GBT and other Green Bank Capabilities

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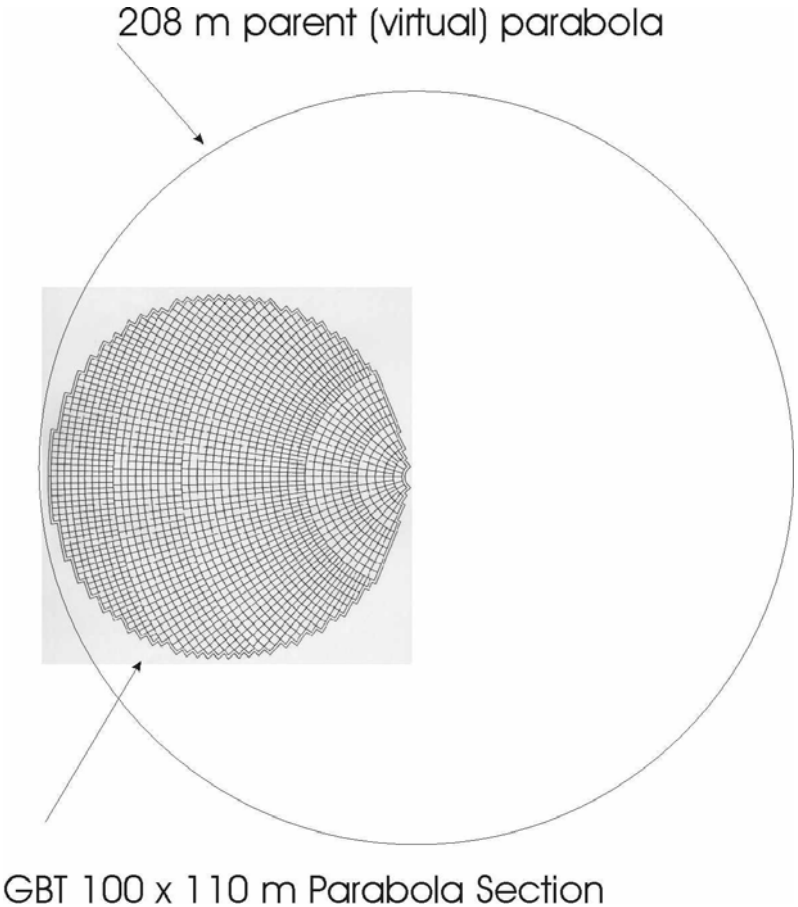
Overview

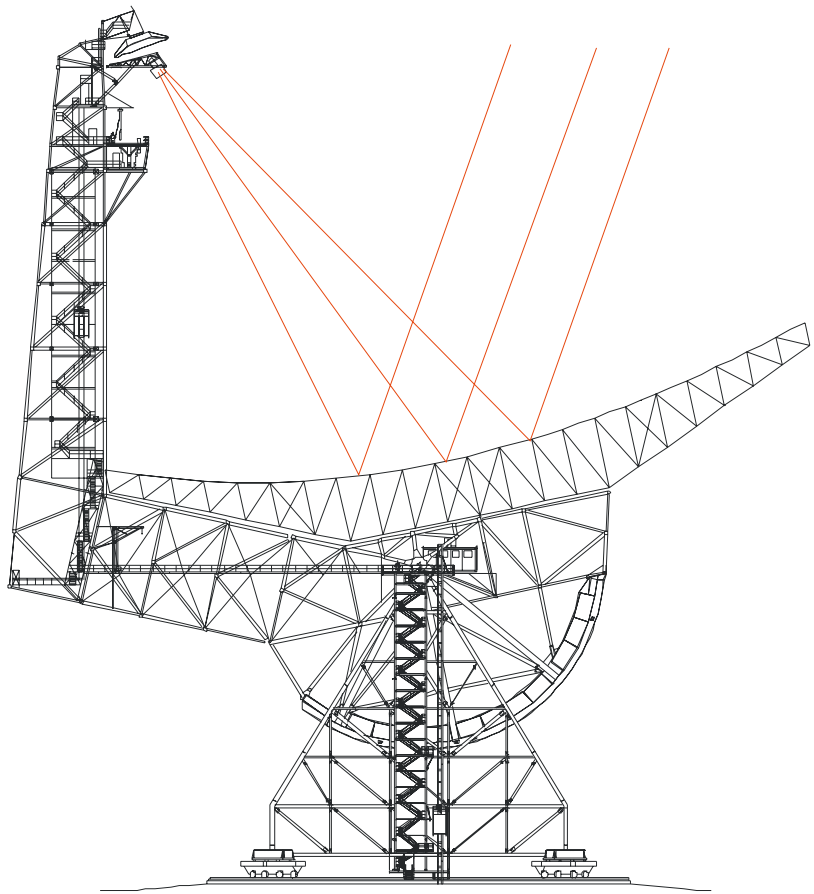
- *General GBT overview*
- *GBT antenna performance*
- *GBT Instrumentation*
- *GBT Weather statistics*
- *Other Green Bank capabilities*
- *(Some interesting GBT wind / surface performance results if time allows.)*

The GBT

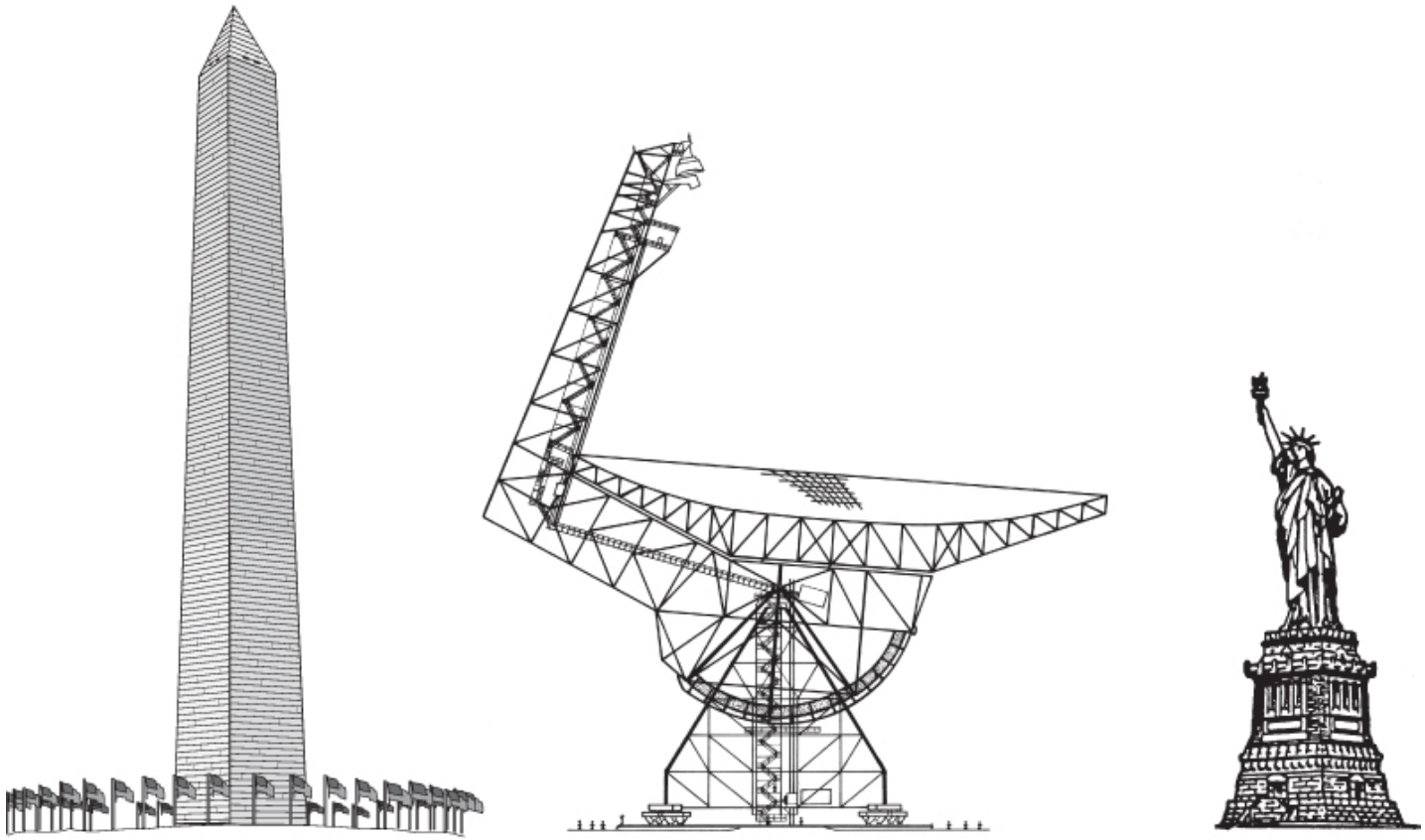
GBT optics

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





GBT Size



GBT Capabilities

- *Extremely powerful, versatile, general purpose single-dish radio telescope.*
- *Large diameter filled aperture provides unique combination of high sensitivity and resolution for point sources plus high surface-brightness sensitivity for faint extended sources.*
- *Offset optics provides an extremely clean beam at all frequencies.*
- *Wide field of view (10' diameter FOV for Gregorian focus).*
- *Frequency coverage 290 MHz – 50 GHz (now), 115 GHz (future).*
- *Extensive suite of instrumentation including spectral line, continuum, pulsar, high-time resolution, VLBI and radar backends.*
- *Well set up to accept visitor backends (interfacing to existing IF), other options (e,g, visitor receivers) possible with appropriate advance planning and agreement.*
- *(Comparatively) low RFI environment due to location in National Radio Quiet Zone. Allows unique HI and pulsar observations.*
- *Flexible python-based scripting interface allows possibility to develop extremely effective observing strategies (e.g. flexible scanning patterns).*
- *Remote observing available now, dynamic scheduling under development.*

Antenna Specifications and Performance

Coordinates	**Longitude: 79d 50' 23.406" West (NAD83)** **Latitude: 38d 25' 59.236" North (NAD83)**
Optics	**Off-axis feed, Prime and Gregorian foci** **f/D (prime) = 0.29 (referred to the 208 m parent parabola)** **f/D (Gregorian) = 1.9 (referred to the 100 m effective aperture)**
FWHM beamwidth	**720"/ν [GHz] = 12.4' /ν [GHz]**
Declination limits	**- 45° to 90°**
Elevation Limits	**5° to 90°**
Slew rates	**35° / min azimuth** **17° / min elevation**
Surface RMS	**~ 350 μm; average accuracy of individual panels: 68 μm**
Pointing accuracy RMS (rss of both axes)	**4" (blind)** **2.7" (offset)**
Tracking accuracy	**~1" over a half-hour (benign night-time conditions)**
Field of View	**~ 7 beams Prime Focus** **100s – 1000s (10' FOV) Hi Freq Gregorian.**

GBT Receivers

Receiver	Freq Range (GHZ)	Focus	Poln	Beams	FWHM	Gain (K/Jy)	Ap. Eff.	SEFD (Jy)	T_{rec} (K)	T_{sys} (K)	BW (MHz)
PF1	.290-.395	Prime	Lin/Circ	1	36'	2.0	70%	35	15	70	240
PF1	.385-.520	Prime	Lin/Circ	1	27'	2.0	70%	28	15	57	240
PF1	.510-.690	Prime	Lin/Circ	1	21'	2.0	70%	24	15	48	240
PF1	.680-.920	Prime	Lin/Circ	1	15'	2.0	70%	12	15	25	240
PF2	.910-1.23	Prime	Lin/Circ	1	12'	2.0	70%	11	15	22	240
L	1.15-1.73	Greg.	Lin/Circ	1	9'	2.0	70%	10	6	20	650
S	1.73-2.60	Greg.	Lin/Circ	1	5.8'	1.9	68%	12	8-12	22	970
C	3.95-5.85	Greg.	Lin/Circ	1	2.5'	1.85	65%	14	12	25	2000
X	8.00-10.0	Greg.	Circ	1	1.4'	1.8	63%	15	13	27	2400
Ku	12.0-15.4	Greg.	Circ	2	54"	1.7	60%	18	14	30	3500
K	18.0-22.4	Greg.	Circ	2	37"	1.5	55%	23	21	30-40	4000
K	22.0-26.5	Greg.	Circ	2	30"	1.5	55%	24	21	30-40	4000
Ka	26.0-40.0	Greg.	Circ	2	24"	1.3	45%	32	20-40	30-60	4000
Q	40.0-49.1	Greg.	Circ	2	16"	1.0	~40%	75-150	35-60	75-150	4000

GBT Sensitivities

Receiver	FWHM	Tsys	Gain (K/Jy)	Ap.Eff	Srms 80MHz (mJy)	Srms 98kHz (mJy)	Srms 24kHz (mJy)	Srms 6.1kHz (mJy)	Srms 1.5kHz (mJy)	Conf (mJy)
Rcvr_342	36'	70 K	2.0	70%	0.47	12.6	25.3	42.2	84.4	920
Rcvr_450	27'	57 K	2.0	70%	0.38	10.3	20.6	34.4	68.7	432
Rcvr_600	21'	48 K	2.0	70%	0.32	8.7	17.3	28.9	57.9	200
Rcvr_800	15'	25 K	2.0	70%	0.17	4.5	9.0	15.1	30.1	91
Rcvr1_2	9'	20 K	2.0	70%	0.11	3.6	7.2	12.1	24.2	19
Rcvr2_3	5.8'	22 K	1.9	68%	0.12	4.1	8.2	13.7	27.4	6.0
Rcvr4_6	2.5'	25 K	1.87	66%	0.14	4.8	9.6	16.1	32.1	0.65
Rcvr8_10	1.4'	27 K	1.8	63%	0.16	5.4	10.9	18.2	36.3	0.13
Rcvr12_15	54"	30 K	1.7	60%	0.19	6.3	12.7	21.2	42.4	0.05
Rcvr18_22	37"	40 K	1.5	51%	0.29	10.0	19.9	33.2	66.5	0.015
Rcvr22_26	30"	40 K	1.5	51%	0.29	10.0	19.9	33.2	66.5	0.009
Rcvr40_52	16"	60 K	1.0	35%	0.63	21.7	43.5	72.7	145.	0.002

- *Radiometer equation sensitivities for 60 seconds integration time.*
- *Delivered continuum results typically 10x theoretical*
- *Baselines are a concern for wide lines or in the presence of continuum*

GBT Backends I

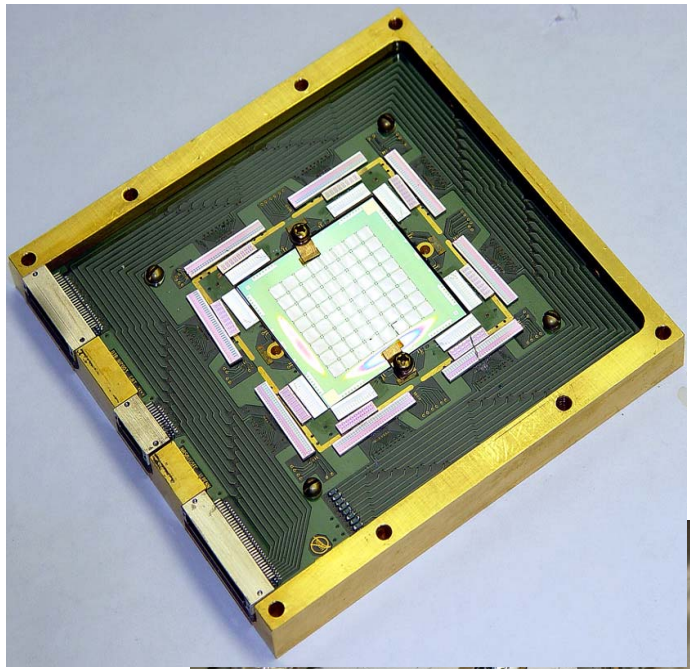
Spectral Line Backends	Characteristics
GBT Spectrometer	Maximum Channels per IF: 262,144 Bandwidth modes: 12.5, 50, 200, and 800 MHz Maximum IF inputs: 8 x 800 MHz or 16 x 50 MHz 3 Level and 9 Level Sampling (in 12.5 and 50 MHz BW) Autocorrelation mode Cross-correlation (polarization) mode available any day now
Spectral Processor	2 x 1024 channel FFT Spectrometer Bandwidth modes: 10, from 0.078 to 40 MHz Maximum IF inputs: 4 per spectrometer Spectrum dynamic range to narrow band signal: >45 dB A/D dynamic range over noise: 10 dB
Continuum backends	
Digital Continuum Receiver (DCR)	V/F Converter into 28 bit counters 16 inputs, 10 switching phases 1, 2, 4, or 8 IF modes
Caltech Continuum Backend	Fast beam switching at 10 kHz simultaneous detection of 2 feeds in 2 polarizations across the full receiver RF band
VLBI Backends	
VLBA	512 Mbits/sec, 8 baseband recorders
S2	128 Mbits/sec in VCR format (8 recorders)
Mark V	

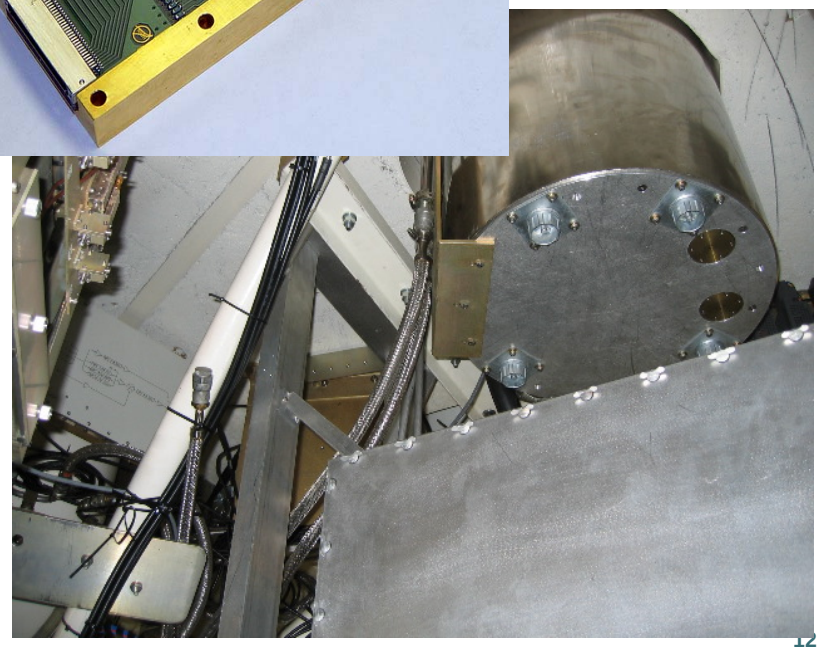
GBT Backends II

Pulsar Backends	
GBT Spectrometer Spigot Mode	12.5, 50, 200, and 800 MHz bandwidth x 2 polarizations 128-1024 frequency channels 1- 4 independent polarizations 2.56 – 81.92 μsec sampling rate 2, 4, 8, and 16 bit sampling
Berkeley-Caltech Pulsar Machine (BCPM)	64 MHz x 2 polarizations 36-256 frequency channels 21-200 μsec sampling rate
Green Bank – Berkeley Pulsar Processor (GBPP)	32 channel coherent dispersion removal processor 10 and 40 MHz bandwidth x 2 polarizations 96 frequency channels, 2 polarizations
Caltech-Green Bank-Swinburne Recorder II (CGSR2) [PI instrument]	128 MHz bandwidth x 2 polarizations 2 independent polarizations 2-bit, 2 μsec sampling data reduced in real-time by processing cluster
Spectral Processor, Pulsar Mode	40 MHz x 2 polarizations 1-4 independent polarizations 1024 frequency channels; 12.8 μsec sampling (minimum)
Green Bank Astronomical Signal Processor (GASP) [PI Instrument]	Real-time, coherent de-dispersion processor with computing cluster

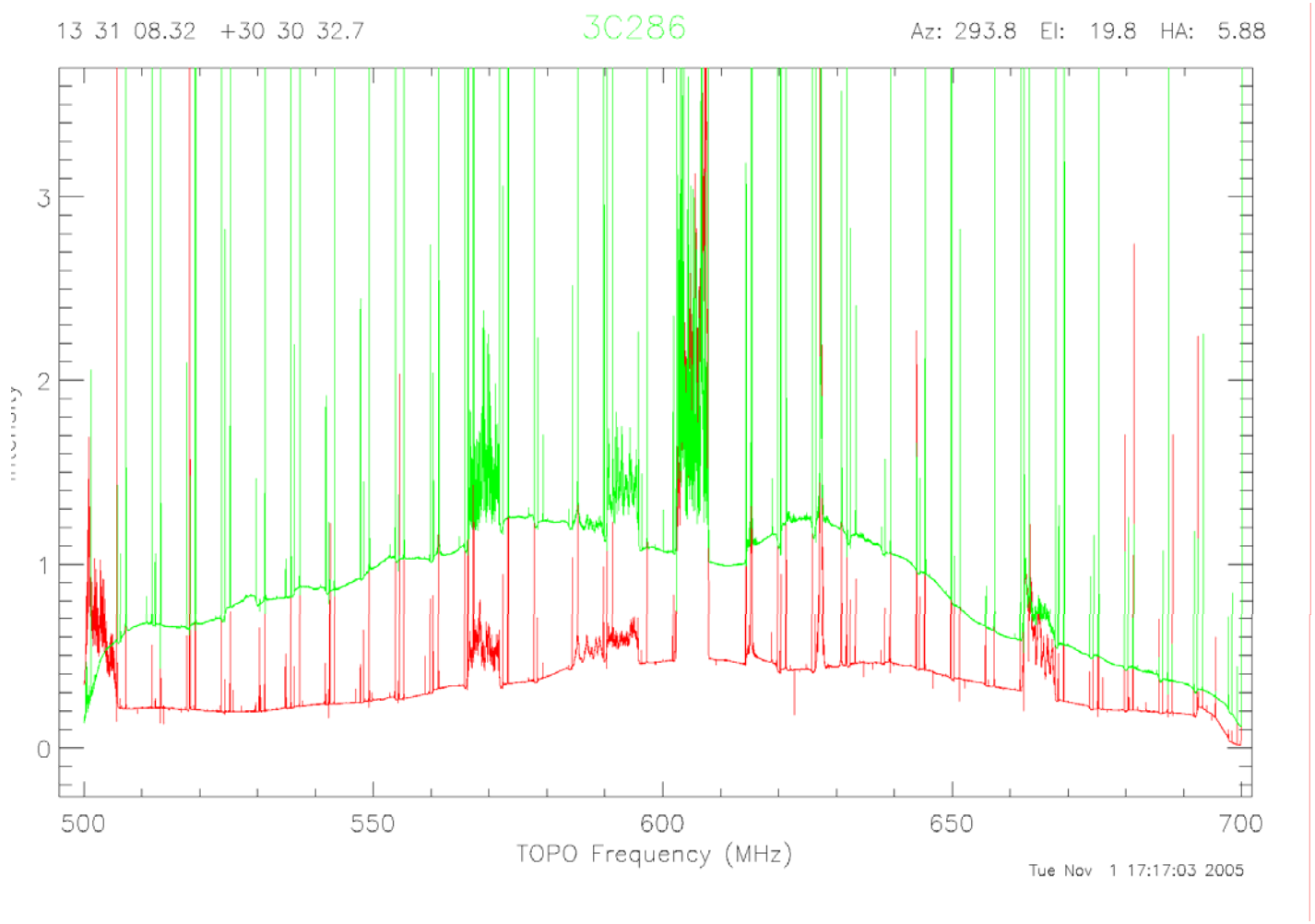
3mm Capabilities: Penn Array Receiver

- *86-94 Ghz band*
- *64-pixel, Nyquist-sampled imaging array*
- *8” fwhm beam*
- *Commissioning winter 06/07*
- Groundbreaking, legacy-class science depends on further antenna development (improved surface accuracy; reduced sensitivity of pointing to wind)





RFI

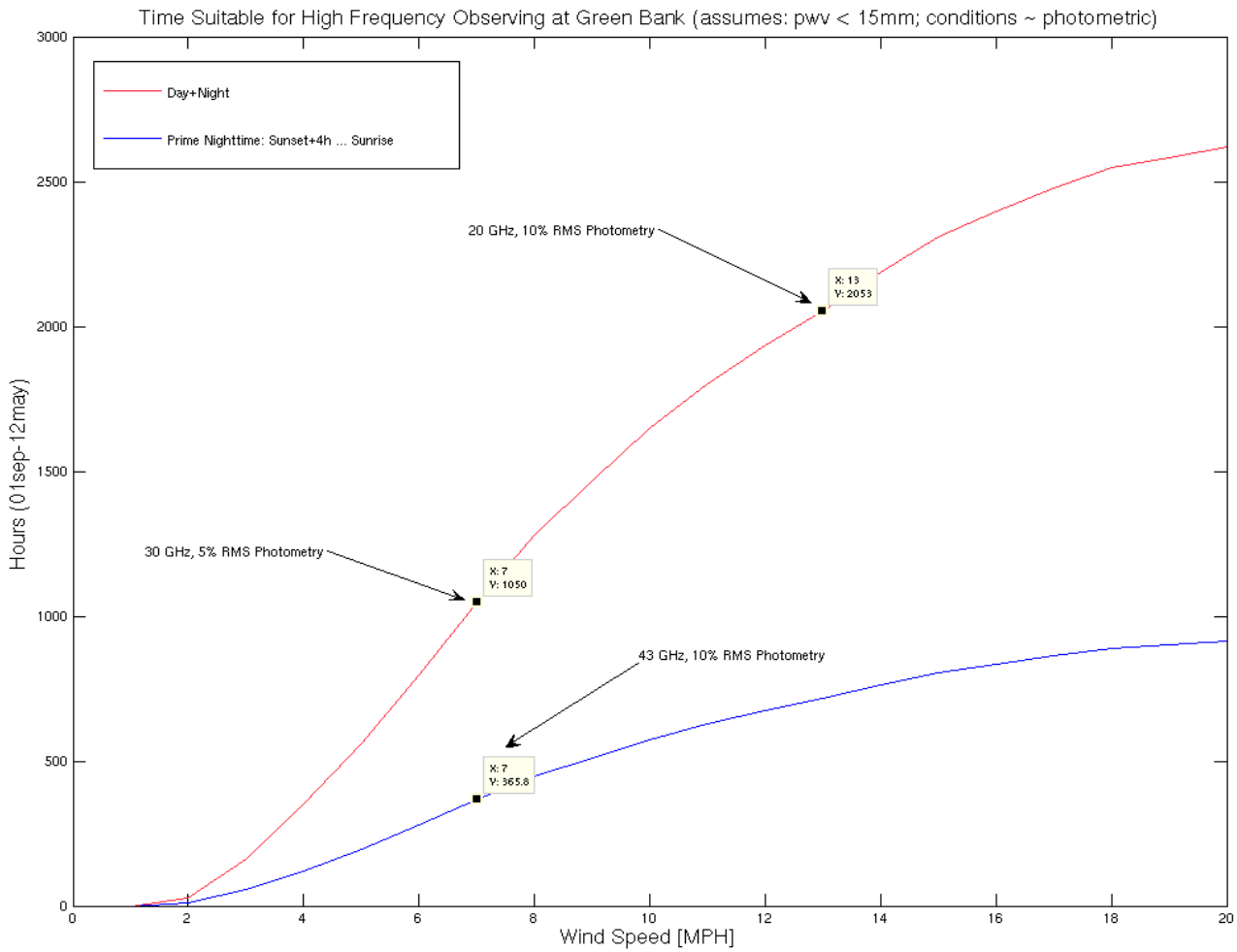


http://www.gb.nrao.edu/IPG/

Green Bank Weather Statistics

- *In the winter, 45% of the time has pwv < 15mm and minimal cloud cover*
- *Wind affects telescope pointing so must also be considered (constraint depends on observing frequency and the required photometric accuracy)*
- *At the higher frequencies, changing solar illumination also affects pointing and limits useful observing to the night time*
- *Bottom Line:*
  - *6300 total hours spent observing per year*
  - *10% RMS @ 20 Ghz: 2050 hrs/year*
  - *5% RMS @ 30 Ghz: 1050 hrs/year*
  - *10% RMS @ 43 Ghz: 365 hrs/year (night only)*
- With present GBT capabilities, legacy-class projects should probably focus on frequencies < 40 Ghz

Green Bank Weather Statistics



Other GBT/Green Bank capabilities

Other Capabilities

- *Can provide (limited) support for visitor instrumentation on the GBT:*
  - *GASP, CGSRII, Portable Fast Sampler*
- *Can provide more extensive support through more formal collaborations*
  - *Caltech Continuum Backend (now complete)*
  - *Zspectrometer (under way)*
- *Can provide infrastructure and (limited) support in NRQZ:*
  - *Solar Radio Burst Spectrometer*
  - *PAPER*
  - *LENS*
  - *Other university experiments*

Other Telescopes

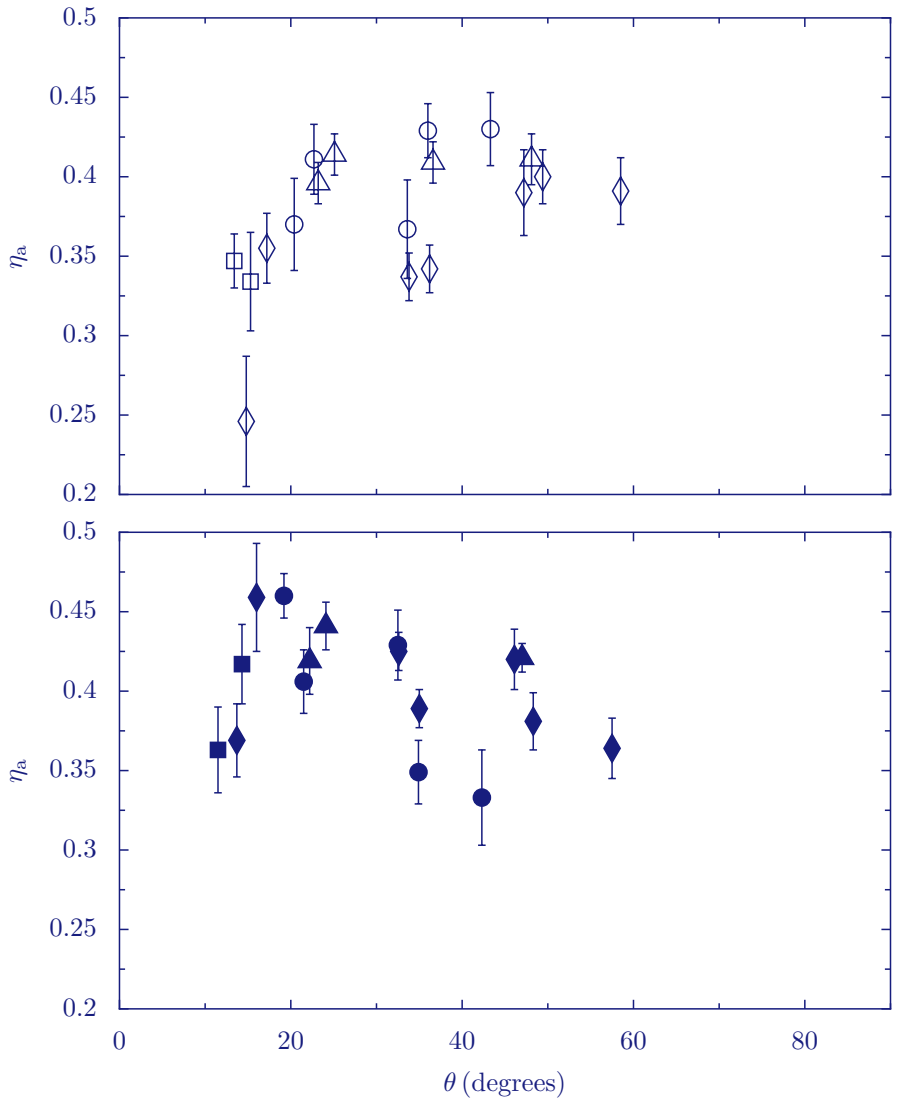
- *13.6m (45ft), 20m (66ft) 43m (140ft)*
- *All provide/accept:*
  - Fiber link to Jansky Lab
  - Automatic Operations
  - Standard NRAO Feed
  - Phase Stable VLBI backend IF
- Potentially useable to ~ 20 – 30 GHz
- 20m: 2deg/sec slew rate

Summer 2007 shutdown

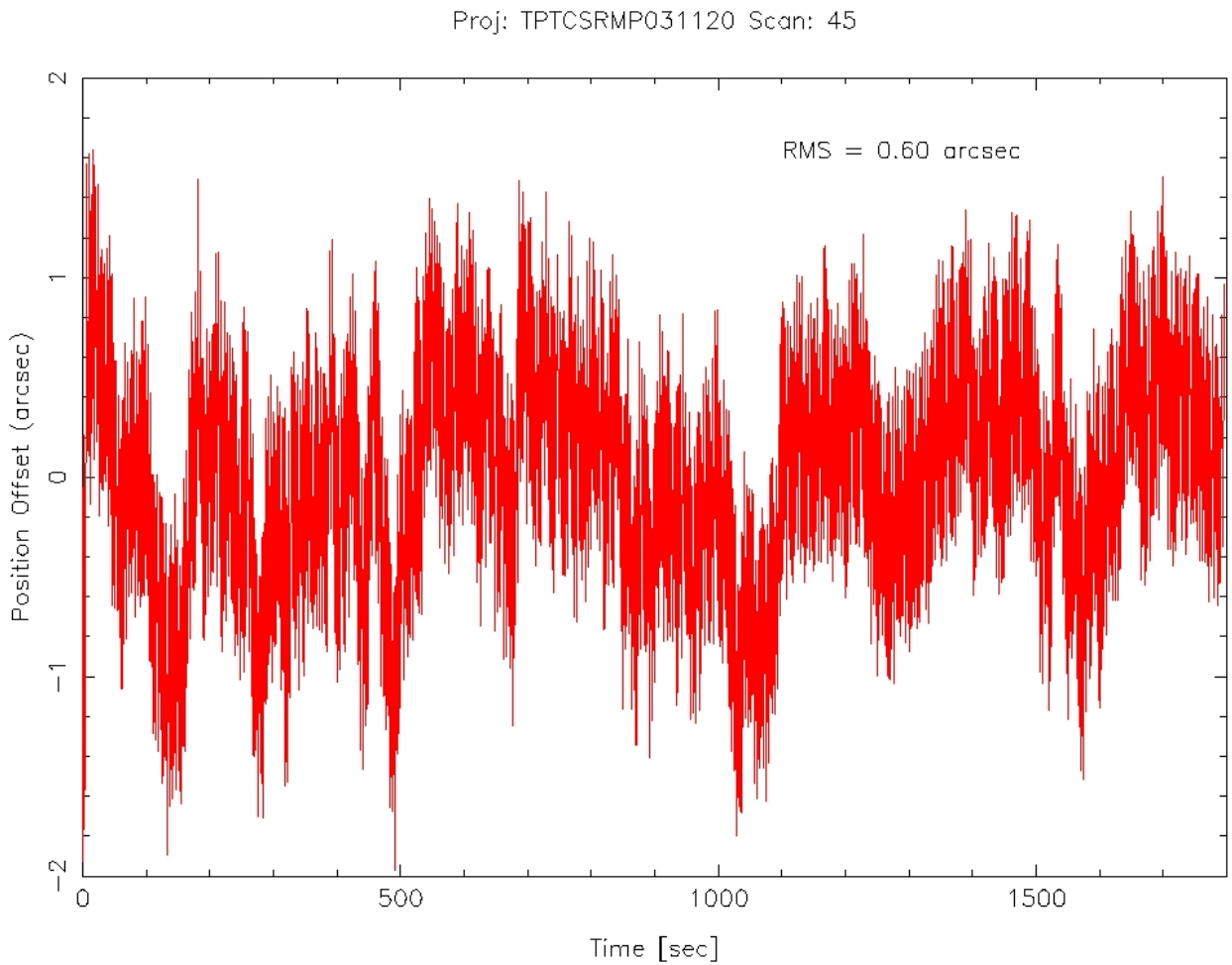
- *Will be suspending normal operations for three months in summer 2007 to refurbish the azimuth track.*
- *Antenna (perhaps with limited instrumentation) may be available as a transit telescope (az, el motion limits not yet decided).*
- *Plans are not yet firm, but expect special call for proposals (for Oct 2006 deadline) with advance details of expected capabilities circulated in advance.*

Surface Accuracy

- *Large scale gravitational errors corrected by "OOF" holography.*
- *Benign night-time rms*
  ~ 350μm
- *Efficiencies:*
  43 GHz: $\eta_S = 0.67$ $\eta_A = 0.47$
  90 GHz: $\eta_S = 0.2$ $\eta_A = 0.15$
- *Now dominated by panel-panel errors (night-time), thermal gradients (day-time)*



14GHz half-power track



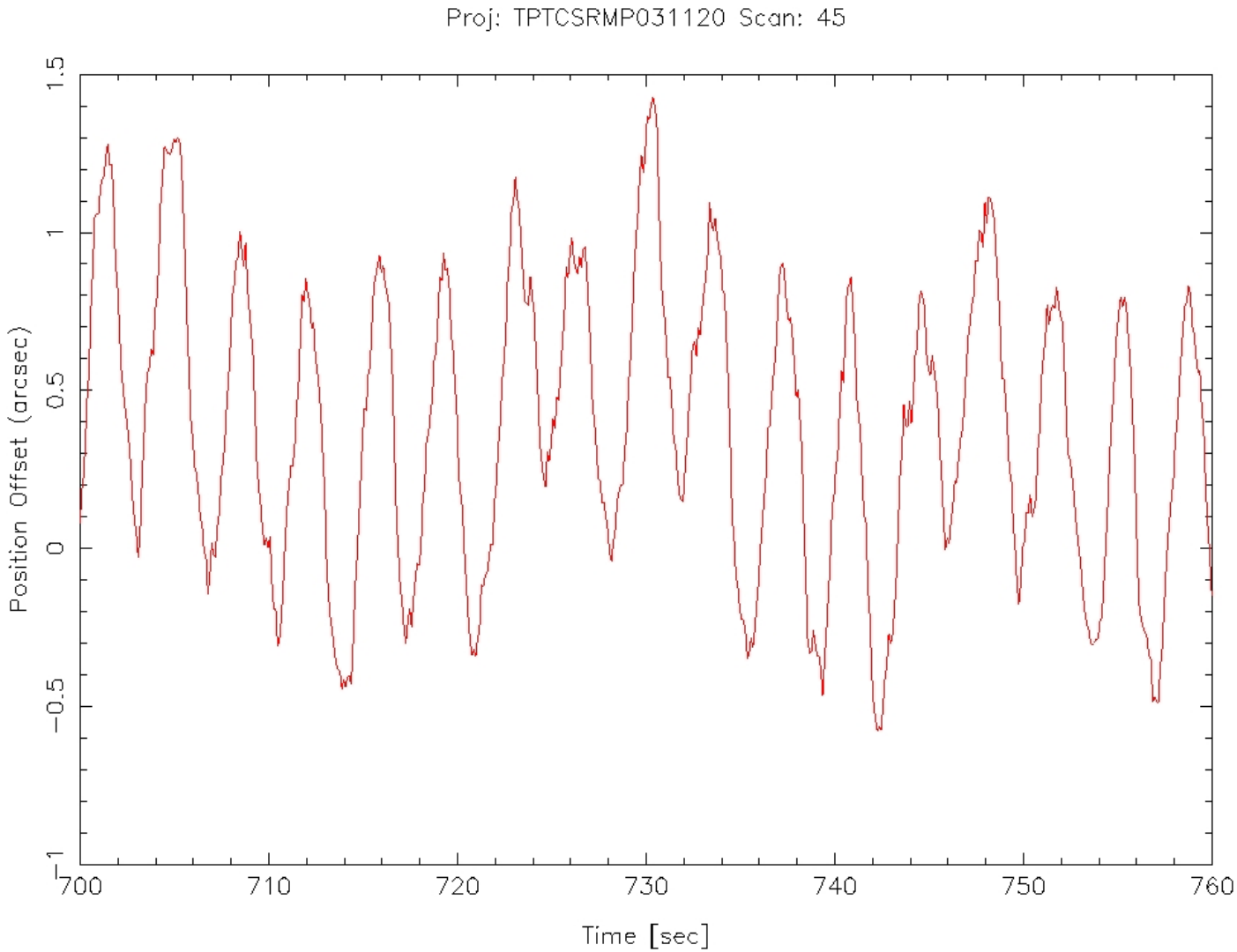
$$\sigma_2 \approx 1 \quad arc\sec$$

$$(Az, El) \approx (290^\circ, 58^\circ)$$

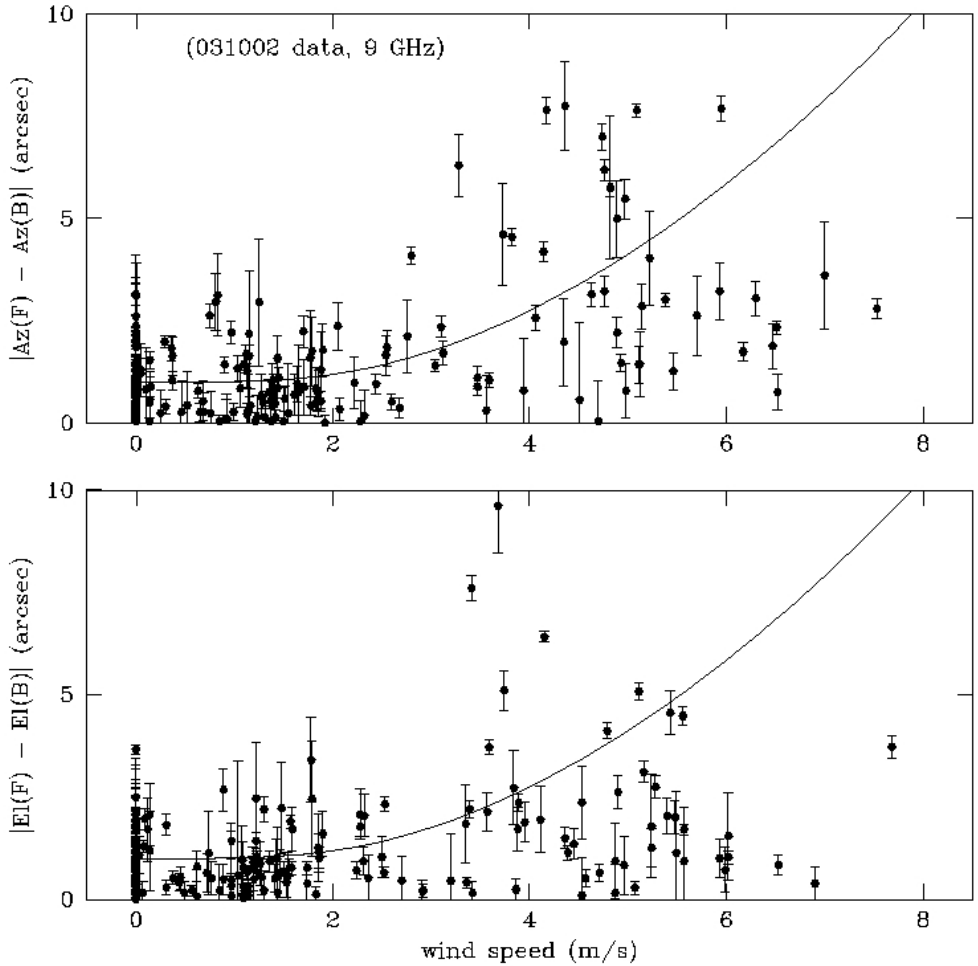
$$(\Delta Az, \Delta El) \approx (1^\circ, 5^\circ)$$

$$\left(\frac{\Delta Az}{\Delta t}, \frac{\Delta El}{\Delta t}\right) \approx (2'/m, 10'/m)$$

14GHz half-power track



Effects of wind



$$\sigma_1(wind) \approx 0.16 \left[\frac{s}{m\ s^{-1}} \right]^2 \quad arc\,\mathrm{sec}$$

$$\sigma_2(wind) \approx \sqrt{2}\,\sigma_1(wind)$$

$$\approx 8'' \ at\ s = 6\ m\ s^{-1}$$

Effects of Wind