CHAMP+ and upGREAT : lessons learned

C. Risacher
Max Planck Institut für Radioastronomie, Bonn, Germany

APEX THz arrays: CHAMP+

- CHAMP array system built originally in the 1990s and used at the CSO (460GHz) until 2003

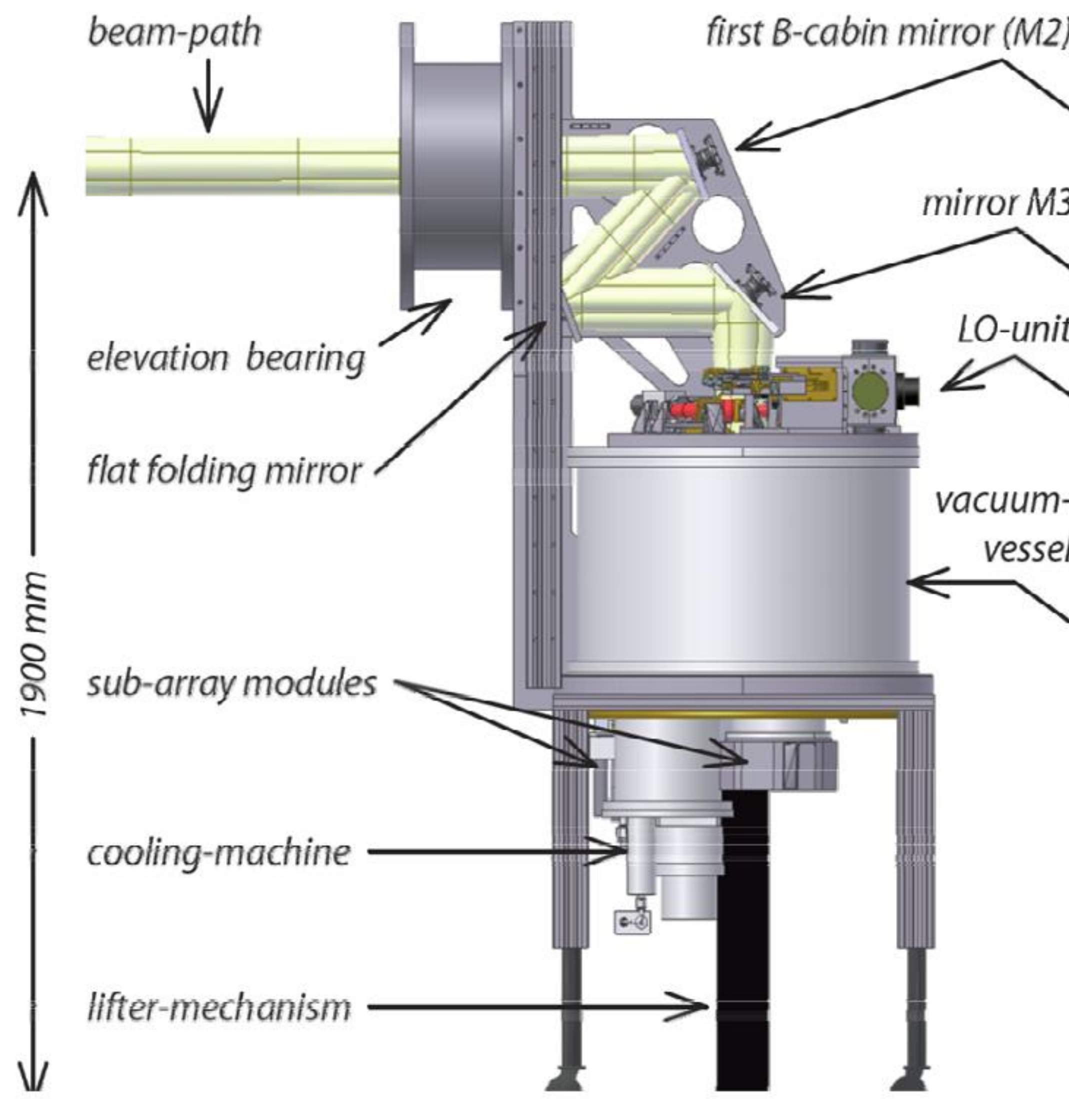
- Upgraded CHAMP+ built in 2005 for the APEX 12m telescope
  - Consist of 7 pixels for 620-720 GHz and 7 pixels for 780-950 GHz (parallel observations)
  - Detectors provided by SRON
  - DSB SIS mixers – quasioptically coupled (lenses array)
  - Receiver uses Martin-Puplett interferometers in cold for
    - LO coupling (diplexer)
    - SSB operation
  - Derotation on sky is achieved by rotating the whole cryostat

SOFIA THz arrays: upGREAT

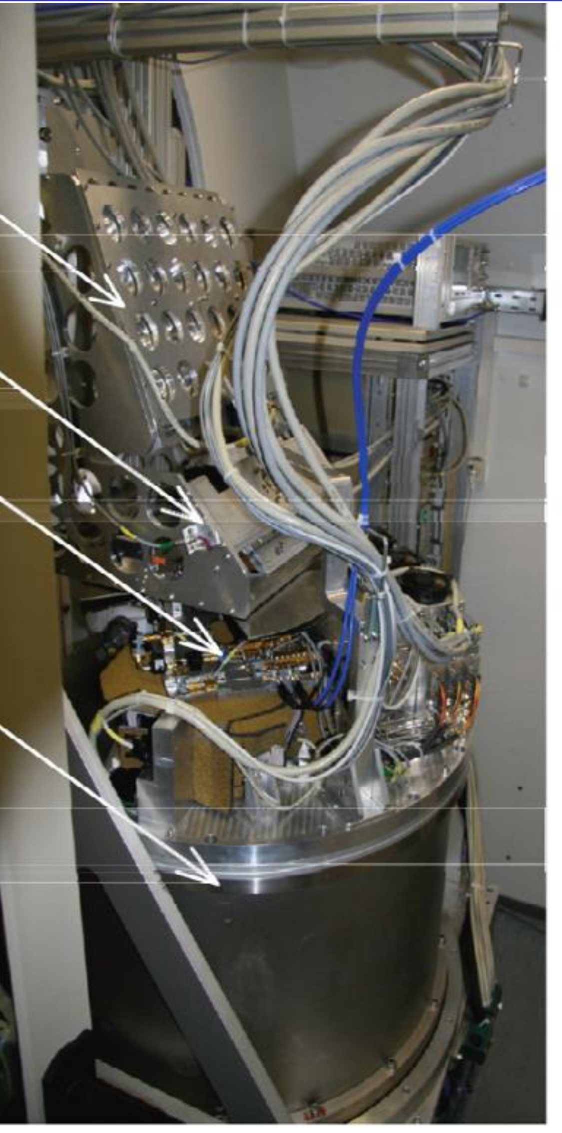
Channel	Frequencies (THz)	Lines of Interest
upGREAT Low Frequency Array (LFA)	1.8 – 2.5 (14 pixels)	OH,[CII],CO series, [OI]
upGREAT High Frequency Array (HFA)	4.7 (7 pixels)	[OI]

- upGREAT arrays built by MPIfR, KOSMA and DLR-Berlin
- Consist of 2x7 pixels 1810-2520 GHz and 7 pixels for 4745 GHz (parallel observations)
- DSB HEB mixers – with horn and waveguide coupled (no lenses)
- Receiver couples LO power using beam splitters (wire-grids/foils 5-10% typical)
- Derotation achieved with a rotating K-mirror

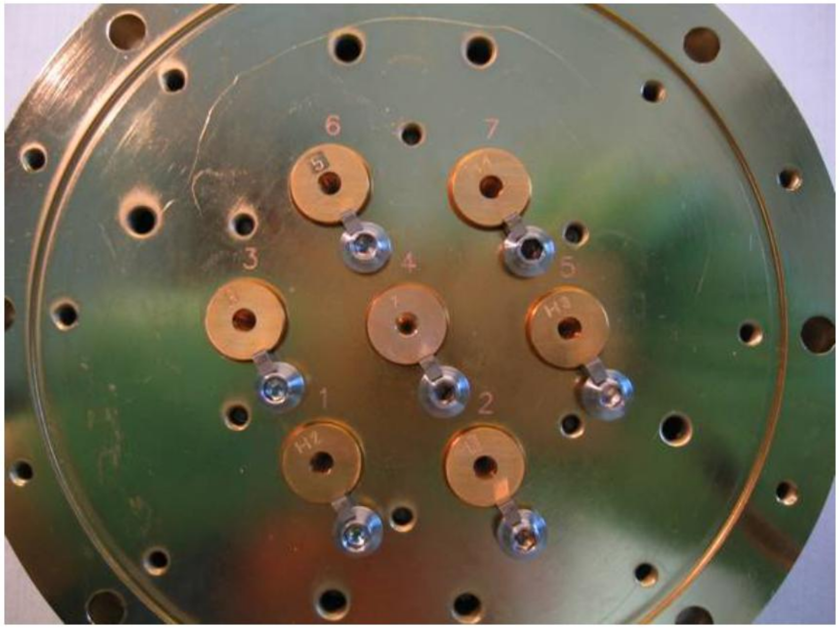
CHAMP+

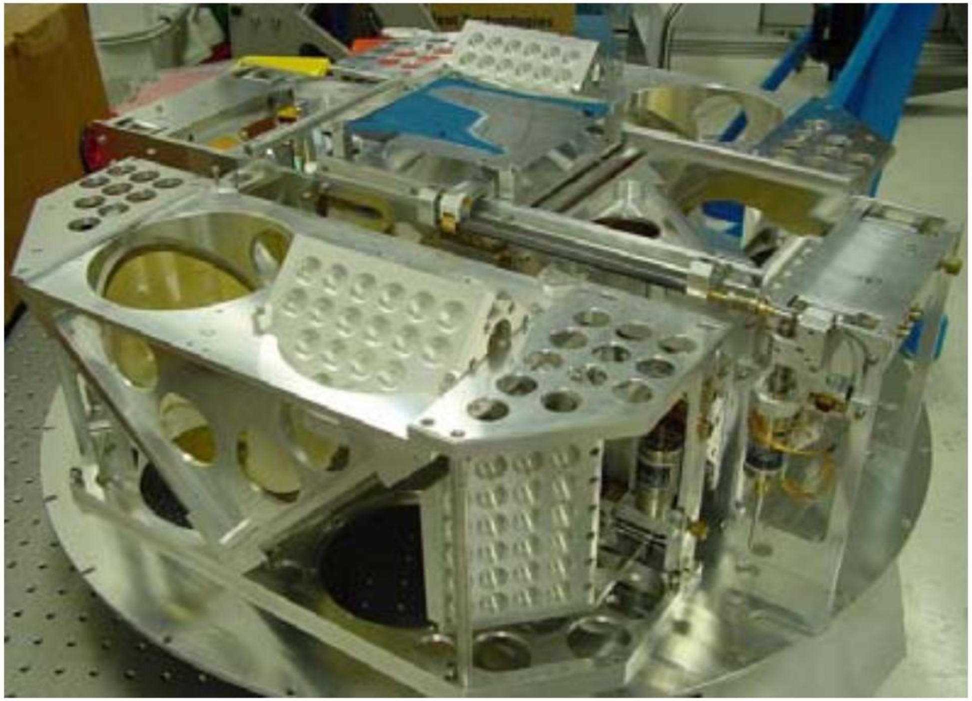


beam-path
first B-cabin mirror (M2)
mirror M3
LO-unit
elevation bearing
flat folding mirror
vacuum-vessel
sub-array modules
cooling-machine
lifter-mechanism
1900 mm

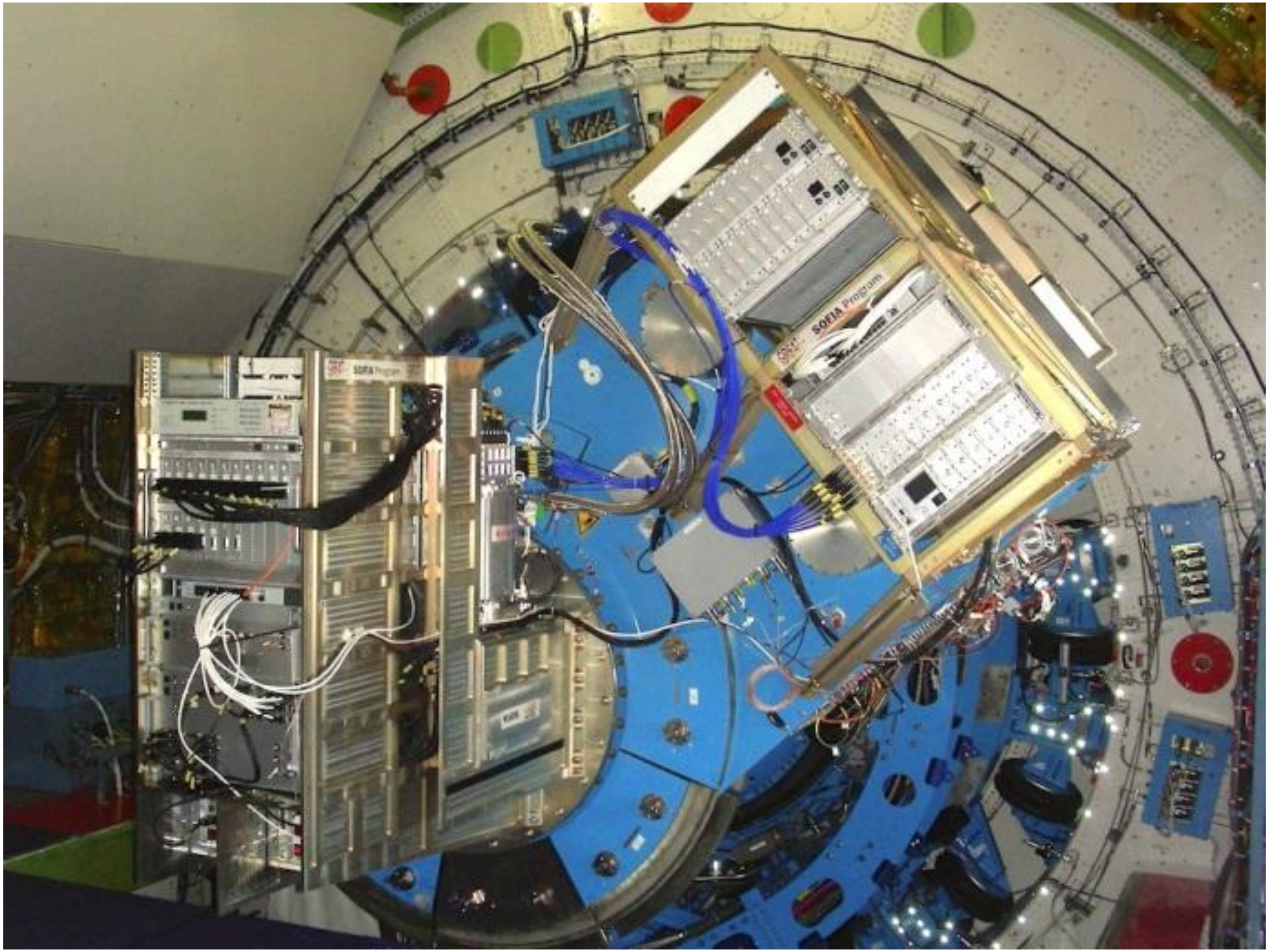


CHAMP+

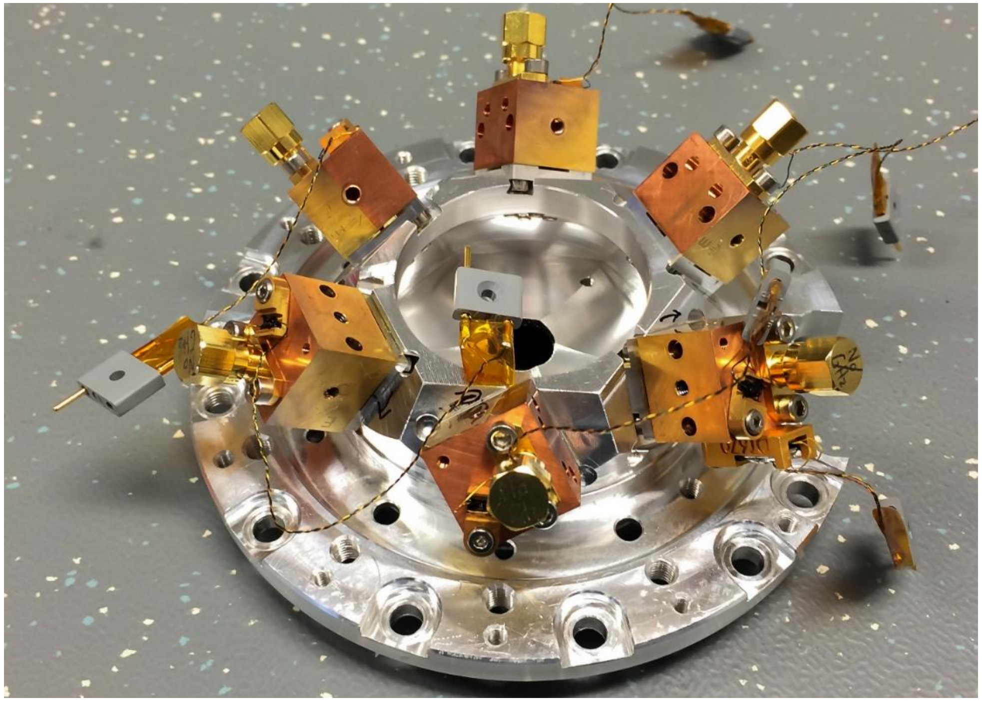




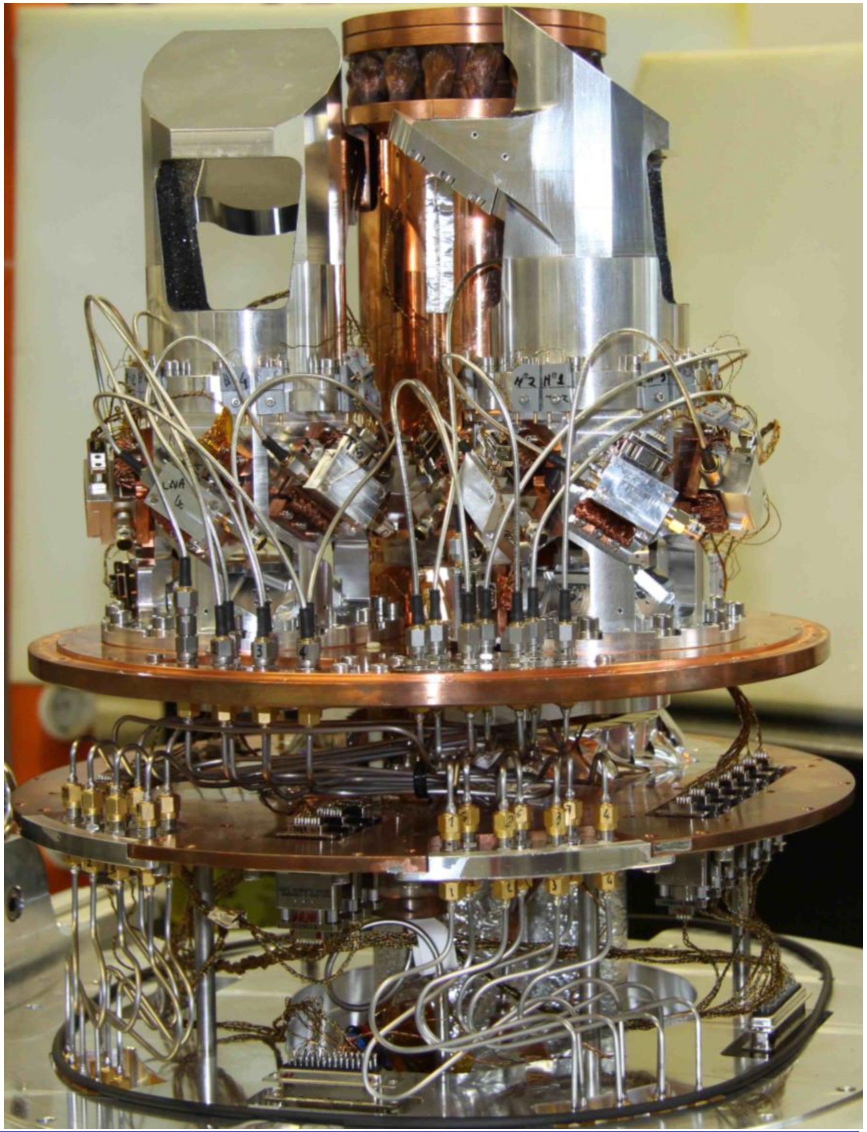
SOFIA / upGREAT



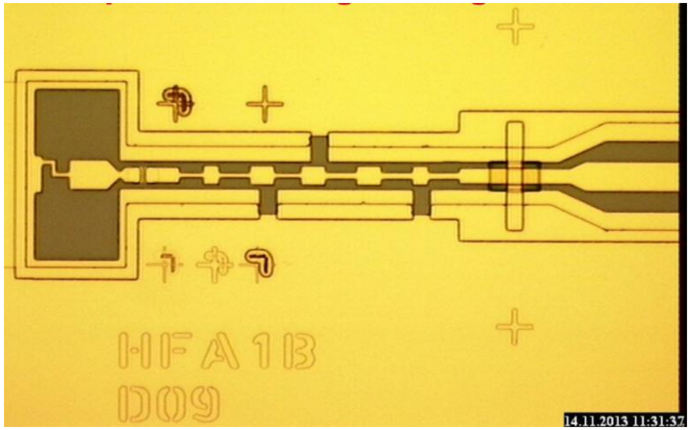
SOFIA / upGREAT arrays



6 offset mixers –
central one not shown



upGREAT components



- Hot Electron Bolometer (HEB) development at KOSMA of NbN HEB on Si
- Devices up to 4.7 THz – all **waveguide based**
- IF bandwidth of ~0.2-3.5 GHz
- spline smooth-wall horns from RPG

(more in talk from K. Jacobs)

- QCL for 4.7 THz (flying DLR-Berlin QCL and KOSMA group also has developed a 4.7 THz QCL)

(more in talk from H-W. Huebers)

- Spectrometer backends – in 2015/2016 16x0-4GHz FFTS available
- from 2017, 26x0-4 GHz and 3x4-8 GHz FFTS available

(more in talk from B. Klein)

THz arrays performance

- CHAMP+ perfomance:

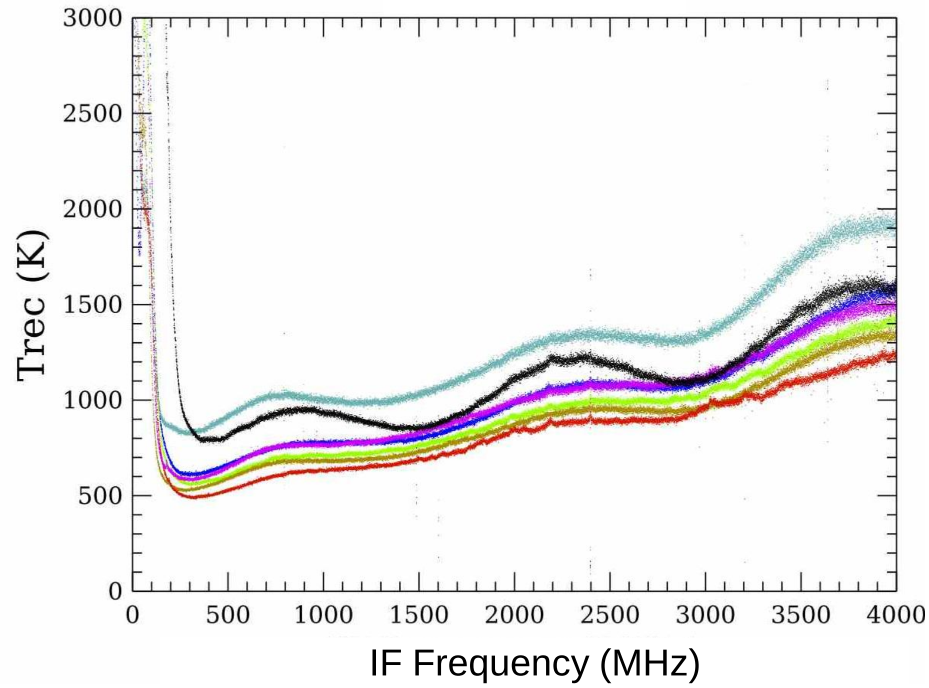
  - Operated nominally from 2005-2015
  - Best performance achieved was ~250K SSB at 690 GHz and ~700K at 810GHz
  - Degradation with time – performance in 2015 -> ~350-400K at 690GHz - >1000K at 810 GHz - Causes not clear
  - IF bandwidth limited by diplexer – 4-8GHz but only 5-7 GHz useful.

- upGREAT perfomance:

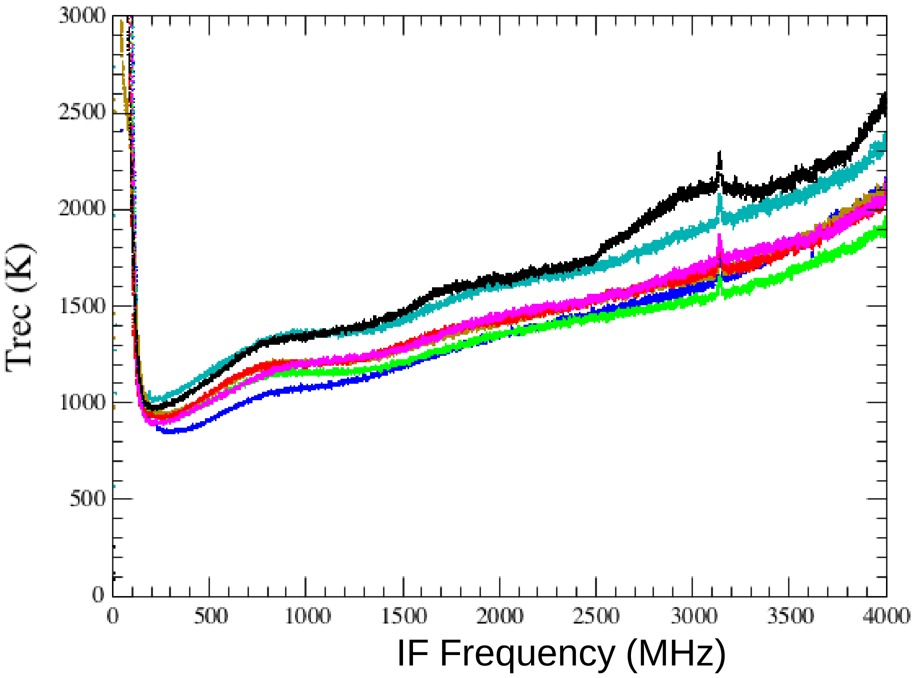
  - 1.9 THz Commissioned in 2015 - 4.7 THz Commissioned in 2016
  - Very good performance achieved, stability sufficient for efficient observations

upGREAT performance

One polarization LFA at 1.9 THz



HFA at 4.7445 THz



APEX THz arrays: CHAMP+

- CHAMP + status:
  - Will be upgraded this year
  - New detectors from SRON
  - New LO from VDI with higher output power
  - Will allow to get rid of the cold diplexer
  - Single side band filter might be removed too
  - IF bandwidth will be from 4-8 GHz

THz arrays: LO diplexers

- CHAMP+/upGREAT challenges:
  - Lack of LO power forced us to use diplexers for CHAMP+
  - Diplexer alignment was extremely complicated (diplexer in cold) – took months of work to have it acceptable
  - Diplexer tried too for the SOFIA 1.9 THz array, same and even worse alignment issues and RF performance heavily degraded. Excess LO noise appears as soon as one channel is not exactly well centered in the diplexer Luckily VDI got us enough power to be able to use the 1.82-2.07 THz region

upGREAT LO limitations

For both systems, LO systems are probably the limiting factor

- For the LFA 1.8-2.5 THz :
  - Very challenging to provide 20-30uW of power for very large bandwidths
  - Technology pushed to the limit – failure rate is high for components (specially power amplifiers). Spurs/spurious also present.

- For the HFA system : No frequency locking yet, no LO power stabilization yet. Those are under consideration. Observations so far can successfully be done, but need some post calibration activities (uses [OI] telluric line).

- Better LO power stability would also allow more efficient OTF observations.

THz arrays: LO balancing

- Balancing of the LO power is very challenging – use of collimating phase gratings to divide the LO beam in 7 equal beams. Possibility to attenuate individual beams on LO flat mirror with absorbers.
- Typically - about 5-6 /7 pixels can be nominally pumped – and 1-2 are either overpumped or underpumped. Degradation of Trec is acceptable as HEB dynamic range is sufficiently large in our case.
- HEB mixers LO power requirement can vary in some sub-arrays within a factor of 2 – 3
- LO alignment can fine tune the distribution, not perfect but helps a lot.
- An ideally tuned system could probably improve the overall observing efficiency by ~10-20%.

APEX / SOFIA THz arrays

- Optical alignment is very challenging too. On SOFIA, need to co-align 2-3 frequency channels on top of each other (<1”). At the limit of our beam measurement/characterization capabilities currently.

- Calibration is challenging for both arrays – atmospheric model – DSB performance – purity – etc.

APEX / SOFIA THz arrays

- Using “classical” technology, 14 pixels is probably close to the limit that can be successfully achieved in our cryostat size
- Cryostat cooling power for HEB arrays was largely sufficient – we could operate 2-3x more pixels (temp was ~3.5K, and would increase to 4.5K with 50 pixels).
- For larger count pixel arrays – more integrated design are indeed needed, if only for ease of integration and servicing.