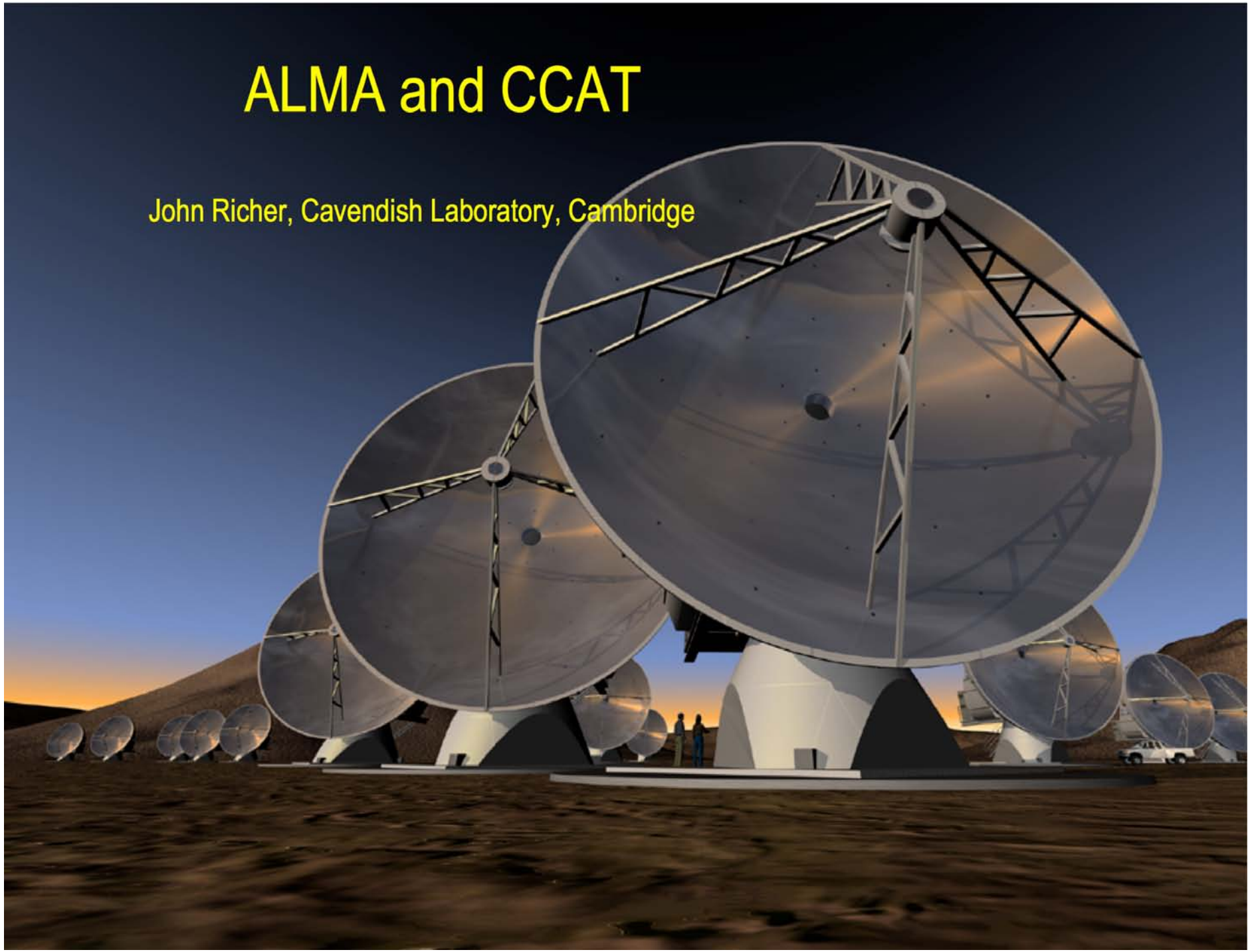
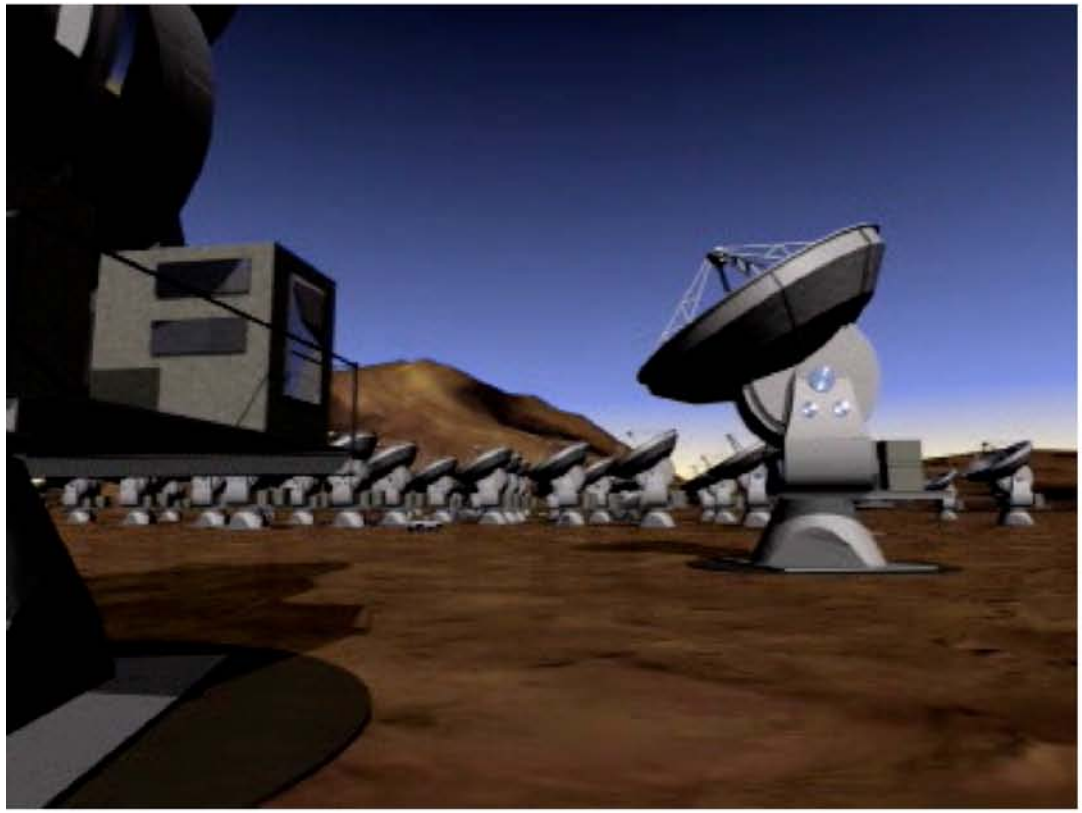
ALMA and CCAT

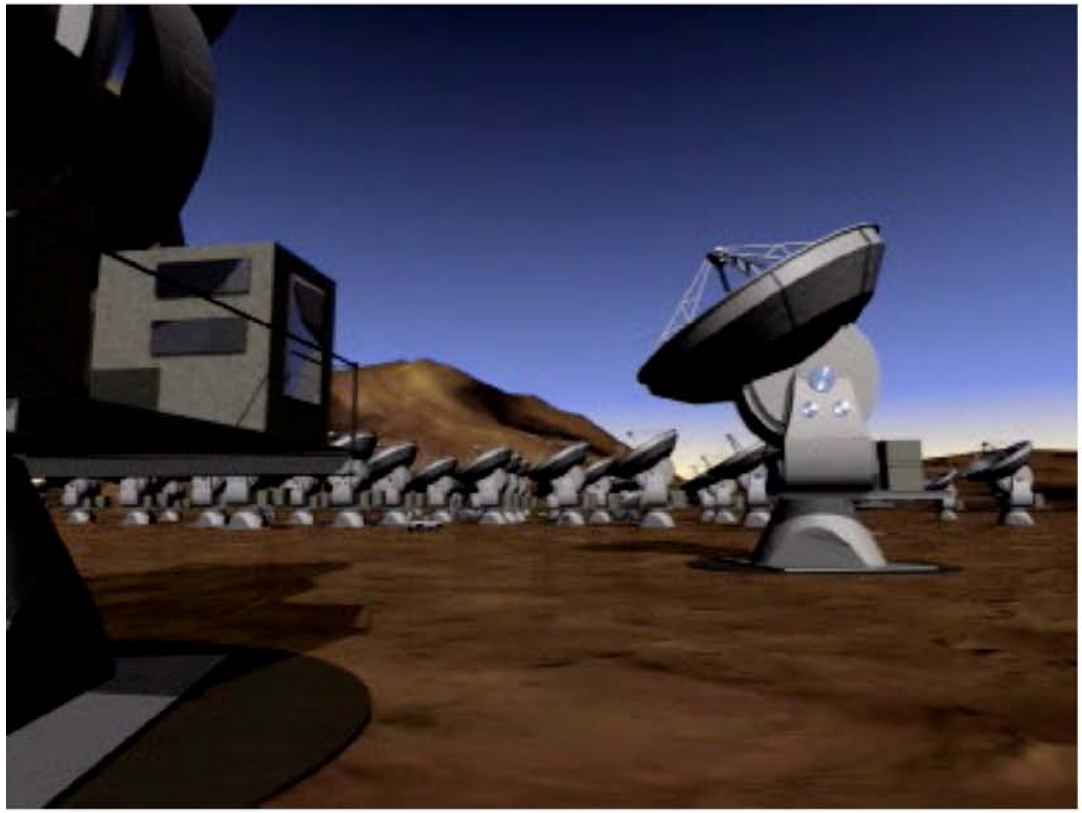
John Richer, Cavendish Laboratory, Cambridge





ALMA: Atacama Large Millimetre Array

- Most complex observatory ever built?
  - 17 countries, circa $1bn
- 54 12-m diameter antennas, plus 12 7-m antennas
- High (5000m altitude) site in Atacama desert, Chile
- Baselines from 15m to 16km
  - Move antennas between 175 pads
- Receivers: low-noise, wide-band (8GHz), dual linear polarisation
- Digital correlator giving very high spectral resolution, 4 Stokes
- Provides sensitive, precision imaging between 30 and 950 GHz
- Construction: 2005-2012
  - First antenna 2007 Q3



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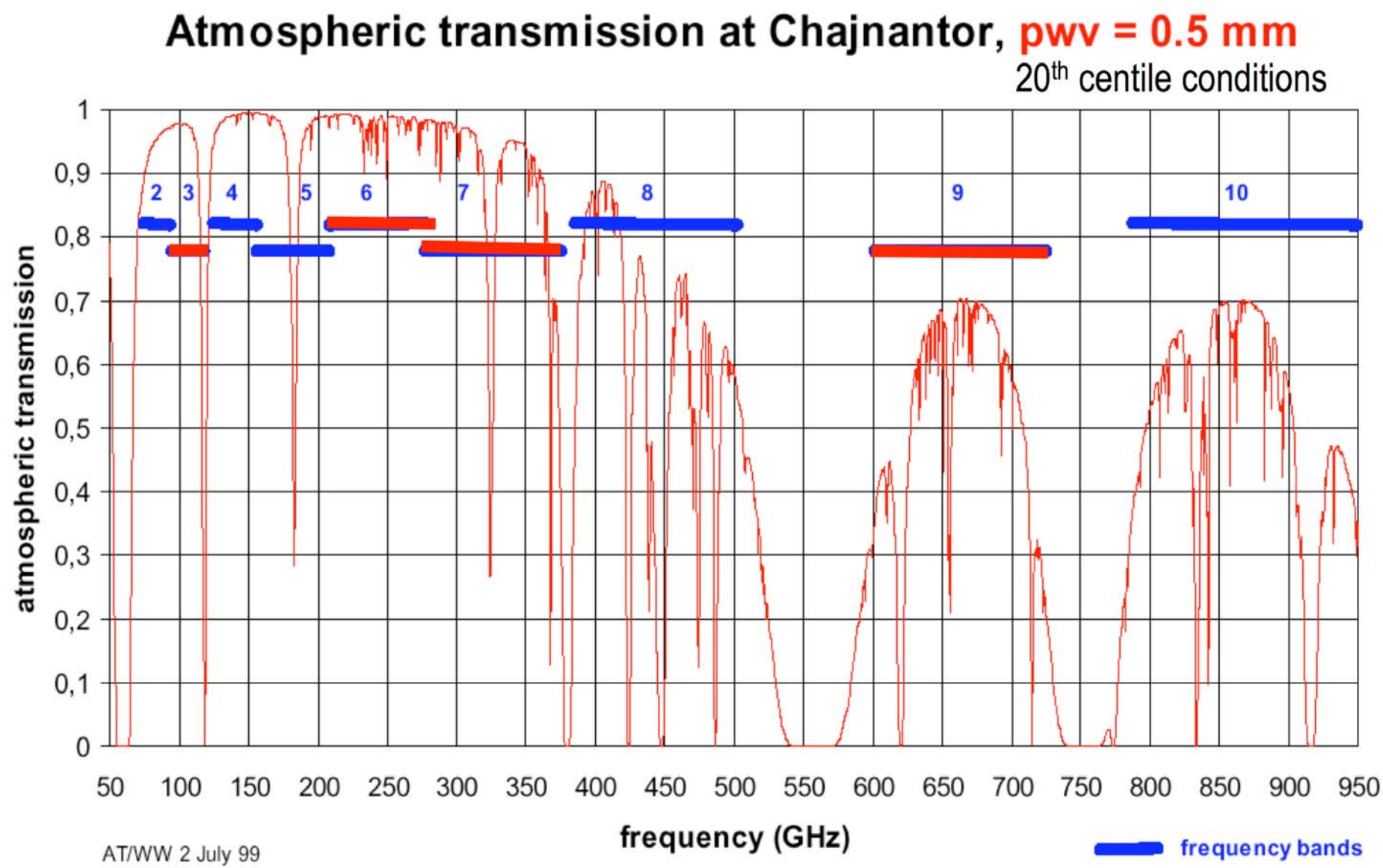
Atmospheric transmission at Chajnantor, pwv = 0.5 mm
20th centile conditions
atmospheric transmission
1
0,9
0,8
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250
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650
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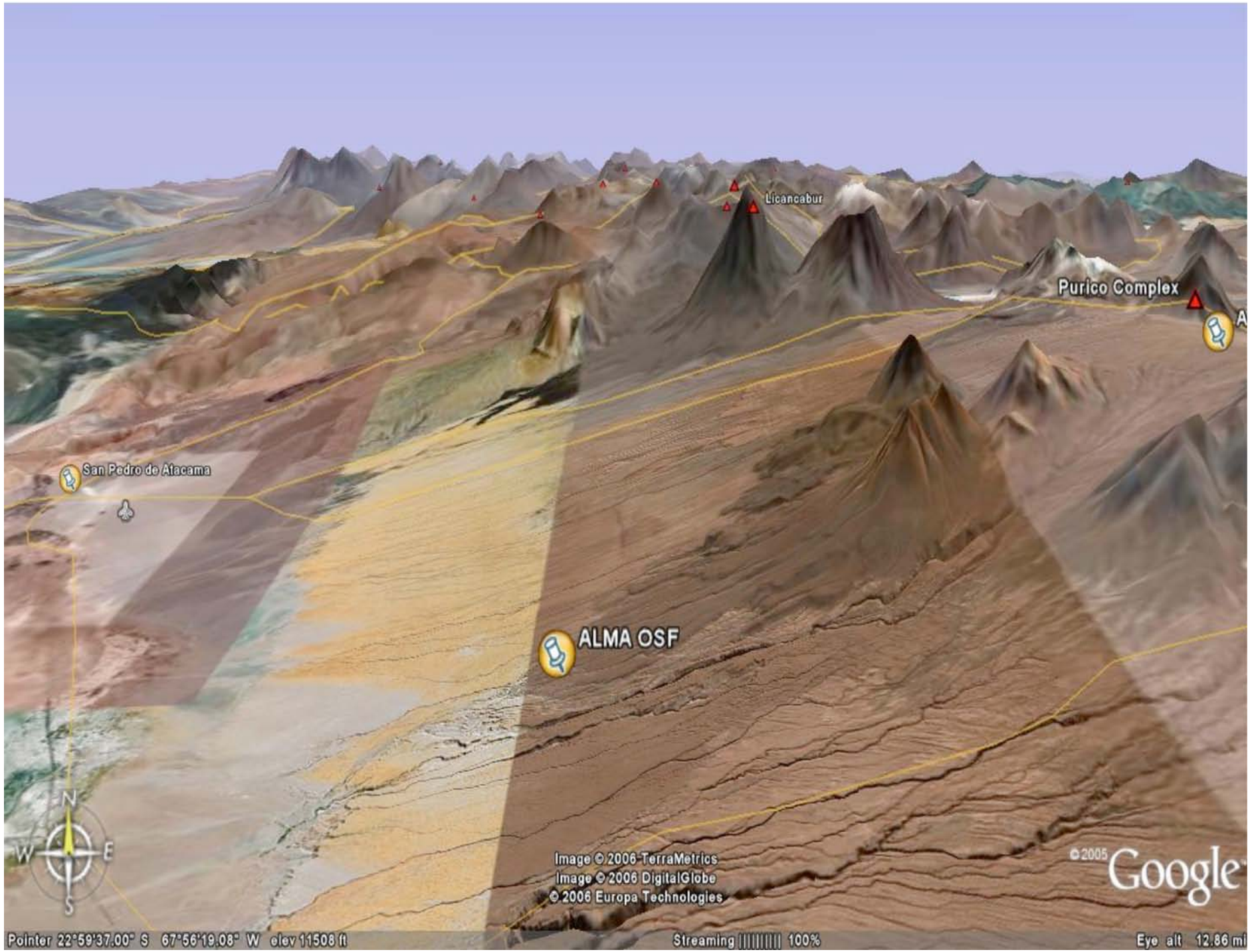
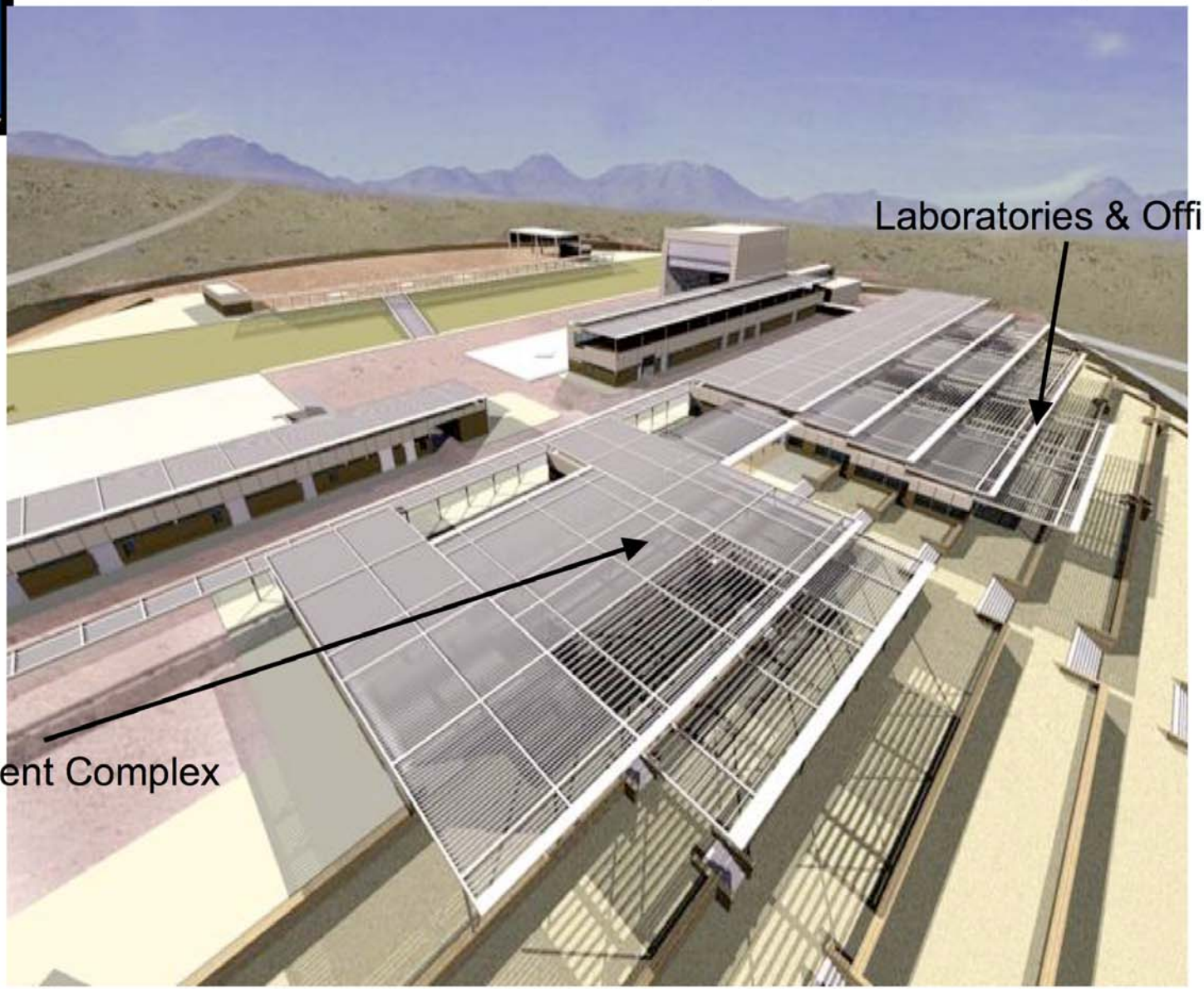
frequency (GHz)
AT/WW 2 July 99
frequency bands


Licancabur
Purico Complex
San Pedro de Atacama
ALMA OSF
N
W
E
S
Image © 2006 TerraMetrics
Image © 2006 DigitalGlobe
© 2006 Europa Technologies
©2005 Google
Pointer 22°59'37.00" S 67°56'19.08" W elev 11508 ft
Streaming 100%
Eye alt 12.86 mi

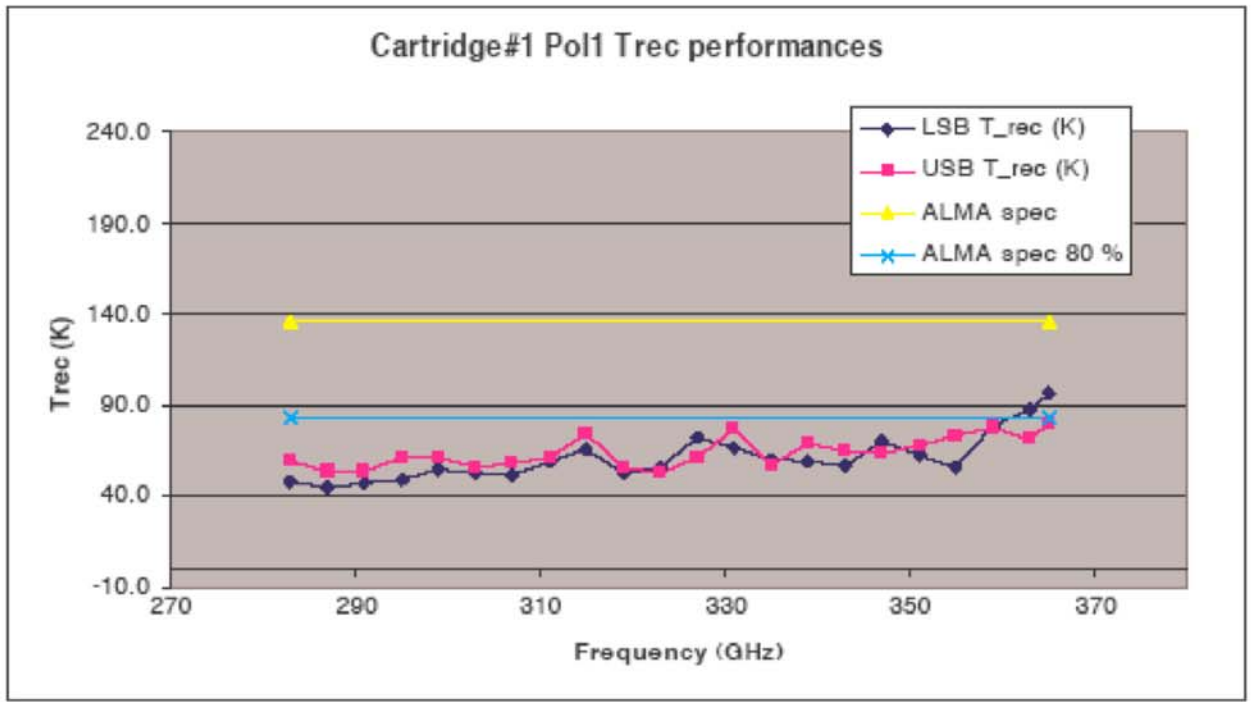
16 5:06PM

Technical Facilities (OSF; 3000m)



TB66

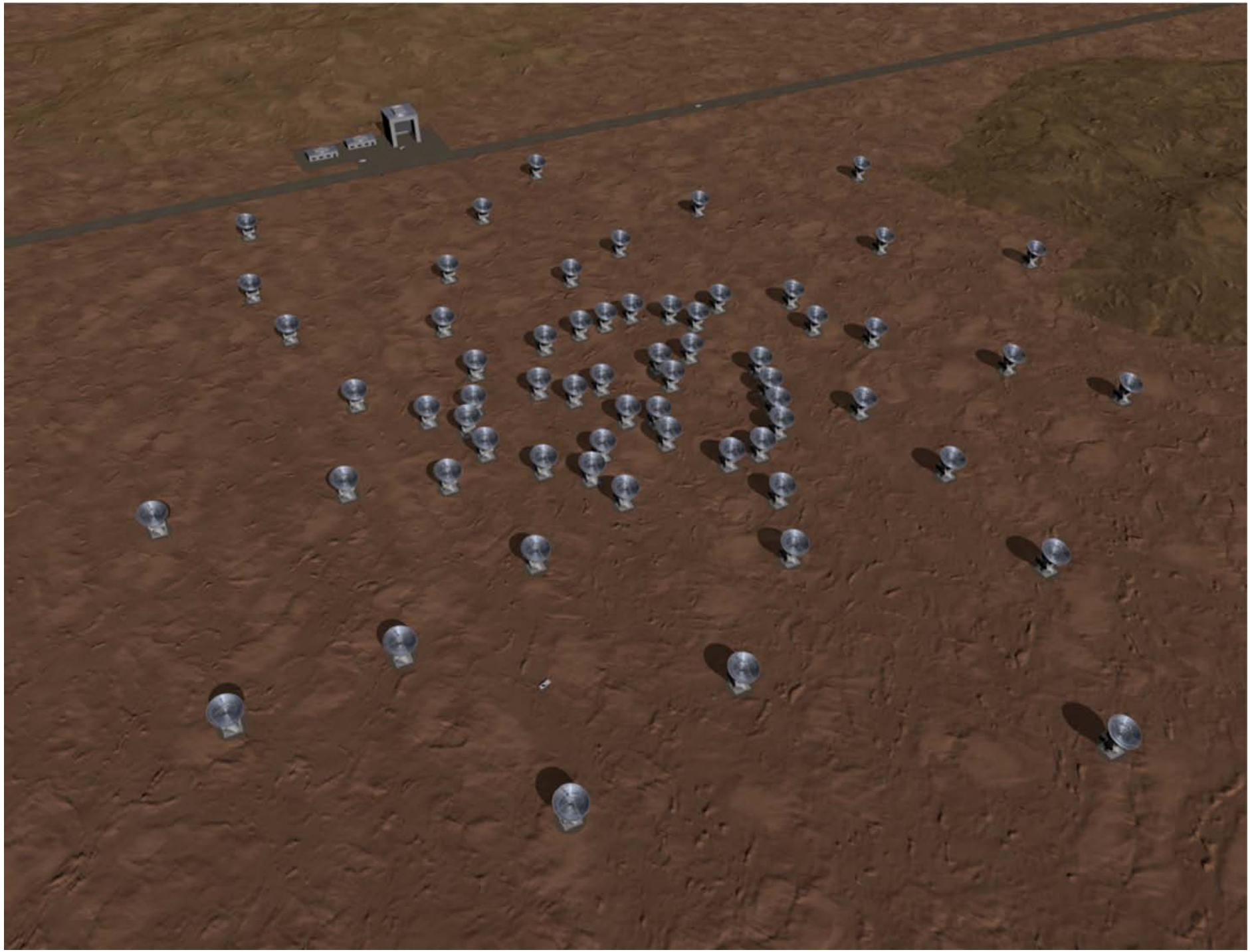
Atacama Large Millimeter Array
Band 7 – achieved performance



- **Compact configuration: Like a 160-m dish**
  - **Sensitivity given by**

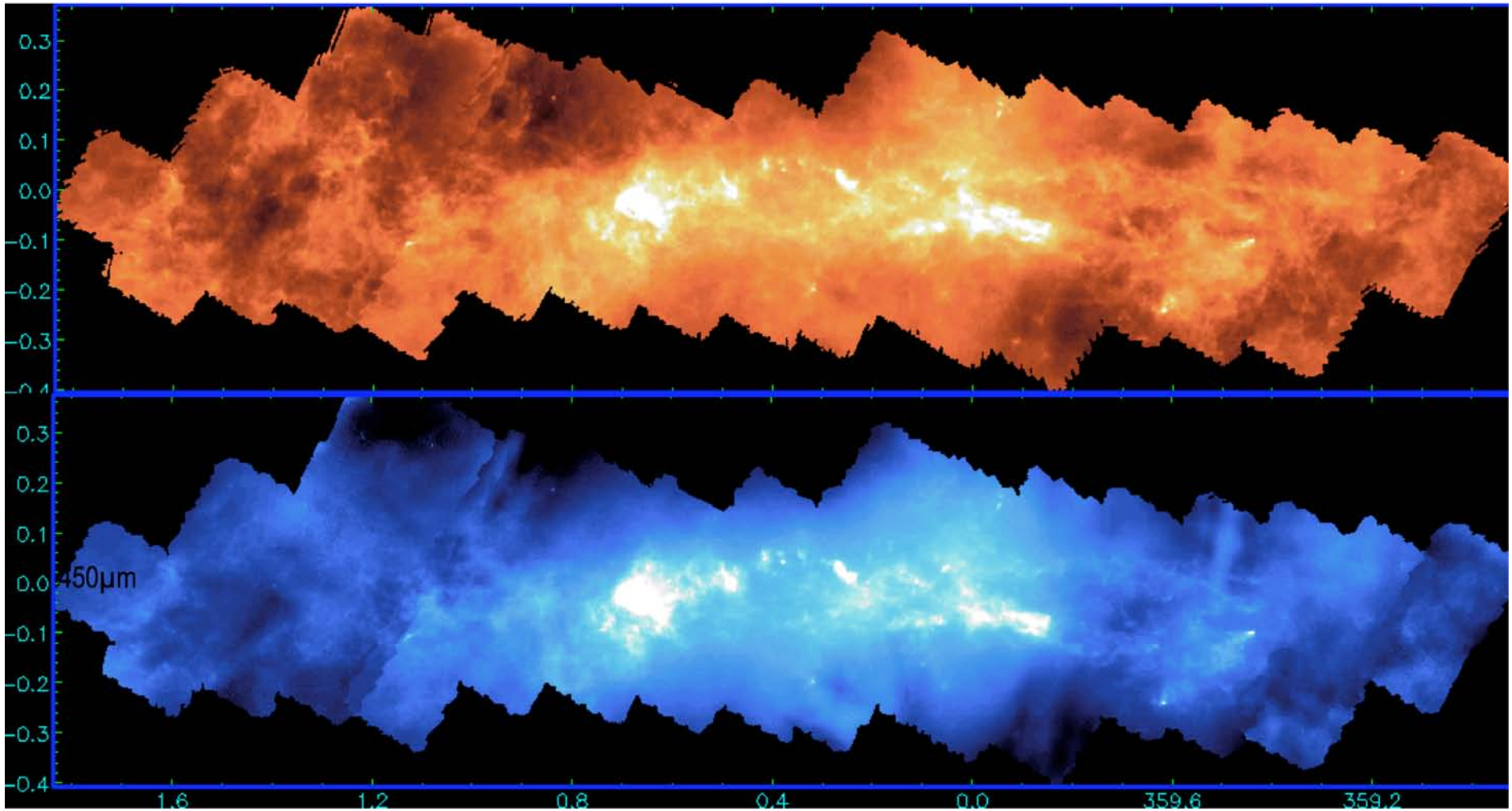
$$\Delta T \approx \frac{kT_{sys}}{\sqrt{Bt}} \frac{1}{fillingFactor}$$

  - **But, missing short spacings, no focal-plane arrays**



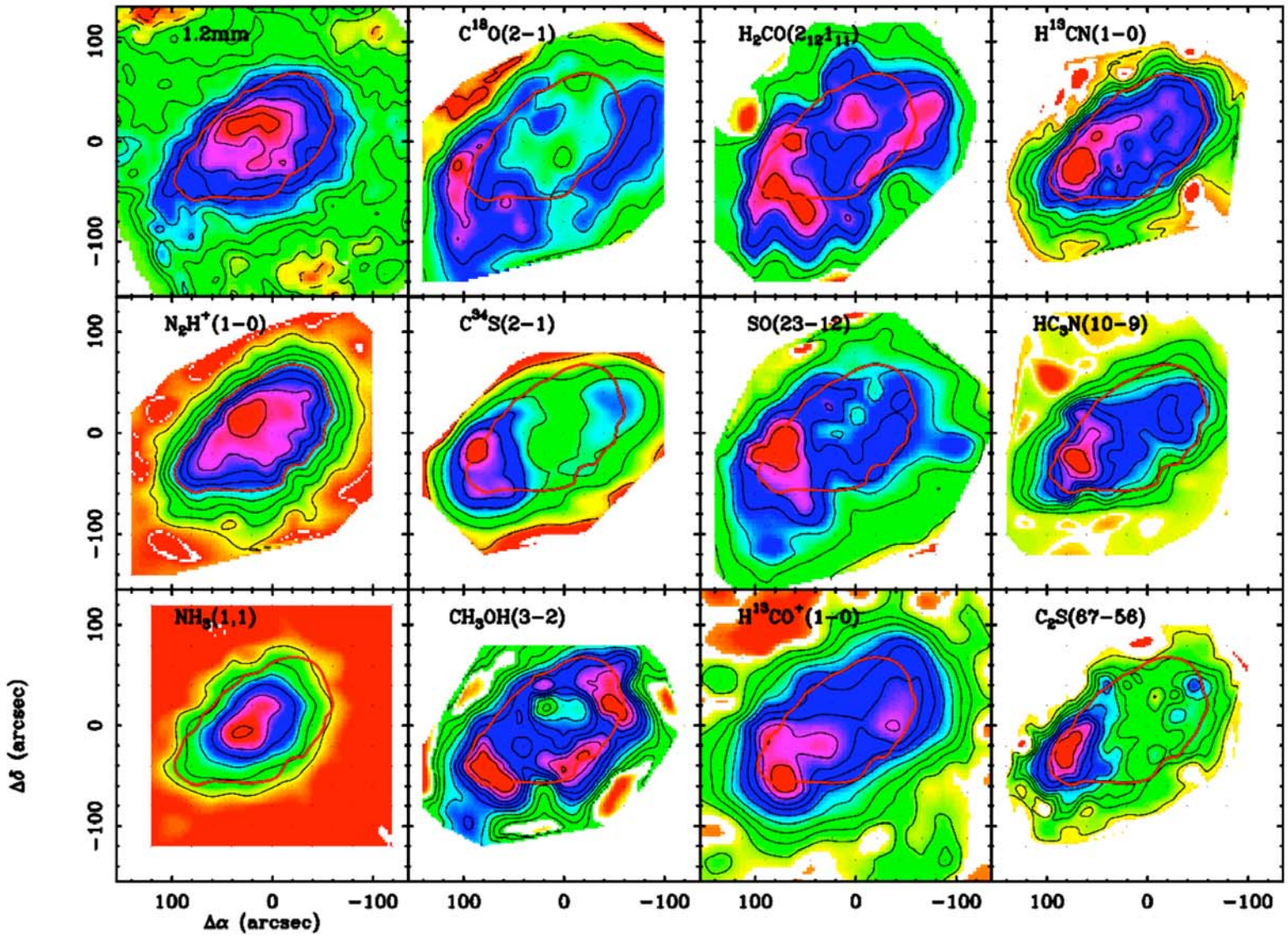
ALMA's Achilles Heal

- Supreme high-resolution, high sensitivity mm/submm telescope
  - 50mas, 1mJy in one second
- But limited survey and extended imaging capabilities
  - Only two (E, H) detectors at the focus; no multiplexing gain
  - Extended images (> primary beam/2), not recovered purely by interferometry
- Many science projects need to image larger regions
  - At 345GHz, FOV = 18 arcsec: *extreme* short spacing problem
  - e.g. local galaxies, star forming cores, even planets!
  - Usually needed for scientific analysis e.g. line/flux ratios
- ALMA Approach: Homogeneous Imaging (Cornwell)
  - Fill hole in uv plane with autocorrelation spectra from the 12-m antennas
  - PLUS ACA: compact array of 7-m antennas

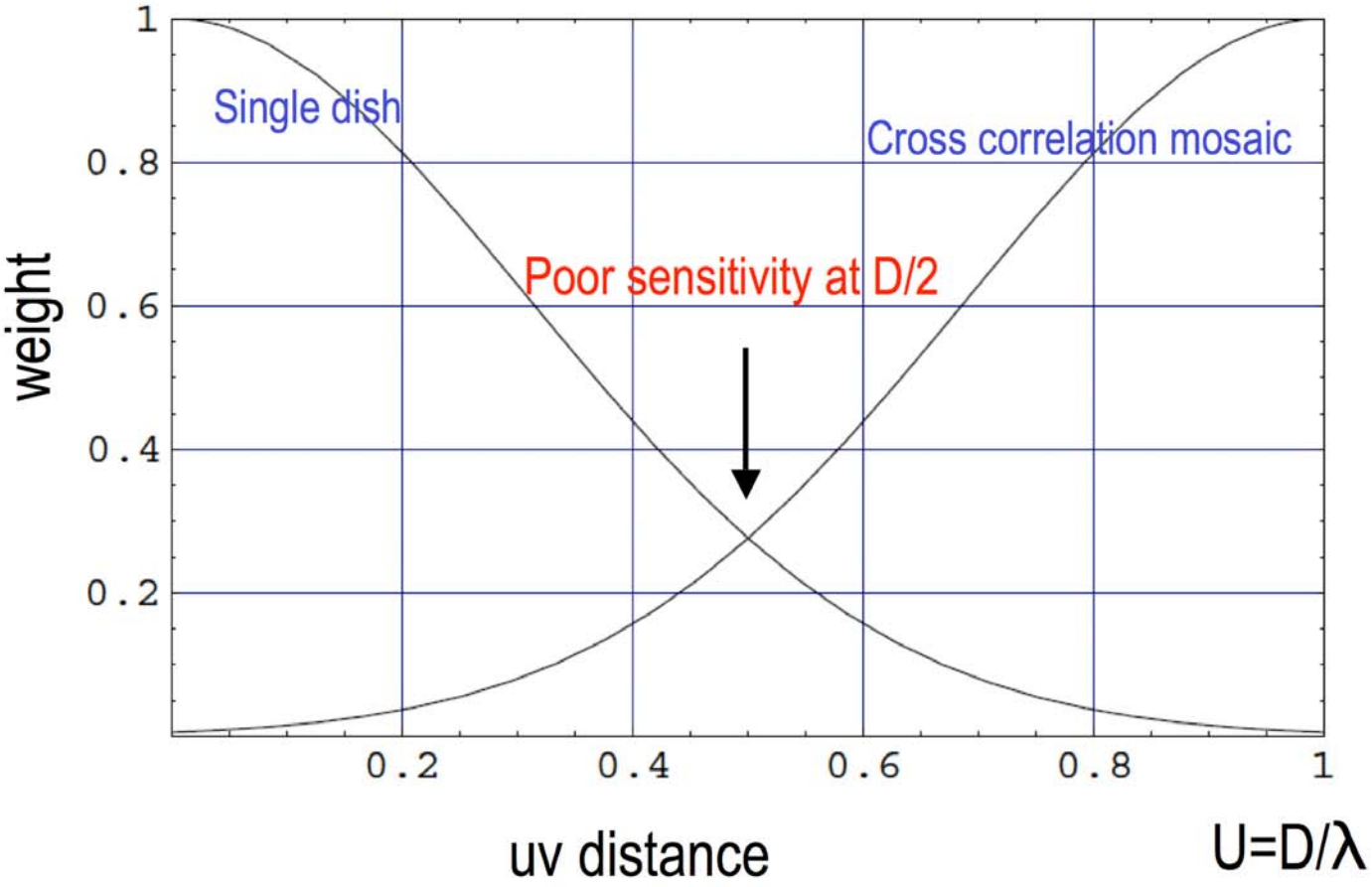


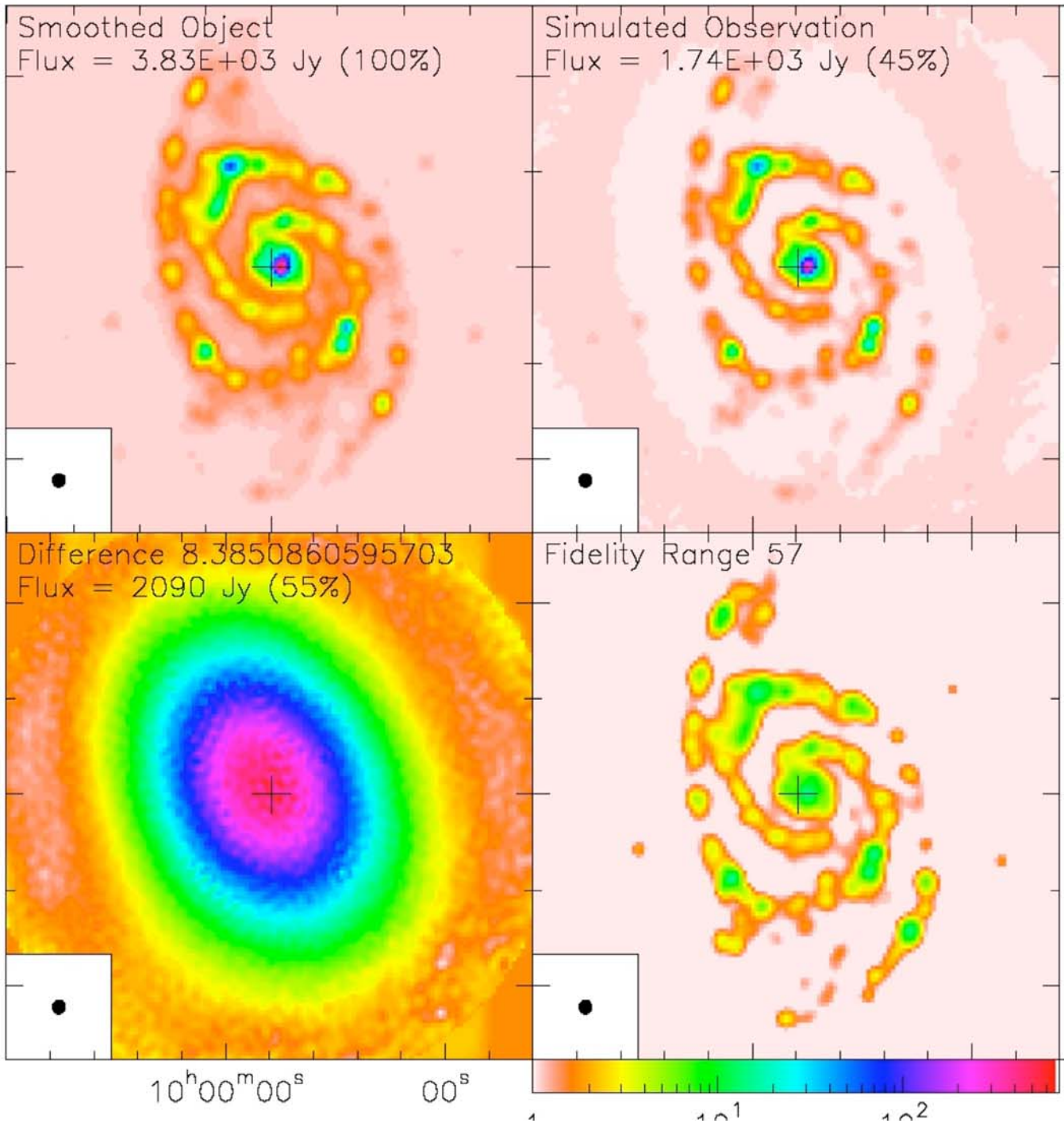
- ALMA survey at 350GHz would be one million pointings
- At 1s per point, would achieve 1.5mJy sensitivity, **~300hours total**
  - But 1 arcsec resolution or better sensitivity (0.6K rms in 1 km/s at this resolution)
  - Many spectral lines in 8GHz passband

Chemistry in L1498:
1000 pointings for ALMA at 350GHz



“Homogeneous Imaging” with ALMA





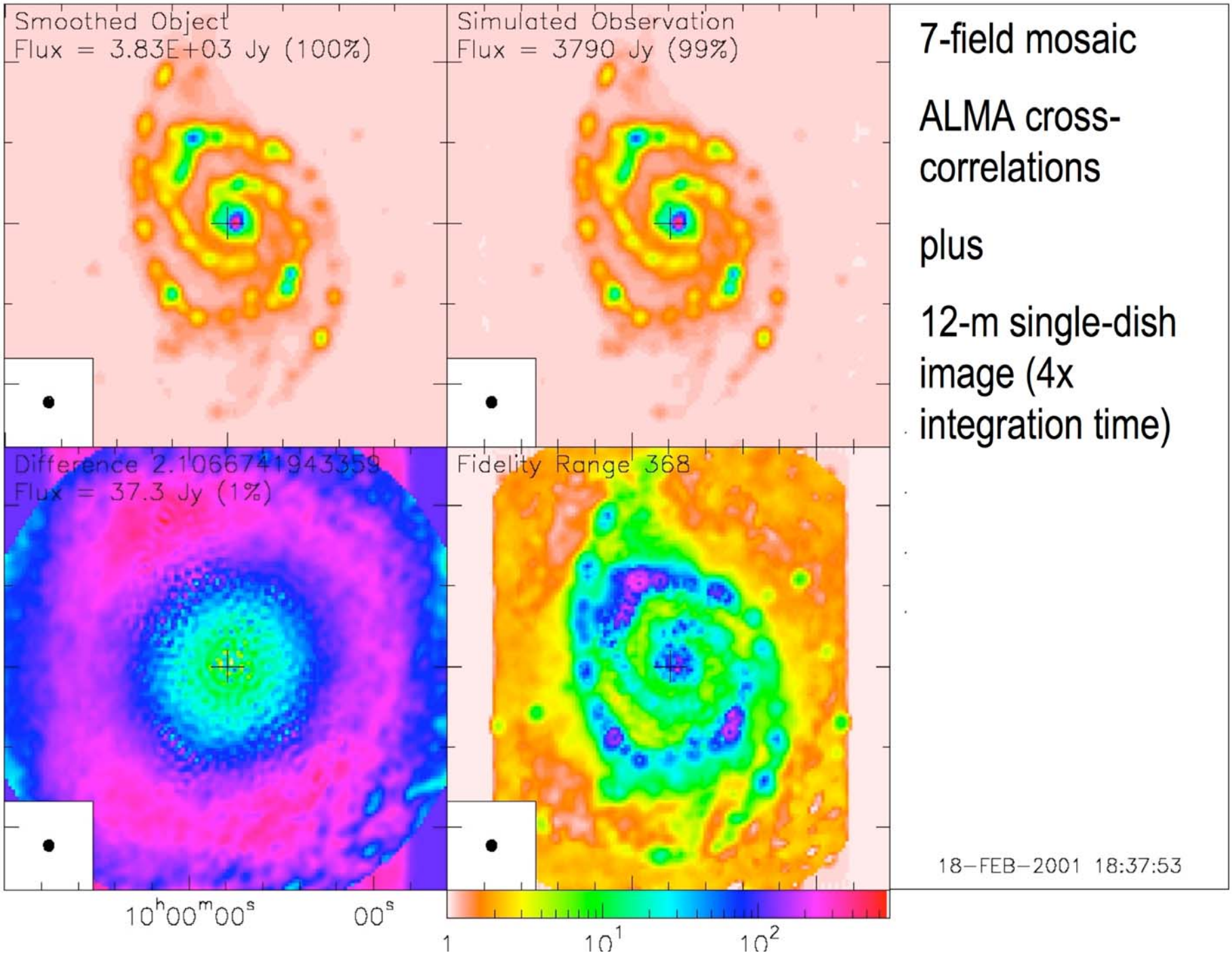
7-field mosaic

ALMA cross-correlations only

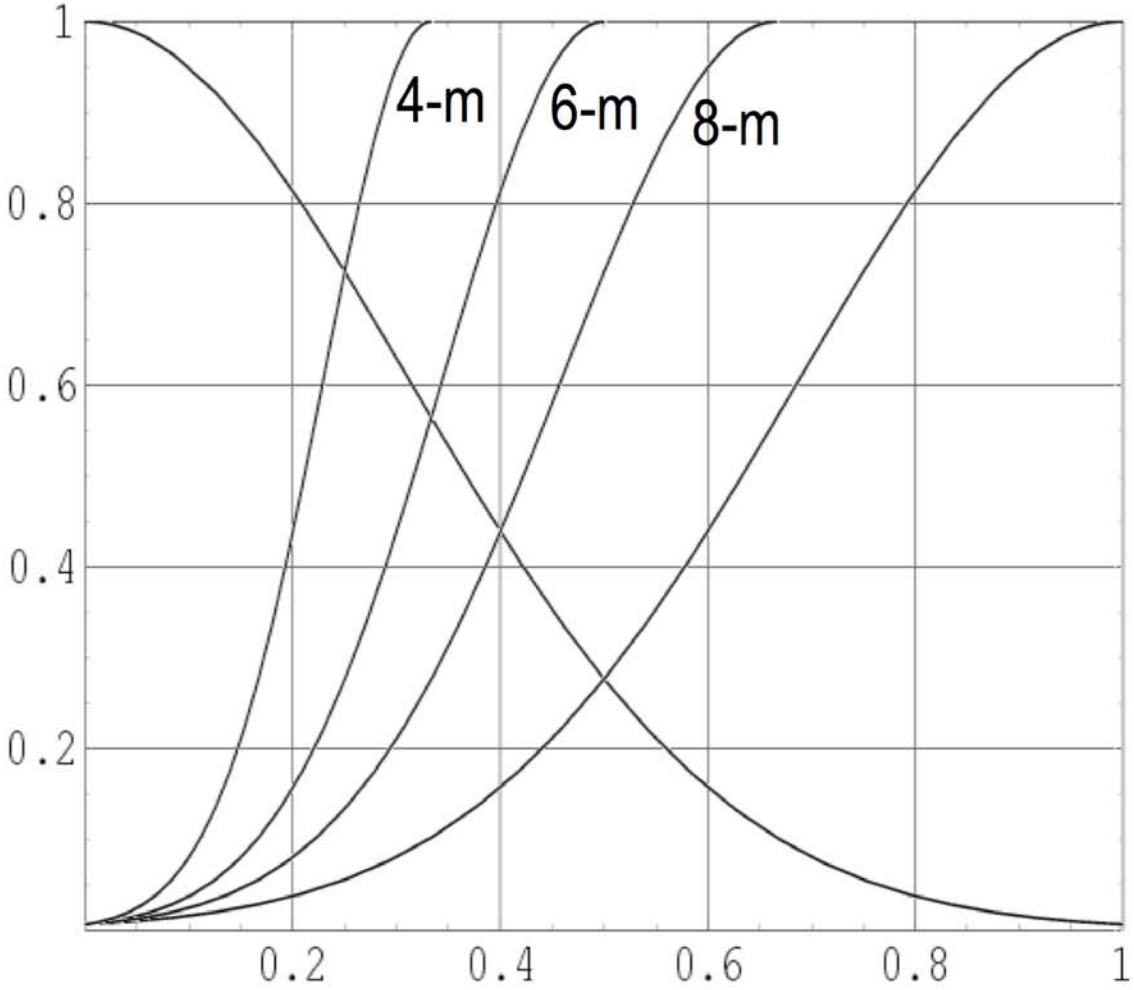
230GHz primary beam is 26 arcsec

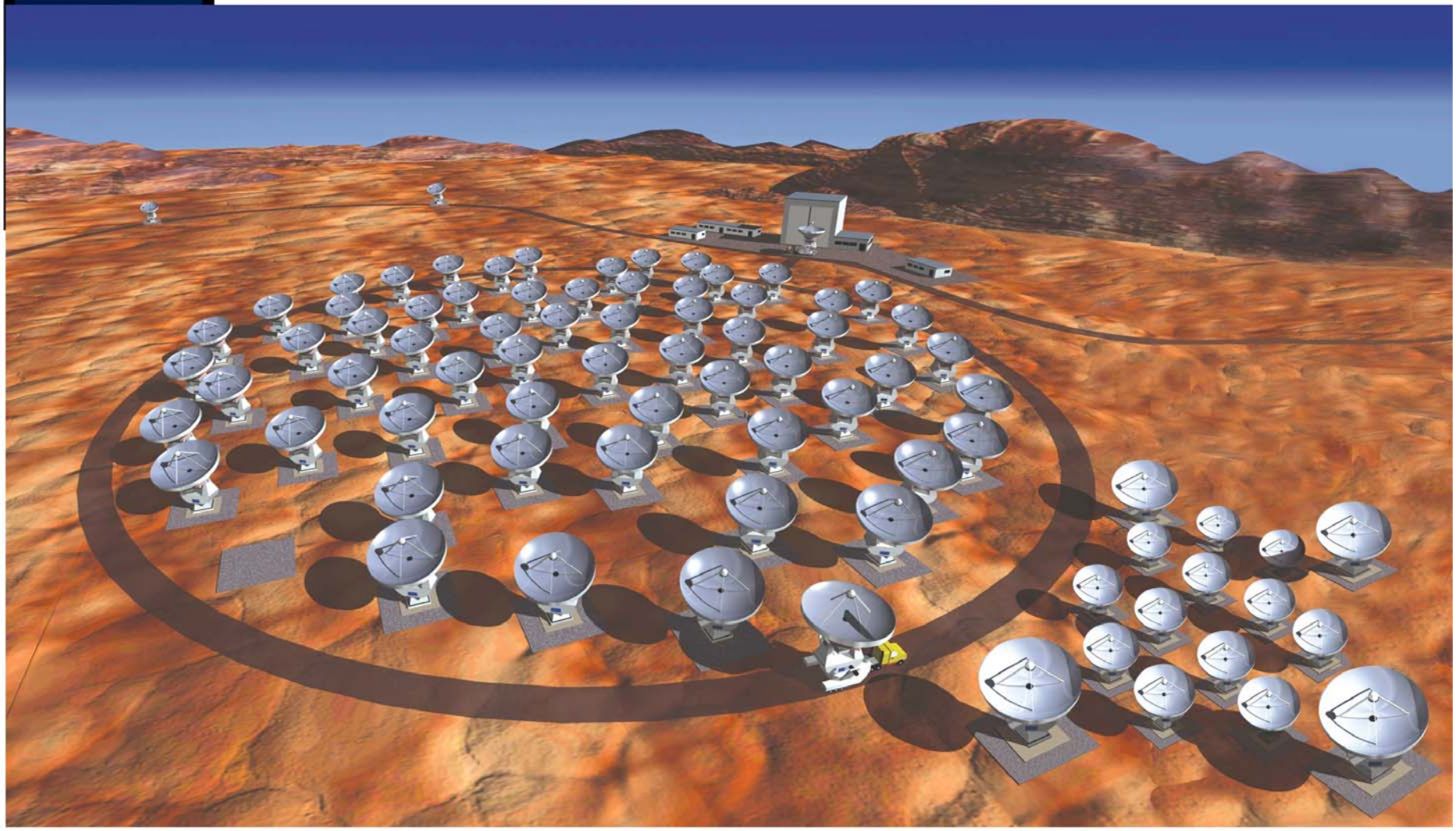
Images are 50 arcsec on a side

18-FEB-2001 17:18:39


Smoothed Object
Flux = 3.83E+03 Jy (100%)
Simulated Observation
Flux = 3790 Jy (99%)
Difference 2.106674194335
Flux = 37.3 Jy (1%)
Fidelity Range 368
10h00m00s
00s
1
10^1
10^2
7-field mosaic
ALMA cross-correlations
plus
12-m single-dish image (4x integration time)
18-FEB-2001 18:37:53

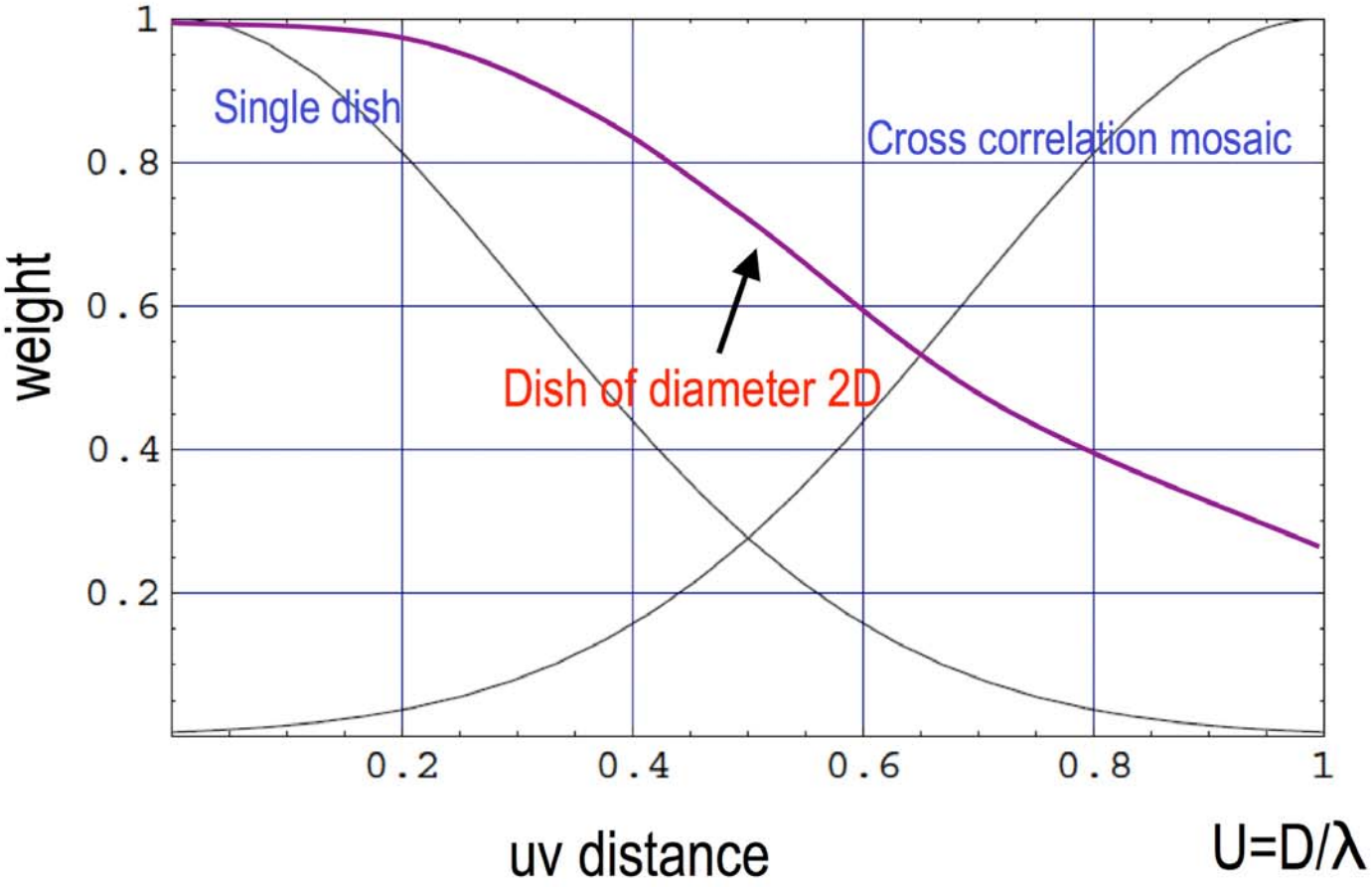
Imaging with ALMA plus array of smaller antennas (ACA: 7-m chosen)





- Atacama Compact Array (ACA)
  - 4x12-m + 12x7-m antennas

Traditional solution: use dish of diameter ≥2D



Large-scale imaging issues for ALMA

- High image fidelity requires
  - very good pointing for *all* 64 antennas
  - well understood primary beam
- Single-dish images with 12-m antennas require
  - Very stable receivers especially for continuum
  - Fast antenna motion
  - Data taking takes time – only 2 detectors in focal plane
  - Only single frequency operation availableComplex data analysis problem
- It can and will be done, but is not trivial
- CCAT could help here if pointing good
  - Need to correct dynamic refraction?

Closing Remarks

- ALMA is the only planned telescope which can
  - image the cold gas in star forming regions down to few AU scales
  - detect, map and find redshift of star forming galaxies to z=10+
- Intrinsically narrow field-of-view instrument
  - Can and will do `surveys', but expensive in terms of time
  - Need to justify angular resolution
- Strong synergy with CCAT:
  - Spectral/spatial surveys at moderate resolution
  - Short spacings for ALMA
  - Peak of the SED at frequencies above 1THz
  - 2012-2013 timesclae is about right