MUSTANG: a Pathfinder Bolometer Array on the GBT

* The Instrument
* Early Science
* Future Plans
* Band 1 complementarity & technology
(*) 30 GHz source counts

Brian Mason (NRAO)

ALMA Band 1 Workshop

Manchester, UK

14sep09

MUSTANG

Multiplexed SQUID TES Array at Ninety Gigahertz

Resolution	9″ (fwhm)
Beam Spacing	5″
Npixel	8x8
T_{sky}	~28 K
Bandwidth	18 GHz

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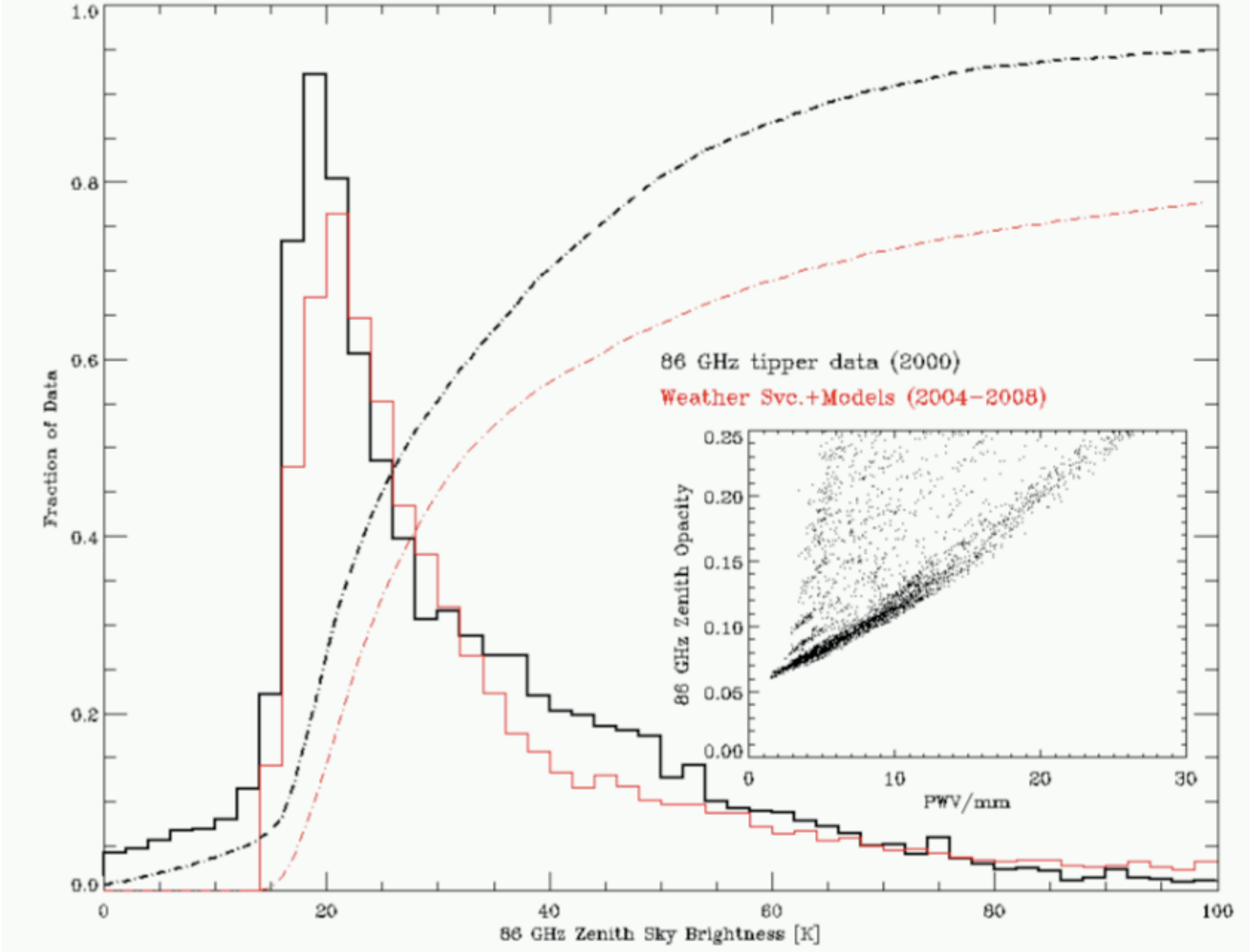
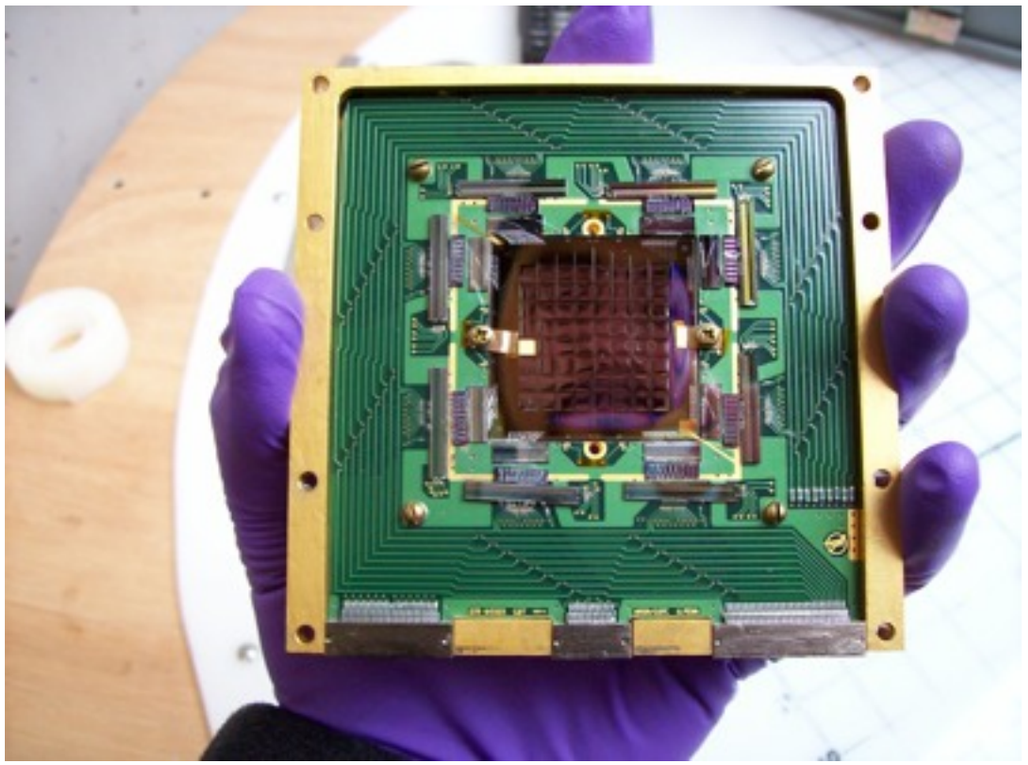
Pwv < 10mm 2000 hrs

+ Wind, night: 500 hrs -> ~60 nights


1.0
0.8
0.6
0.4
0.2
0.0
Fraction of Data
0
20
40
60
80
100
86 GHz Zenith Sky Brightness [K]
86 GHz tipper data (2000)
Weather Svc.+Models (2004–2008)
0.25
0.20
0.15
0.10
0.05
0.00
86 GHz Zenith Opacity
0
10
20
30
PWV/mm

The Instrument

- Reimaging optics
  - lyot stop controls illumination of primary & provides high efficiency
- Closed cycle cryogenics
  - Pulse Tube + He3/He4 fridge
  - successfully operated on GBT for several months
- Time domain SQUID MUX
  - robust, fully tune & bias in 15 min.
- First light in Fall 2006
  - Now open for proposals as a facility instrument (next: Oct 1) http://www.gb.nrao.edu/mustang/

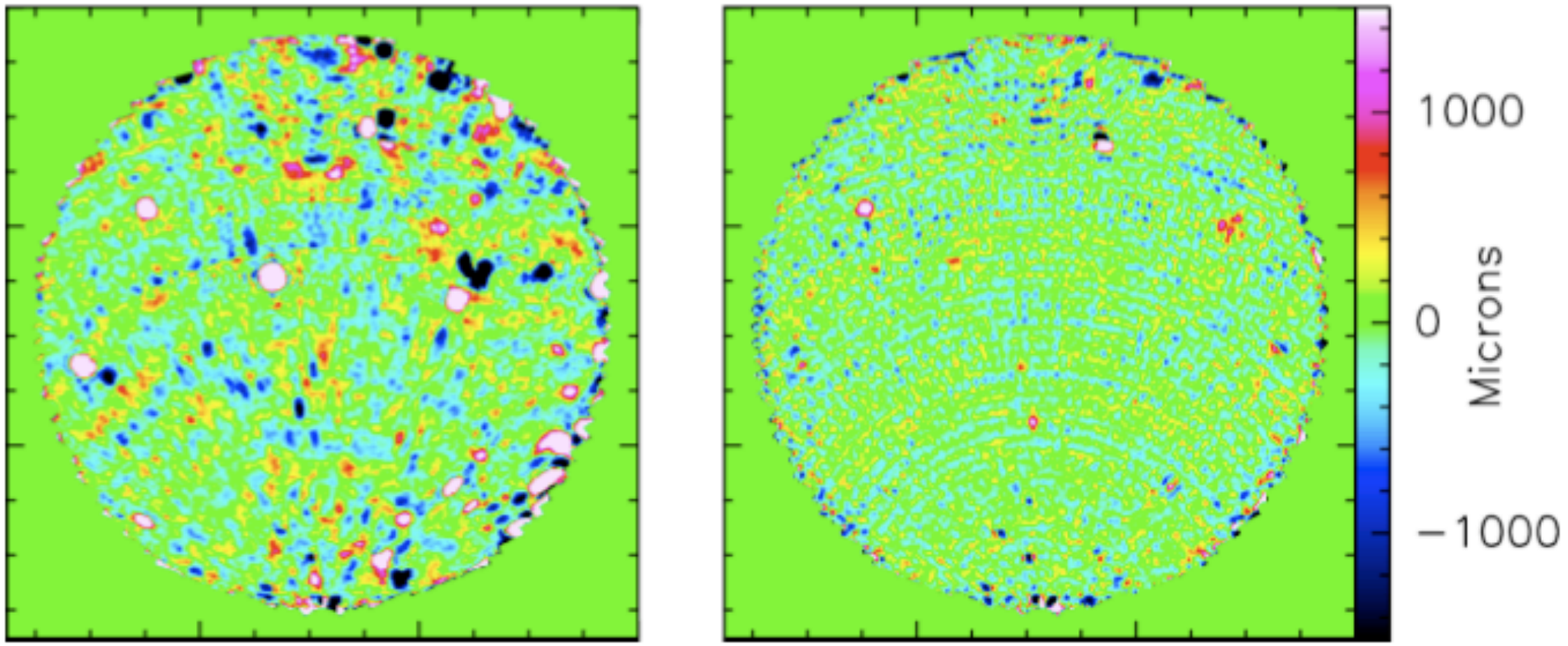


Current Sensitivity

0.4 mJy RMS (9" beam)
over 3'x3' in 1 hour

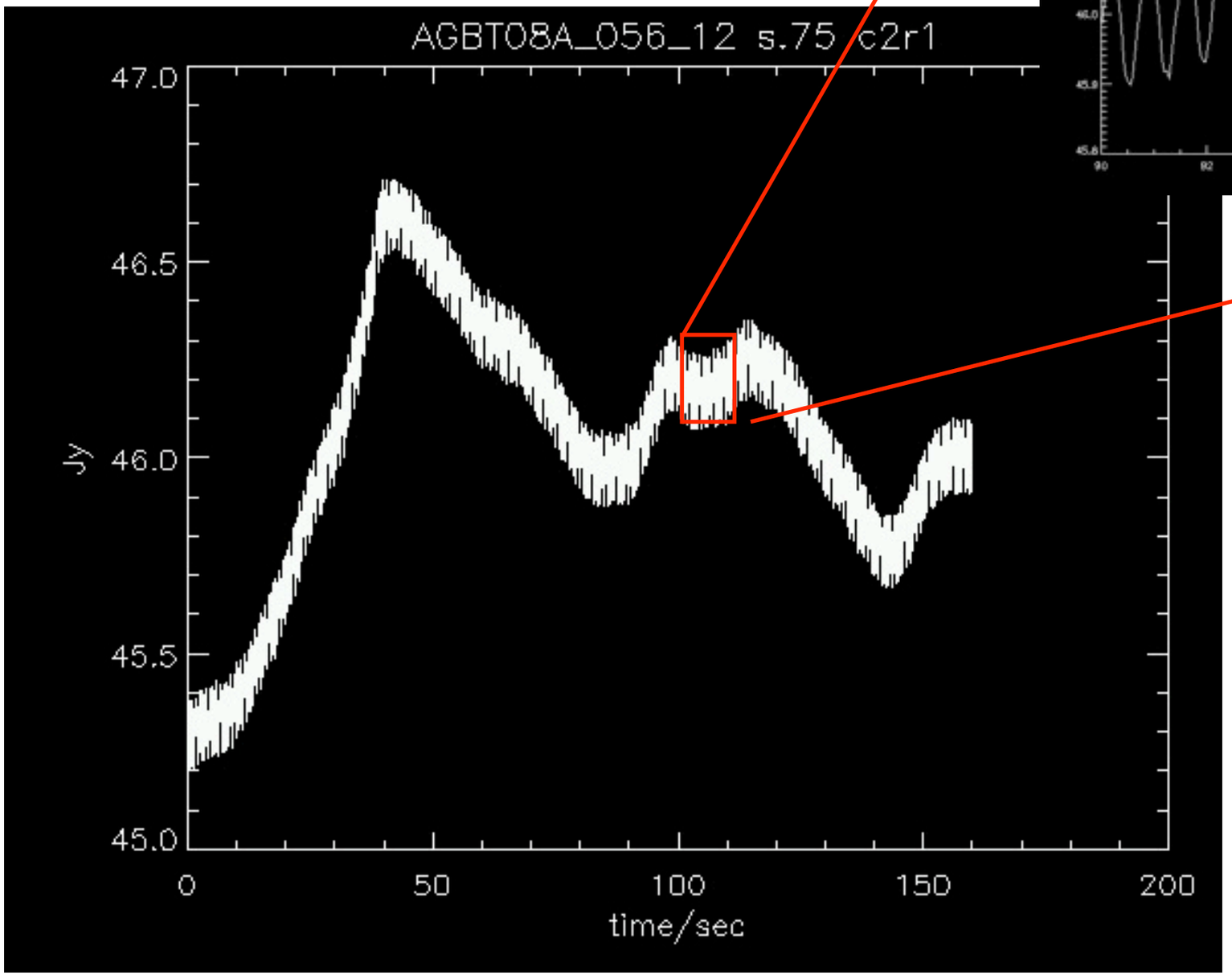
January 4, 2009
v1.3

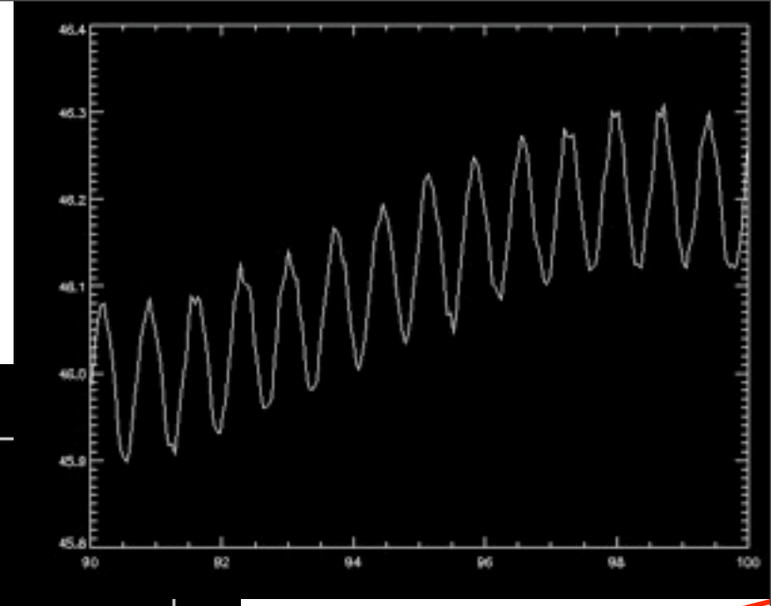
July 24, 2009
v3.05



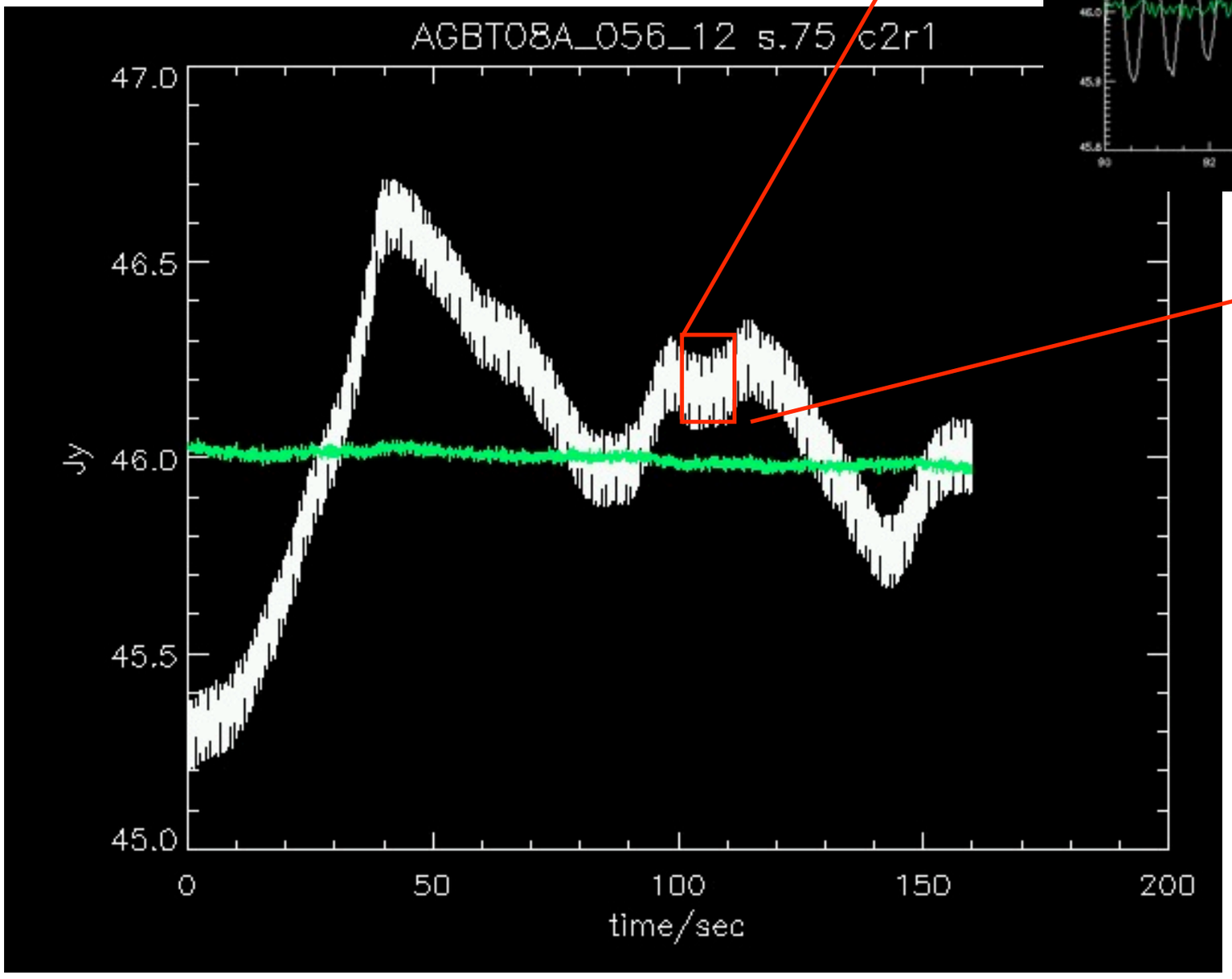
390 micron RMS

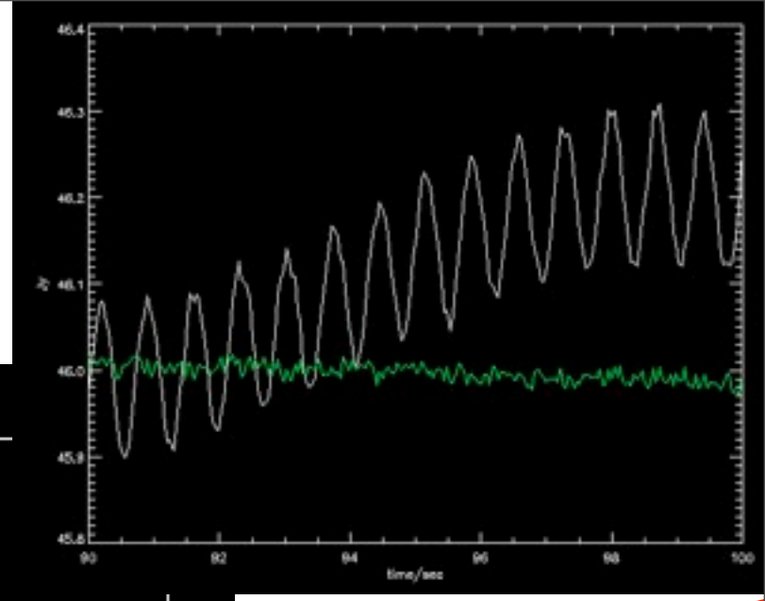
295 micron RMS





Array imaging dramatically reduces single-dish continuum measurements' susceptibility to atmospheric emission & other systematics





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Science of Long-mm Bolometer Arrays on Large Single Dishes

Point source sensitivity: collecting area

Surface brightness sensitivity

+

Resolution

Long-millimeter regime: high-z thermal, SZ; large dust
Grains, optically thin
Dust regime

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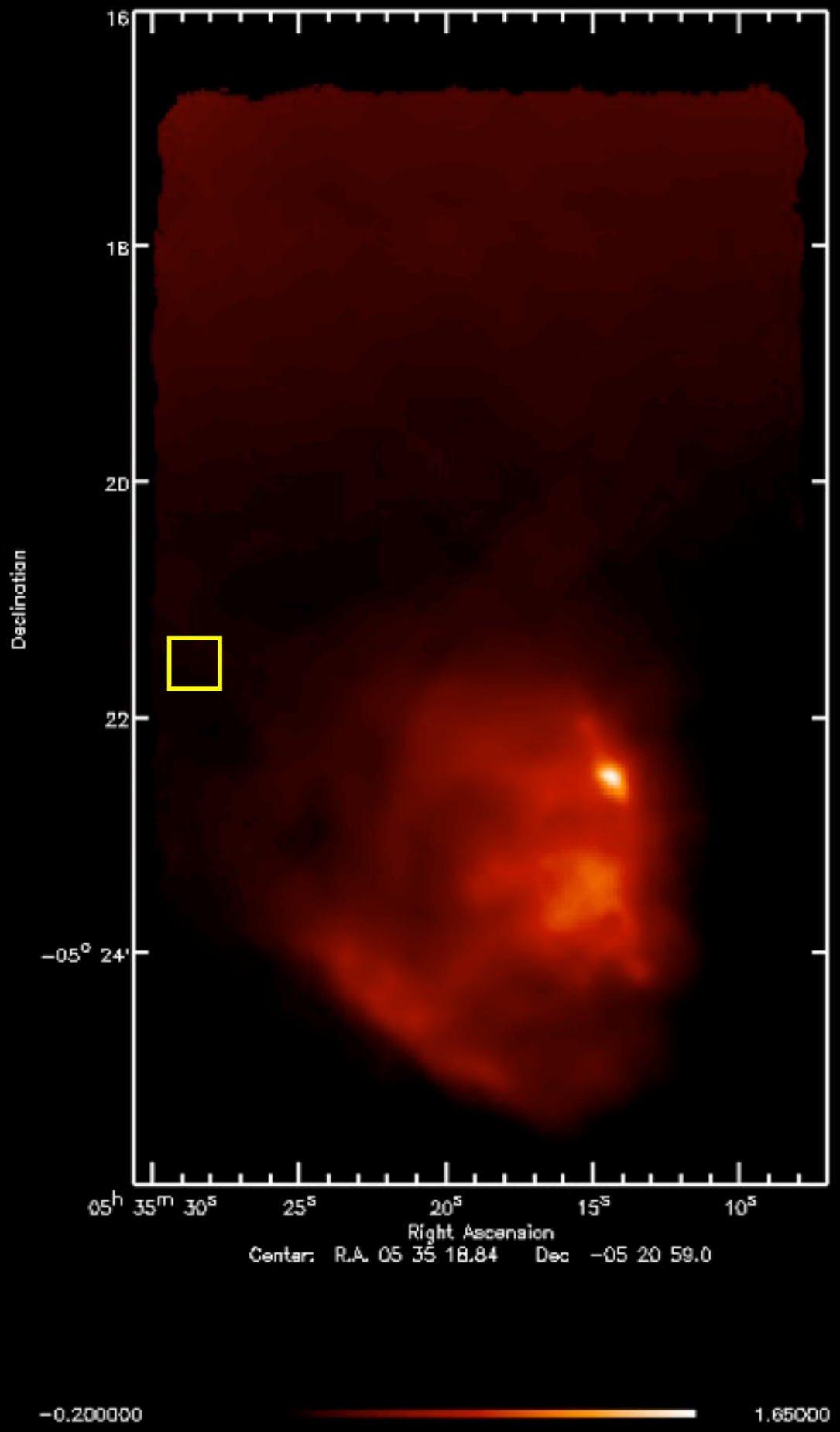
New Frontier: CARMA+SZA, LMT, ALMA band 1, EVLA E-array

Early Science: Orion S/KL



MUSTANG, VLA, GISMO (IRAM 2mm), SCUBA data

(S. Dicker et al. in press)

T_e=11,380 +/- 1050 K

T_d=42 +/- 3 K

Beta = 1.3 +/- 0.1

No significant anomalous microwave component

Other accepted projects:

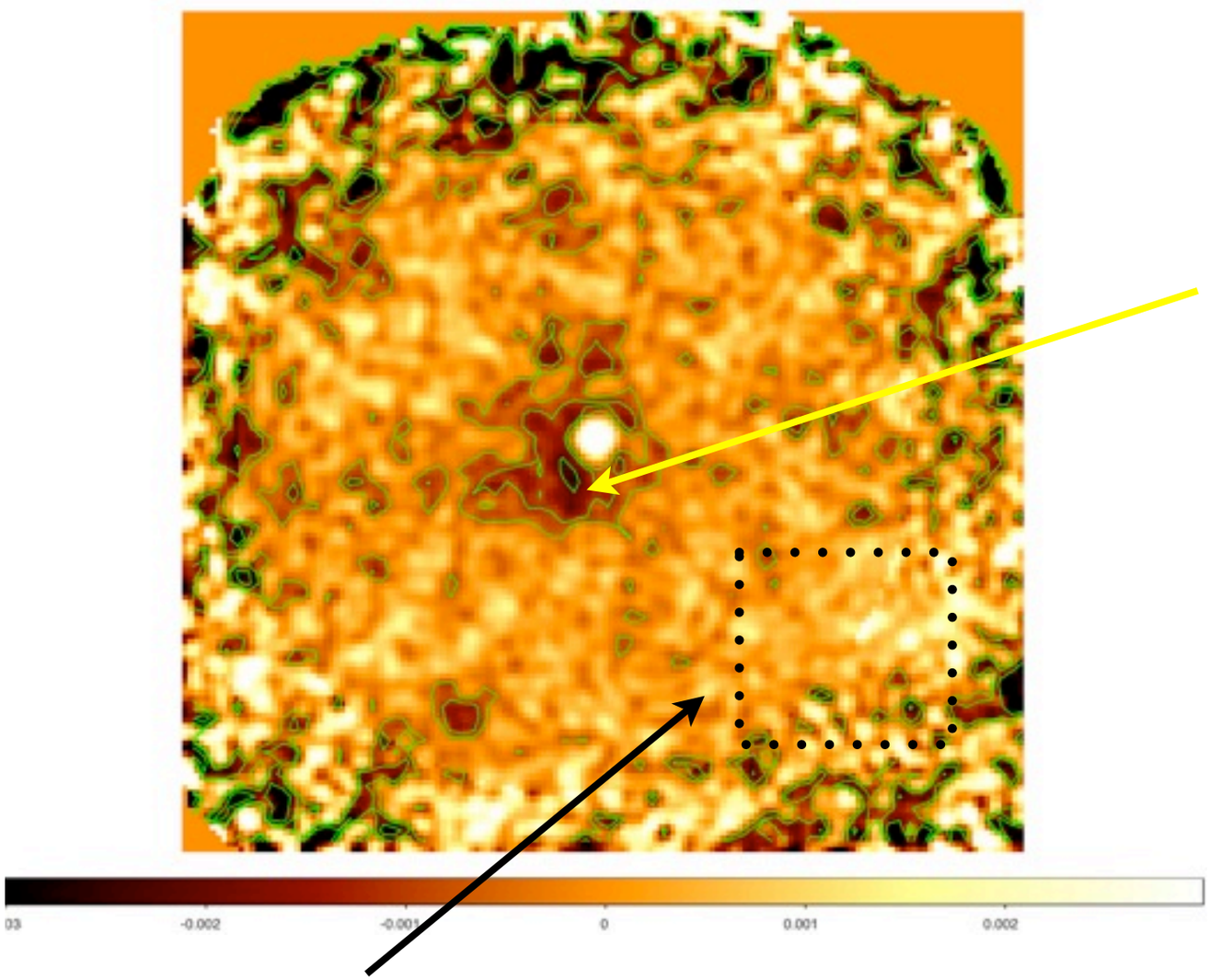
*Imaging isolated protostellar clouds

*Imaging nearby AGN (Cygnus, m87)

*90 GHz point sources

Sgr A

New Results: MUSTANG SZ (RXJ1347-1145)



MUSTANG FOV; typical SZ instrument resolution

Two 4-hour MUSTANG observations: highest resolution (10") image of the SZE to date (manuscript in prep.)

"hot shock" (>25 keV) …

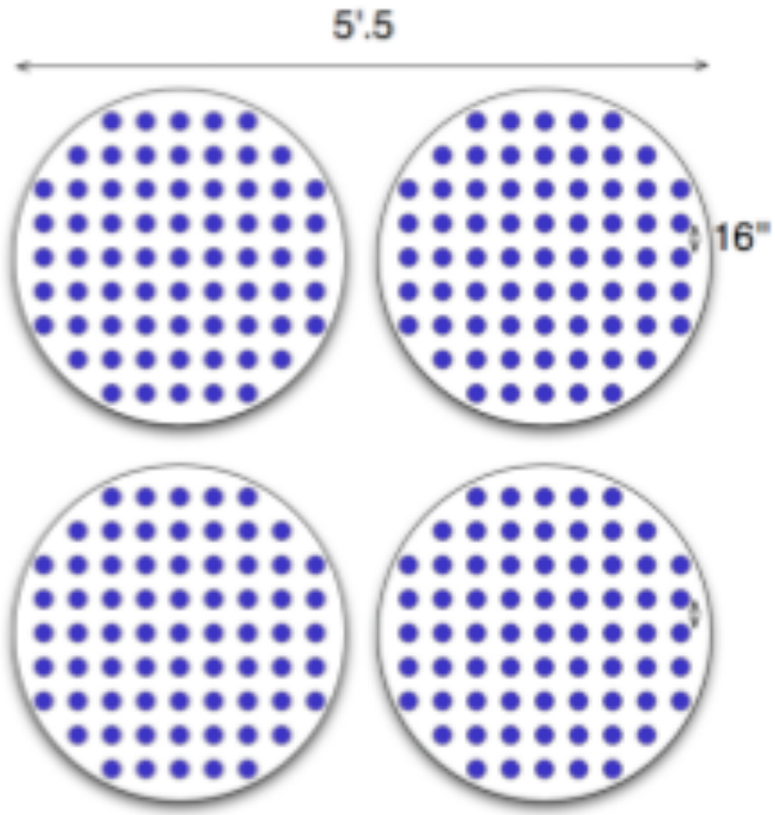
Line of sight "Bullet cluster"?

Important Complementary view to X-rays

- n*T (pressure) vs n^2 * sqrt(T)
- independent of redshift
- Catalog markers of dynamical state
  - Resolve mergers
  - Hot shocks
- Energetics of cluster core
  - Cooling flows
  - ICM bubbles, AGN Feedback

MASTERCAM

- Key technical risks addressed
  - telescope performance
  - magnetic fields
  - TES saturation
  - SQUID tuning & ops.
  - cryo ops on general purpose telescope
- Exploring feedhorn-coupled approach
  - increase per-TES throughput
  - increase FOV (for fixed Ndet)
- Goal: BLIP (28K), 5′ FOV, 9″ beam.
  - 10 microK imaging of 6′x6′ in 2 h (SZ, deep hi-z fields)
  - One deg^2 to 10 microK (~confusion) in 180 h.
  - 30 deg^2 to 2.5 mJy (4 sigma) **per hour** (AGN, calibrator surveys, Galactic & synoptic surveys)



Complementarity of ALMA + Single Dishes

- MASTERCAM: 10x the 3mm mapping speed of ALMA

- Long-mm bolometer arrays on large single dishes can
  - find interesting targets
    - extragalactic: highest-z galaxies (z>5), exceptional AGN (GPS)

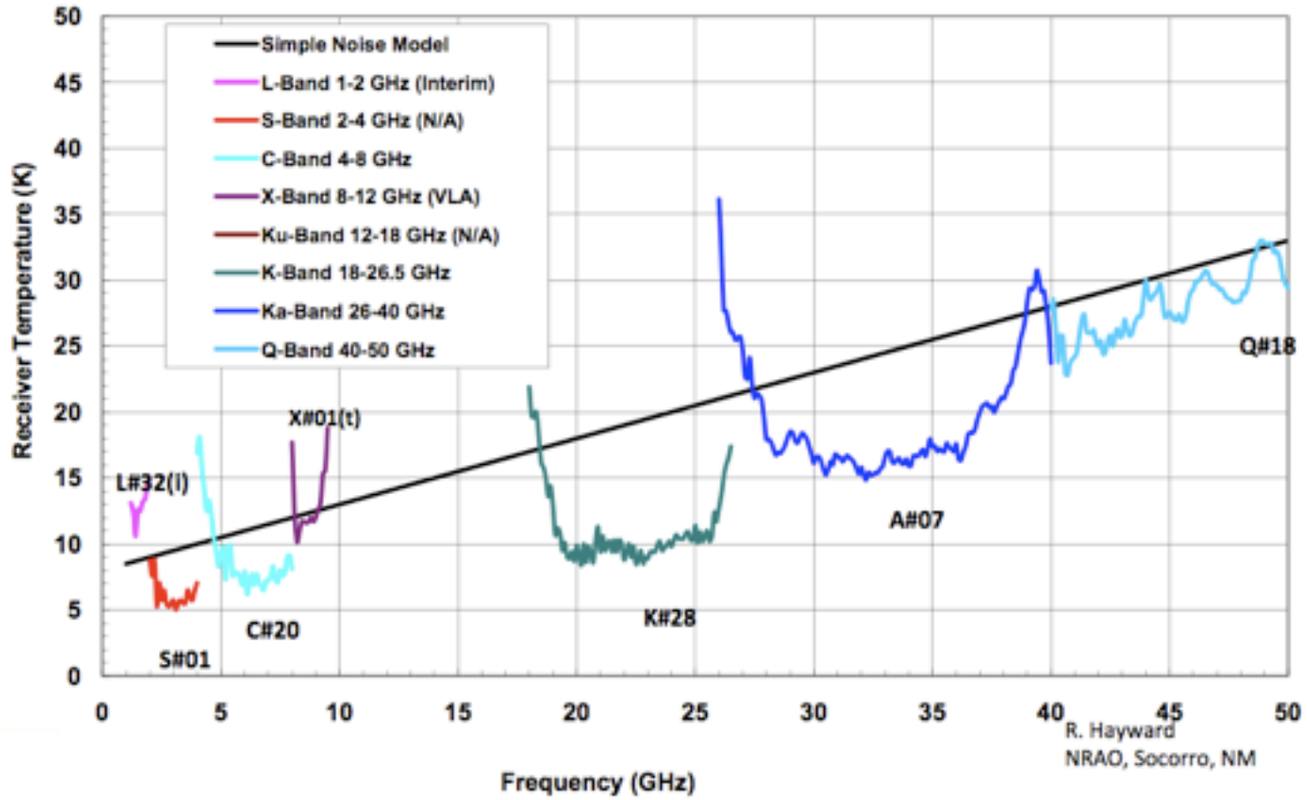
      Band 1 spectroscopic followup

    - galactic: UCHII (7x VGPS resolution, comparable point source sensitivity), cold gas.
  - do support work: calibrator surveys needed for ALMA fast switching modes - long baselines, high frequency
- Band 1 science overlap: high-resolution SZE
  - SPT, ACT survey areas are unreachable by GBT & stretch LMT
  - 100s of clusters ... many at high-z and hard to study with X-rays!

VLA/EVLA

T_{Rx} versus Frequency

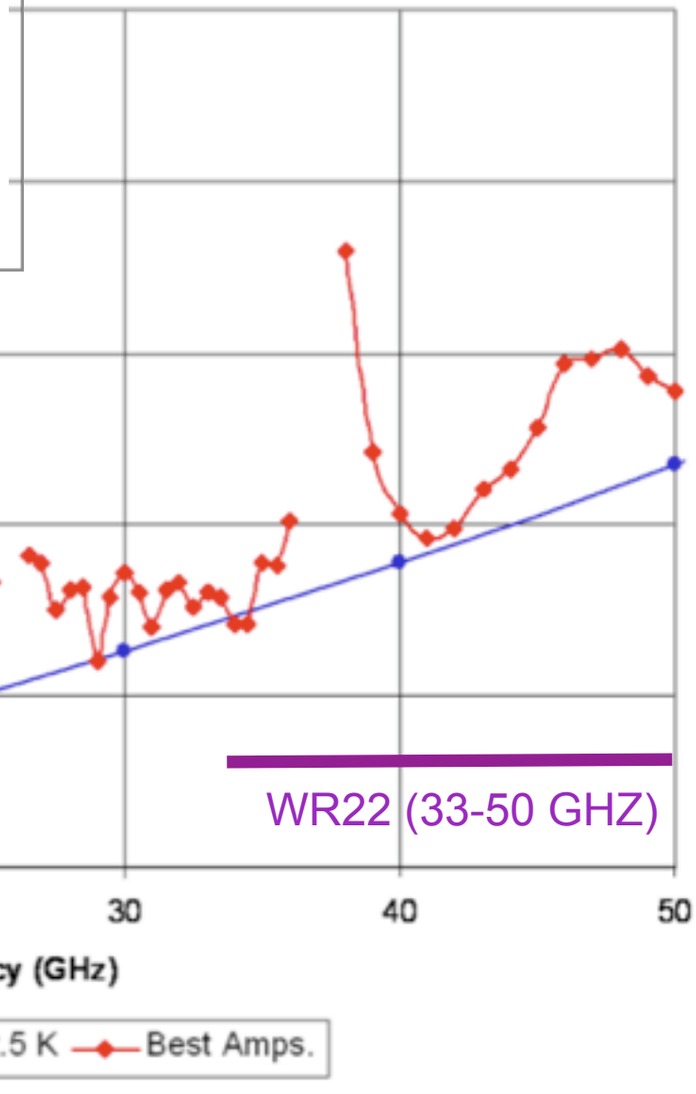
EVLA Project Book - T_{Rx} Requirements (Band Center)								
Band	L	S	C	X	Ku	K	Ka	Q
T_{Rx}	14	15	16	20	25	34	40	48



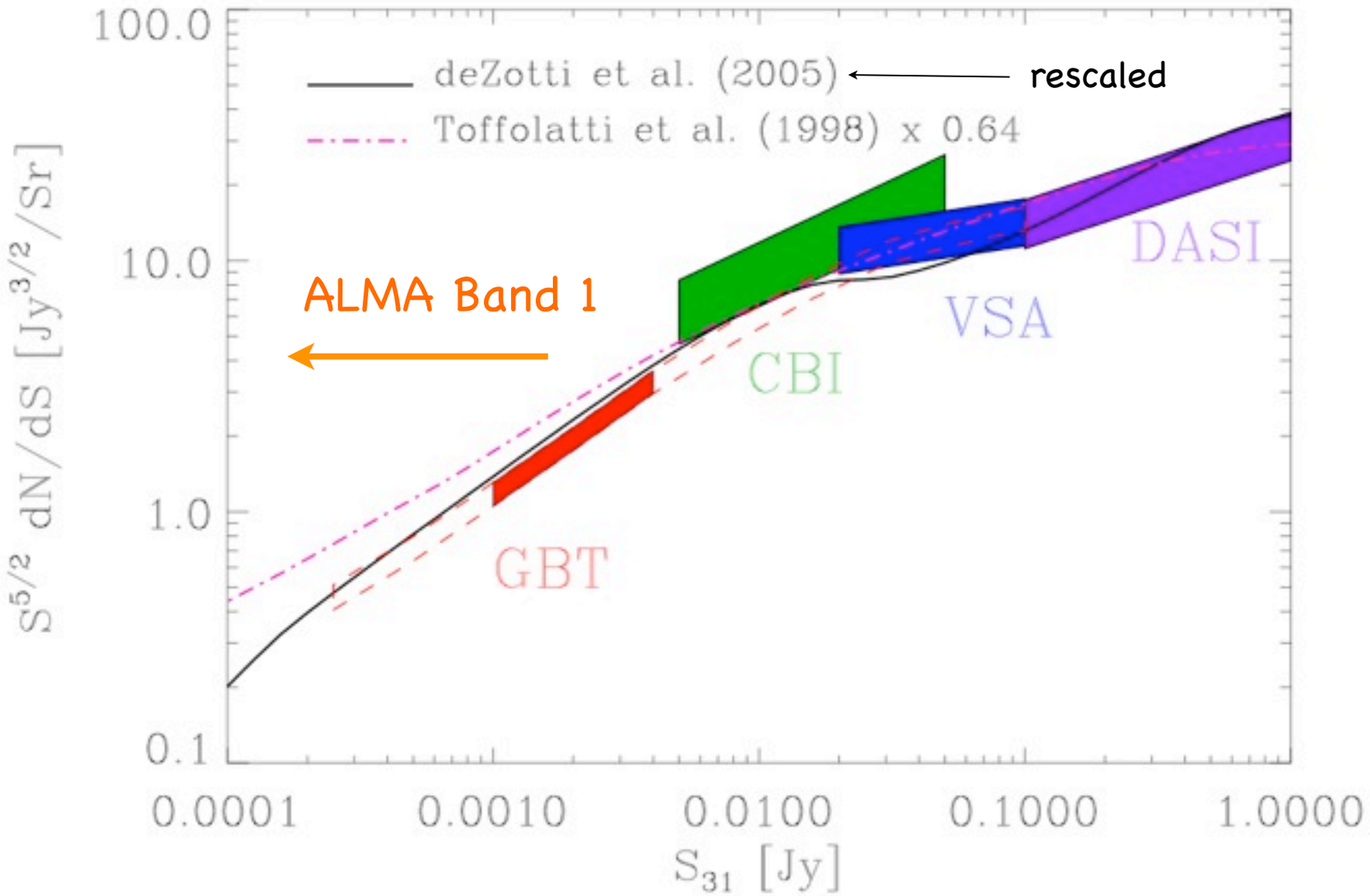
EVLA Receiver temps

*close to existing band 1 spec (< 15K over the freq range 31.5-45 GHz)

Best HEMT performance attained (2009) + predicted best attainable.



From M.Pospieszalski (NRAO/CDL)



GBT+OVRO 30 GHz targeted survey

Mason et al. (2009)

3560 NVSS sources

$N(>1\ mJy) = 17 +/- 2\ deg^{-2}\ (S_{30}/1\ mJy)^{-0.8}$

Consistent with other meas'ts/models (including SZA), can't explain "CBI excess"