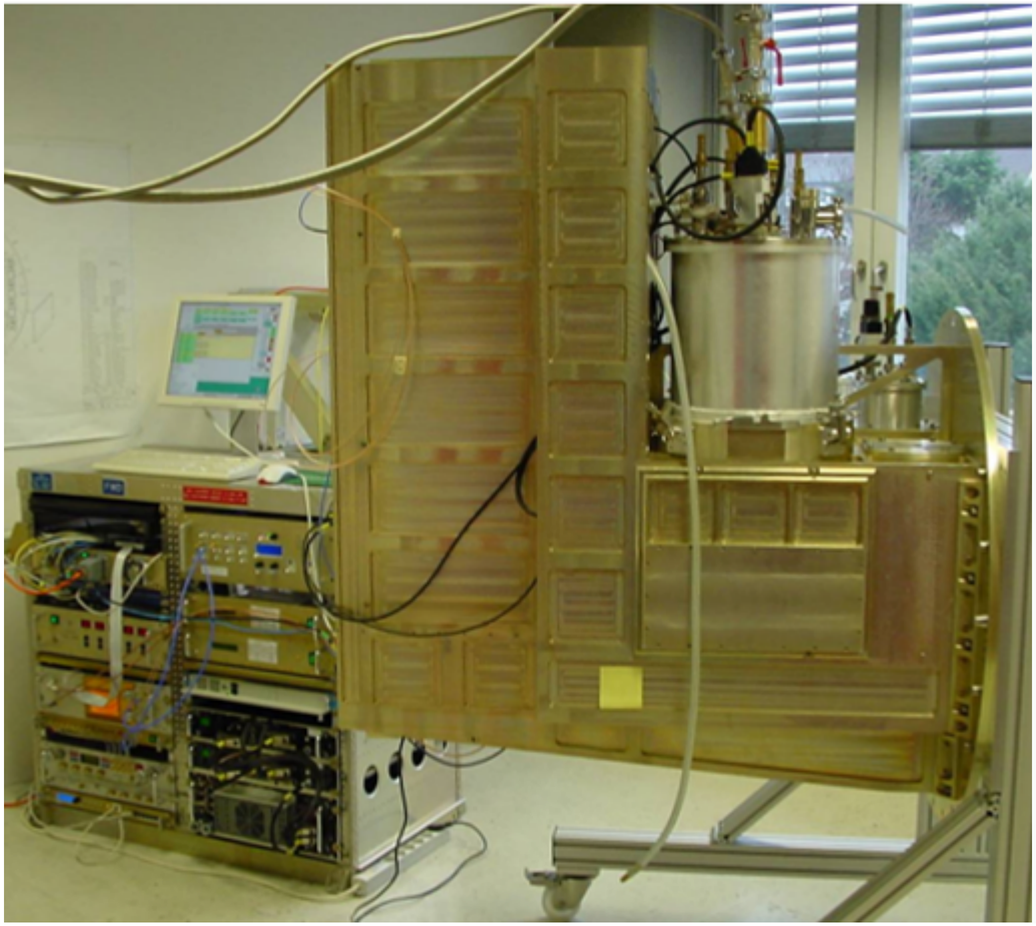
GREAT: an Early Science Instrument for SOFIA

MPIfR
KOSMA
MPS
DLR-PF

GREAT: German REceiver for Astronomy at Terahertz frequencies



GREAT at the pre-shipment review („ready to go“)

Collaborators /WPs:

- MPIfR (2.7 THz channel)
  - R. Güsten (PI)
  - P. v.d. Wal (Structure, Cryostats)
  - S. Heyminck (2.7THz LO, Certification)
  - B. Klein / C. Kasemann (FFTS)
- KOSMA (1.4 & 1.9 THz channel)
  - J. Stutzki (Co-PI)
  - U. Graf et al. (1.4 &1.9THz LO, Optics)
  - K. Jacobs et al. (HEB mixers L&M bands)
  - R. Schieder et al. (Array-AOS)
- DLR-PF (4.7 THz channel)
  - H-W. Hübers et al. (IF, Cold-Load, mixer..)
- MPS
  - P. Hartogh et al. (CO-PI; CTS)

System Description

GREAT is a

- modular heterodyne receiver system in the 1.2 – 5 THz frequency range
  - channel independent components
    - main structure : optics-compartments, LO-compartments, electronics rack
    - cryostats : liquid Helium/Nitrogen cooled dewar
    - calibration unit : liquid Nitrogen cooled cold-load, ambient temp. hot load
    - control-electronics : optics, mixer bias, power supply
    - IF-system : input 4-8 GHz, output 4 times 1.55 – 2.65 GHz for AOS and CTS
    - back-ends (instantaneous bandwidth; resolution is given as equivalent noise bandwidth)
      - AOS-system : 8 times 1.1 GHz, ~1.7 MHz resolution
      - CTS-system : 2 times 210 MHz, ≤ 60 kHz resolution
      - FFTS : 2 times 1.8 GHz, 255 kHz resolution and/or
        : 2 times 750 MHz, 53 kHz resolution

- operating two independent receiver channels simultaneously
  - channel specific components
    - optics : LO-coupling, matching mixer beam to the telescope focal plane
    - LO-system : solid-state, cascading multiplier chains (baseline for L#1 and L#2)
    - mixer device : HEBs (for all GREAT channels)

GREAT Rx channels

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Four channels are in build-up or test-phase:

- L-band (KOSMA): 1.4 THz (L#1) and 1.9 THz (L#2)
  - waveguide HEB-mixers from KOSMA
  - solid-state local oscillators
    (BWO as fall-back option for the 1.9THz channel)

Short Science configuration

- M-band (MPIfR): 2.7 THz
  - HEB-mixers from KOSMA (open structure or waveguide)
  - solid-state local oscillator
- H-band (DLR-Berlin) 4.7 THz
  - open structure HEB-mixers from DLR-PF
  - far infrared laser system (CO_2 laser pumped)
    (quantum cascade laser is an option for the future)

Channel	*Frequencies [THz]*	*Astronomical lines of interest*
low-frequency #1	1.25—1.50	[NII], CO(12-11), $^{(13)}$CO(13-12), HCN(17-16), H_2D^+
low-frequency #2	1.82—1.92	[CII], CO(16-15)
mid-frequency	2.60—2.70	HD
high-frequency	~ 4.7	[OI]

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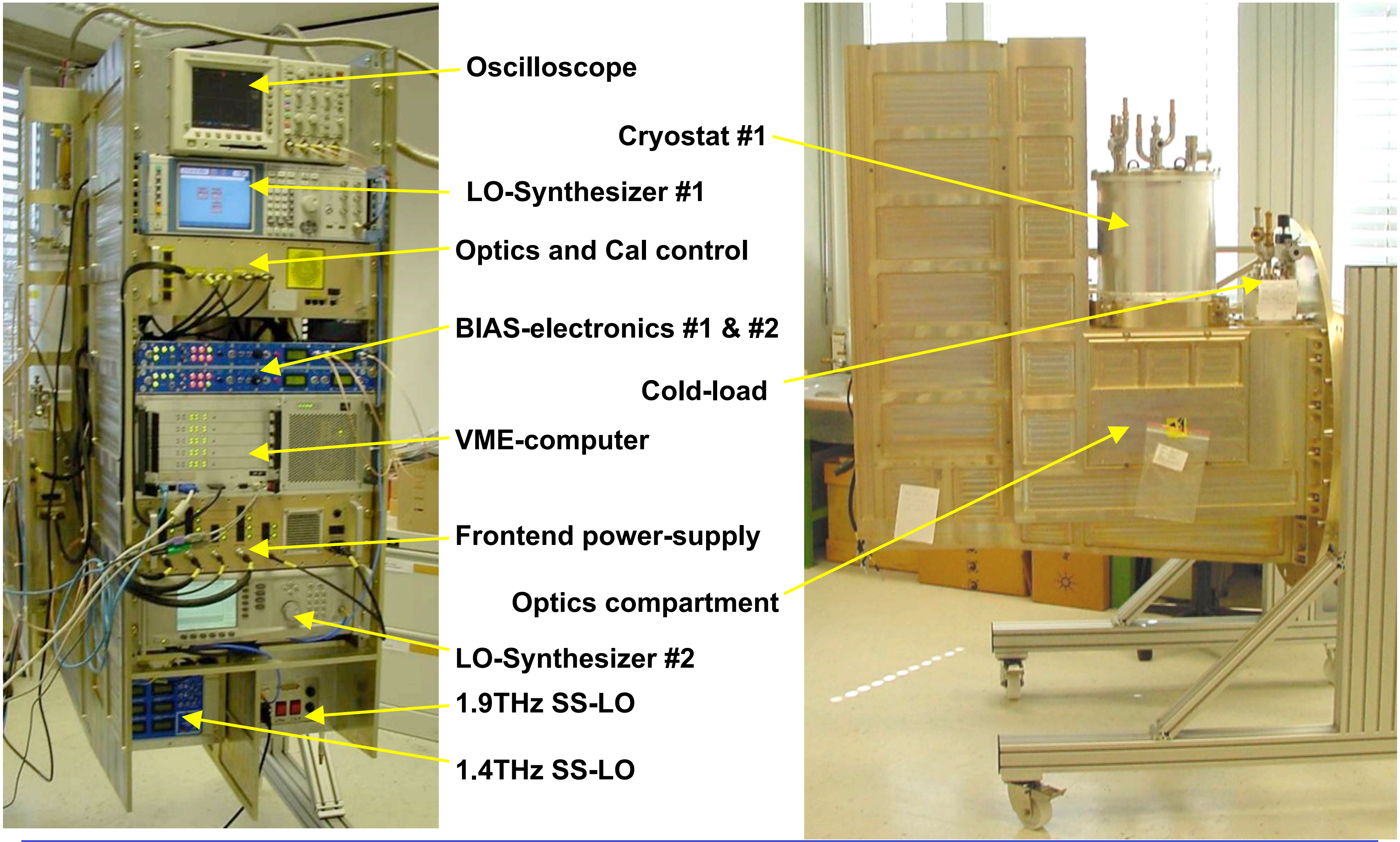

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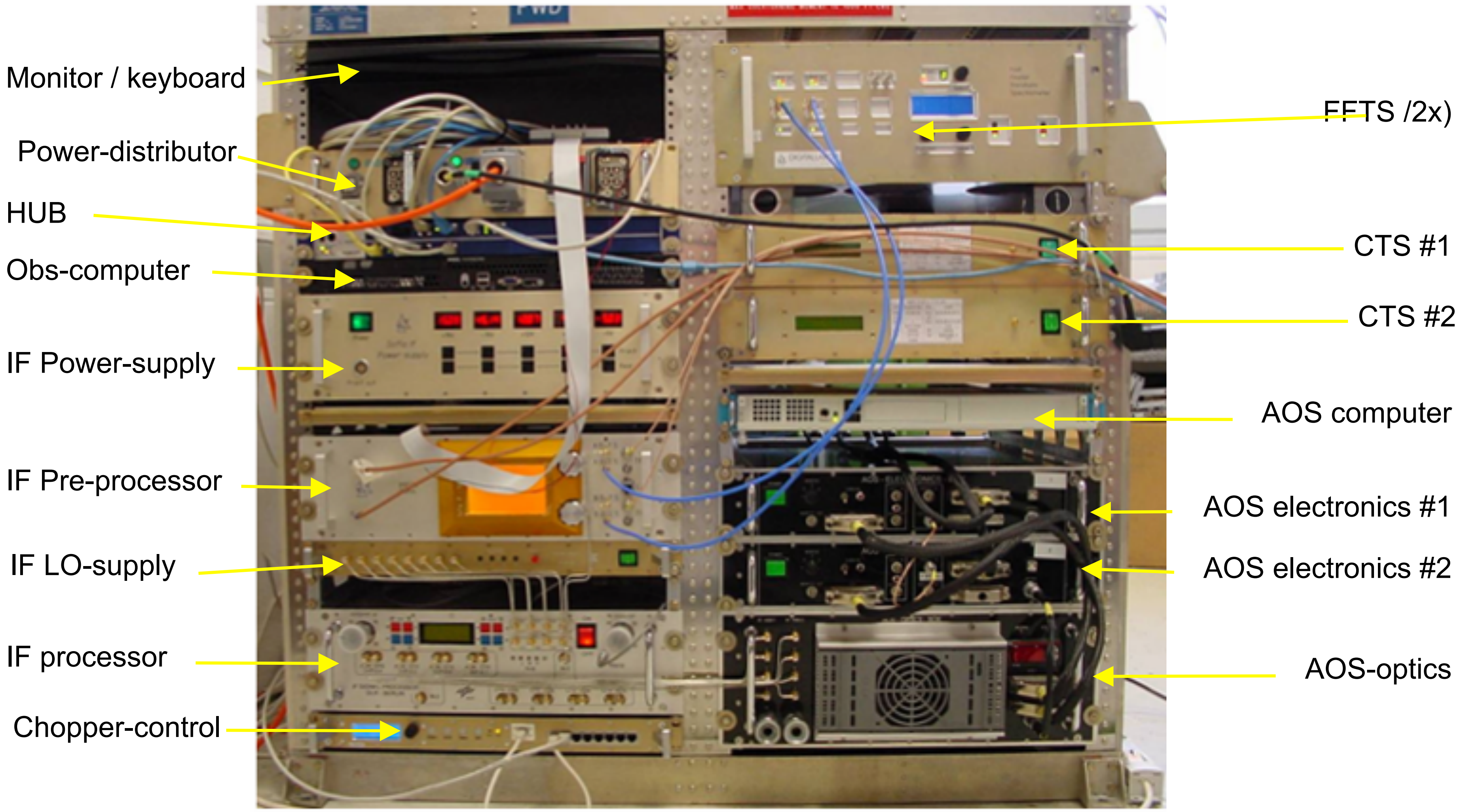
IF & Backends



Frequency Coverage

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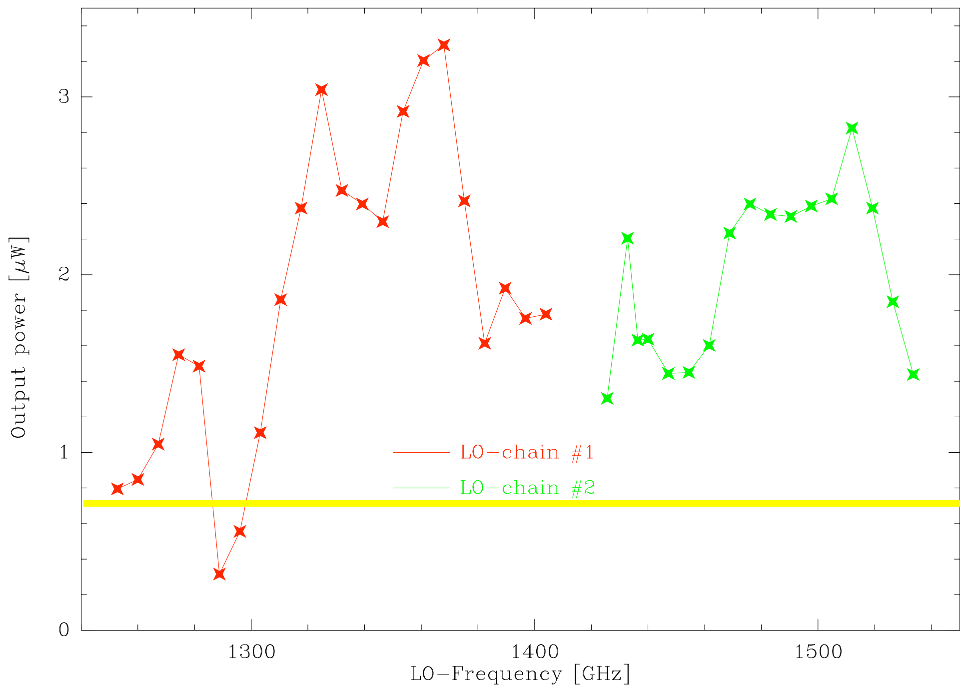
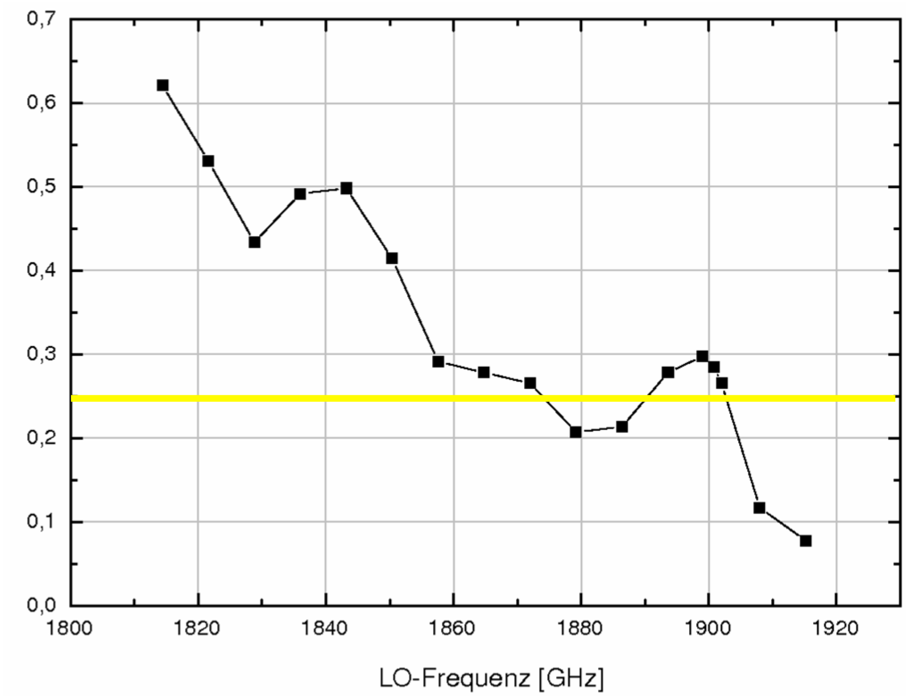
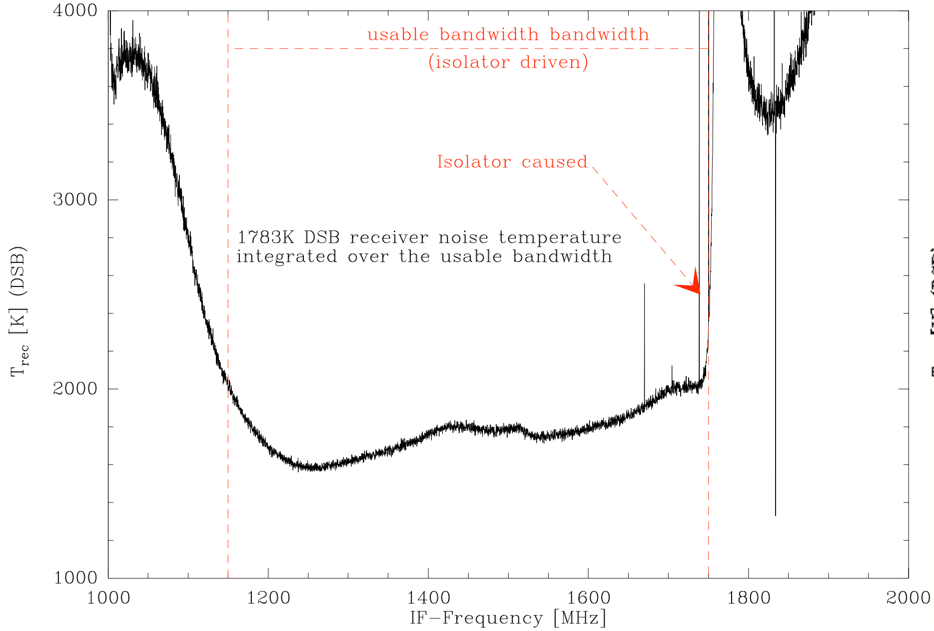
LO-Output power vs. LO tuning frequency
(yellow line indicates minimum power requirement)

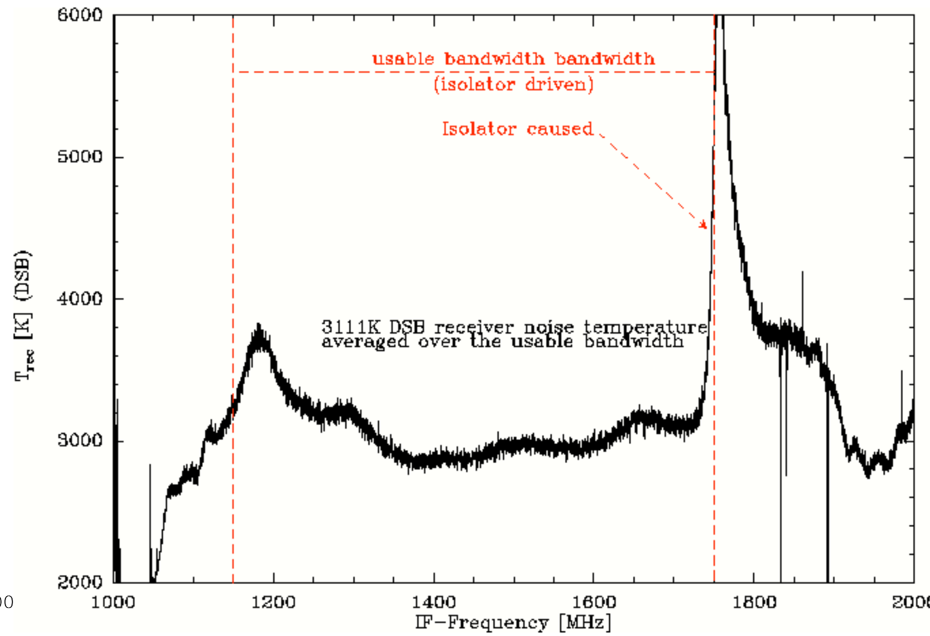




- L#1: 1250 GHz to 1530 GHz
  two exchangeable LO-chains for wide coverage (marked red and green resp.)

- L#2: 1810 GHz to 1905 GHz
  almost continuous coverage, all relevant astronomical lines can be operated





Receiver Temperatures

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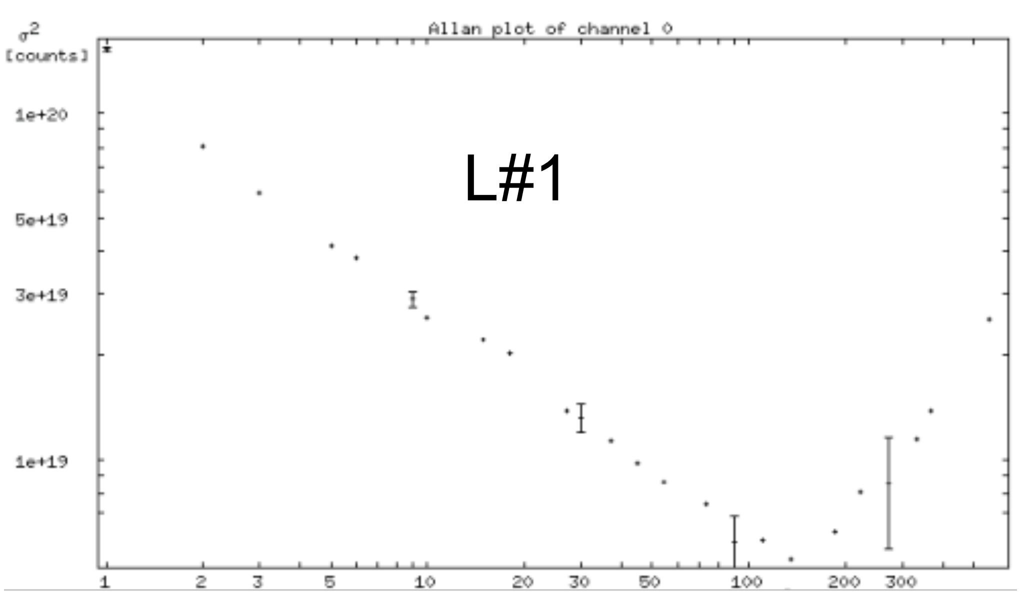
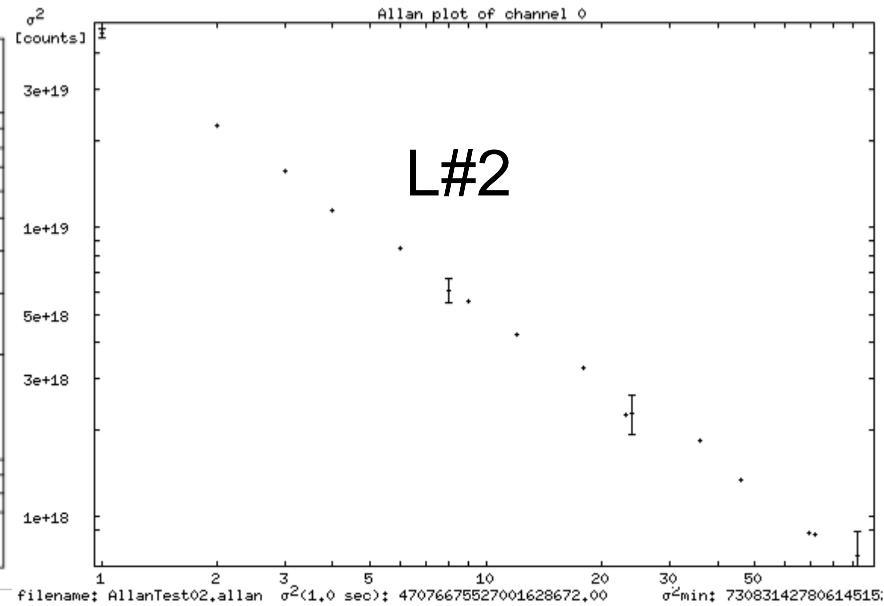
- DSB-receiver noise temperature vs. IF-frequency
  - L#1 @ 1497GHz: 1800K averaged over the usable band
  - L#2 @ 1902GHz: 3000K averaged over the usable band
  - noise temperature includes all losses (uncorrected)
  - bandwidth is limited to 600 MHz by cryogenic isolator

Spectroscopic Stability





- typical Allan-plots (850 kHz resolution), measured with FFTS
  - L#1 tuned to 1497 GHz
  - L#2 tuned to 1902 GHz
  - optics compartment was closed (and evacuated for the L#2 obs)
  - the receiver beam was terminated at an ambient temperature hot load
  - spectroscopic Allan-Variance minimum time > 90s

Schedule towards S/S flights

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- 15.02.09: shipment not later than
- 01.-15.03.09: re-integration, post-shipment inspection
- 01.-30.04.09: GREAT line ops #1
- 15.-27.07.09: re-install, line ops #2 (optional)
- 28.-17.08.09: short science flights with GREAT

- during Short Science, GREAT will be operated in its baseline (L#1 & L#2) configuration
- Basic Science flights may include mid frequency channel (M)
- for Basic Science flights GREAT (operated by the PI team) will be offered to interested SOFIA communities in collaboration with the PI team.

How deep can we go?

- CO J=12-11 1.4969 THz (L#1)
  - T_{rx} = 1800 K , transmission 0.98
  - T_{sys} ~ 4000 K Δv = 1km/s (5 MHz)
  - ΔT ~ 60 mK (rms)
- [CII] 1.902 THz ,157.74 µm (L#2)
  - T_{rx} = 3000 K , transmission 0.8
  - T_{sys} ~ 8300 K Δv = 1km/s (6.3 MHz)
  - ΔT ~ 0.11K (rms)
  - For an unresolved star with a 5 km/s wide line, this corresponds to a one sigma limit ~ 1.7 10^{-17} W/m^2

Outlook and Ongoing Upgrades

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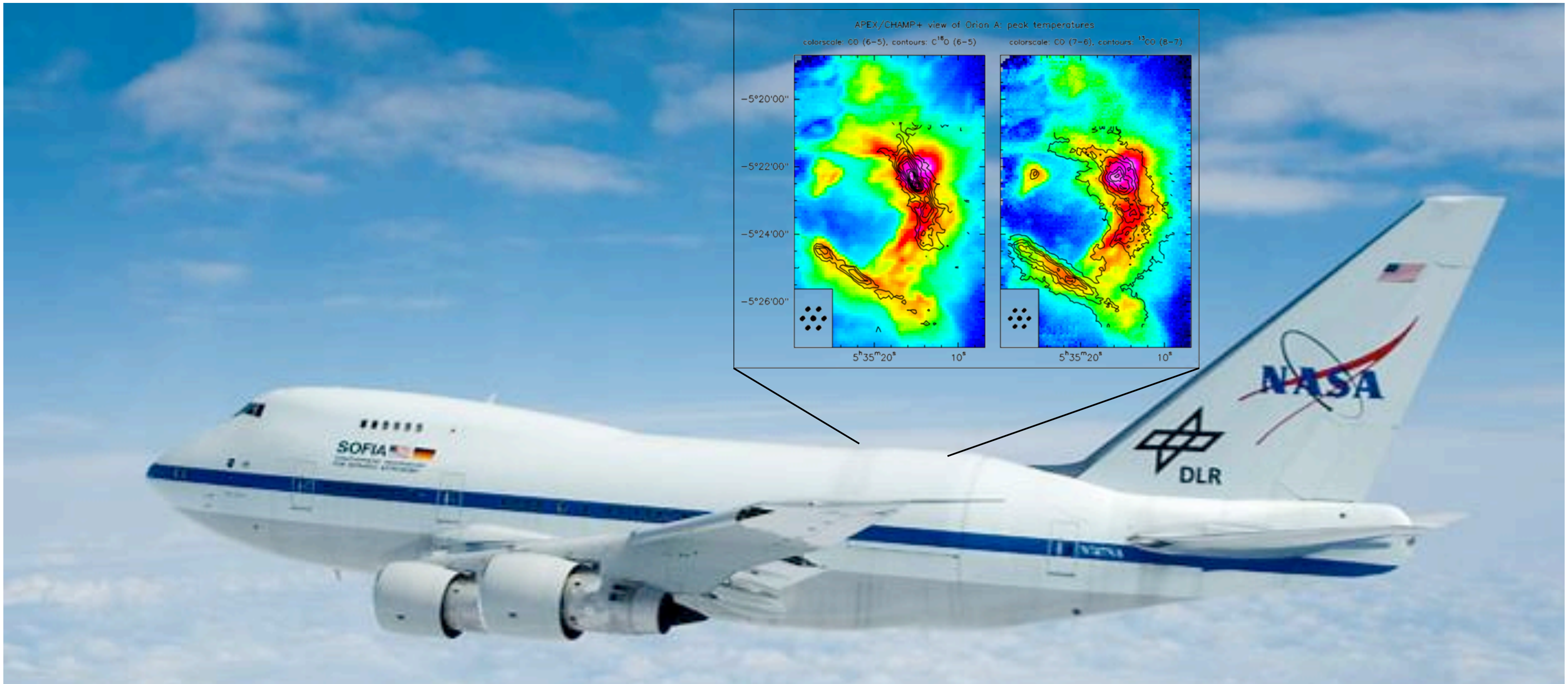

- optimizing the performance of the existing channels and system
  - wider instant. IF-coverage, mixers, LO-system (photonics), back-ends
- additional frequency channels for wider RF-coverage (M, H)
- making use of both polarizations for each channel