Next Steps in Ground Based (Sub) Millimeter Wave Instrumentation

- Instrumentation for large single dish telescopes and its impact on ALMA
- Next Steps in Interferometry Instrumentation
- Where can we rely on industry progress ?
- What do we need to develop by our own ?

Instrumentation for large single dish telescopes and impact on ALMA (I)

Spectroscopy Receivers

Sensitivity, Wideband, Multiband, Multibeam

-wideband : allow instantaneous spectral fingerprinting

-multiband : spectral fingerprinting and
optimized calibration for multi transition analysis

-multibeam : high sensitivity large scale mapping,
source finding, short spacing information
for interferometry

NRO 45m, IRAM 30, JCTM, APEX, ASTE, CSO,
Yebes 40m, GBT, LMT, CCAT,

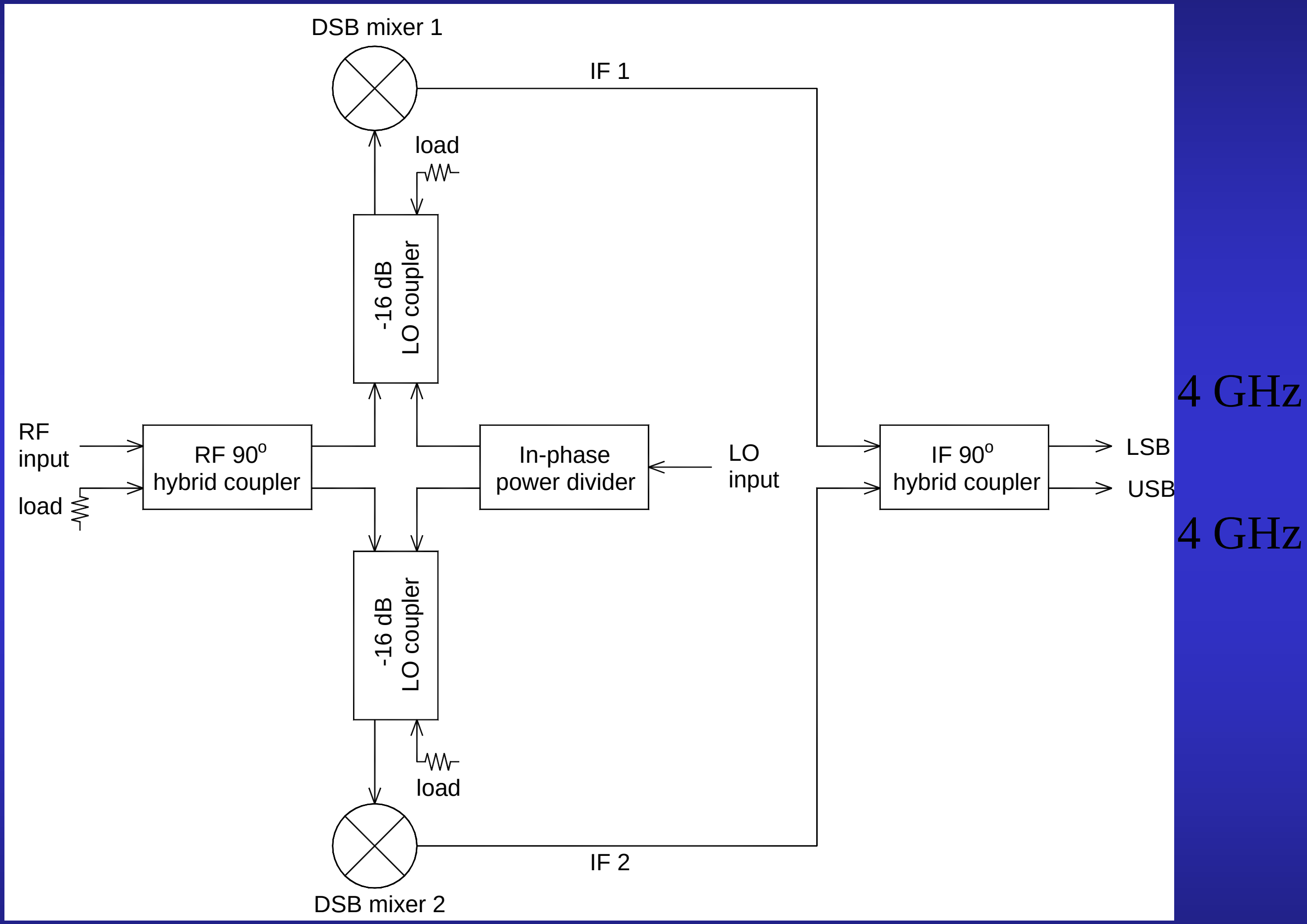
Current ALMA receiver technology is the result of a very interactive community which has been built up through:

-Collaborations on ground based facilities

-HERSCHEL HIFI and SOFIA

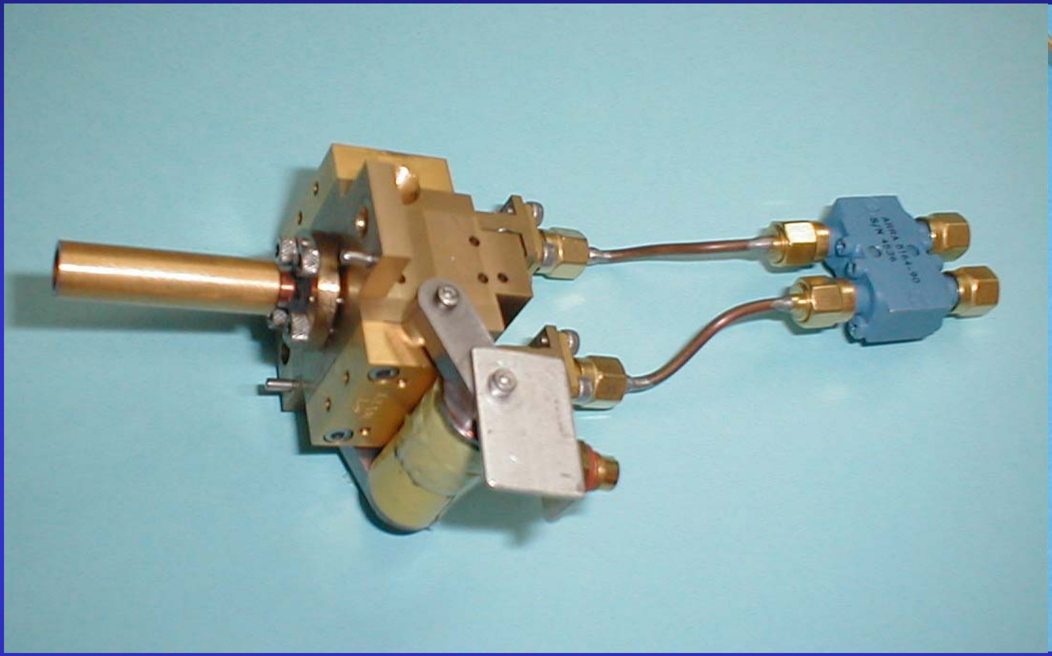
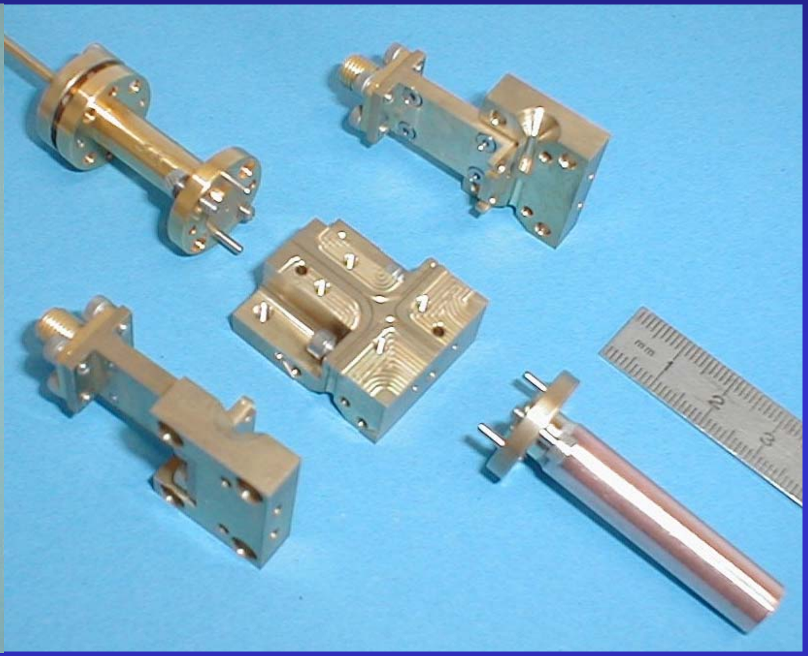
-European FP6 program AMSTAR

Sideband separating (2SB) mixer
B3 to B7



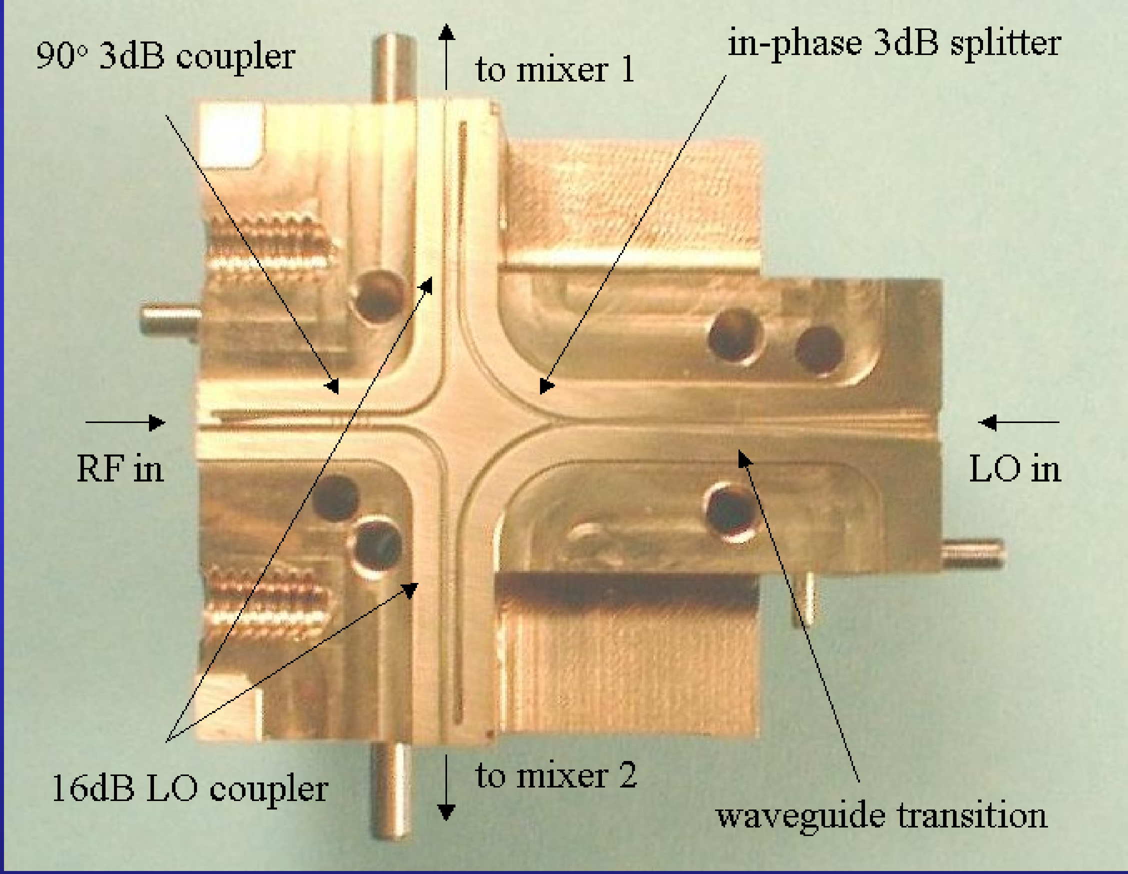
=> 2SB mixer = RF coupler + 2 DSB mixers + IF coupler

325 GHz 2SB mixer assembly

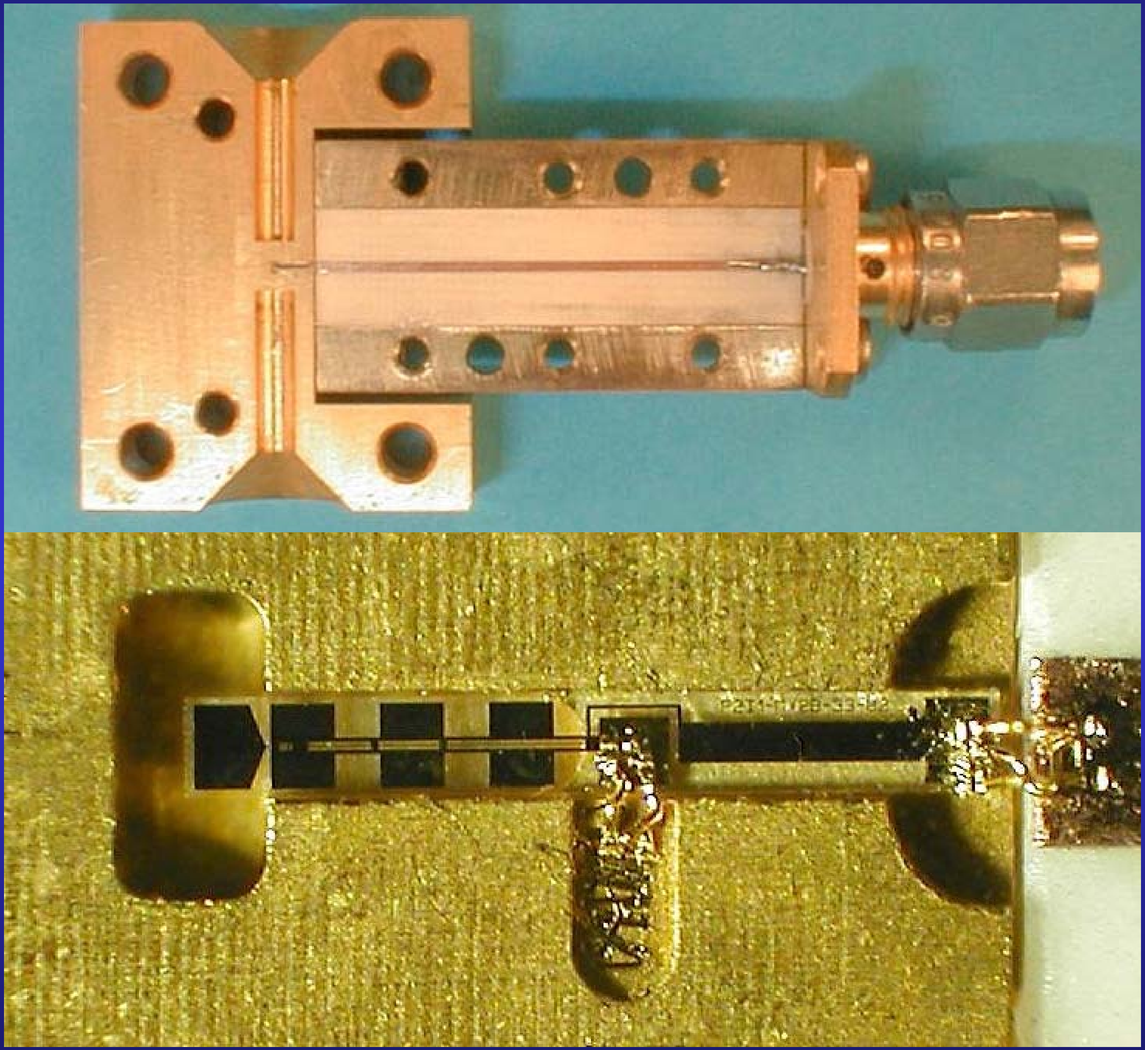



- RF frequency range: 275 – 373 GHz
- IF frequency range: 4 – 8 GHz
- ALMA Band 7/PdBNG Band 4/EMIR Band 4

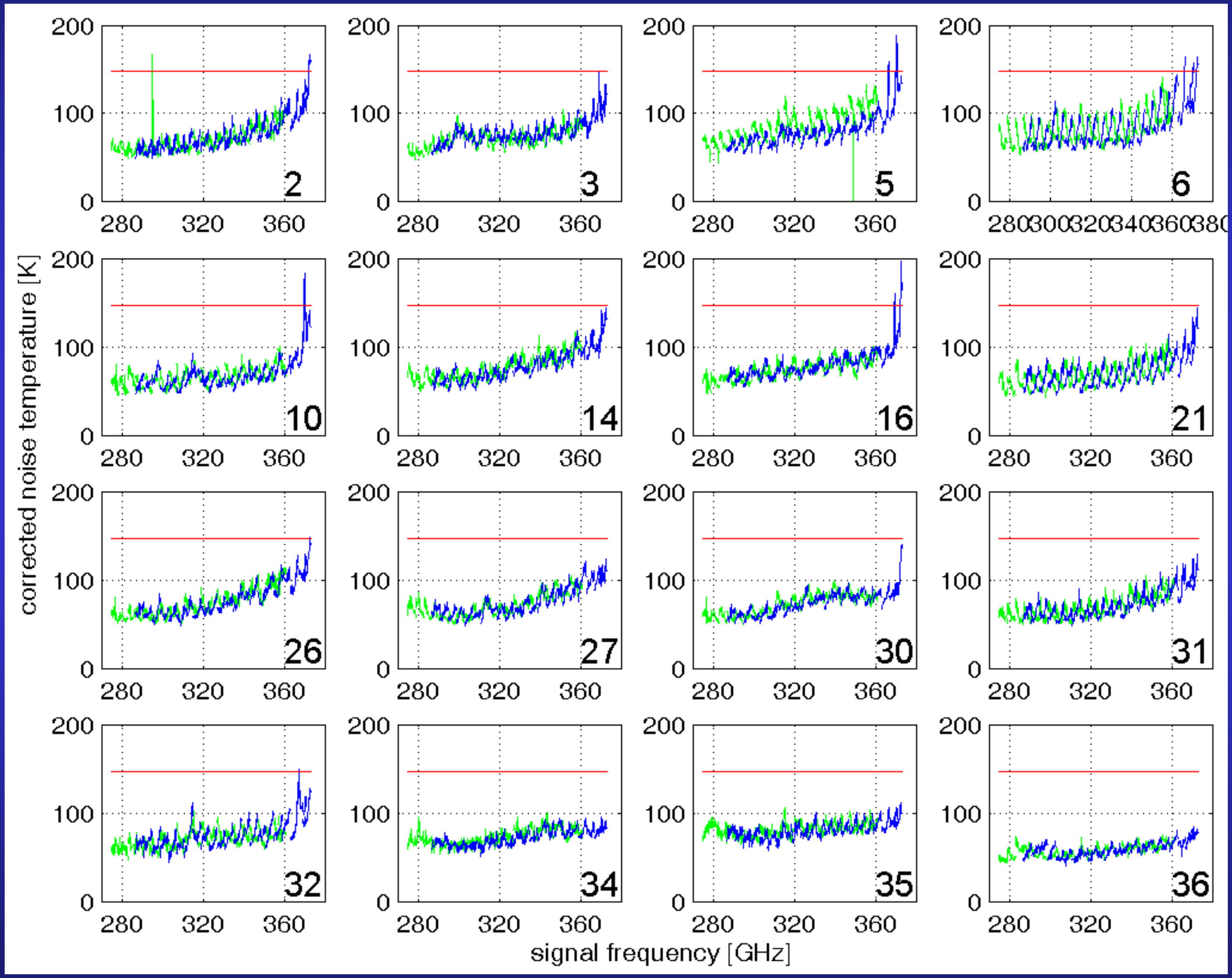
RF waveguide coupler



325 GHz DSB mixer



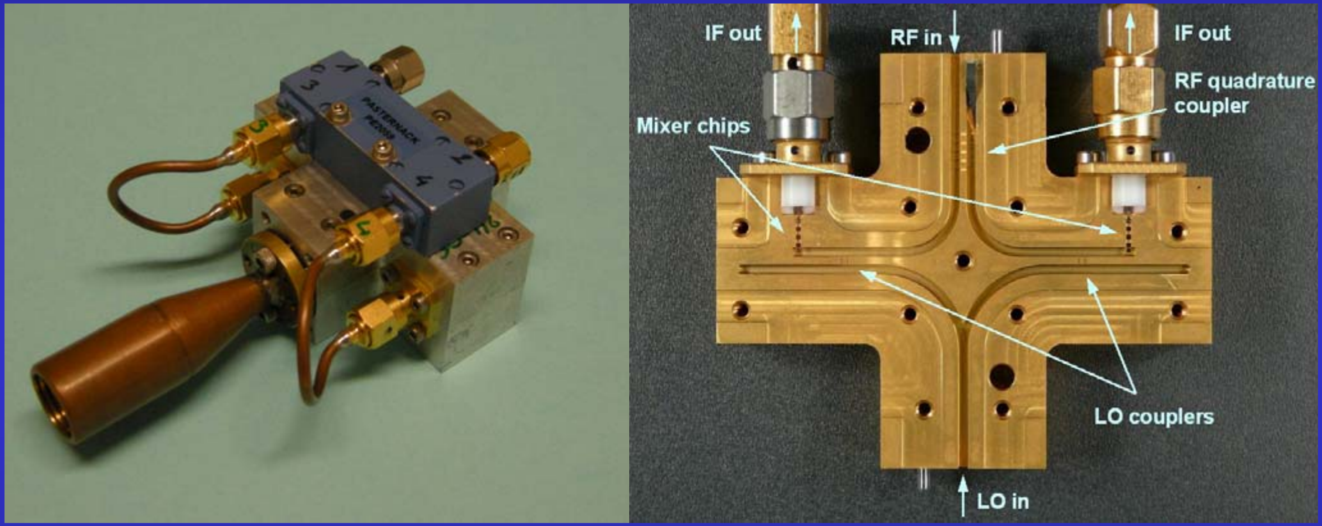
ALMA Band 7: RF noise



The next Steps

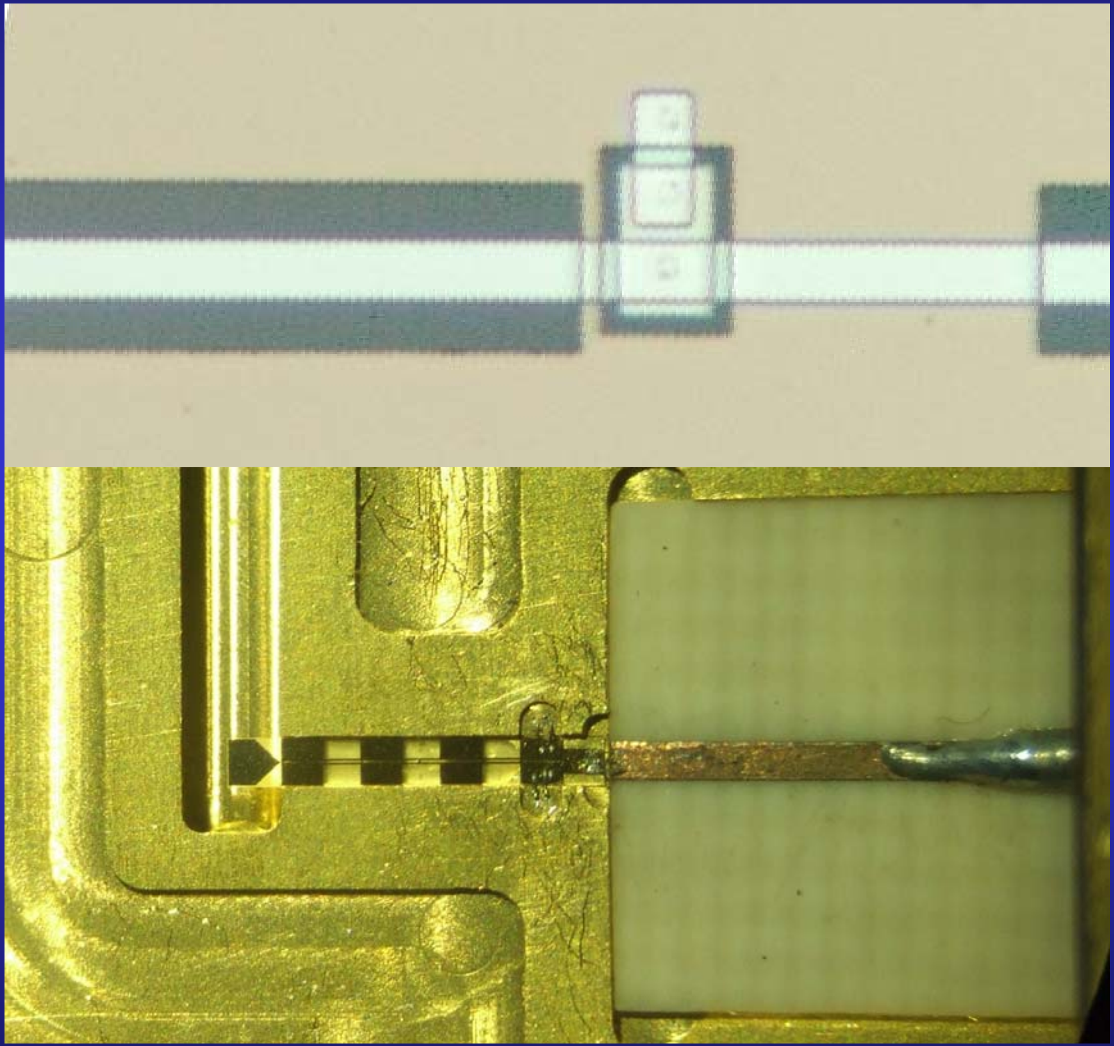
WB 100 GHz 2SB mixer

D. Maier et al 2008

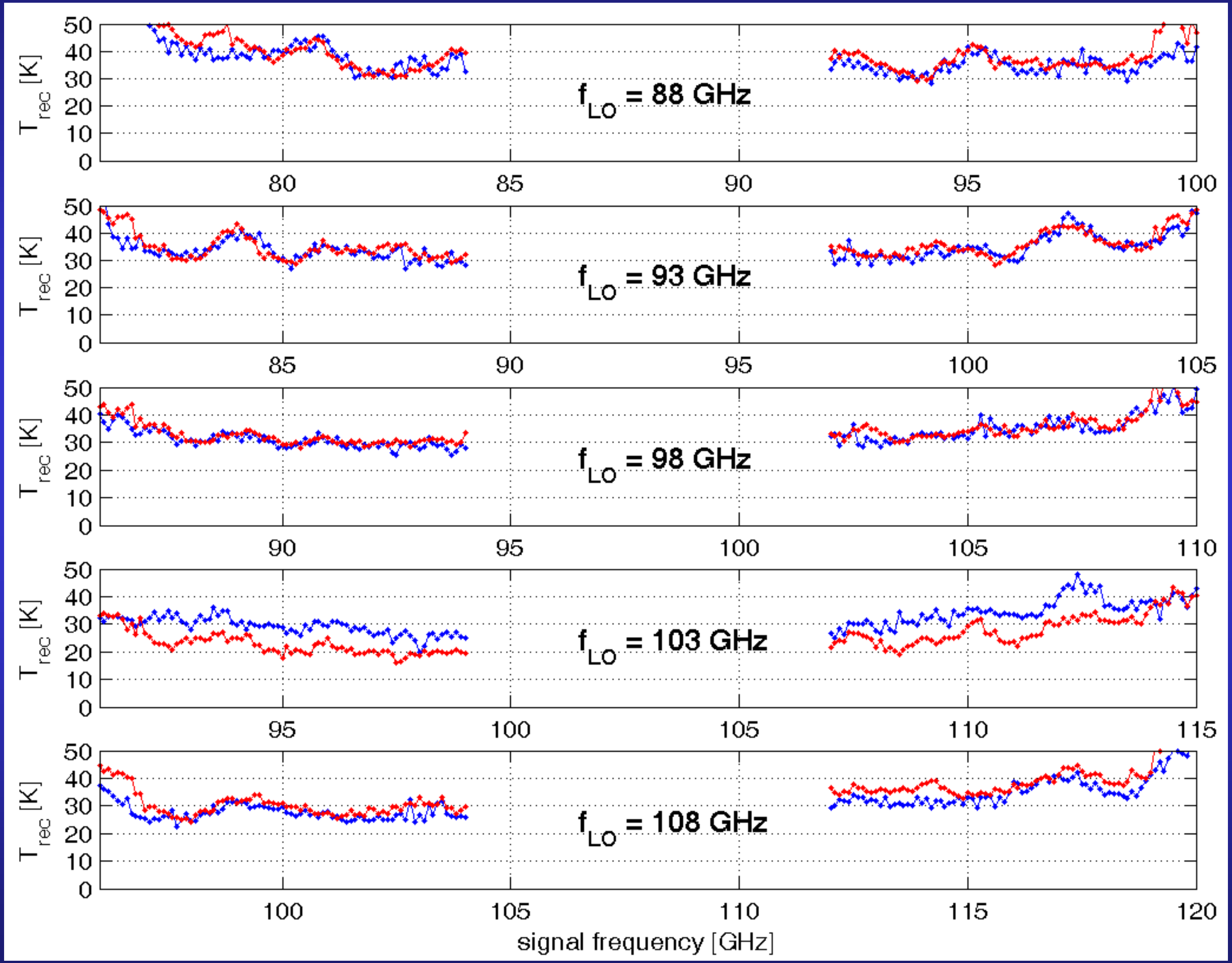


- RF frequency range: 100 – 116 GHz
- IF frequency range: 4 – 12 GHz
- AMSTAR/EMIR Band 1

DSB mixer



IF noise

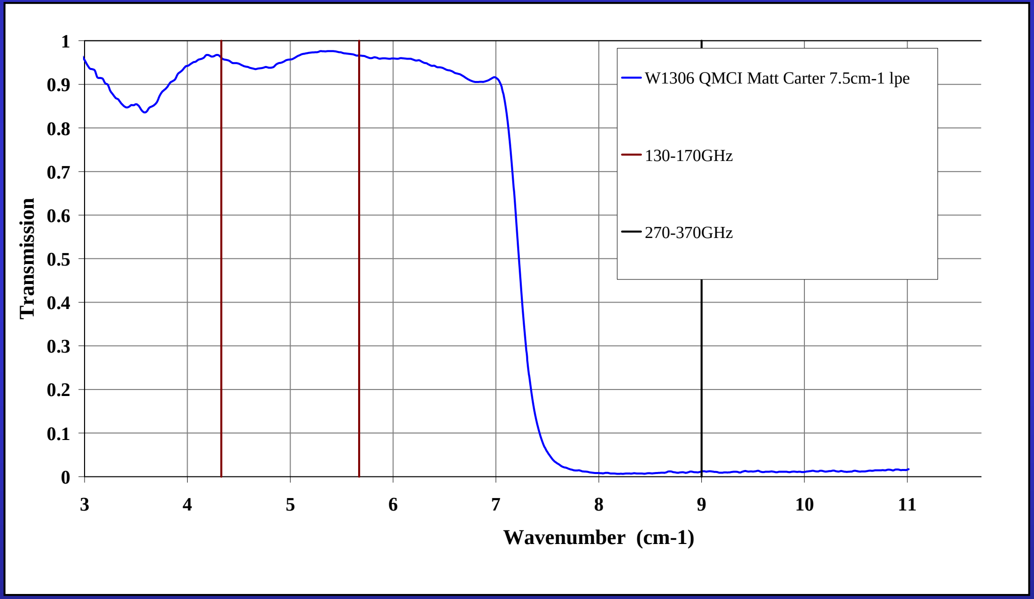


T_rec [K]
f_LO = 88 GHz
f_LO = 93 GHz
f_LO = 98 GHz
f_LO = 103 GHz
f_LO = 108 GHz
signal frequency [GHz]

Multiband dual polarization Operation

High performance dichroic mirrors are becoming available for room temperature operation.

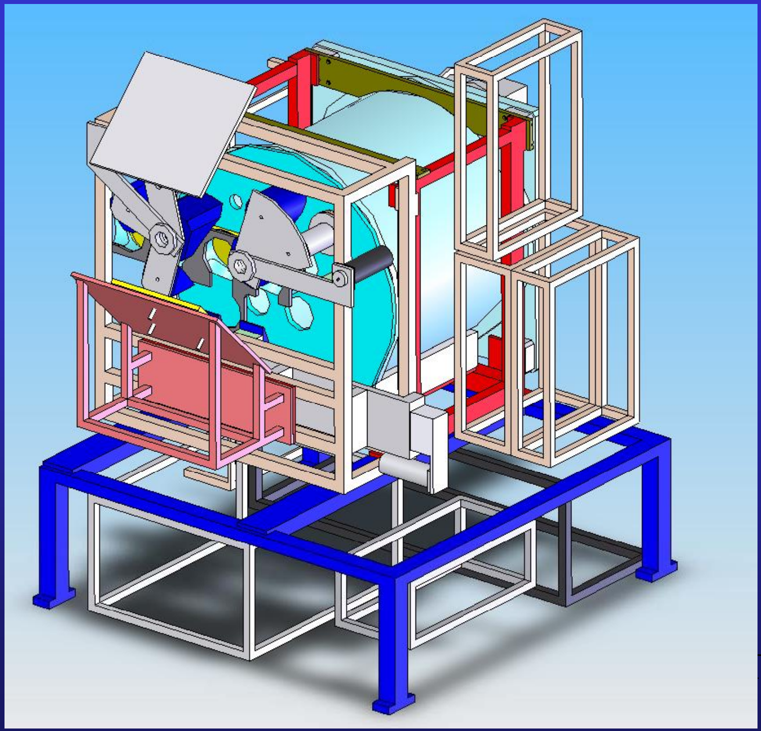
QMC/Univ. Cardiff



Would be very helpful if this technology could be extended to cryogenic operation.

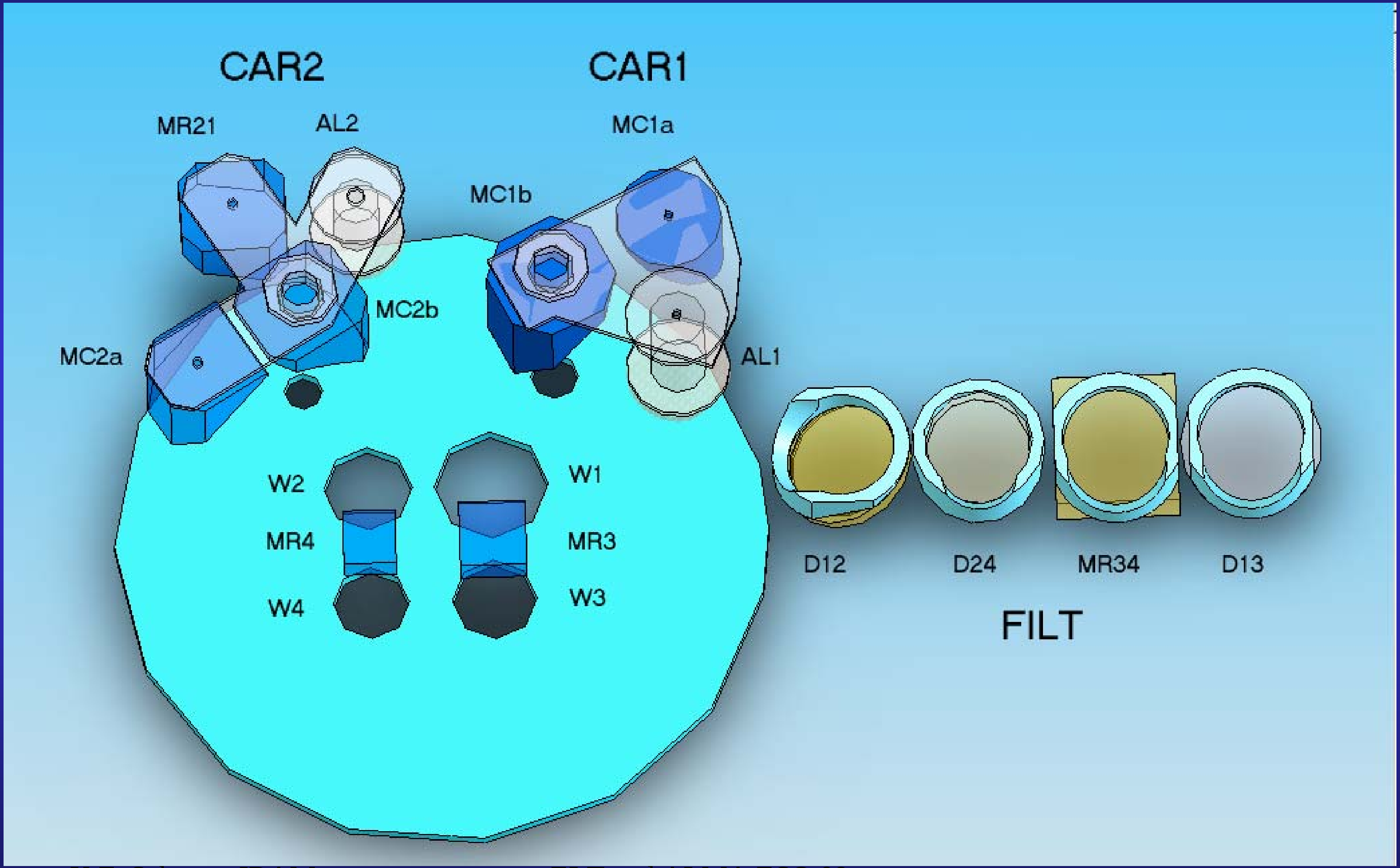
EMIR a new technology receiver at the IRAM 30m telescope (M. Carter et al)

Band	Freq. GHz	Mixer	Tot IF
1	83-117	2P × 2SB 2 × 8 GHz	32 GHz
2	129-174	2P × SSB 1 × 4 GHz	8 GHz
3	200-267	2P × SSB 1 × 4 GHz	8 GHz
4	260-360	2P × 2SB 2 × 4 GHz	16 GHz

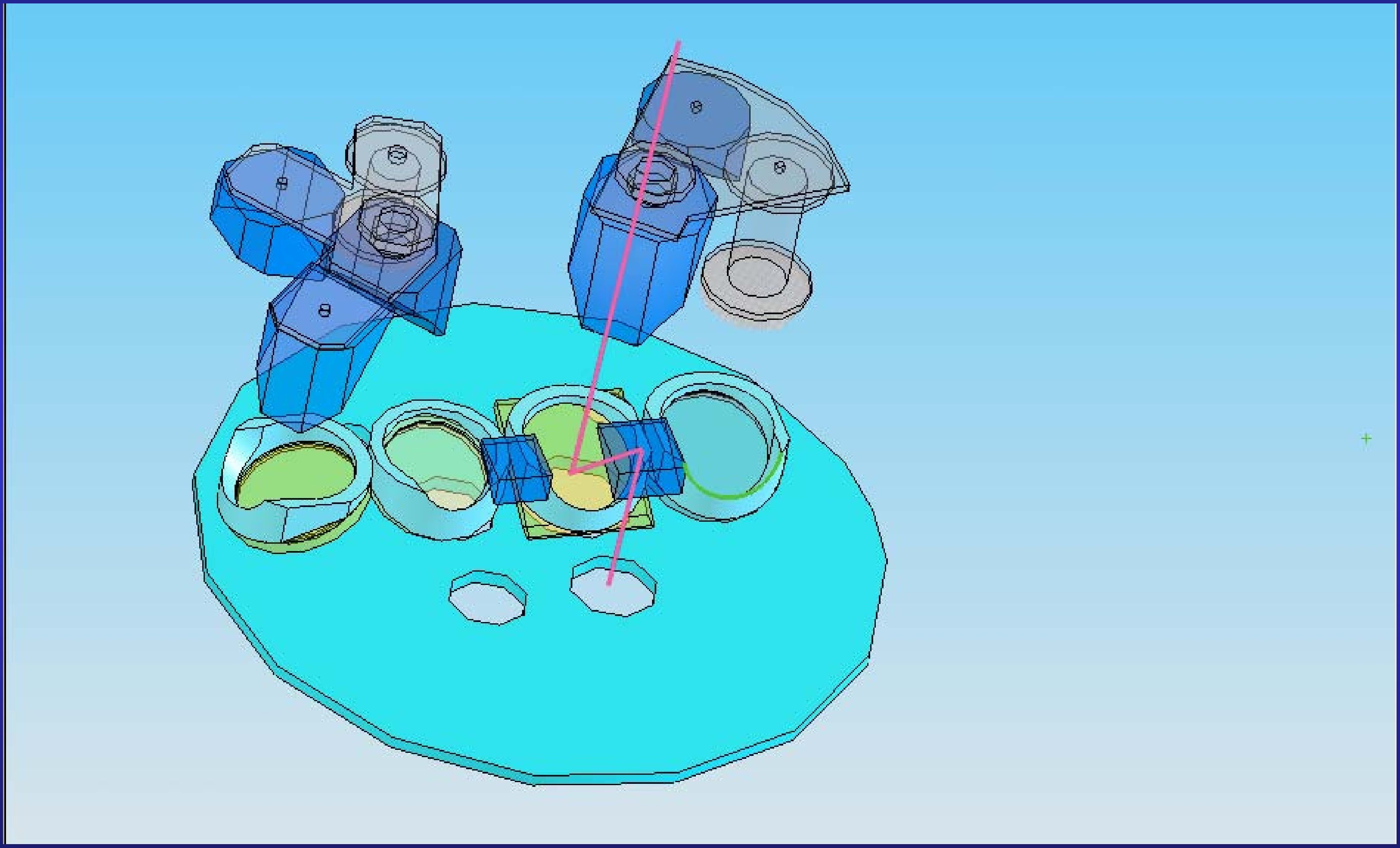


- Baseline mode: one band, Dual Pol
- Dual modes via dichroic plate (aka FSS):
  - B1 + B3 both dual pol
  - B2 + B4 “
  - B1 + B2 “
- Loss due to dichroic plate: <5% specification; <2% goal.

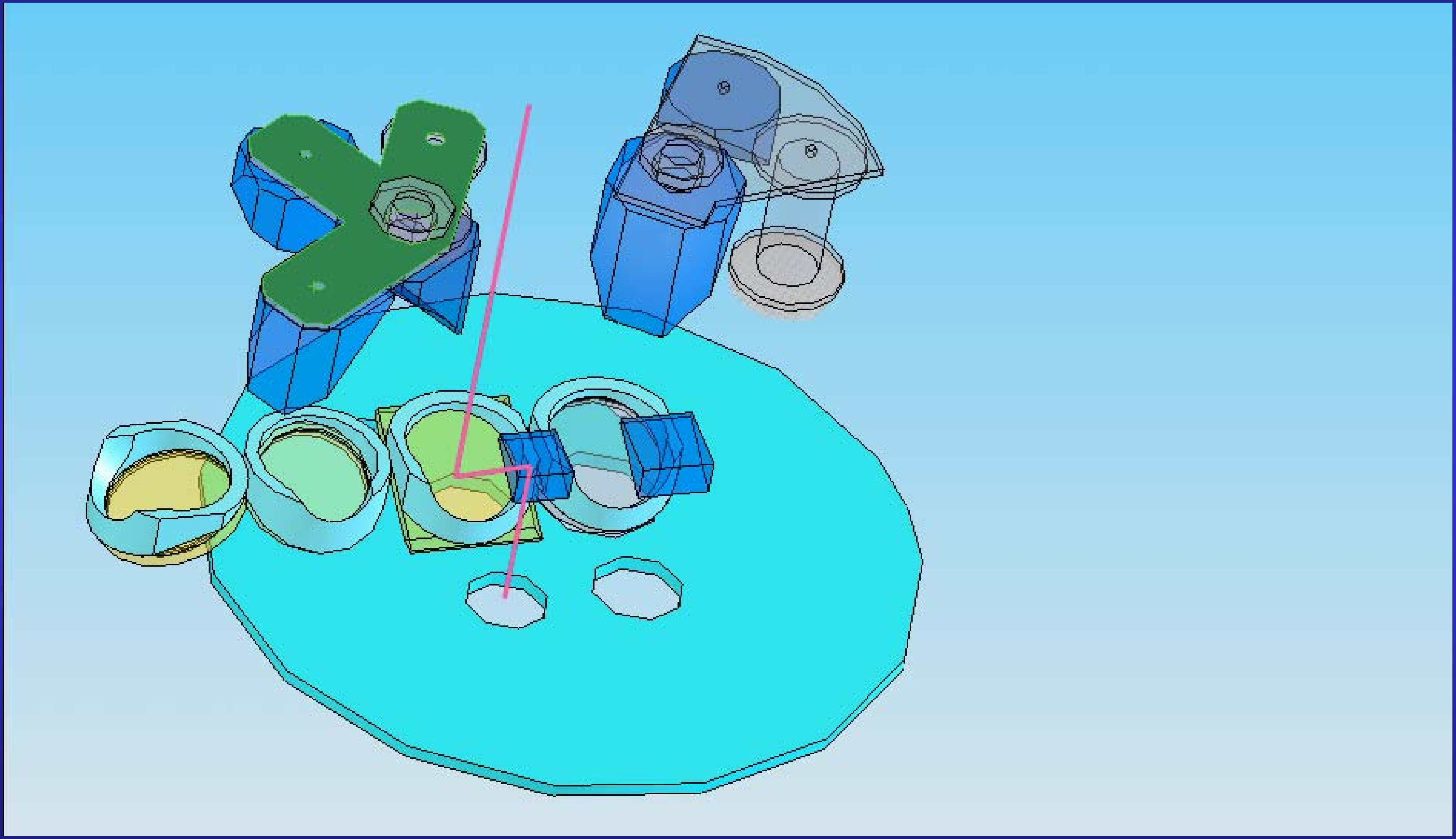
Room Temperature Optics



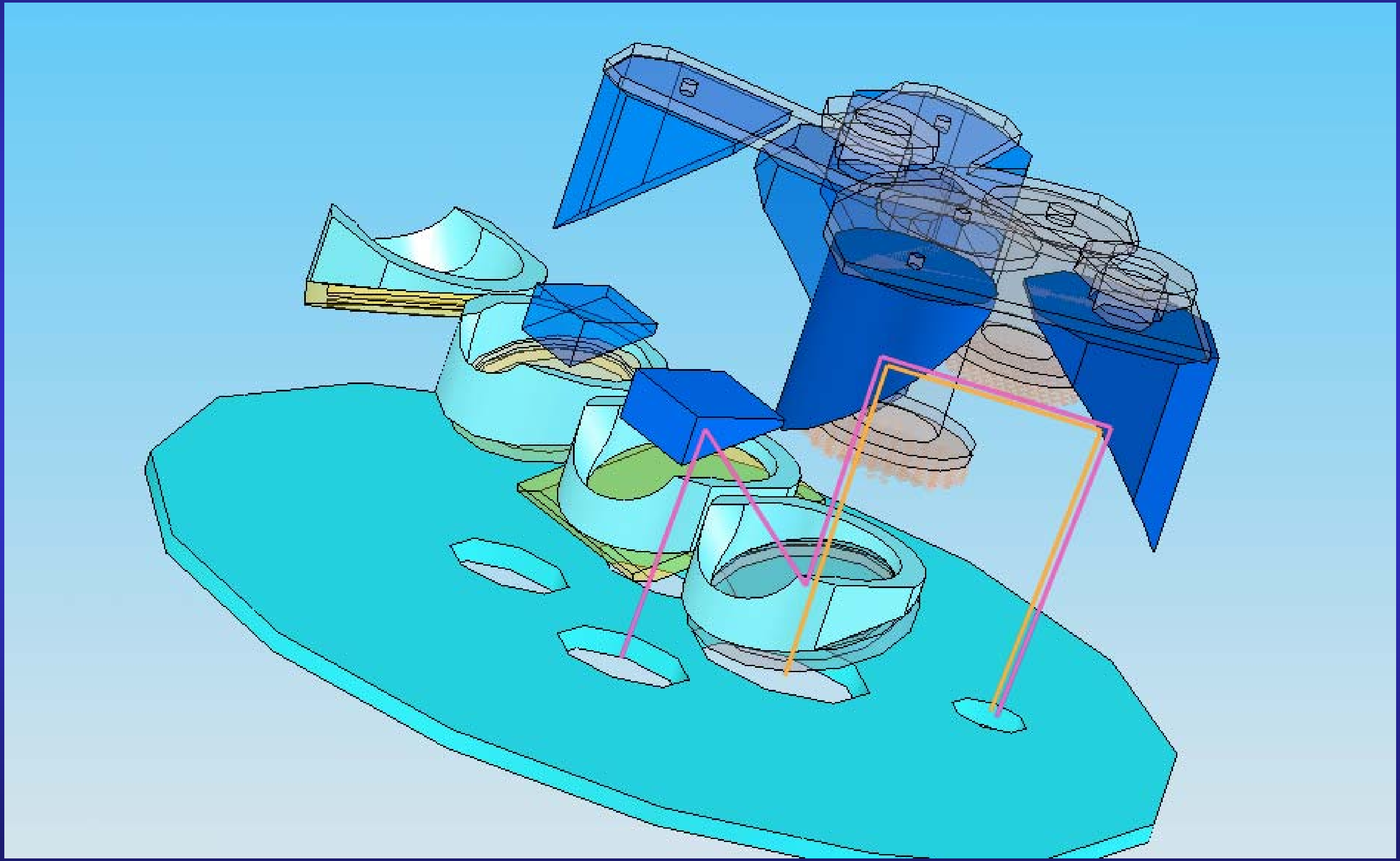
B3 alone



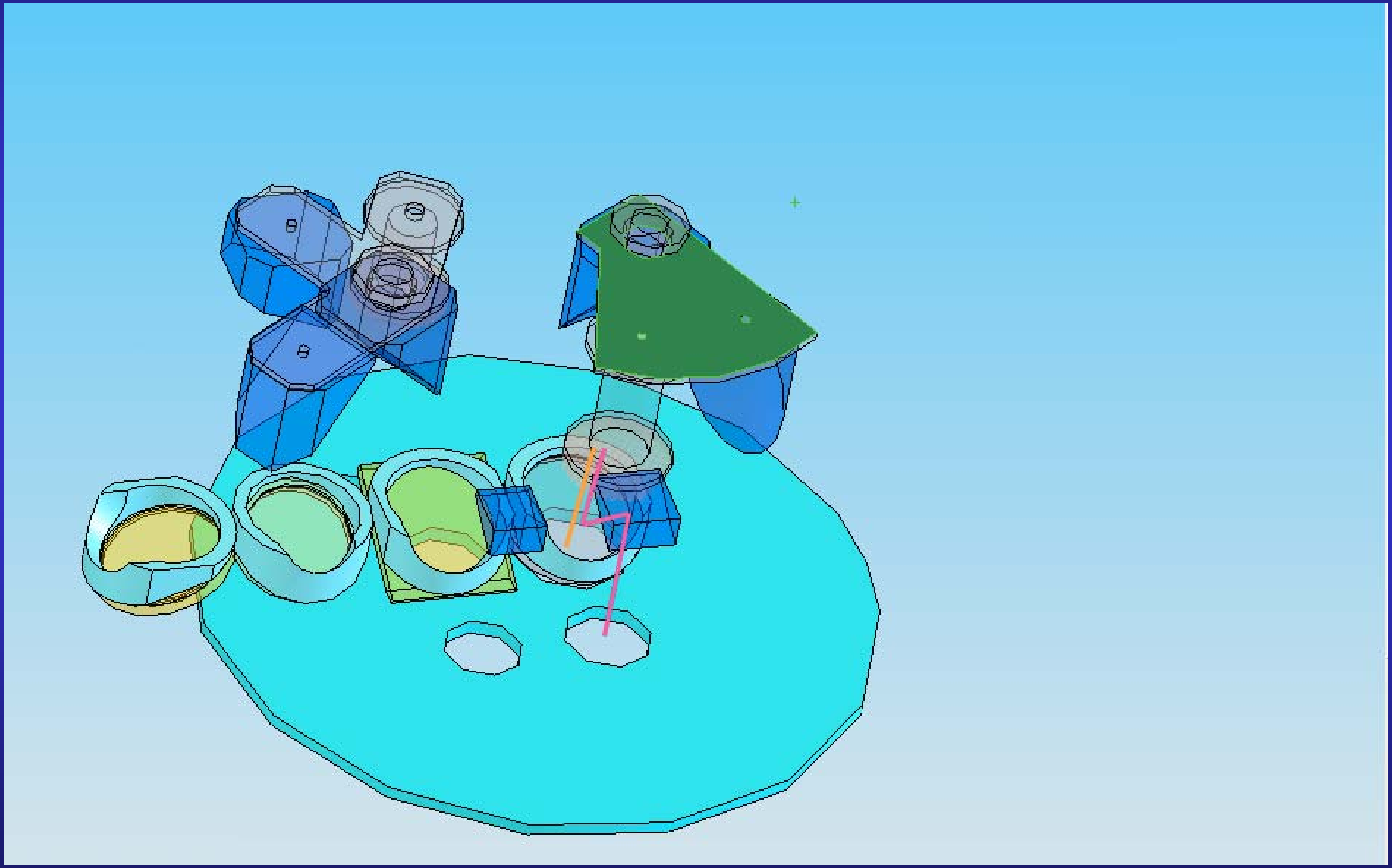
B4 alone



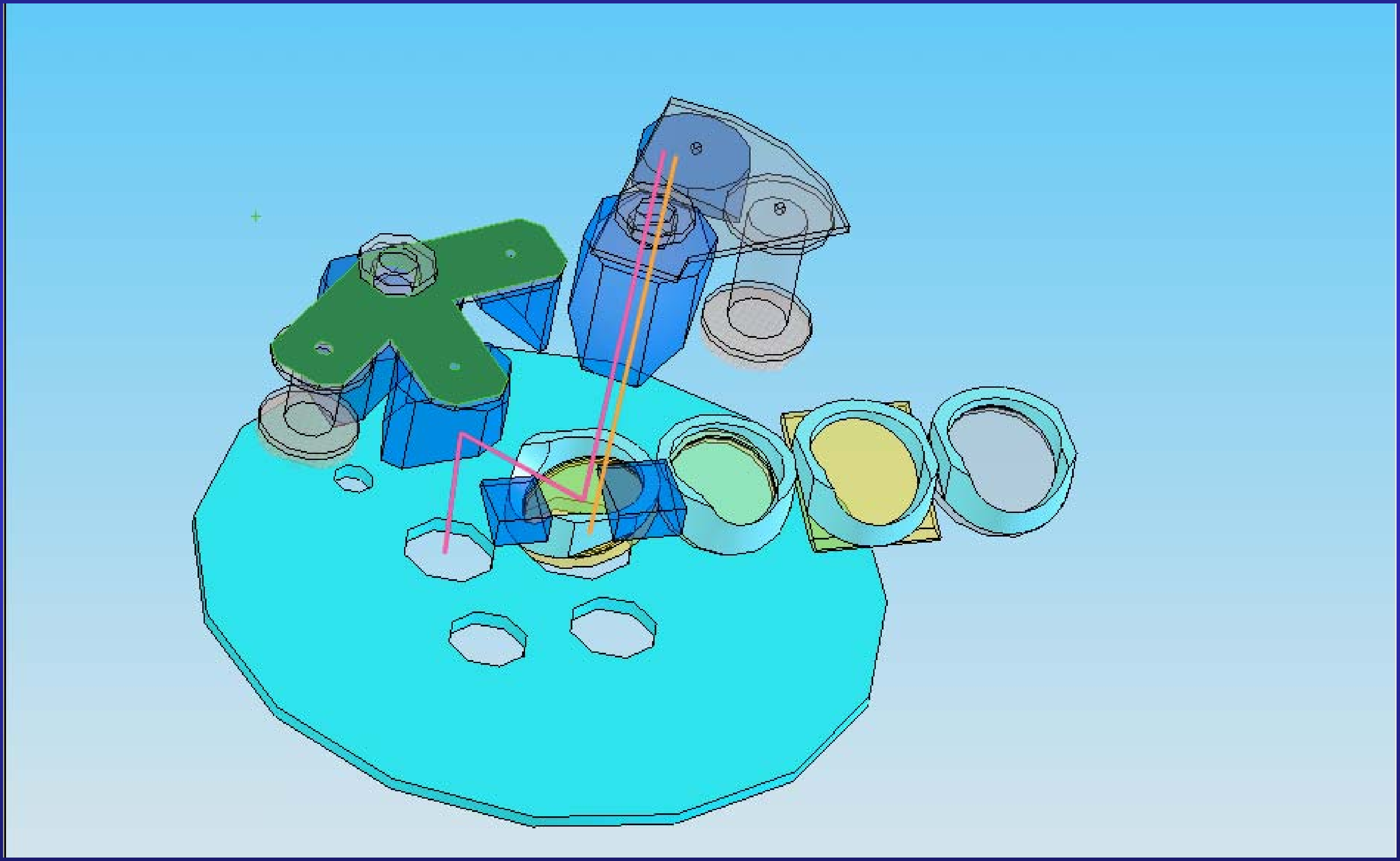
B1 + B3 Cal Cold



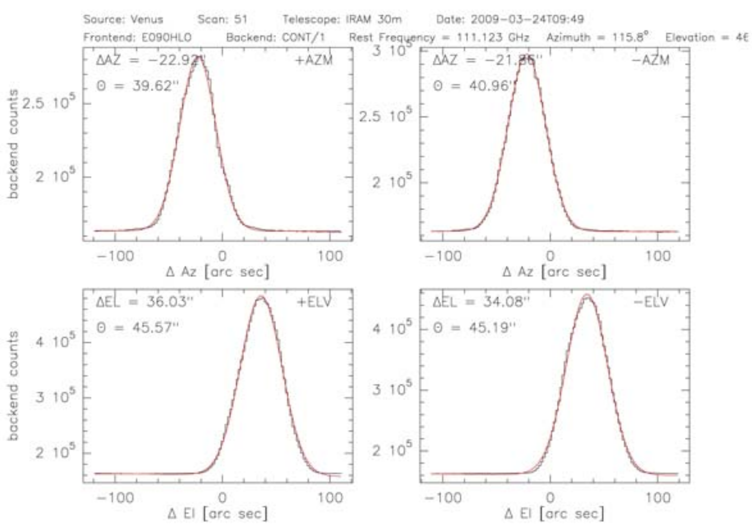
B1 + B3 Cal Amb



B1 + B2



EMIR had first light on Tuesday



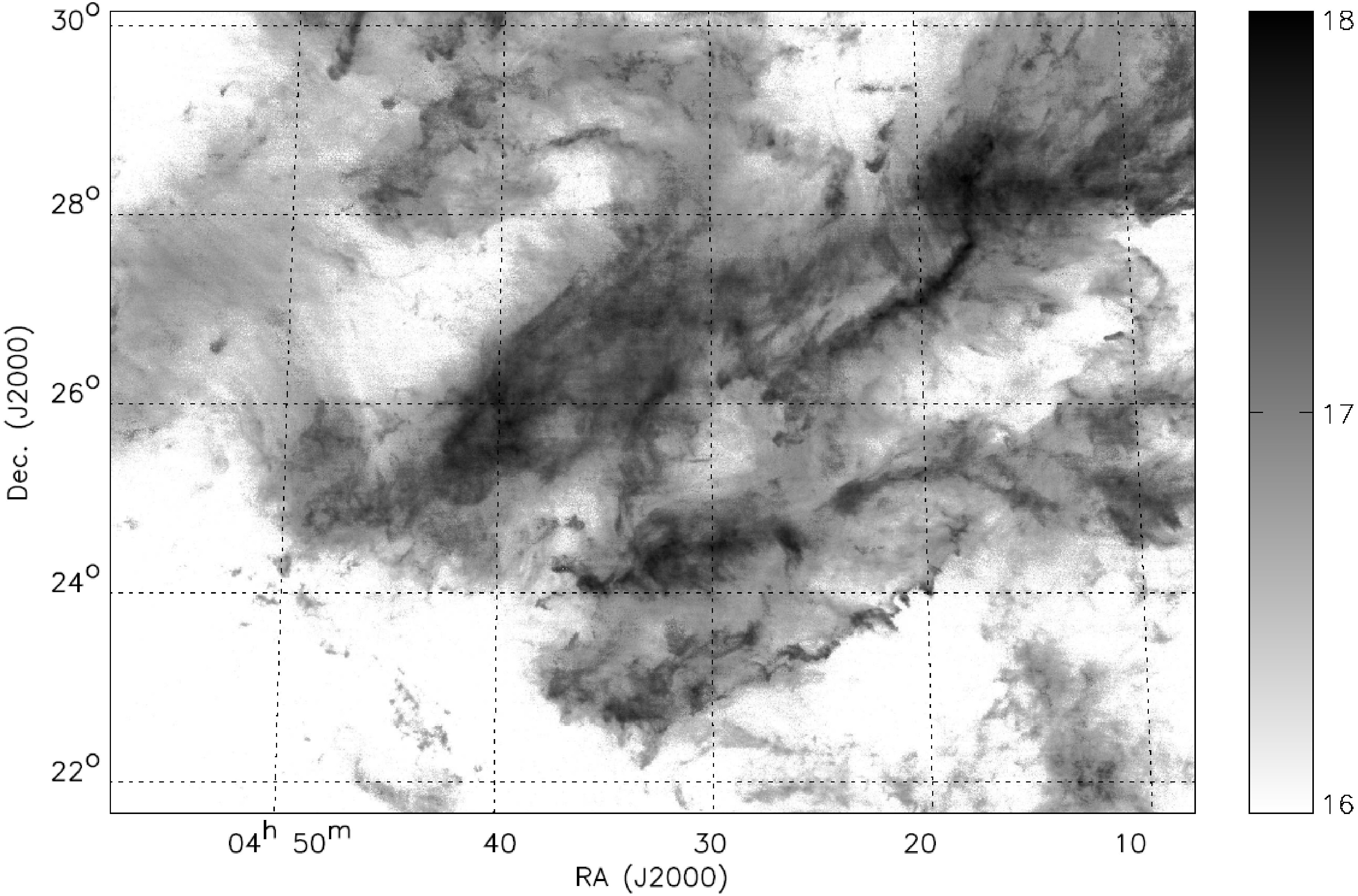
Spectroscopic Multibeam Instruments

After very first attempts in the early 90’s a second generation of multibeam instruments have successfully been commissioned around 2000:

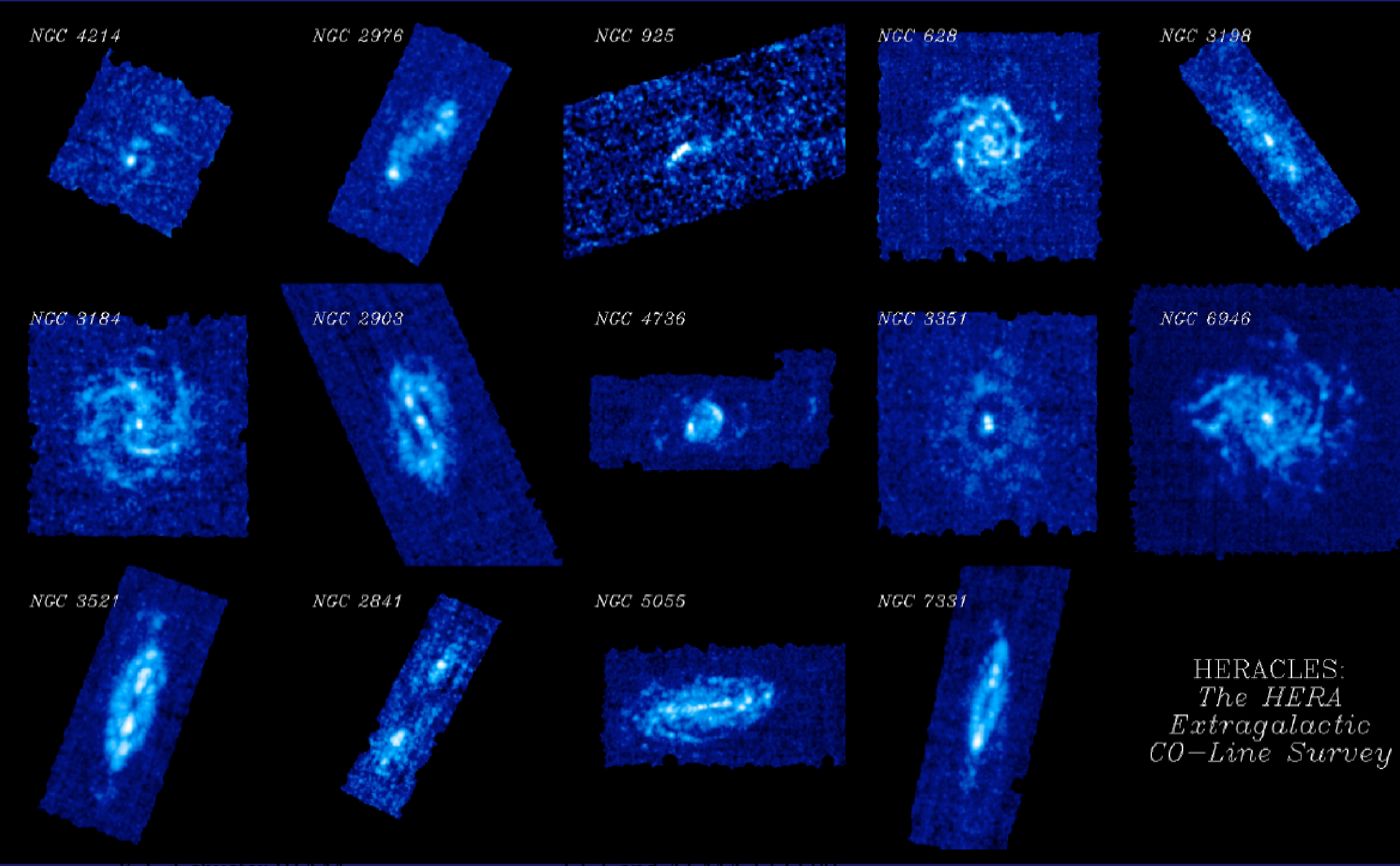
BEARS 3mm at Nobeyama 45m (25 beams)
SEQUOIA 3mm at FCRAO 14m (LMT) (32 beams)
CHAMP(+) 0.7/0.45mm at CSO/APEX (16 beams)
HERA 1.3mm at IRAM 30m (18 beams)
HARP 0.8mm at JCMT (16 beams)

These instruments are largely based on assembled single pixel technology.

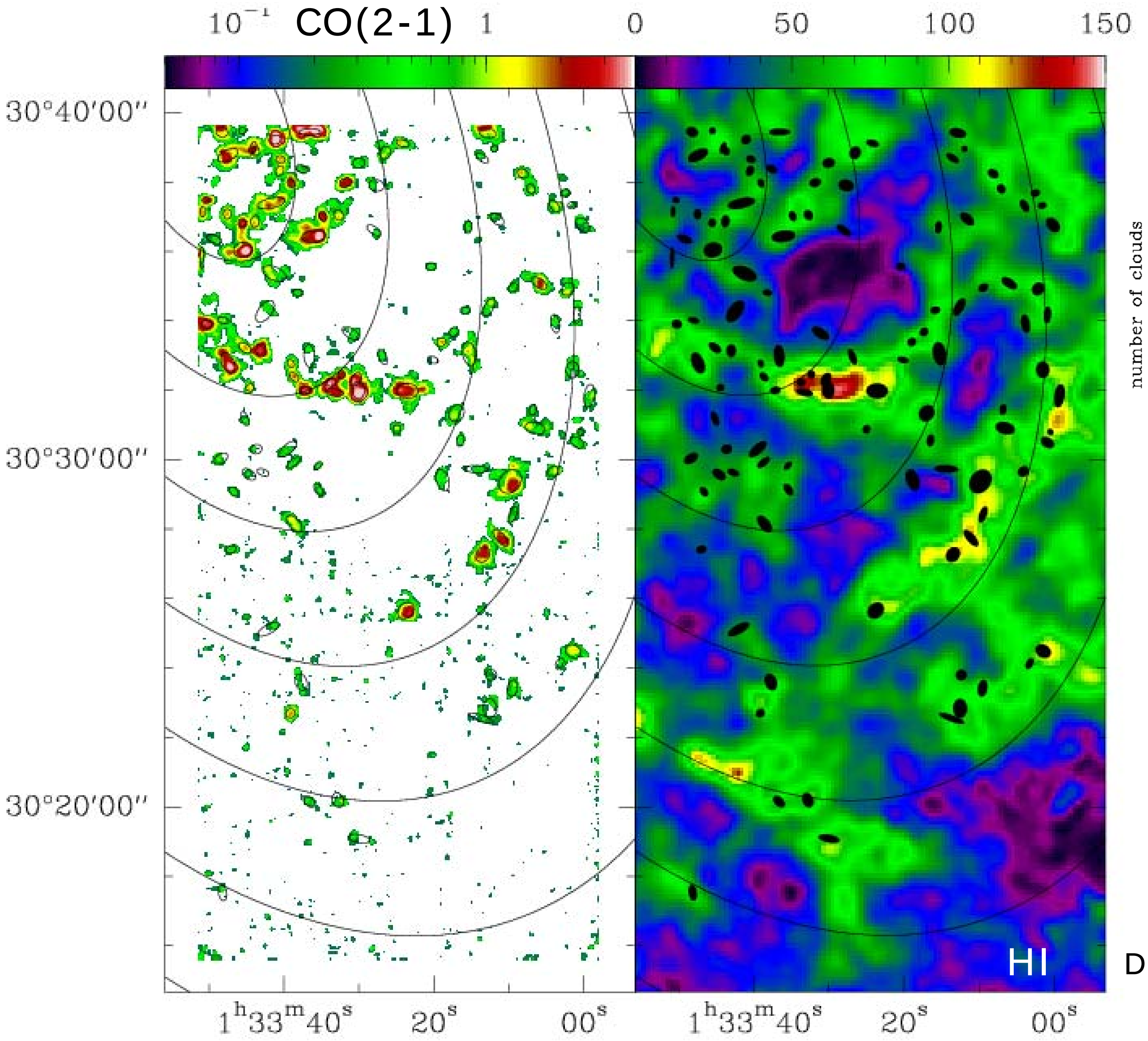
SEQUOIA, CO in Taurus, P. Goldsmith et al 08

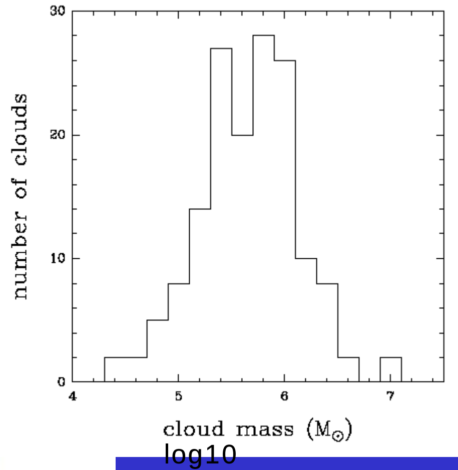


Leroy et al. 2008
IRAM 30m Telescope



M33 Gardan et al 08, and Braine et al, in prep.



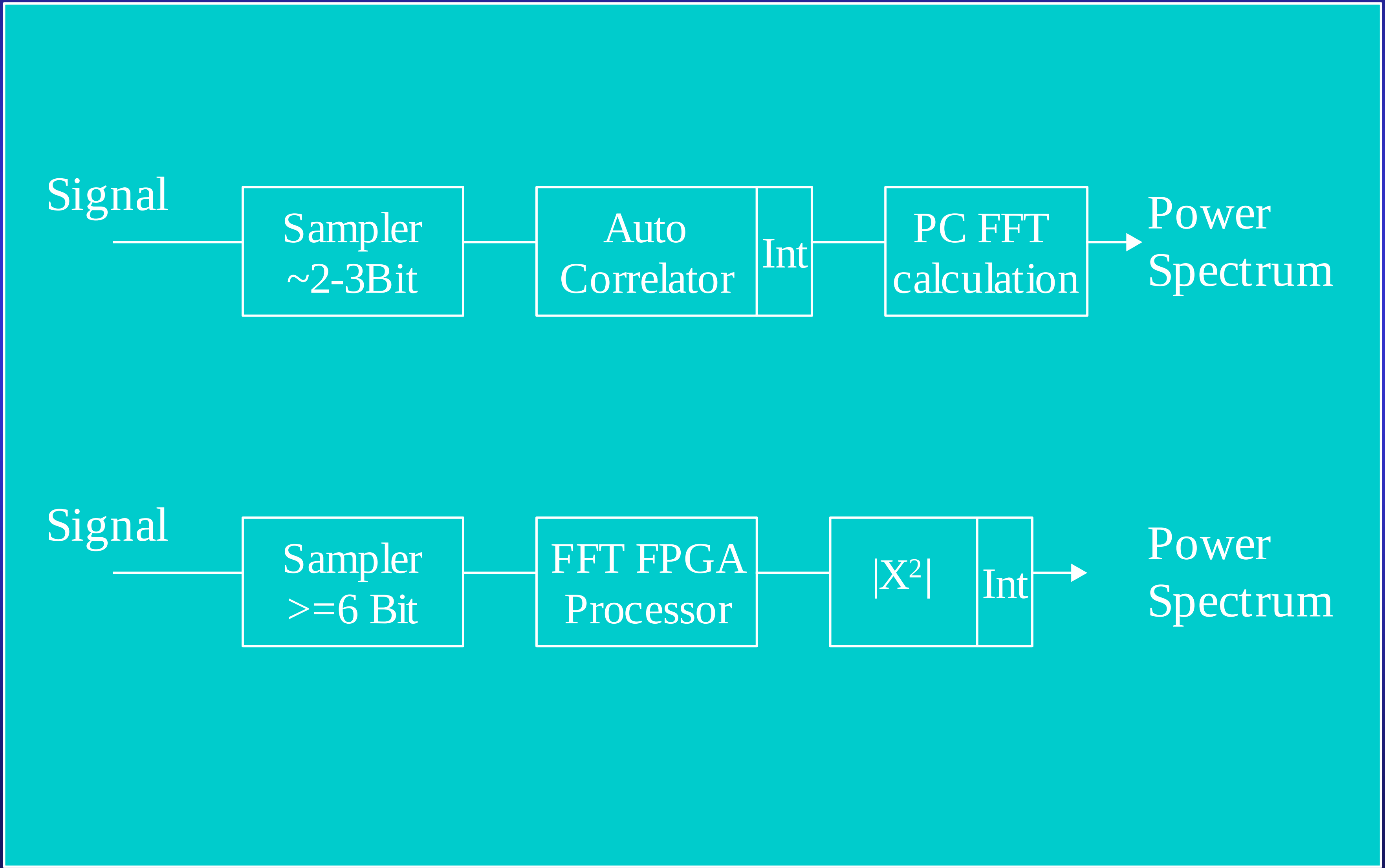


Deul and van der Hulst 87

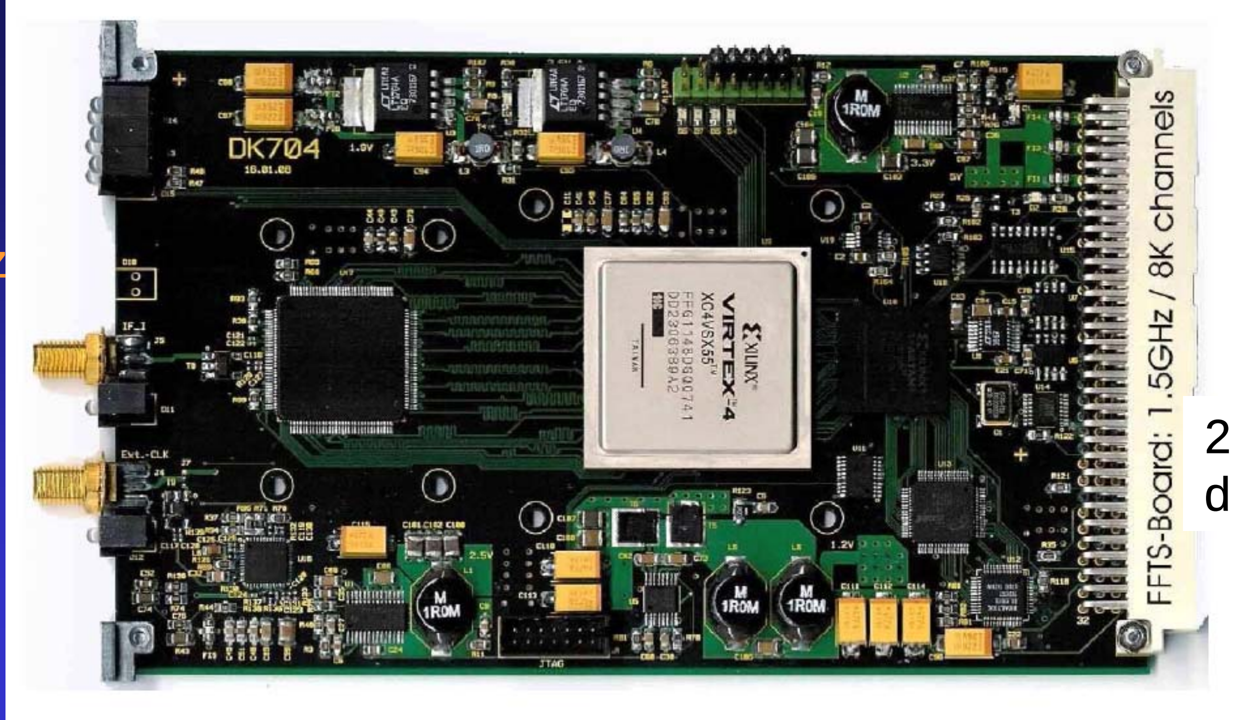
Next generation of spectroscopic multibeam:

- >= 100 Pixels
- deep mapping of CO isotopomeres, HCN, HCO+ in nb galaxies
- Complete mapping of galactic SF regions (within months)
- Need new and integrated technology
- Large number of pixels will be possible due to rapid progress in backend technology but simultaneous wideband will remain a dream.

The DSP Revolution for Spectroscopy Backends



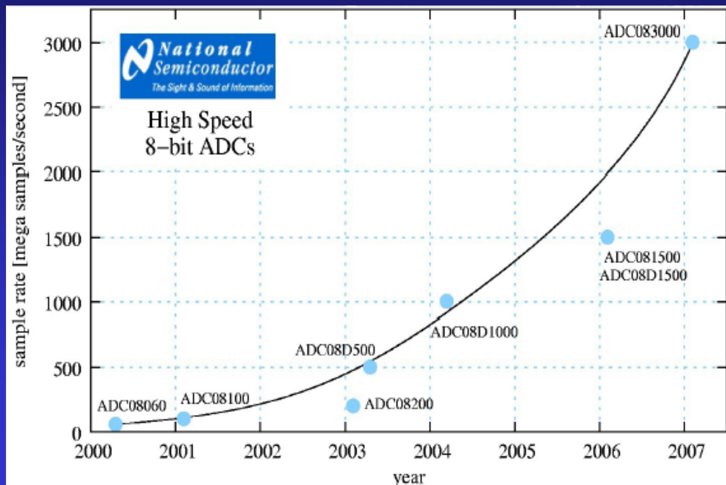
Inp BW
1.5 GHz
200KHz
spacing

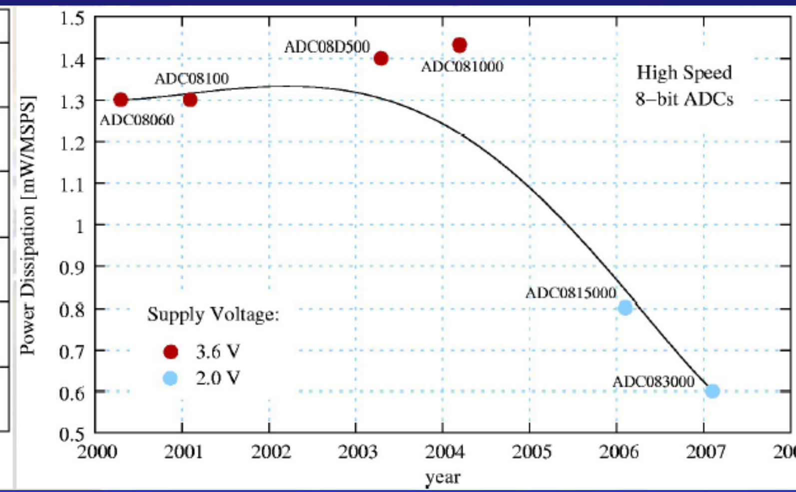


B. Klein
MPIfR Bonn

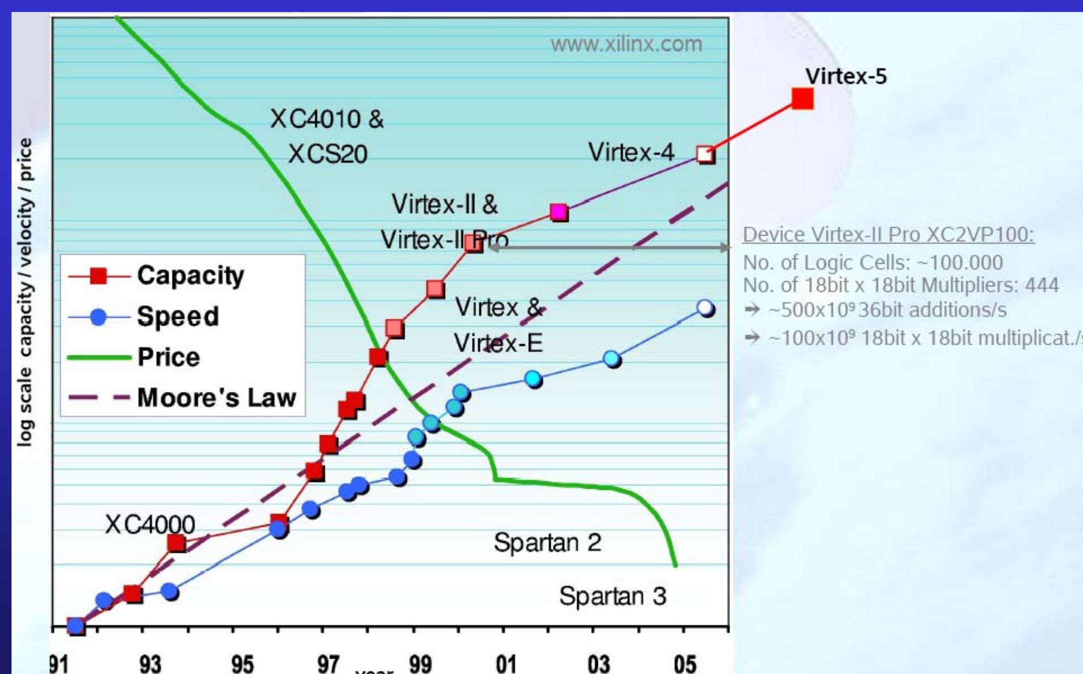
20 units delivered
do IRAM this week

Industrial Building blocks for Backends





Si or SiGe Technology

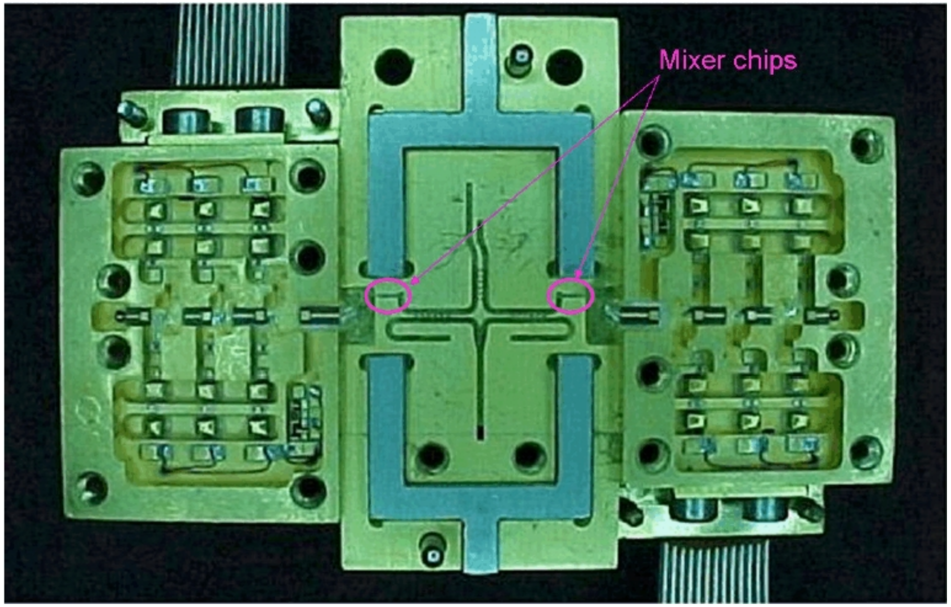


K.F. Schuster IRAM

New Integrated Approaches:

- Integrated reflective cryogenic optics
- Planar integration of couplers
- Integration of cryogenic MMICs into SIS mixer blocks

ALMA Band 6 2SB mixer-preamplifier



A.R. Kerr et al., 2004

Multibeam for Interferometry:

(+)

- Theoretically very tempting in order to capitalize focal plane space.
- We know how to build good small arrays
- Allows for high resolution large scale mapping and Source finding.

(-)

- Requires huge IF transport and correlator power.
- No possibility for derotation => Requires interferometric OTF ability.
- No existing concept how to efficiently (phase) calibrate arrays.

Conclusions

•(Sub-)mm instrumentation is and will stay a very dynamic and rapidly evolving field.

• Upcoming single dish instrumentation will have a major impact on ALMA – astronomically and technically

•Sensitivity, bandwidth and frequency multiplexing upgrades will be available for interferometry within the next 5 years.

•Multibeam instrumentation for interferometry will need considerably more time and development effort and be restricted to one selected band. Unclear how to implement in the ALMA antennas/receivers.

•Need to maintain expertise if such upgrades should be implemented some day at reasonable costs.

•Field will benefit from industrial semiconductor technology (samplers, correlator ASICS and FPGA technology) but direct steering possibilities on specifications will be very limited. Availability of specific GaAs/InP technology is very critical.

- Large FOV Continuum Cameras: The technology race 1 (TES against KID)
- Spectroscopy: sensitivity (and stability), technology race 2, SIS against HEMT
  wideband, multiband, multibeam
- Electronics backends : sampler and DSP
- what we must know about semiconductor industry. GaAs/InP technology critical, might become worse in future.
- Si/SiGe technology makes good progress but needs complete coverage for other industry applications. Detailed specs might not agree (samplers).