THE SUBMILLIMETER ARRAY

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SMA Advisory Committee Meeting

12th October, 2010

OUTLINE

- SMA in brief
- SMA partnership
- Upgrades during the past three years
- Science highlights
- Metrics
- Future improvements

THE SMA IN BRIEF

Collaboration between Smithsonian Astrophysical Observatory and Academia Sinica Institute of Astronomy and Astrophysics

Eight-element interferometer designed to operate from about 200 to 900 GHz

Located on Mauna Kea, close to the JCMT and CSO

6 m diameter antennas with surface accuracy ~ 12 μm

Receivers for 200, 300, 400, and 650 GHz available on all antennas

IF center frequency 5 GHz, bandwidth 2 GHz

Simultaneous operation of low and high frequency receivers

4 GHz bandwidth (x2 sidebands) now possible for single receiver use

Flexible cross-correlation spectrometer with resolution down to 25 kHz

THE SMA PARTNERSHIP

- SMA is a partnership between SAO and ASIAA
  - 85 % SAO, 15 % ASIAA
  - (UH silent partner for science)
- Partnership – SAO could not have a better partner
  - Unfortunately Paul Ho could not make it
  - Great that Ming Tang Chen (ASIAA Director Hilo) is here
  - Really fortunate that Frank Shu could make it
- ASIAA fully engaged in supporting operations
- SAO/ASIAA hardware fully integrated at site

THE SMA IS ALIVE AND WELL

- Scientific output of the SMA is at the highest level
  - Scientific publications still on the rise, 75 in FY-2010
- Wide range of science topics (see later)
  - From planetary science to distant galaxies
  - Recall, three years ago was difficult to detect SMG's
  - Relatively easy today – can even do large programs
- SMA publications have broad authorship
  - Wide user base outside CfA
  - More CfA scientists showing interest, but still need to further expand internal user base

UPGRADES DURING PAST THREE YEARS

Improvements to receivers – ongoing

- Implemented double bandwidth mode
- 400 GHz receiver sets finally performing
- Dual polarization at 345 GHz capability
- Can observe CO 3-2 and 2-1 simultaneously

Improvement in operations

- Phase monitor working – tie to observations
- Extended operations during daytime

VLBI capability

- Developed and implemented phased array processor

IMPROVEMENTS TO RECEIVERS

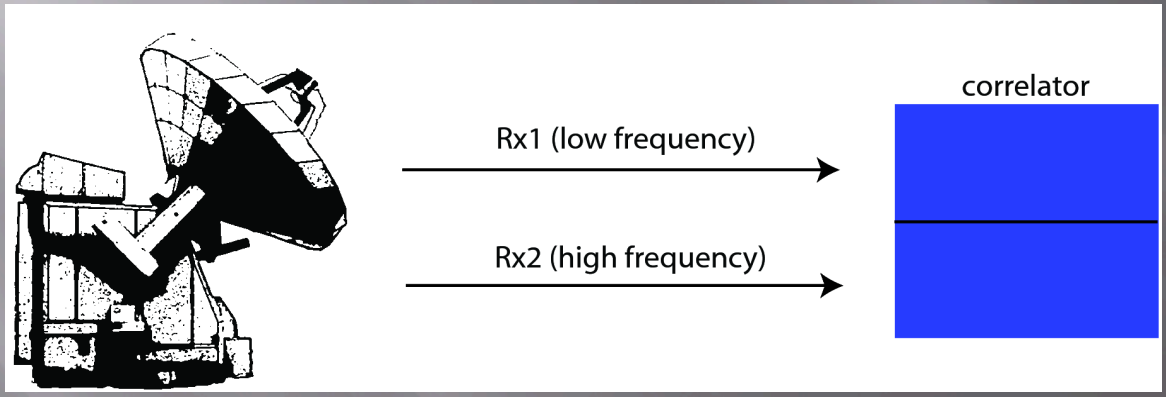
SMA was originally designed for two receiver operation

One high frequency receiver (>350 GHz) with one low (<350 GHz)

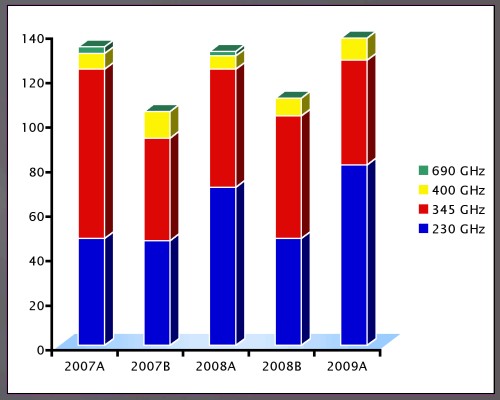
In practice usually use just one receiver due to weather

Half of the transmission system plus correlator remain idle

Idea – double the bandwidth for single receiver operation



Relatively simple, low cost upgrade for high return

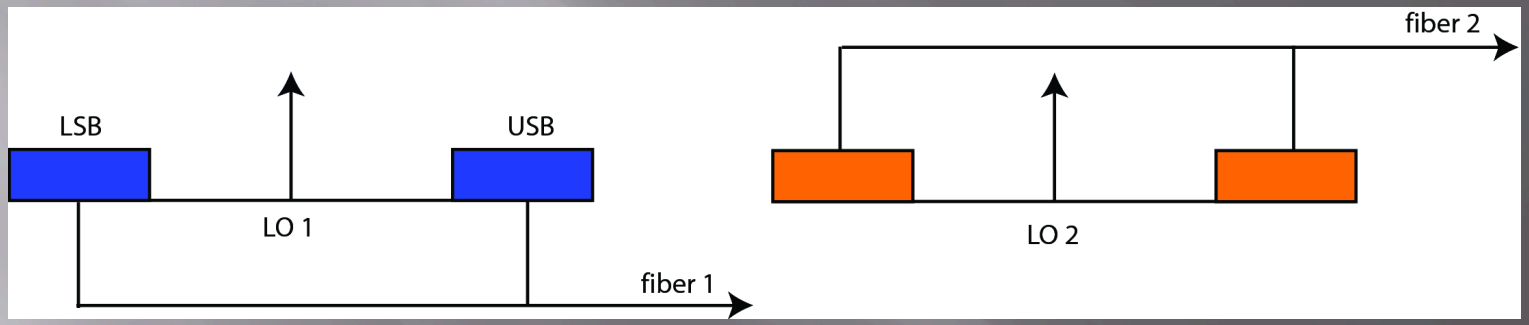


SMA use by band

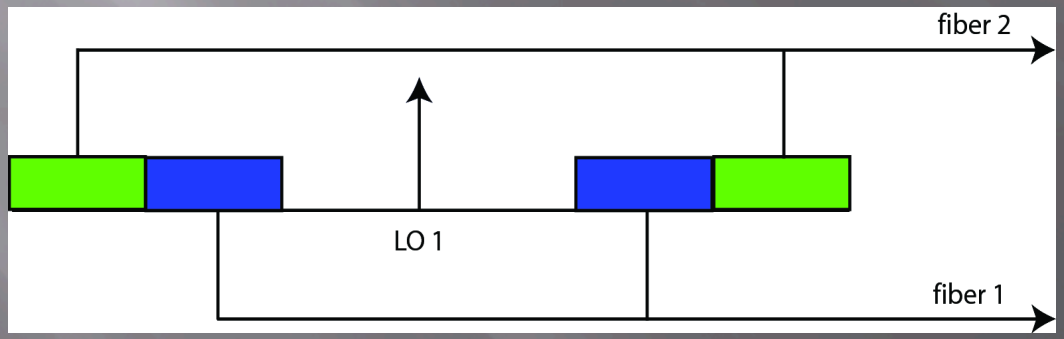
IMPROVEMENTS TO RECEIVERS

Double bandwidth for single receiver use

Two receiver operation:

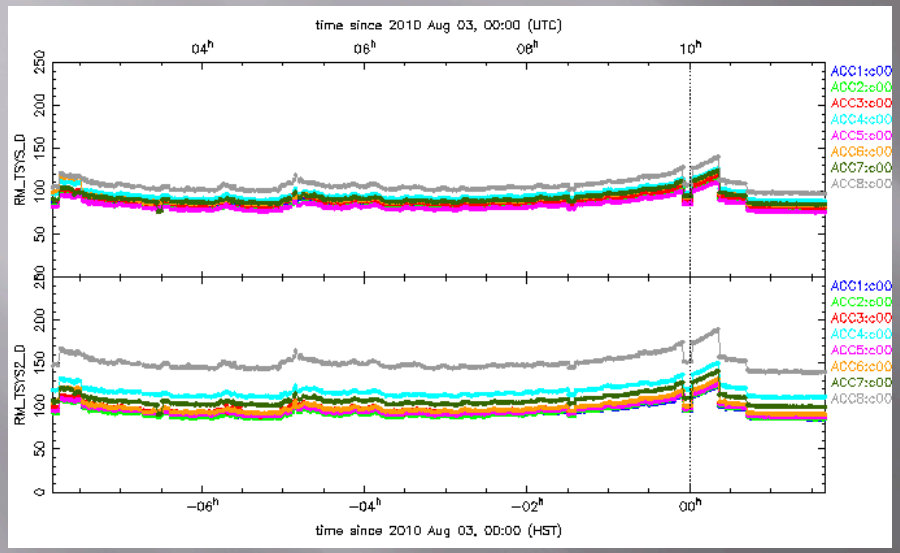


Single receiver operation with twice the bandwidth

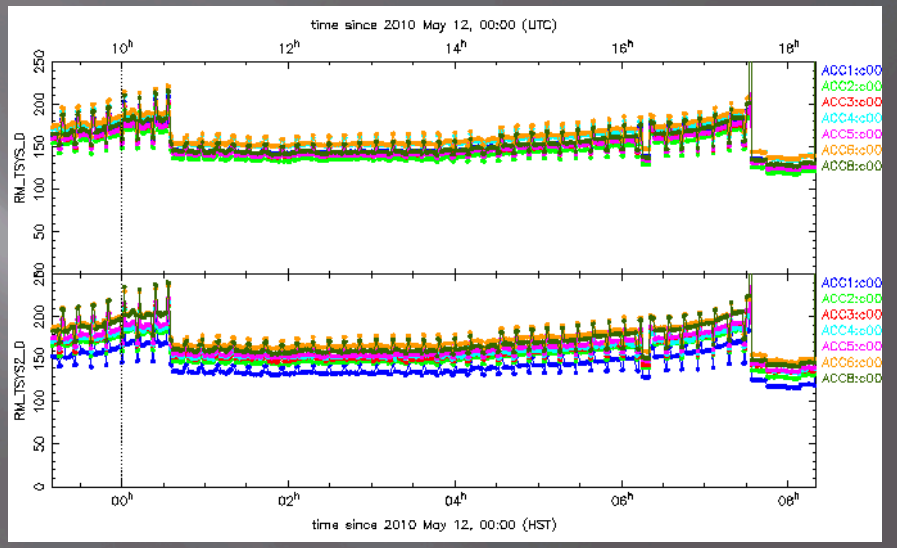


IMPROVEMENTS TO RECEIVERS

Double bandwidth performance
230 GHz operation



Double bandwidth performance
270 GHz operation



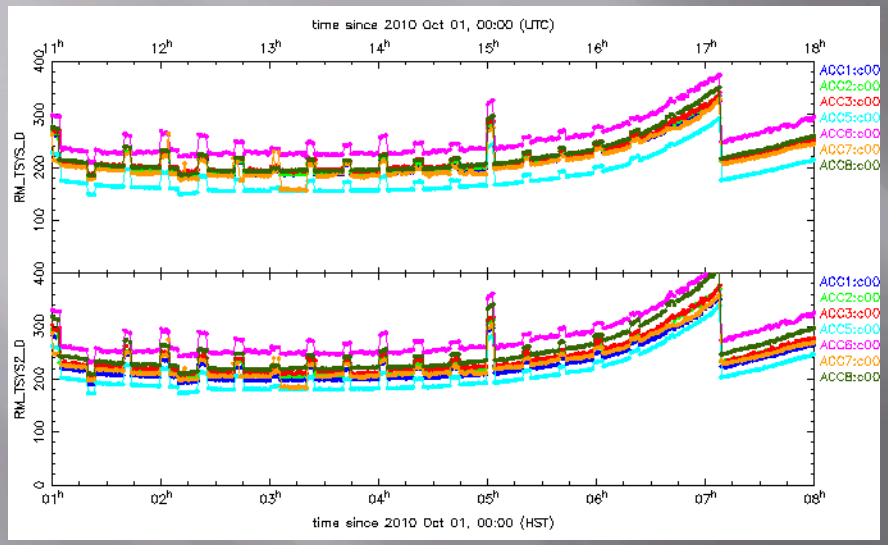
System noise for antenna seven is about 25% higher and 8 Tsys ~ 30 %

345 GHz receiver performance at 270 is almost identical in 4-6 and 6-8 GHz IF

Edward will give more detail of receiver performance in his presentation

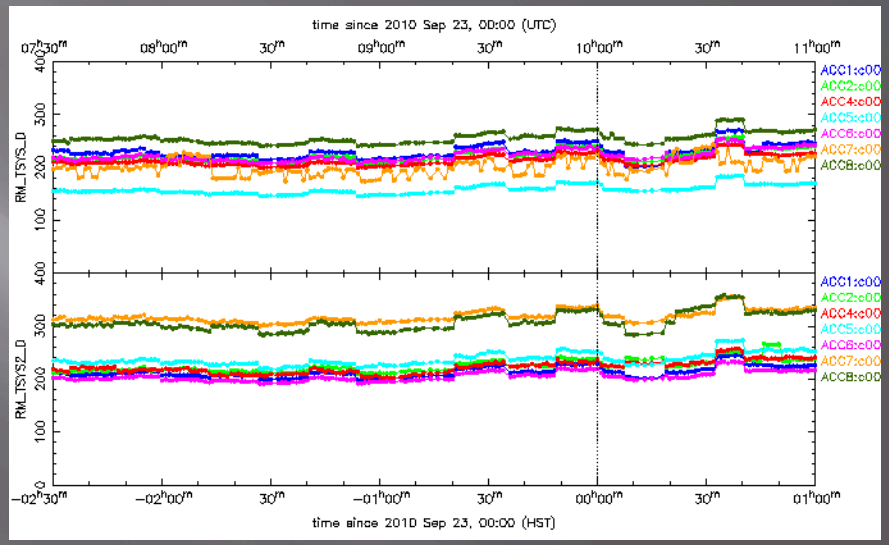
IMPROVEMENTS TO RECEIVERS

Double bandwidth performance
345 GHz operation



Tsys performance across 6-8 GHz IF almost identical to 4-6 GHz band
For antennas 4 and 8 Tsys ~ 30 % more in upper 2 GHz part of band

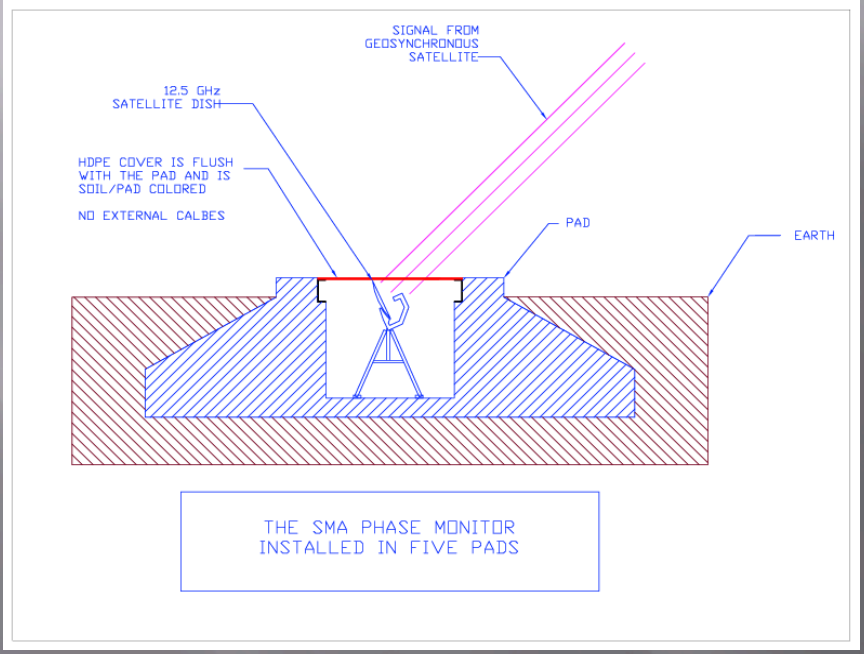
400 and 300 GHz receivers both tuned to 345 GHz for dual polarization observations



300 GHz receivers (top) 400's below
Antenna 5 300 Rx better than others
Antenna 7&8 400 Rx's poorer than others
Large gain for polarimetry ~ 5 in time
Using 230 and 400 GHz receivers together can observe CO 3-2 and 2-1 simultaneously

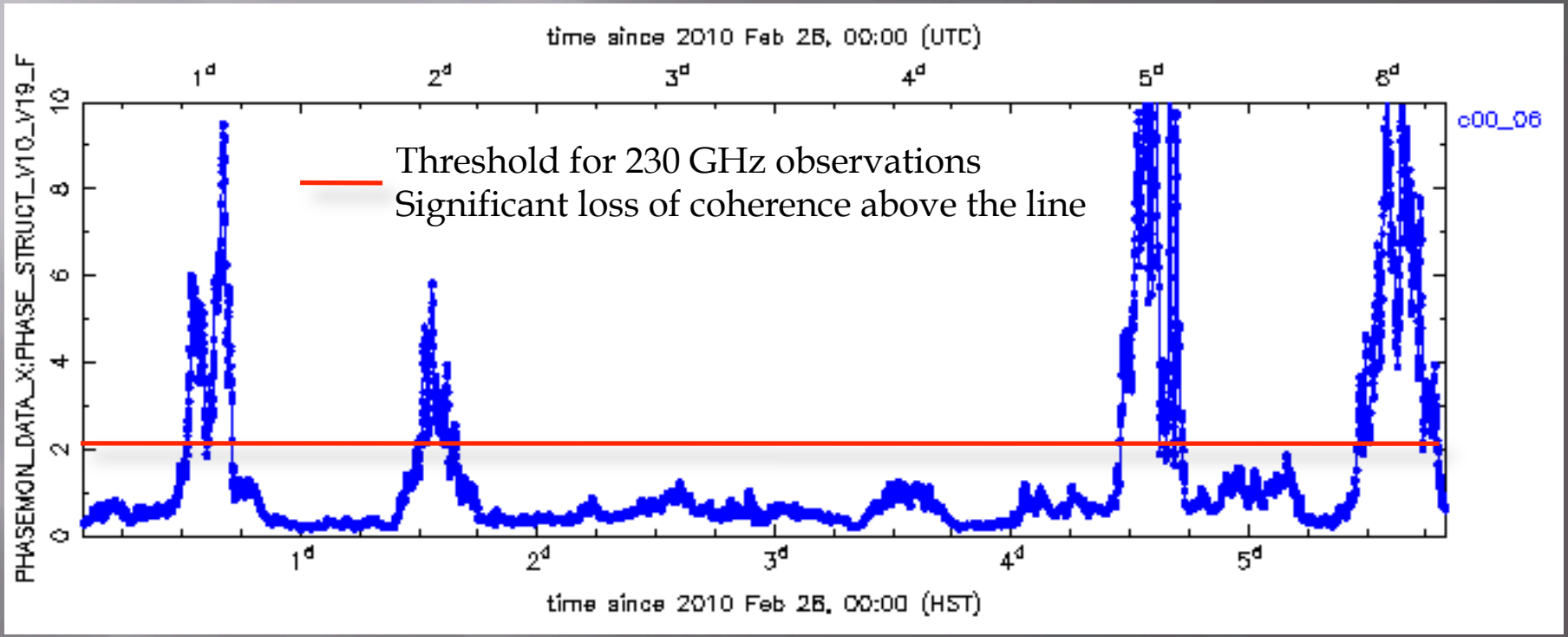
ATMOSPHERIC PHASE MONITOR

- Submillimeter transmission from CSO tau meter
- No independent measure of atmospheric delay
- Build and install phase monitor system



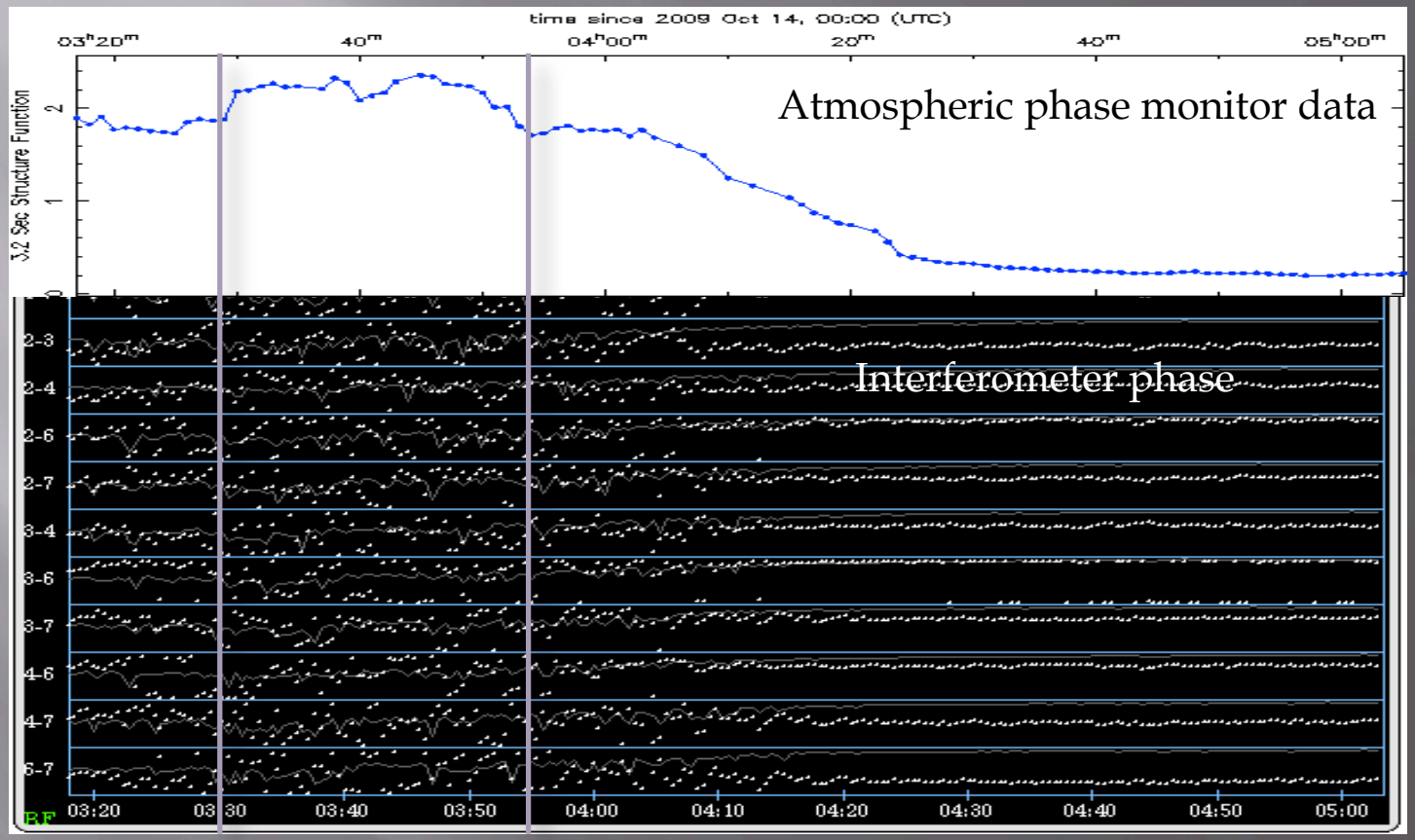
ATMOSPHERIC PHASE MONITOR AND INTERPRETATION OF DATA

- Have designed, built and installed four stations – hidden in antenna pads
- Data now available in all SMA configurations



- Phase monitor output helps scheduling
- Can observe through the day in the very best weather

INTERFEROMETRIC PHASE AND PHASE MONITOR COMPARISON



Significant loss of coherence occurs on all baselines when atmospheric phase ≥ 1 radian

PHASED ARRAY PROCESSOR

IF inputs from 8 antennas

SMA or 6 SMA + CSO + JCMT

Sums signals over 1 GHz BW

Formats data for Mk 5b

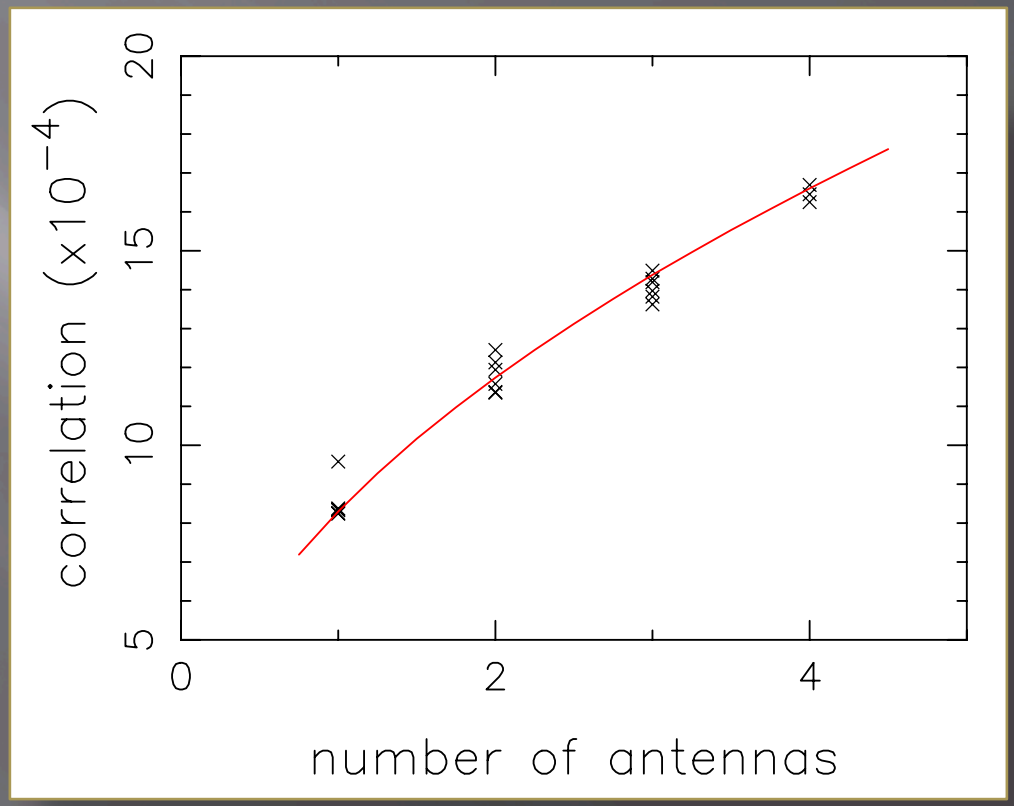
and VLBI

Built-in cross correlator

- tracks phase and delay

Based on CASPER hardware:

- IBOB's and BEE2



Correlation amplitude proportional to square root of number of antennas

SCIENCE HIGHLIGHTS

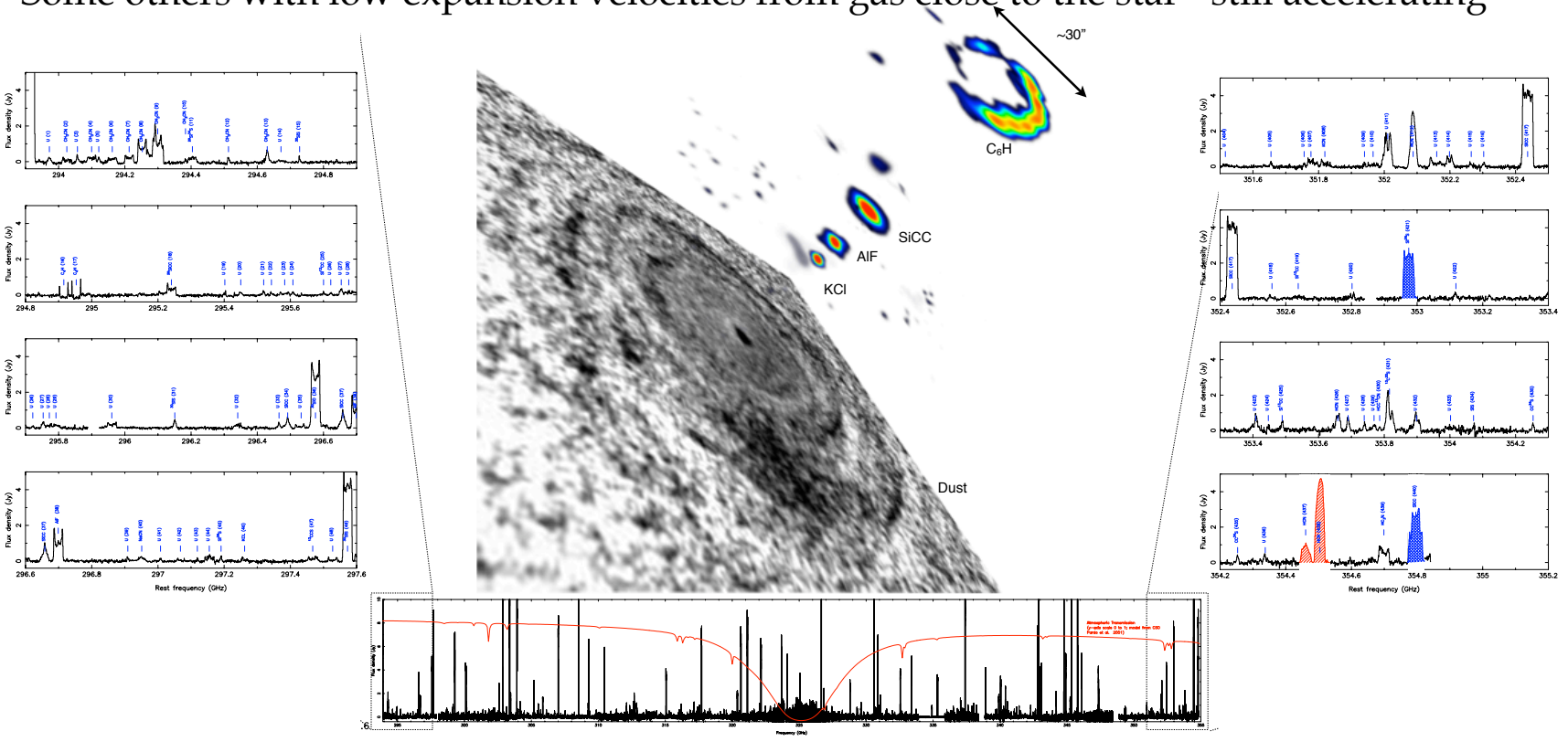
- As a result of instrument upgrades
  - Improved sensitivity
  - Larger programs
- Other
  - Herschel follow-up observations
  - ToO / DDT observations

SCIENCE HIGHLIGHTS
Instrument Upgrades

- Increased sensitivity – predominantly from double bandwidth operation
  - Twice as many observations to same sensitivity
  - Twice the bandwidth for spectral line searches
- Enabled more large programs
  - Completed line survey of Irc+10216
  - Additional surveys of VY CMa, IK Tau, and SgrA*
  - Submillimeter Galaxies (DDT, ToO)
  - Proto-planetary disks and disk chemistry

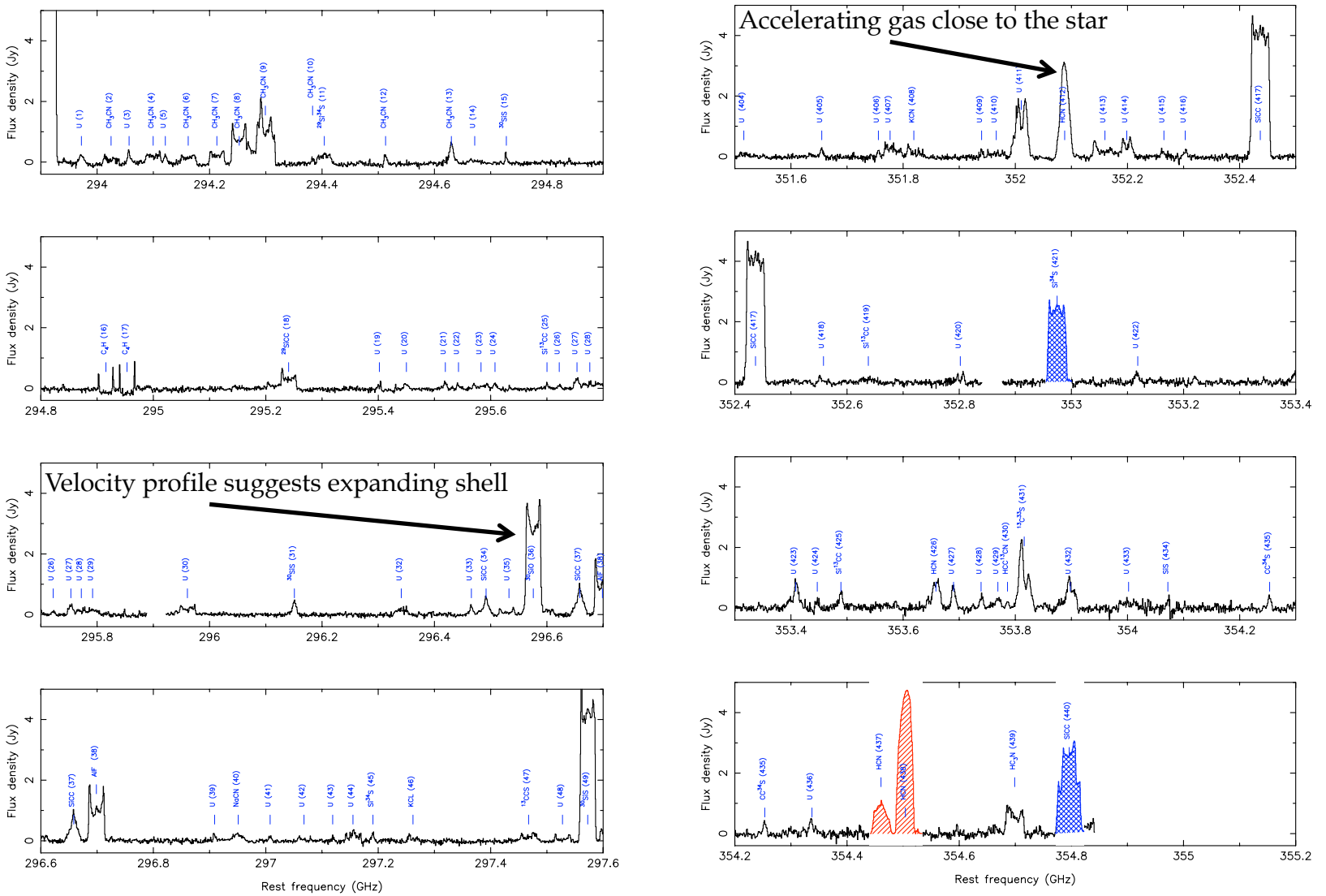
Irc+10216 Spectral Line Survey

Line surveys possible due to 8 GHz instantaneous bandwidth
440 spectral lines detected across 60 GHz bandwidth (~ 294 GHz – 354 GHz)
Many lines have been mapped with clear shell-like structure
Some others with low expansion velocities from gas close to the star - still accelerating



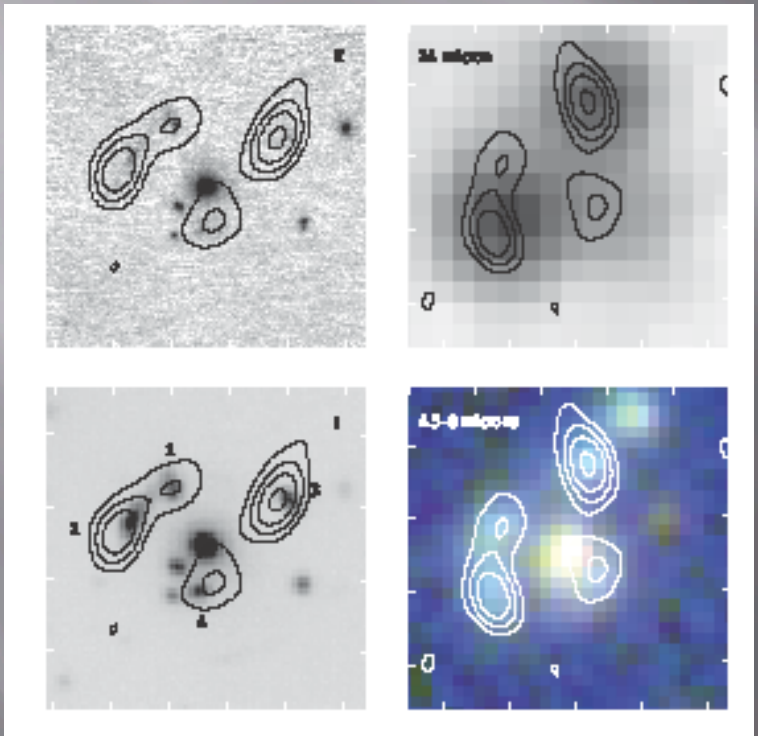
Patel and Young, Sept 2010

Irc+10216 Spectral Line Survey



SCIENCE HIGHLIGHTS
Herschel follow-up

- Multiwavelength observations of a multiply lensed SMG in early Herschel / SPIRE data



Clockwise from the upper left:
Keck Ks-band AO image
Spitzer/MIPS 24 μ m
Spitzer/IRAC data at 4.5, 5.8, and 8 μ m
Subaru SuprimeCam i

Spitzer images do not share the same orientation as the Subaru and Keck images.
All images are 18″ x 18″
In all panels the SMA mm-band observations are overlaid as contours.

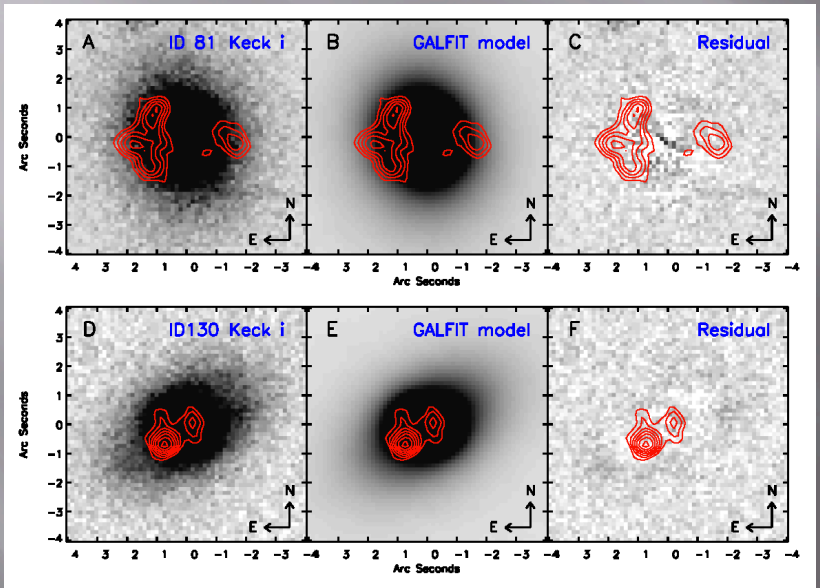
z ~ 3 from Z-spec (CSO) Scott in prep.

Conley et al. HerMES team, Sept 2010

SCIENCE HIGHLIGHTS
Herschel follow-up

- Detection of a population of submm-bright lensed galaxies

  Data from H-ATLAS demonstrates wide area submillimeter surveys can easily detect strong gravitational events with 100% efficiency

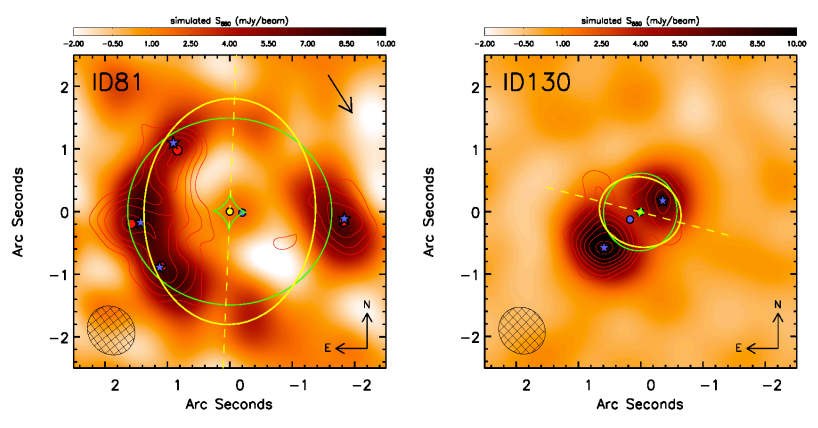


Lensing galaxies observed with Keck

Submm flux mapped with the SMA

z ~ 3.04 for ID 81 (CSO, PdB, GBT)

z ~ 2.63 for ID 130 (PdB, GBT)



LENSMODEL software used to fit SMA data

IR magnification for ID 81 ~ 18 – 31

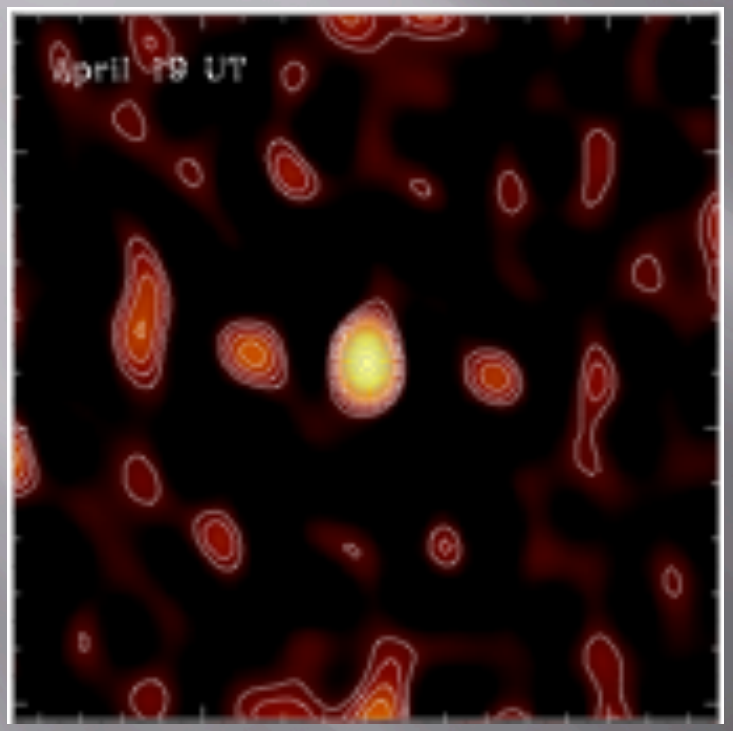
IR magnification for ID 130 ~ 5 – 7

(More detailed work in progress)

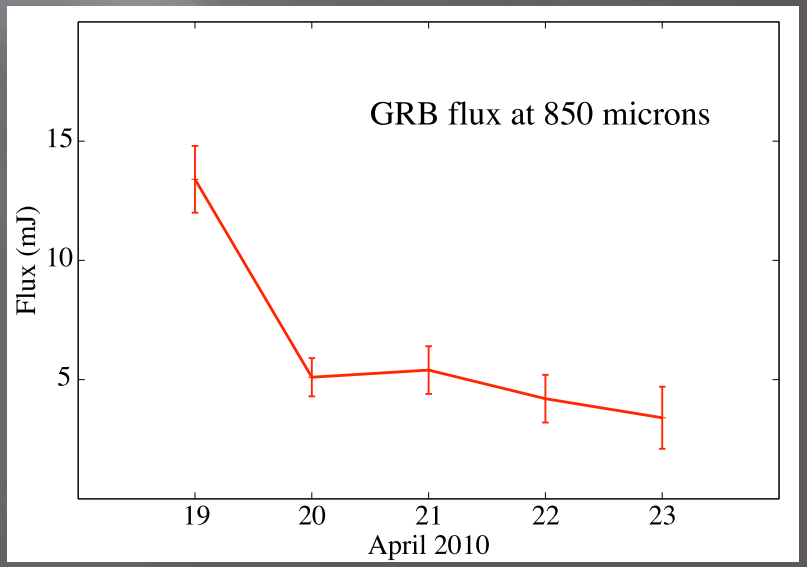
Negrello et al. – Science, Sept 2010

SCIENCE HIGHLIGHTS - Other

- ToO observations of GRB 100418A



April 18th 21:10 UT Swift Burst Alert Telescope triggered and located GRB 100418A at z ~ 0.62
April 19th 11:00 UT SMA alerted, 13:00 on target
Brightest submm flux ever detected at 345 GHz: 14 mJ
Decayed to ~ 3.4 mJ by April 23rd - most detailed follow-up of a GRB at submm wavelengths to date
Following extraordinary bright SMA detection mm observations were triggered at Plateau de Bure and radio observations at WSRT (both for 2 months)



Most complete data set of GRB evolution to date
Optical/NIR spectroscopy X-shooter, (3 epochs)
Optical/NIR imaging GTC, VLT, and Keck
Reverse shock emission detected for the first time in the submillimeter (A. de Ugarte Postigo et al.)

METRICS

- Proposal submissions*
- Completion of programs*
- Publication history

*Past year only, Qizhou will give more complete summary

METRICS – Proposal Submission

November 2009 – November 2010

Science Category	Proposals	Time requests	Fraction (%)
Star Formation	112	278	43.0
Extragalactic	68	287	44.4
Galactic Center	8	21	3.3
Planetary	4	9	1.4
Stellar	16	51	7.9
Totals	208	646	100

Projects above from SAO and ASIAA only
About as much time for extragalactic as star formation
- larger programs, weaker sources

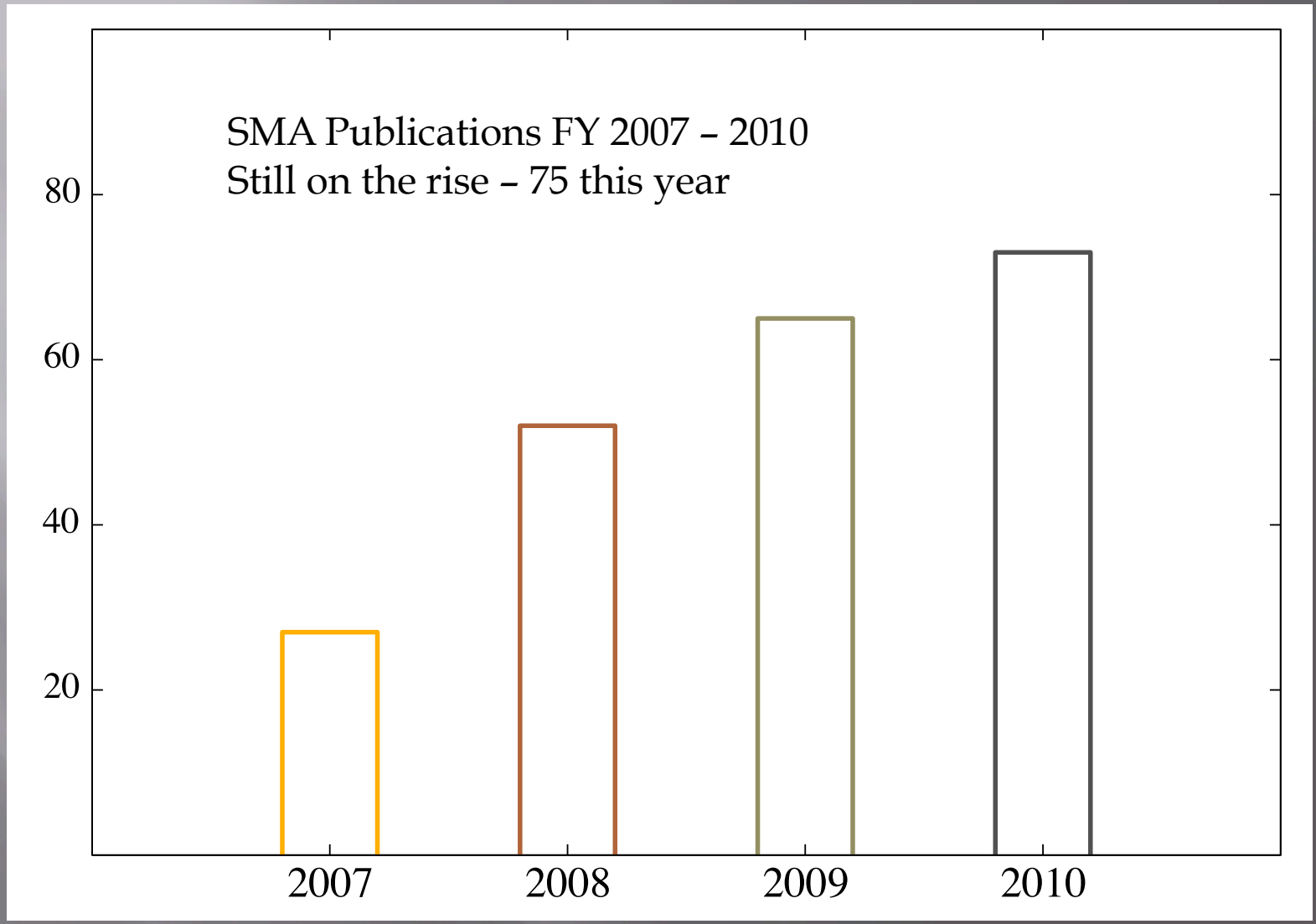
METRICS – Completion of Programs - oversubscription

16 November 2009 – 15 November 2010 *

Weather (PWV)	Time Requests	Oversubscription
< 1 mm	77	3.3
< 2.5 mm	350	2.5
< 4 mm	219	2.5
Totals, summary	646	2.6

* Assumes completion of programs at current rate to 15 November
Exceptional weather and improved SMA performance and scheduling resulted in a 30% increase in success rate compared to previous years
In other words have completed 30% more programs than previously
(*Oversubscription may disappear if we make too many improvements!*)

METRICS - Publications



FUTURE IMPROVEMENTS

- Committee set up September 2009 (Fazio chair)
  - Make recommendations to enable the SMA to continue to be scientifically active during ALMA era
- Considered two main scenarios
  - Remain on Mauna Kea with significant upgrade
  - Move to higher drier site in Northern Chile
- Findings issued May 2010
  - Recommend continued operation on Mauna Kea with significant upgrades

FUTURE COMMITTEE CONSIDERATIONS

- Add additional antennas
  - Problems adding more than two
- Increase the diameter of the reflectors to 7 or 8 m
  - Easy in principle for ~ 40 – 80 % increase in sensitivity
- Increase instantaneous bandwidth
  - Possible on a timescale of about four years
- Add focal plane arrays
  - Difficult – potentially a much longer term prospect

FUTURE COMMITTEE RECOMMENDATIONS*

The following upgrades were recommended

- Develop the most sensitive dual polarization receivers in all frequency bands
- Concentrate initially on 345 GHz, then 230 GHz
- Increase the bandwidth of these receivers as technology develops
- Envision a two-step process
  1) Increase bandwidth from 4 GHz per sideband to 18 GHz
     (Total BW would be: 18x2x2 = 72 GHz)
     This would be a 9-fold increase over current capability
  2) Eventually extend to 30 GHz bandwidth for a 15-fold increase over current performance: 120/8

*Fazio will give more complete, longer term overview of recommendations

STAFFING

- 2007 Advisory Committee
  - Staffing level is limiting progress in the lab
  - Identified three key hires:
    - Site Director (Schinckel replacement)
    - Receiver engineer (Hunter replacement)
    - Instrumentalist/Observer
  - Also endorsed hiring a senior scientist
- Have not managed to hire any of the above in three years
  - Furthermore, have lost:
    - Mike Smith (Mechanical Engineeer)
    - Roger Plante (Mechanical Technicien)
    - Abby Hedden (Postdoc in the lab)
  - Also, Bob Wilson reduced hours to half time
- Upgrading the SMA will be a challenge without more staff