Diffusion MRI

Hohana G. Konell

Rodolfo Correia

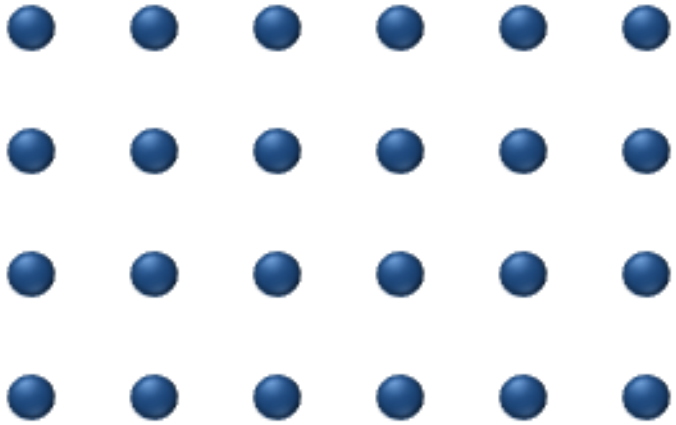
Diffusion

Diffusion is the result of the random walk of molecules which are self-propelled by their thermal energy.

https://imgur.com/gallery/wOyQAaL/comment/628263517

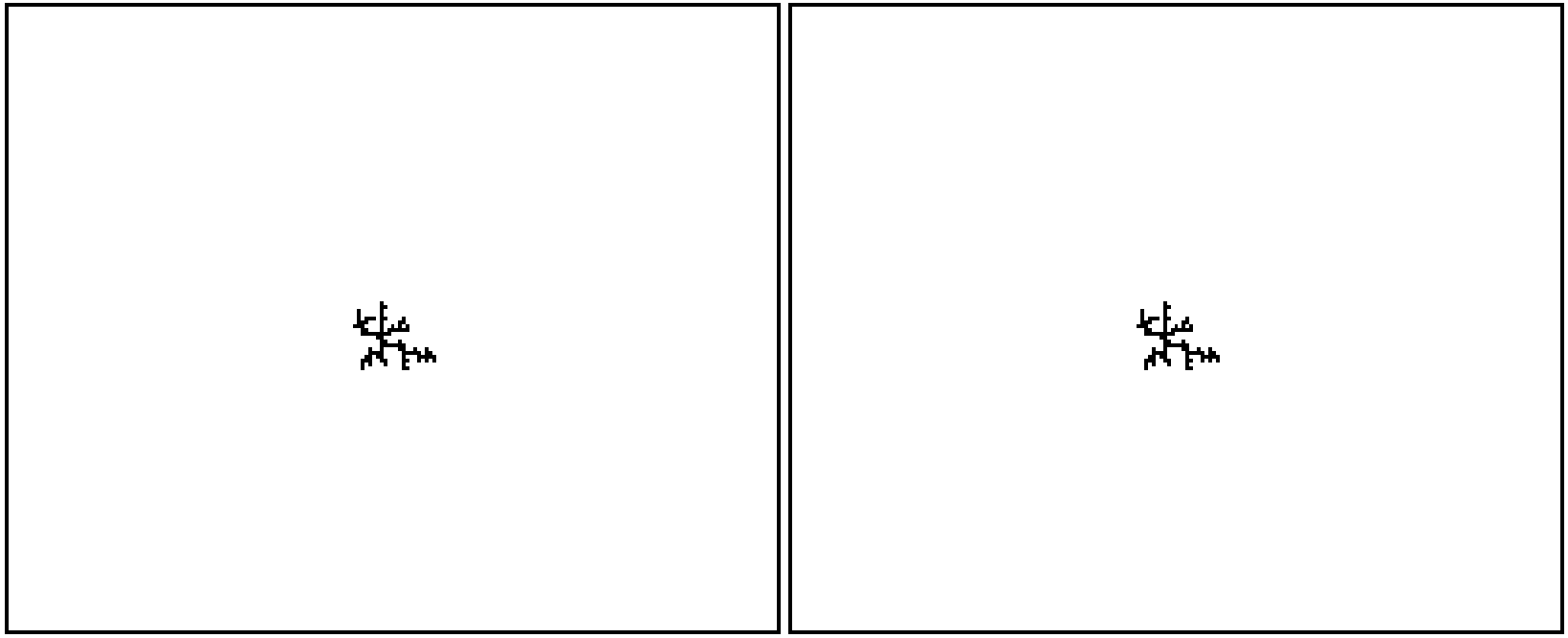
Diffusion

Diffusion is the result of the random walk of molecules which are self-propelled by their thermal energy.

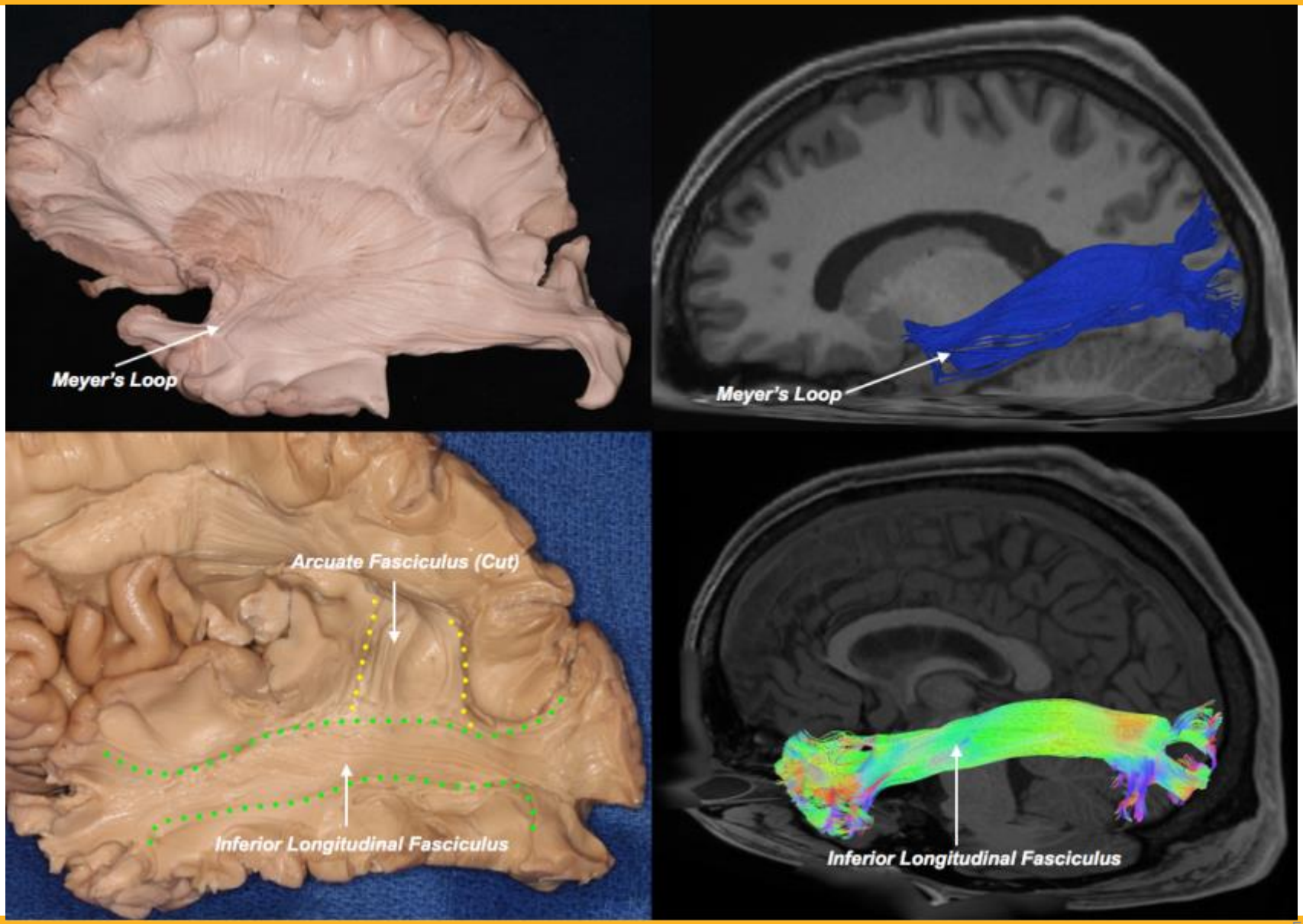


Diffusion

Diffusion is the result of the random walk of molecules which are self-propelled by their thermal energy.

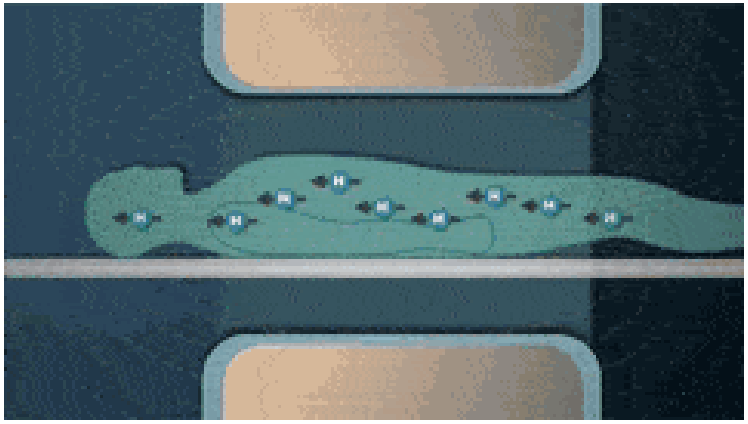


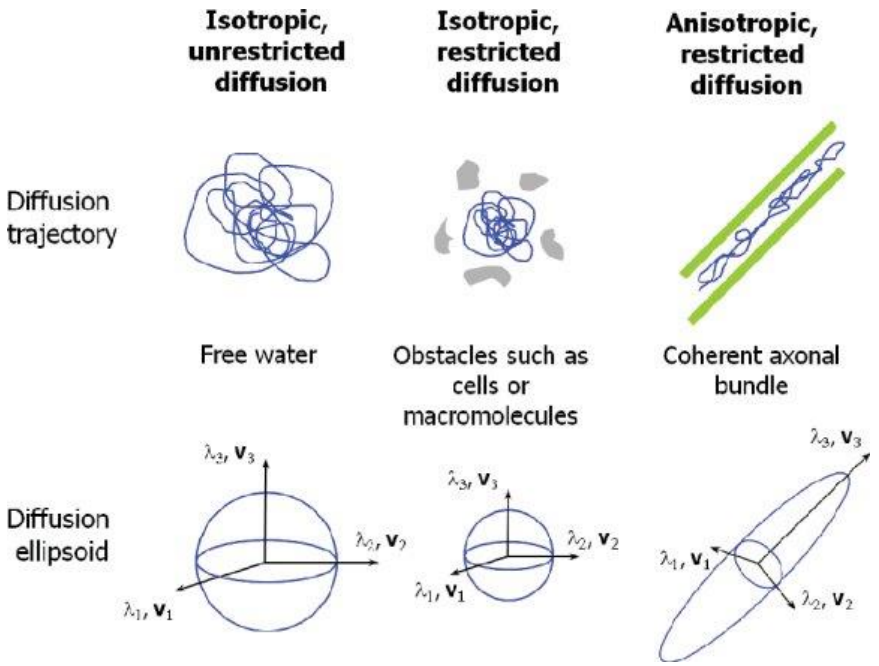
Diffusion


Meyer's Loop
Meyer's Loop
Arcuate Fasciculus (Cut)
Inferior Longitudinal Fasciculus
Inferior Longitudinal Fasciculus

How to measure diffusion using MRI?

Magnetic field created by the MRI causes the atoms in your body to align in the same direction. Radio waves move these atoms out of the original position, and when turned off, the atoms return to their original position and send back radio signals.



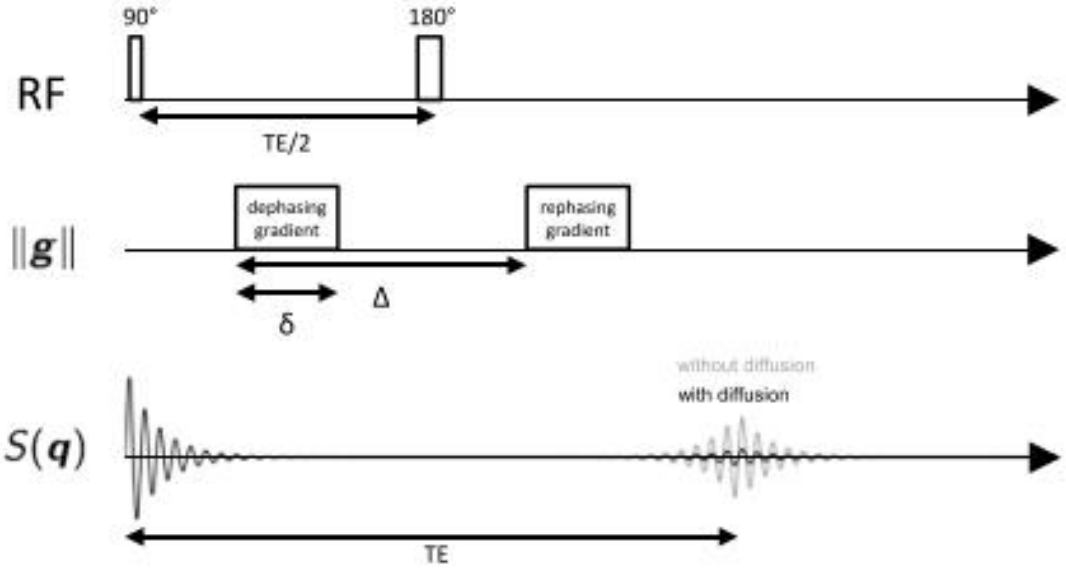


Sharon Geva, Marta Correia & Elizabeth A. Warburton (2011): Diffusiontensor imaging in the study of language and aphasia, Aphasiology, 25:5, 543-558

DW-MRI aims at highlighting the differences in water molecule mobility, irrespective of their direction of displacement.

How to measure diffusion using MRI?

Contrast is influenced by the differences in water molecule mobility
→ diffusion gradients



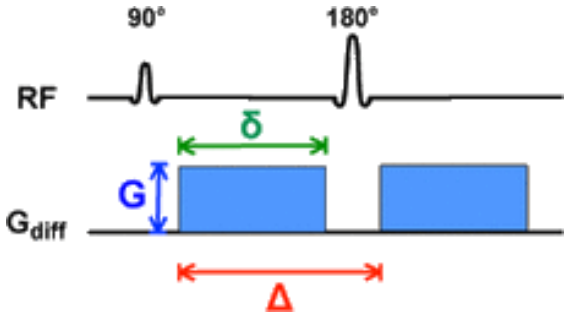
The spins of the immobile water molecules are dephased by the first gradient and rephased by the second.

The spins of the water molecules that move in the direction of the gradients will not be rephased by the second gradient

How to measure diffusion using MRI?

In order to determine the diffusion weighting, the diffusion time (time between the diffusion encoding gradients) has to be taken into account:

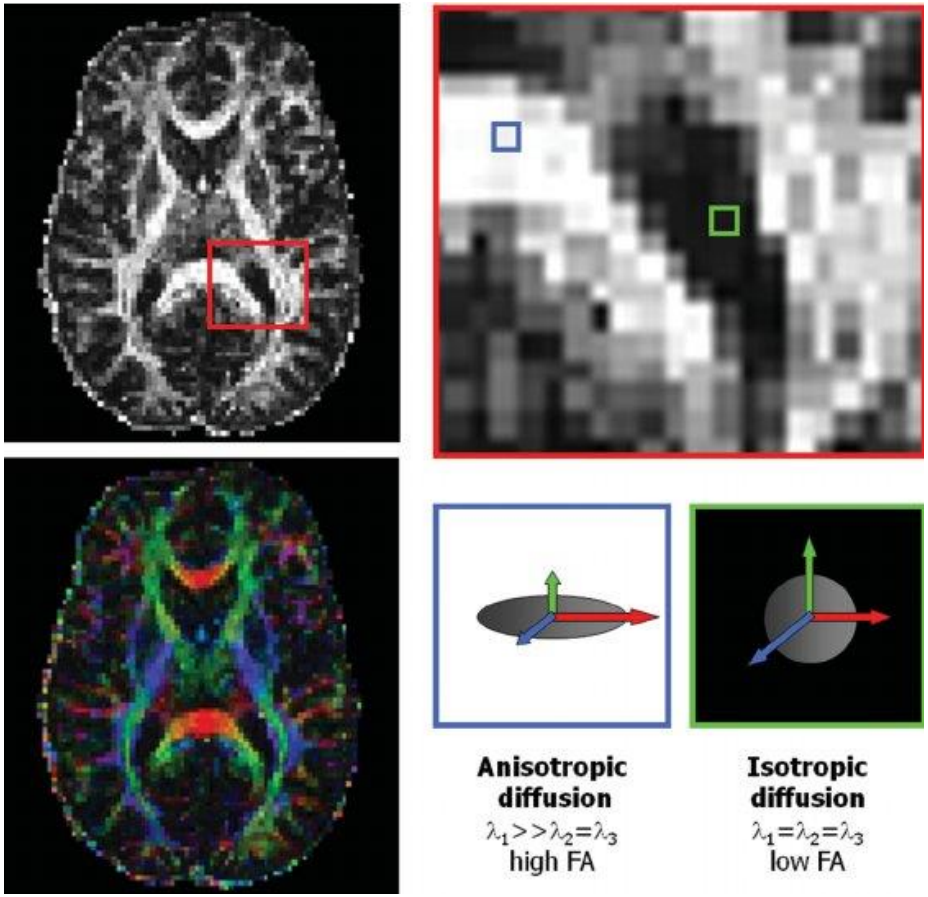
$$b = \gamma^2 \cdot G^2 \cdot \tau^2 \cdot \left(\Delta - \frac{\tau}{3}\right)$$



The higher the *b*-value, the stronger the diffusion effects.

$$S = S_0 e^{-b.D}$$

How to measure diffusion using MRI?



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Diffusion tensor MRI

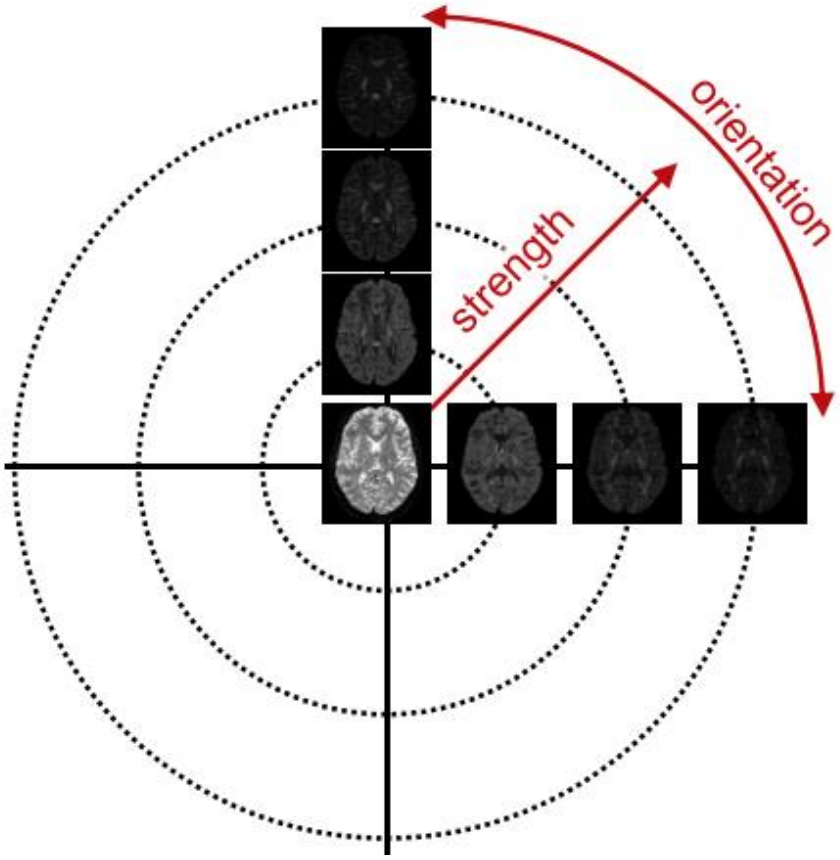
By performing diffusion-weighted acquisitions in at least 6 directions, it is possible to extract the diffusion tensor which synthesizes all the data.

Study the directions of water molecule motion

- If they diffuse in all directions (fractional anisotropy)
- If they attempts to render the direction of a particular diffusion

What we need to know?

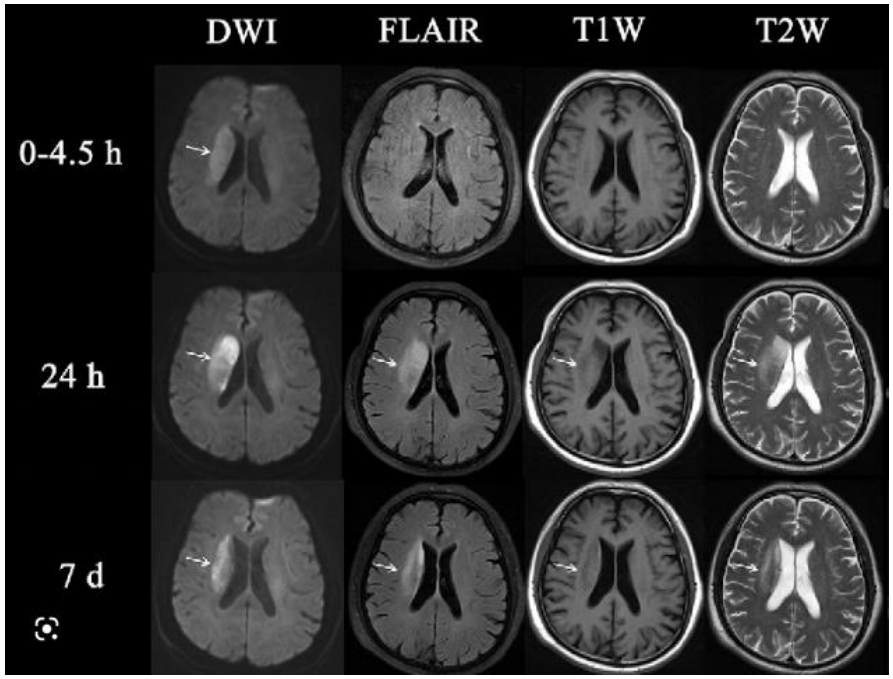
- We collect a series of 3D diffusion weighted images
- Each diffusion-weighted image can be characterized by a 3D vector:
  - magnitude ~ diffusion-weighting strength
  - orientation ~ diffusion-weighting orientation
- More diffusion along the DW orientation → less signal
- More diffusion weighting → more diffusion contrast



Diffusion MRI in the brain

An breakthrough to the white matter assessment using MRI.

- **Stroke**
- Tumors
- Inflammation



Wei, Xiao-er et al. “MRI based thrombolysis for FLAIR-negative stroke patients within 4.5–6h after symptom onset.” *Journal of the Neurological Sciences* 372 (2017): 421-427.

Diffusion MRI in the brain

An breakthrough to the white matter assessment using MRI.

- Stroke
- Tumors
- Inflammation

White matter microstructure

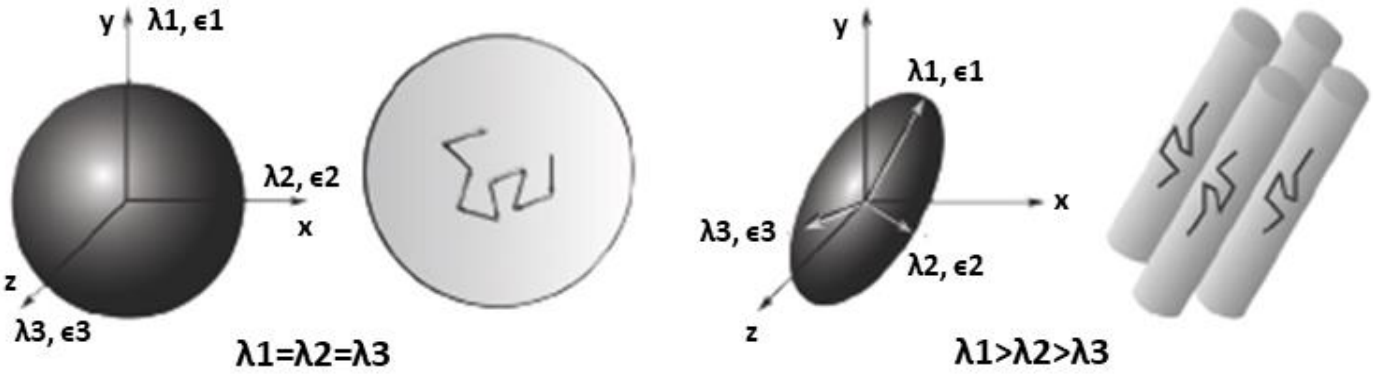
- Neurodegenetive Diseases

Map in vivo the orientation of the white matter fibers

- Surgical planning

Diffusion MRI in the brain

Diffusion Tensor Imaging (DTI)



Fractional Anisotropy (FA): a measure of the degree of directional dependence of the diffusion tensor.

Mean Diffusivity (MD): the average rate of diffusion, averaged over all directions.

Axial diffusivity: this measure is associated with λ1 and contains information of the parallel diffusion to the principal direction.

Radial diffusivity: This measure reflects the perpendicular diffusion to the principal direction of diffusion.

Diffusion MRI in the brain

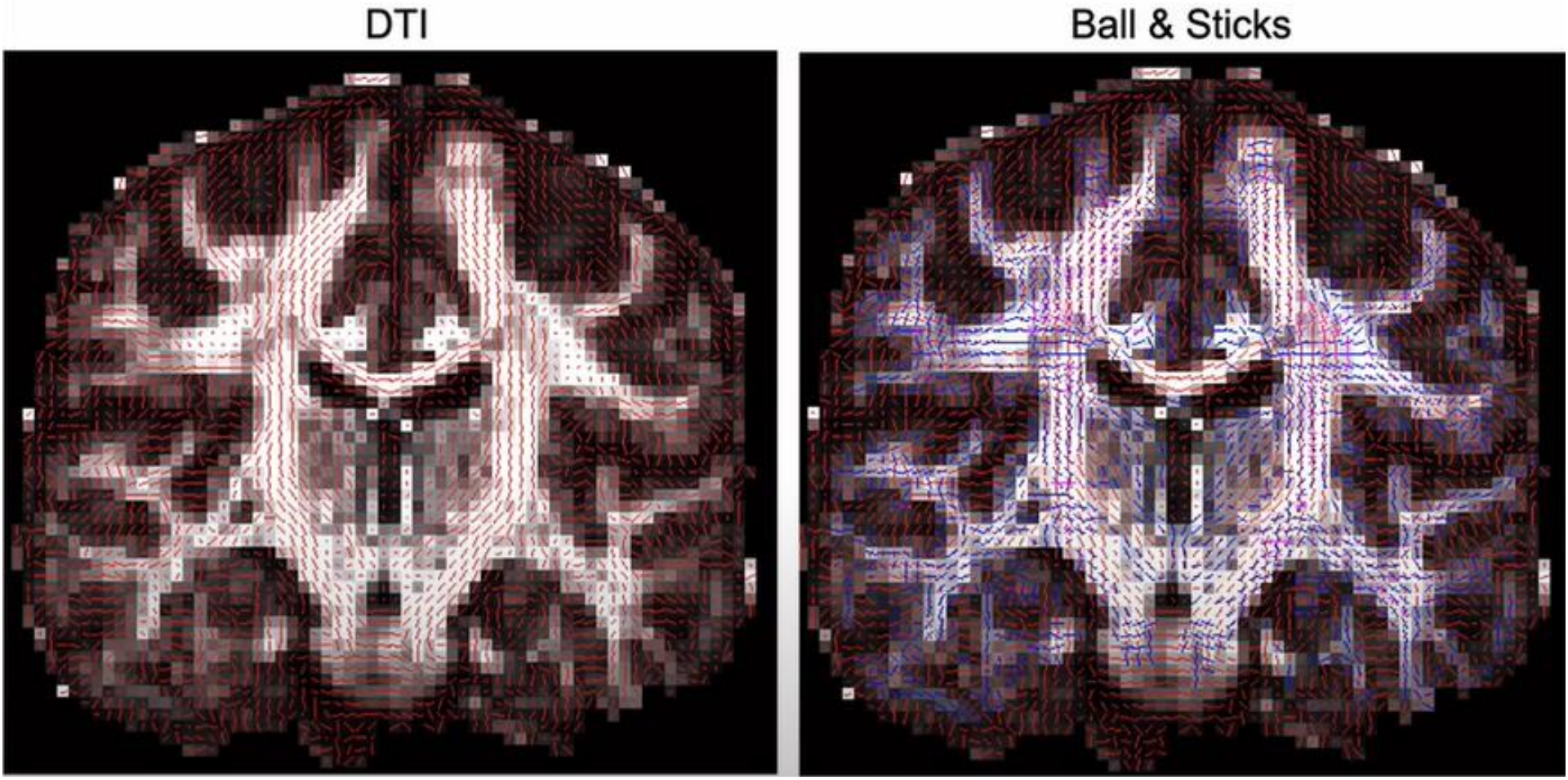
FA	$D_{//}$	$D_{\perp}$	Evidência	Artigos
↓	↓	↑	Desmielinização e lesão axonal	**Animais** Harsan et al,2006 Wu et al, 2007 Schartz et al, 2005 **Humanos** Pierpaoli et al,2001 Werring et al, 2000 Thomalla et al,2004
↓	↓		Lesão axonal (normalmente é a primeira etapa da degeneração walleriana)	**Animais** Song et al, 2003
↓	↑		Lesão axial somente	**Animais** Kinoshita et al, 1999
↓		↑	Desmielinização somente	**Animais** Stanisz GJ, 2001
↓	↑	↑	Aumento do diâmetro axonal e desmielinização	**Humanos** Trapp et al, 1998 Berger et al, 2002

Tractography

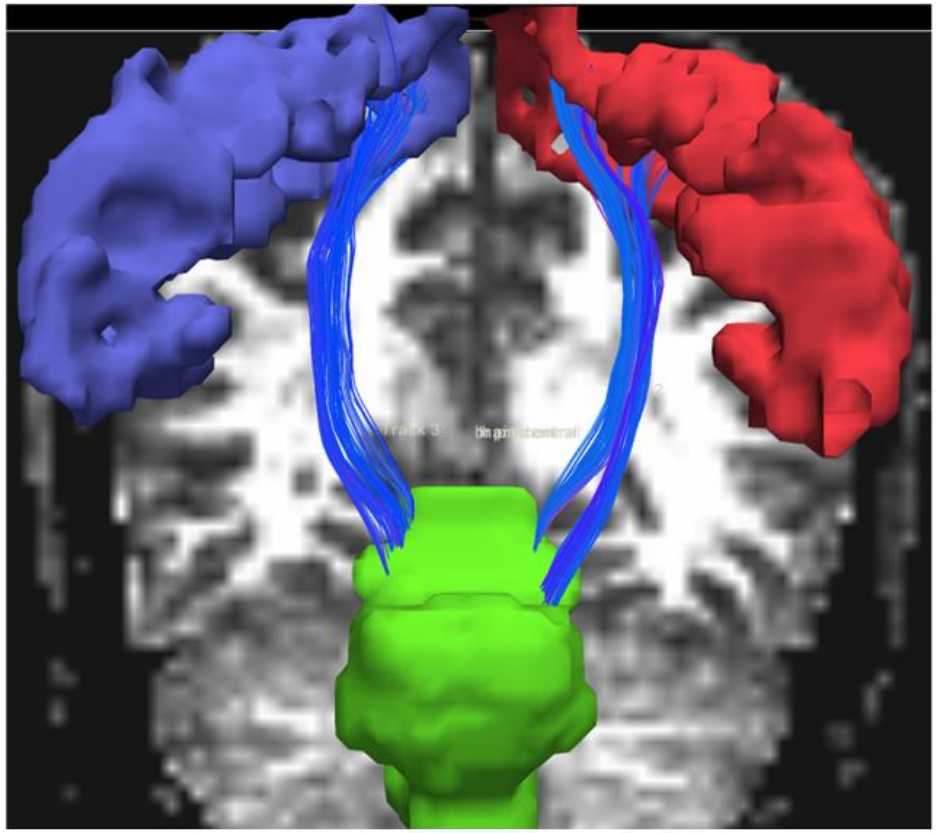
- Tractography refers to the delineation of the path taken by white matter fibre bundles in the brain.

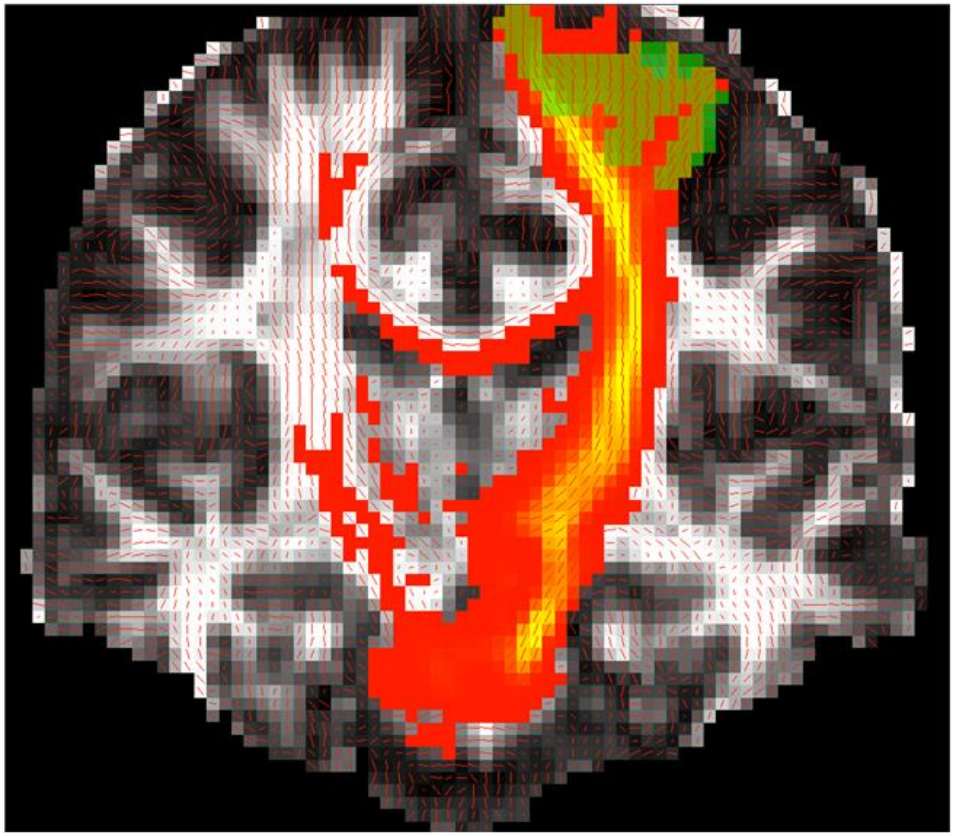
- Deterministic vs Probabilistic
  - Deterministic assumes a single orientation at each voxel
    - FACT
  - Probabilistic assumes a distribution of orientations

Tractography



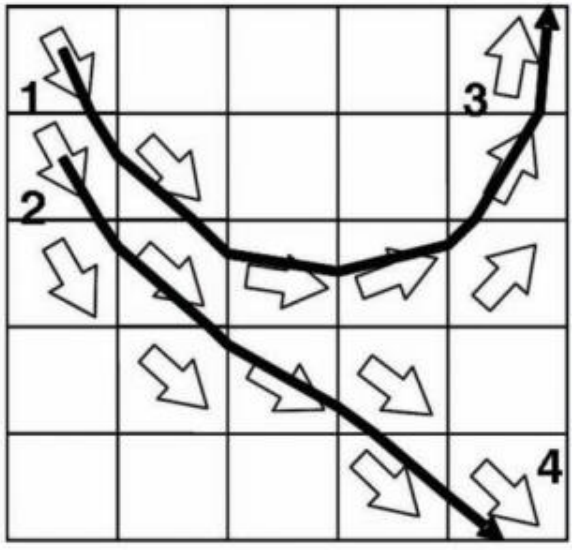
Tractography

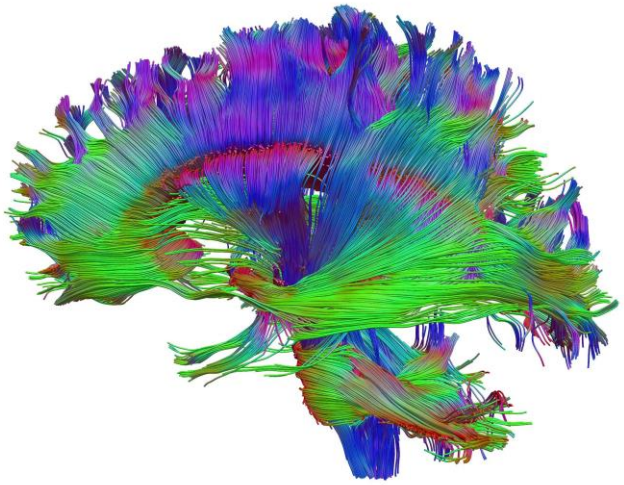




Tractography

- FACT
  - FA threshold
  - Angle threshold





www.inbrainlab.com
hohana. konell@usp.br

OBRIGADA/THANK YOU!!

www.inbrainlab.com
e-mail

Aula Prática!

FSL Pre-processing

- **top-up**
  - Compensation for B0 inhomogeneity
- **eddy_correct**
  - Eddy-current distortions and motion correction
- **bet**
  - Brain Extraction Tool
- **dtifit**
  - Extraction of tensor-based measures maps

https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FDT/UserGuide#Diffusion_data_in_FSL

TRActs Constrained by UnderLying Anatomy

- `trac-all -prep -c $TUTORIAL_DATA/diffusion_tutorial/dmrirc.tutorial`
- `trac-all -bedp -c $TUTORIAL_DATA/diffusion_tutorial/dmrirc.tutorial`
- `trac-all -path -c $TUTORIAL_DATA/diffusion_tutorial/dmrirc.tutorial`

TRACULA

```
# FreeSurfer SUBJECTS_DIR
# T1 images and FreeSurfer segmentations are expected to be found here
#
setenv SUBJECTS_DIR $TUTORIAL_DATA/diffusion_tutorial/fs

# Output directory where trac-all results will be saved
# Default: Same as SUBJECTS_DIR
#
set dtroot = $TUTORIAL_DATA/diffusion_tutorial/trc

# Subject IDs
#
set subjlist = ( subject1 \
                 subject2 \
                 subject3 )

# Input diffusion DICOMs
# If original DICOMs don't exist, these can be in other image format
# but then the gradient table and b-value table must be specified (see below)
#
set dcmlist = ( $TUTORIAL_DATA/diffusion_tutorial/raw/subject1/dwi1/XXX-1.dcm \
                $TUTORIAL_DATA/diffusion_tutorial/raw/subject2/dwi1/XXX-1.dcm \
                $TUTORIAL_DATA/diffusion_tutorial/raw/subject3/dwi1/XXX-1.cdm )

# Diffusion gradient tables (if there is a different one for each scan)
# Must be specified if they cannot be read from the DICOM headers
# The tables must have either three columns, where each row is a gradient vector
# or three rows, where each column is a gradient vector
# There must be as many gradient vectors as volumes in the diffusion data set
# Default: Read from DICOM header
#
set bveclist = ( $TUTORIAL_DATA/diffusion_tutorial/raw/subject1/dwi1/gradients.txt \
                 $TUTORIAL_DATA/diffusion_tutorial/raw/subject2/dwi1/gradients.txt \
                 $TUTORIAL_DATA/diffusion_tutorial/raw/subject3/dwi1/gradients.txt )

# Diffusion b-value tables (if there is a different one for each scan)
# Must be specified if they cannot be read from the DICOM headers
# There must be as many b-values as volumes in the diffusion data set
# Default: Read from DICOM header
#
set bvallist = ( $TUTORIAL_DATA/diffusion_tutorial/raw/subject1/dwi1/bvalues.txt \
                 $TUTORIAL_DATA/diffusion_tutorial/raw/subject2/dwi1/bvalues.txt \
                 $TUTORIAL_DATA/diffusion_tutorial/raw/subject3/dwi1/bvalues.txt )
```

TRACULA

pathstats.overall

pathwayname rh.unc
Count 1500
Volume 247
Len_Min 16
Len_Max 46
Len_Avg 28.85
Len_Center 29
AD_Avg 0.00105722
AD_Avg_Weight 0.00109691
AD_Avg_Center 0.00107635
RD_Avg 0.000595767
RD_Avg_Weight 0.000582685
RD_Avg_Center 0.000569482
MD_Avg 0.000749583
MD_Avg_Weight 0.000754094
MD_Avg_Center 0.000738438
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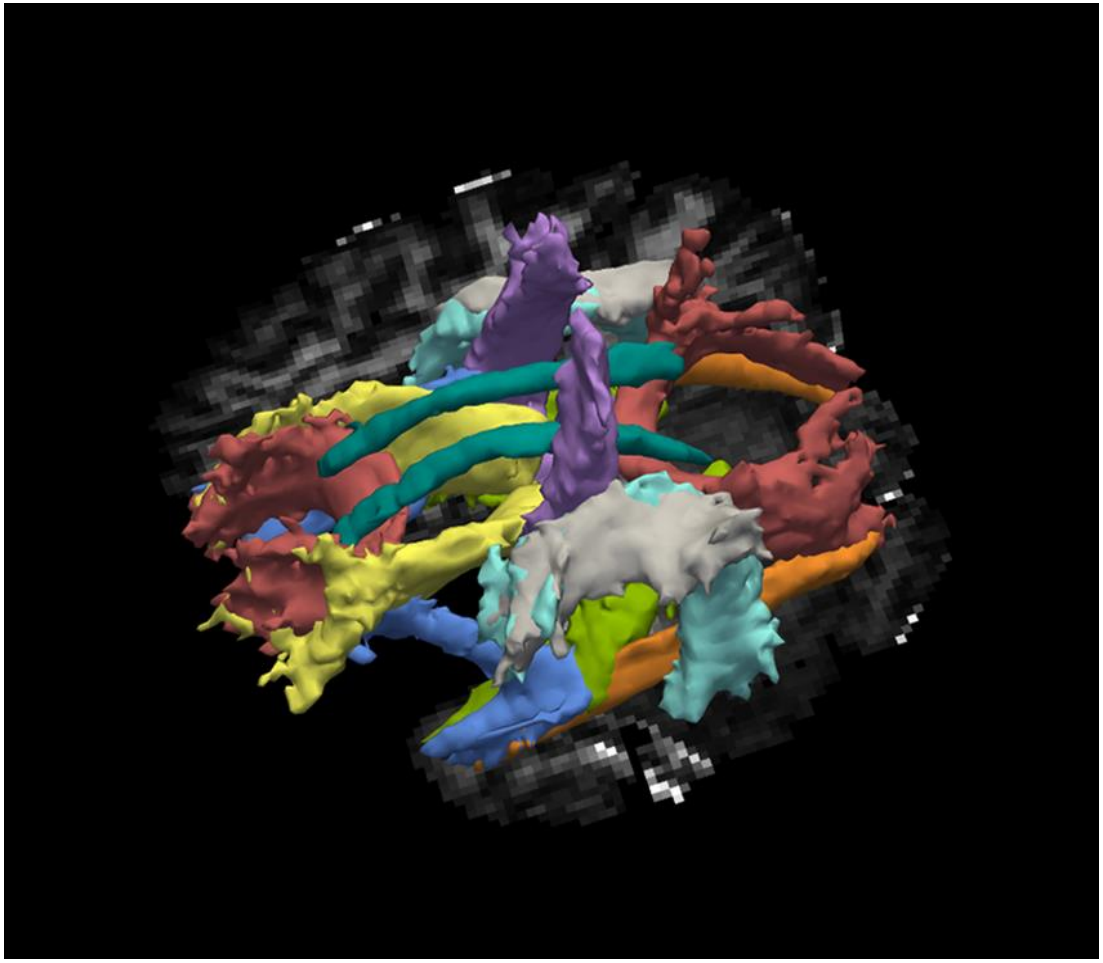
FA_Avg_Weight 0.394924
FA_Avg_Center 0.397165



www.inbrainlab.com
hohana.konell@usp.br

OBRIGADA/THANK YOU!!