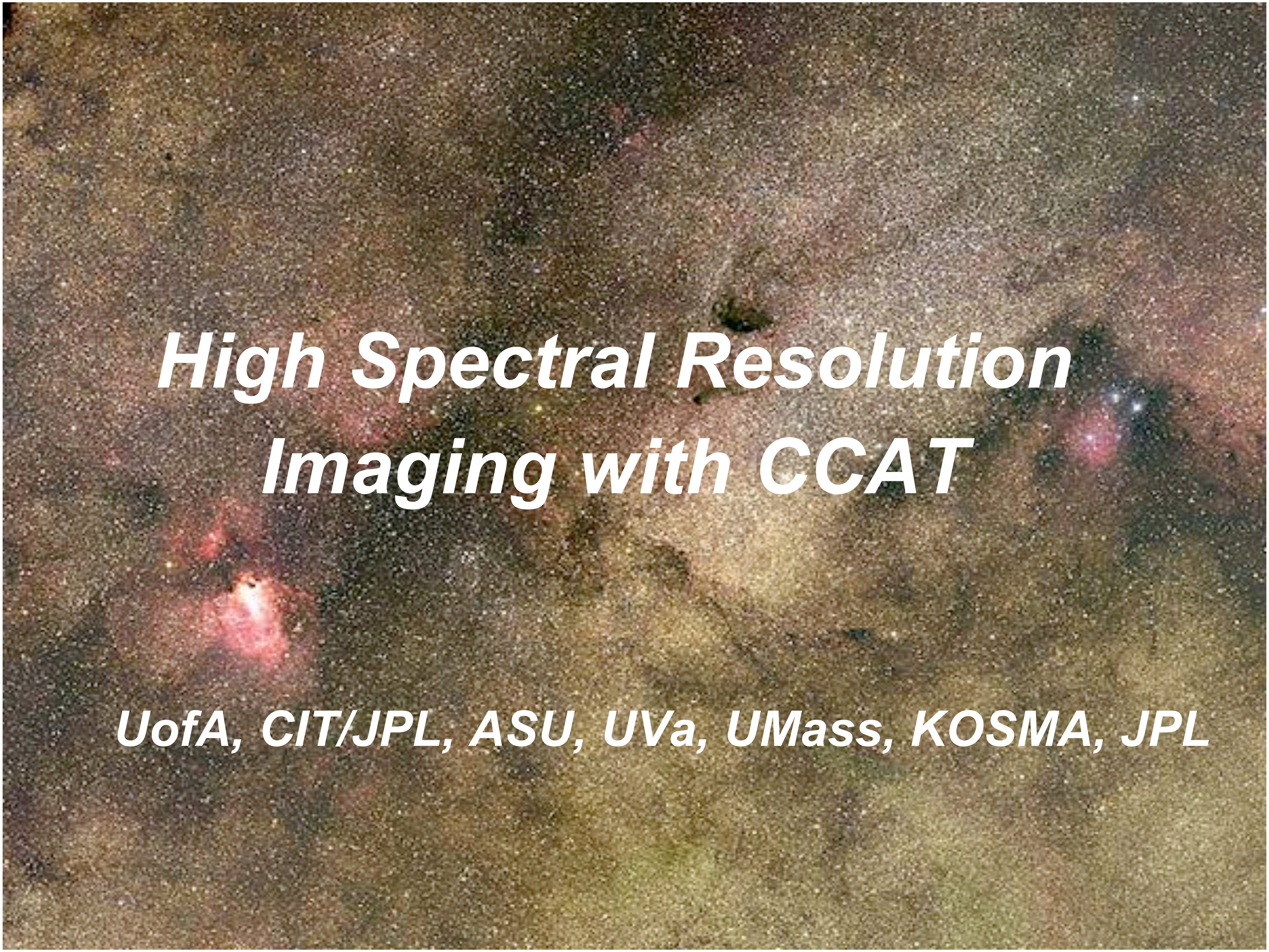
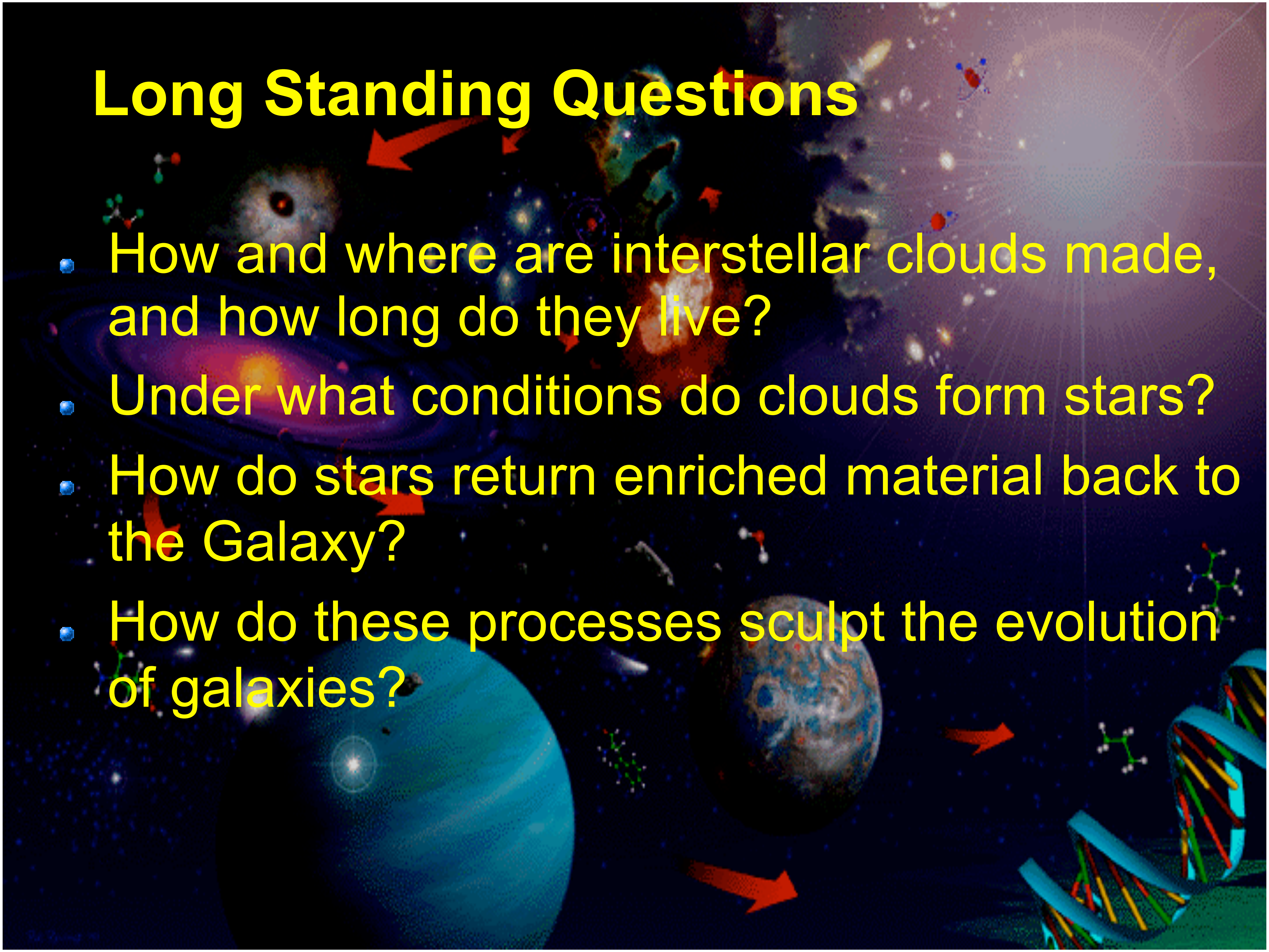
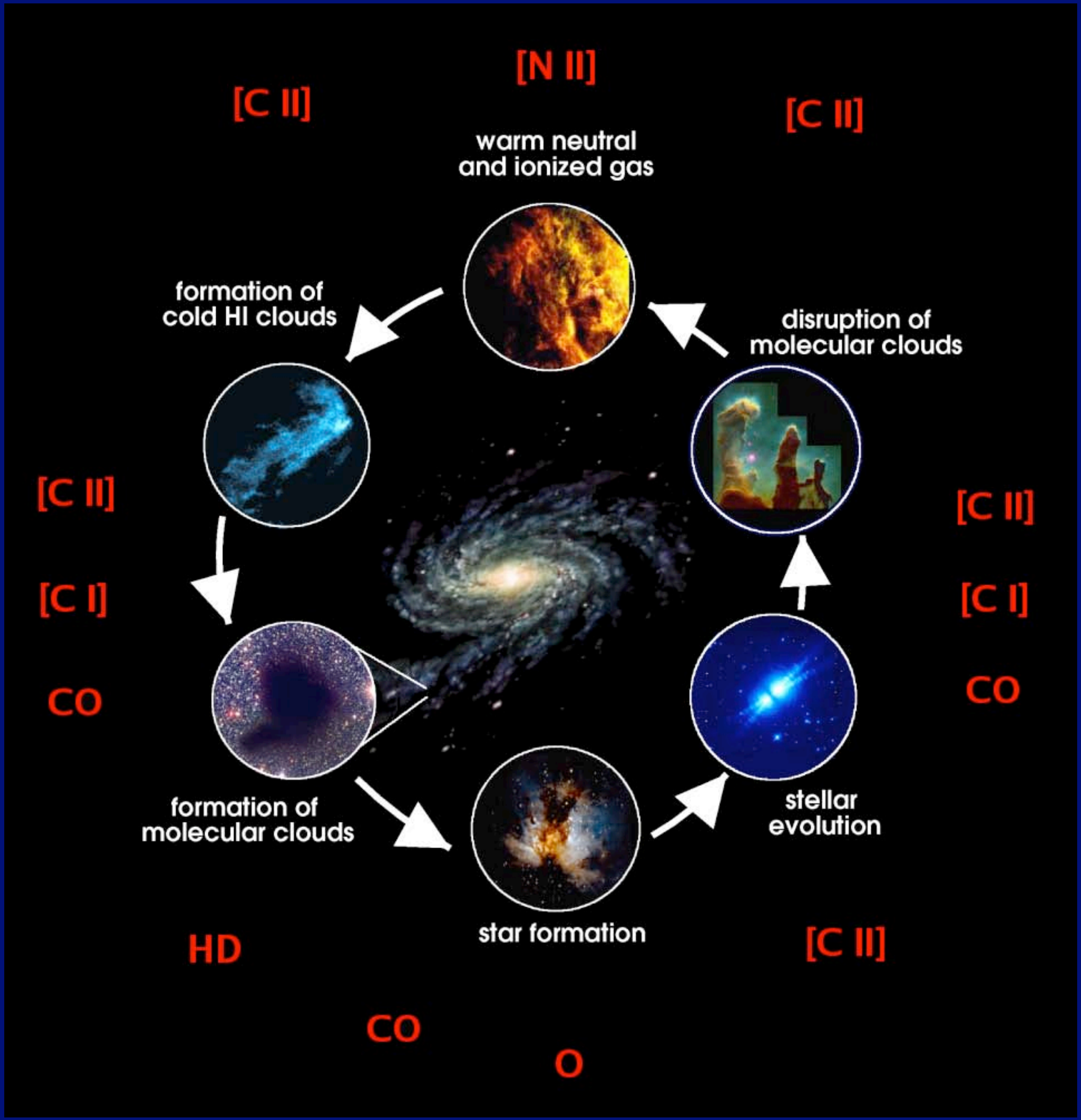

High Spectral Resolution
Imaging with CCAT
UofA, CIT/JPL, ASU, UVa, UMass, KOSMA, JPL

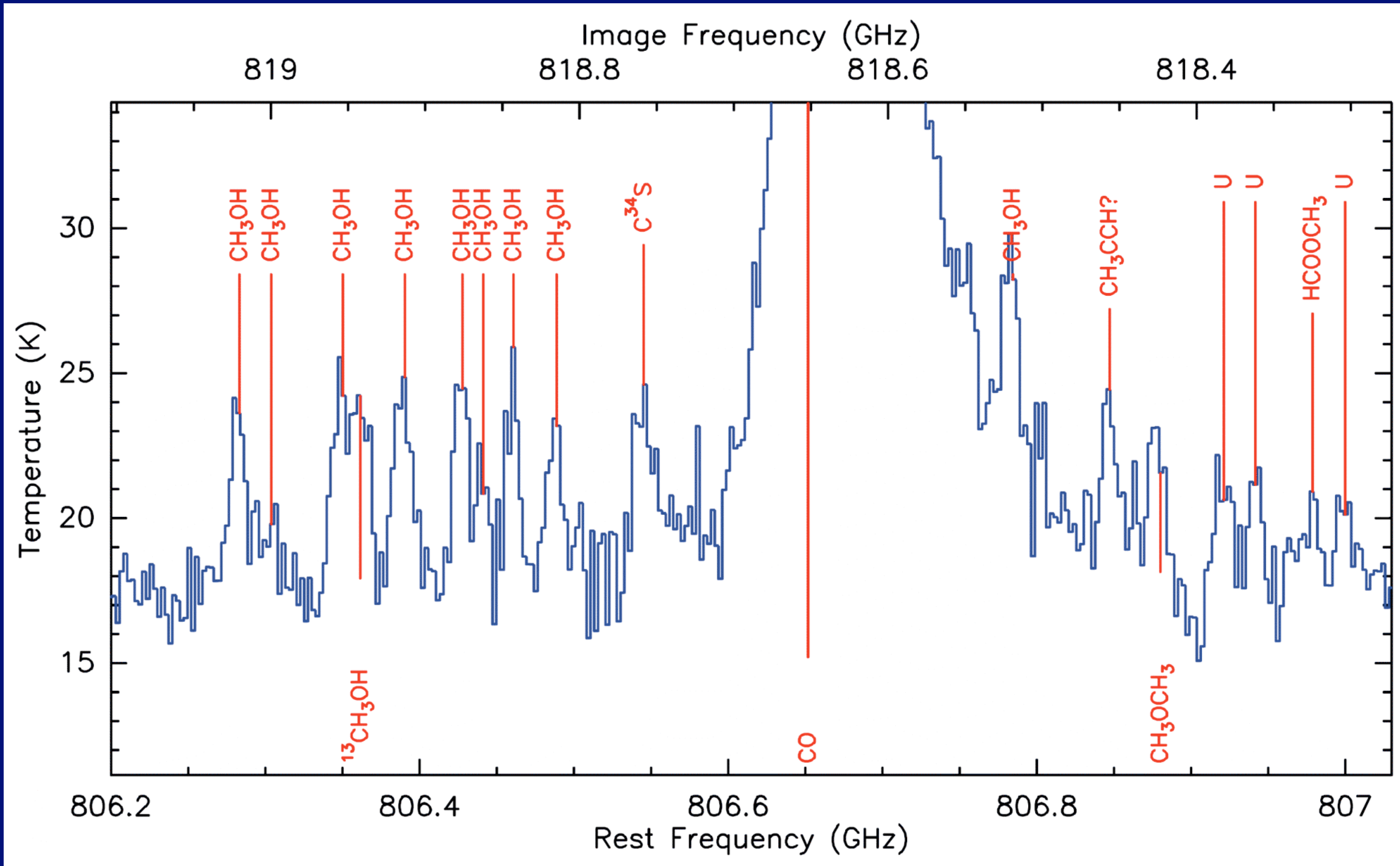

Long Standing Questions
How and where are interstellar clouds made, and how long do they live?
Under what conditions do clouds form stars?
How do stars return enriched material back to the Galaxy?
How do these processes sculpt the evolution of galaxies?



Spectral diagnostics of the interstellar life cycle define a new, pressing need for large-scale, high resolution, ***THz*** spectroscopic surveys!

350μm Line Forest

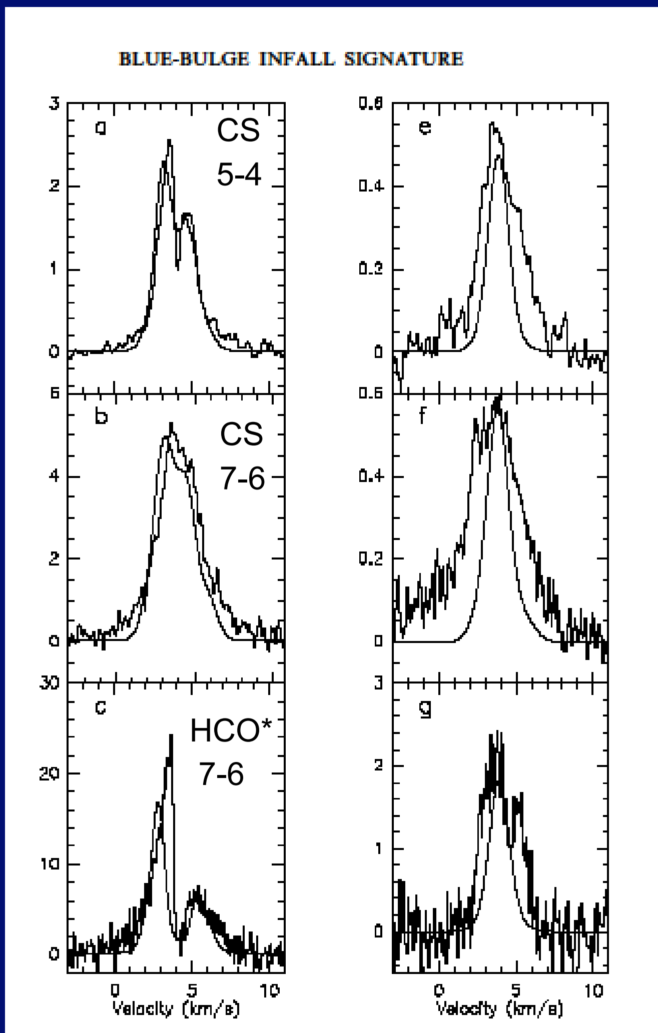
(Lis & Comito ,2006 - CSO)



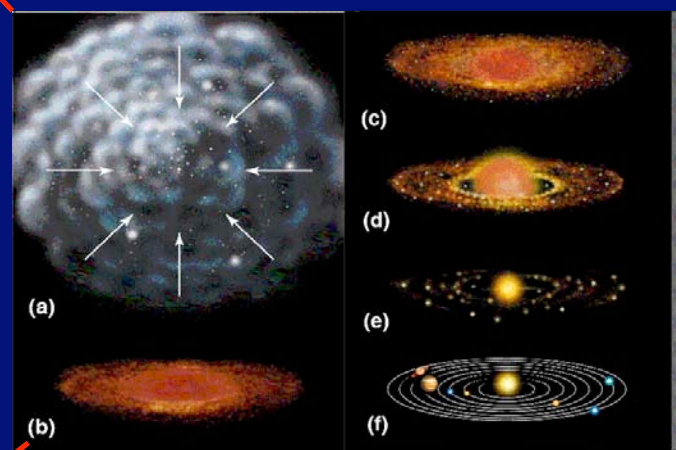
Probing ISM Dynamics

$R>10^6$

(Narayanan et al. 1998)

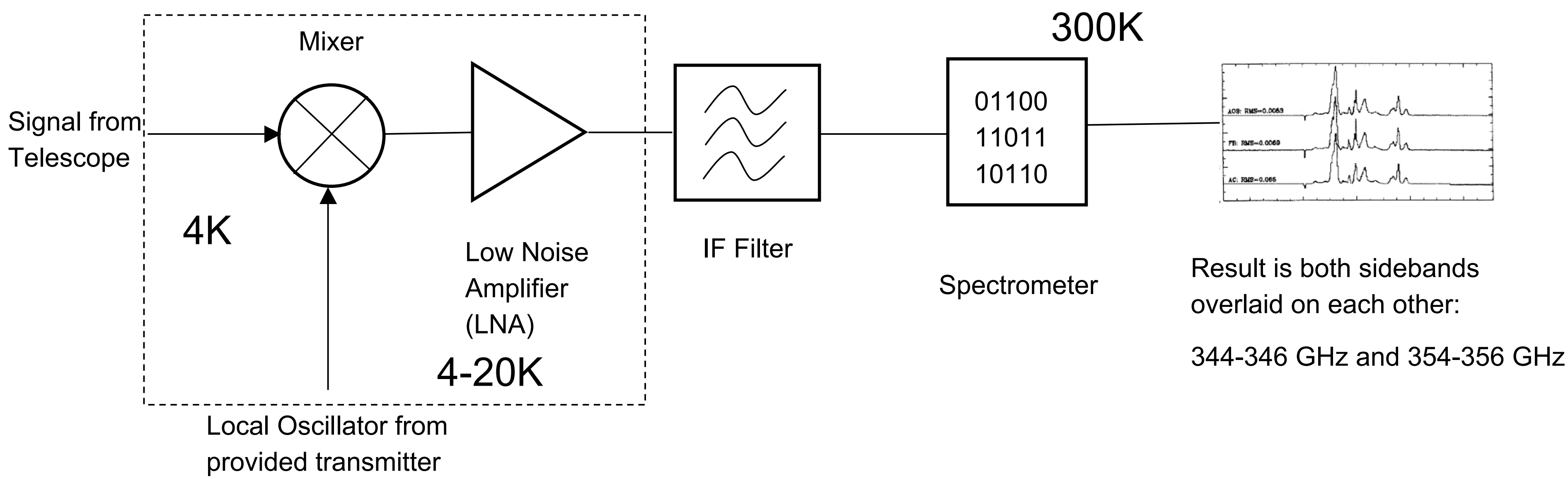


- **Different molecules are formed in regions with different internal and external conditions**



- **Lines are the *only* way to study the dynamics!**

Heterodyne Receivers for THz Radio Astronomy

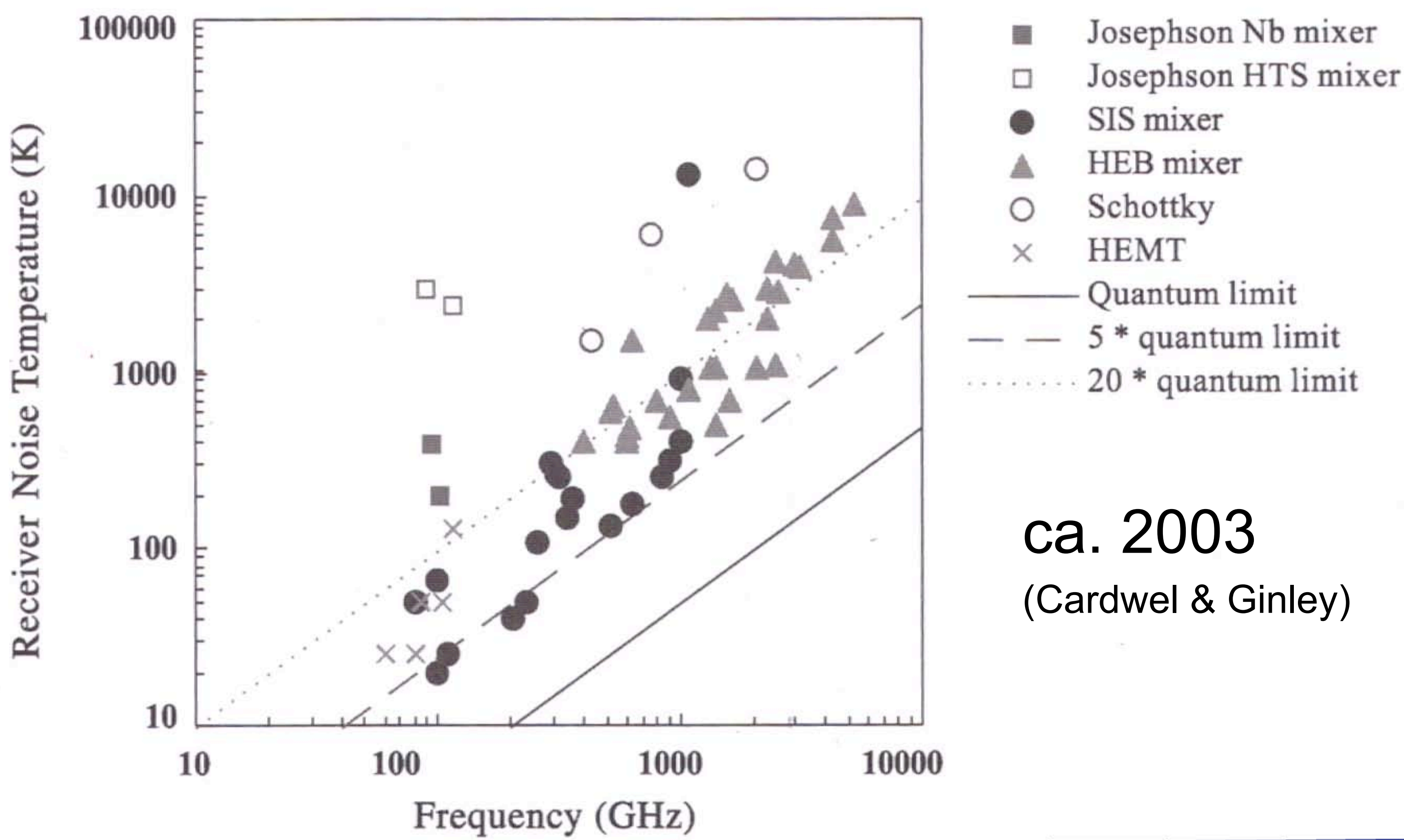


- •For THz astronomy, the frequencies of the signals we're interested in are too high to amplify directly, as in cm-wave radio astronomy.
- •Cryogenic mixers and LNAs are used almost exclusively in radio astronomy: they are at least one order of magnitude more sensitive than room temperature receivers.
- •Each pixel of a heterodyne receiver needs these critical components
- •While the technology to produce single channels has been refined over the years, very little work has gone into multipixel array development.

THz Arrays: Why Now?
A Confluence of Technologies:

- Mixer technology
- LO technology
- Micromachining
- IF amplifiers
- Digital signal processing

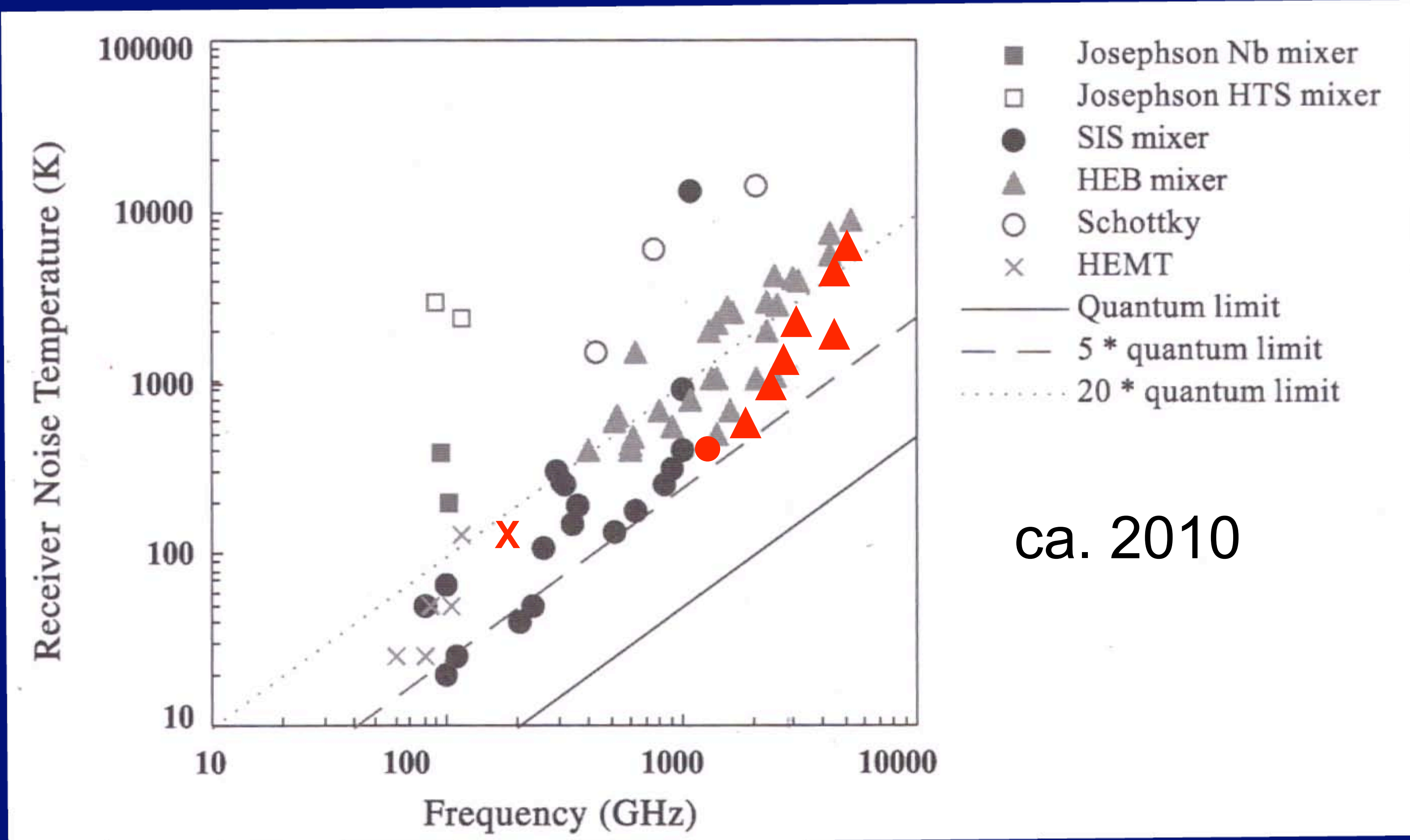
Evolution of Receiver DSB Noise Temperatures



ca. 2003

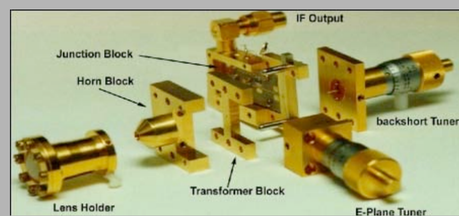
(Cardwel & Ginley)

Receiver DSB Noise Temperatures

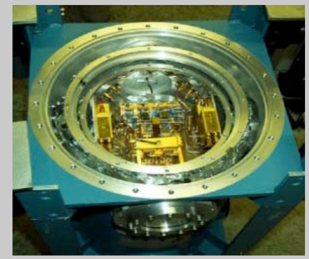


ca. 2010

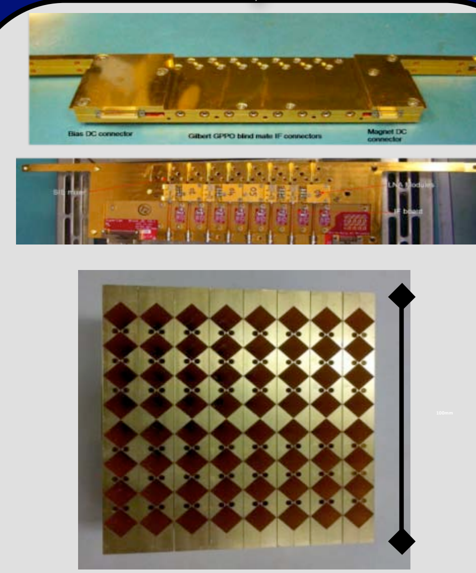
THz Mixer Evolution



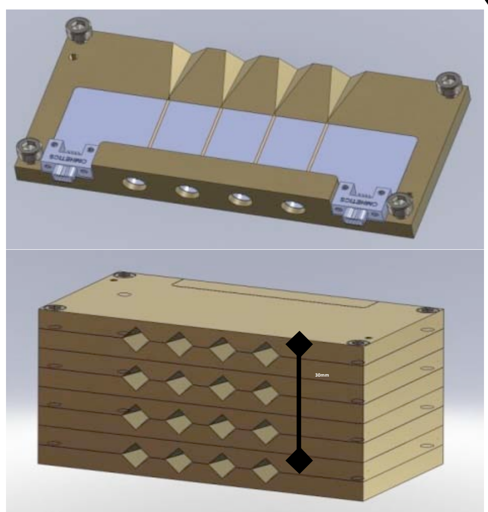
CSO Mixer @ 492GHz: 1990



4 pixel AST/RO array @ 810GHz

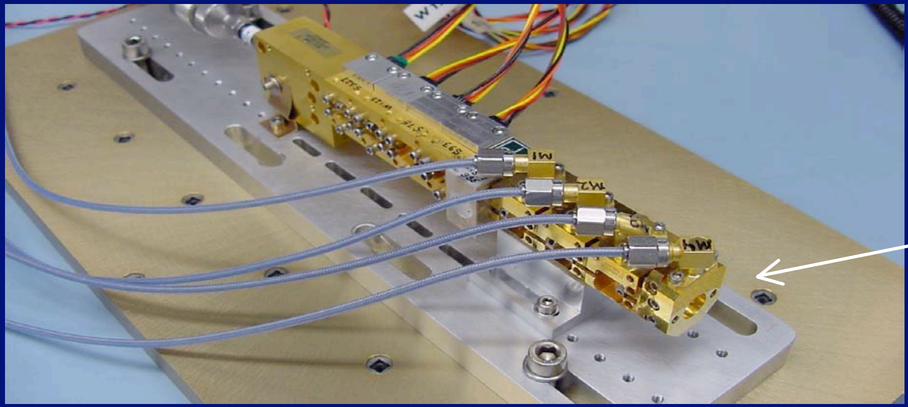


Stacked 1x8 Linear Arrays @ 350 GHz

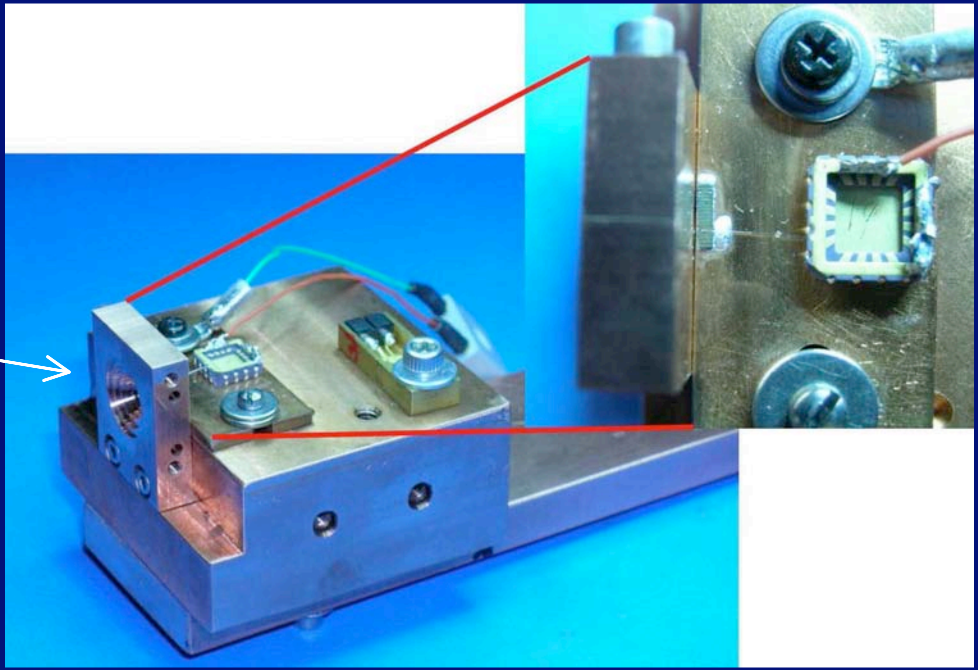


Prototype: 2 THz Stacked Linear Arrays

Local Oscillator (LO) Sources for Arrays



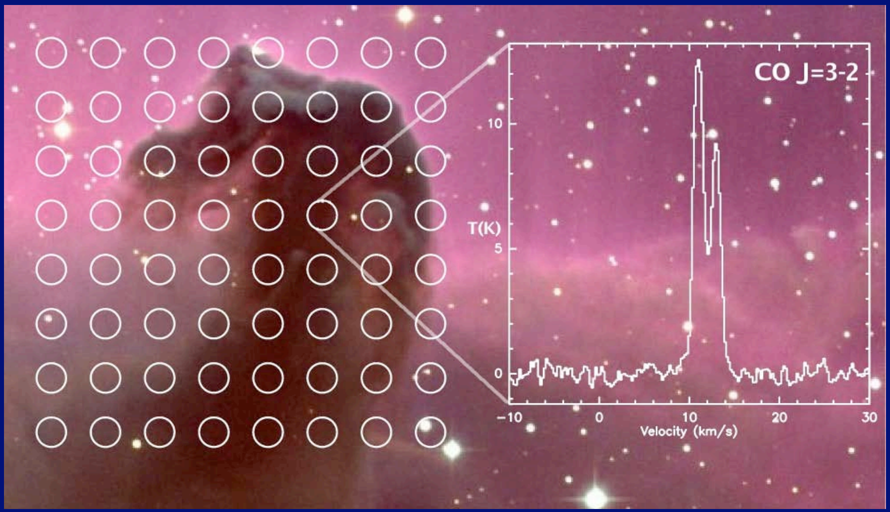
Frequency Multiplied Sources
Freq. ≤ 2.7
(JPL)



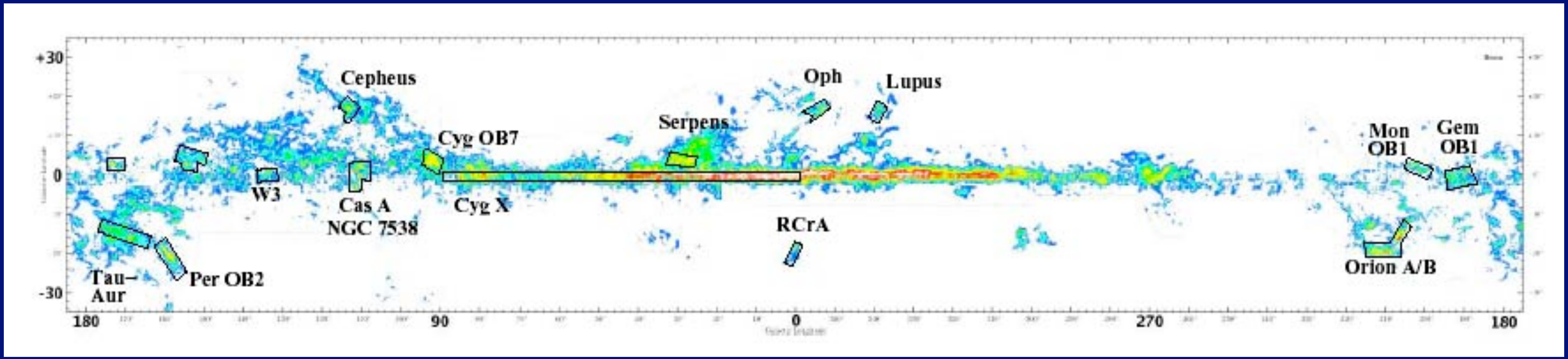
Quantum Cascade Lasers
Freq. ≥ 2.7
(MIT, DLR, SRON)

Large Format Heterodyne Array: SuperCam

- SuperCam is a 8x8 pixel heterodyne array receiver (imaging spectrometer), designed to operate in the 870 μm atmospheric window at the 10m Heinrich Hertz Telescope.
- SuperCam will be two orders of magnitude faster than current generation single pixel receivers..
- Key project: fully sampled $^{12}CO(3\text{-}2)$ and $^{13}CO(3\text{-}2)$ survey of over 500 square degrees of the Galactic plane.

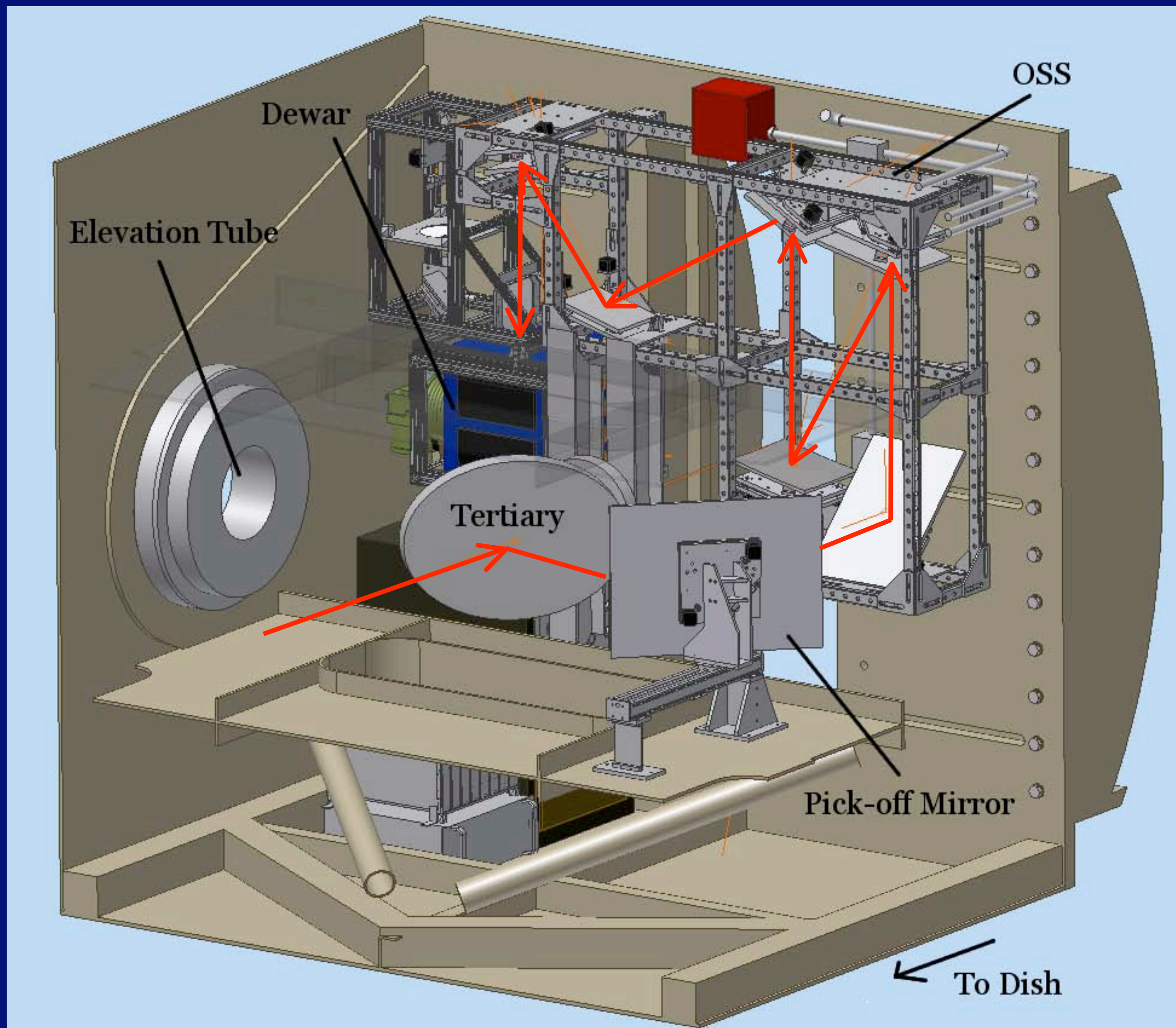


SuperCam Survey

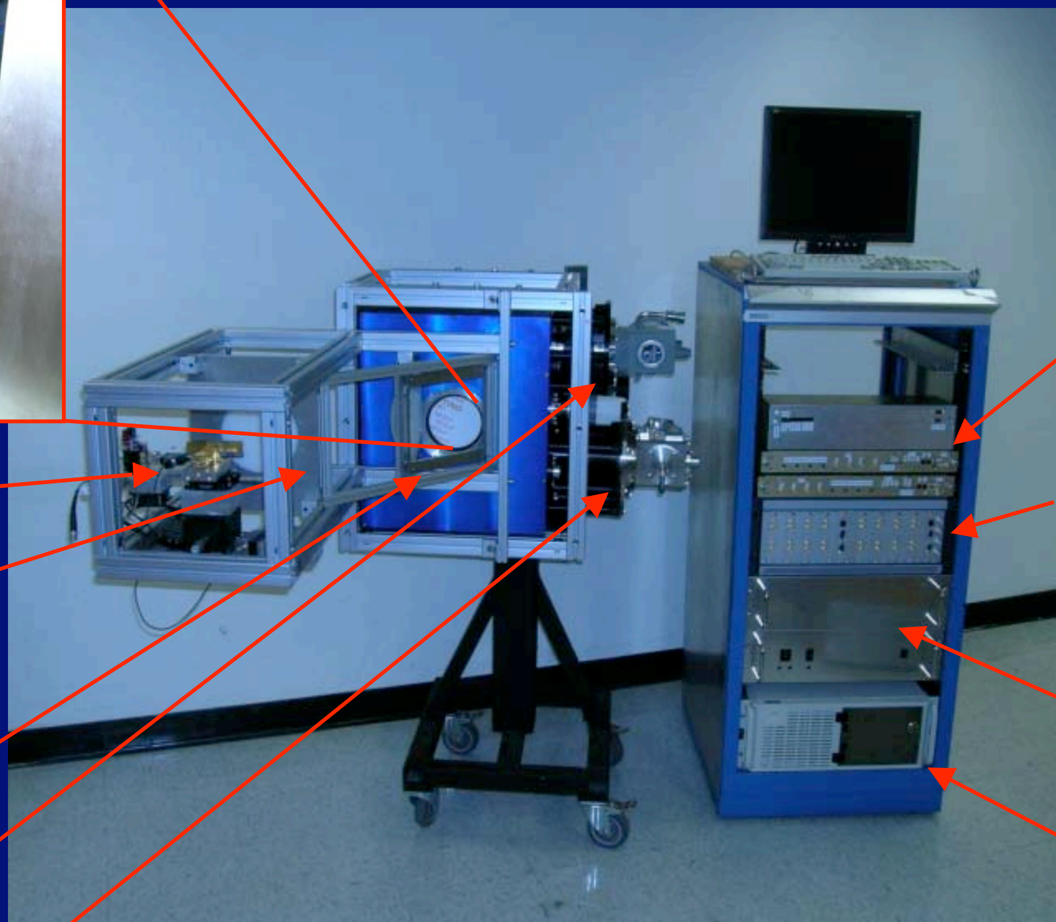


- Proposed Survey: 500 sq. degrees including l=0-90°, and targeted star forming clouds, 22" resolution. 0.3 km/s velocity resolution
- $^{12}CO(3\text{-}2)$ and $^{13}CO(3\text{-}2)$
- 1 MONTH of SuperCam = ~6 YEARS of single pixel observing

SMT Relay Optics



SuperCam System



LO System with 8 way power divider

LO Optics

LO Beamsplitter & dewar window

CTI 350 cooler

Sumitomo 4K cooler

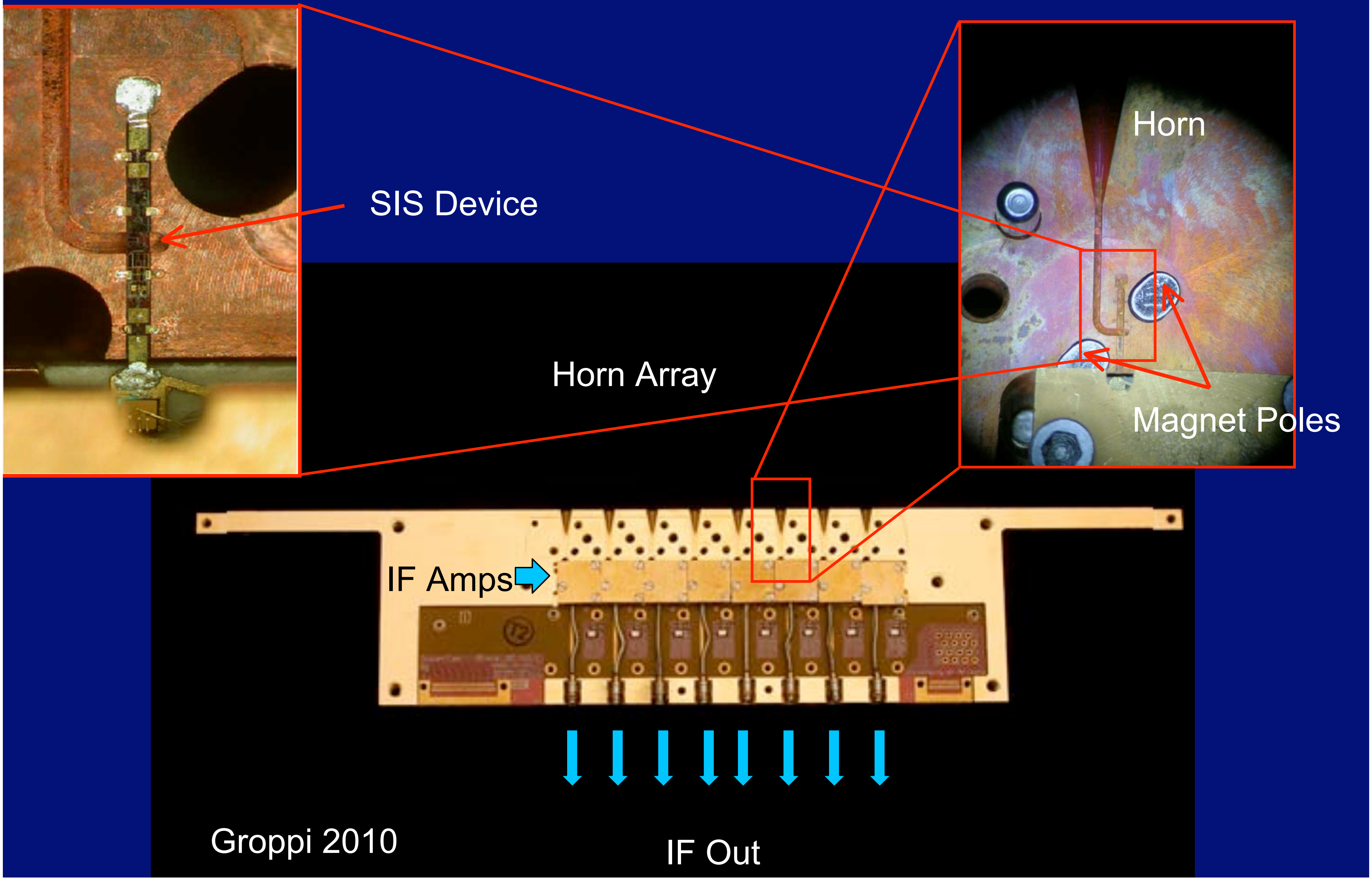
2- 8 channel downconverter modules

Omnisys Spectrometer 64x250 MHz complete system

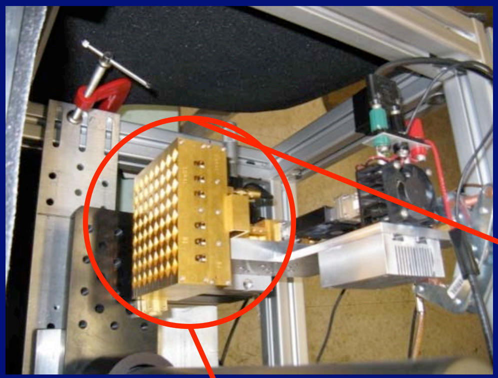
Prototype 8 channel bias system (1 6U card with power supplies)

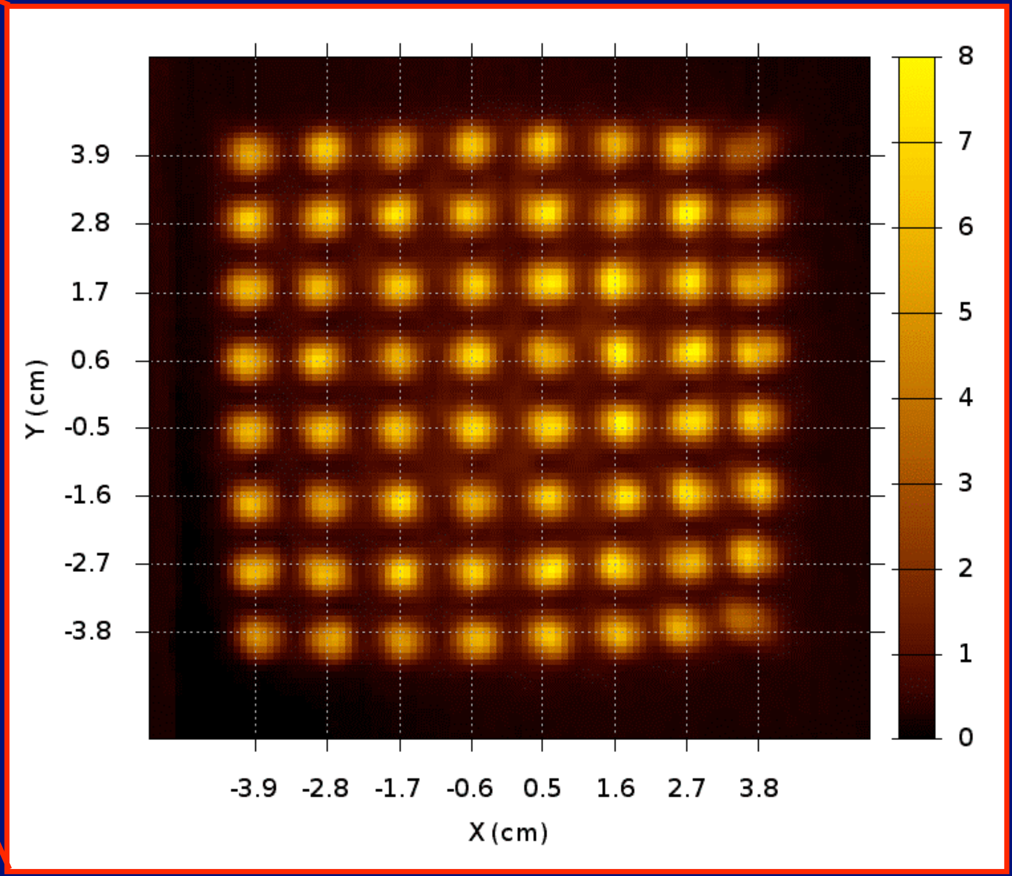
Spectrometer and bias control computer

Anatomy of a SuperCam Subarray



64 Gaussian Beams





SuperCam goes into operation on the SMT this winter!

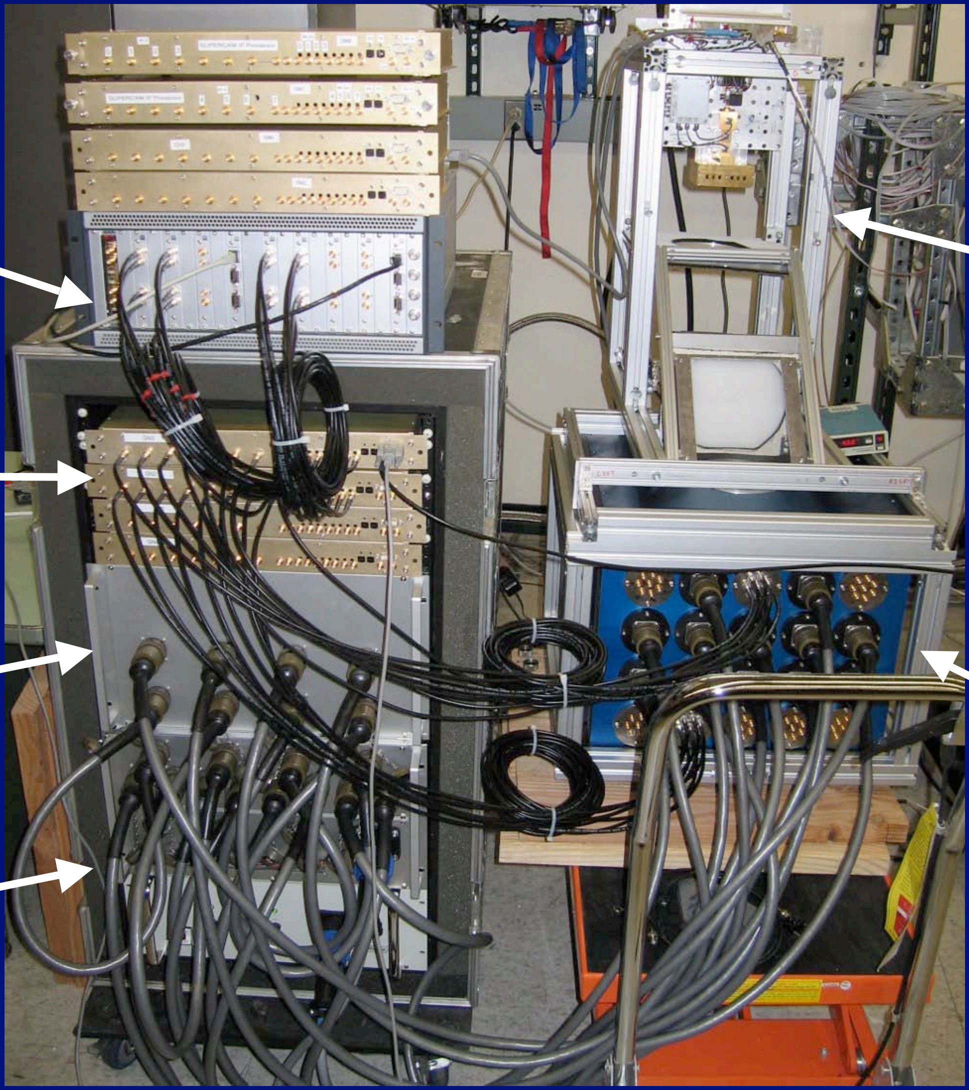
Lab integration of SuperCam

16 GHz FFT spectrometer

IF processor

Preamps

DC bias electronics



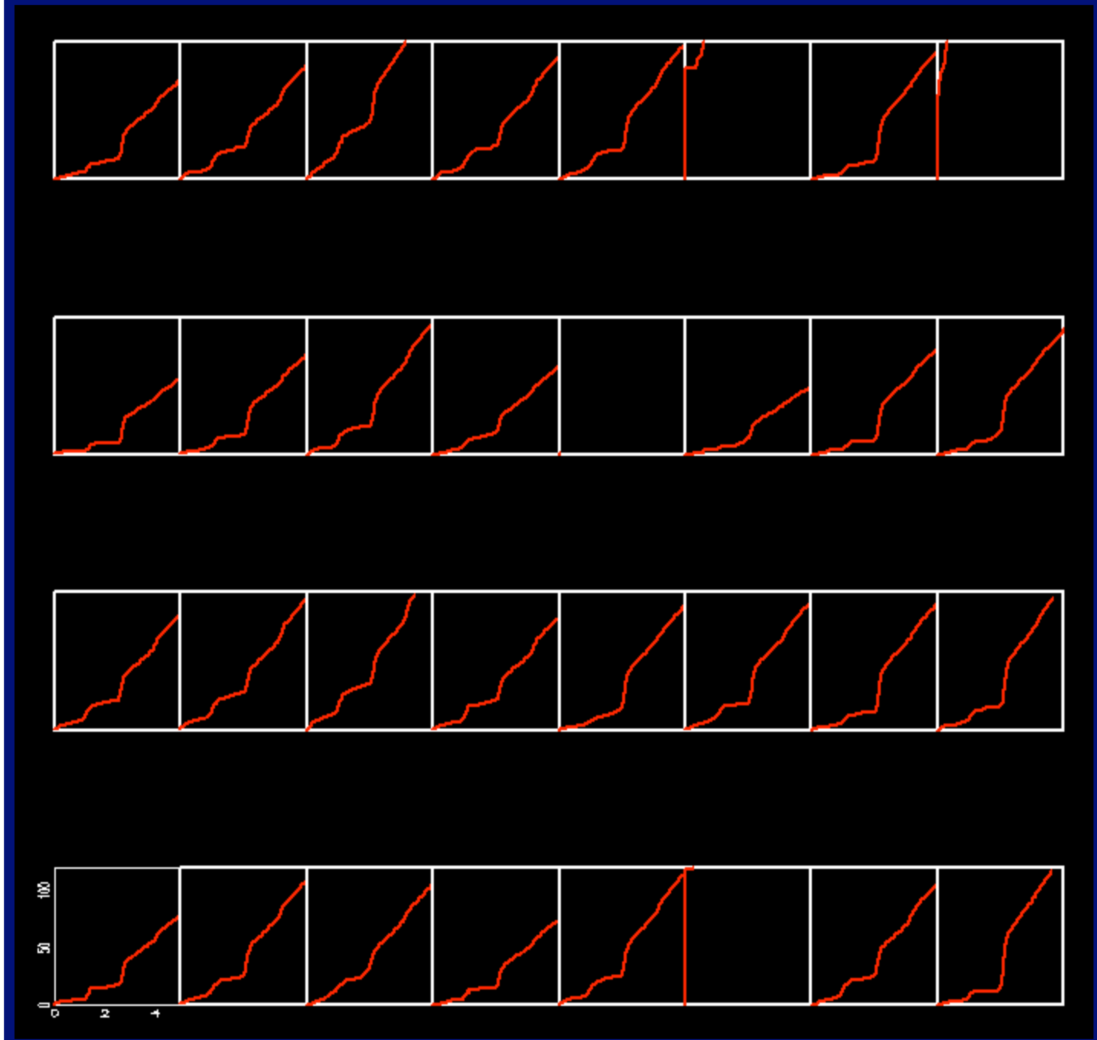
13 mW 345 GHz LO source w/ 64-way waveguide power divider

SuperCam cryostat

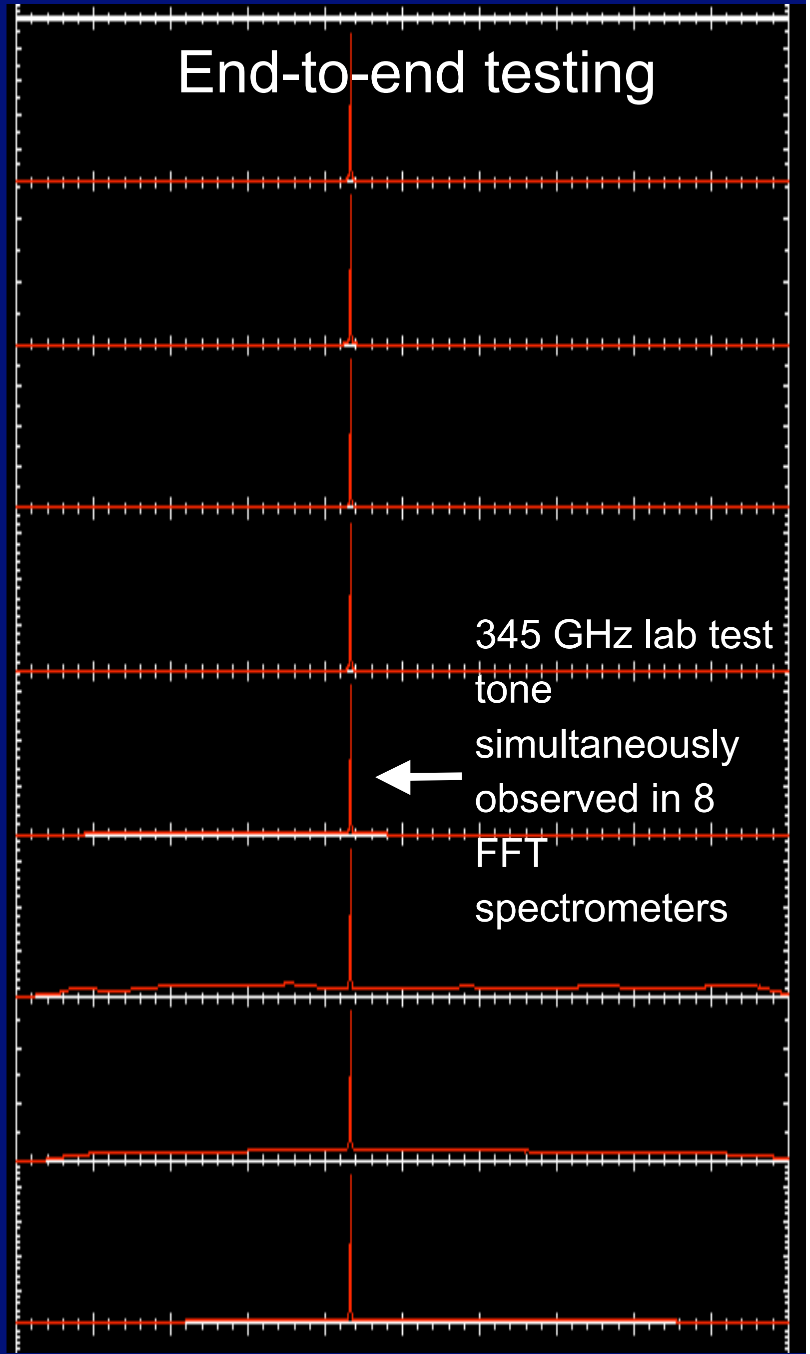
I-V curves of first 32 installed mixers

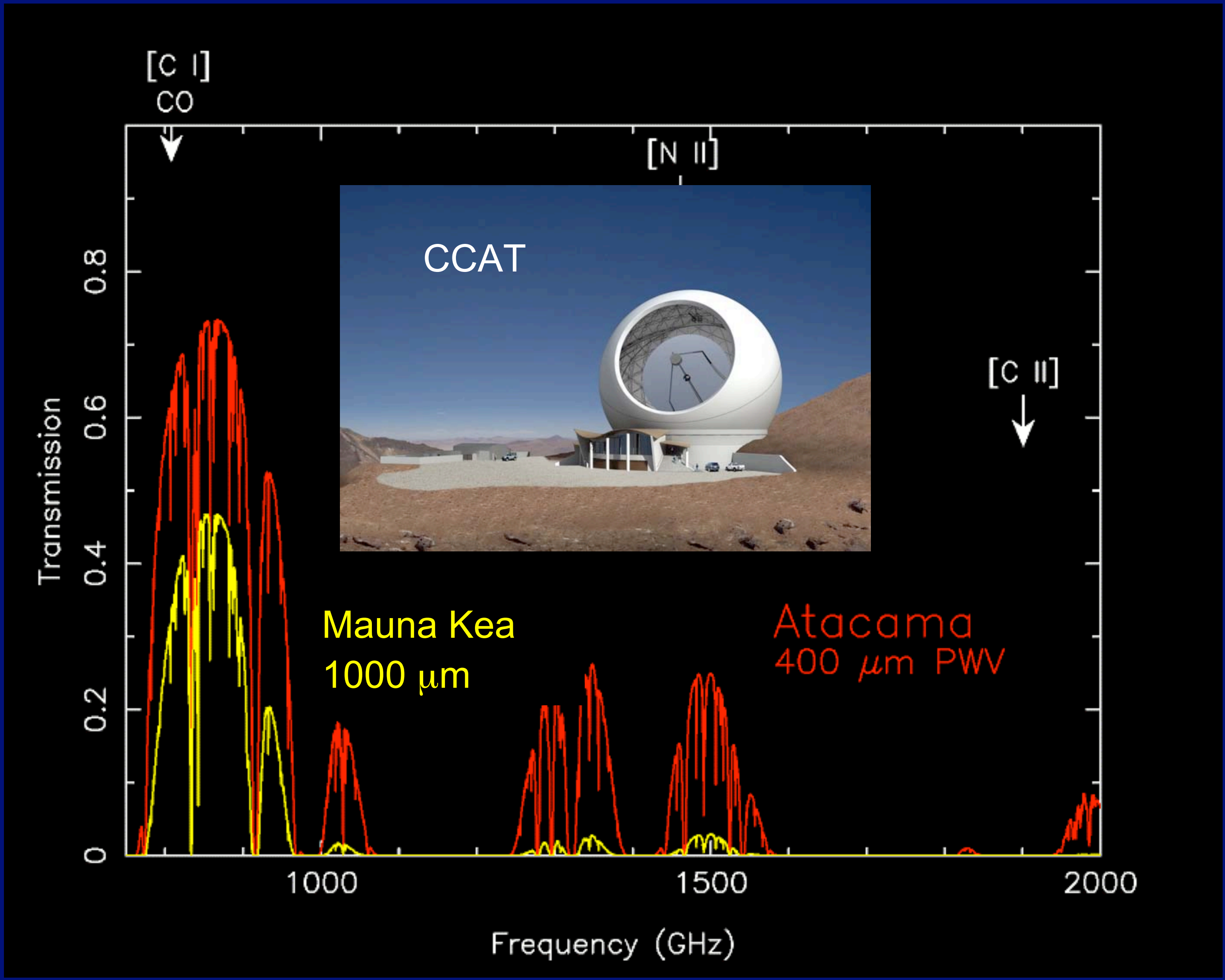
Yield (randomly selected): 28/32 devices

Mixer DSB noise temp range: 65-90K



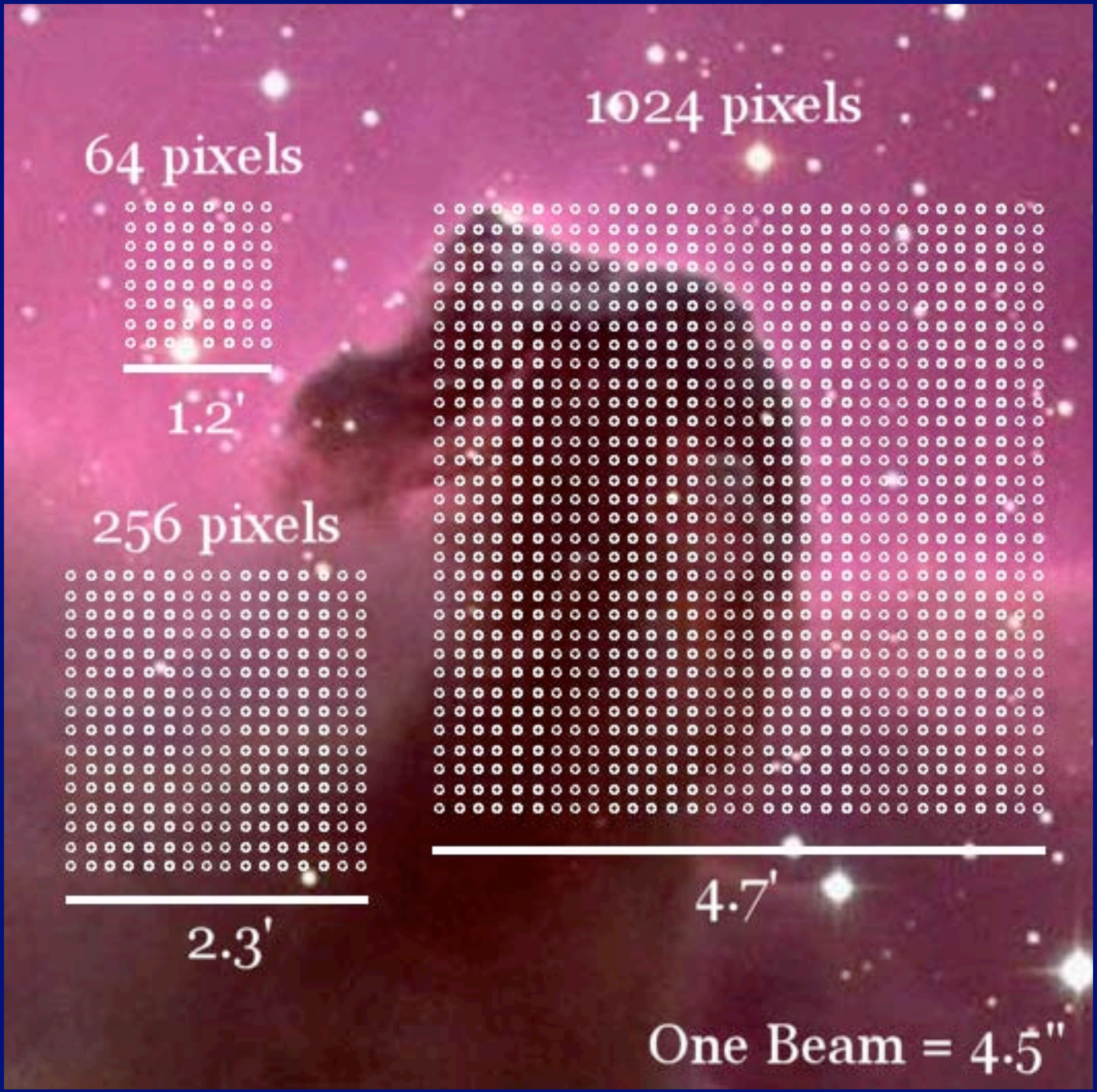
32 more mixers to be installed this month!





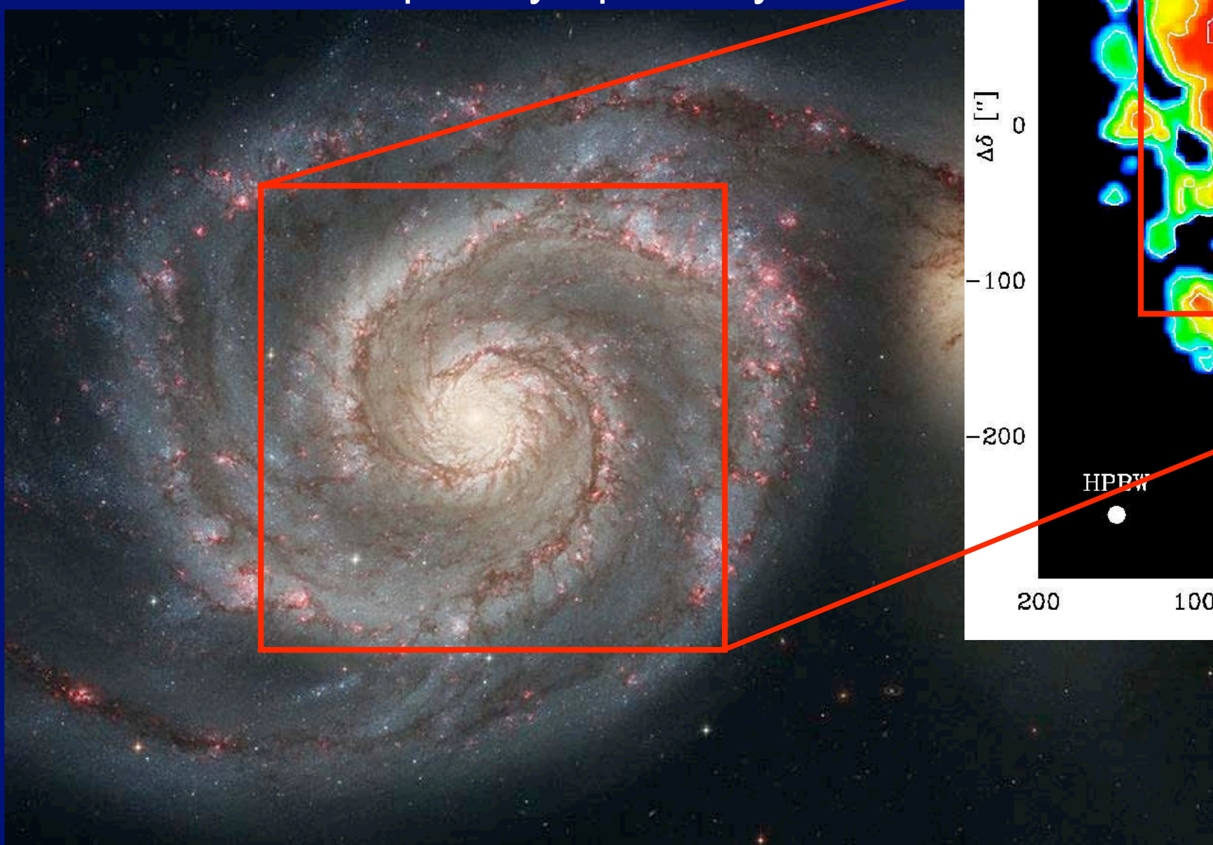
[C I]
CO
[N II]
CCAT
[C II]
Transmission
0
0.2
0.4
0.6
0.8
Mauna Kea
1000 μm
Atacama
400 μm PWV
1000
1500
2000
Frequency (GHz)

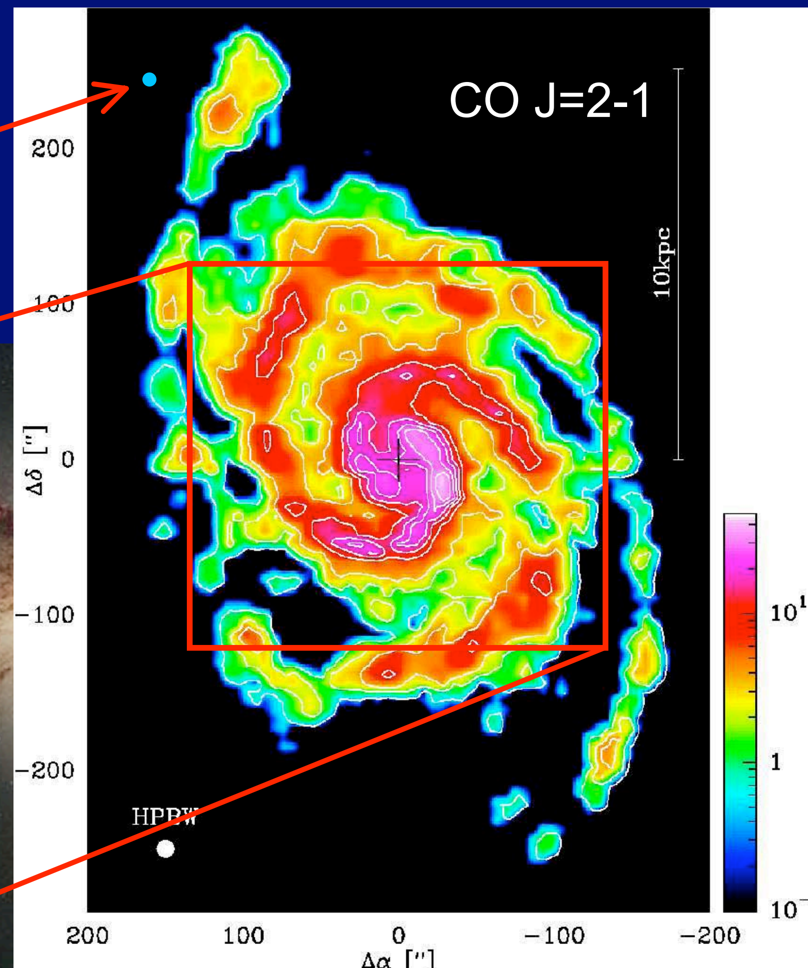
Prospects for Kilo Pixel Arrays



Nearby Galaxies

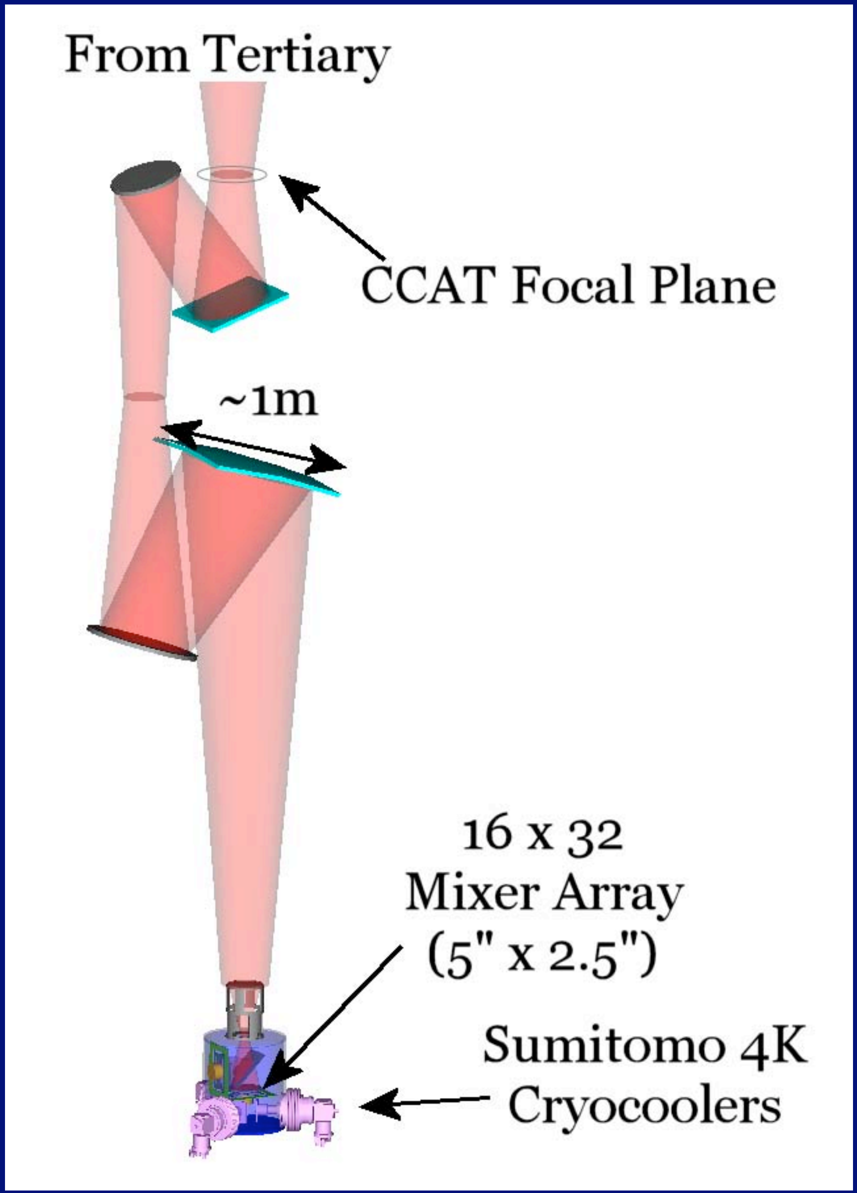
CCAT Beam (660 GHz)
Resolve GMCs/HII regions
➡ Spatially/Spectrally





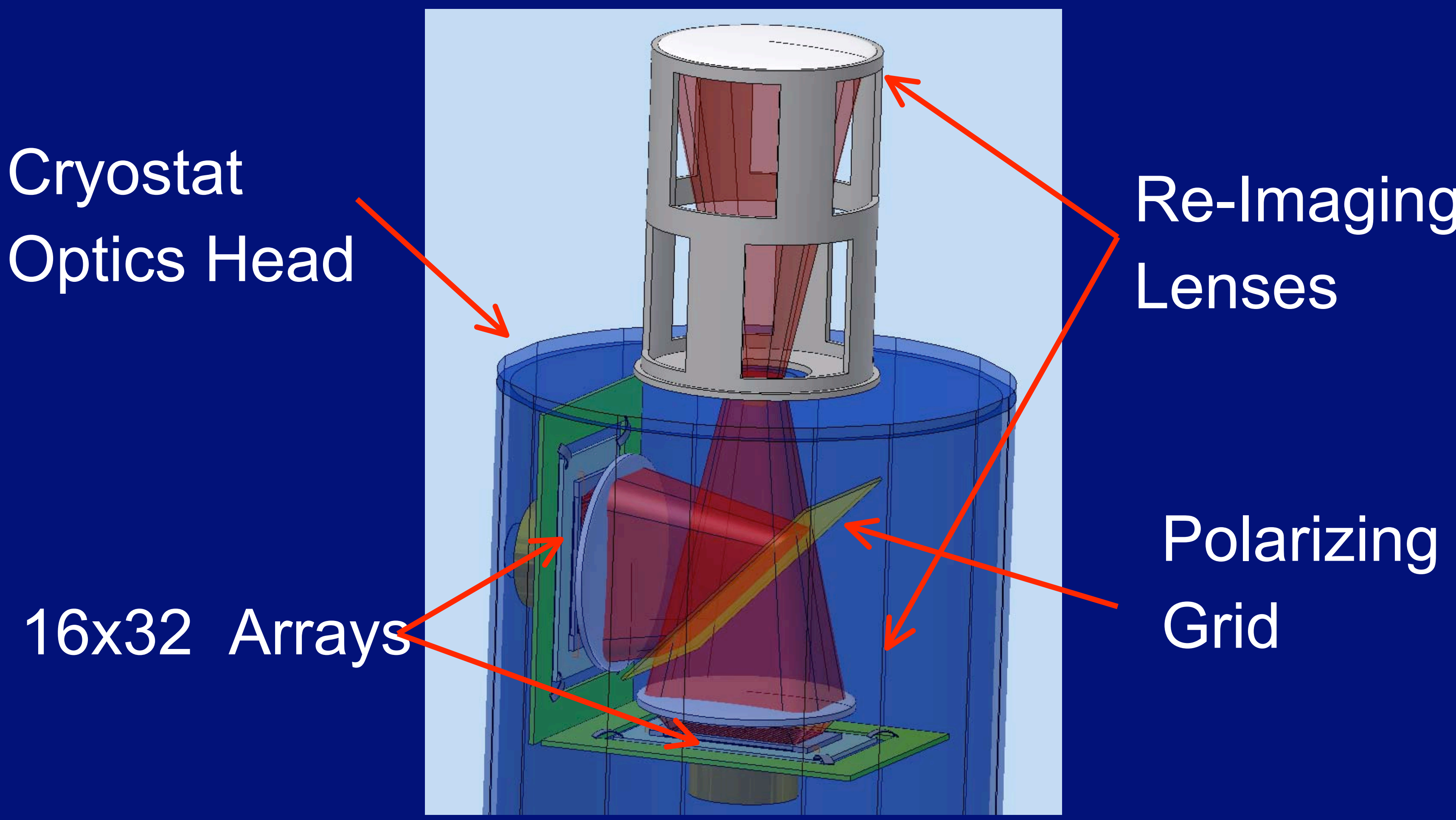
(Kramer et al. 2006)
18 pixel HERA on 30m

Kilo-Pixel Heterodyne Camera for CCAT: KCAM

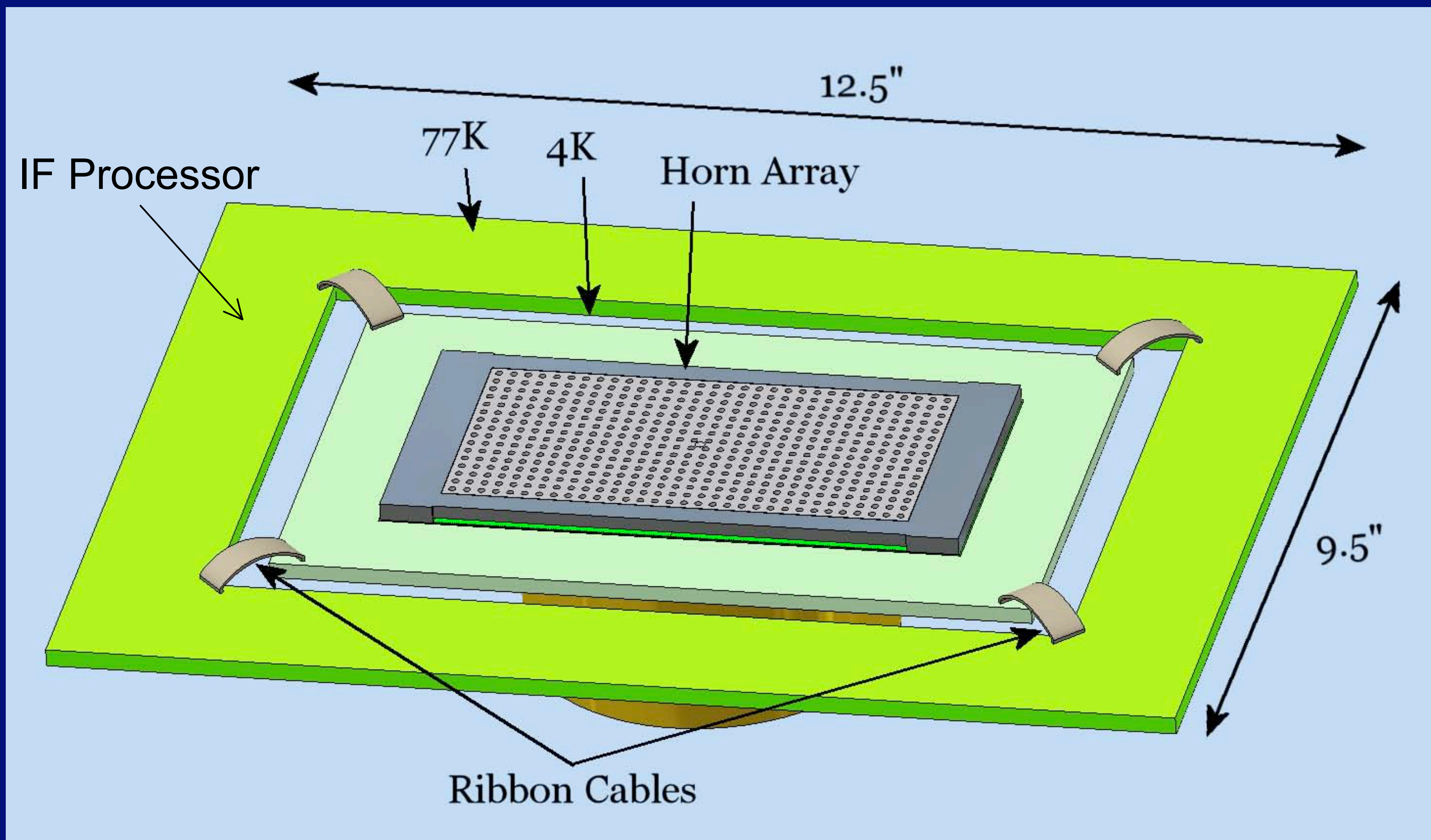


- Stacked,16x8 arrays
- MMIC IF modules
- On-board IF processor
- Solid-State LOs (~5mW)
- >2 GHz/per pixel
- Cryo-Coolers

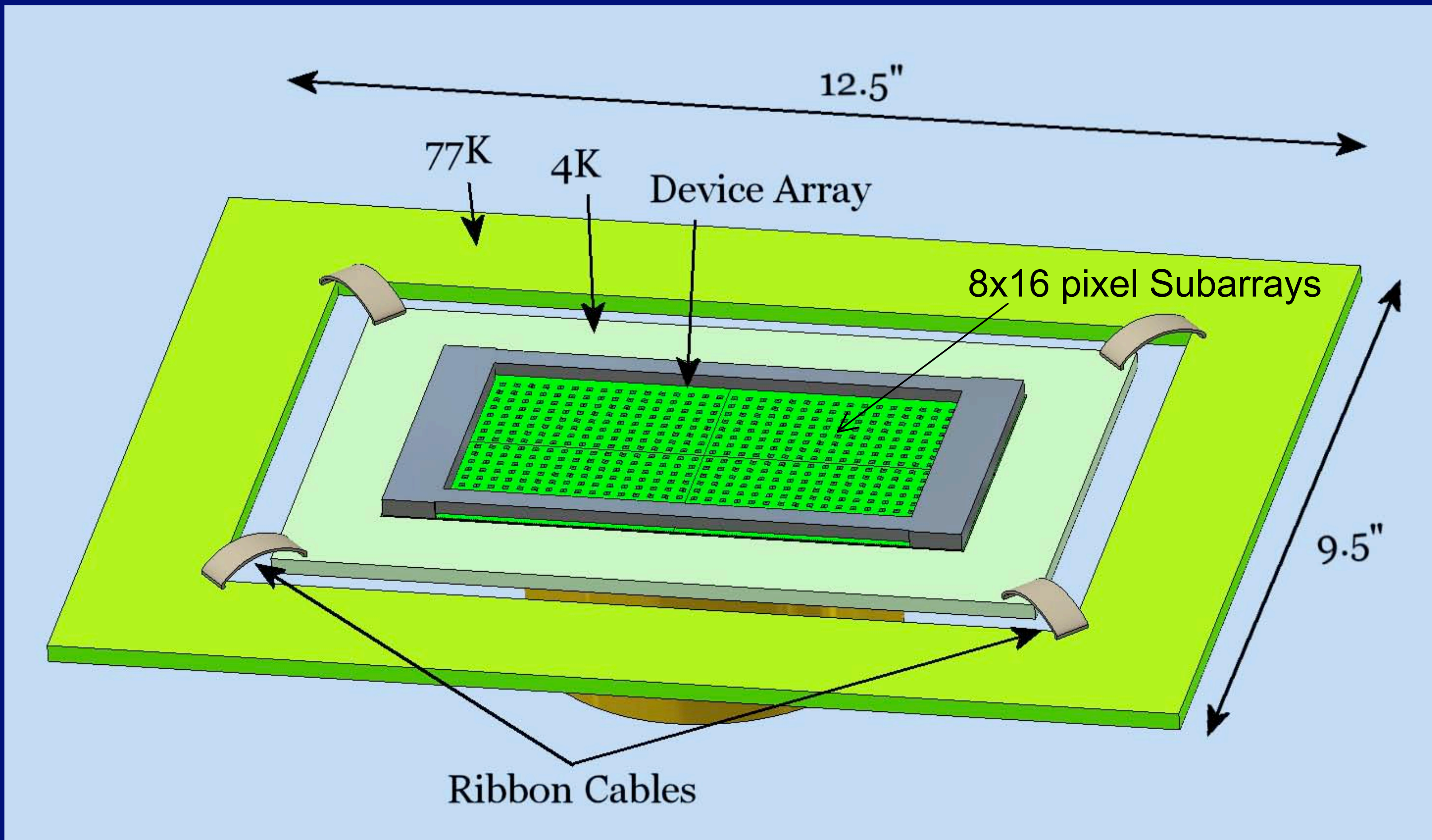
KCAM FPU


Cryostat
Optics Head
Re-Imaging
Lenses
Polarizing
Grid
16x32 Arrays

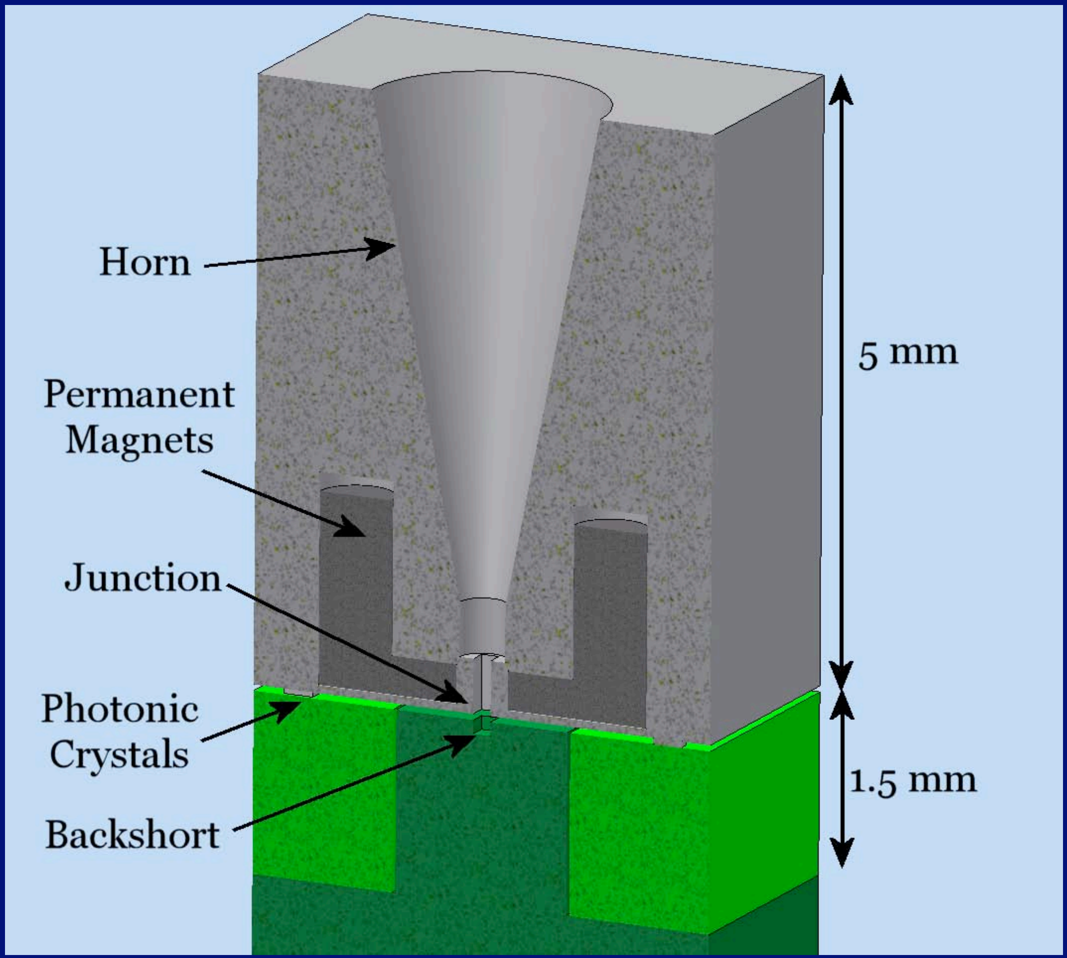
2D Integration: 16x32 Array Concept



2D Integration: 16x32 Array Concept

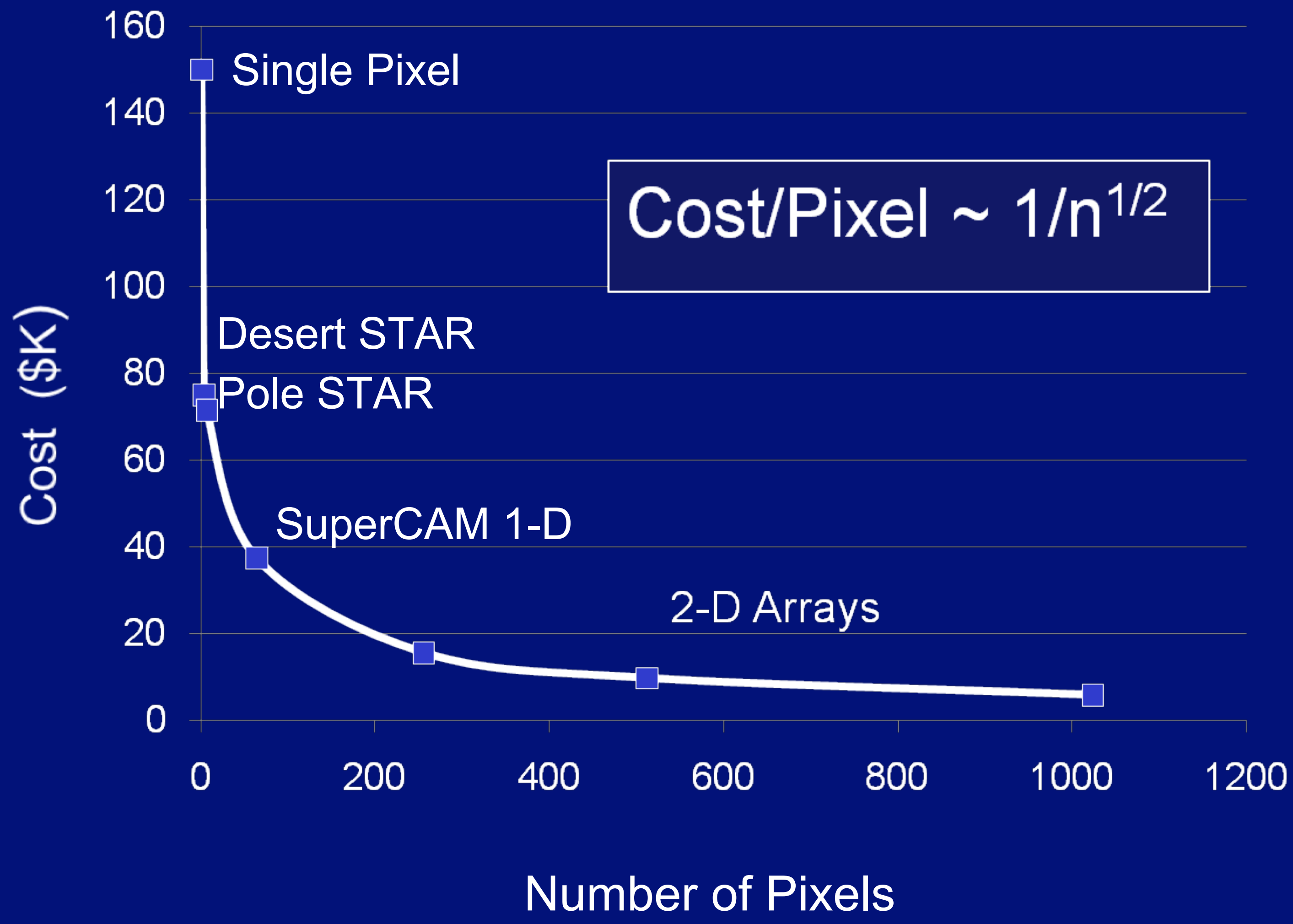


Stacked Pixel Concept



Proof-of-Concept 2D 0.69 THz Array recently funded by NSF:
Work beginning (PI.Groppi ASU/ UofA/CIT/UVa)

Cost/Pixel vs. Size



Summary

- A confluence of technologies now permits the realization of large format heterodyne arrays.
- Integration essential to increasing robustness and minimizing cost.
- By swapping mixer arrays and expanding the spectrometer (1 GHz/pixel), 64 pixel SuperCam could be used on CCAT at 650/810 GHz (~$1M).
- ~1K pixel heterodyne array would cost ~$6M.
- Development of a prototype 2-D integrated array is now ***underway*** (Groppi et al.).

Thank You!