The Green Bank Observatory

National Radio Astronomy Observatory

David Frayer
NRAO

"Planning a GBT Proposal": GBT Science and Capabilities

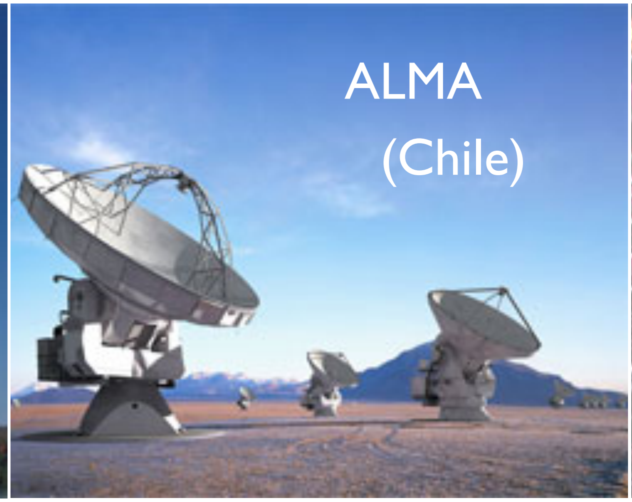
Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

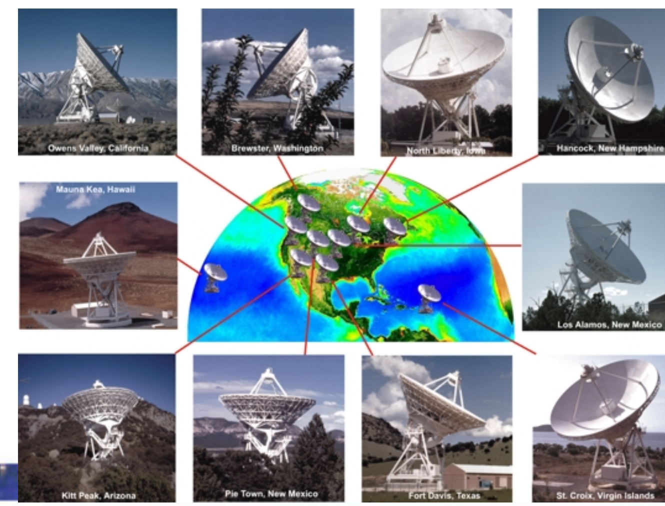
Outline:

- Green Bank and GBT background
- GBT Science
- GBT Capabilities
- GBT Proposal Process and Planning Tools

NRAO telescopes and facilities

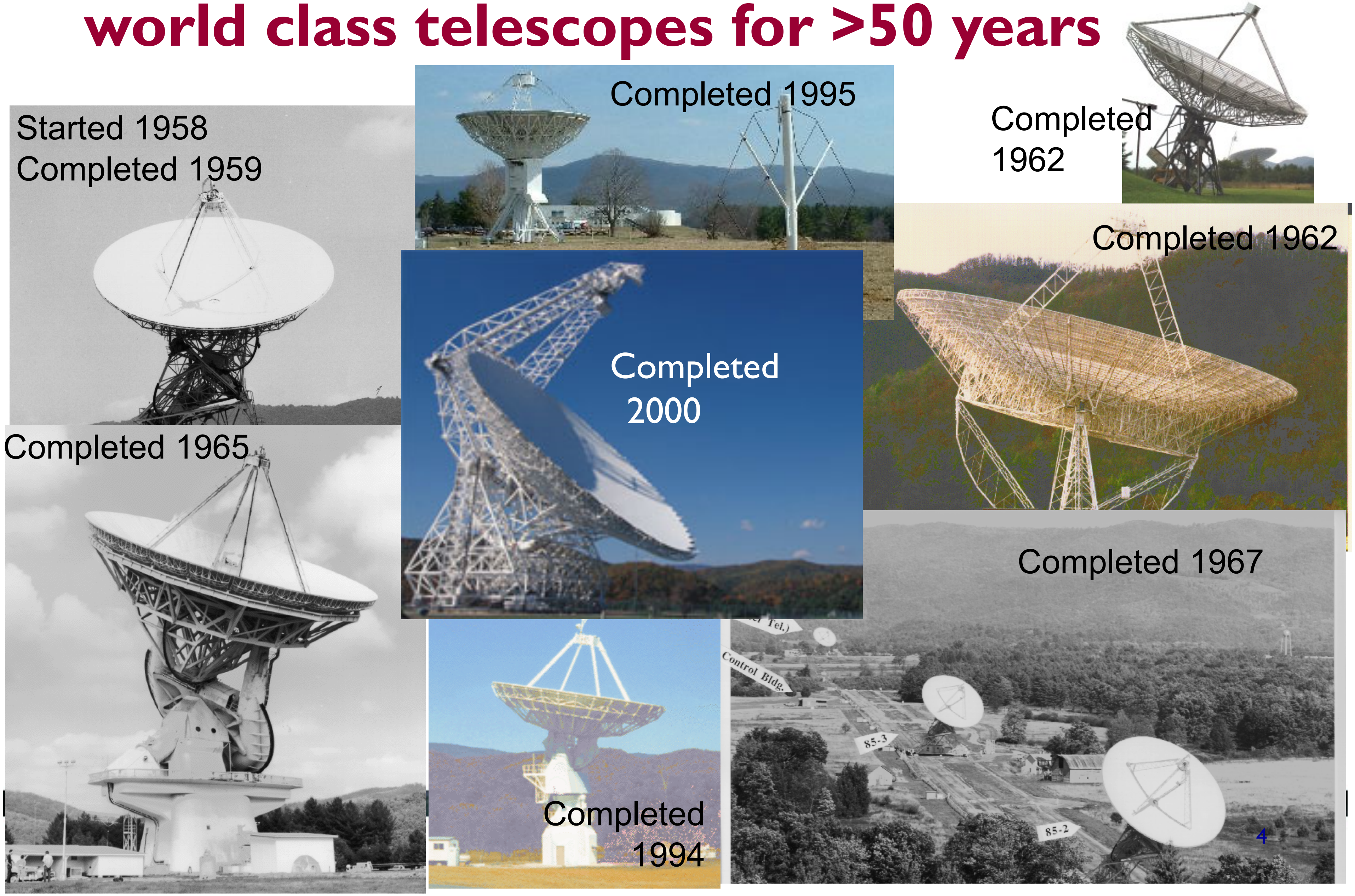
GBT





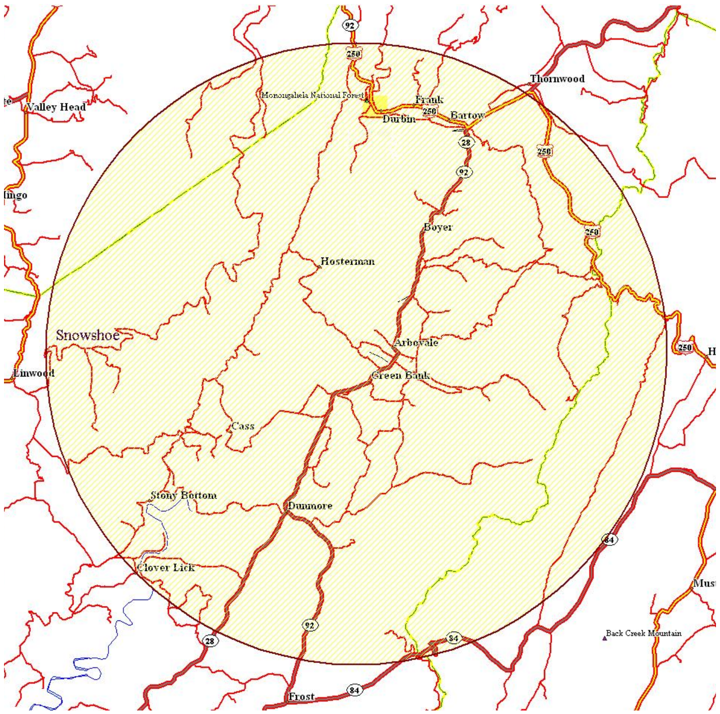
Very Long Baseline Array

Green Bank is original NRAO site, with world class telescopes for >50 years



WV Radio Astronomy Zone

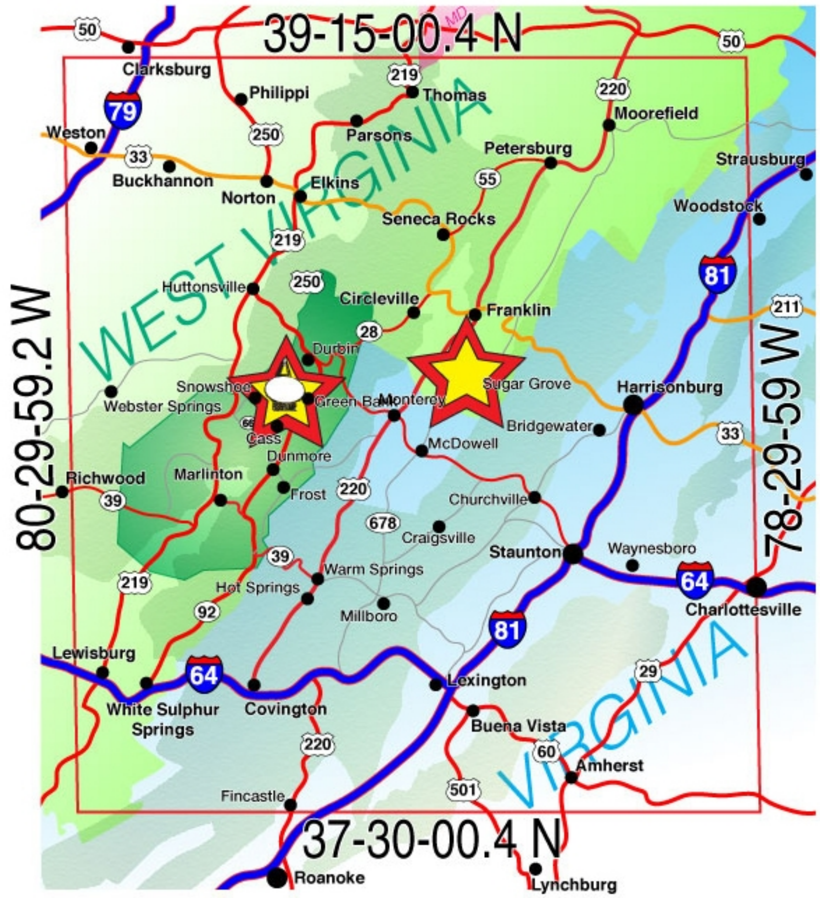
Established by the West Virginia Legislature (1956)



Protection within ten miles of the Observatory

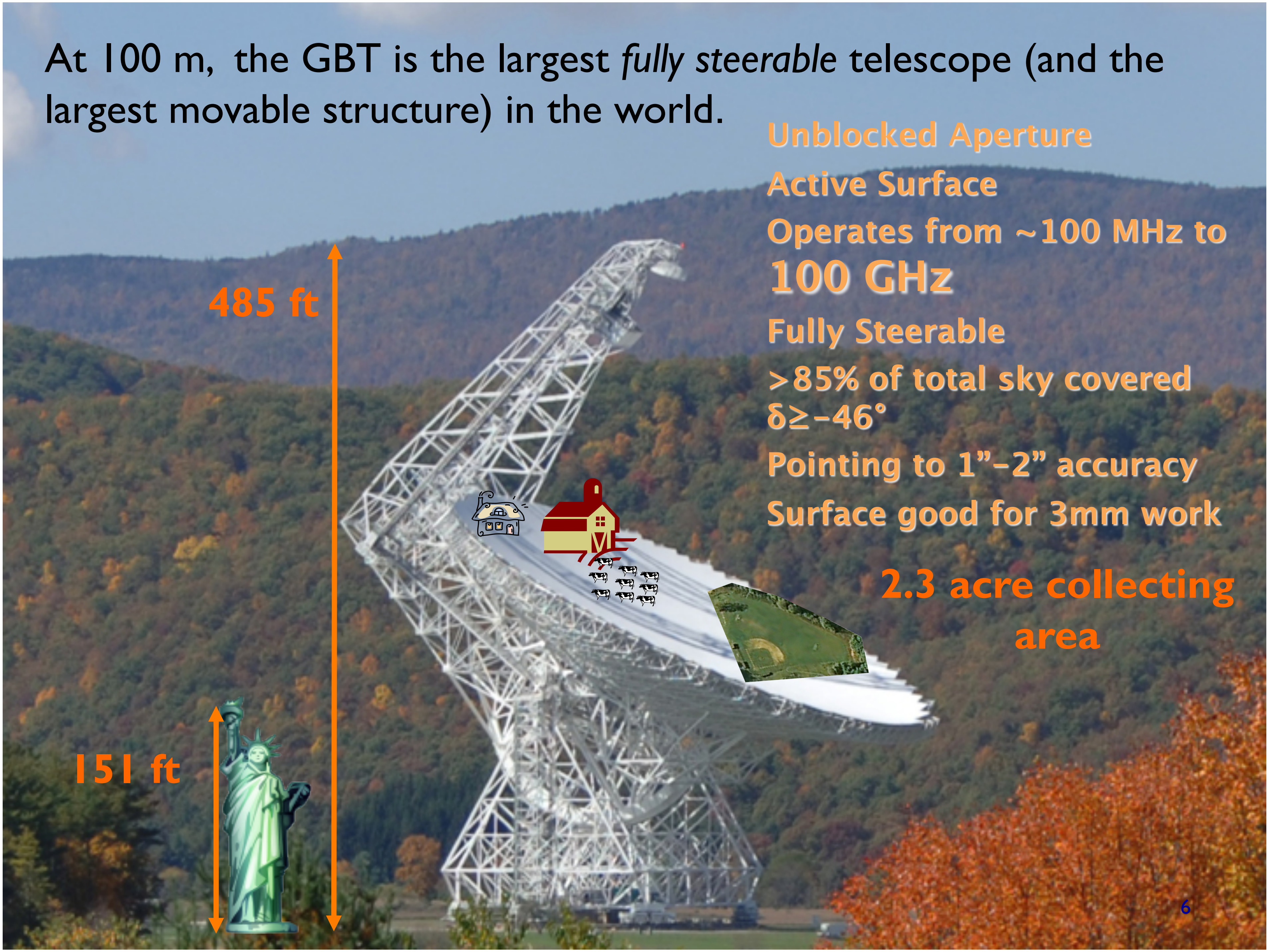
National Radio Quiet Zone

Established by the FCC and NTIA (1957)



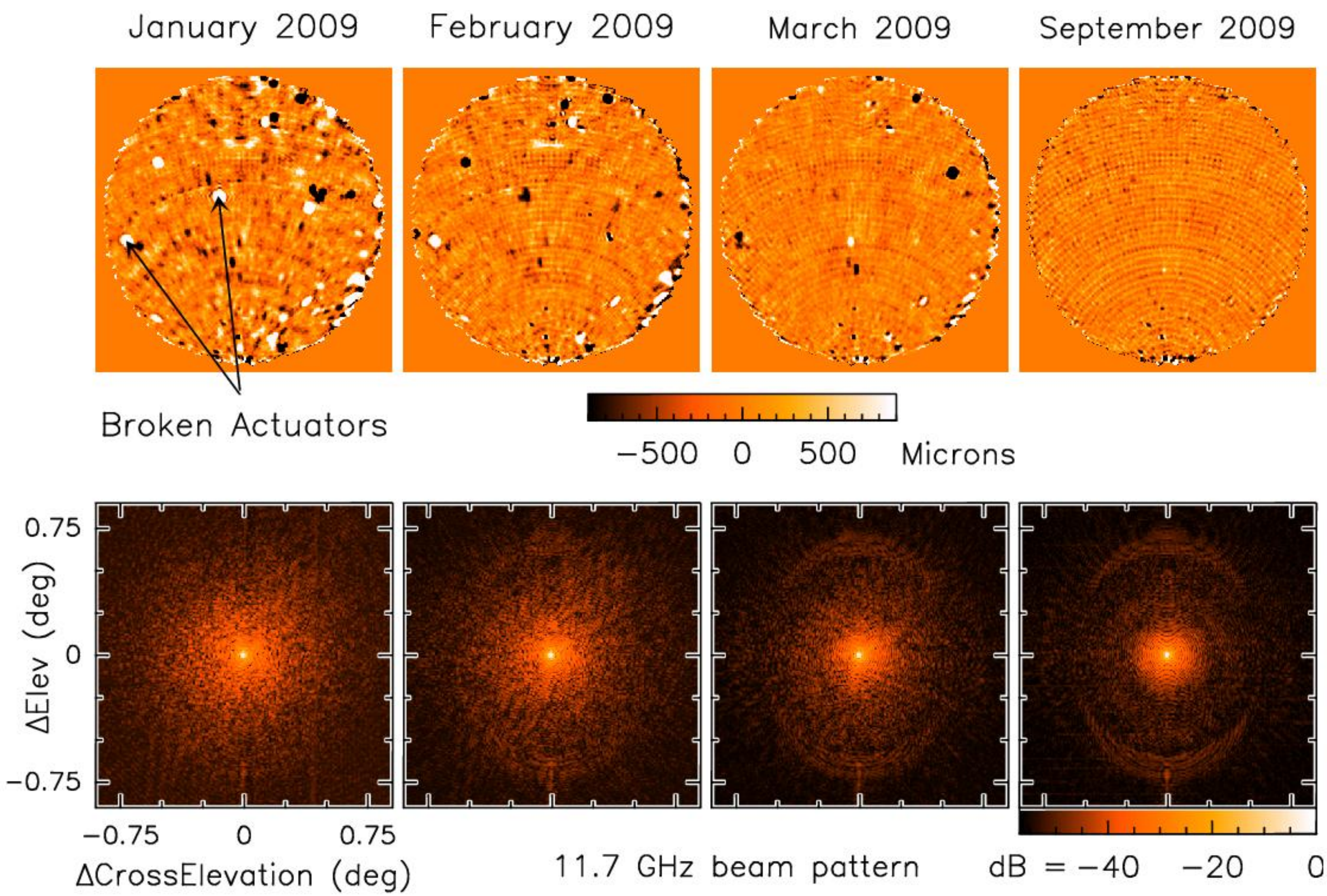
13,000 Square Miles

At 100 m, the GBT is the largest *fully steerable* telescope (and the largest movable structure) in the world.




The Active Surface
2209 actuators
Currently rms < 240μm at night, the goal is 210μm

Improvements to Surface Makes 3mm Possible

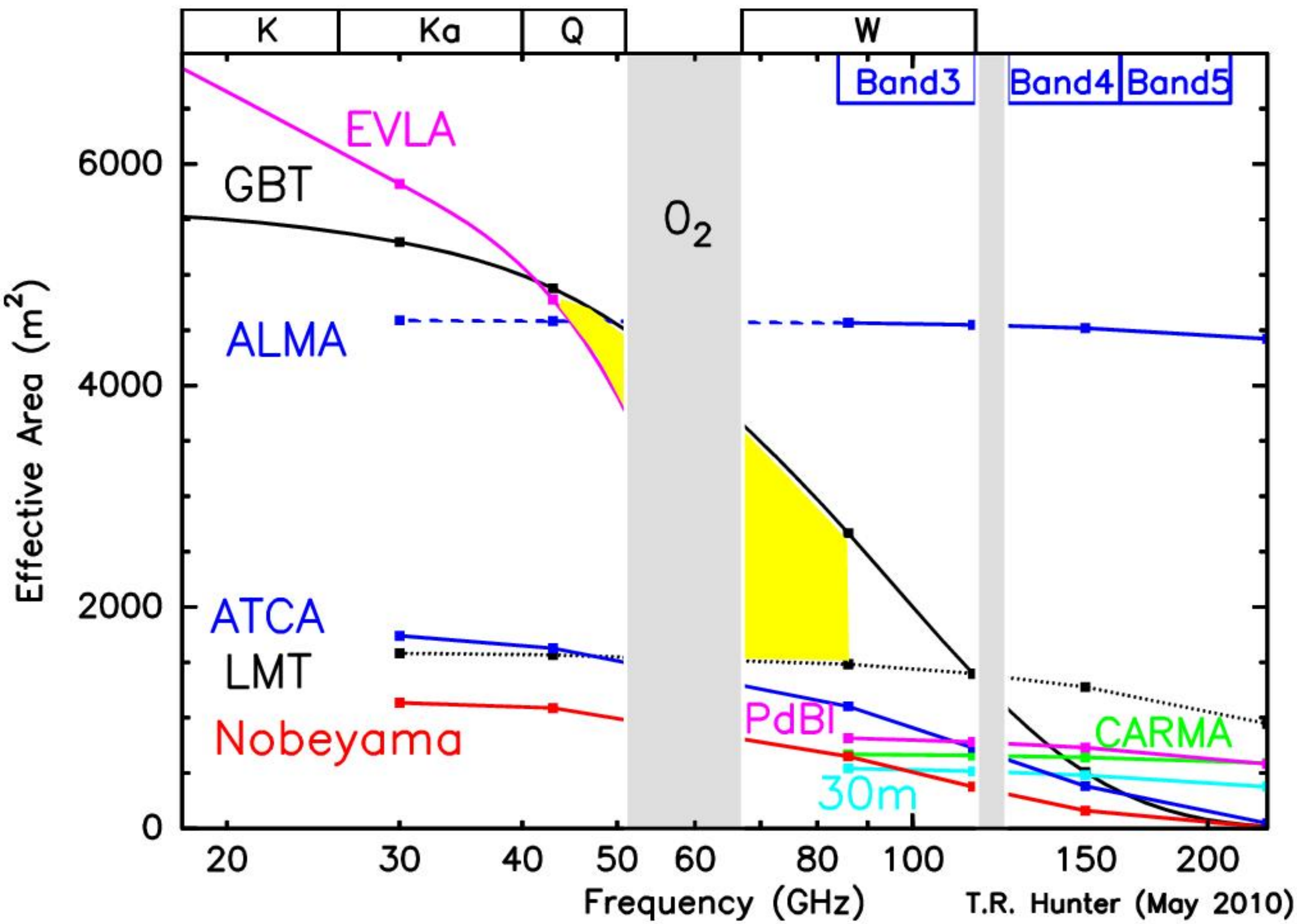


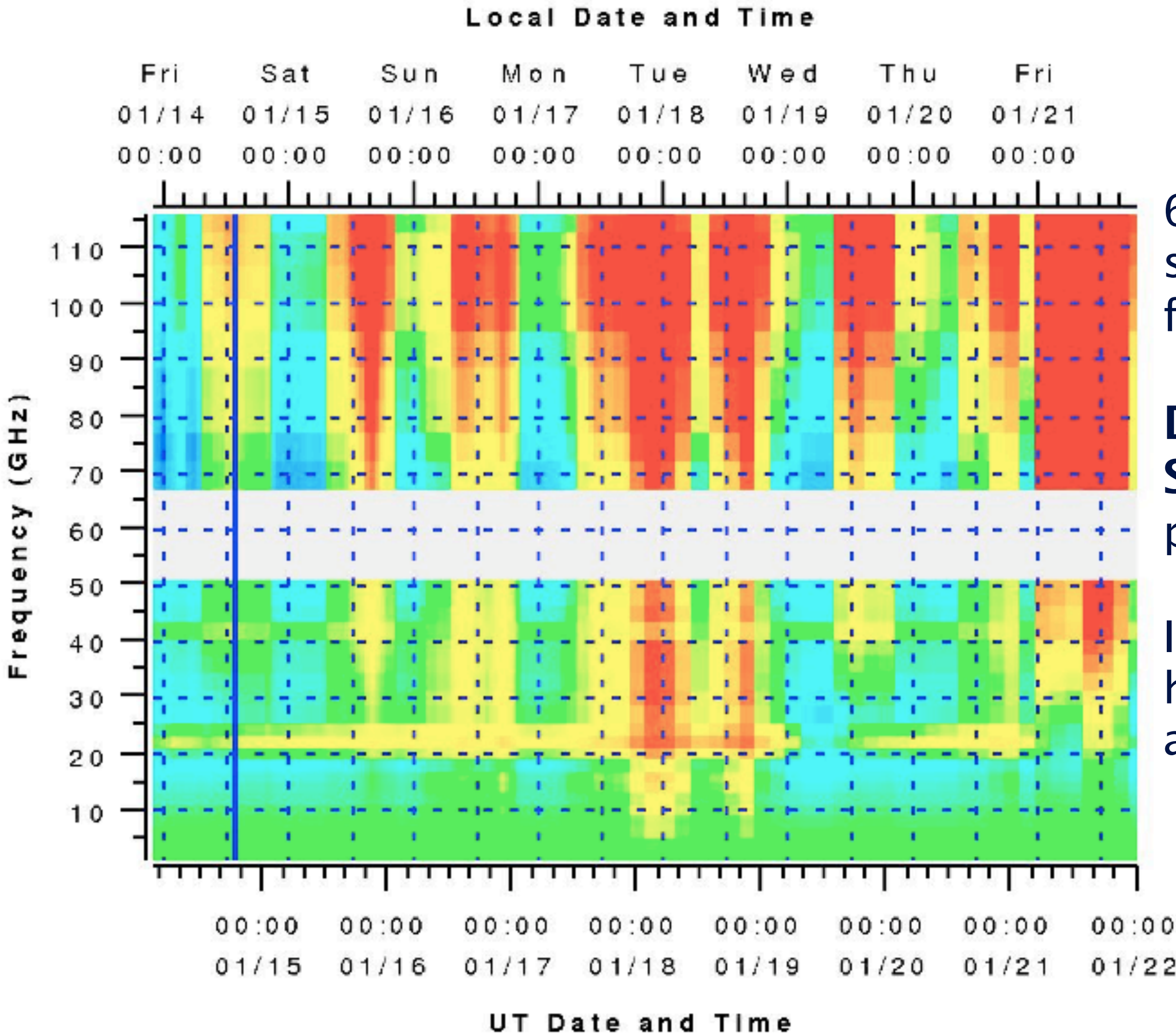
(From Todd Hunter, PTCS group)

GBT Effective Collecting Area (η_a * Area)

Assumes current ~240um rms surface errors➔ 35% at 90 GHz

➔ most sensitive facility at Q and W-low (ALMA-band2, 4mm).





6500 hours a year scheduled
for astronomy on the GBT

Dynamic Scheduling System (DSS) matches the project to the weather

In 2010 there were 1776 hours used at frequencies above 18 GHz

10

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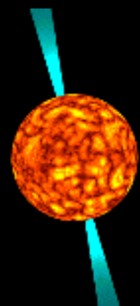
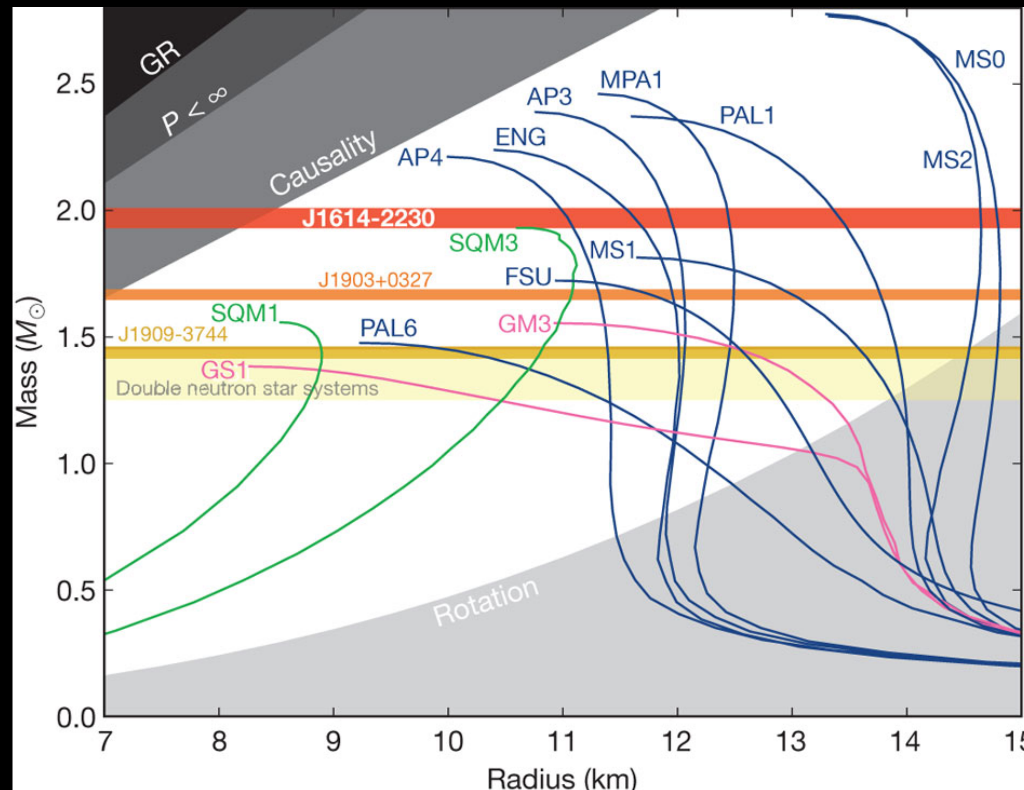
Some Key GBT Science Areas:

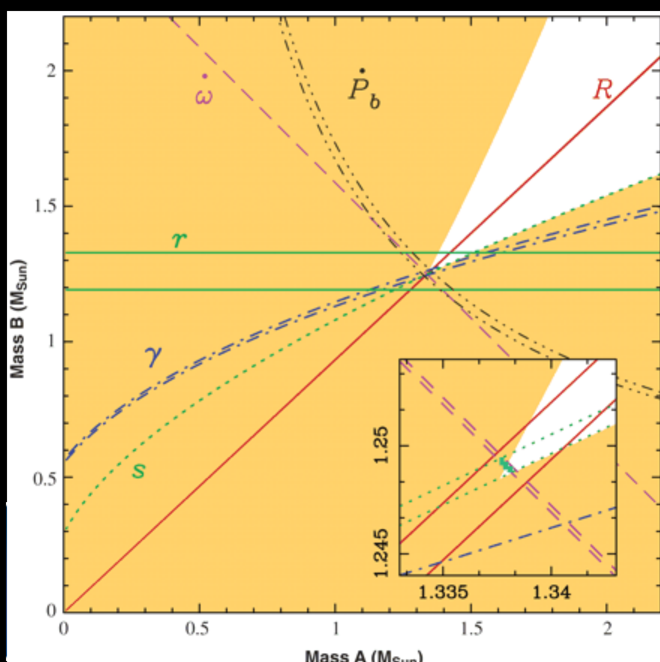
- **(~30%) Pulsars**: Discovery of new pulsars, the most massive pulsar, search for gravitational radiation
- **(~30%) Neutral Hydrogen HI**: Gas masses of local galaxies, Kinematics of galaxy and local group/dark matter, HI intensity mapping at high-redshift
- **(~30%) High-frequency science**:
  - 90 GHz imaging with Mustang
  - CO at redshift (K/Ka{+Zpectrometer}/Q)
  - Interstellar Organic Molecules & Astro-chemistry
  - Masers: black hole masses, distances via proper motions
  - Star Formation: NH3 mapping (KFPA)
- Solar system astronomy (radar mapping)

Pulsar timing results



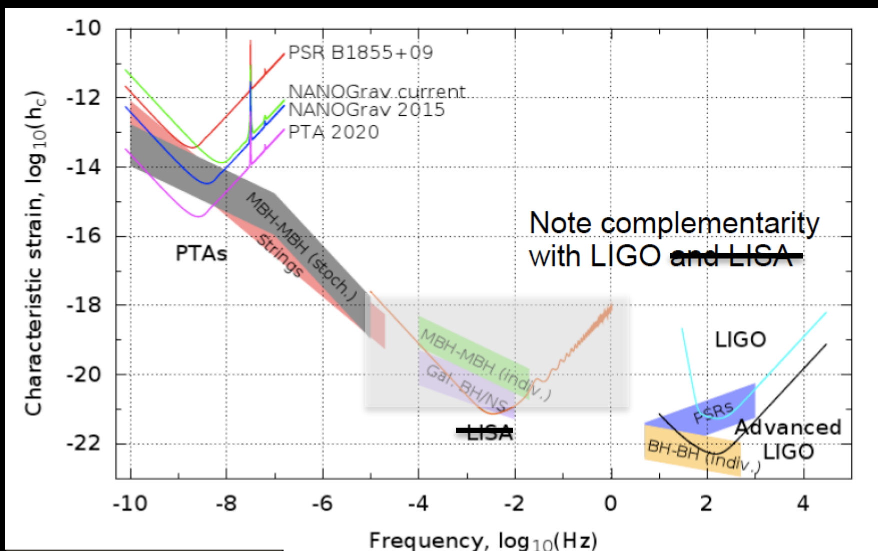


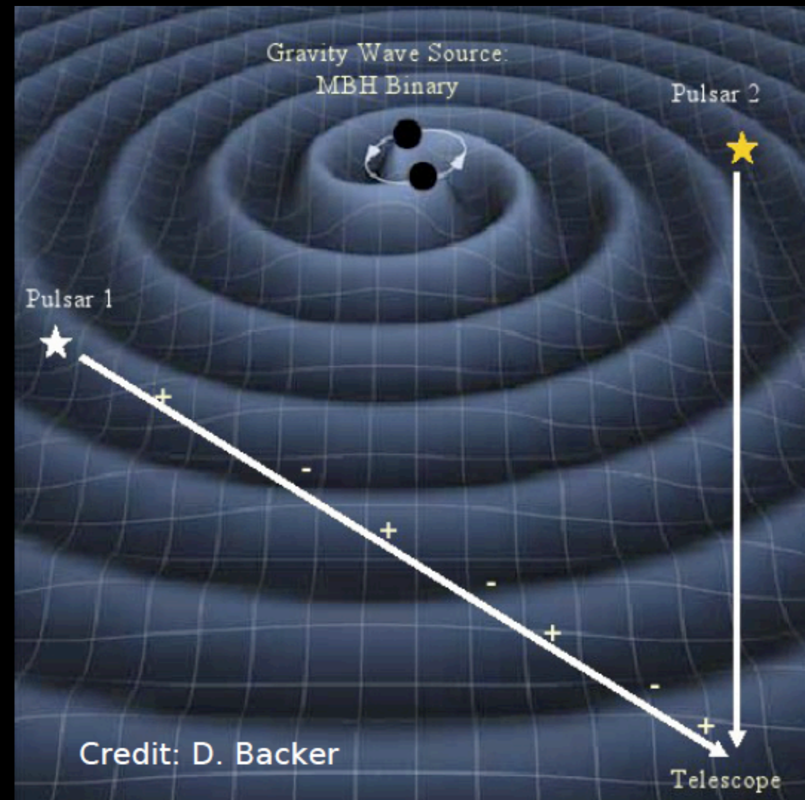
Most massive neutron star
PSG J1614-2230 ~2M(sun)
Demorest et al. 2010



Measuring binary pair eccentricity
to test general relativity

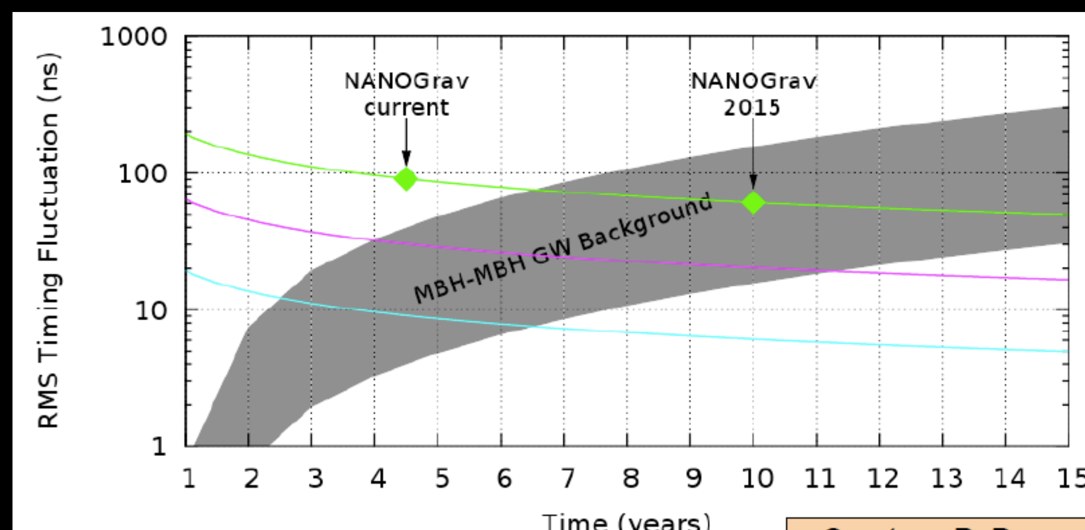
Gravity Waves NANOGrav



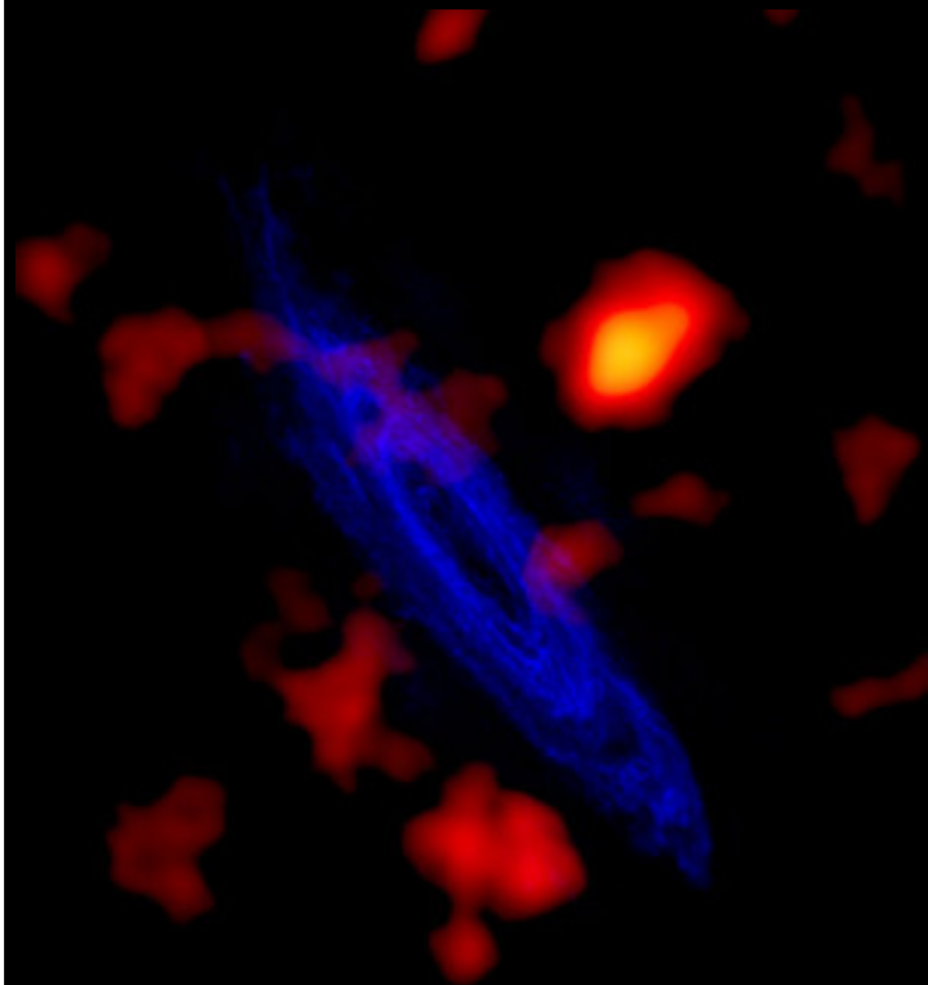


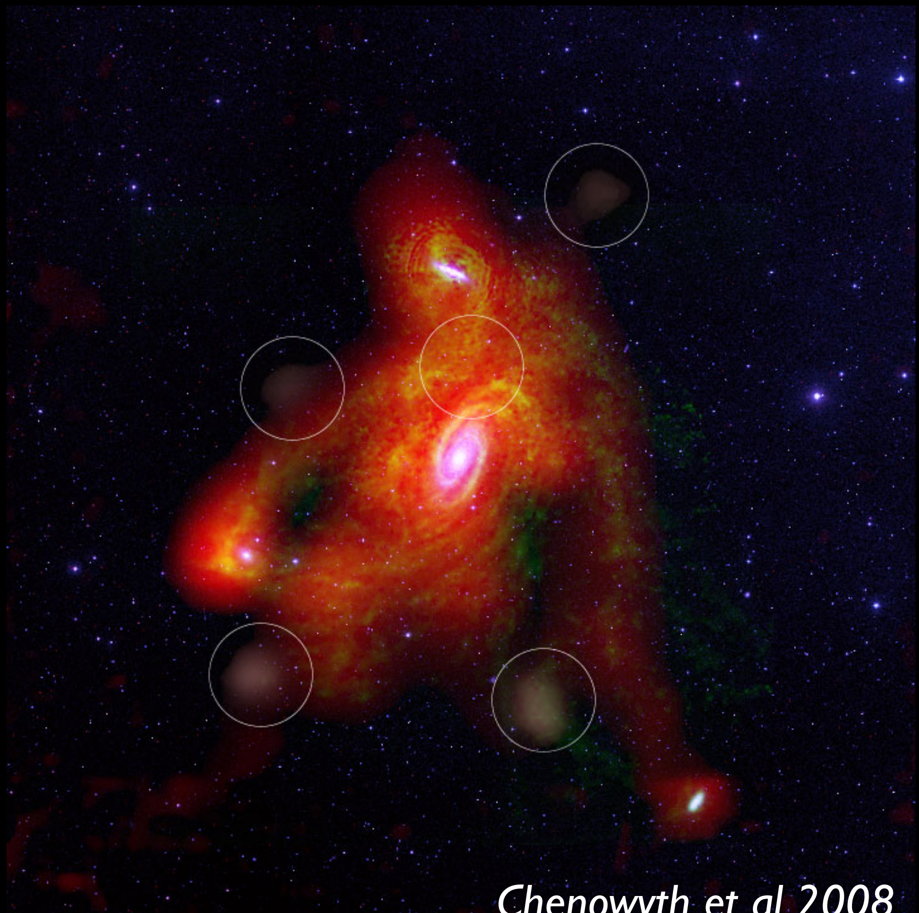
The GBT may provide first detection of gravitational waves

Need 40 pulsars with <100ns timing residuals



Local Galaxies and Dark matter via HI



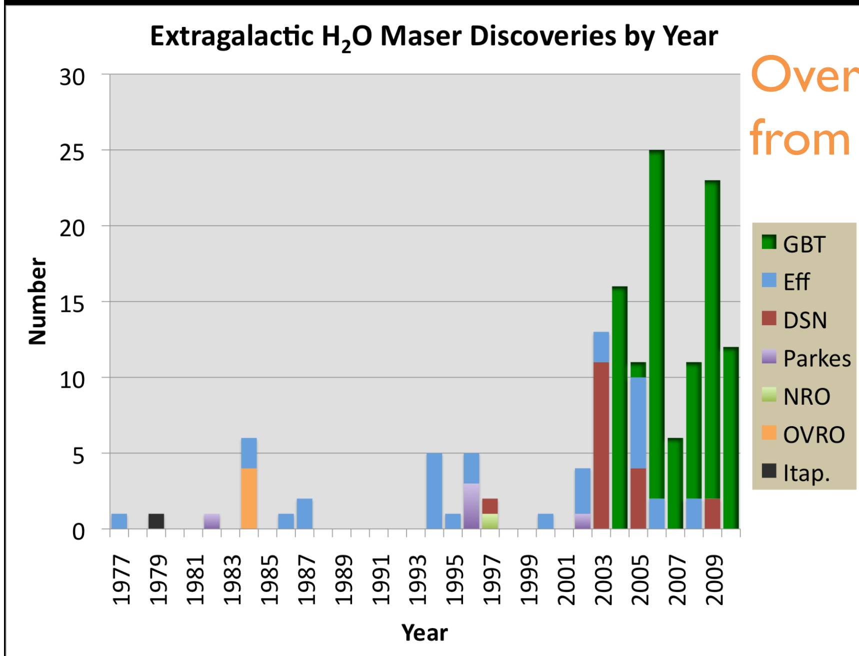


Chenowyth et al 2008

Westerbork + GBT

Thilker et al 2004 ApJ

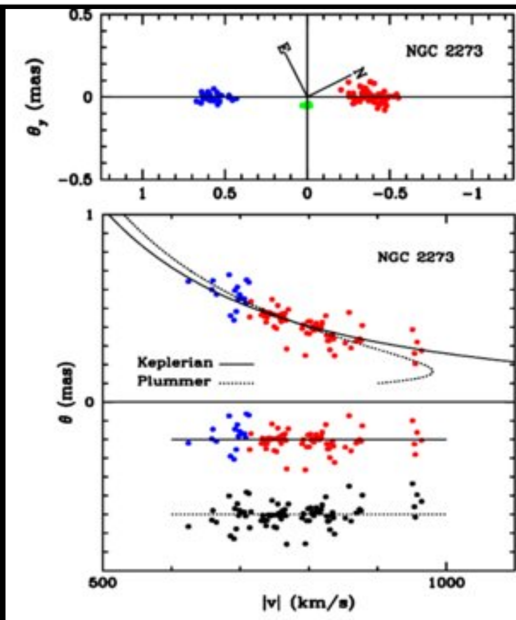
Measurements of Ho and SMBH masses via H20 Masers

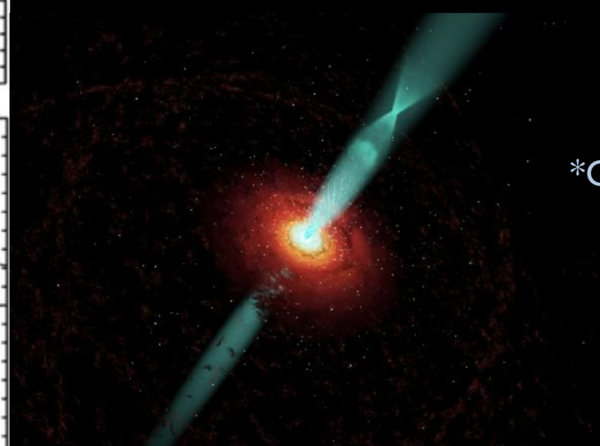


Over 80 masers from the GBT

Measuring H_0 within 3% precision by obtaining geometric distances to water masers in other galaxies*

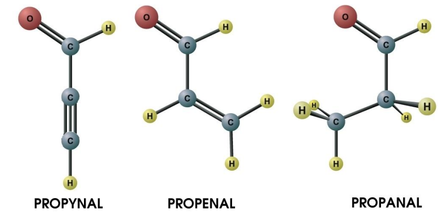
Measuring precise masses of the black holes in megamaser disk galaxies*





*GBT used both for Maser discovery and providing necessary sensitivity to VLBA

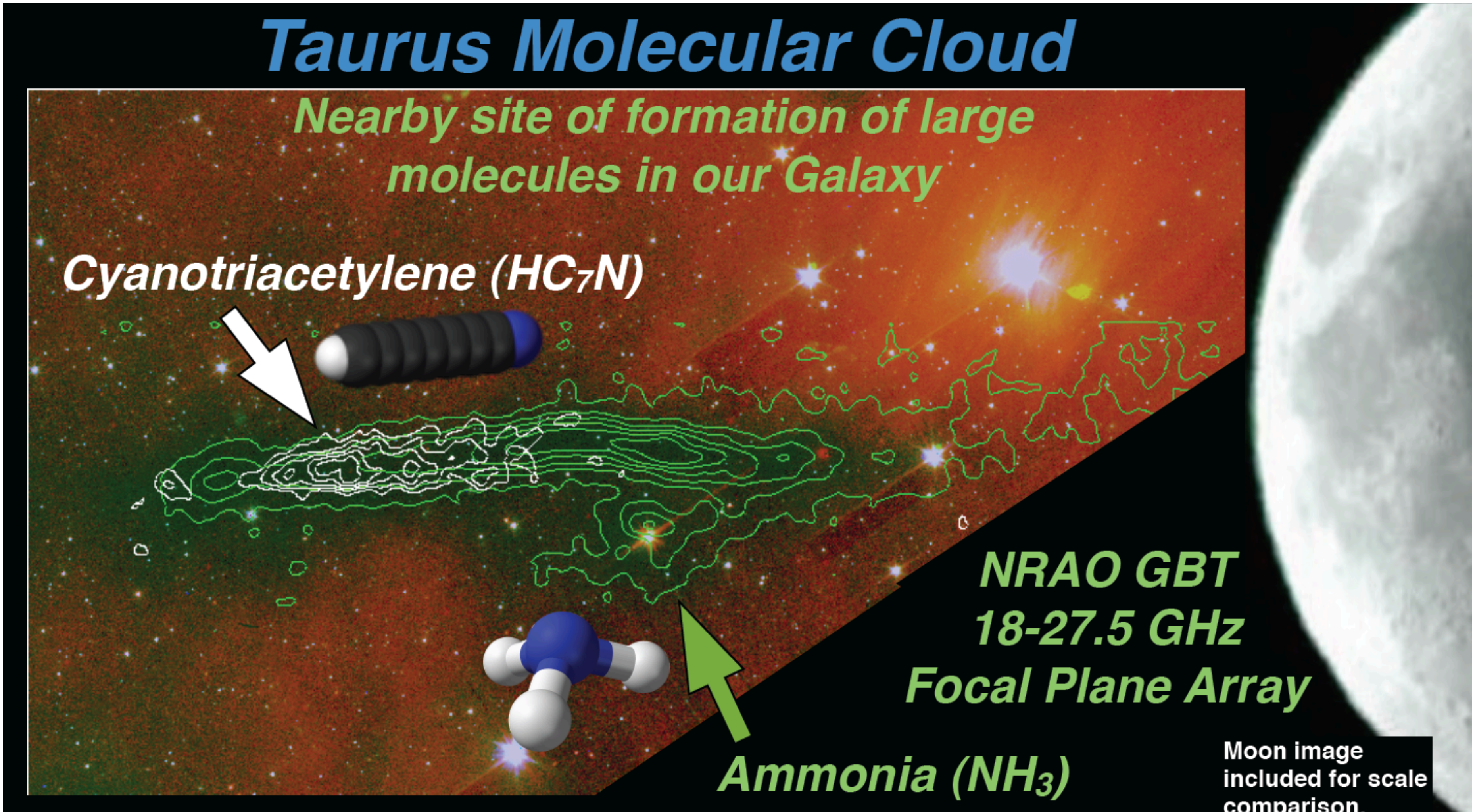
Organic chemistry in interstellar clouds



H_2O (water)
H_2CO (formaldehyde)
NH_3 (ammonia)
CO (Carbon monoxide)
HCOOH (formic acid)
CNCHO (cyanoformaldehyde)
CH_3OH (methanol)
CH_2CHCN (vinyl cyanide)
$HOCH_2CH_2OH$ (ethylene glycol)
CH_3CO_2H (acetic acid)
CH_3CH_2OH (ethyl alcohol)
CH_2OHCHO (glycolaldehyde)

The GBT has detected 14 new interstellar organic molecules
including the first interstellar anions:
C_6H^- & C_8H^-
(McCarthy et al 2006;
Cordiner et al 2011)

Mapping of Star-Formation Regions with the K-FPA



Contours show molecular chemistry dynamics in cold, dark, star forming clouds. White contours mark molecule HC_7N. Green contours mark ammonia distribution. Background image is a color composite of Spitzer Space Telescope IRAC channels 1, 2 and 4 (*Langston et al. 2011*).

Mustang 3mm Imaging of SZ-Effect and Cluster Structure

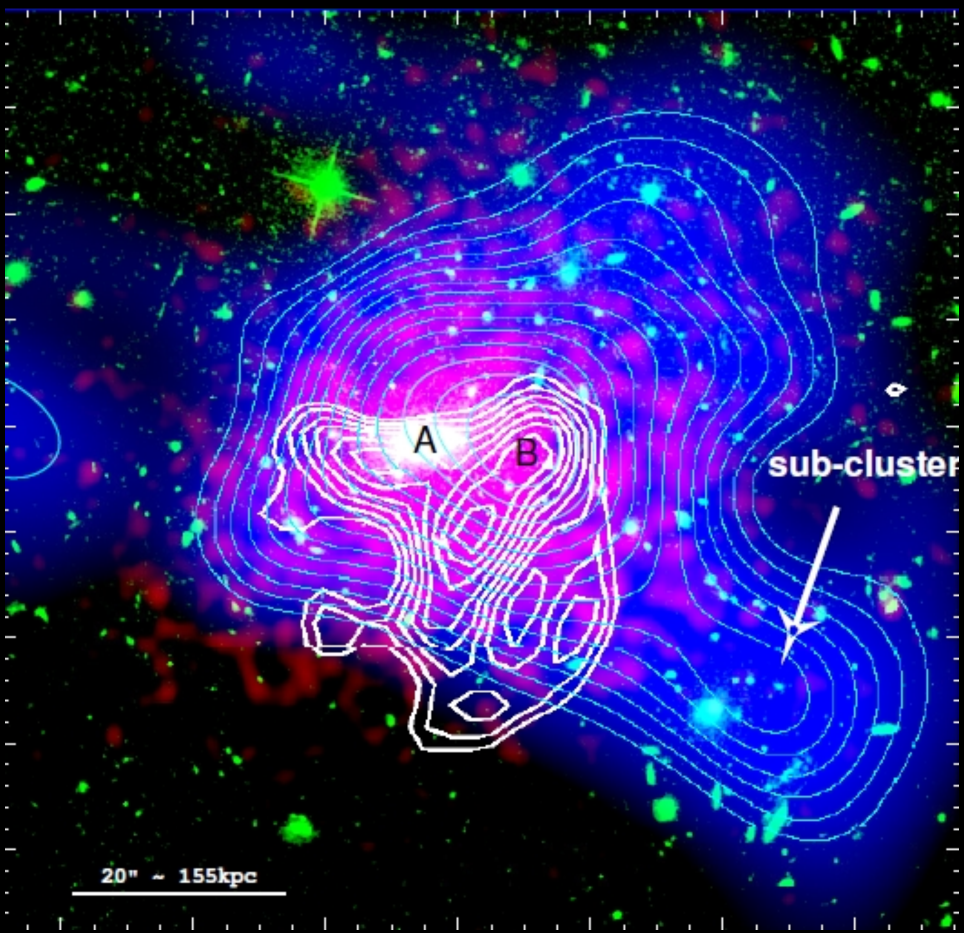
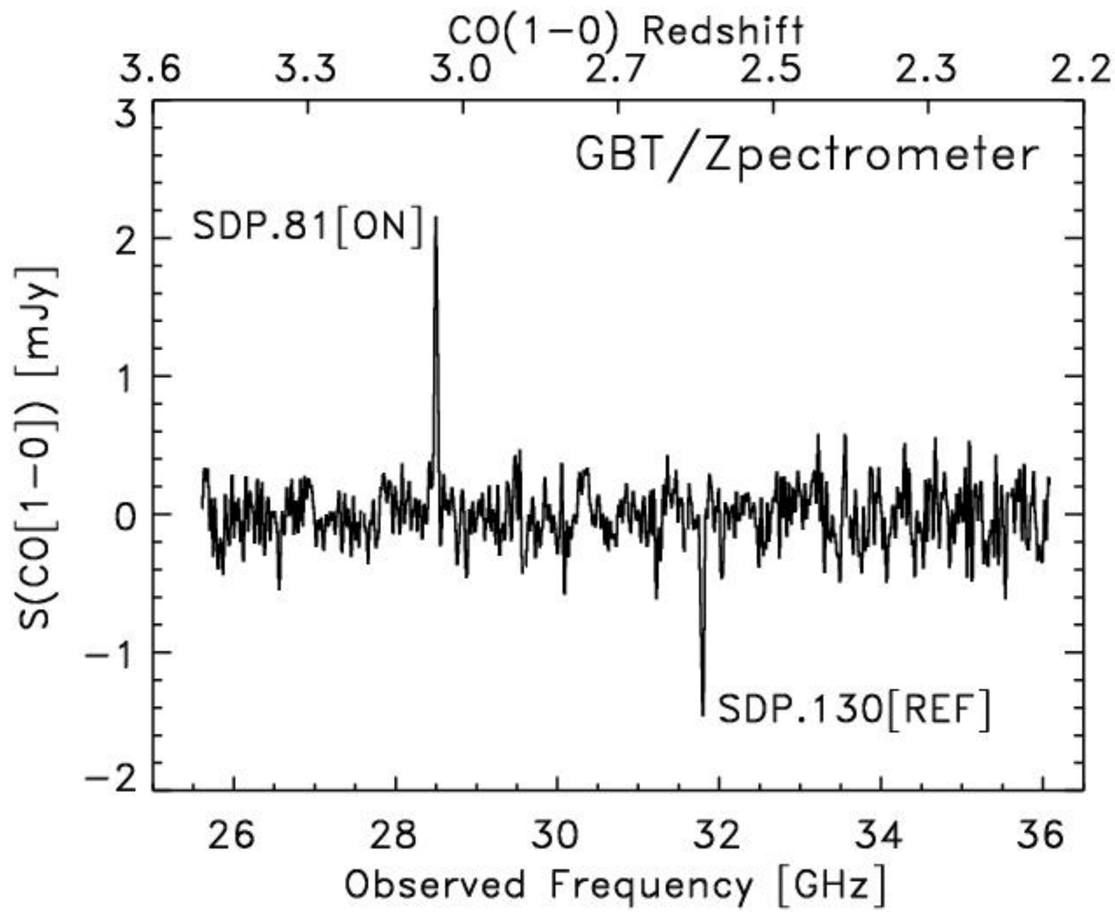


Image of CL1226.9+3332 (z = 0.89); White is MUSTANG; Green is optical (HST); Red is X-ray (Chandra); Blue is mass density (HST) *Courtesy Korngut, et al.*

Studying star formation in the early universe via high-redshift CO

Frayer et al. 2011: Molecular gas measurements and redshifts of ultra-luminous infrared galaxies discovered by Herschel with the GBT/Zpectrometer. (around 15-20 Herschel sources with GBT redshifts)



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Current Instruments – Front Ends

<u>Example lines:</u>

HI, OH → L-Band

NH3, HC5N, C2S, H2O → K-Band

HCN, HNC, HCO+, HDO, DCN, SiO, SO2, H2CO, N2H+, N2D+, CH3CN, C2H → W-band

Receiver	Band	Frequency Range (GHz)	Focus	Polarization	Beams
PF1	342 MHz	.290-.395	Prime	Lin/Circ	1
	450 MHz	.385-.520	Prime	Lin/Circ	1
	600 MHz	.510-.690	Prime	Lin/Circ	1
	800 MHz	.680-.920	Prime	Lin/Circ	1
PF2	——	.910-1.23	Prime	Lin/Circ	1
L-Band	——	1.15-1.73	Greg.	Lin/Circ	1
S-Band	——	1.73-2.60	Greg.	Lin/Circ	1
C-Band	——	3.95-6.1	Greg.	Lin/Circ	1
X-Band	——	8.00-10.0	Greg.	Circ	1
Ku-Band	——	12.0-15.4	Greg.	Circ	2
K-Band	lower	18.0-22.4	Greg.	Circ	~~2~~ 7 (KFPA)
	upper	22.0-26.5	Greg.	Circ	2
Ka-Band	MM-F1	26.0-31.0	Greg.	Circ	2
	MM-F2	30.5-37.0			
	MM-F3	36.0-39.5			
Q-Band	——	38.2-49.8	Greg.	Circ	2
Mustang	——	80-100	Greg.	—-	64
{W-band (4mm Rx)		67-93.3	Greg.	Lin/Circ	2}

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Current Instruments – Front Ends-2

Receiver	FWHM	Gain (K/Jy)	Aperture Efficiency	SEFD (JY)	T_{rec} (K)	T_{sys} (K)
PF1	36′	2.0	70%	23	12	$46 + T_{bg}$
	27′	2.0	70%	22	22	$43 + T_{bg}$
	21′	2.0	70%	11	12	$22 + T_{bg}$
	15′	2.0	70%	15	21	$29 + T_{bg}$
PF2	12′	2.0	70%	9	10	$17 + T_{bg}$
L-Band	9′	2.0	70%	10	6	$20 + T_{bg}$
S-Band	5.8′	1.9	70%	11	6-10	$20 + T_{bg}$
C-Band	2.5′	1.85	70%	8	5	$18 + T_{bg}$
X-Band	1.4′	1.8	70%	15	13	$27 + T_{sky}$
Ku-Band	54″	1.7	70%	18	14	$30 + T_{sky}$
K-Band	37″	1.5	67% → 68%	23	21	$30 - 40 + T_{sky}$
	30″	1.5	65% → 67%	24	21	$30 - 40 + T_{sky}$
Ka-Band	26.8″	1.5	56-64% → 65%	27	20	$45 + T_{sky}$
	22.6″			20		$35 + T_{sky}$
	19.5″			43		$70 + T_{sky}$
Q-Band	16″	1.0	47-56% → 60%	67-134	40-70	$67 - 134 + T_{sky}$
Mustang	10″	—-	20% → 35%	—-	—-	—-

Backends/Spectrometers

- Spectrometer with bandwidths: 800, 200, 50, 12.5 MHz. Maximum resolution is 49 Hz with 12.5MHz bandwidth. Minimum integration times 1-2 sec.
- Spectral Processor (FFT spectrometer) for high-time resolution data (useful at low freq where RFI is an issue).
- Continuum with DCR (digital continuum receiver) for most bands, CCB used for continuum at Ka, and Mustang for continuum at 90GHz.
- GUPPI used for Pulsar Observations
- **VEGAS** (VErsitile GBT Astronomical Spectrometer) is the new replacement for the Spectrometer available in 2012 (FPGA based).

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Bandwidth (MHz)	Number of Spectral Windows	Number of Beams	Channels - Approximate Resolution (kHz)	Mininum Integration Time (sec)	Notes
1500	1 or 2	1	1024 – 1464.844	0.5	1st priority mode
1500	1	2	1024 – 1464.844	0.5	1st priority mode
1000	1 or 2	1	2048 – 488.281	0.7	
1000	1	2	2048 – 488.281	0.7	
800	1 or 2	1	4096 – 195.313	1.3	
800	1	2	4096 – 195.313	1.3	
500	1 or 2	1	8192 – 61.035	2.5	
500	1	2	8192 – 61.035	2.5	
400	1 or 2	1	16384 – 24.414	5.0	
400	1	2	16384 – 24.414	5.0	

Table 7: VEGAS Large Bandwidth, Few Spectral Window Modes.

VEGAS: Supports 8 beams, dual polarization (e.g., K-FPA). Up to 16 windows (one beam), 8 windows (two beams). Maximum continuous bandwidth of 10 GHz, eventually.

Bandwidth (MHz)	Number of Spectral Windows	Number of Beams	Channels - Approximate Resolution (kHz)	Mininum Integration Time (sec)	Notes
250	1 or 2	1	32768 – 7.629	10	
250	1	2	32768 – 7.629	10	
100	1 or 2	1	32768 – 3.052	10	
100	1	2	32768 – 3.052	10	
50	1 or 2	1	32768 – 1.526	10	
50	1	2	32768 – 1.526	10	
25	1 or 2	1	32768 – 0.763	10	
25	1	2	32768 – 0.763	10	
10	1 or 2	1	32768 – 0.305	10	3rd priority mode
10	1	2	32768 – 0.305	10	3rd priority mode
5	1 or 2	1	32768 – 0.153	10	
5	1	2	32768 – 0.153	10	
1	1 or 2	1	32768 – 0.031	10	4th priority mode
1	1	2	32768 – 0.031	10	4th priority mode

Table 8: VEGAS Small Bandwidth, Few Spectral Window Modes.

Bandwidth (MHz)	Number of Spectral Windows	Number of Beams	Channels - Approximate Resolution (kHz)	Mininum Integration Time (sec)	Notes
30	8 or 16	1	4096 – 7.324	10	
30	8	2	4096 – 7.324	10	
15	8 or 16	1	4096 – 3.662	10	2nd priority mode
15	8	2	4096 – 3.662	10	2nd priority mode
10	8 or 16	1	4096 – 2.441	10	
10	8	2	4096 – 2.441	10	
5	8 or 16	1	4096 – 1.221	10	
5	8	2	4096 – 1.221	10	
1	8 or 16	1	4096 – 0.244	10	
1	8	2	4096 – 0.244	10	

Table 9: VEGAS Small Bandwidth, Many Spectral Window Modes.

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VEGAS First Light   Dec 2011

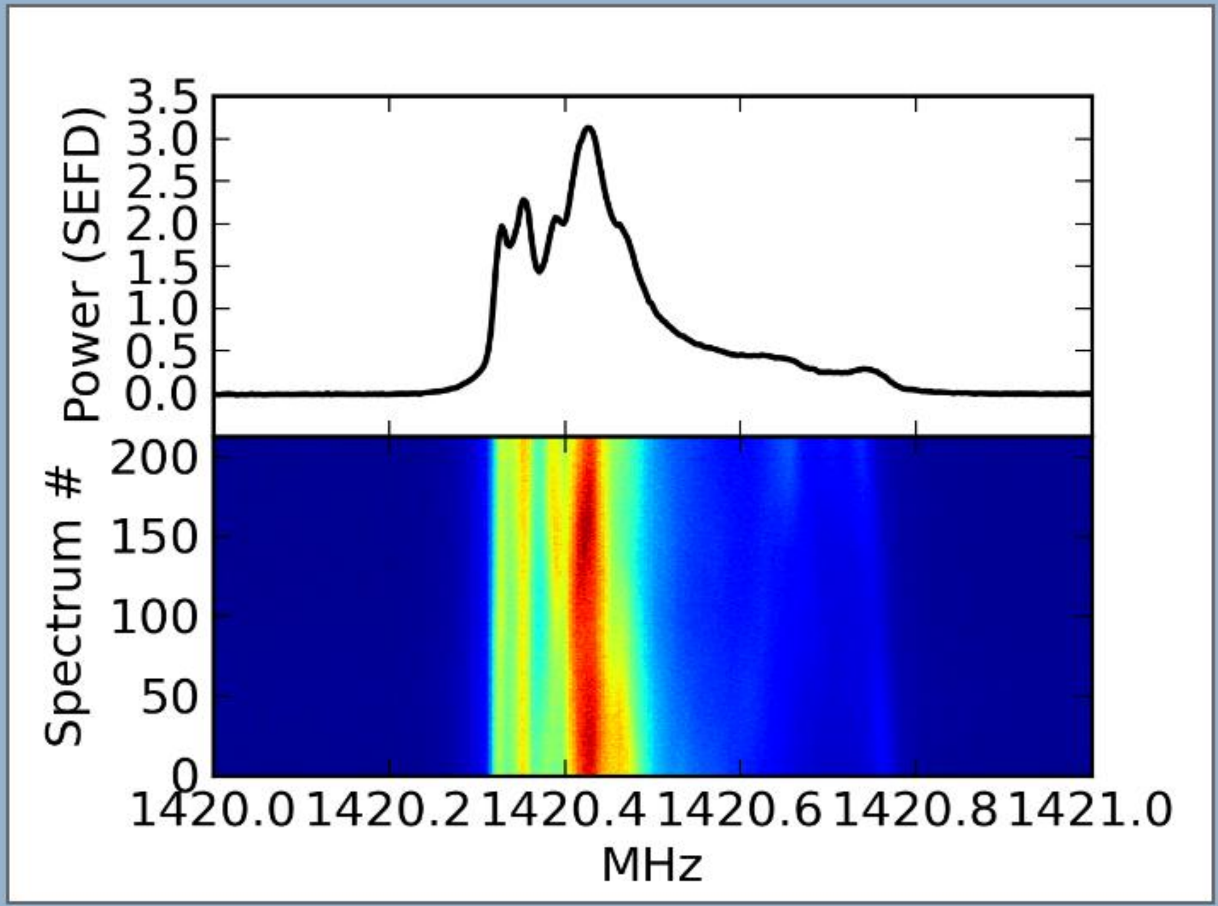


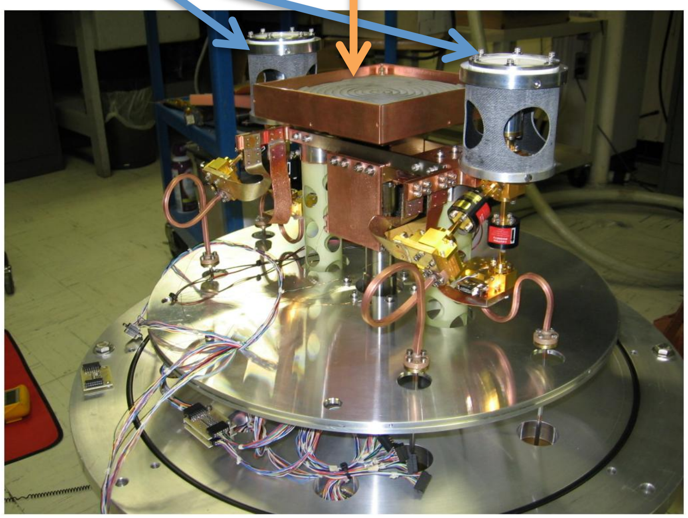
Figure 1. First light HI drift scan observations using VEGAS on 16 Dec 2011.

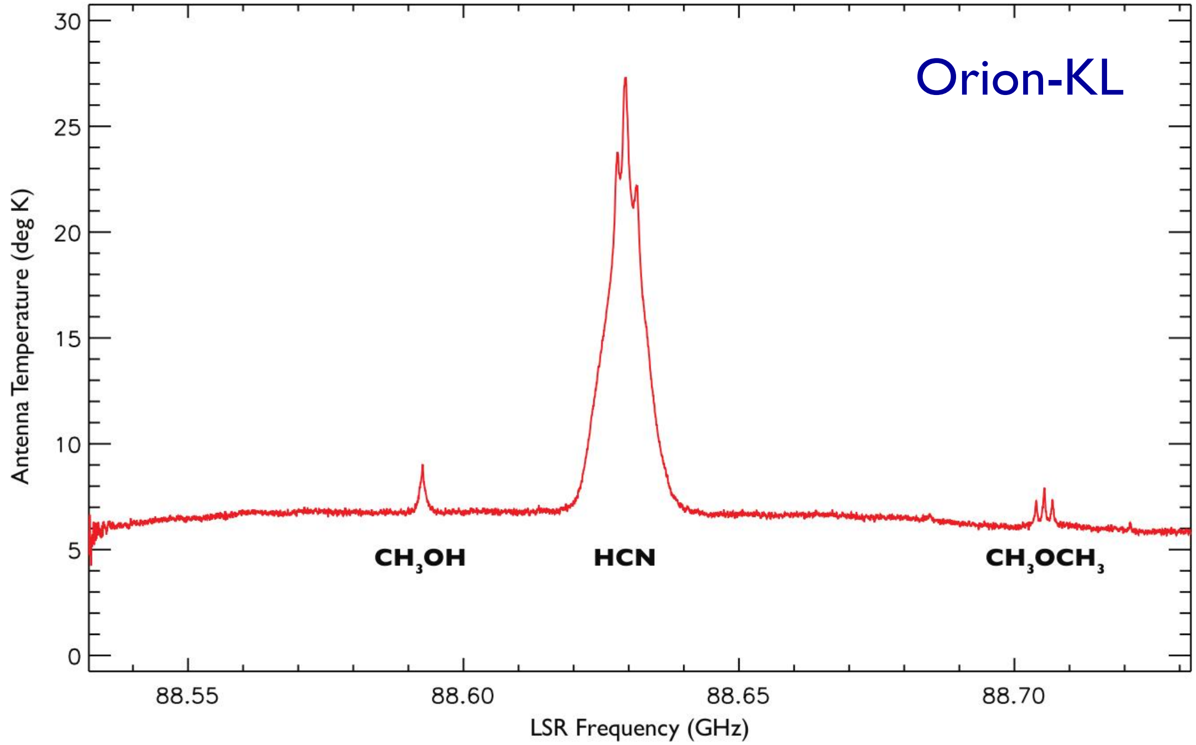
GBT's newest receiver: The 4mm Receiver (67-93.3 GHz). First Light, May 2011: HCN in Orion-KL

{couple of minutes taken during the day in marginal weather}

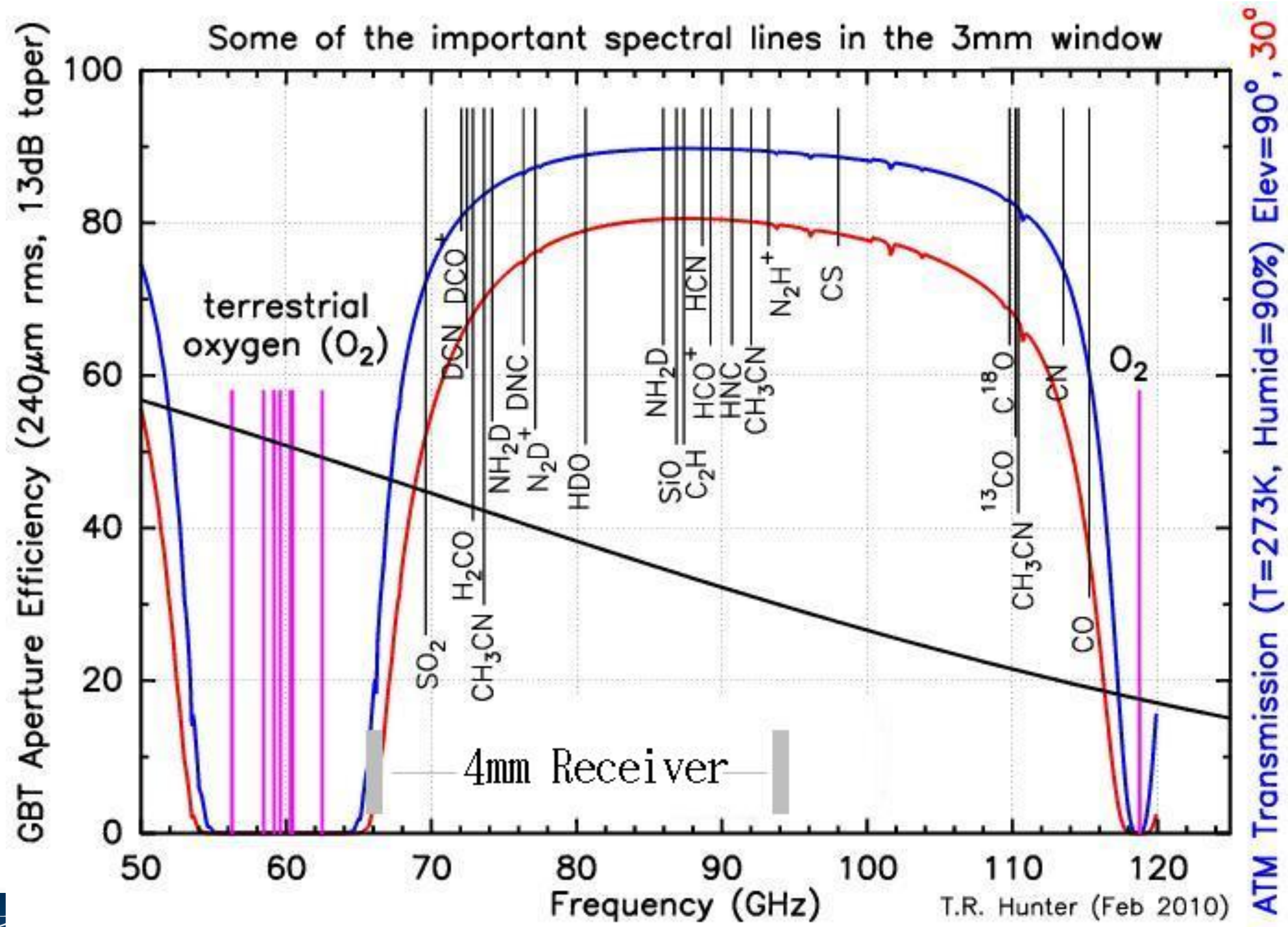
Commissioned: 2012 Jan-Mar

Feeds, Cold Load





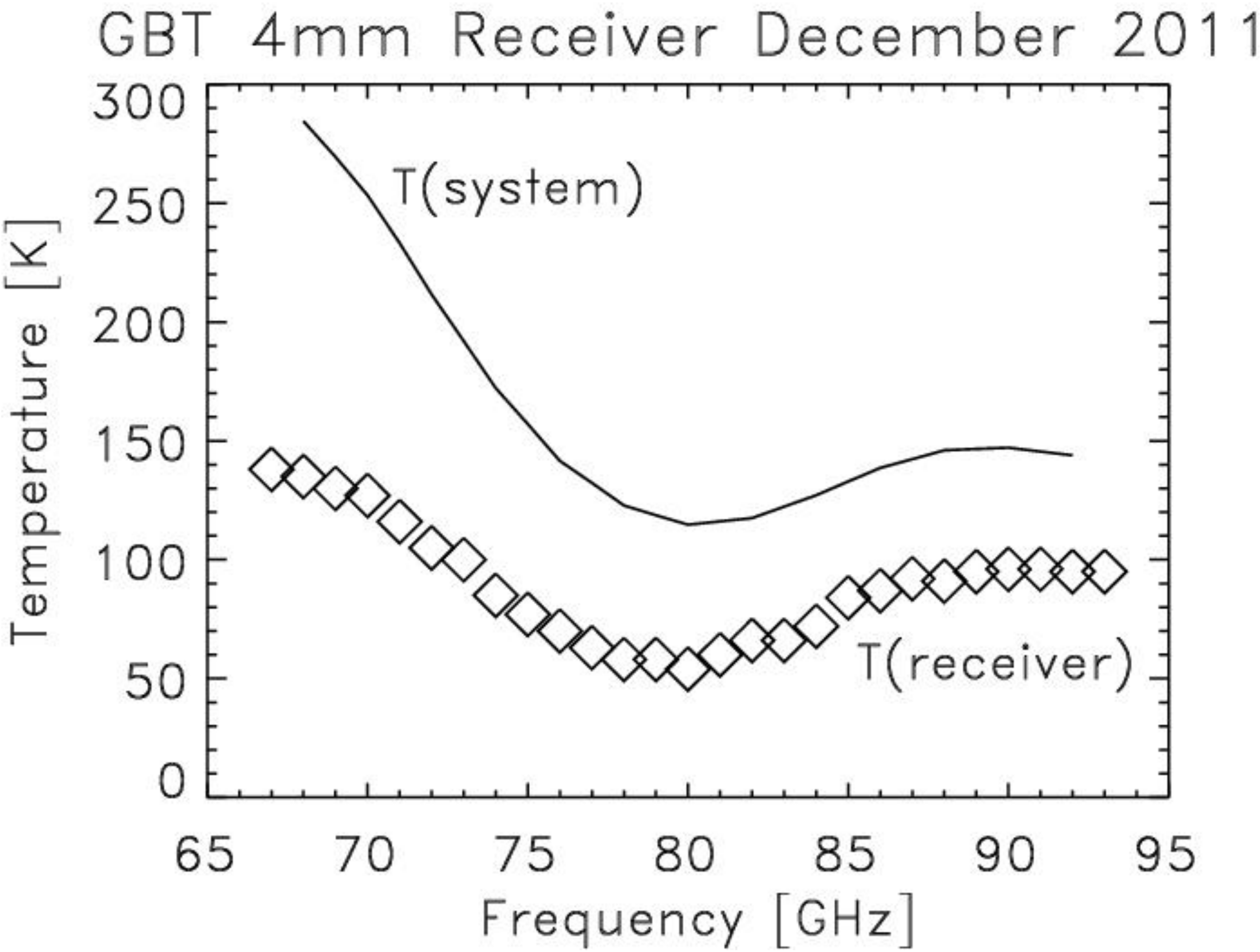
See http://www.gb.nrao.edu/4mm for more details.


Some of the important spectral lines in the 3mm window
GBT Aperture Efficiency (240μm rms, 13dB taper)
ATM Transmission (T=273K, Humid=90%) Elev=90°, 30°
Frequency (GHz)
T.R. Hunter (Feb 2010)
terrestrial oxygen (O2)
4mm Receiver
O2
SO2
CH3CN
H2CO
DCN
DCO+
NH2D
N2D+
DNC
HDO
SiO
C2H
NH2D
HCO+
HCN
HNC
CH3CN
N2H+
CS
13CO
C18O
CH3CN
CN
CO
100
80
60
40
20
0
50
60
70
80
90
100
110
120

4mm System Performance {with current non-optimized amplifiers}

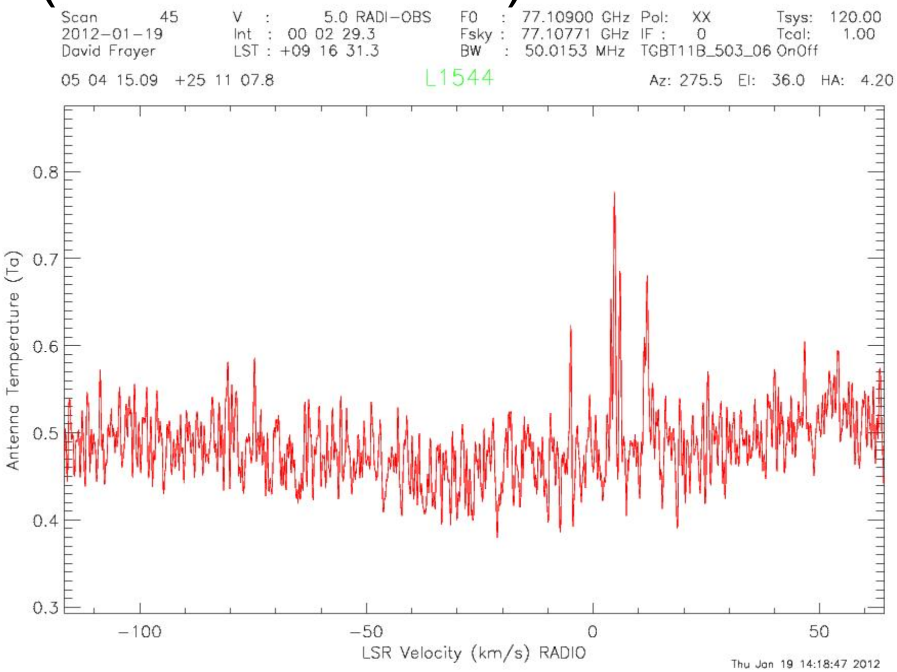
With resources and a bit of effort could reach T(rx) ~40K across the band.

Solid curve shows Tsys for "typical" weather scheduled by DSS. In good weather, sky contributes <30K.

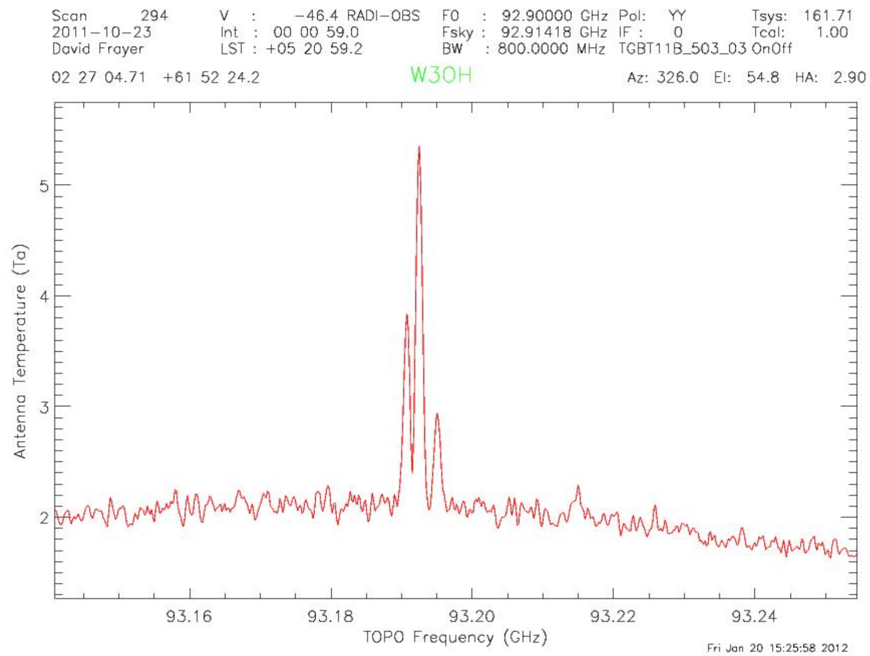


4mm Rx: Cold starless-cores → molecular freeze-out → D-species enhanced

N2D+ in L1544 at 77 GHz
(S. Schnee et al.)



N2H+ in W3OH at 93 GHz



4mm: Dense gas and Molecular Diversity in Nearby Galaxies

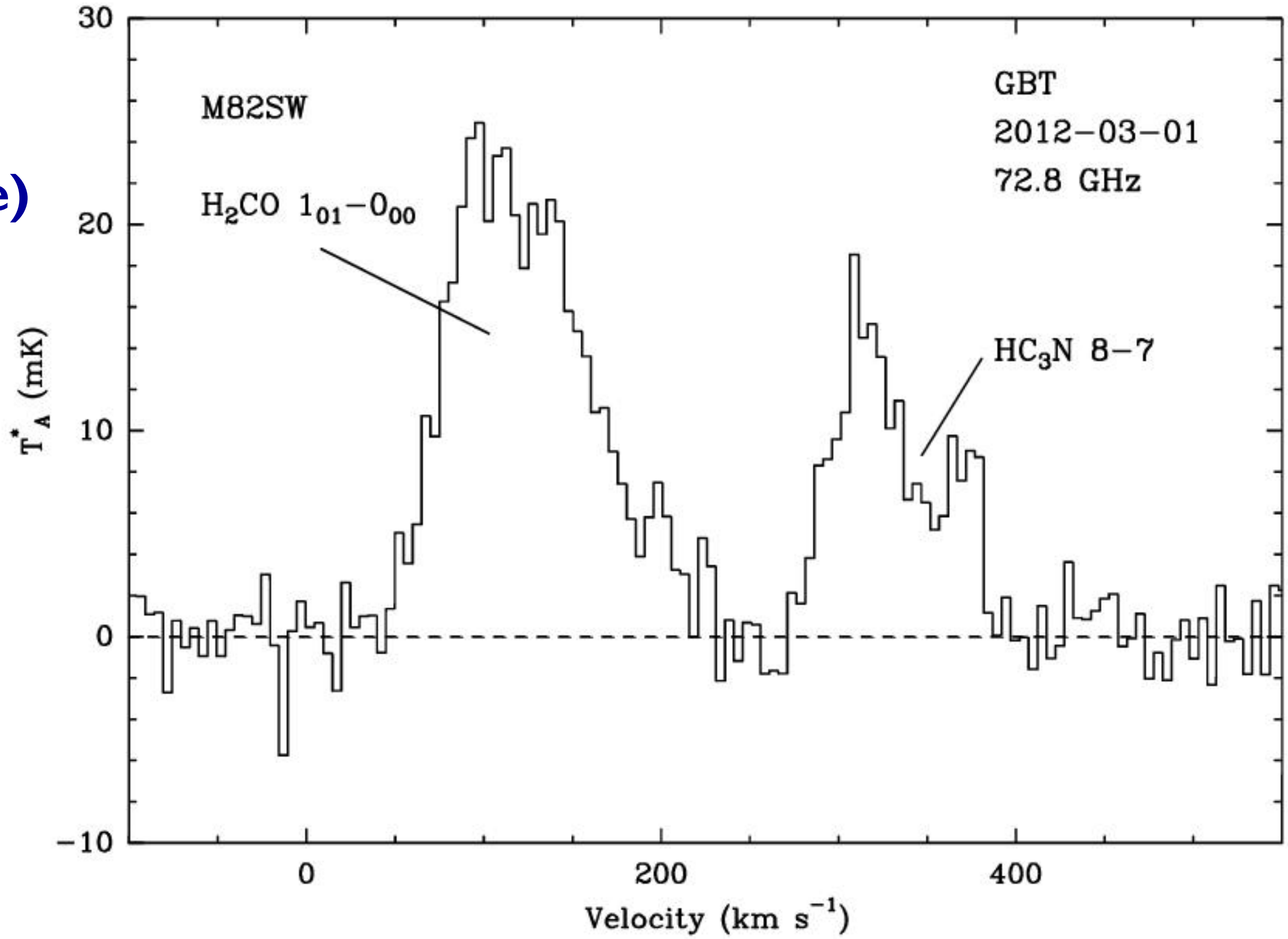
M82

H2CO

(formaldehyde)

& HC3N

(J. Mangum)



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NRAO Semester 2013A Call for Proposals

- **The NRAO Semester 2013A Call for Proposals for the Green Bank Telescope, Jansky Very Large Array, and Very Long Baseline Array/High Sensitivity Array will be published as a special issue of the NRAO eNews on Monday, 9 Jul 2012.**

- **The 2013A proposal submission deadline will be**

Wed, 1 Aug 2012, at 5 p.m. EDT.

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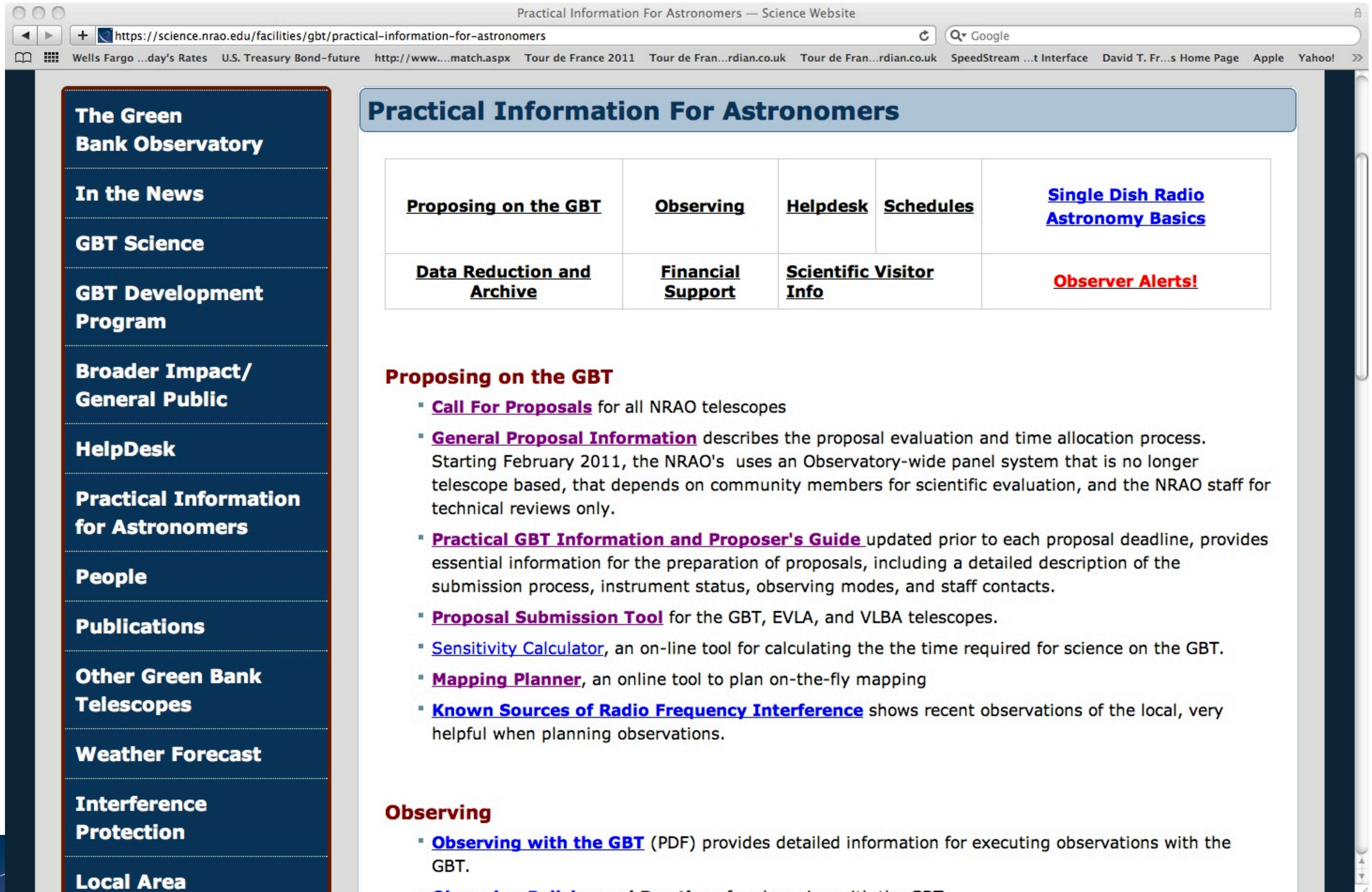
See NRAO web pages for the eNews Proposal call and GBT proposal guide to get the latest information



Practical Information For Astronomers — Science Website

https://science.nrao.edu/facilities/gbt/practical-information-for-astronomers

Wells Fargo ...day's Rates U.S. Treasury Bond-future http://www....match.aspx Tour de France 2011 Tour de Fran...rdian.co.uk Tour de Fran...rdian.co.uk SpeedStream ...t Interface David T. Fr...s Home Page Apple Yahoo!

- The Green Bank Observatory
- In the News
- GBT Science
- GBT Development Program
- Broader Impact/ General Public
- HelpDesk
- Practical Information for Astronomers
- People
- Publications
- Other Green Bank Telescopes
- Weather Forecast
- Interference Protection
- Local Area

Practical Information For Astronomers

Proposing on the GBT	Observing	Helpdesk	Schedules	Single Dish Radio Astronomy Basics
Data Reduction and Archive	Financial Support	Scientific Visitor Info		Observer Alerts!

Proposing on the GBT

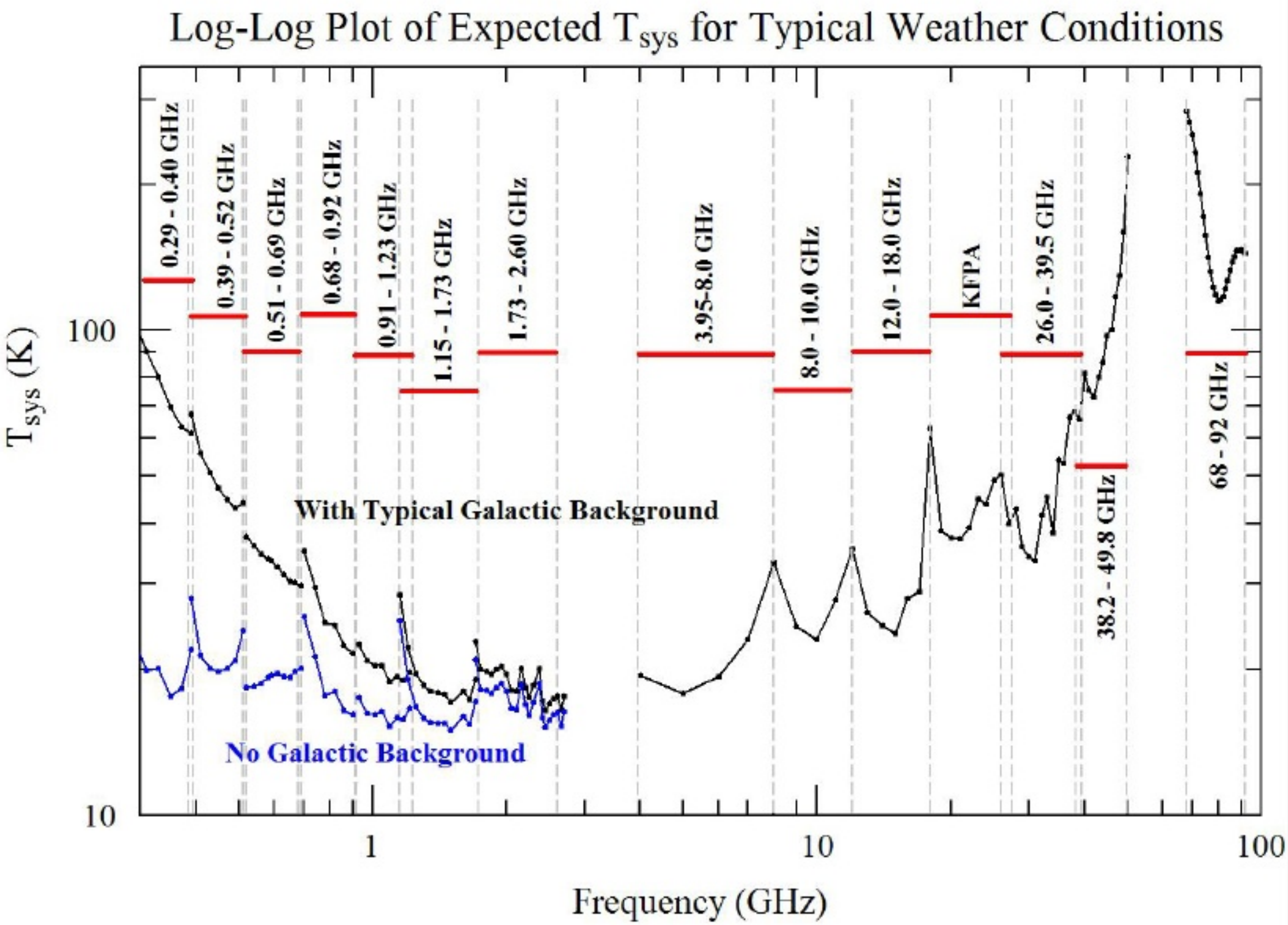
- Call For Proposals for all NRAO telescopes
- General Proposal Information describes the proposal evaluation and time allocation process. Starting February 2011, the NRAO's uses an Observatory-wide panel system that is no longer telescope based, that depends on community members for scientific evaluation, and the NRAO staff for technical reviews only.
- Practical GBT Information and Proposer's Guide updated prior to each proposal deadline, provides essential information for the preparation of proposals, including a detailed description of the submission process, instrument status, observing modes, and staff contacts.
- Proposal Submission Tool for the GBT, EVLA, and VLBA telescopes.
- Sensitivity Calculator, an on-line tool for calculating the the time required for science on the GBT.
- Mapping Planner, an online tool to plan on-the-fly mapping
- Known Sources of Radio Frequency Interference shows recent observations of the local, very helpful when planning observations.

Observing

- Observing with the GBT (PDF) provides detailed information for executing observations with the GBT.
- Observing Policies and Practices for observing with the GBT

GBT Proposal Guide

GBT Performance



GBT Web Links related to proposals:

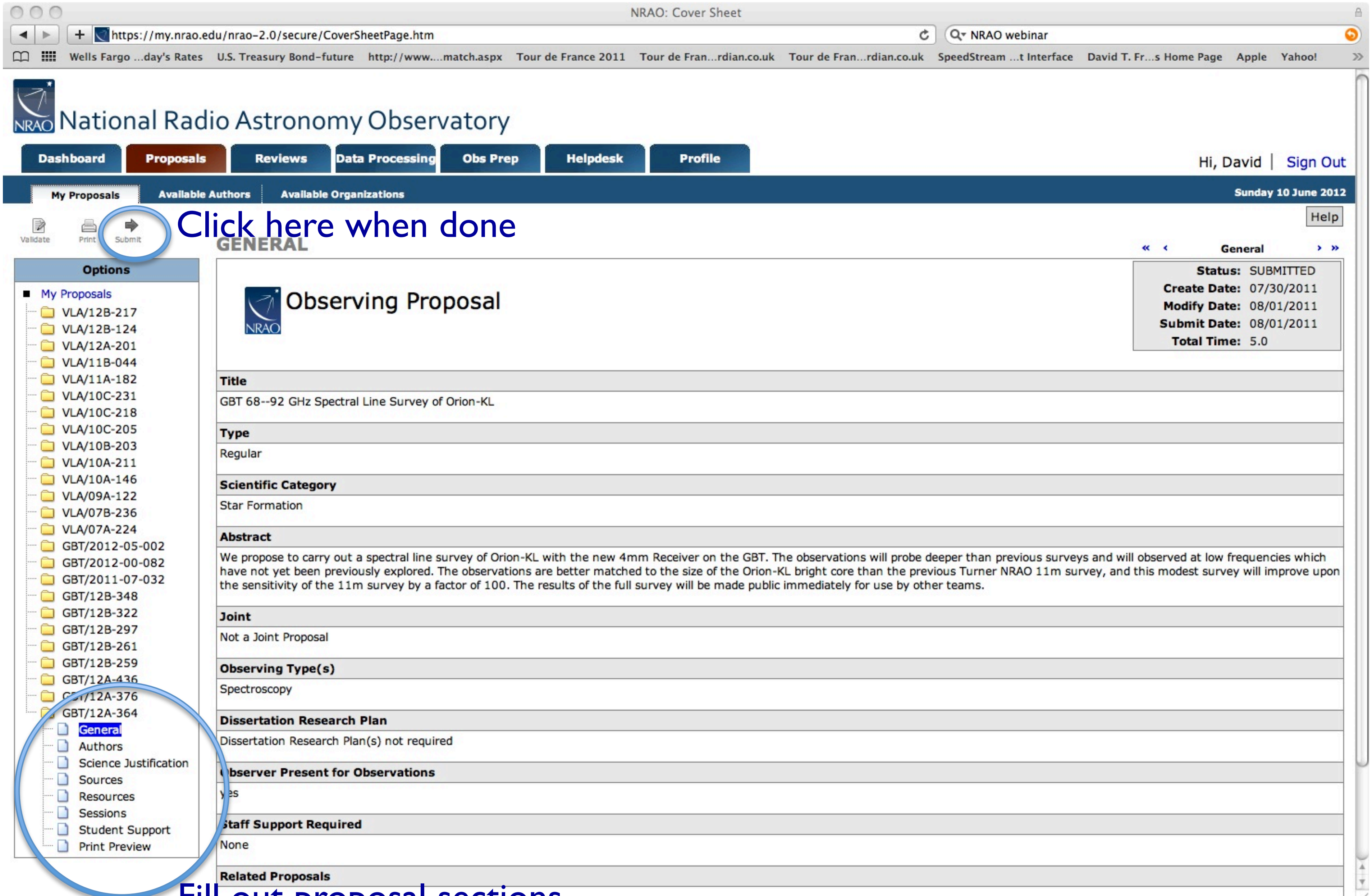
Useful Web Links

Description	Link
GBT Astronomers Web Page	http://www.gb.nrao.edu/astronomers.shtml
Proposal Writing Tips	http://www.naic.edu/~astro/School/Talks/salter_prop.pdf
GBT General Proposal Information	http://www.gb.nrao.edu/gbtprops/generalproposalinfo.shtml
GBT Latest Call For Proposals	http://www.gb.nrao.edu/gbtprops/latestgbtcfp.shtml
GBT Observation Planning	http://www.gb.nrao.edu/~rmaddale/GBT/ReceiverPerformance/PlaningObservations.htm
NRAO Proposal Submission Tool	http://www.gb.nrao.edu/nraoPST.htm
GBT Sensitivity Calculator	http://wwwlocal.gb.nrao.edu/GBT/setups/senscalc.html
GBT Spectral Line Wizard	http://wwwlocal.gb.nrao.edu/GBT/setups/configwiz.html
GBT Pointing Strategies	GBT Observer's Guide
GBT 60 Hour Weather Forecasts	http://www.gb.nrao.edu/~rmaddale/Weather/
GBT Mapping Planner	http://wwwlocal.gb.nrao.edu/GBT/setups/mapplan.html
Spigot Card	http://www.gb.nrao.edu/GBT/spectrometer/spigot_card/index.html
GBT VLBA Recorder	https://safe.nrao.edu/wiki/pub/GB/Knowledge/GBTMemos/GBT_Mark5A_S2.pdf
VLBI Information	http://www.gb.nrao.edu/~fghigo/gbtdoc/vlbinfo.html
Mark5 Single Dish Mode	https://safe.nrao.edu/wiki/bin/view/GB/Data/HowToObserveReduceMark5AandS2Data
Astrid	GBT Observer's Guide
GBTIDL	http://gbtidl.nrao.edu
RFI	http://www.gb.nrao.edu/IPG/
Guppi	https://safe.nrao.edu/wiki/bin/view/CICADA/GUPPiUsersGuide

Table 15: Useful Web Sites for Proposal Writers.

GBT Proposals are submitted via the "PST" (Proposal Submission Tool)

1st step, click here;-)



Click here when done

Fill out proposal sections

Dashboard | Proposals | Reviews | Data Processing | Obs Prep | Helpdesk | Profile

Hi, David | Sign Out

My Proposals | Available Authors | Available Organizations

Sunday 10 June 2012

Validate Print

Help

Options

- My Proposals
  - VLA/12B-217
  - VLA/12B-124
  - VLA/12A-201
  - VLA/11B-044
  - VLA/11A-182
  - VLA/10C-231
  - VLA/10C-218
  - VLA/10C-205
  - VLA/10B-203
  - VLA/10A-211

SOURCES

« ‹ Sources › »

Orion-KL Show Sessions up / down

Order	Name	Position		Velocity	
		Coordinate System	Equatorial	**Convention**	Radio
		Equinox	J2000		
up / down	OrionKL	**Right Acension**	Value: 05:35:14.51 Range(±): 00:00:00.0	**Ref. Frame**	LSRK
		Declination	Value: -5:22:30.6 Range(±): 00:00:00.0	**Velocity**	8.8 km/s

NRAO: Proposals

https://my.nrao.edu/nrao-2.0/secure/GBTResourcesPage.htm

NRAO webinar

Wells Fargo ...day's Rates U.S. Treasury Bond-future http://www....match.aspx Tour de France 2011 Tour de Fran...rdian.co.uk Tour de Fran...rdian.co.uk SpeedStream ...t Interface David T. Fr...s Home Page Apple Yahoo!

NRAO National Radio Astronomy Observatory

Dashboard | Proposals | Reviews | Data Processing | Obs Prep | Helpdesk | Profile

Hi, David | Sign Out

My Proposals | Available Authors | Available Organizations

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Validate Print

New Resource Group Help

Options

- My Proposals
  - VLA/12B-217
  - VLA/12B-124
  - VLA/12A-201
  - VLA/11B-044
  - VLA/11A-182
  - VLA/10C-231
  - VLA/10C-218
  - VLA/10C-205
  - VLA/10B-203
  - VLA/10A-211
  - VLA/10A-146
  - VLA/09A-122
  - VLA/07B-236
  - VLA/07A-224
  - GBT/2012-05-002
  - GBT/2012-00-082
  - GBT/2011-07-032
  - GBT/12B-348
  - GBT/12B-322
  - GBT/12B-297
  - GBT/12B-261
  - GBT/12B-259
  - GBT/12A-436
  - GBT/12A-376
  - GBT/12A-364
    - General
    - Authors
    - Science Justification
    - Sources
    - Resources
    - Sessions
    - Student Support

GBT RESOURCES

« ‹ Resources › »

Orion-KL-4mm Show Sessions up / down

Order	Name	Receiver	Back End
up / down	orion-4mm		GBT Spectrometer - spectral line mode

Rest Frequencies:	68.4,71.2,74,76.8,79.6,82.4,85.2,88,90.8,92 GHz
Bandwidth:	800 MHz
Number of Spectral Windows:	4
Sampling Level:	3
Desired Frequency Resolution:	390. kHz

Help

SESSIONS

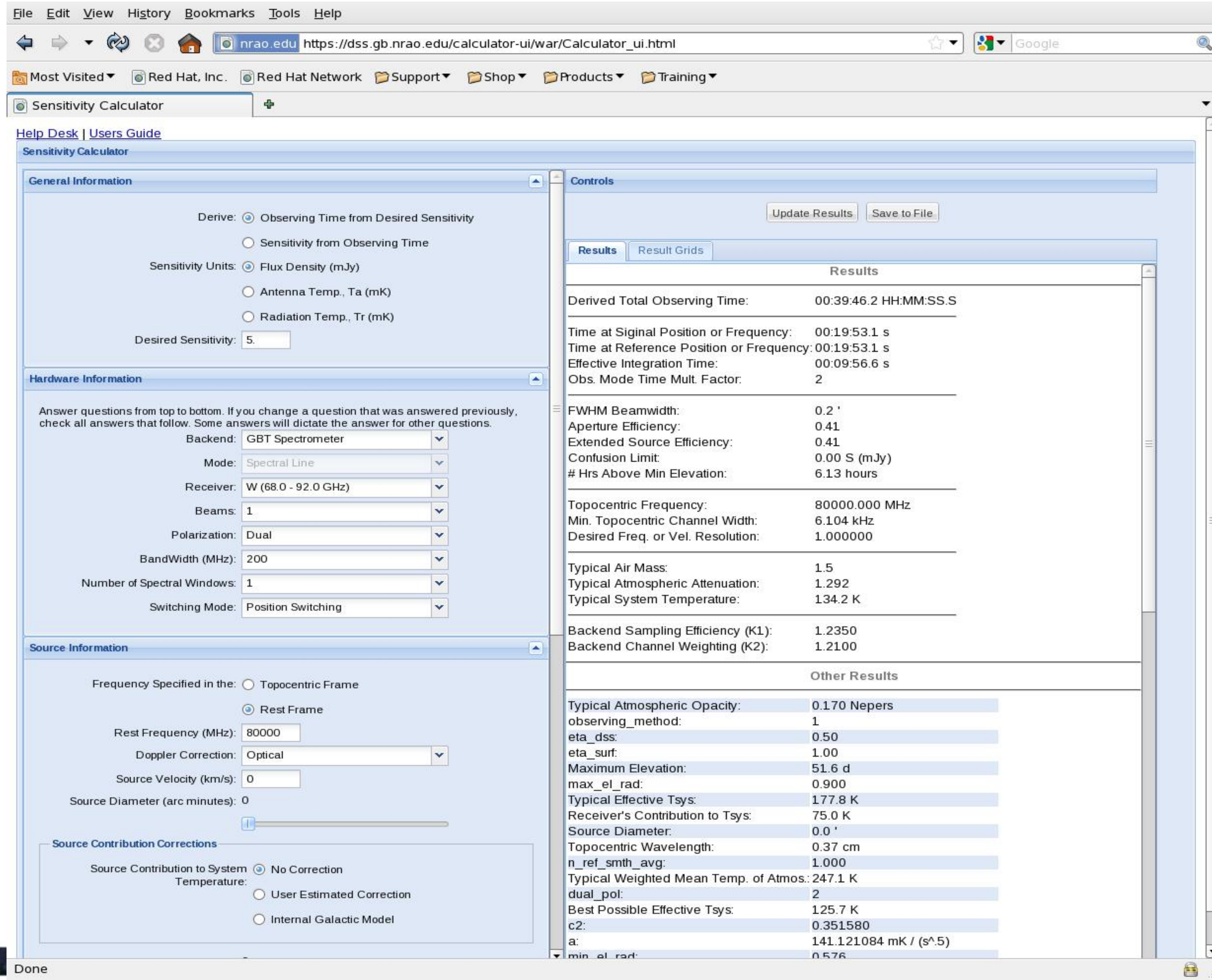
« ‹ Sessions › »

Session	Number of Sessions	Separation	Min. Start LST	Max. End LST	Min. Elevation
orion-4mm	1 X 5.0	0 day	00:00:00	10:00:00	25.0

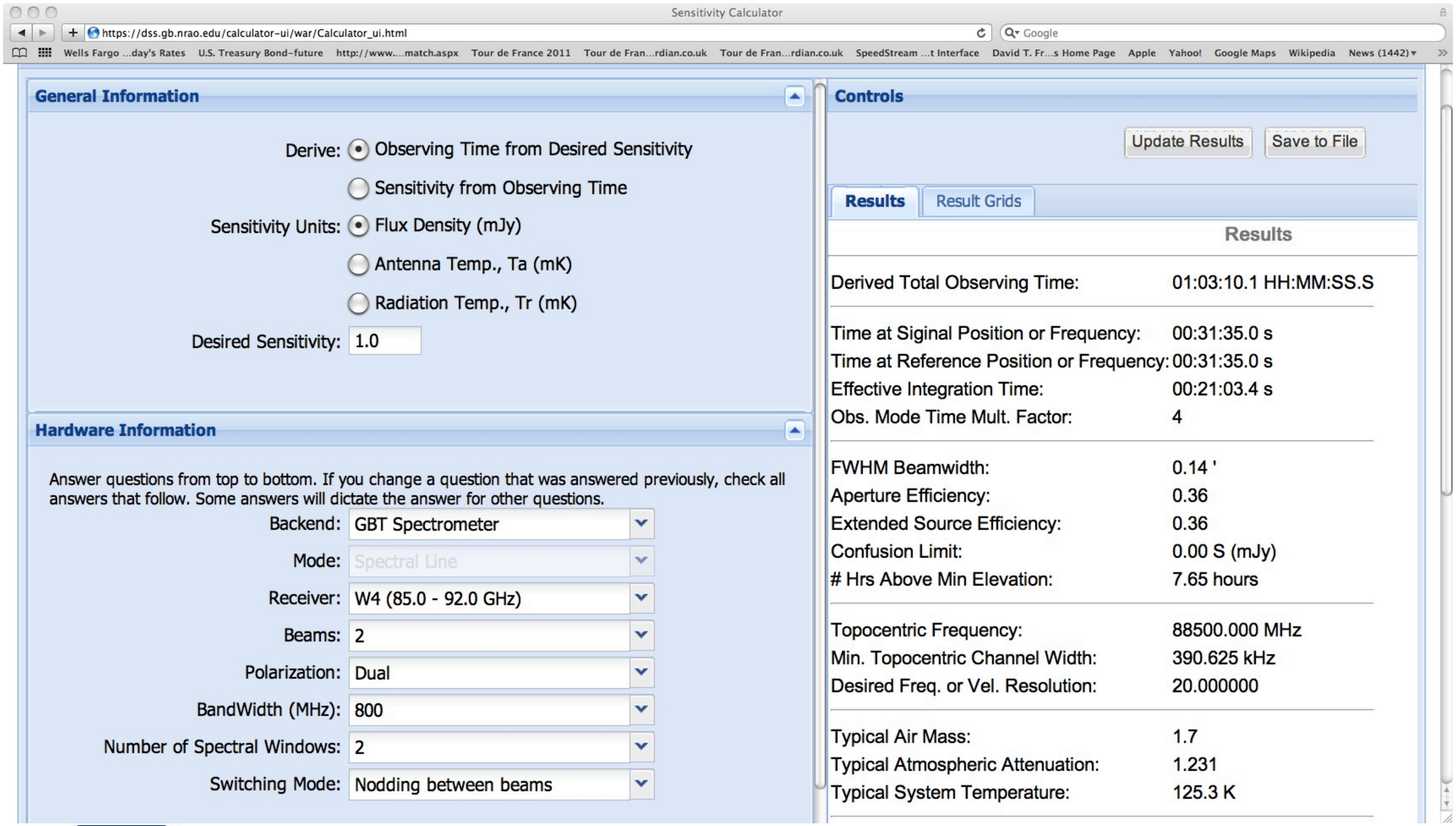
Constraints: Comments:

Source Groups	Resource Groups	Time/Session (hrs)
Orion-KL	Orion-KL-4mm	5.00

Use GBT Sensitivity Calculator for proposal time estimates, and also used for verifying available modes.

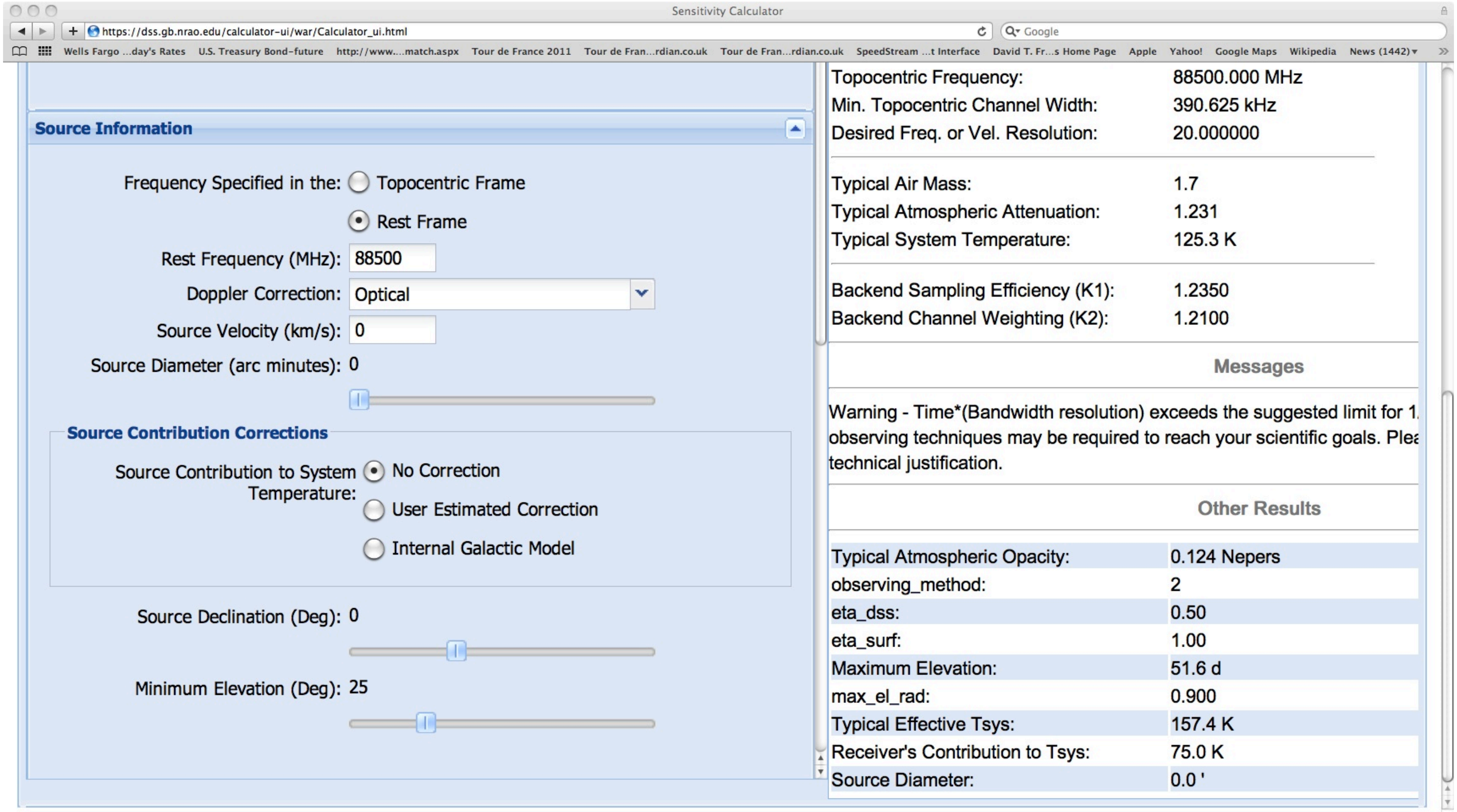


Sensitivity Calculator – Hardware modes



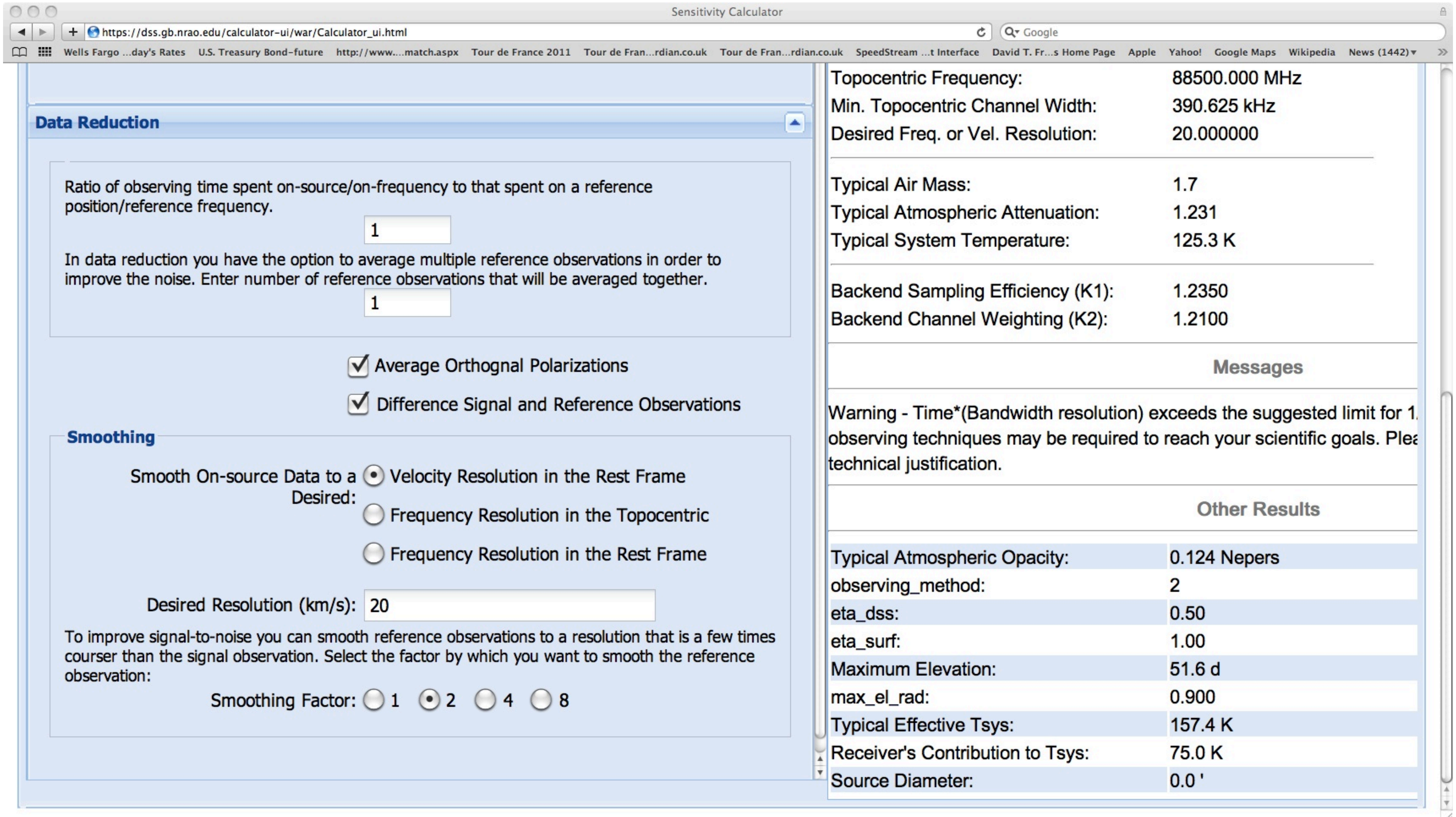
NRAO

Sensitivity Calculator – Source Info



NRAO

Sensitivity Calculator – Data processing



NRAO

GBT Mapping Planner

GBT Mapping Planner

http://www.gb.nrao.edu/GBT/setups/mapplan.html

Wells Fargo ...day's Rates U.S. Treasury Bond-future http://www....match.aspx Tour de France 2011 Tour de Fran...rdian.co.uk Tour de Fran...rdian.co.uk SpeedStream ...t Interface David T. Fr...s Home Page Apple

Plan GBT mapping

On-the-fly mapping with the GBT is done by driving the telescope along one coordinate axis to scan one stripe, then step in the orthogonal direction for the next stripe. The procedures are named "RALongMap" (scanning in the RA or longitude direction), or "DecLatMap" (scanning in the Dec or latitude direction).

Given the desired integration time per pixel, number of pixels per beam, and total size of the area to be mapped, this figures out the scanning rate, number of stripes, and total time required.

Note also its a good idea to increase the map width about 10% in the direction of scanning to avoid scan startup effects.

Receiver	Obs.Freq.	Integration per pixel	Pixels per beam	Map: X width	Map: Y width
Rcvr68_92GHz	89.0 GHz	2.0 sec	2.5	1 arcmin	1 arcmin

Evaluate

GBT Mapping Planner: Results

GBT Map Planner

http://wwwlocal.gb.nrao.edu/cgi-bin/mapplan.py?rcvr=Rcvr68_92GHz&obsfreq=89.0&tint=2.0&pix=2.5&xwid=1&ywid=1

Wells Fargo ...day's Rates   U.S. Treasury Bond-future   http://www....match.aspx   Tour de France 2011   Tour de Fran...rdian.co.uk   Tour de Fran...rdian.co.uk   SpeedStream ...t Interface   David T. Fr...s Home Page   Apple

GBT Map Planner Results

Receiver	Obs.Freq.	Tpix	Pix/beam	X width	Y width
Rcvr68_92GHz	89.0 GHz	2.0 sec	2.5	1.0 arcmin	1.0 arcmin
...					
HPBW(')	DY(')	Xrate('/min)	Tstripe	Xpix	Ypix
0.139	0.056	1.67	0.60 min	18	18
...					
Total Time					
19.80 min					

- HPBW = half power beam width for the given Obs.Freq.
- DY = pixel size (arcmin), and spacing between stripes.
- Xrate = scanning rate in the x-direction.
- Tstripe = time to traverse one stripe.
- Total time includes overhead of 30 seconds per stripe, which is typical for back-and-forth scanning. (One hopes the overhead can be reduced in the future)

Example Astrid commands

If X/Y are RA/DEC with coordinate mode J2000.

- hlen = Offset("J2000", 0.0167, 0)
- vlen = Offset("J2000", 0, 0.0167)
- vdel = Offset("J2000", 0, 0.0009)
- hdel = Offset("J2000", 0.0009, 0)

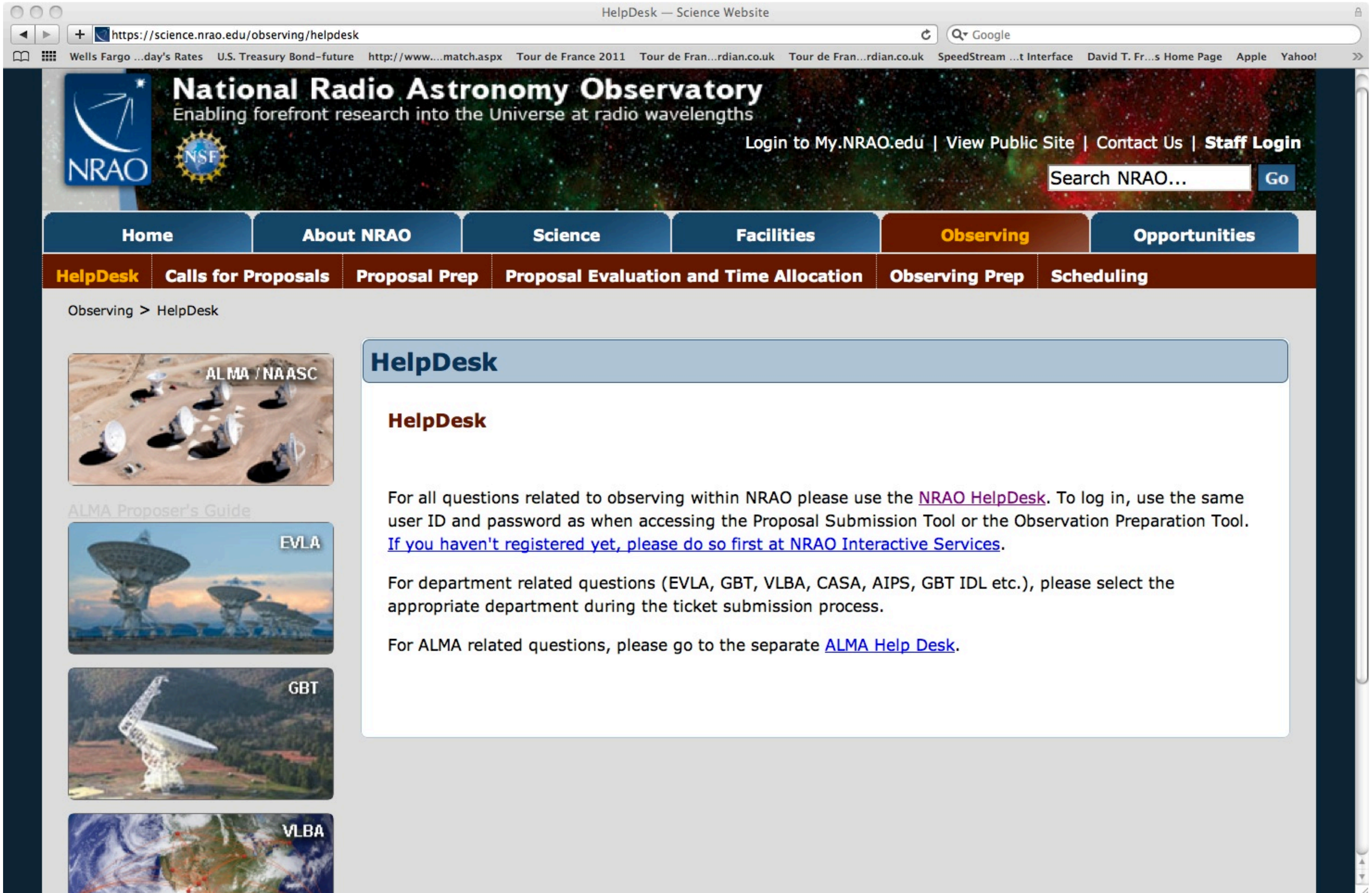
- RALongMap(mapcenter, hlen, vlen, vdel, scanDuration=36)

or

- DecLatMap(mapcenter, hlen, vlen, hdel, scanDuration=36)

NRAO

Help?? --- NRAO HelpDesk



Help?? --- GBT Contacts (listed in GBTpg)

Topic	Staff Member and Contact Details	
General Questions on Capabilities	Toney Minter	tminter@nrao.edu
Proposal submission and scheduling	Toney Minter	tminter@nrao.edu
Pointing, focus calibrations	Frank Ghigo	fghigo@nrao.edu
Receivers	Ron Maddalena	rmaddale@nrao.edu
4mm Receiver	David Frayer	dfrayer@nrao.edu
GBT Spectrometer	Ron Maddalena	rmaddale@nrao.edu
VEGAS	Anish Roshi	aroshi@nrao.edu
Spectral Line Observing	Ron Maddalena	rmaddale@nrao.edu
Continuum Observing	Toney Minter	tminter@nrao.edu
VLBA/VLBI Observing	Frank Ghigo	fghigo@nrao.edu
Pulsar Observing	Scott Ransom	sransom@nrao.edu
Radar Observing	Frank Ghigo	fghigo@nrao.edu
General software issues	Mark Clark	mclark@nrao.edu
GBT/ Green Bank policy	Toney Minter Karen O'Neil	tminter@nrao.edu koneil@nrao.edu
RFI Management	Toney Minter	tminter@nrao.edu
Observational Support	Toney Minter Frank Ghigo Ron Maddalena Dan Perera Dave Frayer Anish Roshi	tminter@nrao.edu fghigo@nrao.edu rmaddale@nrao.edu dperera@nrao.edu dfrayer@nrao.edu aroshi@nrao.edu

Table 14: GBT Contacts

Summary

- The GBT is a powerful instrument – single-dish flexibility, large collecting area, wide-frequency coverage
- Diverse science
- Development ongoing (higher frequency, multi-pixel/ feeds frontends, flexible backends) to enhanced capabilities

➢ **The 2013A proposal submission deadline will be Wed, 1 Aug 2012, at 5 p.m**

NRAO