Conventional Parabolic Single Dishes and the Green Bank Telescope

Single Dish Summer School
August 2003

Phil Jewell
National Radio Astronomy Observatory
Green Bank

Parabolic Single Dishes

- The most common type of single dish radio telescope (beginning with the Reber Telescope in 1937) is a Parabolic Reflector with
  - Azimuth/Elevation mount
    - Azimuth motion by wheel & track or azimuth bearing
    - Some older telescopes are Equatorially mounted
      - e.g., the 140 Foot Telescope
  - Symmetric feed supports for one or both of
    - Prime focus feeds
    - Subreflector (secondary reflector)
      - With Cassegrain or Gregorian Optics
- The GBT is a special case of this:
    - an unblocked section of a parabola.

Parabolic Single Dishes

- Comparatively straightforward to build and structurally analyze
- Have circular, easy-to-interpret beam shapes
- Appropriate for wavelengths from ~1 m to the sub-millimeter
- Other designs may be more appropriate for longer wavelengths and for achieving very large collecting areas

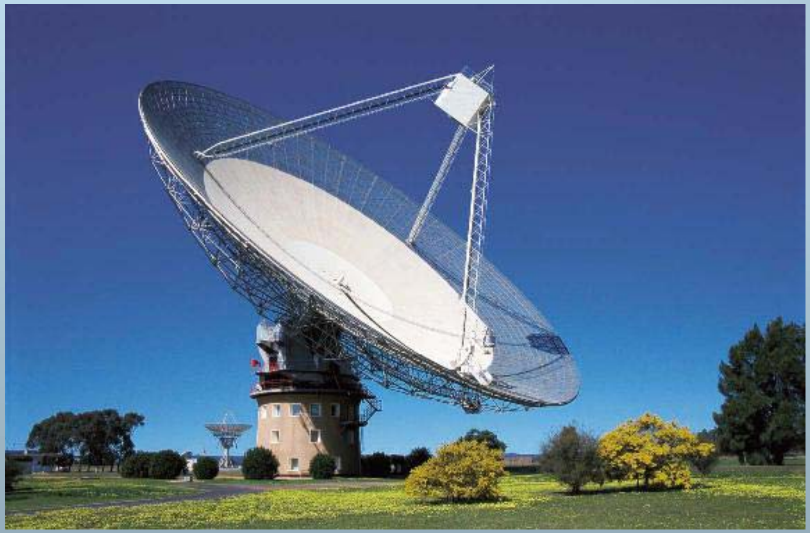
Major Parabolic Single Dishes of the World

- The large majority of the 54 single dish telescopes listed in the school volume article by Chris Salter (p493ff) are conventional paraboloids of this type. We will highlight only a few here:
  - Centimeter-wave telescopes:
    - MPIfR Effelsberg 100m
    - Parkes 64 m
    - Lovell Telescope
  - Millimeter/submm-wave telescopes
    - Kitt Peak 12 m
    - IRAM 30 m Telescope
    - James Clerk Maxwell Telescope (JCMT)
    - Caltech Submillimeter Observatory (CSO)
    - Heinrich Hertz Telescope (SMTO/HHT)
    - Large Millimeter Telescope (LMT/GTM)
  - Centimeter/Millimeter-wave telescopes
    - Nobeyama 45 m Telescope
    - Sardinia Radio Telescope (SRT)
    - Green Bank Telescope (GBT)

Effelsberg Telescope
Max-Planck Institut für Radioastronomie
Effelsberg, Germany

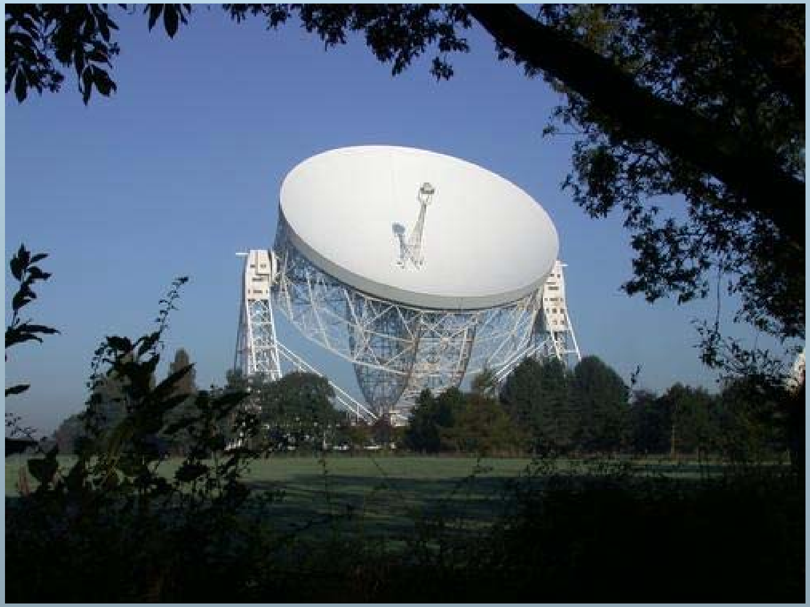
- 100 m Diameter
- Primarily cm-wave, but is used at 7 mm and 3 mm wavelengths
- Performance continues to be upgraded:
  - Surface upgraded
  - Focal Plane Array Receivers available and under development
  - Possible new active subreflector for efficient 3 mm operation

Parkes Radio Telescope
CSIRO
Parkes, NSW, Australia



- 64 m diameter
- Operation to 7 mm
- 13 Beam Focal Plane Array
  - for 1.5 GHz (L-Band)
  - Pulsar & 21 cm HI Surveys

Lovell Telescope
Jodrell Bank Observatory, University of Manchester
Jodrell Bank, England, UK



- Diameter: 76.2 m
- Built in 1950s but undergoing a major upgrade:
  - New reflecting surface
  - High precision surface adjustment
  - New pointing control system
  - Refurbishment of track and foundation
- Will be fully efficient to 6 GHz (5 cm)

Kitt Peak 12 Meter
Kitt Peak, Arizona, USA

- Built by NRAO
  - Completed in 1967
  - Operated by NRAO until 2000
- Pioneering millimeter-wave radio telescope
  - Detected CO, HCN, and dozens of other interstellar molecules
- Now operated by the University of Arizona

30 Meter Telescope
IRAM
Pico Veleta, Spain

- Full function mm-wave observatory for 3 mm, 2 mm, and 1.3 mm bands
- 75 μm surface accuracy
- ~1” pointing accuracy using nearby calibrators
- SIS Receivers for spectroscopy from 80 to 281 GHz
- MAMBO-2 bolometer array (117 pixels) for 1.2 mm continuum imaging

James Clerk Maxwell Telescope (JCMT)
UK, Canada, Netherlands
Mauna Kea, Hawaii (USA)

- 15 m diameter
- ~25 💻m surface accuracy
- SIS Spectroscopy Receivers for 230, 345, 460, 690 GHz
- SCUBA bolometer array (137 pixels) for continuum imaging
- SCUBA-2 (~10,000 pixel camera under development)

Caltech Submillimeter Telescope (CSO)
California Institute of Technology
Mauna Kea, Hawaii (USA)

- 10.4 m “Leighton Dish”
- SIS Spectroscopy Receivers for 230, 345, 490, 665 GHz bands
- SHARC-II bolometer array
  - 12x32 array
  - Filters for 350, 450, 850 μm
- BOLOCAM array
  - 151 pixels for 1.2 mm

Heinrich Hertz Telescope (HHT)
Submm Telescope Obs., Univ. Arizona / MPIfR

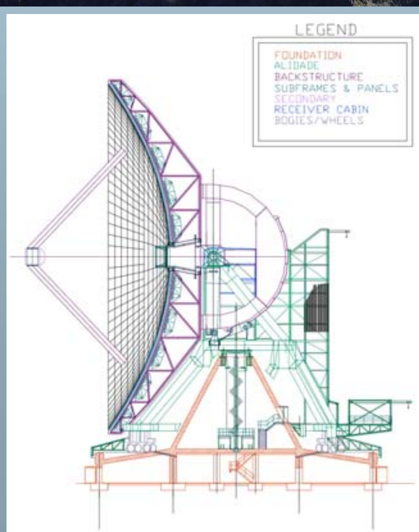
Mount Graham, Arizona (USA)

- 10 m Diameter
- ~15 μm surface accuracy; ~1” pointing
  - Possibly most accurate and best pointing radio telescope in the world
- Instrumentation
  - SIS receivers at
    - 230, 345, 490 GHz
  - 19 element bolometer array

Large Millimeter Telescope / Gran Telescopio Milimétrico (LMT/GMT)

Univ. Mass. / INAOE

Sierra Negra, Puebla, Mexico



- 50 m telescope under construction
- Primarily for 3 mm and 1.3 mm bands
- ~75 μm surface accuracy
- 32-pixel SEQUOIA spectroscopic imaging array for 85-115 GHz band
- “Redshift Machine”
- 144 pixel BOLOCAM-II camera for 1.2 mm continuum imaging

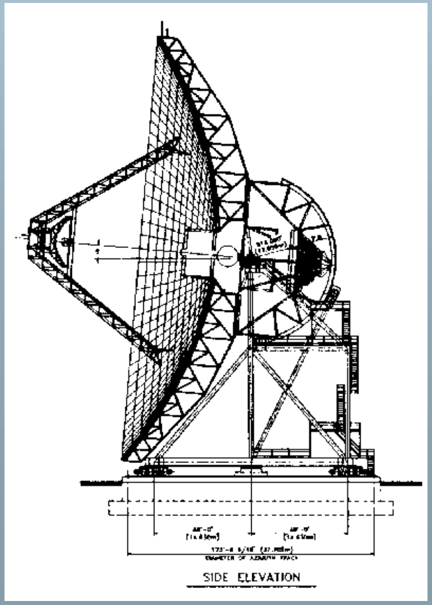
Nobeyama Telescope
Nobeyama Radio Observatory, Univ. Tokyo
Nobeyama, Nagano, Japan

- 45 m Diameter
- ~200 💻m surface accuracy
- Operation at cm waves through 2.6 mm (115 GHz)
- 25 beam SIS receiver for CO imaging observations

Sardinia Radio Telescope (SRT)

Istituto di Radioastronomia

Cagliari, Sardinia



- 64 m telescope under construction
- Planned operation from 300 MHz to100 GHz
- Active surface with lookup tables
- Single dish, VLBI, and DSN modes

Robert C. Byrd Green Bank Telescope

National Radio Astronomy Obs. / National Science Foundation

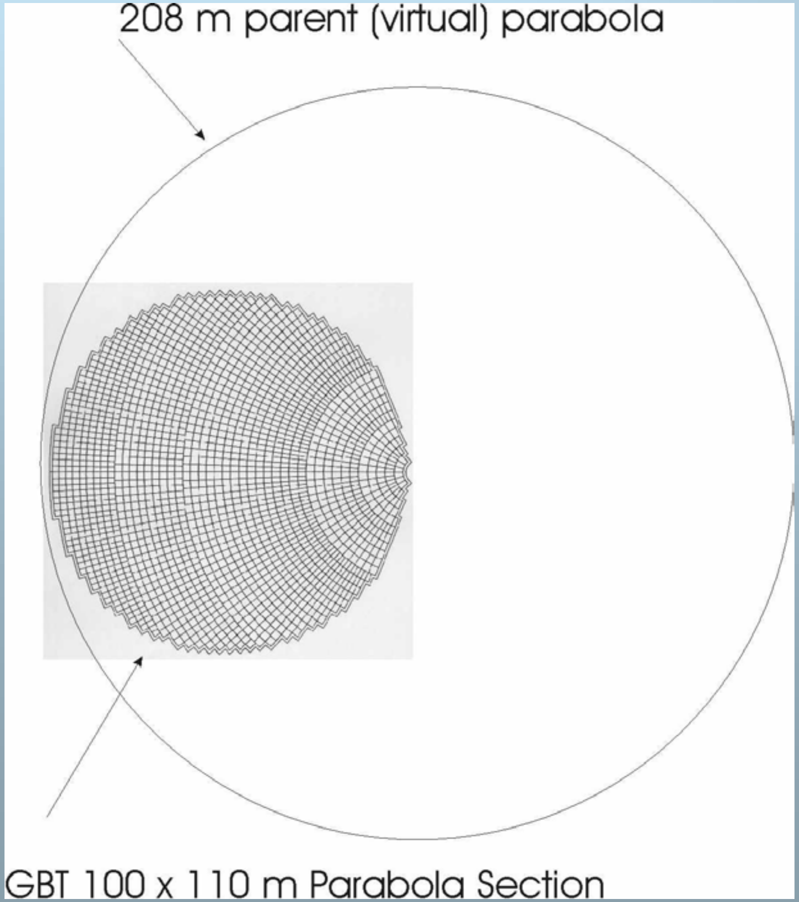
Green Bank, West Virginia, USA

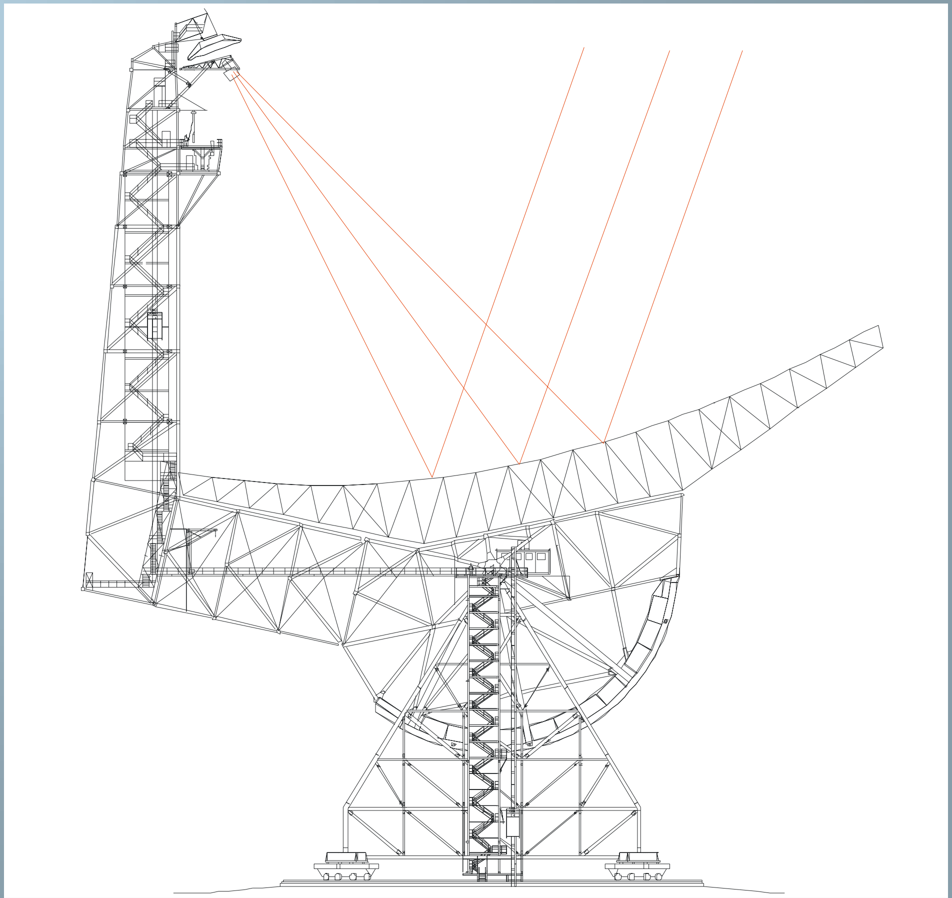
What makes the GBT special?

- Size (100 m) in combination with the following:
- Unblocked main aperture
  - 7854 m^2 collecting area
- Precision Control System
  - Active Surface
  - Metrology
- Frequency coverage
  - 300 MHz to 50 GHz now
  - To ~100 GHz by early 2005
- Located in National Radio Quiet Zone

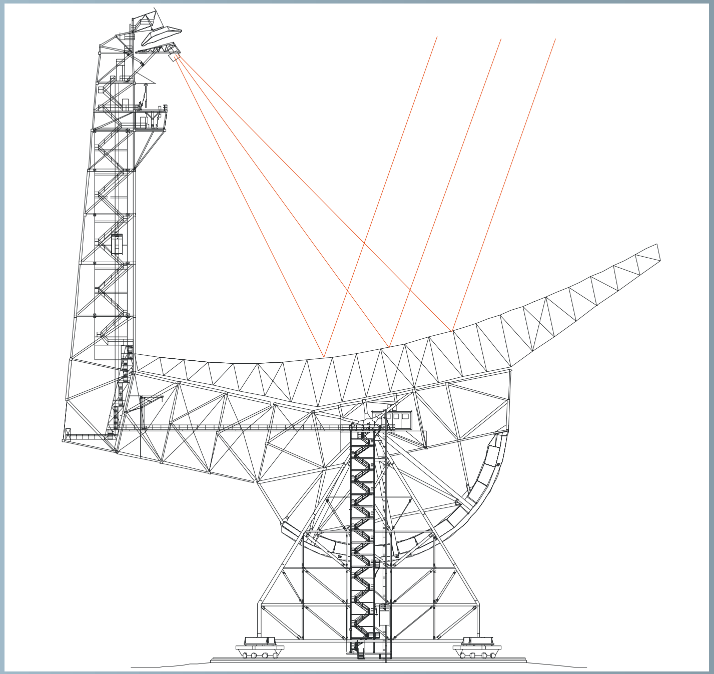
Unblocked aperture

- 100 x 110 m section of a parent parabola 208 m in diameter
- Cantilevered feed arm is at focus of the parent parabola





Advantages of an unblocked aperture



Reduces systematic responses, that are often the ultimate limitation in sensitivity:

- No blockage of incident signal
- Reduced scattering sidelobes
- Reduced spectral standing waves
- Less RFI pickup

GBT active surface system

- Surface has 2004 panels
  - average panel rms: 68 μm
- 2209 precision actuators

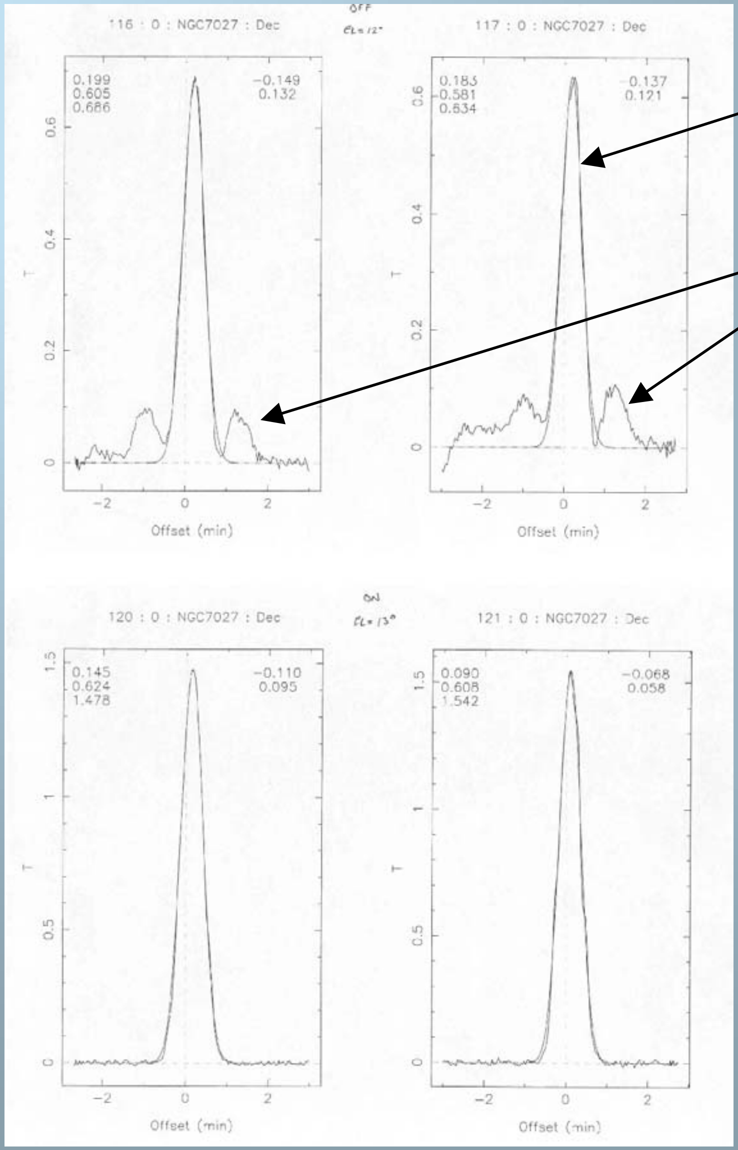
Designed to operate in:

- open loop from look-up table
- closed loop from laser metrology system

Az / El Beam Shapes with Active Surface Off and On

Active Surface OFF

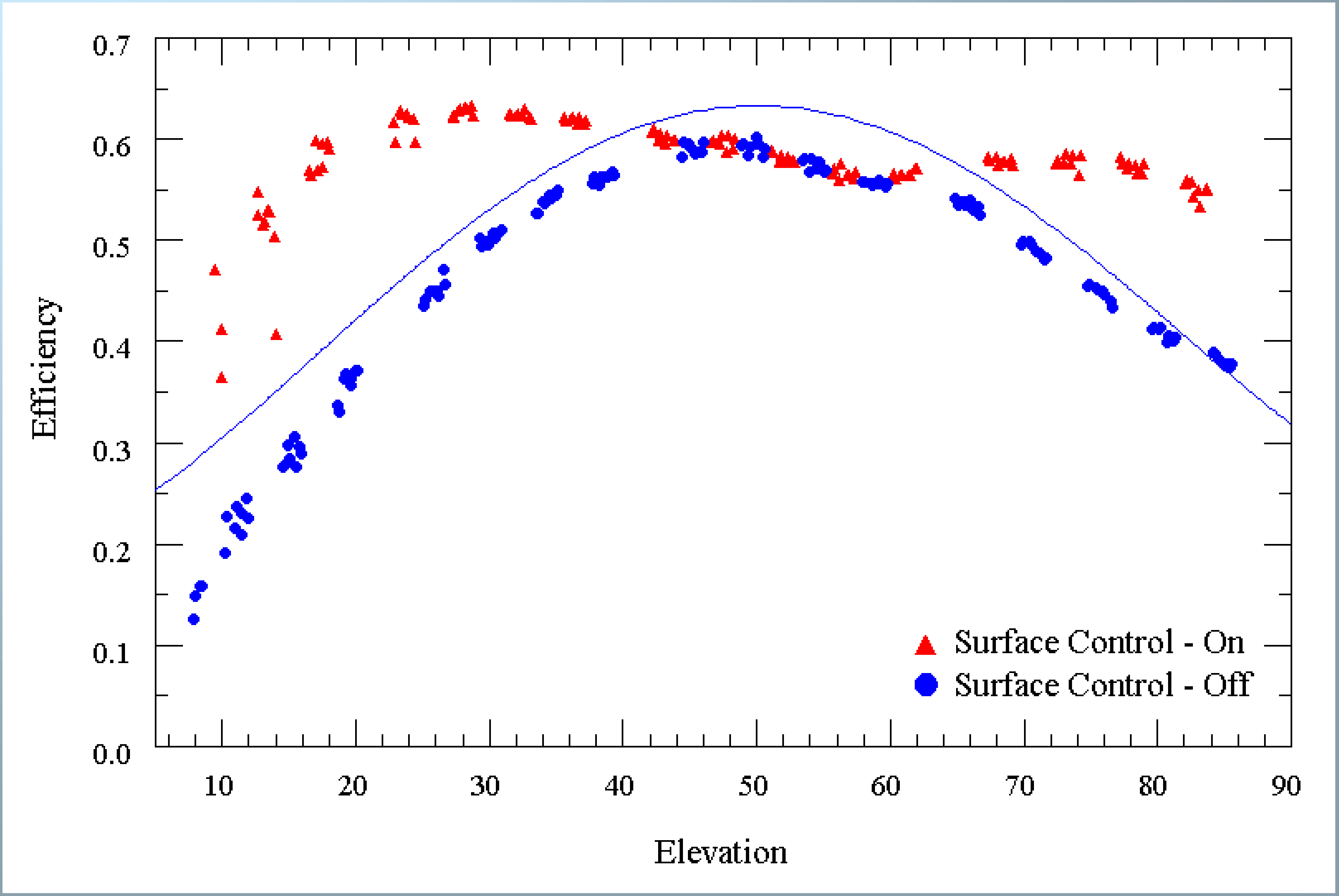
Active Surface ON



Main diffraction beam

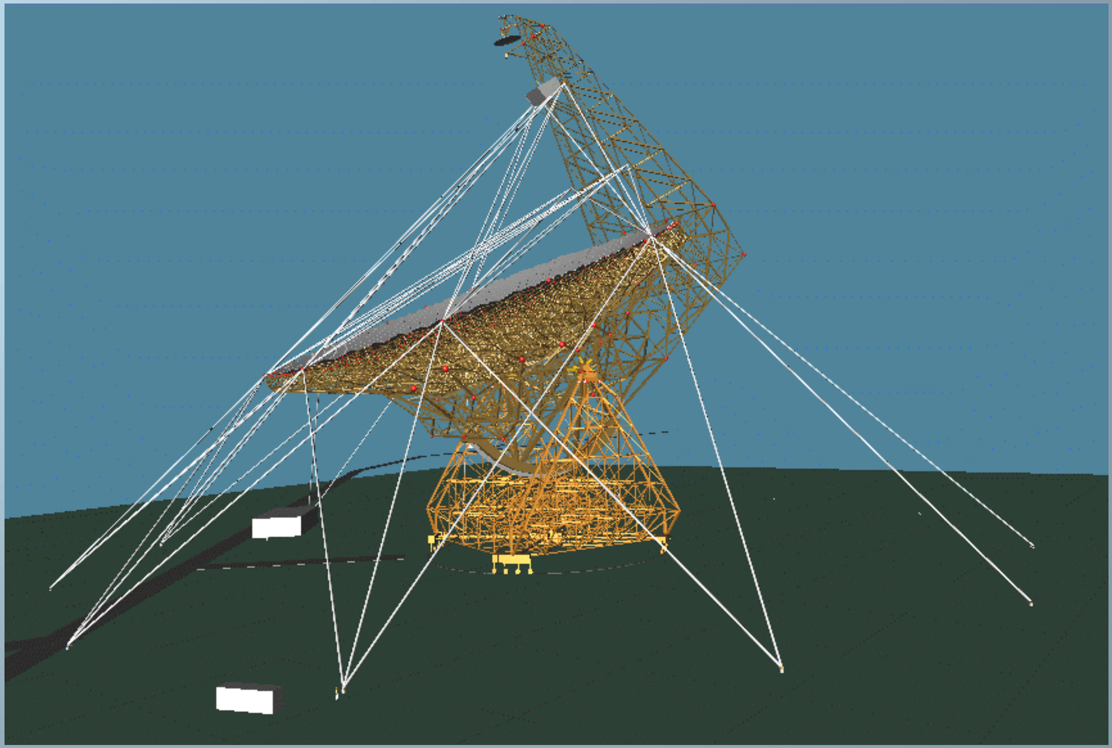
Sidelobes caused by dish distortion

Gain Elevation Curve with Active Surface On



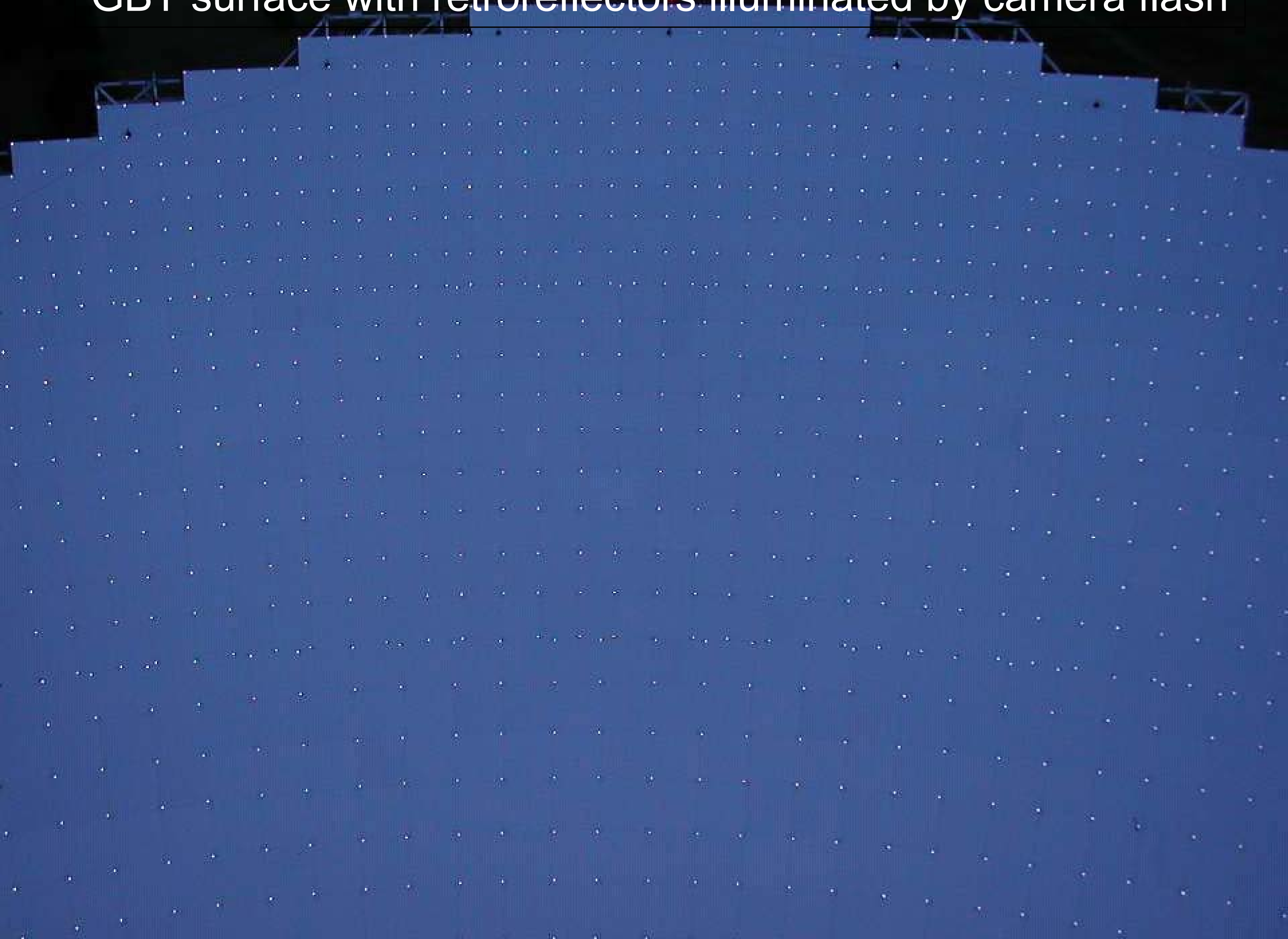
Metrology System

- Plans for 6 laser rangers on the feedarm for surface ranging



- 12 laser rangers on ground monuments for pointing and structural measurements
- Measurement Accuracy: <50μm over 100m

GBT surface with retroreflectors illuminated by camera flash



National Radio Quiet Zone

The GBT is in a 34,000 sq km area in which transmissions from fixed (licensed) transmitters are restricted by US regulations in signal strength at the position of the GBT.

Instrumentation

- Receivers covering most frequencies from 300 MHz to 50 GHz
- 256,000 channel spectrometer
- Backends for continuum, pulsar, VLBI, bi-static radar
- Advanced instrumentation development program
  - Receivers under construction
    - 26-40 GHz receiver
    - 68-92 GHz receiver
  - Penn Array Bolometer Camera
    - 3 mm, 64-pixel camera
    - Delivery in 2005
  - Caltech Continuum Backends
    - Fast sampling backends (Delivery in 2004)
- Possible future instruments
  - Wideband spectrometer for redshift surveys
  - Focal Plane arrays for spectroscopy
  - Large-format bolometer camera

GBT Availability

- The GBT is available to any qualified astronomer through a proposal refereeing system based solely on scientific merit.
- The GBT is scheduled on an annual trimester basis with proposal deadlines on
  - 1 February
  - 1 June
  - 1 October
- A student support program exists for US-based students
- See www.gb.nrao.edu for more information.
- Proposals are welcomed!