The University of Manchester
Jodrell Bank Observatory

Science & Technology Facilities Council

MANCHESTER 1824

Modelling and observing the Sunyaev-Zel'dovich effect in clusters of galaxies

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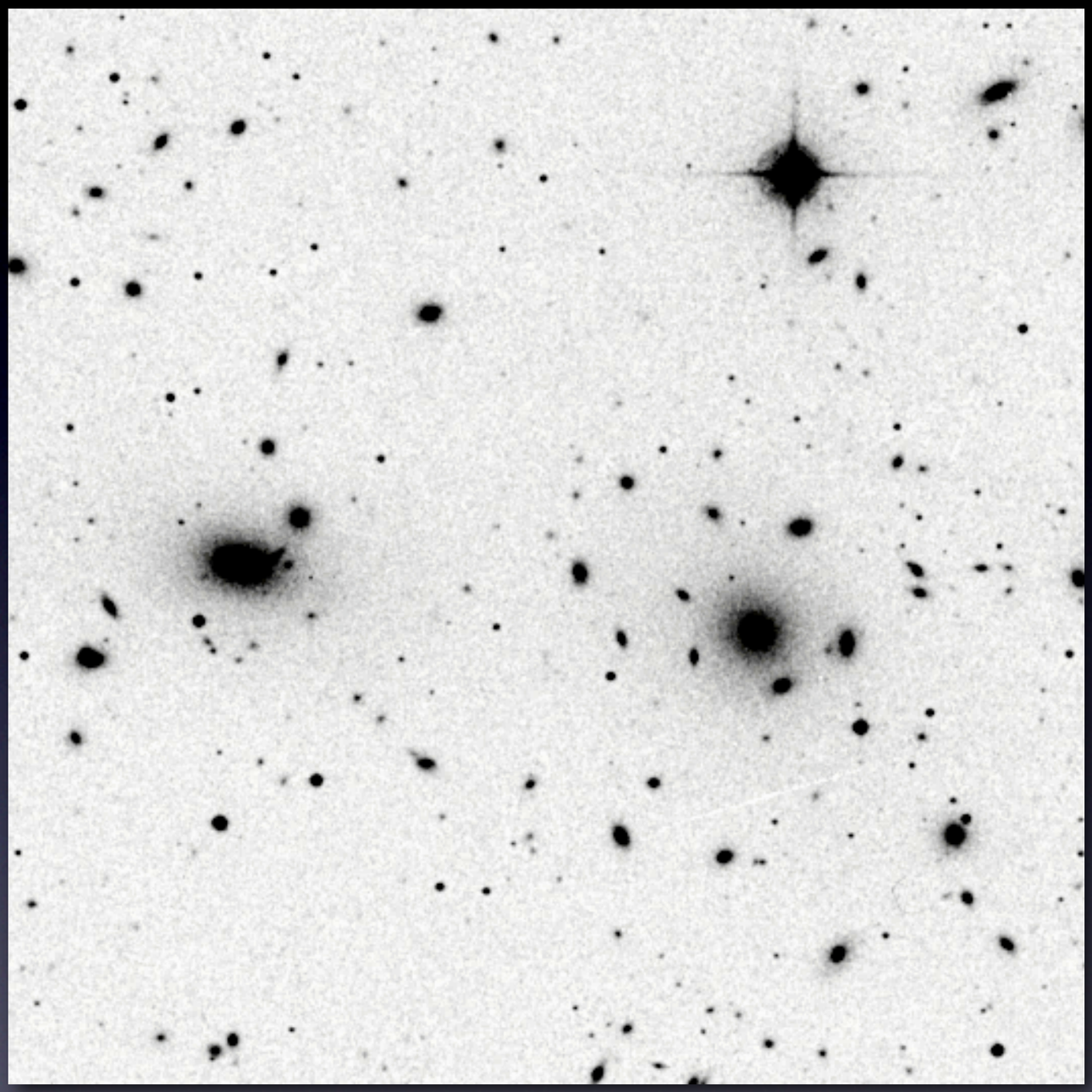
YERAC, 3rd-7th September 2007

Outline

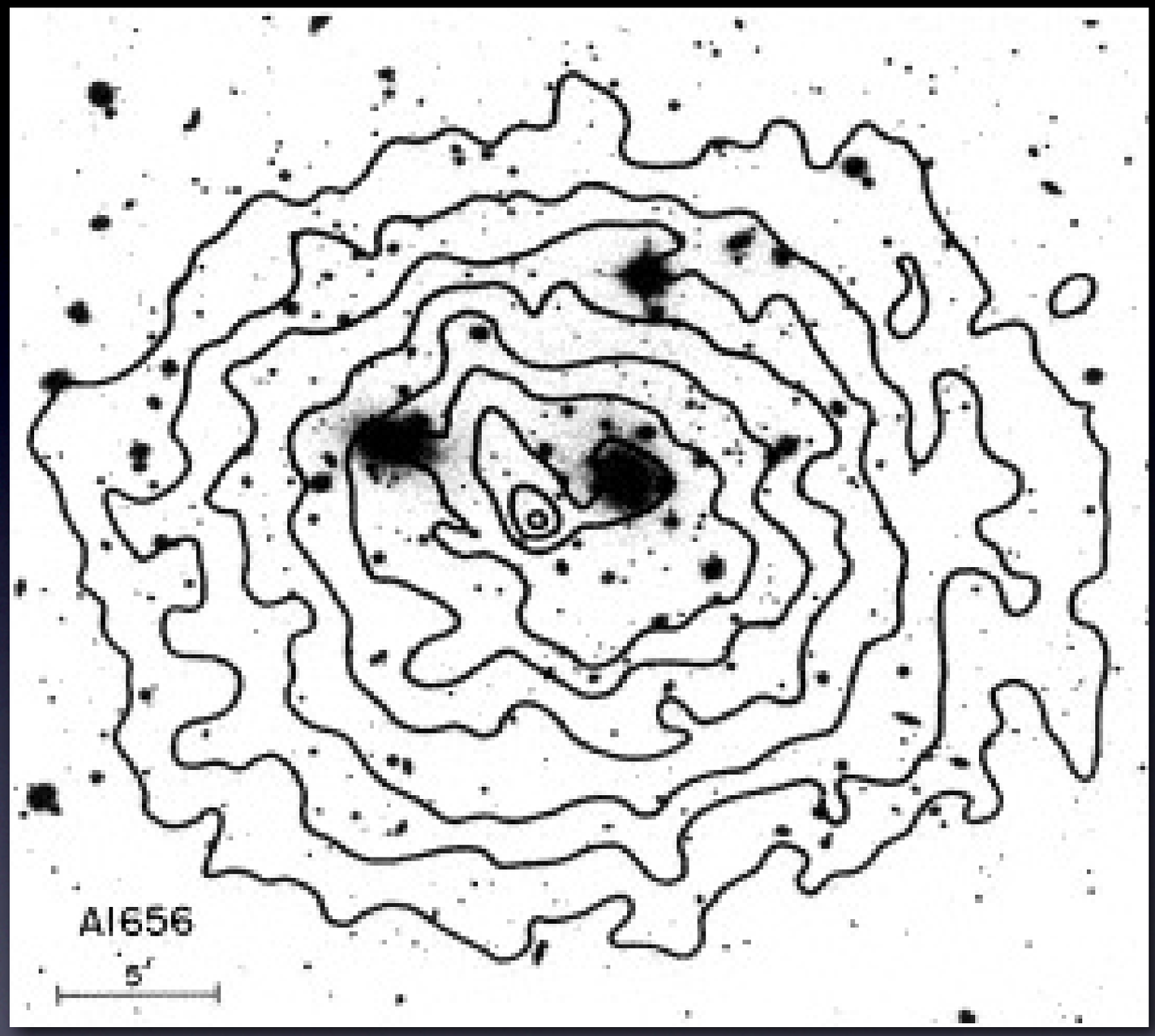
1. Clusters of galaxies
2. Virtual Sky simulations
    a. Cosmology
    b. Cluster model
    c. Foregrounds and noise
3. The One Centimeter Receiver Arrays
4. Future work

1. Clusters of galaxies



Coma Cluster (Abell 1656) at 645nm
From the Digitized Sky Survey

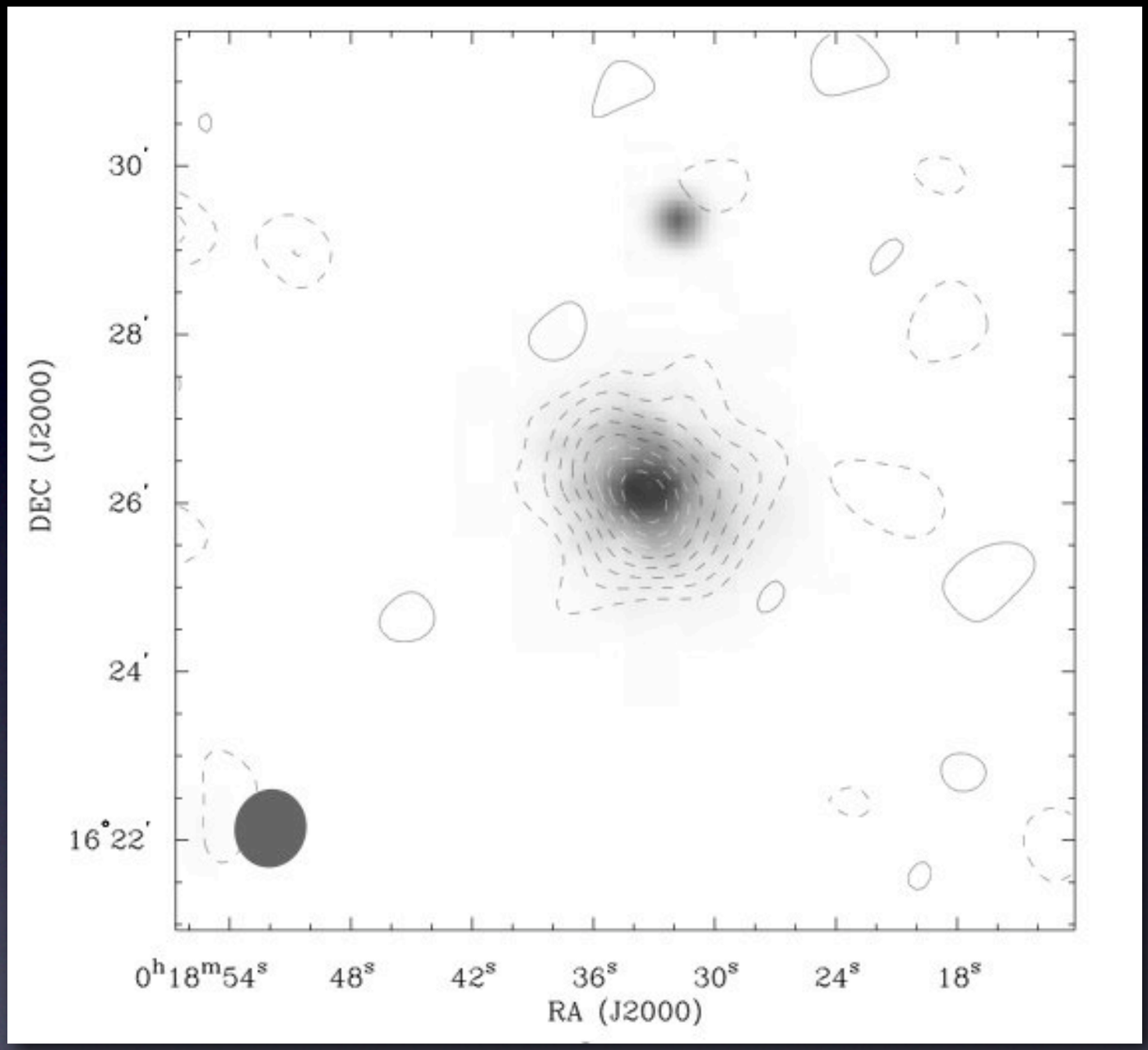
1. Clusters of galaxies



Coma Cluster (Abell 1656) at 0.15nm
From Einstein

Jones and Foreman, 1999, ApJ 511:65

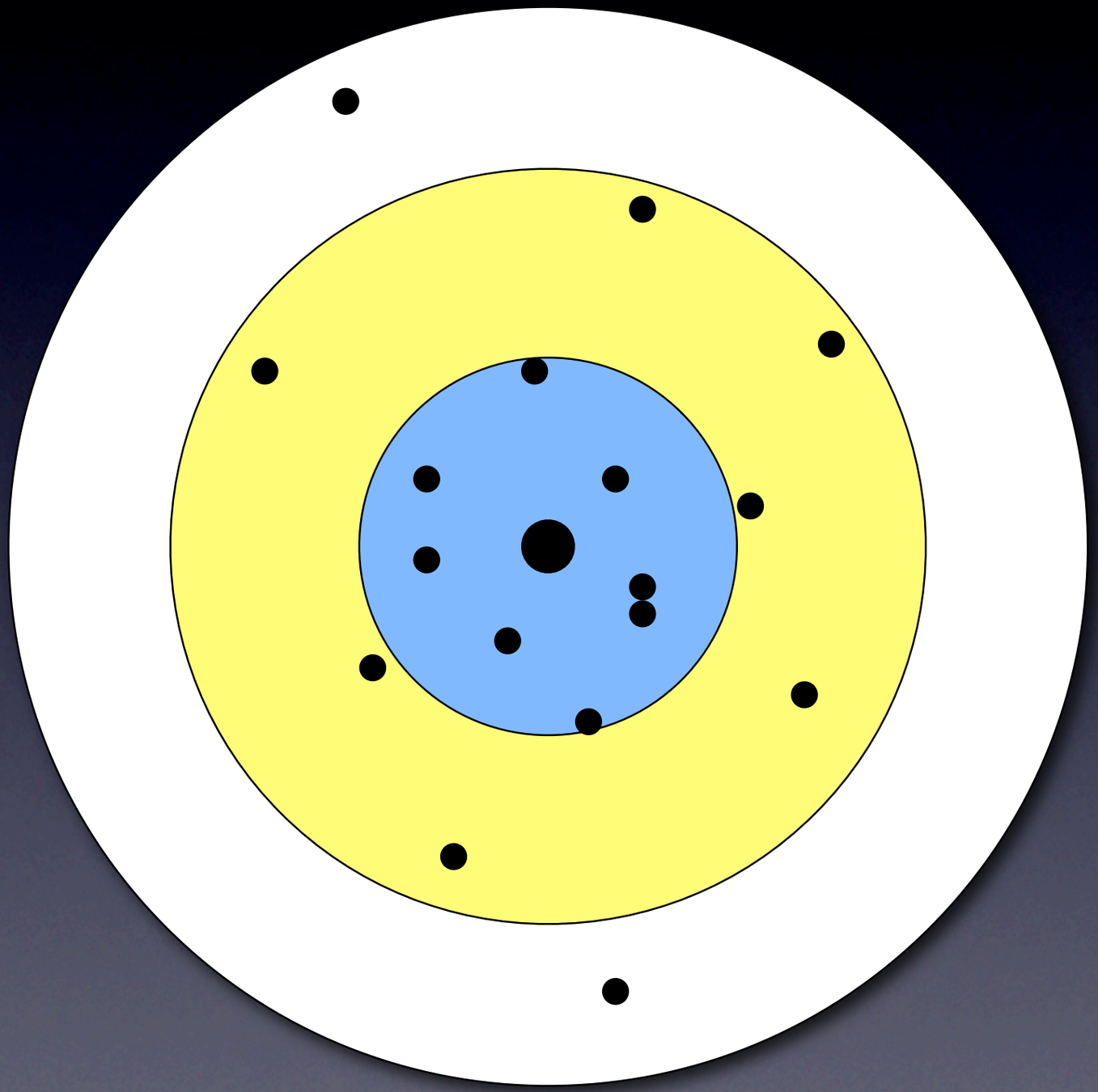
1. Clusters of galaxies



CL 0016+16 at 1cm from OVRO Millimeter Array
Greyscale: X-ray emission from ROSAT

Carlstrom et al., 1996, ApJ 456:L59

1. Clusters of galaxies
Schematic cluster diagram



Black = galaxies
Blue = X-ray emission
Yellow = SZ effect
White = dark matter

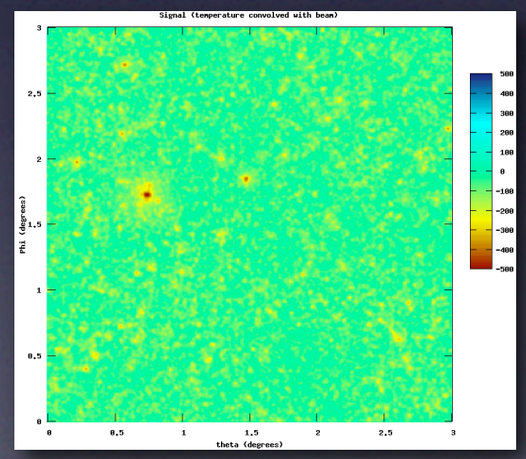
1. Clusters of galaxies
Cosmological probes

- Suggests CMB is primordial [1]
- Can measure distances and the Hubble parameter [2,3]
- Number counts can be used to obtain cosmological parameters [4]
- Problem: confusion [5]

1: Birkinshaw, 1999, Phys. Rep. 310:97
2: Reese et al., 2002, ApJ 581:53
3: Birkinshaw et al., 1991, ApJ 379:466
4. Battye & Weller, 2003, Phys. Rev. D 68:083506 and references therein
5. Lancaster et al., 2004, MNRAS 359:16

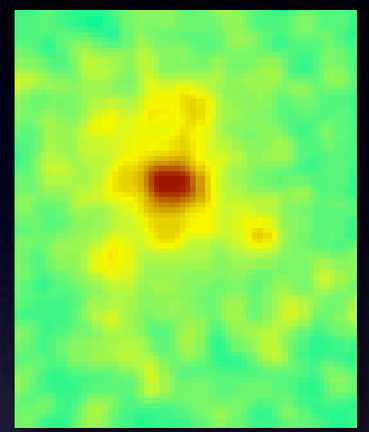
2. Building a Virtual Sky
a. Cosmology

- CMB anisotropies from the power spectrum (from CAMB) [1]
- Either randomly distribute clusters, or use N-body simulations, e.g. Pinocchio [2]
- Use theoretical mass and redshift distributions [3]



1: Lewis et al., 2000, ApJ 538:473; www.camb.info
2: Monaco et al., 2002, MNRAS 331:587
4. see e.g. Battye & Weller, 2003, Phys. Rev. D 68:083506

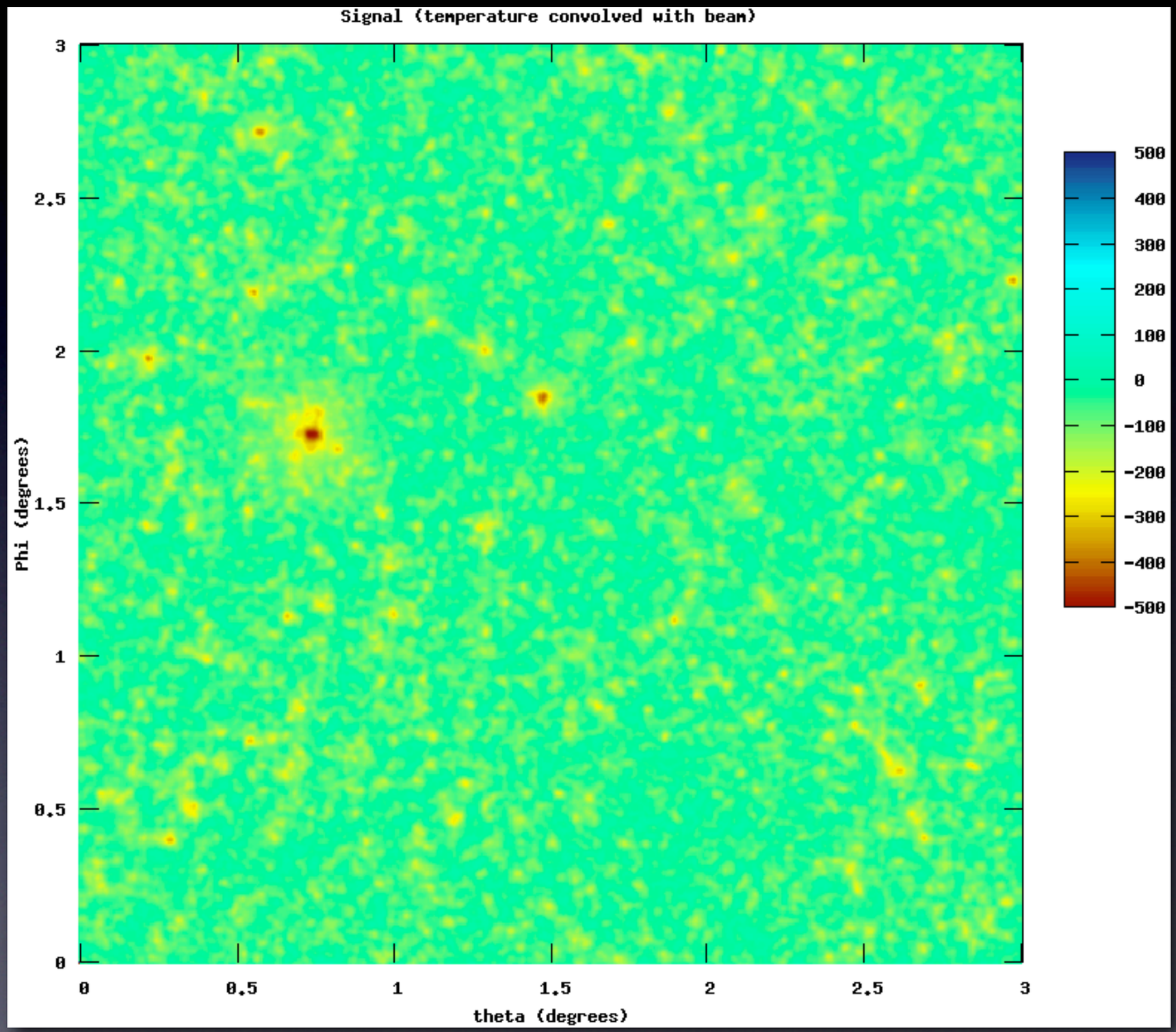
2. Building a Virtual Sky
b. Cluster model



- Know θ, ϕ, z, M
- Need to calculate $n_e(r)$, $T_e(r)$
- Two cluster components - gas and dark matter - so two profiles
- Assume isothermality, standard profile, spherical symmetry to create a cluster model [1]

1. e.g. Battye & Weller, 2003, Phys. Rev. D 68:083506

2. Building a Virtual Sky

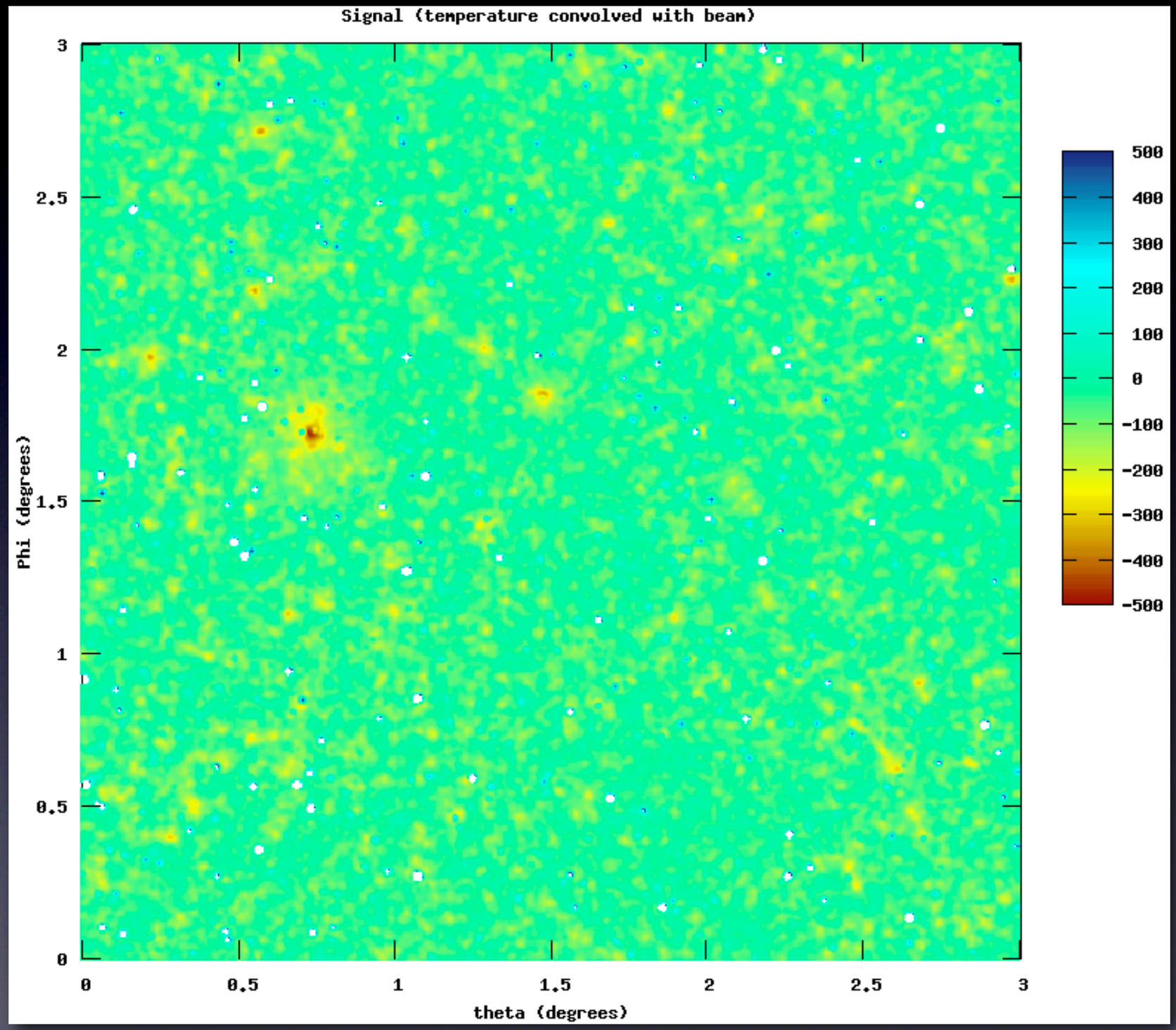


An example

2. Building a Virtual Sky
c. Foregrounds and noise

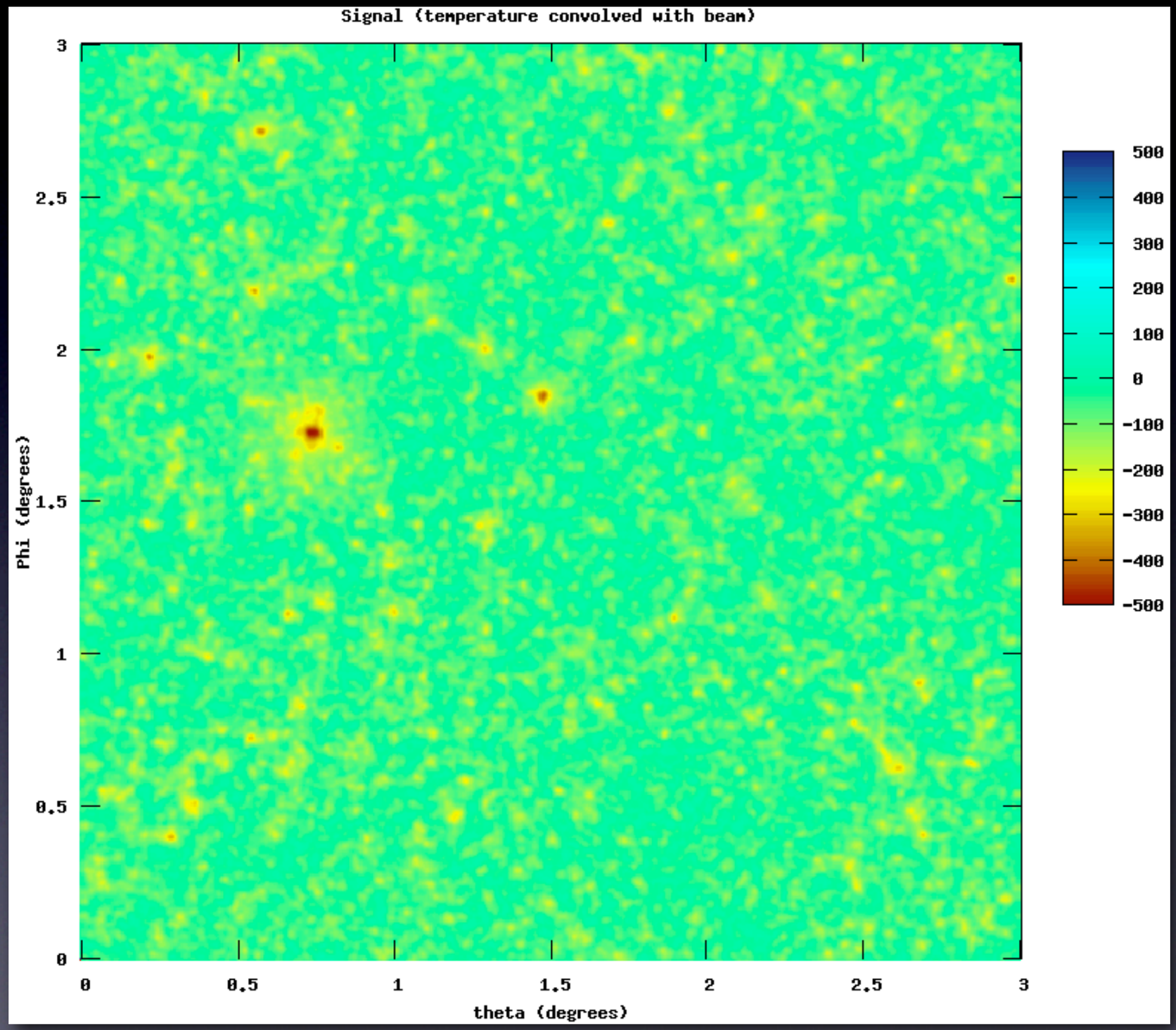
- Dusty galaxies (infrared point sources)
- AGN (radio point sources)
- + other unresolved sources
- Our galaxy
- Tropospheric turbulence
- Receiver noise and imperfections

2. Building a Virtual Sky



With point sources

2. Building a Virtual Sky



Without point sources

3. The One Centimeter Receiver Arrays

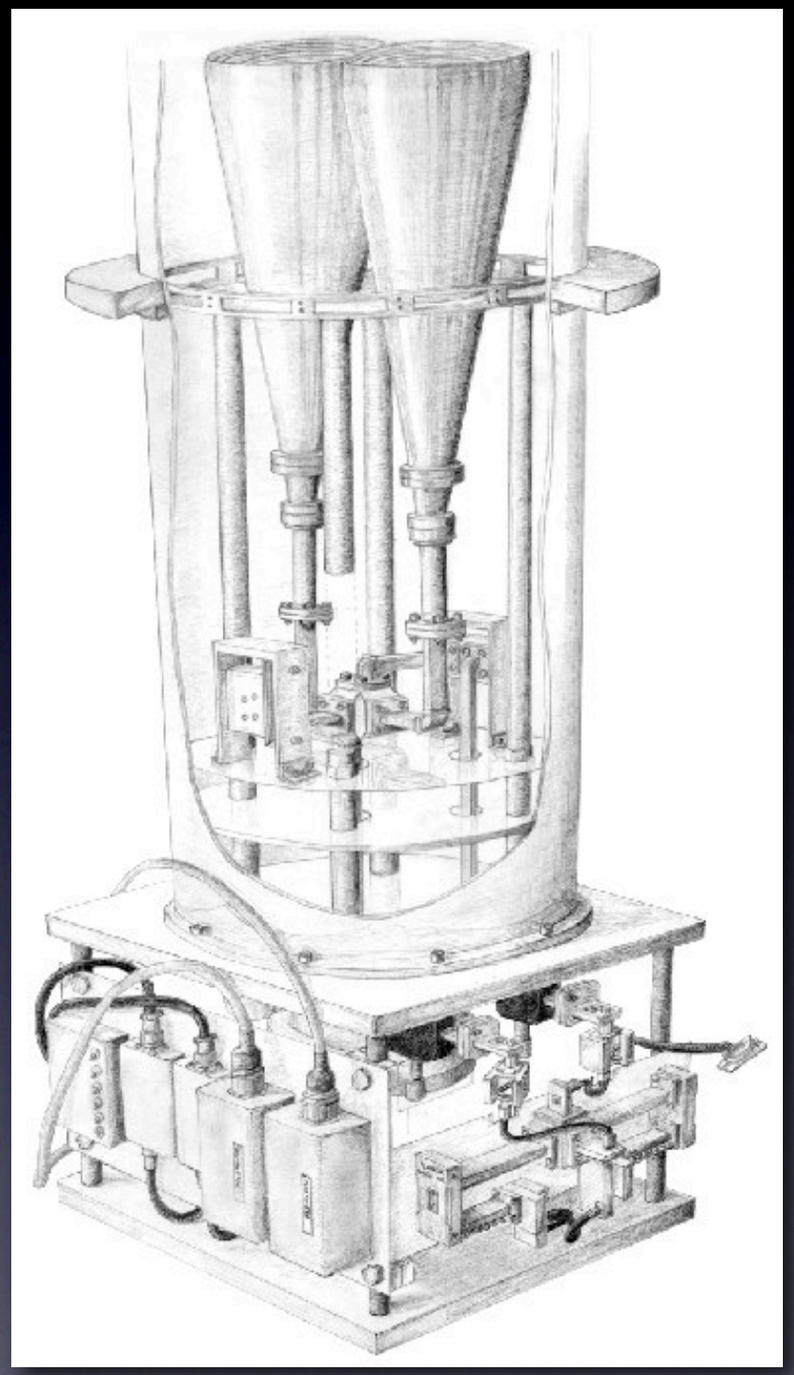
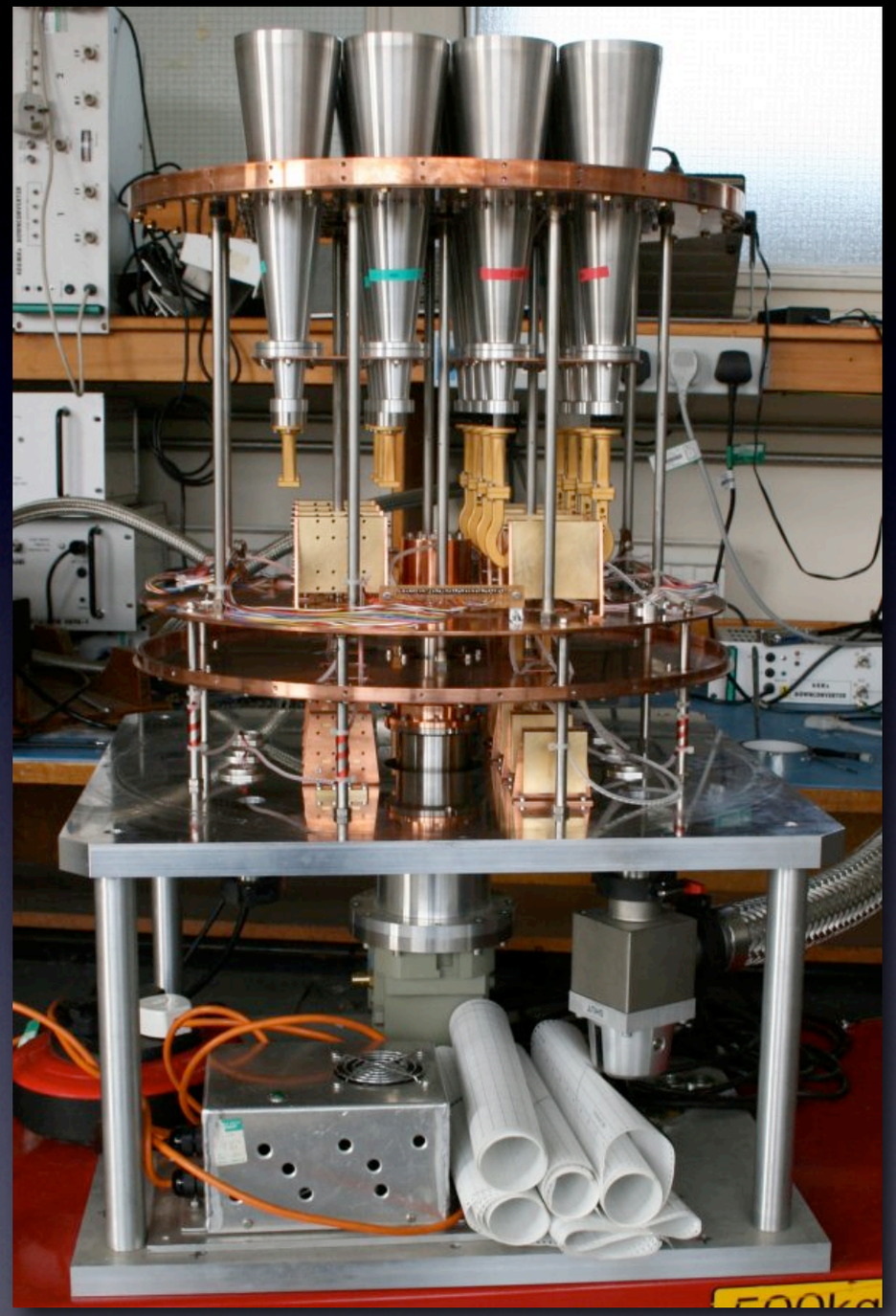


Image credit: Stuart Lowe

OCRA-p (prototype)

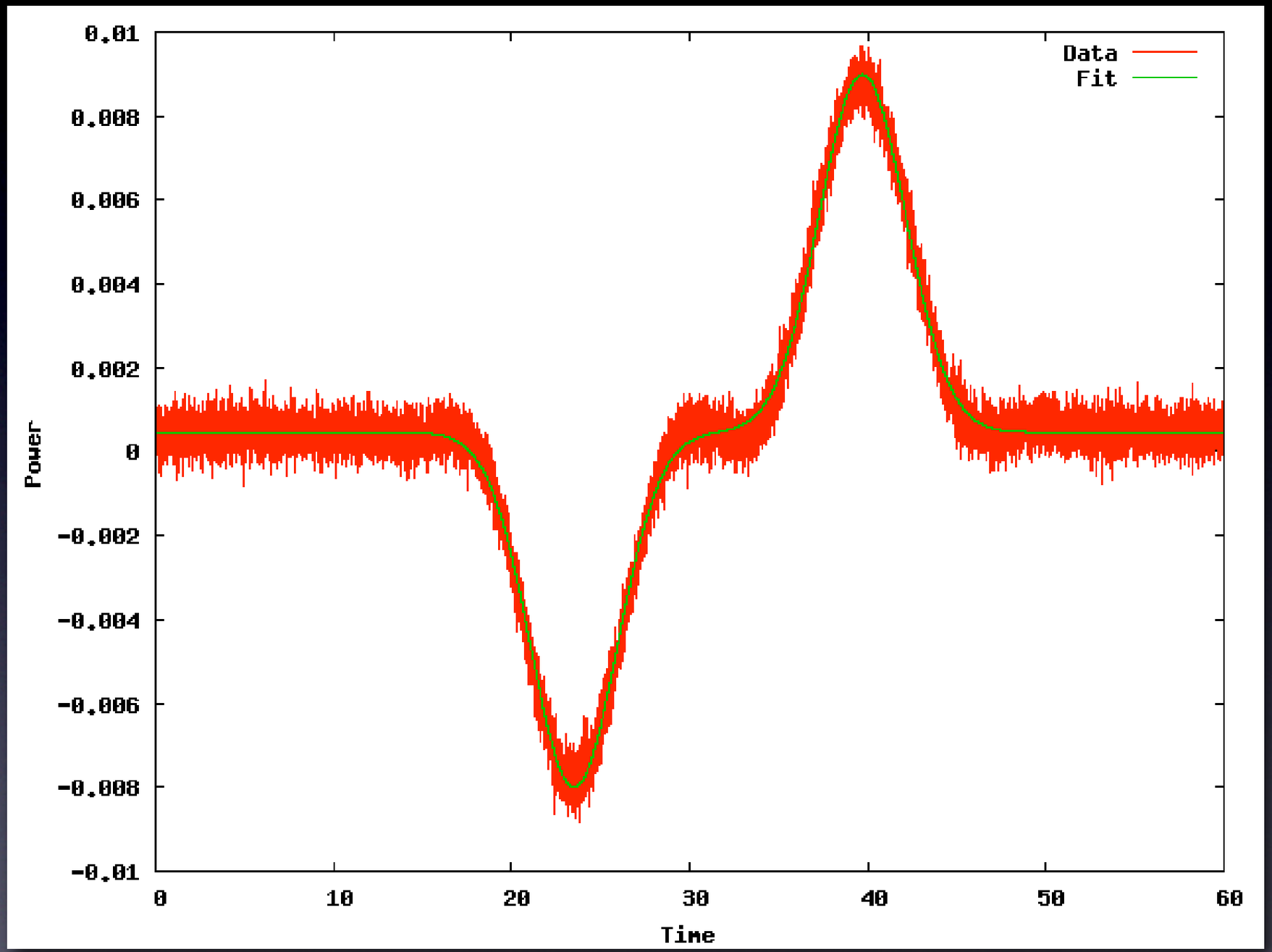


OCRA-F (FARADAY)

3. The One Centimeter Receiver Arrays

32m telescope at the Torun Centre for Astronomy

3. The One Centimeter Receiver Arrays



Simulated scan across a point source from an OCRA-F pair

3. The One Centimeter Receiver Arrays

- Results so far:
  - Lowe et al. (2007), "30 GHz flux density measurements of the Caltech-Jodrell flat-spectrum sources with OCRA-p", arXiv: 0707.3368
  - Lancaster et al. (2007), "Preliminary Sunyaev-Zel'dovich observations of galaxy clusters with OCRA-p", MNRAS, 378, 673

  ... and more to come

4. Future work

- Improvements to the (Virtual) Sky
- Understanding and modeling the 30GHz atmosphere
- Optimising the observational strategy
- Commissioning of OCRA-F
- Blind surveys for point sources
- Follow-up for Planck cluster survey
- First blind survey for SZ clusters?

... watch this space in 2008!