Long-Wavelength (≥ 850 m) Camera Options for a 25-m Atacama Telescope

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Issues to Consider

- Primary operating mode
- FOV
- Pixel size
- architecture/detector type
- optical loading
- sky noise
- scan strategies

Primary Operating Mode

- Assumption: long-wavelength cameras are used in wide-field survey mode most of the time
  - certainly in line with CMB/SZ science
  - also a good bet for dusty galaxies – can reach to highest *z* at 850 μm and 1.1 mm, but need to survey lots of sky
  - well-matched to large galactic surveys also
  - of course, they should be designed so they can be used in single-source photometry mode, chopped mode, or jiggle mode

FOV

- Simple: since the long-wavelength camera operates in survey mode, it should have the largest possible FOV
- Is 1 deg^2 a reasonable goal? The beam FWHM will be ~ 8" at 350 GHz, 18" at 150 GHz, so 10000 pixels covers 0.05 deg^2 at 350 GHz, 0.25 deg^2 at 150 GHz. This is not implausible on the timescale of the project.
- How does this affect the telescope design? What must be done to maintain good image quality and low spillover across such a wide field of view?

Pixel Size

- Feedhorn-coupled: 2*f*λ close-packed is the standard.
  - Arguments can be made that the loss of optical efficiency in going to smaller horns is recovered by the increase in pixel count
  - We have found with Bolocam that it tends to be a wash or the lost optical efficiency results in all kinds of problems (truncated beams, too much spillover even on cold surfaces)
  - With f/2 or f/3 optics feeding the focal plane, *f*λ ~ 2 mm at 350 GHz, ~ 5 mm at 150 GHz. 100 2*f*λ pixels on a side corresponds to 40 cm and 100 cm, respectively. Big!
  - Matches JPL/Caltech antenna-coupled design; development of a 128-element unit cell is beginning now

Pixel Size

- Bare arrays: ~0.5$f\lambda$ to ensure full instantaneous sampling
  - Provides full coverage of the FOV, no need to jitter to Nyquist sample
  - Focal plane area is fully utilized
  - Most efficient use of telescope (assuming fixed per-pixel sensitivity) – simply get more pixels on sky for given FOV
  - However, some arguments against at long wavelengths
    - Griffin, Bock, and Gear (2002) show that, at long wavelengths, instrument loading can be problematic without good beam definition. Not an issue at shorter wavelengths due to high atmospheric loading.
    - For sky subtraction, spatial dynamic range (FOV/pixel size) is important. For a fixed number of detectors, the spatial dynamic range is larger with feedhorns.

Architecture/Detector Type

- Given the large focal planes being contemplated, TES detectors with time-domain or frequency domain multiplexing are really the only option
    - though perhaps on timescale of project KIDs will prove a better prospect...
- Architecture:
    - if bare array, then a SCUBA2-style or pop-up architecture is probably best because they minimize lost focal plane area
    - if feedhorn, then an antenna-coupled architecture is probably best since a 10000 element feedhorn assembly is a daunting challenge to weight, cooling power, and fabrication

Optical Loading

- Given the high quality of the site, optical loading from the telescope is a high priority at the longest wavelengths
  - At 150 GHz, the telescope could in fact be the dominant load. Even on Mauna Kea, we expect a median of only 15K from the atmosphere.
  - At 350 GHz, median loading is 45K at Chajnantor (if I understood Gordon's table correctly), so telescope less of an issue.

Sky Noise

- There will be sky noise, even at 150 GHz.
- In removing sky noise, one loses information at length scales larger than the FOV. Beam smoothing removes information smaller than the beam. The ratio FOV/beam must therefore be as large as possible to permit access to intermediate length scales.
  - It may be possible to recover some long length scale information by iterative techniques, but it is fundamentally difficult to separate long-wavelength astronomical signals from long-timescale sky noise
- Chopping of course helps a great deal, but information is lost. This is especially problematic for wide-field CMB/SZ measurements.
- Scanning faster helps. The telescope should be designed to either
  - scan quickly: ≥ few am/sec so signal above 1 Hz (careful with bk of envelope!)
  - have chopping secondary with a chop throw ≥ FOV
  - have a tilting mirror at an image of the primary and oversized intervening optics (e.g. gregorian with tilting flat tertiary, cassegrain with tilting flat quarternary)

Scan Strategies

- For wide-field mapping, scan strategy influences
  - how susceptible one is to sky noise
  - how efficient one's observing time is (i.e., time in turnarounds)
  - how cross-linked one's final maps are, and thus how well striping can be removed
- SHARCII has had success with Lissajous and box-scan modes
  - NEPs more demanding at longer wavelengths (few x 10^{-16} vs. few x 10^{-17})
- It is important to understand what requirements are put on the telescope by the possible scan strategies/observing modes:
  - how fast can one scan and maintain pointing?
  - how fast can one scan without exciting mechanical vibration?
  - how far can one chop the secondary or tilt a scanning mirror while maintaining good image quality and low spillover?