TEMPLATES AND ATLASES

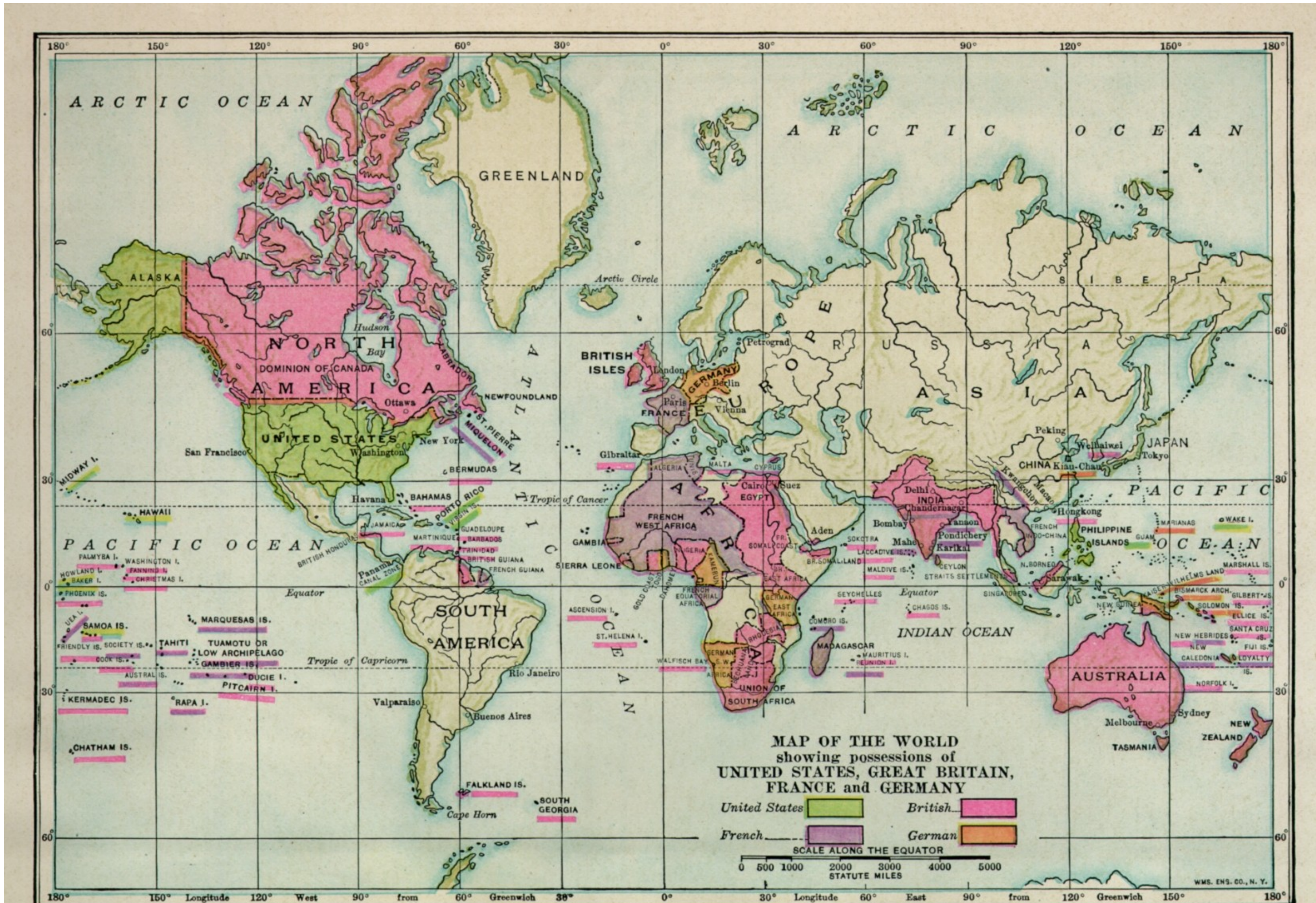


FIG. 1.

Abbrevs used here

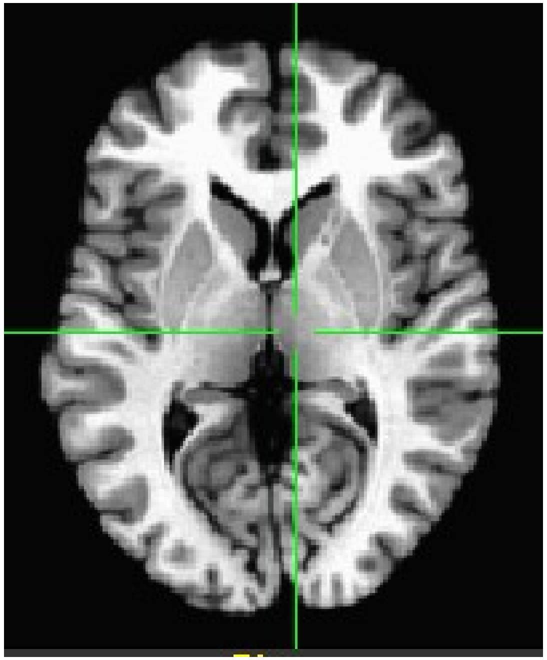
abbrev	= abbreviation
AKA	= also known as
anat	= anatomical
corr	= correlation
diff	= difference
dset	= dataset
e.g.	= exempli gratia (= "for example")
EPI	= echo planar image
Ex	= example
FOV	= field of view
i.e.	= id est (= "that is")
ijk	= coordinate indices (integer)
NB	= nota bene (= "note well")
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.



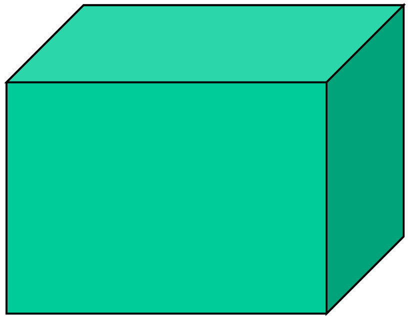
TT_N27+tlrc

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).

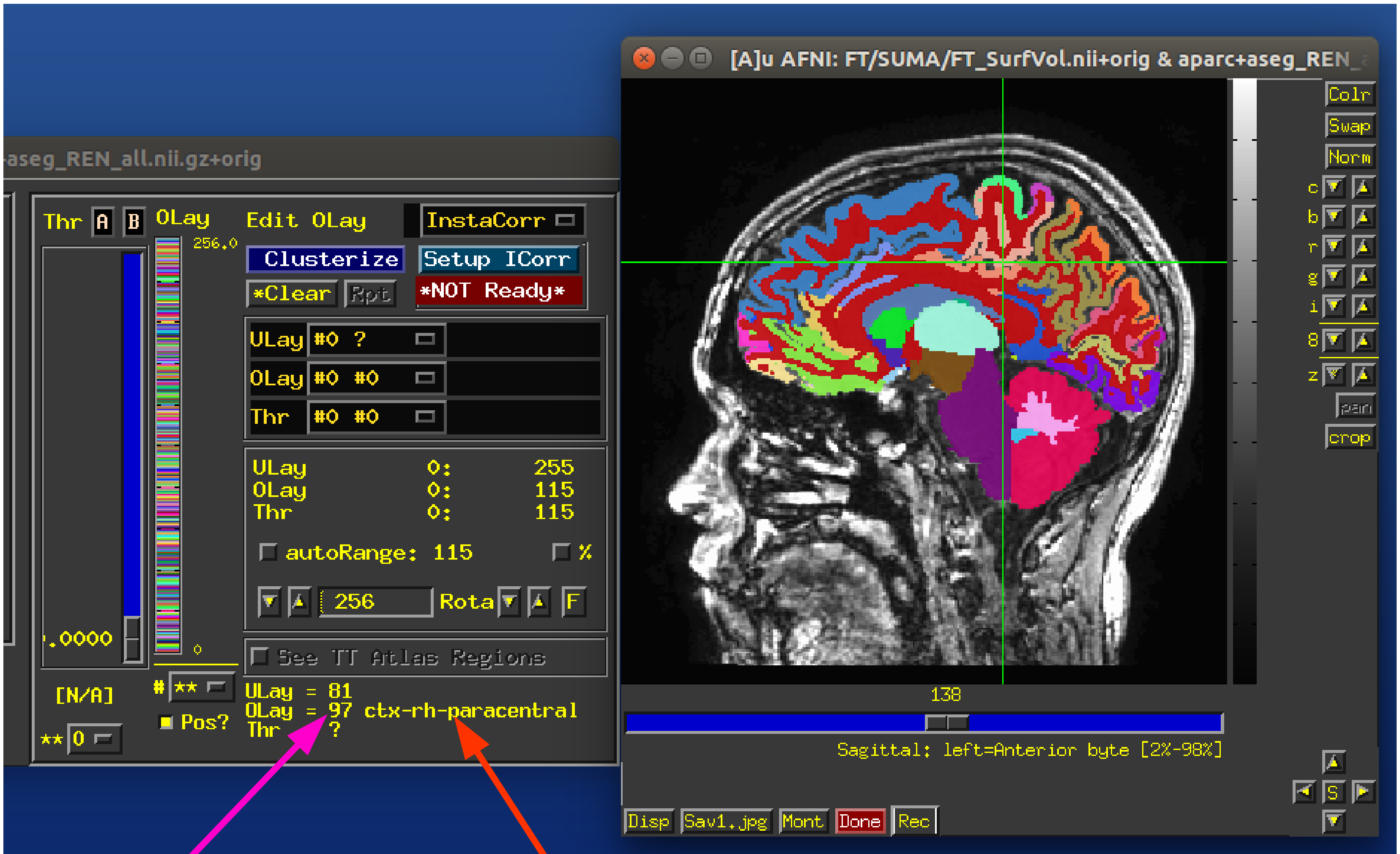
Ex: Brodmann_pijn_afni.nii.gz, my_roidset+orig.

Brodmann_pijn_afni.nii.gz

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



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

MNI_CAEZ_N27

MNI152_T1_2009c

Haskins_Peds

What important properties does each dset here have?

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

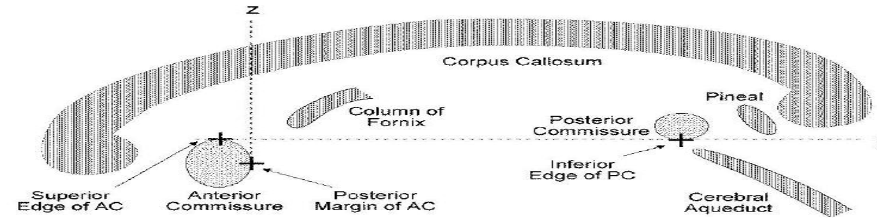
Try to pick a template that...

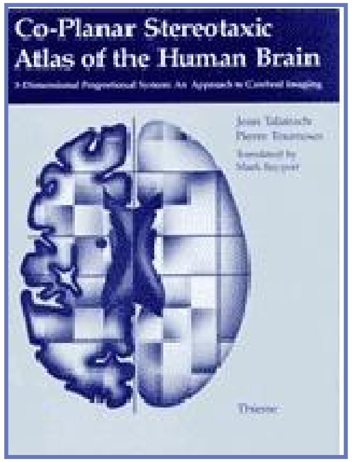
- is similar to the subject group: neonates, pediatric, young adults, elderly, macaque, rabbit...
- is of the same modality and coverage as your data sets
- has a relevant atlas segmentation.

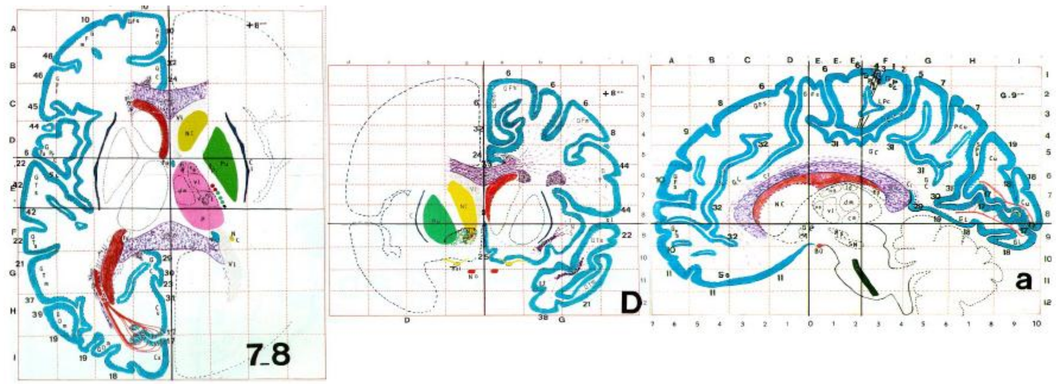
You can also make your own template (and maybe an atlas too):

- 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**
      - **And soonish make_template_dask.py**

Talairach Templates, Procedures







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

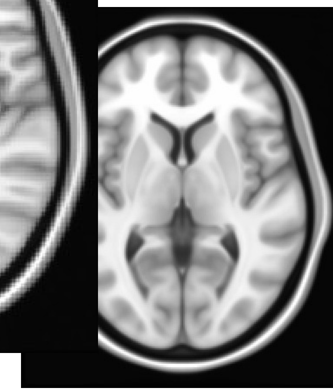
The Many Faces of MNI Templates

MNI_305 -
the first MNI template, ("sort of Talairach AC-PC") 1992

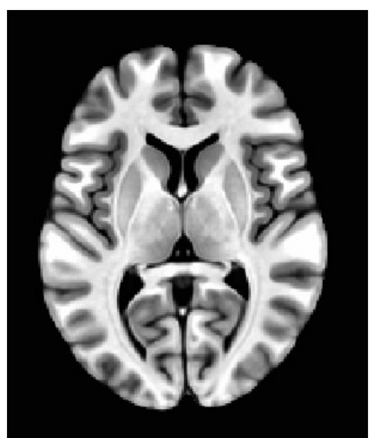
MNI N27
MNI_caez_N27, "Colin brain", 1998

MNI_152 (2mm)
MNI cohort of ICBM452, 2001

MNI_2006 asym
"6th generation"
(FSL,SPM)



MNI_2006 sym
(MNI)

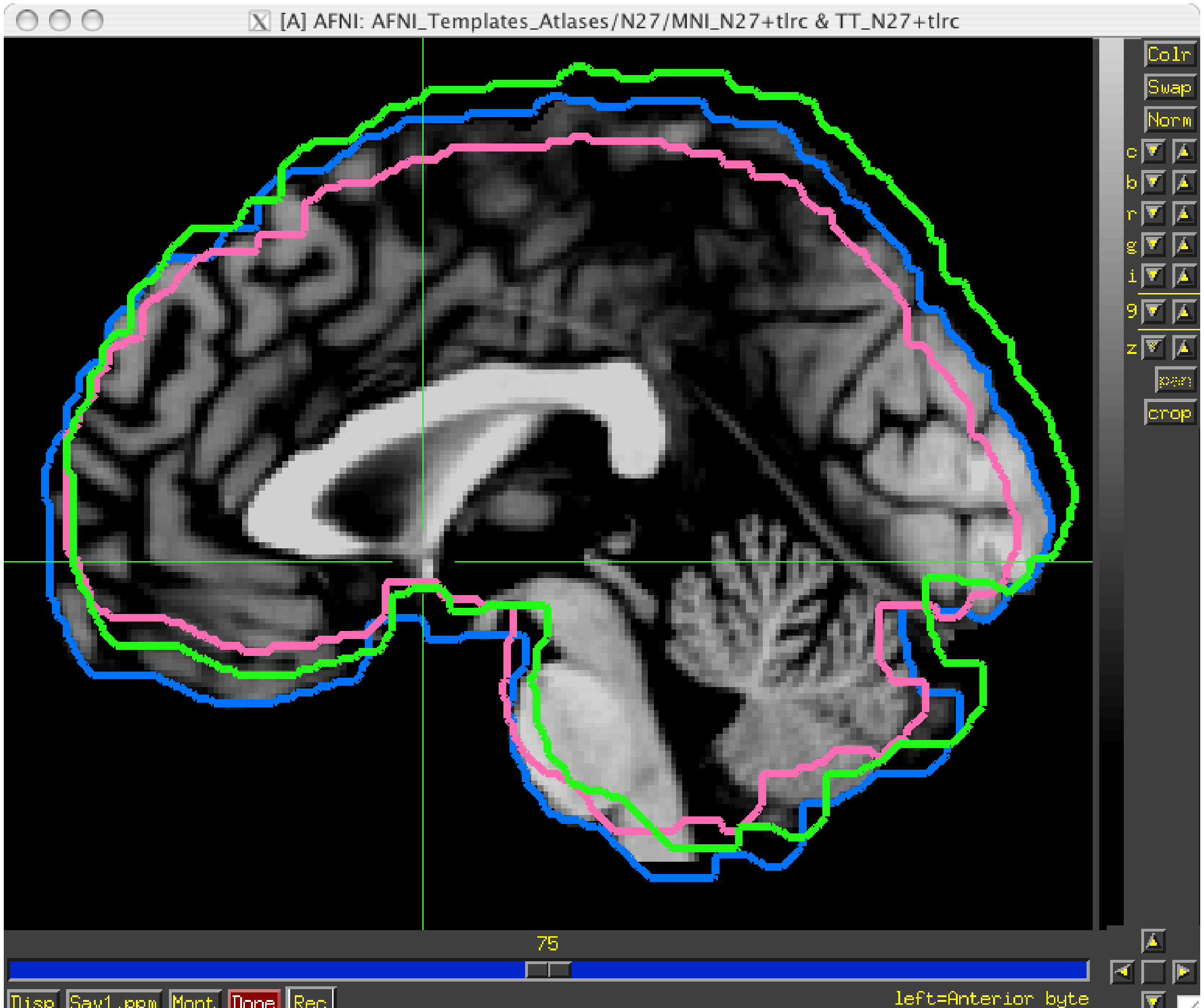


MNI_2009c asymmetric. Unifized in AFNI. a,b,c versions, symmetric/asymmetric, different grids 1mm,0.5mm, 2011

+Other MNIs: MNI_ANAT (SPM Anatomy Toolbox), HCP40, HCP900, Mai-MNI,....

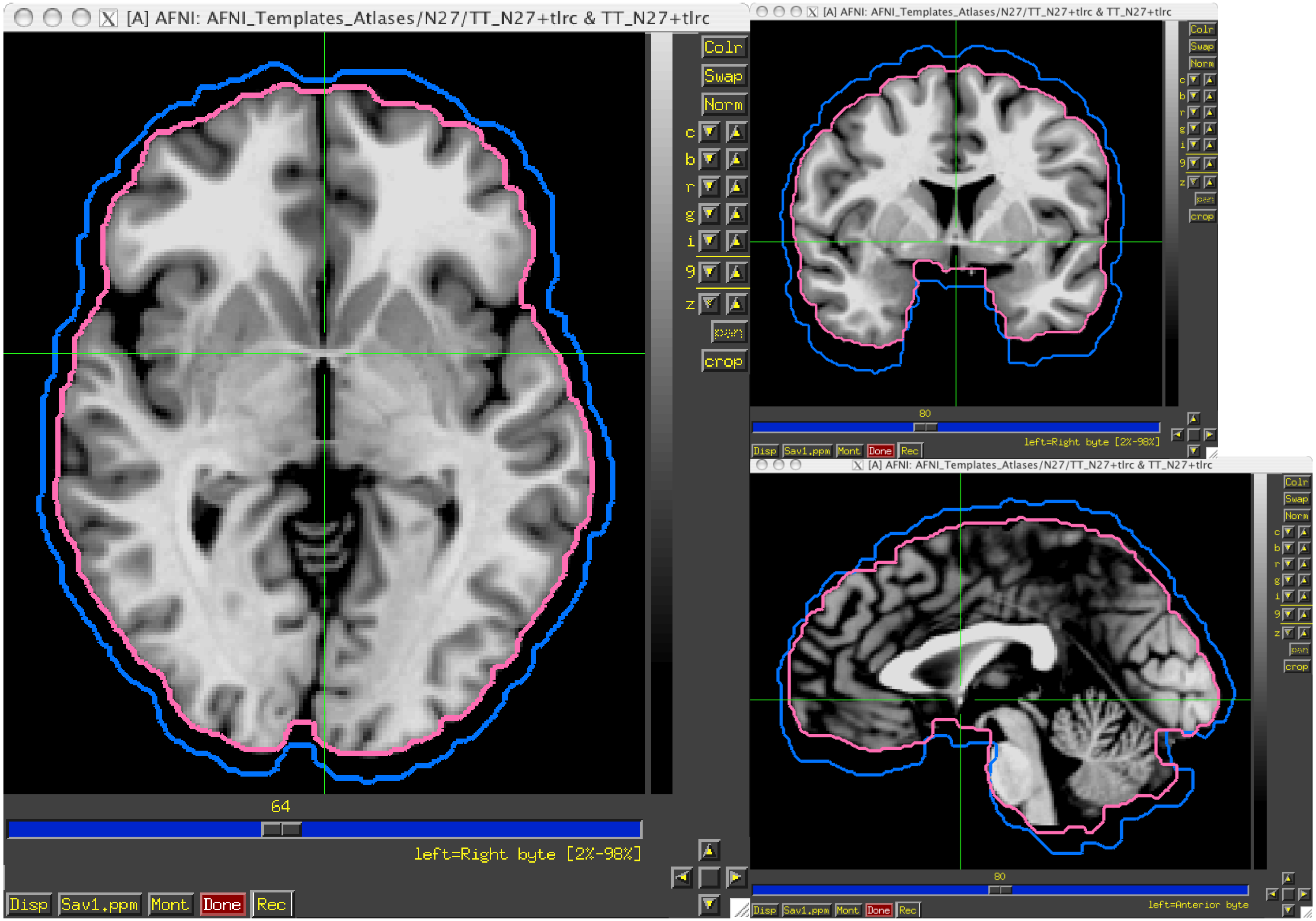
Template spaces differ in origin

TLRC, MNI, and MNI-Anat



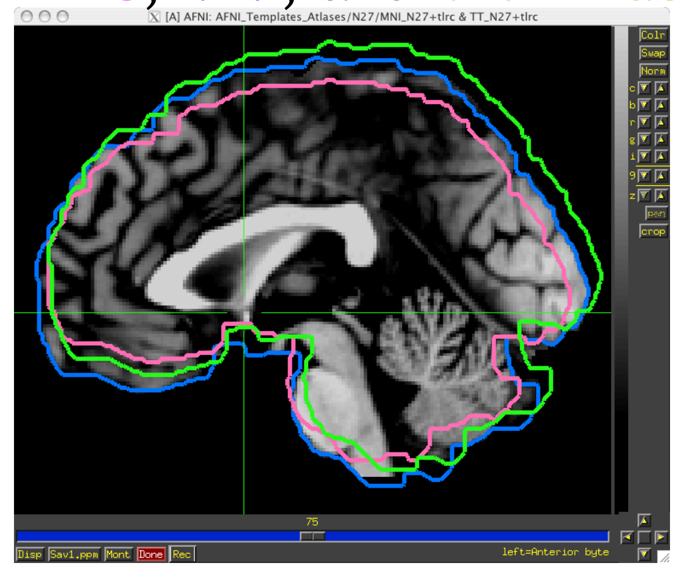
Template spaces differ in size

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



From space to space

TLRC, MNI, and MNI-Anat



<u>For going between TLRC and MNI:</u>

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`**)

<u>For going between MNI and MNI Anat (Eickhoff et al., 2005):</u>

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

<u>Going between TLRC and MNI Anat (as practiced in whereami):</u>

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

Add (0, 4, 5)

Finding your space

```
3dinfo -space -prefix *.HEAD *.nii.gz
HaskinsPeds                         HaskinsPeds_NL_atlas1.01
HaskinsPeds                       HaskinsPeds_NL_template1.0
MNI_N27                                        MNI_caez_N27
MNI_N27                                      MNI_caez_gw_18
MNI_N27                                      MNI_caez_lr_18
MNI_N27                                      MNI_caez_ml_18
MNI_N27                                     MNI_caez_mpm_22
MNI_N27                                              TT_N27
MNI_N27                                       TT_caez_gw_18
TT_N27                                        TT_caez_lr_18
TT_N27                                        TT_caez_ml_18
TT_N27                                       TT_caez_mpm_22
MNI                             BN_Atlas_246_1mm.nii.gz
MNI_N27                                     Brodmann.nii.gz
MNI_2009c_asym                     Brodmann_pijn_afni.nii.gz
MNI_2009c_asym                  FS.afni.MNI2009c_asym.nii.gz
TT_N27                                 FS.afni.TTN27.nii.gz
HaskinsPeds HaskinsPeds_NL_template1.0_SSW.nii.gz
MNI_2009c_asym                        Julich_MNI2009c.nii.gz
MNI_N27                                Julich_MNI_N27.nii.gz
MNI_2009c_asym                 MNI152_2009_template.nii.gz
MNI_2009c_asym             MNI152_2009_template_SSW.nii.gz
MNI_2009c_asym                 MNI_Glasser_HCP_v1.0.nii.gz
```

Templates included with AFNI

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

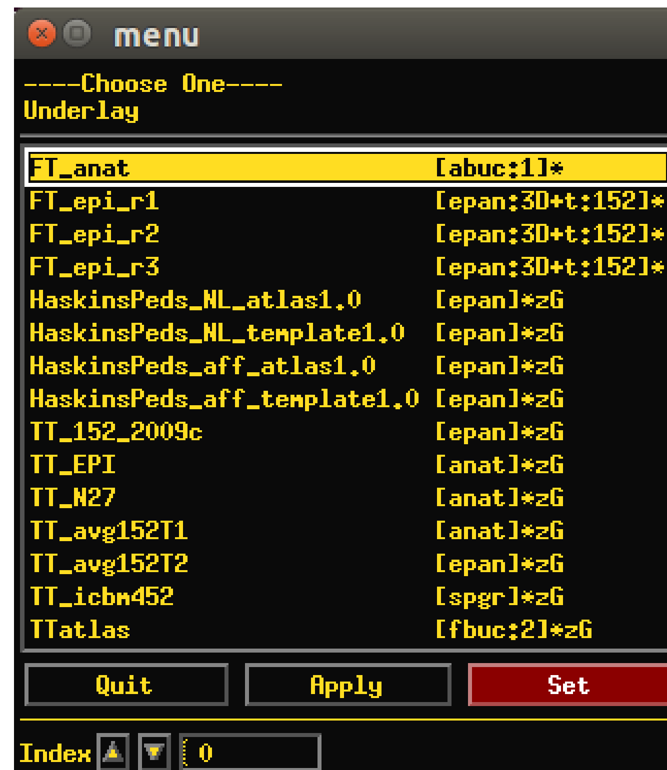
Set the **AFNI_GLOBAL_SESSION** variable in your ~/.afnirc file, e.g.,:

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

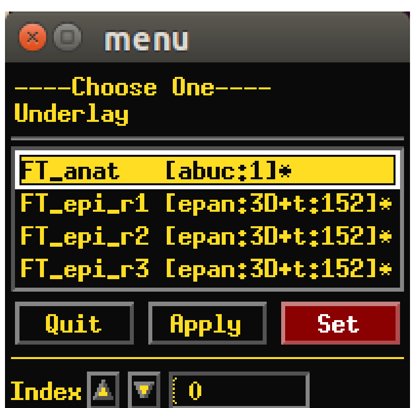
All dsets there will appear in your "Underlay" or "Overlay" menu in the AFNI GUI. (Use full path of directory, no "~" or "$HOME".)

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

after



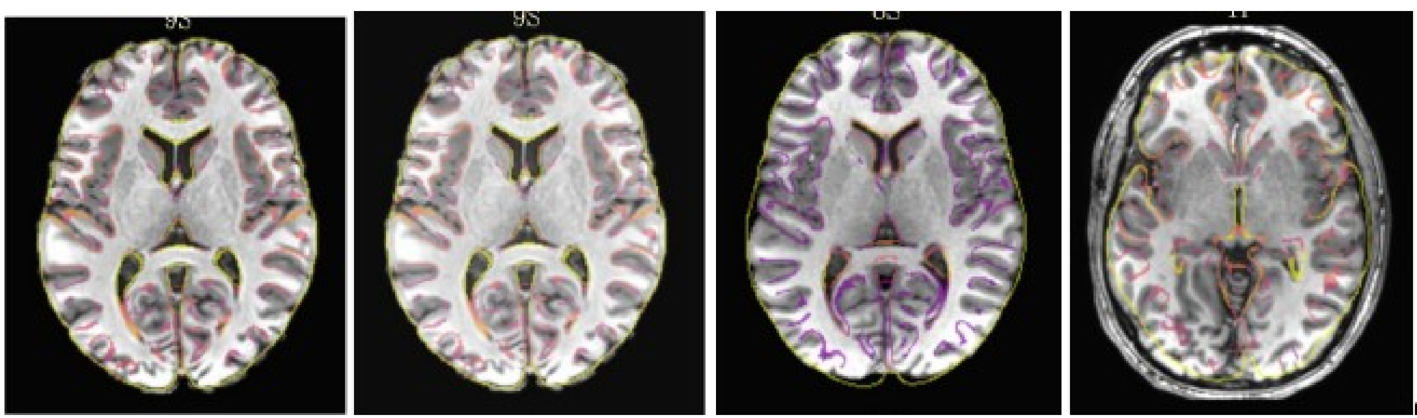
before



Trading Spaces

How to transform data to a standard template space

- **@SSwarper** – skullstrip and align data to some select standard spaces
- **@animal_warper -** skullstrip, align data to animal template and bring atlas into native space
- **auto_warp.py** -combination affine and nonlinear alignment to a template
- **@auto_tlrc** – affine alignment to a template
- Manual talairach



@SSW AW @at manual

Trading Spaces with afni_proc.py

```
-blocks ... tlrc volreg
-volreg_tlrc_warp
-tlrc_base $tpath/$btemplate      (runs @auto_tlrc)
-tlrc_NL_warp                     (runs auto_warp.py)
```

For @SSwarper output, add these:

```
-copy_anat anatSS.${subj}.nii          \
-anat_has_skull no                     \
-tlrc_NL_warp                          \
-tlrc_NL_warped_dsets                  \
         anatQQ.${subj}.nii            \
         anatQQ.${subj}.aff12.1D       \
         anatQQ.${subj}_WARP.nii
```

Standard spaces

Reasons to use a standard template space:

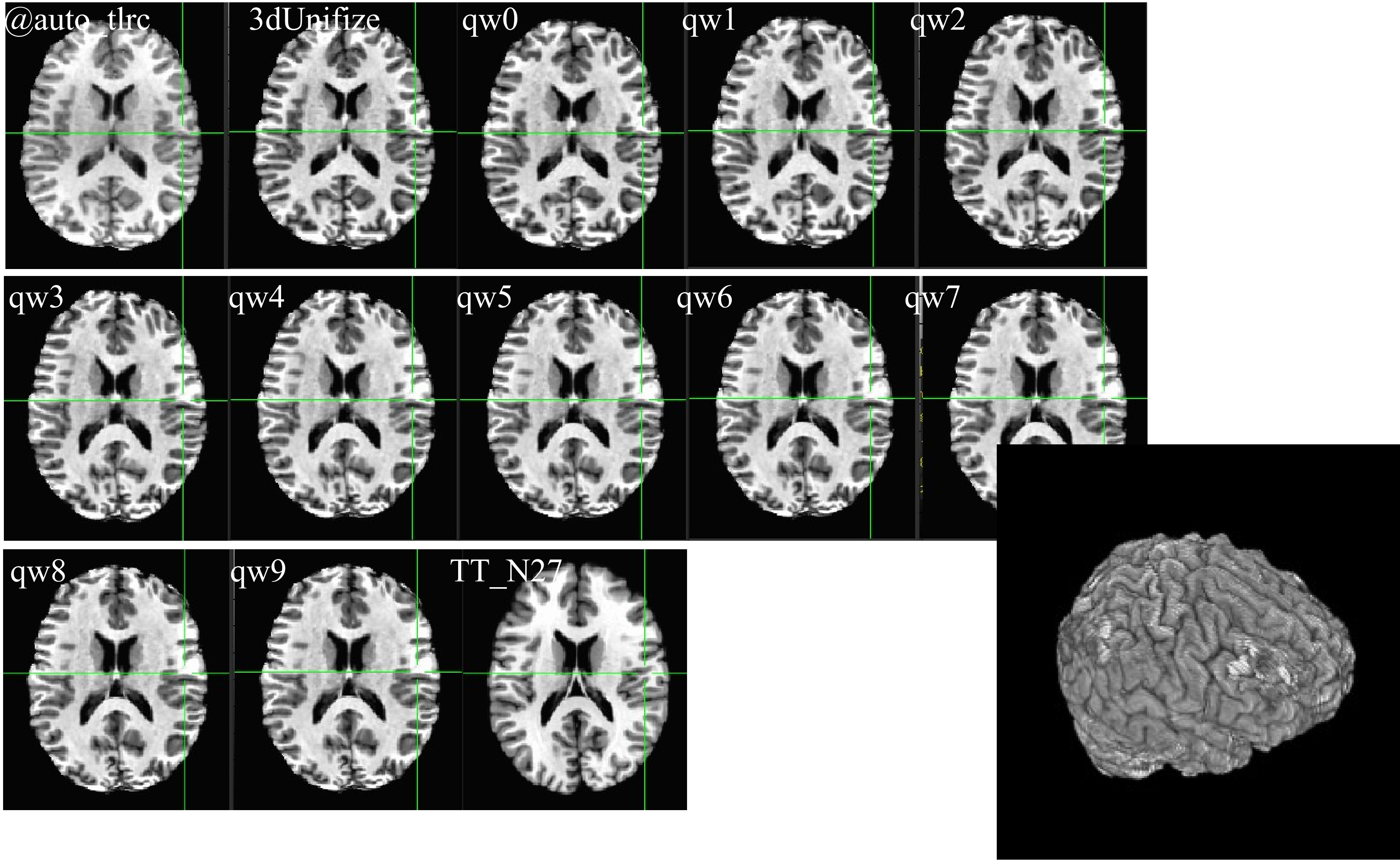
- Compare across subjects and groups easily for every voxel in the brain
- Standardize coordinates with others
- Know where a voxel is automatically from an atlas
- Mostly automated and no specific ROI drawing required

Reasons <u>not</u> 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
- Methods like DTI require much of the processing to be done in subject space
- Surface analysis
- Surgical, subject-specific coordinates for TMS, DBS (but can still use template alignment to move atlases to subject space)

Nonlinear alignment to template

3dQwarp, through multiple levels of refinement →



Nonlinear alignment to template

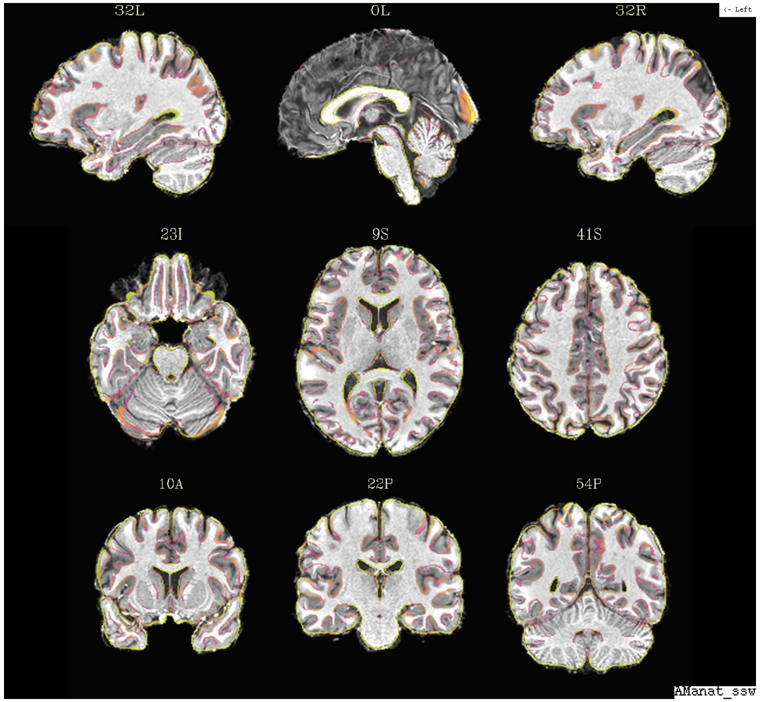
Multiple nonlinear alignment tools in AFNI

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



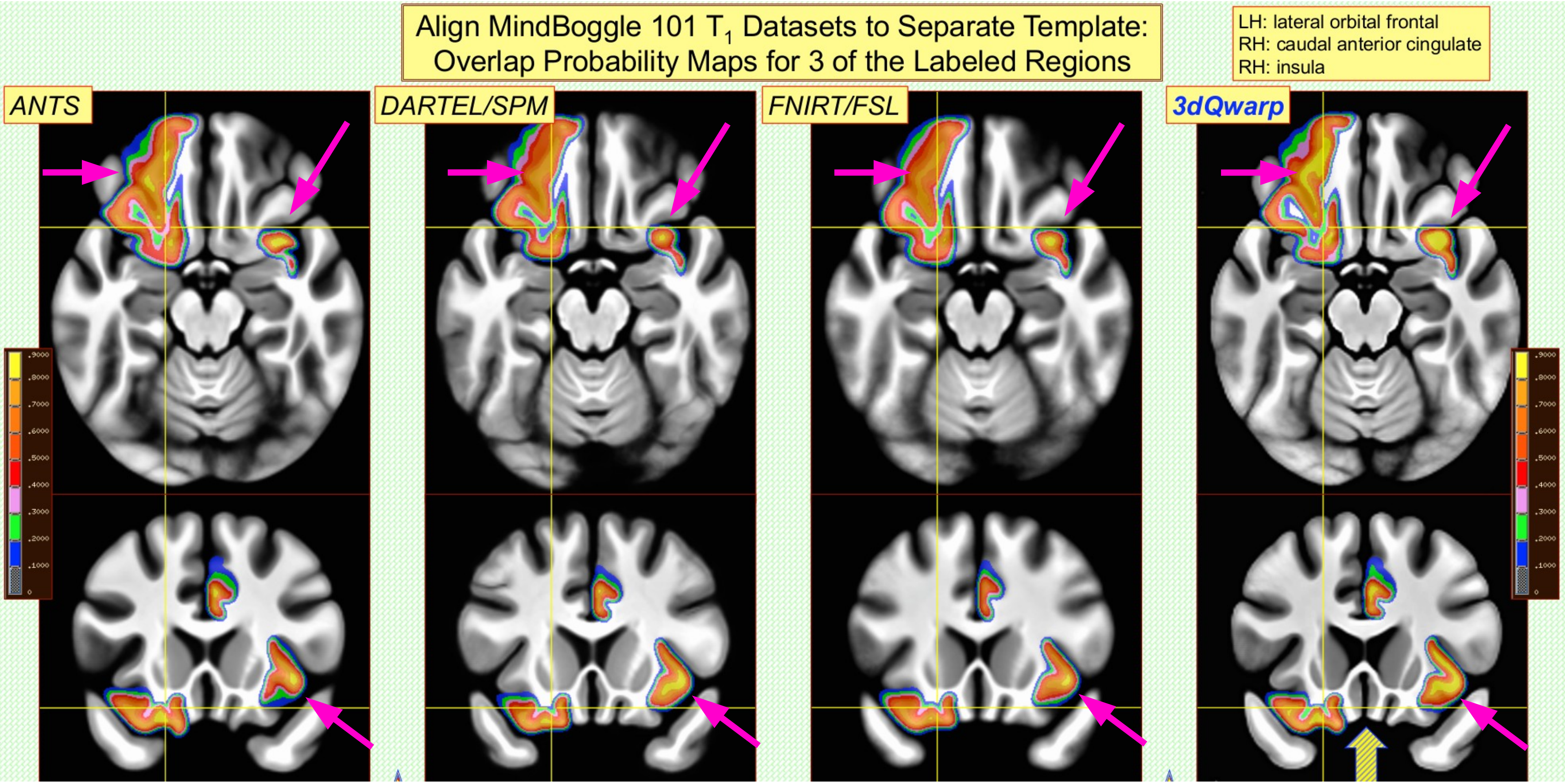
+ @SSwarper uses a multi-volume base; several exist for standard templates already, and more can be made-- see full description for these online:

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

Measuring quality of alignment

<u>Can compare 3dQwarp with other available nonlinear alignment tools</u>

+ For a group of subjects, estimate warp from anat to template
+ Apply warp to labeled ROIs, and measure % overlap in results. (Yellow: >90% overlap)



ANTS, DARTEL and FNIRT run with default settings

(Cox & Glen, 2013, OHBM)

2023 Atlas Overhaul
a new dawn, a new day

Cleaning Up:

Removal of TTatlas+tlrc - Talairach daemon

Removal of other older SPM Anatomy Toolbox atlases, no MNI_ANAT atlases

Adding On:

Addition of Brodmann-Pijnenburg atlases MNI_N27 and MNI_2009d

Addition of JulichBrain atlases for MNI_N27 and MNI_2009c

Addition of FreeSurfer atlases for TT_N27 and MNI_2009c

Making Changes:

Default Atlas for “Show atlas colors”, “Go to atlas location” is Brodmann_Pijn_AFNI (MNI_2009c)

Atlases identified with specific template spaces for MNI - MNI_N27, MNI_2009c.

Atlas versions and description in AFNI header and in NIFTI header

Default atlas search updated

Default template space list for coordinates shown is TLRC, MNI (no MNI_ANAT)

Going where the atlases live

AFNI binary directory for datasets and configuration

AFNI_atlas_spaces.niml describe the distributed atlases

CustomAtlases.niml and SessionAtlases.niml allow for more atlases and templates

Saving the Environment (in .afnirc)

AFNI_ATLAS_LIST "CA_ML_18_MNI,DKD_Desai_MPM" "ALL"

AFNI_TEMPLATE_SPACE_LIST “MNI,TLRC”

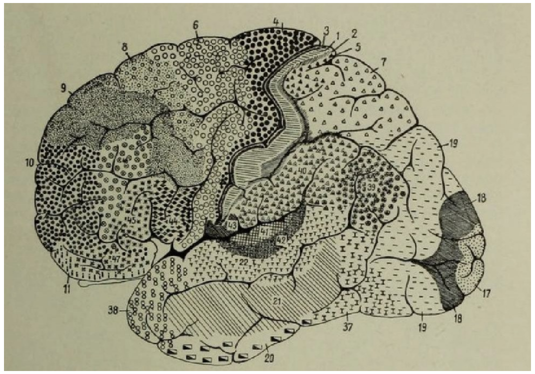
AFNI_ATLAS_COLORS CA_ML_18_MNI

AFNI_SUPP_ATLAS_DIR ~/MyAtlases

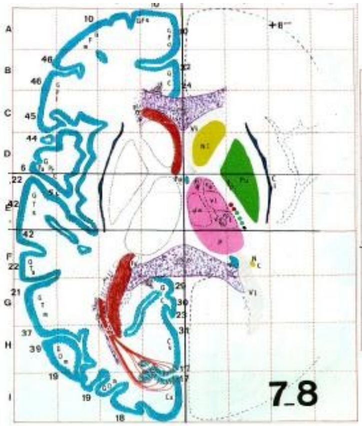
AFNI_WHEREAMI_DEC_PLACES 2

AFNI_WHEREAMI_MAX_SEARCH_RAD 3

Early Atlases -Talairach Daemon

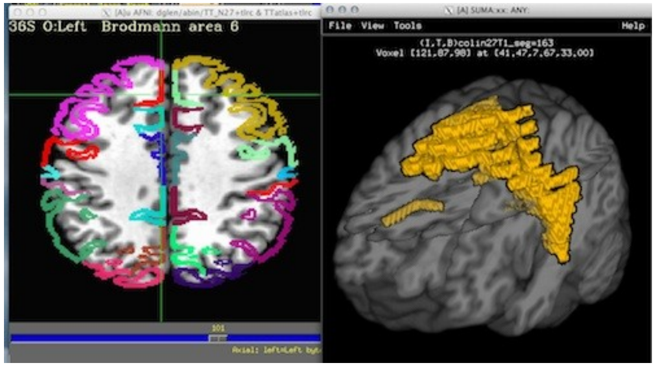


Brodmann, 1909

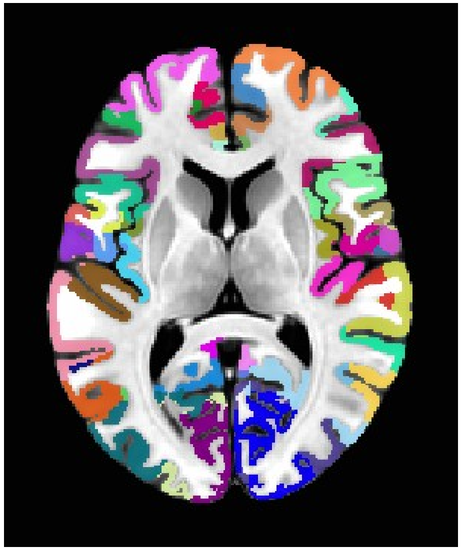


Talairach, 1988
Half brain- 5mm slices
No MRI volume

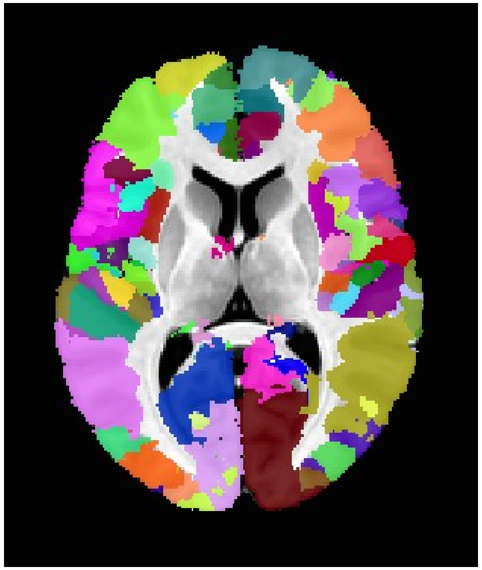
Lancaster, 2000



Removed from
AFNI, 2023?

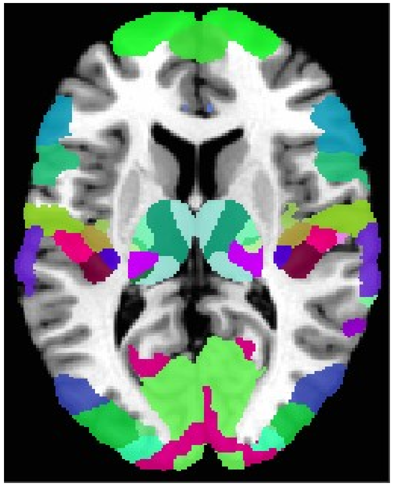


Brodmann-Pijnenburg
"Classical atlases" - Heuvel group
MNI_N27
MNI_2009c (AFNI reprojection)

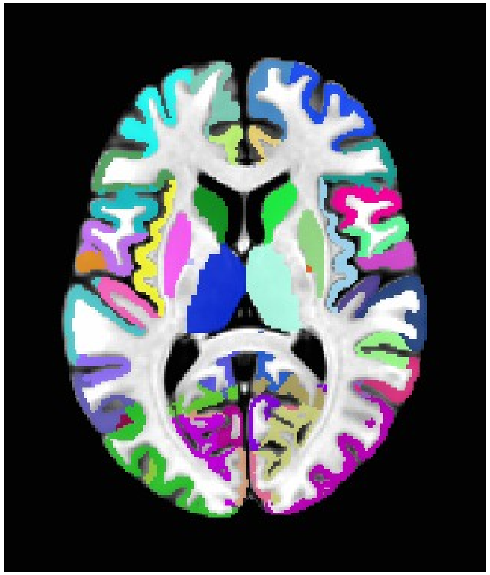


JulichBrain 3.0
(replacing Eickhoff-Zilles atlases)
157 region MPM (probabilistic available from EBRAINS)
MNI_N27
MNI_2009c
(AFNI working with EBRAINS and Julich groups for updates)

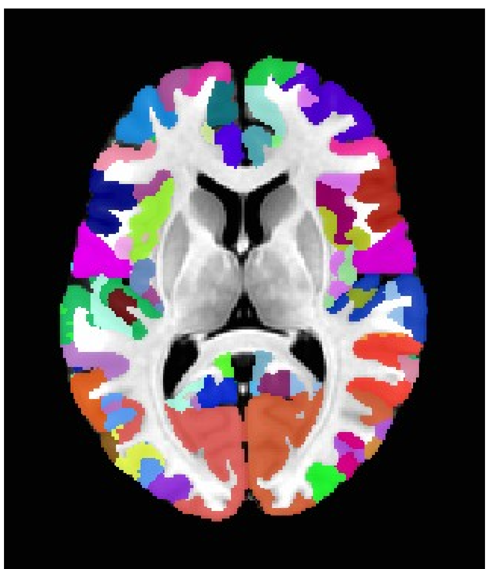
Eickhoff-Zilles Macrolabel (AAL)
MNI_N27 (shifted)
TT_N27 (transformed)



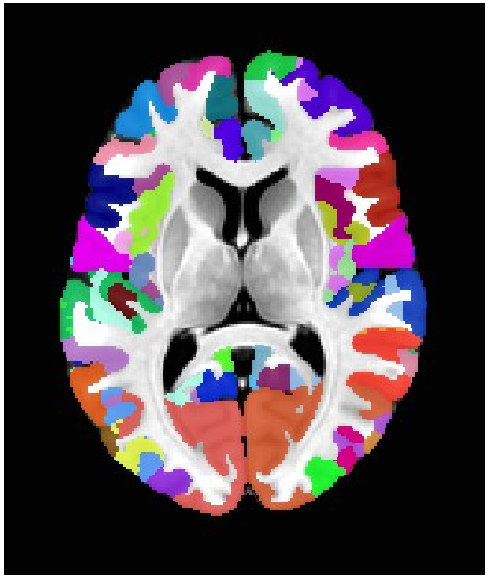
Eickhoff-Zilles MPM 2.2
MNI_N27 (shifted)
TT_N27 (transformed)
10 subject probabilistic atlases also available



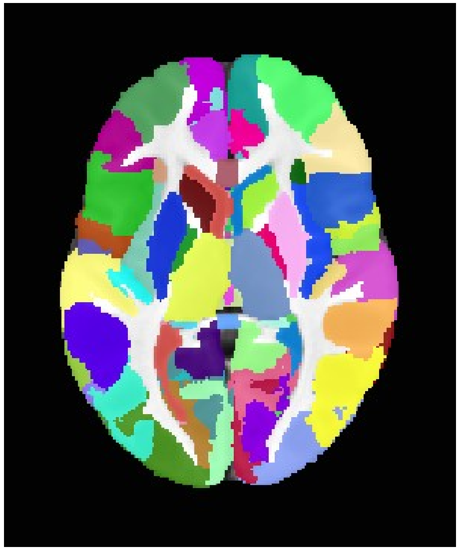
Freesurfer recon-all
Destrieux Gray matter regions
TT_N27
MNI_2009c



HCP Glasser
360 region - FMRI task-based
MNI_2009c - AFNI projection with Megan Robinson, Michael Beauchamp - Baylor

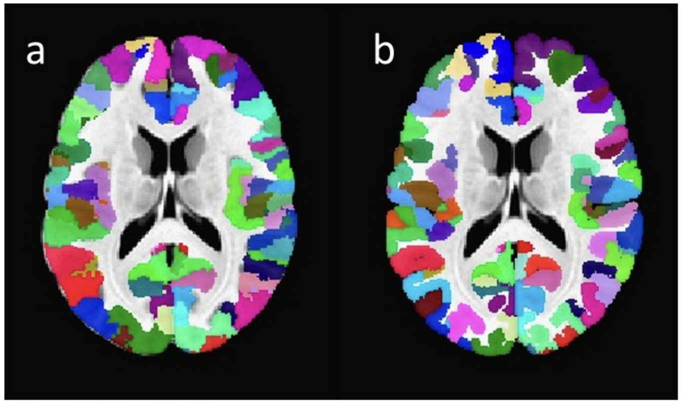


Brainnetome
DTI-based, L. Fan, T. Jiang
HCP-40 (~MNI_2009c)
246 regions

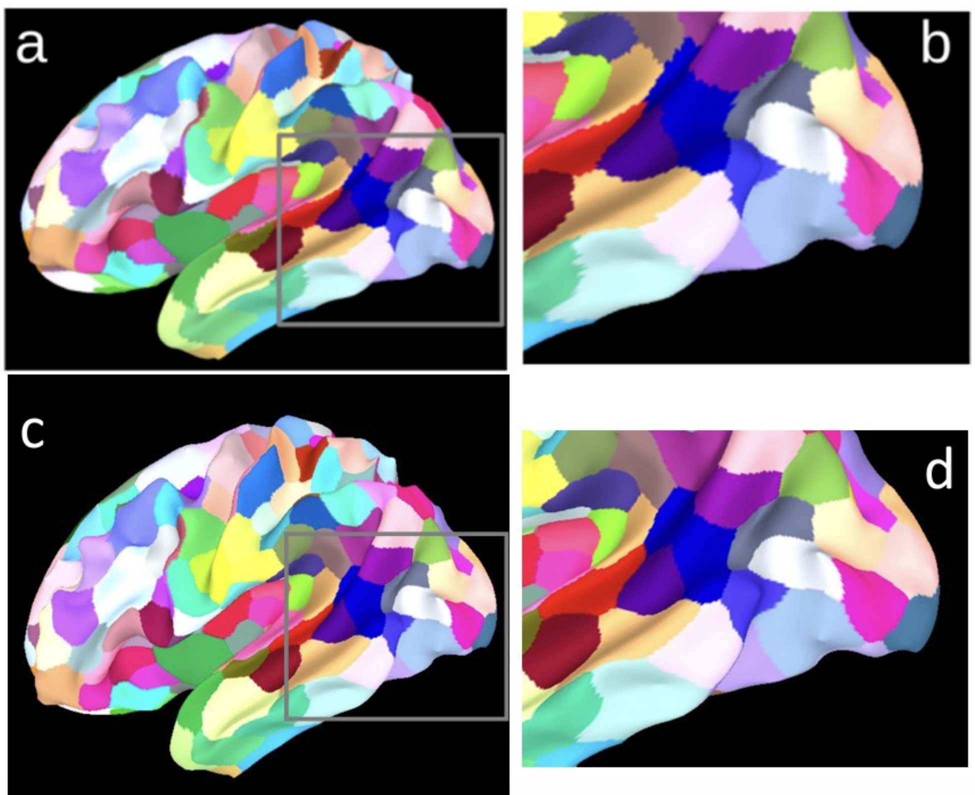


Haskins Pediatric
MNI_2009c
75-subject 10 year old median age
(6-13 years)
AFNI-Haskins, P. Molfese

Schaefer-Yeo atlases -available on AFNI website



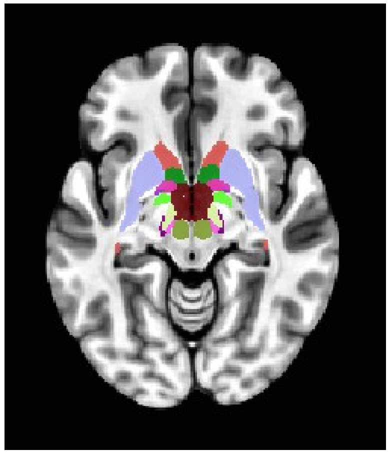
Resting state based regions of similar sizes labeled by overlap with 7 or 17 resting state networks and anatomical regions.



100 - 1000 regions per atlas

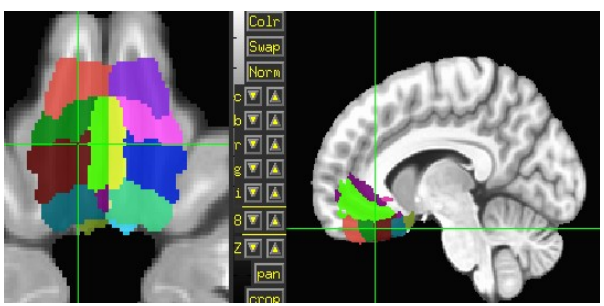
AFNI version
Modally smoothed on surface and projected into MNI_2009c volume

400 region 17-network atlas shown here



Pauli subcortical atlas

MPM atlas
AFNI version MNI_2009c space



Ventromedial Prefrontral Cortex
(vmPFC, Scott Mackey)

MPM atlas
AFNI version MNI_2009c

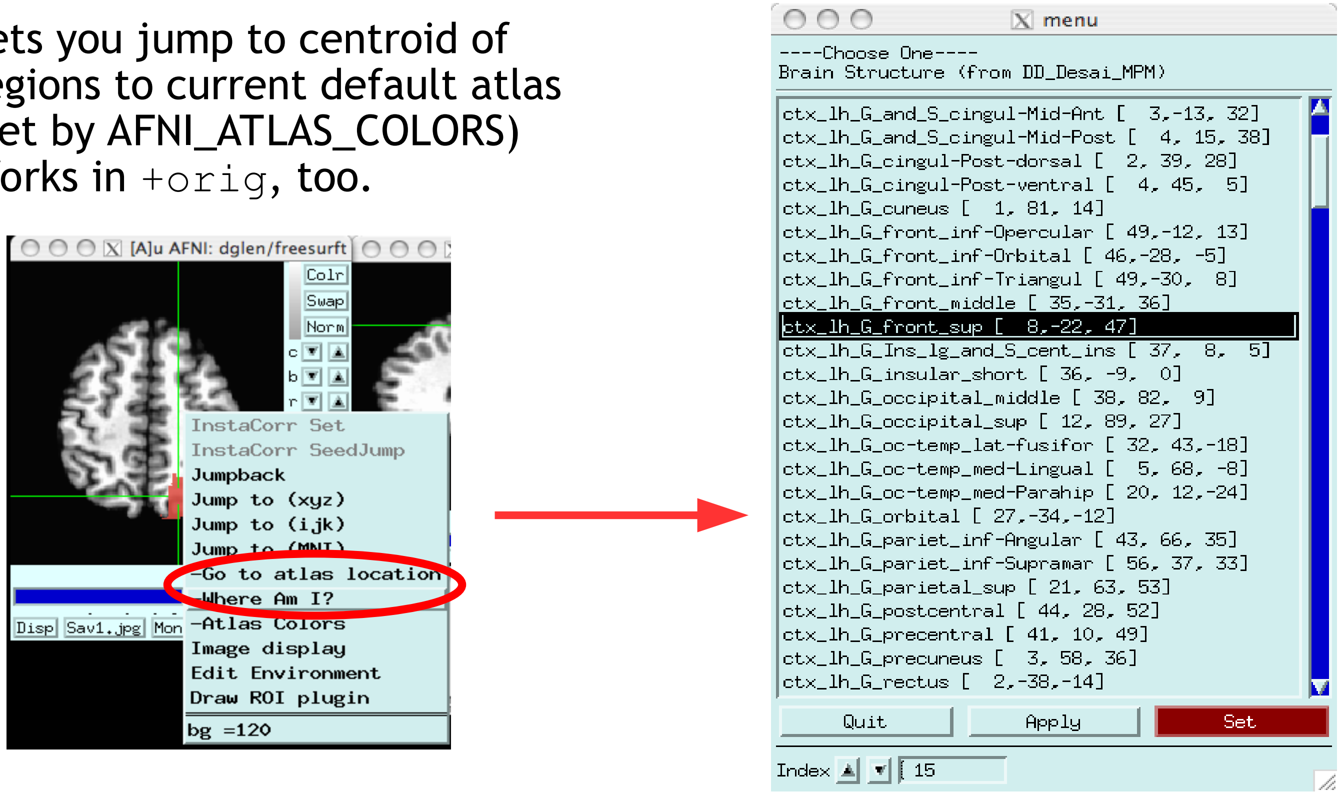
Using atlases in AFNI GUI

- Some fun and useful things to do with `+tlrc` datasets are on the 2D slice viewer.
  ***Ex:* can be run in ~/AFNI_data6/afni/**

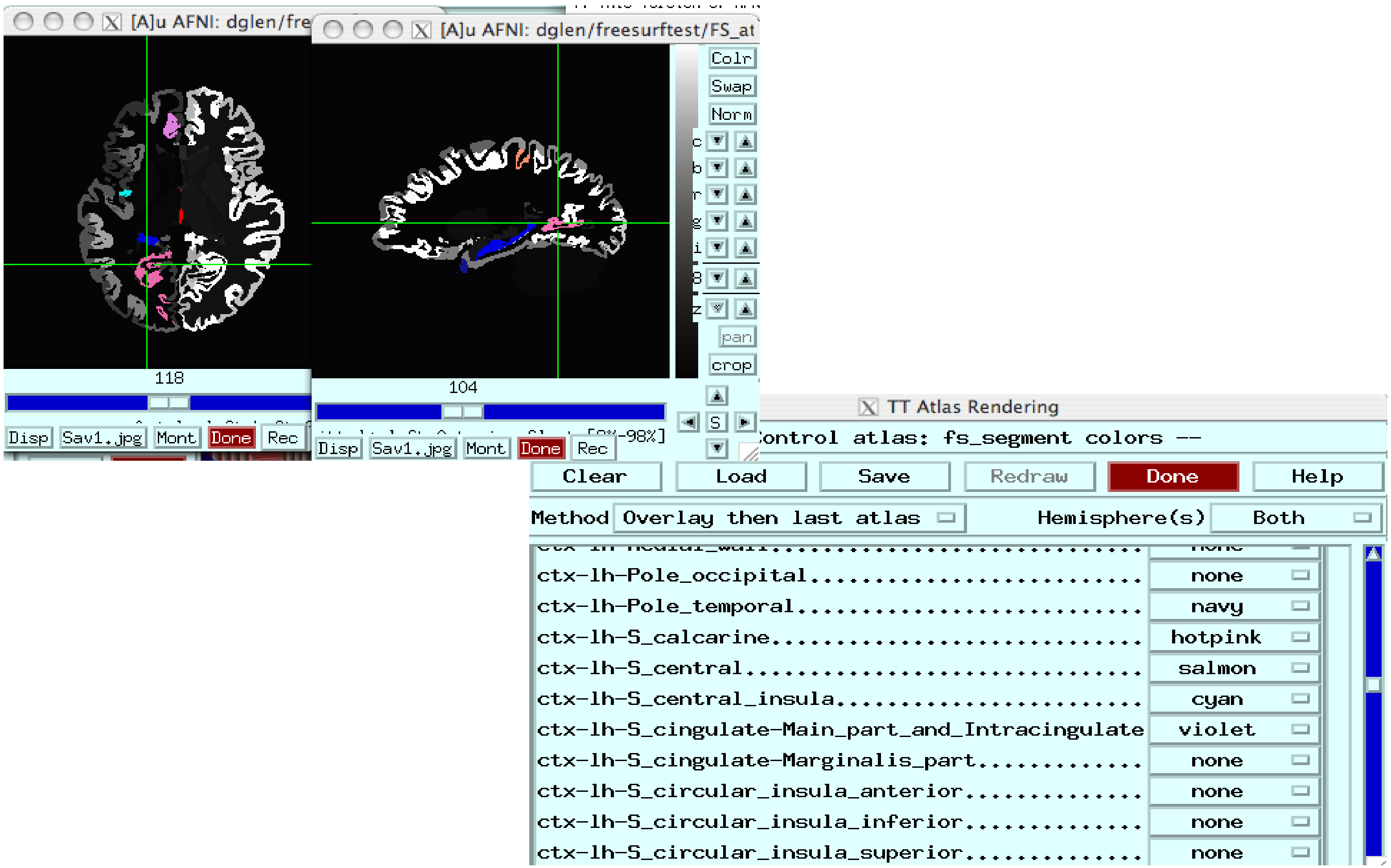
  1) Right click to get menu:

  - **[Go to Atlas Location]**

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



✧ [Atlas colors]



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

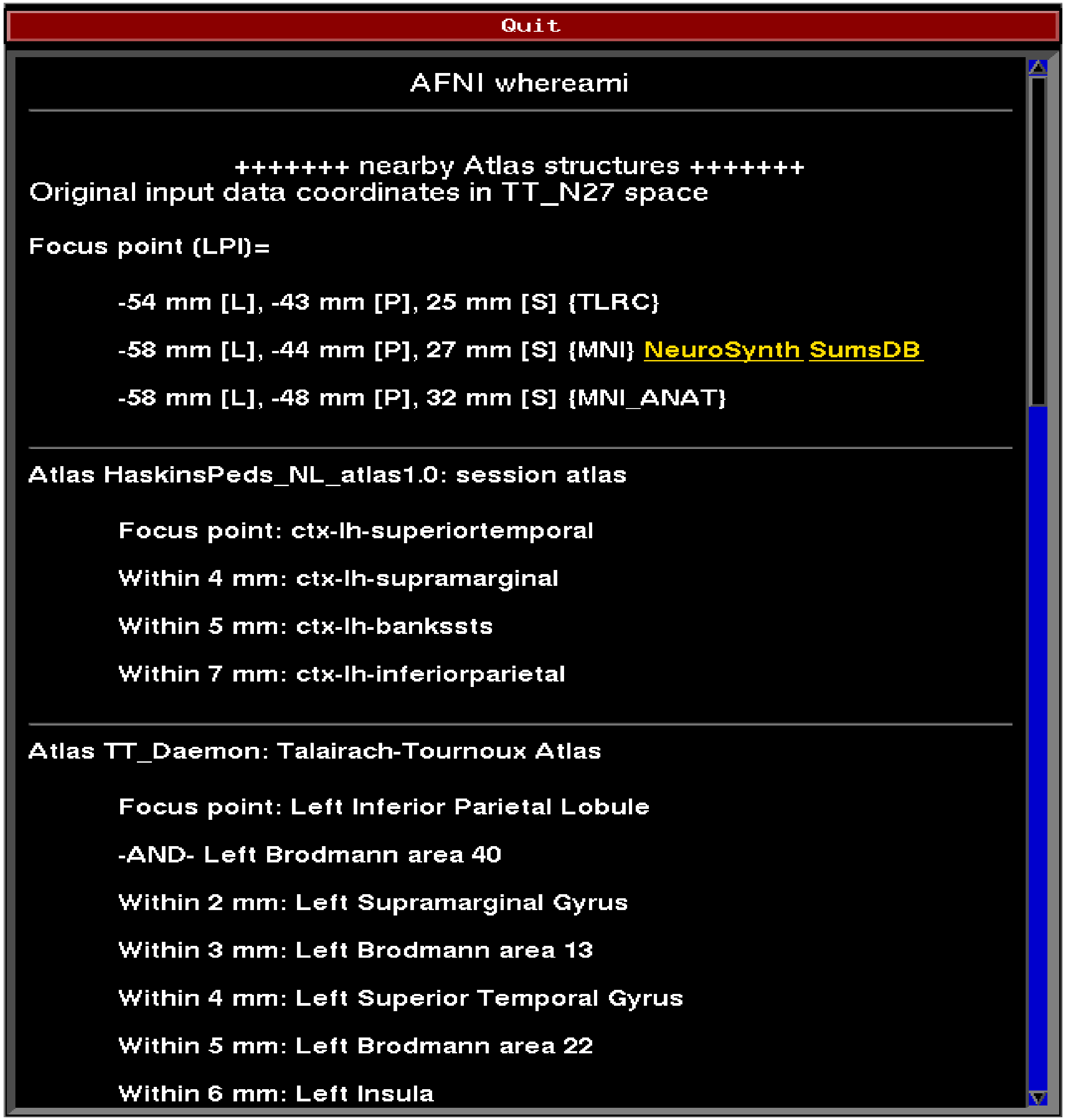
✧ **[Where am I?]**

Shows you where you are in various atlases and spaces

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

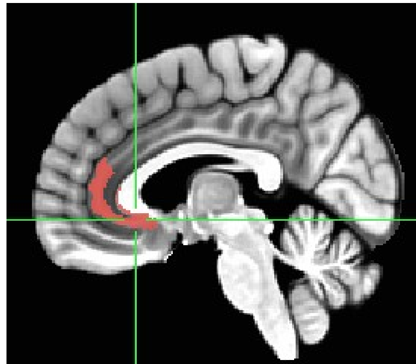
For atlas installation, and much, much more, see help in command line version:

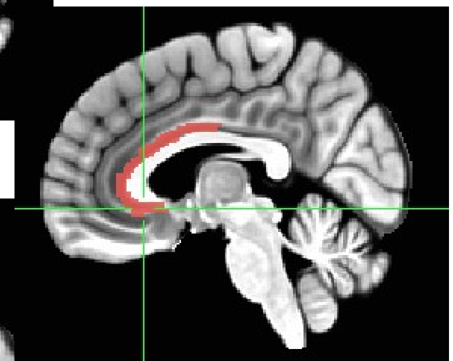
`whereami -help`



What's in a name ... or a coordinate?

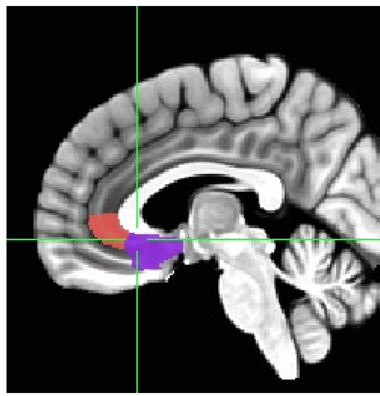
FS (MNI2009c) rostral anterior cingulate





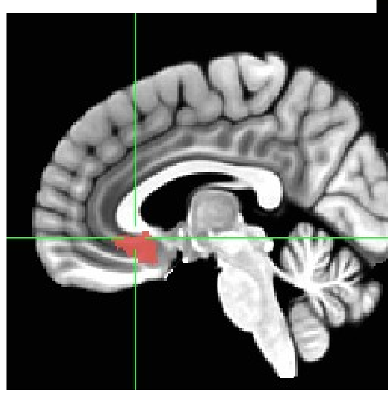
Brainnetome A24rv_right

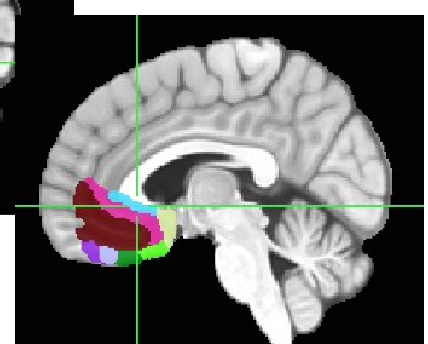
HCP Glasser area A24 (red) and area 25 (purple)



Brodmann-Pijnenburg BA24

JulichBrain Area_s24 (sACC)





Ventromedial Prefrontal Cortex atlas (Area_s24 (sACC) in cyan)

whereami on the command line

Try these simple examples:

whereami -show_atlases ← Citation info and descriptions

whereami -space MNI 20 10 5 ← Understand coordinate order. Use -lpi or default -rai?

whereami -show_atlas_code

3dinfo -labeltable ~/abin/MNI_caez_ml_18+tlrc.

3dinfo -atlas_points ~/abin/MNI_caez_ml_18+tlrc.

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 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/
```

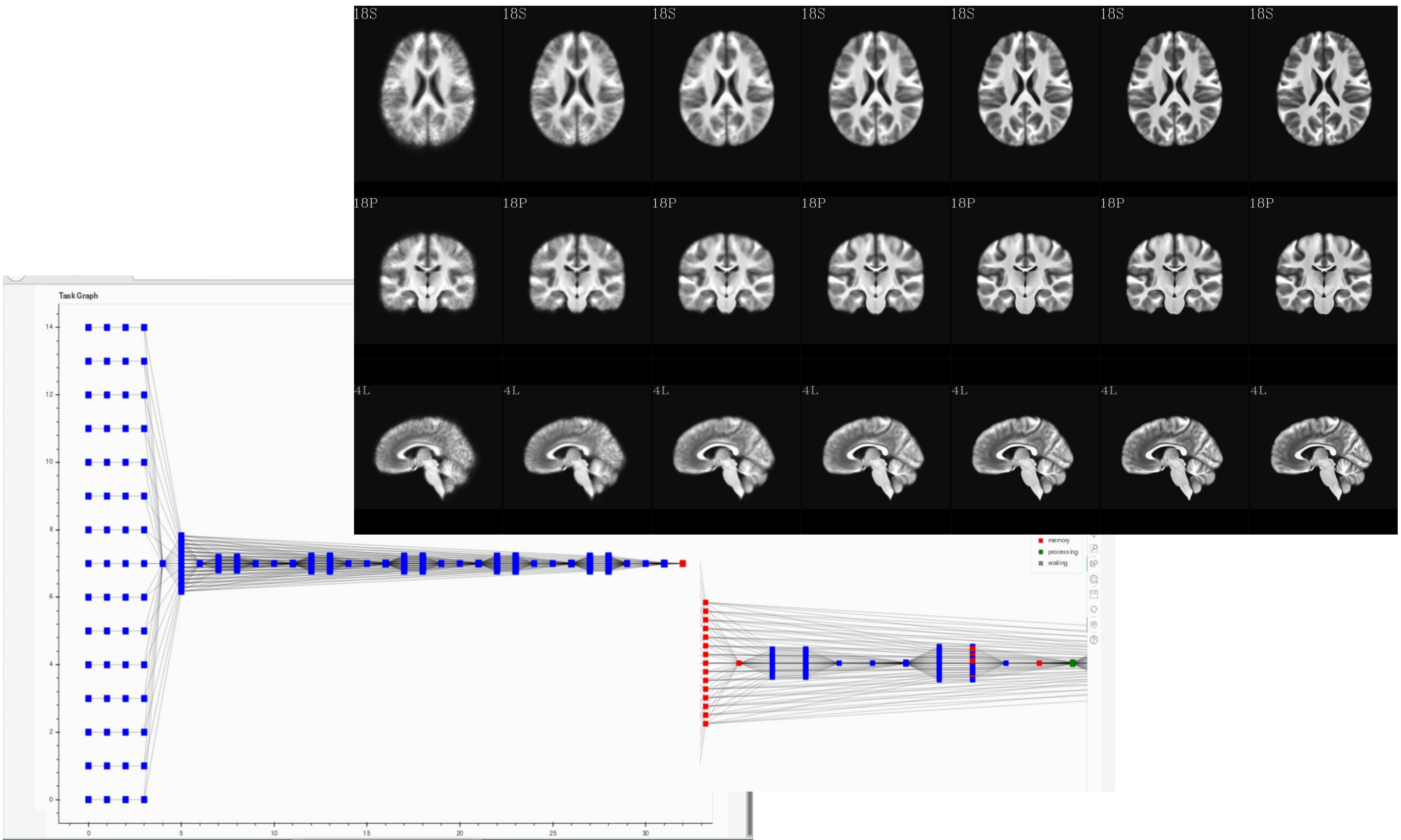
Then:

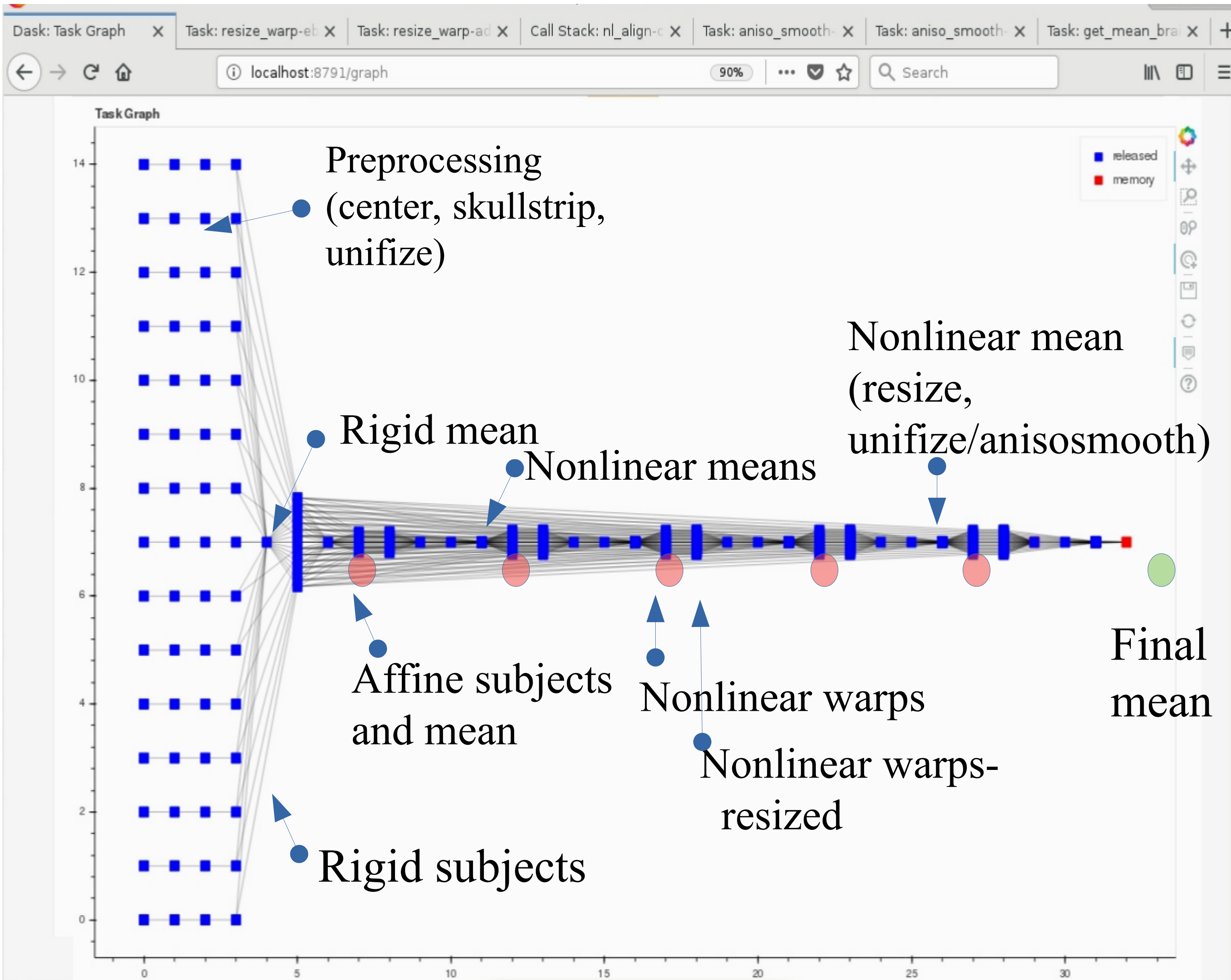
```
@Atlasize -space MNI -dset atlas_for_all.nii \
                  -lab_file keys.txt 1 0 -atlas_type G
```

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

Make your own template

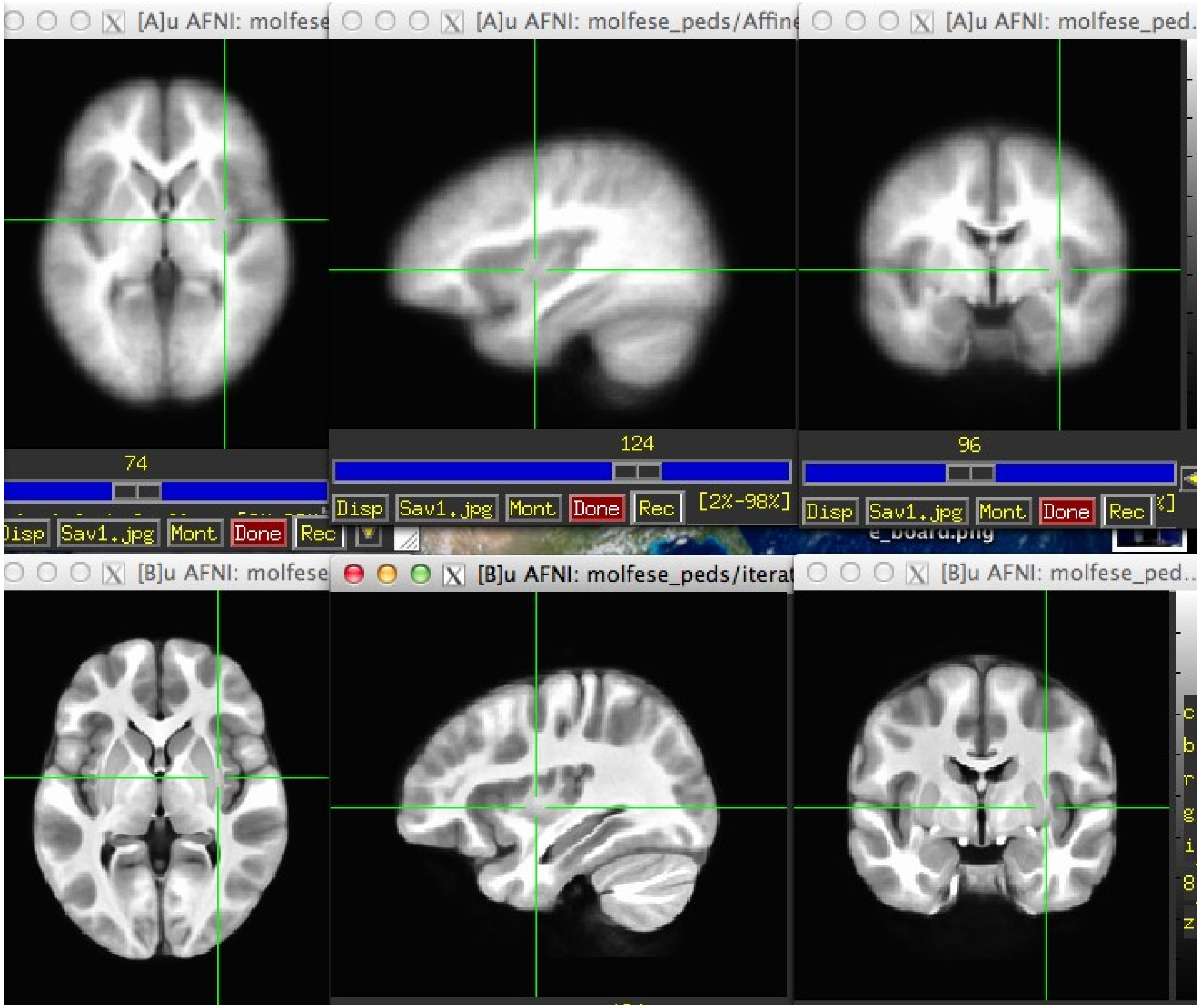
make_template_dask.py - Dask parallelization - 10, 100 or 1000 subjects on a cluster, server or PC





Dask Template task graph

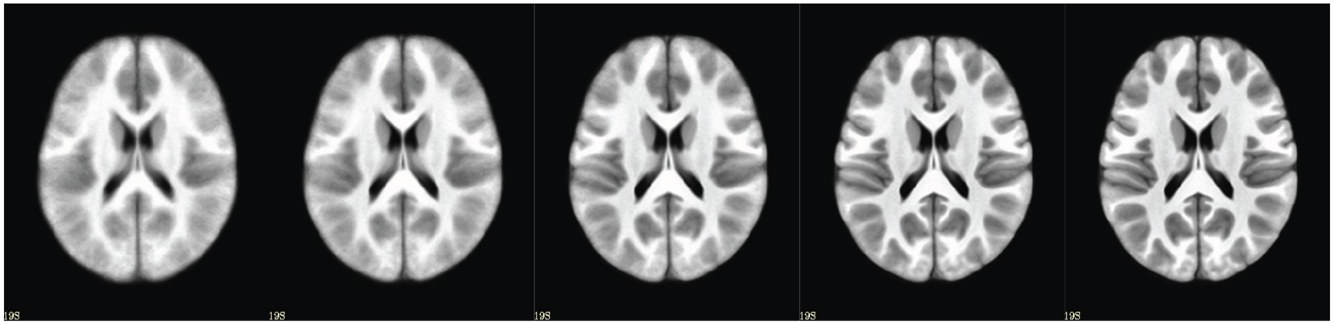
Haskins Pediatric Atlas: the templates



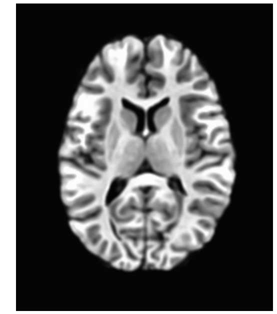
Affine Group

Nonlinear Group I – iterative

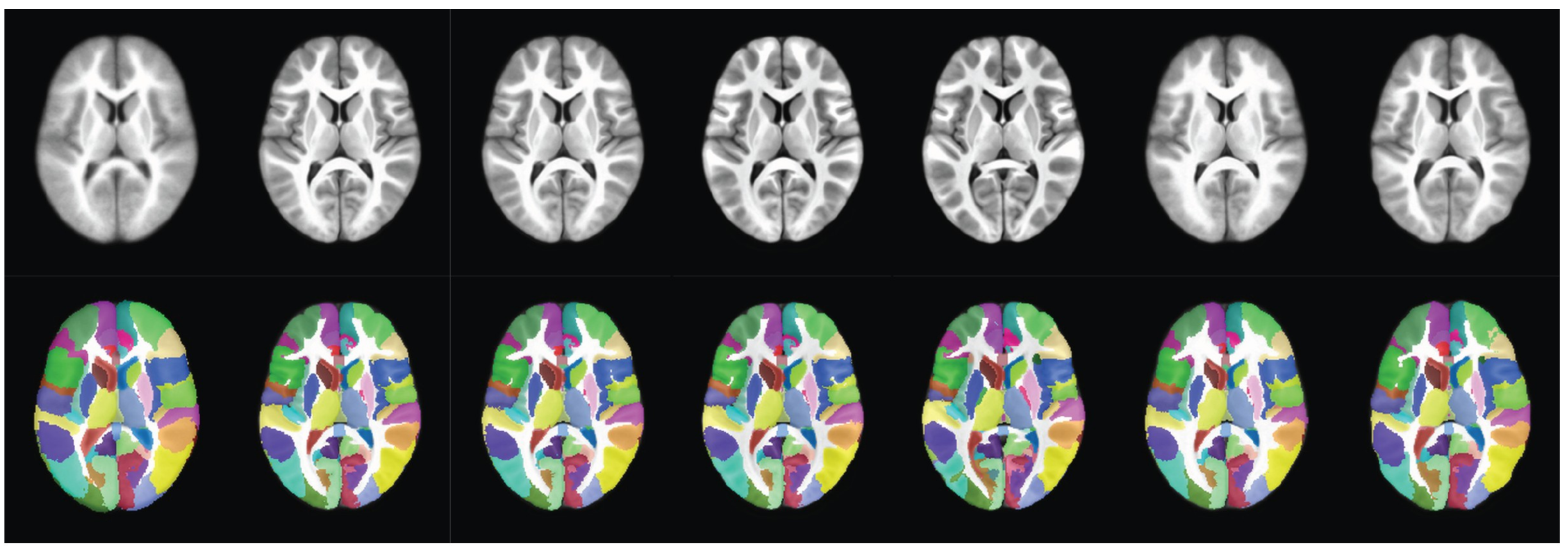
ALTERNATIVE ATLAS CREATION TECHNIQUES: ITERATIVE AND TYPICAL METHODS



Iterative nonlinear alignment to affine template with progressively smaller patch sizes

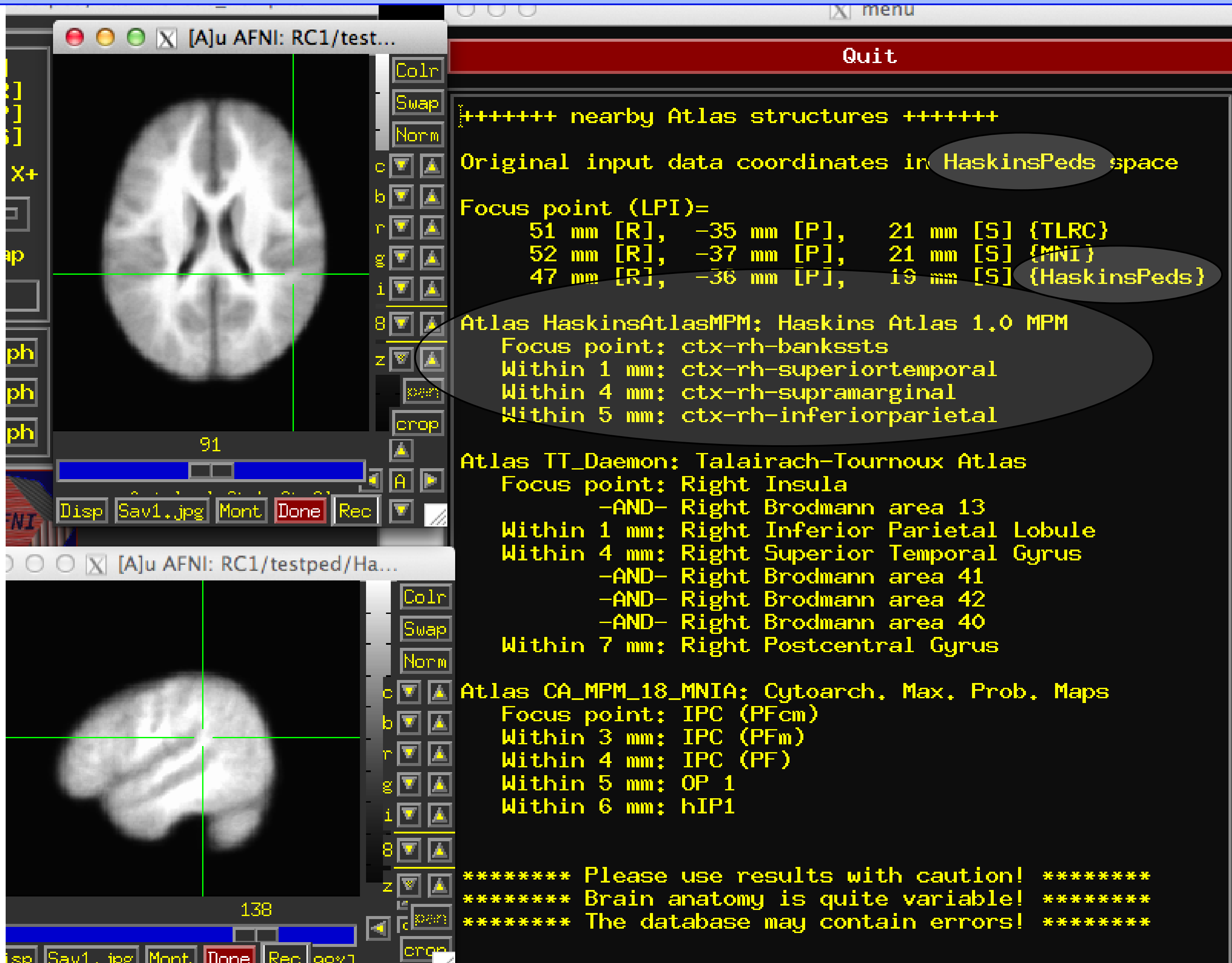


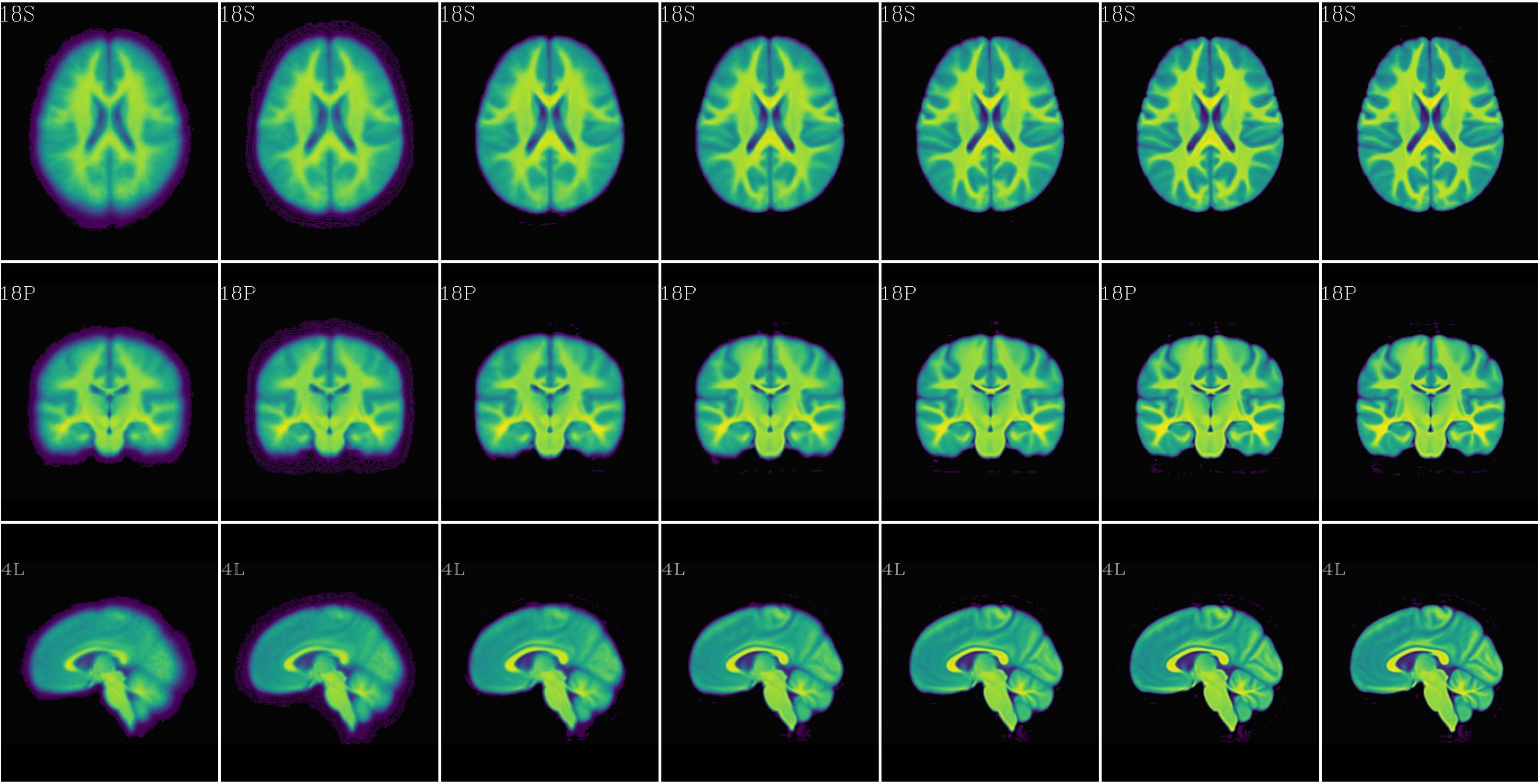
"Typical" Brain



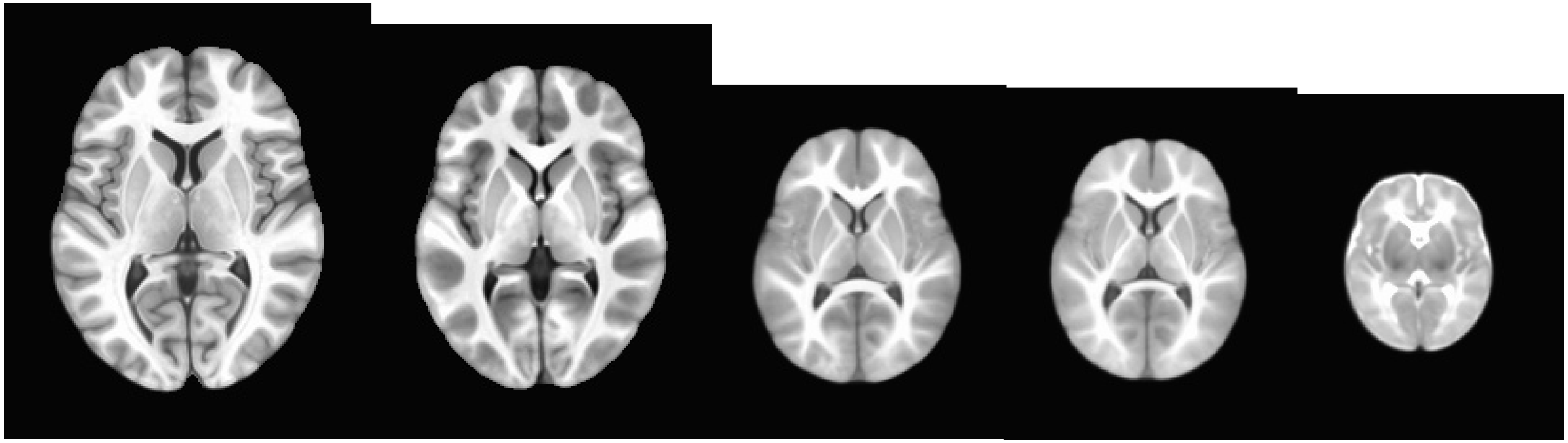
Affine | Affine Iterative | Typical Iterative | MNI Iterative | Nonlinear to MNI | Nonlinear to Affine | Nonlinear to Typical

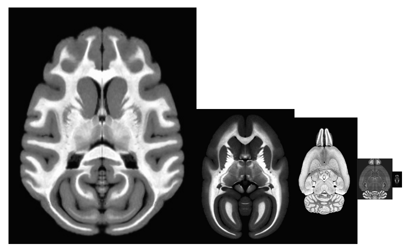
Haskins Pediatric Atlas





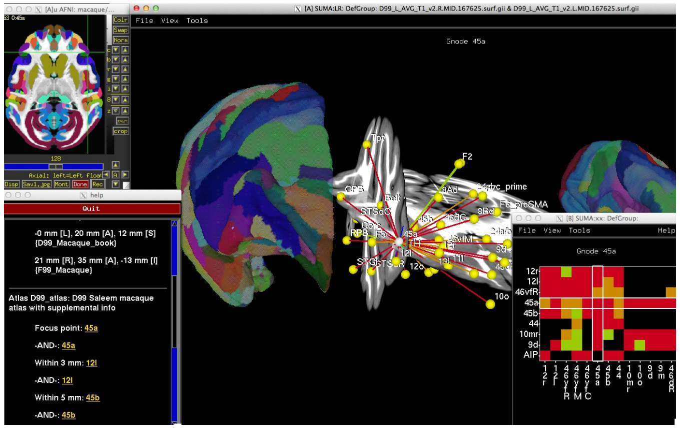
Indian Brain Template C2: IBT
@Install_IBT

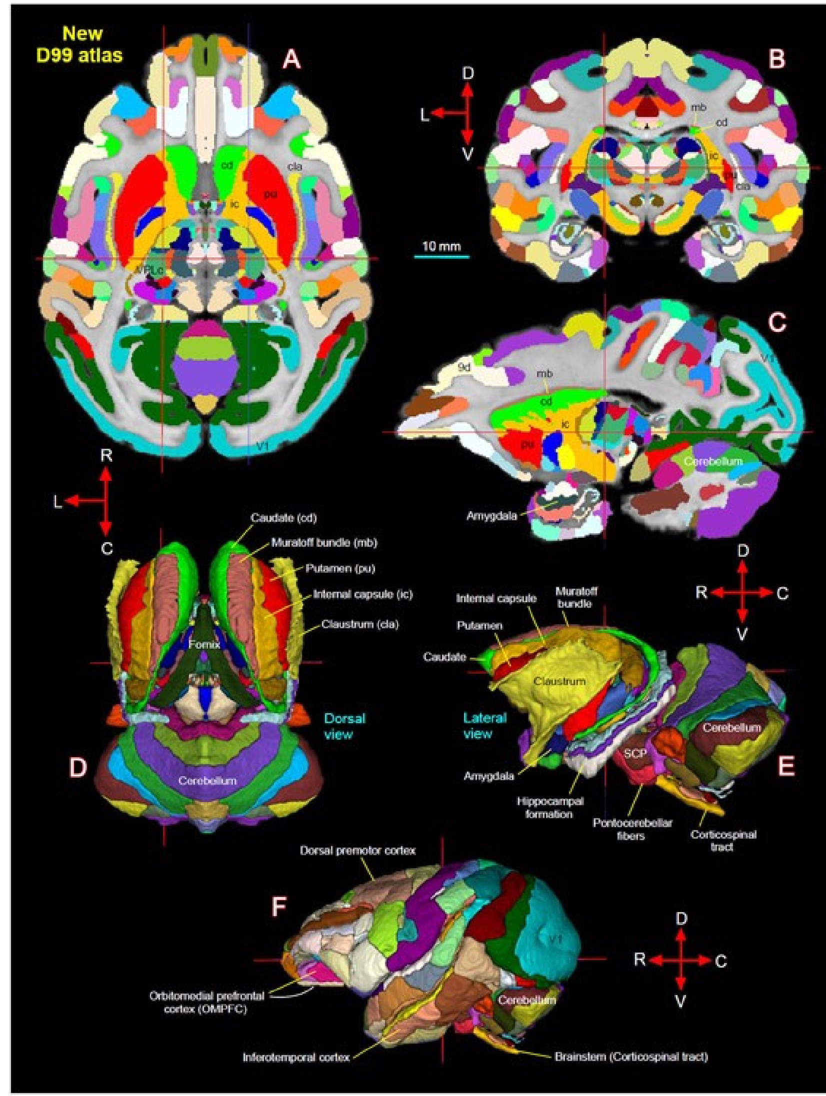




Templates and Atlases across Species in AFNI

Saleem macaque atlas – MRI, surfaces, connections, subcortical regions

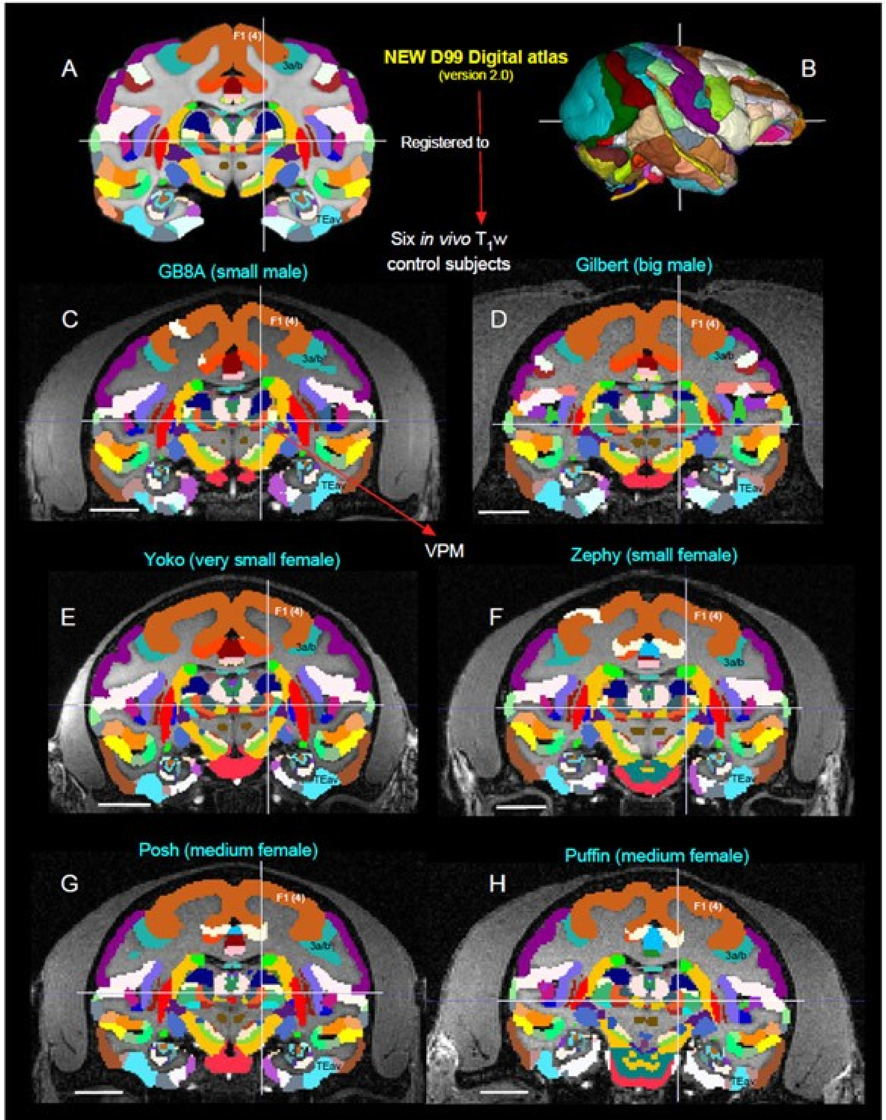




@Install_D99_macaque

Very soon Marmoset subcortical atlas too!

@Install_D99_macaque - install templates, atlas and set AFNI variables



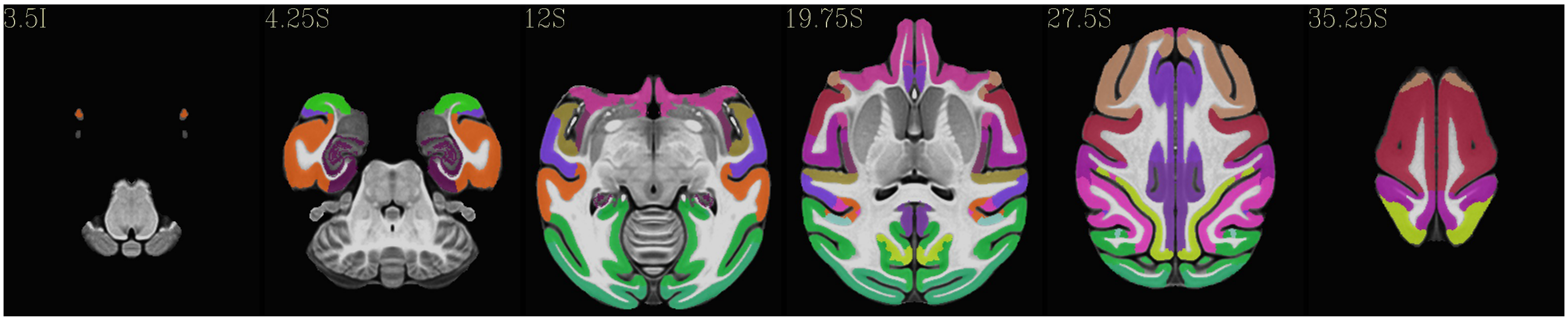
Alignment with @animal_warper

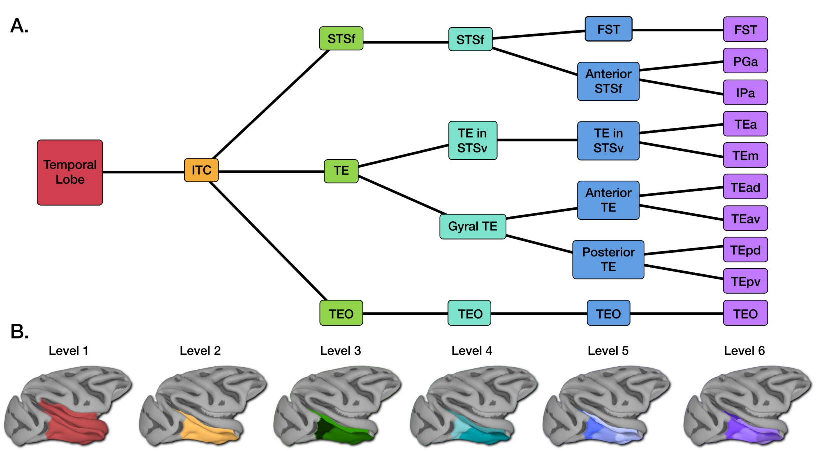
-feature_size to control for various animal resolution “features” - blurring and neighborhood size for alignment costs

Moves dataset to template space and atlases to native space

NMT (NIH Macaque Template)

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





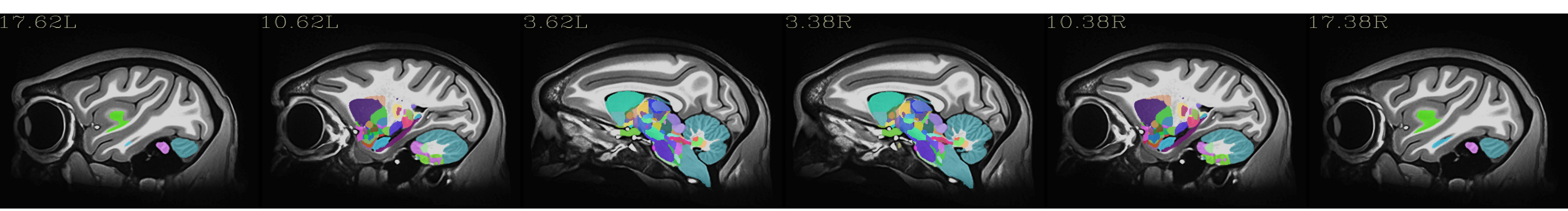
With CHARM -

6 level cortical hierarchical atlas!

And SARM -

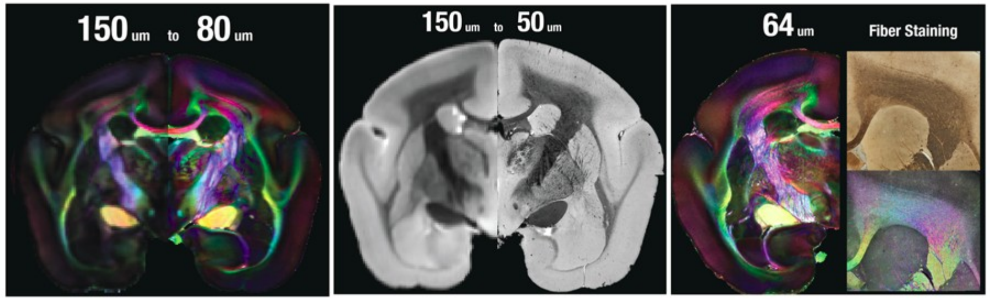
6 level subcortical hierarchical atlas!

@Install_NMT

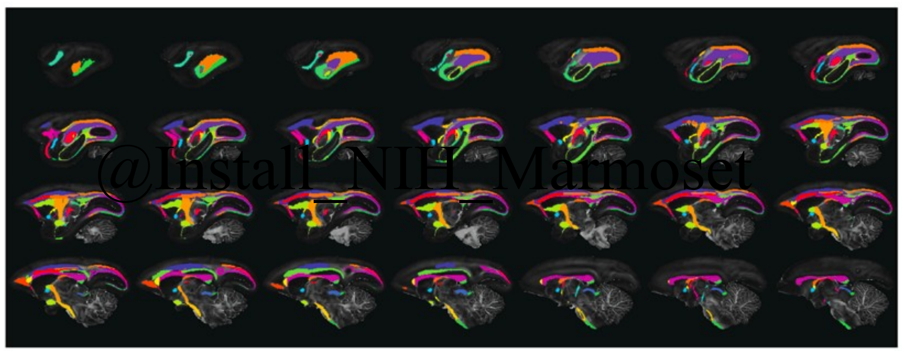


2018: *improved* NIH Marmoset Template

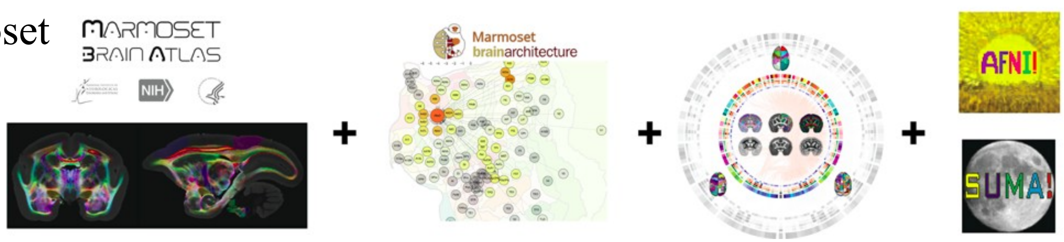
Better Data



Detailed labels

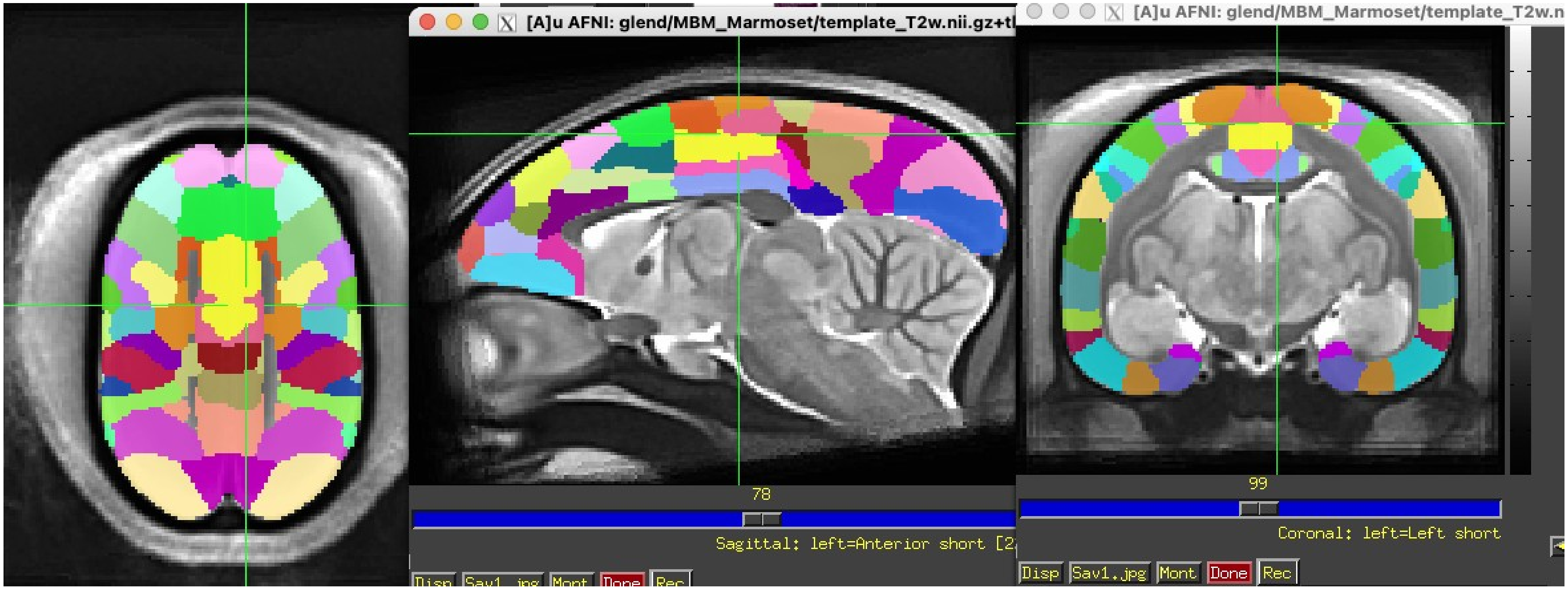


Support with tracing data, connectome and atlas utilities



(Liu et al., 2018, SfN)

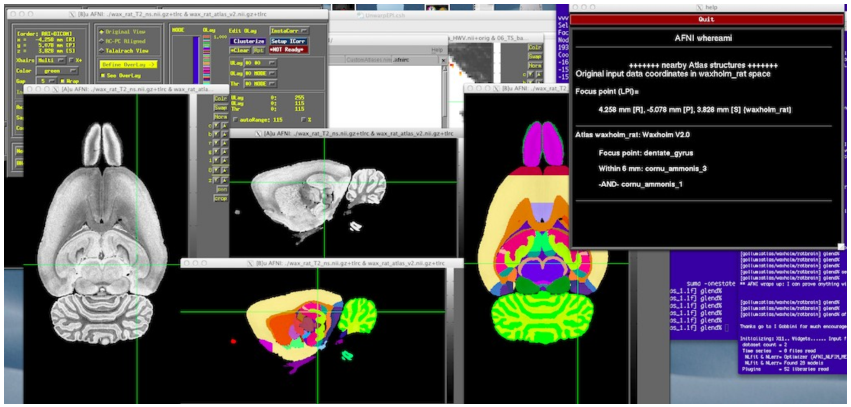
2020:more *improved MBM* Marmoset Population Template MBMv3

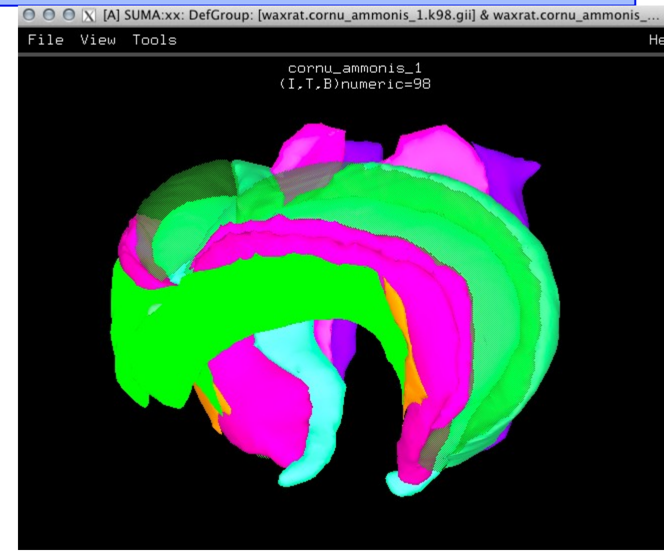


@Install_MBM_Marmoset,
MBMv4 - resting state networks soon

Rats and Mice

Waxholm Rat Atlas - Papp, et al. - AFNI version

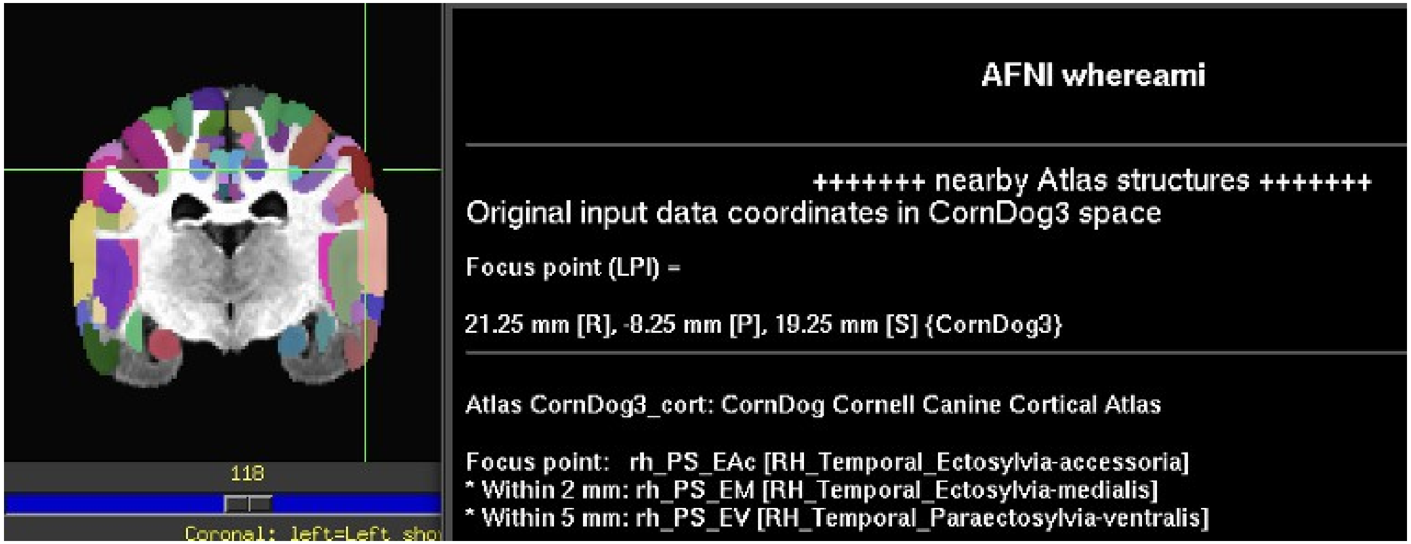




Allen Mouse CCF3 - AFNI version

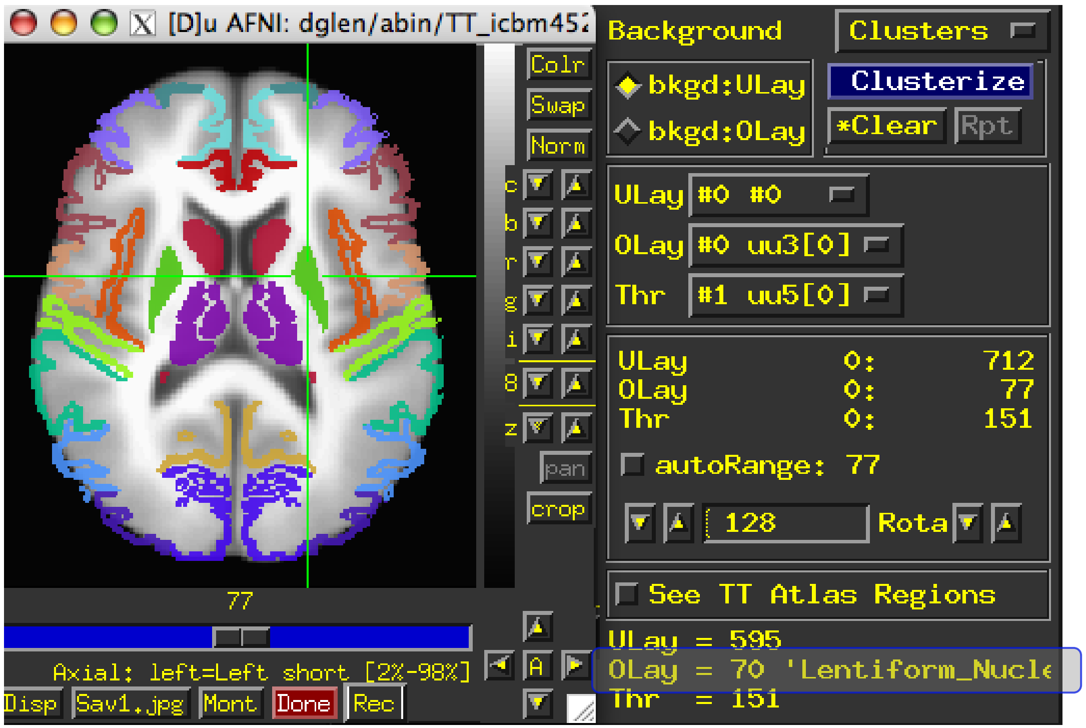
And Dogs

CornDog - Philippa Johnson at Cornell

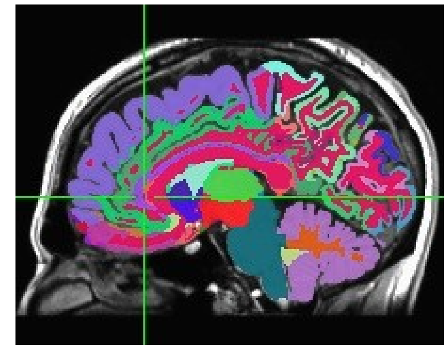


Individual Subjects

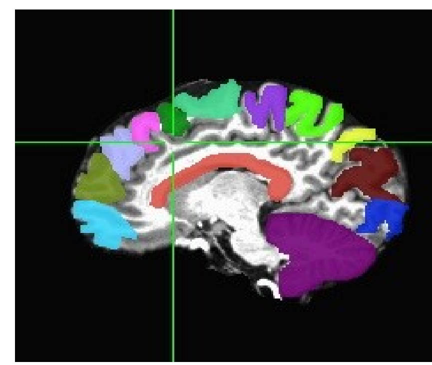
@SUMA_MakeSpecFS – atlasizes too!



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



FreeSurfer segmentation



Manual segmentation