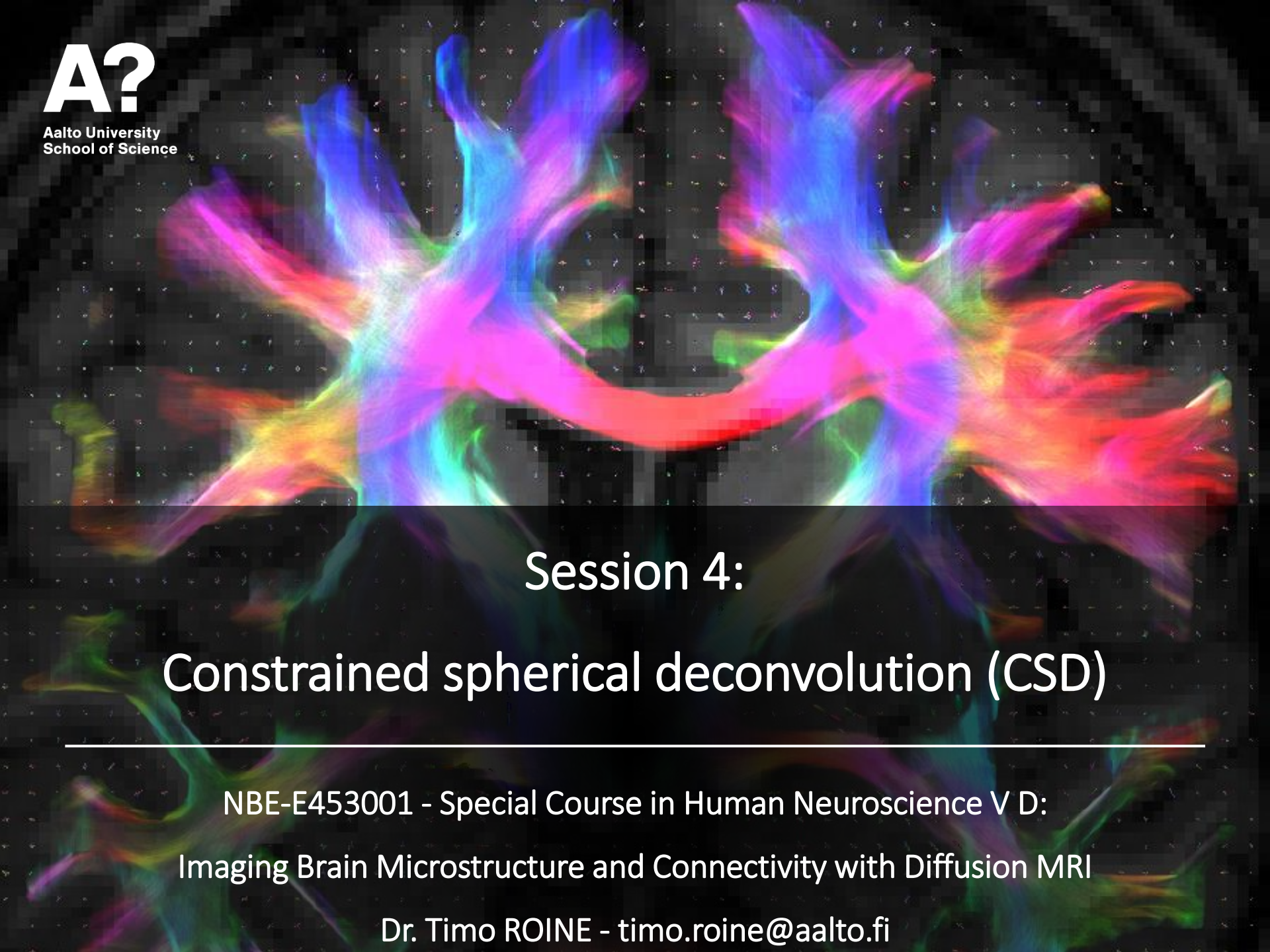

Aalto University
School of Science

# Session 4:

# Constrained spherical deconvolution (CSD)

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NBE-E453001 - Special Course in Human Neuroscience V D:

Imaging Brain Microstructure and Connectivity with Diffusion MRI

Dr. Timo ROINE - timo.roine@aalto.fi

# Session 3 outline

Basics of CSD

Group discussion in Flinga

Quiz (10 min)

Break (5 min)

Practical demonstration of CSD

Discussion and feedback

Assignments before session 5

# Intended learning outcomes

By completing the course, the student can

- **understand diffusion MRI acquisition and analysis methods**
- describe applications of these methods
- **explain the principles of investigating brain microstructure and structural brain connectivity with diffusion MRI**
- **recognize issues in applying these methods in research and clinic**
- apply diffusion MRI methods to investigate brain microstructure and structural brain connectivity (e.g., analyze a dataset or design a project)

# Course outline

**Session 3: Diffusion tensor imaging (14.5.)**
Self-study, lecture, practical demonstrations, group discussion, individual reflection, quiz

Homework: Learning log (DL 18.5.) self-study, return first draft of project work report (DL 20.5.)

**Session 4: Constrained spherical deconvolution and tractography (21.5.)**

Self-study, lecture, practical demonstrations, group discussion, individual reflection, quiz

Homework: Learning log (DL 25.5.). self-study, give peer feedback on the project work report (DL 29.5.)

# Course outline

**Session 5: Connectivity networks and microstructural analyses (30.5.)**

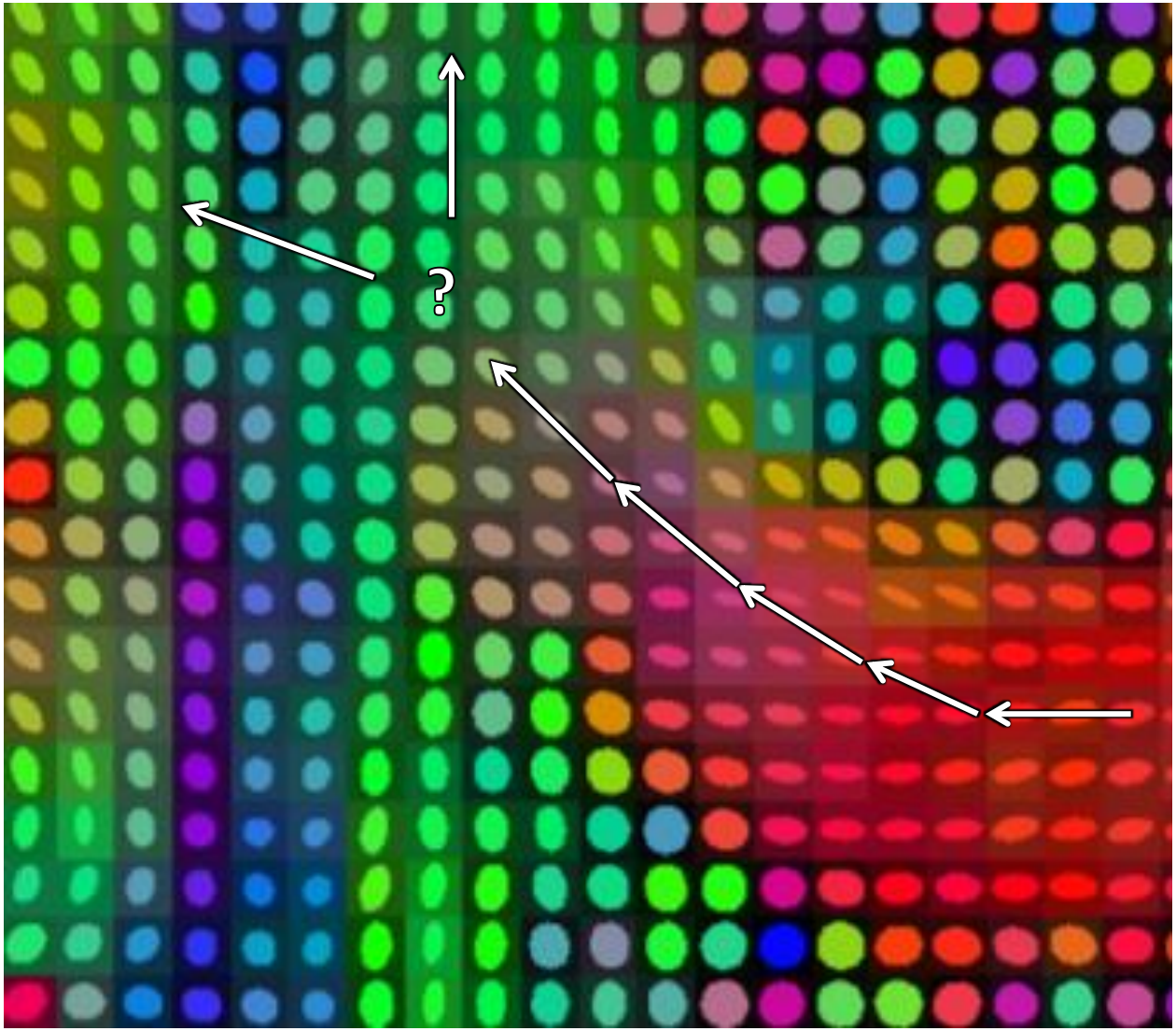
Self-study, lecture, practical demonstrations, group discussion, individual reflection, quiz

Homework: Learning log + self-study, return project work report (5.6.)

**Session 6: Summary of the course, presentations of project works (6.6.)**
Seminar presentations, lecture, group discussion, feedback, individual reflection

Can this be changed to Friday 7.6. 12:15-14:00?

# Main shortcoming of DTI: no fiber crossings



# Prevalence of crossing fibers

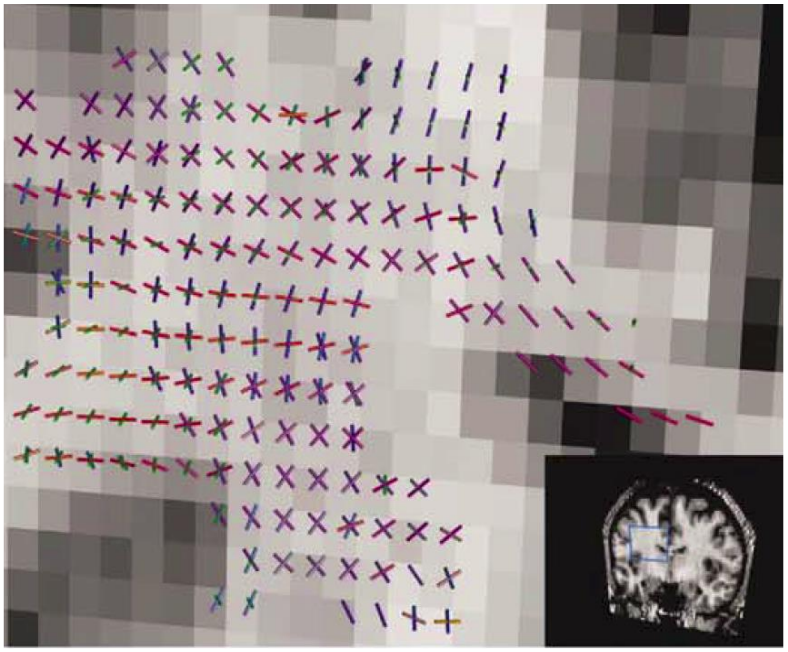


**TABLE I. Percentages of single and multifiber voxels throughout the WM for CSD and bedpostx and for different subjects**

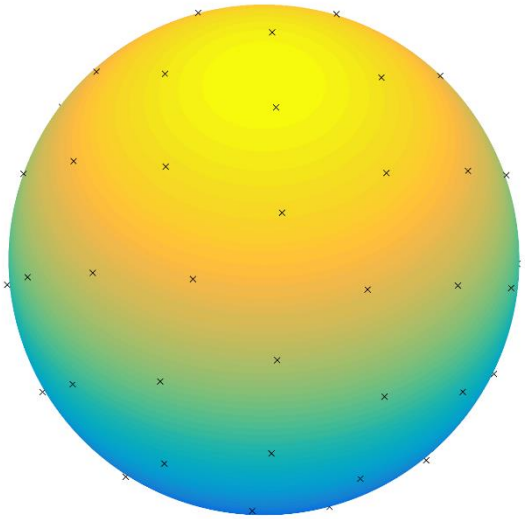
| No. of orientations | | 1 | 2 | ≥3 | ≥2 |
|---|---|---|---|---|---|
| CSD | Subject 1 | 9.5% | 47.1% | 43.3% | **90.5%** |
| | Subject 2 | 8.4% | 45.0% | 46.6% | **91.6%** |
| bedpostx | Subject 1 | 36.1% | 62.9% | 0.9% | **64.0%** |
| | Subject 2 | 37.5% | 61.9% | 0.4% | **62.3%** |
| Behrens et al. [2007] | | ~ 67.7% | ~ 33.3% | 0% | ~ **33%** |

For reference, we also included the estimates previously reported in Behrens et al. [2007].

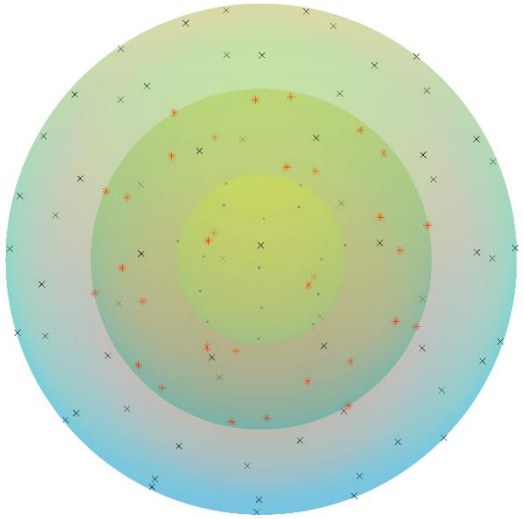
*Jeurissen et al. 2013*

# Diffusion-weighted q-space schemes

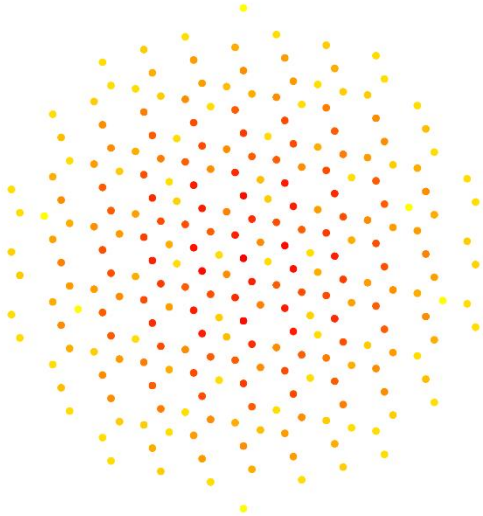
A) Single-shell



B) Multi-shell



C) Diffusion spectrum imaging

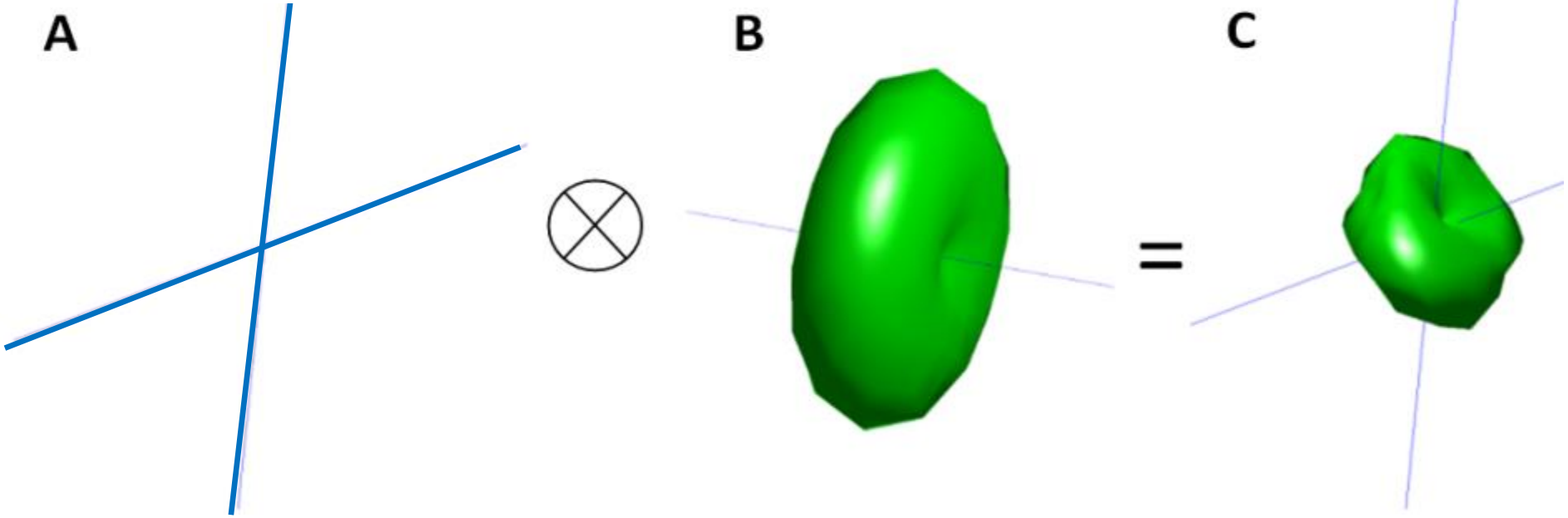


# Constrained spherical deconvolution (CSD)

- Assumption: the DW signal $S(\theta, \phi)$ is the convolution of:
  - the fiber orientation distribution $f(\theta, \phi)$ and
  - the signal of a single coherently oriented fiber population, response function $r(\theta)$

$$S(\theta, \phi) = f(\theta, \phi) * r(\theta)$$

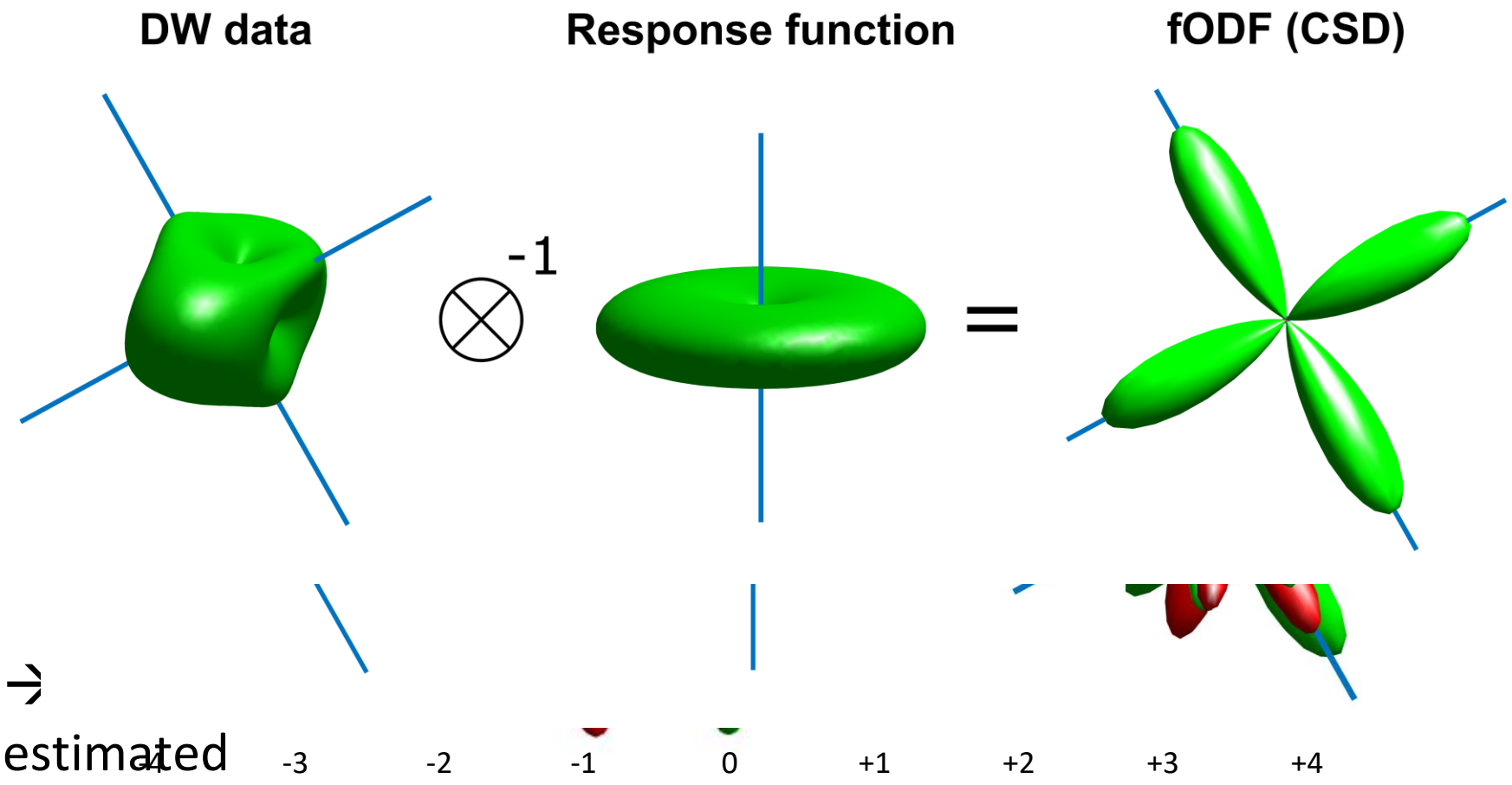
Fiber orientation distribution (fODF) Response function (RF) DW signal



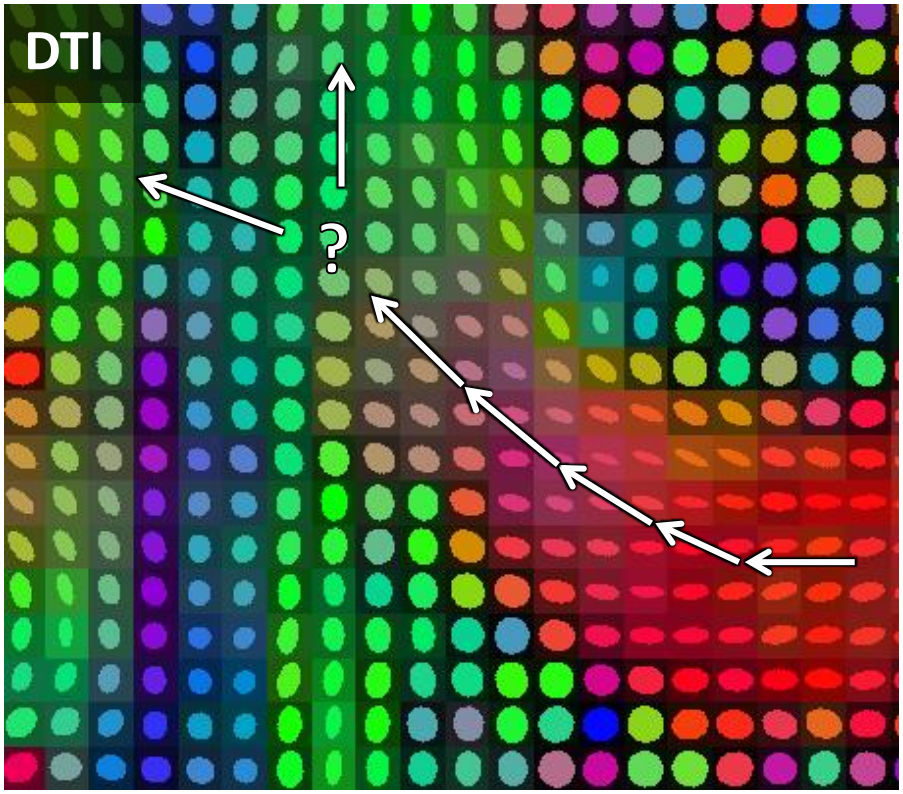


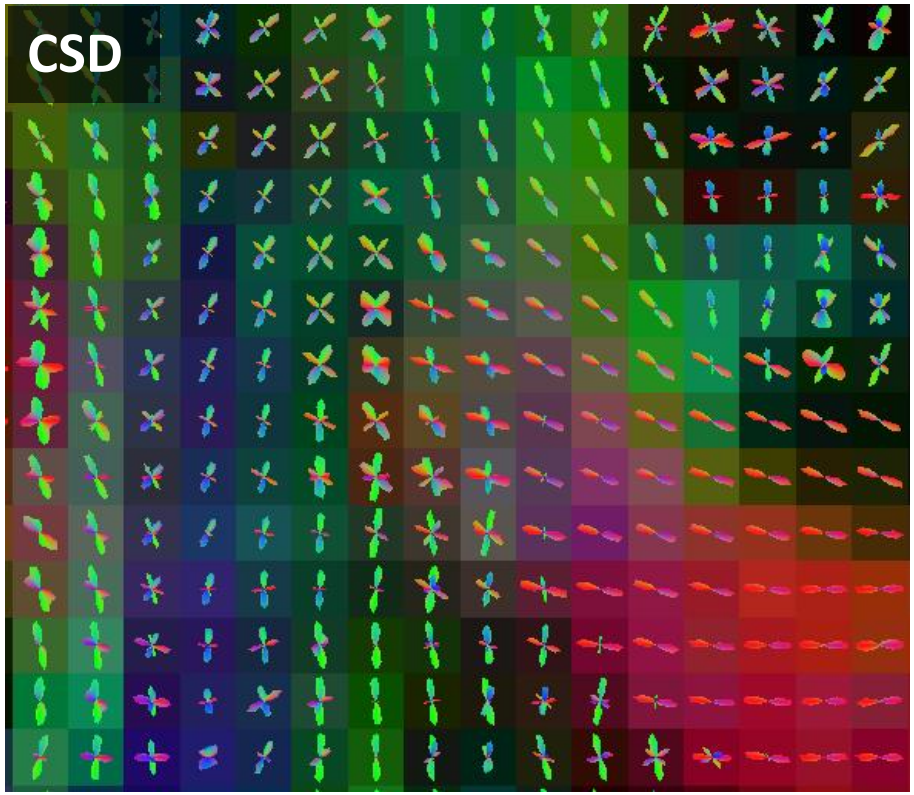

*Tournier et al. 2004, 2007*

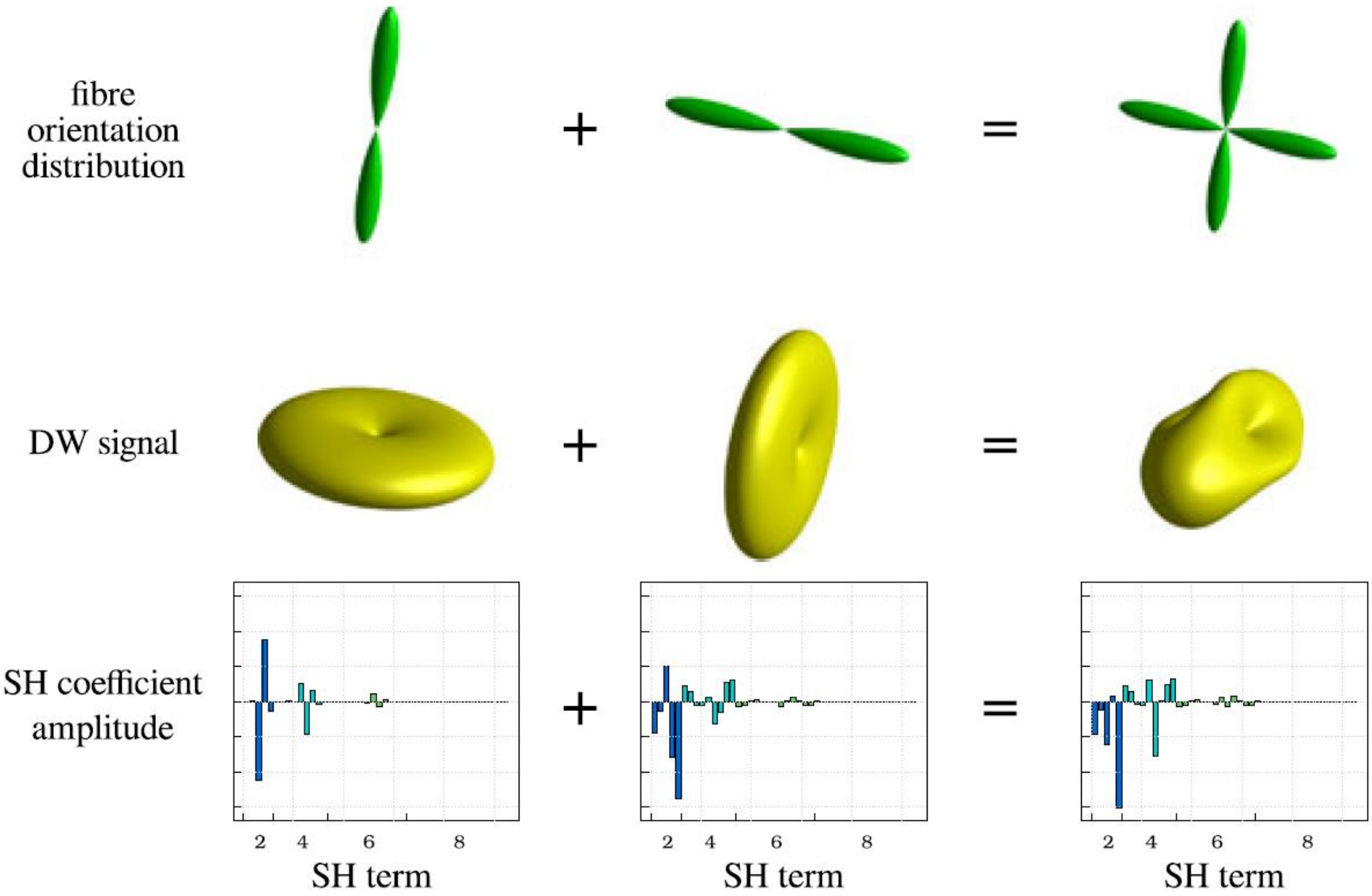
# Inverting the problem



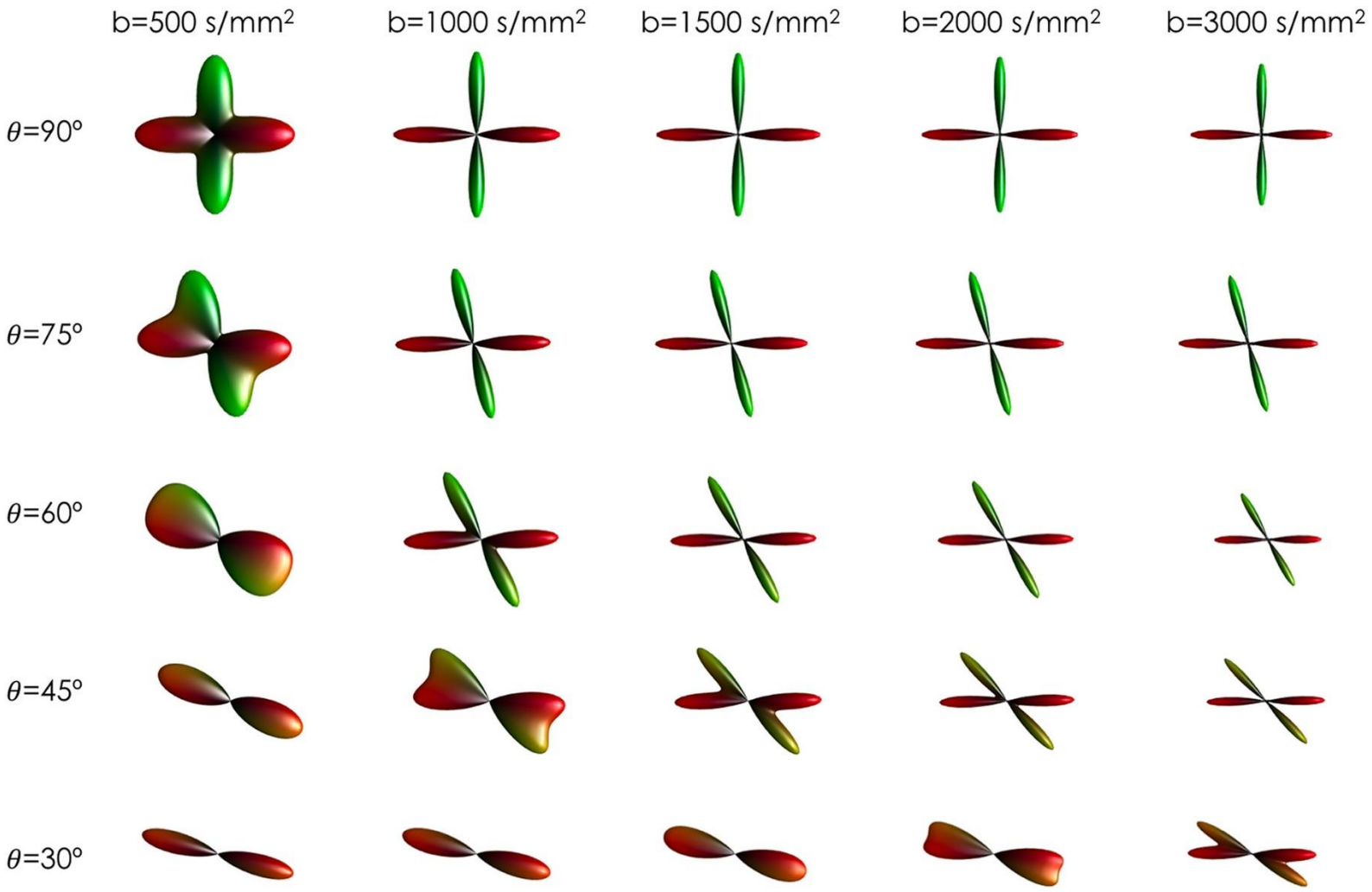
# Comparison of DTI and CSD






Tournier et al. 2013



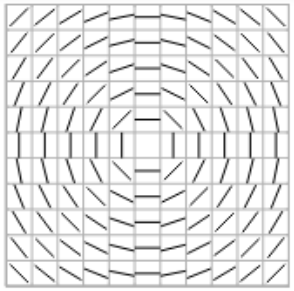

Tournier et al. 2013

# Tractography algorithms

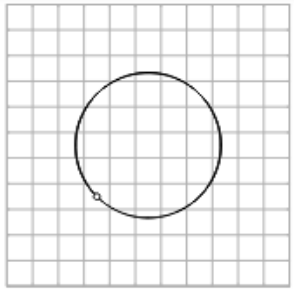
- Single-fiber vs. multi-fiber
- Deterministic vs. probabilistic
- Local vs. global
- An example: Euler integration

$$\boldsymbol{r}_{i+1} = \boldsymbol{r}_i + \boldsymbol{v}(\boldsymbol{r}_i)\Delta$$

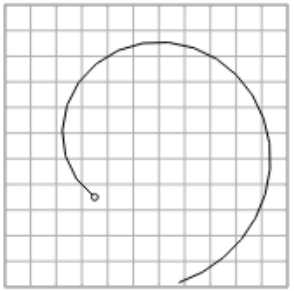
seed point $r_0$
corresponding fiber orientation $v(r_i)$
step size $\Delta$



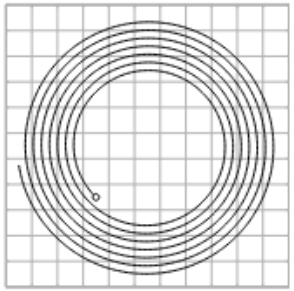
(a) Orientation field



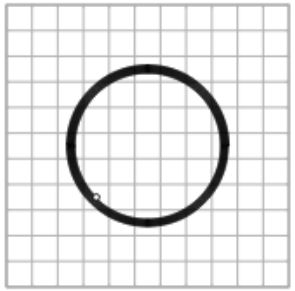
(b) Ground truth



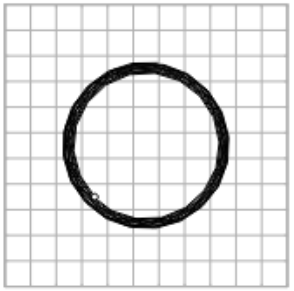
(c) Euler, step size: 1



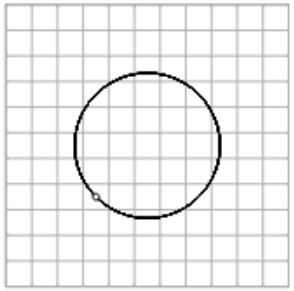
(d) Euler, step size: 0.1



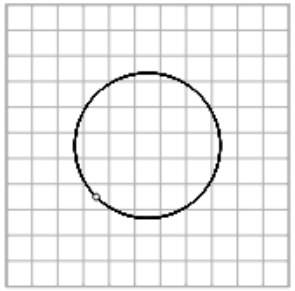
(e) Euler, step size: 0.01



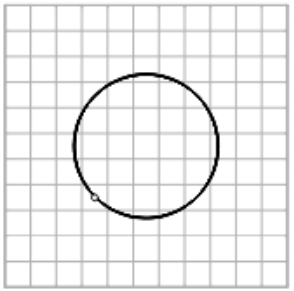
(f) RK2, step size: 1



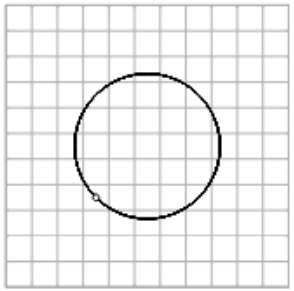
(g) RK2, step size: 0.1



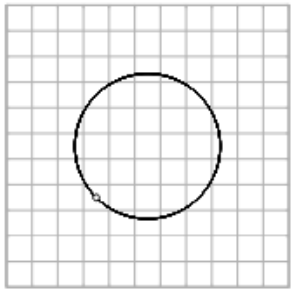
(h) RK2, step size: 0.011



(i) RK4, step size: 1



(j) RK4, step size: 0.1

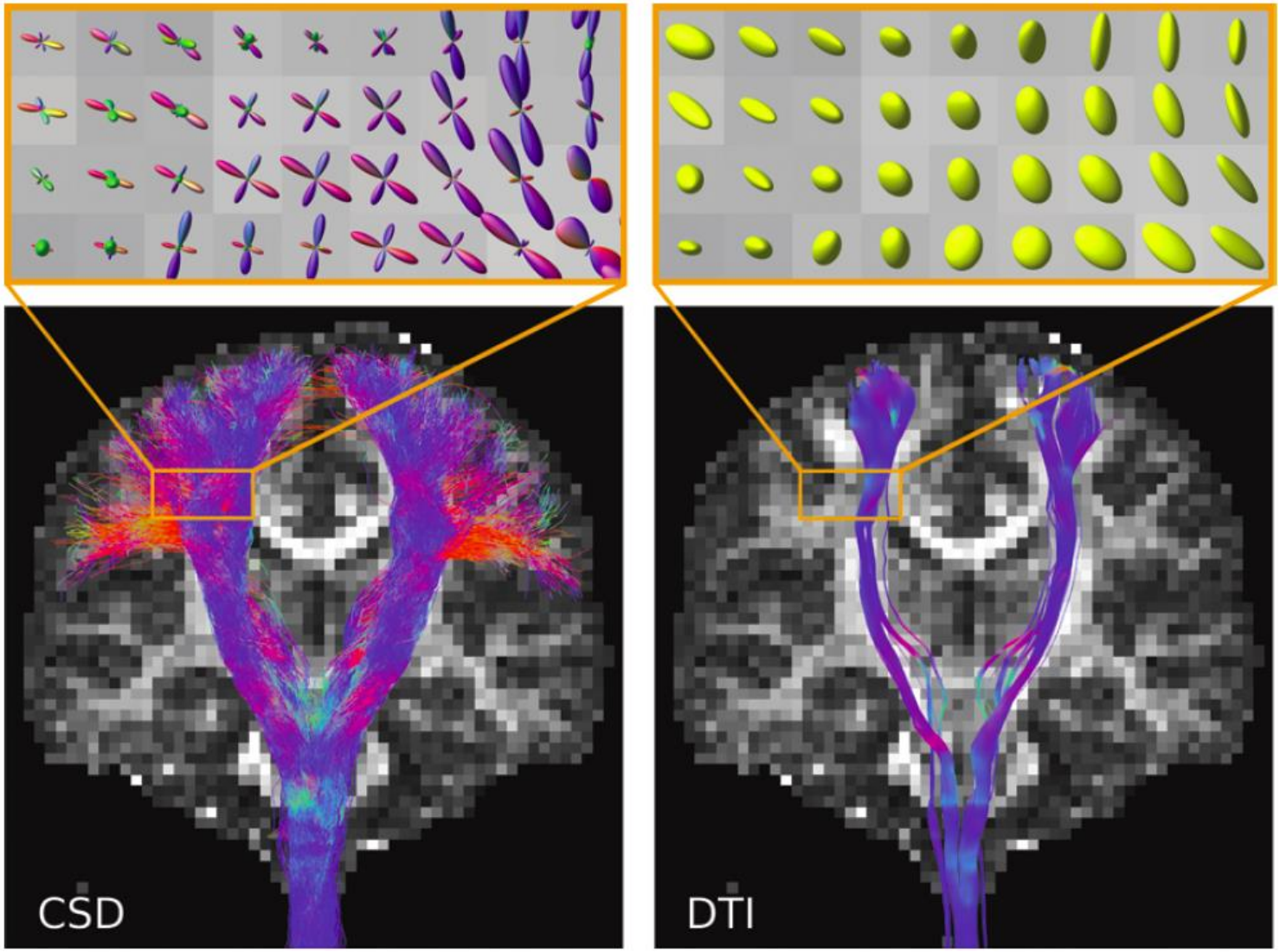


(k) RK4, step size: 0.01



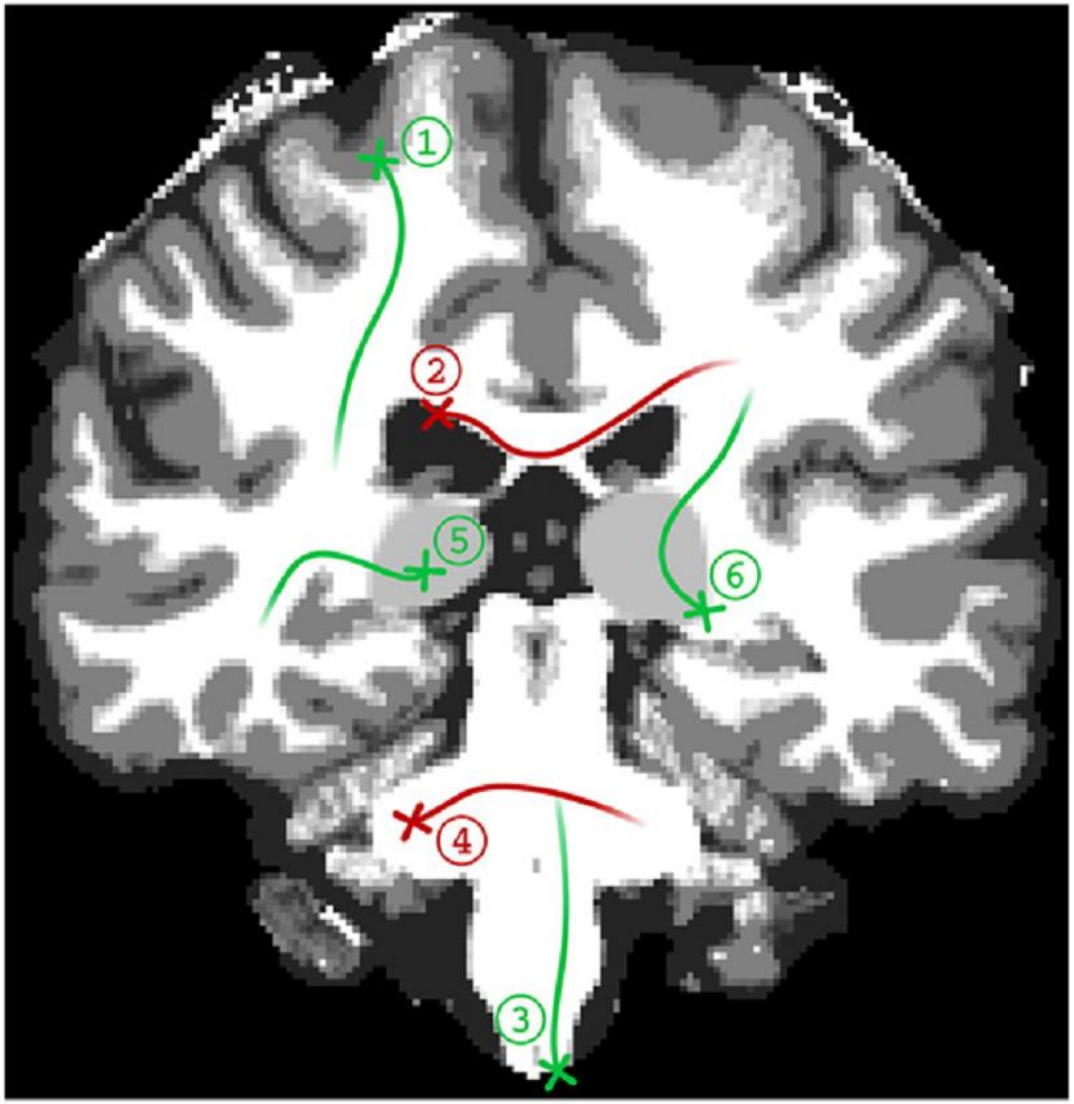
Jeurissen, PhD thesis 2012

# DTI- vs. CSD based tractography



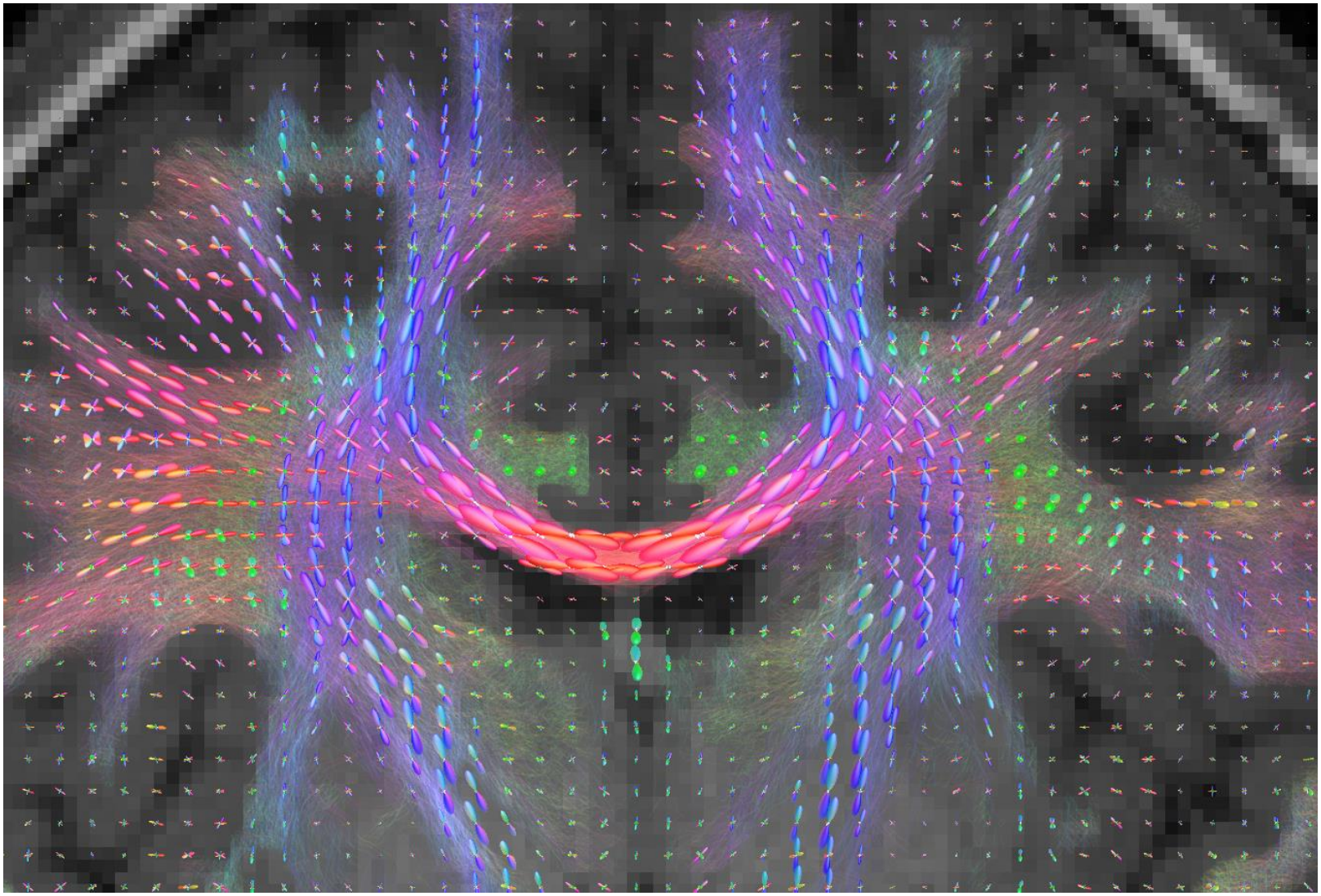

*Farquharson et al. 2013*

# Anatomical priors for tractography

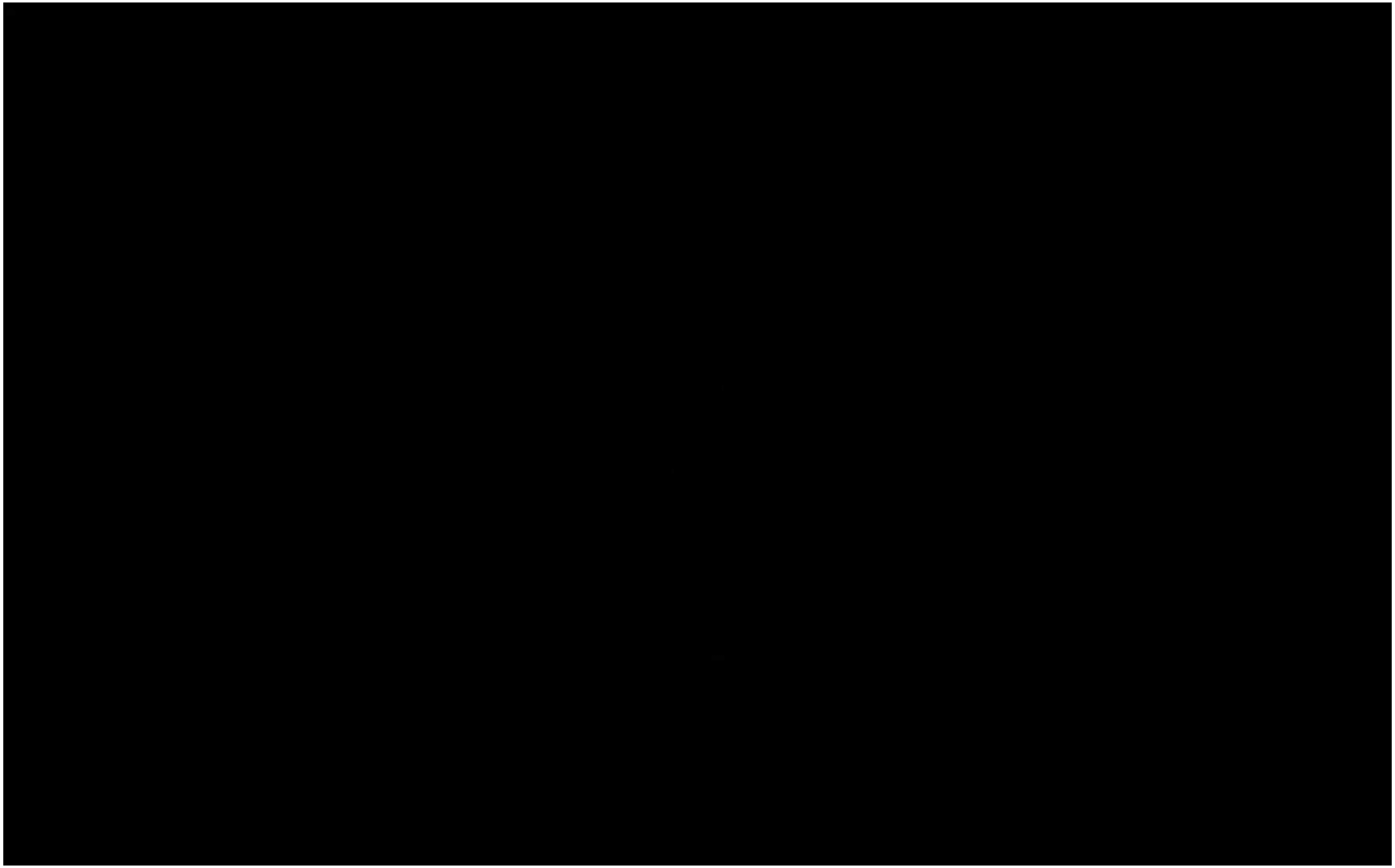



*Smith et al. 2012, 2013*

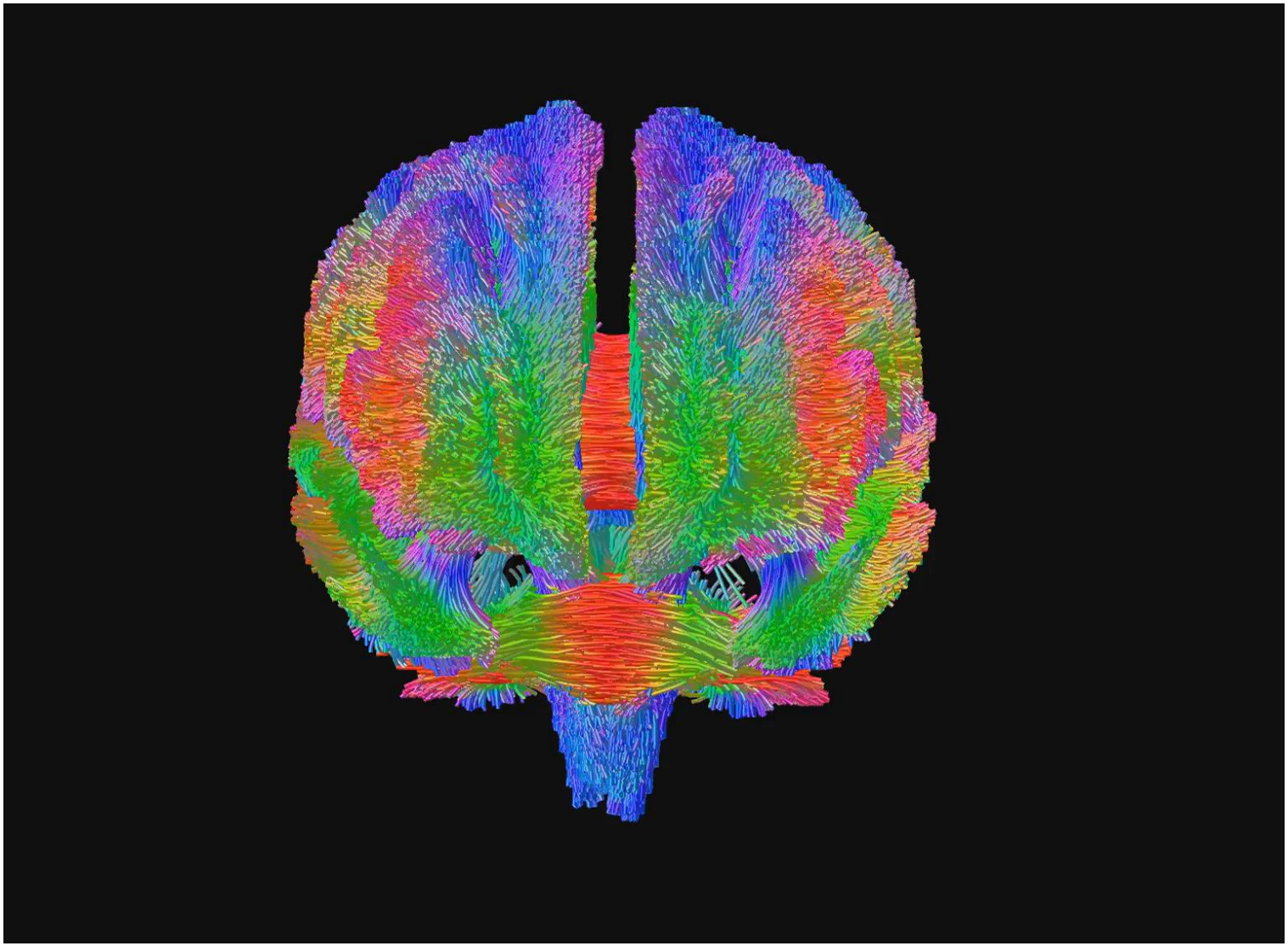
# CSD-based tractography



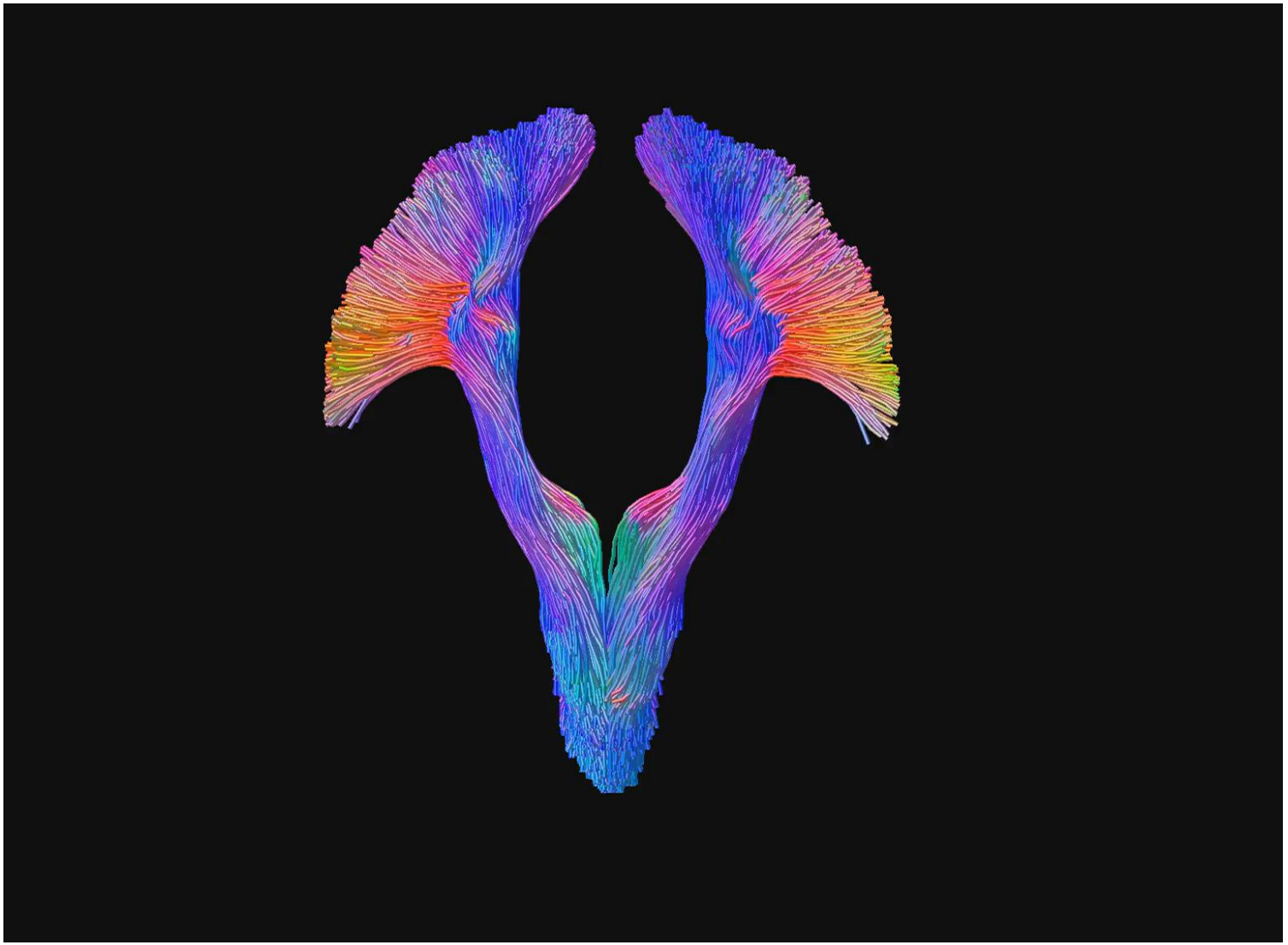
# CSD-based tractography



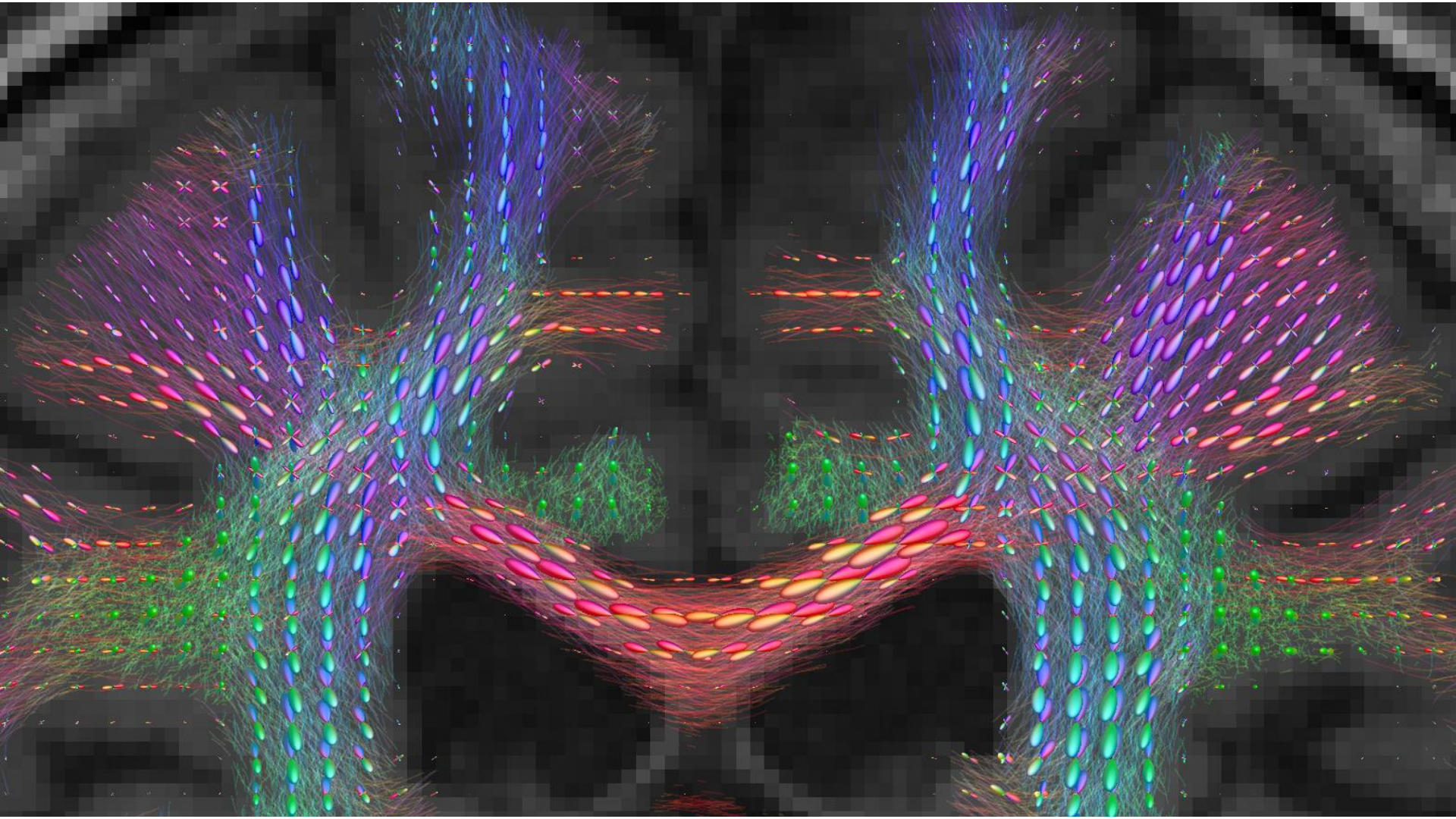
# CSD-based tractography



# CSD-based tractography



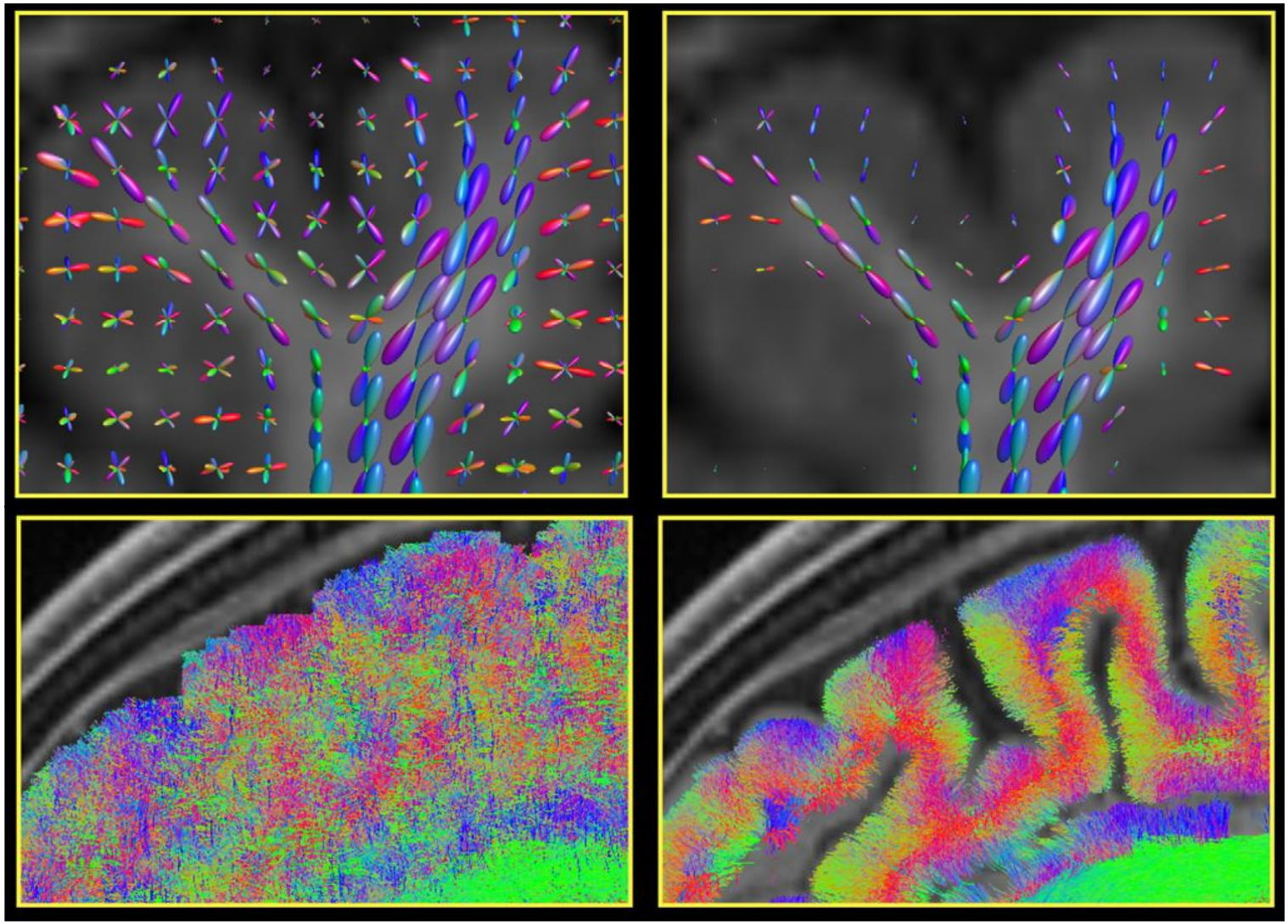
# Multi-tissue approaches





*Roine et al. 2014, 2015*

# Multi-tissue approaches



*Jeurissen et al. 2014*

# Peer-feedback on the project plan

- Reply to the thread of submission. Everyone comments individually – at least two bullet points per person per project plan/draft report.
- Constructive comments! For instance, answer these questions:
  - What is good in the proposed approach/project?
  - What possible challenges do you see and how would you address them?
  - Is the literature review sufficient/relevant to the topic? How could it be improved?