MANCHESTER 1824

The University of Manchester

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Point sources and atmosphere simulations for Clover

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Outline

1. Point sources
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   - Radio sources
   - Infrared sources
   - Resulting spectra
   - Future work (?)
2. Atmosphere
   - Model
   - Program structure
   - Future work

Part 1: Point sources

Method

- Use given dN/dS, spectral indices and percentage polarization
- Create a (long!) list of point sources with random positions
- At each frequency, scale source fluxes and create maps
- Based on code written as part of Virtual Sky, primarily aimed at simulating the SZ effect

Method

- Uses high-resolution HEALPix maps (Nside of 4096; 51.5 arcsecond resolution) for I, Q and U components
- Outputs a map at each frequency (97, 150, 220 GHz)
- 4.5GB per map (combined T, Q and U)
- Holds up to 2 maps in memory at once: needs 64 bit computer with ~ 10GB RAM

Method

- Total number of sources from

$$N_{\rm tot} = \Delta\Omega \int_{S_{\rm min}}^{S_{\rm max}} \frac{dN}{dS_\nu} dS_\nu .$$

Convert to temperatures using:

$$T = \frac{S_\nu}{\theta^2_{\rm pixel} \frac{dB}{dT}},$$

$$\frac{dB}{dT} = \frac{2k}{c^2} \left(\frac{kT_{\rm CMB}}{h} \right)^2 \frac{x^4 e^x}{(e^x - 1)^2},$$

$$x = h\nu / k_{\rm B} T_{\rm CMB}$$

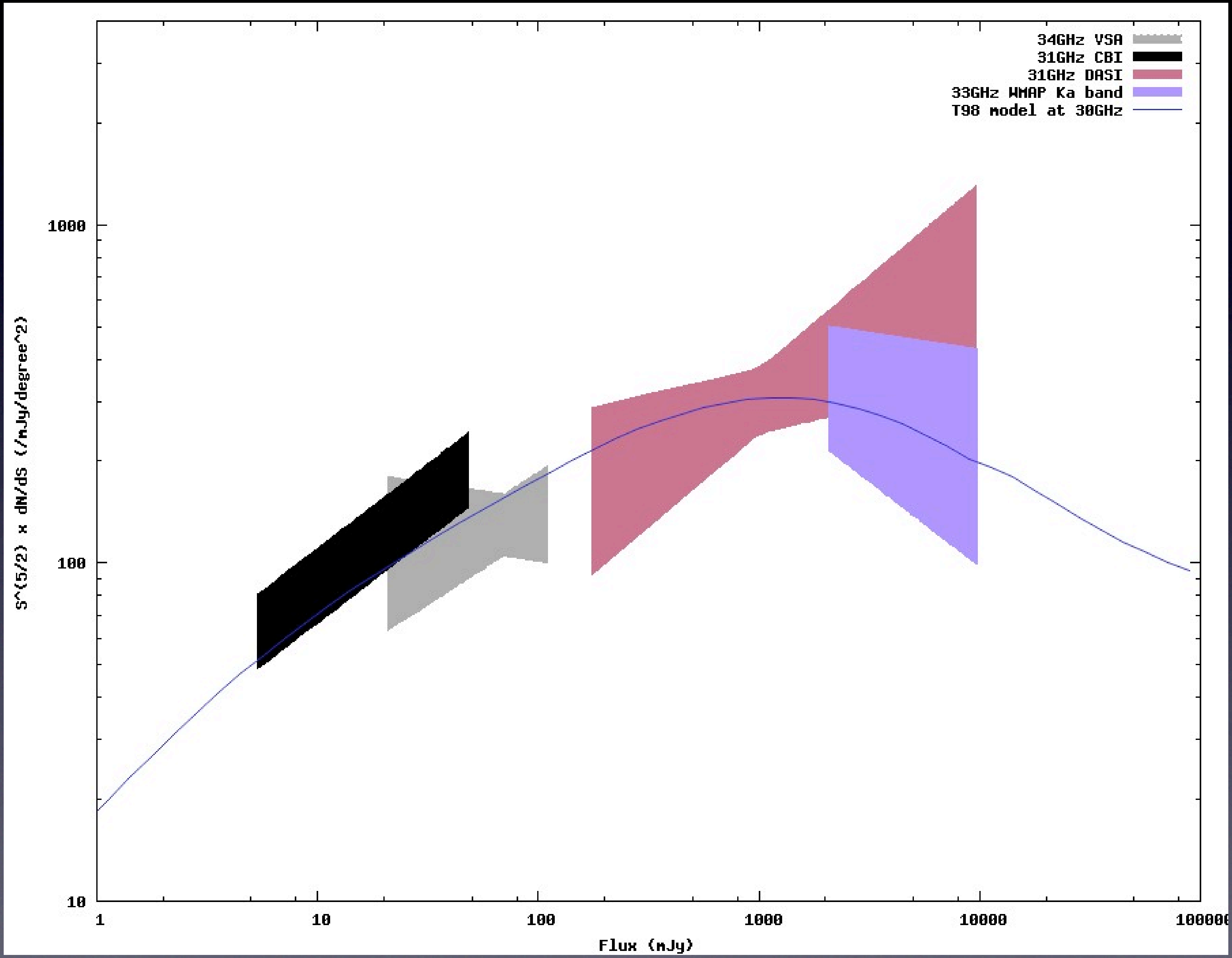
Radio sources

- Using Toffolatti (1998) model at 30 GHz rescaled by 0.7
- Put in sources between $10^{-1.5}$ and 10^{5} mJy at 30GHz (~ 18.6 million)
- Source fluxes scaled using a power law:

$$\frac{S_\nu}{S_{30\mathrm{GHz}}} = \left(\frac{\nu}{30\mathrm{GHz}}\right)^\alpha$$

  α is a random number from a gaussian distribution, mean -0.3, $\sigma_\alpha = 0.36$, from comparison of 9C (15 GHz) and VSA (33 GHz) observations

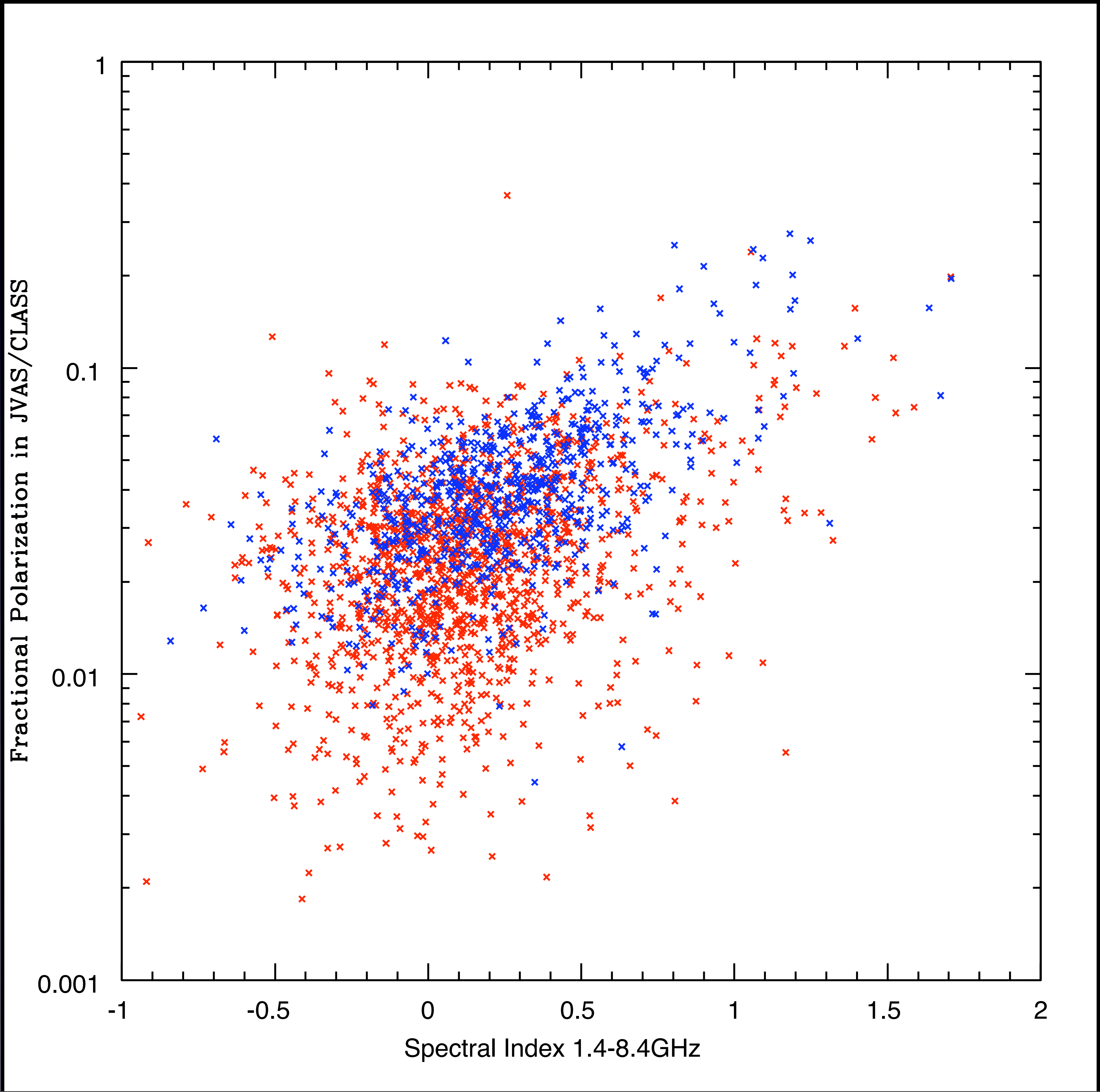
Radio sources



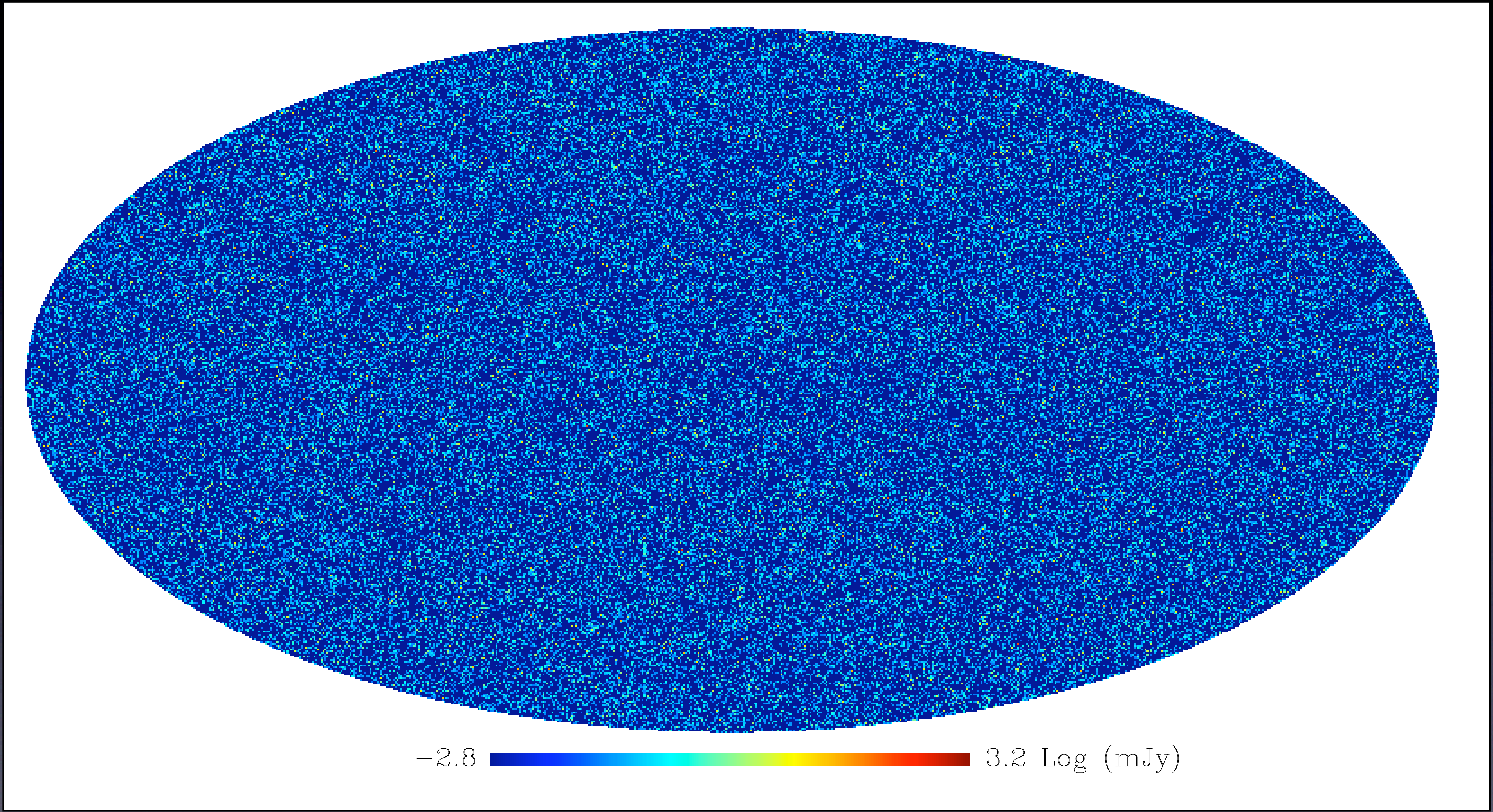
Radio sources

- Polarization fraction assumed to depend on spectral index: $F_{\rm pol} = 0.02 - 0.1\alpha + R_{0.01}$ From fit to JVAS+CLASS/NVSS sample
- R: Random number with a spread of 0.01
- On average, sources in maps 5% polarized
- Steep spectrum sources have highest percentage polarization
- Q, U flux then calculated by $S_{\rm Q} = S_{\rm T} F_{\rm pol} \sin(2\pi R) \quad S_{\rm U} = S_{\rm T} F_{\rm pol} \cos(2\pi R)$ R is a random number between 0 and 1

Radio sources



Radio sources



Infrared sources

- Using fit to SCUBA observations by Borys et al. (2003):

$$\frac{dN}{dS_\nu} = \frac{N_0}{S_0}\left[\left(\frac{S}{S_0}\right)^\alpha + \left(\frac{S}{S_0}\right)^\beta\right]^{-1}$$

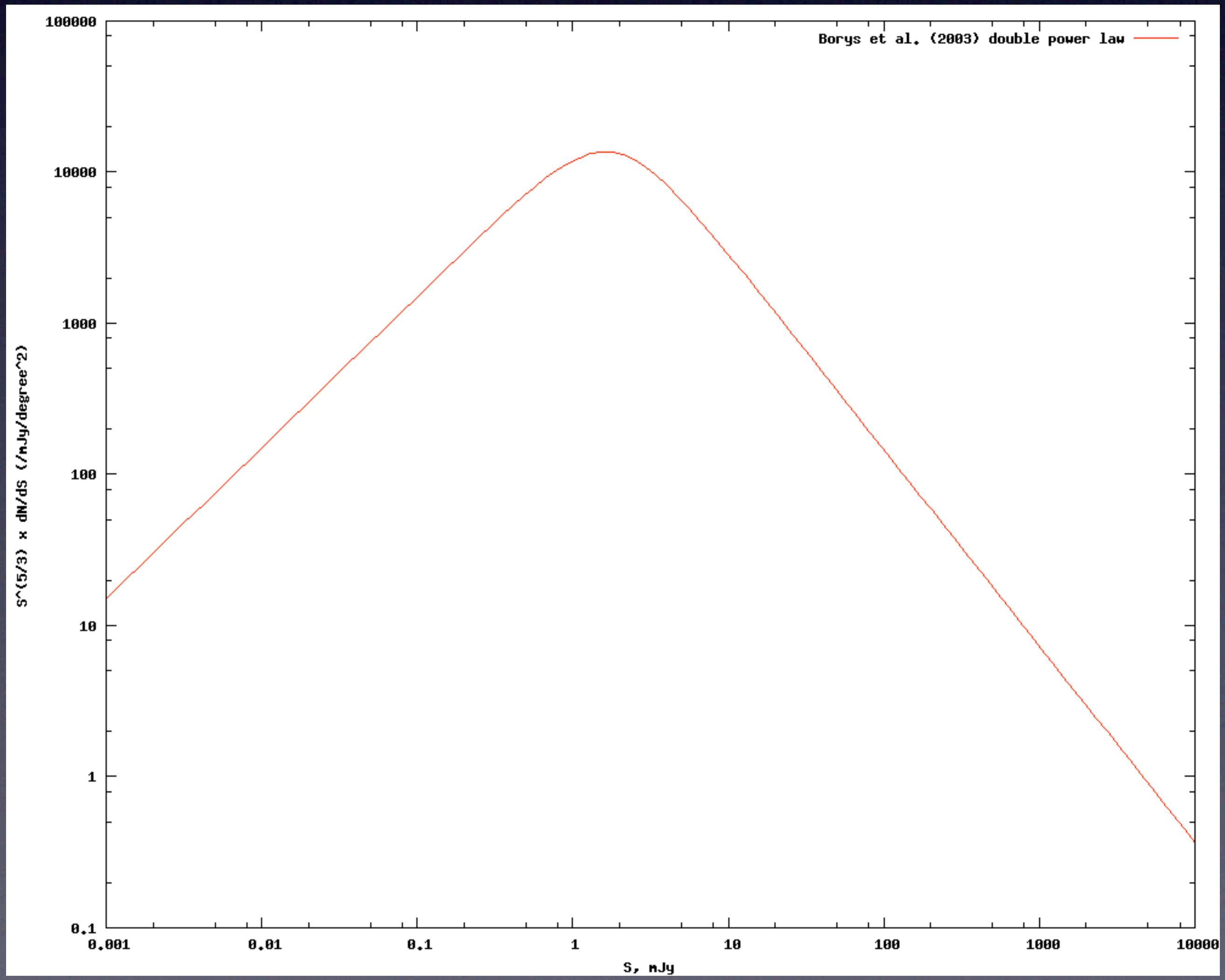
  where $\alpha = 1$, $\beta = 3.3$, $N_0 = 1.5 \times 10^4$ deg^{-2} and $S_0 = 1.8$ mJy

- Scaled using a power law

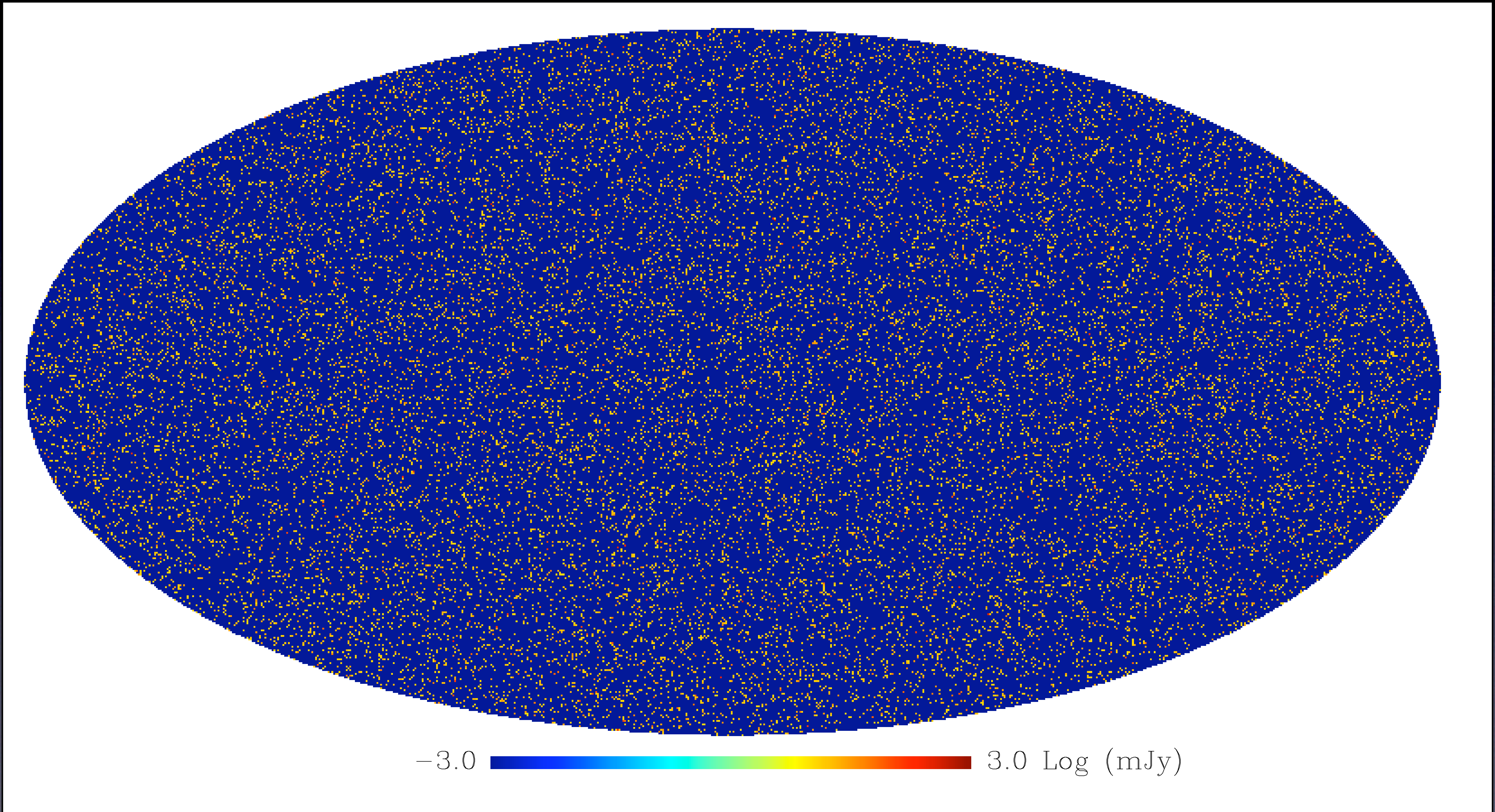
$$\frac{S_\nu}{S_{350\mathrm{GHz}}} = \left(\frac{\nu}{350\mathrm{GHz}}\right)^{2.5}$$

Infrared sources

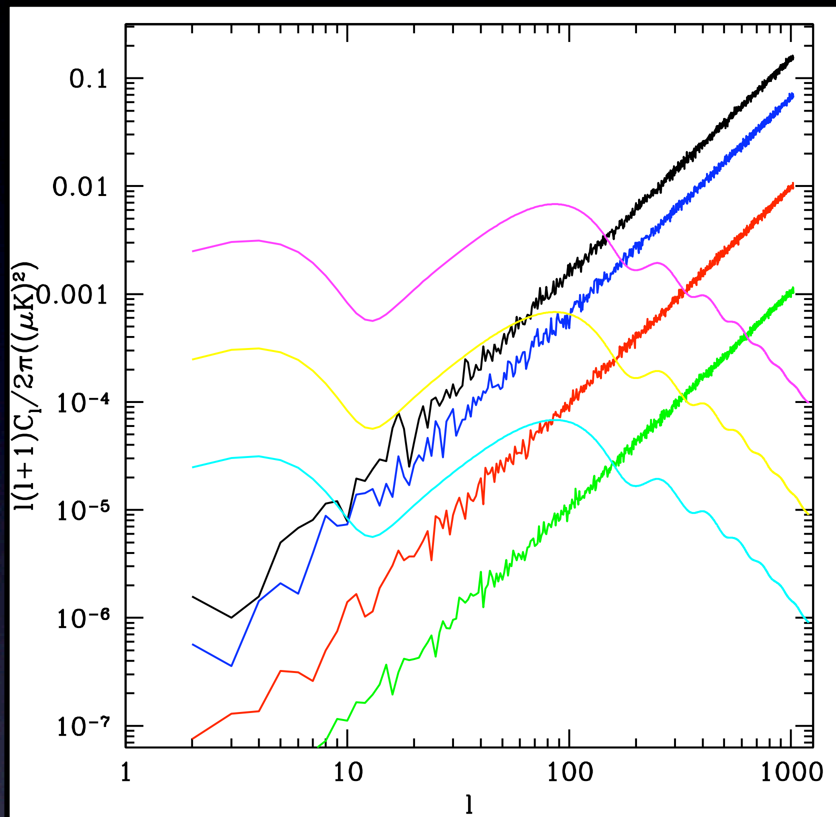
- Put in sources between 10 and 10^5 mJy at 350GHz (~ 5.1 million)
- Polarization fraction assumed: 0.01 (1%)
- M82 1% pol.
- Arp 220 < 1.5%
- Not statistically constrained



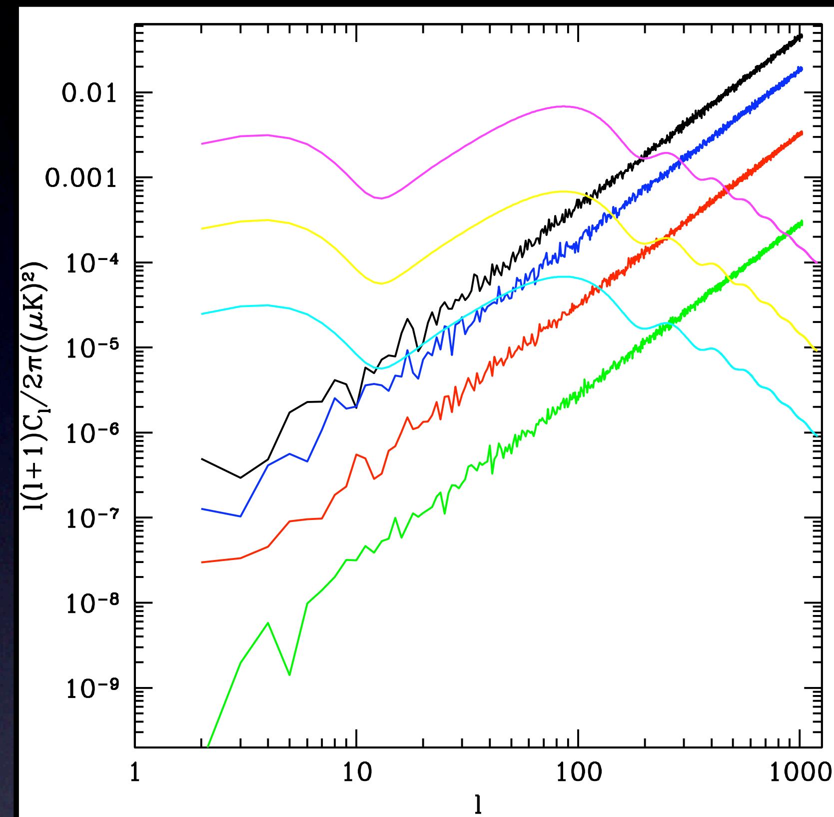
Infrared sources



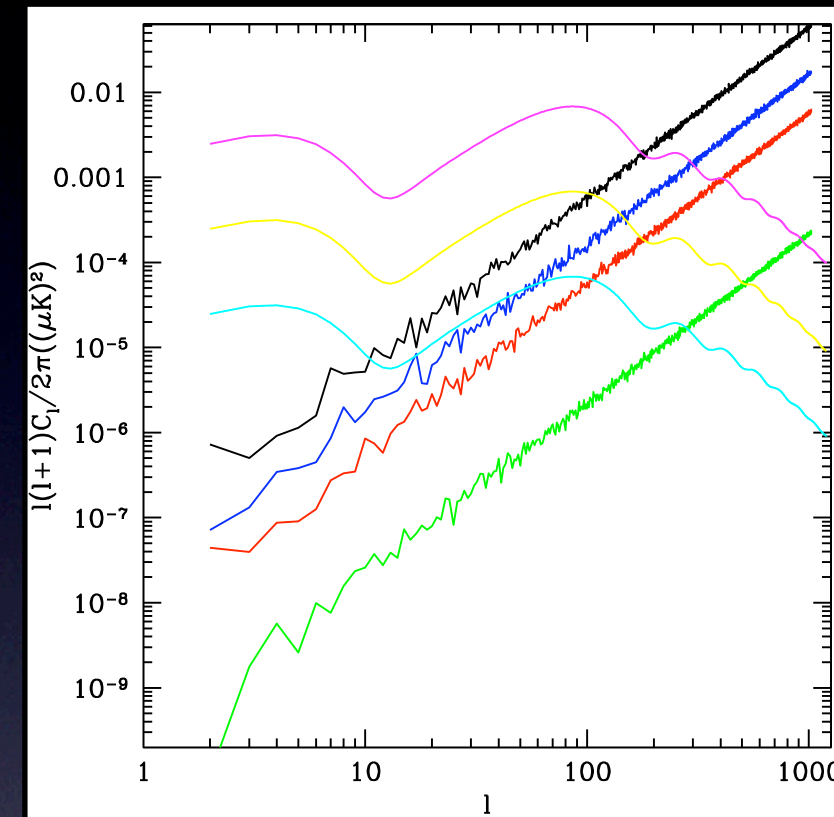
Resulting spectra



97 GHz



150 GHz



220 GHz

Graphs by Mike Preece

Point sources: black: uncut,

blue: 1Jy, red: 100mJy, green: 10mJy

CMB: pink: r=0.1, yellow: r=0.01, blue: r=0.001

Future work (?)

- Need to know polarization fractions better (preferably also number counts)
  - Jackson, Browne and Battye observing WMAP 22GHz sources with VLA at 8.4, 22, 43 GHz, full polarization.
  - ATCA have also done observations
- Should spread flux over multiple pixels if position is not in pixel centre
- Clustering of sources?

Part 2: Atmosphere

Model

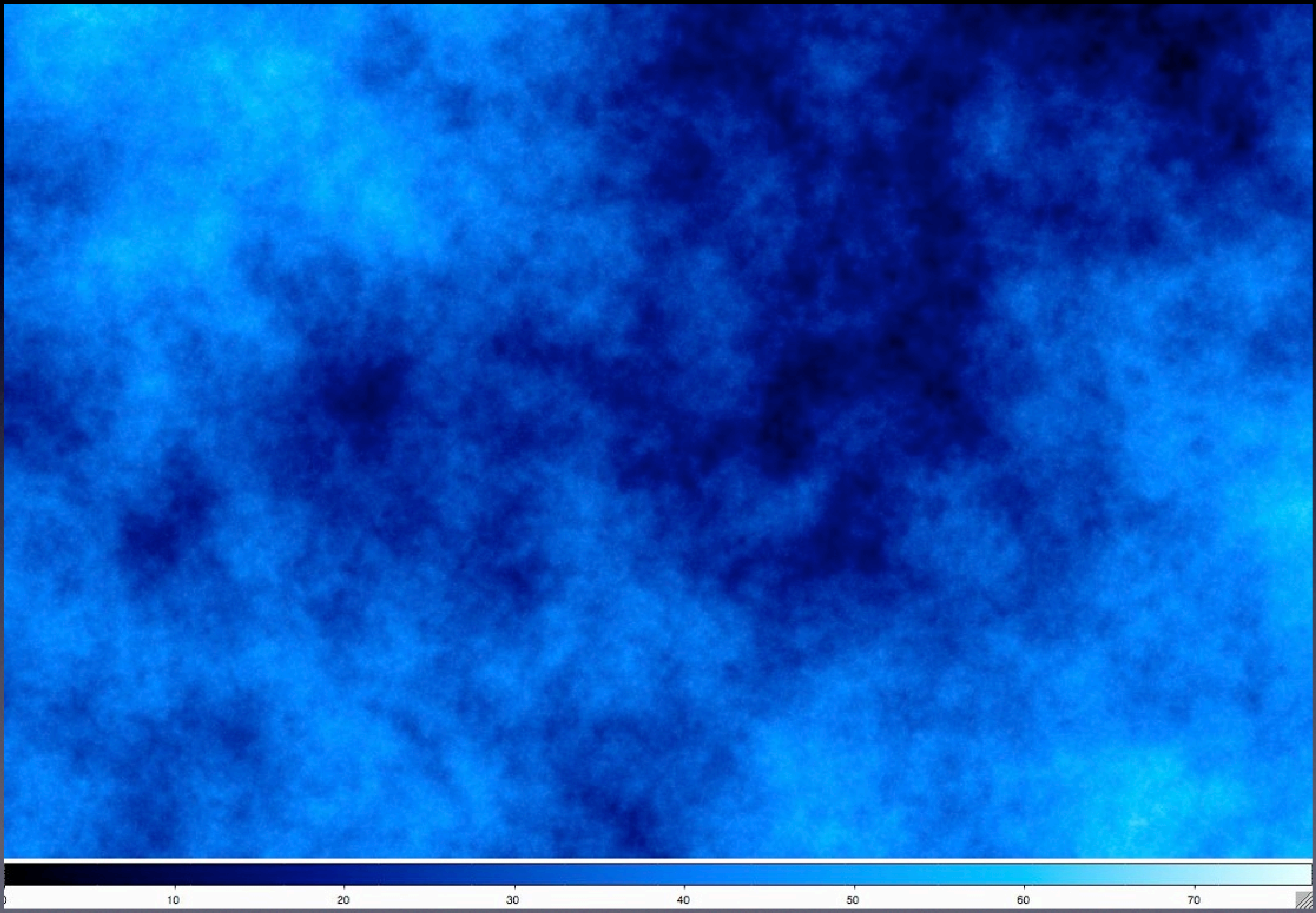
- Fractal model
- Creates 2D atmosphere layer(s)
- Add power on largest scales, then iteratively add power on smaller scales
- Static model; "blown" across sky at constant rate
- Based on "UMBRELLA" code written by Stuart Lowe to simulate OCRA observations

UMBRELLA: Upper Millimeter Band Receiver Emulator for Large Linked Arrays

Model

- Parameter values currently used are:
  - Atmosphere Layer at 500m
  - 0.2m pixel size, 2049 pixels wide (~400m)
  - Fluctuating temperature of 260K
  - Spectrum of 0.5, fluctuations of 10K
  - Constant optical depth of 0.1 (should depend on frequency & much too large!)
  - Moves at 10m/s

Model

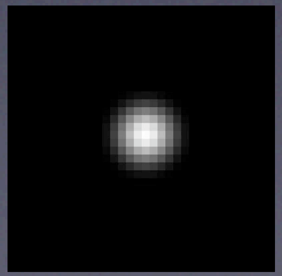
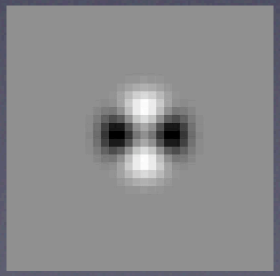
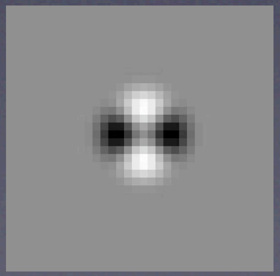


Program structure

- Three C/C++ programs:
  - create_atmosphere Written
    Creates a series of atmosphere segments
  - get_atmosphere_signal Partially written
    Reads in atmosphere, convolves it with a telescope beam, returns timestream of signal
  - test_atmosphere_signal Partially written
    Will calculate spectra, do various tests on atmosphere signal. For testing only.

Program structure

- get_atmosphere_signal in more detail:
  - Reads in atmosphere segments as needed
  - Reads in beam patterns, creates matrices of the real-space beams TT, QT UT at atmosphere resolution (interpolated)
  - Reads in telescope pointing positions (but assumes telescope is pointing to the zenith)

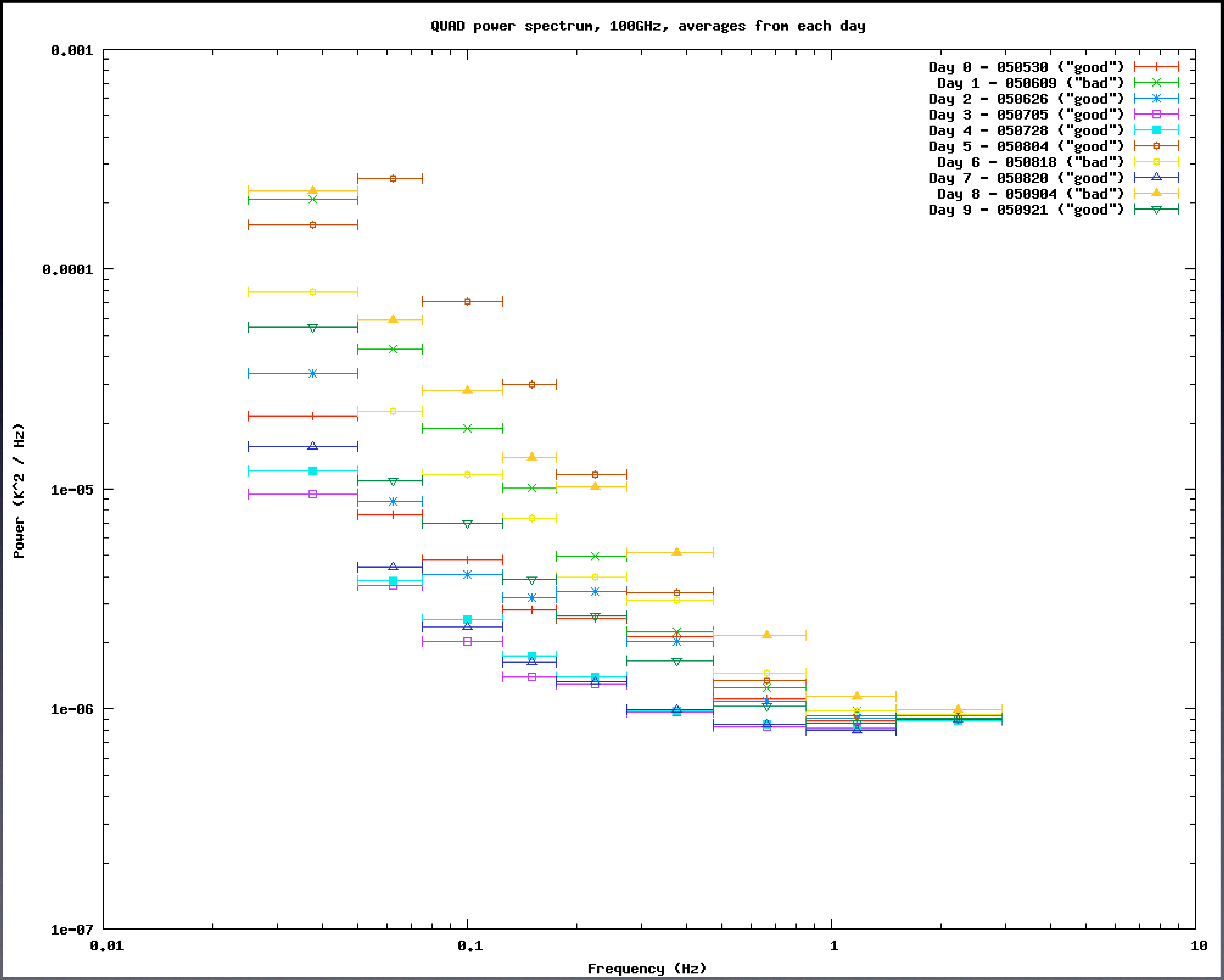
Program structure

- get_atmosphere_signal in more detail, continued:
  - Calculates a value for the atmosphere at each timestep in the positions file
  - Saves value to disk
  - Only deals with one beam at a time: run multiple times for multiple beams
  - Run time is about an hour on 1 CPU
  - Signal file ~ 100MB, atmosphere ~ 10GB

Future work

- Complete test_atmosphere_signal
- Add multi-frequency support
- Use more realistic parameters
  Compare with QUAD spectra
  Also use model of optical depth vs. freq.
- Add gaussian random noise component
- Use 3D beam model to project beam onto layer at different zenith angles?
- ... ("the sky's the limit")

QUAD power spectrum, 100GHz



QUAD power spectrum, 150GHz