(Galactic) Radio Astronomy in Chile: an historical perspective

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Atacama: The driest desert in the world

Optical Astronomy Observatories in northern Chile; 1960s

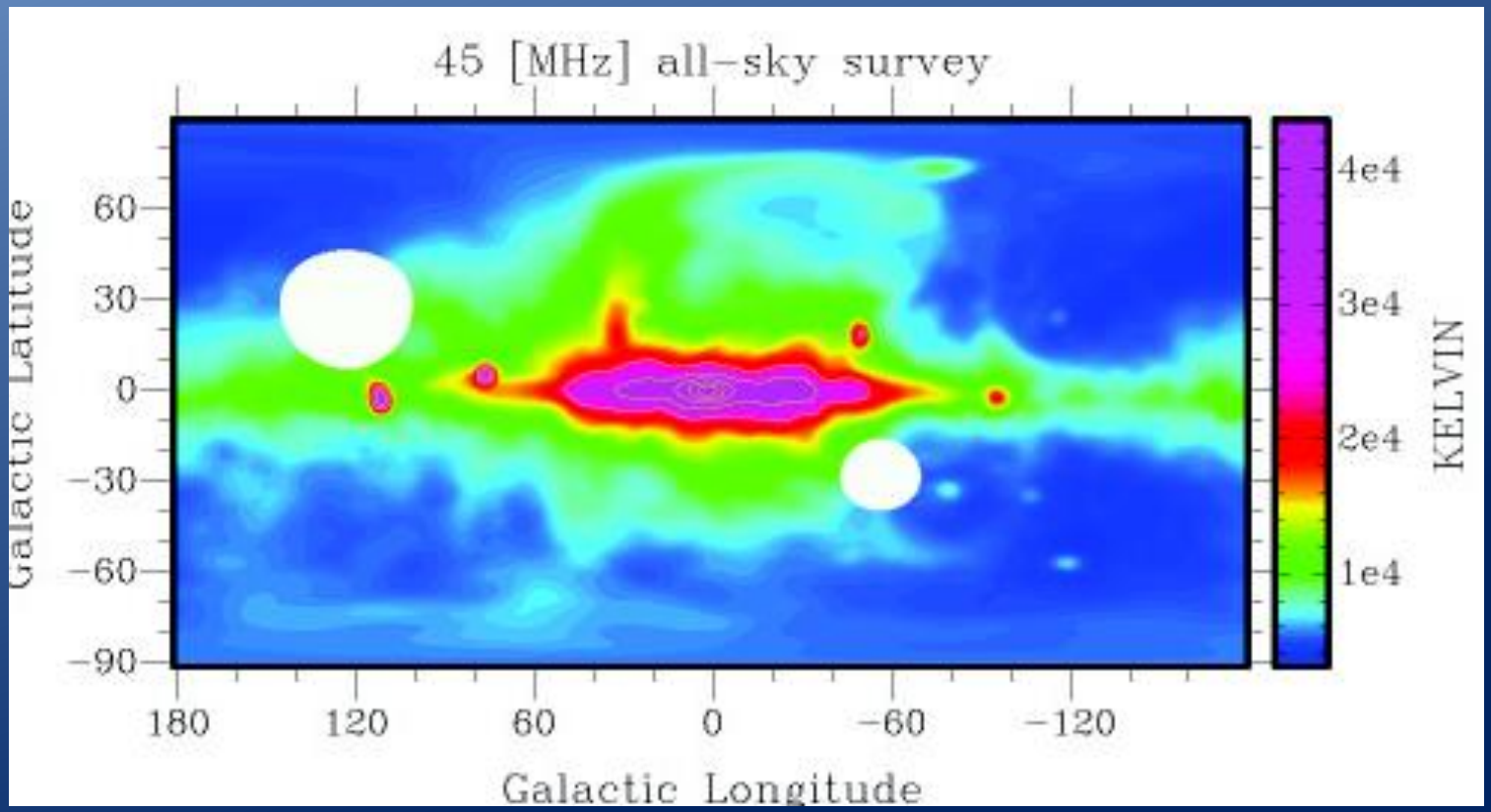

1971 Las Campanas (CARSO)


1969 La Silla (ESO)


1966 Cerro Tololo (CTIO-NOAO)

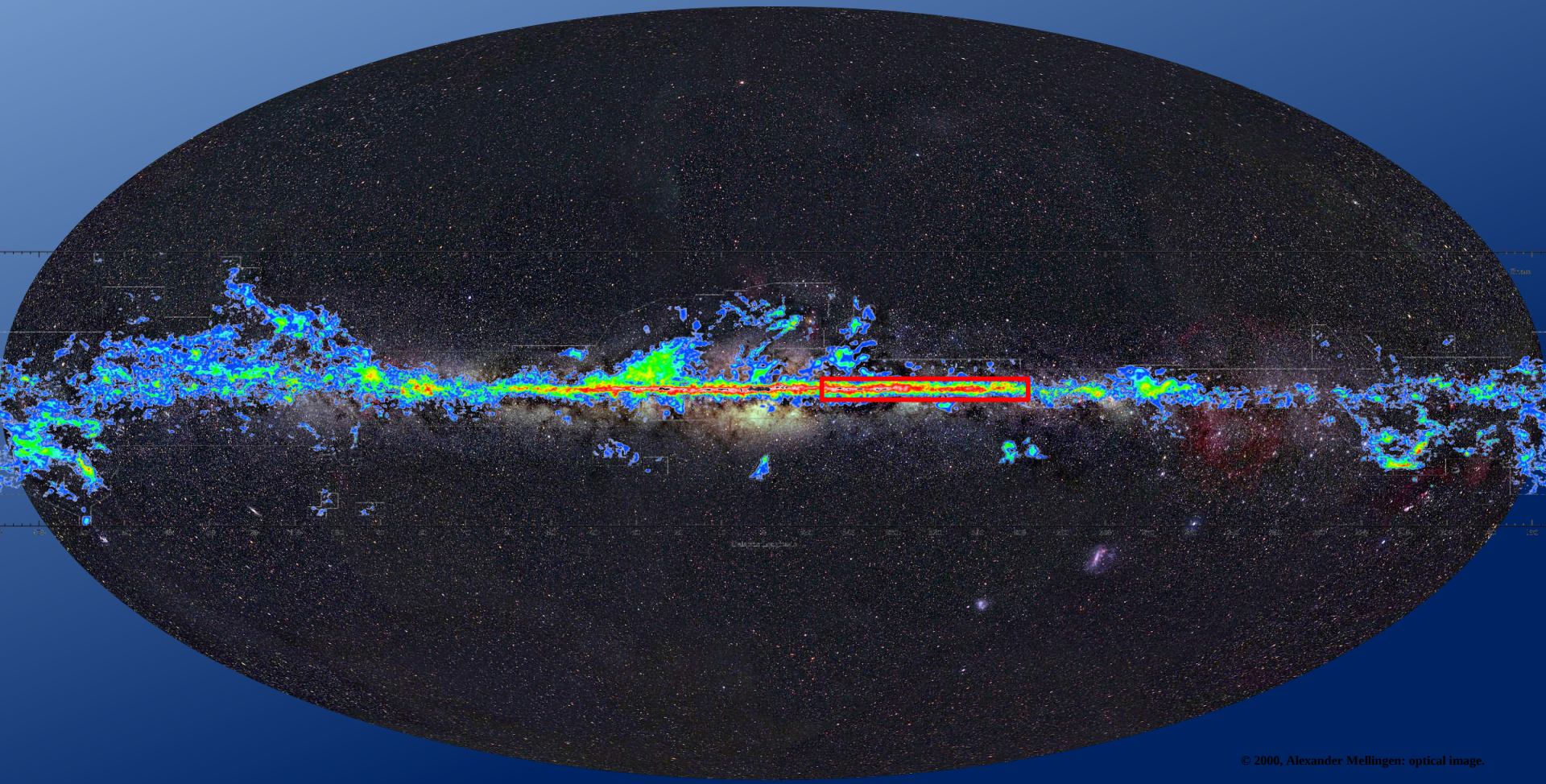
Early radio astronomy in Chile : Maipú Observatory (1959-2000)
43-46 MHz; 528 dipoles in 10.000 m^2; first in Latin America
Prof. Jorge May, Universidad de Chile (U. Florida)

- First complete map of the full sky at 45 MHz
- Lowest frequency map available (U. Chile - U. Hyogo)



RADIO OBSERVATORIO DE MAIPU, NOVIEMBRE 1979

The Milky Way

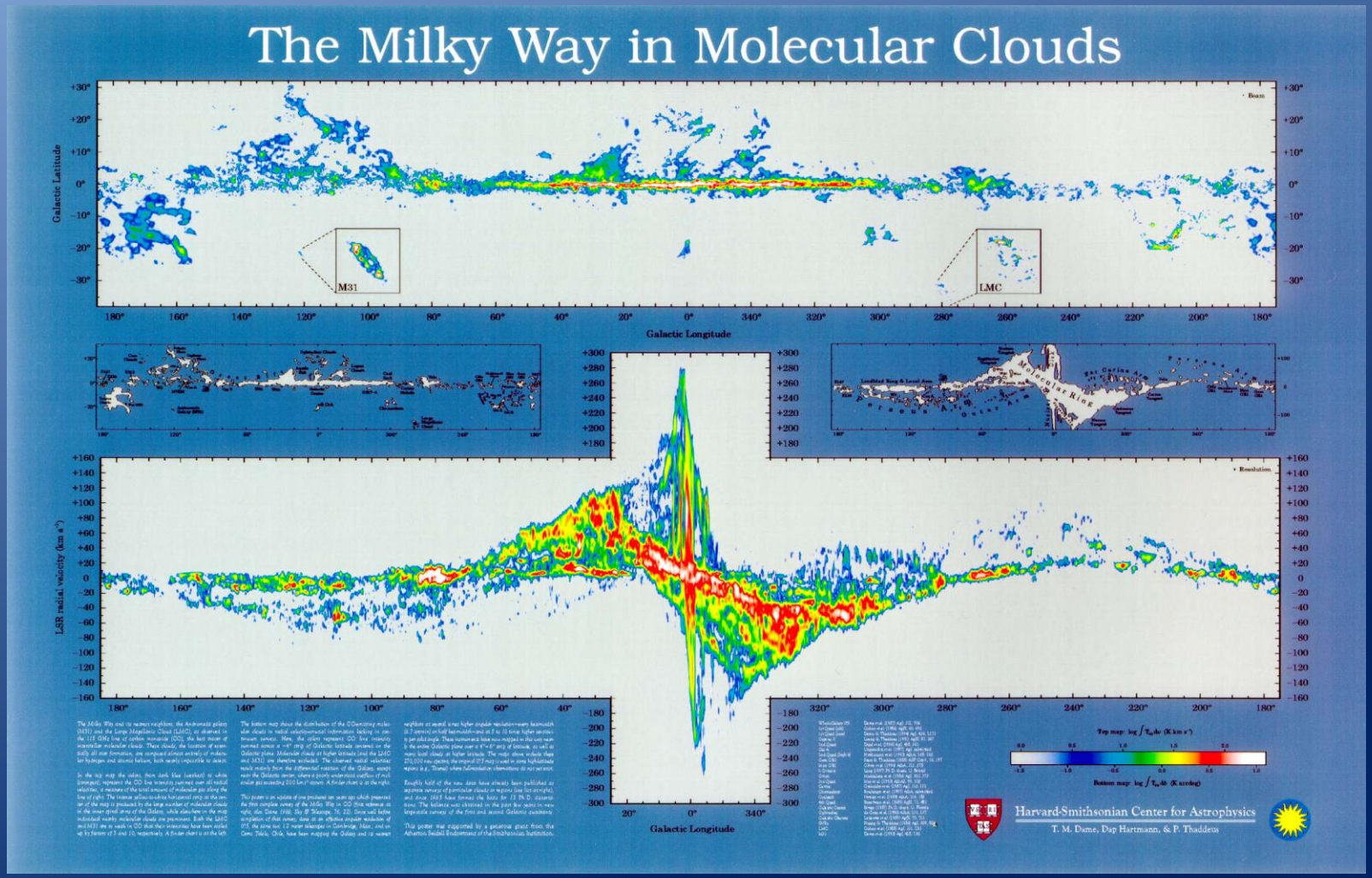


E.E.Barnard's dilemma (1900)

Holes in the heavens or obscuring matter?

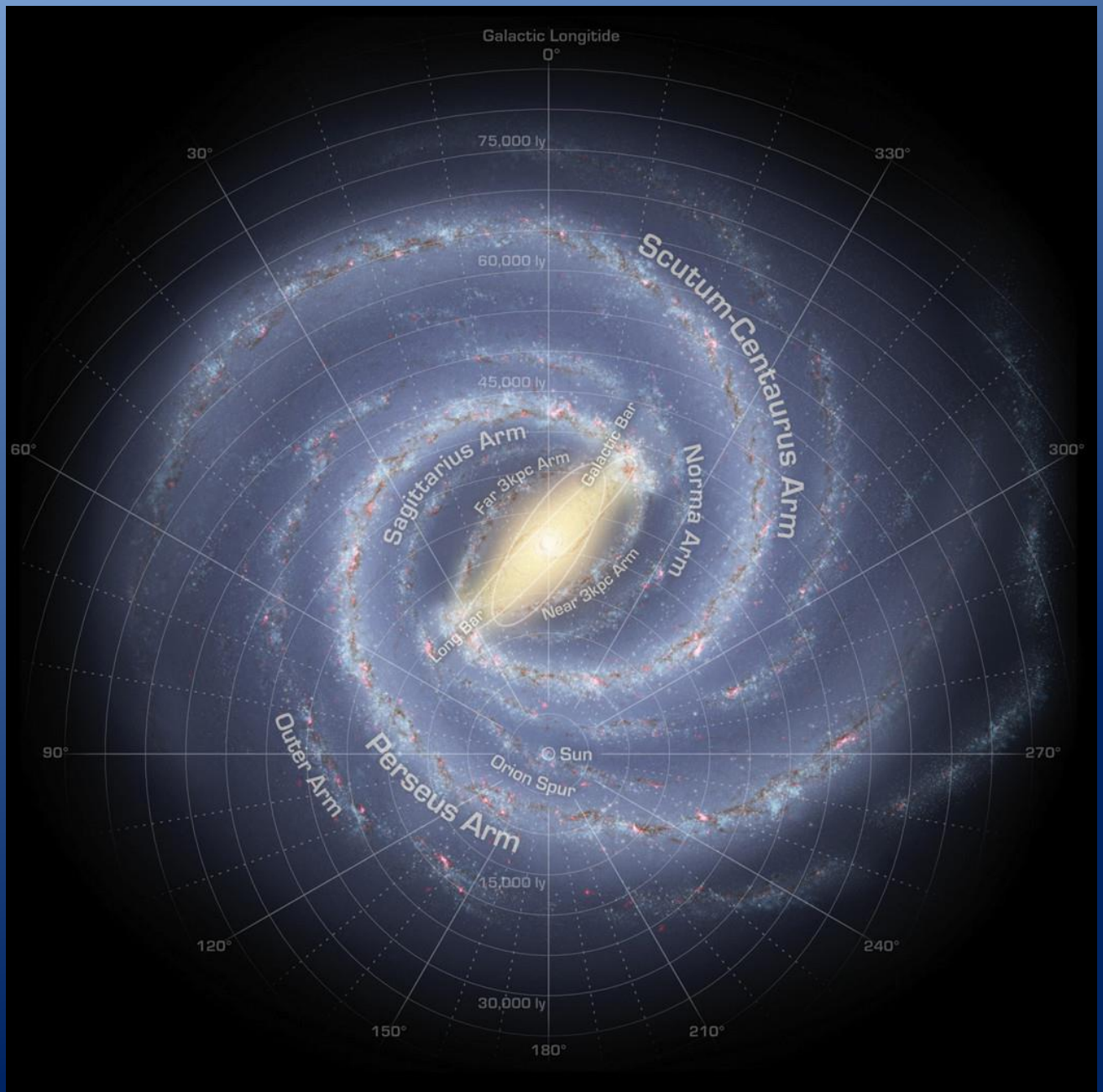
(A.Eddington: "flying with one wing")

Molecular gas: CO survey of the Galaxy



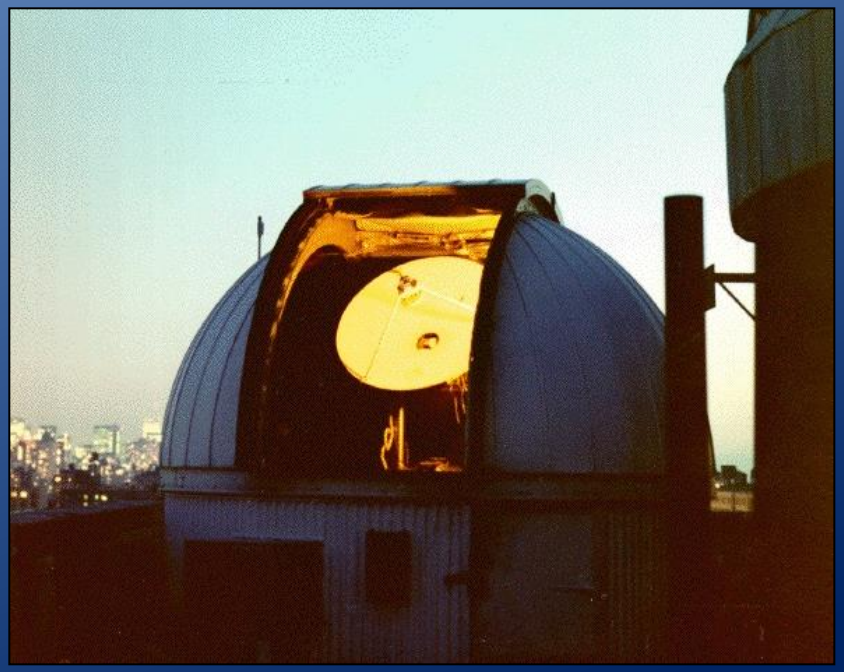
Face-on sketch view of the Galaxy obtained from optical, infrared, and mm data

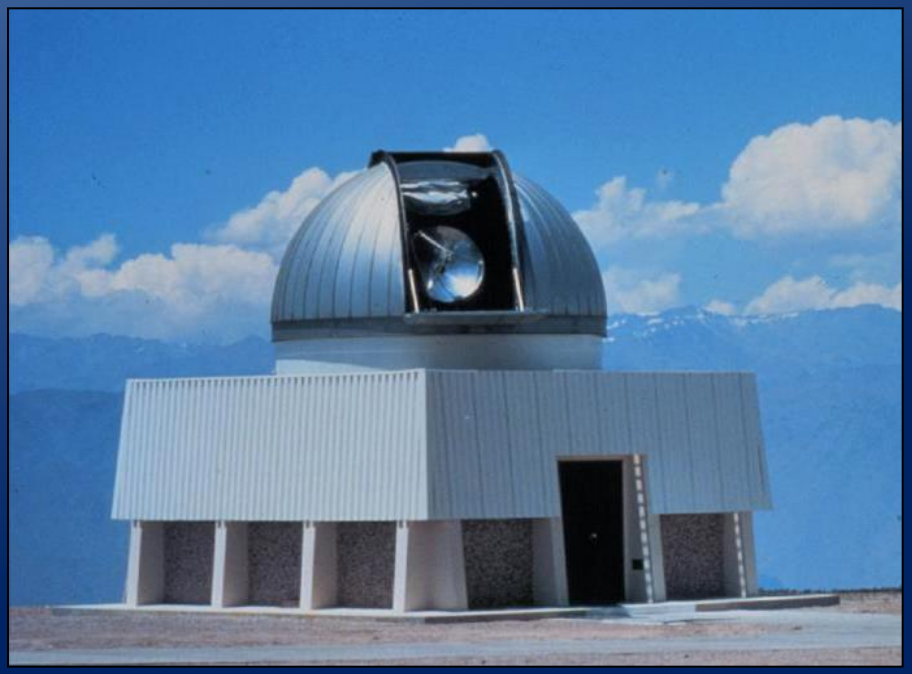
(Churchwell et al. 2009)



1.2m mm-wave Telescopes: Molecular Clouds in the Milky Way
Columbia University-Universidad de Chile
PI P. Thaddeus

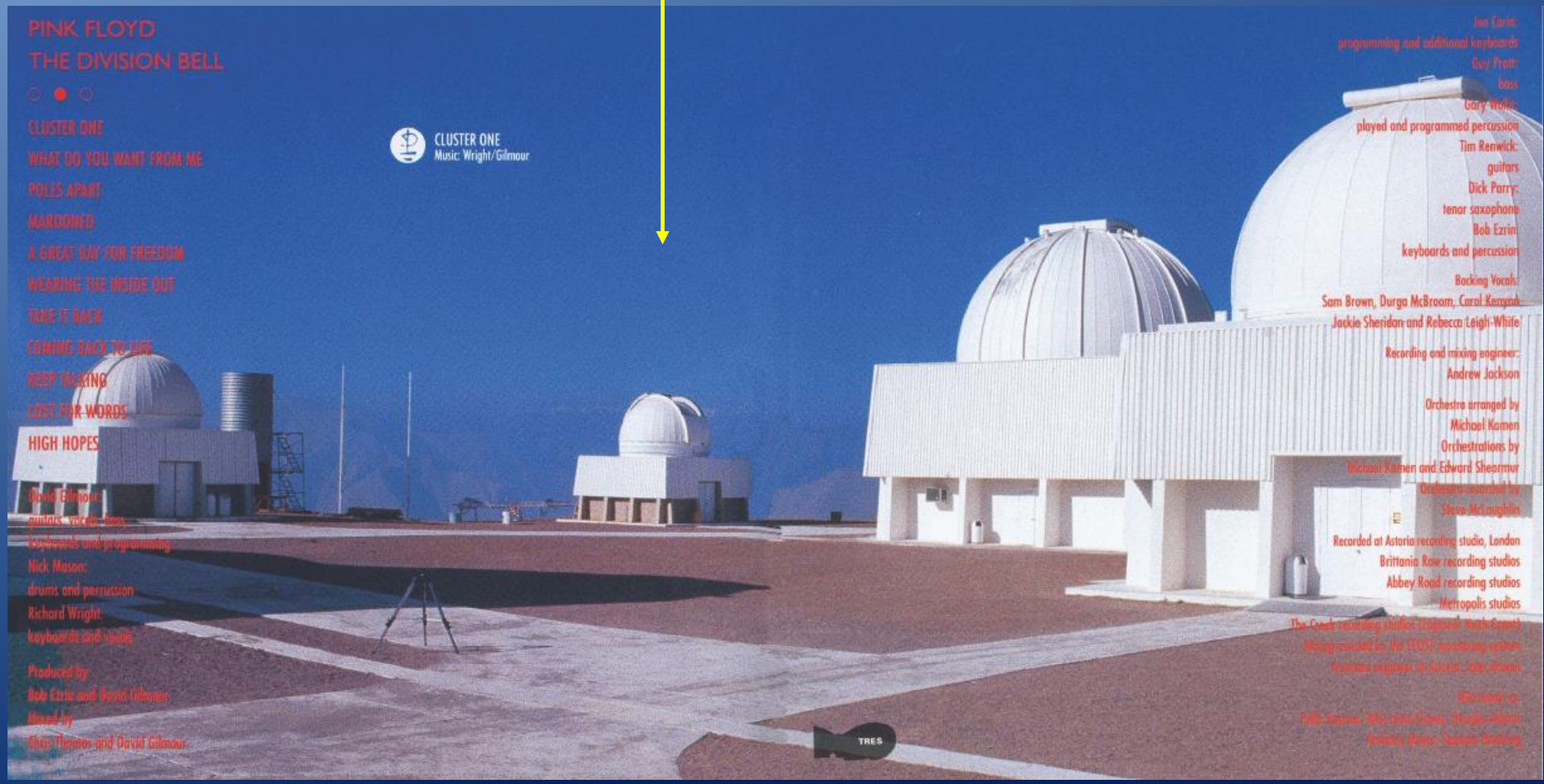
- Twin telescopes built at Columbia University (1976-1982)
- Southern Mini to Cerro Tololo, Chile (1982)
- Northern Mini to CFA (1986)
- Resolution = 8´ @ 115 GHz





NASA-Goddard, NY 1982
Southern mm-wave Telescope; first dedicated instrument in SH

1.2m Southern mm-Wave Telescope (Mini)



Astron. Astrophys. 174, 78–84 (1987)

ASTRONOMY AND ASTROPHYSICS

Ara OB1: A stellar association formed by the action of an energetic event?

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[2] Observatorio Astronómico La Plata, Universidad Nacional de La Plata, Av. Paseo del Bosque S/N, 1900 La Plata, Argentina
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Received July 16, 1985; accepted February 14, 1986

Summary. Neutral hydrogen (at $\lambda = 21$ cm) and carbon monoxide (at $\lambda = 2.6$ mm) line observations of the interstellar medium in the neighbourhood of the association Ara OB1 are reported. The observed H I distribution indicates the presence of an expanding structure. The total H I mass associated with such feature amounts to 4800 solar masses, and its momentum and kinetic energy are $\sim 4\ 10^4\ M_\odot$ km s^{-1} and $3\ 10^{48}$ erg, respectively. The H I structure, 42 pc in diameter, expands at a speed of 10 km s^{-1}. A possible origin for the expanding H I structure, and a genetic link between such structure and Ara OB1 are proposed.

Key words: clusters: open, and associations – interstellar medium: bubbles – radio lines: 21-cm – stars: formation of

covers an area of roughly one square degree, its nucleus being the open cluster NGC 6193 ($l = 336.^\circ7$; $b = -1.^\circ6$). The low density ionized gas of the low surface brightness nebula RCW 108, in which the association is embedded, was studied by Cersosimo (1982).

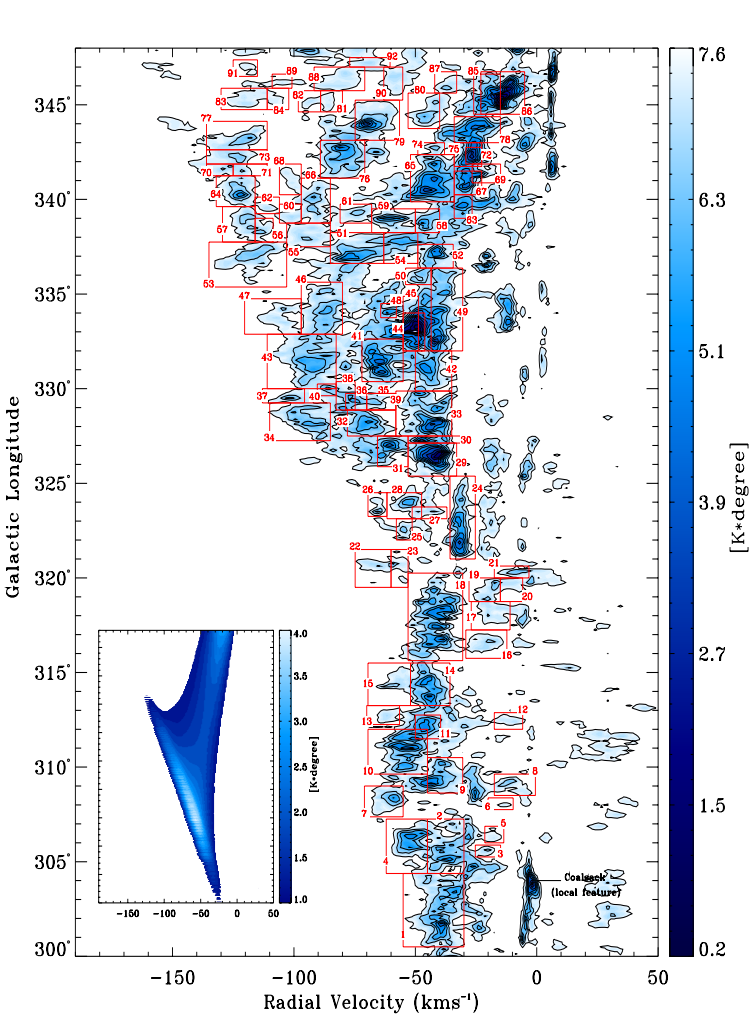
At almost two degrees northwest of the open cluster a spectroscopically peculiar Of star, HD 148937, is found. Such star is located within a large and nearly circular H II region, which is bounded by a thin dust shell (Westerlund, 1960). A physical interaction between the large H II region around HD 148937 and NGC 6193 was suggested by Bruhweiler et al. (1981).

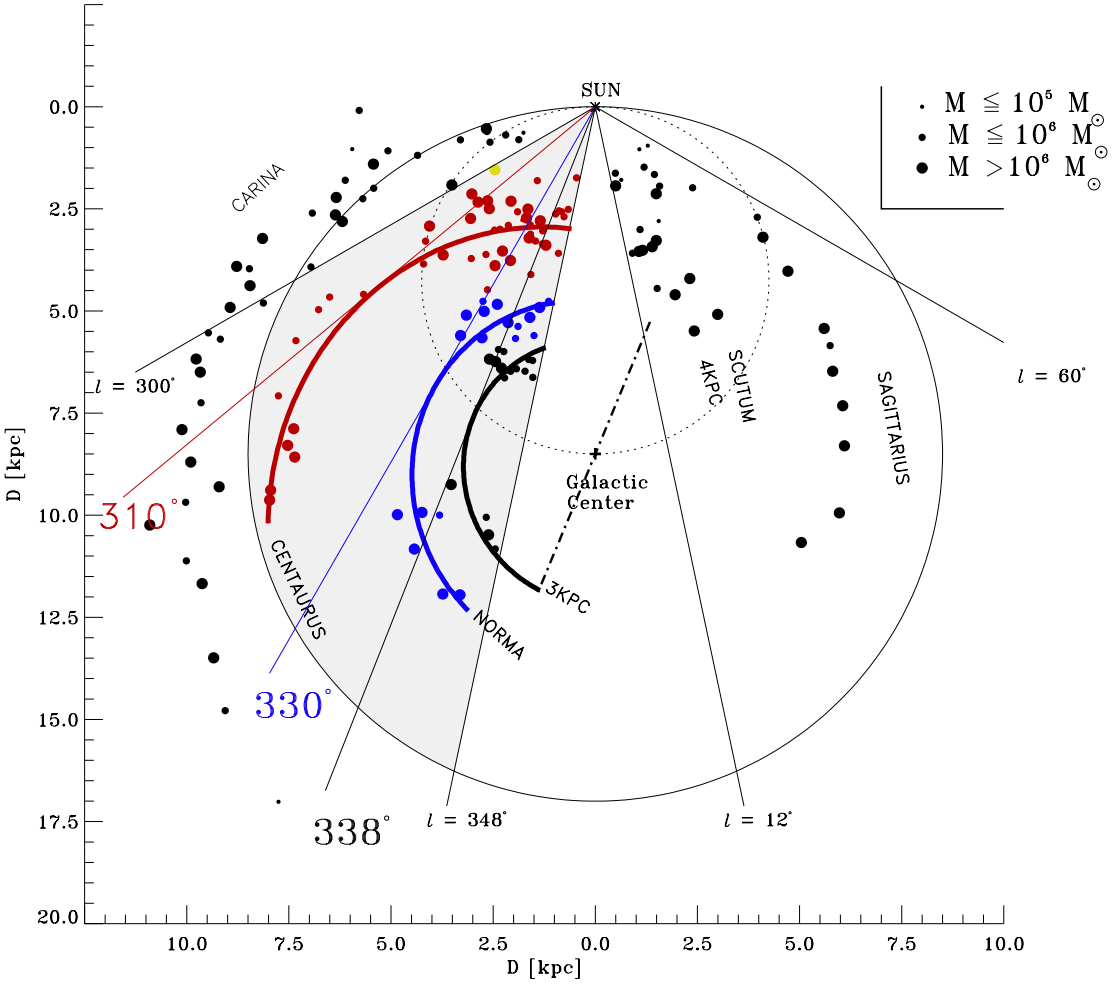
Several signposts indicate that star-forming processes may still be going on in the area (Shaver and Goss (1970); Frogel and Persson (1974); Obscuring material, mainly identified as the dark clouds FS 332, FS 335 and FS 337 (Feitzinger and Stuwe, 1984), is

INDIVIDUAL CLOUD ANALYSIS:

THE CO EMISSION IS DOMINATED BY GMCs WHICH TRACE THE SPIRAL ARMS

P. García et al. 2013: new 4th quadrant analysis





STUDY CASE: G331.5 GMC in Norma Spiral Arm
Among most massive in the Galactic disk (1985)
Little distance ambiguity, close to arm tangent
HII Regions, SNRs

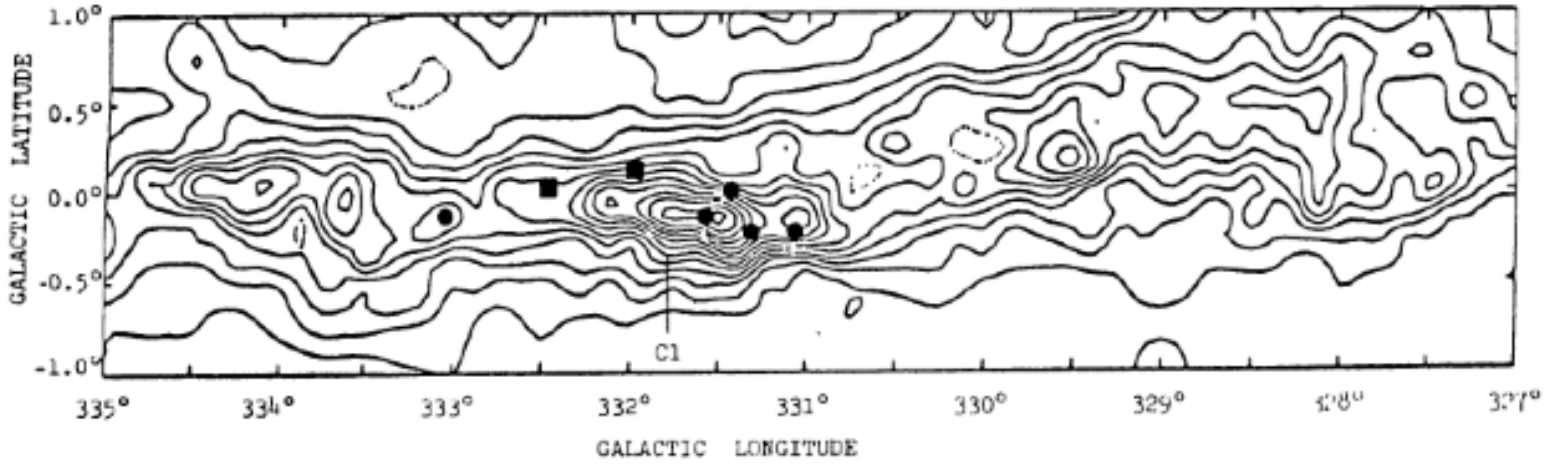
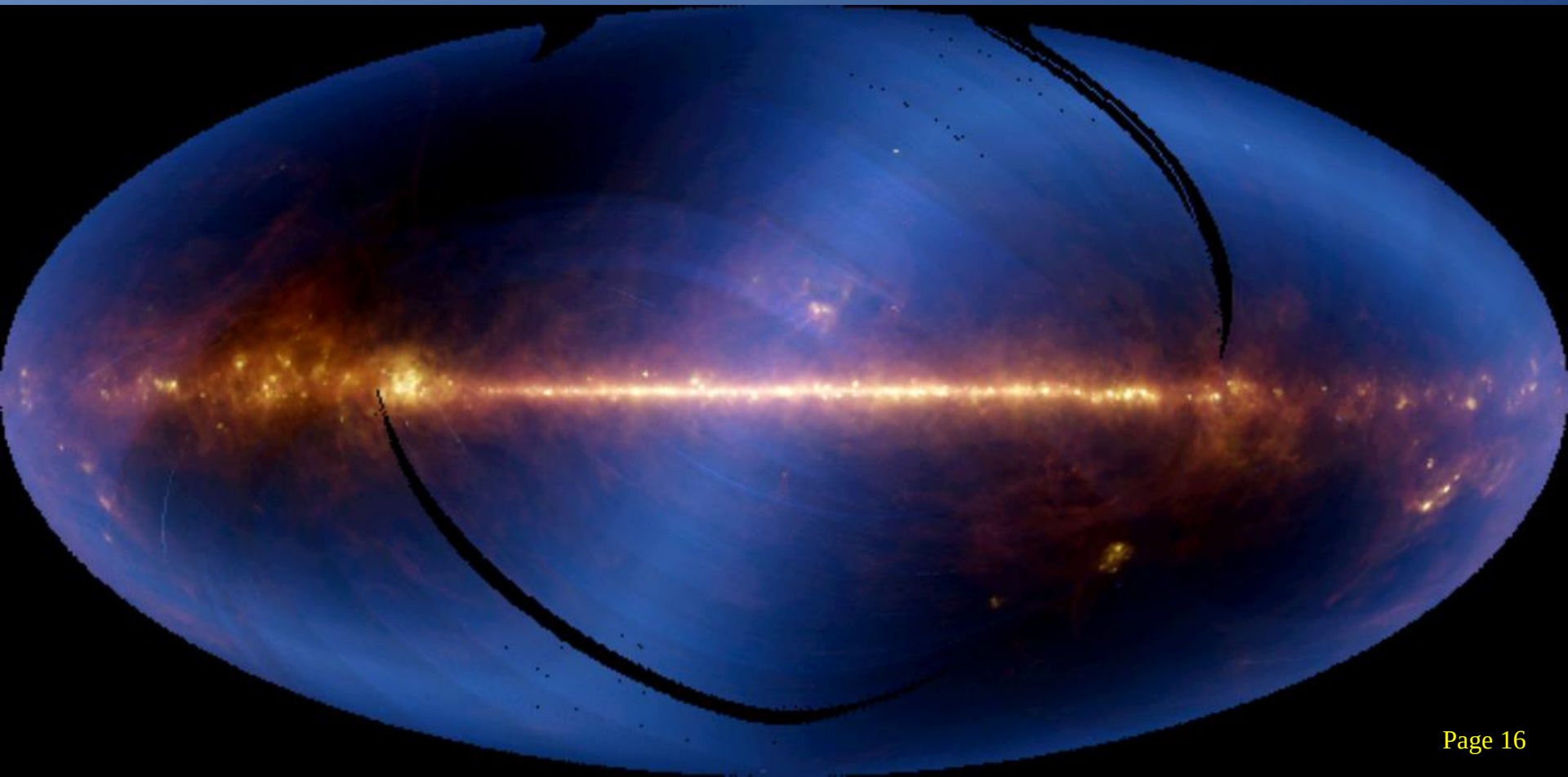


Figure 3. ℓ, v map of CO emission integrated over the highest velocity range (-120 < v < -80 km/s). Complex 1, in the figure, has a kinematical (near) distance of about 7 kpc. HII regions in the area are shown as filled circles, and SNRs as filled squares.

IRAS
BLUE = 12 um
GREEN = 60 um
RED = 100 um

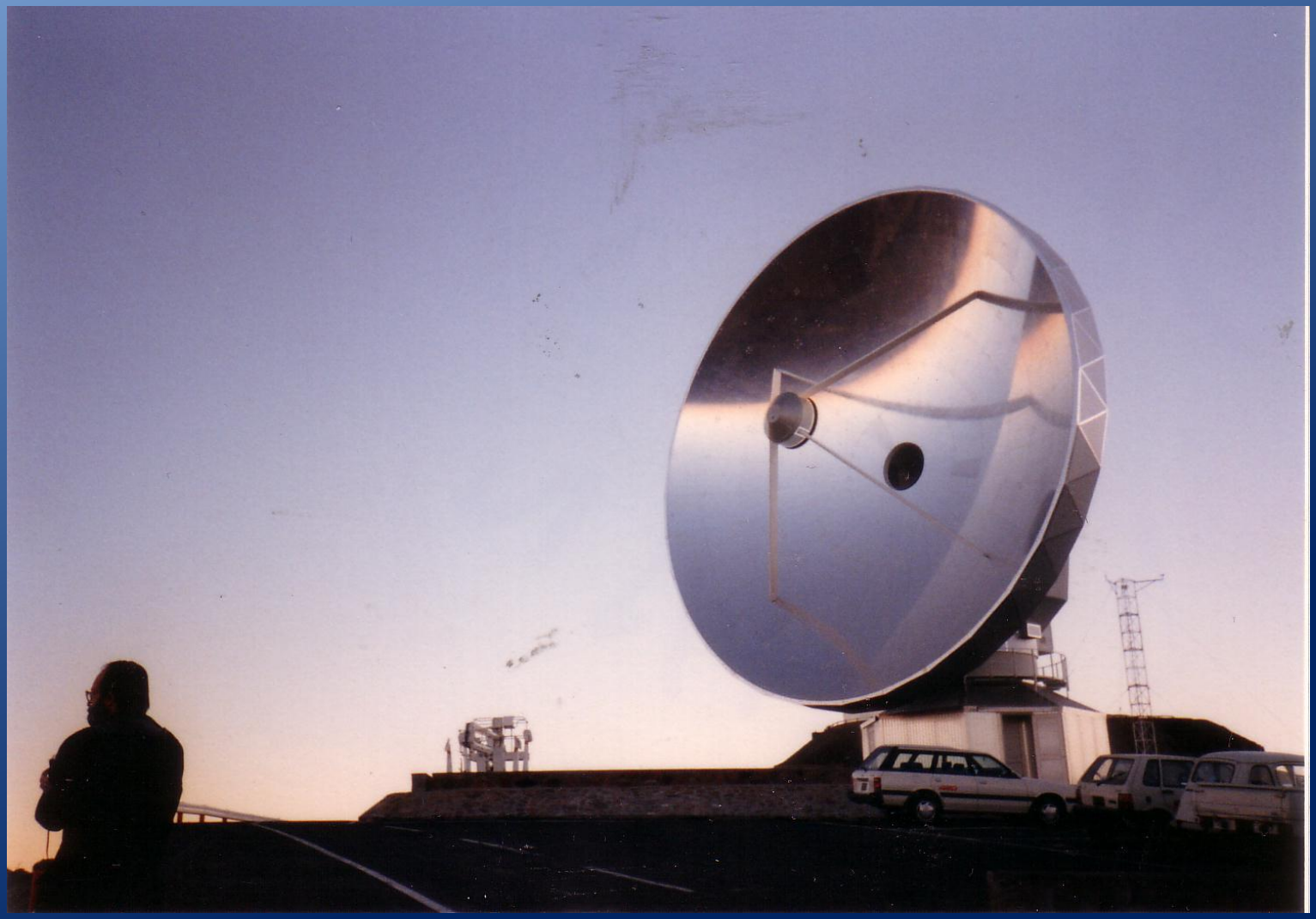
IRAS: STAR FORMATION IN THE GALAXY:

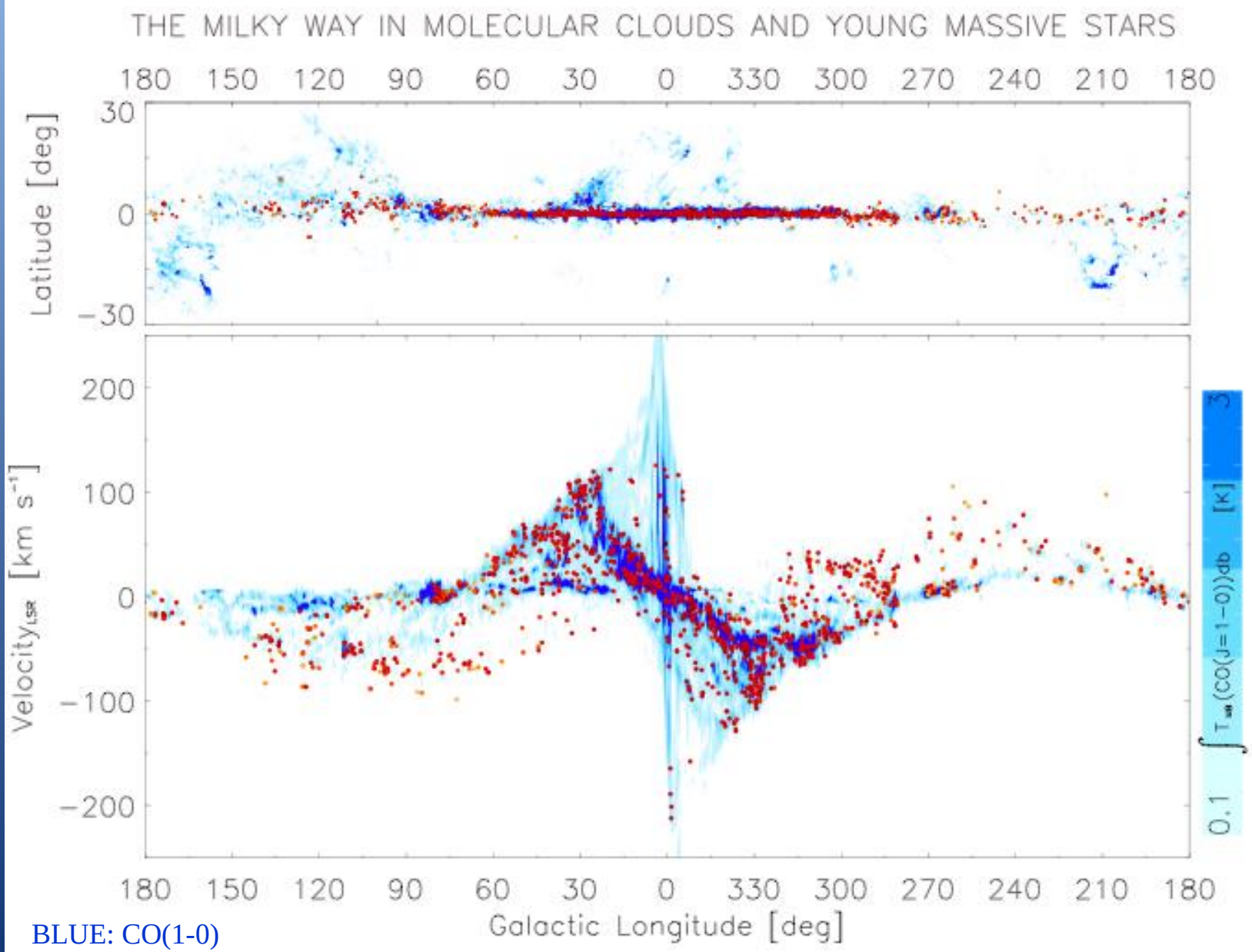
FAR INFRARED EMISSION FROM DUST HEATED BY MASSIVE STARS;
DUST ASSOCIATED WITH MOLECULAR GAS;
FIR POINT SOURCES ASOCIATED WITH HIGH DENSITY CLUMPS



SEST (Swedish ESO Sub-millimeter Telescope); La Silla Observatory, 1988 PI R. Booth
15m diameter antenna; 100 – 345 GHz frequency range; Res. = 45” @ 115 GHz

SEST and L.A. Nyman, Telescope Scientist; present ALMA Head of Science Operations





BLUE: CO(1-0)

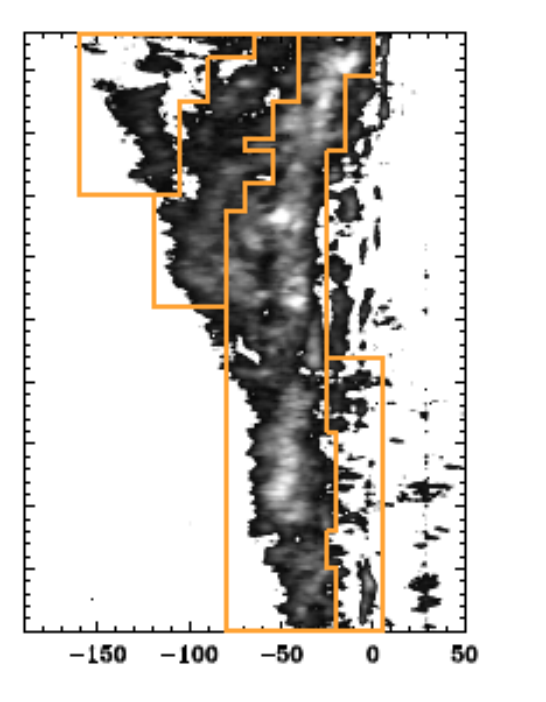
RED: CS(2-1): 1200 UC H II REGIONS FROM IRAS PSC DETECTED WITH SEST AND ONSALA 20M

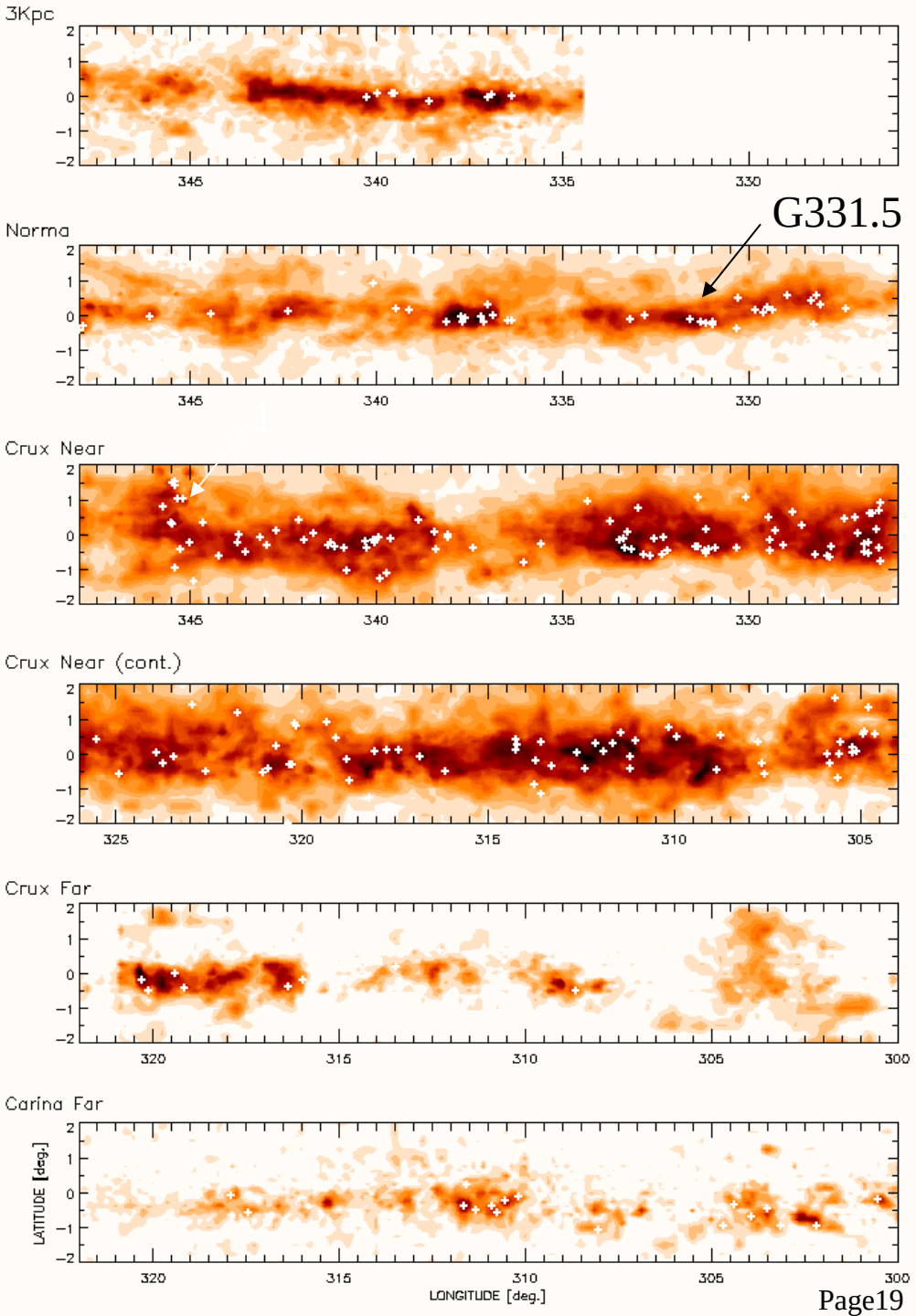
MASSIVE STARS FORM IN THE DENSE CORES OF GIANT MOLECULAR CLOUDS

COLOR: CO(1-0) INTEGRATED IN VELOCITY, WITHIN RANGES OF SPIRAL ARMS IN SOUTHERN GALAXY

CROSSES: MASSIVE STAR FORMING REGIONS DETECTED IN CS(2-1) (SEST)

NORMA G331.5:
D = 7.4 KPC IN TANGENT OF NORMA SPIRAL ARM.





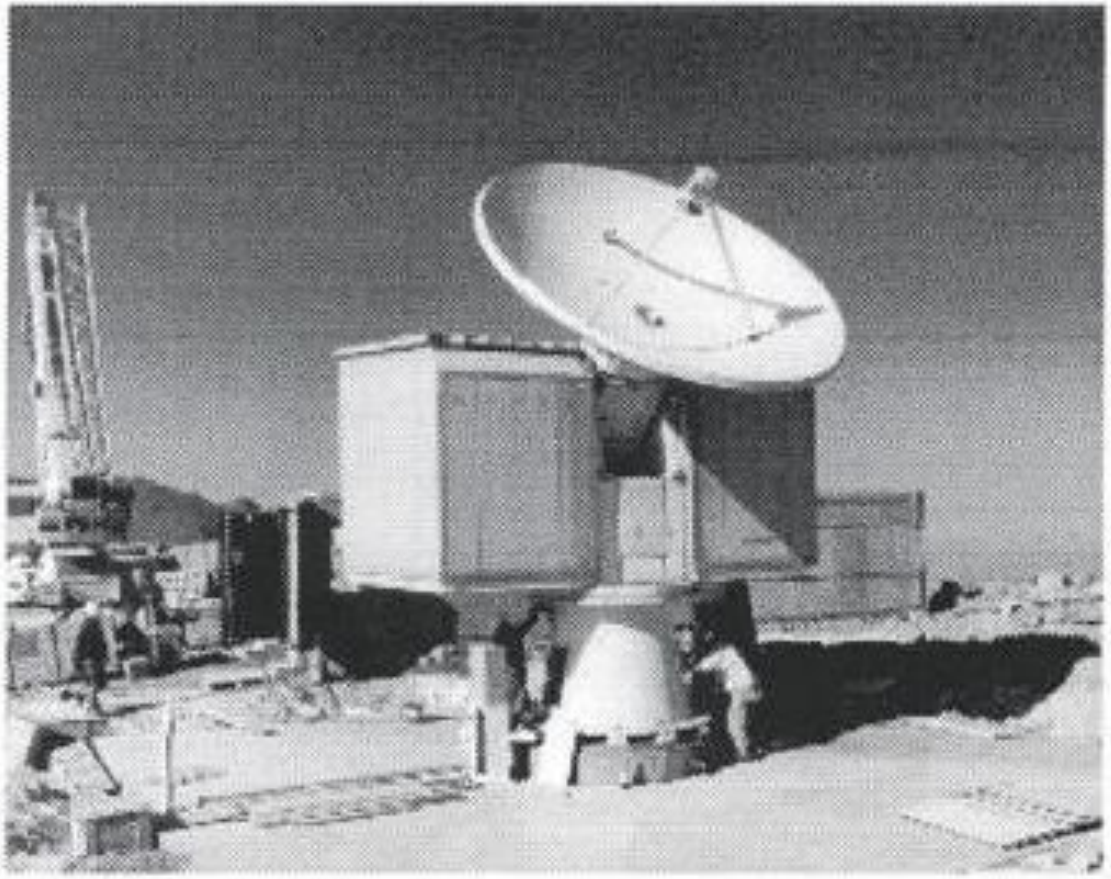
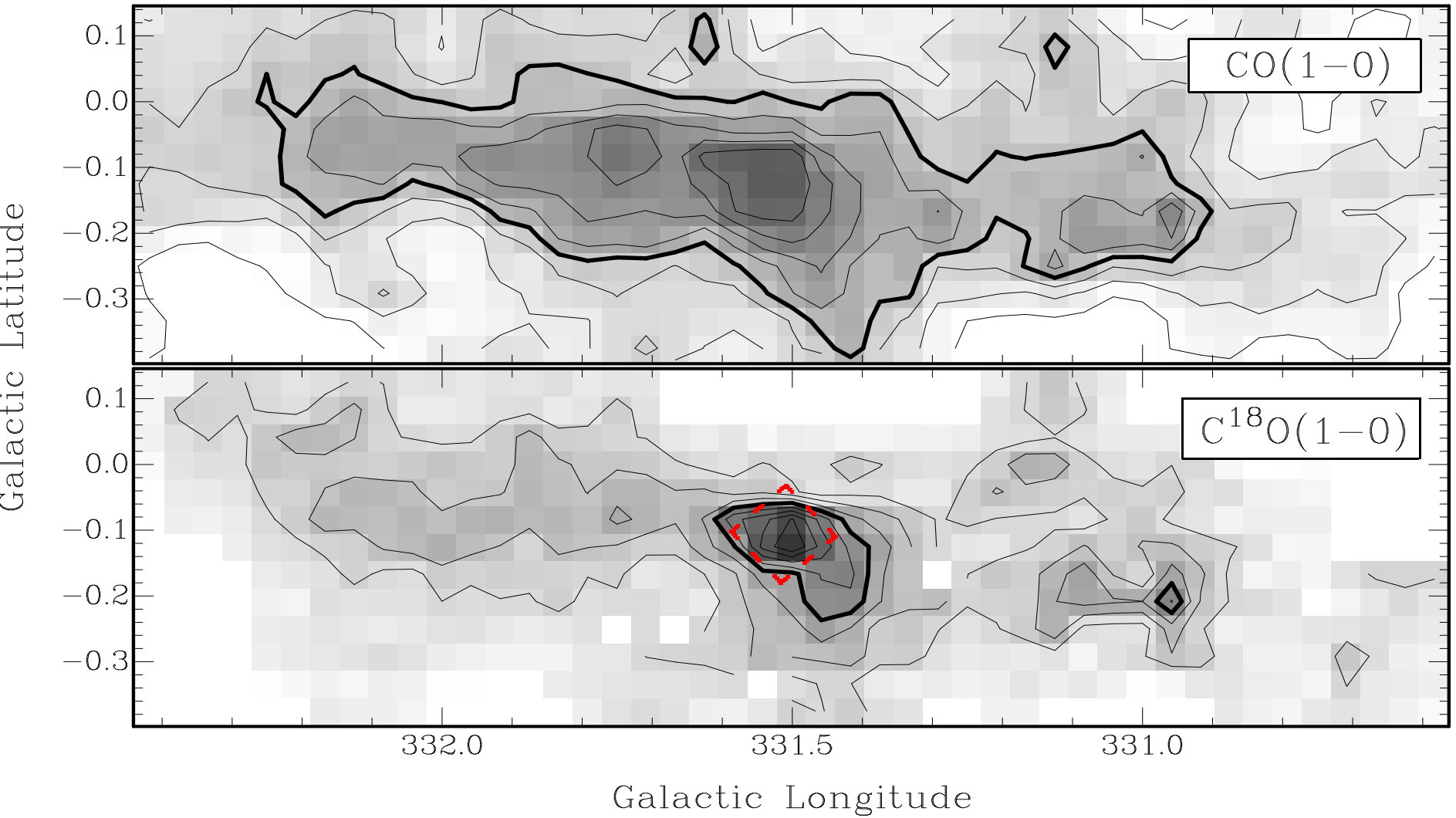
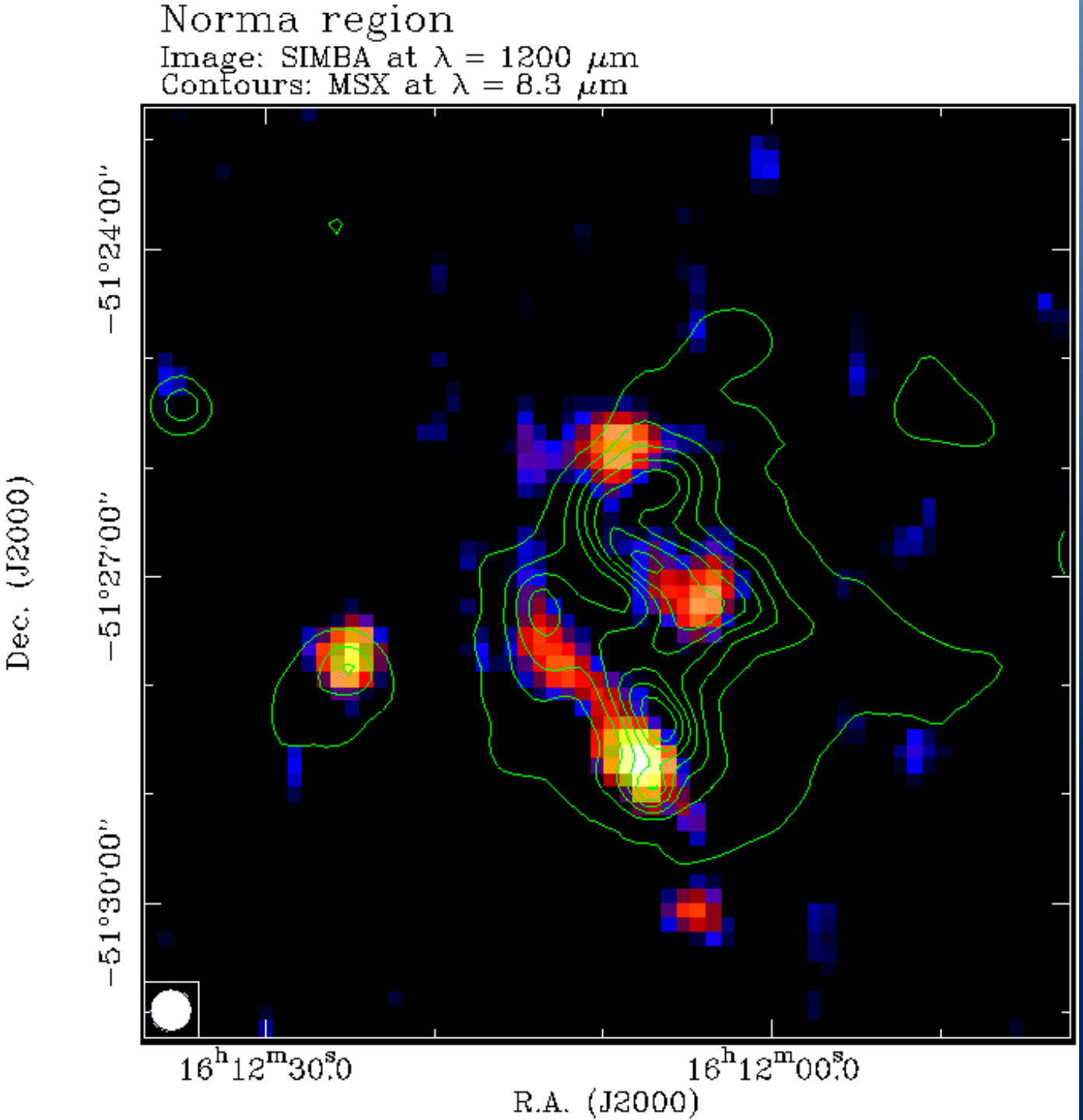


Figure 2. The 4-meter millimeter-wave telescope named NANTEN (=southern sky in Japanese) installed at Las Campanas Observatory in Chile.

Nagoya University NANTEN Telescope (Y. Fukui, 1995)
86 – 230 GHz coverage, 4m antenna, Las Campanas Observatory

NANTEN MAP OF NORMA G331.5; RESOLUTION 2.5 arcmin
3.5 MILLION SOLAR MASSES





ZOOMING IN THE DUST WITH SEST

SIMBA BOLOMETER (2001)

G331.5 MOLECULAR CLOUD CORE:

CONTINUUM EMISSION FROM DUST HEATED BY FORMING STARS

IN THE MEANTIME: THE ALMA SITE AT 5000 m, ATACAMA, CHILE (1994)

GENERAL VIEW OF PAMPA CHAJNANTOR

70 km from San Pedro town; 170 km from Calama, major mining city

Site survey expedition for NAOJ LMSA (pre ALMA); 1994

ALMA Site in Chile

NRAO & NAOJ test interferometers (1995-1996)

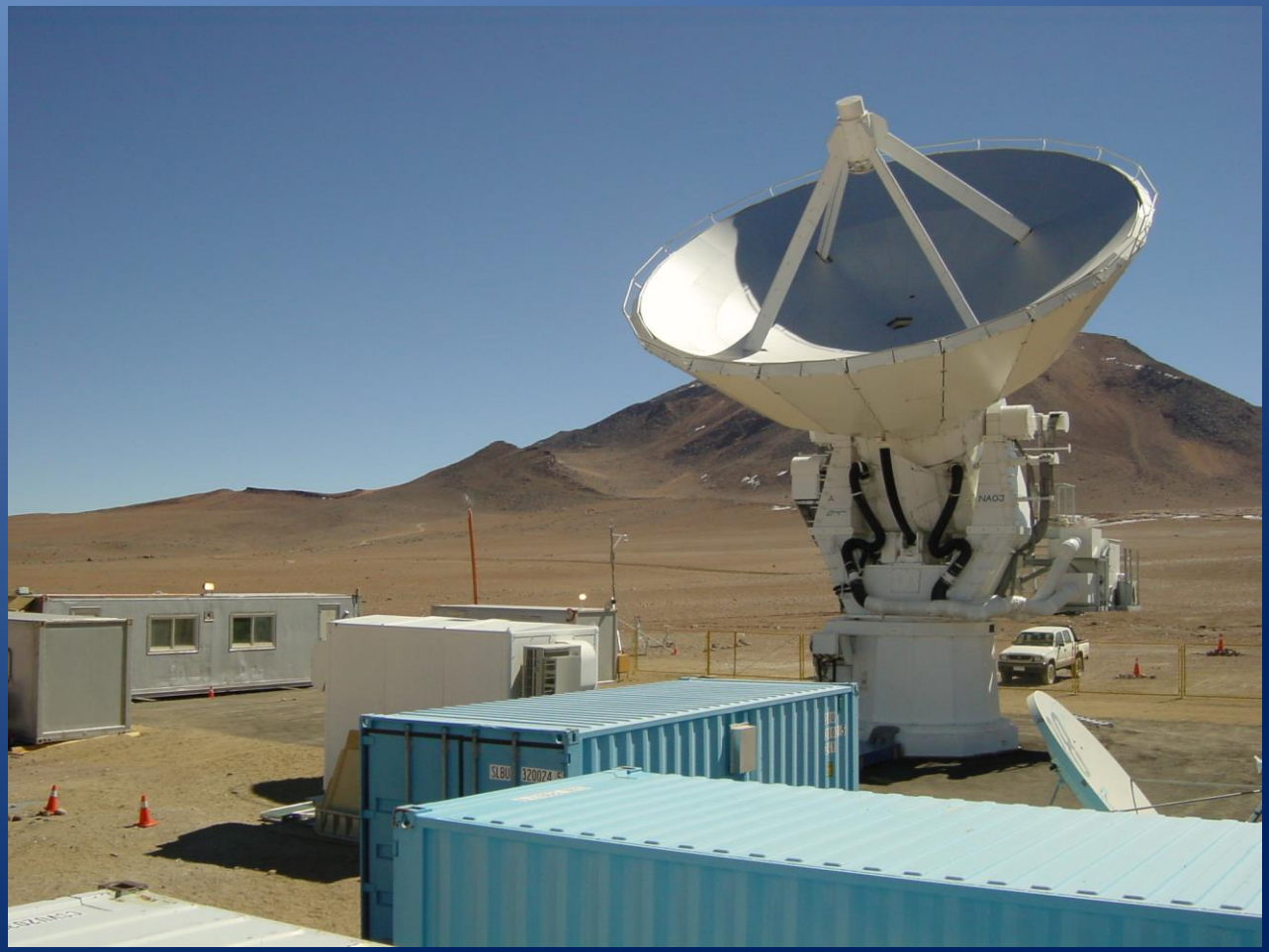
UNIVERSIDAD DE CHILE OBTAINED FIRST PERMIT FOR LAND SCIENCE USE

1st Instrument at the ALMA Site: CalTech Cosmic Background Imager (CBI 1999; PI Tony Readhead)

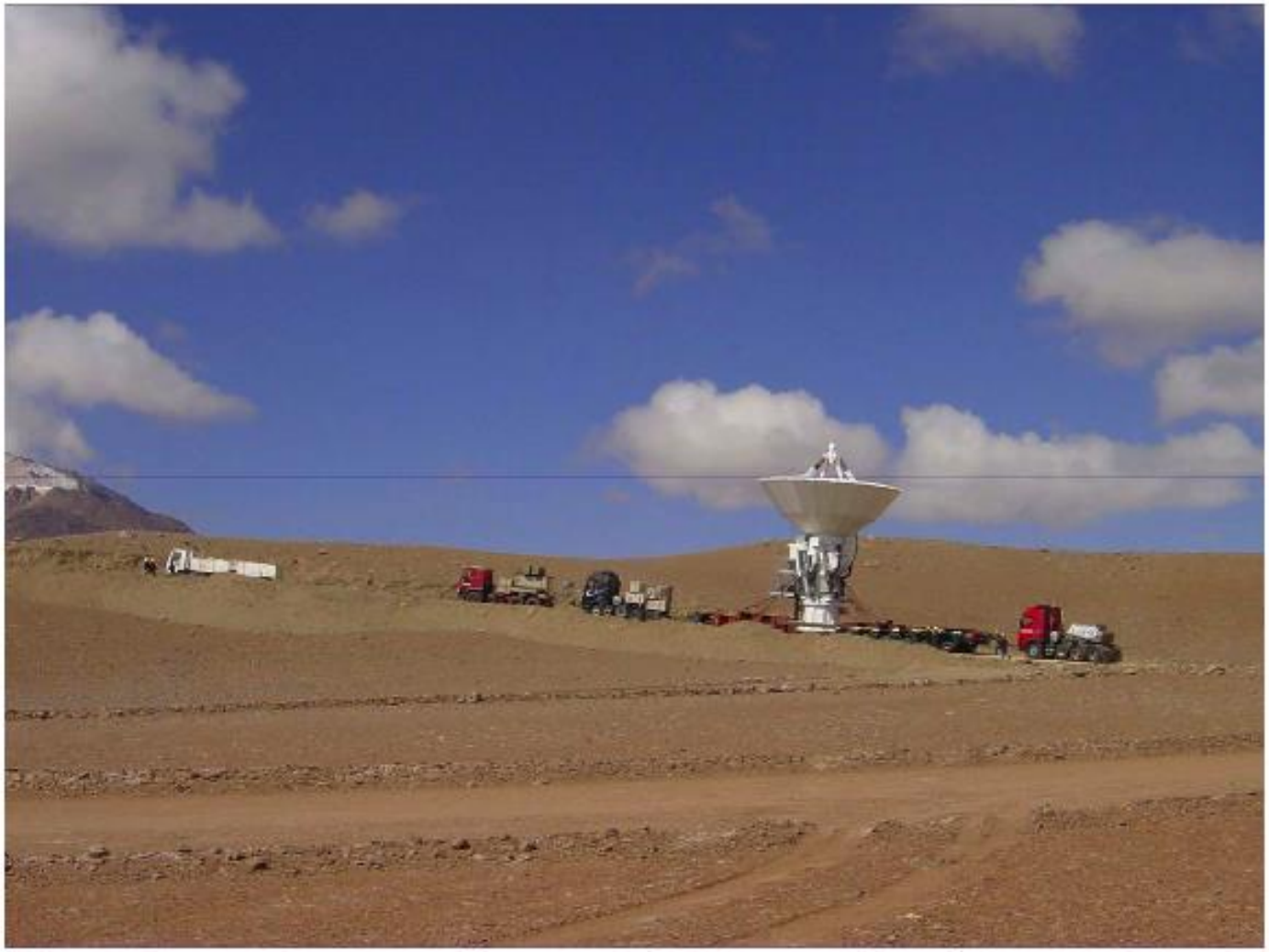
Observations of the polarized microwave background with microkelvin sensitivity. Galactic microwave foreground.

- First generation of Chilean engineers in mm-wave instrumentation trained at CBI.
- Test of astronomical operations at the site.

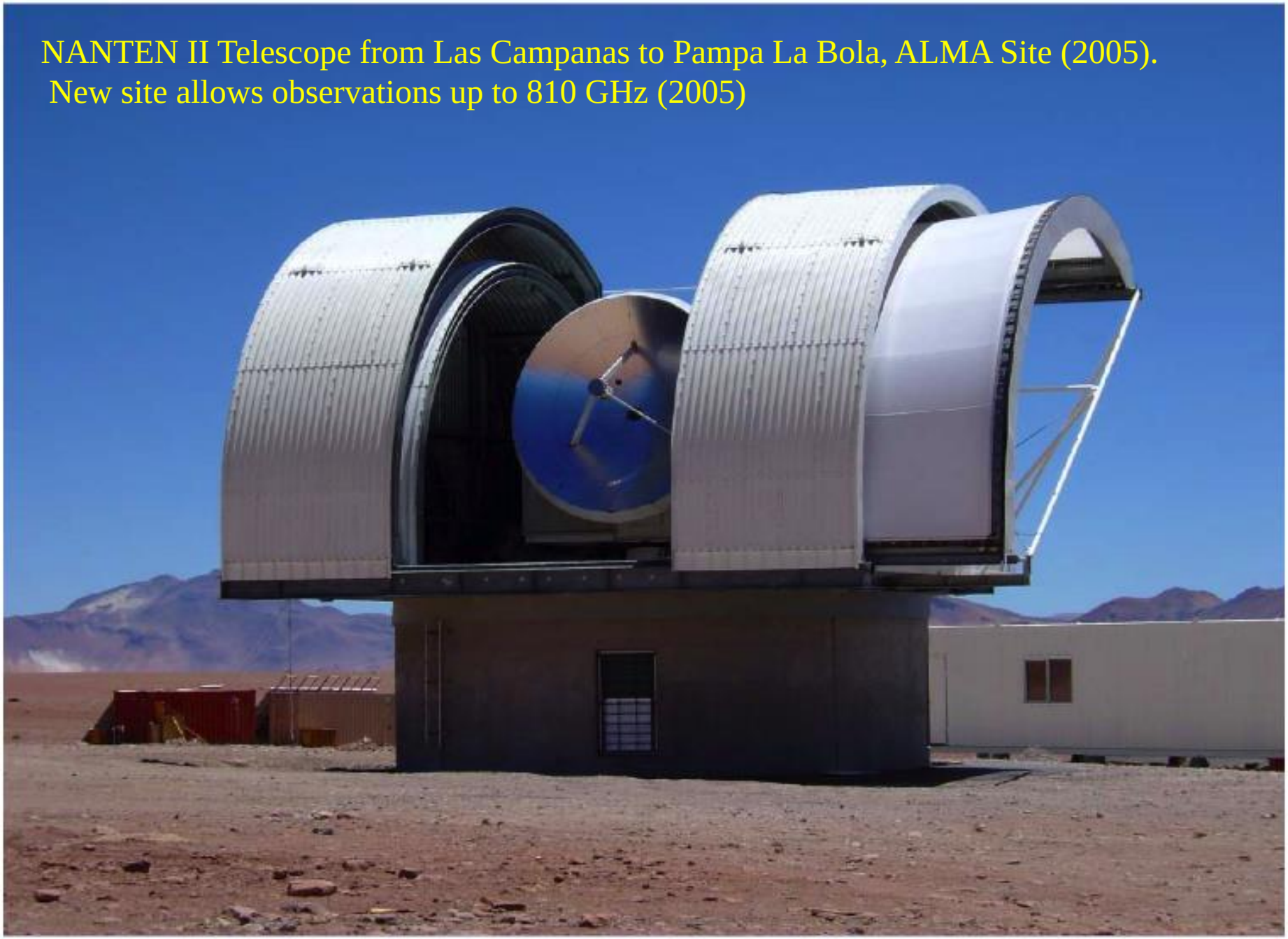
Atacama Submillimeter Telescope Experiment (Japan ASTE 10 m Telescope, NAOJ , 2004) Present day frequency range up to 800 GHz



TRANSPORT OF ASTE TO PAMPA LA BOLA AT 4850 M , CHILE , MARCH 2002 (S. SAKAMOTO)



NANTEN II Telescope from Las Campanas to Pampa La Bola, ALMA Site (2005).
New site allows observations up to 810 GHz (2005)



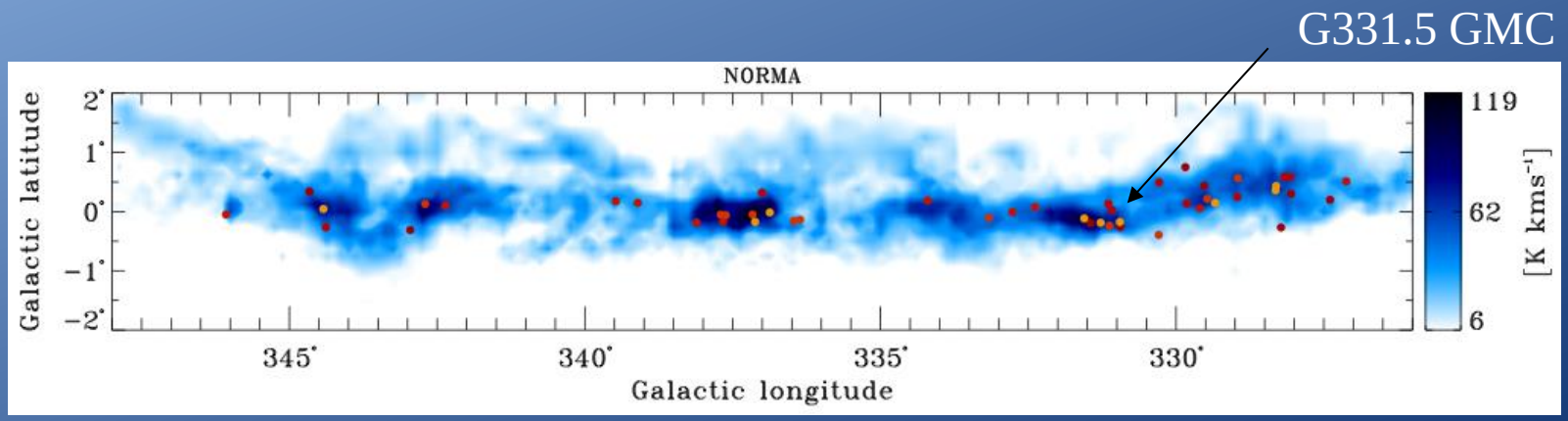
Atacama Pathfinder Experiment (APEX 12 m Telescope)

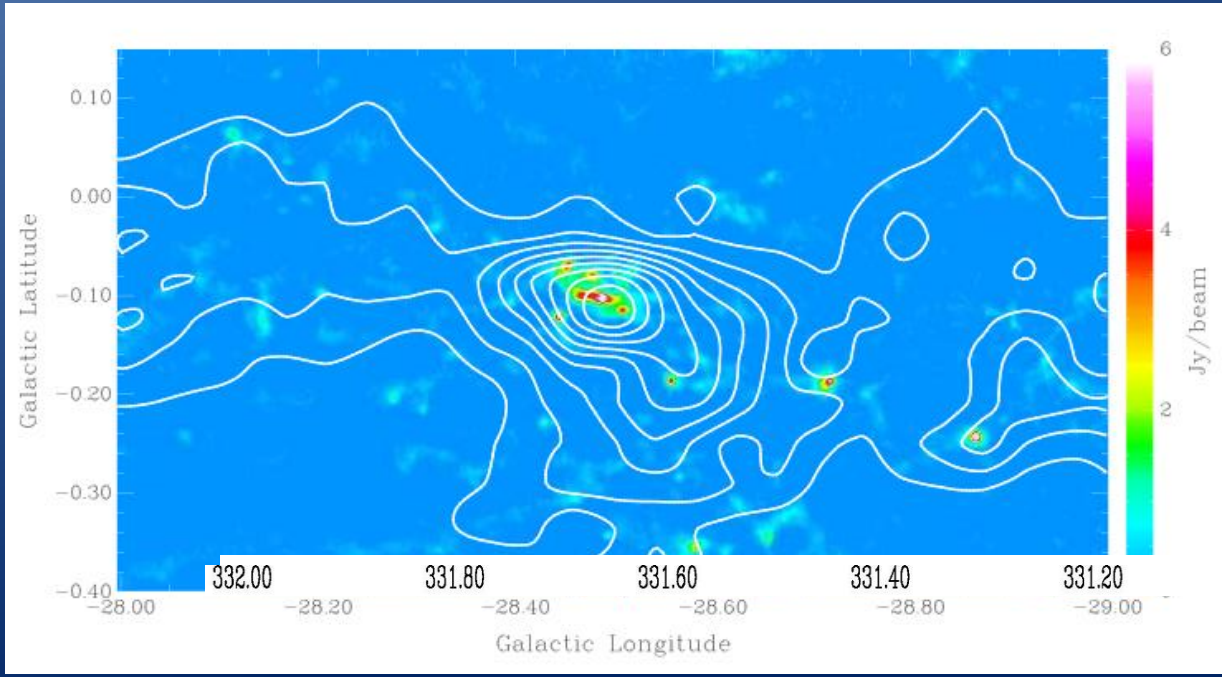
Chajnantor (ALMA site, Chile, 5.050 m)

MPIfR (K. Menten), ESO, Onsala (2005)

230 Ghz to 1 THz

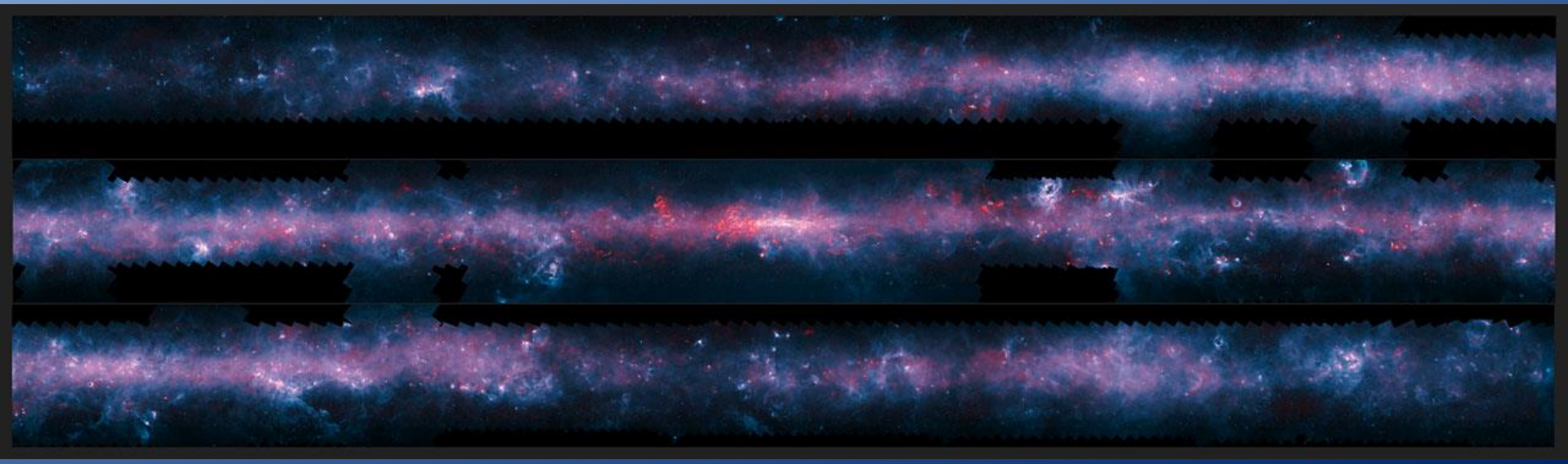
Back to Astronomy:
The G331.5 GMC/Massive Star Forming Region in Norma; APEX LABOCA camera at 0.87 mm





- Distance: 7.4 kpc
- FIR luminosity: $3.6 \times 10^6 L_\odot$
- Contours: NANTEN $C^{18}O$ GMC mass: $3.5 \times 10^6 M_\odot$
- Color: APEX/LABOCA 0.87 mm dust continuum emission

THE ATLASGAL SURVEY OF THE SOUTHERN GALAXY AT 0.87 mm (APEX-LABOCA)
Csengeri et al 2016

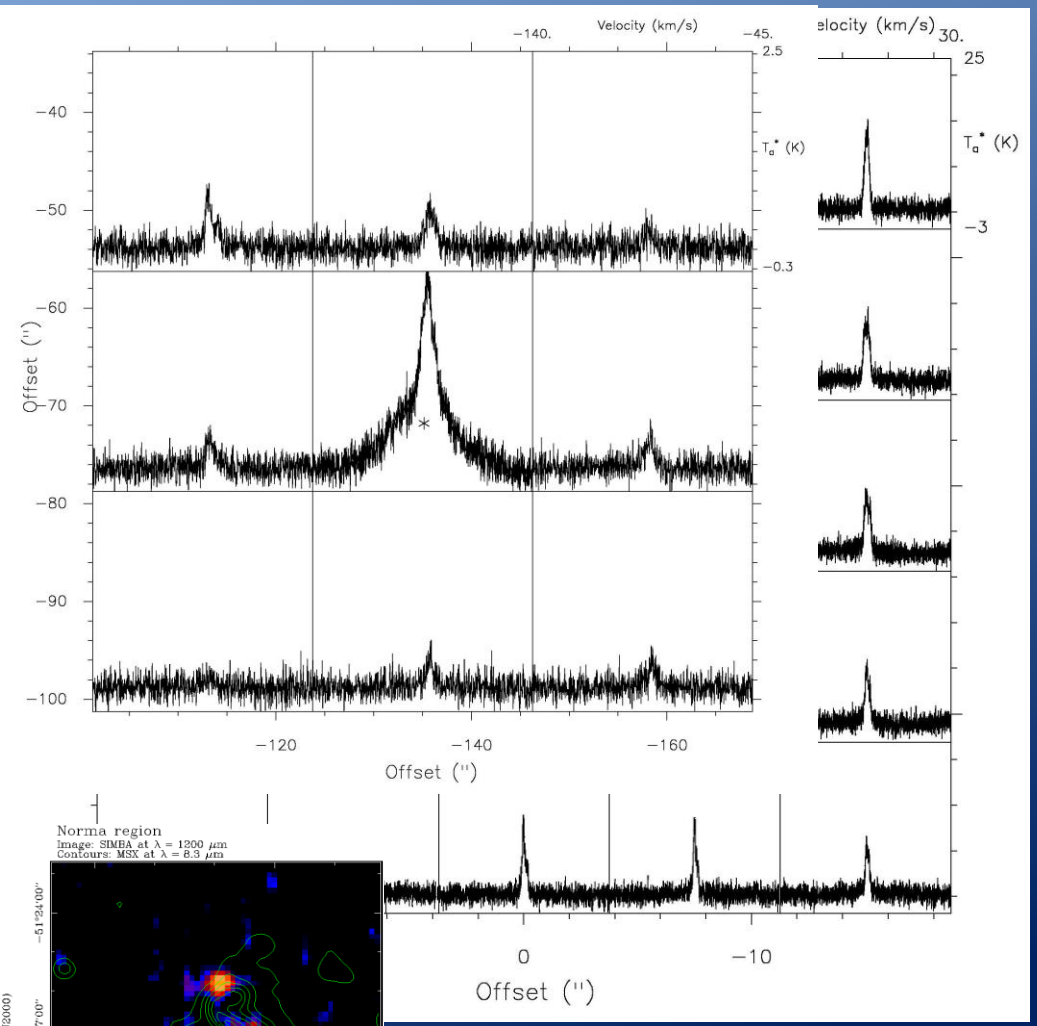


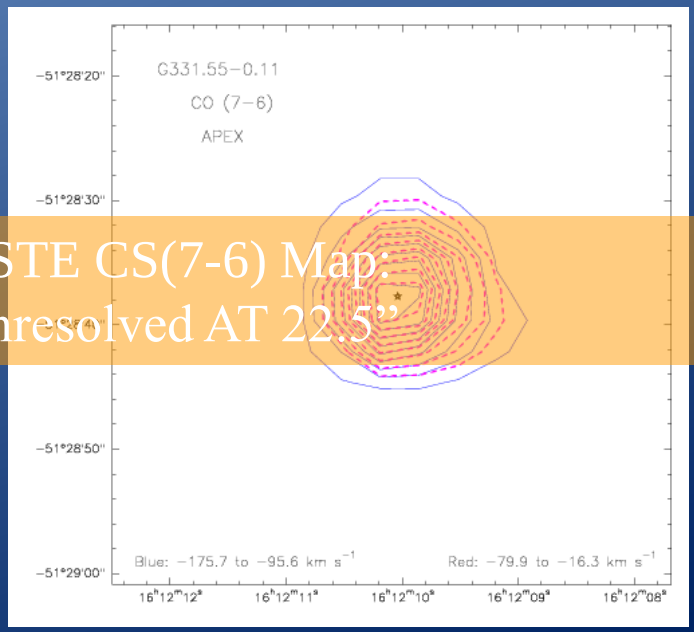
Red: ATLASGAL 0.87 mm

Blue: Spitzer/Glimpse 3.6-8 microns

Extended Red: Planck data

Discovery of a massive molecular outflow in G331.5-0.1



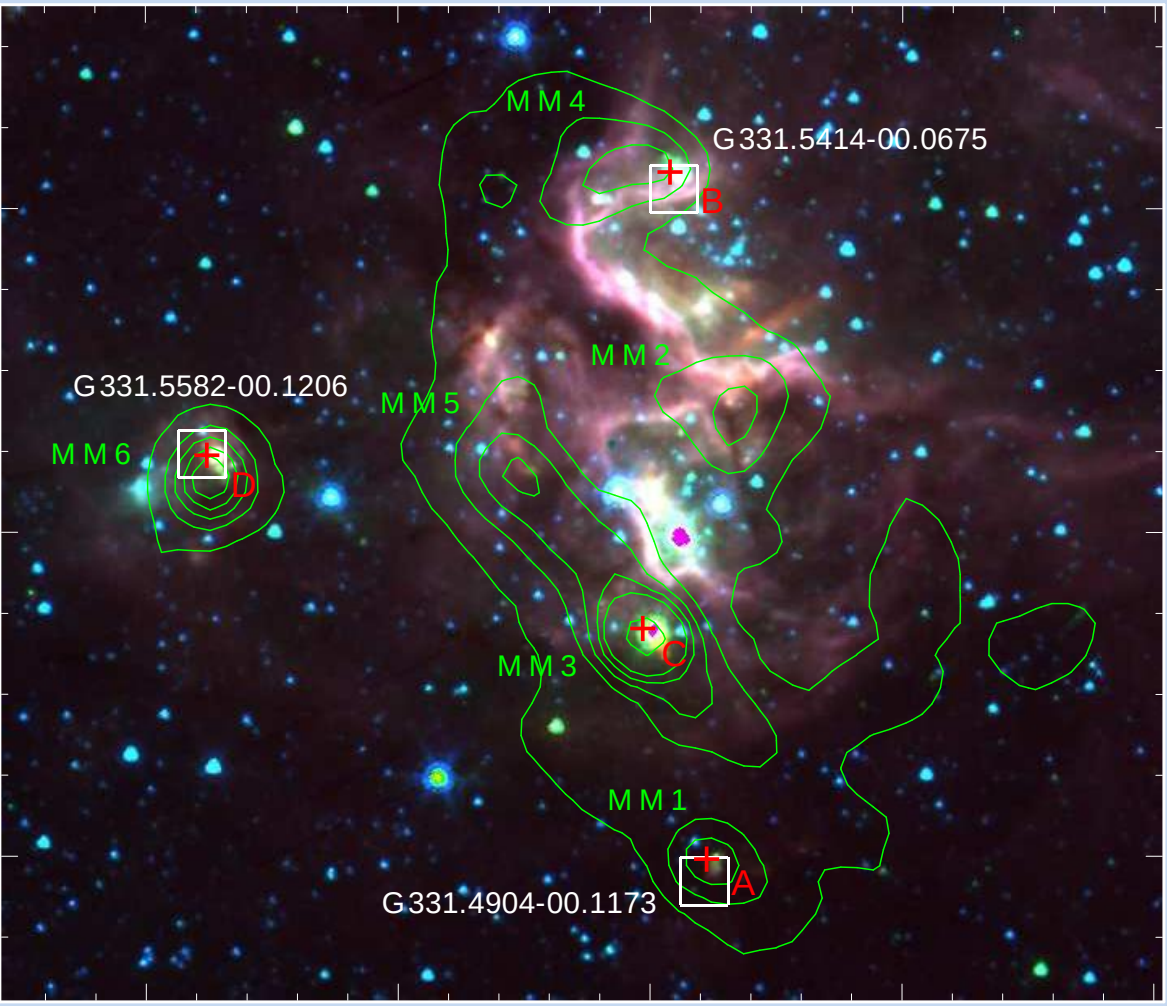


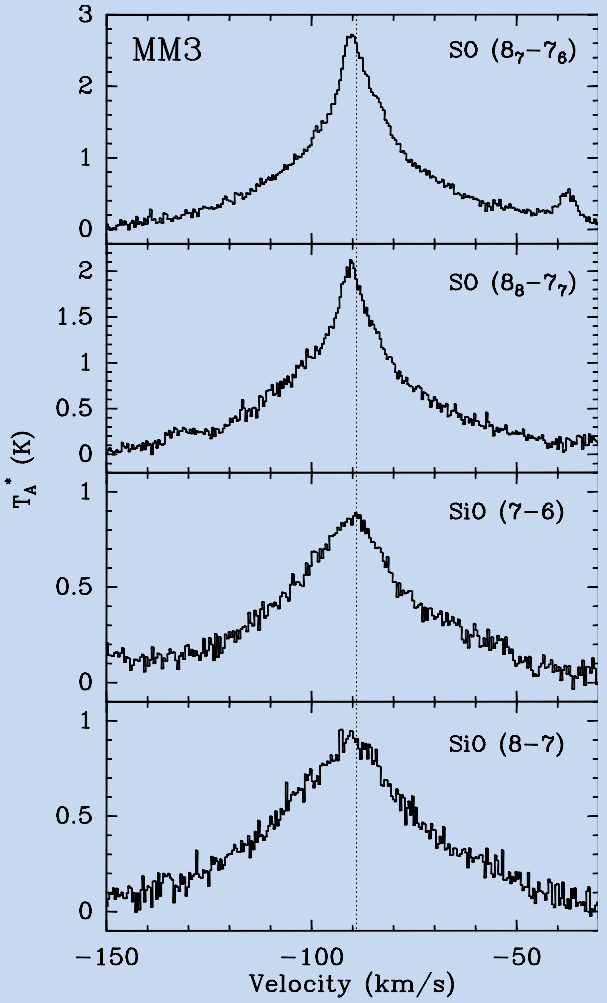
ASTE CS(7-6) Map: Unresolved AT 22.5”

- APEX CO (7-6): Res 7.7”
- Velocity width (ZP)160 km/s
- Dynamic timescale: less than 3×10^3 yrs.

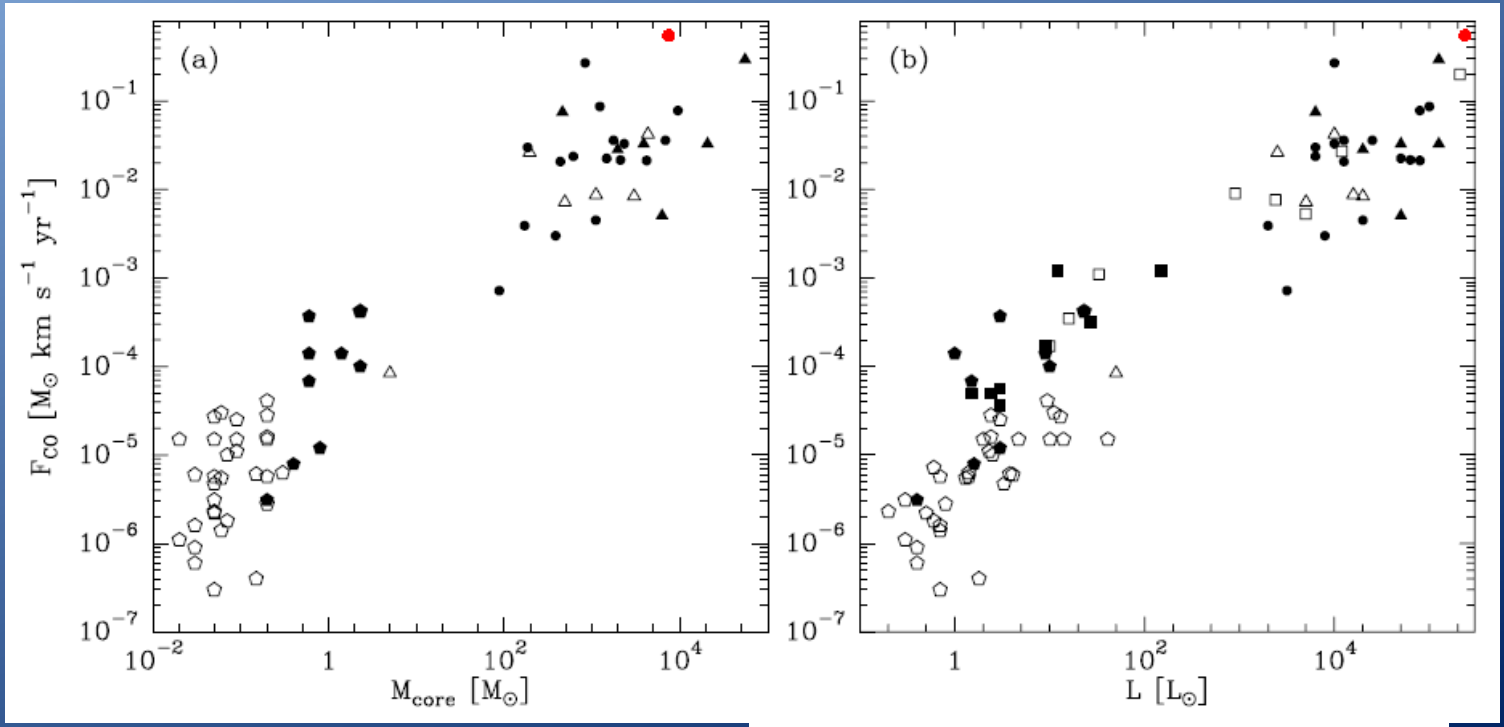
Contours: APEX-LABOCA 0.87 mm continuum
Colors: SPITZER-IRAC mid infrared

APEX spectra of shocked gas in clump MM3; High velocity molecular outflow G331.512-0.103





Mass and momentum loss rate



Beuther et al., 2002b

Mass loss rate:

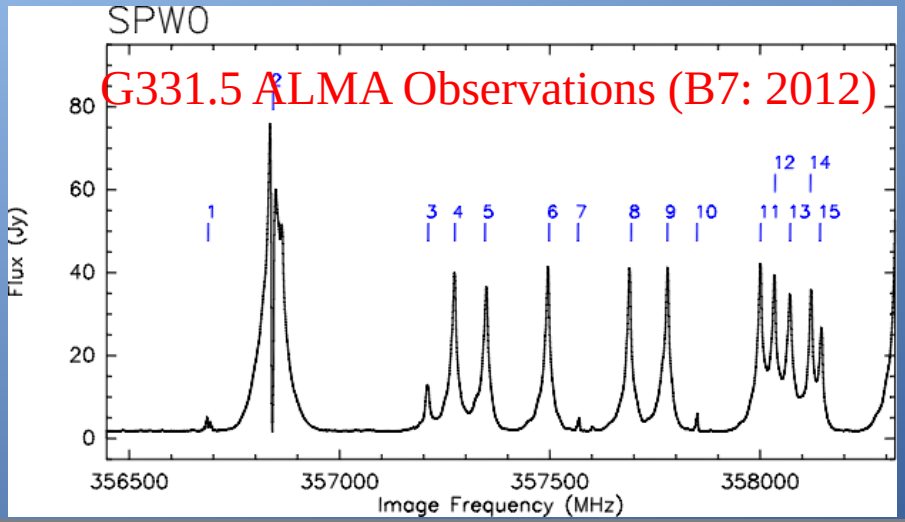
$$\dot{M}_w \sim 3 \times 10^{-4}\ M_\odot\ \mathrm{yr}^{-1}$$

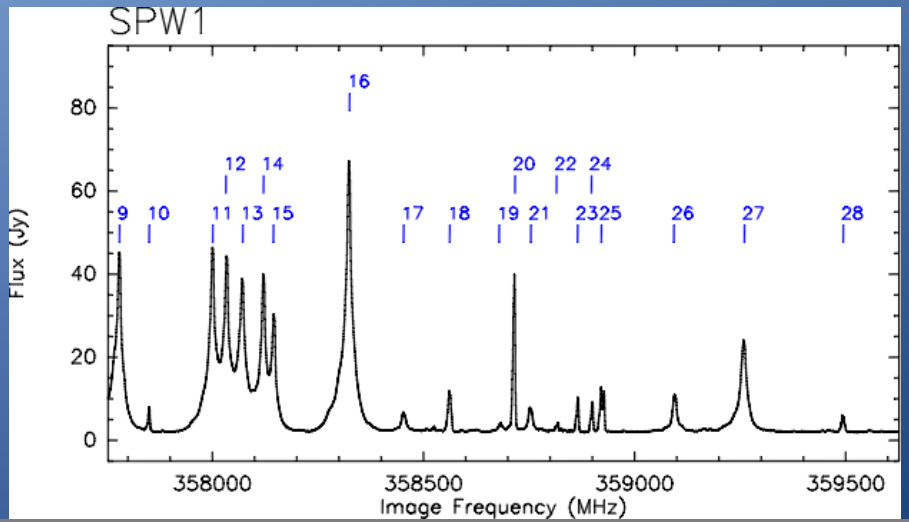
High mass loss rate consistent with source luminosity ~10^6 L⊙.

Spectral index of 1.1 between 4.8 and 8.6 GHz : free-free emission from thermal jet.

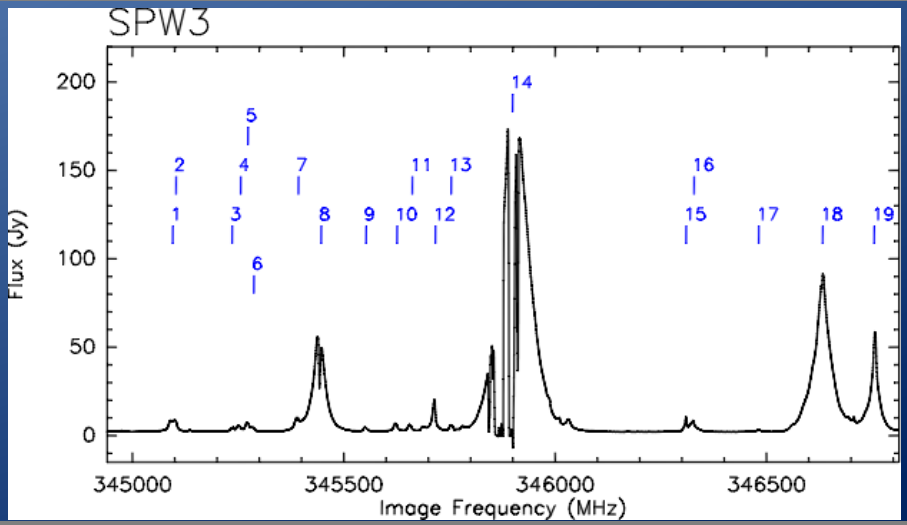
The ALMA Telescope: Science operations in 2012;
Largest (sub)mm-wave telescope in the world;
66 antennas: 54x12m + 12x7m, 35 to 950 GHz;
North America, Europe, East Asia; collaboration with Chile

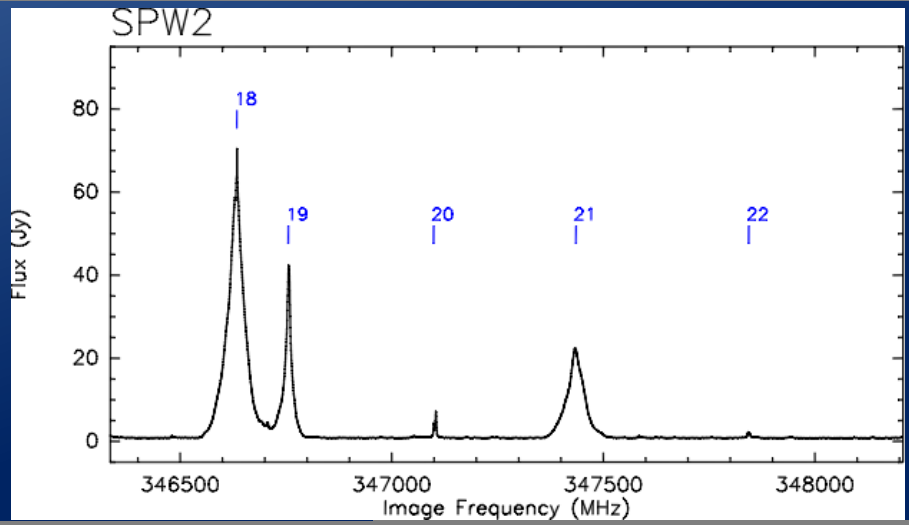
G331.5 ALMA Observations (B7: 2012)





1 CH3OCH3 8(4,5)-7(3.4)
2 HCO+ v=0 4-3
3 34SO2 v=0 20(0,20)-19(1,19)
4 SO2 v=0 13(4,10)-13(3,11)
5 SO2 v=0 15(4,12)-15(3,13)
6 SO2 v=0 11(4,8)-11(3,9)
7 CH3OCH3 18(2,17)-17(1,16)
8 SO2 V=0 8(4,4)-8(3,5)
9 SO2 v=0 9(4,6)-9(3,7)
10 Unidentified
11 SO2 v=0 7(4,4)-7(3,5)
12 SO2 v=0 6(4,2)-6(3,3)
13 SO2 v=0 17(4,14)-17(3,15)
14 SO2 v=0 5(4,2)-5(3,3)
15 SO2 v=0 4(4,0)-4(3,1)
16 SO2 v=0 20(0,20)-19(1,19)
17 34SO2 v=0 23(4,20)-23(3,21)
18 Unidentified
19 CH3OCHO v=0 29(12,18)-28(12,17)A
20 CH3OHv t=0 4(1,3)-3(0,3)
21 S18O 9(9)-8(8)
22 Unidentified
23 CH3CCH v=0 21(3)-20(3)
24 CH3CCH v=0 21(2)-20(2)
25 CH3CCH v=0 21(1)-20(1) / CH3CCH v=0 21(0)-20(0)
26 Unidentified (possible 34SO2 v=0 15(2,14)-14(1,13))
27 SO2 v=0 25(3,23)-25(2,24)
28 CH3OCH3 12(3,10)-11(2,9)





1 34SO2 v=0 15(4,12)-15(3,13)
2 34SO2 v=0 11(4,8)-11(3,9)
3 CH3OCH3 35(2,33)-35(1,34)
4 Possible SO2 v=0 5(5,1)-6(4,2)
5 34SO2 v=0 8(4,4)-8(3,5)
6 NH2CHO 17(0,17)-16(0,16)
7 Unidentified (possible 34SO2 v=0 9(4,6)-9(3,7))
8 H13CN v=0 J=4-3
9 SO2 v=0 26(9,17)-27(8,20)
10 34SO2 v=0 7(4,4)-7(3,5)
11 34SO2 v=0 6(4,2)-6(3,3)
12 HC3N v=0 J=38-37
13 34SO2 v=0 6(4,2)-6(3,3)
14 CO v=0 3-2
15 CH3OHv t=0 5(4,2)-6(3,3)-- / CH3OHv t=0 5(4,1)-6(3,4)++
16 NS J=15/2-13/2,Omega=1/2,F=17/2-15/2,I=f
17 SO2v2=1 19(1,19)-18(0,18)
18 SO2 v=0 16(4,12)-16(3,13)
19 SO2 v=0 19(1,19)-18(0,18)
20 H13CO+ 4-3
21 SiO v=0 8-7
22 SO+ J=15/2-13/2,Omega=1/2,I=e

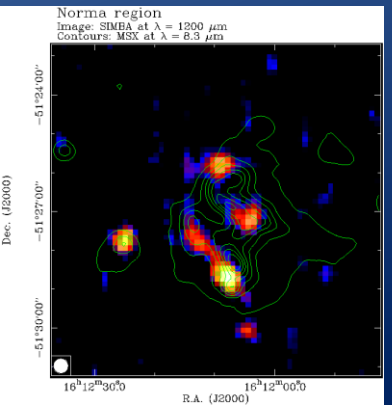
*G331.5 with ALMA; Channel maps of SiO (8-7)

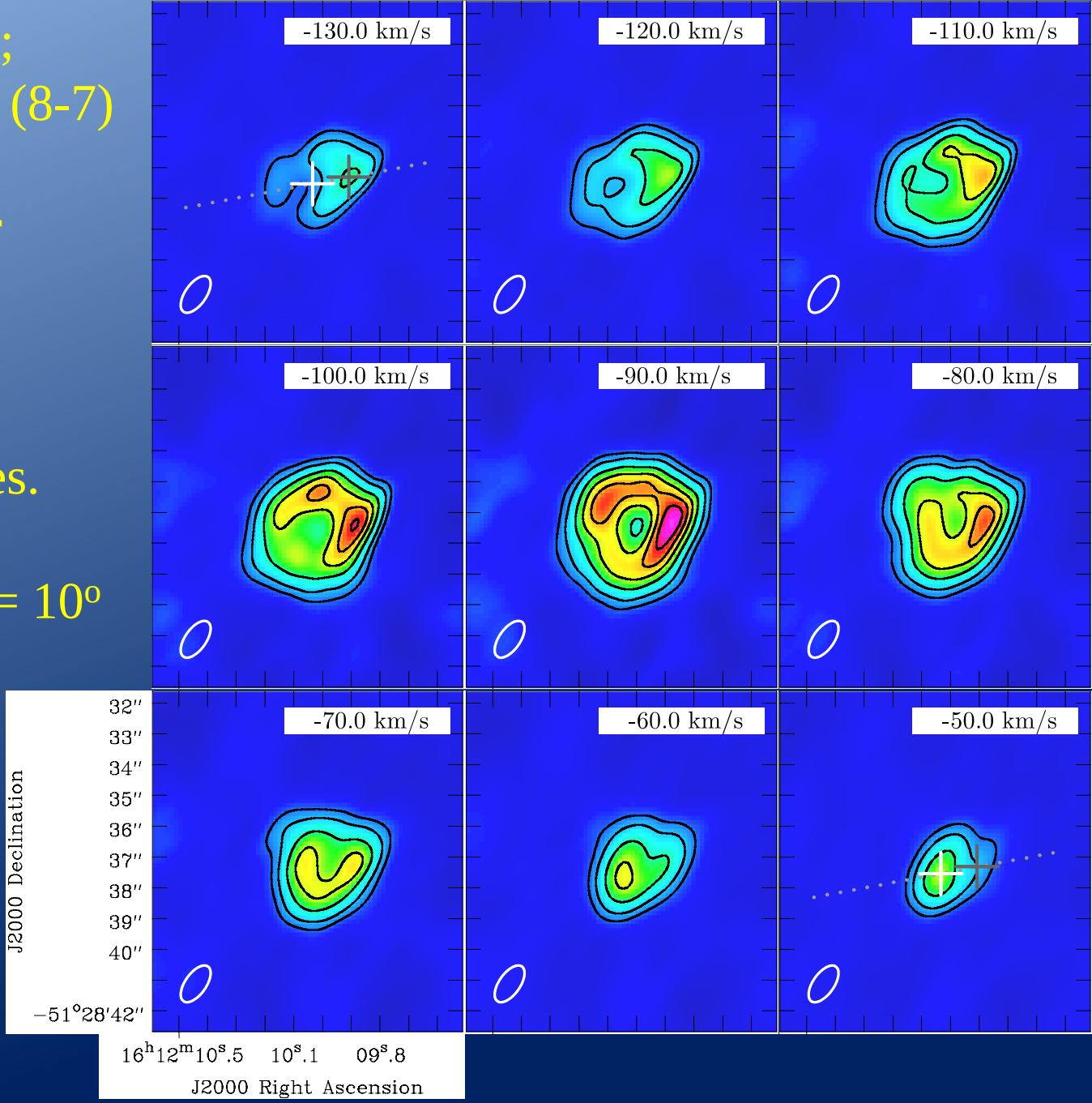
*Central map: disk or projected shell

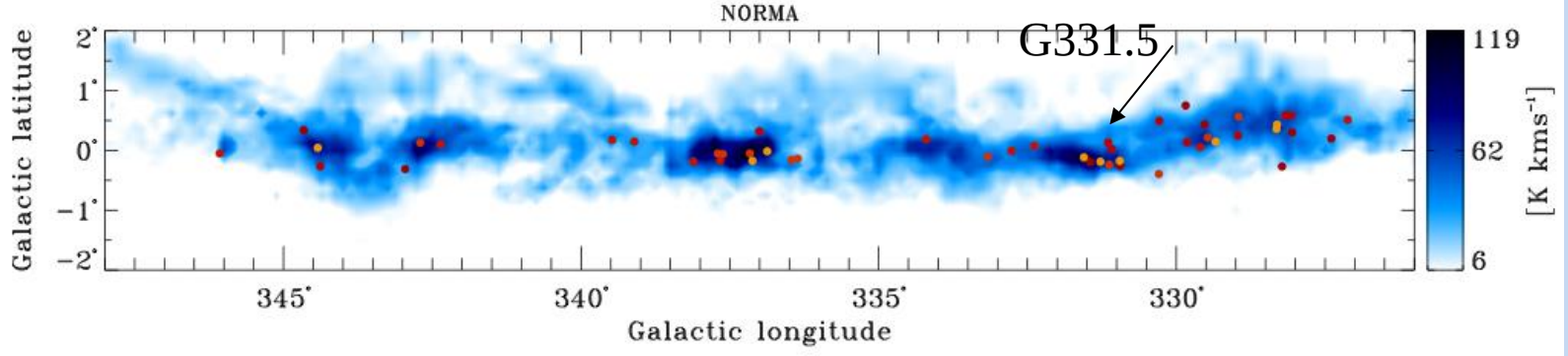
*Gray/white crosses: Blue/red outflow lobes.

•Outflow inclination = 10^{o}
•Resolution: 1 arcsec

M. Merello Thesis



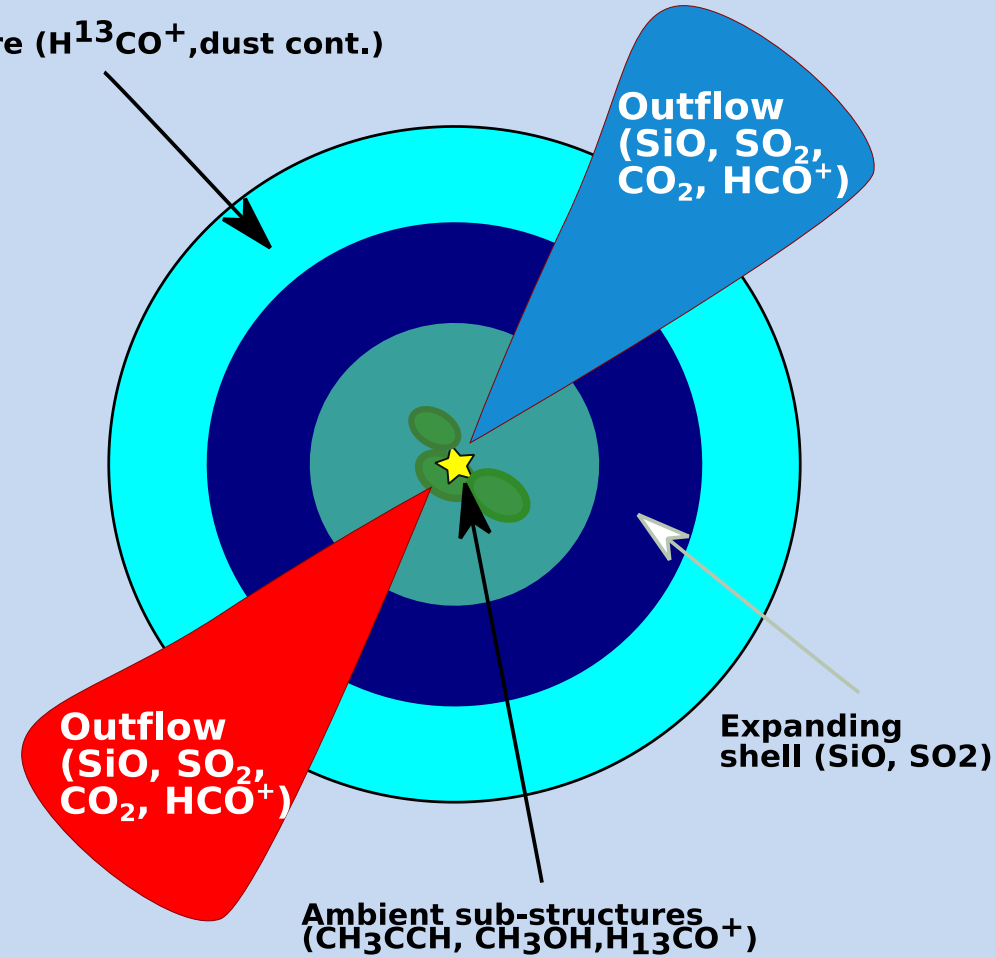




MINI: Resolution 480" (1985)

Sketch model of G331.5 Molecular Outflow

ALMA Resolution: 1" (2012)



C. Hervías Thesis

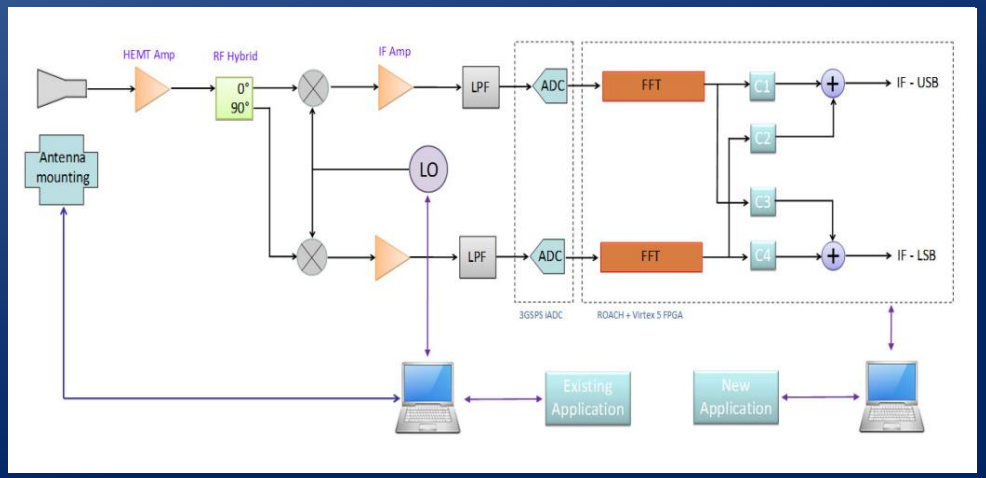
Nicolas Duronea (IAR)

- In the meantime: relocation of the Southern MINI to Cerro Calán, (OAN, Universidad de Chile, 2005-2009)

The 1.2 m telescope at U. Chile OAN, Cerro Calán

- Hands-on training for Astronomy students
- Engineering graduate and undergraduate theses.
- Receiver upgrade with hybrid mixer and FPGA digital SB separation spectrometer
- SCIENCE: Finish up all sky survey for gamma ray foreground ID

Southern Mini at Cerro Calán, July 2013



Digital sideband separating mixer using FPGA technology (ROACH; R. Finger, R. Rodriguez).

The U. Chile Millimetre Wave Laboratory (2005)
Centre for Astrophysics and Associated Technologies (2008-)

- Joint effort of Astronomy and Electrical Engineering.
- Development of front-end and digital back-end technology
- Training of undergrad and grad students (joint PhD program)
- International collaboration in state-of-the-art projects:
- ALMA Band 1 Receiver Prototype (2008-2012)

Main Current Projects

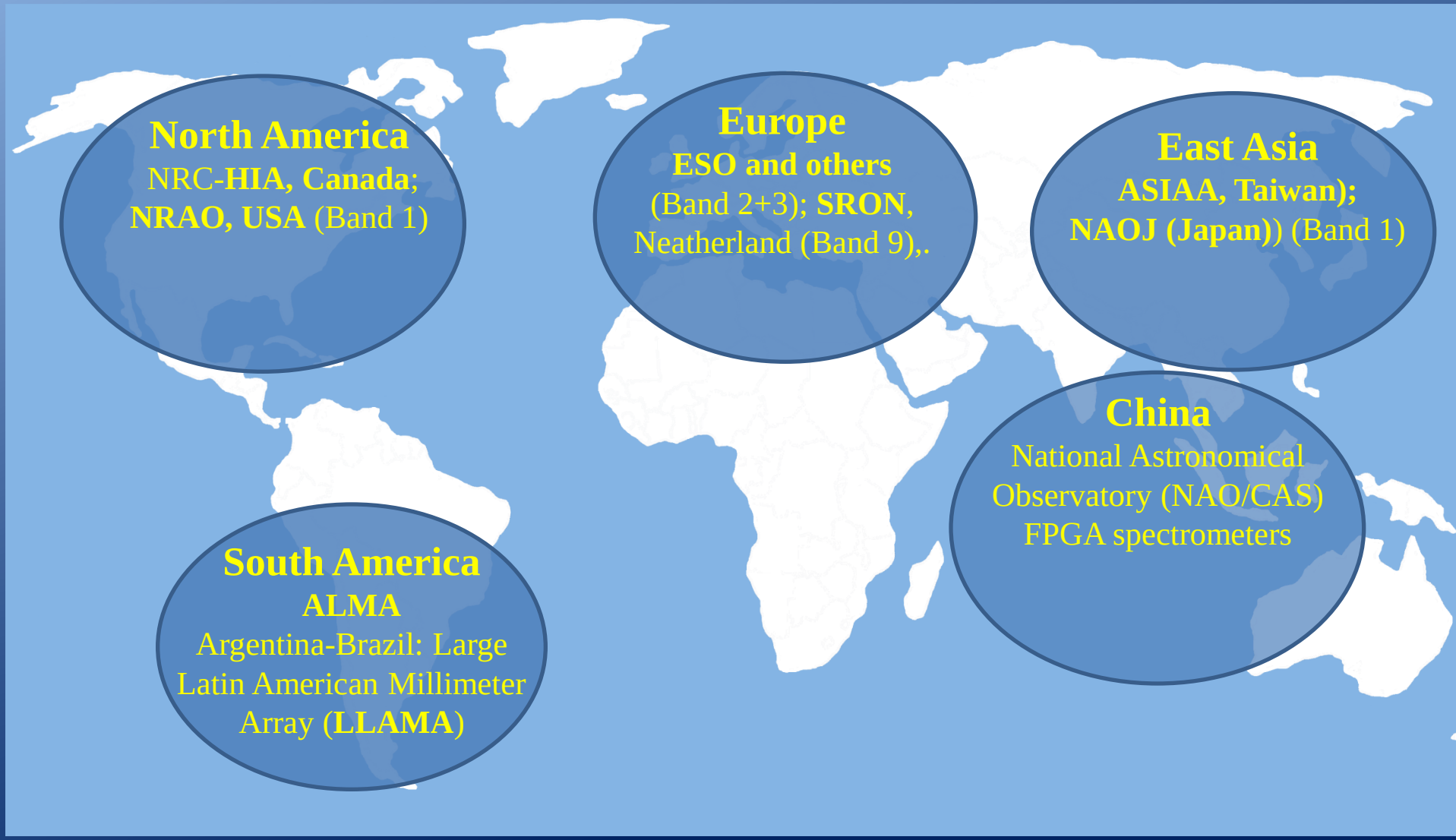
1. ALMA Band 1 Optics full design and fabrication
2. ALMA Band 2+3 Optics design and prototype
3. LLAMA Bands 1 and 3 Heterodyne Receivers
4. FPGA-based Digital Spectrometers
5. 1.2 m Mm-wave Telescope upgrading
6. Technology transfer

MM-WAVE LAB MACHINE SHOP:
KERN CNC MILL (CATA, 2008)
SCHAUBLIN CNC LATHE (QUIMAL, 2014)

ALSO: PHOTONICS LAB AT FCFM
(QUIMAL 2015)

BAND 1 HORNS MACHINED WITH NEW LATHE (2015)
Formerly 1 week; now one hour

International Collaborations



Muchas Gracias y Feliz Aniversario 50 IAR !

2009 September

In memory of Prof. Jorge May (1936-2011)