

# Multi-shell multi-tissue fODF tractography improves V1-V2 macaque connectivity mapping

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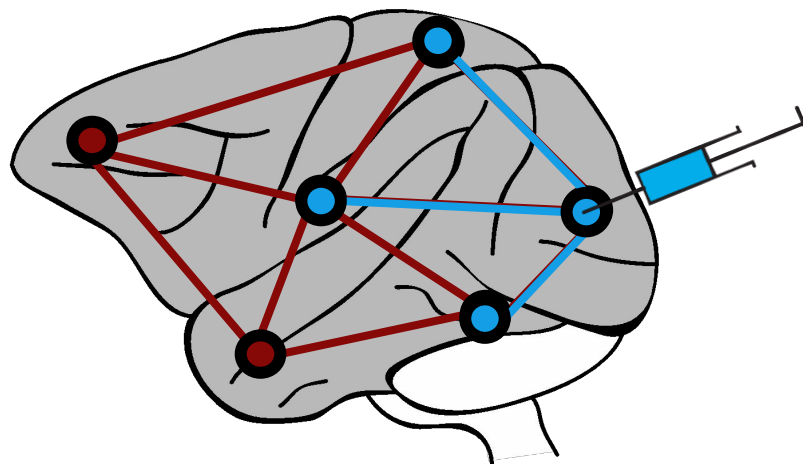
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# How to validate a tractography?

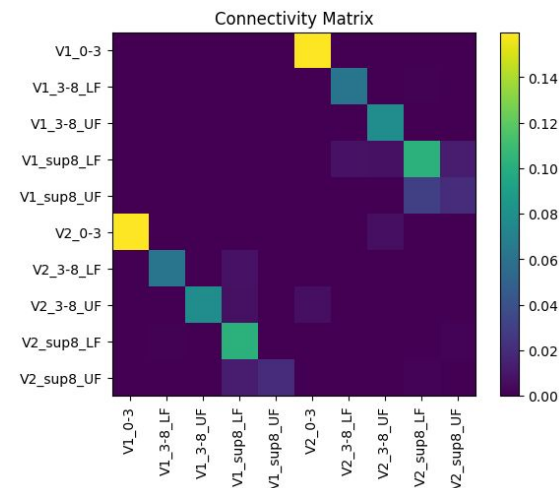
- Tract tracing in the V1-V2 visual cortex.
- Connectivity matrix from the tract tracing.



Tract-tracing

Ground-truth  
connectivity matrix<sup>1</sup>

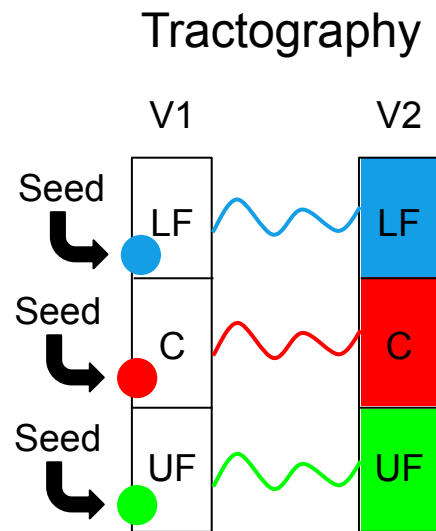
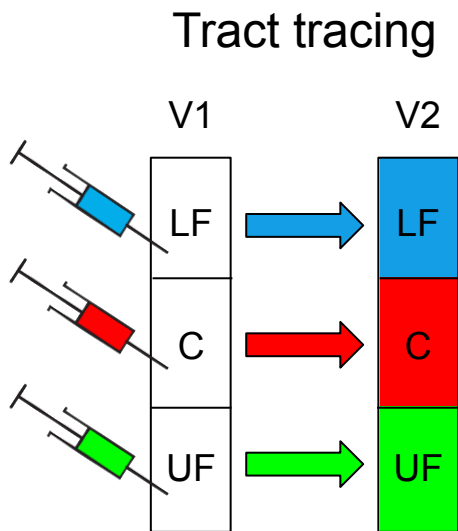
**Acronyms:**  
0\_3: central  
3\_8: paracentral  
(parafovea)  
sup8: far periphery  
LF: Lower Field  
UF: Upper Field



<sup>1</sup>Markov, N. T. et al. *Cerebral Cortex* 2014; unpublished data from Kennedy lab.

# Objective: tractography validation!

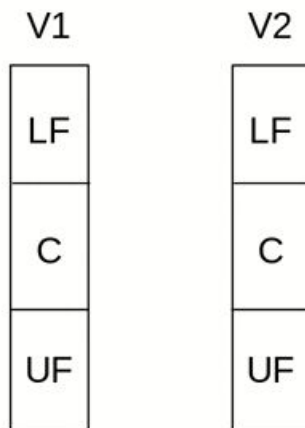
- Improve dMRI tractography for connectivity mapping
  - Reproduce retinotopy of the visual field. i.e. v1LF -> v2LF, etc...
    - Binary connections
    - Weighted connections (Fraction of labelled neurons vs Tract-Count)
  - Good cortical coverage



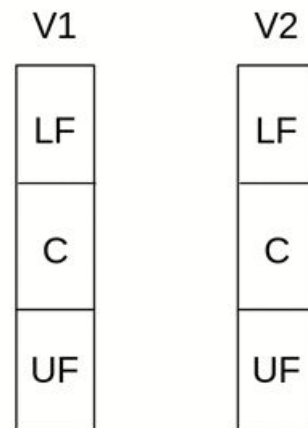
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## Tract tracing



## Tractography



# Dataset

- State of the art acquisition
  - Multi-shell acquisition:  $b=2000, 4000$  and  $6000 \text{ s/mm}^2$
  - 64 same directions per shell
  - High image resolution:  $0.3 \text{ mm}$  isotropic ( $300 \text{ micron}$ )
  - High field Strength:  $7.0\text{T}$

Study	Image resolution	Field Strength	b-values (in $\text{s/mm}^2$ )	Number of directions
Thomas et al 2014 (macaque)	0.25mm	7.0T	4800	121
Calabrese et al 2015 (mouse)	0.042mm	9.4T	4000	120
Azadbakht et al 2015 (macaque)	0.8mm 0.43mm	4.7T	4000 8000	61 120
Knosche et al 2015 (pig)	0.51mm	4.7T	4009	61
Van den Heuvel et al 2015 (macaque)	1,1mm	3T	1000	60
Donahue et al 2016 (macaque)	0.43mm	4.7T	4000 8000	61 120
present study (macaque)	0.3mm	7.0T	2000,4000,6000	64,64,64

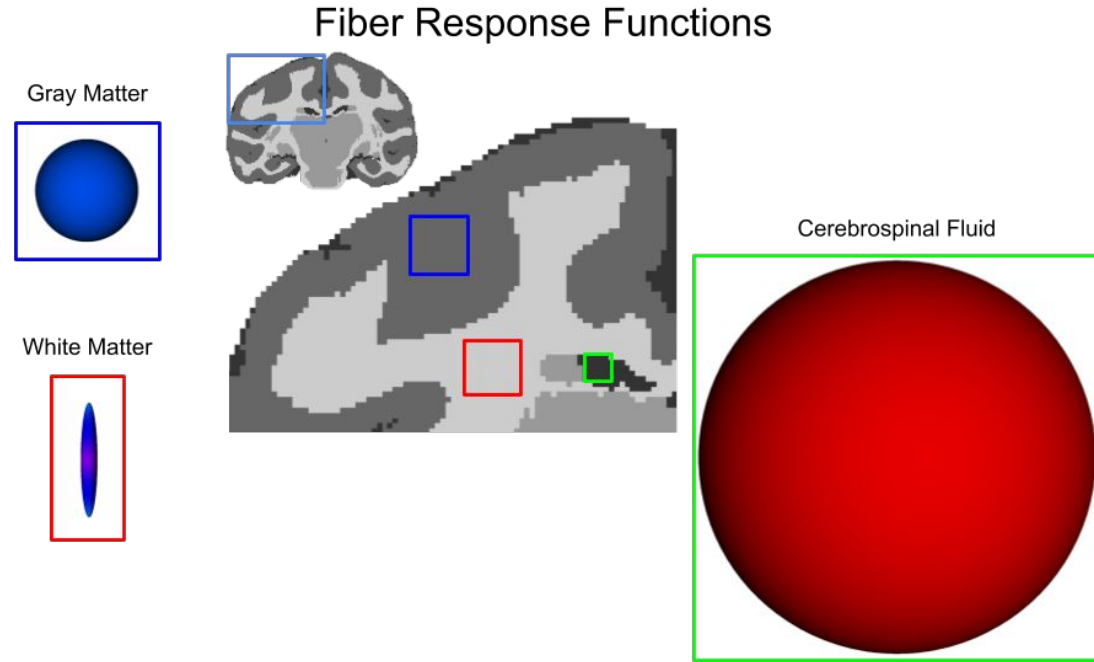
# fODF estimation

- Multi-shell Single Tissue fODF CSD:
  - The fiber response function is estimated from the WM.
  - Wrong deconvolution kernel in regions of partial volume, gray matter and CSF.
- Multi-shell Multi Tissue fODF CSD
  - One fiber response function for each tissue type.
  - Better estimation of the partial volume

Key step: Response function estimation

# Response function estimation

- Estimated on the  $b=2000$  s/mm<sup>2</sup> images.
- Tissues manually segmented.



Fiber Response Functions shape in mm<sup>2</sup>/s

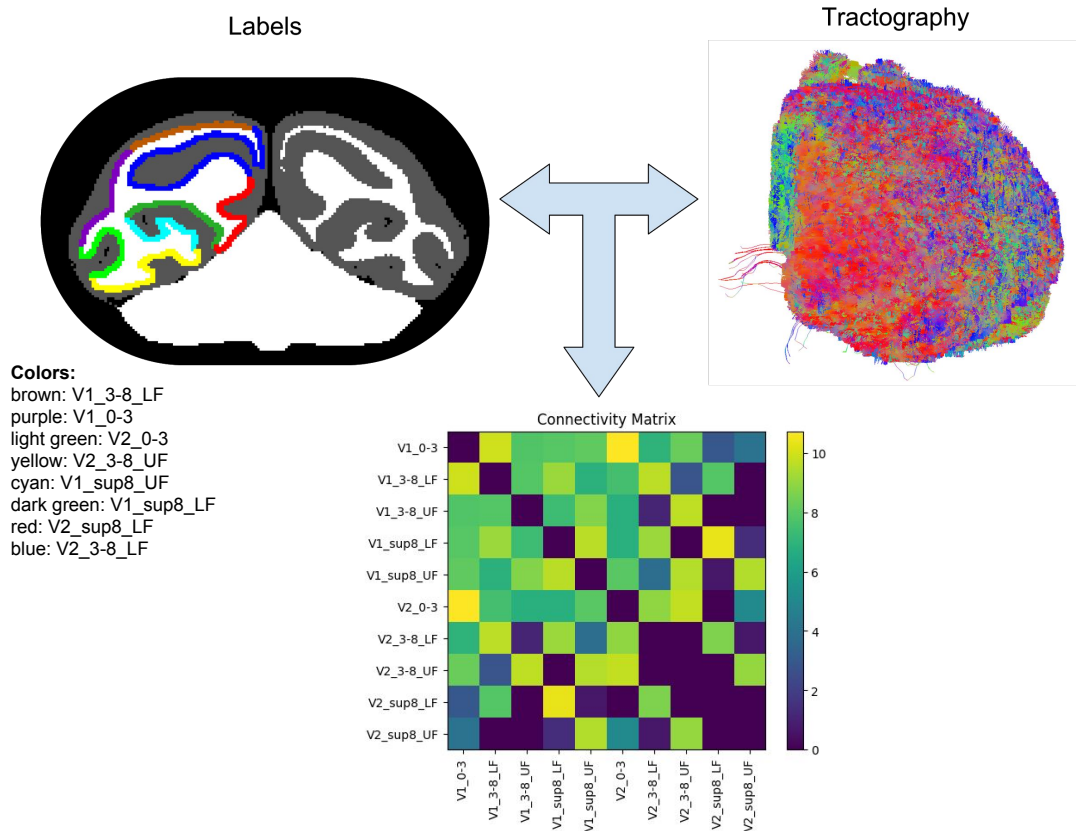
White matter  
 $5 \times 10^{-4}$ ,  $7 \times 10^{-5}$ ,  $7 \times 10^{-5}$

Gray matter  
 $4.5 \times 10^{-4}$ ,  $4.5 \times 10^{-4}$ ,  $4.5 \times 10^{-4}$

Cerebrospinal fluid  
 $1.7 \times 10^{-3}$ ,  $1.7 \times 10^{-3}$ ,  $1.7 \times 10^{-3}$

# Tractography and connectivity mapping

- Probabilistic particle filter tractography<sup>2</sup> from white-matter gray matter interface
- 1 million streamlines between 0.3 mm and 15 mm.
- Connectivity mapping between V1 and V2.

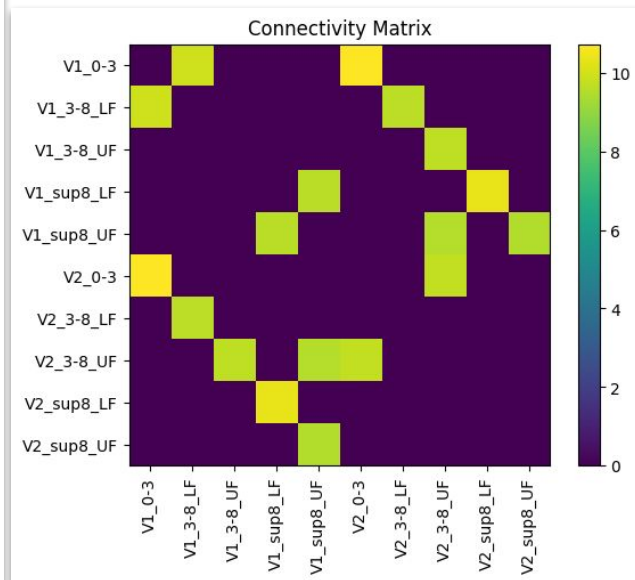
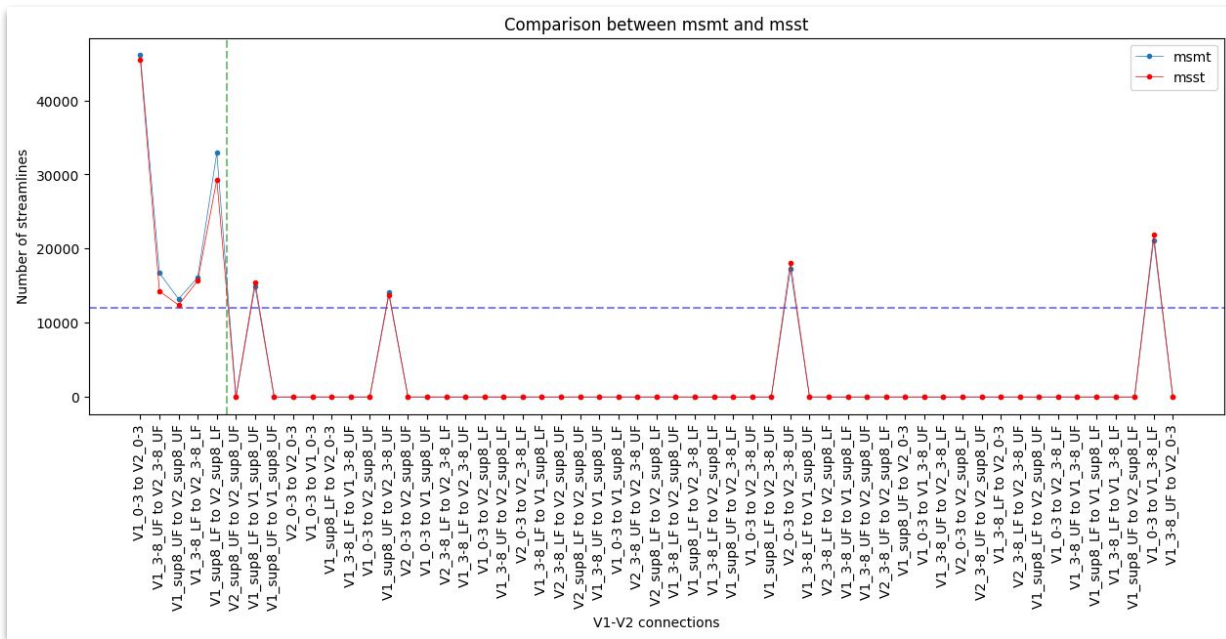


<sup>2</sup>Girard et al. *NeuroImage* 2014



# Results

## Connectivity mapping and V1-V2 connections



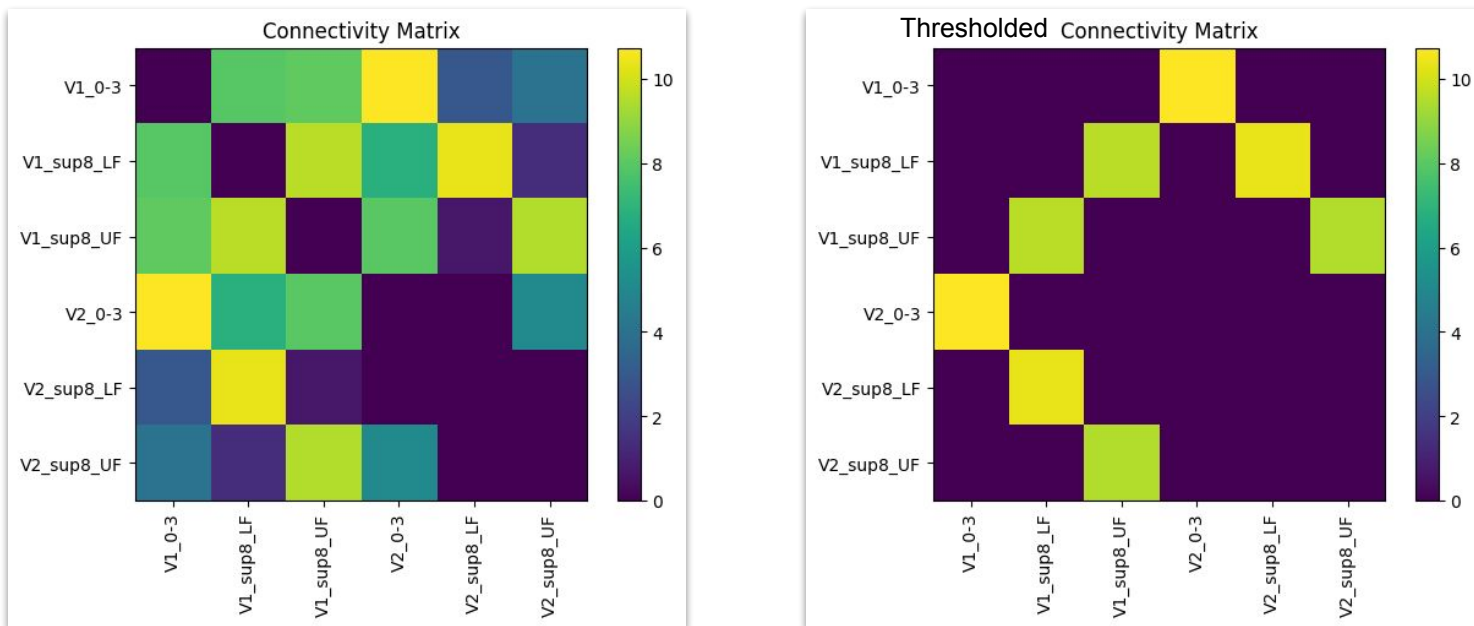
# Results

**Percentage of coverage for the single tissue vs multi tissue fODF tractography**

Connection	Total percentage	Percentage per label
V1_0-3/V2_0-3	57% / 58%	V1_0-3: 64% / 66% V2_0-3: 52% / 52%
V1_3-8_LF/V2_3-8_LF	52% / 53%	V1_3-8_LF: 44% / 44% V2_3-8_LF: 63% / 65%
V1_3-8_UF/V2_3-8_UF	27% / 29%	V1_3-8_UF: 37% / 39% V2_3-8_UF: 24% / 25%
V1_sup8_LF/V2_sup8_LF	45% / 49%	V1_sup8_LF: 37% / 40% V2_sup8_LF: 59% / 63%
V1_sup8_UF/V2_sup8_UF	33% / 36%	V1_sup8_UF: 26% / 28% V2_sup8_UF: 51% / 56%

# Results

Connectivity mapping without 3-8 connections (paracentral)



# Conclusion

- The multi-shell multi tissue fODF globally improve the tractography:
  - Increase of **6.8% valid connections** with a low increase of 0.6% invalid connections.
  - Find **all valid bundles** and only 4 invalid bundles on 45 potential invalid bundles.
  - The cortical coverage is **improved by 3%**.
  - The correlation with the quantitative FLN (fractions of labelled neurons) tract tracing connectivity mapping & tract-count connectivity matrix from tractography is **0.85**.

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imeka 

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