Fornax Mosaic Observations on 26 Sep 2010

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1. Observations and General Reductions

A test of observations of Fornax A (0321-37) was observed on 26 Sep 2010. The observations contained 16 spw, each with 64 2 MHz channels, and covered 4.0 to 6.0 GHz. All Stokes were recorded. The flux density calibrator was 3C48, the polarization angle calibration was 3C138 and the D-term+phase calibrator of J0334-4008, a quasar about 4 deg from Fornax.

The mosaic region covered the central region of the western lobe of Fornax A and the 22 pointing are shown in Fig. 1. Each pointing was scheduled for 120 sec, giving about 90 seconds of integration time and 30 seconds for source change. Since the sky position changes were less than 10 arcmin, the change time should be somewhat less.

The importasdm and averaging of the data sampling from 1 sec to 6 sec was done in cv-post-b, and then transported to Charlottesville for further processing. The data processing steps were 'typical', and some key results are given below:

1. The flux density information from 3C48 was written from the casapy calmodel at 5 GHz for this source.
2. Major antenna flags were: all of ea13; spw 8-15 for ea16.
3. The first 20 channels in spw 0, 8 and the last 15 channels in spw 7 and 15 were flagged. These are at the edge of the two major frequency groups. Also, channels 0 to 20 in spw 15 had to be flagged for some unknown reason.
4. I don't know if the on-line flags were applied (it was hard finding this information). About 6 seconds of data for each scan were quacked.
5. The bandpass amplitude and phases were normal.
6. The gaincal/fluxscale, using 3C48, gave

   J0334 1.839 to 2.117 Jy between 4.1 and 5.9 GHz

   3C138 4.52 to 3.50 Jy between 4.1 and 5.9 GHz
7. Applied total intensity calibration using J0334

2. Polarization Calibration

The polarization calibration consisted of three steps: First, after total intensity calibration, a large delay between the RL and LR was measured and removed. This was done in 'gaincal', with gaintype 'KCROSS' on 3C138. The size was about 0.3 nsec, so it wrapped over several cycles between 4 and 6 GHz. Perhaps, this calibration should be more routinely checked as a system calibration.

The absolute angle calibration from 3C138 then proceeded. Because of the wide-bandwidth the following setjy was used for 3C138:

```
#  Put in 3C138 I,Q,U,V

taskname = 'setjy'
default (taskname)
vis = 'fornax_split.ms'
field = '28'
for i in range(0,16):
    spw = str(i)
    FF = (4.13*(15-i) + 3.13*i)/15
    QQ  =FF * 0.113 * cos(-10.5*3.1416/180.0)
    UU  =FF * 0.113 * sin(-10.5*3.1416/180.0)
    fluxdensity = [FF, QQ,UU,0.0]
    print i, FF, QQ,UU
    setjy()

#  find pol angle

taskname = 'polcal'
default (taskname)
vis = 'fornax_split.ms'
caltable = '0518_Xphs'
gaintable = ['gain2','cal.Xdel']
gainfield = ['28','28']
poltype = 'X'
field = '28'
refant = '7'
polcal()
```

The phase/D-term calibration J0334 was then imaged and found to have to be polarization by about 1.3%. The full polariization model for this source was made using

```
taskname = 'setjy'
default (taskname)
vis = 'fornax_split.ms'
#field = '1'
field = '14'
for i in range(0,16):
    spw = str(i)
    FF = (1.76*(15-i) + 1.97*i)/15
    QQ  = -0.022 * FF / 1.865
    UU  = +0.022 * FF / 1.865
    fluxdensity = [FF, QQ,UU,0.0]
    print i, FF, QQ, UU
    setjy()
```

and then using poltype D in polcal. Thus, four gain tables were used in applycal (the bandpass was applied in the original data set in cv-post-b: the temporal gain for RR and LL, the delay difference between RL and LR, the absolute polarization angle from 3C138, and the D-terms from J0334.

3. Wide-band Imaging of Phase Calibrator

The phase-calibrator J0334 was imaged in three ways over the wide bandwidth: (1) an'mfs' image of all 16 spw's at once; (2) an 'mfs' image of each spw, and then the average; (3) an 'mfs image of all 16 spw's using nterms=2 in order to determine the spectral index as well. A contour diagram of the three images are shown in Fig. 2. The casapy execution times were 0.3, 1.5 and 1.4 minutes, respectively.

Clearly, the wideband image (MF2 in center), for which the source emission and spectrum are determined, is much better than MF1 imaging (top) which produces one image across the entire 4-6 GHz range. The image at the bottom for which an image for each spw has been made, and then averaged over the 16 spw, is nearly as good as the

MF2 image. The clean box was placed only around the bright source, so that the faint source to the left has some dirty sidelobes. The resolution of he MF2 image is somewhat better than the other two images. The execution time for the MF2 and Summed images were about the same.

4. Imaging of Fornax-A

The best image of Fornax-A was made a low resolution. For any of the 22 field, the visibility amplitude versus uv spacing was something like that shown in Fig. 3. For the low resolution Fornax image, a taper of 1.5 klambda was used to obtain about a $60''$ resolution. The mosaic mode of all 21 fields was used with only one angular scale because of the restricted range of uv-baselines. Because of the deep negative sidelobes, the cleaning boxes had to be carefully chosen and modified as the cleaning progressed in order not to include the negative features in the best clean image.

A comparison of this image with the same region at 1.5 GHz obtained with the VLA in the 1980's is shown in Fig. 4. The lumpy features at 5 GHz correspond to regions of slight increases in the intensity at 1.5 GHz. This is almost certainly an artifact of cleaning an image in which the extended emission is missing: clean tends to pile the emission is resolution-sized blobs. It is clear from this comparison that without single-dish data, a scientifically viable image of EVLA data alone cannot be obtained for Fornax.

The high resolution image of Fornax, made with the casapy multi-scale mosaicing mode, worked well but the resulting image of about $15''$ is also not trust-worthy.

Images of Q and U polarization were also made. The calibration should be accurate to $< 1\%$, but the images are subject to the loss of large-scale emission and have not been analyzed in any detail.

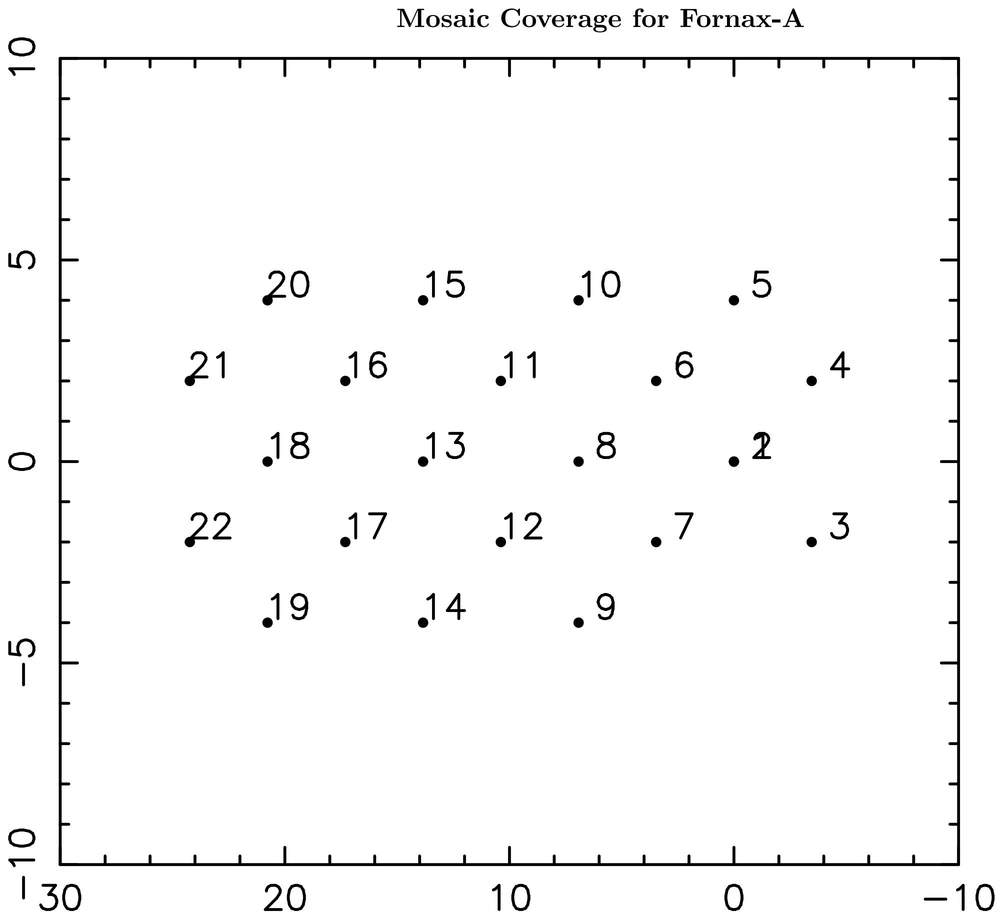

Fig. 1.— The locations of the mosaic used for the part of the western lobe of Fornax-A. Each point is the phase center and the y- and x-axes scales are in arcmin.

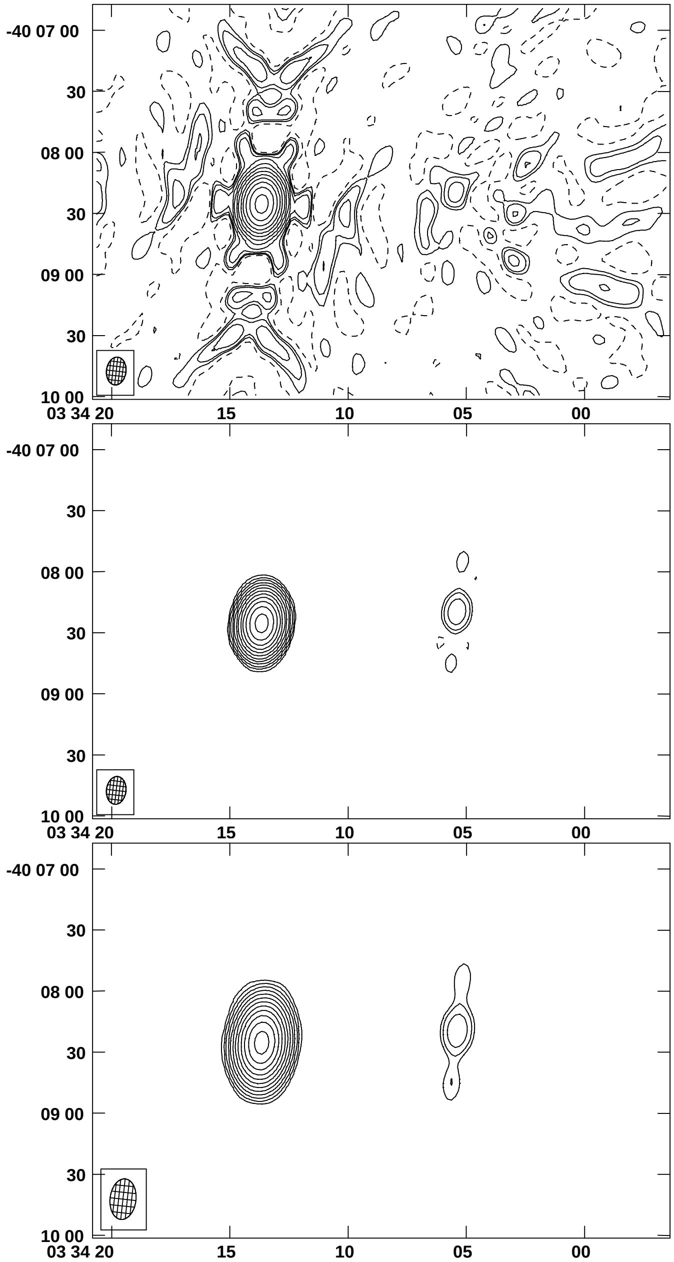

Fig. 2.— Contour plots of three types of images. Top: MF1, middle: MF2, bottom: sum of spw parts. All contour levels are at 0.0007 x (-1,1,2,4,8,16,32,64,128.250,500,1000,2000).

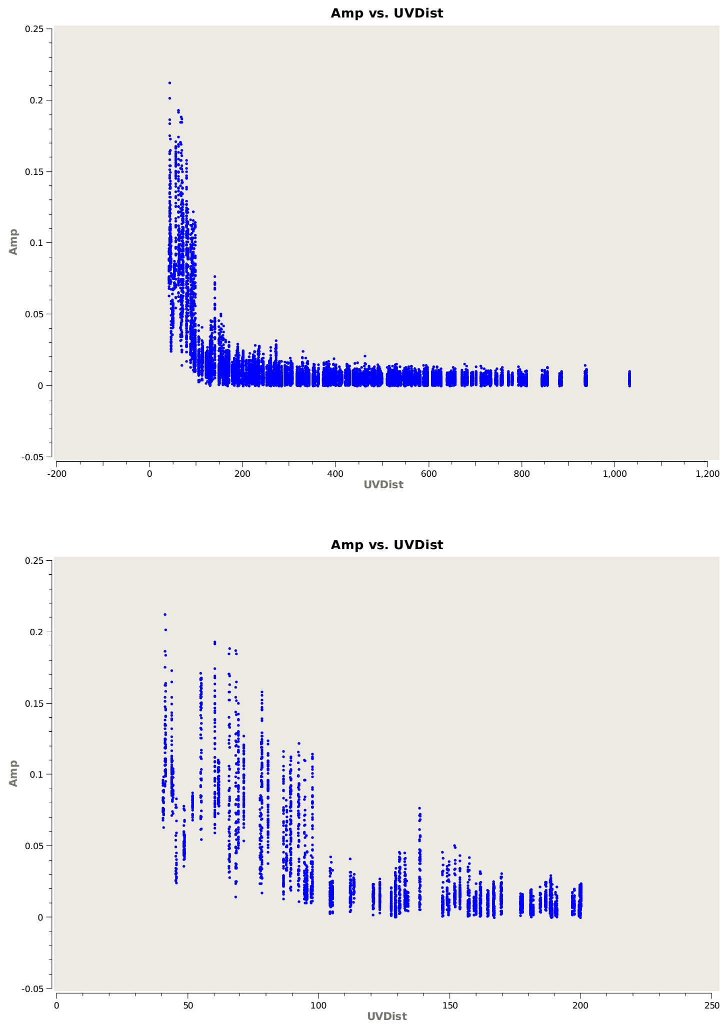

Fig. 3.— Visibility amplitude versus uv-spacing for fornax13 field. Top plot shows the complete uv-distance and the bottom plot shows only the inner 70-m. The maximum correlated flux density is about 0.2 Jy, but the field contains between 0.8 to 1.0 Jy. The data were average over all channels and over 60 seconds, but each spectral window point is plotted.

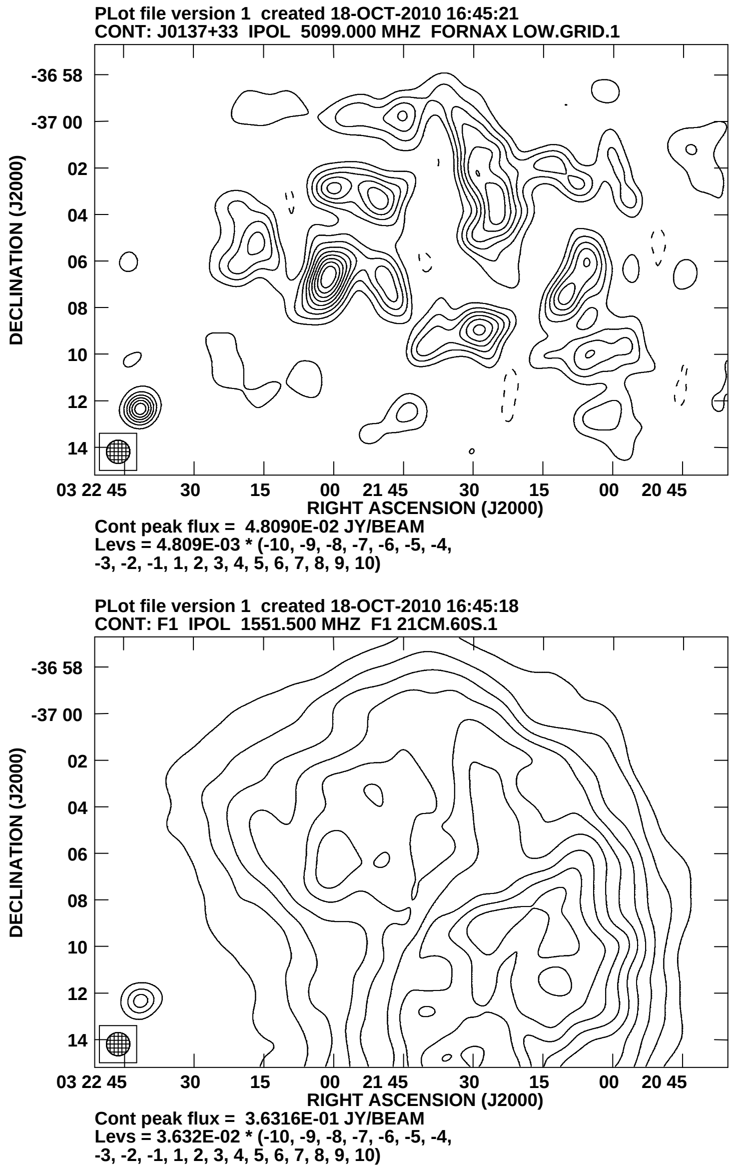

Fig. 4.— Contour plots of Fornax-A Western lobe at 60″ resolution. The top plot is for the 4 to 6 GHz data without single dish input. The bottom plot is for the 1.5 GHz VLA image that included single dish data. The contour levels are -10,10,20,30,40,50,60,70,80,90% of the peak The point component in the lower left is the radio core in the nucleus of NGC1316. The faint one contour circle at 03h22m45s, -37d06' at 5 GHz is at the location of the interacting galaxy NGC1317. It is not present in the 1.5 GHz image.