BLAST

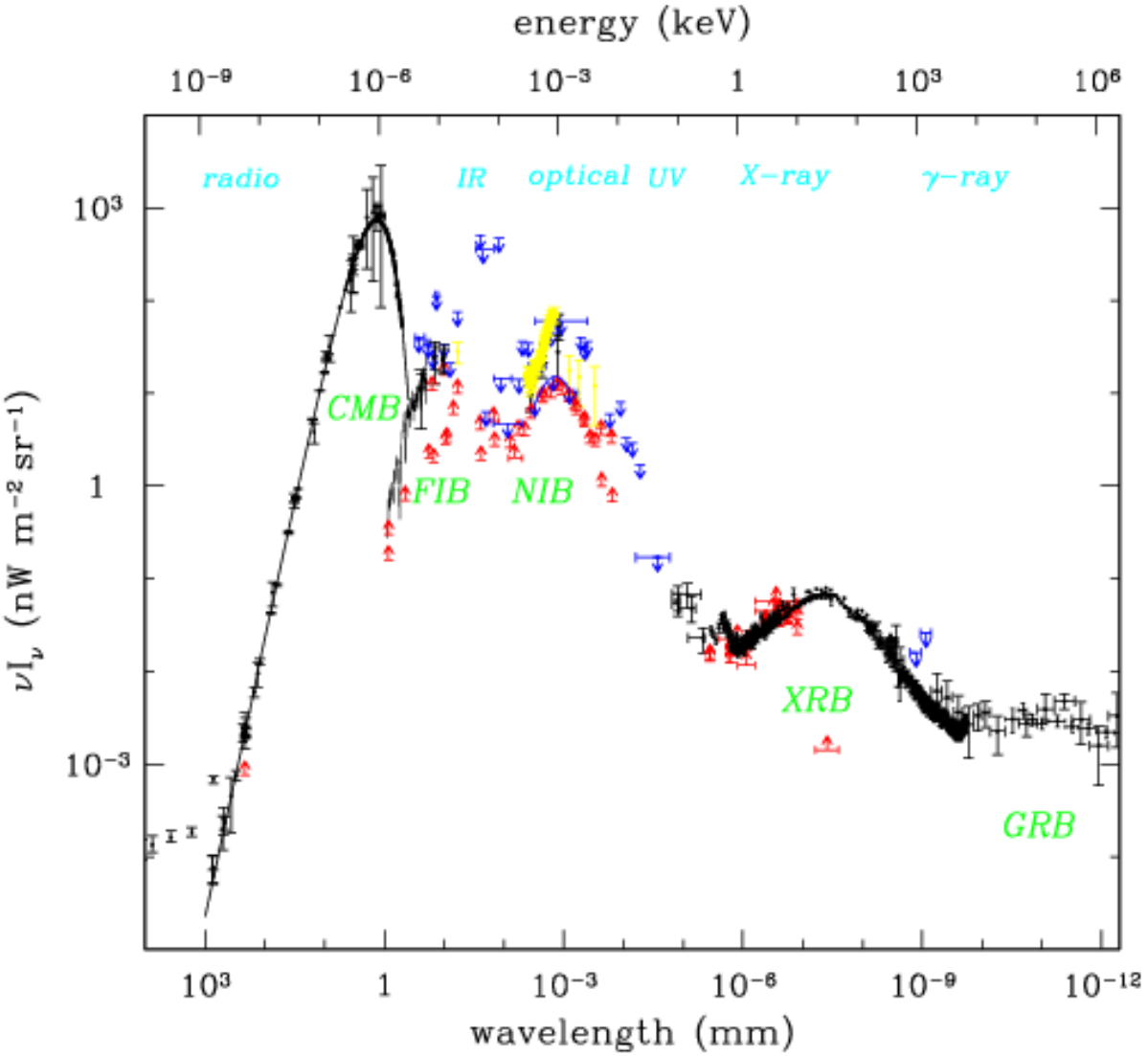
Balloon-borne Large-Aperture Sub-millimeter Telescope

Don Wiebe

(University of Toronto)

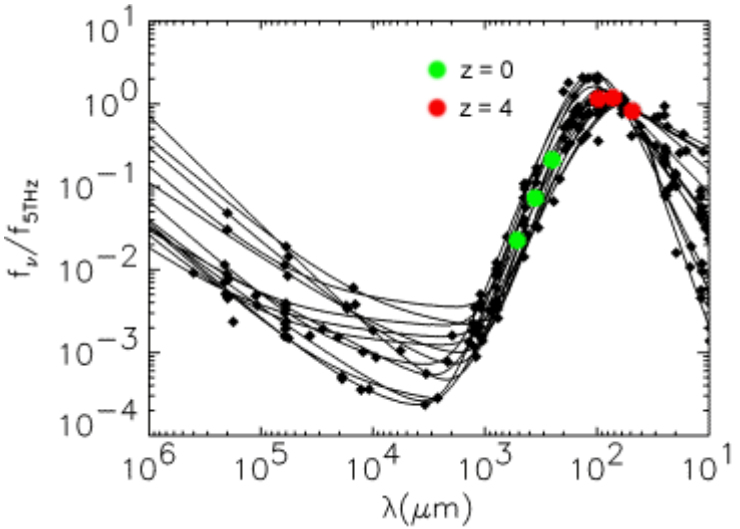
CMB Workshop – 28 March 2008

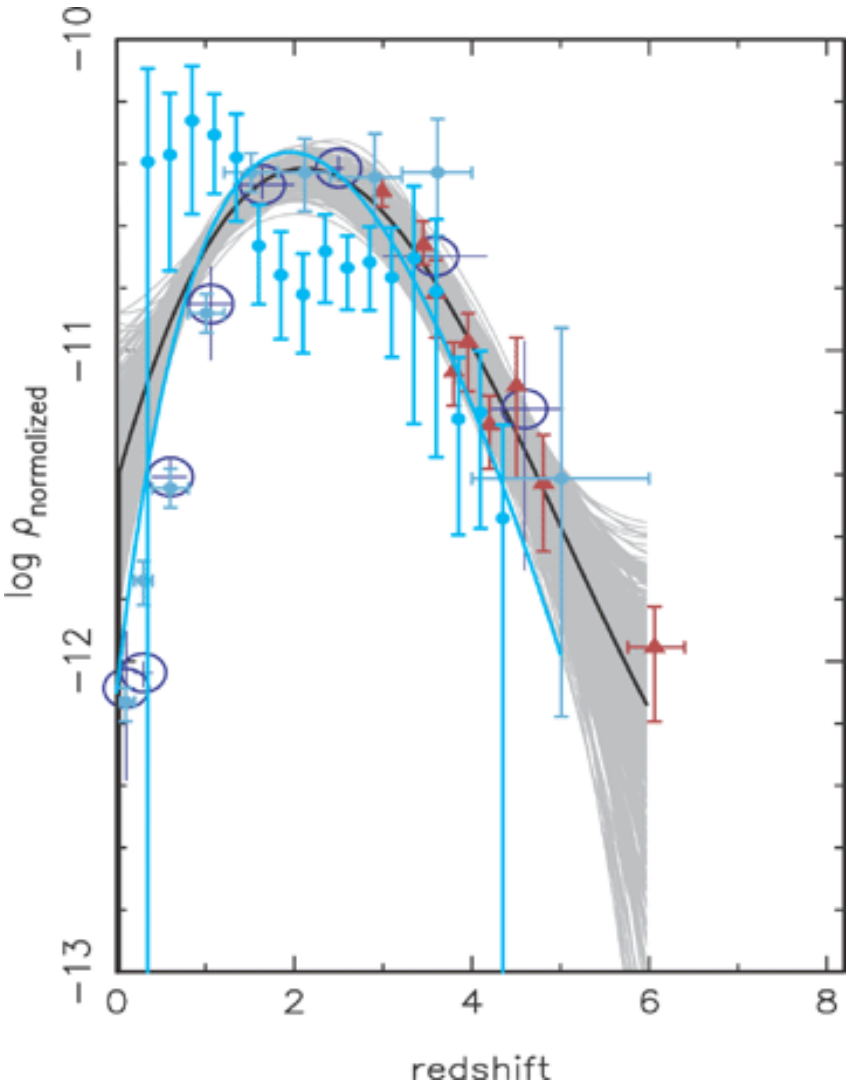
BLAST Science



Extragalactic Science

- Star formation in the high redshift Universe
- 1000s of high-z sources in two 10 deg^2 fields
- BLAST bands bracket the peak -> photo-z

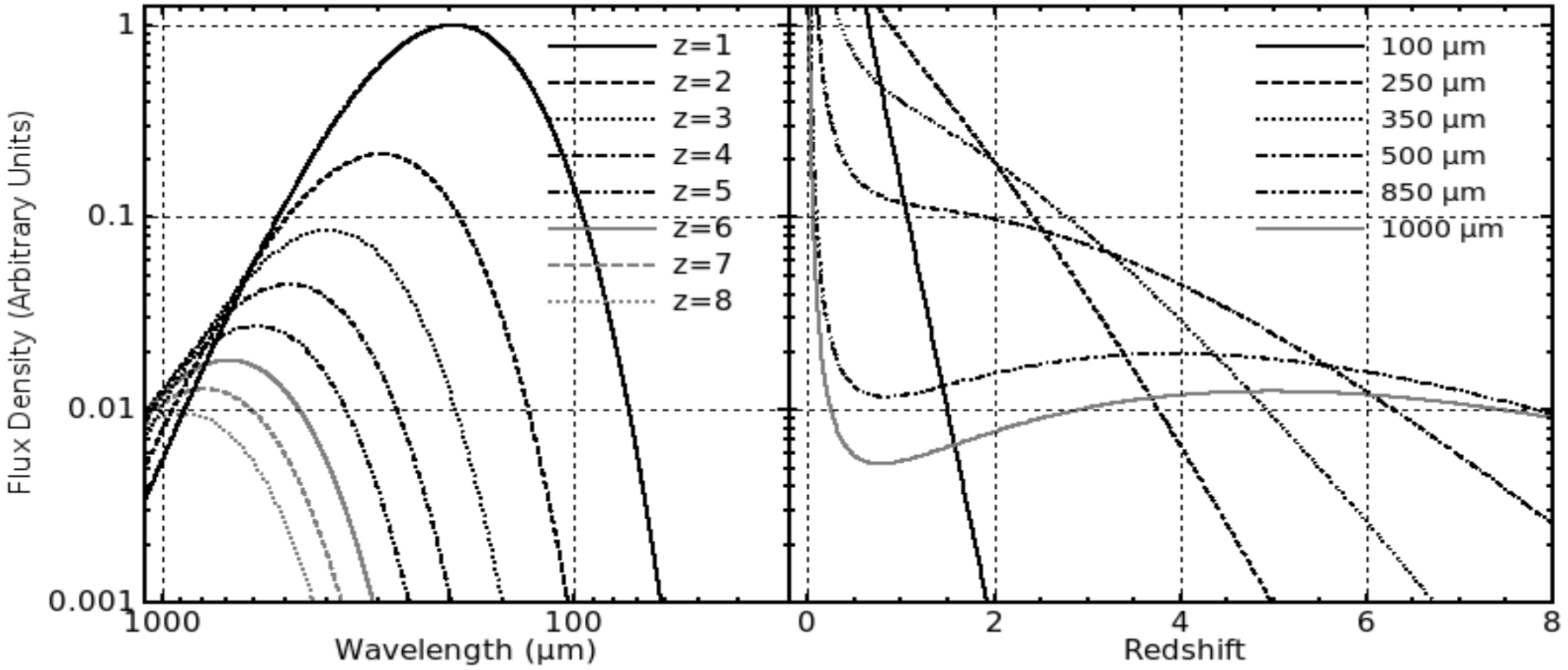




Wall, Pope & Scott 2008

K-Correction

- Extragalactic observations helped by negative K-correction
- Higher redshift object may be brighter



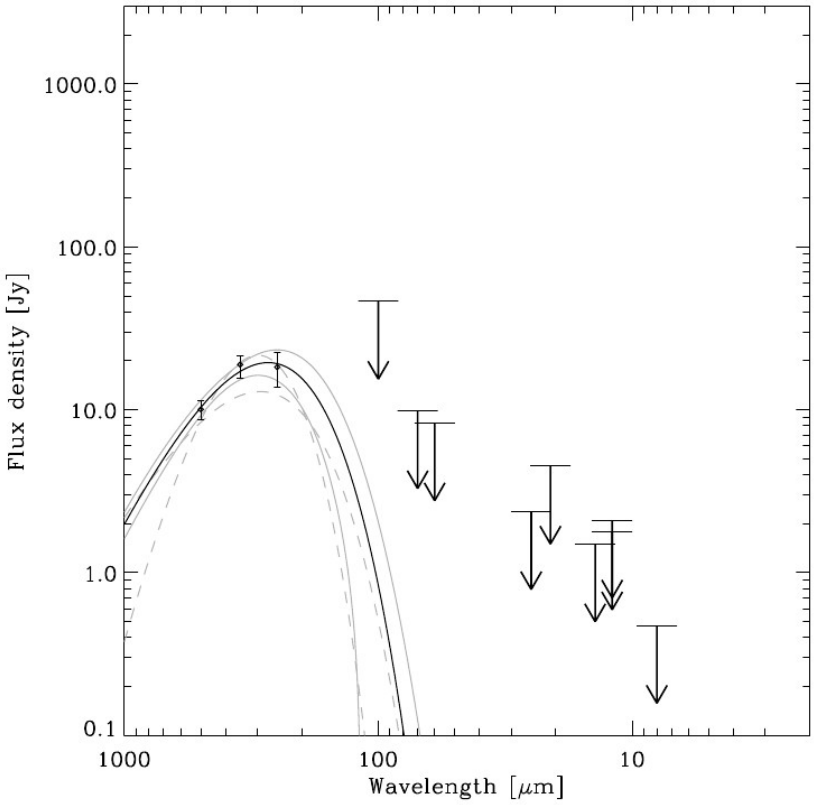
Galactic Science

- Detection of high-mass proto-stellar objects (HMPOs) in the Galaxy
- Probe the earliest stages of star formation

12 K source detected→ by BLAST

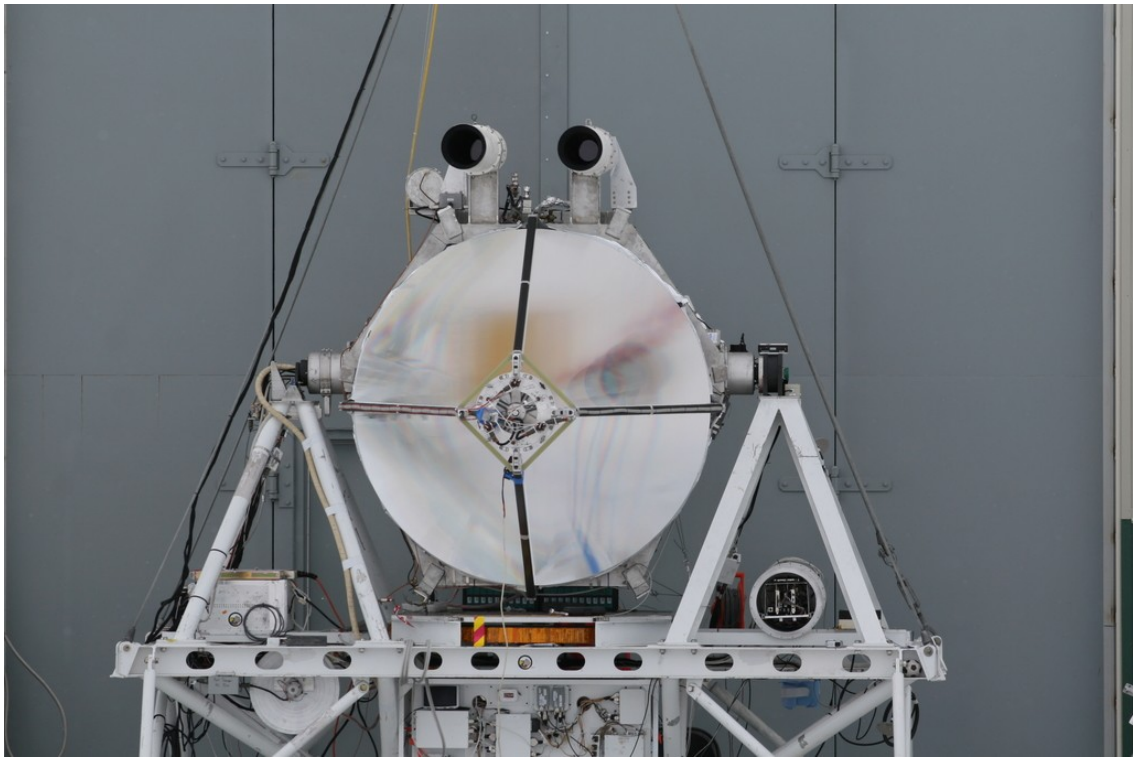
Chapin *et. al.* ApJ, in press (2008)

arXiv:0711.3461



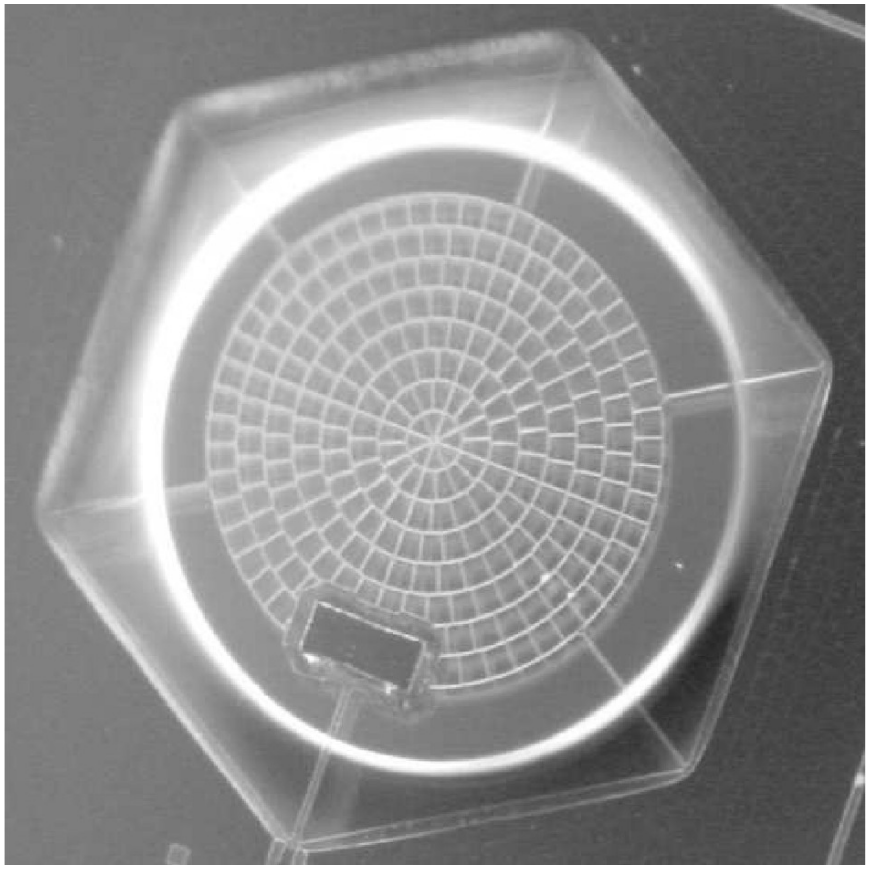
The BLAST Platform

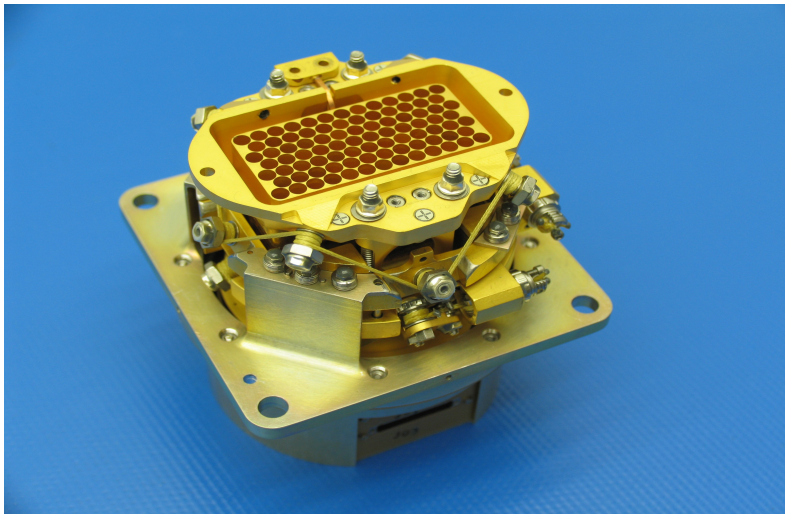
- 2 metre primary
- 43, 88, and 149 “spider-web” bolometers at 500μm, 350μm, 250μm
- Cryostat to cool detectors to 0.3 K
- Star cameras + gyroscope based pointing system
- Solar powered



Bolometers

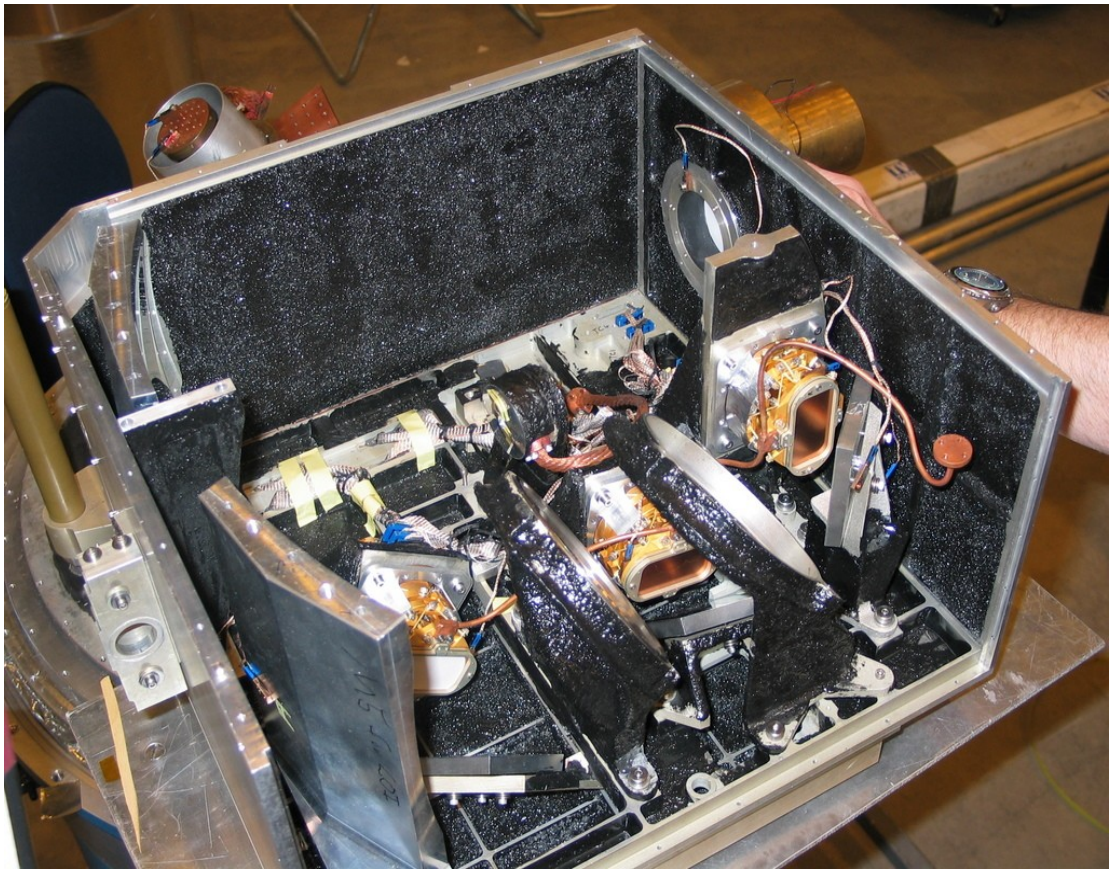
- 43, 88, 143 NTD bolometers in three arrays
- Horn fed



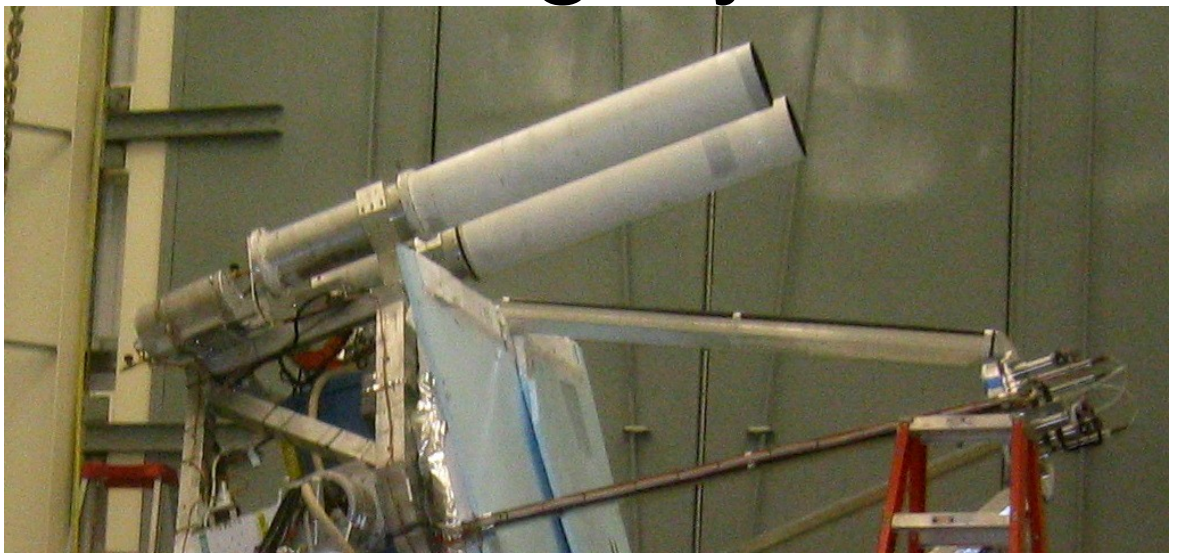


The Telescope

- 2 metre Cassegrain
- Movable secondary to correct for thermal defocussing
- Cold corrective optics
- Filters define bands

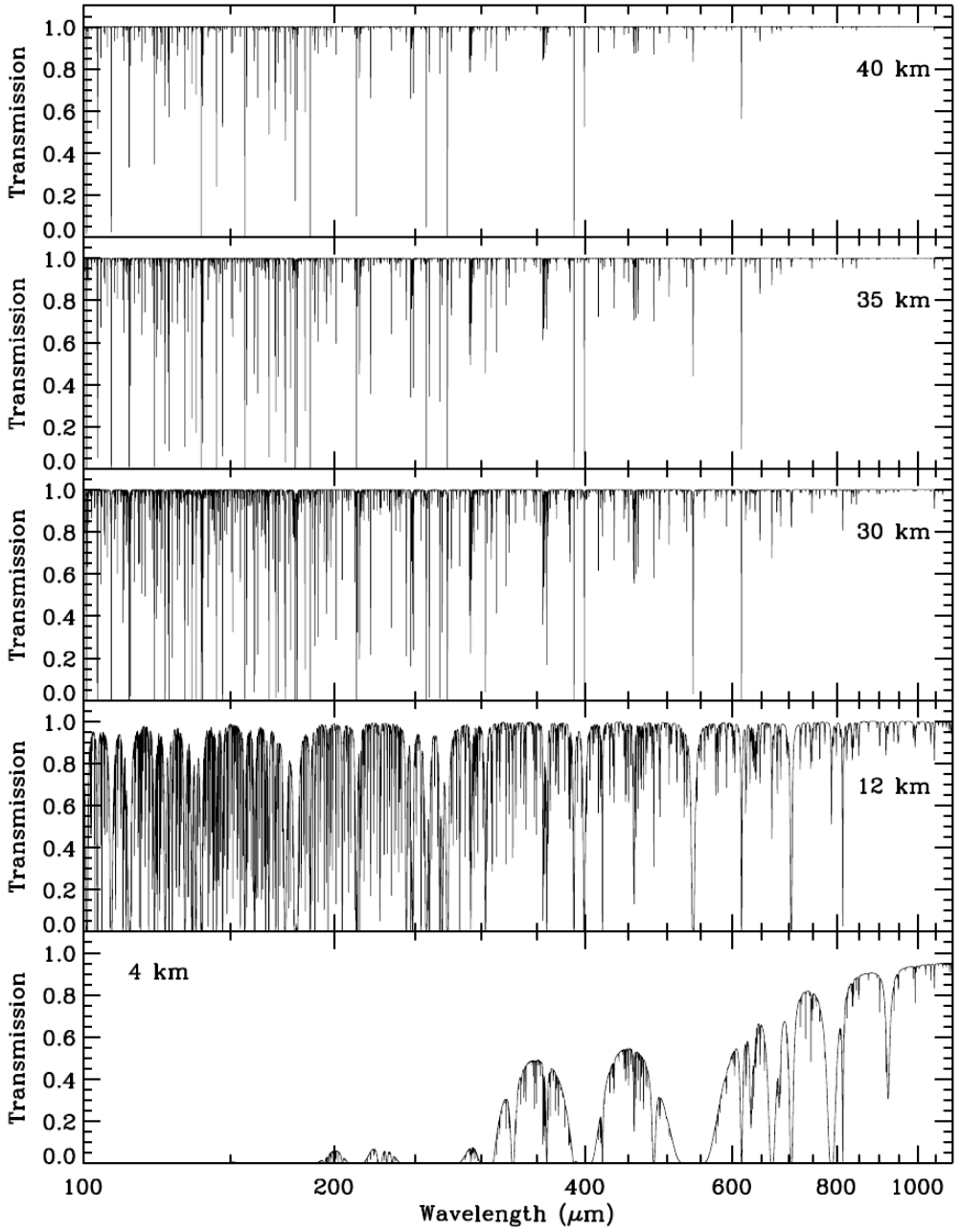


Pointing System



- Primary pointing accomplished by gyroscopes and star cameras.
  - Star cameras give absolute pointing @ ~1 Hz
  - Gyros give rate data @ 100 Hz
- Require < 1' pointing accuracy in-flight
- < 2” pointing reconstruction post flight

The Atmosphere is Opaque



← BLAST on a balloon

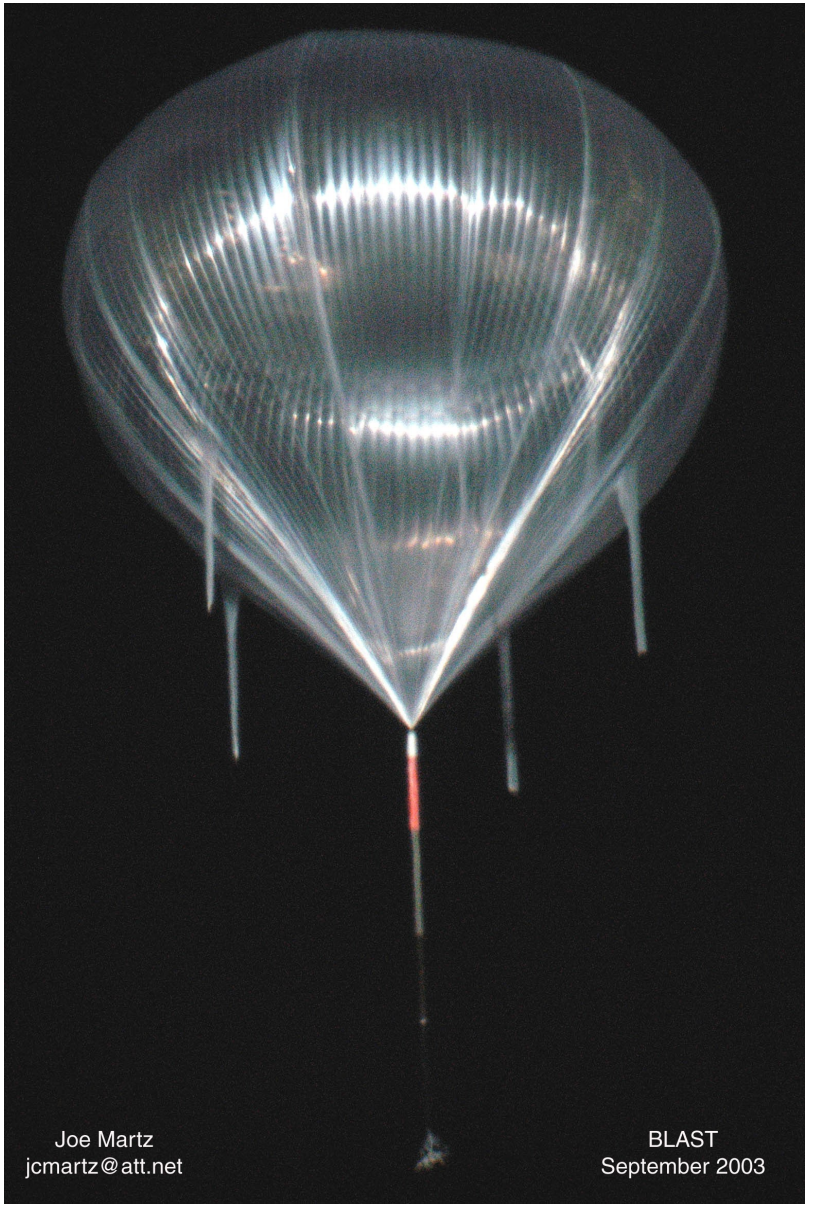
← SOFIA on an airplane

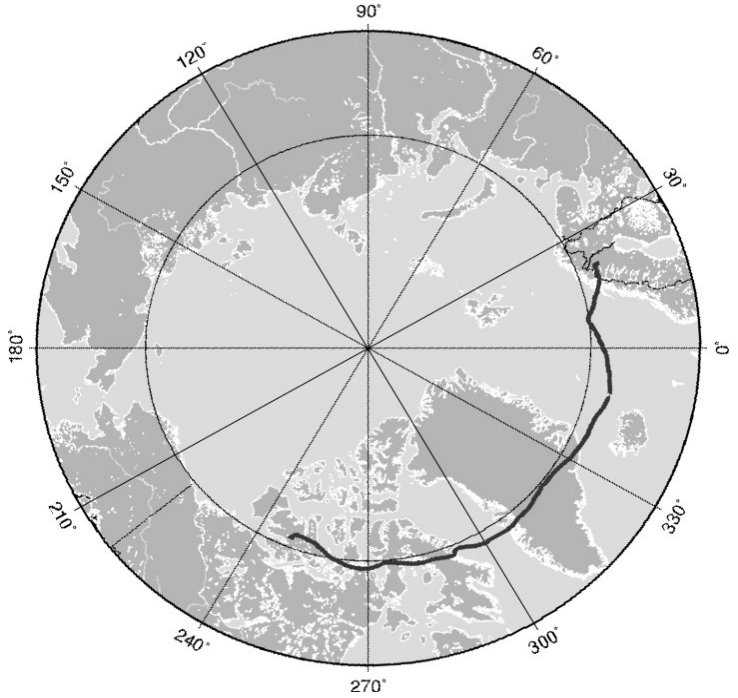
← SCUBA on a mountain

← SPIRE on *Herschel*

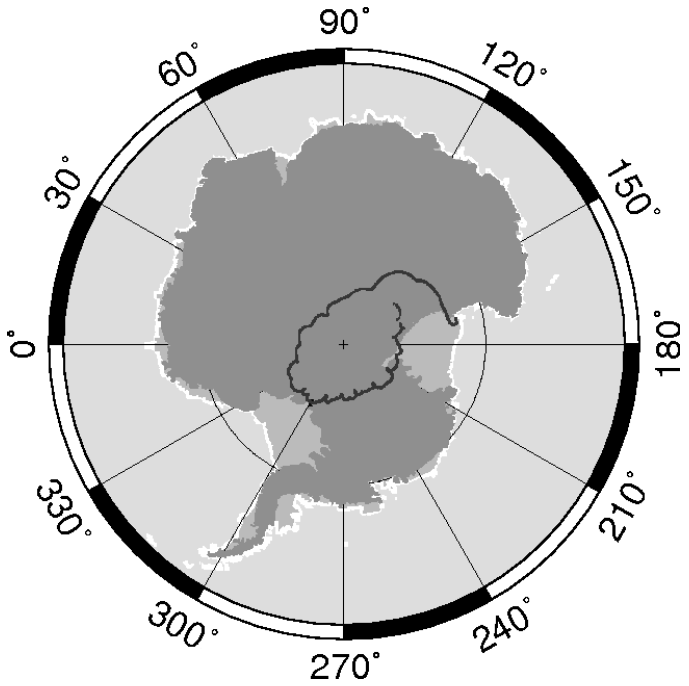
B is for Balloon

- ~38 km up on a 1,000,000 m^3 helium filled balloon





Flights

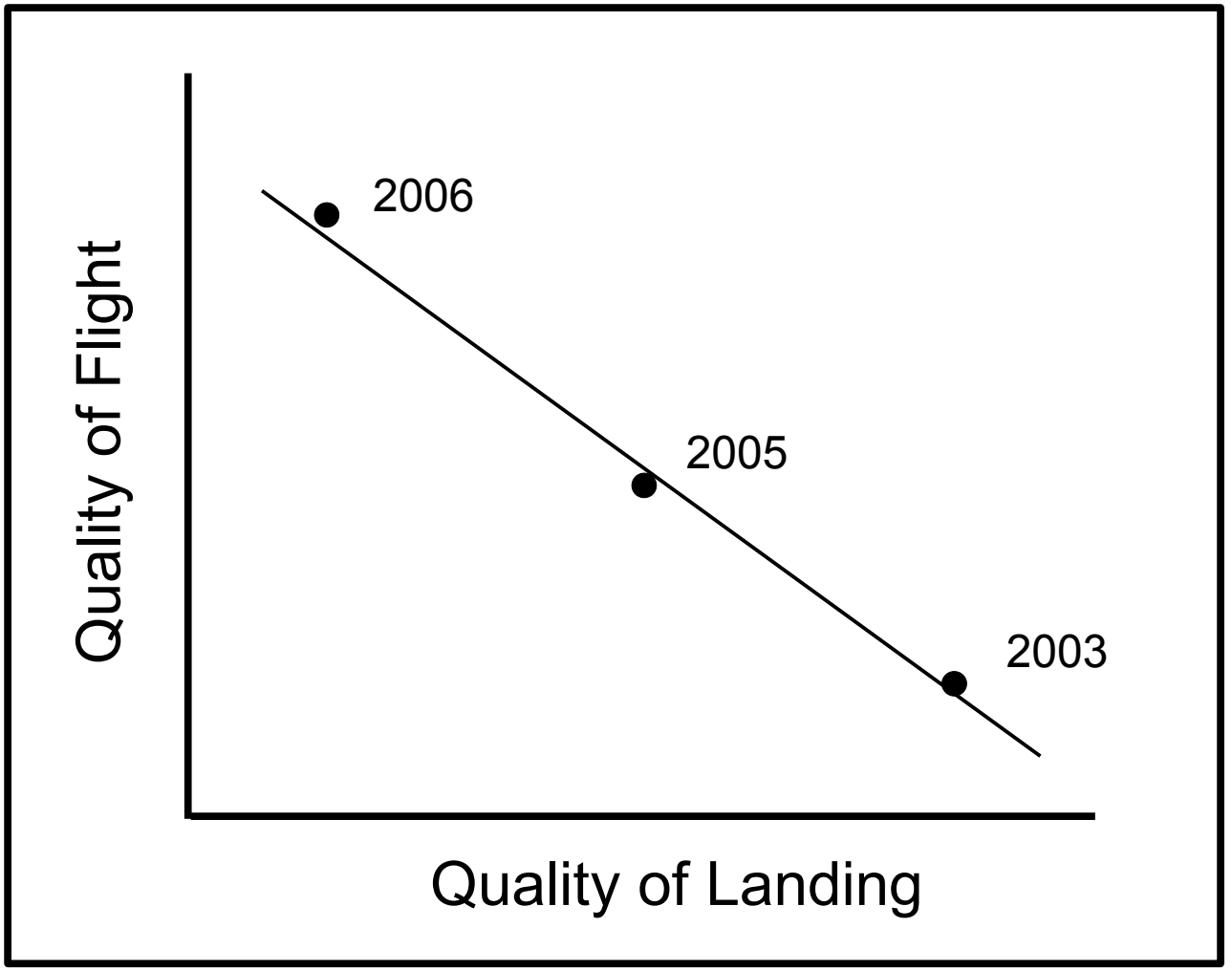


- June 2005 Sweden to Canada
- 100 hours of data
- Problem with optical system
- First results in press

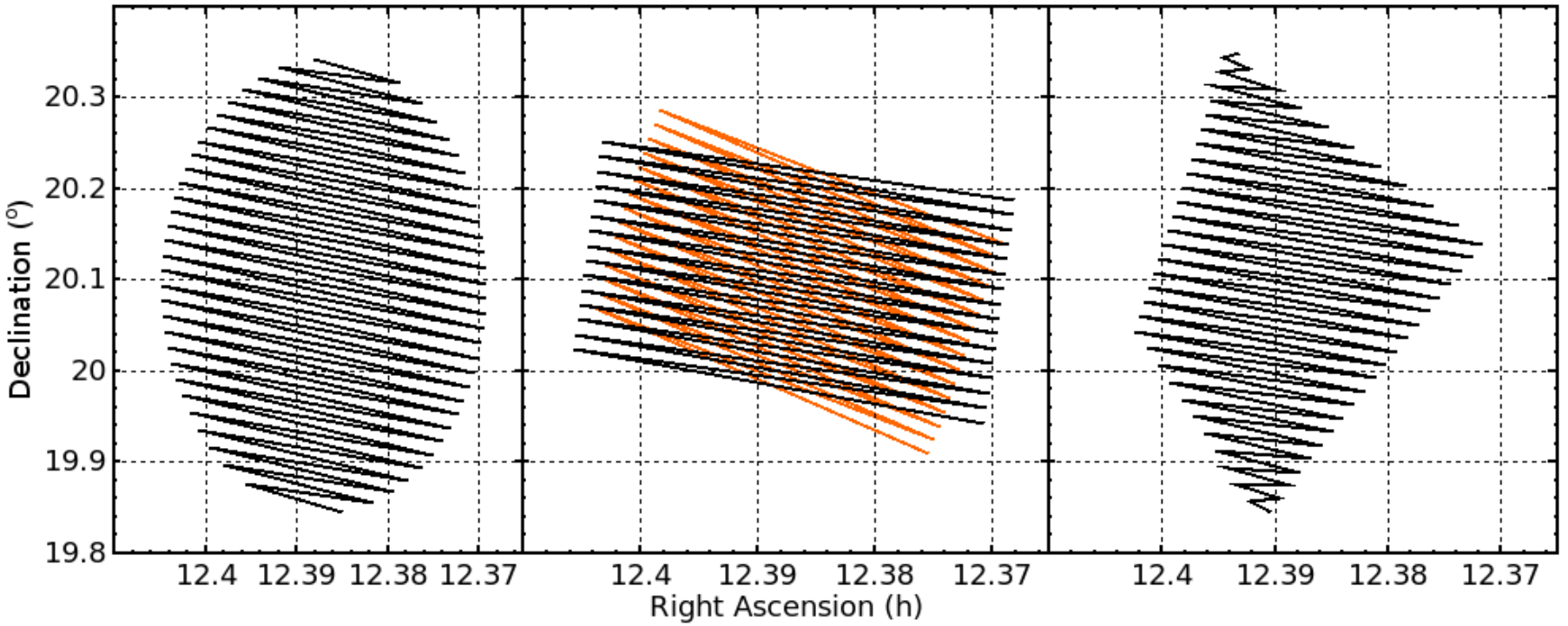
- December 2006 around Antarctica
- 250 hour of data
- Analysis underway

Landing can be Tricky

Correlation Analysis



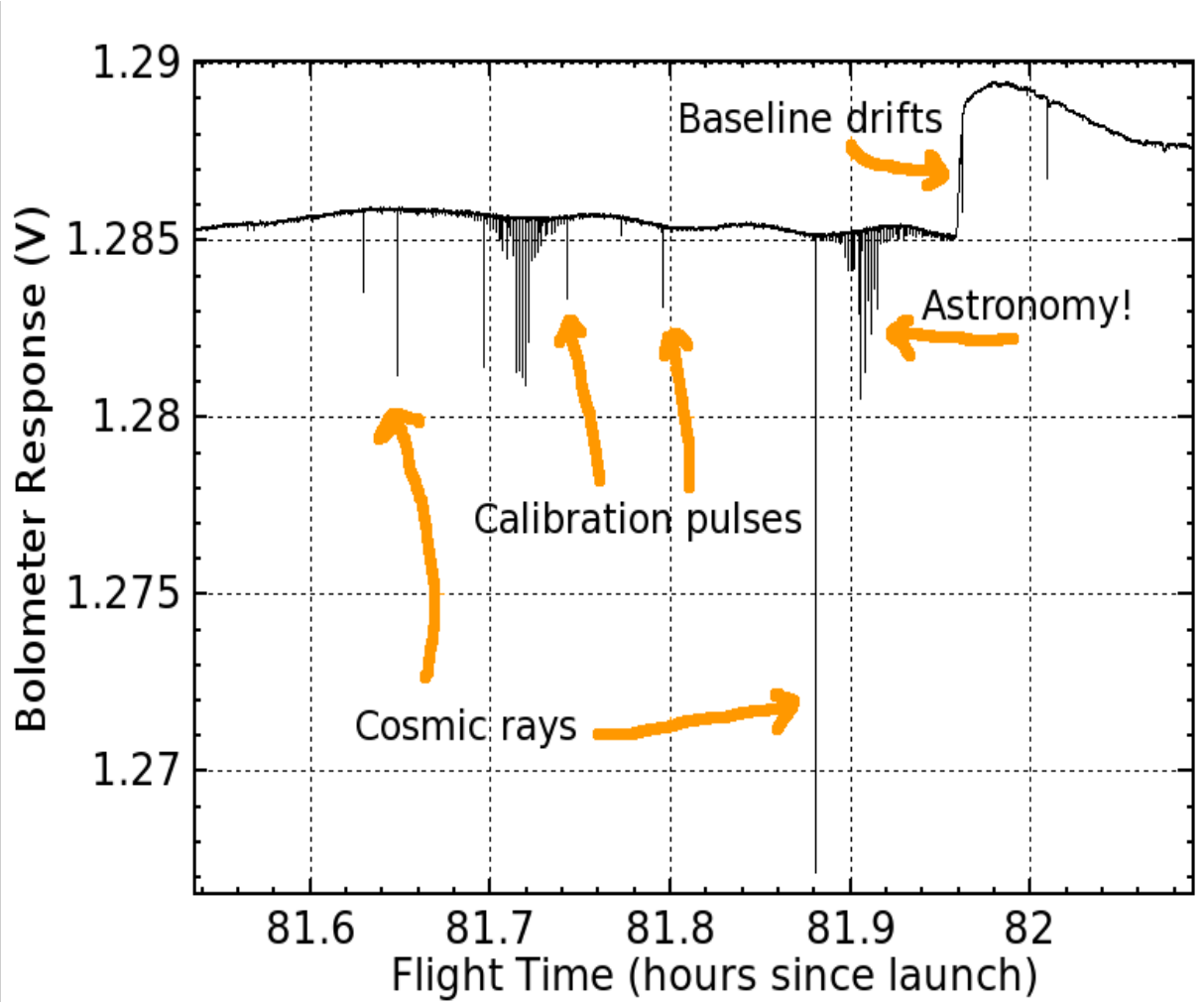
How BLAST Observes the Sky



- BLAST is a scanning experiment
  - Raster in azimuth @ 0.1°/s while stepping in elevation
- Star camera solutions on turarounds

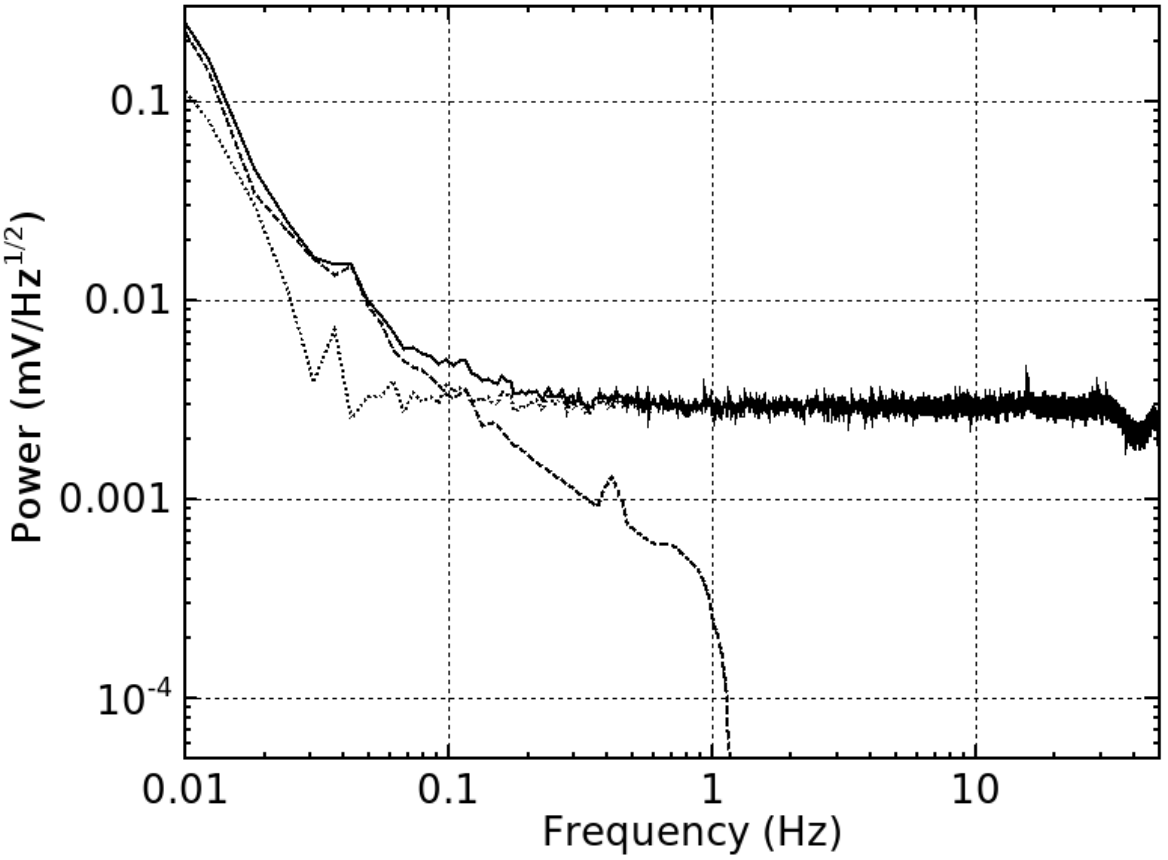
Very few people like bolometer traces

- Need to clean, and calibrate them



BLAST noise properties

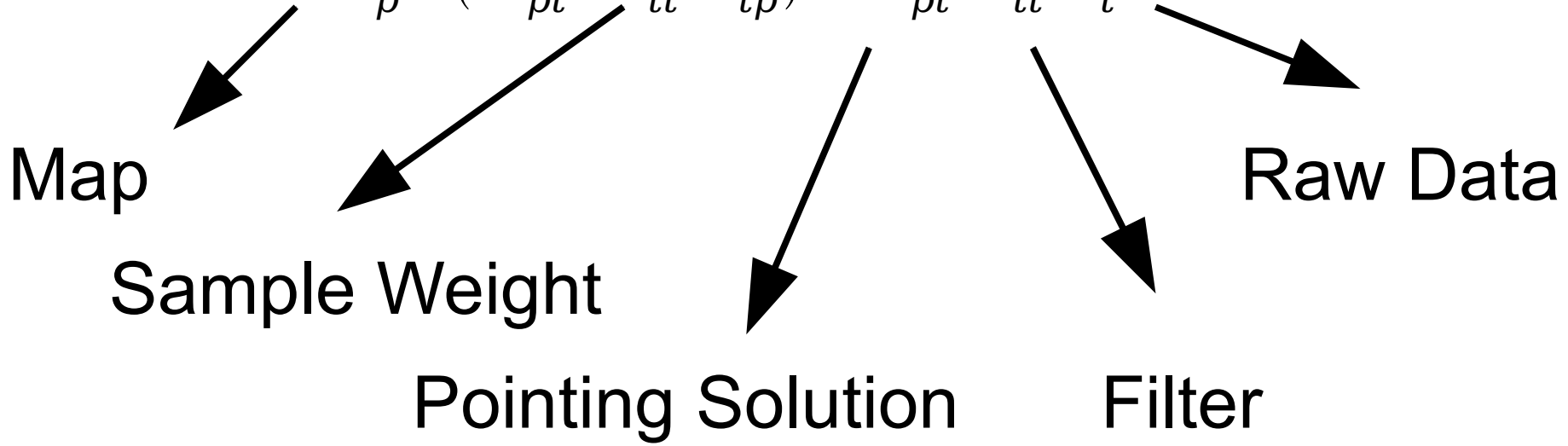
- Large 1/f component
- Highly correlated between detectors



Map Making

- Linear operation
- The map maker's equation:

$$\hat{\boldsymbol{\Delta}}_p = (P^T_{pt} W_{tt} P_{tp})^{-1} P^T_{pt} F_{tt} \boldsymbol{d}_t$$



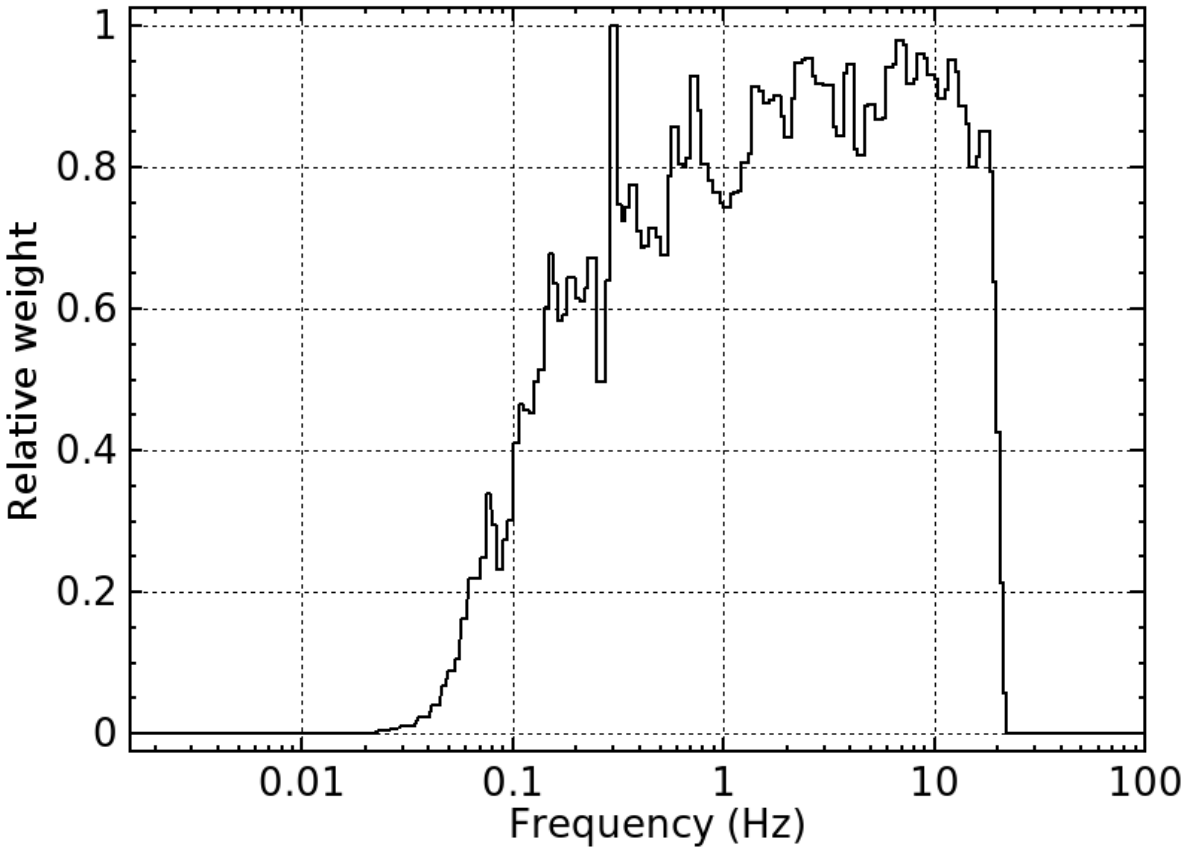
- Data is filtered, binned, and renormalised
- What is a good choice for F_{tt} and W_{tt}?

Map Making

- BLAST has three map makers:
  - **Optibin:** a modified naïve map maker
- Two maximum likelihood map makers:
  - **SANEPIC:** matrix solver
  - **Almagest:** iterative solver

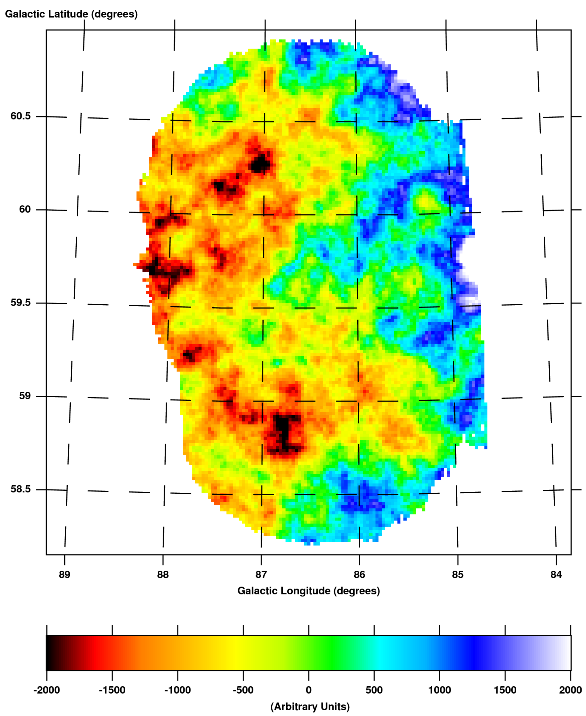
Limitations

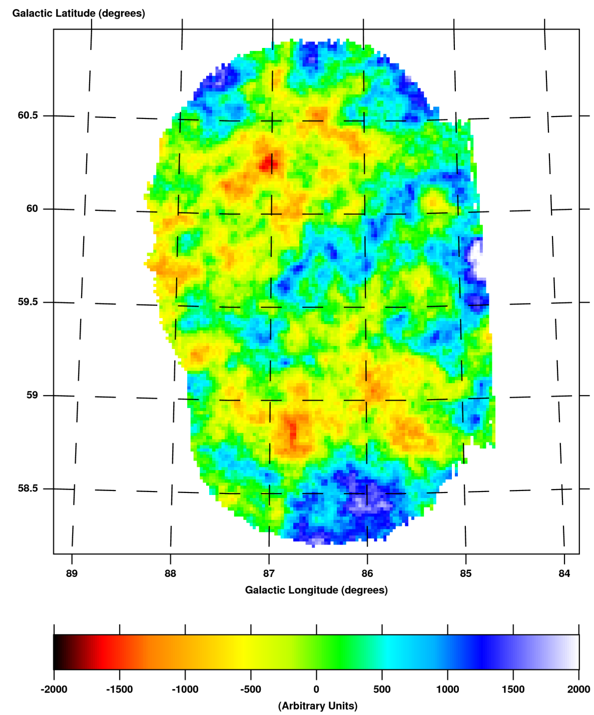
- The map makers can only do as well as the noisy data permits.
- Specifically:
  - No large scale modes

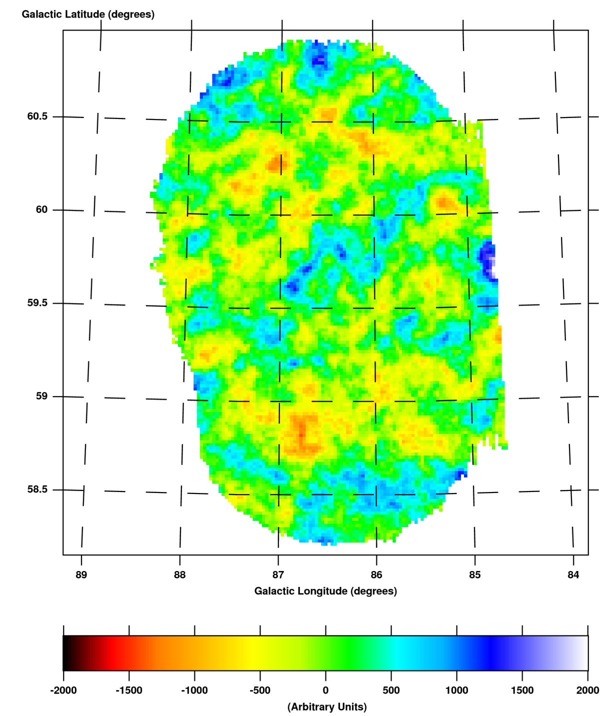


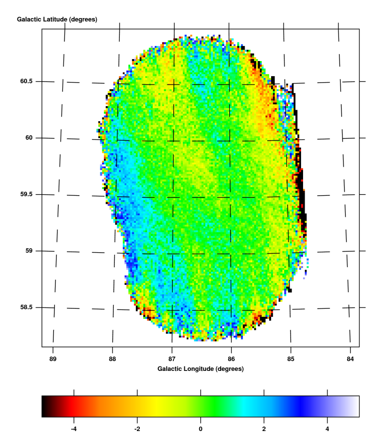
Simulations

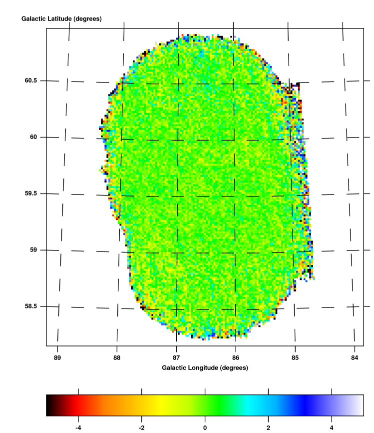
- Simulate Galactic Cirrus (k^{-3})





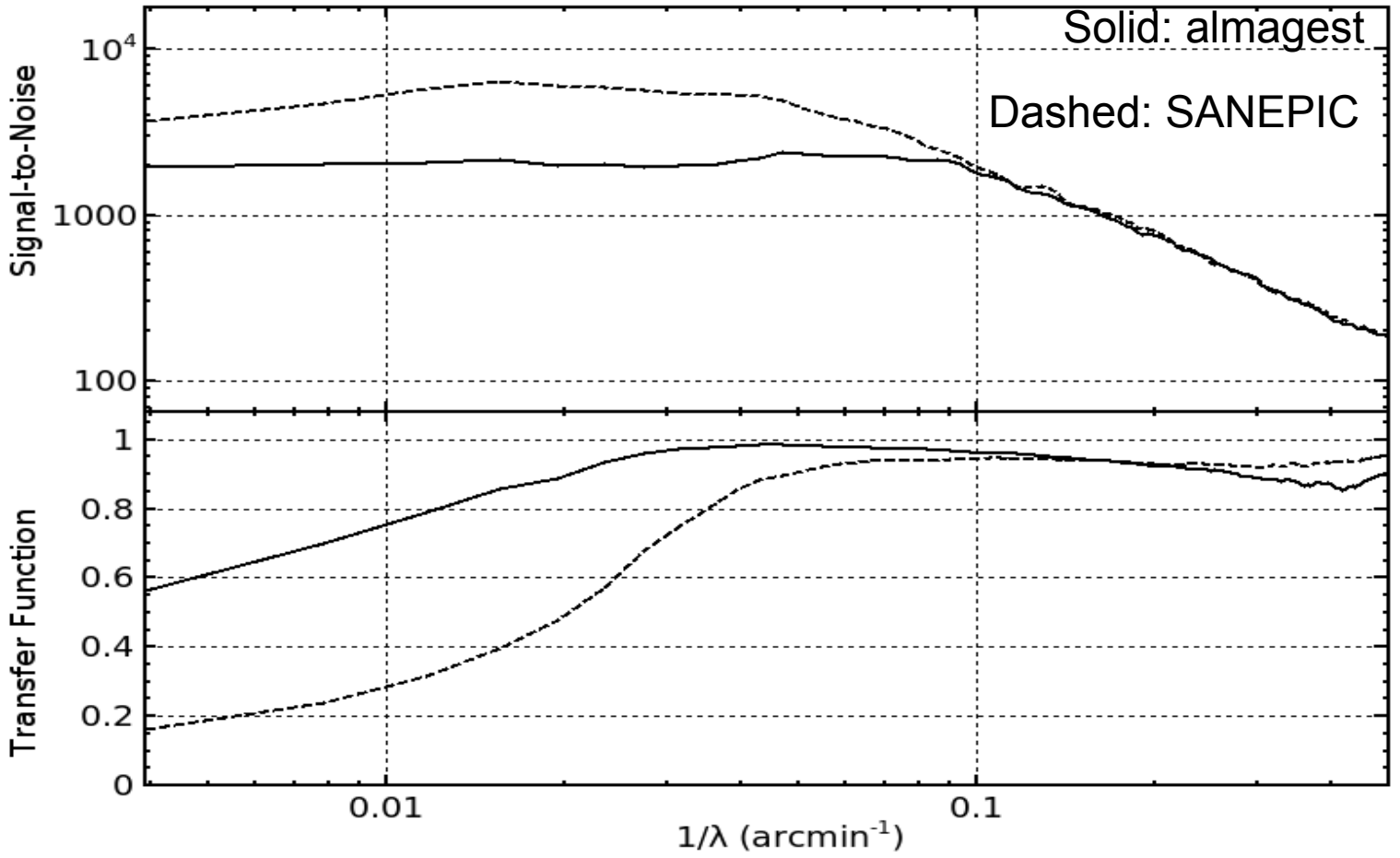




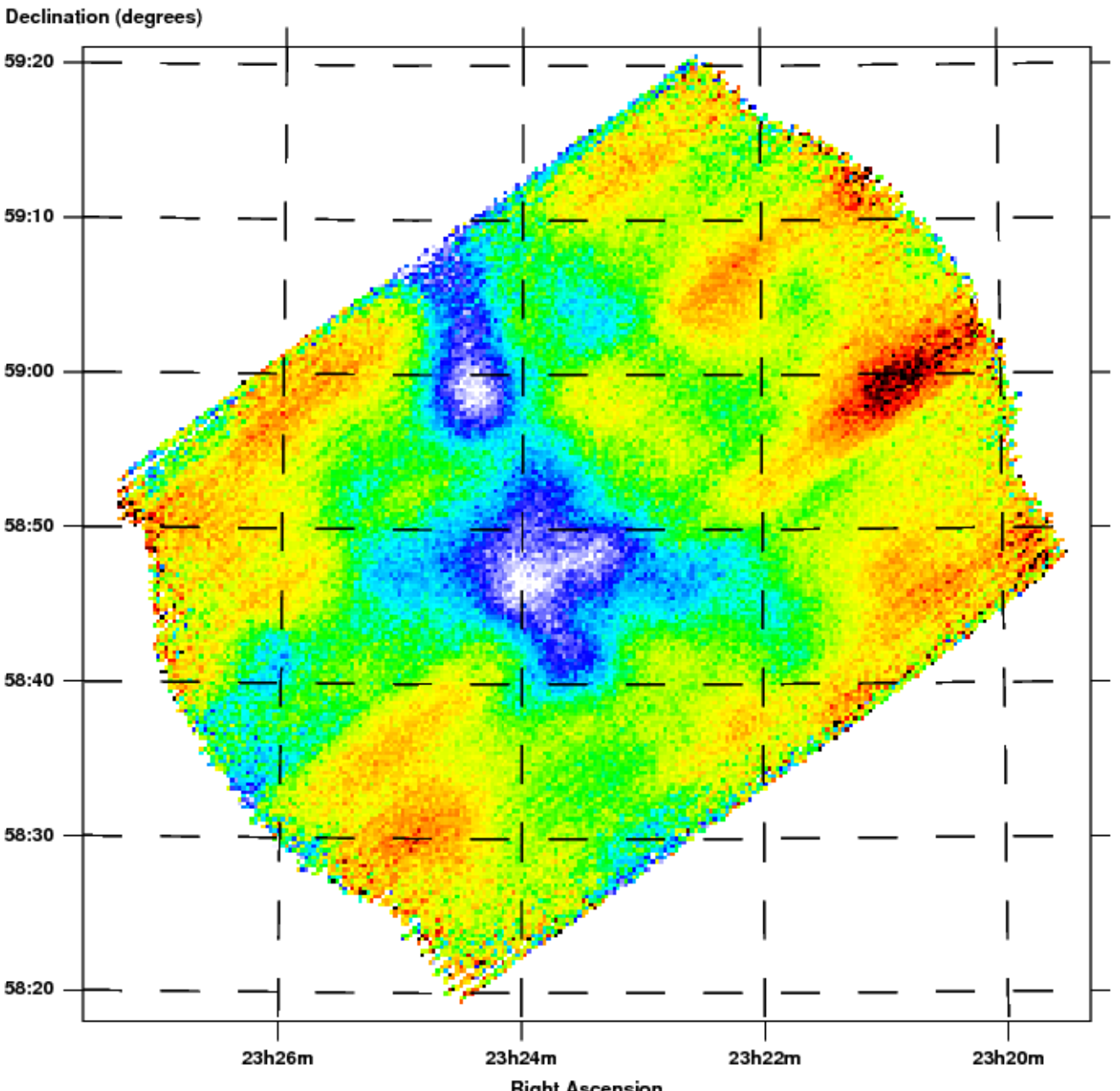


Performance

- The map makers do well with small to medium scales (<0.25º)

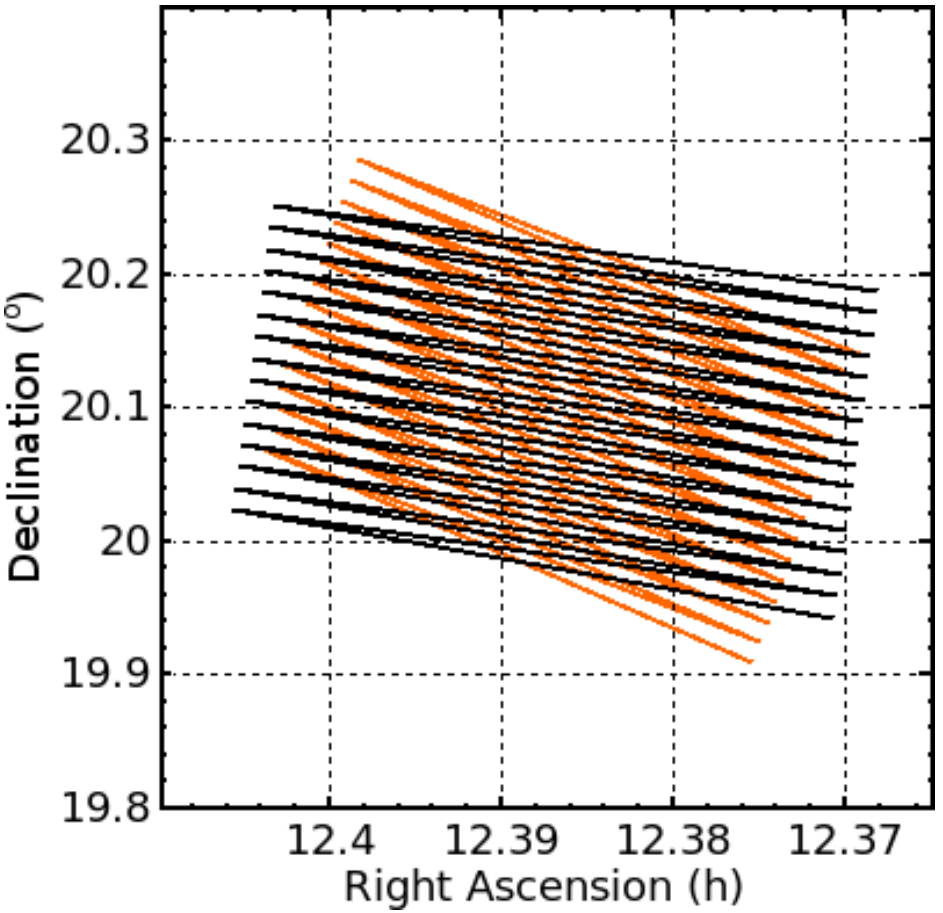


Cas A SNR

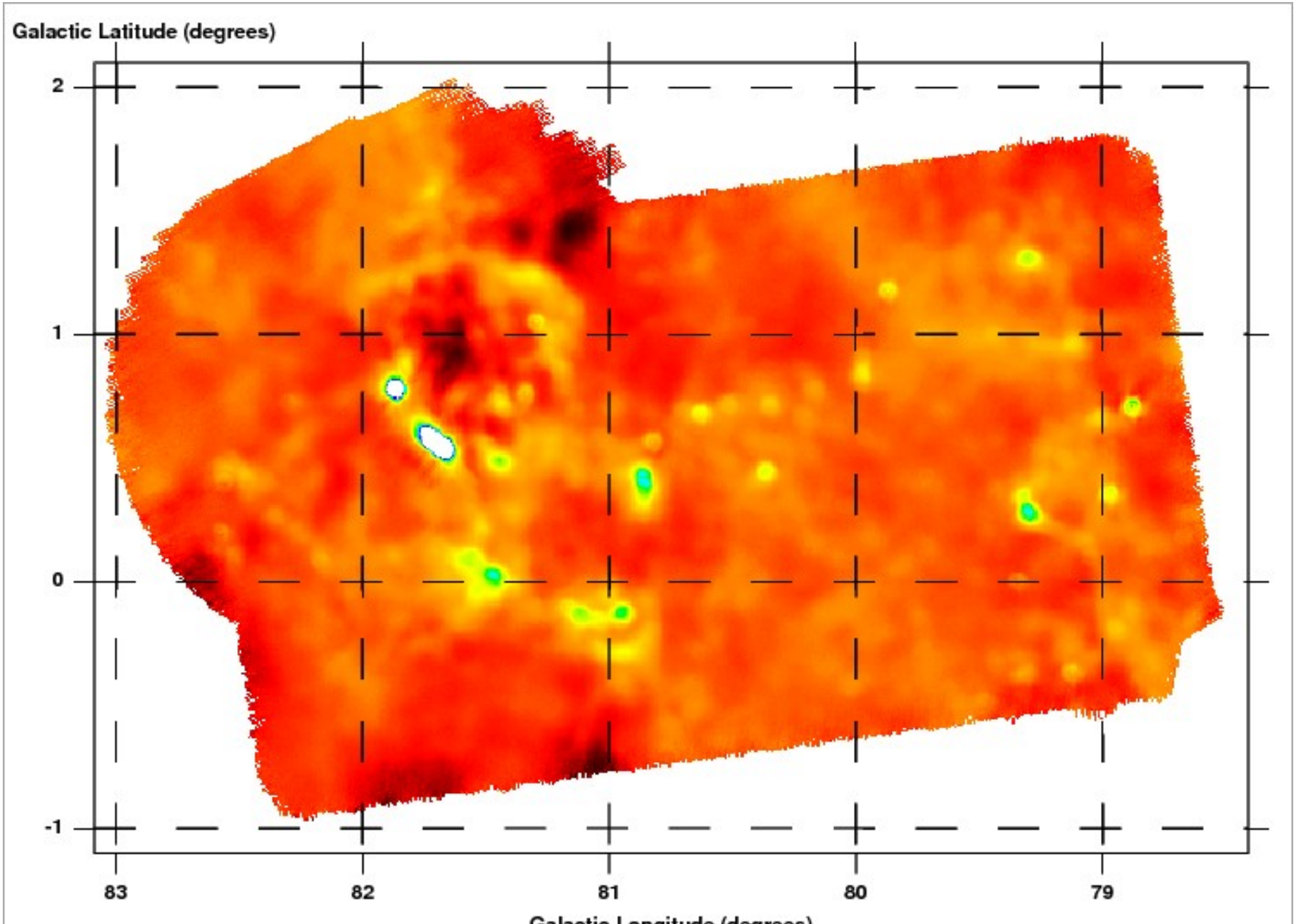

Declination (degrees)
59:20
59:10
59:00
58:50
58:40
58:30
58:20
23h26m
23h24m
23h22m
23h20m
Right Ascension

Cross-linking

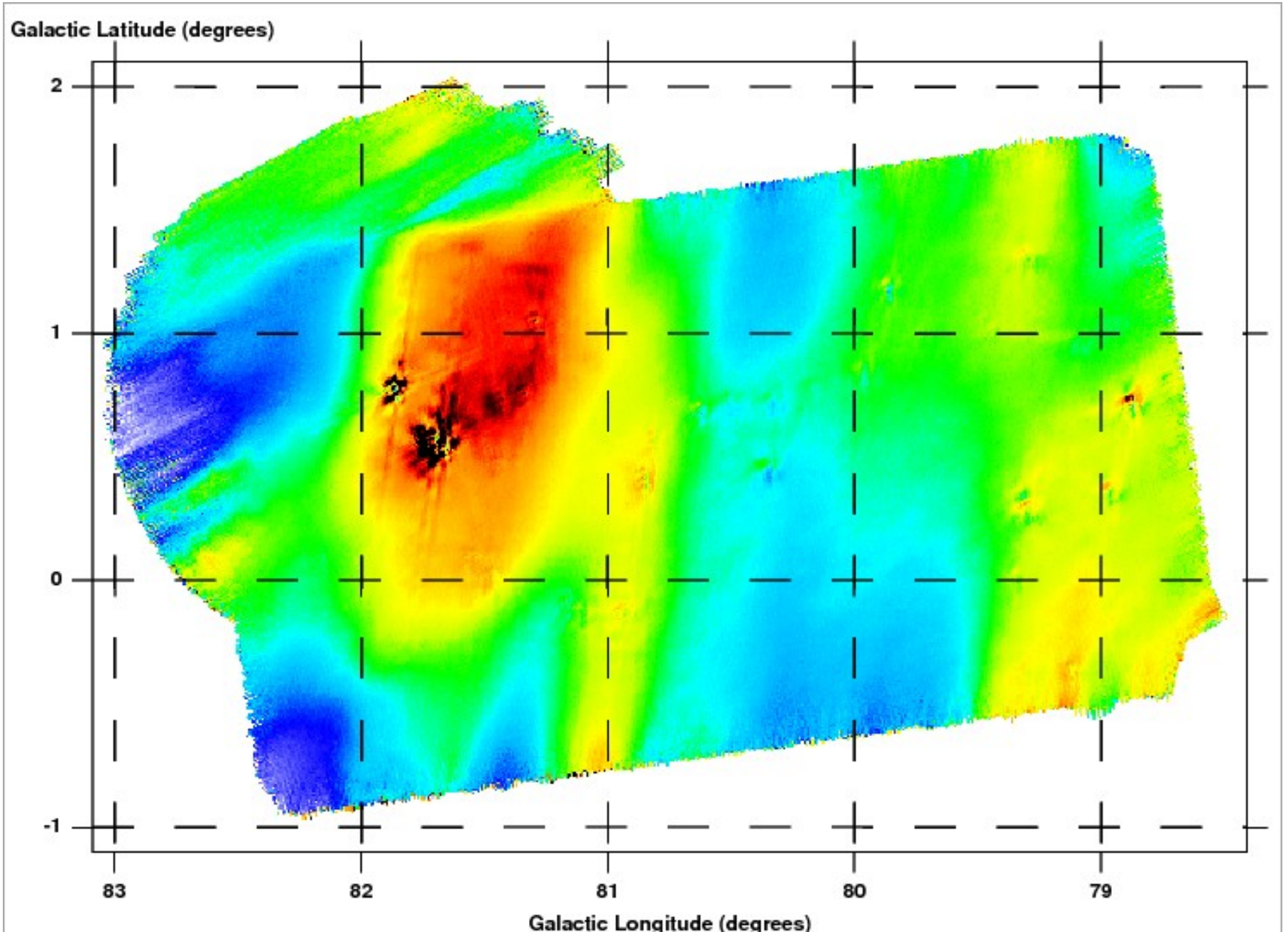
- Cross-linking samples low modes in one direction as higher modes in another.



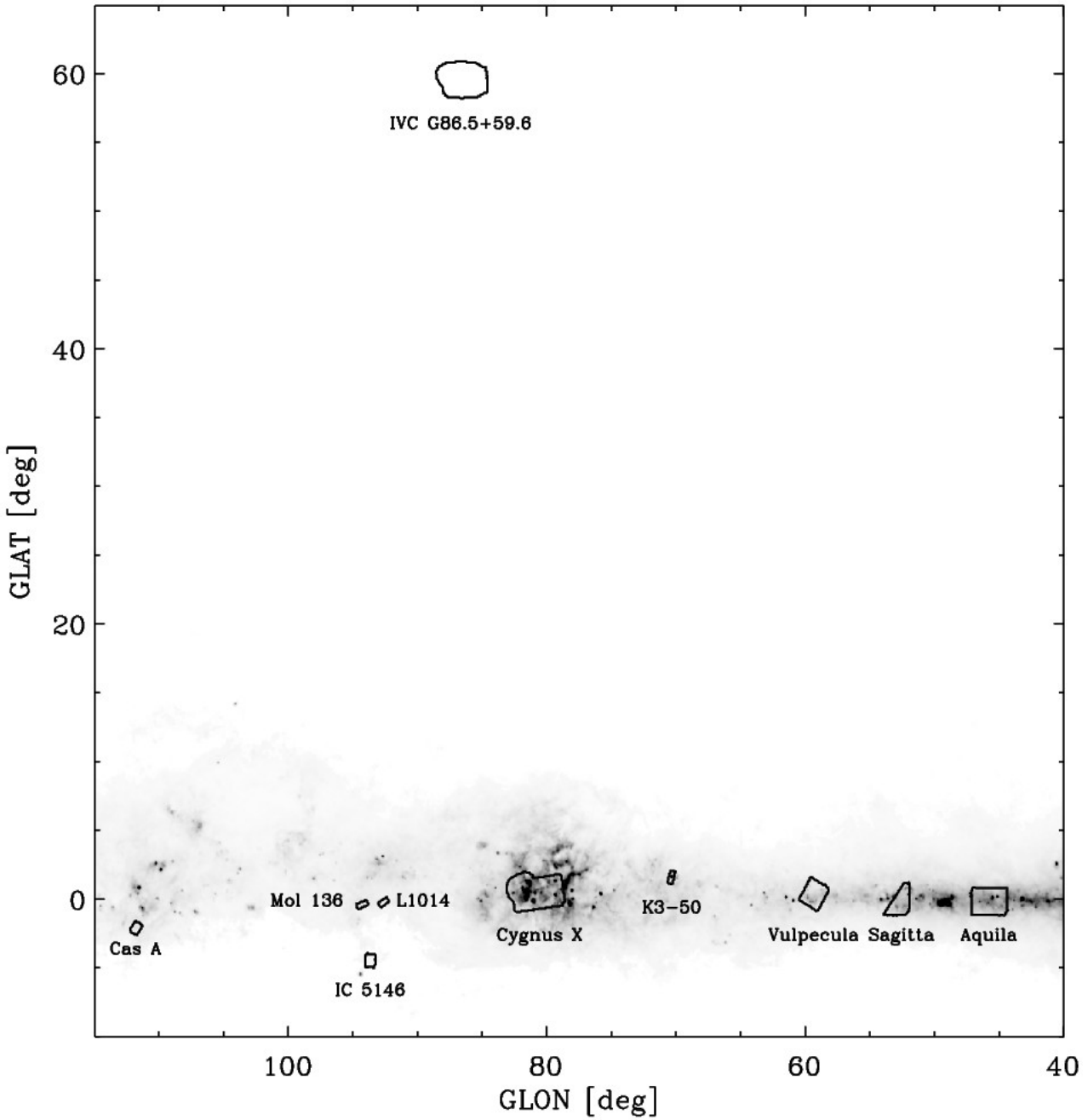
Cygnus X



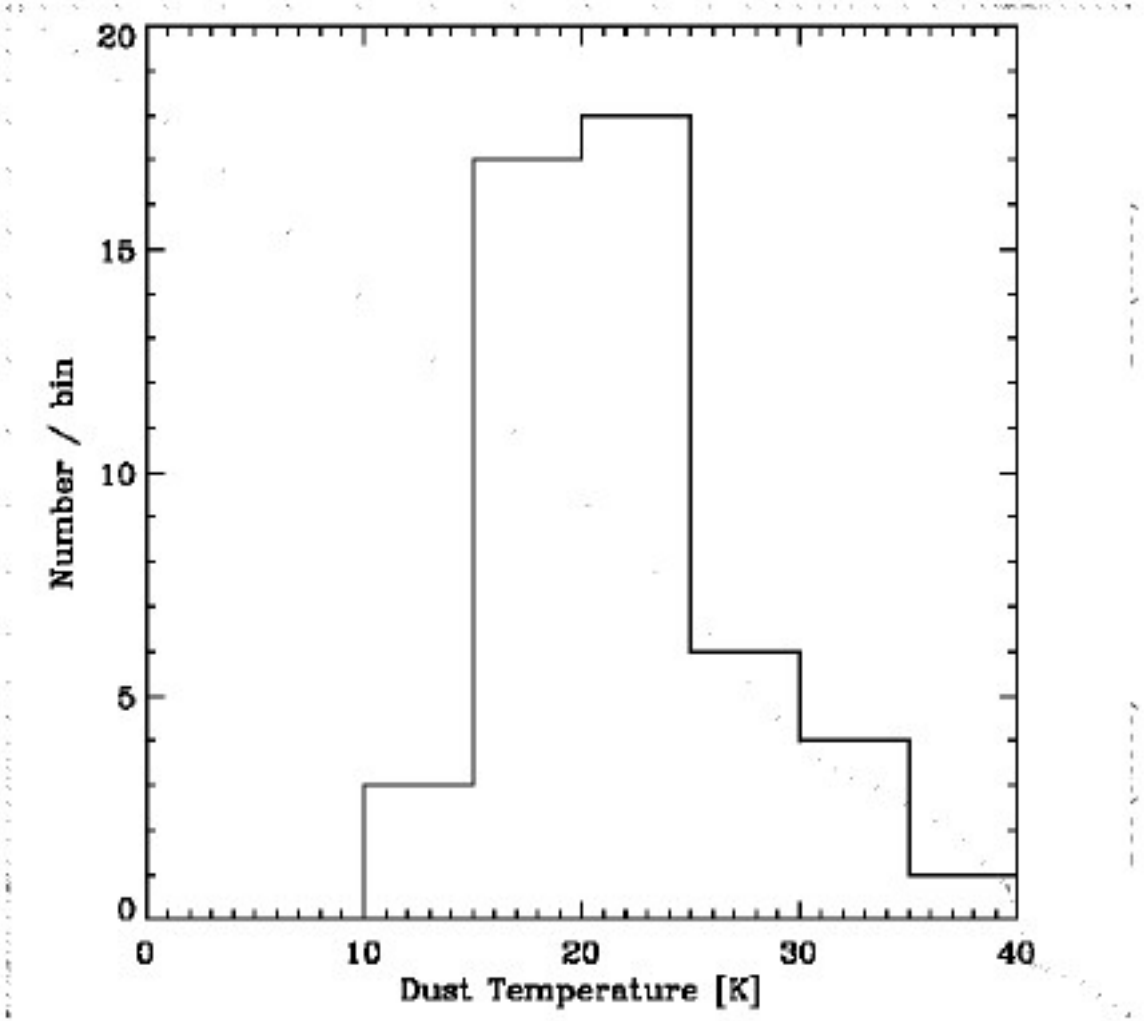
Cygnus X Difference Map

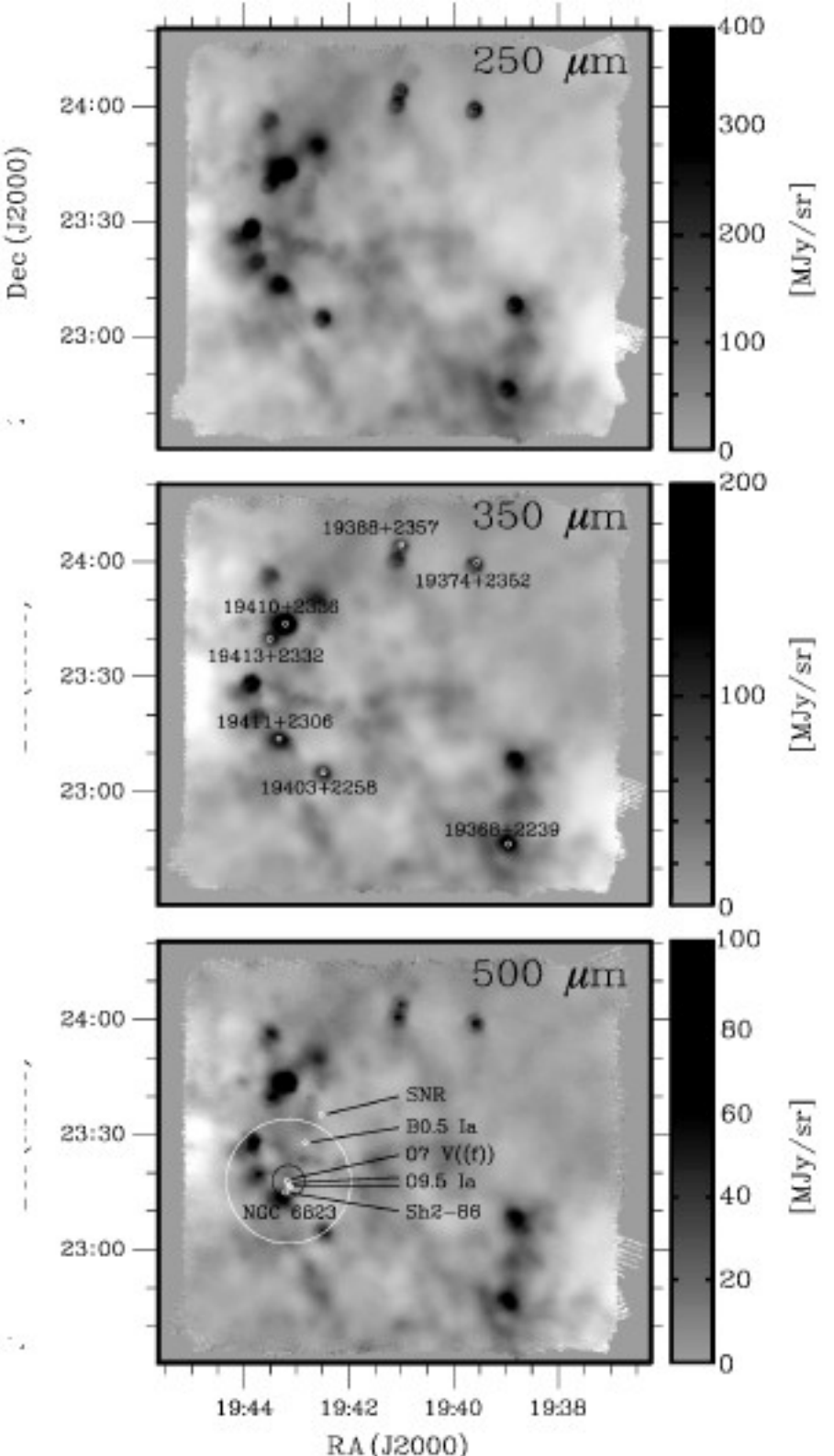


BLAST05 Observations



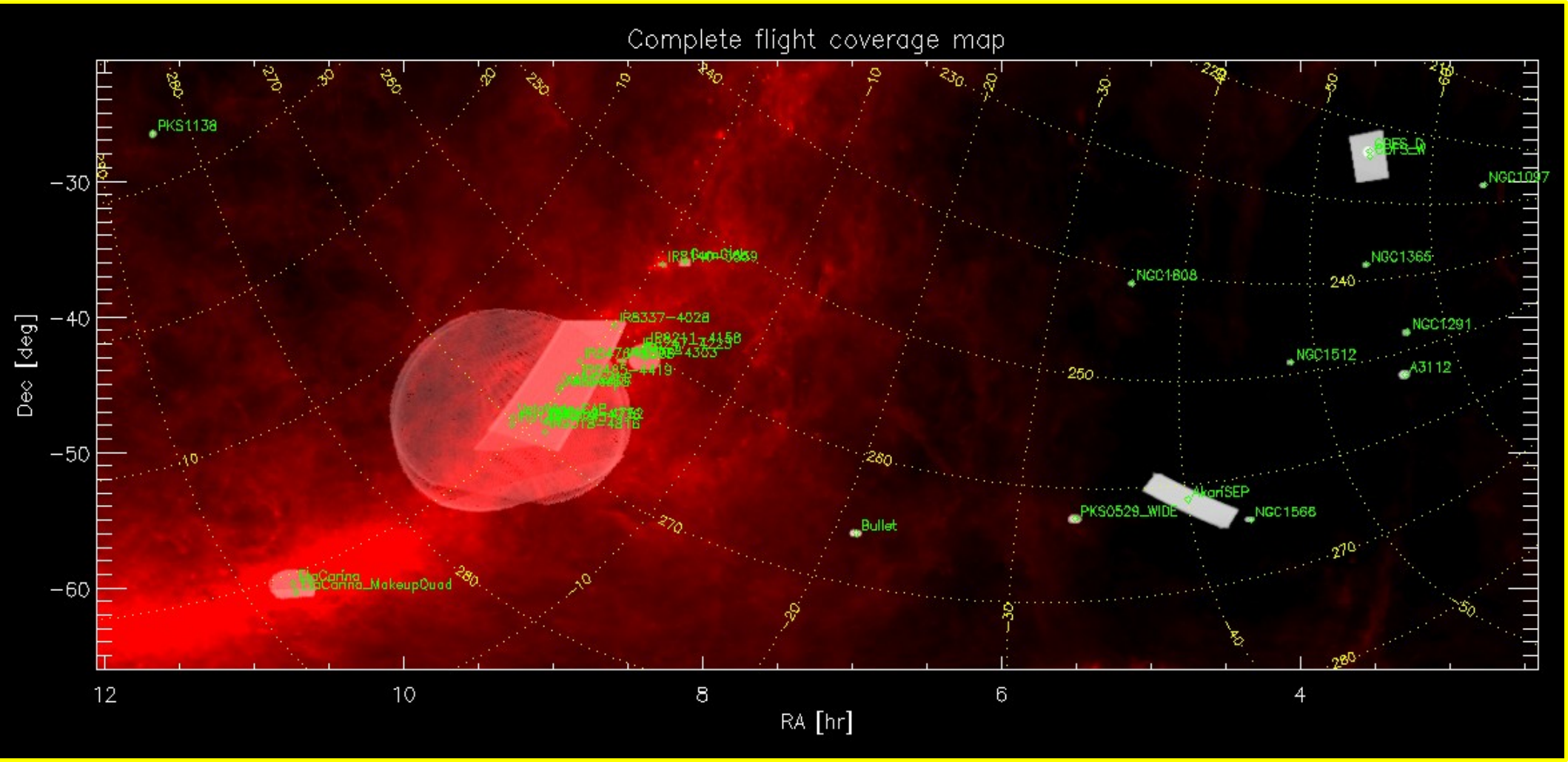
Three Colour sub-mm map of massive star formation in Vulpecula.. 60 sources.





[Chapin et al, 2008]

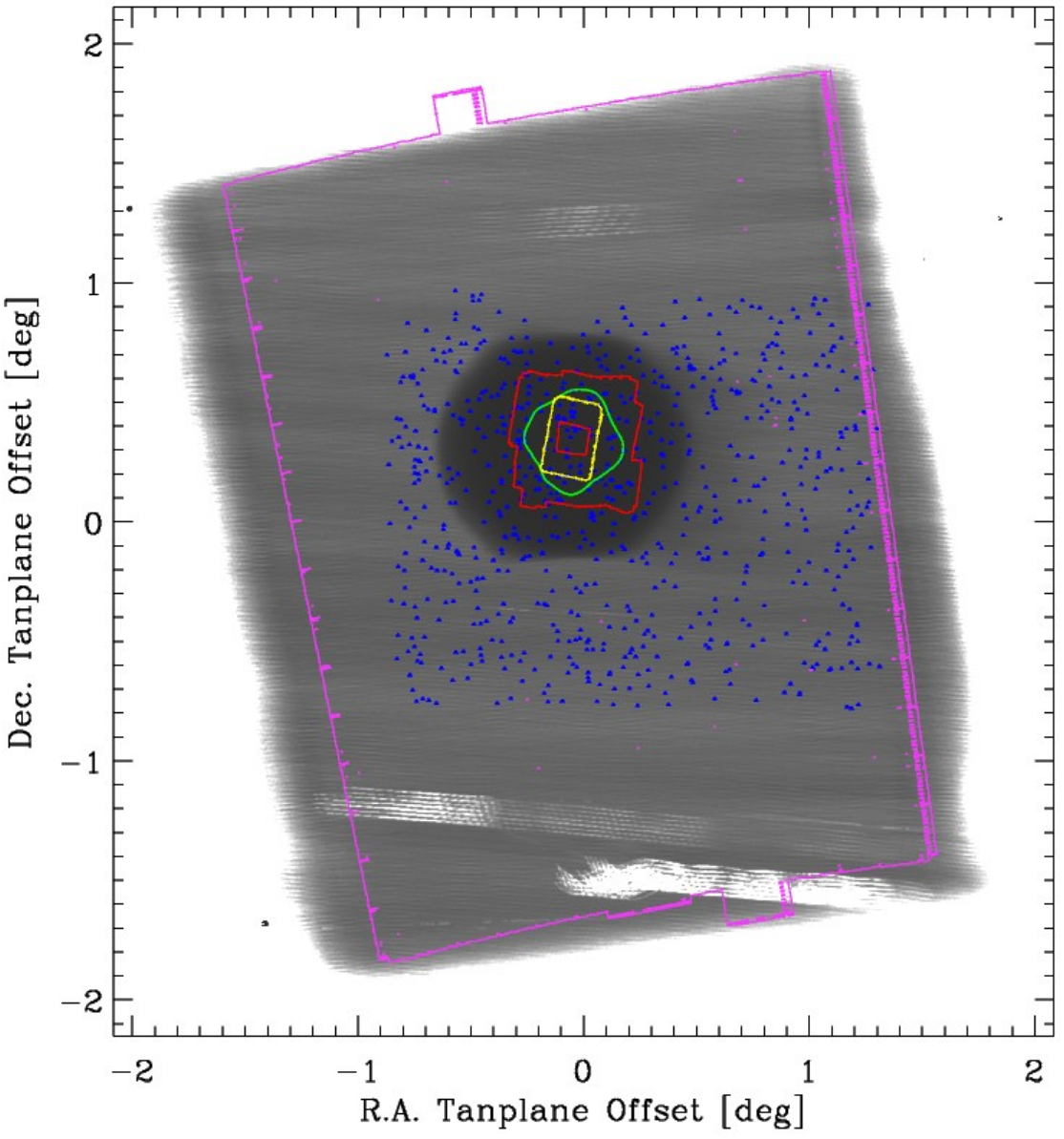
BLAST06 observations



GOODS South

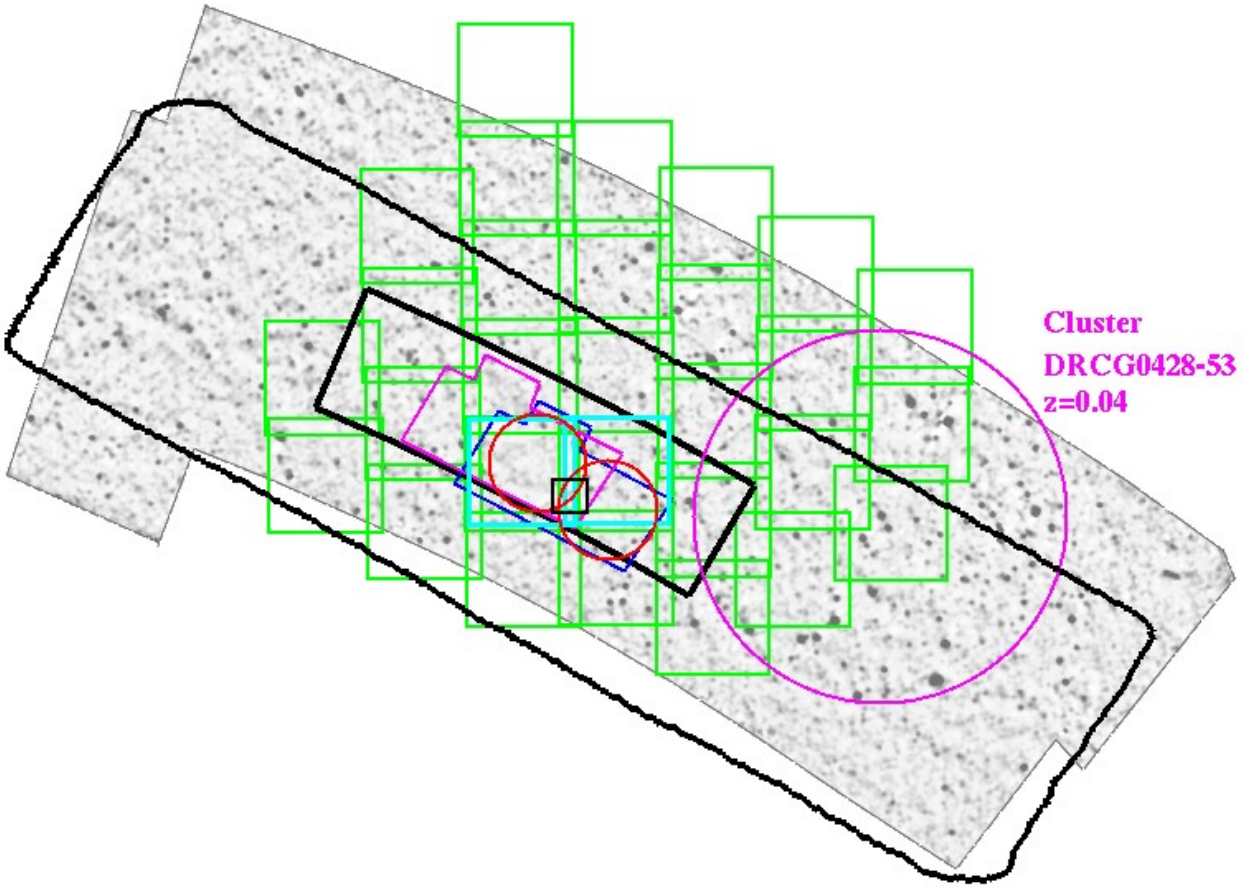
- 10 deg^2 survey with 18 mJy rms depth
- Deeper 0.6 deg^2 survey embedded

background: noise map
Spitzer SWIRE
ATCA radio sources
Spitzer FIDEL
Chandra 1-Ms
Spitzer GOODS



South Ecliptic Pole

- 8.5 deg2 survey w/ 15 mJy rms depth



background: AKARI 90 μm
big outline: BLAST
green: CTIO 4-m R-band
med outline: AKARI FIS
magenta: AKARI IRC
blue: AKARI IRC
cyan: optical multi-band
red: radio
small square: AzTEC

The future of BLAST

- Cryostat (detectors) and primary mirror were recovered.
- We can a polariser to make BLASTpol...

UPenn
Mark Devlin
Simon Dicker
Jeff Klein
Marie Rex
Chris Semisch
Matt Truch

INAOE (Mexico)
David Hughes

UBC
Ed Chapin
Mark Halpern
Gaelen Marsden
Guillaume Patanchon
Douglas Scott

U of Puerto Rico/IRA-INAF
Luca Olmi

U of Miami
Josh Gundersen
Nick Thomas

Brown University
Greg Tucker

Cardiff University
Peter Ade
Matt Griffin
Peter Hargrave
Phil Mauskopf
Enzo Pascale
Carole Tucker
Bruce Sibthorpe

U of T
Peter Martin
Barth Netterfield
Marco Viero
Don Wiebe
Colin Borys

JPL
Jamie Bock

http://blastexperiment.info