Radio Astronomy at Umass and Large Millimeter Telescope

Min S. Yun

NEROC Radio Science Symposium

Outline

- Radio Astronomy at Univ. of Massachusetts Amherst
  - LMT operation (Pete Schloerb, Min Yun, Grant Wilson, Alex Pope, Kamal Souccar)
  - Heterodyne Instrumentation (Neal Erickson, Gopal Narayanan)
  - Continuum Instrumentation (Grant Wilson)
- Large Millimeter Telescope (LMT)
  - 50-m telescope completed
  - Some Science Highlights
  - TolTEC Community Legacy Surveys
  - Next Steps
    - LMT US Consortium
    - Future Instrumentations and Experiments

Large Millimeter Telescope (LMT)

- bi-national project: Mexico (70%), UMASS (30%)

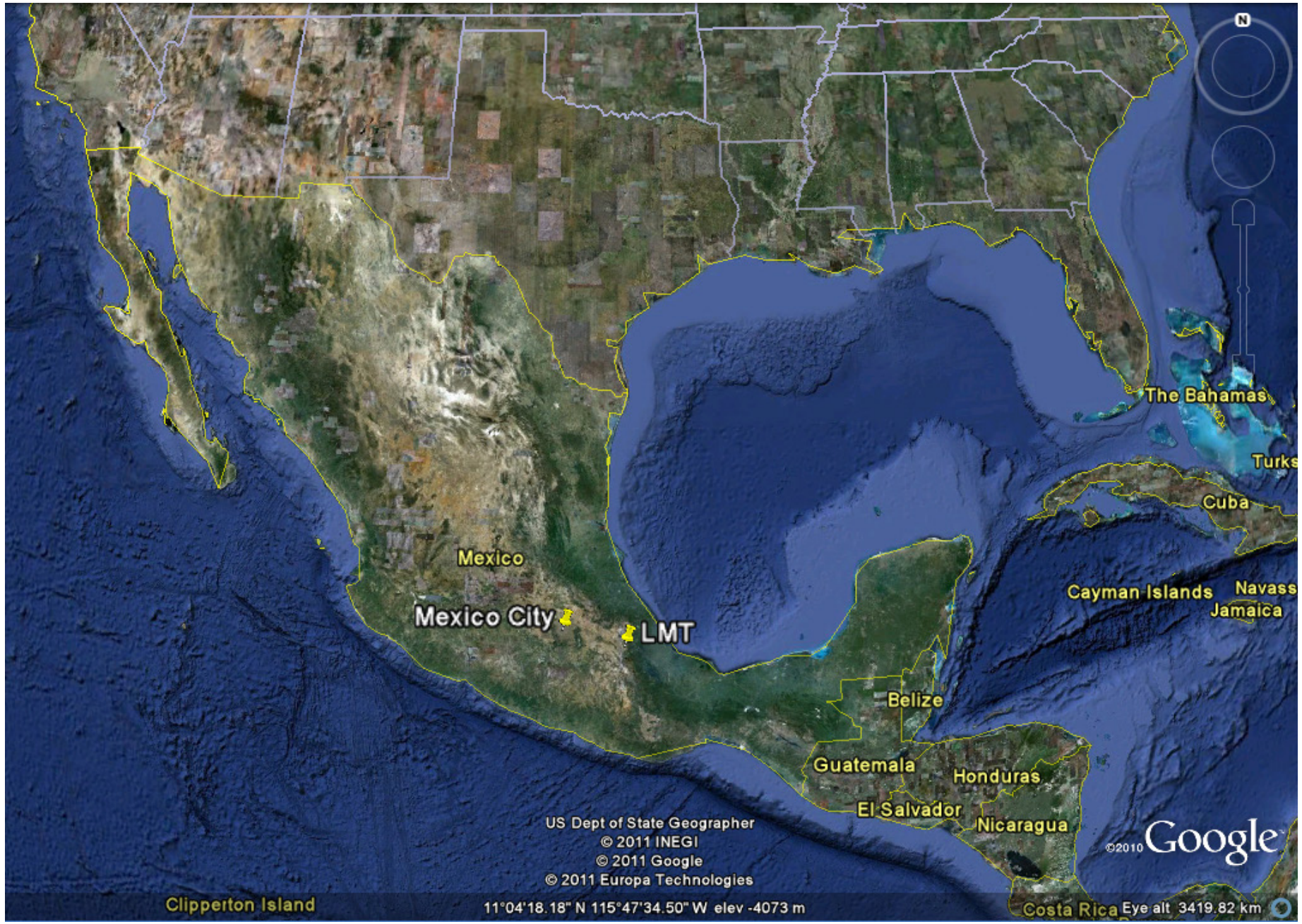
- **50-m primary reflector** (180 segments)
  - 1440 sub-panels (Media Lario: composite electroformed Nickel + Aluminum honeycomb, Rhodium coating)

- active primary surface r.m.s. (~70 microns goal) to **compensate deformations due to gravity & thermal**

- operational wavelengths: 1.1 - 4 mm (**0.85mm**)
- beam resolution (FWHM): 5 - 18 arcsec (**4 arcsec**)
- FOV: 4 arcmin diameter (**12´-15´ diam**)

- LMT 32-m shared–risk Early Science (2014-2017)
  - 13 months observing (integrated)
  - 20 publications / 10 PhDs, 4 MSc

- **LMT 50-m commissioning 2018**


N
The Bahamas
Turks
Cuba
Mexico
Mexico City
LMT
Cayman Islands
Navass
Jamaica
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
US Dept of State Geographer
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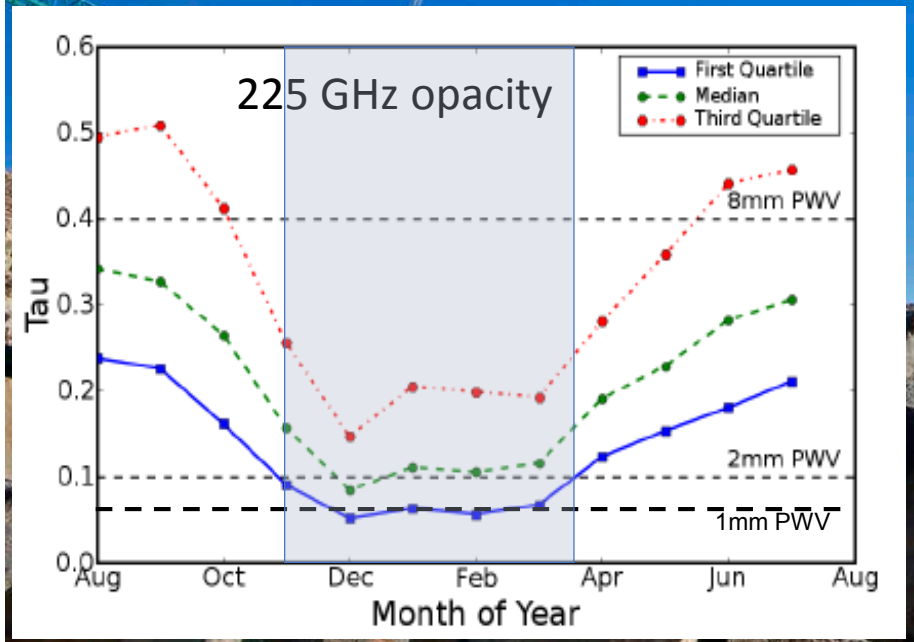
Clipperton Island
11°04'18.18" N 115°47'34.50" W elev -4073 m
Eye alt 3419.82 km


Pico de Orizaba
5740 m; 18832 ft
LMT
Volcán Sierra Negra
4600m; 15091 ft
Credit. R.J. Terlevich

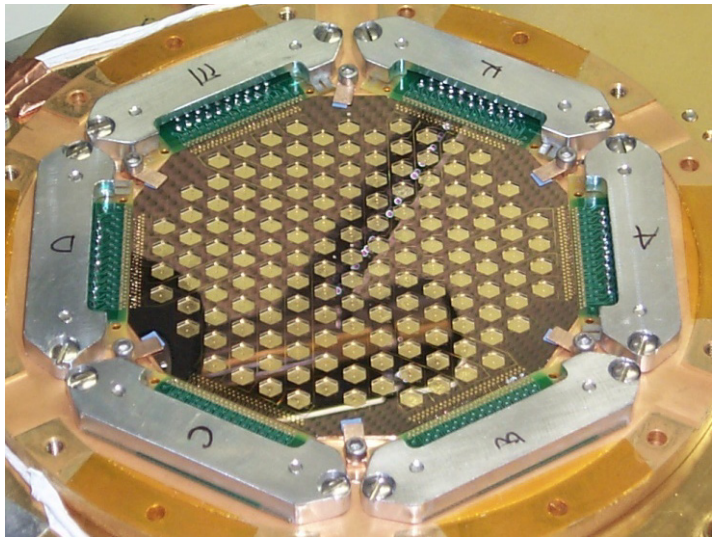
Volcán Sierra Negra, Puebla (4600m, 15000 ft.)

- Atmospheric transparency (1.3mm median transmission)
  - winter 90%
  - summer 70-80%

300 hours, opacity < 0.06
- submm conditions

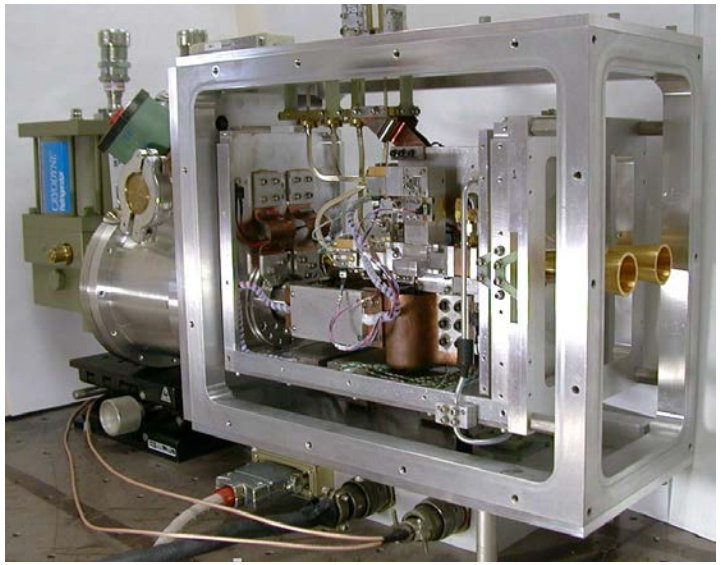


LMT 32-m first-light scientific instrumentation



AzTEC

- 1.1mm camera (144 pixels - bolometers)
- SiNi spider-web mesh, NTD Ge thermistors
- 30 sq. arcmin/ hr / mJy^2
- wide-field & confusion-limited continuum mapping
- operational JCMT(2005), ASTE (2007-2008), LMT 32-m (>2014)

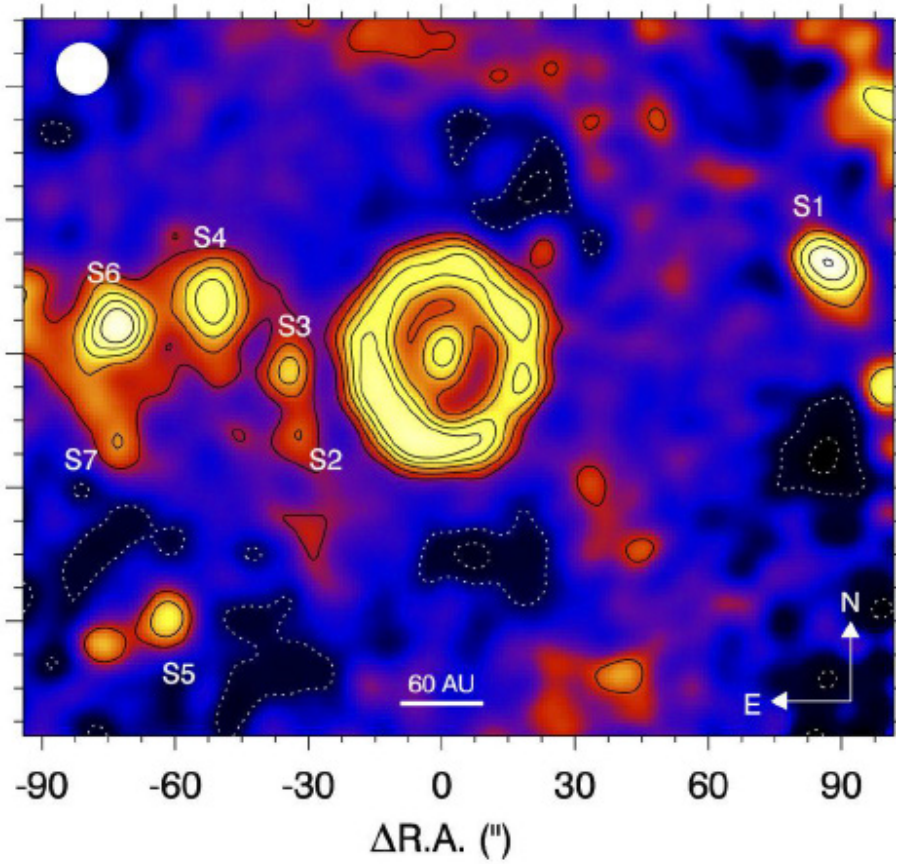


Redshift Search Receiver

- 2 pixels (dual-pol) – 1 KHz beam-switch
- 75 – 111 GHz instantaneous bandwidth; 31MHz (~100 km/s resolution) at 90GHz;
- Receiver temp ~ 60K; stable baselines
- detect multiple molecular-lines without prior information on galaxy redshift
- operational FCRAO-14m (2007-2008), LMT 32-m (>2014)

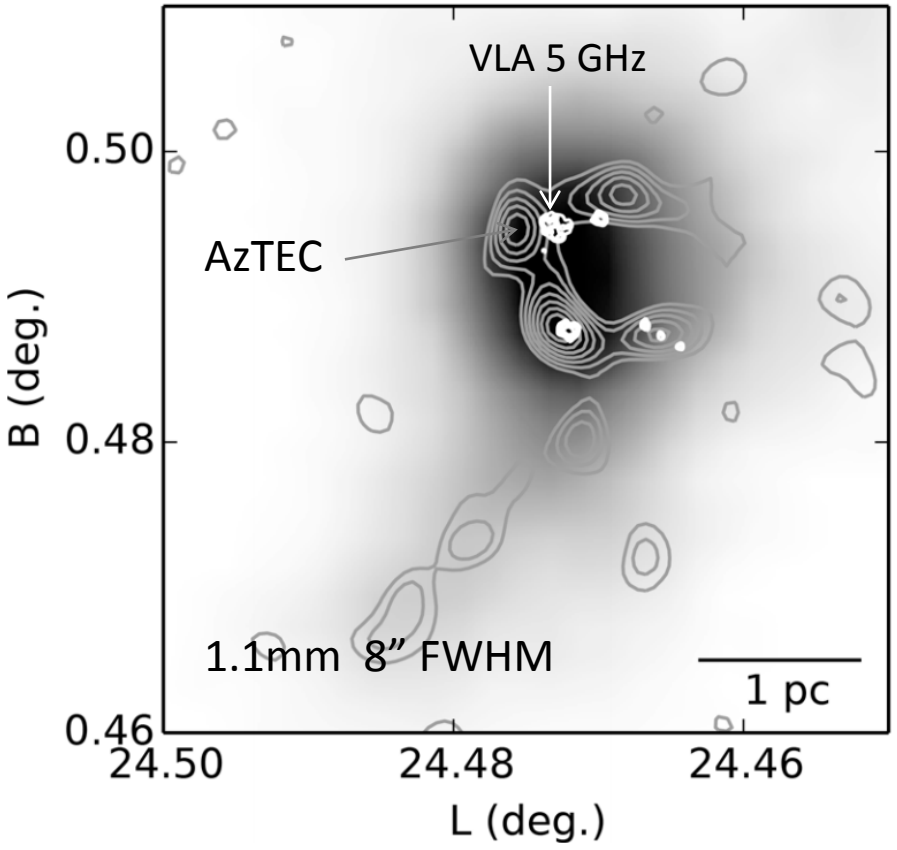
Early Science with the LMT 32-m (AzTEC)

"Deep AzTEC millimeter observations of Epsilon Eridani and its surroundings"



Miguel Chávez et al., 2016, MNRAS, 462, 2285

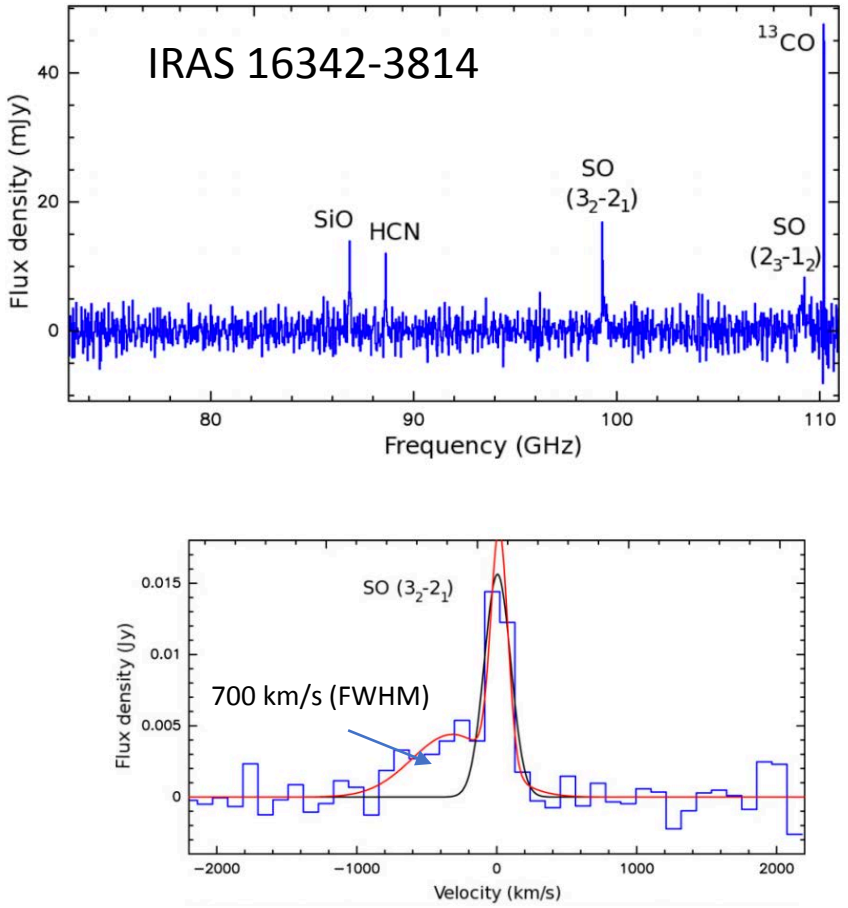
"Fragmentation of molecular clumps in the Galaxy"



Mark Heyer et al., 2018, MNRAS, 473, 2222

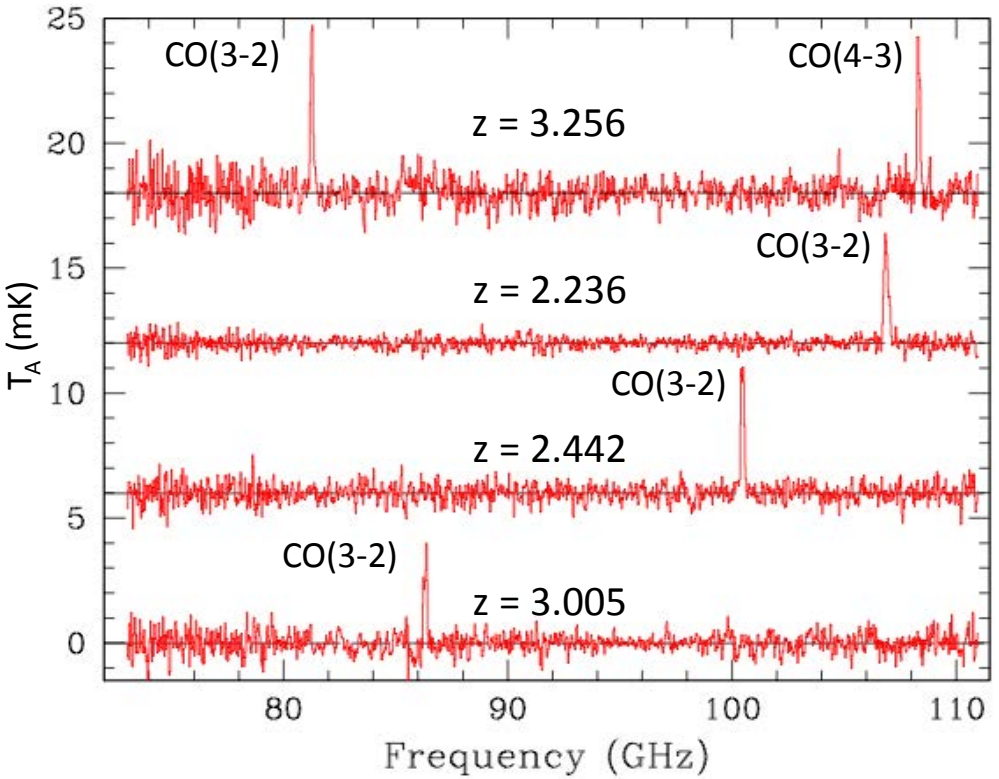
Early Science with the LMT-32m (Redshift Search Receiver)

"Molecules in the extreme outflow of a protoplanetary nebula"



Arturo Gómez-Ruiz et al., 2017, MNRAS, 467, L61

" Extremely luminous high-z sources identified by Planck"

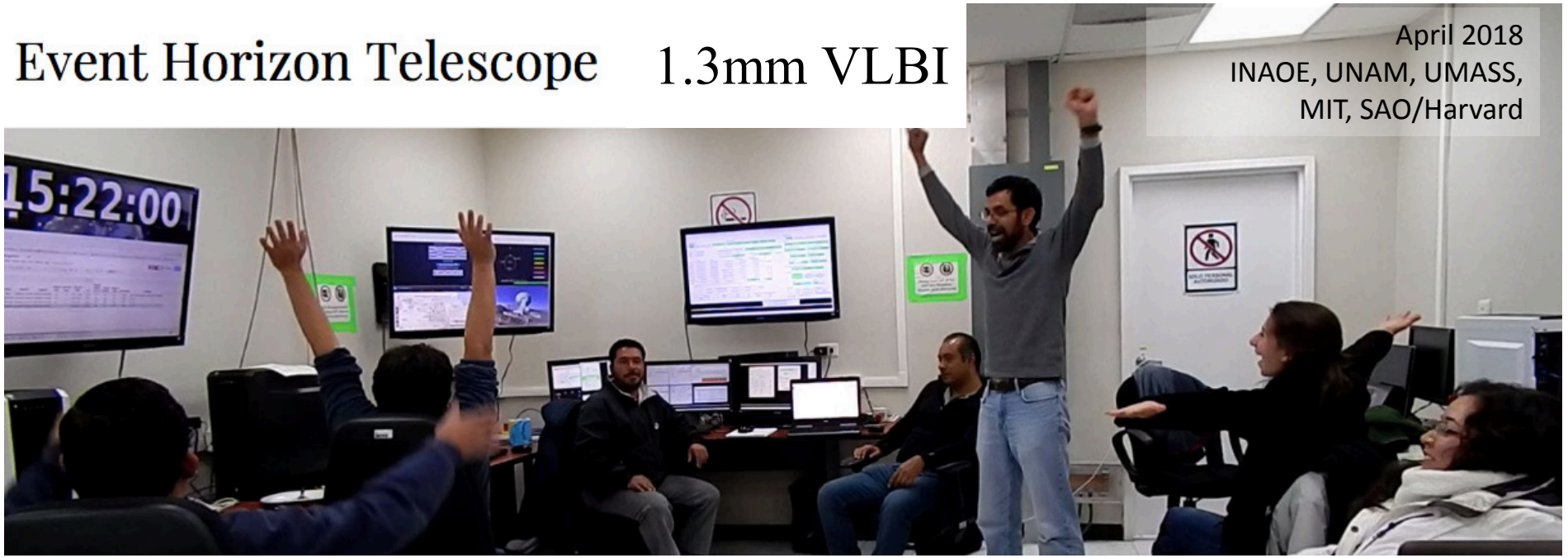


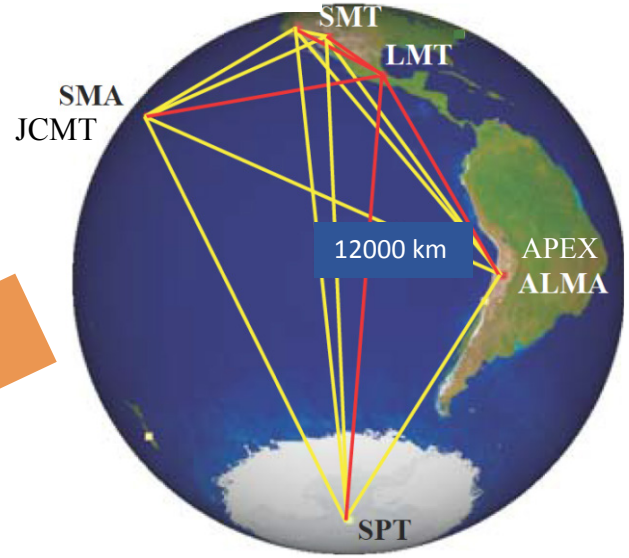
$M(gas) \simeq 6 - 80 \times 10^{11}\ \mu^{-1}\ M_\odot$

$L_{FIR} \leq 3 \times 10^{14}\ \mu^{-1}\ L_\odot$

Kevin Harrington et al., 2016, MNRAS, 458,4383

Event Horizon Telescope 1.3mm VLBI



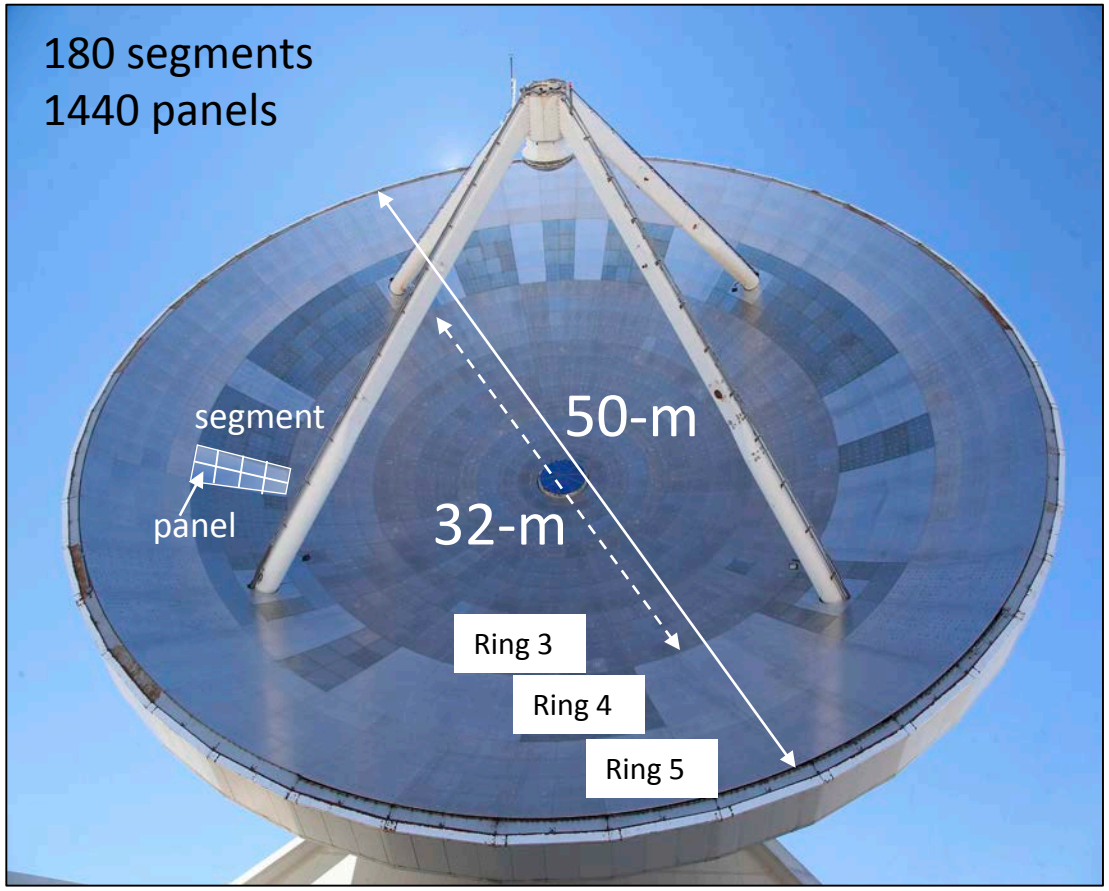


FIRST RESULTS February 2019

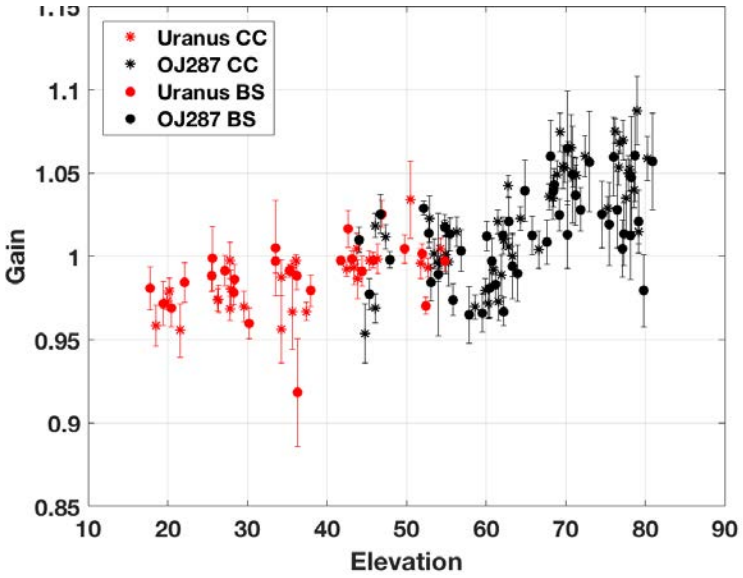
Observations of Sgr A* & M87 – April 2017 y 2018

LMT 50-m Primary Reflector Surface with Active Control

- Photogrammetry + FEM provides correction (look-up table) of gravitational and thermal deformations

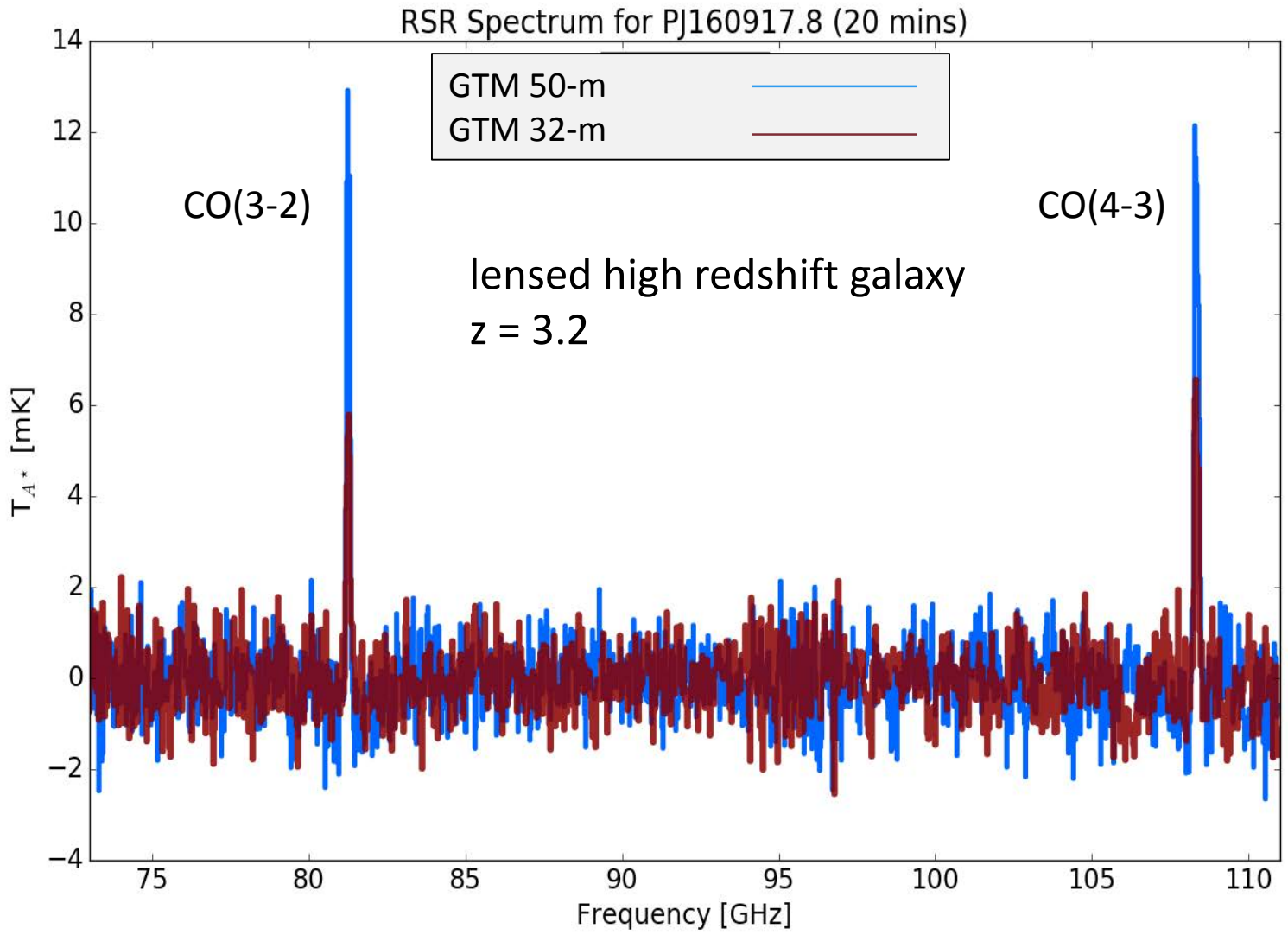


Gain curve 3mm (LMT 32-m)

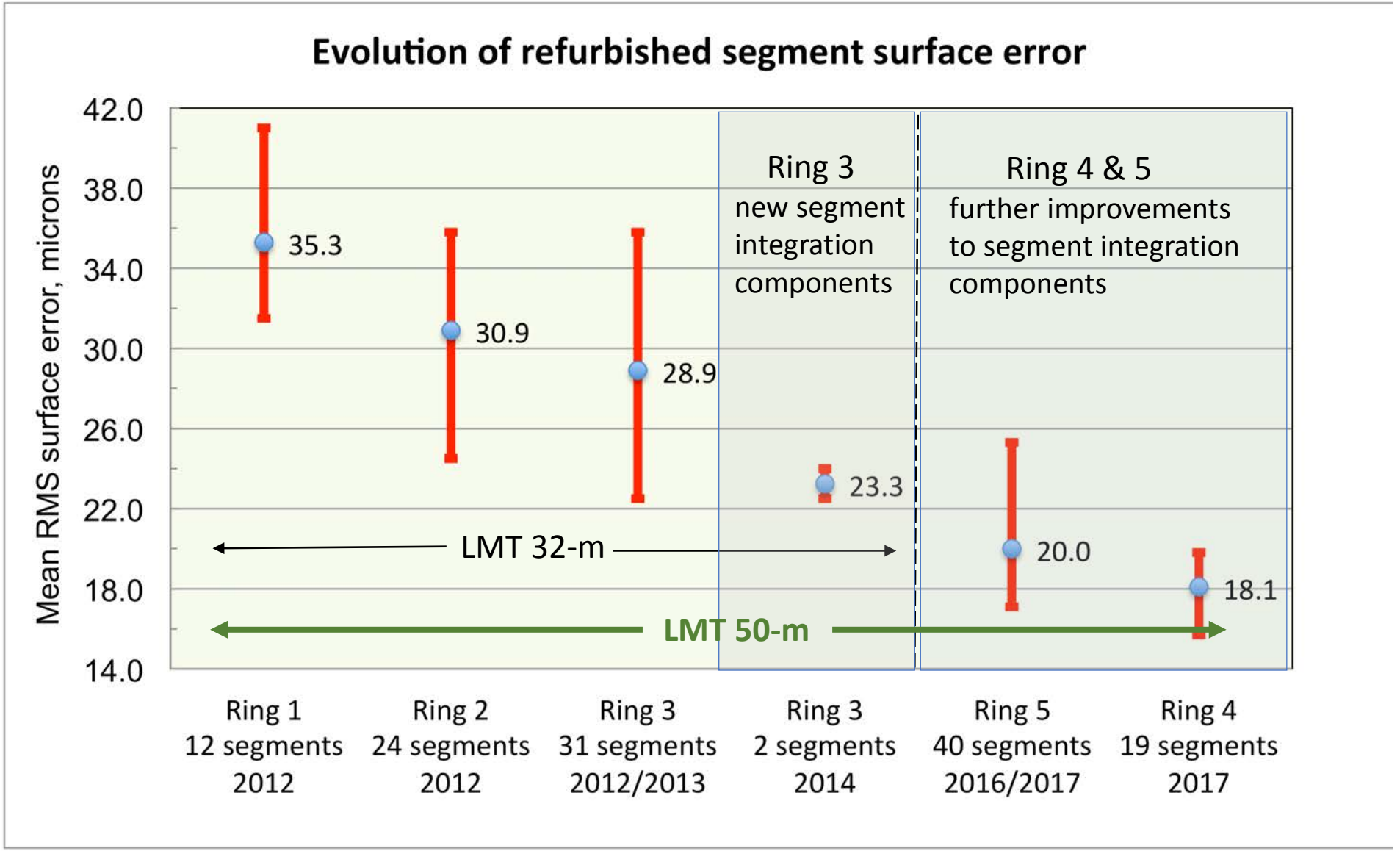


Constant gain +/- 5% over full operational elevation range

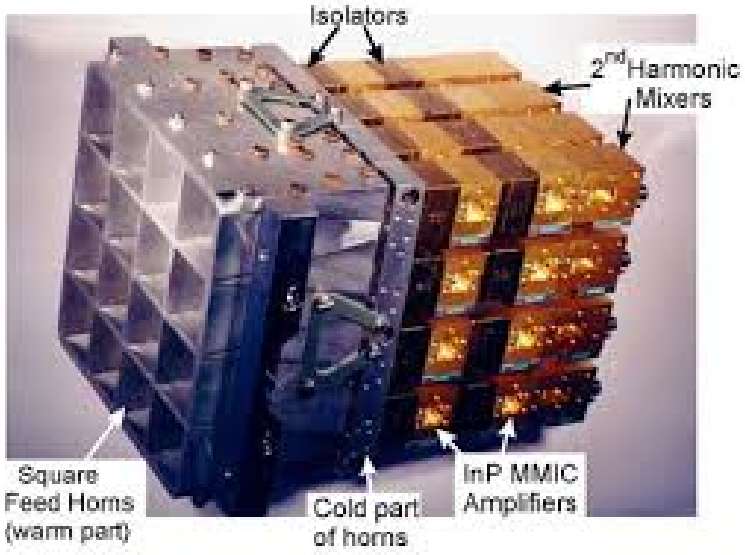
RSR 3mm - LMT 50m vs. LMT 32-m



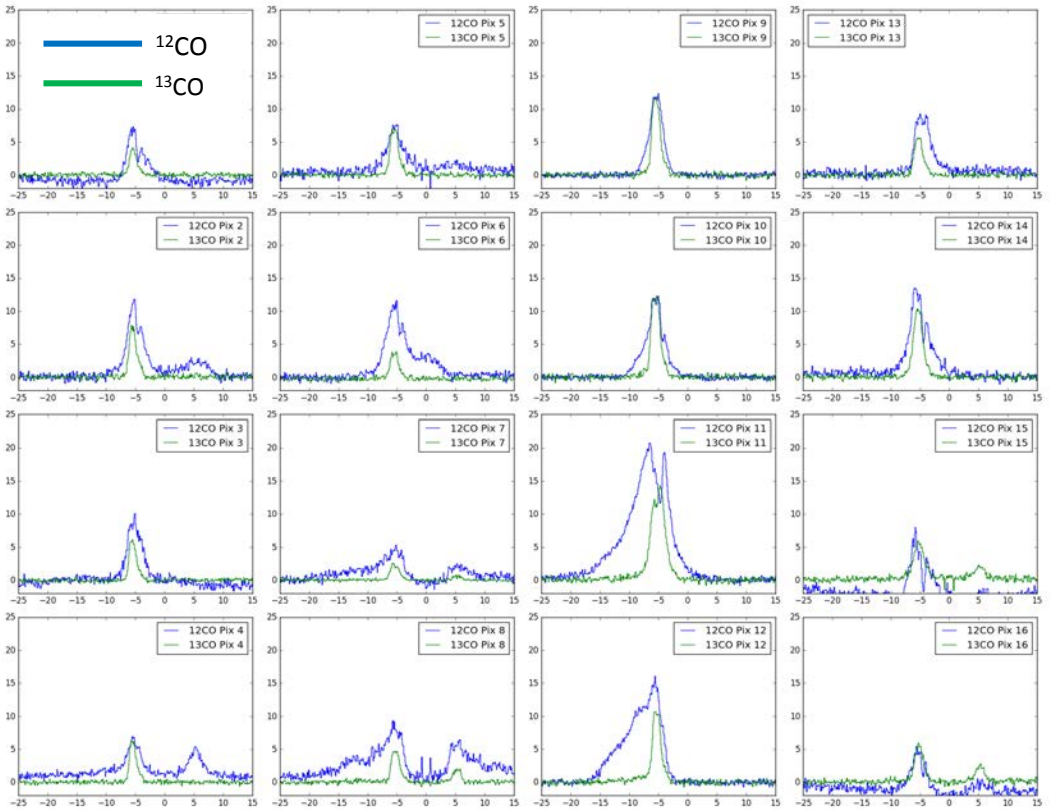
LMT – a submillimeter telescope



SEQUOIA - 3mm heterodyne array – 4 x 4 pixels



IRAS 16293-2422 (commissioning data)



- LSB (85-100 GHz)
- USB (100-115 GHz)

NEW!!

Mode	Bandwidth (ΔV_B)	Number of Channels (N_{CH})	Resolution ($\Delta\nu$)
N	200 MHz (600 km/s)	8192	24 kHz (0.072 km/s)
I	400 MHz (1200 km/s)	4096	98 kHz (0.294 km/s)
W	800 MHz (2400 km/s)	2048	391 kHz (1.173 km/s)

Note: bandwidth and resolution values in velocity units have been estimated at 100 GHz (midband).

The TolTEC Imaging Polarimeter

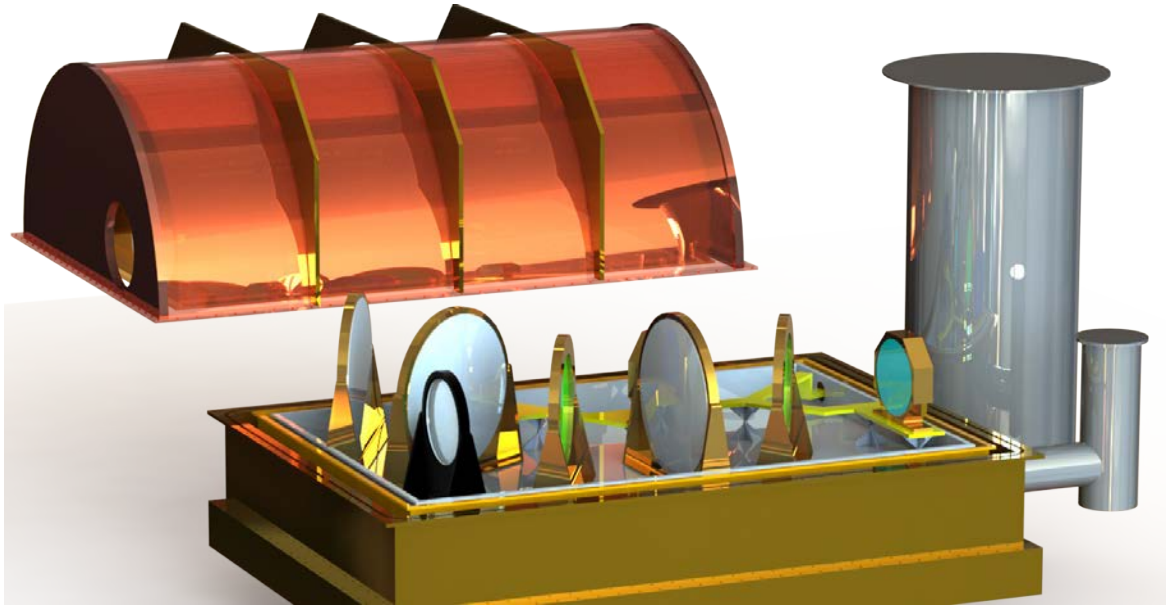
	2mm	1.4mm	1.1mm	Units
Beam Size	9.5	6.3	5.0	arcsec FWHM
NEFD	0.5	0.88	1.3	mJy sqrt(s)
# Detectors	900 1200	1800 ?	3600 4006	
Mapping Speed	11-74	3-22	2-13	$Deg^2/mJy^2/hr$

Approach/Constraints

- 10+ year facility instrument
- Minimal technology development
- Distributed work load across several institutions
- Heavy student involvement
- Parallel scientific involvement through public surveys
- Cryostat must fit in UMass elevator

The new TolTEC camera for the 50m LMT

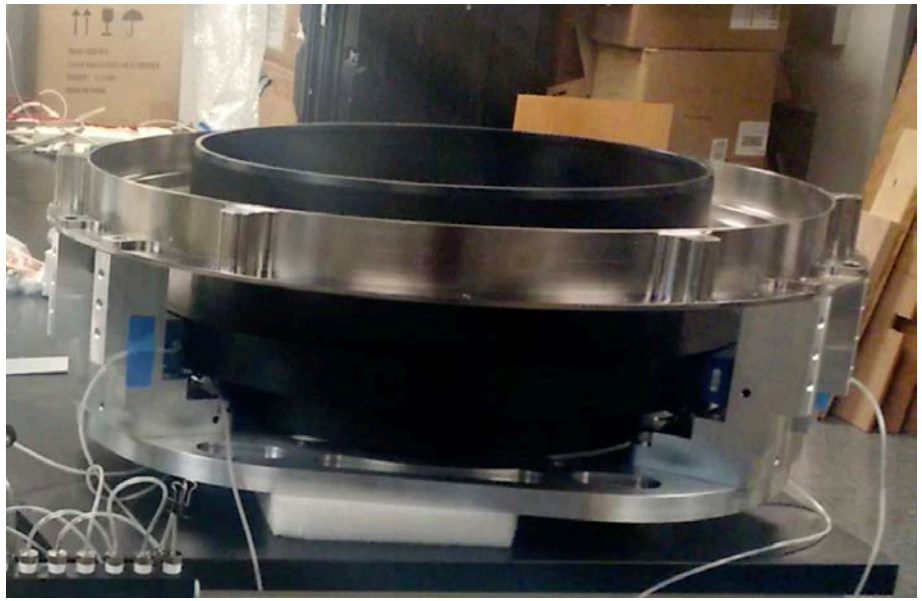
Band Center	2.1m m	1.4mm	1.1mm	Units
Beamsize (FWHM)	10	6.5	5	arcseconds
Number of Detectors	900	1800	3600	
Number of Pixels	450	900	1800	
Mapping Speed Range[1]	10-70	3-20	2-12	$deg^2/mJy^2/hr$



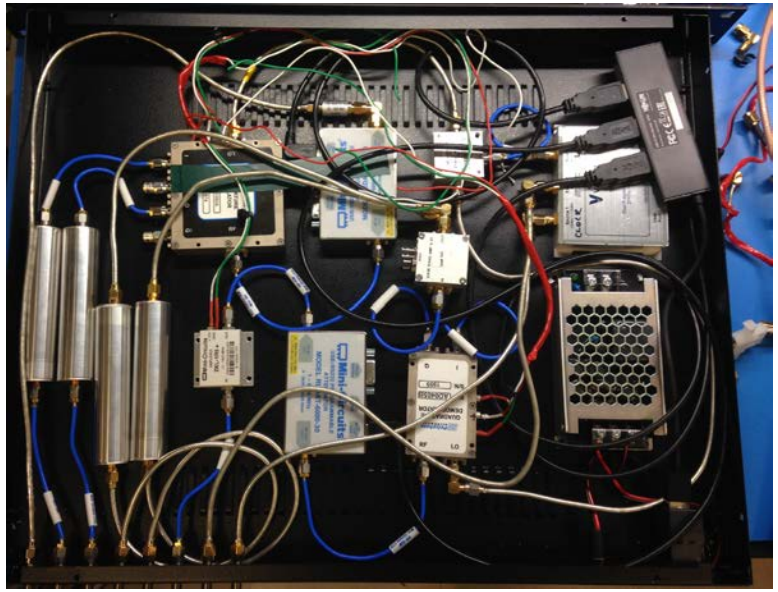
PI: Grant Wilson (UMass)

Project scientists: Itziar Aretxaga (INAOE), Alexandra Pope (UMass)

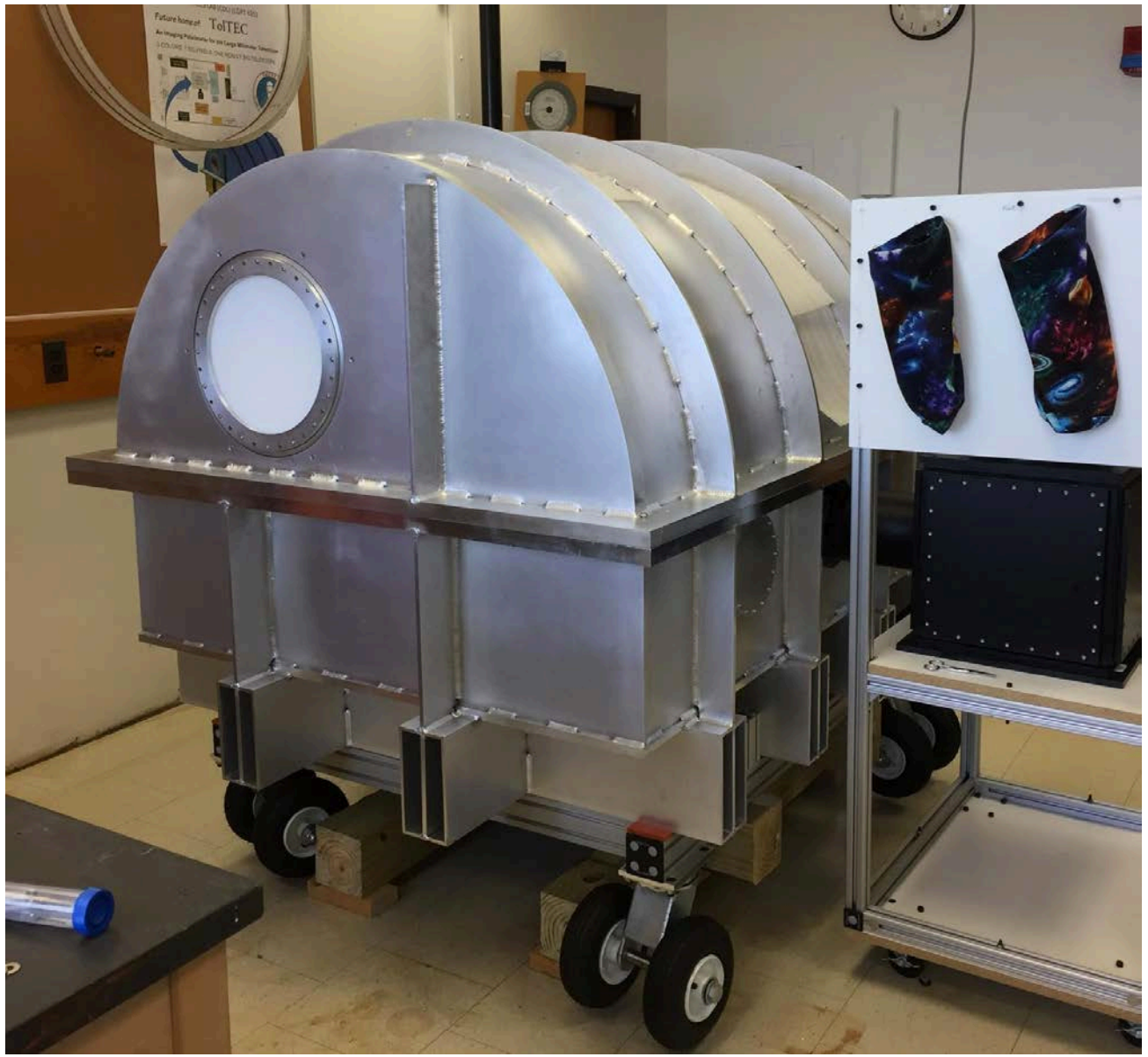
- fills FOV of LMT at 2.1, 1.4, 1.1mm
- simultaneous imaging/polarimetry
- mapping speed ~100x AzTEC
- NSF/MSIP funded (9/15/2016)



HWP rotator (Northwestern)



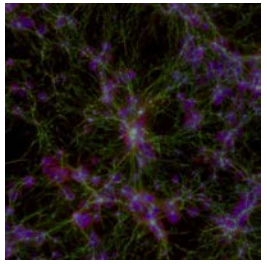
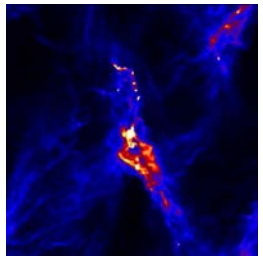
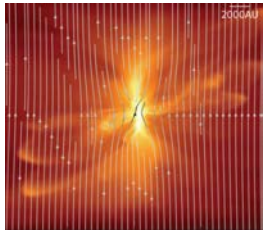
Readout Electronics (ASU)



Main Cryostat (UMass)

TolTEC Public Legacy Surveys: 100 hours each

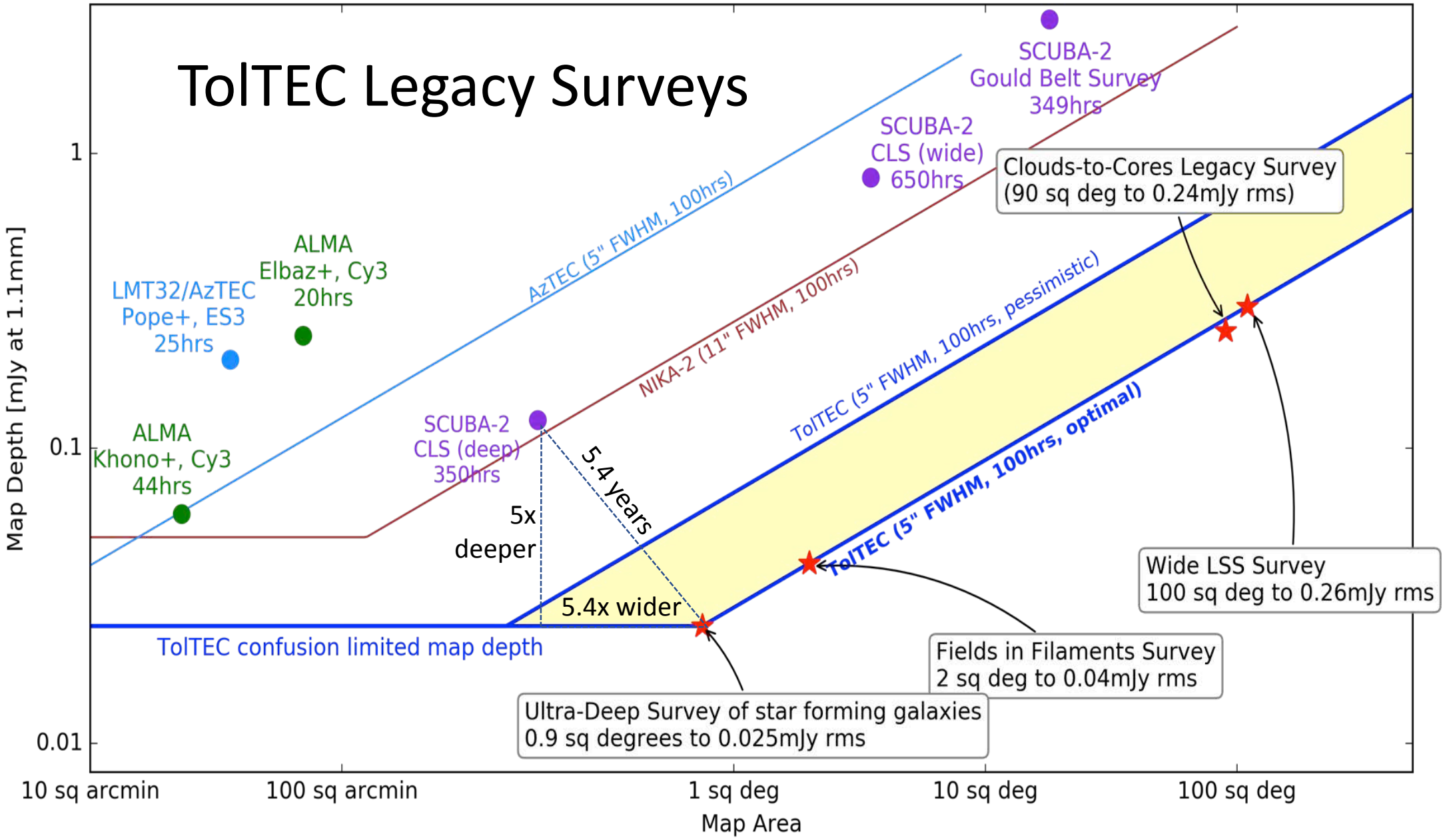
- **The Ultra-deep Survey of Star-forming Galaxies**
- **The Large Scale Structure Survey**
- The Clouds-to-Cores Legacy Survey (C2C)
- The Fields in Filaments Legacy Survey (FiF)

Survey definition and data will be public!

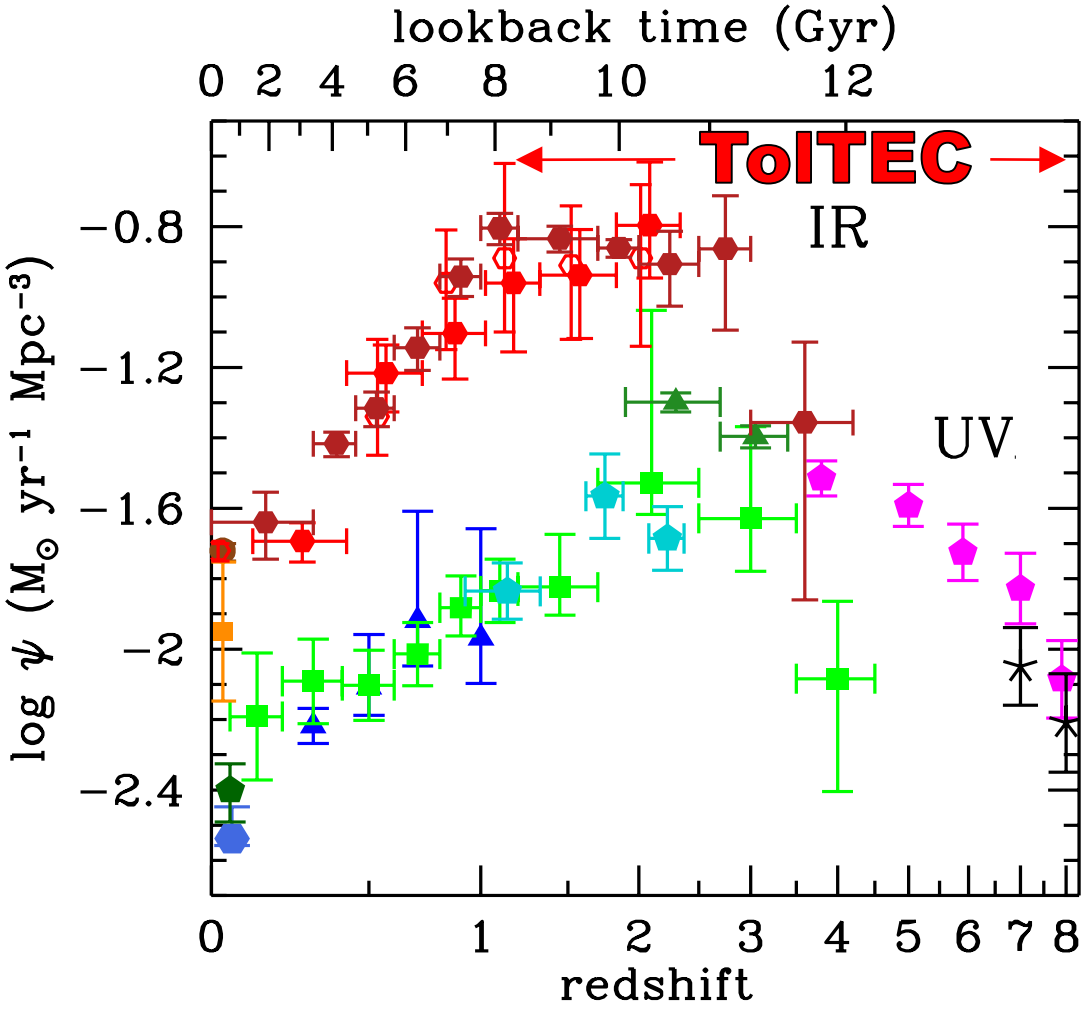
- Field selection and depths defined in community workshops (workshop planned at UMass for Oct 25/26)

Interested? Sign up at our website: *toltec.astro.umass.edu*


TolTEC Legacy Surveys
SCUBA-2
Gould Belt Survey
349hrs
SCUBA-2
CLS (wide)
650hrs
Clouds-to-Cores Legacy Survey
(90 sq deg to 0.24mJy rms)
AzTEC (5" FWHM, 100hrs)
NIKA-2 (11" FWHM, 100hrs)
TolTEC (5" FWHM, 100hrs, pessimistic)
TolTEC (5" FWHM, 100hrs, optimal)
ALMA
Elbaz+, Cy3
20hrs
LMT32/AzTEC
Pope+, ES3
25hrs
ALMA
Khono+, Cy3
44hrs
SCUBA-2
CLS (deep)
350hrs
5x
deeper
5.4 years
5.4x wider
TolTEC confusion limited map depth
Wide LSS Survey
100 sq deg to 0.26mJy rms
Fields in Filaments Survey
2 sq deg to 0.04mJy rms
Ultra-Deep Survey of star forming galaxies
0.9 sq degrees to 0.025mJy rms
Map Depth [mJy at 1.1mm]
1
0.1
0.01
10 sq arcmin
100 sq arcmin
1 sq deg
10 sq deg
100 sq deg
Map Area

TolTEC Ultra Deep (UD)

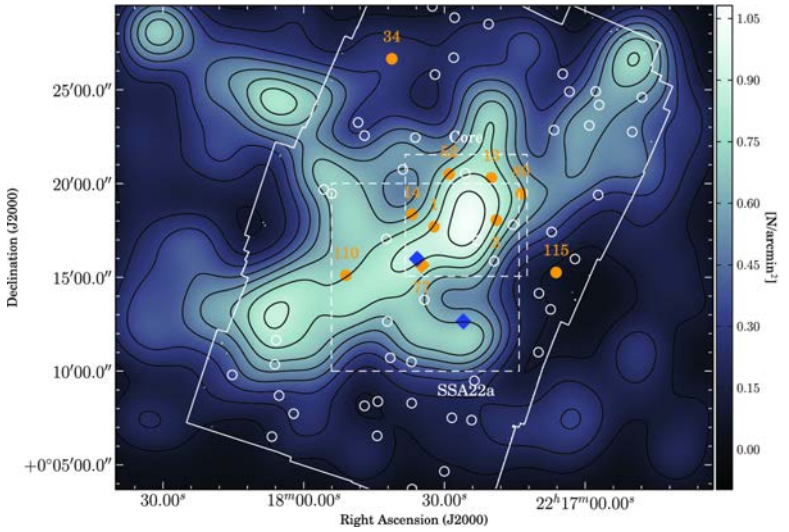
~1 sq deg to LIRG limit

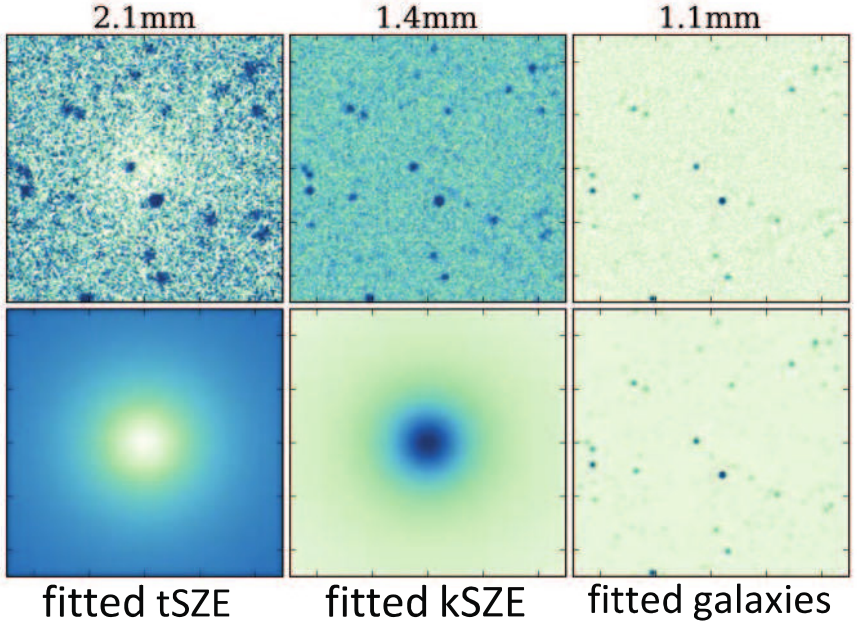


Madau & Dickinson 2014

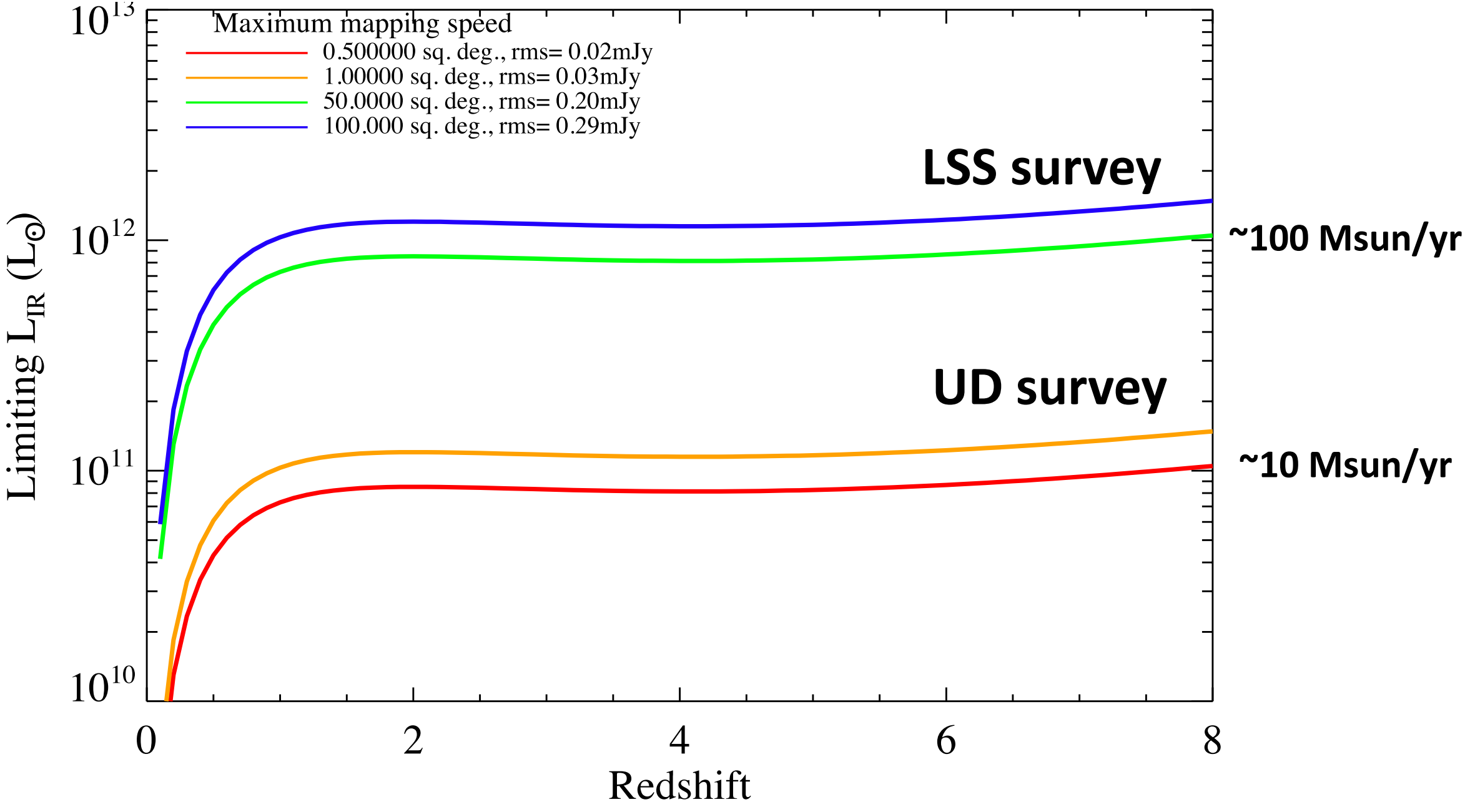
TolTEC Large Scale Structure (LSS)

~100 sq deg to ULIRG limit

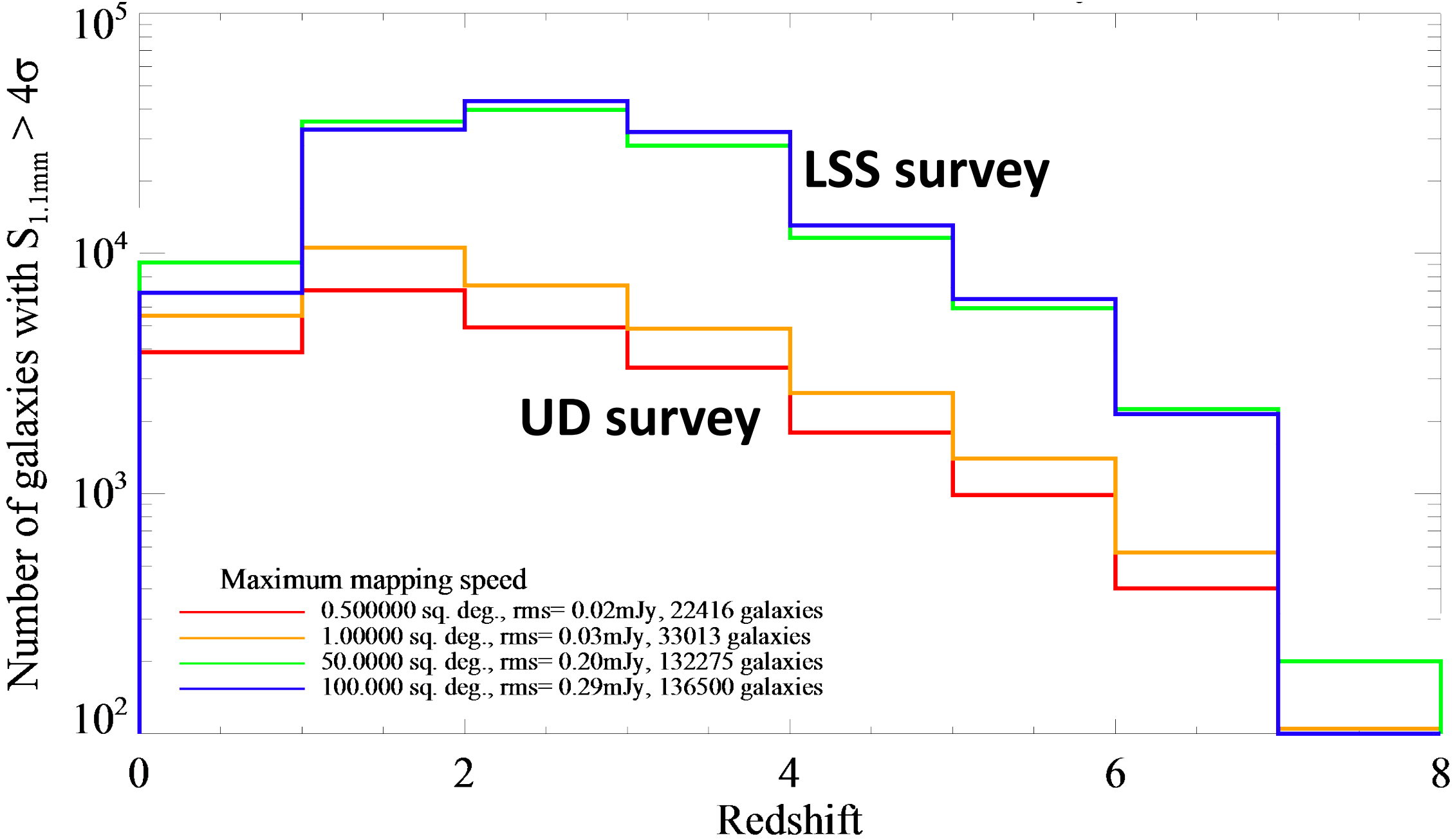




TolTEC 100 hour surveys



TolTEC 100 hour surveys



TolTEC Timeline

2017 – mid 2019 – Develop plans for surveys in coordination with wider community.

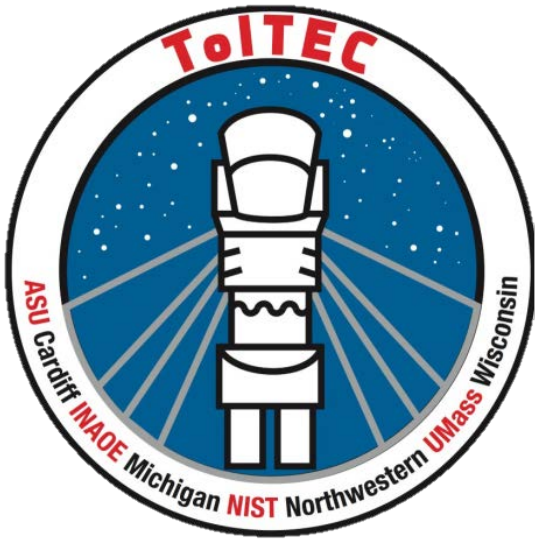
2019 – start of commissioning and First Light observations

Dec 2019 – start Survey Observations (phase 1)

Nov 2020 – Data release 1 (phase 1 data)

Dec 2020 – start Survey Observations (phase 2)

Aug 2021 – Data release 2 (phase 1+2 data)



Join a working group: *toltec.astro.umass.edu*

TolTEC by the Numbers

- 7000+ polarization sensitive KID detectors
- 3 bands (2mm, 1.4mm, 1.1mm)
- 7 institutions
- 54 institutional people contributed to instrument so far
- 23 students and postdocs (so far)
- 4 Legacy Surveys (+6 more after funding period)
- 1000 hours of LMT time for public surveys
- 8 Survey Coordinators
- 285 Astronomers involved in Legacy Survey definition exercises
    - 83 people registered for Thursday-Friday workshop

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