The Submillimeter Array

David J. Wilner (Harvard-Smithsonian CfA) & SMA Team

Historical Perspective

Overview of Capabilities

Early Science Examples

The SMA is a collaborative project of the Smithsonian Astrophysical Observatory, part of the Harvard-Smithsonian Center for Astrophysics, and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)

Key People

SMA Director.....Jim Moran

Project Scientist.....Paul Ho

Receiver/Antenna.....Ray Blundell

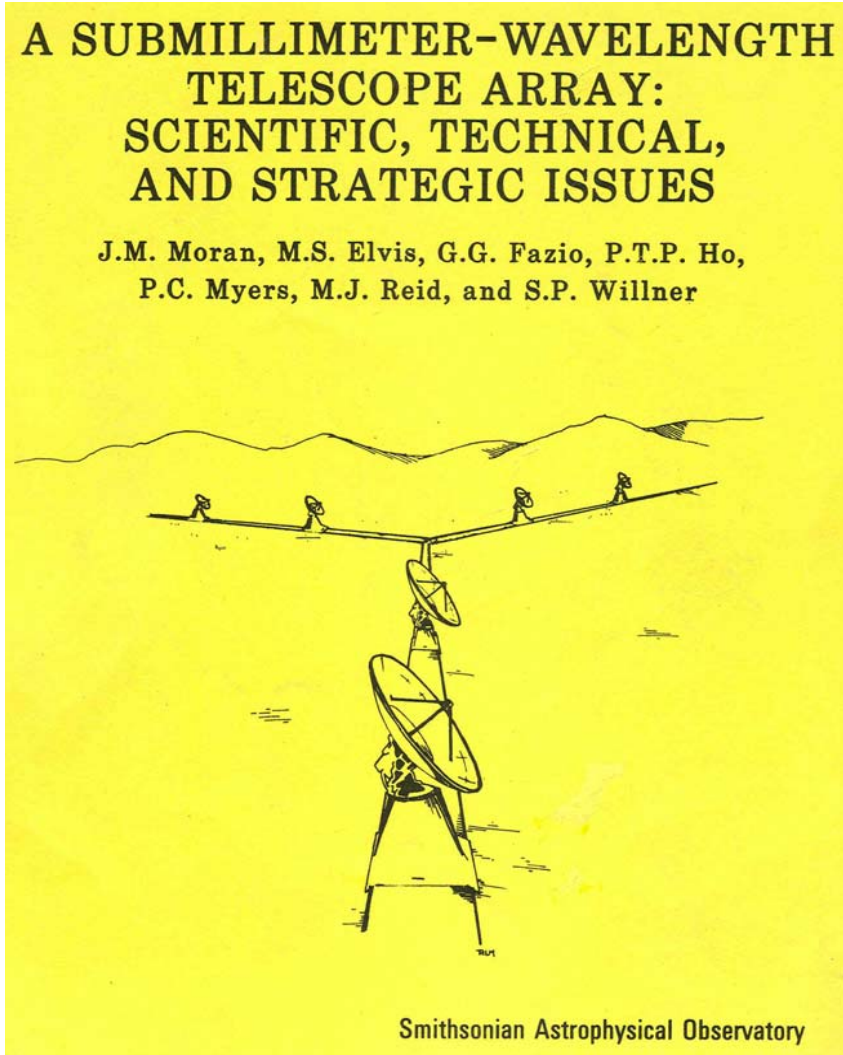
Technical.....Bob Wilson

Operations (Hilo).....Ant Schinckel

ASIAA.....Sun Kwok

SMA Project Development

- 1984: SAO Study:
  - six 6 m antennas
  - subarcsecond resolution
  - high altitude site
  - receiver development
- 1992: SAO becomes antenna contractor
- 1994: OSDA U. Hawaii
- 1996: ASIAA expansion
  - add two antennas $\rightarrow$ eight
- 1998: fringes at Haystack
- 1999-2003: antennas deployed to Mauna Kea



Mauna Kea Submillimeter Valley

1998

SMA Dedication
November 2003

SMA Specifications (and drivers)

Antennas: 8 antennas of 6 m diameter, 12 μm rms surface
cost + imaging speed + collecting area (~JCMT)

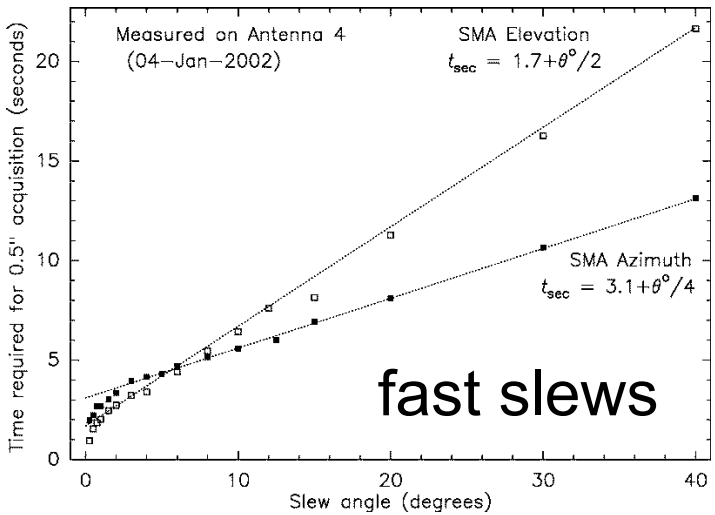
Configurations: 24 pads in four rings
baseline lengths 8 - 508 m,
subarcsecond resolution, best 0.1”

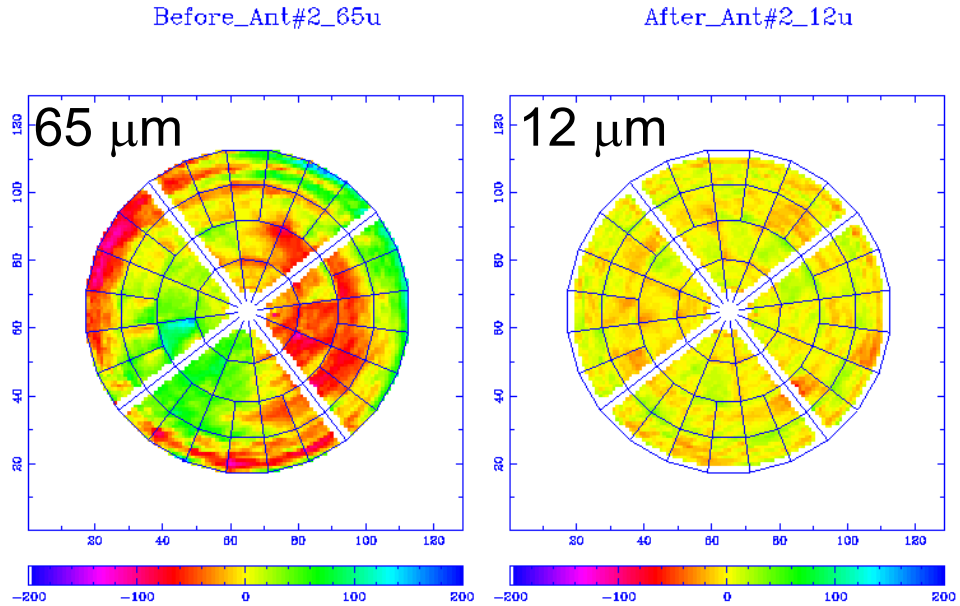
Receivers: max 8 per antenna; 2 simultaneously (late 2004)
full frequency coverage of atmospheric windows
dual polarization; “high” & “low” for calibration
177-256 GHz (8 in operation)
256-360 GHz (8 in operation)
320-420 GHz (start 2005), 420-520 GHz (future)
600-720 GHz (6 in operation, 2 soon)
780-920 GHz (future)

Correlator: 2 GHz bandwidth, 0.1 MHz resolution
sensitivity, span/resolve extragalactic/galactic lines

SMA Antennas

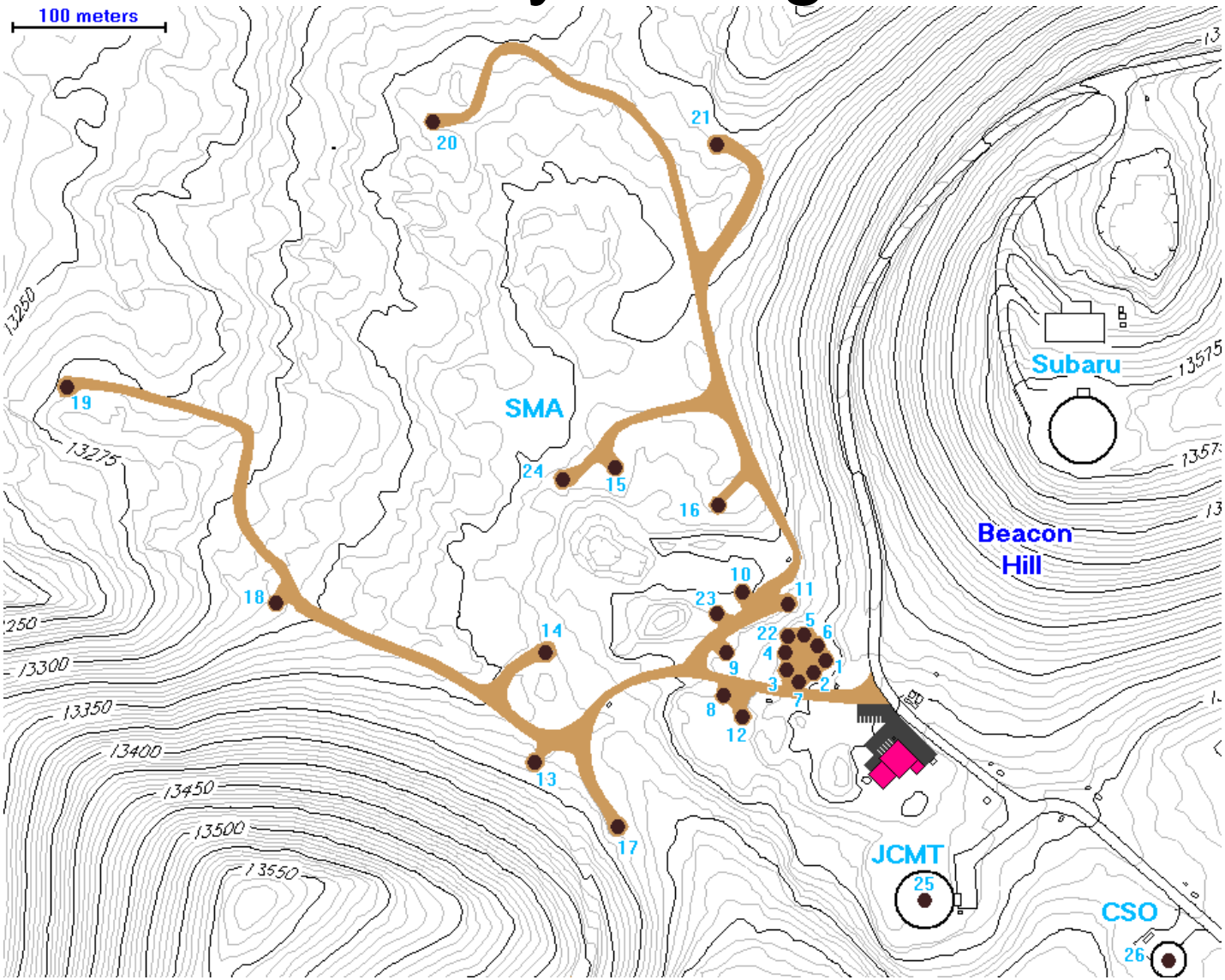
- f/0.4, surface 72 aluminum panels, carbon fiber bus





- near-field holography 232.4 GHz
- pointing rms 2” - 5” (night), improvements under study

Array Configurations

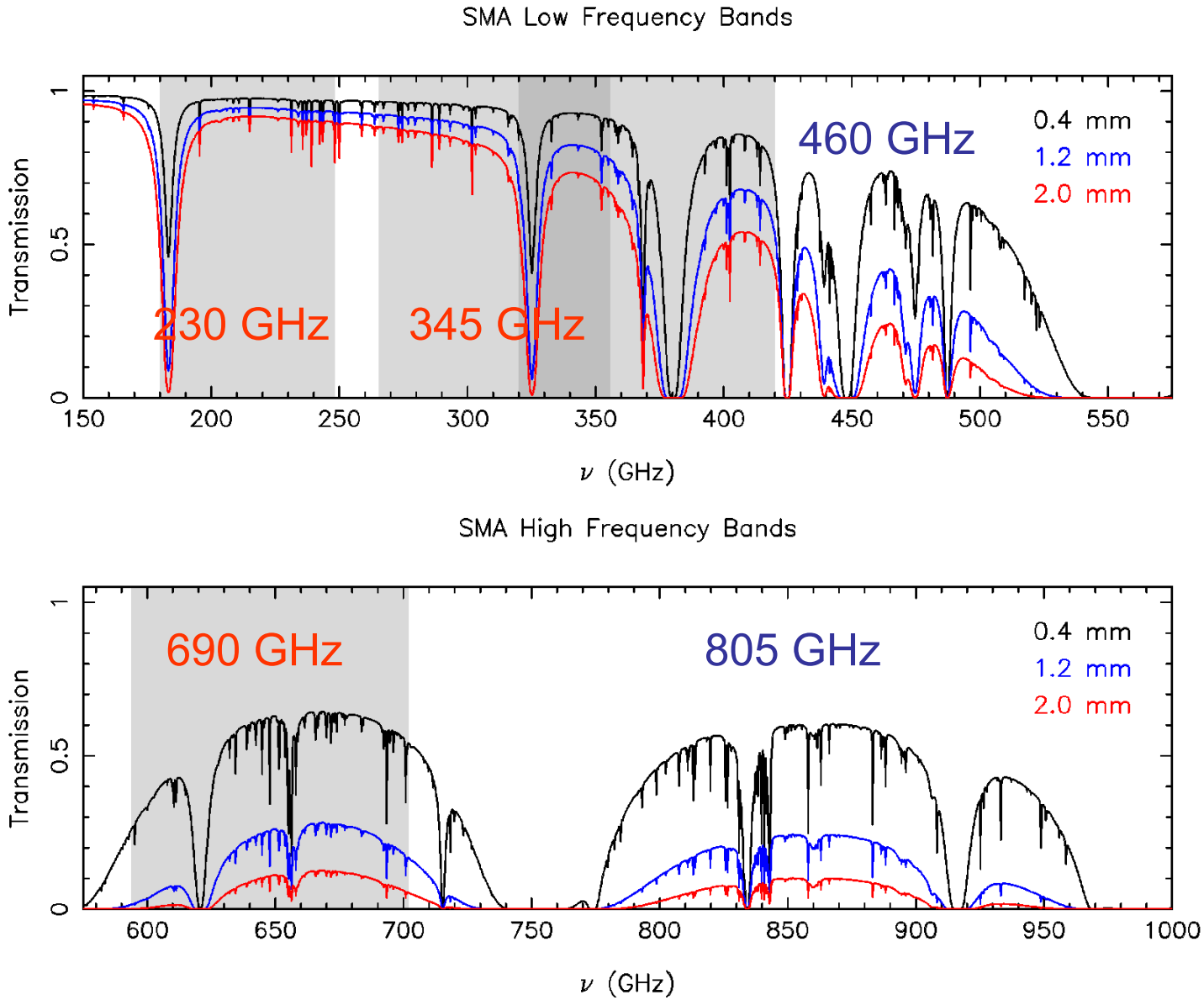


4 tangent "rings" based on Reuleux Triangles (Keto '97)

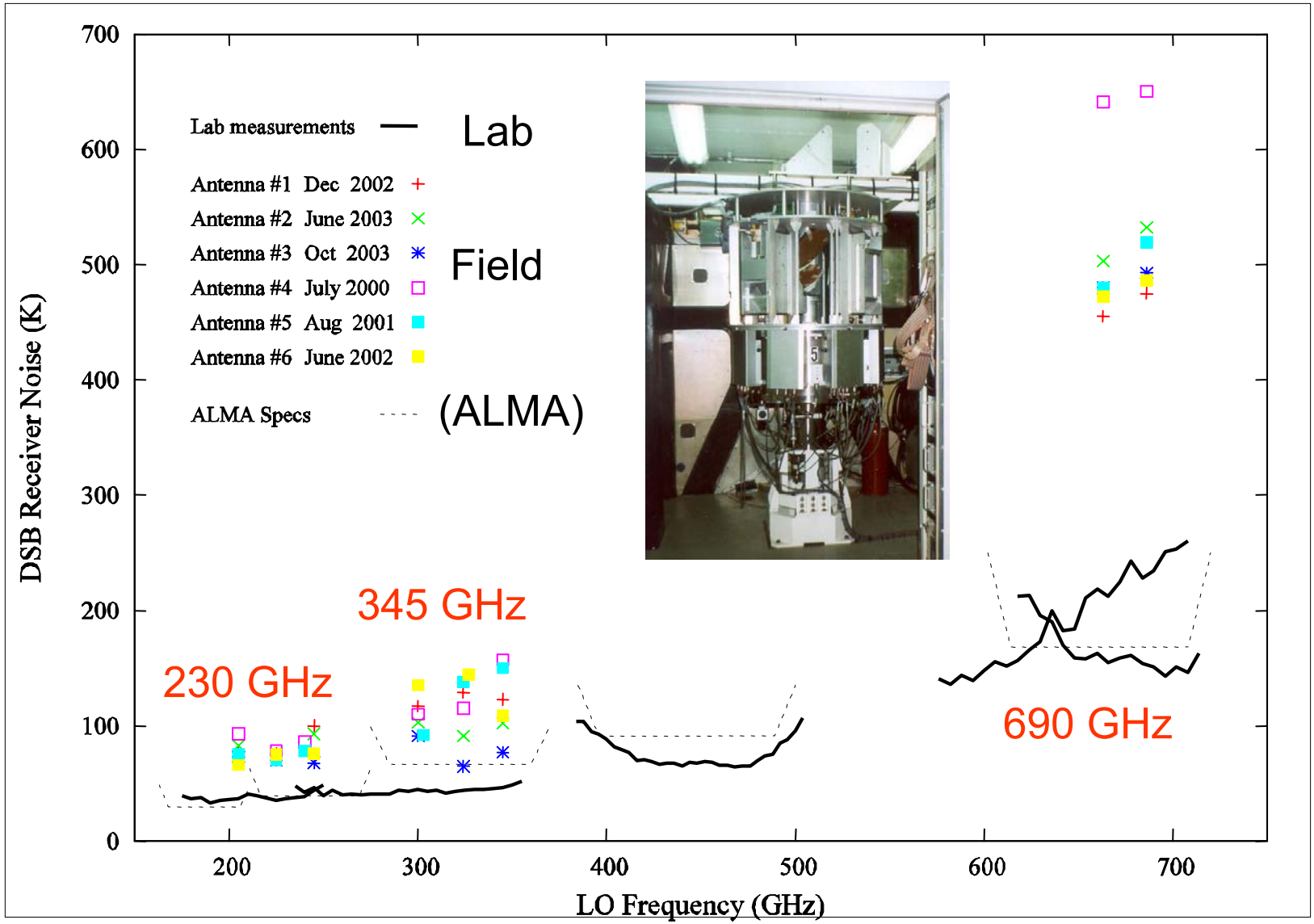
activate outer pads early 2005

JCMT/CSO link tests start 2005

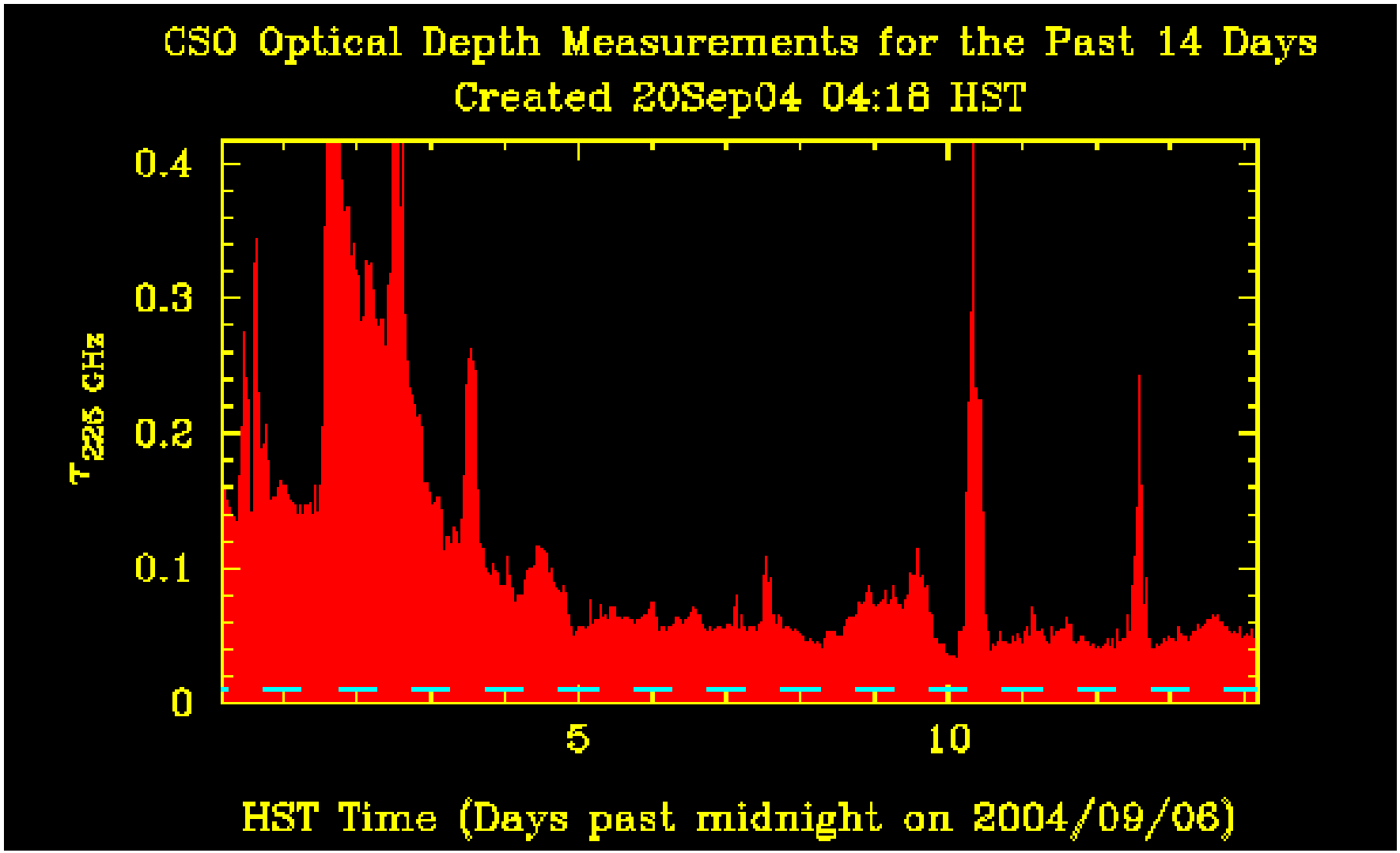
Receiver Bands/Atmospheric Transmission



Receiver Performance (R. Blundell)



Weather: CSO τ_{225} for last two weeks

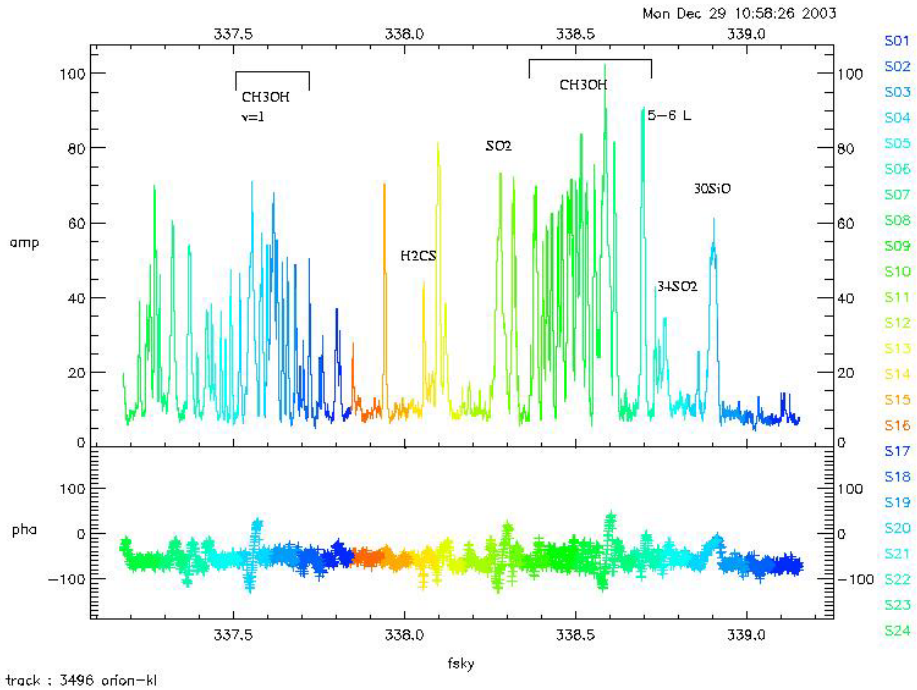


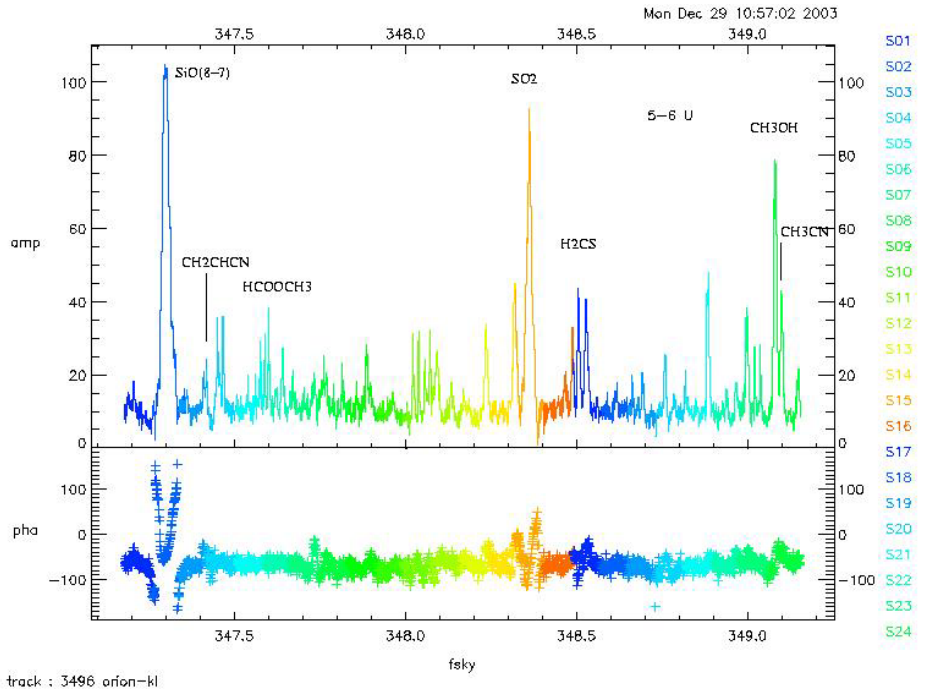
Correlator

LSB: 2 GHz = 24x82 MHz

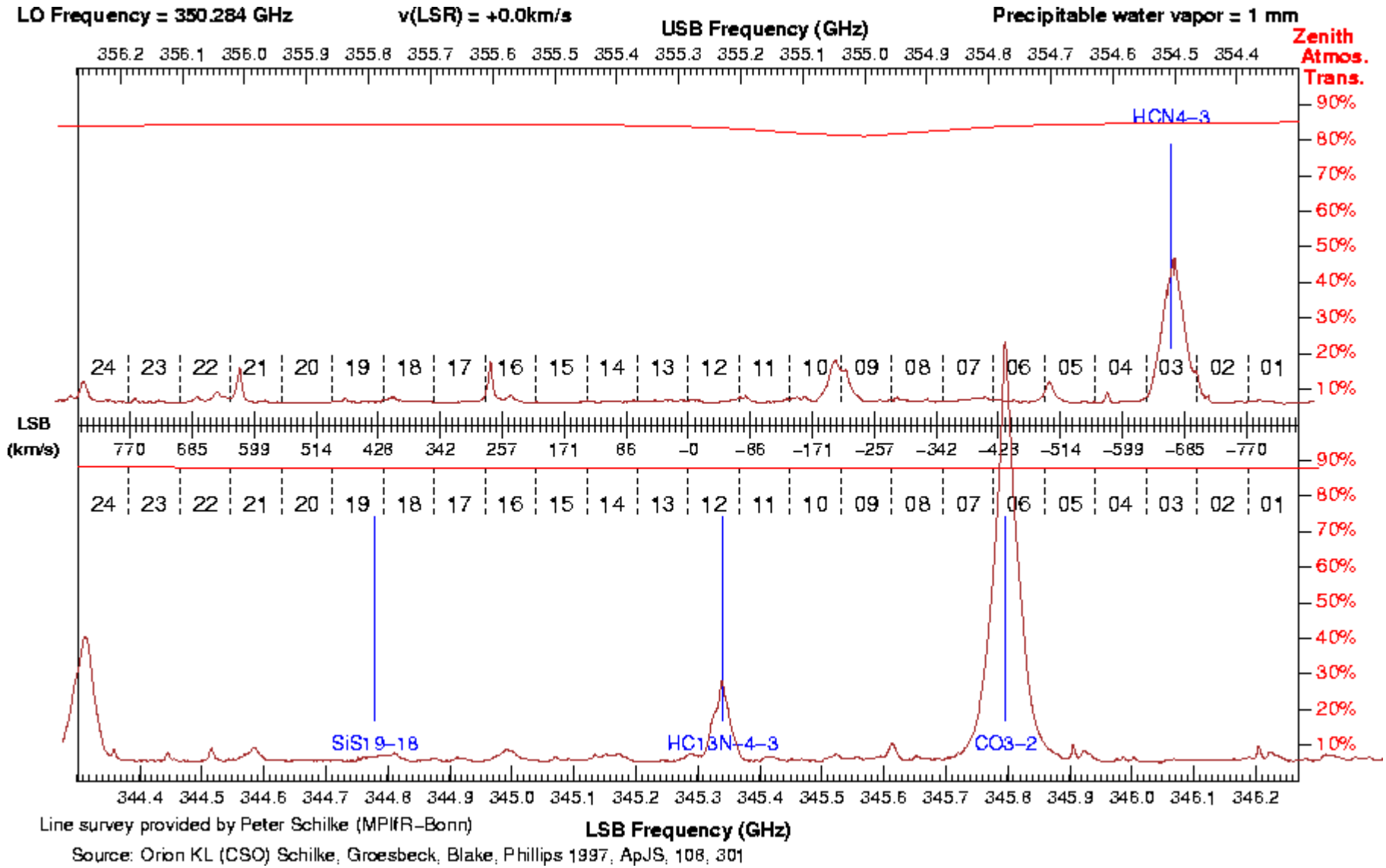
USB: 2 GHz = 24x82MHz

e.g. Orion-KL, Beuther et al., in prep

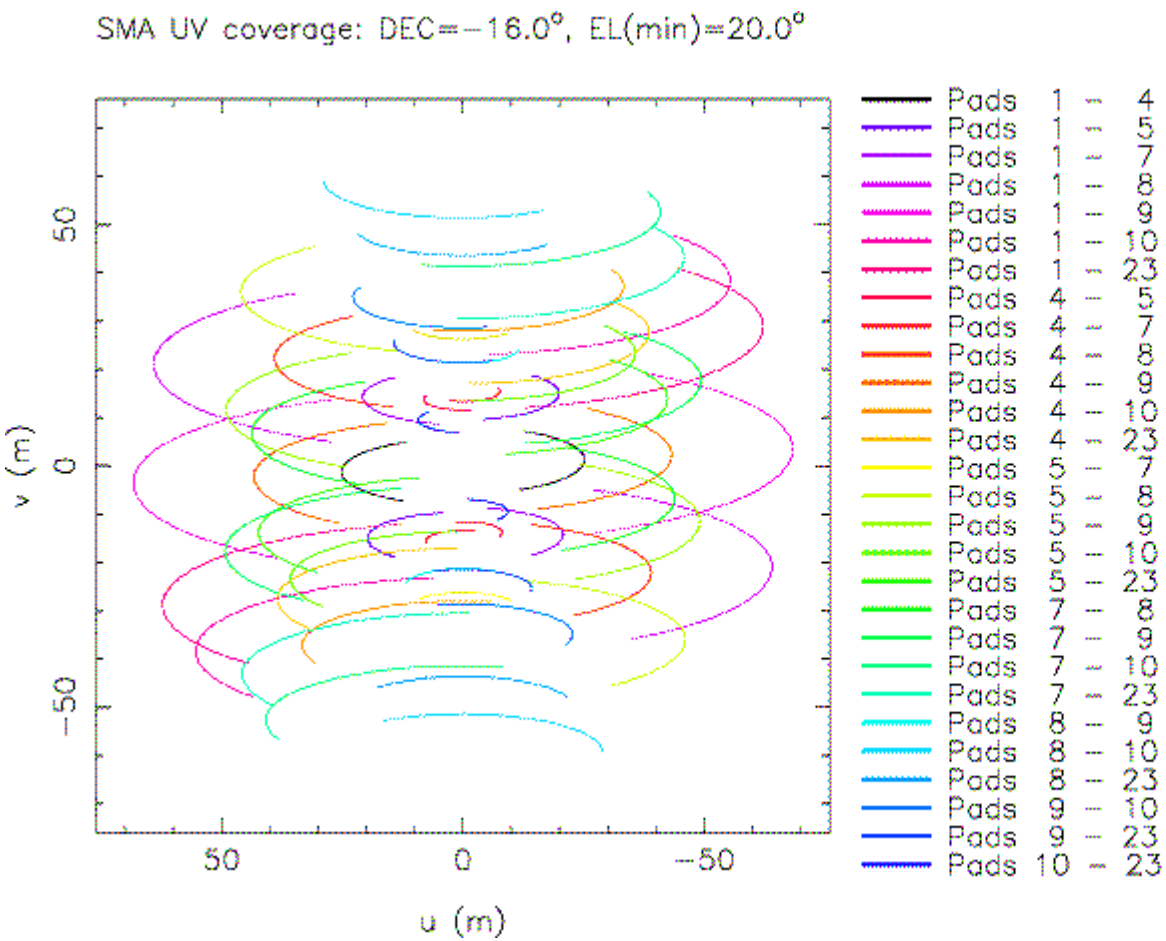




Passband Visualization Tool



Beam Calculator/Sensitivity Estimator



UV_{max} = 69.1 m

UV_{min} = 7.0 m

NOISE ESTIMATE (Natural Weights)

ν=345.8 GHz

η_{AP}=0.706 (dish σ_{RMS}=25 μm)

T_{RX}(DSB)=149.4 K

τ=0.247 (τ_{225}=0.069)

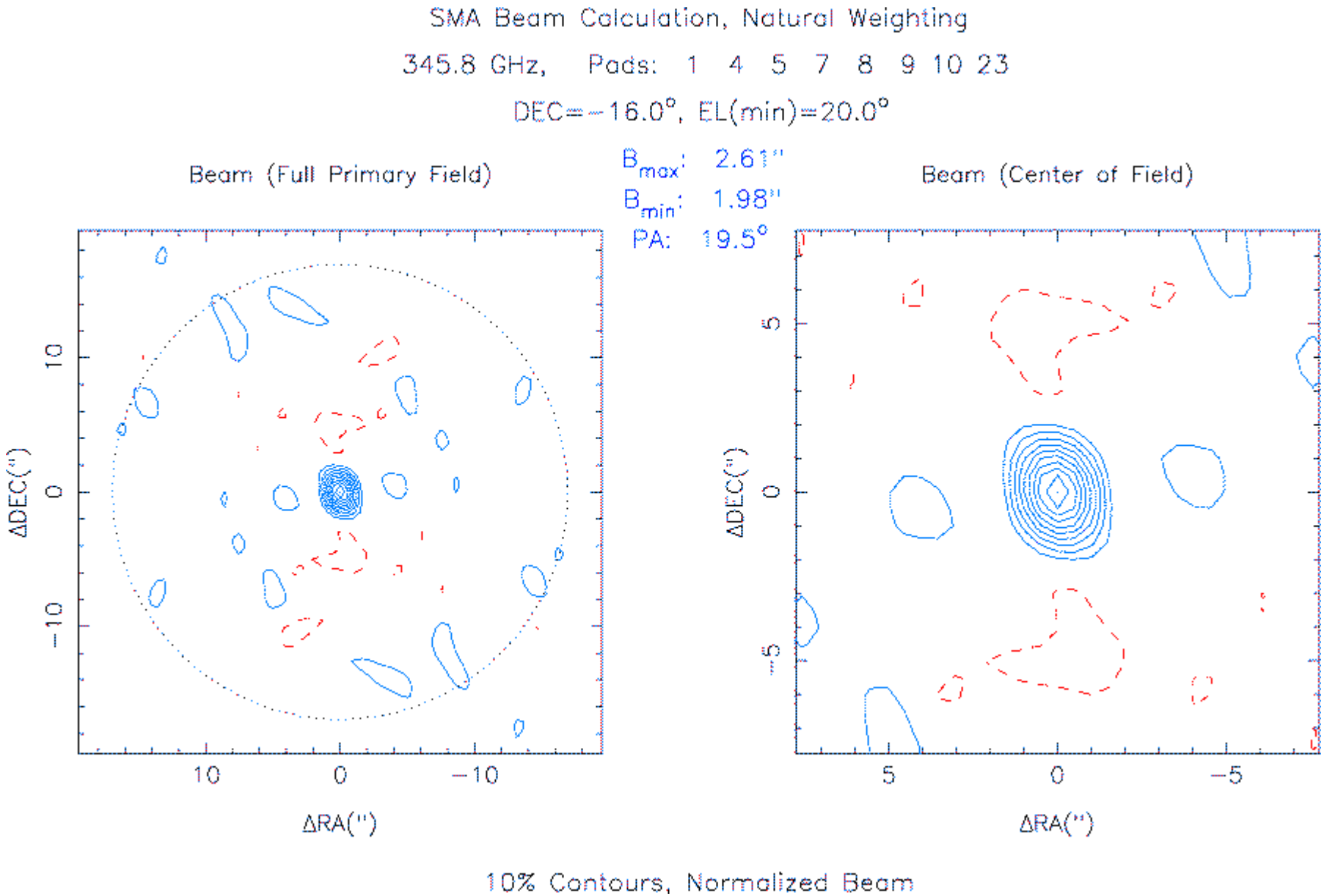
Zenith T_{SYS}^{*}(SSB)= 599.6 K

On source int. time= 5.45 h

Beam size = 2.61" × 1.98"

BANDWIDTH	RMS NOISE/BEAM	
2 GHz	2.3 mJy	2.03 K
100 km/s	9.7 mJy	2.45 K
1 km/s	96.9 mJy	3.71 K

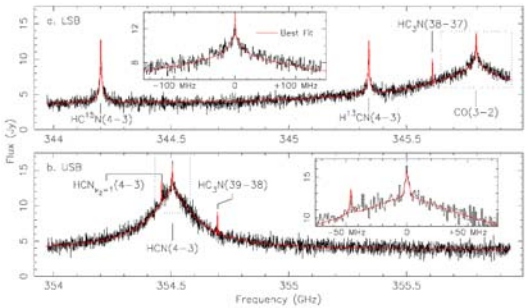
Beam Calculator/Sensitivity Estimator



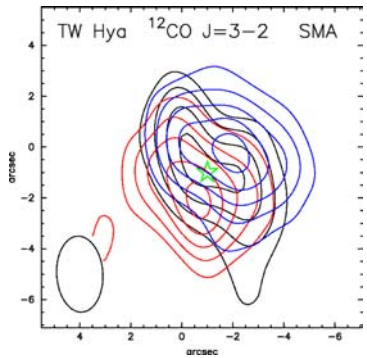
Early Science Projects

- 18 papers in press (astro-ph); ApJ Letters Special Issue

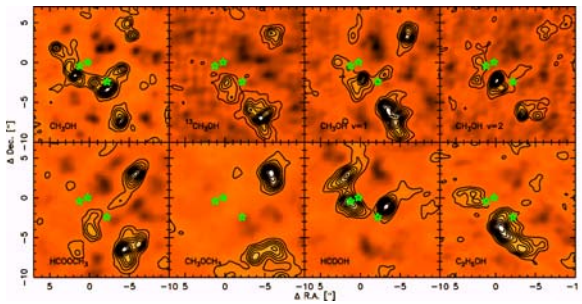
1. Solar System



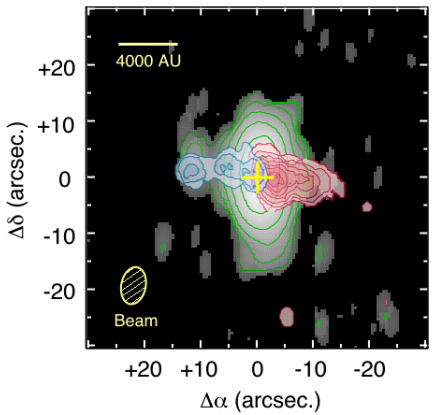
2. Low-mass SF



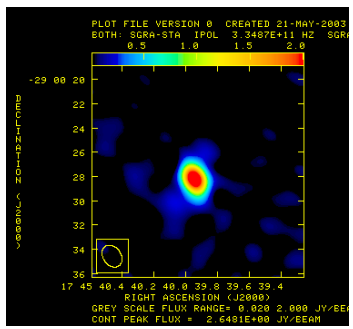
3. High-mass SF



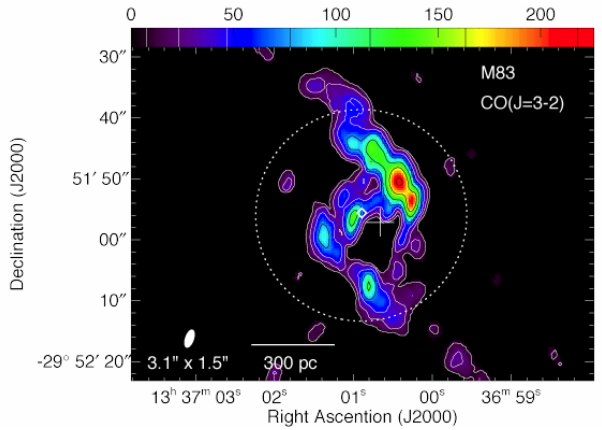
4. Evolved Stars



5. Galactic Center

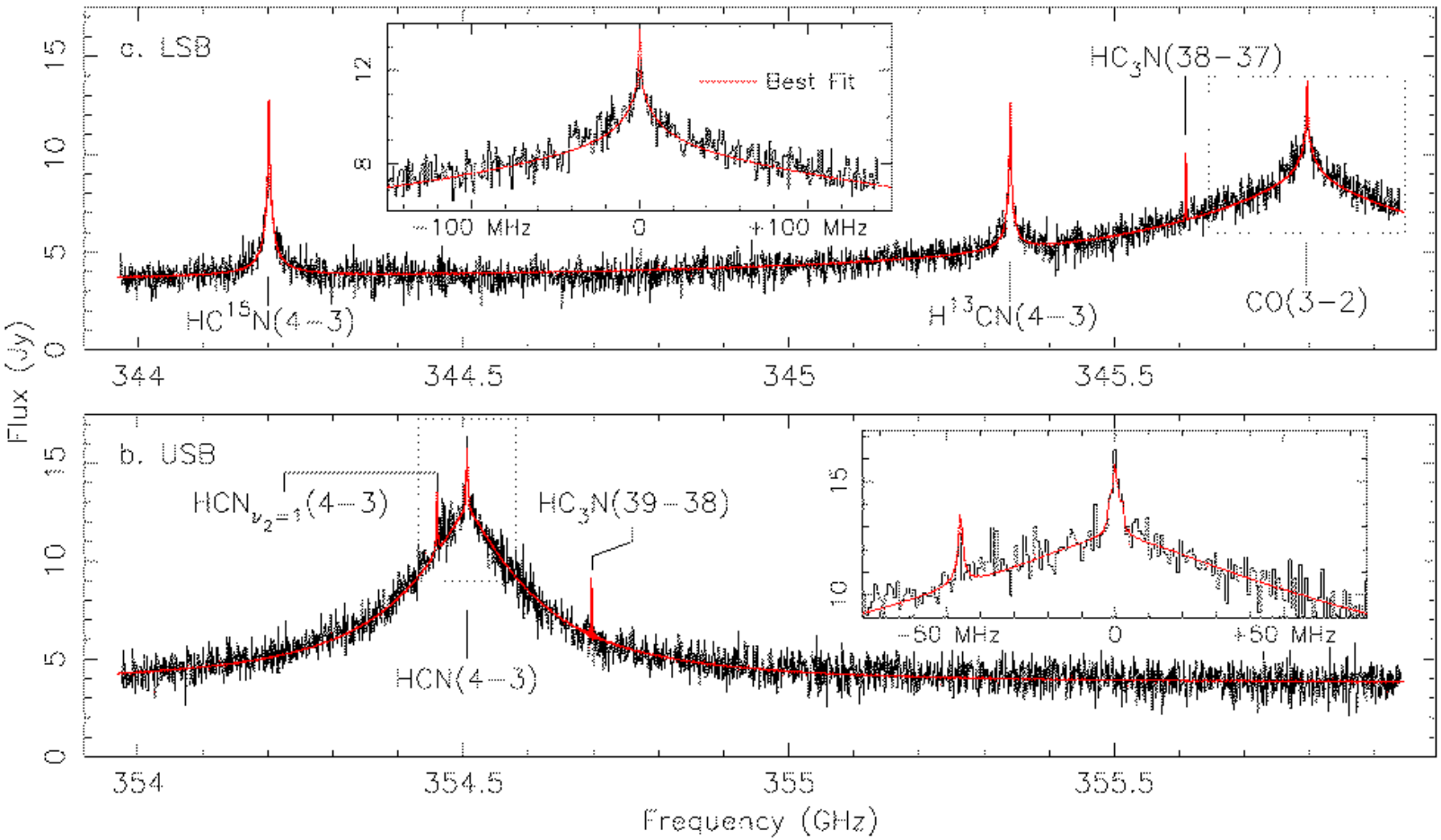


6. Galaxies



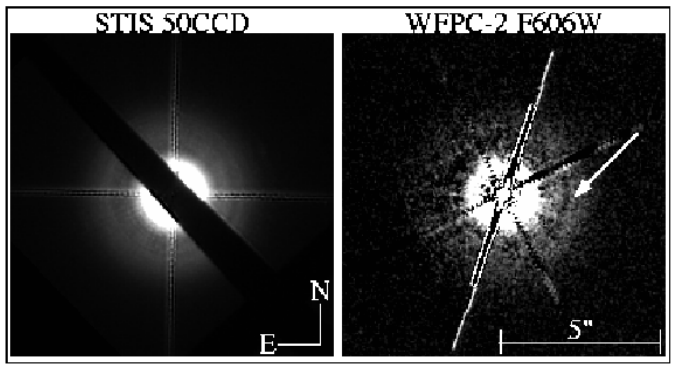
Titan (Gurwell)

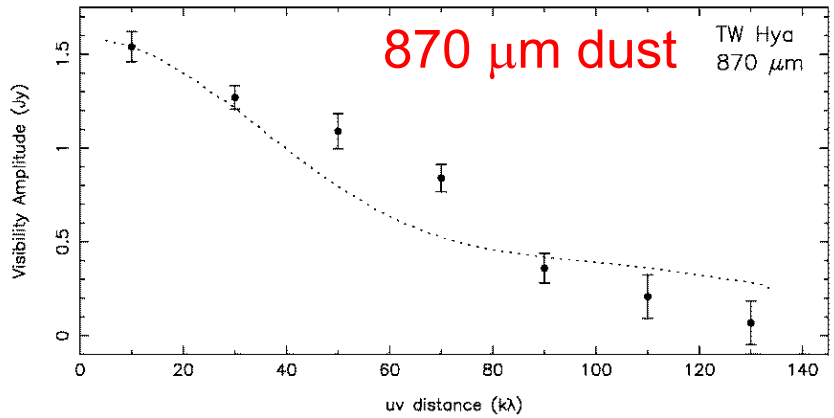
- CO(3-2), HCN(4-3) and isotopes, other nitriles

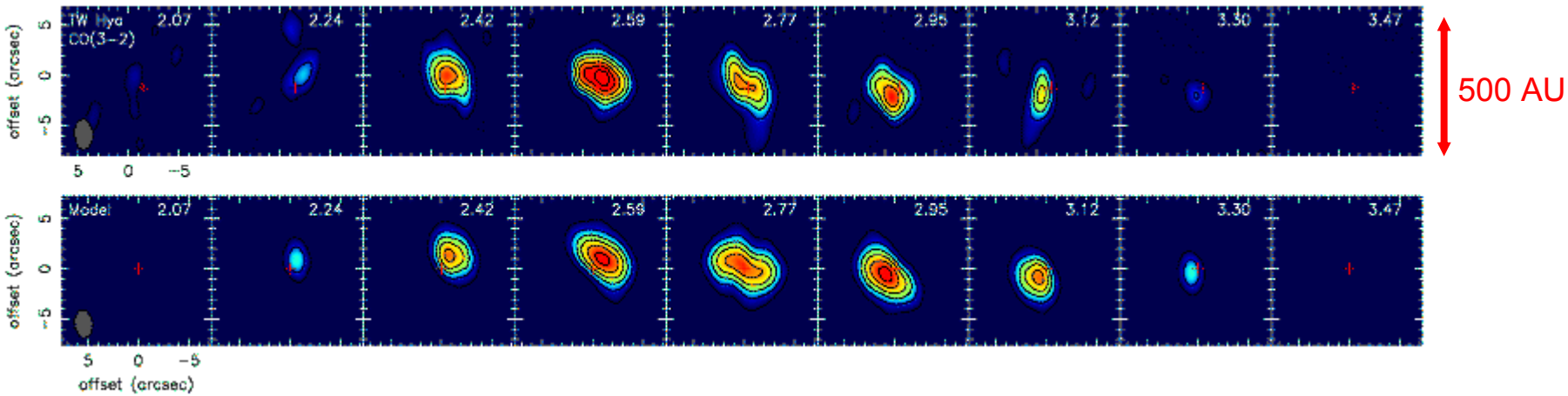


TW Hya (Qi et al.)

- most nearby protoplanetary disk at 56 pc (dec. -34)
- dust, CO J=3-2: disk structure, kinematics, M_*, chemistry

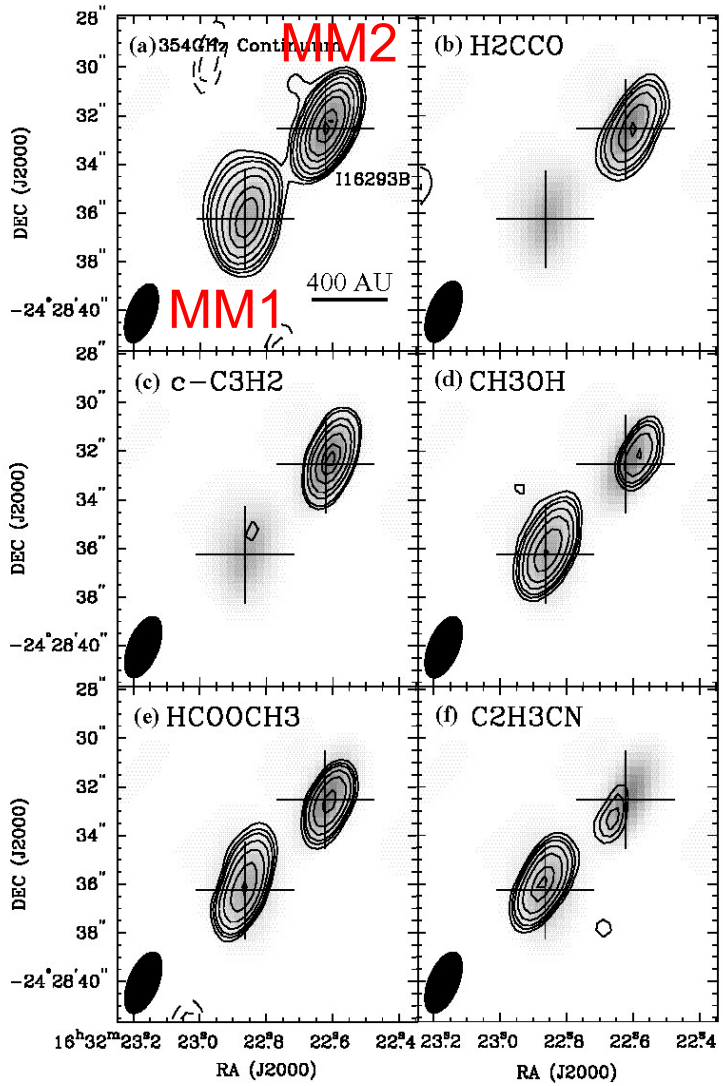






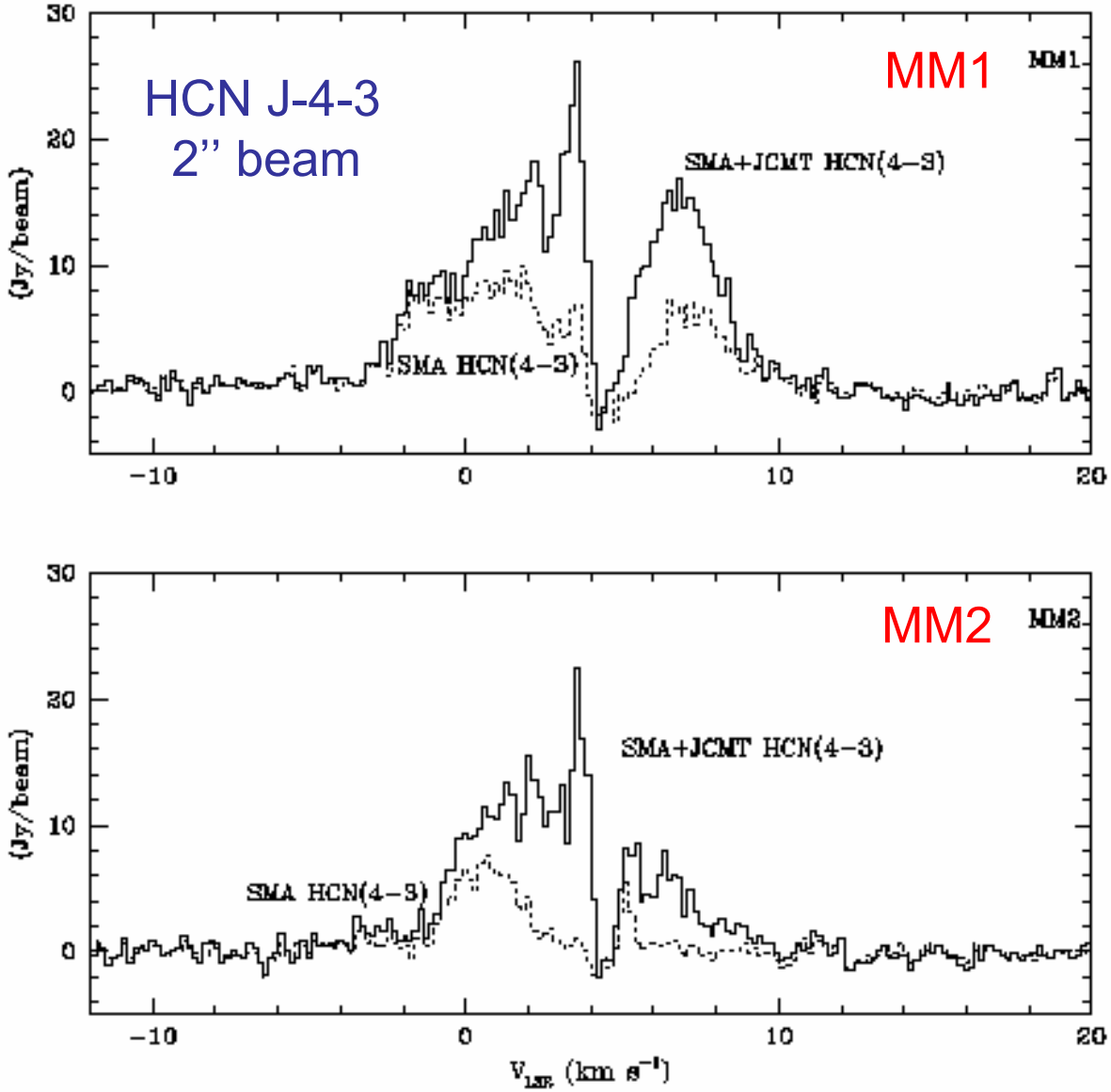
IRAS16293 Chemistry (Kuan et al.)

- binary protostar,
  5” projected separation
  D=150 pc, L~20 $L_{sun,}$
- common envelope
- “hot core” chemistry,
  e.g. C_2H_3CN, $HCOOCH_3$,
  T>100 K, n>10^6 cm^{-3}
- high resolution images show differentiation between the two cores

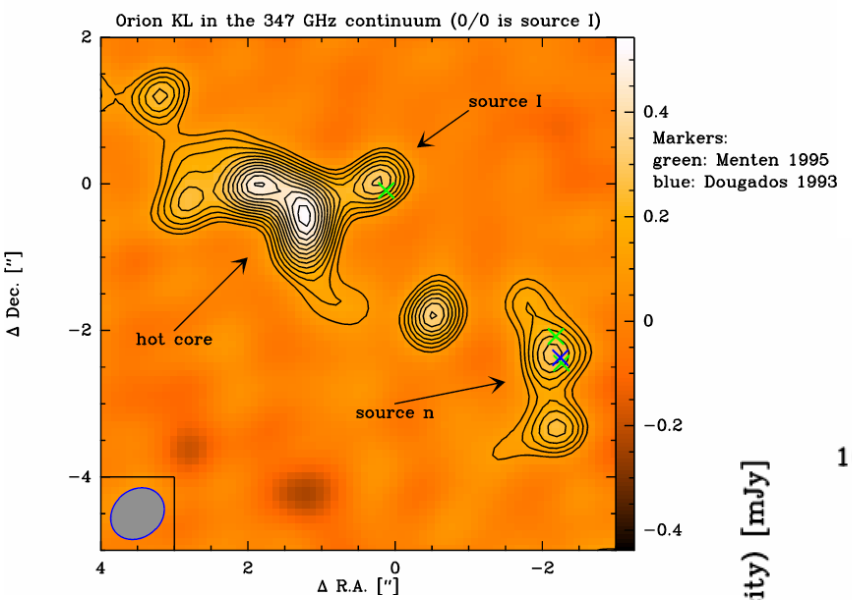


IRAS16293 Kinematics (Takakuwa et al.)

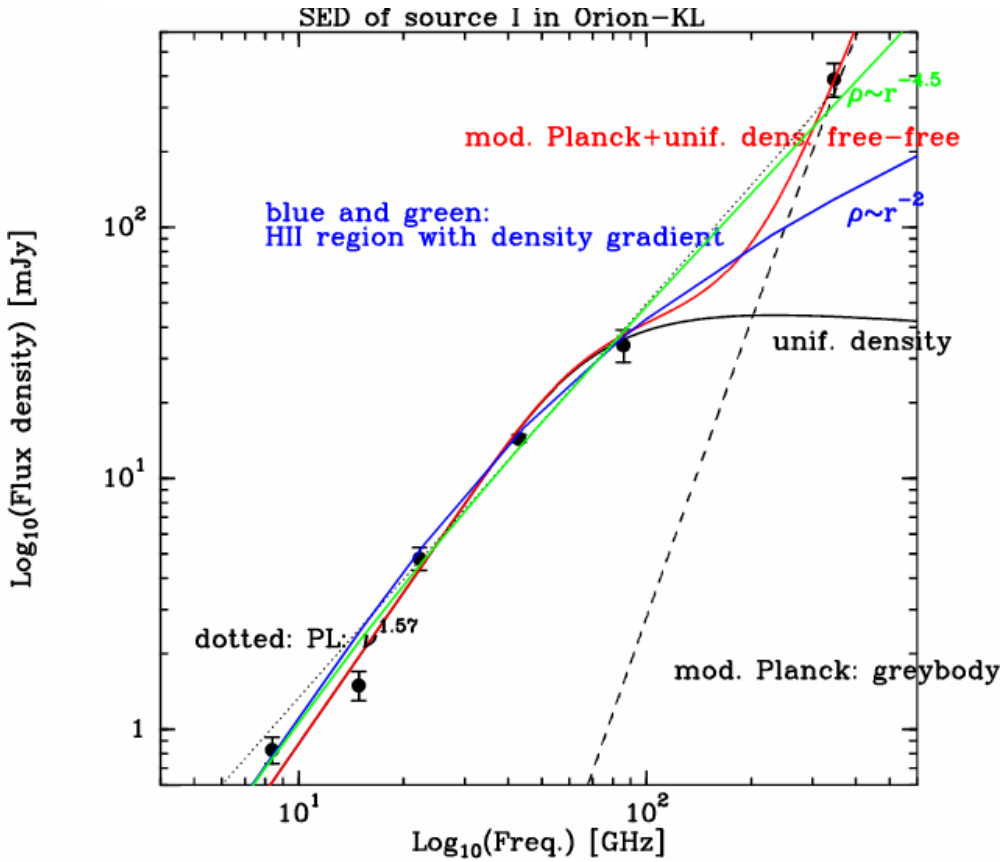
- early example of collapse from redshifted absorption; controversial
- HCN J=4-3 traces high densities in envelope/outflow
- include JCMT short spacings
- inverse P-Cygni profile against dust continuum



Orion-KL (Beuther et al.)



- first subarcsecond submillimeter image



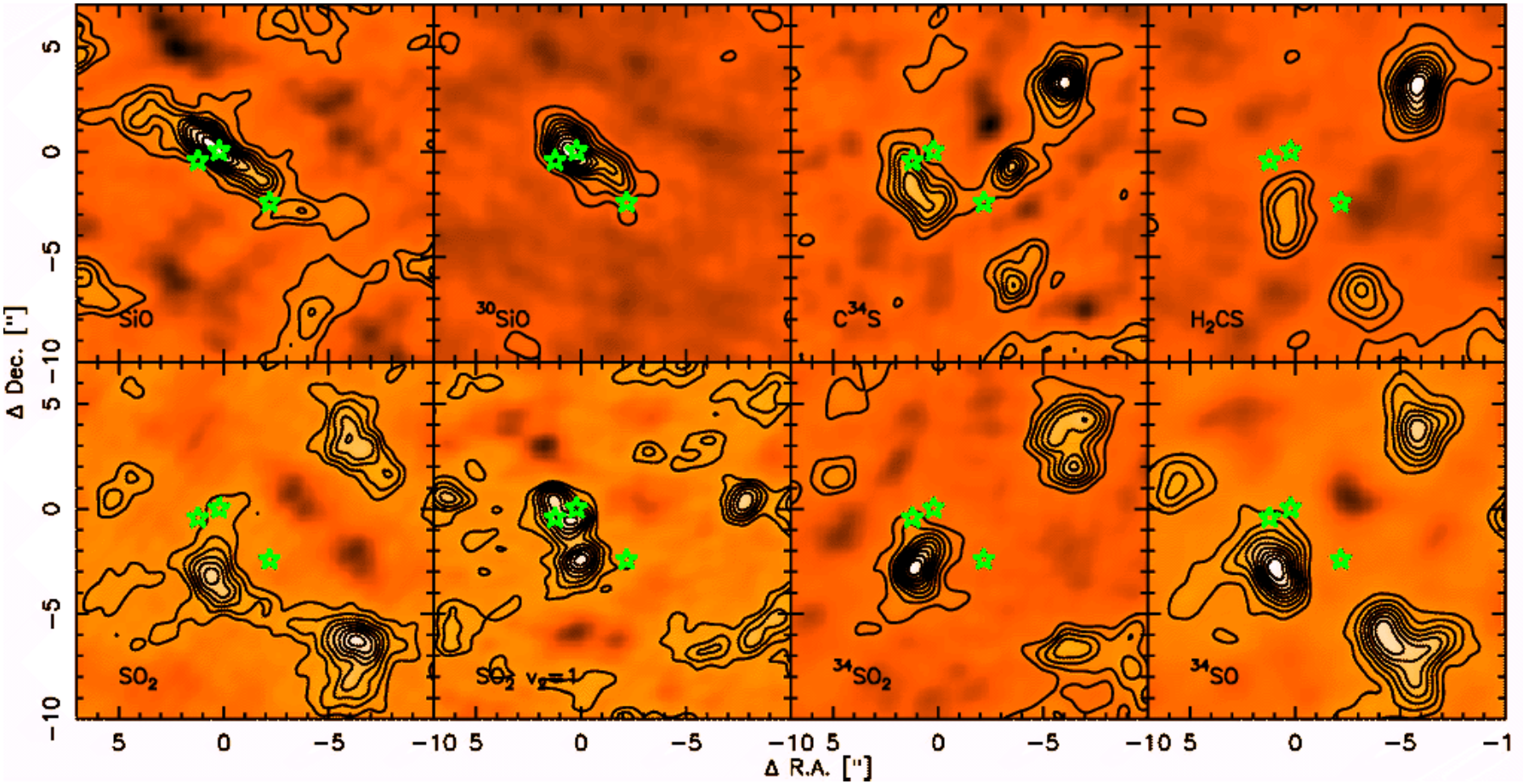
- nature of source "I" continuum emission: HII region + dust?

  or

  H- free free?

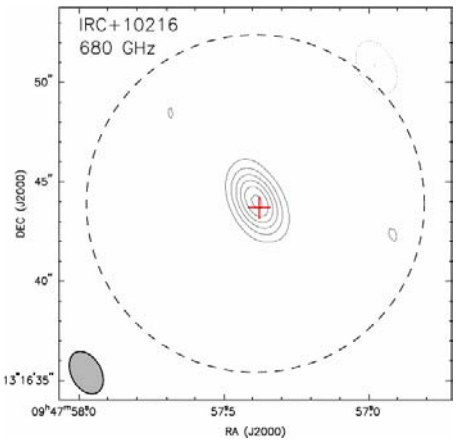
Orion-KL (Beuther et al.)

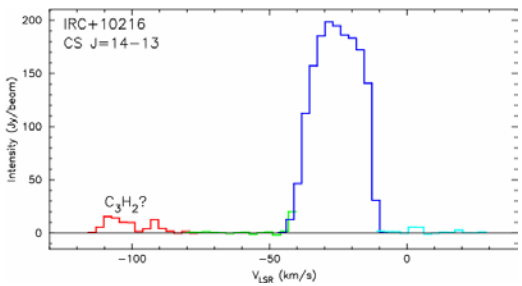
- spectral line images! (no confusion at source I)

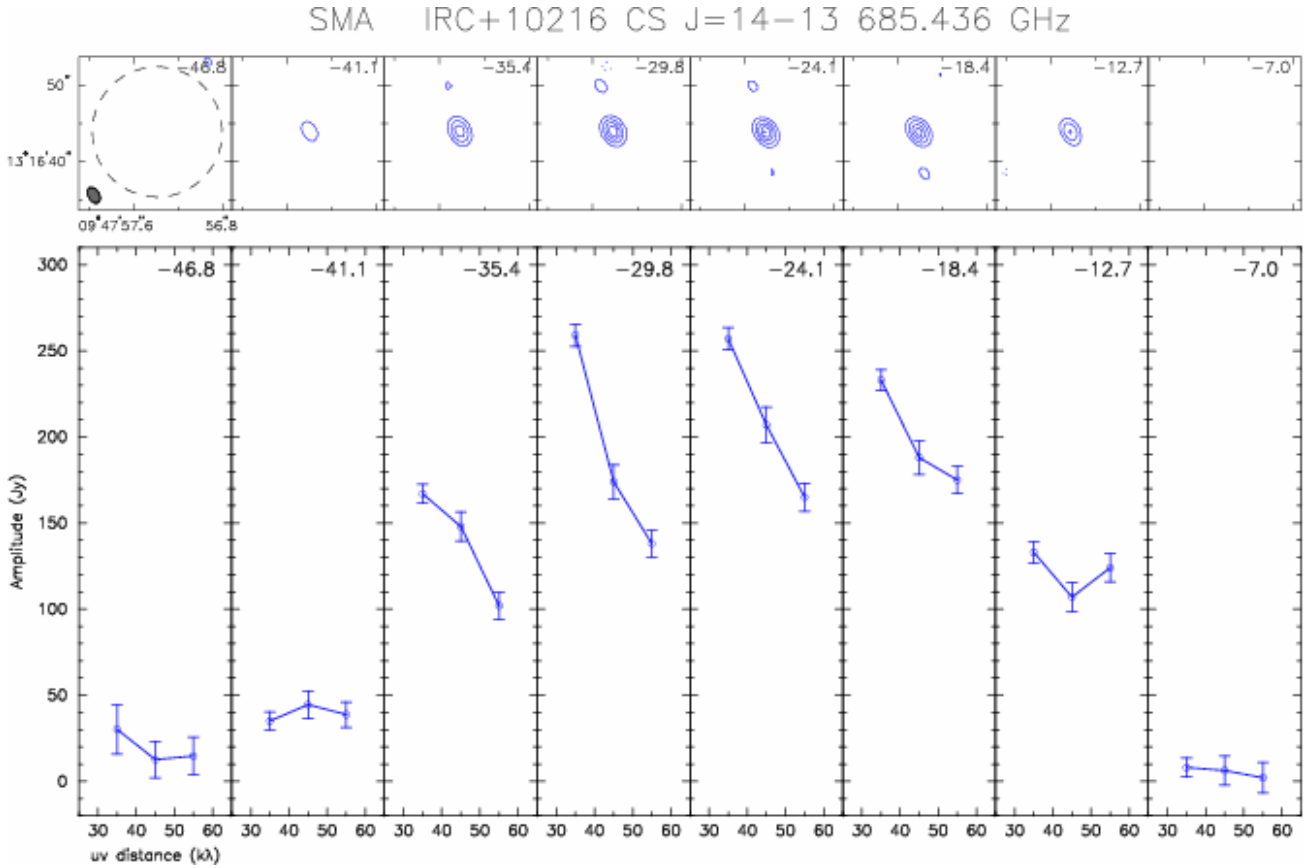


IRC+10216 CS J=14-13 (Young et al.)

- nearby AGB star with rich circumstellar chemistry
- first 690 GHz band image (3 antennas)

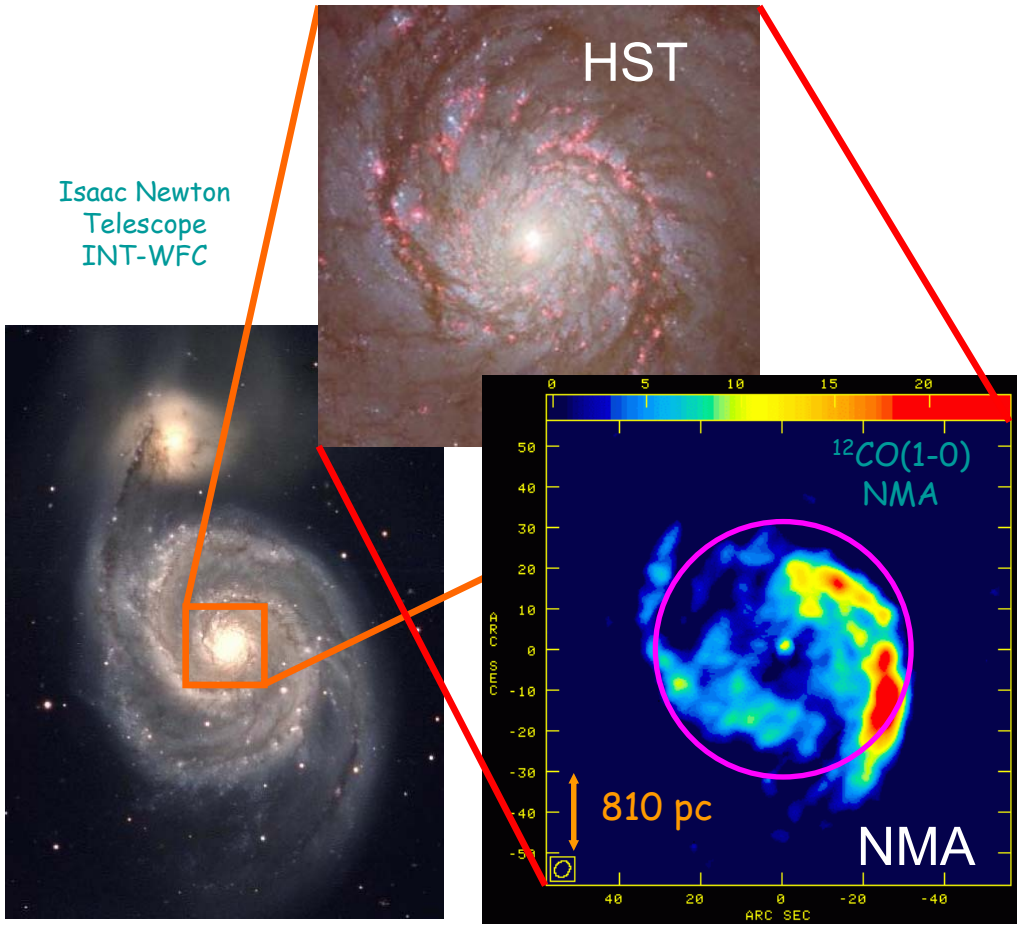






M51 (Matsushita et al.)

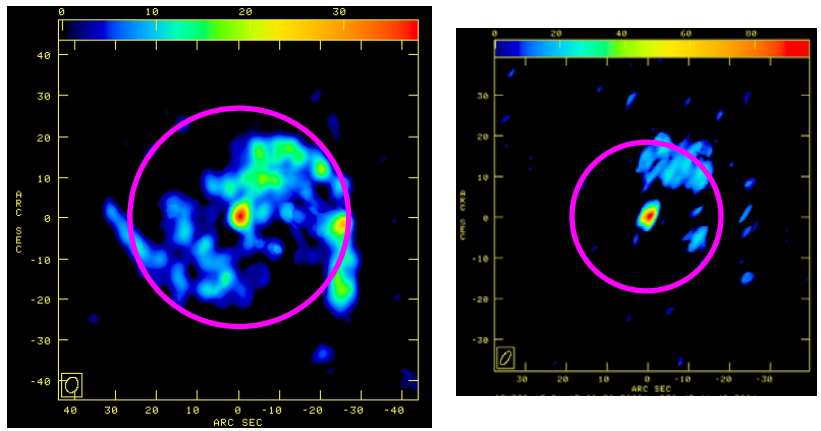
- grand design spiral, D=8.4 Mpc



Sakamoto et al. (1999)

^{12}CO(2-1) SMA

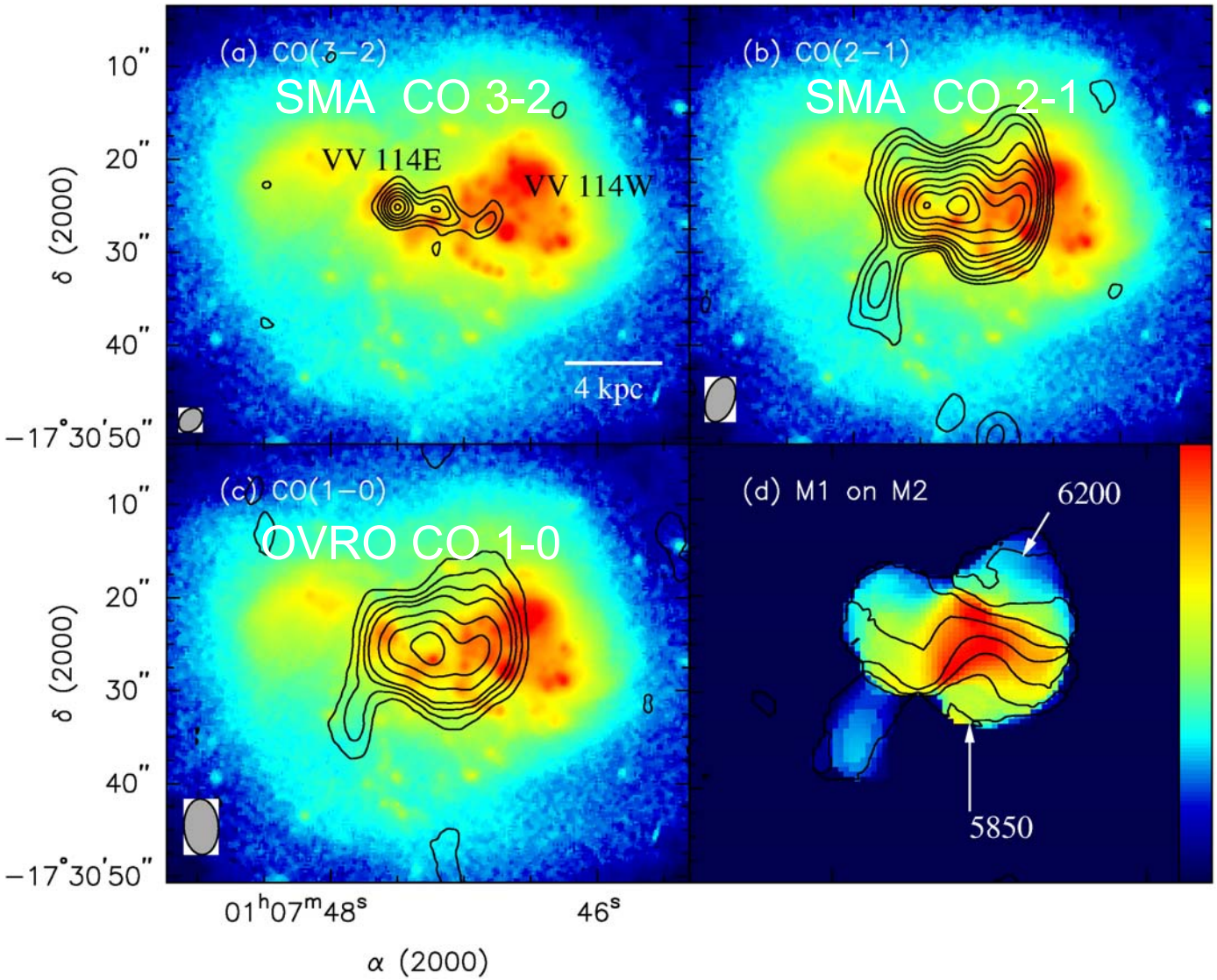
^{12}CO(3-2) SMA



nucleus warm (~100 K) and dense (~10^4 cm^{-3})

AGN/Starburst activity

VV114 Interacting Galaxies (Iono et al.)



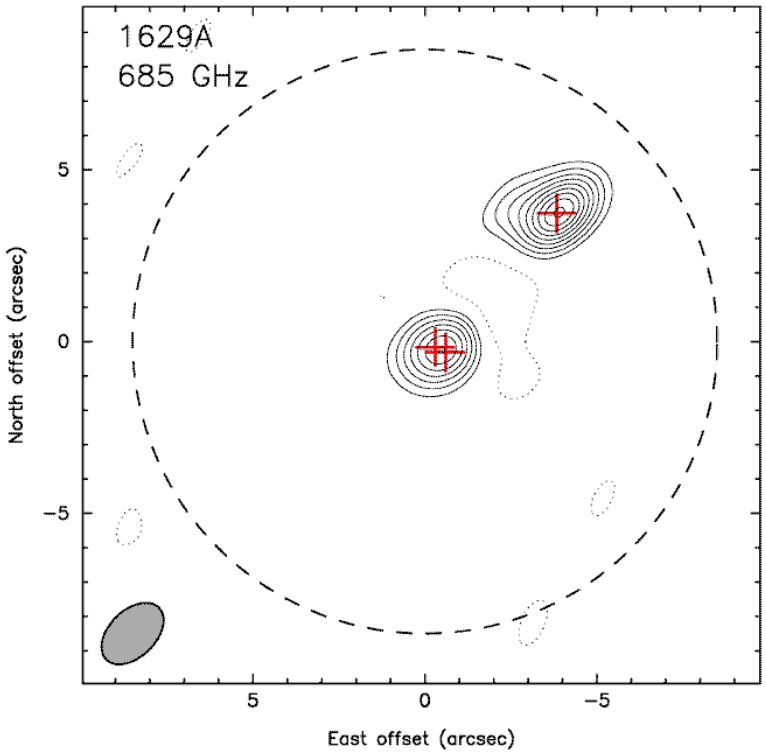
- CO J=2-1 in both galaxies and in overlap
- CO J=3-2 dense gas in VV114E
- velocity dispersion largest in overlap

Observing Time and Proposals

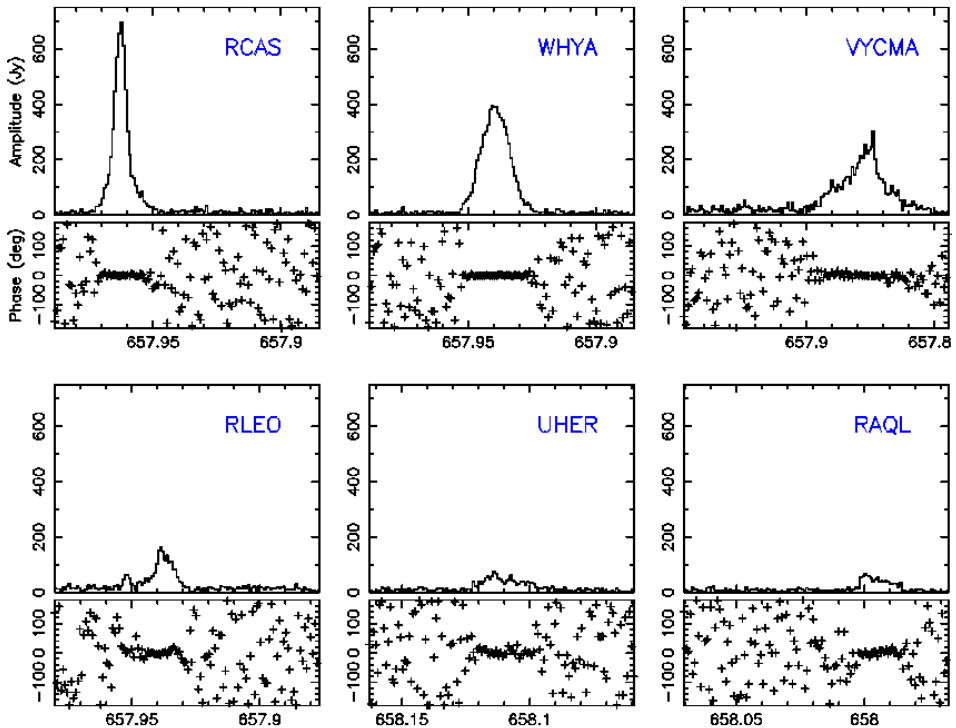
- science observations
  - 5 nights per week (2 nights for engineering/commissioning)
  - typically ~50% suitable for 345 GHz band
- partner fractions: CfA:ASIAA:IfA = 72:13:15
  - partners have independent time allocation procedures
- last CfA proposal deadline: Sep 16, 2004 for Nov-Apr
  - ~ 50 proposals received; some very large time requests
  - up to 10% of CfA time to external PI's with CfA collaboration
  - 690 GHz band and long baselines internal for now
- next CfA deadline: Mar 2005; more time for visitors
- see http://sma1.sma.hawaii.edu for tools, forms, call

Prospects for 690 GHz Band

- must be ready for the best weather!
- dual band operation will facilitate calibration
- more antennas → better self-calibration



IRAS16293 (5 antennas)

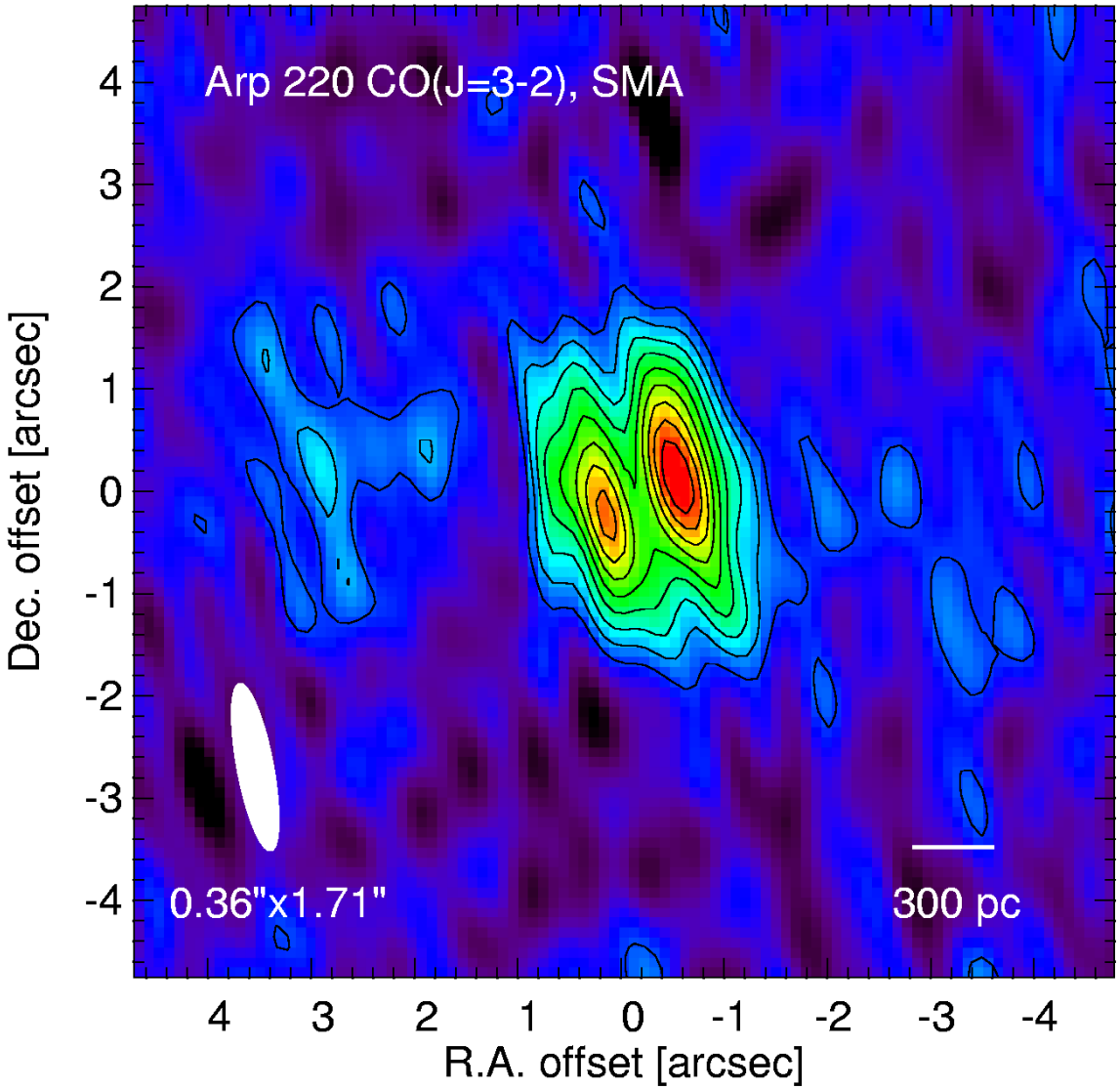


use 658 GHz H_2O masers?

SMA Development

- 2004: dual band operation→ more 690 GHz
- 2005: activate outer pads → highest resolution
- 2005: JCMT-CSO link tests (“eSMA”)
- 2005+: receivers for 320-420 GHz; dual pol 320-355 GHz
- *???: receivers for 490 GHz and 805 GHz bands*
- *???: more pads for > 500 m baselines*
- ongoing calibration issues
  - improve pointing, esp. daytime
  - improve bandpass calibration (noise drawer)
  - phase correction tests (continuum, IRMA,183 GHz H_2O line)

Arp 220 (Sakamoto et al.)



- first test of long baselines (pad 18) April 2004
- 345 GHz band atmospheric "seeing" can be very good, esp. at night
- CO J=3-2, resolve E-W double nucleus, θ_{min} = 0.36"

SMA opens Submillimeter Interferometry for ALMA

submm

END