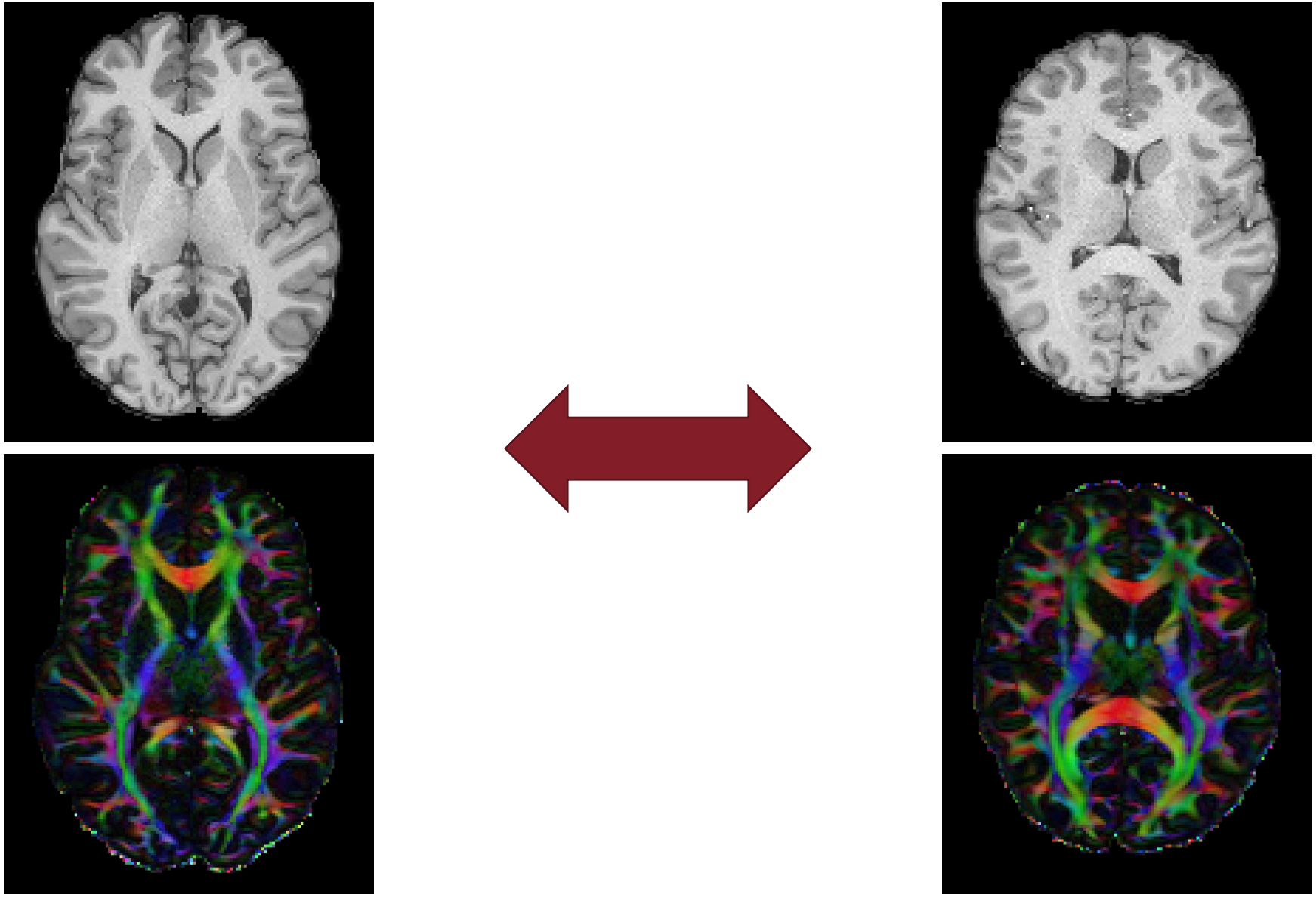
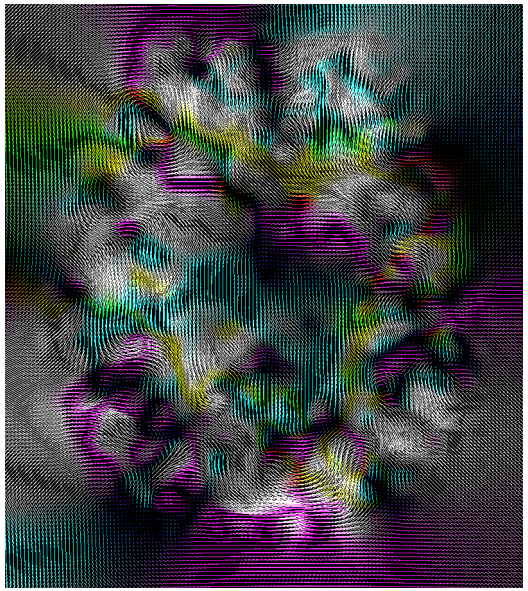
MMORF

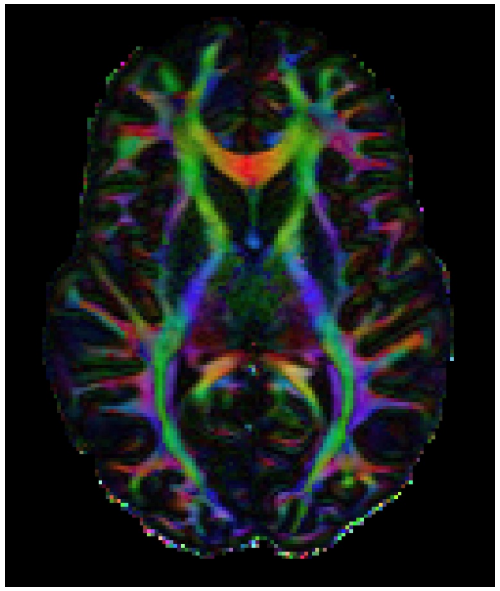
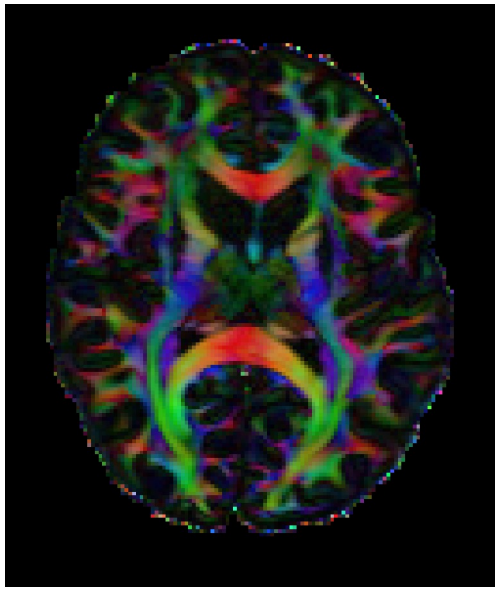
FSL's MultiMOdal Registration Framework

Multimodal registration:

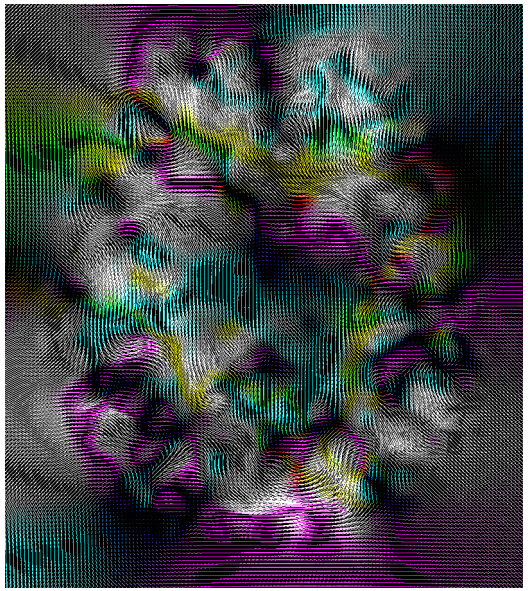


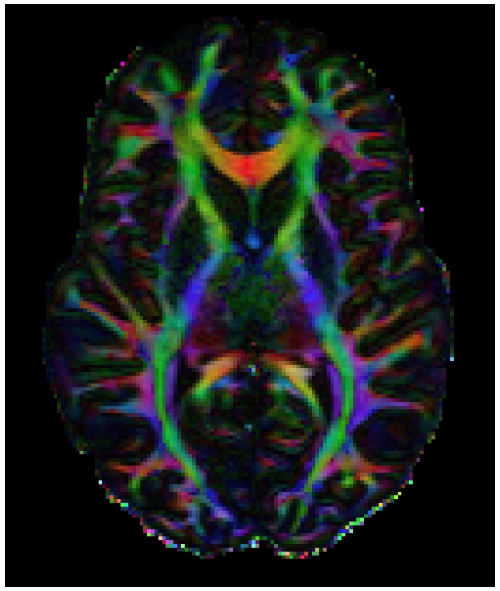
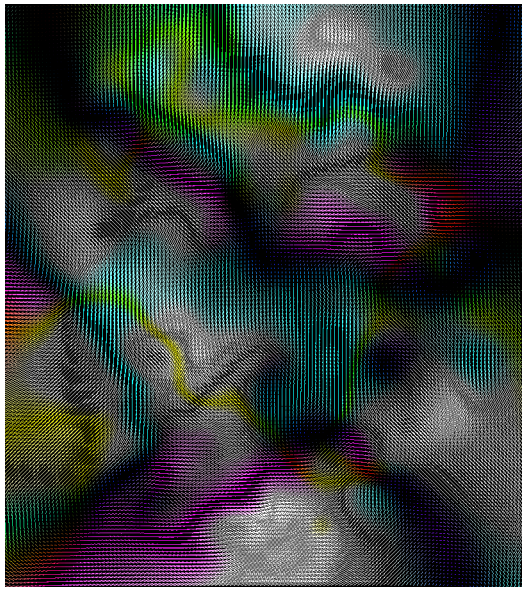
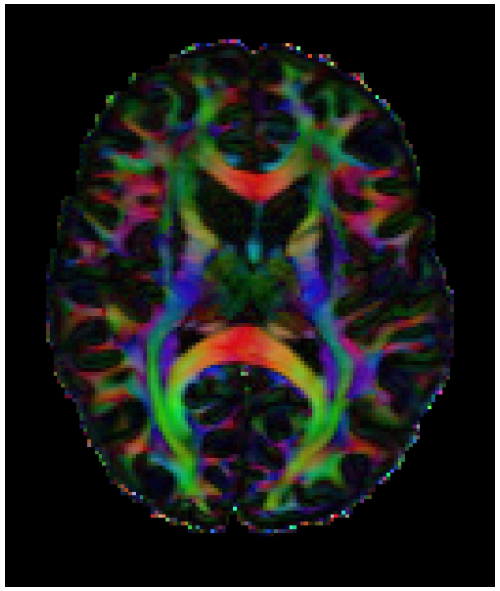
Multimodal registration:

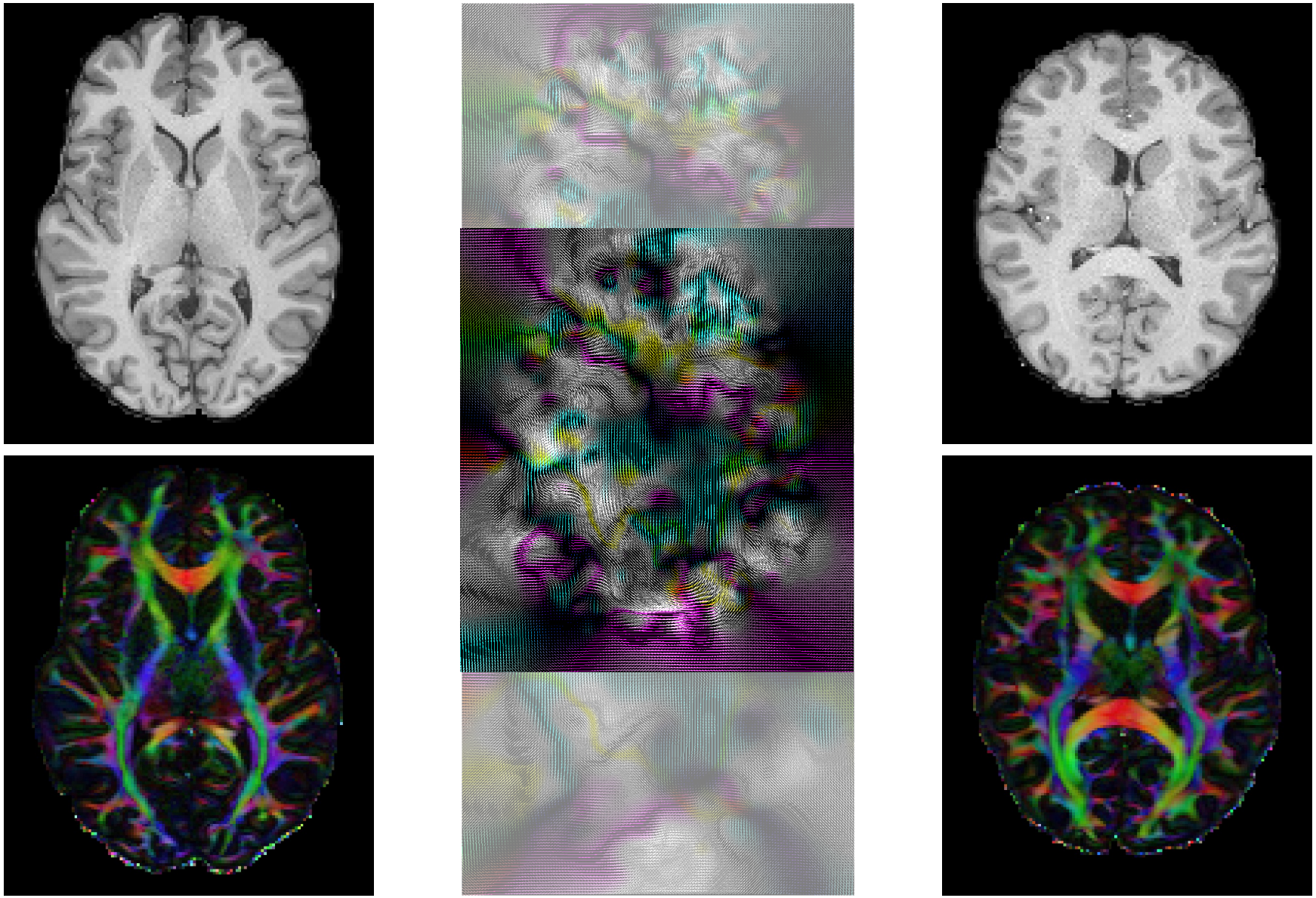



Multimodal registration:

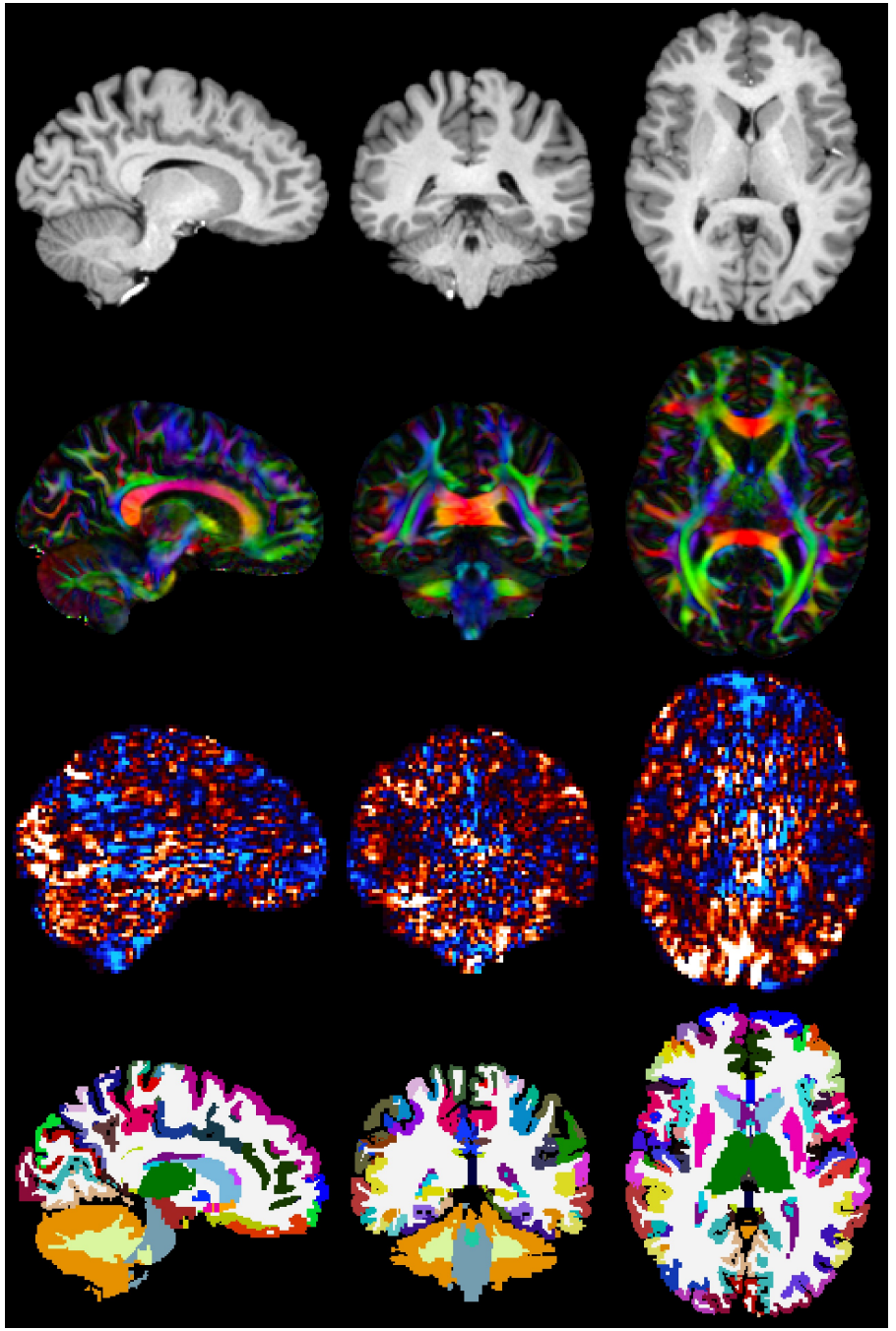




Multimodal registration



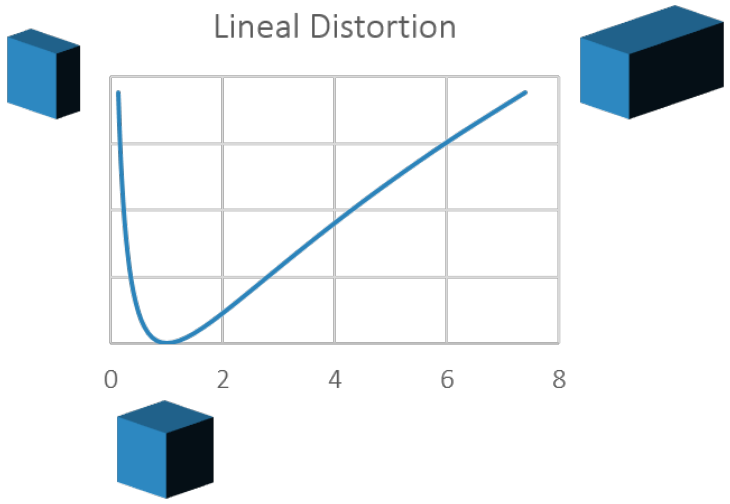
MMORF

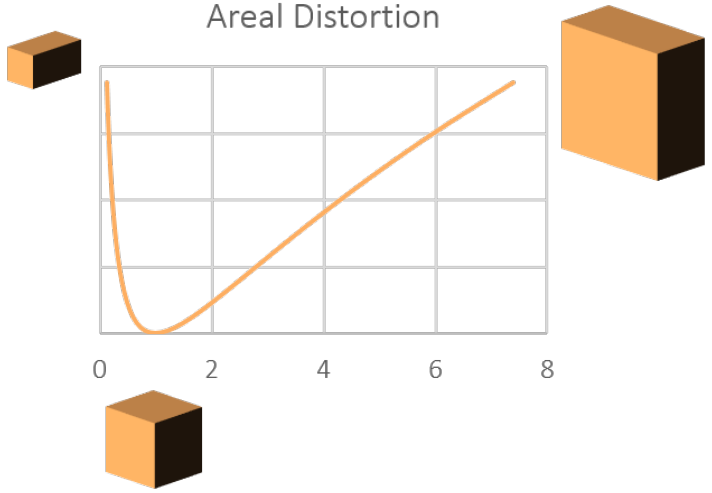
- Nonlinear volumetric
  - B-spline free form deformation
- Scalar images
  - Symmetric mean squared error
  - Multiplicative bias field estimation
- Tensor images
  - Symmetric mean squared L^2 error
  - Finite strain reorientation
- Regularisation
  - Symmetric local rigidity (SPRED)
  - Diffeomorphic
- FSL compatible
  - FNIRT-style warps
  - FLIRT affine as initialisation
  - DTIFIT tensor format
- GPU parallelised
  - Fast…
  - …but needs a GPU

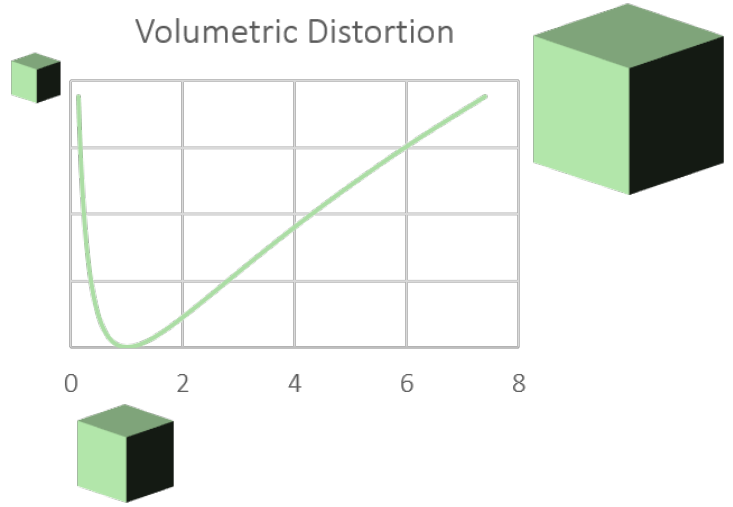


Regularisation

- Log-normal prior on changes in length, area and volume
- Promotes preservation of volume and shape
  - Locally rigid
- Enforces diffeomorphism
  - No folds or tears
- Still allows for large changes
  - Such as ventricle expansion/contraction







Potential Advantages of MMORF

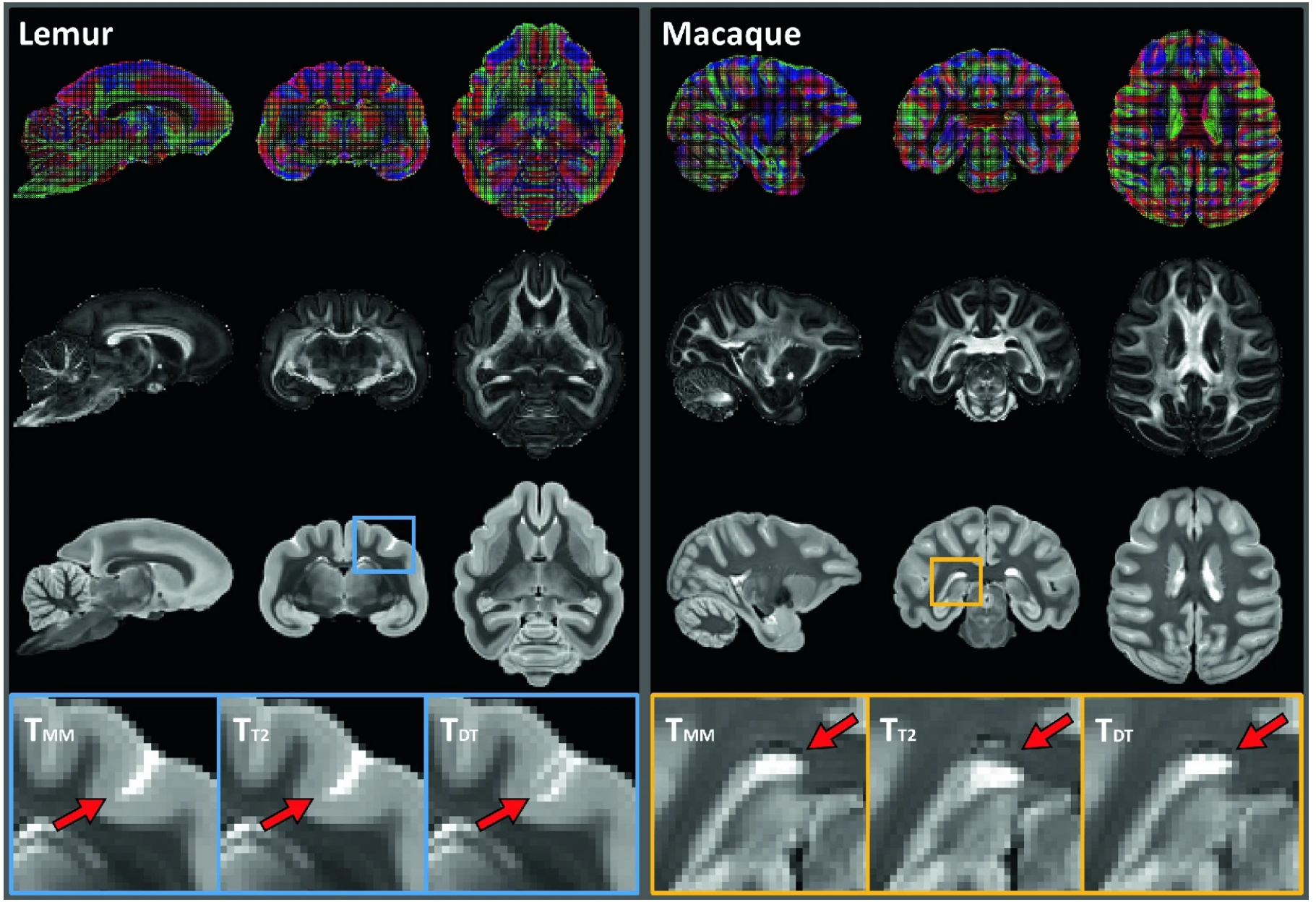
- Better overall accuracy (with less distortion)
  - More modalities = more information driving alignment
- Single warp for multimodal datasets
  - No need to register each modality individually
  - Within-subject correspondence across modalities maintained in standard space
- Structural analyses (VBM, TBM, segmentation propagation)
  - Benefits from MMORF's anatomically plausible regularisation
- Voxelwise diffusion analyses
  - When driving registration with DTI
- Fixelwise diffusion analyses
  - Using the new WHIM tool from Hossein Rafipoor

Better overall accuracy (with less distortion)

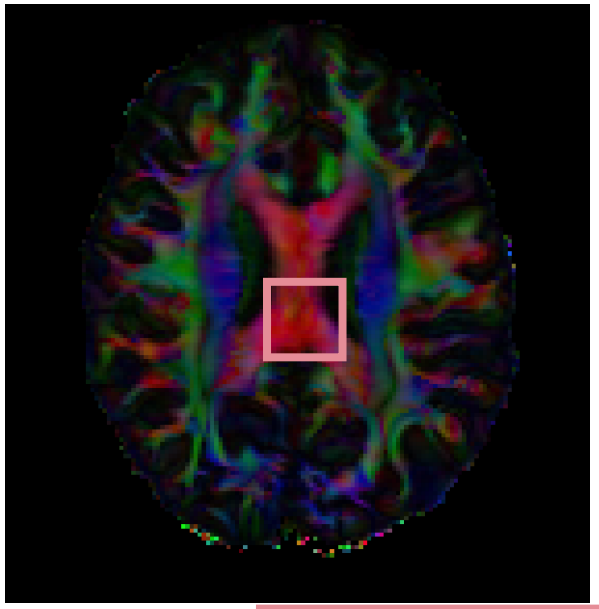
	FreeSurfer Labels				DTI			tfMRI	Distortion	
	Subcort		Cort		OVL	CLV1	CPV3	CM	|J|	CVAR
	JI	MHD	JI	MHD						
FLIRT	0.46* (0.24)	0.73* (0.81)	0.20* (0.09)	2.05* (1.03)	0.669* (0.030)	0.802* (0.022)	0.755* (0.021)	53.36* (58.36)	- (-)	- (-)
FNIRT	0.61* (0.27)	0.37* (0.60)	**0.41* (0.15)**	1.12* (0.80)	0.776* (0.017)	0.873* (0.012)	0.854* (0.010)	11.94* (14.22)	1.86* (0.140)	1.50* (0.029)
ANTs	0.65 (0.24)	0.35 (0.60)	0.40 (0.14)	**1.10 (0.79)**	0.802* (0.018)	0.886* (0.011)	0.867* (0.010)	5.50* (8.58)	**1.20 (0.071)**	1.37* (0.021)
ANTS-MM	0.64* (0.23)	0.35* (0.54)	0.39* (0.13)	**1.10 (0.79)**	0.815* (0.014)	0.894* (0.008)	**0.872 (0.007)**	2.01* (3.40)	1.35* (0.069)	1.41* (0.018)
DR-TAMAS	0.64* (0.26)	0.37* (0.61)	0.37* (0.14)	1.19* (0.820)	0.817* (0.012)	0.896* (0.008)	0.870* (0.008)	1.31* (4.83)	1.39* (0.089)	1.37* (0.022)
MMORF	**0.66 (0.27)**	**0.31 (0.60)**	0.40 (0.14)	**1.10 (0.76)**	**0.825 (0.015)**	**0.900 (0.008)**	**0.872 (0.007)**	**- (-)**	**1.20 (0.062)**	**1.35 (0.014)**

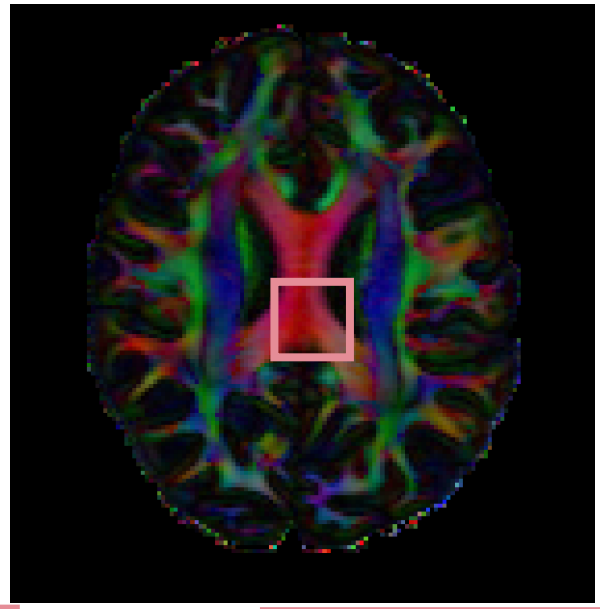
Lange F. et al; MMORF—FSL's MultiMOdal Registration Framework. *Imaging Neuroscience* 2024; 2 1–30. doi: https://doi.org/10.1162/imag_a_00100

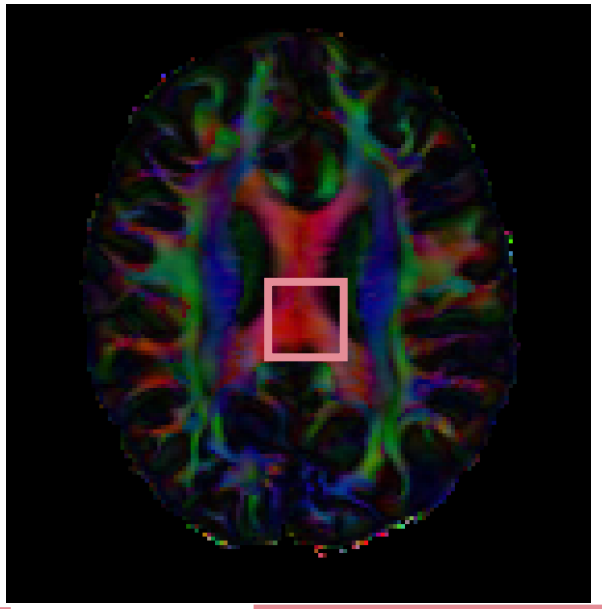
Multimodal benefits



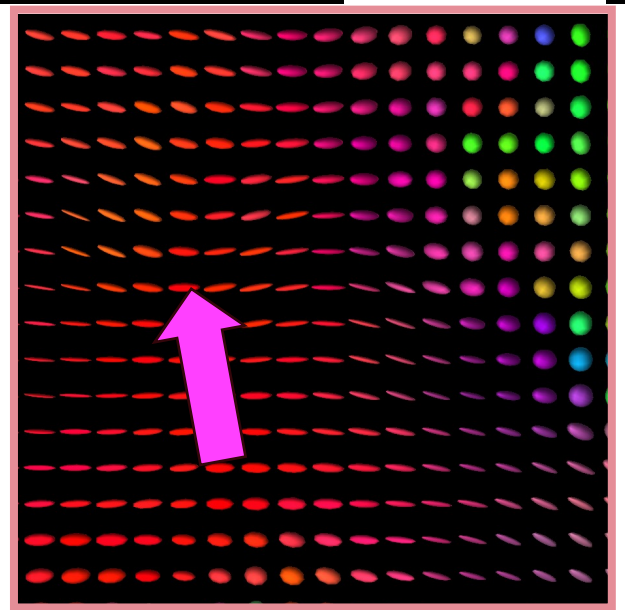
Voxelwise Diffusion Analyses







T1



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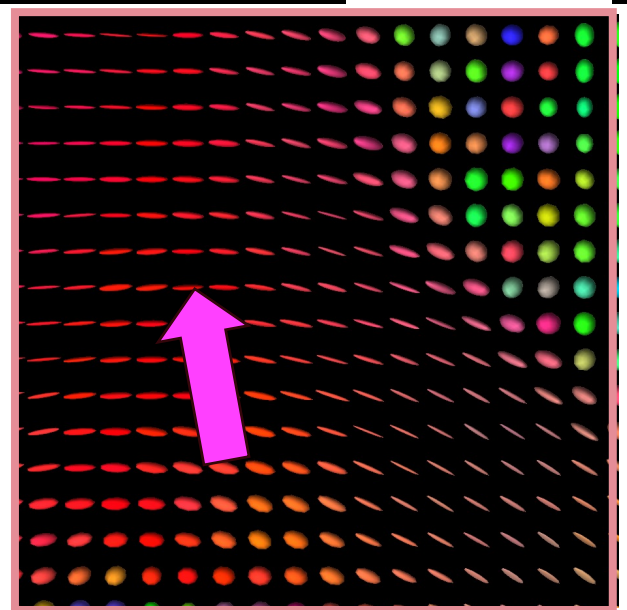
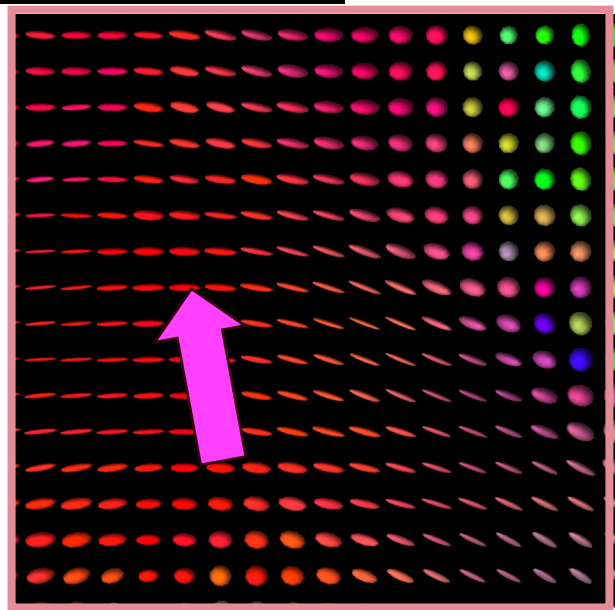


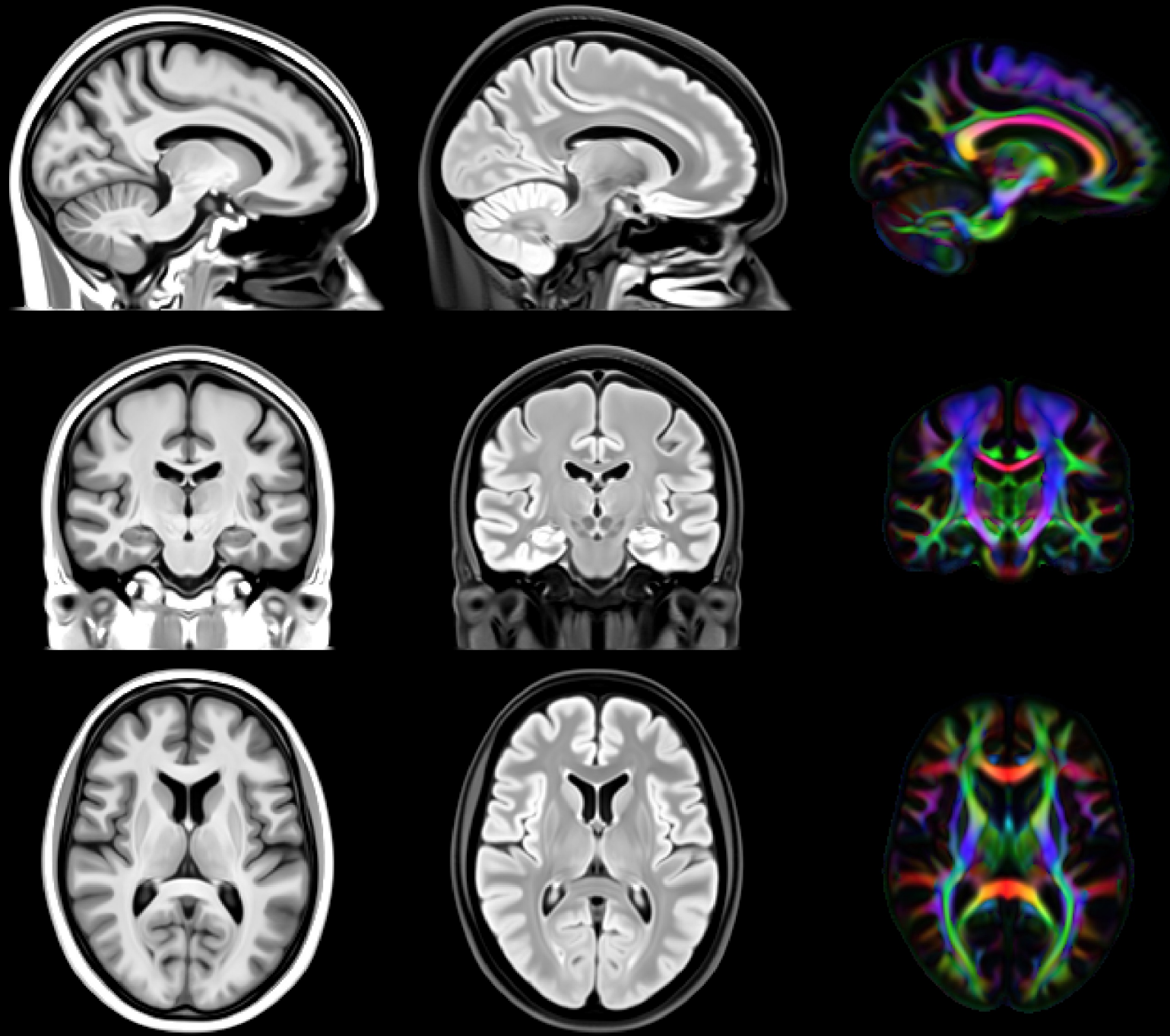
MM



Installing MMORF

- Install FSL
  - Since 6.0.7
- Create or install into a conda environment
  - `conda create -p ./mmorf_env -c https://fsl.fmrib.ox.ac.uk/fsldownloads/fslconda/public/ -c conda-forge fsl-mmorf-cuda-10.2`
- Download Singularity image
  - https://git.fmrib.ox.ac.uk/flange/mmorf_beta/

Oxford Multimodal Template (OMM-1)



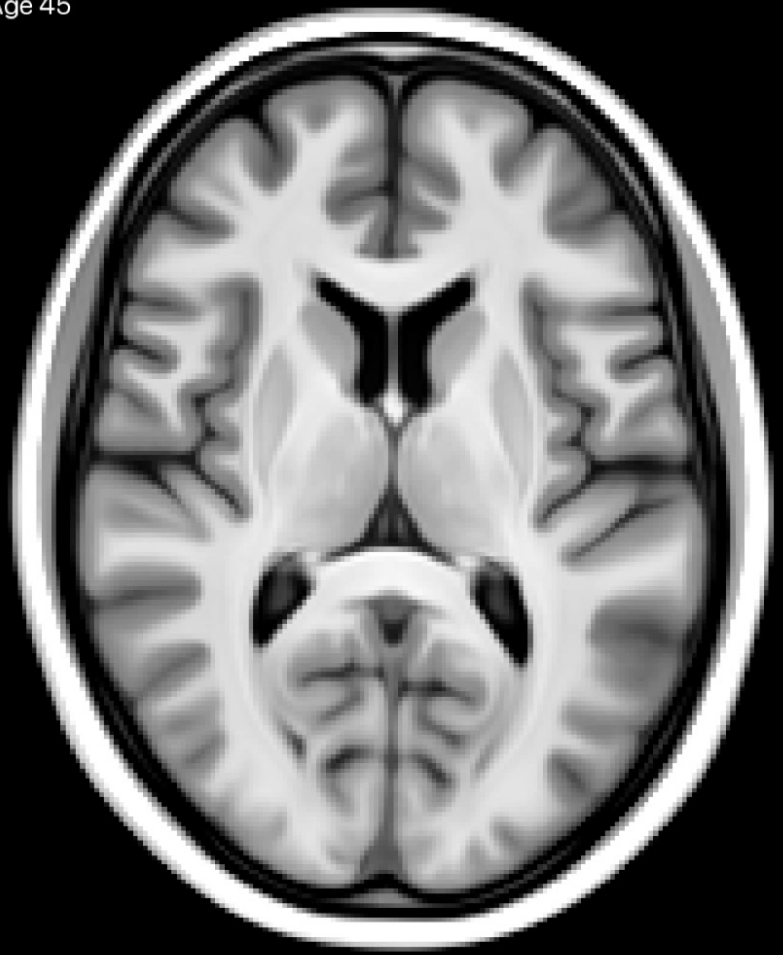
- 240 UKB individuals
- 50-55 YOA
- 50% female
- T1w, T2 FLAIR, DTI modalities
- A new standard for multimodal imaging analysis
- Unifying volumetric analysis space across modalities in UKB
- Available in FSL 6.0.7.6 and up

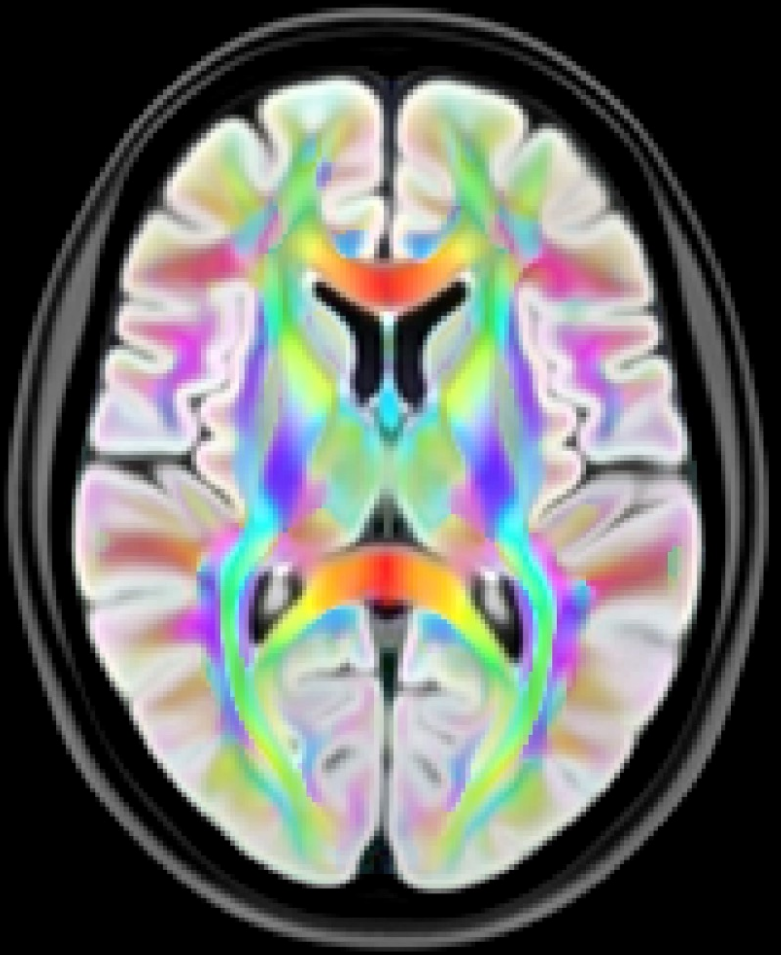
Arthofer C. et al; Internally-consistent and fully-unbiased multimodal MRI brain template construction from UK Biobank: Oxford-MM bioRxiv 2023.11.30.569378; https://doi.org/10.1101/2023.11.30.569378

Age-dependent Templates

- Trained on over 37,000 UKB individuals
- 45-82 YOA
- Model trajectories of healthy ageing
- Remove template-age bias

Age 45





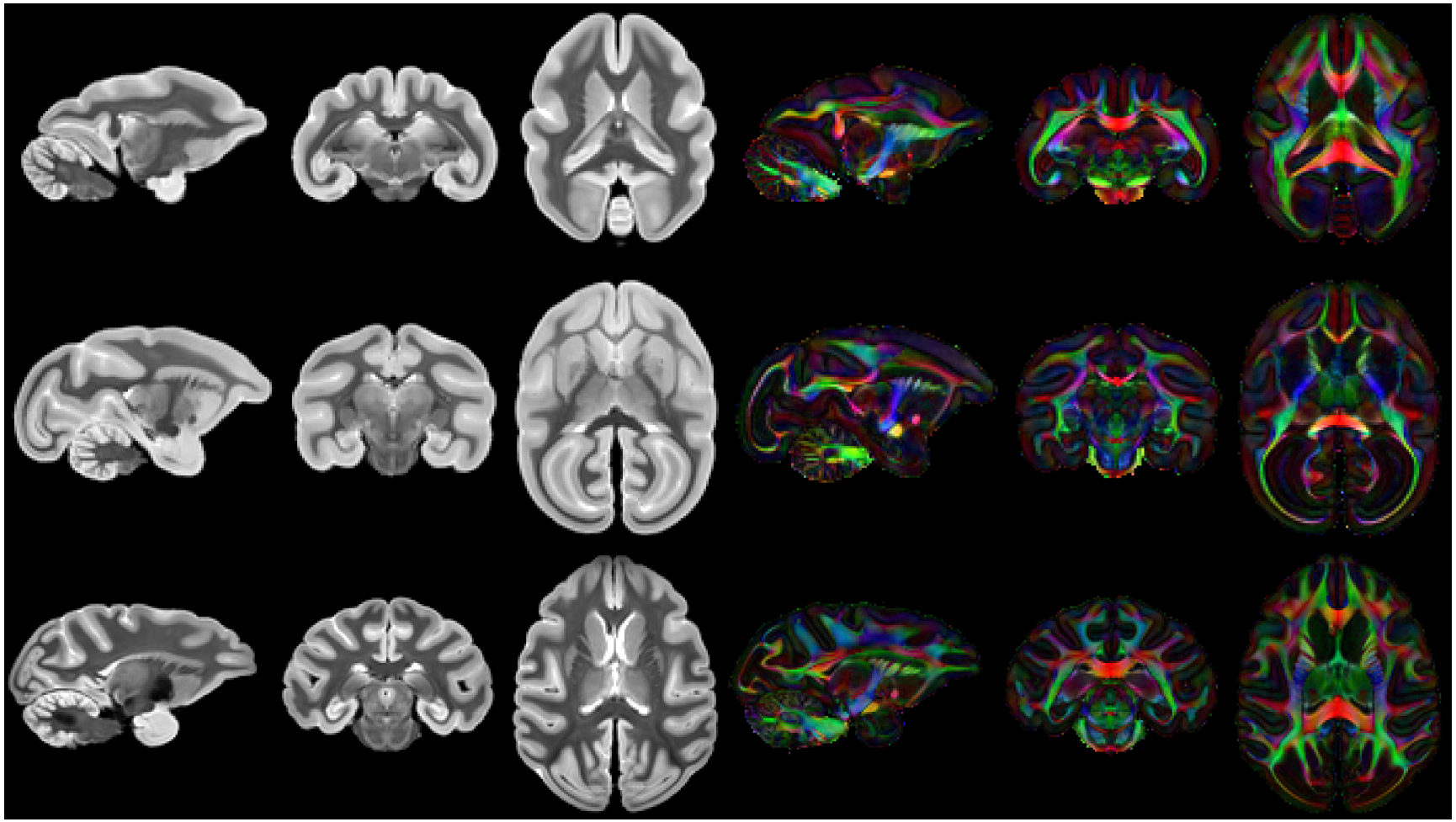
NHP

Lea Roumazeilles

lemur

squirrel monkey

macaque



Roumazeilles L, Lange FJ, et al, Cortical Morphology and White Matter Tractography of Three Phylogenetically Distant Primates: Evidence for a Simian Elaboration, Cerebral Cortex, 2021;, bhab285, https://doi.org/10.1093/cercor/bhab285

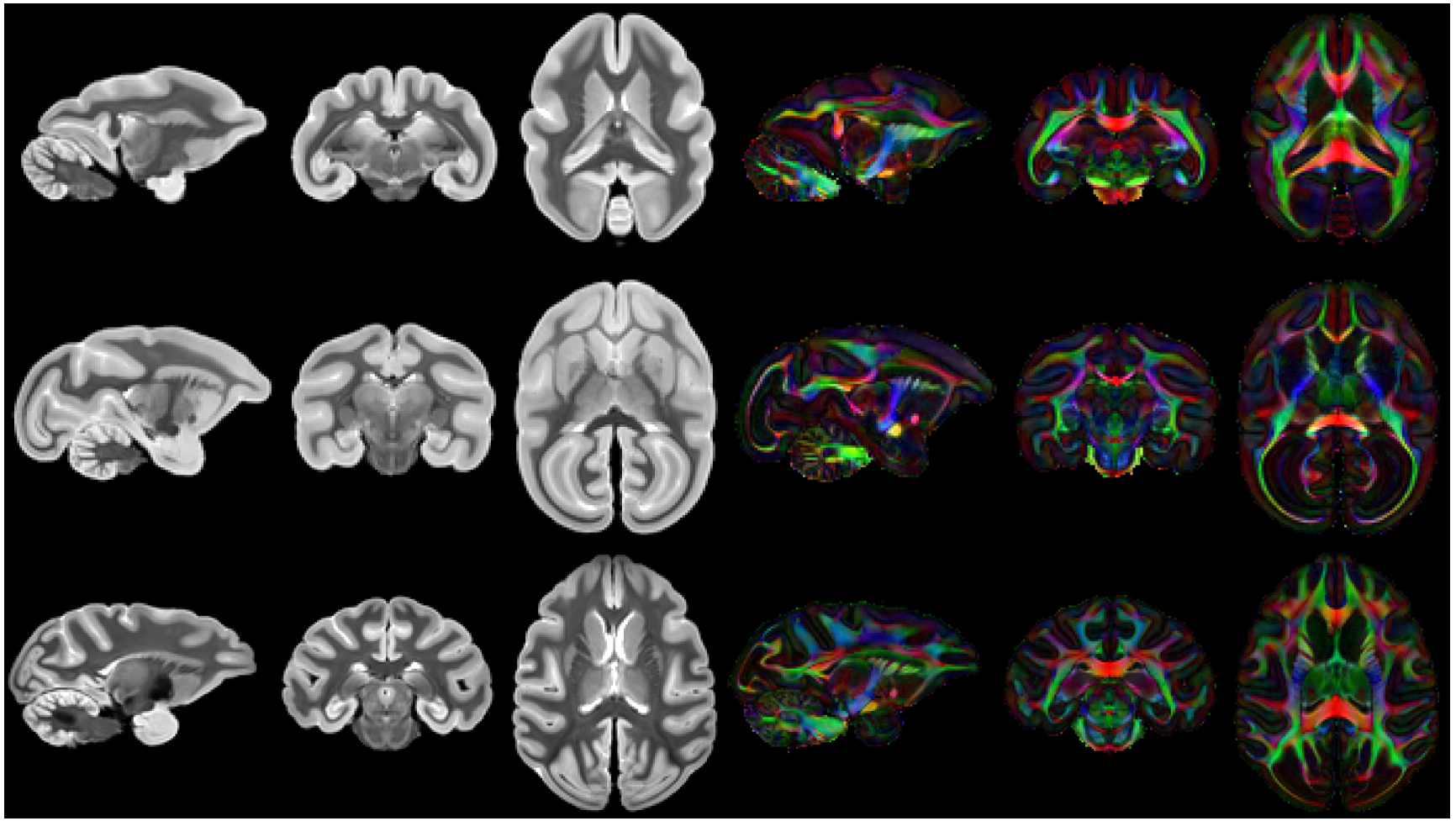
NHP

Lea Roumazeilles

lemur

squirrel monkey

macaque



https://git.fmrib.ox.ac.uk/cart/mm-template-construction