Report on SMA activities

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Mauna Kea Users' Committee Meeting

September 27th, 2007

Outline

- Staffing – Hilo
- Look back - projects planned for FY-07
- Current status of planned projects
- A few science results
- Projects planned for FY-08
- Proposal statistics and metrics
- Summary

Staffing - Hilo

- Ant Schinckel resigned from SMA, December 2006
- George Nystrom Interim Director of Hilo Operations since January 2007 (Hilo staff greatly appreciate having George as Interim – working very well)
- Post-docs are now all based in Cambridge
- Have four telescope operators, recently hired a fifth
- Recently hired Chris Schaab – correlator engineer
- Alison Peck resigned from SMA, April 2007
- Glen Petitpas now schedules observations
  - works very well with SAO TAC chair (Mark Gurwell)

SMA Projects for FY-07

Complete 300 GHz receiver upgrades	Done/ongoing
Complete installation of 320-420 GHz receivers	Ongoing
Complete upgrades to antennas 7 and 8	Done
Install improved calibration system	Done
Decide on type of phase correction scheme	Done
Implement true compact configuration	Done
Improve data flow	Ongoing

Instrumentation summary

(300 GHz upgrades and 400 GHz installation high priority)

Designation	Frequency range	Polarization
200	180 – 250 GHz	↗
300	266 – 355 GHz	↗
400*	320 – 420 GHz	↖
650	600 – 700 GHz	↖

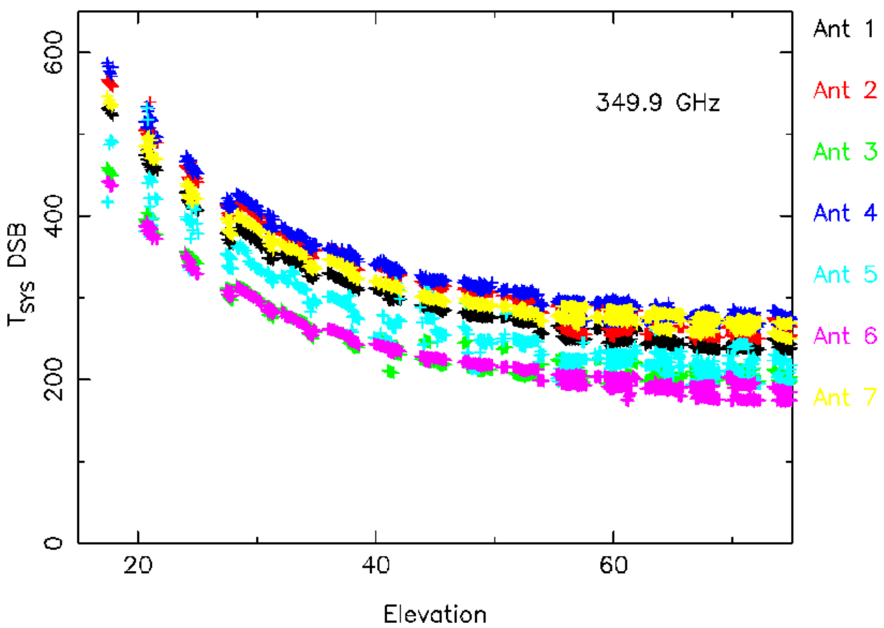
Heterodyne receivers to preserve phase – SIS for low-noise
IF centered at 5 GHz, 2 GHz wide
All receivers housed in a single cryostat, cooled to 4 K
Polarization diplexing enables dual receiver operation:
*Currently have four 400 GHz receivers in operation

Complete 300 GHz upgrades

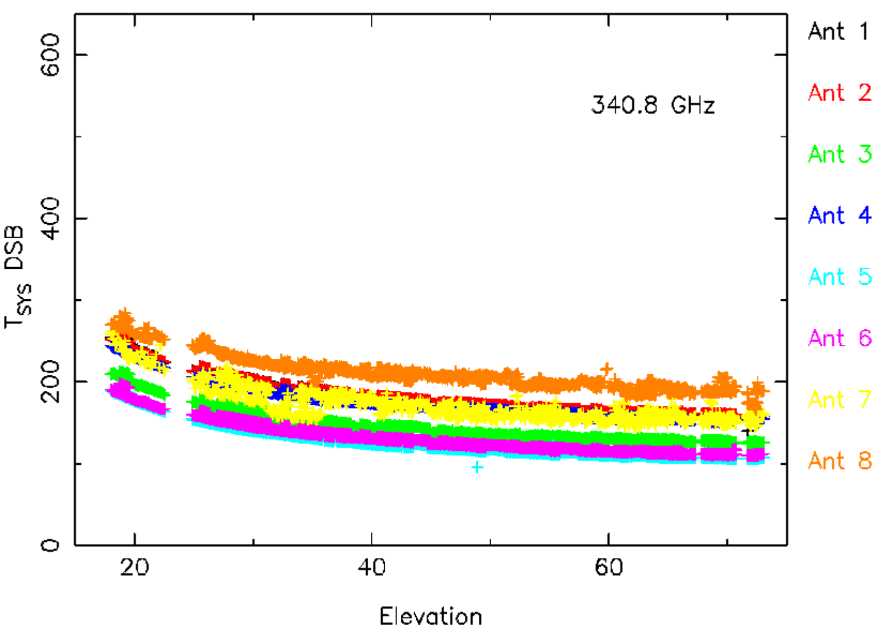
- A number of improvements have been made to reduce T_{rx} and improve tuning and reliability
  - Swap out ageing NRAO-type IF amplifiers
  - Change infra-red filtering at 80 K
  - Select better SIS mixer chips
  - Replace frequency multipliers with fixed-tuned units

300 GHz on-telescope performance

Seven antennas
(2005 - 2006)



Eight antennas
(Current performance)



Average receiver noise has been reduced

Spread in T_{rx} has also been reduced (one outlier)

Finish installing 320-420 GHz receivers

(Remains a high priority for the SMA)

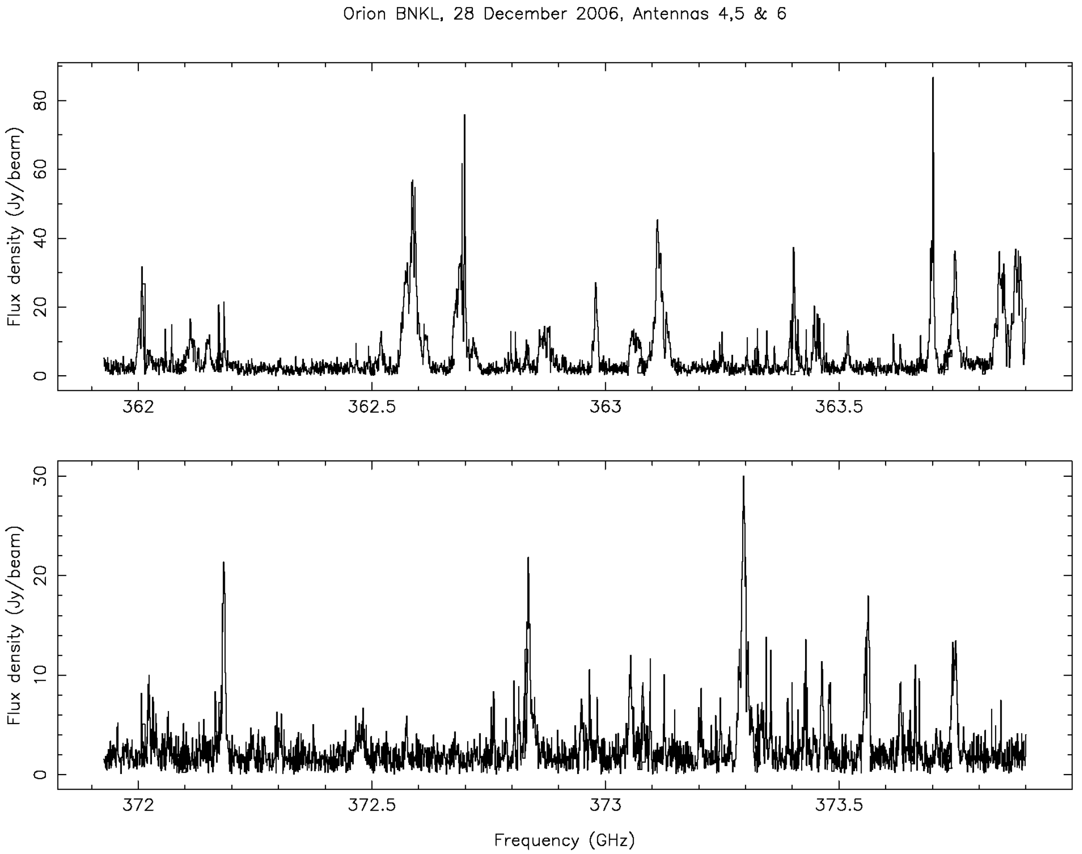
- Additional receiver sets for 320 - 420 GHz
  - Extends frequency coverage of the SMA
  - Increases angular resolution over 350 GHz by 20%
  - Should improve phase transfer tests (400 vs 650 GHz)
- With 300 GHz receivers
  - Full polarization capability across 320 – 340 GHz
  - Increased sensitivity over 320 – 355 GHz frequency range
  - Simultaneous observations of:

    $C^{18}O(3\text{-}2)$, $^{13}CO(3\text{-}2)$, $C^{17}O(3\text{-}2)$, $^{12}CO(3\text{-}2)$
- With 200 GHz receivers
  - Observe different transitions of same molecular species

Extend frequency coverage

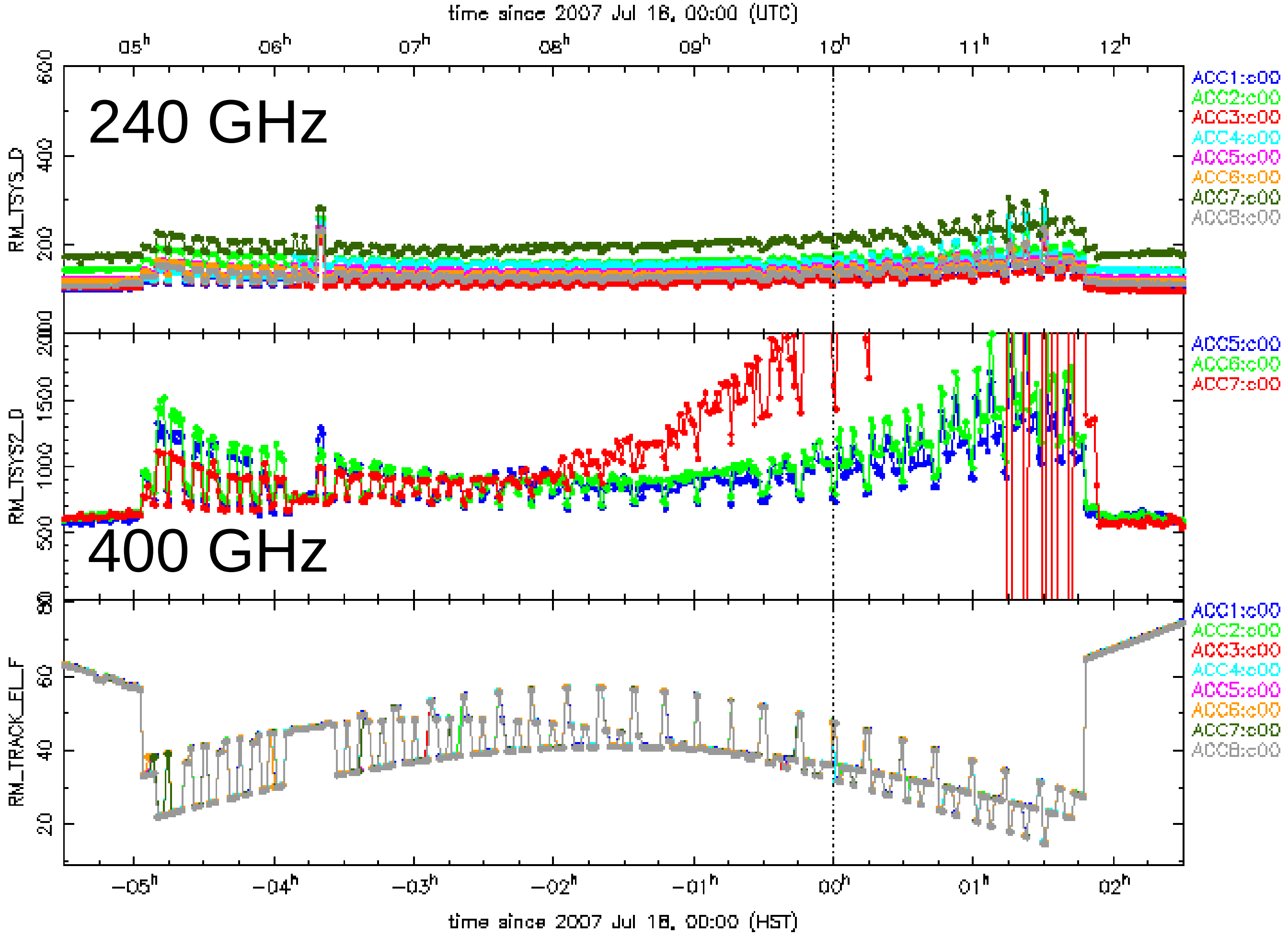
- Frequency coverage now includes 355 - 420 GHz

Test observations with 3 antennas towards Orion, December 2006



Dual frequency polarimetry tests

Quarter wave plates: 3λ/4 at 240 GHz, 5λ/4 at 400 GHz



Problems and difficulties

- 400 GHz receiver sets not performing as well as expected
  - Mixer chip mask set has errors
  - Mask currently being remade
- Installation going slower than originally planned
  - Currently 4 installed, about to install a fifth
  - Basically manpower limited

Bring all antennas up to standard of the best

- Major effort by Hilo-based SAO and ASIIA staff, and by staff in Cambridge and Taipei
  - Antenna 8 completion took about 10 months
  - Antenna 7 completion took about half that time
- Work included
  - Elevation lead-screw, azimuth encoders, roof repairs, air handler replacement, various electrical upgrades, cryostat rebuild and numerous receiver modifications, antenna optics and receiver alignment

Other antenna upgrades

- New type azimuth encoders in all but antenna 5
- Air handler systems for cabin temperature control
  – Maintain cabin air temperature to better than 1°C
- Improvements to holography system
  – Remote switching between antennas
  – Can measure two antennas simultaneously
  – Can also use two receivers in a single antenna (useful for diagnostic purposes)

Antenna surface figures

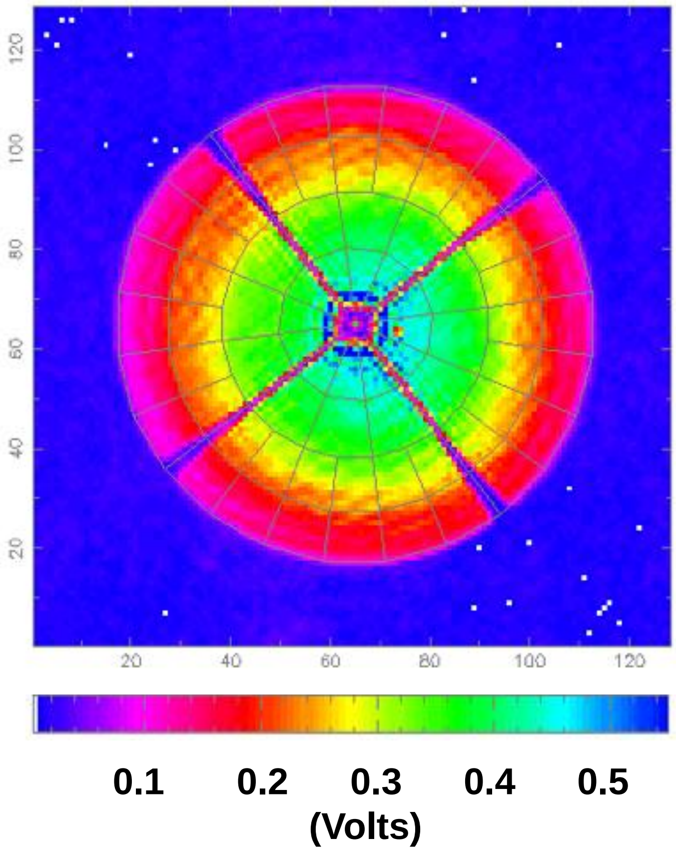
Little change from last year, the majority of antennas either meet or are very close to the12 μm specification

Antenna number	1	2	3	4	5	6	7	8
September 2006	13	13	17	25	14	16	13	11
July 2007	12	13	16	17*	14	17*	12	11

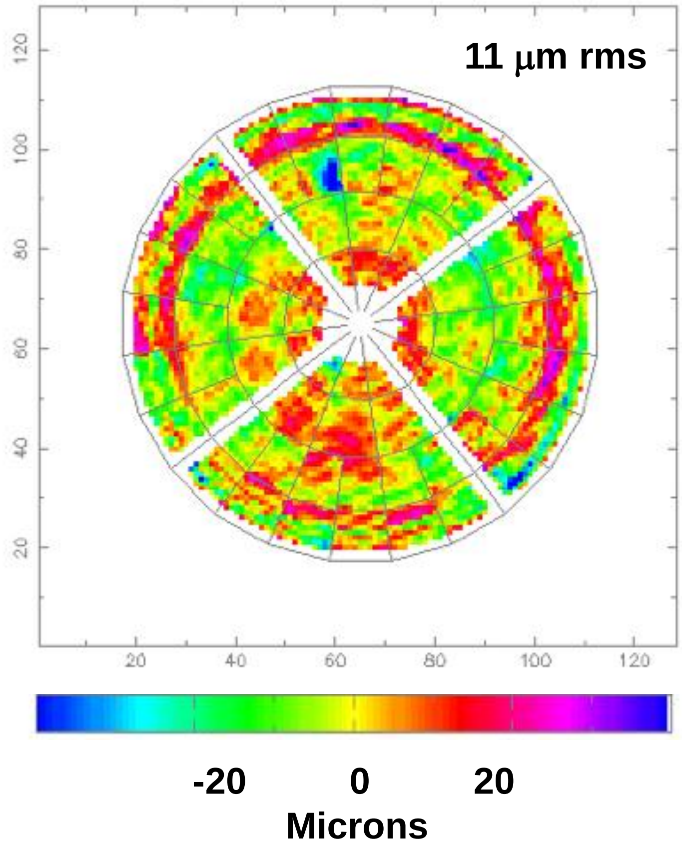
* Offset illumination pattern, needs to be corrected

Antenna eight is now the best*

*Illumination pattern



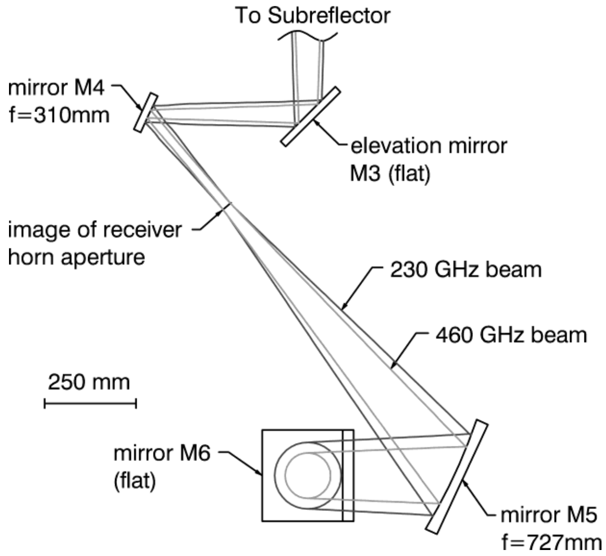
*Surface error map



Two temperature calibration scheme

(Aids receiver diagnostics and enables automatic polarimetry)

Automatically switched room-temperature and heated loads, plus waveplate selection and operation

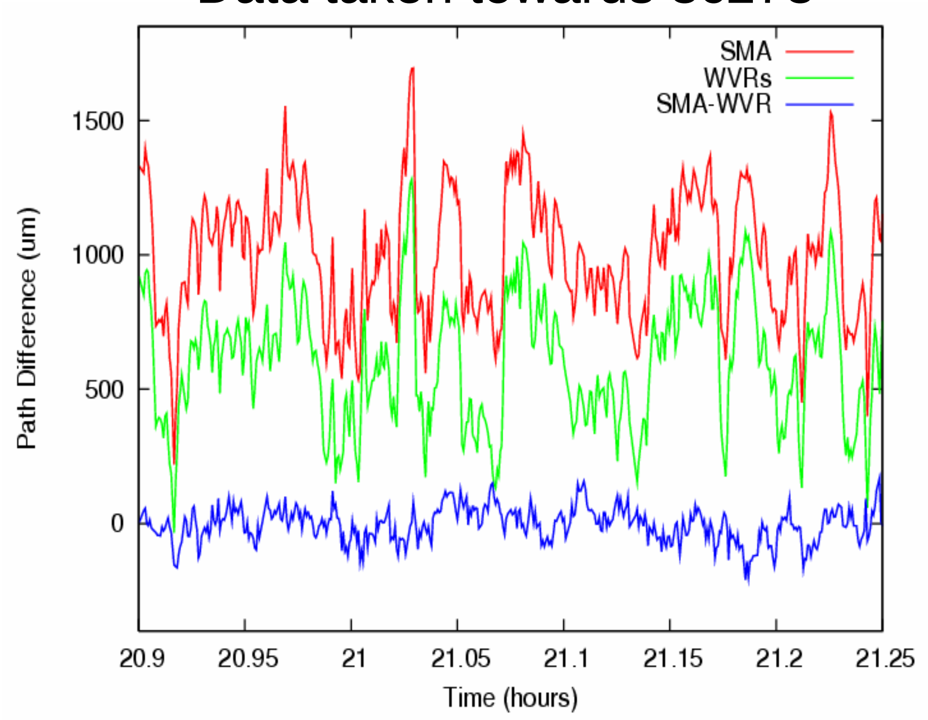


Decide on a phase correction scheme

- 2006 – investigated the problem jointly with the ALMA WVR group
- Tests were carried out under differing weather conditions and on a number of baseline lengths

- ALMA WVR path difference is similar to interferometer delay
- The noise is predominantly atmospheric and can probably be corrected for

Data taken towards 3c273



Phase correction scheme for the SMA

- Drawbacks with ALMA scheme
  - Requires dedicated set of purpose-built receivers
  - Lose one SMA polarization: equivalent to one receiver
  - Costs expected to be ~ 150 – 200 k$ per unit

- Use existing SMA receivers to measure atmospheric O_3
  - Existing SMA receivers can do this at many frequencies
  - However, do need dedicated spectrometer in each antenna
  - More later

Implement true compact configuration

(Increases spatial dynamic range – can better image extended emission)

- Use elevation hard stops to prevent collision

Sub-compact array in operation since February 2007

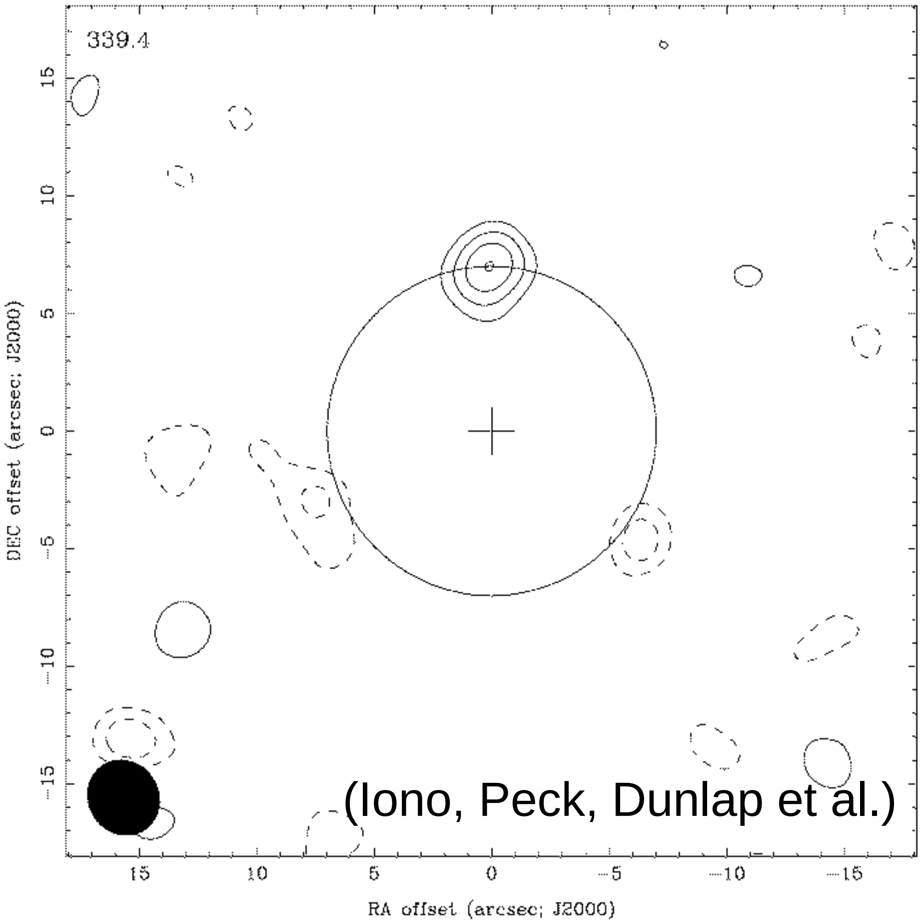
A few science results

(predominantly from improved capability)

- Improved sensitivity at 300 GHz
- Increased spatial dynamic range
  – Sub-compact configuration
- Improved polarimetry capability
  – Automatic wave-plate operation
  – More plates available for other frequencies
- Improved correlator capability
  – Better sideband separation

8mJy SCUBA Galaxy

(First SMA detection of a Submillimeter Galaxy - from last meeting)



(Iono, Peck, Dunlap et al.)

Improved sensitivity at 350 GHz:

Two nights to detect 8mJy SHADES source with SMA at same position as the radio source

Several other attempts to detect submillimeter galaxies produced non-detections

SMA Follow-up Observations of AzTEC COSMOS sources

(Large project to pinpoint Submillimeter Galaxies for further study)

J. D. Younger, G. G. Fazio, J. Huang (CfA)

M. S. Yun, G. Wilson, T. Perera, K. Scott, J. Austermann (U Mass)

M. L. N. Ashby, M. A. Gurwell, K. Lai, A. B. Peck, G. Petitpas, D. Wilner (CfA)

D. Iono, K. Kohno, R. Kawabe (NAOJ)

D. Hughes, I. Aretzaga (INAOE),

J. Lowenthal (Smith)

T. Webb (McGill),

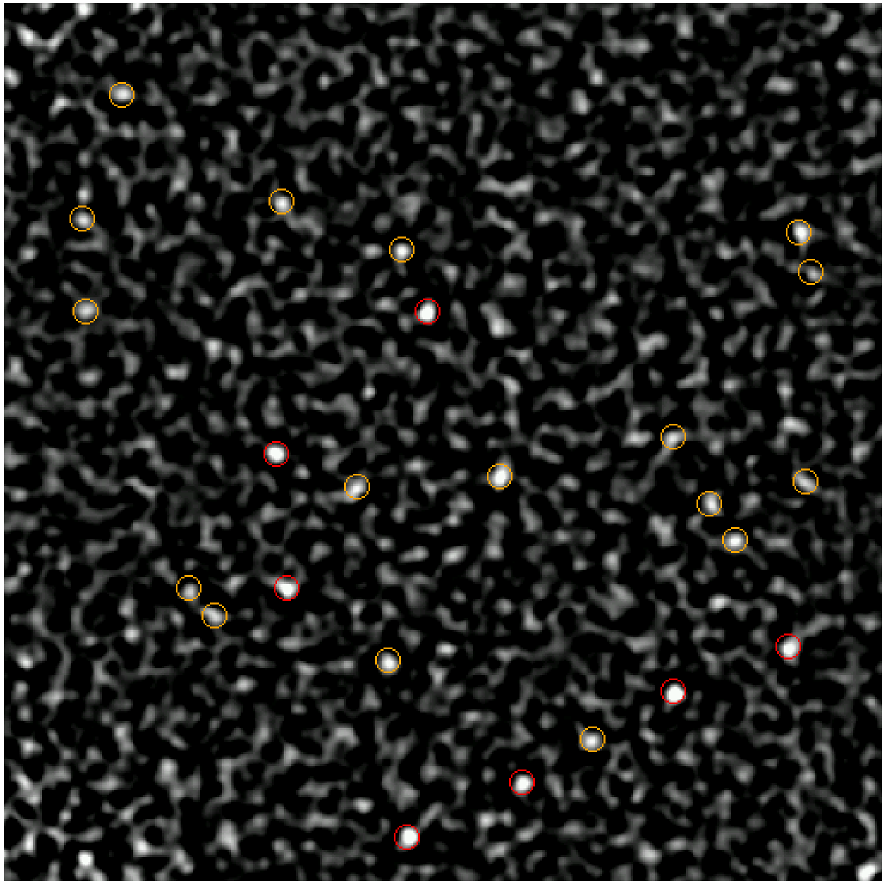
A. Martinez-Sansigre, E. Schinnerer, V. Smolcic (MPIA)

S. Kim (Sejong Univ)

Observations of COSMOS field

(Improved sensitivity of 300 GHZ receivers)

- AzTEC camera observations (1.1 mm wavelength; 14 arcsec resolution) on the JCMT of the COSMOS field (0.15 deg^2) detected 44 submm galaxies (SMGs) above 3.5σ.
- Follow-up SMA observations of the seven brightest detected all seven SMGs and pinpointed their location to 0.2 arcsec
- Follow-up observations by HST (ACS), SPITZER (IRAC and MIPS), and Very Large Array (VLA) revealed the detailed properties of these sources.

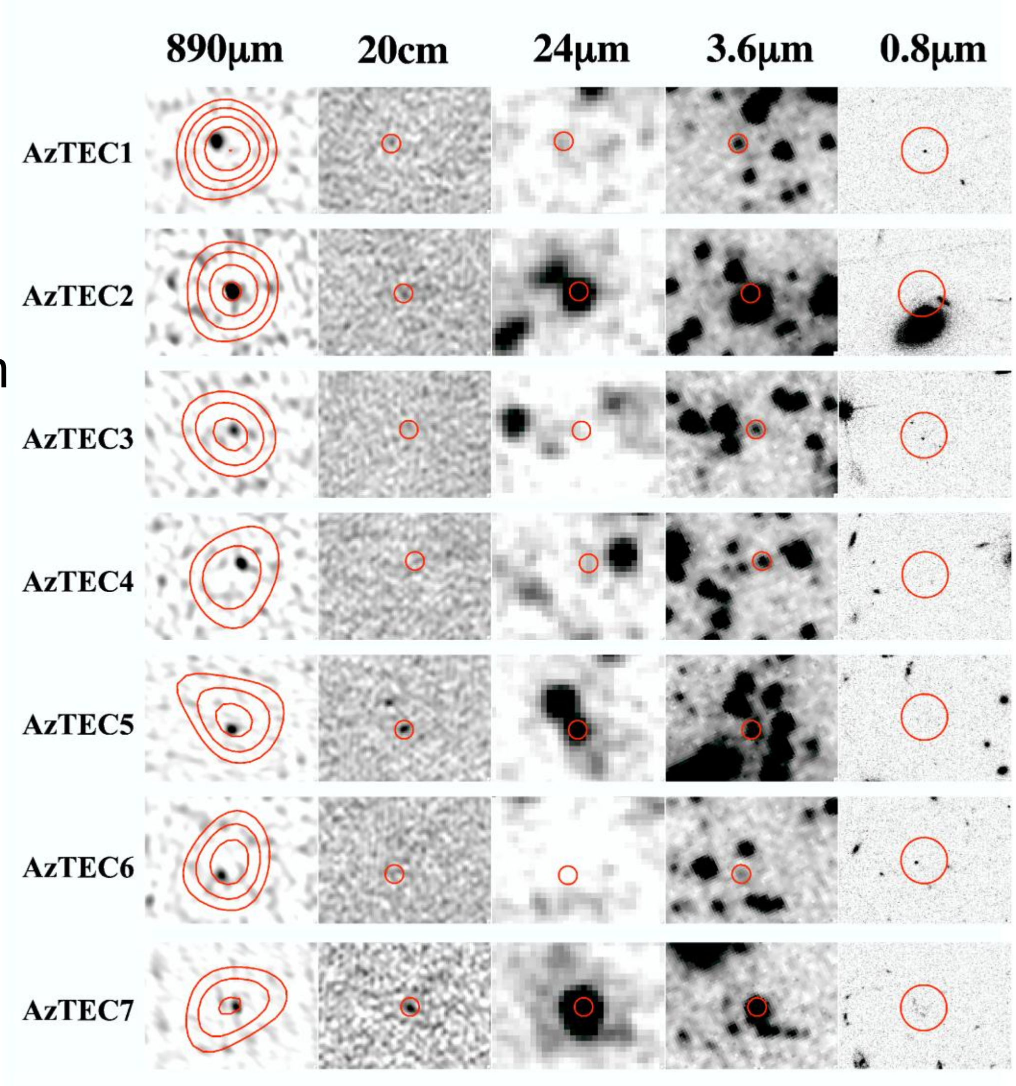


The AzTEC/COSMOS Survey
(Scott et al. 2007)

Extreme Starbursts at High-z

(Younger, Fazio, et al.)

- Half of luminous cosmic energy density from dusty sources
- Flux limited sample of seven "COSMOS" AzTEC sources observed with the SMA:
  - 0.2" astrometry
  - reliable counterpart identification
- multi-wavelength properties of 5/7 argue for z>3

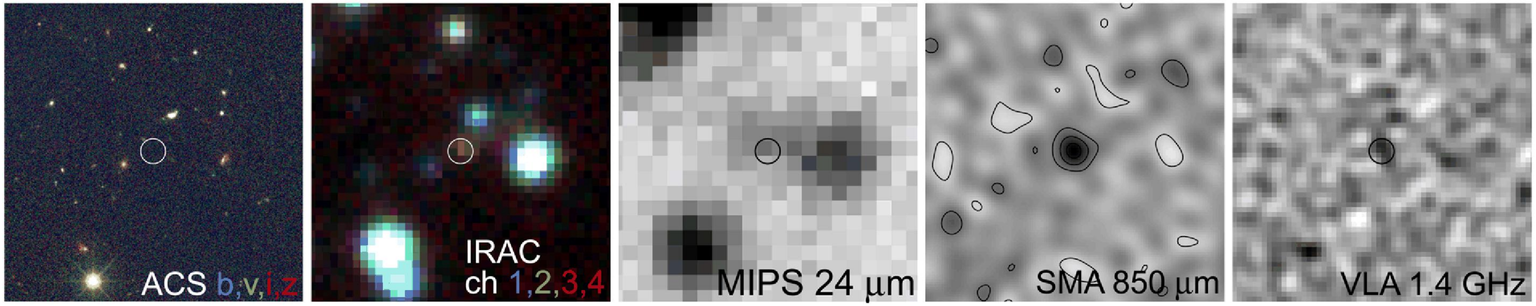


Younger et al. 2007

Extreme Starbursts at High-z

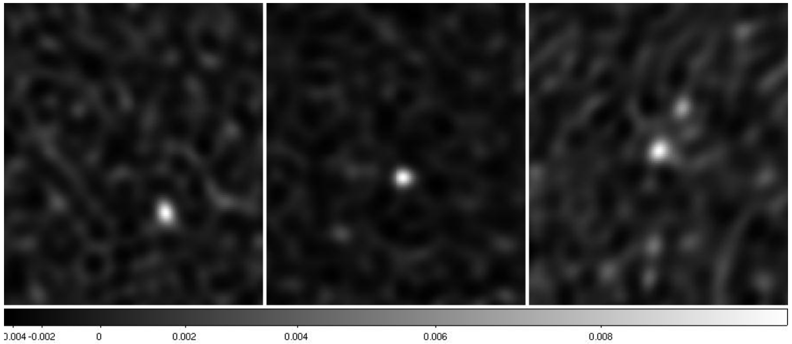
(Work from other groups)

- "strong" submm, weak/no radio, no optical, no 24 μm
- L. Cowie: one GOODS-N SCUBA source, likely z>4



Wang et al., submitted

- D. Hughes: galaxy formation in overdense 4C41.17 z=3.8 protocluster, follow-up three AzTEC 1.1 mm sources

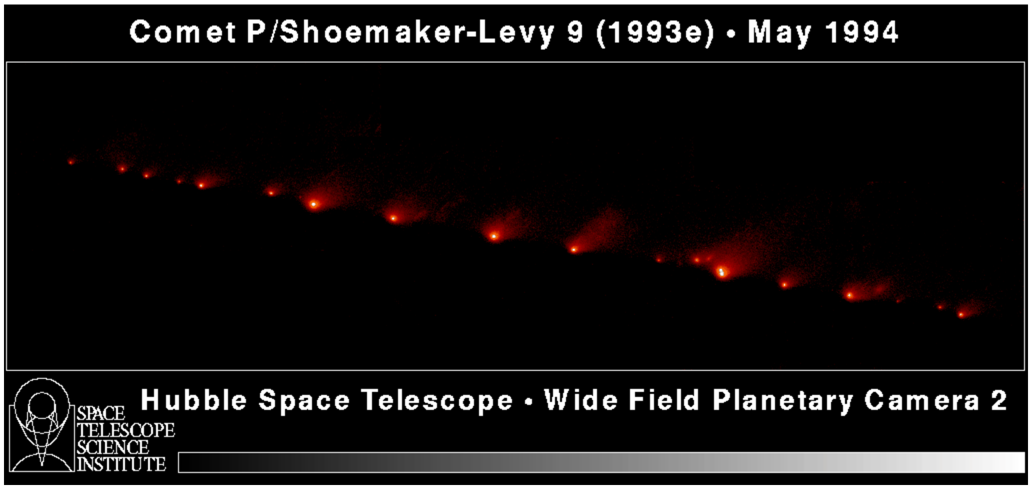


n.b. 100% SMA detection rate for AzTEC sources

Summary of SMG Observations

- Significant improvements in the sensitivity and stability of the SMA now permit the observation at 890 microns of galaxies at z > 3.
- The SMA is essential in locating the precise position of these high-z galaxies, measuring their size and multiplicity; when combined with multiwavelength observations permits the determination of SEDs/photo-z.
- Brightest submm galaxies detected by SMA may be at high redshift (z > 3); important for determining SFR in early Universe.

HCN on Jupiter…from Comet SL9
(Background)



Shoemaker-Levy slams into Jupiter, July 1994

Deposits material into troposphere and stratosphere

Loss of HCN due to Dynamics

(Improved spatial dynamic range – subcompact configuration)

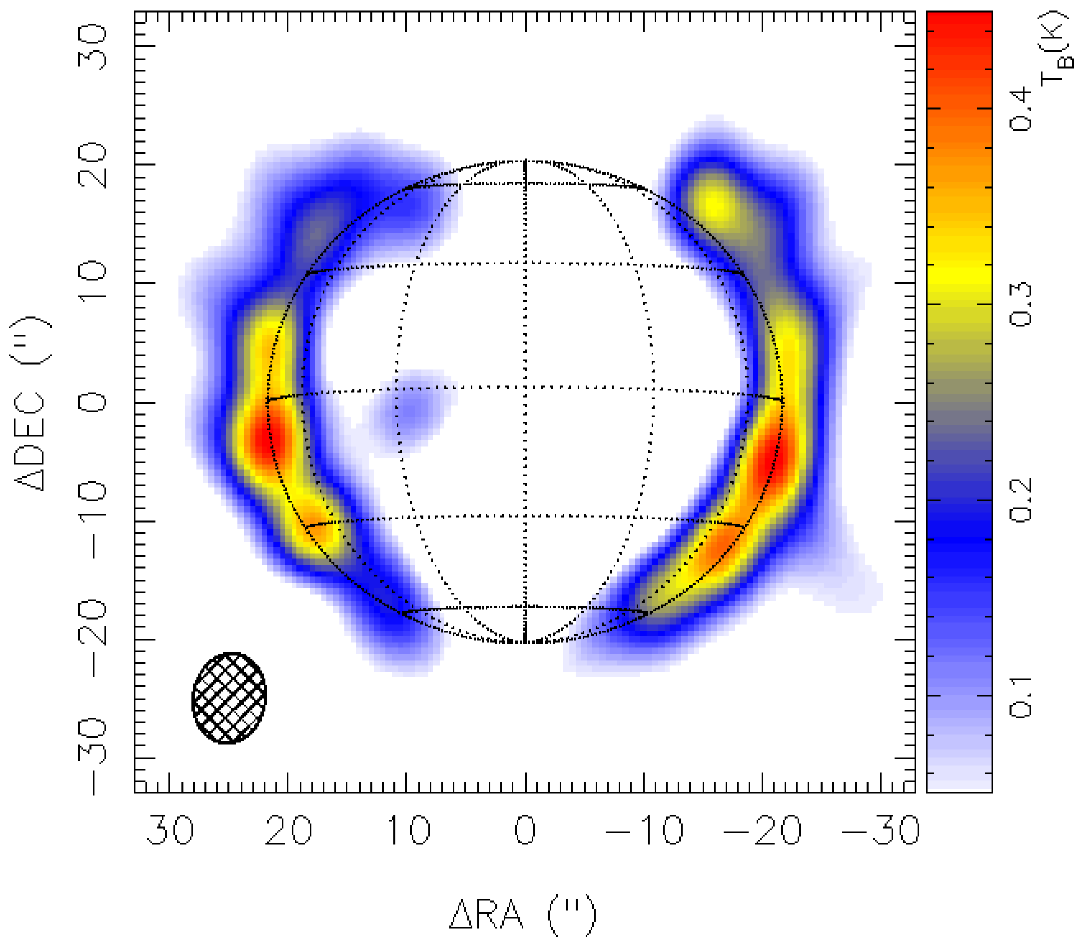
HCN mass loss from 1998-2006 ~factor of 8. No detections of daughter species (e.g. CH3CN) implies mass loss rate primarily due to dynamics (transport) not photochemistry.

Hypothesized downward transport near poles, driving HCN to higher pressures and temperatures where it is destroyed in favor of methane and ammonia.

SMA imaging from April 2007 strongly supports this view.

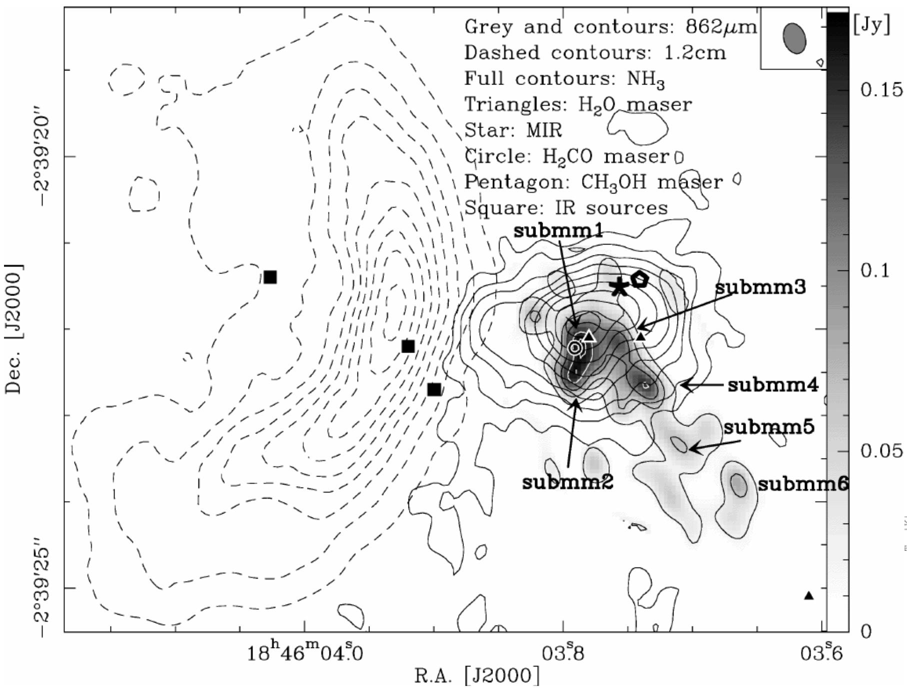
HCN(3-2) integrated emission, 28 April 2007

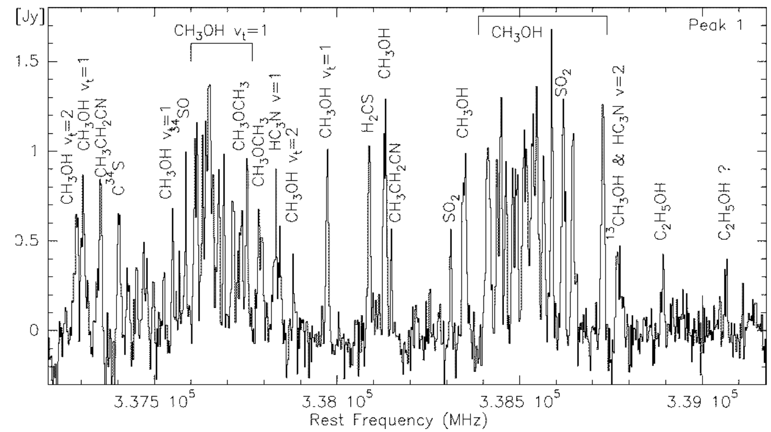
Moreno and Gurwell, in prep

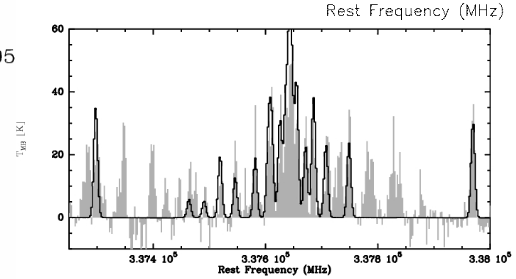


Prototypical Hot Core G29.96

(Improved sideband separation)







Beuther et al. 2007

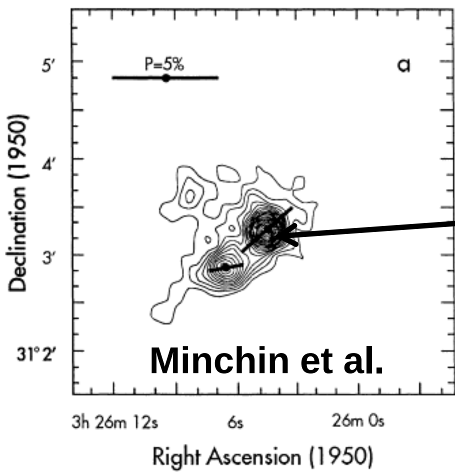
- hot core resolved into 6 sources: “proto-Trapezium” (separations ~ 2000 AU)
- plethora of lines in 4 GHz bandpass
  - at least 80 lines from 18 species (including isotopologues, vibrational lines)
  - improved sideband separation aids with line identification
  - chemical differentiation, physical conditions, kinematics

Submillimeter Polarimetry

(Automatic polarimetry possible using new calibration scheme)

- Use dust polarization to study magnetic fields
- Previous single dish measurements (CSO, JCMT)
  low angular resolution (~14") but good sensitivity
- Interferometer array observations (OVRO, BIMA)
  improved resolution but inadequate sensitivity
  (CARMA will be better).
- SMA offers high angular resolution **with** good sensitivity

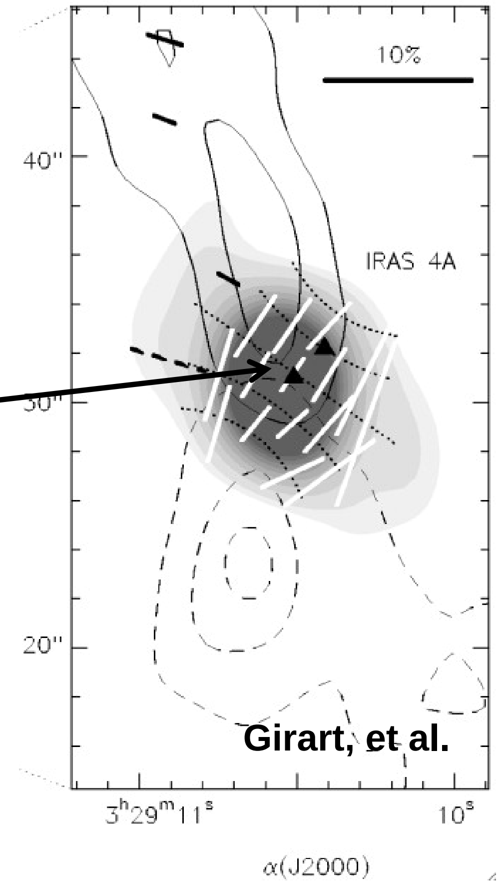
Previous polarimetry observations

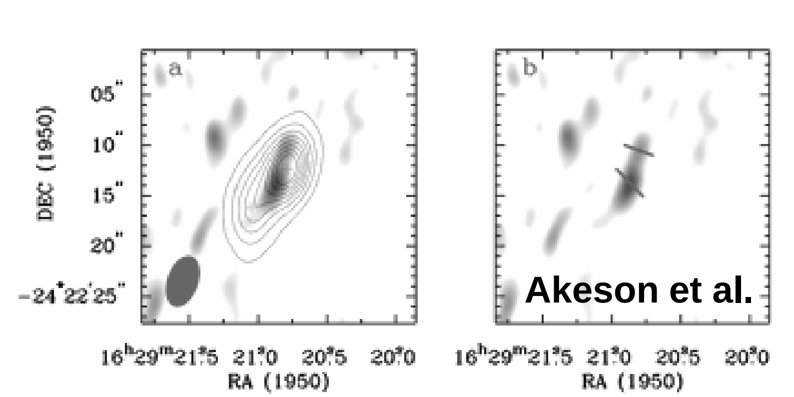


NGC1333 IRS 4A
Class 0 low mass protostar:

JCMT observations at 350 GHz

BIMA observations at 230 GHz



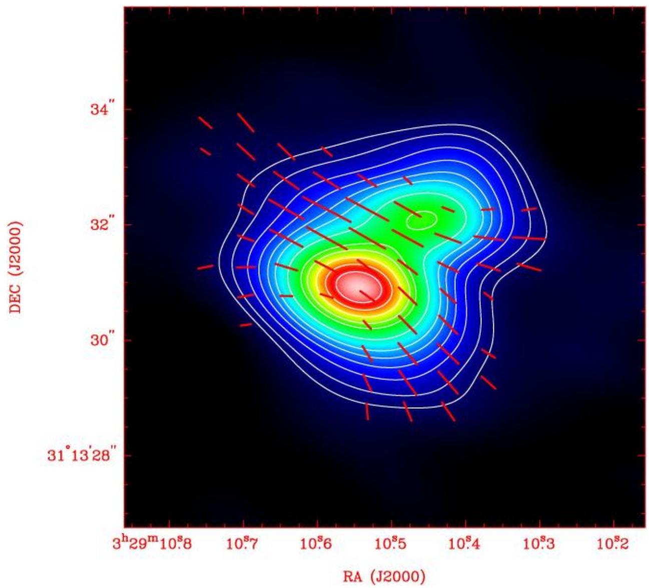


IRAS 16293 OVRO observations at 86 GHz

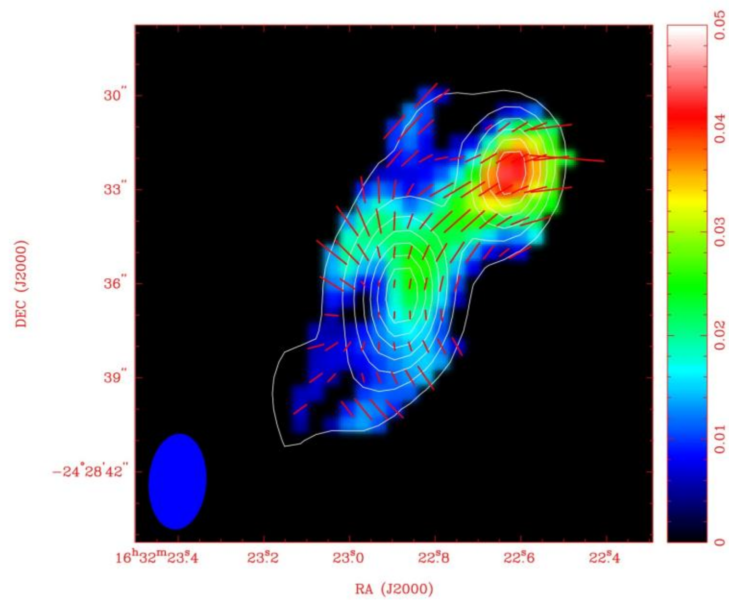
SMA Polarimetry Observations

(Much better than previous observations with other instruments)

- Importance of magnetic fields in star-formation?
- Hourglass shape is long predicted “smoking gun” of magnetic forces resisting gravity



NGC1333 IRAS4A
Girart et al., 2006



IRAS 16293 A/B
Rao et al., in prep

SMA Projects for FY-08

Complete installation of 320-420 GHz receivers

Improve 650 GHz receivers

Double bandwidth for single receiver operation

Test and begin implementation of phase correction scheme

Test and field an atmospheric phase monitor

Improve data flow

Improve 650 GHz Receivers

(Improved sensitivity is critical for calibration)

- Significant improvement is expected (factor of 2 – 3)
- Copy modifications to 300 GHz receivers:
  - Use quartz instead of Zitez for IR filtering
  - Use coated quartz vacuum window instead of Teflon
- and:
  - Remove Martin-Puplett diplexer and use VDI multiplier with one tuner (Phase Shifter)
  - Replace Teflon lens with a cooled quartz lens
  - Replace mixer with newer design with SIS mixer chips to be fabricated at the University of Cologne

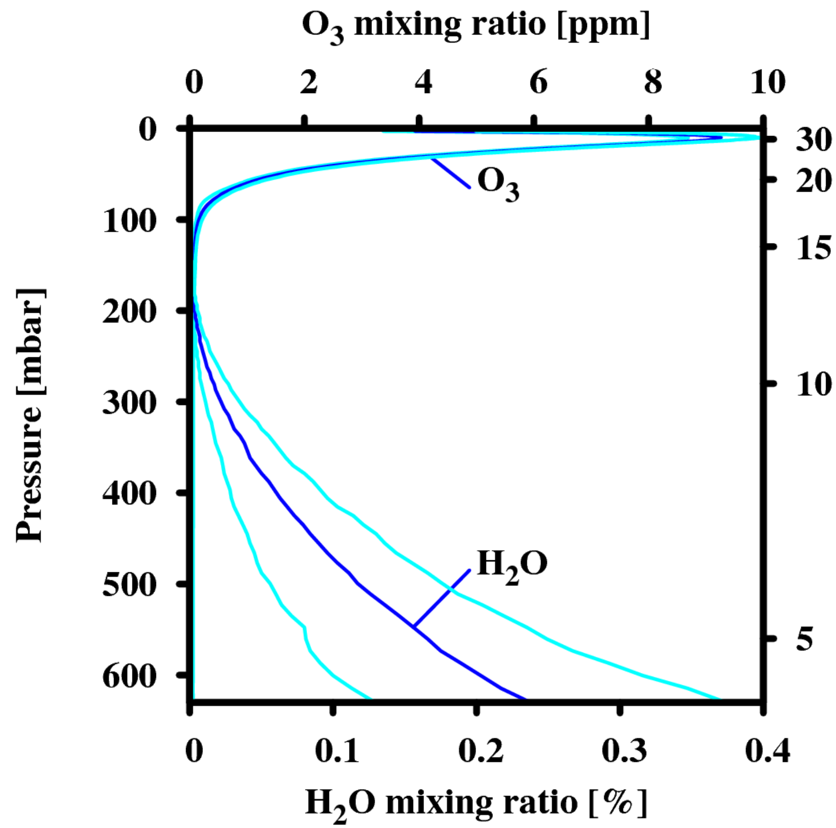
Double Bandwidth with One Receiver

(Better continuum sensitivity, more instantaneous spectral coverage)

- Would work with any receiver, but most useful for the 600's. Limited usefulness where the 400's could be used with a lower frequency receiver.
- Minimal changes are required.
  - Remove 3.75-6.25 GHz filter in dewar. Replace isolators at LNA input, replace a few commercial amplifiers (most will be ok).
  - LO can be derived from 200 MHz reference in cabin.
- Switches in the system can also be used to calibrate high freq. IF bandpass with the low freq. receiver.
- Engineering personnel are available.

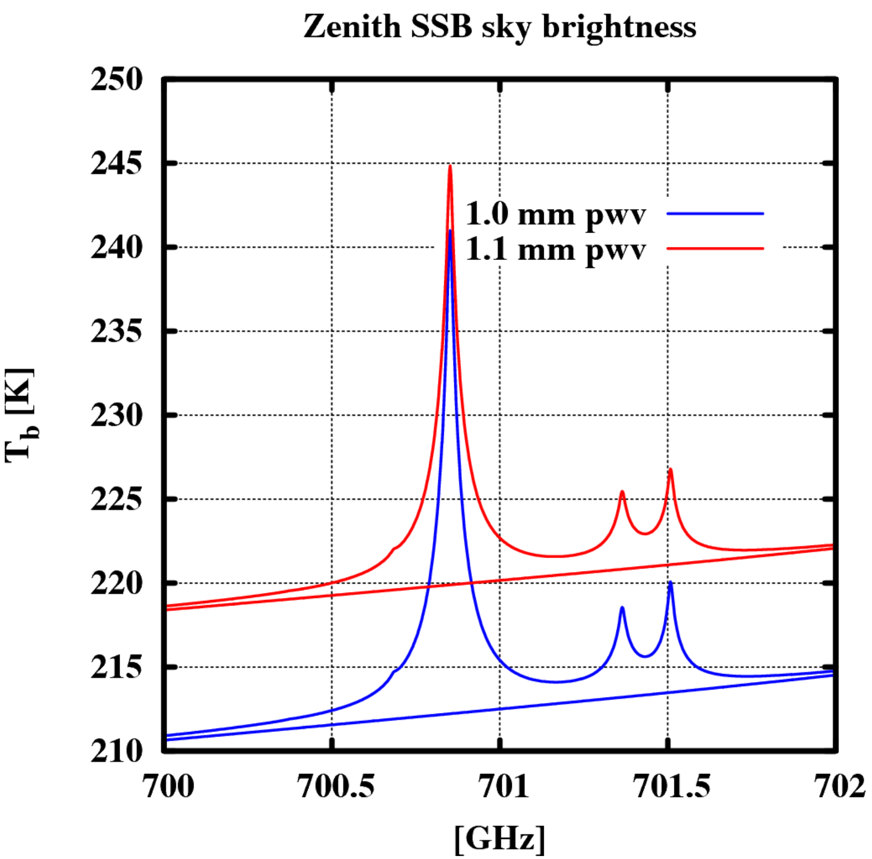
Phase correction using O_3 Radiometry

- H_2O and O_3 profiles well-separated. (Mauna Kea year-round quartiles at right.)
- H_2O varies quickly, over short horizontal scales
- O_3 varies slowly, common mode over array
- Use O_3 line emission to probe H_2O fluctuations
- Employ existing astronomical receivers



O_3 Radiometry – example

- Observable is O_3 line contrast
- In this example, O_3 peak to wing contrast decreases 4 K as pwv increases 0.1 mm (~ 500º delay at 690 GHz)
- ~ 1 K DSB change averaged over 100 MHz BW
- Rx sensitivity ~ 50 mK in 2.5 s for T_{sys} = 750 K
- 25º delay estimate in 2.5 s (similar to the ALMA wvr).



O_3 Radiometry – plans

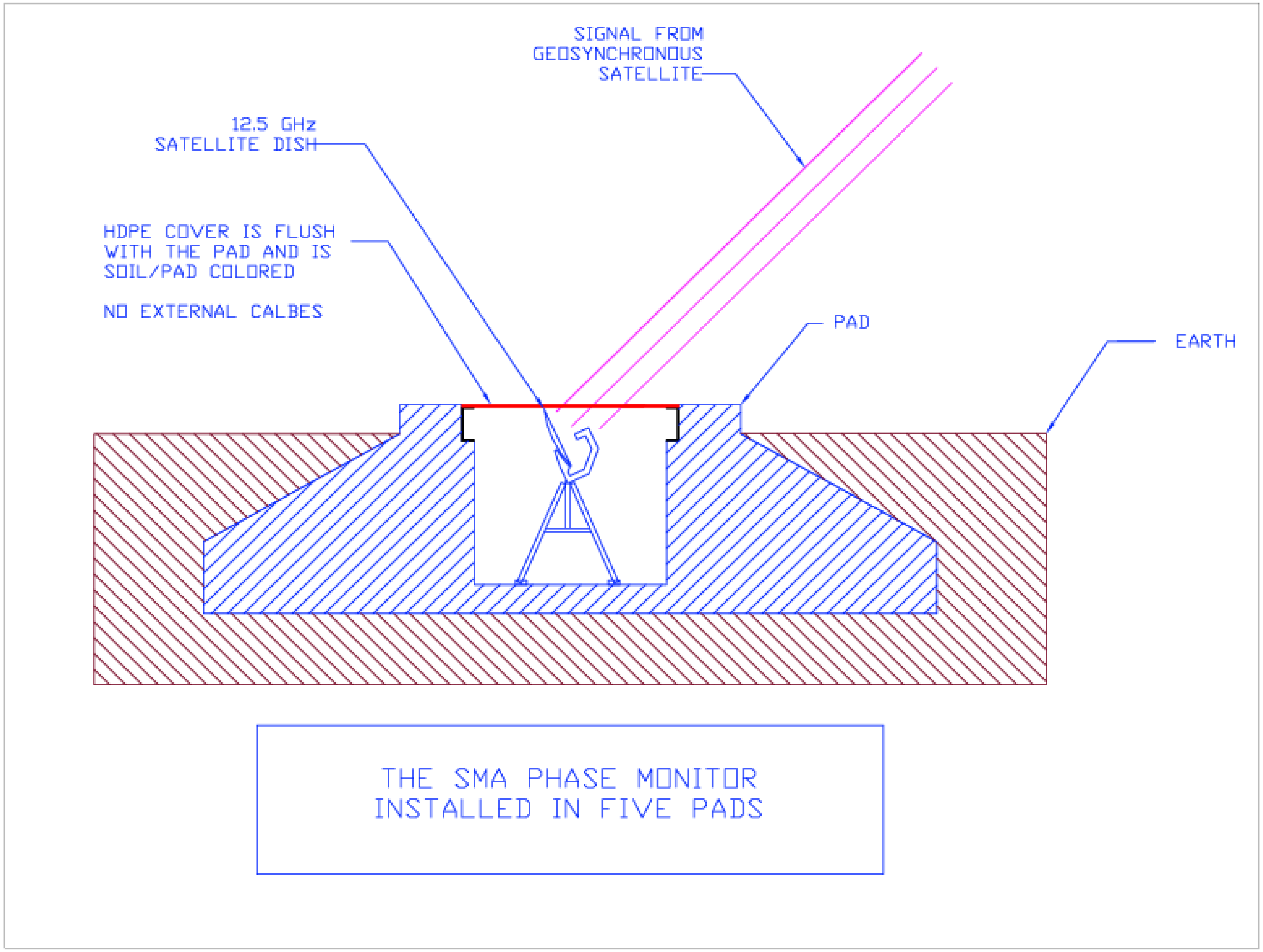
- Equip each antenna with a stable, single-dish spectrometer for phase correction.
- Two Acqiris 1 GHz FFT spectrometers already purchased ~$30,000 each
- Downconverters, software under development in the receiver lab.
- Two antenna tests planned for Nov 2007

Atmospheric Phase Monitor

(More efficient observing)

- Data may be used to
  - Choose optimal observing frequency and project for current conditions (Phase stability and τ are only weakly correlated.)
  - Chose optimal time of observing calibrators
  - Determine Phase stability trends at the site
- Monitor will run 24/7 and produce uniform data for the Mauna Kea community in real time.
- Replaces Masson system which we no longer have a permit for.
- Use inexpensive satellite TV components
  - LNB – Invacom QPH-031 provides horn, orthomode transducer, LNA and quadrature hybrid to allow four polarizations to be observed. Noise figure 0.4 dB, price $79 ea. for 1-9.

Phase Monitor Antenna in an SMA Pad



Proposal tracking plus filler program

- Proposals tracked on-line from submission to completion
  - Pi’s can log on to view status of observing proposals
  - Data examined on a daily basis to determine quality
  - Automatic tracking of time devoted to partner institutes

- April 2007 internal proposals for short time requests
  - Idea is to move towards maximizing array usage
  - Some limitations on proposal types (partner institutes only)
  - Move to daytime observing (tests planned at 230 GHz)

Allocations and Overall Performance

294 SAO tracks allocated (126 A ranked) over last three completed semesters

	A Tracks	B Tracks
Nov 05 - Apr 06	34 (~81%)	31 (~54%)
May 06 - Oct 06	41 (~98%)	23 (~40%)
Nov 06 - Apr 07	42 (~100%)	33 (~63%)

Science Publications (Refereed)

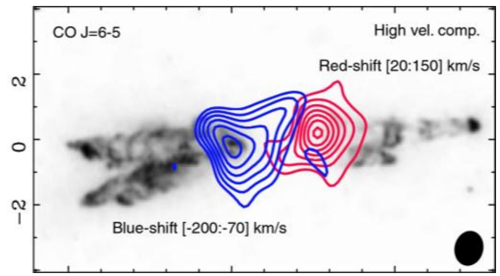
	2004	2005	2006	2007*	Total
Star Formation	8	10	12	23	53
Extragalactic	4	1	4	7	16
Stellar	3	-	3	4	10
Galactic Center	-	-	2	1	3
Solar System	1	1	-	1	3
Other	2	-	1	-	3
Totals	18	12	22	36	88

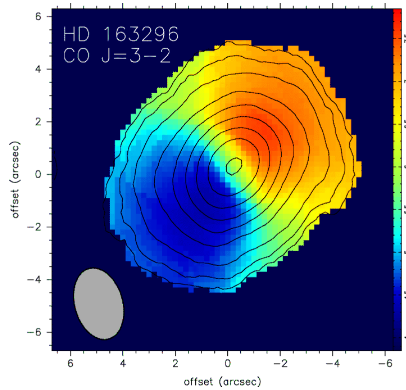
*through August 23

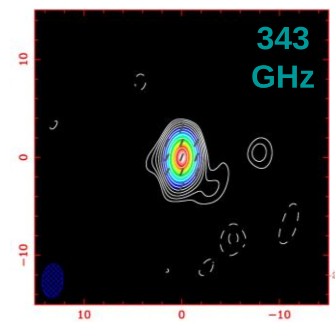
SMA publications are ramping up as more (and longer term) programs are completed.

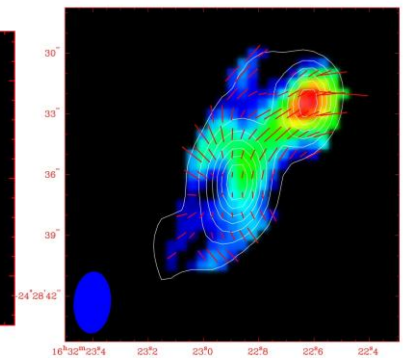
Summary

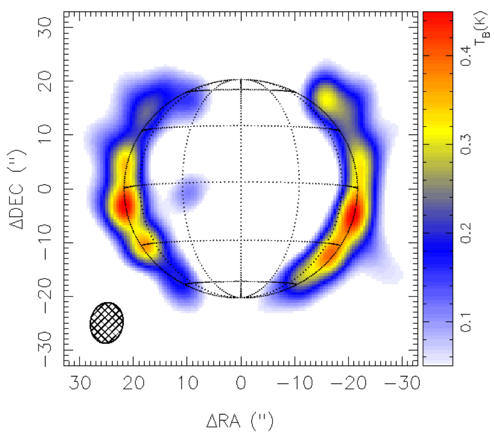
- The SMA is a working instrument
  - publication rate now 1 refereed paper per week
  - wide range of very exciting science results

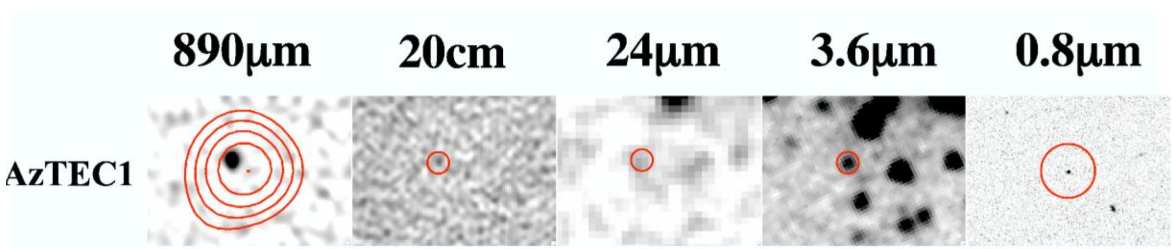












- lots more to come