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:

\[ \Delta T = T - T_0 = \frac{E}{C} \]

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

\[ \tau = \frac{C}{G} \]

- Temperature rise is **proportional** to the incoming energy
LABOCA design

LABOCA 295-channel

LABOCA Wafer

Silicon Wafer
Si$_3$N$_4$ Membrane with metal film absorber
NTD Ga thermistor
Niob- and Gold
LABOCA optics
LABOCA @ APEX

B-cabin

A-cabin

C-cabin
Bolometers: Sensitivity through bandwidth

Radiometer Formular: \( dT \sim T_{sys} \left(B \times t_{int}\right)^{-0.5} \)

LABOCA pass band

SiS receivers:

Spectroscopy:
\( B \sim \) few KHz- few MHz

Continuum:
\( B \sim 1-8 \) GHz

Bolometers:
\( B \sim 100 \) GHz
(matched to Atmospheric Transmission window)
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:
obolometers 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

- **Bolometers**
  - 280mK
  - 12 cables; 26 channels each (shared microphonics)

- **JFETs**
  - 77K

- **4 Amps**
  - 290K

- **Backend Computer**
  - “ABBA” 1kHz sampling (synchronized with bias freq.)
  - Low pass filtering
  - Down sampling 25 Hz

- **Frontend Computer**
  - Ampl. Gains
  - Temperature control etc.

- **APECS**

- **Bridge Computer**
  - 1kHz

- **Fits file**

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?
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
Limitations for the scanning speed:
- High frequency cut off Bolos,
- position information of 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\(^{\circ}\)/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()
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 things 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)
2) Atmospheric attenuation of the signal expressed as zenith opacity ($\tau_{\text{zenith}}$)

$$S_{\text{obs}} = S_0 \cdot \exp(-\frac{1 \cdot \tau_{\text{zenith}}}{\sin(\text{el})})$$

$$S_{\text{obs}} = S_0 \cdot \exp(-\tau_{\text{los}})$$

Planet (known flux density from models)

$S_0$ [Jy]

Zenith tau determined via:
- a) Skydips
- b) From PWV from radiometer
3) Determine the average response which converts the detector output voltage to flux density:

\[ C = \frac{U_{\text{obs}}}{(S_{\text{Planet}} e^{-\tau_{\text{los}}})} \text{[V/Jy]} \]

This factor is well determined and implemented in BOA

“primary calibrators”: Mars, Uranus, Neptune

“secondary calibrators” Compact, non-variable sources (e.g. hot cores)
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
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 fcts:

<table>
<thead>
<tr>
<th>Command</th>
<th>Duration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pspiral</td>
<td>20s</td>
<td>multi purpose:</td>
</tr>
<tr>
<td>pspirall</td>
<td>35s</td>
<td>pointing, calibration</td>
</tr>
<tr>
<td>spiralras</td>
<td>4x20s</td>
<td>deep FoV mapping</td>
</tr>
<tr>
<td>spirallras</td>
<td>4x35s</td>
<td></td>
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<td>fx fy fz</td>
<td></td>
<td>standard focus (no scanning)</td>
</tr>
<tr>
<td>mfx mfy mfz</td>
<td></td>
<td>mapping focus (pspiral for each focus position)</td>
</tr>
</tbody>
</table>

bolotip    |     | does a hot-sky & skydip scan               |
recycle    |     | moves telescope to Az=180; El 45           |

This also exists for spectroscopy

wcpoint, wlpaint wfx, wfy wfz

BoA

boa>redpnt(scannr,tau)
boa>redcal(scannr,tau)
pccor 0.5, 1.5
boa>redweak(scannr,tau)
also returns the array sensitivity !!!
boa>redfoc(scannr)
boa>redmfoc(scannr)
returns:
fccor -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

- point on source
- Optimize the response and beam shape
- this is the first calibration scan
- determine zenith tau

Pointing source near target

- center on source
- ~1h science
- next calibration scan
- verify pointing

Science obs

- source ‘xxx’
- obsOTF(r=4)

Skydip

- determine zenith tau

Calibration

- point on source
- fx/fy/fz or mfx/mfy/mfz
- spirall (20s – single spiral)
- spirall (35s – single spiral)
- bolotip
- spiralras (4x 20s – raster of spirals)
- spirallras (4x 35s – raster of spirals)
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!