# TEMPLATES AND ATLASES

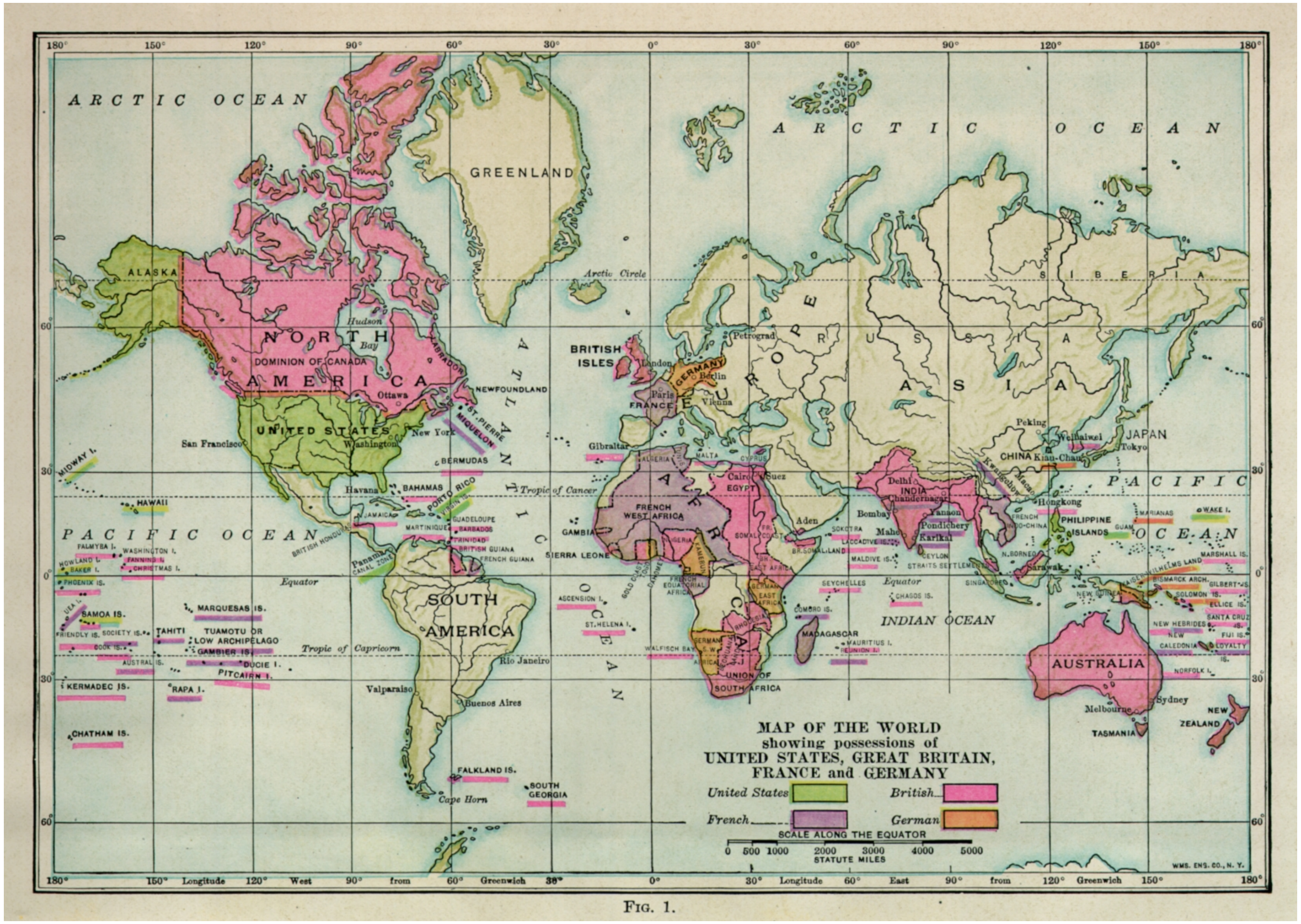


FIG. 1.

# Abbrevs used here

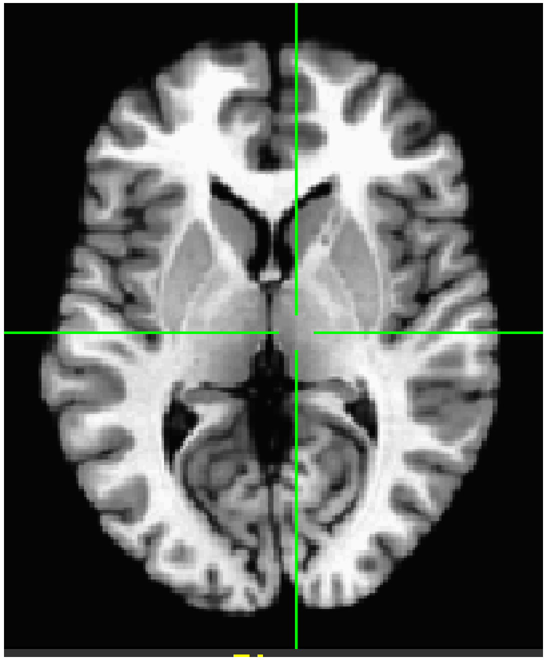
abbrev = abbreviation
AKA = also known as
anat = anatomical
corr = correlation
diff = difference
dset = dataset
e.g. = exempli gratia (= “for example”)
EPI = echo planar image
Ex = example
FOV = field of view
i.e. = id est (= “that is”)
ijk = coordinate indices (integer)
NB = nota bene (= “note well”)
phys = physics or physical
ref = reference
ROI = region of interest
subj = subject
vol = volume
vox = voxel(s)
xyz = physical coordinates (units of mm)

# Definitions

**Template**

A reference dataset (typically whole brain) used for matching shapes, reporting coordinates of results, etc.

*Ex*: TT_N27+tlrc, MNI_EPI+tlrc, TT_ICBM452+tlrc.



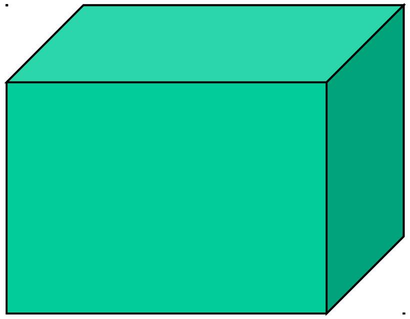
TT_N27+tlrc

# Definitions

**Template Space**

An (x, y, z) coordinate system shared by many datasets in alignment with a template.

*Ex*: TLRC (Talairach-Tourneaux), MNI, MNI_ANAT, ORIG.



To see what “space” a dset is in, type:

```
3dinfo -space DSET_NAME
```

# Definitions

**A note on AFNI usage of "tlrc":**

The "+tlrc" extension in a dataset's name is used to denote that the volume in question is in **a** standardized space; it does not always mean that the standard space in question is the Talairach-Tournoux one, specifically-- it could be MNI, pediatric template, macaque, ...

Hopefully the context makes things clear.

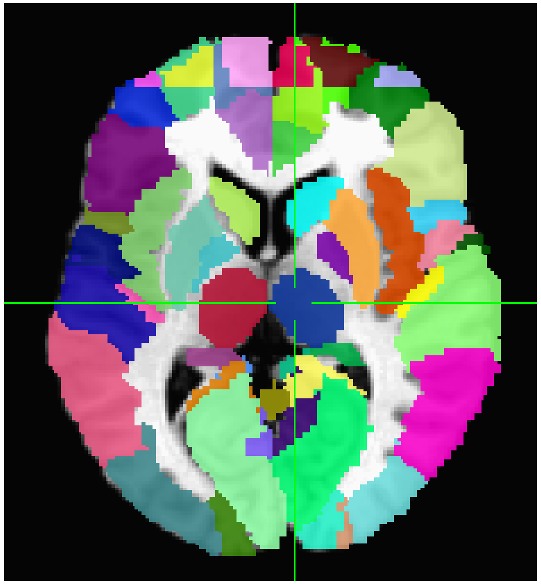
(Typically, there are so many templates for a given space now-- MNI, for example, has several templates-- that one really has to specify the full file name of a template to be able to refer to it unambiguously, anyways.)

# Definitions

**Atlas**

A dset containing segmentation or parcellation information. It can be considered a “map” of ROIs: each ROI is defined as a set of voxels with a certain integer value (and a string label can be attached to each ROI).

*Ex*: TTatlas+tlrc, TT_N27_EZ_ML+tlrc, my_roidset+orig.

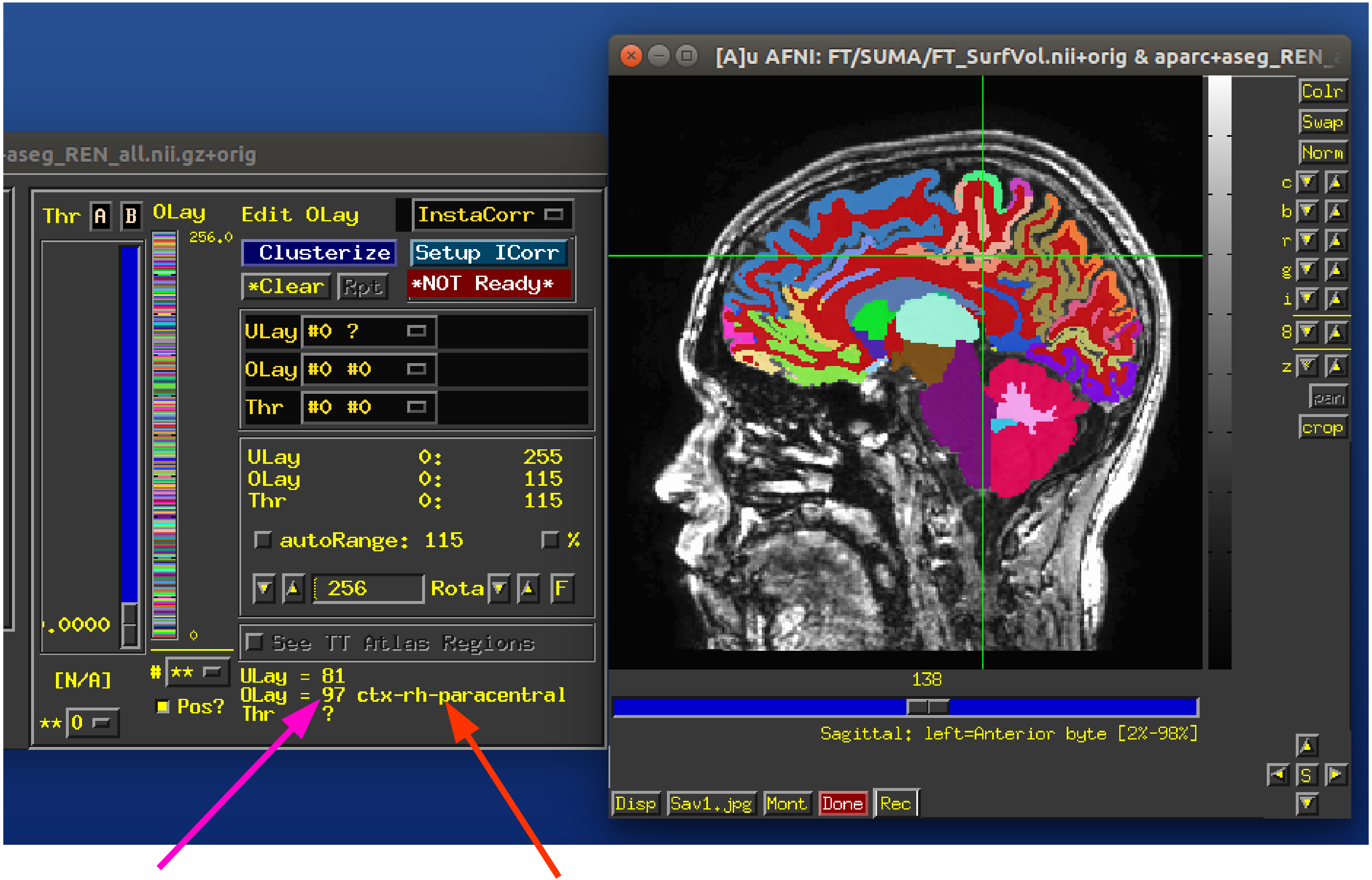


TT_N27_EZ_ML+tlrc

*See more description about templates+atlases (including making your own) on the AFNI website:*
https://afni.nimh.nih.gov/pub/dist/doc/htmldoc/template_atlas/framework.html

# Definitions

## Atlas (or general ROI) label in GUI



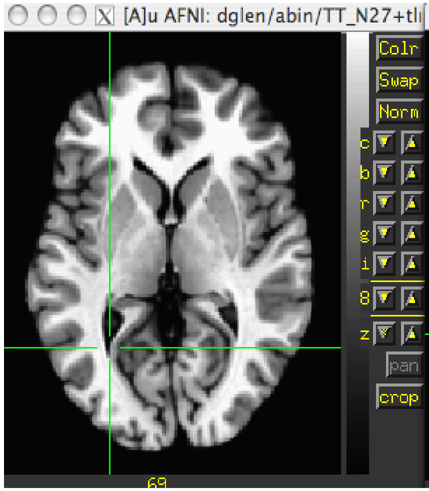
```
ULay #0 ?
OLay #0 #0
Thr  #0 #0

ULay   0:   255
OLay   0:   115
Thr    0:   115

autoRange: 115
256   Rota

ULay = 81
OLay = 97 ctx-rh-paracentral
Thr  = ?

Sagittal: left=Anterior byte [2%-98%]
```

integer value of ROI

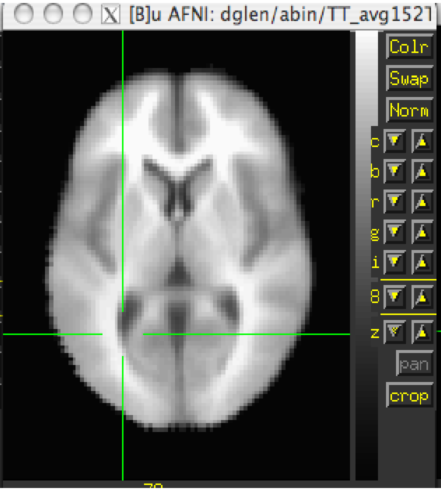
associated string label

# Templates included with AFNI

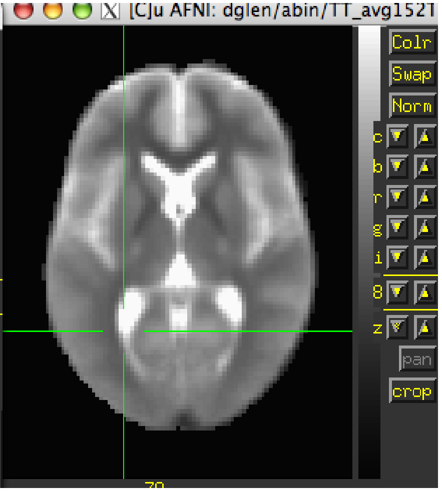
After default AFNI installation, these templates (and others) would be in **~/abin/:**



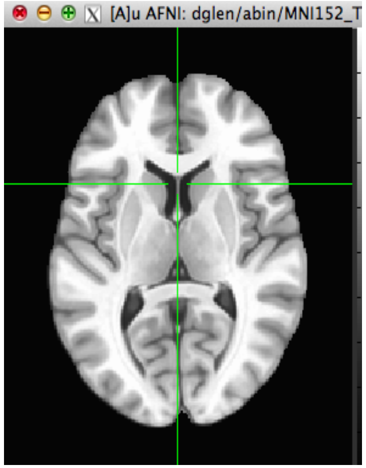
TT_N27



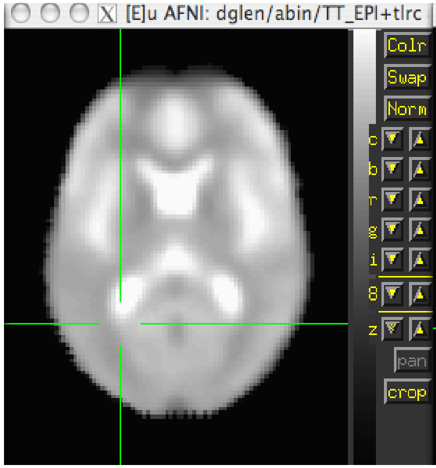
TT_avg152T1



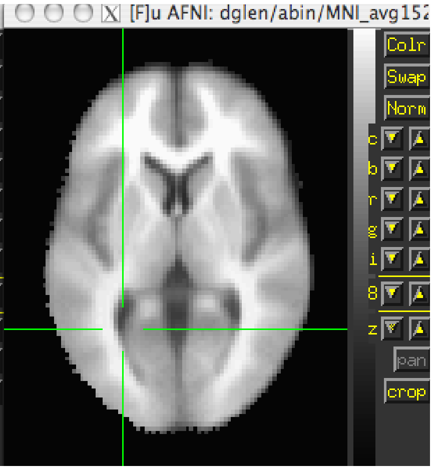
TT_avg152T2



MNI152_T1_2009c



TT_EPI



MNI_avg152T1

*And a quick question: what important properties does each dset here have?*

# Templates included with AFNI

A helpful note on viewing templates (or any dsets) **each time** you open up the AFNI GUI, regardless of directory!

Set the **AFNI_GLOBAL_SESSION** variable in your ~/.afnirc file, e.g.,:

```
    AFNI_GLOBAL_SESSION = /home/nmandela/abin
```

All dsets there will appear in your “Underlay” or “Overlay” menu in the AFNI GUI. (Use full path of directory, no “~” or “$HOME”.)

# Templates included with AFNI

A helpful note on viewing templates (or any dsets) **each time** you open up the AFNI GUI, regardless of directory!

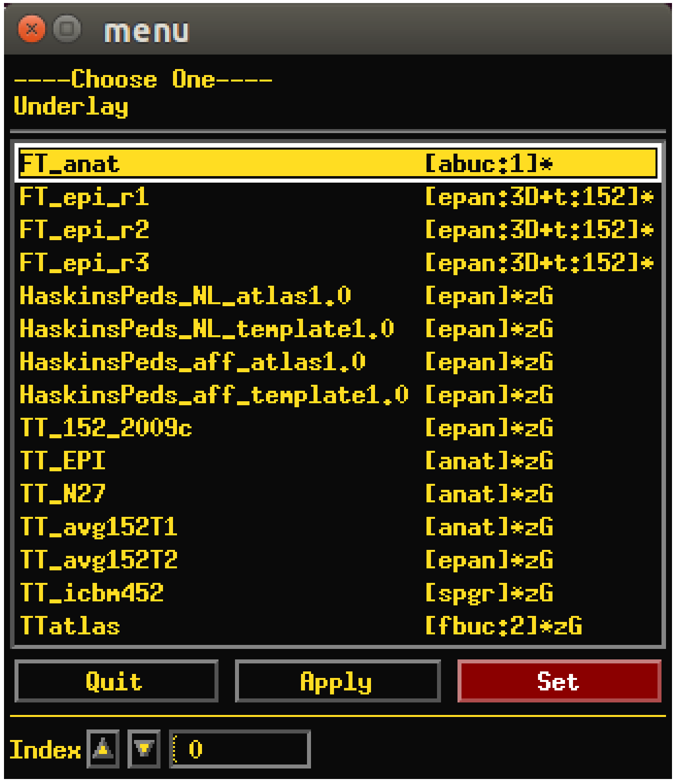
Set the **AFNI_GLOBAL_SESSION** variable in your ~/.afnirc file, e.g.,:

```
AFNI_GLOBAL_SESSION = /home/nmandela/abin
```

All dsets there will appear in your "Underlay" or "Overlay" menu in the AFNI GUI. (Use full path of directory, no "~" or "$HOME".)

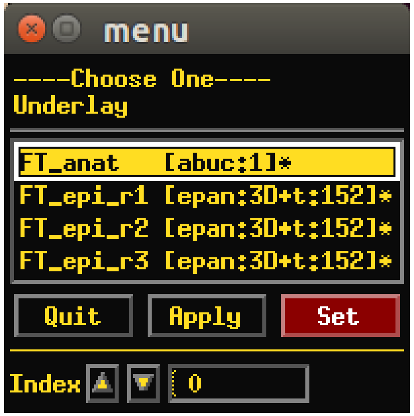
*Ex*: then open AFNI GUI in some directory, say:
`~/AFNI_data6/FT_analysis/FT/`

*after* →



```
FT_anat                      [abuc:1]*
FT_epi_r1                    [epan:3D+t:152]*
FT_epi_r2                    [epan:3D+t:152]*
FT_epi_r3                    [epan:3D+t:152]*
HaskinsPeds_NL_atlas1.0      [epan]*zG
HaskinsPeds_NL_template1.0   [epan]*zG
HaskinsPeds_aff_atlas1.0     [epan]*zG
HaskinsPeds_aff_template1.0  [epan]*zG
TT_152_2009c                 [epan]*zG
TT_EPI                       [anat]*zG
TT_N27                       [anat]*zG
TT_avg152T1                  [anat]*zG
TT_avg152T2                  [epan]*zG
TT_icbm452                   [spgr]*zG
TTatlas                      [fbuc:2]*zG
```

*before* →



```
FT_anat   [abuc:1]*
FT_epi_r1 [epan:3D+t:152]*
FT_epi_r2 [epan:3D+t:152]*
FT_epi_r3 [epan:3D+t:152]*
```

# Standard spaces

**Reasons to use a standard template space:**

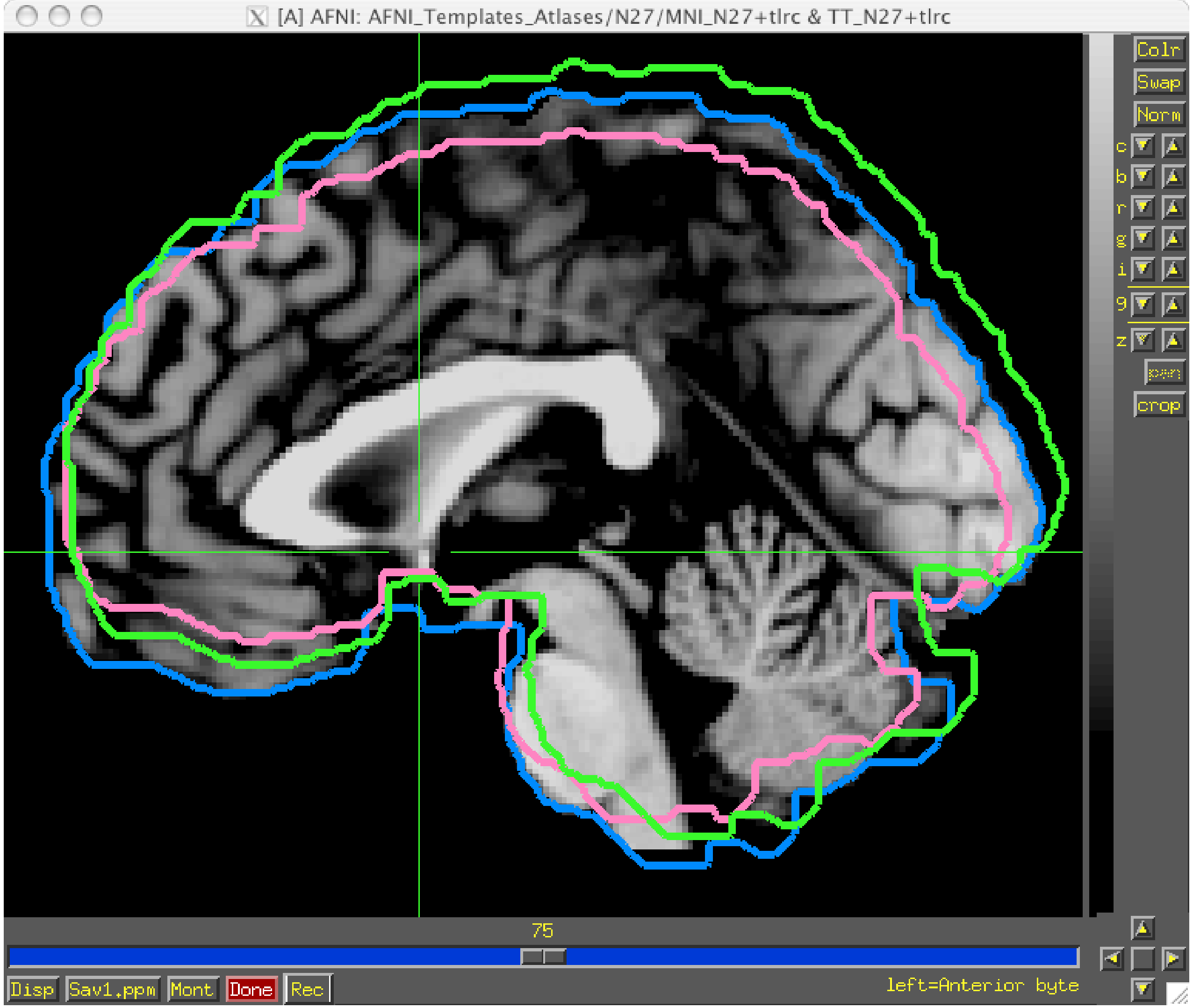
- Compare across subjects and groups easily for every voxel in the brain
- Standardize coordinates with others
- Know where a voxel is automatically from an atlas
- Mostly automated and no specific ROI drawing required

**Reasons not to use a standard template space:**

- Inconsistency among subjects
- Inconsistency among groups – elderly versus younger
- Use consistent anatomical ROIs with good anatomical knowledge
- Lower threshold for multiple comparison adjustments

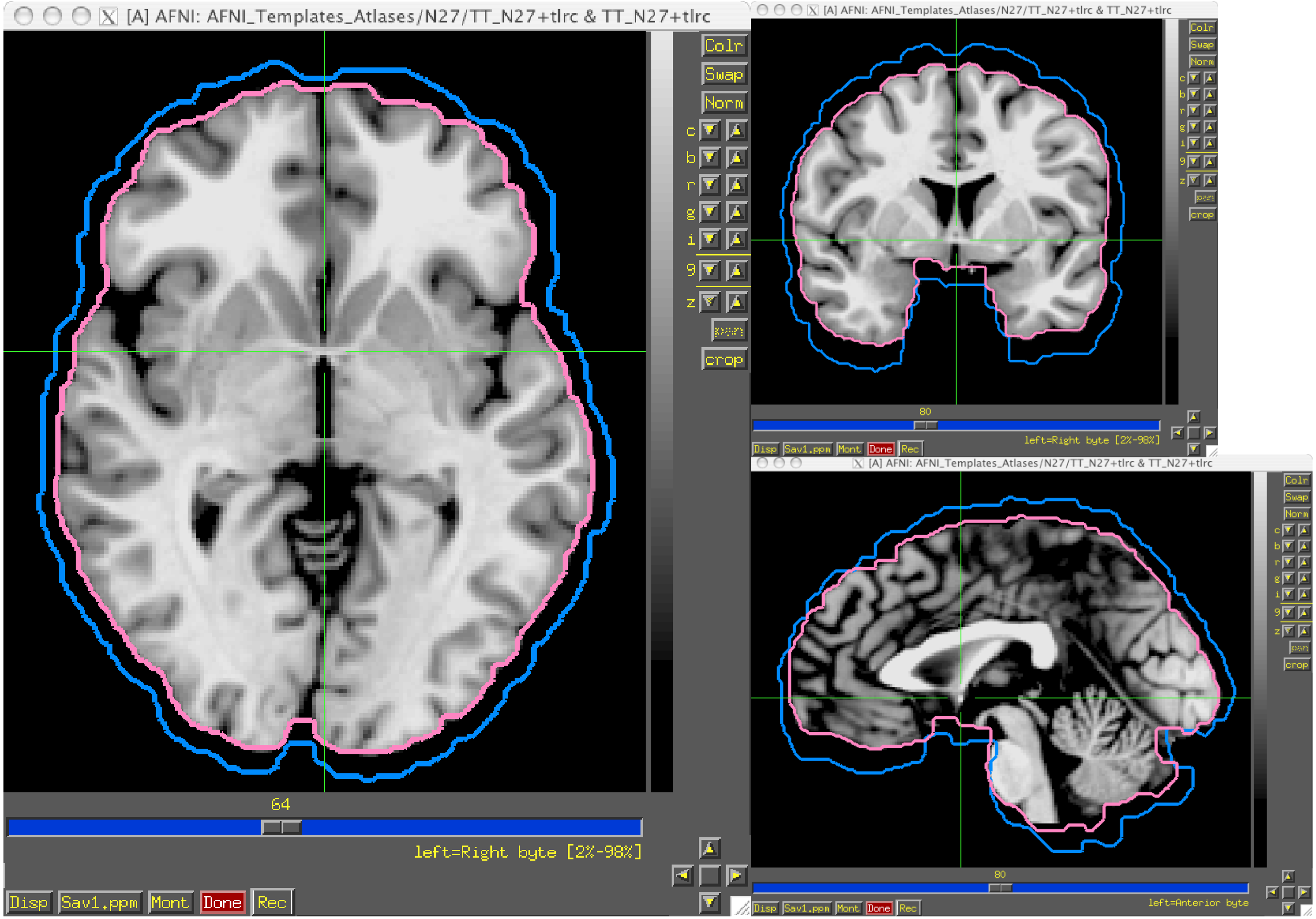
# Template spaces differ in origin

## TLRC, MNI, and MNI-Anat



# Template spaces differ in size

The **MNI** brain is larger than the **TLRC** brain.



# From space to space

**For going between TLRC and MNI:**

Approximate equation

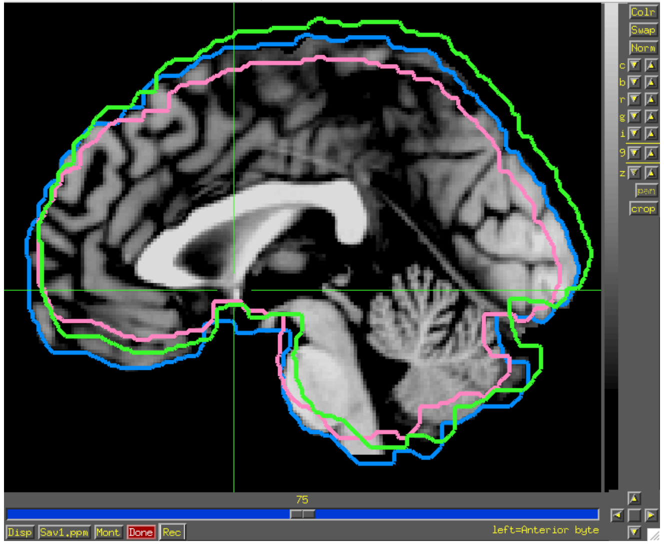
→ used by **`whereami`** and **`3dWarp`**

A manual TLRC transformation of MNI template to TLRC space

→ used by **`whereami`** (as precursor to MNI Anat.), based on N27 template

Multiple space coordinates reported in **`whereami`** output (**`AFNI_ATLAS_TEMPLATE_SPACE_LIST`**)

TLRC, MNI, and MNI-Anat



**For going between MNI and MNI Anat (Eickhoff et al., 2005):**

MNI + (0, 4, 5) = MNI Anat. (in RAI coordinate system)

**Going between TLRC and MNI Anat (as practiced in whereami):**

Go from TLRC (TT_N27) to MNI via manual transform of N27 template

Add ( 0, 4, 5 )

# Choosing a template

**Try to pick a template that...**

- is similar to the subject group: neonates, pediatric, young adults, elderly, macaque, rabbit...
- is of the same modality and coverage as your data sets
- has a relevant atlas segmentation.

# Choosing a template

**Try to pick a template that...**

- is similar to the subject group: neonates, pediatric, young adults, elderly, macaque, rabbit...
- is of the same modality and coverage as your data sets
- has a relevant atlas segmentation.

**You can also make your own template (and maybe an atlas too):**

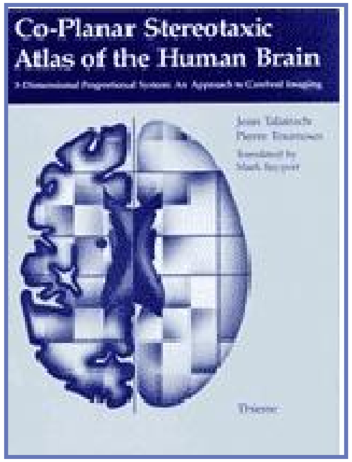
- Individual or group template
  - Group: average or iterative (discussed more later)
- Scripts/commands exist in AFNI
  - *Ex*. Haskins pediatric atlas
    - ➥ several methods tested
    - ➥ best approach: *iterative nonlinear alignment*
      - ➪ **@toMNI_Awarp, @toMNI_Qwarpar**

# Registration To Standard Spaces

## Transforming Datasets to Talairach-Tournoux Coordinates

- The original purpose of AFNI (*circa* 1994 A.D.) was to perform the transformation of datasets to Talairach-Tournoux (stereotaxic) coordinates
- The transformation can be manual, or automatic
- In manual mode, you must mark various anatomical locations, defined in

  Jean Talairach and Pierre Tournoux  
  "Co-Planar Stereotaxic Atlas of the Human Brain"  
  Thieme Medical Publishers, New York, 1988



  - Marking is best done on a high-resolution T1-weighted structural MRI volume
- In automatic mode, you need to choose a template to which your data are aligned. Different templates are made available with AFNI's distribution. You can also use your own templates.
- Transformation carries over to all other (follower) datasets in the same directory
  - This is where the importance of getting the relative spatial placement of datasets done correctly in `to3d` really matters
  - You can then write follower datasets, typically functional or EPI timeseries, to disk in Talairach coordinates
    - Purpose: voxel-wise comparison with other subjects
    - May want to blur volumes a little before comparisons, to allow for residual anatomic variability: AFNI programs `3dmerge` `or` `3dBlurToFWHM`

# Automatic Talairach transform (affine) with @auto_tlrc

- In the olden days, people would spend a lot of time transforming data to standard space by hand (see Supplement slides for how to perform the Manual TLRC transform using the AFNI GUI by setting AC-PC landmarks).
- Here, we describe how to perform a TLRC transform ***automatically*** using AFNI's **@auto_tlrc** (used by *afni_proc.py* for linear affine alignment to standard space).
  - Differences from Manual Transformation:
    - Instead of setting AC-PC landmarks and volume boundaries by hand, the anatomical volume is warped (using 12-parameter affine transform) to a template volume in TLRC space.
    - The Anterior Commisure (AC) center is no longer at xyz = (0,0,0), and the size of brain box is that of the template you use.
      - For various reasons, some good and some bad, templates adopted by the neuroimaging community are not all of the same size. Be mindful when using various atlases or comparing standard-space coordinates.
    - You, the user, can choose from various templates for reference (just be consistent in your group analysis).
    - It is easy + automatic. Just check final results to make sure nothing went seriously awry.

# @auto_tlrc example

- To run in AFNI_data6/afni/
  Transform the subj anat to a template space (output: `anat_TT+tlrc`):

```
@auto_tlrc                        \
    -base TT_N27+tlrc             \
    -suffix _TT                   \
    -input anat+orig
```

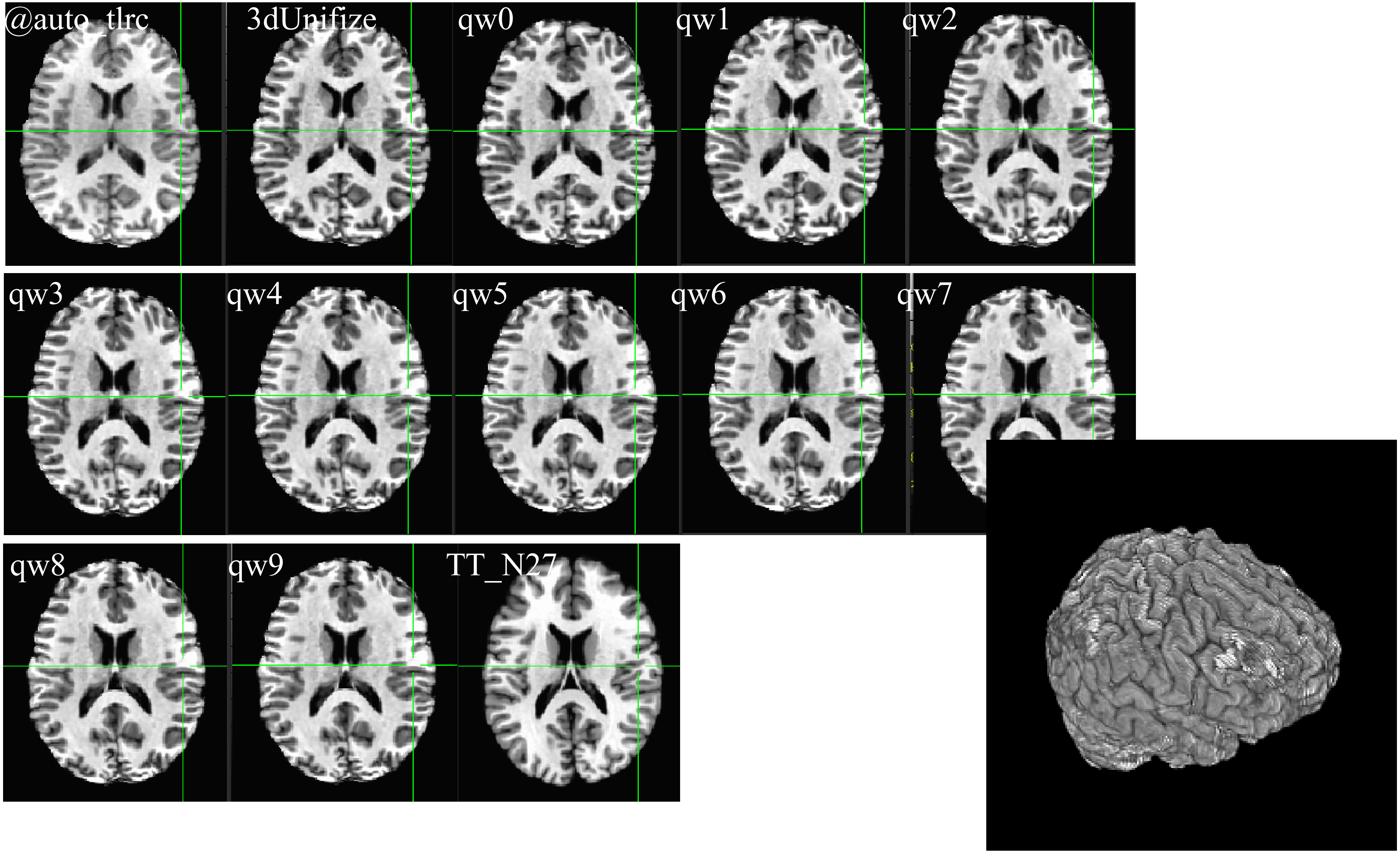
- Then apply the transform stored in **`anat_TT+tlrc`**'s header to a "follower dset" (here, func data), specifying output resolution at 3 mm (output: `func_slim_TT+tlrc`):

```
@auto_tlrc                        \
    -apar anat_TT+tlrc            \
    -input func_slim+orig         \
    -suffix _TT                   \
    -dxyz  3
```

- Instead of **TT_N27**, you could also use the **icbm452,** or the mni's **avg152T1** template, or any other template you like
  (see **@auto_tlrc -help** for a few good words on templates)

# Nonlinear alignment to template

## 3dQwarp, through multiple levels of refinement →



# Nonlinear alignment to template

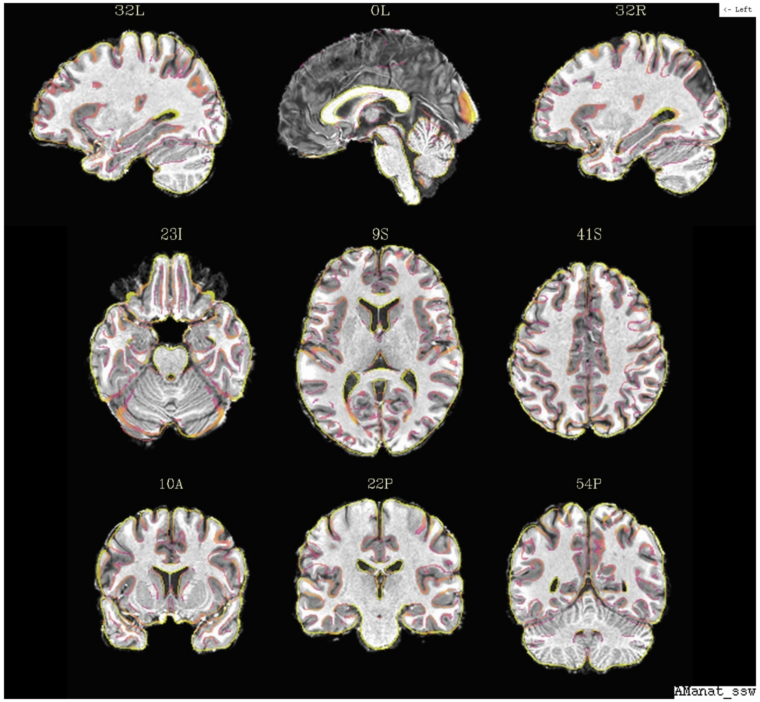
## Multiple nonlinear alignment tools in AFNI

**3dQwarp**: the standard nonlinear workhorse

**auto_warp.py**: wrapper for alignment functionality, ~simpler syntax (@auto_tlrc + 3dQwarp together)

*Ex:*
```
auto_warp.py -base MNI152_T1_2009c+tlrc. \
        -suffix _awarp -input strip+orig.
```

**@SSwarper**: skull stripping and alignment in one-- and bonus automatic QC images →



+ @SSwarper uses a multi-volume base; several exist for standard templates already, and more can be made-- see full description for these online:

https://afni.nimh.nih.gov/pub/dist/doc/htmldoc/template_atlas/sswarper_base.html

# Measuring quality of alignment

**Can compare: nonlinear alignment vs affine alignment**

+ Estimate warp from subject anat to template for a group of subjects
+ Apply warp when processing FMRI data (here, resting state)
+ Check changes in seed-based correlation maps between results
  - better method would have higher corr in GM networks and lower corr in WM.

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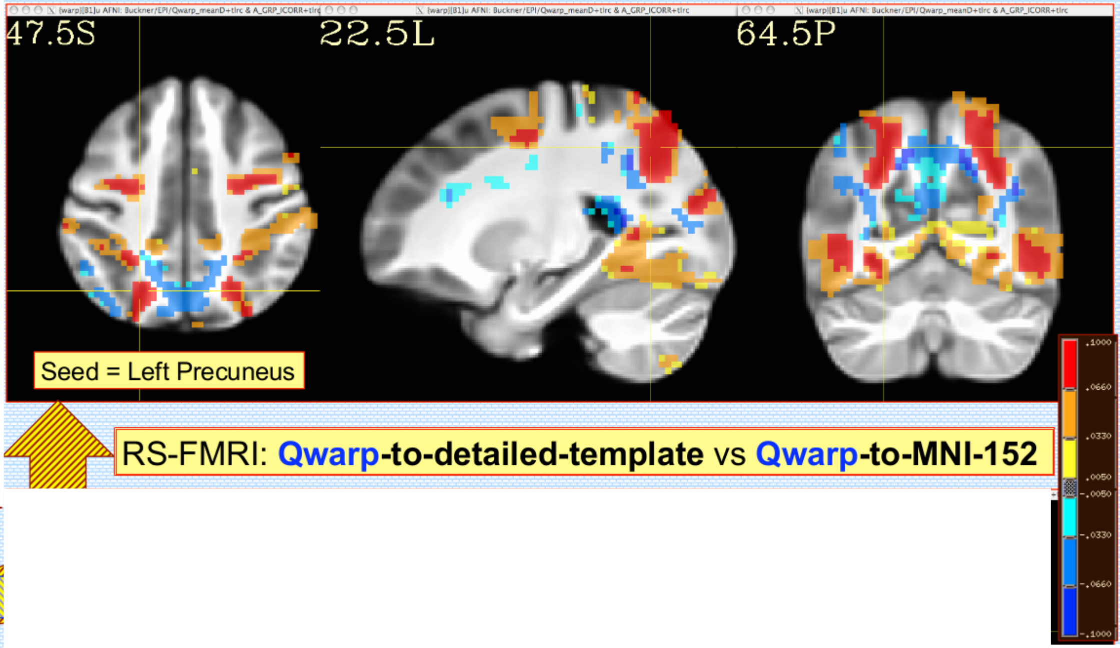
**red**: [0.066, 0.100] corr
*increase* for 3dQwarp results

**blue**: [0.066, 0.100] corr
*decrease* for 3dQwarp results



RS-FMRI: **Qwarp-to-detailed-template** vs **Qwarp-to-MNI-152**

- ◆ ***3dQwarp*** ➔ align 188 Cambridge datasets from FCON-1000
- ◆ Underlay = template-ized $T_1$ anats
- ◆ Overlay = difference in mean seed-based correlation maps when using ***3dQwarp*** alignment to detailed template ***versus***
  - ❖ [**upper**] affine alignment to MNI-152

*(Cox & Glen, 2013, OHBM)*

# Measuring quality of alignment

**Can compare: using detailed vs non-detailed template for nonlinear alignment**

+ Estimate warp from subject anat to template for a group of subjects
+ Apply warp when processing FMRI data (here, resting state)
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  - better method would have higher corr in GM networks and lower corr in WM.

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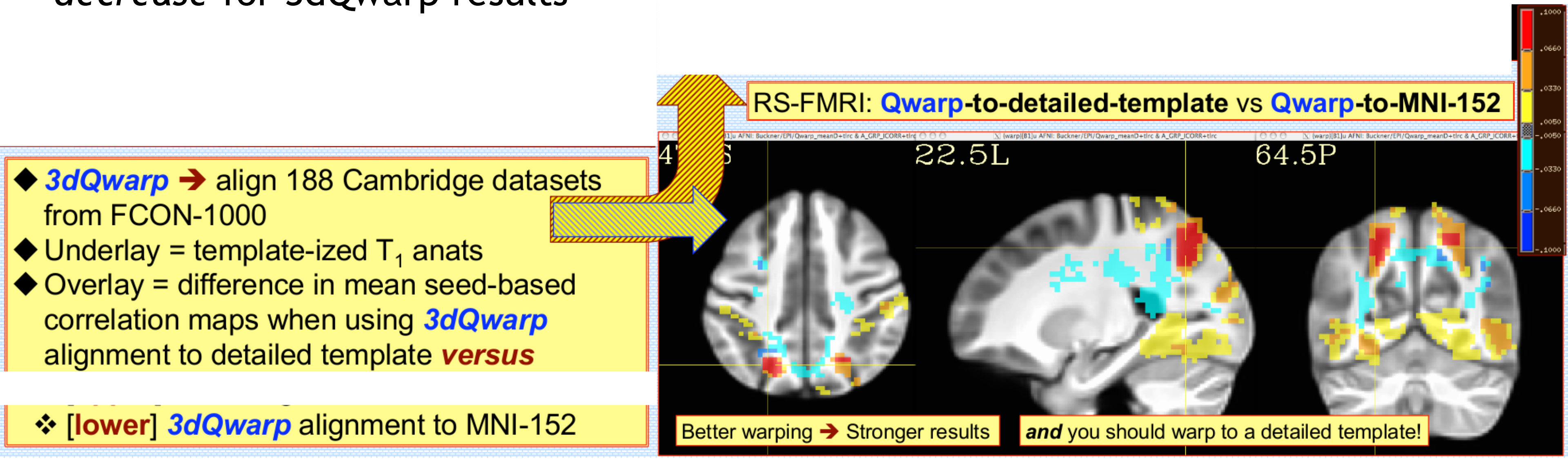
  - better method would have higher corr in GM networks and lower corr in WM.

**red**: [0.066, 0.100] corr
*increase* for 3dQwarp results

**blue**: [0.066, 0.100] corr
*decrease* for 3dQwarp results



◆ ***3dQwarp*** ➔ align 188 Cambridge datasets from FCON-1000
◆ Underlay = template-ized $T_1$ anats
◆ Overlay = difference in mean seed-based correlation maps when using ***3dQwarp*** alignment to detailed template ***versus***
❖ [lower] ***3dQwarp*** alignment to MNI-152

RS-FMRI: **Qwarp-to-detailed-template** vs **Qwarp-to-MNI-152**

Better warping ➔ Stronger results

***and*** you should warp to a detailed template!

*(Cox & Glen, 2013, OHBM)*

# Measuring quality of alignment

**Can compare 3dQwarp with other available nonlinear alignment tools**

+ For a group of subjects, estimate warp from anat to template
+ Apply warp to labeled ROIs, and measure % overlap in results.

ANTS, DARTEL and FNIRT run with default settings

*(Cox & Glen, 2013, OHBM)*

# Measuring quality of alignment

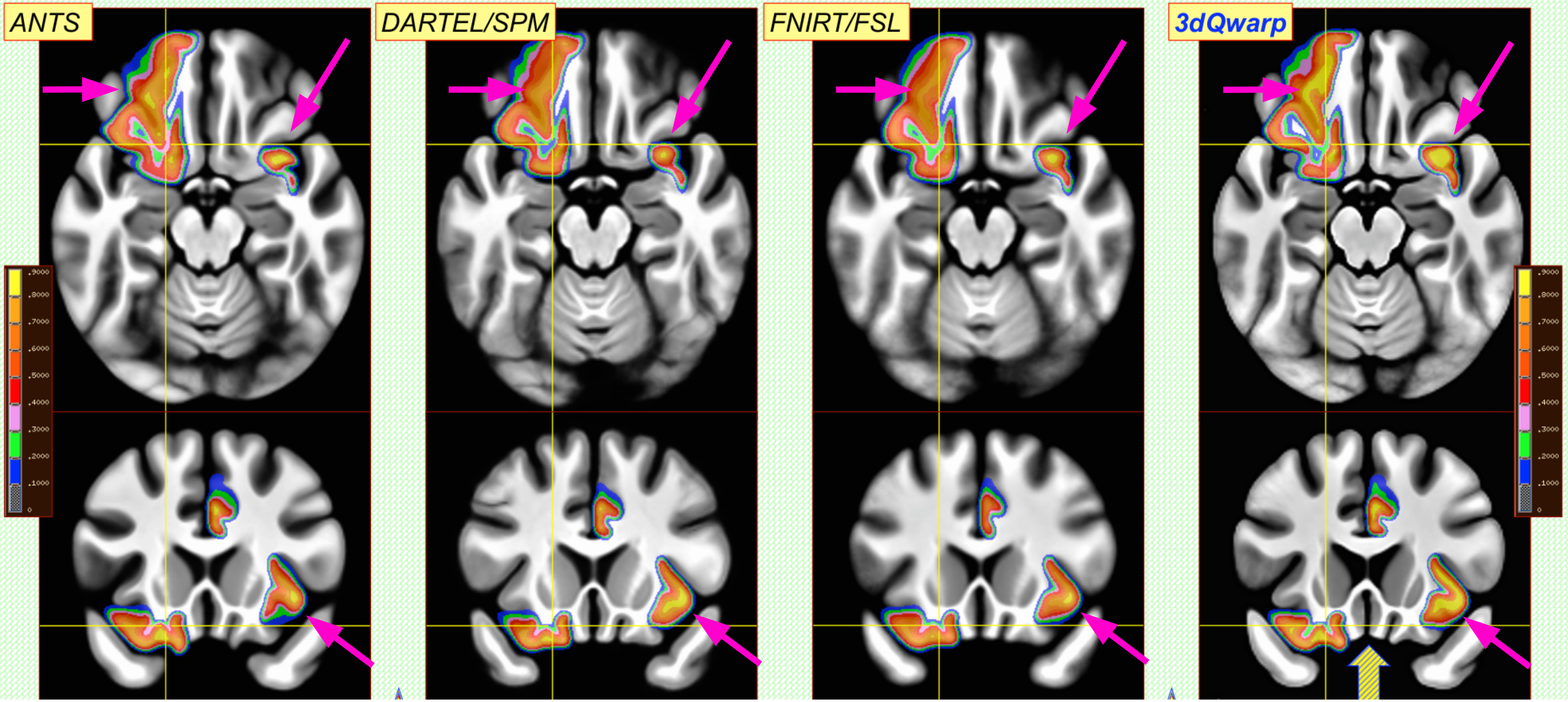
**Can compare 3dQwarp with other available nonlinear alignment tools**

+ For a group of subjects, estimate warp from anat to template

+ Apply warp to labeled ROIs, and measure % overlap in results. (Yellow: >90% overlap)

Align MindBoggle 101 $T_1$ Datasets to Separate Template:
Overlap Probability Maps for 3 of the Labeled Regions

LH: lateral orbital frontal
RH: caudal anterior cingulate
RH: insula



ANTS, DARTEL and FNIRT run with default settings

*(Cox & Glen, 2013, OHBM)*

# Nonlinear alignment to standard space

**Advantages**

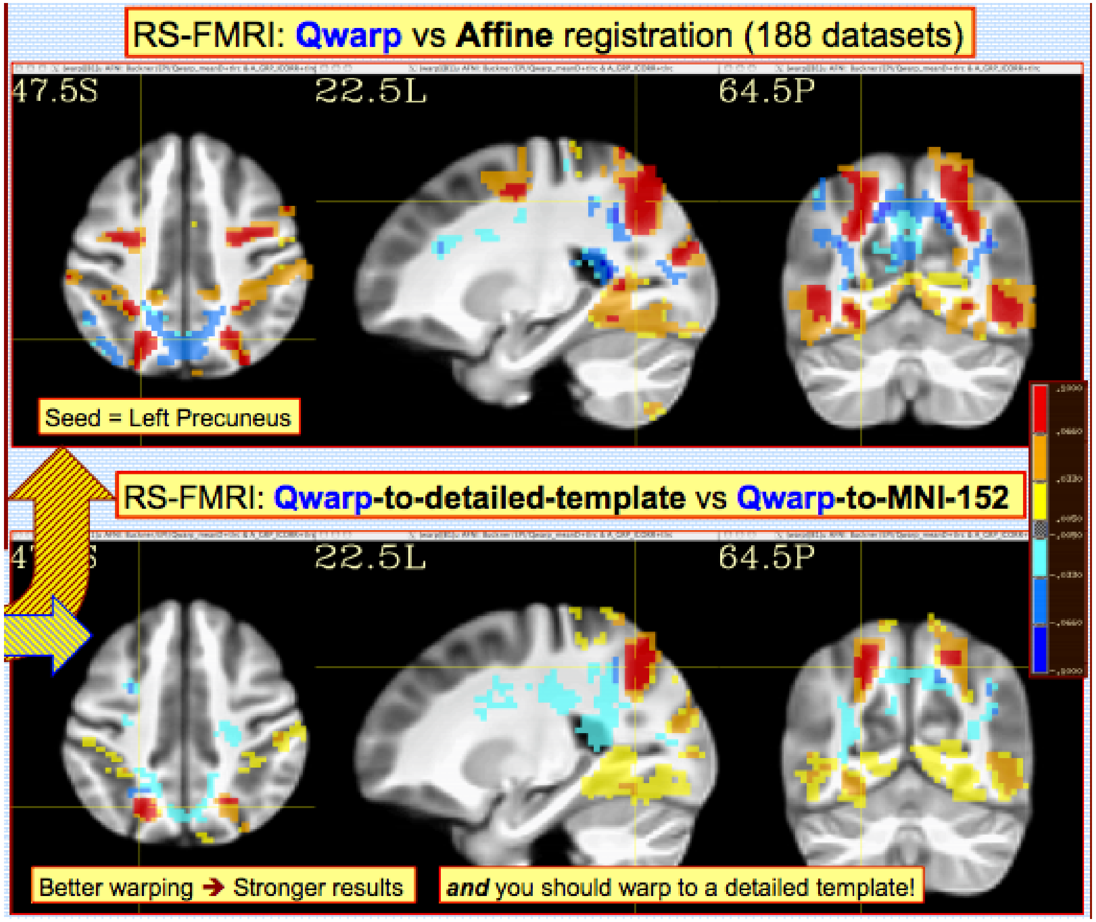
- Better spatial correspondence across data

  → consistent data reinforces across group
- Final data matches template (reporting coordinates, etc.)

**Disadvantages**

- Individual data is distorted
- Aligned data matches template. Choose template carefully
- Skullstripping must be done much more carefully

  → note that **@SSwarper** actually *combines* nonlinear warping with skullstripping, so benefit now!
- Processing time much slower (but... such is life)



RS-FMRI: **Qwarp** vs **Affine** registration (188 datasets)

Seed = Left Precuneus

RS-FMRI: **Qwarp-to-detailed-template** vs **Qwarp-to-MNI-152**

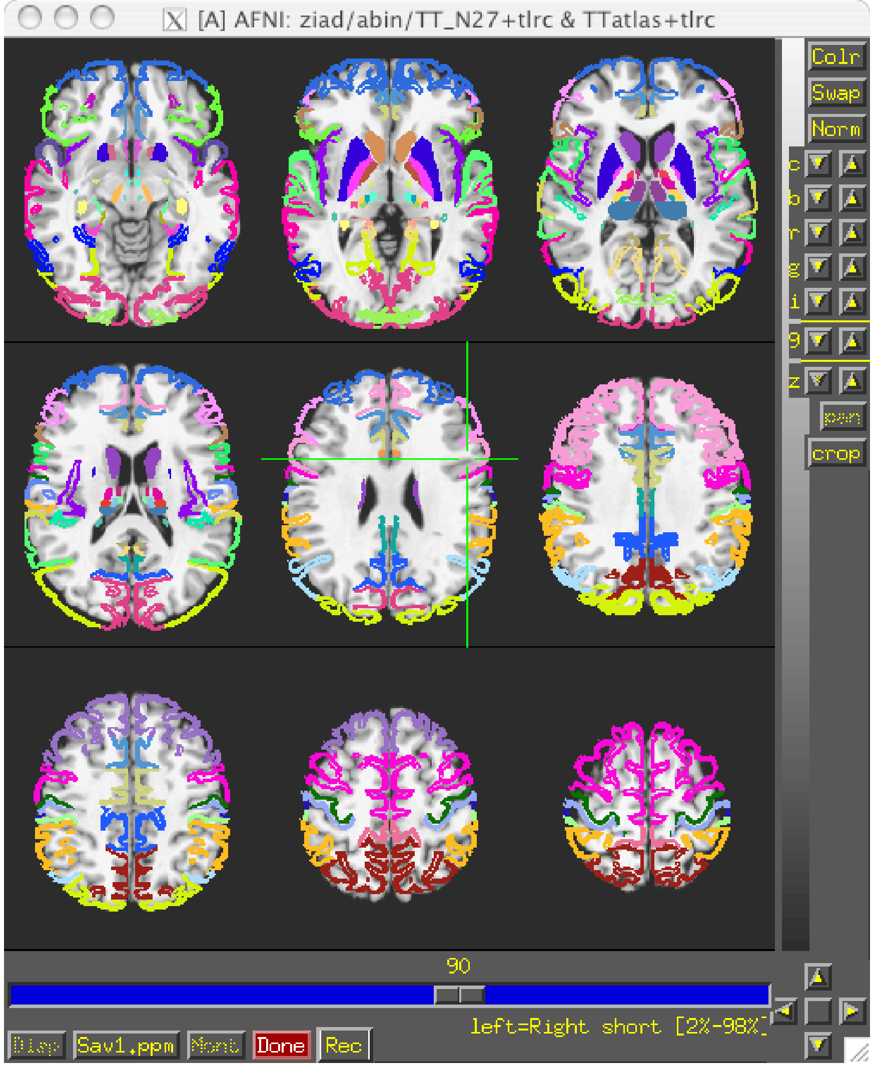
Better warping → Stronger results

*and* you should warp to a detailed template!

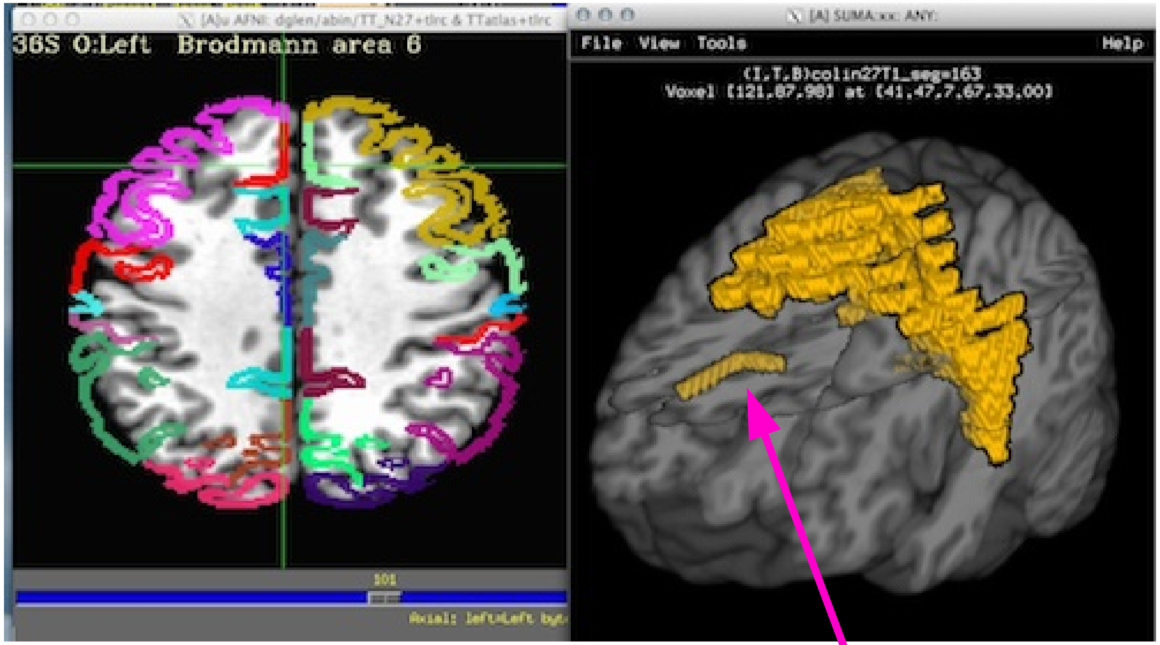
*(Cox & Glen, 2013, OHBM)*

# Atlases distributed with AFNI: TT_Daemon

- TT_Daemon : Created by tracing Talairach and Tournoux brain illustrations.
  - Generously contributed by Jack Lancaster and Peter Fox of RIC UTHSCSA)



# Caution: Talairach Daemon (TT_Daemon) problems



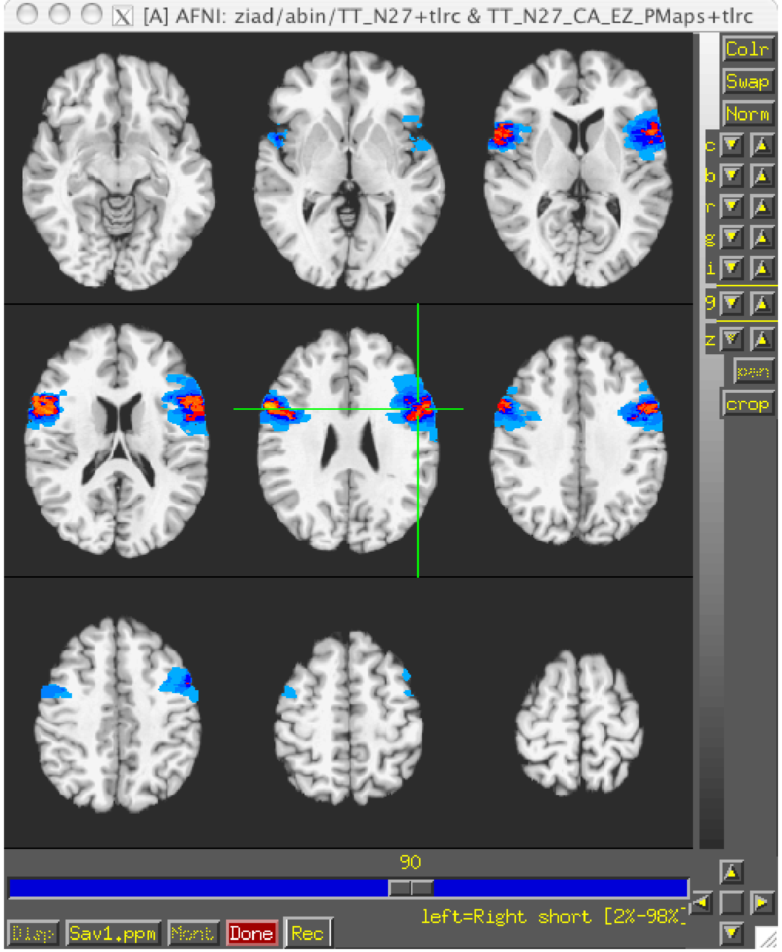
```
36S 0:Left  Brodmann area 6
```

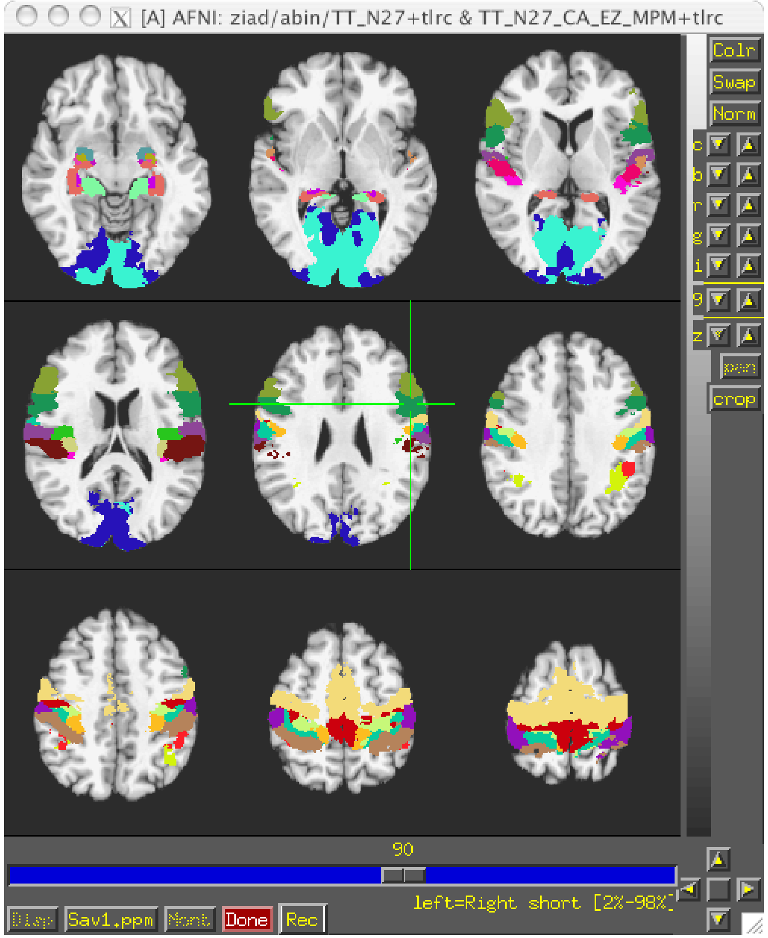
```
(I,T,B)colin27T1_seg=163
Voxel [121,87,98] at [41.47,7.67,33.00]
```

This piece is labeled as BA 6, but is really another part.

# Atlases distributed with AFNI: “Anatomy Toolbox”

- CA_N27_MPM, CA_N27_ML, CA_N27_PM: Anatomy Toolbox's atlases with some created from cytoarchitectonic studies of 10 human post-mortem brains
  - ◇ Probabilistic maps and max. probability maps generously contributed by K. Amunts, S. Eickhoff, and K. Zilles of IME, Julich, Germany





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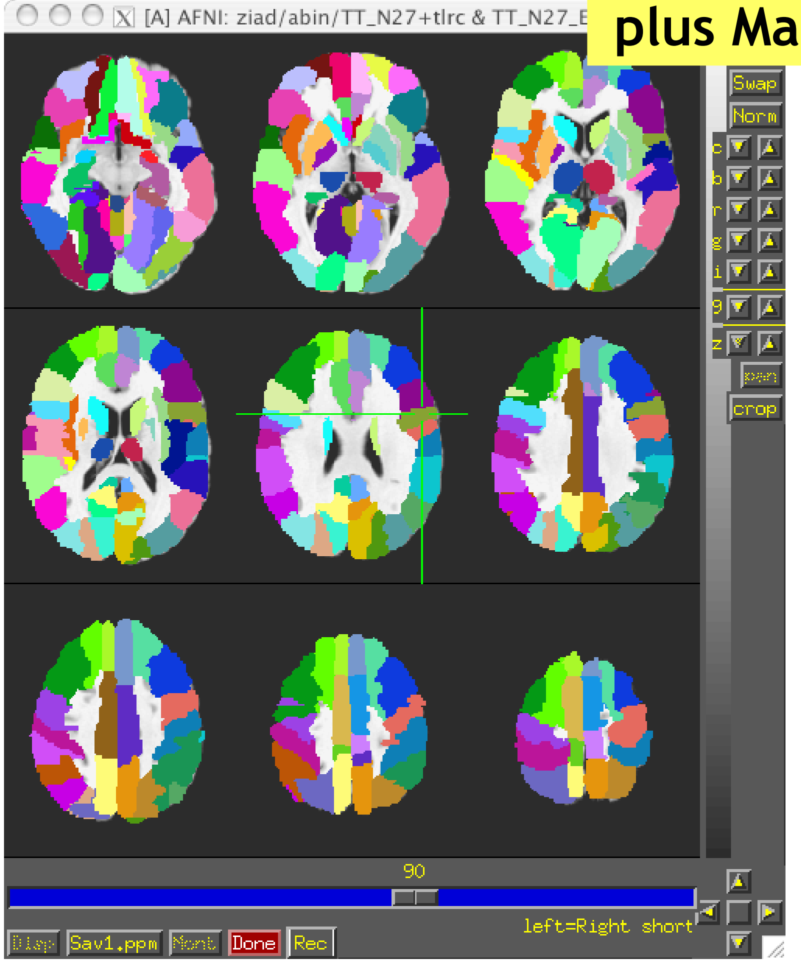
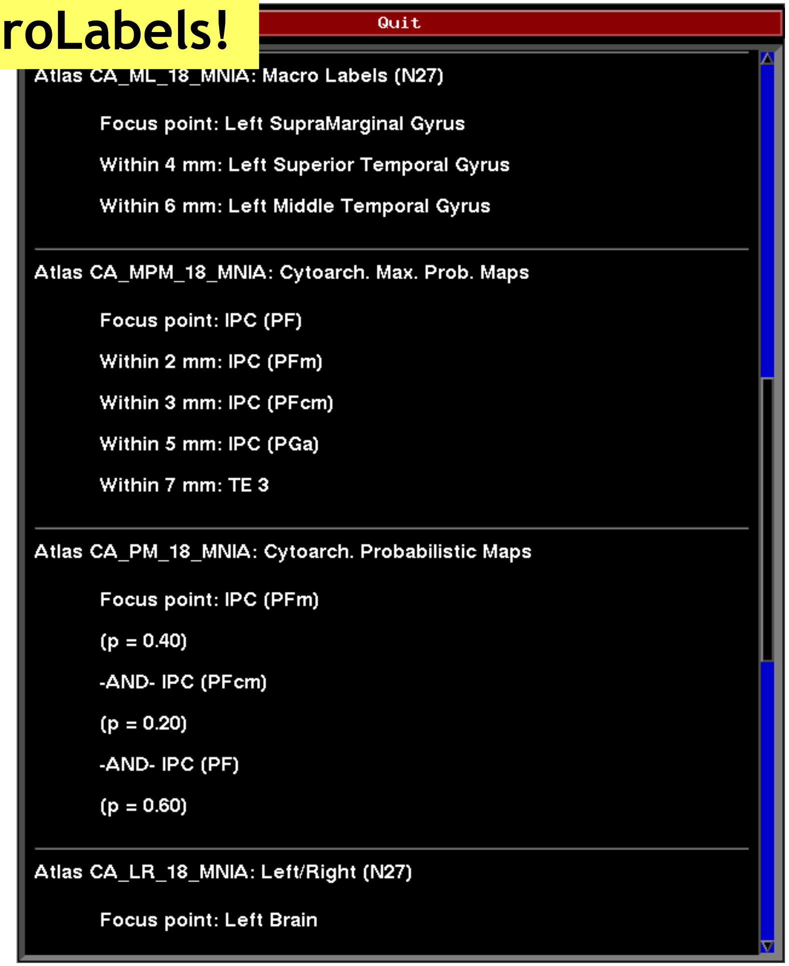
**plus MacroLabels!**

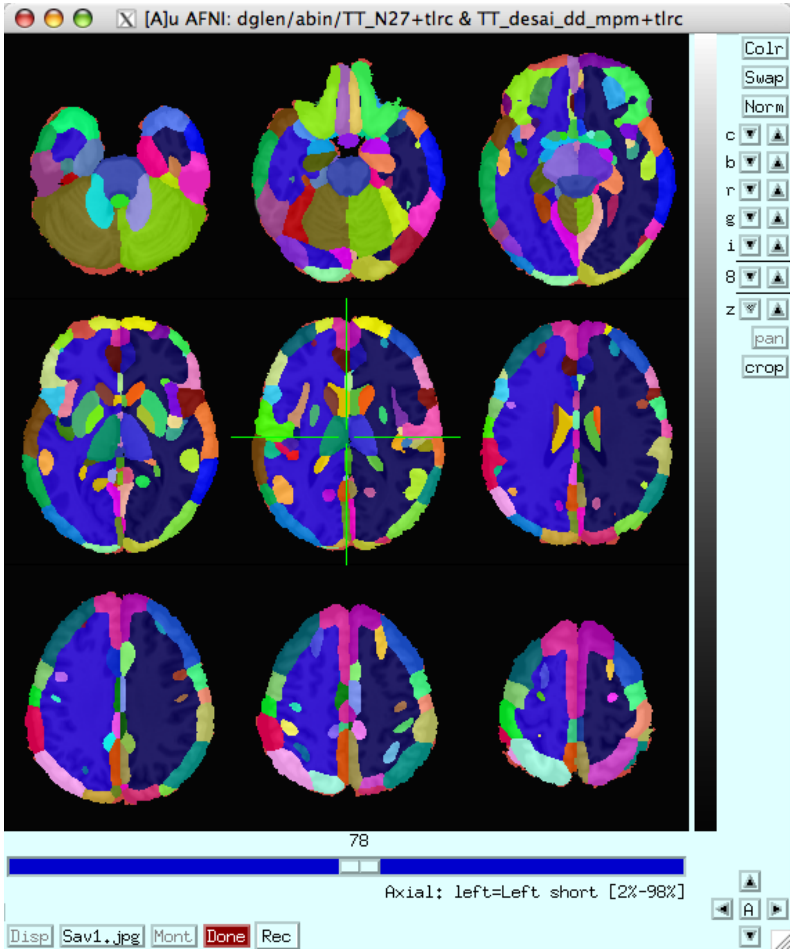


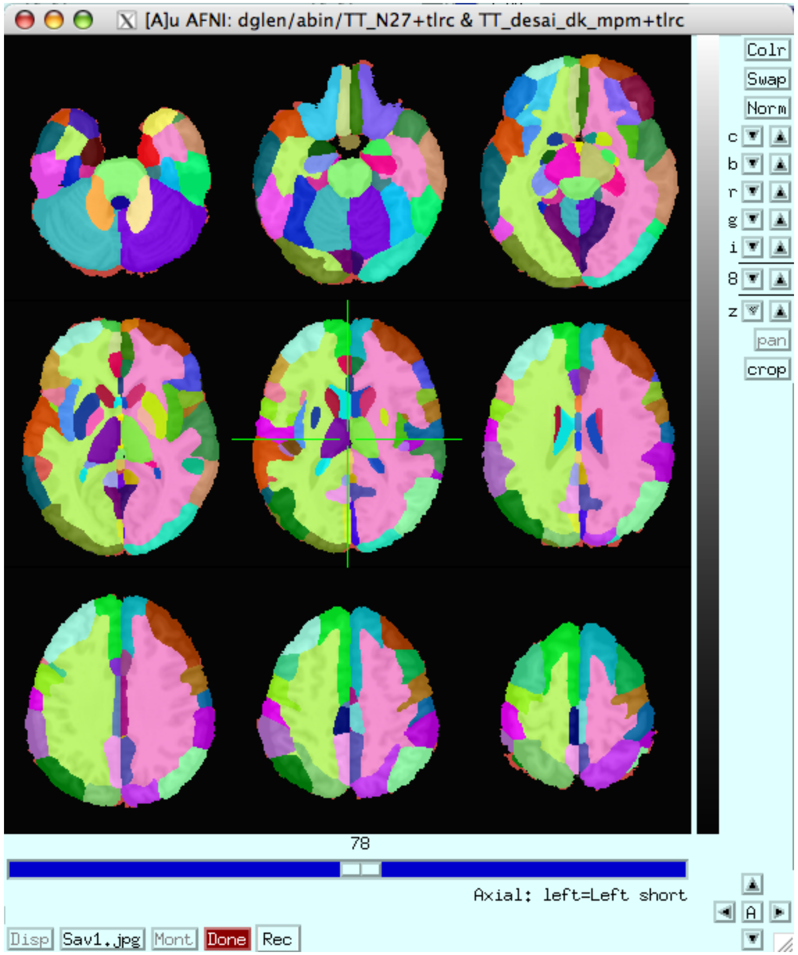


```
Atlas CA_ML_18_MNIA: Macro Labels (N27)

      Focus point: Left SupraMarginal Gyrus

      Within 4 mm: Left Superior Temporal Gyrus

      Within 6 mm: Left Middle Temporal Gyrus

Atlas CA_MPM_18_MNIA: Cytoarch. Max. Prob. Maps

      Focus point: IPC (PF)

      Within 2 mm: IPC (PFm)

      Within 3 mm: IPC (PFcm)

      Within 5 mm: IPC (PGa)

      Within 7 mm: TE 3

Atlas CA_PM_18_MNIA: Cytoarch. Probabilistic Maps

      Focus point: IPC (PFm)

      (p = 0.40)

      -AND- IPC (PFcm)

      (p = 0.20)

      -AND- IPC (PF)

      (p = 0.60)

Atlas CA_LR_18_MNIA: Left/Right (N27)

      Focus point: Left Brain
```

# Atlases distributed with AFNI: Desai PMaps and MPMs

- Atlases generated with typical AFNI pipeline using *@auto_tlrc* and FreeSurfer segmentation across multiple subjects





# Using atlases in AFNI GUI

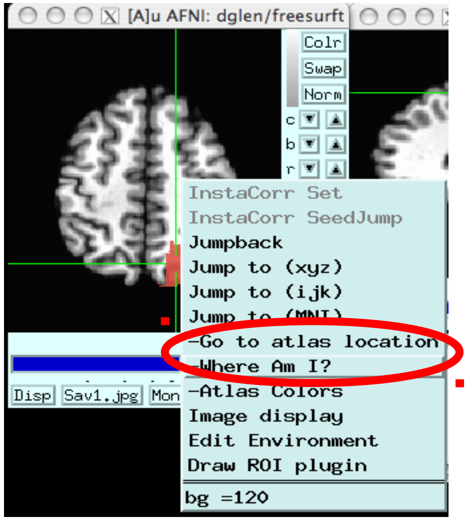
- Some fun and useful things to do with `+tlrc` datasets are on the 2D slice viewer.

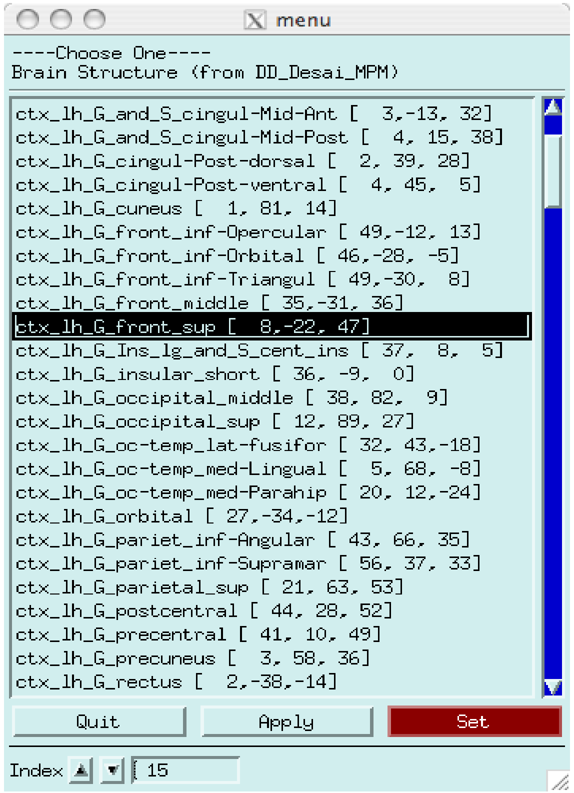
*Ex:* **can be run in ~/AFNI_data6/afni/**

**1) Right click to get menu:**

◇ [Go to Atlas Location]

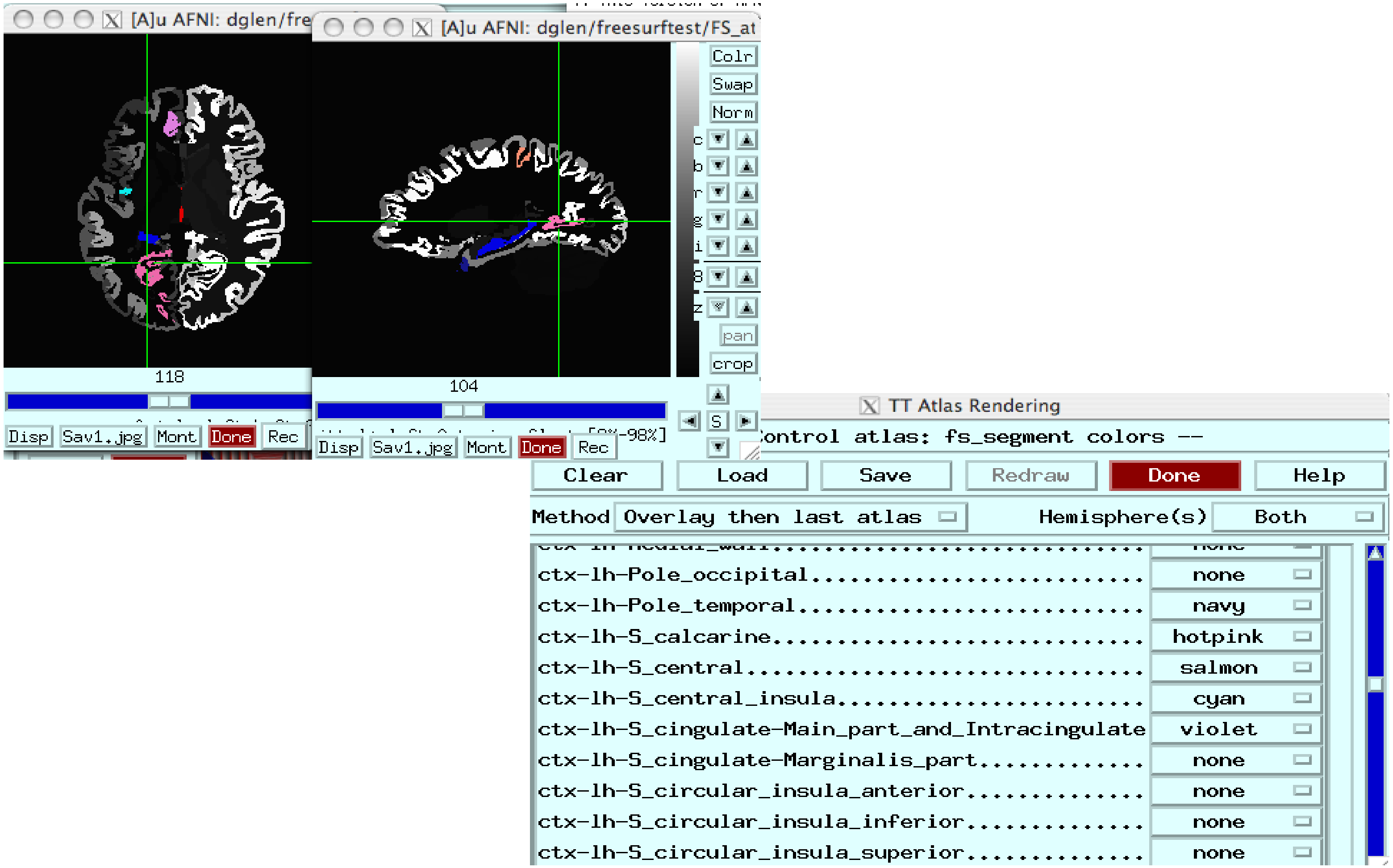
Lets you jump to centroid of regions to current default atlas (set by AFNI_ATLAS_COLORS) Works in `+orig`, too.





```
----Choose One----
Brain Structure (from DD_Desai_MPM)
ctx_lh_G_and_S_cingul-Mid-Ant [  3,-13, 32]
ctx_lh_G_and_S_cingul-Mid-Post [  4, 15, 38]
ctx_lh_G_cingul-Post-dorsal [  2, 39, 28]
ctx_lh_G_cingul-Post-ventral [  4, 45,  5]
ctx_lh_G_cuneus [  1, 81, 14]
ctx_lh_G_front_inf-Opercular [ 49,-12, 13]
ctx_lh_G_front_inf-Orbital [ 46,-28, -5]
ctx_lh_G_front_inf-Triangul [ 49,-30,  8]
ctx_lh_G_front_middle [ 35,-31, 36]
ctx_lh_G_front_sup [  8,-22, 47]
ctx_lh_G_Ins_lg_and_S_cent_ins [ 37,  8,  5]
ctx_lh_G_insular_short [ 36, -9,  0]
ctx_lh_G_occipital_middle [ 38, 82,  9]
ctx_lh_G_occipital_sup [ 12, 89, 27]
ctx_lh_G_oc-temp_lat-fusifor [ 32, 43,-18]
ctx_lh_G_oc-temp_med-Lingual [  5, 68, -8]
ctx_lh_G_oc-temp_med-Parahip [ 20, 12,-24]
ctx_lh_G_orbital [ 27,-34,-12]
ctx_lh_G_pariet_inf-Angular [ 43, 66, 35]
ctx_lh_G_pariet_inf-Supramar [ 56, 37, 33]
ctx_lh_G_parietal_sup [ 21, 63, 53]
ctx_lh_G_postcentral [ 44, 28, 52]
ctx_lh_G_precentral [ 41, 10, 49]
ctx_lh_G_precuneus [  3, 58, 36]
ctx_lh_G_rectus [  2,-38,-14]
```

## ◇ [Atlas colors]



ontrol atlas: fs_segment colors --

Method: Overlay then last atlas

Hemisphere(s): Both

| | |
|---|---|
| ctx-lh-Pole_occipital | none |
| ctx-lh-Pole_temporal | navy |
| ctx-lh-S_calcarine | hotpink |
| ctx-lh-S_central | salmon |
| ctx-lh-S_central_insula | cyan |
| ctx-lh-S_cingulate-Main_part_and_Intracingulate | violet |
| ctx-lh-S_cingulate-Marginalis_part | none |
| ctx-lh-S_circular_insula_anterior | none |
| ctx-lh-S_circular_insula_inferior | none |
| ctx-lh-S_circular_insula_superior | none |

Lets you show atlas regions over your own data (works only in `+tlrc`).

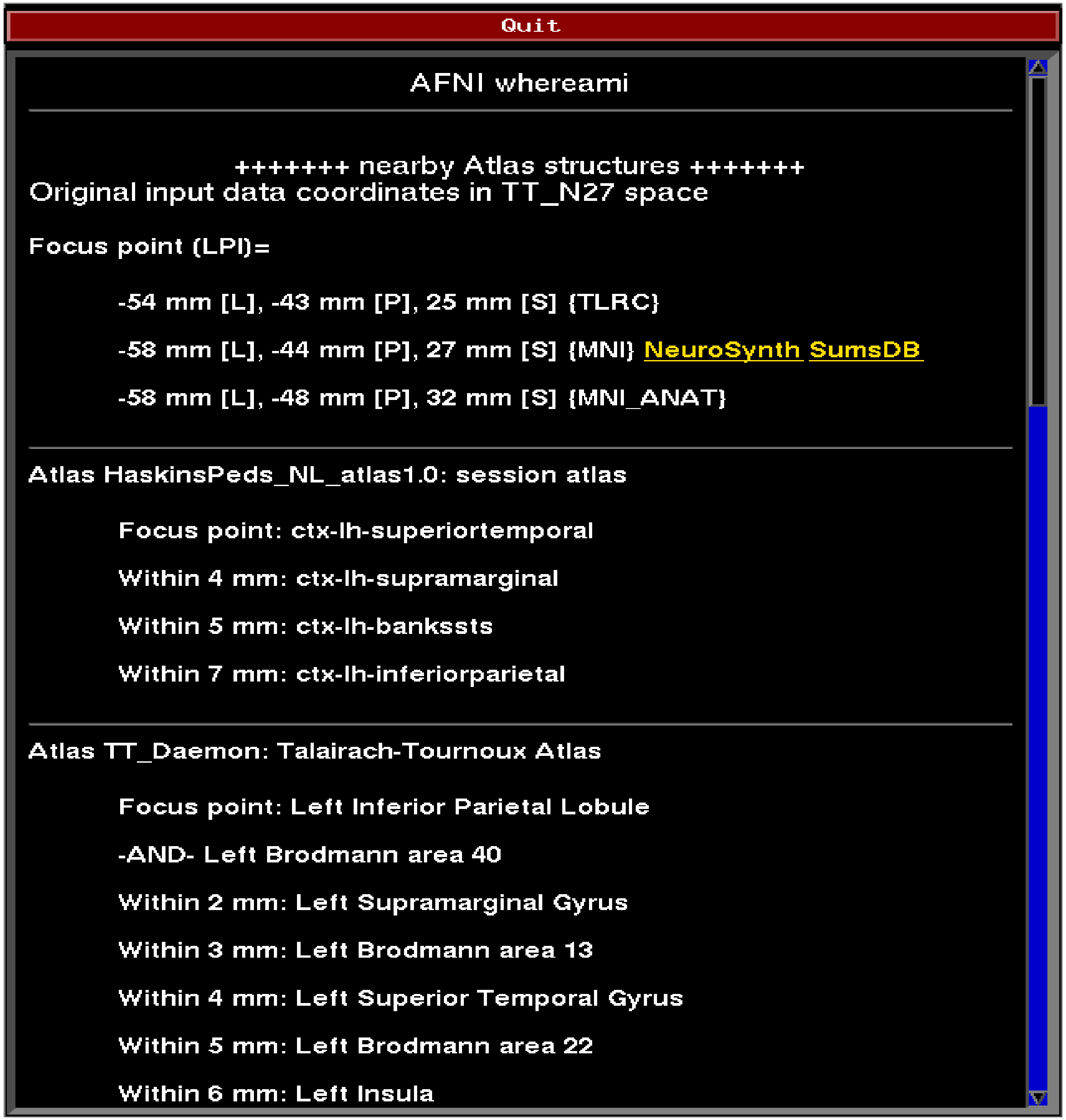
- **[Where am I?]**

Shows you where you are in various atlases and spaces

*(works in* `+orig` *too, if you have a transformed parent)*

For atlas installation, and much, much more, see help in command line version:

**`whereami -help`**



```
                              AFNI whereami

              +++++++ nearby Atlas structures +++++++
Original input data coordinates in TT_N27 space

Focus point (LPI)=

     -54 mm [L], -43 mm [P], 25 mm [S] {TLRC}

     -58 mm [L], -44 mm [P], 27 mm [S] {MNI} NeuroSynth SumsDB

     -58 mm [L], -48 mm [P], 32 mm [S] {MNI_ANAT}

Atlas HaskinsPeds_NL_atlas1.0: session atlas

     Focus point: ctx-lh-superiortemporal

     Within 4 mm: ctx-lh-supramarginal

     Within 5 mm: ctx-lh-bankssts

     Within 7 mm: ctx-lh-inferiorparietal

Atlas TT_Daemon: Talairach-Tournoux Atlas

     Focus point: Left Inferior Parietal Lobule

     -AND- Left Brodmann area 40

     Within 2 mm: Left Supramarginal Gyrus

     Within 3 mm: Left Brodmann area 13

     Within 4 mm: Left Superior Temporal Gyrus

     Within 5 mm: Left Brodmann area 22

     Within 6 mm: Left Insula
```

# whereami on the command line

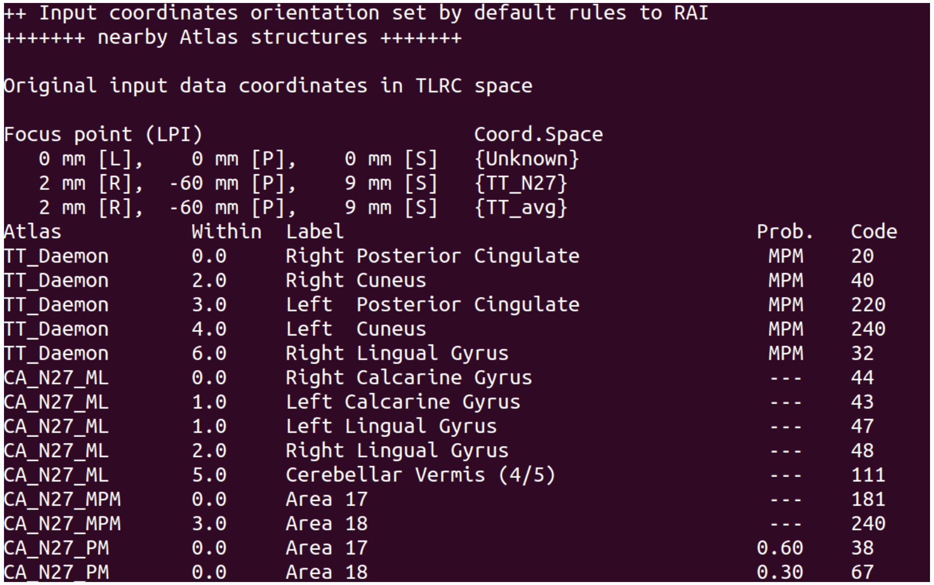
**whereami** can combine usefully with **3dClusterize**:

1) **3dClusterize** finds cluster volumes, and
2) **whereami** provides detailed info like overlap with atlas regions

***Ex*: can be run in ~/AFNI_data6/afni/**

```
# Threshold the index-0 vol (an F-stat) at >9.5 and
# find clusters with >=1000 voxels
3dClusterize -1sided RIGHT 9.5                \
    -clust_nvox 1000 -NN 1                    \
    -inset func_slim+orig -ithr 0 -idat 0     \
    > clusts.1D
```

```
# Use the center of mass coords in
# cols [1,2,3] to show location according
# to several atlases (TT, MNI, etc.); also
# shows nearby structures
whereami                   \
    -coord_file            \
    clusts.1D'[1,2,3]'     \
    -tab | more
```



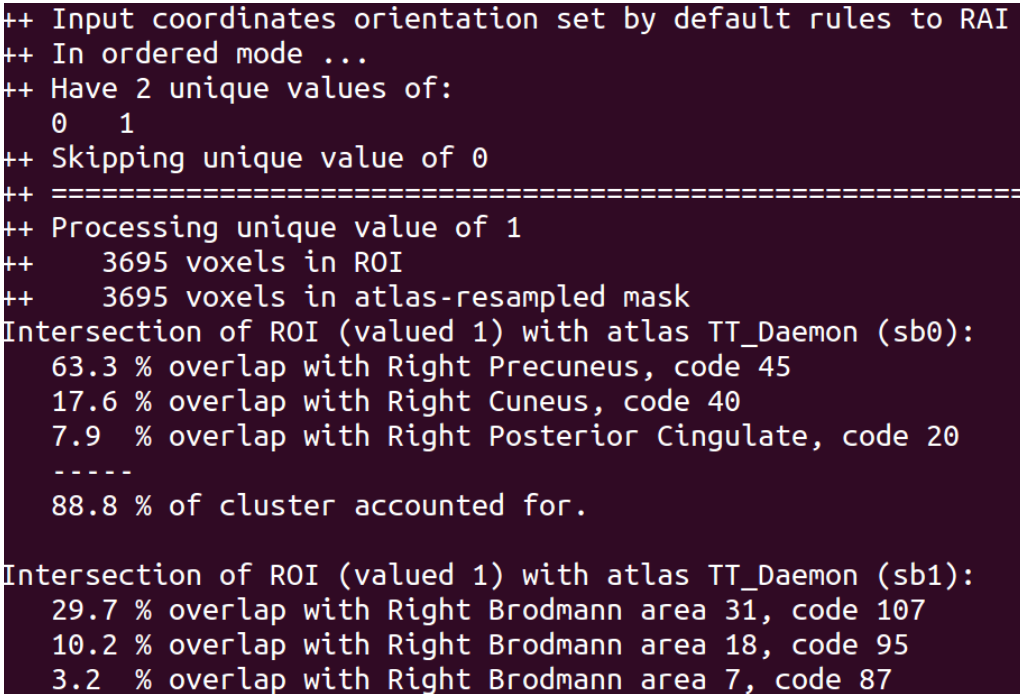
```
++ Input coordinates orientation set by default rules to RAI
+++++++ nearby Atlas structures +++++++

Original input data coordinates in TLRC space

Focus point (LPI)                       Coord.Space
   0 mm [L],     0 mm [P],     0 mm [S]   {Unknown}
   2 mm [R],   -60 mm [P],     9 mm [S]   {TT_N27}
   2 mm [R],   -60 mm [P],     9 mm [S]   {TT_avg}
Atlas           Within  Label                                   Prob.   Code
TT_Daemon       0.0     Right Posterior Cingulate                MPM    20
TT_Daemon       2.0     Right Cuneus                             MPM    40
TT_Daemon       3.0     Left  Posterior Cingulate                MPM    220
TT_Daemon       4.0     Left  Cuneus                             MPM    240
TT_Daemon       6.0     Right Lingual Gyrus                      MPM    32
CA_N27_ML       0.0     Right Calcarine Gyrus                    ---    44
CA_N27_ML       1.0     Left Calcarine Gyrus                     ---    43
CA_N27_ML       1.0     Left Lingual Gyrus                       ---    47
CA_N27_ML       2.0     Right Lingual Gyrus                      ---    48
CA_N27_ML       5.0     Cerebellar Vermis (4/5)                  ---    111
CA_N27_MPM      0.0     Area 17                                  ---    181
CA_N27_MPM      3.0     Area 18                                  ---    240
CA_N27_PM       0.0     Area 17                                 0.60    38
CA_N27_PM       0.0     Area 18                                 0.30    67
```

# whereami on the command line

**whereami** can also report the overlap of ROIs with atlases

*Ex:* **can be run in ~/AFNI_data6/afni/**

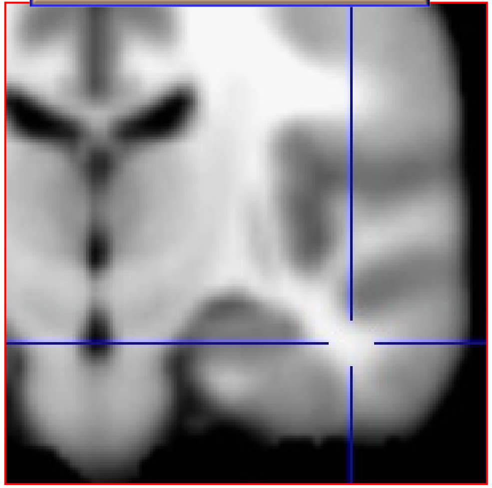
```
# Quick way to make test ROI a sphere at a given location)
echo -14 66 23 > tmp.txt
3dUndump                 \
  -xyz                   \
  -prefix tmproi.nii.gz  \
  -master anat+tlrc      \
  -datum byte            \
  -srad 9.5              \
  tmp.txt

# report overlap
whereami \
    -omask tmproi.nii.gz
```



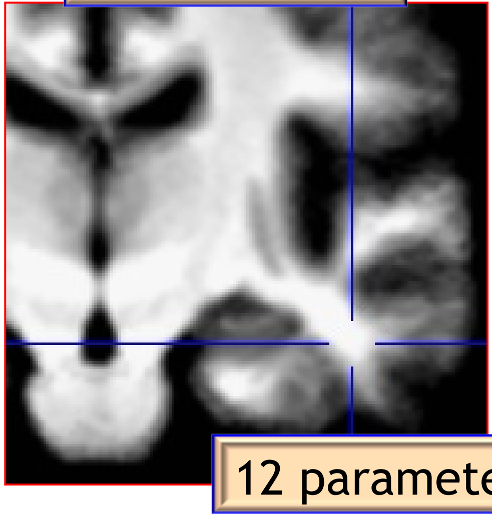
```
++ Input coordinates orientation set by default rules to RAI
++ In ordered mode ...
++ Have 2 unique values of:
   0   1
++ Skipping unique value of 0
++ ==========================================================
++ Processing unique value of 1
++    3695 voxels in ROI
++    3695 voxels in atlas-resampled mask
Intersection of ROI (valued 1) with atlas TT_Daemon (sb0):
   63.3 % overlap with Right Precuneus, code 45
   17.6 % overlap with Right Cuneus, code 40
   7.9  % overlap with Right Posterior Cingulate, code 20
   -----
   88.8 % of cluster accounted for.

Intersection of ROI (valued 1) with atlas TT_Daemon (sb1):
   29.7 % overlap with Right Brodmann area 31, code 107
   10.2 % overlap with Right Brodmann area 18, code 95
   3.2  % overlap with Right Brodmann area 7, code 87
```

# Make your own template

MNI 152 template



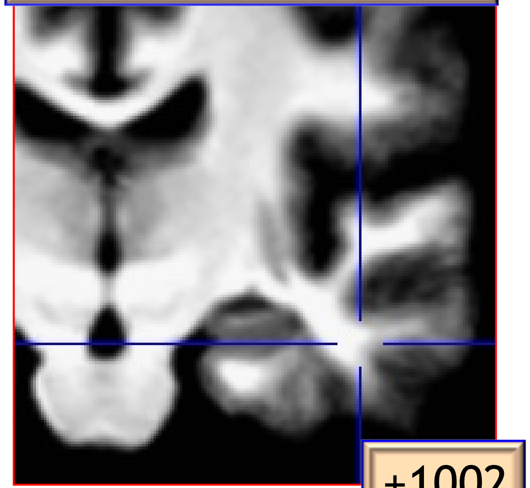
Linear = Affine



12 parameters

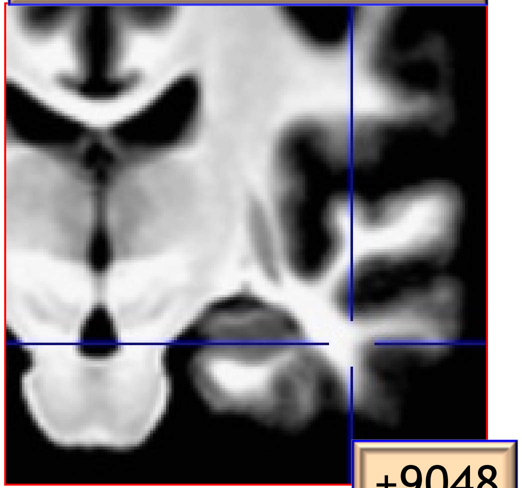
`@toMNI_Awarp`
`@toMNI_Qwarpar`
Averages of 21
3 Tesla brain volumes
with varied
levels of refinement in
the nonlinear warping
(smaller patch=more refinement)

Nonlinear: Patch=101



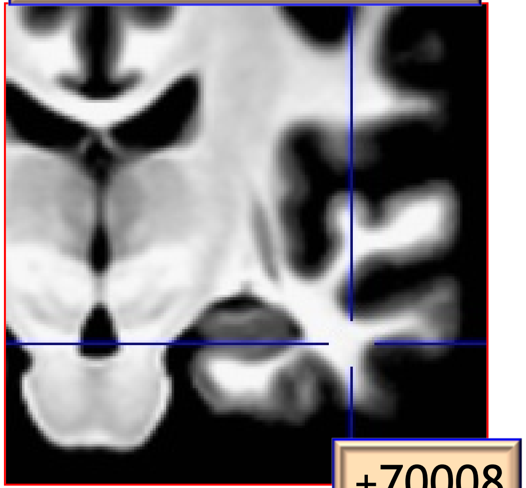
+1002

Nonlinear: Patch=49



+9048

Nonlinear: Patch=23



+70008

# Make your own atlas!

- New atlases – easy and fun. Make your own!
  - make available in AFNI GUI and whereami and to other user

```
@AfniEnv -set AFNI_SUPP_ATLAS_DIR ~/MyCustomAtlases/
```

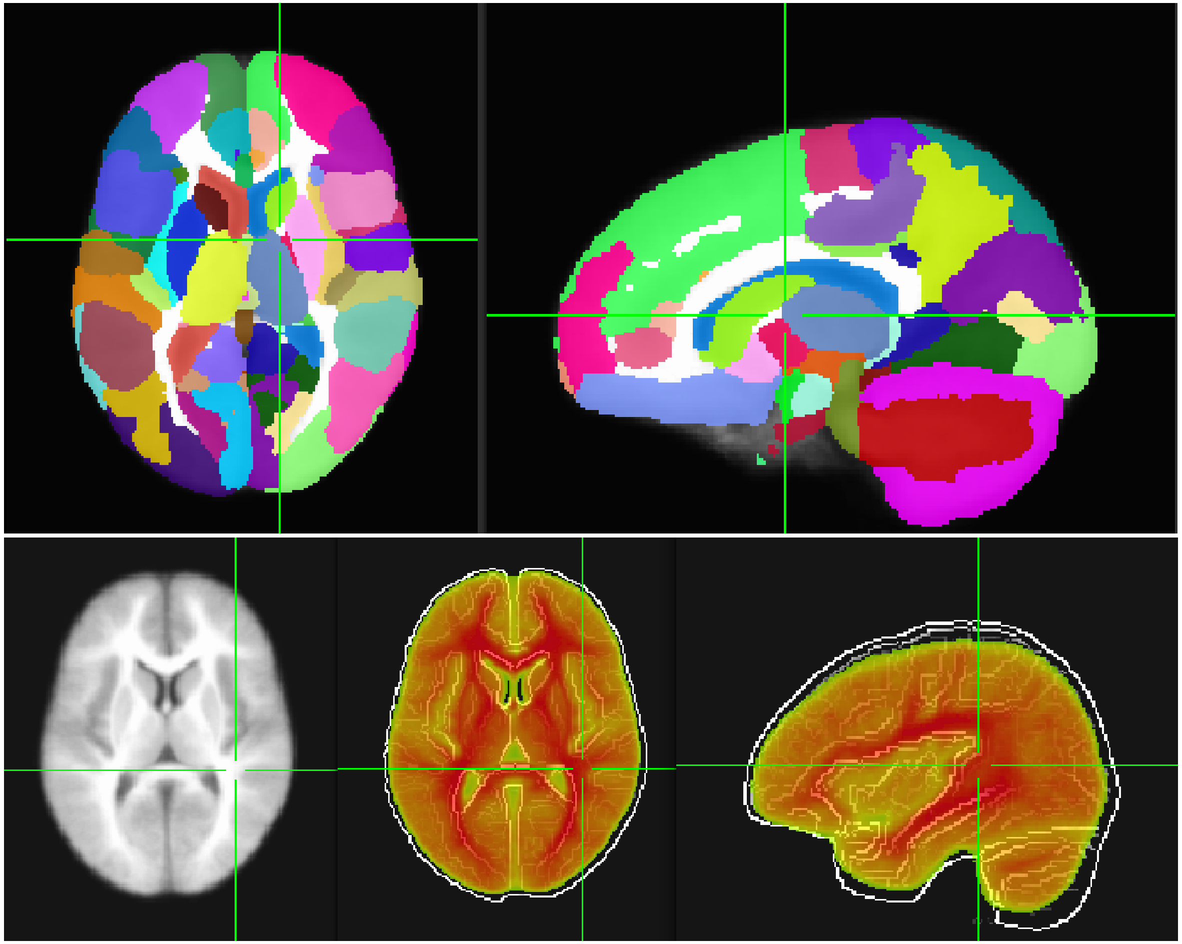
Then:

```
@Atlasize -space MNI -dset atlas_for_all.nii \
                  -lab_file keys.txt 1 0 -atlas_type G
```

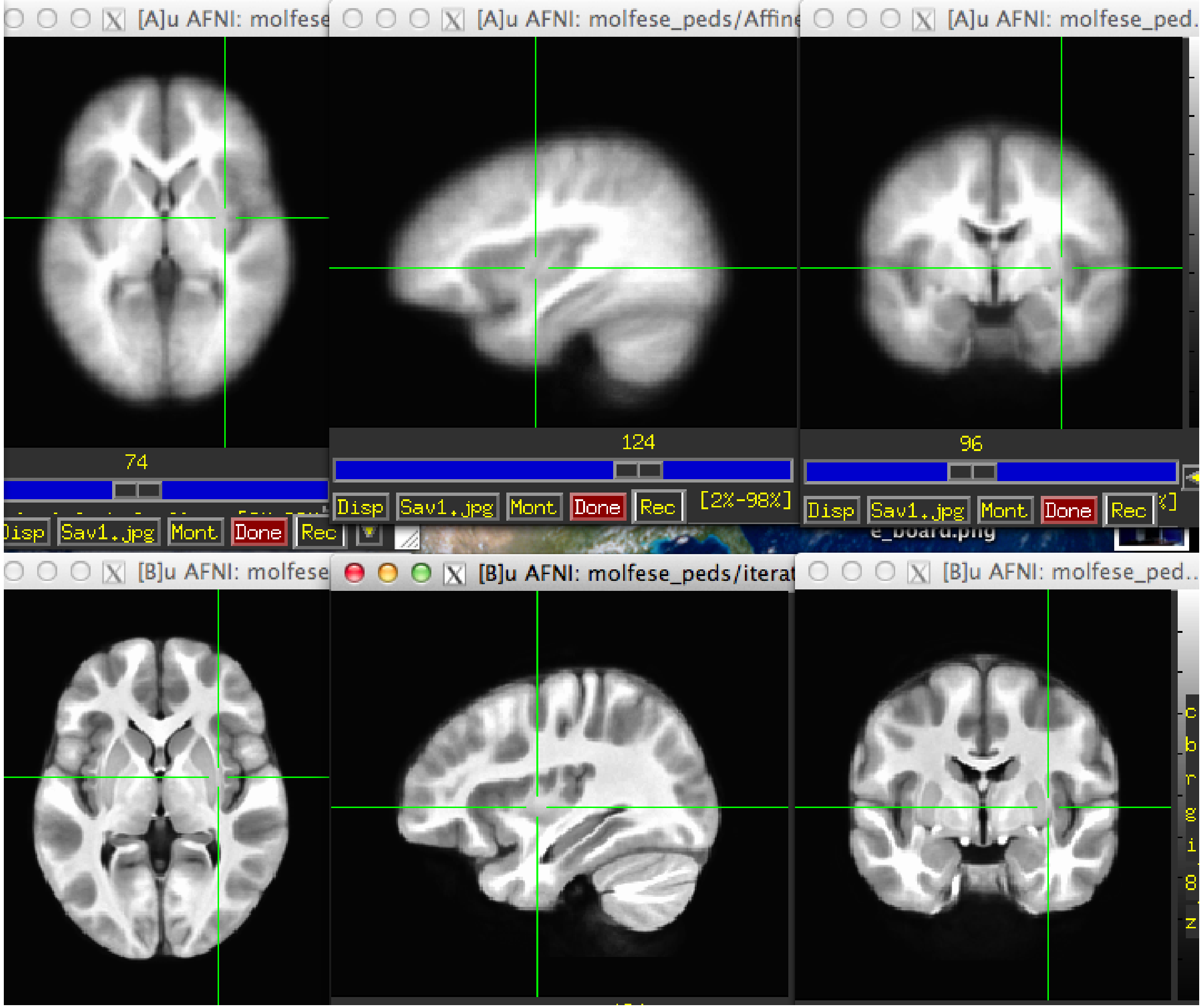
In ~/MyCustomAtlases/ you will now find atlas_for_all.nii along along with a modified CustomAtlases.niml file.

# Haskins Pediatric Atlas

- Pediatric brain atlas and templates (7-12 years old) – Peter Molfese, (formerly Haskins Labs, now at NIH - woohoo!)
- Manually corrected segmentation from Freesurfer.
- Probabilistic, MPM and template
- ~75 subjects → 500 (ages 6-13)
- Affine, nonlinear averages, ideal/typical subjects, outliers



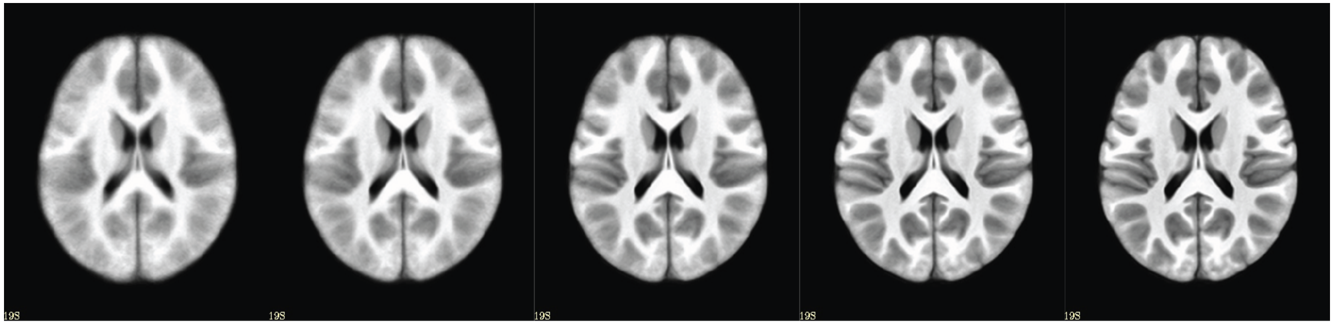
# Haskins Pediatric Atlas: the templates



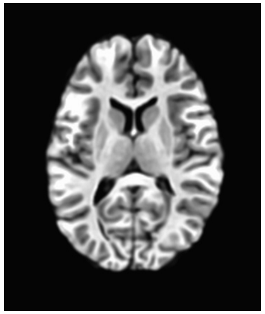
Affine Group

Nonlinear Group I – iterative

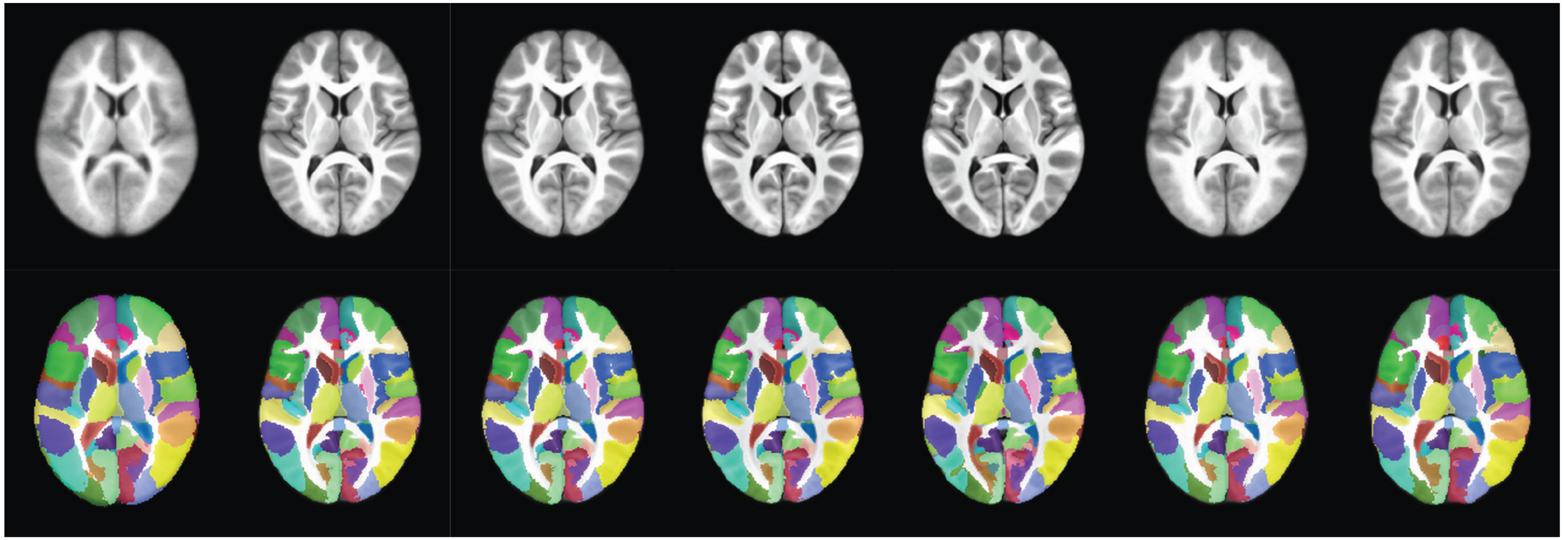
# ALTERNATIVE ATLAS CREATION TECHNIQUES: ITERATIVE AND TYPICAL METHODS



Iterative nonlinear alignment to affine template with progressively smaller patch sizes



**“Typical” Brain**



Affine

Affine Iterative

Typical Iterative

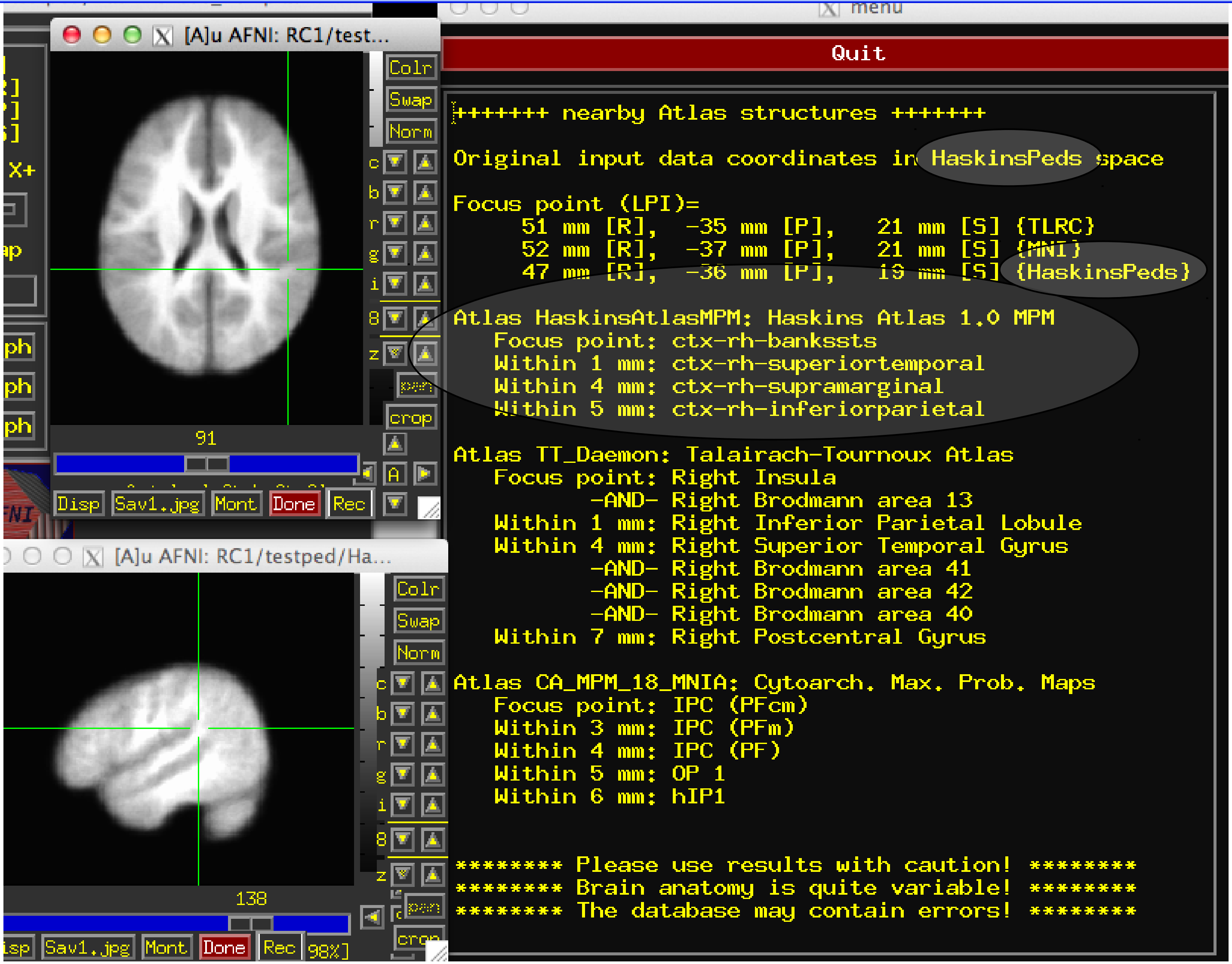
MNI Iterative

Nonlinear to MNI

Nonlinear to Affine

Nonlinear to Typical

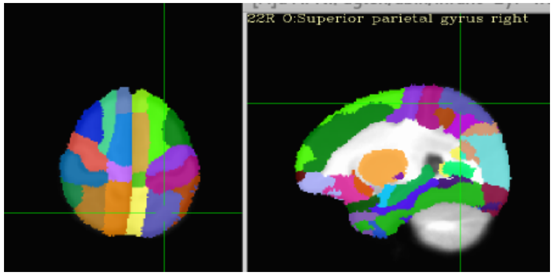
# Haskins Pediatric Atlas

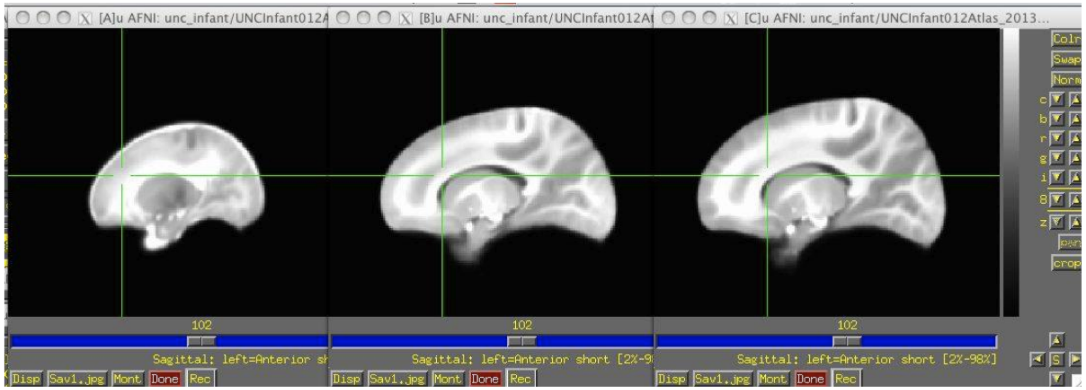


```
+++++++ nearby Atlas structures +++++++

Original input data coordinates in HaskinsPeds space

Focus point (LPI)=
     51 mm [R],  -35 mm [P],   21 mm [S] {TLRC}
     52 mm [R],  -37 mm [P],   21 mm [S] {MNI}
     47 mm [R],  -36 mm [P],   19 mm [S] {HaskinsPeds}

Atlas HaskinsAtlasMPM: Haskins Atlas 1.0 MPM
   Focus point: ctx-rh-bankssts
   Within 1 mm: ctx-rh-superiortemporal
   Within 4 mm: ctx-rh-supramarginal
   Within 5 mm: ctx-rh-inferiorparietal

Atlas TT_Daemon: Talairach-Tournoux Atlas
   Focus point: Right Insula
          -AND- Right Brodmann area 13
   Within 1 mm: Right Inferior Parietal Lobule
   Within 4 mm: Right Superior Temporal Gyrus
          -AND- Right Brodmann area 41
          -AND- Right Brodmann area 42
          -AND- Right Brodmann area 40
   Within 7 mm: Right Postcentral Gyrus

Atlas CA_MPM_18_MNIA: Cytoarch. Max. Prob. Maps
   Focus point: IPC (PFcm)
   Within 3 mm: IPC (PFm)
   Within 4 mm: IPC (PF)
   Within 5 mm: OP 1
   Within 6 mm: hIP1


******** Please use results with caution! ********
******** Brain anatomy is quite variable! ********
******** The database may contain errors! ********
```

# Atlases and Templates Available!

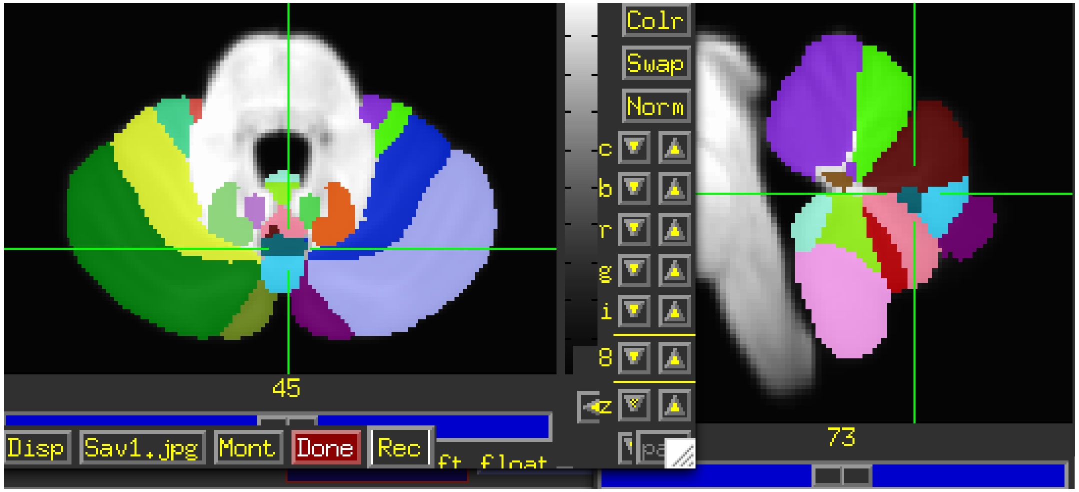
- Infant brain atlas and templates – neonate, 1-year, 2-year. Contributed by Feng Shi, UNC





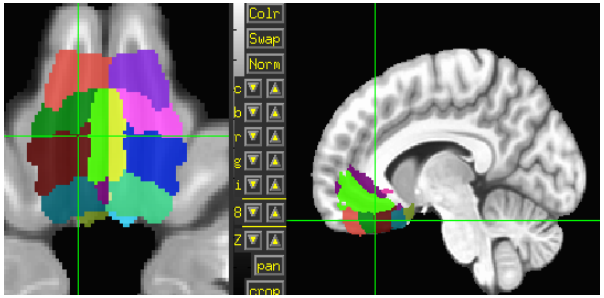
UNC infant templates and atlases – neonate, 1 yr, 2 yr old

- Cerebellum atlas and templates – Jorn Diedrichsen,UCL,UK contribution



# More Atlases and Templates Available!

Ventromedial Prefrontral Cortex (vmPFC, Scott Mackey)

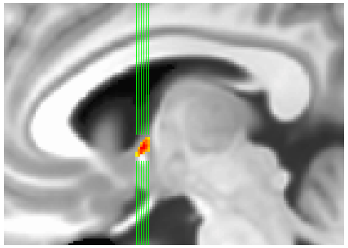


Waxholm Rat Atlas - Papp, et al.

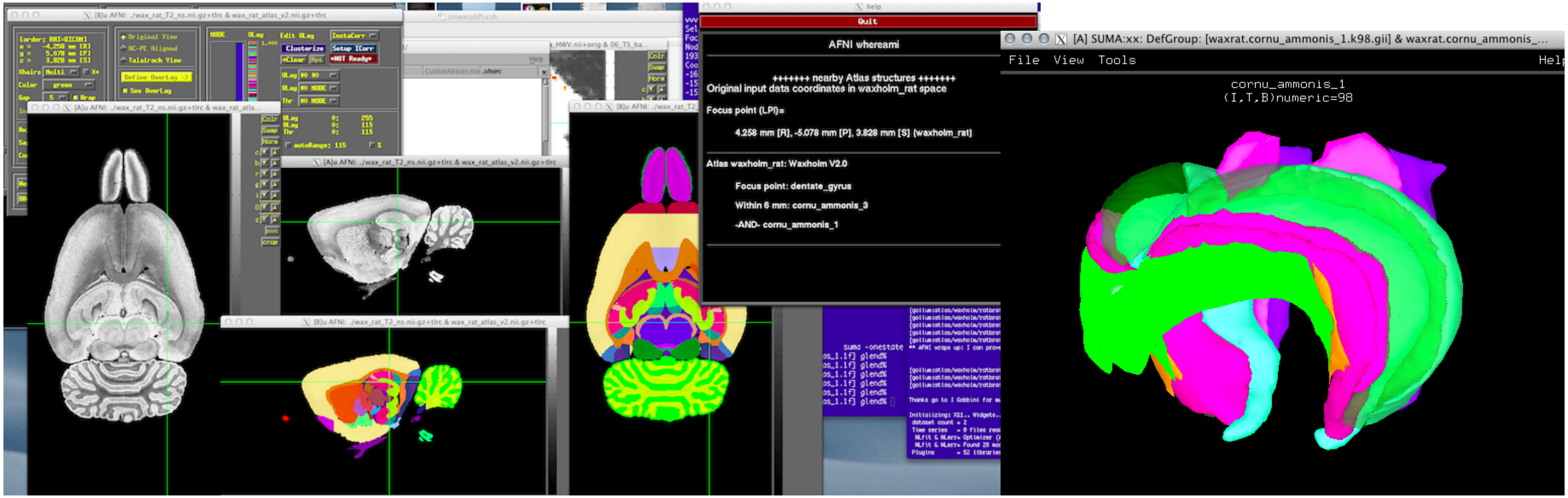
Rat brain templates in Paxinos space – Karolinska Institute, Woo Hyun Shim MGH contributions

**All of these are user requests or contributions!**

***What do you need?***



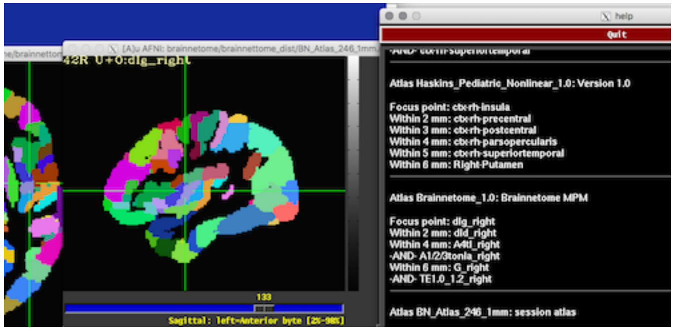
BNST – Torrisi, NIMH



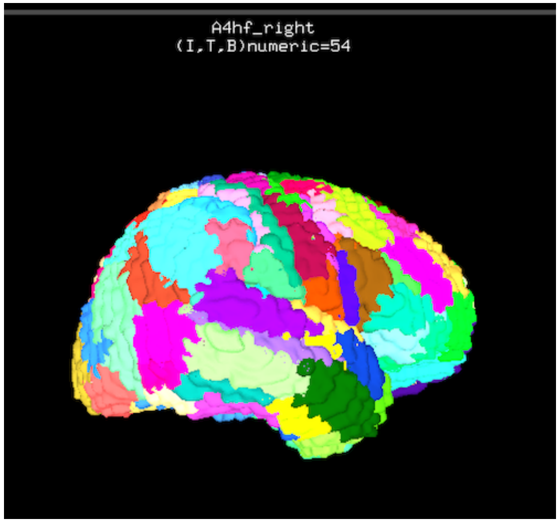
```
AFNI whereami

+++++++ nearby Atlas structures +++++++
Original input data coordinates in waxholm_rat space

Focus point (LPI)=

    4.258 mm [R], -5.078 mm [P], 3.828 mm [S] {waxholm_rat}

Atlas waxholm_rat: Waxholm V2.0

    Focus point: dentate_gyrus

    Within 6 mm: cornu_ammonis_3

    -AND- cornu_ammonis_1
```

# Even More Atlases and Templates Available!

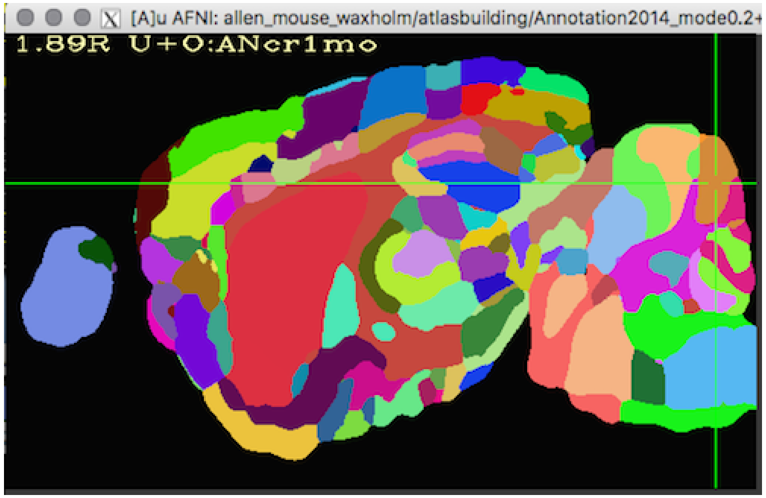
## Brainnetome



```
Atlas Haskins_Pediatric_Nonlinear_1.0: Version 1.0

Focus point: ctx-rh-insula
Within 2 mm: ctx-rh-precentral
Within 3 mm: ctx-rh-postcentral
Within 4 mm: ctx-rh-parsopercularis
Within 5 mm: ctx-rh-superiortemporal
Within 6 mm: Right-Putamen

Atlas Brainnetome_1.0: Brainnetome MPM

Focus point: dlg_right
Within 2 mm: dld_right
Within 4 mm: A4tl_right
-AND- A1/2/3tonla_right
Within 6 mm: G_right
-AND- TE1.0_1.2_right

Atlas BN_Atlas_246_1mm: session atlas
```



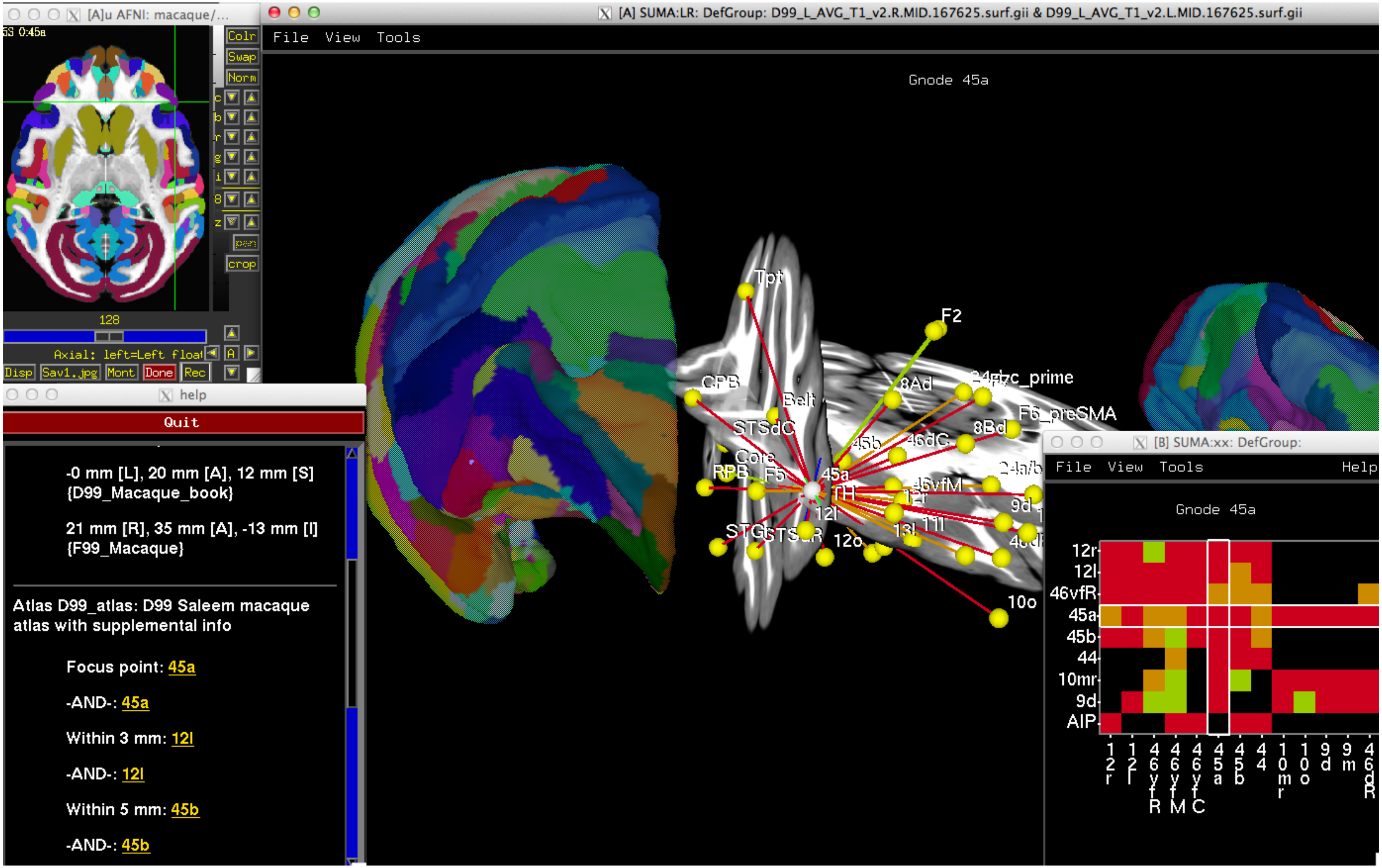
## Allen Mouse Brain



**All of these are user requests or contributions!**

***What do you need?***

# Saleem macaque atlas – MRI, surfaces, connections, supplemental webpages



-0 mm [L], 20 mm [A], 12 mm [S]
{D99_Macaque_book}

21 mm [R], 35 mm [A], -13 mm [I]
{F99_Macaque}

Atlas D99_atlas: D99 Saleem macaque atlas with supplemental info

Focus point: 45a

-AND-: 45a

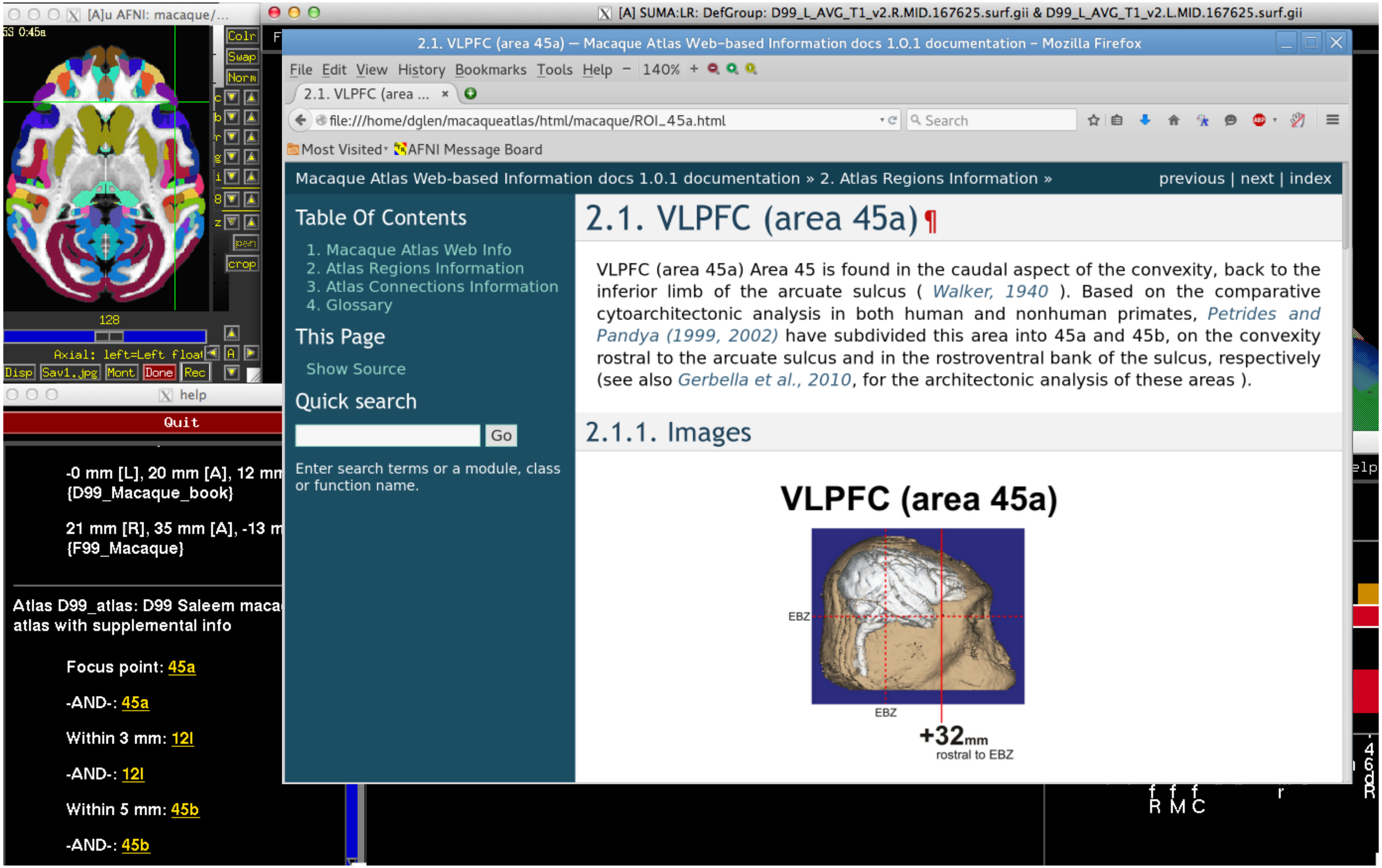
Within 3 mm: 12l

-AND-: 12l

Within 5 mm: 45b

-AND-: 45b

# Saleem macaque atlas – MRI, surfaces, connections, supplemental webpages (in development)



## 2.1. VLPFC (area 45a)

VLPFC (area 45a) Area 45 is found in the caudal aspect of the convexity, back to the inferior limb of the arcuate sulcus ( *Walker, 1940* ). Based on the comparative cytoarchitectonic analysis in both human and nonhuman primates, *Petrides and Pandya (1999, 2002)* have subdivided this area into 45a and 45b, on the convexity rostral to the arcuate sulcus and in the rostroventral bank of the sulcus, respectively (see also *Gerbella et al., 2010*, for the architectonic analysis of these areas ).

### 2.1.1. Images

-0 mm [L], 20 mm [A], 12 mm
{D99_Macaque_book}

21 mm [R], 35 mm [A], -13 m
{F99_Macaque}

Atlas D99_atlas: D99 Saleem maca
atlas with supplemental info

Focus point: 45a

-AND-: 45a

Within 3 mm: 12l

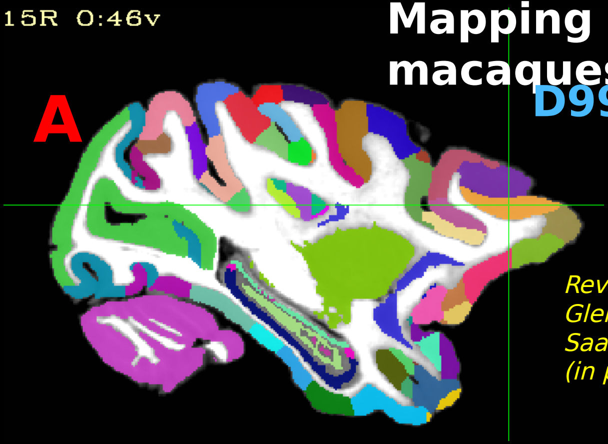
-AND-: 12l

Within 5 mm: 45b

-AND-: 45b

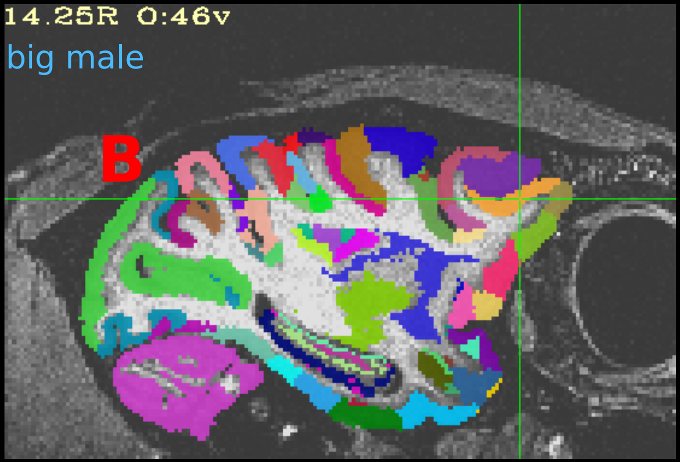
# Mapping the digital atlas onto different macaques MRI

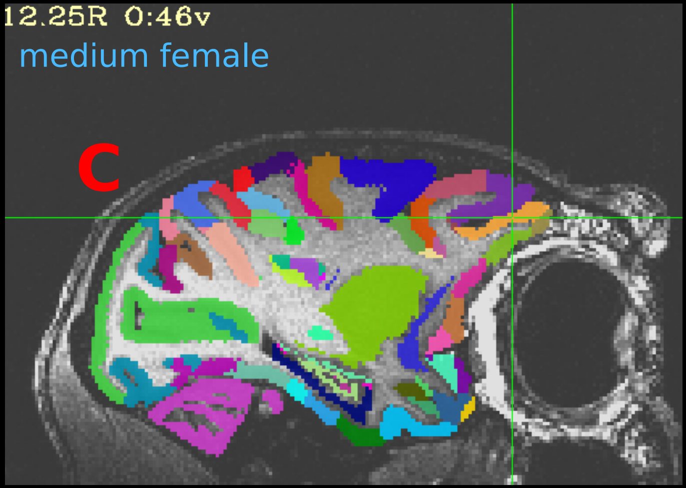
## D99 – Digital atlas

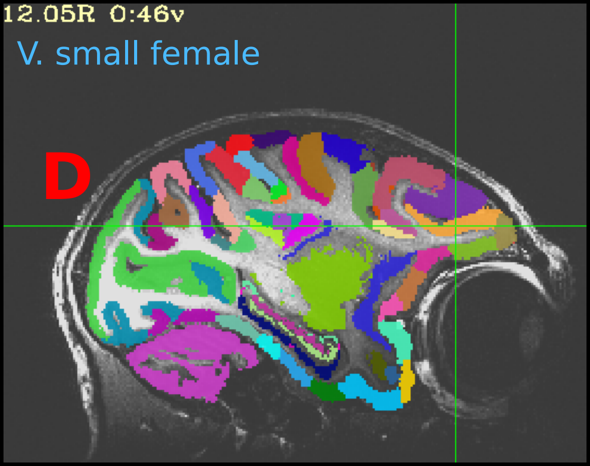


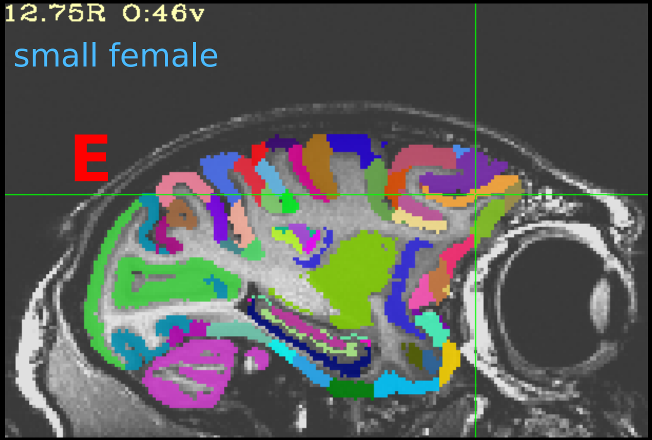
*Reveley, Gruslys, Ye, Samaha, Glen,
Saad, Seth, Leopold, and Saleem
(in preparation)*

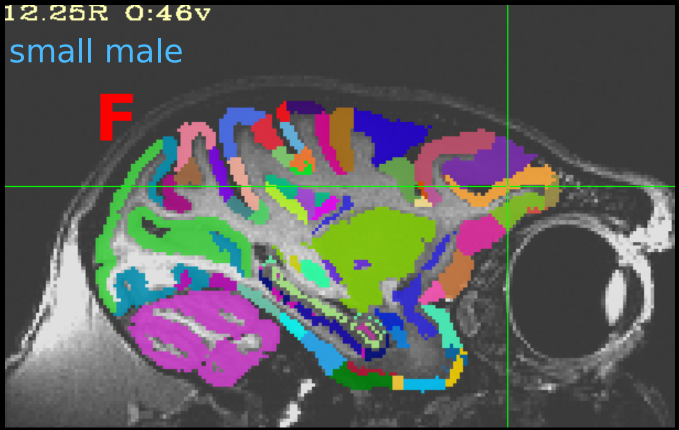
**Spatial transformation of the atlas segmentation to each macaque's native space**





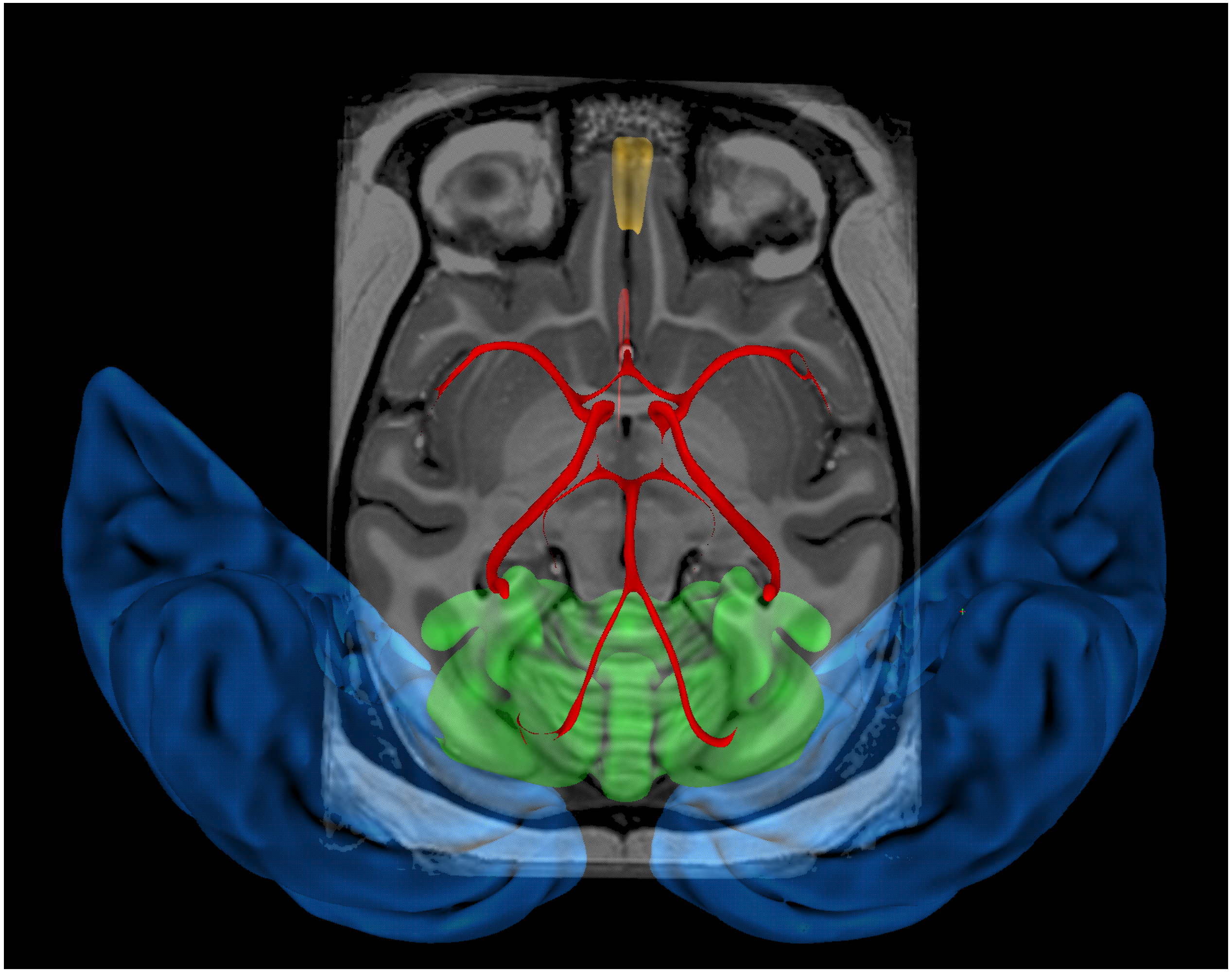






# NMT (NIH Macaque Template)

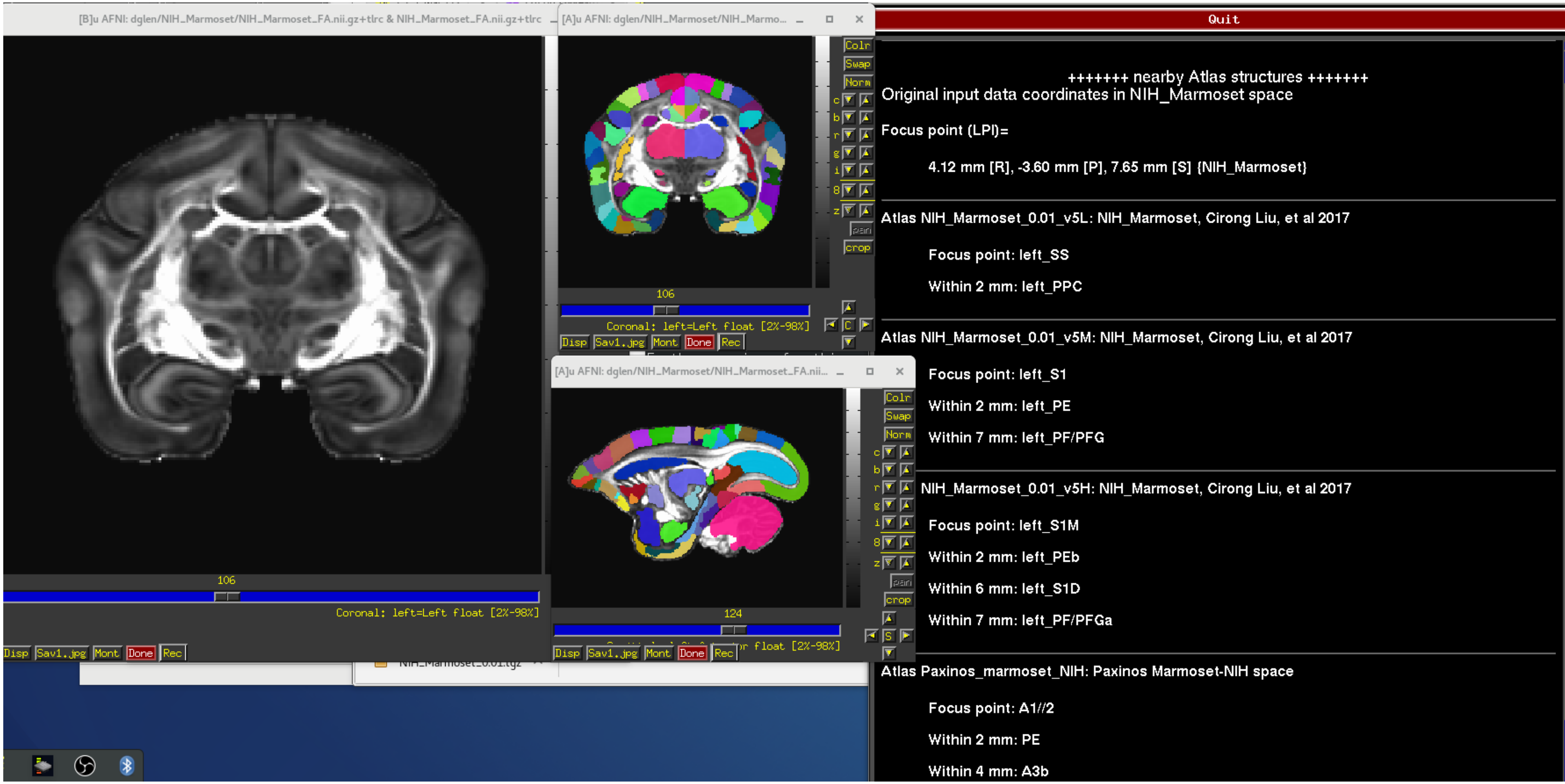
Group template from 31 macaques (+ surfaces, GM/WM/CSF segmentation)



(Seidlitz, et al., 2017)

# NIH Marmoset Template

## Individual marmoset template - **150um** resolution

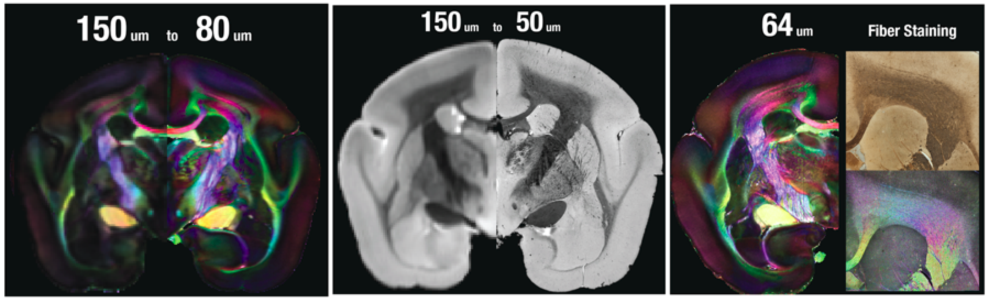


```
                  +++++++ nearby Atlas structures +++++++
Original input data coordinates in NIH_Marmoset space

Focus point (LPI)=

      4.12 mm [R], -3.60 mm [P], 7.65 mm [S] {NIH_Marmoset}

Atlas NIH_Marmoset_0.01_v5L: NIH_Marmoset, Cirong Liu, et al 2017

      Focus point: left_SS

      Within 2 mm: left_PPC

Atlas NIH_Marmoset_0.01_v5M: NIH_Marmoset, Cirong Liu, et al 2017

      Focus point: left_S1

      Within 2 mm: left_PE

      Within 7 mm: left_PF/PFG

NIH_Marmoset_0.01_v5H: NIH_Marmoset, Cirong Liu, et al 2017

      Focus point: left_S1M

      Within 2 mm: left_PEb

      Within 6 mm: left_S1D

      Within 7 mm: left_PF/PFGa

Atlas Paxinos_marmoset_NIH: Paxinos Marmoset-NIH space

      Focus point: A1//2

      Within 2 mm: PE

      Within 4 mm: A3b
```

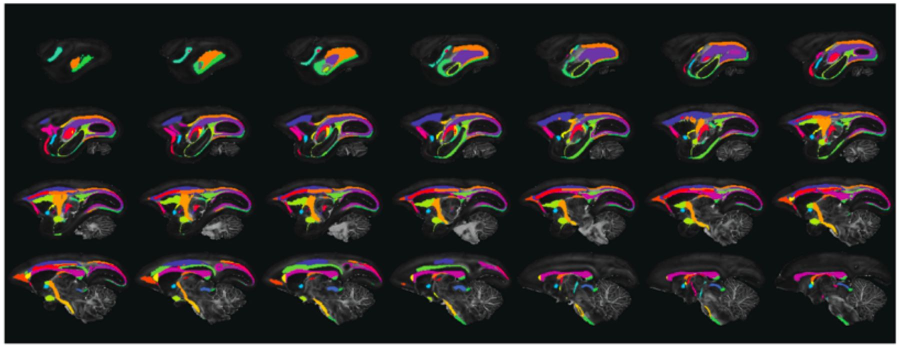
*(Liu, Ye, Yen, Newman, Glen, Leopold, Silva, 2018)*

# 2018: *improved* NIH Marmoset Template

## Better Data

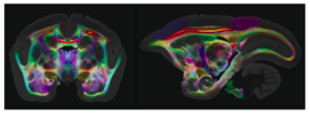


## Detailed labels



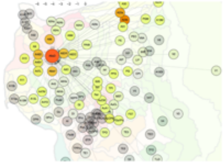
## Support with tracing data, connectome and atlas utilities

MARMOSET BRAIN ATLAS



+

Marmoset brainarchitecture



+

+

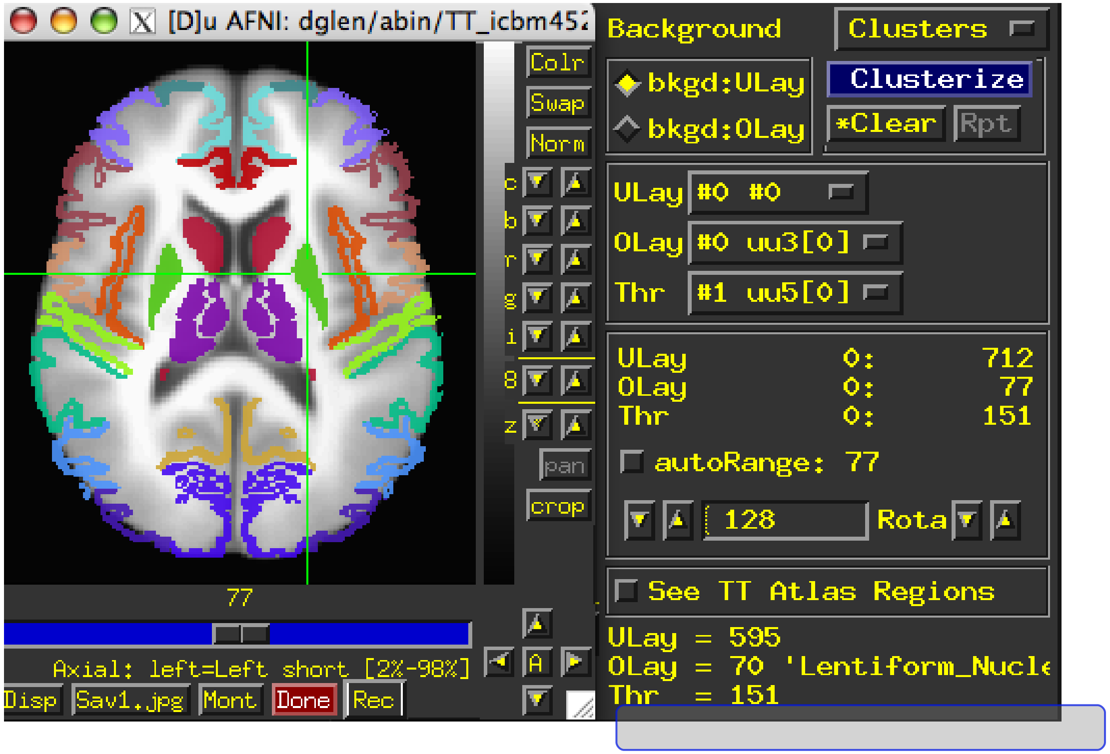
AFNI!

SUMA!

(Liu et al., 2018, SfN)

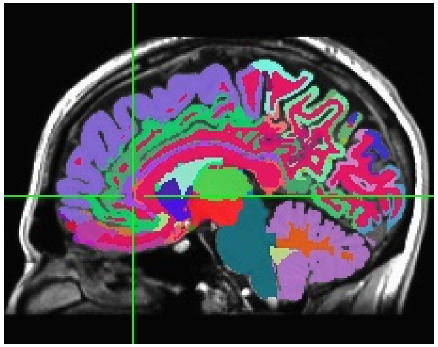
# Individual Subjects

## @SUMA_MakeSpecFS – atlasizes too!

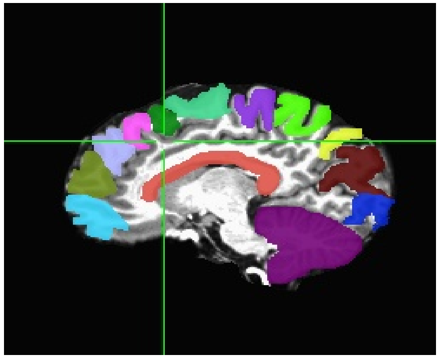


```
Axial: left=Left short [2%-98%]
◆ bkgd:ULay
◇ bkgd:OLay
ULay #0 #0
OLay #0 uu3[0]
Thr  #1 uu5[0]
ULay       0:    712
OLay       0:     77
Thr        0:    151
☐ autoRange: 77
128   Rota
ULay = 595
OLay = 70 'Lentiform_Nucle
Thr  = 151
```

Overlay panel shows structure name. Now FreeSurfer segmentation can also be used in **whereami.**



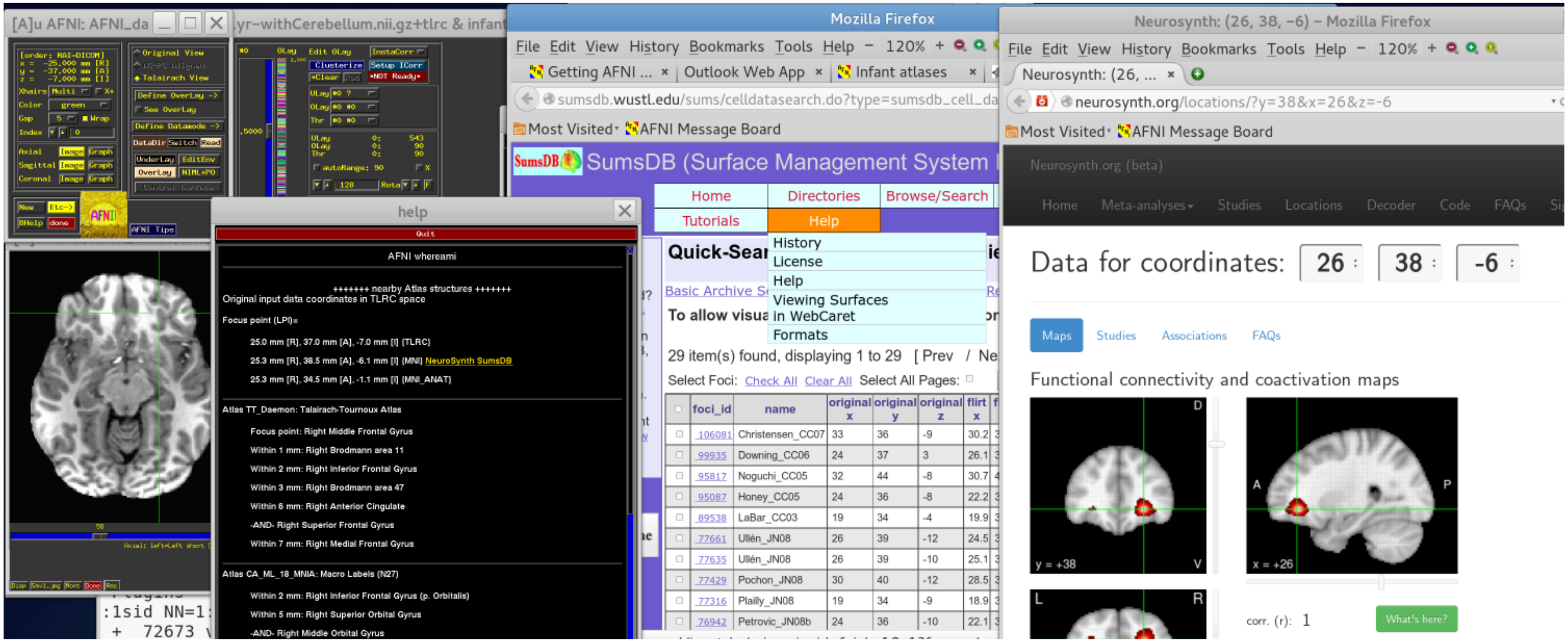
FreeSurfer segmentation



Manual segmentation

# Web-based atlases

Several presently available (probably a growing number): NeuroSynth, LinkrBrain, BrainMap.org, Allen Brain, ...



```
AFNI whereami

+++++++ nearby Atlas structures +++++++
Original input data coordinates in TLRC space

Focus point (LPI)=

    25.0 mm [R], 37.0 mm [A], -7.0 mm [I] {TLRC}
    25.3 mm [R], 38.5 mm [A], -6.1 mm [I] {MNI} NeuroSynth SumsDB
    25.3 mm [R], 34.5 mm [A], -1.1 mm [I] {MNI_ANAT}

Atlas TT_Daemon: Talairach-Tournoux Atlas

    Focus point: Right Middle Frontal Gyrus
    Within 1 mm: Right Brodmann area 11
    Within 2 mm: Right Inferior Frontal Gyrus
    Within 3 mm: Right Brodmann area 47
    Within 6 mm: Right Anterior Cingulate
    -AND- Right Superior Frontal Gyrus
    Within 7 mm: Right Medial Frontal Gyrus

Atlas CA_ML_18_MNIA: Macro Labels (N27)

    Within 2 mm: Right Inferior Frontal Gyrus (p. Orbitalis)
    Within 5 mm: Right Superior Orbital Gyrus
    -AND- Right Middle Orbital Gyrus
```

29 item(s) found, displaying 1 to 29 [ Prev / Ne

Select Foci: Check All Clear All Select All Pages: ☐

| ☐ | foci_id | name | original x | original y | original z | flirt x |
|---|---|---|---|---|---|---|
| ☐ | 106081 | Christensen_CC07 | 33 | 36 | -9 | 30.2 |
| ☐ | 99935 | Downing_CC06 | 24 | 37 | 3 | 26.1 |
| ☐ | 95817 | Noguchi_CC05 | 32 | 44 | -8 | 30.7 |
| ☐ | 95087 | Honey_CC05 | 24 | 36 | -8 | 22.2 |
| ☐ | 89538 | LaBar_CC03 | 19 | 34 | -4 | 19.9 |
| ☐ | 77661 | Ullén_JN08 | 26 | 39 | -12 | 24.5 |
| ☐ | 77635 | Ullén_JN08 | 26 | 39 | -10 | 25.1 |
| ☐ | 77429 | Pochon_JN08 | 30 | 40 | -12 | 28.5 |
| ☐ | 77316 | Plailly_JN08 | 19 | 34 | -9 | 18.9 |
| ☐ | 76942 | Petrovic_JN08b | 24 | 36 | -10 | 22.1 |

Data for coordinates: 26 38 -6

Functional connectivity and coactivation maps

corr. (r): 1

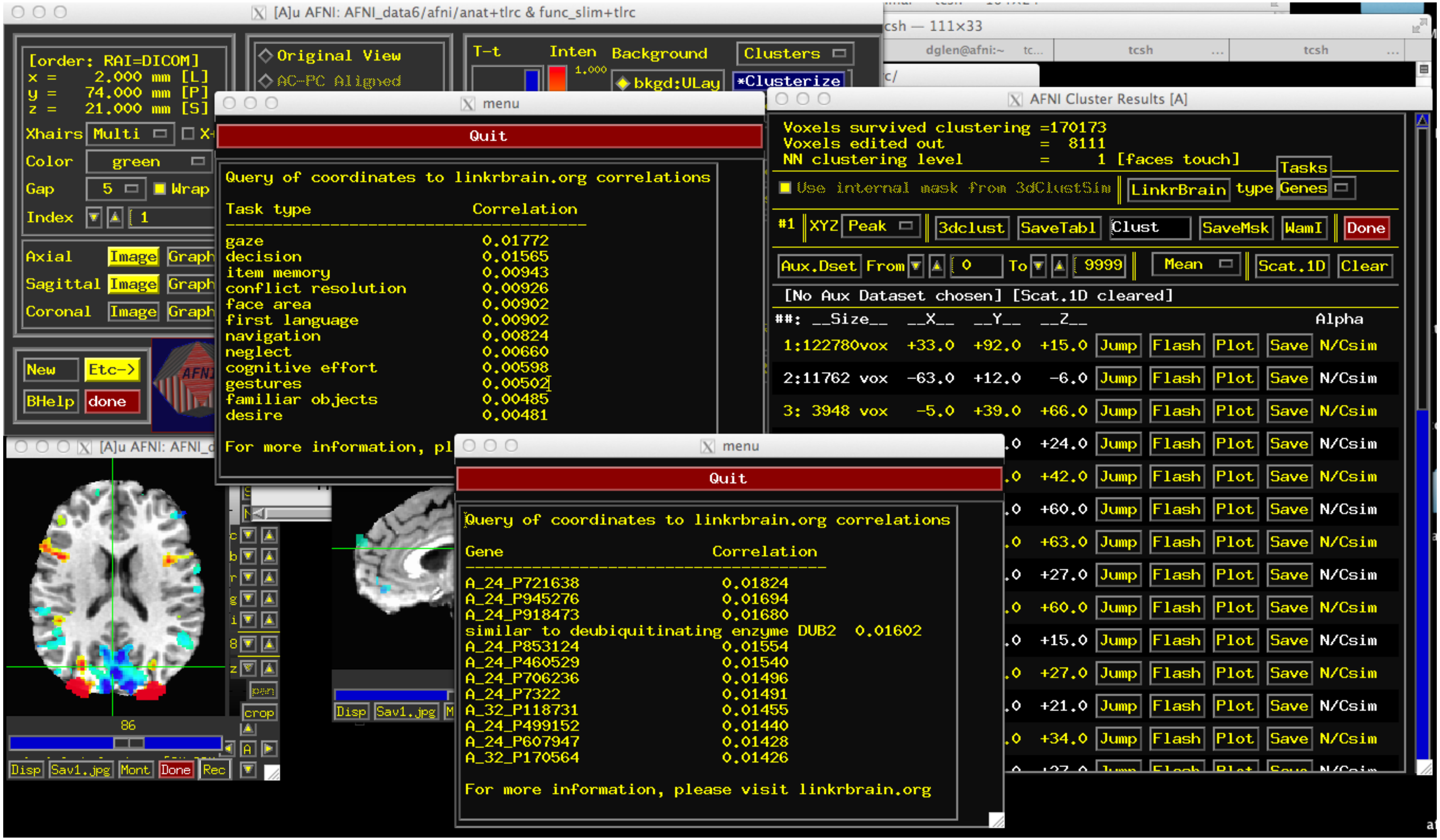
set each of the following environment variables in ~/.afnirc to YES:

**AFNI_WEBBY_WAMI**

**AFNI_NEUROSYNTH**

# Web-based atlases

## LinkrBrain - coordinates



[A]u AFNI: AFNI_data6/afni/anat+tlrc & func_slim+tlrc

```
[order: RAI=DICOM]
x =     2.000 mm [L]
y =    74.000 mm [P]
z =    21.000 mm [S]
```

```
Query of coordinates to linkrbrain.org correlations

Task type                     Correlation
---------------------------------------
gaze                           0.01772
decision                       0.01565
item memory                    0.00943
conflict resolution            0.00926
face area                      0.00902
first language                 0.00902
navigation                     0.00824
neglect                        0.00660
cognitive effort               0.00598
gestures                       0.00502
familiar objects               0.00485
desire                         0.00481

For more information, pl
```

AFNI Cluster Results [A]

```
Voxels survived clustering =170173
Voxels edited out          =   8111
NN clustering level        =      1 [faces touch]
```

```
[No Aux Dataset chosen] [Scat.1D cleared]
##: __Size__  __X__  __Y__  __Z__                                Alpha
 1:122780vox  +33.0  +92.0  +15.0 Jump Flash Plot Save N/Csim
 2:11762 vox  -63.0  +12.0   -6.0 Jump Flash Plot Save N/Csim
 3: 3948 vox   -5.0  +39.0  +66.0 Jump Flash Plot Save N/Csim
                            .0  +24.0 Jump Flash Plot Save N/Csim
                            .0  +42.0 Jump Flash Plot Save N/Csim
                            .0  +60.0 Jump Flash Plot Save N/Csim
                            .0  +63.0 Jump Flash Plot Save N/Csim
                            .0  +27.0 Jump Flash Plot Save N/Csim
                            .0  +60.0 Jump Flash Plot Save N/Csim
                            .0  +15.0 Jump Flash Plot Save N/Csim
                            .0  +27.0 Jump Flash Plot Save N/Csim
                            .0  +21.0 Jump Flash Plot Save N/Csim
                            .0  +34.0 Jump Flash Plot Save N/Csim
```

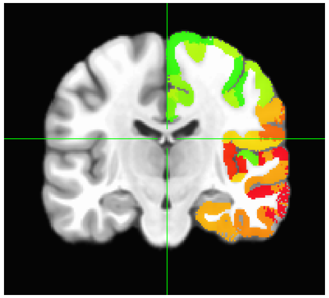
menu

```
Query of coordinates to linkrbrain.org correlations

Gene                             Correlation
---------------------------------------------
A_24_P721638                      0.01824
A_24_P945276                      0.01694
A_24_P918473                      0.01680
similar to deubiquitinating enzyme DUB2  0.01602
A_24_P853124                      0.01554
A_24_P460529                      0.01540
A_24_P706236                      0.01496
A_24_P7322                        0.01491
A_32_P118731                      0.01455
A_24_P499152                      0.01440
A_24_P607947                      0.01428
A_32_P170564                      0.01426

For more information, please visit linkrbrain.org
```

set **AFNI_LINKRBRAIN** to YES

# In Development

- New templates and template spaces – fully supported in AFNI
  - macaque
  - rat, mouse, human
  - pediatric, …
- On-the-fly transformations through all available template spaces
- Extra information about atlas structures
- HAWG standardized format – atlases for everyone!



HCP atlas - Glasser → Megan Robinson and Mike Beauchamp

# Supplements

extra stuff

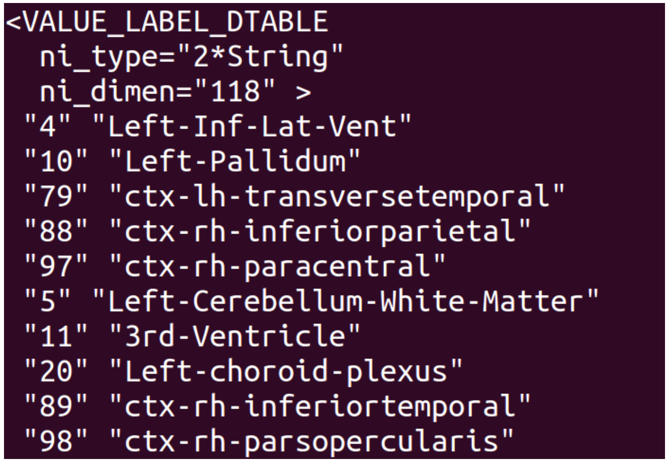
# S1: Labeltables

## Reading/creating labeltables

The text or string description of each ROI can be added to a dset by creating a “labeltable” that is either added to a file’s header or is a separate file pointed to in the header.

To view a labeltable on a dset:

**`3dinfo -labeltable DSET_NAME`**



```
<VALUE_LABEL_DTABLE
  ni_type="2*String"
  ni_dimen="118" >
 "4" "Left-Inf-Lat-Vent"
 "10"  "Left-Pallidum"
 "79"  "ctx-lh-transversetemporal"
 "88"  "ctx-rh-inferiorparietal"
 "97"  "ctx-rh-paracentral"
 "5" "Left-Cerebellum-White-Matter"
 "11"  "3rd-Ventricle"
 "20"  "Left-choroid-plexus"
 "89"  "ctx-rh-inferiortemporal"
 "98"  "ctx-rh-parsopercularis"
```

# S1: Labeltables

## Reading/creating labeltables

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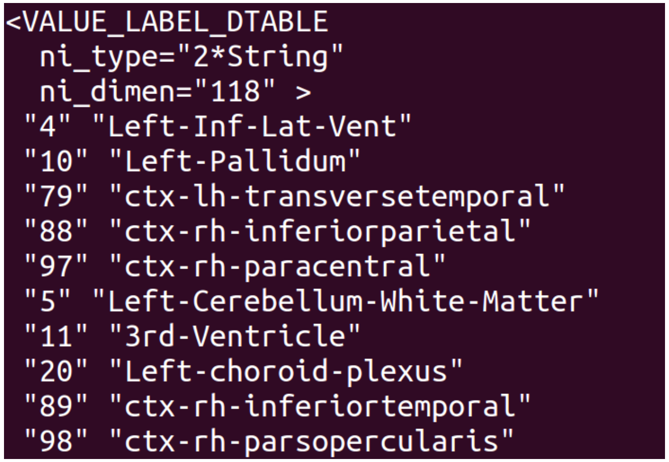
To view a labeltable on a dset:

```
3dinfo -labeltable DSET_NAME
```



```
<VALUE_LABEL_DTABLE
  ni_type="2*String"
  ni_dimen="118" >
 "4" "Left-Inf-Lat-Vent"
 "10" "Left-Pallidum"
 "79" "ctx-lh-transversetemporal"
 "88" "ctx-rh-inferiorparietal"
 "97" "ctx-rh-paracentral"
 "5" "Left-Cerebellum-White-Matter"
 "11" "3rd-Ventricle"
 "20" "Left-choroid-plexus"
 "89" "ctx-rh-inferiortemporal"
 "98" "ctx-rh-parsopercularis"
```

To make a labeltable and attach it to a file:

```
@MakeLabelTable                      \
    -lab_file   LABEL_FILE 1 0   \
    -labeltable OUTPUT_LT            \
    -dset       DSET_NAME
```

where `LABEL_FILE` contains one column of integer keys and one column of string values; `OUTPUT_LT` is the name for the created new table; and `DSET_NAME` is the dset it gets attached to.

# S2: Manual transform to Talairach space using AFNI GUI

To start, right click on "DataDir" in the GUI or set AFNI_ENABLE_MARKERS to YES in ~/.afnirc.

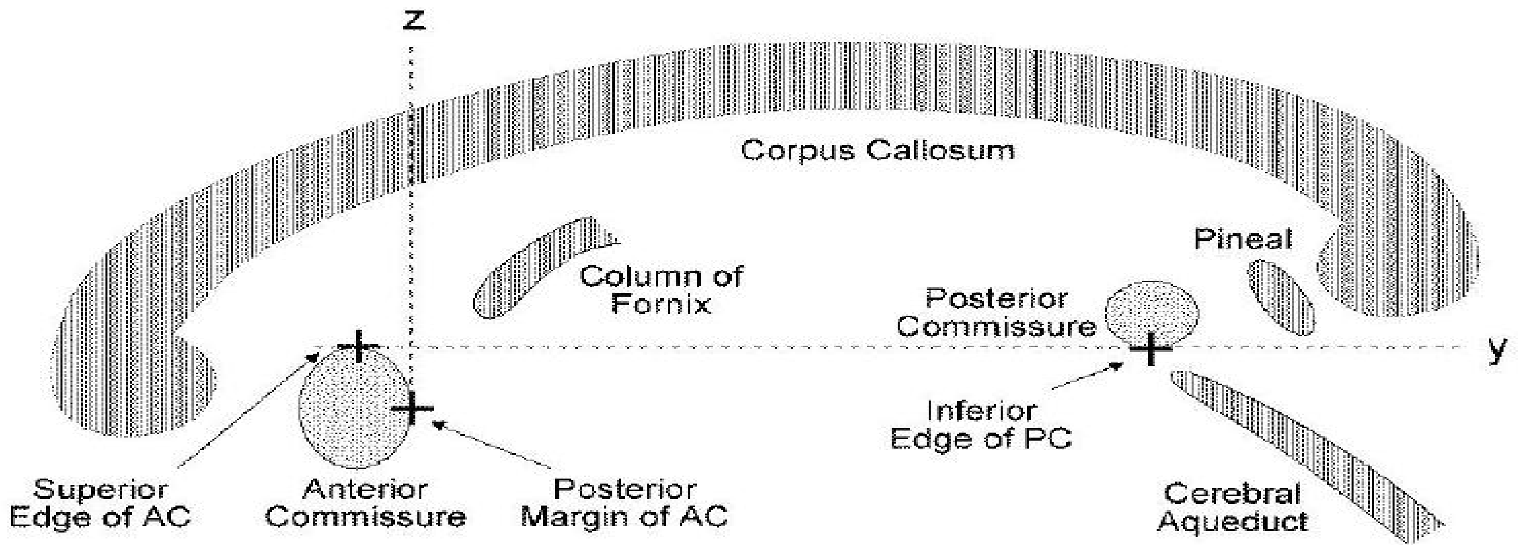
Manual Transformation proceeds in two stages:

1) Alignment of AC-PC and I-S axes (to +acpc coordinates)
2) Scaling to Talairach-Tournoux Atlas brain size (to +tlrc coordinates)

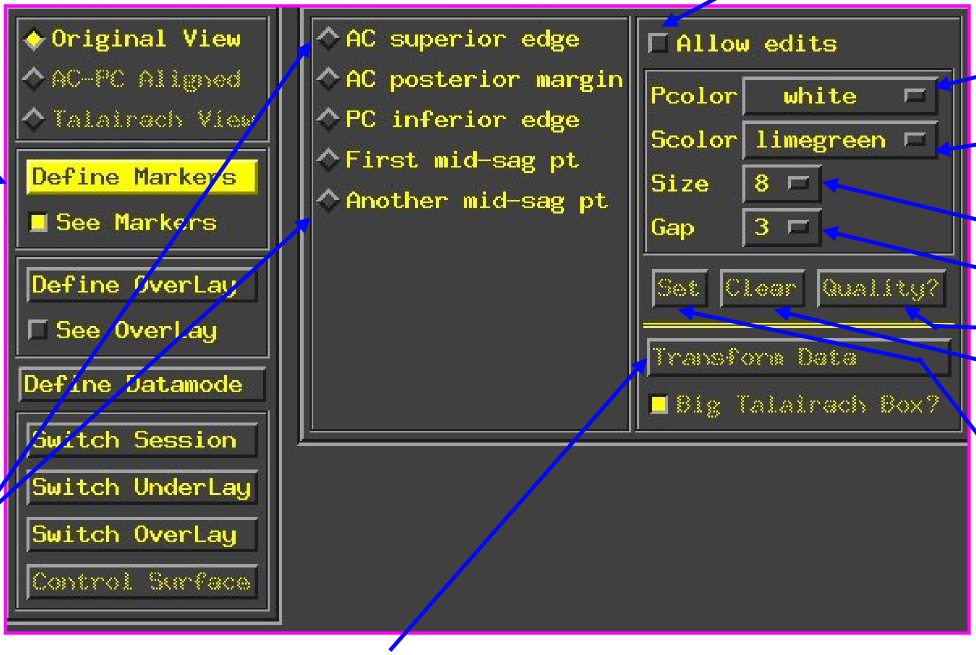
- Stage 1: Alignment to **+acpc** coordinates:
  - Anterior commissure (AC) and posterior commissure (PC) are aligned to be the y-axis
  - The longitudinal (inter-hemispheric or mid-sagittal) fissure is aligned to be the yz-plane, thus defining the z-axis
  - The axis perpendicular to these is the x-axis (right-left)
  - Five markers that you must place using the [Define Markers] control panel:

    AC superior edge = top middle of anterior commissure
    AC posterior margin = rear middle of anterior commissure
    PC inferior edge = bottom middle of posterior commissure
    First mid-sag point = some point in the mid-sagittal plane
    Another mid-sag point = some other point in the mid-sagittal plane

  - This procedure tries to follow the Atlas as precisely as possible
    - Even at the cost of confusion to the user (e.g., you)



Press this IN to create or change markers



Pcolor white
Scolor limegreen
Size 8
Gap 3

Click Define Markers to open the "markers" panel

Color of "primary" (selected) marker

Color of "secondary" (not selected) markers

Size of markers (pixels)

Size of gap in markers

Clear (unset) primary marker

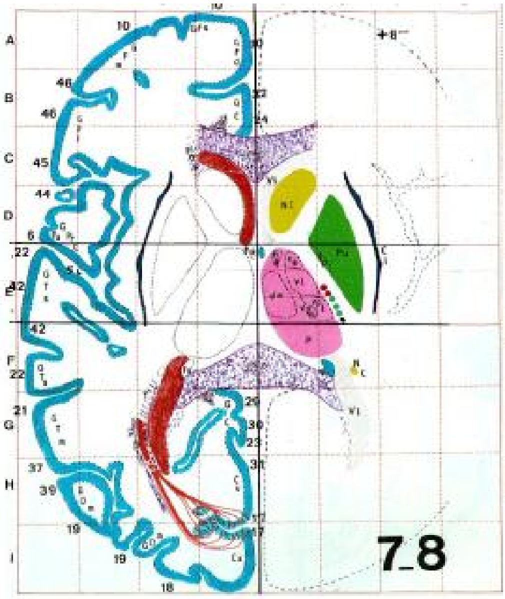
Set primary marker to current focus location

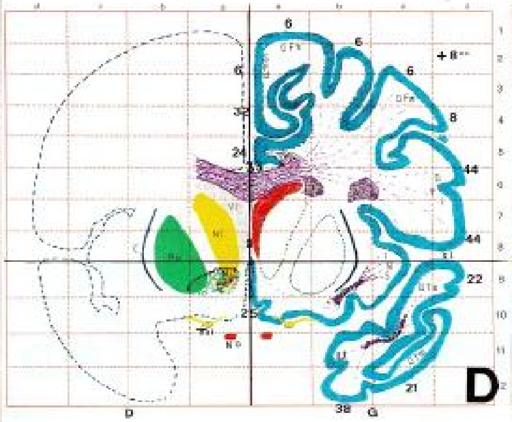
Select which marker you are editing

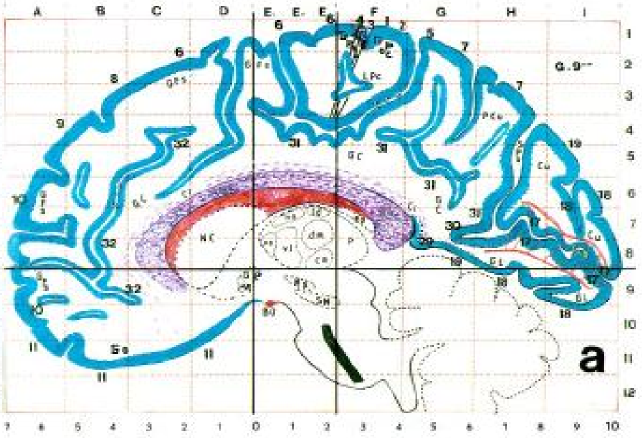
Carry out transformation to +acpc coordinates

Perform "quality" check on markers (after all 5 are set)

- **Stage 2: Scaling to Talairach-Tournoux (+tlrc) coordinates**:
  - Once the AC-PC landmarks are set and we are in ACPC view, we now stretch/shrink the brain to fit the Talairach-Tournoux Atlas brain size (sample TT Atlas pages shown below, just for fun)

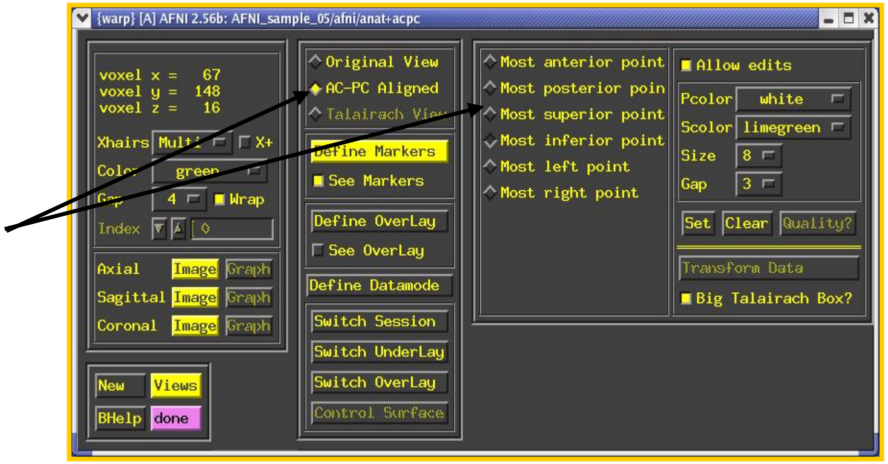






- **Selecting the Talairach-Tournoux markers for the bounding box**:
  - There are 12 sub-regions to be scaled (3 A-P x 2 I-S x 2 L-R)
  - To enable this, the transformed `+acpc` dataset gets its own set of markers
    - Click on the **[AC-PC Aligned]** button to view our volume in ac-pc coordinates
    - Select the **[Define Markers]** control panel
  - A new set of six Talairach markers will appear and the user now sets the bounding box markers (see Appendix C for details):

**Talairach markers appear only when the AC-PC view is highlighted**



{warp} [A] AFNI 2.56b: AFNI_sample_05/afni/anat+acpc

voxel x = 67
voxel y = 148
voxel z = 16

Xhairs Multi ☐ X+
Color green
Gap 4 ■ Wrap
Index 0

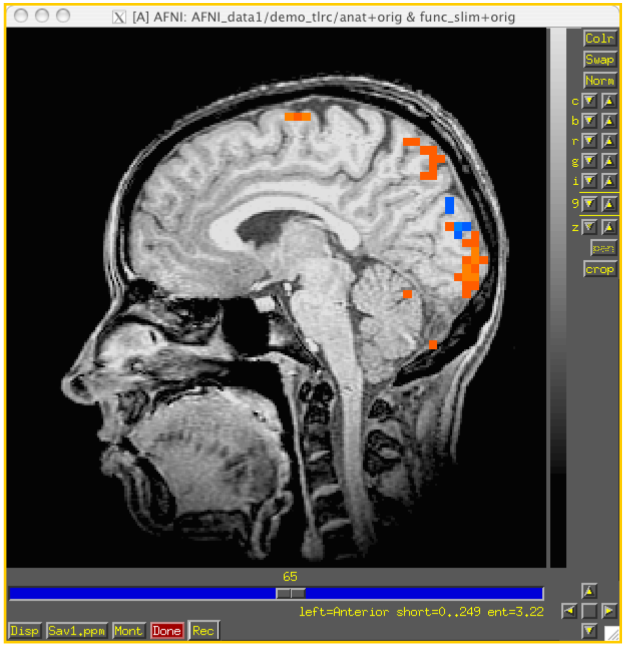
Pcolor white
Scolor limegreen
Size 8
Gap 3

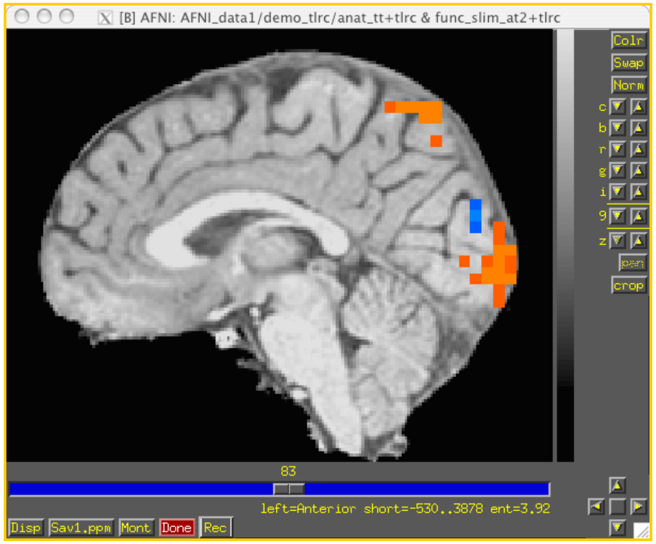
  - Once all the markers are set, and the quality tests passed. Pressing **[Transform Data]** will write new ***header*** containing the Talairach transformations (see Appendix C for details)
    - Recall: With AFNI, spatial transformations are stored in the header of the output

# @auto_tlrc Results are Comparable to Manual TLRCing

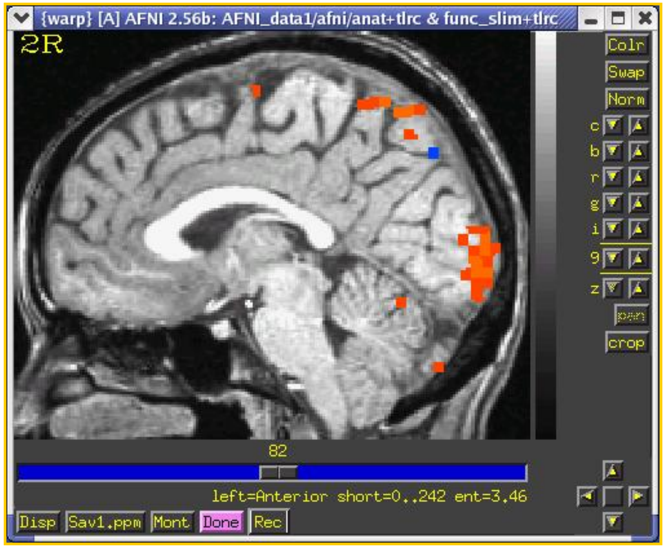
Comparison of results from “follower” func dsets: similar reduction in spurious voxels with high correlation.

**Original**





**@auto_tlrc**



**Manual**