Welcome to Sinergia Summer School 2021 on Brain Dynamics on the Connectome

Swiss National
Science Foundation

Sinergia – interdisciplinary, collaborative and breakthrough

The faculty

Patric Hagmann
Patric's expertise: MRI processing, brain connectivity

Serge Vulliemoz
Serge's expertise: epilepsy, EEG source imaging and connectivity

Gijs Plomp
Gijs' expertise: dynamic functional connectivity

Gustavo Deco
Gustavo's expertise: Computational modelling in brain dynamics

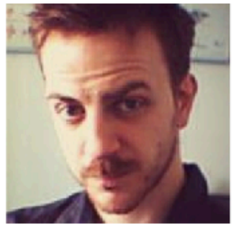
Pieter van Mierlo
Pieter's expertise: dynamic causal functional connectivity

Katharina Glomb
Katharina's expertise: signal processing on connectome-based graph, combination of structural and functional connectivity

Maria Rubega
Maria's expertise: electrical source imaging

Marco Pizzolato
Marco's expertise: diffusion MRI modelling

Isotta Rigoni
Isotta's expertise: EEG analyses, functional connectivity



David Pascucci
David's expertise: dynamic causal functional connectivity, combination of structural and functional connectivity

Sébastien Tourbier
Seb's expertise: medical image analysis, reproducible workflows, open-science, BIDS and BIDS App standards

Joan Rué Queralt
Joan's expertise: combination of structural and functional connectivity

Jolan Heyse
Jolan's expertise: computational modelling and dynamic causal functional connectivity

Ane Lopez
Ane's expertise: computational modelling of brain dynamics

Manel Vila-Vidal
Manel's expertise: computational modelling of brain dynamics

Jonathan Wirsich
Jonatha's expertise: functional MRI and EEG analysis, brain connectivity

Nicolas Roehri
Nicolas' expertise: EEG and SEEG analysis, wavelet transform, epilepsy research

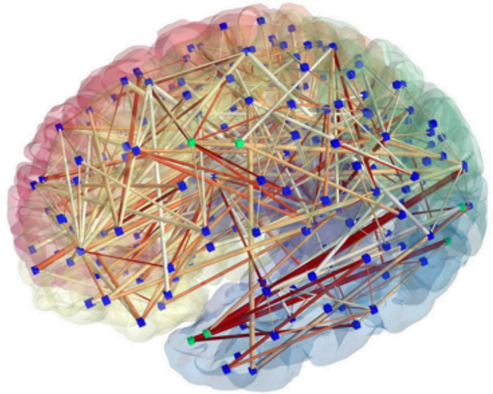
ORGANIZERS

We are here to help. Don't hesitate to ask us any question.

https://sinergiaconsortium.bitbucket.io/index.html

SINERGIA CONSORTIUM BRAIN COMMUNICATION PATHWAYS

Welcome to the Brain Communication Pathways Sinergia Consortium website.



This consortium is composed of an international team of neuroscientists coming from Lausanne University Hospital and University of Lausanne, University of Geneva and Geneva University Hospital, Ecole Polytechnique Fédérale de Lausanne all based in Switzerland as well as University of Fribourg (Switzerland), University Pompeu Fabra in Spain and Ghent University in Belgium. The consortium is funded by a Sinergia Grant from the Swiss National Science Foundation.

The project consists in exploring brain communication pathways by combining diffusion based quantitative structural connectivity and EEG source imaging with application to physiological and epileptic networks.

Specific aims are:

- Develop a reconstruction framework, which will provide, from ESI and dMRI data, a brain network representation. To each node, representing a cortical region, an electrical source will be associated (time series). Each edge will represent an existing fiber tract to which information of length, size, axonal diameter distribution and myelination will be associated.
- Develop new methods to constrain ESI sources by using structural connectivity information.
- Determine the connection specific propagation delays by combining microstructural information and phase lags in well-defined visual stimulus paradigms and intracranial electrophysiology.
- Fit new computational models of spontaneous activity and epilepsy to study criticality in the brain.
- Develop a dedicated analysis framework to follow and characterize the propagation of spatio-temporal coupling with a dynamic network model.
- Explore with this framework mechanisms of connectome constrained functional connectivity in the visual system and associated feed-forward and –backward mechanisms.
- Explore with this framework the mechanisms of seizure onset, propagation and inter-ictal resting activity in epileptic patients.

Project keywords

Brain Connectomics
Effective Connectivity
Communication through Coherence
Diffusion MRI
Microstructural Imaging
Electrical Source Imaging
Functional Brain Dynamics
Epilepsy

PRINCIPAL INVESTIGATORS

Prof. Patric Hagmann (lead)
Radiology Research Center
Department of Radiology
Lausanne University Hospital (CHUV)
Rue Centrale 7, 4th floor
CH-1003 Lausanne
Switzerland

Prof. Serge Vulliémoz
EEG and Epilepsy Unit
Department of Neurology
University Hospital of Geneva
Rue Gabrielle Perret-Gentil 4
CH-1205 Geneva
Switzerland

Prof. Christoph Michel
Faculty of Medicine
Faculty of Medicine
University of Geneva
Campus Biotech
Chemin des Mines 9
CH-1202 Geneva Switzerland

Prof. Jean-Philippe Thiran
Signal Processing Laboratory (LTS5)
EPFL-STI-IEL-LTS5
Station 11
CH-1015 Lausanne
Switzerland

PROGRAMME

The Sinergia Summer School 2021 will take place online in GatherTown/Zoom over two days, from October Monday 11th to Tuesday 12th 2021.

	Monday	Tuesday
8:30	Introductory words by Patric Hagmann	
09:00	Get to know each other	LECTURE 2.1 Analysis of Brain Networks
9:30	Lecture 1.1 Building the Connectome	LECTURE 2.2 Functional Connectivity (FC) and Dynamic FC
10:00	Morning break	Morning break
10:30	LECTURE 1.2 Diffusion and Tractography	LECTURE 2.3 Combining Structure and Function
11:00	LECTURE 1.3 EEG Basics	LECTURE 2.4 Connectome Spectral Analysis
11:30	LECTURE 1.4 Electrical Source Imaging	LECTURE 2.5 Computational Modelling
12:00	Lunch break	Lunch break
13:00	Tutorial 1 Brain Imaging Data Structure BIDS	Tutorial 4 Dynamic Functional Connectivity
14:00	Tutorial 2 Anatomical and Diffusion pipelines	Tutorial 5 Connectome Spectral Analysis
15:00:	Afternoon break	Afternoon break
15:30	Tutorial 3 EEG pipeline	Tutorial 6 Computational Modelling
16:30	Social event (TBD)	Wrap up by Serge Vulliemoz

Lecture 1.1
Building the Connectome

Patric Hagmann, MD, PhD
Associate Professor
Department of Radiology
Lausanne University Hospital and University of Lausanne
Switzerland

Connectome

From Wikipedia, the free encyclopedia

For the 2012 book, see Connectome (book).

A **connectome** (/kəˈnɛktoʊm/) is a comprehensive map of neural connections in the brain, and may be thought of as its "wiring diagram". More broadly, a connectome would include the mapping of all neural connections within an organism's nervous system.

At multiple scales [edit]

Brain networks can be defined at different levels of scale, corresponding to levels of spatial resolution in brain imaging (Kötter, 2007, Sporns, 2010).[21][22] These scales can be roughly categorized as microscale, mesoscale and macroscale. Ultimately, it may be possible to join connectomic maps obtained at different

White matter fiber tracts, the macroscopic connectome

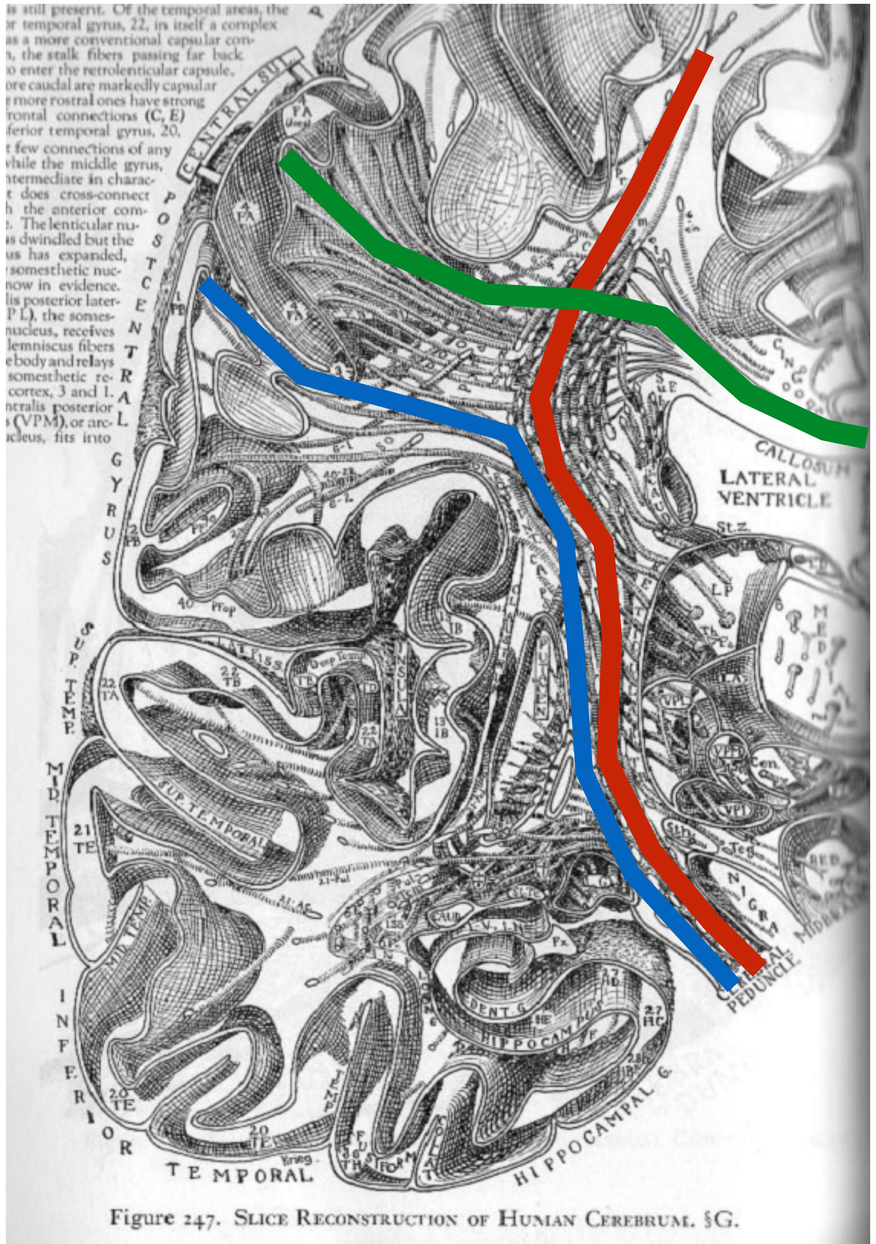
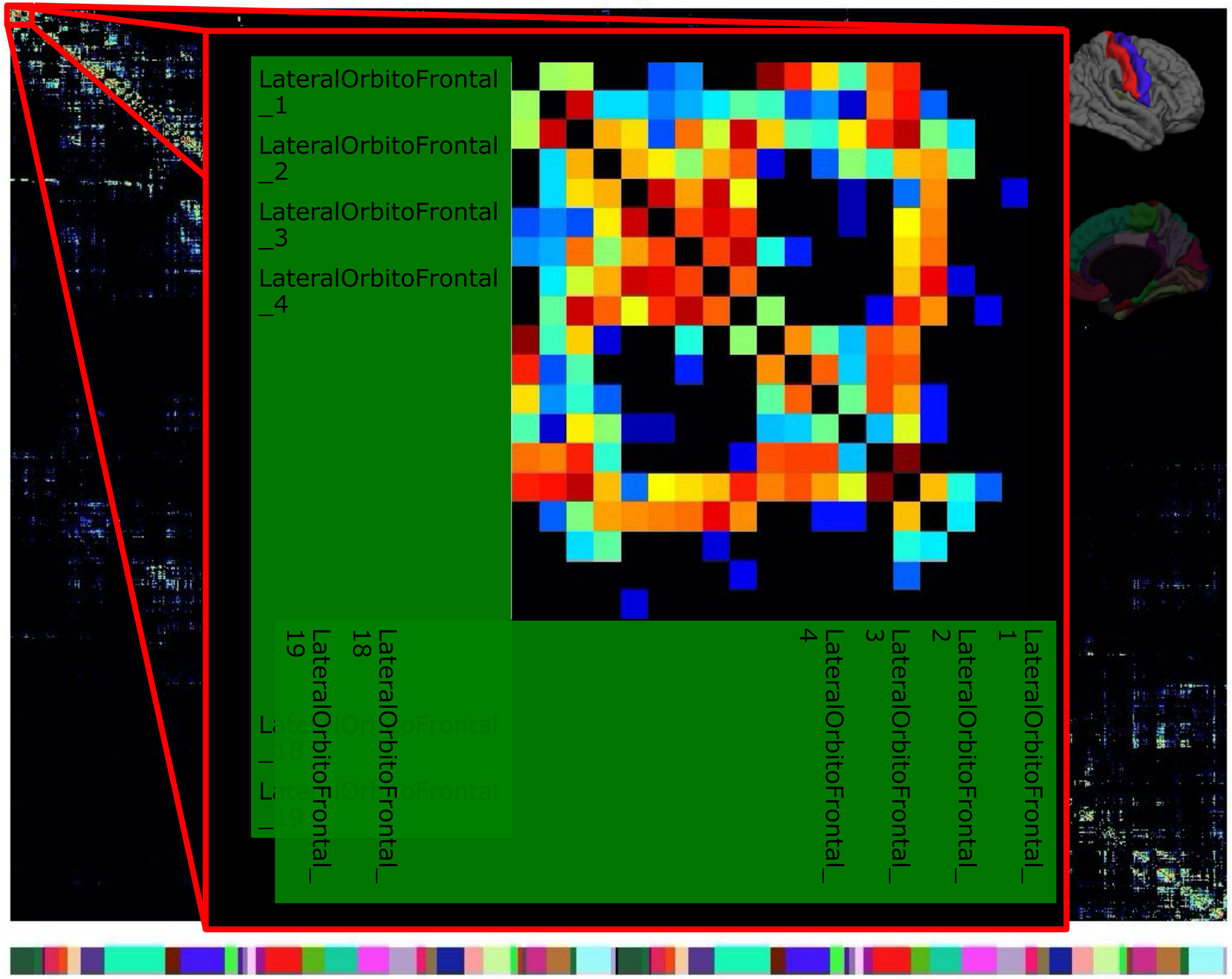


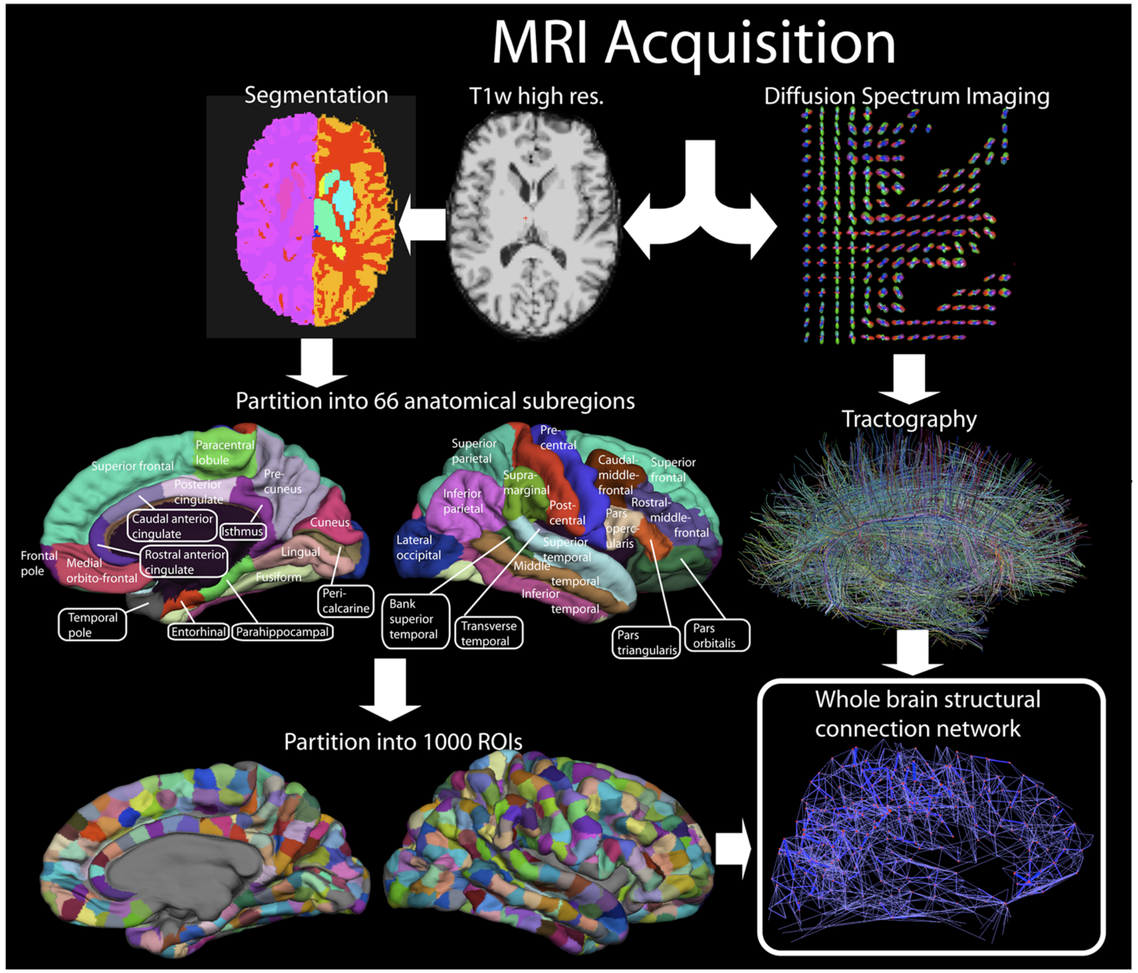
Figure 247. Slice Reconstruction of Human Cerebrum. §G.

Wendel JS Krieg, 1963

Connectivity Matrix



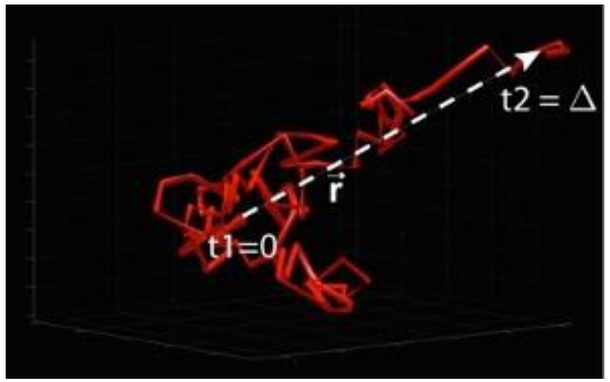
What are the steps?

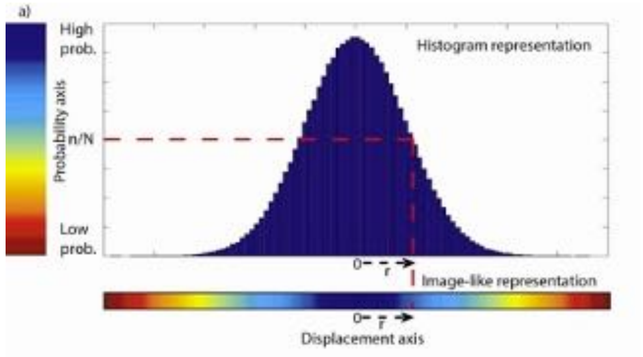


- Acquisition
- ODF reconstruction
- Tractography
- Segmentation, partition in ROIs
- Linking ROIs and fibers
- Connectivity map

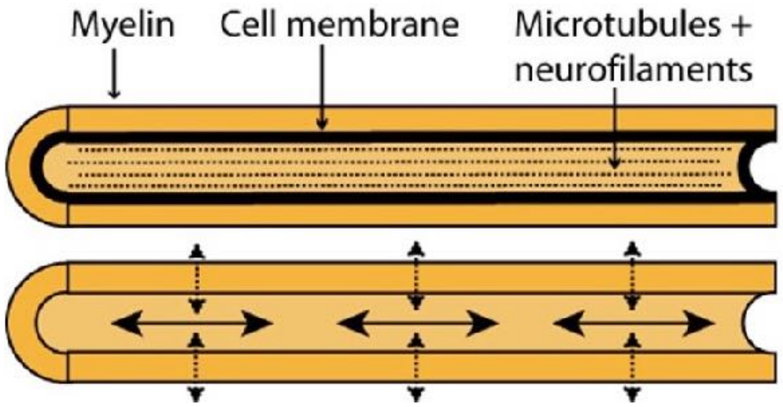
Hagmann et al, 2008

Brownian motion

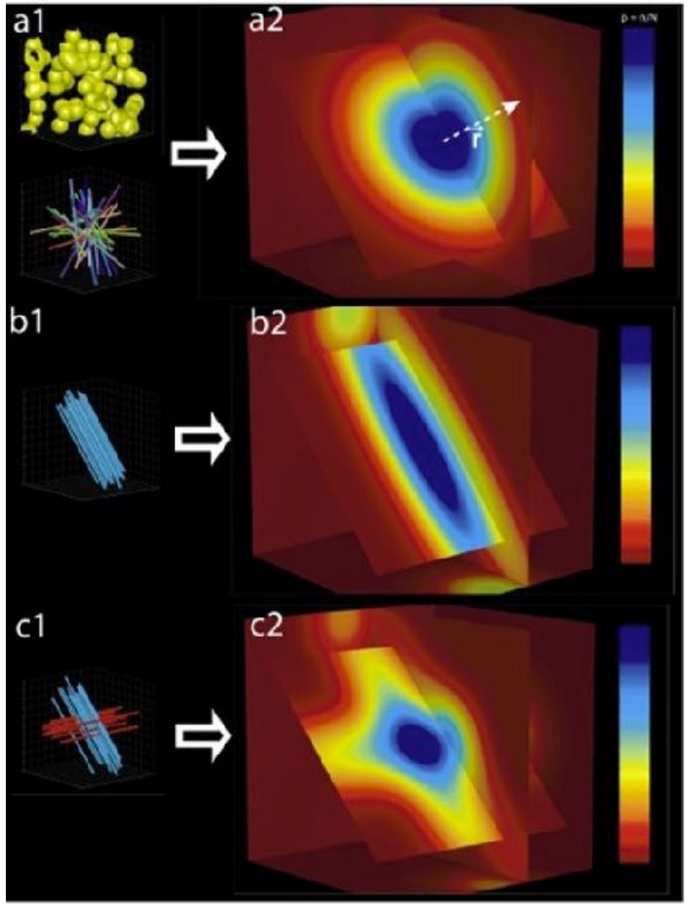




Diffusion restriction

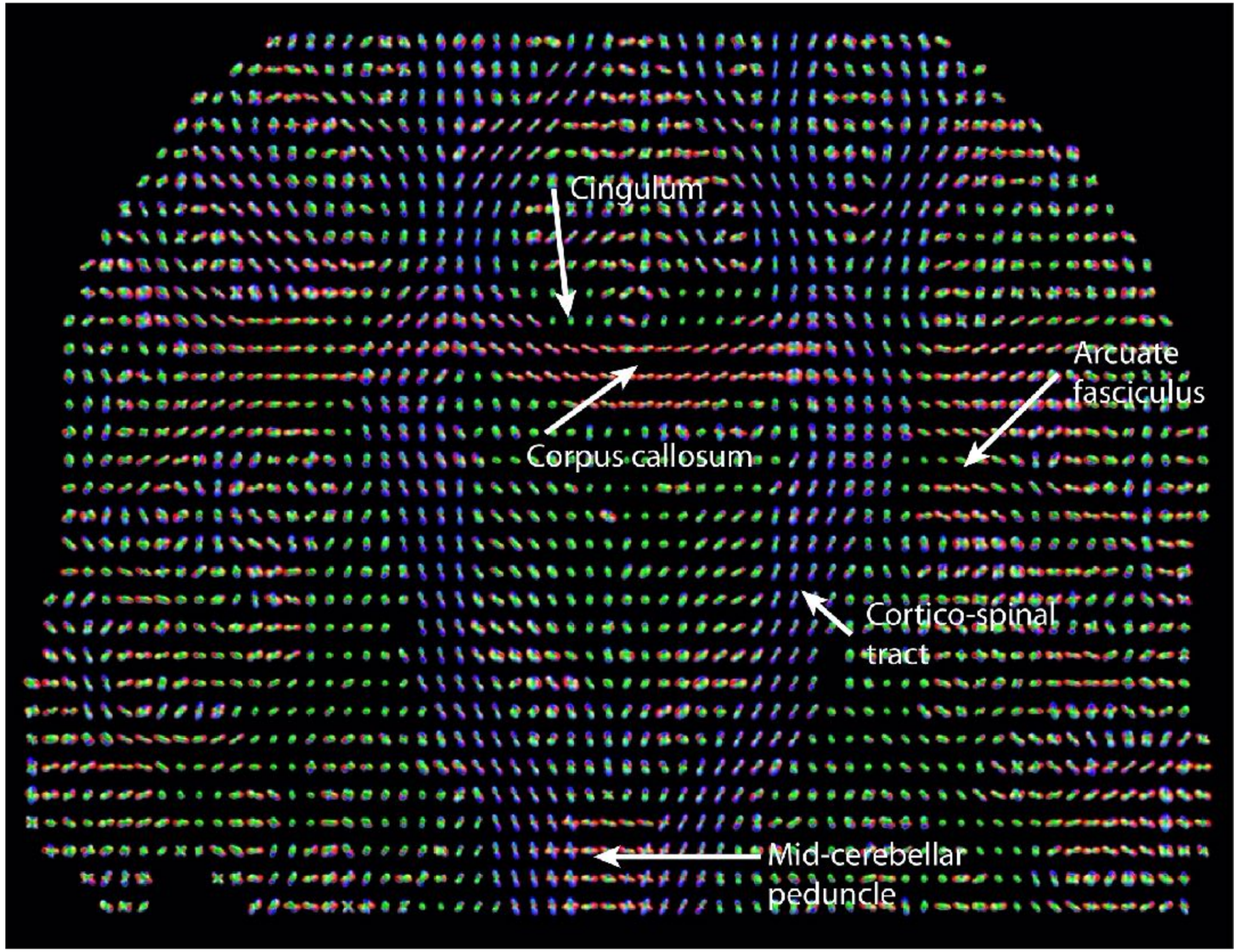


Orientation in tissue

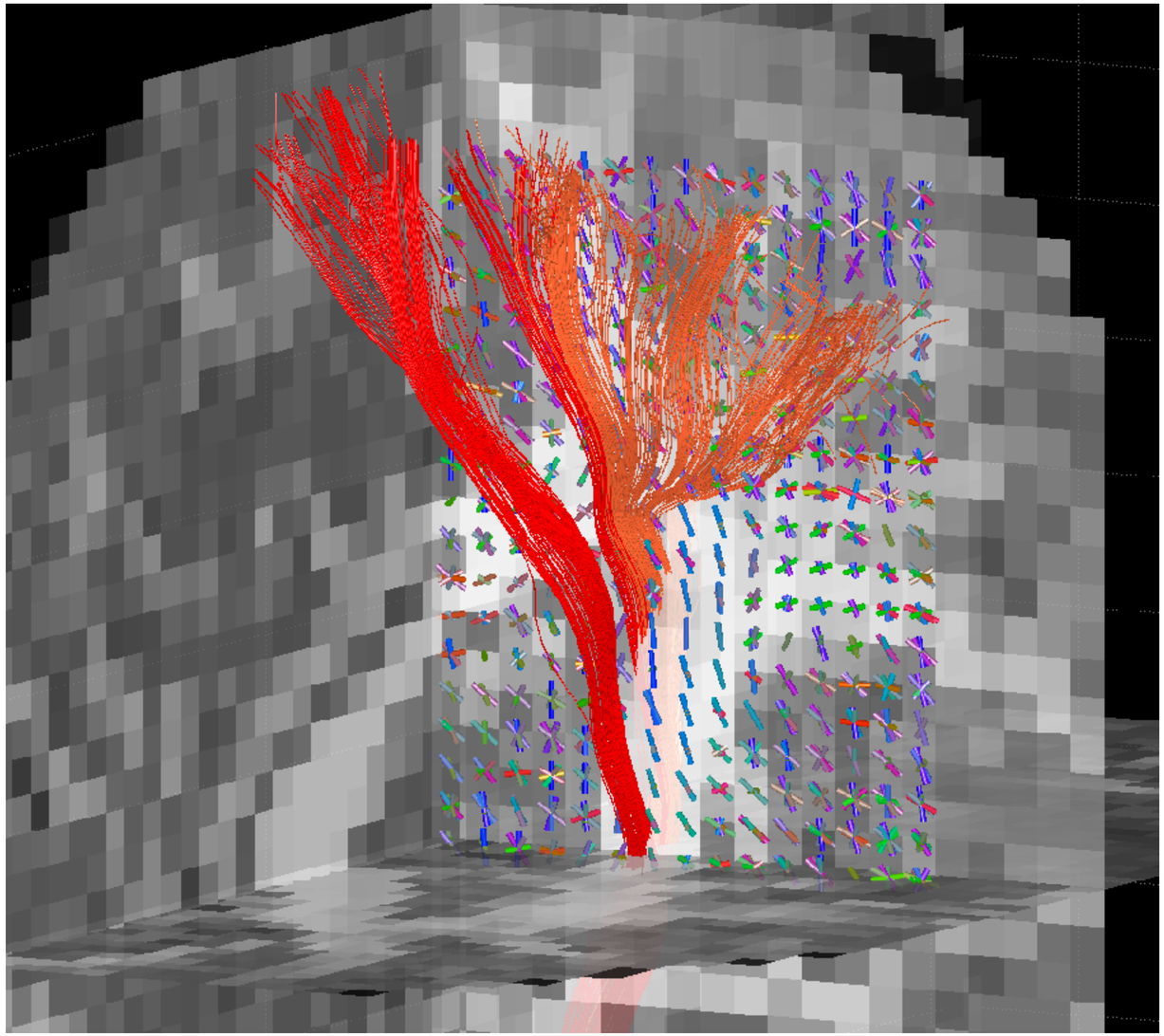


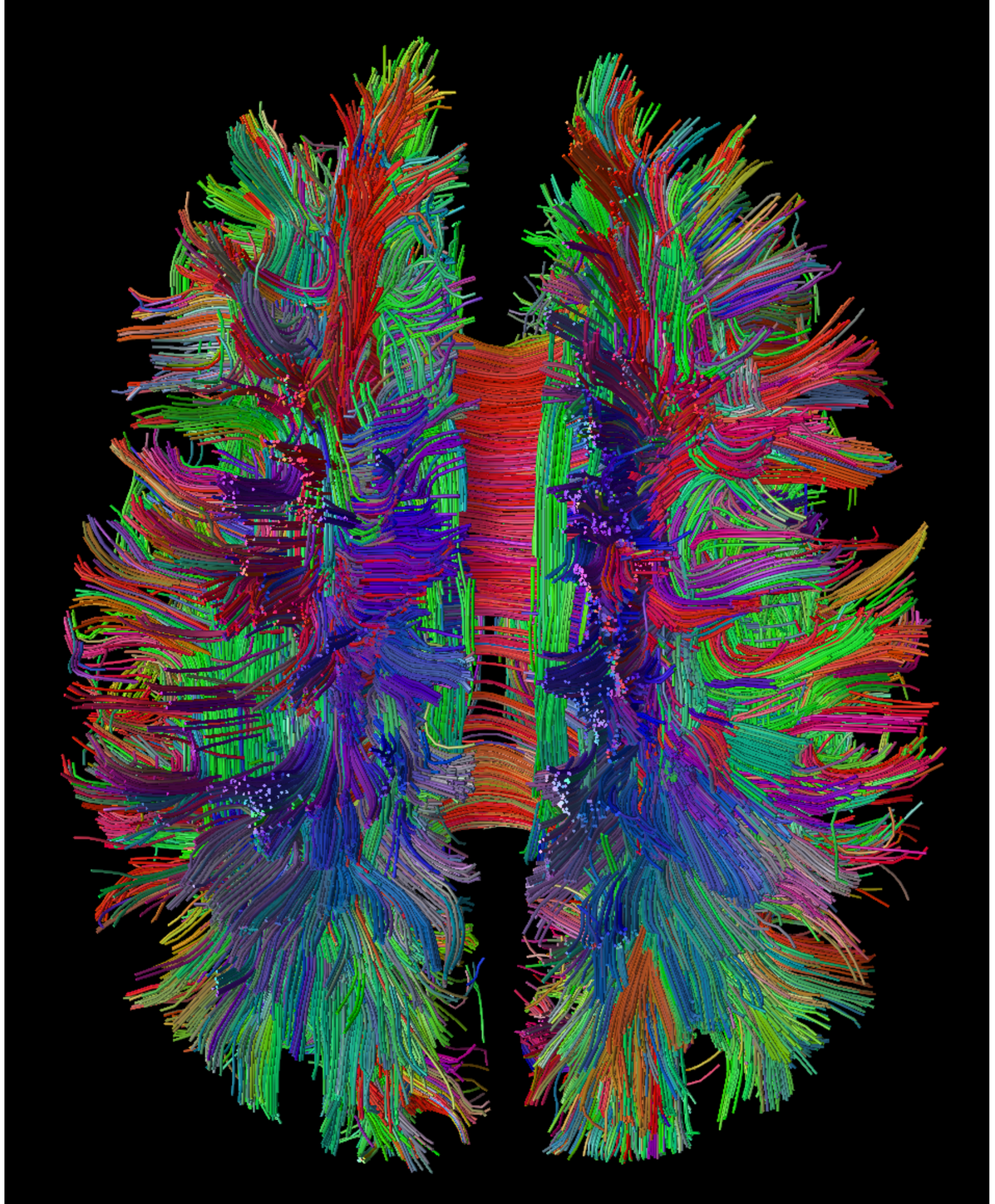
Hagmann et al, Radiographics 2006

Example of diffusion imaging

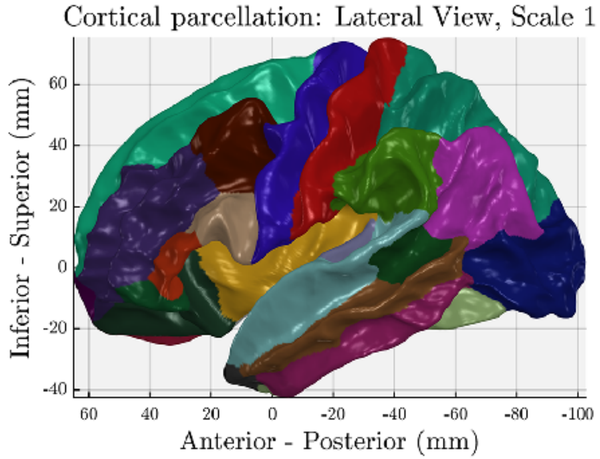


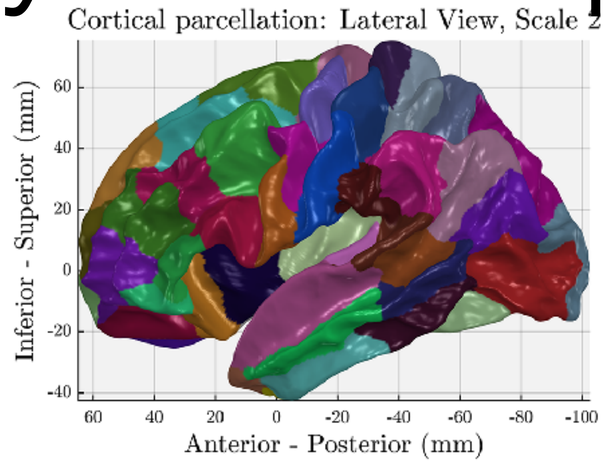
What is tractography ?

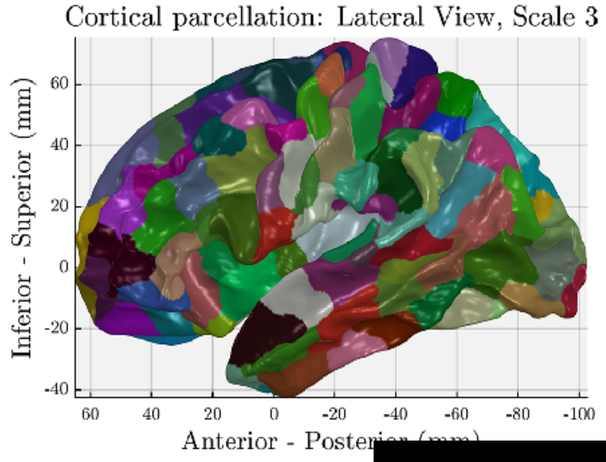


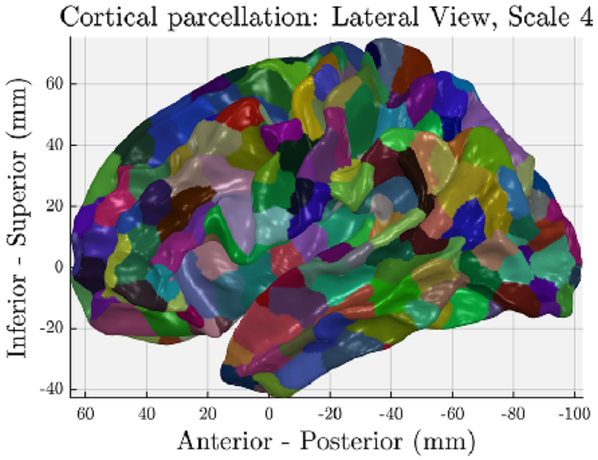


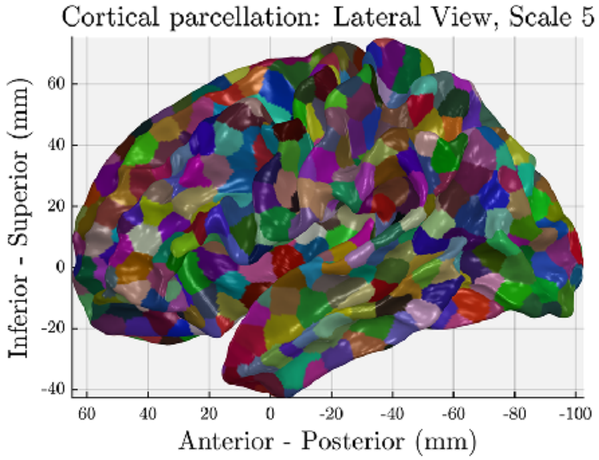
Gray matter parcellation

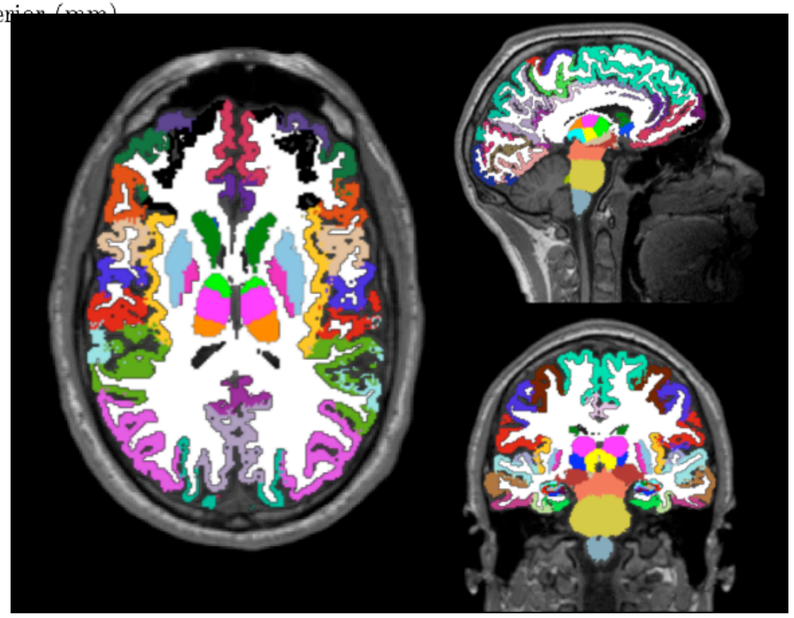






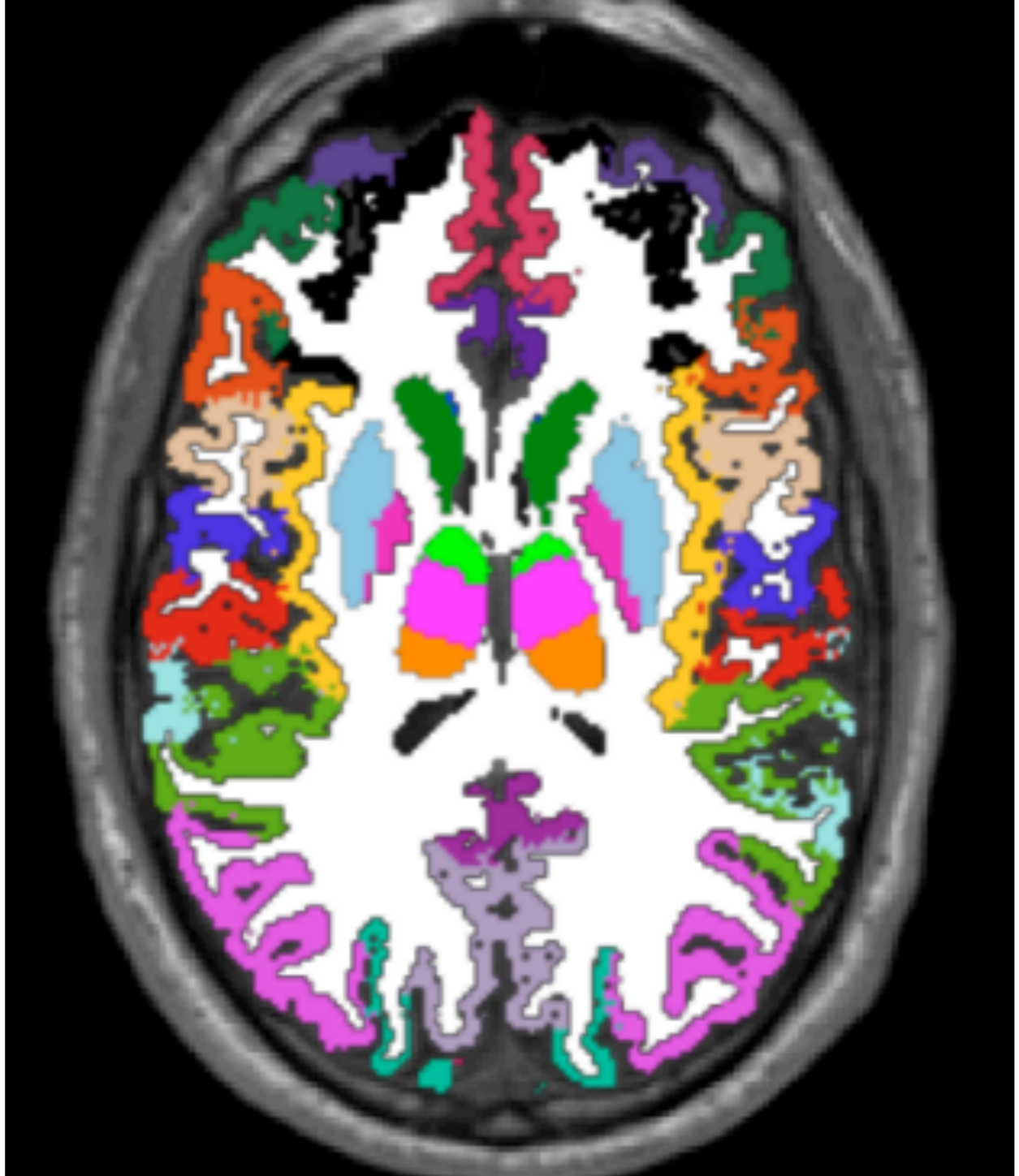


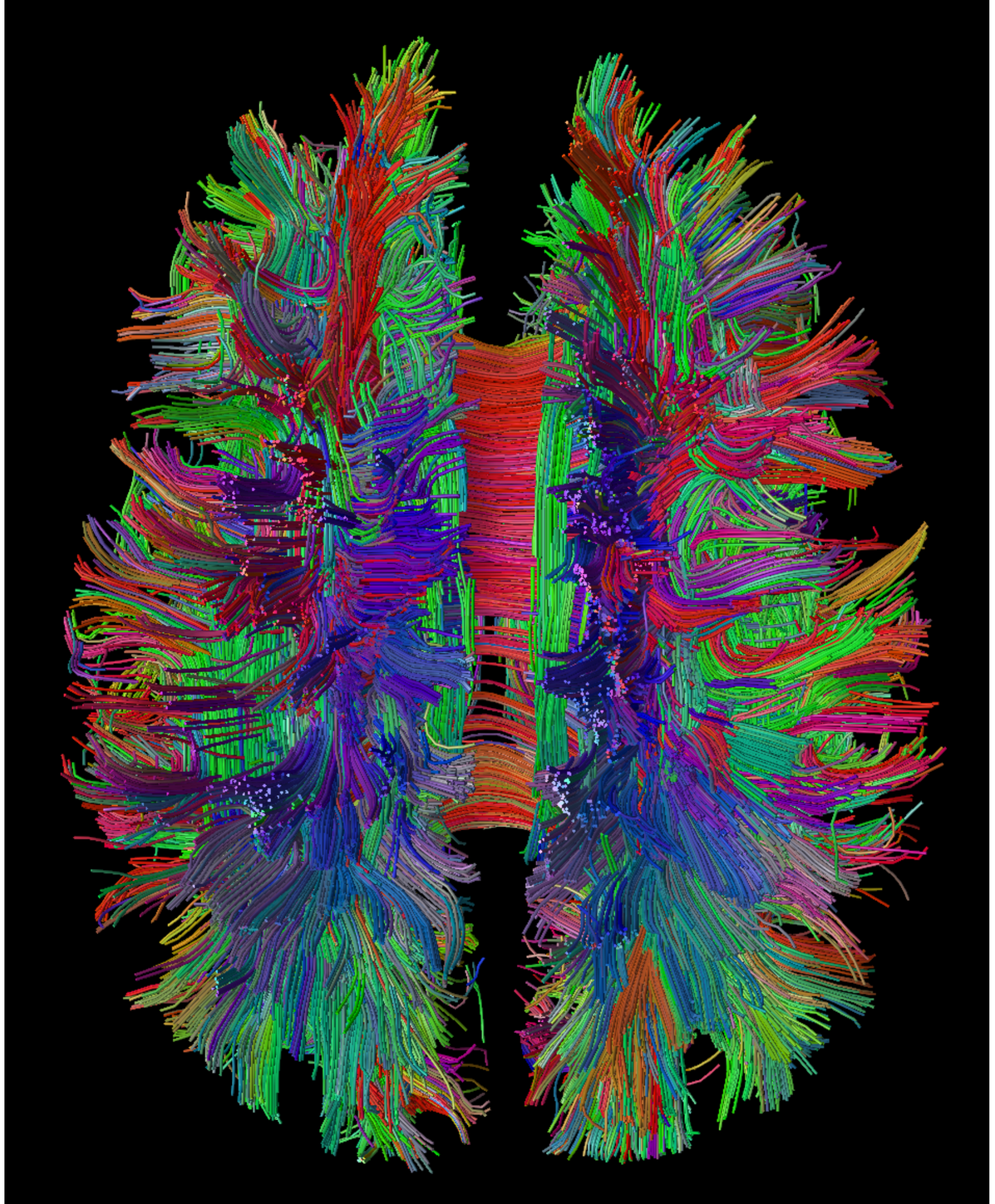


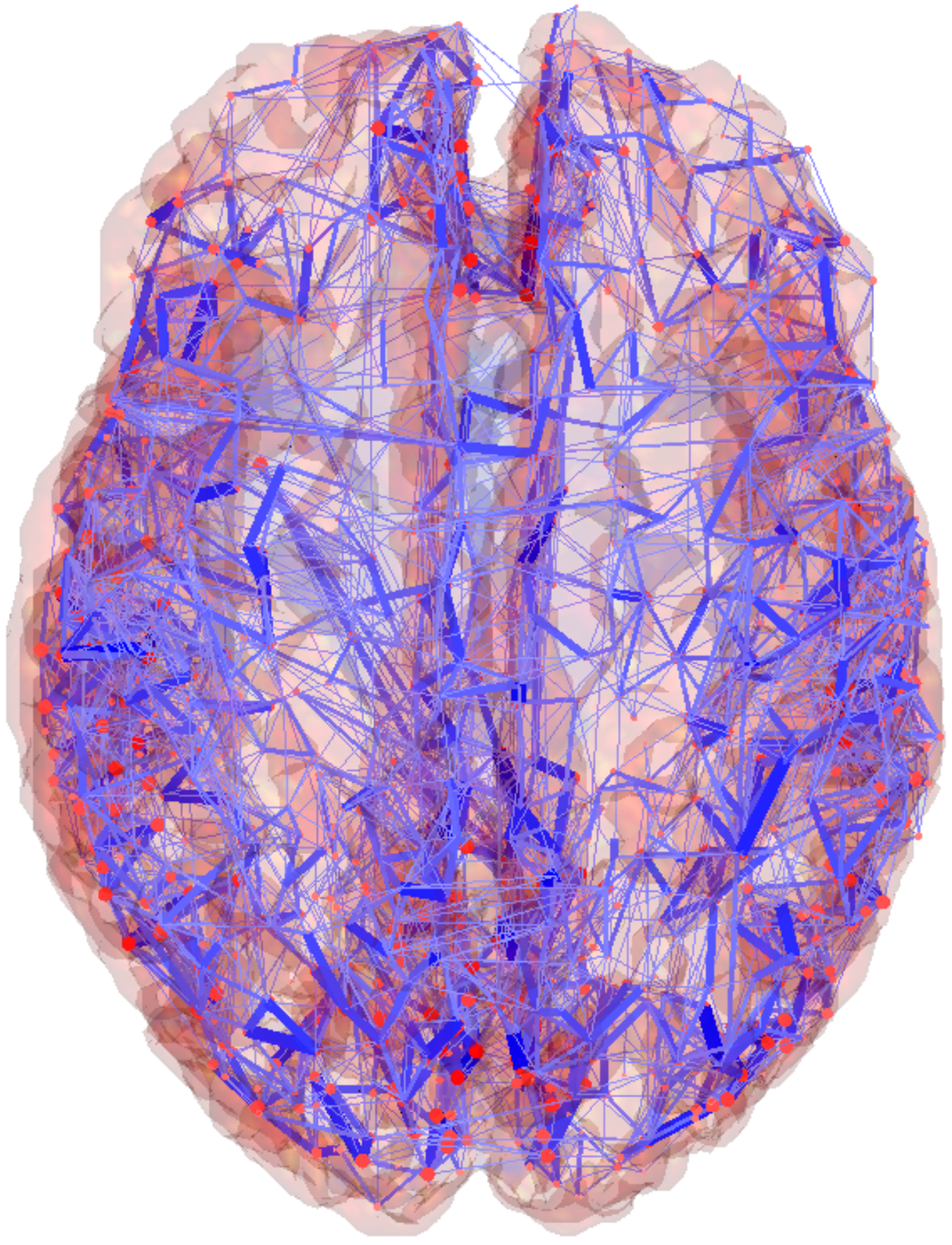


Courtesy Drs Aleman & Tourbier

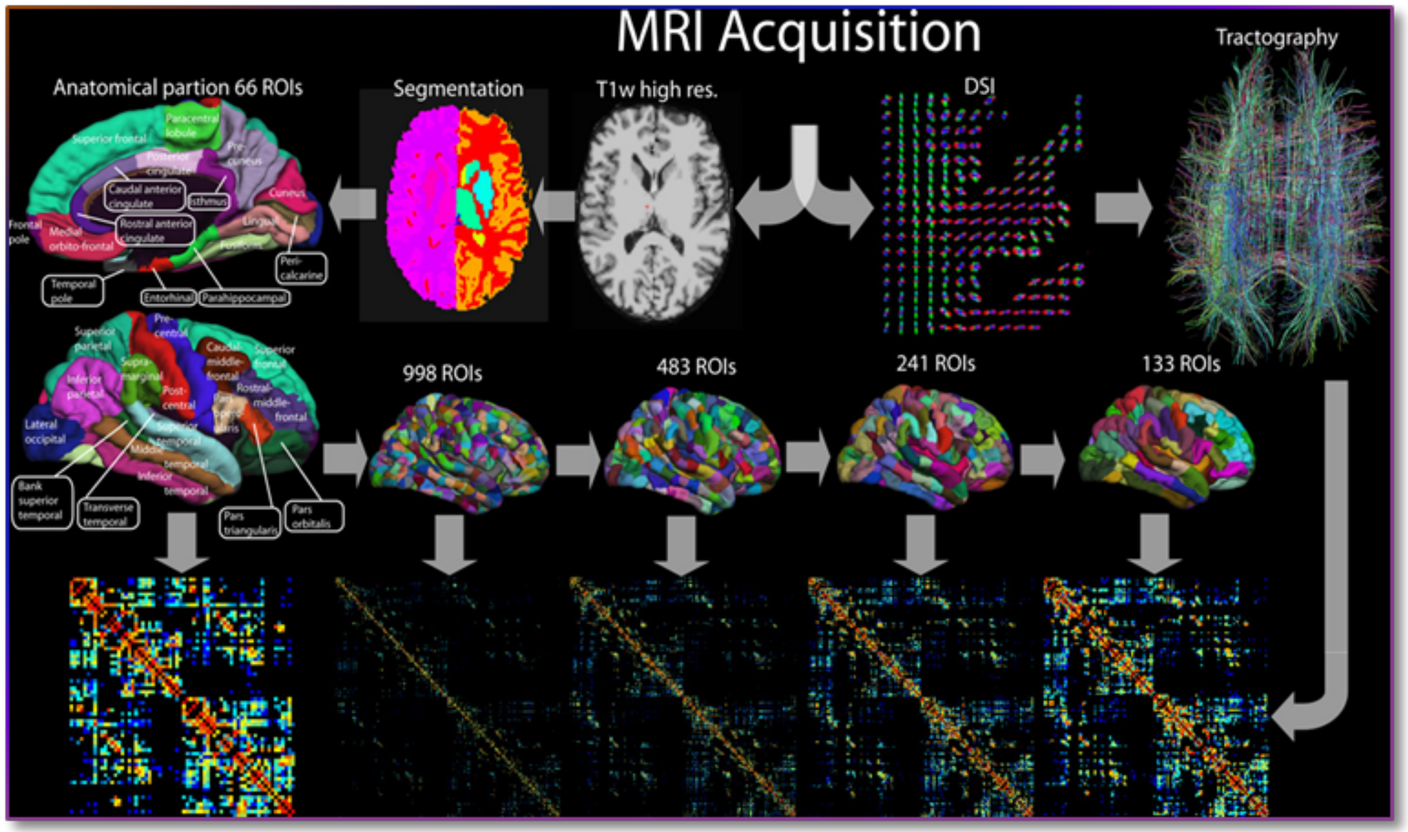
https://multiscalebrainparcellator.readthedocs.io/en/latest/#

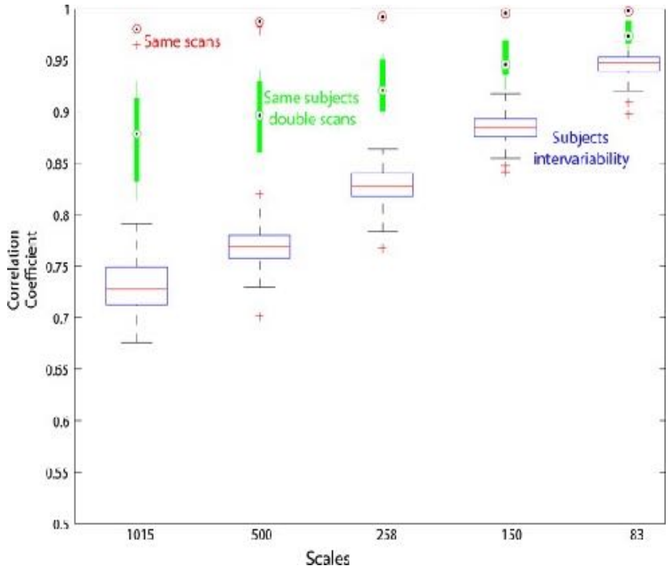






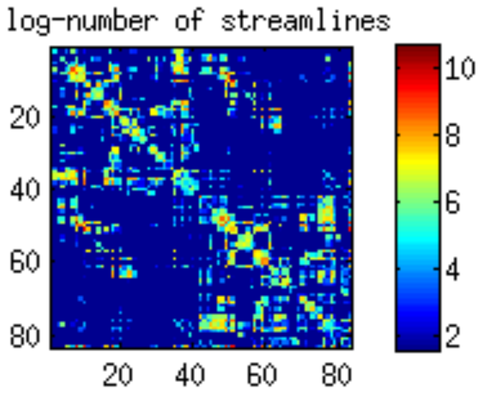
Which cortical partition?

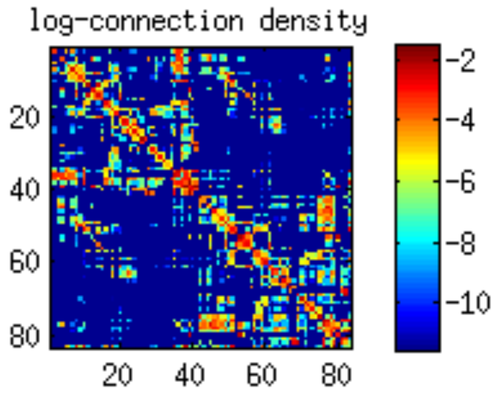


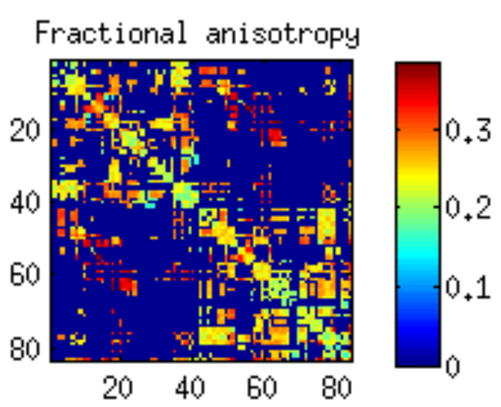


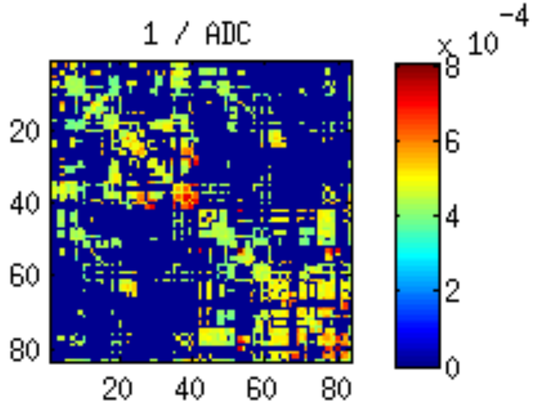
Cammoun & al, JNM 2012

Which edge weight?



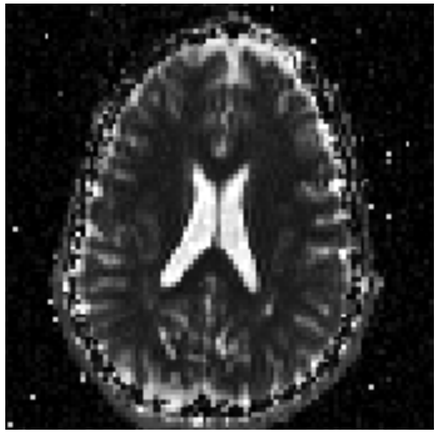




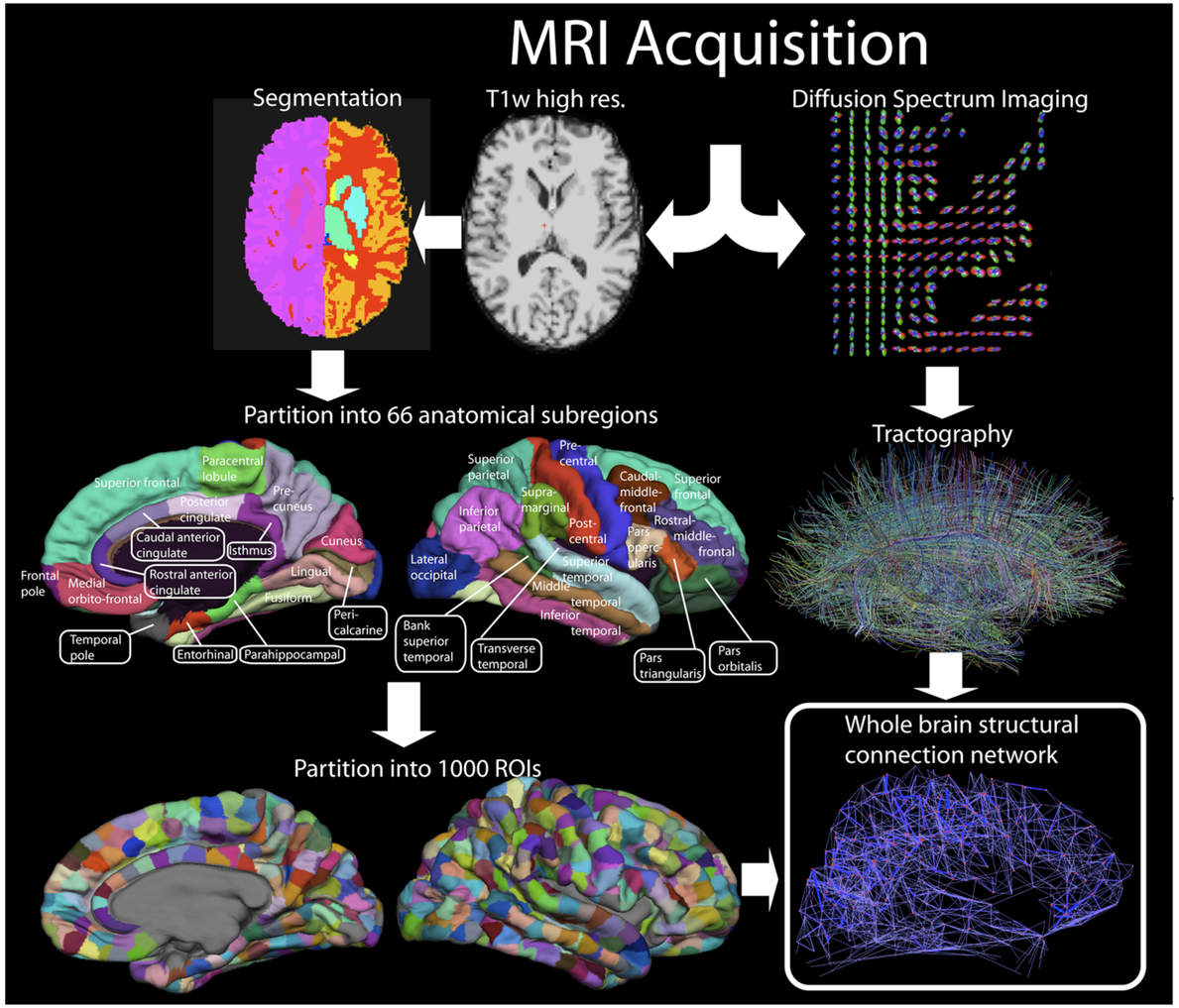


FA scalar map

ADC scalar map

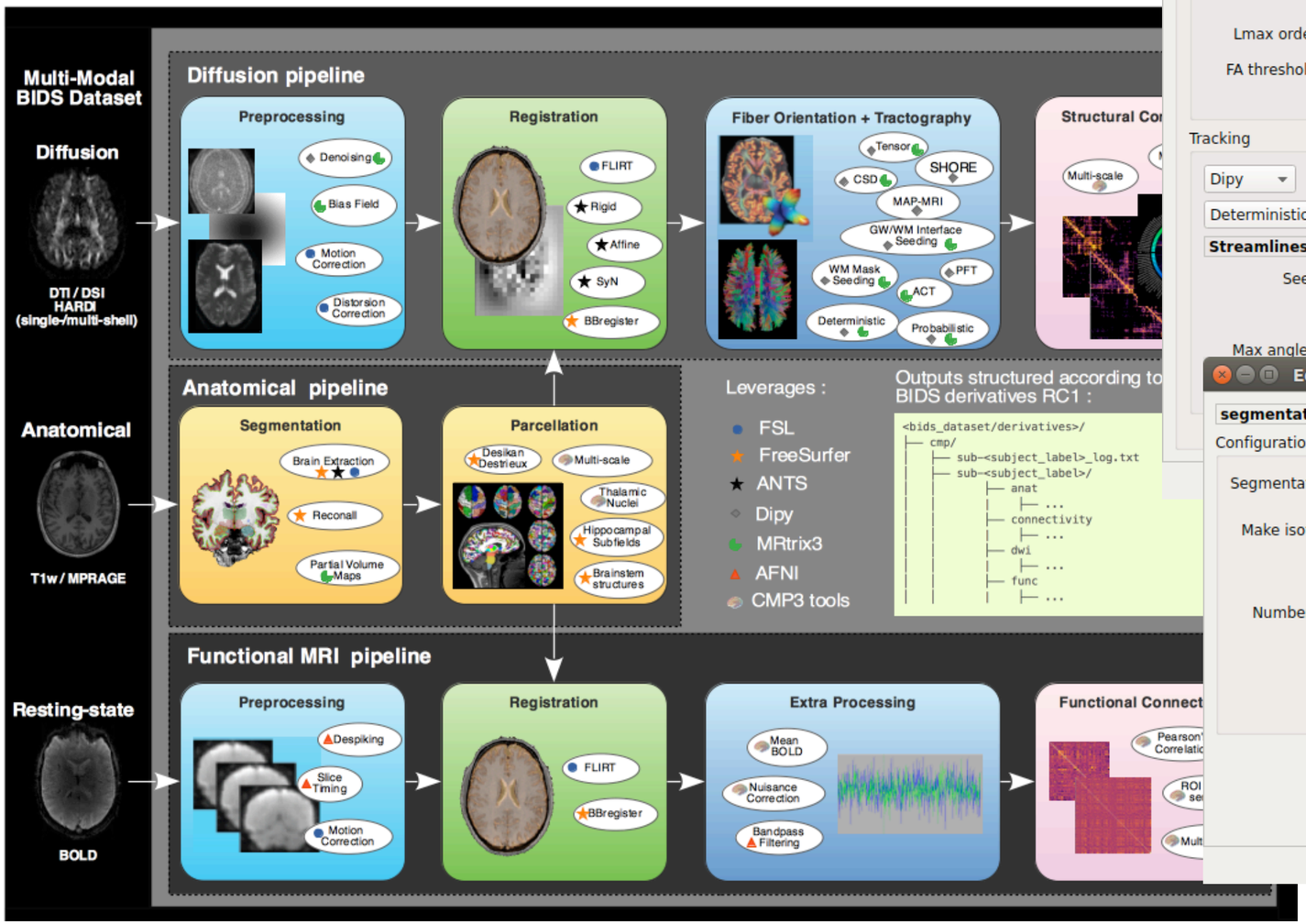


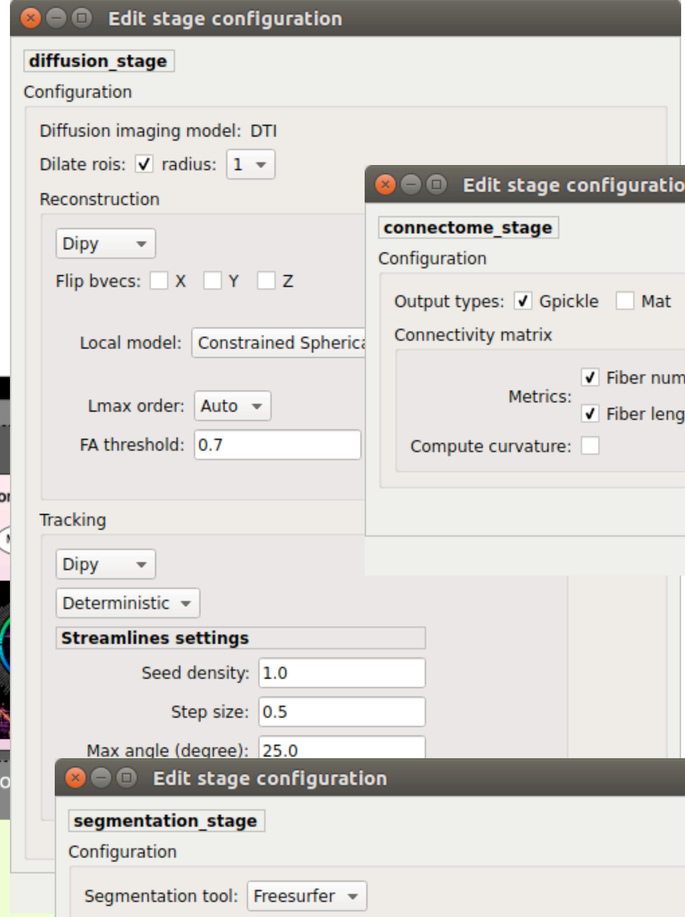
Let’s recap

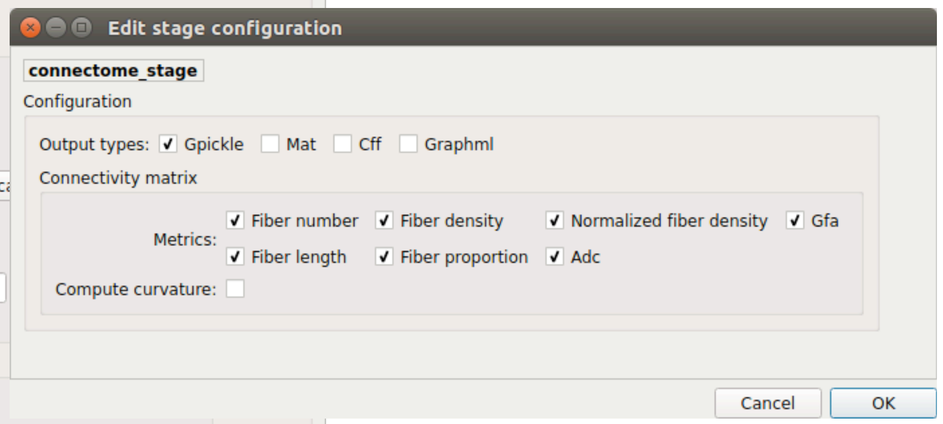


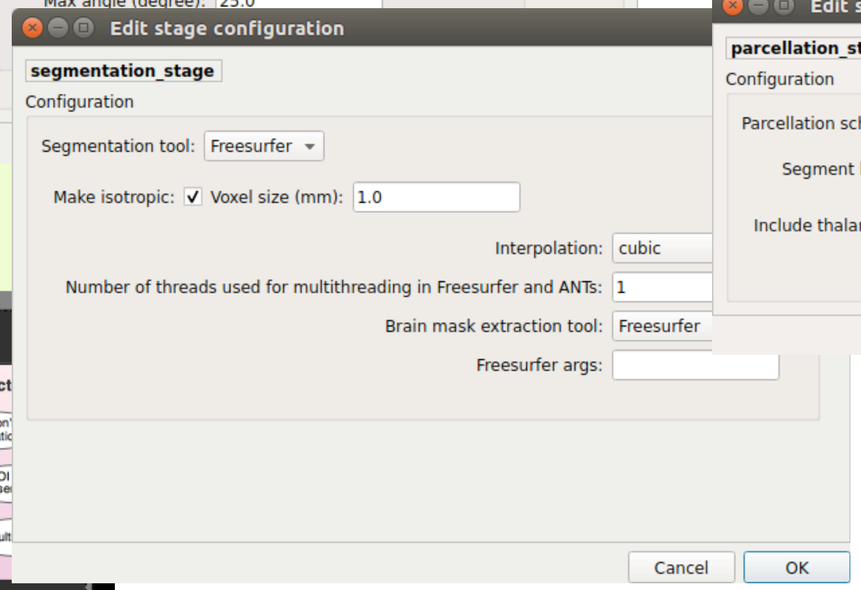
Hagmann et al, 2008

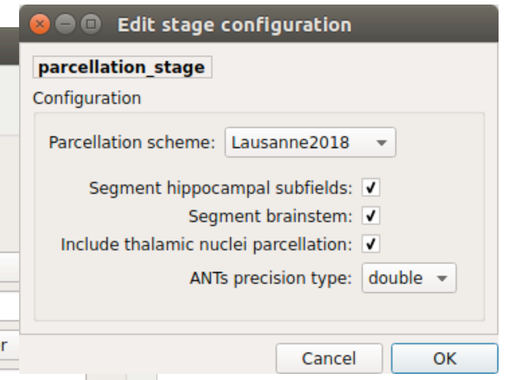
Connectome Mapper 3







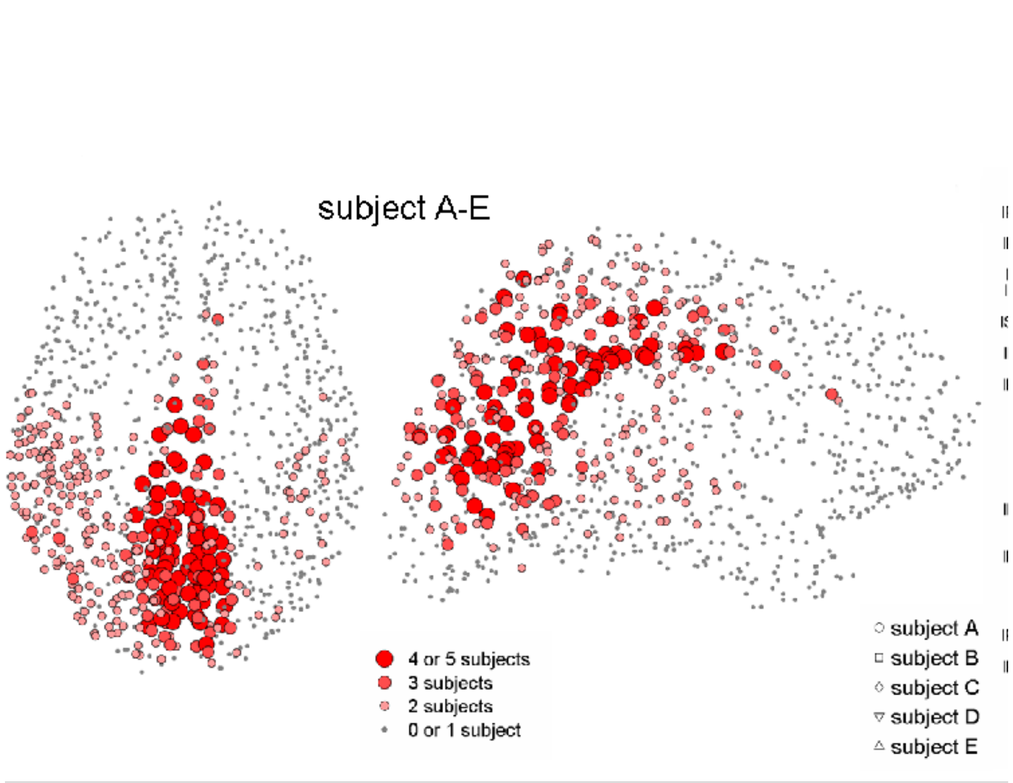


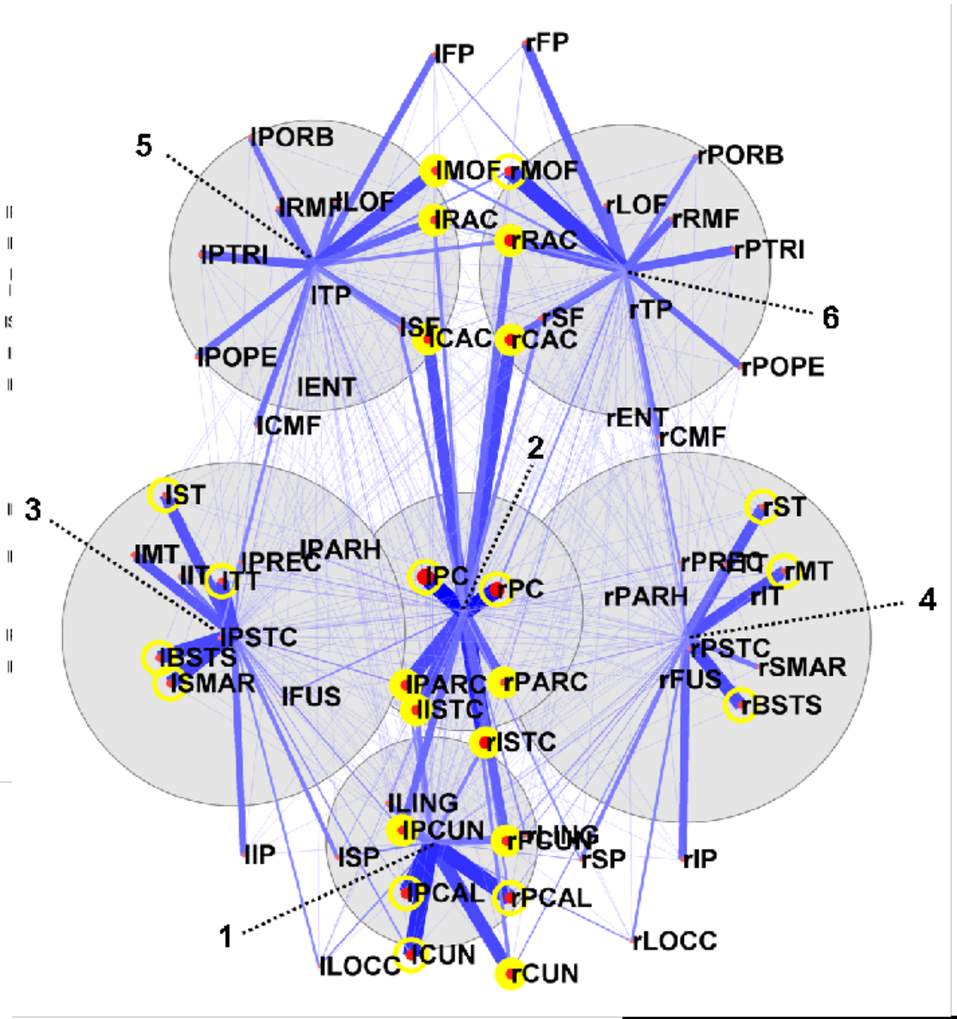


https://connectome-mapper-3.readthedocs.io/en/latest/

Brain Dynamics on the Connectome
Summer School 2021

Now we are ready to analyze the brain network



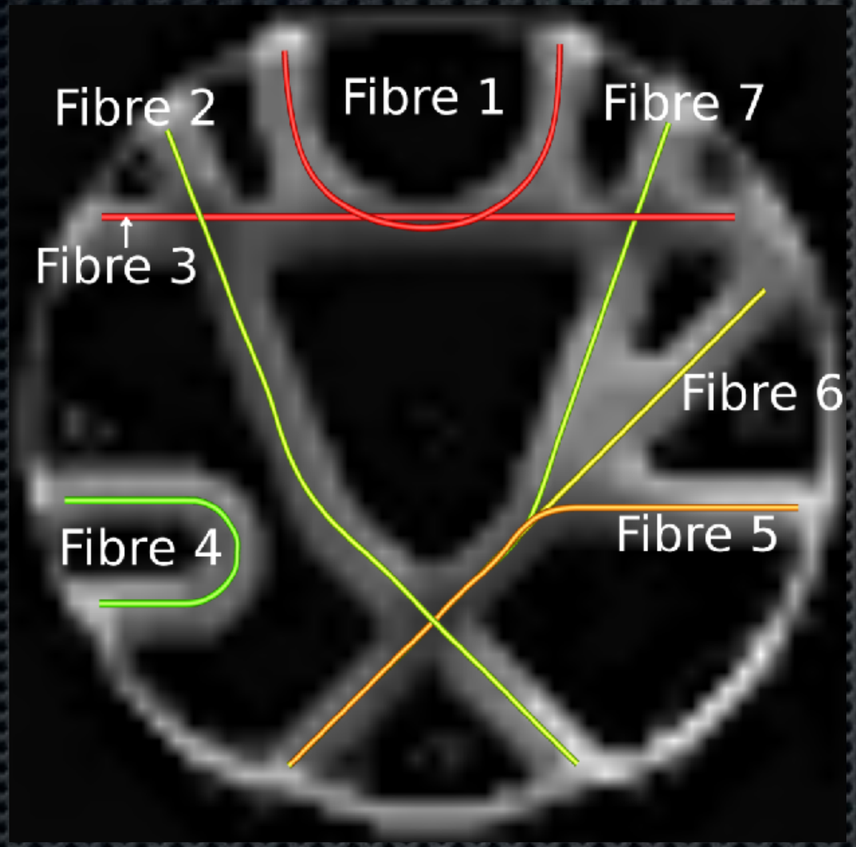


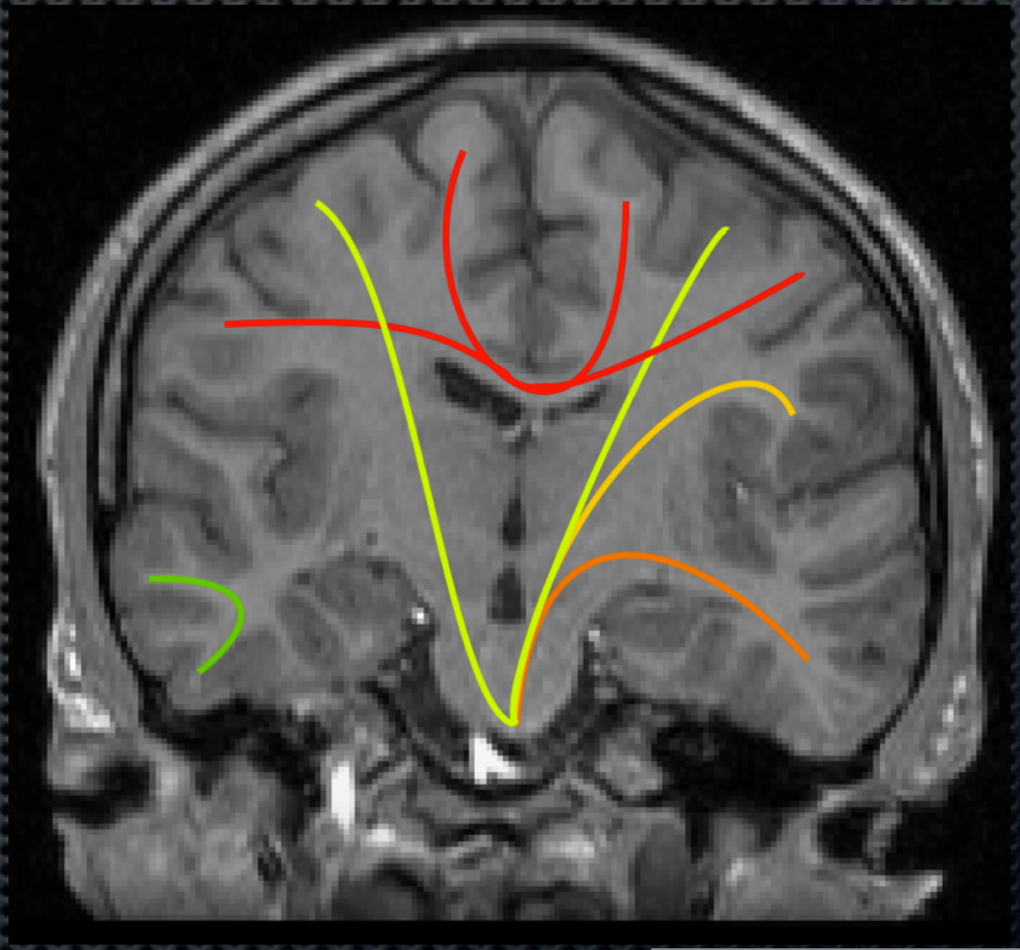
Adapted from Hagmann & al Plos Bio 2008

What about validation?

Courtesy Maxime Descosteaux

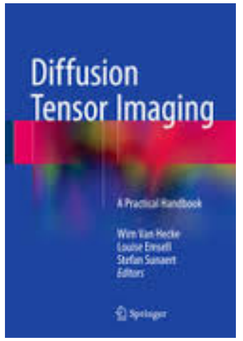
Building synthetic ex vivo phantoms - *FiberCup phantoms*

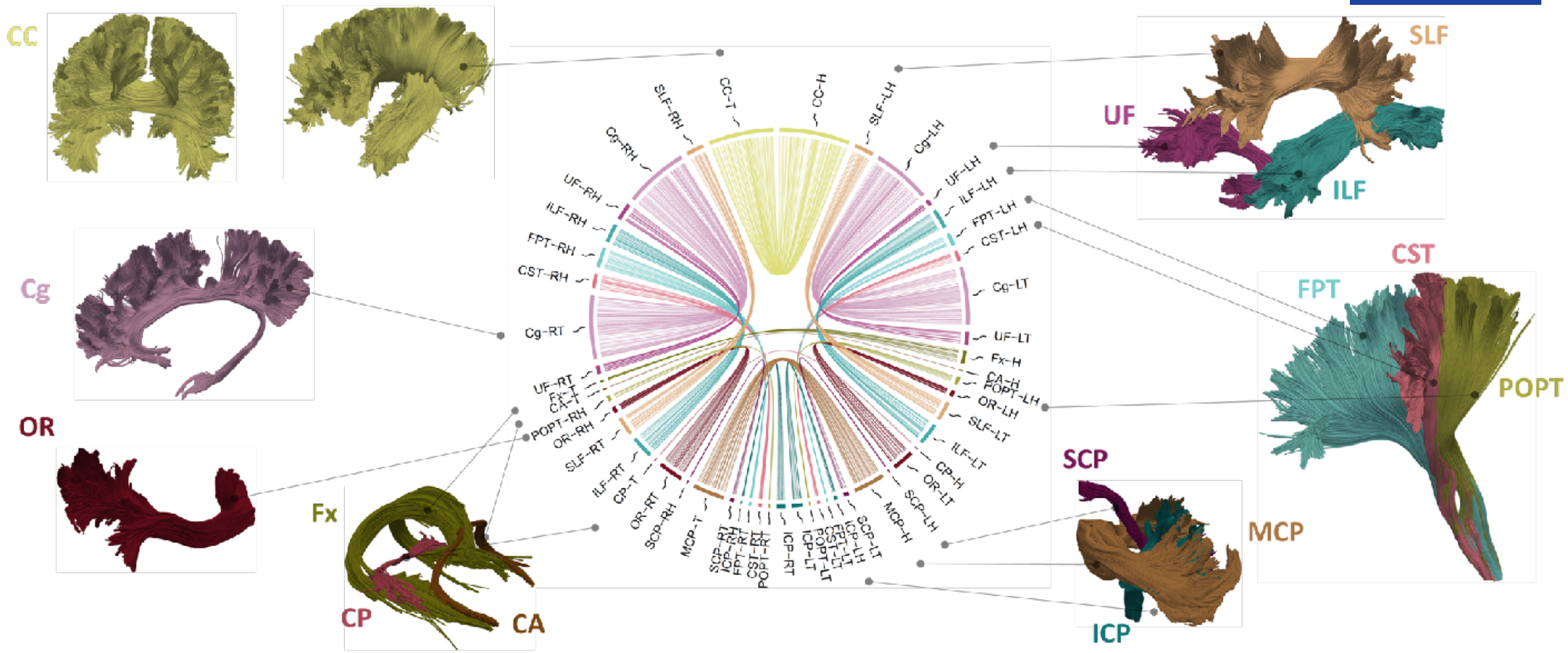




Schilling & al, Mag Res Med 2019

- Includes 25 well-known ground truth bundles
- Exact ground truth connectivity (terminations)
- Covers ~70% of the white matter





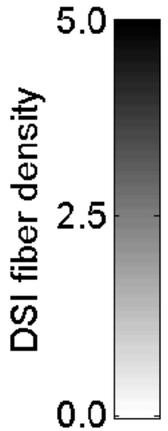
ISMRM 2015 Tractography challenge data

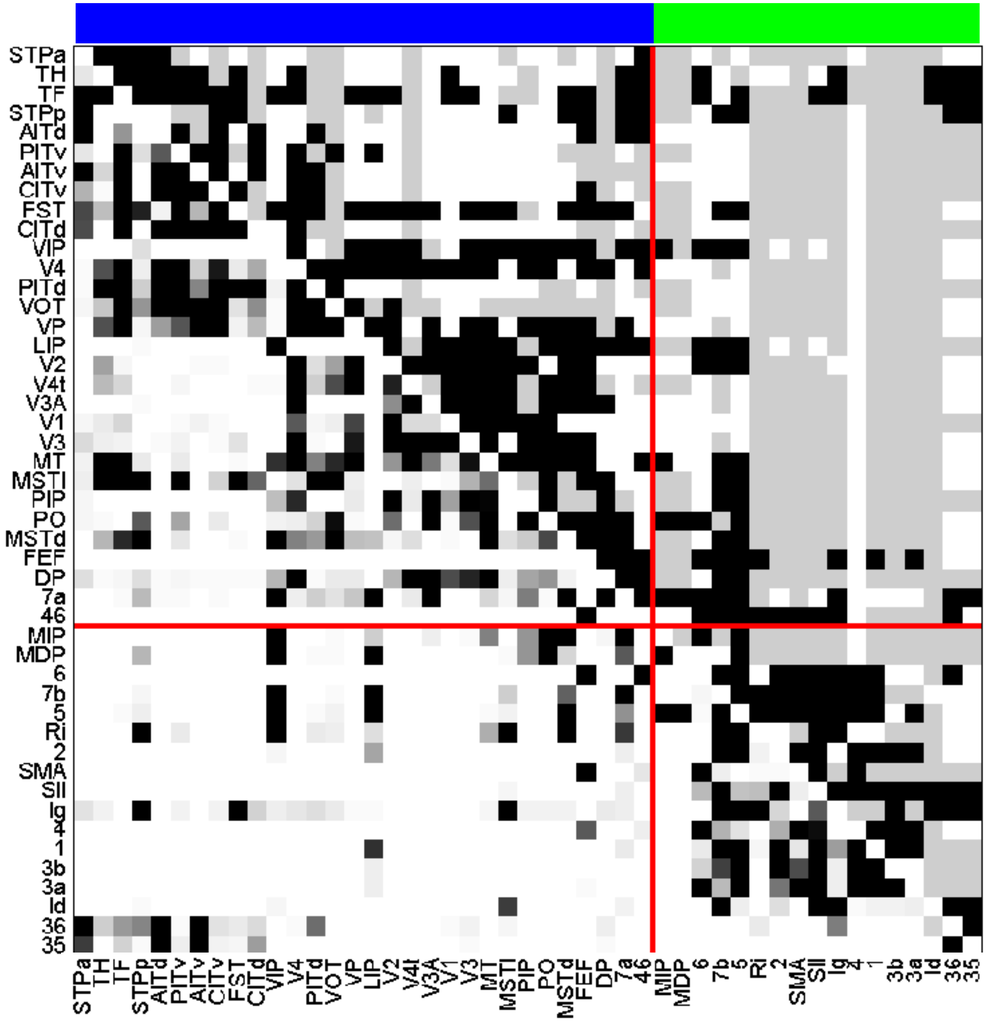
Courtesy Maxime Descosteaux

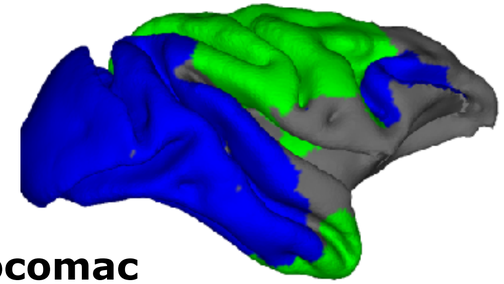
FiberFox: Neher, Laun, Stieltjes, Maier-Hein. Mag Res Med (2014)

Matching DSI with CoCoMac

DSI fiber density







Cocomac data (symmetrized)

known present

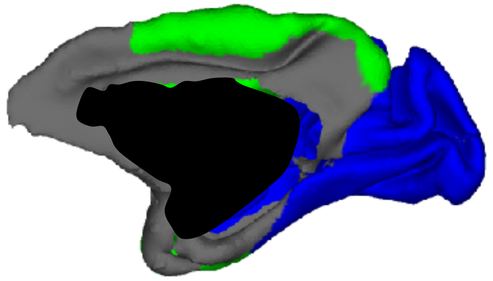
unknown

known absent

79%

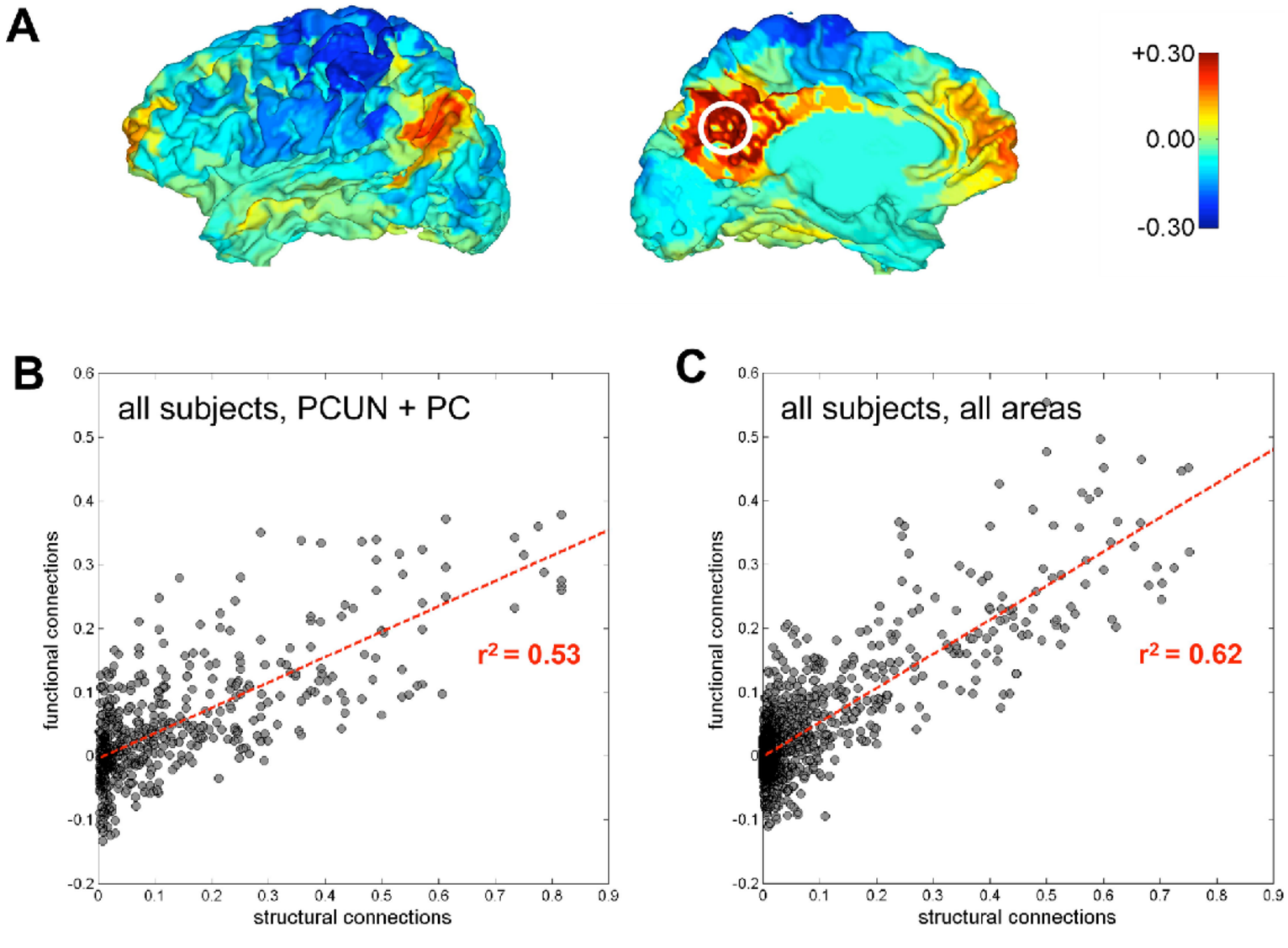
15%

6 %



Adapted from Hagmann & al Plus Bio 2008

In human in-vivo validation



Adapted from Hagmann & al Plos Bio 2008

Thanks to an amazing sinergia team!

… and many who are not on the picture