

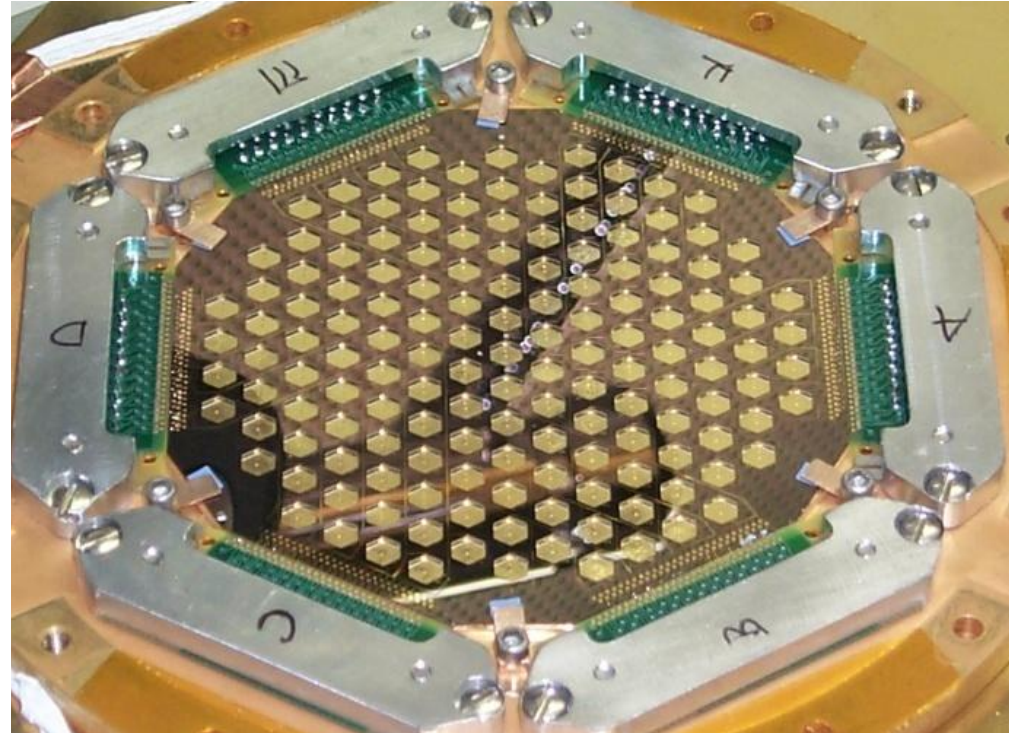
An Introduction to the AzTEC Data Reduction



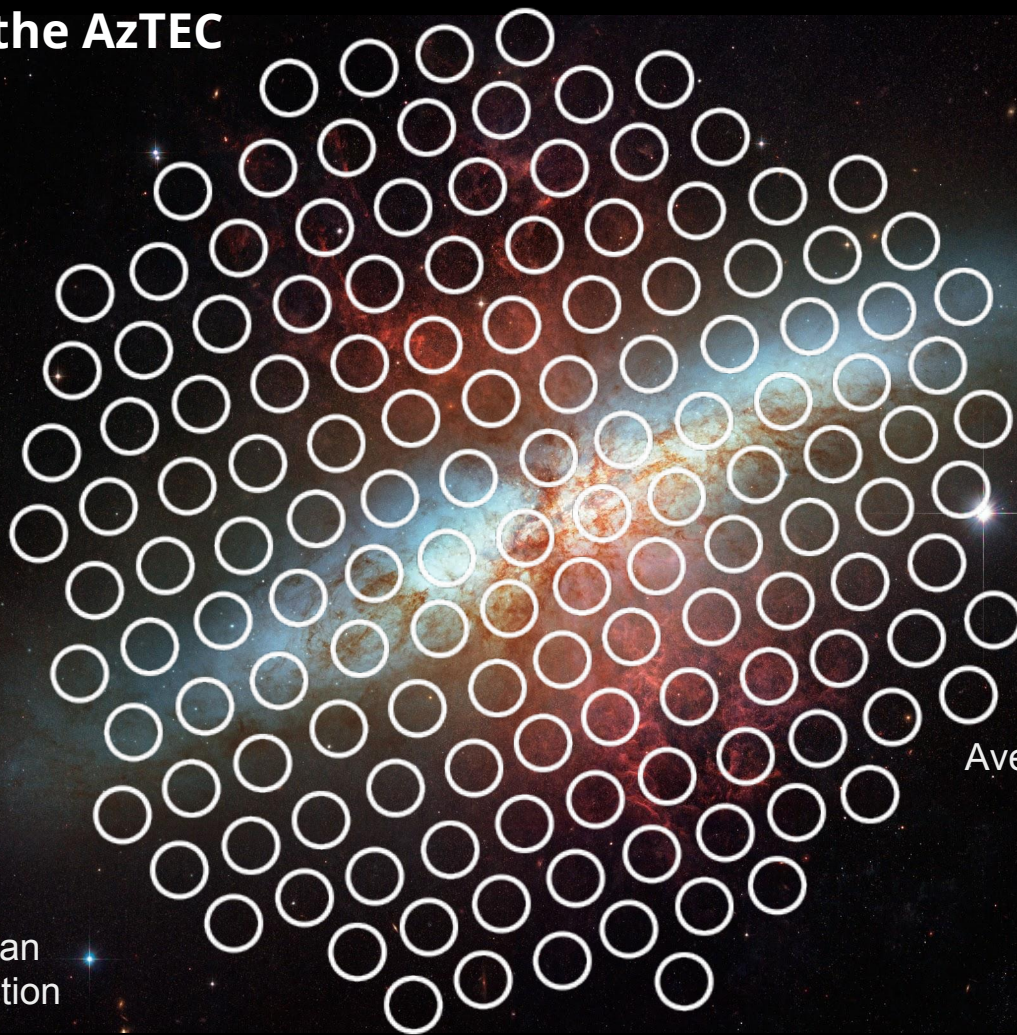
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Catedrático CONACyT/GTM
2018 Guillermo Haro Workshop

Aztronomical Thermal Emission Camera (AzTEC)

- Continuum millimeter wavelength observing at 1.1mm (270 GHz).
- Integrated by 144 Si-Ni detectors:
 - Spider-web mesh bolometers.
 - Negative transition detectors (NTD).
 - Frecuencia de muestreo 64 Hz.
- Cooled down to 0.3K with a closed cycle ^3He - ^4He fridge.
- Angular Resolution at LMT is 8.5 arcsec.
- FoV ~ 1.5 arcmin.
- Mapping speed: 0.1 sq. deg. / mJy/s²



Sky footprint of the AzTEC array



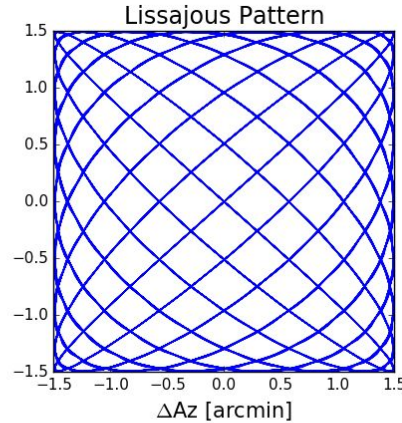
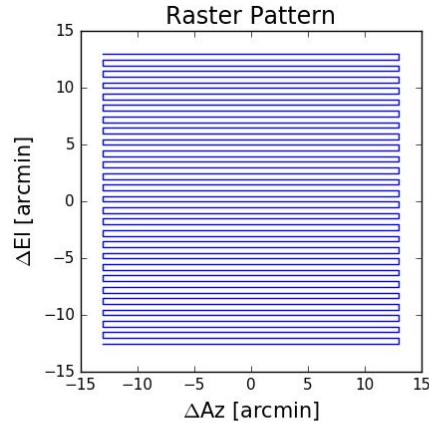
Array is configured in an
closed-pack configuration

Average detector separation is
 $1.4 f\lambda$ (~ 12 arcsec).

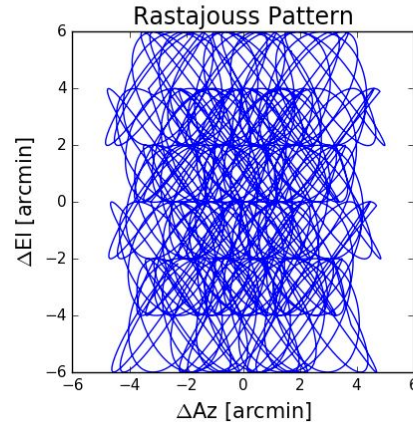
A “snapshot” is not
fully sampled spatially

Scanning Patterns

- **Raster** or “Large Map” mode
- Recommended for maps larger than 20 sq. arcmin.
- Not very efficient due to the overhead time on scan turn-arounds.
- Requires pixel cross-linking by scanning in a perpendicular direction



- **Lissajous** is used for photometry mode observations (30” diameter) and small map mode (1.5’ diameter).
- Does not require pixel cross-linking



- Combination of a relatively slow raster scan with a fast lissajous pattern.
- Scans over a fixed sky area (20 sq.arcmin)
- Less sensitive to turn-arounds effects

Aims of the pipeline

- Extract the signal from astronomical sources accurately.
- Mitigate the effects introduced by the scanning pattern, atmospheric emission and instrumental noise.

As a general rule the data detected by AzTEC can be written as:

$$d = P(M, A, t) + N$$



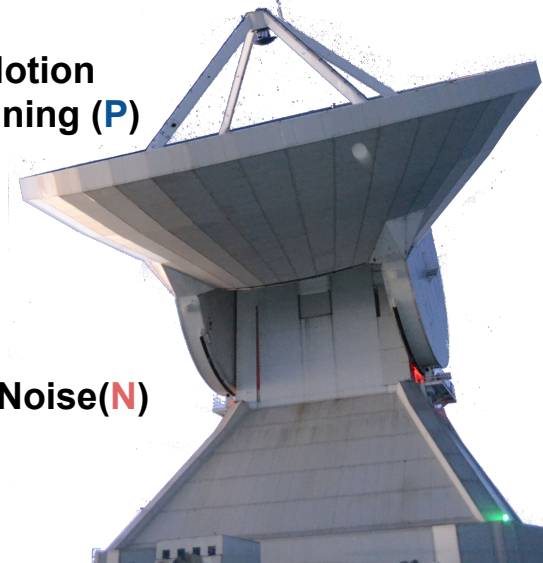
Astronomical
Object (M)

Atmosphere(A)

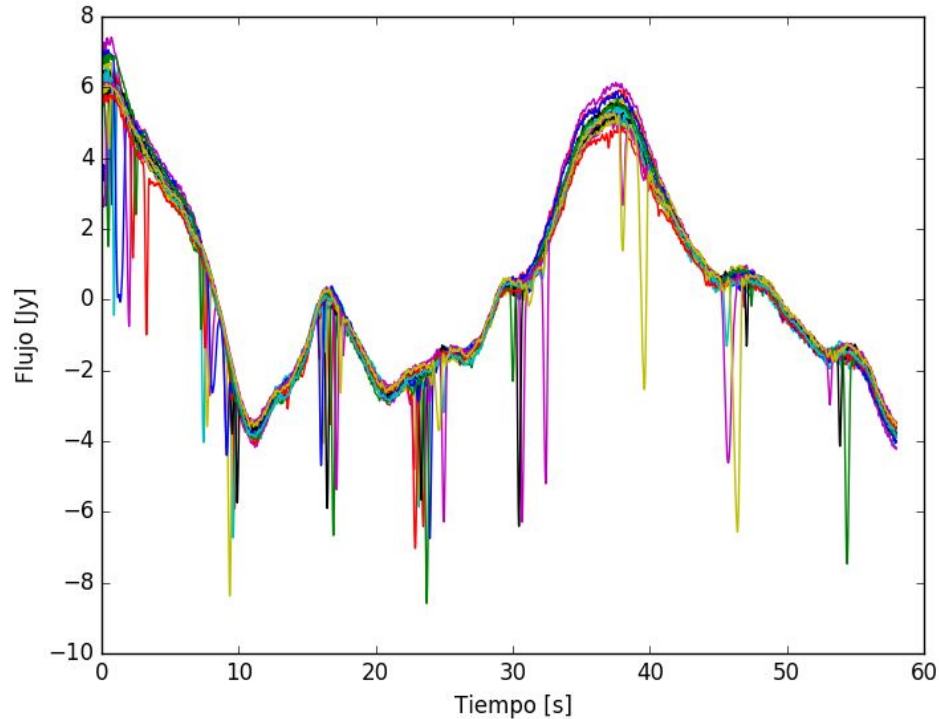


Telescope Motion
Tracking+Scanning (P)

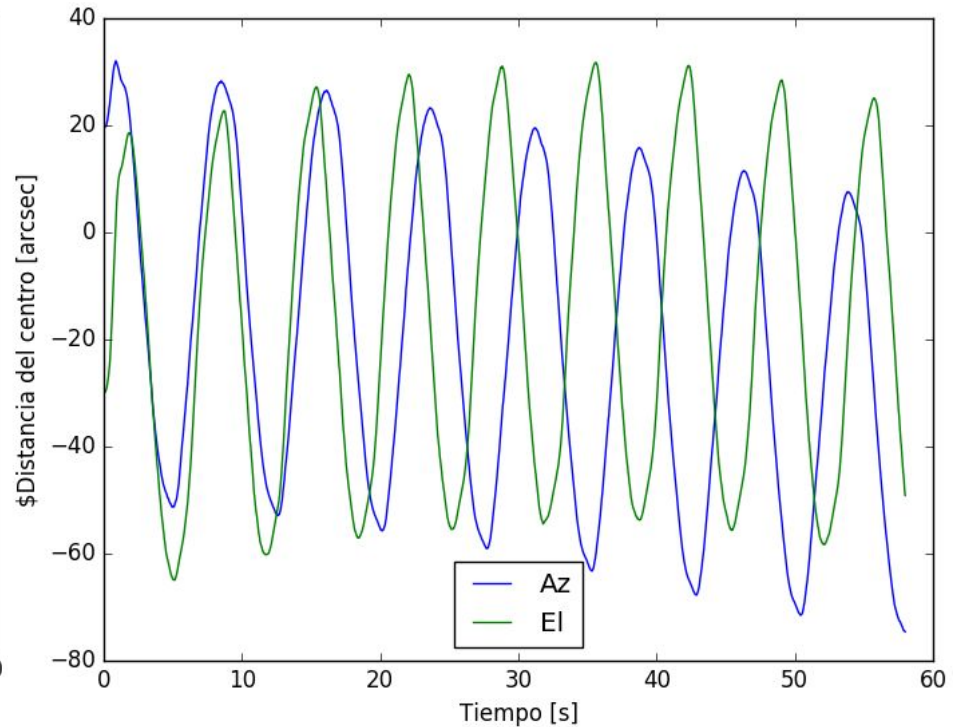
Instrumental Noise(N)



Raw Timestreams

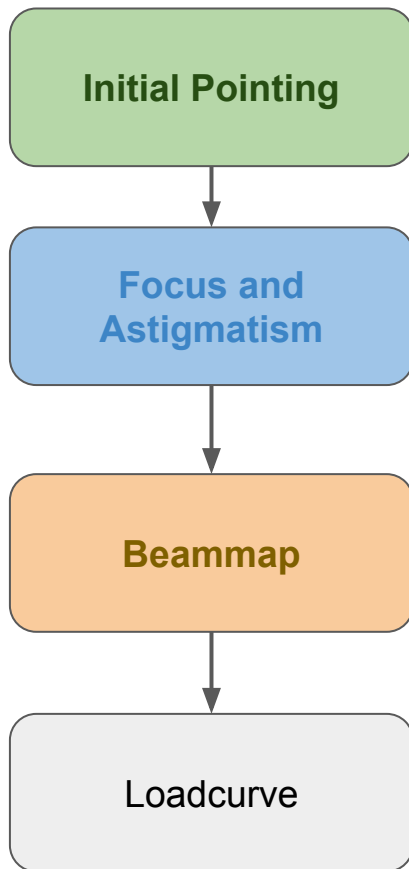


- Bolometer timestreams record the sky brightness as a function of time.
- On raw data the atmosphere emission dominates



- Raw data include the position timestreams. They describe the sky position of the center of the array.

AzTEC Observing Setup



Astrometry Corrections

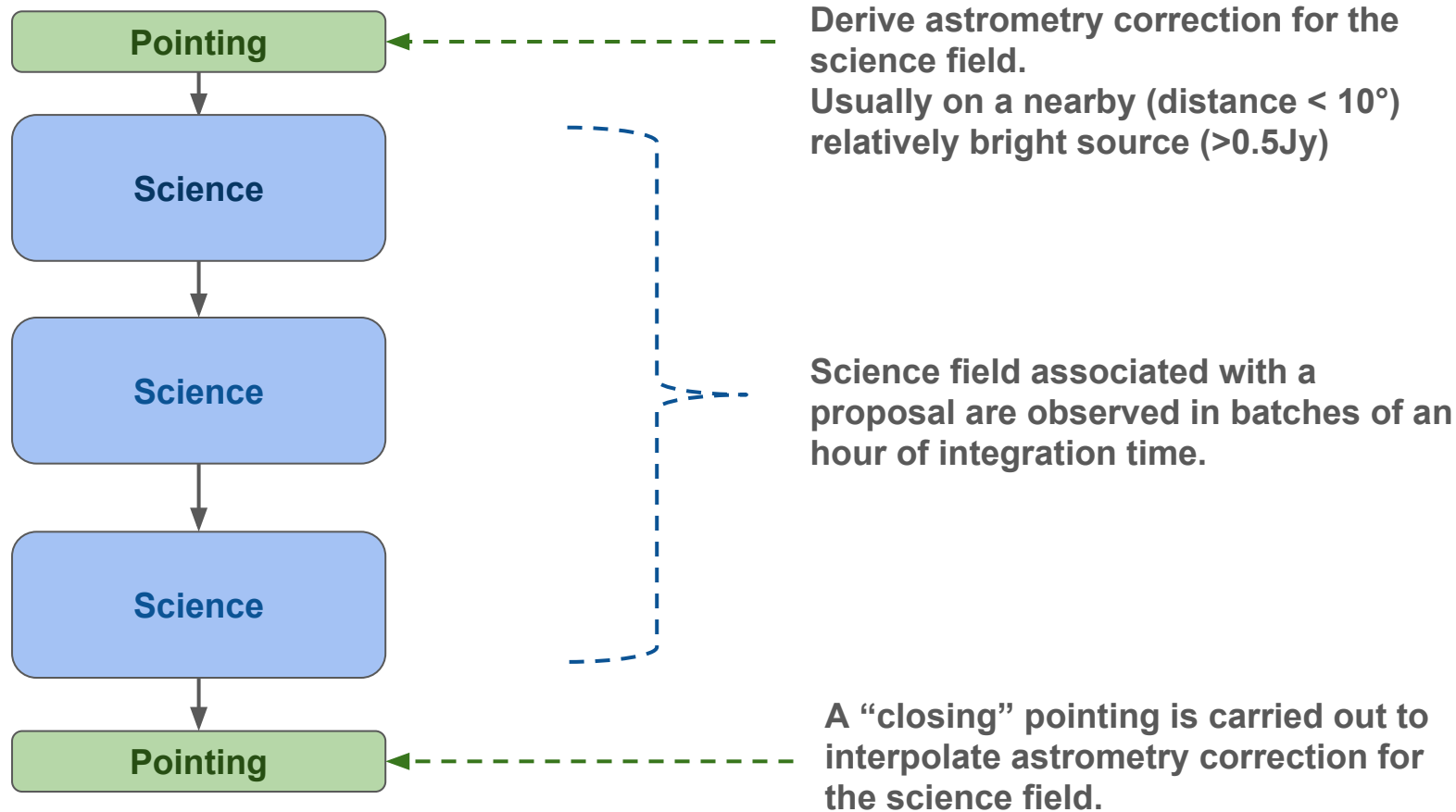
Observe a Bright ($>2\text{Jy}$) point source ($\theta < 8.5''$)
Usually a nearby QSO

Optimization of the secondary position and primary active surface system in order to correct for gravitational and thermal effect.

Measure the position of each bolometer relative to the array center.
Derive the gain and beam pattern of each detector

Electronic calibration of the bolometers

AzTEC Science Observation Scheme



The AzTEC Pipeline

Electronic glitch and
cosmic ray removal

PCA (Point Source),
CMP (Extended)

Time to map
space conversion

Raw Data

1
2
...
N

Signal
Conditioning

Atmosphere
Removal

Noise
Simulation

Map
Creation

AzTEC C++ pipeline (aka **macana**)

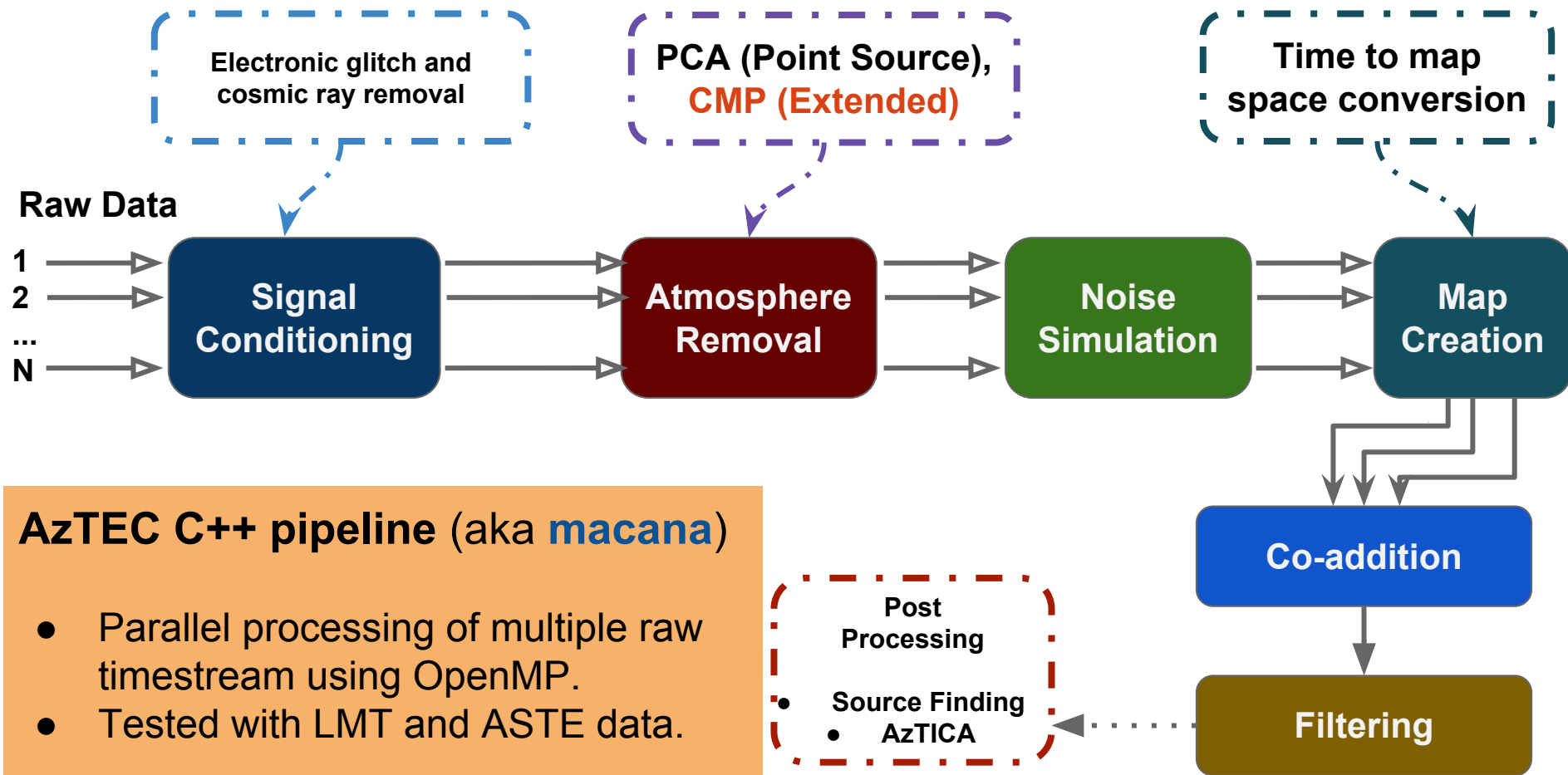
- Parallel processing of multiple raw timestream using OpenMP.
- Tested with LMT and ASTE data.

Post
Processing

- Source Finding
 - AzTICA

Co-addition

Filtering

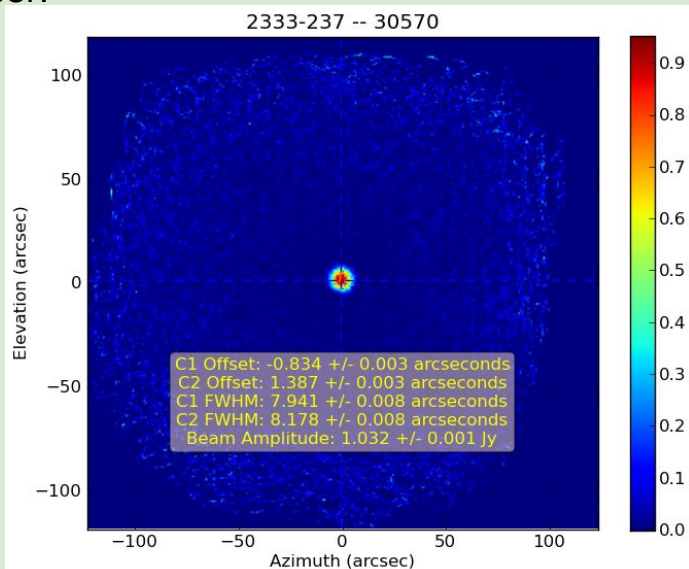


AzTEC Raw Data Products

The AzTEC backend records its observations in the **NetCDF** format. It is optimized for real-time recording of time series.

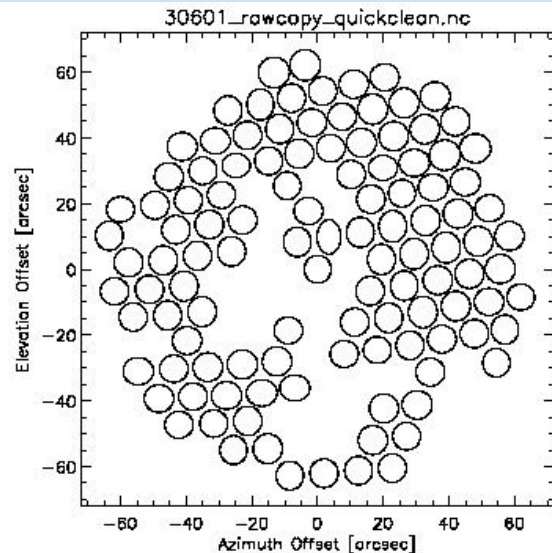
P.I. Products

Science and pointing files are delivered to the user.



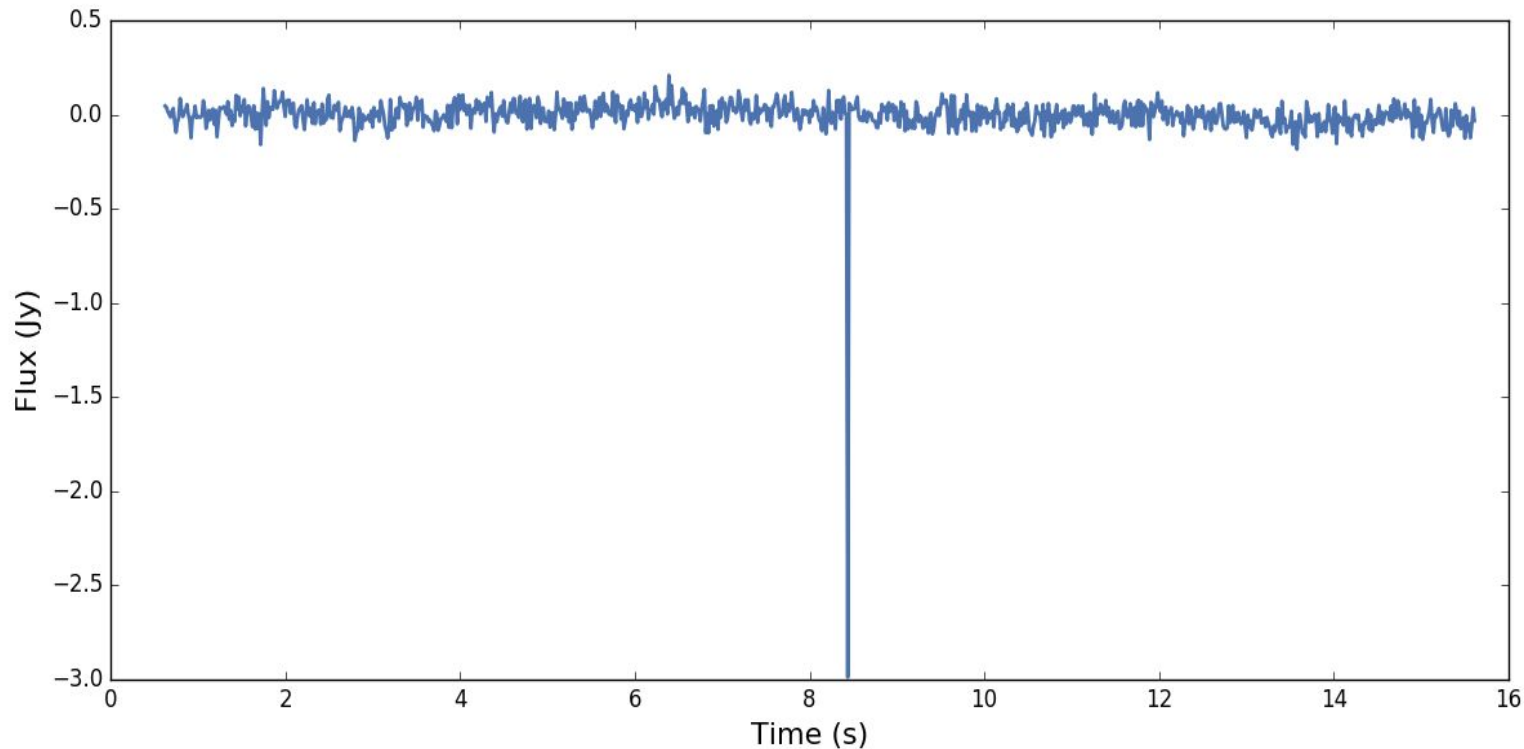
Global Products

Beammaps and loadcurves are included in the pipeline distribution. Release at the end of season



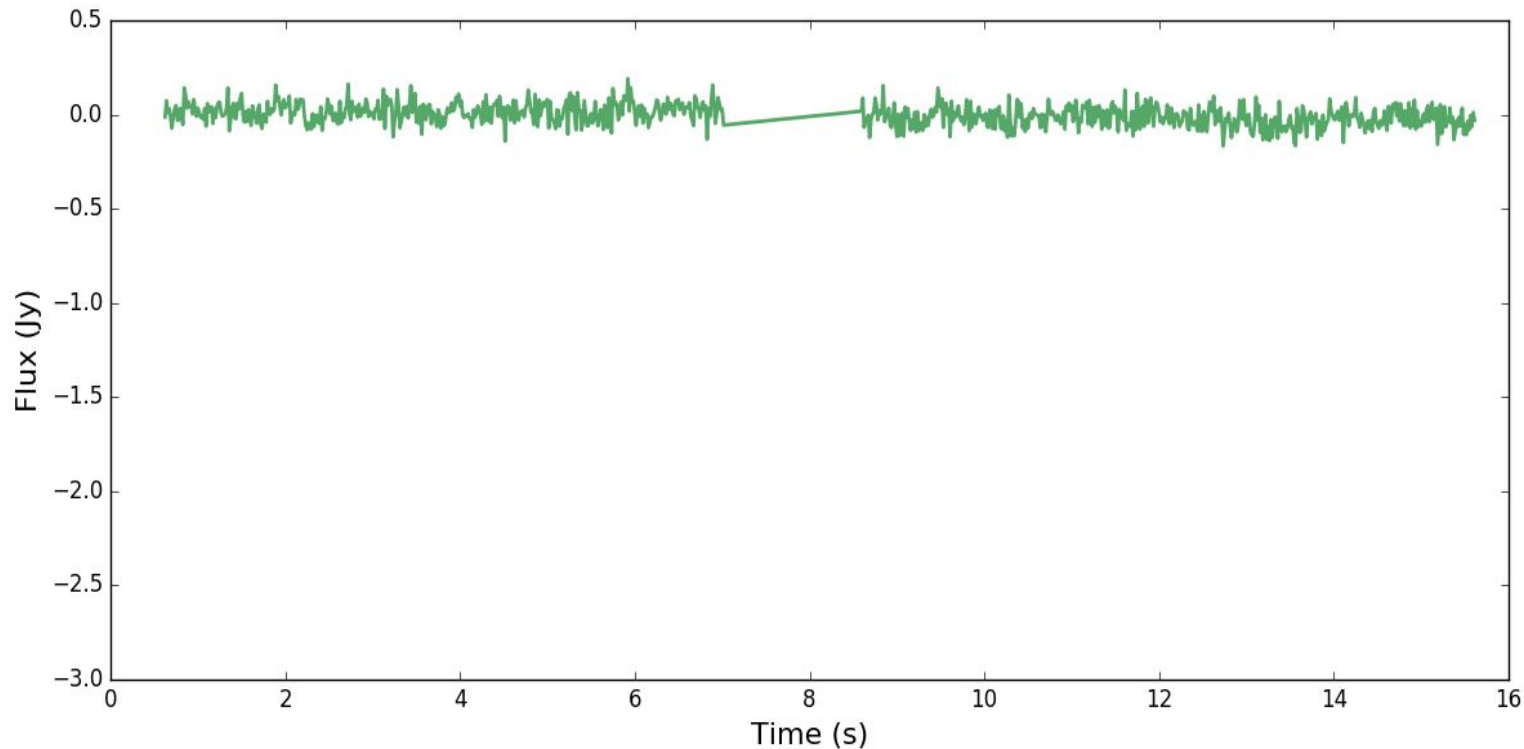
Signal Condition

A three step process: (a) Removal of cosmic rays (despiking), (b) Reduction of sample-to-sample noise (low pass filtering) and (c) creation of auxiliary timestream (flags, kernel and pointing)



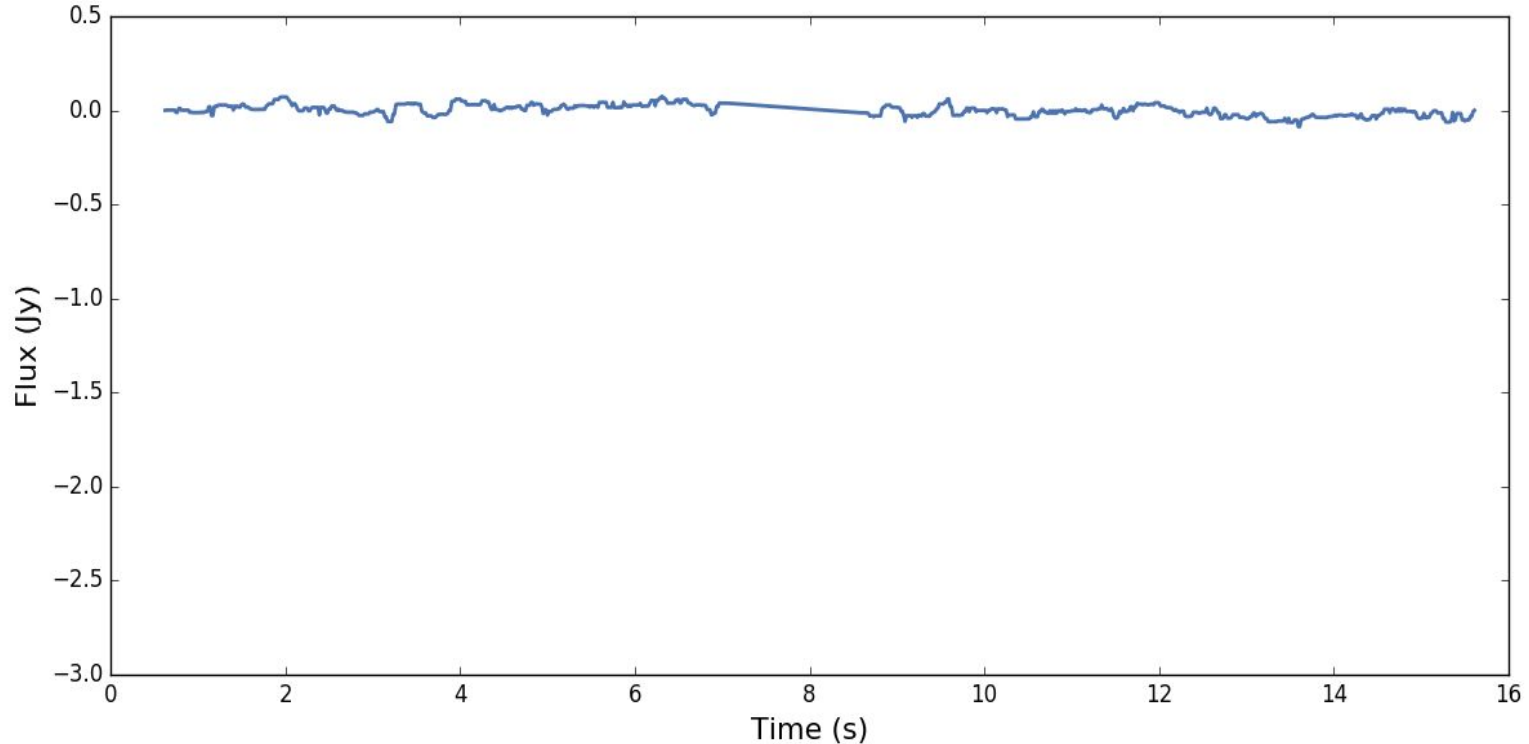
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Analysis of Point Source v.s. Extended Source

For each AzTEC detector the timestream data can be written as: $\mathbf{d} = \mathbf{PM} + \mathbf{A} + \mathbf{N}$

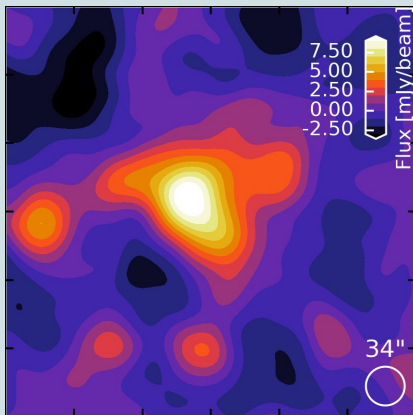
Principal Component Analysis:

Blind decomposition of the bolometer timestreams. It build the bolometer array covariance matrix $\mathbf{C}$:

$$\mathbf{C} = \mathbf{d}^T \mathbf{d}$$

$\mathbf{C}$ is transformed to the eigenvector space.

Hypothesis: The atmosphere signal is strongly correlated, therefore by removing the largest eigenvalues we preserve the astronomical signal



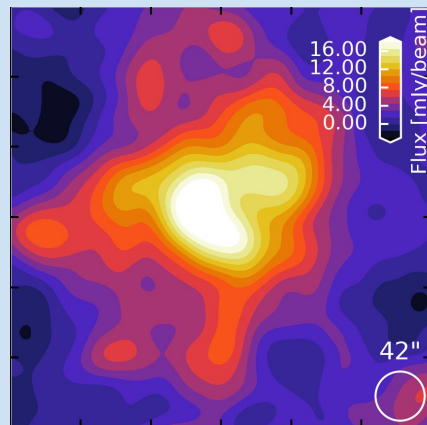
Cottingham Method:

Assumes that the atmosphere contribution is smooth and can be represented by a spline basis:

$$\mathbf{A} = \alpha \mathbf{B}$$

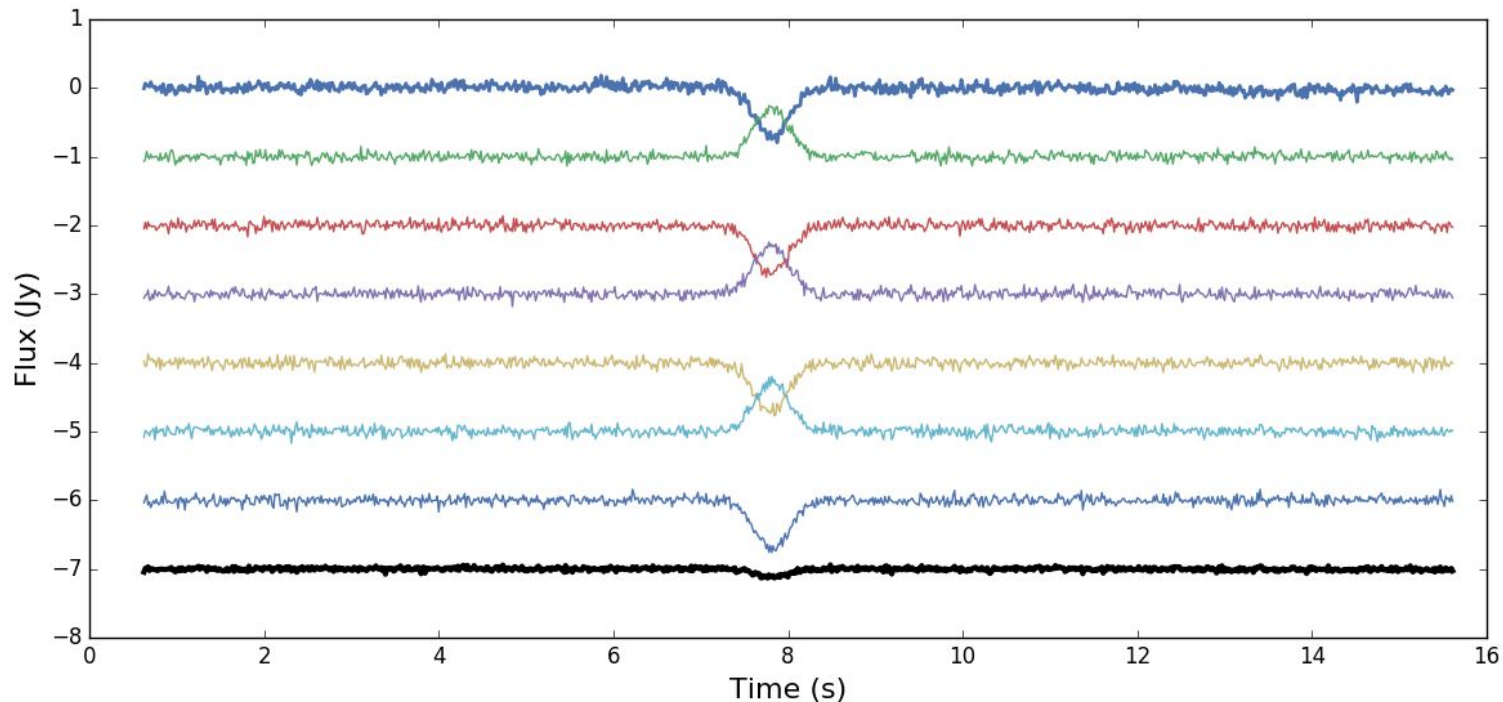
Optimal estimation of the atmosphere taking into account the bolometer sky position.

Hypothesis: The atmosphere signal is a common-mode component to the array.



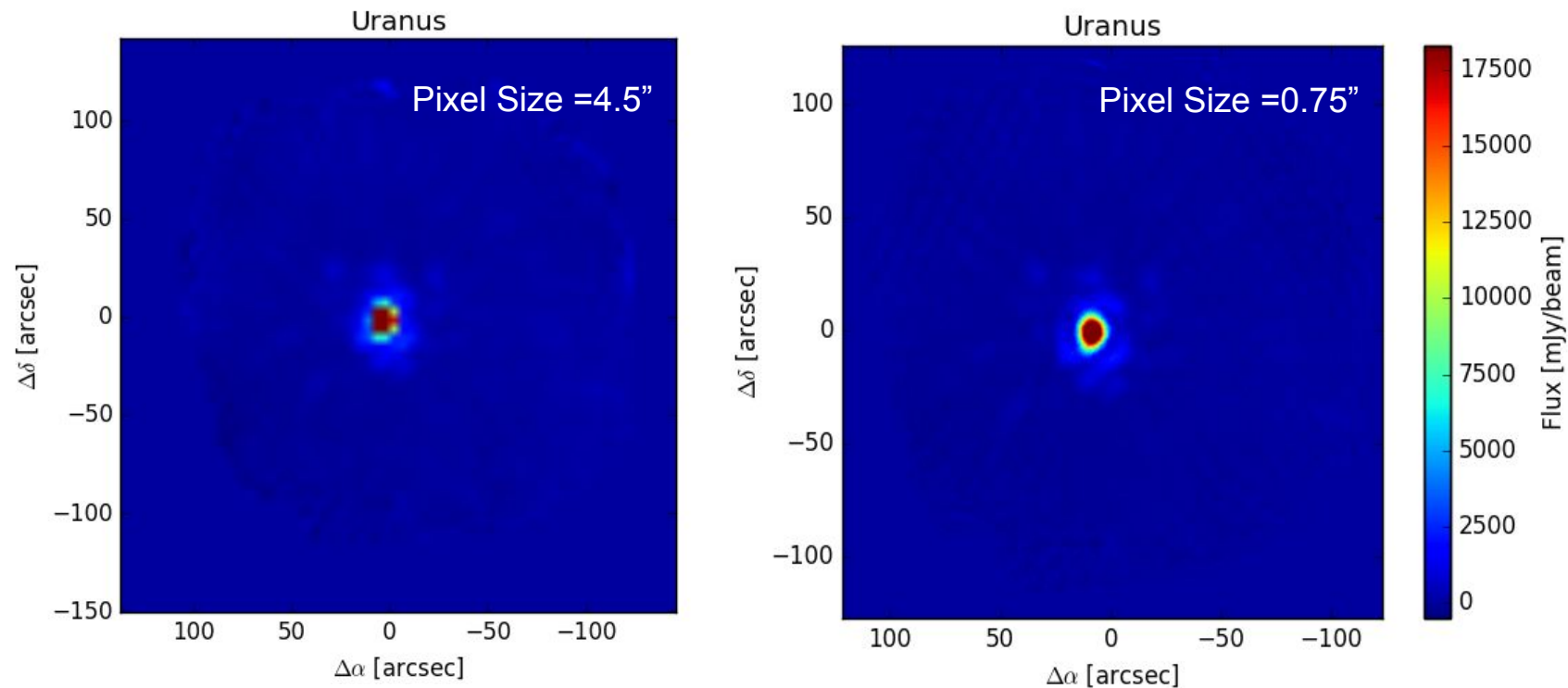
Noise Simulation

To get a better measurement of the noise properties of the final map a timestream is randomly multiplied by ± 1 to create a set of fake timestreams. Then a subset of fake timestreams is processed in the same fashion as the signal map



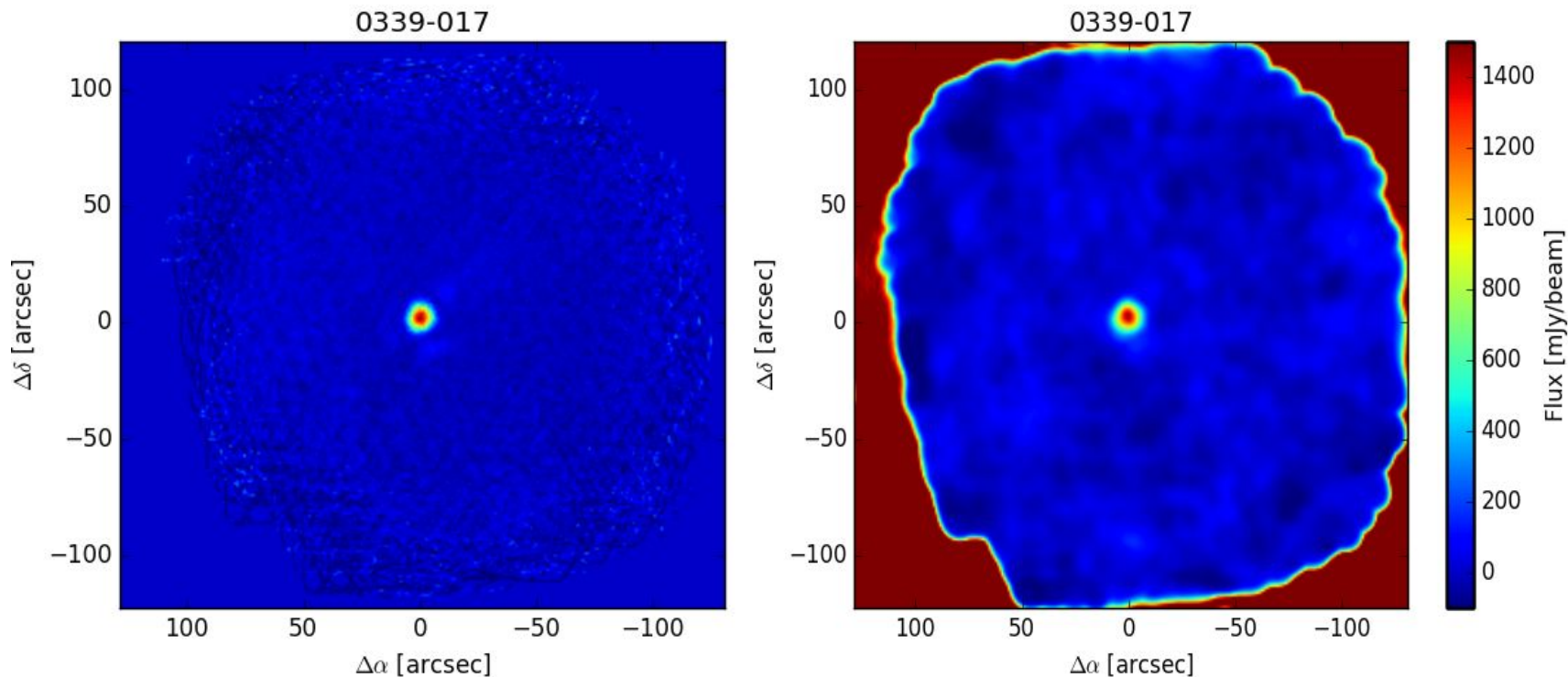
Map Making

For the pipeline the output map pixel size is an arbitrary parameter. It is a compromise between the number of sample per pixel and the number of pixels per beam. A rule of thumb is $\sim 1/10$ of the beam size.



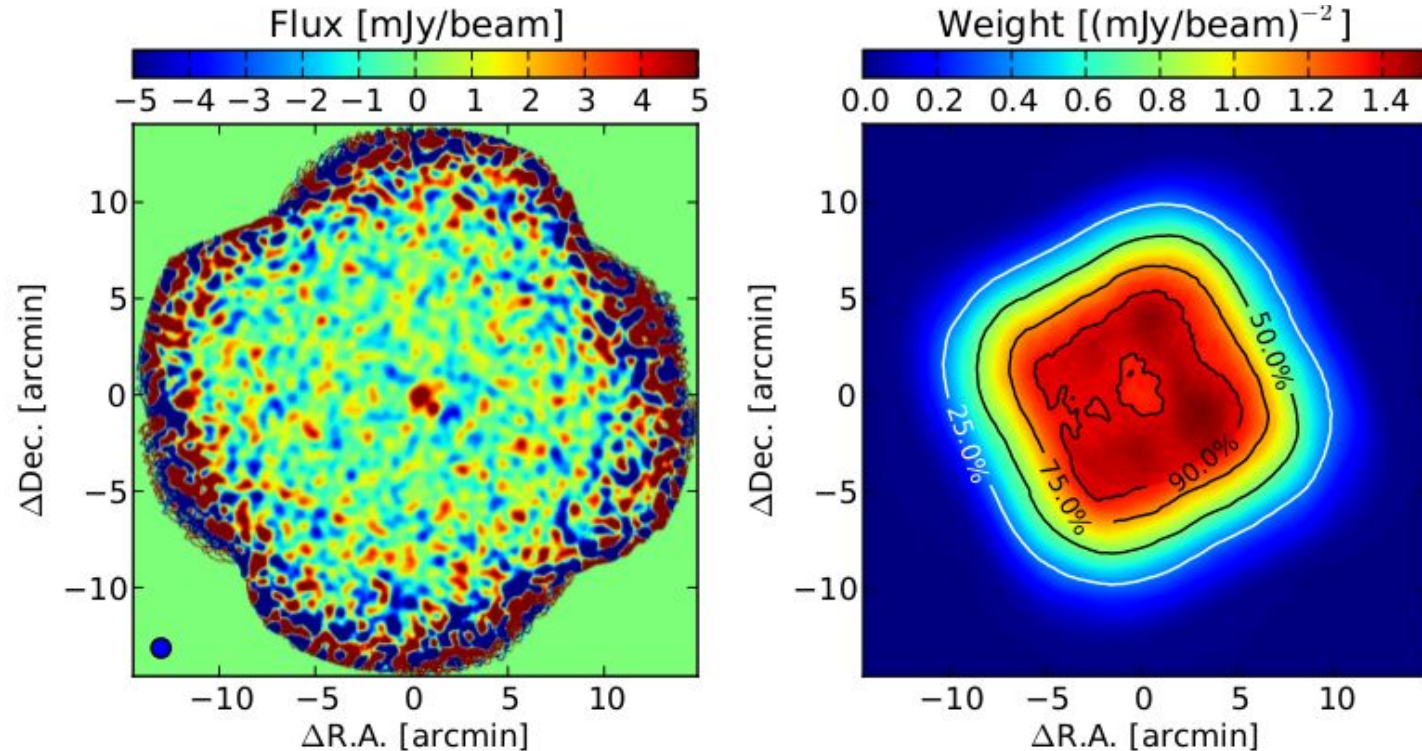
Wiener Filter

Optimal filtering taking into account the sky coverage of the map. It is designed to increase the S/N ratio of point sources. For extended sources a regular gaussian beam should be used.



Data Products

The AzTEC pipeline create four main data products: a signal map (Jy), a coverage map (Jy^{-2}), a S/N map and a PSF map. These are stored in the NetCDF file format. The [fitswriter utility](#) can convert them to fits files



ToI TEC/MusCAT pipeline development

Define design requirements:

- Three wavelengths
- ~7000 Detectors
- ~480 Hz data freq
- Polarization signals
- Require to process 120Gb/hr of observation
 - Time constraint, produce results in less than an hour
- Legacy surveys aim to produce wide area maps of ~100 sq. deg. on 100hr.

~900 times the data density of AzTEC!!

Currently under development

- Codename **citlali**.
- Targeted for multi-node computing cluster
 - PI-version for smaller projects





Thank you!