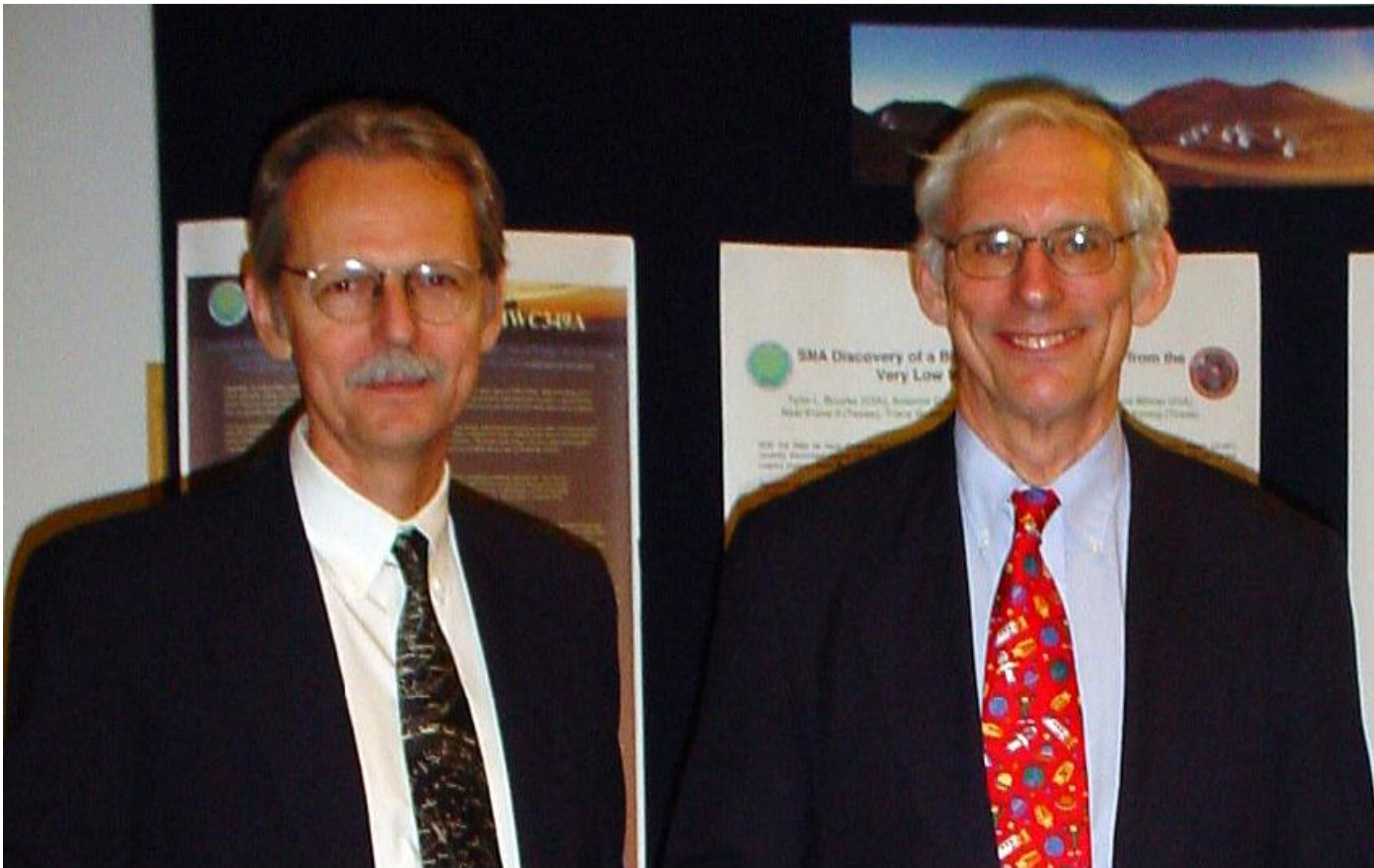
Report on SMA activities

Ray Blundell

Mauna Kea Users' Committee Meeting

October 5, 2006

SAO Director Charles Alcock, and outgoing SMA Director Jim Moran, at the SMA reception at the Center for Astrophysics, 15 October 2005.



SMA Projects for FY 06 (Moran)

500 kW Emergency Generator	- September 06
O_2 Enrichment System: 21 → 26%	- March 06
All 350 GHz Receivers to $T_{rx} < 85K$	- Ongoing
Bring Antennas 7 & 8 up to Specification	- Ongoing
Commission 320 - 420 GHz Receivers	- Ongoing
e-SMA pilot program (SMA + JCMT + CSO)	- Resume October 06
VLBI capability	- Maser since March 06
Active Phase Correction System	- Under review

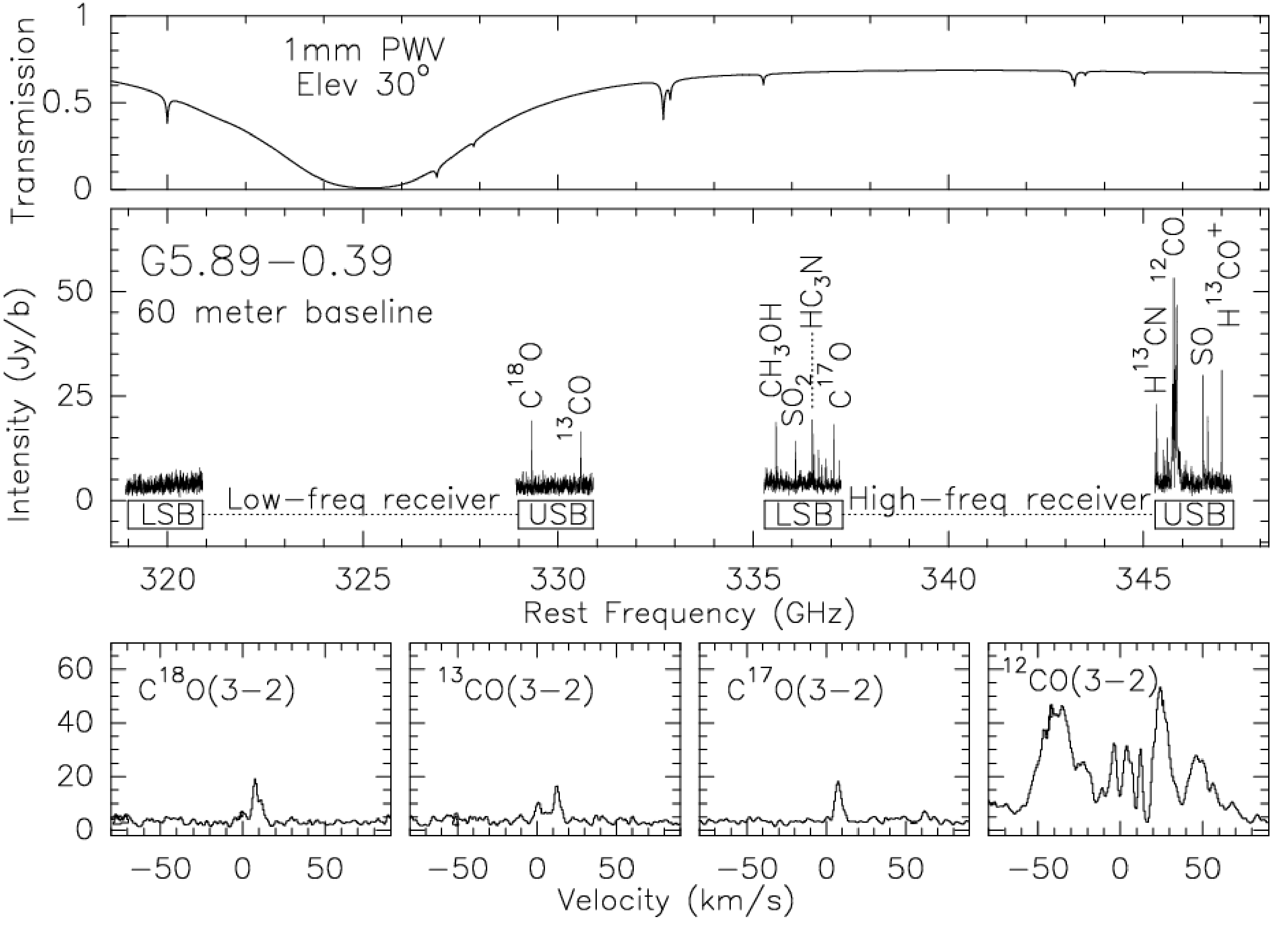
Upgrades to antennas 7 and 8

Primary focus: check receiver optics alignment, and bring the antenna mounts up to the full specification.

Remove receivers, disassemble, measure critical mechanical parts, modify as needed, reassemble, realign receiver (Hilo lab.)
Perform maintenance on Daikin cold-head and compressor unit
Remove Optics cage, disassemble, measure, realign
Remove 4/5/6 optics plate, support structures, measure and realign as needed (Cambridge labs.)
Update electrical and control systems (deice readback, enclosure heaters, external enclosure latch problems, E-stop upgrade, deice zone repairs, complete wiring, install guards, etc)
Maintenance (Strip azimuth motors inspect adjust meshing of gears, rebuild elevation leadscrew (8), chopper checks, overhaul chiller, make cabin roof repairs, paint ….

Most of antenna 8 upgrades completed December 2005 (8 months)
Antenna 7 upgrades should be complete by November 2006 (5 months)

300 and 400 GHz receivers tuned to detect 4 isotopic CO transitions simultaneously (Hunter)



The e-SMA and VLBI activities

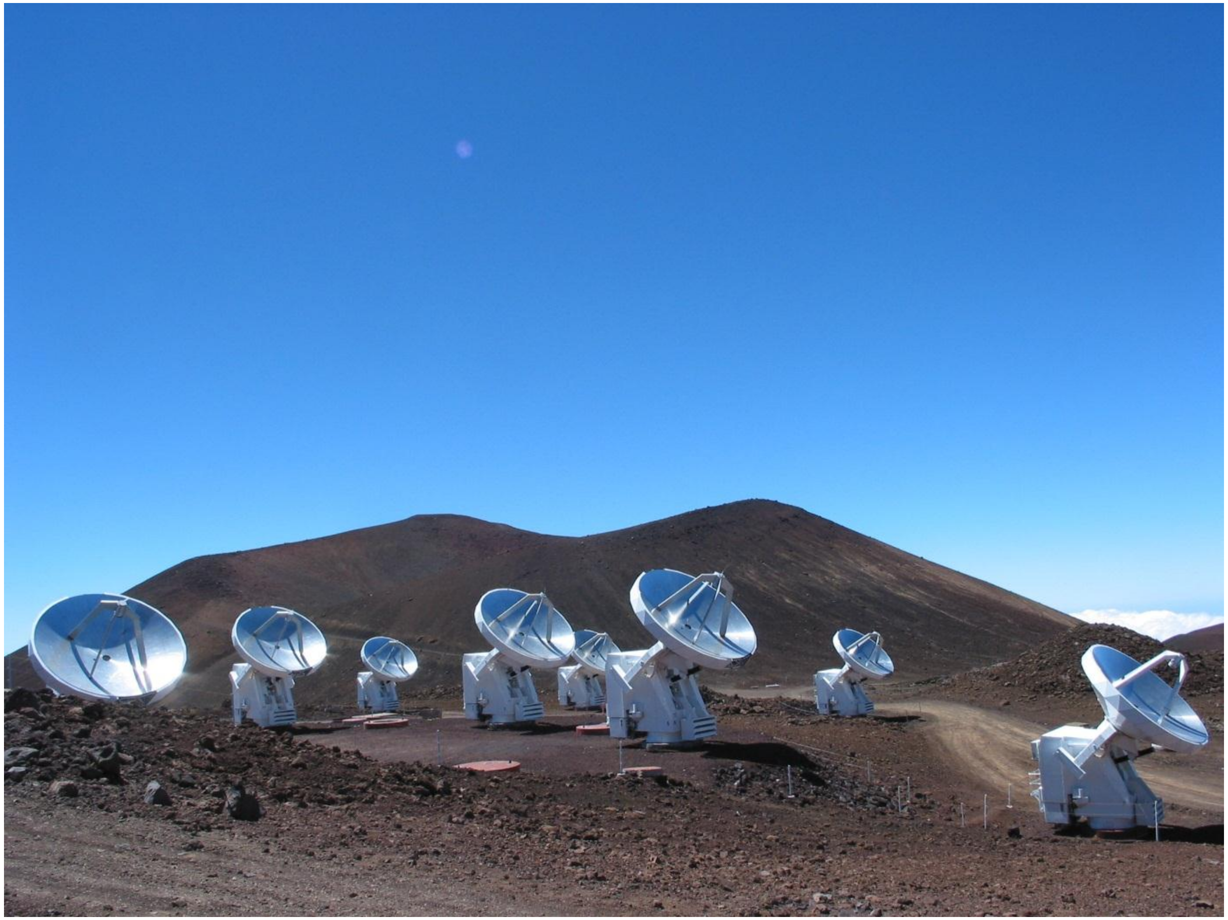
e-SMA

- Has been relatively low priority
- However, joint tests planned for 10, 11 October, 7 November 2006.
- JCMT – refurbished 345 GHz receiver due around November 2006
- CSO – 280 – 420 GHz receiver now available
- Need to plan 2007 program

VLBI

- Maser (SAO built) and Data recording (Mk VB) housed at SMA
- e-SMA fibers to CSO used for reference transmission and data return
- First observing run (CSO and HHT in Arizona) late March 2006
- No fringes yet – probably due to a software problem in correlator.

Active Phase Correction System for the SMA



The SAO/ASIAA Submillimeter Array (SMA)
Mauna Kea, Hawaii

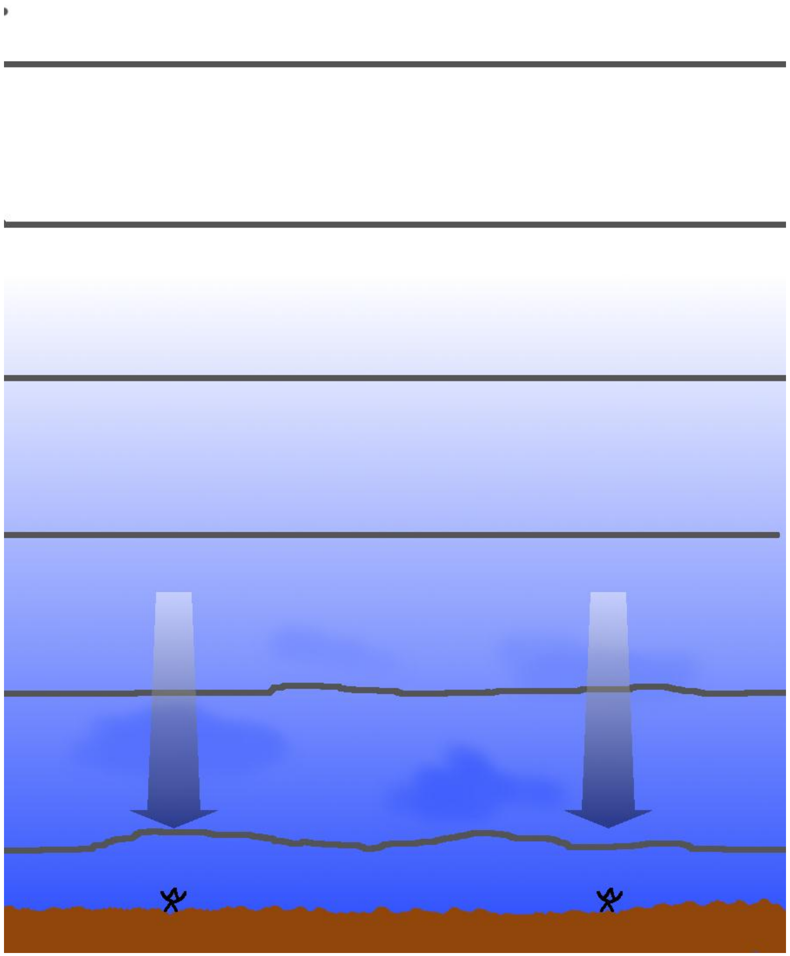
Active Phase Correction System for the SMA

Water vapor causes variable delay, distorting wavefront

Delay is approximately proportional to water vapor column density along boresight

Estimate column density from water vapor emission along each line of sight

From high altitude, 183 GHz line is a good choice for sensitivity, using several channels across line



Active Phase Correction System for the SMA

Prototype WVRs developed for ALMA jointly by Cambridge University and Onsala Space Observatory (R. Hills et al.)

Eight channels across 183 GHz water line

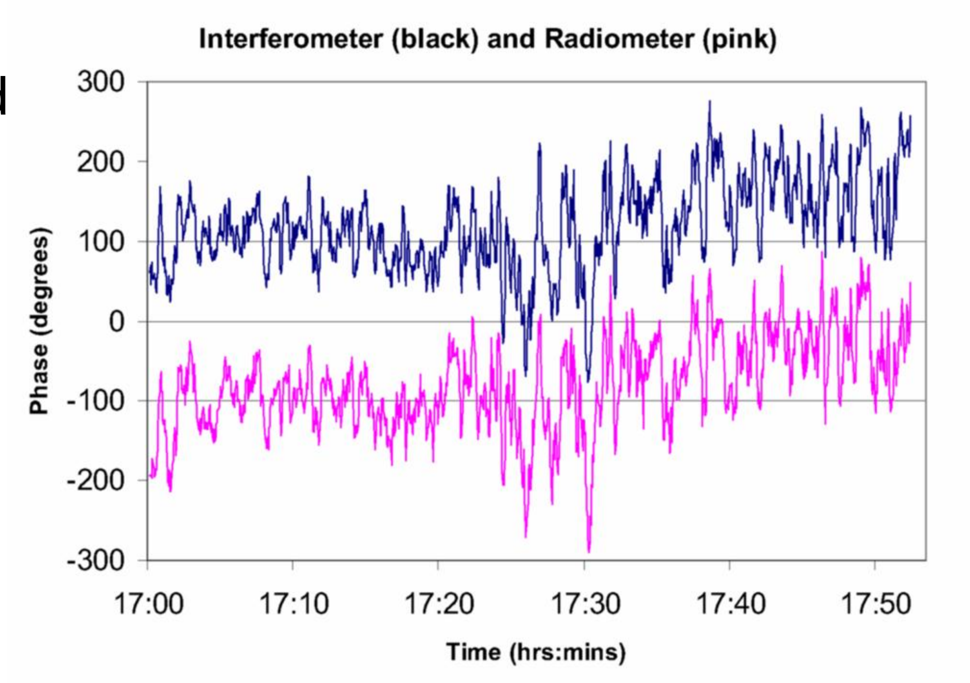
- Cambridge: Sideband-separated correlating radiometer
- Onsala: Dual-Dicke DSB

Installed for tests in two SMA antennas since January 2006

- Coaxial with astronomical beams
- Integrated with SMA software system

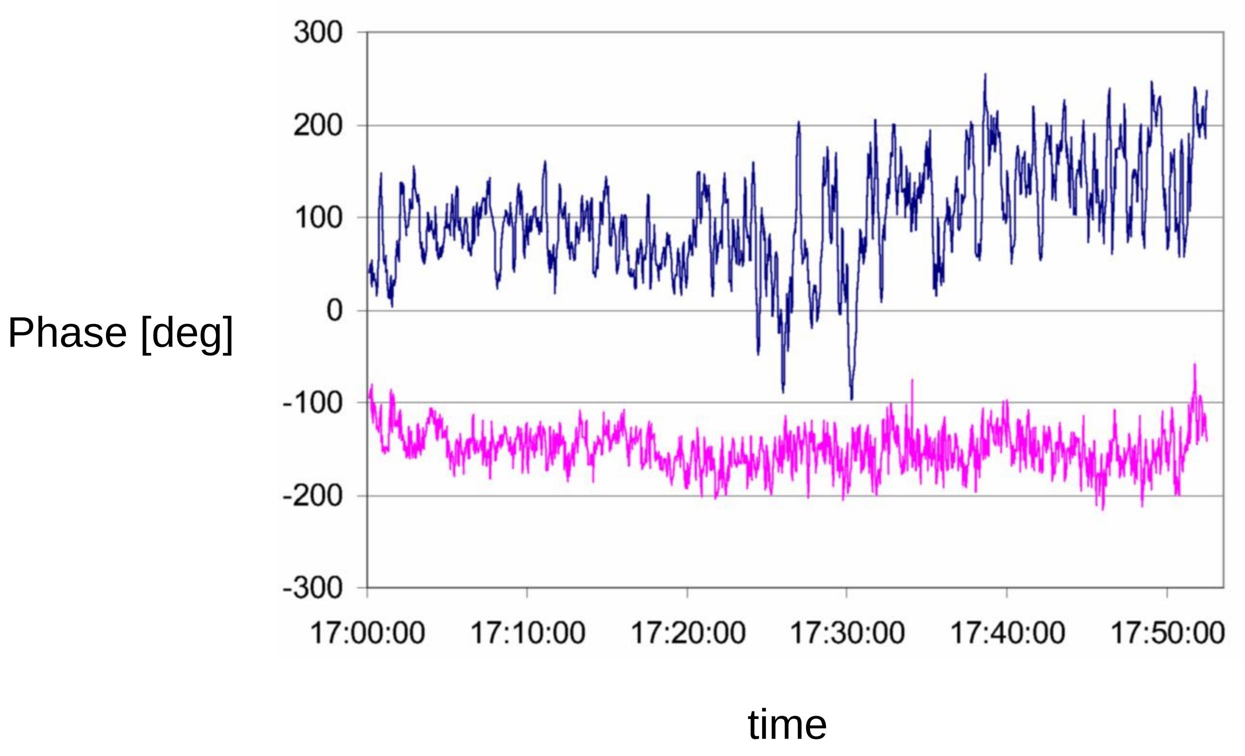
WVR phase vs. SMA phase, Feb 24 2006

- 200 m baseline
- SMA 230 GHz phase derived from bright quasar 3c273, averaged across sidebands
- WVR phase is delay, from pwv estimate, scaled to wavelength
- Special fast (2.5 s) SMA integration cycle



Corrected phase, Feb 24 2006

(Richard Hills, Mike Reid)



Other upgrades/improvements/tests during FY 06

Improved receiver cabin temperature control

Routine operation in the very-extended configuration (500 m baselines)

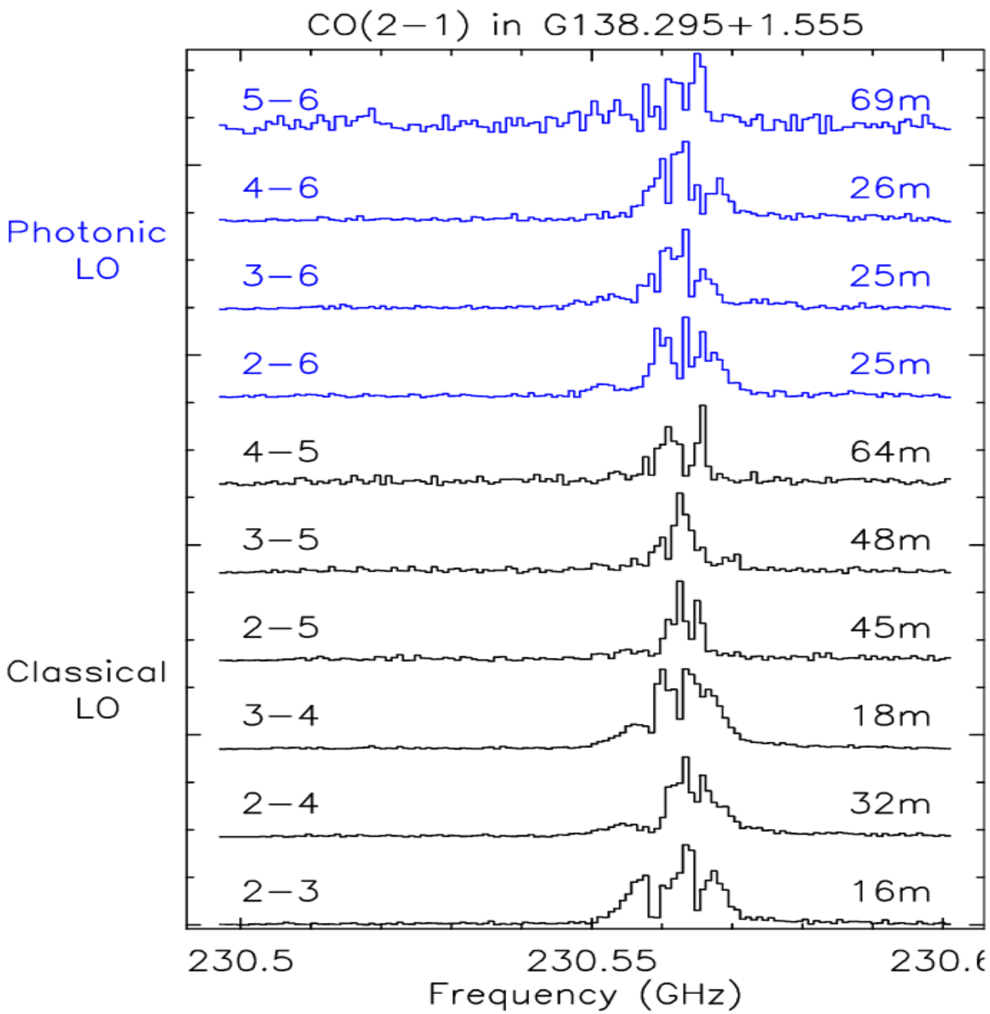
High resolution correlator mode implemented

Side-band rejection improved from -12 dB to -25 dB

Tested photonic local oscillator on one antenna as part of interferometer

Antenna surfaces improved – most now to design goal

Photonic LO Demonstration



CO spectra obtained between pairs of antennas using both Classical (Gunn –multiplier) and photo-mixer LO's
No real difference between the two LO schemes

Good news for ALMA as it will use a photonic LO as a phase reference

SMA Antenna Surface – current status (TKS)

Antenna number	1	2	3	4	5	6	7	8
05 October 2005	22 μm	14 μm	15 μm	18 μm	20 μm	22 μm	22 μm	21 μm
September 2006	13 μm	13 μm	17 μm	25 μm	14 μm	16 μm	13 μm	11 μm

Antenna 3 needs to be measured, antennas 4 and 6 need illumination checks before going forward

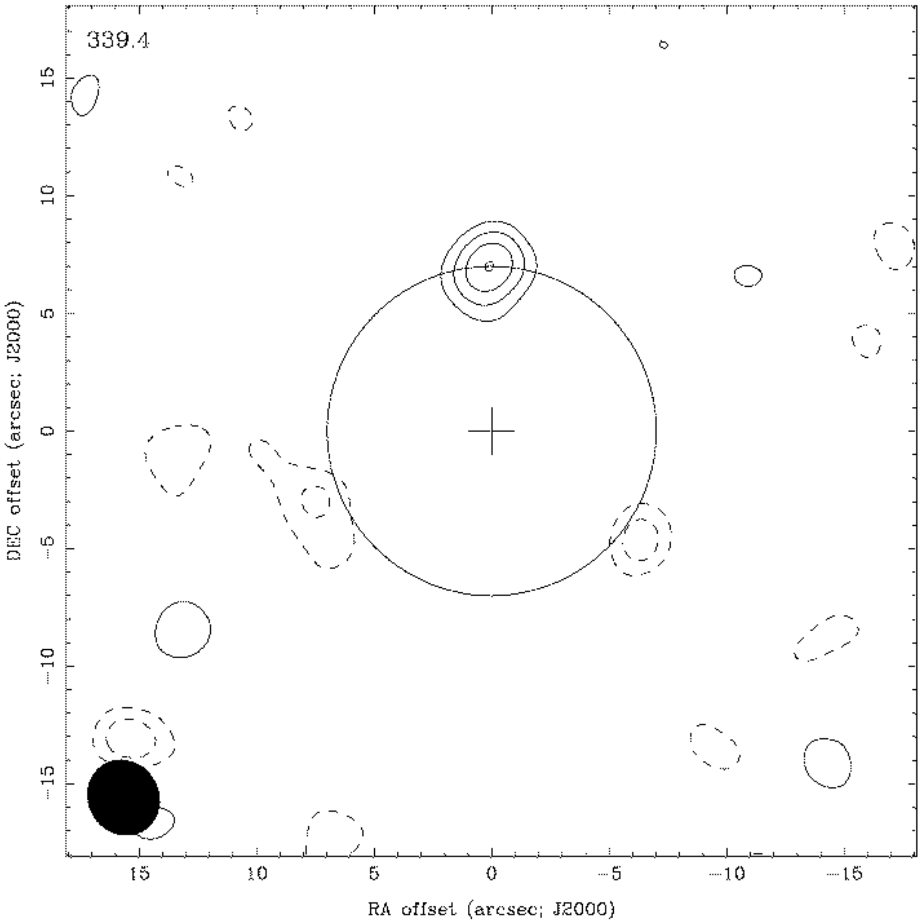
Science impacted by improved SMA capabilities

1. Improved sensitivity across the 300 GHz band
   – SXDF850.6 (Iono)
     2 tracks detect 8 mJy SHADES source, coincident with radio source

2. High resolution correlator modes (0.065 kms^{-1})
   – Oph A (Bourke, Myers)
     N_2D^+ line, starless core filamentary structure

3. Very extended configuration sub-arcsecond resolution
   – CO (2-1) in NGC253 (Sakamoto)
     Starburst galaxy with remarkable molecular gas structure
   – GM Aur disk (Wilner)
     349 GHz continuum shows hole in protoplanetary disk
   – High resolution image of Uranus (Gurwell)

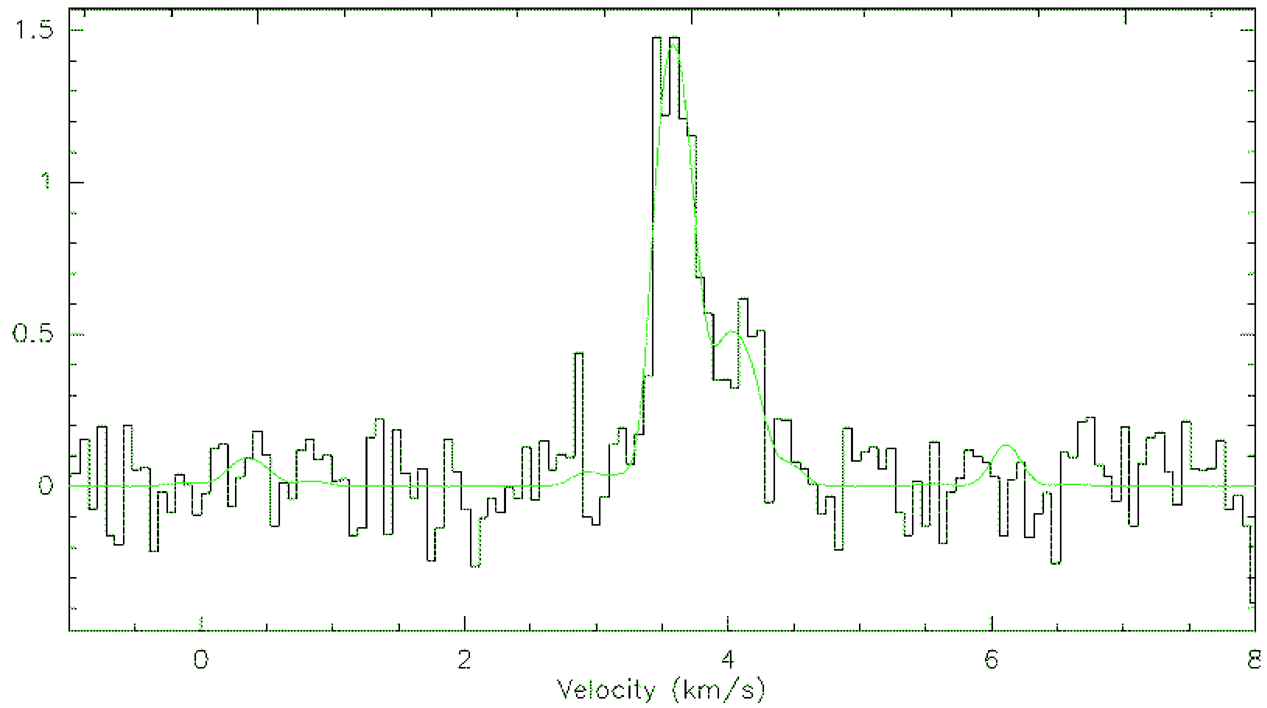
8mJy SCUBA Galaxy (Iono, Peck, Dunlap et al.)



8mJy SHADES source
Detected with SMA at
Same position as
Radio source

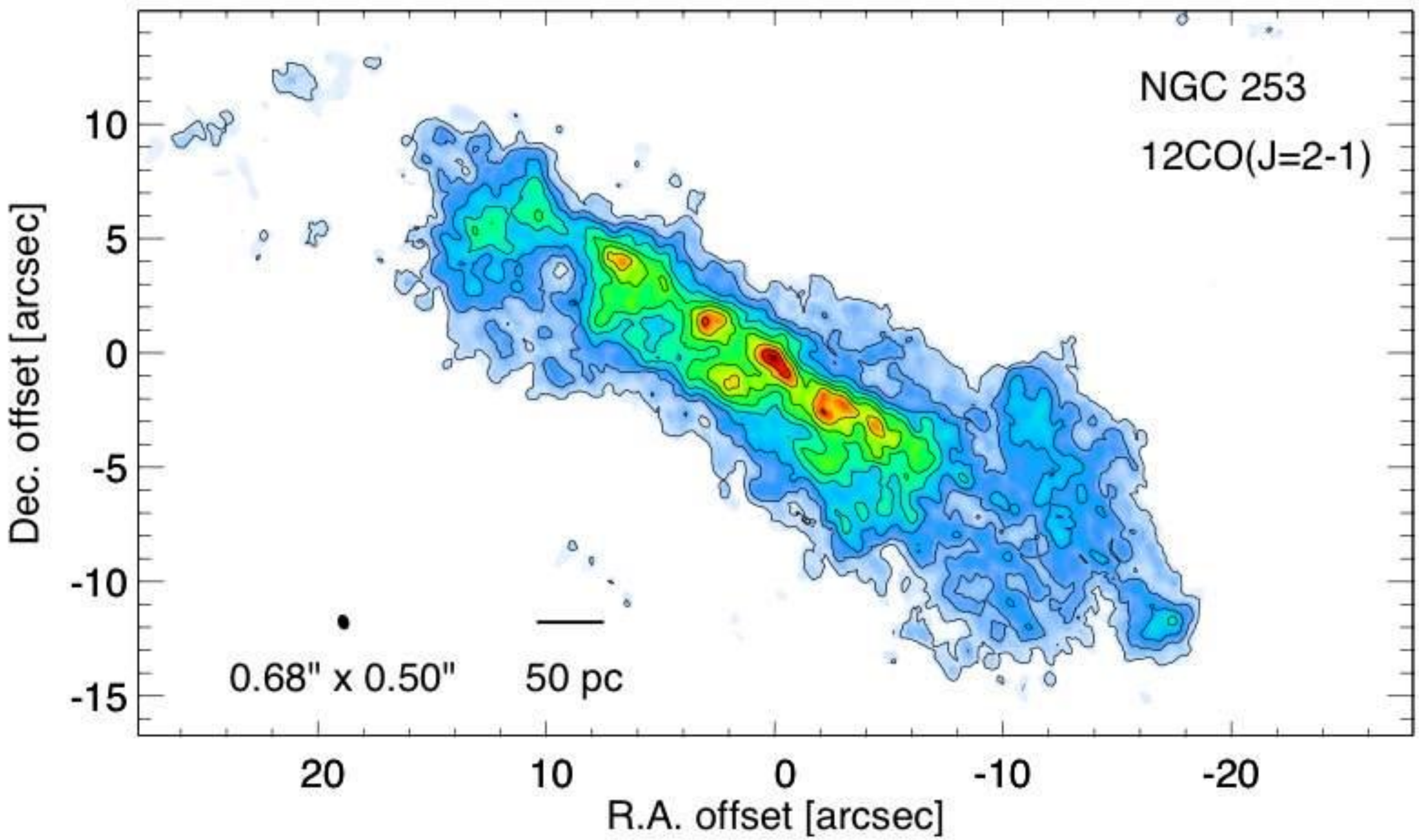
However, several other
attempts at detecting
submillimeter galaxies
have produced non-
detections

OphN6 Starless Core in Cluster Environment (Myers, Bourke)



Brightness temperature spectrum of the N_2D^+(3-2) line at peak position (K) using new high spectral resolution capability of 50 kHz (0.065 kms^{-1}).
Best-fit LTE model has FWHM line width 0.25 kms^{-1}. (subsonic)
The line asymmetry is due primarily to hyperfine structure.

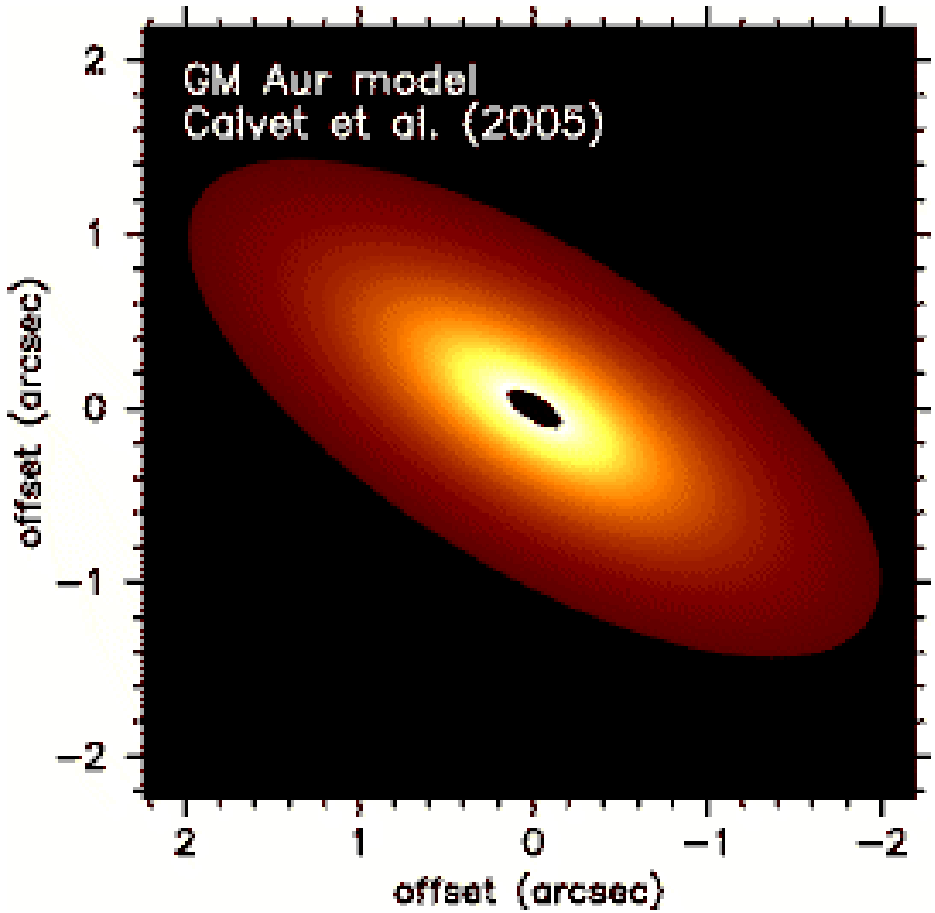
Starburst ISM at 10 pc resolution : NGC 253



Subarcsecond image of molecular gas in NGC 253 -- one of the prototypes of starburst galaxies.

credit : SMA observations by Sakamoto et al. (2006, in prep.)

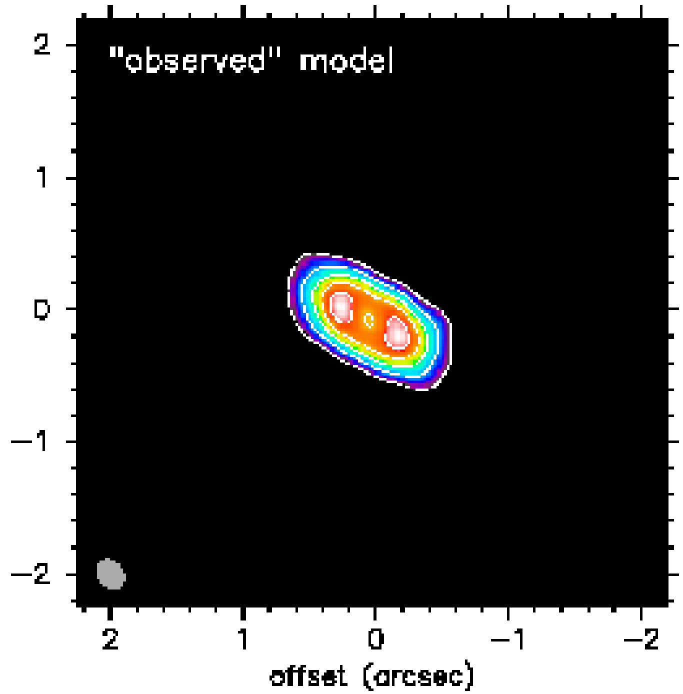
GM Aurigae Protoplanetary Disk Inner Hole (Wilner)



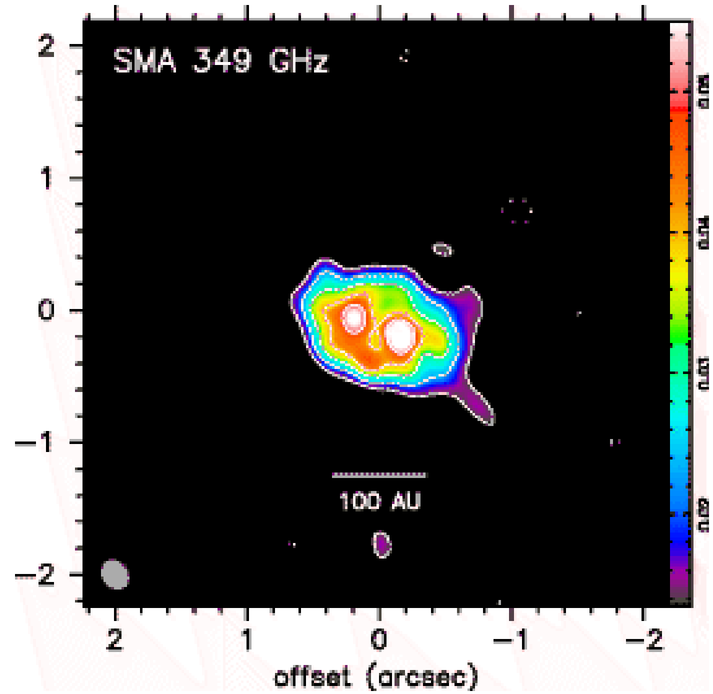
Calvert: Spitzer observations show signs of clearing in the inner disk of GM Aur.

Model fit: optically thick outer disk directly exposed to stellar radiation and an inner region with small amounts of dust to render it optically thin.

GM Aurigae Protoplanetary Disk Inner Hole (Wilner)



What the model predicts for SMA observations of GM Aur



What we see with the SMA Resolution 0.2x0.3 arcsec

Big projects starting to show results

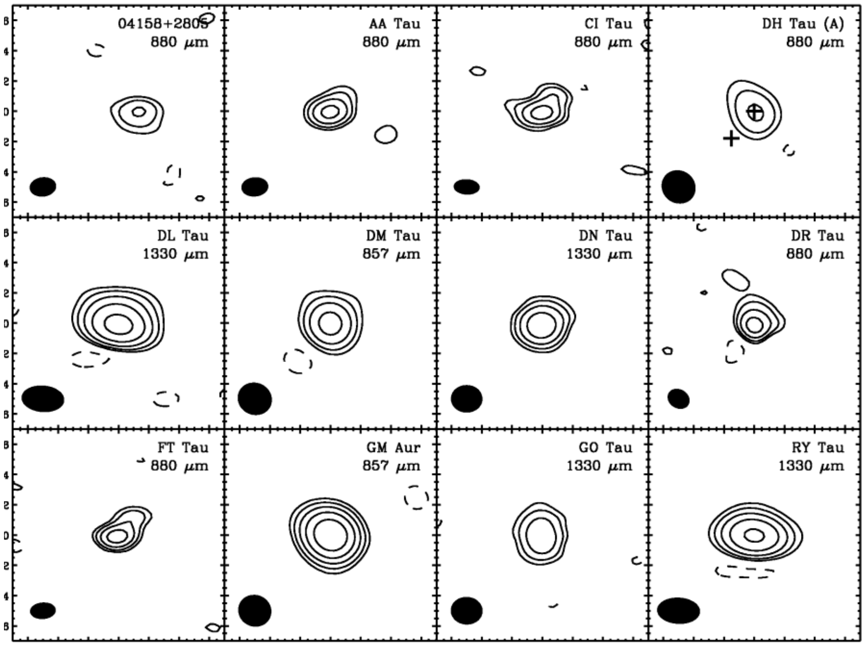
1. Structure of circumstellar disks (Andrews) IfA Ph.D. thesis
   24 sources, mostly continuum

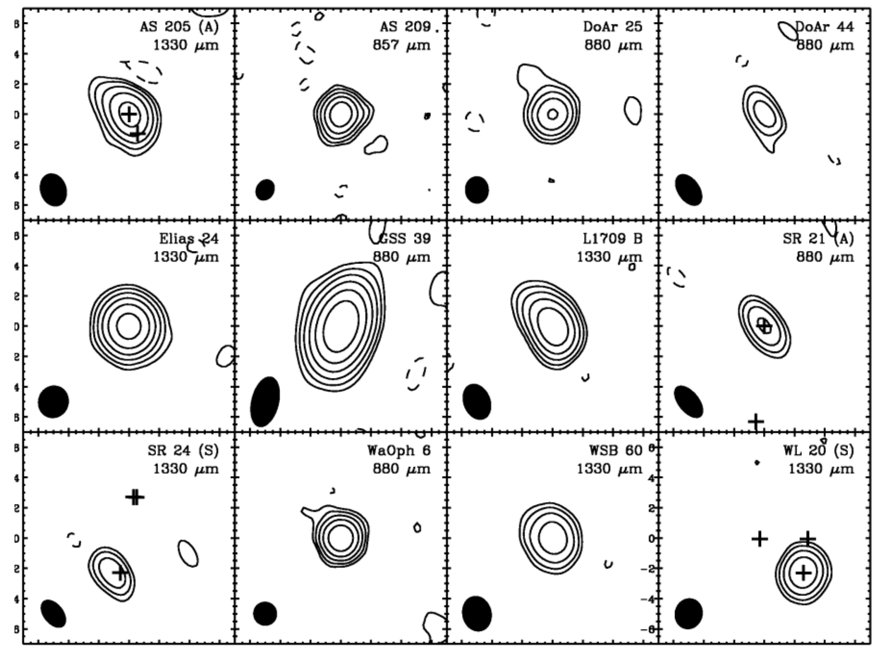
2. ULIRG Legacy Project (C. Wilson)
   Image gallery of galaxies with CO emission

3. SMA survey of low-mass protostars (Jorgensen, Myers)
   8 Class 0 protostars, continuum and several spectral lines

4. SgrA* (Marrone, Moran) Harvard Ph.D. thesis
   Latest Rotation Measure, accretion rate, and variability

Protoplanetary Disk Survey (Sean Andrews, IfA)

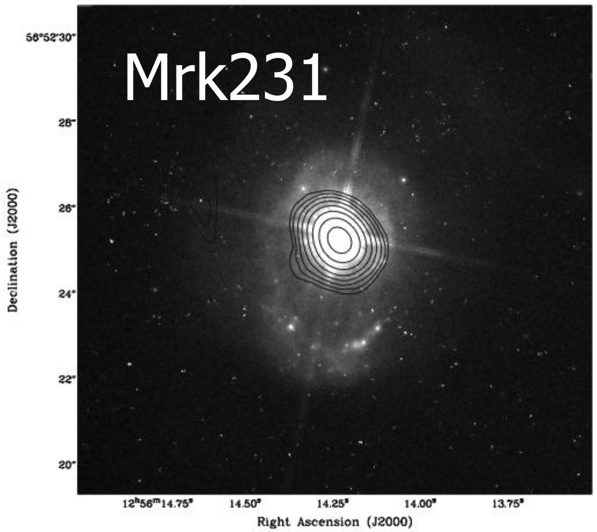


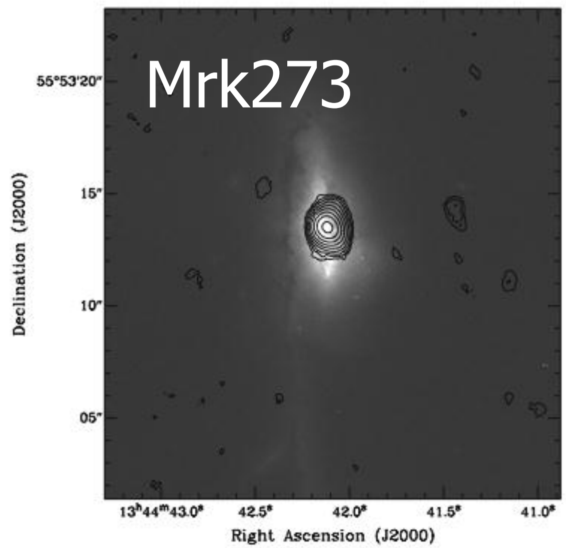


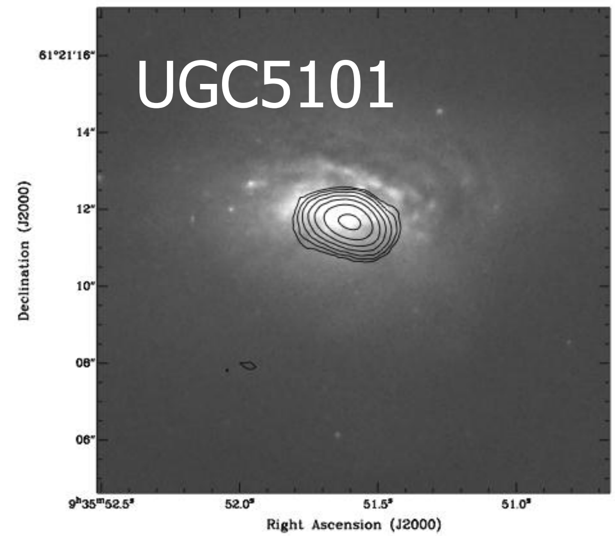
GM Aur

studied in detail by Wilner 5x resolution

Warm, dense molecular gas traced with carbon monoxide emission (Wilson el al.)

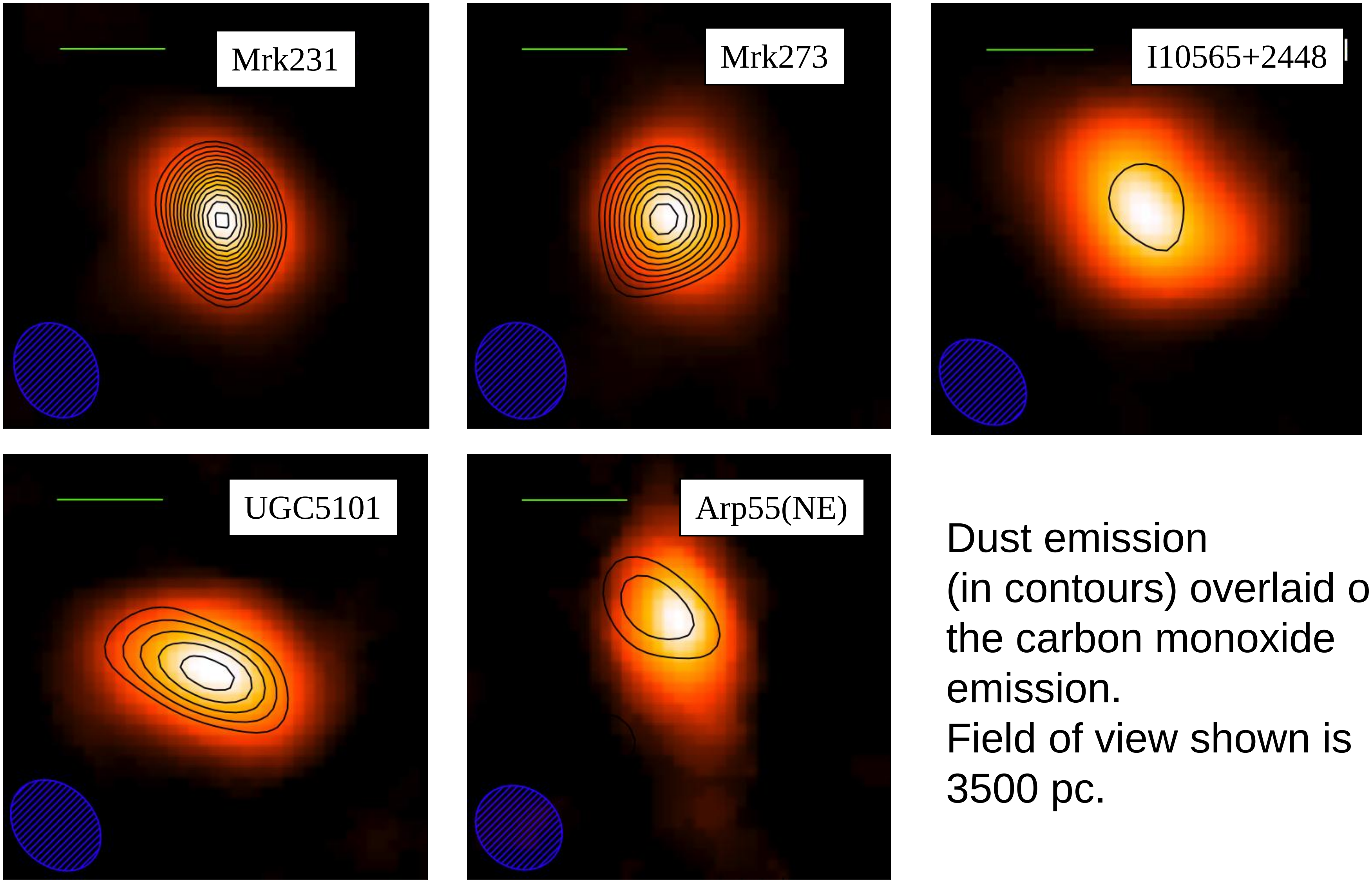






- Studied 12 luminous and ultraluminous infrared galaxies
  - distances less than 600 million light years (200 Mpc)
  - far-infrared luminosities greater than 10 times the total luminosity of the Milky Way ($L_{FIR} > 2.5 \times 10^{11}\ L_o$)
- Spatial resolution of better than 2500 light years (800 pc)

Cool dust traced with 850 μm emission (Wilson et al.)



Dust emission (in contours) overlaid on the carbon monoxide emission.
Field of view shown is 3500 pc.

The Gas to Dust Mass Ratio (Wilson et al.)

Galaxy	M_{dust} (10^7 $M_\odot$)	M_{H_2} (10^9 $M_\odot$)	Gas/Dust Ratio
Mrk231	4.43	4.13	93
Mrk273	3.26	5.10	156
10565+2448	1.27	3.10	244
UGC5101	3.45	2.66	77
Arp55(NE)	1.79	1.18	66
Arp55(SW)	<0.75	0.65	>87

Average gas/dust ratio = 120 +/- 30 (in agreement with Milky Way)

Suggests we are determining the gas masses correctly in the central regions where all the action is

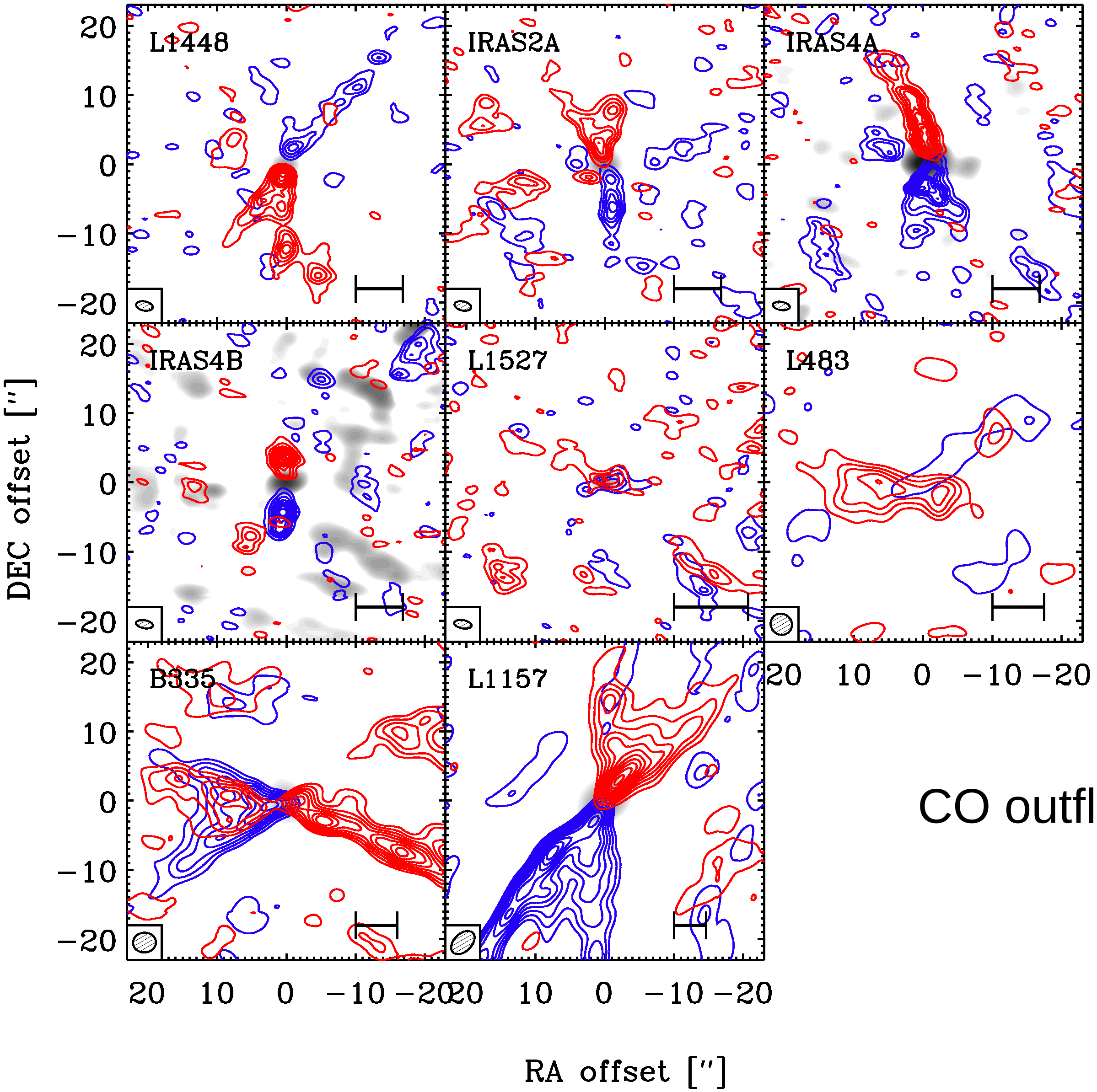
Important because the gas provides the fuel for the star formation and black hole accretion activity

SMA survey of low-mass protostars (Joergensen)

- Spectral line and continuum survey of 8 low-mass protostars
- Submillimeter needed to probe deep into protstellar envelopes
- Lower frequency interferometry sensitive to outer envelope
- Single dish instruments don't have enough spatial resolution
- Project well-suited to the SMA
- Study dynamical structure, excitation conditions, and chemistry
- Warm dense gas studied at high angular resolution 1-3 arcsec
- Observe high excitation lines of most common molecular species
- Can observe CO HCO^+ CS SO H_2CO CH_3OH and SiO in just 3 tunings

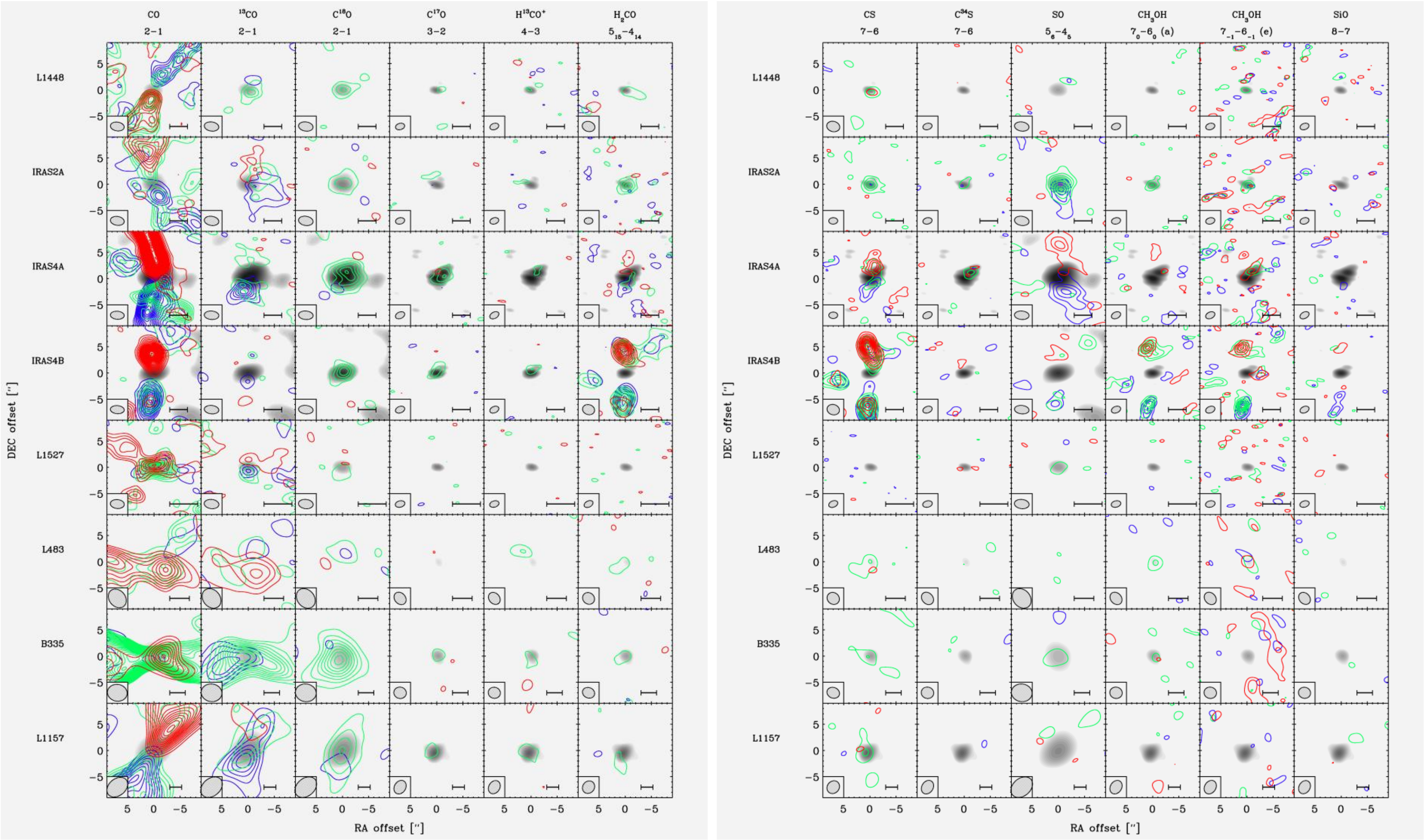
- Prominent highly collimated outflows present in CO 2-1 in all sources
- Compact continuum emission seen in all sources
- Shocks present on all scales

SMA survey of low-mass protostars (Joergensen)

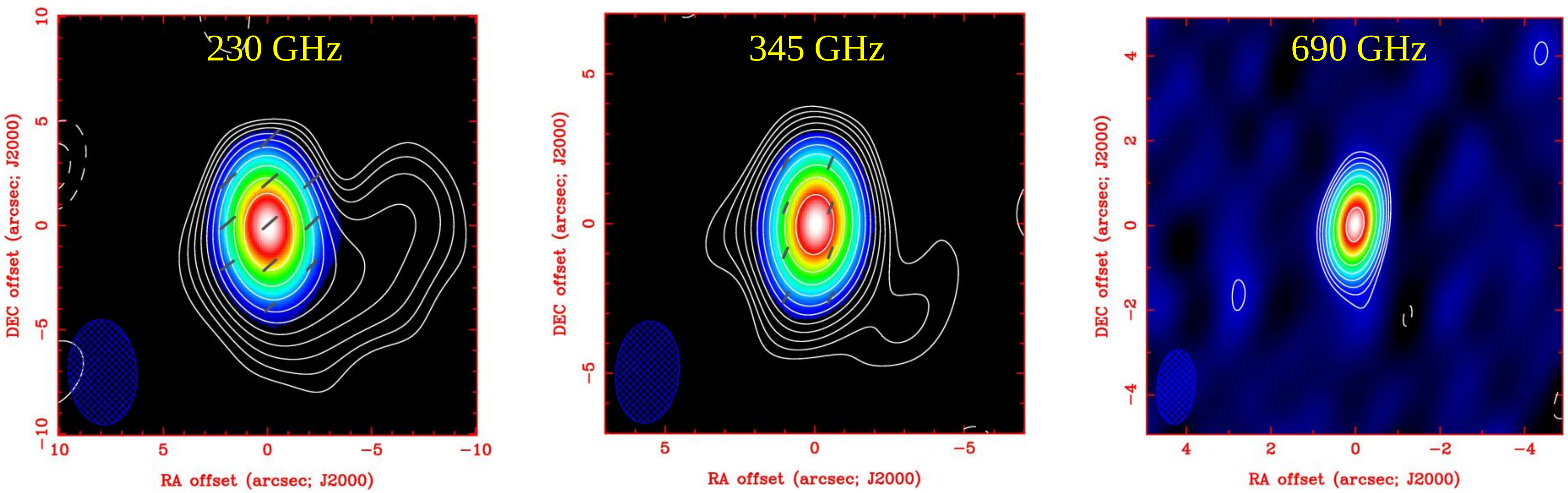


CO outflows

SMA survey of low-mass protostars (Jοergensen)



Submillimeter Properties of Sagittarius A*: Polarization and 230-690 GHz Spectrum & the SMA Polarimeter



Dan Marrone
Harvard University
August 31, 2006

Conclusions and Future Work (Marrone)

- Unambiguous measurement of Faraday rotation caused by accretion disk associated with SgrA*
  - Determined accretion rate of 10^{-7} to 10^{-9} M_{Sun}/yr
- Also measured intraday variability in intrinsic polarization
- SMA polarimetry now possible from 230 to 690 GHz:
  - Well-sampled light curves show complex LP variability
  - Flares suggestive of orbiting spots observed
- 690 GHz polarimetry
  - Will confirm RM through large 230-690 GHz PA difference (50º)
- Comparisons with other wavelengths
  - Flare finally caught in many bands, analysis beginning
- Future dual band measurements should enable variations in accretion rate to be observed (real time)
  - Possibly Track periodic events in inner accretion disk
  - May lead to measurement of the black hole spin

Some nice images and other science with the SMA
All well-matched to SMA's capabilities

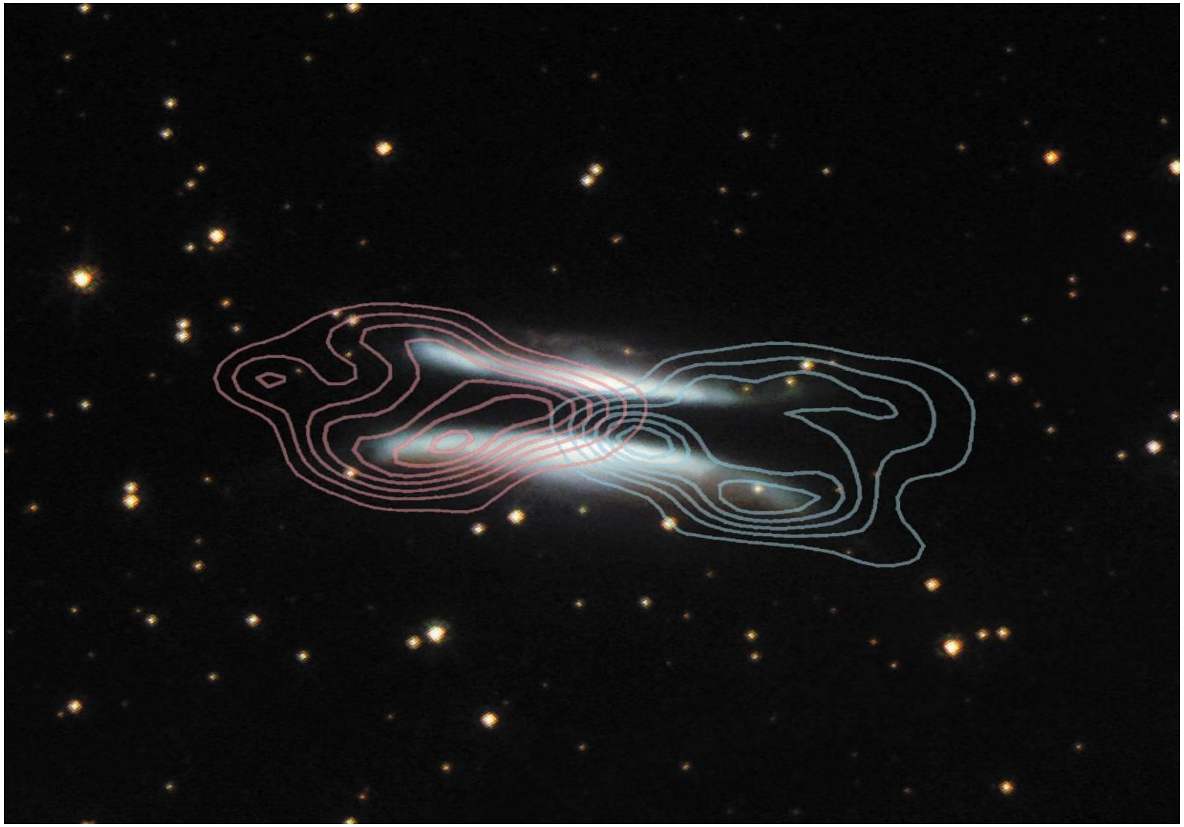
1. Gomez's Hamburger (Bujarrabal, Fong)
   Beautifully resolved evolved star envelope Keplerian disk

2. Massive protocluster (Zhang)
   Chemical variations

3. Massive protoclusters (Hunter)
   A forest of lines in twin hot cores

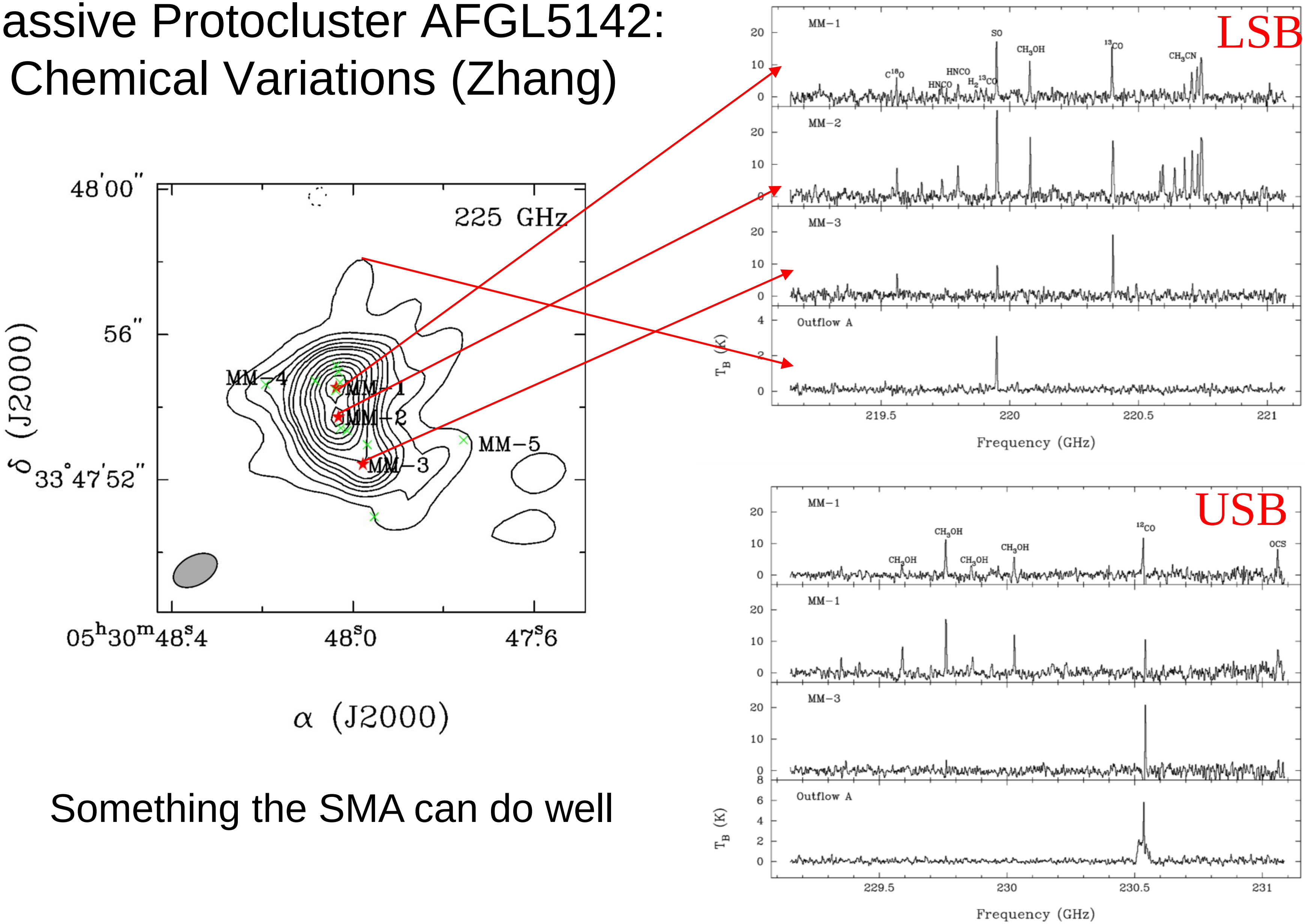
4. Planetary science (Gurwell)
   High resolution image of Uranus

Gomez's Hamburger (Bujarrabal)



CO 2-1 reveals beautiful rotating disk in Proto-Planetary Nebula

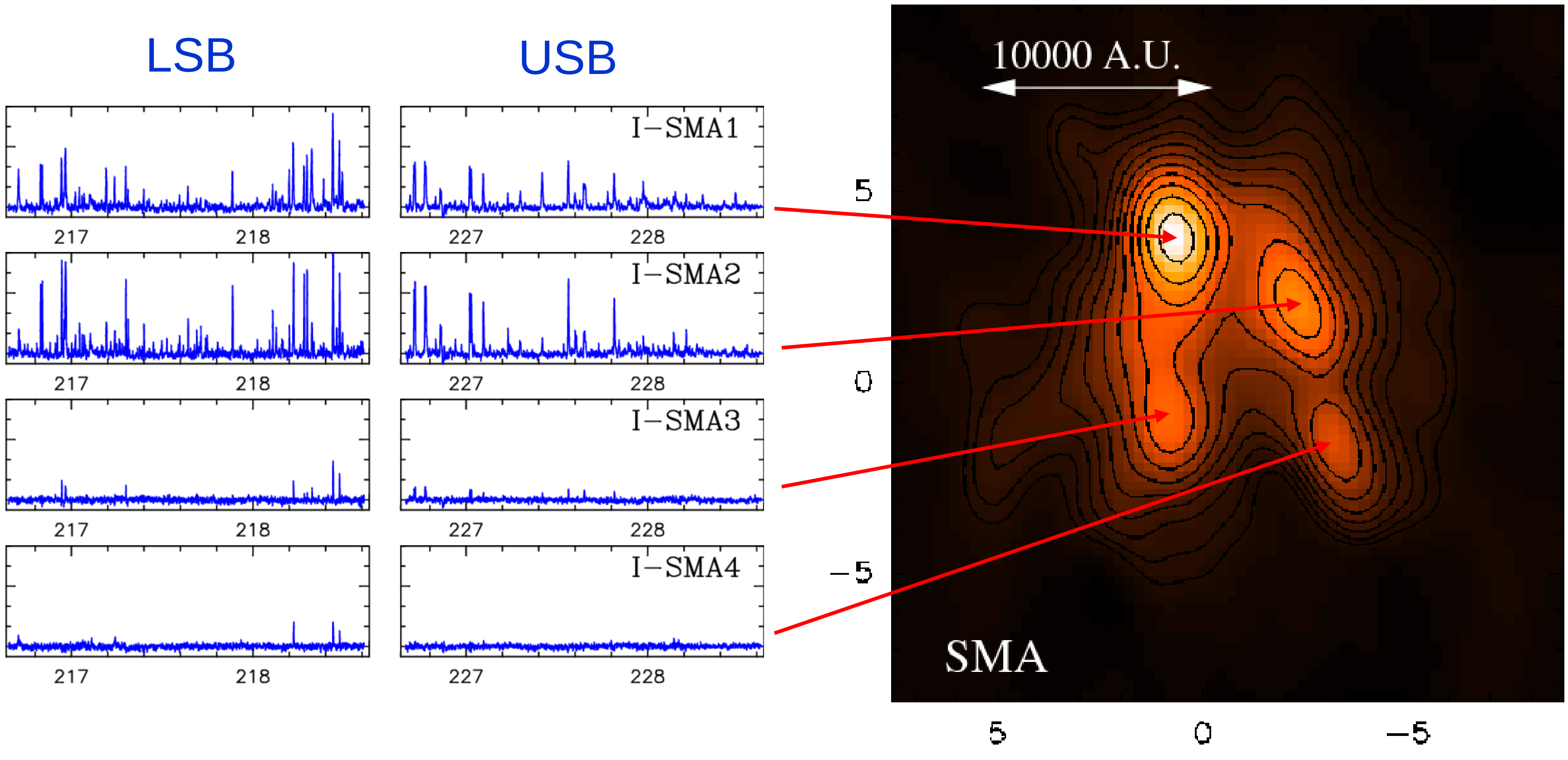
Massive Protocluster AFGL5142: Chemical Variations (Zhang)



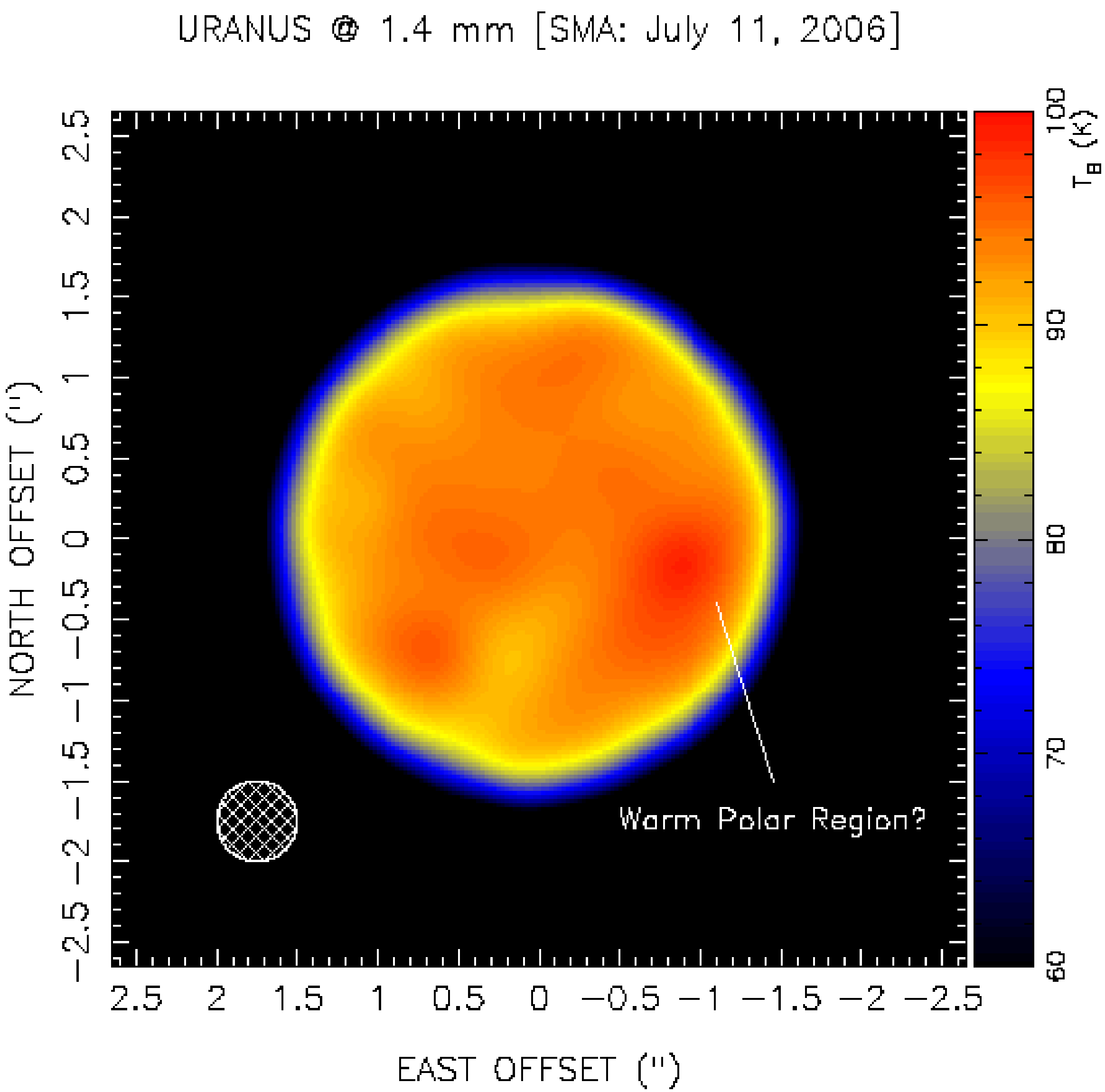
Something the SMA can do well

SMA spectra of the dust cores (Hunter)
NGC6334I

Twin hot cores with prodigious line emission (~100 features)
Line-to-continuum ratio ~ 30%
UCHII region shows very little line emission (23 features)
Fourth source has essentially no lines (T<30K)



High resolution image of Uranus (Gurwell)



Proposal statistics November 1 2005 – April 30 2006

	CfA	External	Total
• Star-formation	17	14	31
• Extragalactic	14	10	24
• Stellar	6	3	9
• Planetary	2	0	2
• Galactic center	1	0	1
• Other	0	1	1
• Total	40	28	68

Proposal statistics May 1 2006 – October 31 2006

	CfA	External	Total
• Star-formation	28	16	44
• Extragalactic	12	10	22
• Stellar	3	3	6
• Planetary	3	1	4
• Galactic center	2	1	3
• Other	1	0	1
• Total	49	31	80

Proposal statistics November 1 2006 – April 30 2007

	Total	CfA	External
• Star-formation	36		
• Extragalactic	21		
• Stellar	9		
• Planetary	0		
• Galactic center	1		
• Other	1		
• Legacy	3		
• Total	72	40	32

Oversubscribed by 3:1 (2.5:1 CfA, 4.7:1 External)

Productivity and Impact of Radio Telescopes
Virginia Trimble and Paul Zaich

Publications of the Astronomical Society of the Pacific, 118: 933–938, 2006 June 2006.

Papers from 2001, citations from following three years
Millimeter and Submillimeter Facilities

	Papers	Citations
IRAM interferometer	10.5	212
Owens Valley Radio Observatory	21.1	282
Berkeley-Illinois-Maryland Association	23.3	302
Nobeyama interferometer	6.8	34

SMA

2003	1
2004	18 (special ApJ issue)
2005	11
2006	23 (Jan. through Oct.)

SMA Projects for FY 07

Complete 300 GHz receiver upgrades

Complete installation of 320-420 GHz receivers

Complete upgrades to antennas 7 and 8 (Air handlers, encoders)
(Migrate towards eight-antenna operation)

Install improved calibration systems
(2 temperature loads + automatic λ\4 waveplates in each antenna)

Decide on type of phase correction scheme to implement

Implement true compact configuration

Improve data flow