

The Green Bank Telescope and ALMA

a powerful instrument for enhancing ALMA science
GBT and ALMA development synergies

Felix J. Lockman
NRAO

Unblocked Aperture

Low sidelobes gives high dynamic range

Resistance to Interference

Excellent spectral Baselines

Excellent sensitivity to low surface brightness

Frequency coverage from 100 MHz-100 GHz

Spectroscopy, Continuum, Pulsar, VLBI

>85% Sky Coverage $\delta \geq -46^\circ$

Pointing to 1"-2" accuracy

Surface good for 3mm work

Active Instrument Development Program

Site Protected by a 13000 km² Radio Quiet Zone



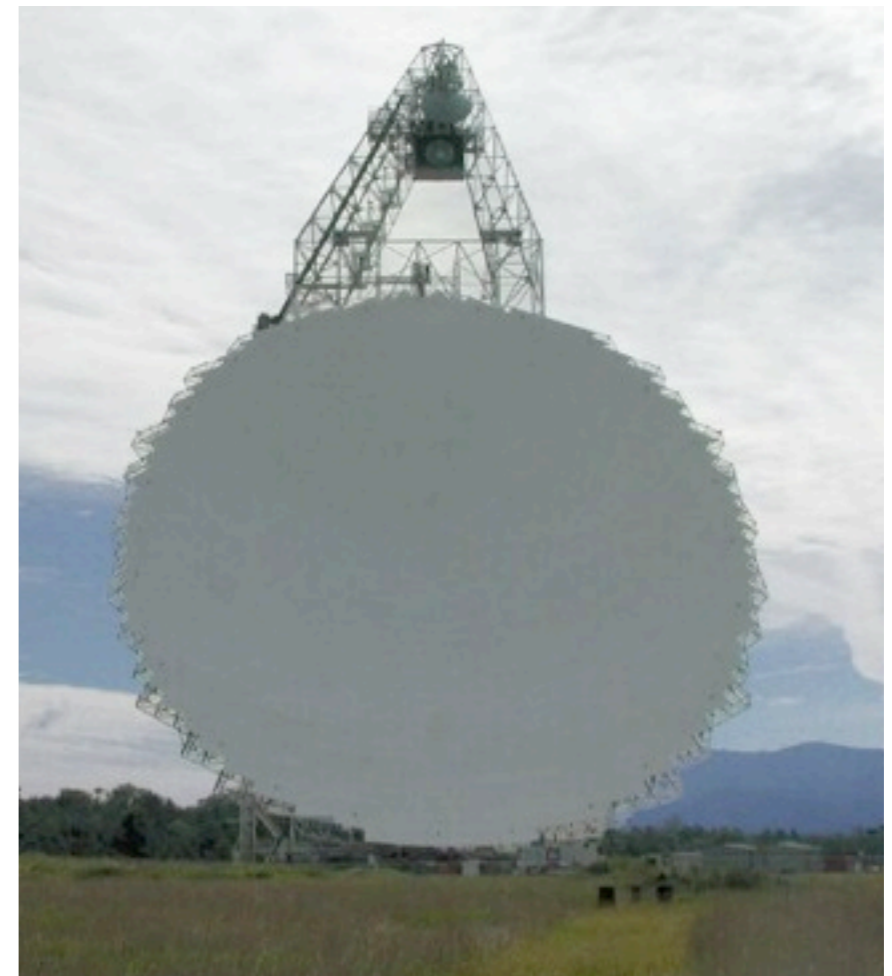
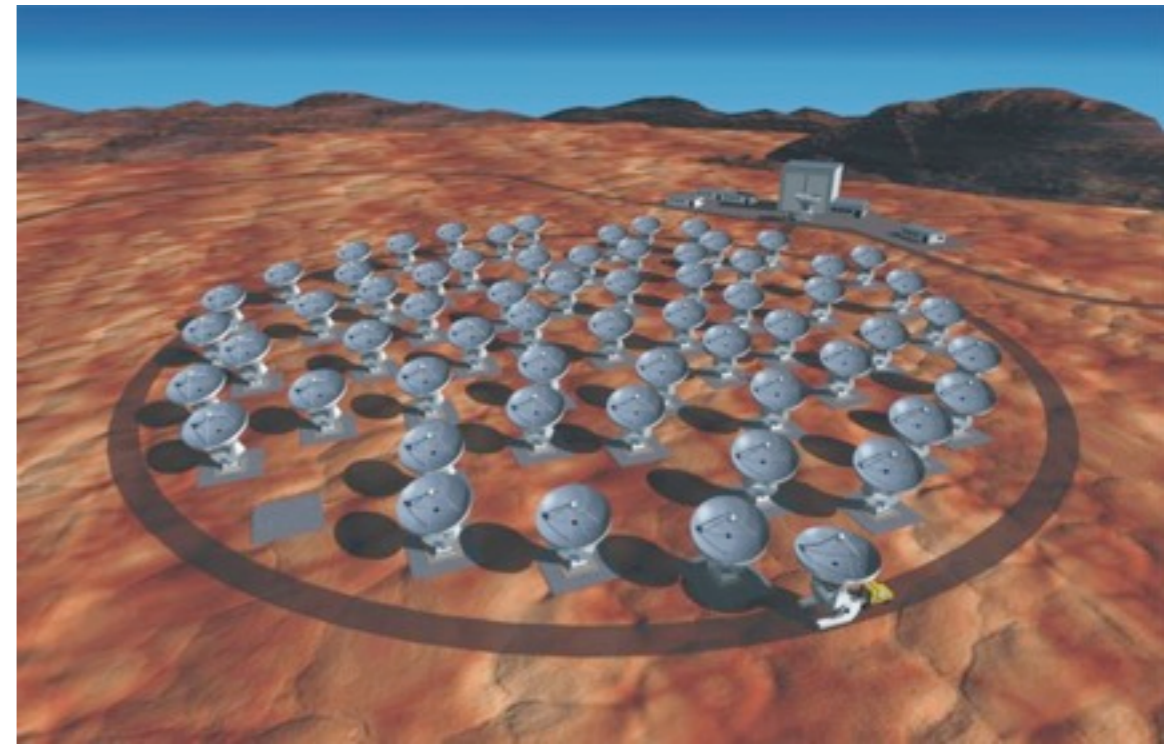
ALMA - GBT Synergies

Scientific

Wide Field Mapping
Surface Brightness Sensitivity
Frequency Coverage
VLBI

Development

Wide Band 3mm receiver
Large Data Sets

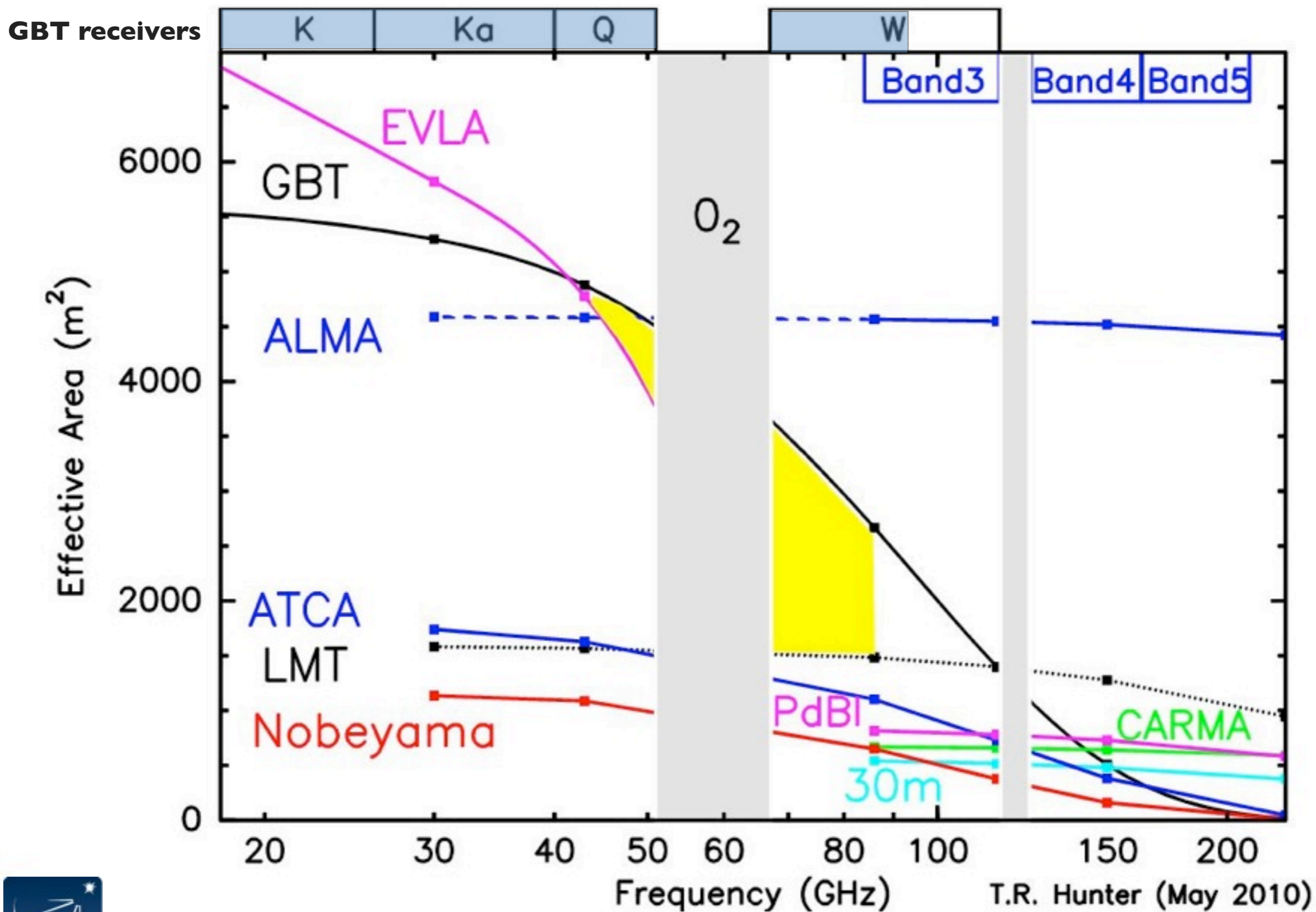


GBT Status

- Surface
 - $\sigma < 250\mu$ at night, the goal is 210μ
- Track
 - Replaced summer 2007
- Pointing
 - 5" rms blind, ~2" offset under best conditions
- Motion and tracking
 - New digital servo being implemented -- Phase 0
 - New turret motor allows receiver changes at any elevation
- Weather
 - Wind limit increased from 20/25 mph to 35/40 (9/11 m/s to 16/18)
 - Temperature limit lowered from 0° F to -10° F (-19 C to -23 C)
 - Half Azimuth slew rate below 17° F (-8 C)
 - Dynamic Scheduling ~60% of the time



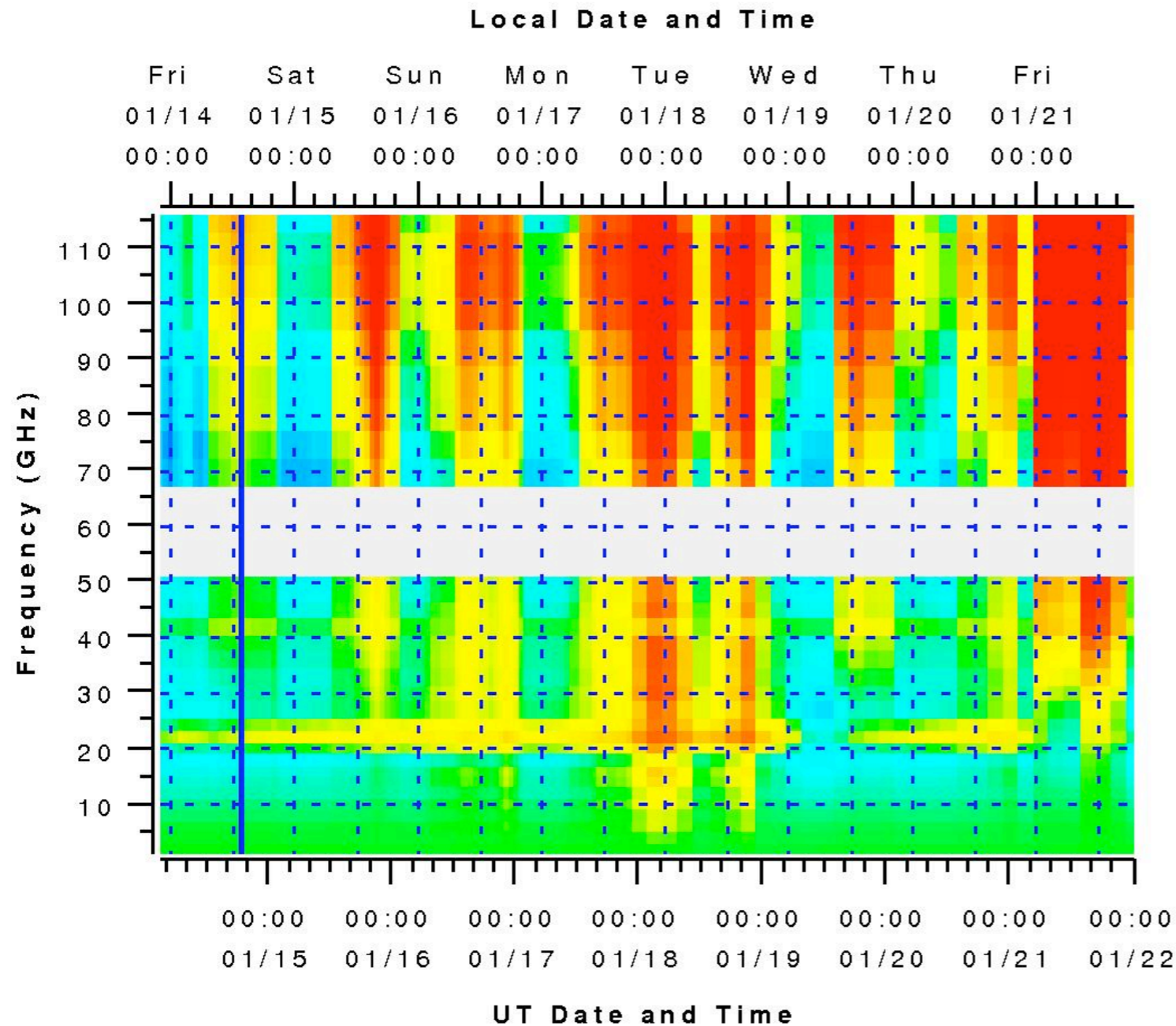
GBT High Frequency Performance



Ronald J Maddalena
National Radio Astronomy Observatory
Green Bank, WV

**GBT Dynamic Scheduling
matches the project
to the weather**

Overview: DSS Relative Efficiencies without Limits (η/η_{mi})



1776 hours of observing
at >18 GHz dynamically
scheduled in 2010 --
this amount should rise in
the coming years

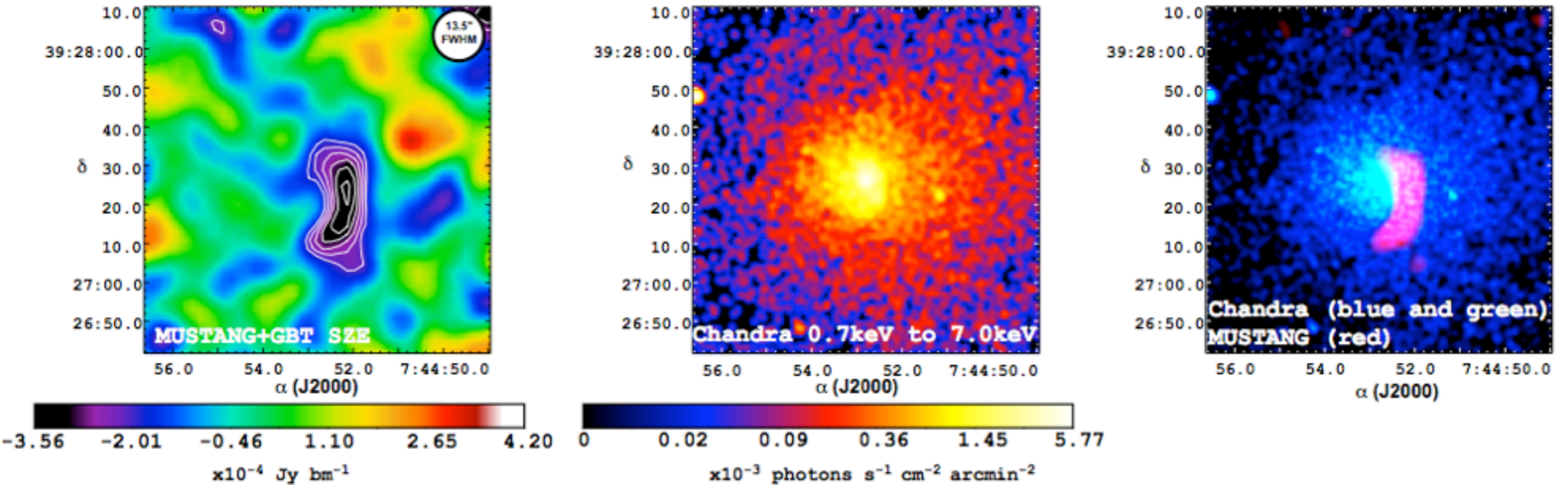


MACS0744+3927

previously unknown/unexpected weak shock near the core of this cluster

Korngut et al. (submitted)

MUSTANG
64-pixel 90 GHz bolometer array
now routinely imaging the SZE
at $\approx 10''$ resolution

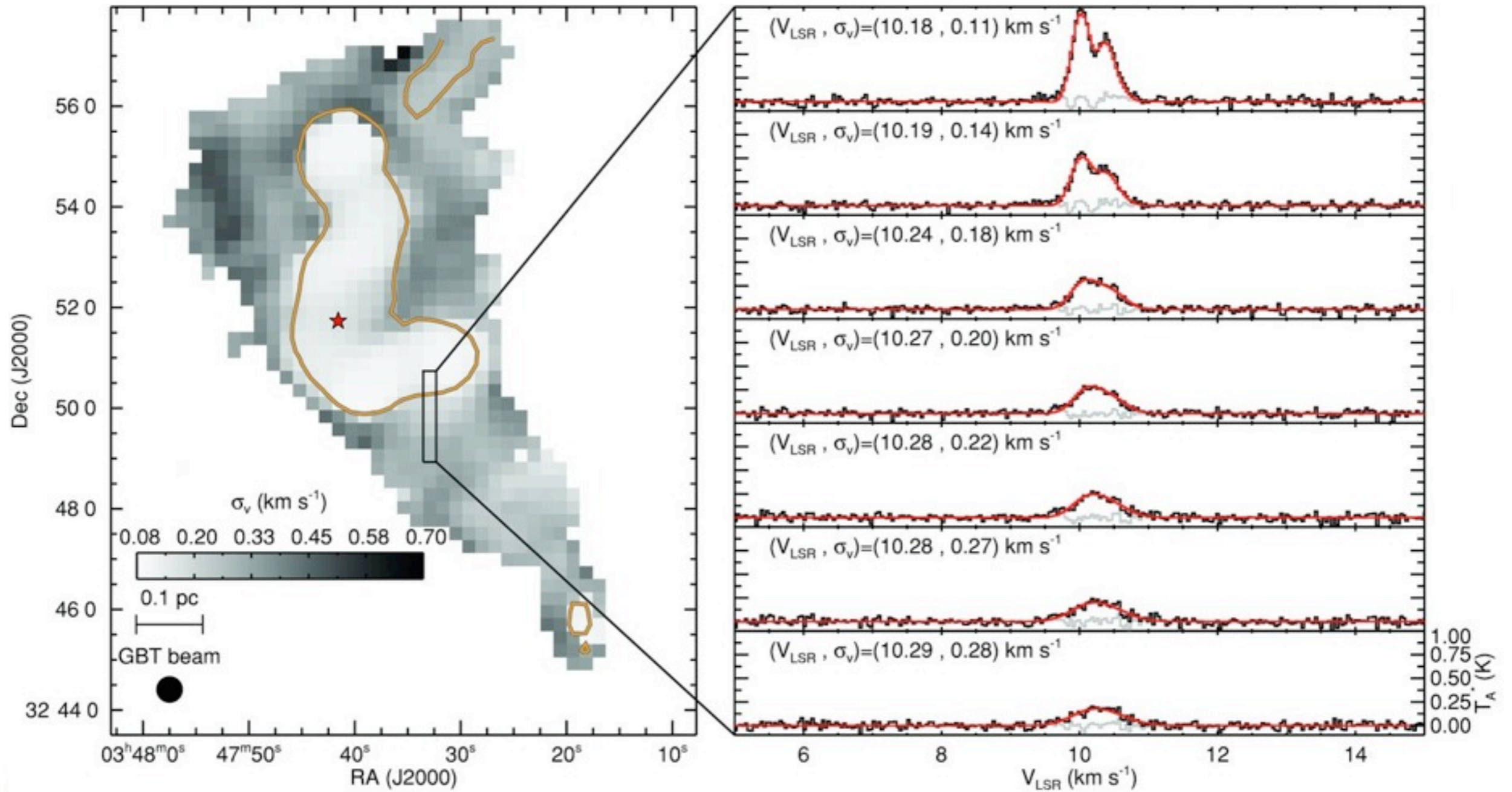


9'' (FWHM) on GBT; 40''x40'' FOV
Sensitivity: rms ~ 3 mK $\text{sec}^{1/2}$
– 3'x3' region to 0.4 mJy (RMS) in one hour
– integrates down for at least 12 hours

The Context of Star Formation

Direct Observation of a Sharp Transition to Coherence in Dense Cores

Pineda et al 2010, ApJ

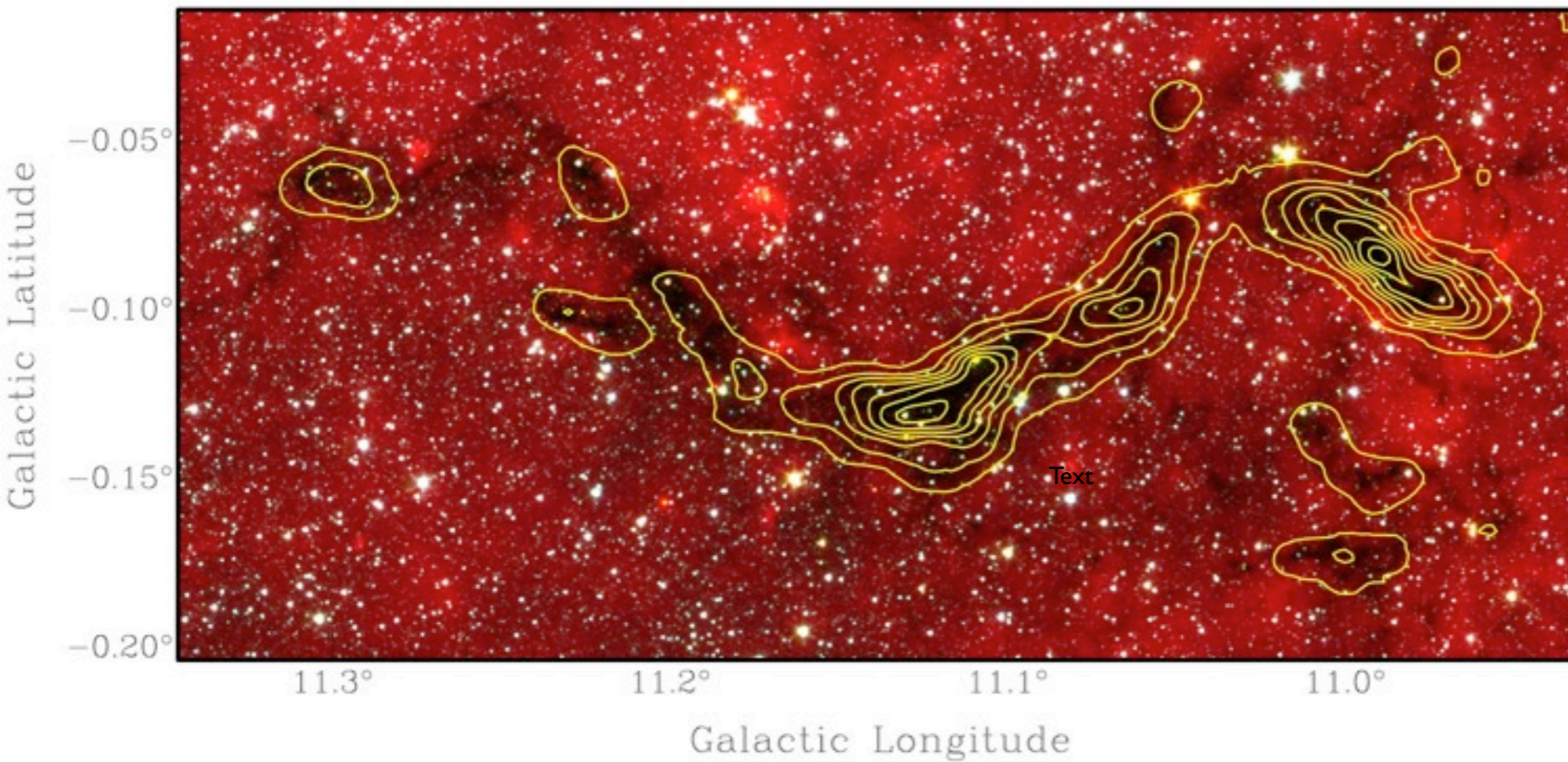


GBT Instrument Development Program

- K-band Focal Plane Array 7 pixels for 18-27 GHz
 - Completed and in regular use
- 4mm two-pixel receiver for 68-92 GHz spectroscopy
 - Under construction, commissioning late 2011, see <http://www.gb.nrao.edu/4mm>
- FPGA based spectrometer with up to 128 spectral windows
 - Under construction with CASPER group UCB, testing late 2011
- MUSTANG-2 bolometer array >100x faster than MUSTANG
 - Proposed but not yet funded
- W-band 100 pixel Focal Plane array 68-116 GHz (ALMA Band 3)
 - Under study but not yet funded
- Phased Array Receivers
- Data management



The GBT K Band Focal Plane Array is up and running



KFPA
NH₃ (1,1)

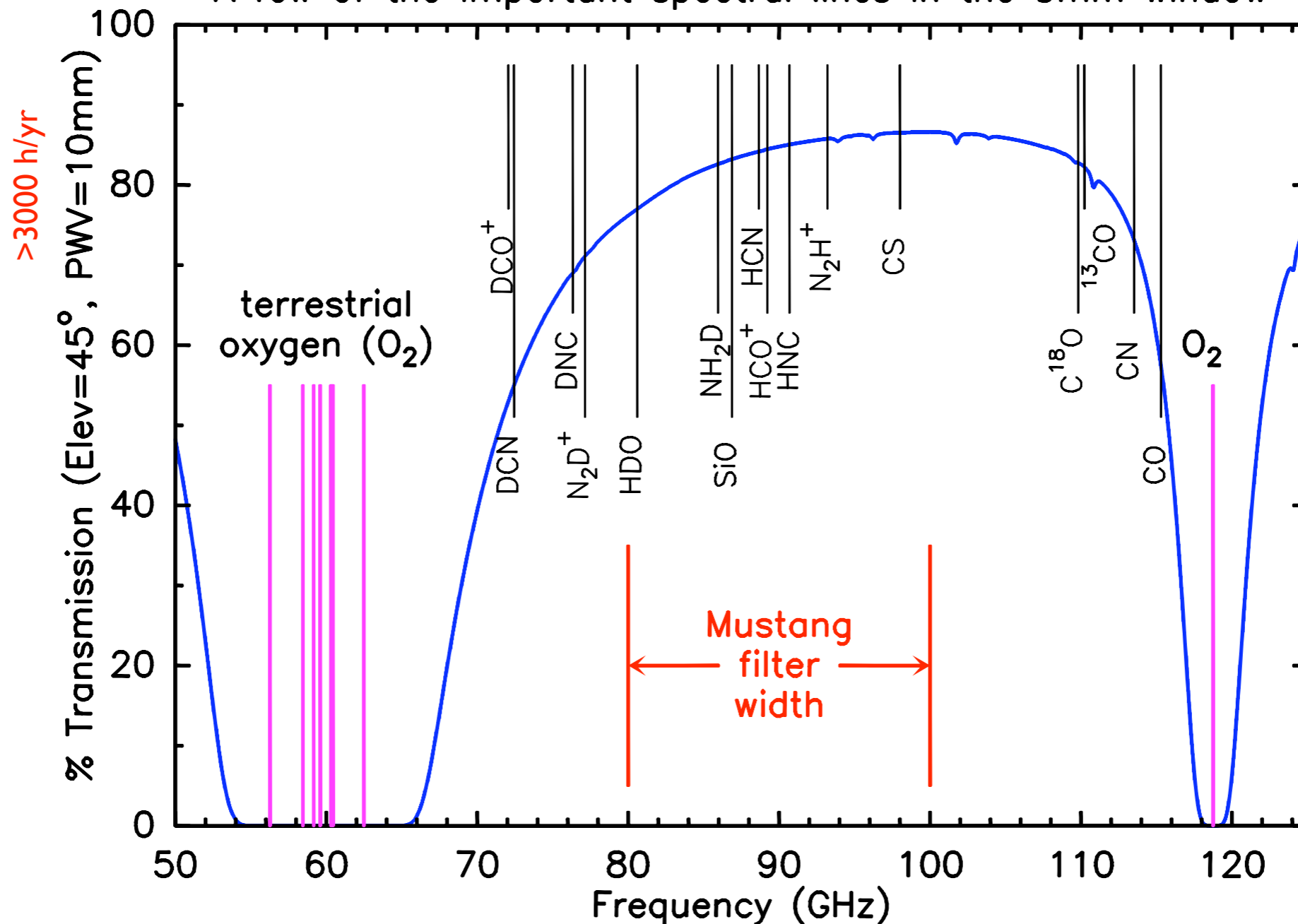
26'x12' field

Ammonia mapping of dark clouds
Finn & Jackson

4mm Receiver Spectral Coverage

Available on the GBT in late 2011

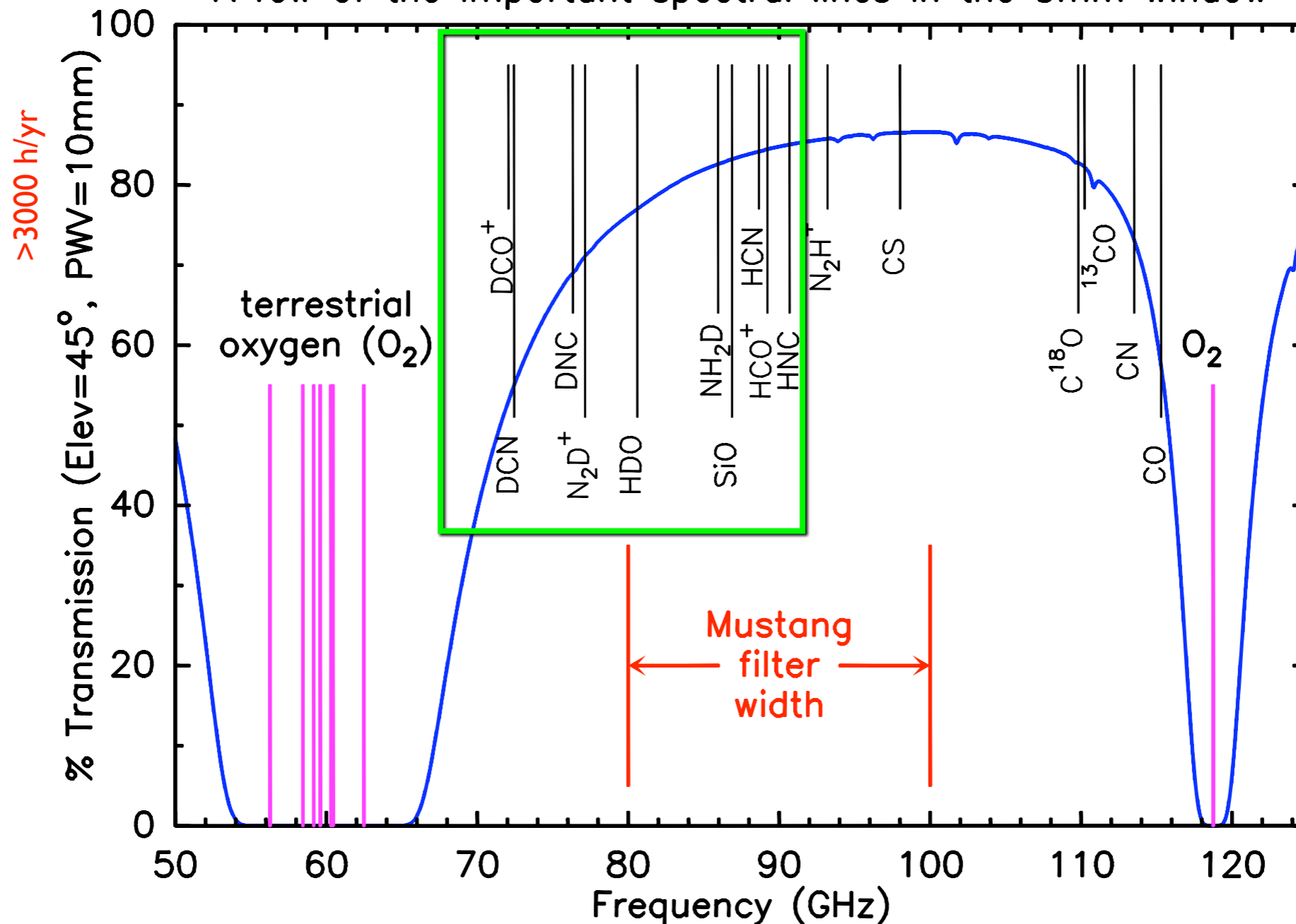
A few of the important spectral lines in the 3mm window



4mm Receiver Spectral Coverage

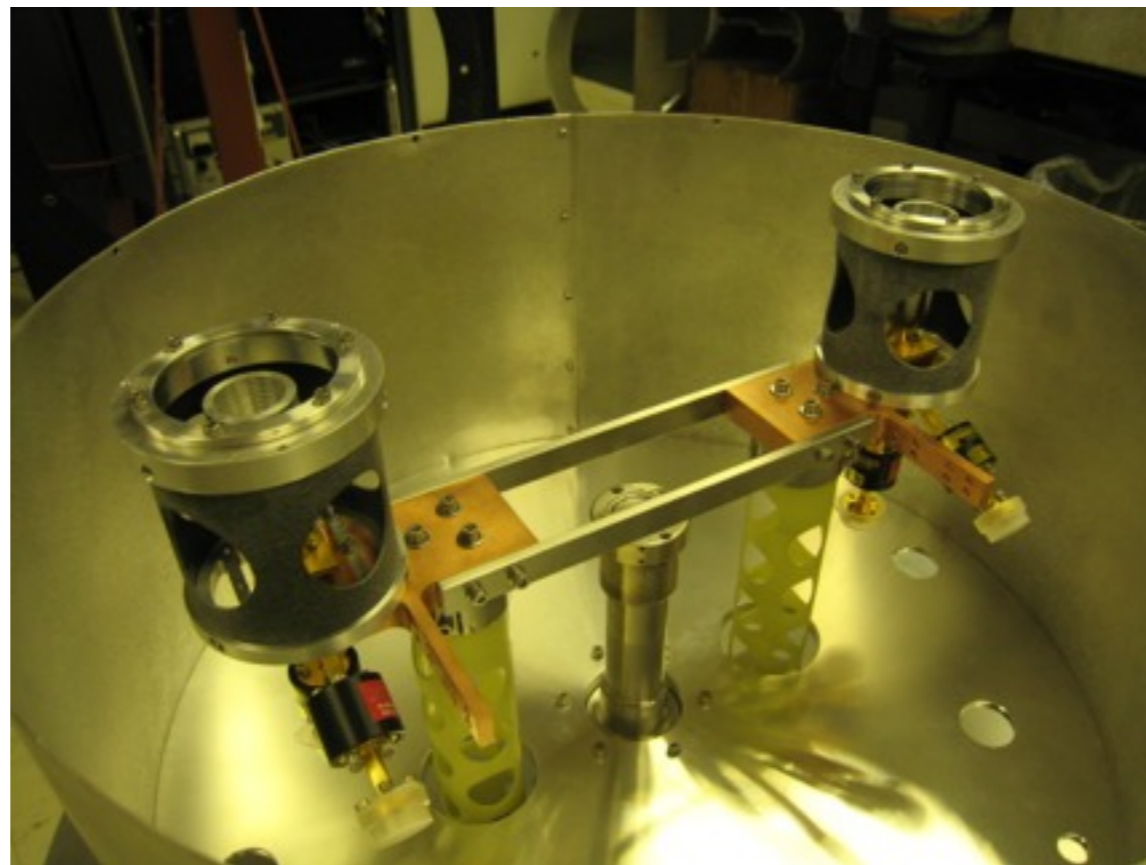
Available on the GBT in late 2011

A few of the important spectral lines in the 3mm window



GBT 4mm Receiver Project

- # Tunable frequency range: 68–92 GHz (Coverage to 93.2GHz is highly desirable.)
- # HPBW 11" to 8"
- # $T_{\text{sys}} = 100$ K
- # Polarization: Dual linear with selection of circular using a 1/4 wave plate for VLB observations.
- # Number of beams: Two beams each with dual polarization
- # Beam separation: 4.7 arcmin
- # Calibration with cold, ambient, and sky loads using optical table



GBT Performance -- March 2011

Freq (GHz)	Tsys (K, za=0)	η_a %	K/Jy	SEFD (Jy)
1.2-6.0	20	70	2.0	10
10-16	25	65	1.85	15
20.0	40 ^a	65	1.85	20 ^a
45.0	70 ^a	60*	1.70	40 ^a
85.0 ^b	100-150 ^{a,b}	32*	0.91	110-165 ^{a,b}

* Requires periodic Out-Of-Focus Holography measurements

a) In median winter weather

b) Under construction -- completion expected late 2011

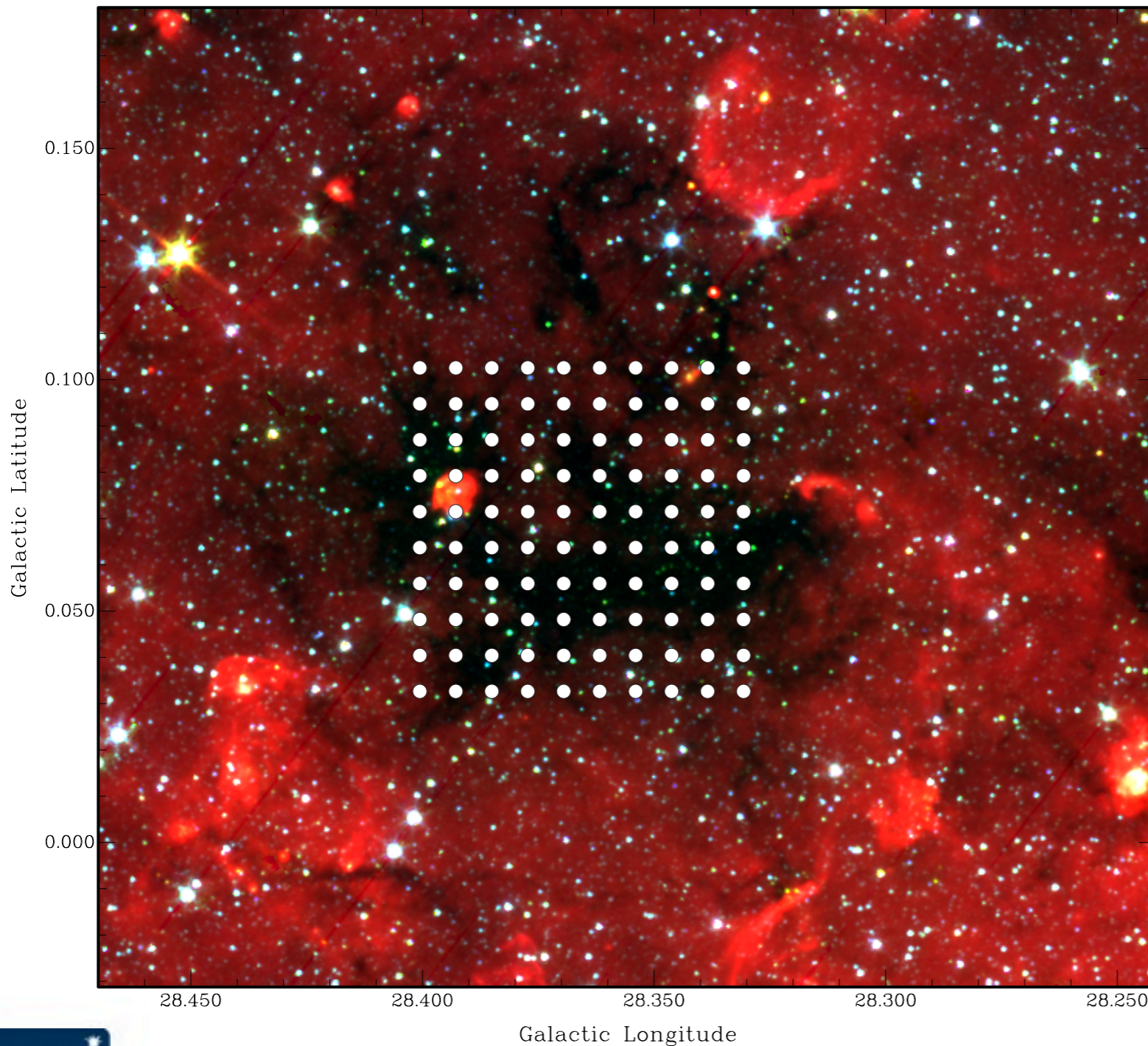
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Planned 3mm Focal Plane Array

a wide field mapping complement to ALMA Band 3



GBT 3mm FPA
footprint on
an Infrared
Dark Cloud

 ALMA primary
beam at 3mm

**Wide band low noise
3mm receiver development**

FLAG -- Focal Plane L-Band Array for the GBT

B. Jeff, K. Warnick et al (BYU)

J.R. Fisher, R. Norrod, A. Roshi (NRAO)

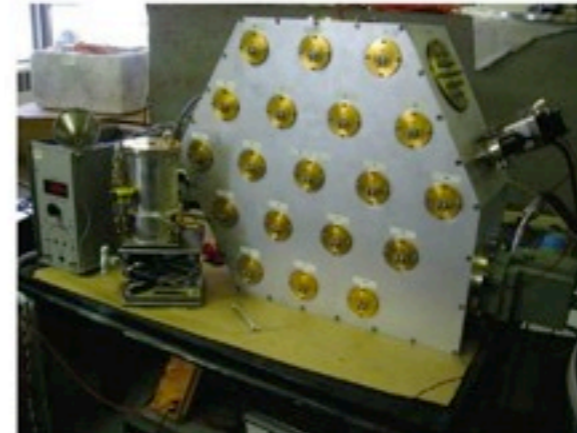


- 19 dual polarized elements. Cryogenic PAF system
- $T_{\text{sys}} \sim 20$ K; Aperture efficiency ~ 75 to 80 %
- 7 beams; spacing 0.5 FWHM to 1 FWHM
- Frequency coverage – 1300 to 1800 MHz; Backend for processing signals

Estimated Data Rates

- GBT Focal Plane Array Peak Rates:
 - 7-element Focal Plane Array
 - Approximately 10 MB/s or 0.8 TB/day
 - 100-element Focal Plane Array (coming in 4-5 years):
 - ~1 GB/s ~ 80 TB/day
- Current rates:
 - Average data rate, currently: <1 MB/s or 3 GB/day
 - Maximum data rate, currently: 300-500 MB/s

Future data rates are >27,000 times current rates



Slide from Amy Shelton

Innovations in Data-Intensive Astronomy

May 3 – 5, 2011
Green Bank, West Virginia

Amy Shelton ashelton@nrao.edu

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