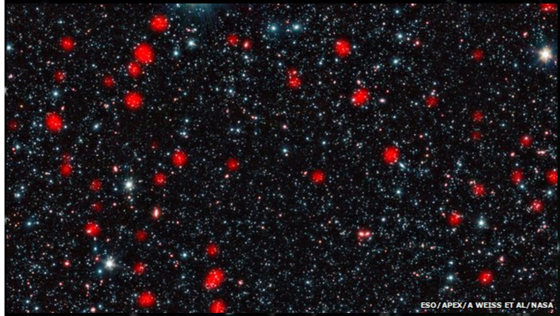
Laboca in a nutshell



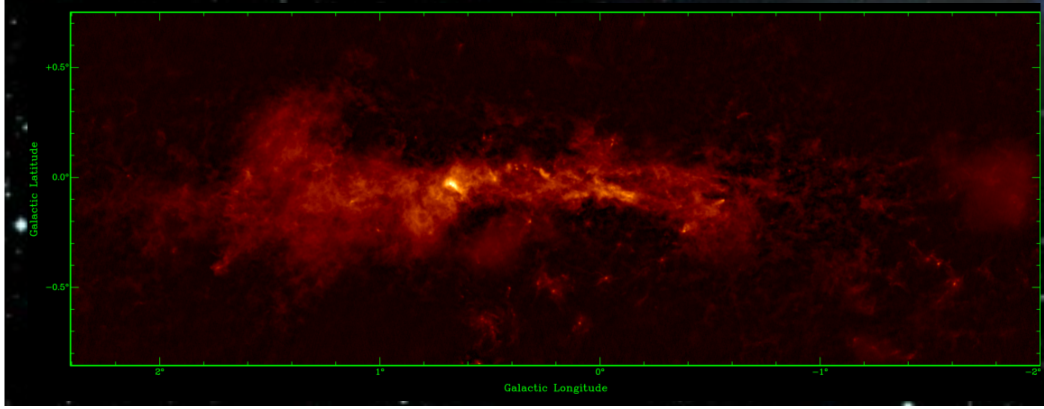
Total power Bolometer Array

operating at 850 μm

295 pixels

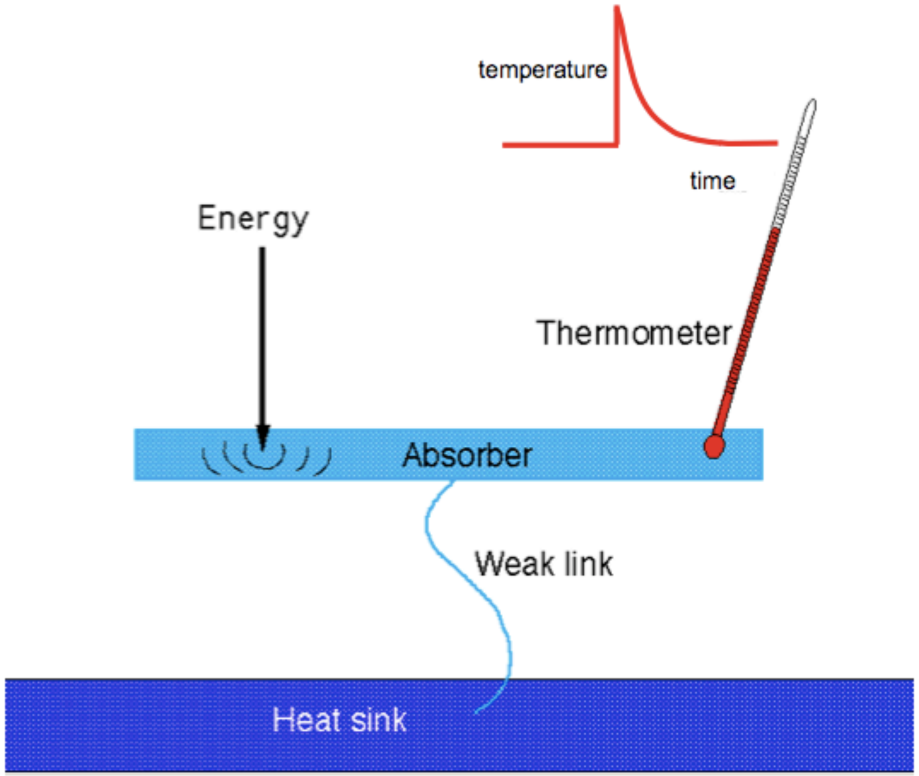
Field of view 11’

Science:
cold dust nearby and far



Bolometer Principle

Two components: A *sensitive thermometer* and high cross-section *absorber*



- Thermometer and absorber are connected by a weak thermal link to a heat sink
- Incoming energy is converted to heat in the absorber:

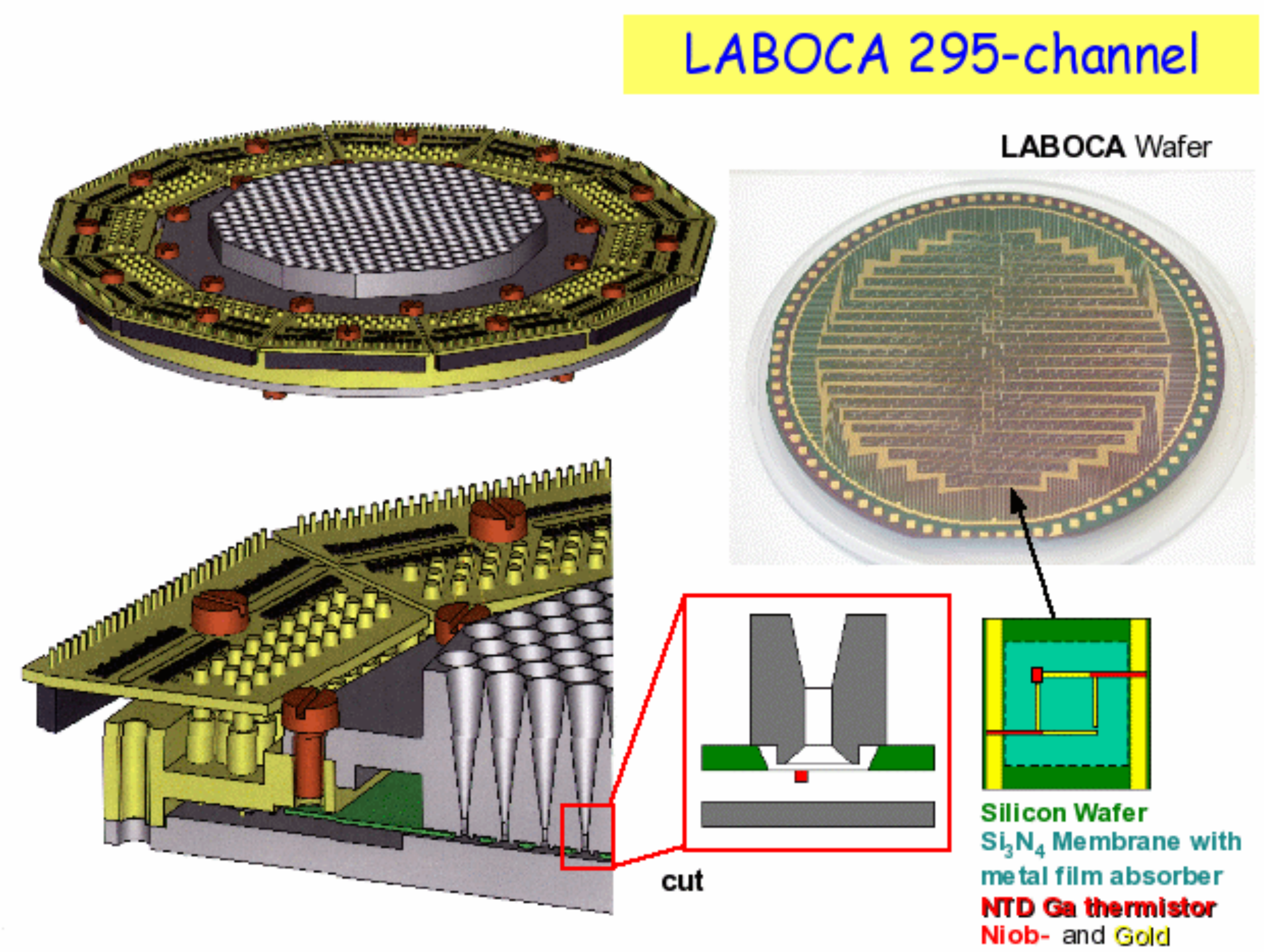
$\Delta T = T - T_0 = E/C$

Temperature rise decays as power in absorber flows out to the heat sink

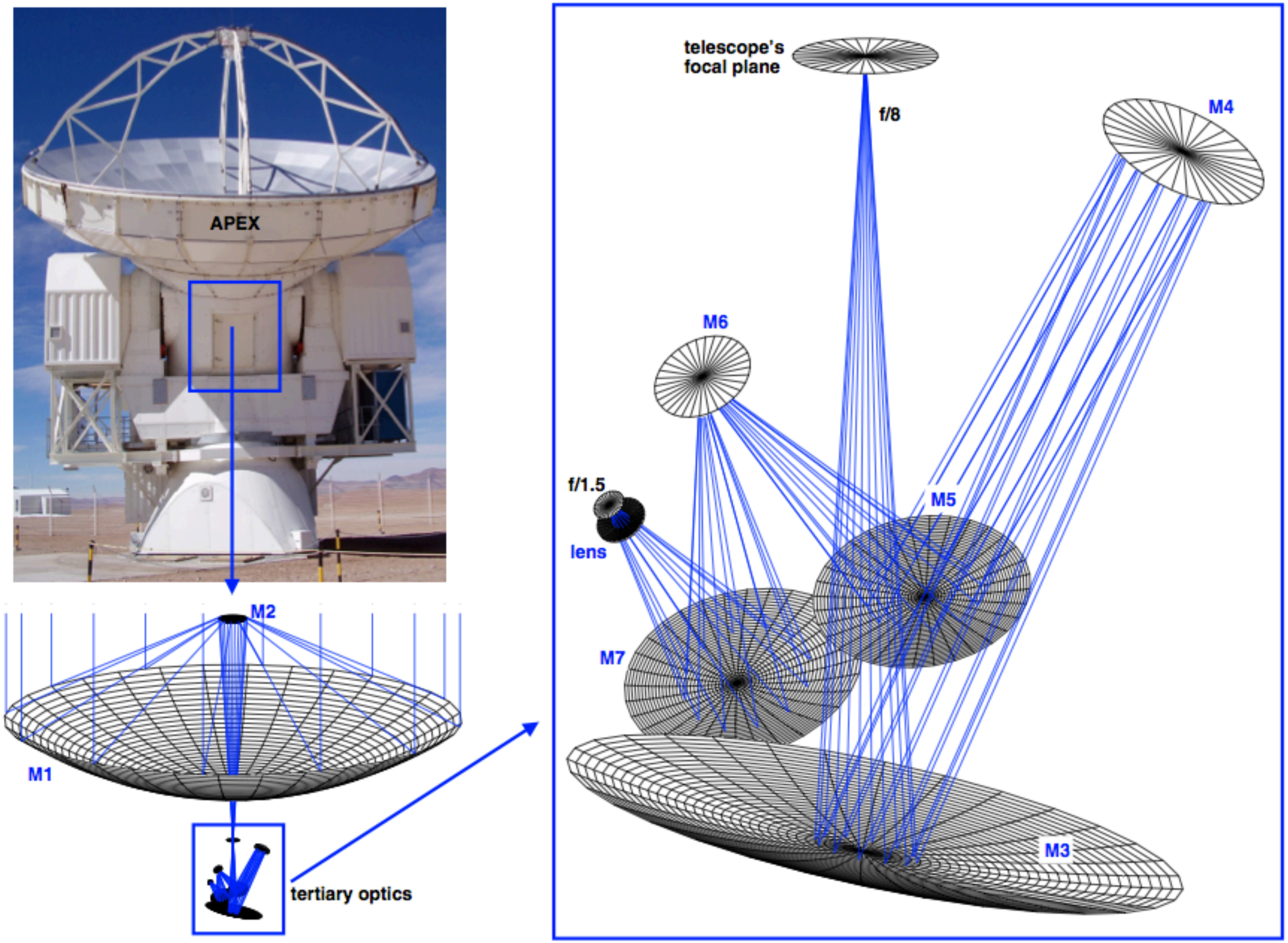
$\tau = C/G$

- Temperature rise is proportional to the incoming energy

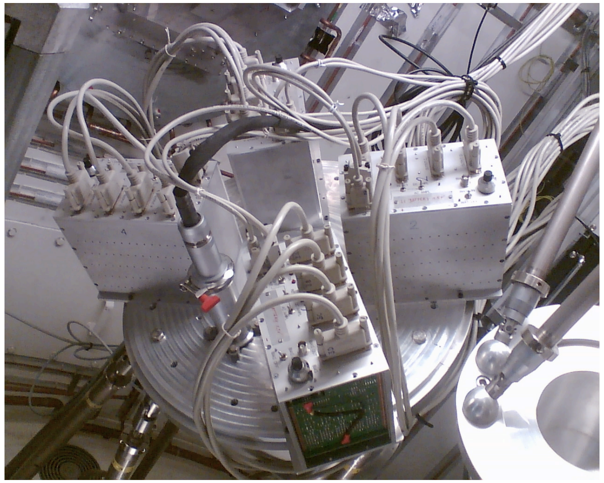
LABOCA design

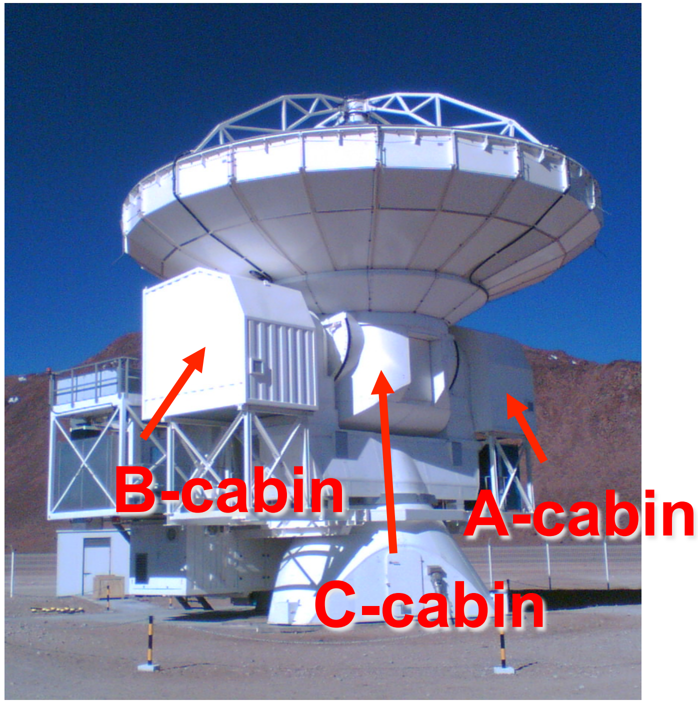


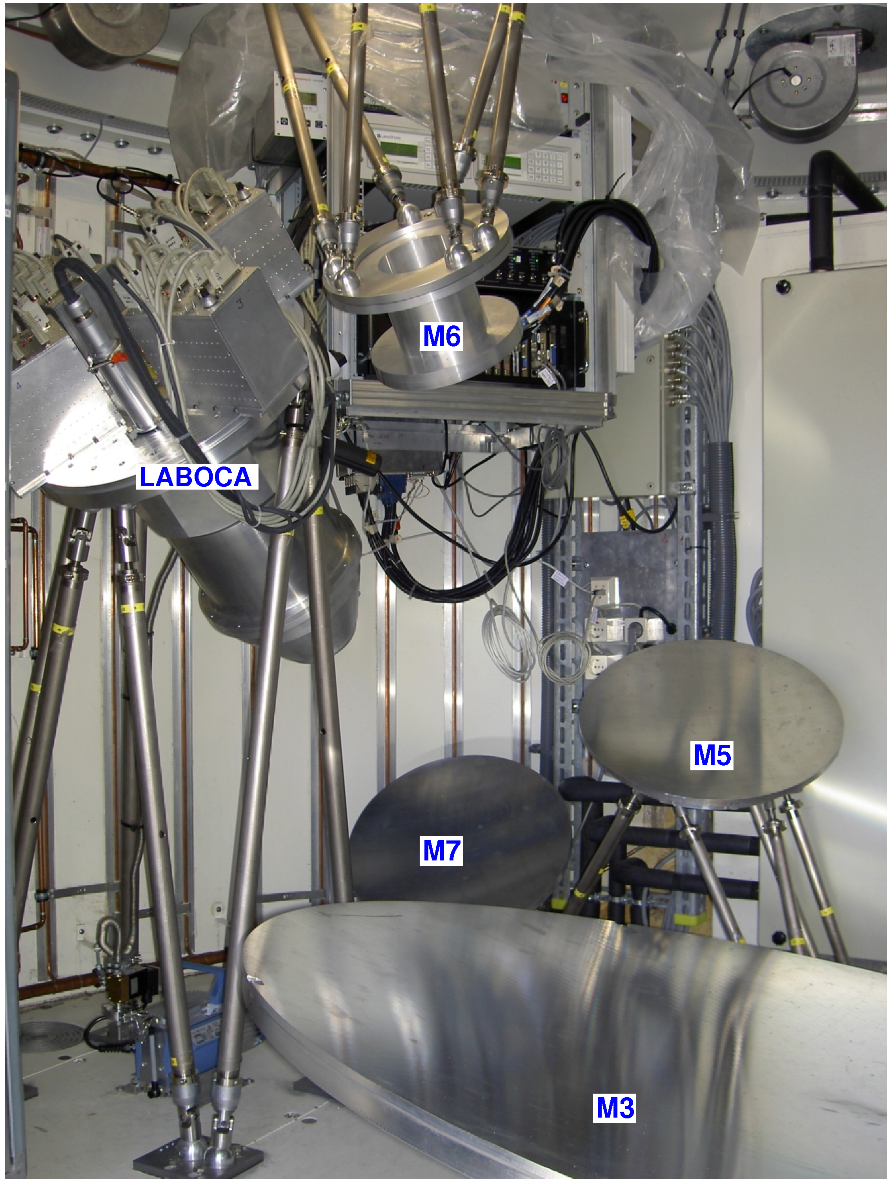
LABOCA optics



LABOCA @ APEX



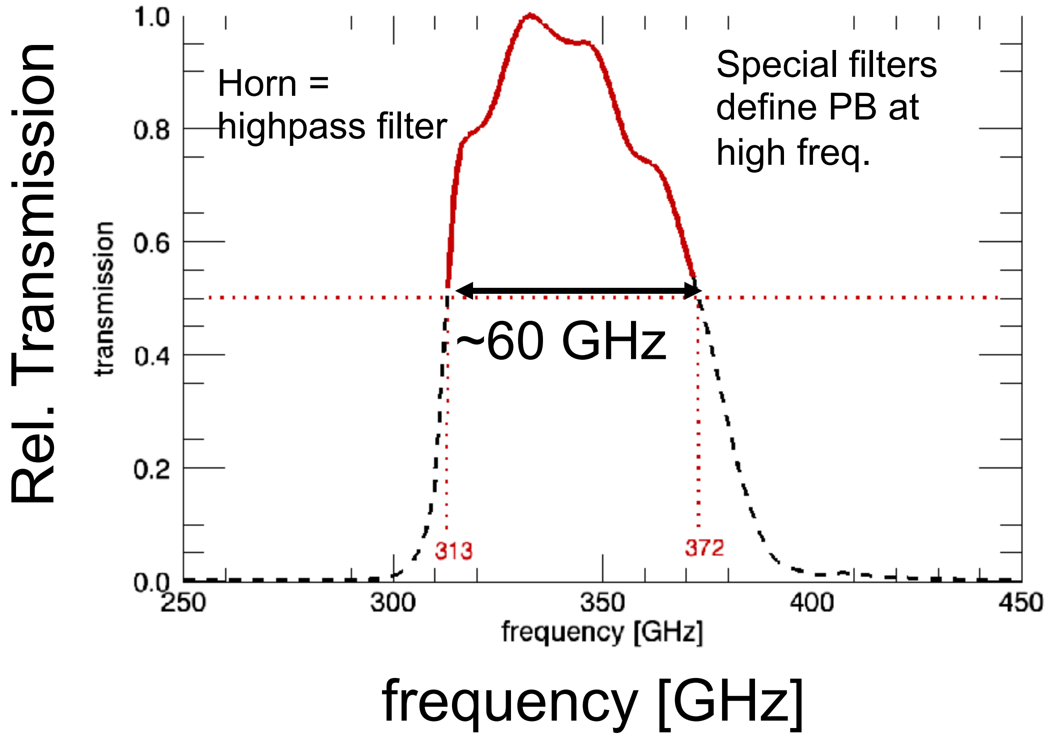




Bolometers: Sensitivity through bandwidth

Radiometer Formular: $dT \sim T_{sys} (B * t_{int})^{-0.5}$

LABOCA pass band



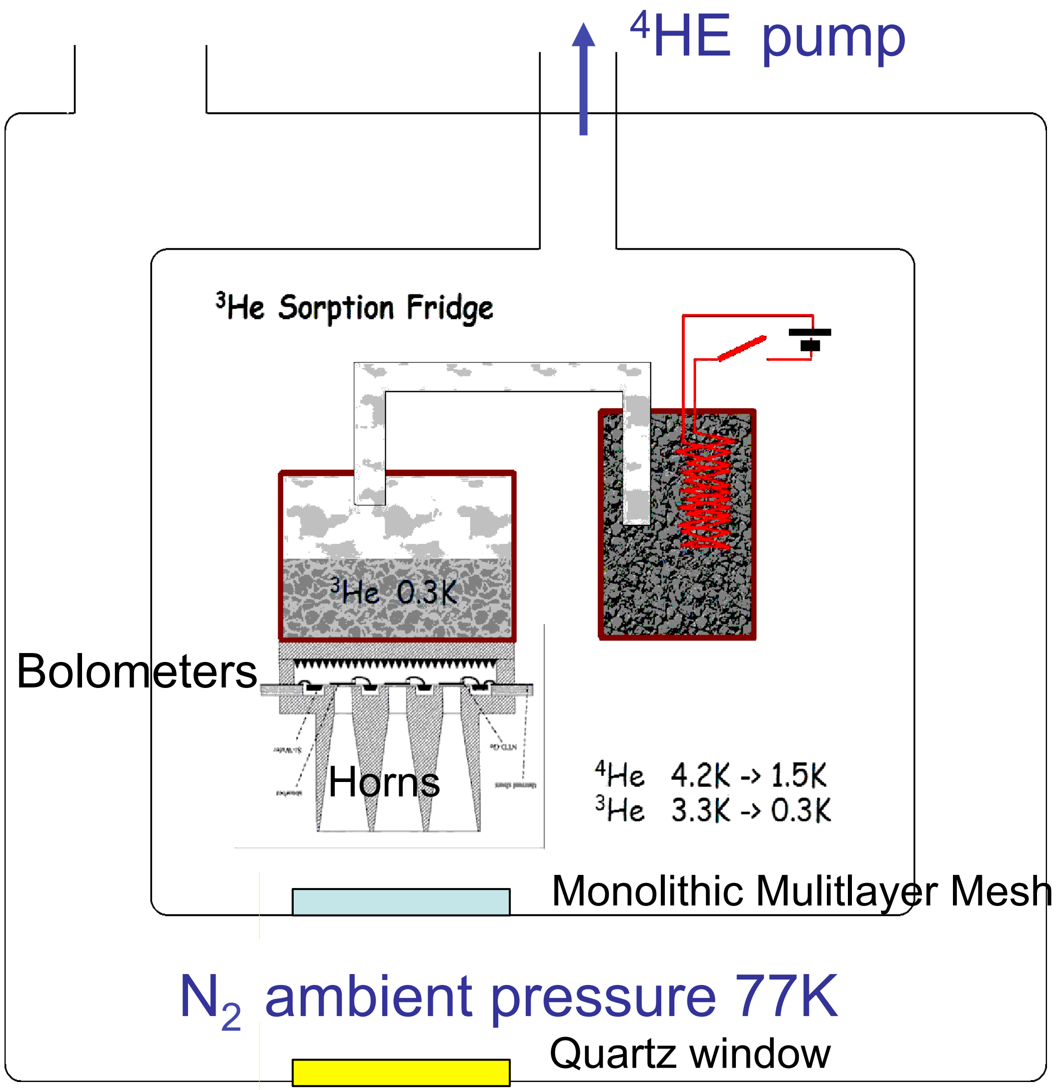
SiS receivers:

Spectroscopy:
B ~ few KHz- few MHz
Continuum:
B ~ 1-8 GHz

Bolometers:

B ~ 100 GHz
(matched to Atmospheric Transmission window)

Cooling system



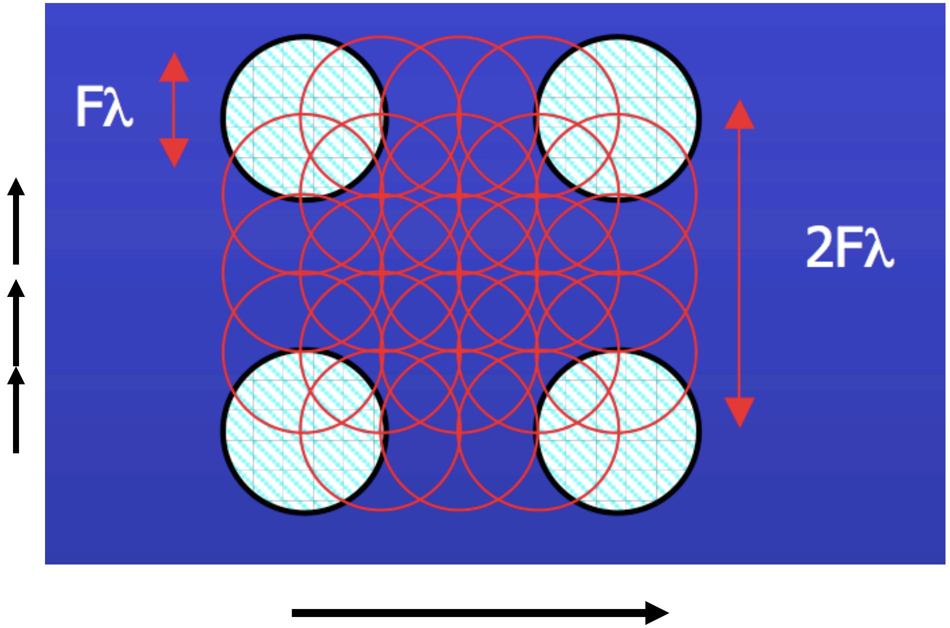
LABOCA operates at 280mK

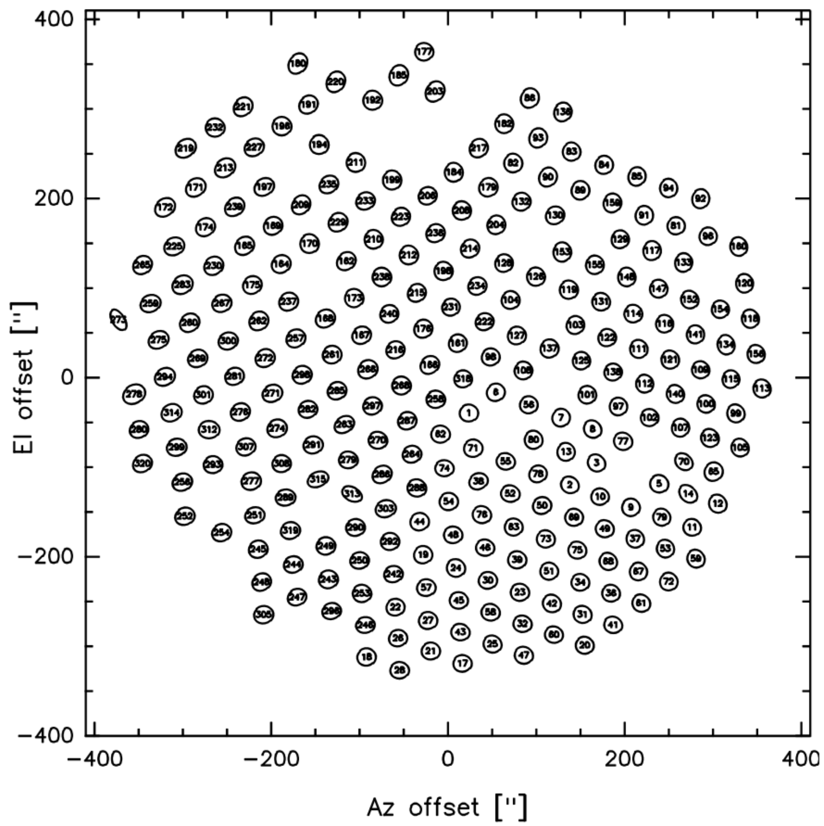
achieved via He7 sorption cooler in open LHe4 bath

Hold time of sorption coolers determines operation time

12h for LABOCA recycling takes 2h

Horn Arrays are not CCD like!

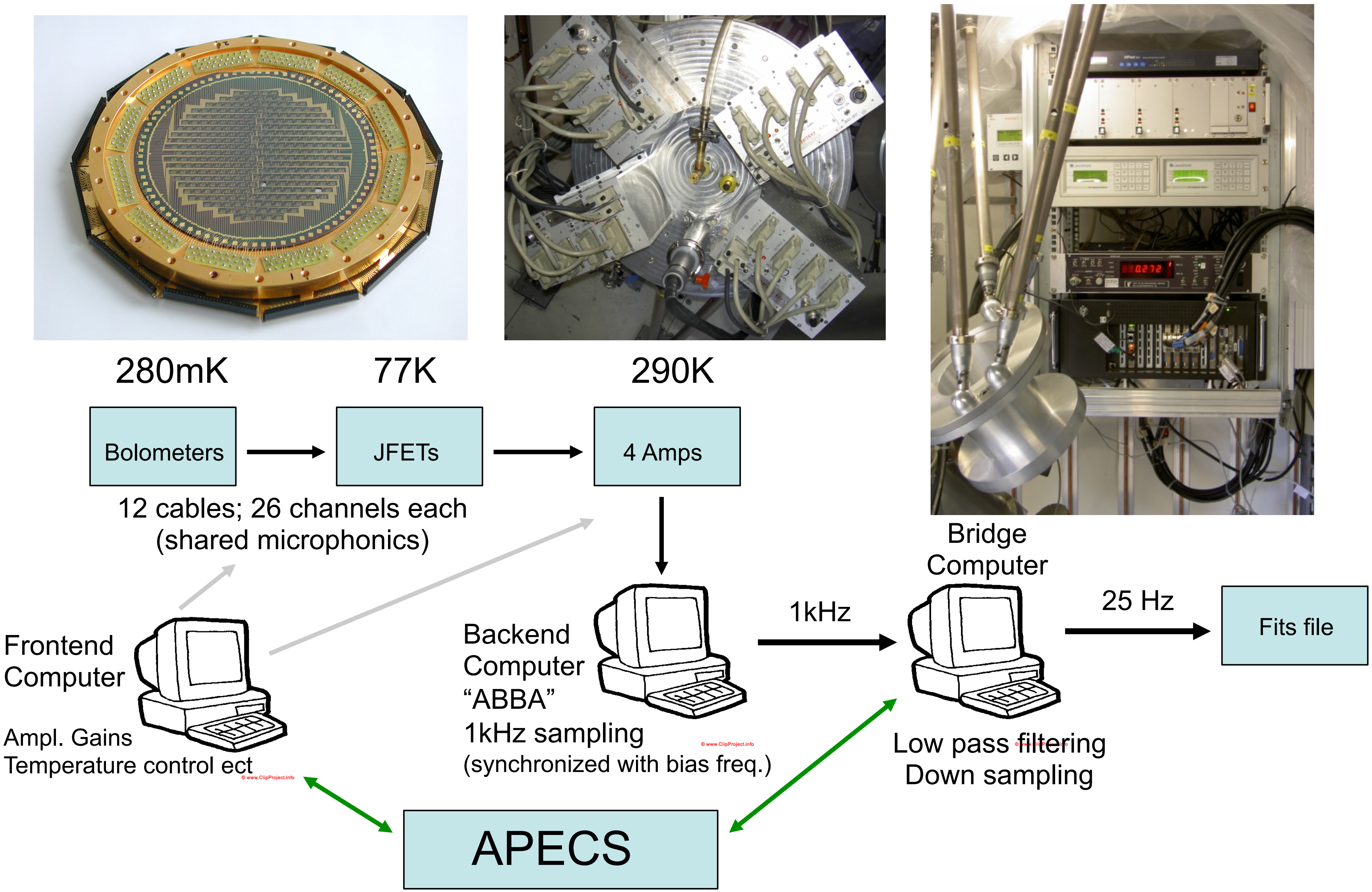




Horns:
bolometers are double beam paced on the Sky

To obtain a fully sampled image:
mapping required (16 position for each bolometer = half beam spaced)

Laboca Infrastructure



Day even at Night: The miracle of ground based mm/submm continuum observations

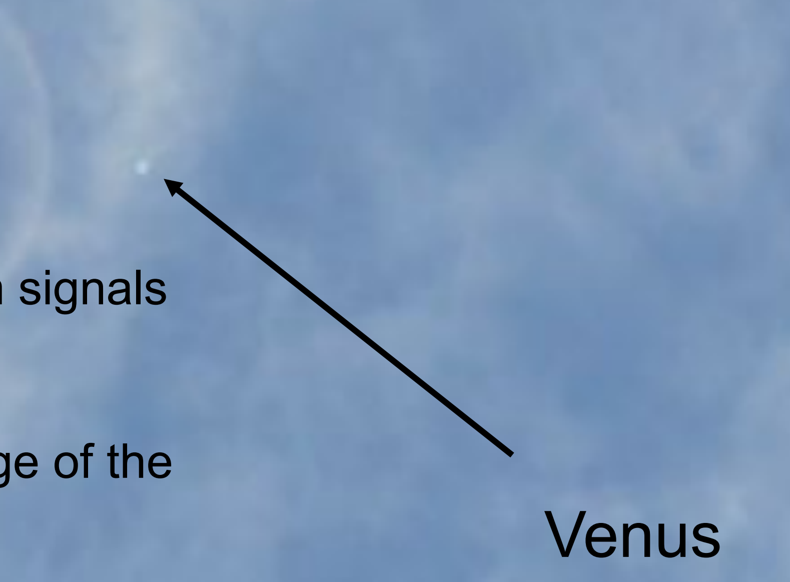
Atmosphere:
270 K, line of sight opacity 0.3
-> You look through a 70K screen…

…which emits a signal of ~4000 Jy/b…
and changes by few 100 Jy/b within a few seconds…

..and nevertheless we do detect continuum signals of ~1mJy/b (4.000.000 times weaker!)

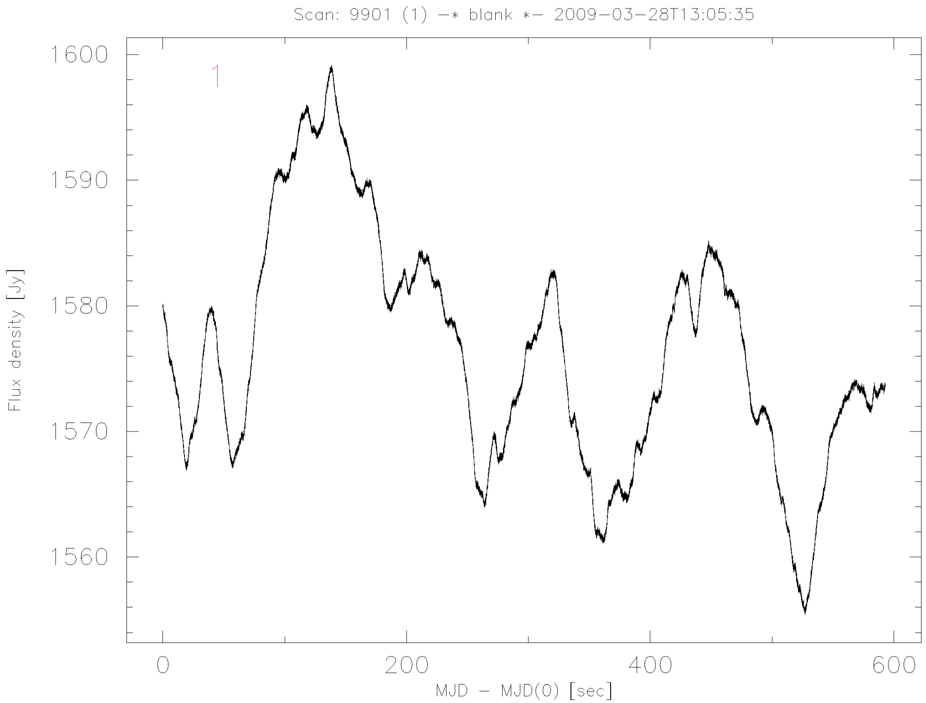
… allowing to detect sources out to the edge of the universe…

How does that work?

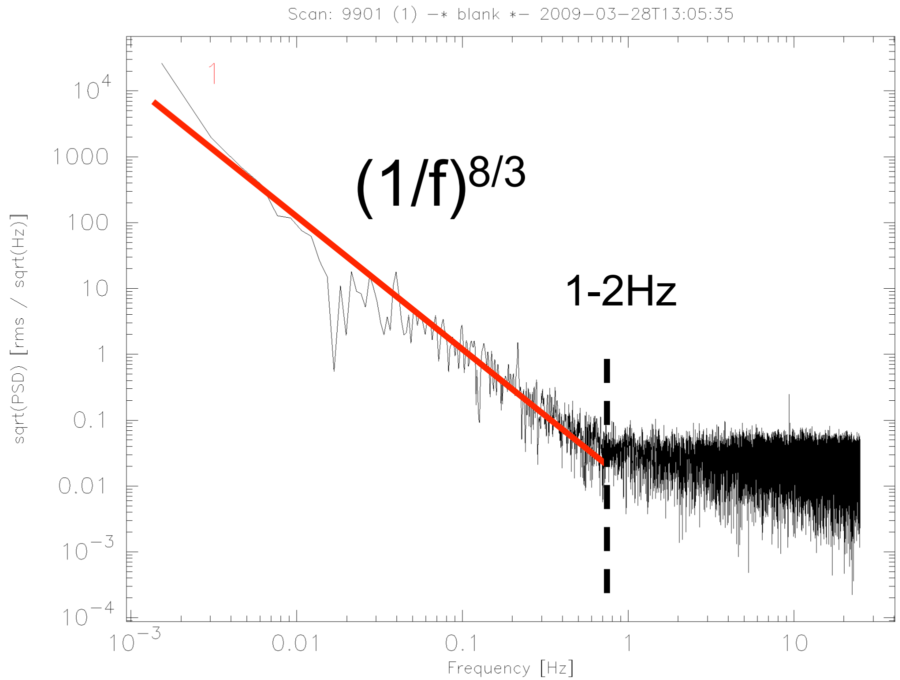


Sky Signal (noise)

signal on sky



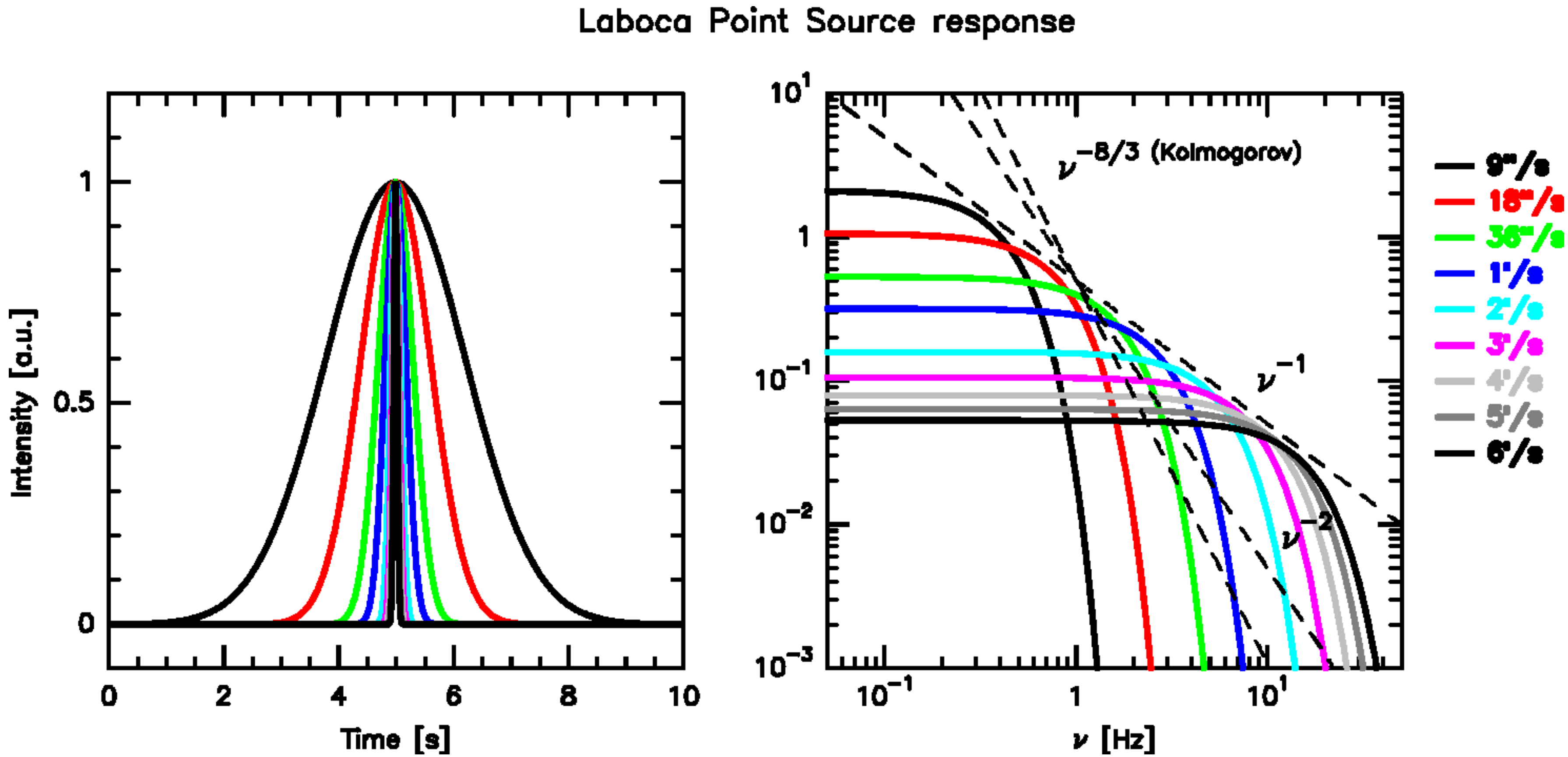
sky power spectrum



Even atmospheric fluctuations are brighter than almost all astronomical sources!
Spectrum of the Atmosphere drops with a power-law (Kolmogorov)
Atmosphere typically has little variations at frequencies >1-2Hz.

-> Observations are best carried out such, that the astronomical signal
is modulated to frequencies above the atmospheric fluctuations

Why do we scan?

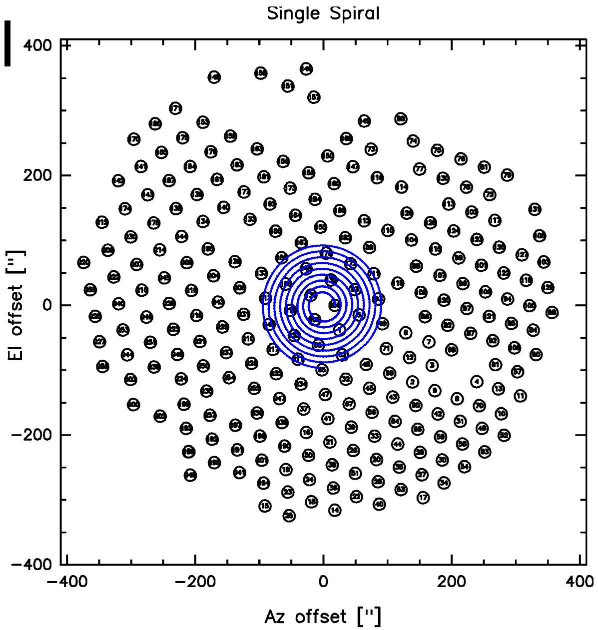


Limitations for the scanning speed:
- High frequency cut off Bolos,
- position informationof the telescope (48ms):
for Nyquist: limit @ 345Ghz ~3' /s.

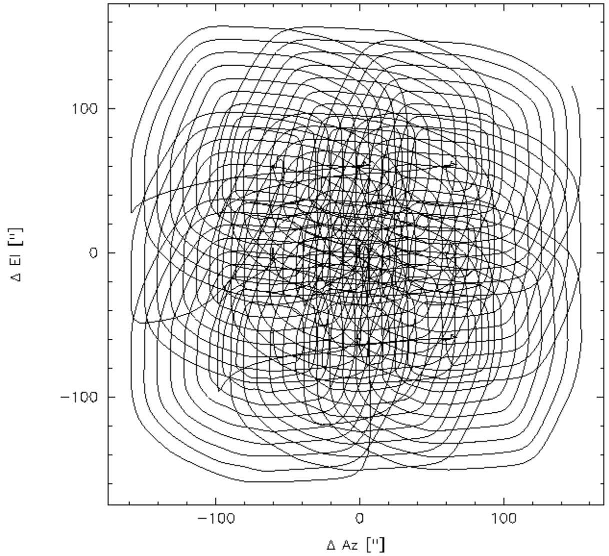
max scanning speed determines dump time
(25 Hz for LABOCA)

Laboca Scanning patterns

Spiral



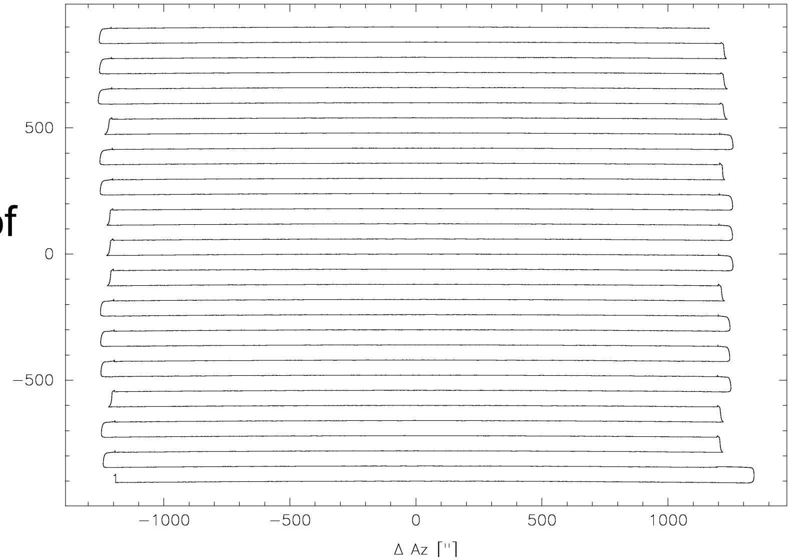
Raster-Spirals

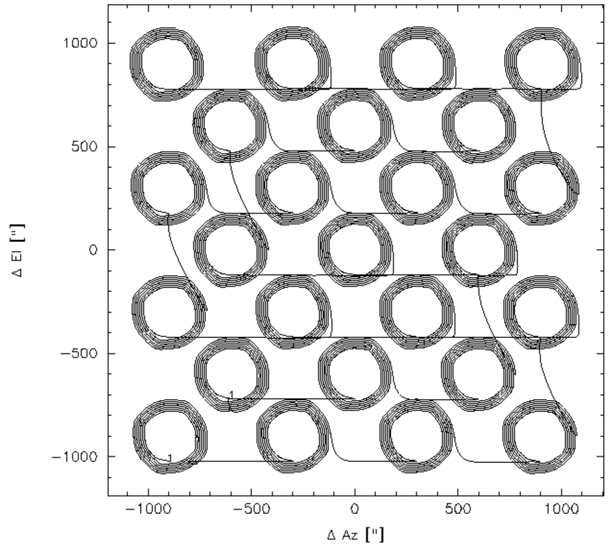


OTF

Speed:
0.5-3'/s

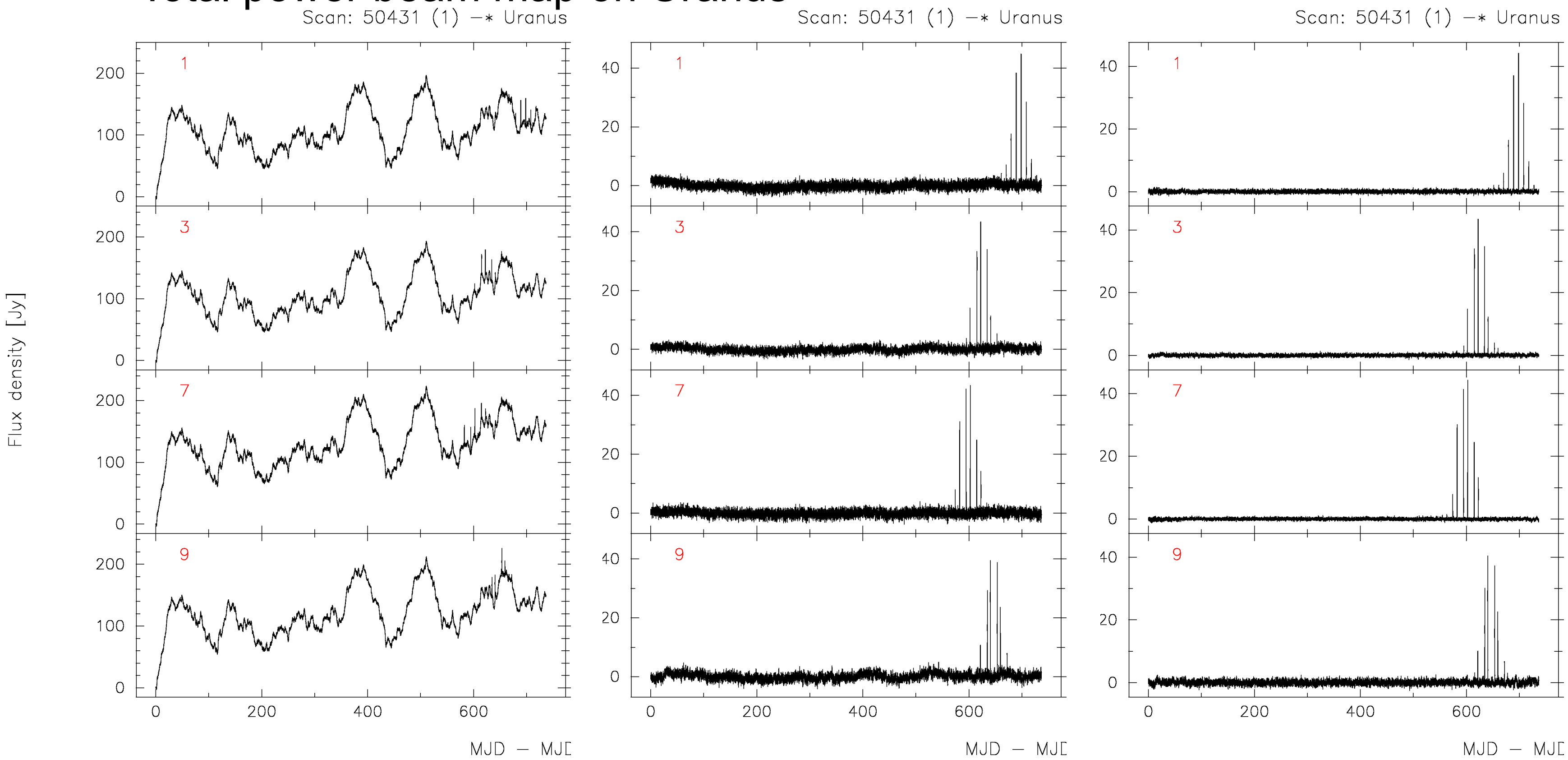
upper limit from position readout of the Antenna (48ms)





Correlated Noise (removal)

Total power beam map on Uranus



Calibrated and flat-fielded signal

Median signal of all bolometers subtracted

(sky signal and temperature drifts removed)

Median signal of bolometers sharing the same amplifier + bolometers on the same cable subtracted
(electronic 1/f noise and microphonics)

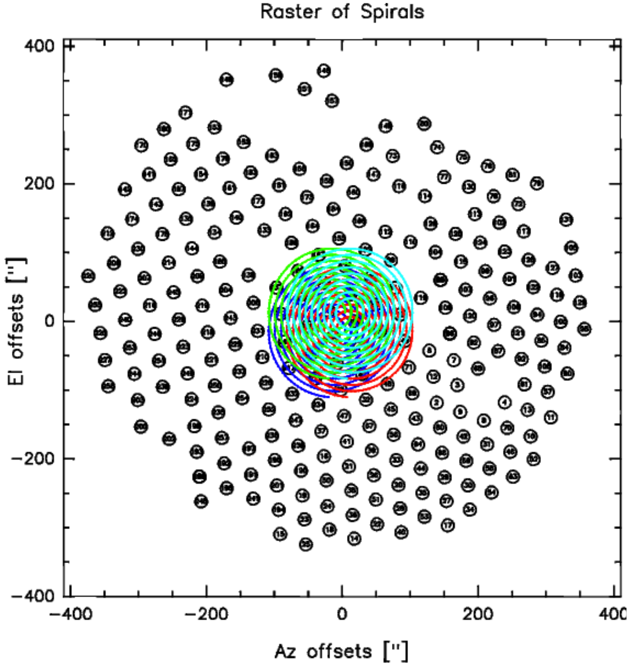
Field of view mapping

Over time we have lost a significant number of bolometers (~230 left)

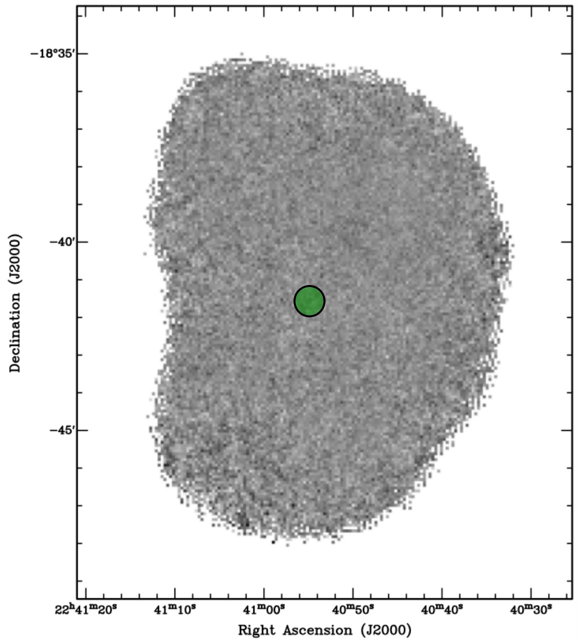
This implies that the coverage is no longer homogenous across the FoV for standard compact mapping patterns

Compact source should be moved to the most sensitive part of the array => ref52()

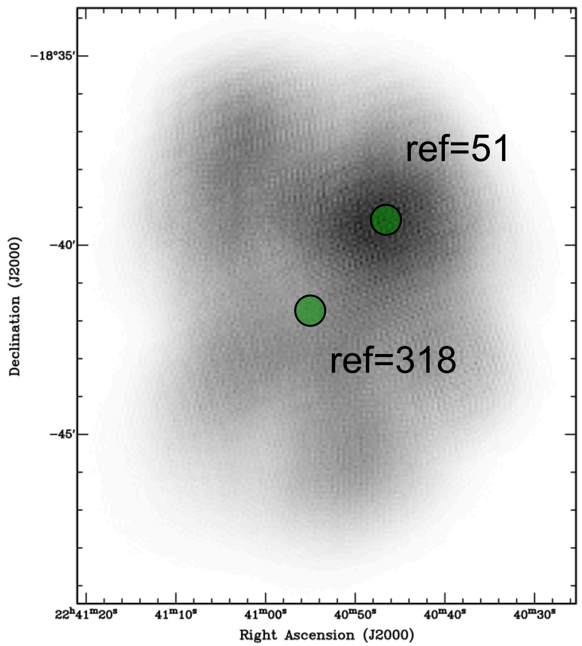
spirallras



flux



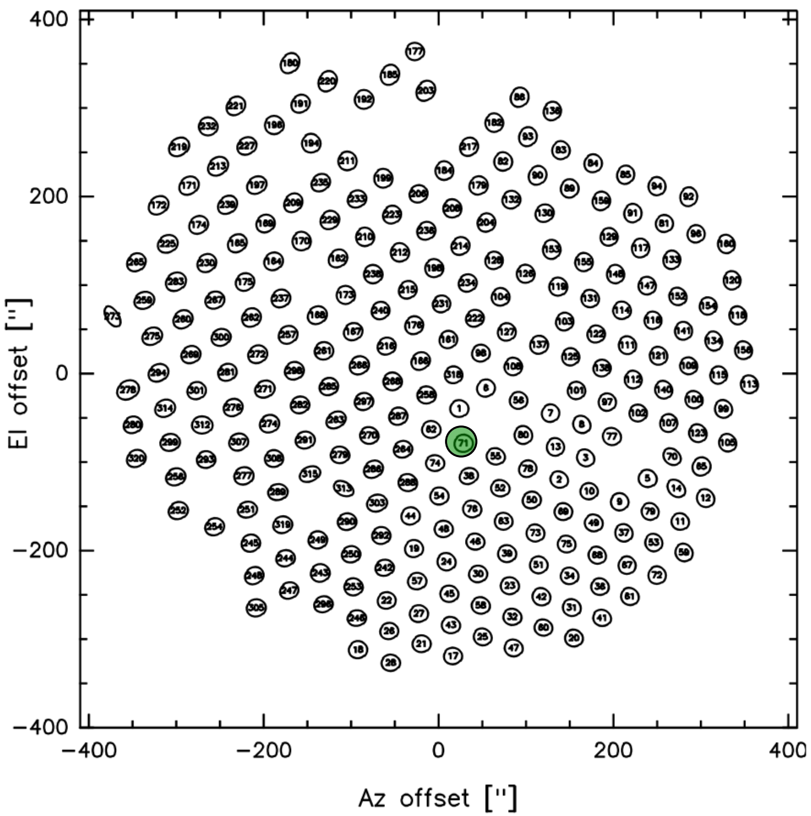
weights

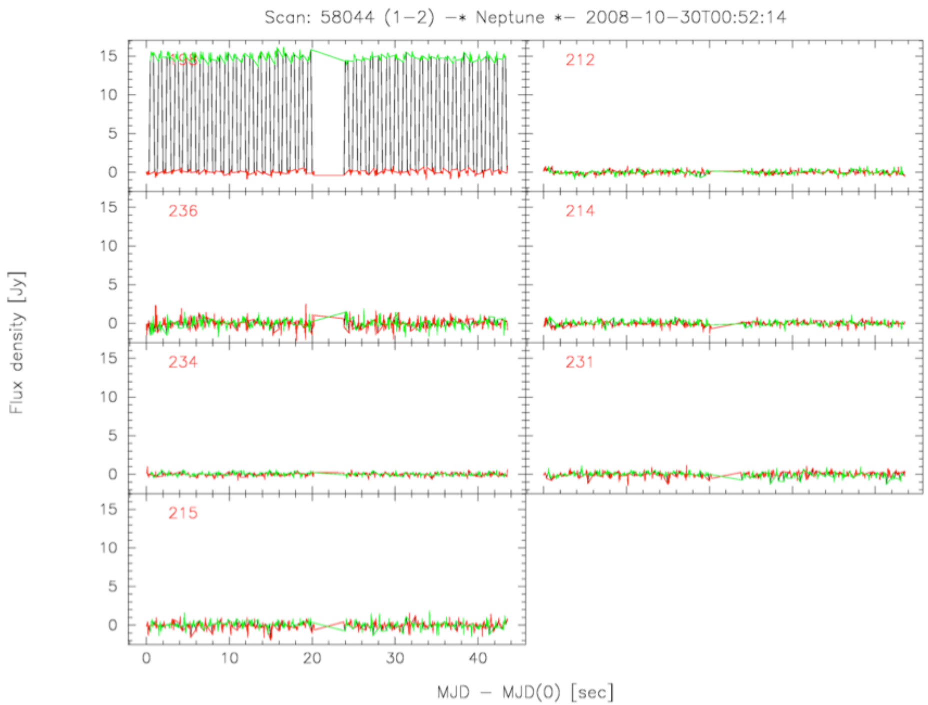


Photometry mode

Standard symmetric WSW observations with a single pixel near the optical axis (Channel 71)

Requires stable condition; otherwise imbalances compromise observations of faint sources



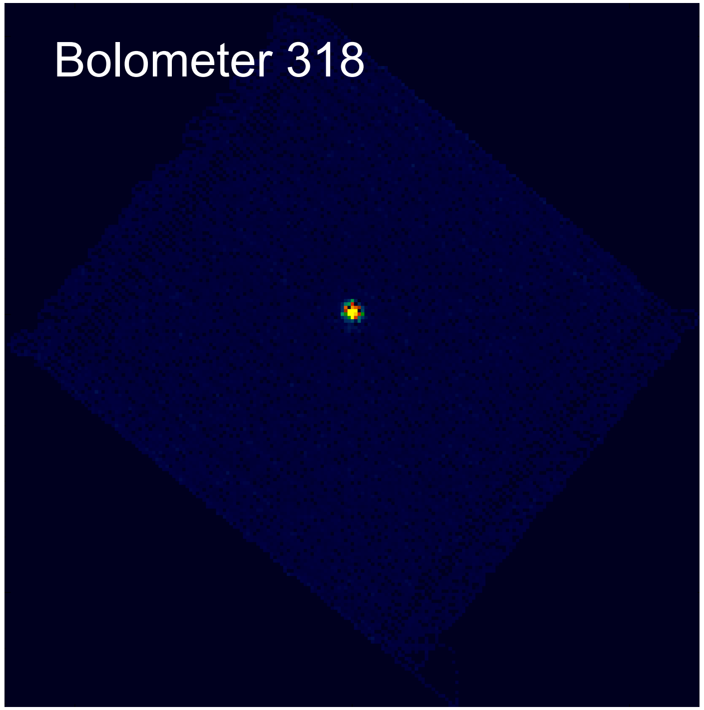


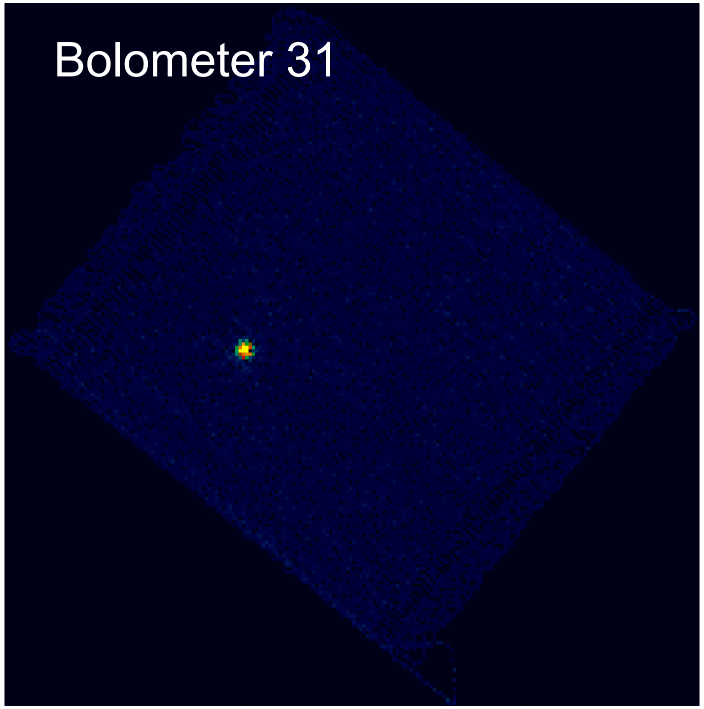
Calibration

Three thinks need to be known:

1) Positions of all bolometer in the array and their relative responses (Flat Field); list of cross talkers

determined via “beam maps” on a strong source by APEX staff (full sampled map for each bolo)



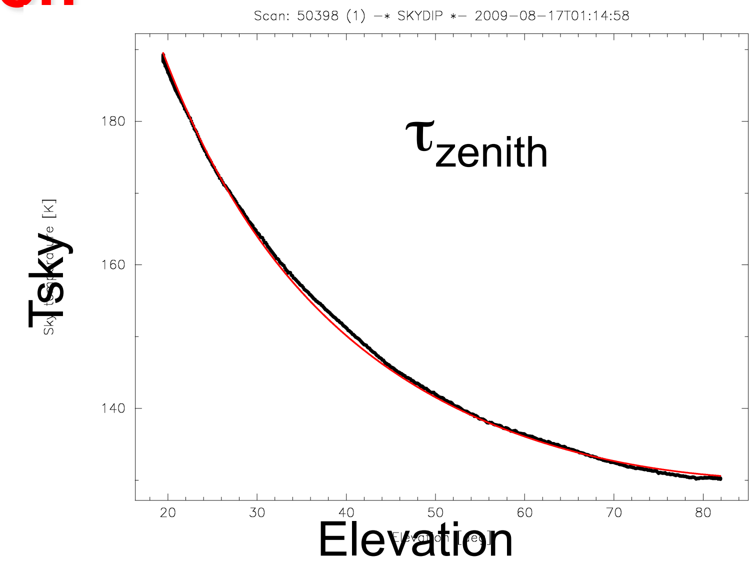


Calibration

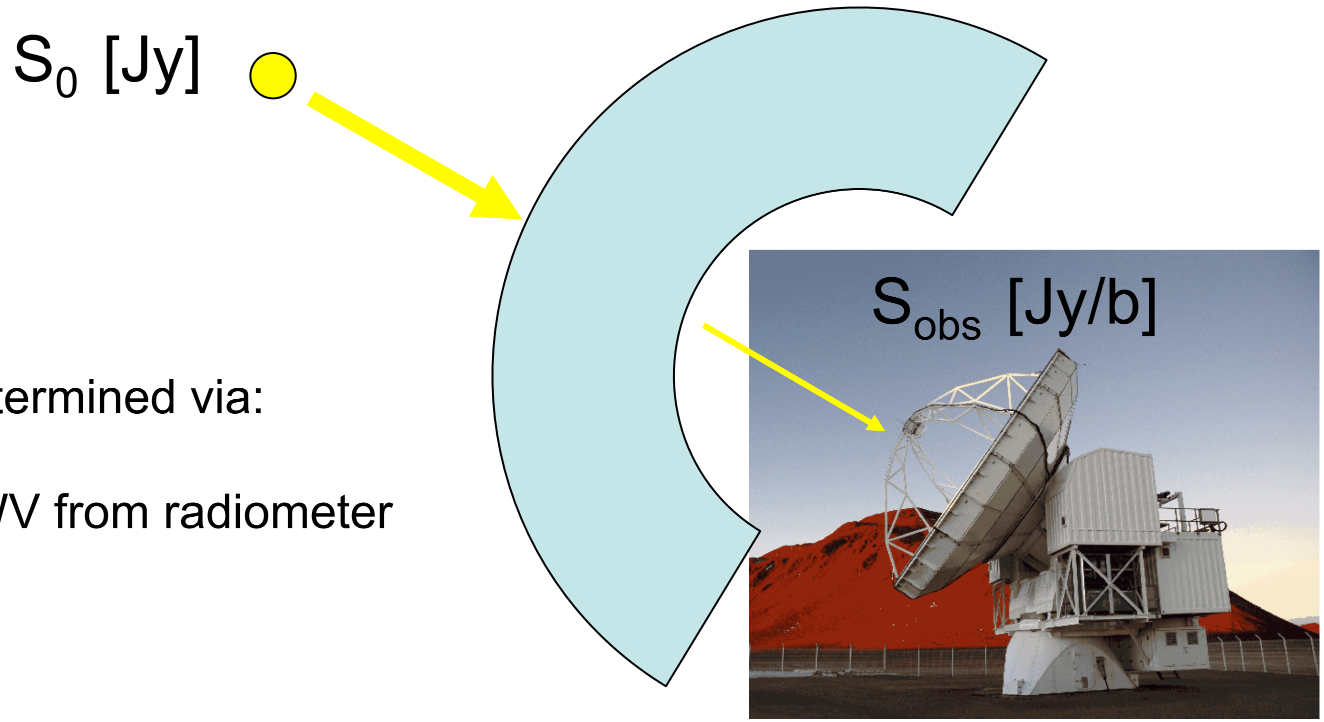
2) Atmospheric attenuation of the signal

expressed as zenith opacity (τ_{zenith})

$S_{obs} = S_0 * \exp(-1*\tau_{zenith}/\sin(el))$
$S_{obs} = S_0 * \exp(- \tau_{los})$



Planet (known flux density from models)



Zenith tau determined via:
a) Skydips
b) From PWV from radiometer

Calibration

3) Determine the average response which converts the detector output voltage to flux density:

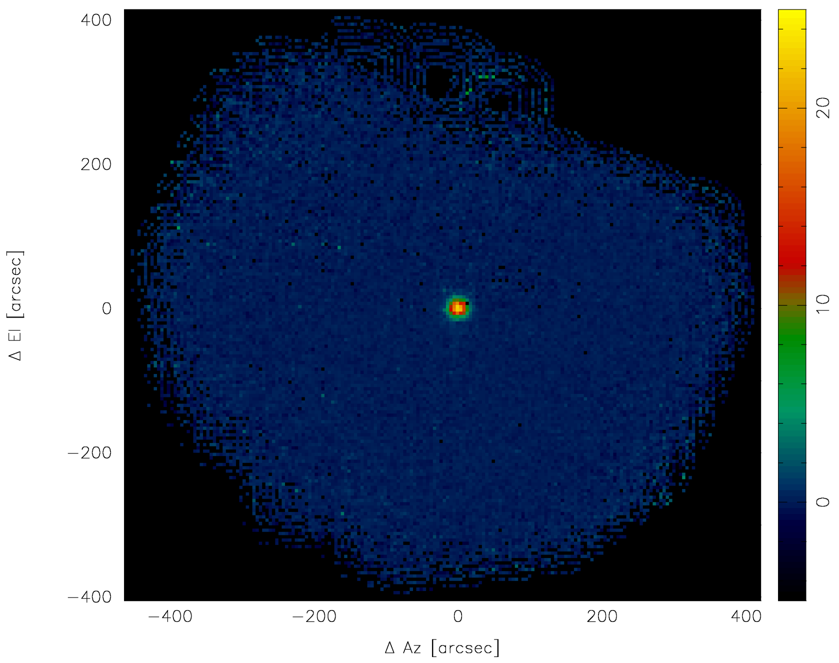
$$C = U_{obs} / (S_{Planet}\, e^{-\tau los}) \; [V/Jy]$$

This factor is well determined and implemented in BOA

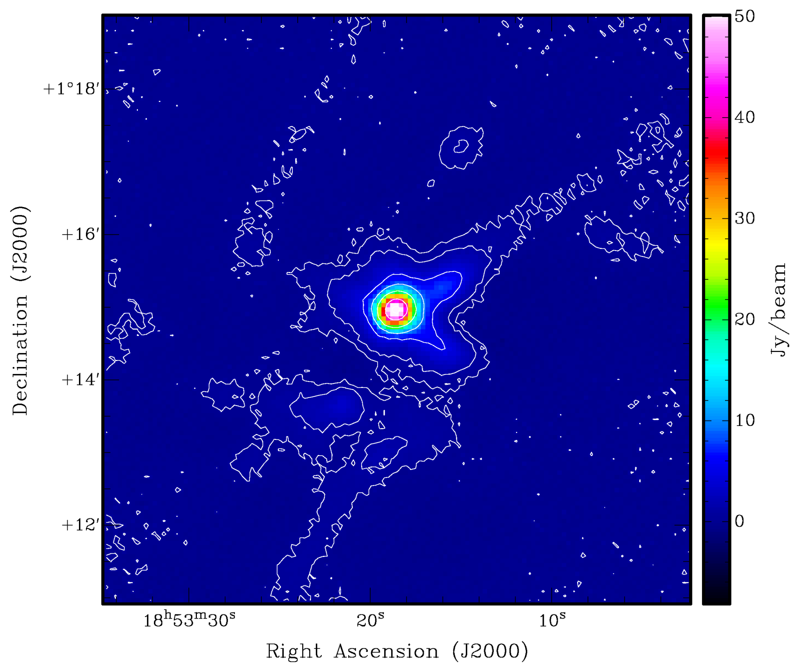
"primary calibrators":
Mars, Uranus, Neptune

"secondary calibrators"
Compact, non-variable sources (e.g hot cores)

Neptune



G34.3



Spatial filtering

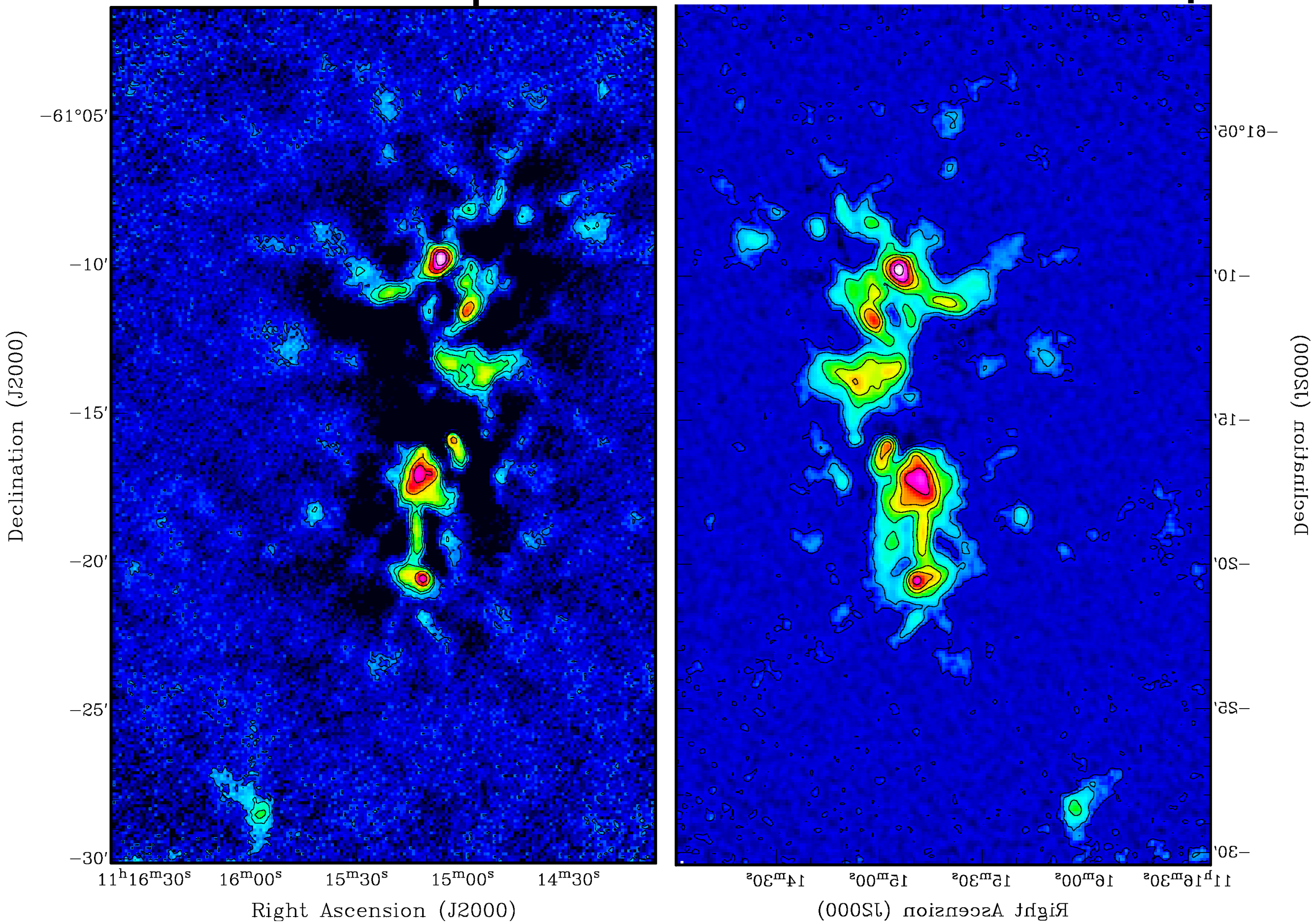
Correlated Noise removal acts
like a spatial filter (extend emission seen by
all bolometers is removed from the map)

Extended structure can be recovered to some degree by construction of a source model and iterative processing of the time series.

Rule of thumb:
only structures ~1/2 array size can be reconstructed

iterate with model

first map → final map



Observing commands / reduction commands

APECS

In your setup macro the following line
needs to be included:

execfile('/homes/software/apecs/start_laboca.apecs')

This defines all standard observing fkts:

pspiral	20s	multi purpose:
pspirall	35s	pointing, calibration
spiralras	4x20s	deep FoV mapping
spirallras	4x35s	

fx fy fz	standard focus (no scanning)
mfx mfy mfz	mapping focus (pspiral for each focus position)
bolotip	does a hot-sky & skydip scan
recycle	moves telesope to Az=180; El 45

This also exists for spectroscopy

wcpoint, wlpoint wfx, wfy wfz

BoA

boa>redpnt(scannr,tau)
boa>redcal(scannr,tau)
pcorr 0.5, 1.5

boa>redweak(scannr,tau)
also returns the array
sensitivity !!!

boa>redfoc(scannr)
boa>redmfoc(scannr)
returns:
fcorr -0.23,'z'

boa>redsky(scannr)
returns tau_zenith

For targets:
boa>redmap(scannr)
boa>redscansmulti([[1011,1015],
[1017,1021],tau)

Typical observing session

	Planet or strong 2nd	*pspiral (20s – single spiral)* *pspirall (35s – single spiral)*
pointing	center on source	
focus x/y/z	Optimize the response and beam shape	*fx/fy/fz or mfx/mfy/mfz*
calibration	this is the first calibration scan	*pspiral (20s – single spiral)* *pspirall (35s – single spiral)*
skydip	determine zenith tau	*bolotip*
	Pointing source near target	*source 'xxx'* *spiralras (4x 20s – raster of spirals)* *spirallras (4x 35s – raster of spirals)*
pointing	center on source	
Science obs		
⋮	~1h science	*source 'xxx'* *obsOTF(r=4)*
Science obs		
calibration	next calibration scan	
skydip		
pointing	verify pointing	
Science obs		
⋮		

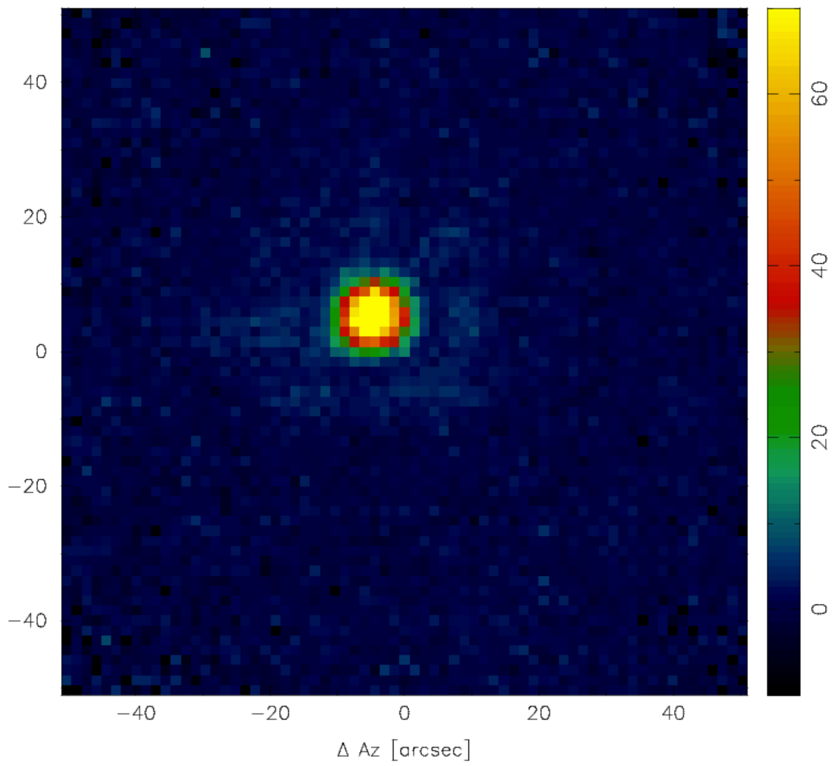
Don't assume things are ok – check it!

For each calibrator/pointing scan you get
a fully sampled image of the source ; i.e. the PSF

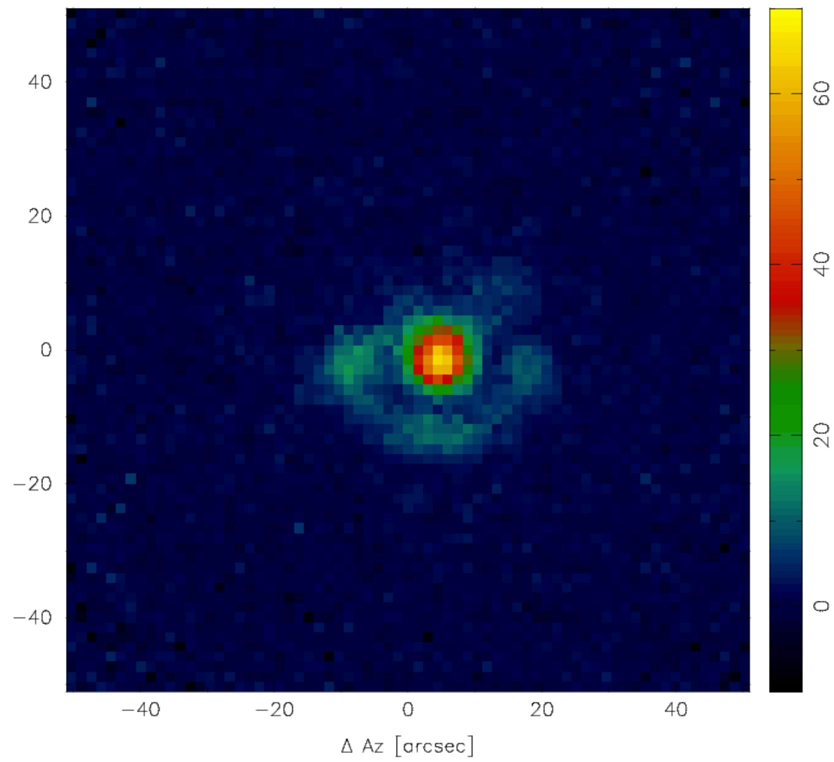
Use this to verify your focus setting in case you do not see the expected
Flux on a calibrator (this is also very useful in unstable conditions where
it can be difficult to determine the focus settings)

2nd example is LABOCA's sensitivity; this number is displayed in the BOA
reduction every time you reduce a faint source (should be of order 55-65 mJy sqrt(s)

Boa redcal(56789); 97%



Boa redcal(56781); 73%



Planning your mapping strategy

Always scan along the minor axis (best frequency modulation)
Make sure the map is big enough that at least half of the array is off source!

This may not be the best in terms of observing time, but gives you a better result!