APEX: Observing in mm and sub-mm

Palle Møller and Carlos De Breuck

Connecting back ….

If you have a great idea, then it either:

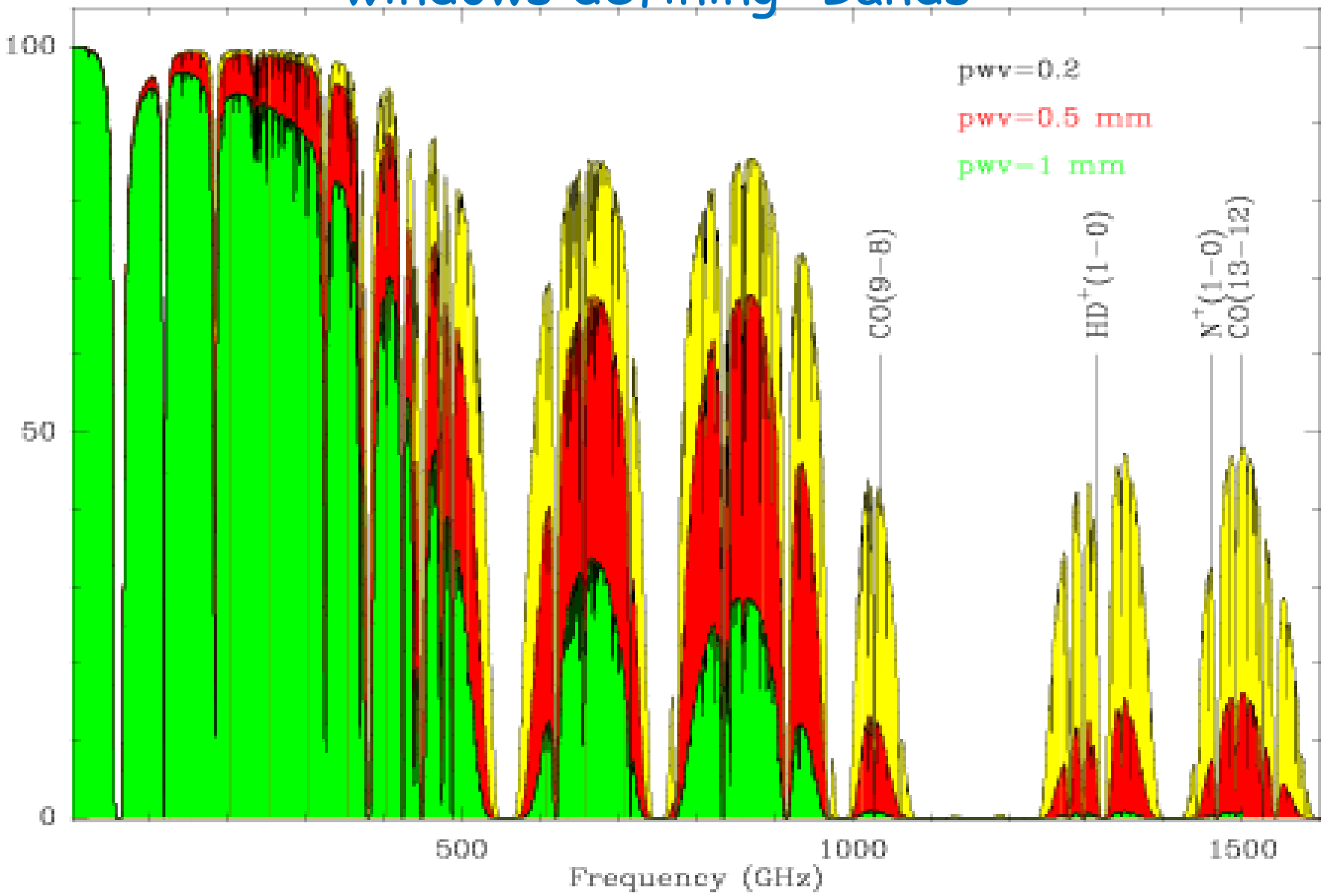
- has already been done,
- it is *not* that great an idea,
- or you are lucky that it has only just now become possible to do!

APEX: Observing in mm and sub-mm

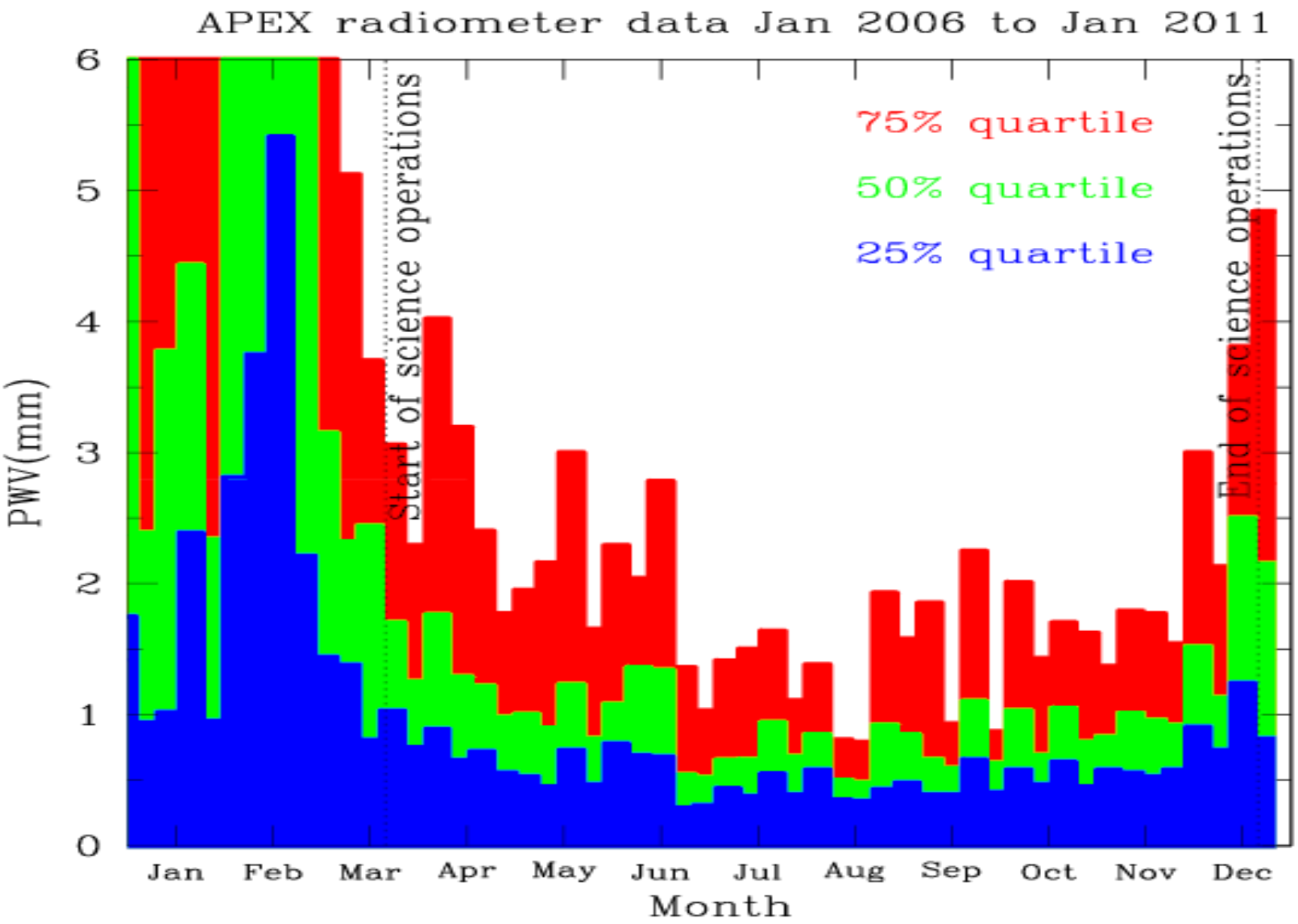
At 5100 m

Precipitable Water Vapour

windows defining "Bands"



Precipitable Water Vapour statistics



The APEX telescope

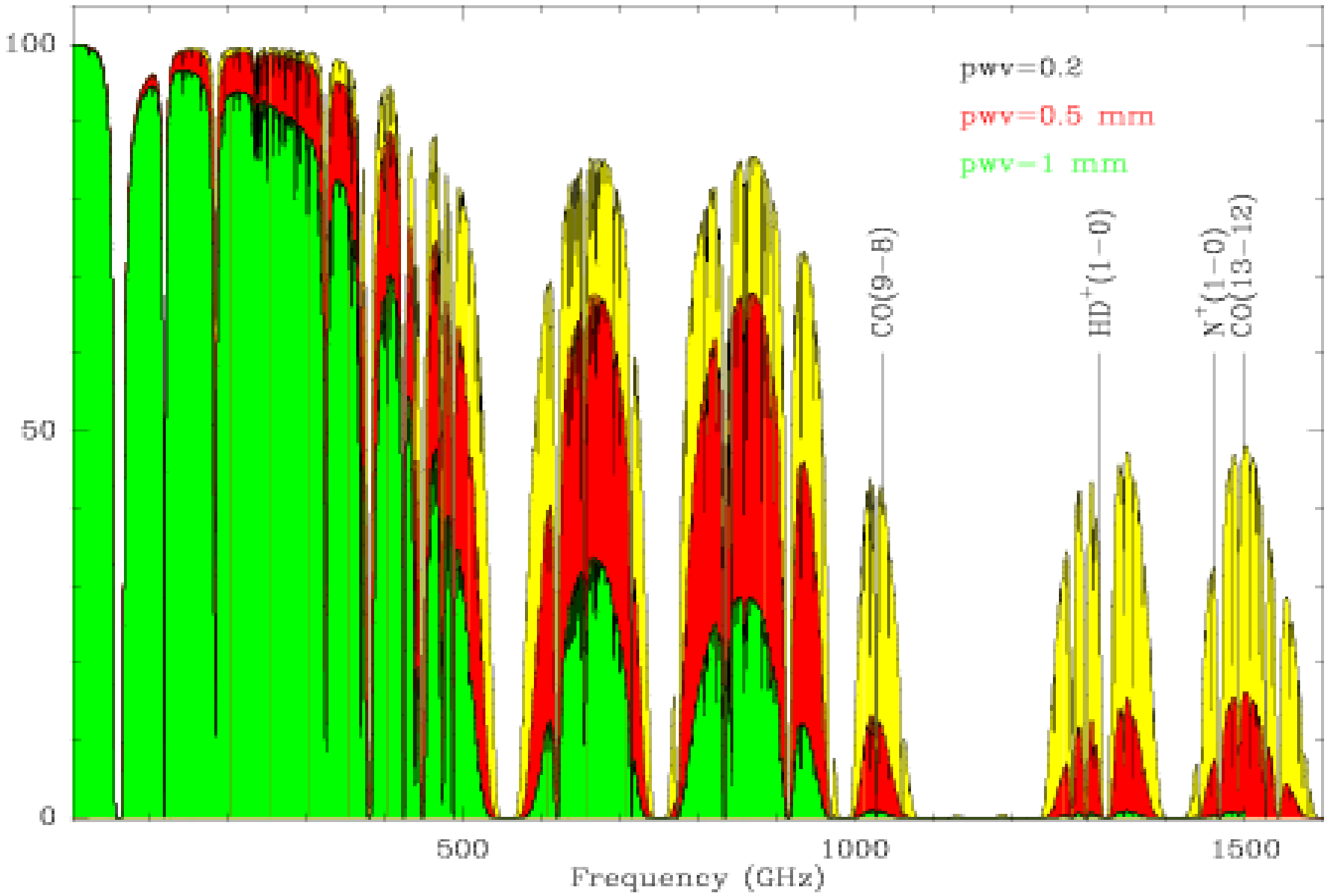
- Based on ALMA (Vertex) proto-type 12m antenna.
- Major upgrade of metrology system has improved pointing accuracy to rms<1.5".
- 14 μm rms surface accuracy. No etching ⇒ 30° Sun avoidance, but daytime operations possible.
- Wobbler: Azimuth only, max 2 Hz, 150" throw.
- 2 Nasmyth + Cassegrain cabin: up to 8 instruments.
- Service mode only observatory.

Swedish Heterodyne Facility Instrument
SHFI

- 4 single pixel receivers in 1 cryostat:
  - APEX-1: 211 to 275 GHz. Only instrument to observe with PWV>2mm. Large programmes for PWV>2mm explicitly solicited in CfP.
  - APEX-2: 275 to 370 GHz.
  - APEX-3: 385 to 500 GHz.
  - (APEX-T2: 1.25 to 1.39 THz. (being repaired))
- Backend:
  - 2 XFFTS units of 2.5 GHz each.
  - covers 4 GHz with fixed offset.
  - 32786 channels (76 kHz or 0.1 km/s resolution).

A1 A2 A3

T2

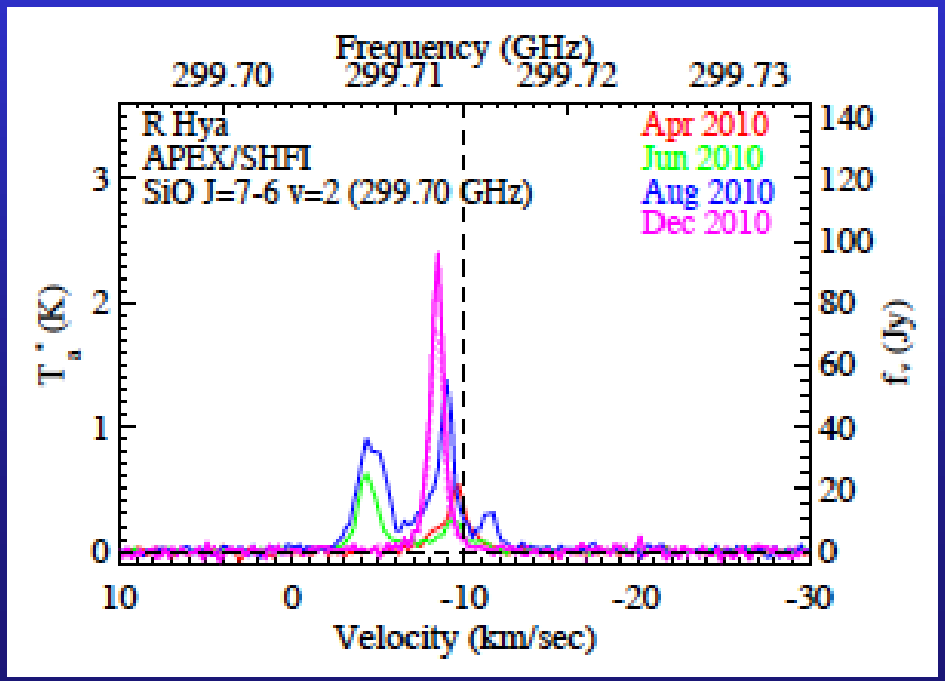

100
50
0
500
1000
1500
Frequency (GHz)
pwv=0.2
pwv=0.5 mm
pwv=1 mm
CO(9–8)
HD+(1–0)
N+(1–0)
CO(13–12)

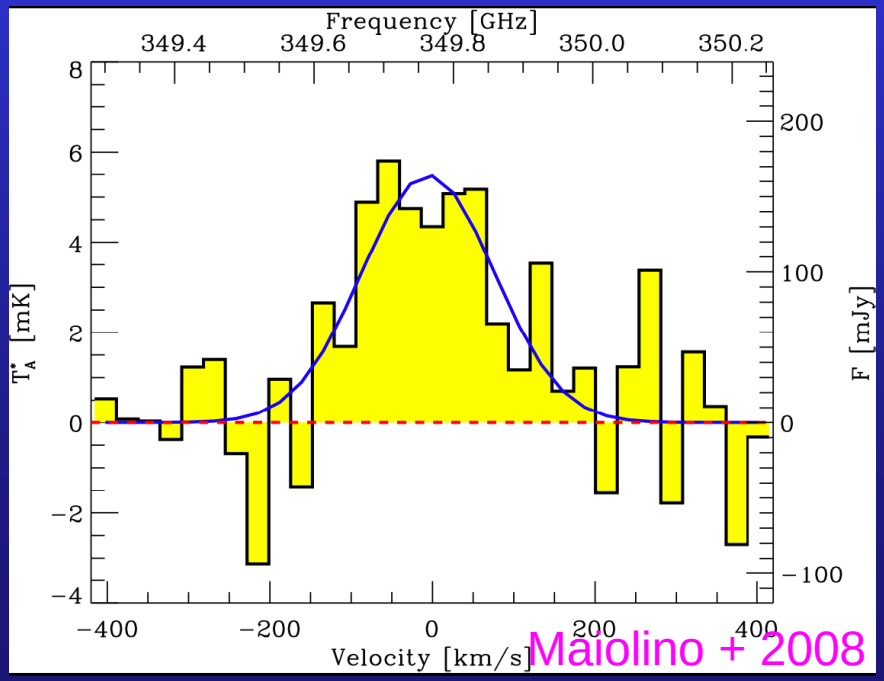
SHFI observing modes

- Wobbler switching modes:
  - Alternate with 0.5 to 2 Hz between on & off position using M2 to allow sky subtraction.
  - Wobbler can only move in Azimuth ⇒ off position changes with HA.
- Position switching:
  - Point telescope every ~10s between on & off.
  - Allows to point to known source-free position.
- On The Fly (OTF) mapping:
  - Efficient mapping of large areas.
  - Creates data cubes.
- Rasters and "Hacar/Stanke" multiple on's + off.

Selected SHFI science areas

- Chemistry of comets.
- Dense gas tracers in star forming regions / AGB stars.
- Variability in masers (e.g. SiO).
- CO(2-1), (3-2) and (4-3) in local universe.
- [CII] detections in high redshift AGN/SMGs.

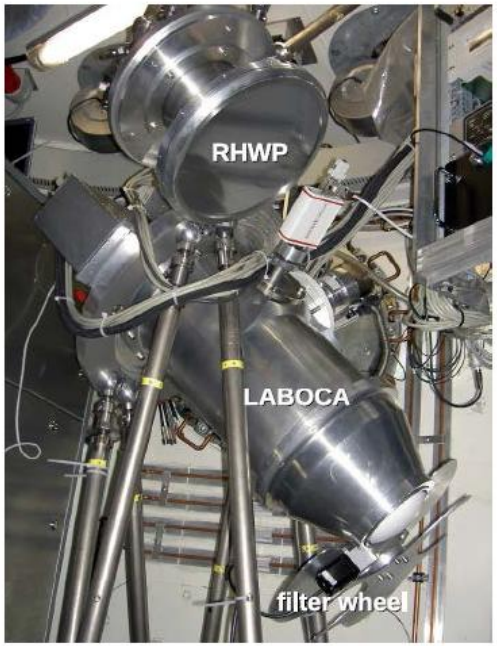


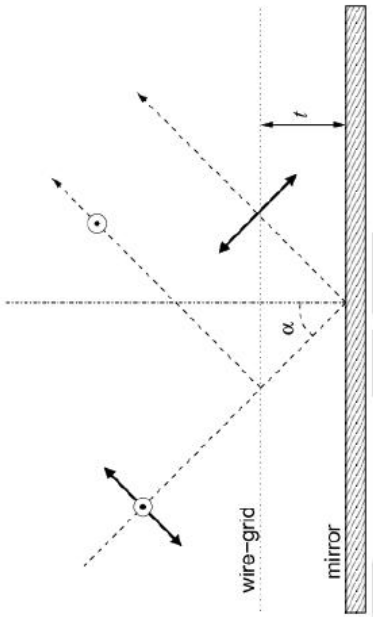


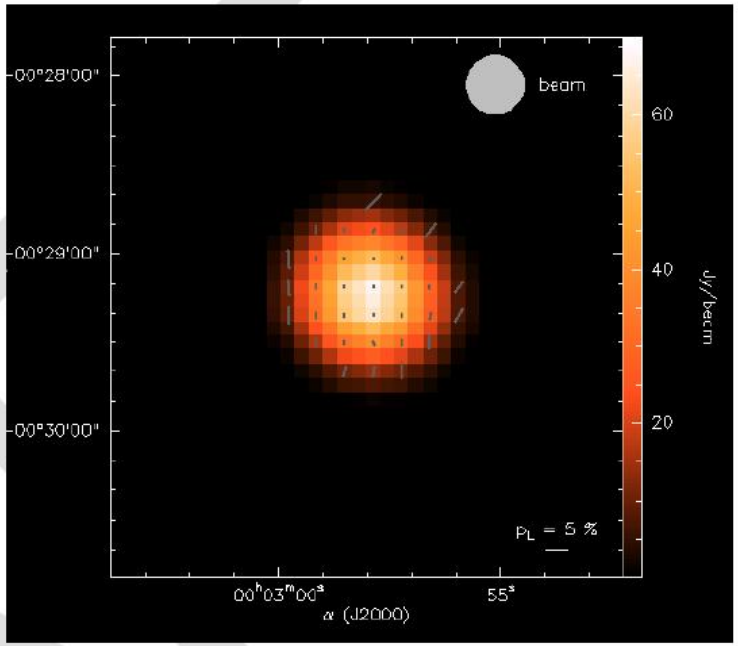
Maiolino + 2008

LABOCA 850μm bolometer

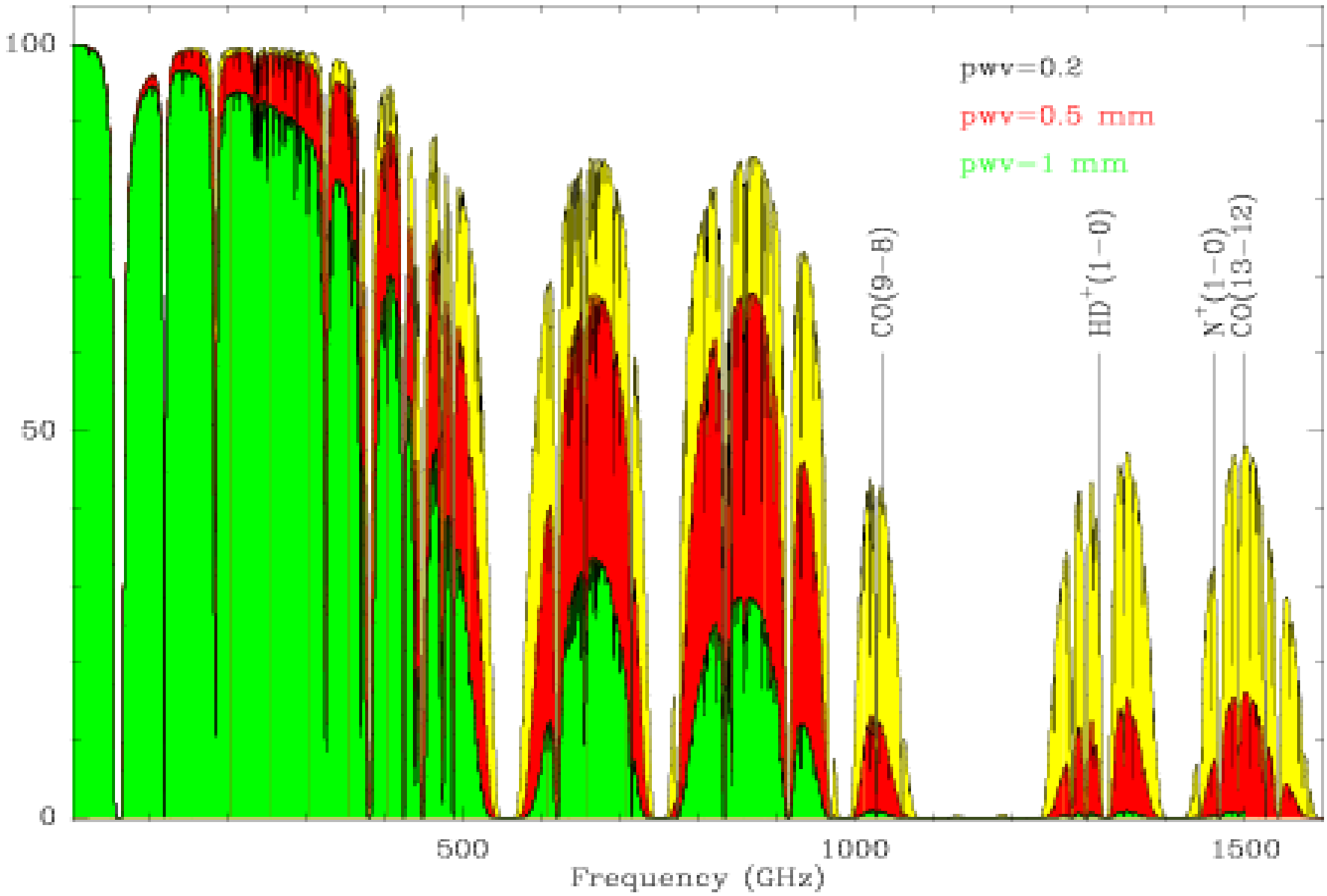
- 295 channel array at 850 μm (11′ FoV).
- Liquid Nitrogen and Helium cooled to 0.3 K.
- 20″ spatial resolution.
- Ideal to map extended emission to ~5′ scales.





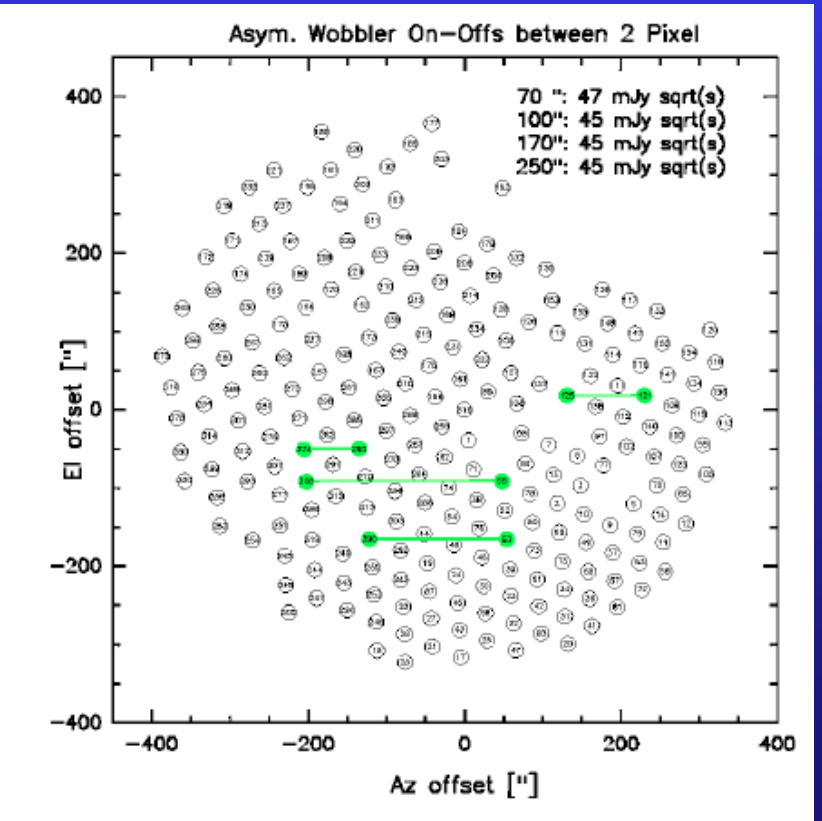


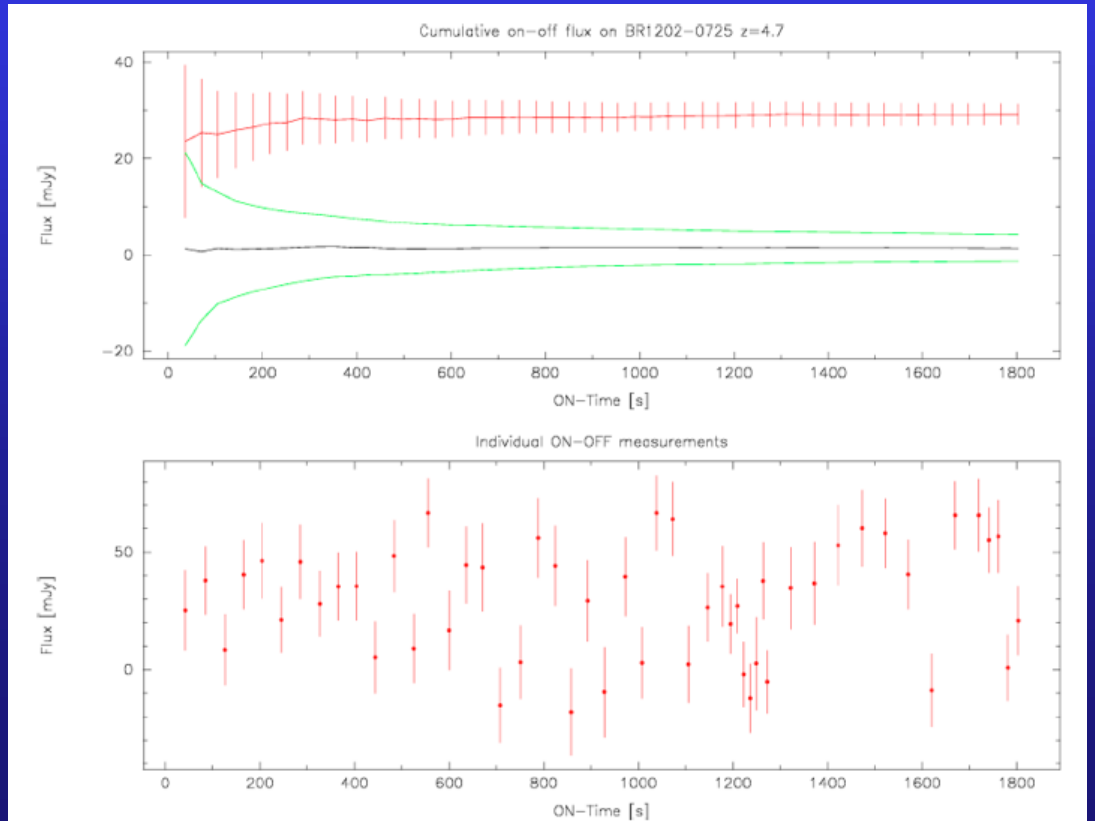
Laboca Saboca



L/SABOCA photometry mode

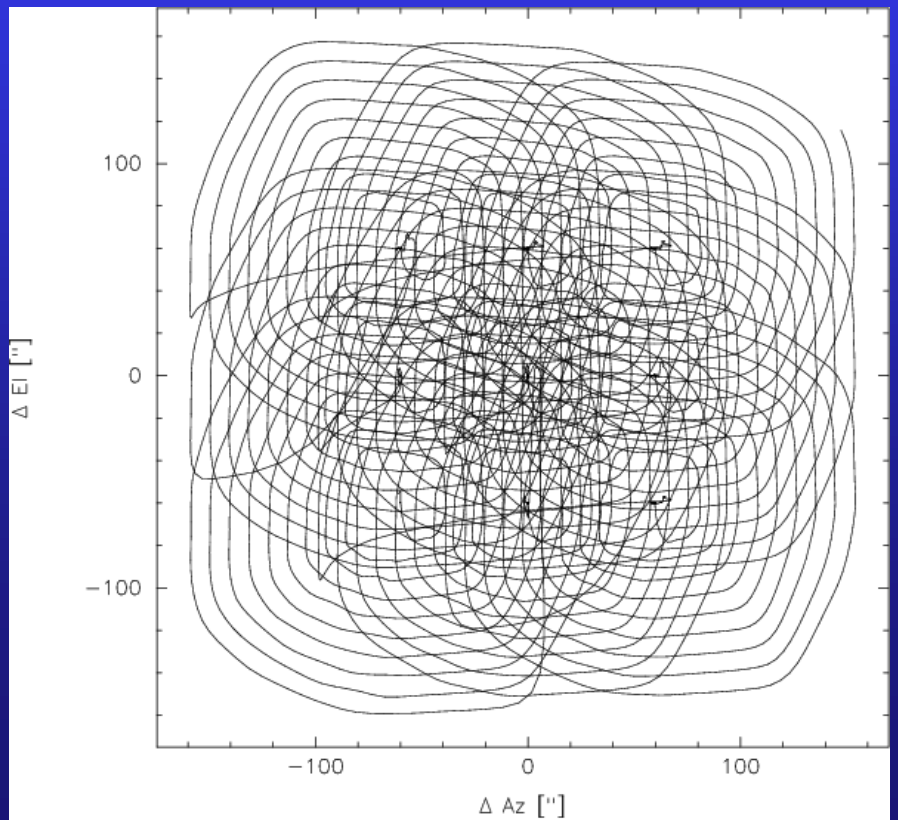
- If source position is known to few arcsec accuracy, one would like to spend most of the time with the source on one of the bolometers.
- Warning: receiver & atmosphere instabilities often dominate. Flux less accurate than mapping!

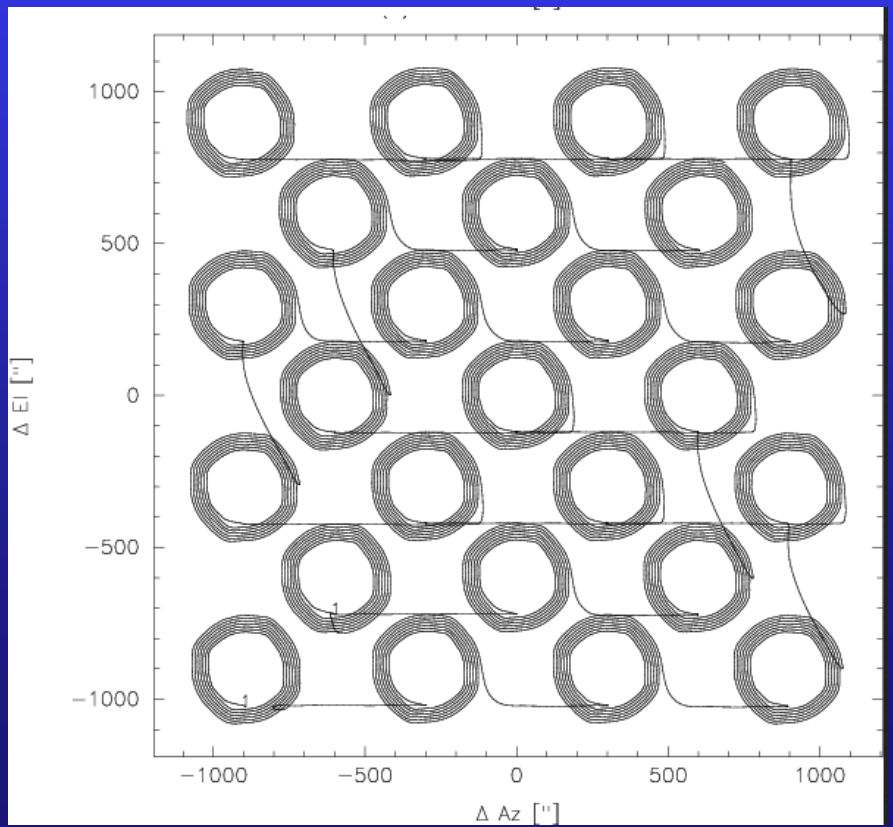




Fast scanning patterns

- Telescope needs to move faster over bolometer pixels than sky variations.
- Most used pattern are (raster of) spirals.
- For >30' maps, On The Fly becomes more efficient.

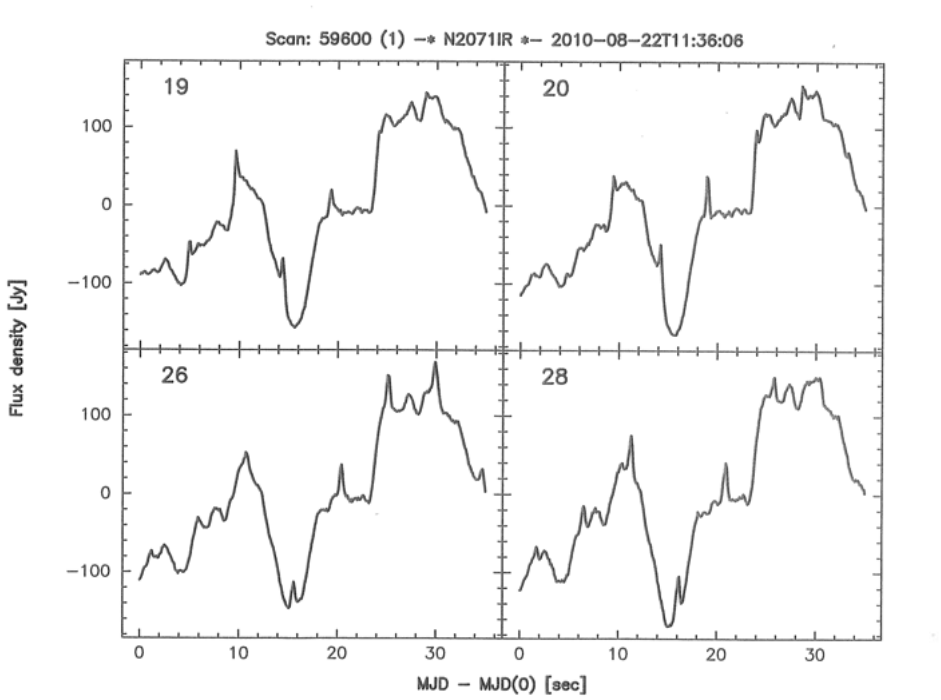




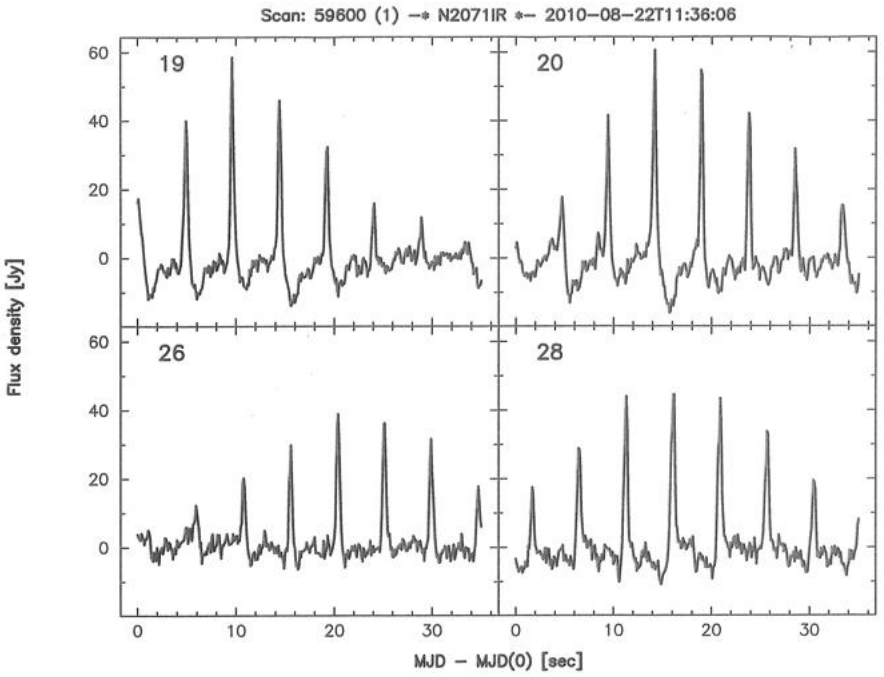
LABOCA time streams

- Sky >> brighter than sources (except Jupiter).
- Sky signal is seen by all bolometers, allowing removal of correlated sky noise.

Before sky subtraction

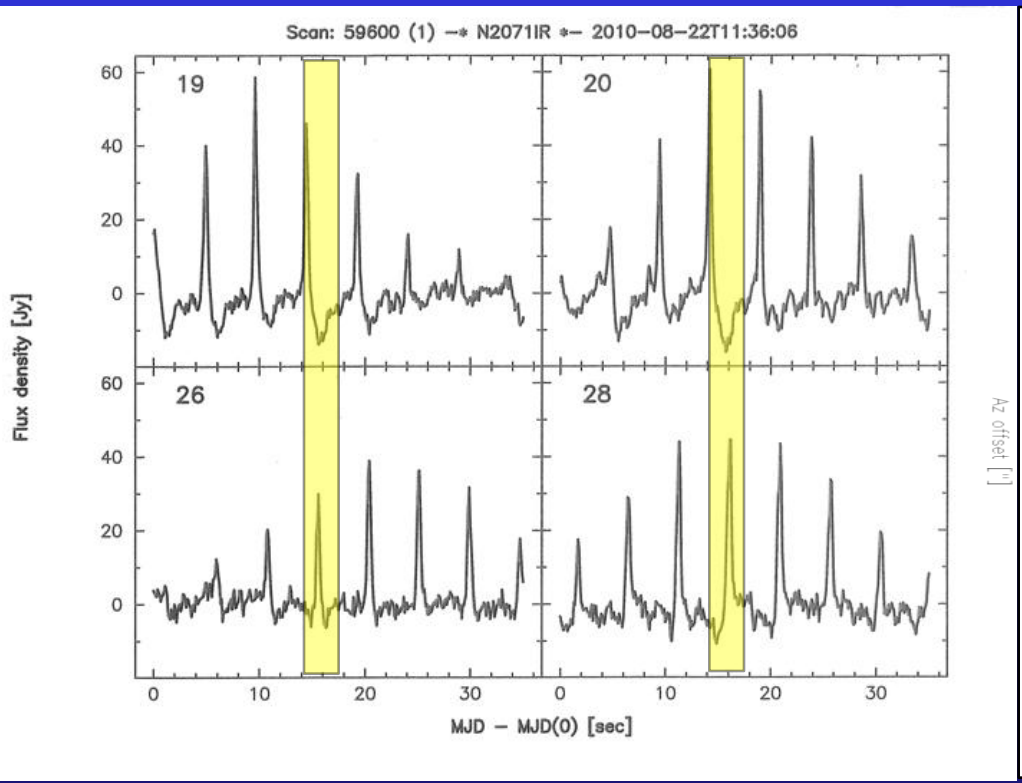


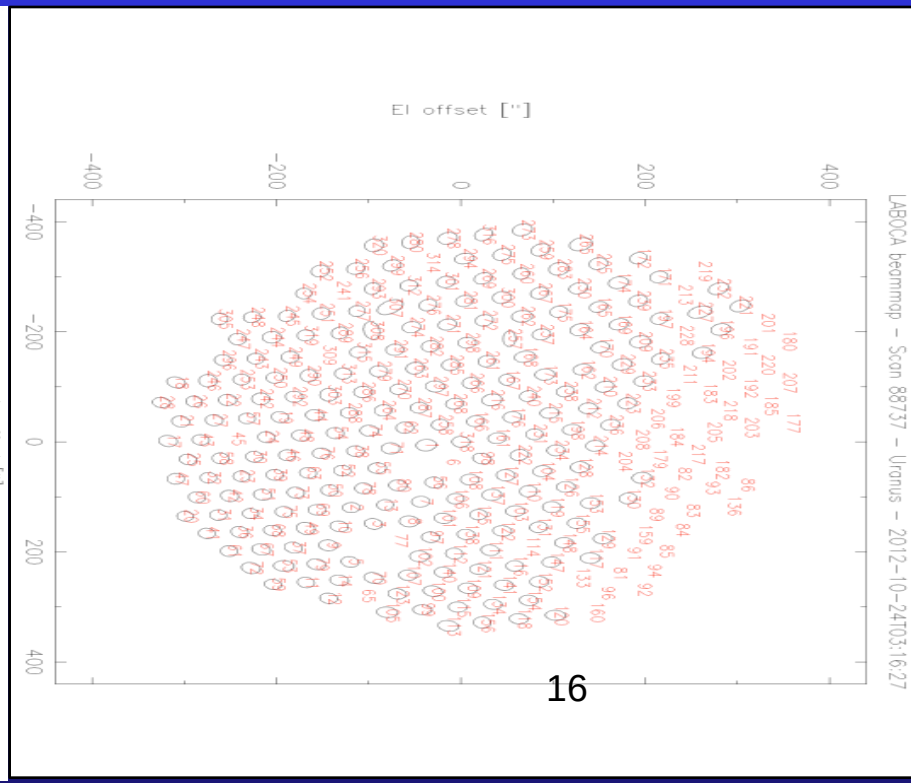
After sky subtraction



From time streams to maps

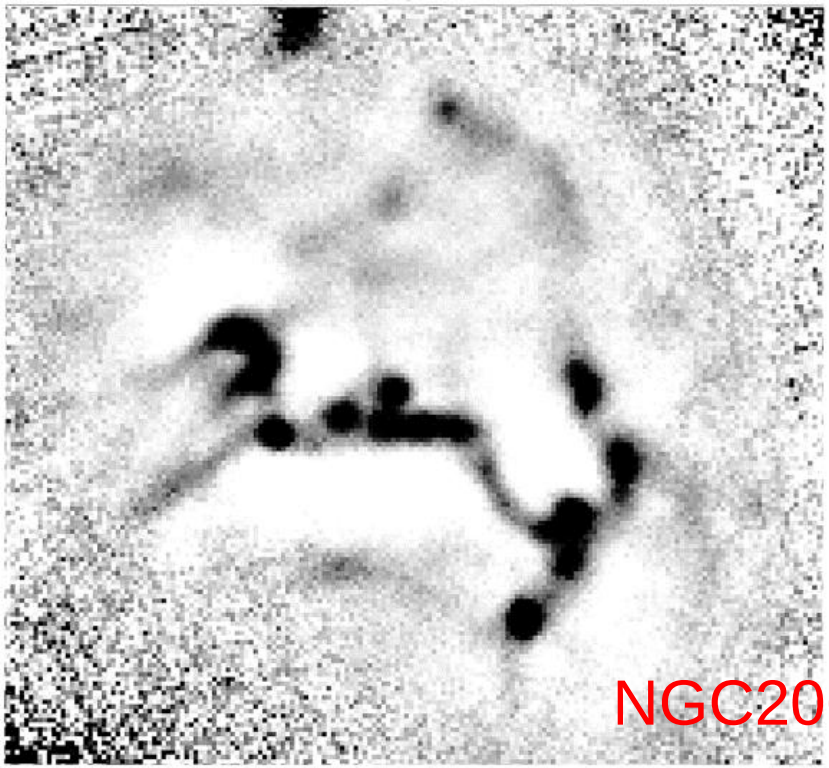
- Signal from a source is detected by several nearby bolometers while scanning.
- Use receiver parameters to map timestream on a RA-DEC map + correct for relative gains (flatfield).

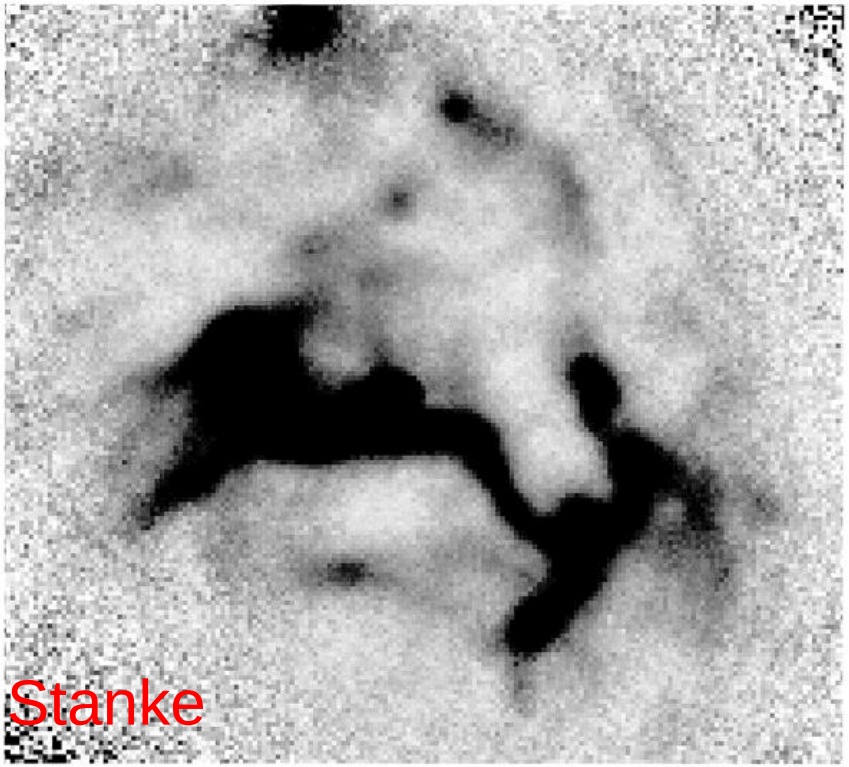




Iterative source models

- Extended source structure may resemble sky noise variations in the time streams.
- Insert source model into time streams.
- >30 iterations needed to "clean" maps.

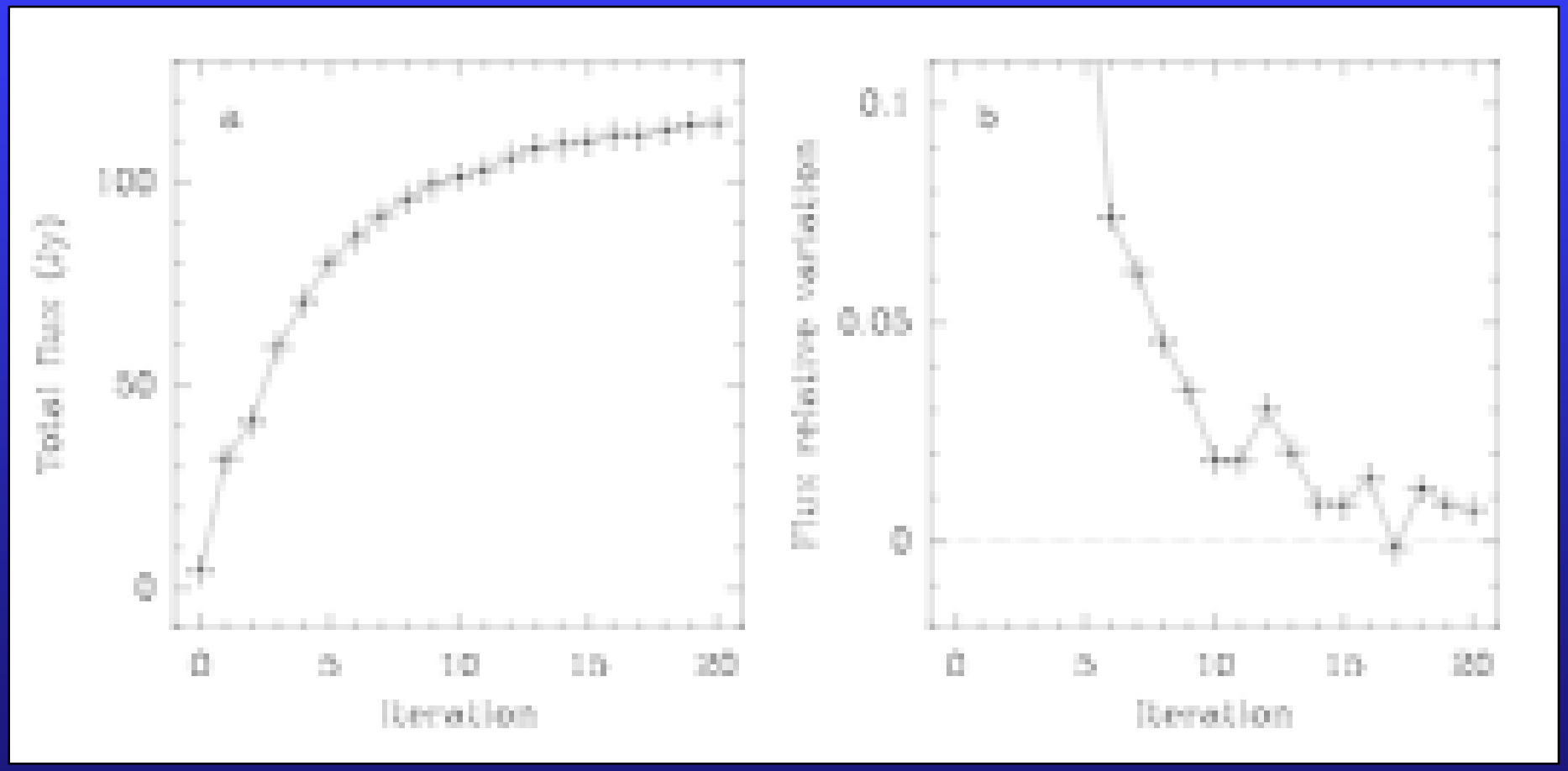




NGC2068, T. Stanke

Model iterations

- Each iteration recovers more of the source flux.



Belloche et al. 2011

Short wavelength bolometers

- SABOCA array of 37 TES bolometers at 350 μm.
- Artemis 16x16 pixel at 450 μm prototype array operated in 2007/2009 (as visitor instrument).
- Built by CEA/Saclay, based on PACS technology.
- Simultaneous 450/350/200 μm imaging in 2.6'x4.7' (1'x1' @200 μm) with 5760 fully sampled pixels (~8" FWHM).
- Prototype has produced science, main instrument planned for early 2014 (ESO visitor instrument).
- Science niche: wide-field submm mapping with 3x better spatial resolution than Herschel/SPIRE.

Artemis in 2014

- 450+350+200μm bolometer array with 4'x2' field of view.
- Uses Herschel/PACS bolometer technology.
- Re-installation in late May 2014.

– Full focal plane with 8 detectors at 350μm.

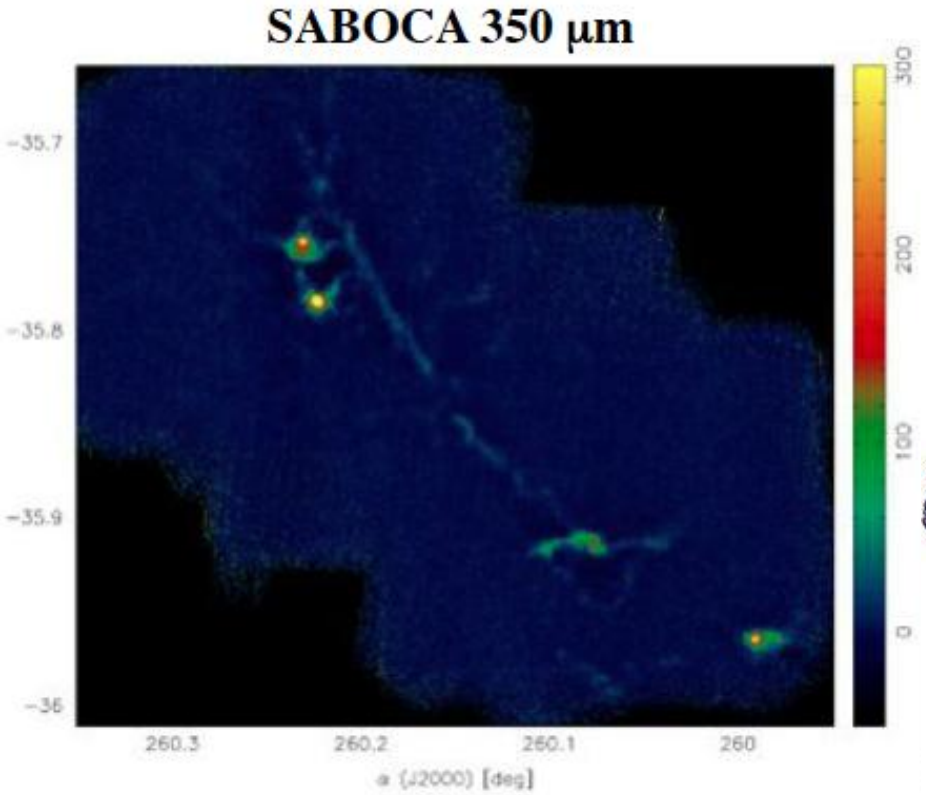
– Partial 450μm array might be offered, more coming in 2015.

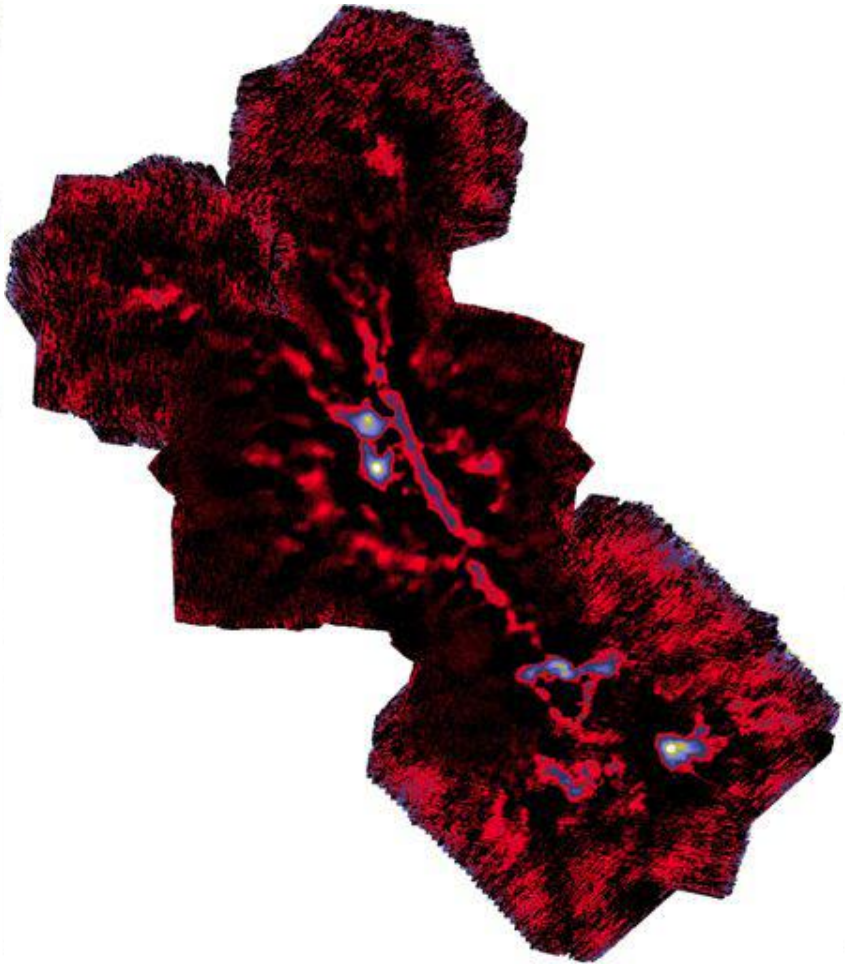
– Open to full ESO community, replacing SABOCA.

– Preliminary observing time calculator available.

– Data reduction pipelines to be released soon.

Comparison of SABOCA & Artemis images of NGC6334





Ph. André – APEX2014 Ringberg – 20/01/2014

Supercam (Swedish+ESO PI instrument)

– 64 pixel 345 GHz receiver built by Arizona Radio Observatory.

– First 3 runs on SMT (formerly HHT). Atmospheric conditions not great of 345 GHz work.

– Swedish initiative to bring Supercam to APEX as a visitor instrument.

– Installation of Supercam on optical axis precludes use of LABOCA, so instrument can only be offered in certain months.

– Planned installation late November 2014, operations during Swedish + ESO time in December 2014.

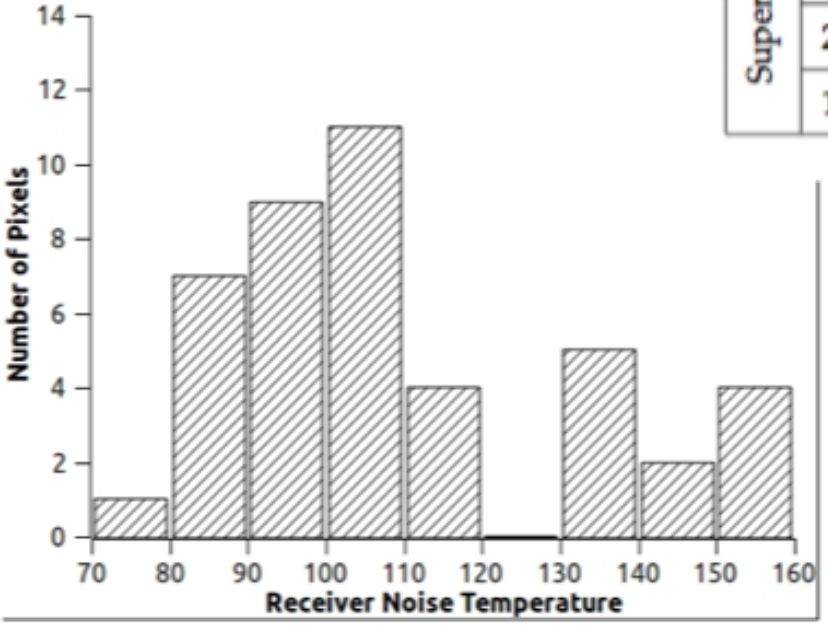
– Instrument pipeline to be publicly released.

– Most likely offered again in ESO P95.

– PI Chris Walker wants Supercam to produce science, either with our without his collaboration, i.e. no requirement to include instrument team on proposals, no blocked science.

Supercam Receiver noise temperatures

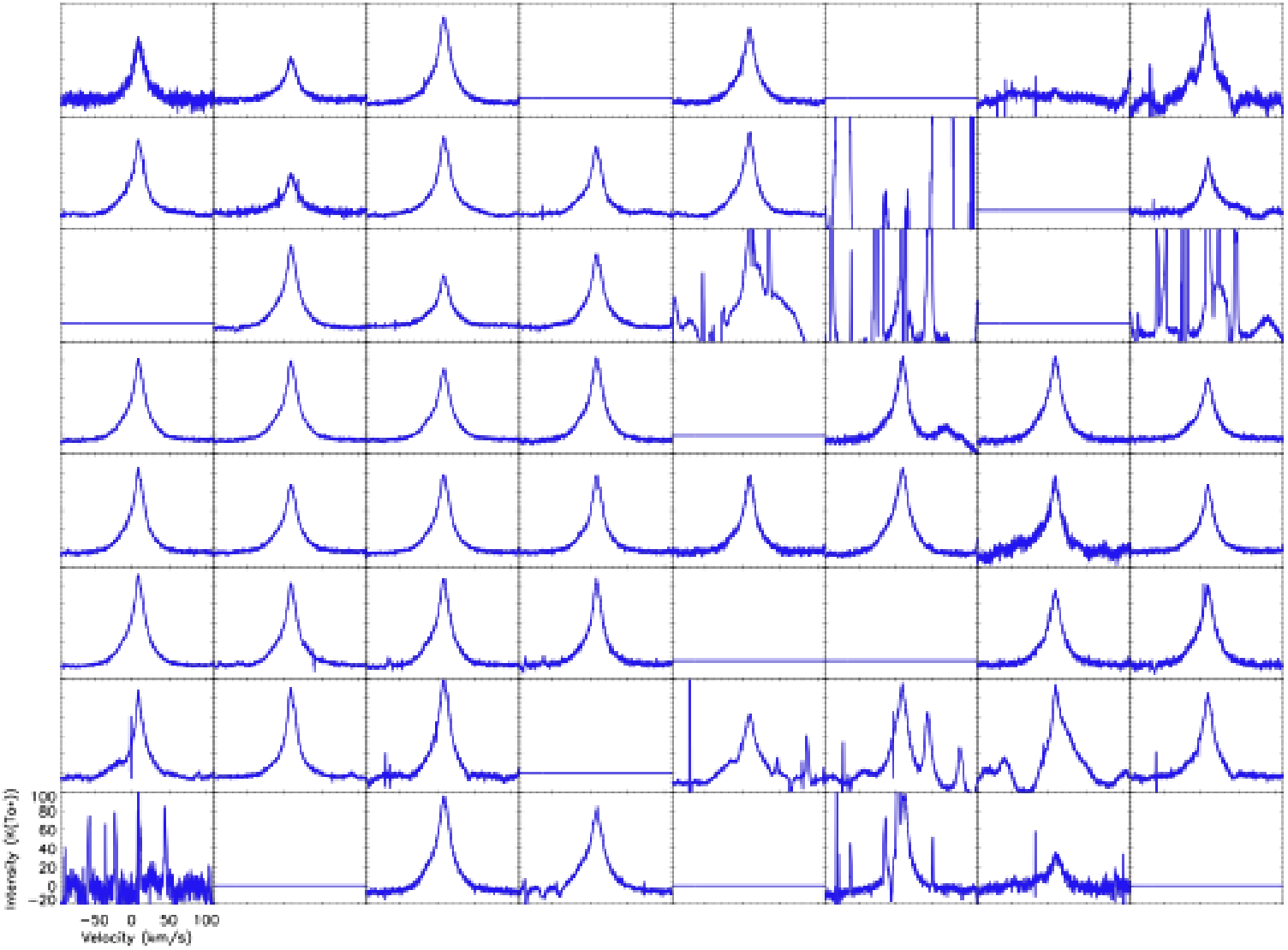
SuperCam Subarray Number	Pixel Number 1	2	3	4	5	6	7	8
8	458.5	228.8	153.3	NC	156.0	NC	109.2	253.3
7	153.3	243.1	110.9	132.1	116.3	458.5	NC	141.1
6	NC	79.1	148.3	156.0	102.6	138.8	NC	132.1
5	95.0	86.7	102.6	93.6	NC	105.8	118.1	107.5
4	102.6	134.3	105.8	102.6	81.5	95.0	420.0	89.4
3	92.1	95.0	88.0	85.4	NC	NC	92.1	104.2
2	192.7	92.1	102.6	NC	92.1	136.5	116.3	99.5
1	556.4	NC	89.4	84.1	NC	105.8	340	NC



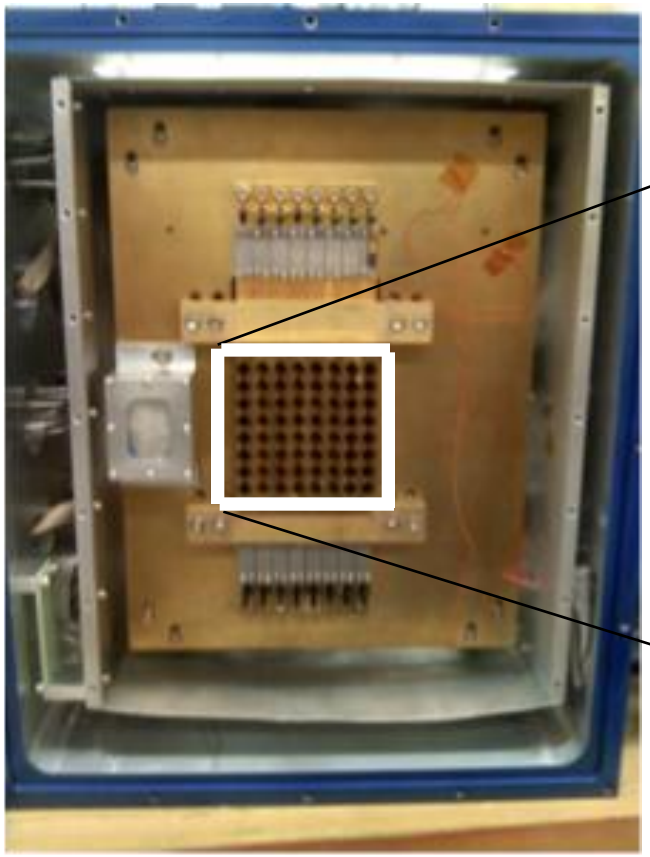
– 81% of pixels working.

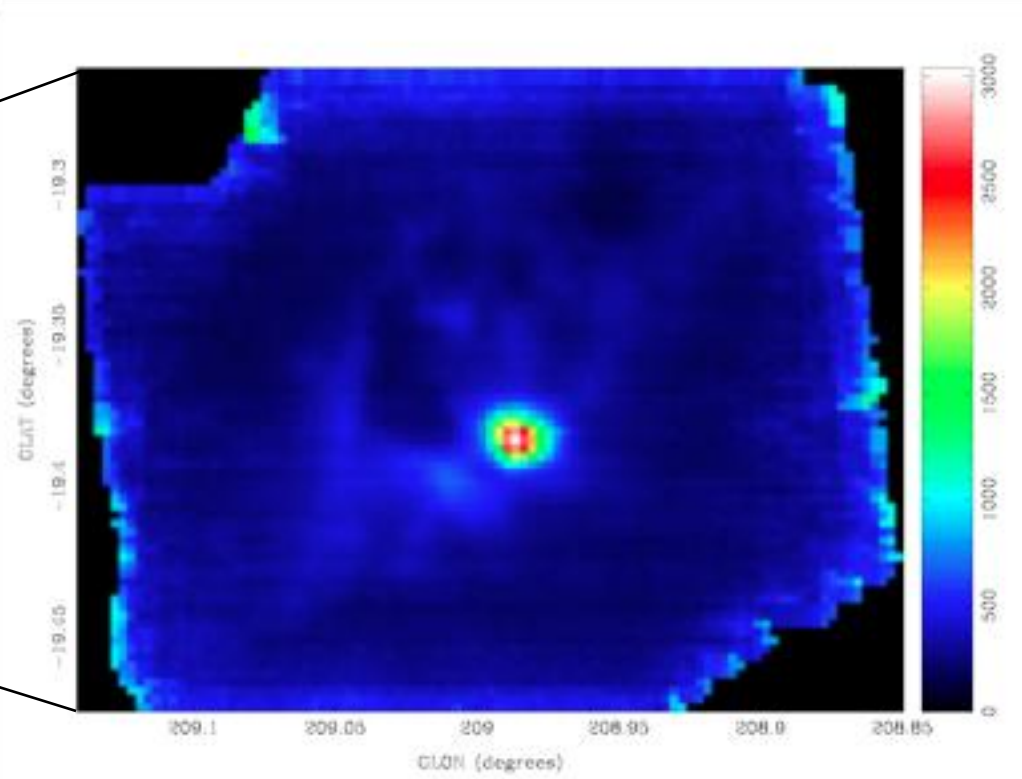
– Noise-weighted median Trec=104K

Supercam/SMT spectra of Orion A



Supercam/SMT CO(3-2) image of Orion A





Hints on APEX proposals

- APEX proposals evaluated by same OPC as VLT.
- LST pressure is not uniform. Galactic Centre is often more highly oversubscribed.
- PWV>2mm conditions (SHFI/APEX-1) are less demanded. Larger proposals solicited.
- Contact instrument team well in advance before submitting a proposal on a PI instrument.
- 24h operations ⇒ sources observable in both periods. For high frequency work, submit when sources are observable during night + morning.
- Joint APEX+VLT(I) proposals encouraged!

The APEX project

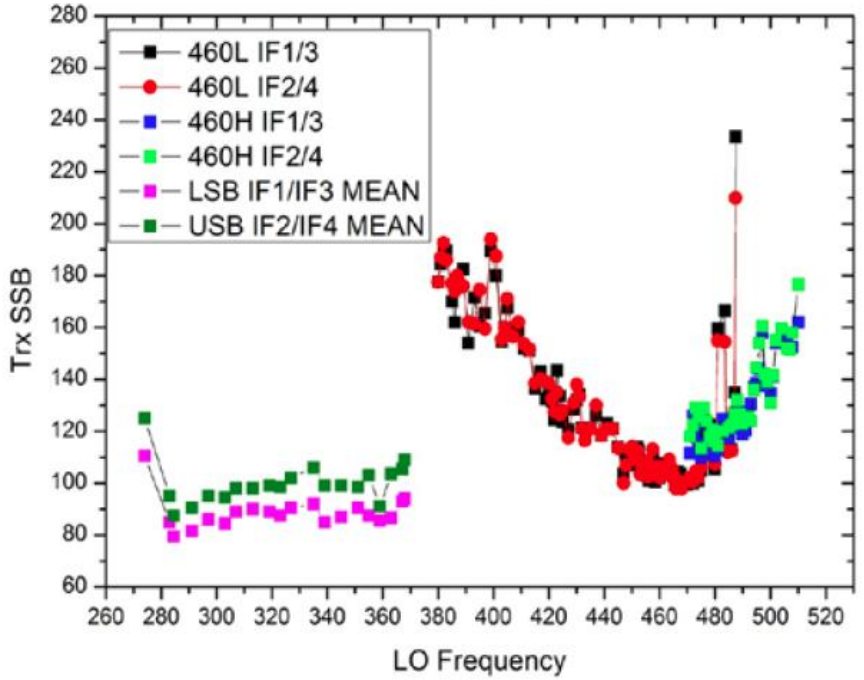
- Collaboration 50% MPG (MPIfR Bonn), 27% ESO, 23% Sweden (Onsala).
- Agreement extended till end of 2017, additional 2 year extension being considered.
- All facility instruments open to ESO community, as well as PI instruments in collaboration with the instrument teams.
- Oversubscription ~3:1 (PWV dependent)

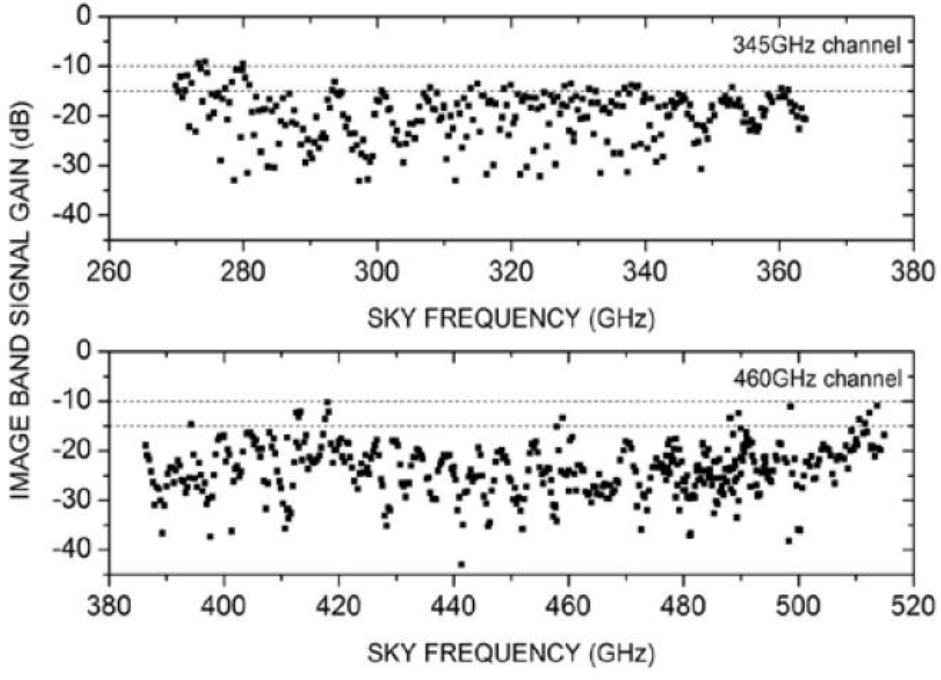
APEX archive at ESO

- All ESO and Onsala data are validated by APEX staff in Chile, transferred via network and made available to PI.
- Delay of data delivery: aim <2 days, allowing feedback to ongoing observations.
- Quicklook reductions also available.
- ESO and Onsala data become public after 1 year proprietary period.
- Reduced data and catalogues for CDFS available, ATLASGAL coming this year.

FLASH (MPI PI instrument)

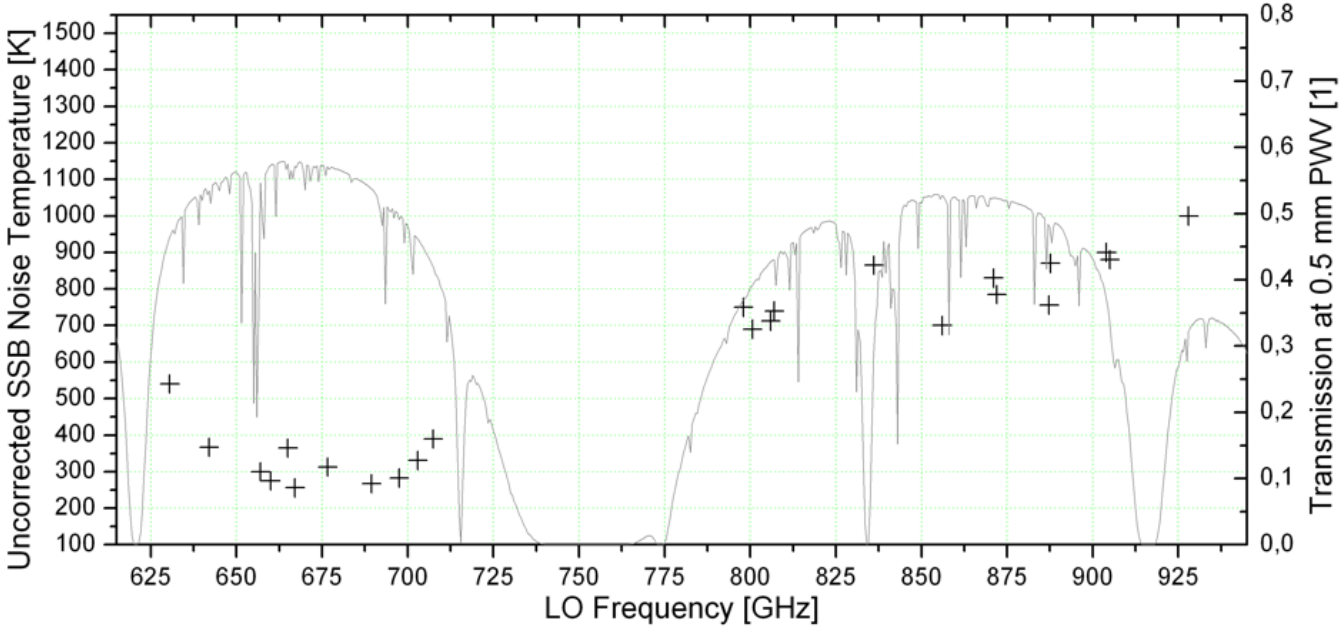
- Up to 3 days/period available for ESO, in collaboration with MPIfR. Contact Rolf Güsten >2 weeks before deadline.
- Dual band receiver: 2x4 GHz (280-370 GHz, ALMA band 7) + simultaneously 2 GHz (385-510 GHz).
- Very stable baselines, ideal for spectral line surveys.





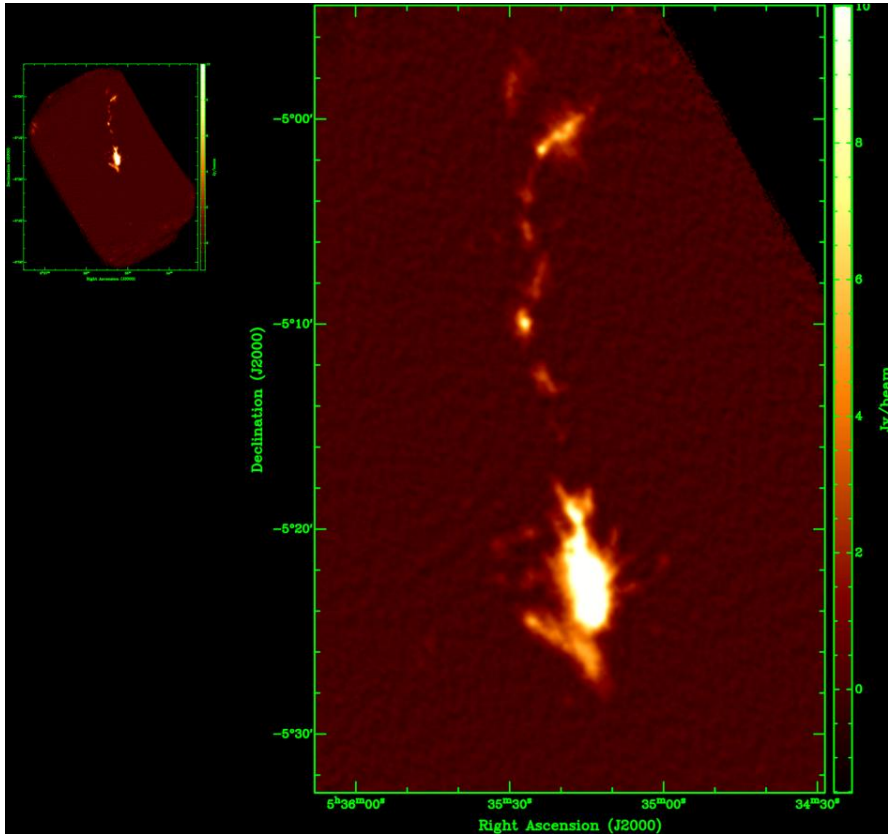
CHAMP+ (MPI PI instrument)

- Open to ESO on fixed dates, in collaboration with MPIfR. Contact Rolf Güsten >2 weeks before deadline.
- Spin-off from Herschel/HIFI.
- 7 beams (620-720 GHz) + simultaneously 7 beams (780-950GHz) in hexagonal layout with 3GHz bandwidth.
- Ideal for mapping of CO(6-5) and CO(7-6).



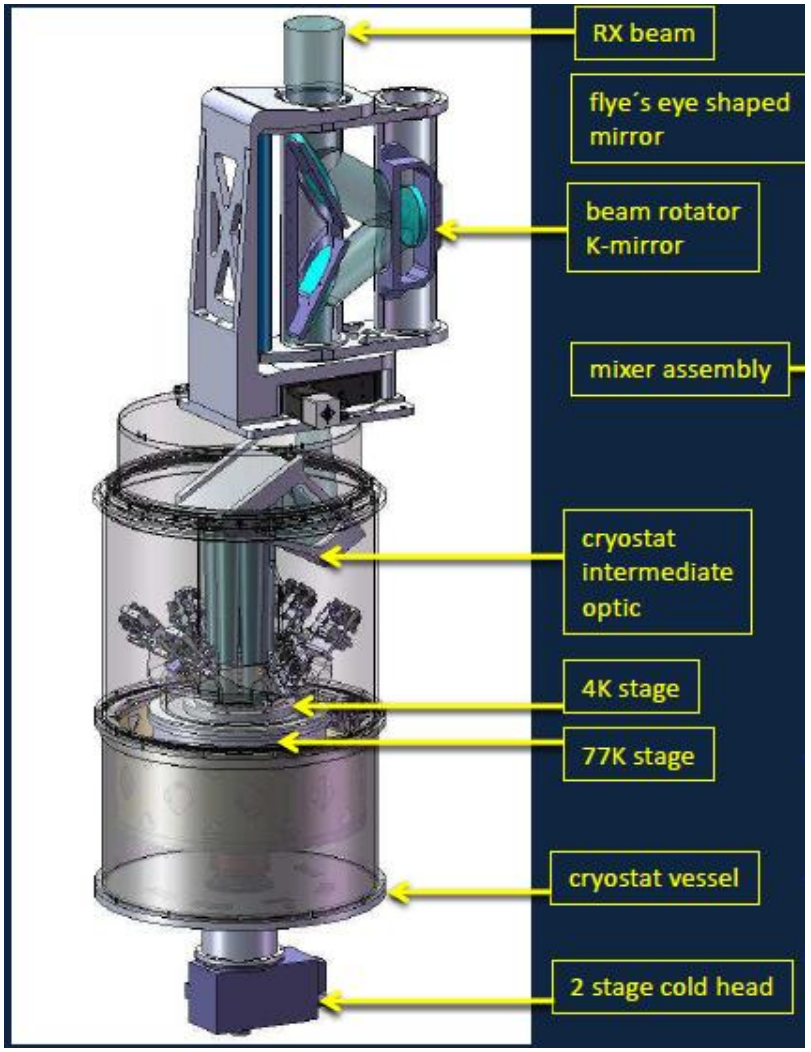
MPIfR PI instruments (1)

- ZEUS-2 (350-850µm broadband IFU spectrograph)
  - new technical run planned for late September 2014.
- MKIDS camera 3520pix @850µm + 21600pix @350µm:
  - First test run in Dec. 2014.
  - 15‘x15’ Field of View.
  - First light on Orion in December 2013, only at 850µm.
  - Next commissioning run planned for July 2014.



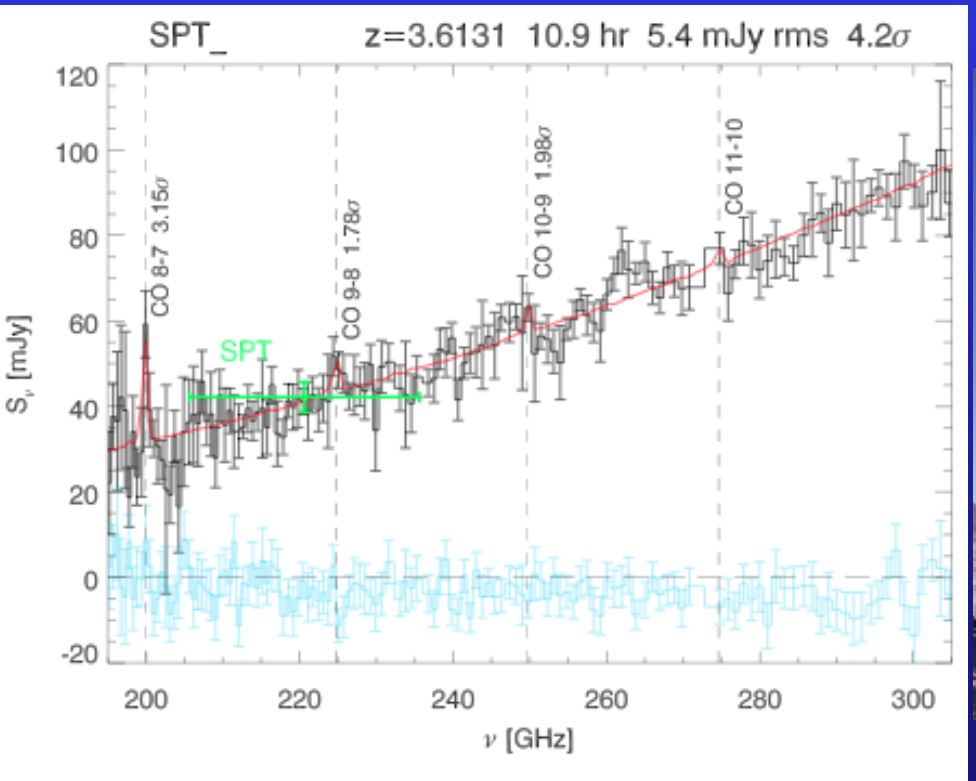
MPIfR PI instruments (2)

- LASMA
  - 7 pixel 262-374 GHz.
  - Rotating K-mirror to keep stable cryostat & cables.
  - 2SB receivers based on IRAM ALMA band 7 development.
  - XFFTS backends covering 4 GHz in each sideband, i.e.7x2x4=56 GHz bandwidth.
  - First installation planned for November 2014.



Broadband spectrographs

- Zspec 190-310 GHz was at APEX 2011-2012. Science results on lensed submm galaxies.
- ZEUS-2 195-640μm "IFU" coming in 2014.
- Low spectral resolution, but huge bandwidth.



A band 5 receiver for APEX

– APEX board approved to start this project as a Swedish+ESO PI instrument, with MPIfR contribution on backends.

– Covers 160 to 210 GHz, close to water line (needs good site).

– Will eventually return to ALMA to be refurbished as a spare for ALMA band 5. In the meantime, it will serve as an on-the-field science & technology testbed.

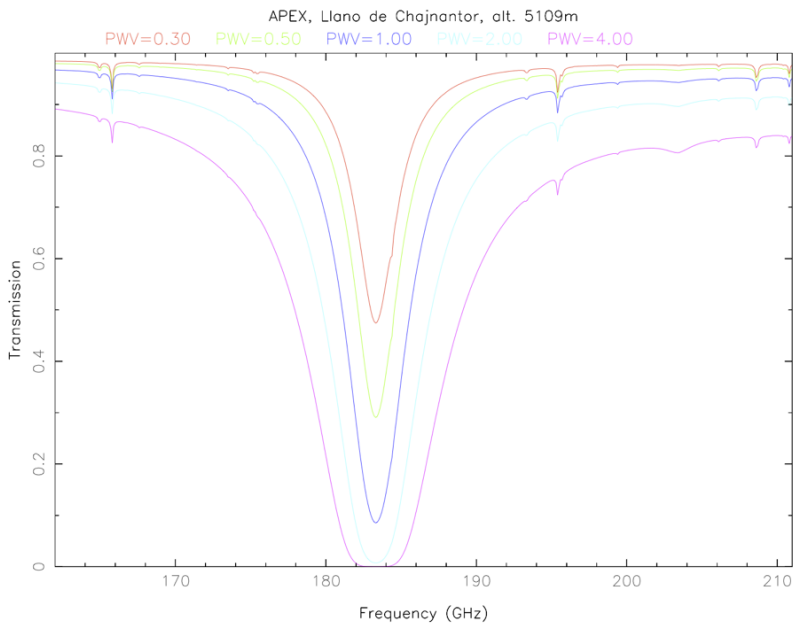
– Receiver in Nasmyth A cabin will additional ALMA cartridges. Unres community.

– Aim to commission by March 20

–Open to full ESO community.

– Science cases:

- new molecular lines.
- 183 GHz water line.
- CO(2-1) out to z<0.414



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- Liquid Nitrogen and Helium cooled to 0.3 K.
- 20″ spatial resolution.
- Ideal to map extended emission to ~5′ scales.
- POLKA polarimeter as MPIfR PI instrument