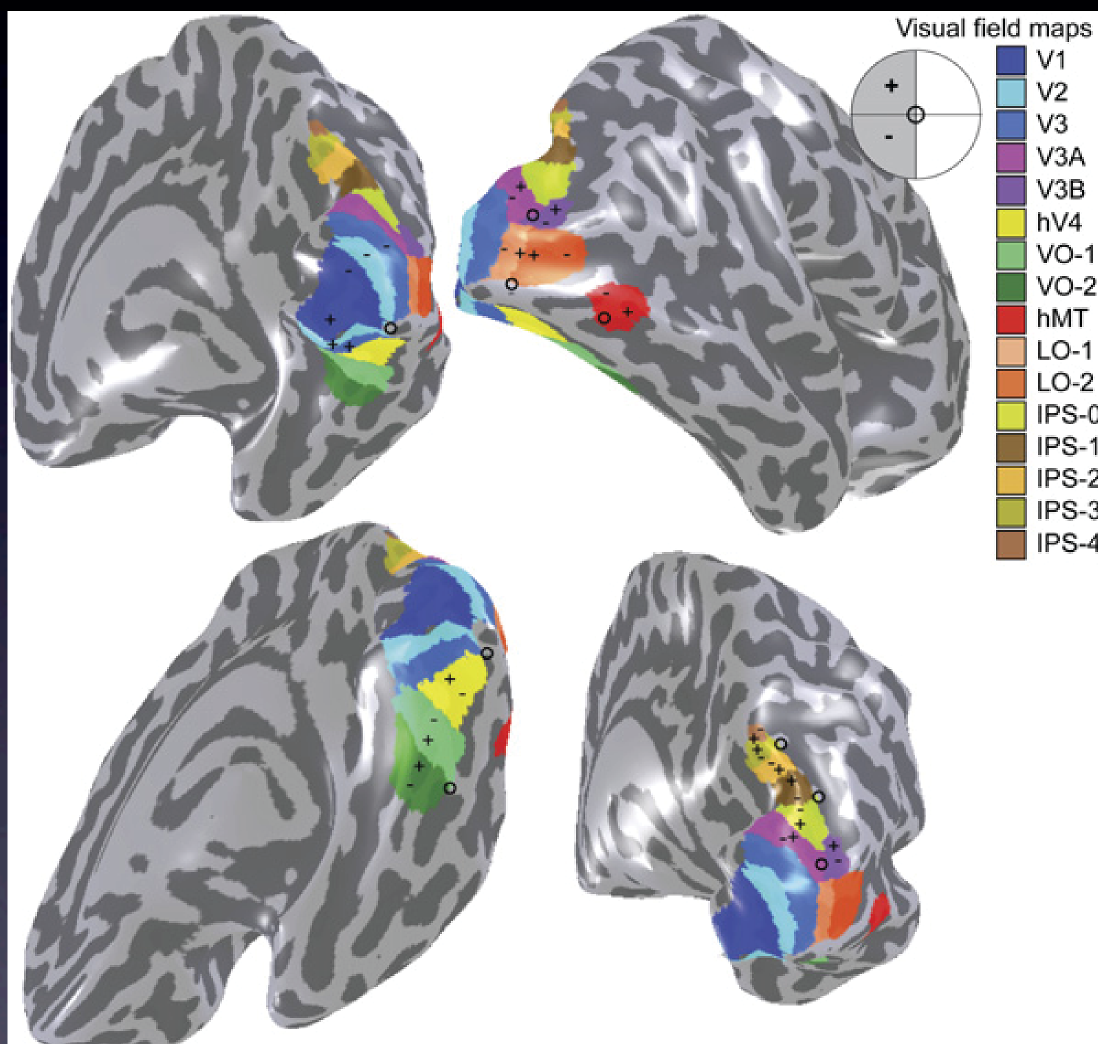
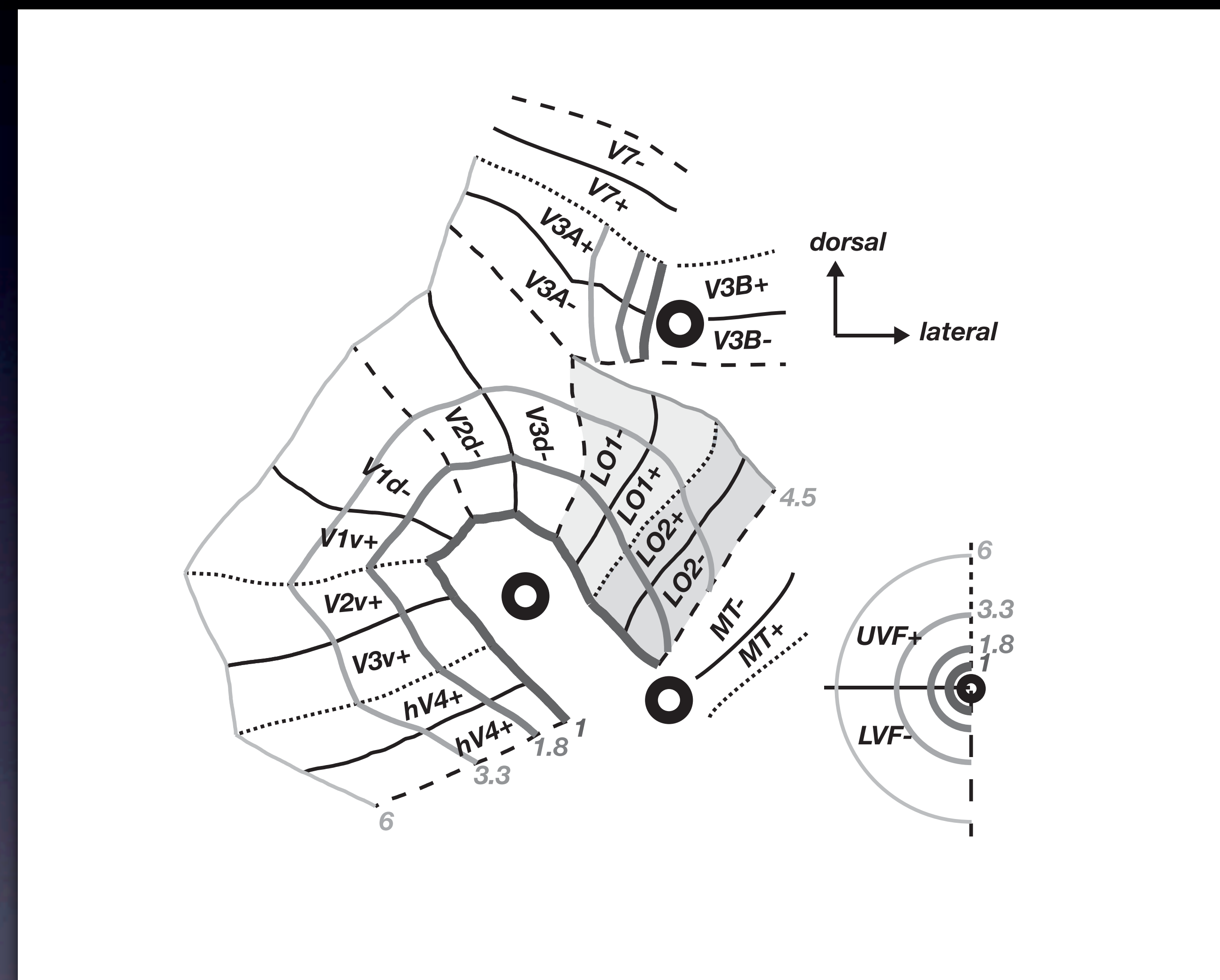
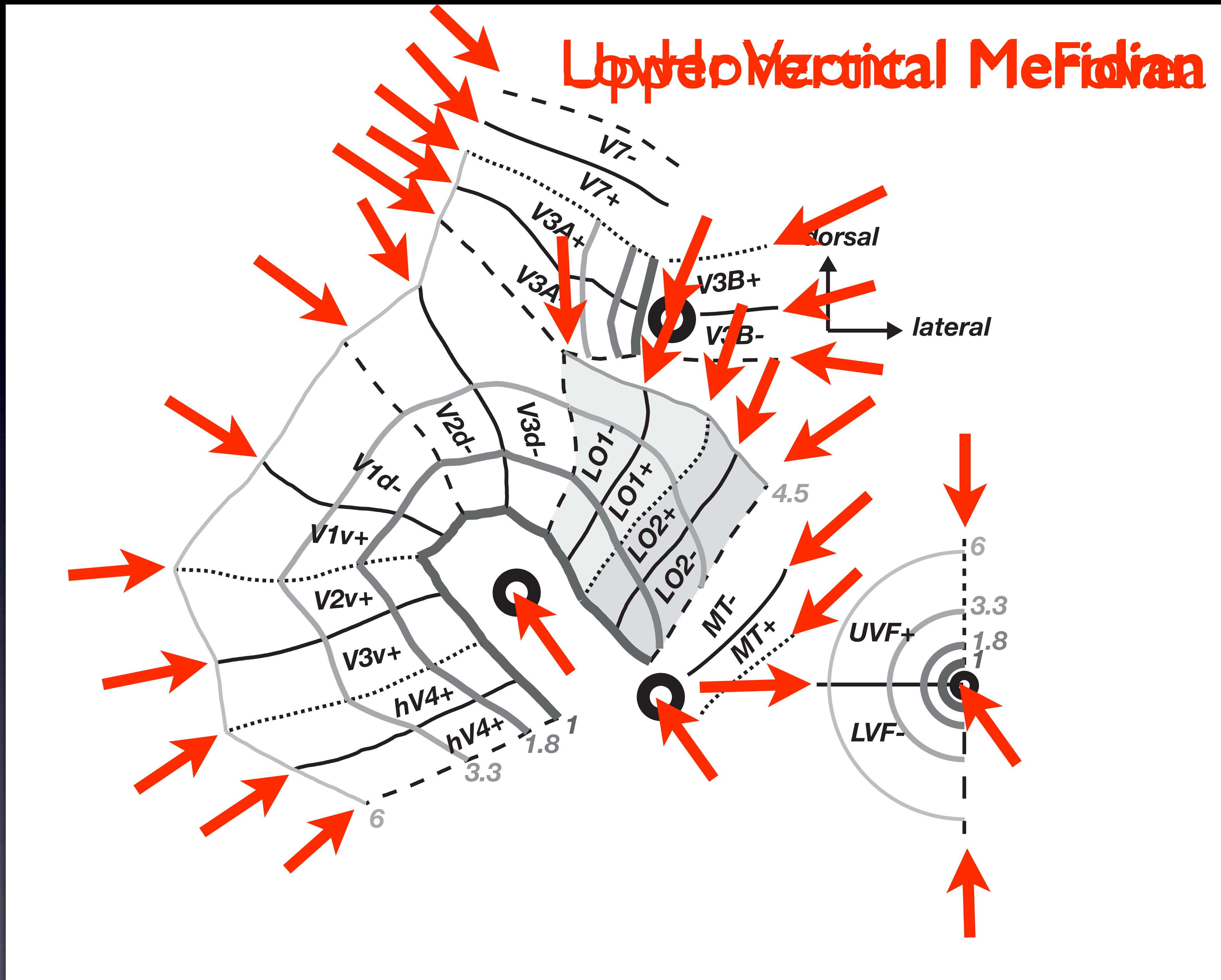
Retinotopy Tutorial

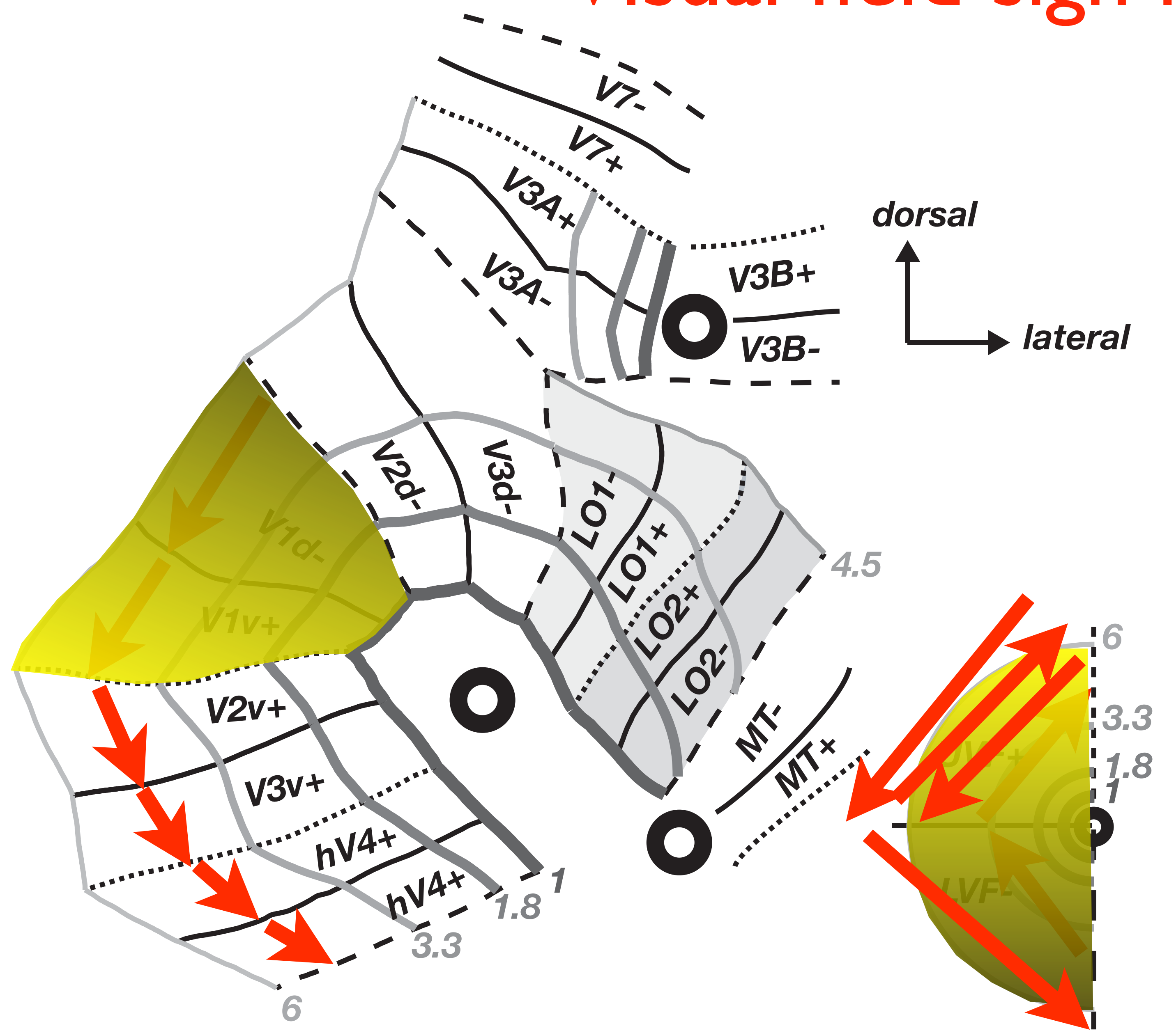

Visual field maps
V1
V2
V3
V3A
V3B
hV4
VO-1
VO-2
hMT
LO-1
LO-2
IPS-0
IPS-1
IPS-2
IPS-3
IPS-4


V7-
V7+
V3A+
V3A-
V3B+
V3B-
dorsal
lateral
V1d-
V2d-
V3d-
LO1-
LO1+
LO2+
LO2-
4.5
V1v+
V2v+
V3v+
hV4+
hV4+
MT-
MT+
UVF+
LVF-
6
3.3
1.8
1
1
1.8
3.3
6

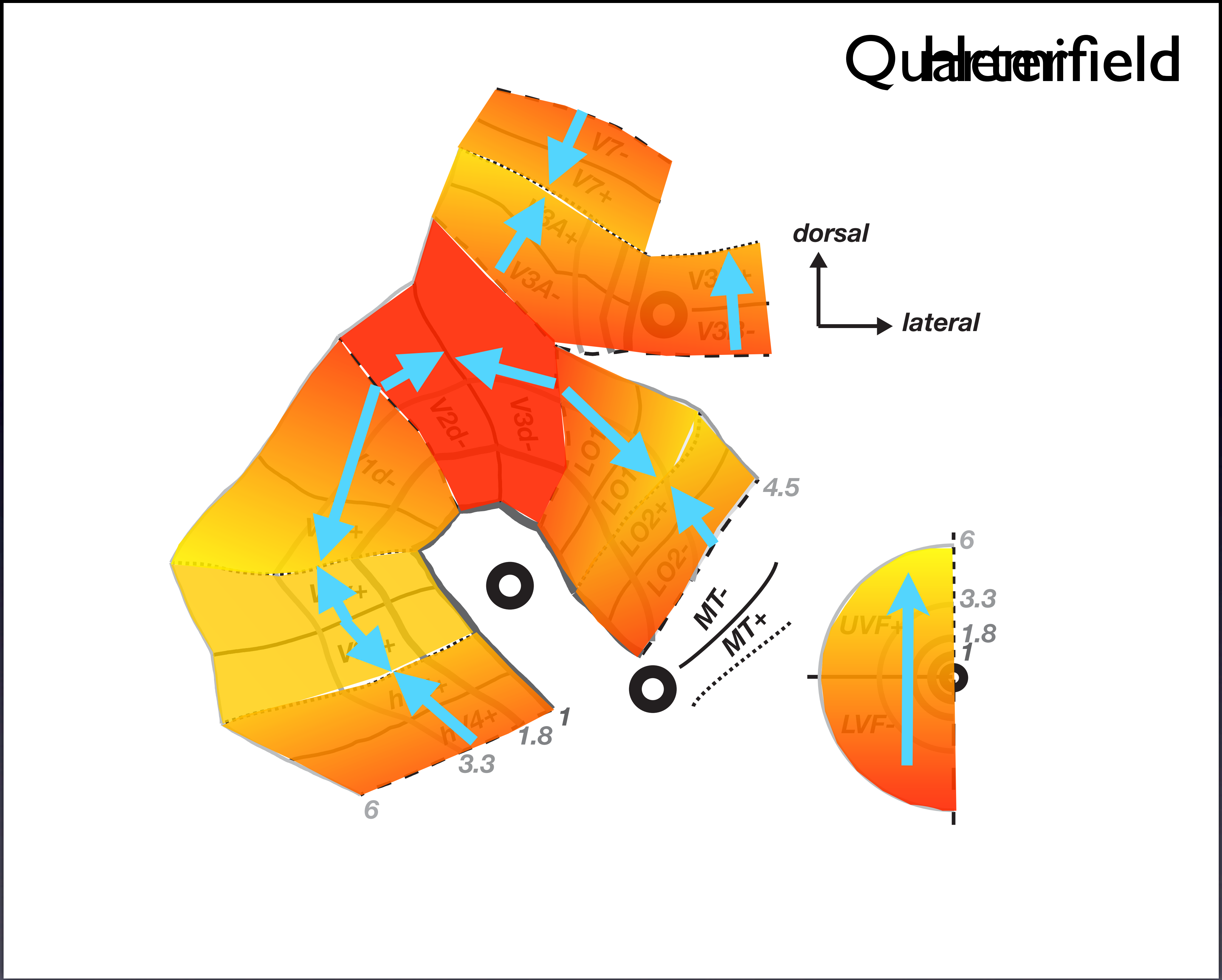


Larsson & Heeger (2006) JN 26:13128-42

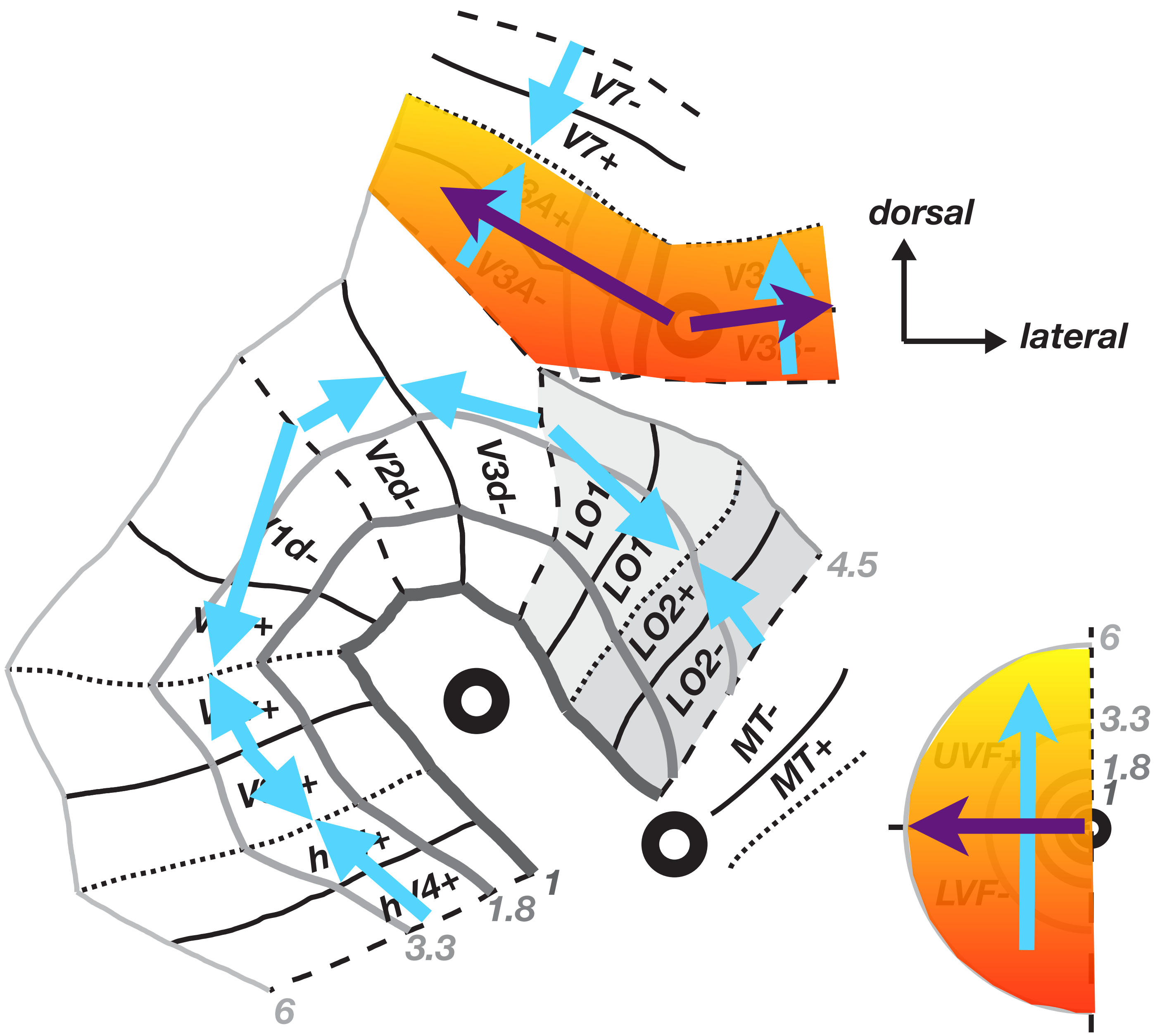
Visual field sign reversal



Larsson & Heeger (2006) JN 26:13128-42



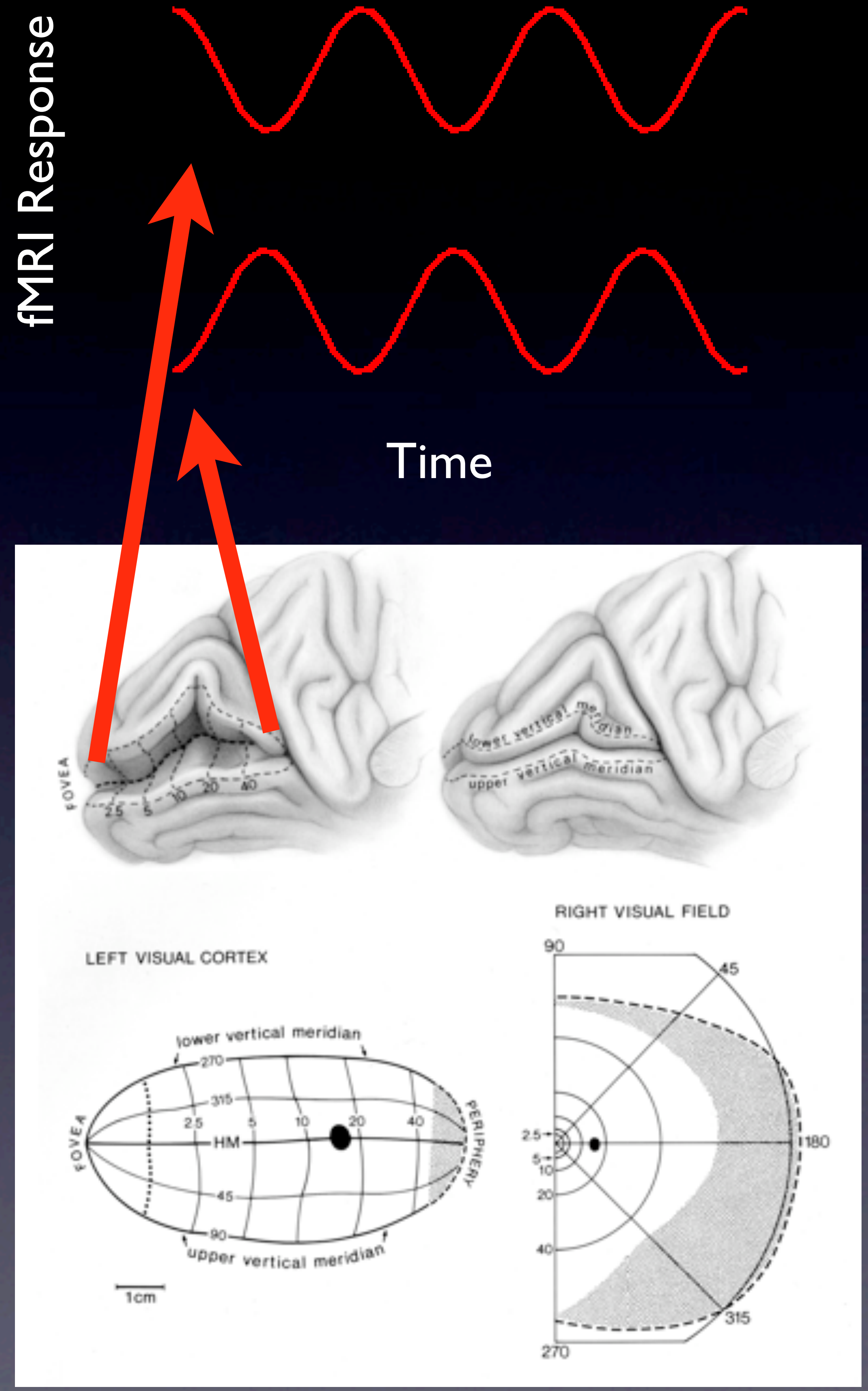
Larsson & Heeger (2006) JN 26:13128-42



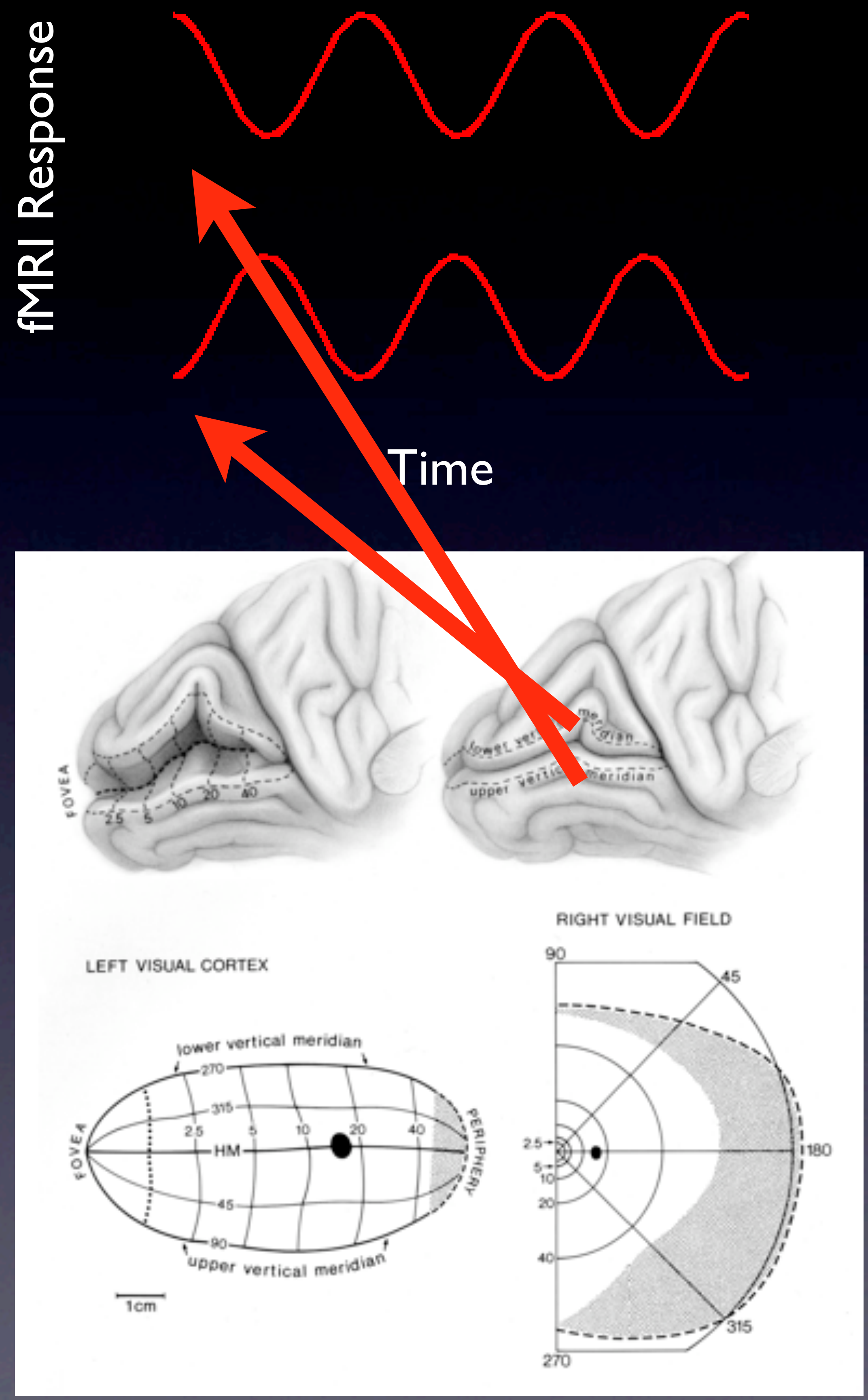
Larsson & Heeger (2006) JN 26:13128-42

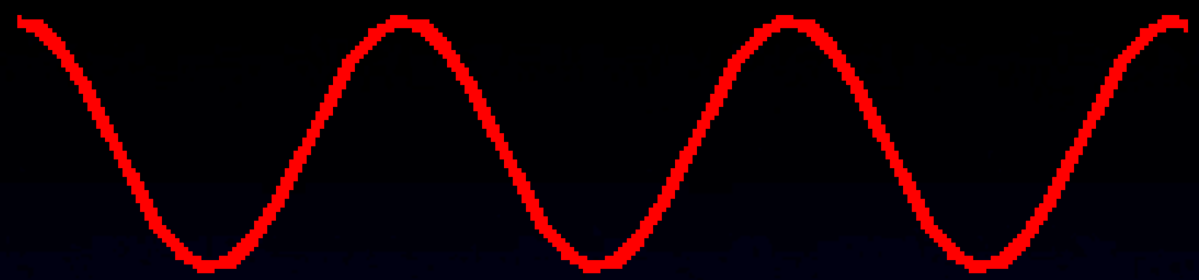
Topographic mapping with travelling wave stimulus

Rings stimulus gives eccentricty



Wedges stimulus gives polar angle





Phase: Eccentricty or polar angle of response field

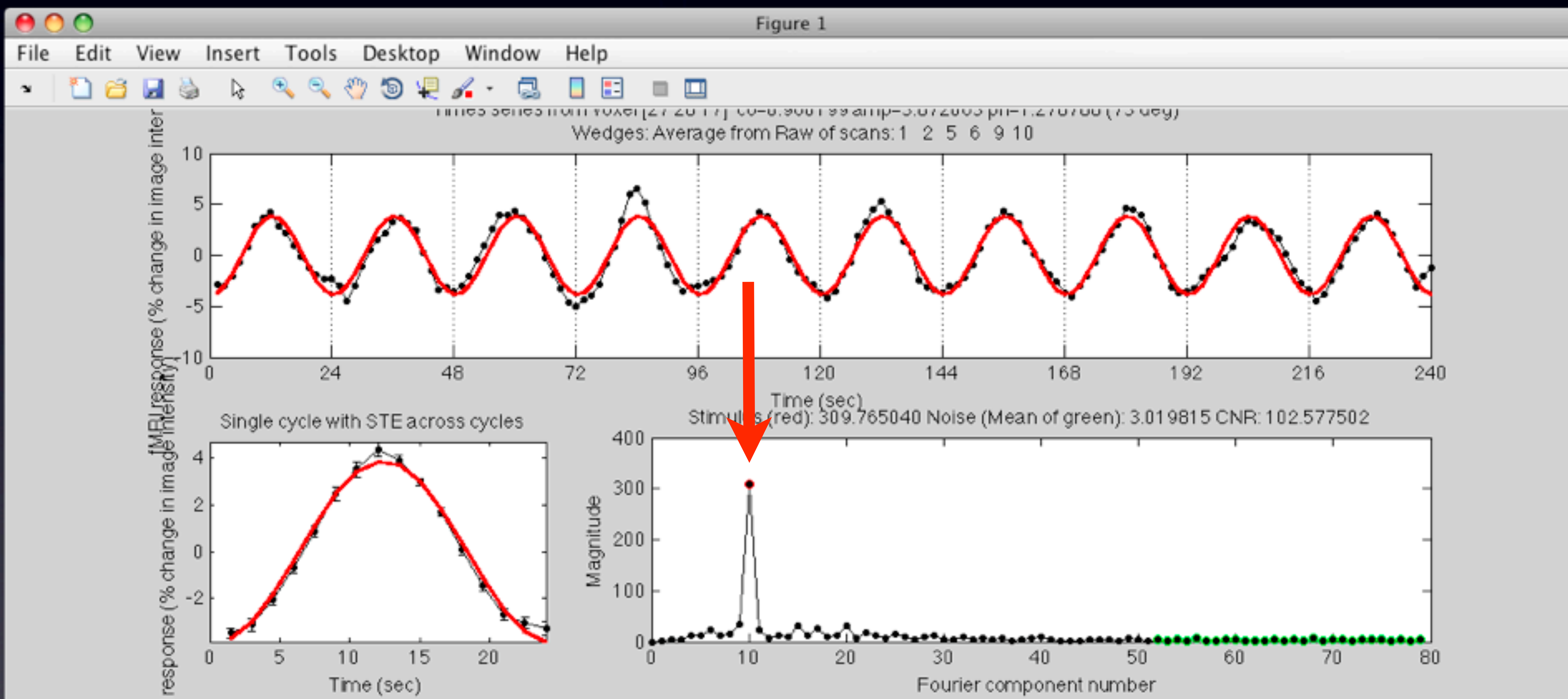
In principle, you get a continuous read-out of visual field location with phase.

Amplitude: Percent signal change

Coherence: Measure of how good the response is

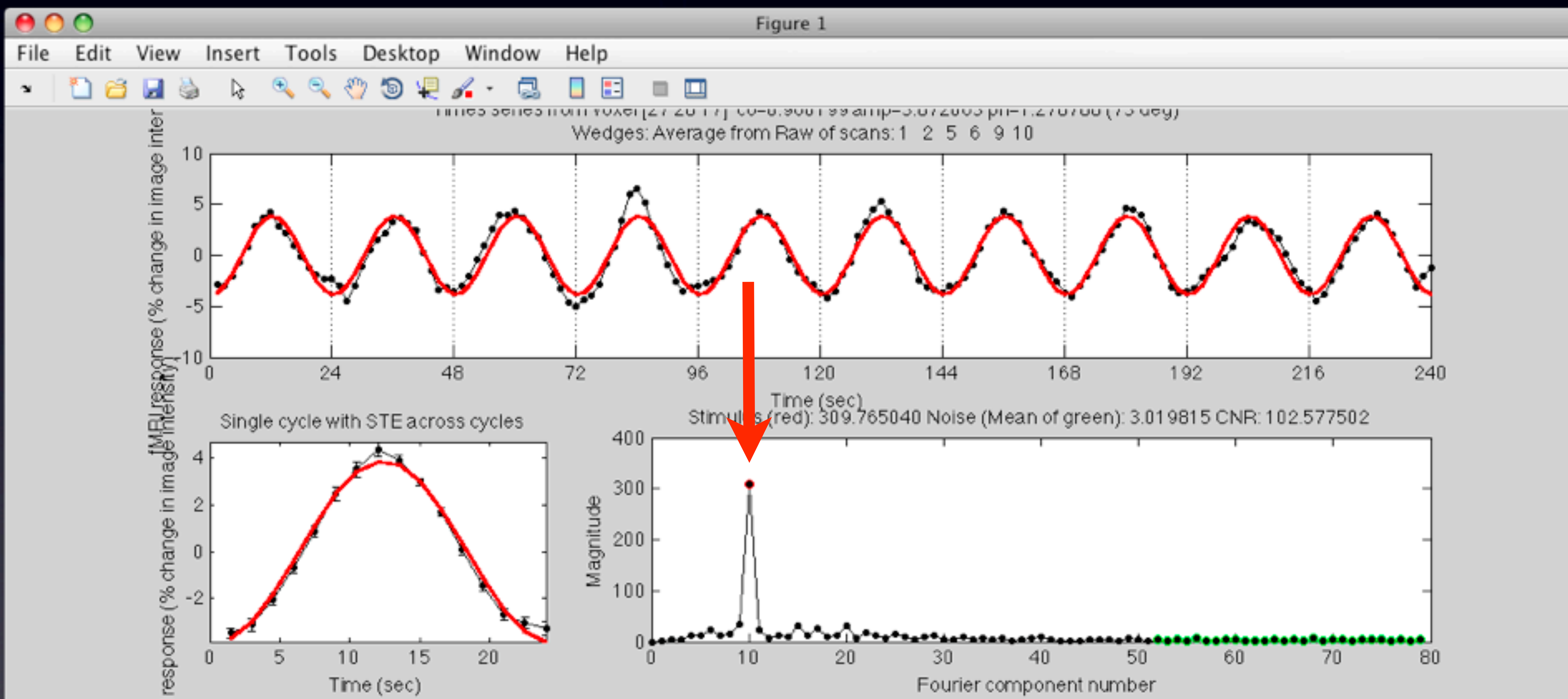
$$\text{Coherence} = \frac{\text{Response amplitude at stimulus frequency}}{\text{Sum of response amplitude at } \textit{all} \text{ frequencies}}$$

(A number between 0 - 1)

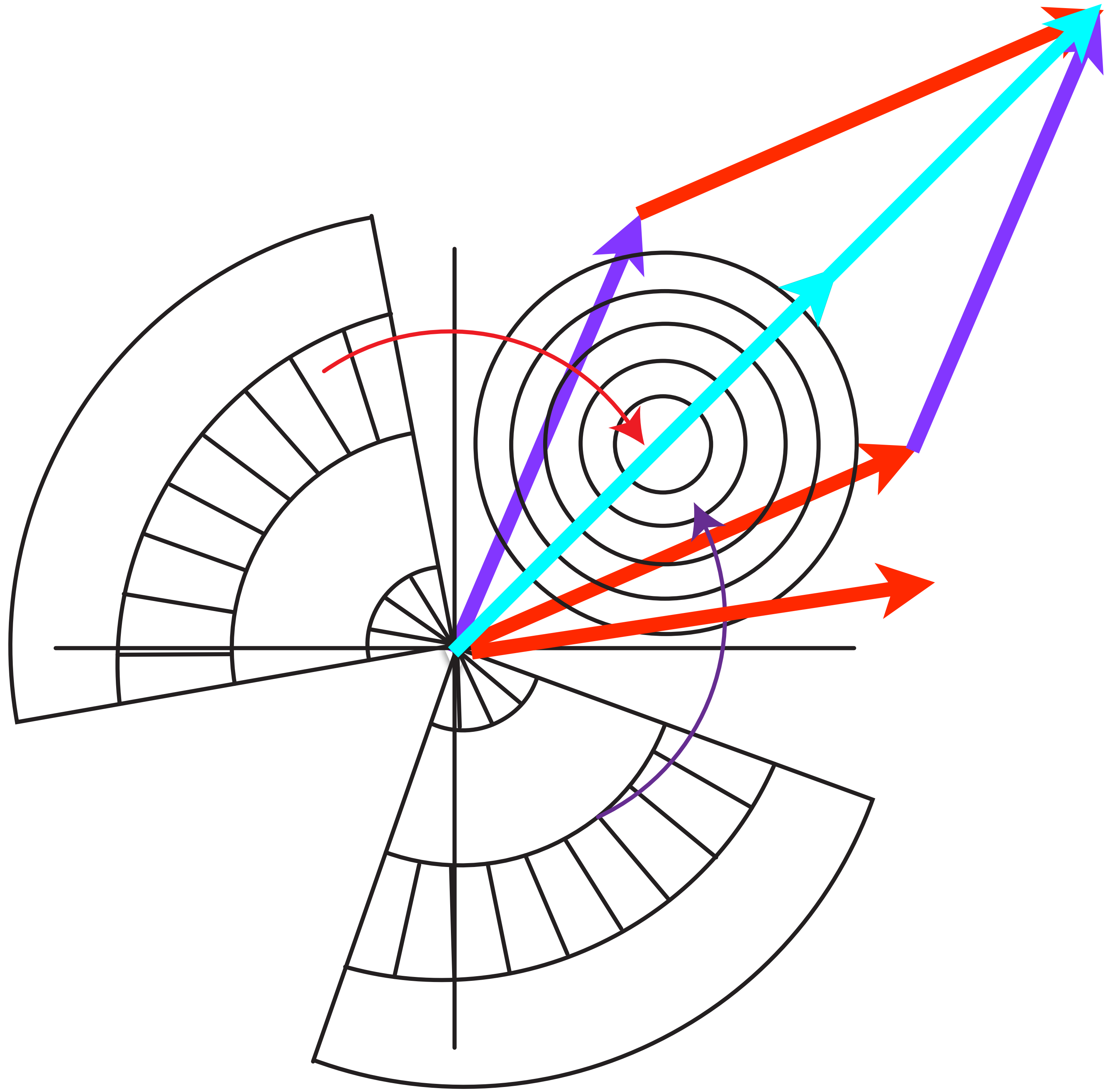


$$\text{Contrast-to-noise ratio} = \frac{\text{Response amplitude at stimulus frequency}}{\text{Mean of response amplitude at } \textit{noise} \text{ frequencies}}$$

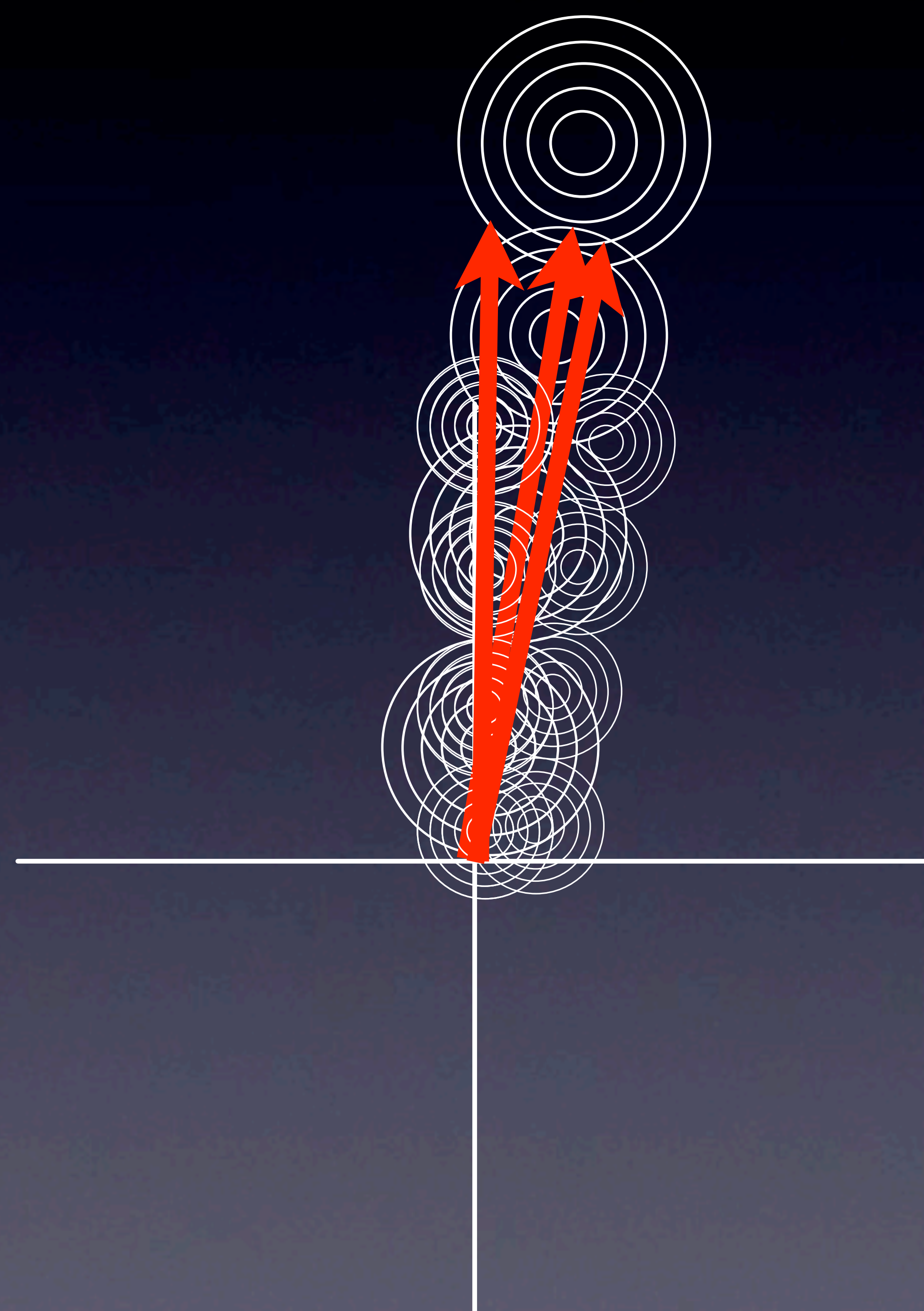
Unbounded number (bigger the better)



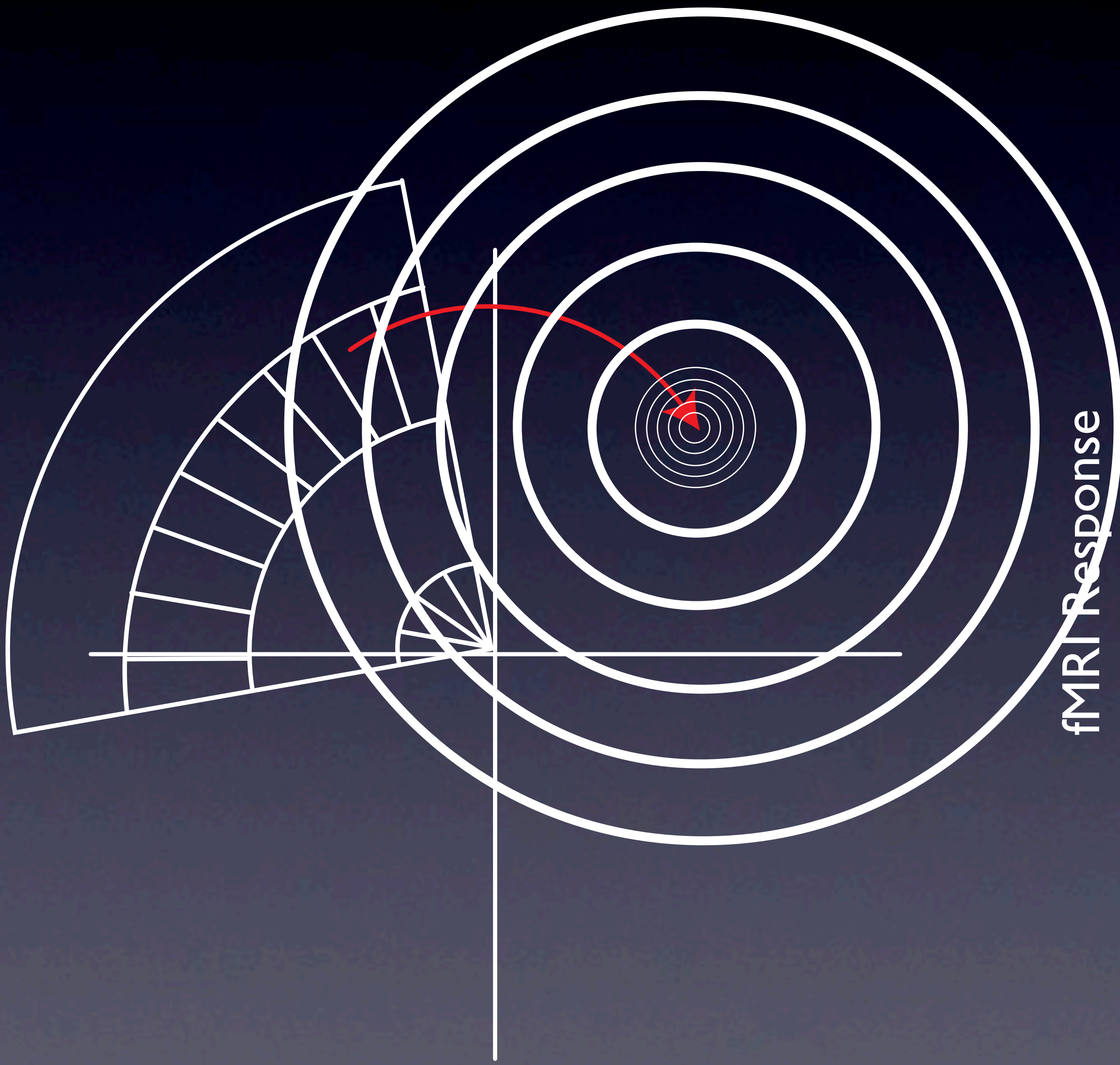
Tricks for dealing with hemodynamic lag

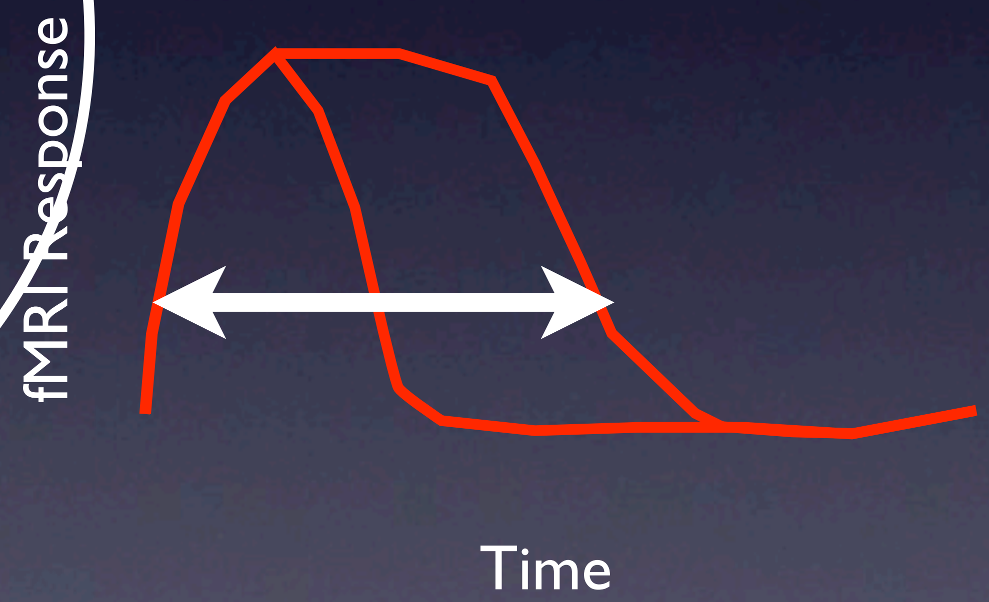


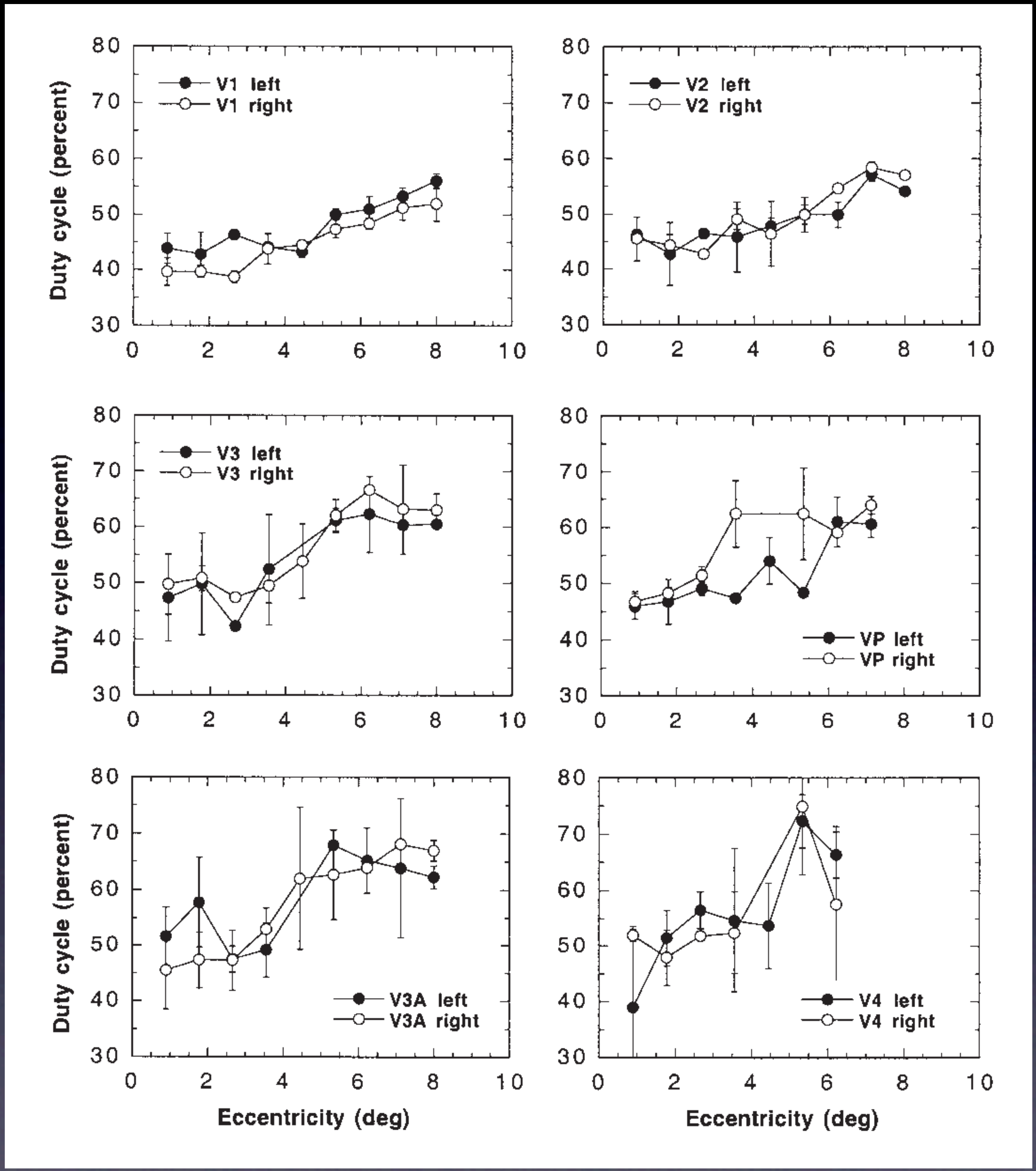
Why we might not get perfect vertical meridian response



Measuring receptive field size with duty-cycle

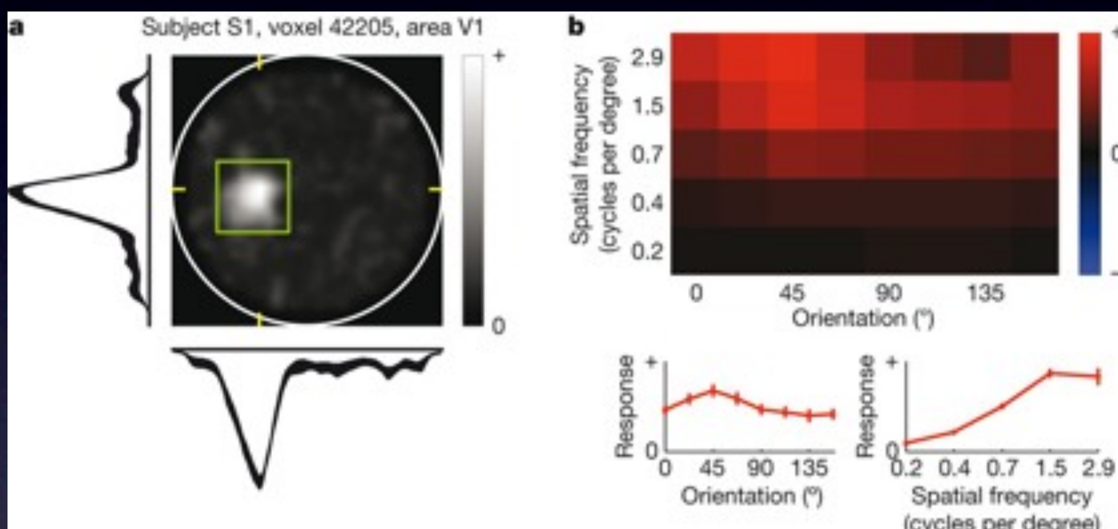




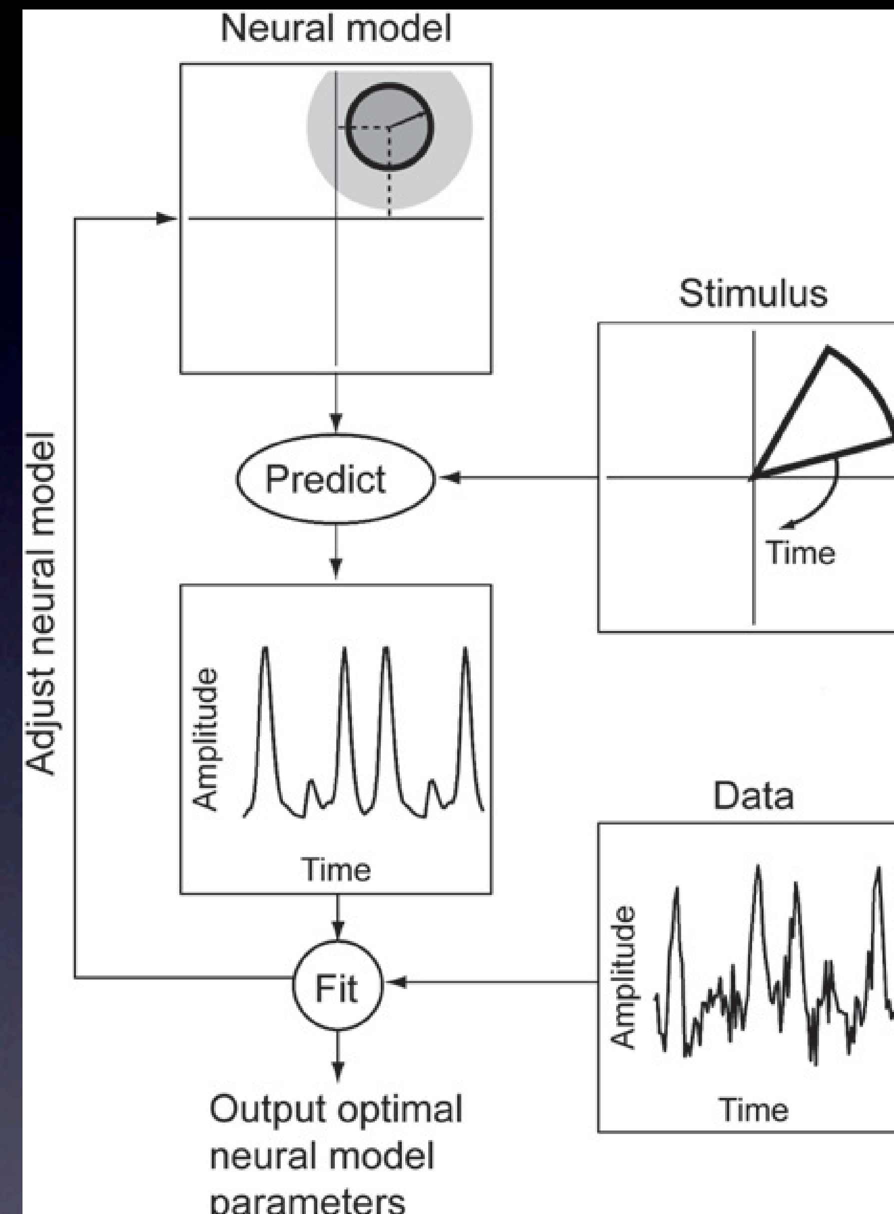


Smith, Singh, Williams & Greenlee (2001) Cereb Cortex 11:1182-90

Estimate "receptive field" of voxel, rather than use response phase

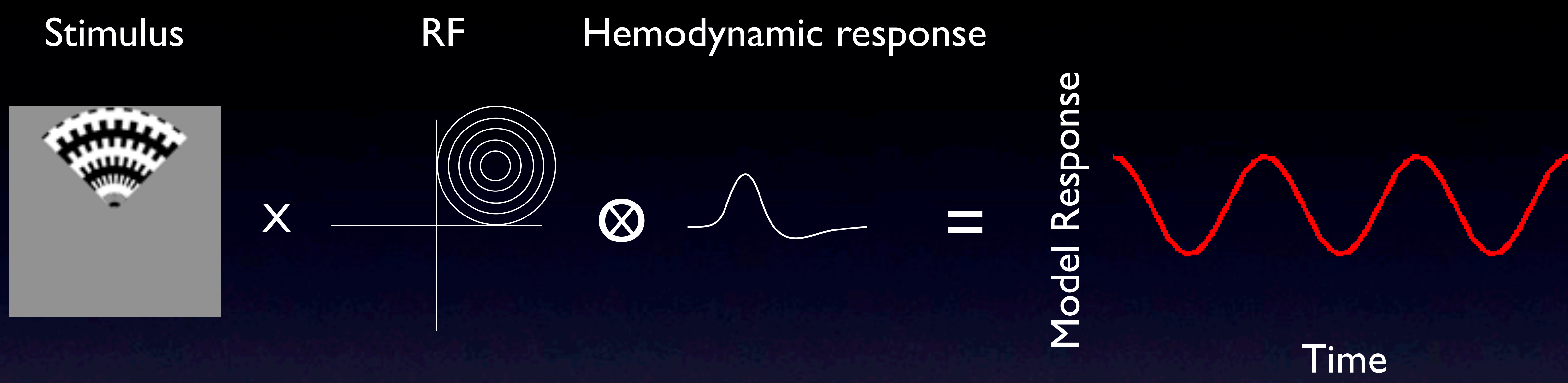


Kay, Naselaris, Prenger & Gallant (2008)
Nature 20:352-5



Dumoulin & Wandell (2008) Neuroimage
39:647-60

Model response of voxel



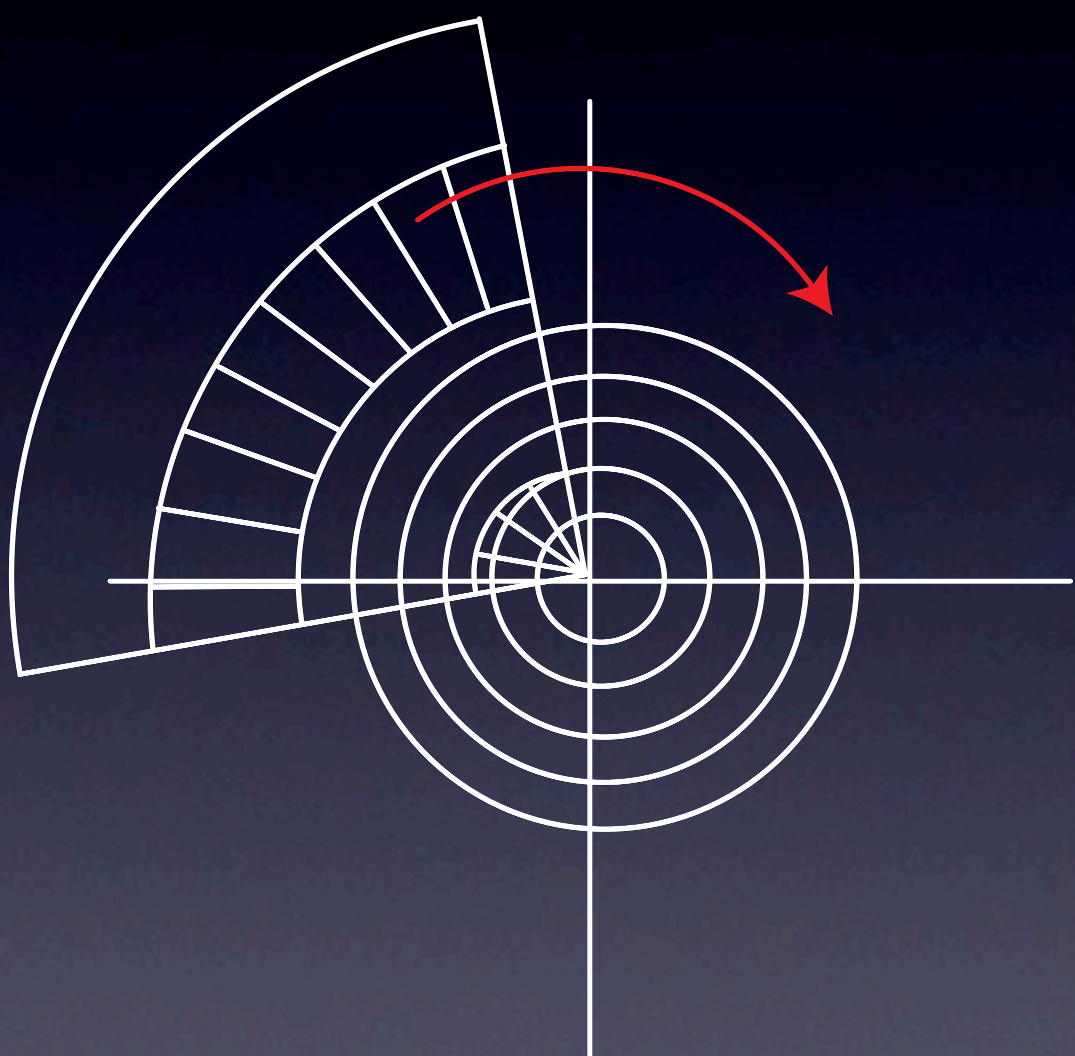
1) Adjust parameters (e.g. RF location & size + hemodynamic lag & width) to generate response that best matches the measured response.

2) Model can include any property you want to measure (e.g. spatial frequency tuning, orientation tuning)

3) You can use any stimulus that probes the responses you are interested in (e.g. wedges & rings are ok)

4) Fit will likely be nonlinear (i.e. takes a long time to compute)

Turning off stimulus to get response from foveal response fields



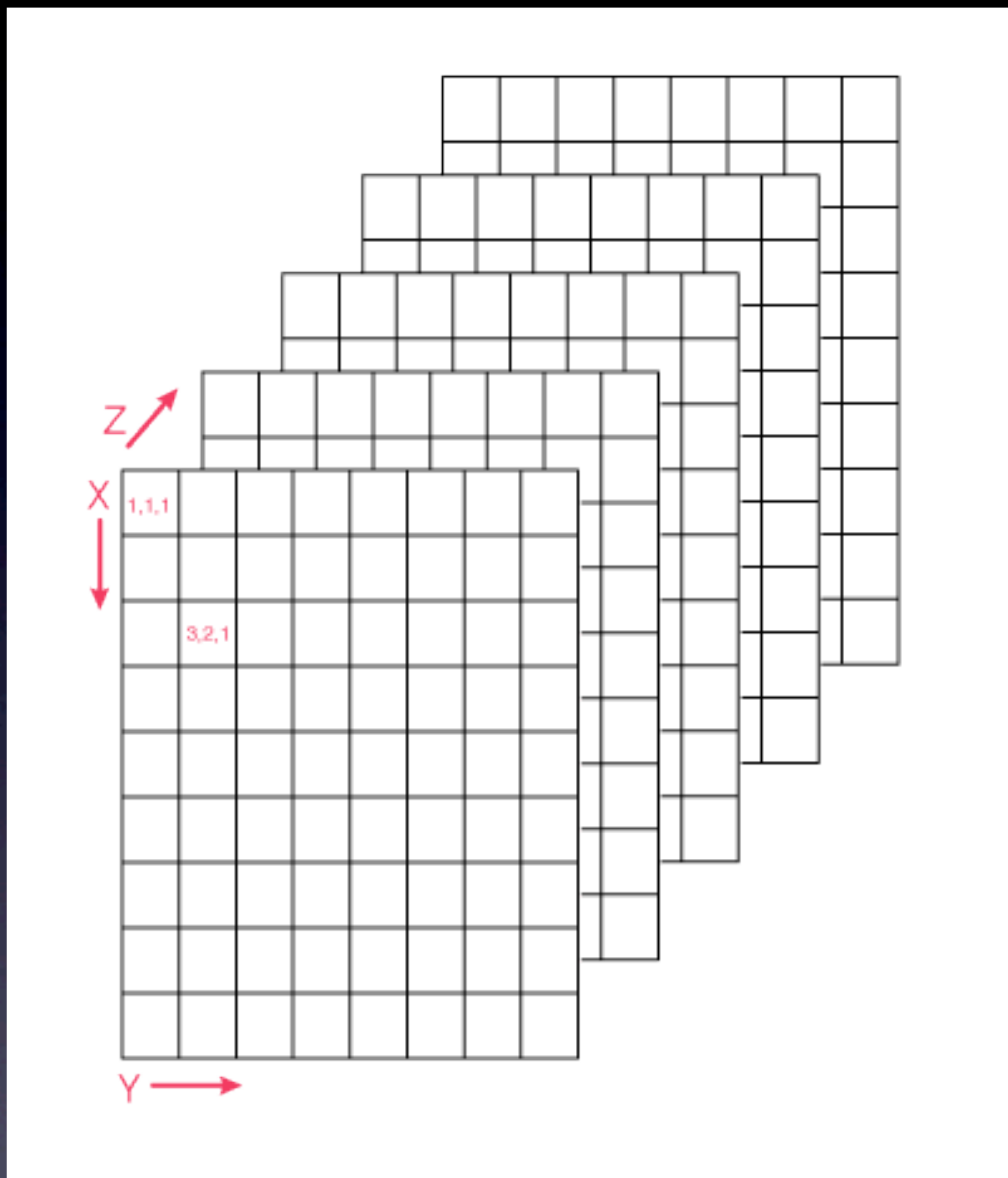
Nifti image format

- Neuroimaging Informatics Technology Initiative (Bob Cox - NIH)
- Backwards compatible with Analyze
- Sharing data between different programs (e.g. mrTools, BrainVoyager, AFNI, FSL etc)
- Contains slice orientation info in header

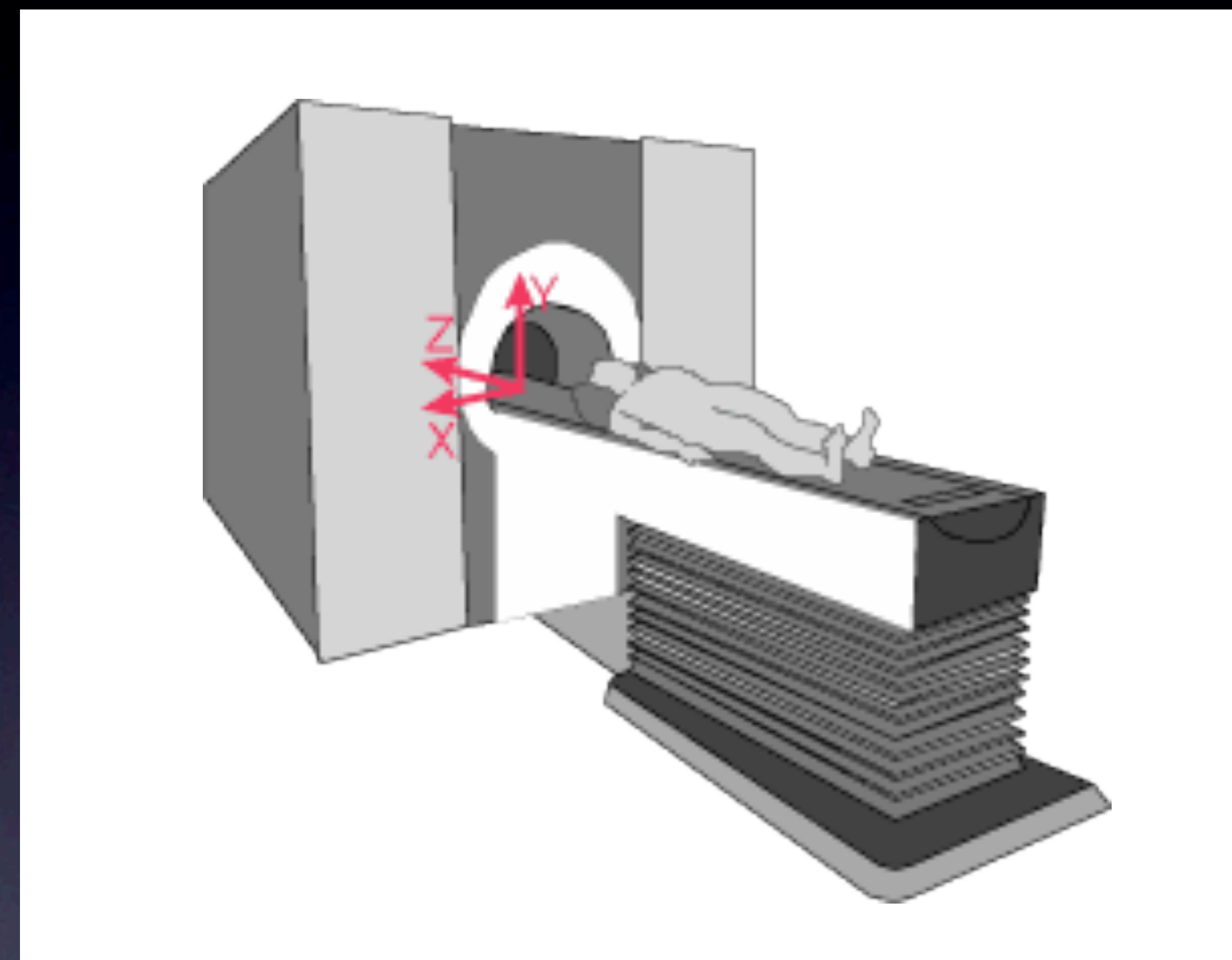
Nifti image format

- Qform (usually the orientation of your slices in the magnet)
- Sform (usually the orientation of your slices in the magnet aligned to the volume anatomy)
- Qform_code and Sform_code can be (0 = not set, 1 = magnet coordinates, 3 = talairach coordinates)

Image coordinates



Magnet coordinates



Magnet coordinates — Qform — Image coordinates

$$\begin{pmatrix} x_{mag} \\ y_{mag} \\ z_{mag} \\ 1 \end{pmatrix} = \begin{pmatrix} rs_{11} & rs_{12} & rs_{13} & t_{xmm} \\ rs_{21} & rs_{22} & rs_{23} & t_{ymm} \\ rs_{31} & rs_{32} & rs_{33} & t_{zmm} \\ 0 & 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_{img} \\ y_{img} \\ z_{img} \\ 1 \end{pmatrix}$$

Magnet coordinates | Qform | Image coordinates

$$\begin{pmatrix} x_{mag} \\ y_{mag} \\ z_{mag} \\ 1 \end{pmatrix} = \begin{pmatrix} rs_{11} & rs_{12} & rs_{13} & t_{xmm} \\ rs_{21} & rs_{22} & rs_{23} & t_{ymm} \\ rs_{31} & rs_{32} & rs_{33} & t_{zmm} \\ 0 & 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_{img} \\ y_{img} \\ z_{img} \\ 1 \end{pmatrix}$$

So the Qform is the transformation that converts a voxel location in the image to a location in mm in the magnet.

i.e. Qform = image2magnet

Magnet coordinates = Qform · Image coordinates

$$\begin{pmatrix} x_{mag} \\ y_{mag} \\ z_{mag} \\ 1 \end{pmatrix} = \begin{pmatrix} rs_{11} & rs_{12} & rs_{13} & t_{xmm} \\ rs_{21} & rs_{22} & rs_{23} & t_{ymm} \\ rs_{31} & rs_{32} & rs_{33} & t_{zmm} \\ 0 & 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_{img} \\ y_{img} \\ z_{img} \\ 1 \end{pmatrix}$$

Qform = Rotation · Scaling · Translation

$$\begin{pmatrix} rs_{11} & rs_{12} & rs_{13} & t_{xmm} \\ rs_{21} & rs_{22} & rs_{23} & t_{ymm} \\ rs_{31} & rs_{32} & rs_{33} & t_{zmm} \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} r_{11} & r_{12} & r_{13} & 0 \\ r_{21} & r_{22} & r_{23} & 0 \\ r_{31} & r_{32} & r_{33} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 & t_{ximg} \\ 0 & 1 & 0 & t_{yimg} \\ 0 & 0 & 1 & t_{zimg} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

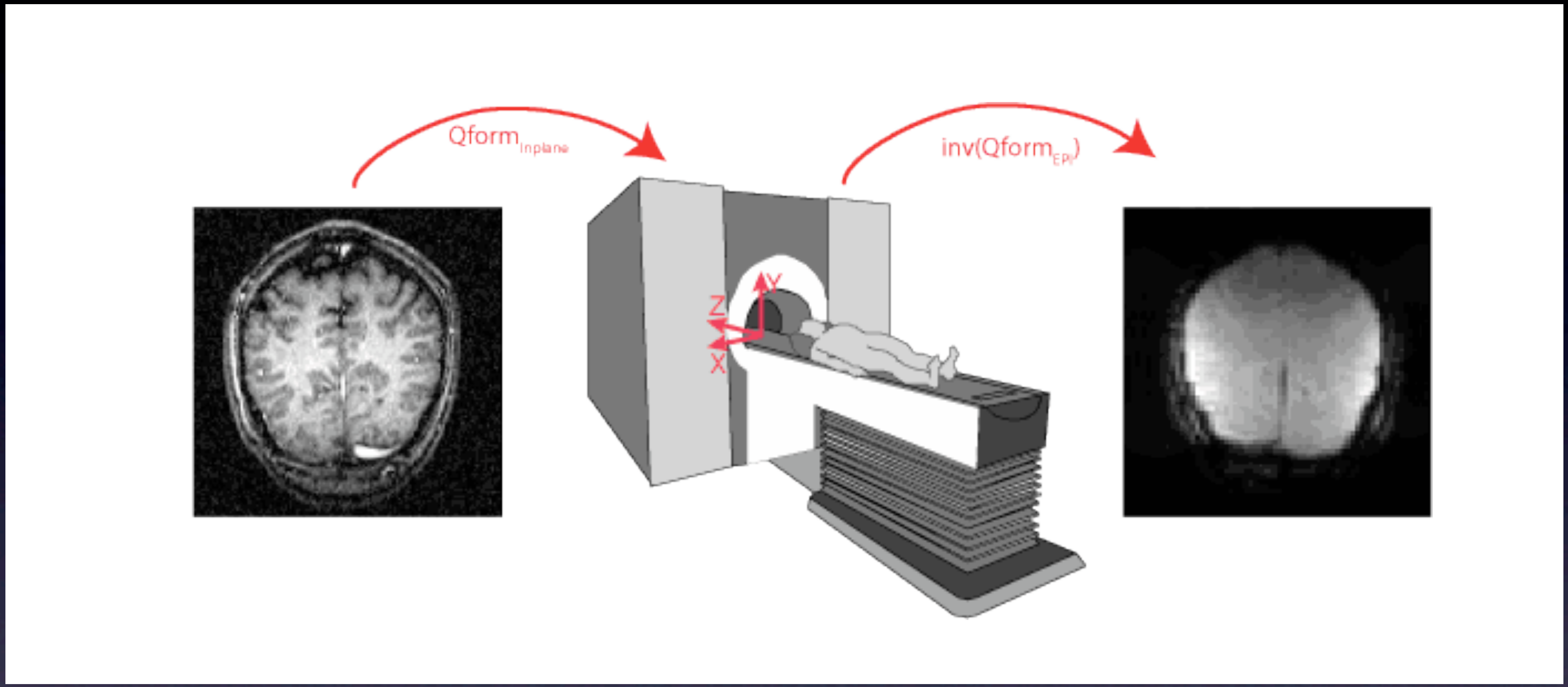
- Remember that matrix multiplication is non-commutative (order matters!!!!)
- Scaling factors usually specify voxel size
- Nifti's image coordinates are 0 (not 1) based

Magnet coordinates = Qform · Image coordinates

$$\begin{pmatrix} x_{mag} \\ y_{mag} \\ z_{mag} \\ 1 \end{pmatrix} = \begin{pmatrix} rs_{11} & rs_{12} & rs_{13} & t_{xmm} \\ rs_{21} & rs_{22} & rs_{23} & t_{ymm} \\ rs_{31} & rs_{32} & rs_{33} & t_{zmm} \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & -1 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_{img} \\ y_{img} \\ z_{img} \\ 1 \end{pmatrix}$$

But mrT... or you

To transform from an inplane voxel location to an epi voxel location

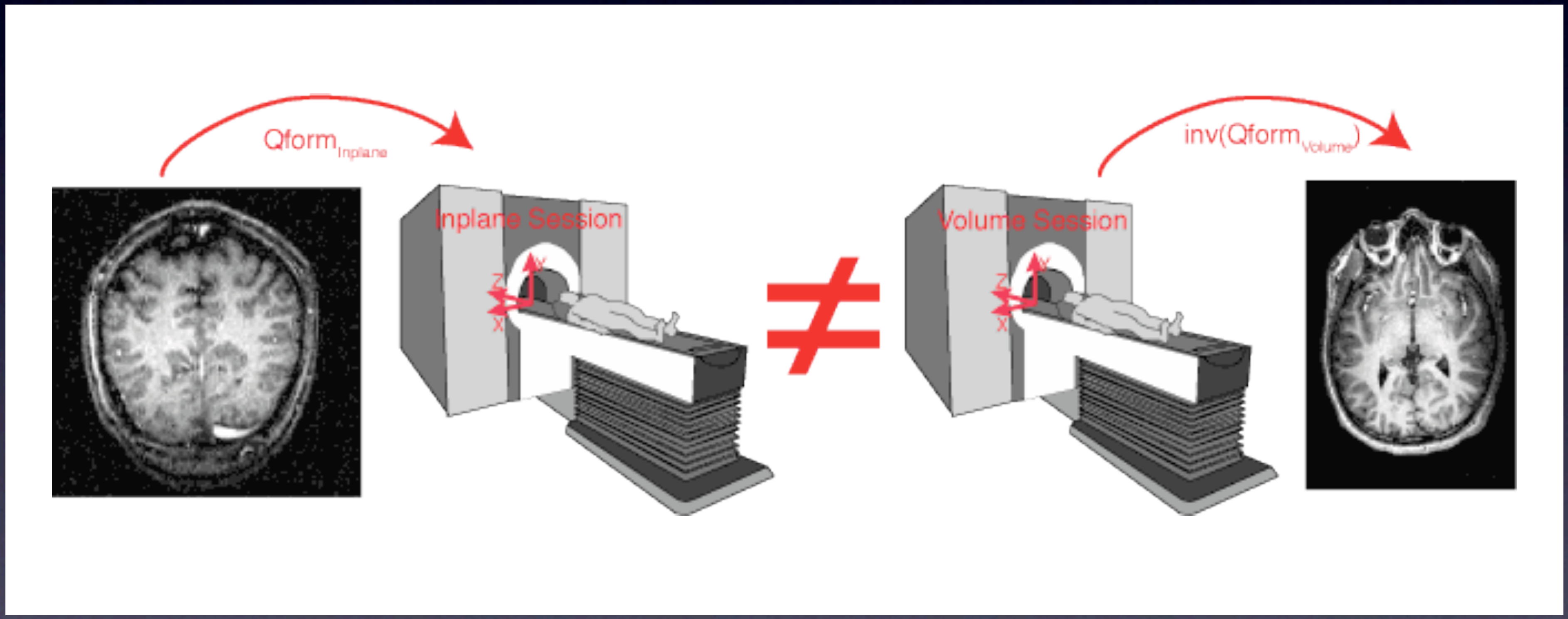


inplane2epi = inplane2magnet * magnet2epi

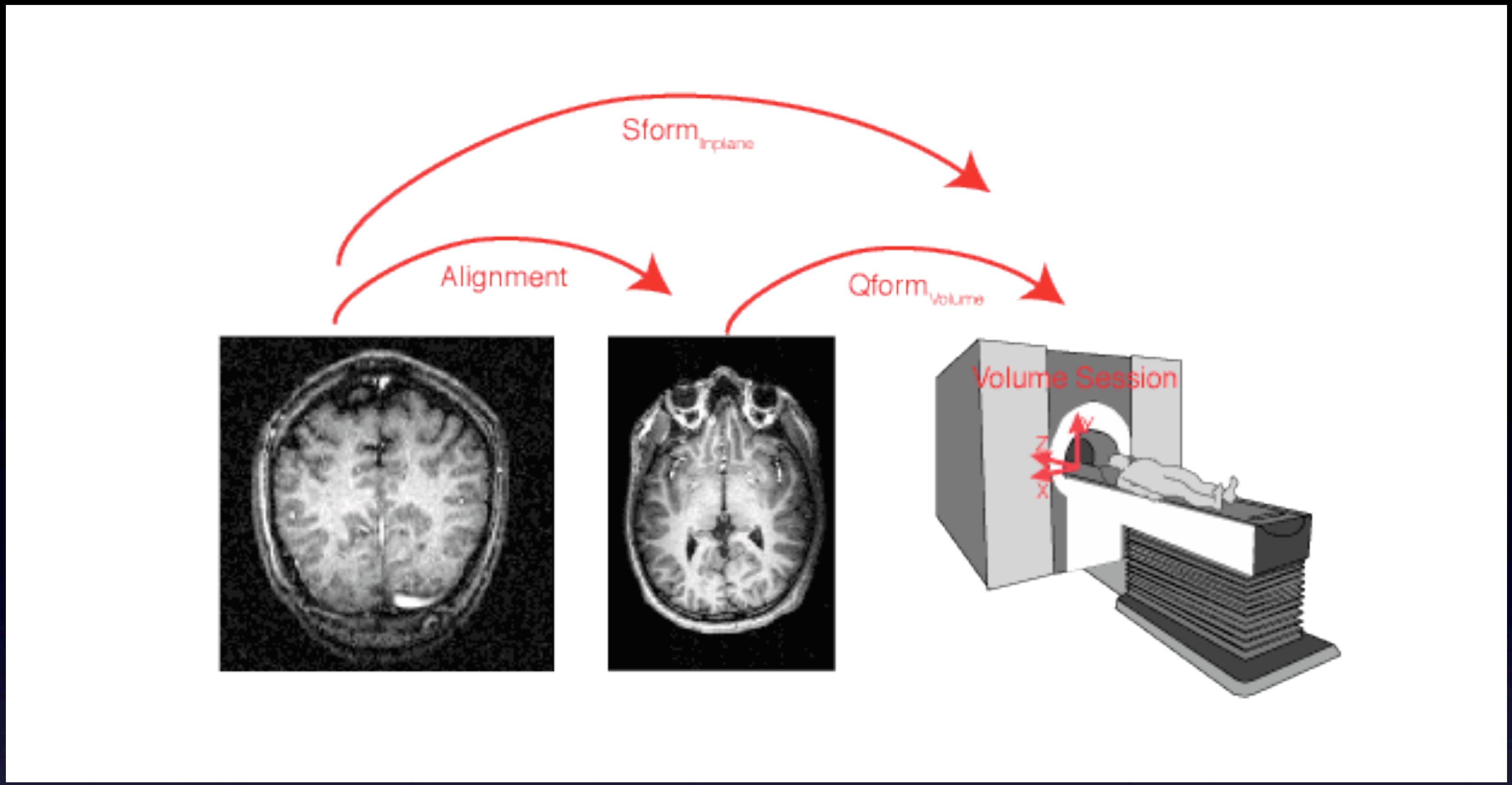
inplane2epi = inplane2magnet * inv(epi2magnet)

$$\begin{pmatrix} x_{EPI} \\ y_{EPI} \\ z_{EPI} \\ 1 \end{pmatrix} = \left(Qform_{EPI} \right)^{-1} \cdot \left(Qform_{inplane} \right) \cdot \begin{pmatrix} x_{inplane} \\ y_{inplane} \\ z_{inplane} \\ 1 \end{pmatrix}$$

But, what about when you want to transform from a volume to a inplane taken on different days



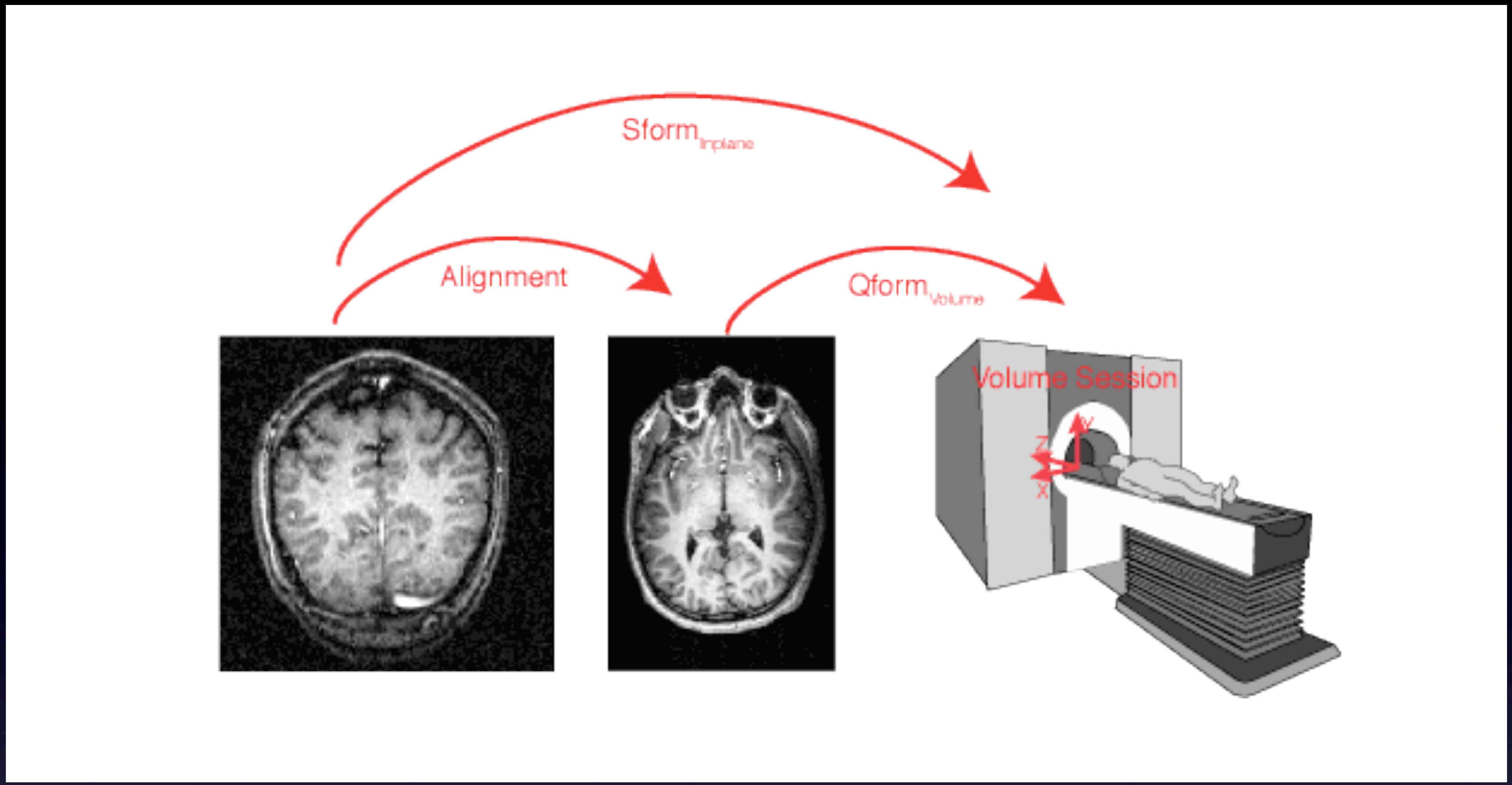
We need an alignment!



- Find the transformation that minimizes the difference between the inplane and volume (i.e. inplane2volume) using mrAlign

- Then make the sform of the inplane be a transformation into the magnet coordinates *as if* the head were in the same place as when the volume was taken.

We need an alignment!

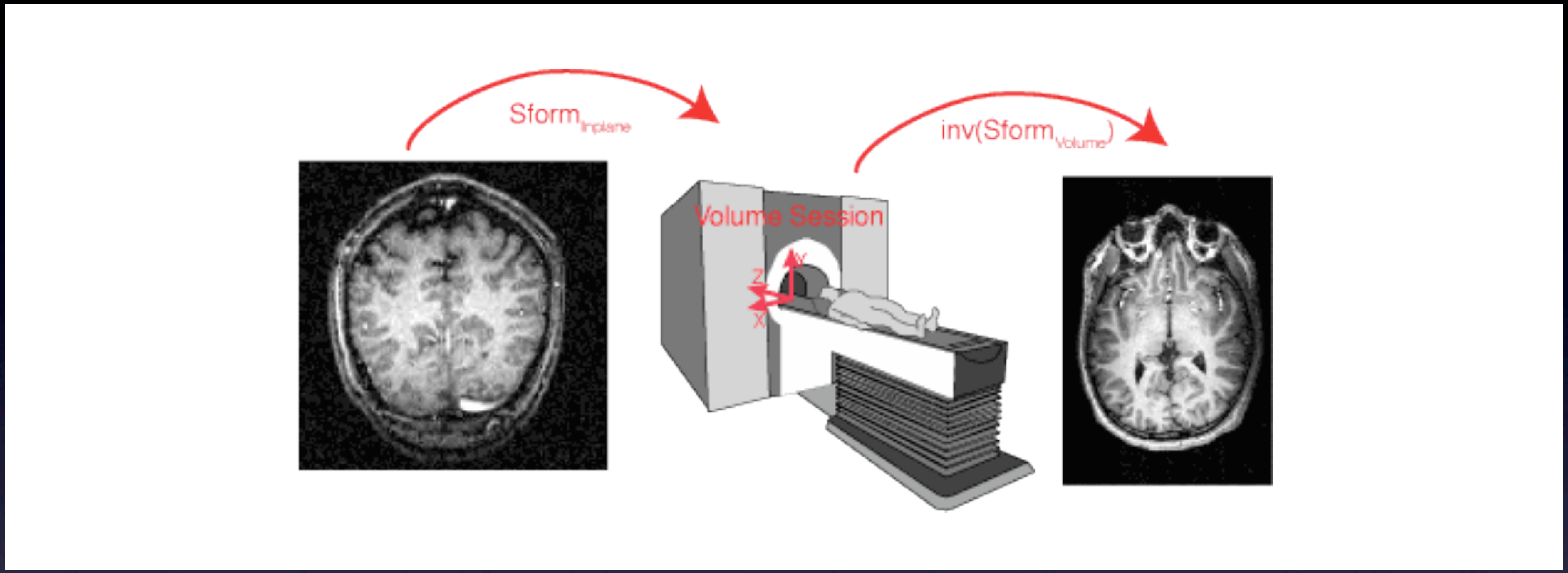


$\text{sform}_{\text{inplane}} = \text{inplane2magnet}_{\text{volume session}}$

alignment qform of volume

$\text{sform}_{\text{inplane}} = \text{inplane2volume} * \text{volume2magnet}_{\text{volume session}}$

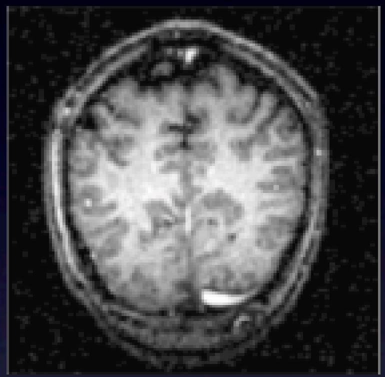
Now transforming inplane to volume coordinates is easy!



$$\begin{pmatrix} x_{volume} \\ y_{volume} \\ z_{volume} \\ 1 \end{pmatrix} = \left(Sform_{volume} \right)^{-1} \cdot \left(Sform_{inplane} \right) \cdot \begin{pmatrix} x_{inplane} \\ y_{inplane} \\ z_{inplane} \\ 1 \end{pmatrix}$$

Once you have aligned the inplane to the volume, you can use the header information to align the EPI's to the volume

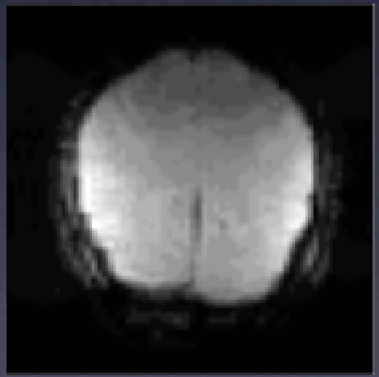
Inplane



$Qform_{inplane}$ = $inplane2magnet_{epi\ session}$

$Sform_{inplane}$ = $inplane2magnet_{volume\ session}$

EPI



$Qform_{epi}$ = $epi2magnet_{epi\ session}$

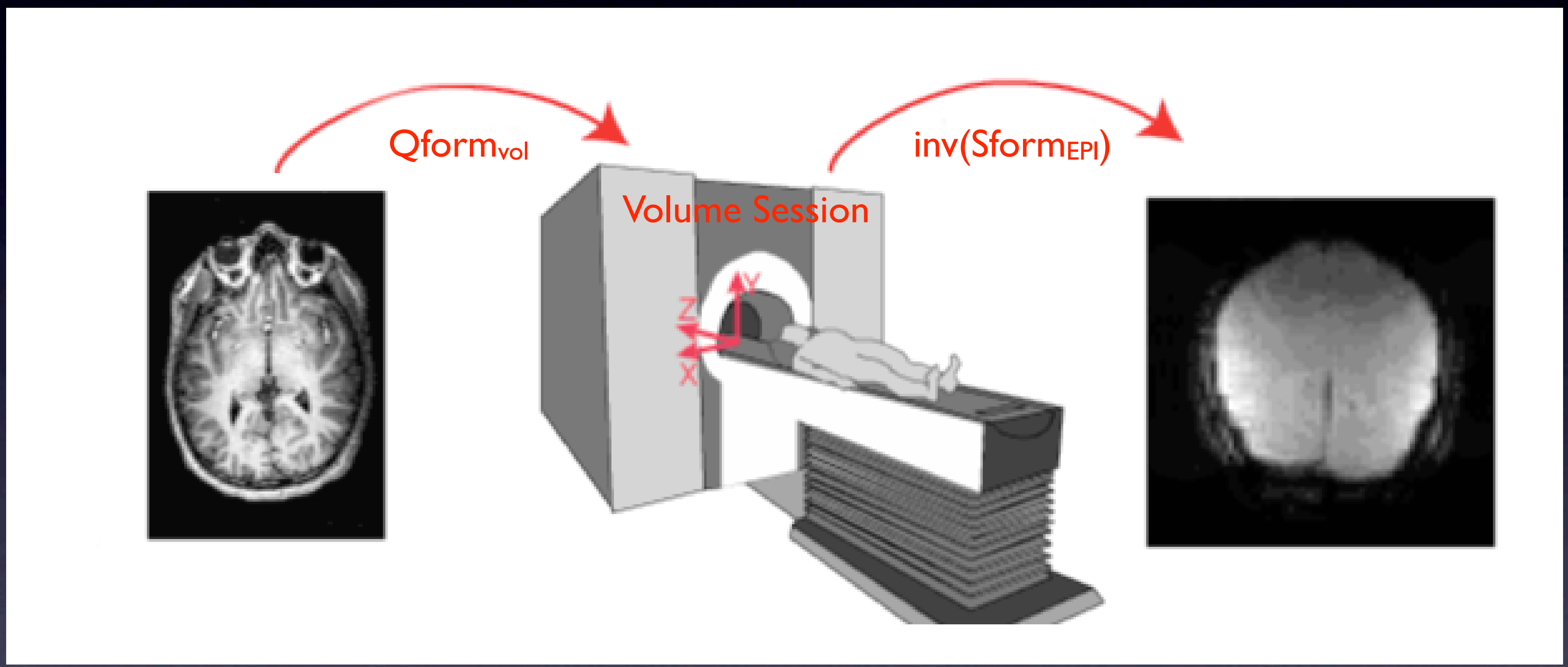
$Sform_{epi}$ = $epi2magnet_{volume\ session}$

$epi2magnet_{epi\ session}$ x $magnet_{epi\ session}2inplane$ x $inplane2magnet_{volume\ session}$

$Qform_{epi}$ x $inv(Qform_{inplane})$ x $Sform_{inplane}$

$epi2magnet_{volume\ session}$

Now to display on any volume (or surface or flat map) we can convert from volume coordinates to epi coordinates



Note that we always align to a "canonical" volume, so that the sform = $\text{image2magnet}_{\text{volume session}}$

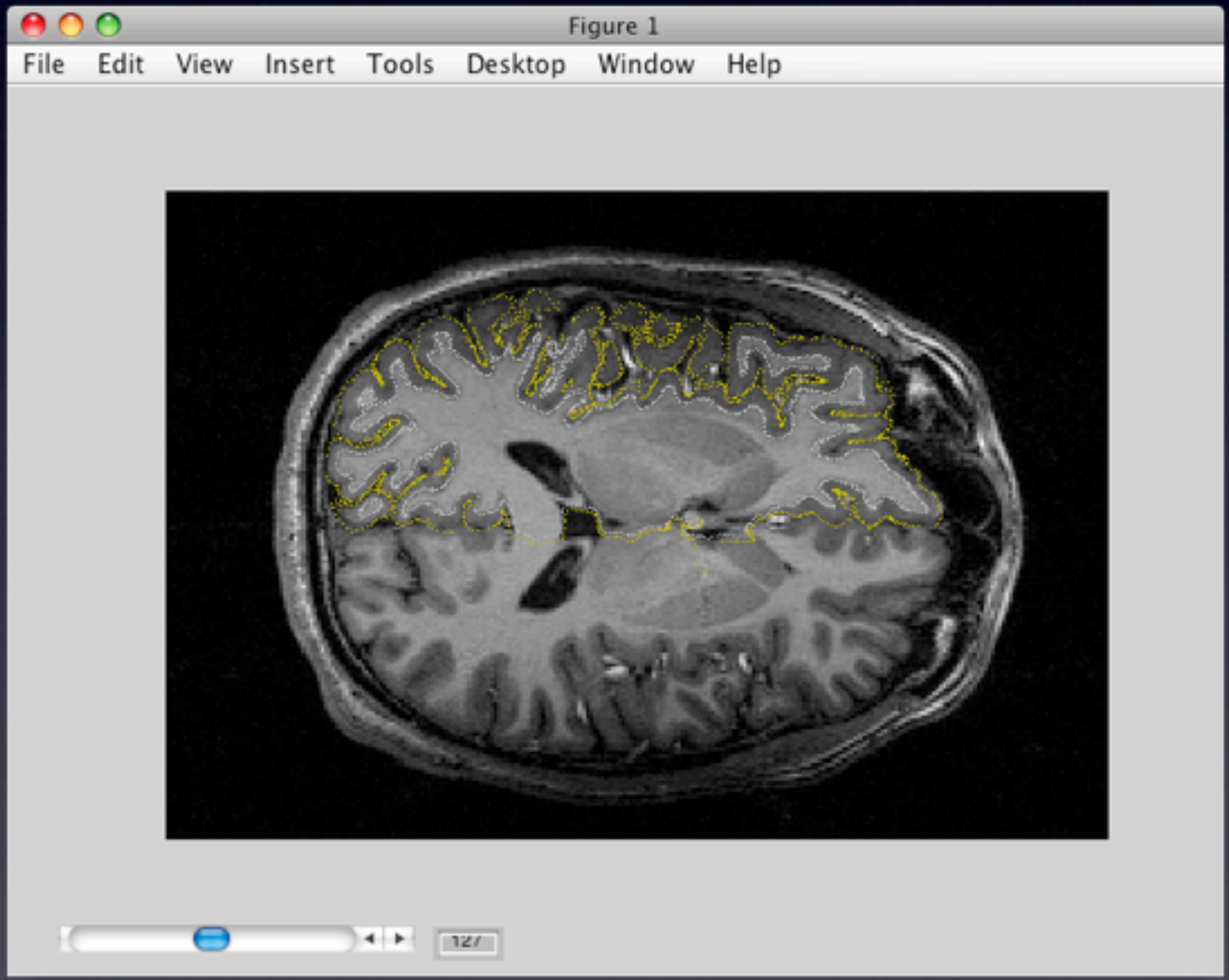
So, the volumes sform is set to its own qform (by doing "Set base coordinate frame")

Surfaces and flat maps

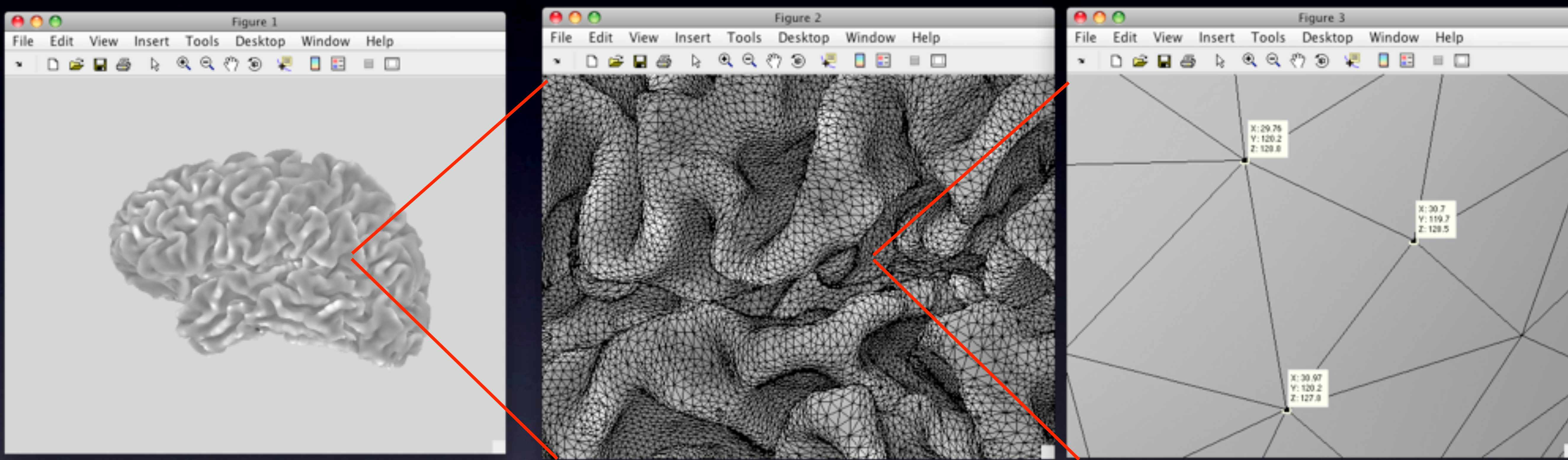
Segmentation

Use Free Surfer, SurfRelax, Caret or other software to segment gray/white matter. (i.e. find the volume coordinates of outer and inner surface of cortex).

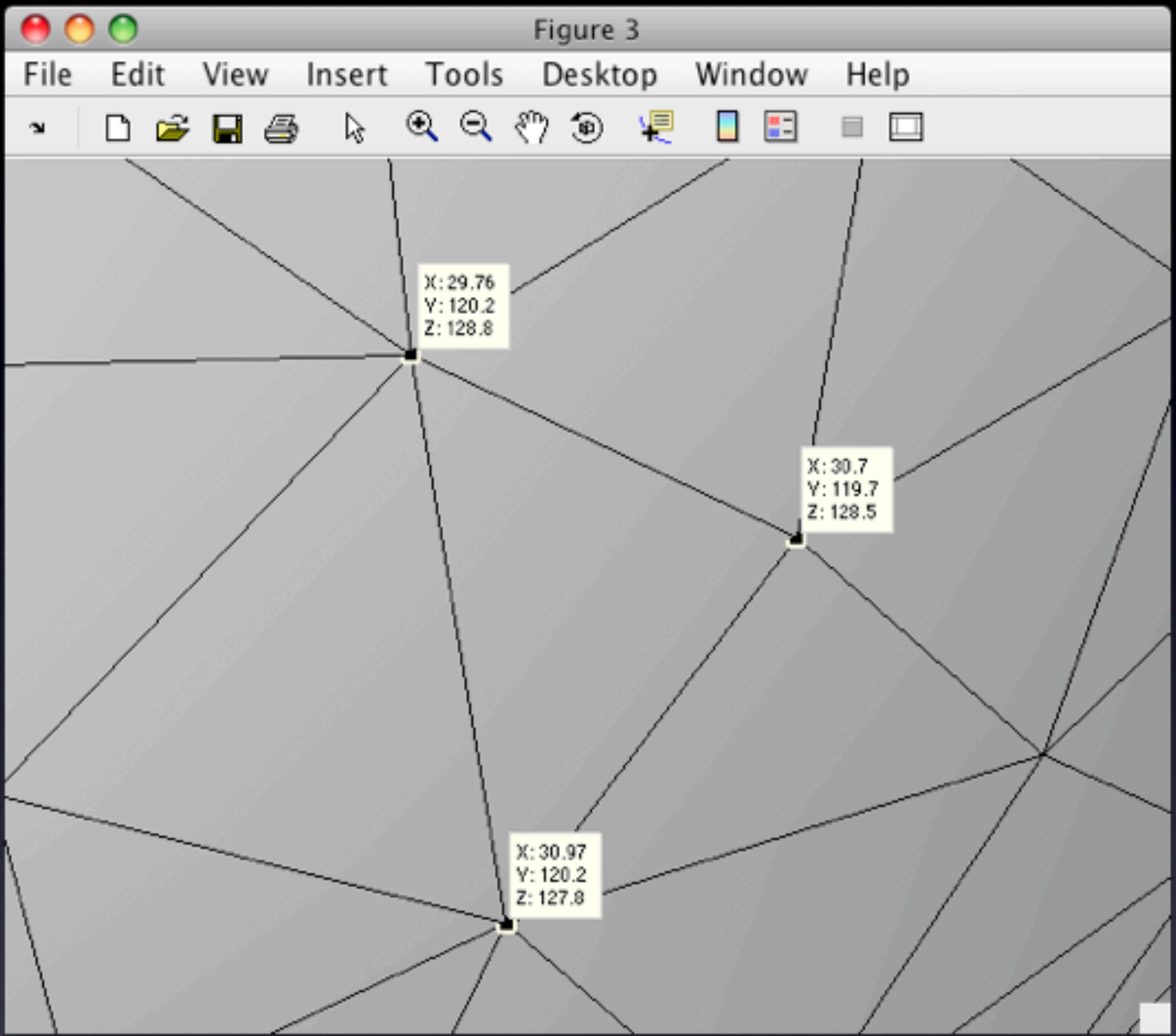
This will generate 2 files: Inner and Outer surface



Triangulated surface



Triangulated surface



Surfaces are a list of vertices and their corresponding location in the volume:

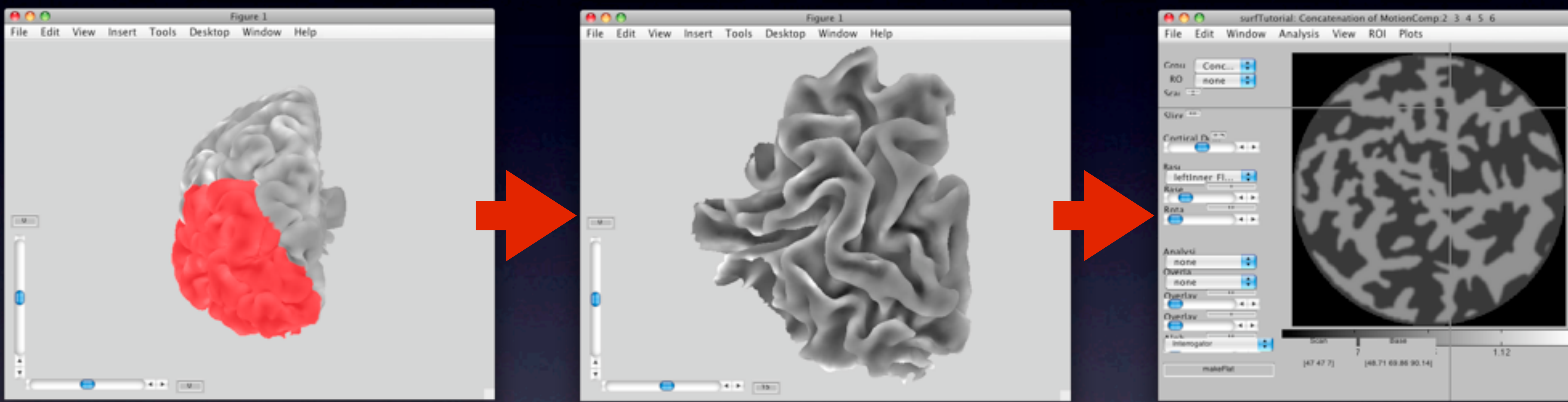
Vertex 1 = [29.76 120.2 128.8]
Vertex 2 = [30.7 119.8 128.5]
Vertex 3 = [30.97 120.2 127.9]
...

And a list of trios of vertices that are in each triangle:

Triangle 1 = [Vertex 1, Vertex 2, Vertex 3]
Triangle 2 = [Vertex 2, Vertex 17, Vertex 5]
...

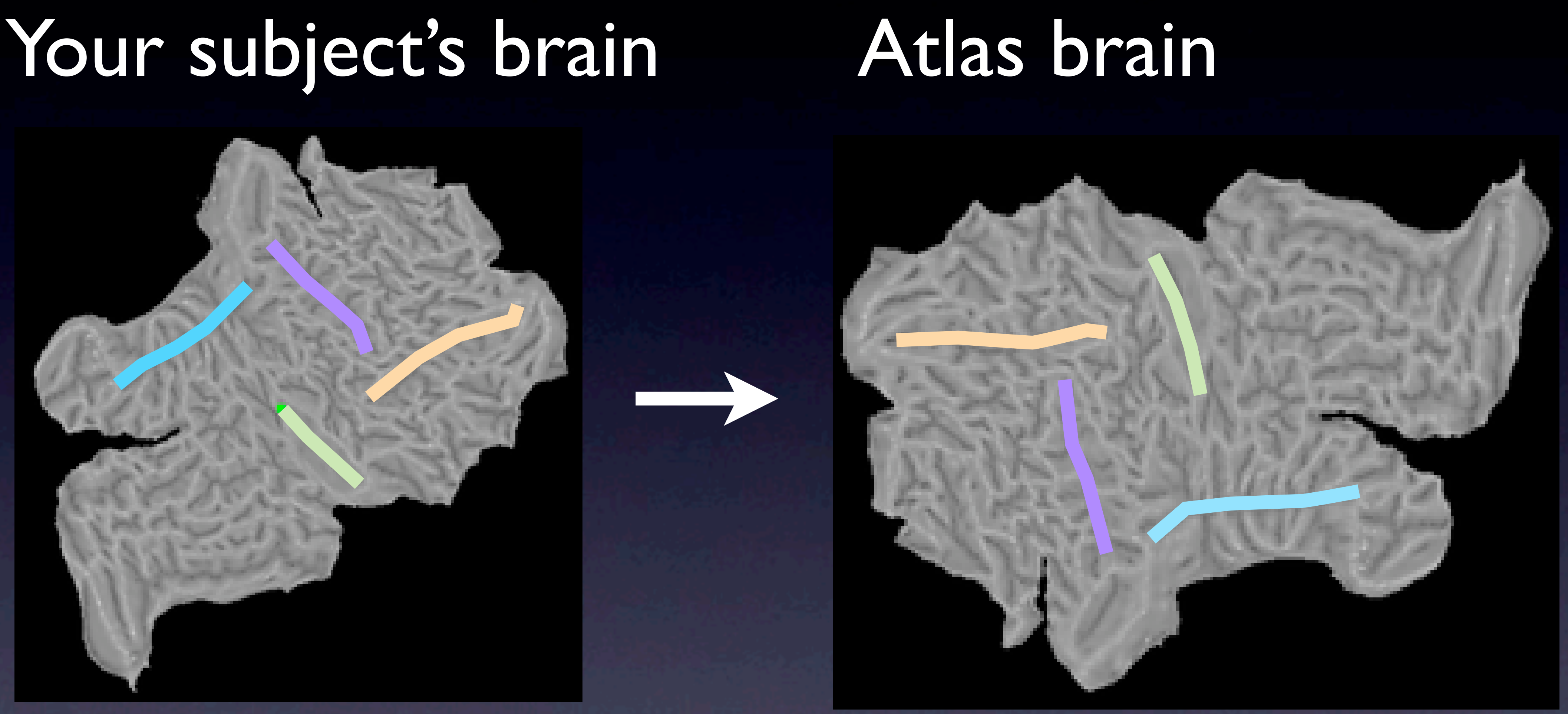
So, surfaces (and flat maps) need the volume2magnet transformation of the volume they were created from (i.e. the volumes sform).

Flat maps



Every point on the flat map corresponds to a location in the volume, so again, we use the volume sform for the flat map.

Surface based registration using Caret



http://brainvis.wustl.edu/wiki/index.php/Main_Page