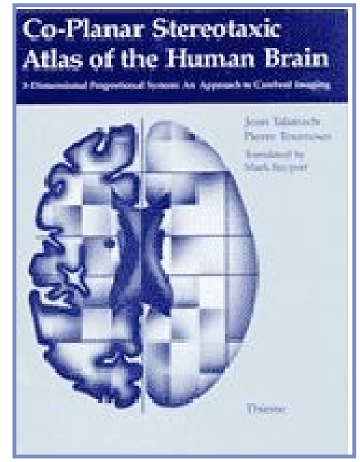
Transforming Datasets to Talairach-Tournoux Coordinates

- The original purpose of AFNI was to perform the transformation of datasets to Talairach-Tournoux (stereotaxic) coordinates
- The transformation is user-controlled, not automatic (yet)
- 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
- The transformation defined by the manually placed markers then carries over to all other 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 functional datasets to disk in Talairach coordinates
    - Purpose: voxel-wise comparison with other subjects
    - May want to blur functional maps a little before comparisons, to allow for residual anatomic variability: AFNI program **`3dmerge`**

- 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)

- 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:

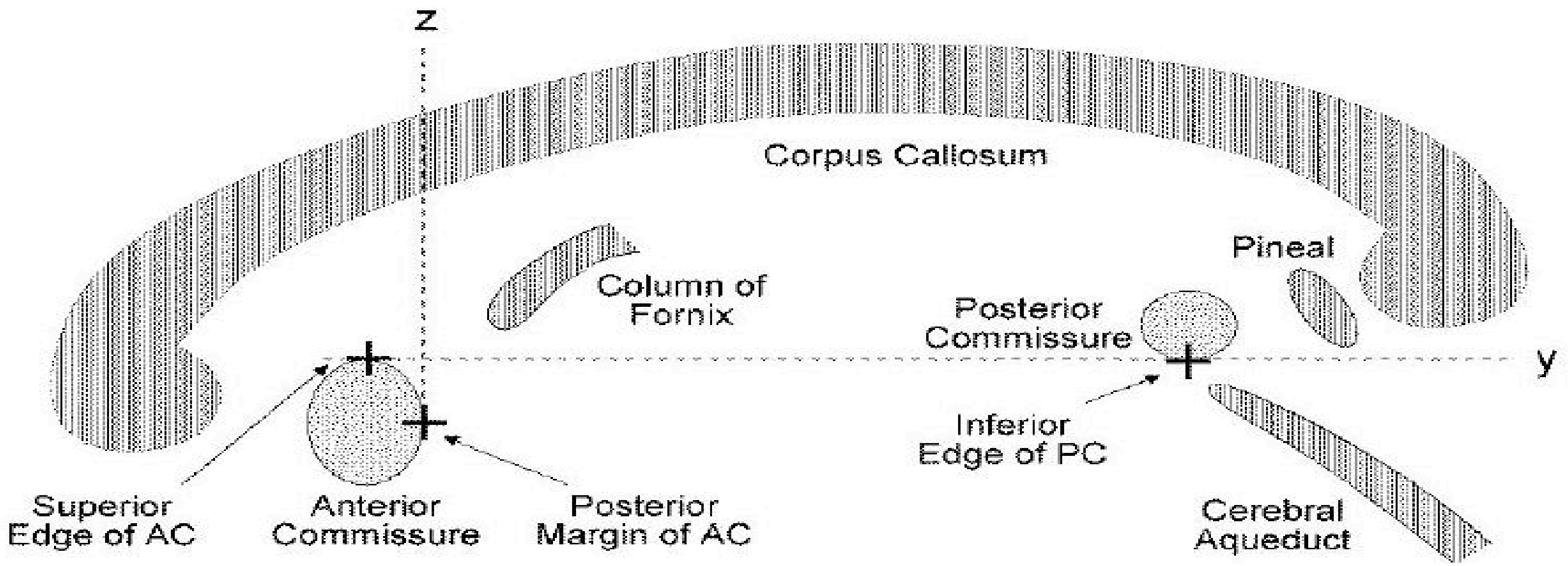
    AC superior edge = top middle of anterior commissure

    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)



[Define Markers]

Press this IN to create or change markers

Color of “primary” (selected) marker

Color of “secondary” (not selected) markers

Size of markers (pixels)

Size of gap in markers

Select which marker you are editing

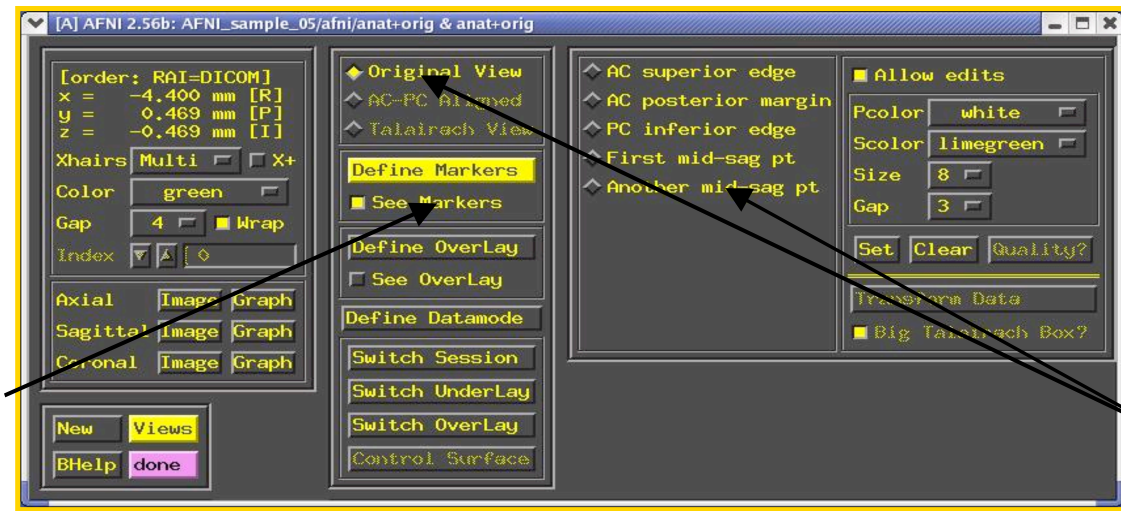
Clear (unset) primary marker

Set primary marker to current focus location

Carry out transformation to +acpc coordinates

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

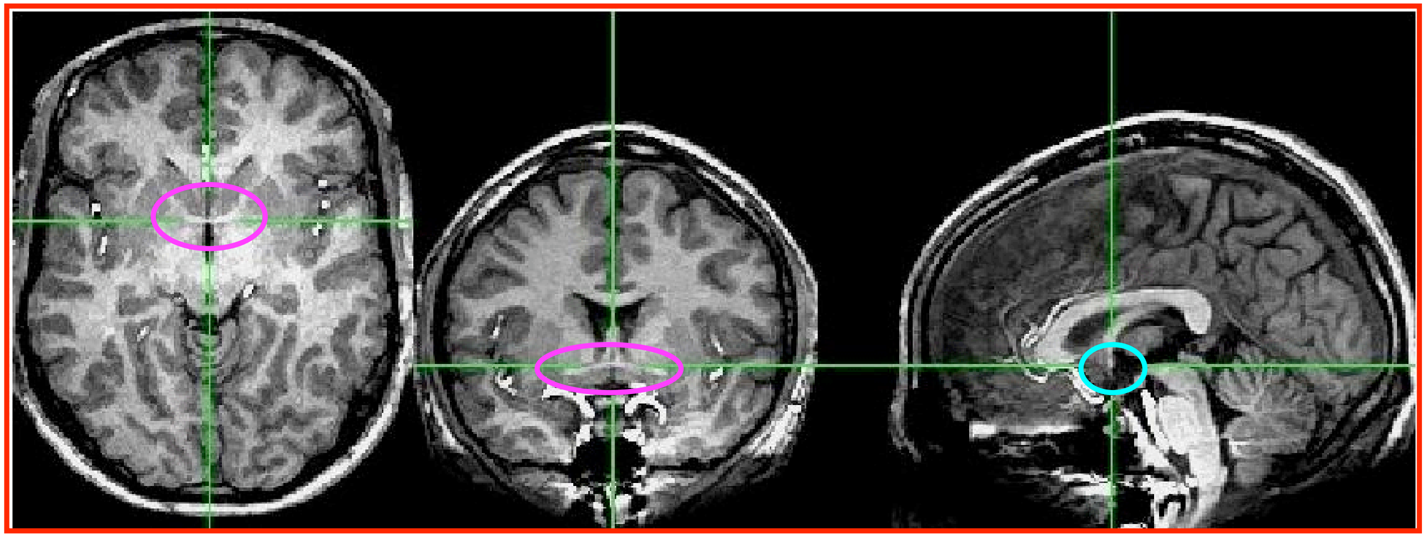
- **Class Example - Selecting the ac-pc markers:**
  - ✧ **cd AFNI_data1/demo_tlrc** ⇒ Descend into the `demo_tlrc/` subdirectory
  - ✧ **afni &** ⇒ This command launches the AFNI program
    - ➥ The "**&**" keeps the UNIX shell available in the background, so we can continue typing in commands as needed, even if AFNI is running in the foreground
  - ✧ Select dataset **anat+orig** from the **[Switch Underlay]** control panel



Press IN to view markers on brain volume

The AC-PC markers appear only when the orig view is highlighted

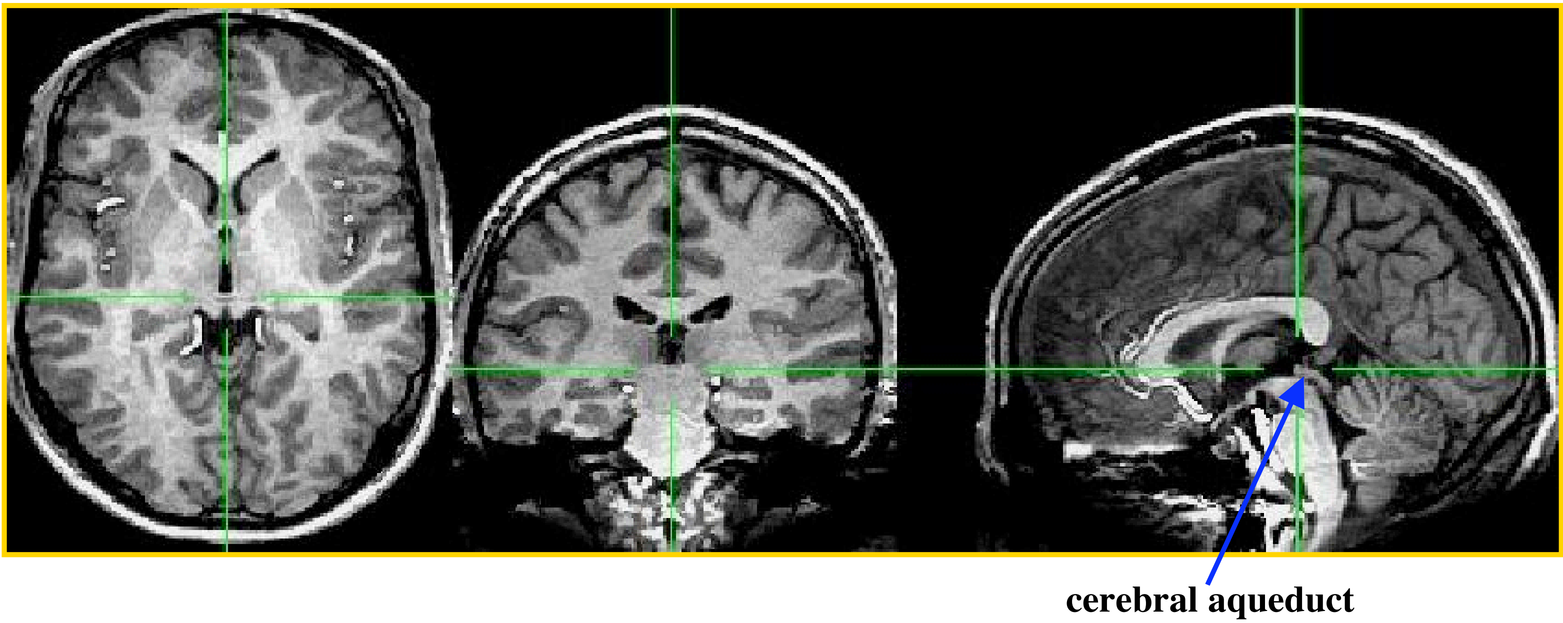
- ✧ Select the **[Define Markers]** control panel to view the 5 markers for ac-pc alignment
- ✧ Click the **[See Markers]** button to view the markers on the brain volume as you select them
- ✧ Click the **[Allow edits]** button in the ac-pc GUI to begin marker selection



✧ First goal is to mark top middle and rear middle of **AC**

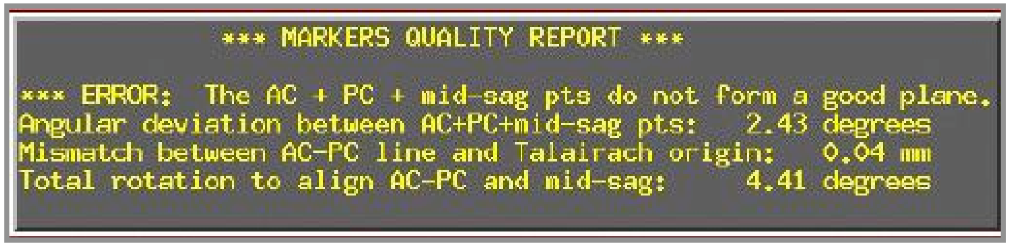
- **Sagittal**: look for AC at bottom level of corpus callosum, below fornix
- **Coronal**: look for "mustache"; **Axial**: look for inter-hemispheric connection
- Get AC centered at focus of crosshairs (in Axial and Coronal)
- Move superior until AC disappears in Axial view; then inferior 1 pixel
- Press IN **[AC superior edge]** marker toggle, then **[Set]**
- Move focus back to middle of AC
- Move posterior until AC disappears in Coronal view; then anterior 1 pixel
- Press IN **[AC posterior margin]**, then **[Set]**

- <u>Second goal is to mark inferior edge of **PC**</u>
  - This is harder, since PC doesn't show up well at 1 mm resolution
  - Fortunately, PC is always at the top of the cerebral aqueduct, which does show up well (at least, if CSF is properly suppressed by the MRI pulse sequence)

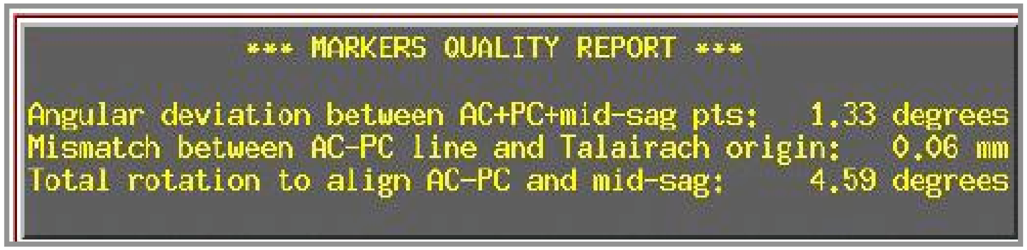


  - Therefore, if you can't see the PC, find mid-sagittal location just at top of cerebral aqueduct and mark it as **[<u>PC inferior edge</u>]**
- <u>Third goal is to mark **two inter-hemispheric points** (above corpus callosum)</u>
  - The two points must be at least 2 cm apart
  - The two planes AC-PC-#1 and AC-PC-#2 must be no more than **2º** apart

- Once all 5 markers have been set, the **[Quality?]** Button is ready
  - You can’t **[Transform Data]** until **[Quality?]** Check is passed
  - In this case, quality check makes sure two planes from AC-PC line to mid-sagittal points are within 2°
    - Sample below shows a 2.43° deviation between planes ⇒ ERROR message indicates we must move one of the points a little



- Sample below shows a deviation between planes at less than 2°. Quality check is passed

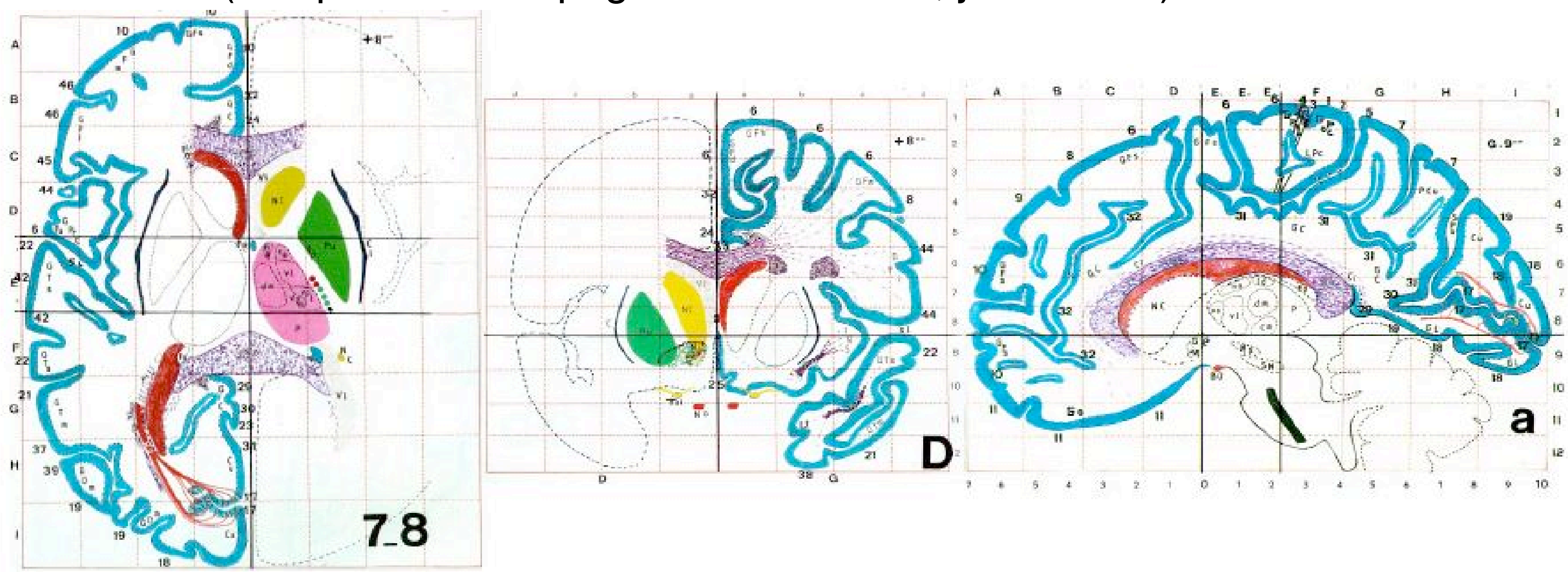


- We can now save the marker locations into the dataset header

- When **[Transform Data]** is available, pressing it will close the **[Define Markers]** panel, write marker locations into the dataset header, and create the `+acpc` datasets that follow from this one
  - The **[AC-PC Aligned]** coordinate system is now enabled in the main AFNI controller window
  - In the future, you could re-edit the markers, if desired, then re-transform the dataset (but you wouldn't make a mistake, would you?)
  - If you don't want to save edited markers to the dataset header, you must quit AFNI without pressing **[Transform Data]** or **[Define Markers]**

- **`ls`** ⇒ The newly created ac-pc dataset, **`anat+acpc.HEAD`**, is located in our `demo_tlrc/` directory
- At this point, only the header file exists, which can be viewed when selecting the **[AC-PC Aligned]** button
  - more on how to create the accompanying **`.BRIK`** file later…

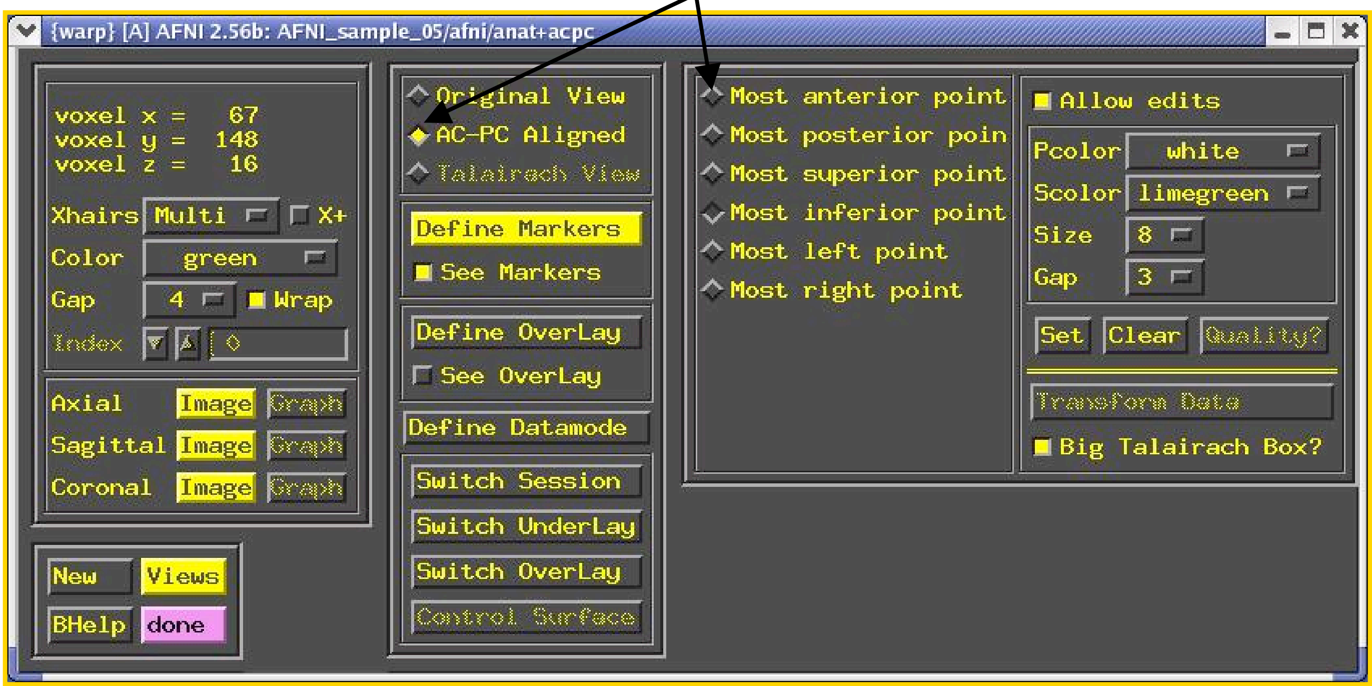
- **Scaling to Talairach-Tournoux (+tlrc) coordinates:**
  - We now stretch/shrink the brain to fit the Talairach-Tournoux Atlas brain size (sample TT Atlas pages shown below, just for fun)



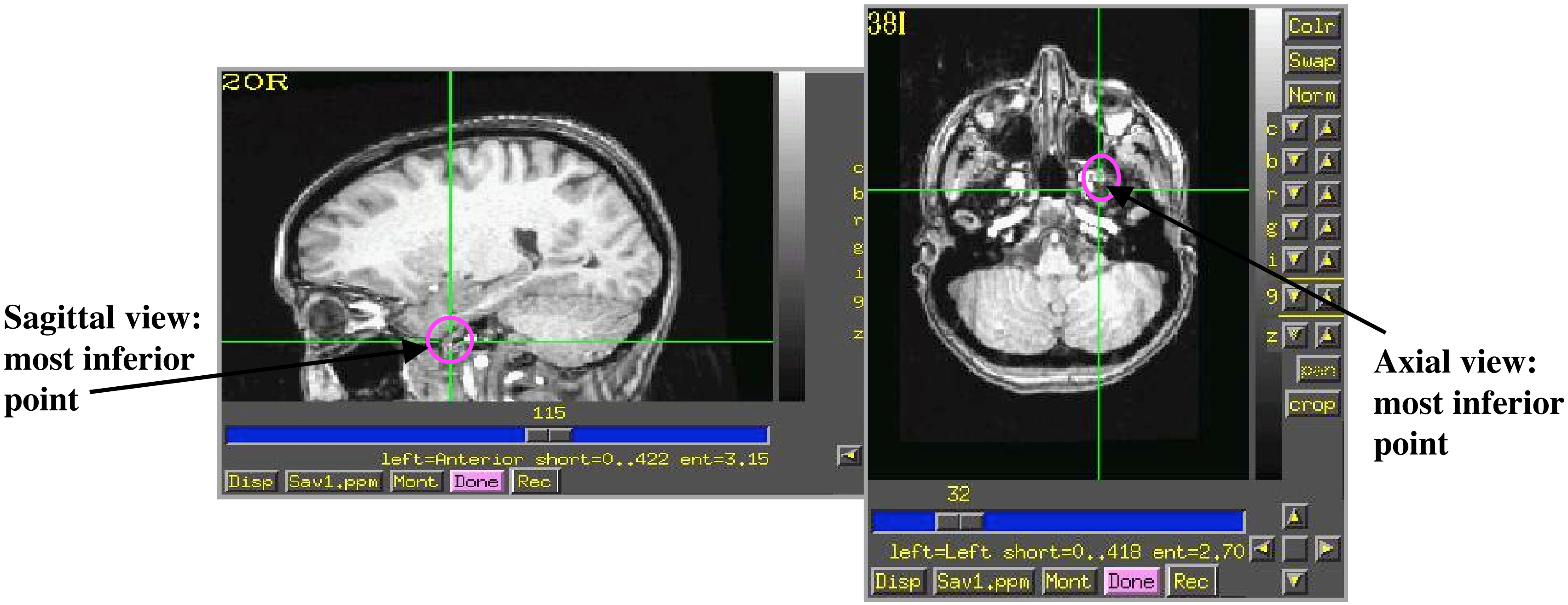
Most anterior to AC	70 mm		
AC to PC	23 mm		
PC to most posterior	79 mm	Length of cerebrum	172 mm
Most inferior to AC	42 mm		
AC to most superior	74 mm	Height of cerebrum	116 mm
AC to left (or right)	68 mm	Width of cerebrum	136 mm

- **Class example - Selecting the Talairach-Tournoux markers:**
  - 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:

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



- ✧ Using the same methods as before (i.e., select marker toggle, move focus there, **[Set]**), you must mark these extreme points of the cerebrum
  - ➥ Using 2 or 3 image windows at a time is useful
  - ➥ Hardest marker to select is **[Most inferior point]** in the temporal lobe, since it is near other (non-brain) tissue:



- ➥ Once all 6 are set, press **[Quality?]** to see if the distances are reasonable
  - ➢ Leave **[Big Talairach Box?]** Pressed **IN**
  - ➢ Is a legacy from earliest (1994-6) days of AFNI, when 3D box size of `+tlrc` datasets was 10 mm smaller in `I`-direction than the current default

- Once the quality check is passed, click on **[Transform Data]** to save the +tlrc header
- **ls** ⇒ The newly created +tlrc dataset, **anat+tlrc.HEAD**, is located in our demo_tlrc/ directory
  - At this point, the following anatomical datasets should be found in our demo_tlrc/ directory:

    anat+orig.HEAD **anat+orig.BRIK**

    anat+acpc.HEAD

    anat+tlrc.HEAD

  - In addition, the following functional dataset (which I -- the instructor -- created earlier) should be stored in the demo_tlrc/ directory:

    func_slim+orig.HEAD
    func_slim+orig.BRIK

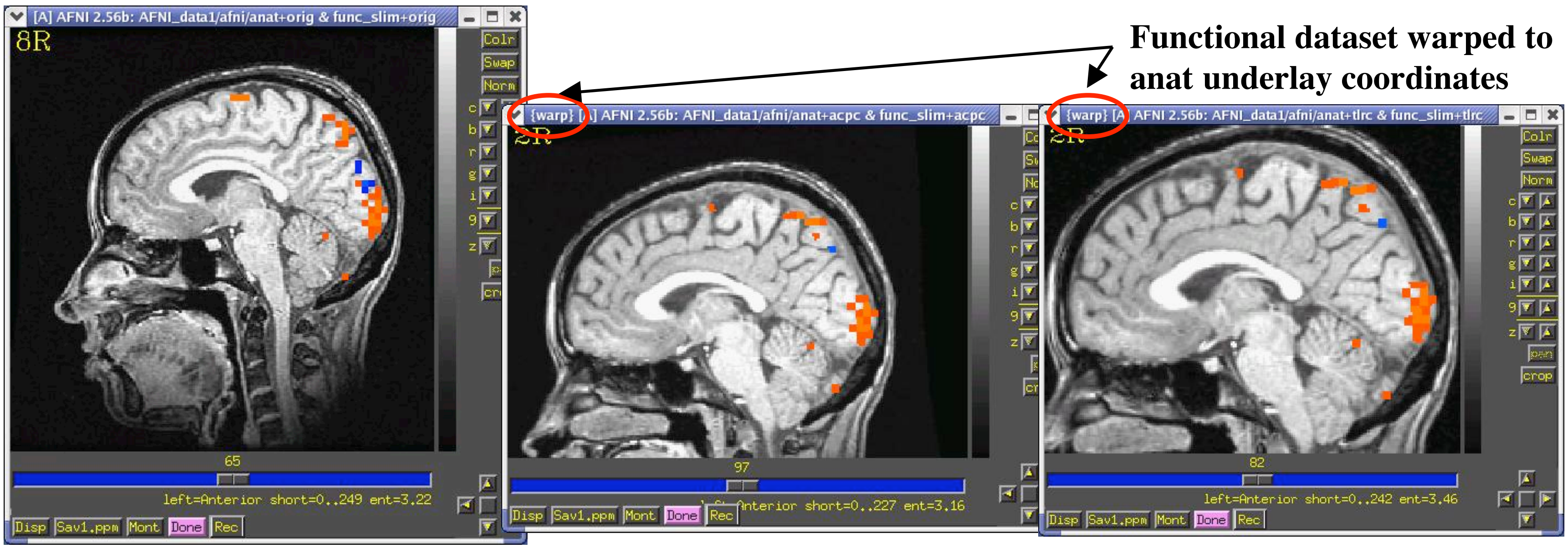
    - Note that this functional dataset is in the +orig format (not +acpc or +tlrc)

- **Automatic creation of "follower datasets":**
  - ✧ After the anatomical `+orig` dataset in a directory is resampled to `+acpc` and `+tlrc` coordinates, all the other datasets in that directory will *automatically* get transformed datasets as well
    - ➥ These datasets are created automatically inside the interactive AFNI program, and are not written (saved) to disk (i.e., only header info exists at this point)
    - ➥ How followers are created (arrows show geometrical relationships):

```
anat+orig  →  anat+acpc  →  anat+tlrc
    ↑             ↓              ↓
func+orig     func+acpc      func+tlrc
```

    - ➥ In the class example, **func_slim+orig** will automatically be "warped" to our anat dataset's ac-pc (**anat+acpc**) & Talairach (**anat+tlrc**) coordinates
      - ➢ The result will be **func_slim+acpc.HEAD** and **func_slim+tlrc.HEAD**, located internally in the AFNI program (i.e., you won't see these files in the `demo_tlrc/` directory)
        - To store these files in `demo_tlrc/`, they must be written to disk. More on this later…

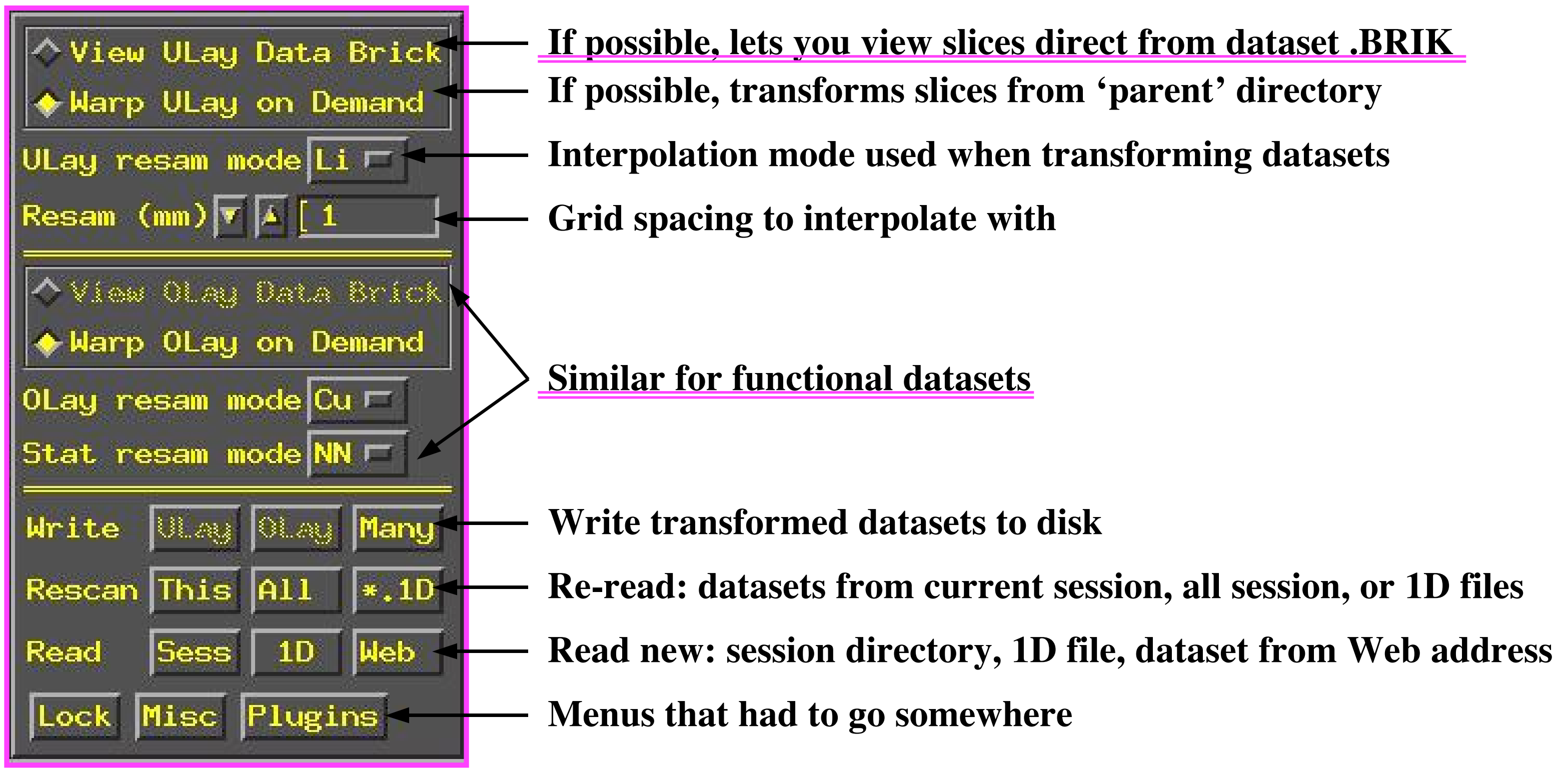
- How does AFNI actually create these follower datsets?
  - After **[Transform Data]** creates **anat+acpc**, other datasets in the same directory are scanned
    - AFNI defines the geometrical transformation ("warp") from **func_slim+orig** using the **to3d**-defined relationship between **func_slim+orig** and **anat+orig**, AND the markers-defined relationship between **anat+orig** and **anat+acpc**
      - A similar process applies for warping **func_slim+tlrc**
    - These warped functional datasets can be viewed in the AFNI interface:



func_slim+orig → "func_slim+acpc" → "func_slim+tlrc"

- Next time you run AFNI, the followers will automatically be created internally again when the program starts

- "Warp on demand" viewing of datasets:
  - AFNI doesn't actually resample all follower datasets to a grid in the re-aligned and re-stretched coordinates
    - This could take quite a long time if there are a lot of big 3D+time datasets
  - Instead, the dataset slices are transformed (or warped) from `+orig` to `+acpc` or `+tlrc` for viewing as needed (on demand)
  - This can be controlled from the **[Define Datamode]** control panel:



AFNI titlebar shows warp on demand: `{warp}[A]AFNI2.56b:AFNI_sample_05/afni/anat+tlrc`

- **Writing “follower datasets” to disk:**
  - Recall that when we created **anat+acpc** and **anat+tlrc** datasets by pressing **[Transform Data]**, only **.HEAD** files were written to disk for them
  - In addition, our follower datasets **func_slim+acpc** and **func_slim+tlrc** are *not* stored in our demo_tlrc/ directory. Currently, they can only be viewed in the AFNI graphical interface
  - Questions to ask:
    1. How do we write our anat **.BRIK** files to disk?
    2. How do we write our warped follower datasets to disk?
  - To write a dataset to disk (whether it be an anat .BRIK file or a follower dataset), use one of the **[Define Datamode]** ⇒ **Write** buttons:

ULay writes current underlay dataset to disk

OLay writes current overlay dataset to disk

Many writes multiple datasets in a directory to disk

- **Class exmaple - Writing anat (Underlay) datasets to disk:**
  - ✧ You can use **[Define Datamode]** ⇒ **Write** ⇒ **[ULay]** to write the current anatomical dataset .BRIK out at the current grid spacing (cubical voxels), using the current anatomical interpolation mode
  - ✧ After that, **[View ULay Data Brick]** will become available
    - ➥ **ls** ⇒ to view newly created .BRIK files in the **demo_tlrc/** directory:

      anat+acpc.HEAD   **anat+acpc.BRIK**

      anat+tlrc.HEAD   **anat+tlrc.BRIK**

- **Class exmaple - Writing func (Overlay) datasets to disk:**
  - ✧ You can use **[Define Datamode]** ⇒ **Write** ⇒ **[OLay]** to write the current functional dataset .HEAD and BRIK files into our demo_tlrc/ directory
  - ✧ After that, **[View OLay Data Brick]** will become available
    - ➥ **ls** ⇒ to view newly resampled func files in our demo_tlrc/ directory:

      func_slim+acpc.HEAD   **func_slim+acpc.BRIK**

      func_slim+tlrc.HEAD   **func_slim+tlrc.BRIK**

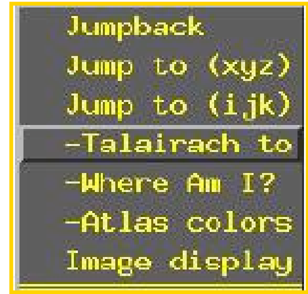
- Command line program **adwarp** can also be used to write out `.BRIK` files for transformed datasets:

  `adwarp -apar anat+tlrc  -dpar func+orig`

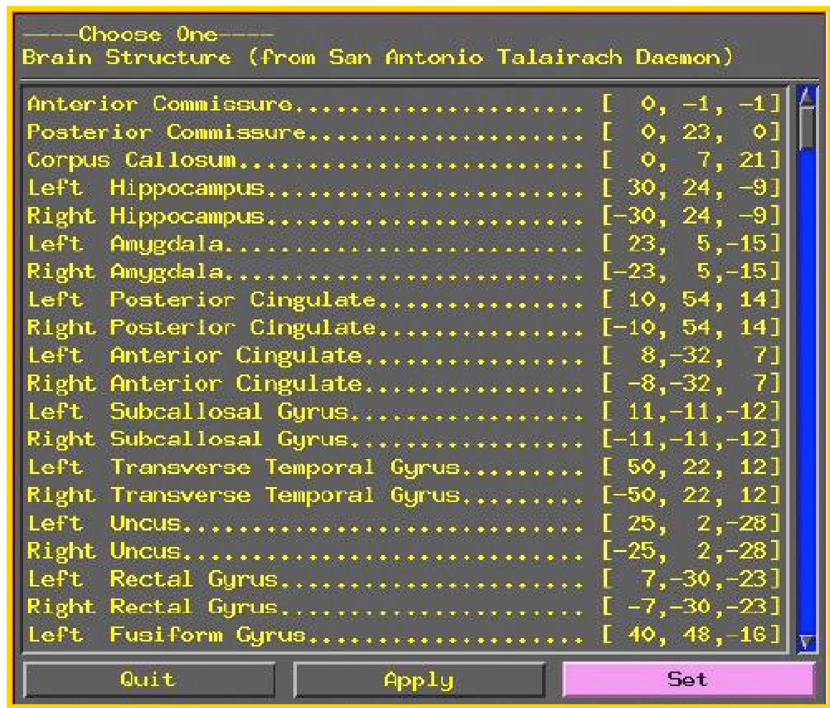
  - The result will be: **`func+tlrc.HEAD`** and **`func+tlrc.BRIK`**

- Why bother saving transformed datasets to disk anyway?
  - Datasets without `.BRIK` files are of limited use:
    - You can't display 2D slice images from such a dataset
    - You can't use such datasets to graph time series, do volume rendering, compute statistics, run any command line analysis program, run any plugin…
      - If you plan on doing any of the above to a dataset, it's best to have both a `.HEAD` and `.BRIK` files for that dataset

- Some fun and useful things to do with `+tlrc` datasets are on the 2D slice viewer Buttton-3 pop-up menu:

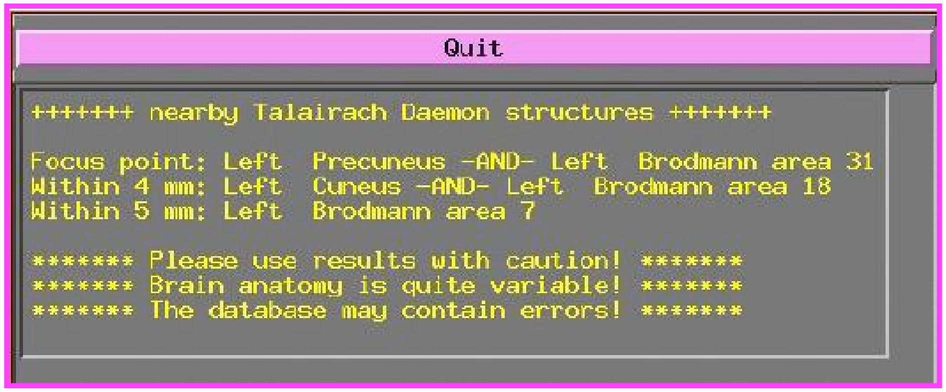


  ✧ **[Talairach to]**



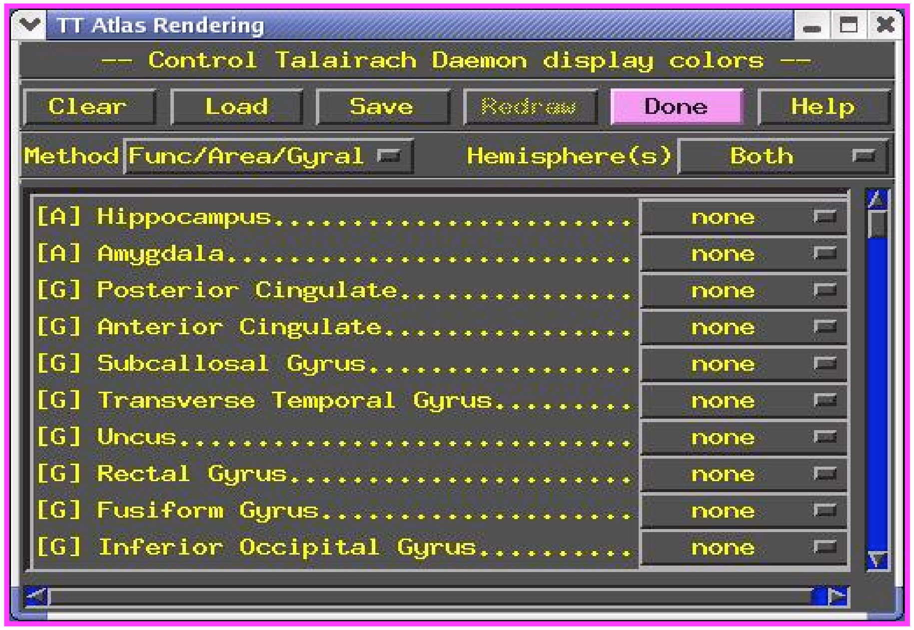
Lets you jump to centroid of regions in the TT Atlas (works in `+orig` too)

✧ **[Where am I?]**



Shows you where you are in the TT Atlas (works in `+orig` too)

✧ **[Atlas colors]**



Lets you display color overlays for various TT Atlas-defined regions, using the Define Function See TT Atlas Regions control (works only in `+tlrc`)