ヒトの脳の拡散MRI解析

Diffusion MRI Analysis of the Human Brain

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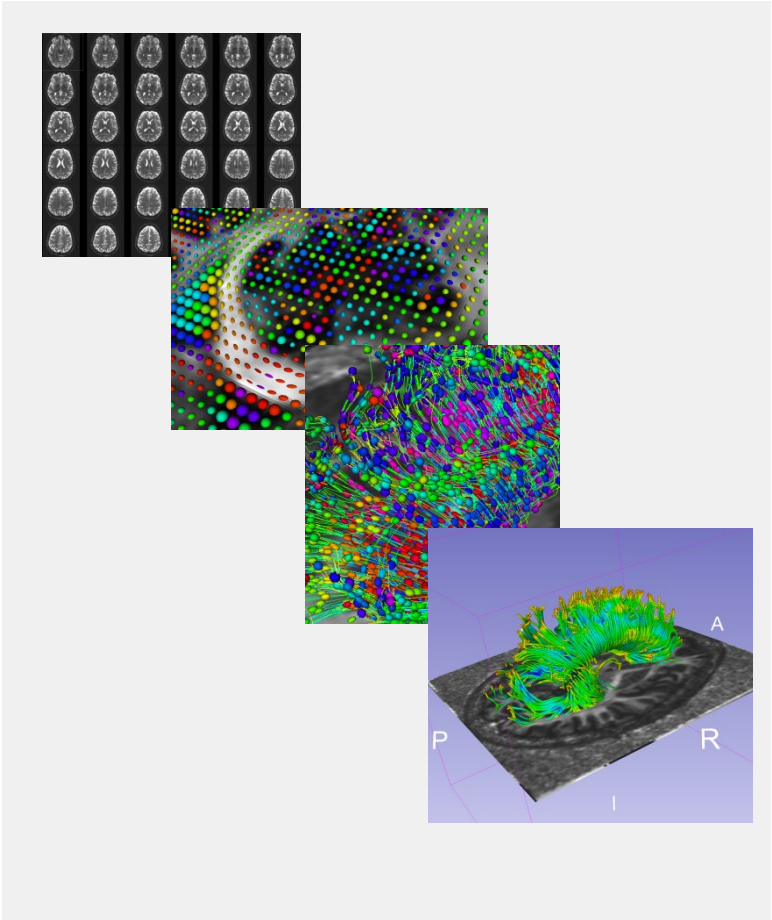
概要

Tutorial Outline



This tutorial is an introduction to the fundamentals of Diffusion MRI analysis, from computation of DTI data to 3D visualization of fiber tracts.

fundamentals ：基礎
computation：計算
visualization： 可視化
fiber tracts：脳白質線維束

Diffusion MRI Analysis of the Human Brain, S.Pujol, ARR 2012-2017

Tutorial Outline

- Part 1: Basics of Diffusion MRI mapping of white matter pathways

mapping：地図（＝画像）の作成

white matter pathways：白質（の線維神経）路

- Part 2: Hands-on Diffusion MRI analysis using 3D Slicer

3D Slicer ：ソフトウェアの名前

Learning Objectives

Following this tutorial, you will be able to

1) Compute a **diffusion tensor imaging** (DTI) volume from a diffusion weighted MRI scan

2) Understand the **shape of the diffusion tensor ellipsoid** in different regions of the brain

3) Reconstruct the **3D trajectory of white matter tracts** from DTI data

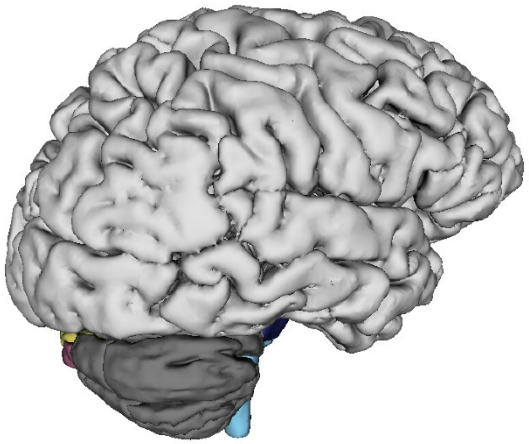
diffusion tensor：拡散テンソル
ellipsoid：楕円体
Trajectory：軌跡
white matter tracts：(脳)白質神経束

Tutorial Outline

- **Part 1: Basics of Diffusion MRI mapping of white matter pathways**

- Part 2: Hands-on Diffusion MRI analysis using 3D Slicer

Human Brain



The human brain weighs between 1,300 and 1,400 g and contains

100, 000,000, 000 (100 billions) neurons.

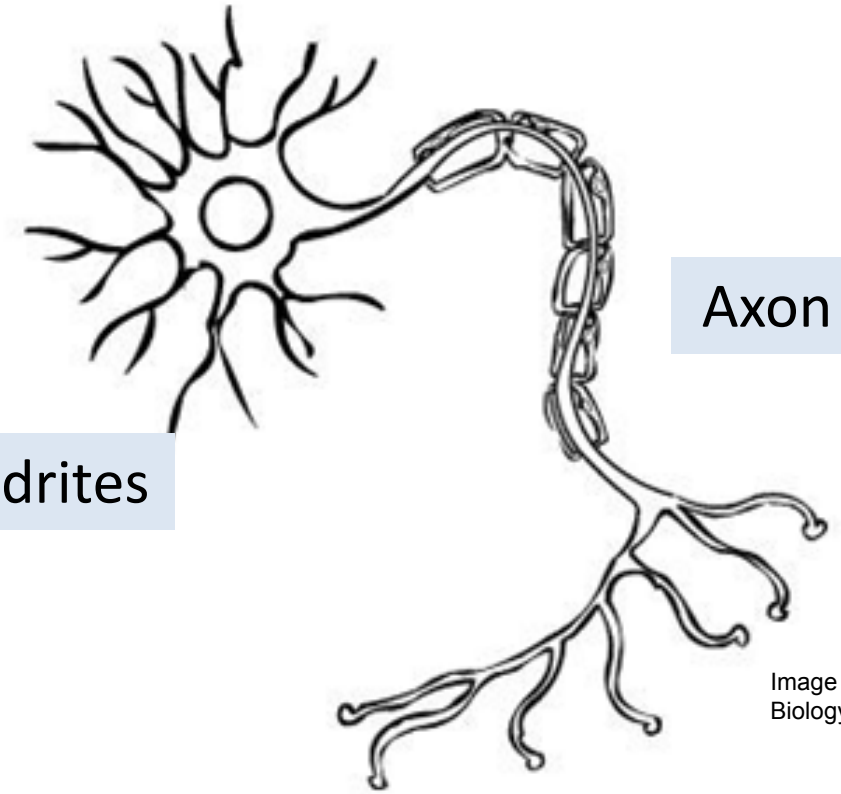
ニューロン: 神経細胞

神経細胞

Neuron

細胞体

Cell Body



Axon 軸索

Dendrites

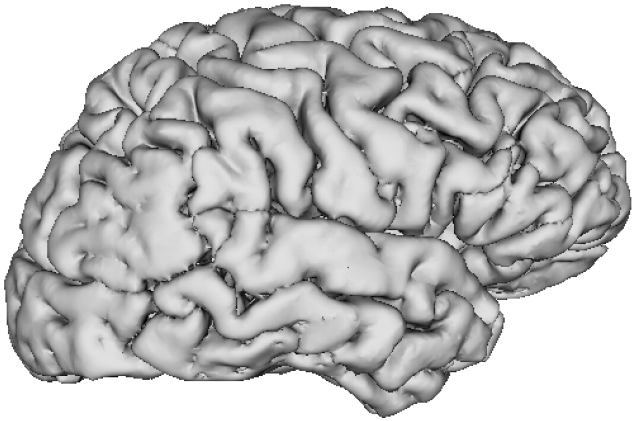
樹状突起

Image source: BSC1007C Introductory Biology, State College of Florida

Axons terminals

軸索終端

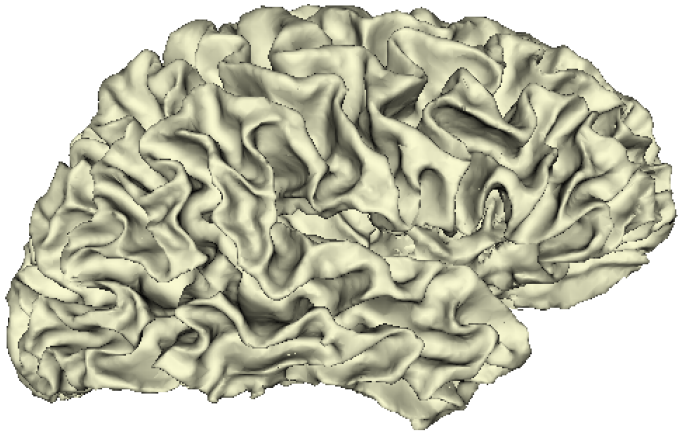
Human Brain



灰白質

Grey Matter

(neuron cell bodies)



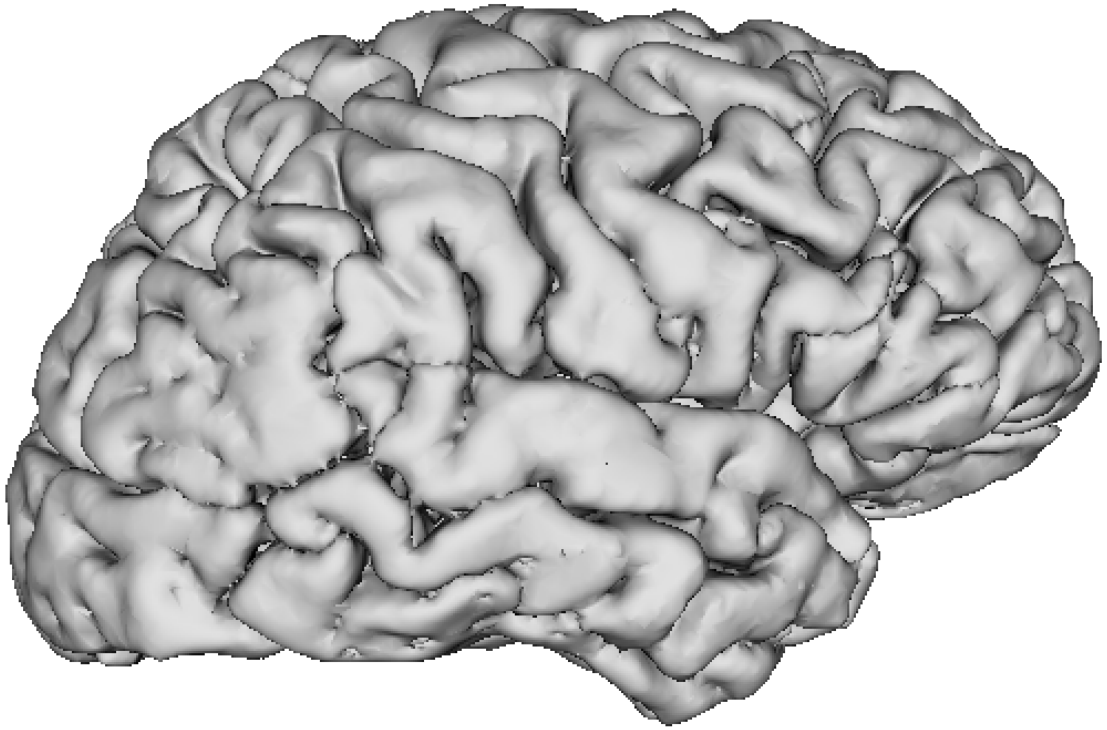
白質

White Matter

(neurons axons)

大脳皮質

Cerebral Cortex

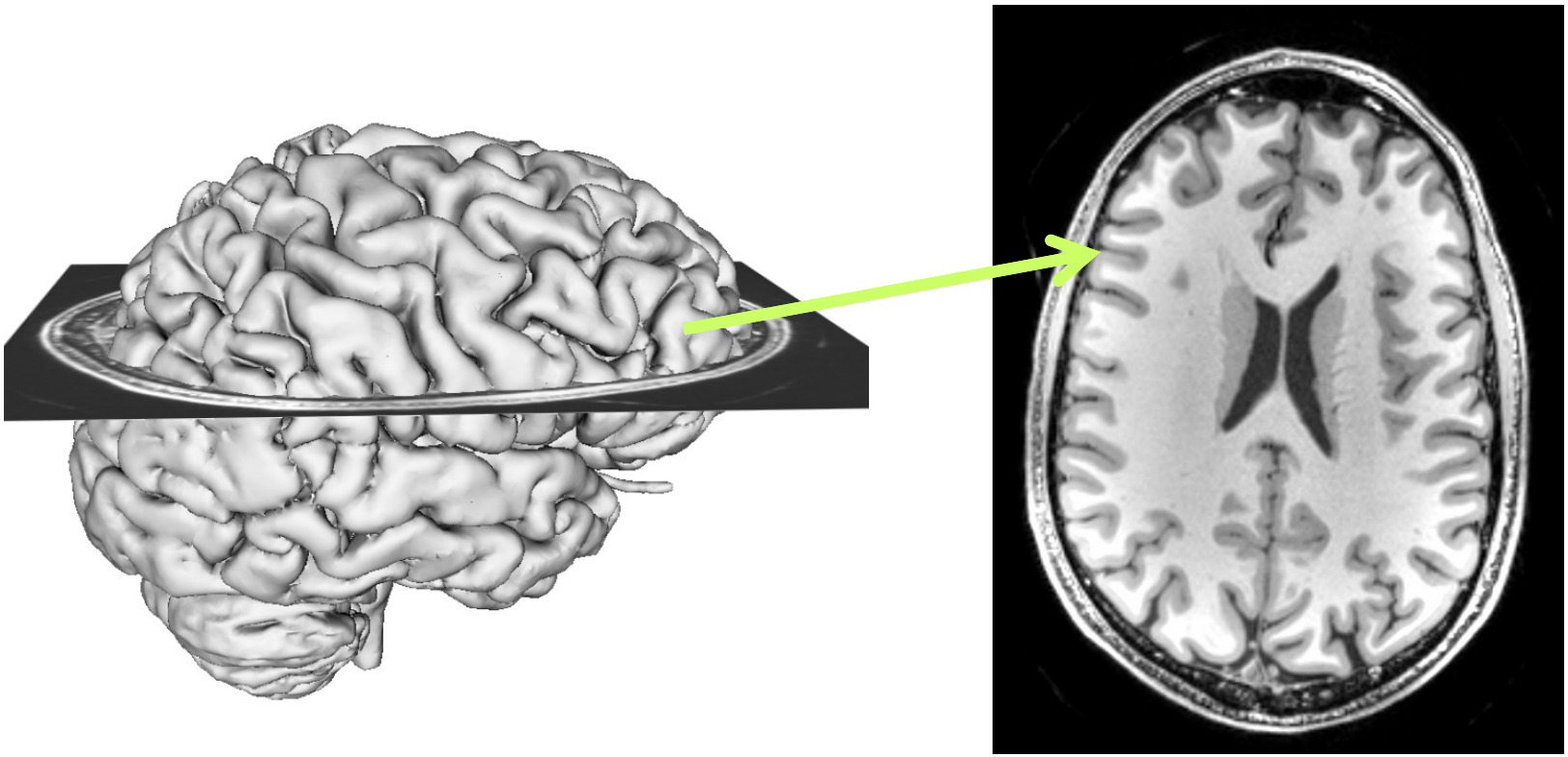


The cerebral cortex is composed of folded **grey matter**

折り畳まれた

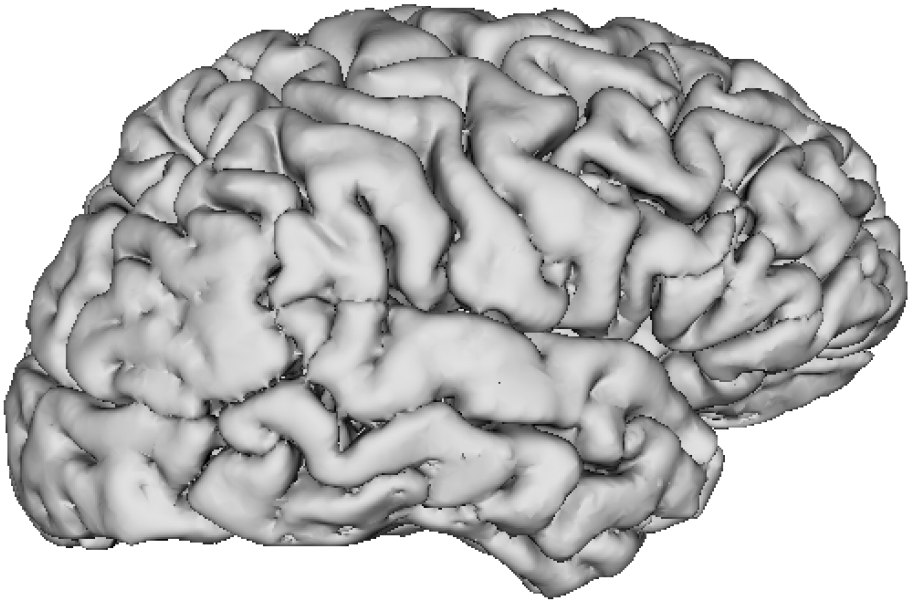
大脳皮質

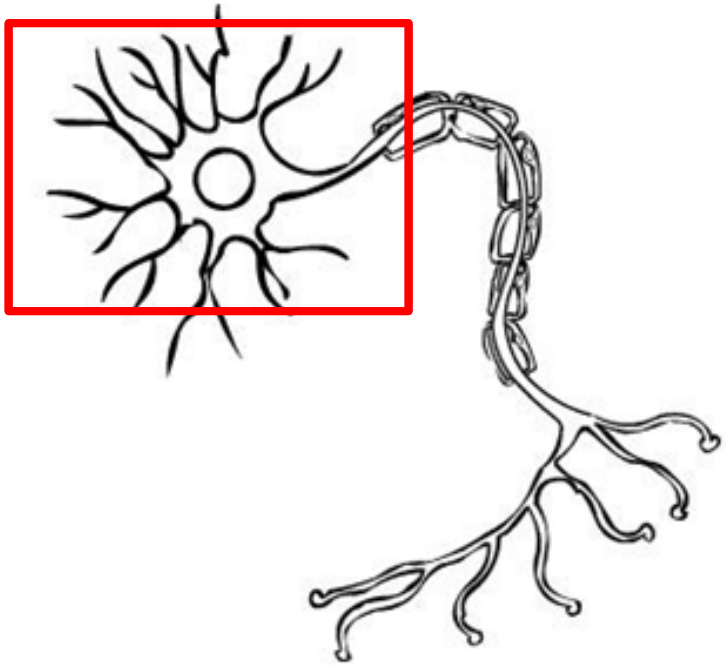
Cerebral Cortex



大脳皮質

Cerebral Cortex





Grey Matter

(neuron cell bodies)

大脳皮質

Cerebral Cortex

頭頂葉

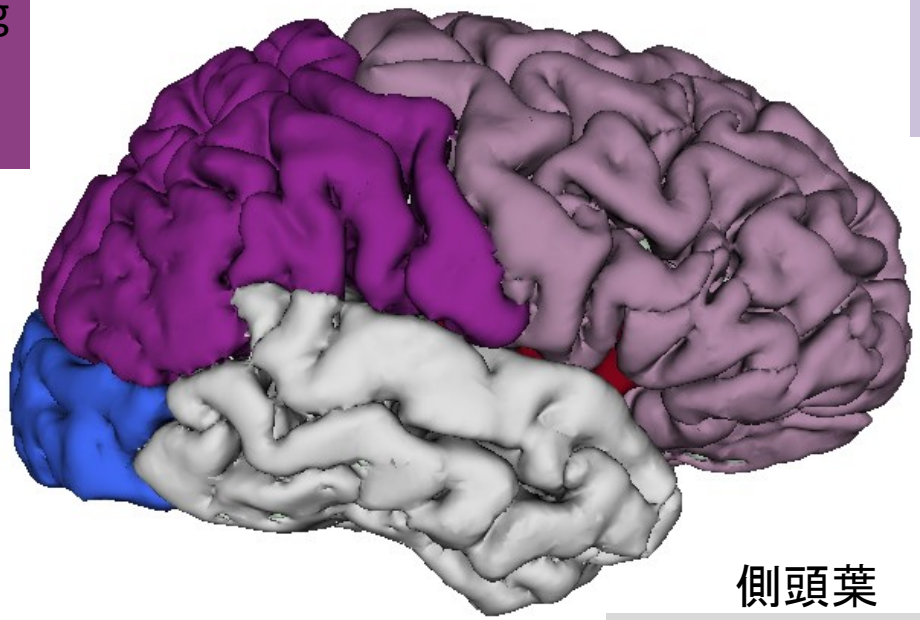
Parietal Lobe:
Reception and processing of sensory information from the body

sensory：感覚の

後頭葉

Occipital Lobe:
Vision

vision：視覚



前頭葉

Frontal Lobe:
Decision making
Problem solving
Planning

意思決定
問題解決
計画

側頭葉

Temporal Lobe:
Memory
Emotion
Hearing
Language

記憶
感情
聴覚
言語

The cortex is divided into four sections called **lobes**.

葉

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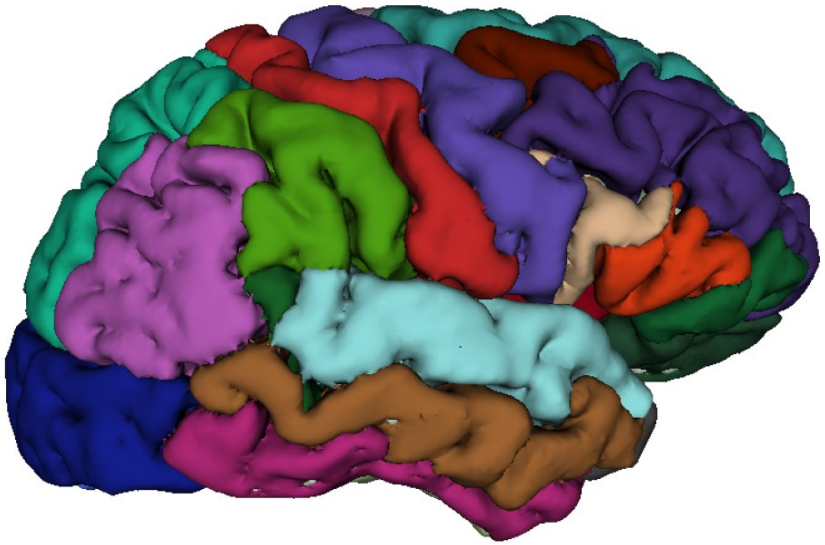
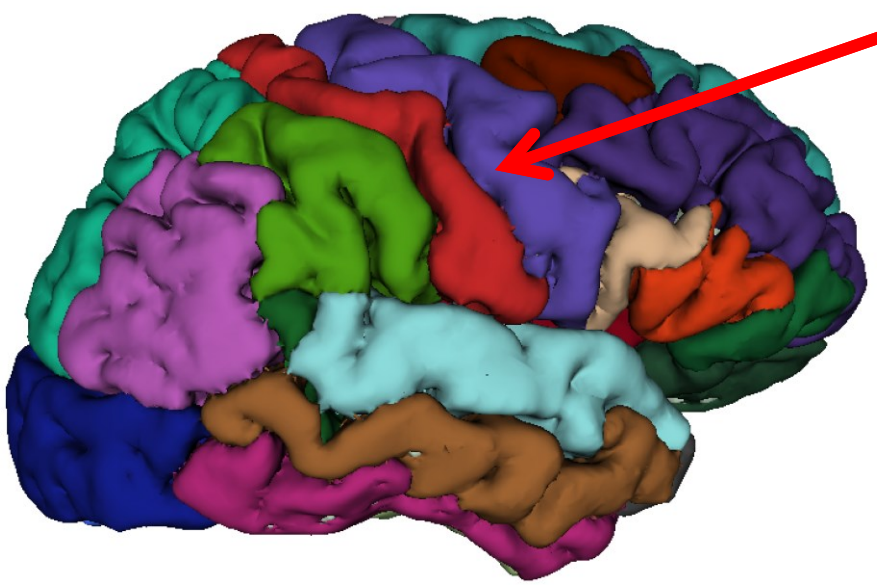
Cerebral Cortex



The lobes can be divided into functional areas involved in **movement, vision**, **hearing**, **touch**, **smell**, **thinking** and **reasoning**.

運動
Motor System



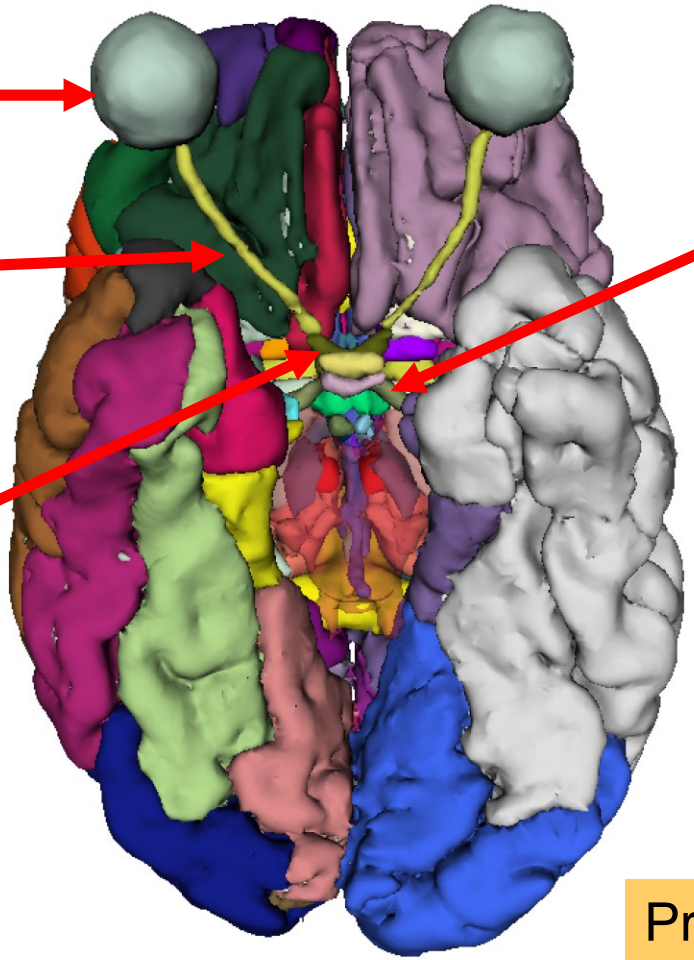
一次運動野

Primary Motor Cortex:

- Located in pre-central gyrus of the frontal lobe
- Responsible for voluntary movement

pre-central gyrus：中心前回
voluntary movement：自発的運動

視覚の
Visual System



Eyeball

Optic nerve
視神経

Optic chiasm
視交叉

Optic tract
視神経管

一次視覚野
Primary Visual Cortex

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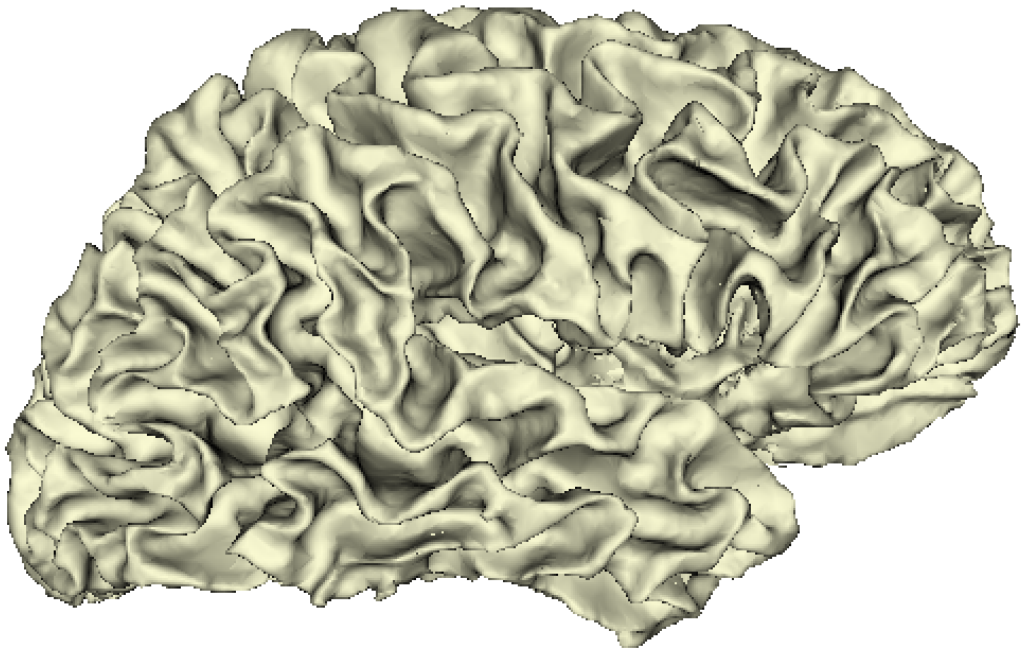
脳白質

Cerebral White Matter



The human brain white matter is composed of myelinated axons.

有髄軸索

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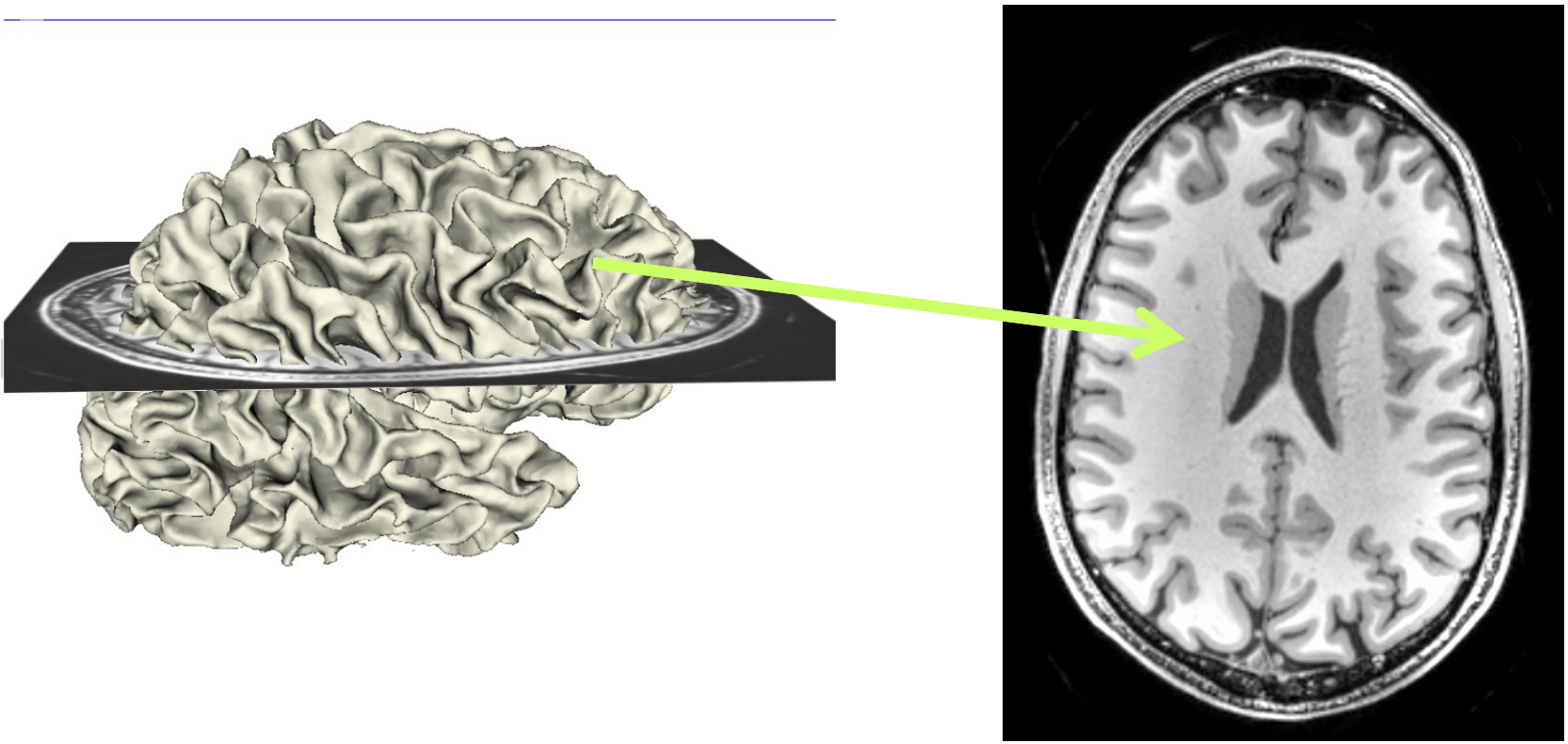
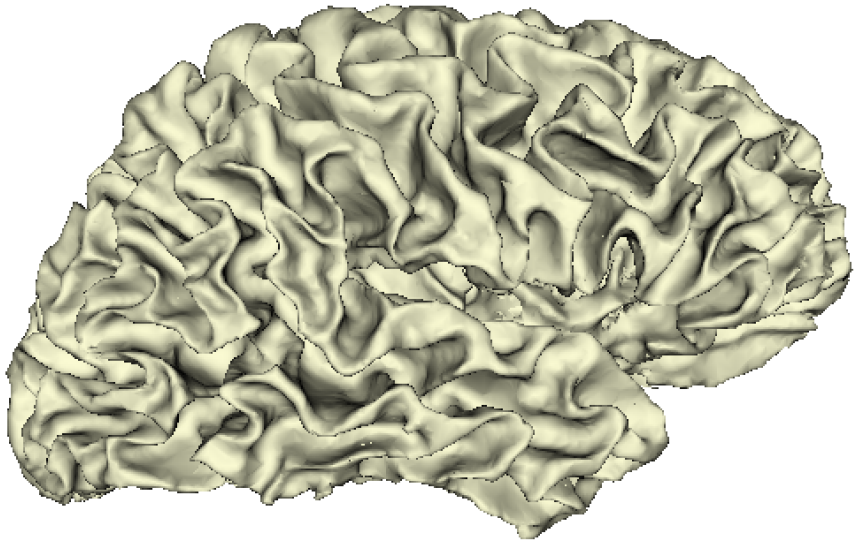
脳白質

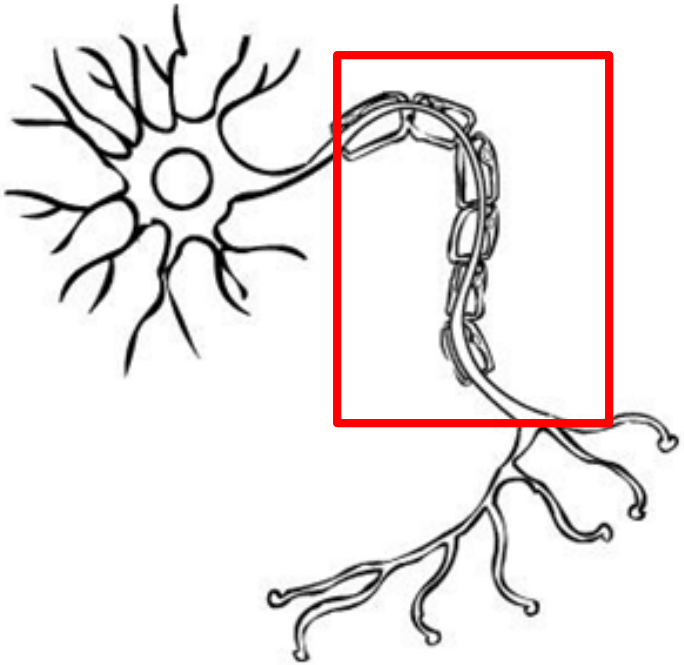
Cerebral White Matter



脳白質

Cerebral White Matter

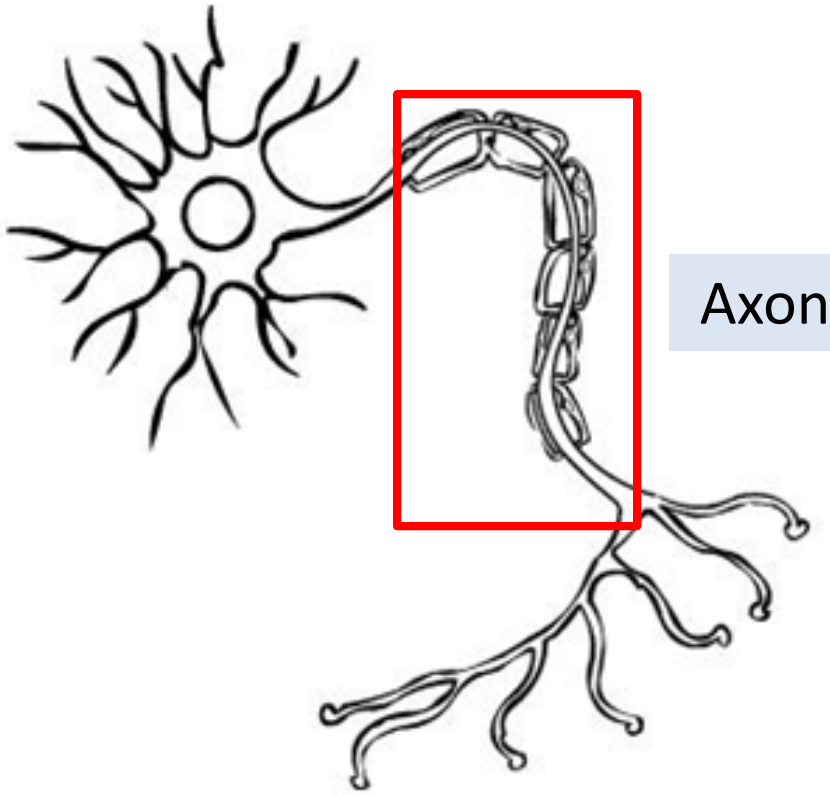




White Matter

(neurons axons)

神経細胞
Neuron



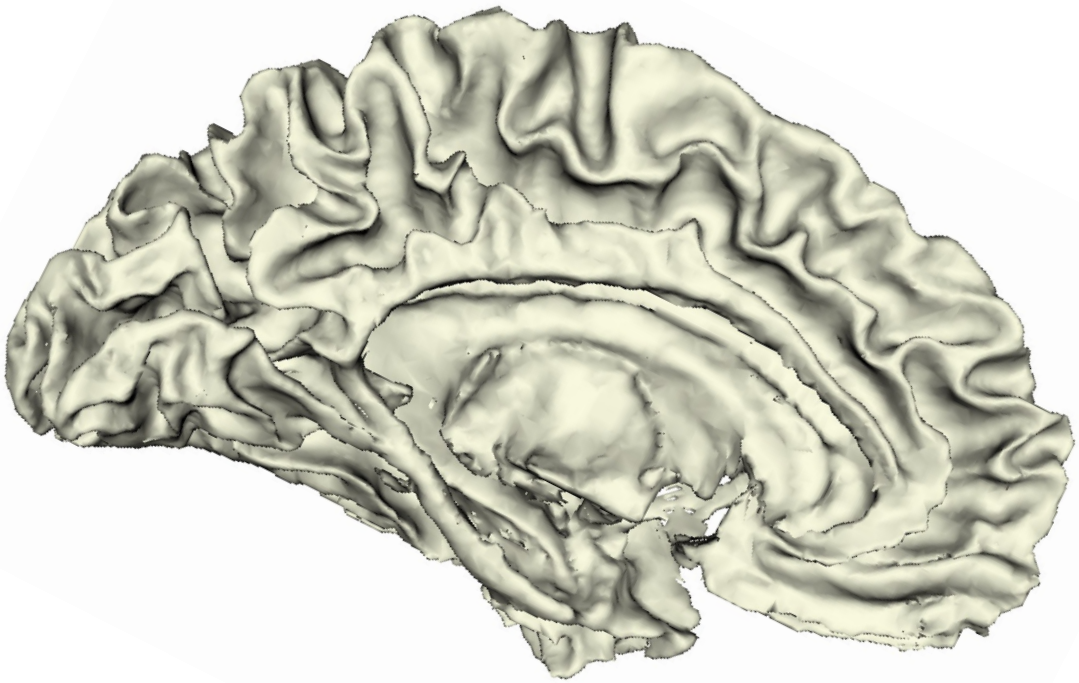
- Axons are coated with electrical insulation called **myelin** ミエリン
- Myelin increases the **speed of electrical communication** between neurons

Image source: BSC1007C Introductory Biology, State College of Florida

electrical insulation：(電気)絶縁体

白質の構造

White Matter Structure



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白質の構造

White Matter Structure

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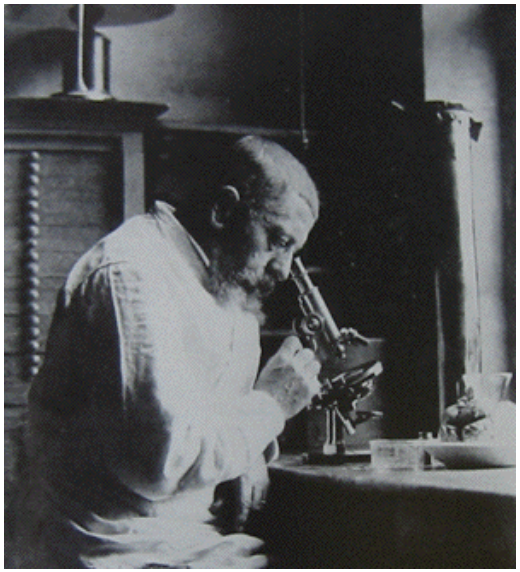
ヒトの脳の白質

Human White Matter Exploration

調査



Joseph Jules and Augusta Dejerine: Neuroanatomy atlas based on myelin-stained preparations

Neuroanatomy atlas：(脳)神経解剖学図譜
myelin-stained preparations:ミエリン染色

(Anatomie des centres nerveux, Paris, 1895-1901)

（人名）

Dejerine Atlas

Les fibres de projection du manteau cérébral sont des fibres corticifuges.

Leurs aractères communs.

Leur trajet.

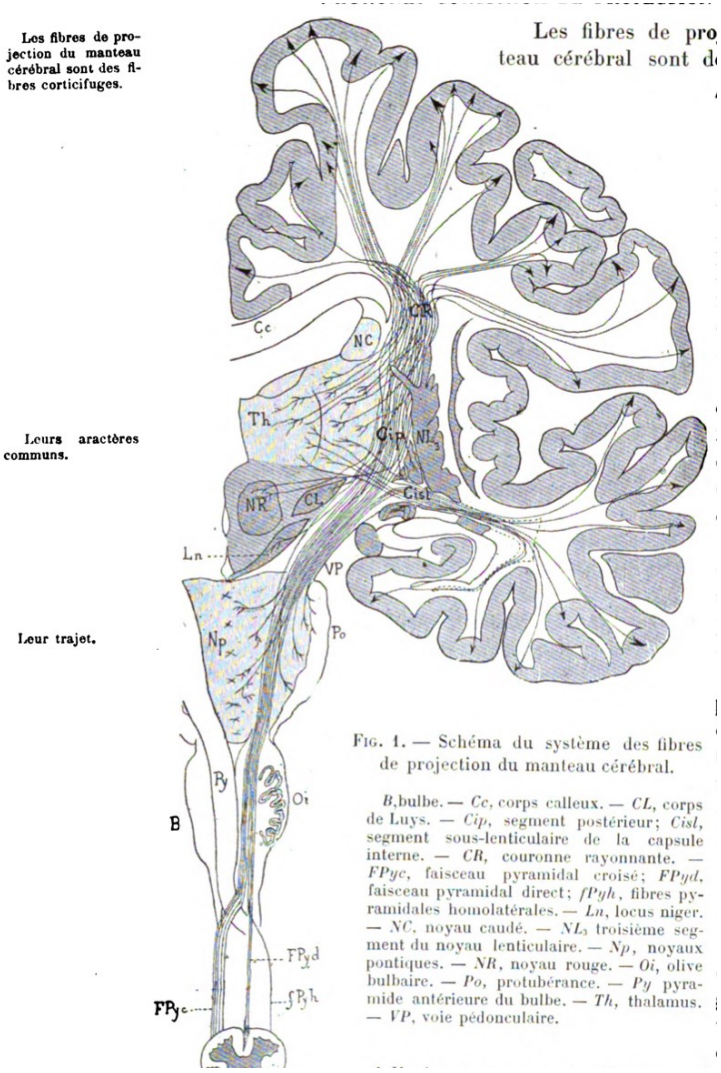
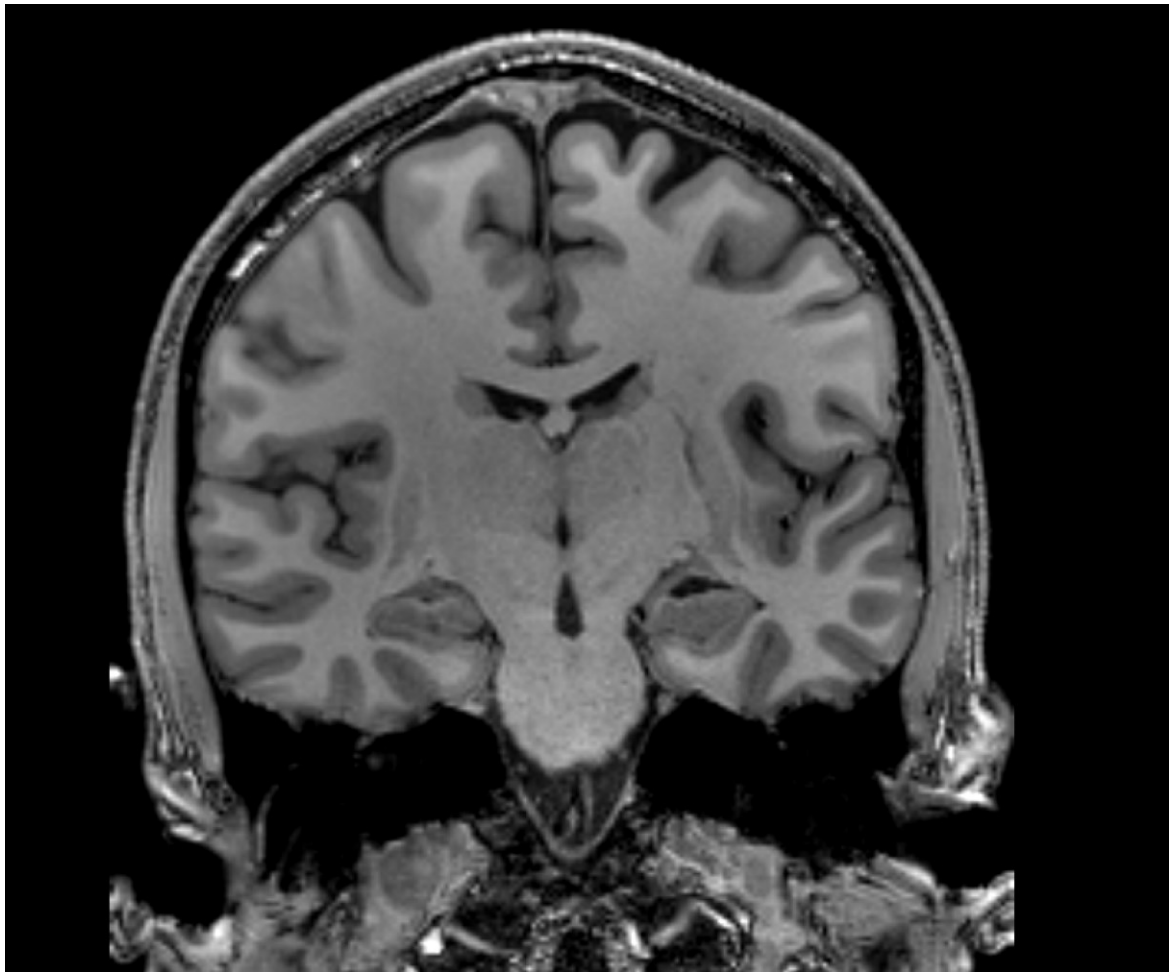


FIG. 1. — Schéma du système des fibres de projection du manteau cérébral.

B, bulbe. — *Cc*, corps calleux. — *CL*, corps de Luys. — *Cip*, segment postérieur; *Cisl*, segment sous-lenticulaire de la capsule interne. — *CR*, couronne rayonnante. — *FPyc*, faisceau pyramidal croisé; *FPyd*, faisceau pyramidal direct; *fPyh*, fibres pyramidales homolatérales. — *Ln*, locus niger. — *NC*, noyau caudé. — *NL*$_3$ troisième segment du noyau lenticulaire. — *Np*, noyaux pontiques. — *NR*, noyau rouge. — *Oi*, olive bulbaire. — *Po*, protubérance. — *Py* pyramide antérieure du bulbe. — *Th*, thalamus. — *VP*, voie pédonculaire.

構造の（形の）⇔機能の（functional）

Structural MRI



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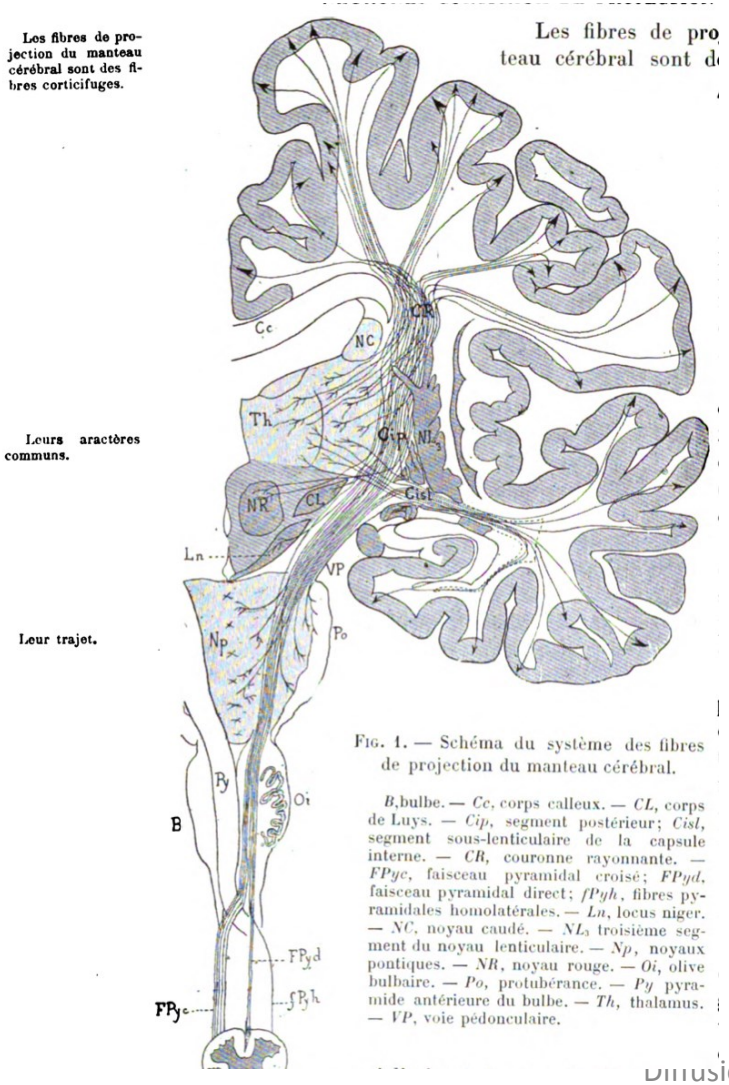
構造の（形の）

Structural MRI



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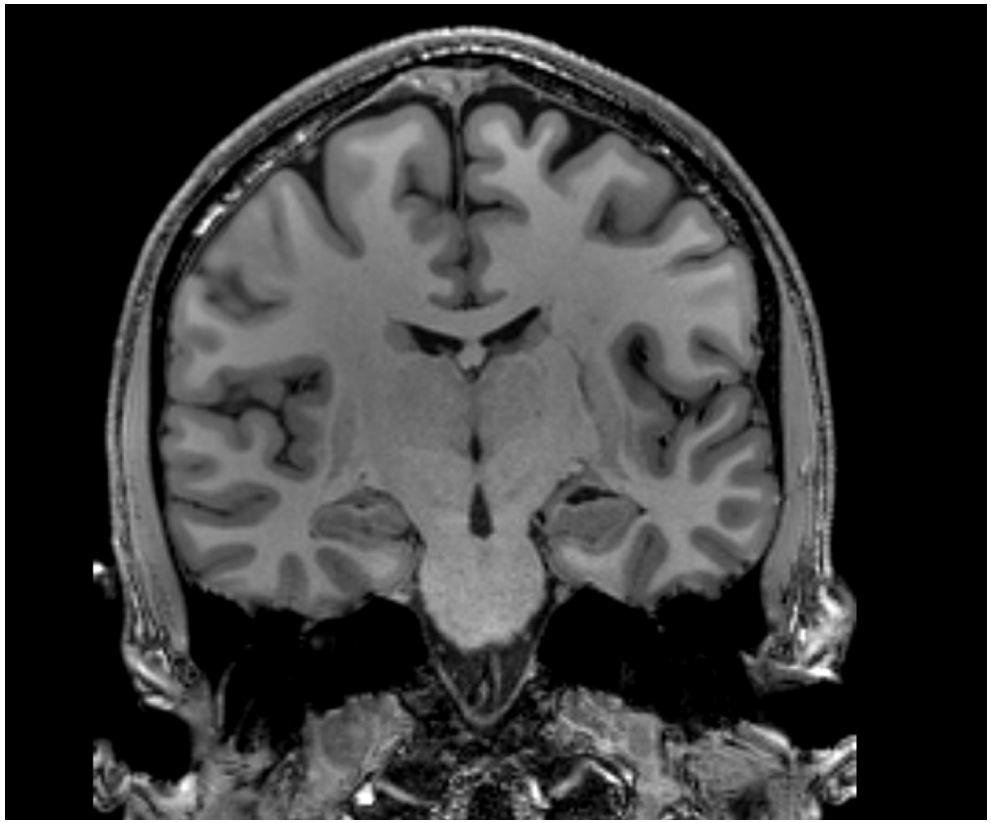

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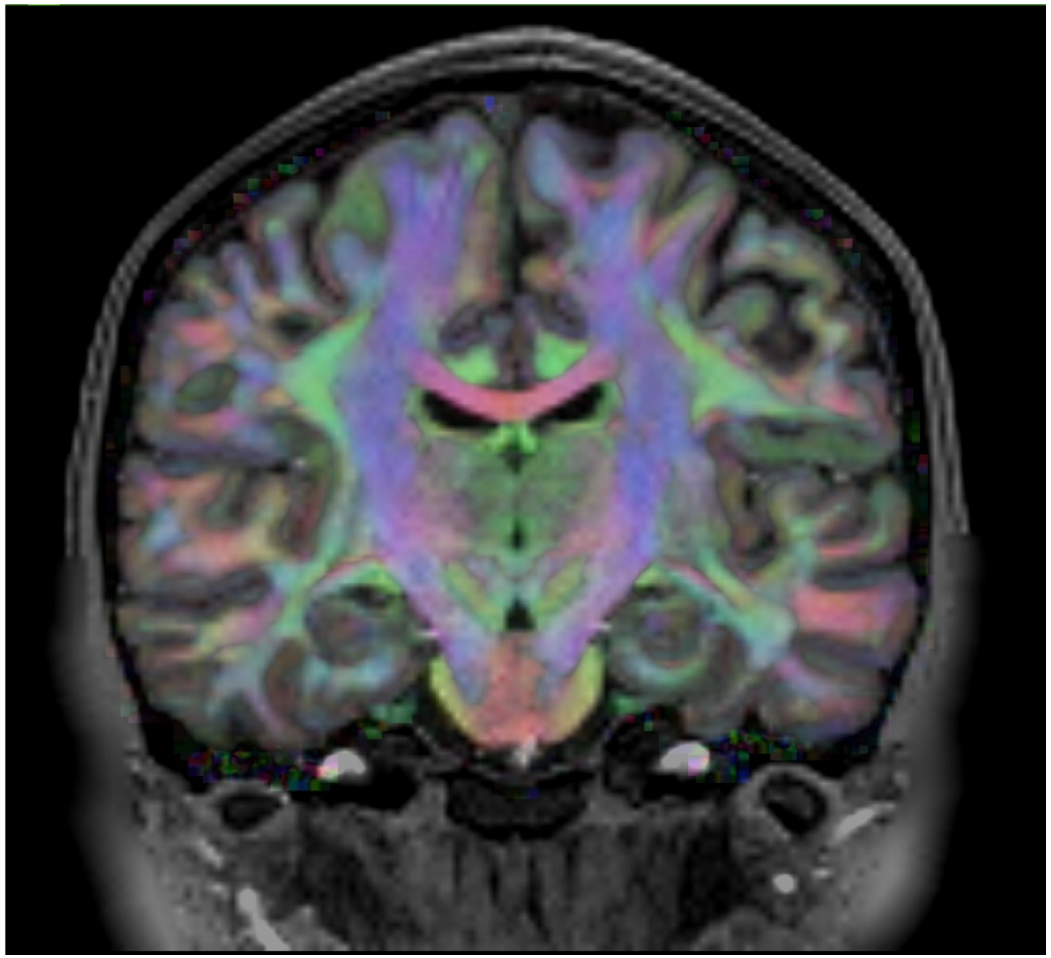
拡散強調MRI

Diffusion-weighted MRI



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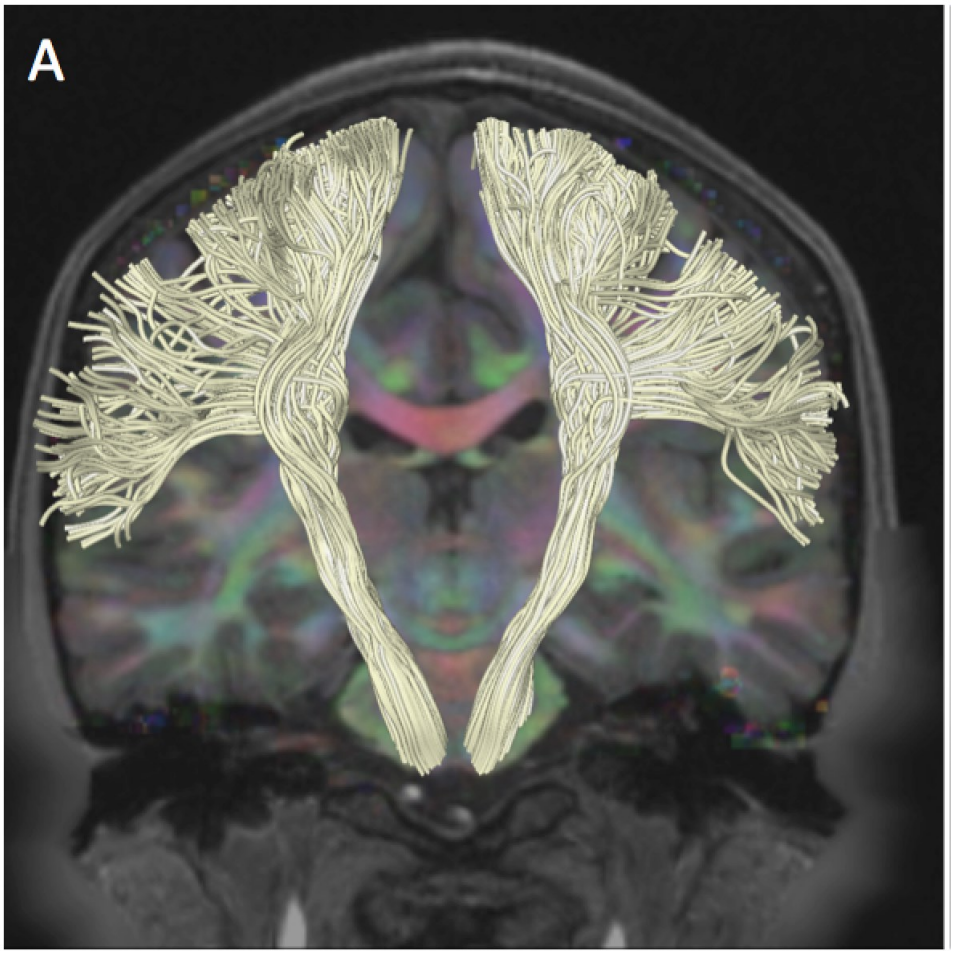
トラクトグラフィ＝神経束像

Tractography



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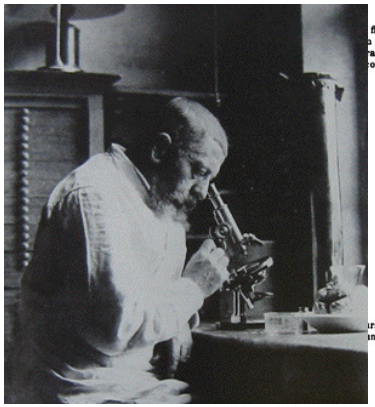
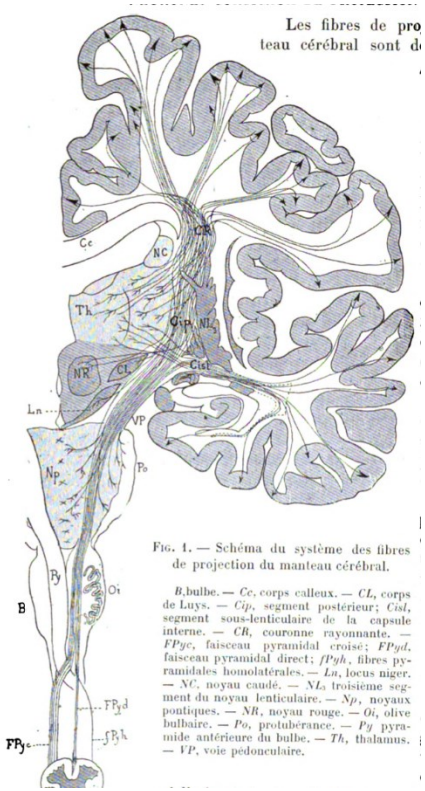
脳白質の調査

White Matter Exploration





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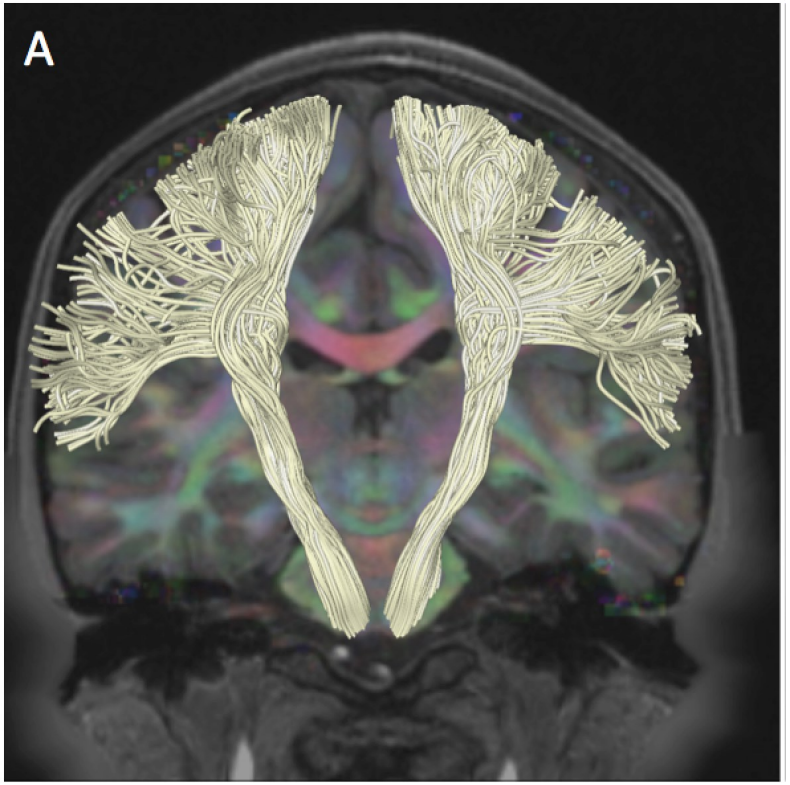

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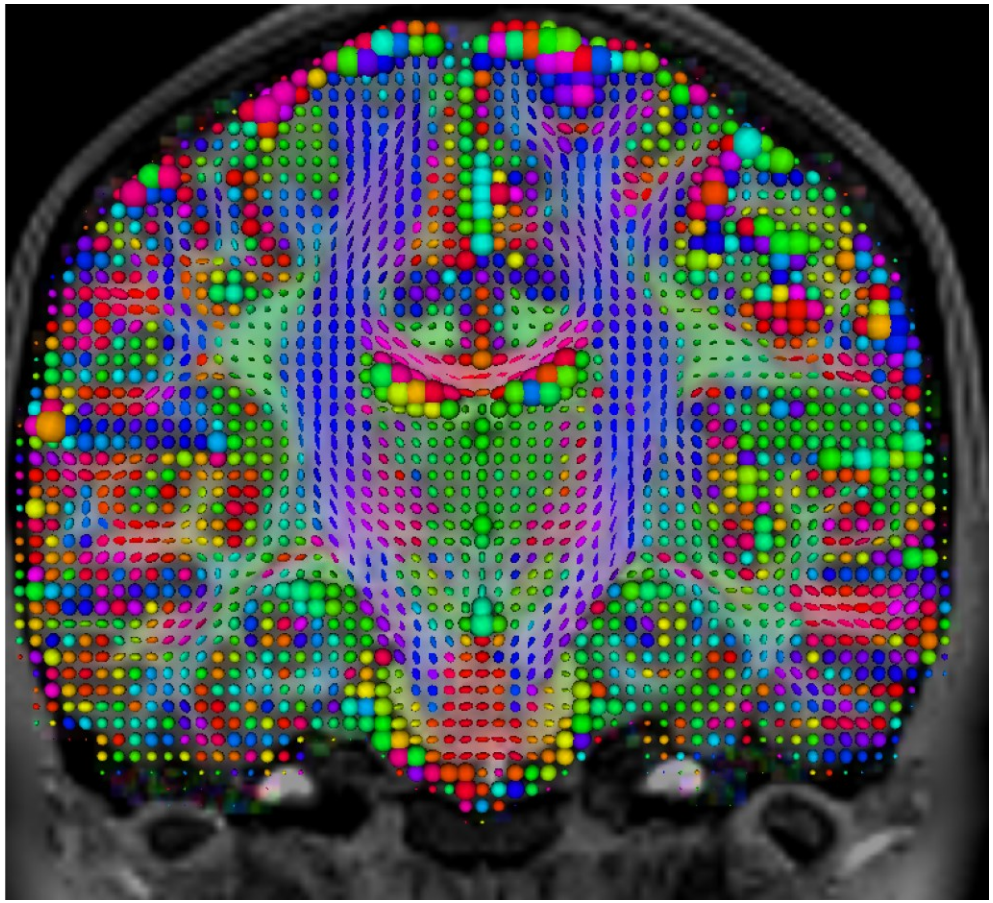
拡散強調像

Diffusion Weighted MRI



非侵襲＝患者にダメージがない

- First **non-invasive** window on white matter anatomy

- Measurement of the diffusion of water molecules in the brain using diffusion sensitizing gradients

diffusion of water molecules：水分子の拡散
diffusion sensitizing gradients：拡散検出傾斜（磁場）

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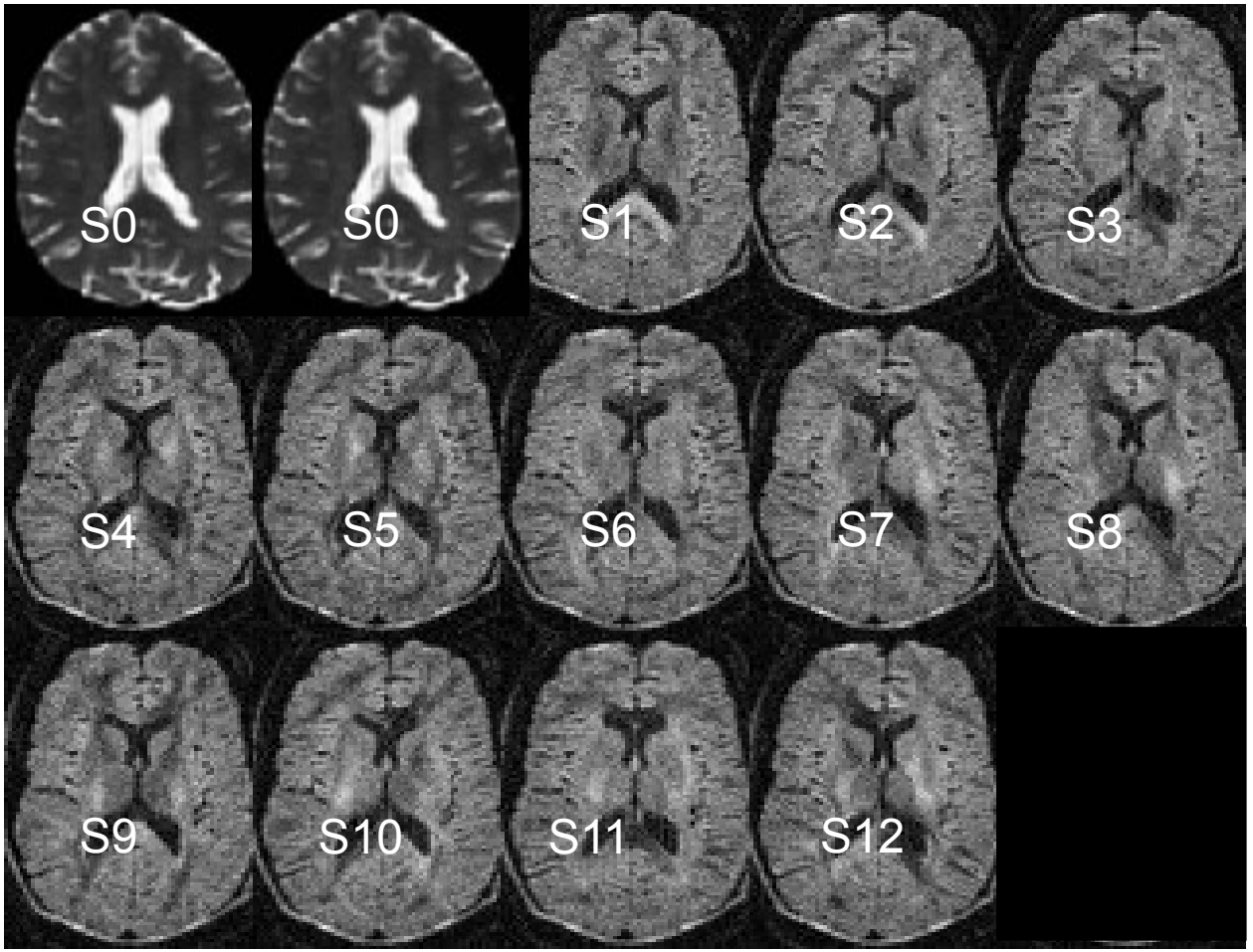
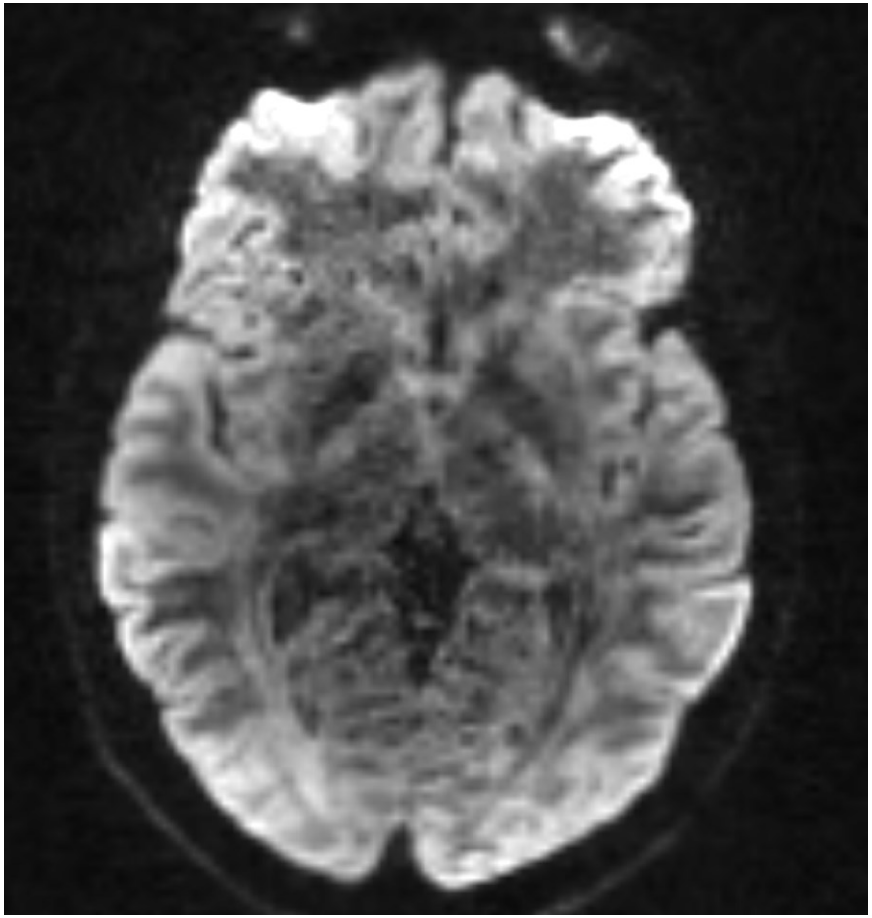
Diffusion Weighted MRI



In this example, the DWI scan was acquired with 12 diffusion sensitizing gradient directions (S1-S12) and 2 non-diffusion sensitizing gradients (S0)

Diffusion Weighted MRI



- In **grey matter and cerebrospinal fluid**, the displacement of water molecules is identical in all directions: the diffusion is **isotropic**

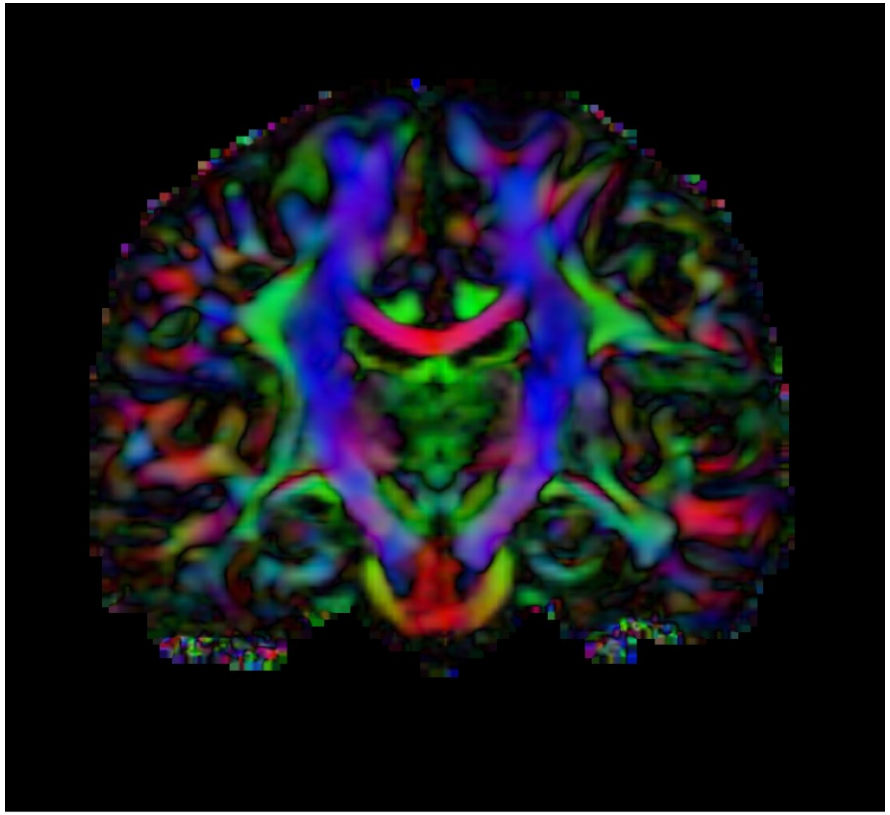
cerebrospinal fluid (CSF)：脑脊髓液
Isotropic：等方的

- In **white matter**, myelin sheets and axonal membranes act as barriers: the diffusion is **anisotropic**

membrane ：膜
Isotropic：非等方的

拡散テンソルイメージング

Diffusion Tensor Imaging



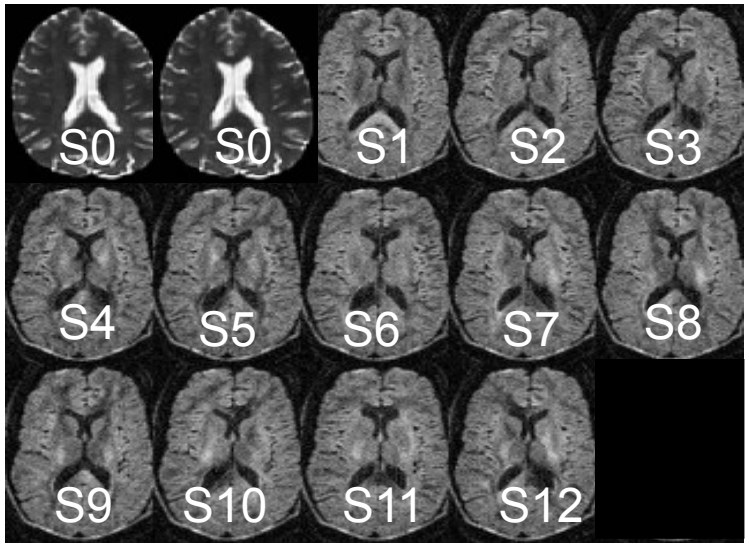
Diffusion Tensor Imaging (DTI) is a **mathematical framework** that was developed to model the **anisotropic diffusion** of water molecules in the brain.

mathematical framework：
　数学的フレームワーク（手法群）
anisotropic diffusion：
　非等方な（方向によって異なる）拡散
water molecule：水分子

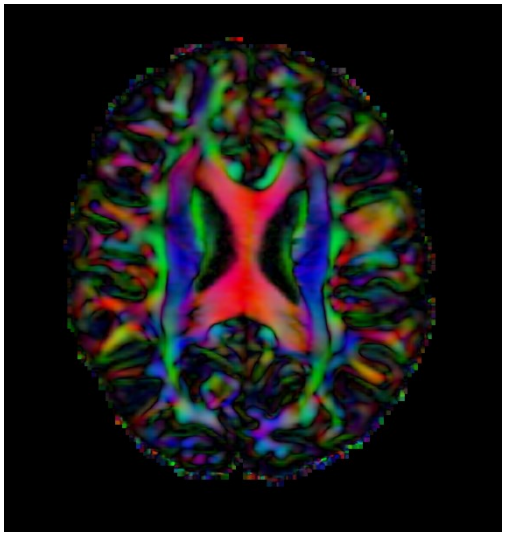
DWI(diffusion weighted image)：拡散強調像　　拡散テンソル画像

From DWI to DTI

DWI



DTI



Stejskal-Tanner (1965)　$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$

gradient：
拡散検出傾斜（磁場）

Si: DWI volume acquired with ith gradient
S0: Baseline volume

baseline ：基準
Volume：ボリュームデータ
（3次元画像）

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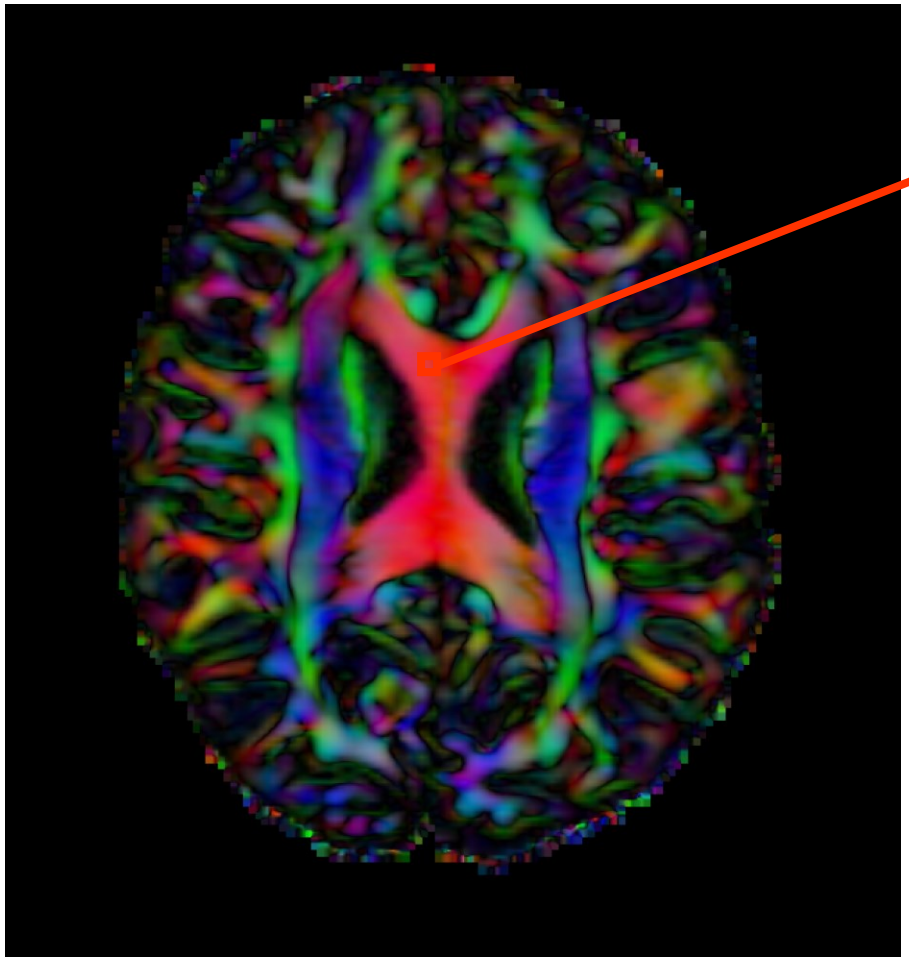
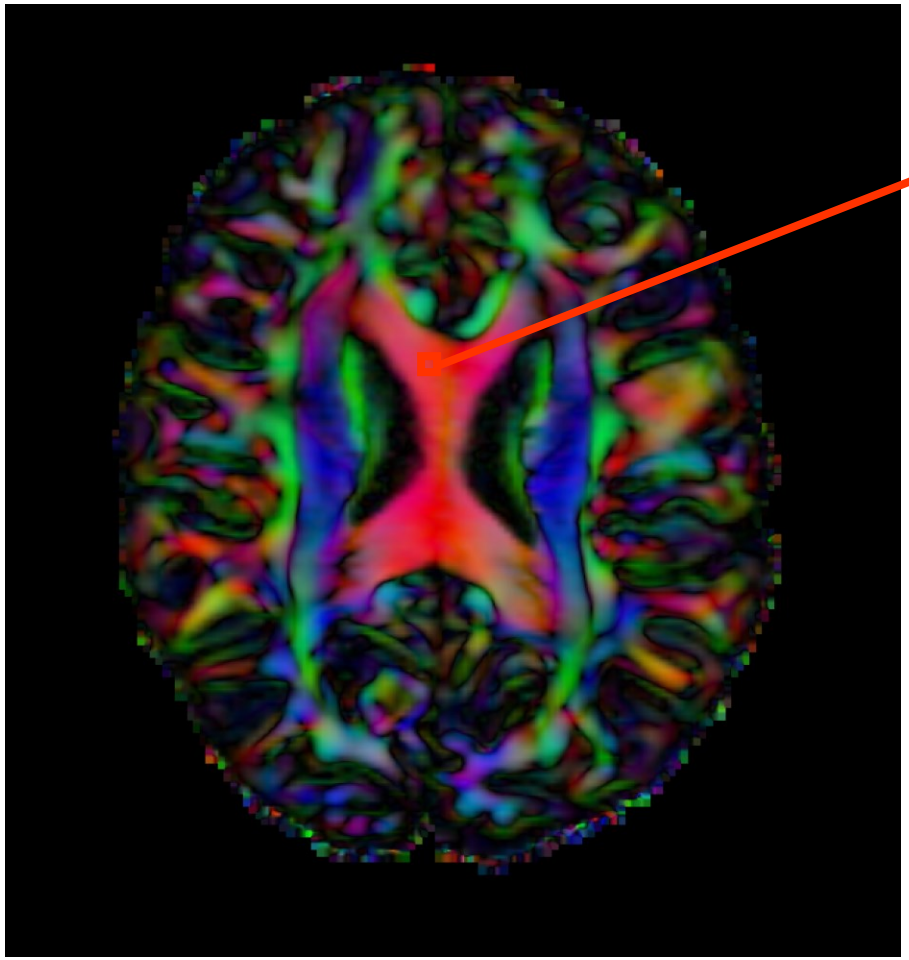
拡散テンソルイメージング

Diffusion Tensor Imaging



$$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$$

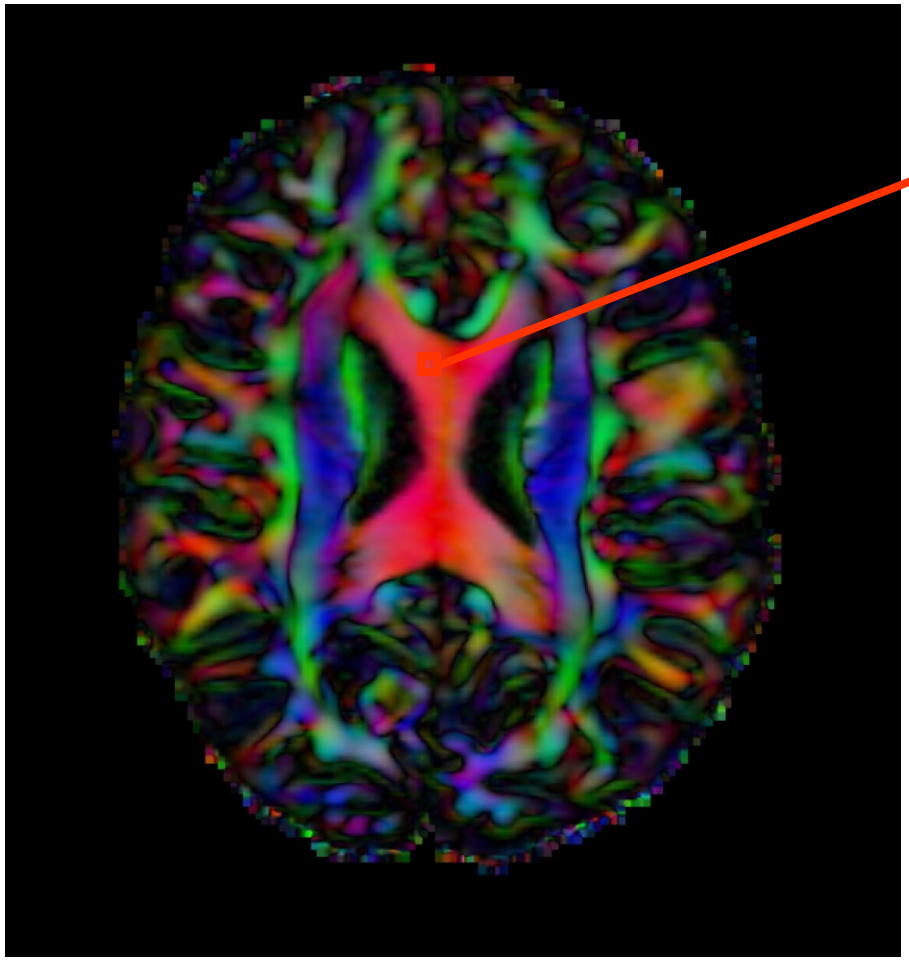
Diffusion Tensor Imaging



$$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$$

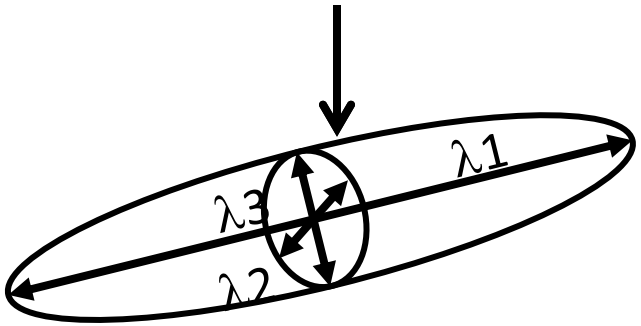
$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$

Diffusion Tensor Imaging



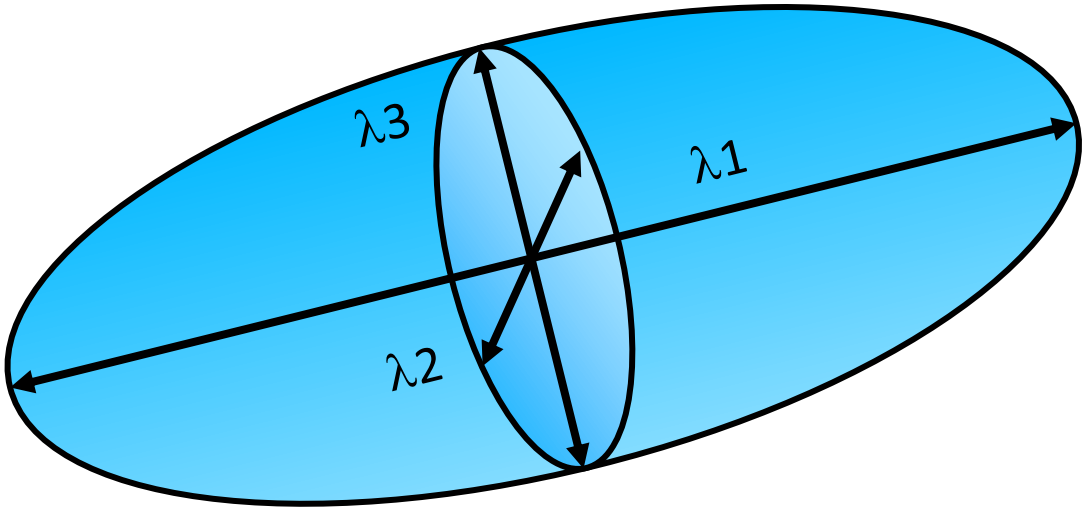
$$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$$

$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$



拡散テンソル

Diffusion Tensor



- The **diffusion tensor** in each voxel can be visualized as an ellipsoid.

voxel：ボクセル＝画素

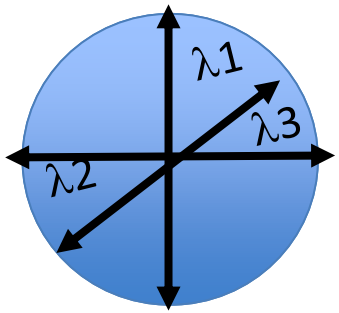
- The **principal directions of diffusion** of water molecules correspond to the axis of the ellipsoid.

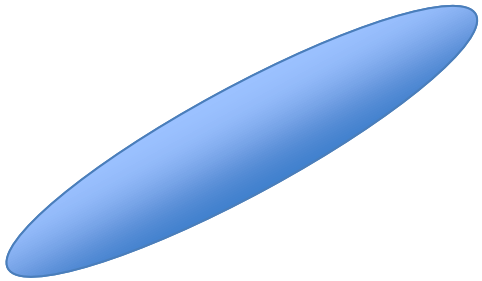
principal directions of diffusion：拡散の主方向

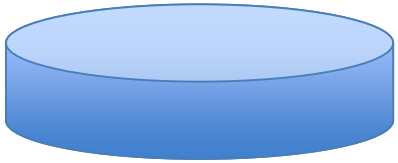
Diffusion MRI Analysis of the Human Brain, S.Pujol, ARR 2012-2017

拡散テンソル

Diffusion Tensor







$\lambda 1 = \lambda 2 = \lambda 3$

$\lambda 1 >> \lambda 2, \lambda 3$

$\lambda 1 \sim \lambda 2 >> \lambda 3$

Isotropic media
(CSF, grey matter)

Anisotropic media
(white matter)

脳梁（のうりょう）

Corpus Callosum

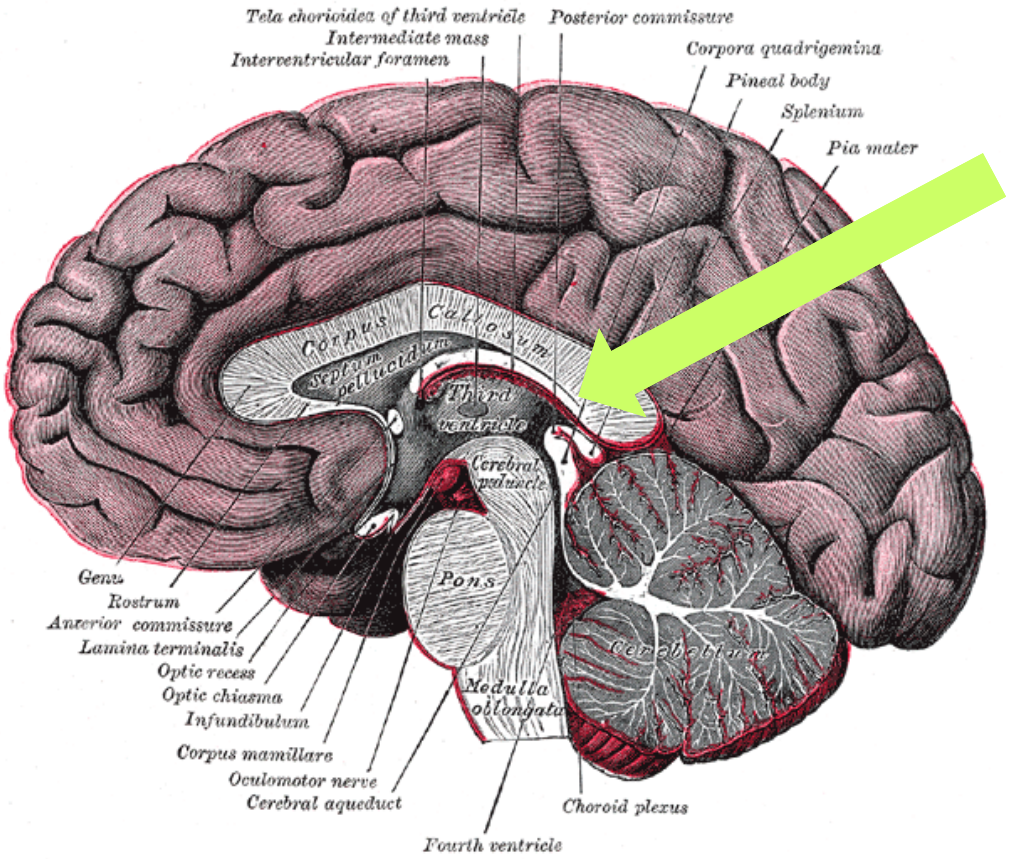


Image from Grey's Anatomy

- The corpus callosum is a broad thick bundle of white matter fibers that connect the left and right hemisphere.
  半球
- It is the largest white matter structure in the brain

脳梁（のうりょう）

Corpus Callosum

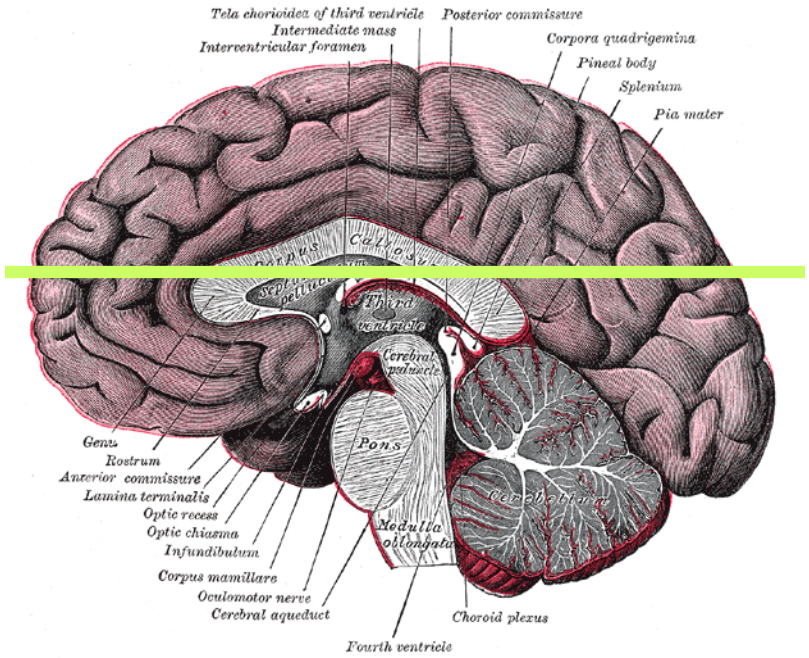
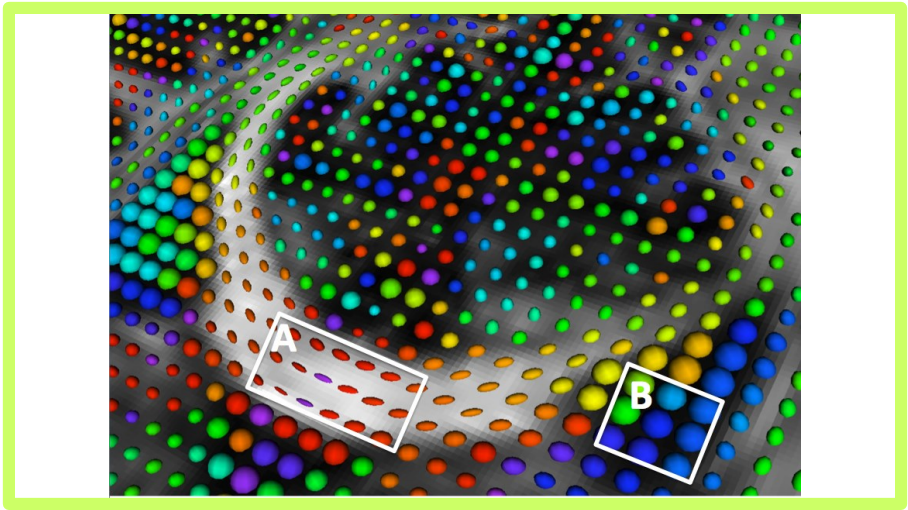
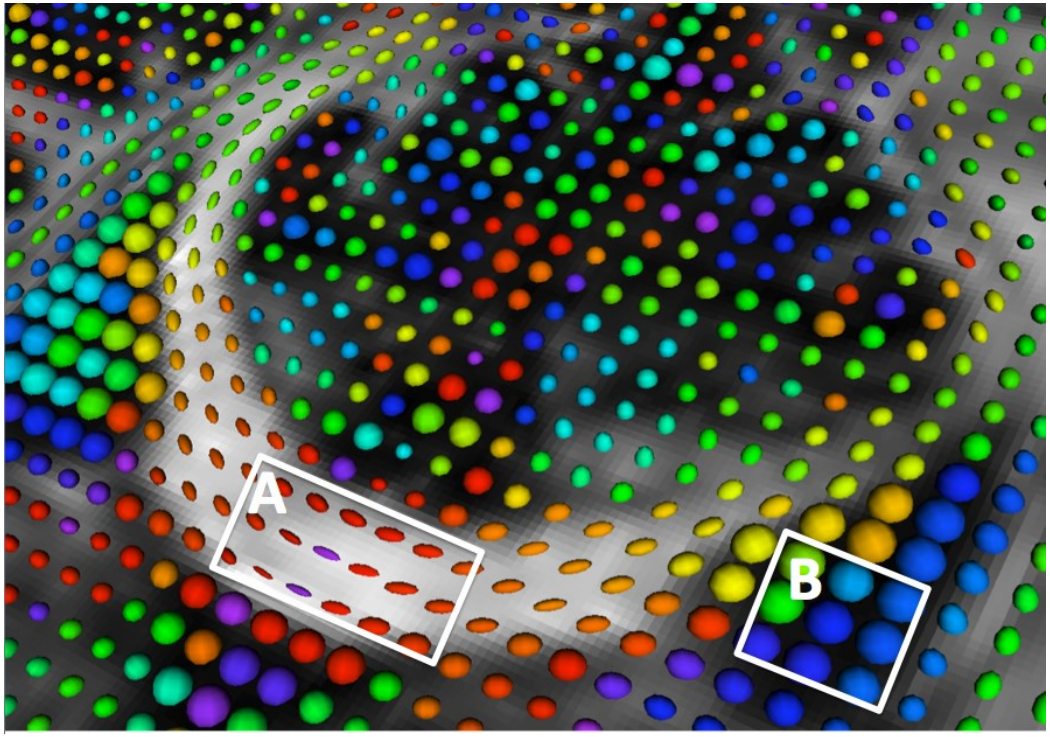


Image from Grey's Anatomy



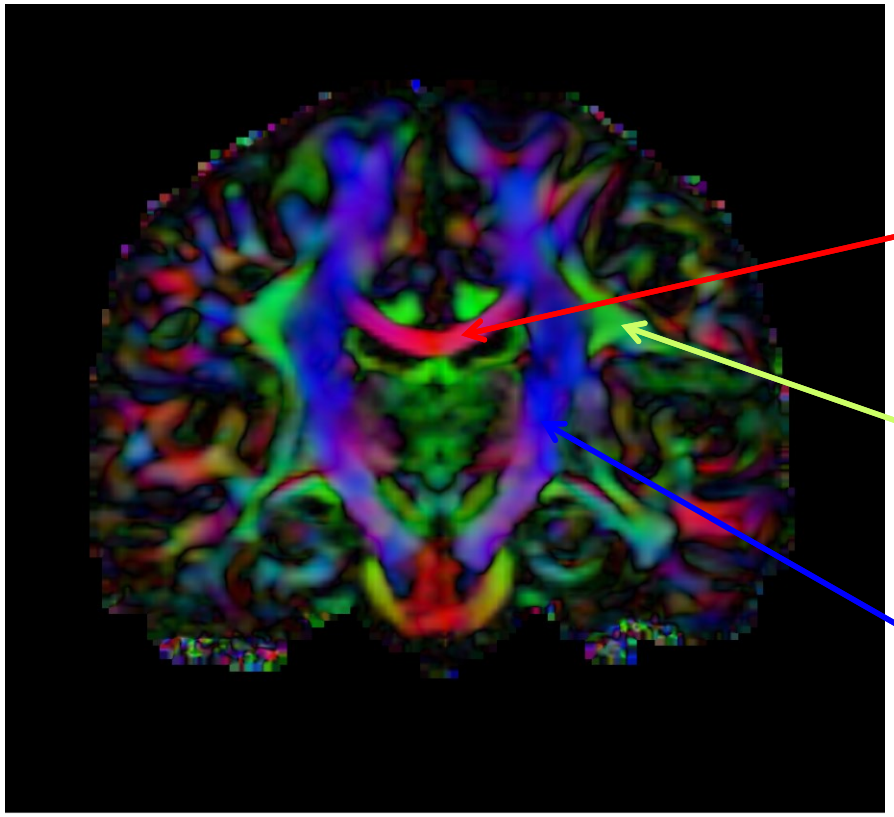
Diffusion Tensor Ellipsoid 楕円体



A: White Matter: Anisotropic Diffusion

B: CSF: Isotropic Diffusion

DTI Color Map



Color coding:

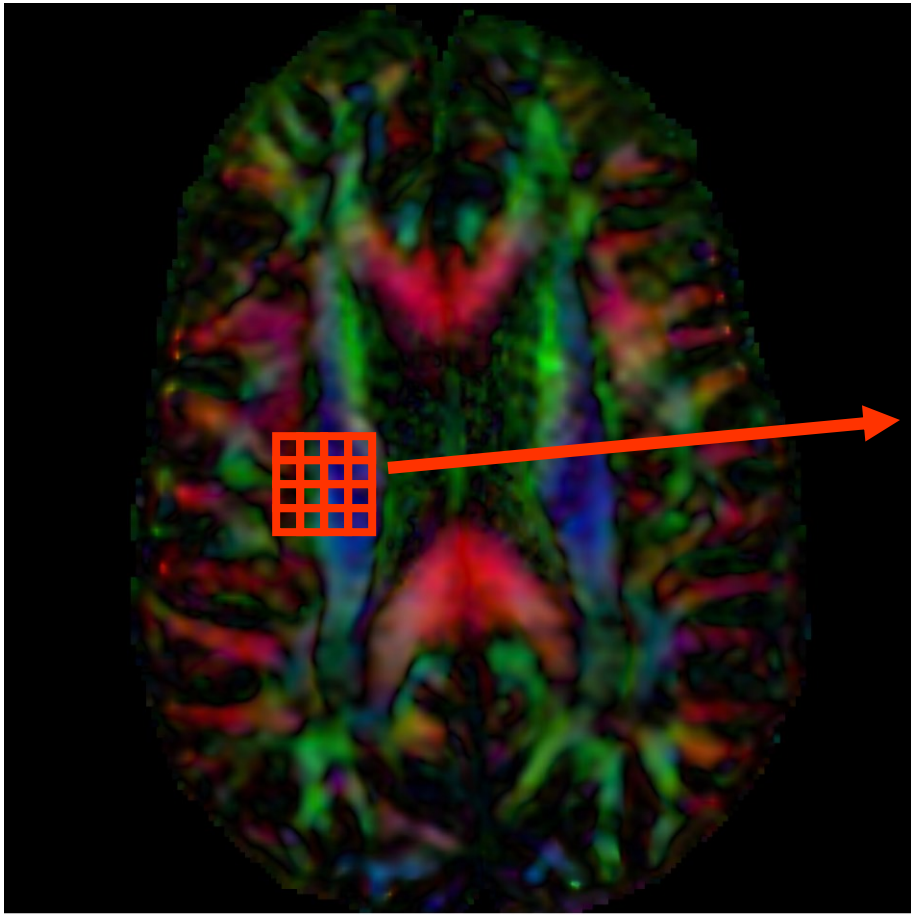
Red: left-right
(e.g. corpus callosum)

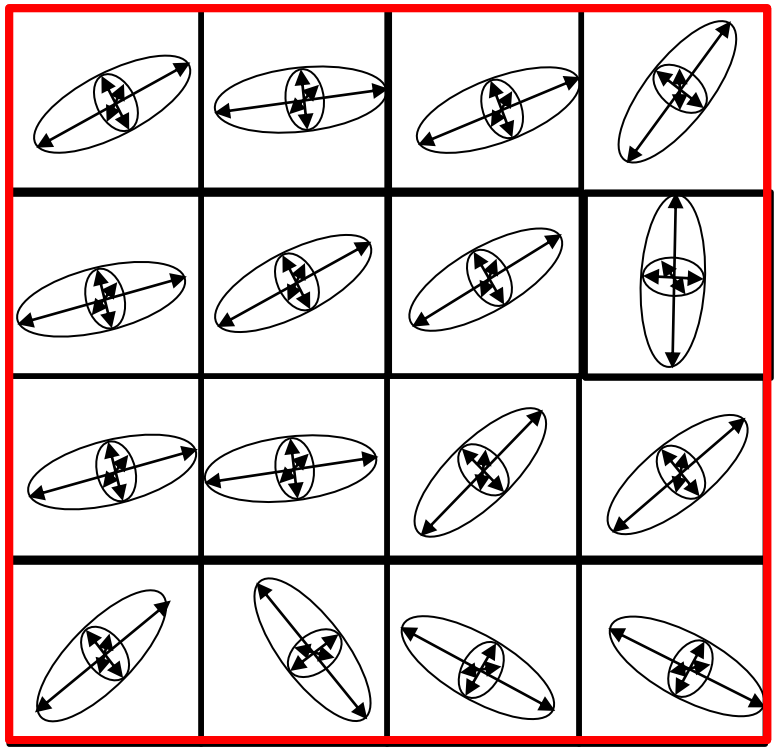
Green: anterior-posterior (e.g superior portion of cingulum)
上部帯状回

Blue: inferior-superior (e.g. corticospinal tract)
皮質脊髄路

トラクトグラフィ＝神経束像

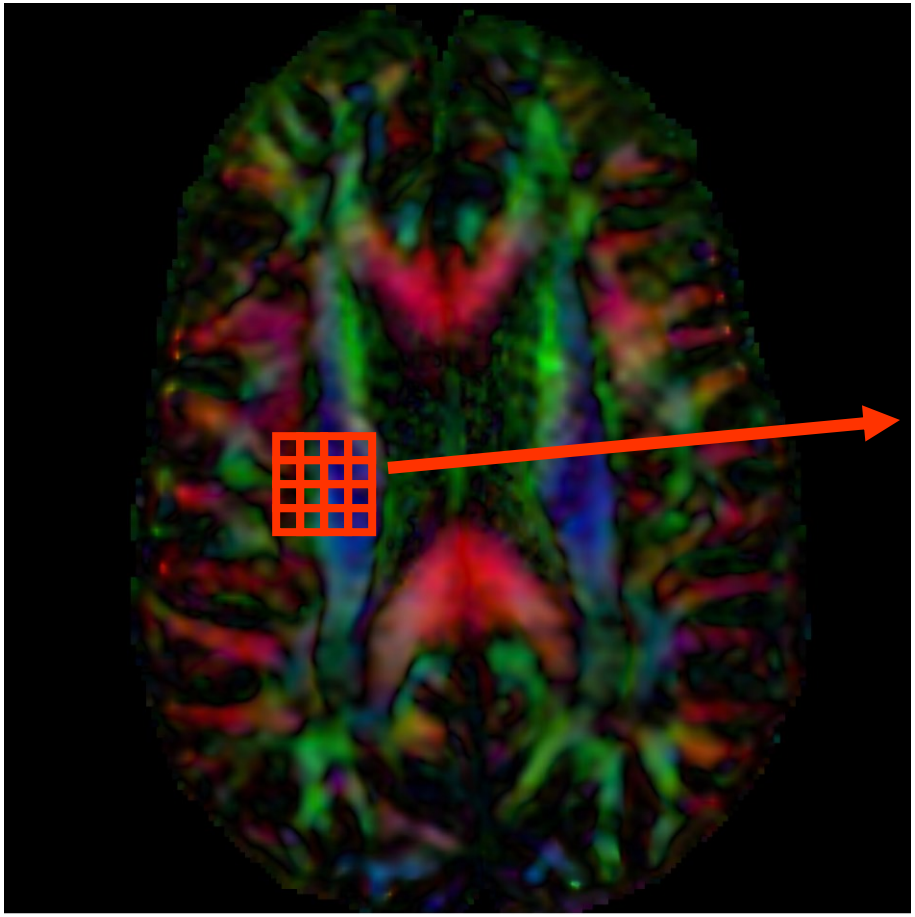
DTI Tractography

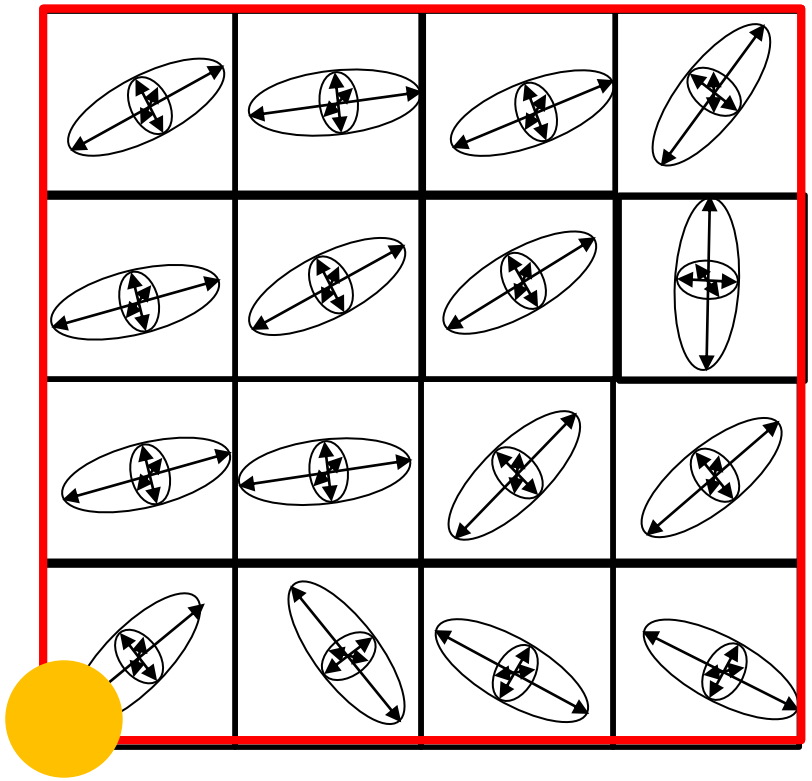




トラクトグラフィ＝神経束像

DTI Tractography

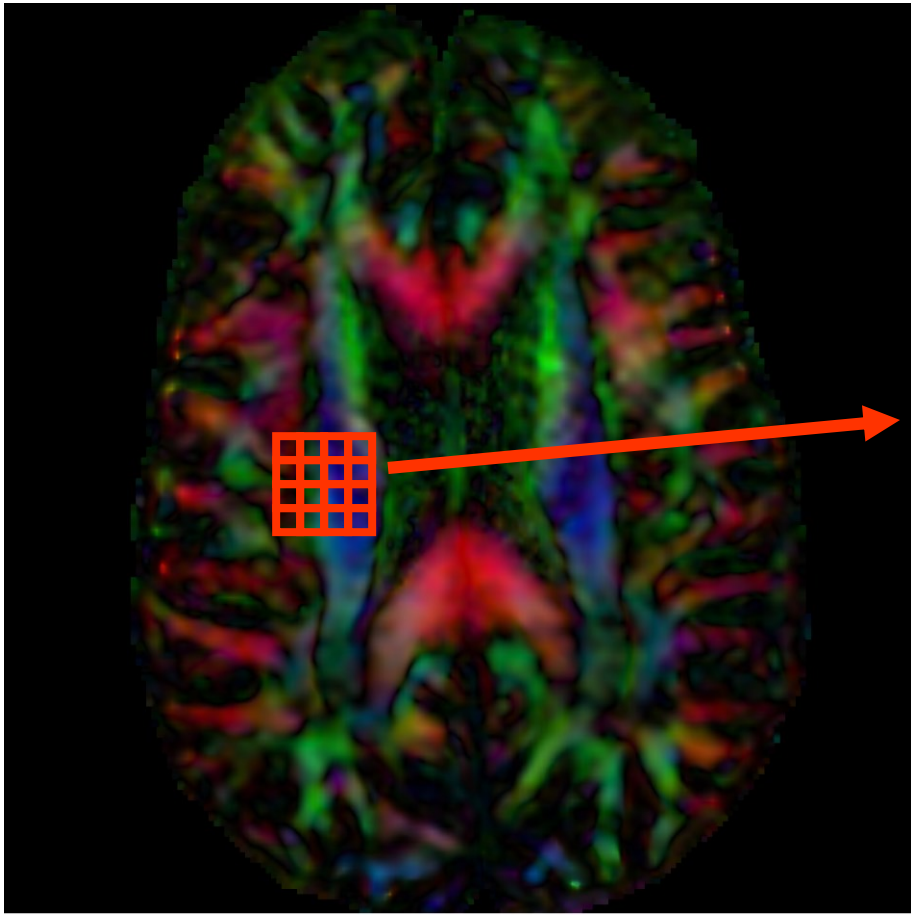


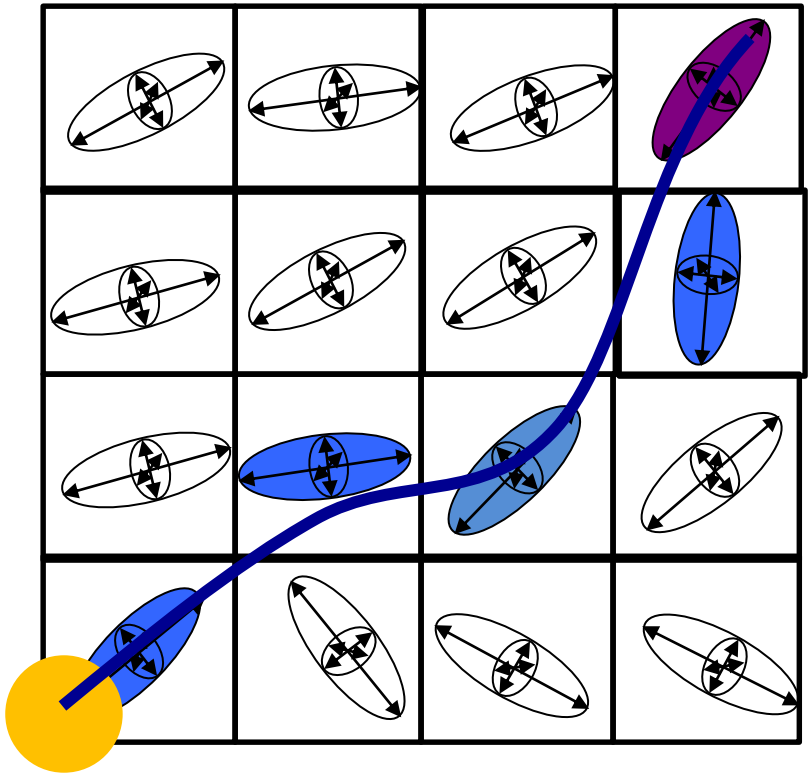


Seed Point

トラクトグラフィ＝神経束像

DTI Tractography



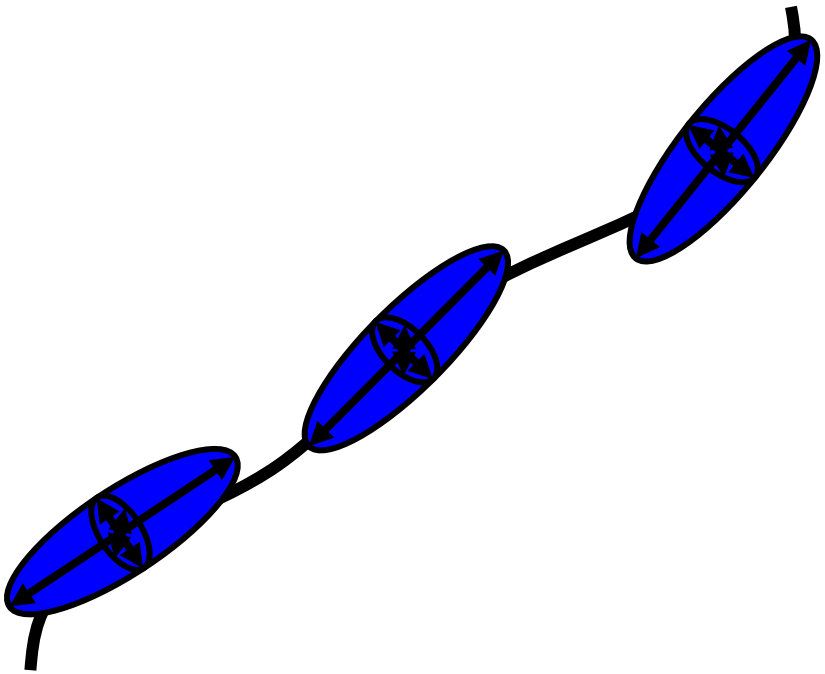


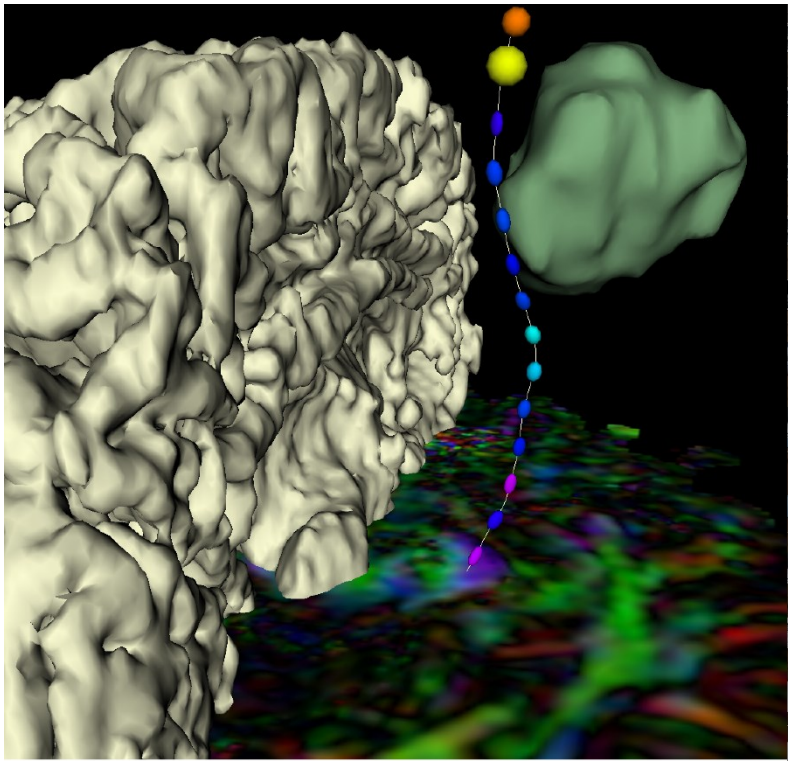
Seed Point

seed：種（たね）＝追跡開始点

トラクトグラフィ＝神経束像

DTI Tractography





再構成（像）

DTI tractography provides 3D reconstruction of the trajectory of white matter pathways

軌跡

白質神経路

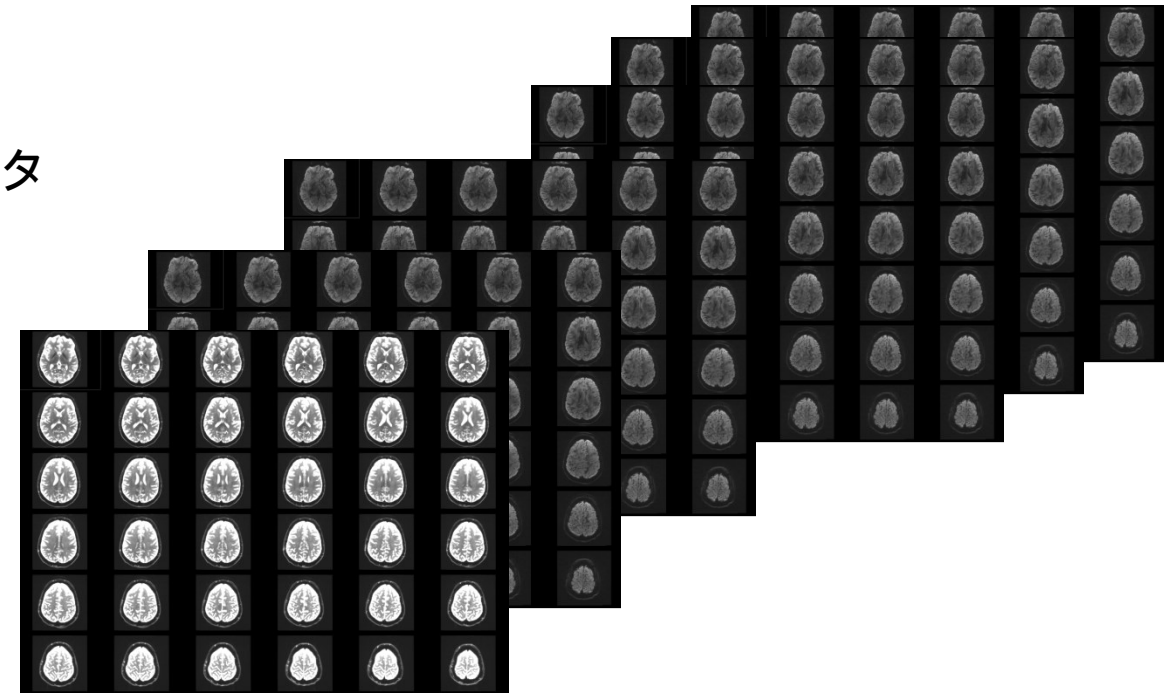
Tutorial outline

- Part 1: Basics of Diffusion MRI mapping of white matter pathways

- **Part 2: Hands-on Diffusion MRI analysis using 3D Slicer**

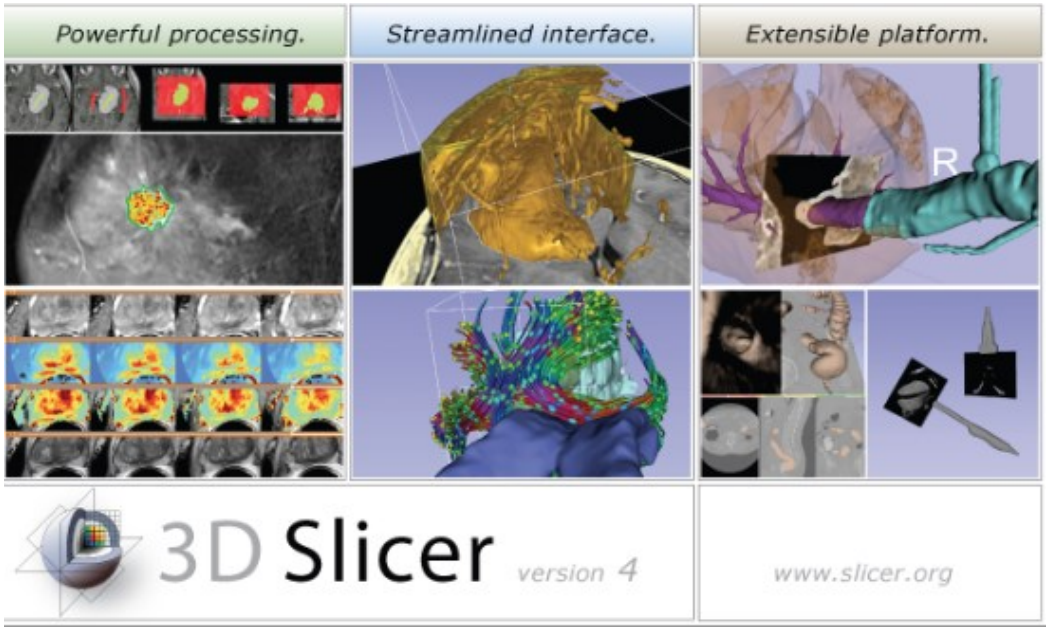
Tutorial DWI Dataset

Volume：
ボリュームデータ
＝3次元画像



The Diffusion Weighted Imaging (DWI) dataset is composed of 1 volume acquired without diffusion-sensitizing gradient (baseline), and 41 volumes acquired with 41 different diffusion-sensitizing gradient directions.

Tutorial Software

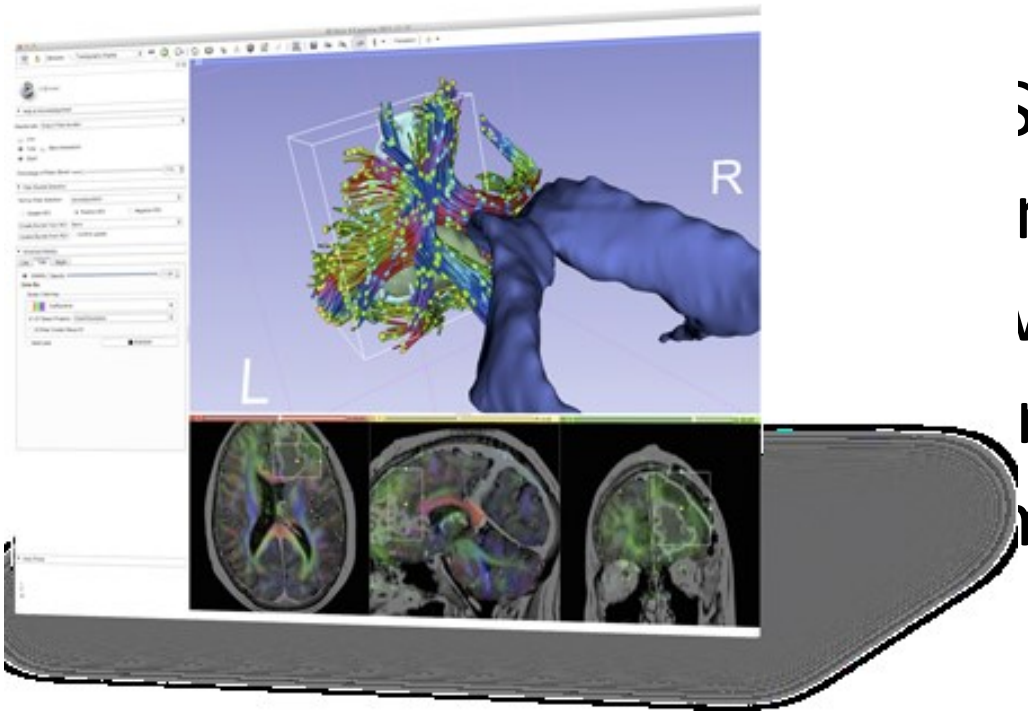


The tutorial uses the 3D Slicer software version 4.3

Disclaimer

It is the responsibility of the user of 3DSlicer to comply with both the terms of the license and with the applicable laws, regulations and rules. Slicer is a tool for research, and is not FDA approved.

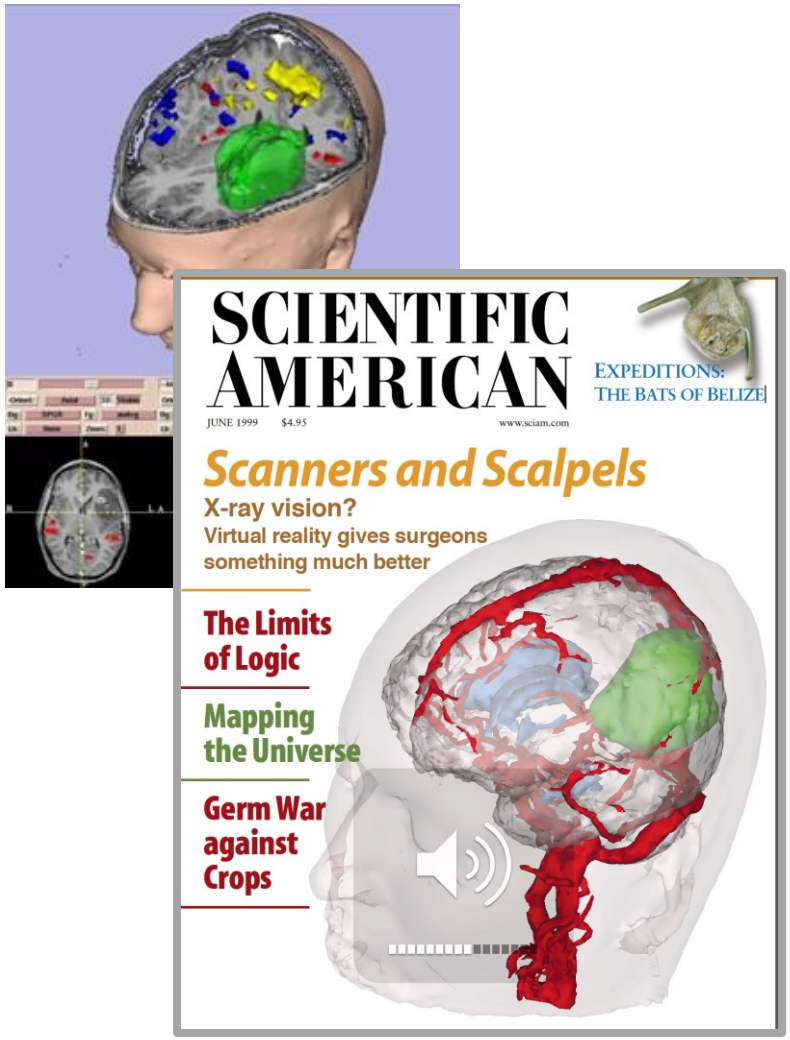
3D Slicer



オープンソース:
プログラムのソースコードが公開されている

Slicer or ‘Slicer’ is an
n-source platform for
ving, analyzing and
racting with
medical imaging data

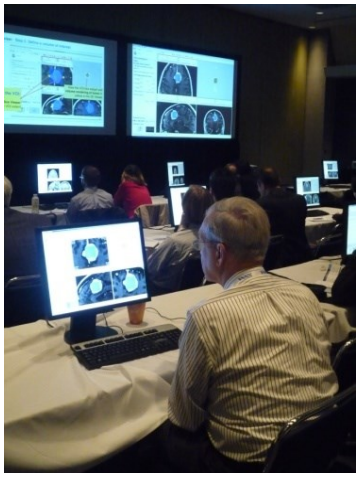
3D Slicer History



- 1997: Slicer starts as a Master's thesis project between Harvard Medical School and the MIT in Boston, MA

Master's thesis：（大学院）修士の学位

3D Slicer History



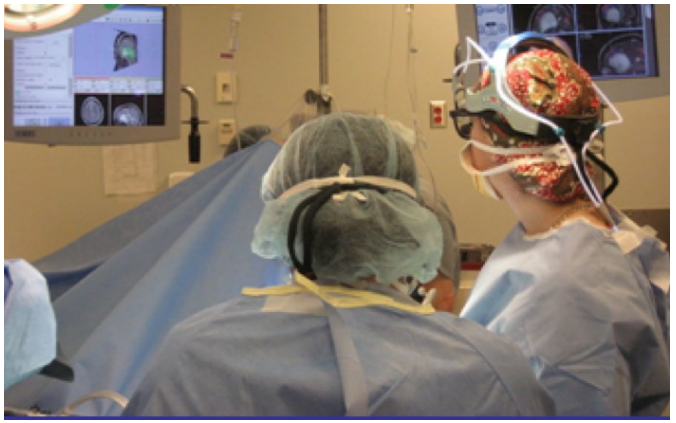


- 1997: Slicer starts as a Master's thesis project between Harvard Medical School and the MIT in Boston, MA
- 2017: Slicer is an open-source software platform for medical research used around the world

学際的な（＝様々な専門の人が使える）プラットフォーム（ソフトウェア環境）

A multi-disciplinary platform

An open-source platform for imaging scientists



An end-user application for clinicians

A software platform that is both
easy to extend for scientists & easy to use
for clinicians

Bridging the gap to accelerate translational research

橋渡し的な研究

$$\frac{\partial}{\partial x_i}\frac{\partial}{\partial x_k}A$$

$$\frac{\partial}{\partial x_k}\nabla\cdot\vec{A} = \nabla^2 A_k + \frac{1}{c}\frac{\partial}{\partial x_k}\frac{\partial}{\partial t} + \frac{1}{c^2}\frac{\partial}{\partial t^2} = \frac{4\pi}{c}J_k$$

$$-\nabla^2 A_k + \frac{1}{c^2}\frac{\partial^2 A_k}{\partial t^2} + \frac{\partial}{\partial x_k}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial\phi}{\partial t}\right) = \frac{4\pi}{c}J_k$$

$$-\nabla^2\vec{A} + \frac{1}{c^2}\frac{\partial^2\vec{A}}{\partial t^2} + \vec{\nabla}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial\phi}{\partial t}\right) = \frac{4\pi}{c}\vec{J}$$

```
// set up the database
if (argc > 1)
{
  QString directory(argv[1]);
  settings.setValue("DatabaseDirectory", directory);
  settings.sync();
}

if ( settings.value("DatabaseDirectory", "") == "" )
{
  databaseDirectory = QString("./ctkDICOM-Database");
  std::cerr << "No DatabaseDirectory on command line or in settings.  Using \"" << databaseDirectory.toLatin1().data() << "\".\n";
} else
{
  databaseDirectory = settings.value("DatabaseDirectory", "").toString();
}
```

3DSlicer

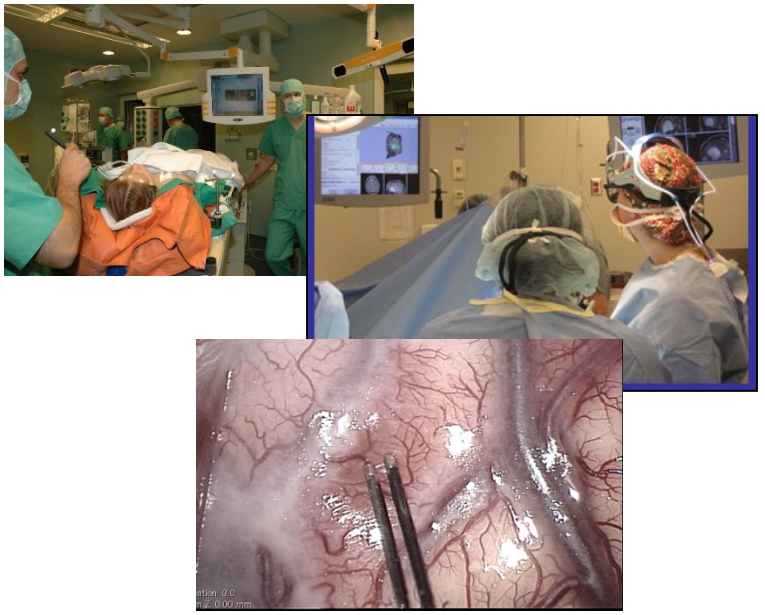


Image courtesy of Arya Nabavi, MD

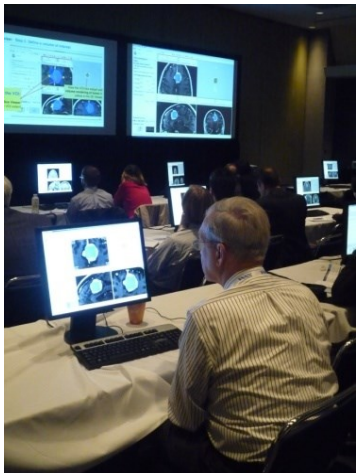
Algorithm Development

アルゴリズム開発

Problem solving

問題解決

3D Slicer Community

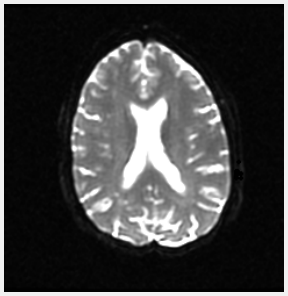




- Clinicians 臨床医
- Clinical researchers 臨床研究者
- Engineers
- Postdoctoral fellows ポスドク
- Medical Students
- Engineering students
- Software developers
- Staff researchers 教員
- MR Technologists MRIの技術者

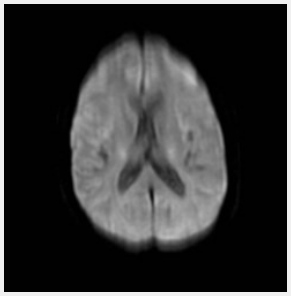
MR Diffusion Analysis Pipeline

パイプライン＝処理の手順



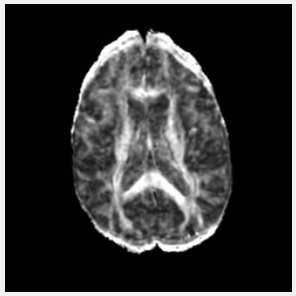
DWI
Acquisition

拡散強調像取得



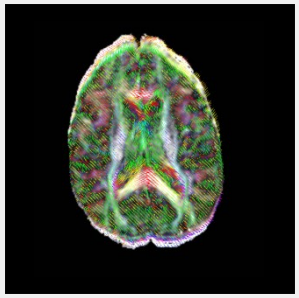
Tensor
Calculation

拡散テンソル計算



Scalar
Maps

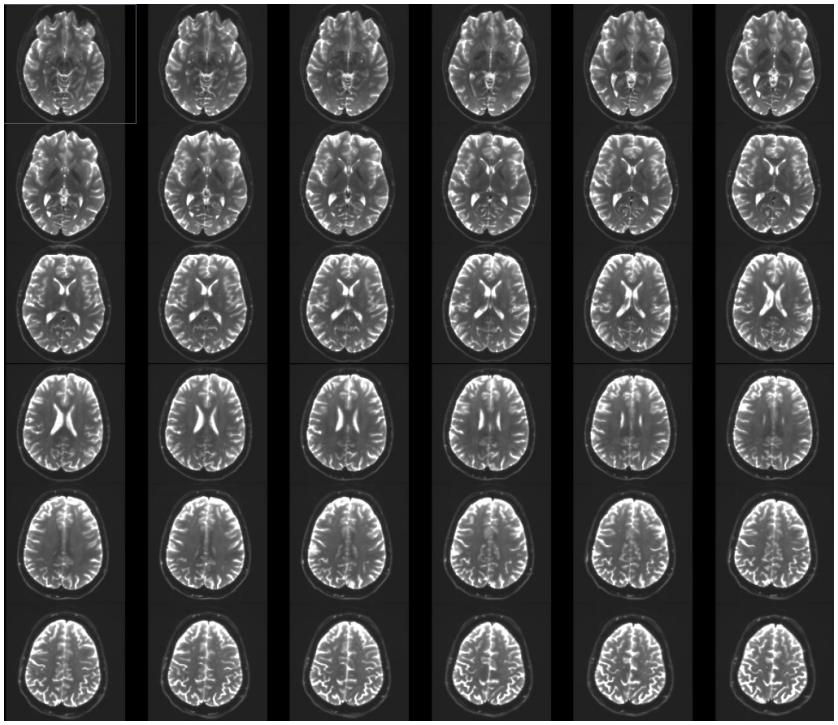
スカラ画像＝
拡散に関する
画像特徴



3D
Visualization

3次元可視化

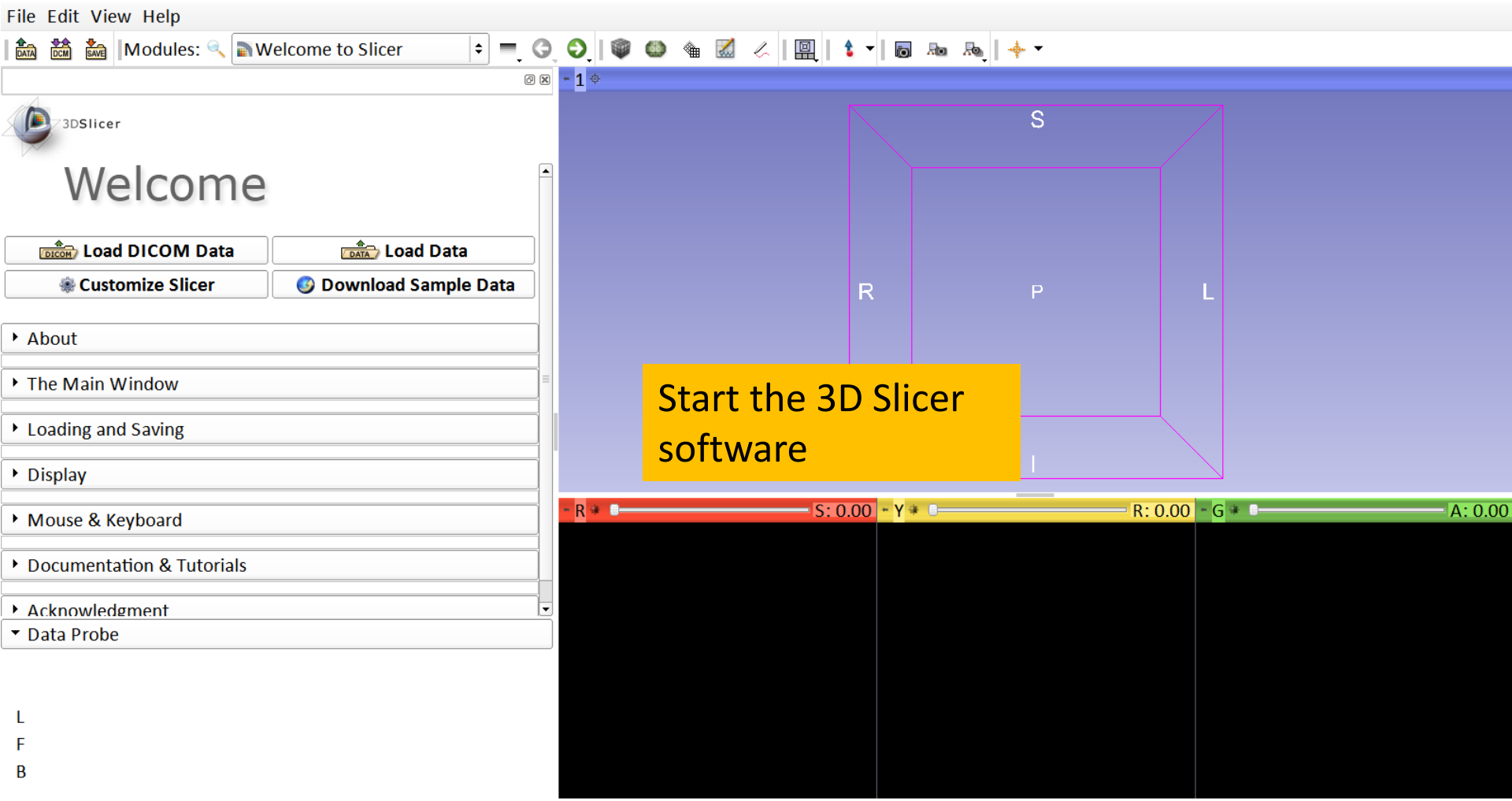
Diffusion MRI Analysis of the Human Brain,
S.Pujol, ARR 2012-2017



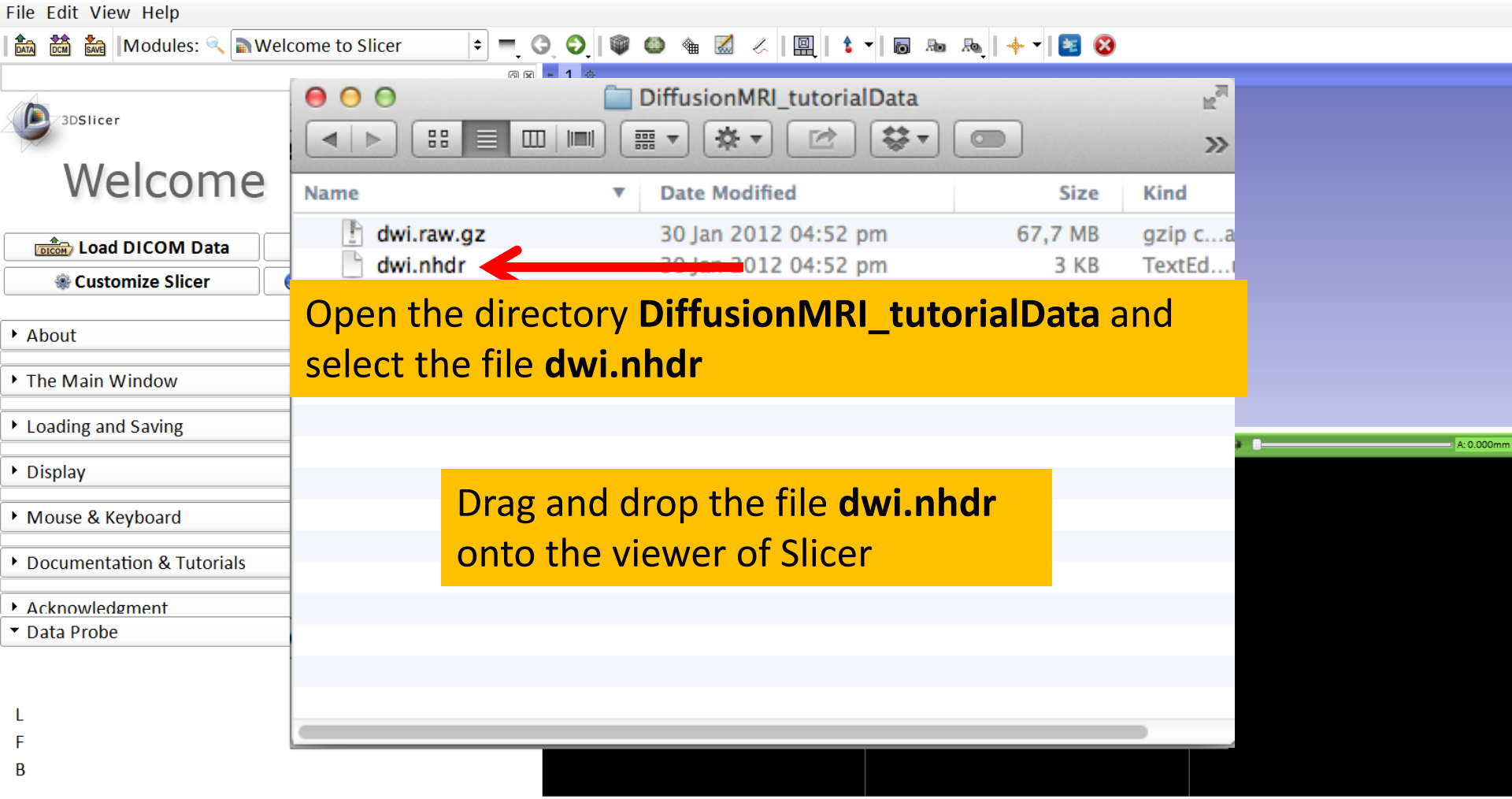
Step 1: Loading the DWI dataset and mask

データの読み込みとマスキング

Loading the DWI Dataset

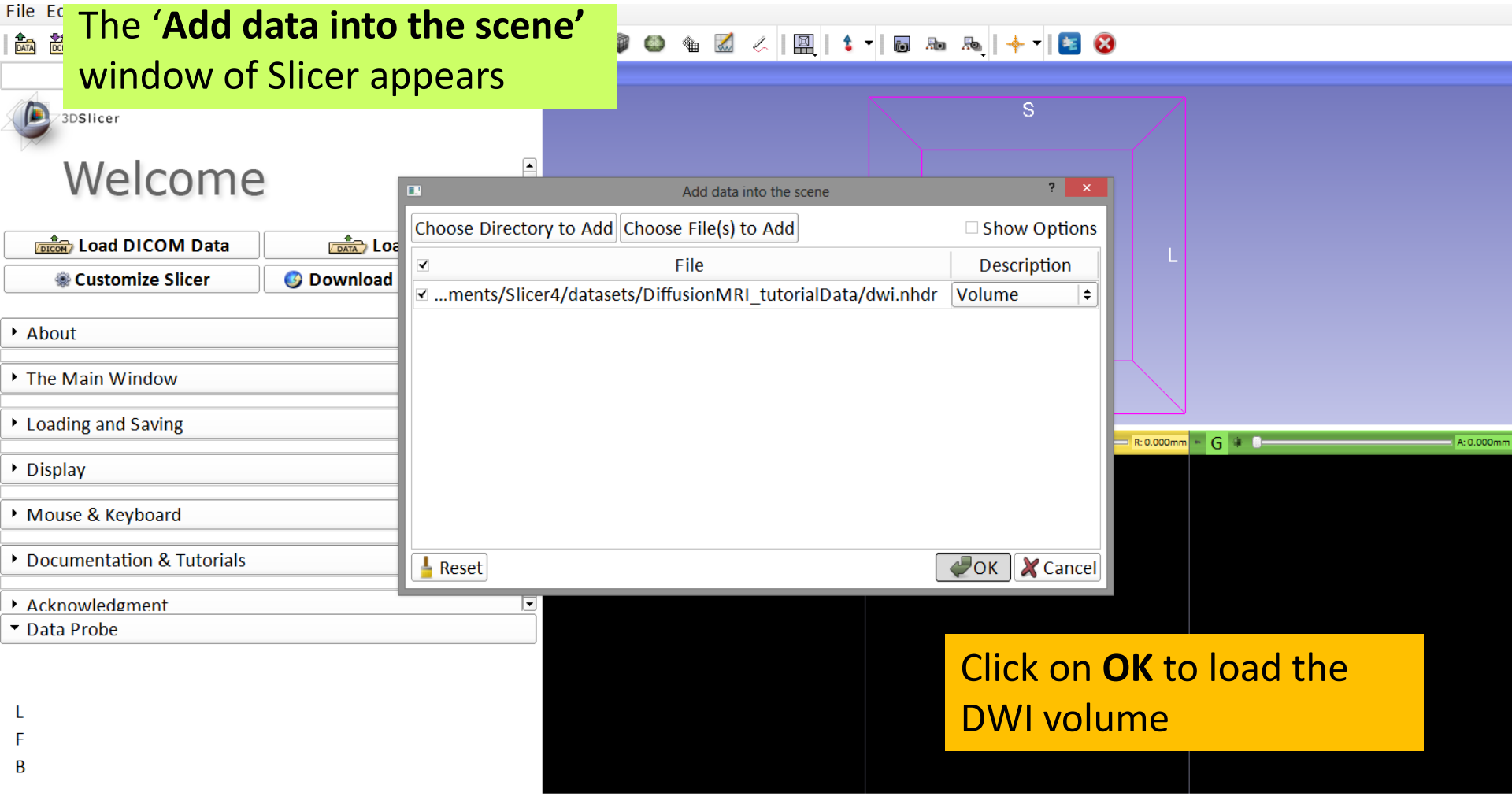


Loading the DWI Dataset



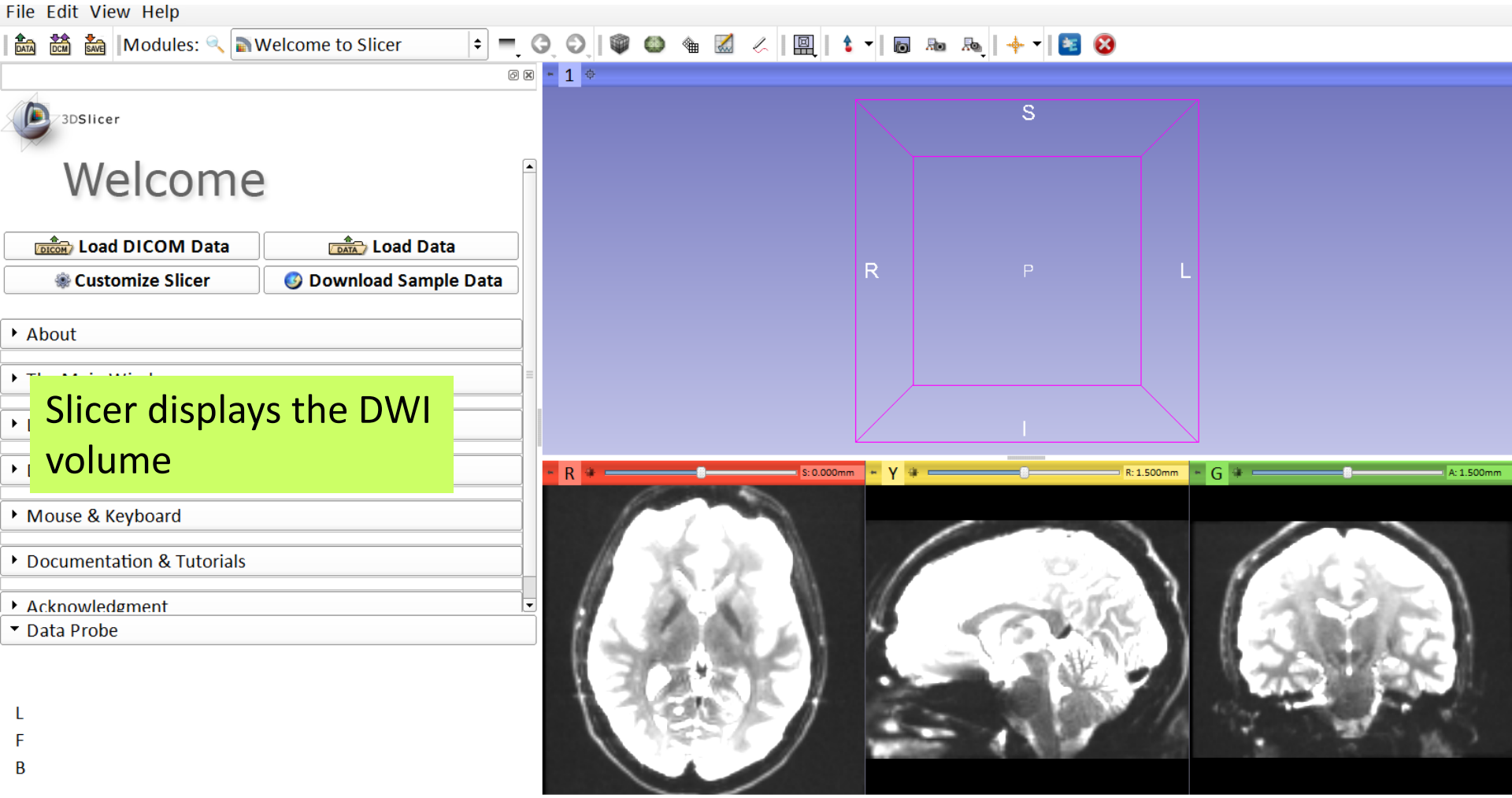
Loading the DWI Dataset

The **'Add data into the scene'** window of Slicer appears

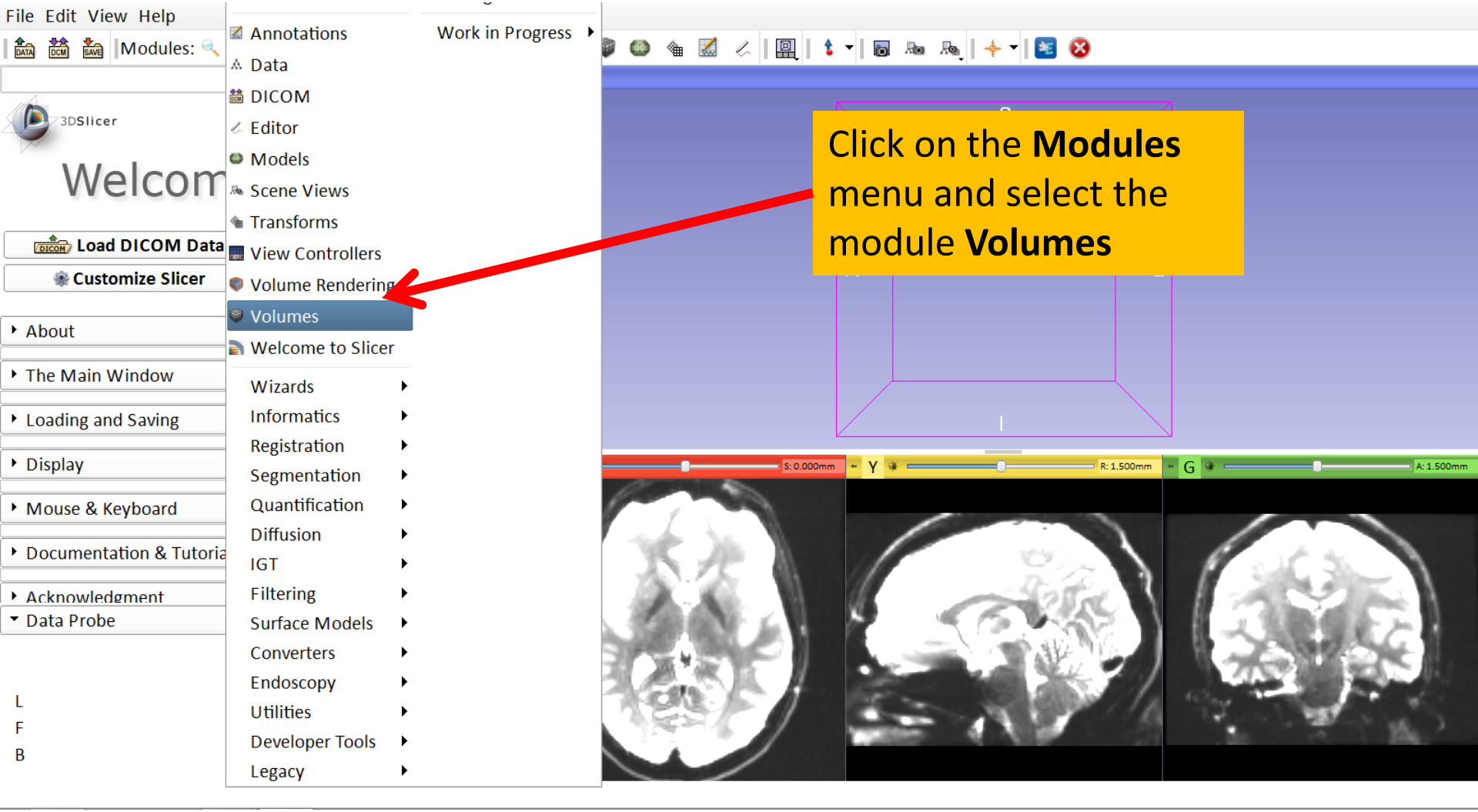


Click on **OK** to load the DWI volume

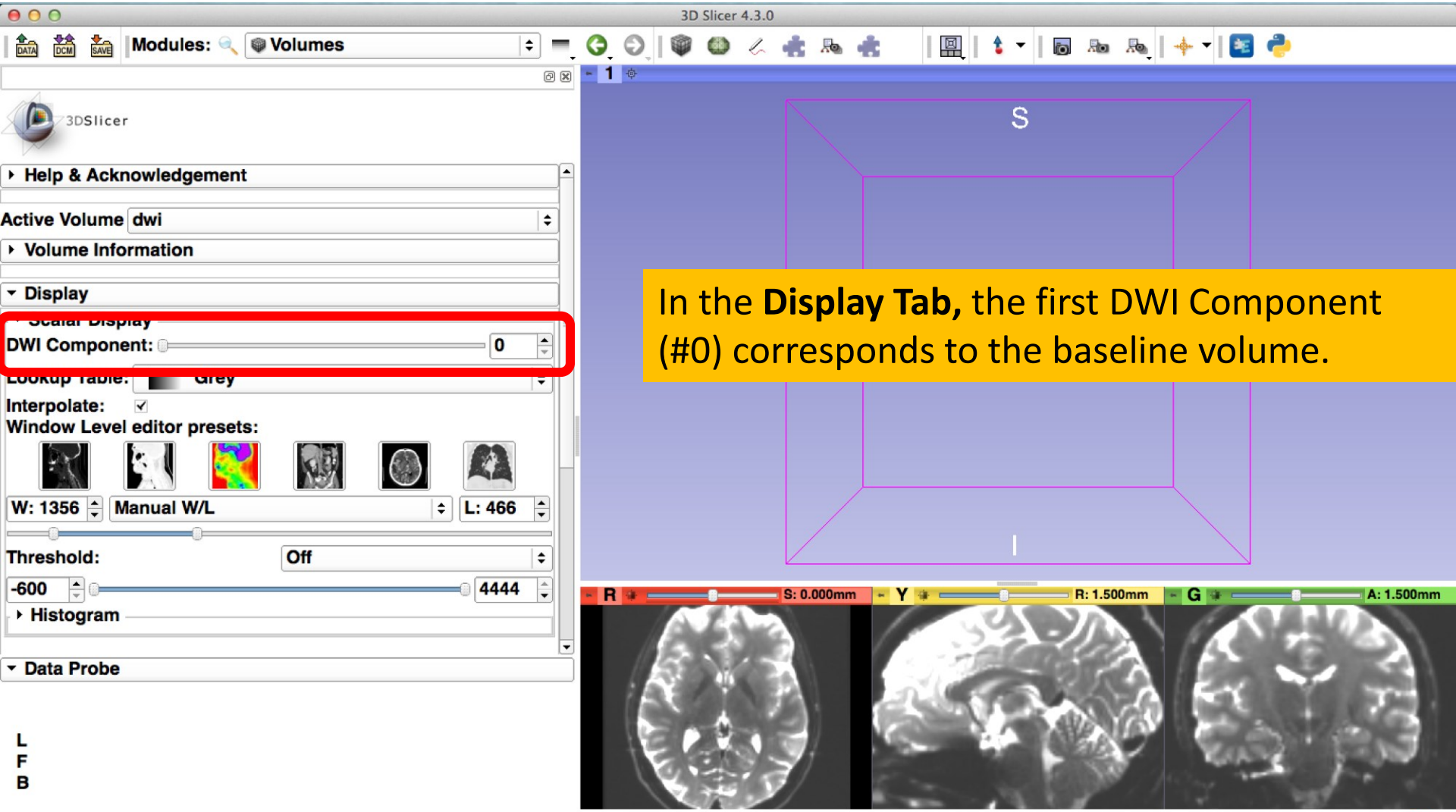
Loading the DWI Dataset



Loading the DWI Dataset

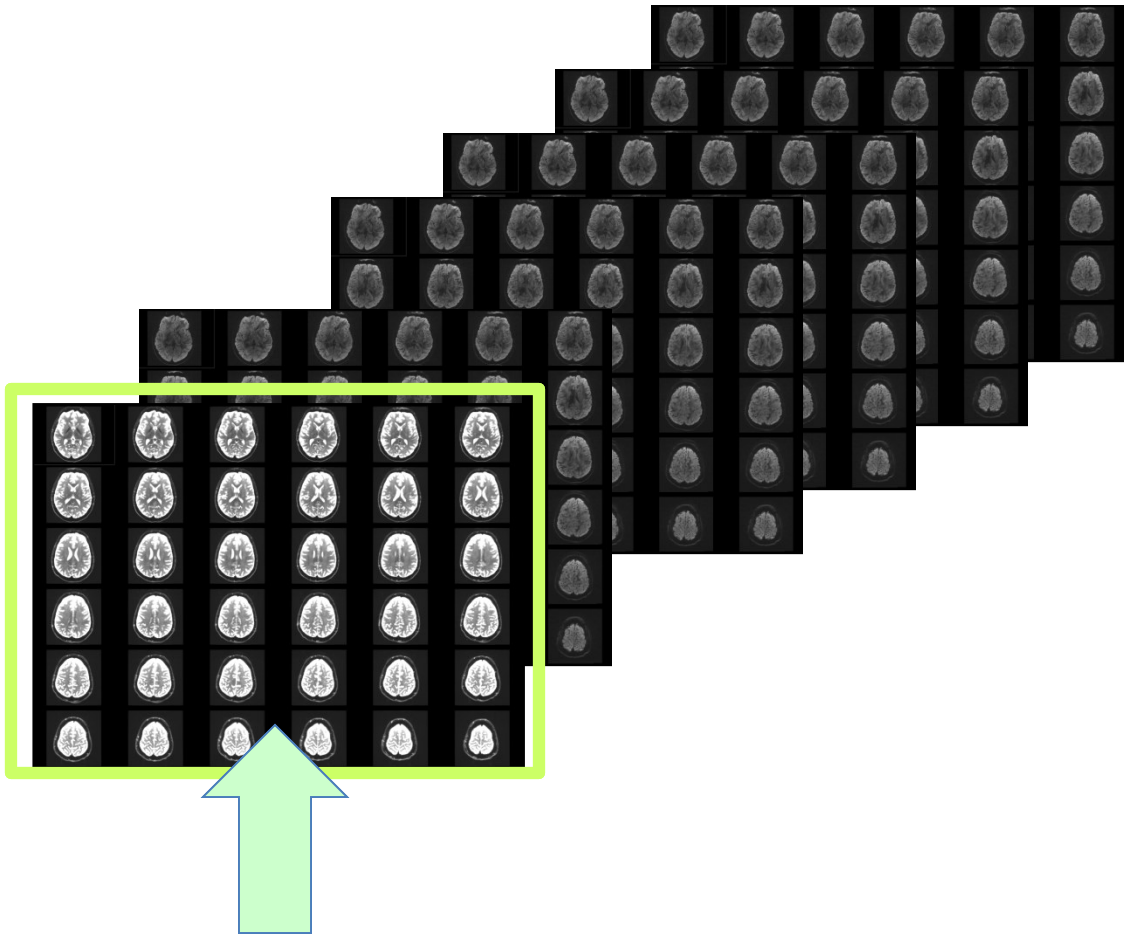


Loading the DWI dataset



In the **Display Tab,** the first DWI Component (#0) corresponds to the baseline volume.

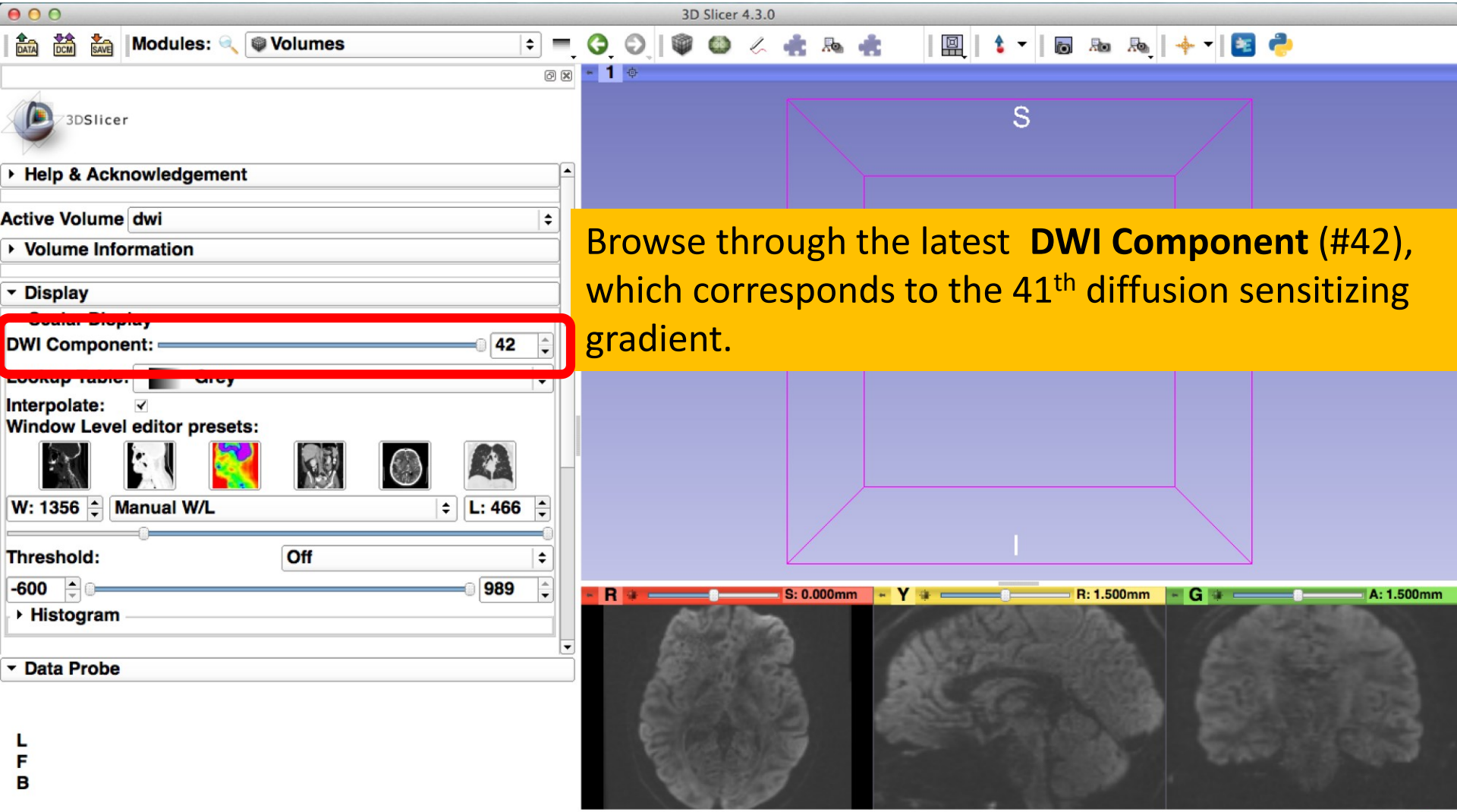
Tutorial DWI Dataset



Baseline Volume

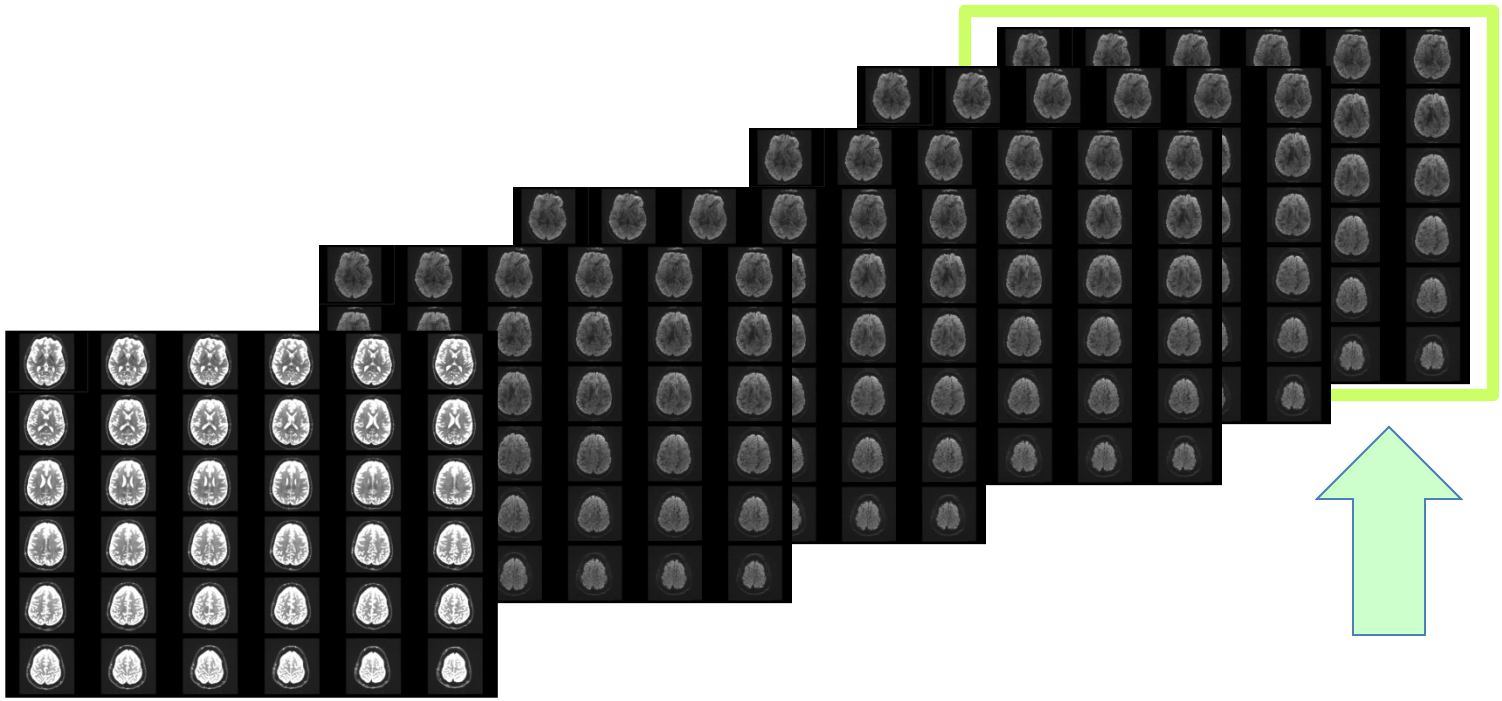
基準ボリューム

Loading the DWI dataset



Browse through the latest **DWI Component** (#42), which corresponds to the 41th diffusion sensitizing gradient.

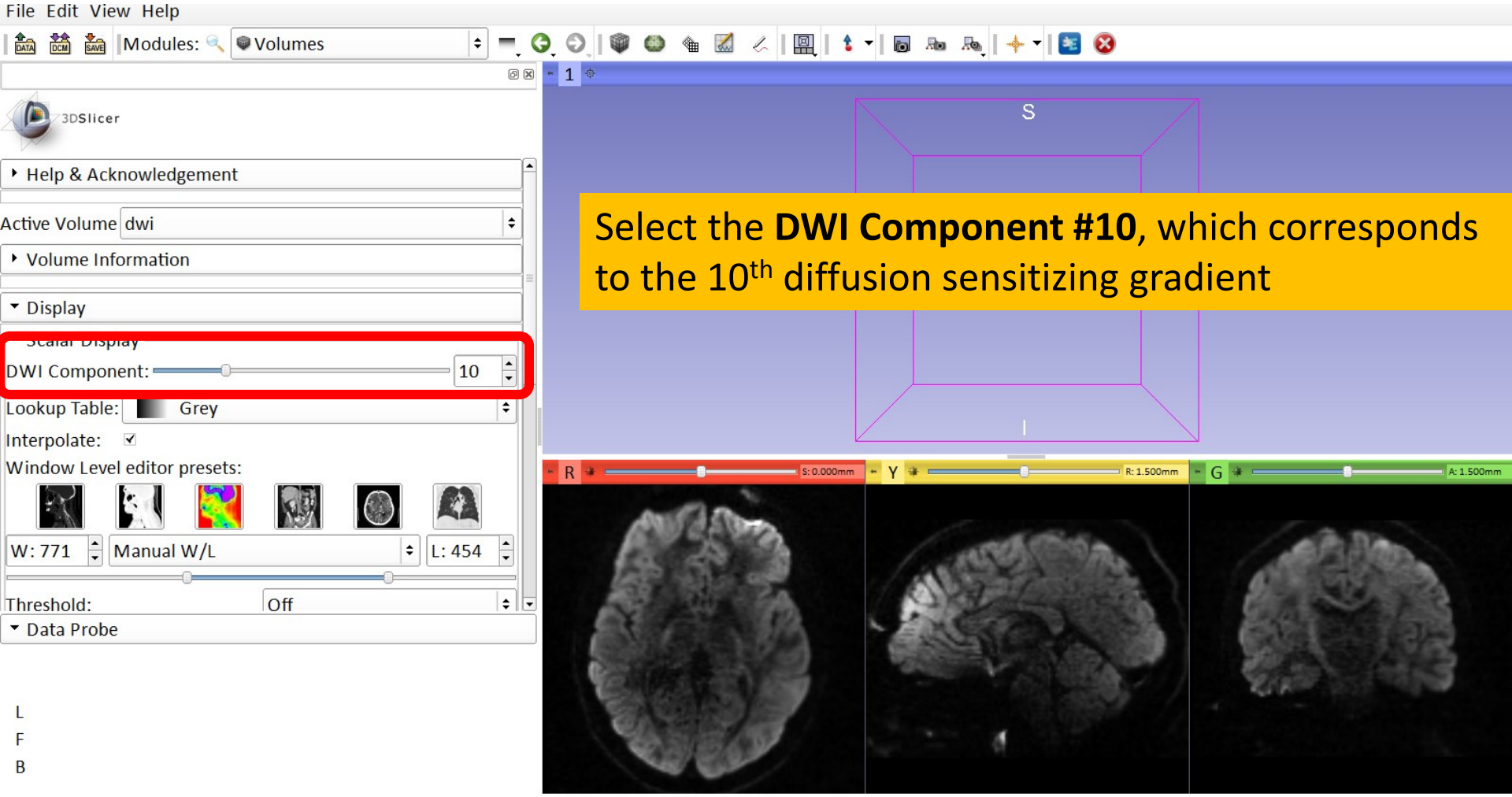
Tutorial DWI Dataset



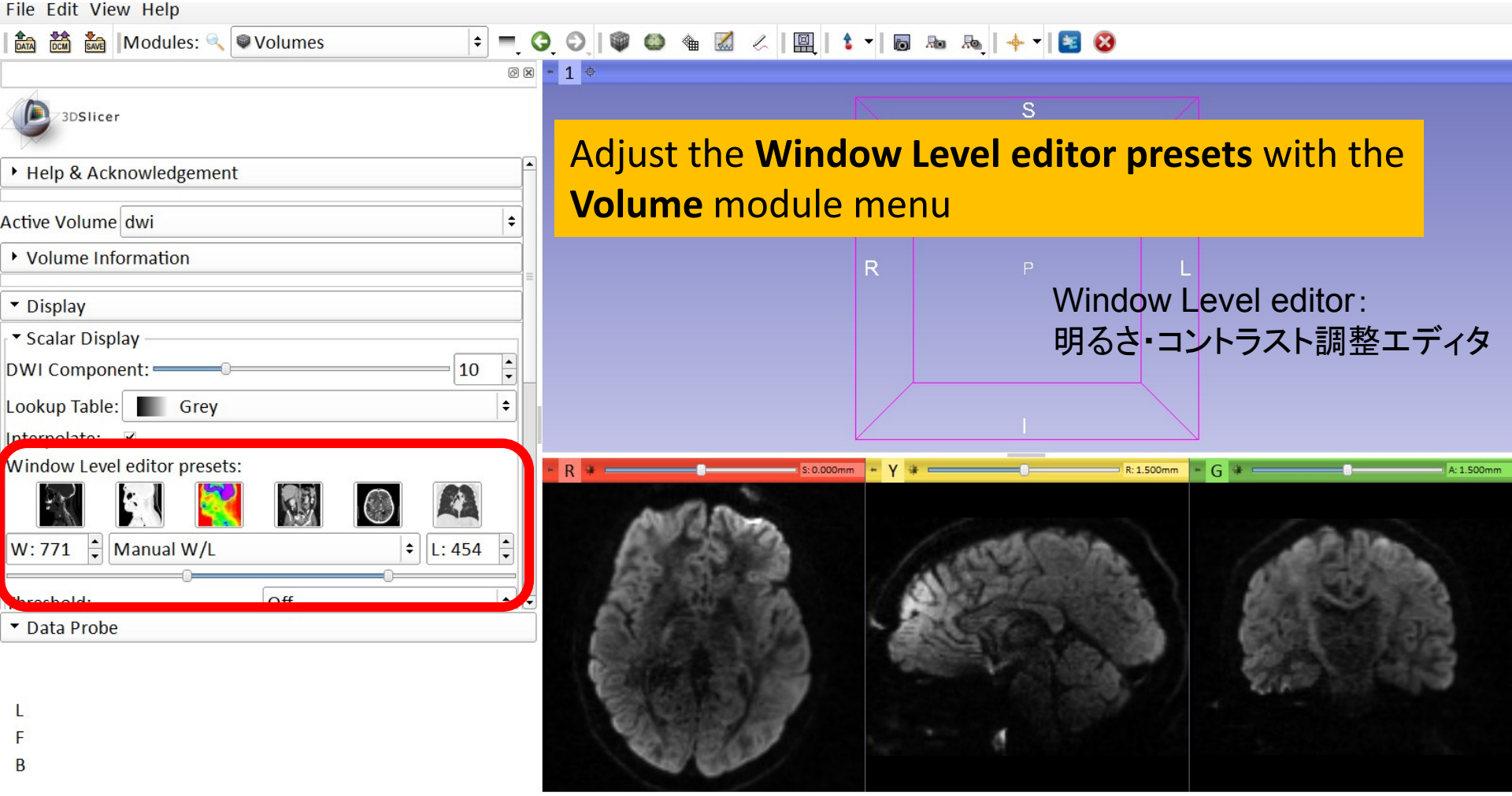
42th diffusion sensitizing gradient

42番目の（方向の）拡散検出磁場

Loading the DWI Dataset

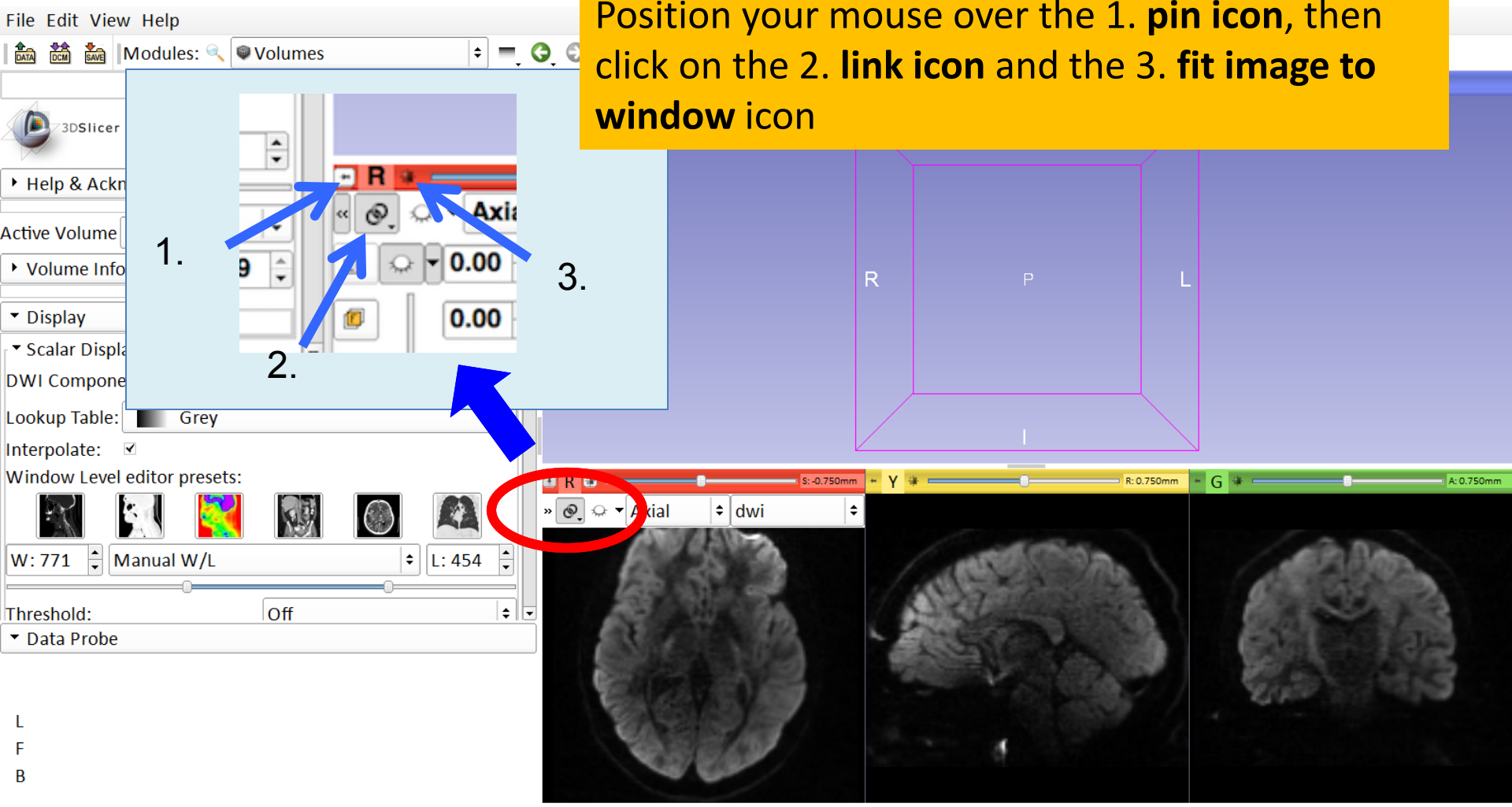


Loading the DWI Dataset



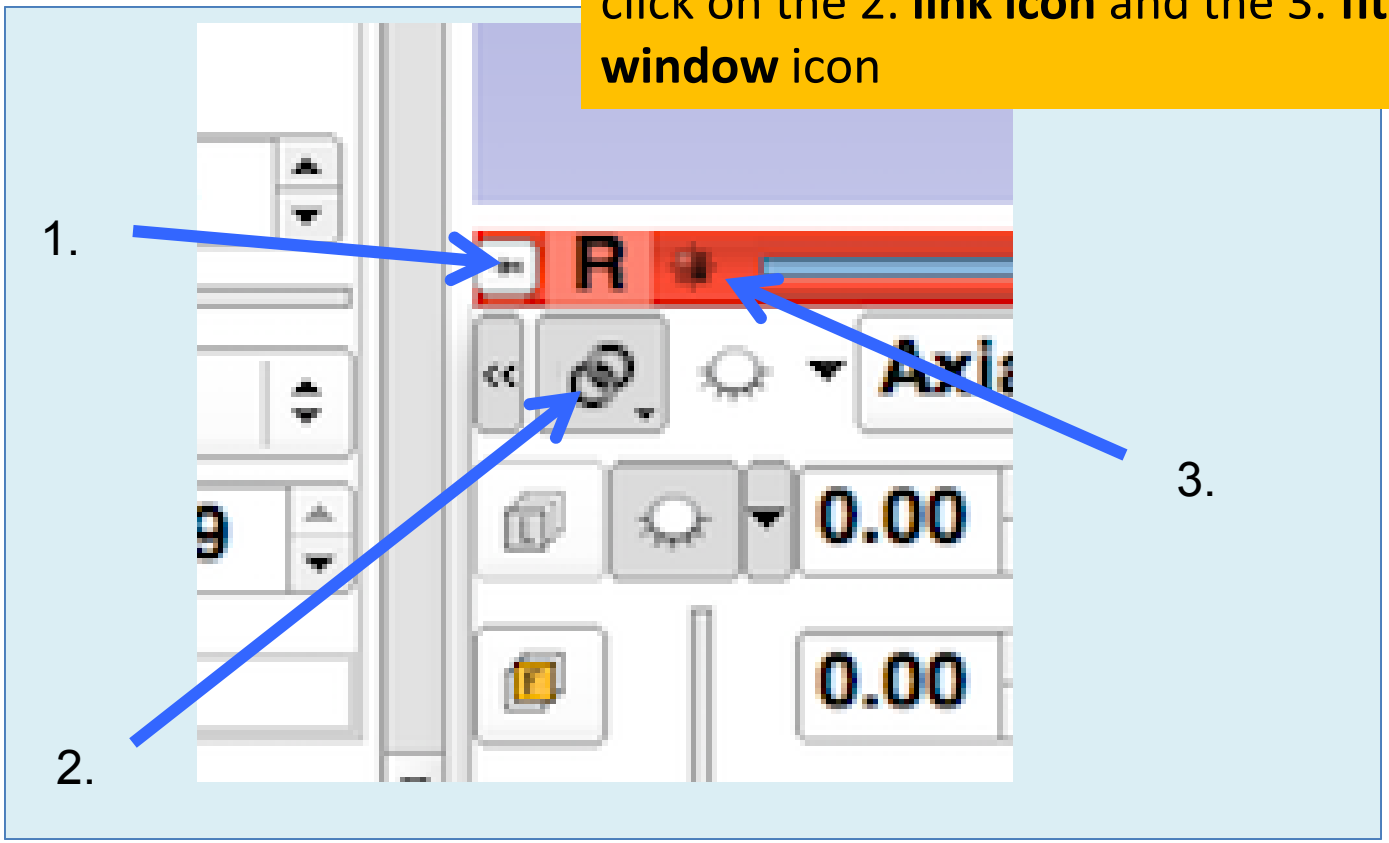
Loading the DWI Dataset

Position your mouse over the 1. **pin icon**, then click on the 2. **link icon** and the 3. **fit image to window** icon

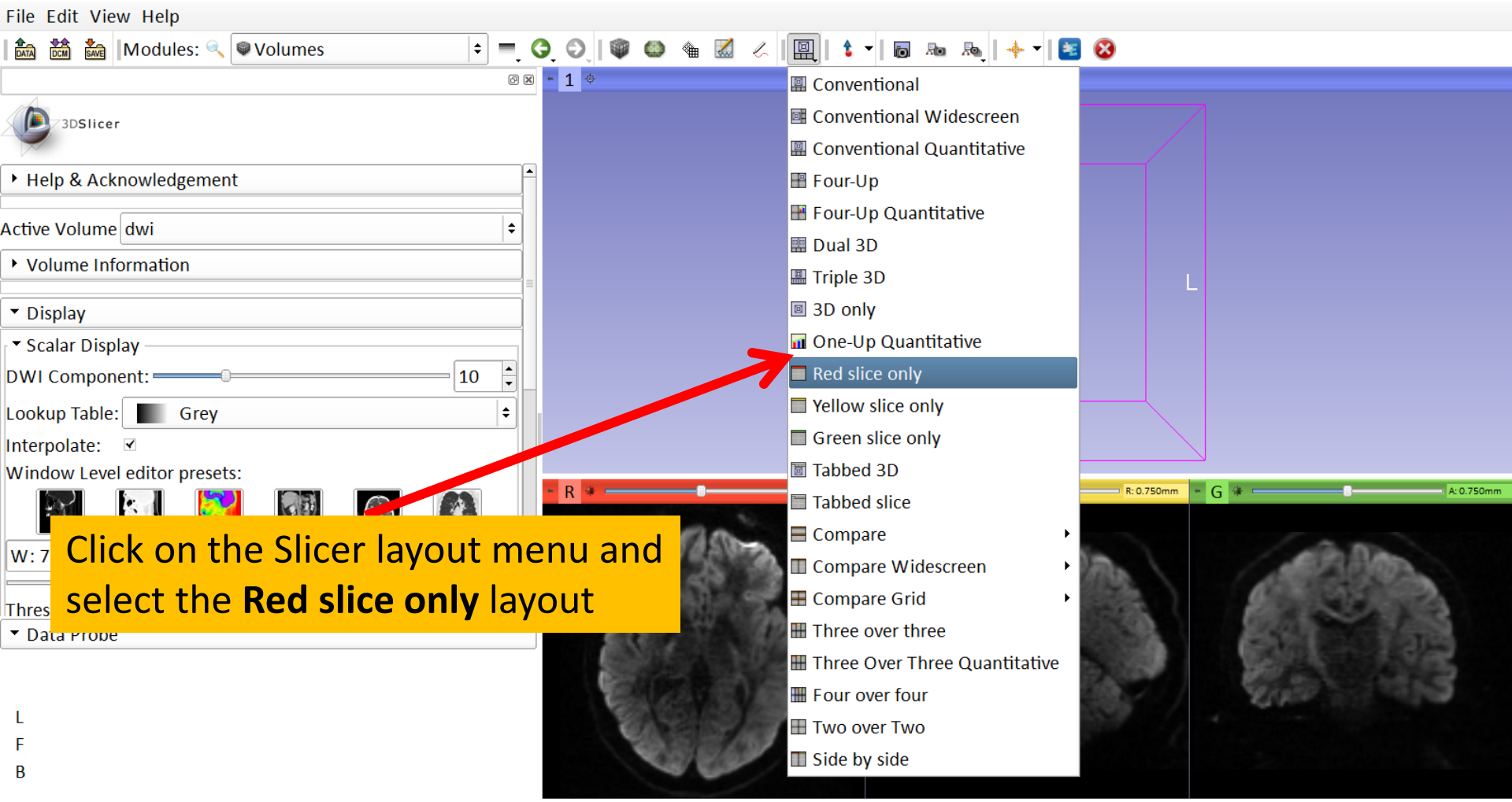


Loading the DWI Dataset

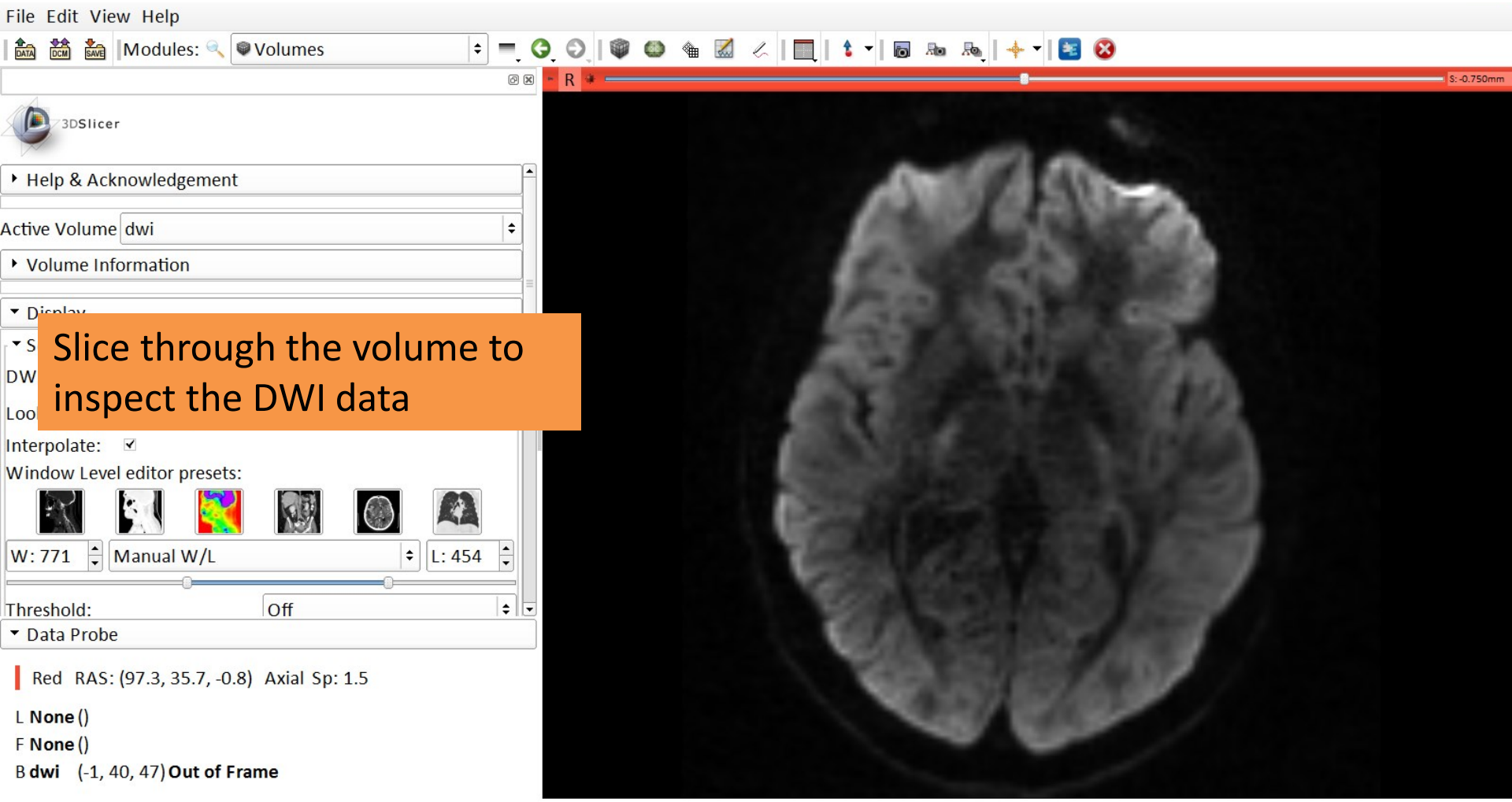
Position your mouse over the 1. **pin icon**, then click on the 2. **link icon** and the 3. **fit image to window** icon



Loading the DWI Dataset

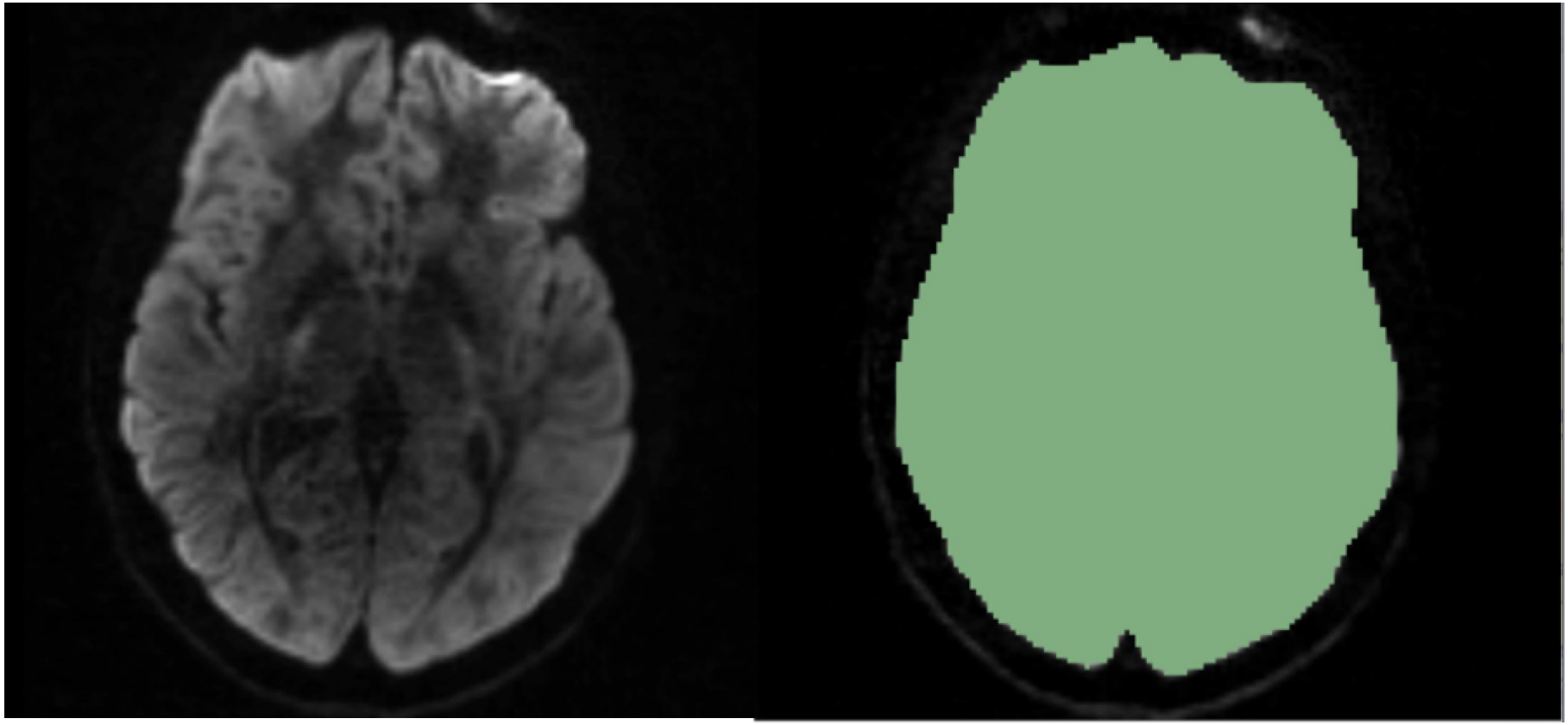


Loading the DWI Dataset



Inspect:
しらべる

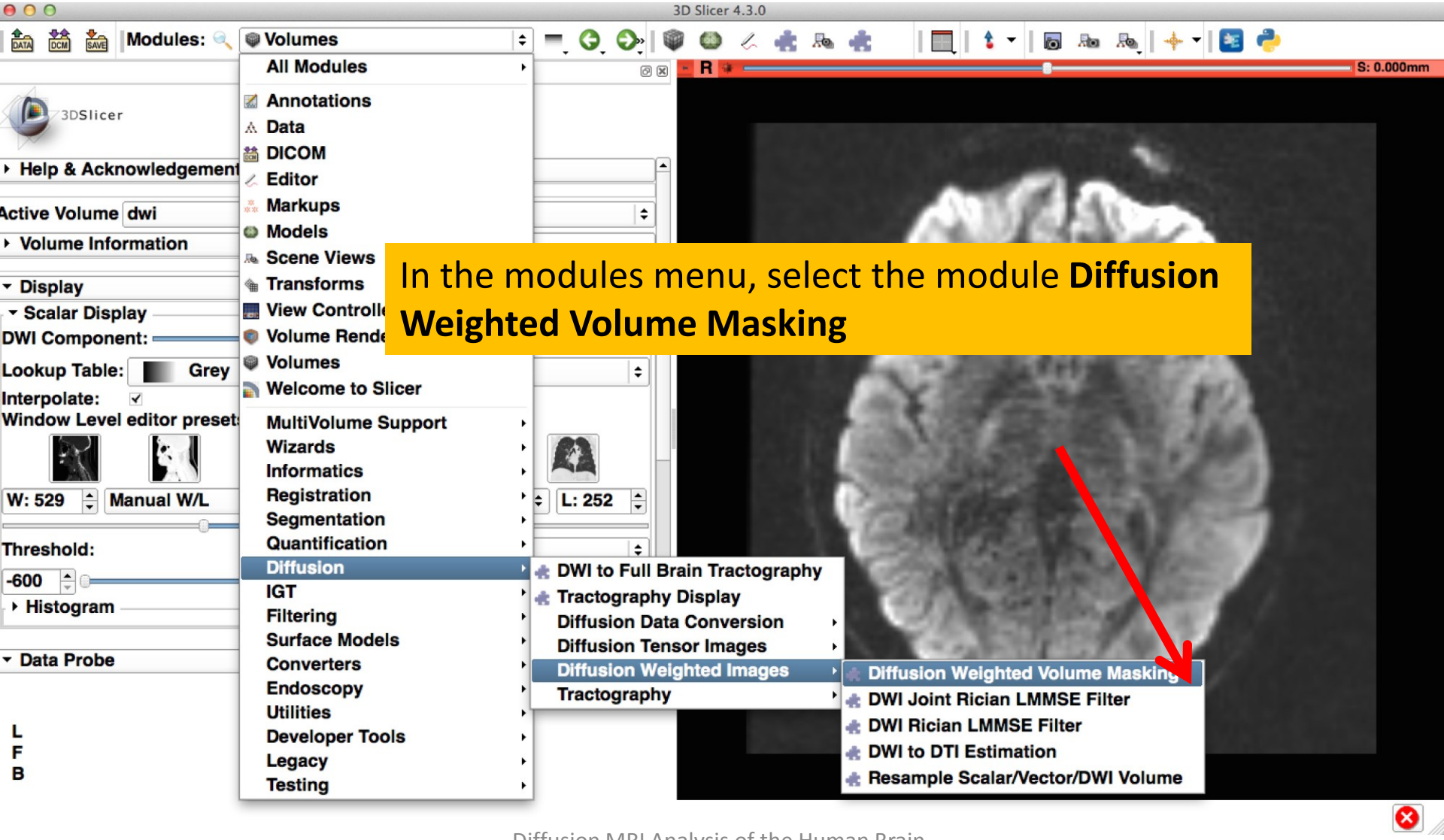
DWI Dataset and DWI Mask



マスク:
処理の範囲を
限定するエリア

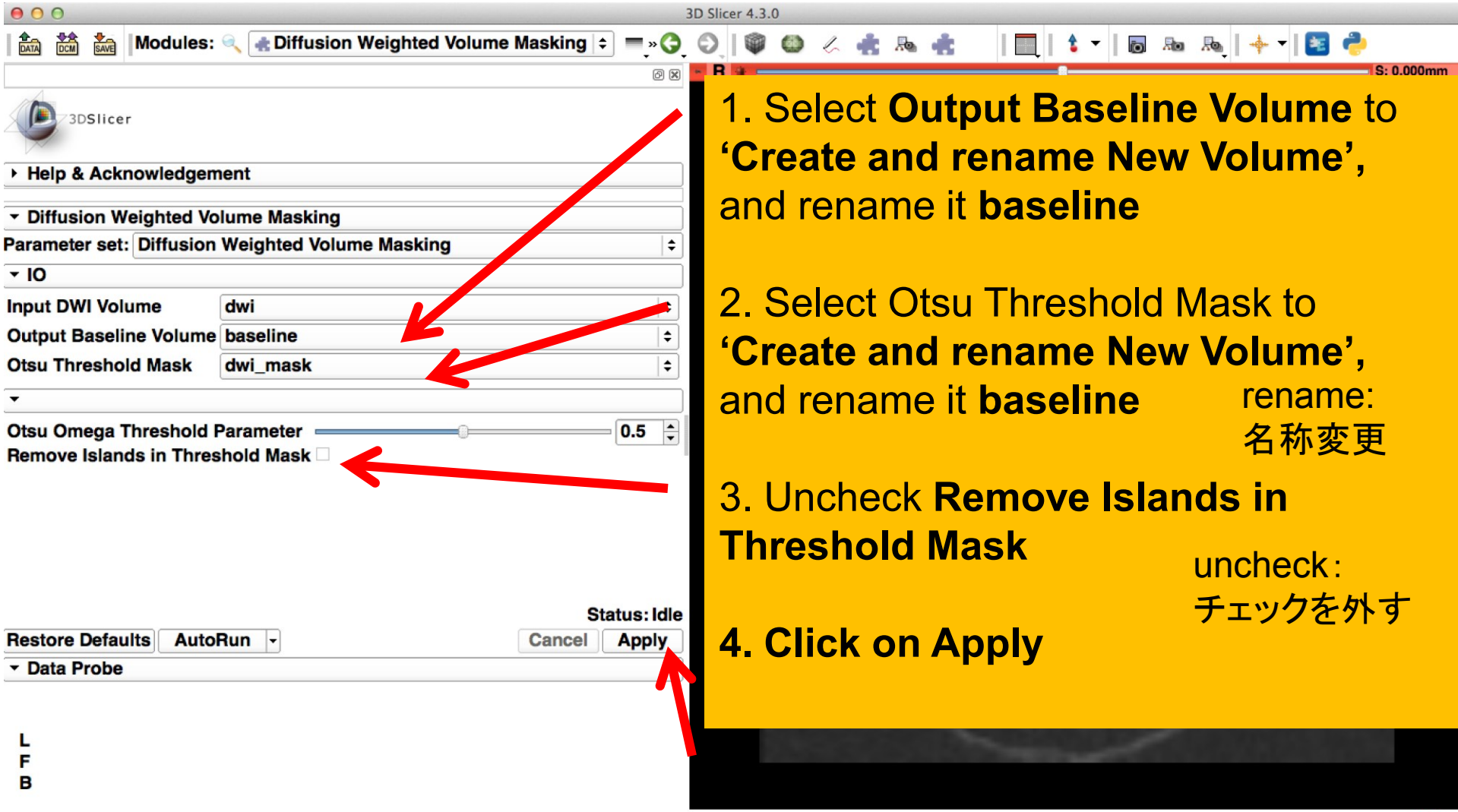
Diffusion MRI Analysis of the Human Brain,
S.Pujol, ARR 2012-2017

Creating the DWI Mask

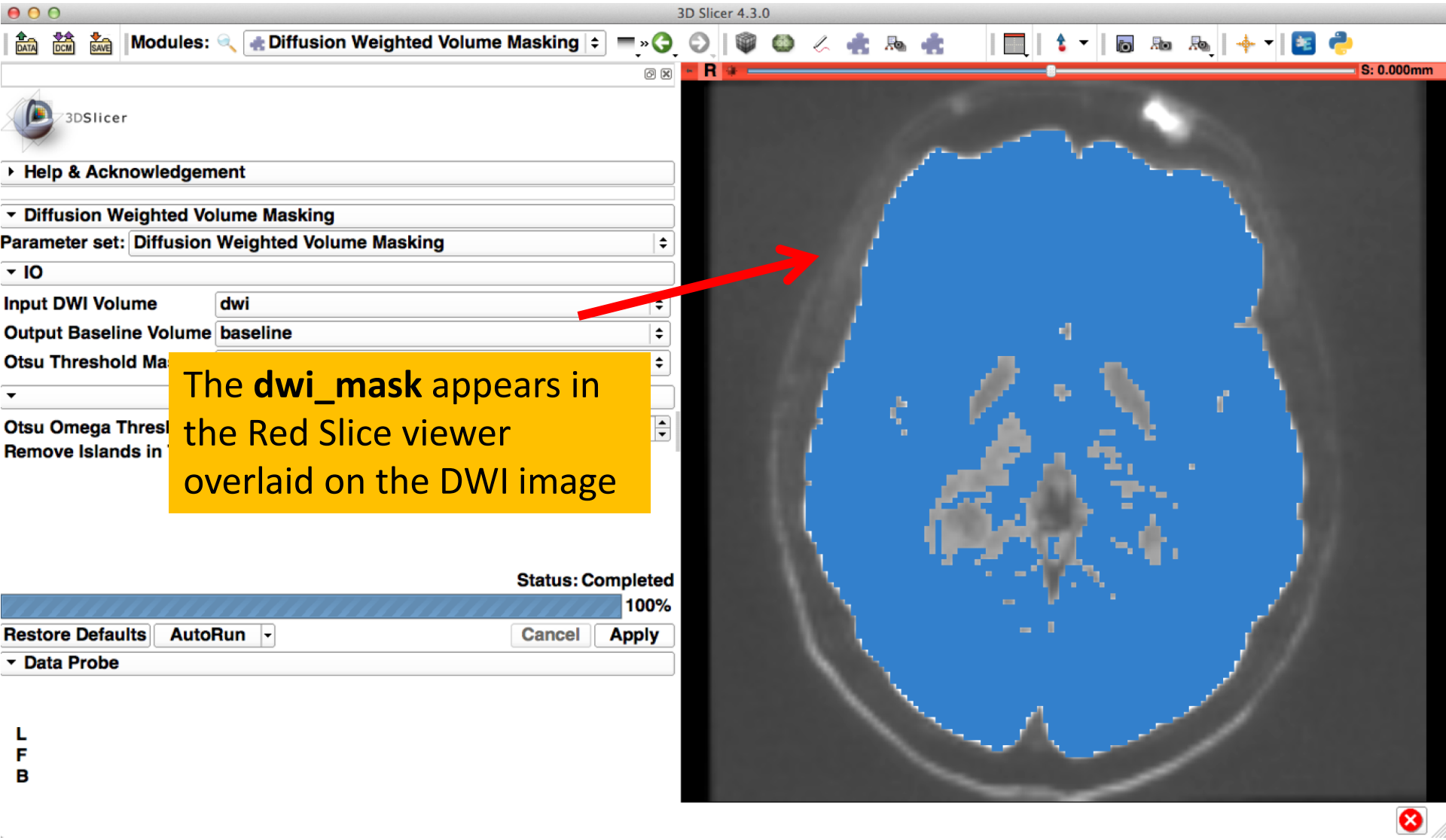


In the modules menu, select the module **Diffusion Weighted Volume Masking**

Creating the DWI Mask

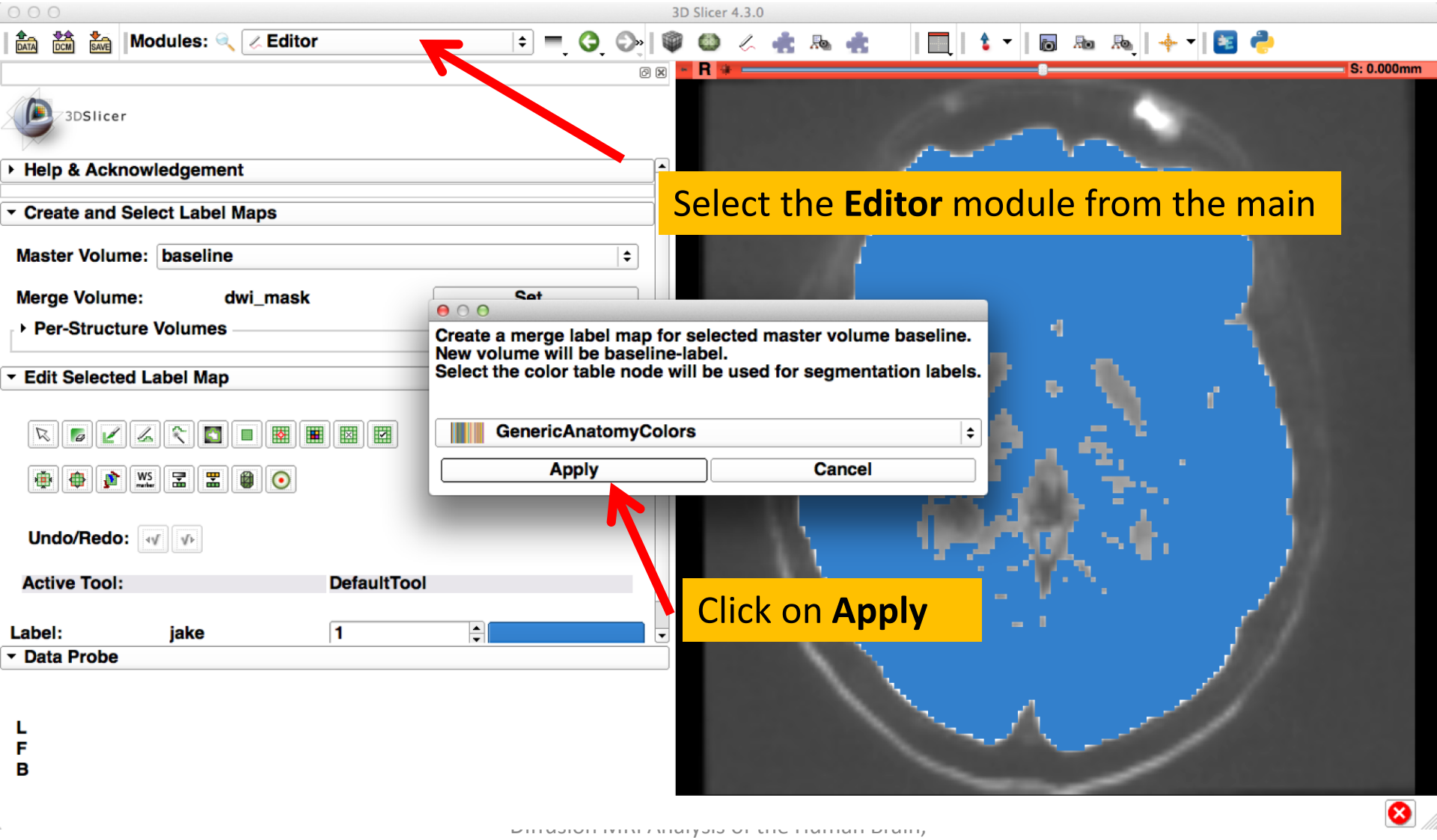


Loading the DWI Mask

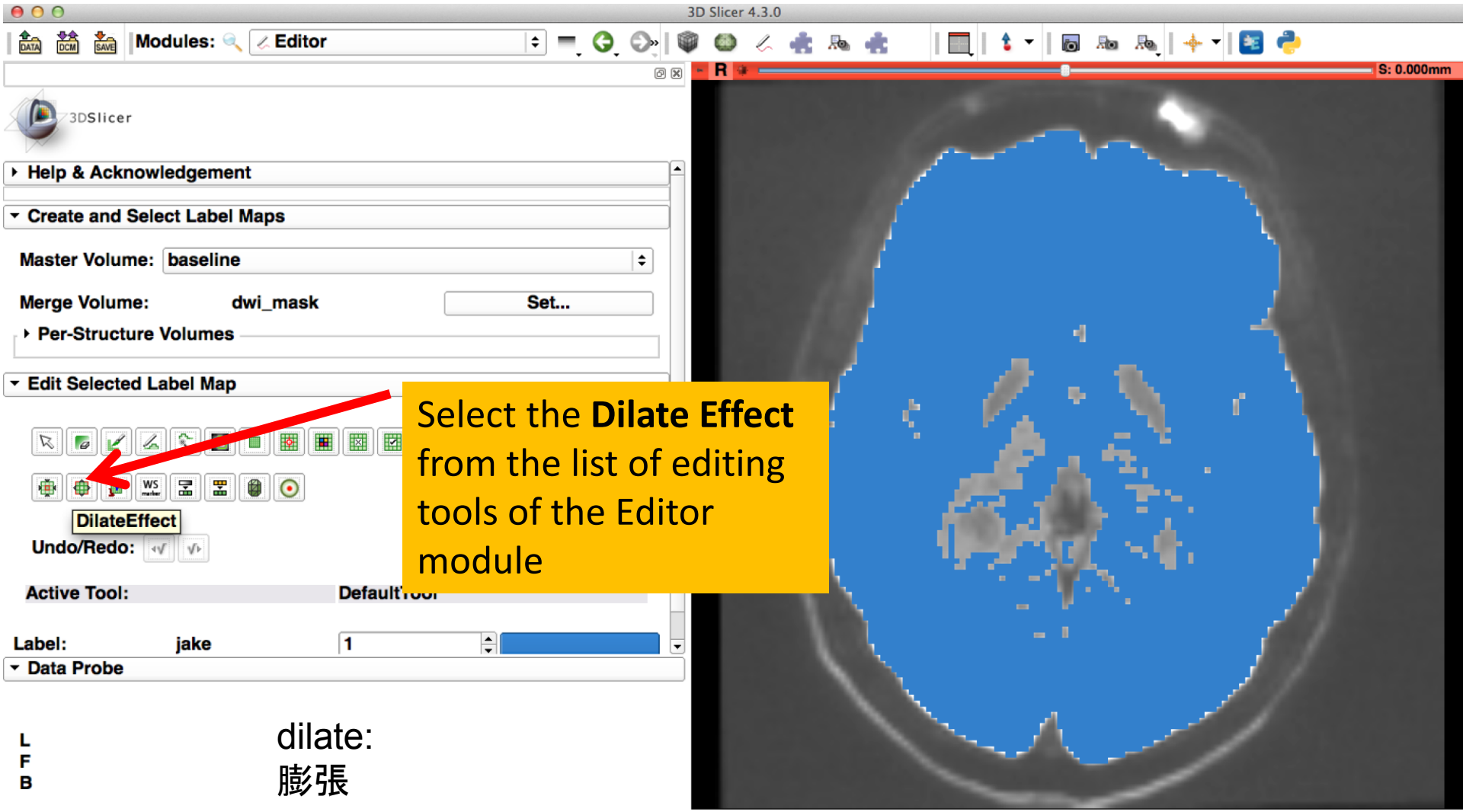


The **dwi_mask** appears in the Red Slice viewer overlaid on the DWI image

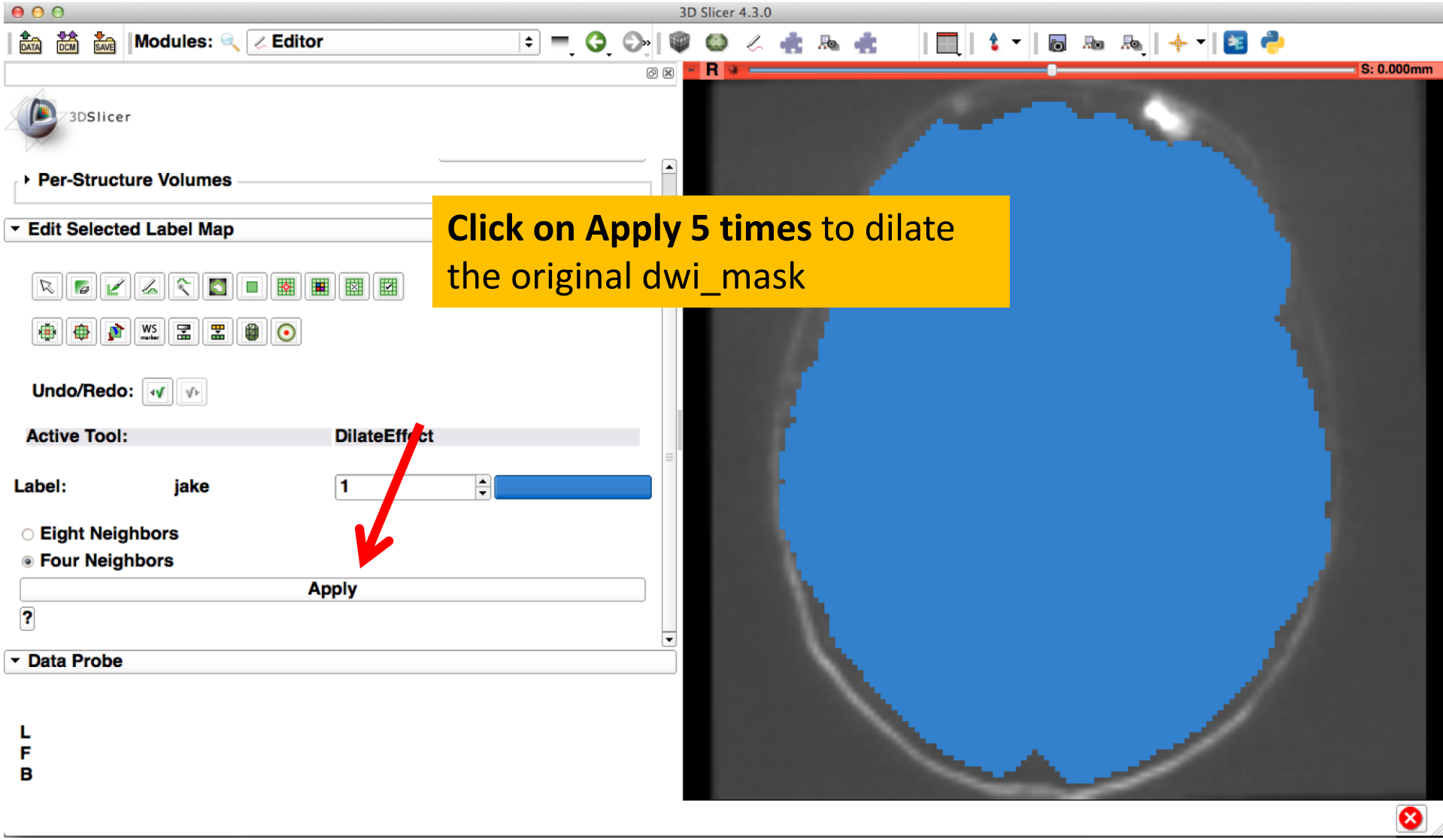
Loading the DWI Mask



Loading the DWI Mask

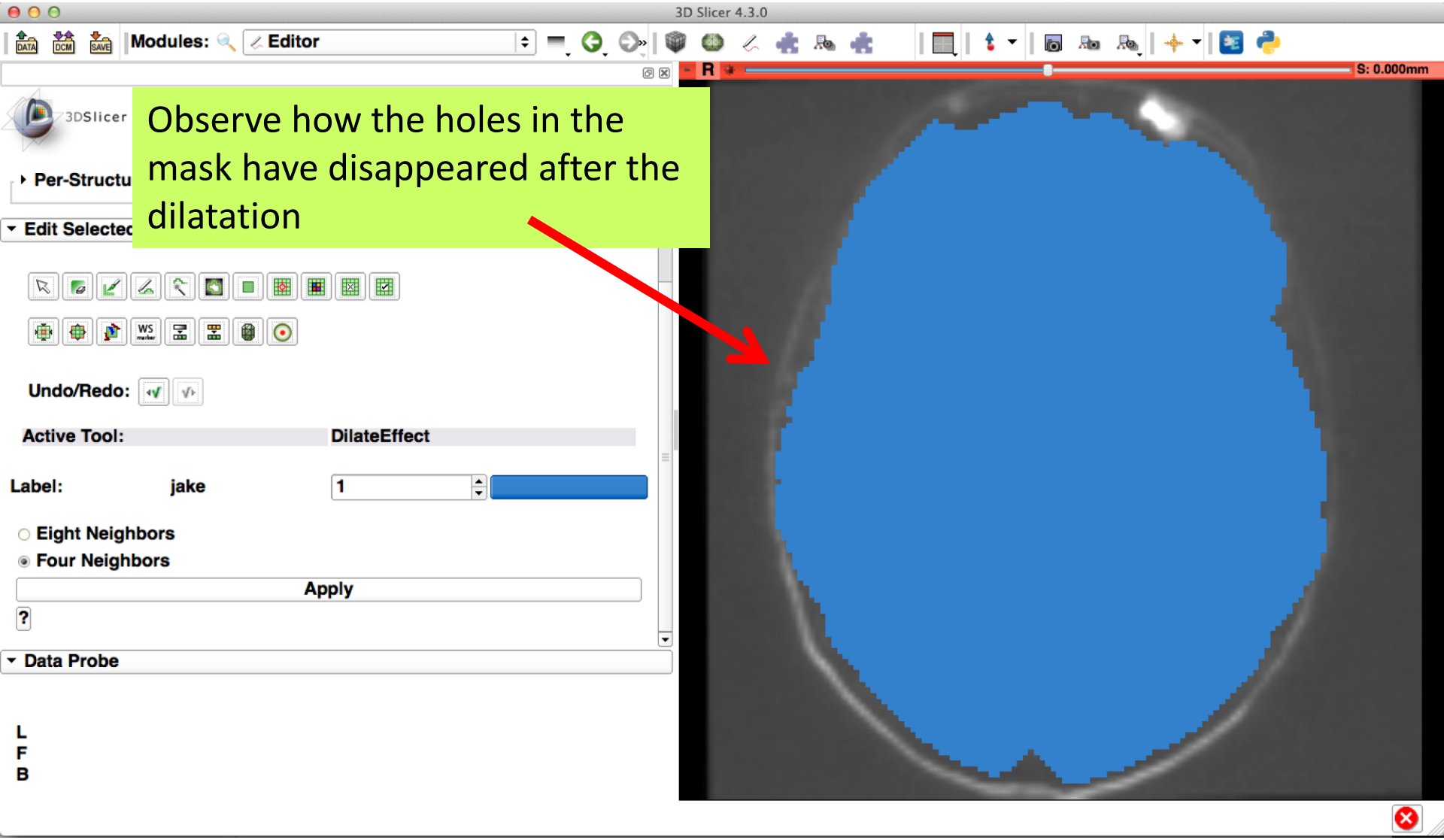


Loading the DWI Mask

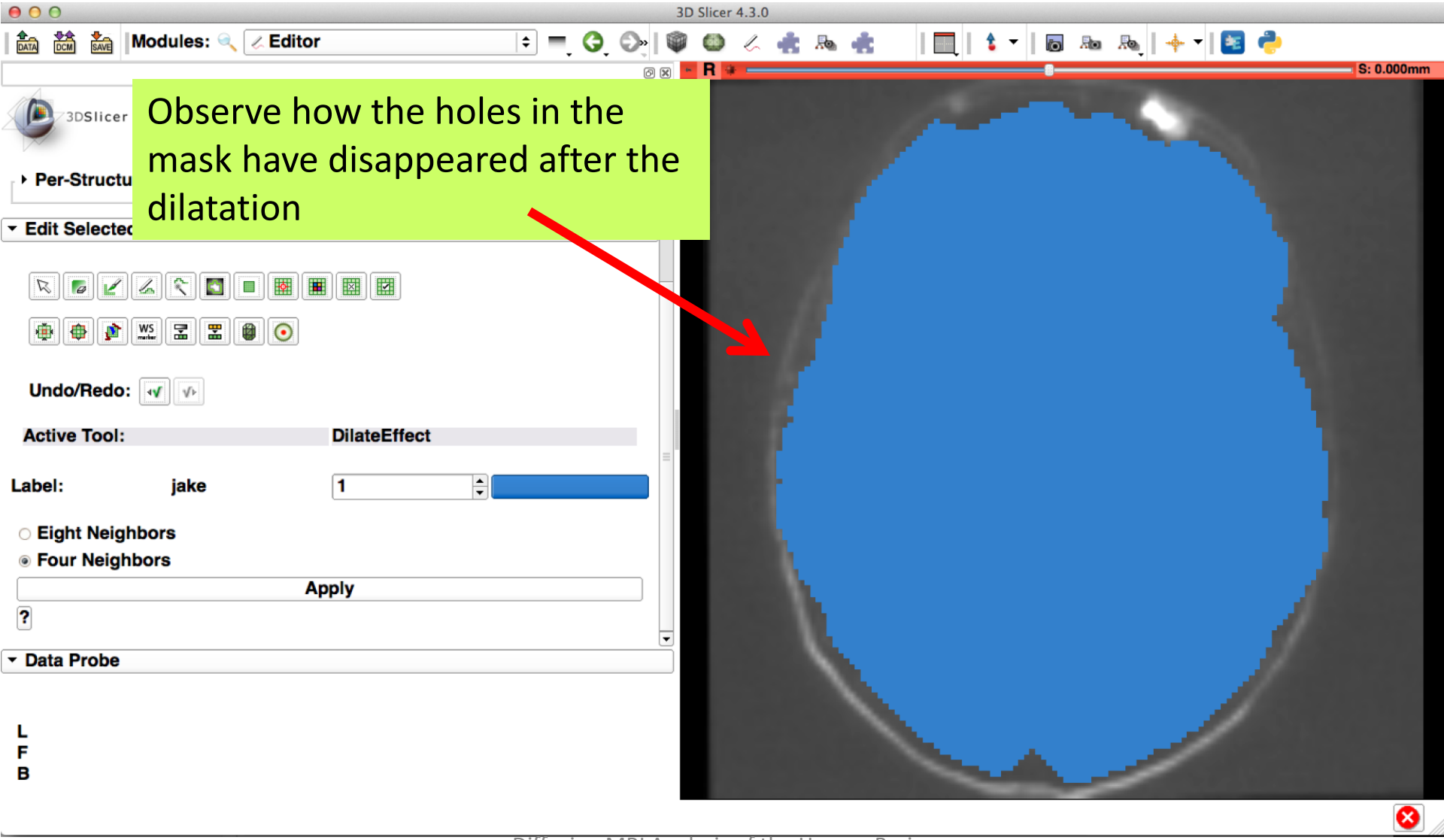


Click on Apply 5 times to dilate the original dwi_mask

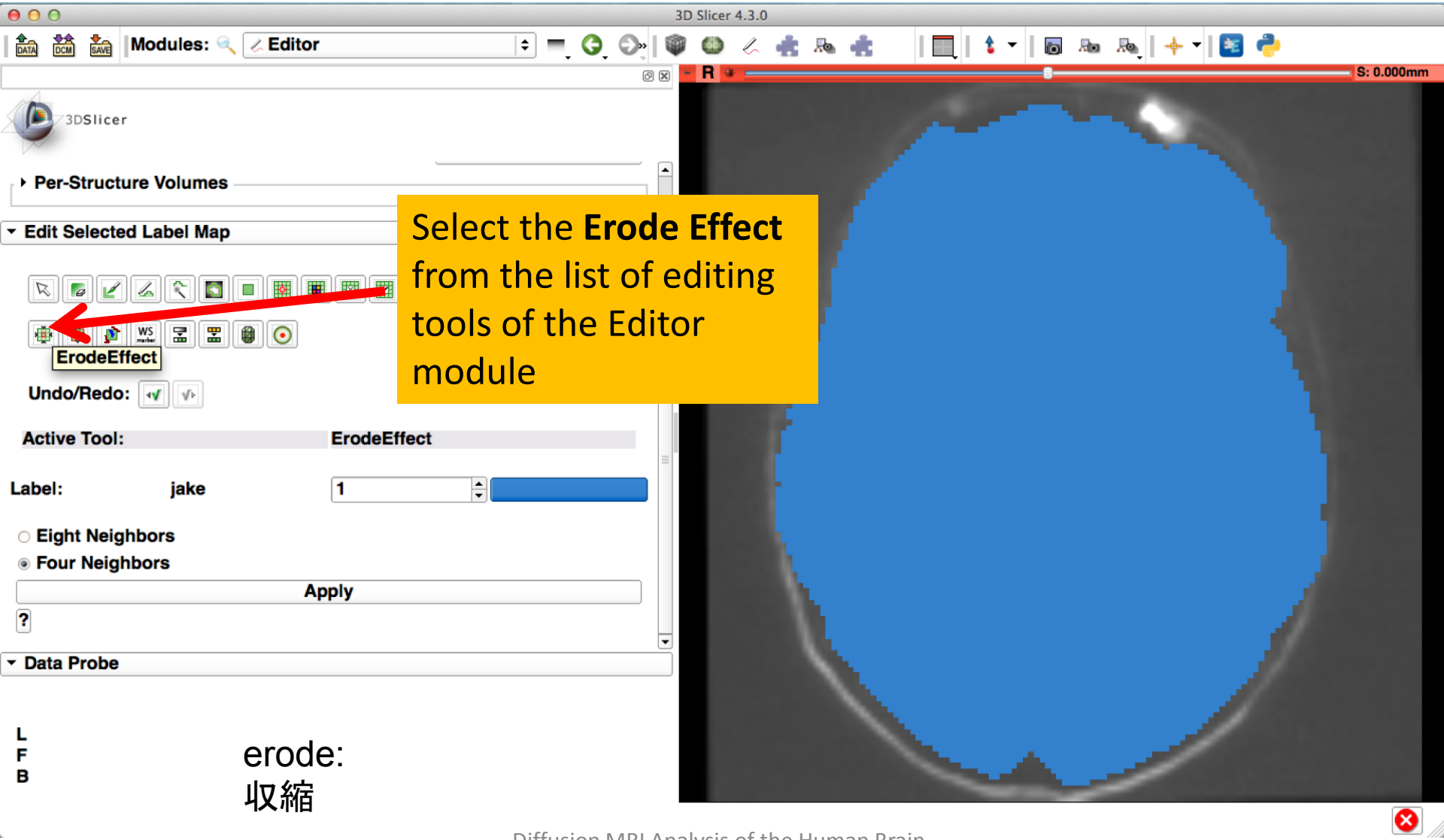
Loading the DWI Mask



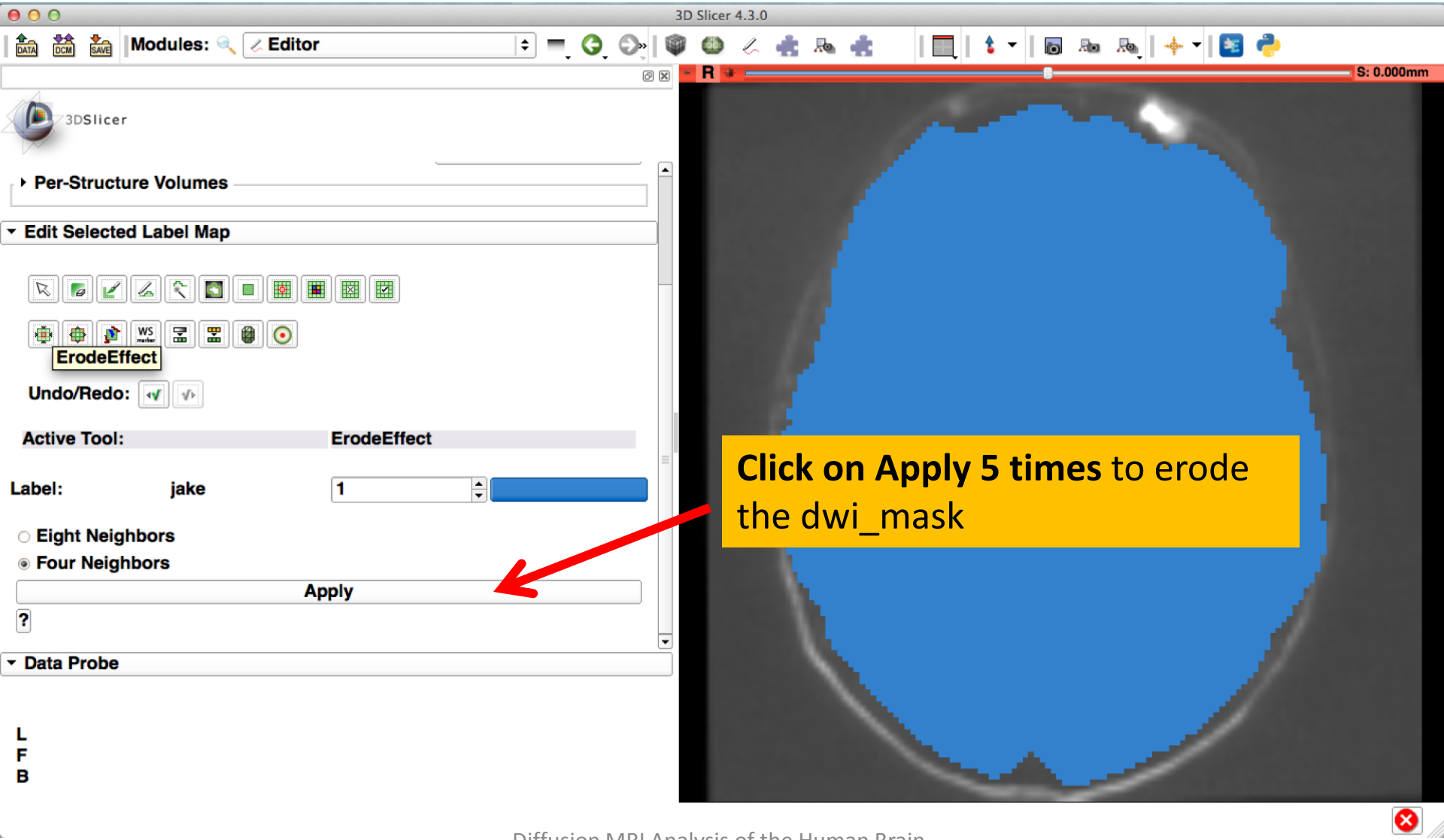
Loading the DWI Mask



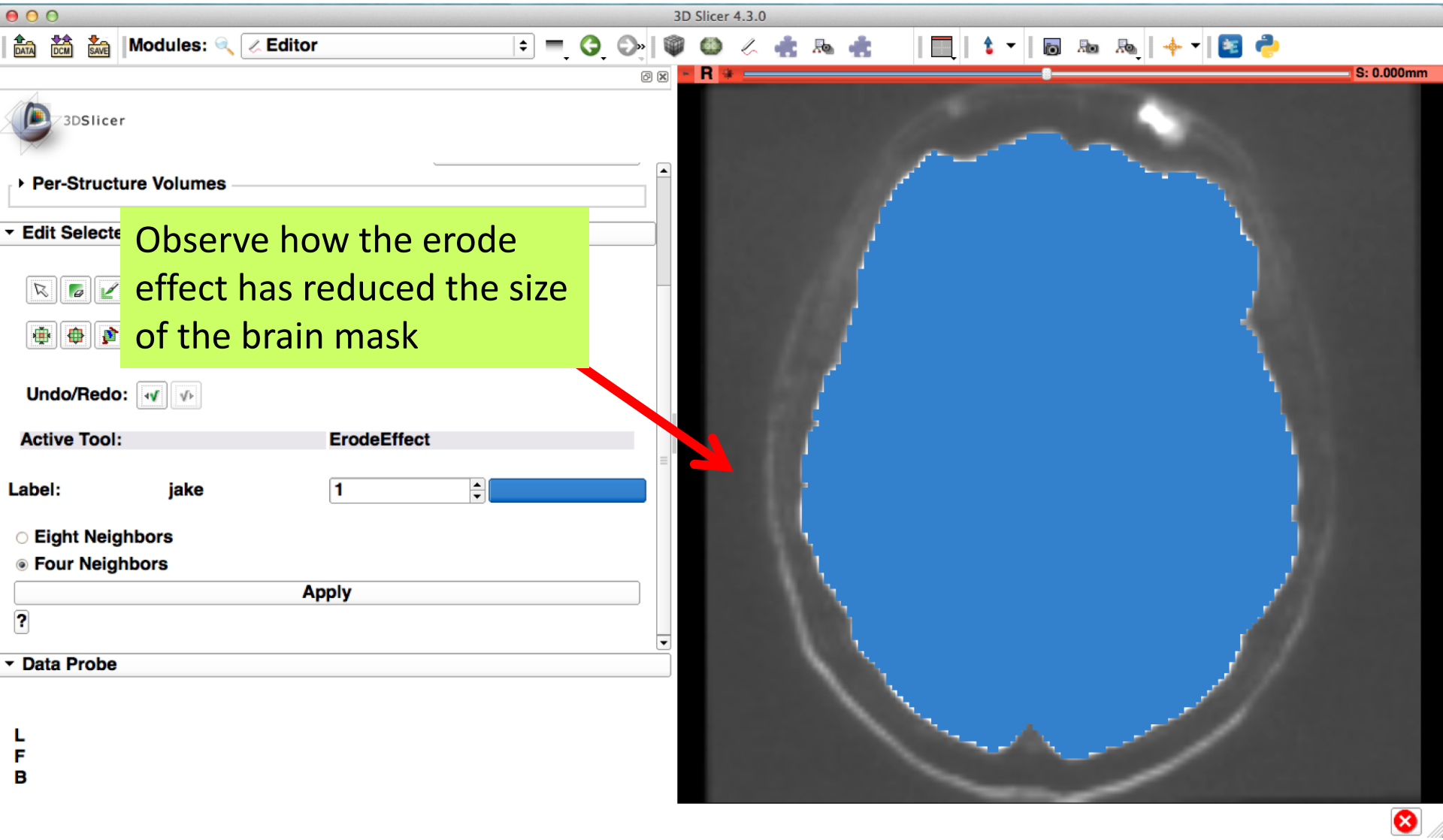
Loading the DWI Mask



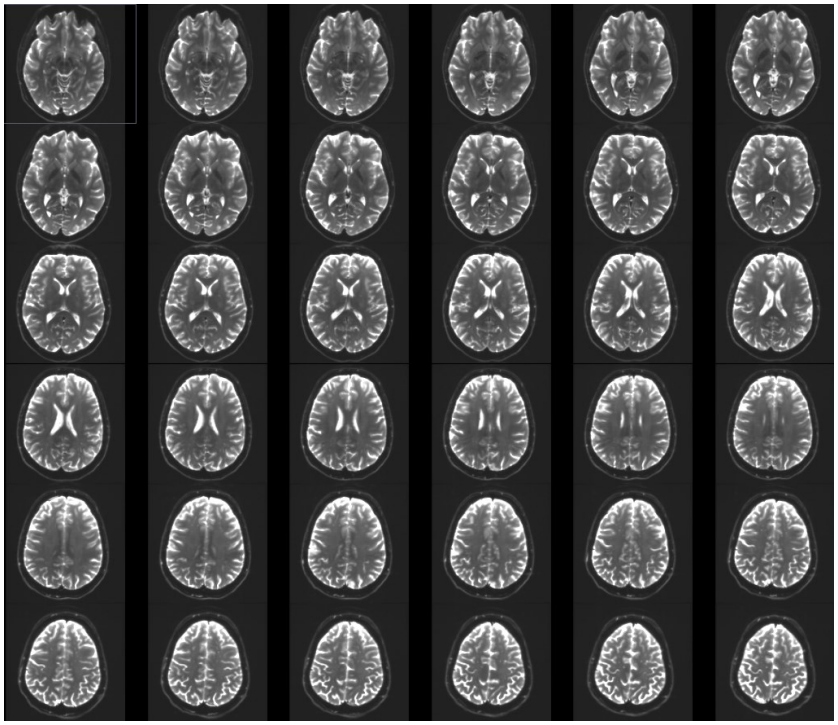
Loading the DWI Mask



Loading the DWI Mask



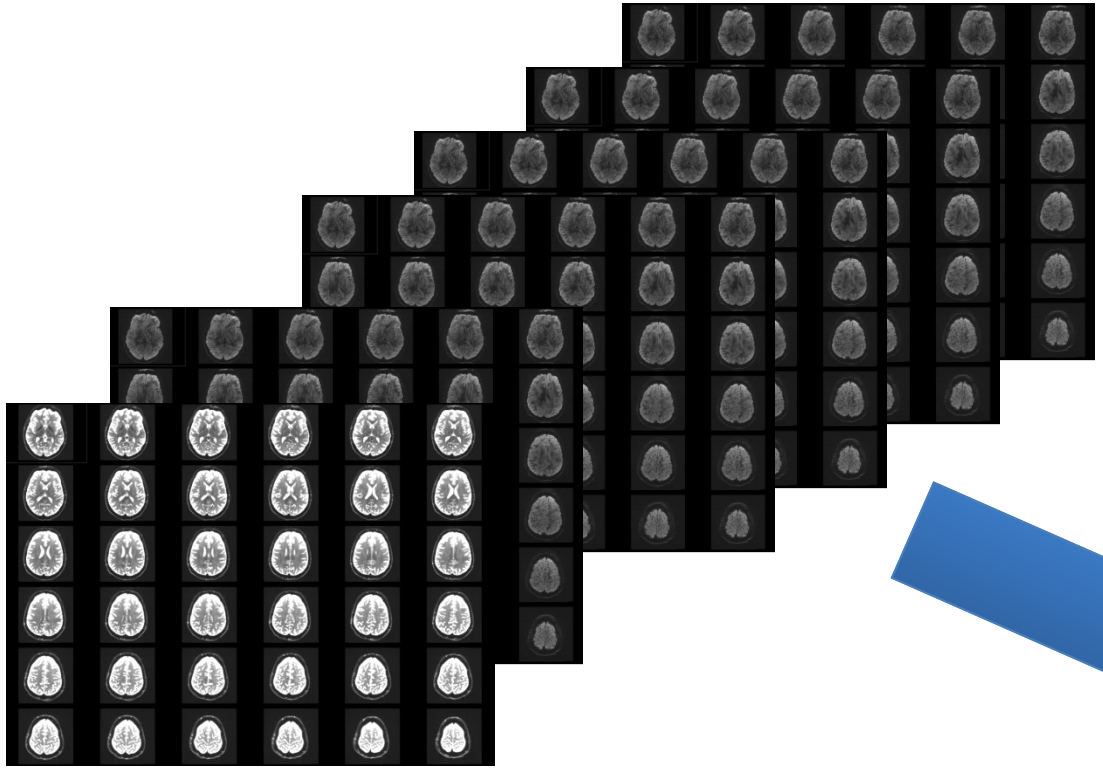
Observe how the erode effect has reduced the size of the brain mask

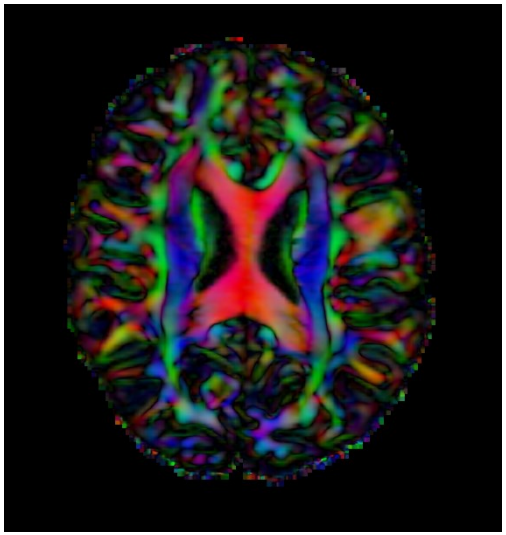


Step 2: Computing the DTI dataset

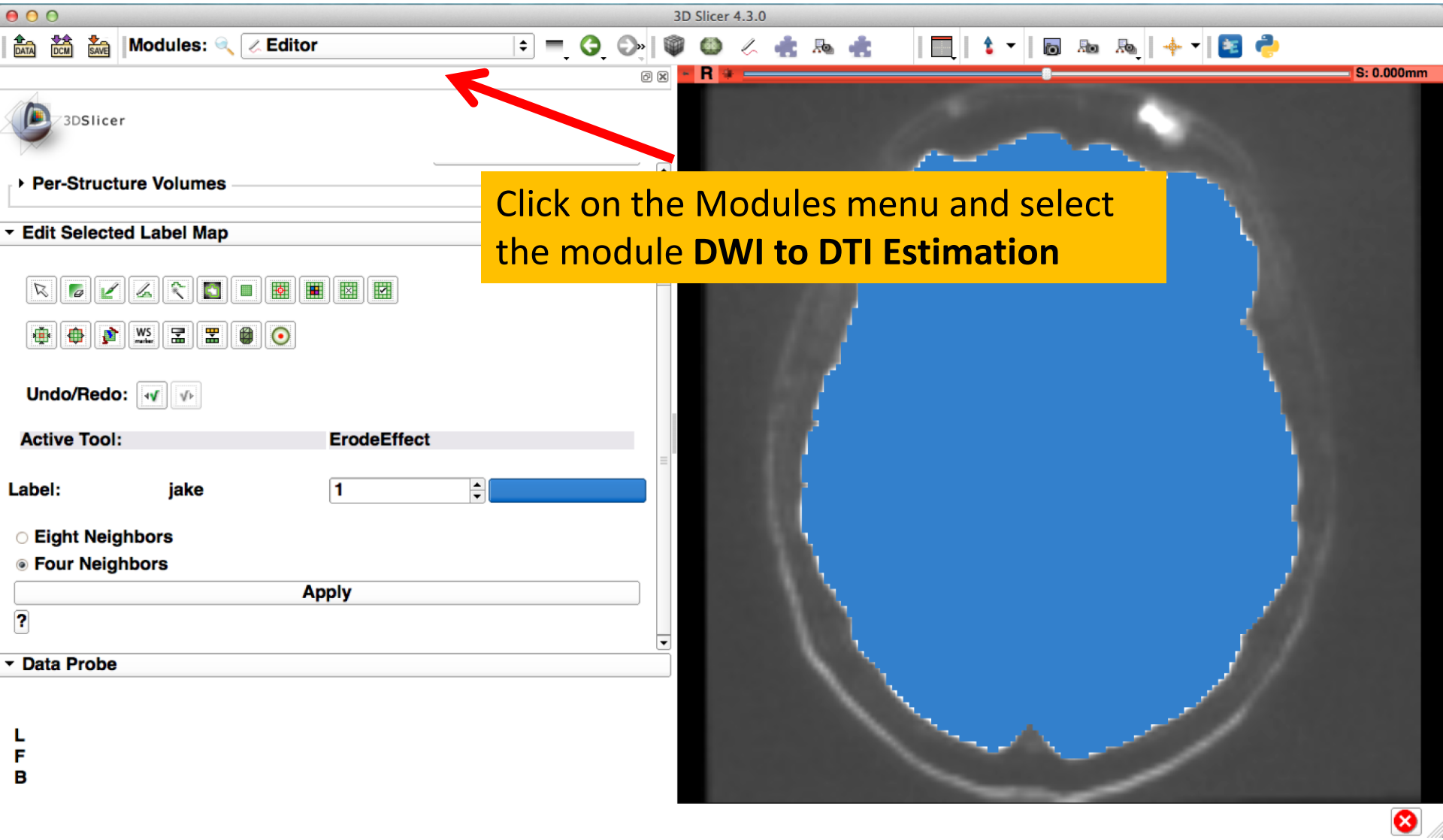
拡散テンソル画像データの計算

From DWI to DTI

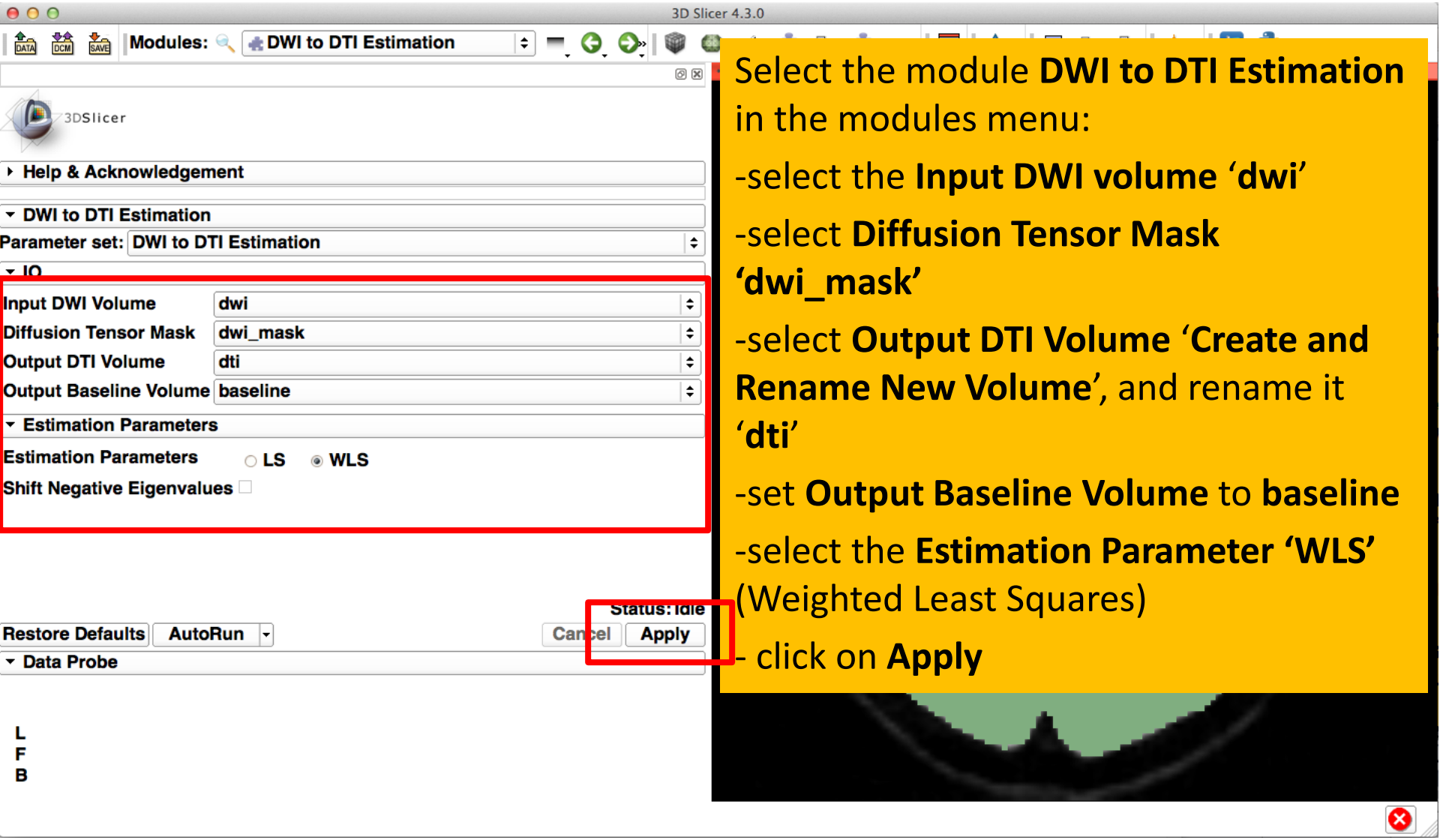




From DWI to DTI



From DWI to DTI



Select the module **DWI to DTI Estimation** in the modules menu:

-select the **Input DWI volume 'dwi'**

-select **Diffusion Tensor Mask 'dwi_mask'**

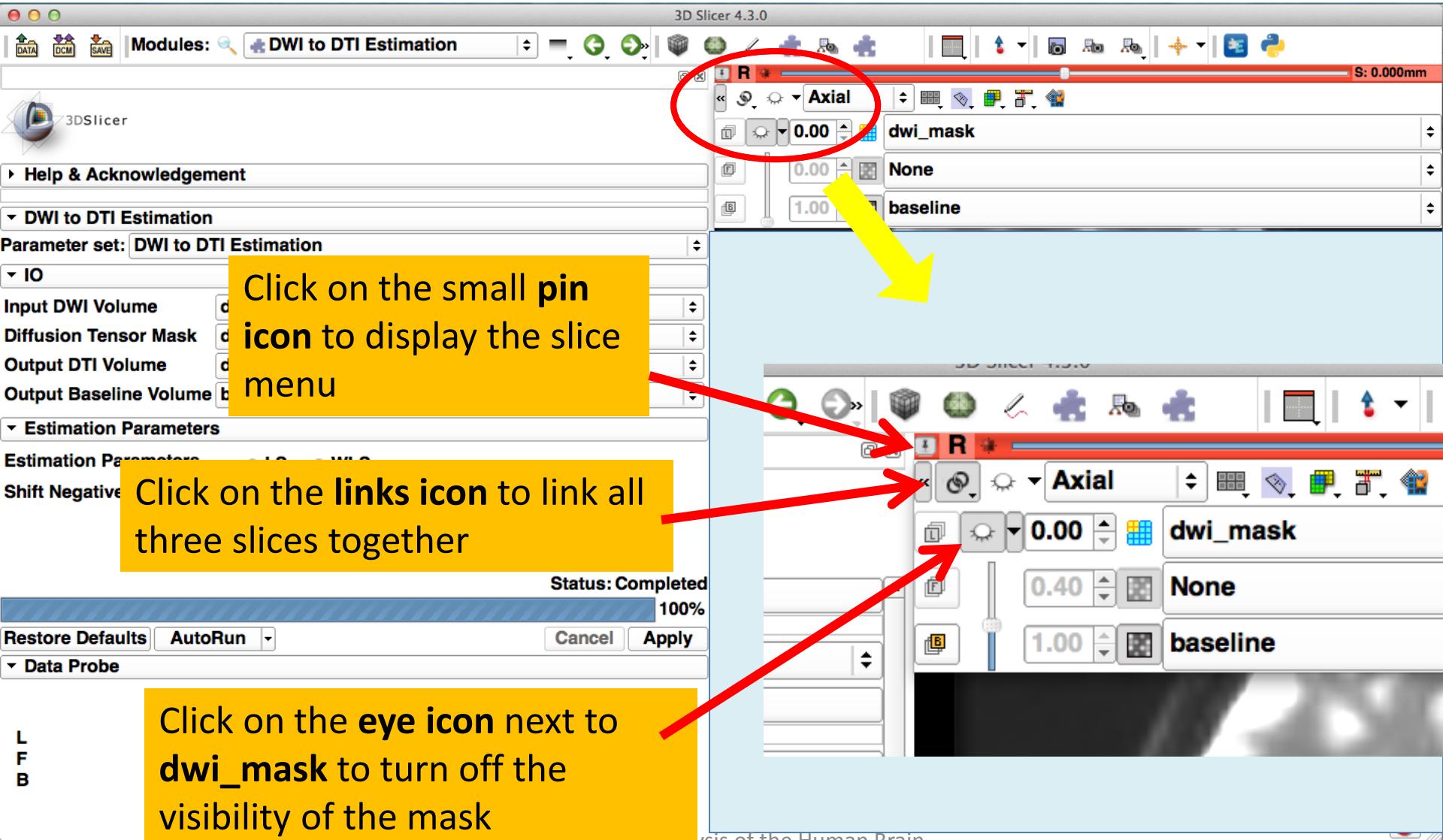
-select **Output DTI Volume 'Create and Rename New Volume'**, and rename it **'dti'**

-set **Output Baseline Volume** to **baseline**

-select the **Estimation Parameter 'WLS'** (Weighted Least Squares)

- click on **Apply**

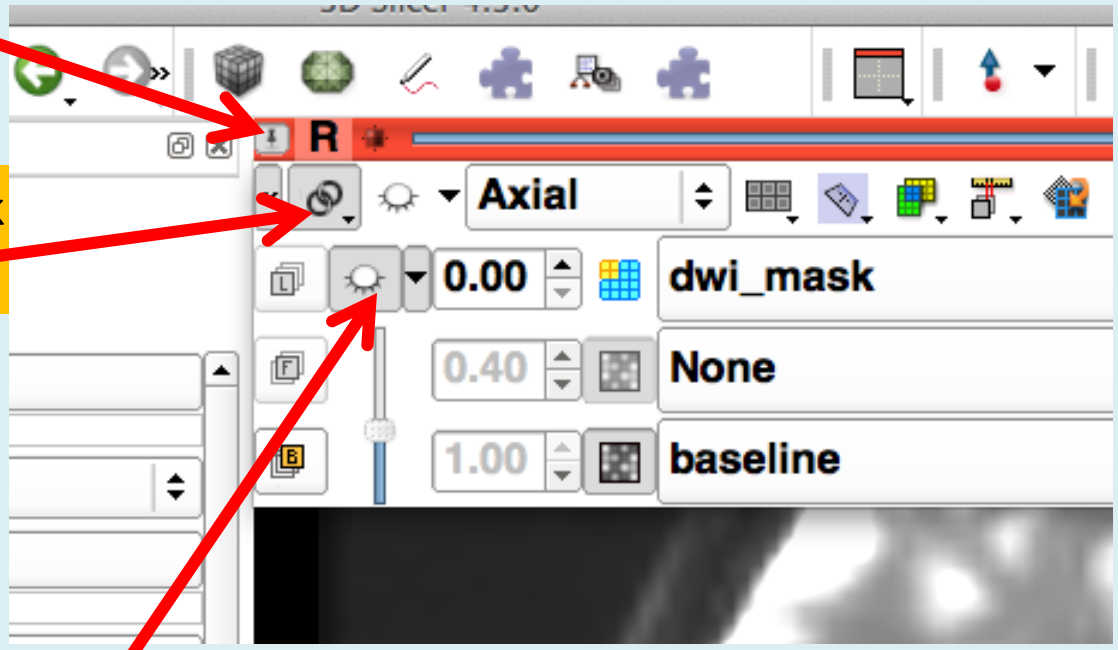
From DWI to DTI



From DWI to DTI

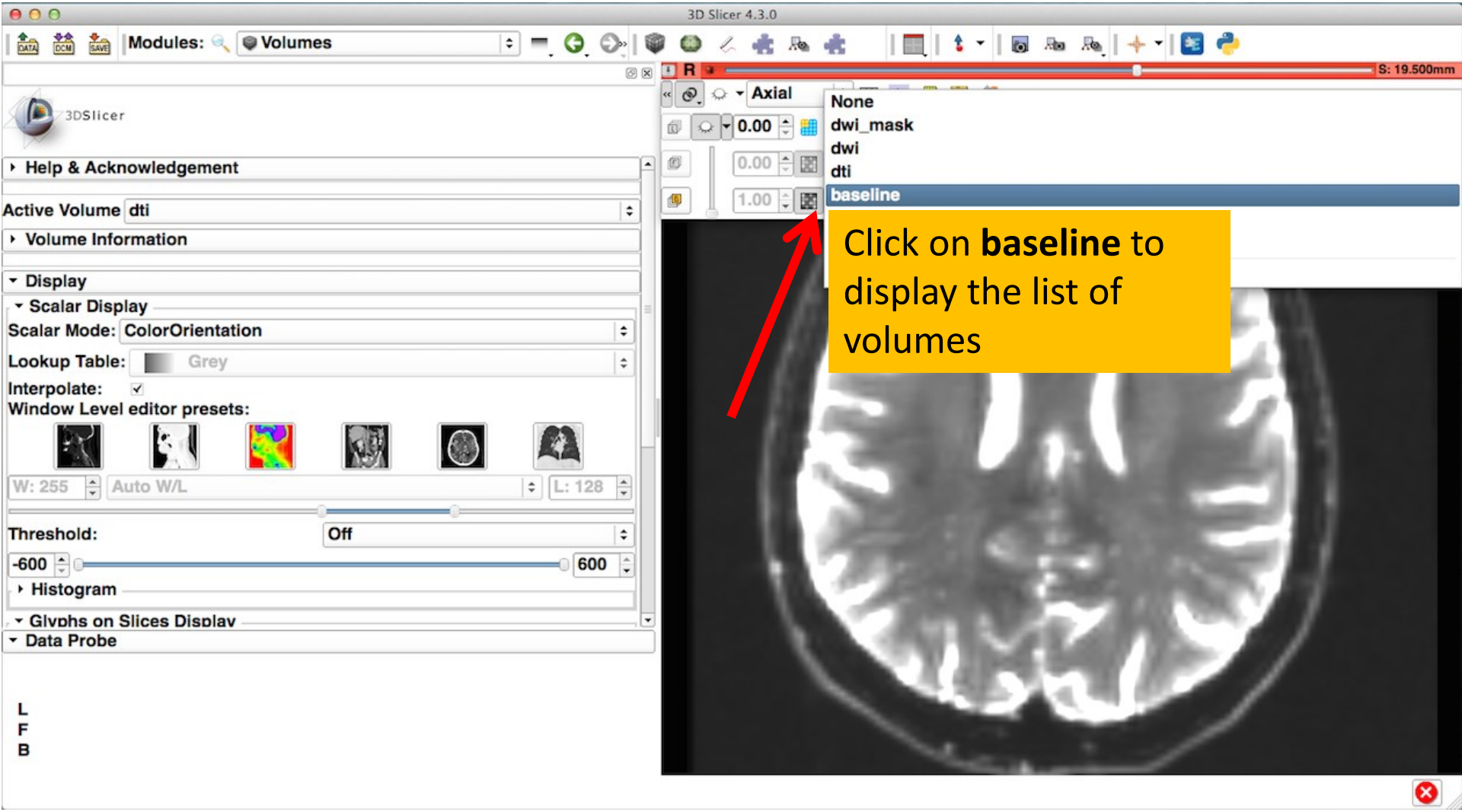
Click on the small **pin icon** to display the slice menu

Click on the **links icon** to link three slices together

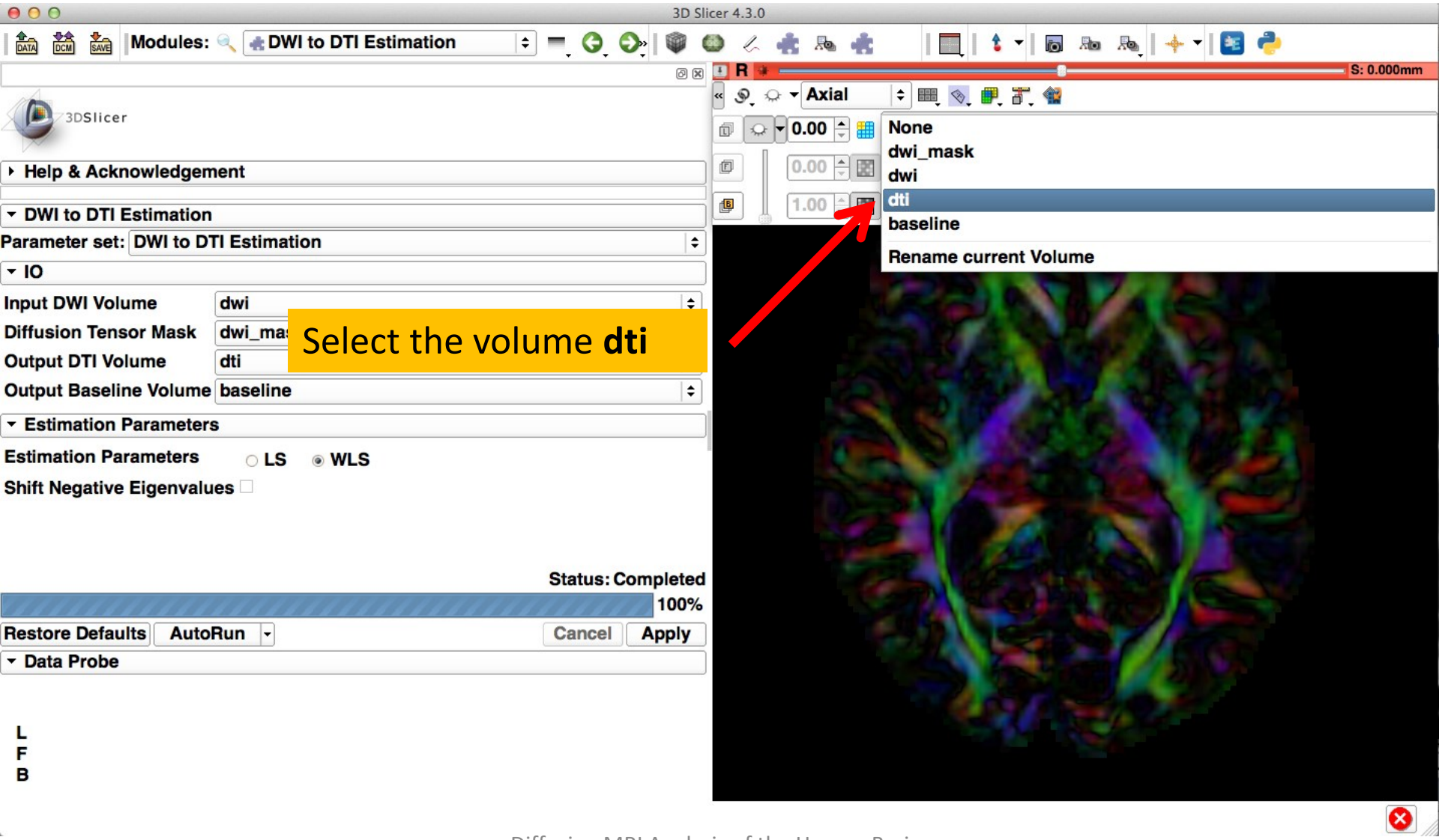


Click on the **eye icon** next to **dwi_mask** to turn off the visibility of the mask

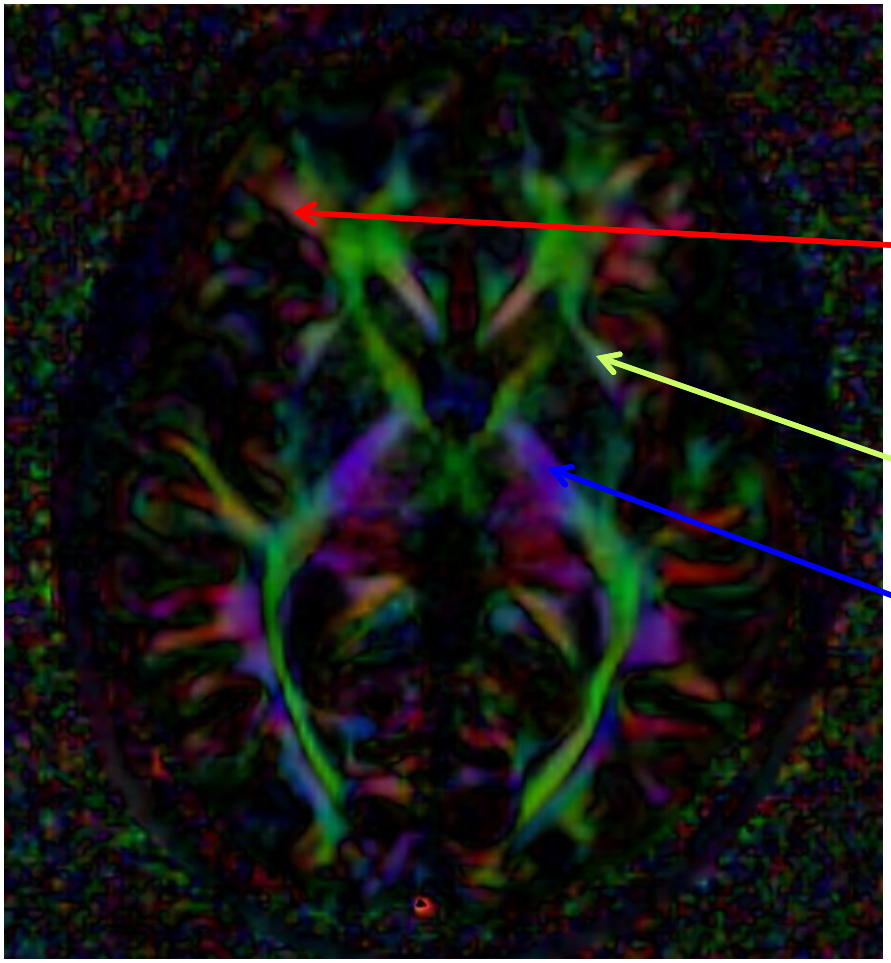
From DWI to DTI



From DWI to DTI



DTI Color Map



Color coding:

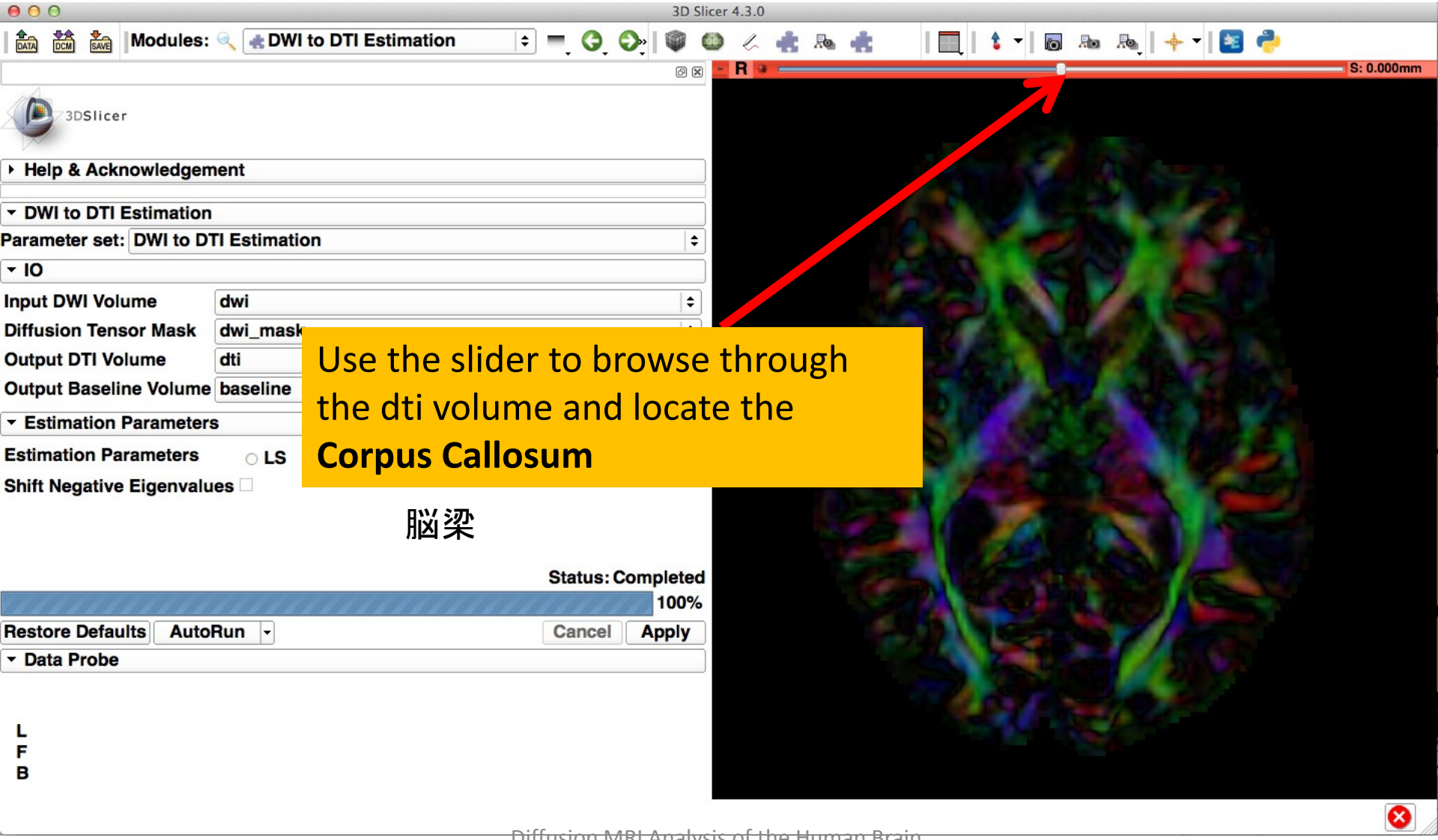
カラーコーディング
＝色付け

Red: left-right

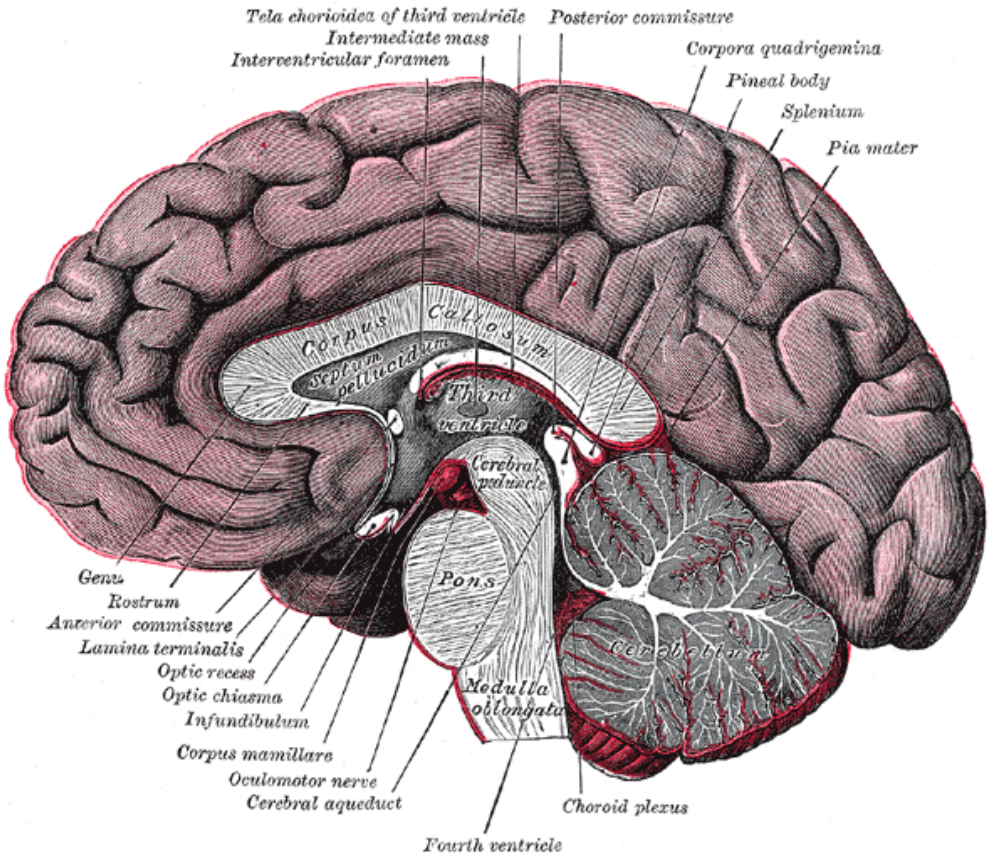
Green: anterior-posterior

Blue: inferior-superior

Exploring the DWI Dataset



Corpus Callosum

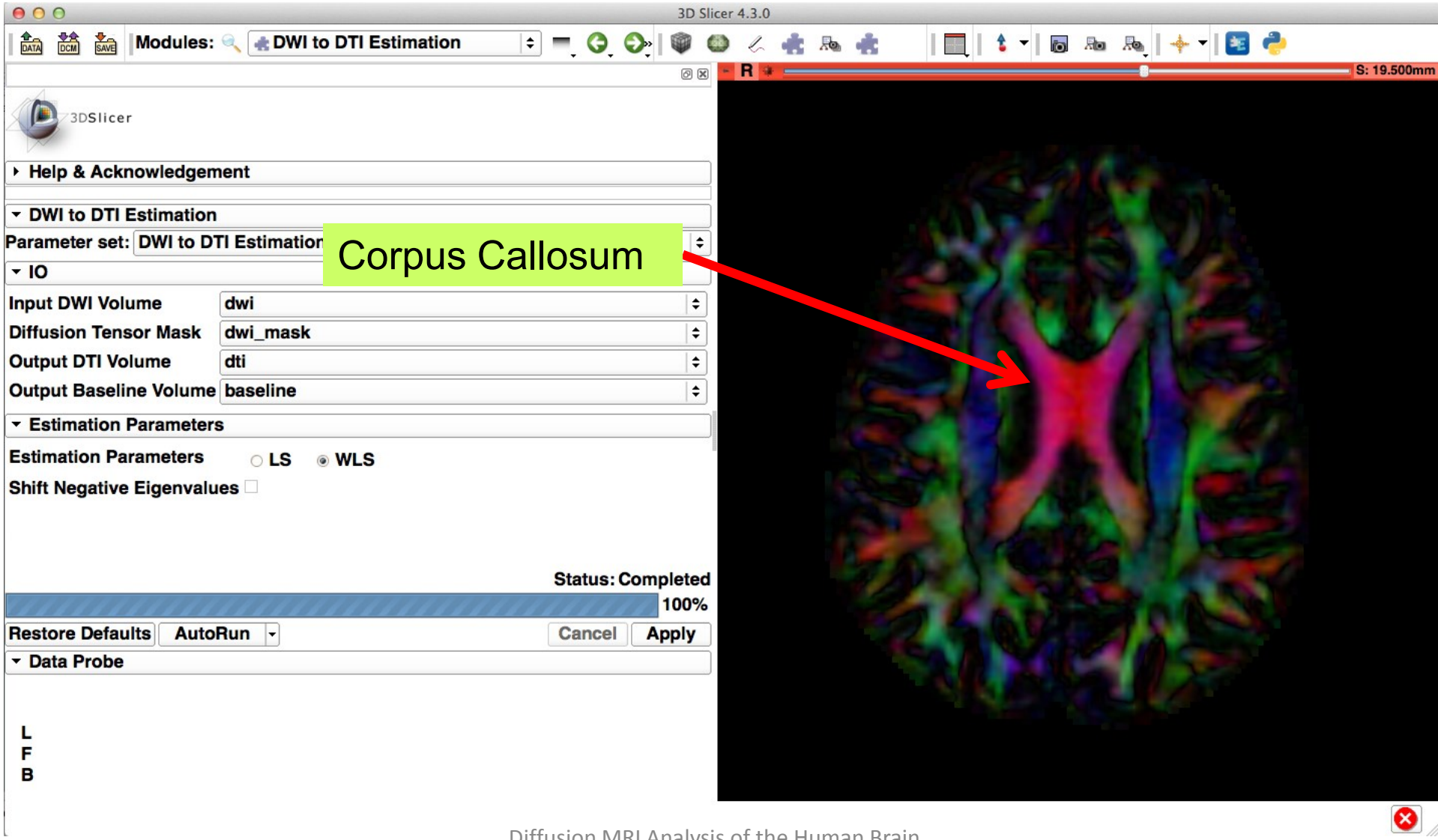


The corpus callosum is a broad thick bundle of dense myelinated fibers that connect the left and right hemisphere. It is the largest white matter structure in the brain

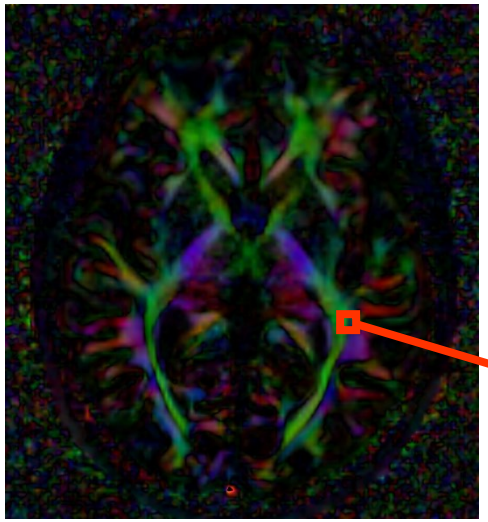
hemisphere：半球

Image from Grey's Anatomy

Corpus Callosum



Diffusion Tensor Data



$$S_i = S_0 e^{-b\hat{g}i^T \underline{D} \hat{g}_i}$$

Stejskal-Tanner equation (1965)

$$\underline{\mathbf{D}} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$

The diffusion tensor $\underline{D}$ in the voxel (I,J,K) is a 3x3 symmetric matrix.

スカラ画像＝拡散の特徴を表す画像

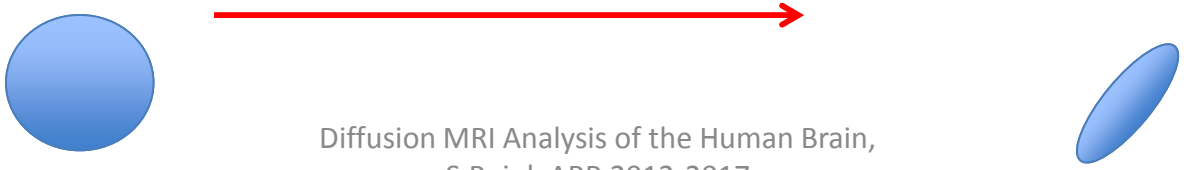
Scalar Maps: Fractional Anisotropy

Fractional Anisotropy(FA)：比率による非等方性

- FA(D) is intrinsic（固有） to the tissue and is independent（独立） of the direction of the diffusion sensitizing gradients.

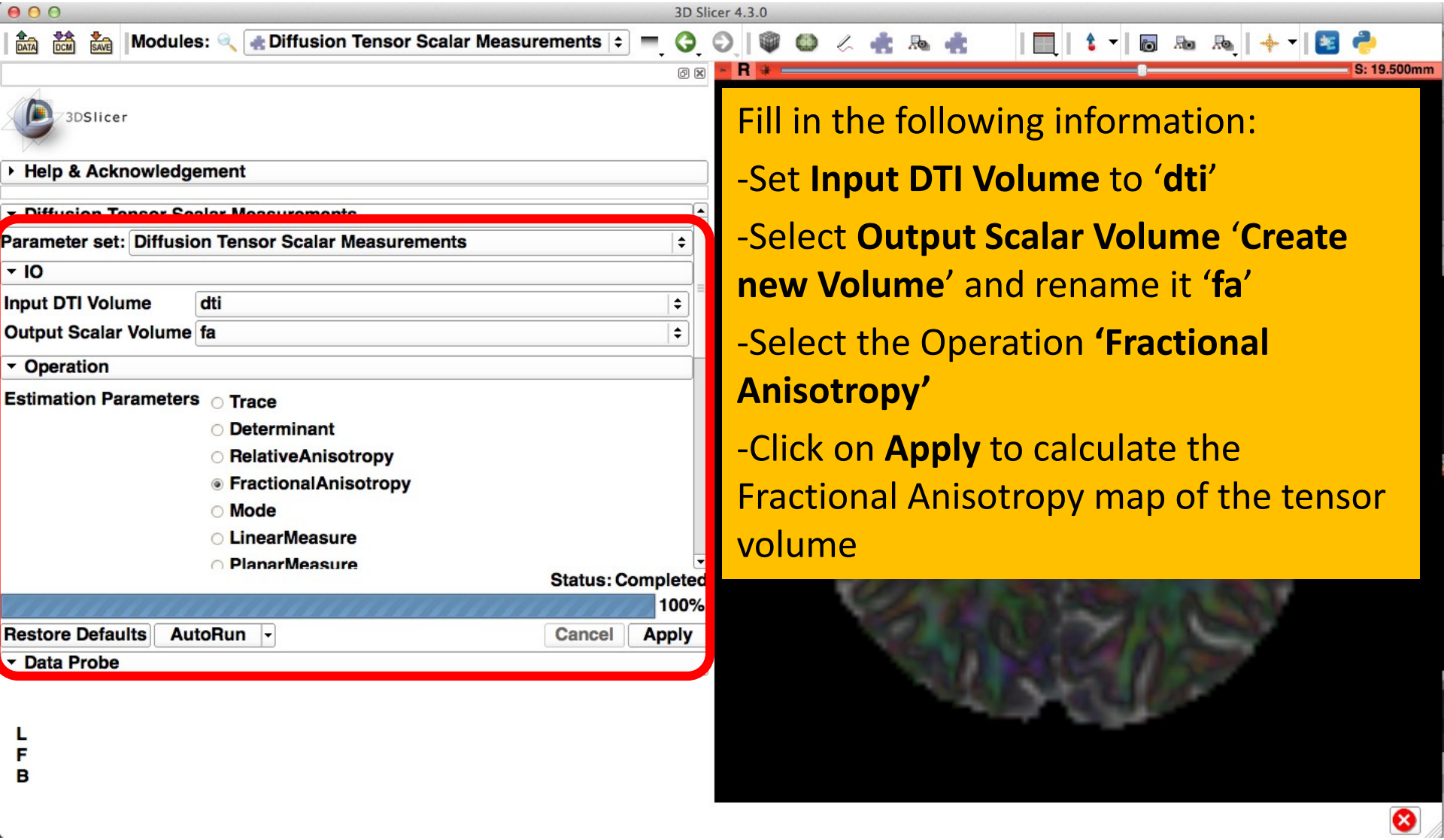
- FA(D) can be used to characterize（特徴づける） the shape (degree of ‘out-of-roundness’) of the diffusion ellipsoid

- Low FA: High FA:



Diffusion MRI Analysis of the Human Brain, S.Pujol, ARR 2012-2017

Fractional Anisotropy



Fill in the following information:

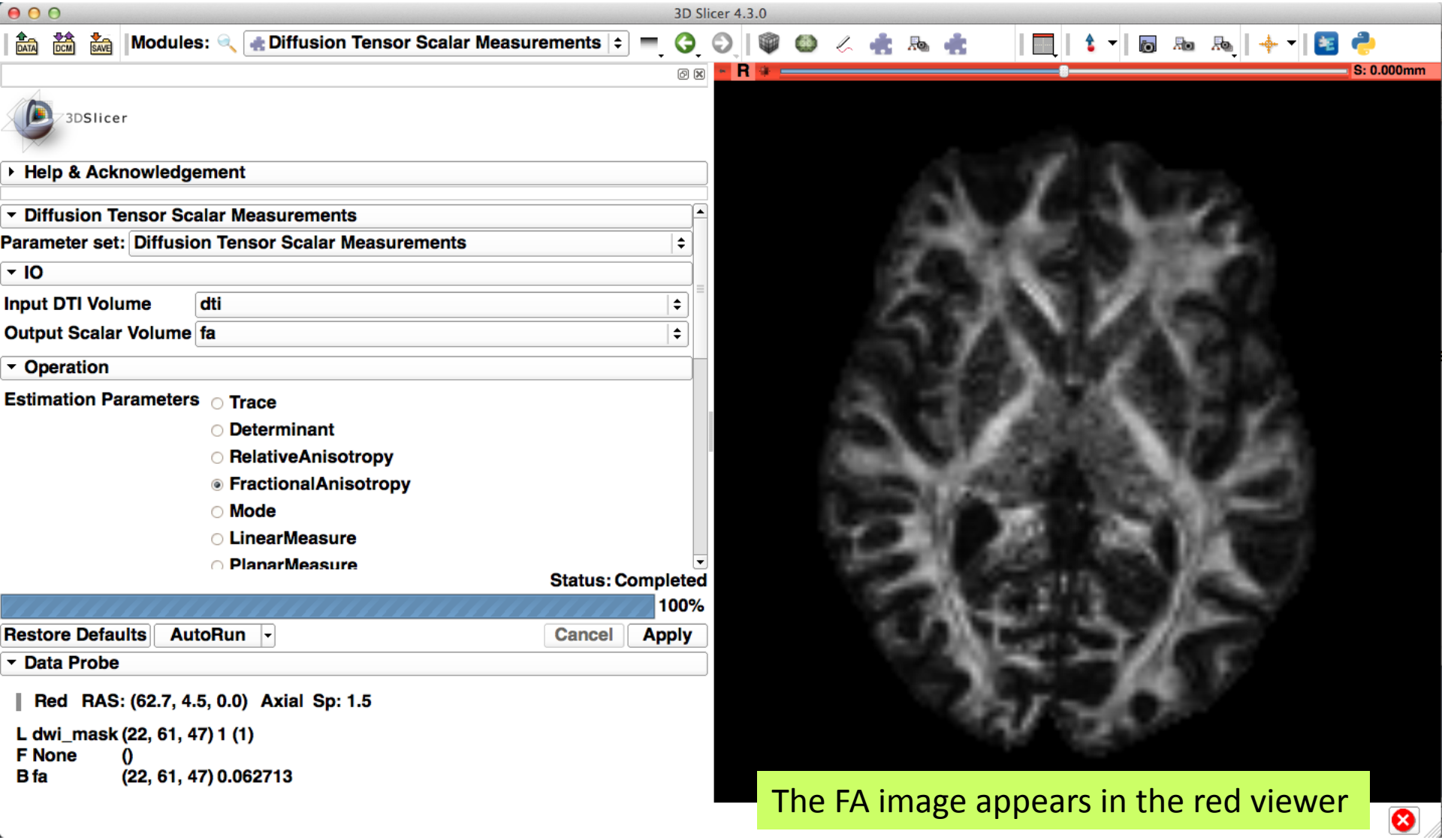
-Set **Input DTI Volume** to '**dti**'

-Select **Output Scalar Volume** '**Create new Volume**' and rename it '**fa**'

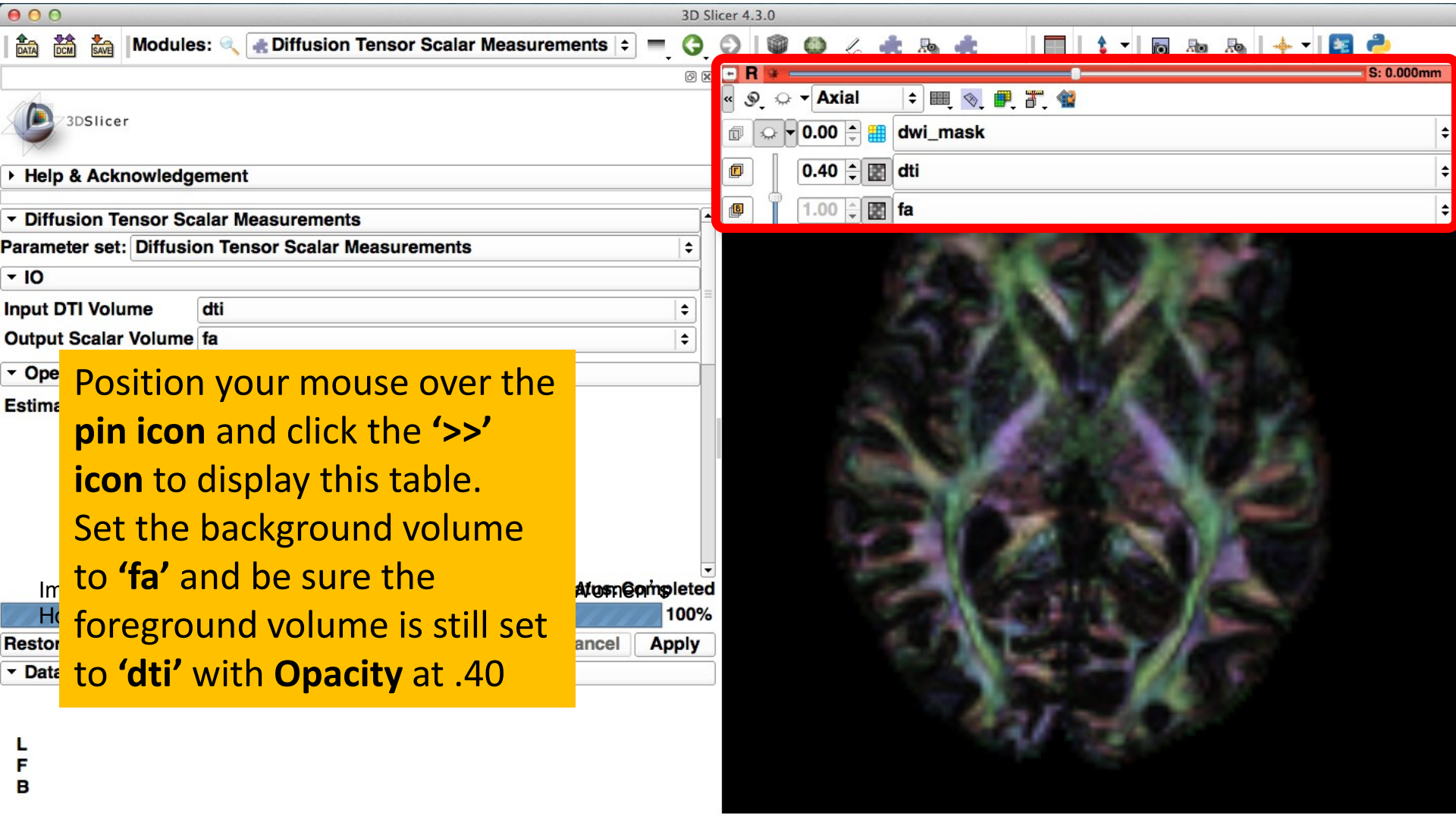
-Select the Operation **'Fractional Anisotropy'**

-Click on **Apply** to calculate the Fractional Anisotropy map of the tensor volume

Fractional Anisotropy

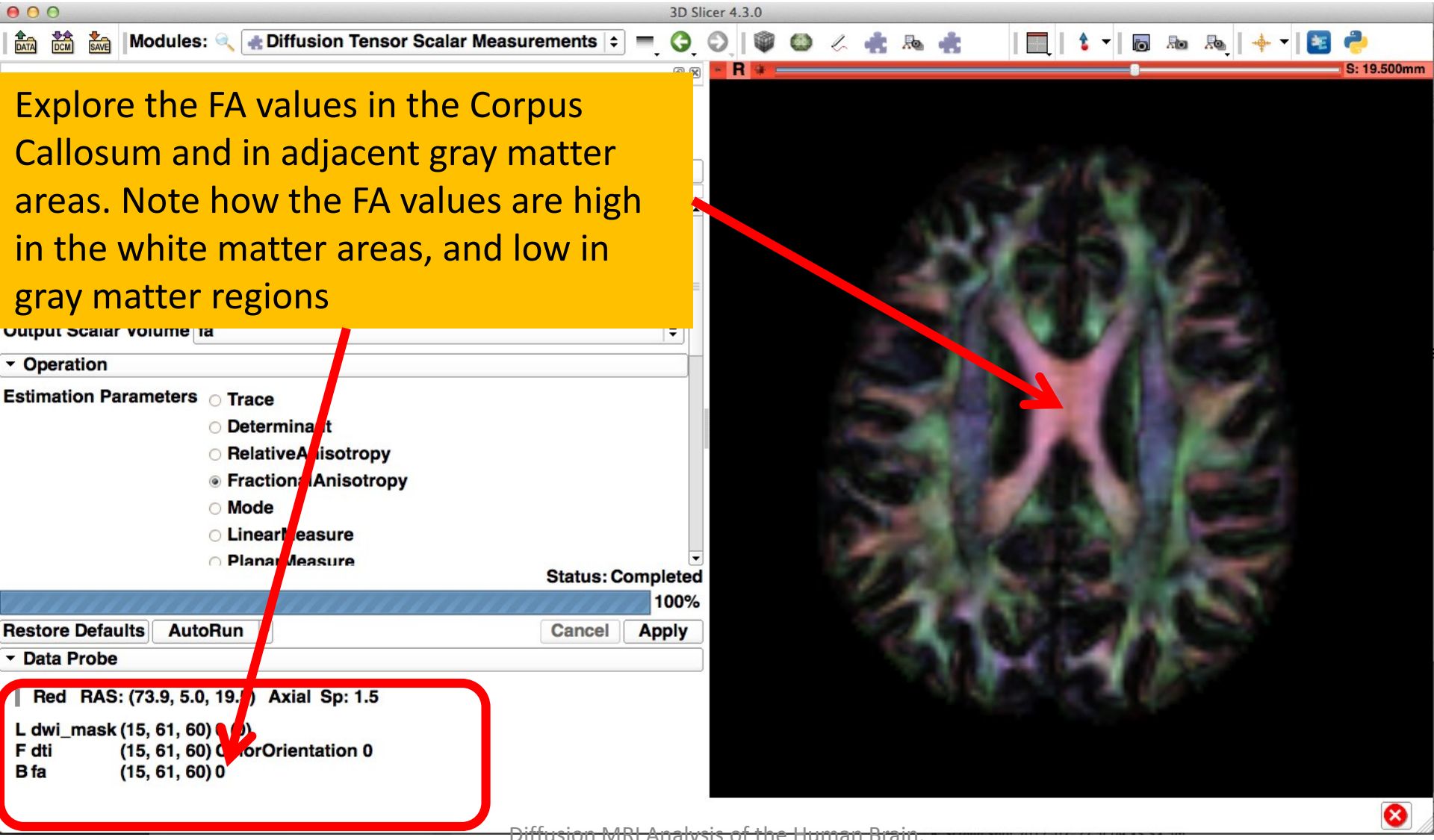


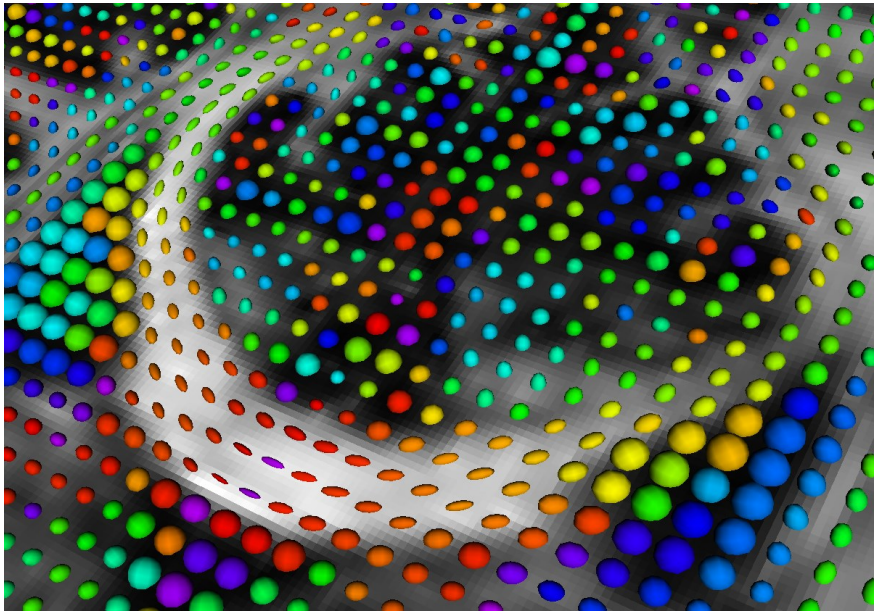
Fractional Anisotropy



Position your mouse over the **pin icon** and click the **'>>' icon** to display this table. Set the background volume to **'fa'** and be sure the foreground volume is still set to **'dti'** with **Opacity** at .40

Fractional Anisotropy



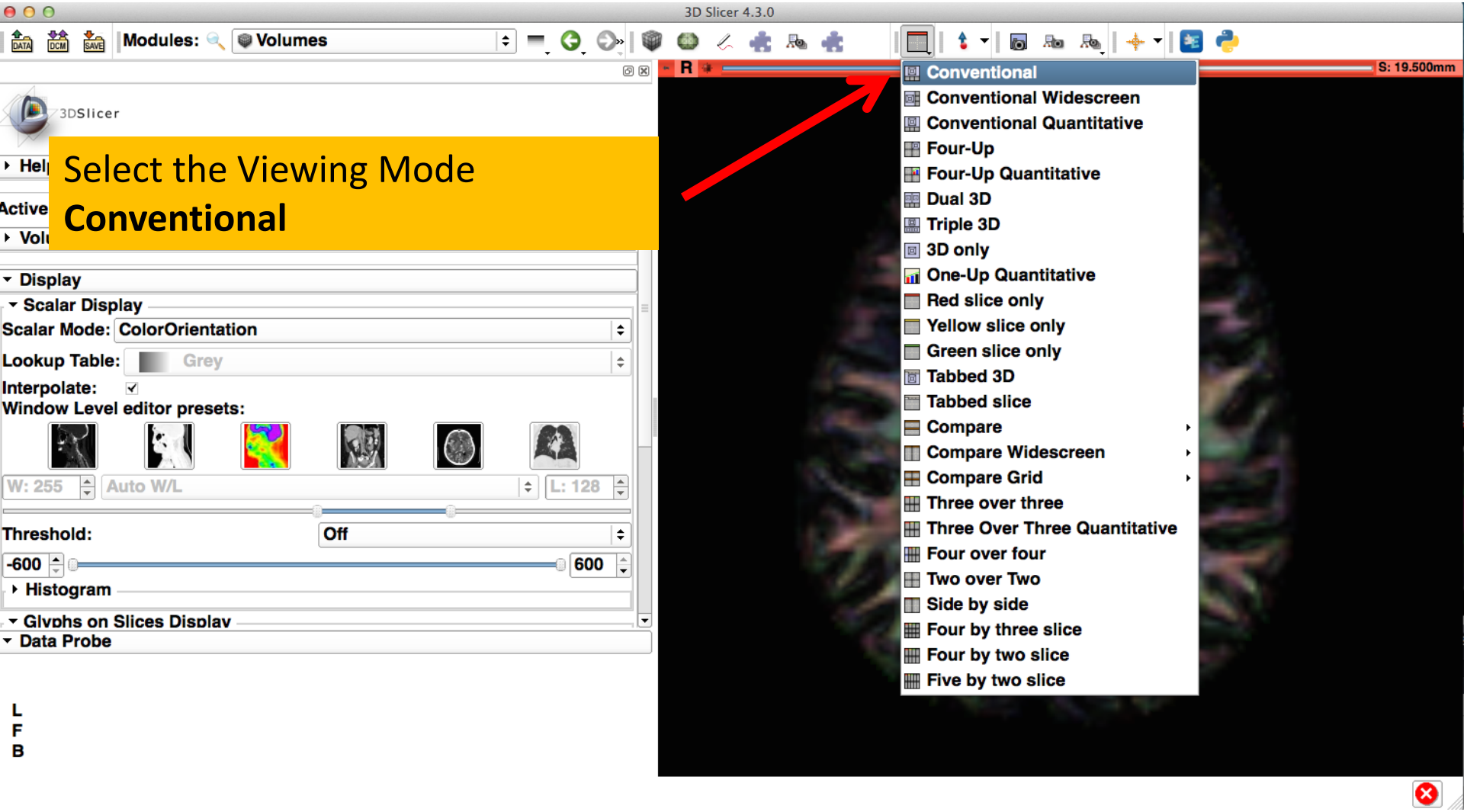


Step 3: Visualizing the diffusion tensor data

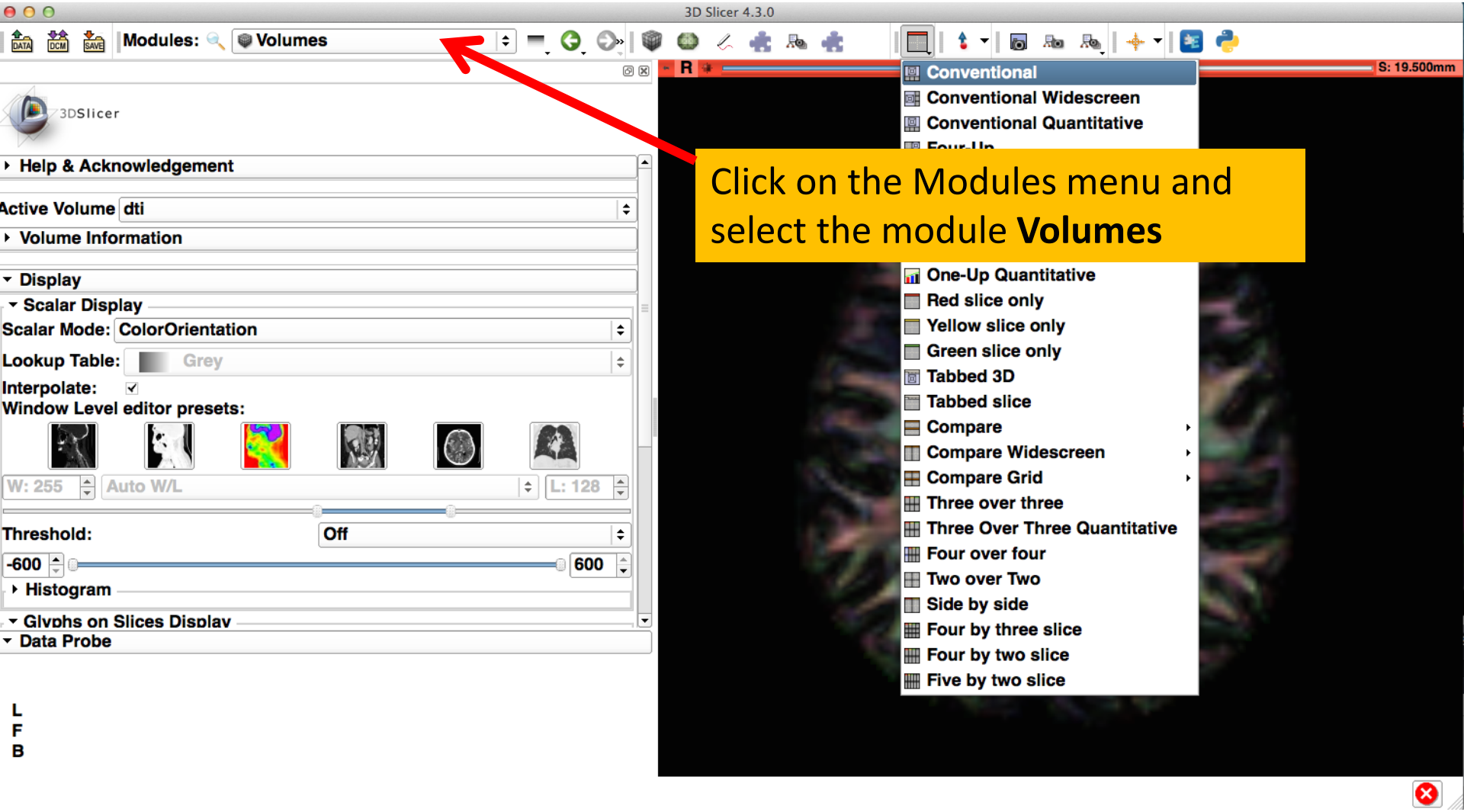
拡散テンソルデータの可視化

グリフ：表示用オブジェクト（楕円体など）

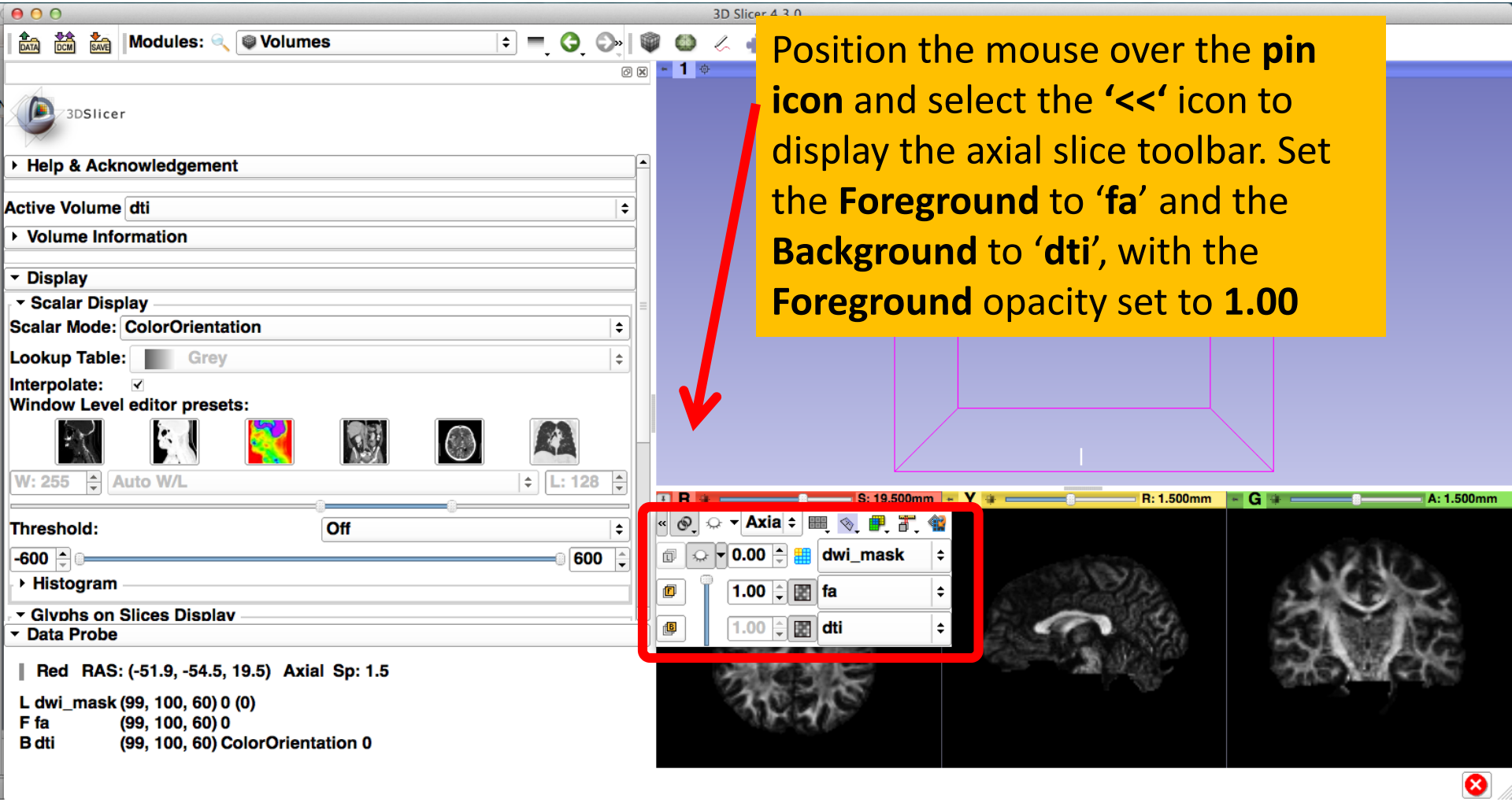
3D Visualization: Glyphs



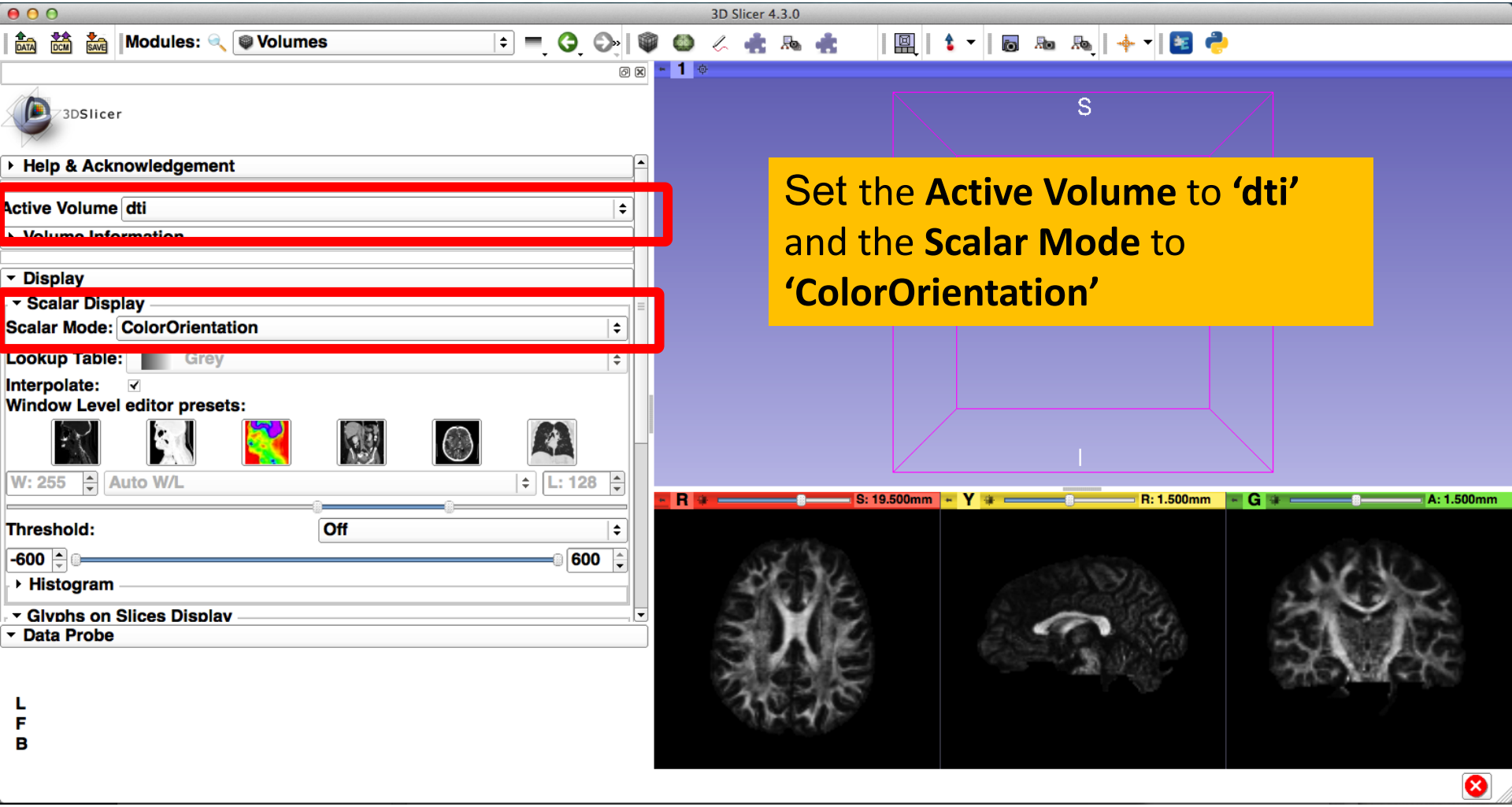
3D Visualization: Glyphs



3D Visualization: Glyphs

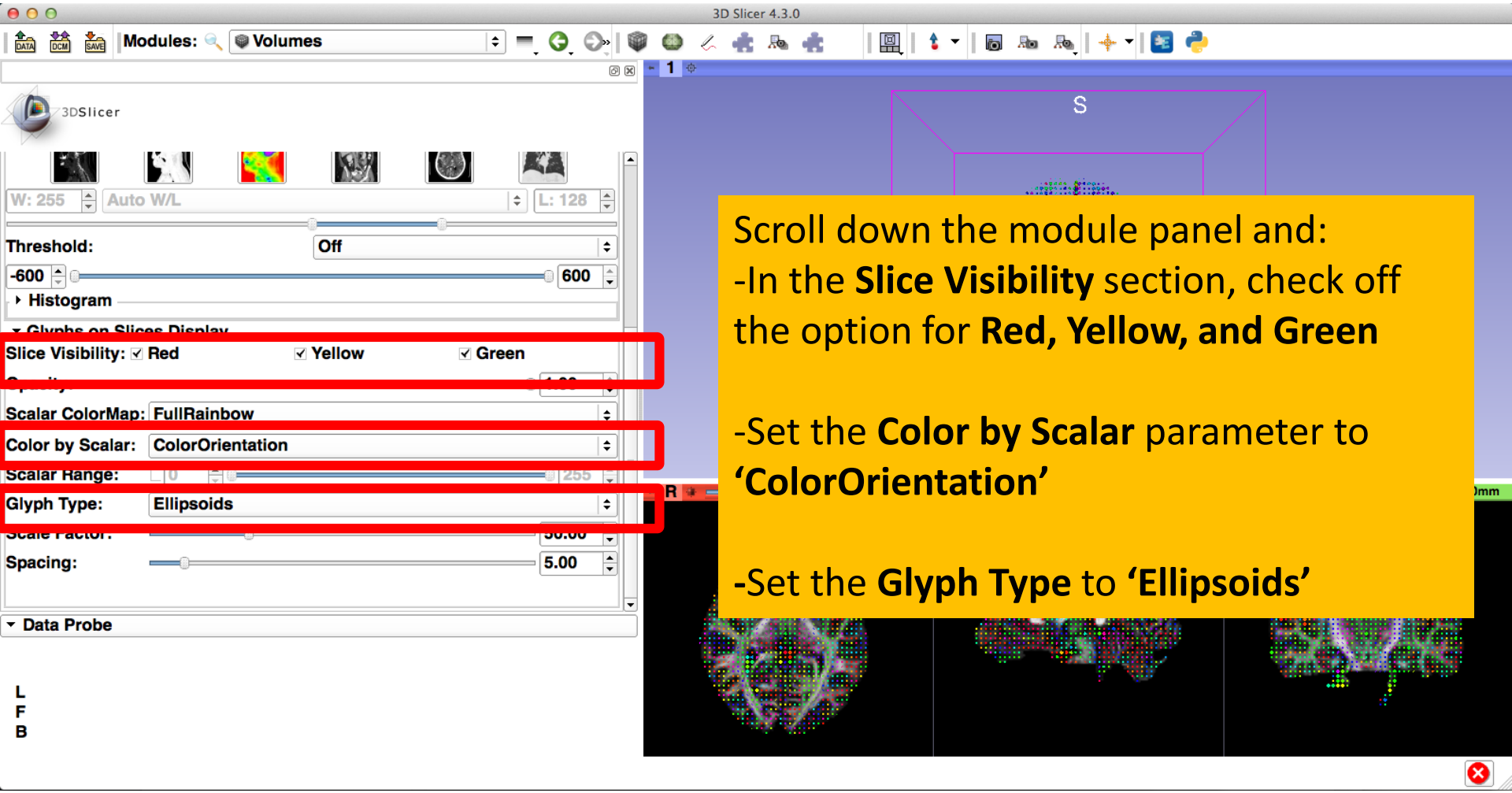


3D Visualization: Glyphs



3D Visualization: Glyphs

Scroll down：スクロールバーで画面を下に移動

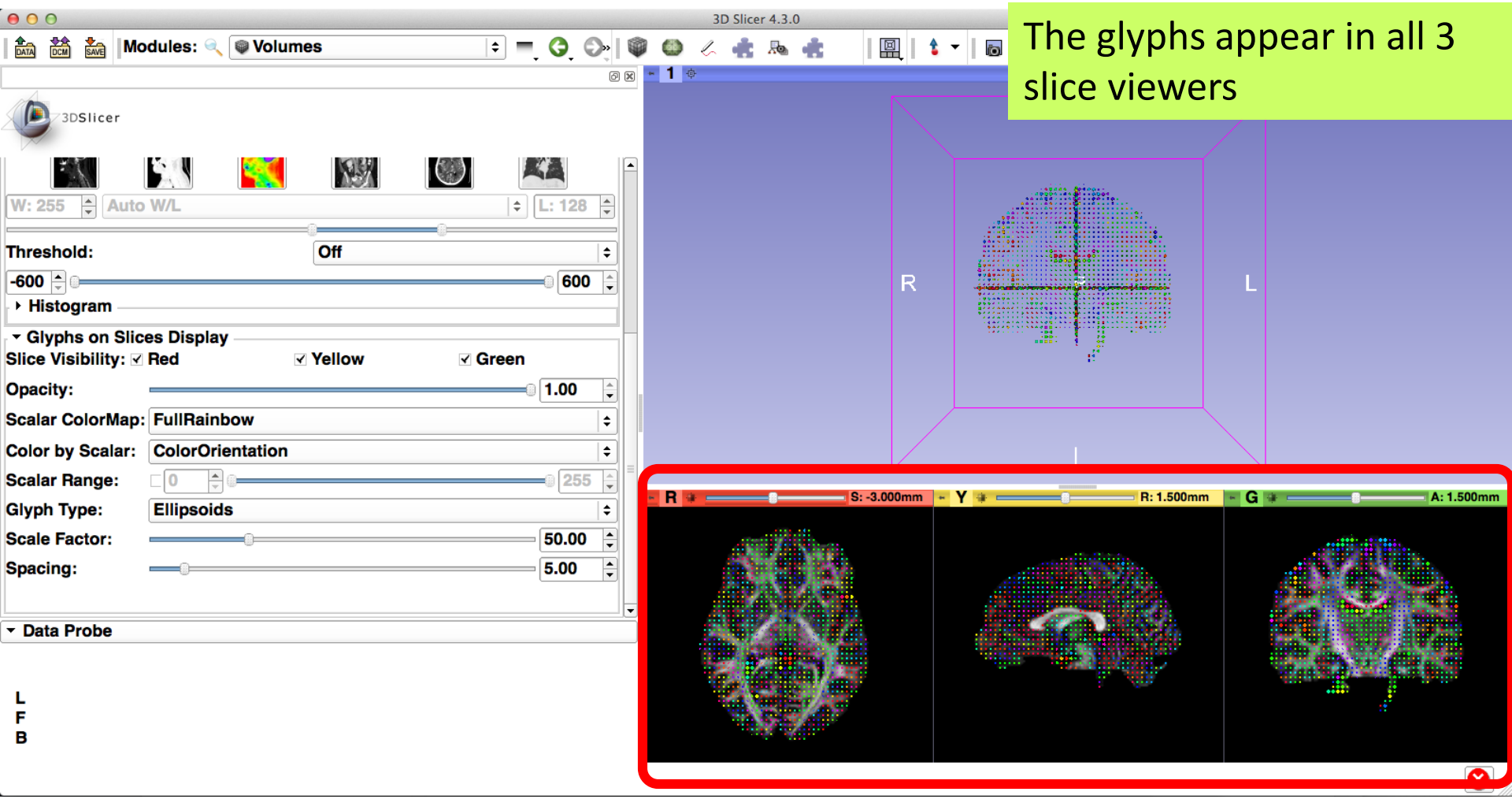


Scroll down the module panel and:
-In the **Slice Visibility** section, check off the option for **Red, Yellow, and Green**

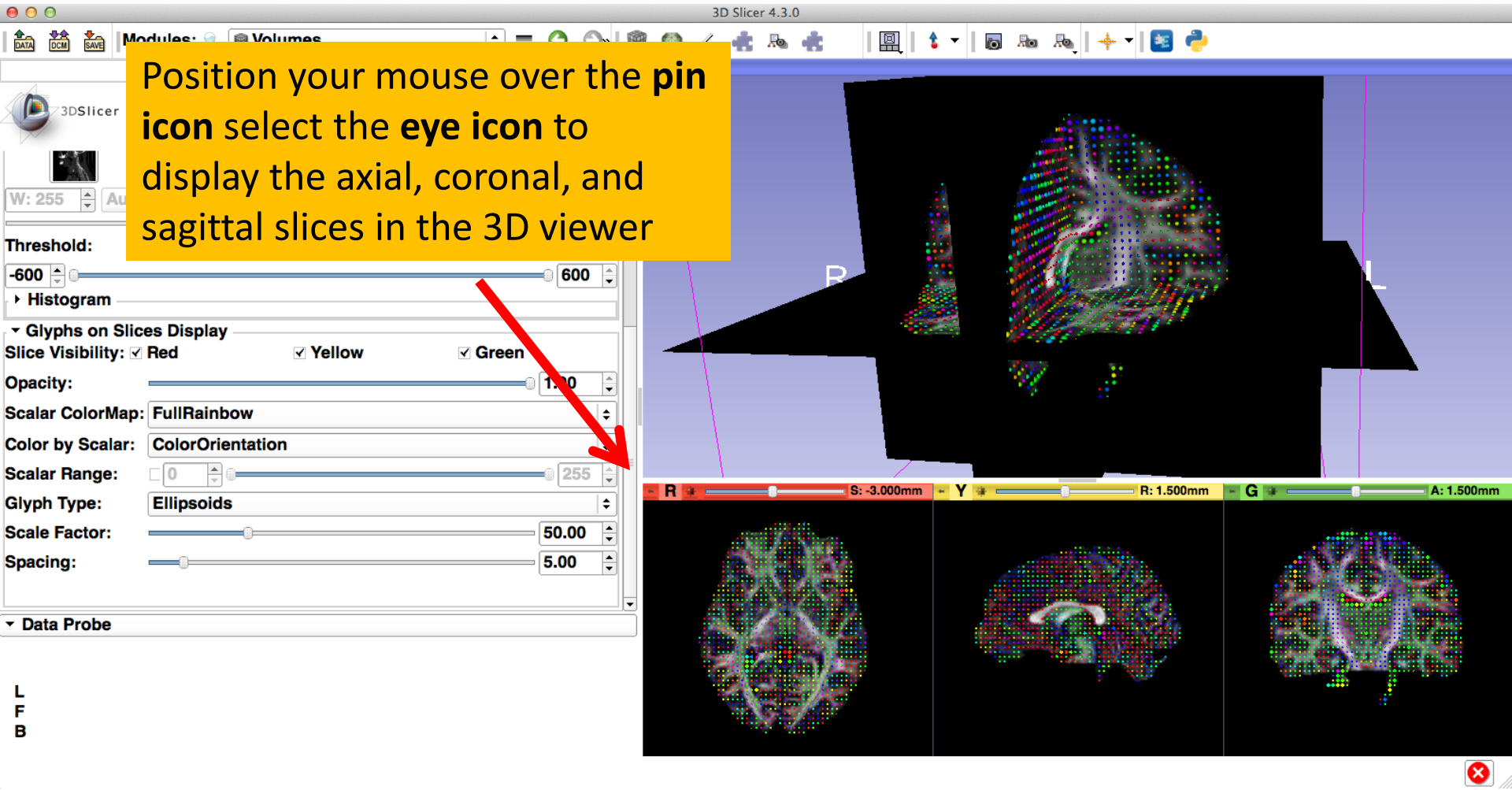
-Set the **Color by Scalar** parameter to **'ColorOrientation'**

-Set the **Glyph Type** to **'Ellipsoids'**

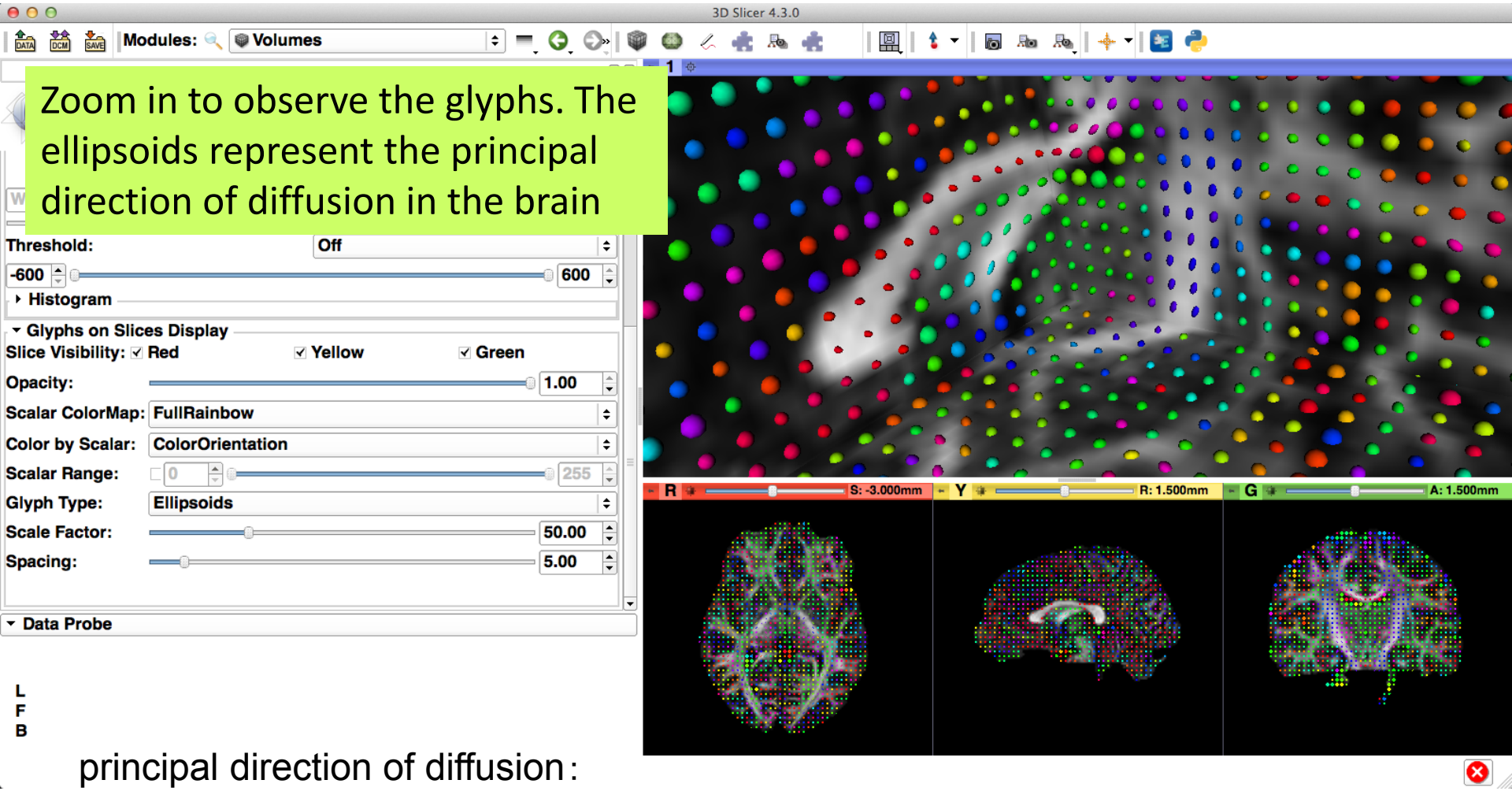
3D Visualization: Glyphs



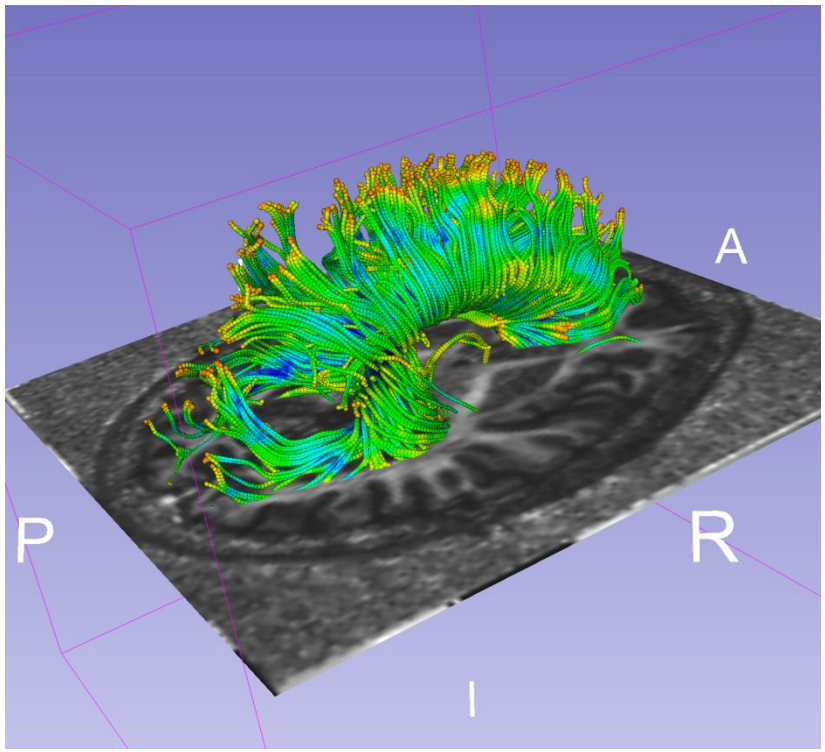
3D Visualization: Glyphs



3D Visualization: Glyphs



principal direction of diffusion:
拡散の手方向

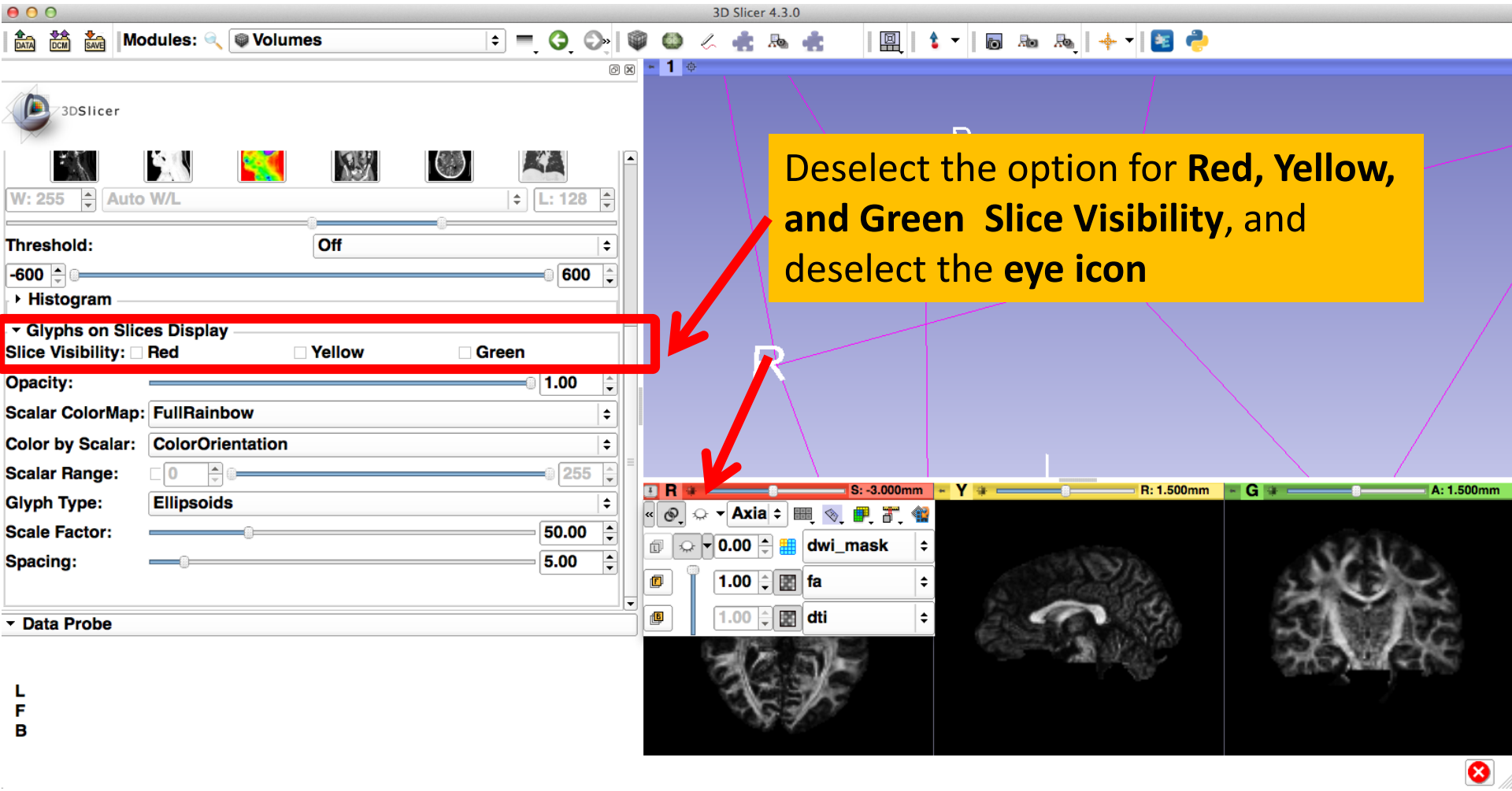


Step 4: Generating fiber tracts

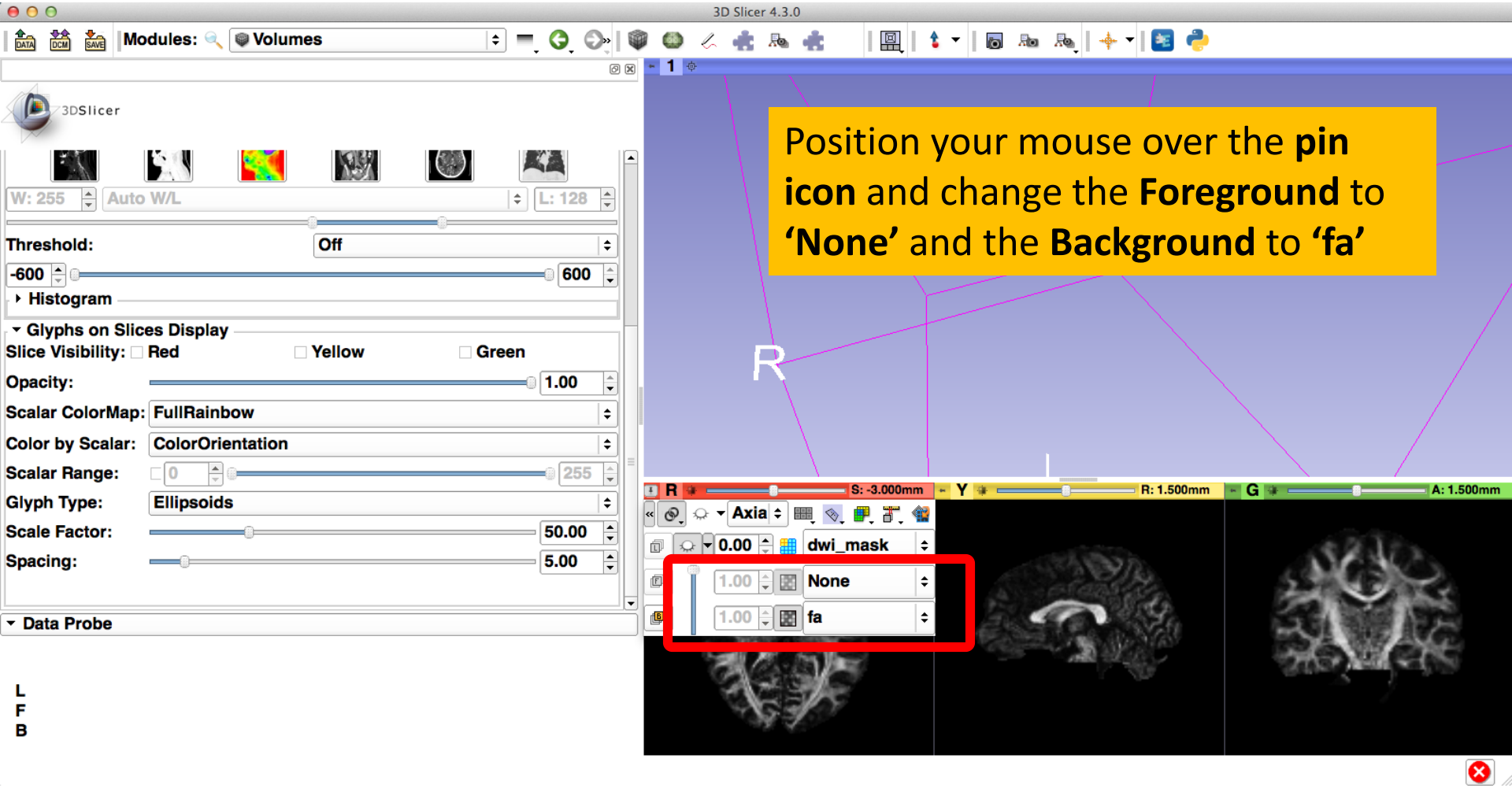
線維束の生成

Diffusion MRI tractography

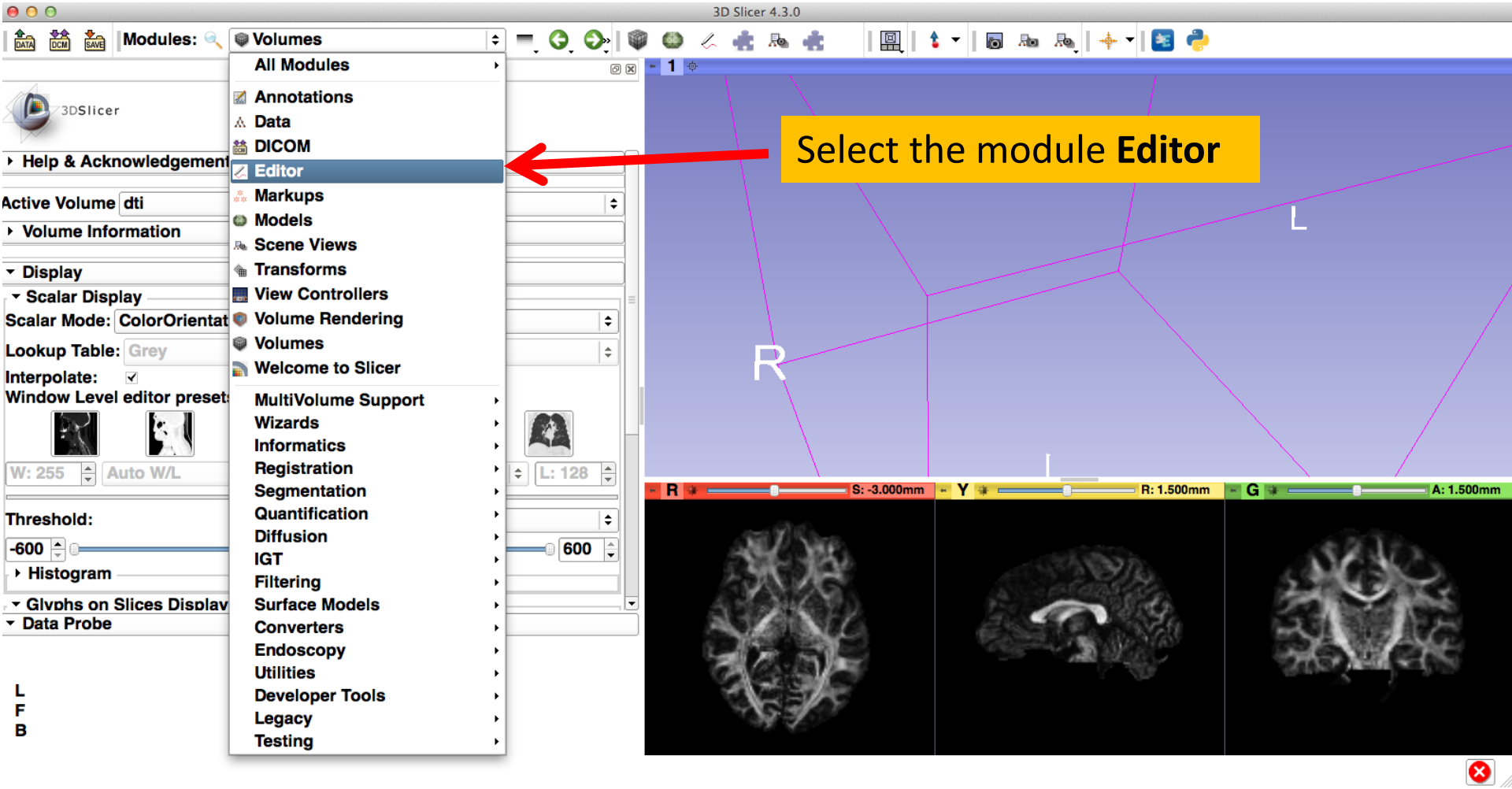
deselect：選択を外す



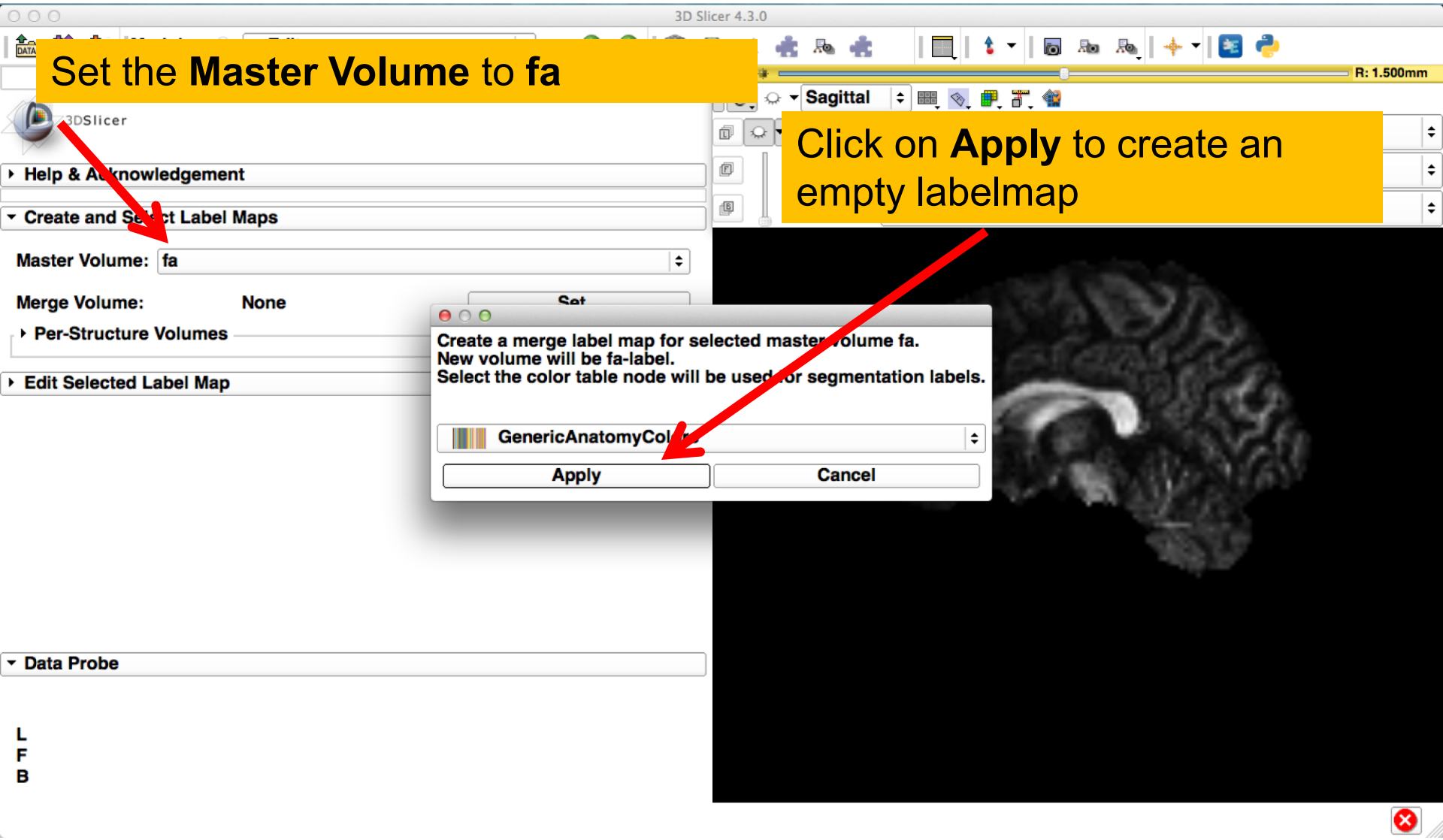
Diffusion MRI tractography



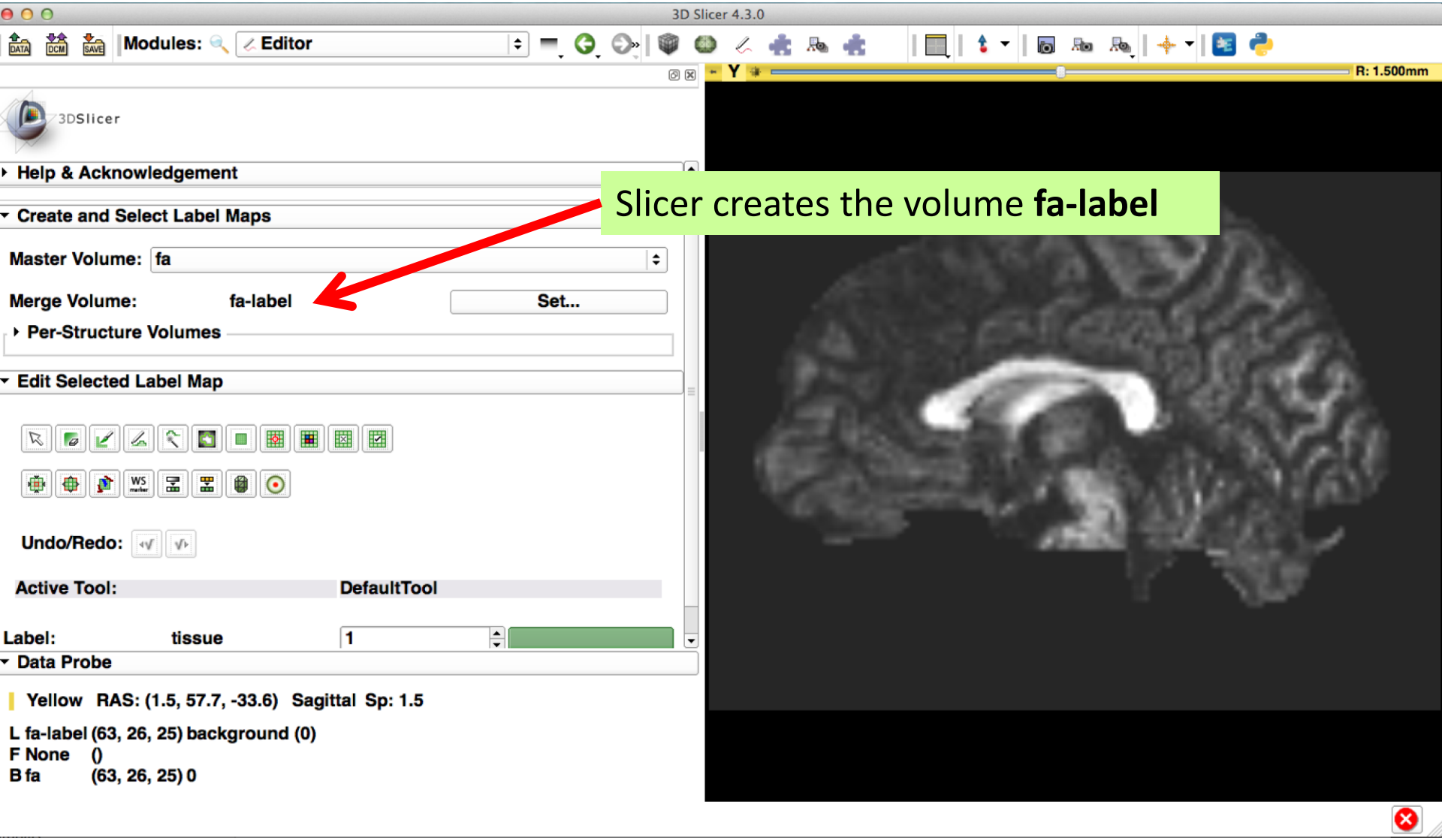
Diffusion MRI tractography



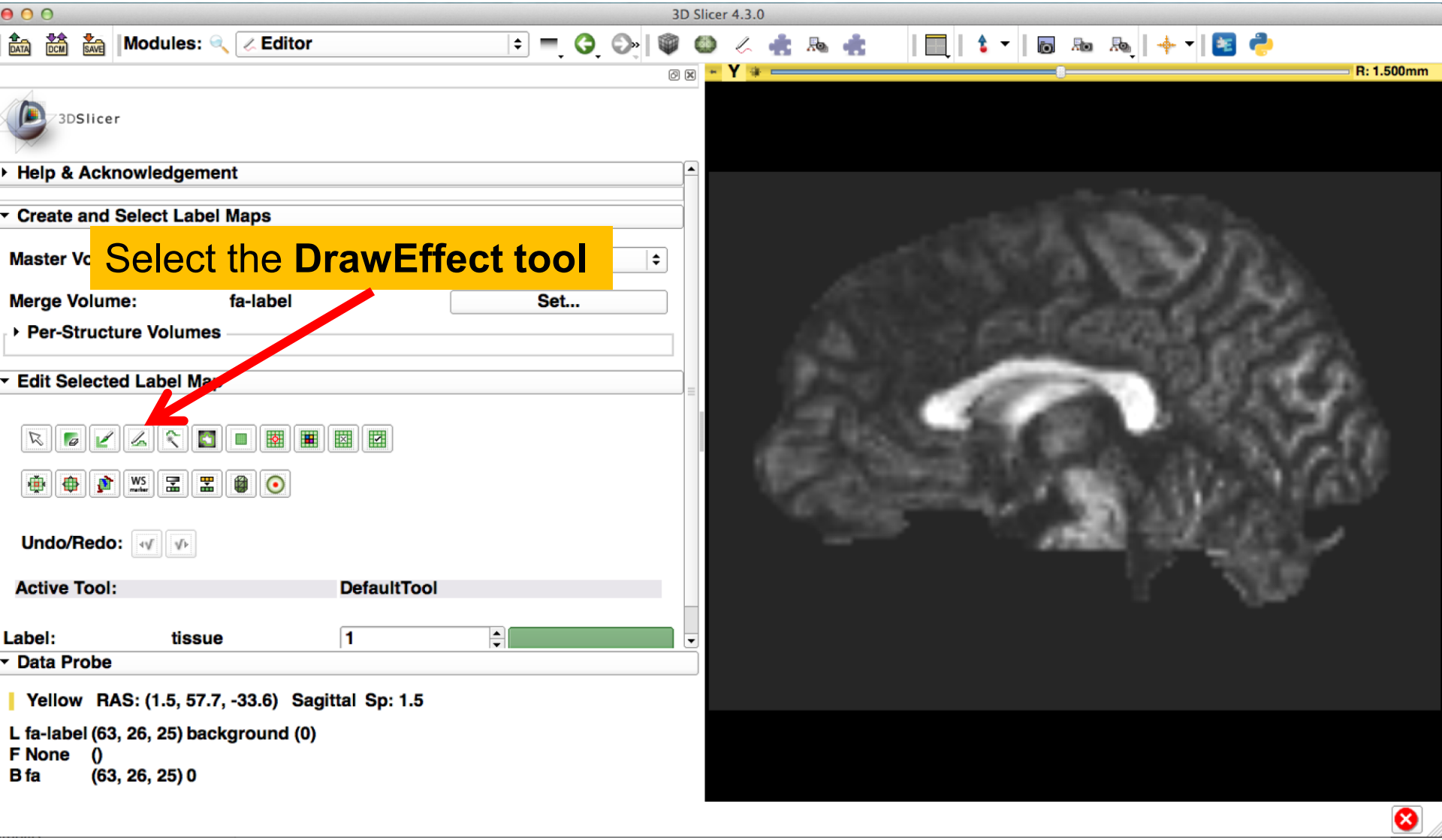
Diffusion MRI tractography



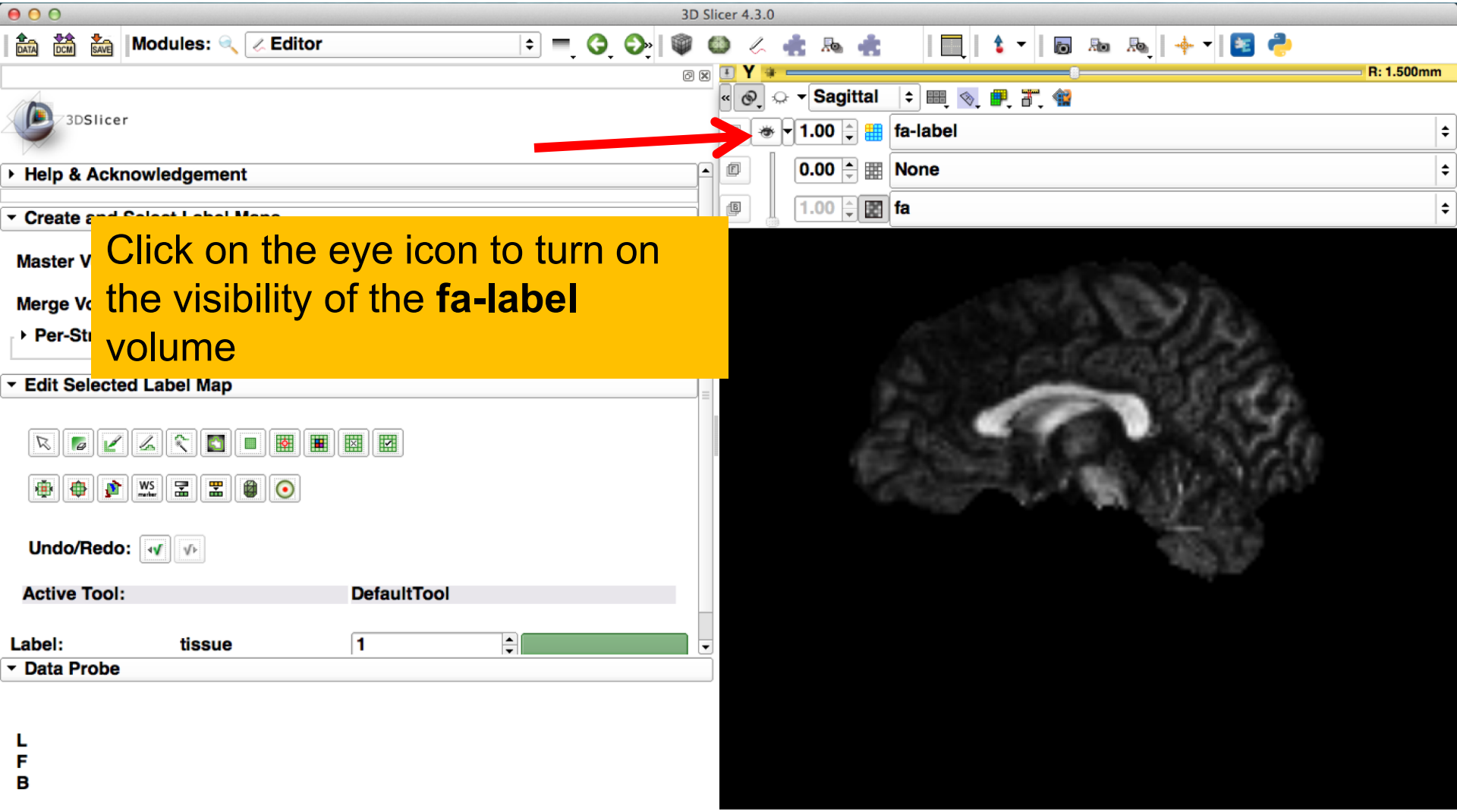
Diffusion MRI tractography



Diffusion MRI tractography

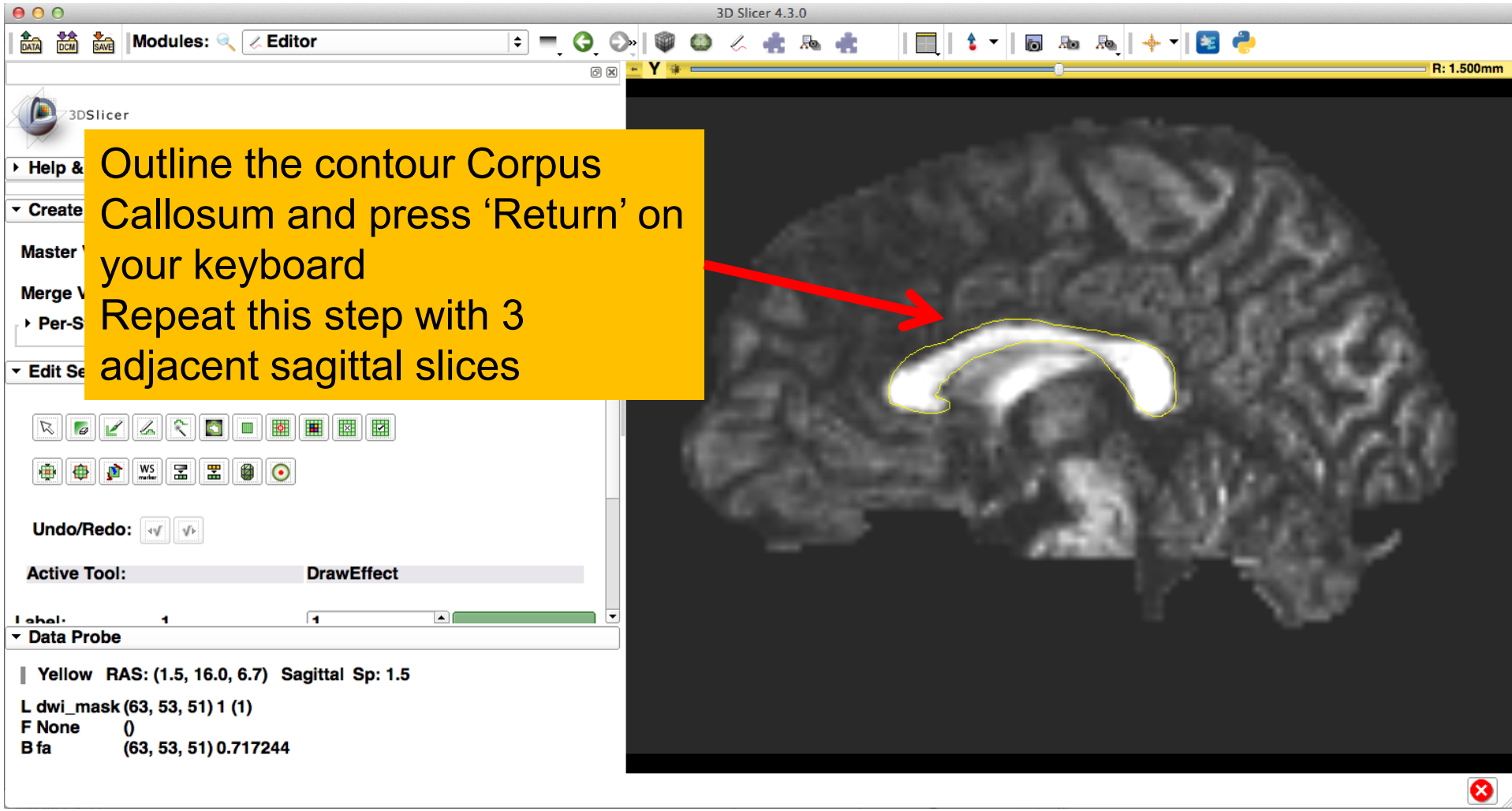


Diffusion MRI tractography



Diffusion MRI tractography

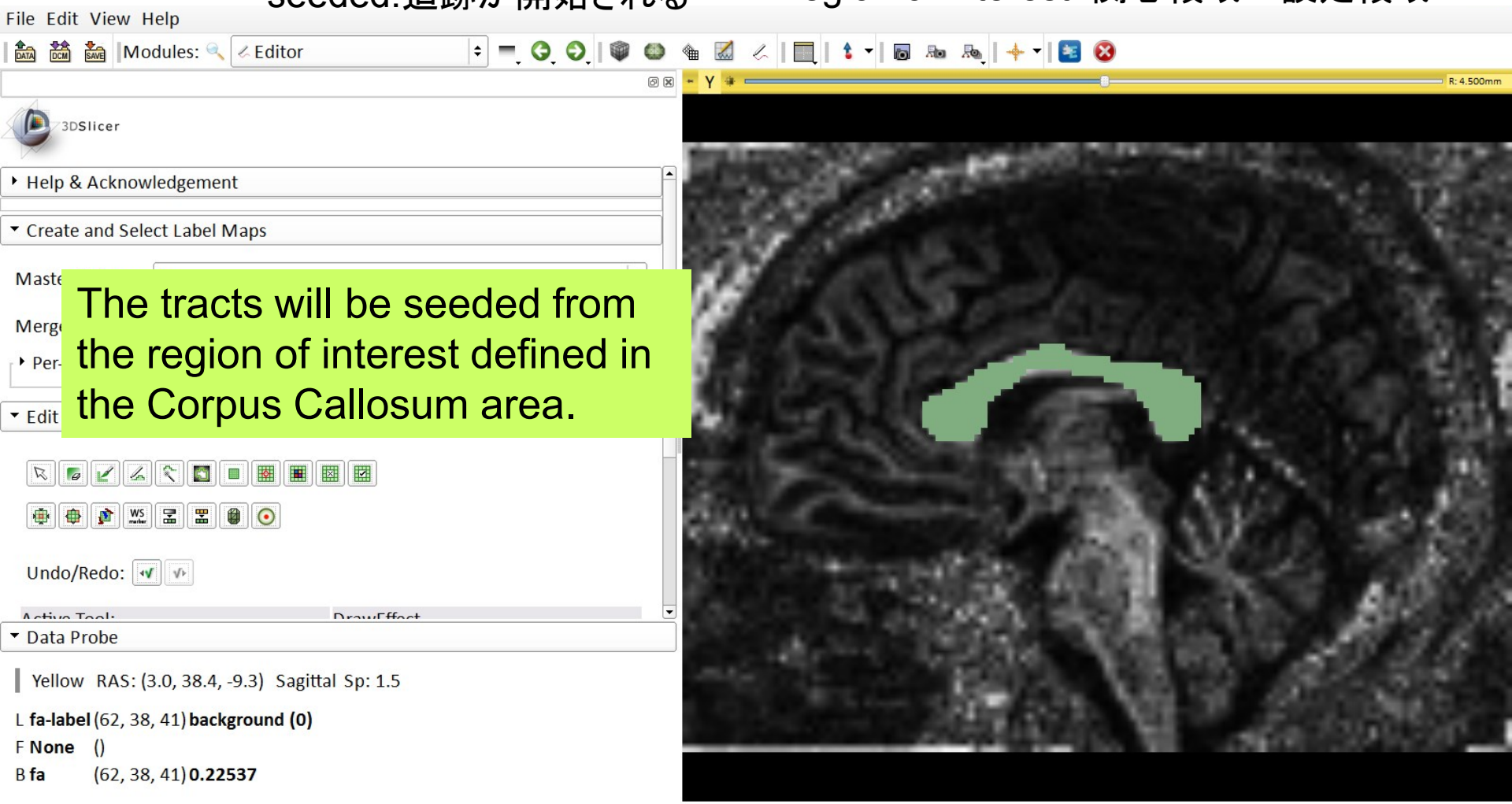
outline：輪郭を描く　adjacent：隣接した　sagittal：サジタル（脳を左右に分割するような）



Diffusion MRI tractography

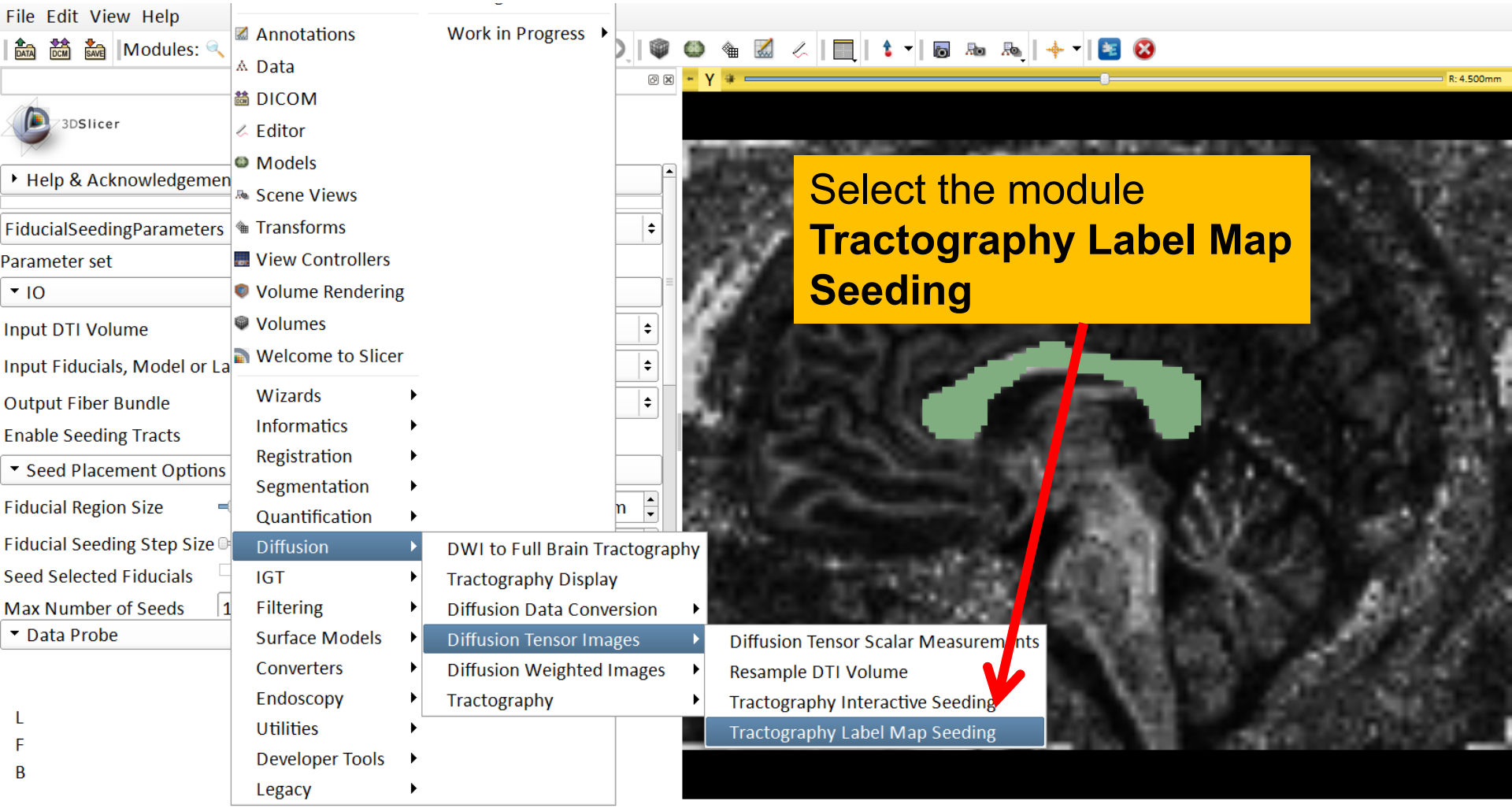
seeded:追跡が開始される

region of interest :関心領域＝設定領域

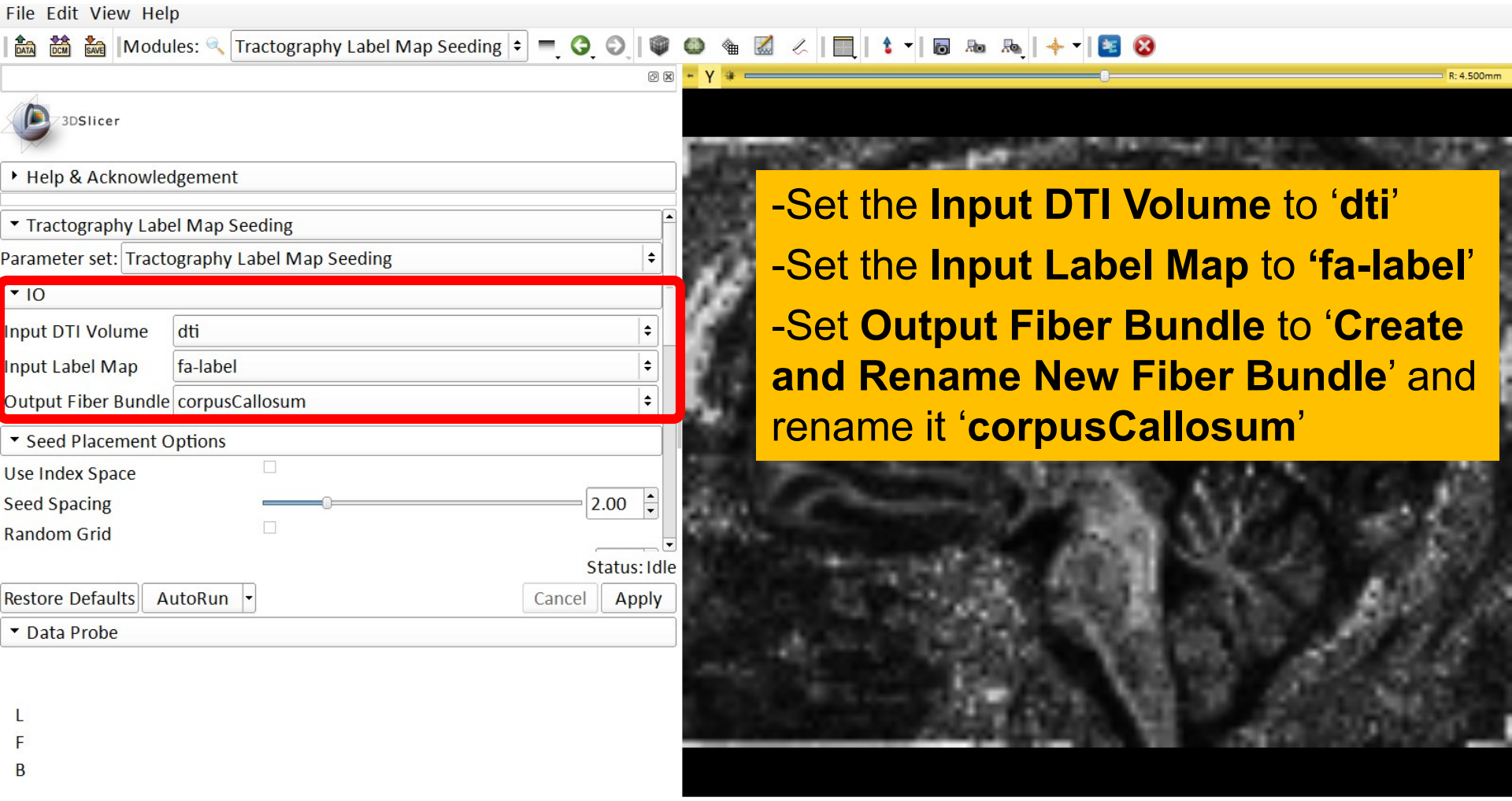


The tracts will be seeded from the region of interest defined in the Corpus Callosum area.

Diffusion MRI tractography

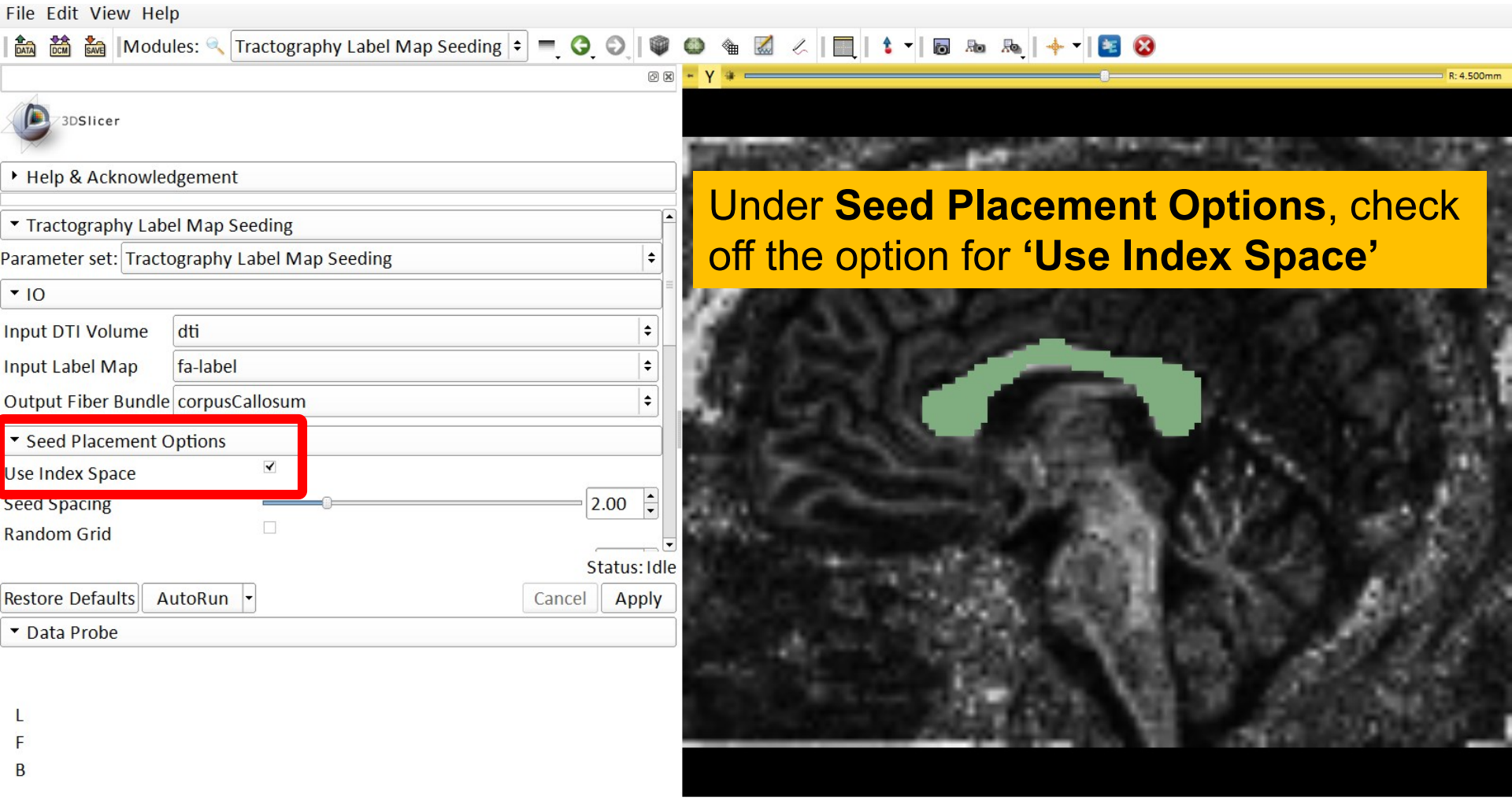


Diffusion MRI tractography



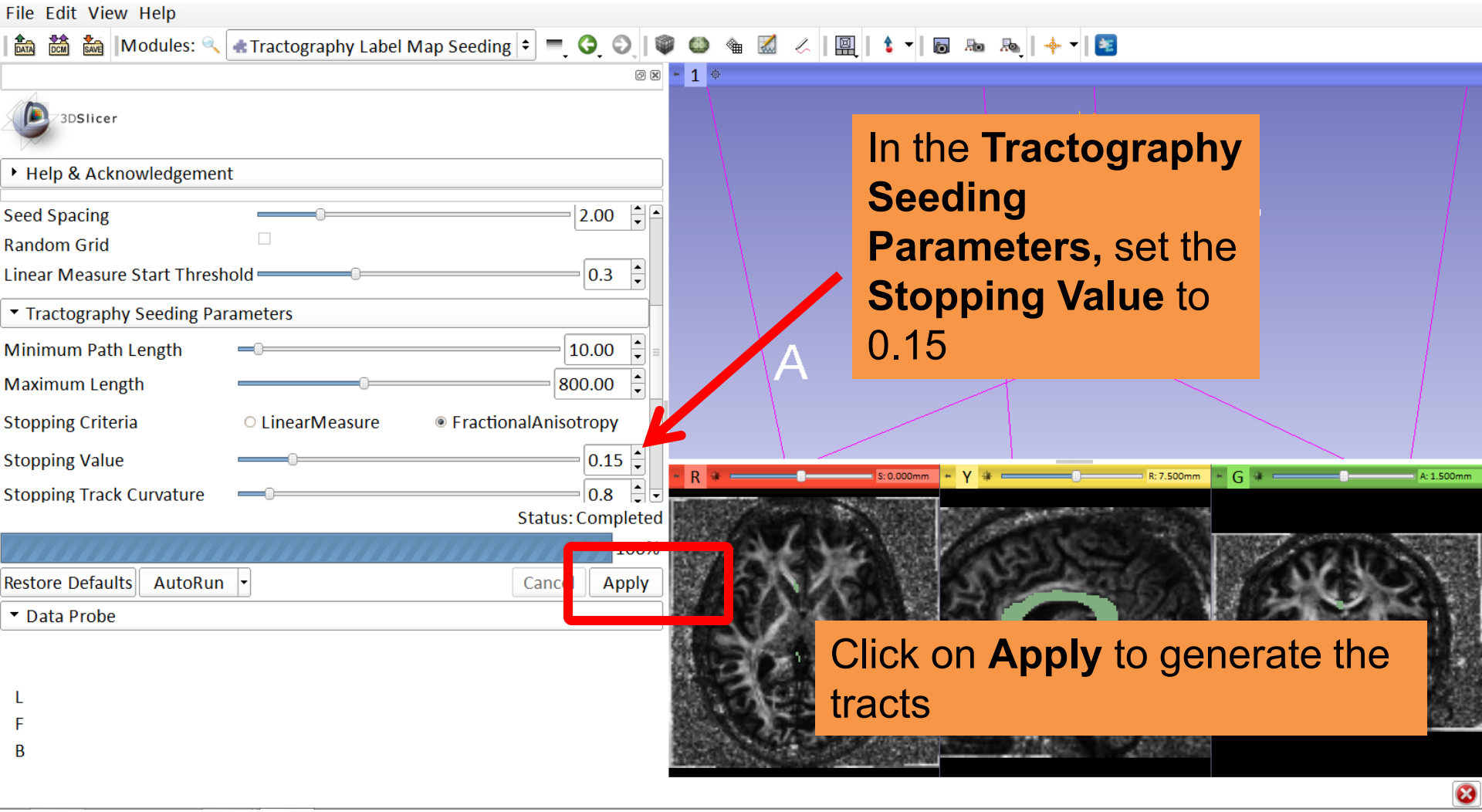
ROI (region of interest) :関心領域＝設定領域

ROI Drawing



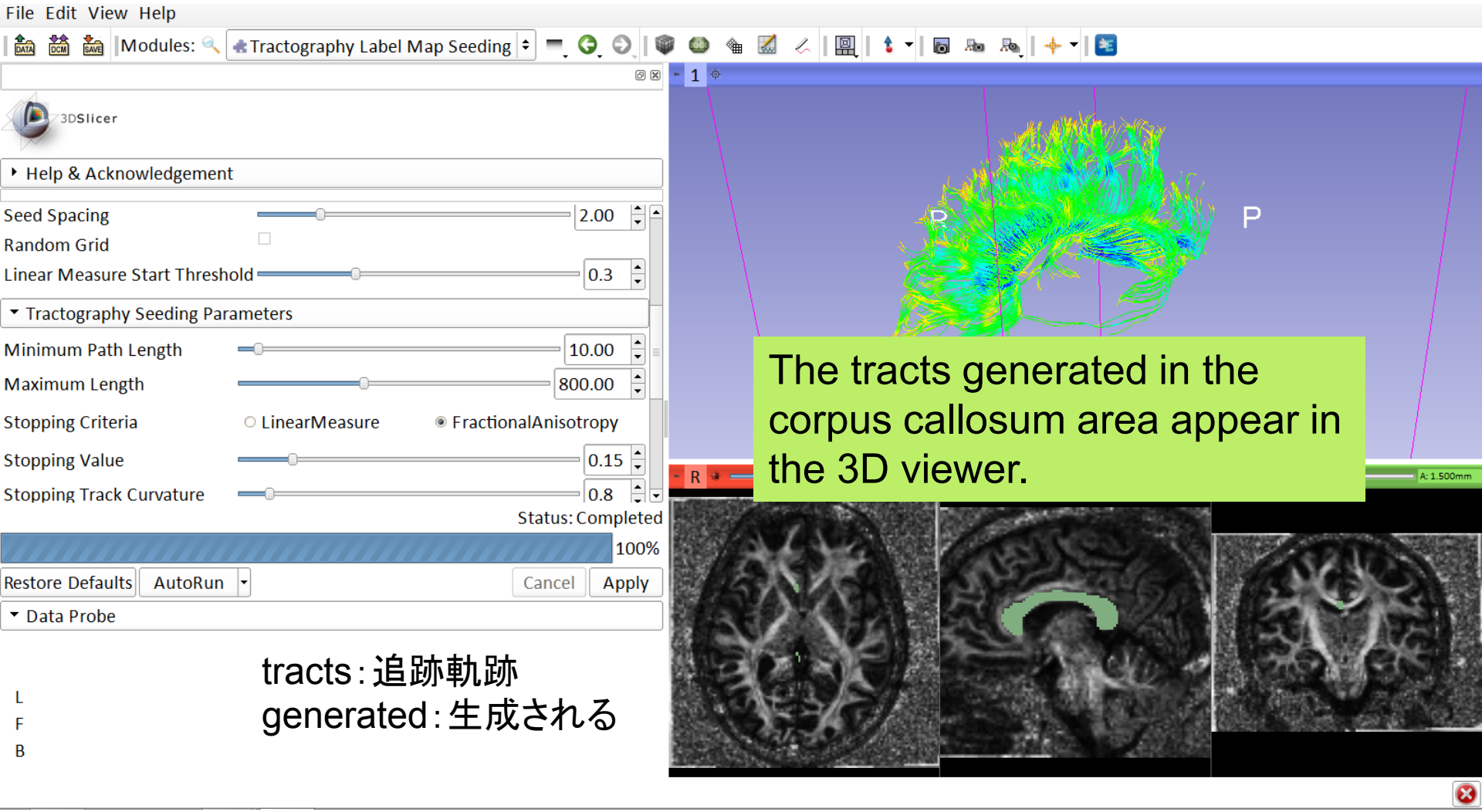
ラベルマップ（ROI）による追跡開始点設定

Labelmap Seeding: Tracts



ラベルマップ（ROI）による追跡開始点設定

Labelmap Seeding: Tracts



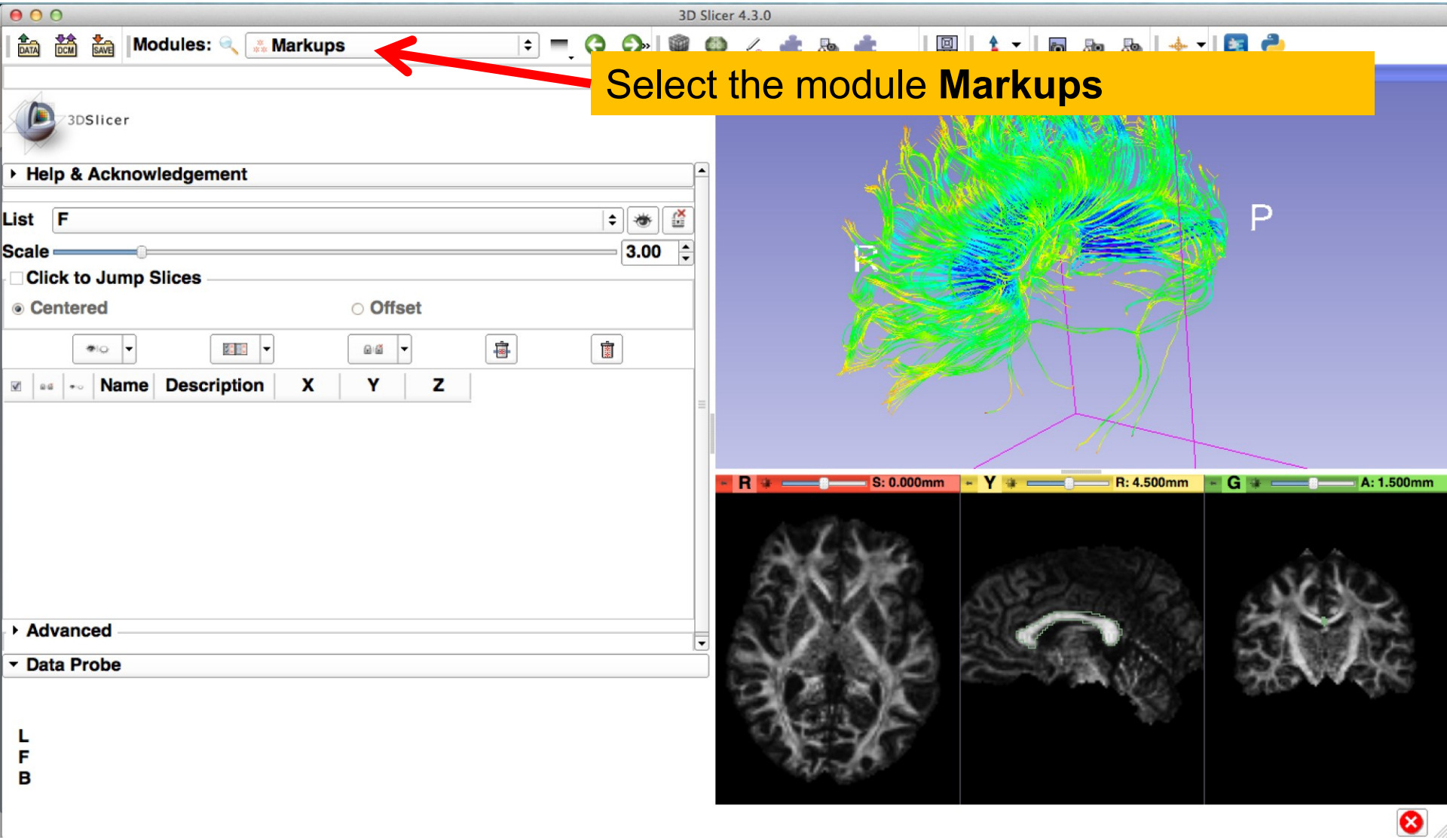
The tracts generated in the corpus callosum area appear in the 3D viewer.

tracts：追跡軌跡
generated：生成される

基準点による追跡開始点設定

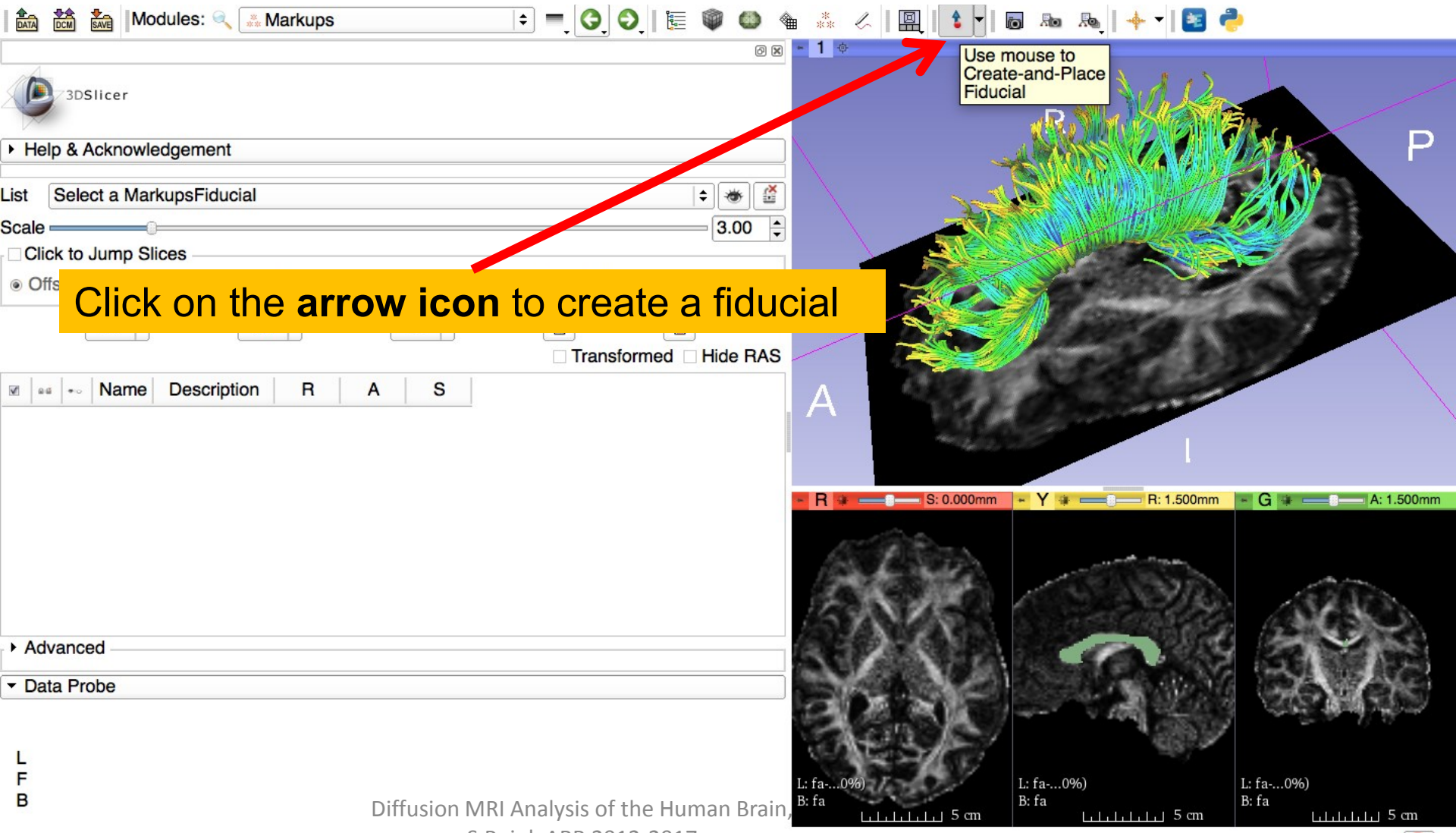
fiducial：基準（点）

Fiducial Seeding

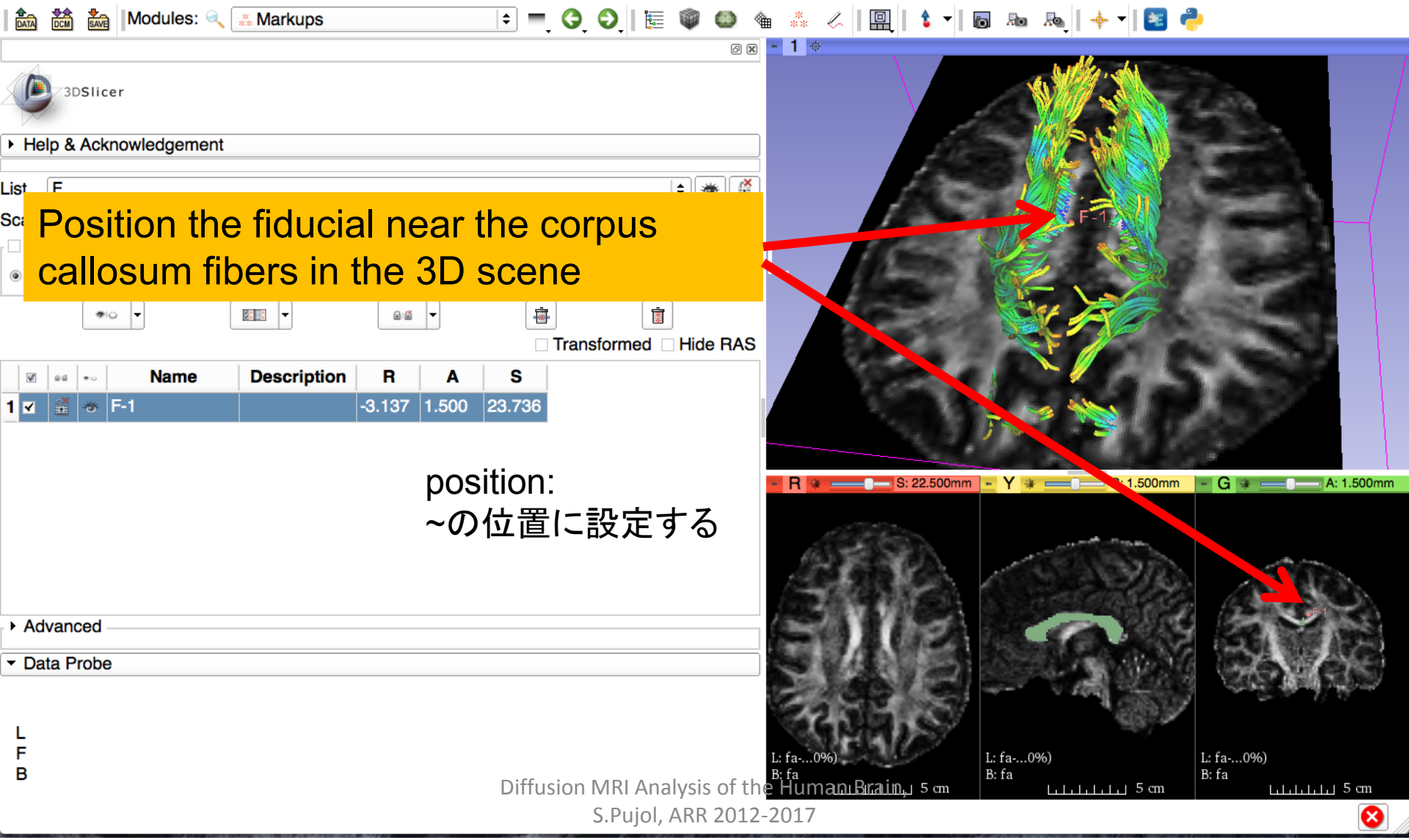


基準点による追跡開始点設定

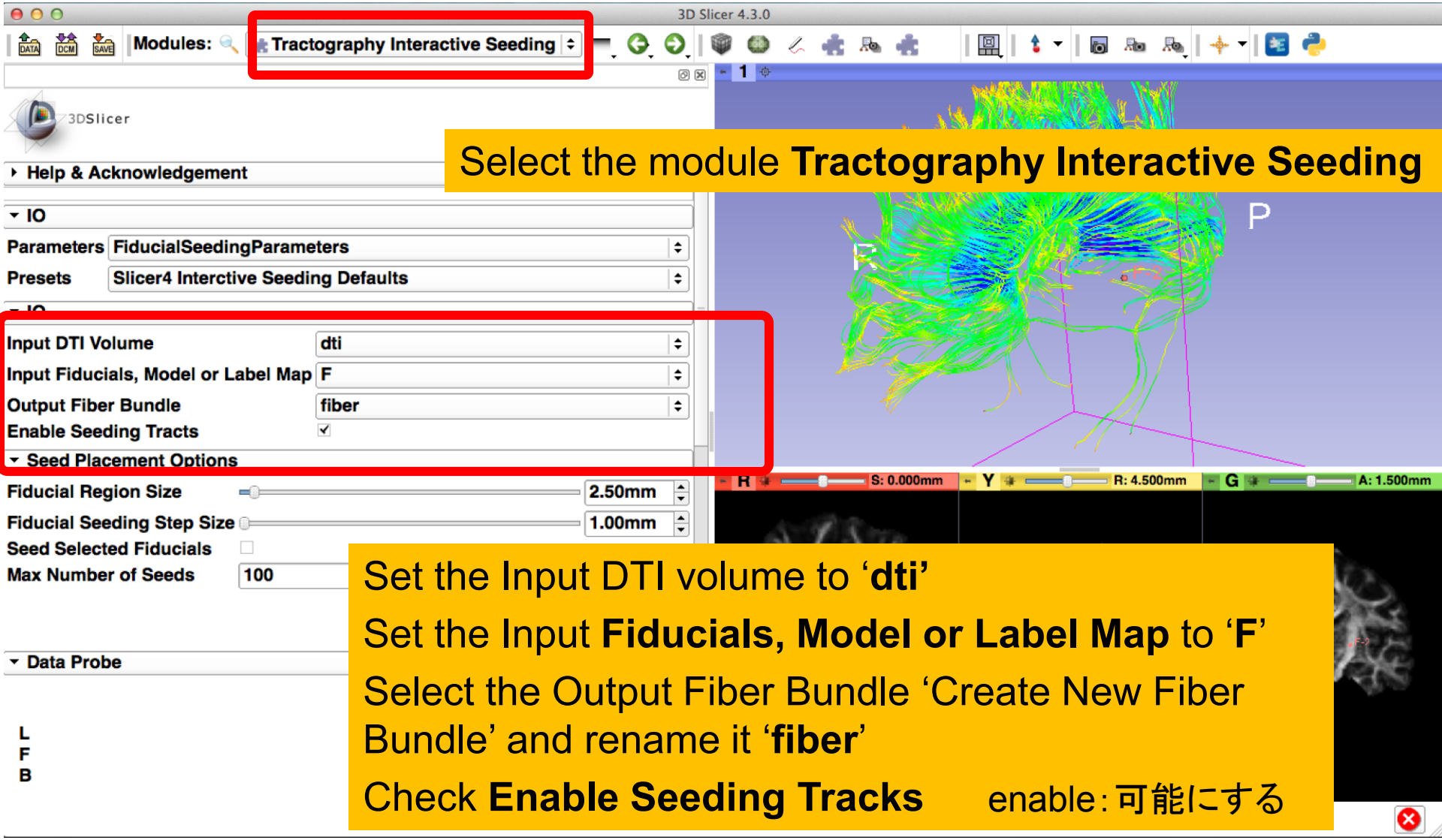
Fiducial Seeding



Fiducial Seeding



Fiducial Seeding



Select the module **Tractography Interactive Seeding**

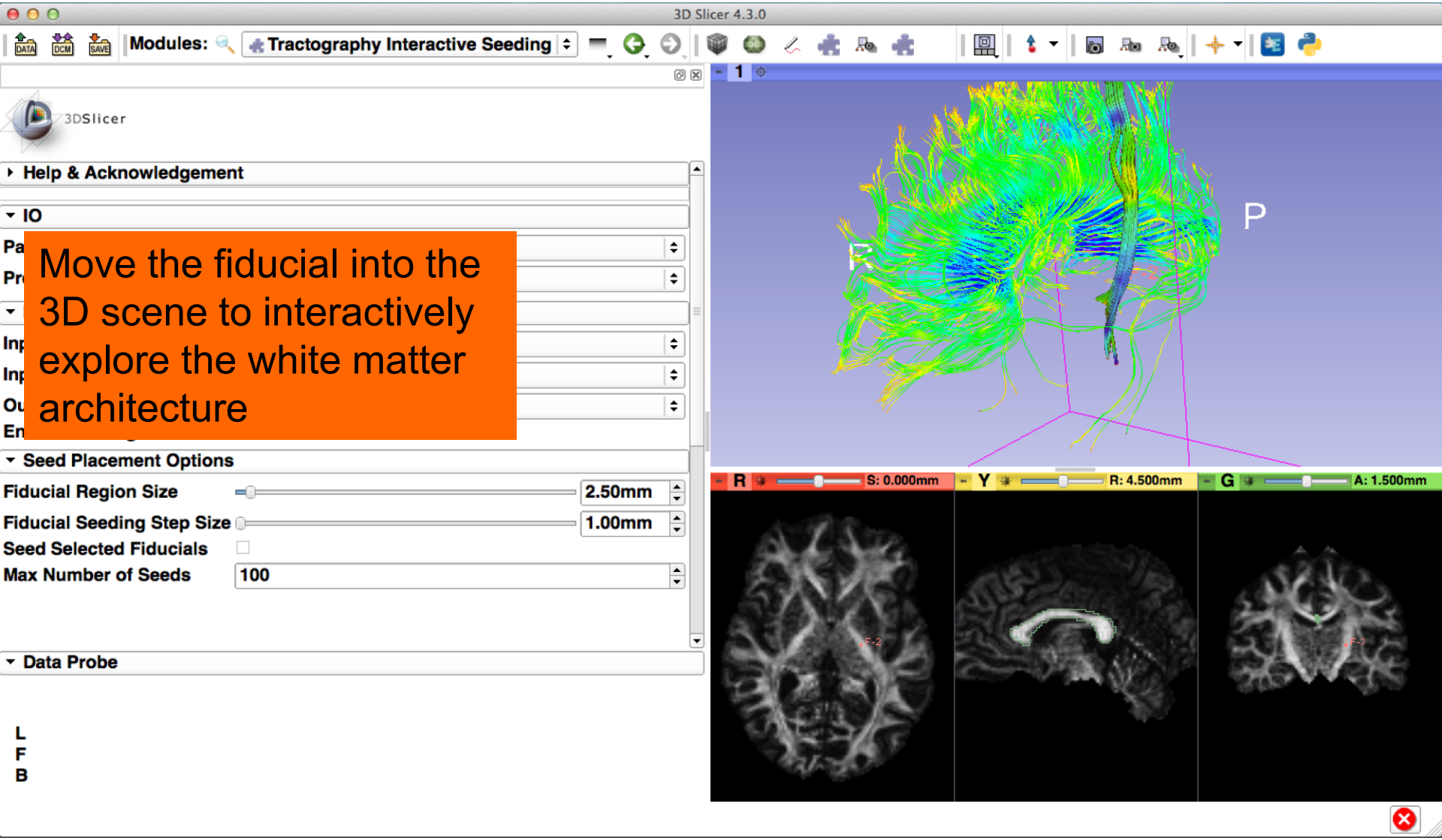
Set the Input DTI volume to '**dti**'

Set the Input **Fiducials, Model or Label Map** to '**F**'

Select the Output Fiber Bundle 'Create New Fiber Bundle' and rename it '**fiber**'

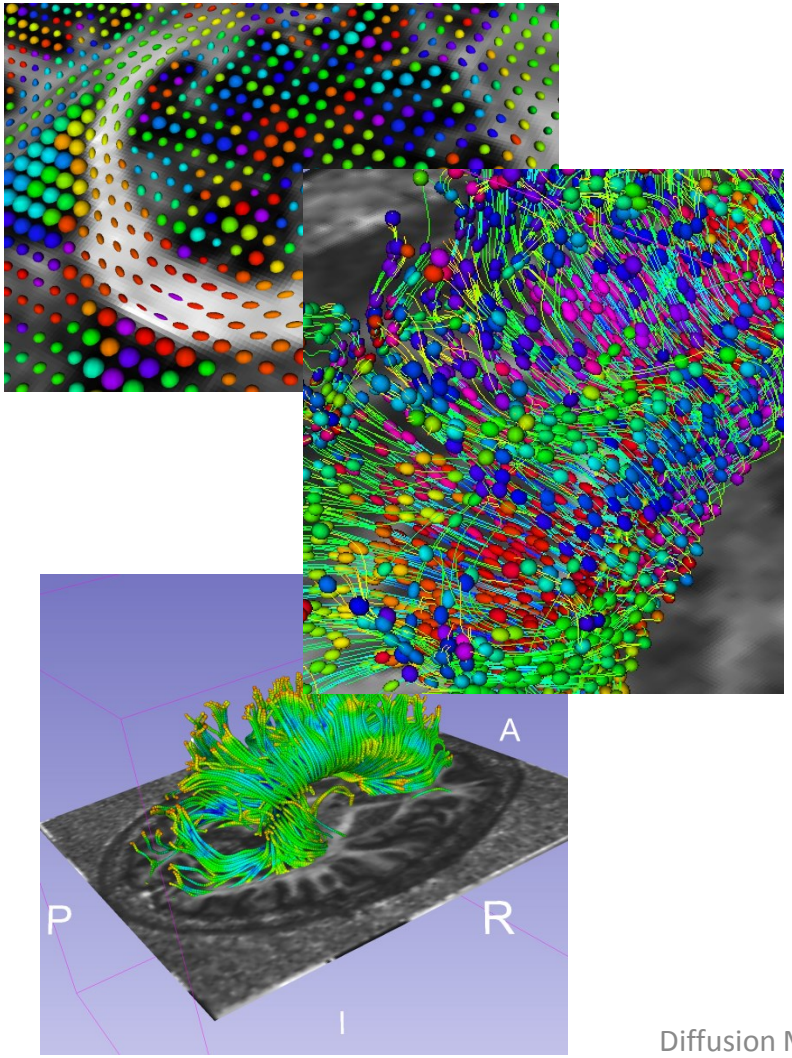
Check **Enable Seeding Tracks** enable: 可能にする

Fiducial Seeding



結論

Conclusion



This tutorial guided you through the different steps of a Diffusion MR analysis pipeline, from tensor estimation to 3D tracts visualization, for exploring and studying the 3D architecture of the brain white matter.

pipeline：処理のパイプライン（手順）
Architecture： 構造

Acknowledgments

- National Alliance for Medical Image Computing (NA-MIC)
  NIH U54EB005149

- Neuroimage Analysis Center (NAC)
  NIH P41RR013218