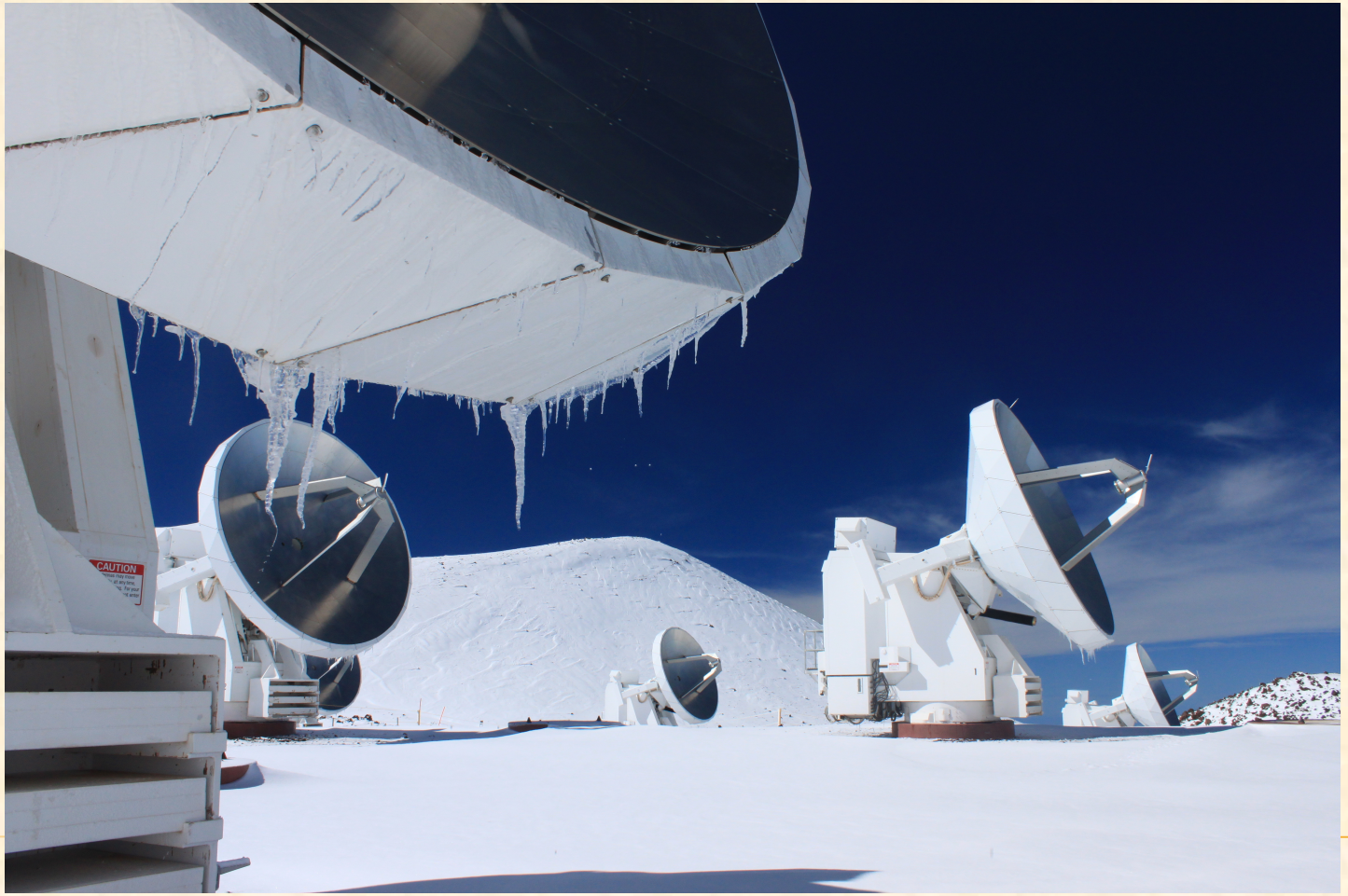
SMA Capabilities



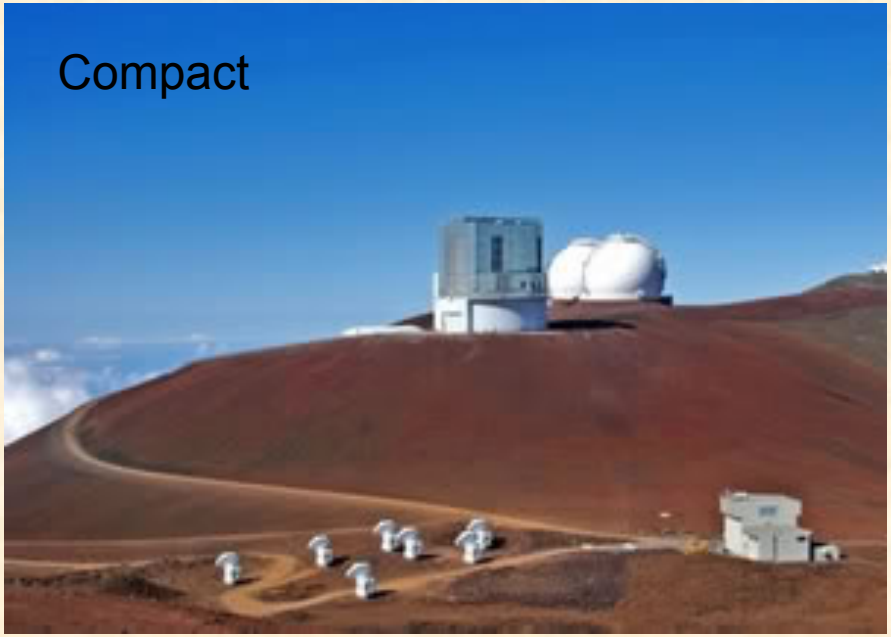
Raymond Blundell
June 09 2014

The Sub-millimeter Array, Mauna Kea, Hawaii (SMA)

Eight 6m antennas

Antennas transported between different stations using purpose-built transporter

Four configurations for different resolutions
sub-compact, compact, extended and very extended (>500 meters)



Reconfiguring the Array

We can synthesize an antenna 50, 100, 200, or 500 meters across
Reconfiguration takes about 2 days

Each antenna weighs about 50 tonnes

The Future – 3 Choices

Spend lots of money

More antennas

Multi pixel receivers

Extremely large …… infinitely large correlator ……..

The Future – 3 Choices

Spend lots of money

- More antennas
- Multi pixel receivers
- Extremely large …… infinitely large correlator …….

Do absolutely nothing

The Future – 3 Choices

Spend lots of money

- More antennas
- Multi pixel receivers
- Extremely large …… infinitely large correlator …….

Do absolutely nothing

Something in between

Report on Activities at the SMA

by
Jim Moran
Director, SMA, through Friday

Mauna Kea Users' Meeting

September 29, 2005

Capabilities

Antennas: 8 antennas of 6 m diameter, 12 μm rms surface

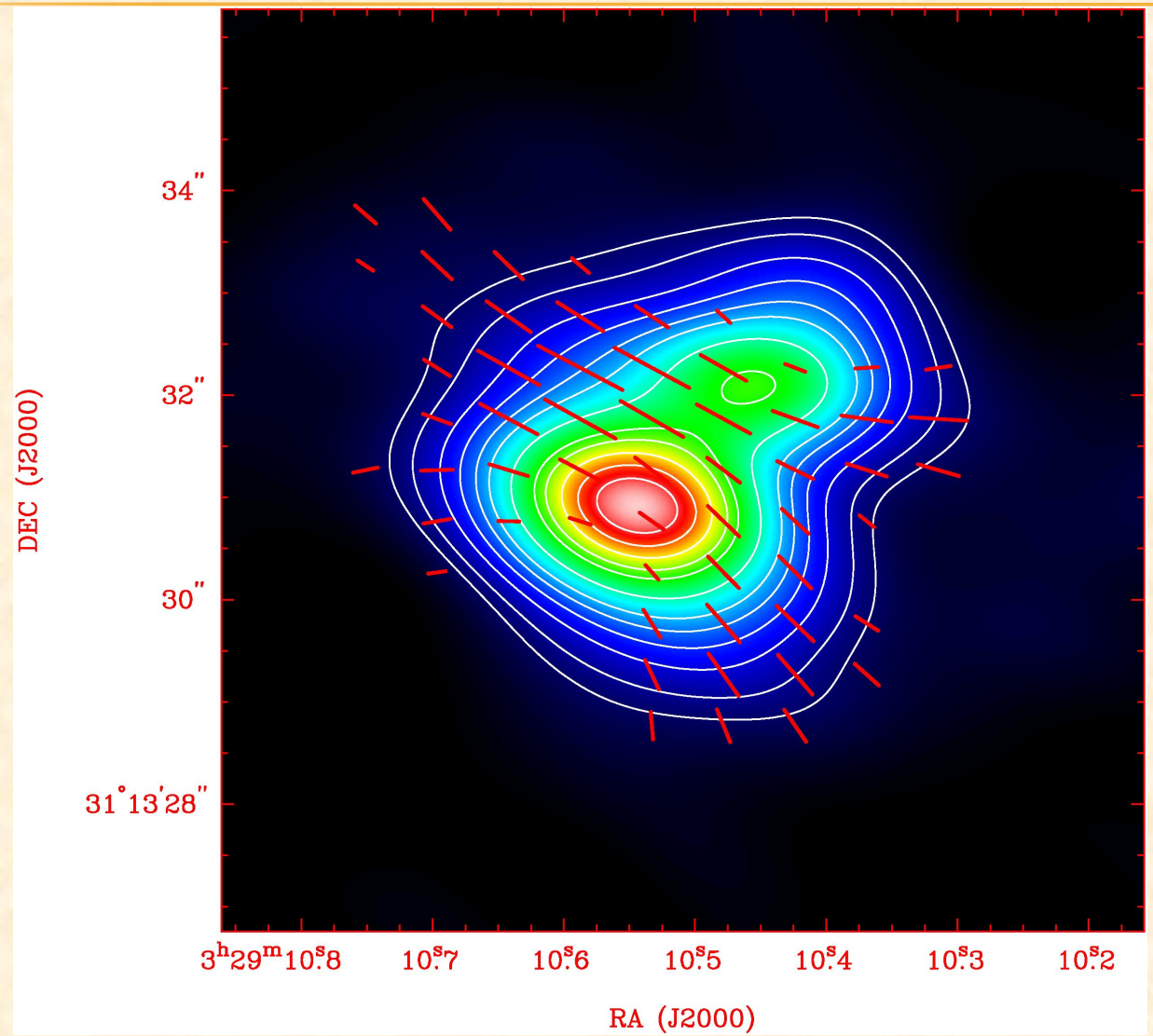
Configurations: 24 pads in four rings
baseline lengths 8 - 508 m,

Receivers: max 8 per antenna; 2 simultaneously

177-256 GHz (8 in operation)
256-360 GHz (8 in operation)
320-420 GHz (start May 2005)
420-520 GHz (future)
600-720 GHz (6 in operation, 2 more in Dec 2005)
780-920 GHz (future)

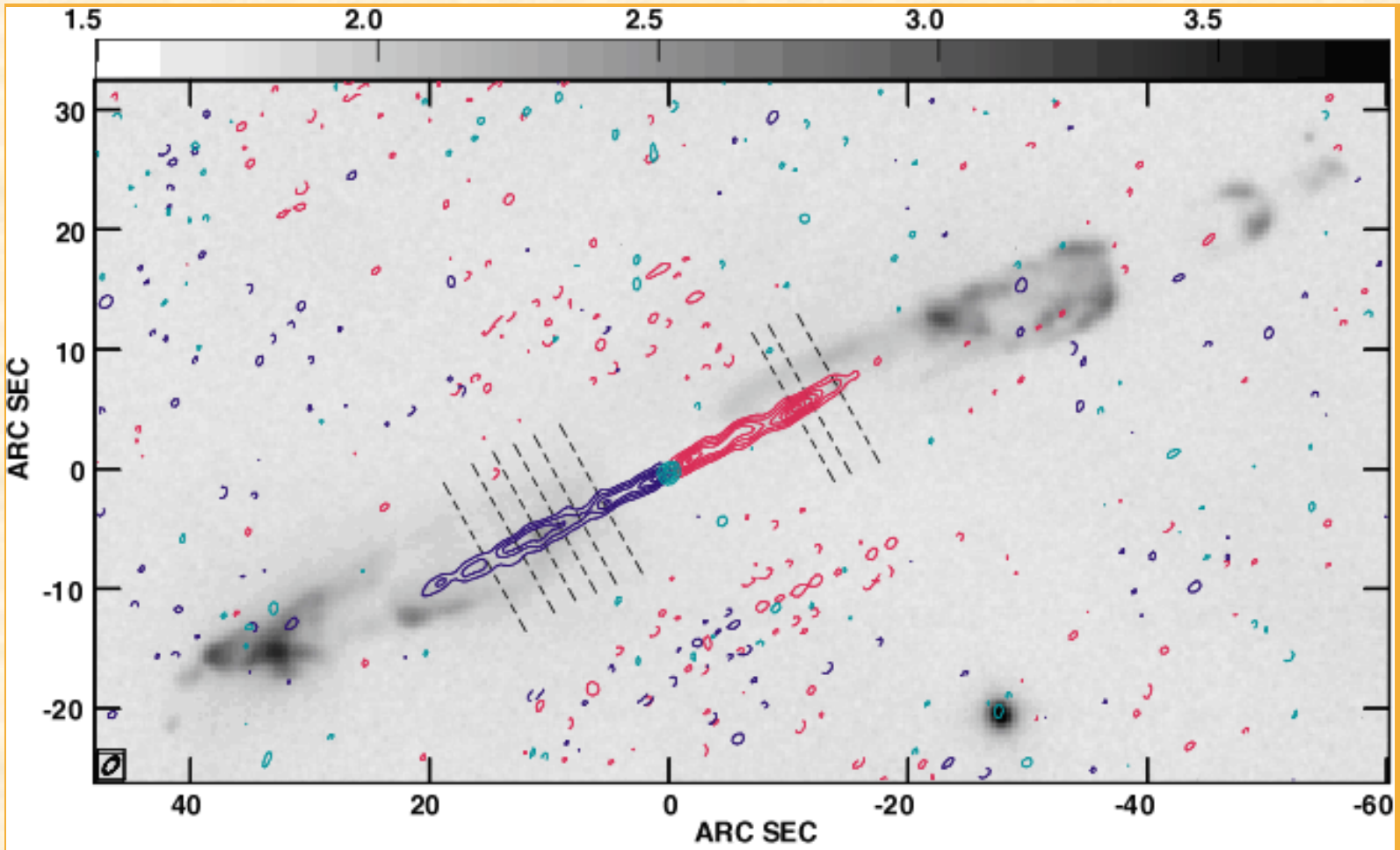
Correlator: 2 GHz bandwidth, 1 MHz resolution at full bw/2rcvrs

NGC1333/IRAS4A 345 GHz Total Intensity and linear polarization (B field)



Rao, Girart & Marrone, 2005

SMA Image of SiO (5-4) in HH211

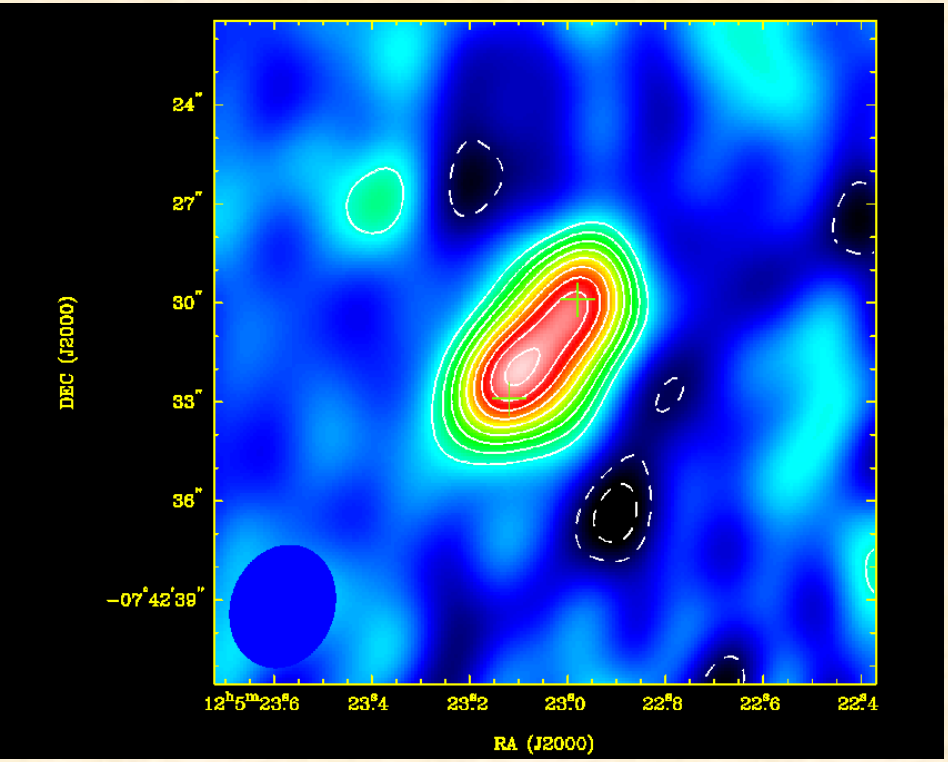


beam: 1.60″ x 0.88″ P.A. -40.7 deg.

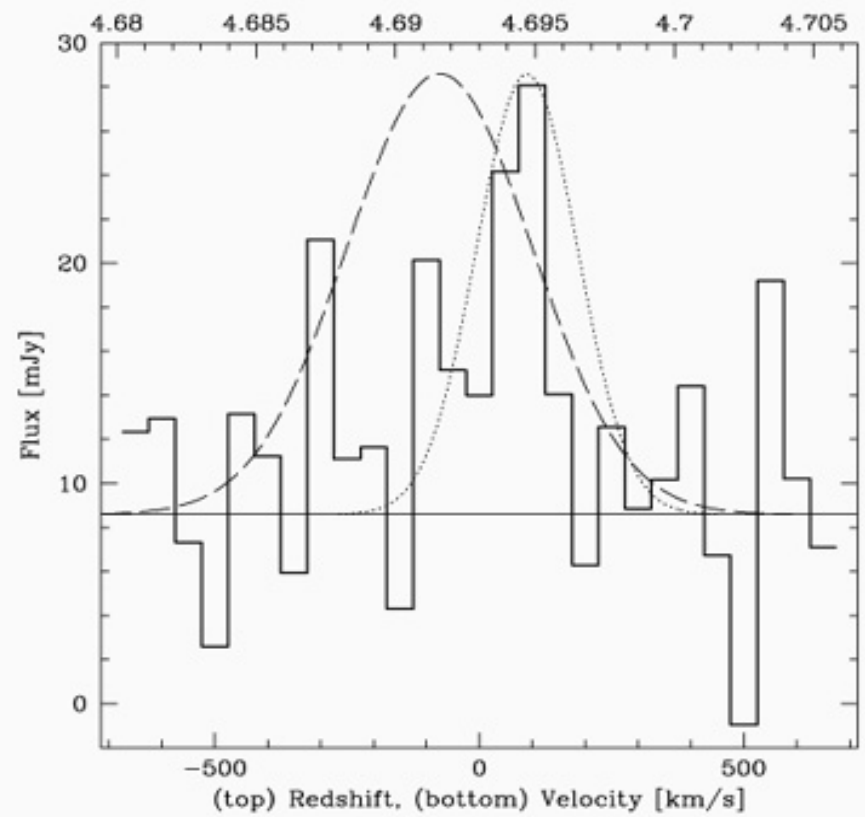
Hirano et al 2005

CII line at z = 4.7 in BR1202-0725 (334 GHz)

Continuum image (900 microns)



Red shift



Iono et al., 2005

Report on SMA activities

Ray Blundell

Mauna Kea Users' Committee Meeting

October 5, 2006

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

Science impacted by improved SMA capabilities

1. Improved sensitivity across the 300 GHz band
   - SXDF850.6 (Iono)

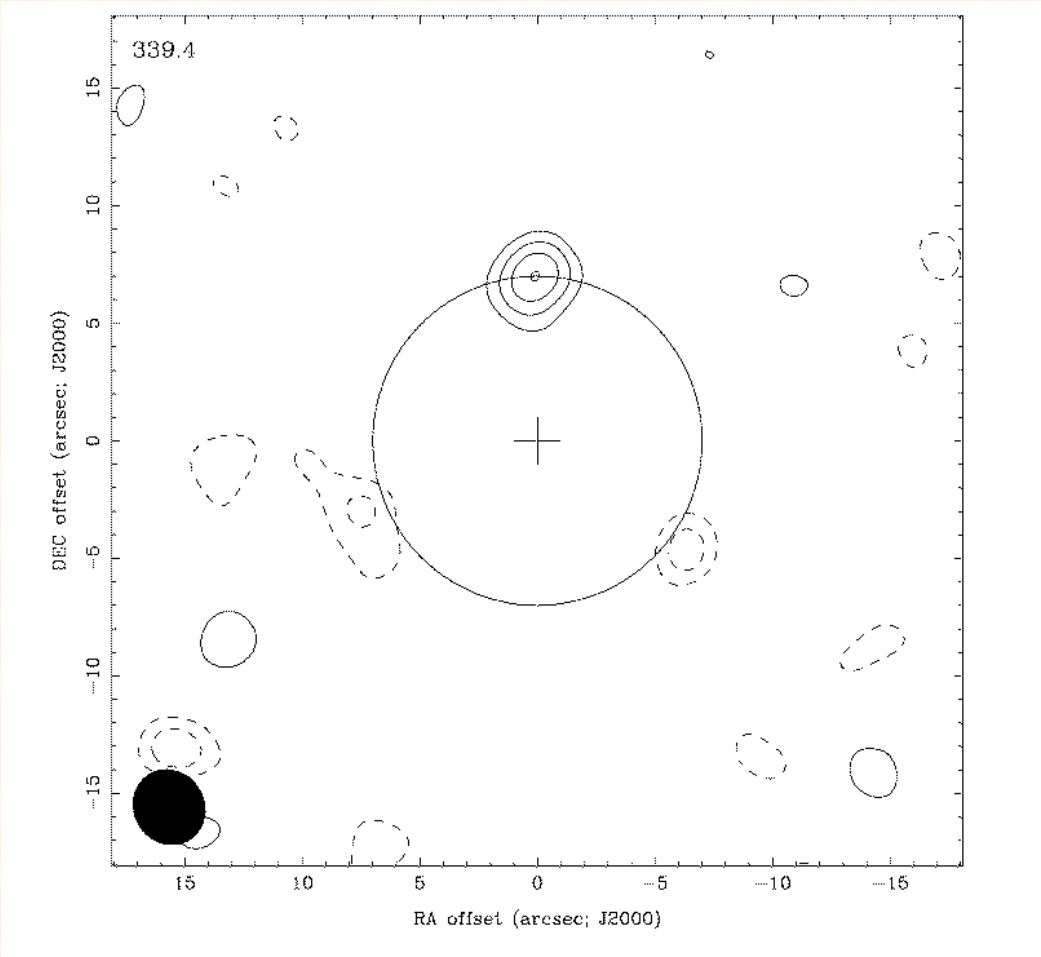
     2 tracks detect 8 mJy SHADES source, coincident with radio source

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)

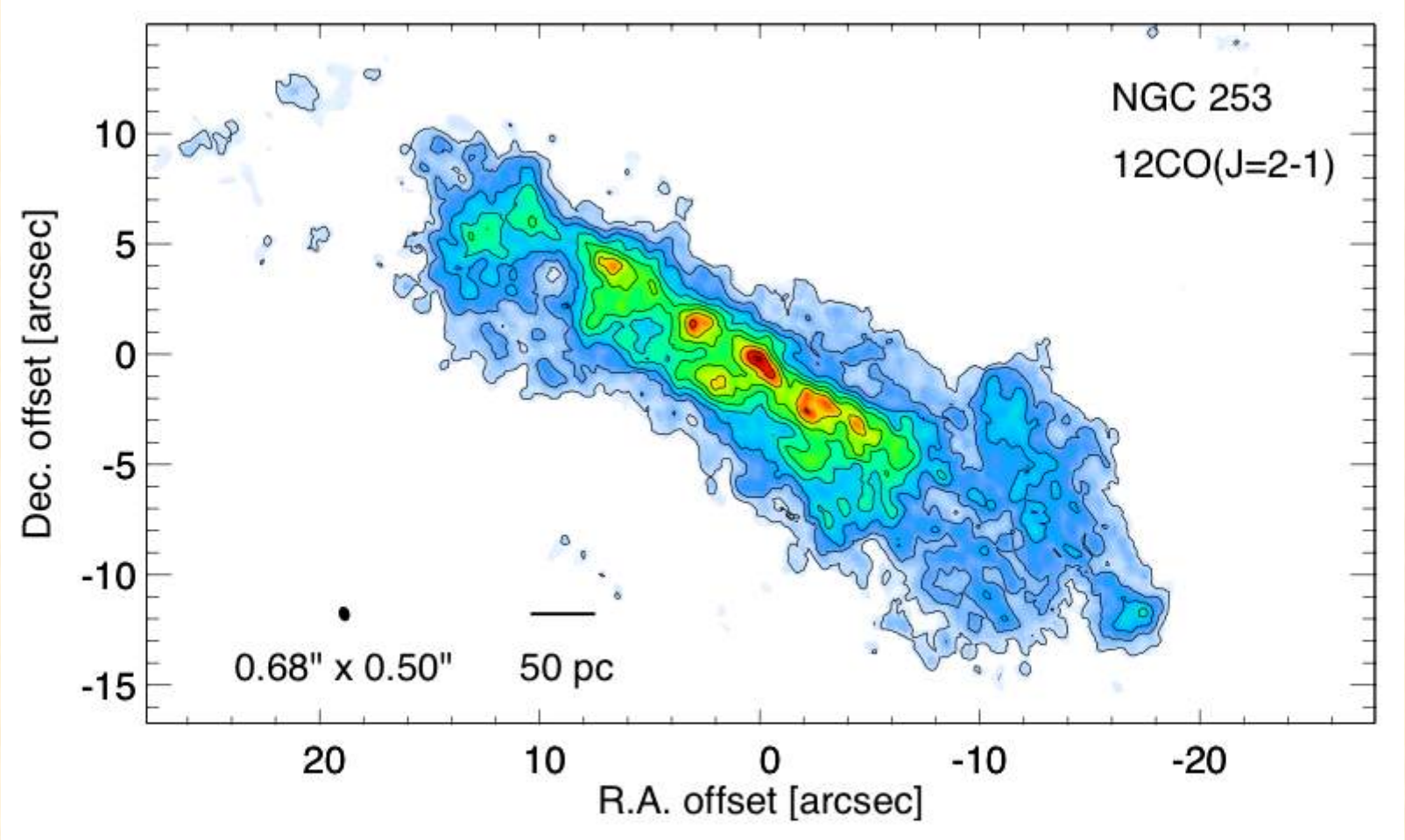
8mJy SCUBA Galaxy (Iono, Peck, Dunlap et al.)



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

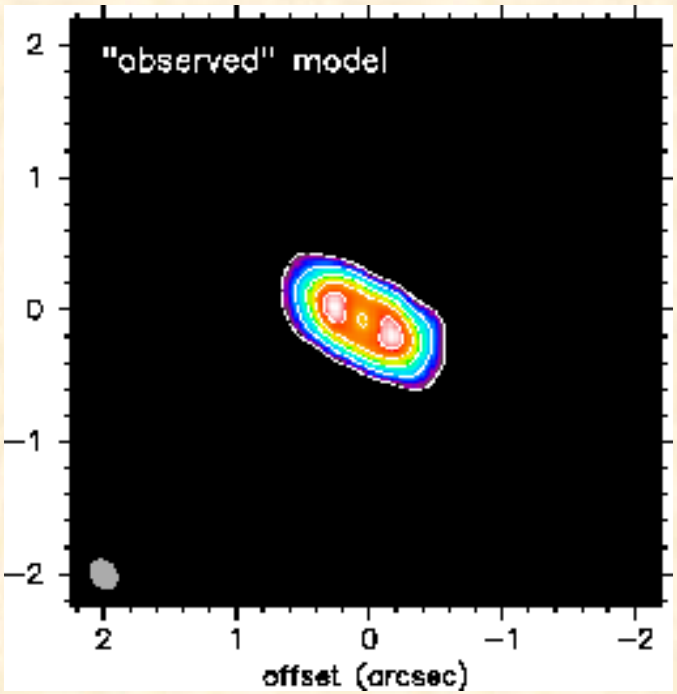
However, several other attempts at detecting submillimeter galaxies have produced non-detections

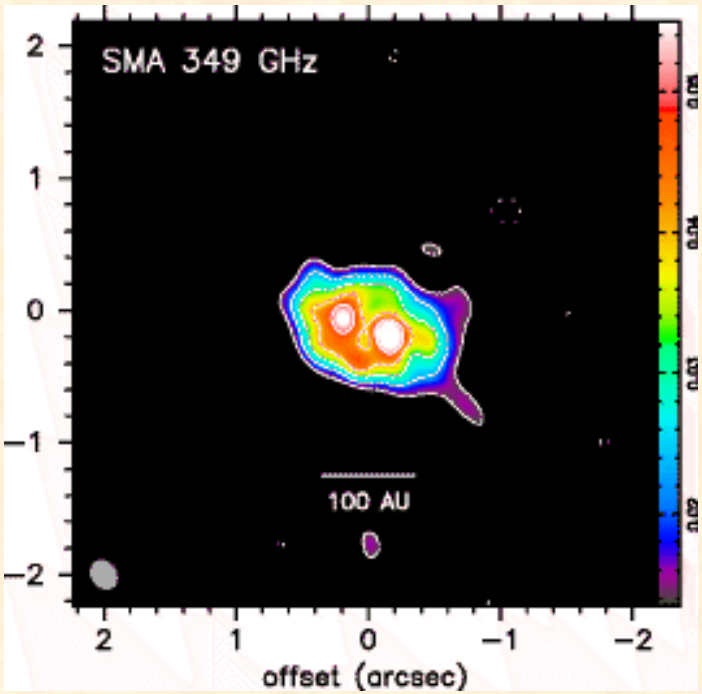
NGC 253 Prototypical starburst at high resolution



Subarcsecond image with ~ 10 pc resolution (Sakamoto et al in prep)

GM Aurigae Protoplanetary Disk Inner Hole



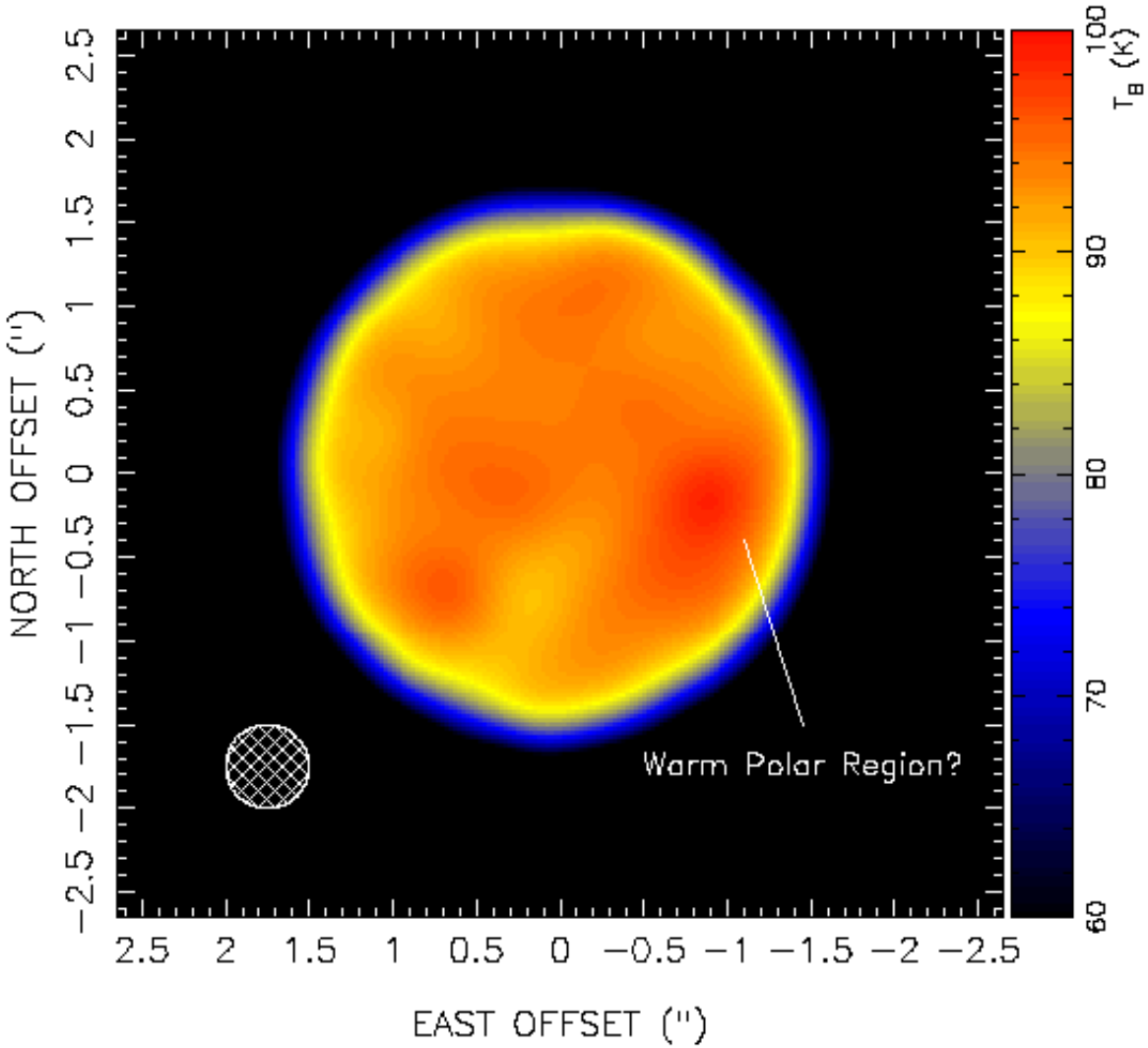


Model prediction for SMA observations of GM Aur

High resolution SMA image
Resolution 0.2x0.3 arcsec

(Wilner et al)

High resolution image of Uranus



(Gurwell)

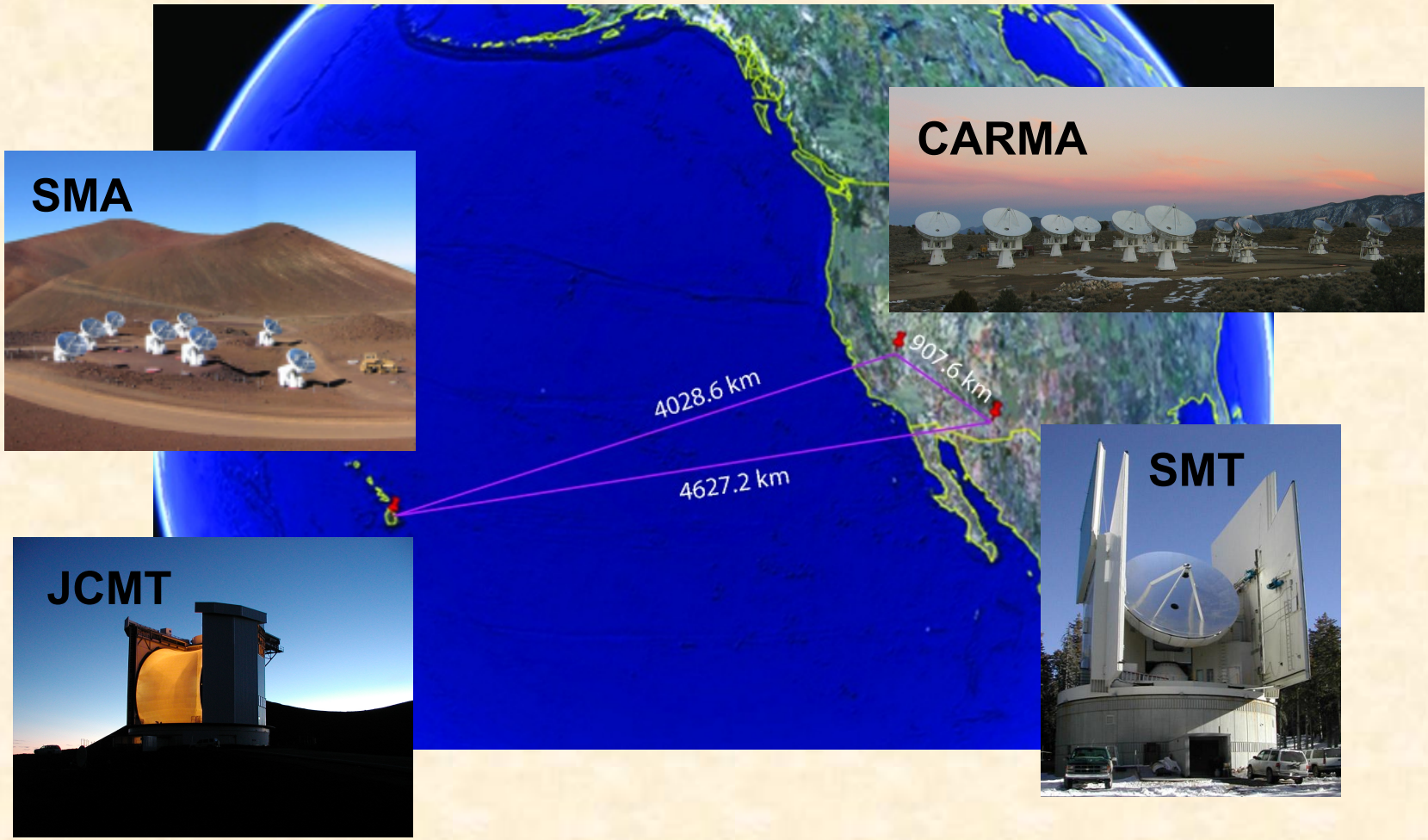
Smithsonian Astrophysical Observatory
Submillimeter Array

Report on SMA activities
Ray Blundell

Mauna Kea Users' Committee Meeting
October 2nd, 2008

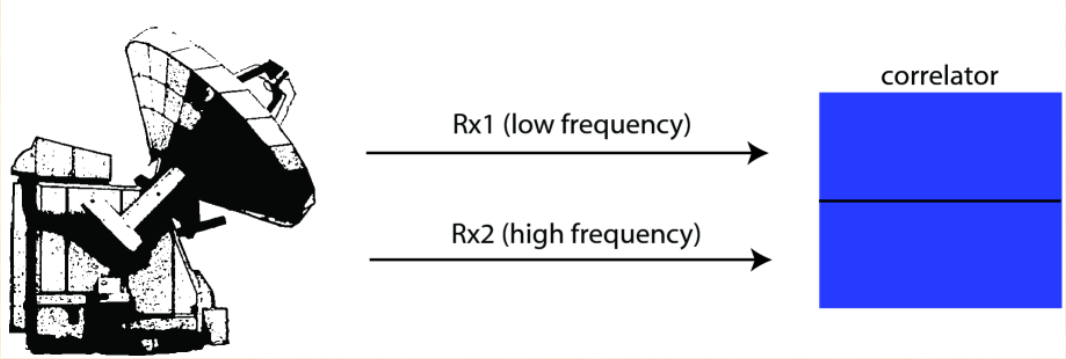
Smithsonian Astrophysical Observatory
Submillimeter Array

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



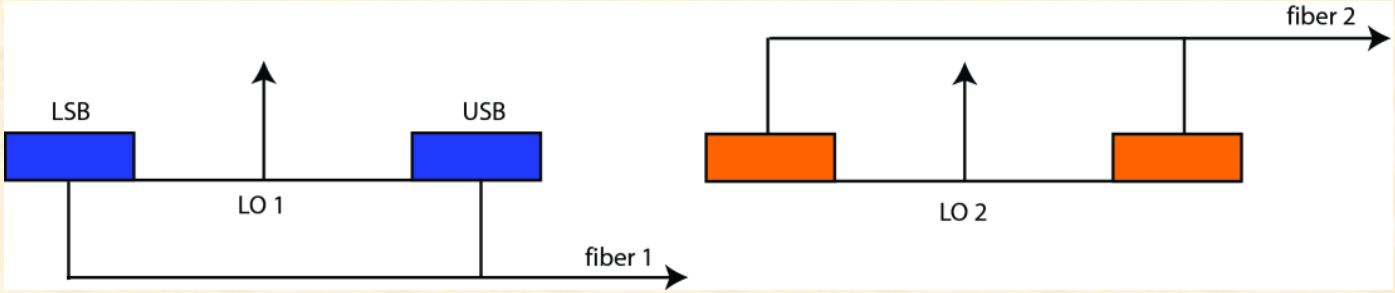
Double bandwidth for single receiver use

- 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

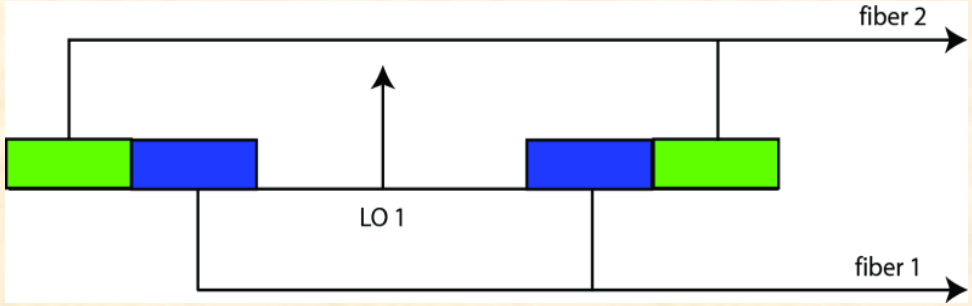


Double bandwidth for single receiver use

Two receiver operation



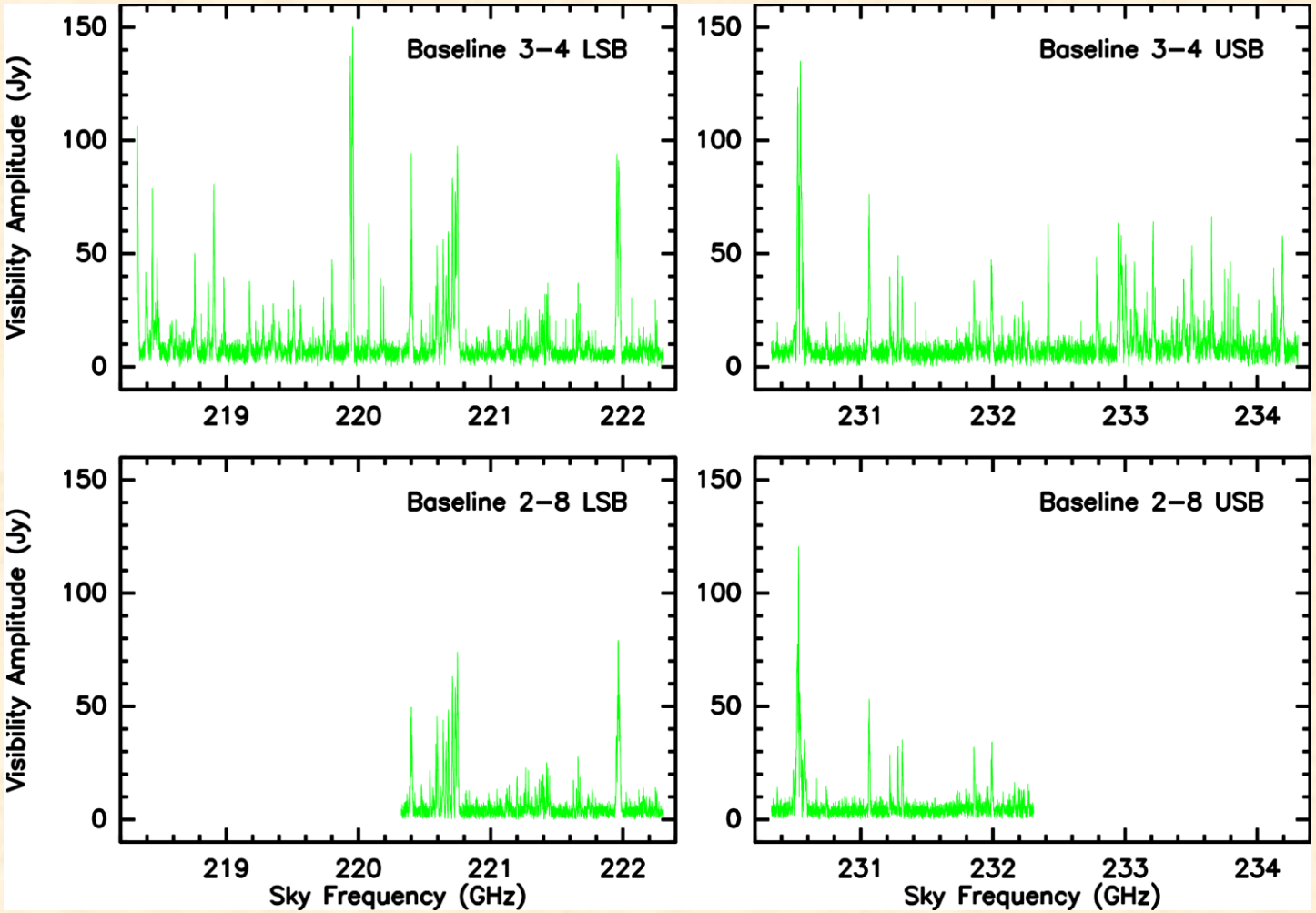
Single receiver, double bandwidth



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

Smithsonian Astrophysical Observatory
Submillimeter Array

Observations using Bandwidth Doubler (Young)



The Submillimeter Array

Raymond Blundell

Mauna Kea Users' Meeting

September 30, 2010

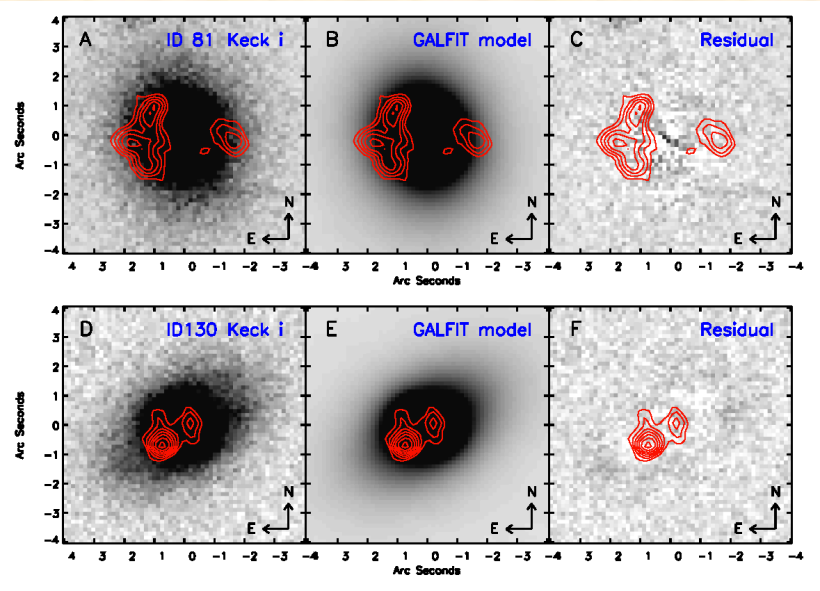
Instrument Upgrades

- 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*
  - Transition disks and planet formation

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

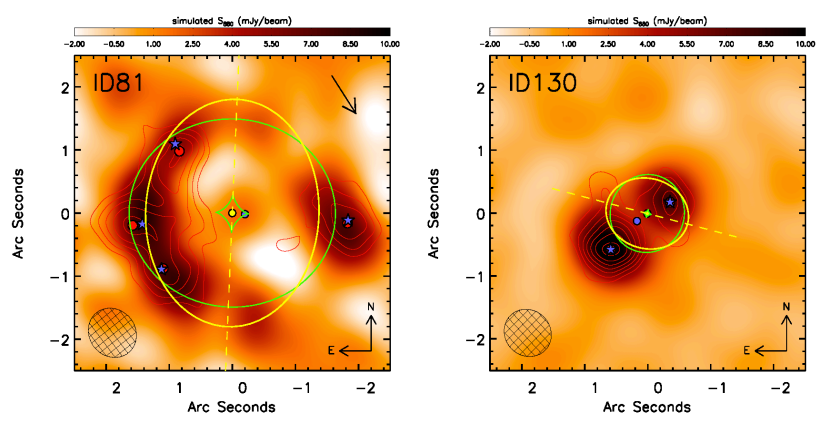


Lensing galaxies observed with Keck

Submm flux mapped with the SMA

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

z ~ 2.63 for ID 130 (PdB, GBT)

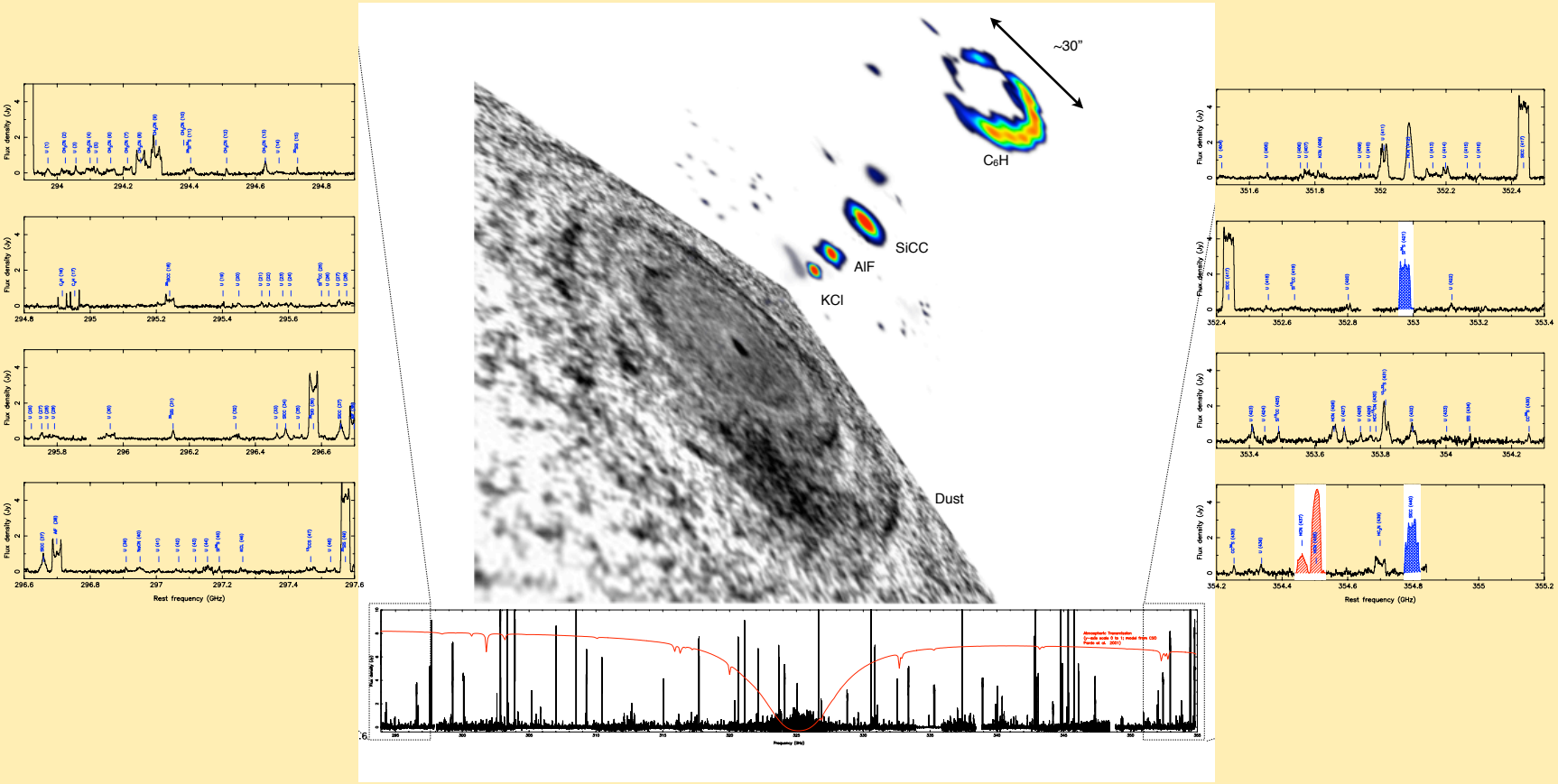


LENSMODEL software used to fit SMA data
IR magnification for ID 81 ~ 18 to 31
IR magnification for ID 130 ~ 5 to 7
(More detailed work in progress)

(Negrello et al. – Science, Sept 2010)

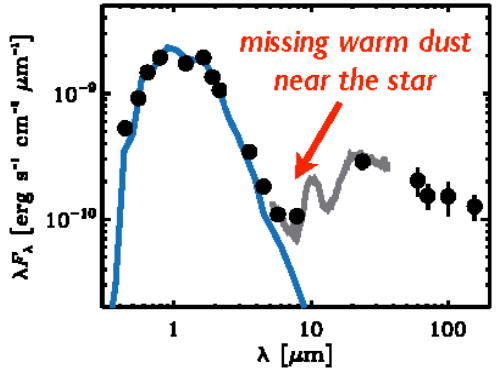
Irc+10216 Spectral Line Survey

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

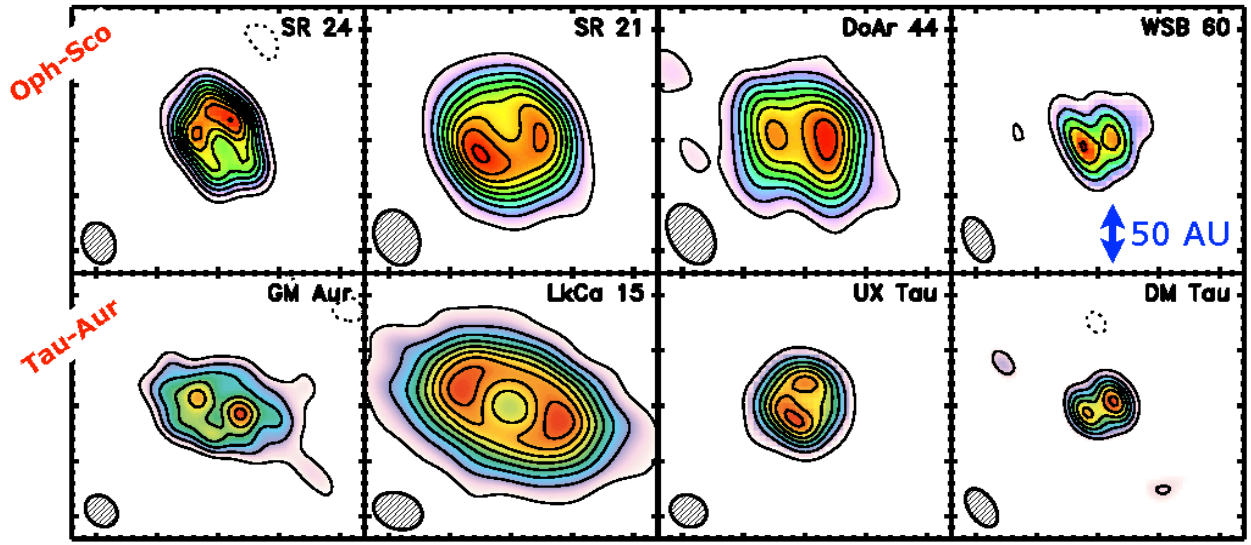
PROTOPLANETARY TRANSITION DISKS
High Resolution Imaging



protoplanetary transition disks

inner part of disk cleared by tidal perturbations from young, long-period giant exoplanets

- SMA resolves cavities at 880 microns
- new way to hunt for 1 Myr-old planets!



[Hughes et al. 2009; Andrews et al. 2009, 2010]

Need ALMA for ~ 20 times better resolution

(Andrews)

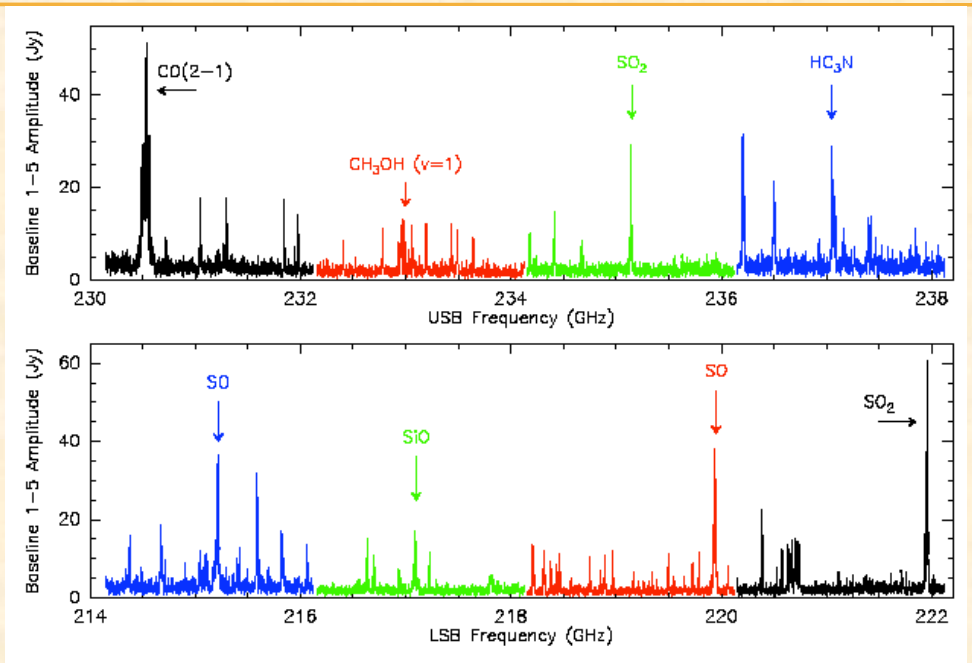
THE SUBMILLIMETER ARRAY

Raymond Blundell

Mauna Kea Users' Meeting

October 4, 2012

NEW WIDE-BAND IF OPTIONS FOR THE SMA 1.3 mm RECEIVER BAND

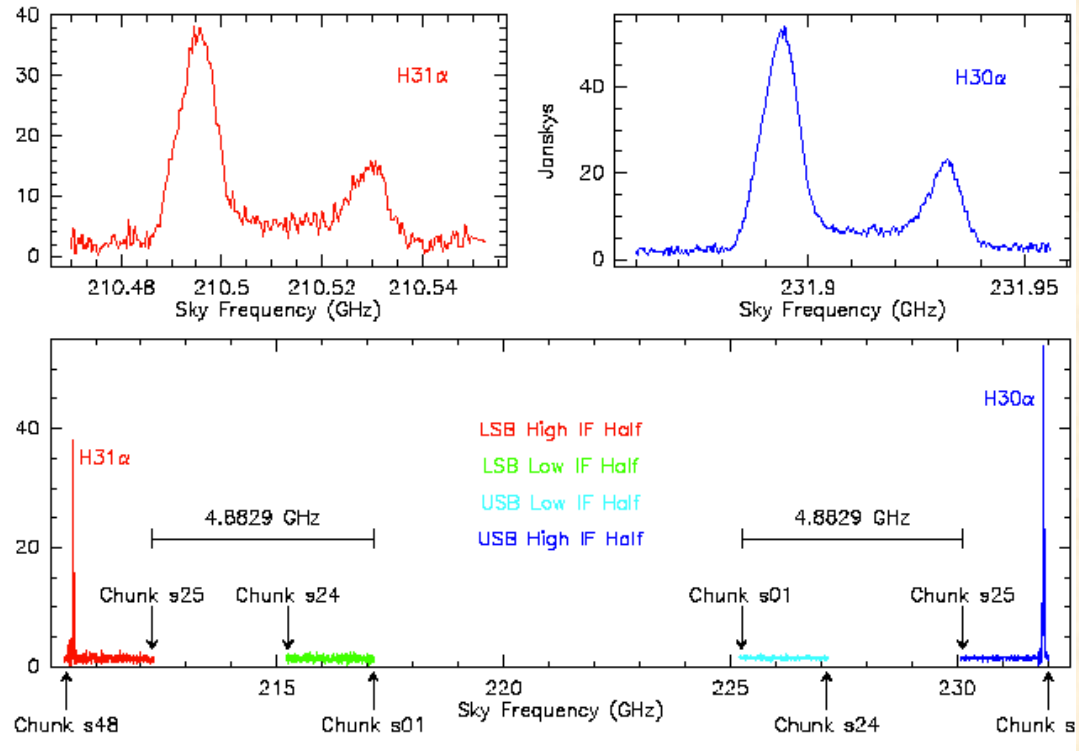


(YOUNG & TONG)

On-sky test observations towards Orion BN/KL on a single baseline: The black spectra show the original 4 – 6 GHz spectral region. The red spectra show the additional coverage obtained in the 'Bandwidth Doubled' mode of operation introduced in 2010, with the usual 12 GHz LO sent to the BDA.

A 14 GHz LO provides spectral coverage over the 8 – 10 GHz IF range, shown in green, and a 16 GHz LO provides coverage over the 10 – 12 GHz range, shown in blue.
Correlator upgrade required to fully utilize x2 increase in receiver bandwidth

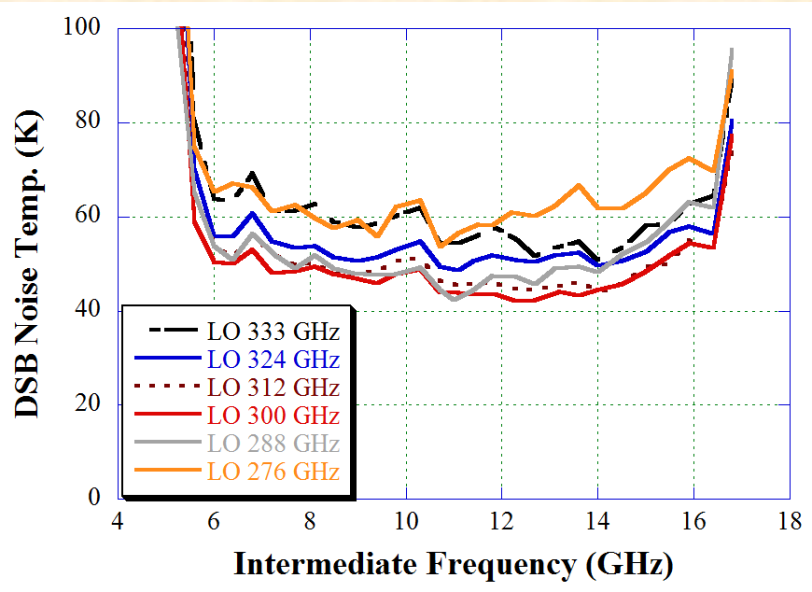
NEW OBSERVING MODE FOR THE 2012B SEMESTER

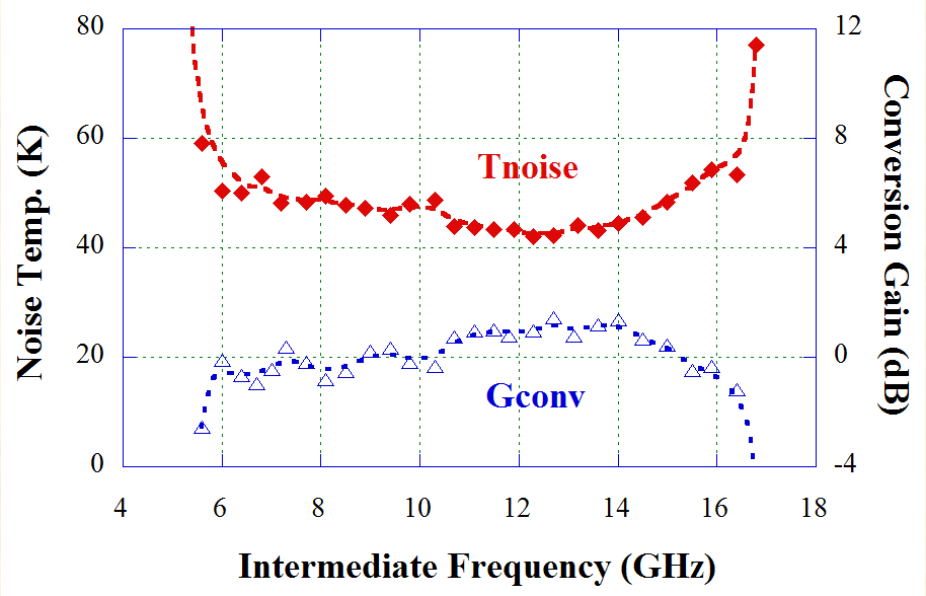


(YOUNG & TONG)

Because changing the LO to the Bandwidth Doubler Assembly allows the two halves of a sideband to span as much as 8 GHz, which is also the separation between the lowest USB frequency and the highest LSB frequency, one can now target any two spectral lines which are separated by less than 24 GHz, either by putting them both in one sideband, which offers coverage for up to 8 GHz separation, or by putting them in different sidebands for up to 24 GHz separation.

NEW WIDE-BAND RECEIVERS FOR THE 0.86 mm BAND





Following upgrades to 1.3 mm receivers, need to do the same with 0.86 mm receivers
New 0.86 mm receiver has low-noise across a 6 – 16 GHz IF compared to 4 – 8 previously
In addition, the noise at the band edges 260, 350 GHz is as low as at band center previously
However, need to work towards extending IF down to 4 GHz
Expect installation of new receivers to begin early 2013

TONG

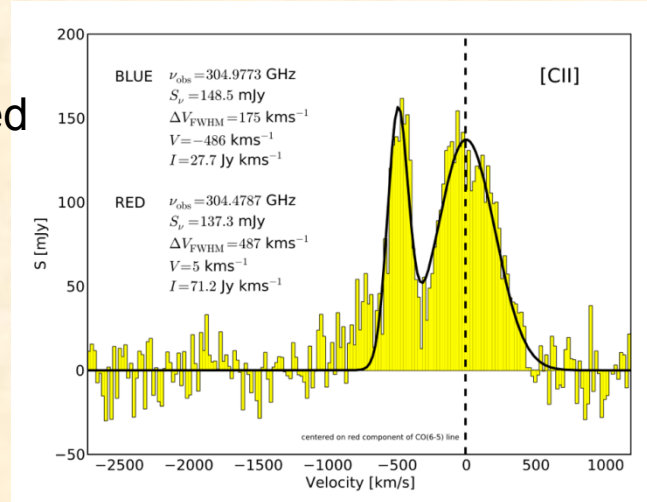
HIGH RESOLUTION IMAGING OF 35 LENSED SMG's

Bar above each frame is one arc-second in length

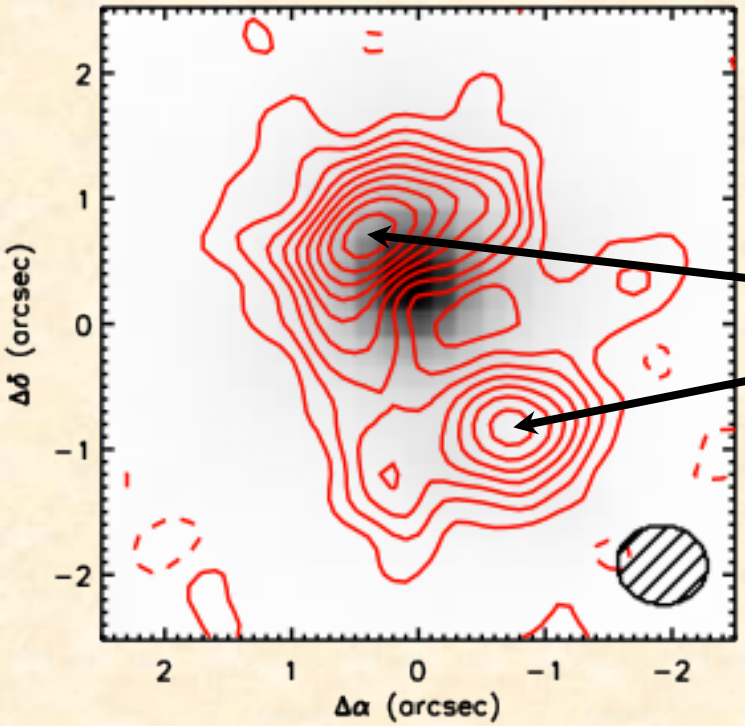
(BUSSMAN)

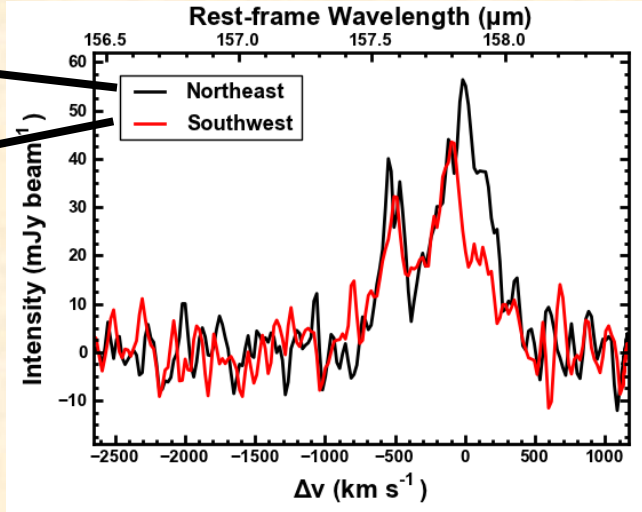
CII IN A SUBMILLIMETER GALAXY AT Z = 5.2

Right: unresolved CII spectrum at 304 GHz
Lower right: compact, extended, very extended summed to resolve components



SMA – red contours (z = 5.2)
Subaru I band – grayscale (z = 0.6)





(RAWLE)

Current Status of SMA Instrumentation

Have focused on improving 230 and 345 GHz receivers

Improved sensitivity – factor of 30% reduction in noise
Improved bandwidth – factor of 2 times wider than original 2 GHz
Cannot yet exploit full potential of receiver bandwidth improvements
Factor of three (over original) by adding SWARM at half speed
1 receiver, 2 sidebands, 4 GHz wide = 8 GHz (2x original BW)
or 2 receivers, 2 sidebands, 2 GHz wide = 8 GHz (2x original BW)
Plus
1 receiver, 2 sidebands 2 GHz wide = 4 GHz more
or 2 receivers, 2 sidebands, 2 GHz wide = 4 GHz more

Factor of four by adding SWARM at full speed = 8 + 8 = 16 GHz total

Mauna Kea is a really good mm site, not so good for submm

Observing time split roughly 50/50 for 230 and 345 bands

Concentrate further on improvements to receivers in these bands

Receiver Upgrades

Current situation in the Cambridge lab

345 GHz receivers with IF from 4 to 12 GHz
with reasonable performance up to 16 GHz IF

230 GHz receivers with IF from 4 to 12 GHz
and with reasonable performance up to 14 GHz

400 GHz receivers with IF from 4 to 12 GHz

Need more correlator capacity to take full advantage of receivers

Excellent collaboration between Edward Tong and Min-Jye Wang (ASIAA) in developing low noise SIS mixer chips

Entirely possible, even near term, to achieve 2 to 18 GHz receiver IF

Correlator Upgrades

Obvious need to add additional signal processing capability
- Limited in-house ability to design and implement high speed digital cards
- Also, producing large numbers of analog channels a challenge
- CASPER approach seemed the most appealing
  - – especially true in light of limited staffing levels

Initial approach
- Develop correlator based on ROACH 2 hardware
- Modular approach – each section with same capacity as current
- ASIC correlator (has been in operation for more than 10 years)

Cooperative effort
- Digital Back End development and implementation (Cambridge)
- IF system upgrades (Cambridge and Hilo)
- Additional down-converter assemblies (Hilo staff)
- On-site infrastructure (Hilo staff)
- On-sky tests (All)

Correlator Upgrades - SWARM

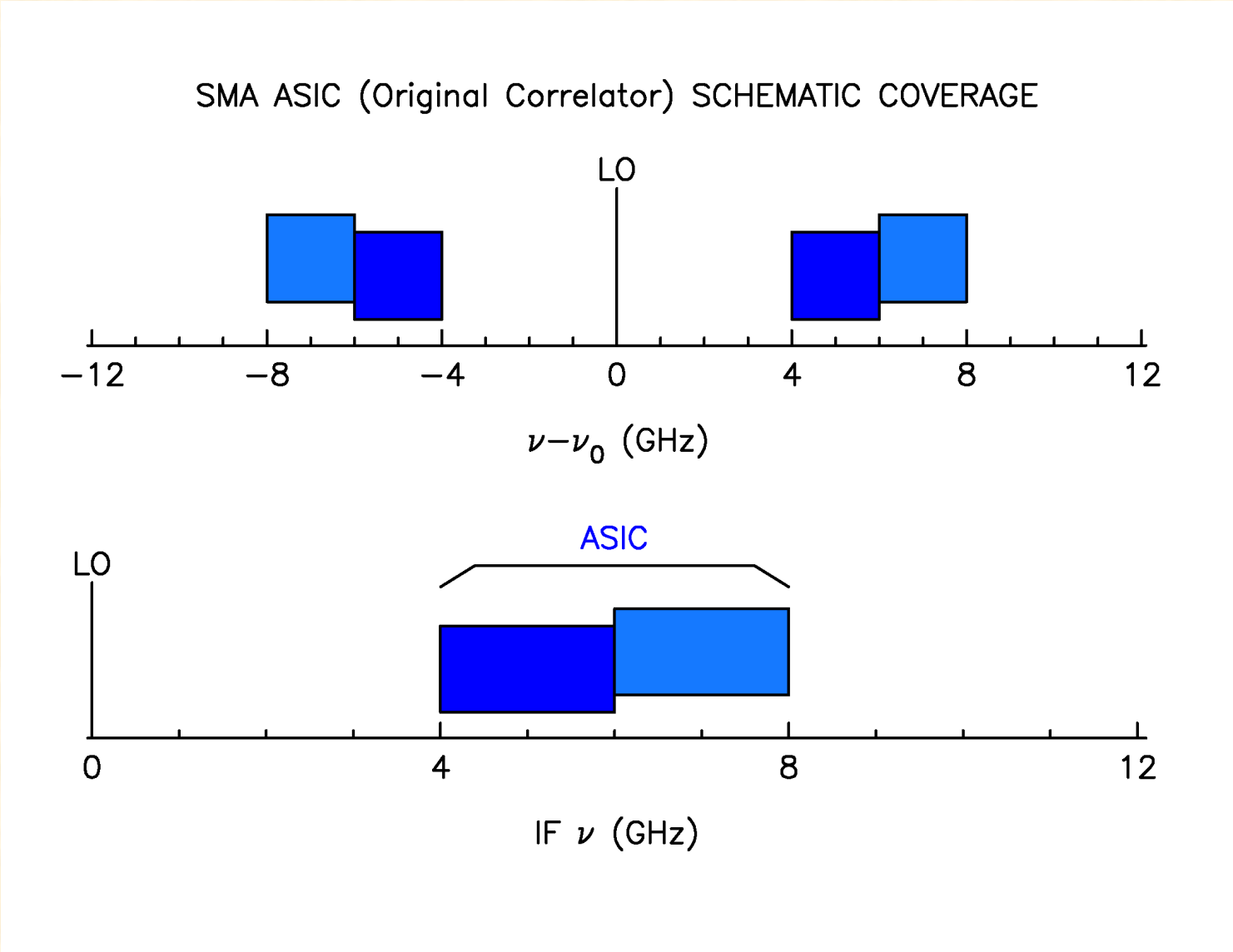
First, limited, on-sky tests February 2013

Commissioning tests at half speed (half bandwidth) ongoing
- Current system enables 4-8 GHz using ASIC correlator
- Plus 8-9 and 11-12 GHz using SWARM
- Doubling the speed remains a challenge
  - but will complete the 8-12 GHz IF addition

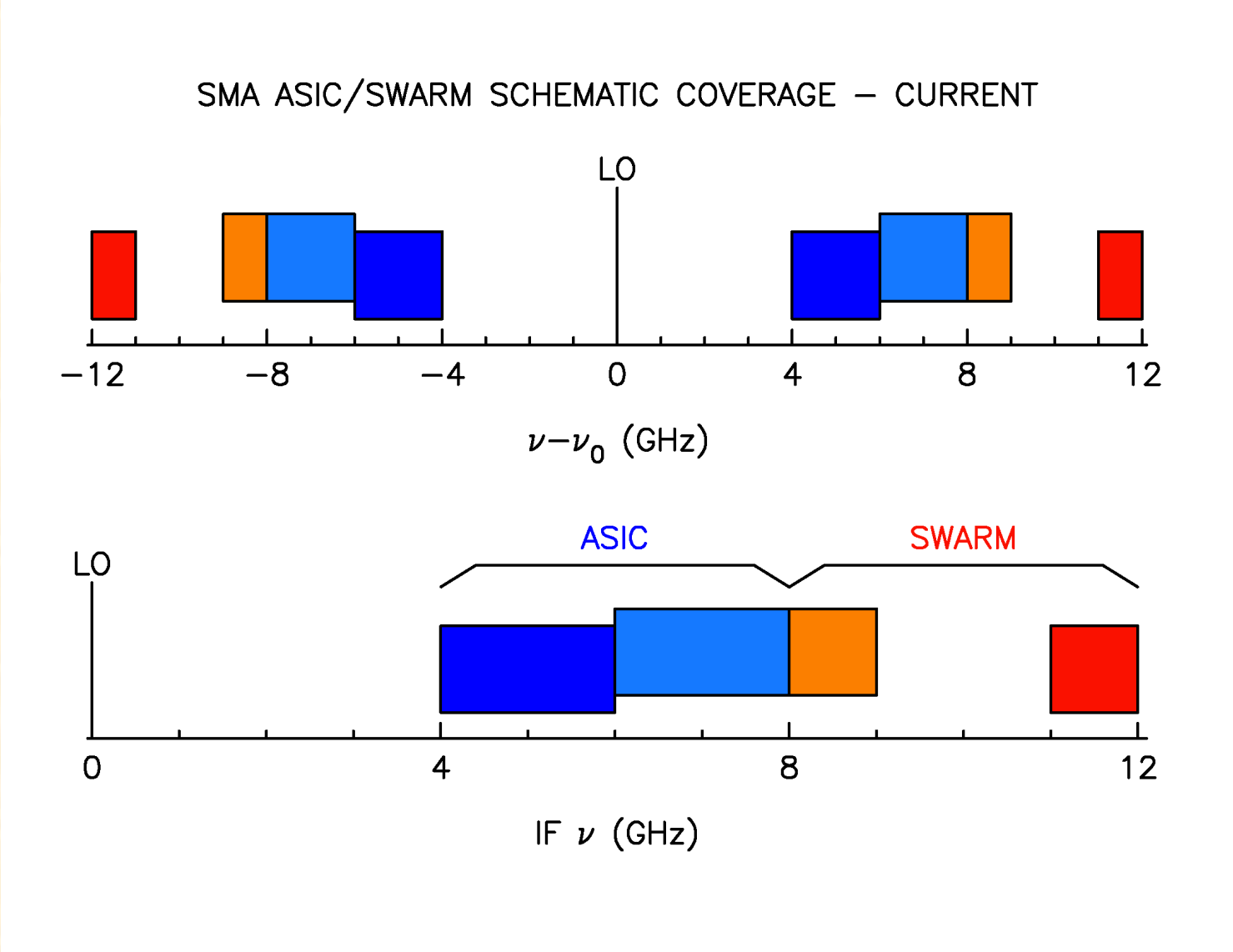
Assuming full speed operation
- Produce 3 more units ASAP
- Additional infrastructure required in Hawaii
- Would accommodate 2 DSB receivers, each with 4-12 GHz IF
- Total throughput = 2 x 2 x 8 = 32 GHz
- (Current ASIC correlator retired)

Very straightforward approach to increase SMA throughput

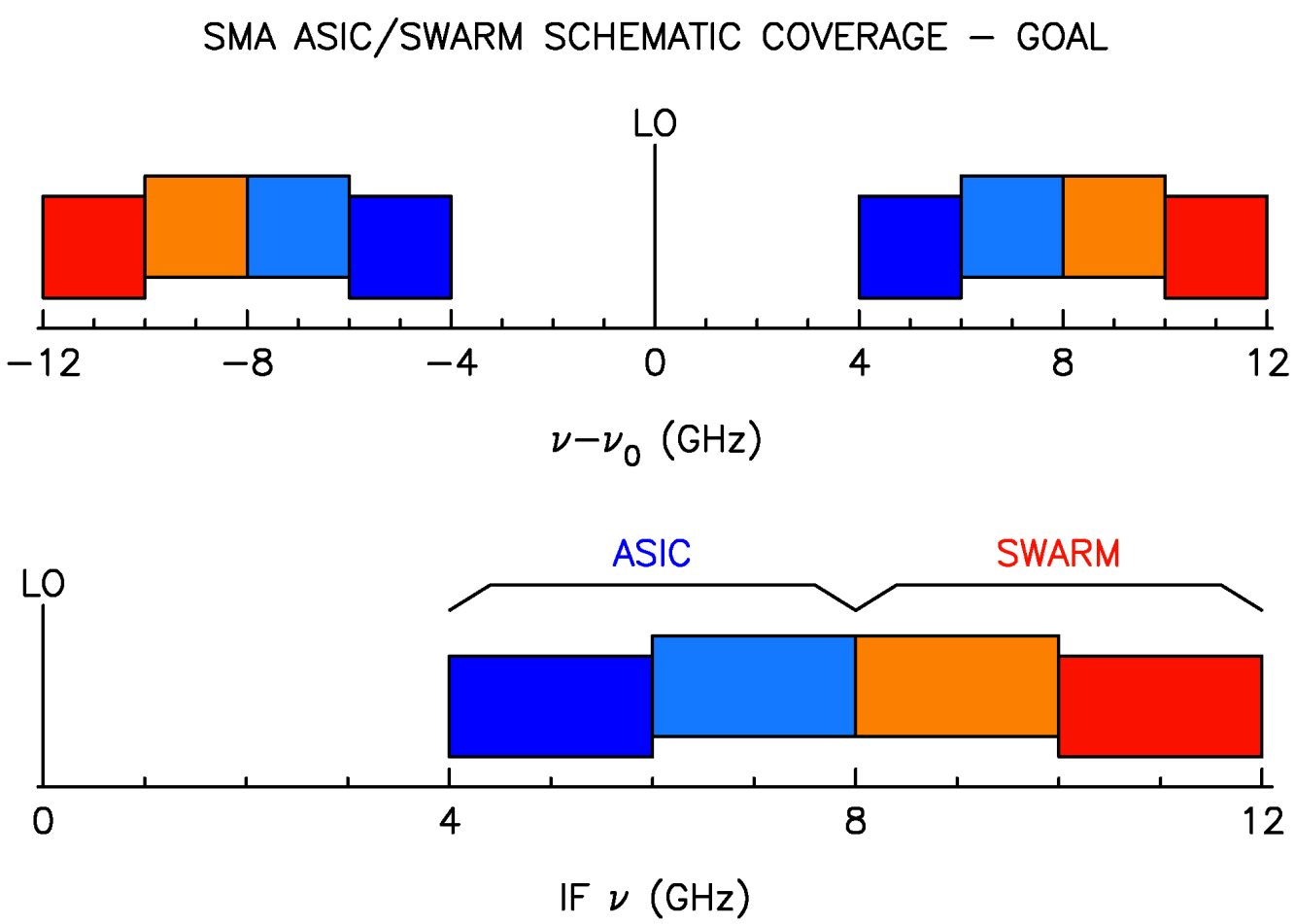
Current Observations - SMA ASIC Correlator



Actual - SMA ASIC Correlator + half SWARM



Next call for proposals - add SWARM



Longer Term

Finish commissioning of SWARM

Build second unit (key components already on order)

Then build third …… eighth SWARM

(Retire current ASIC correlator at some point)

This would enable 2 x 2 x 16 = 64 GHz bandwidth to be processed
With only modest increase required in receiver bandwidth

*** This would be 8 x current BW, or 4 x BW with 1st SWARM ***

Spectral line sensitivity can only be improved via dual polarization

Need a second set of 230 GHz receivers