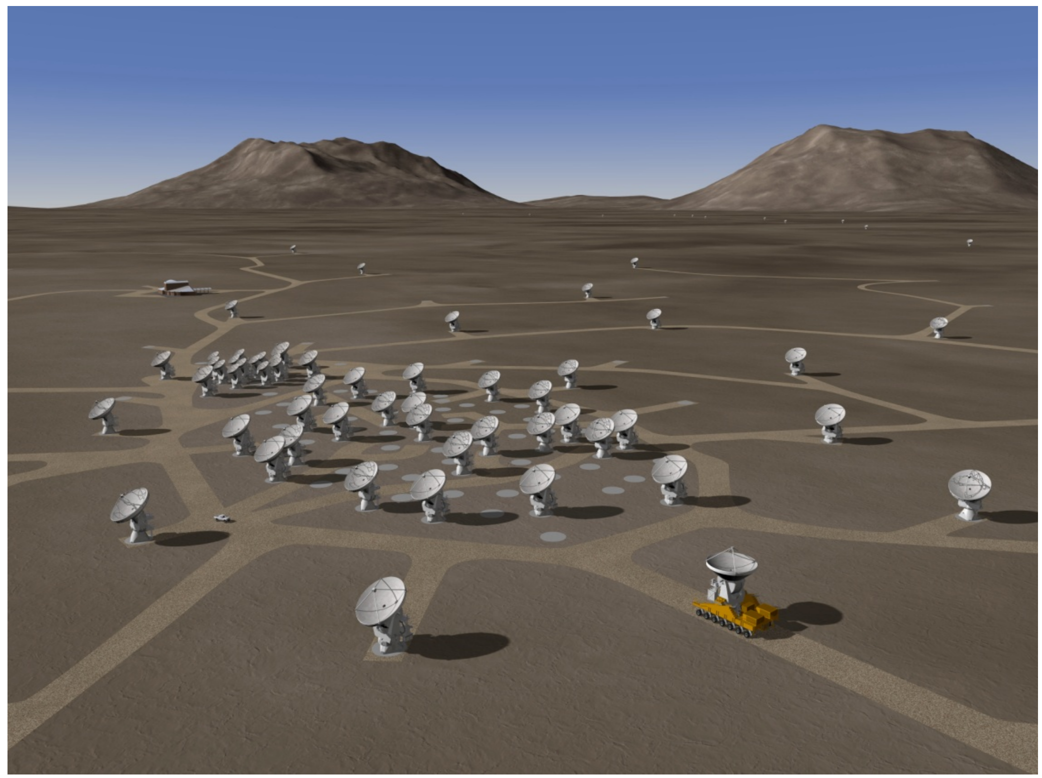
The Invisible Universe (c1972)

The Evolution of Millimeter-Wave Astronomy
at the
National Radio Astronomy Observatory

From this → *To this*

36-ft telescope (1967)



ALMA telescope (estimated completion September 2013)

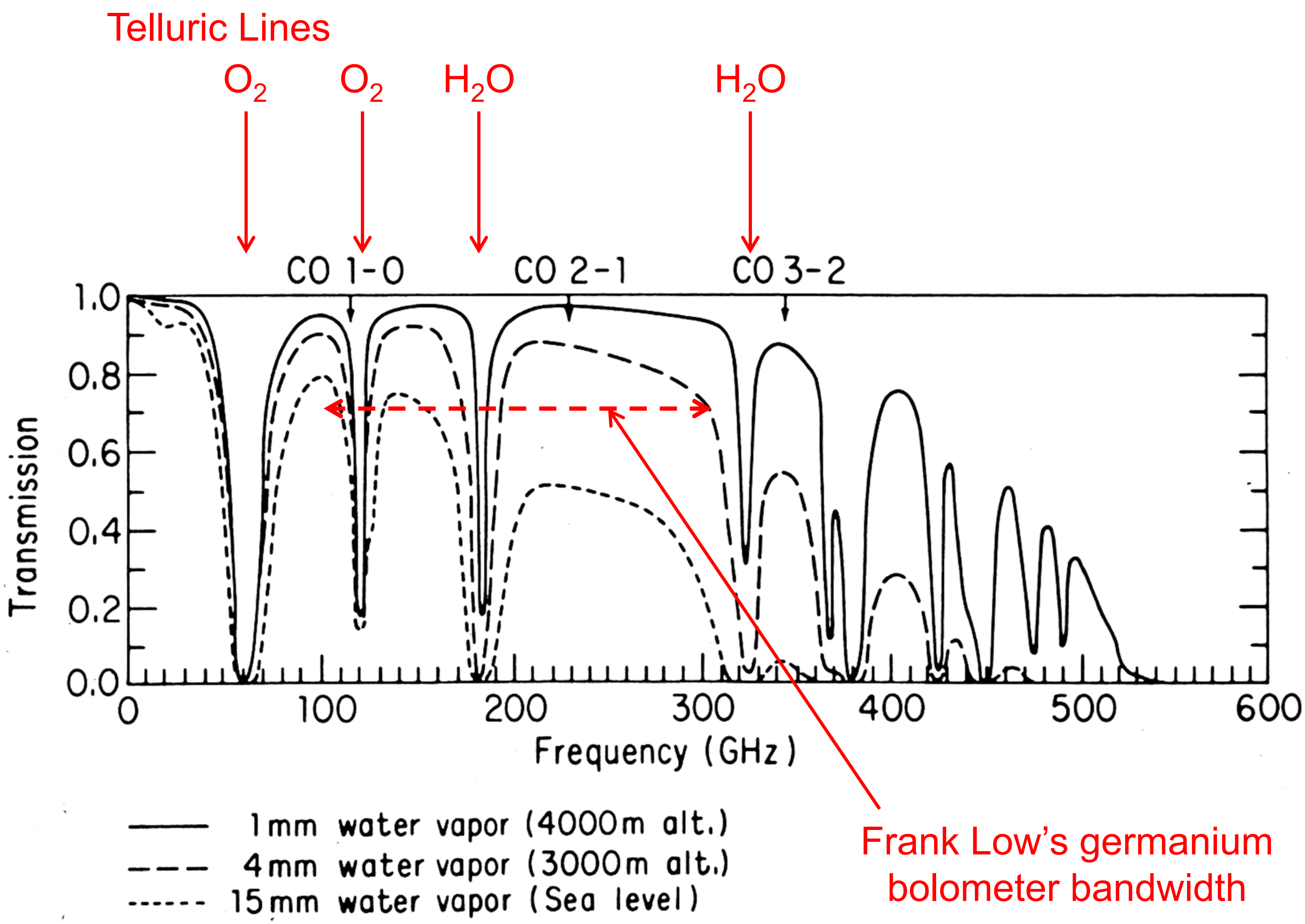
Frank Low and his family moved to NRAO in Greenbank and into astronomy

From Edie Low

The Birth of the 36-ft Telescope

- 1956 NSF gives AUI $4M to build the NRAO in Green Bank, WVa
- 1961 Frank Drake *lures* Frank Low to Green Bank from Texas Instruments, Dallas
- 1962 Tests with 5-ft paraboloid show GB unsuitable for mm-wave astronomy
- 1962 AUI asks the NSF for $1.5m to build a 36-ft mm-wave telescope
- 1963 Tucson site (Kitt Peak) chosen, with support agreement with KPNO
- 1964 Rohr Corporation wins construction bid
- 1967 First “light”!
- 1968 Enters regular service as a visitor-telescope

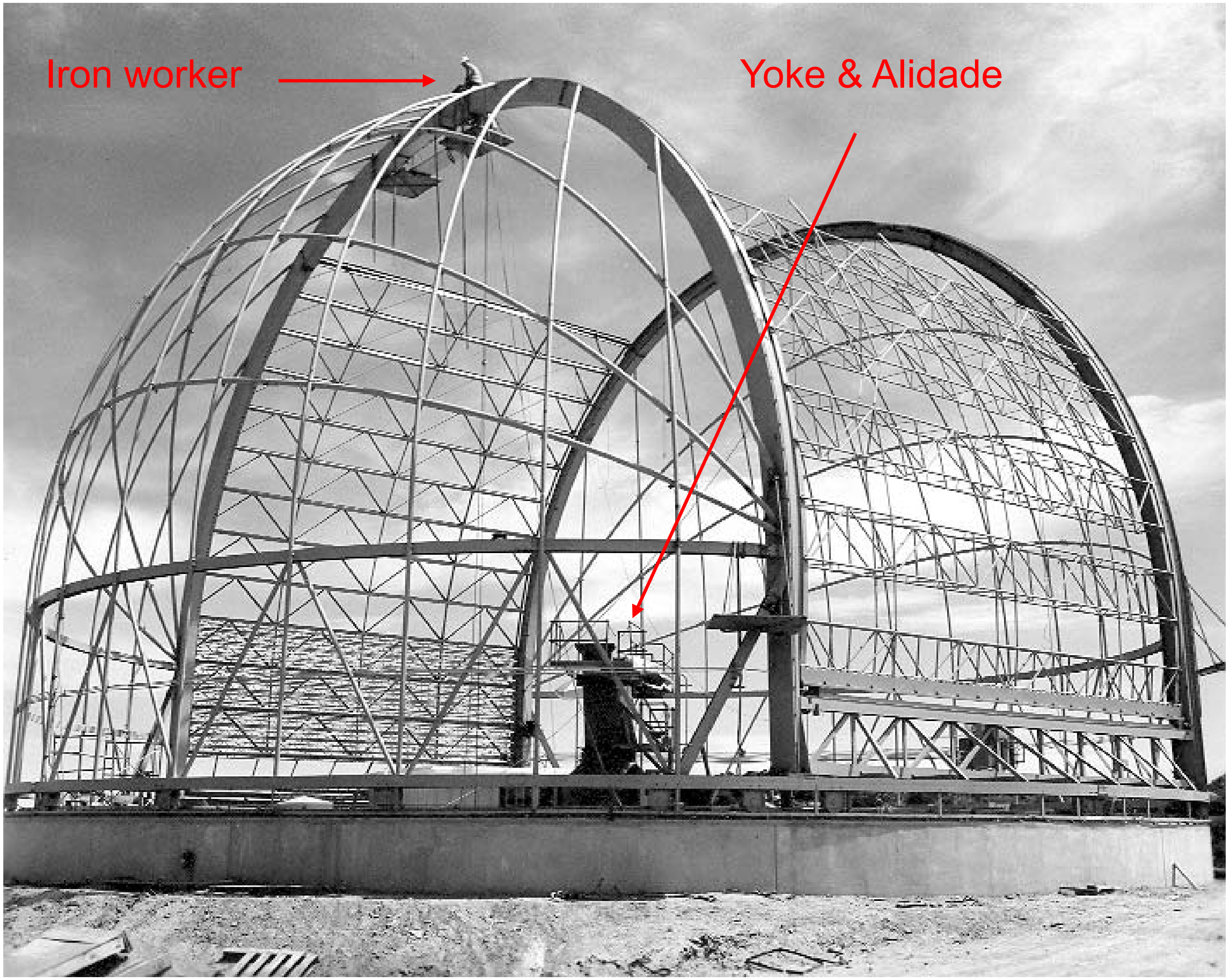
Atmospheric Transmission at Zenith

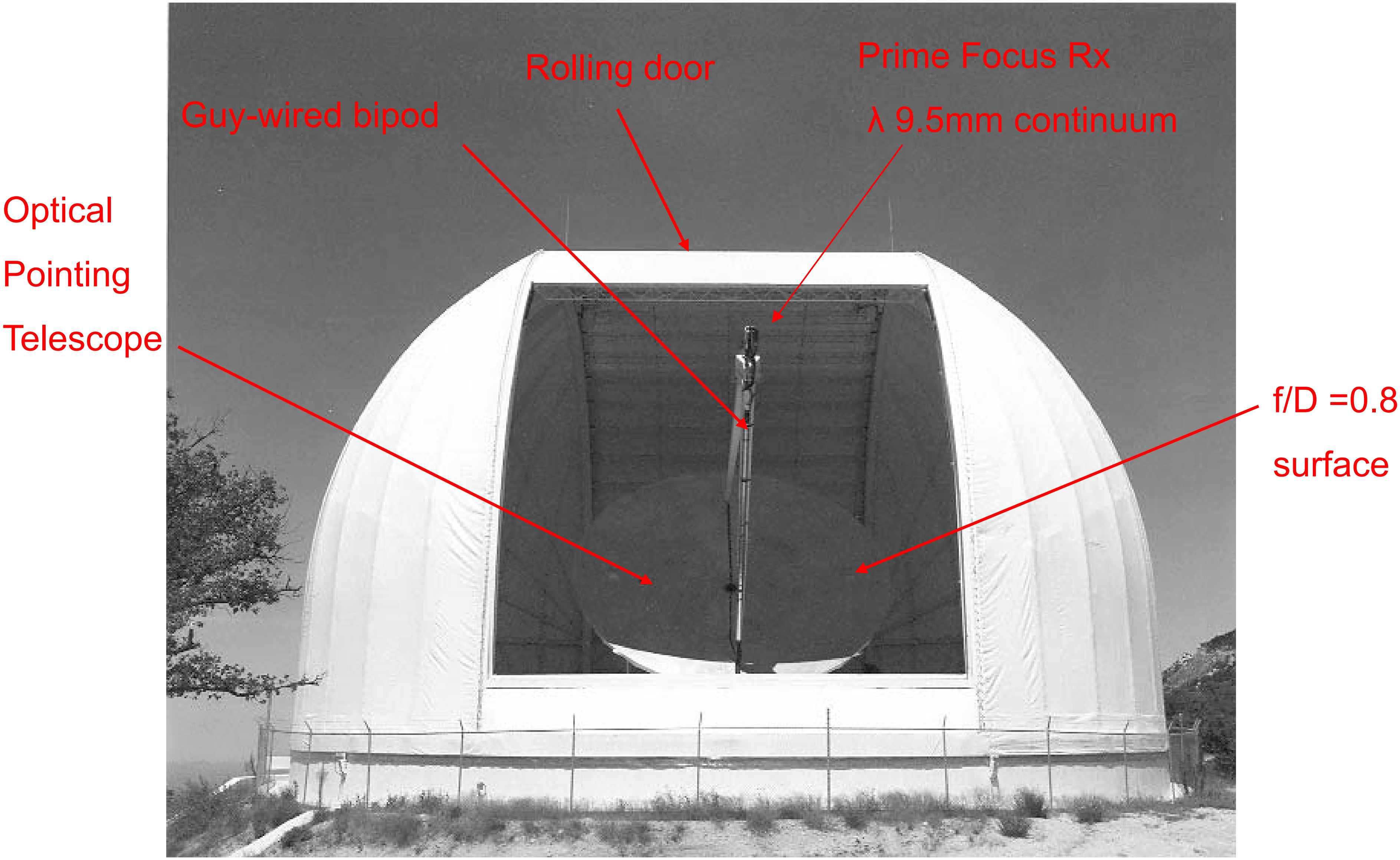



Rohr Corporation milling machine in Chula Vista, CA

36-ft reflector near Winterhaven, CA, en route to Kitt Peak. February 1966

Construction of Astrodome on Kitt Peak





36-ft telescope within the fabric “astrodome” 1967

One of four variable speed azimuth drives for astrodome

Performance Report Card at Delivery

Item	**Goal**	**Result**
Surface RMS	~50µm	140µm ± 10µm
Pointing RMS	10 arc sec	Unstable
Surface stability	Good in darkness	Temperature dependent
Source tracking	Astronomical	Computer too slow
Drive Servo performance		Poor
Azimuth brakes	Slew arresting	Leaked constantly; unreliable
Dome tracking	No vignetting	Motion control too coarse
Receiver capability	Prime focus	Good

Rapidly Evolving Demand

- Detection of Interstellar “Radio” Molecules: “The Gold Rush”
- Development of Telescope-Independent mm-wave Intensities
- Lower-noise Receivers
- Local Oscillator Improvements
- Greatly Improved Software
- Stable Filter Banks for Spectroscopy
- *Huge* Improvement in Reliability of Electronics

Interstellar “Radio” Molecules

Predicted by

I. S. Shklovsky in 1949, 1952 in Russian Literature

C. H. Townes in 1955, IAU Symposium 4, Jodrell Bank, England

Discovered:

In 1963 1 (OH)

By 1969 4

In 1970 CO (1-0) with the NRAO 36-ft Telescope

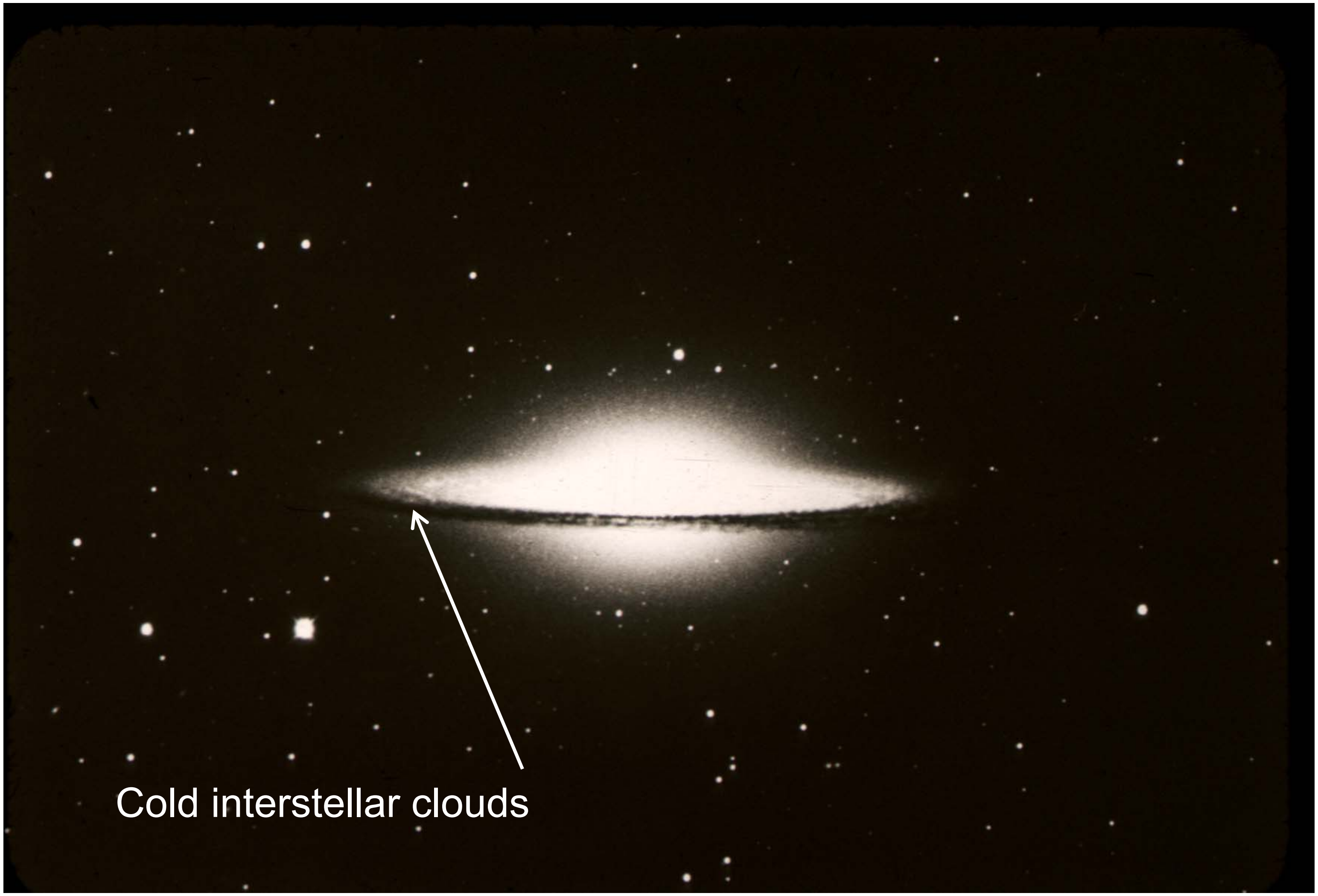
The 20^{th} Century Gold Rush began!

By 1972 About 8

By 1985 About 53

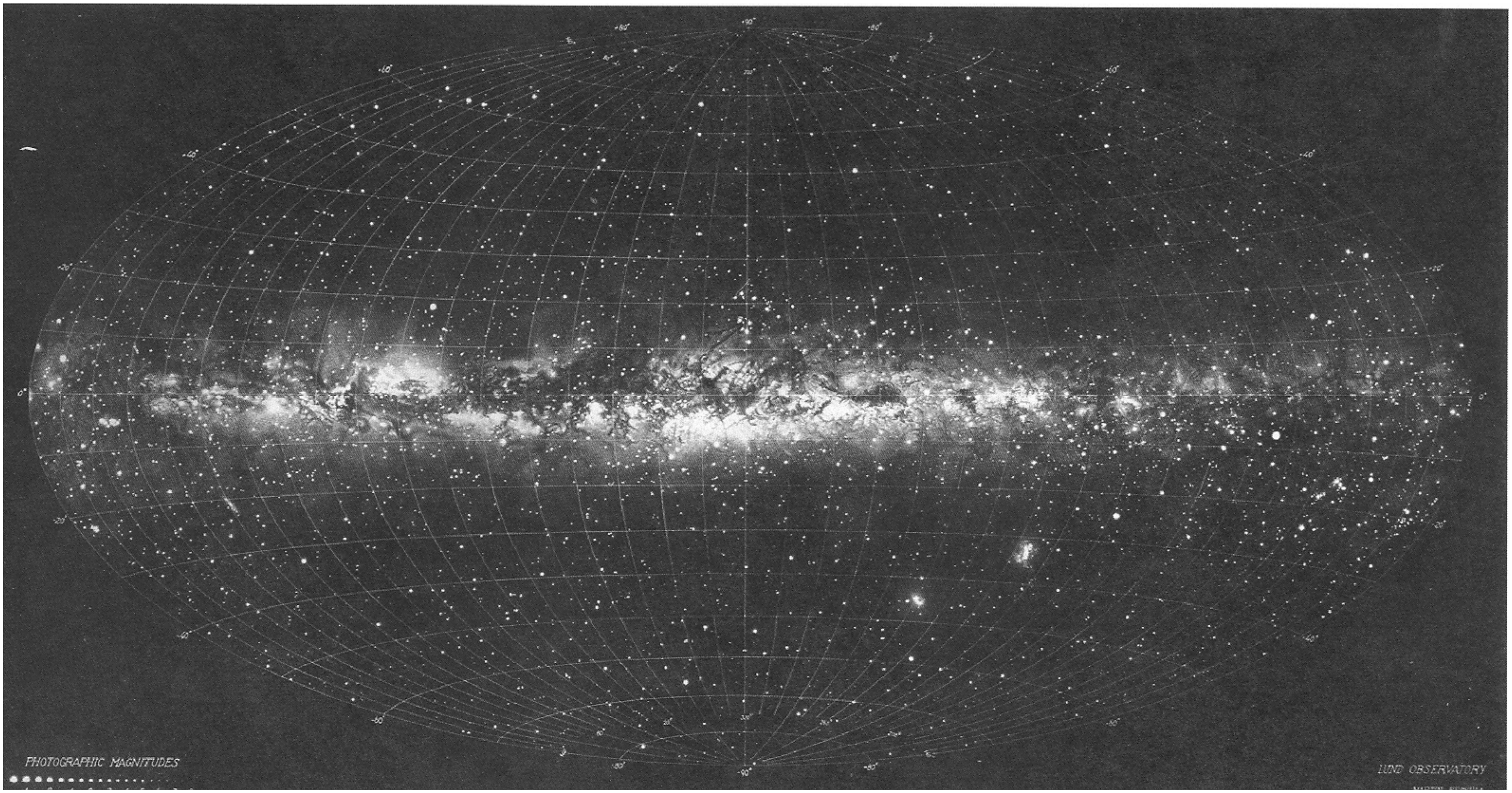
By 2011 About 125

Spiral Galaxy Seen Edge-On



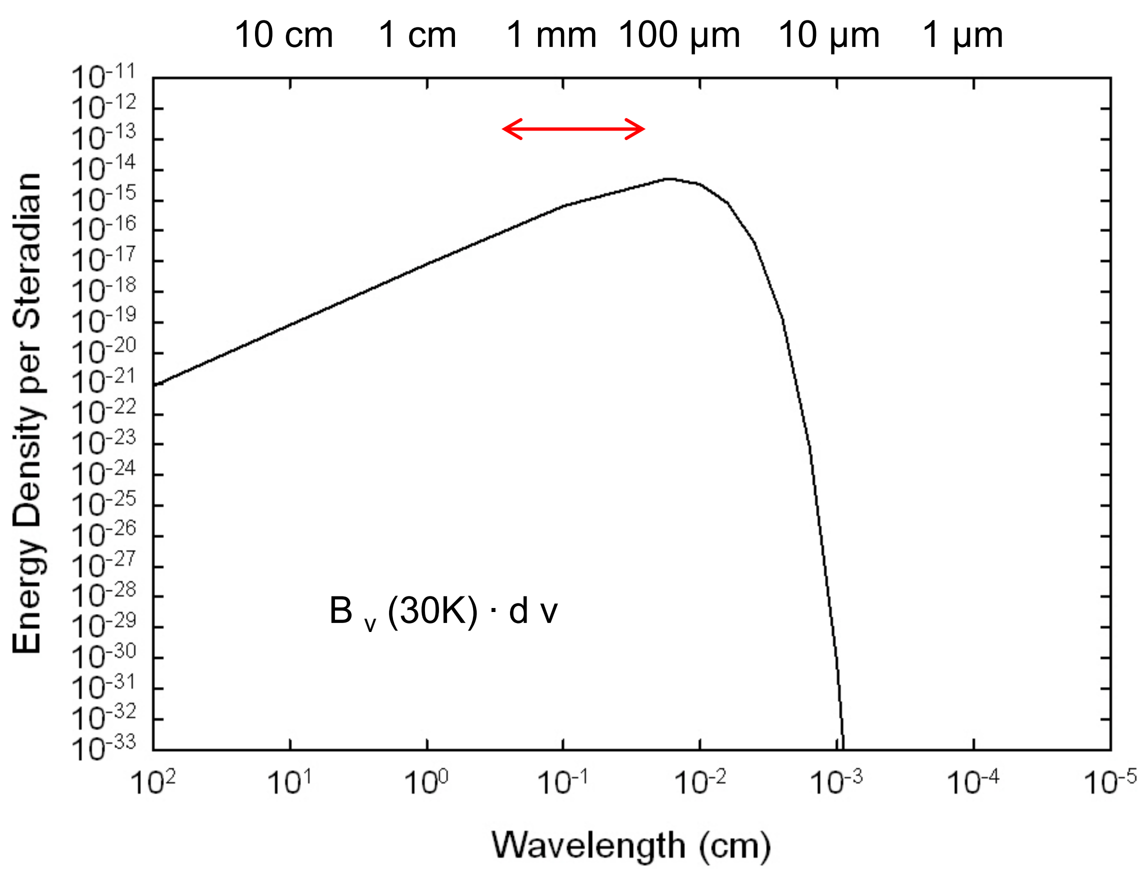
Sombrero Galaxy in Virgo, KPNO Photo

The Milky Way



Drawing by Martin & Tatiana Keskula. © Lund Observatory.

Dark Interstellar Gas Clouds



Atmospheric transparency also a factor

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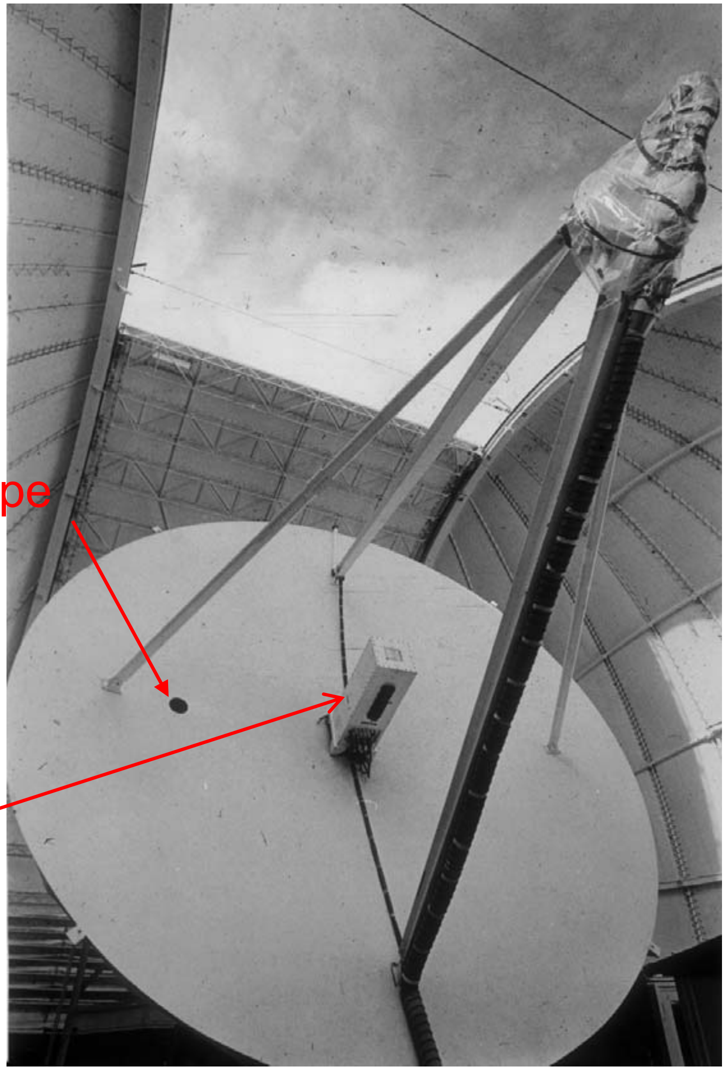
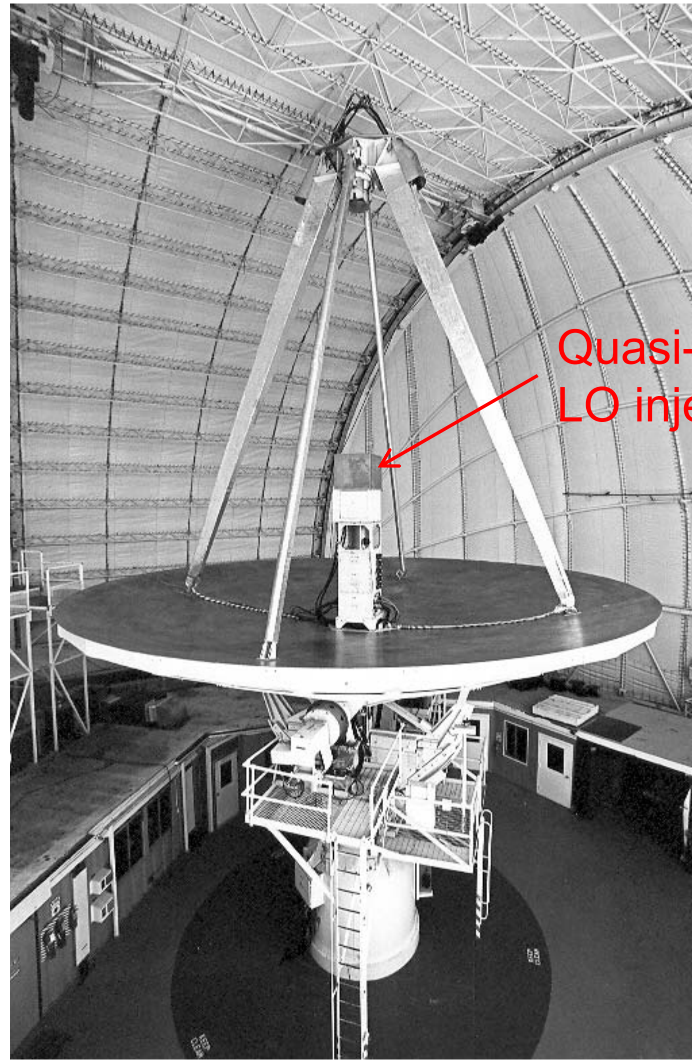
First Cryogenic Vertex Receiver





From 1973 → 1981

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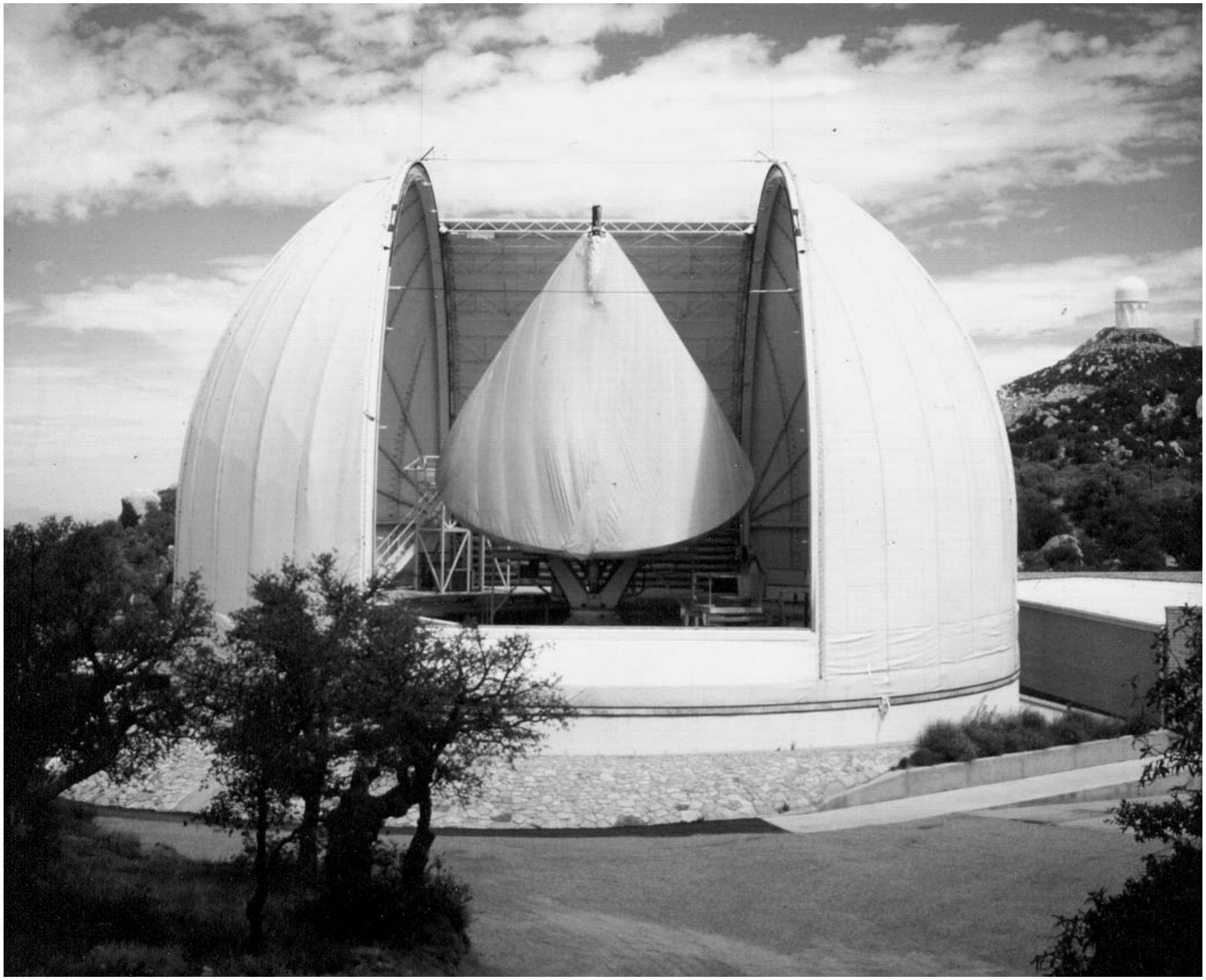
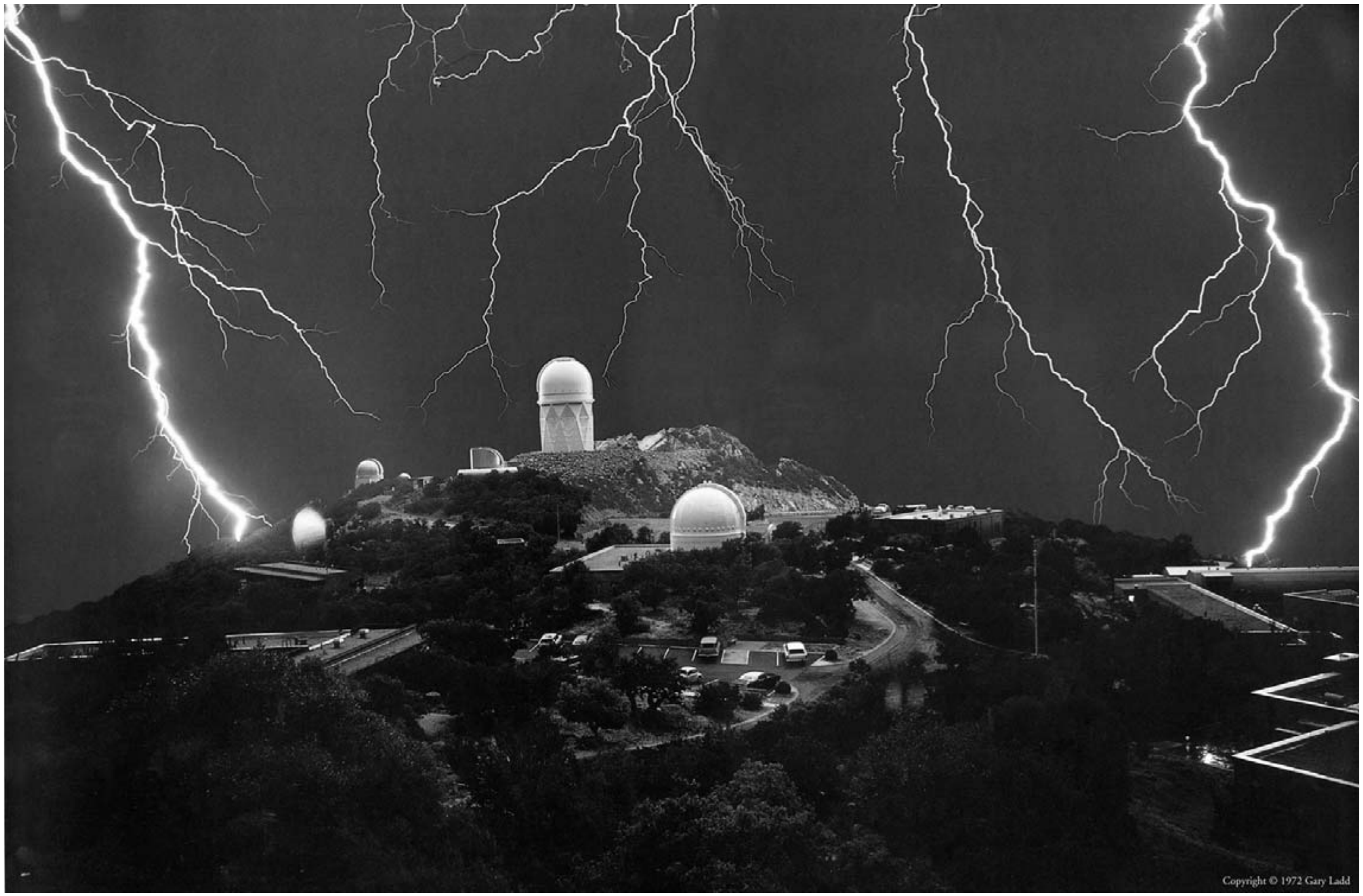
Seriously Flawed surface

The “Teepee”, a Desperate Measure

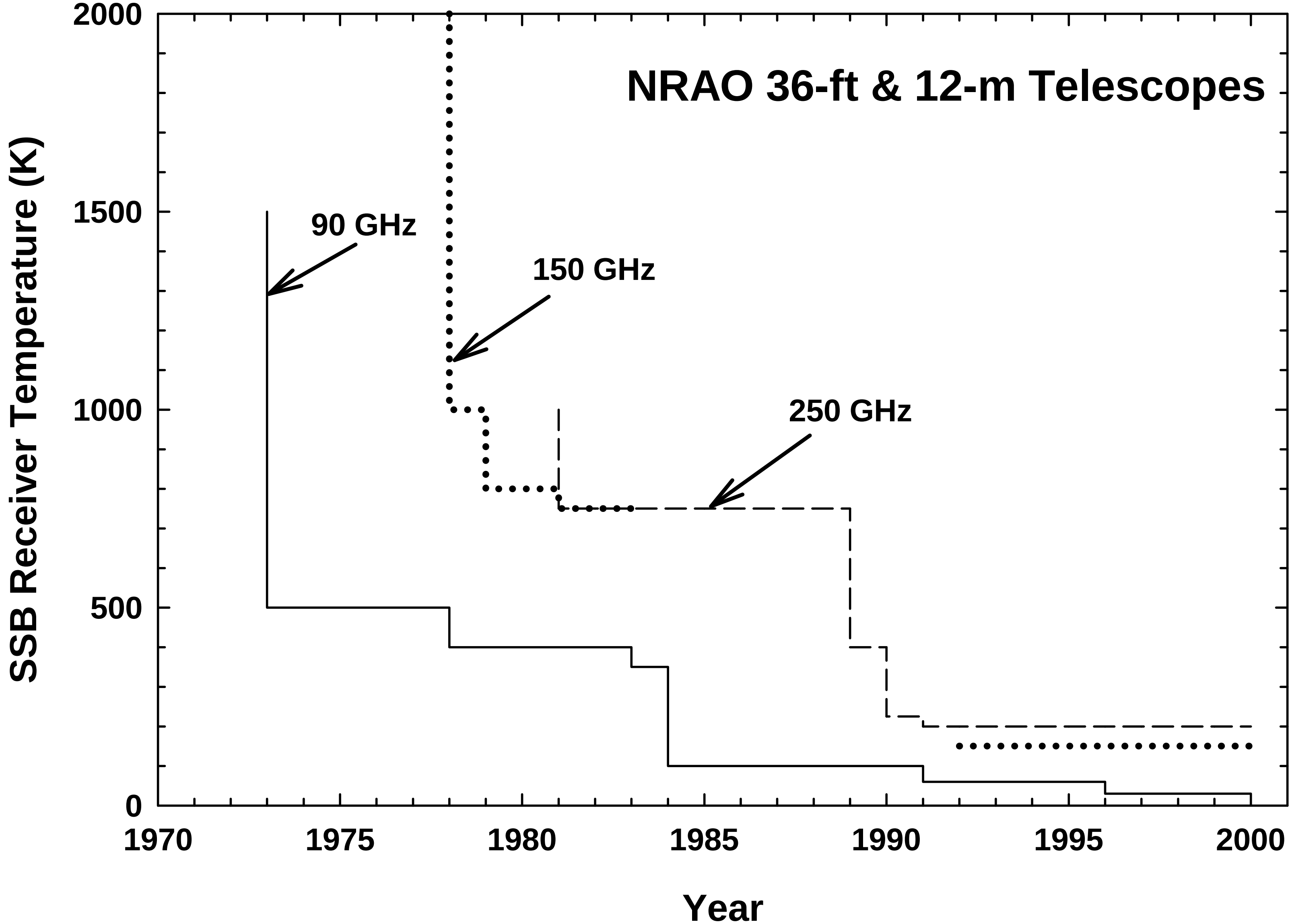


Thunderstorms: “Evils” we could do little about



Kitt Peak, Arizona

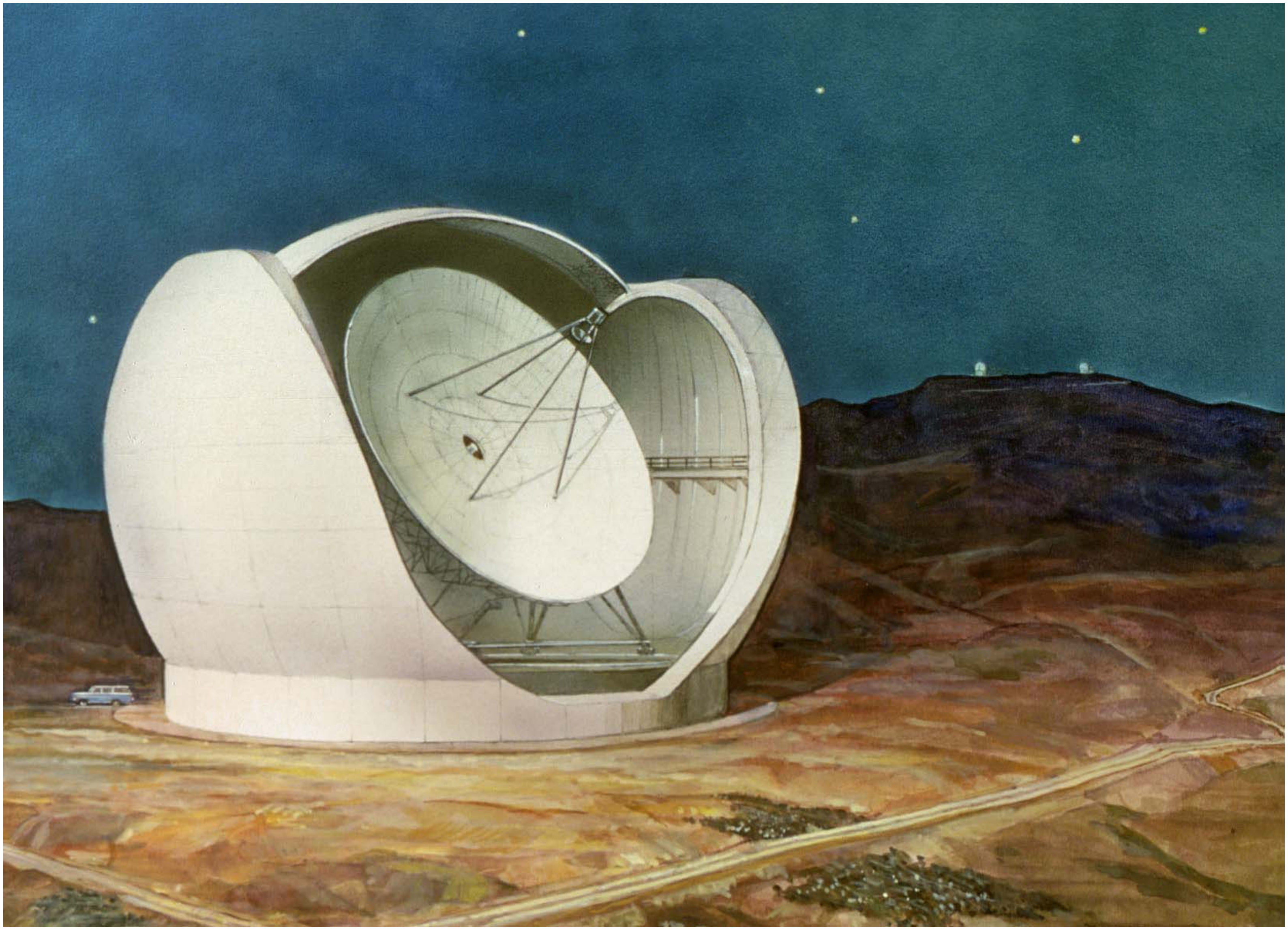
Improvements in Receiver Sensitivity



25-m mm-wave Telescope

- 1974 Dave Heeschen proposed replacing the 36-ft telescope
- Barry Turner appointed as committee chair
- Never-funded “homologous” NRAO 65-m Telescope Scaled to 25m
- 1975 Mark Gordon became Project Manager
- 1977 AUI submitted construction proposal to build on Mauna Kea
- 1980 President Carter included it in his FY 1981 Budget Request
- 1981 Disaster!

Artist's Rendering of the 25-m Telescope on Mauna Kea



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25-m Telescope Proposal dies:

➔ Go to Plan B

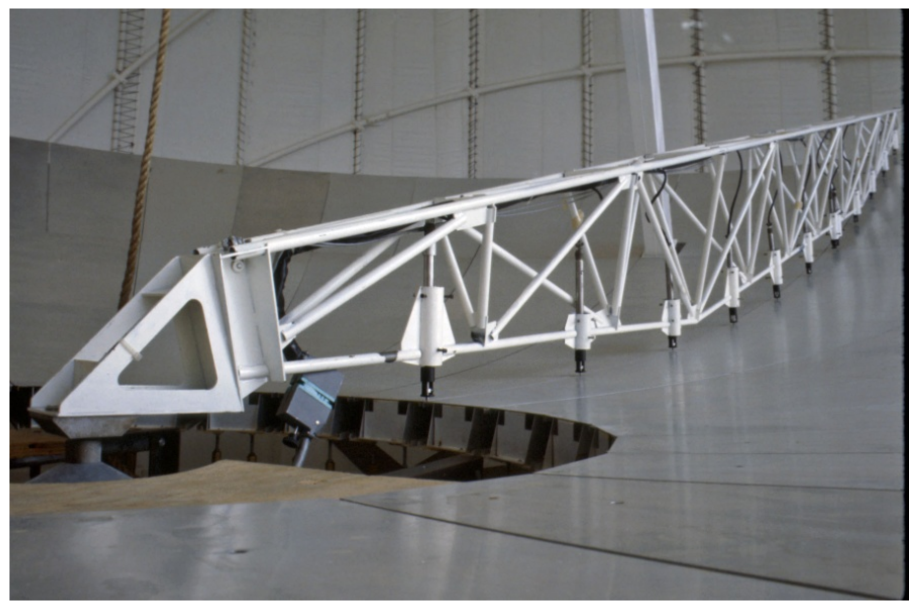
- 1981 NRAO decides to replace the 36-ft surface with a 12-m surface
- 1983 Barrett Committee II recommends an mm-wave array

Plan B

- •1981 NRAO decides to replace the 36-ft surface with a 12-m surface
- •1983 Barrett Committee II recommends an mm-wave array
- •1990 AUI proposal to the NSF to construct 40 8-m mm-wave antennas
- •1994 NRAO proposes construction at Llano de Chajnantor, Chile
- •1998 ESO and NRAO merge array projects into ALMA: 64 12-m antennas
- •2003 Groundbreaking for ALMA
- •2013 Expected "Completion" of ALMA

Constructing the 12-m Surface

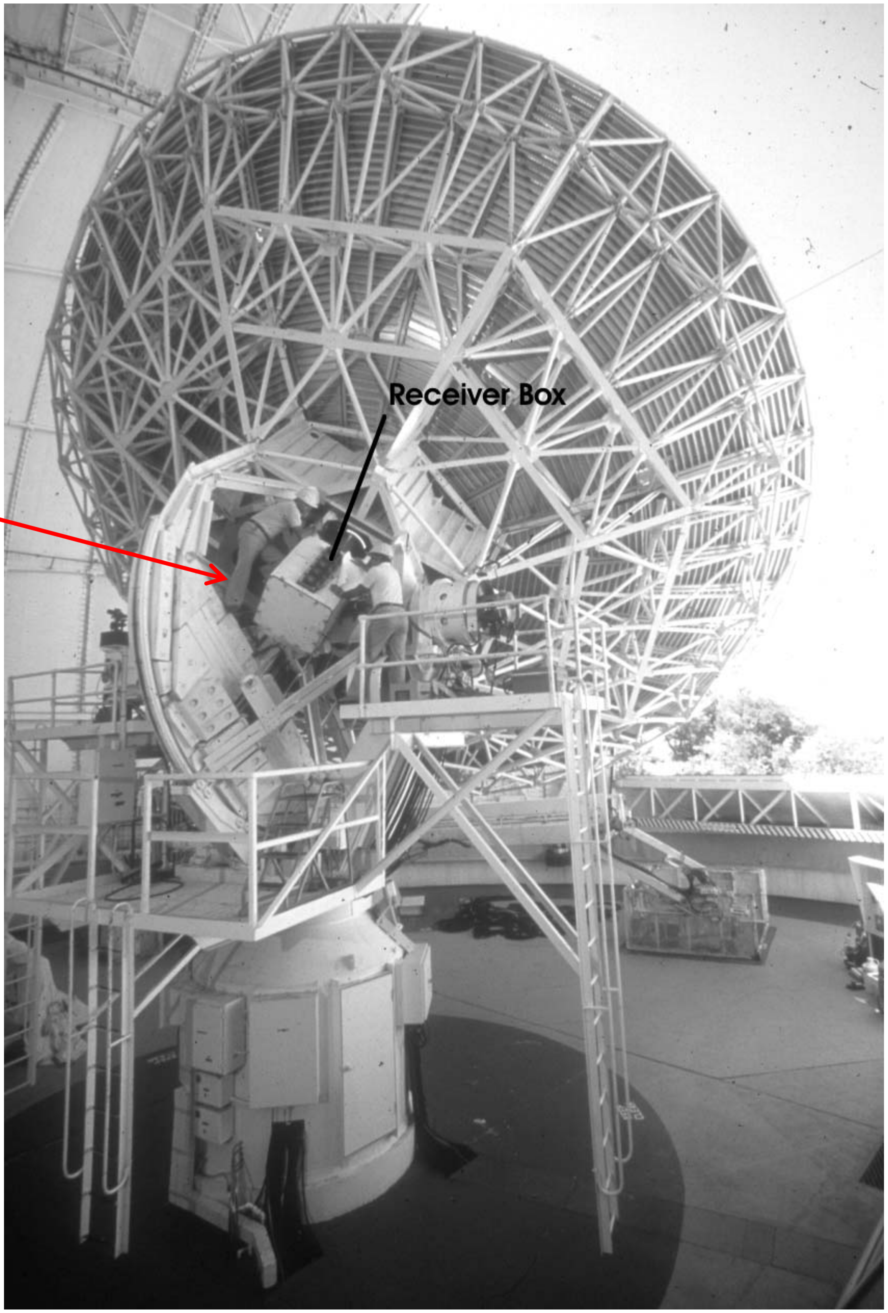
John Ralston and Bill Horne attaching surface panels



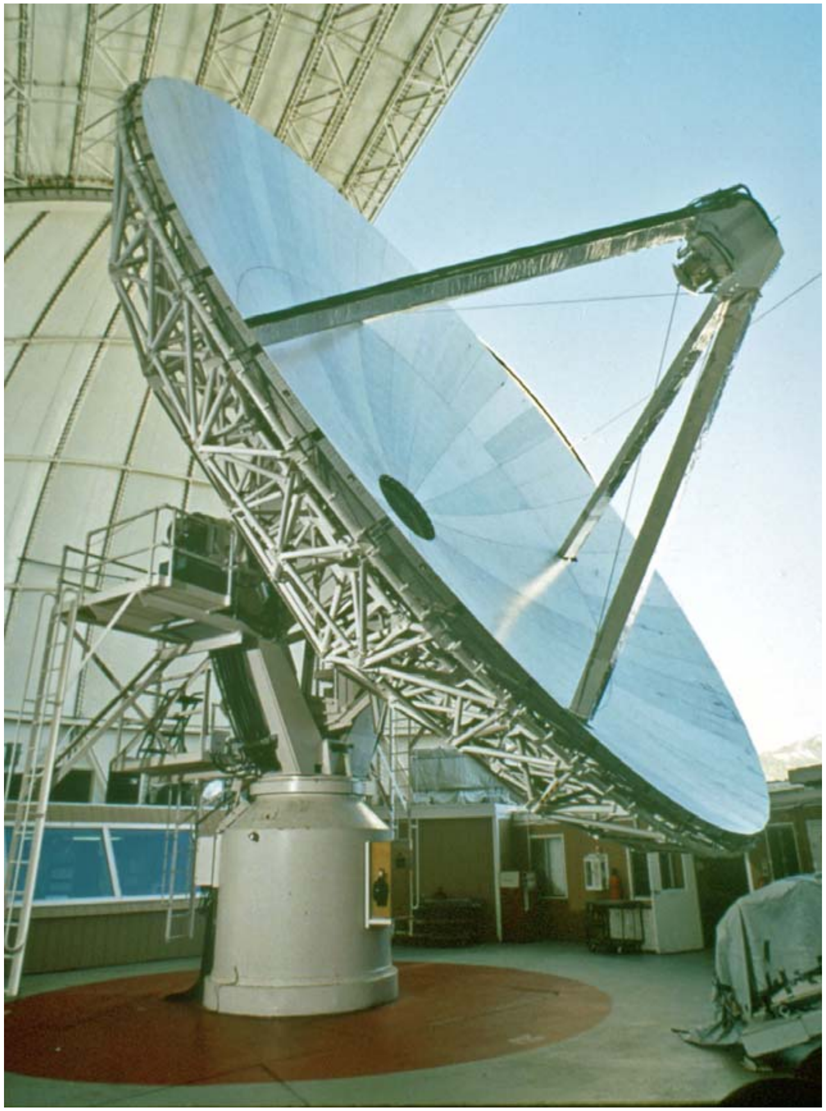
Panel setting truss

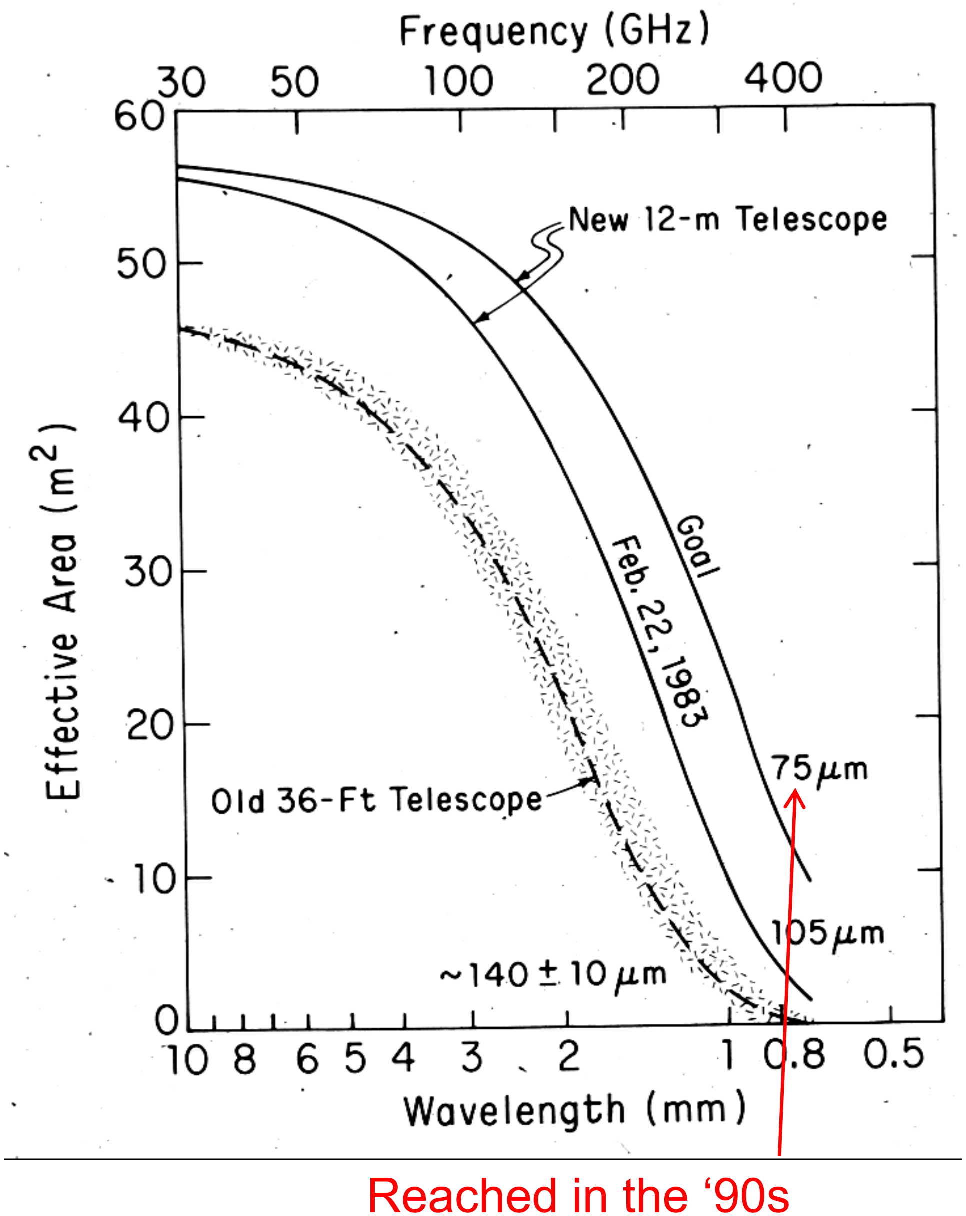
Backstructure

4 selectable Cassegrain Rx positions



1984: A Good mm-wave Telescope at Last!





Plan B --- continued

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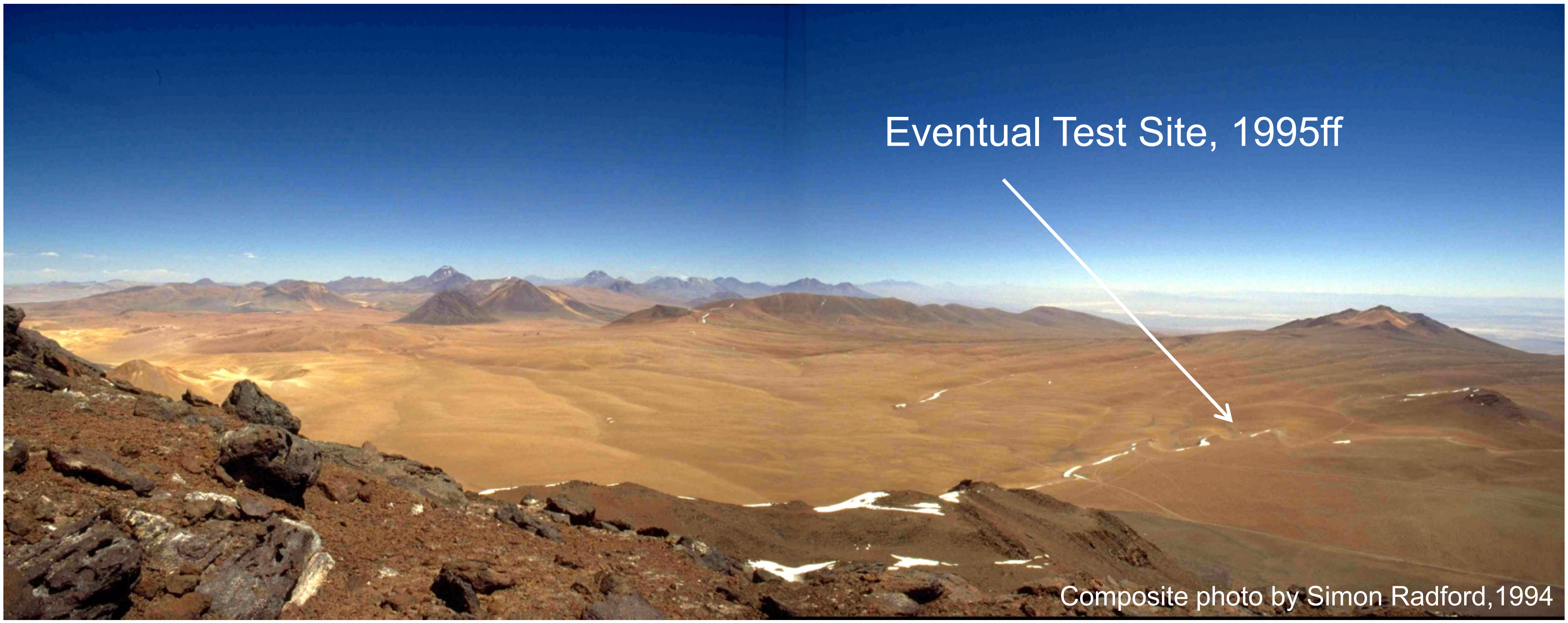
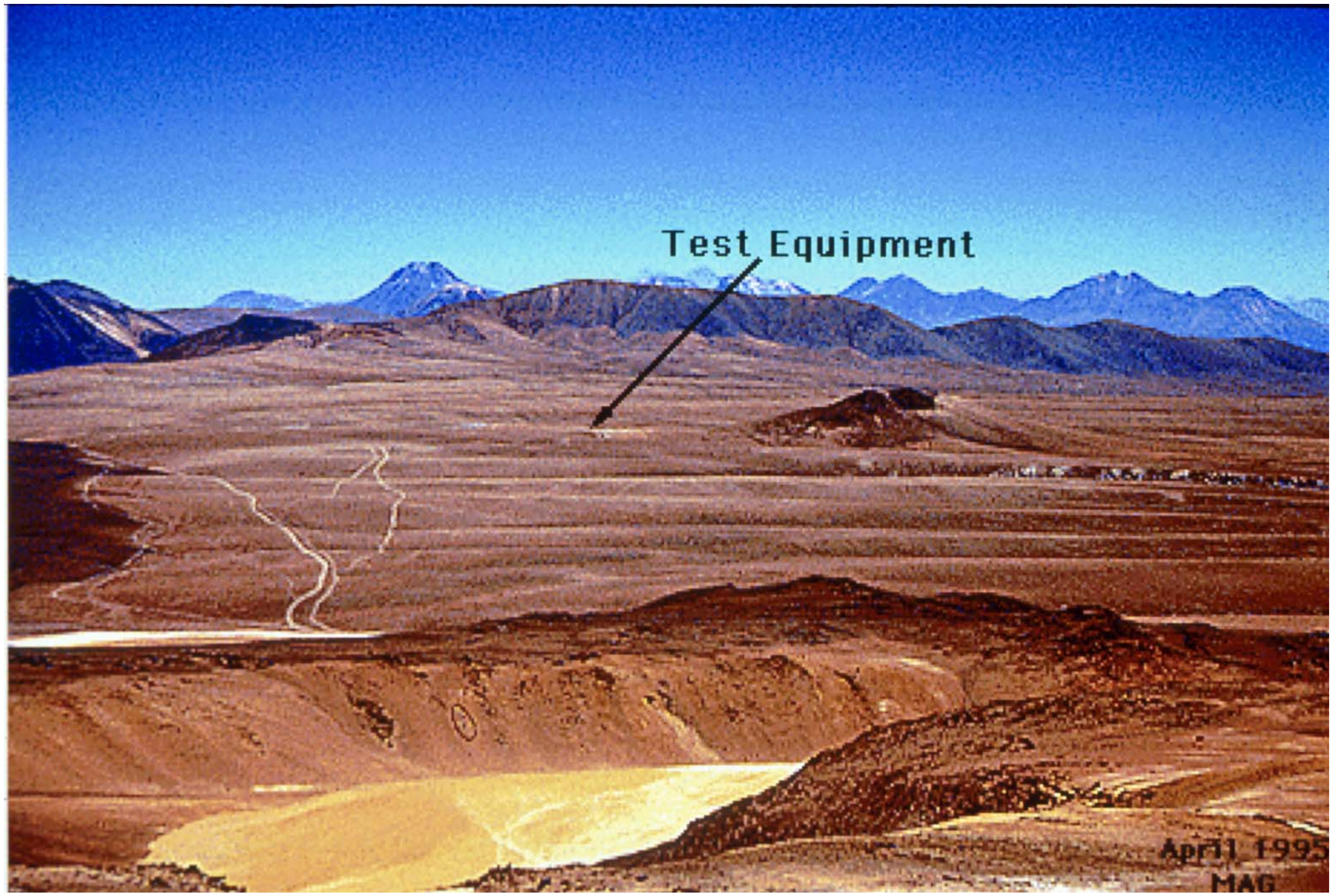
Llano de Chajnantor, Chilean Andes
16,500 ft (5,000 m)



View south from a 16,800 ft location on Cerro Chajnantor. The geological “bench” [llano] lies east of the village of San Miguel de Atacama

Llano de Chajnantor, 1995



Site test equipment now in place. View from Cerro Toco

November, 2010 ALMA

Llano de Chajnantor, Chile, 16,500 ft altitude

Eight 12-m Antennas

Array Support Facility

October, 2011   ALMA

22 antennas, both 12-m and 7-m types

Summary

- Developing cutting-edge hardware is tedious. *Really?*
- New telescopes produce new stuff. *Who knew?*
- Federal funding is much more difficult than it was in the 1960s. *Ya think?*
- University and national observatories have love-hate relationships.

From stupid restructuring of the NSF!

- When hardware becomes perfected, we abandon it. *Never, never be content!*

The End