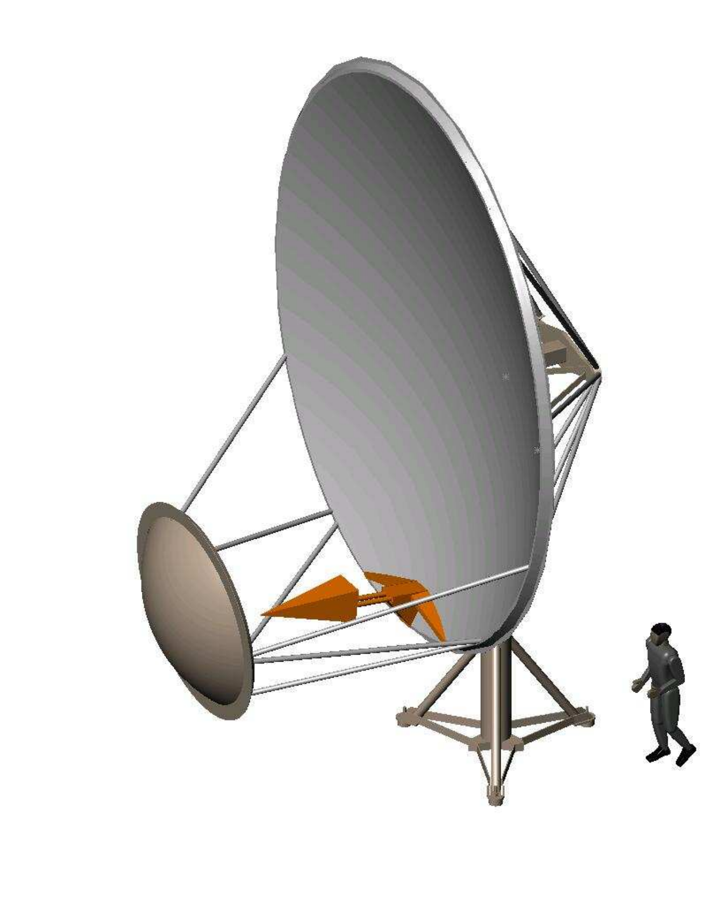
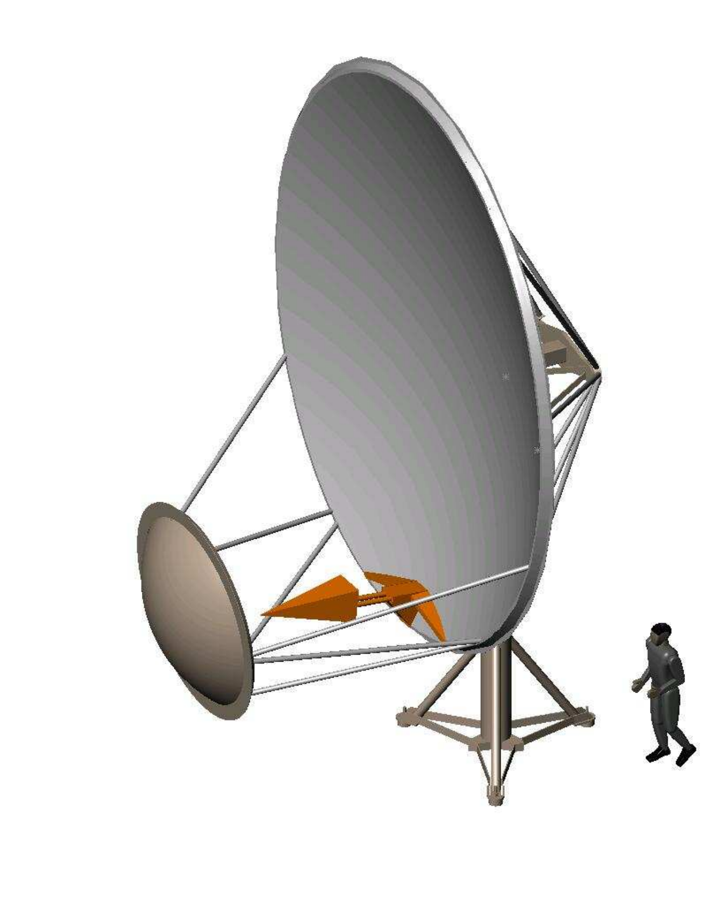
The Allen Telescope Array



Douglas Bock
Radio Astronomy Laboratory
University of California, Berkeley

Socorro, August 23, 2001

The Allen Telescope Array



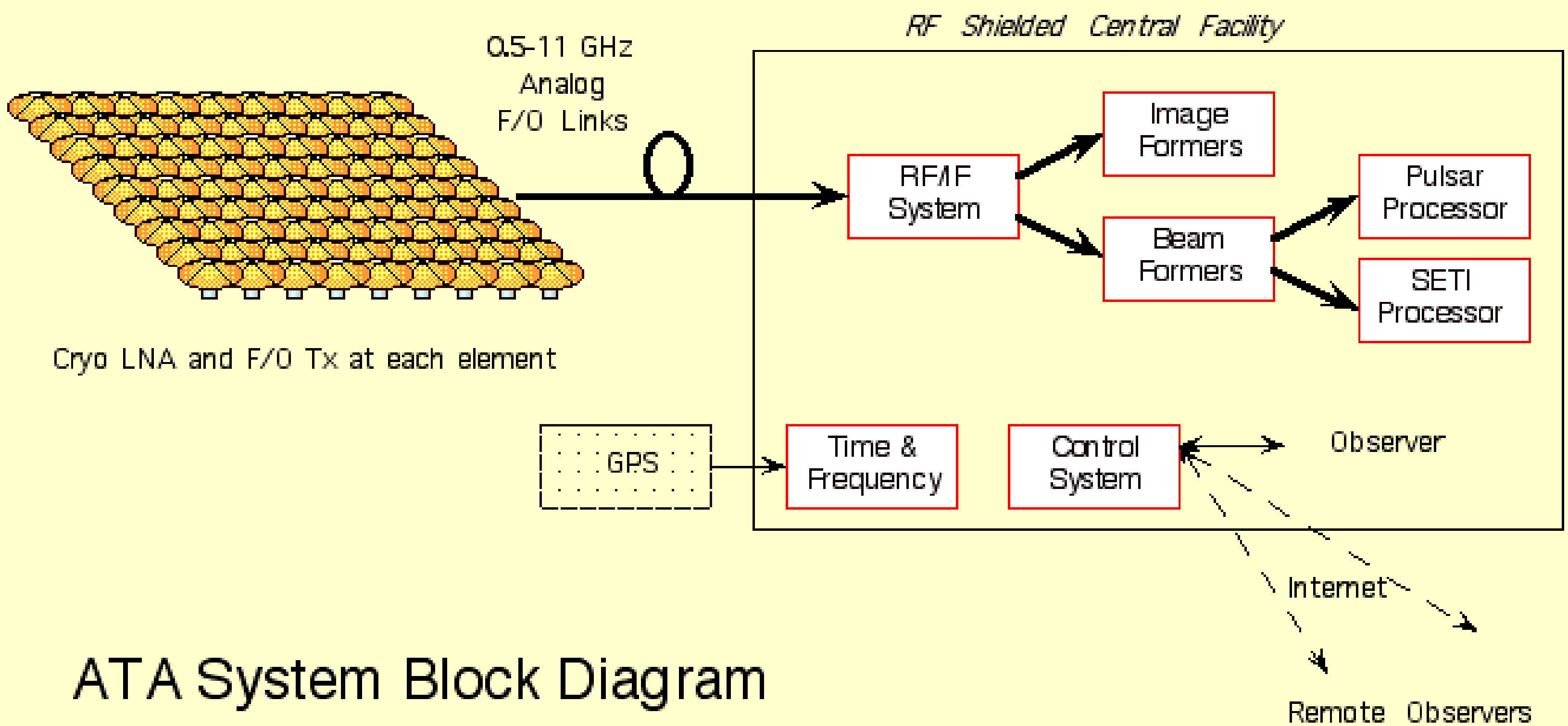
Outline:

- System description
- Science goals
- Antenna configuration

ATA: What is It?

- Massively parallel array of small dishes
  - ***350 elements*** each 6.1 m in diameter
  - total collecting area ***larger than 100 m dish***
  - 0.5 – 11.2 GHz ***simultaneously***
  - ***multiple*** beams
- **Must be *much* cheaper than existing arrays**
- Joint project of SETI Institute and UC Berkeley
- Funded by private donations
- Access to the community determined by NSF contribution (but collaborative projects also possible)

ATA System Overview



ATA System Block Diagram

IF Processing

Tradeoffs to be made	**Likely to achieve**
# RF tunings (LO1's)	4
# Beams (dual poln.) per RF tuning	4
BW per beam	100 MHz
Constraints on beam locations	primary beam?
Image and alias rejection	30–40 dB

Total of 16 dual polarization beams

Only 5 K$ per antenna

Correlator

- Image entire primary field of view
- Large number of antennas is a challenge
- Achievable BW will be set by funding
- F/X design looks best for large N
- Potential for using industry terabit switching
- Likely 1024 channels in maximum BW 100 MHz

Beamformers ⇨ Backends

- Multiple beams speed up SETI searches
  - More than 1 star per field of view
  - Run in anticoincidence to identify RFI
  - Enables **simultaneous SETI and radio astronomy**
- Pulsar research will be a major use
- RA spectrometer in addition to correlator?
- *Active RFI suppression*

ATA Performance

Number of Elements	350		
Element Diameter	6.10	m	
Total Geometric Area	1.02E+04	m^2	
Aperture Efficiency	63%		
Effective Area	6.44E+03	m^2	
	2.33	K/Jy	
System Temperature	43	K	
System Eqiv. Flux Density	18	Jy	
Ae/Tsys	150	m^2/K	
Effective Array Diameter	687	m	Natural Weighting
Frequency	1	10	GHz
Primary FoV	3.5	0.4	degree
Synthesized Beam Size	108	11	arc sec
Number of Beams	>4		
Continuum Sensitivity			
BW	0.2	GHz	Confusion
Flux Limit in 10 sec	0.41	mJy	0.1 mJy at 1.4 GHz
Spectral Line			
Resolution	10	km/s	
Frequency	1	10	GHz
BW	3.E+04	3.E+05	Hz
Integration Time	1000	1000	sec
RMS brightness	0.70	0.22	K

Unique features of the ATA

- Wide field of view (2.5° @ 1.4 GHz)
- Large-*N* design (*N*=350, D=6.1 m)
- Broad instantaneous frequency coverage (0.5–11.2 GHz)
- Ability to conduct several simultaneous observing programs

Key ATA science drivers

- HI
  - All sky HI, $z < 0.03$, Milky Way at 100 σ
  - 25% of northern sky to $z \sim 0.2$
  - Zeeman
- Magnetic Fields
- Temporal Variables
  - Pulsar Timing Array
  - Pulsar survey follow-ups
  - Extreme Scattering Events
  - Transients
- SETI
  - 100,000 FGK stars
  - Galactic plane survey (2nd generation DSP)

Configuration Requirements

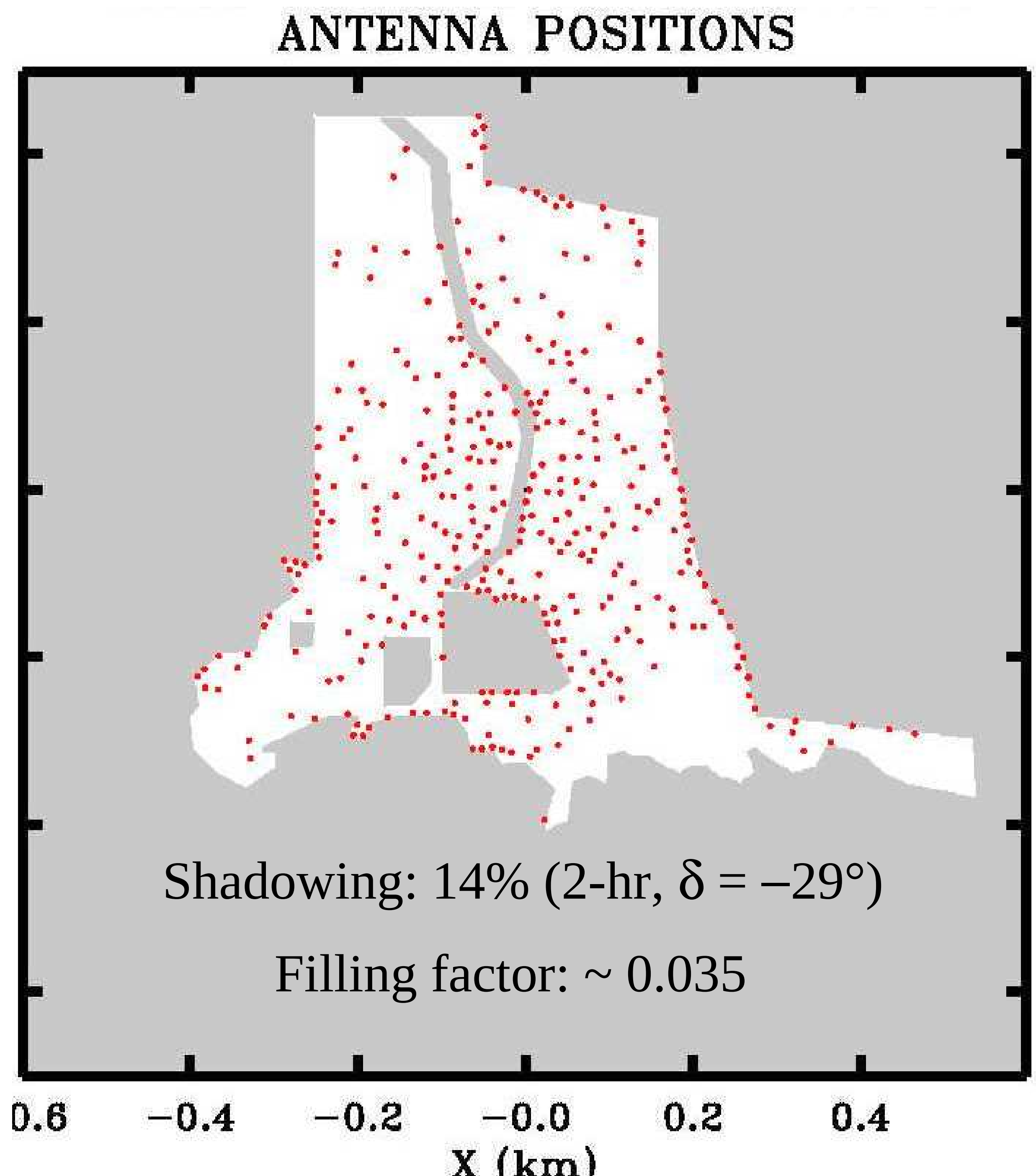
- SETI and pulsars/transients
  - low sidelobes
  - minimum shadowing
  - image southern sources
  - minimum confusion
- Imaging projects — snapshots!
  - low sidelobes
  - sufficient resolution but good sensitivity to extended structure (for HI, best resolution which matches T_b sensitivity to z-sensitivity)

Hat Creek Observatory

41° N, 121° W (Far northern California)

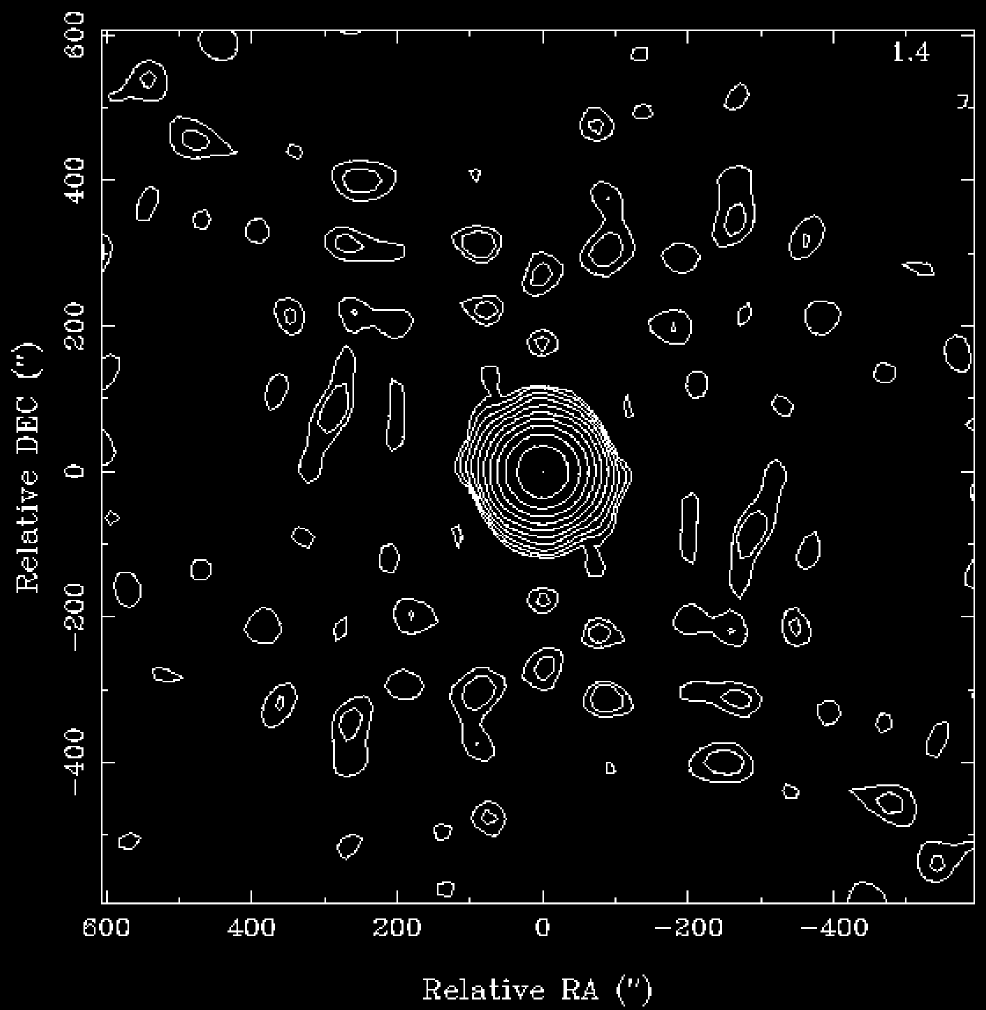
Optimizing *uv* Coverage

- Fit *uv* coverage to a Gaussian model
  (F. Boone 2001a,b; A&A submitted and in prep.)
- Model minimizes near sidelobes and forces a round beam (at chosen declination)
- Maintains ‘complete’ *uv* coverage (to 440 m baselines)
- Far sidelobes 1/*N* (rms)

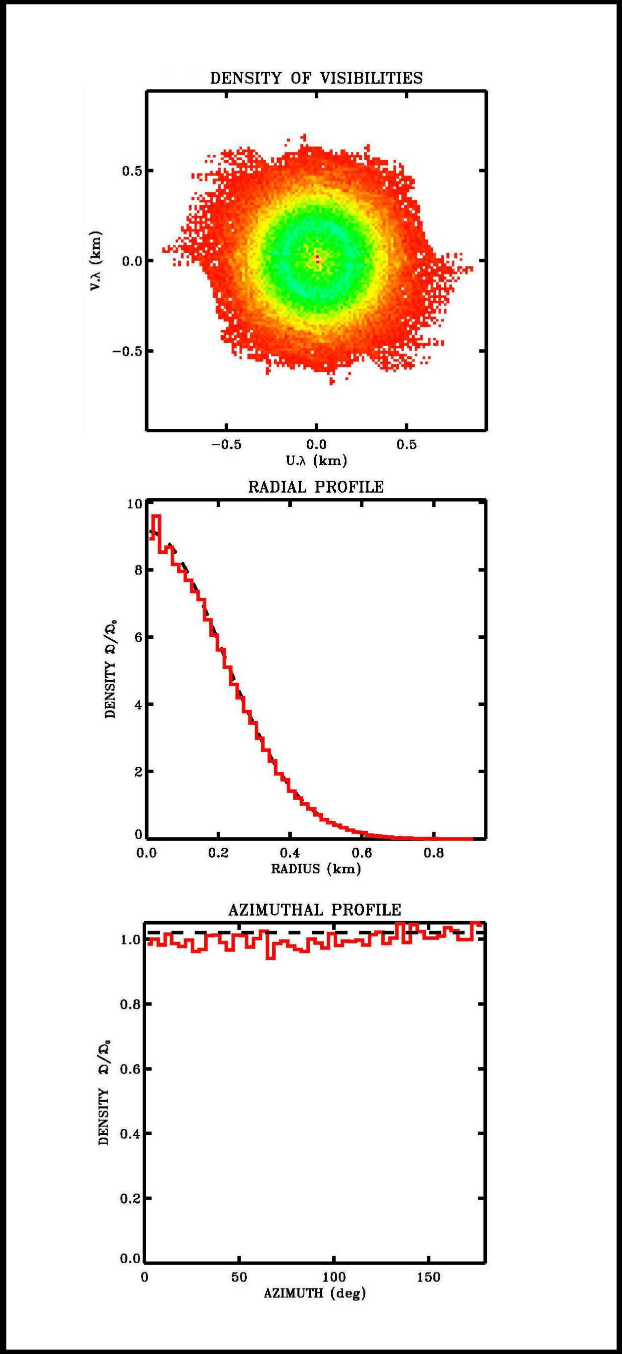

ANTENNA POSITIONS
Shadowing: 14% (2-hr, δ = –29°)
Filling factor: ~ 0.035
0.6
−0.4
−0.2
−0.0
0.2
0.4
X (km)

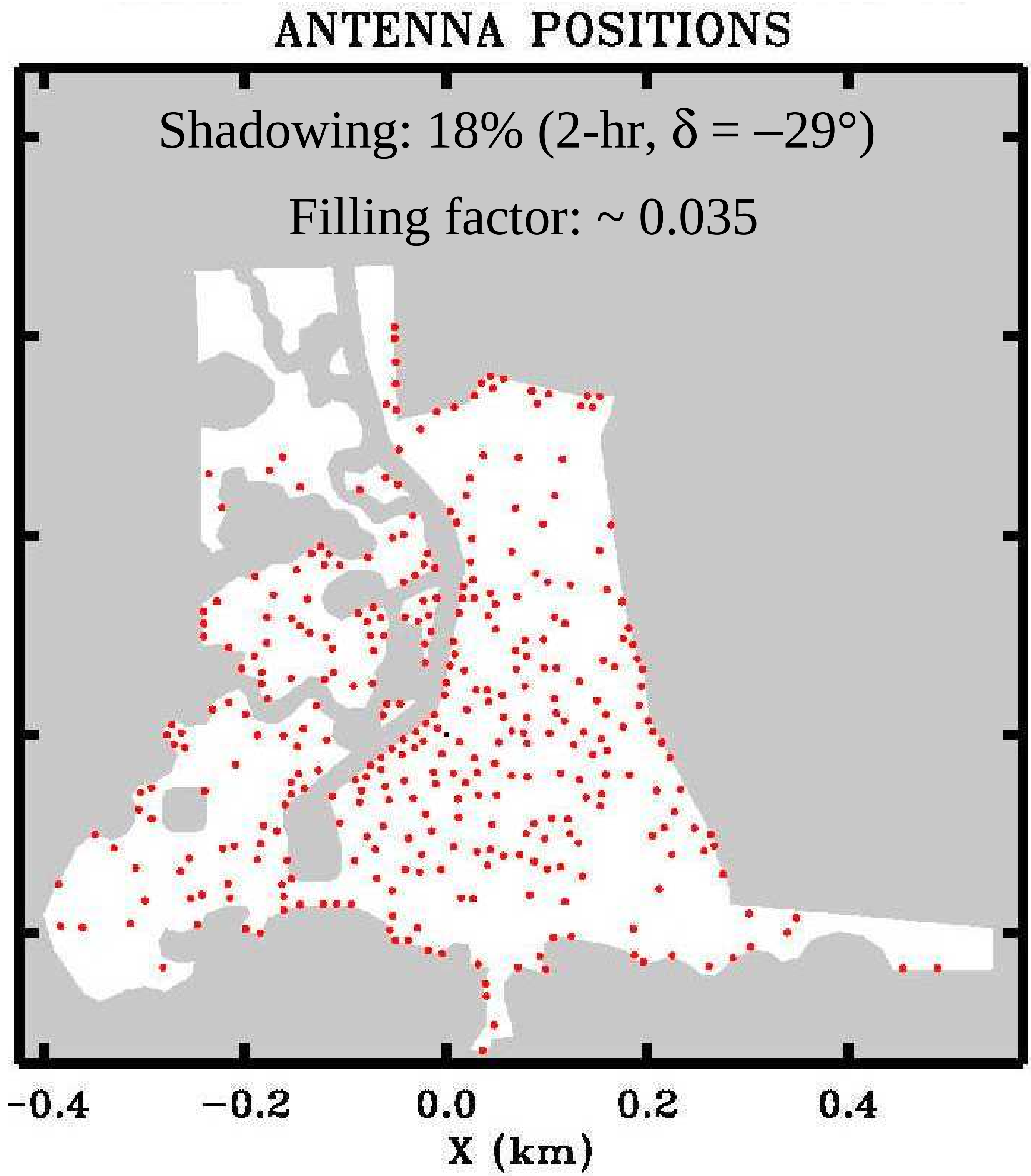
Nat. weighted beam 78″ × 78″ at δ = 5°
(ν = 1.4 GHz)

Sidelobes: near 0.9% peak; far 0.3% rms



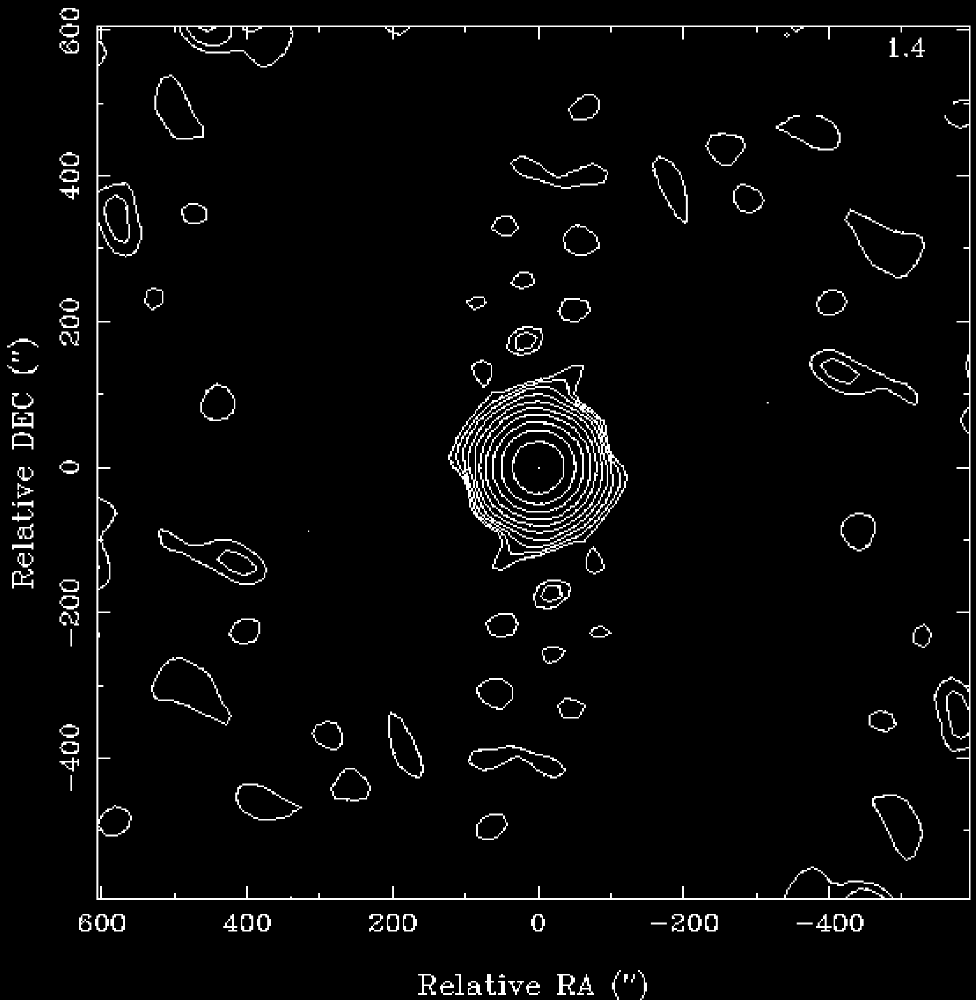
Contours: 0.3, 0.5, 0.9 … %



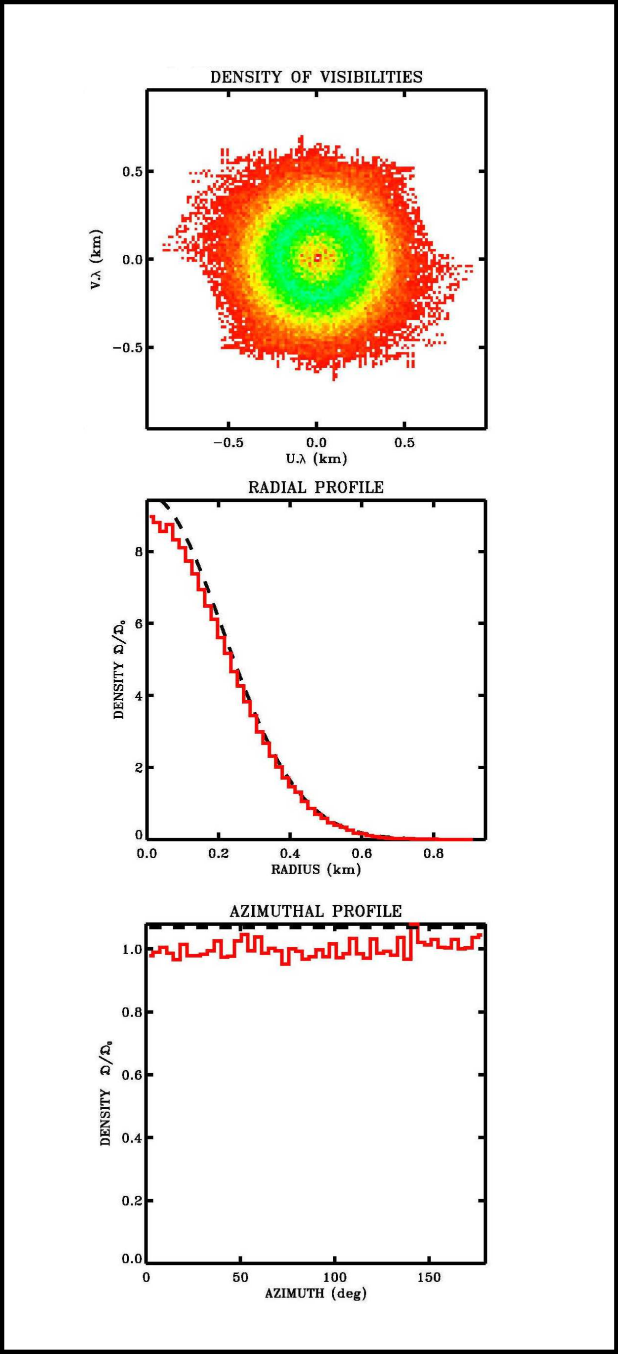

ANTENNA POSITIONS
Shadowing: 18% (2-hr, δ = –29°)
Filling factor: ~ 0.035
−0.4
−0.2
0.0
0.2
0.4
X (km)

Nat. weighted beam 78″ × 78″ at δ = 23°
(ν = 1.4 GHz)

Sidelobes: near 0.7% peak; far 0.3% rms

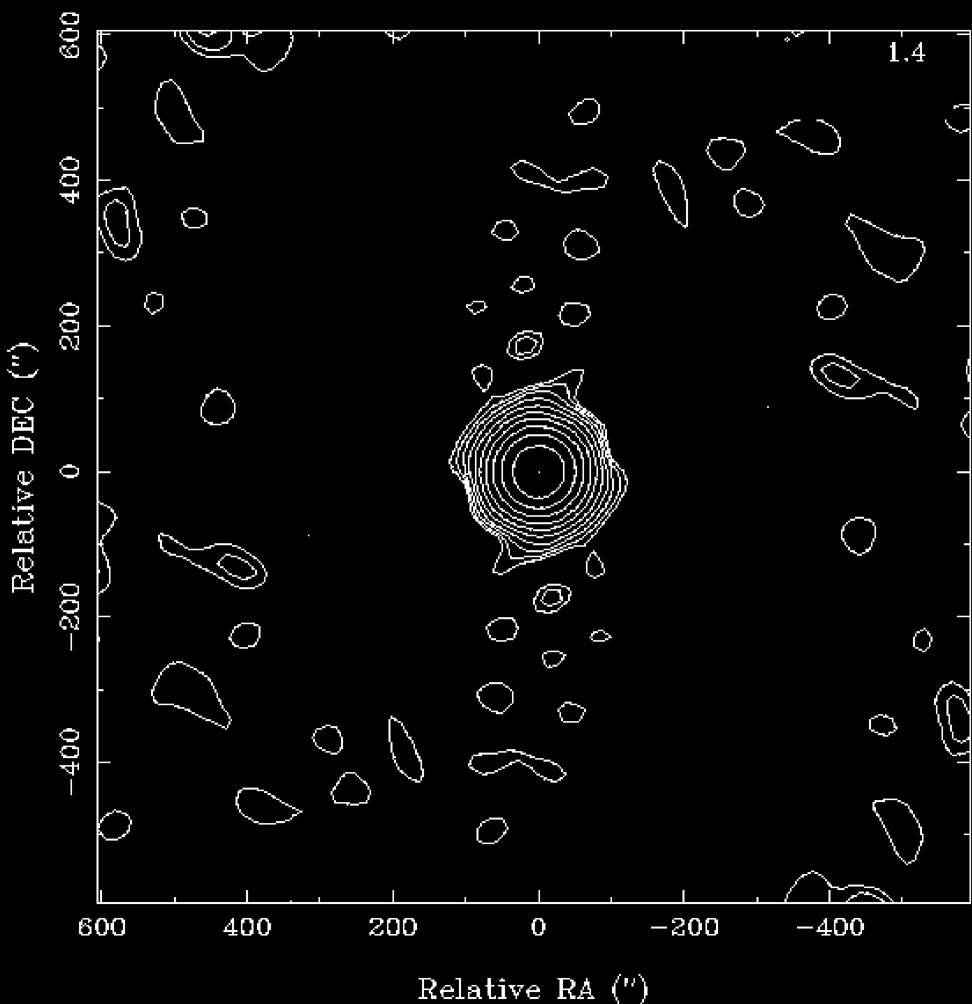


Contours: 0.3, 0.5, 0.9 … %



Nat. weighted beam 78″ × 78″ at $\delta = 23°$
(ν = 1.4 GHz)

Sidelobes: near 0.7% peak; far 0.3% rms



Contours: 0.3, 0.5, 0.9 … %

Re-weight for rounder beam and sidelobes < 0.1%
→ < 10% loss in sensitivity

Truncate at B_{max} = 440 m
(limit of complete *uv* coverage)
→ 84″ beam, sidelobes 1.5%

Put antennas in the road
→ sidelobes 0.5%

Lose 10% of antennas
→ sidelobes ∈2%

Random position error (1 m)
→ no effect

cf. the most compact configuration possible

- Antennas within 280 m diameter (filling factor 0.15) [0.039]
- Antennas still random (0.3% rms far sidelobes)
- Uniform distribution (5% near sidelobes [0.7%])
- Transit beam 150″ [78″]
- Shadowing 59% (2-hr, $\delta = -29°$) [18%]

Mosaicing faint, extended structure

	ATA 350	**VLA E-array**
ND (mosaicing speed)	2135	675
F (filling factor)	0.039	0.18
NDF	84	124
Shortest baseline	11 m	35 m
Spatial dynamic range	54.5	8.04
Snapshot near sidelobes	0.7 %	7 %

Timeline for ATA

- **1999-2001**
  - R&D phase
  - Rapid Prototyping Array
  - Site selection
  - Preliminary design reviews
- **2001-2002**
  - Design phase
  - Critical design reviews
  - Production Test Array
  - Plan construction phase
- **2003-2004**
  - Begin construction
  - First use of partial array
- **2005**
  - First hectare complete
  - Feed into SKA technology decision point