Smithsonian Astrophysical Observatory
Submillimeter
Array

Report on SMA activities

Ray Blundell

Mauna Kea Users' Committee Meeting

October 2nd, 2008

Outline

- Look back – projects planned for FY 2008
- Current status of planned projects
- A few interesting science results
- Projects planned for FY 2009
- Proposal statistics, metrics

SMA Projects for FY 2008

- Complete installation of 320 – 420 GHz receiver sets
- Improve 650 GHz receiver performance
- Test and field an atmospheric phase monitor
- Double system bandwidth for single receiver operation
- Test and begin installation of phase correction scheme

Current status of planned projects

Complete installation of 320 – 420 GHz receiver sets

- Seven receivers installed, but with poor performance
- Fabrication difficulties continue at JPL
- Test mixer chips for 460 GHz have been fabricated at IRAM
- These offer good performance in the lab at SAO
- Might use these if fabrication issues at JPL continue

Improve 650 GHz receiver performance

- New mixer design completed at SAO
- SIS mixer chips in fabrication at University of Cologne
- Expect delivery of test chips October 2008

Test and field an atmospheric phase monitor

- Two station system working in the lab at SAO
- Performance implies better than 10° resolution at 650 GHz on sky

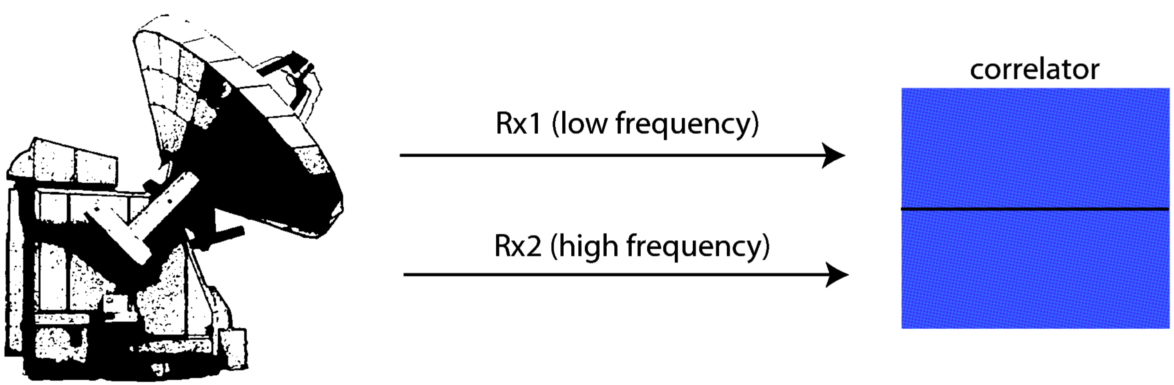
Double bandwidth for single receiver operation*

Test and begin installation of phase correction scheme*

** See next few slides*

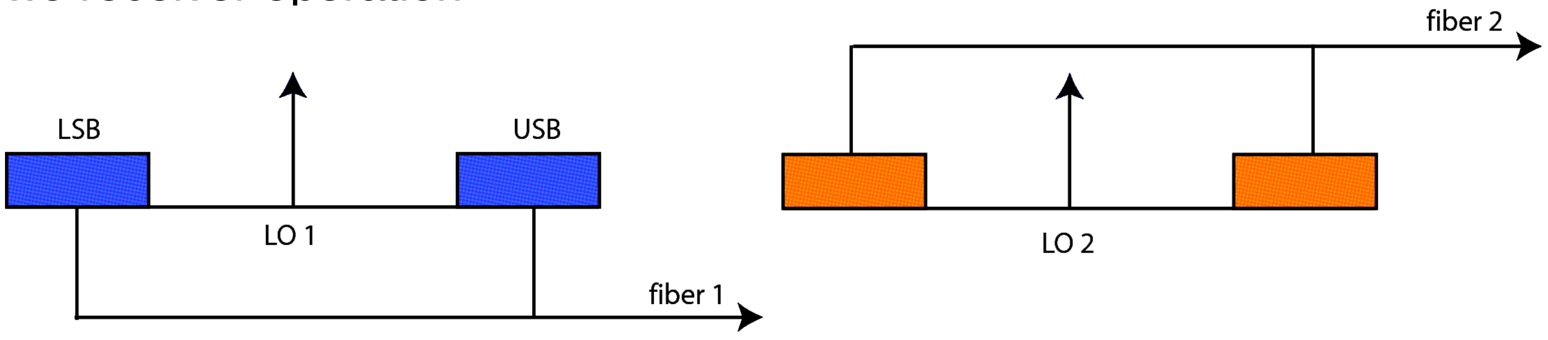
Double bandwidth for single receiver use

- The SMA was originally designed for two receiver operation - one high frequency (>350 GHz), plus one low frequency
- In practice usually use just a single receiver (weather)
- Half of the transmission system and correlator remain idle

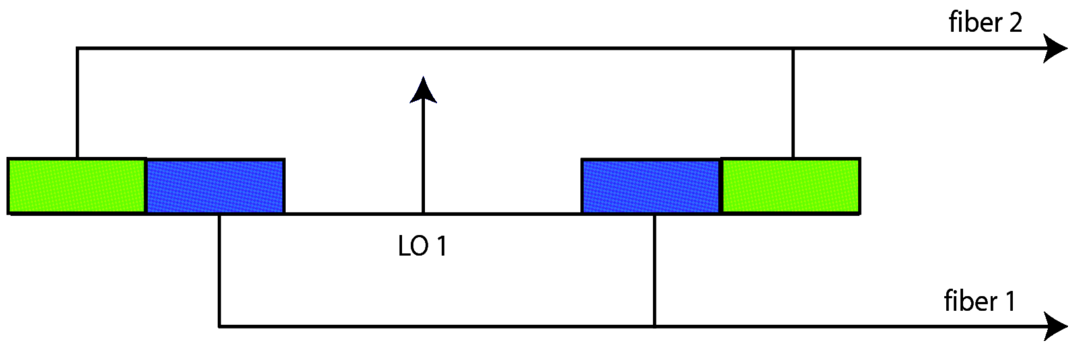


Double bandwidth for single receiver use

Two receiver operation

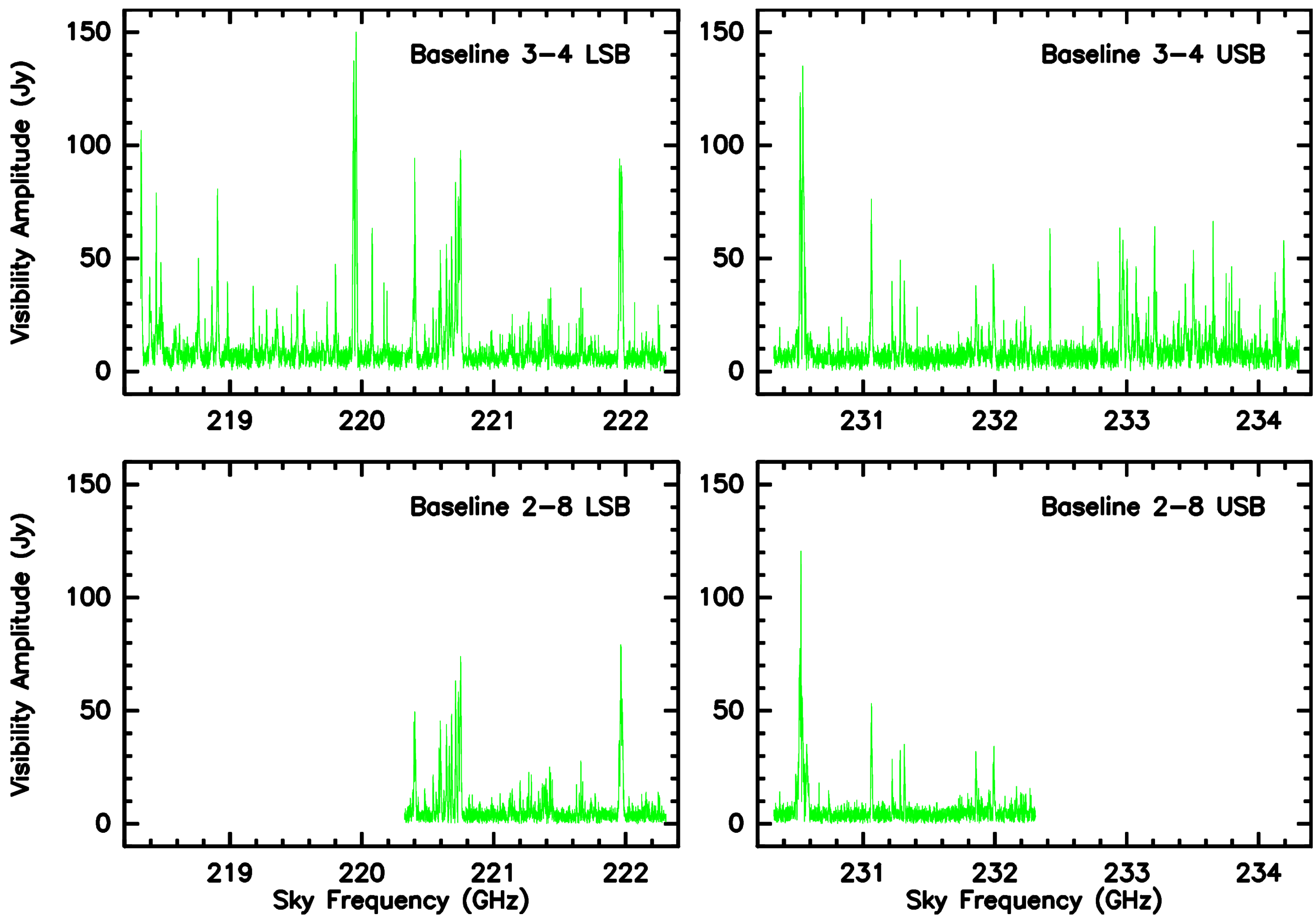


Single receiver, double bandwidth

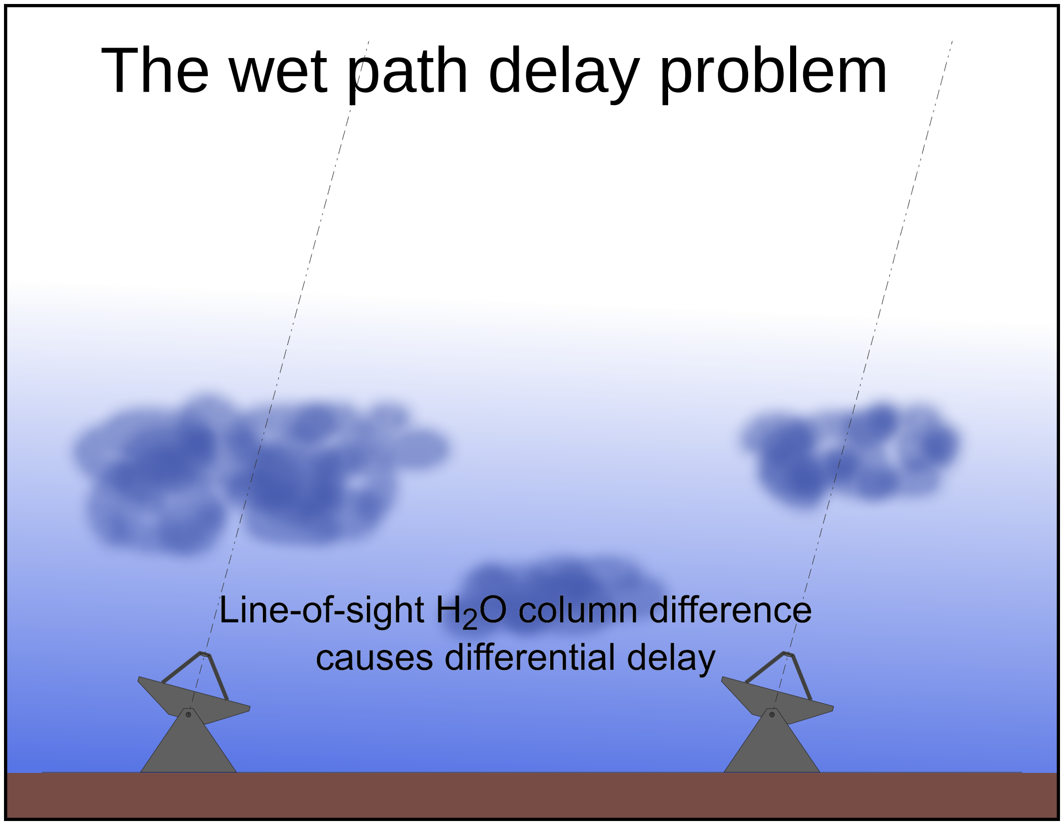


Four antennas currently equipped with BW doubler hardware
All will be equipped by November 2008, ahead of 2008B

Observations using Bandwidth Doubler (Young)



Adaptive optics at the SMA



Example: at 690 GHz (λ=435μm) the excess path is ~ 7*PWV

Complete loss of coherence for line-of-sight ΔPWV of ~ 50 μm

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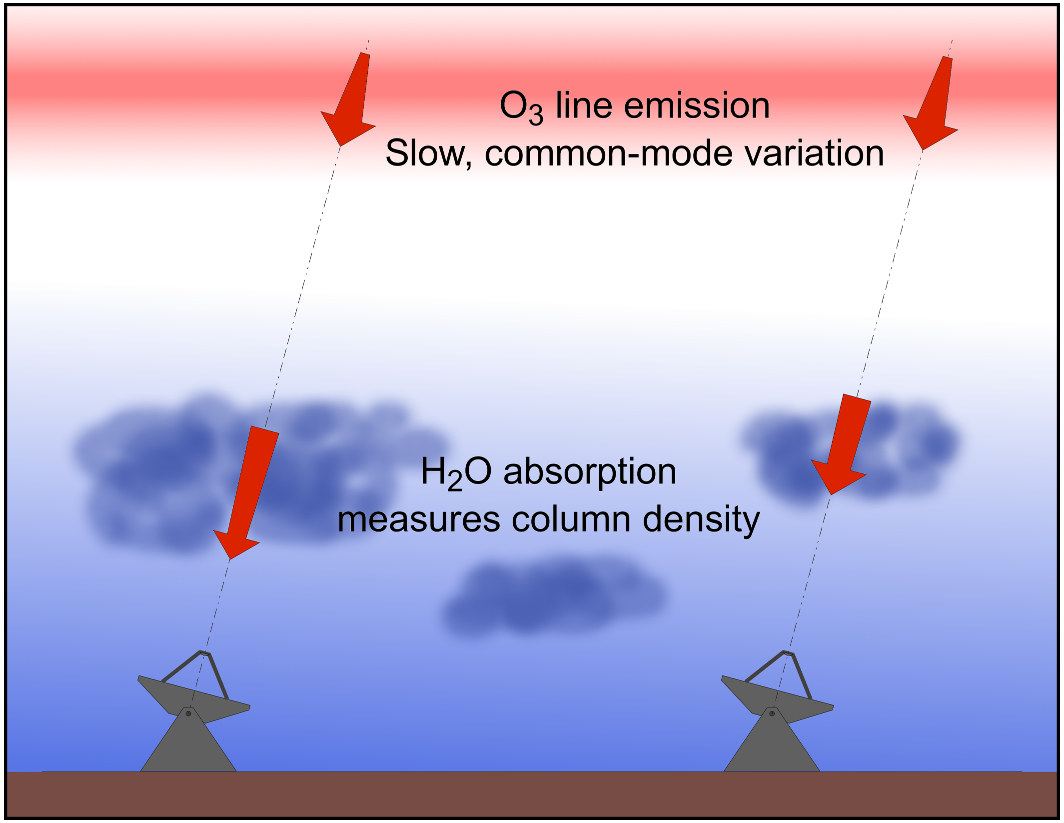
Ozone radiometry (Paine)



Look at ozone line in passband of astronomical receiver in use
Foreground absorption by water vapor reduces line contrast
Line width ~ 100 MHz, fits well within receiver passband

Comparison of phase correction methods

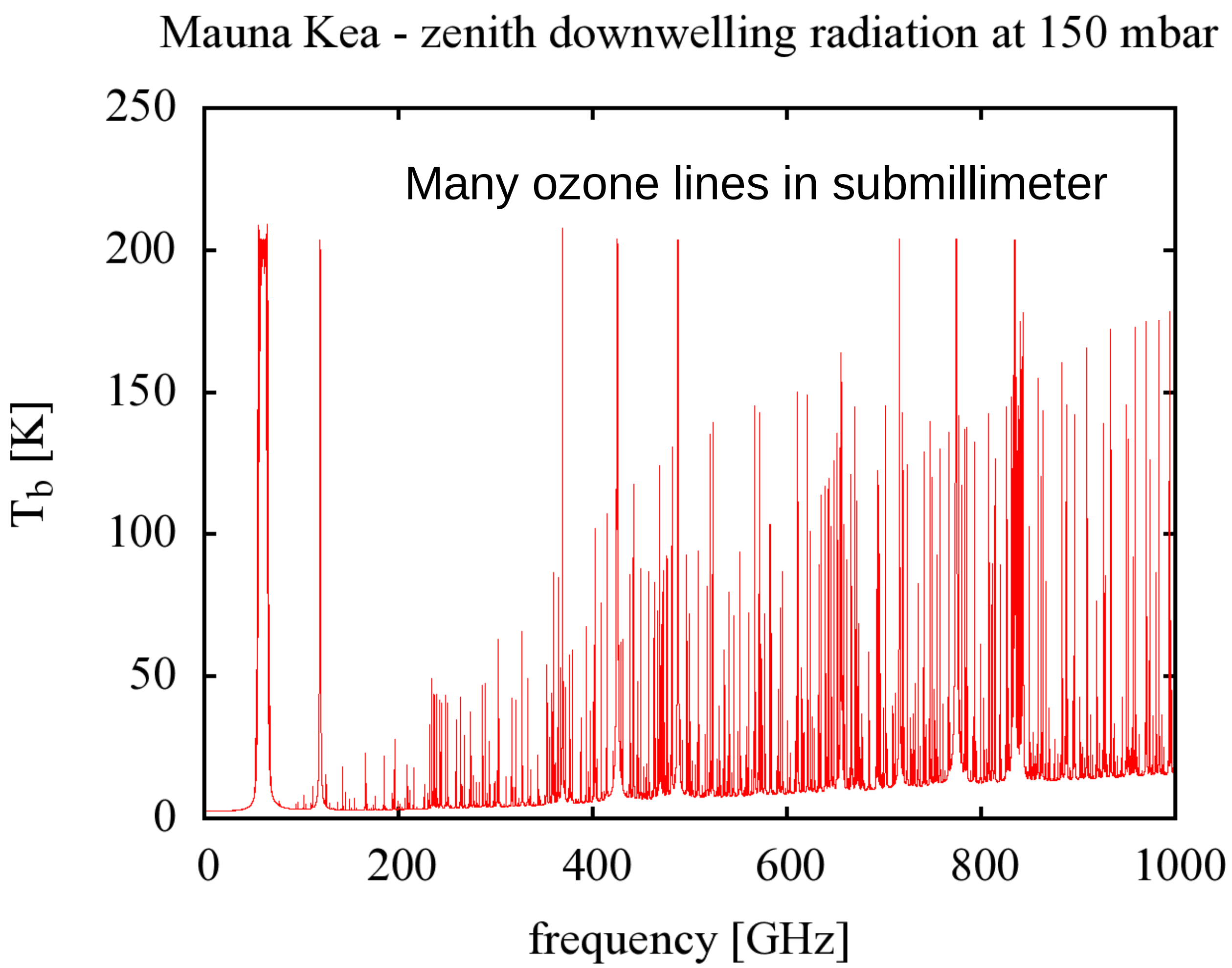
Water vapor radiometry
(Previously tested at SMA with mixed results)

- Measures water in emission
- Broader line offers better inherent sensitivity
- Requires auxiliary dedicated broad band receiver

Ozone radiometry

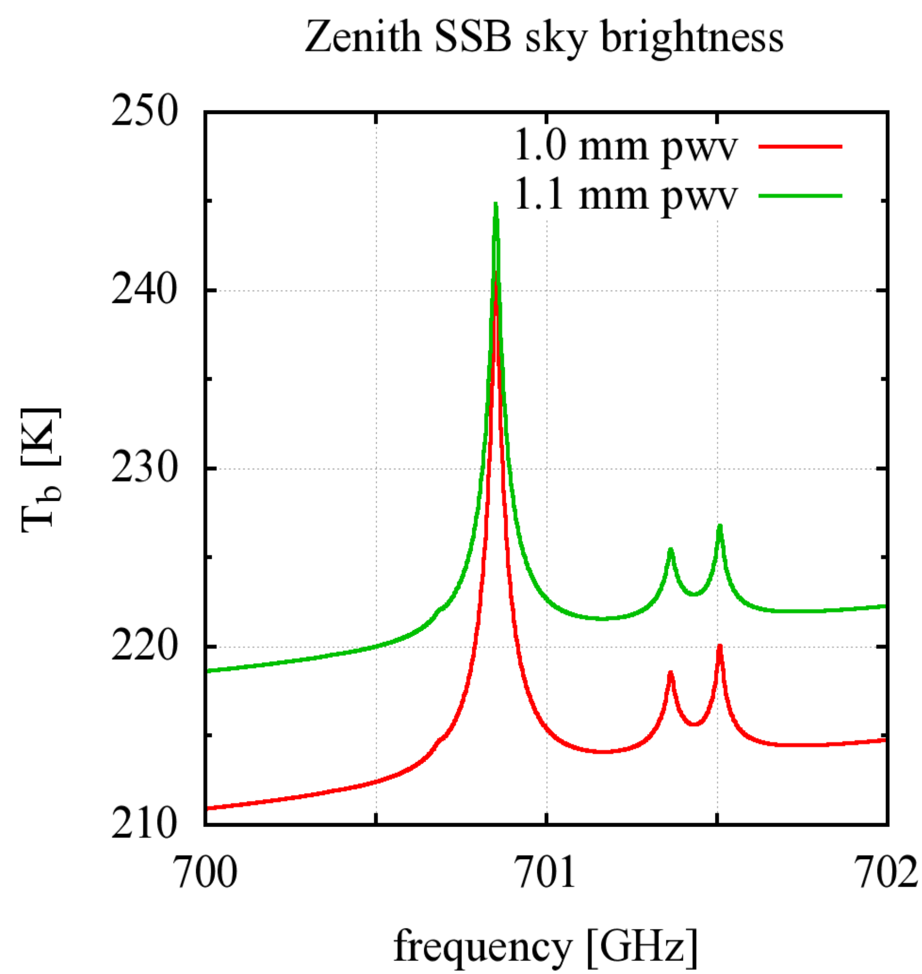
- Measures water in transmission
- Narrower line offers better stability – all analog elements of signal path are common mode
- Uses astronomical receiver in use

Downwelling spectrum at tropopause

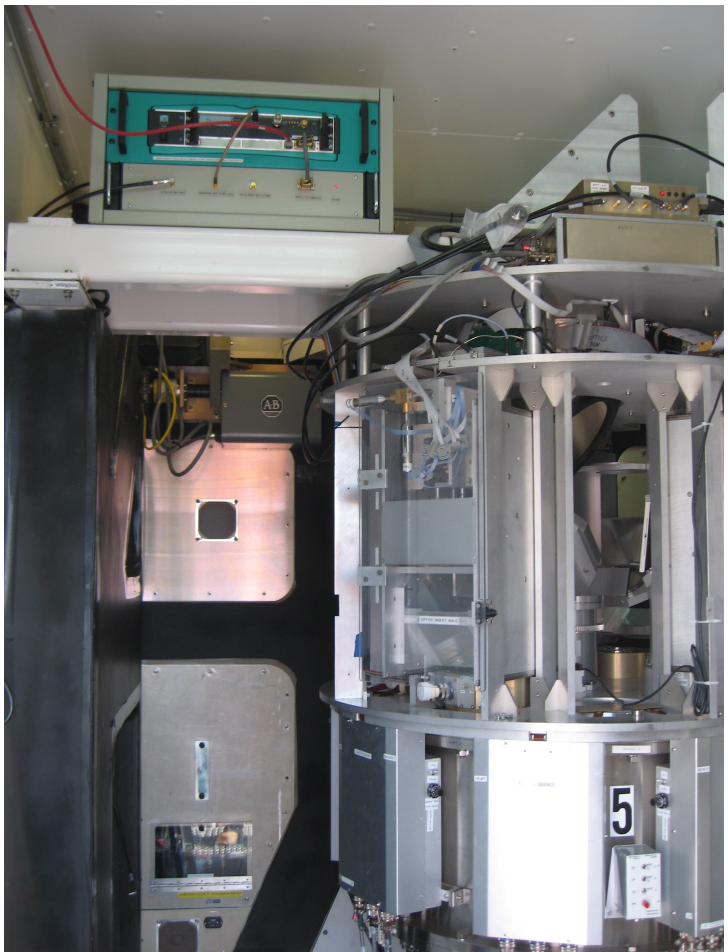


Example – O_3 at 700.9 GHz

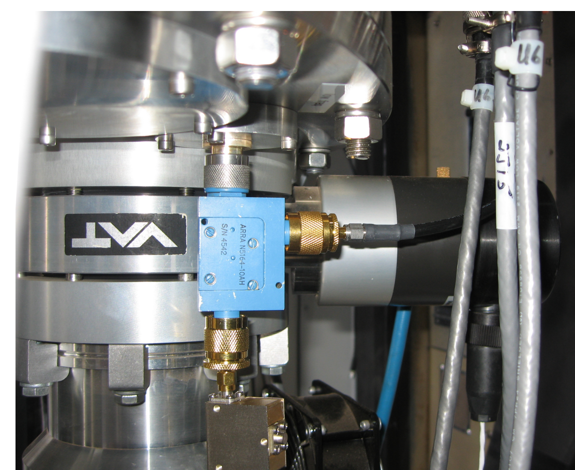
- O_3 line in USB of SMA with CO 6→5 in LSB
- 100 μm pwv change produces 680 μm path change (560° phase change).
- Change in line contrast is 1.1 K DSB, when averaged over 100 MHz equivalent width.
- For T_{sys} = 500 K, t = 2.5 s, 100 MHz bandwidth, ΔT = 32 mK.
- Equivalent sensitivity is 23 μm path change (19° phase change).
- For two-antenna difference, phase sensitivity is 27°, corresponding to 11% loss.



Progress at the SMA

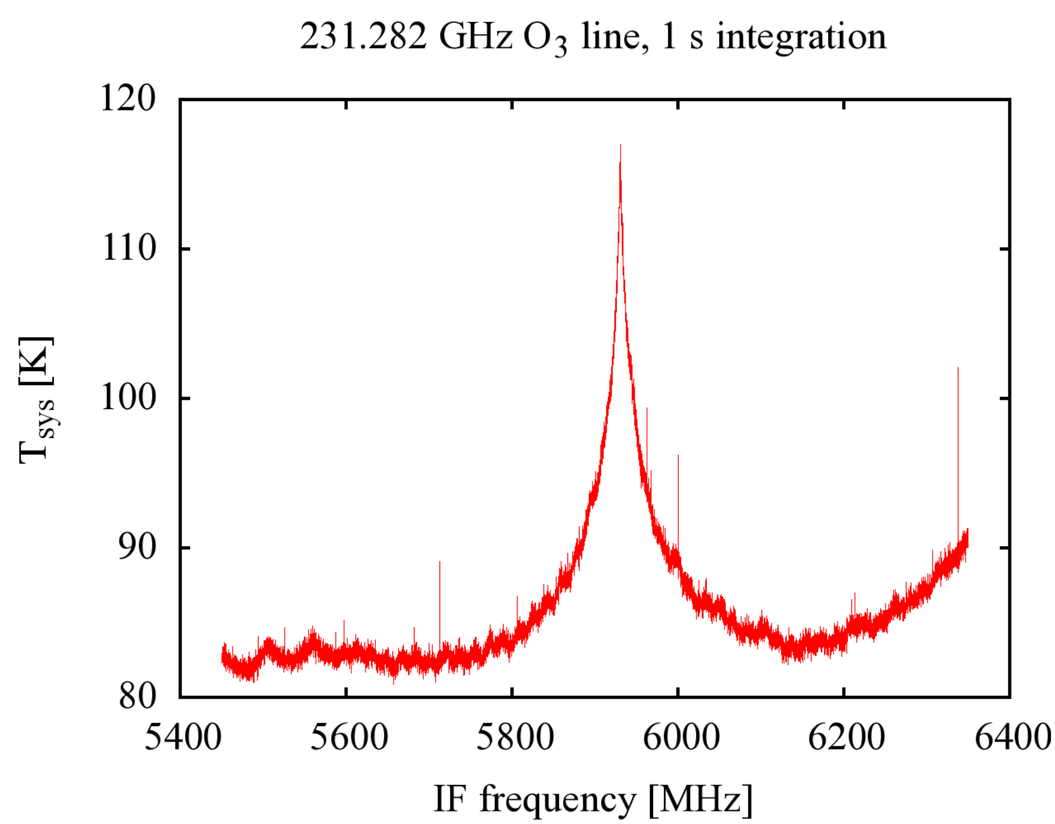


- New dedicated back end fed by IF tap
- 2 Gs / s , 16k channel FFT analyzer (Acqiris AC240)
- 1 GHz spectral window tunable across SMA IF by a programmable downconverter
- Single-antenna tests since January 2008, second system installed June 2008.



SMA O_3 line spectrum using SMA receivers

- 1 s integration, 61 kHz channels, so noise is about 0.4 K / channel at T_{sys} = 100 K
- Note fast uncalibrated baseline ripple from subreflector reflection varies with elevation and focus tracking.
- Also RFI from digital clocks, but affected bandwidth is minimal.
- With an accurate atmospheric model, ripple and RFI which vary slowly in time can be rejected by recursive filtering.



Next Steps

Begin two antenna tests

- Correlation of large-scale fluctuations between near antennas
- Delay correction tests on quasars

Improvements to SMA calibration

Algorithm development

- Track receiver gain fluctuations between calibrations
- Make best use of real time meteorological data

A few interesting SMA science results

Published

- **Younger resolved submm galaxies**
- Wolf Butterfly star
- **Sakamoto arp220 CO(3-2) and continuum**
- Lim 3c84 CO(2-1) in cooling flow
- Marrone SgrA* flare
- Andrews DoAr25 protoplanetary disk
- Hughes 49Cet CO(2-1) disk
- Weintroub MWC349 Hα recomb line masers
- Wilson Luminous Infrared galaxy survey

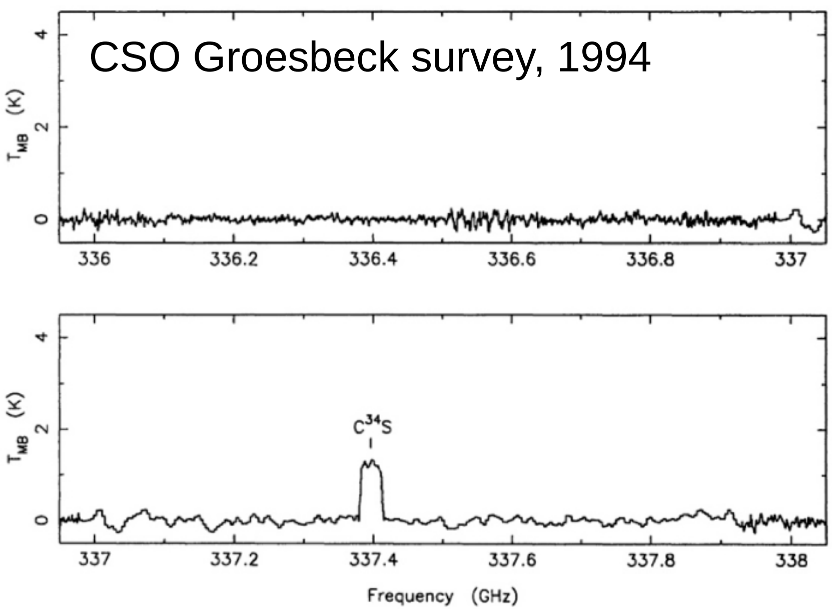
Not yet published

- Krips NGC253 starburst CO(6-5)
- **Patel IRC+10216 line survey**
- Martin arp220 line survey
- Andrews Oph vex disk sample
- Girart G31 high mass polarization
- Zhang/Qui high mass outflows
- Hunter NGC6334 high mass line forest
- **Li small scale magnetic fields in NGC6334**
- Espada Cen A CO(2-1)
- Salome 3c84 CO(3-2) in cooling flow
- Clemens Resolved interaction at z~3.6

With other observatories

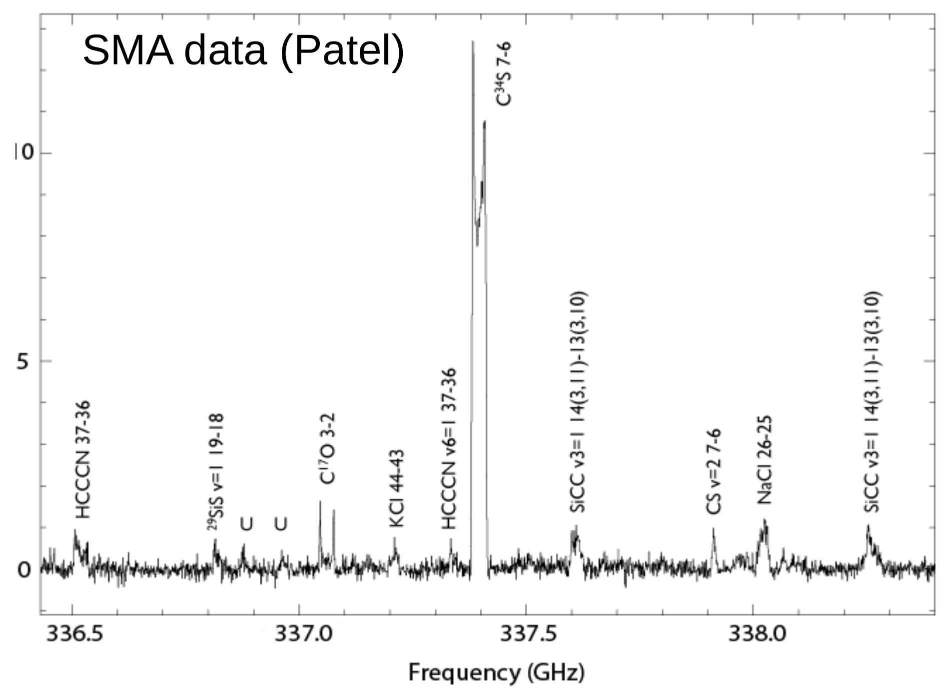
- **Bottinelli e-SMA observations towards PKS1830-211**
- **Doelman VLBI observations towards SgrA***

SMA line survey towards Irc+10216



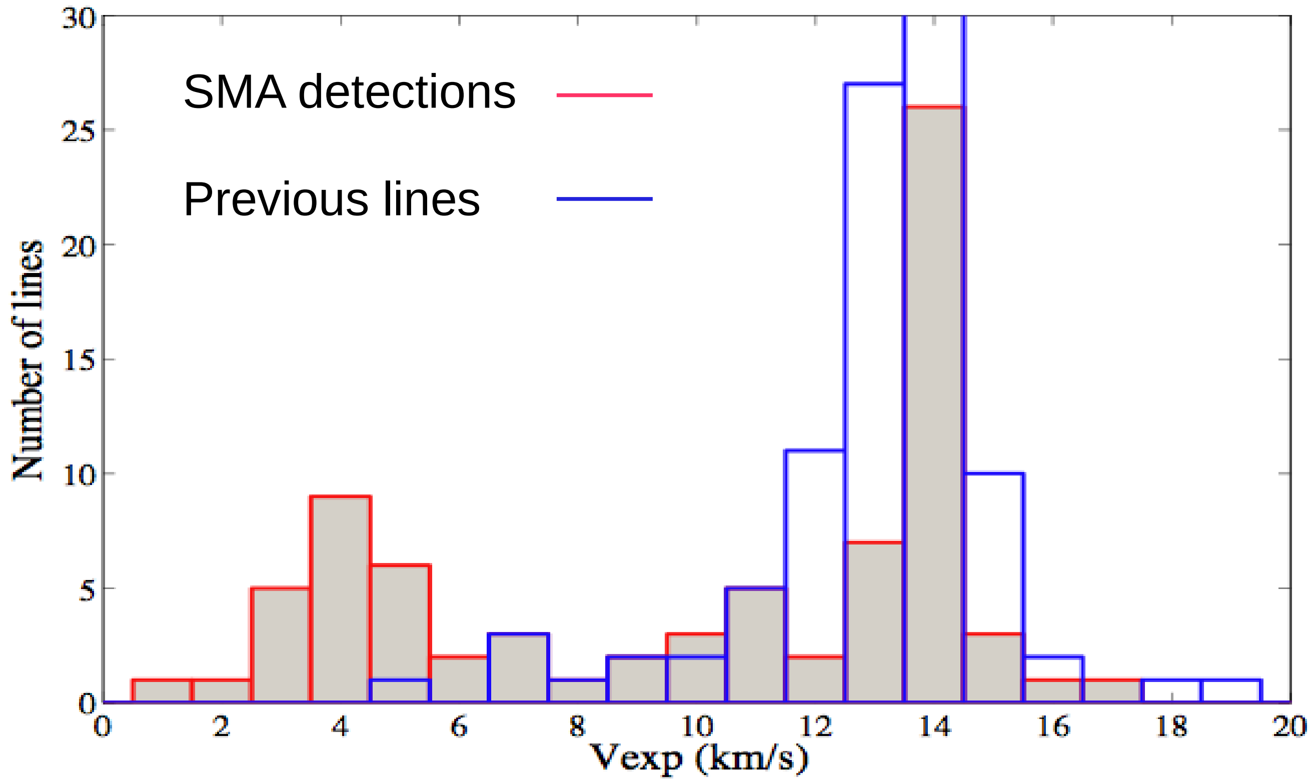
Line surveys traditionally done with single dish telescopes: CSO, JCMT, 30 metre ....

Irc+10216 has been observed extensively with > 10 other surveys



- SMA survey covers 300 – 350 GHz range
- About half complete
- 50 new detections so far
- 24 lines not yet identified

Many new lines detected at low expansion velocity



Low expansion velocity emission suggests material is still undergoing acceleration and has not yet reached terminal velocity

Spatial distribution of these new lines is very compact ~ 0.2'' (~ 60AU)

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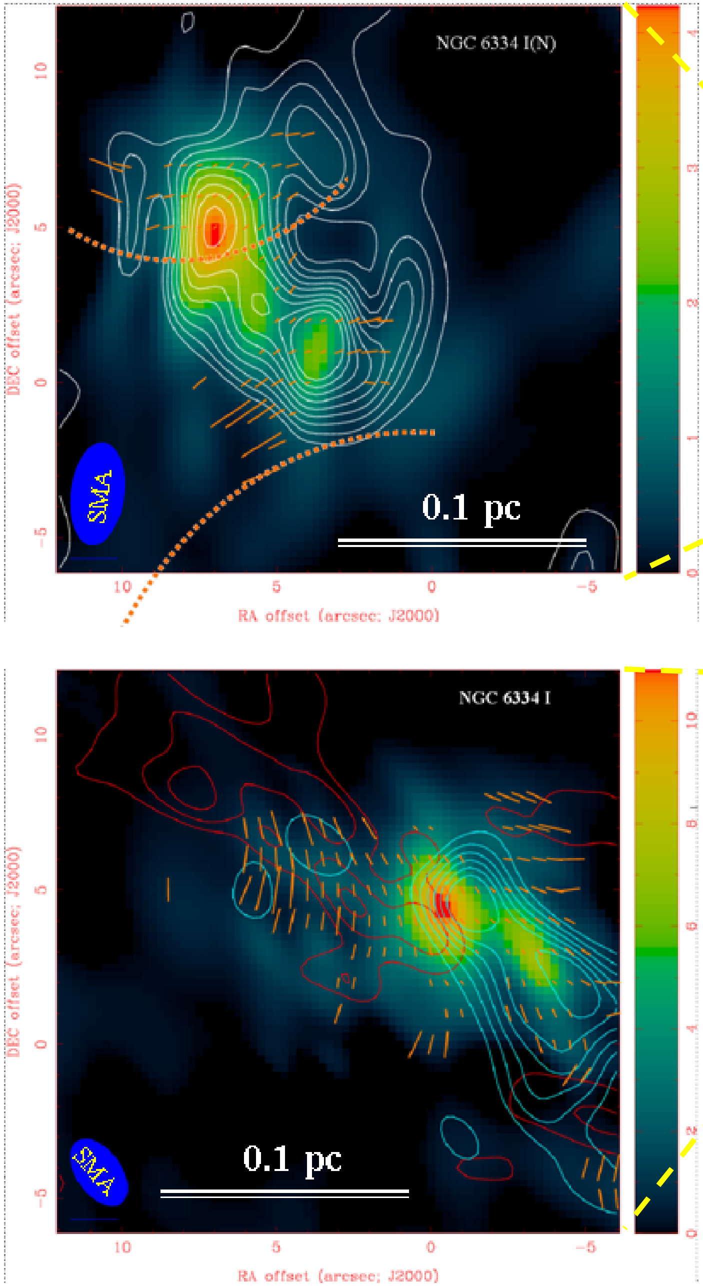
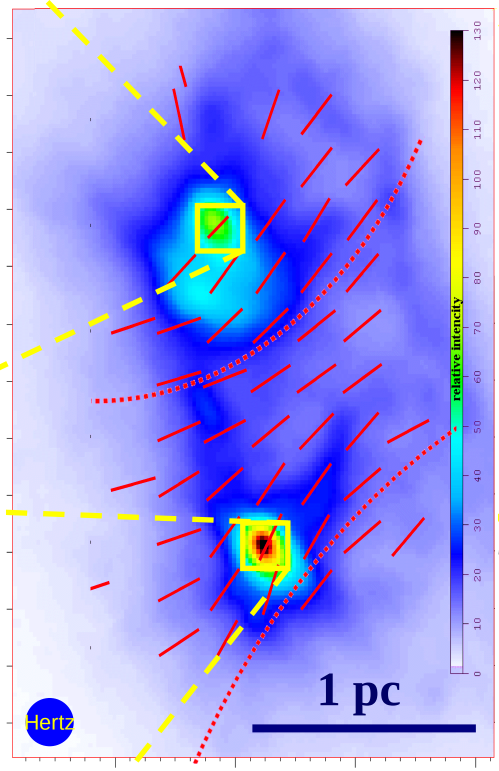
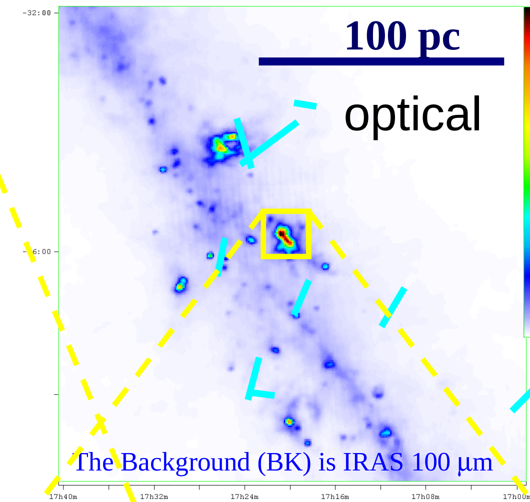
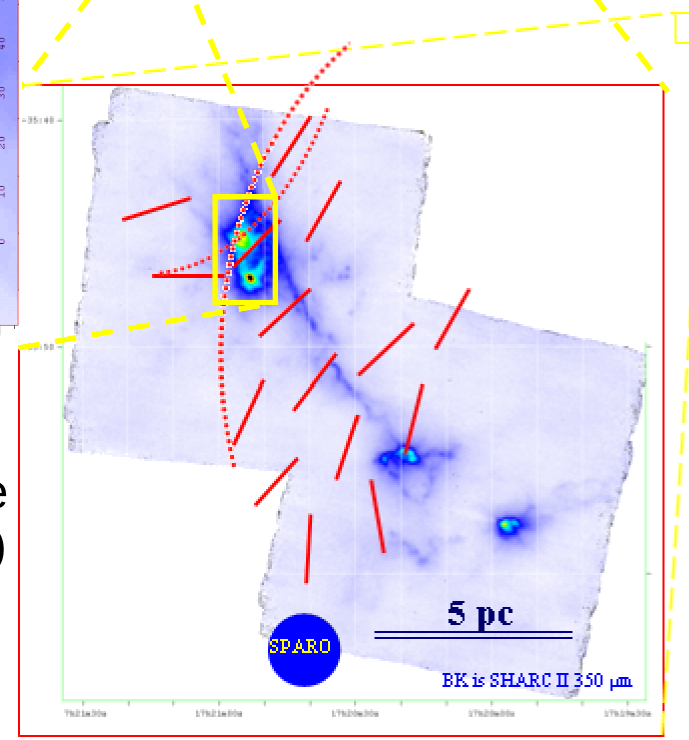
Multi-scale magnetic field observations of NGC6334





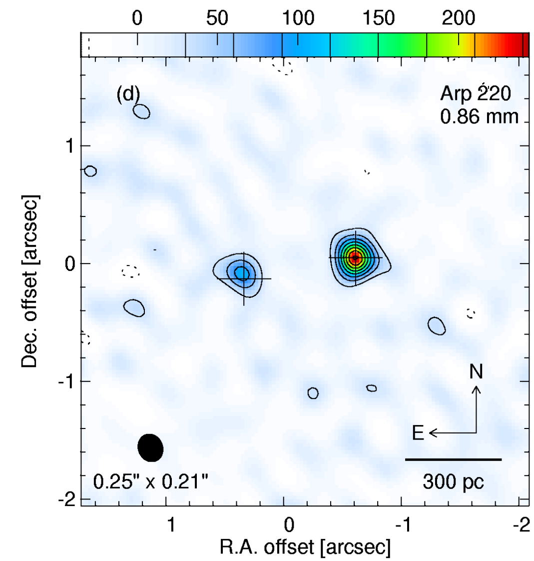


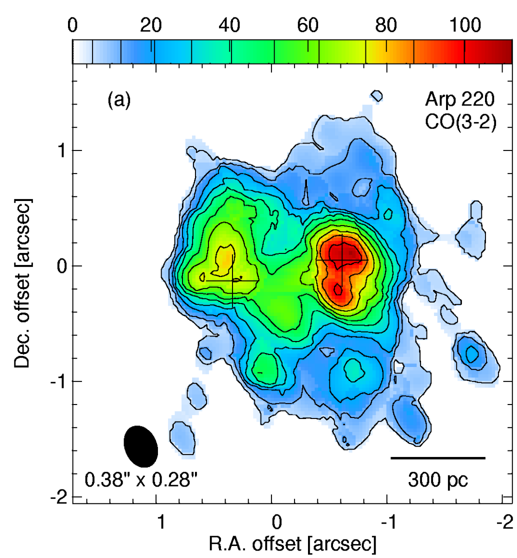


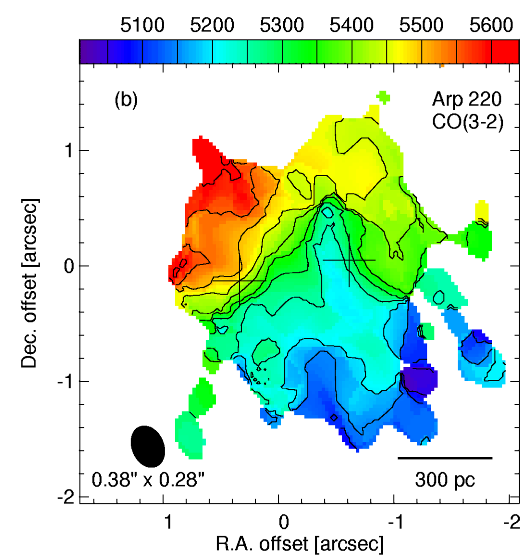
Less correlation on the smallest size-scale (Li)

Galaxy collisions and mergers (Sakamoto)

- merging is basic tenet of galaxy formation and evolution over cosmic time
- **SMA** observations
  - template: Arp 220
  - image cold clouds of gas and dust where star clusters are made
- two galactic nuclei, advanced merger, obscured black hole (AGN in West)
- Note sizescale in continuum
- Independently rotating disks from CO moment 1 map

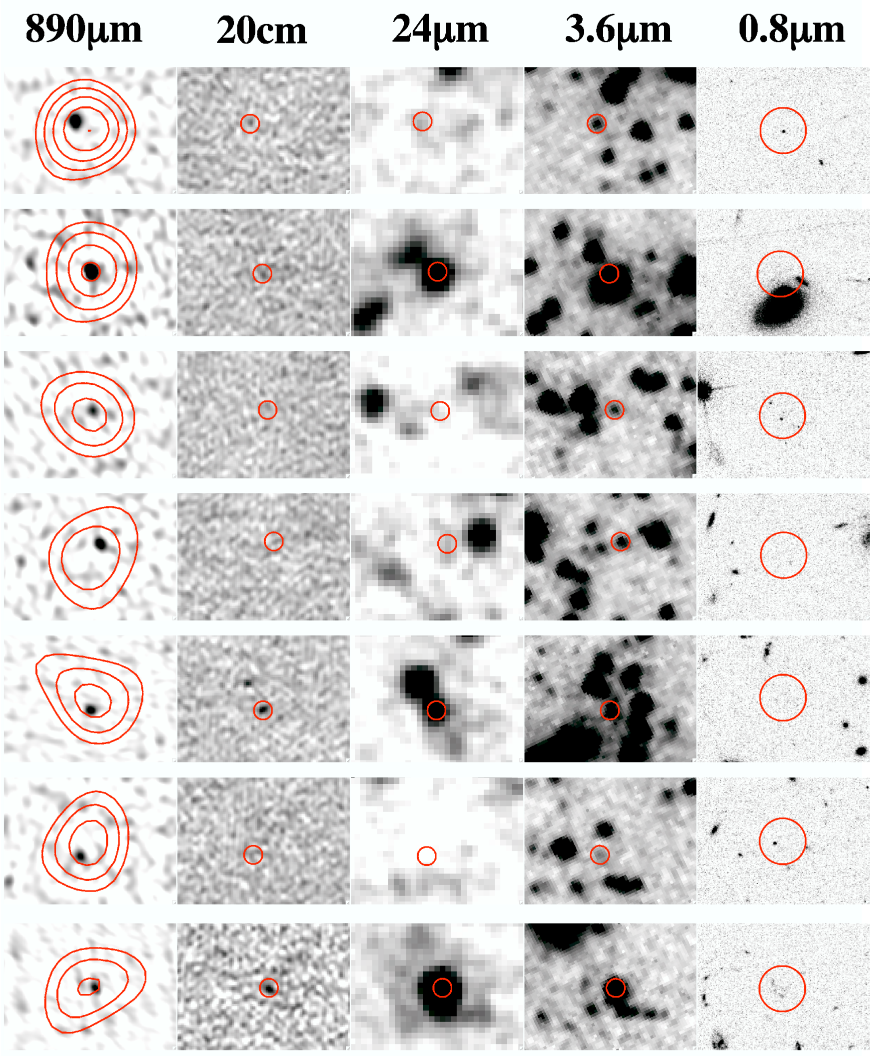






Extreme starbursts in the early universe (Younger)

- half of luminous cosmic energy density comes from dust enshrouded sources
- **SMA** observations
  - "COSMOS" field
  - 0.2 arcsec astrometry
  - **the only way** to reliably identify counterparts at other wavelengths
- a population of massive galaxies with extreme star formation when universe was < 20% of current age



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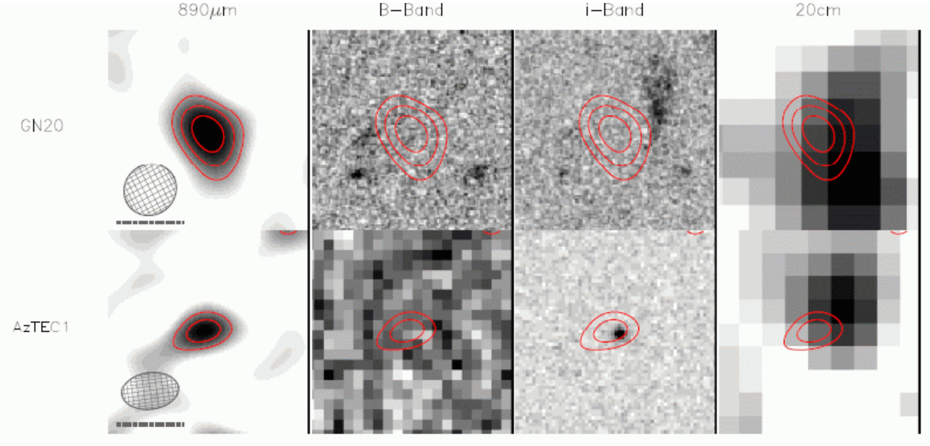
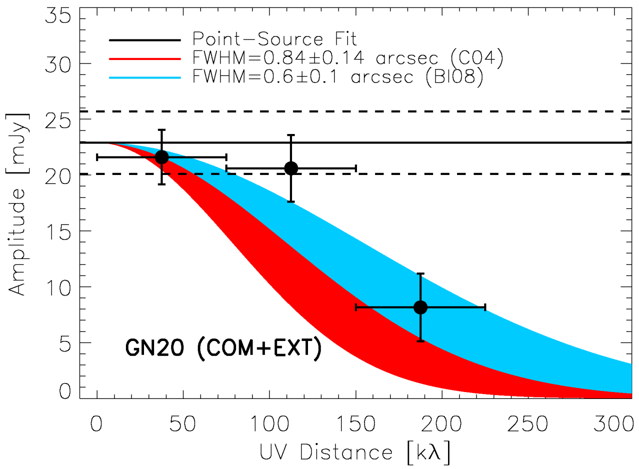
Extreme starbursts in the early universe (Younger)

- physical nature of most luminous submm galaxies?
- **SMA** observations
  - GOODS-N 20, COSMOS/AzTEC1
  - B band dropouts: z ~ 4
  - measure subarcsec sizes
  - physical scale of restframe far-ir emission: ~ 4 kpc
- suggest starbursts at Eddington limit set by radiative feedback

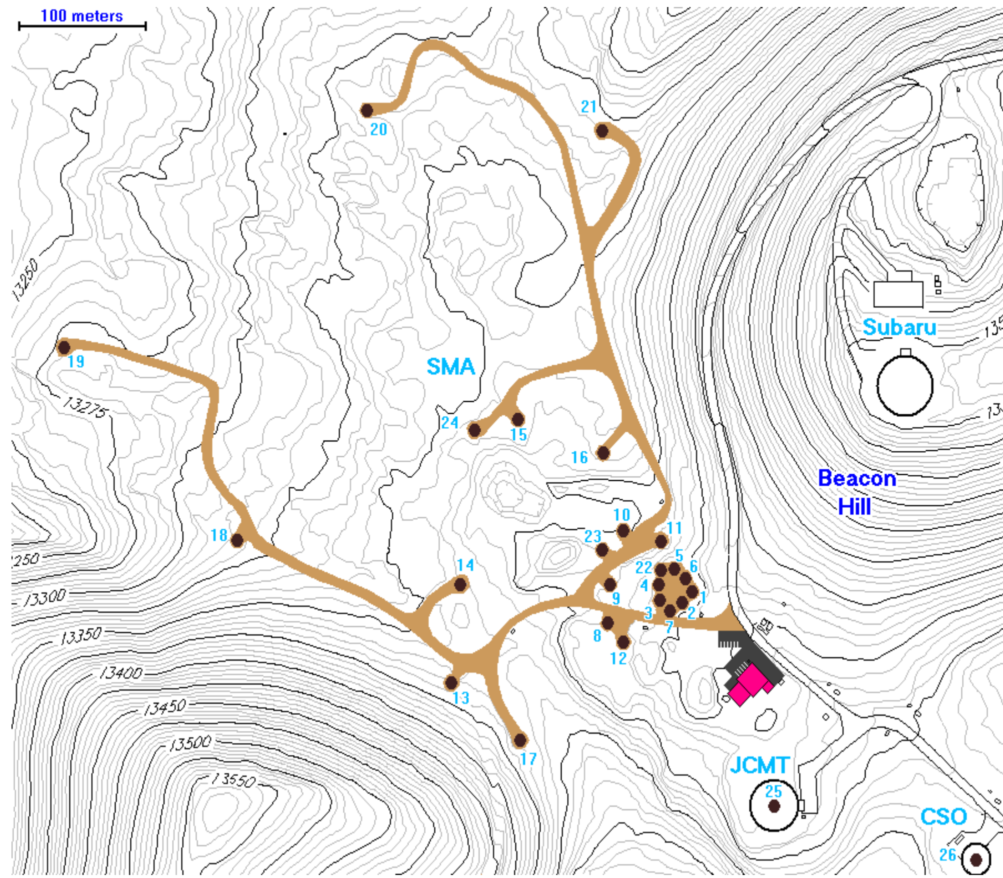




e-SMA: Increased spatial resolution and sensitivity

	Maximum Baseline	Area
SMA	508 m	161 m^2
SMA+CSO	782 m	201 m^2
SMA+JCMT	624 m	238 m^2
e-SMA	782 m	278 m^2

	rms flux in an 8 hour track	
SMA	0.551 mJy	1.00
SMA+CSO	0.519 mJy	0.94
SMA+JCMT	0.393 mJy	0.71
e-SMA	0.375 mJy	0.68

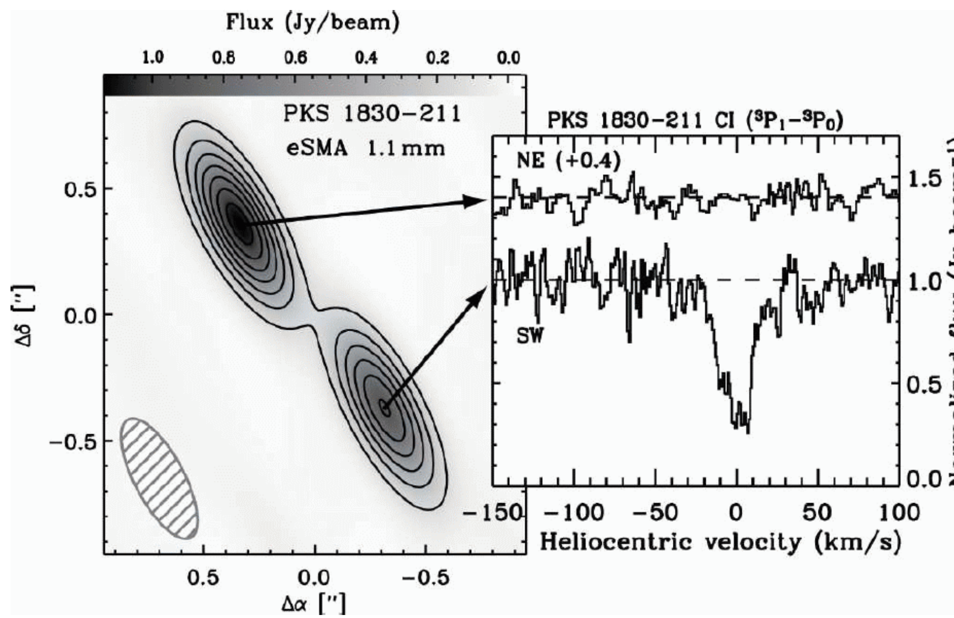


e-SMA, z=0.89 Molecular Clouds (Bottinelli)

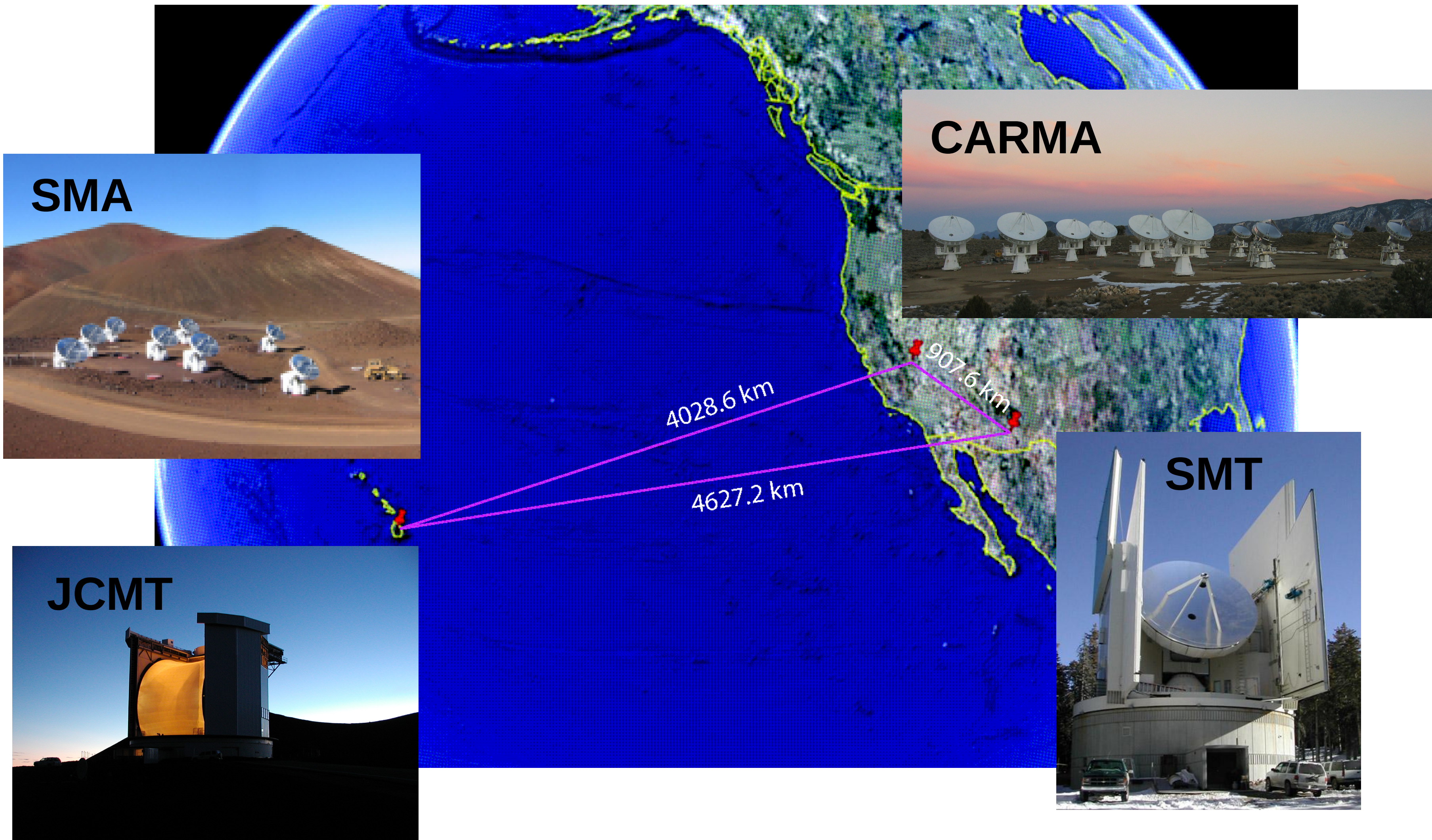
- SMA + JCMT + CSO
  - commissioning ongoing
  - up to 2x sensitivity
  - up to 1.5x resolution

- Test science observation
  - probe cold interstellar medium in galaxy at z=0.89, lens of PKS1830-211
  - measure neutral atomic carbon relative to CO, in absorption
  - C/CO ratios suggest dense cores and translucent clouds

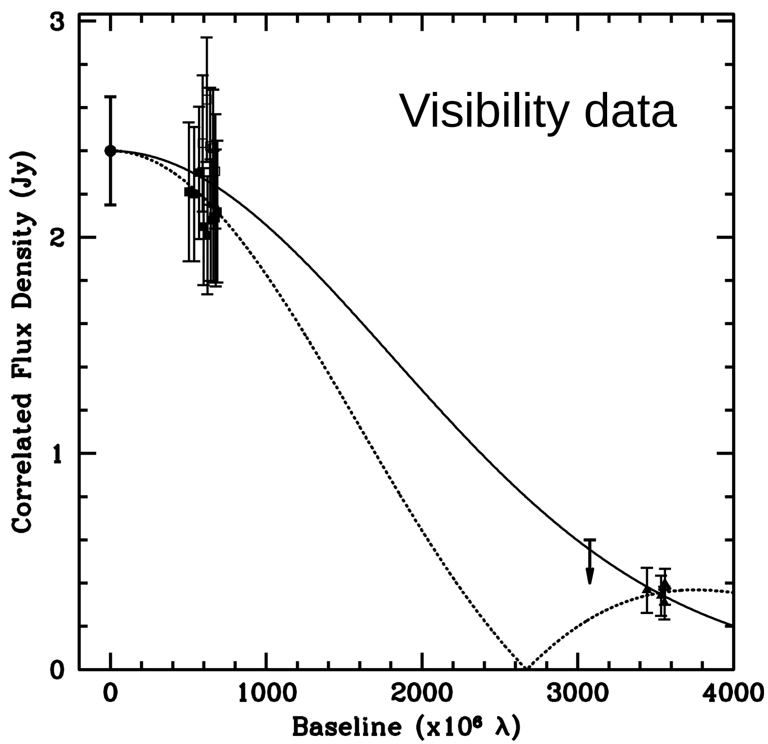
(No CI in northern component, 1" away)

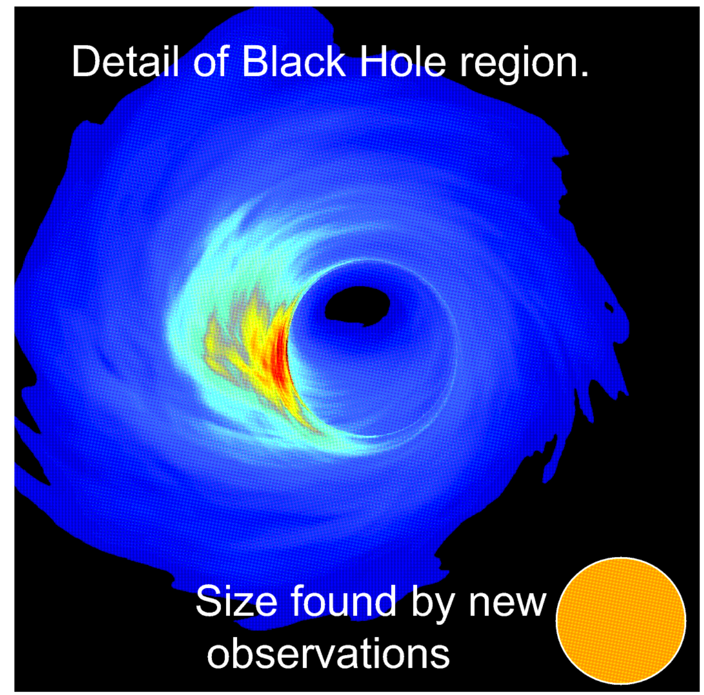


1.3 mm VLBI towards the Galactic Center
Maximum projected baseline ~ 3.5 10^9 λ



Event horizon scale structure of SgrA* (Doelman)





Size-scale of 37 microarcseconds for intrinsic diameter of SgrA* < expected apparent size of event horizon

Emission may not be centered on SgrA* but arises in surrounding accretion flow

Projects planned for FY 2009

- Install improved 320 – 420 GHz receiver sets
- Improve 650 GHz receiver performance
- Test and field an atmospheric phase monitor
- Begin routine science observations with BW doubler
- Incorporate phase correction scheme
- Build phased array processor for improved VLBI

Observations completed since Oct 07

Semester 2007B: 01 November 2007 – 30 April 2008

	SAO	UH	ASIAA
• Completed	83	12	13
• Remaining	11	4	4
• Expected totals	94	16	17
• Target (from %)	91	16	19

Semester 2008A: 01 May 2008 – 31 October 2008

	SAO	UH	ASIAA
• Completed	80	14	14
• Target (from %)	78	13.5	16.5

Observing requests for SAO time

- Observing time is in high demand:
  - 452 CfA observing proposals in past 3 years (253 int, 199 ext)
  - over-subscription high where SMA capabilities are unique:

    <4.0mm pwv (“230 GHz”) 1.3:1

    <2.5mm pwv (“345 GHz”) 4.1:1

    <1.0mm pwv (“690 GHz”) 4.8:1

- Distribution of published papers in various fields:

Star Formation	60%	Galactic Center	4%
Extragalactic	19%	Solar System	3%
Stellar	11%	Other	3%

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Refereed articles published with SMA data