Imaging With a 32-Antenna Allen Telescope Array

M.C.H. Wright and G.R. Harp

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We compare the imaging performance of the ATA-32 and the full ATA array with the VLA.

The starting picture is shown in Figure 1. This picture has the advantage that the eye is quite sensitive to imaging defects in a recognisable picture, so we made images as would be produced from observations with the ATA and with the VLA, currently the world's largest array of telescopes for radio astronomy.

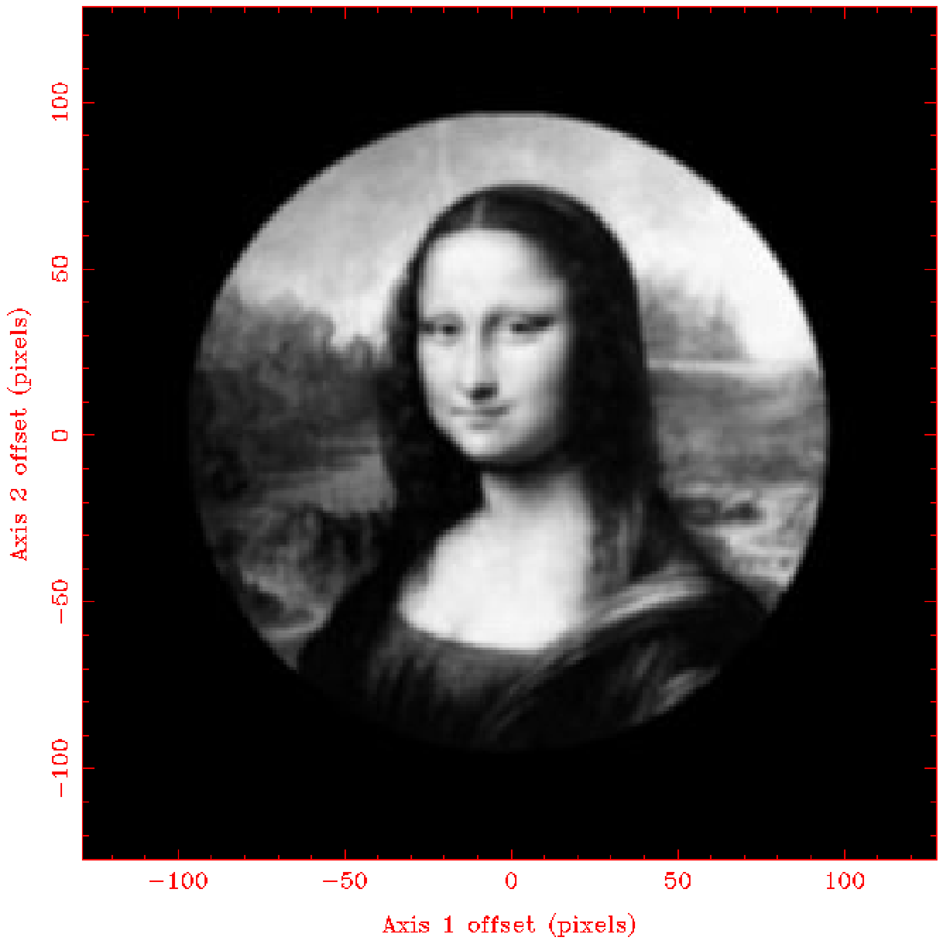

Figure 1

Although, this picture is not an astronomical image, it has many of the same attributes as the distribution of radio emission from objects like galaxies and supernova remnants. The painting has a finite angular extent with large and small scale structures which follow a power law Fourier spatial frequency composition almost identical to the supernova remnant Cassiopia A which we have used in previous studies of the imaging performance of radio telescopes such as the ATA and the 64-antenna millimeter wavelength array currently being built in Chile. We could also make a favorable comparison between ALMA and ATA's imaging performance, but the VLA is better known.

We generated uvdata by sampling this image with 3 different interferometer arrays i) 350 antenna ATA (ATA-350) ii) 32 antenna ATA (ATA-32) iii) VLA-D configuration.

The image was scaled to fit within the primary beam of the ATA 6.1 m antennas at a frequency 1.42 GHz. In order to obtain a more complete uv-coverage for ATA-32 and VLA-D we sampled the uvdata at 1 hour intervals over 8 hours for all three arrays. The resulting images are shown in Figures 2-4. We ignore the smaller primary beam of the VLA and use the VLA-D configuration which gives about the same resolution as the ATA-350.

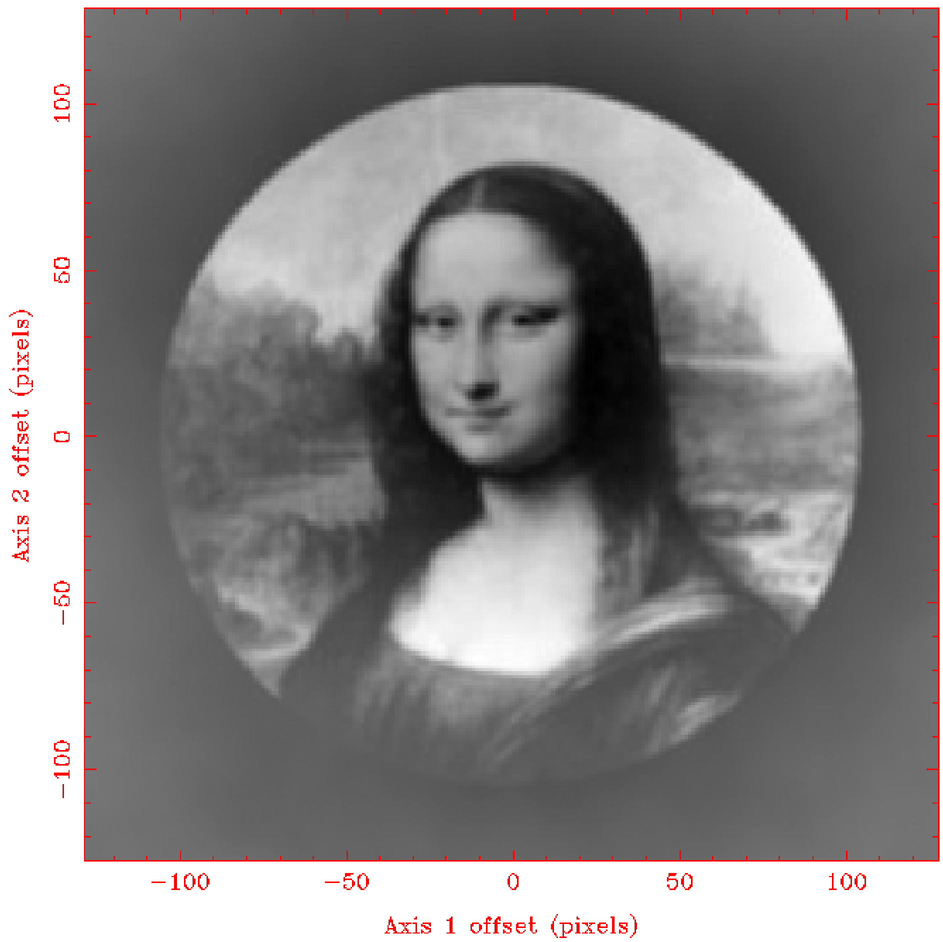

Figure 2: Image obtained with ATA-350 sampled at 1 hour intervals.

ATA-350 has almost complete uv-coverage between minimum and maximum spatial frequencies set respectively by the antenna dish diameter and the maximum separation of the antennas. Spatial frequencies smaller than the antenna dish diameter cannot be obtained by direct interferometer observations without shadowing the aperture. This leads to the well known "short spacing problem" which manifests itself on this image by the lack of total black and white, and missing large scale structure which is less apparent. The angular resolution, beam FWHM = 40 x 37 arcsec, is limited by the maximum spatial frequencies sampled and shows up as a loss in detail of small scale features in the image.

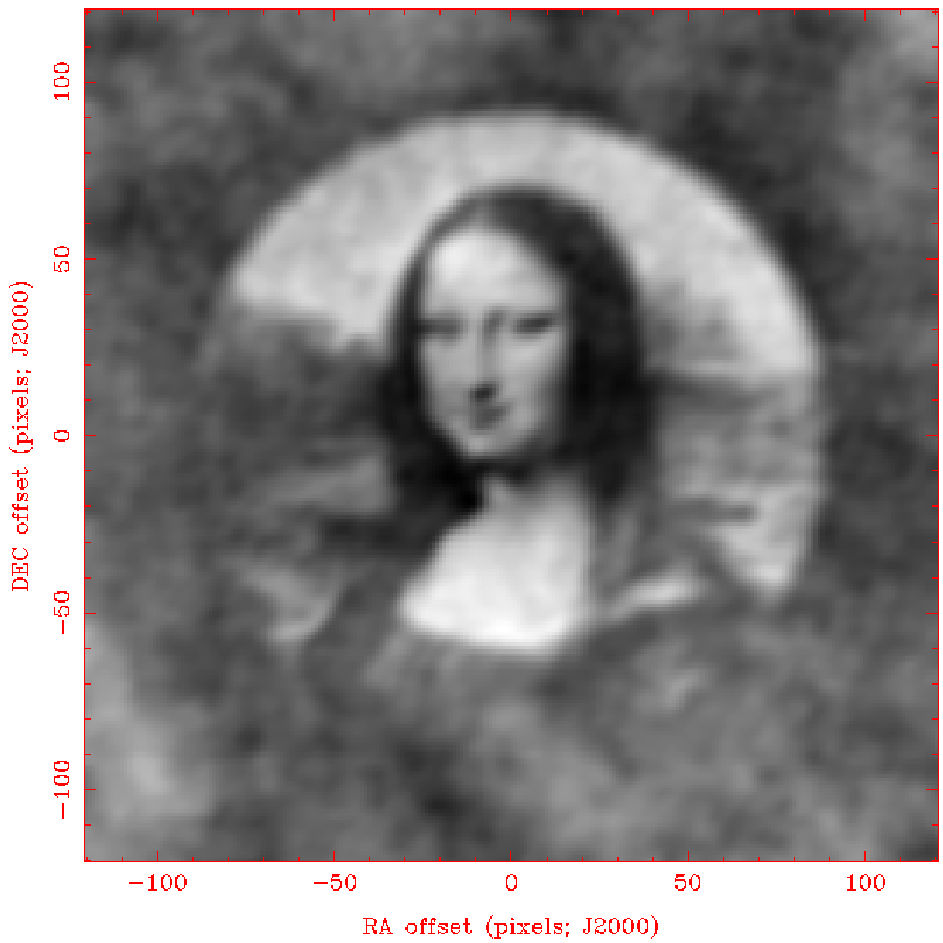

Figure 3: Image obtained with ATA-32 sampled at 1 hour intervals.

The loss in image fidelity in the ATA-32 image obtained with 1 hour uv-samples is quite apparent. The resolution, beam FWHM = 177 x 104 arcsec, is about 3 times lower, and the inadequate uv-sampling leads to the blotchy appearance.

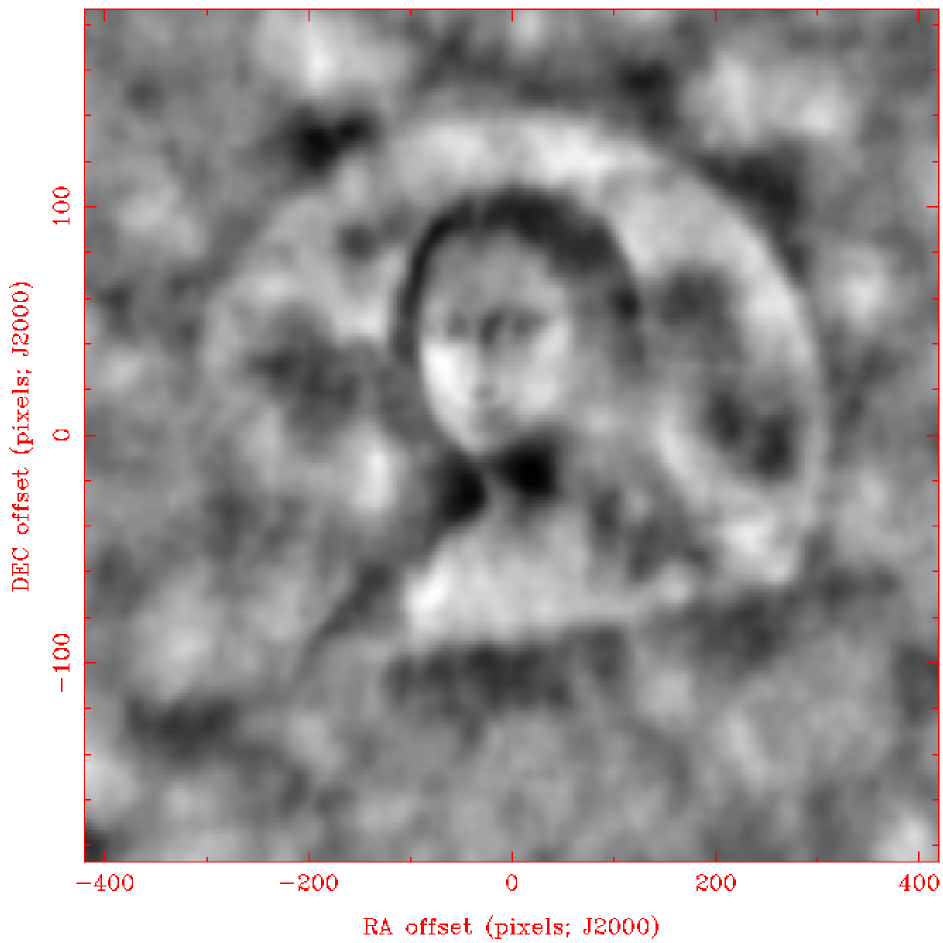

Figure 4: Image obtained with VLA-D sampled at 1 hour intervals.

The VLA has antennas distributed along 3 radial arms which leads to the hexagonal sidelobe pattern in the VLA-D image. Although the number of antennas and maximum spacing is similar to ATA-32, there is considerable loss in image fidelity with the sparse uv-coverage obtained with 1 hour samples.

Although the 350 antenna ATA provides almost complete uv-coverage in a single snapshot, samples at 1 hour intervals with ATA-32 and VLA-D give inadequate uv-coverage for this complex image. The uv-coverage can be improved by sampling the uv-data more frequently. In Figures 5-6 we show the ATA-32 and VLA-D images obtained with 2 minute samples to provide complete sampling along each uv-trajectory. (The Nyquist sample interval for a 1 km maximum antenna separation of 6 m dishes is ~ 2.8 min)

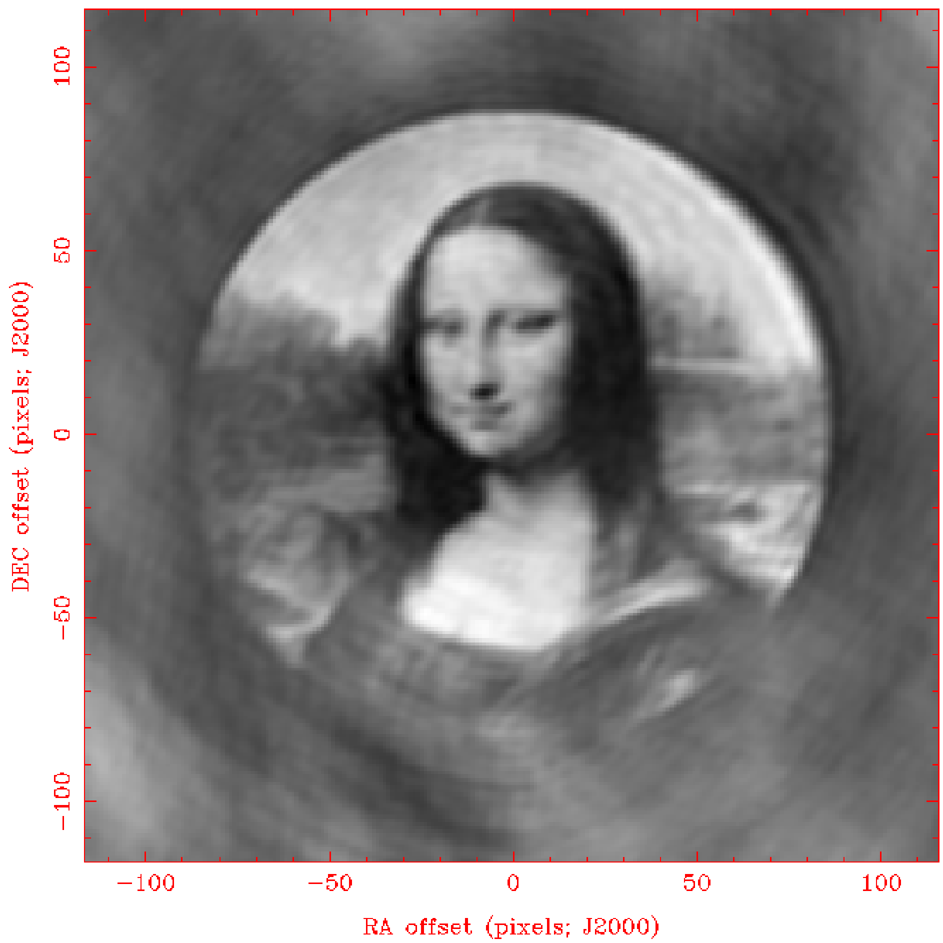

Figure 5: Image obtained with ATA-32 sampled at 2 minute intervals.

The ATA-32 image is improved with 2 minute uv-samples, but still not as good as ATA-350 with 1 hour samples. The angular resolution of ATA-32 with 2 minute samples is about the same as with 1 hour samples, but the better sampling improves the image fidelity. The ring sidelobe pattern is the edge diffraction pattern from the circular uv-distribution, and results from weighting the data to obtain a more uniform uv-sampling.

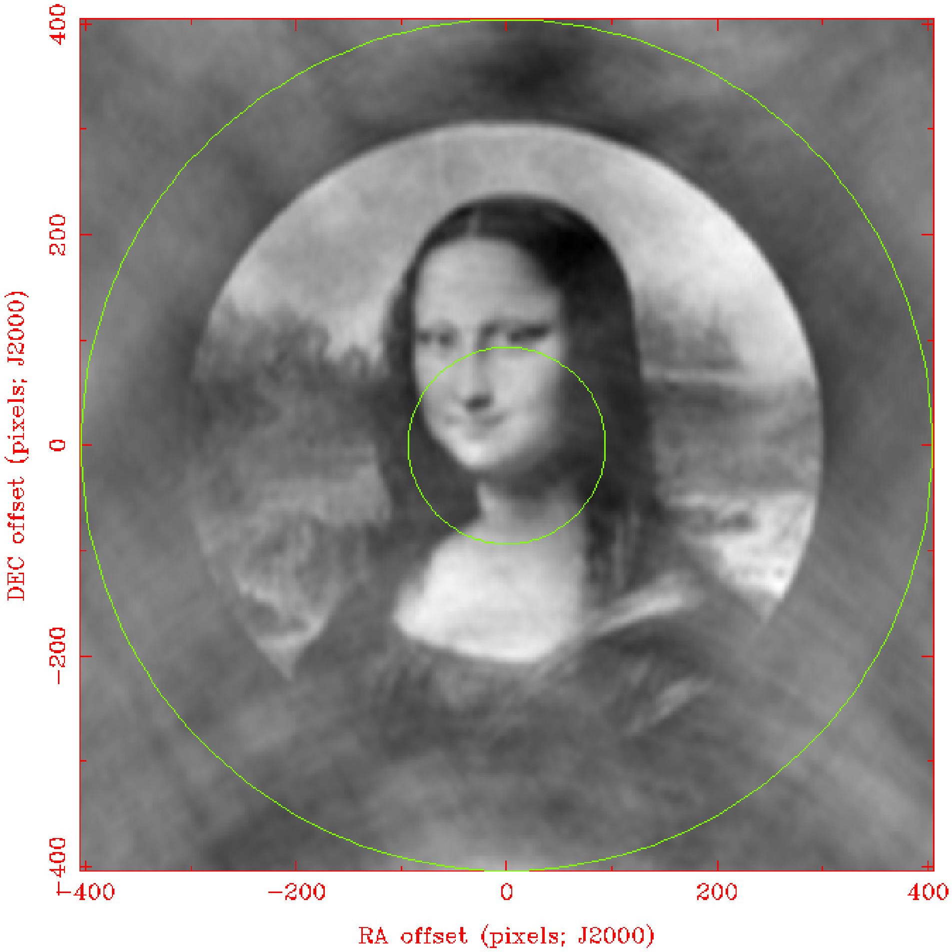

Figure 6: Image obtained with VLA-D sampled at 2 minute intervals.

The 2 minute sampling improves the uv-coverage considerably, and the VLA-D image is greatly improved. The angular resolution, beam FWHM = 75 x 38 arcsec, is better than ATA-32, and this gives better resolution of the small scale structure than ATA-32, although larger scale structures are not as well reproduced. The hexagonal sidelobe pattern is still apparent, but is reduced.

In Figure 6 the large and small circles show the ATA and VLA primary beam width (FWHM) at this frequency. In practice a VLA observation for this image would need a mosaic observation which would further limit the image fidelity due to pointing and primary beam errors (See, for example, Cornwell, Holdaway & Uson, 1993, A&A 271, 697) and the time muliplexing required for mosaic observations would decrease the SNR by the ratio of the dish diameters (a factor 6.1/25).

All these images could be improved by deconvolution, which would reduce the sidelobe pattern. Deconvolution techniques are less successful on poorly sampled, or low signal to noise images, and can take 10-100 times the image processing time as for the original image formation. ATA-350 is designed to provide a nice Gaussian synthesised beam pattern so that deconvolution will not normally be required.

The ATA will be an exceptional survey instrument with it's large field of view and excellent imaging capability, whereas the VLA is a better choice for high resolution.

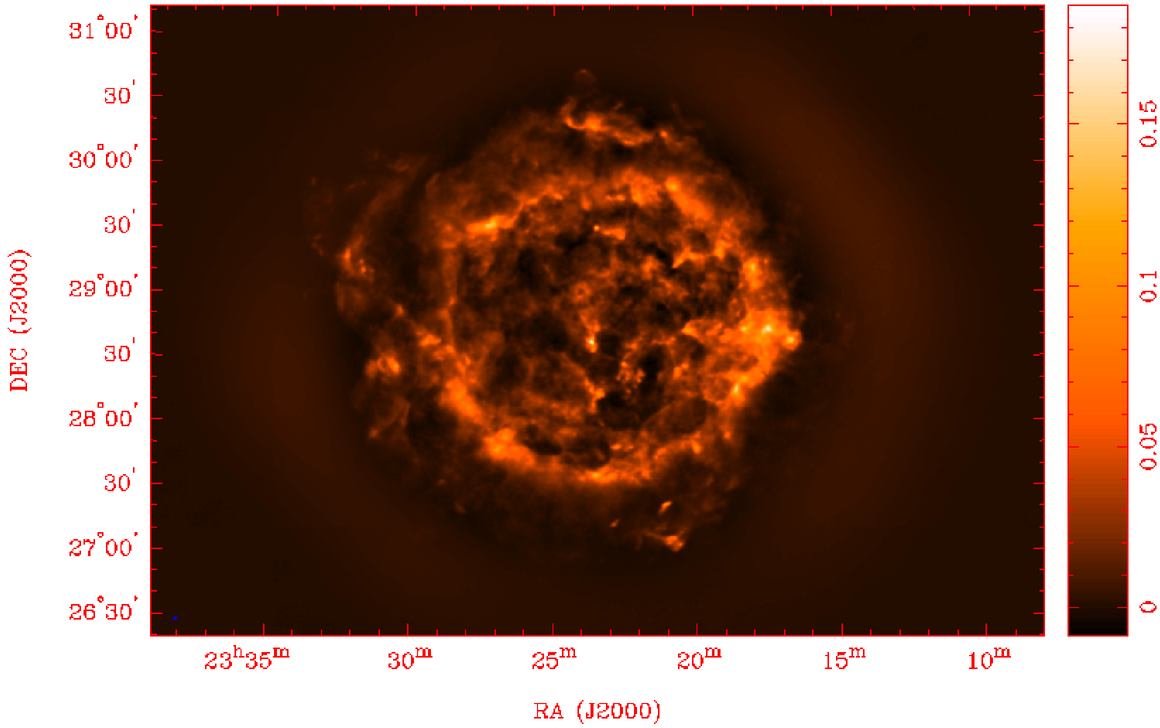

Figure 7: A mosaic MFS Image of Cas A scaled up 40 x real size.

Imaging with the ATA has simulated for a range of source sizes and declinations using the MIRIAD software. Figure 7 shows a Mosaic MFS Image of Cas A scaled up 40 x real size, imaged with the ATA at 1.42 GHz. We generated uv-data for a snaphot observation by the ATA using a VLA image of Cas A as source model. The image is 4 degrees on a side. The synthesised beam FWHM, 77 x 78 arcsec is shown in the lower left corner. For more details see ATA memo 52 - Allen Telescope Array Imaging.