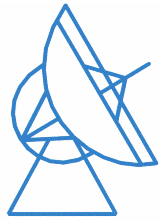

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für Radioastronomie

MPI PI INSTRUMENTS in APEX,

open for collaborations in the submm windows!

Miguel Angel Requena Torres
Max-Planck-Institut für Radioastronomie
Bonn, Germany

APEX :: *Atacama Pathfinder EXperiment*

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APEX during late sunset. The reflections on the antenna outline the positions of the adjustments screws (five for each of the 264 aluminum panels) that had to be adjusted with a few µm accuracy. The rms surface accuracy of the individual panel is 5µm

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Telescope:

Location:	Llano de Chajnantor, 50 Km east San Pedro de Atacama, northern Chile
Coordinates:	Latitude : 23º00"20.8' South Longitude :67º45'33.0" West Elevation : 5105 m
Diameter:	12 m
f/D:	8
Beam width:	(FWHM) 7.8" * (800 / f [GHz])
Main reflector:	264 aluminum panels, average panel surface r.m.s. 5 micron
Surface accuracy:	17 micron rms
Pointing accuracy:	2" rms over sky
Mounting:	Alt-Az
Receiver cabins:	2 Nasmyth + 1 Cassegrain
Mass:	125 000 kg
Manufacturer:	Vertex Antennentechnik

MPI PI instruments

and submm windows

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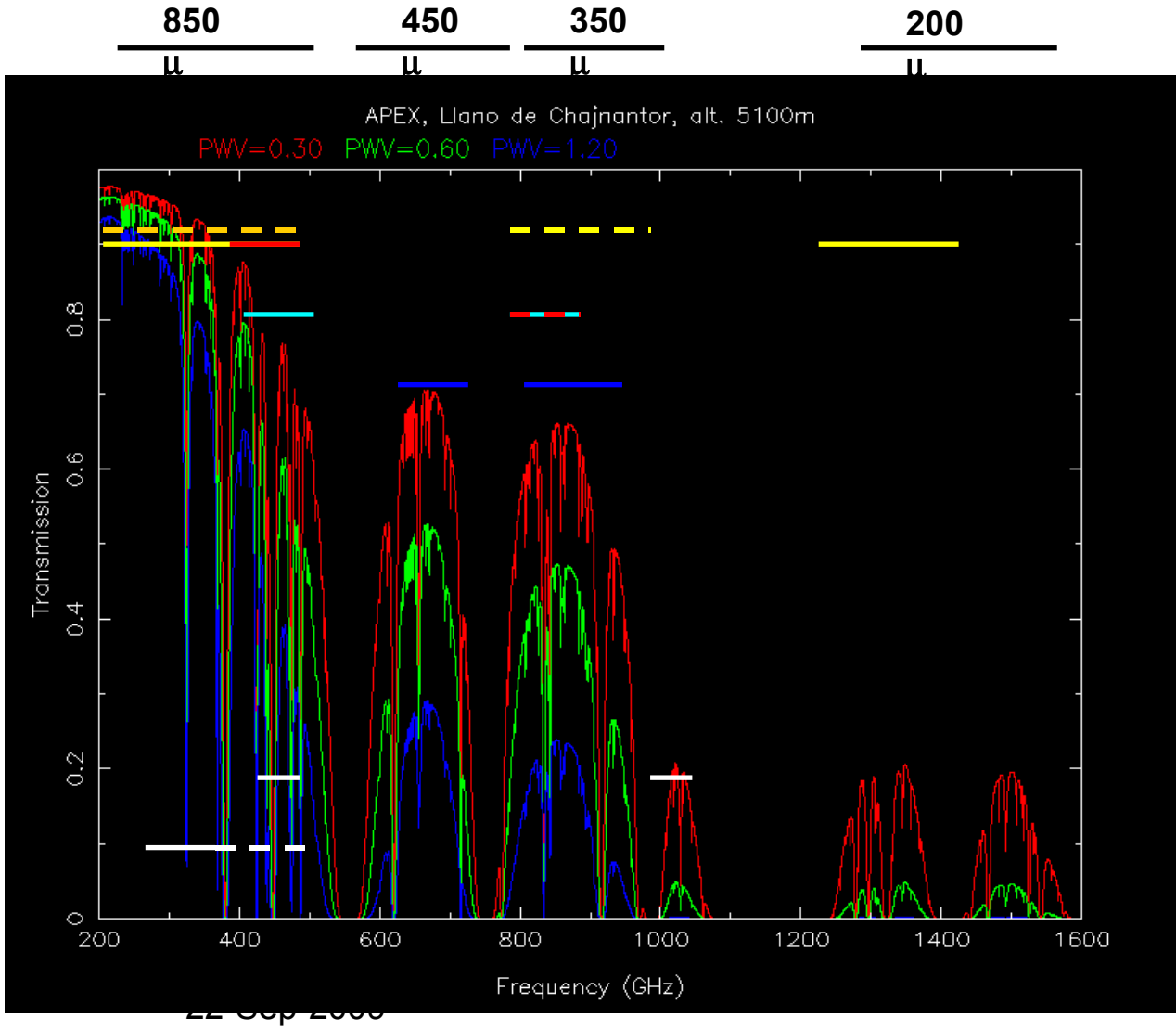
- The present
  - FLASH
  - CHAMP+
  - APEX-SZ
- In commissioning:
  - THz
- The future
  - LASMA



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FLASH

a First Light APEX Submillimeter Heterodyne instrument

Photograph of FLASH installed at the Nasmyth A-cabin of the APEX-telescope

FLASH was build up by

S. Heyminck, C. Kasemann, R. Güsten, B. Klein

We acknowledge support from

Dr. U.Graf (KOSMA) for the design drawings for the FLASH cryostat

Dr. G. de Lange (SRON) for providing the 800 GHz SIS mixer

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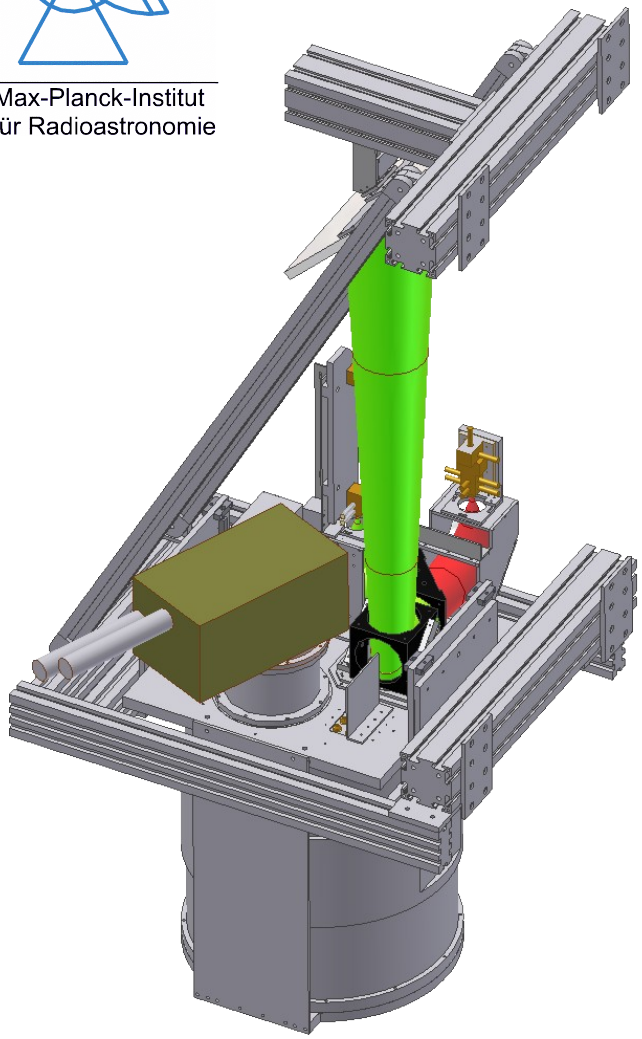
System overview



CAD-model of FLASH including the beam-path (green: 460GHz and red: 810GHz). The closed-cycle cooler is shown in brown. The mixers and big parts of the optics are inside the vacuum tube.

- a **dual channel** heterodyne instrument
- operating at the **460GHz and the 810GHz** atmospheric window
  - **simultaneous** measurements in both bands
  - results in good relative calibration between the bands
- the first light APEX heterodyne receiver

Features:

- **closed cycle cooler**
  - No logistics for liquid He and liquid nitrogen needed
- tuning range:
  - **414-500GHz**
  - **790-840GHz + 875-885GHz** (LO-limited)
- **two channel FFTS** as Backend

Actually, only the 460GHz window is used, as CHAMP+ is operational!

First results

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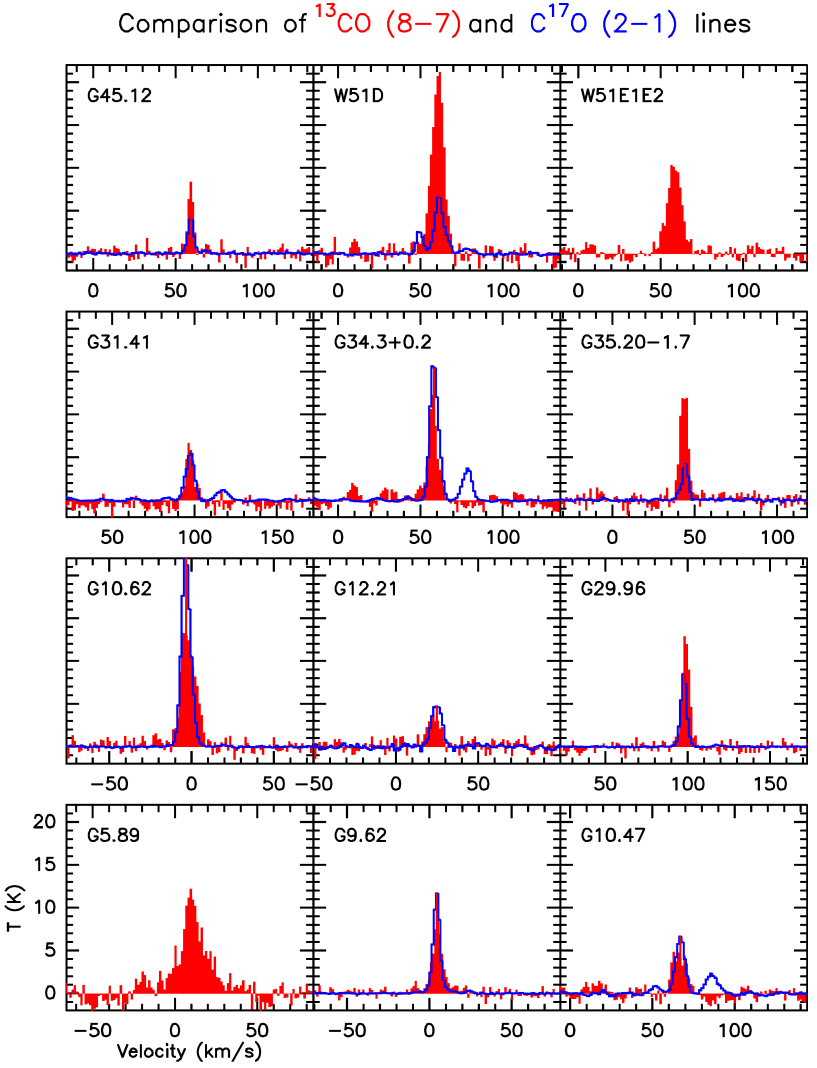
12 massive star forming cores in the inner Galaxy were observed

- in several transitions
  - CO (4-3), CO (7-6)
  - ^{13}CO (8-7),
  - CI (1-0)
- Comparing with C^{17}O (2-1) observations
  (done at IRAM 30m telescope on Pico Veleta, Spain)
- ^{13}CO (8-7) line at 881 GHz was detected
  - in each observed core



Wyrowski et al. 2006, A&A 454, L95-L98

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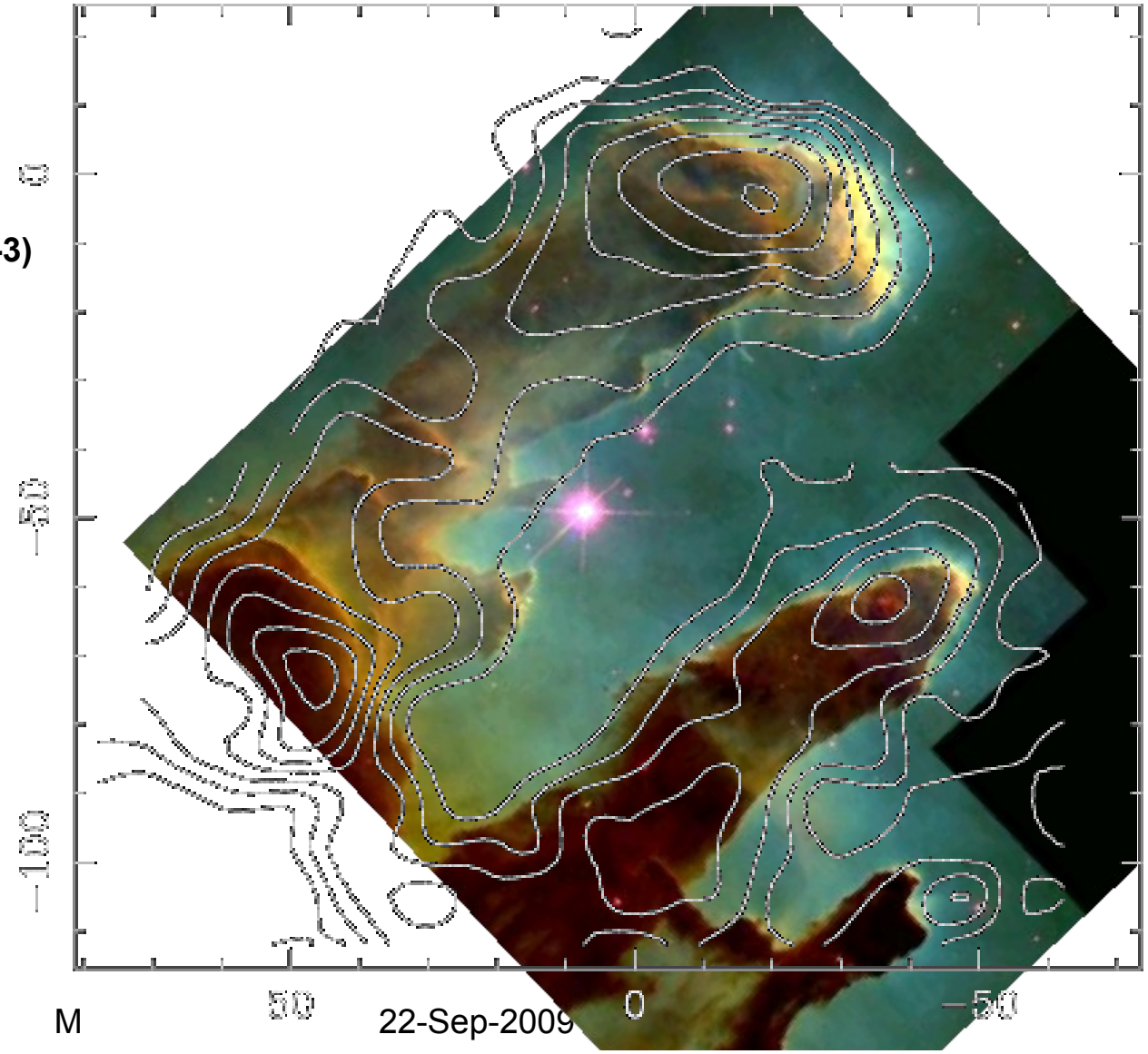
EAGLE Nebula M16l in CO(4-3)

APEX-FLASH-Observation of CO(4-3) overlaid on corresponding HST view of the Eagle Nebula M16l



More data! Coming soon

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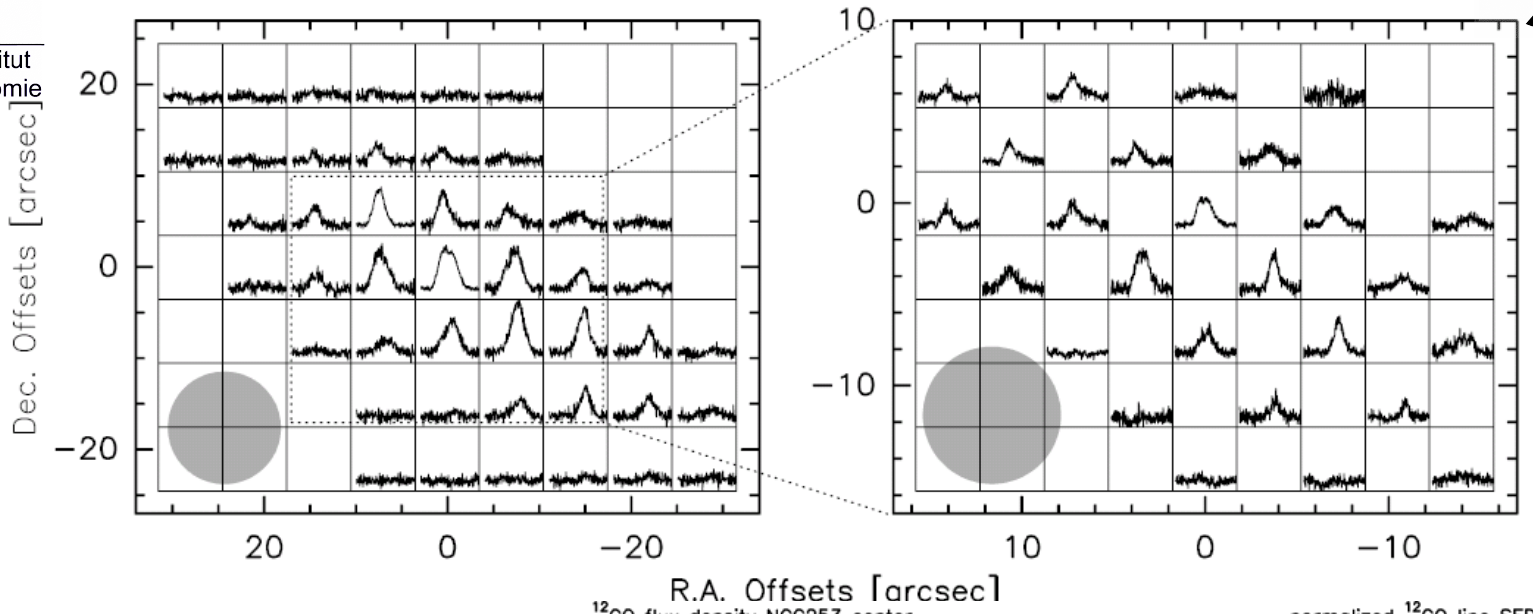
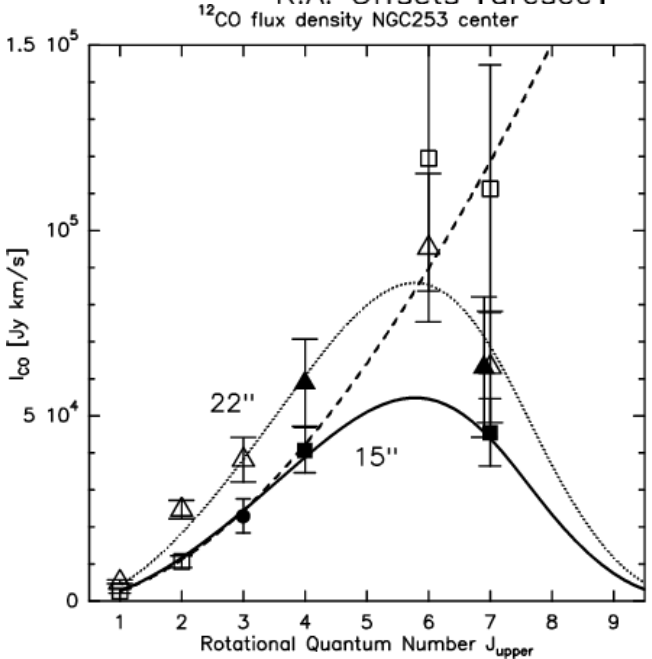
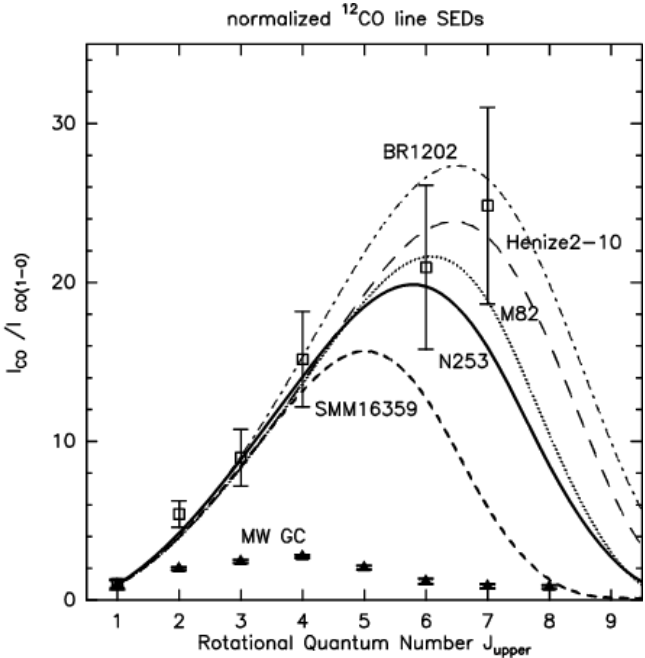


NGC253, Güsten et al. 2006
A&A 454, L115-L118

CO SED

Velocity integrated CO flux density Vs Rotational quamtum number





ESO day, Madrid M

Submillimeter Heterodyne Arrays for APEX

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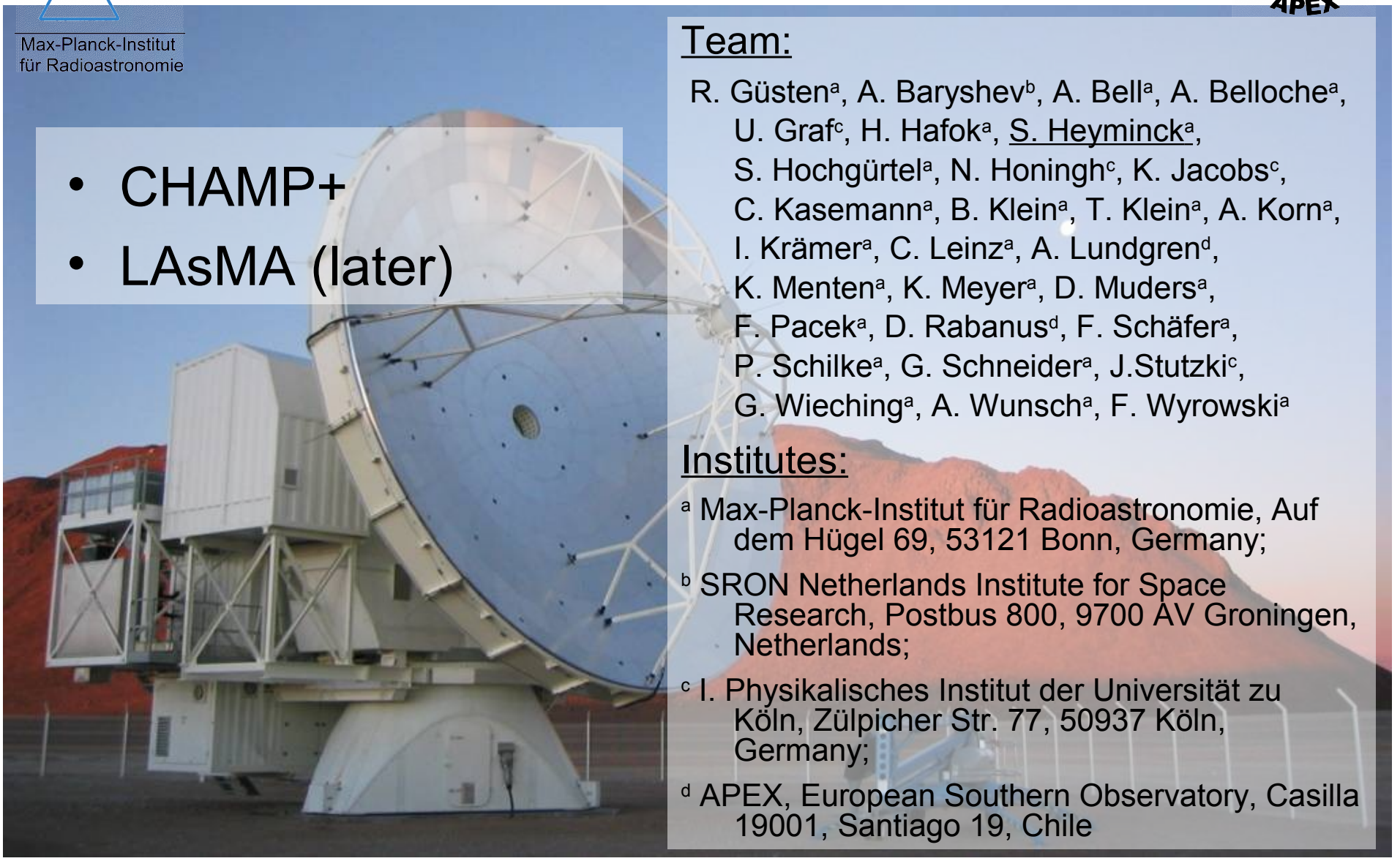
für Radioastronomie



- CHAMP+
- LAsMA (later)

Team:

R. Güsten[a], A. Baryshev[b], A. Bell[a], A. Belloche[a], U. Graf[c], H. Hafok[a], S. Heyminck[a], S. Hochgürtel[a], N. Honingh[c], K. Jacobs[c], C. Kasemann[a], B. Klein[a], T. Klein[a], A. Korn[a], I. Krämer[a], C. Leinz[a], A. Lundgren[d], K. Menten[a], K. Meyer[a], D. Muders[a], F. Pacek[a], D. Rabanus[d], F. Schäfer[a], P. Schilke[a], G. Schneider[a], J.Stutzki[c], G. Wieching[a], A. Wunsch[a], F. Wyrowski[a]

Institutes:

[a] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany;

[b] SRON Netherlands Institute for Space Research, Postbus 800, 9700 AV Groningen, Netherlands;

[c] I. Physikalisches Institut der Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany;

[d] APEX, European Southern Observatory, Casilla 19001, Santiago 19, Chile

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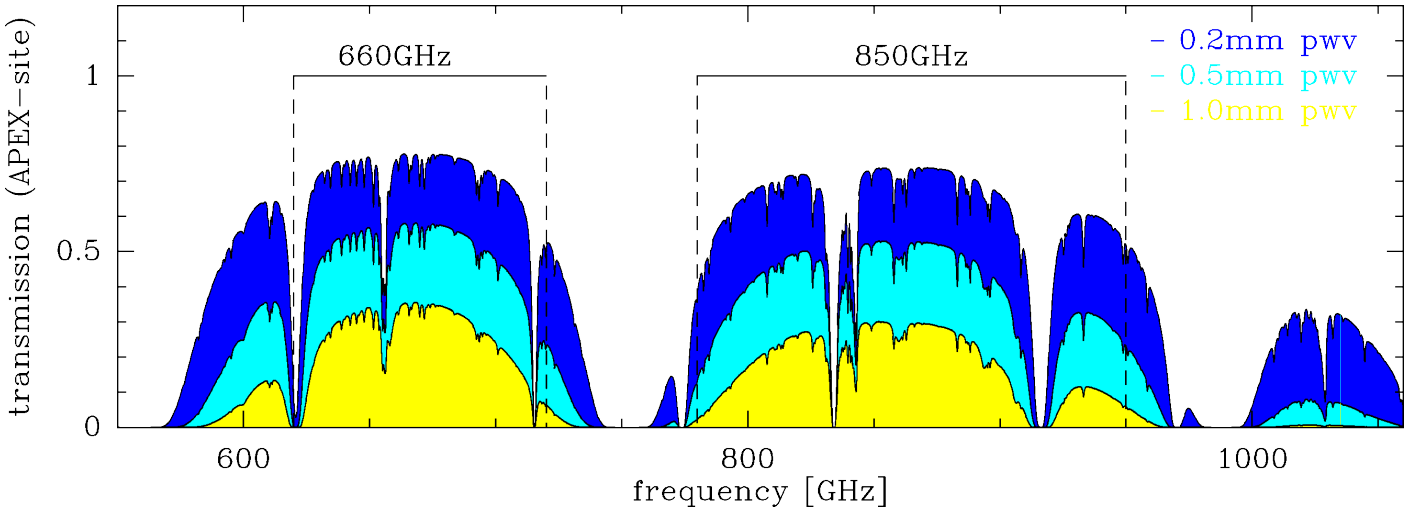
CHAMP+ zenith transmission at Chajnantor



- Atmospheric sub-millimeter windows are wide open from exceptional good sites like Chajnantor / Chile:

  excluding the Bolivian winter (mid of January to end of March)
  - 50% of the time < 1.0 mm pwv
  - 25% of the time < 0.6 mm pwv
  - at prime weather conditions < 0.3 mm pwv

➔ but still time of excellent weather is very limited

CHAMP+:
Instrument description

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für Radioastronomie

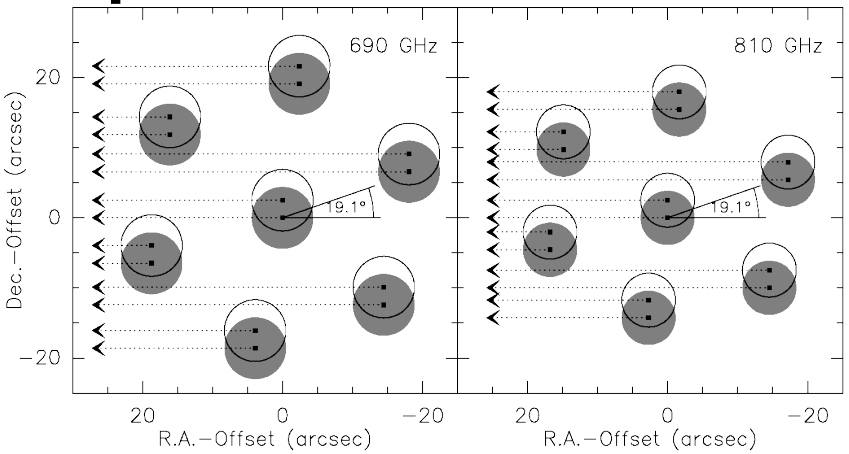
Atacama Pathfinder EXperiment
APEX

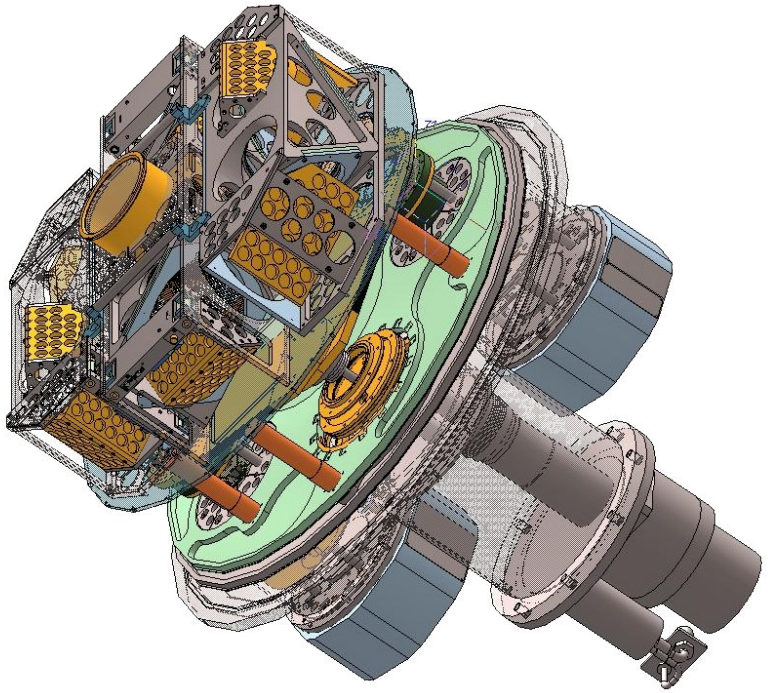
- **two 7-pixel sub-arrays**

(620 – 720 GHz and 780 – 950 GHz)

orthogonal polarizations - parallel observations

- **fixed tuned DSB SIS-mixers (SRON)**
  - **mixer instant. bandwidth: 4 – 8 GHz**
- **main optics cooled to 15 K**
- **SSB-filter for both sub-arrays**
  - **image side-band terminated at 15 K**
- **quasi-optical LO-injection**
  - **Martin-Puplett interferometer as diplexer**
  - **phase-gratings for LO-power distribution**
- **image de-rotation**
- **backend/IF - 2.8 GHz instantaneous bandwidth**
- **fully remote controlled operation**





Heterodyne Arrays

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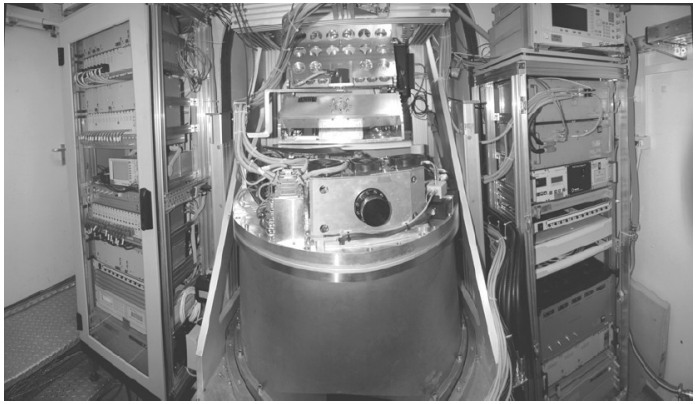
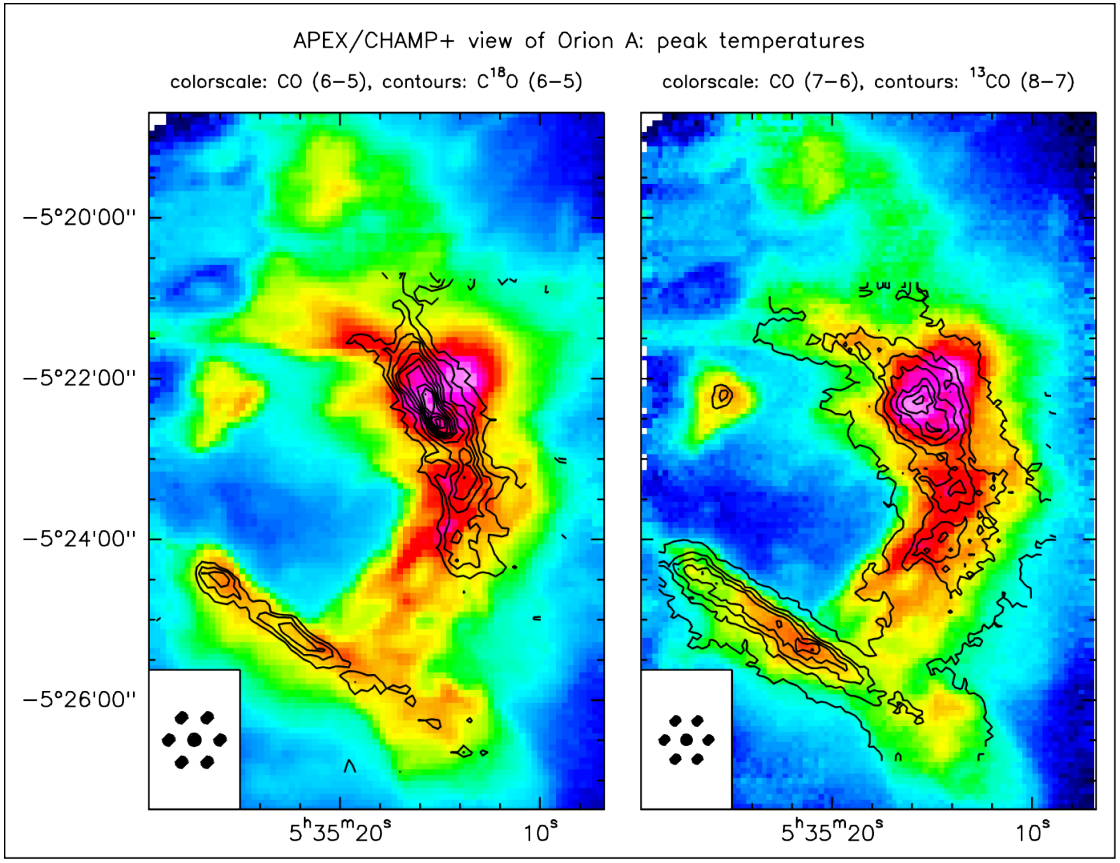


- Orion OTF-Map
- approx. 1Million spectra
- 1s dump time per spectrum

➔ ~25 hrs on source incl. overheads



Peng et al. 2009, to be submitted

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CHAMP+ outside the MPI

Atacama Pathfinder EXperiment
APEX

APEX-CHAMP+ high-J CO observations of low-mass young stellar objects

HH46

CO(6-5)

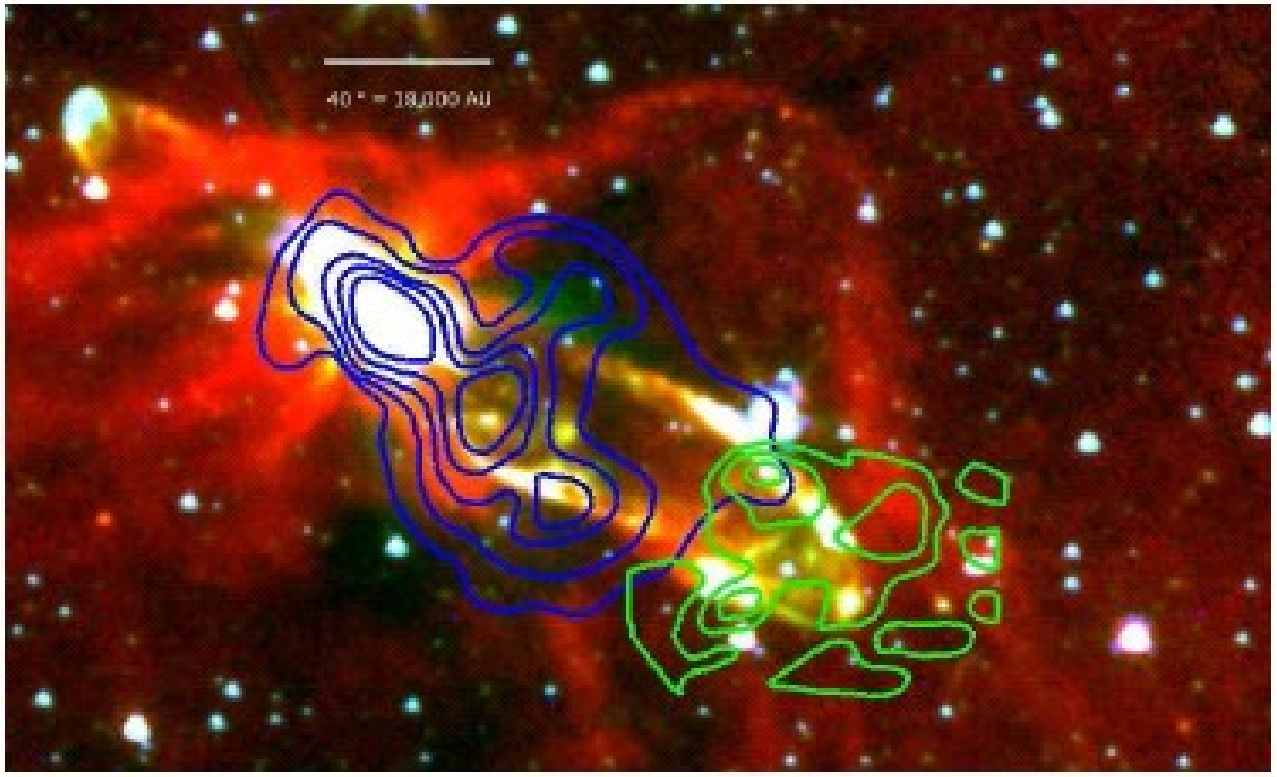
CI (2-1)

IMAGE:

Spitzer-IRAC

1- green

4- red



T. A. van Kempen, et al. 2009, A&A, 501, 633 and A&A accepted (astro-ph 0908.3446)

APEX-SZ camera

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für Radioastronomie

Atacama Pathfinder EXperiment
APEX

Consortium

- **UC Berkeley/ LBNL Group**
- **Boulder**
- **MPIfR/AIfA Bonn**
- **Cardiff**
- **Onsala**
- **ALMA/ESO**
- **MPI for Extraterrestrial Physics**

Sunyaev-Zel'dovich effect (SZE) is the name given to the process by which the Cosmic Microwave Background (CMB) blackbody spectrum is distorted by the presence of galaxy clusters.

Contact in the MPI:
Kaustuv Basu

The APEX-SZ Camera

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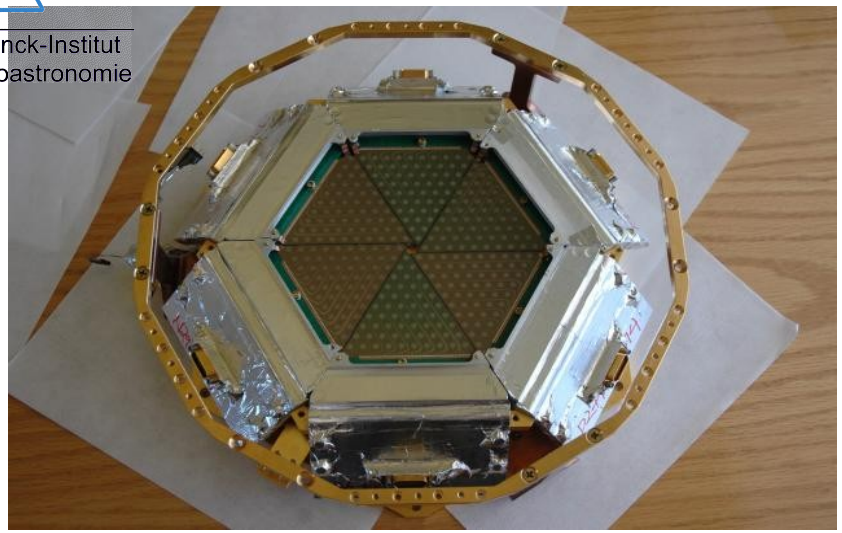


PI instrument on APEX, commissioned Spring 2007, approx 300 hours of data

Demonstrates new technologies for SZ experiments

APEX-SZ Characteristics

Bolometer array composed of 330 transition edge sensors (TES)

0.4 degree field of view

Spectral band centered on 150 GHz (wavelength = 2 [mm])

Single-moded conical horns

Multiplexed detector readout using SQUIDs

Single detector NET of ~700 [μK√ s]

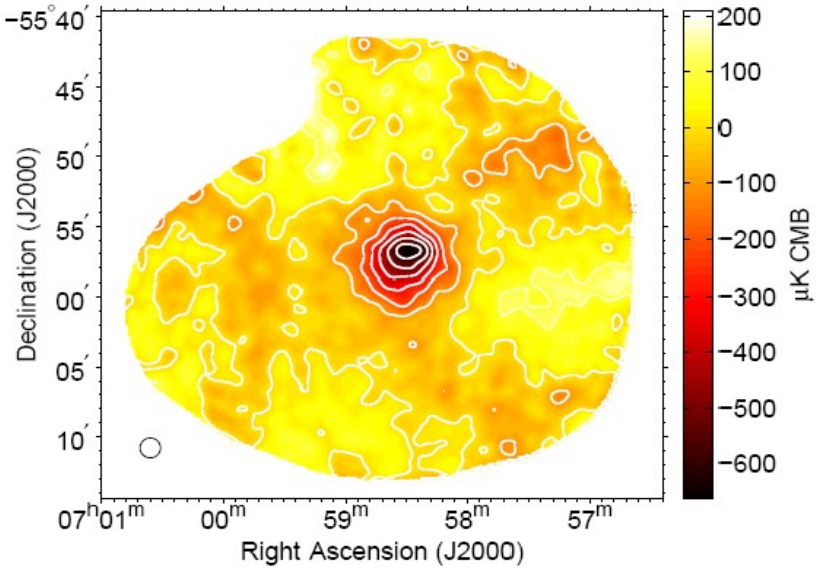
Pulse-tube cooler and Helium-10 refrigerator

Detector array temperature of 300 [mK]

Powerful camera for targeted cluster observation

Results from the APEX-SZ Experiment

Max-Planck-Institut für Radioastronomie

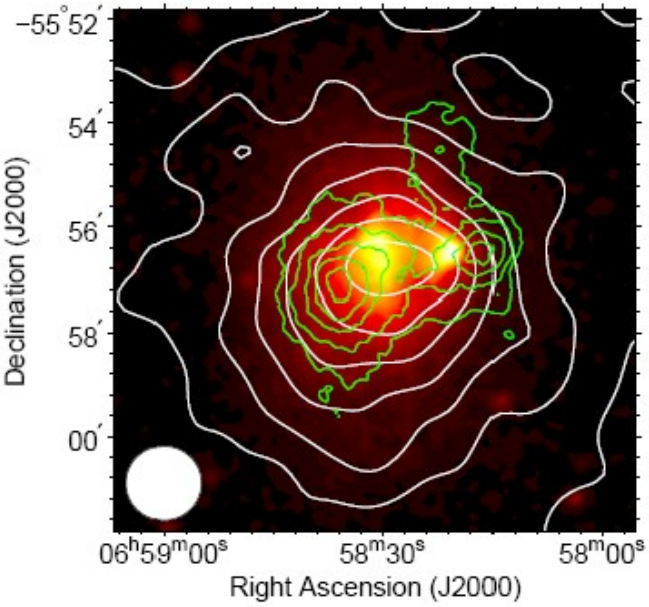


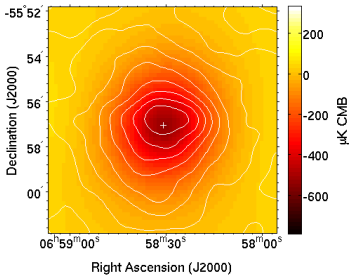
23 sigma detection, 10.7 ± 0.8 keV

The Bullet cluster (1E 0657-56)

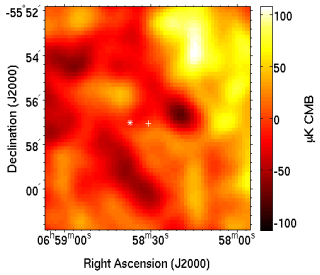
Halverson, Lanting et al. (ApJ 2009, 701, 42)

X-ray image with APEX-SZ white contours and weak-lensing (green contours)

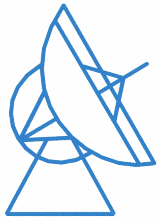




Beta model fit



residual map



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AND… in the near future

1THz Receiver System

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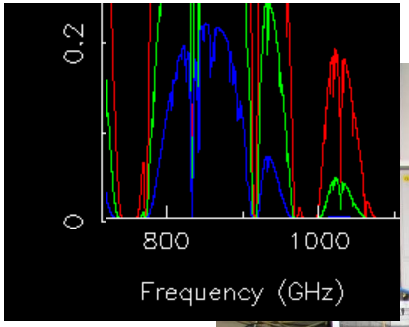
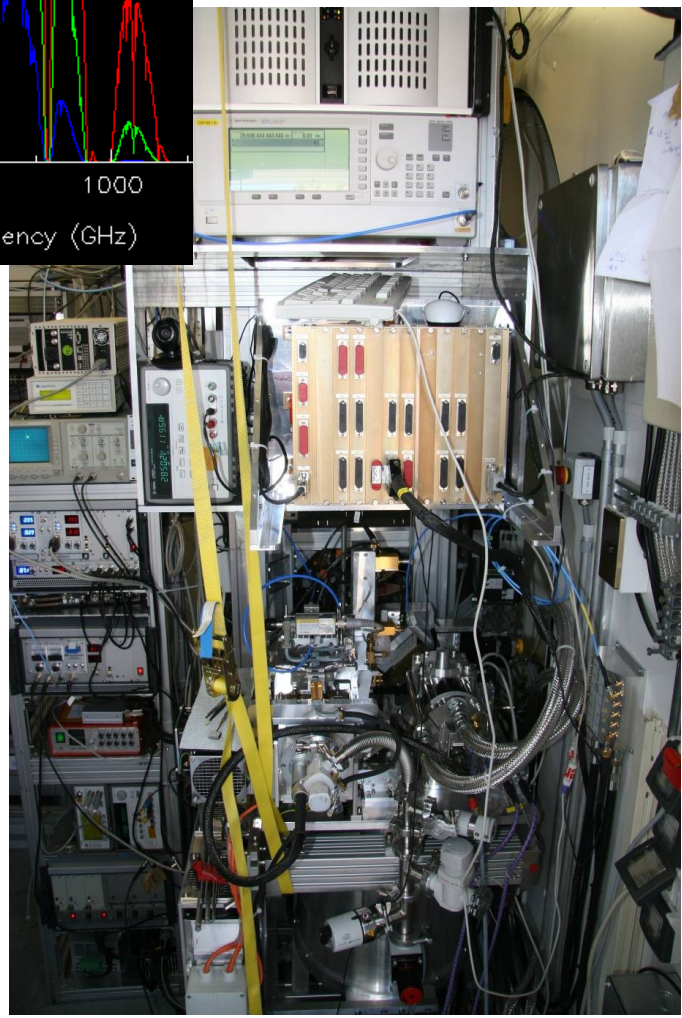
Atacama Pathfinder EXperiment
APEX

In Commissioning, Two pixels receiver, one in the THz window and another in the 480GHz window for pointing!

- **1 THz**
  - **SIS mixer**
  - **4-8GHz IF Bandwidth**
  - **Trec: ~580K DSB @ 1031GHz**
  - **LO: cooled active multiplier chain @ 120K, cooling system: stirling cooler**
  - **LO coverage 970-1040GHz**
  - **LO injection in quasi-optical mixer path: Martin-Puplett Interferometer**
- **480GHz**
  - **SIS mixer**
  - **2GHz-4GHz IF Bandwidth**
  - **Trec: ~180K DSB @ 480GHz**
  - **LO: GUNN oscillator multiplier chain @ 300K**
  - **LO coverage 460-490GHz**
  - **LO injection in quasi-optical mixer path: Mylar foil**
- **General:**
  - **RX cryocooler: Sumitomo, RX Temperature 4K**
  - **APECS system commands RX frequency**
  - **1THz LO subsystem is fully remote controlled via PC and in-house developed LabVIEW software package**





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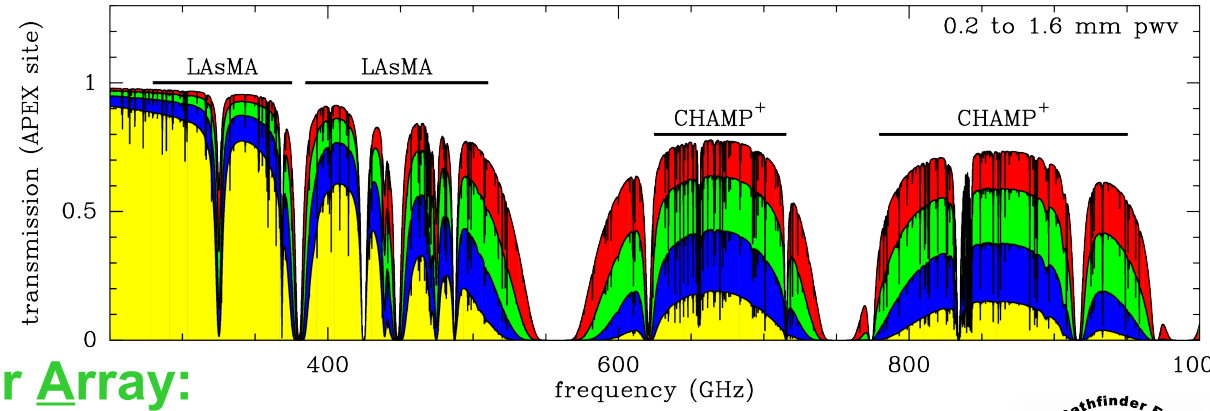
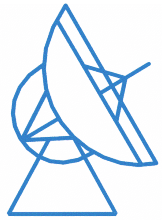
LAsMA



Large APEX sub-Millimeter Array:

- 7-pixel at **280–375 GHz** and 19-pixel at **380–510 GHz**
  - operating on orthogonal polarizations allows for parallel observations
  - hexagonal beam-pattern
- fixed tuned DSB SIS mixers (Cologne Uni.)
  - mixer instant. bandwidth 4-12GHz
- frequency-independent optics (Gaussian telescope setup)
- SSB-filters for both sub-arrays (image side-band terminated at 20K)
- quasi-optical LO-injection
  - Martin-Puplett interferometer as diplexer
  - phase-gratings for LO-power distribution
- K-mirror as image de-rotator
- full remote controlled
- using of the CHAMP+ IF-system and A-FFTS at the beginning
  - Individual IF and FFTS-System with wider bandwidth as upgrade



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To observe, contact first
R. Guesten at the MPI.
guesten@mpifr-bonn.mpg.de