University of Wisconsin
SCHOOL OF MEDICINE
AND PUBLIC HEALTH

2-simplex data

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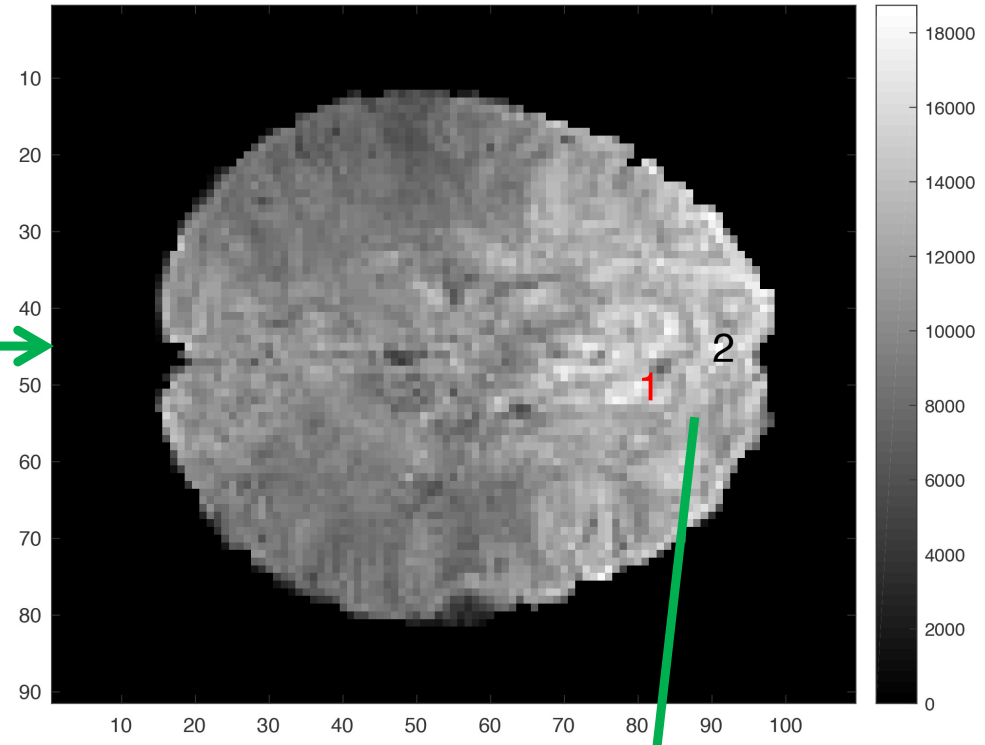
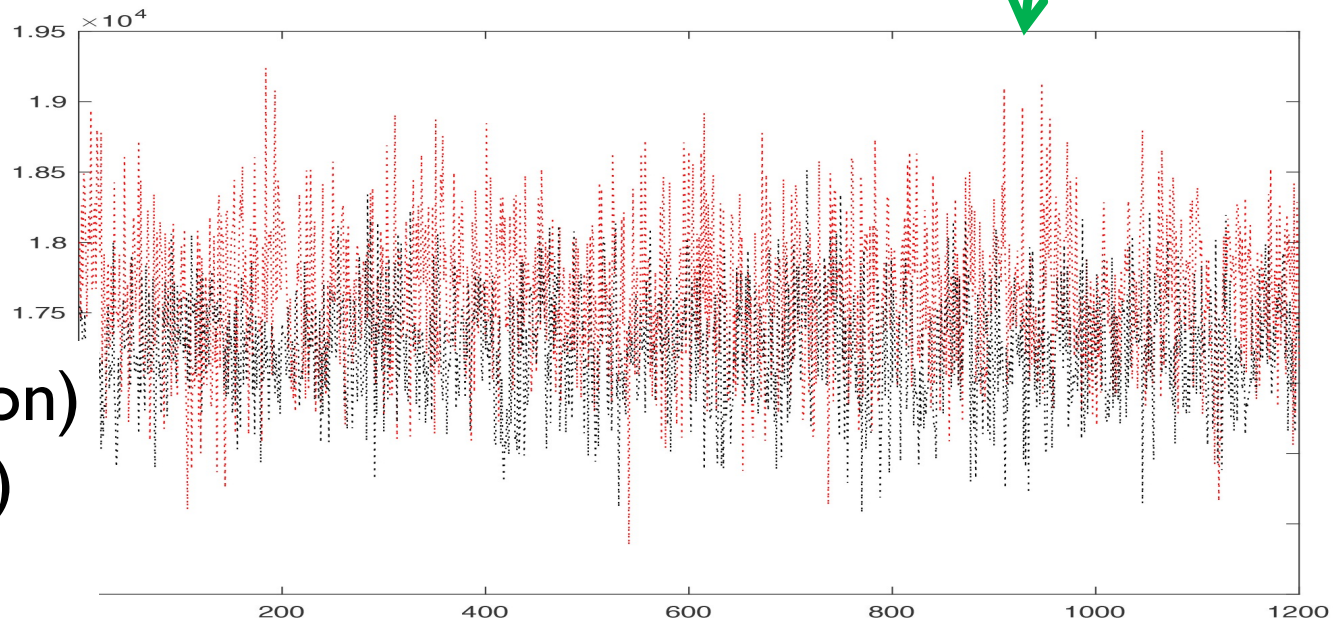
Dynamic 0-simplex Data

Resting-state functional magnetic resonance imaging (rs-fMRI)

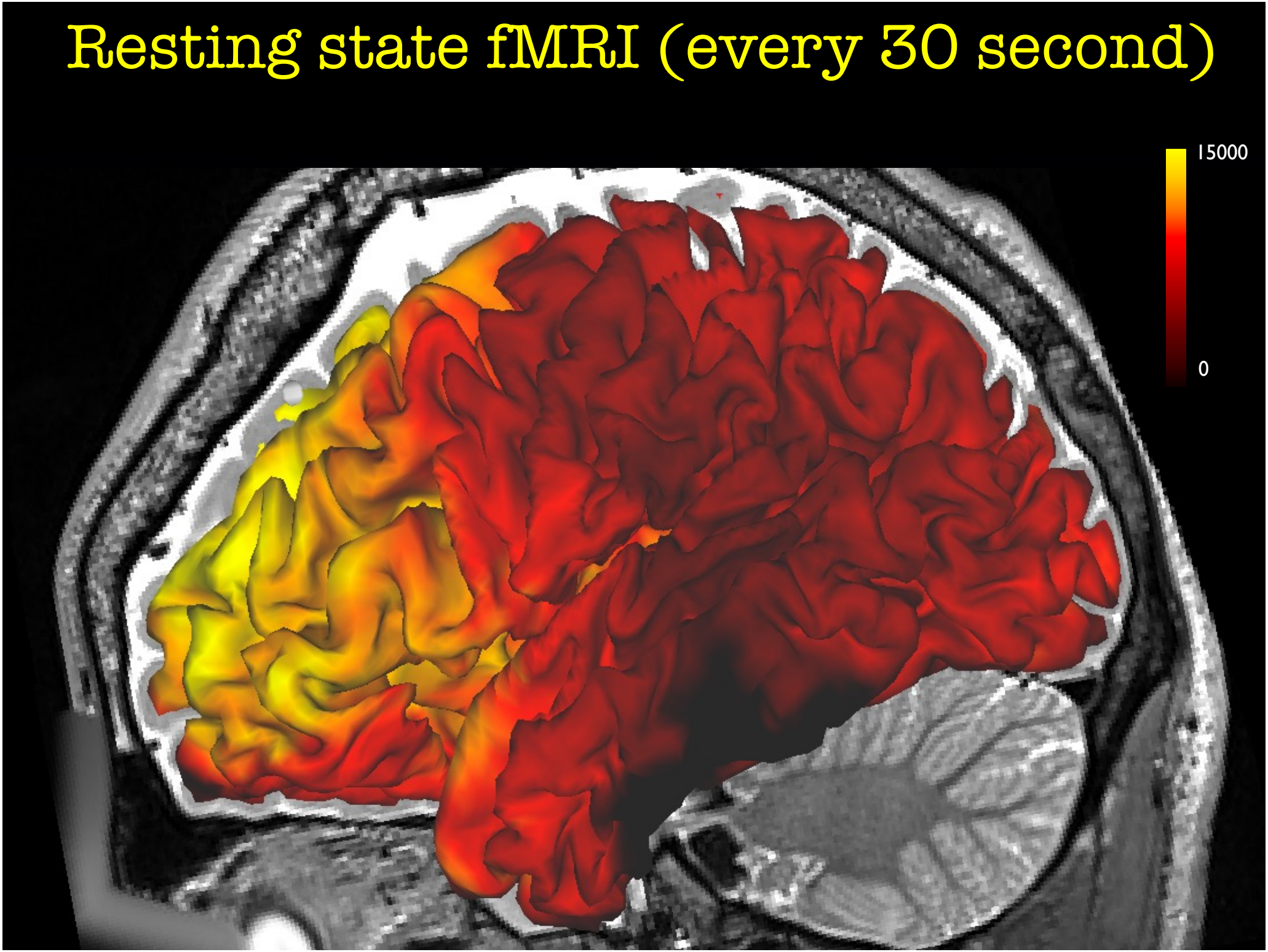


Waisman Center
UW-Madison

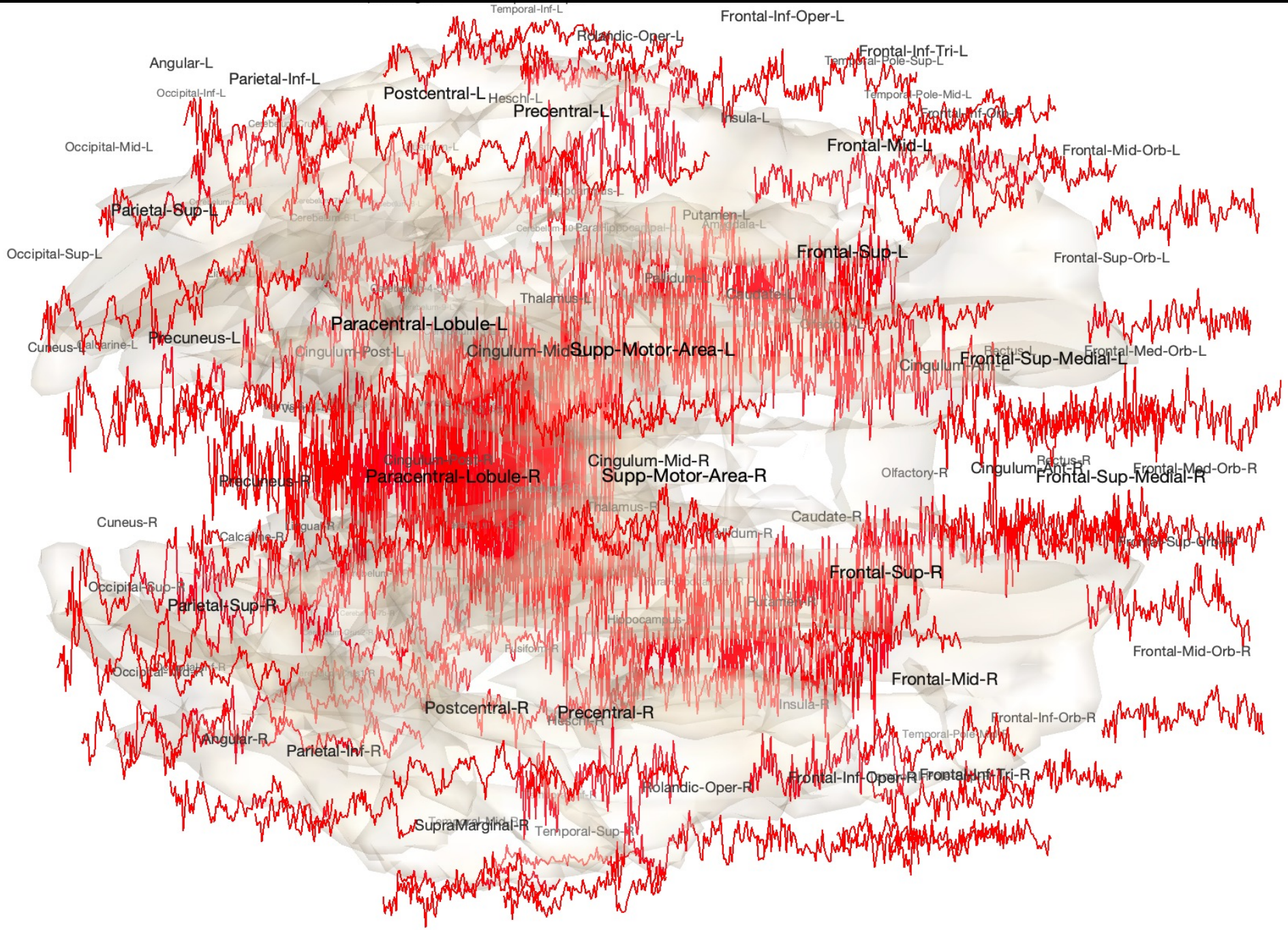


295 time points (Madison)
1200 time points (HCP)
→ 10-15 minutes

Resting state fMRI (every 30 second)

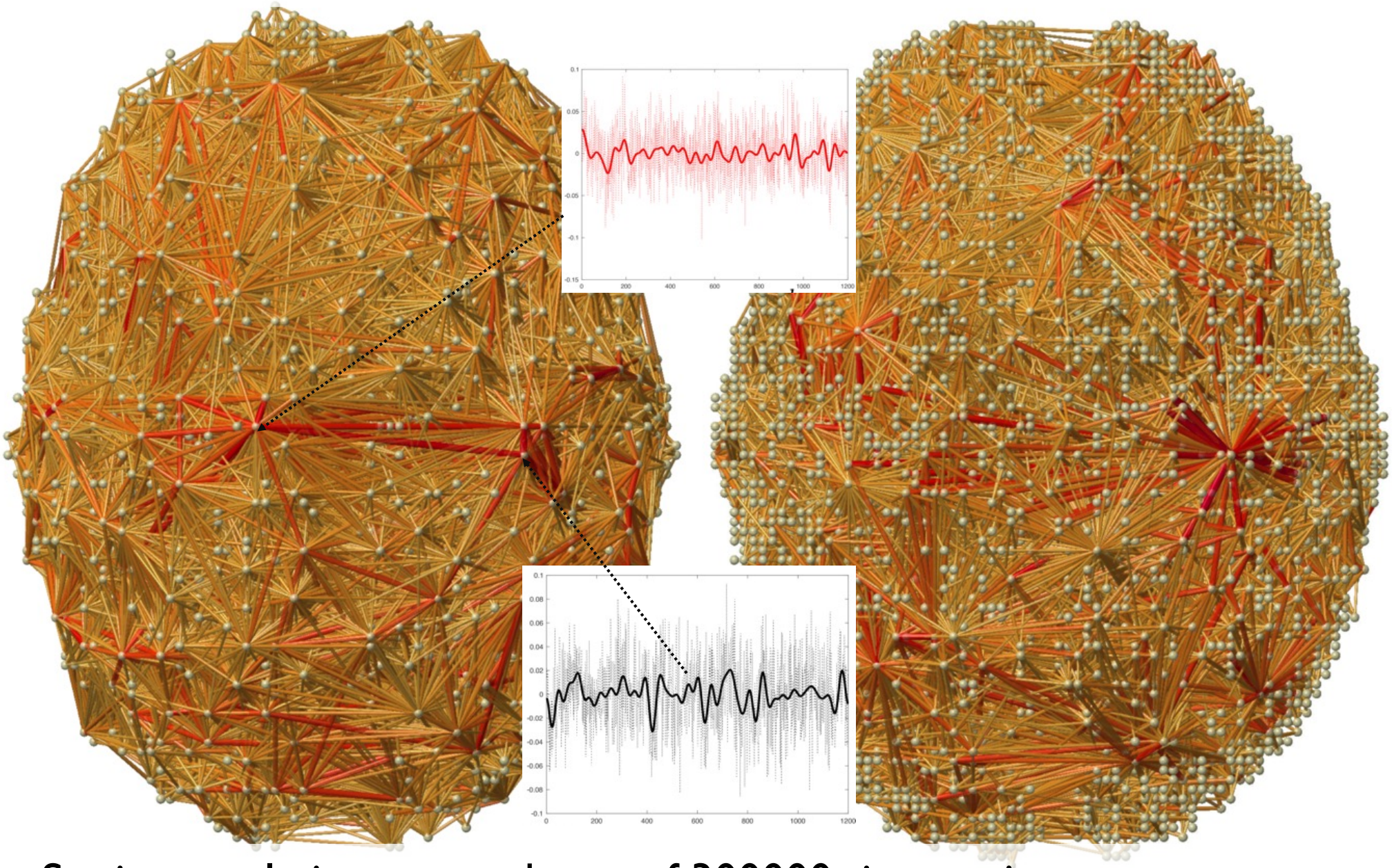


Average functional MRI within parcellation



Dynamic 1-simplex Data

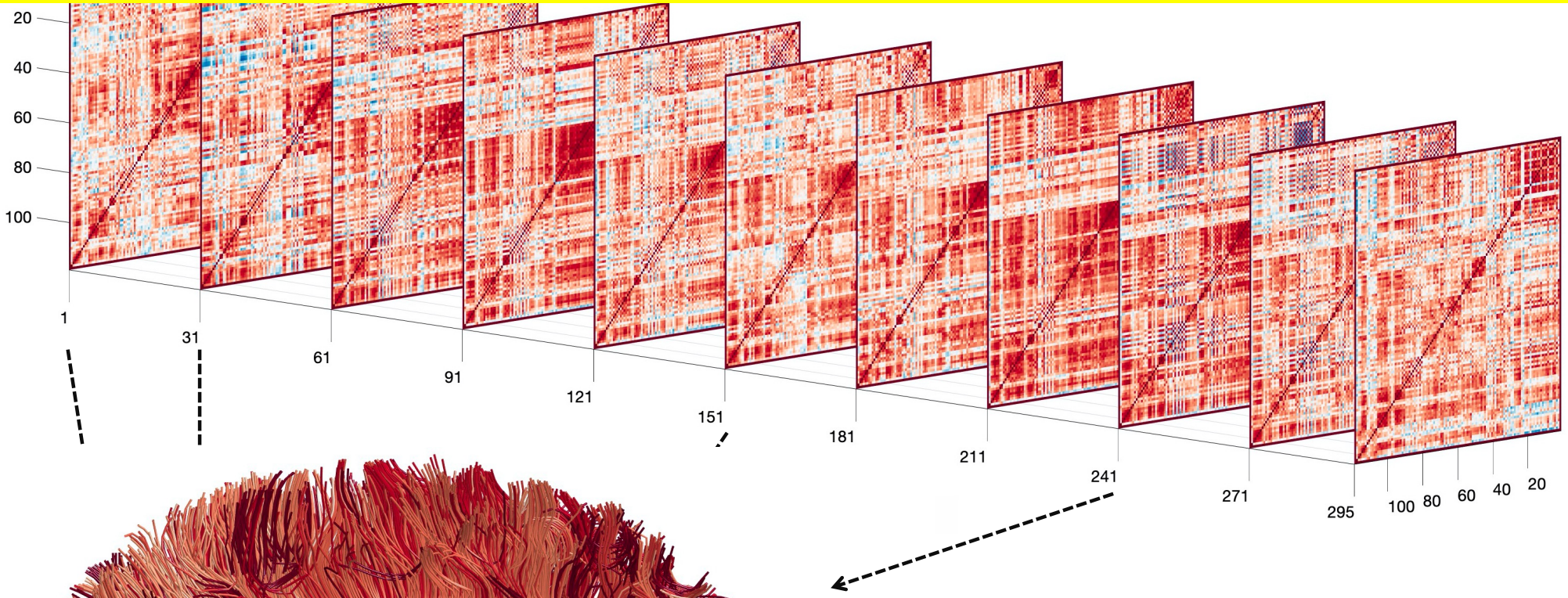
Correlation brain network at voxel level (1mm)

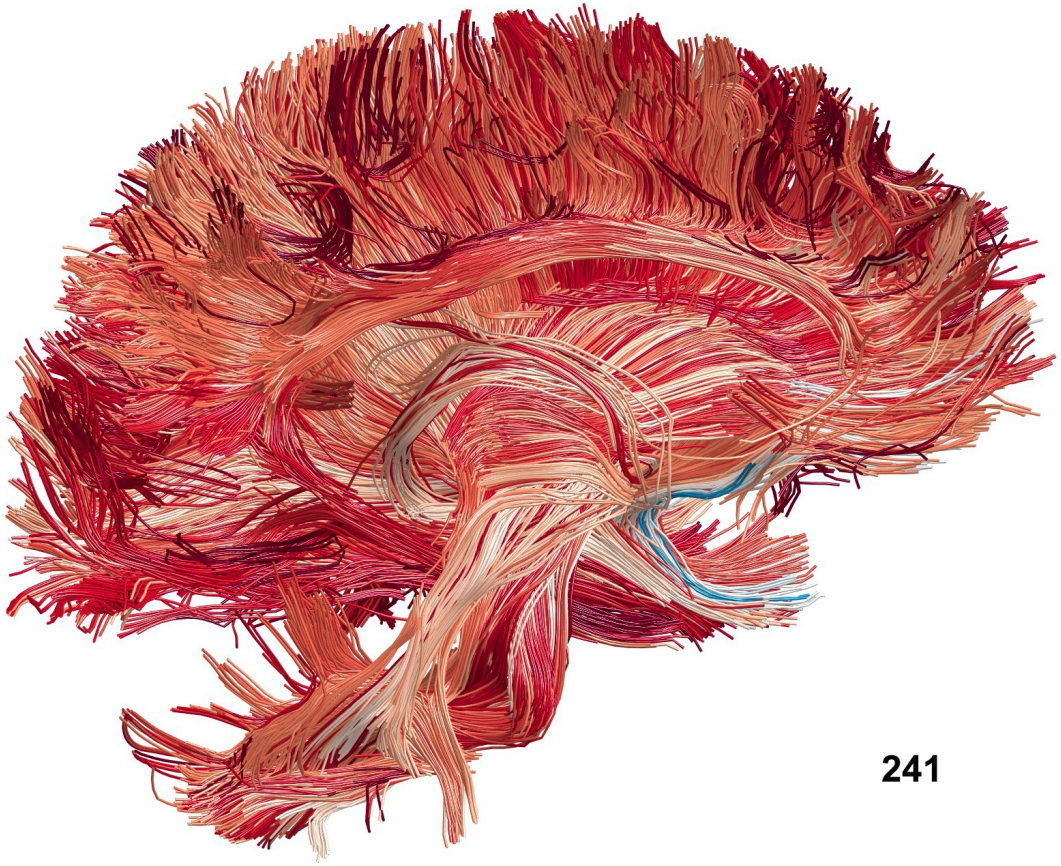


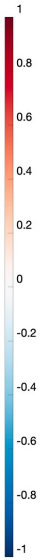
Static correlation network out of 300000 time series

Complete graph with about $300000^2/2$ cycles.

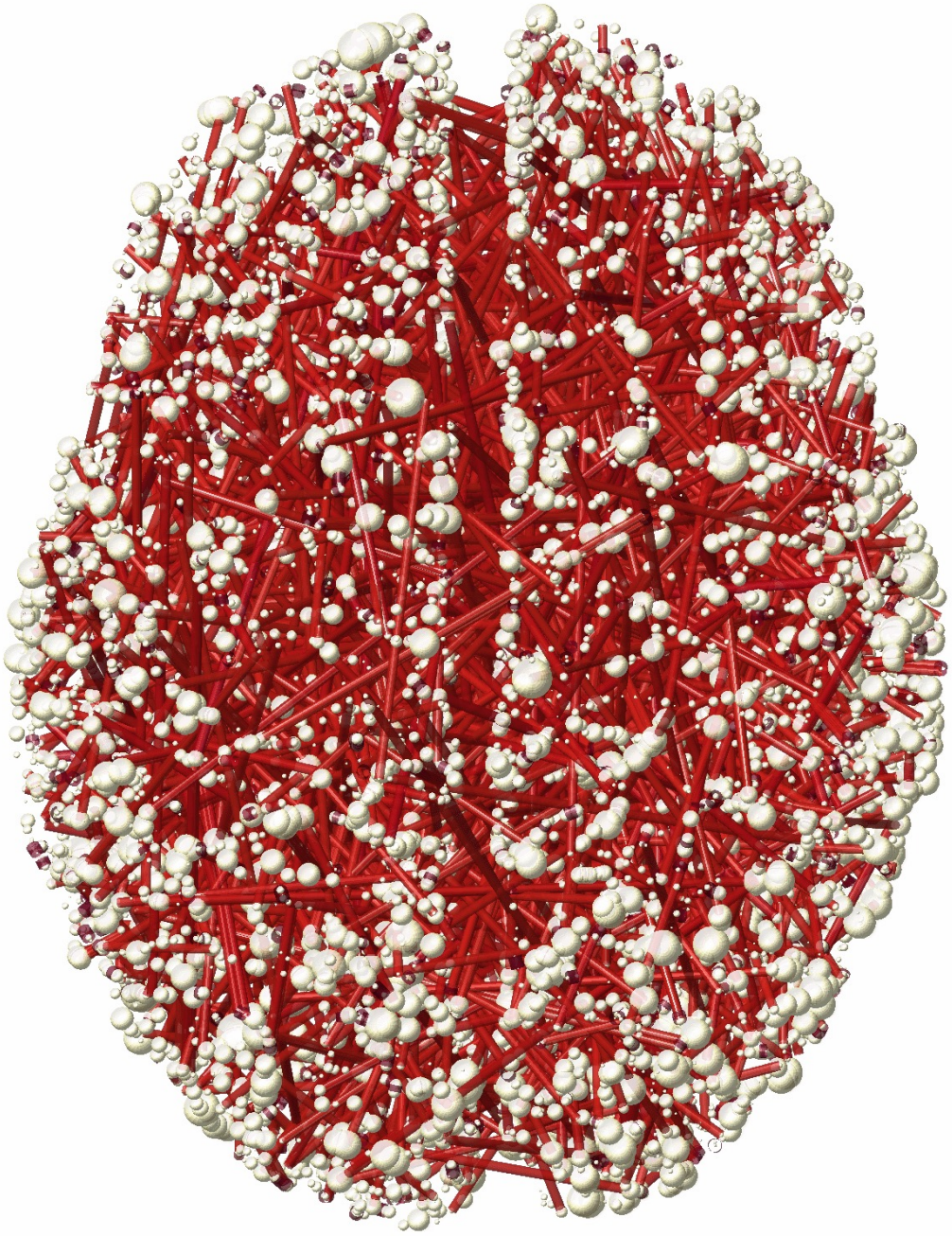
Time series of correlation matrices of size 116 x 116







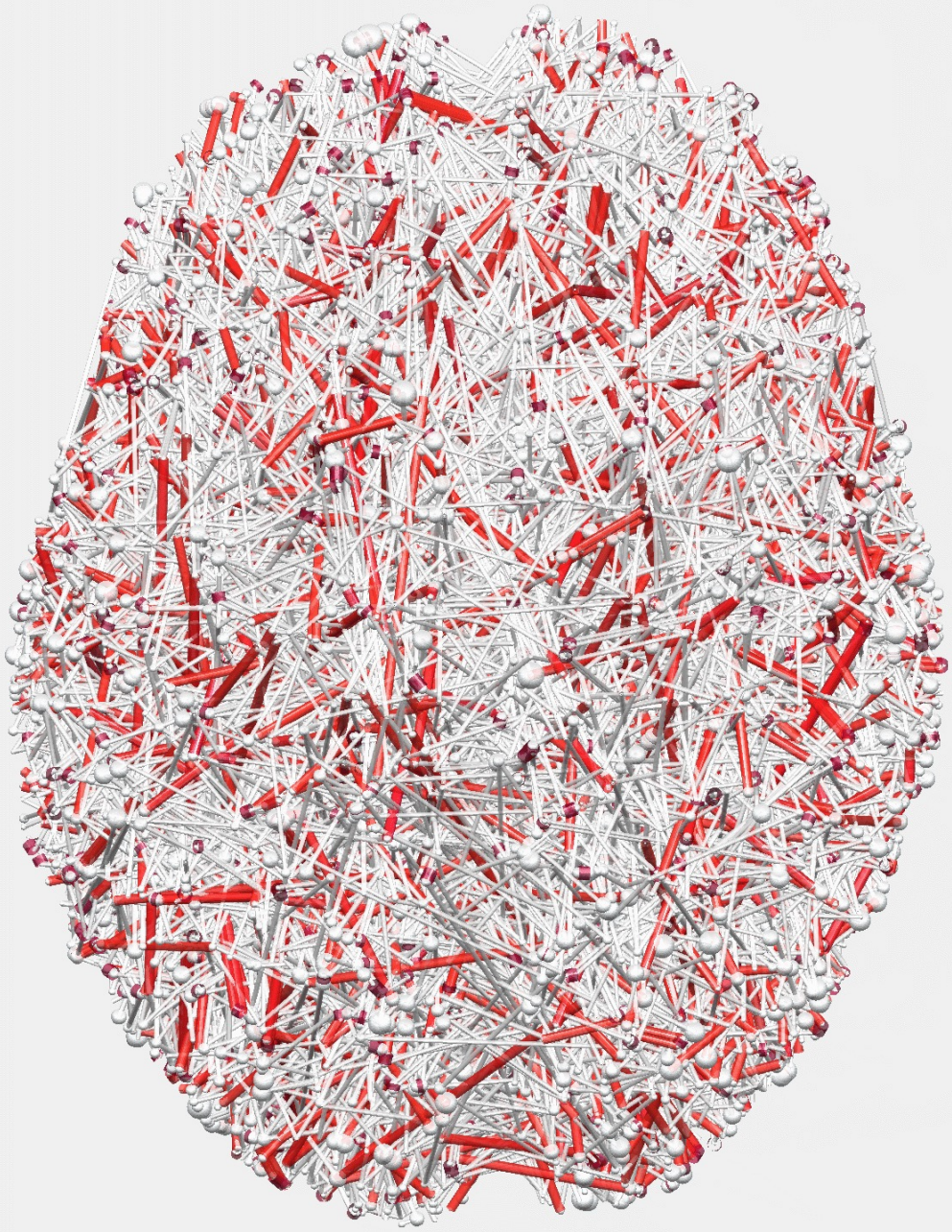
Dynamically changing functional connectivity superimposed on top of white matter fibers



12000 nodes Rs-fMRI correlation network (thresholded at 0.7) over 20seconds sliding window for 72 seconds

Every 0.72 second is compressed into 0.1 second.

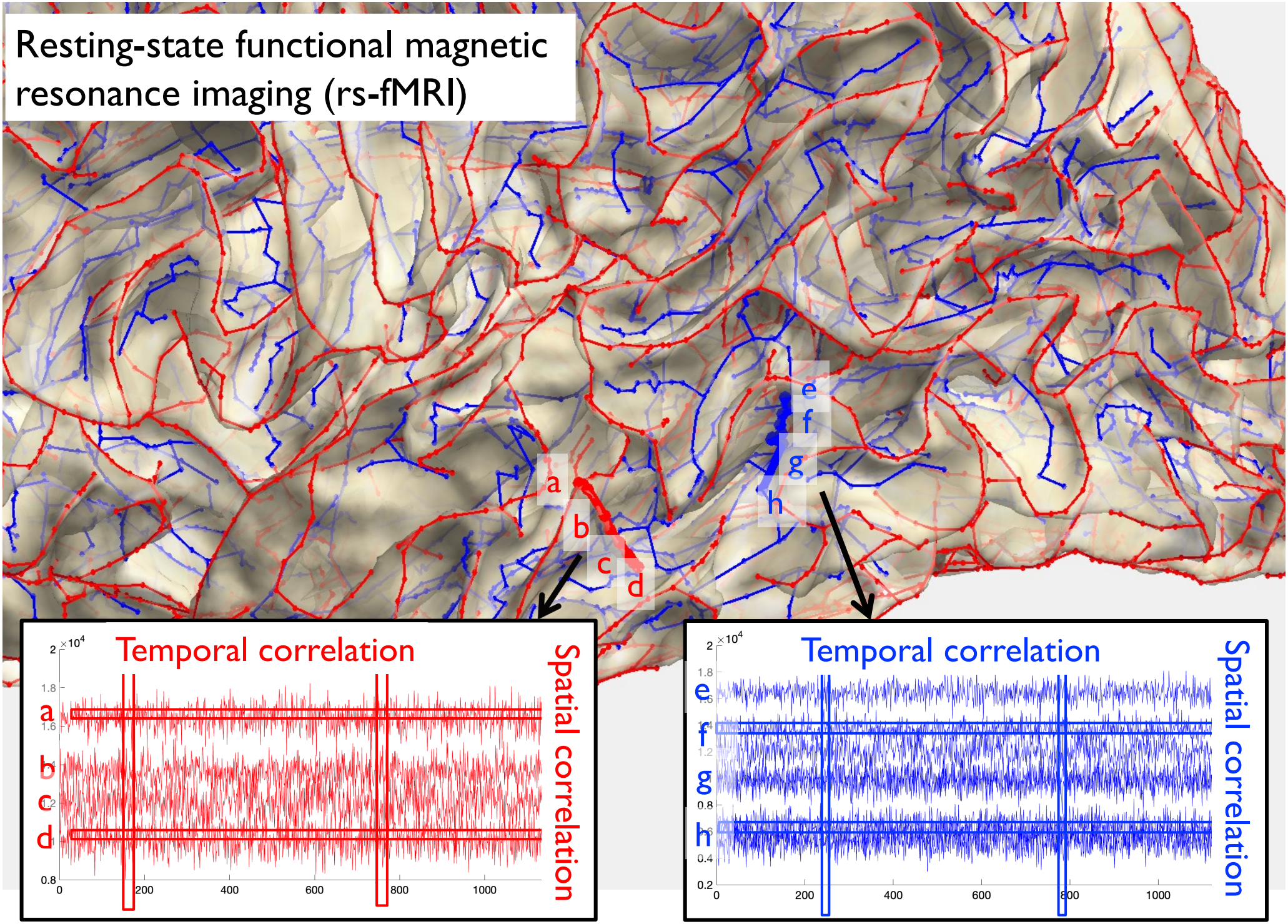
Across time and subjects, they do not align!



Dynamics of 12000 nodes rs-fMRI network

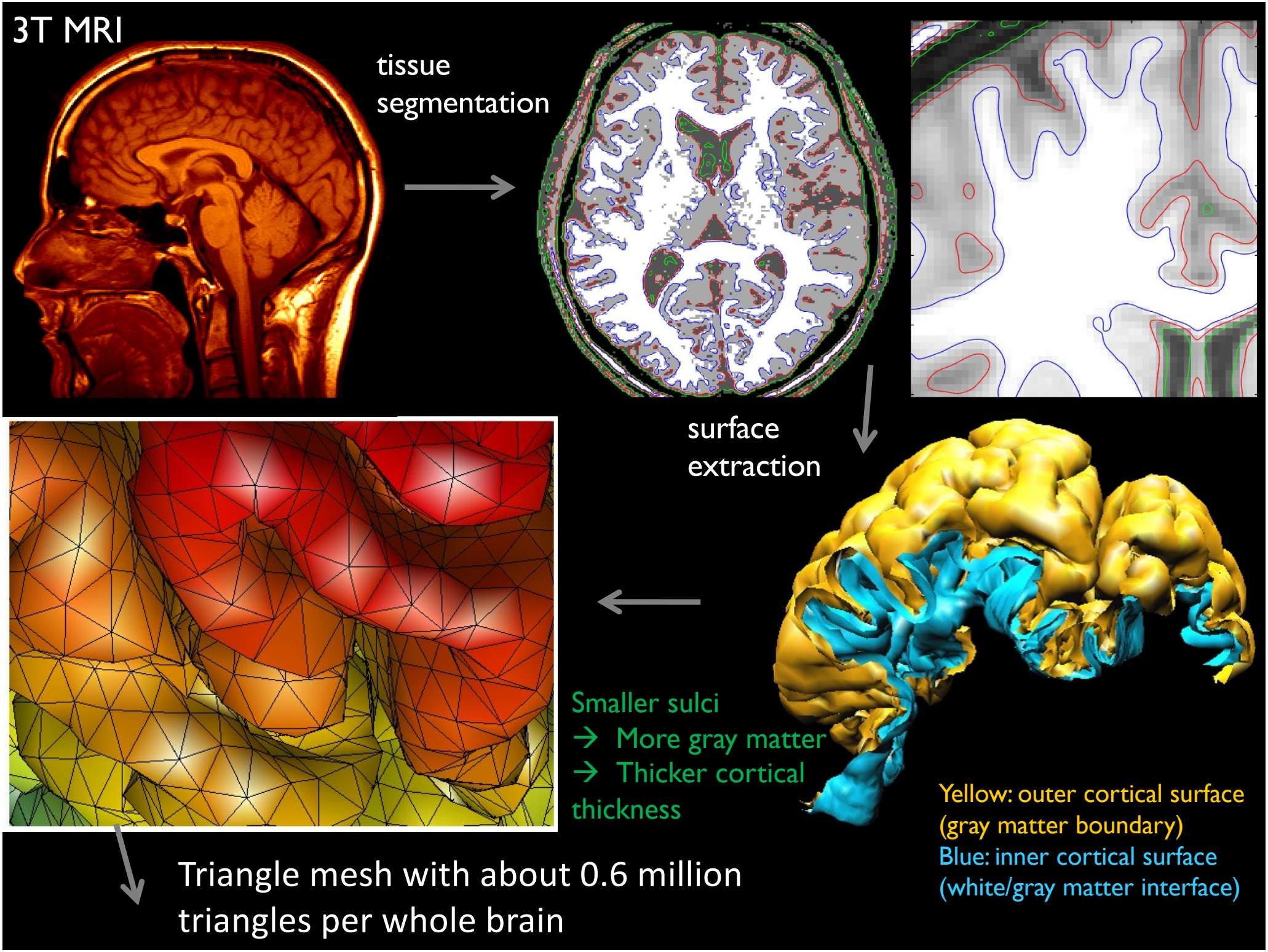
White edges = stable backbone 0D topology =maximum spanning tree.

Red edges = Edges that are added to to MST to form a cycle

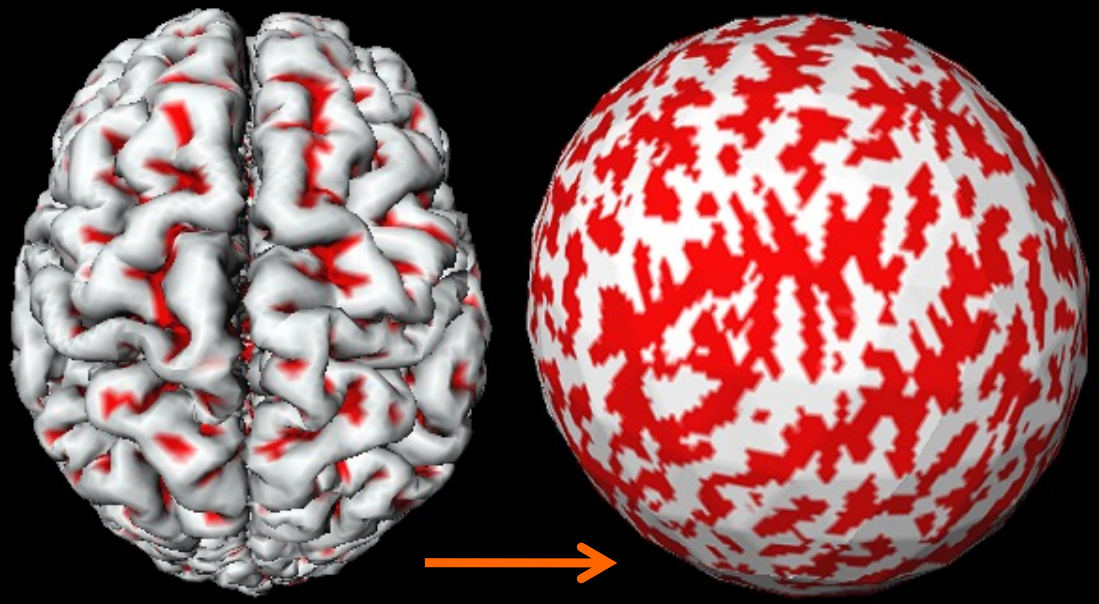

Resting-state functional magnetic resonance imaging (rs-fMRI)
a
b
c
d
e
f
g
h
Temporal correlation
Spatial correlation
Temporal correlation
Spatial correlation

Static
2-simplex Data

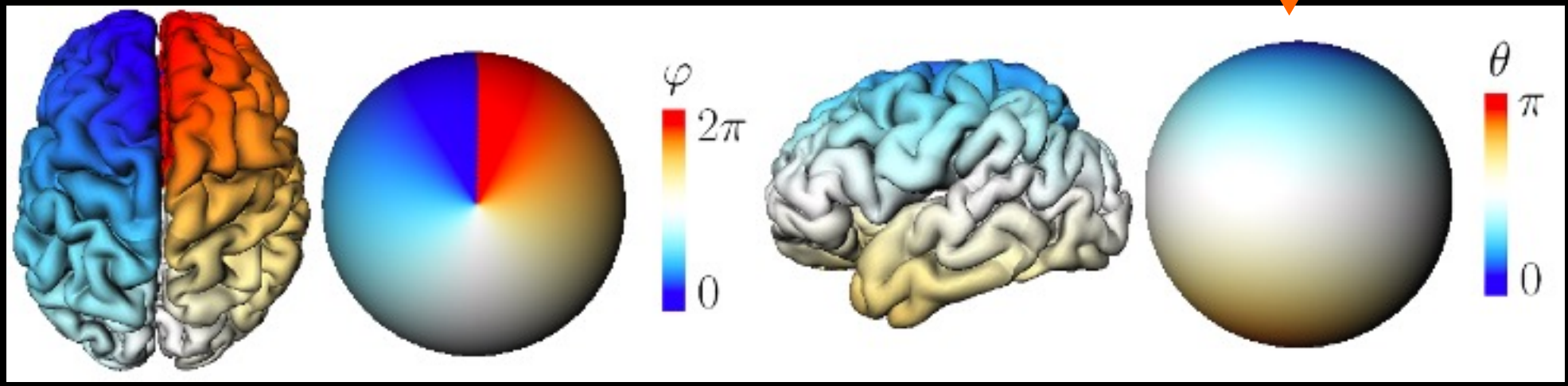

3T MRI scanner
SIGNA
Premier


3T MRI
tissue segmentation
surface extraction
Smaller sulci
→ More gray matter
→ Thicker cortical thickness
Yellow: outer cortical surface (gray matter boundary)
Blue: inner cortical surface (white/gray matter interface)
Triangle mesh with about 0.6 million triangles per whole brain

Cortical surface flattening



FreeSurfer deformable surface algorithm



Spherical angles

Data structure for triangle mesh – analogous to cubical complex

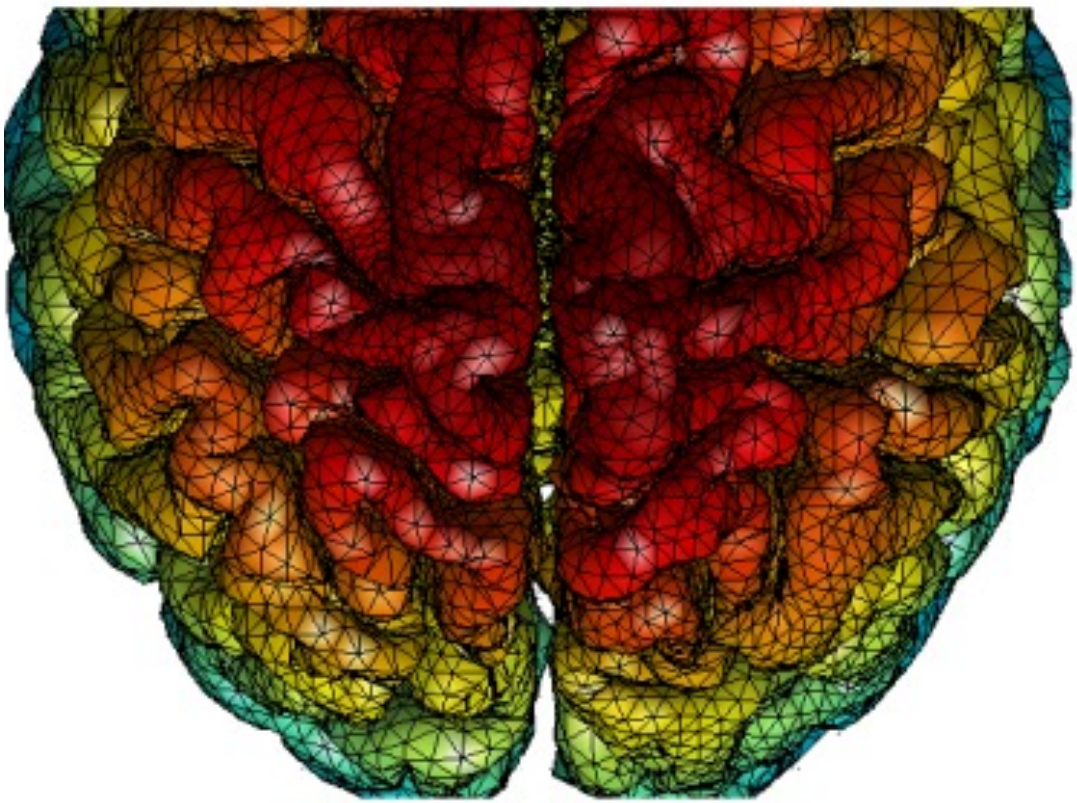
```
>>surf =
   vertices: [1282x3 double]
     faces: [2560x3 double]
```

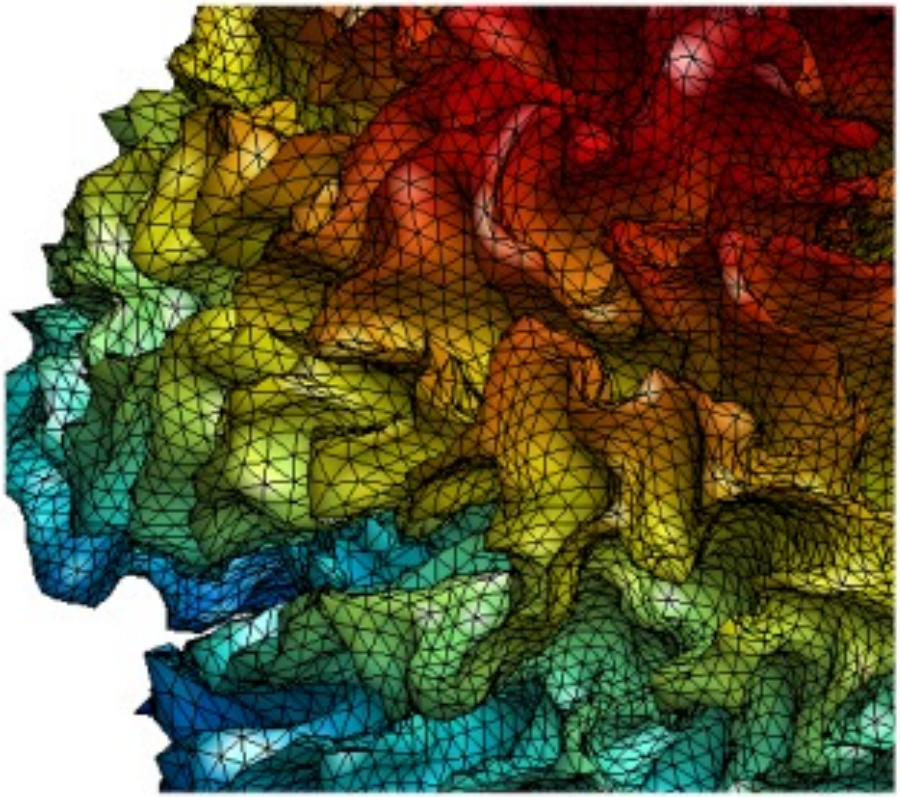
structured array

```
>>surf.faces
ans =
        1       2       3
        1       4       2
        1       3       5
       ...
```

```
>> surf.vertices
ans =
   75.0000   93.0000   51.5050
   74.5050   93.0000   52.0000
   75.0000   92.5050   52.0000
    ...
```

vertex coordinates





How many edges in surface mesh?

Since two adjacent triangles share the same edge, the *total number of edges* is $2|E| = 3|F|$.

How many edges in surface mesh?

Example.

```
surface =

  struct with fields:

    vertices: [5916×3 double]
       faces: [11824×3 double]
       edges: [17736×2 double]
```

Check 2E = 3F

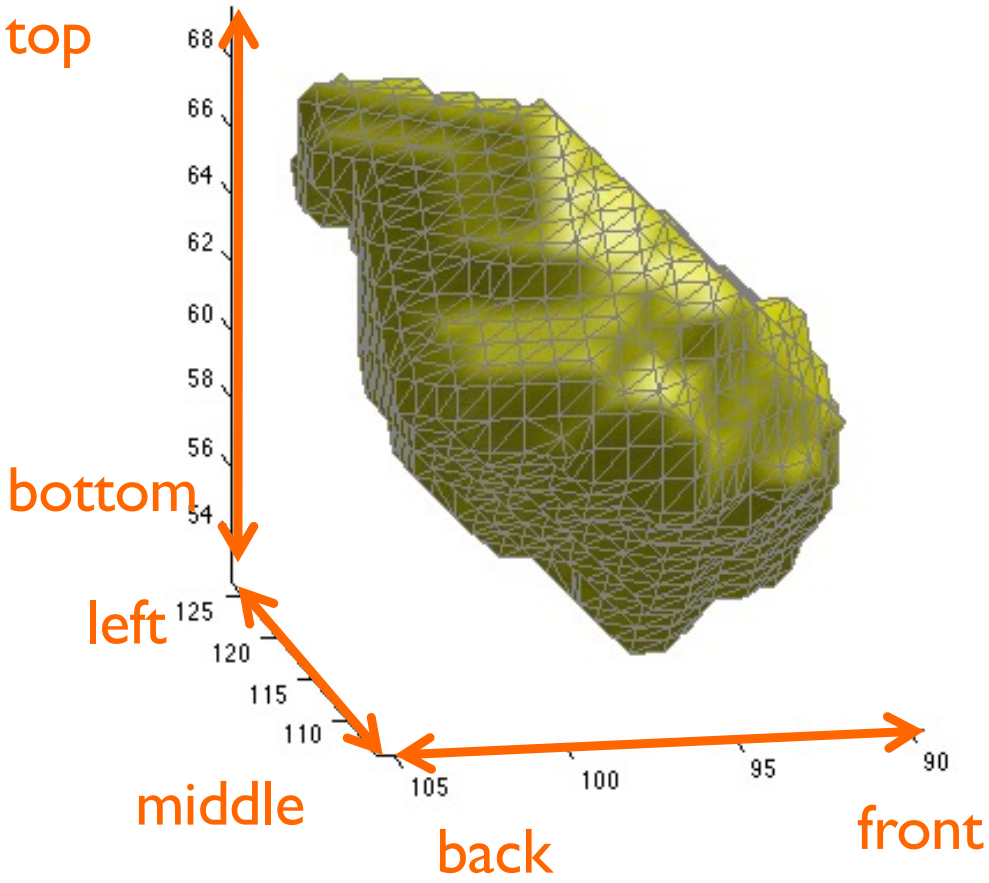
Euler characteristic of surface mesh

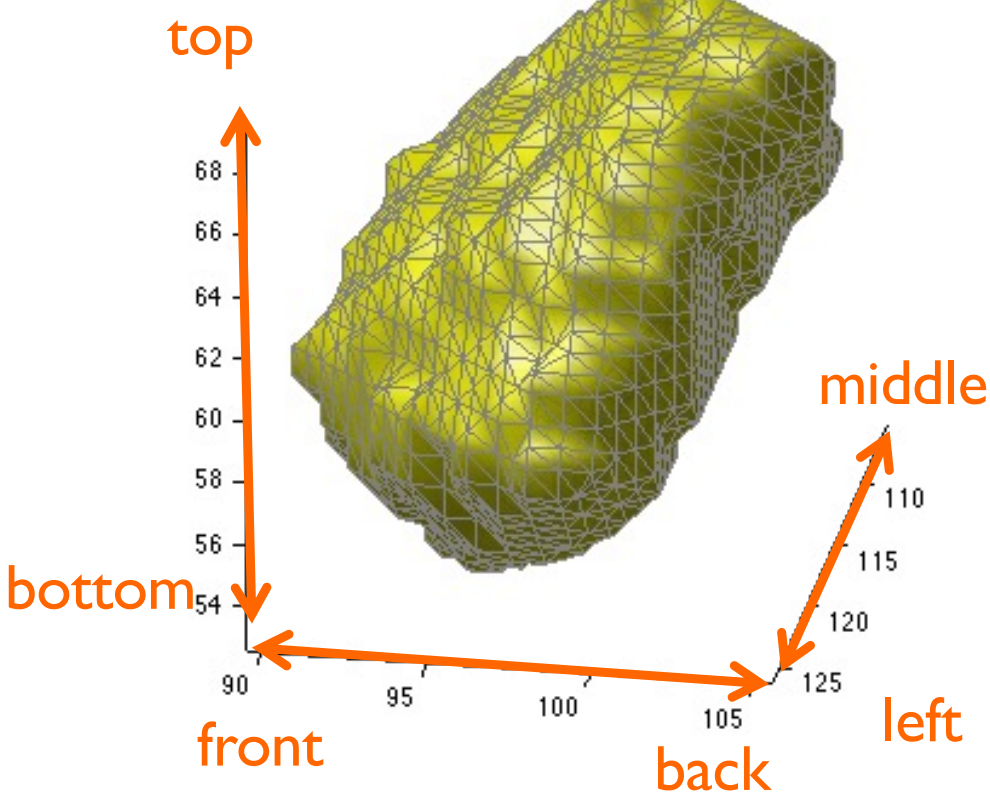
For simplicial complex (e.g., a triangulated surface),

Euler characteristic (EC) = |V| - |E| + |F|
is topologically invariant.

For surface mesh topologically equivalent to a sphere:
EC = |V| - |E| + 2/3|E| = |V| - 1/3|E|

2D surface mesh of the left amygdala

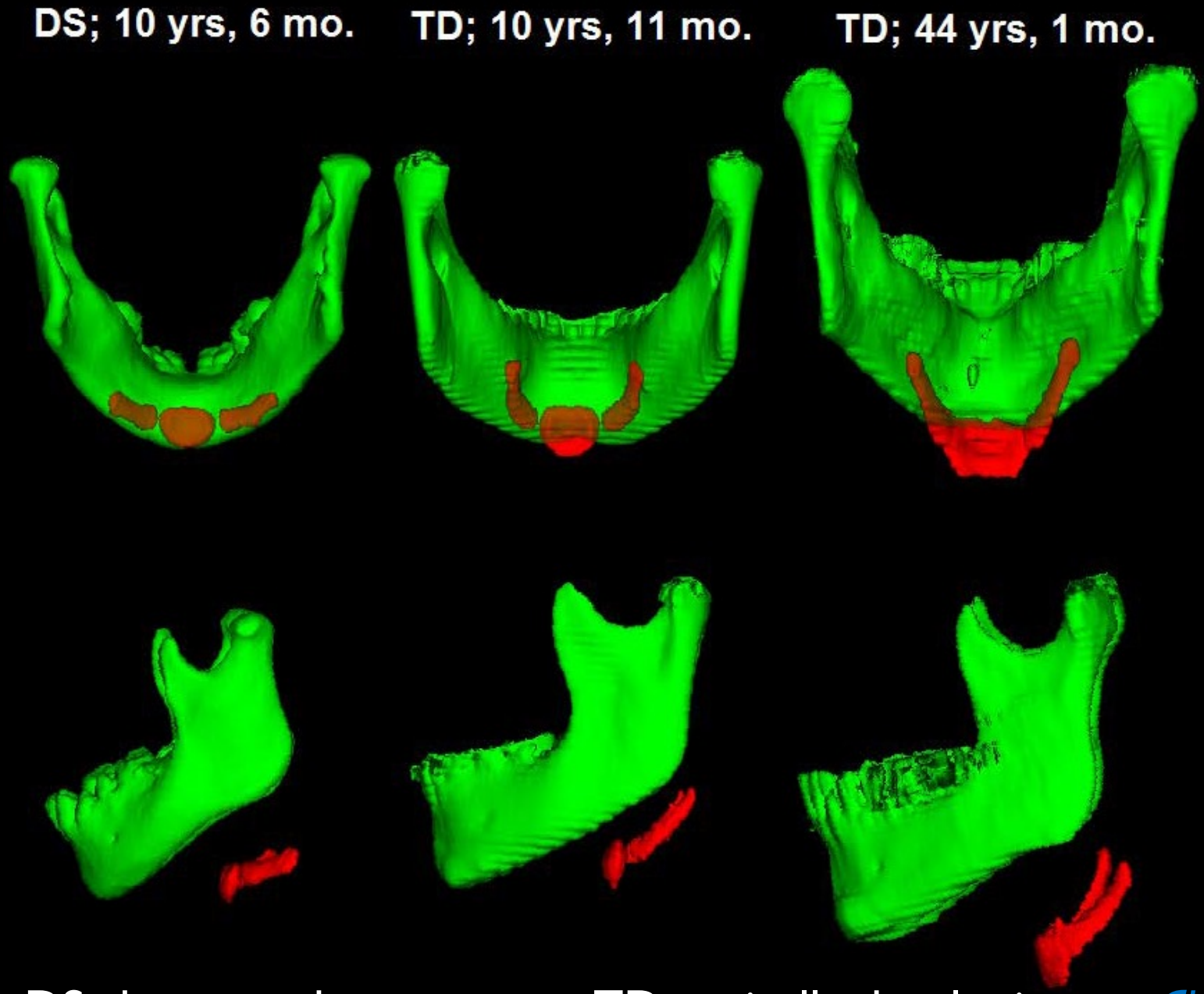




Functional regression: Filter out geometrical noises.

Functional registration: Align functional data in a common space

Topology changing bone fusion



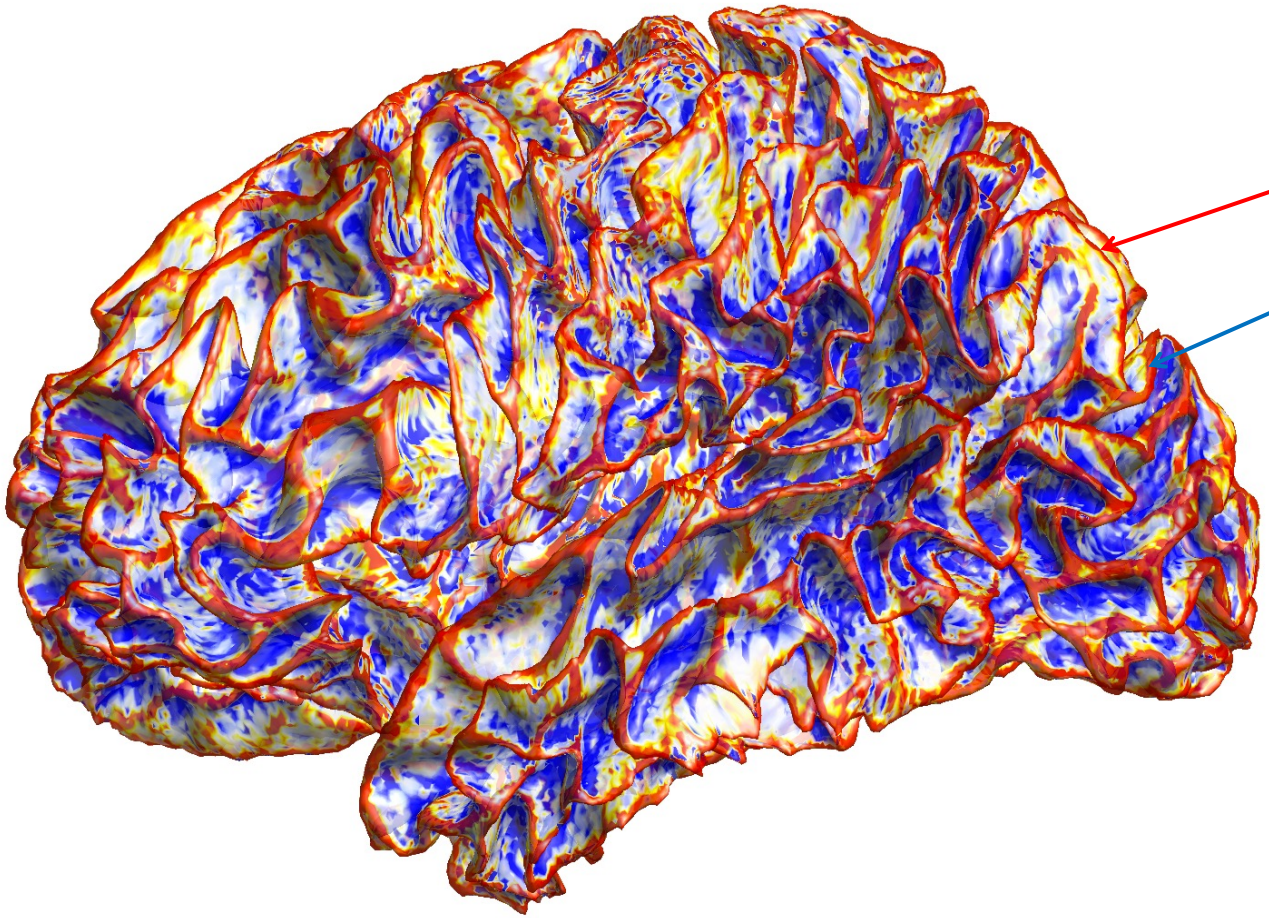
DS: down syndrome

TD: typically developing

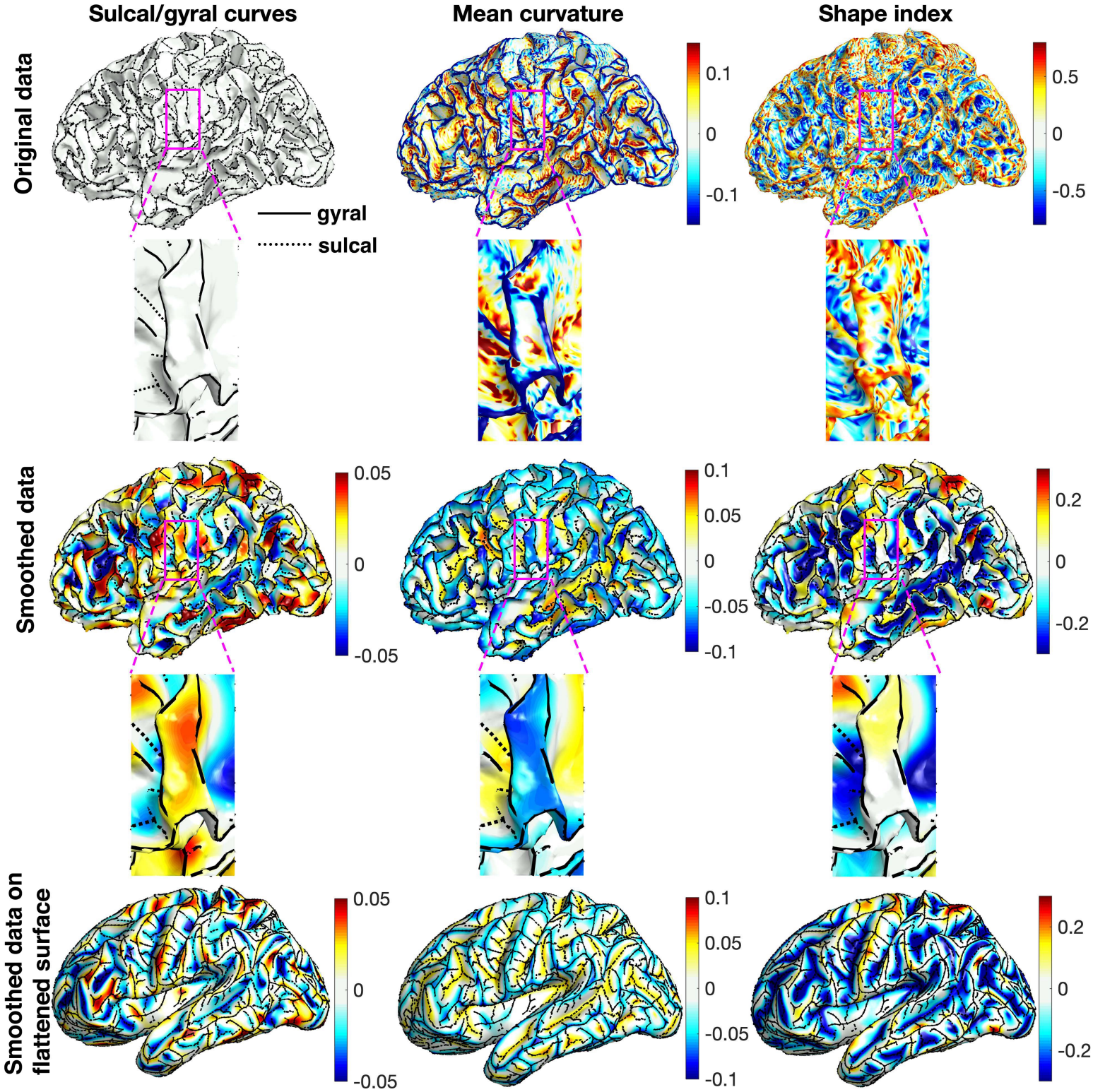
Chung et al. 2020

Fast Polynomial Approximation of Heat Kernel Convolution on Manifolds and Its Application to Brain Sulcal and Gyral Graph Pattern Analysis

Shih-Gu Huang, Ilwoo Lyu, Anqi Qiu, and Moo K. Chung



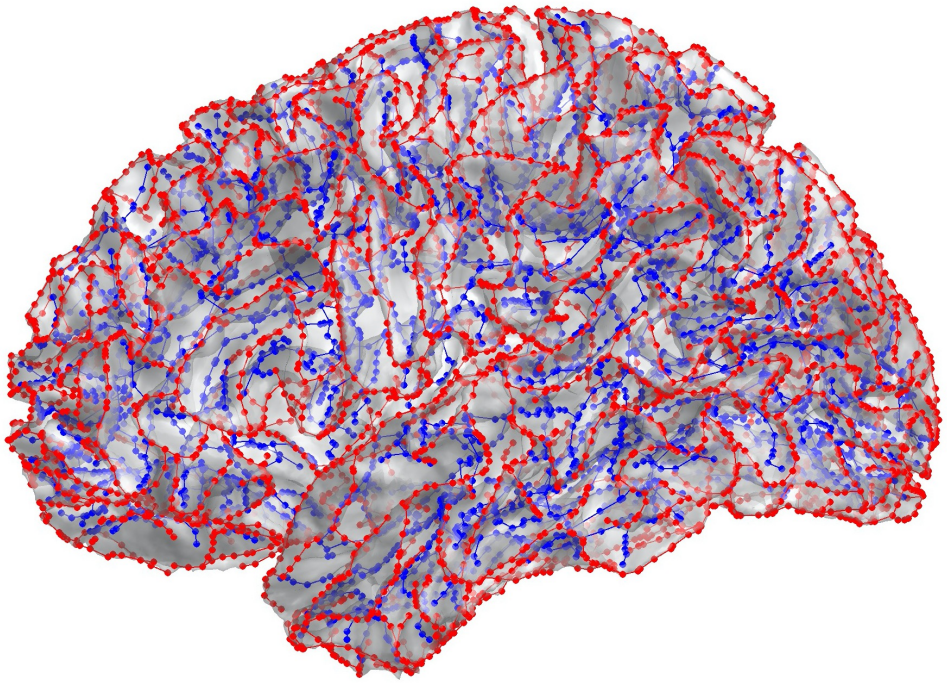
Threshold
mean curvatures
+Dijkstra's algorithm

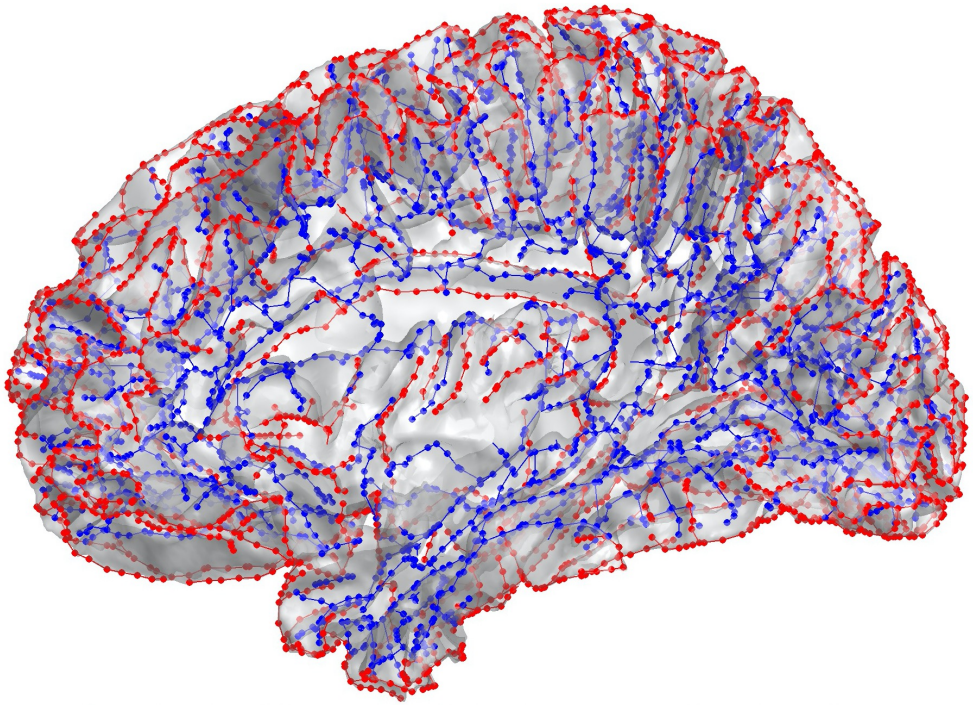


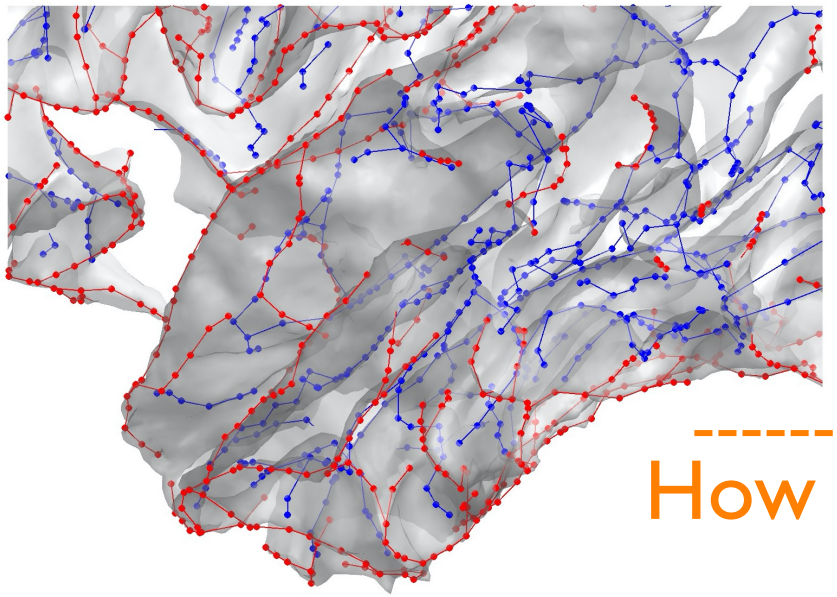
Sulcal/gyral curves superimposed on top of other surface indices

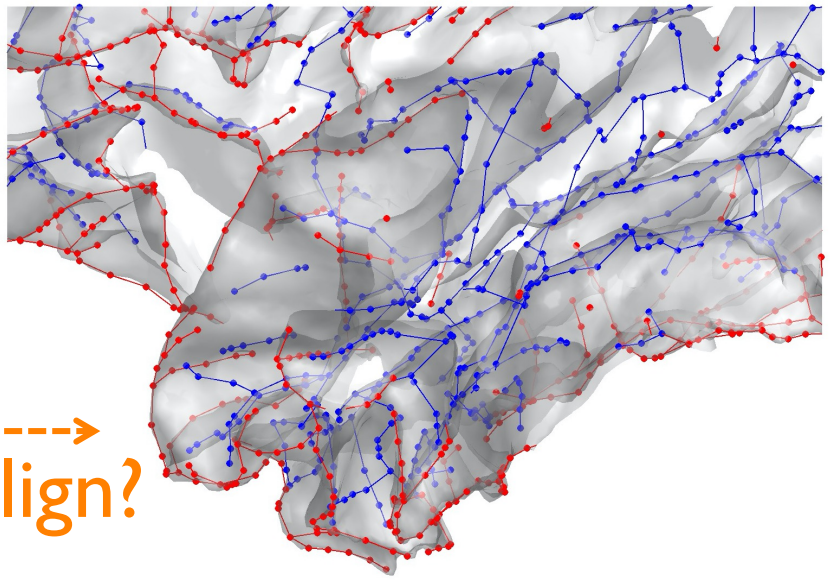
[Huang et al. 2019 IEEE Tractions on Medical Imaging]

Sulcal/gyral trees in two different subjects









How to align?

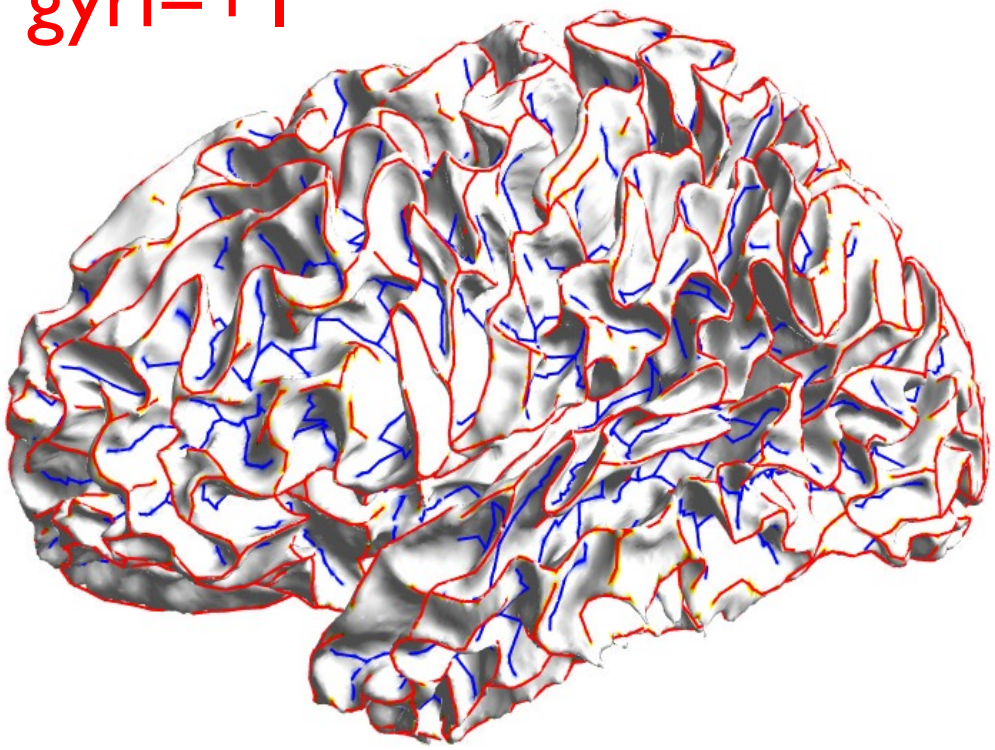
Sulci = valley regions

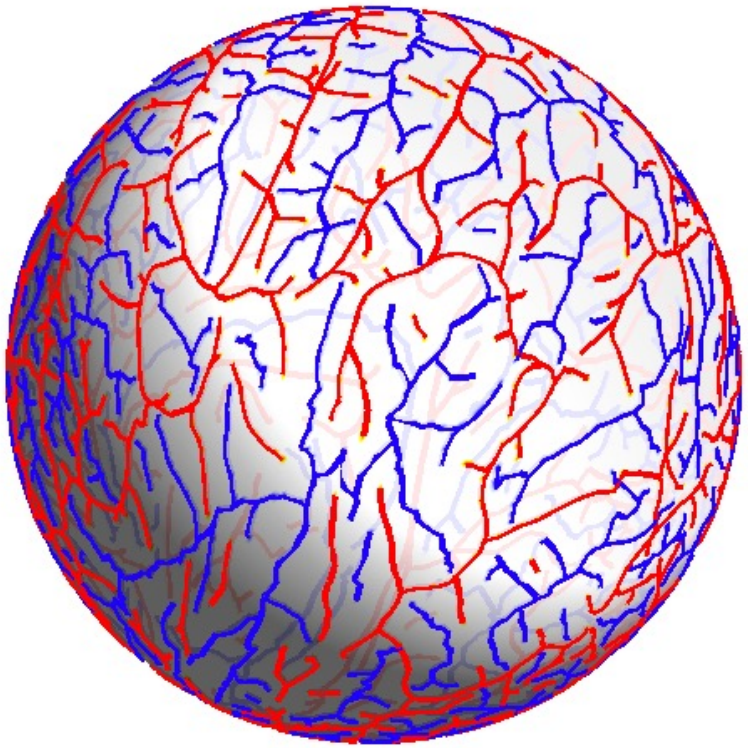
Gyri = mountain regions

3D volume projection

sulci = -1

gyri=+1

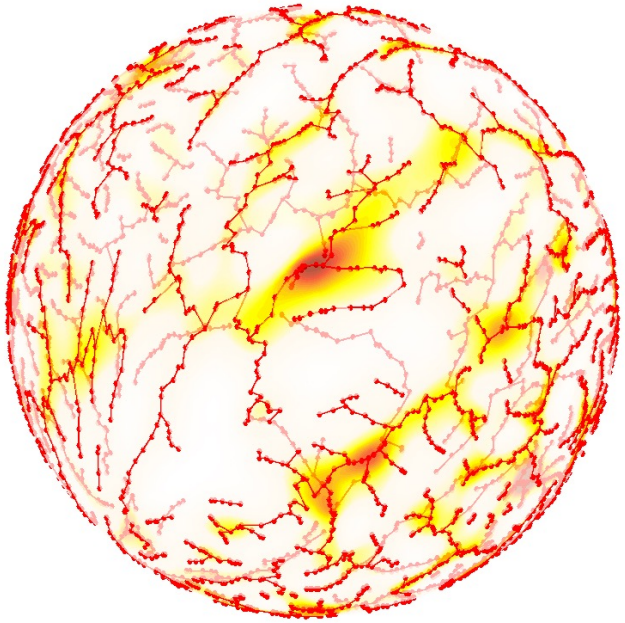




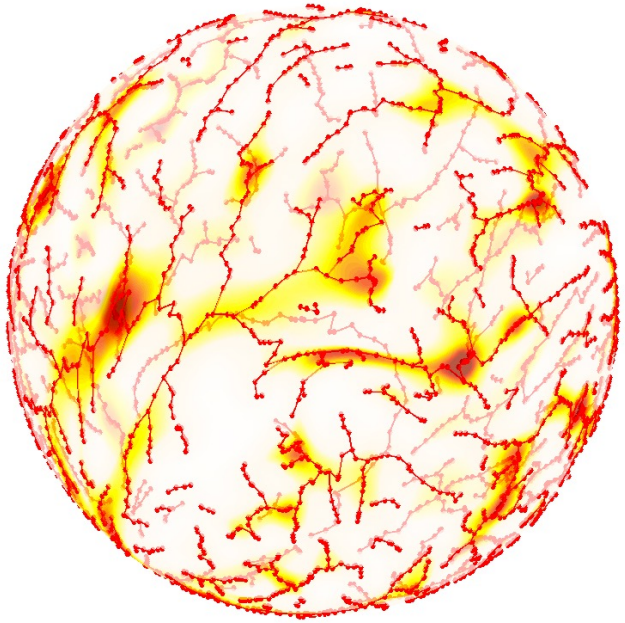
White matter surface

Trees on 2-sphere

Optimal transform (Wasserstein distance)



Registration



$$f_1(x) = \frac{1}{q}\sum_{i=1}^{q}\delta(x - x_i)$$

$$K_\sigma * f_1(x) = \frac{1}{q}\sum_{i=1}^{q}K_\sigma(x, x_i)$$

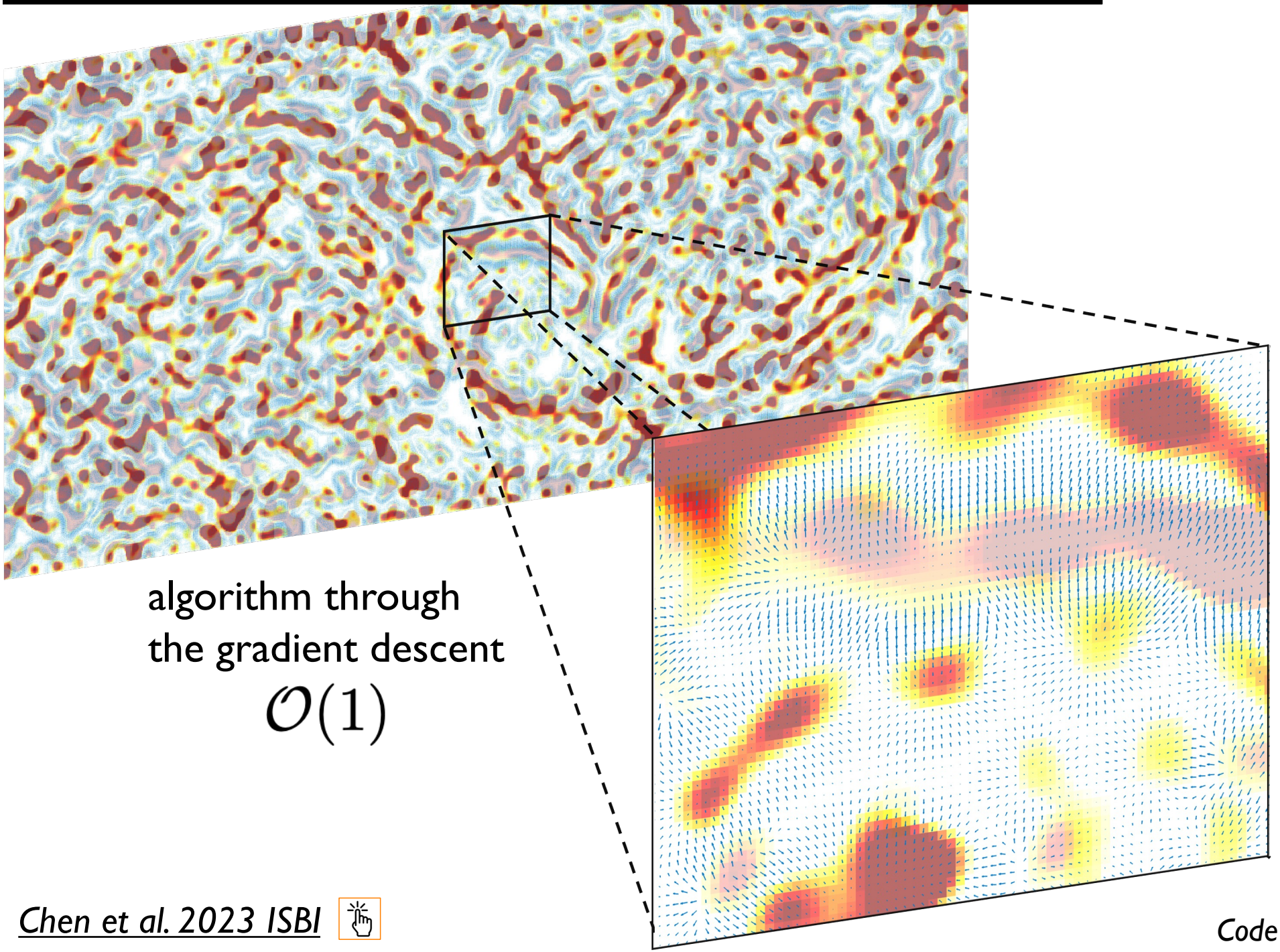
$$f_2(y) = \frac{1}{q}\sum_{i=1}^{q}\delta(y - y_i)$$

$$K_\sigma * f_2(y) = \frac{1}{q}\sum_{i=1}^{q}K_\sigma(y, y_i)$$

Chen et al. 2023 ISBI

Code

Nonlinear registration of sulcal pattern



algorithm through
the gradient descent

$\mathcal{O}(1)$

Chen et al. 2023 ISBI

Code