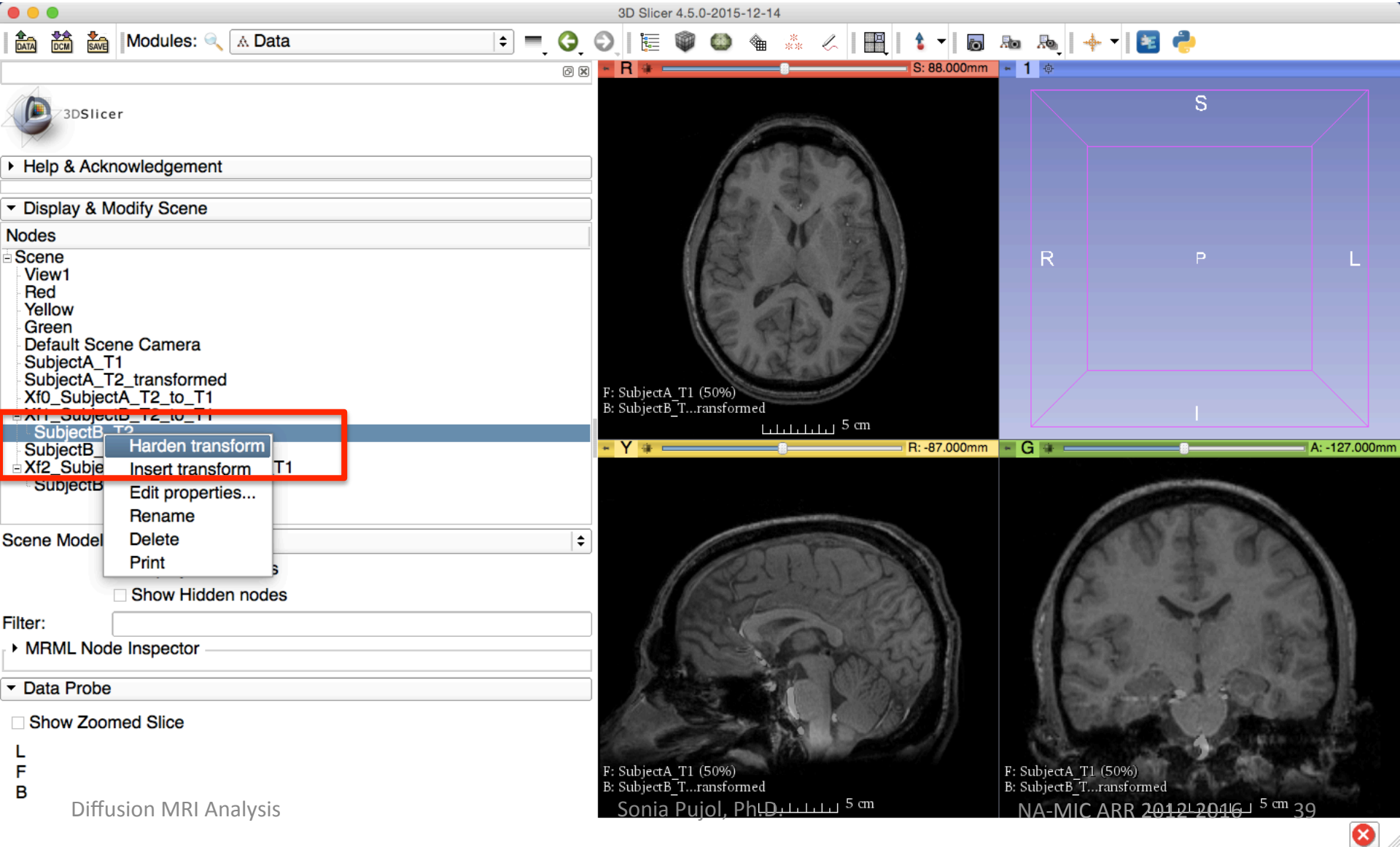
Rename Transformed Volume



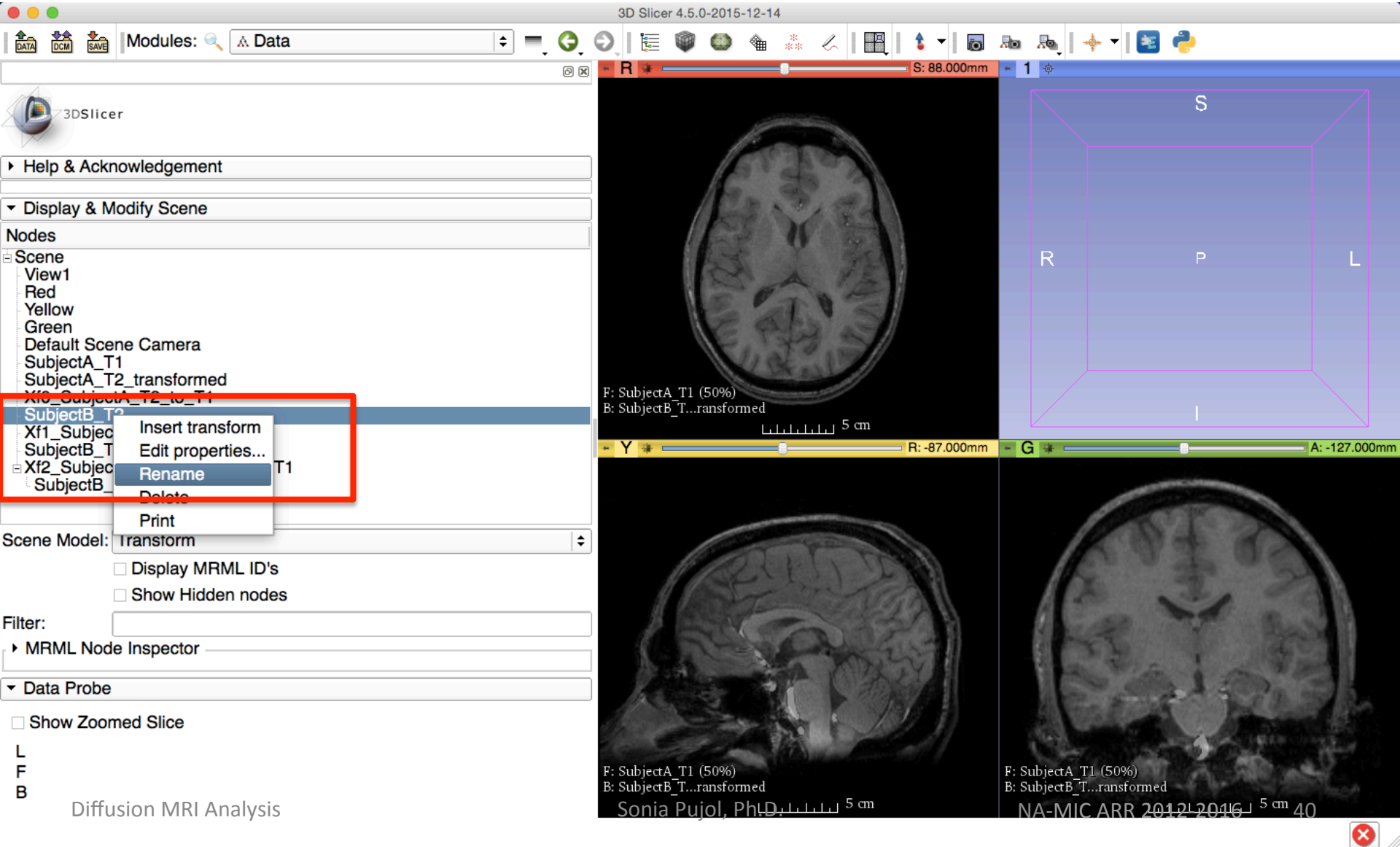
Rename Transformed Volume



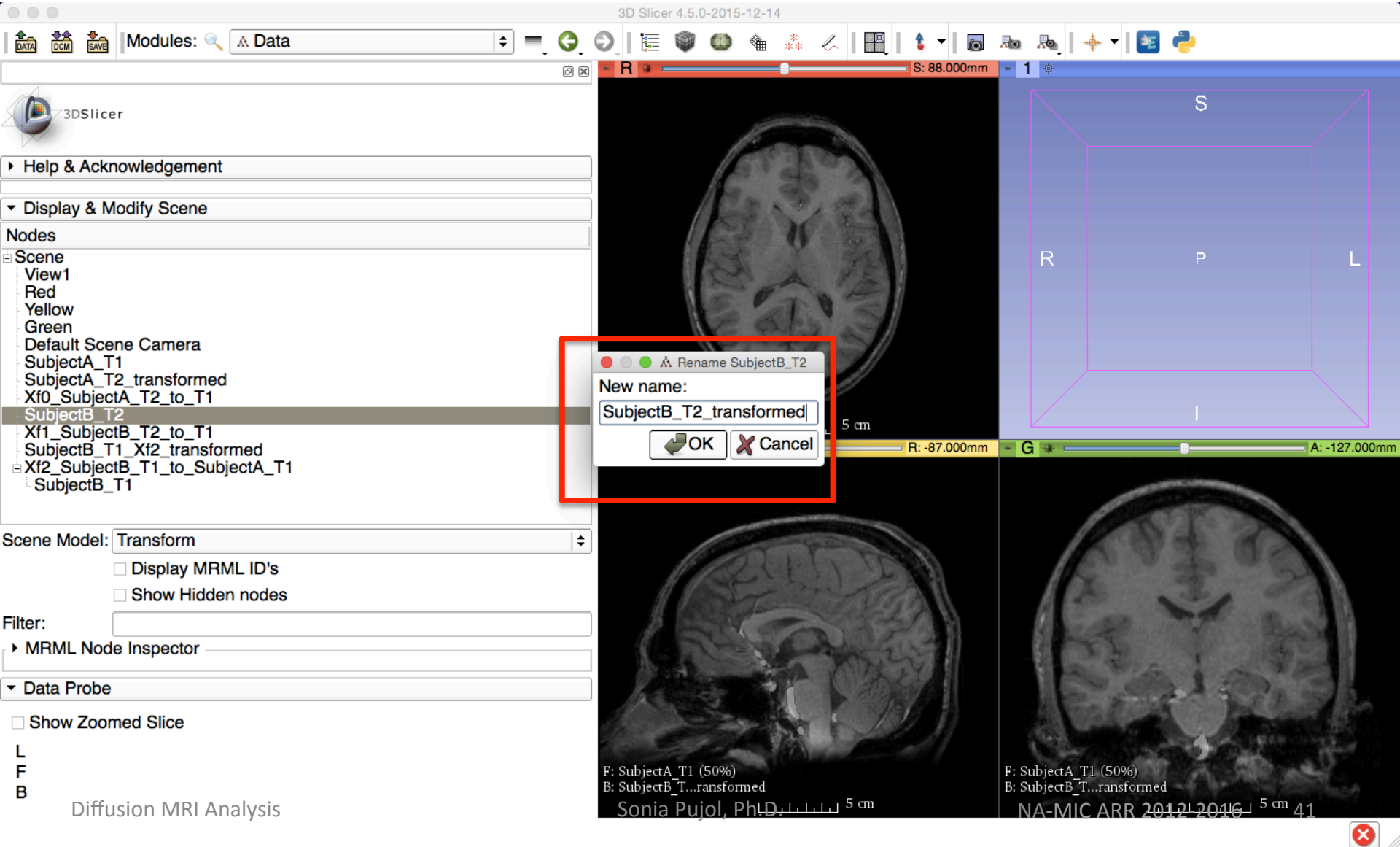
Harden Transform Xf1 (Subject B: T2 to T1)



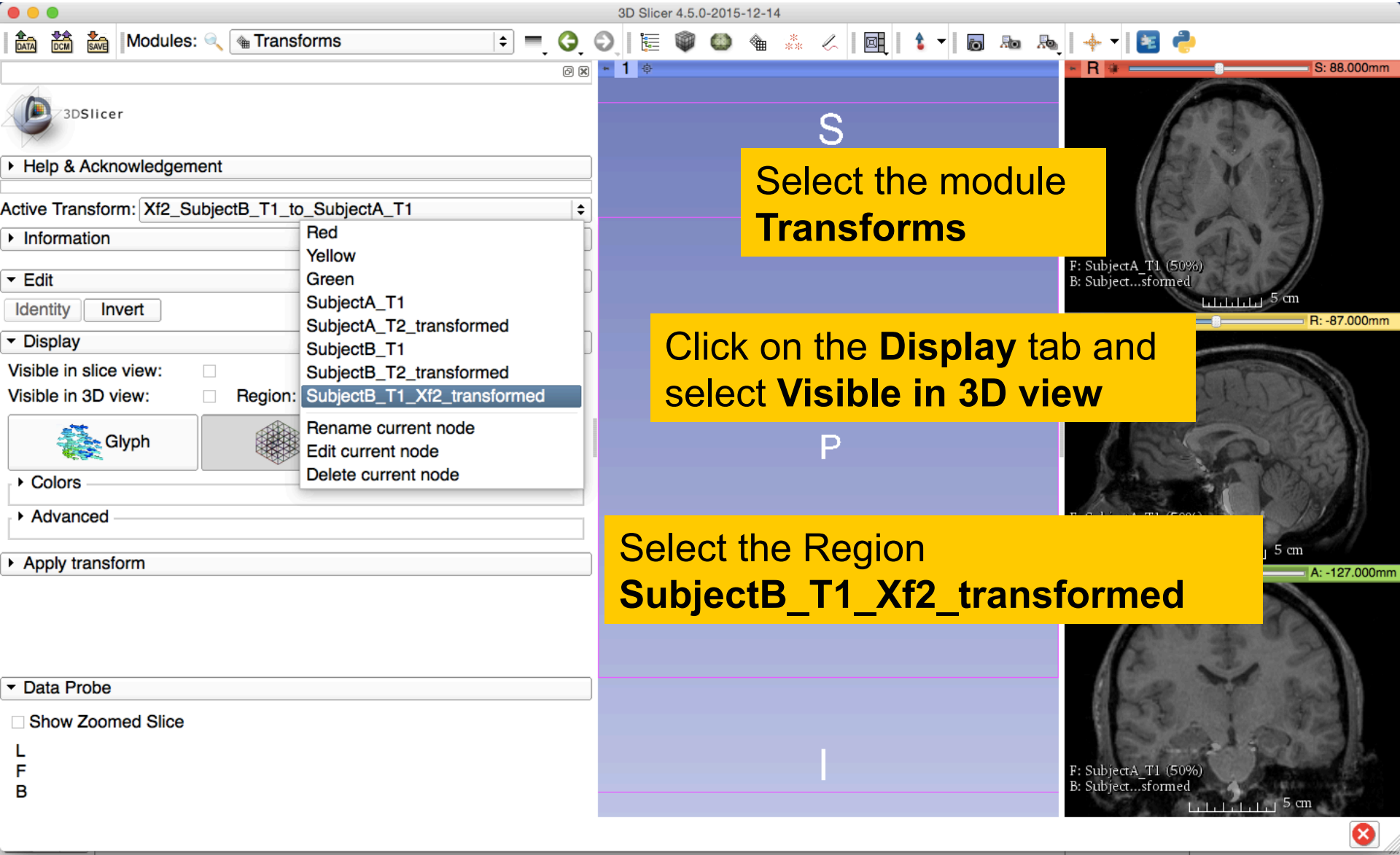
Renamed Transformed Volume



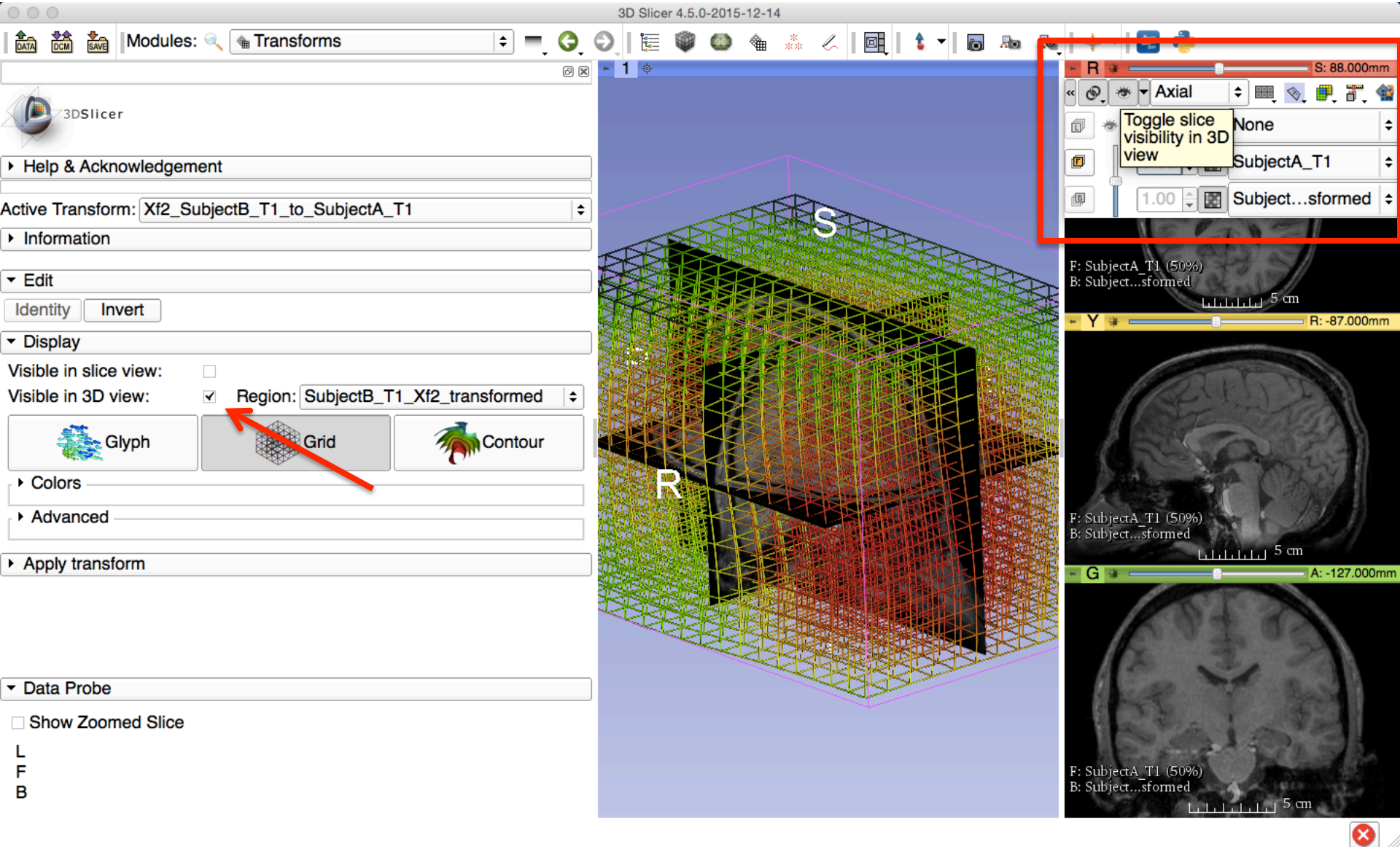
Rename Transformed Volume



Visualizing Xf3 (Subject B T1 to Subject A T1)



Visualizing Xf3 (Subject B T1 to Subject A T1)



Acknowledgments



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