Open-source diffusion MRI for cancer research

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Diffusion MRI (dMRI)

- Only non-invasive probe of brain's microstructure

- Measure water diffusion in many orientations using MRI

- Map brain connections

- Tractography

slower diffusion

axons

faster diffusion
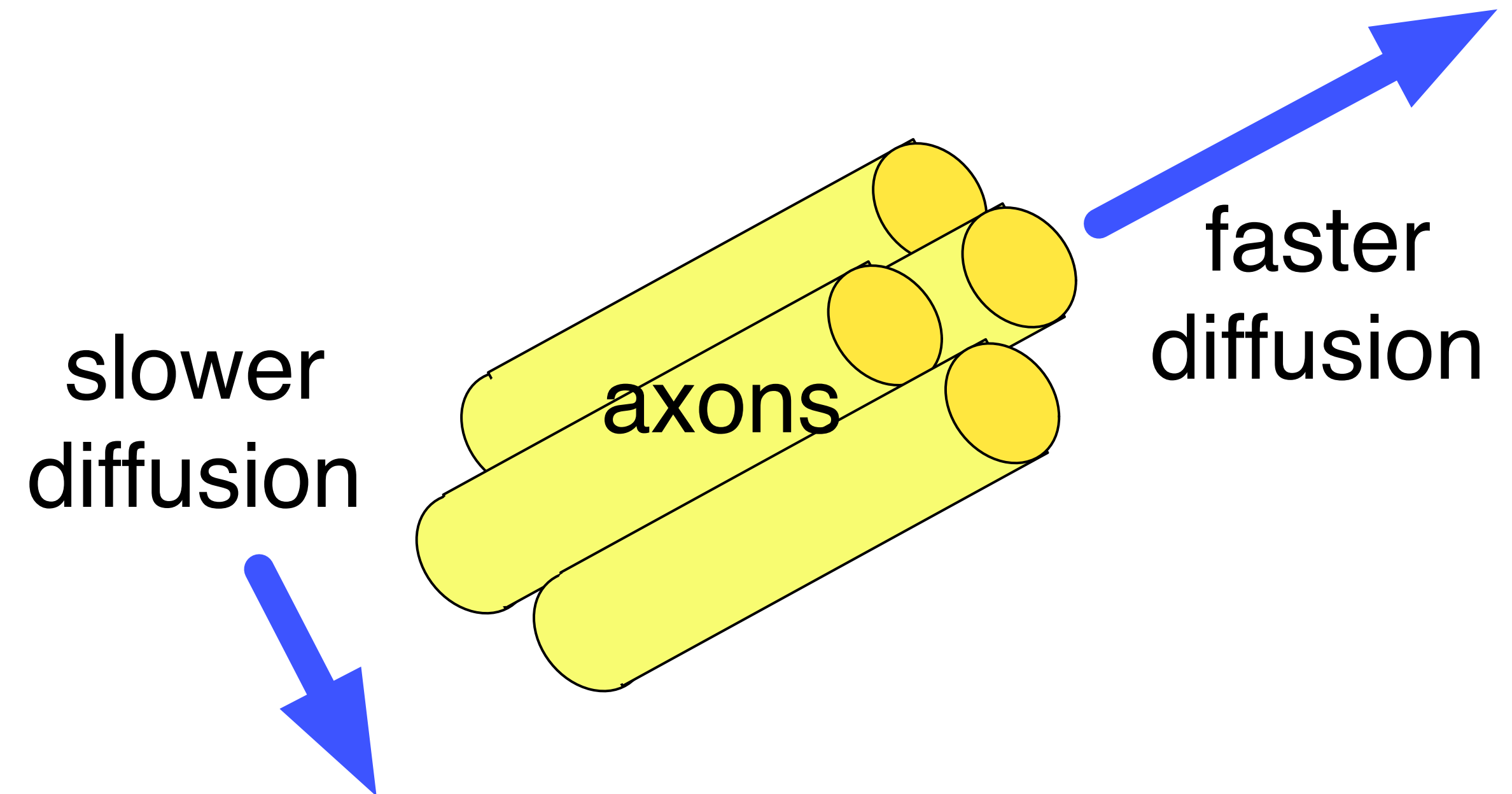
Neurosurgery for Brain Tumors

- Maximal tumor resection improves patient outcome

- dMRI: Map white matter tracts

- dMRI: Map brain microstructure

- dMRI is used for surgical planning and neuronavigation during surgery.

glioblastoma
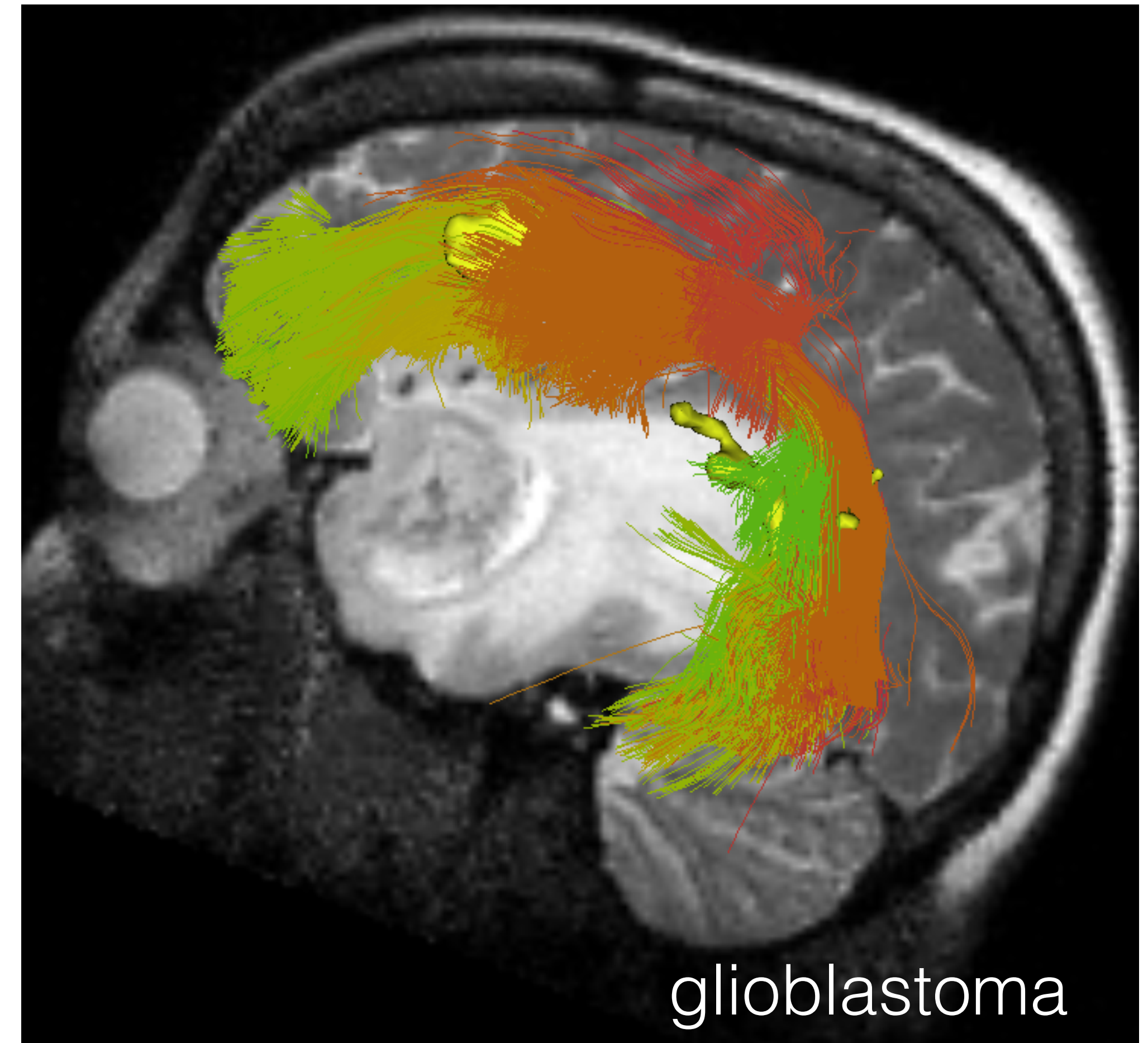
SlicerDMRI U01

- Create state-of-the-art dMRI workflows for brain cancer research.

- 3D Slicer: Open-source platform for visualization, surgical planning, surgical navigation, and medical image computing

- Latest improvements are available:

  - www.slicer.org

  - https://github.com/SlicerDMRI
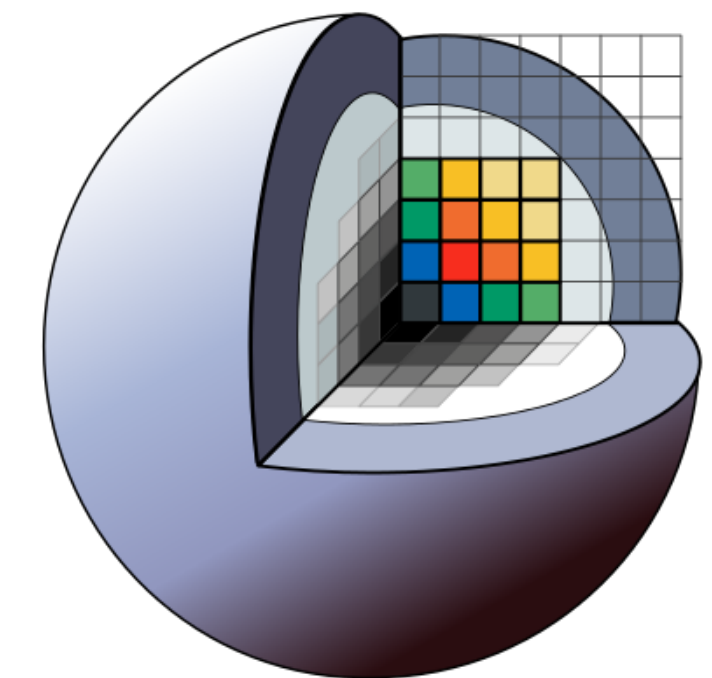
Year 1: DICOM Tractography

- First implementation of the standard

- DCMTK: Open-source DICOM library

- Slicer DICOM I/O module

- DICOM <-> major research formats

- Future interoperability with commercial neurosurgical neuronavigation!

Table C.8.X-2
TRACTOGRAPHY RESULTS MODULE ATTRIBUTES

| Attribute Name	Tag	Type	Attribute Description
Include Table 10-12 "Content Identification Macro Attributes"			
Content Date	(0008,0023)	1	The date the content creation started.
Content Time	(0008,0033)	1	The time the content creation started.
Track Set Sequence	(0066,0101)	1	Describes the track sets that are contained within the data. One or more Items shall be included in this sequence.
>Track Set Number	(0066,0105)	1	Identification number of the Track Set. Uniquely identifies a track set within this SOP instance. Shall start at a value of 1, and increase monotonically by 1.

Research: Tractography for Neurosurgery

- Tractography challenges: crossing fibers, edema, displacement

- Analysis challenge: identify key tracts from 100,000's of fibers

Tractography

Language

Motor
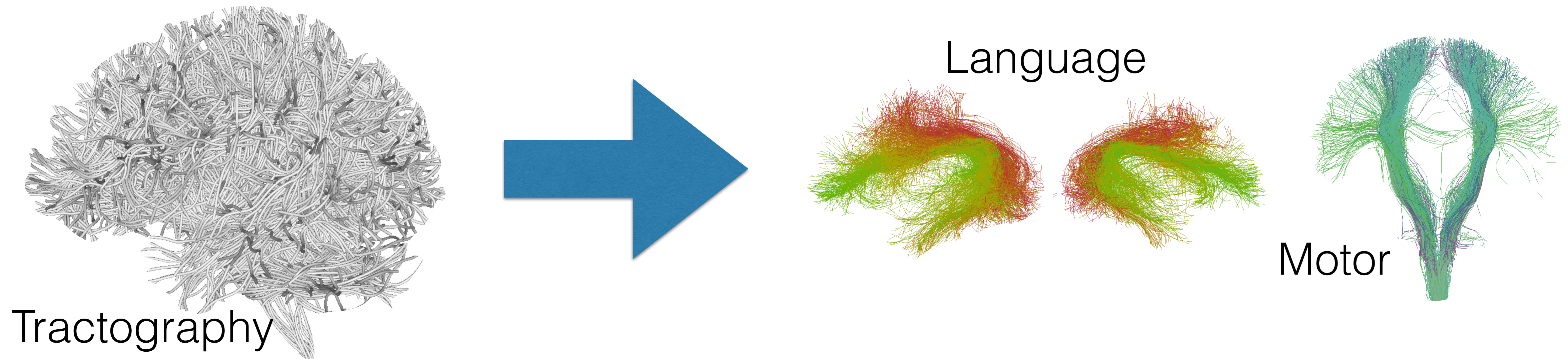
Challenge: Crossing Fibers

- Clinical method: Diffusion tensor (DTI)

- Models one tract per voxel

- Multi-fiber models needed [1] [2]
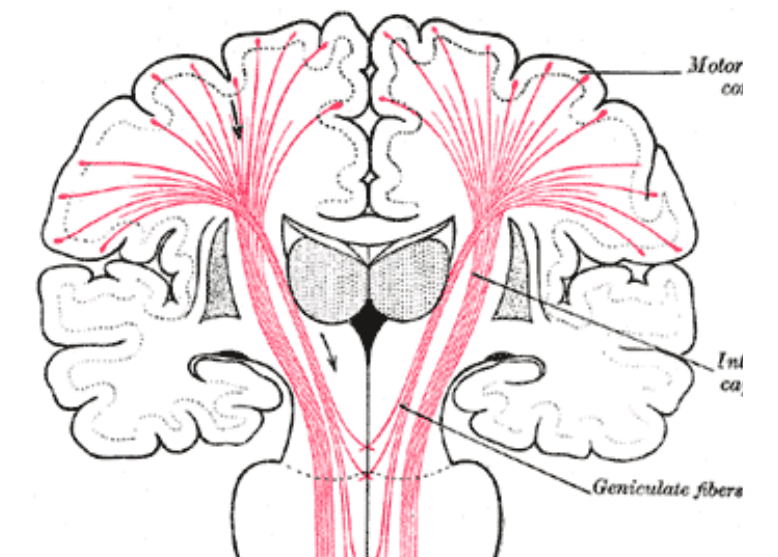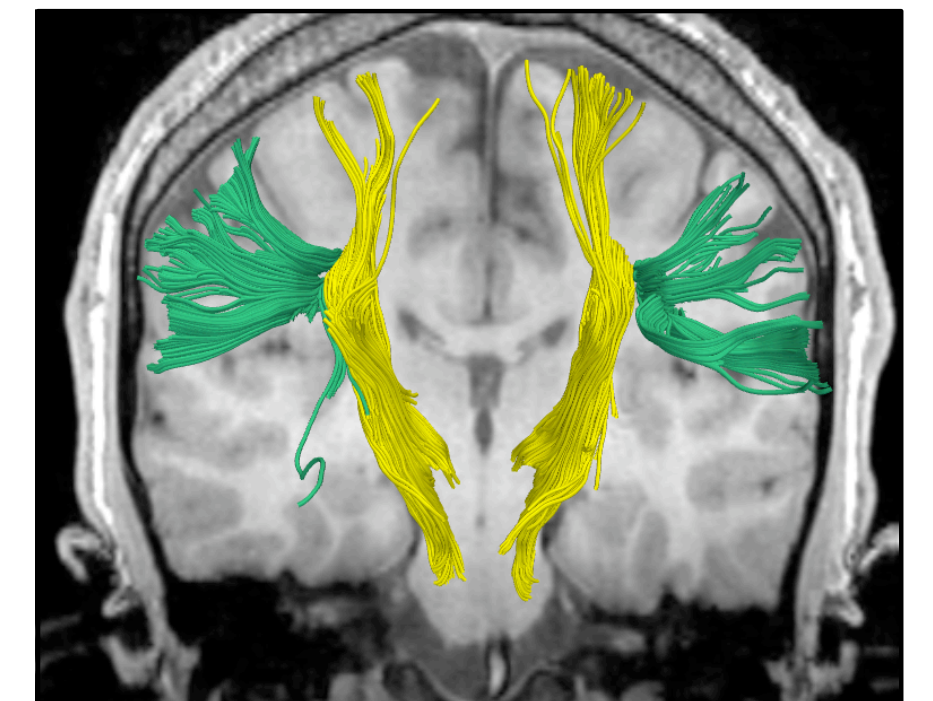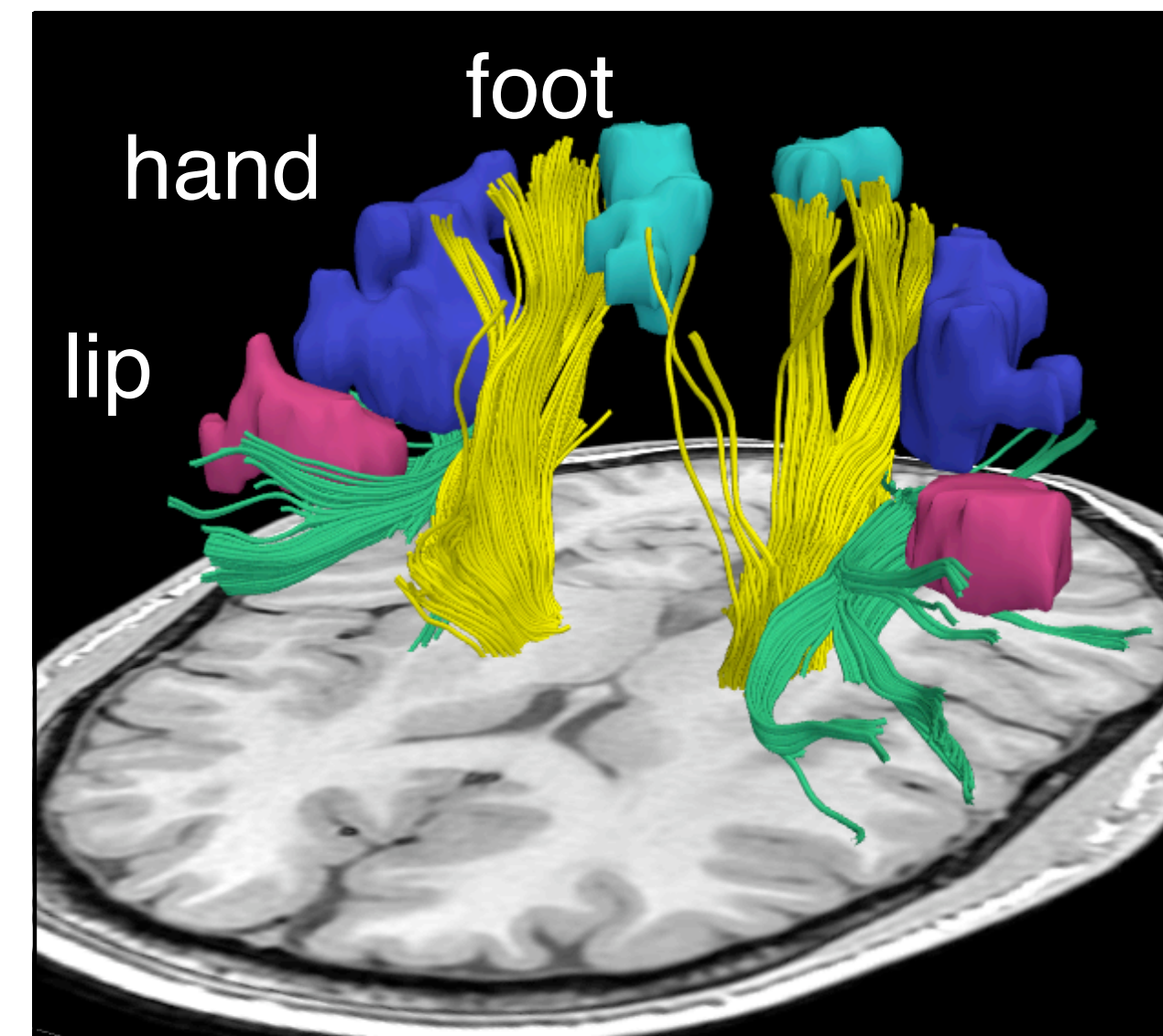
false negative

[1] A. A. Qazi, A. Radmanesh, L. O'Donnell, G. Kindlmann, S. Peled, S. Whalen, C.-F. Westin, A.J. Golby, Resolving crossings in the corticospinal tract by two-tensor streamline tractography: method and clinical assessment using fMRI, NeuroImage 47 (2009) T98–T106
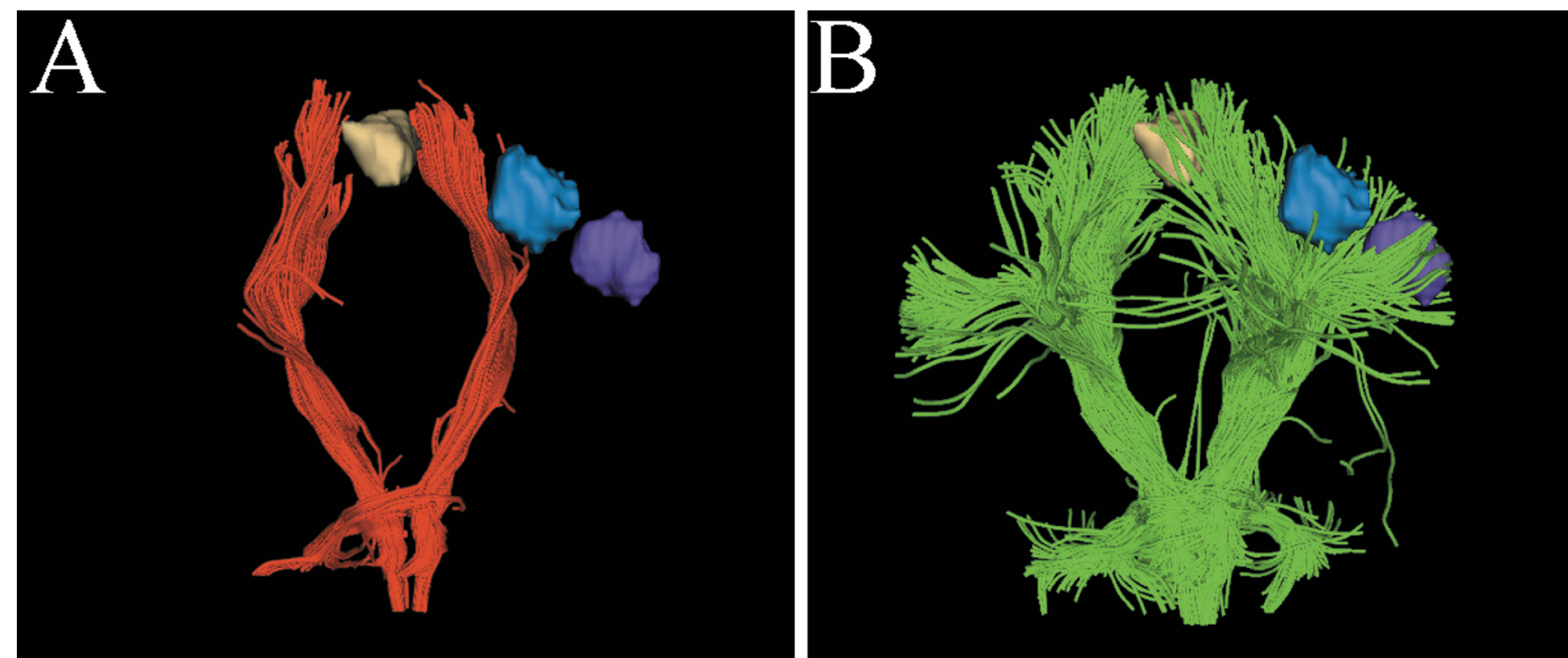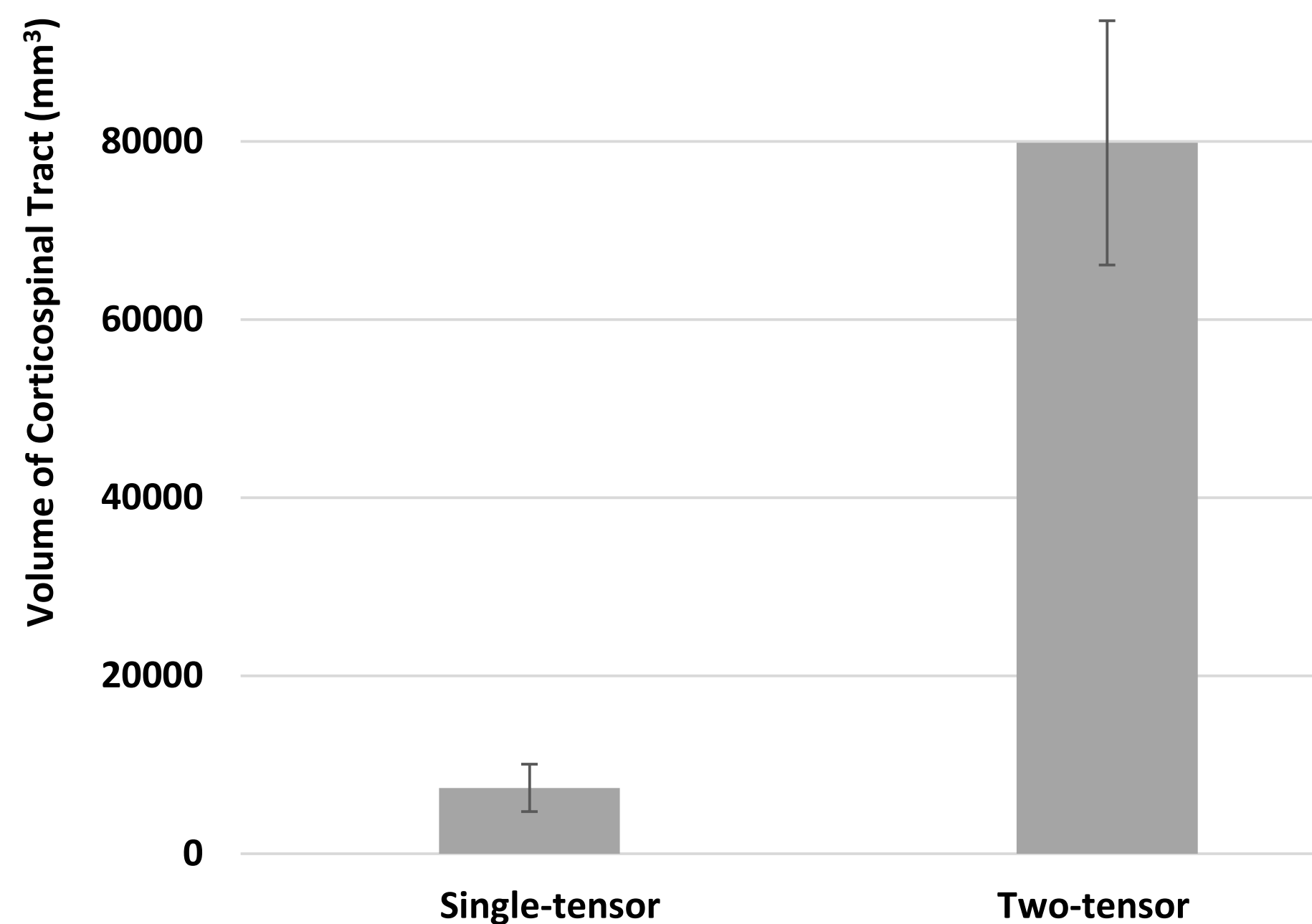
[2] C. Nimsky, Fiber tracking – we should move beyond diffusion tensor imaging, World neurosurgery 2014

Challenge: Edema

- Peritumoral edema increases water around tumor

- Changes dMRI signal

- Increases difficulty of tractography

metastatic carcinoma
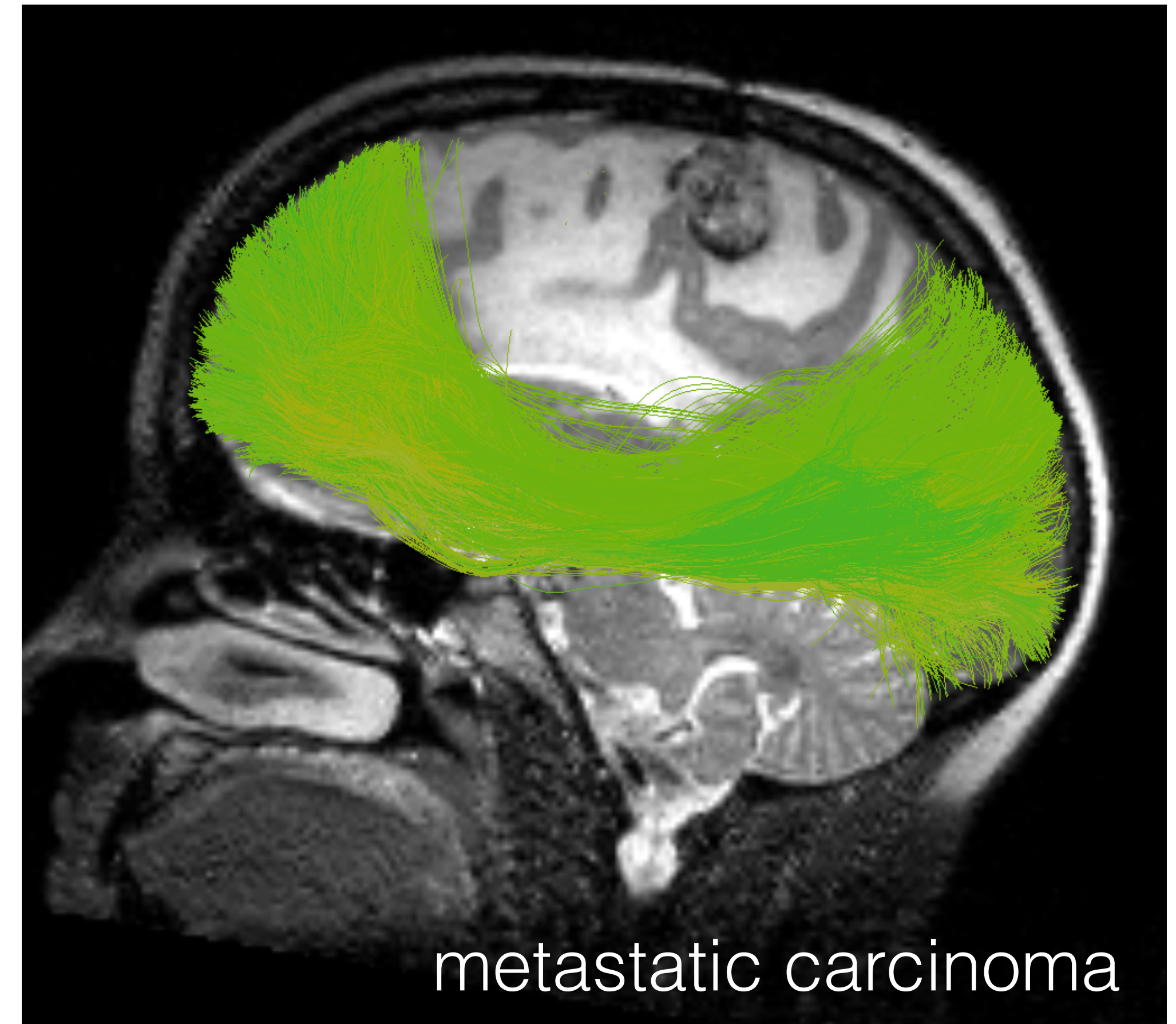
Robustness to crossings, edema

[3] Chen, Zhenrui, et al. "Corticospinal tract modeling for neurosurgical planning by tracking through regions of peritumoral edema and crossing fibers using two-tensor unscented Kalman filter tractography." International journal of computer assisted radiology and surgery 2016

[4] Chen, Zhenrui, et al. "Reconstruction of the arcuate fasciculus for surgical planning in the setting of peritumoral edema using two-tensor unscented Kalman filter tractography." NeuroImage: Clinical 2015

Challenge: Identification of Important Tracts

- Brain is highly connected: 100,000's of "fibers"

- Current clinical method: interactive selection of fibers

- Time consuming, operator-dependent, and variable [5] [6]
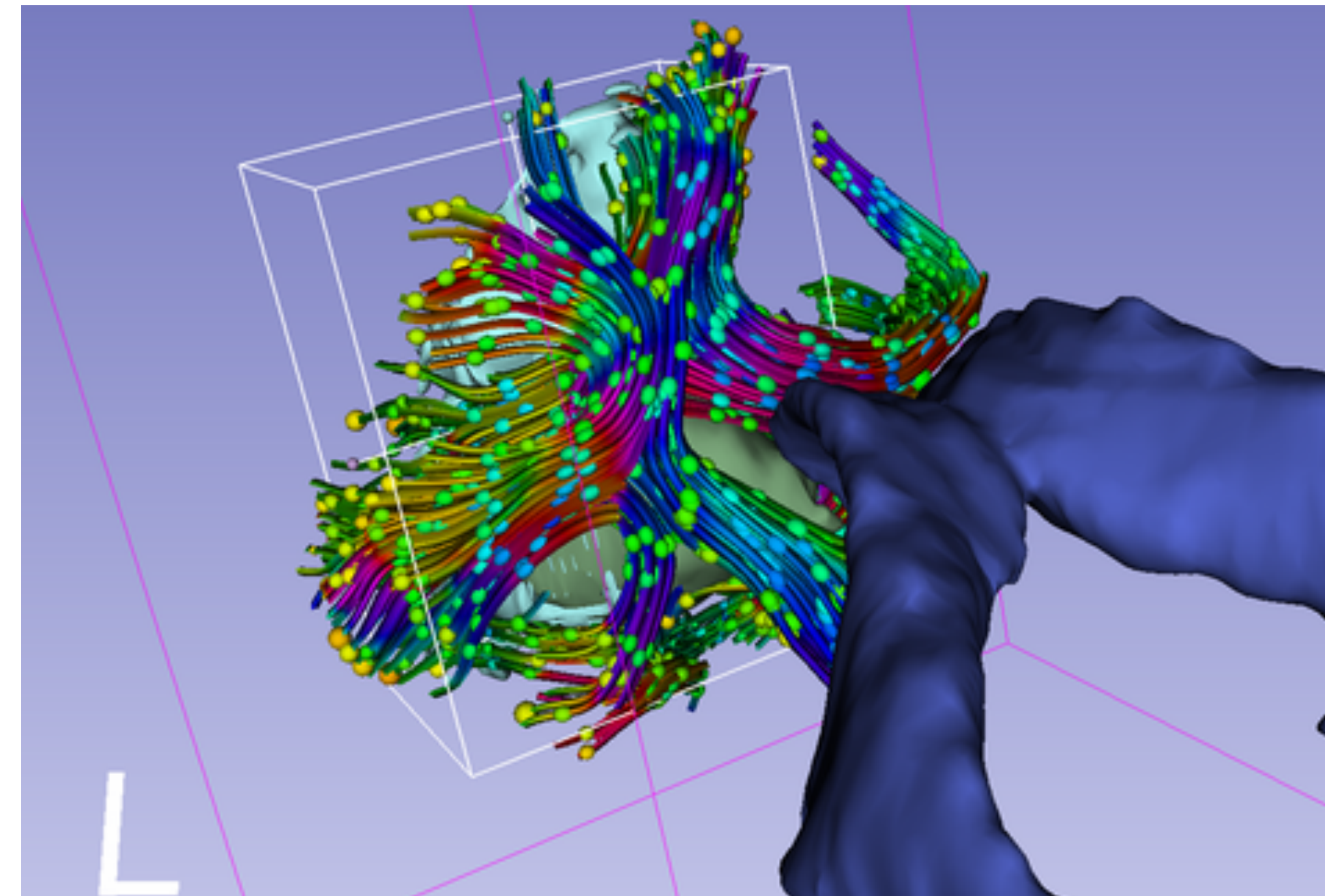
[5] U. Burgel et al, Fiber tracking with distinct software tools results in a clear diversity in anatomical fiber tract portrayal., Central European Neurosurgery 2009
[6]   A. Radmanesh et al. Comparison of seeding methods for visualization of the corticospinal tracts using single tensor tractography, Clinical neurology and neurosurgery 2015.
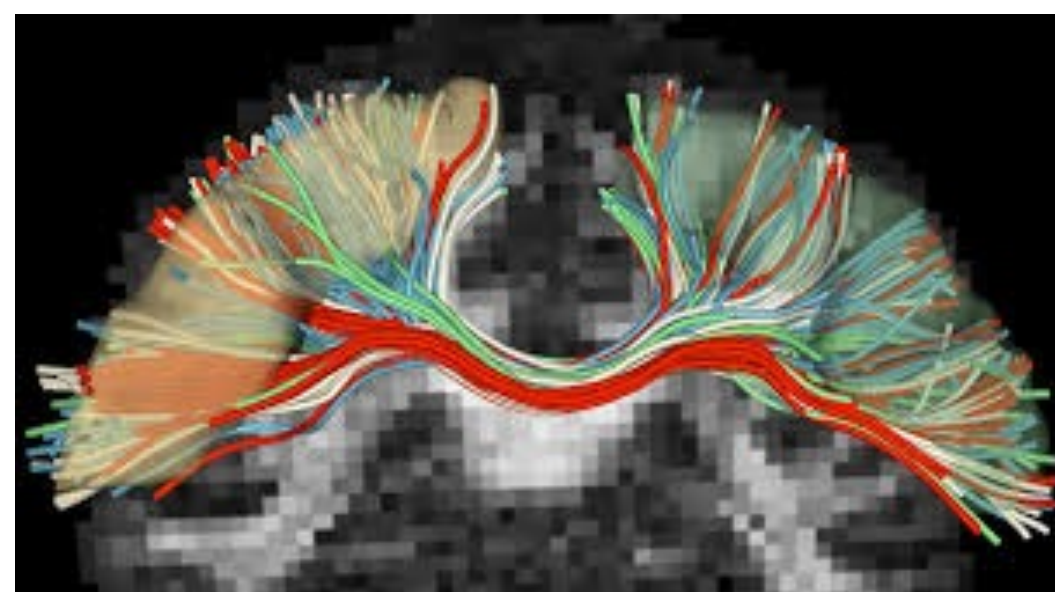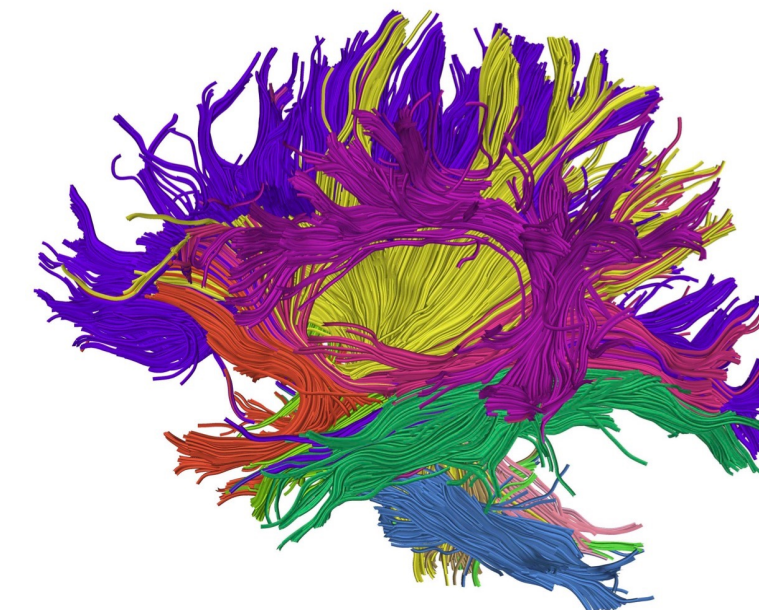
Open-source tools for dMRI

www.slicer.org

ITCR
U01CA199459
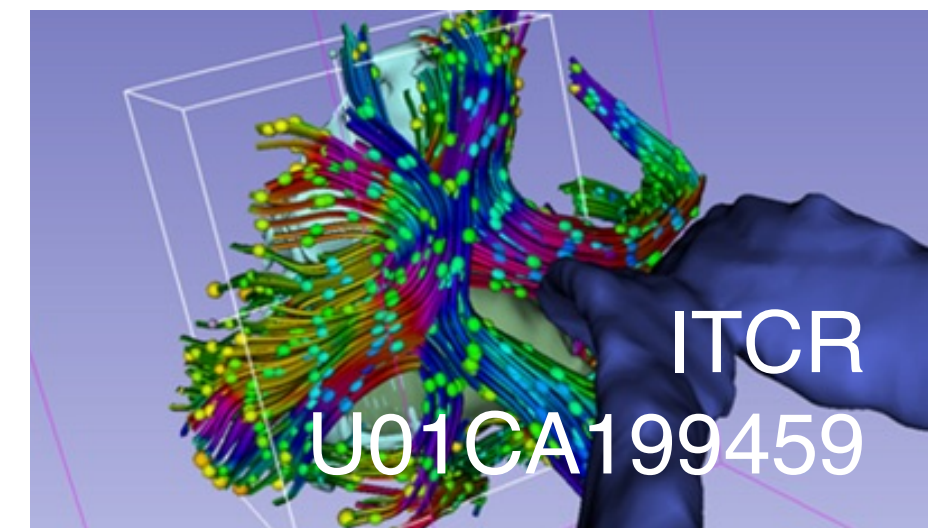
github.com/SlicerDMRI

tractography visualization, dMRI quantification, anatomical hierarchies

github.com/pnlbwh/ukftractography

multi-fiber tractography

github.com/SlicerDMRI/whitematteranalysis

tract clustering and registration

Thank You

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