Cosmology with the South Pole Telescope

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What is the Big Picture?
How does SPT fit into it?
Where are we now?


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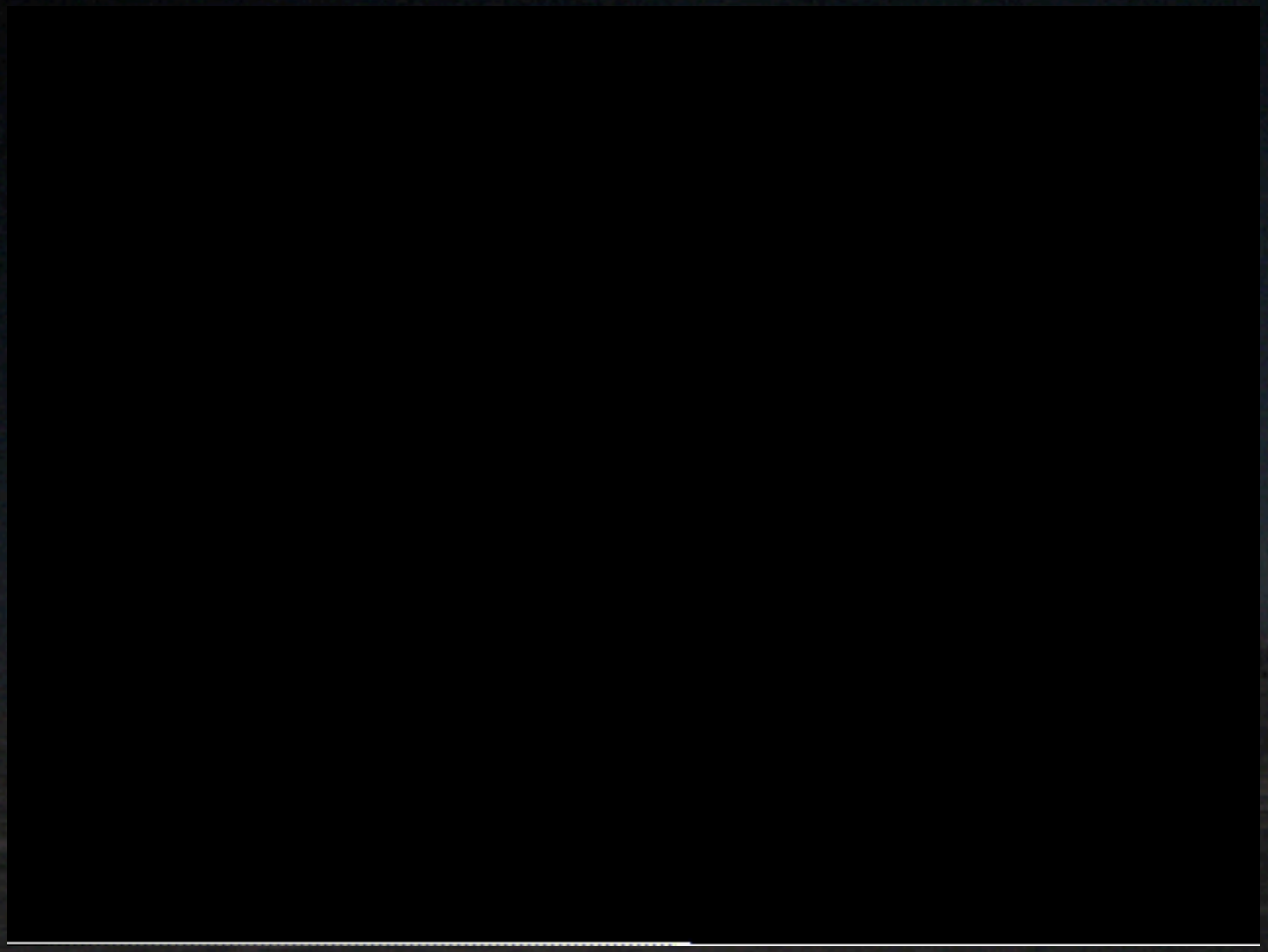
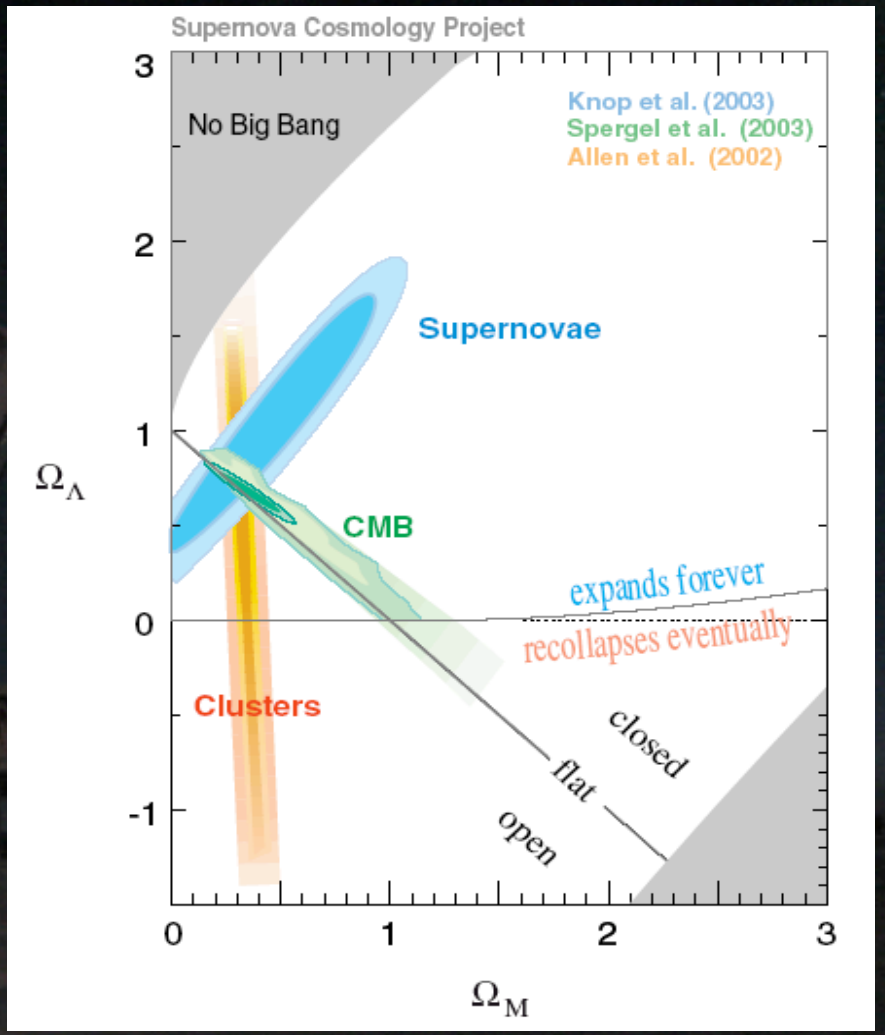
The Current Story



Movie by A. Kravtsov

- Primordial distribution of density fluctuations
  - Dominated by Cold Dark Matter
  - Harrison-Zeldovich spectrum
- Evolves gravitationally
  - small structures form first
  - Dark Energy kicks in recently
- Seeds from inflation
  - Provides initial density fluctuations
  - flatness and isotropy
  - makes monopoles hard to find!
- Better known as inflationary-ΛCDM or the concordance model of cosmology

Evidence arises from complimentary precision measurements



What else would we like to know?

- CDM: primordial distribution
  - Is it really consistent with a scale-invariant spectrum?
  - Normalization has degenericies with Ω_M
- What's up with Λ?
  - Measure its effect on structure formation
- Inflation
  - Did it really happen?
  - Can we say something more specific about it?


What is the Big Picture?
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Bigger is better...

SPT Collaboration

THE UNIVERSITY OF CHICAGO

John Carlstrom (P.I)

Steve Padin (Proj. Manager)

Stephan Meyer
Clem Pryke
Tom Crawford
Jeff McMahon
Clarence Chang

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Ryan Keisler
Lindsey Bleem
Jonathan Stricker

Berkeley University of California

William Holzapfel
Adrian Lee
Helmuth Spieler
Martin White

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Tom Montroy
Zak Staniszewski

Sherry Cho
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Huan Tran
Martin Lueker
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Antony Stark

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Joe Mohr

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Nils Halverson

JPL

Erik Leitch

McGill

Matt Dobbs
Gil Holder
Trevor Lanting

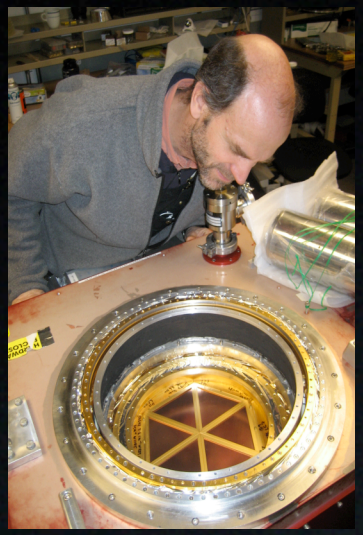
UCDAVIS UNIVERSITY OF CALIFORNIA

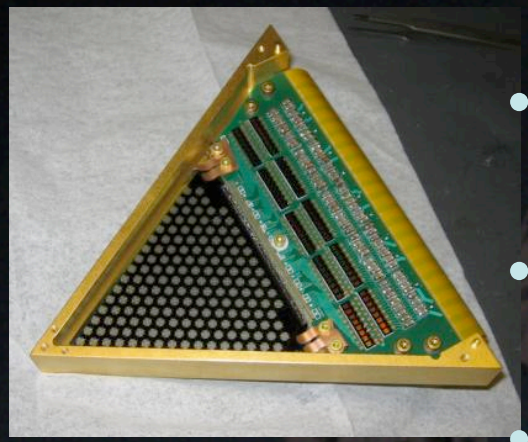
Lloyd Knox
Jason Dick

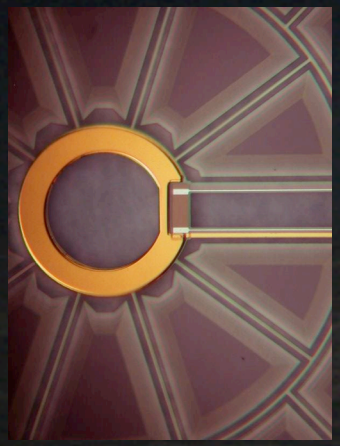
Big mirror

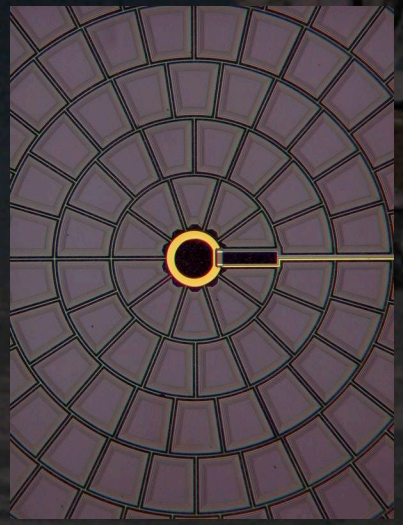
- 10-m primary reflector
- inner 7.5-m illuminated gives 1 arcmin resolution
- 1 degree FOV

Big focal plane







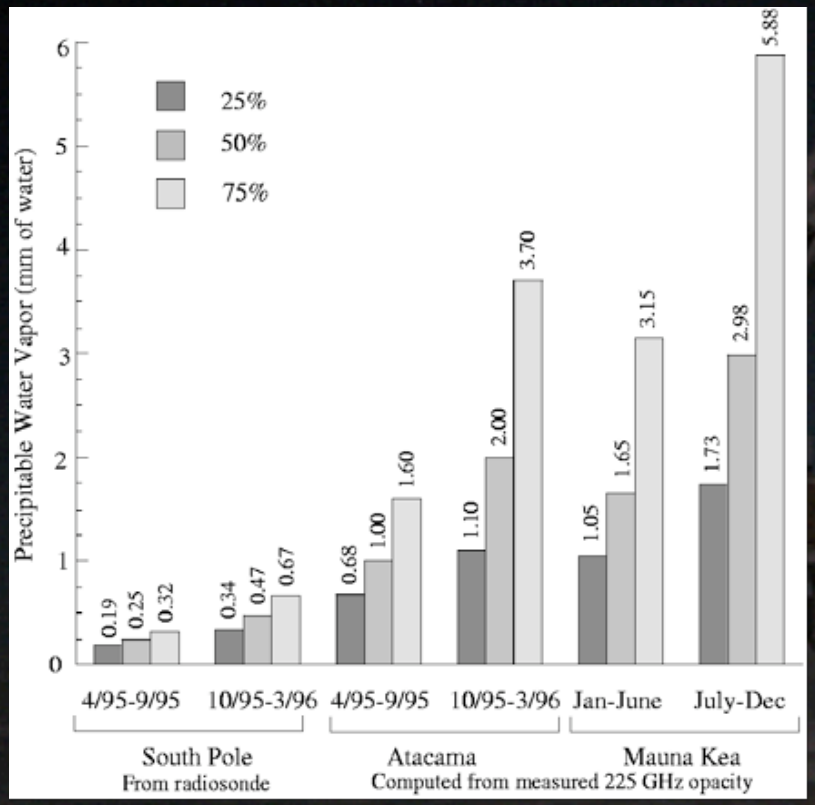


- Bolometers are now background limited (sky noise dominated)
- Use lots of bolometers to integrate noise down faster
- At cryogenic temperatures... would like to minimize wiring
- TES-bolometers
  - good linearity
  - multiplexed SQUID readout
  - micro-fabricate large arrays

More details

- One secondary optic at 10K
  - Cold “Lyot” stop minimizes loading from non-sky sources
- Three levels of shielding
  - Ground shield (2009), co-moving baffels, outer guard ring
- 1.5 arcsec pointing accuracy
- Up to 4 deg/sec scan rate

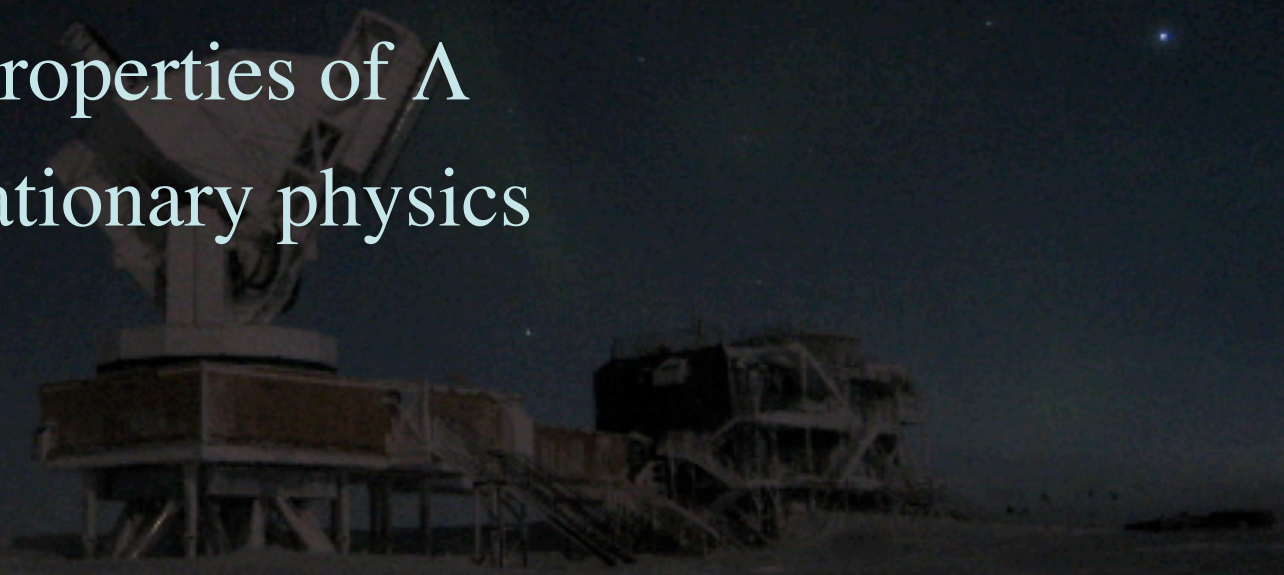
Seeing at the South Pole



- High and Dry
- Stable atmosphere
- Dark during the Winter
- Good for astronomy... also good for astronomers??

Science Goals

- Constrain primordial fluctuation spectrum
- Measure properties of Λ
- Probe inflationary physics



Mapping primordial CDM density fluctuations

- Map high-ℓ CMB
- Use large ℓ range to constraint spectral index for the distribution of primordial fluctuations
- Use tSZ to constrain normalization

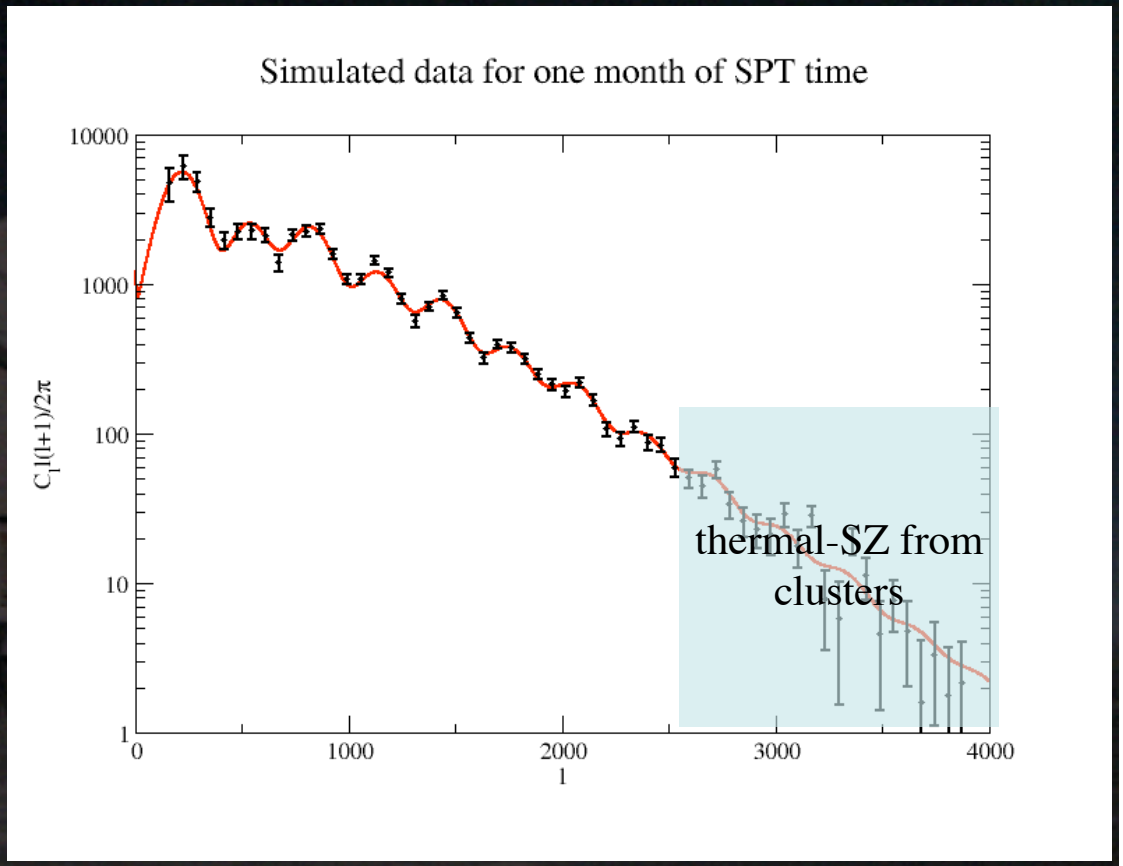
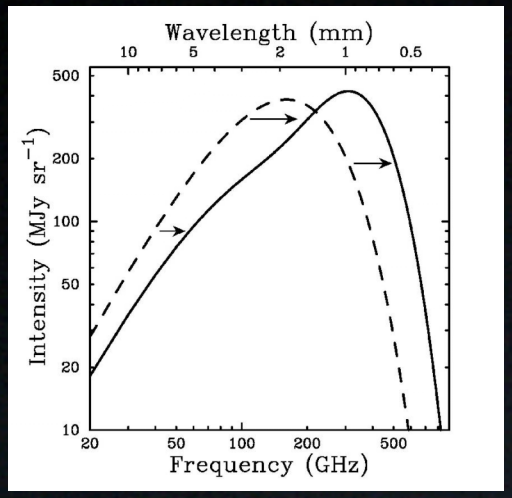
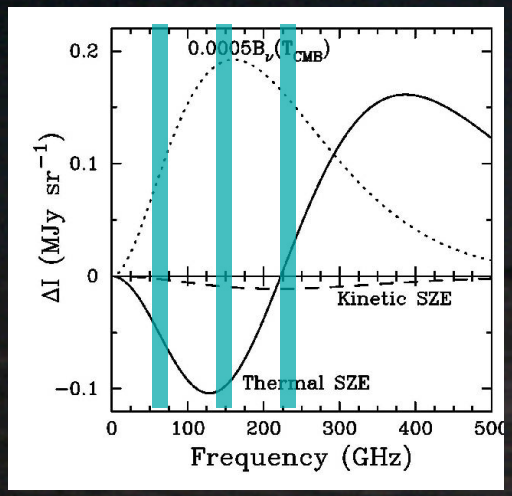


Figure from J. Dick

Aside: thermal Sunyaev-Zeldovich

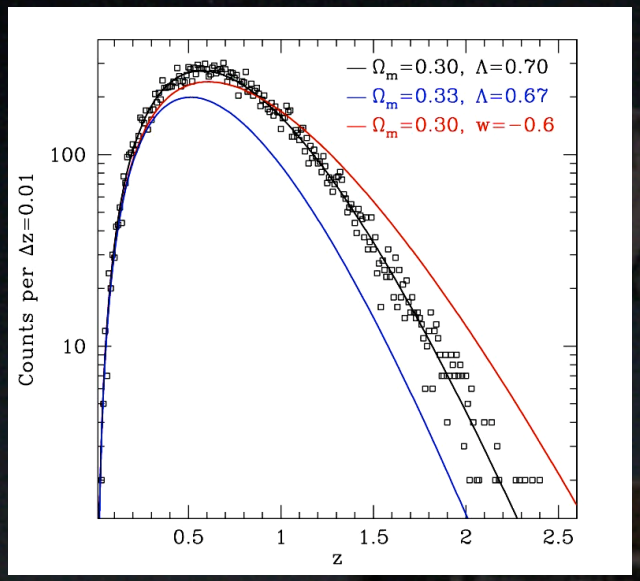


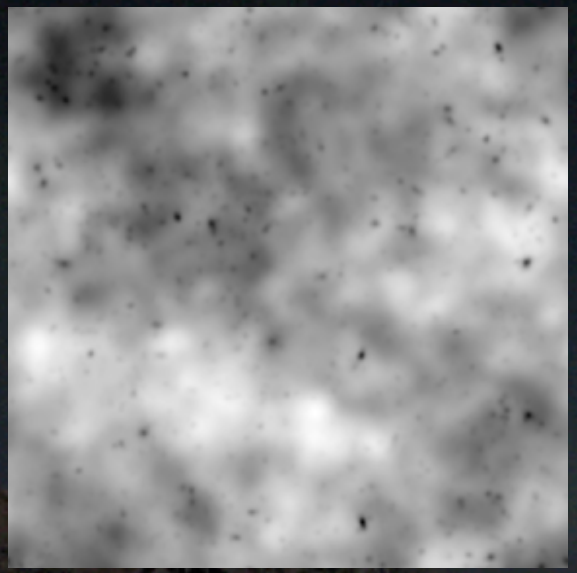


- Hot gas from clusters scatter CMB photons
- CMB hotter in the past cancels red-shifting of photons... red-shift independent!
- Integrated distortion is proportional to total thermal energy in the gas... related to cluster mass

Carlstrom, Holder, Reese Ann. Rev. Astron. Astrophys. 40:643-680, 2002

Measuring impact of Λ on structure growth

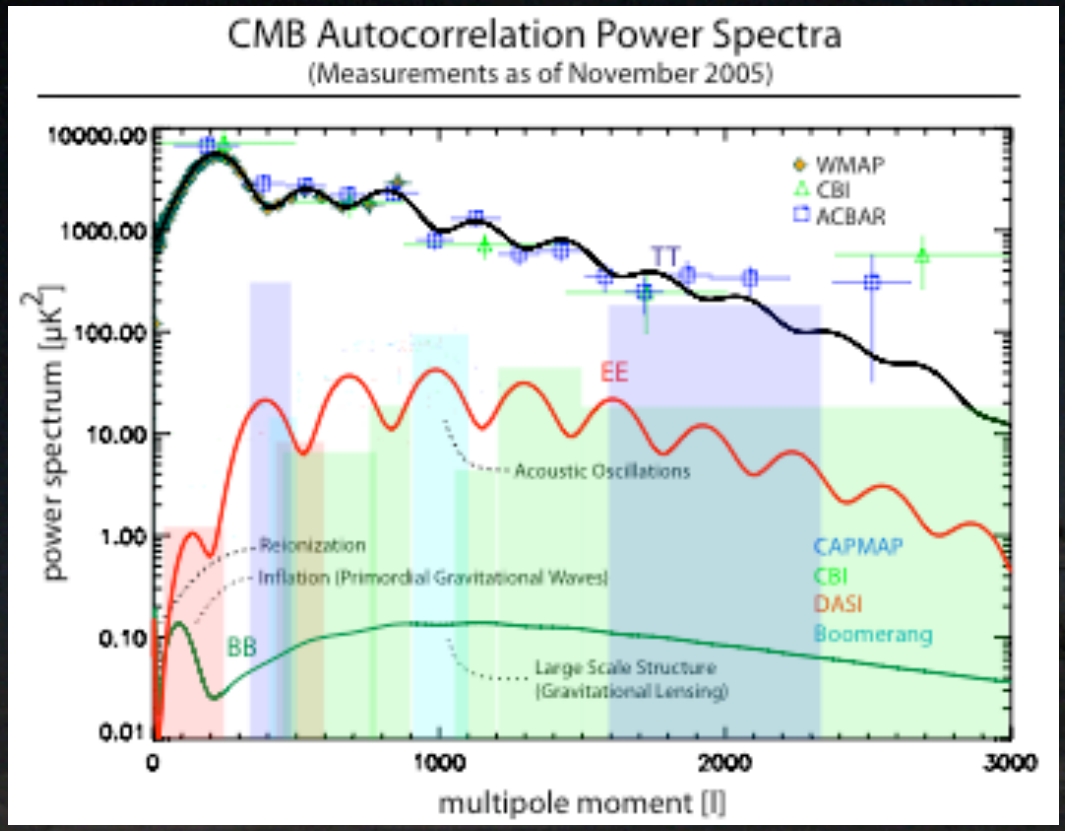




Figures courtesy of T. Crawford & G. Holder

- Use tSZ to find all massive clusters
- Combine with photometric redshifts (DES) to obtain dN/dMdz

Probing inflation... polarization!

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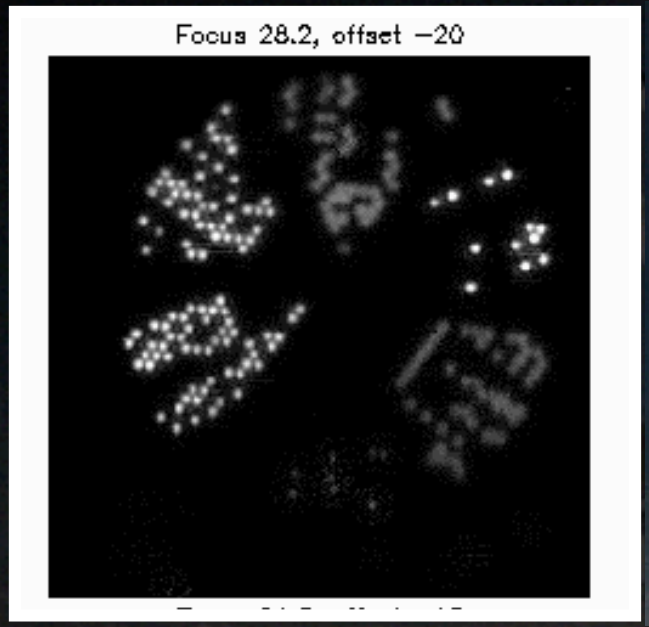
Telescope construction... Austral summer 2006-7

The crew...

First light (Feb 16,2007) and then darkness...

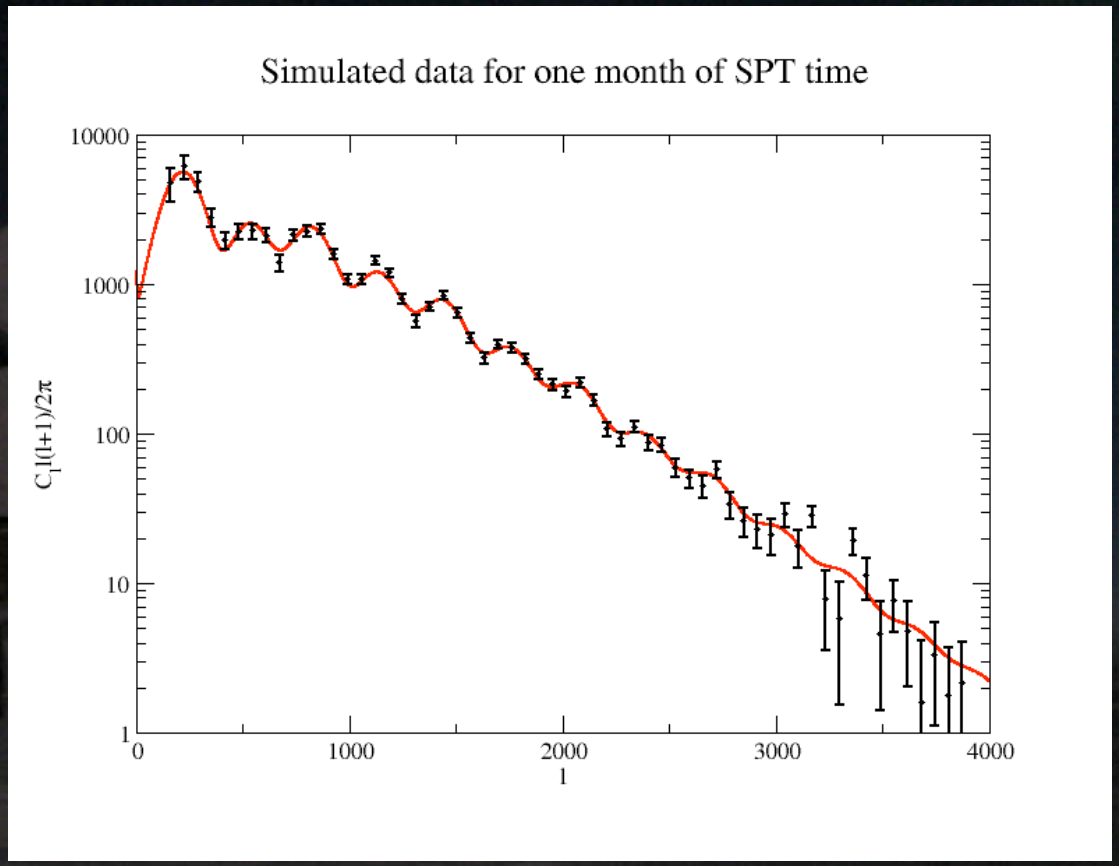


Current status

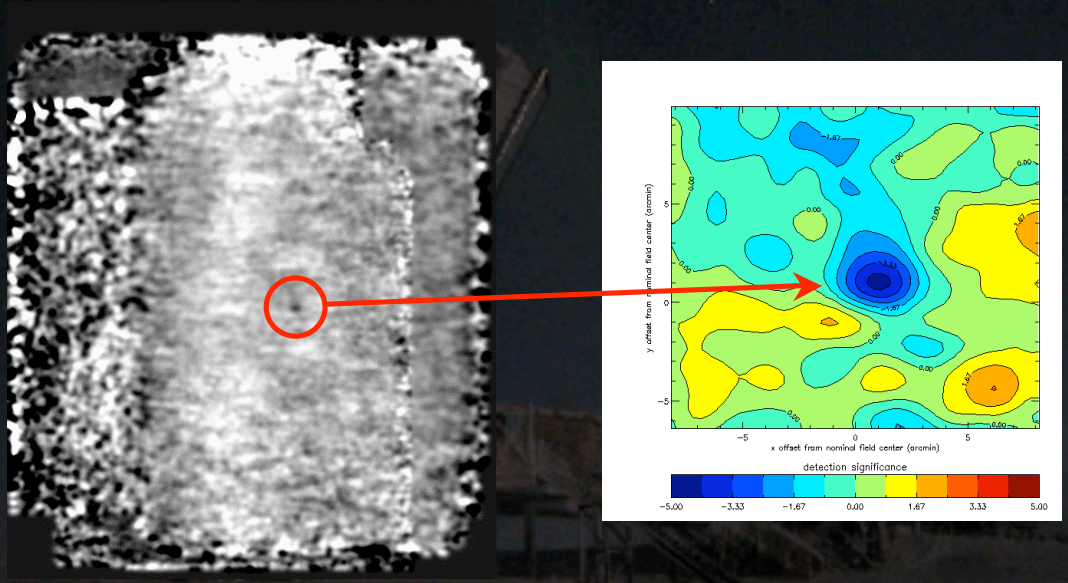
- Diffraction limited beams
  - 1 arcmin at 150GHz
- 480 bolometers live per night
  - largest bolometer focal plane at these frequencies!
  - dominant loss from cryogenic wiring/electronics issues
- Noise a little high from initially conservative detector parameters
- Optical throughput is a little low... don't know why
- Mirror surface of 40 μm rms (target 60)

High-ℓ CMB expectations

- Simulation of MASTER Monte-Carlo CMB extraction pipeline
- Inputs for noise from actual detector performance on SPT
- No point sources or foregrounds
- Only first attempt



Can you see the cluster?



Cluster survey

- Abell AS1063 observed (>5σ in ~1 hour observing)
- Grinding away on BCS fields
  - existing optical data
  - ultra-deep on small region for study of systematics
- Data is flooding in. Anyone want to help?

Next season

- Returning to Pole with a new focal plane
  - lower noise
  - higher coupling
- Repair/replace cryogenic electronics
  - increase yield
- Improve cryogenic performance
  - increase duty cycle on sky

The future of SPT: SPTpol

- Systematics are the issue
- "Cross-polarization"
  - incorrect polarization angle... confusing one mode for the other
  - inducing polarization... getting polarization when there is none

Xpol and big reflectors

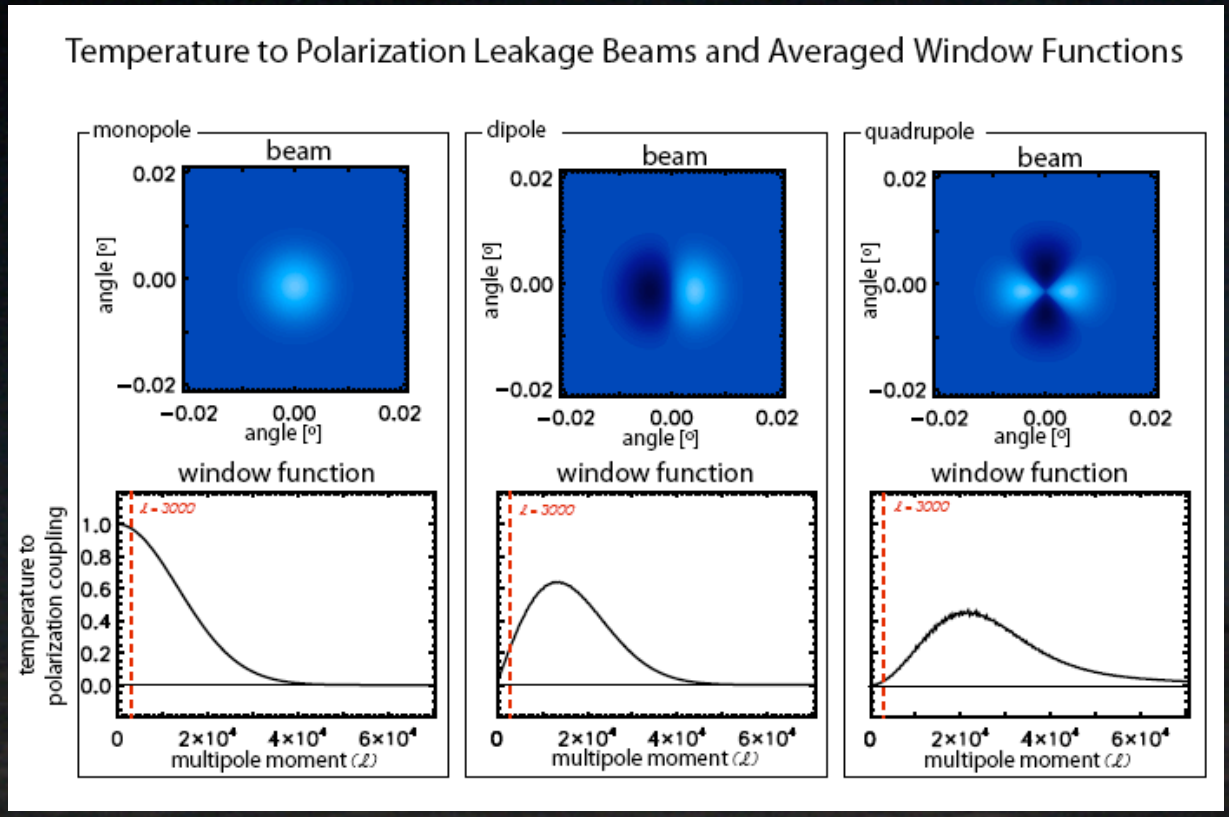
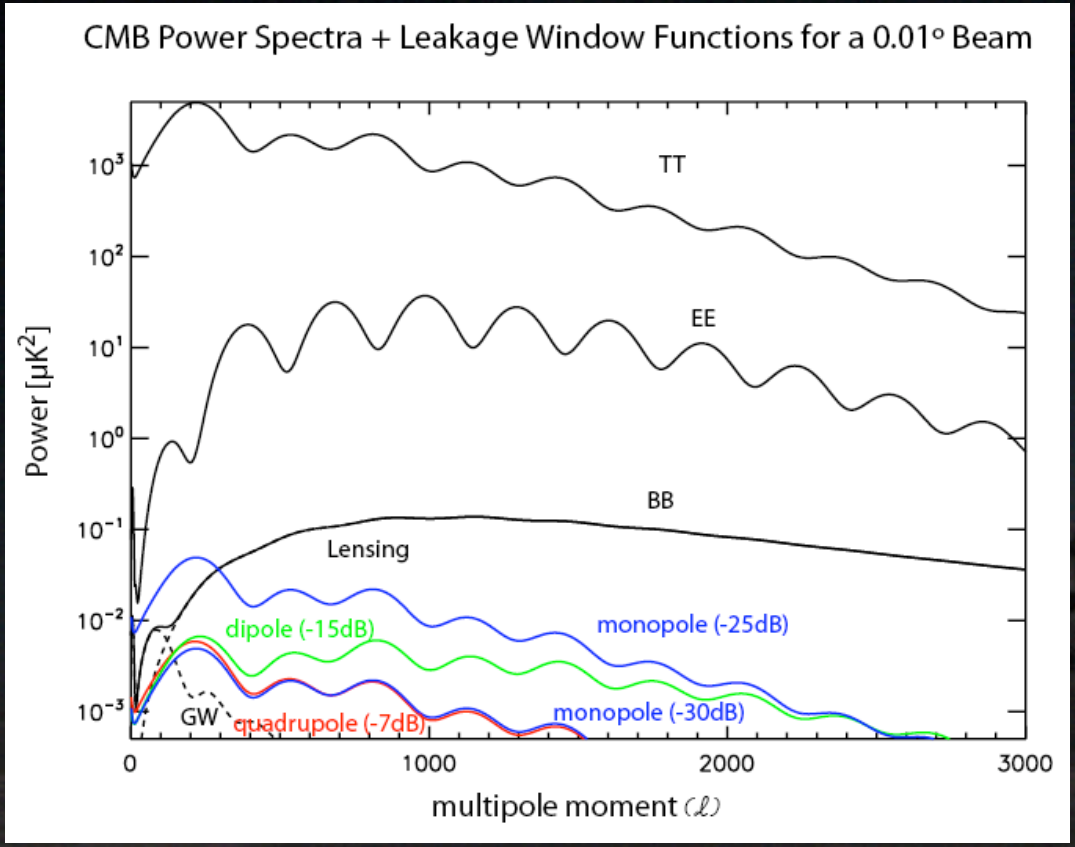


Figure from J. McMahon

Xpol and big reflectors



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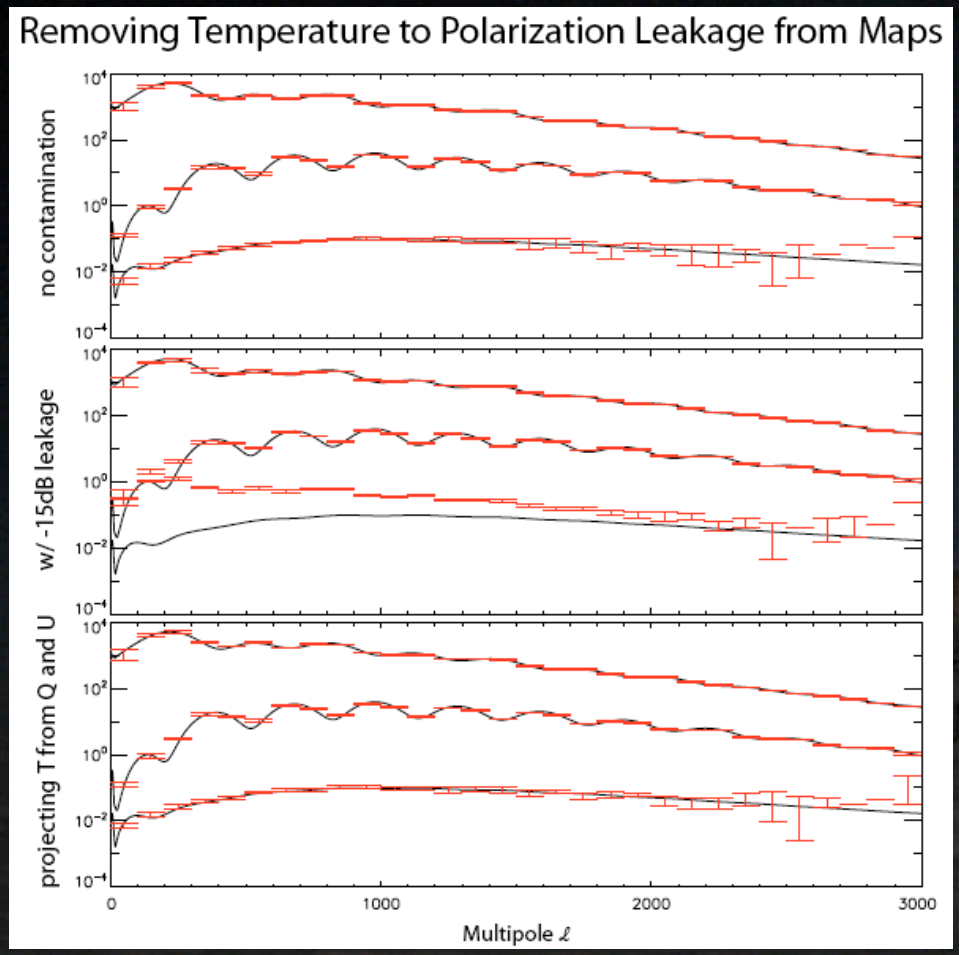
Xpol and big reflectors



- Only monopole leakage matters for $\ell<3000$
- non-crosslinked scans make it easy to identify the contaminated modes
- project out modes to obtain clean spectra

Figure from J. McMahon

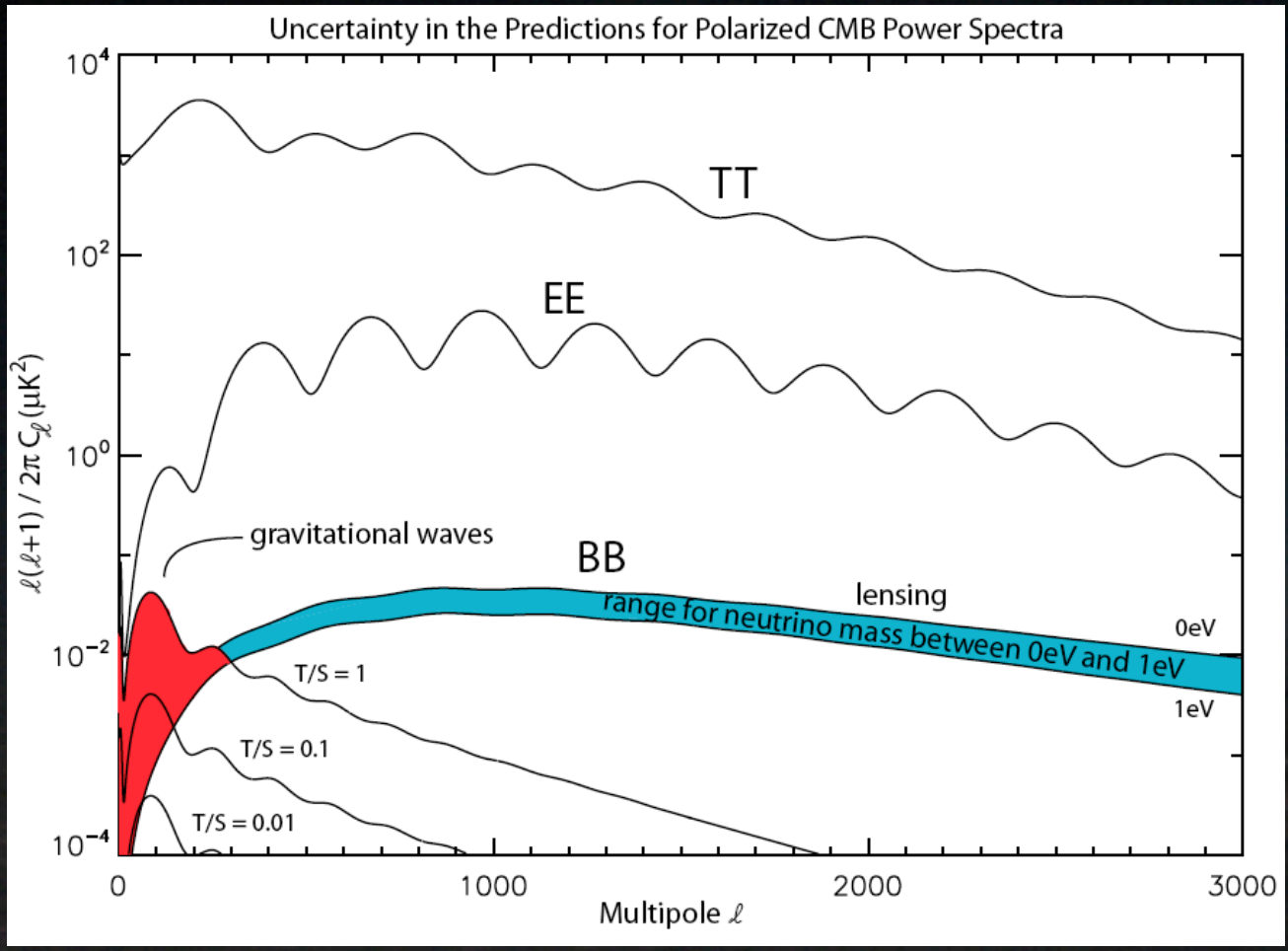
A New Polarization-sensitive focal plane

- Still need lots of detectors (1000 pairs)
- Pairs of detectors need to be well matched to minimize detector induced x-pol
- Major R&D investment
  - new detector initiative with ANL and NIST
  - exploring three different focal plane designs
- Advantages of TESs remain. Upgrade multiplexing readout.

More than cosmology?

- SPT can say a lot about inflationary-ΛCDM
- Can't say what makes up inflaton, Λ, or CDM
- Might have sensitivity to WDM (neutrinos)

Astro-particle physics



Summary

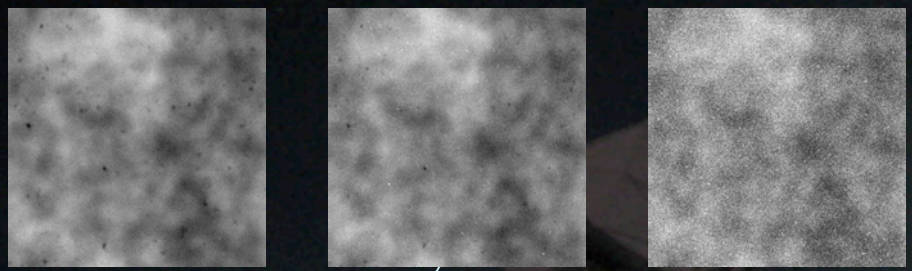
- SPT construction is complete
- High-ℓ CMB will measure amplitude and spectrum of primordial CDM density fluctuations
- Aggressive plan to survey 4000 sq deg cluster survey (measure effect of Λ on growth)
- Developing polarimeter for probing inflation and constrainting neutrino mass
- Bigger is better. Looking for more collaborators for both hardware and data analysis.

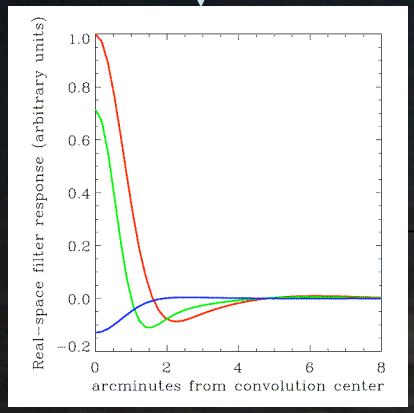
A bright future

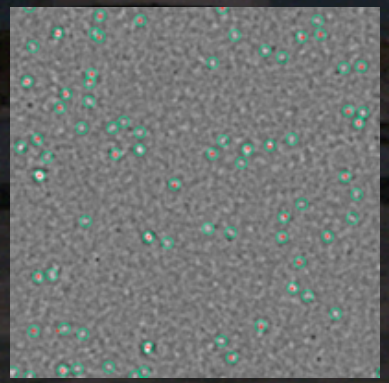
Cluster detection

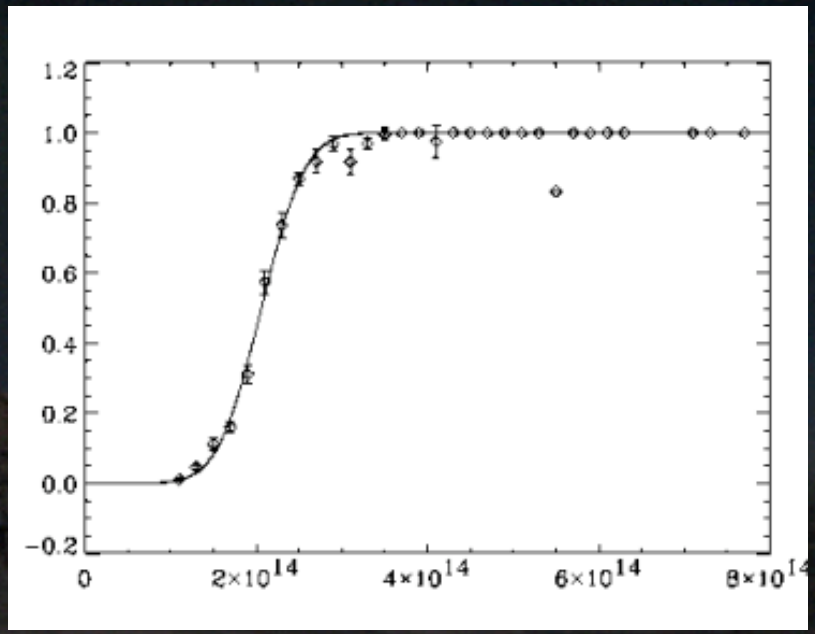
T. Crawford; Schulz & White (2003)

90 GHz 150 GHz 220 GHz



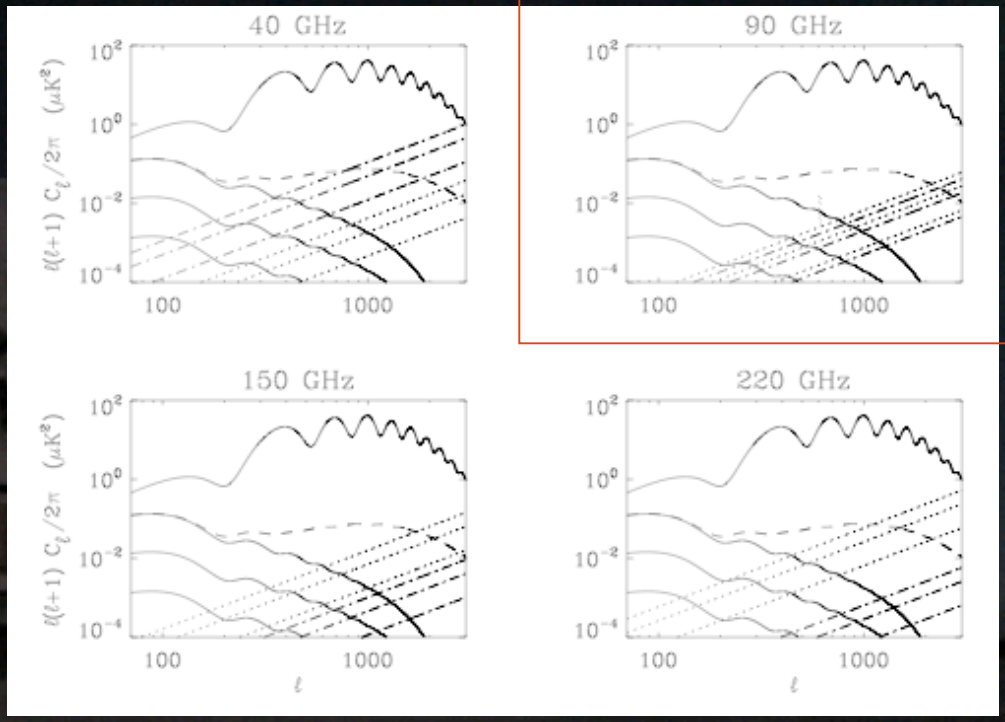




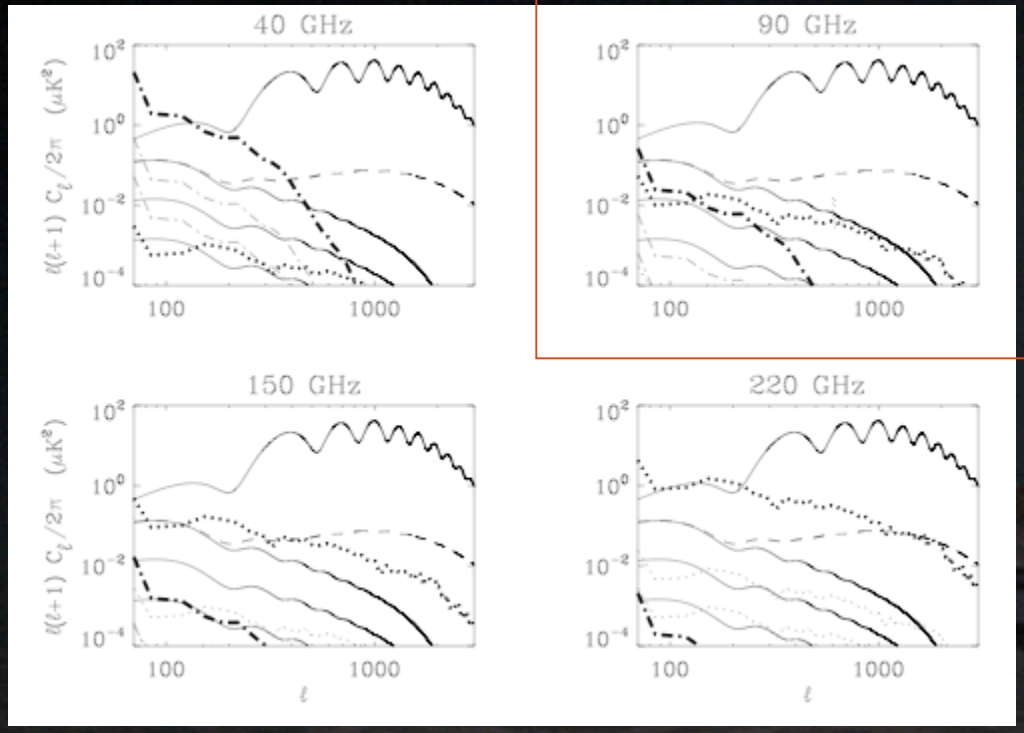


Foregrounds: point sources
(T. Crawford)

- Assume point source flux distribution is the same as other measured regions
- Evolve into bands of interest (β=2.6 for dusty galaxies and β=-0.45 for synchotron emitting AGN)
- Cut at 10 mJy (5σ detection @ 90 GHz is 1 mJy)
- Polarization fractions of 2.5%, 5%, and 7.5%



Foregrounds: diffuse (T. Crawford)



- Synchrotron (Haslam w/ β=-2.7) and dust maps (Finkbeiner et. al. 1999, FIRAS)
- polarization fractions of 5%-15% (synch.) and 2.5%-7.5% (dust)
- Still looks pretty good @ 90 GHz even if 100% polarized