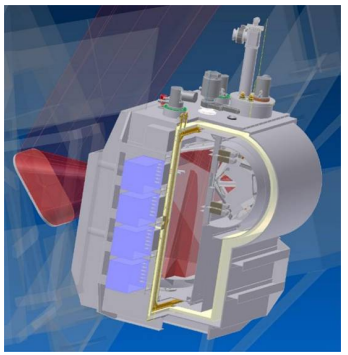
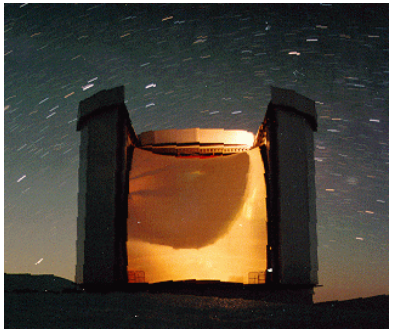
SCUBA-2 mapping

Andy Gibb

SCUBA-2 software developer
University of British Columbia





SCUBA-2 mapping

- SCUBA-2 recap
- Mapping the sky
  - Areal coverage
  - Astrometry
  - Atmospheric and instrumental effects
- SCUBA-2 mapping
  - Small maps: Stare and DREAM
  - Large maps: Scan (Pong)

SCUBA-2 recap

- 15-m JCMT (8 to 15 arcsec beam)
- Simultaneous 850 and 450 μm observation
- 5120 pixels in 4 sub-arrays at each wavelength
- Orientation fixed in Nasmyth (⇒ sky rotation)
- Fully-sampled at 850 μm (but not at 450 μm)
- Field of view: 8 arcmin diameter
- Data recorded at 200 Hz (= 5 ms)
- Total power ⇒ NO chopping!

Mapping the sky

- Main issues:
  - Areal coverage
  - Astrometry
  - Atmospheric effects
  - Instrumental effects

$\Rightarrow$ Mapping with SCUBA-2 unlike most other instruments

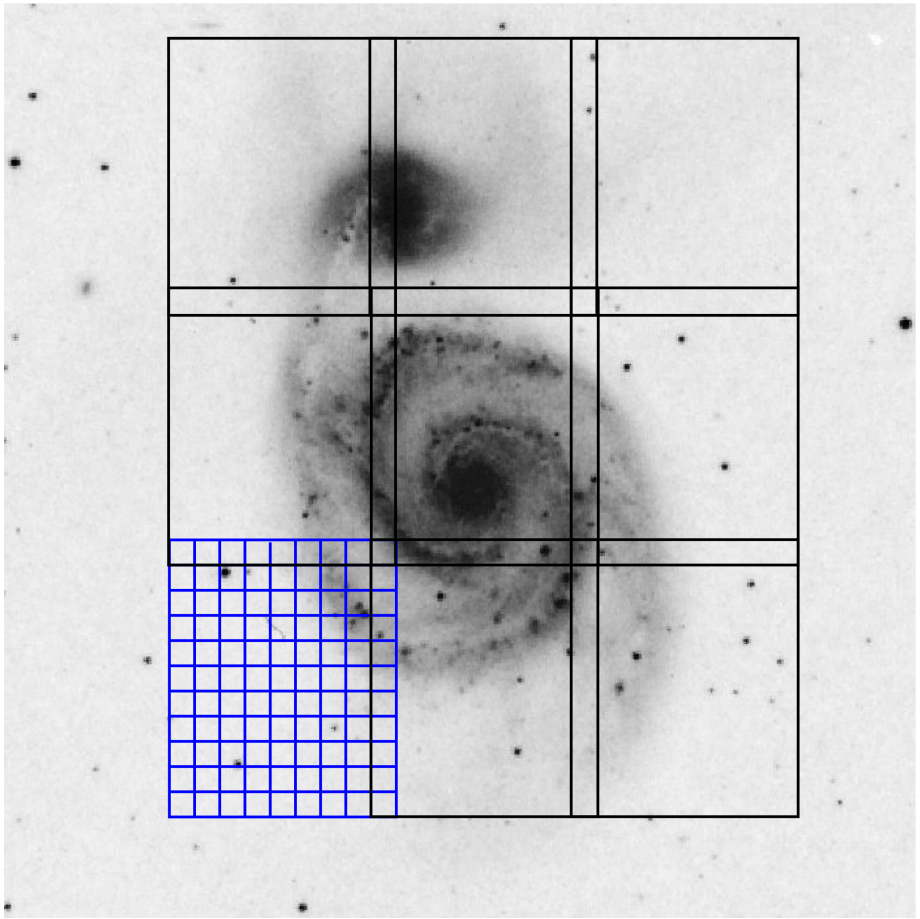
Mapping the sky — areal coverage

- Instantaneous sky = 20626 sq deg (to horizon)
- 10 arcmin FoV $\Rightarrow$ 750,000 pointings (68 years at 1 min per point)!
- Solution:
  - Big detectors (optical/near-IR)
  - Be content with small maps (radio/mm/submm)
  - Alternative radio: `small´ telescopes

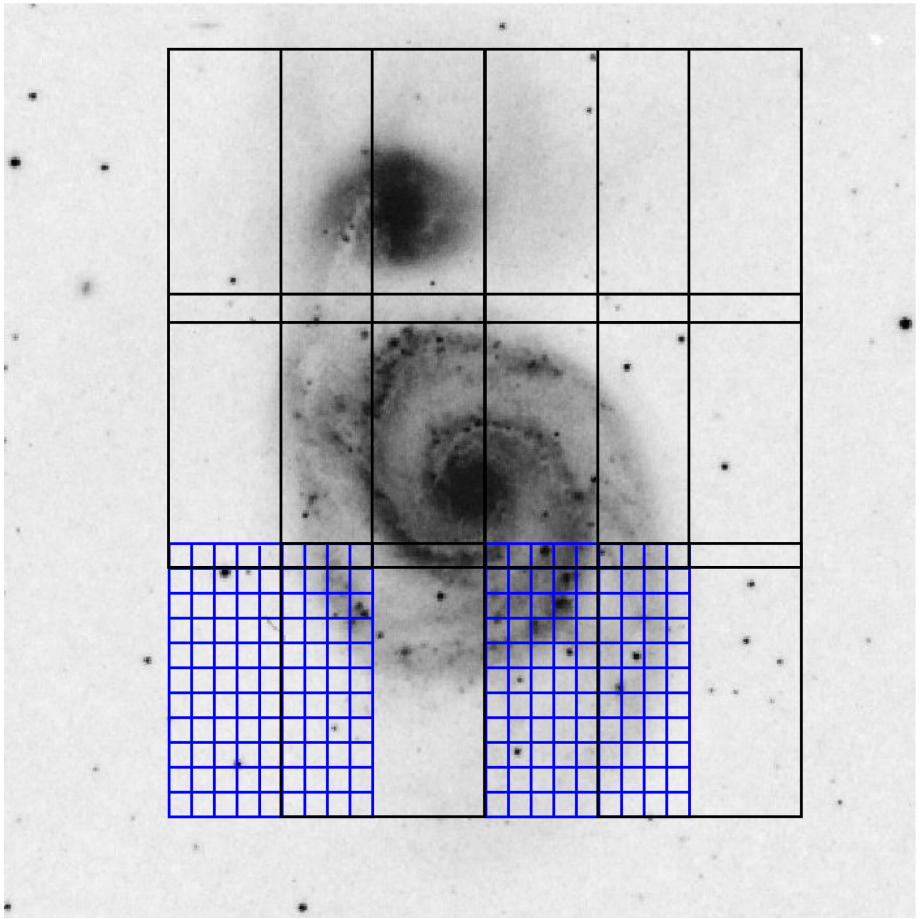
Mapping the sky — areal coverage

- Mosaicking
  - Individual pointings to cover area >> detector
  - Single detector
- Dither & drizzle
  - Big detector = $\sum$ smaller detectors + gaps
  - Fill in gaps, deal with undersampling of PSF
  - Instrumental effects (relative pixel responses)

Mapping the sky — areal coverage



Classical mosaic/grid map



Dither pattern to fill in gap

Mapping the sky — astrometry

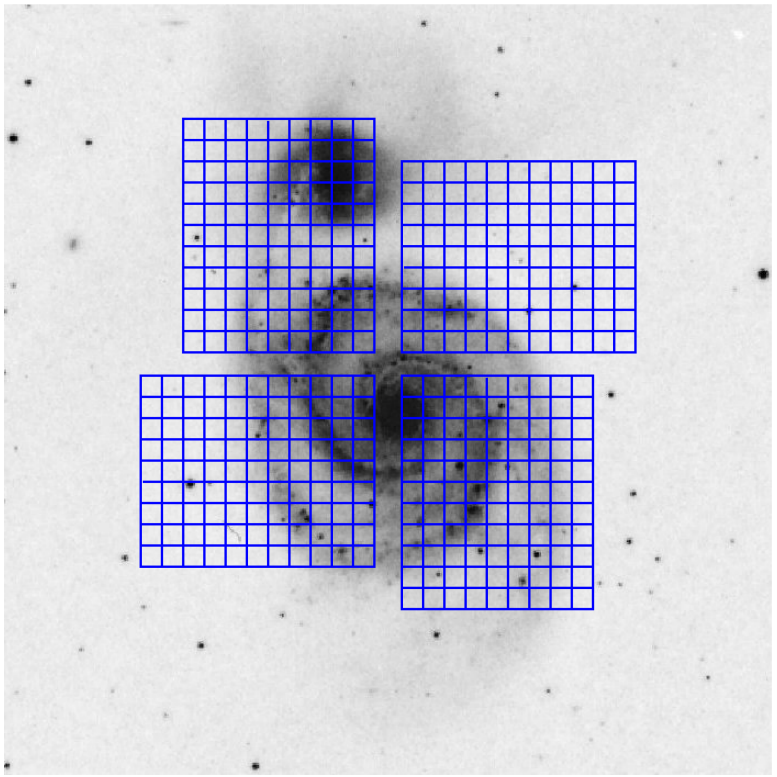
- Two cases:
  1. Telescope pointing accuracy > resolution
     - Use objects of known position every frame
     - Optical/IR
  2. Telescope pointing accuracy < resolution
     - Regular calibration with objects of known position
     - Radio/mm/submm
     - Need accurate pointing model (blind)

Mapping the sky — atmospheric and instrumental effects

- Submillimetre atmosphere is bright
  - Up to 100,000x brighter than source
- Submillimetre atmosphere is variable
  - Variations 100x brighter than source
  - Timescale < typical exposure (integration) time
  - Sky is correlated across array (allows subtraction)
- Detector responses vary with input signal
  - Also vary with time (~typical exposure time)

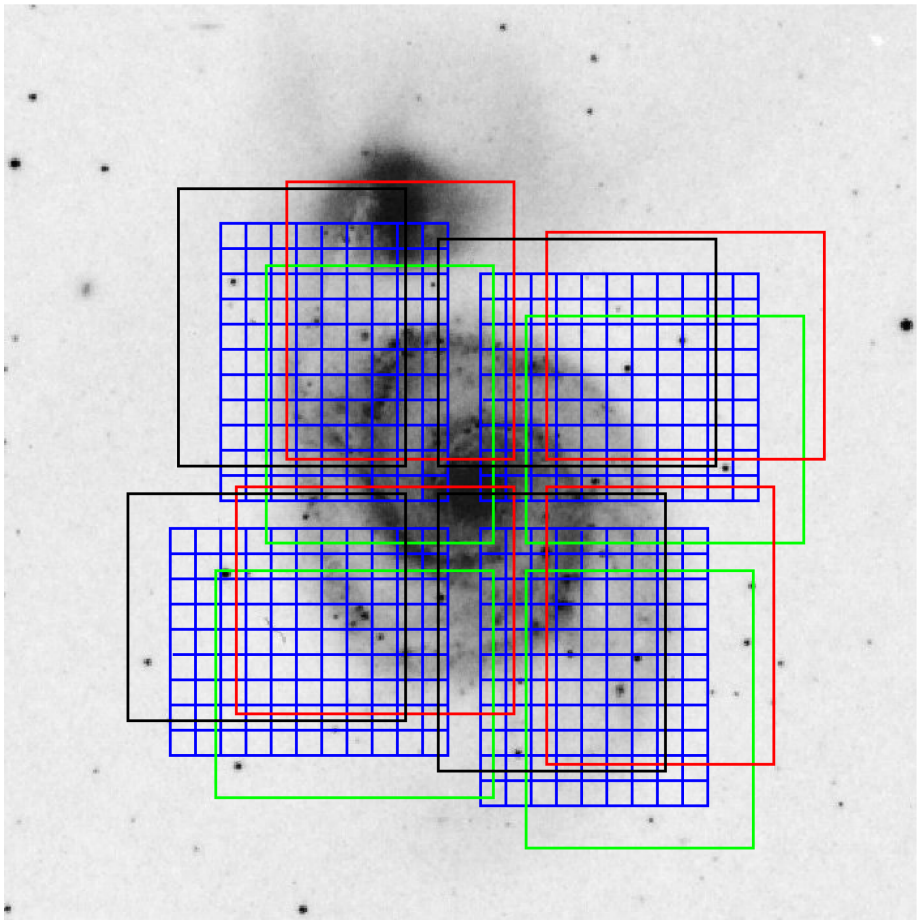
SCUBA-2 detector layout

- Four sub-arrays at each wavelength
- Sub-array = 40x32 pixels
- Pixel spacing = 6.3 arcsec
- 4 pixel gap between sub-arrays



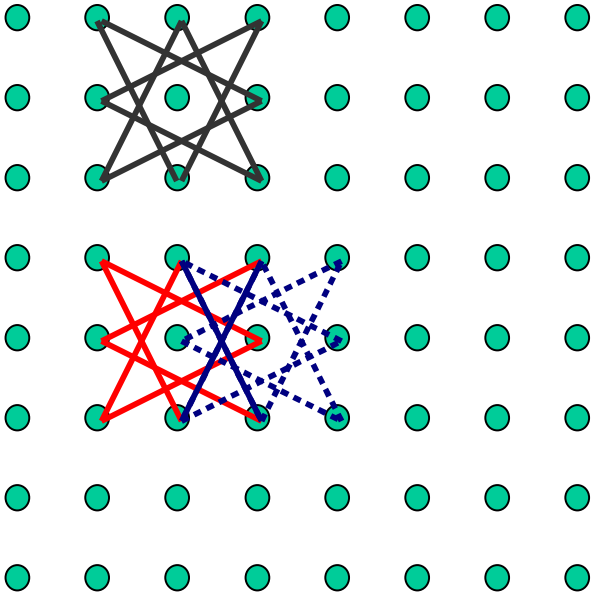
SCUBA-2 mapping: Stare

- Integrate and average every 1 to 3 sec (sky rotation)
- Need to fill in gaps, fully sample 450 μm
- Microstep: offset by several (+ ½) pixels
- Need stable detectors



SCUBA-2 mapping: DREAM

- Dutch REal-time Acquisition Mode
- Move secondary mirror $\rightarrow$ mini-map for each bolometer
- Mini-maps overlap
- Redundancy



SCUBA-2 mapping: DREAM

- Bolometers see same patch of sky
- Solve for relative responses
- Produce image every 1 to 3 sec
- Microstep to fill in gaps, fully sample 450 μm
- Remember: use Stare and DREAM if source size < array size (sky subtraction removes larger scales)

SCUBA-2 mapping: Scan

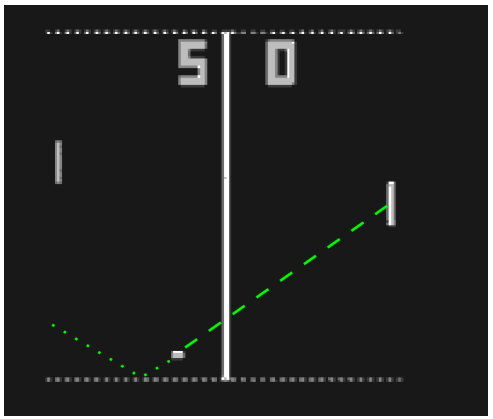
- Large maps: scan telescope across source (all total-power bolometer arrays do this)
- But longer elapsed time + total power means:
  - Atmospheric variations
  - Instrumental variations
- Multiple independent measurements, distinguish spatial vs temporal variations
- Pong (or box-scan): revisit points on different timescales

SCUBA-2 mapping: Scan

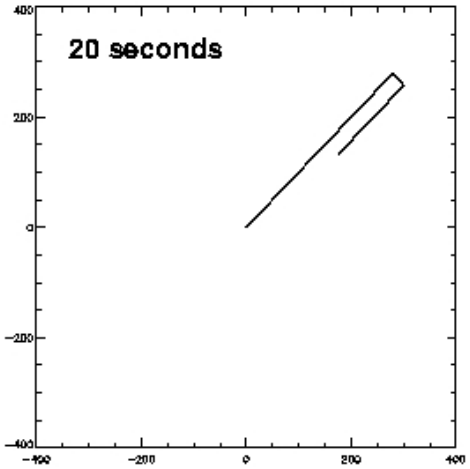
- Continuous readout at 200 Hz while scanning
- Scan speed up to 600 arcsec s^{-1} (ensure Nyquist sampling at 450 μm)
- Observe same sky position multiple times:
  - Multiple bolometers while scanning
  - Revisit with same bolometers
- Preserve structure on all scales
- Automatically fully samples 450 μm

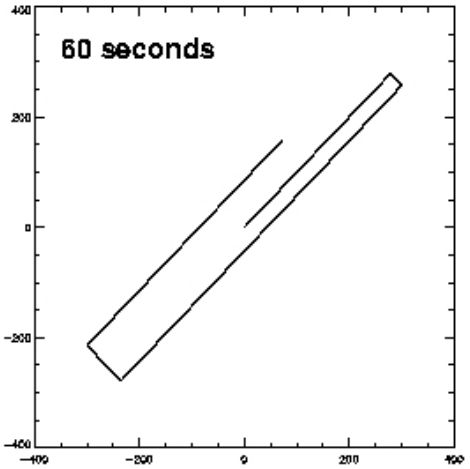
SCUBA-2 mapping: Pong

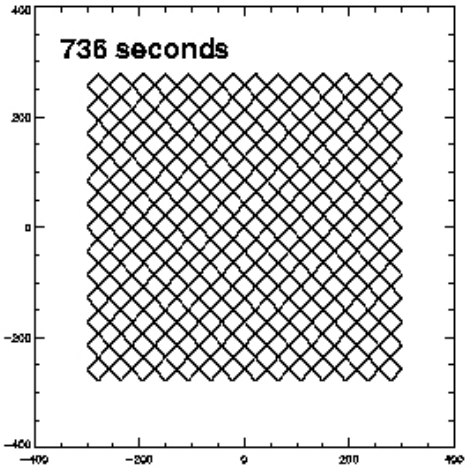
Pong: the (prehistoric) video game



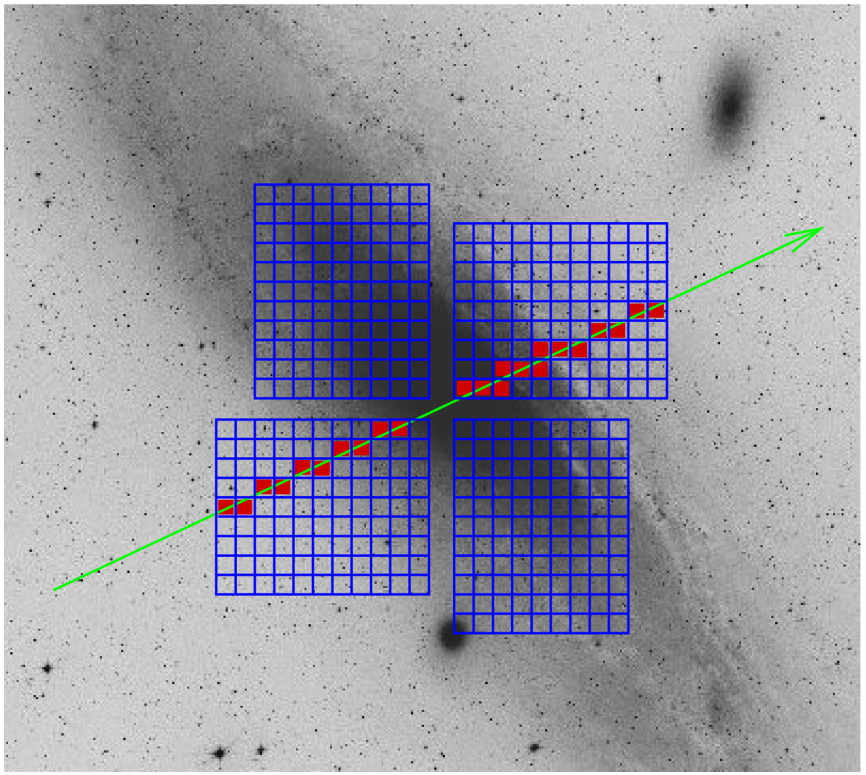
CSO box scan (SHARC-II)



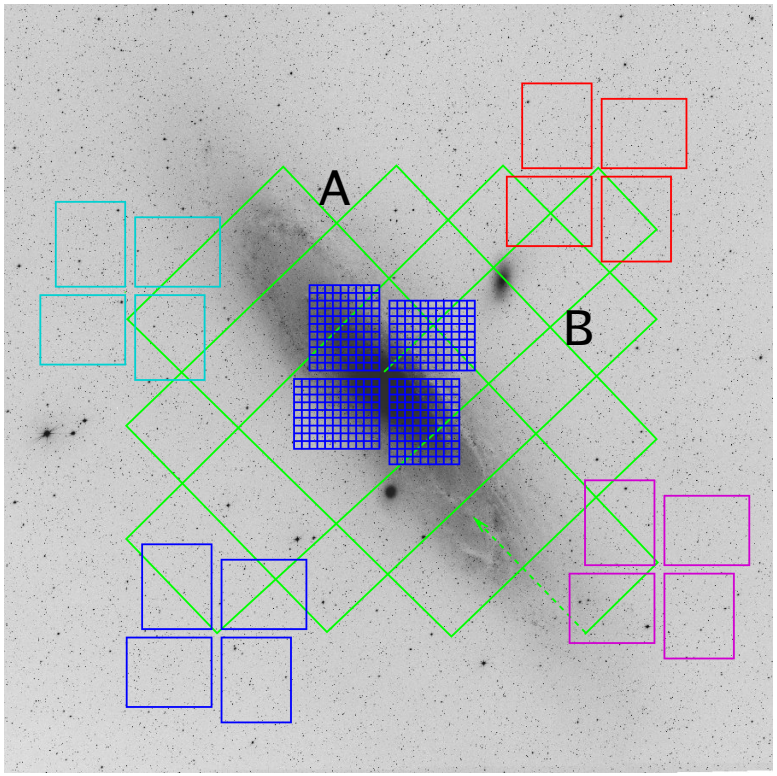




SCUBA-2 mapping: Pong

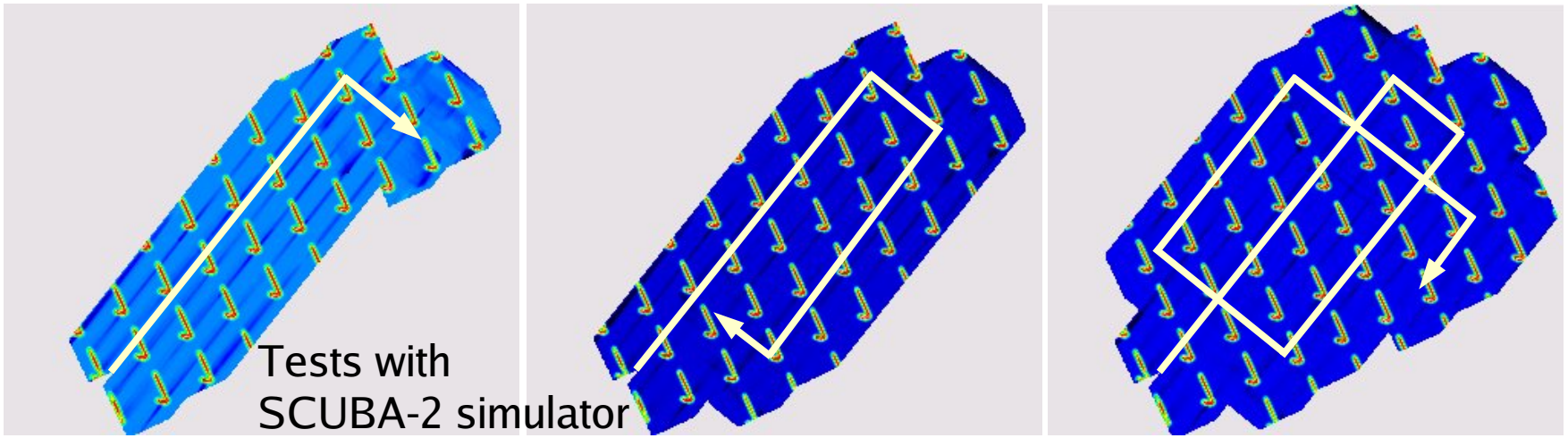


All detectors along scan direction contribute to single output pixel



Time to revisit point A different from that to revisit point B

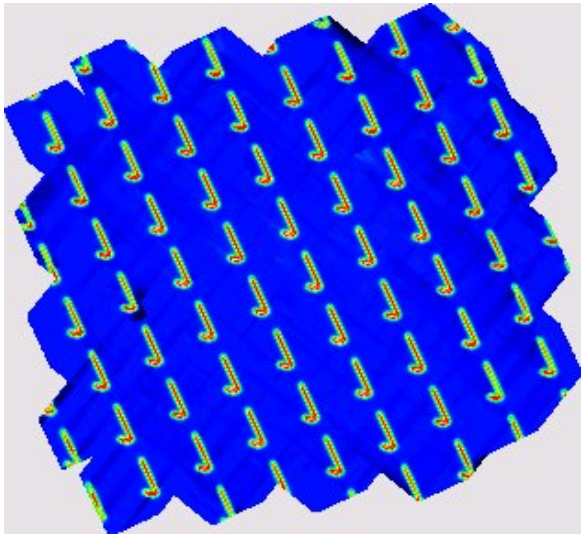
SCUBA-2 mapping: Pong

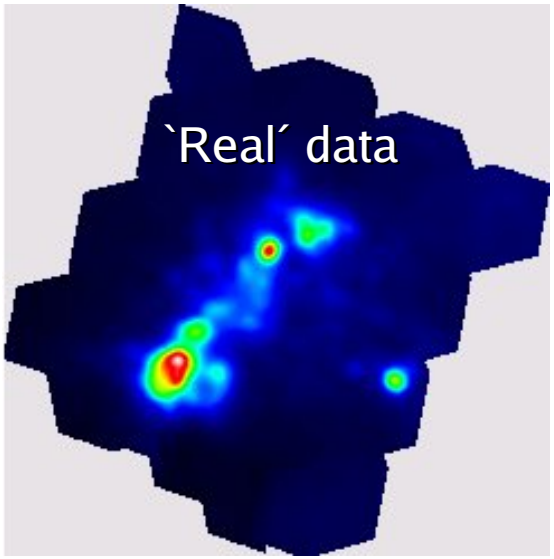


Tests with
SCUBA-2 simulator

Time →

Completed map: corrected for instrumental drift, extinction and atmosphere

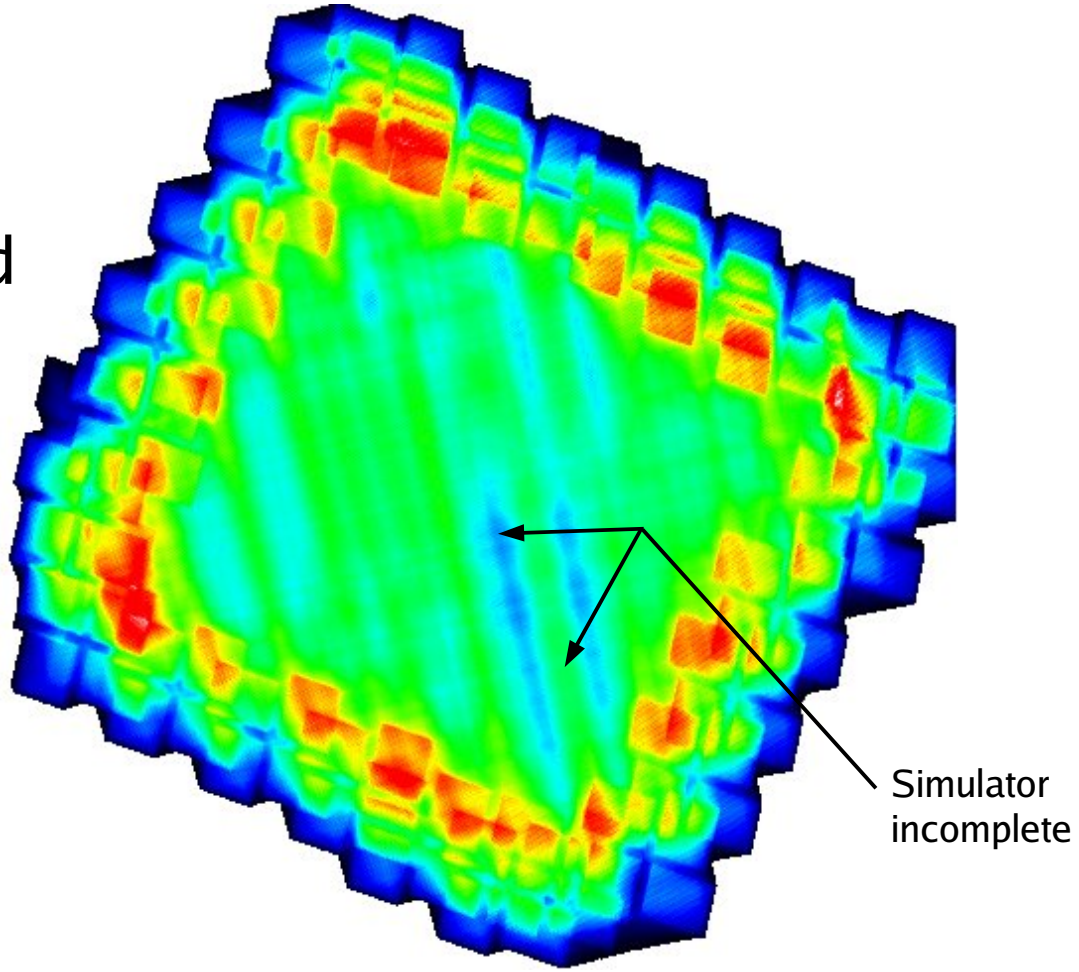




SCUBA-2 mapping: Pong

Hits-per-pixel:

- Uniform central area
- Higher near turn-around

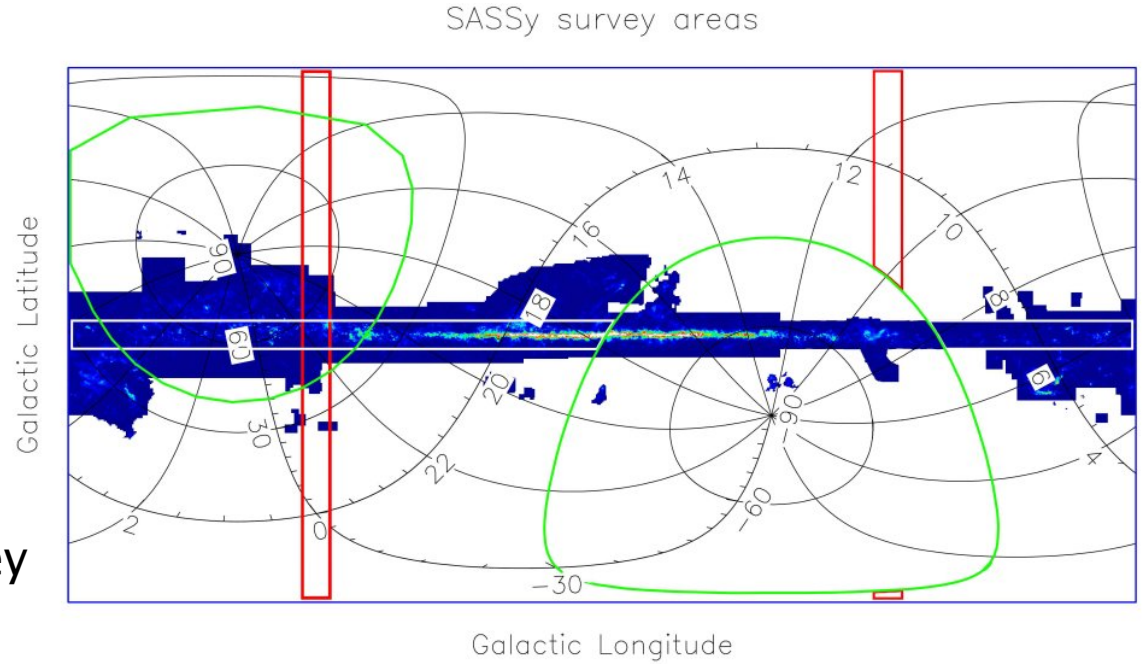


SCUBA-2 data processing: SMURF

- Data reduction: pipeline based
- Pipeline ⇒ no user intervention
- Aims:
  - Scientifically-meaningful image at end of night
  - User doesn't have to be an expert in submm data reduction
- SMURF: SubMillimetre User Reduction Facility

SCUBA-2 mapping: surveys

- Large FoV allows wide-field submm imaging for the first time (thousands of square degrees)
- See Russell Redman's talk on Legacy Surveys



SCUBA-2 `All Sky´ Survey (SASSy)

SCUBA-2 mapping: summary

- Small maps:
  - Stare — if detectors stable over minutes
  - DREAM — if detectors stable over seconds
- Large maps:
  - Pong — satisfies scan pattern requirements
- Key point:
  - Multiple observations of same sky position to disentangle atmospheric and instrumental effects

Software & mapping team

UBC:

- Andy Gibb: agg@phas.ubc.ca
- Ed Chapin: echapin@phas.ubc.ca
- Douglas Scott: dscott@phas.ubc.ca
- Jen Balfour: jbalfour@phas.ubc.ca

JAC:

- Tim Jenness: t.jenness@jach.hawaii.edu

ATC:

- Dennis Kelly: bdk@roe.ac.uk

Project websites

SCUBA-2 data reduction software (smurfware?)

http://scuba2.jach.hawaii.edu/

SCUBA-2 systems analysis and software

http://www.roe.ac.uk/ukatc/projects/scubatwo/documents/software/

SCUBA-2 project home page

http://www.roe.ac.uk/ukatc/projects/scubatwo/

JCMT home page

http://www.jach.hawaii.edu/JCMT/index.html