Donders Institute
for Brain, Cognition and Behaviour

ICMRM 12

Detailed laminar characteristics of the human neocortex revealed by NODDI and histology

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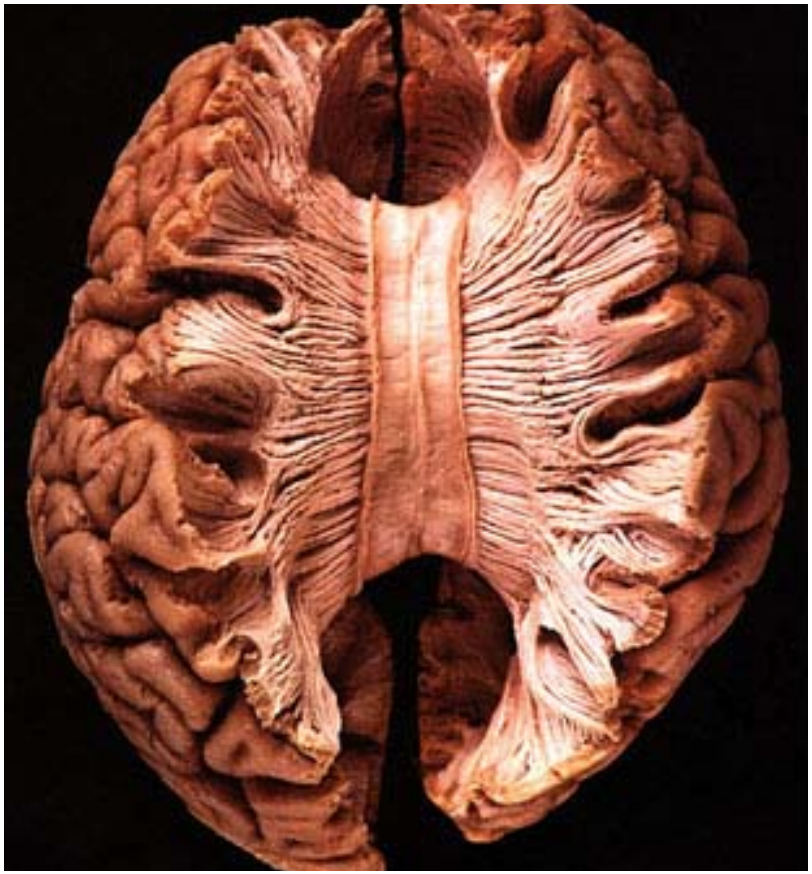
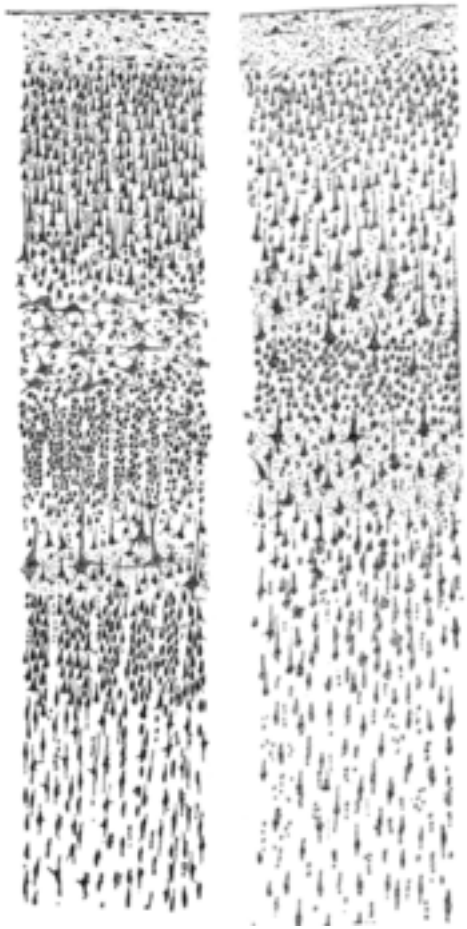
UCL

Neocortex and cytoarchitectonic mapping

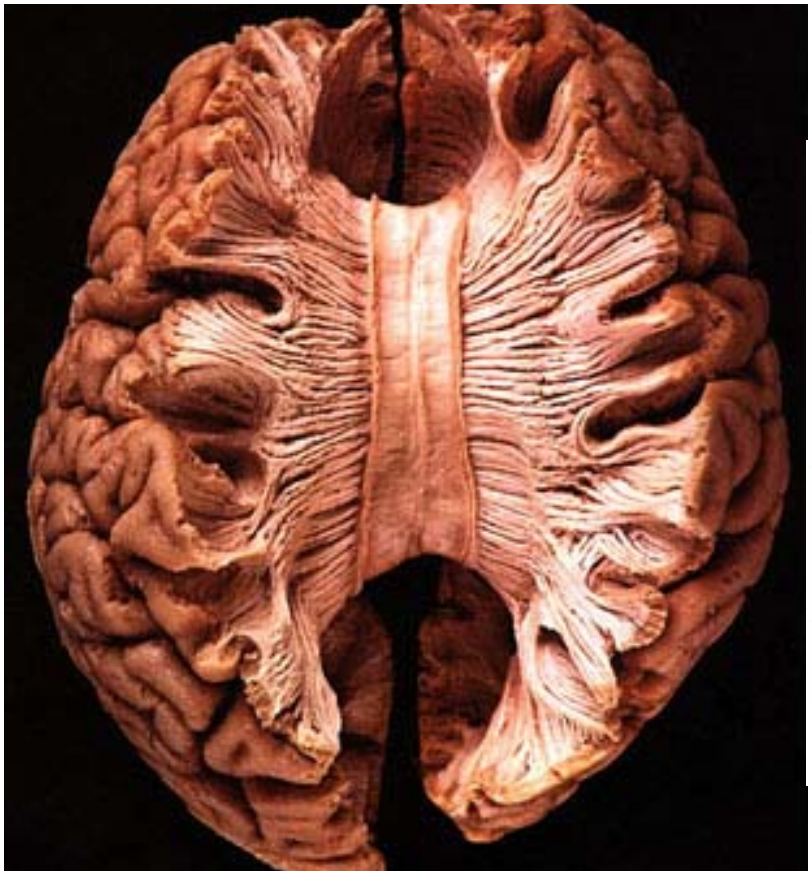


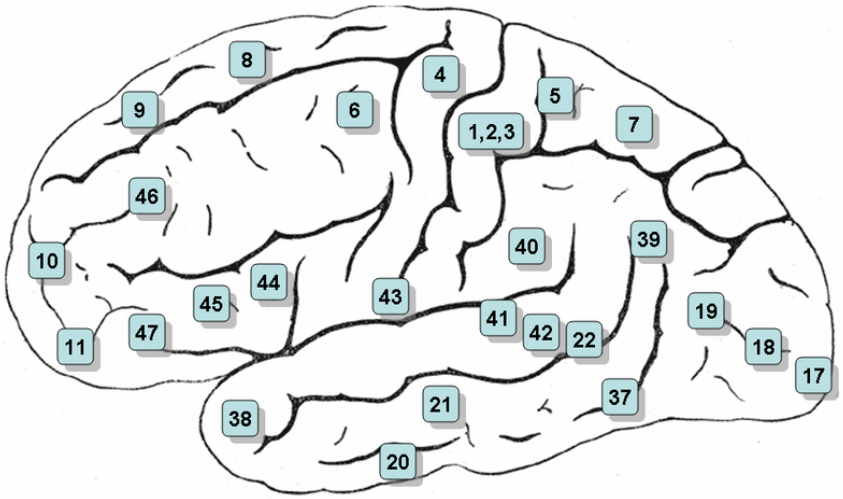


Visual cortex

Motor cortex

Neocortex and cytoarchitectonic mapping



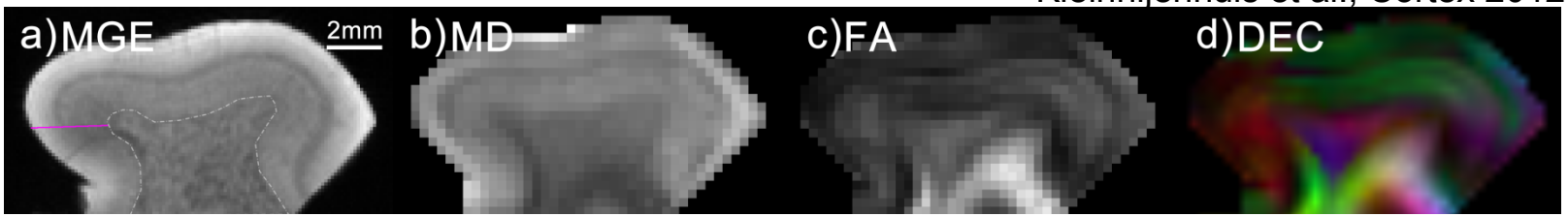


Broadmann areas

Towards in vivo cytoarchitecture

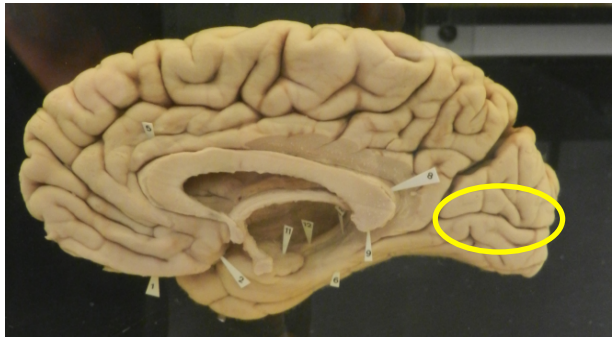
- Diffusion can be used as structural probe
- Tensor metrics vary over cortical layers

Kleinnijenhuis et al., Cortex 2012



- Purpose of the current work:
  - extension to multishell
  - histology

Samples of human V1



- post-mortem interval (< 24 h)
- fixed in formalin (> 1 month)

- 1 cm^3 calcarine sulcus (V1)
- soaked in phosphate buffered saline (> 72 h)
- scanned in proton-free liquid

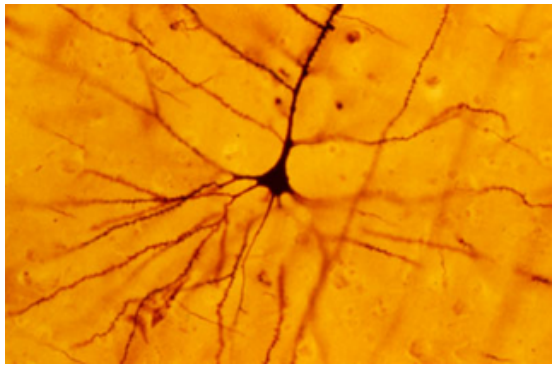
Diffusion Weighted Imaging

- System:
  - 9.4T Bruker BioSpec; G_{max} = 660 mT/m
  - cryogenic mouse brain coil (20-30 K)
- PGSE with segmented EPI readout
- TR/TE = 6750/26 ms
- 0.2 mm isotropic voxels
- 8 shells x 384 (sample A) / 54 directions (sample B)
  - b = [0 1000 3000 4000 8000 12000 16000 20000] smm^{-2}
  - δ/Δ = 8/12 ms

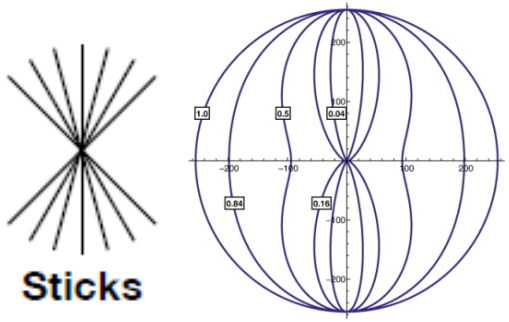
Neurite Orientation Dispersion and Density Imaging

- NODDI multicompartment tissue model (Zhang et al., NI 2012)

  1. neurite volume fraction
  2. extra-cellular volume fraction
  3. isotropic volume fraction
  4. isotropic restriction compartment
     ➔ ex vivo only (Alexander et al, 2010)



  – Watson distribution
     ➔ mean orientation **μ** and concentration **κ**
     ➔ modeling WM & GM

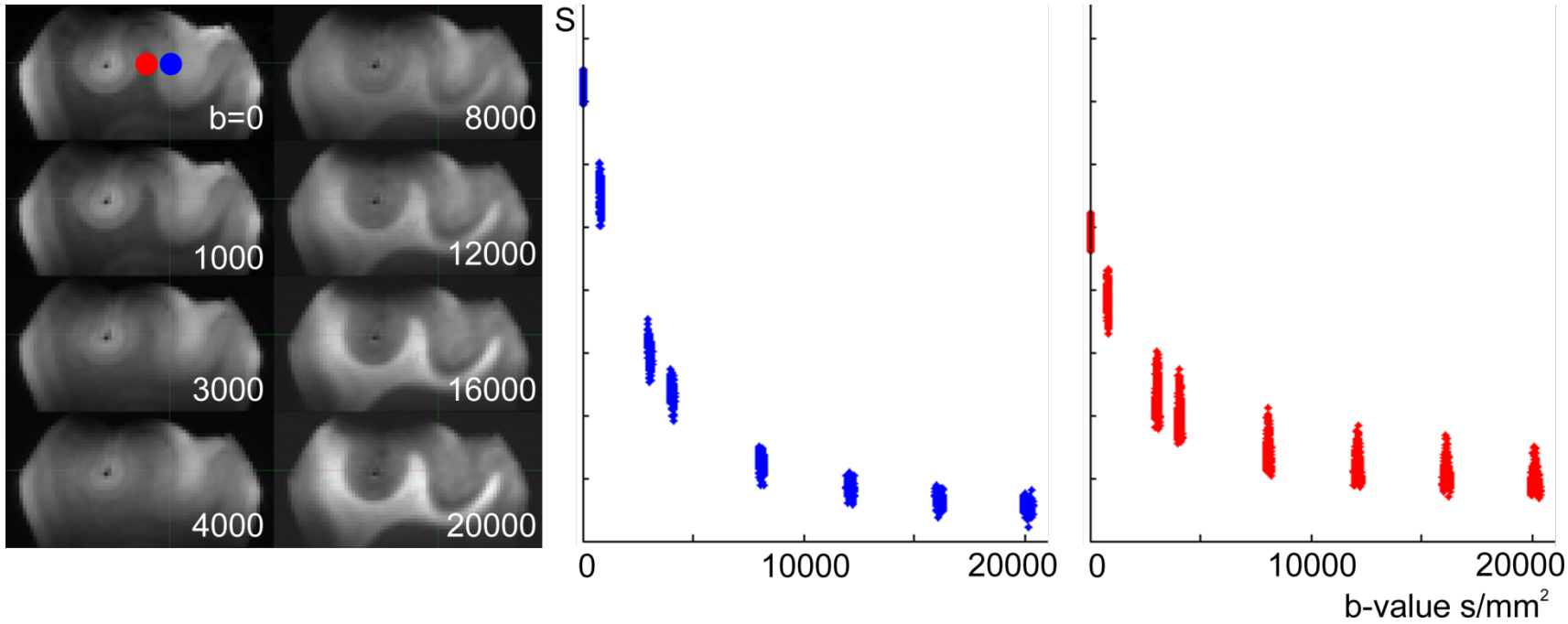


Data impression

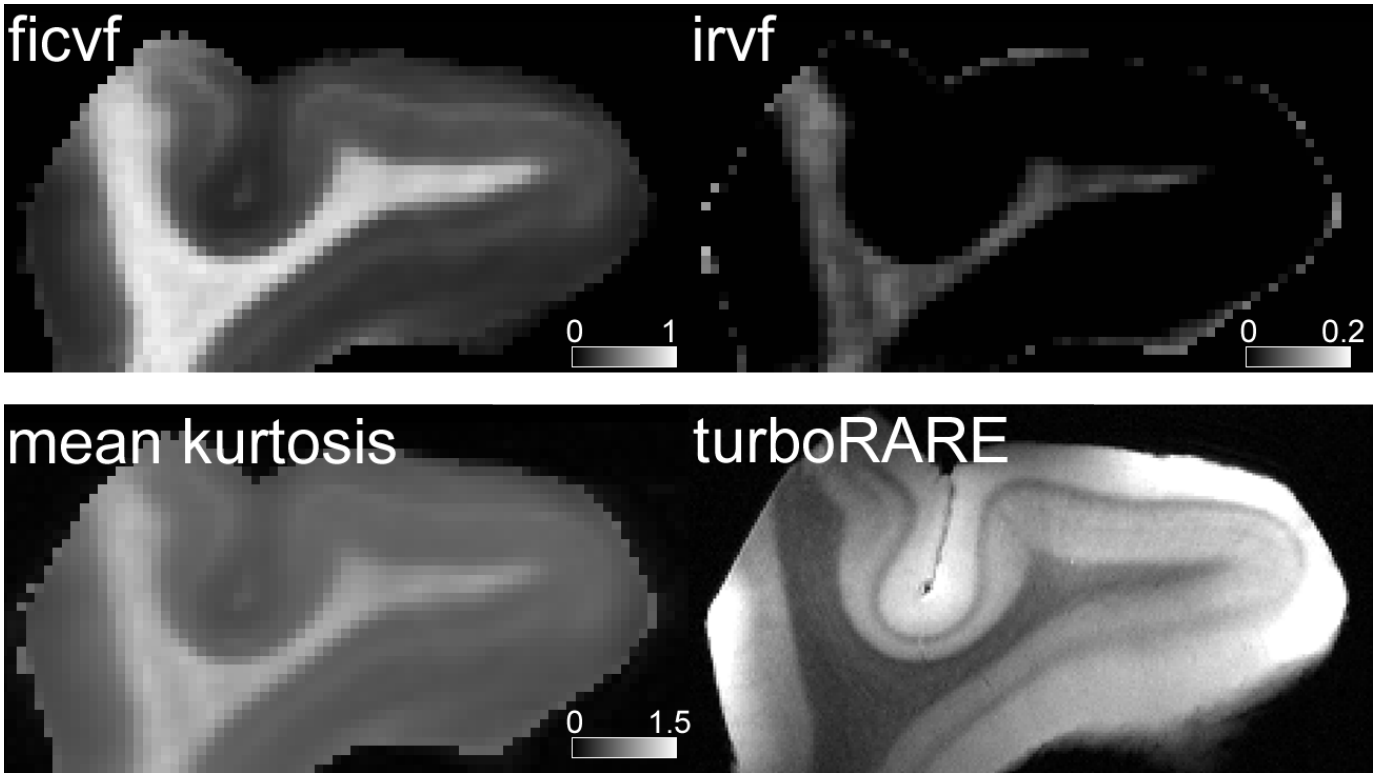
Normalized shell means

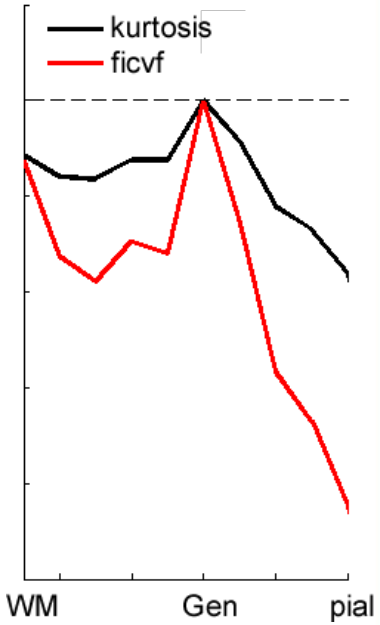
GM voxel

WM voxel

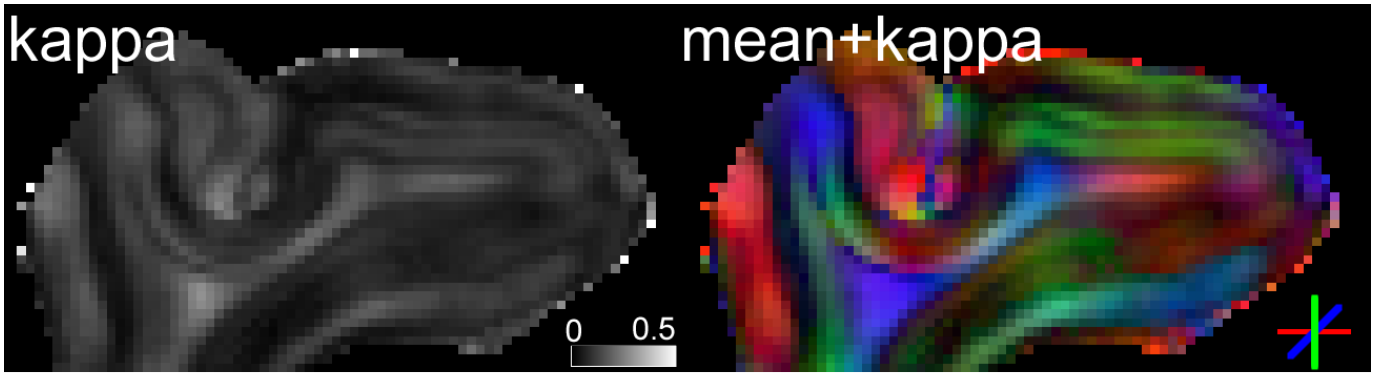


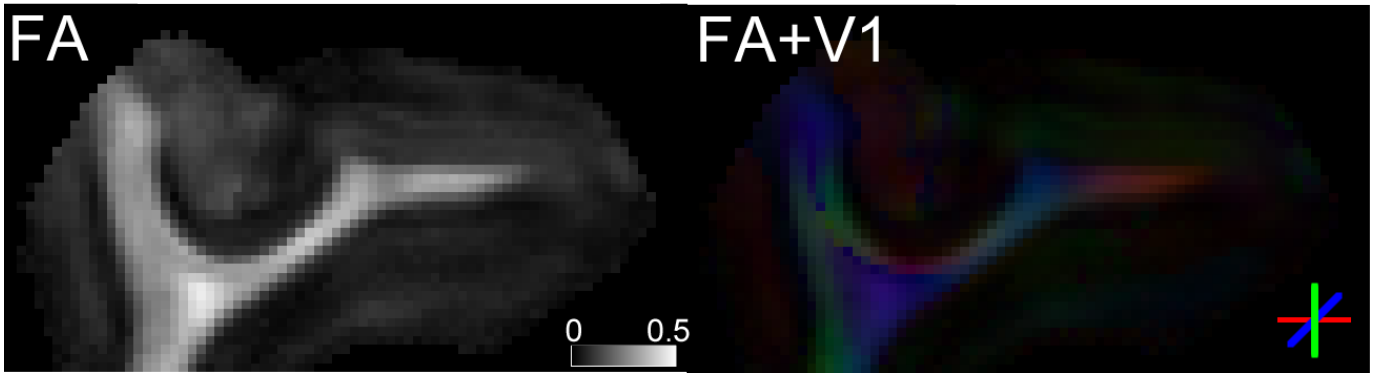
Volume fractions

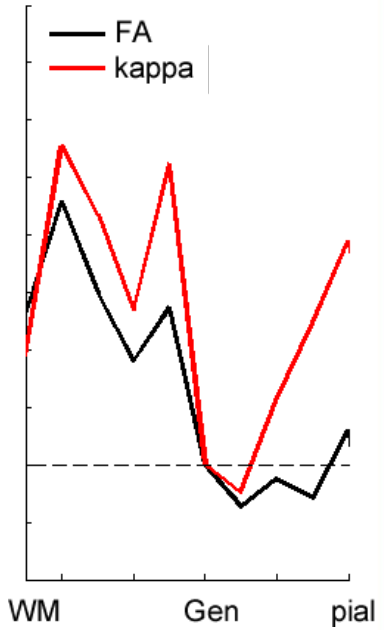




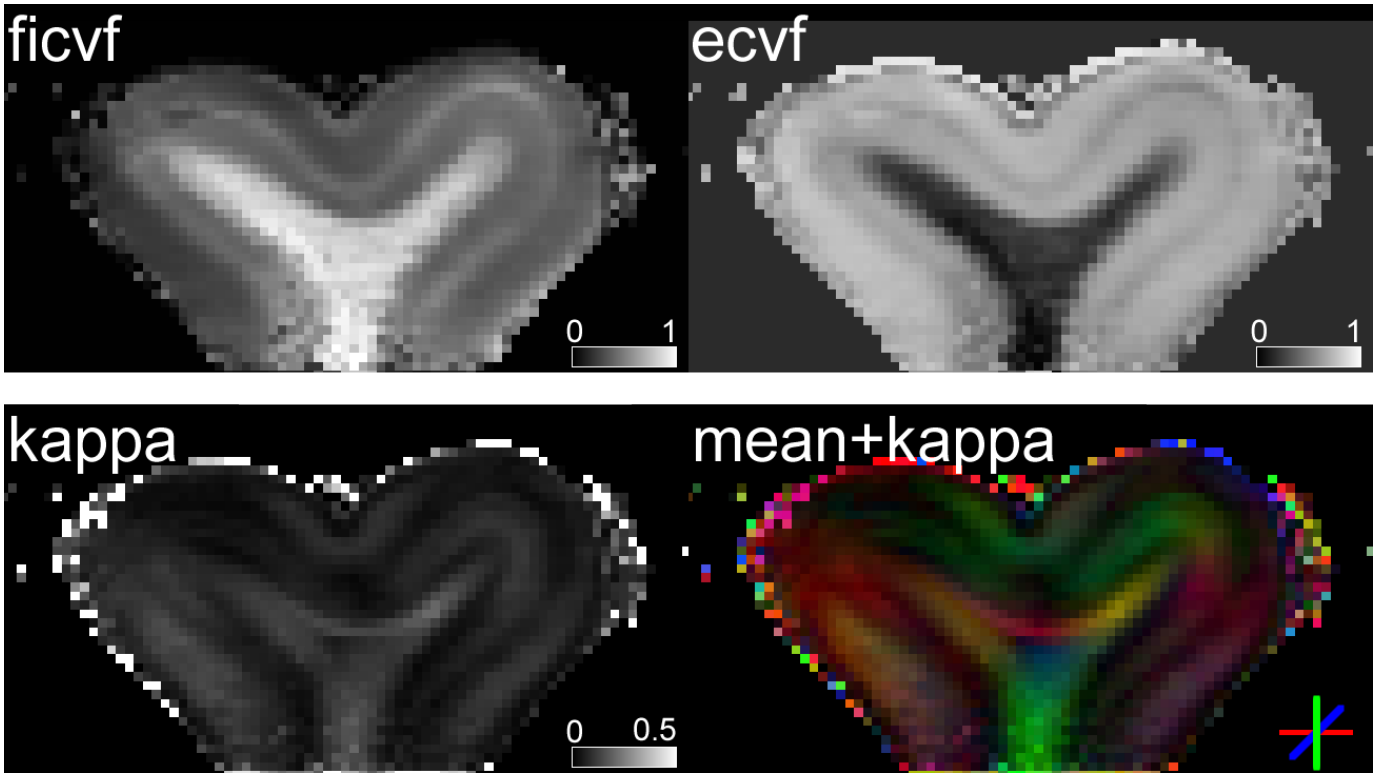
Orientation dispersion





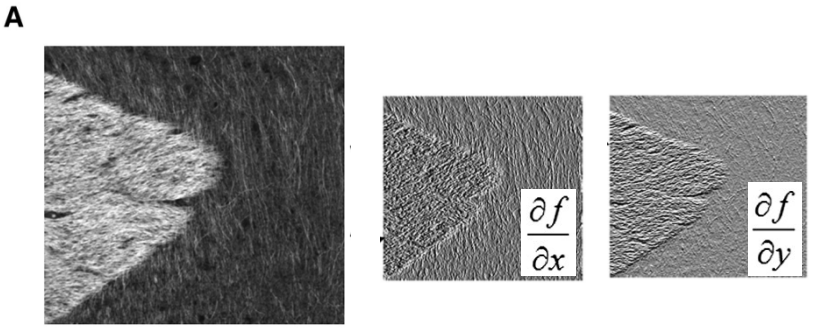


Sample B (54 directions)

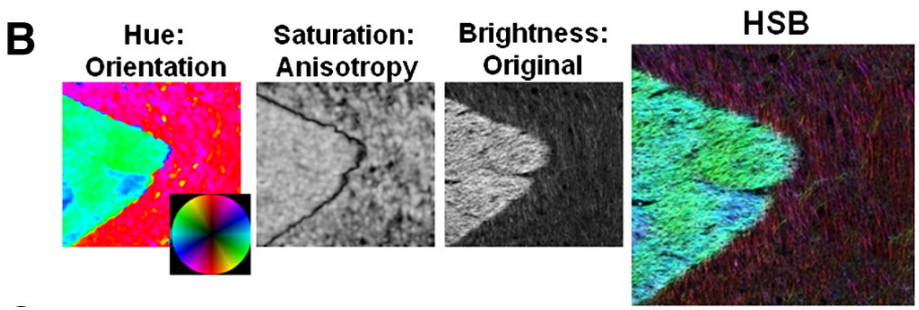


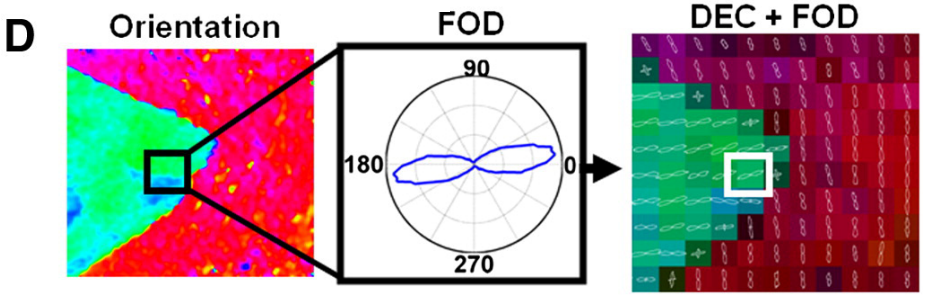
Histology

- Samples bisected and embedded in parafin
- Stains on consecutive 5 µm sections:
  - Hematoxylin (cell bodies) & Eosin (cytoplasm)
  - Luxol Fast Blue (myelin)
  - Bodian (axons)
- Virtual slice microscopy (20 X)



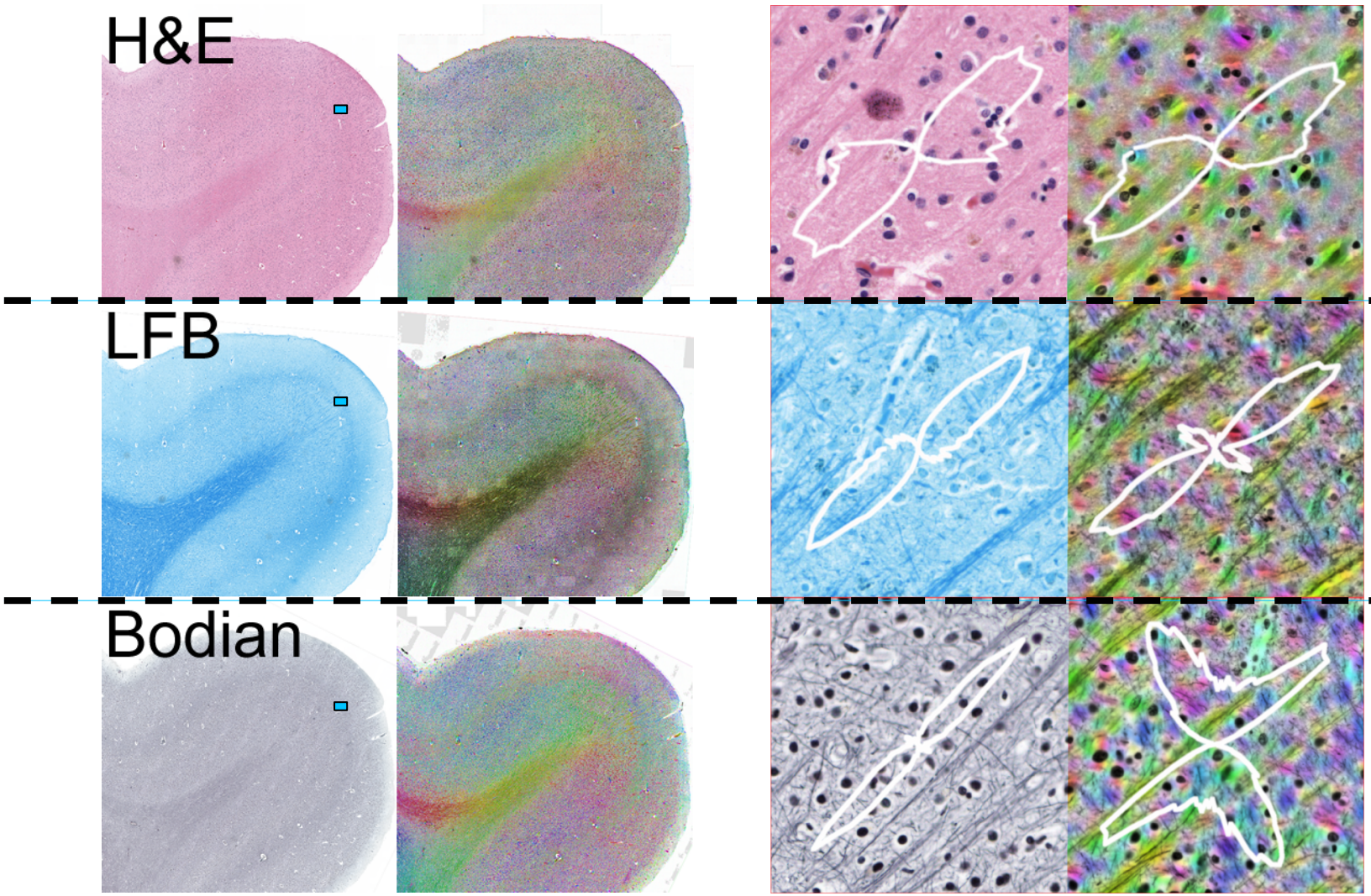
- Structure tensor analysis (Budde and Frank, 2012)



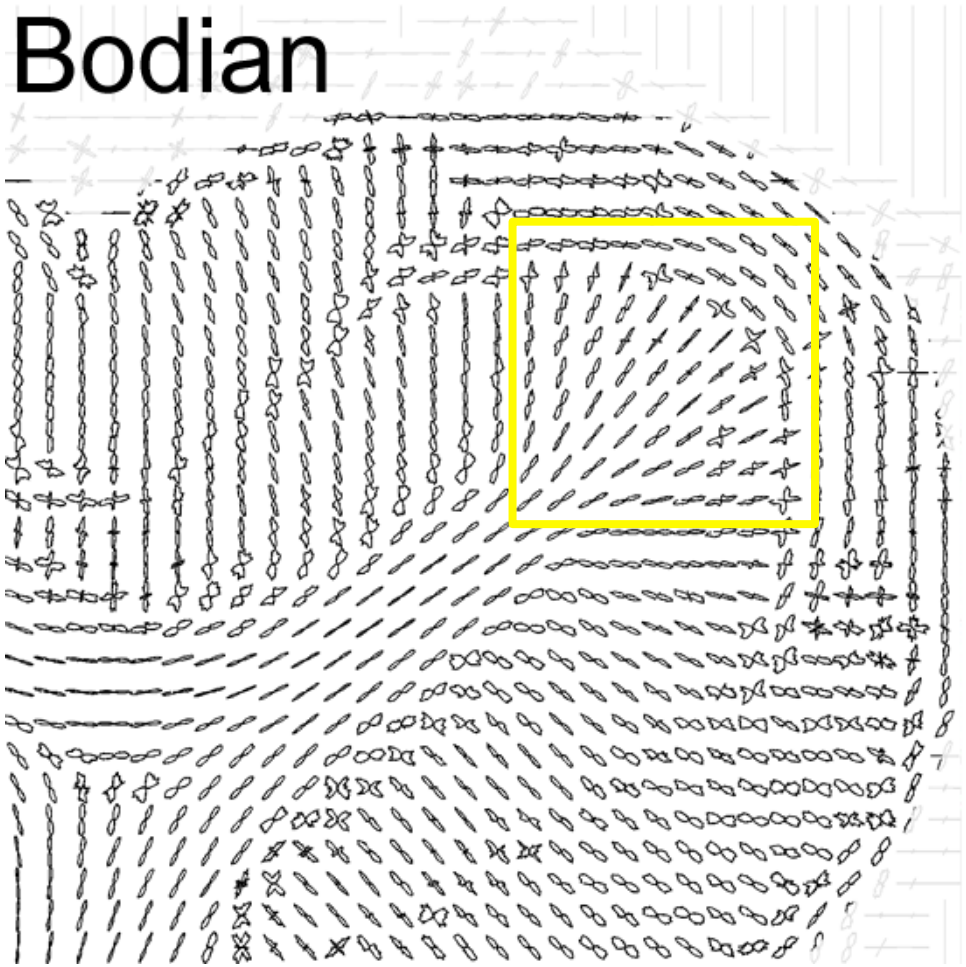


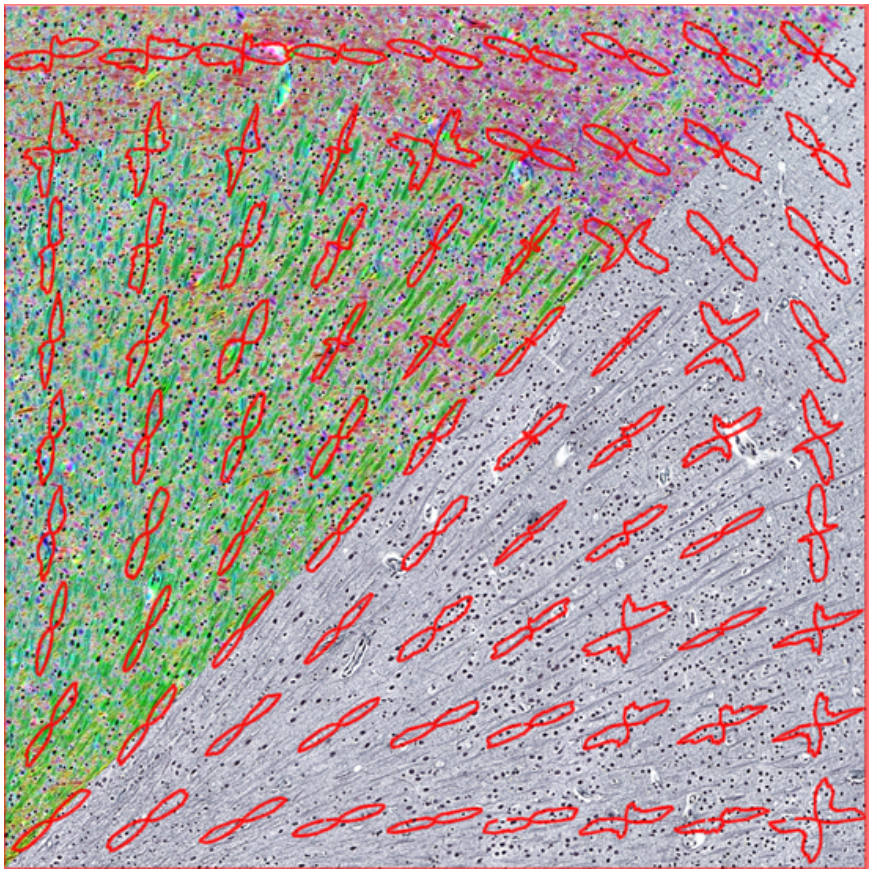
Tile 1 Tile 2

Histology



Histology





Conclusions

NODDI

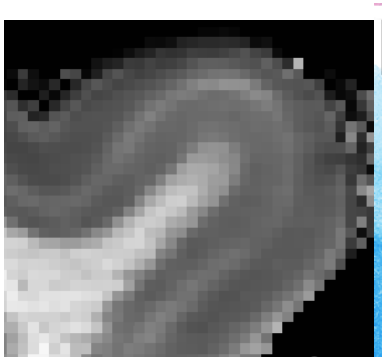
- High layer discriminability
- Sharp delineation of layer boundaries in GM and WM
- Interpretable measures
- Cortical *in vivo* investigations feasible in clinical scan times

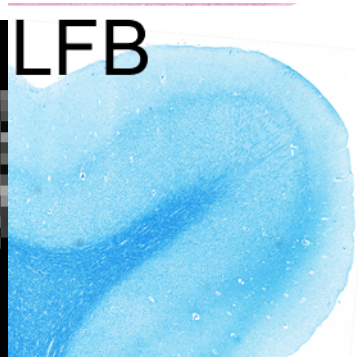
Conclusions

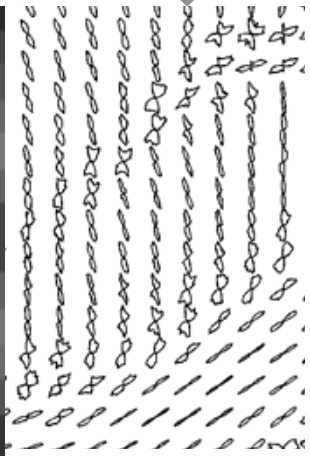
Histology

- Structure tensor useful in human, cortical histology

- Neurite volume fraction resembles myelin and axon stains
- Orientation dispersion reflected in histological 2D FODs







- no histological label for dendritic space included

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Thank you

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