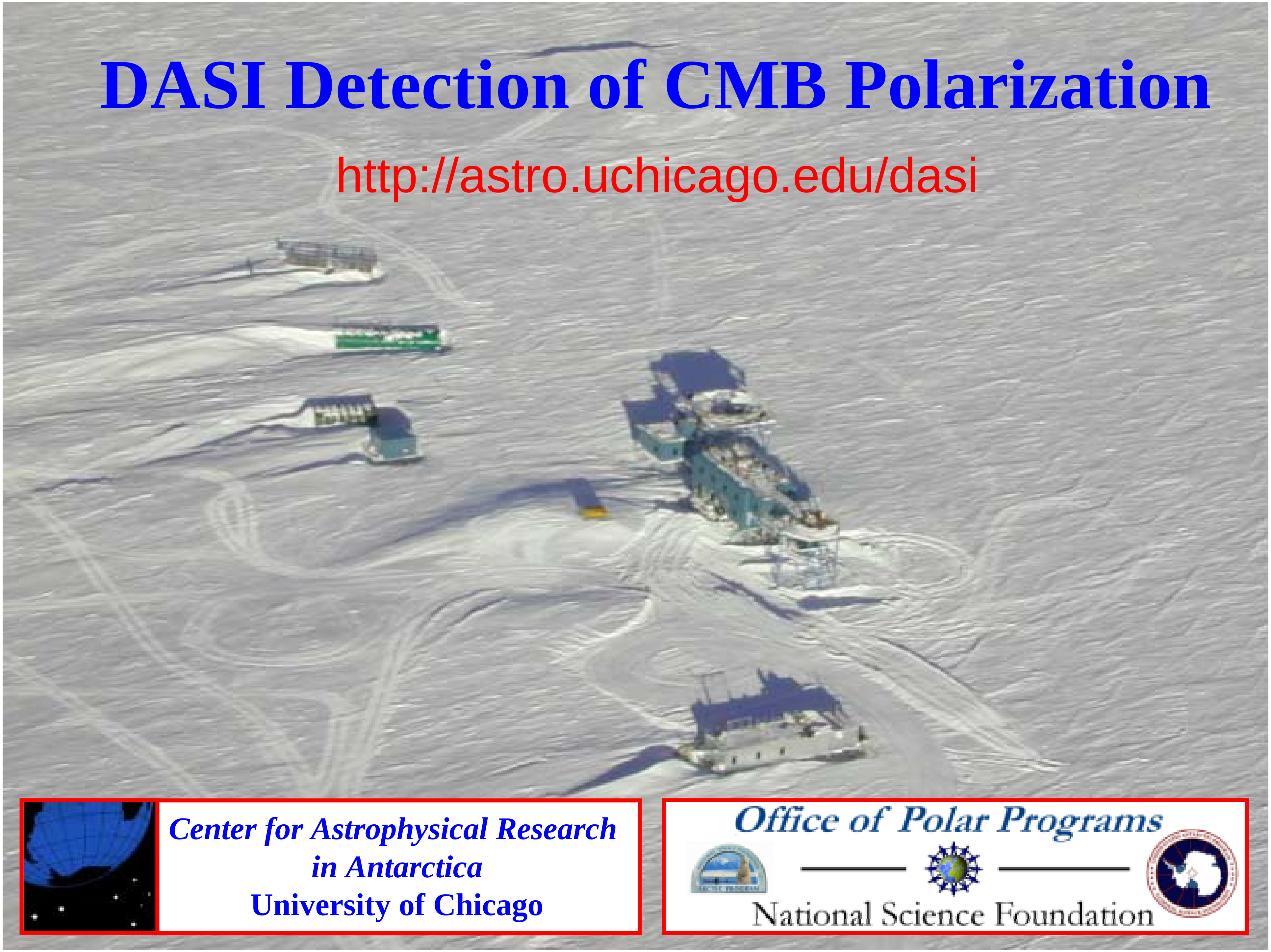
DASI Detection of CMB Polarization

http://astro.uchicago.edu/dasi



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DASI PolarizationTeam

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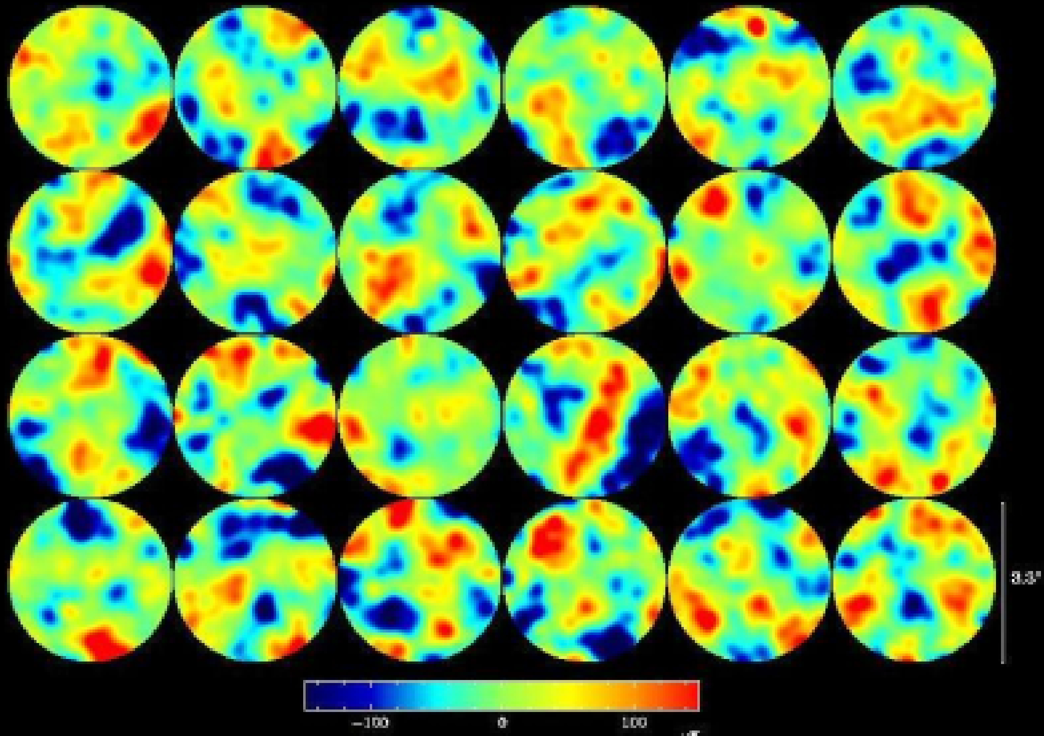
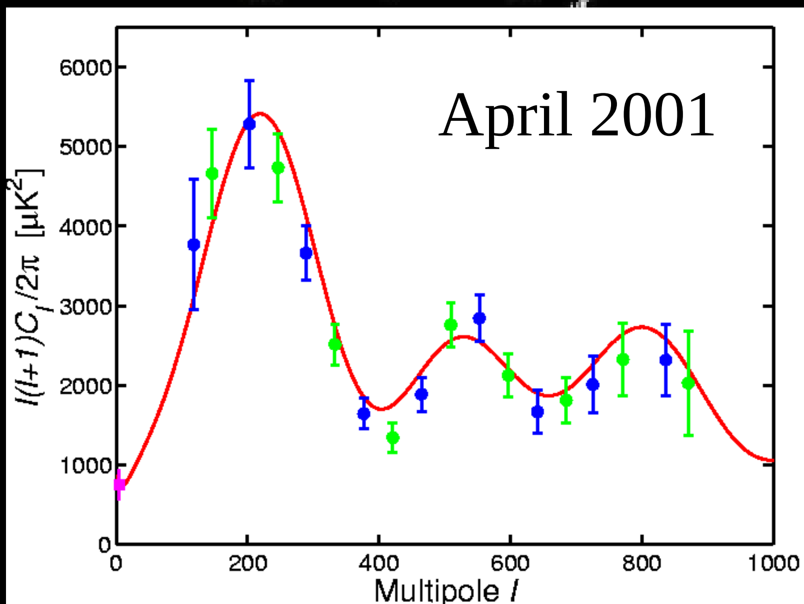
DASI, March 2000

DASI 1st Season Results





The numbers:

Weak h prior, $h > 0.45$
and $\tau_c \leq 0.4$

$\Omega_{TOTAL} = 1.04 \pm 0.06$

$\Omega_B h^2 = 0.022^{+0.004}_{-0.003}$

$\Omega_{CDM} h^2 = 0.14 \pm 0.04$

$n_s = 1.01^{+0.08}_{-0.06}$

Strong h prior, $h = 0.72 \pm 0.08$
and $\tau_c \leq 0.4$

$\Omega_{TOTAL} = 1.00 \pm 0.04$

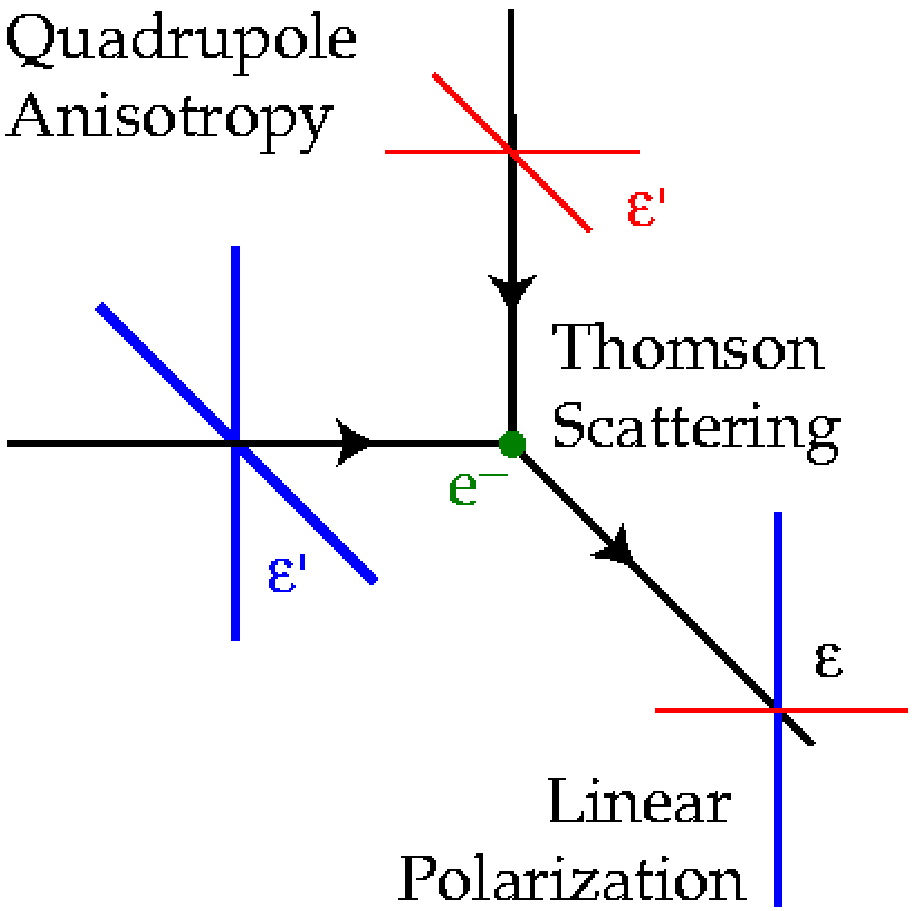
$\Omega_M = 0.40 \pm 0.15$

$\Omega_\Lambda = 0.60 \pm 0.15$

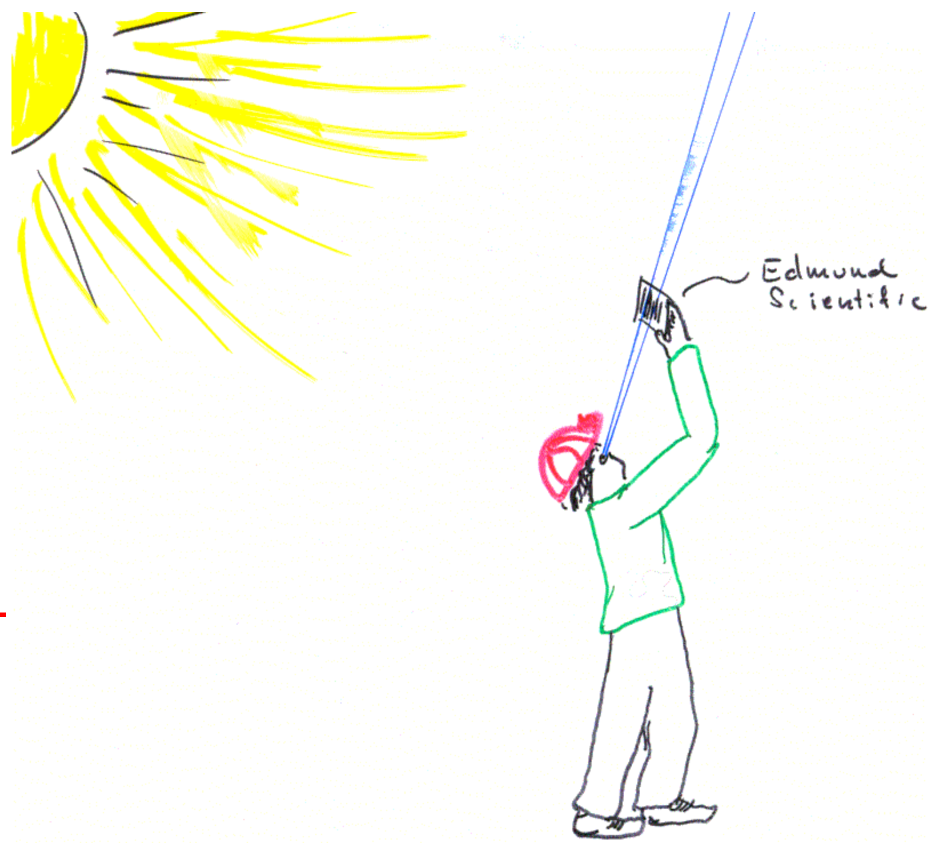
DASI papers I, II & II (astro-ph/0104488 – 90)

CMB Polarization

Due to Thomson scattering –
polarization must be there if theoretical framework is correct



from W. Hu's web page



Why measure CMB Polarization?

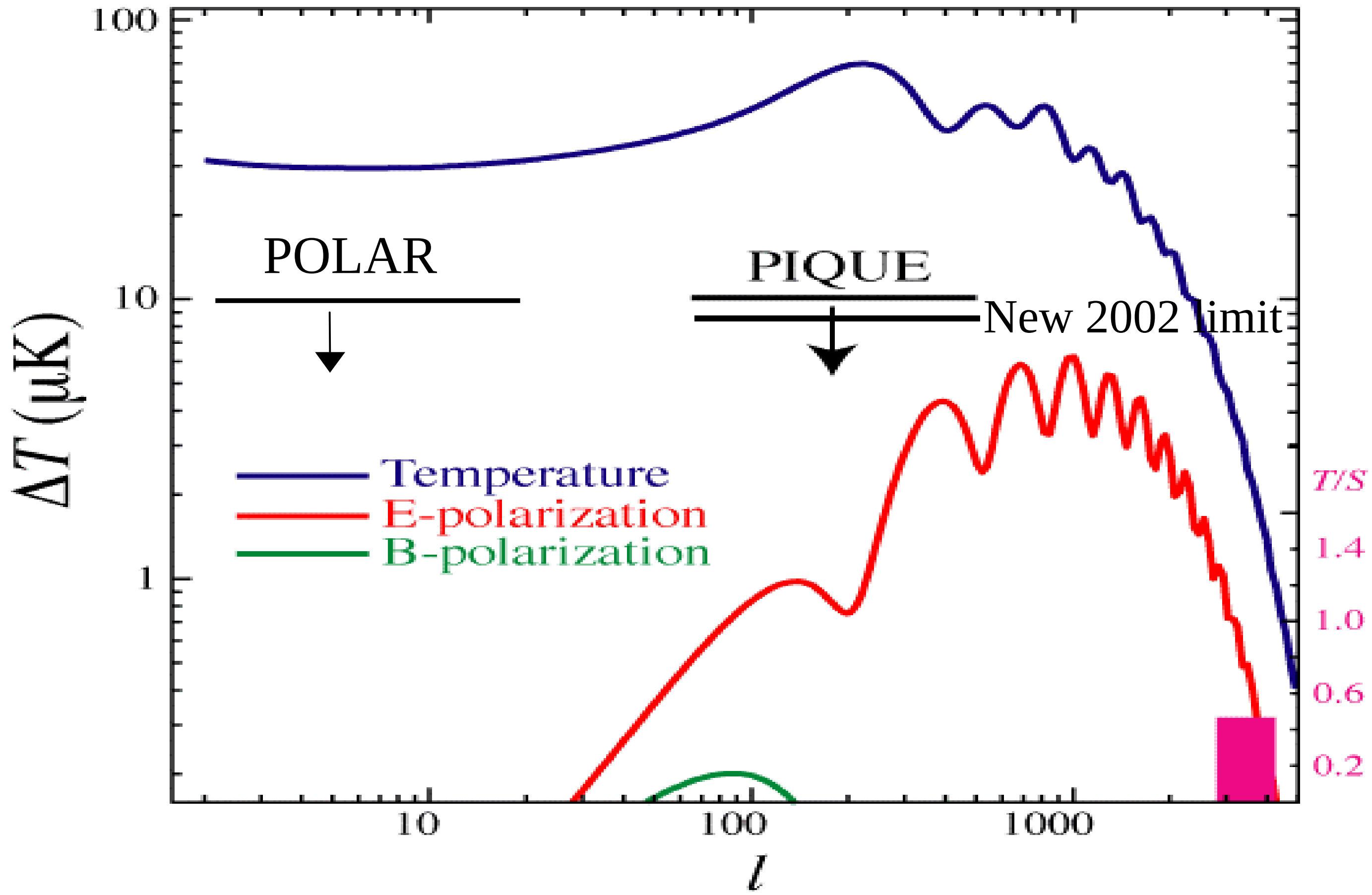
Directly measures dynamics in early universe

Critical test of the underlying theoretical framework
→ if it's not there at the predicted level, we're back to the drawing board.

Future:

- Can triple the number of CMB observables
  → better constraints
- And, eventually, perhaps, measure the primordial gravity wave and directly test Inflation prediction and energy scale (this is going to be hard!)

CMB Polarization

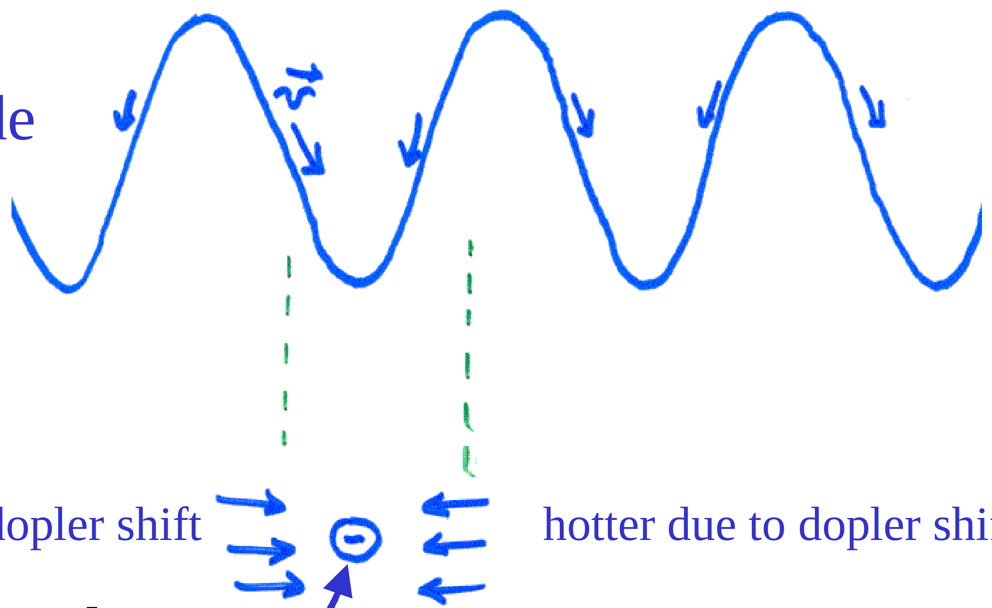


Simultaneous differencing of 2 polarization states

- using correlation receivers with HEMT amplifiers

POLAR: Keating et al. astro-ph/0107013; PIQUE: Hedman et al. astro-ph/0204438

Generating CMB Polarization



Before decoupling:

→ electron 'sees' only a local monopole

During decoupling:

→ mean free path increases and electron 'sees' quadrupole

→ scattered light is polarized

E-mode from density modes (scalar fluctuations) ***has to be there!***

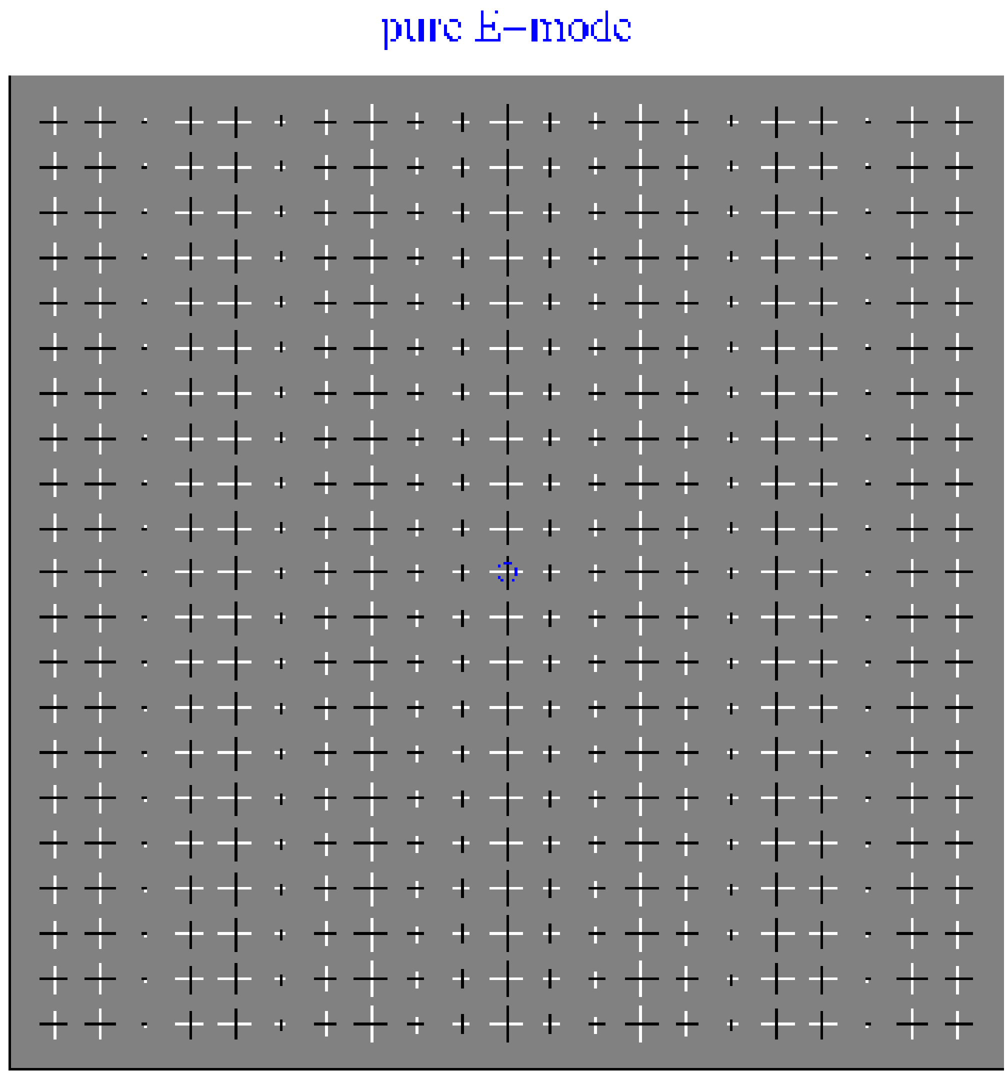
E & B-mode from gravity waves (tensor)

E-mode Polarization (curl free)

Polarization parallel or perpendicular
to wave vector

Density (scalar) fluctuations
generate only E-Polarization

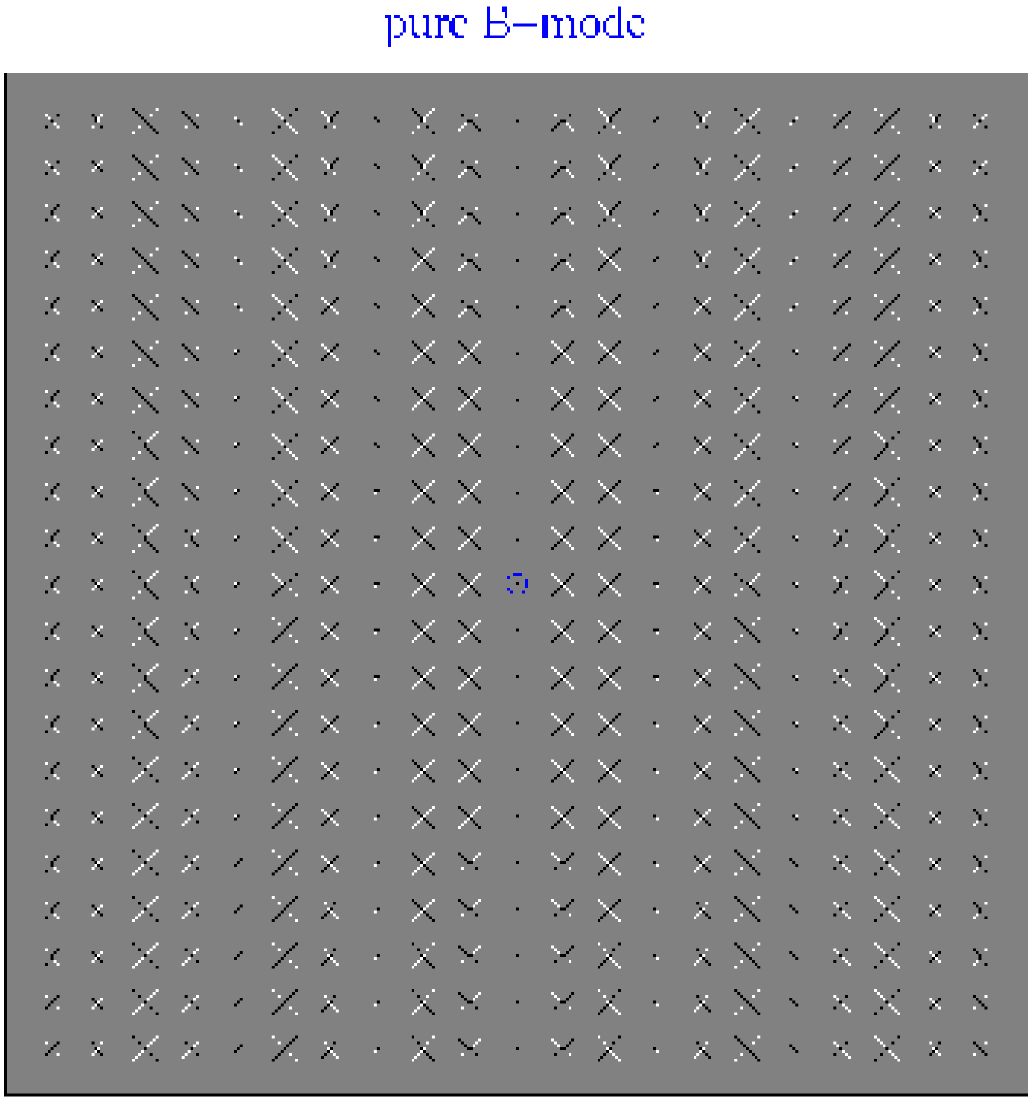
No curl component
(‘Stokes’ law on close loop = 0)



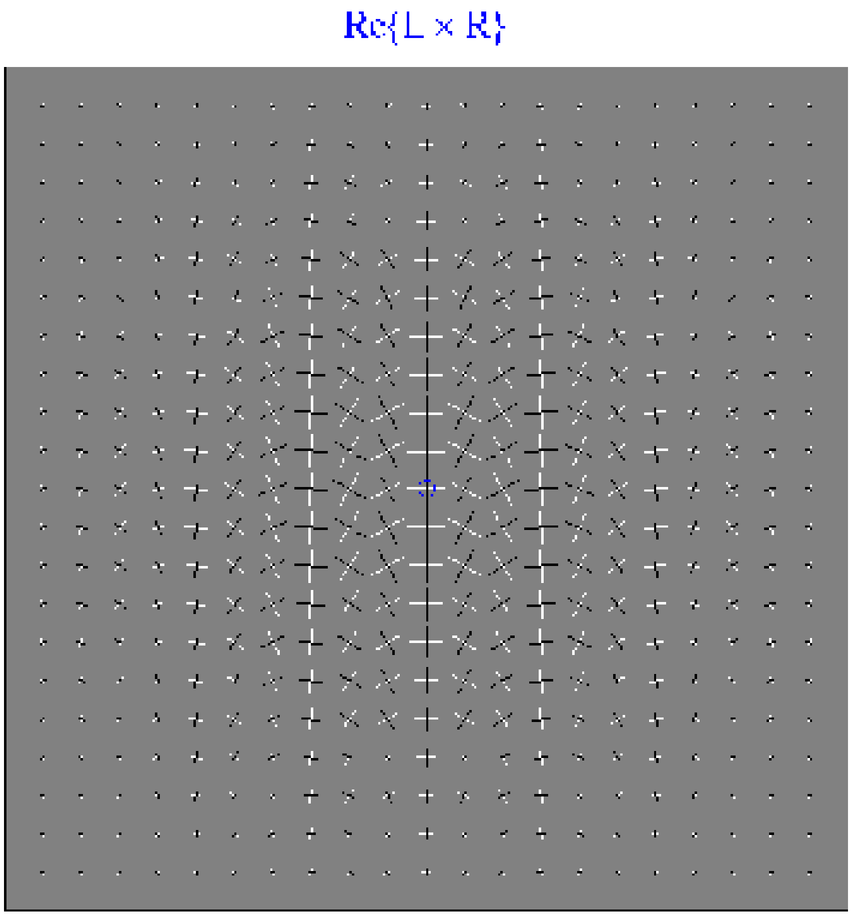
B-mode Polarization (curl component)

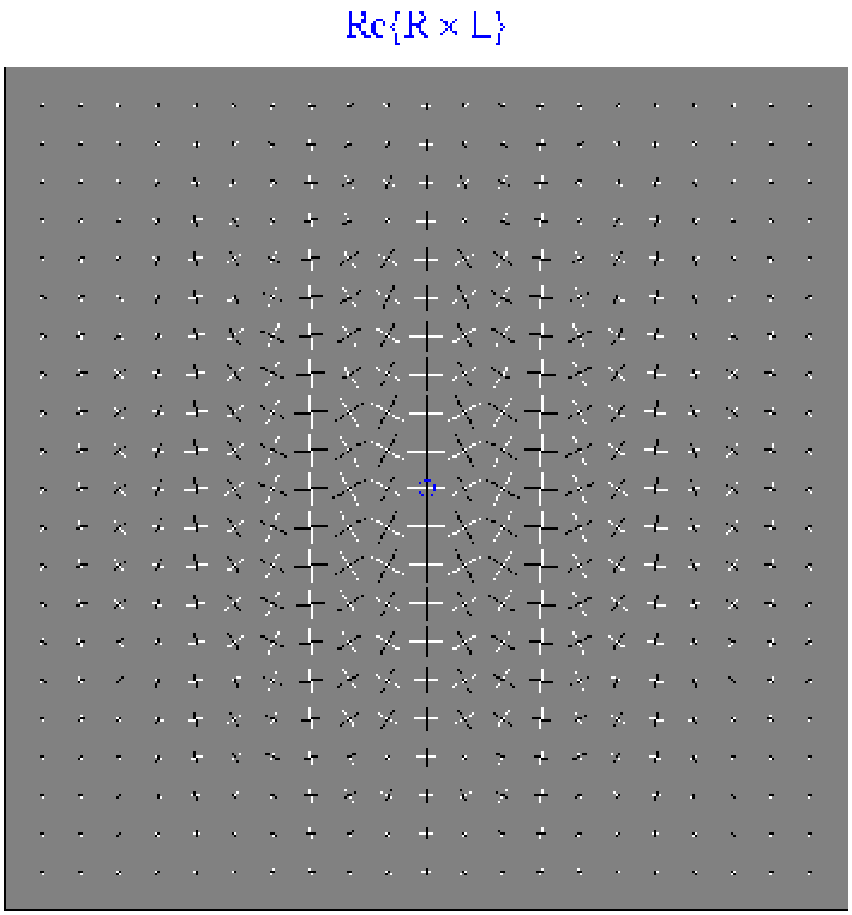
Polarization oriented at 45 degrees to wave vector

Curl component
(‘Stokes’ law on close loop $\neq 0$)



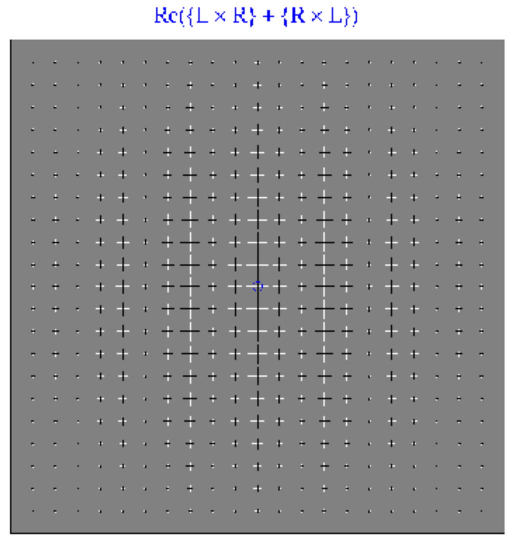
Interferometer ‘cross’ circular polarization response

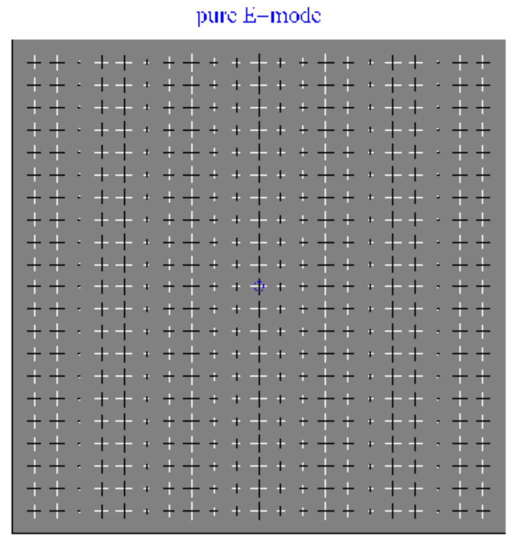




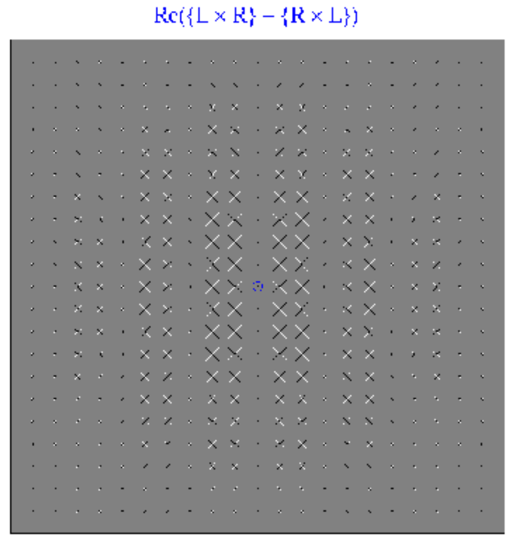
Interferometer ‘cross’ circular polarization response

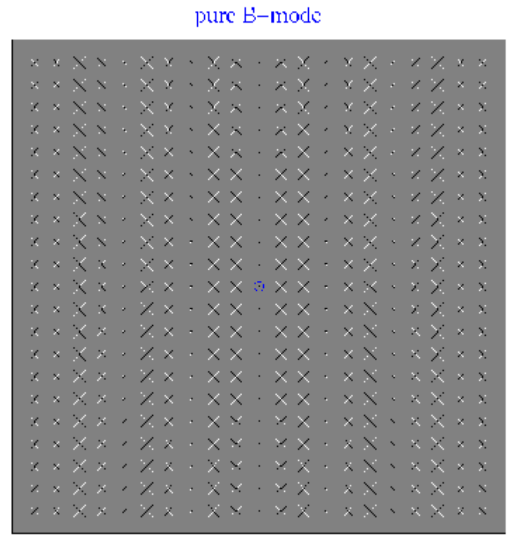
Add →



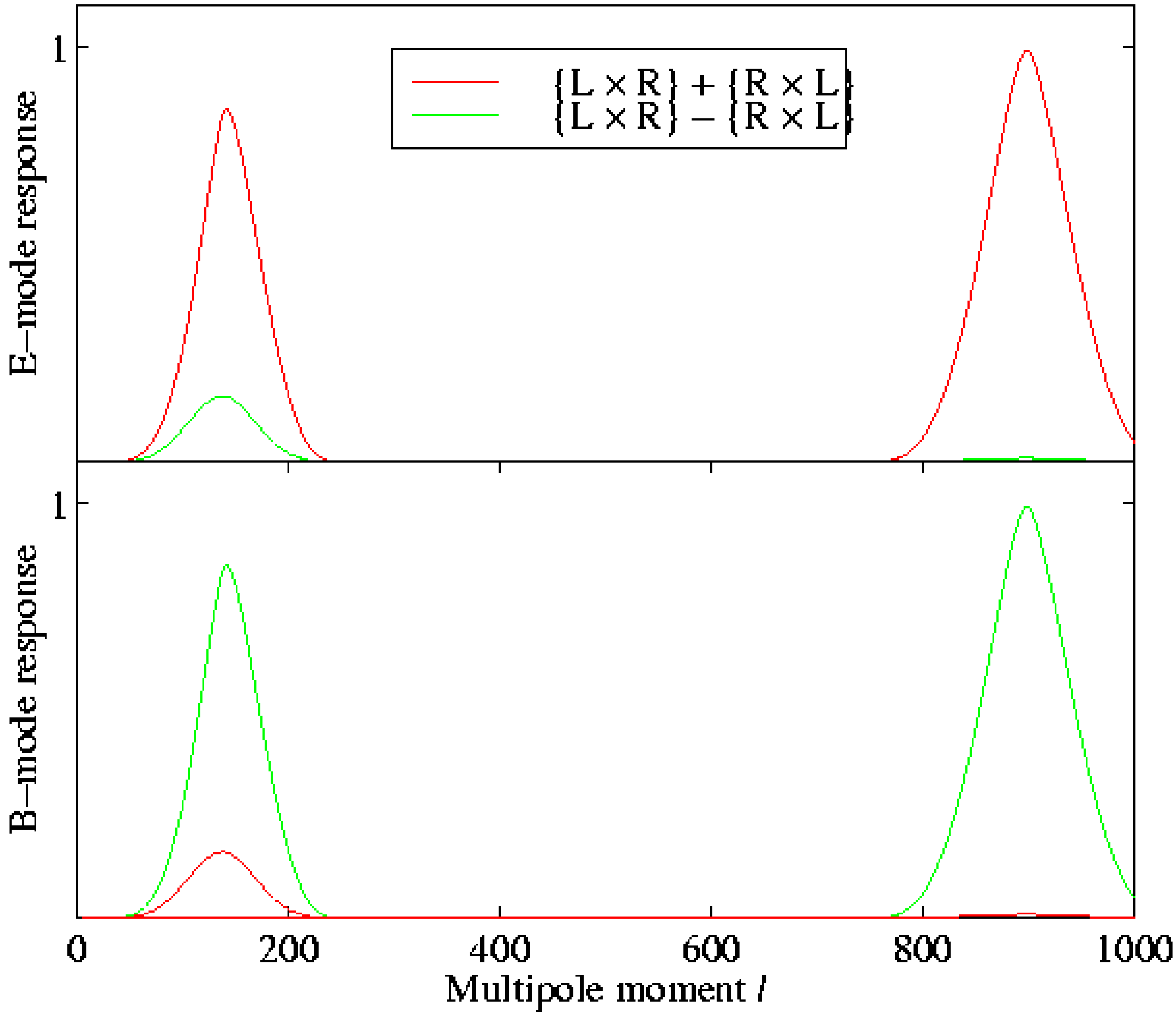


Subtract→

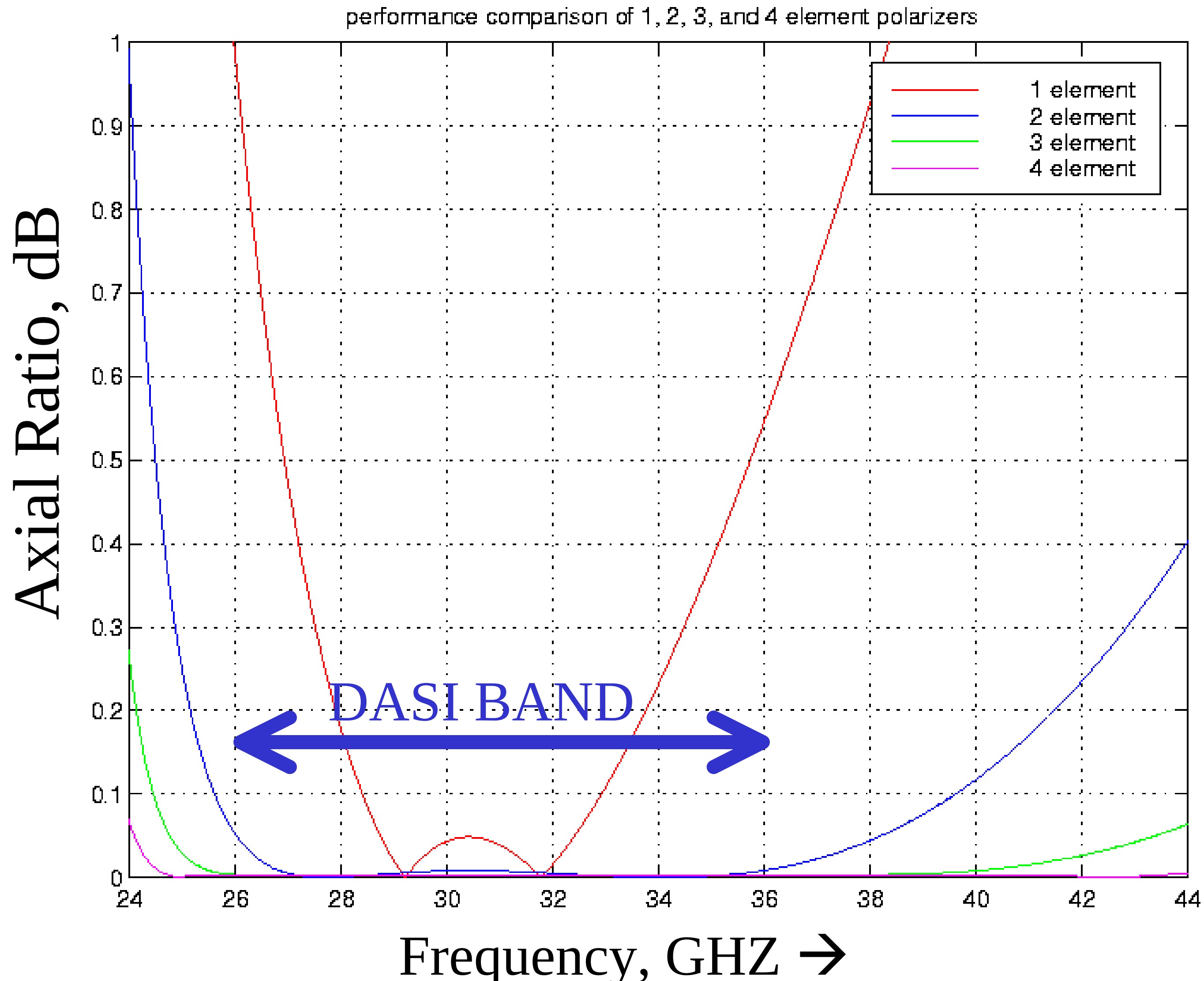




DASI polarization window functions for two baselines



DASI Achromatic Waveguide Polarizers



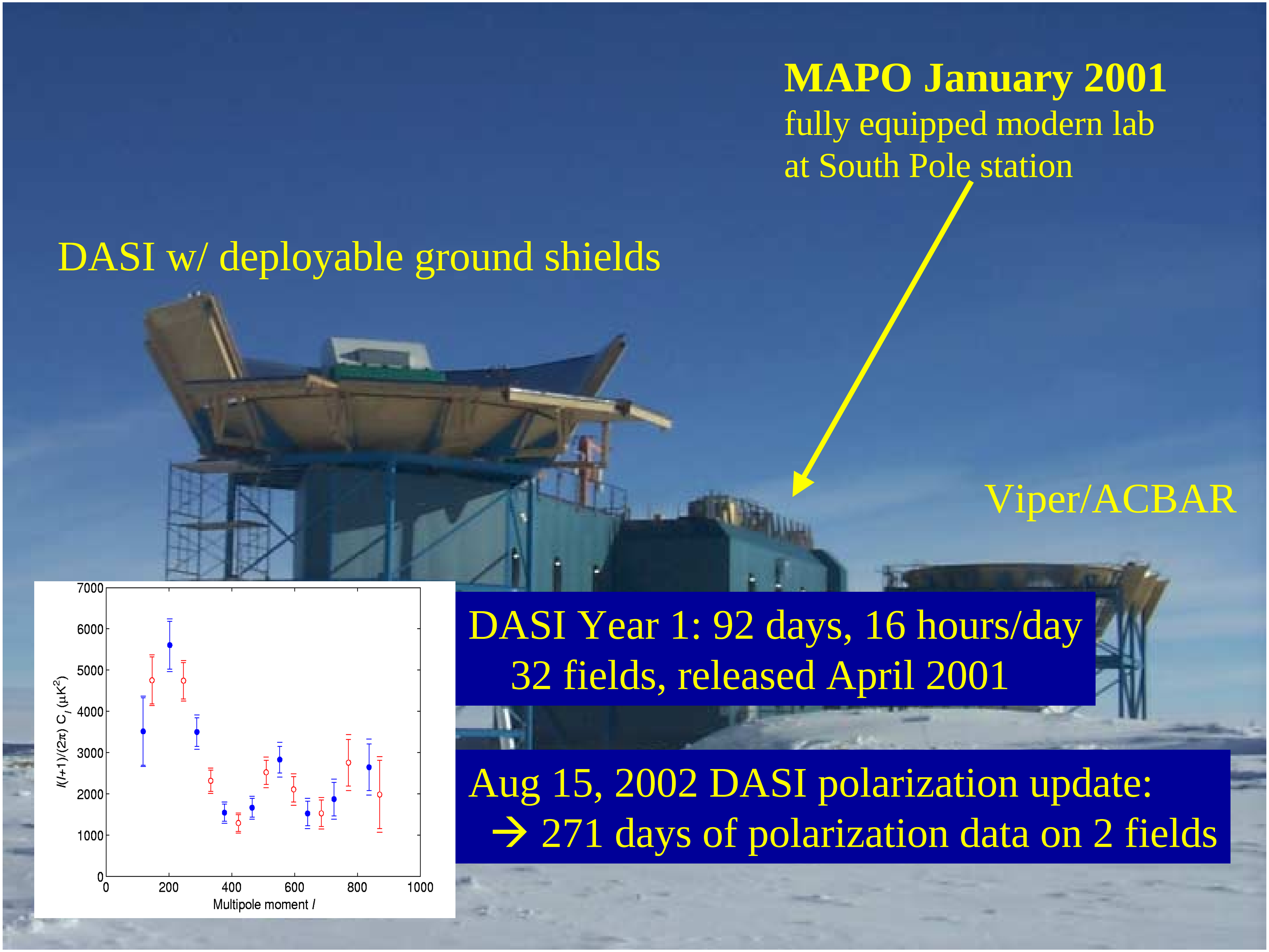
by John Kovac

Installing at South Pole for 2001 Season

MAPO January 2001
fully equipped modern lab
at South Pole station

DASI w/ deployable ground shields

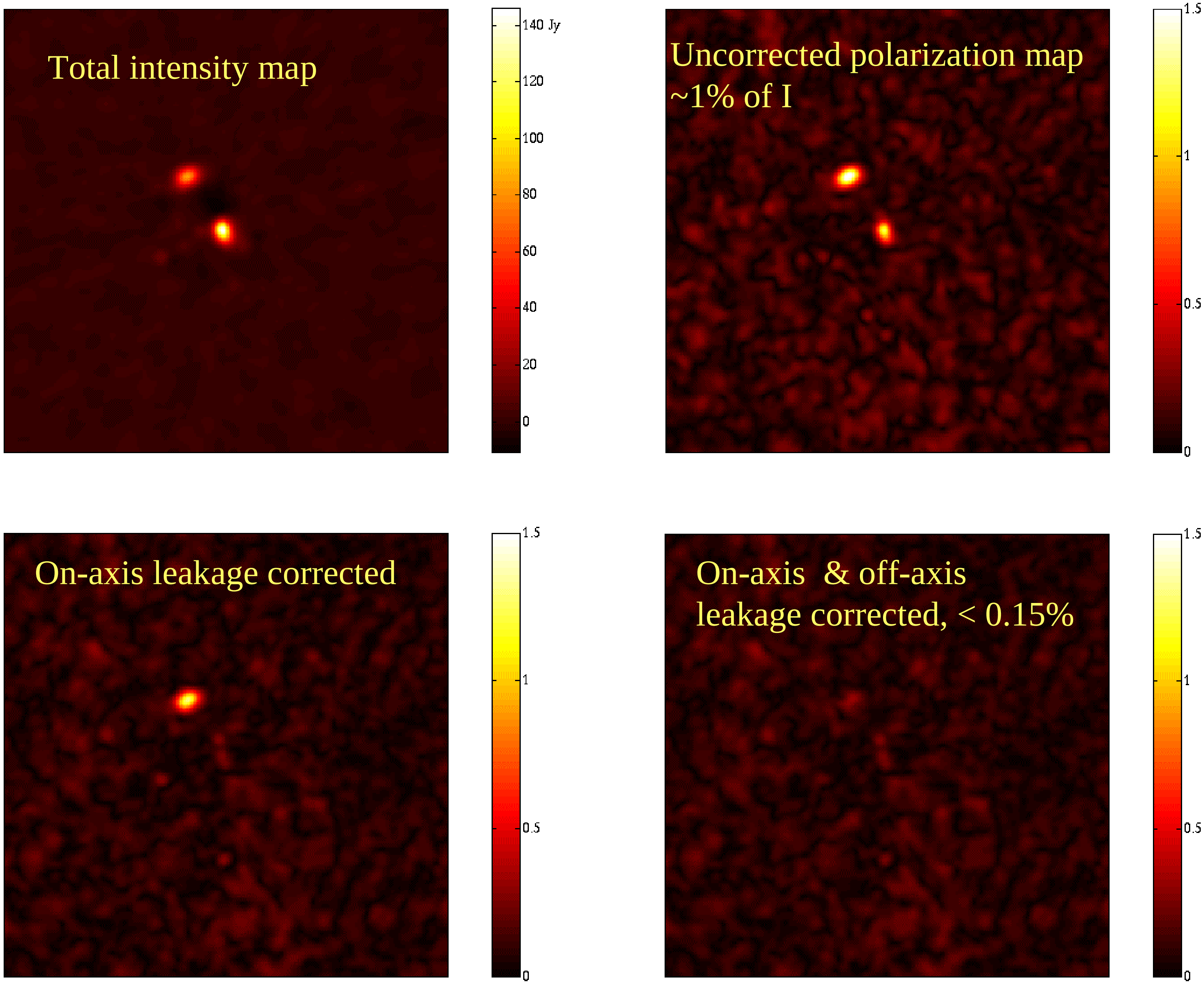
Viper/ACBAR



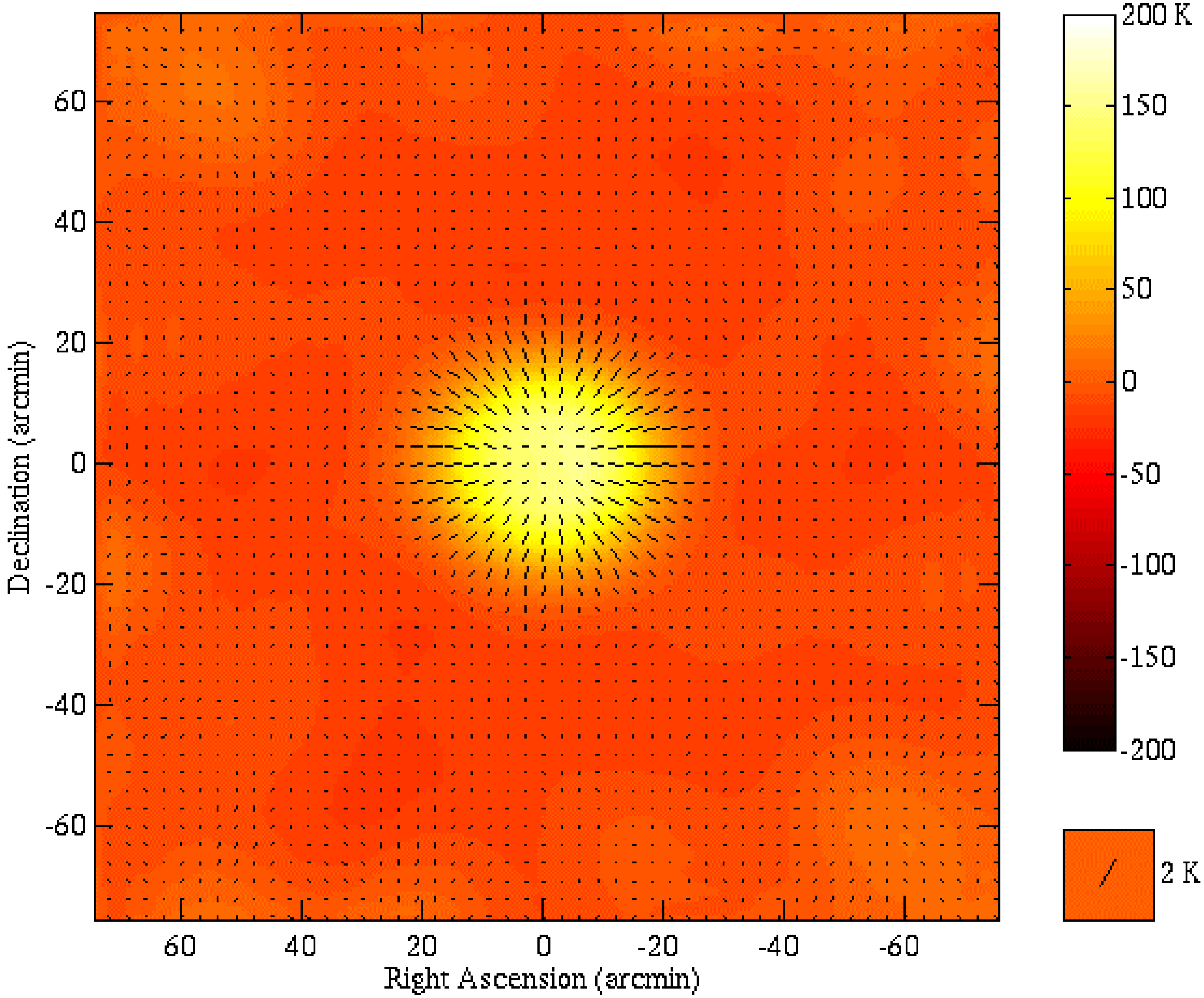
DASI Year 1: 92 days, 16 hours/day
32 fields, released April 2001

Aug 15, 2002 DASI polarization update:
→ 271 days of polarization data on 2 fields

DASI Polarimetry of Galactic Star-Formation Region NGC 6334

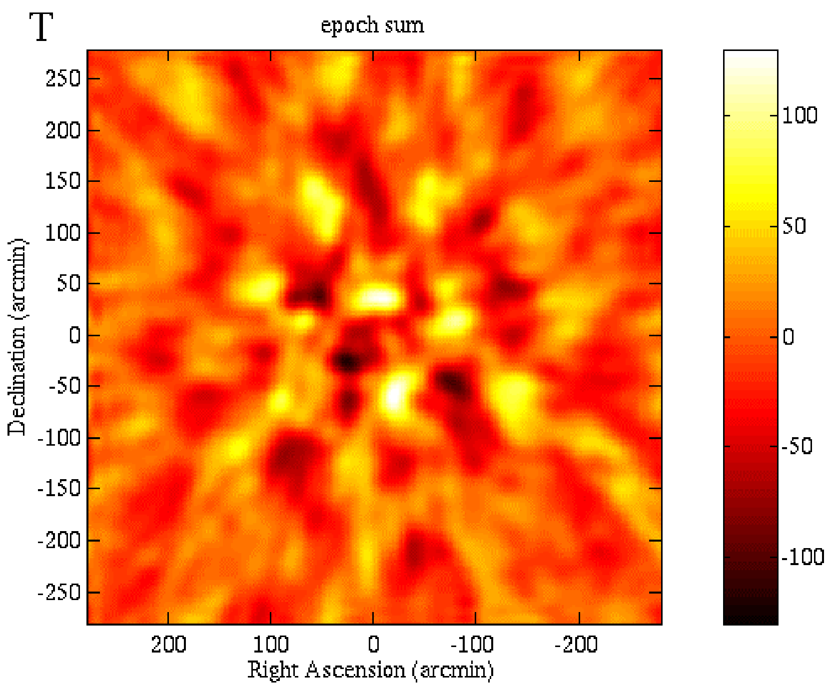


DASI Moon Polarization Map

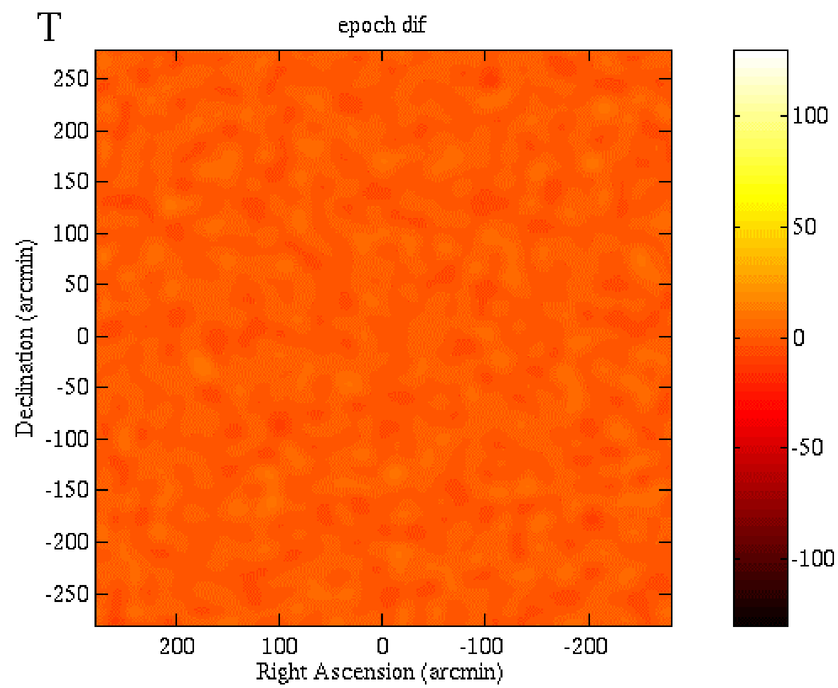


Sum and Difference CMB Maps

(also constructed and passed 300 data consistency tests)



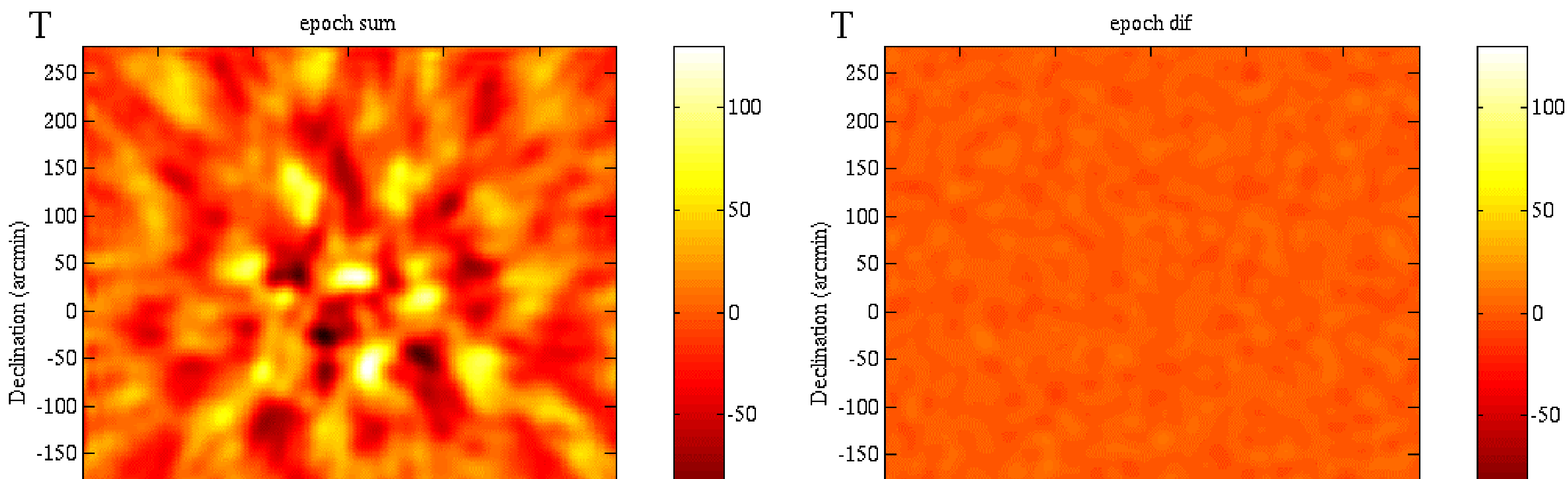
σ = 70 μK



σ = 2.7 uK

Sum and Difference CMB Maps

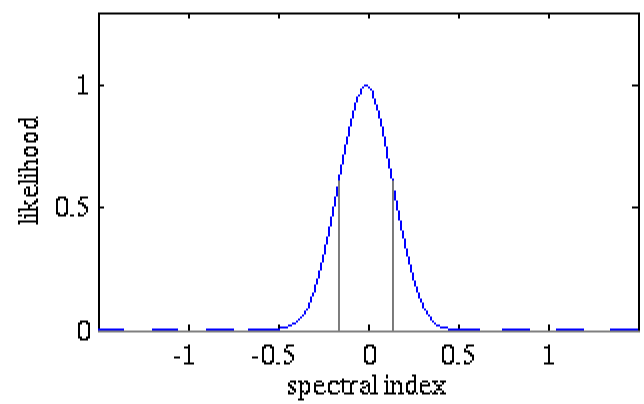
(also constructed and passed <u>300 data consistency tests</u>)



Temperature spectral index: $\beta = -0.01 \pm 0.15$

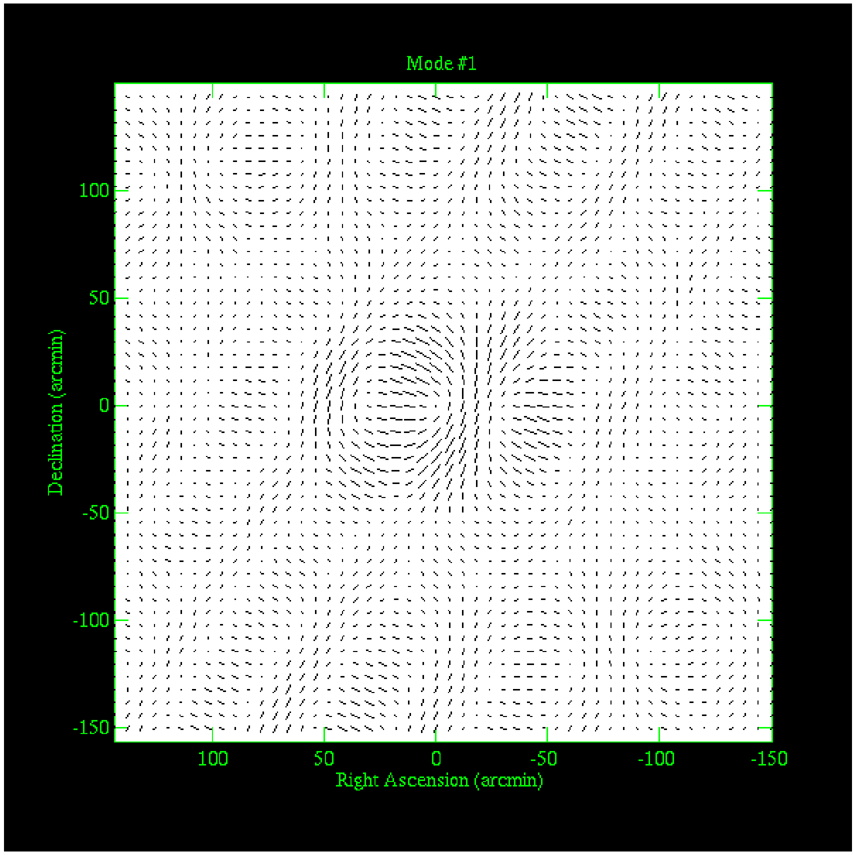
Where $\beta = 0$ corresponds to 2.73K spectrum,

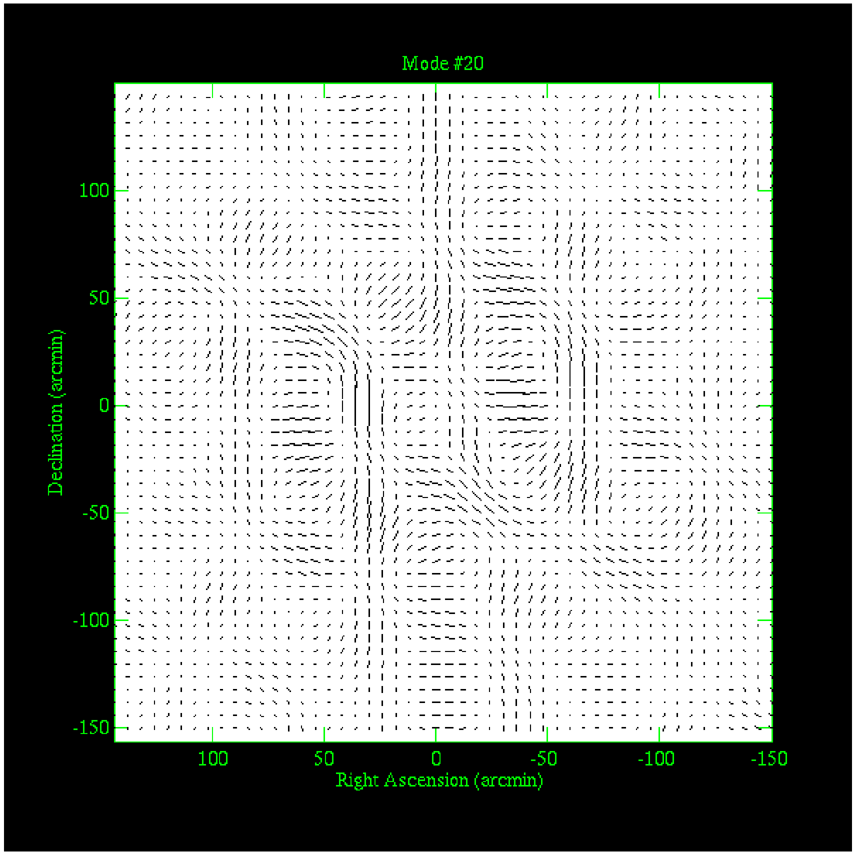
i.e., $I(\nu) \propto I_{2.73K}\nu^{\beta}$,



Examples of s/n eigenmodes

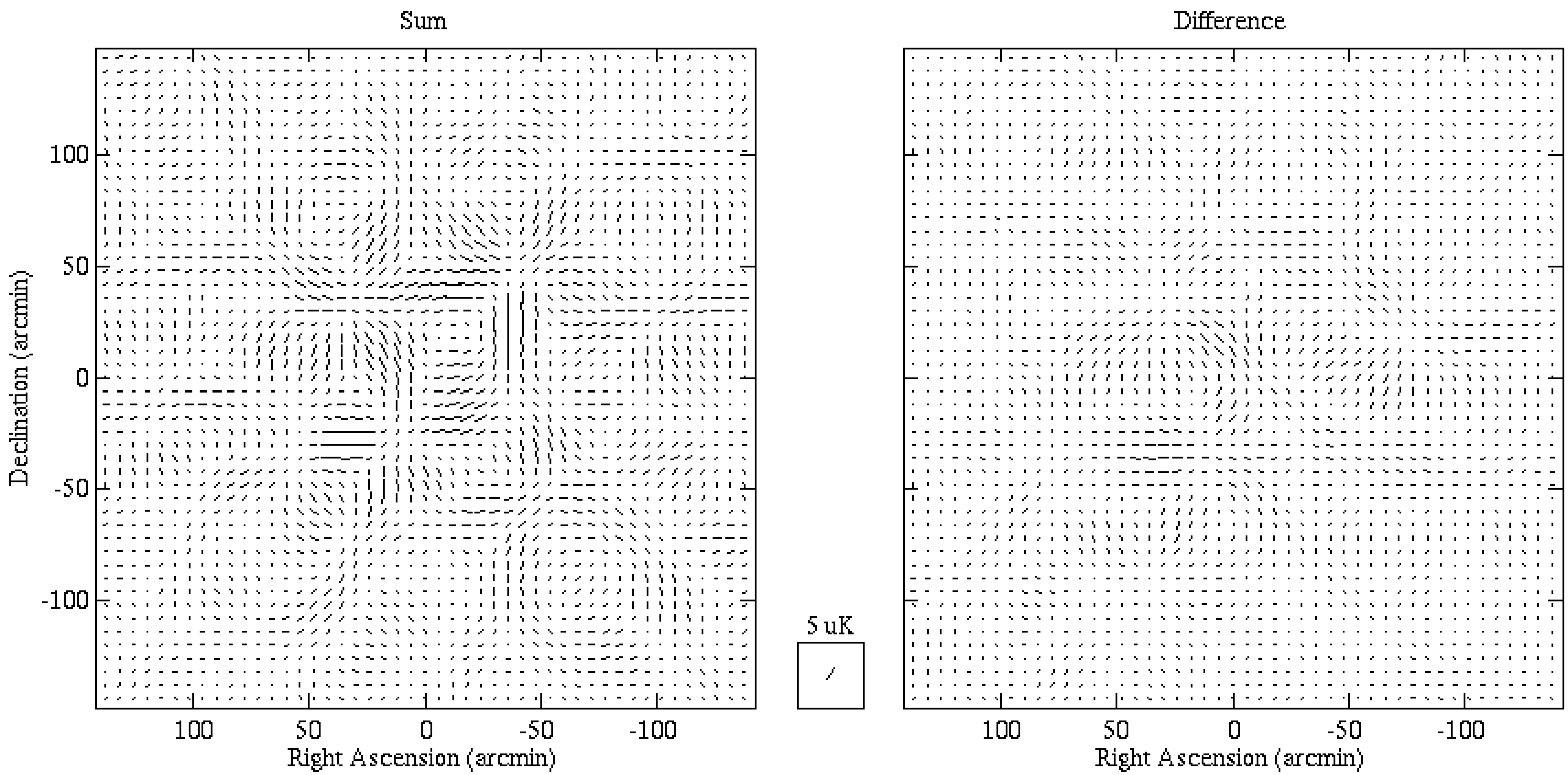
(expect 34 modes with average s/n > 1)





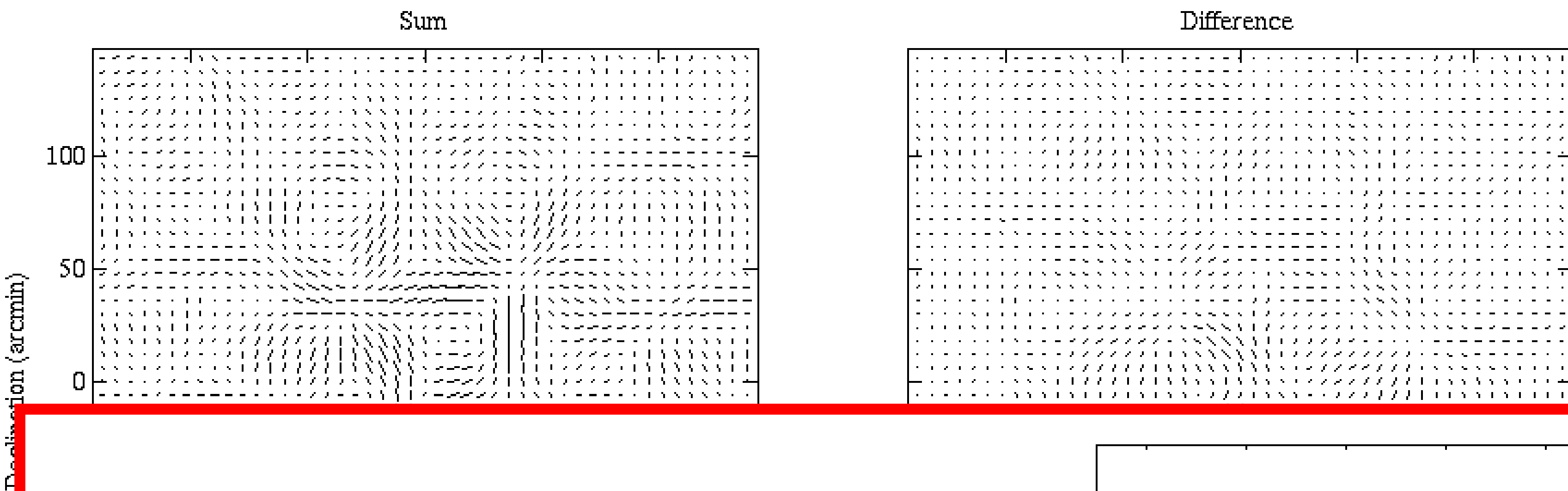
Sum and Difference DASI Eigenmode Polarization Maps

(34 modes with average s/n > 1 modes)

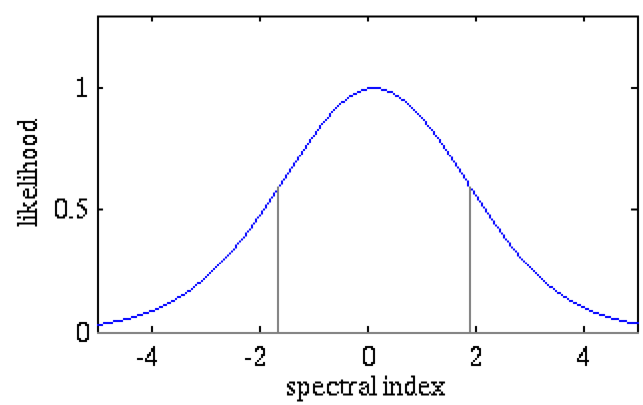


Sum and Difference DASI Eigenmode Polarization Maps

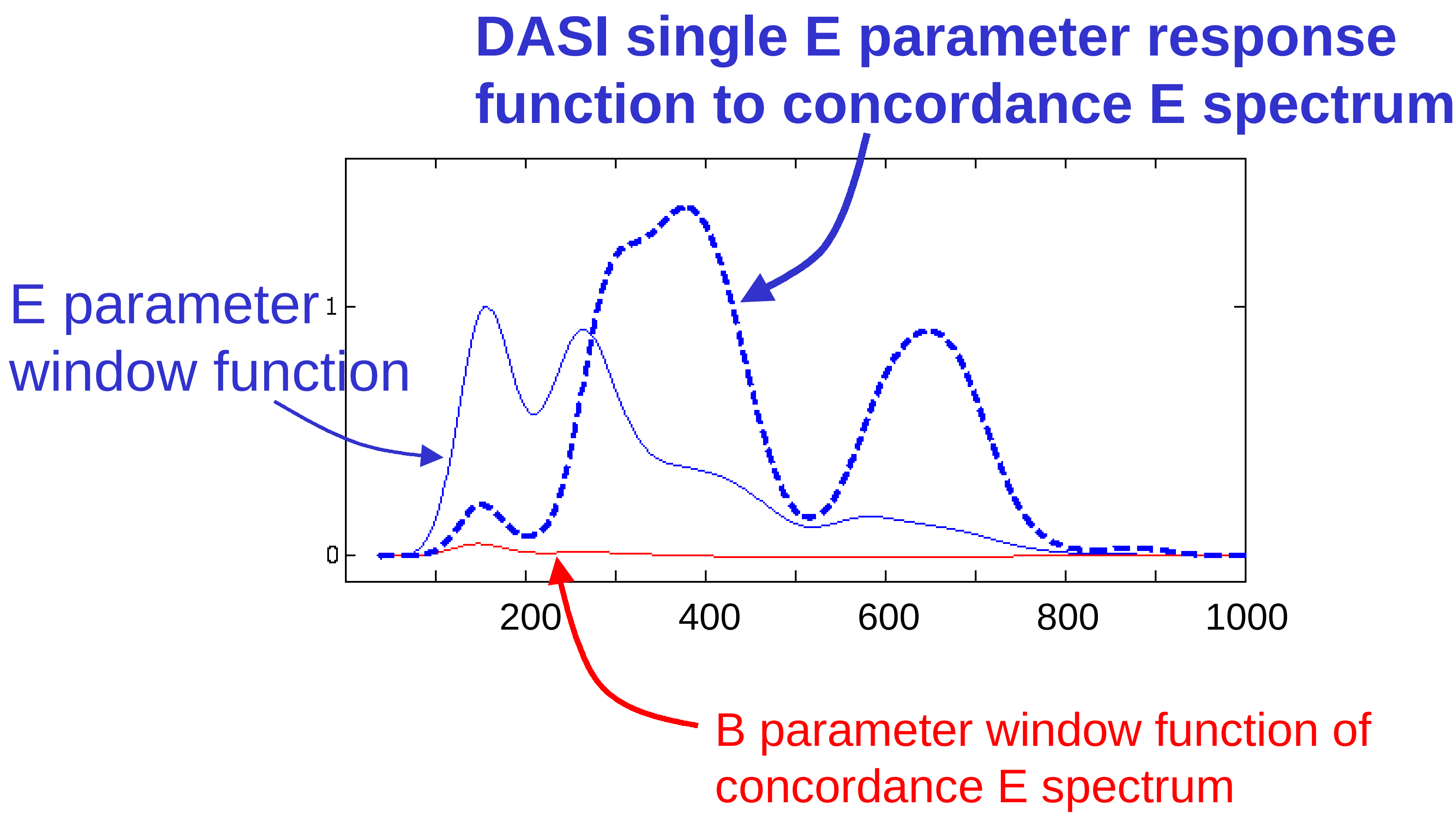
(34 modes with average s/n > 1 modes)



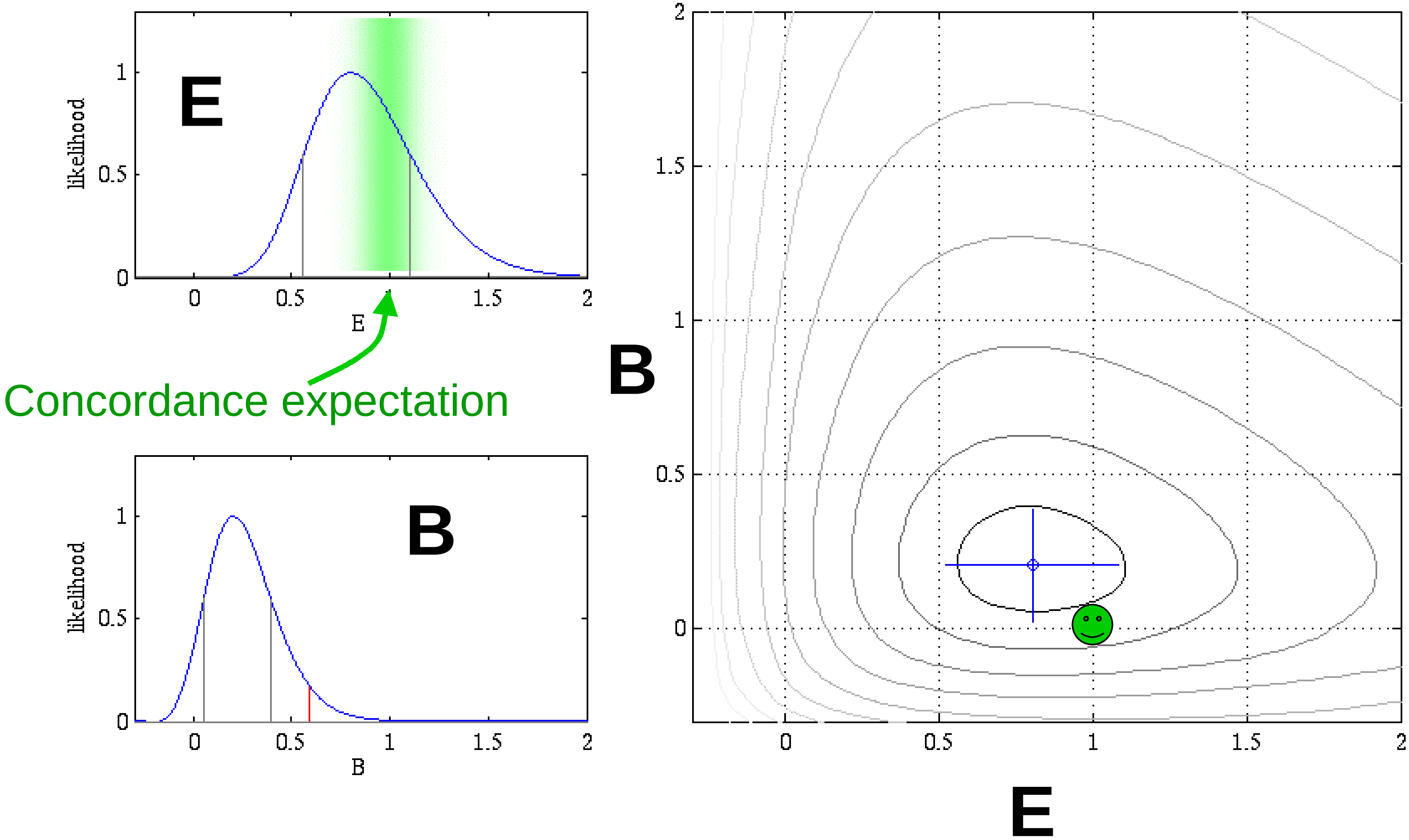
E spectral index : β = 0.17 ± 1.8
(using all modes)



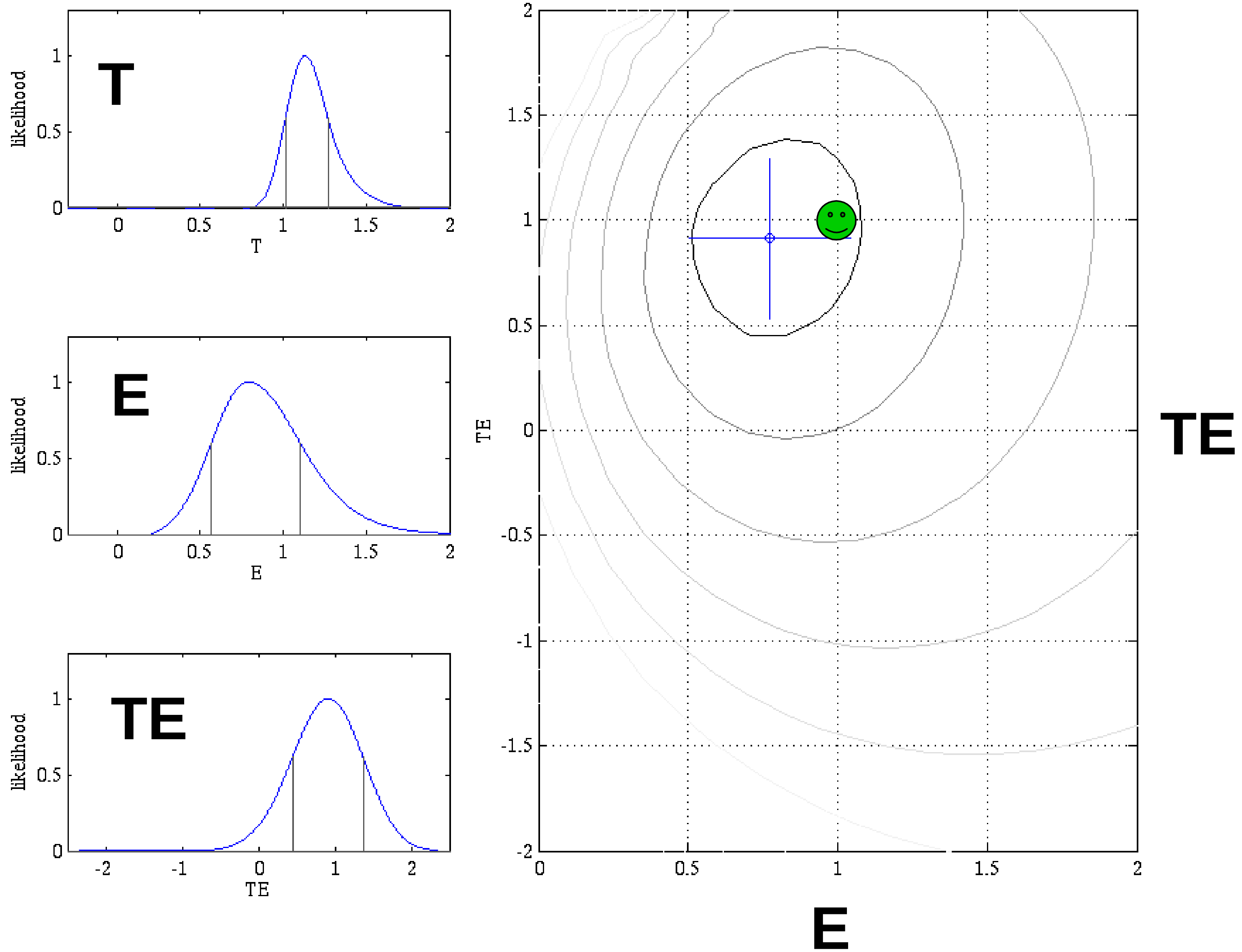
DASI Response to Scalar E-mode Polarization



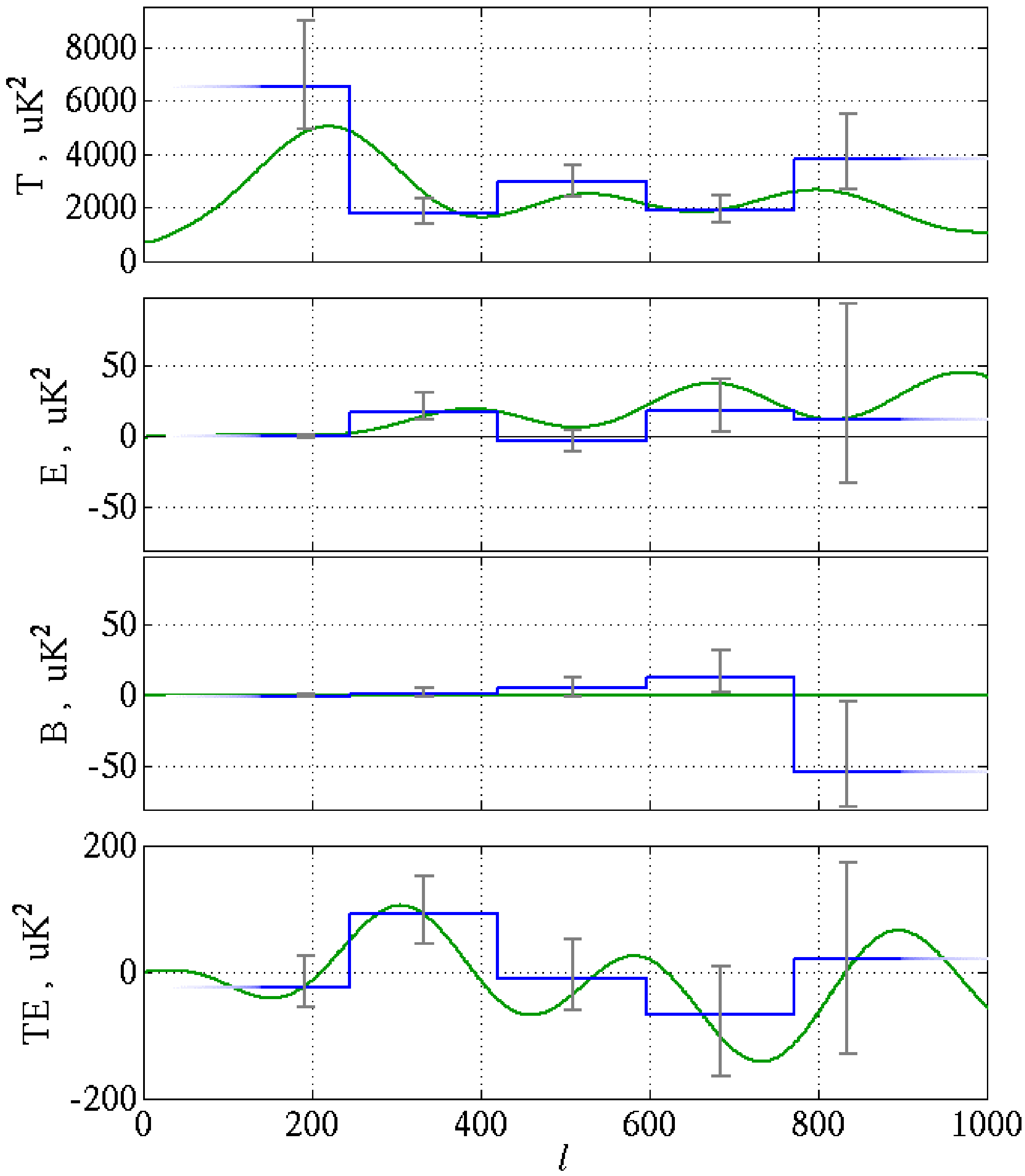
DASI Constraint on Scalar E-mode Polarization



Constraints on T, E, & TE



T, E, B, TE Bandpowers



Goodness of Fit Tests

Consistency with concordance model: excellent

Consistency with null hypothesis:

T=0: $< 10^{-16}$ from Chi-square

E=0: $< 10^{-6}$ from Chi-square,
Likelihood ratio,
(Monte Carlo $<< 10^{-3}$)

TE=0: < 0.05 from Likelihood analyses
and Monte Carlo)

Foregrounds?

- Regions picked for exceptionally low Galactic foregrounds
- Thermal spectral index found
- Points source contamination extensively simulated (mean shift in E: 3%, rms 4%)
- Foregrounds should produce E *and* B

Summary

- DASI has detected E-mode CMB polarization with high confidence (~5σ) and at a level consistent with the theoretical prediction.
- TE detected at 95% C.L. and consistent with theoretical prediction.
- Papers will be posted at http://astro.uchicago.edu/dasi and astro-ph by end of the weekend.

Thanks to:

- National Science Foundation and Raytheon Polar Services
- CARA
- The Caltech Cosmic Background Imager (CBI) team
- Center for Cosmological Physics