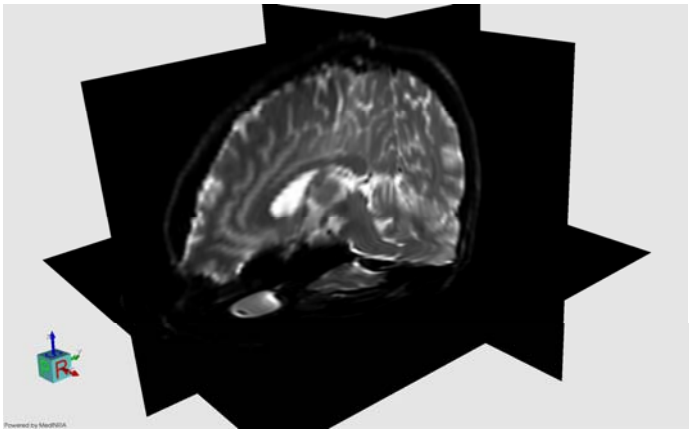

# Constructing Diffusion Tensor Atlases

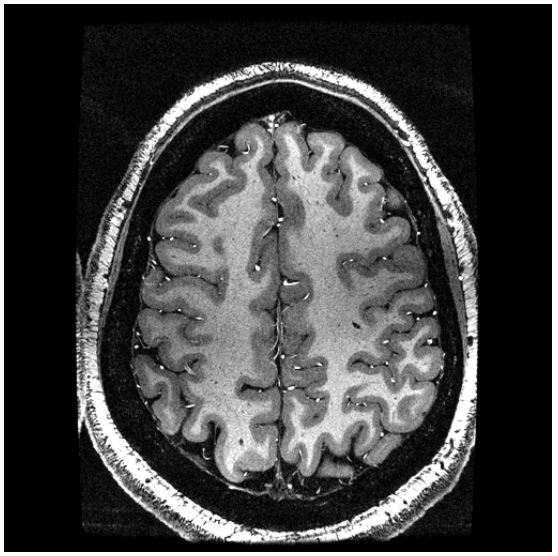
B.T. Thomas Yeo

Advisors @ INRIA: Olivier Clatz, Xavier Pennec, Nicholas Ayache

# Traditional MRI

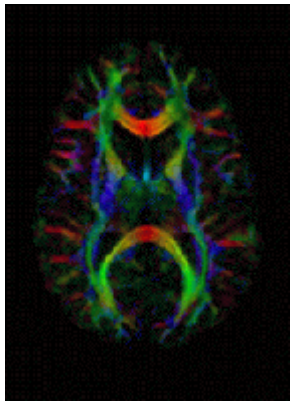


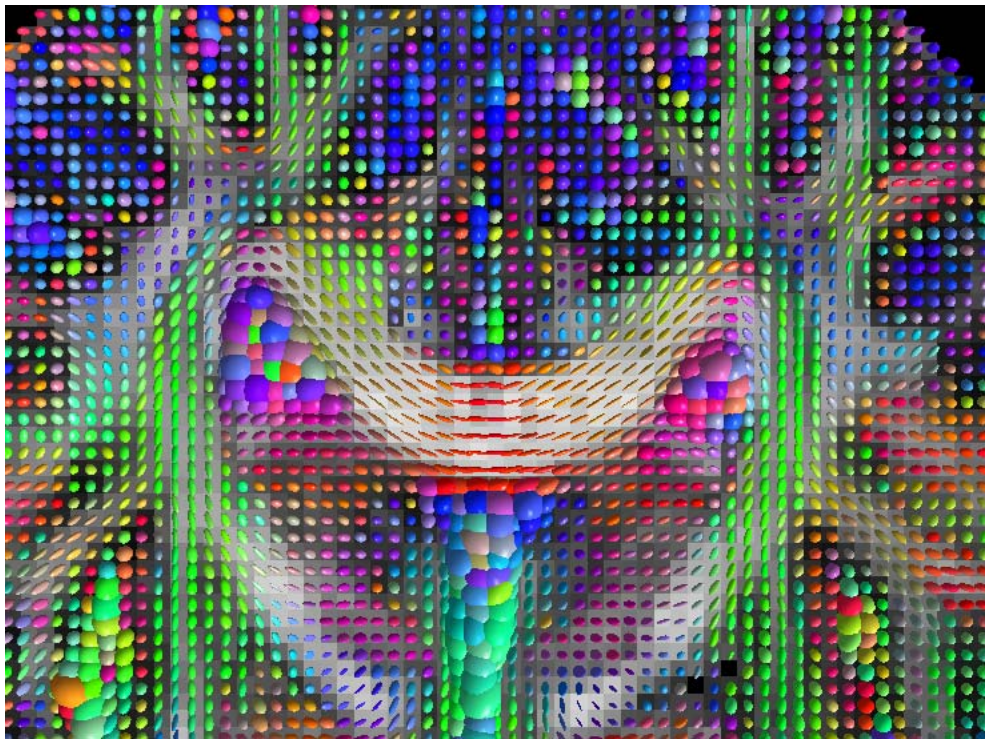
- MRI = Magnetic Resonance Imaging
- Measures tissue magnetic property
- Tissues with different magnetic properties have different MR intensity
- 3D Image: Each pixel (voxel) has a scalar



# Diffusion Tensor MRI (DTI)


- Relatively New Imaging Modality
- Measures direction and strength of water diffusion
- 3D image: Each pixel (voxel) has a 3x3 Positive Definite Matrix (or Tensor)
- Principal Eigenvector = Principal Diffusion Direction





# What is Registration? What for?


- Process of aligning / deforming images into “common space” for meaningful comparison
- In this “common space”, the deformed images have the “same” structures appearing in the “same” spatial locations
- Intra-Subject
  - Same person imaged on different dates
  - Same person imaged on different modalities
- Inter-Subject
  - variability AND/OR similarity in normal population
  - control group vs disease group

# What is an Atlas? What for?


- An atlas is a summary of a population of images
- Suppose you have already applied an algorithm X that registers 100 images into a “common space”
- To compare new image to the 100 images
  - You can re-run algorithm X with 101 images

    OR

  - You can summarize the 100 images with an atlas and register the new image to the atlas with an algorithm Y

# How to Create an Atlas


- To summarize 100 images with an atlas
- Warp the 100 training images into some common space
- In this common space, the deformed images look the “same”
- Compute regressors (statistical or otherwise) describing the images in the common space
- Use the regressors to deform a new image into the common space so that the deformed image is well-aligned to training images

# Goal 1: create a DTI atlas


- Warp the 100 DTI training images into a common space and compute regressors
- Technical Caveat:
  - In registration, objective function usually non-convex
  - Suppose F is some non-convex function
  - For a scalar:
    - F(scalar) = scalar
  - For a Positive Definite (PD) Matrix:
    - F(PD) ≠ PD

# Log-Euclidean Tensor Computation

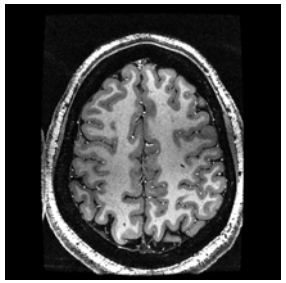
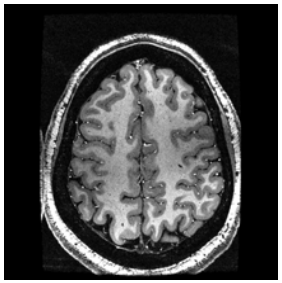
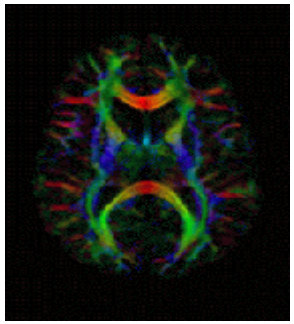
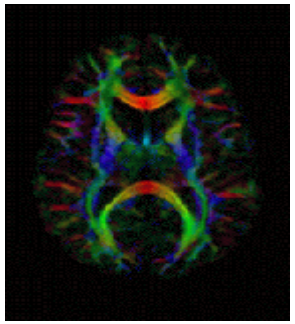

- Novel vector space for PD Matrices with associated “Log-Euclidean” metric

(Arsigny, Filliard, Pennec and Ayache, 2006)

- Good Properties:
  - Fast and Simple
  - Inverse Invariant
  - Translation Invariant
  - Similarity Invariant

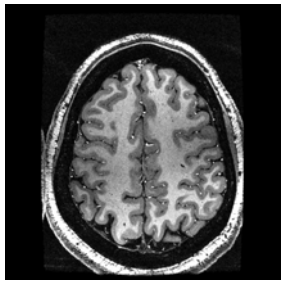
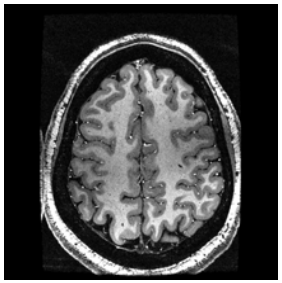
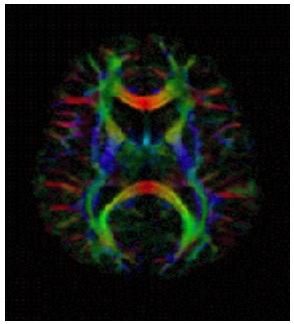
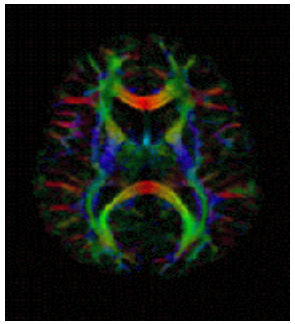
# Goal 2: What MRI tells us about DTI

- Question: How well can we align DTI images by only aligning traditional MRI images?

| | Subject 1 | Subject 2 |
|---|---|---|
| MRI |  |  |
| DTI |  |  |

# Goal 2: What MRI tells us about DTI

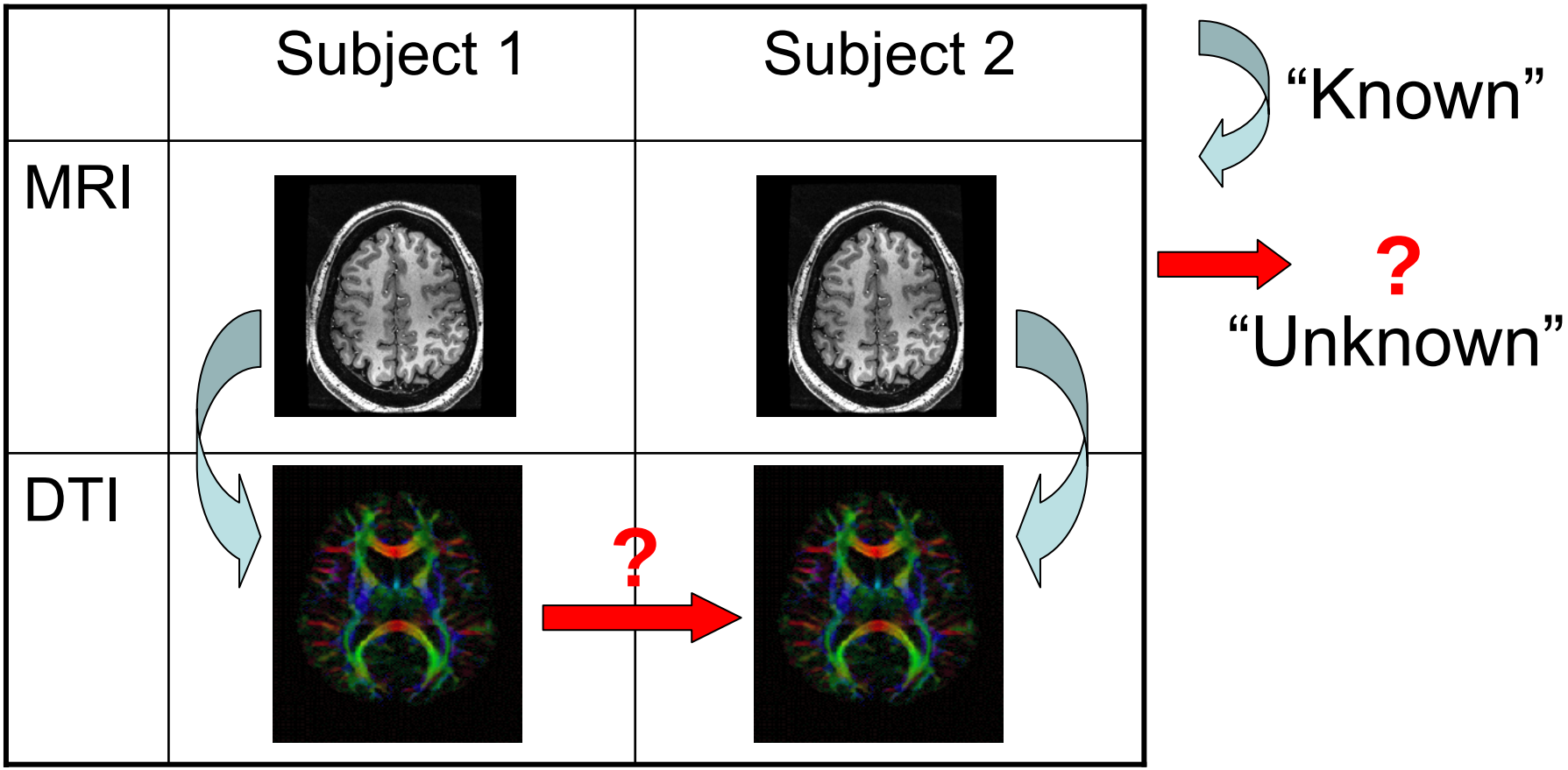

- Question: Can we align DTI images by only aligning traditional MRI images?

| | Subject 1 | Subject 2 |
|---|---|---|
| MRI |  |  |
| DTI |  |  |

"Known"

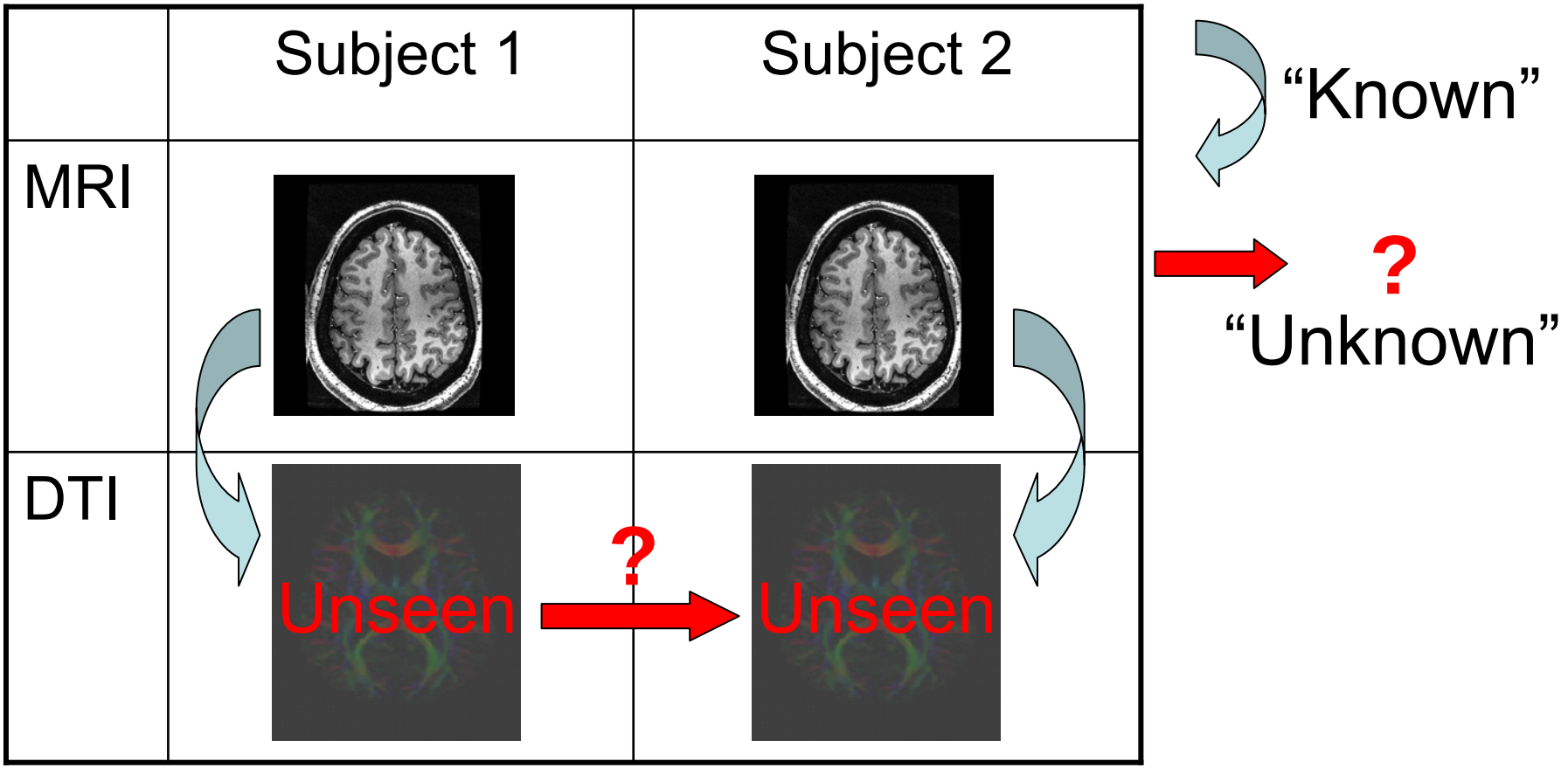
# Goal 2: What MRI tells us about DTI

- Question: Can we align DTI images by only aligning traditional MRI images?



# Goal 2: What MRI tells us about DTI


- Question: Can we align DTI images by only aligning traditional MRI images?

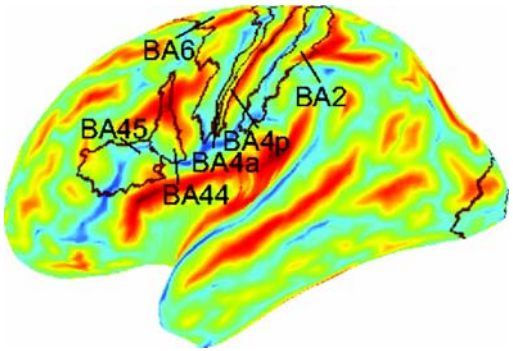


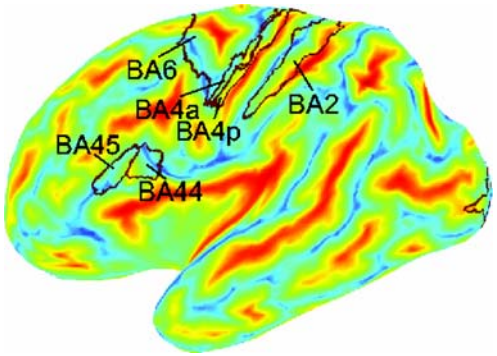
# Predictiveness of Image Modalities


- Why? Biologically, Computationally Interesting
- Part of a general class of imaging problems:
  - How to align image modality 1 in order to align image modality 2?
  - Each imaging modality measures different tissue properties
    - Exploring the relationships between the different tissue properties
    - How one tissue property predicts another
    - How one structure affects another structure which might not be nearby

# Progress Towards Goal 2


- We have developed a new method of atlas building that facilitates goal 2 (Yeo *et al*., in submission)
- Can we align Brodmann areas by only aligning cortical folds?



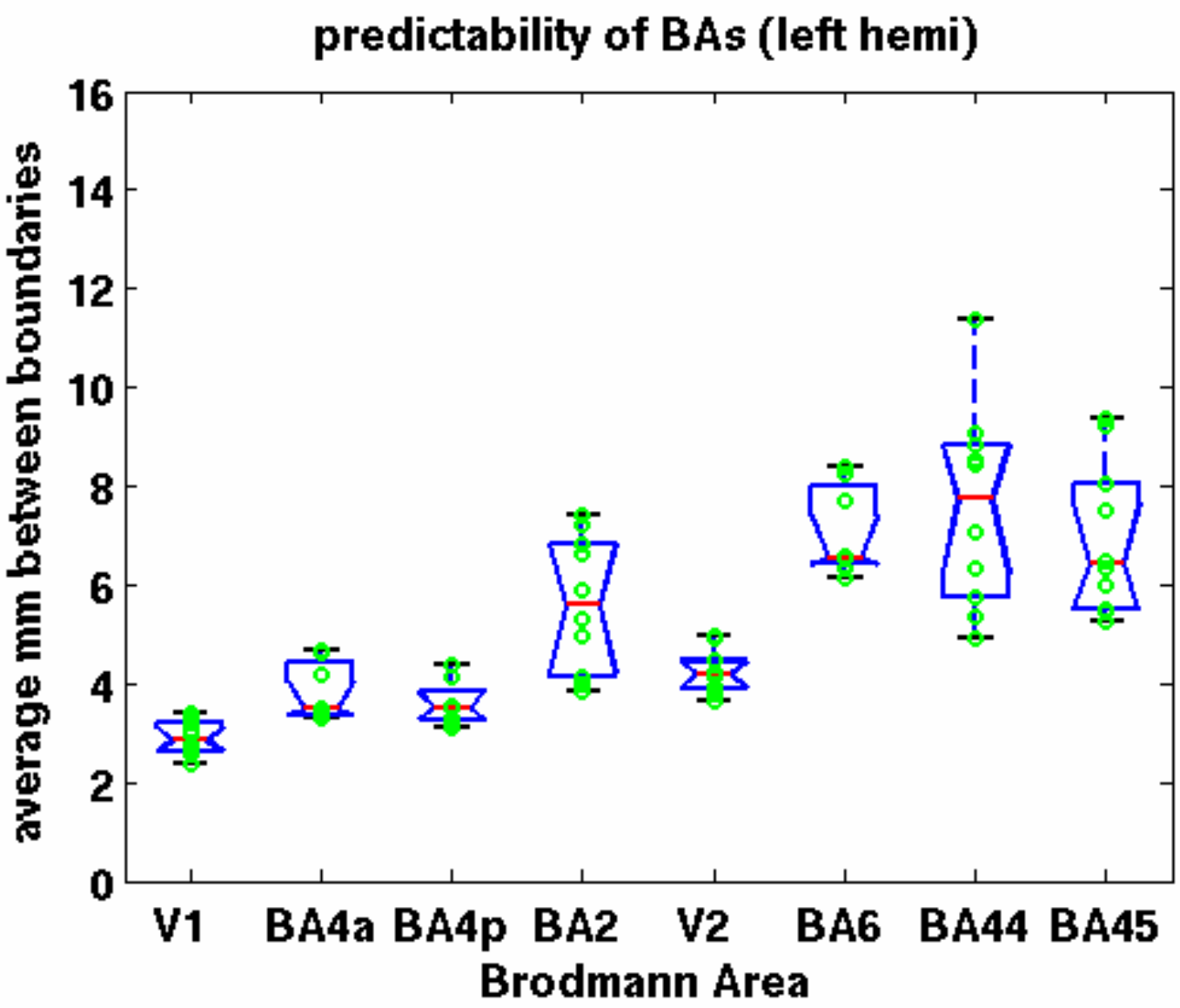

- Black Boundaries: Brodmann Areas
- Red/Blue Colors: Represent Cortical Fold Depth
- Brodmann areas variable wrt folding

Joint work with Mert Sabuncu, Karl Zilles, Polina Golland and Bruce Fischl

# Atlas Building

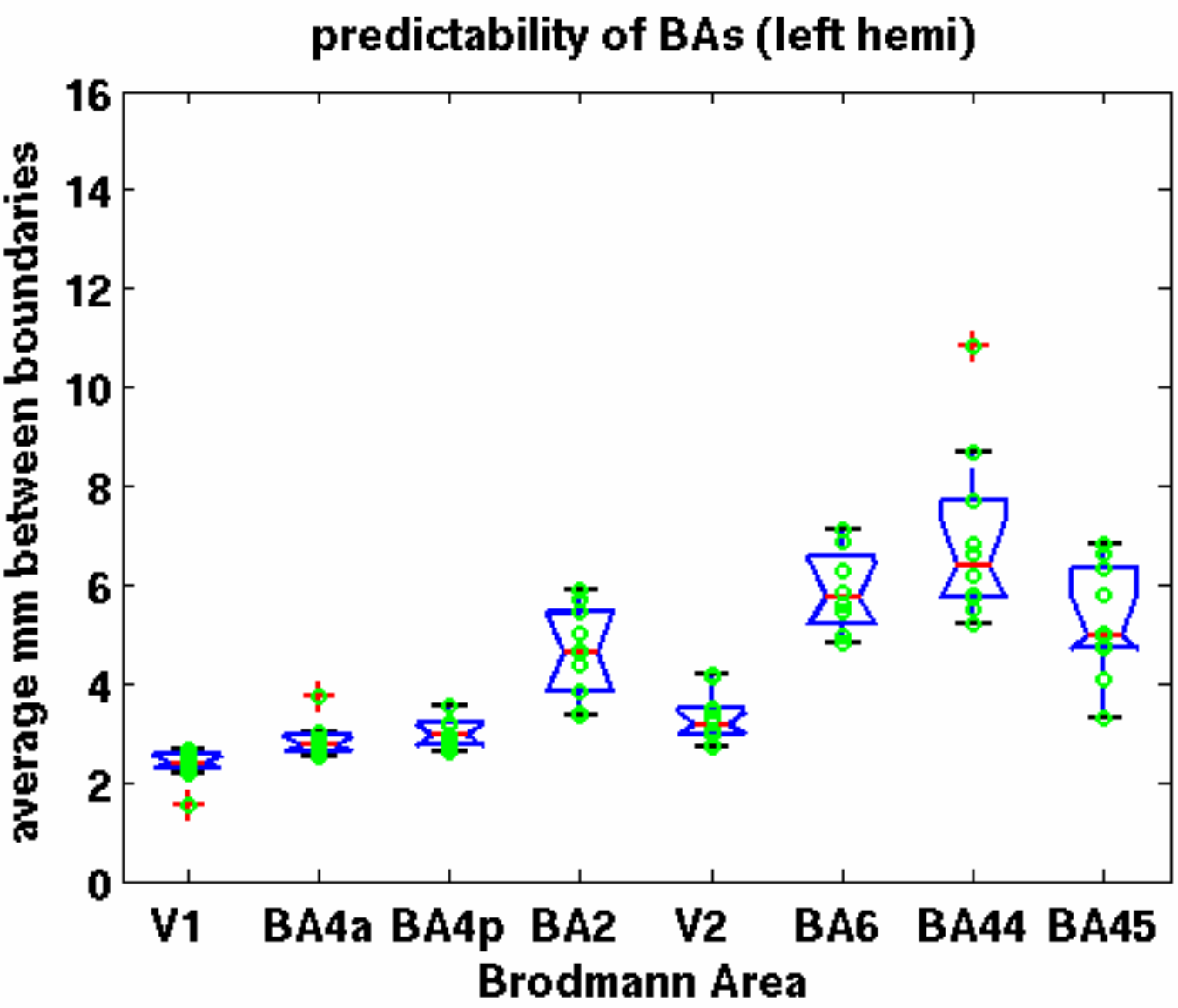

- Goal: Build a cortical fold atlas so that aligning a new brain to the cortical fold atlas results in good alignment of underlying Brodmann areas to the training images in the atlas
- Fundamental assumption in atlas building literature: To create a cortical fold atlas, the cortical folds of the deformed training images should be well-aligned in the common space
- Assumption flawed in this case because Brodmann areas are variable wrt cortical folds:
  - Good cortical fold alignment $\not\Rightarrow$ Good Brodmann area alignment

# Usual Atlas: Left Hemisphere




Small values implies better alignment

# Our Atlas: Left Hemisphere




Small values implies better alignment

# The Plan this Summer…


- Leverage on Log-Euclidean metric to build a DTI atlas based on DTI images
- Apply atlas building framework to build a traditional MRI atlas that aligns/predicts DTI images


# Thank You