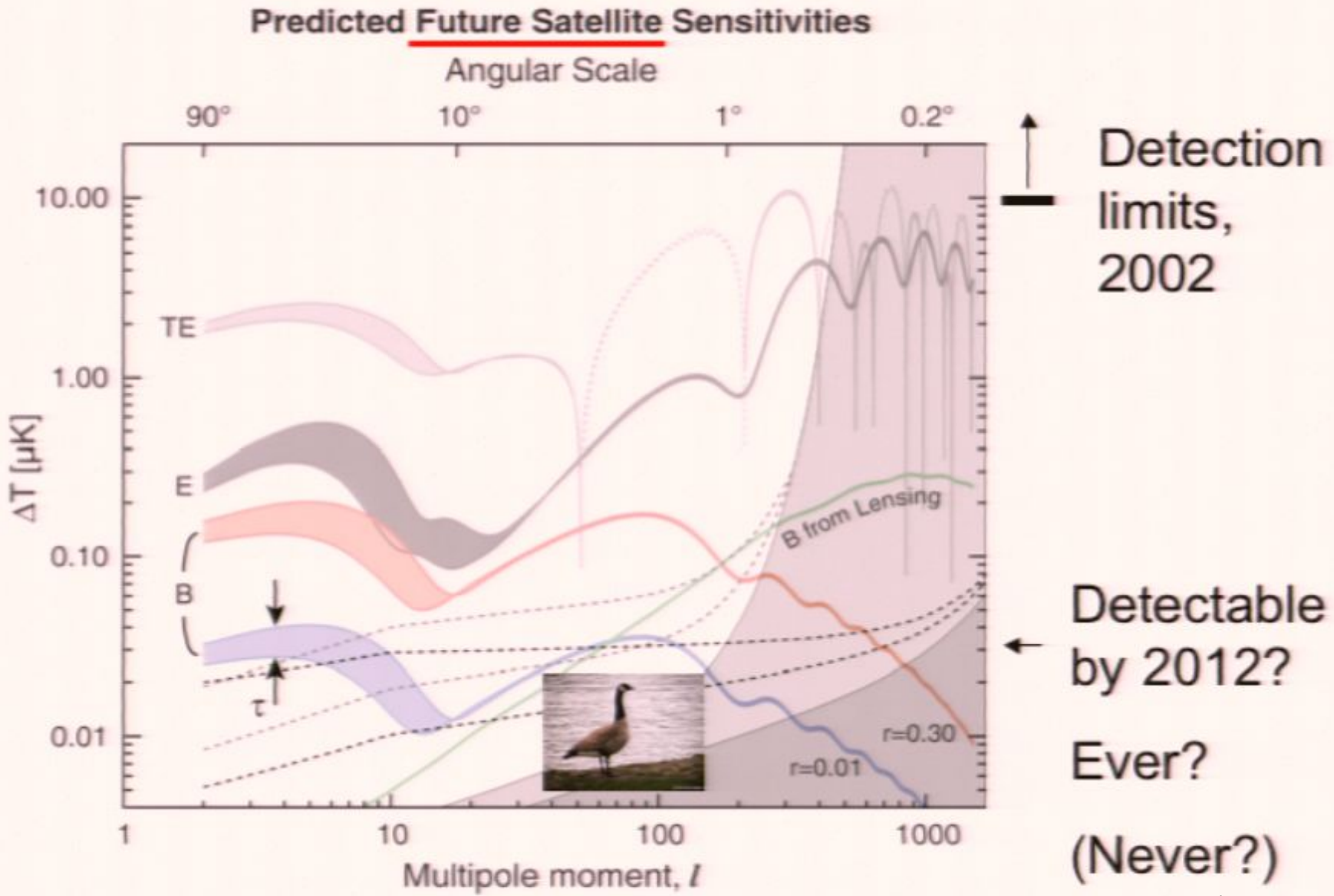
Title: Wild Goose Chase

Date: Sep 12, 2007 04:30 PM

URL: http://pirsa.org/07090043

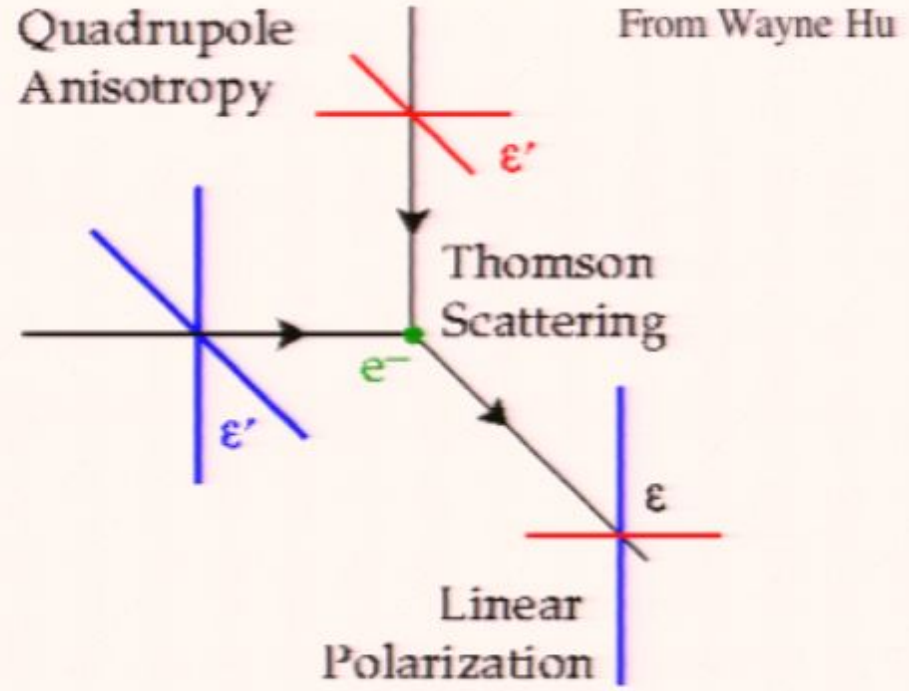
Abstract:

"Wild Goose Chase": a pursuit of anything as unlikely to be caught as a wild goose, any foolish, fruitless, or hopeless quest.



"CMB Task Force Report" arXiv:astro-ph/0604101

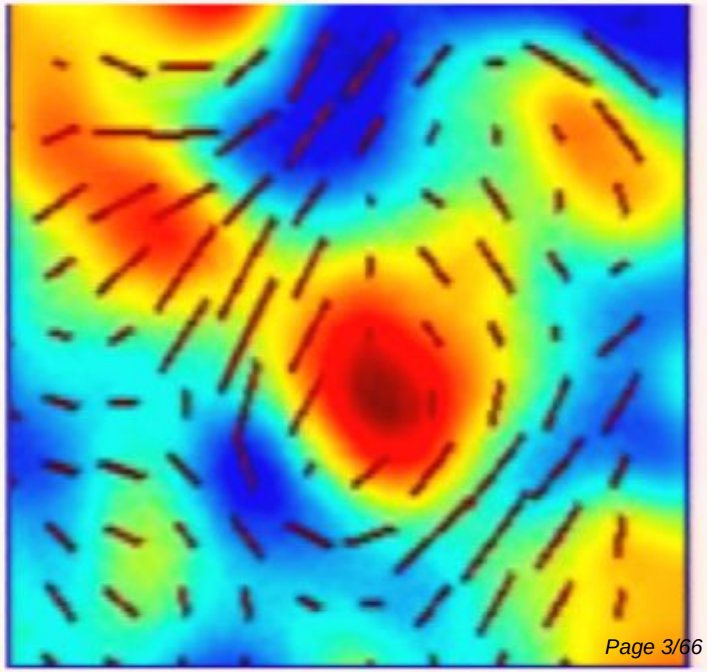
CMB Polarization



- Polarization of the CMB is produced by Thompson scattering of a quadrupolar radiation pattern.

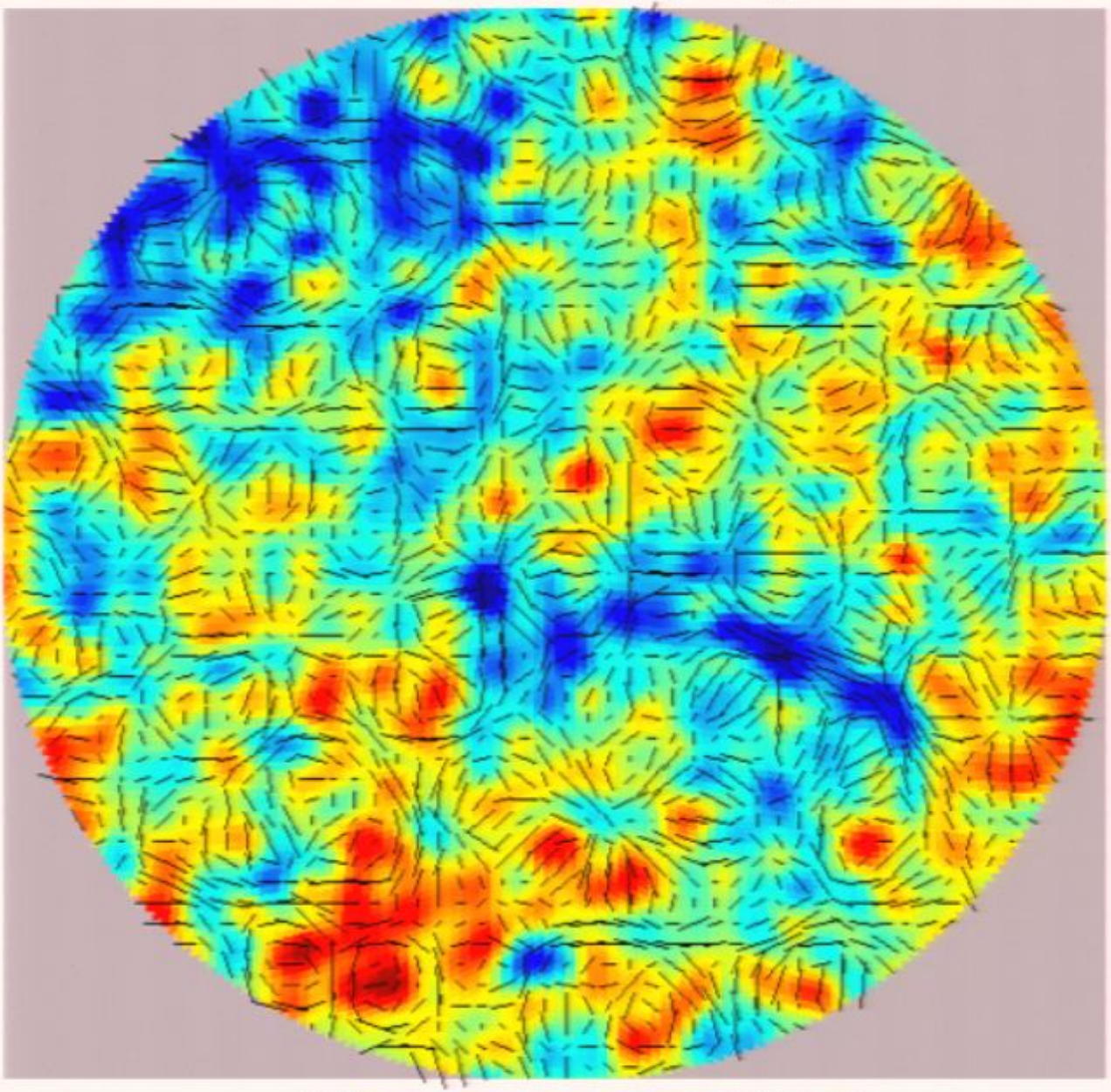
- A component of the polarization is correlated with the temperature anisotropy.

- Whenever there are free electrons, the CMB is polarized.



Scalar Perturbations

42′ beam, 30deg. diam. polar cap



−200 200 μK

3.47 μK

Eric Hivon

Scalar+Tensor Perturbations

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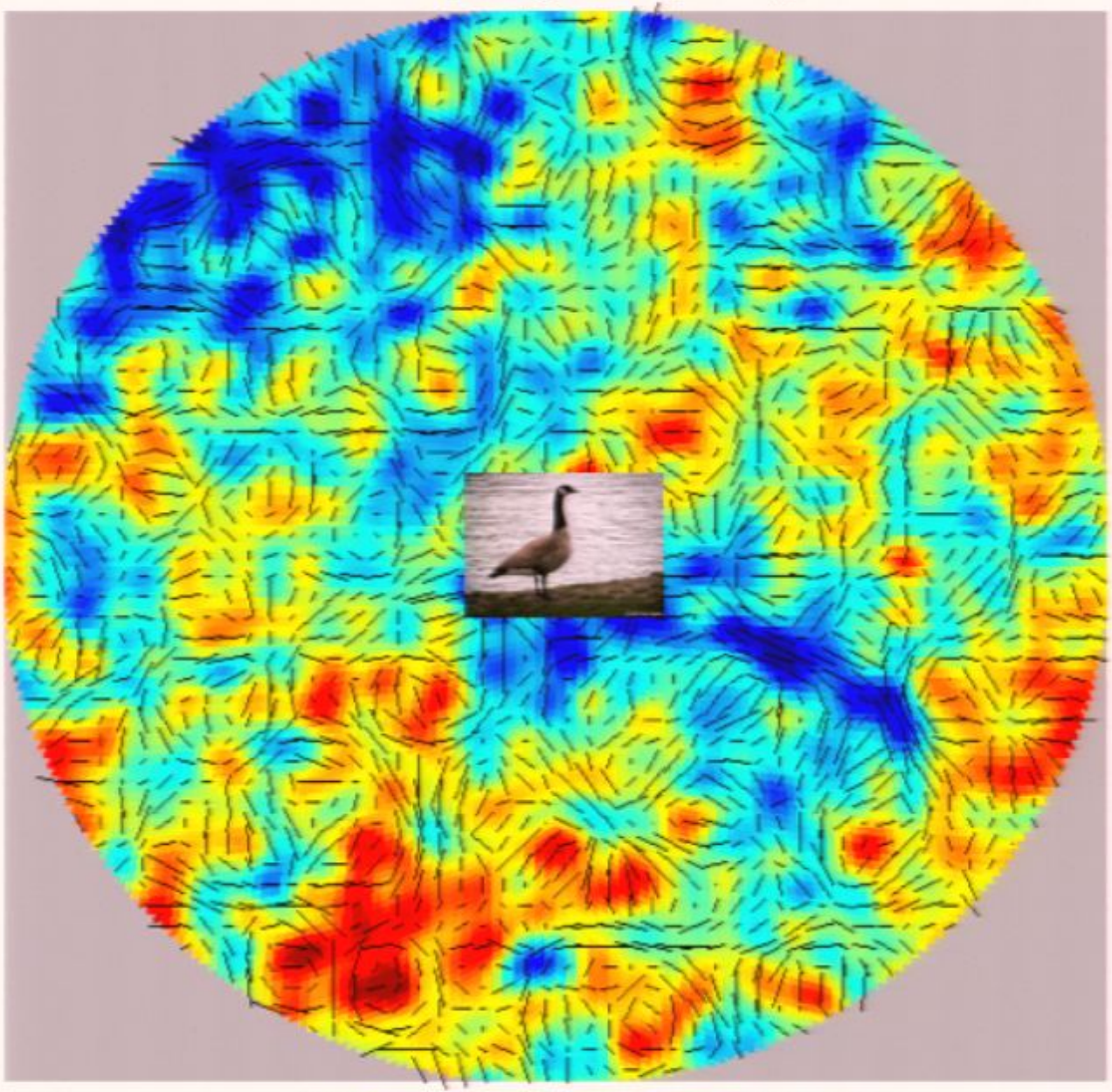

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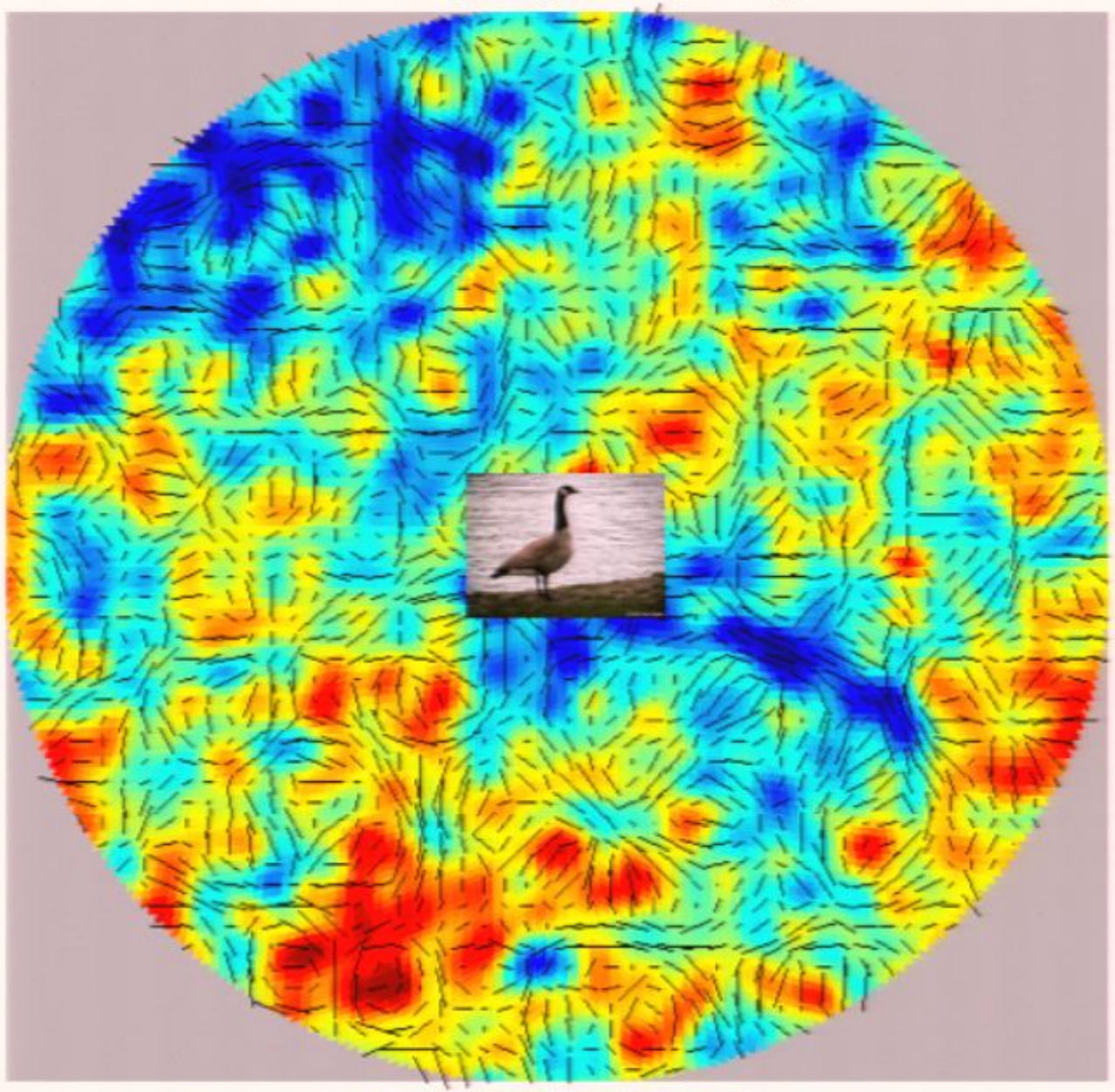
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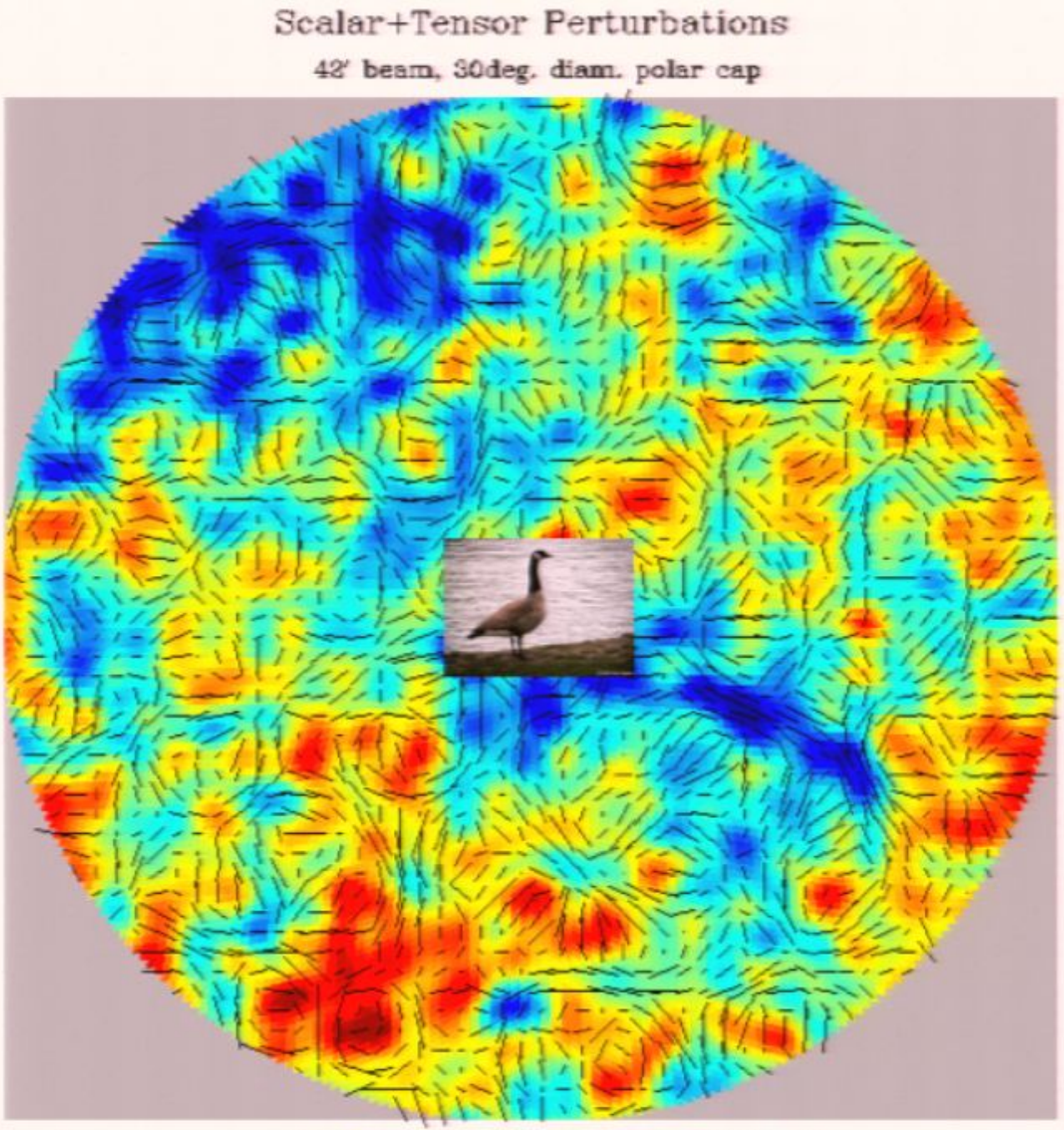
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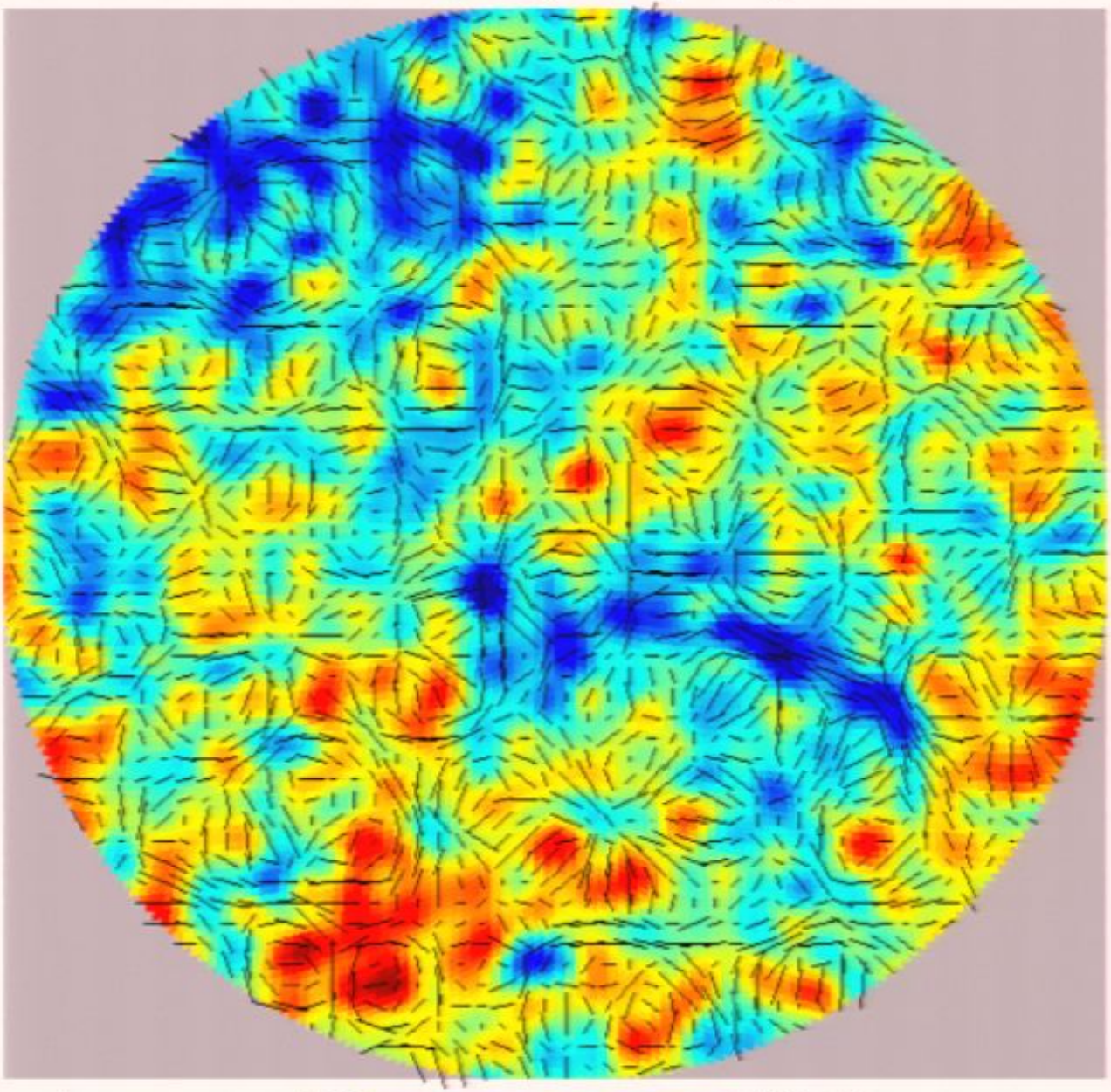

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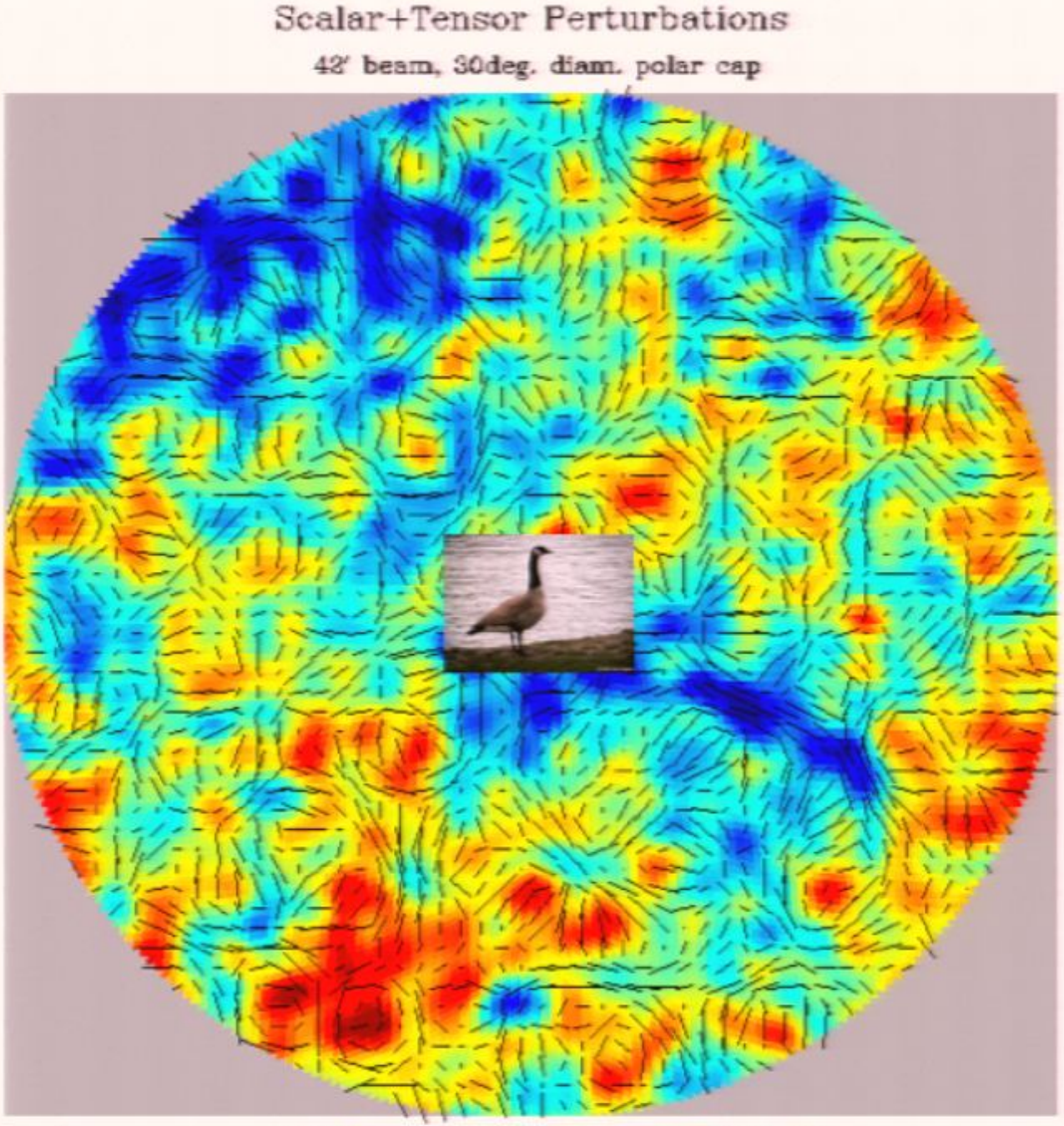
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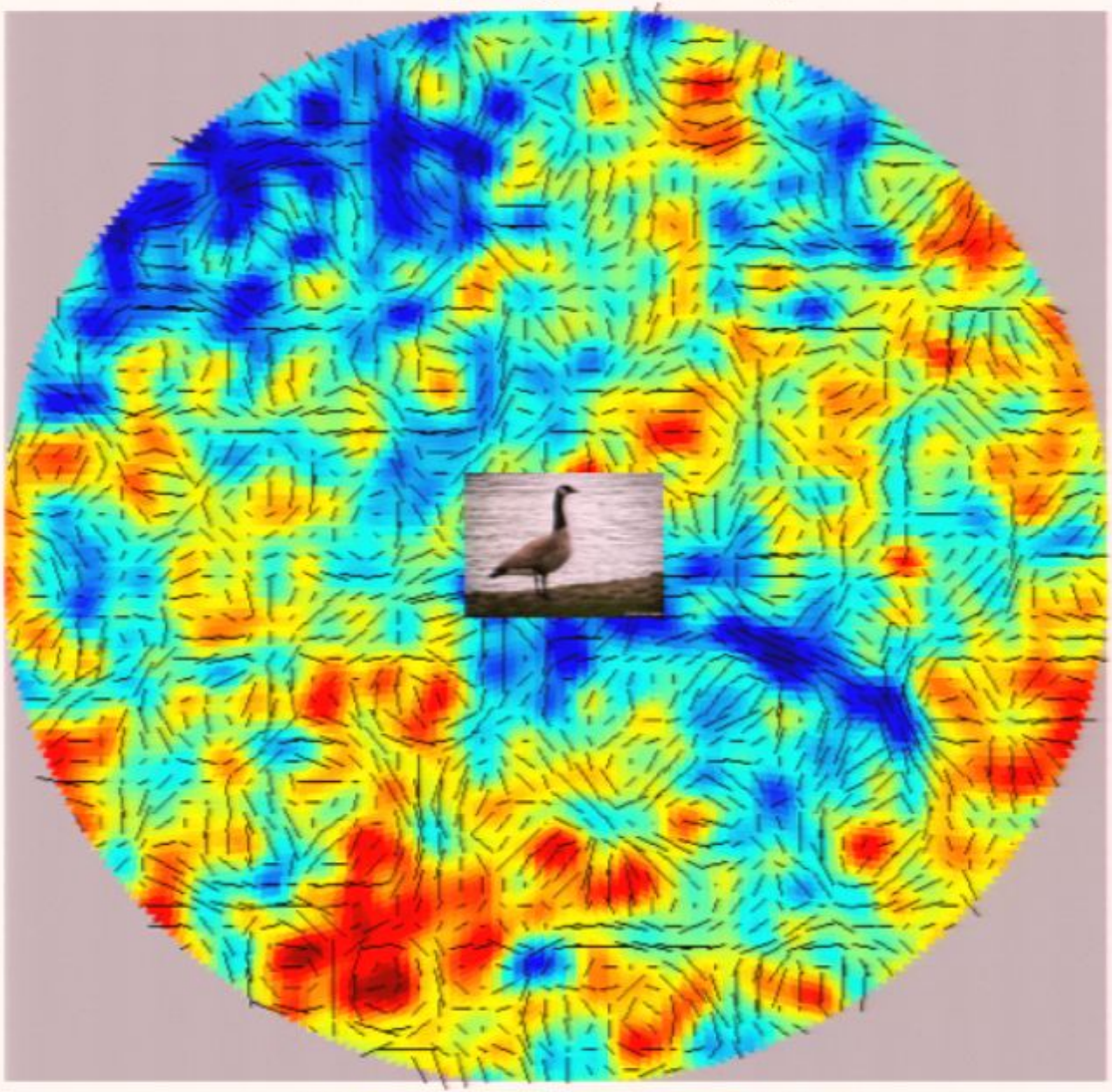

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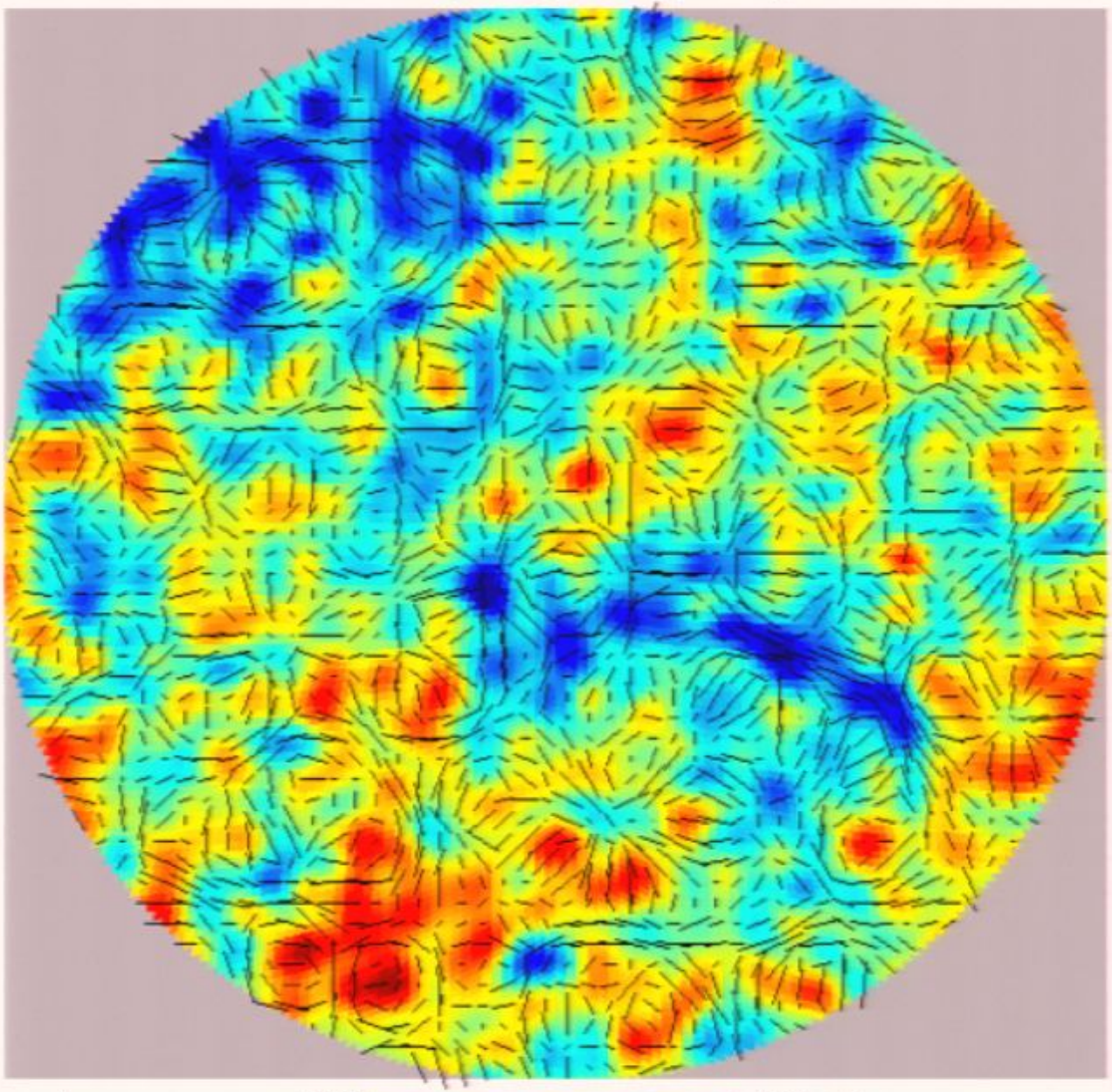

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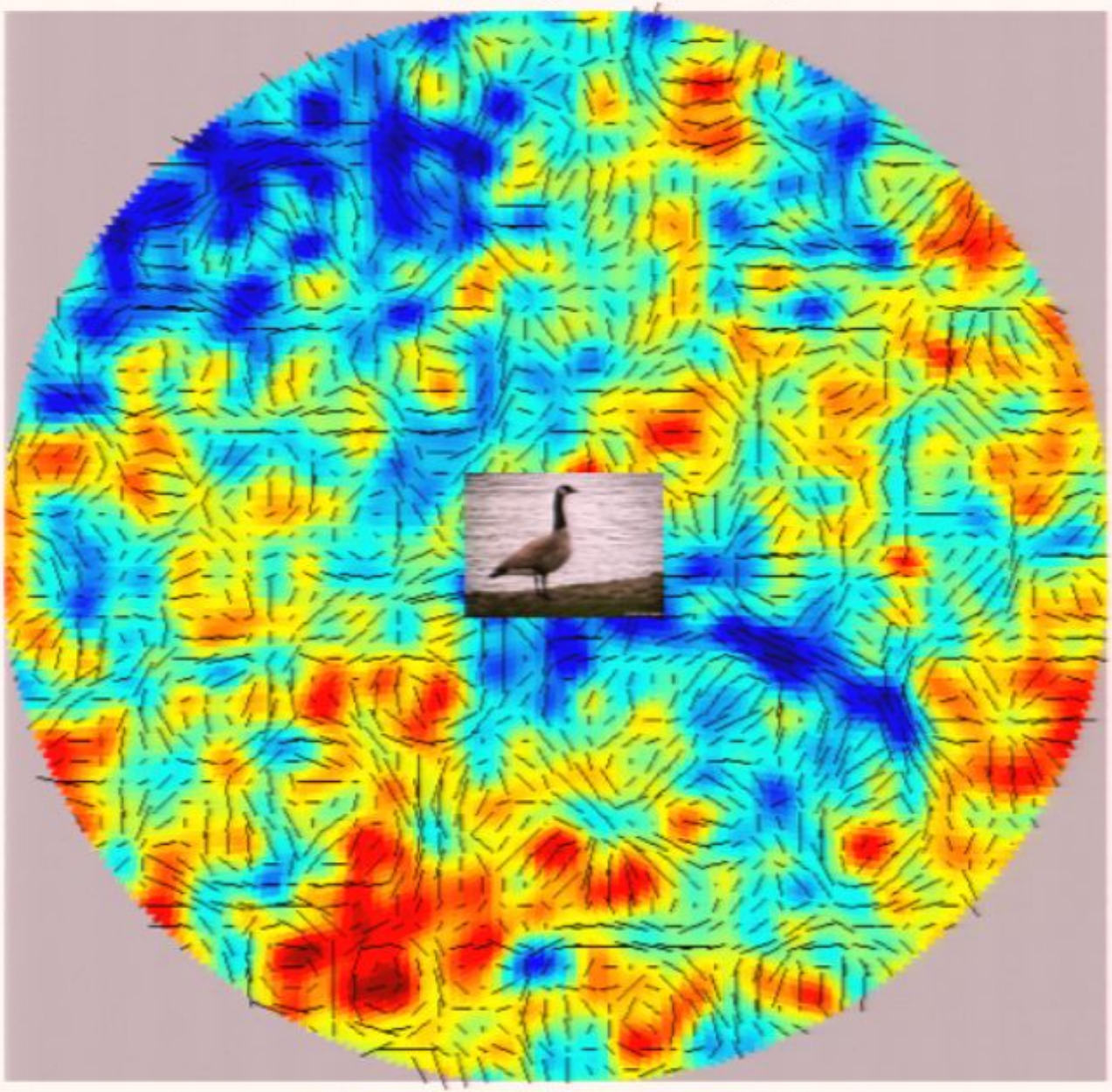

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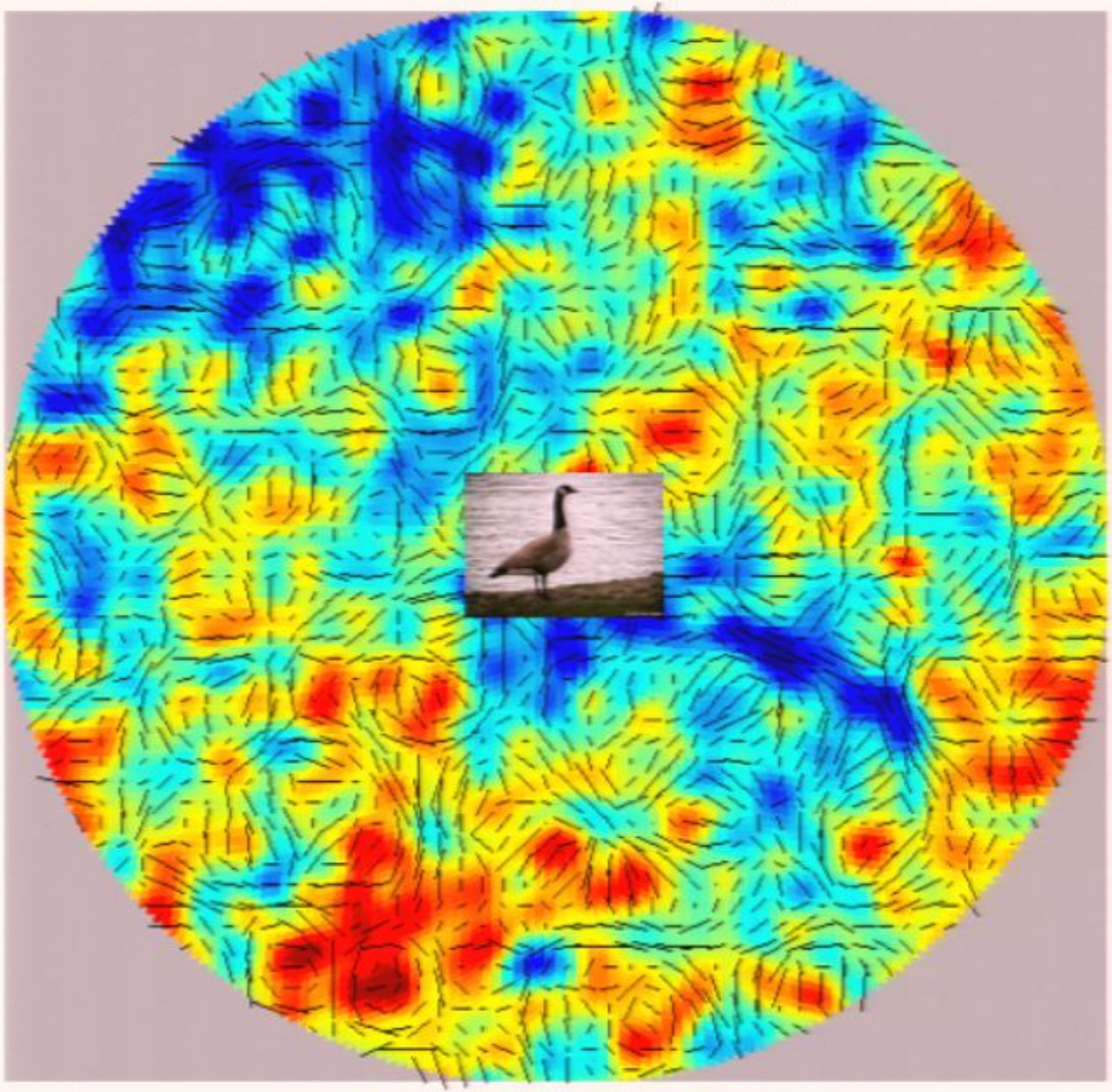

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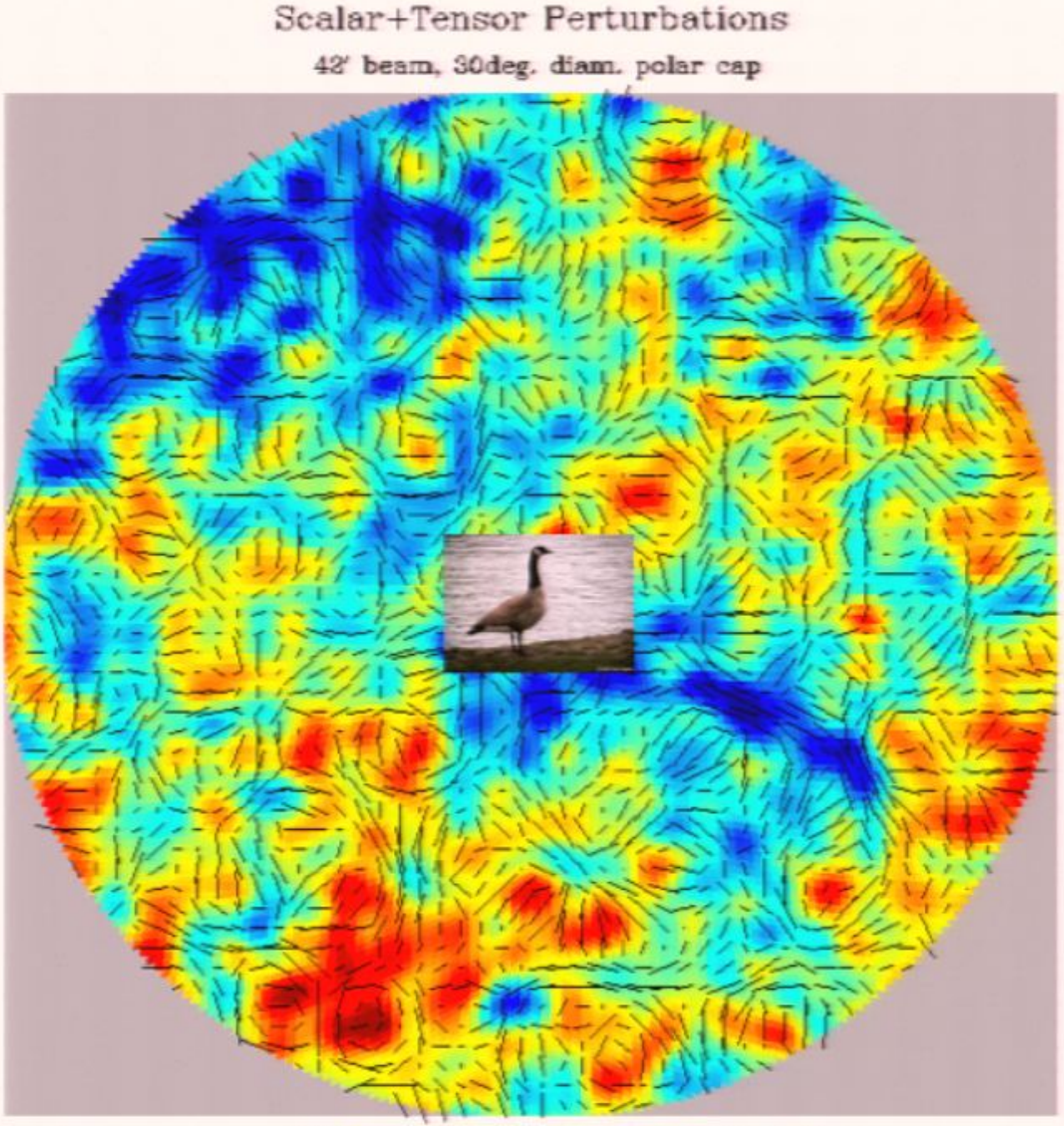
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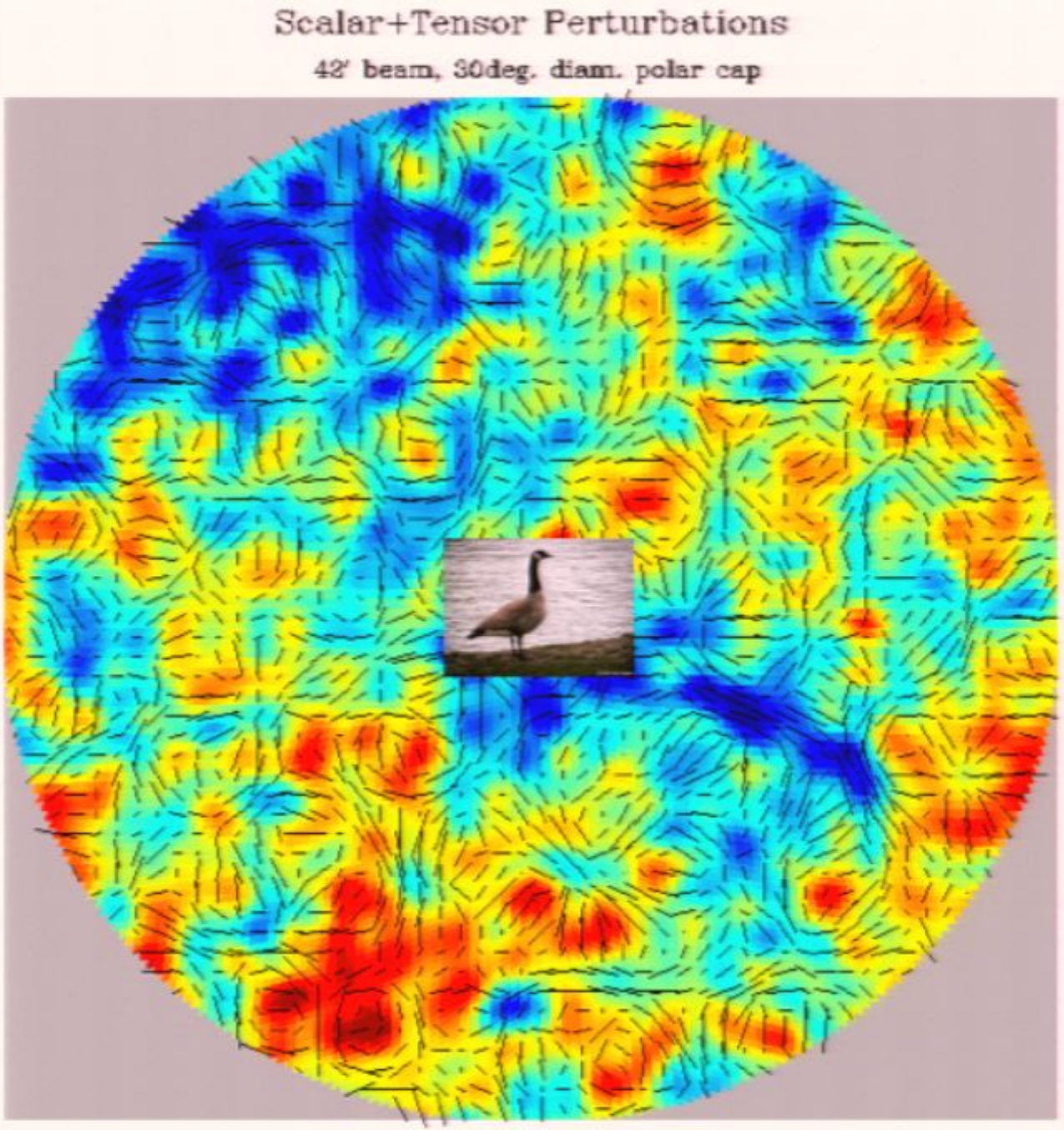
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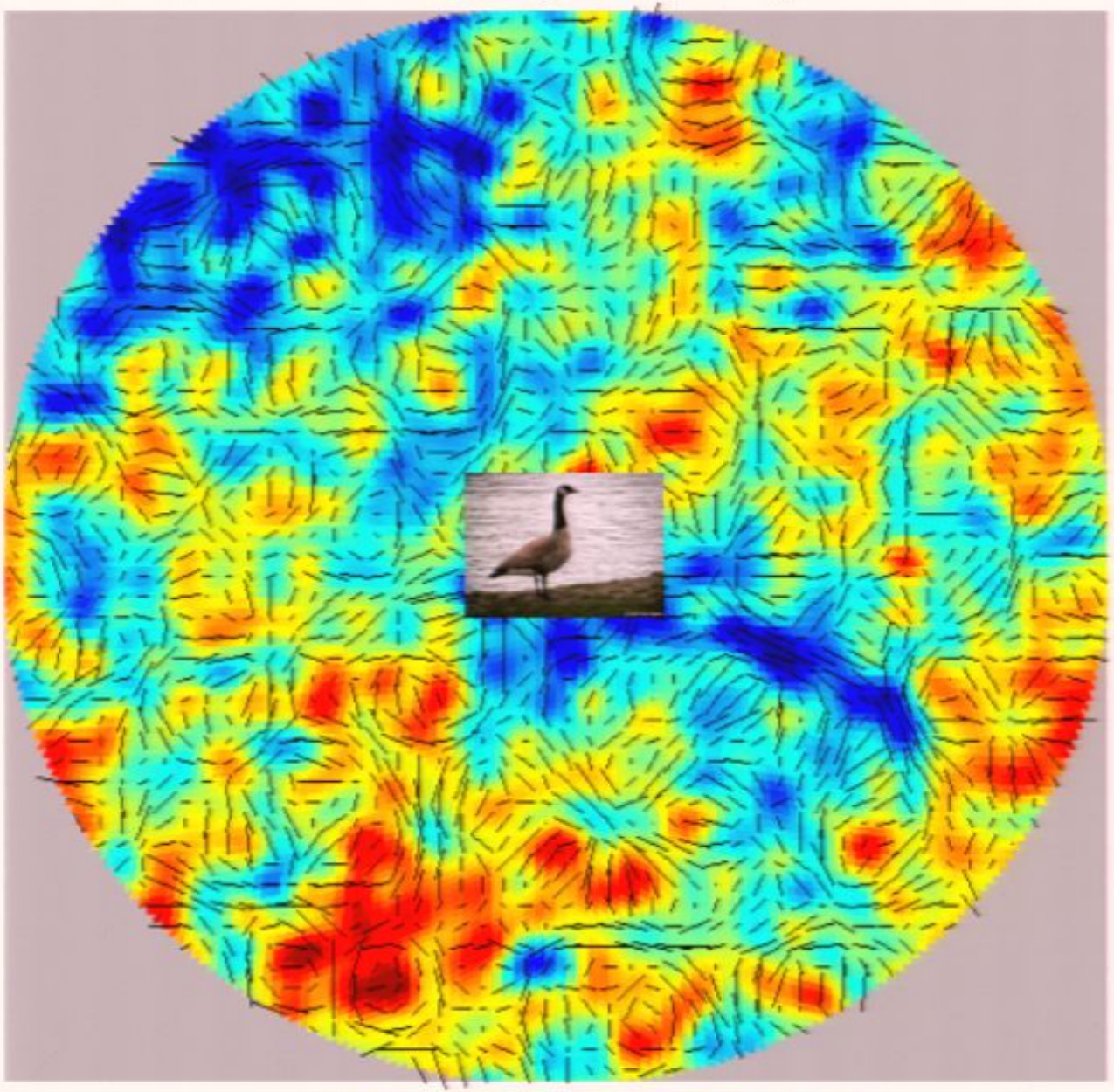

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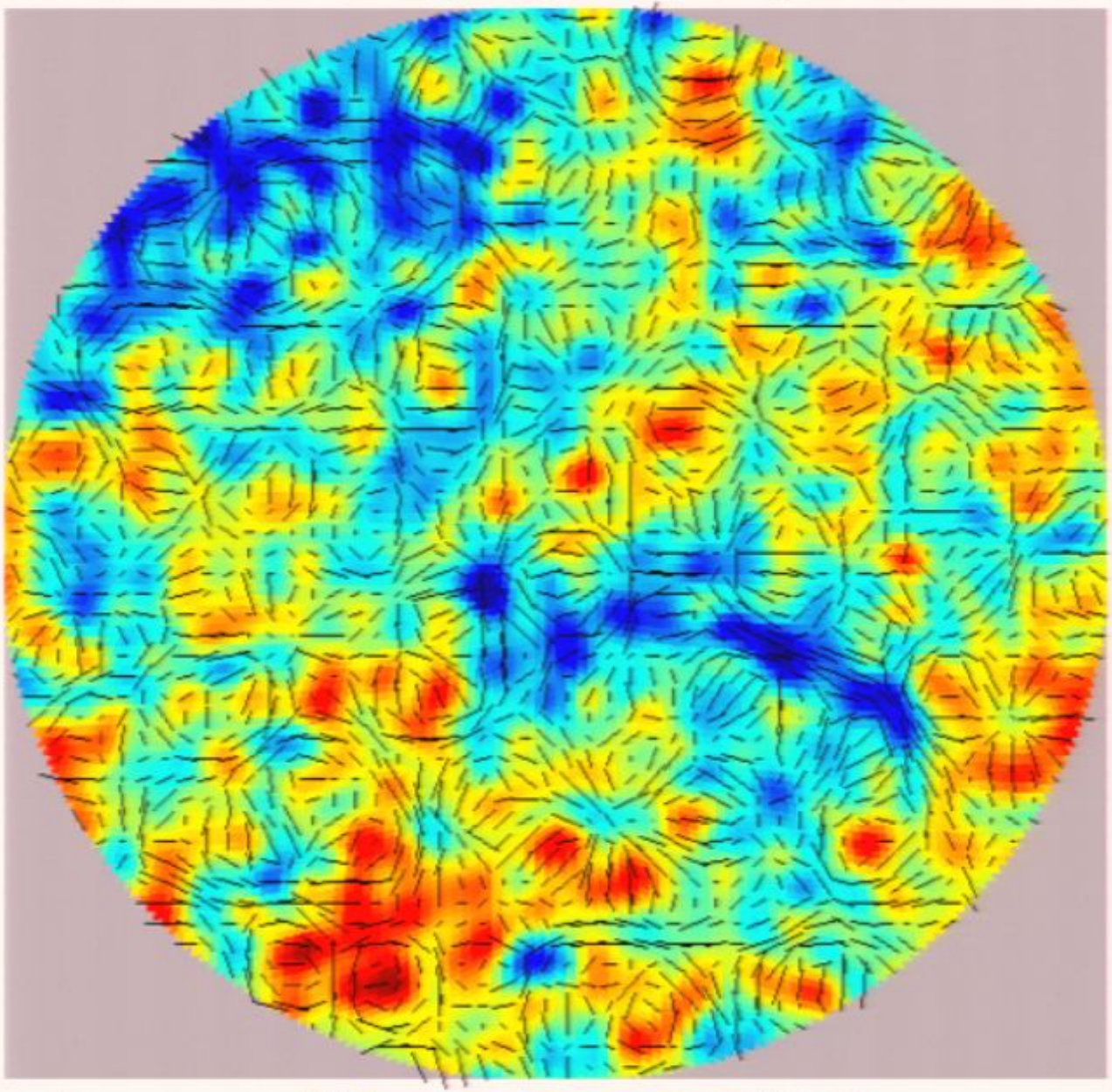

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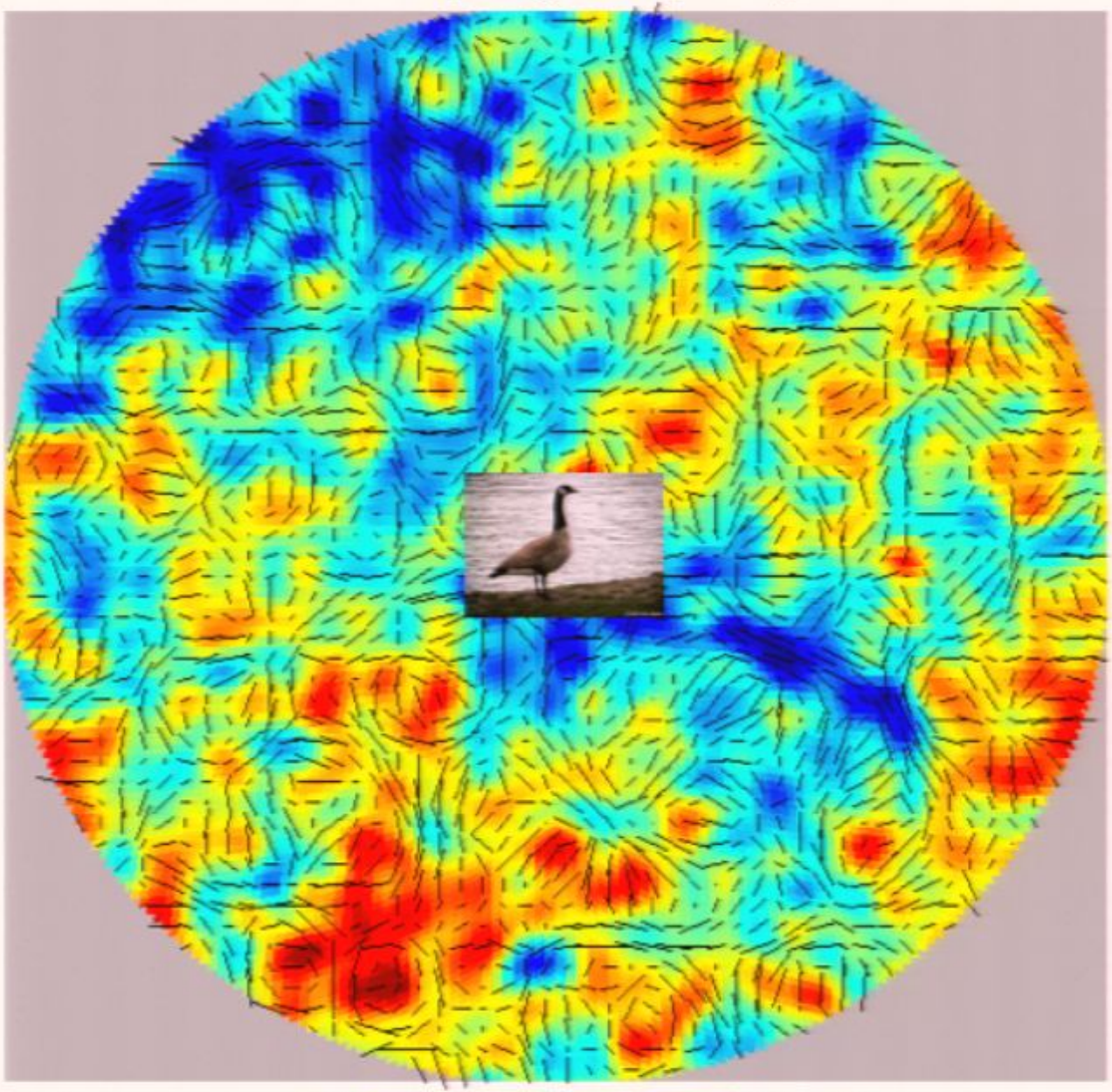

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3.75 μK

The Wild Goose Chasers

(partial list)

• WMAP	now	
• BICEP	now	
• QUIET	2008	partial funding
• BICEP2 / SPUD	2009 - 2012	prop. pending
• Planck	2009 - 2011	funded
• SPIDER	2010	funded
• CLOVER	???	funded
• SPTpol / ACTpol	???	ideas
• A future satellite	> 2018	dreams

Much time and money is being spent on goose traps, in the hopes of measuring how big the goose is.

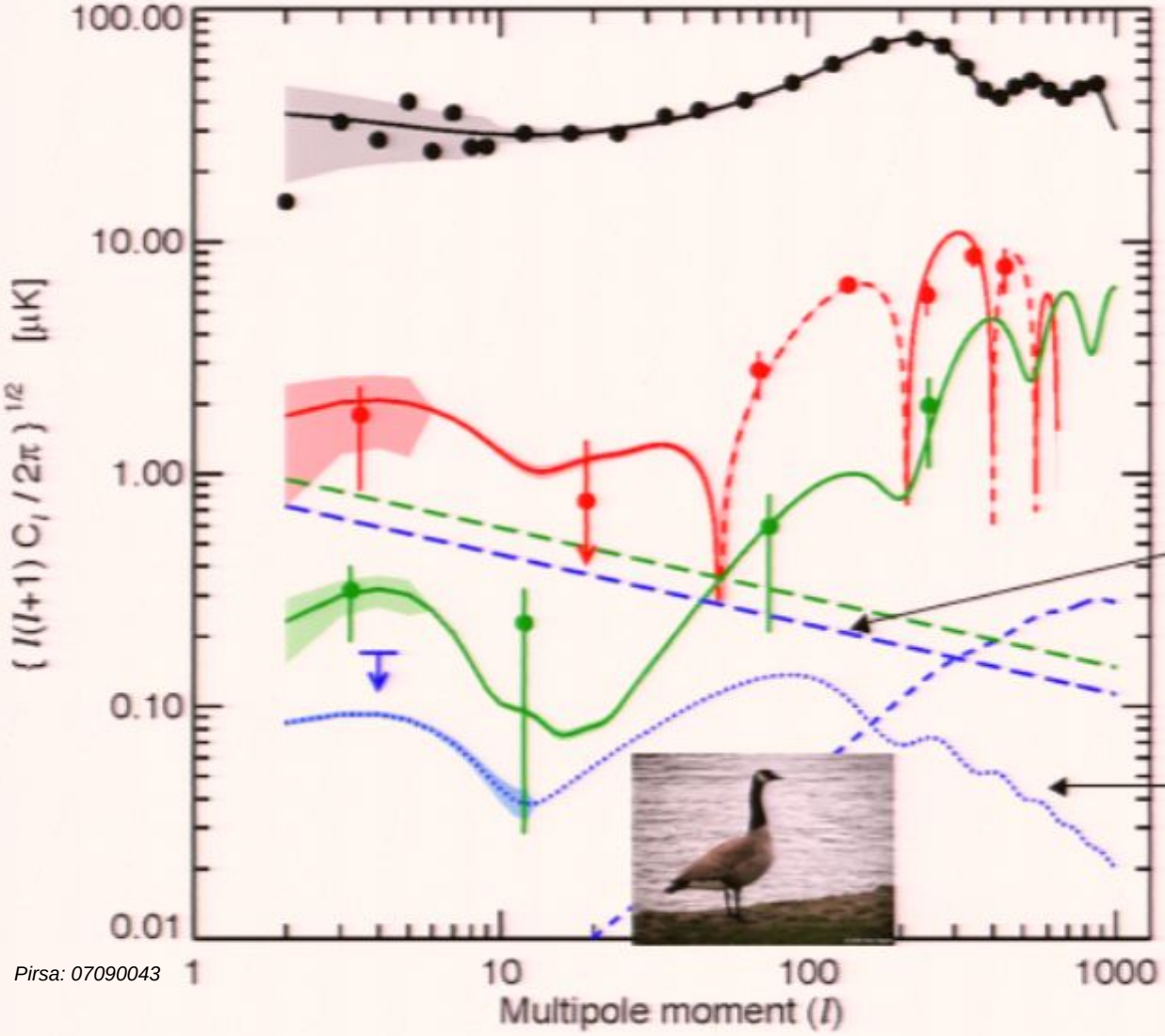
-

It would be very valuable to know as quickly as possible if there is, in fact, a goose.

How to flush out the goose?

- Foregrounds: 150 GHz
  small, clean patch
- Systematics: Small, cold telescope
- Sensitivity: Lots! (New technology)
- Site: South Pole

Foregrounds Matter!!

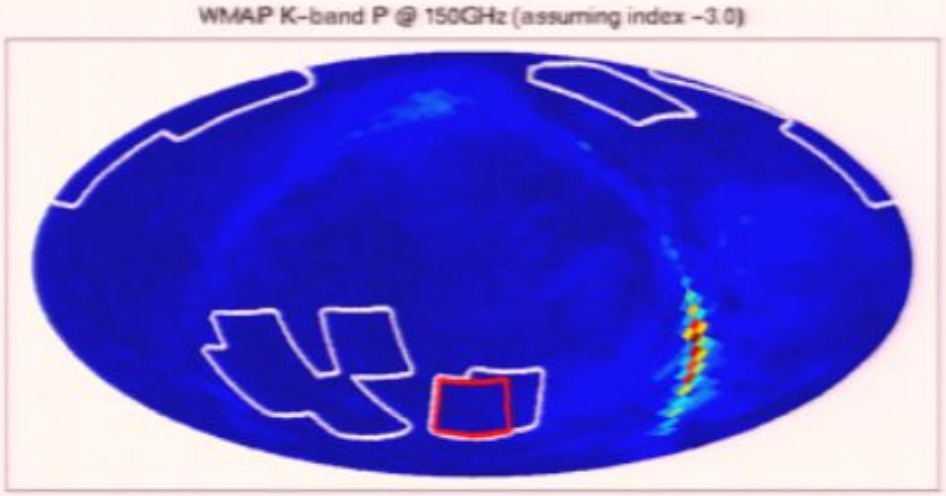


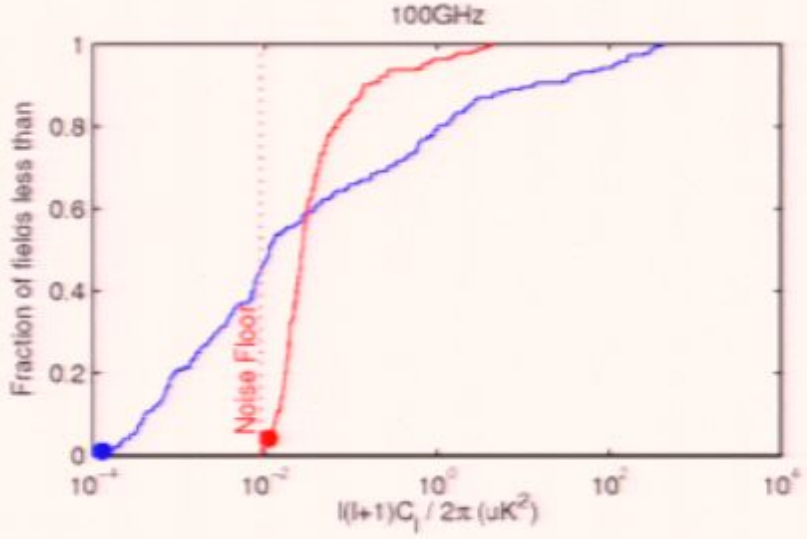
Foregrounds at
65 GHz

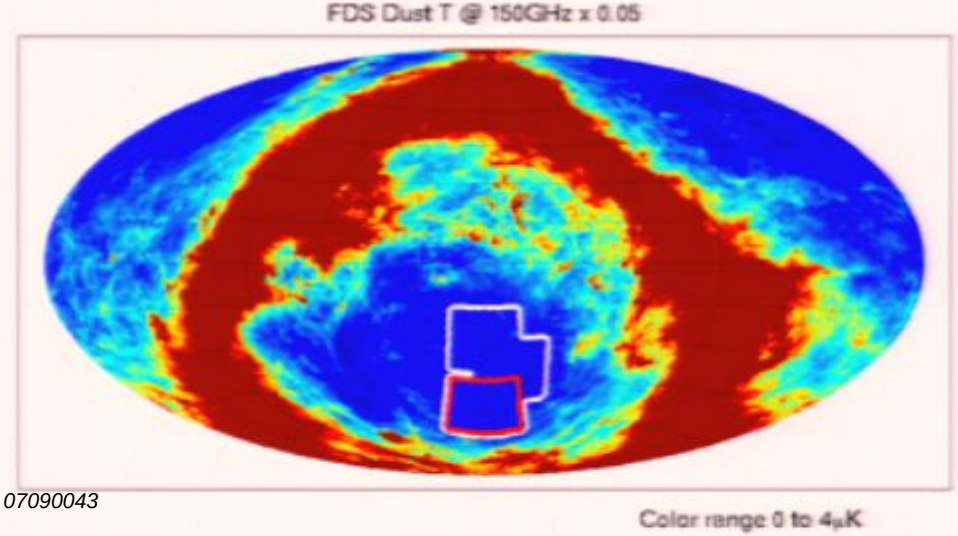
r = 0.3

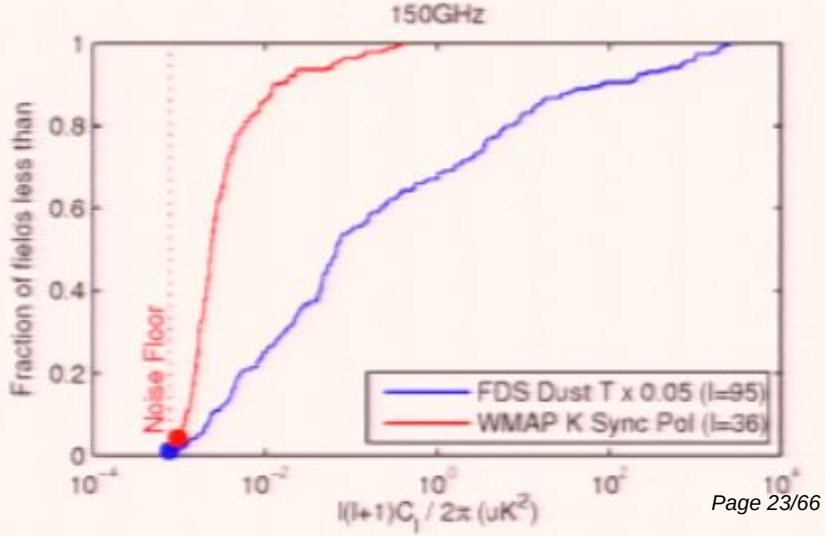
(a BIG goose)

So why 150 GHz?









Clem Pryke

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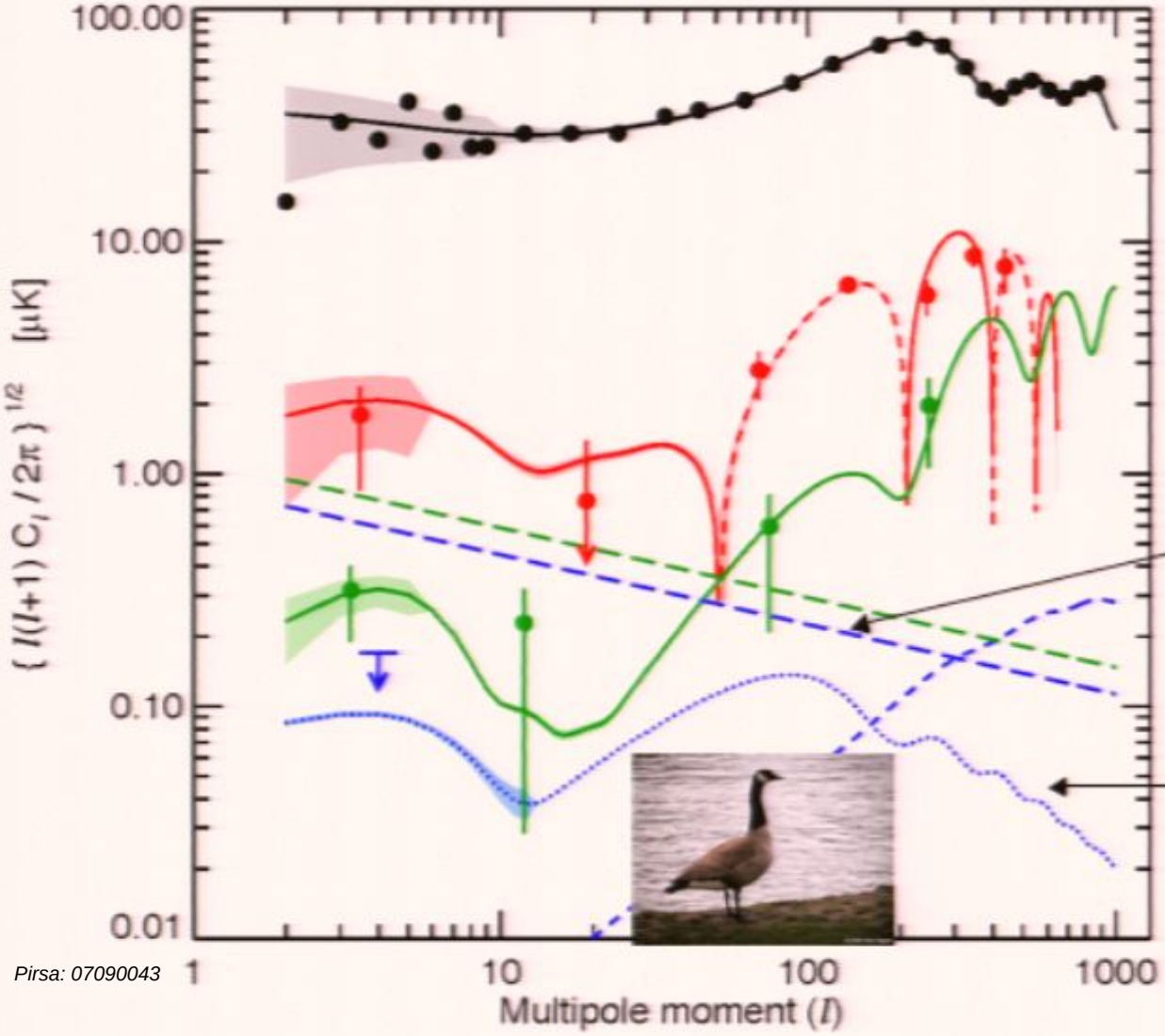

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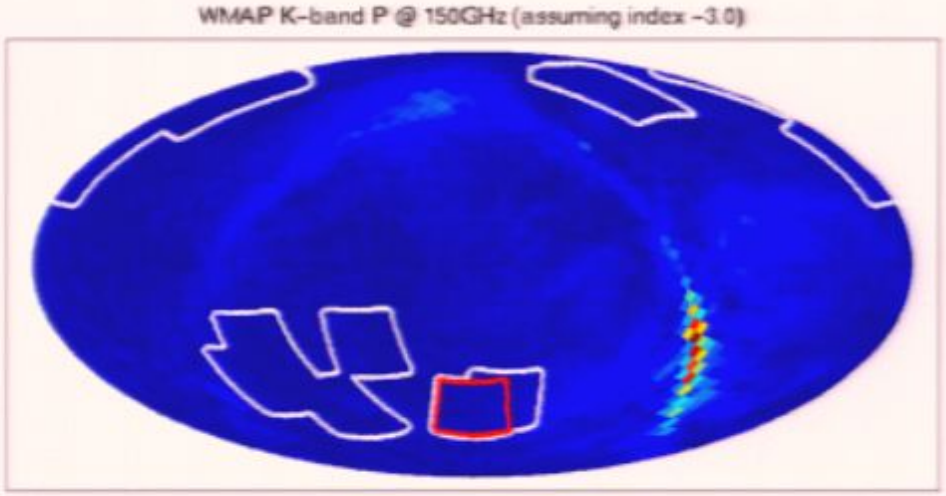

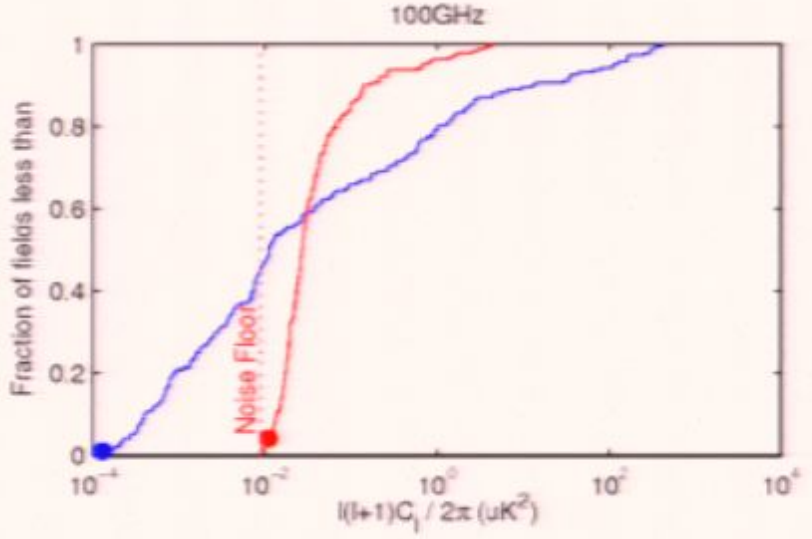

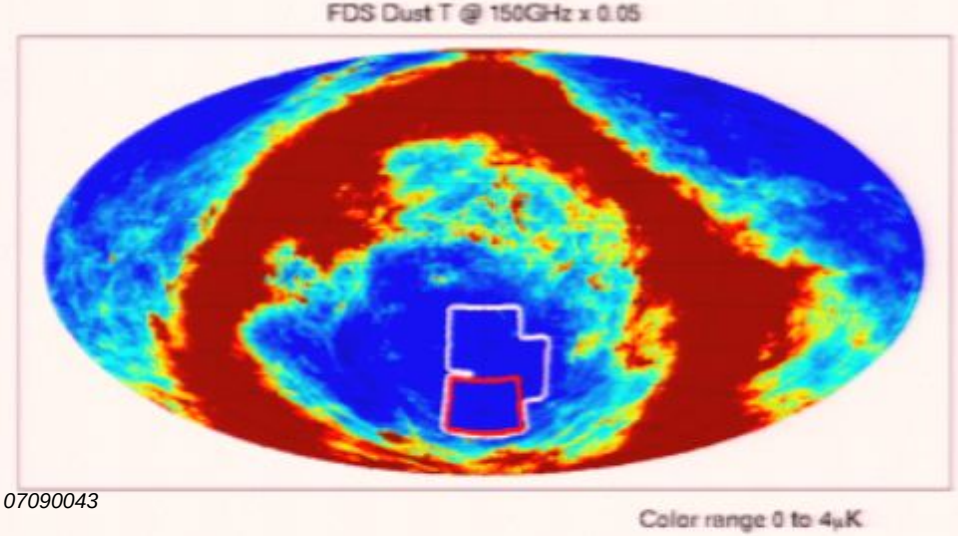

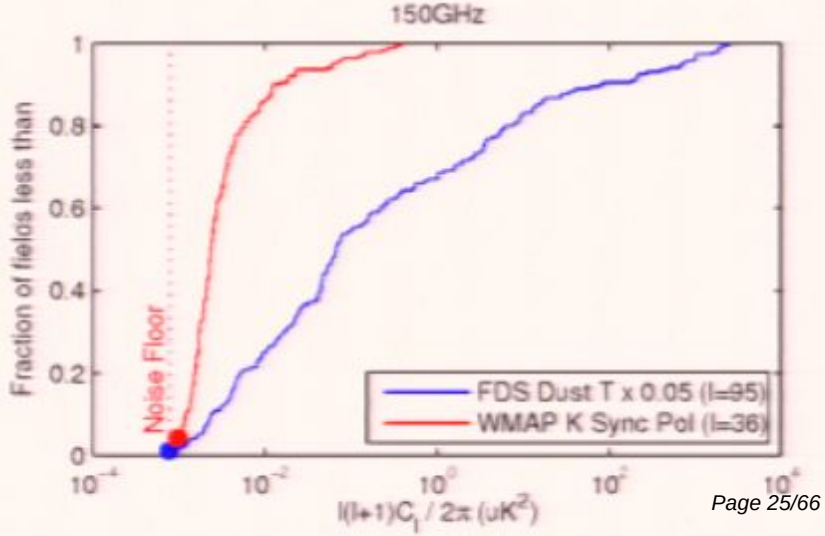

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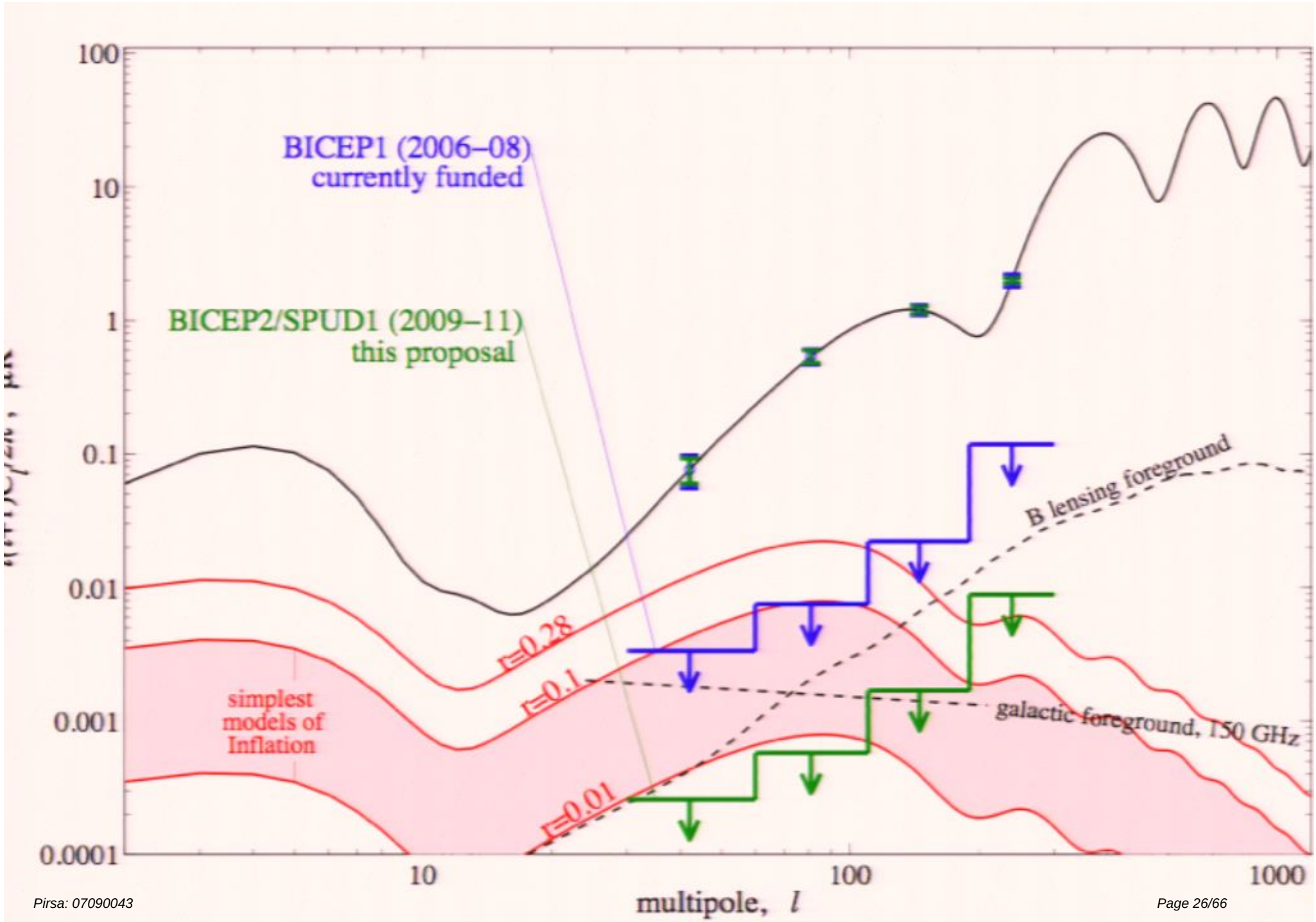
BICEP1 (2006–08)
currently funded
BICEP2/SPUD1 (2009–11)
this proposal
B lensing foreground
galactic foreground, 150 GHz
r=0.28
r=0.1
r=0.01
simplest
models of
Inflation
100
10
1
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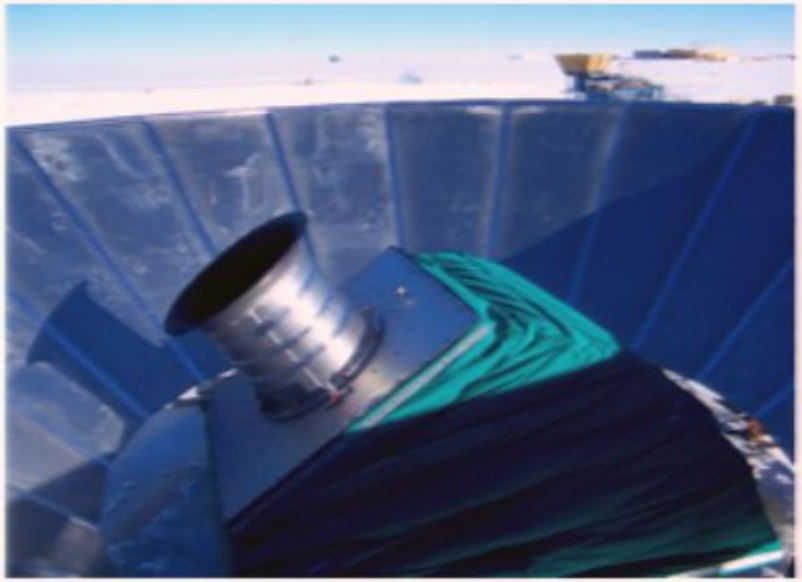
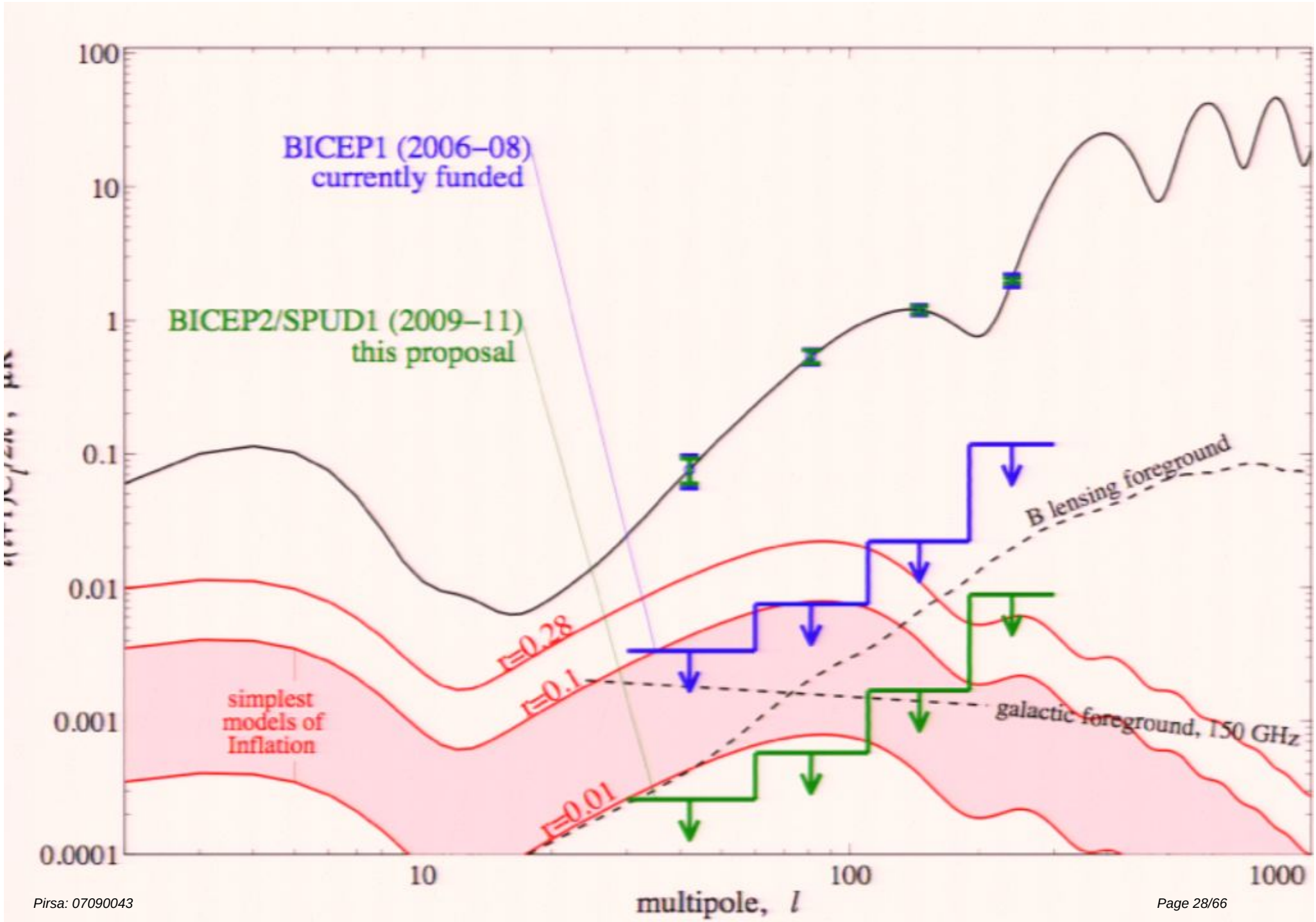
multipole, l

Why a small aperture?



- Aperture filling waveplate
- Aperture filling calibration
- Stability of (4K) telescope & beams
- Superior sidelobe suppression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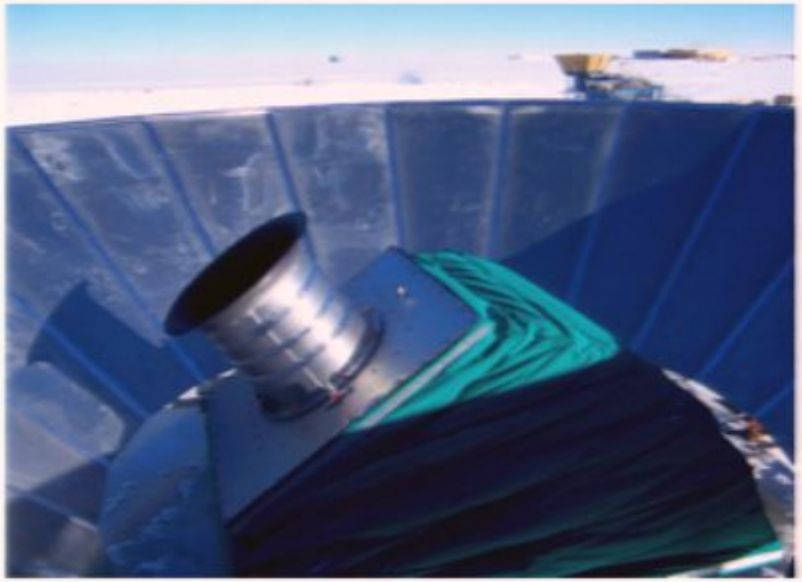

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Why the South Pole?

- Best target region observable 24/7, 10 months per year.
- Altitude ~ 10,500 feet.
- Sun below horizon for 6 months
- Extremely stable, dry atmosphere
- Easy access to telescope (!?)
- Simple, low-cost logistics (!?)

Why the South Pole?

Club Med for CMB Experimentalists

(The U.S. spends ~ $200M/year to maintain a presence at the South Pole. The stated reason is to do science.)

BICEP

Caltech / JPL

Andrew Lange
Ki Won Yoon
Cynthia Chiang
John Kovac
Chao-Lin Kuo
Denis Barkats
Jamie Bock
Darren Dowell
Hien Nguyen
Peter Mason
Erik Leitch

U.C. San Diego

Brian Keating
Evan Bierman

CEA, Grenoble
Lionel Duband
IAS, Paris
Eric Hivon
Nicolas Ponthieu

U.C. Berkeley

Bill Holzapfel
Yuki Takahashi

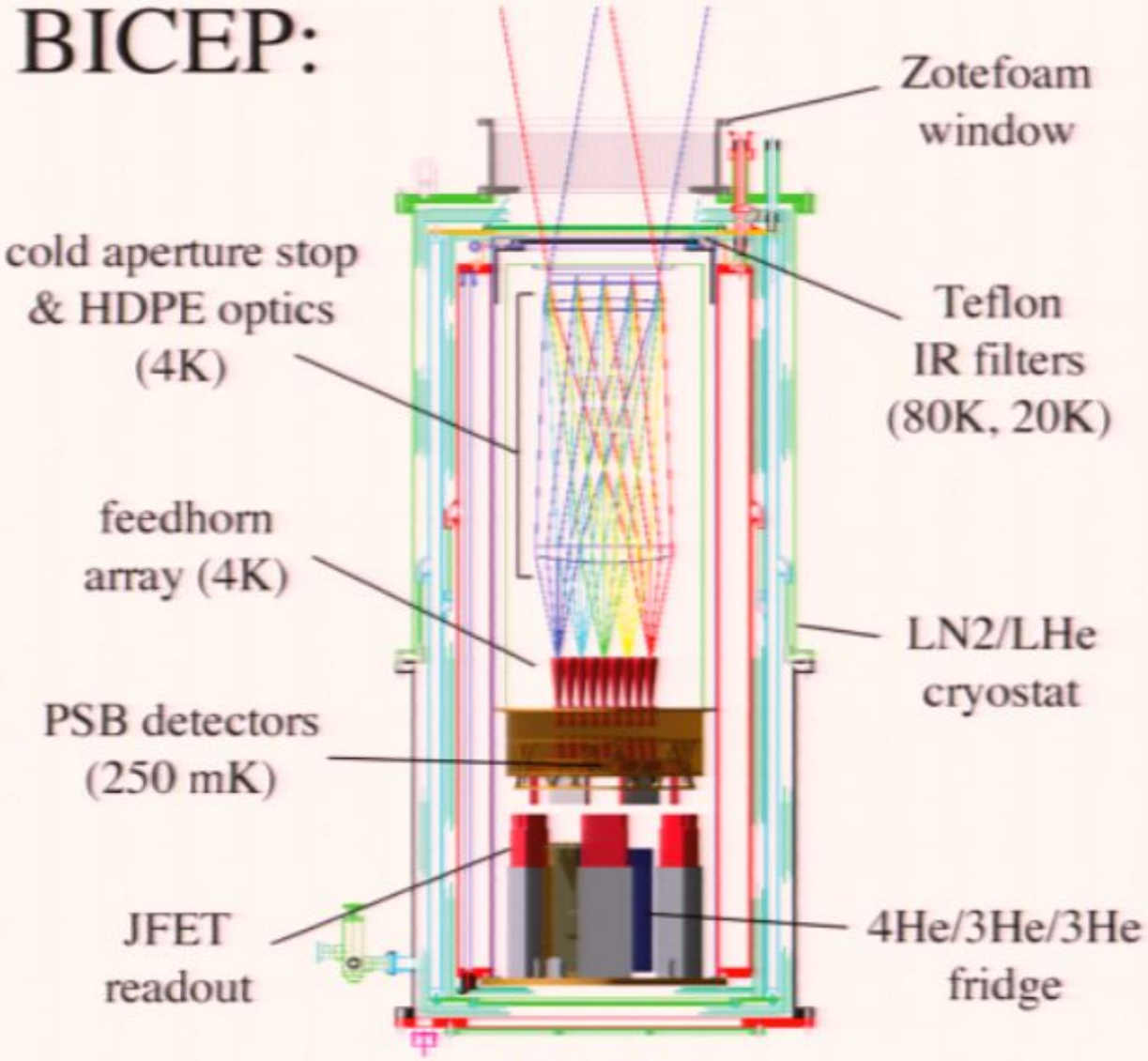
Cardiff University
Peter Ade

NSF

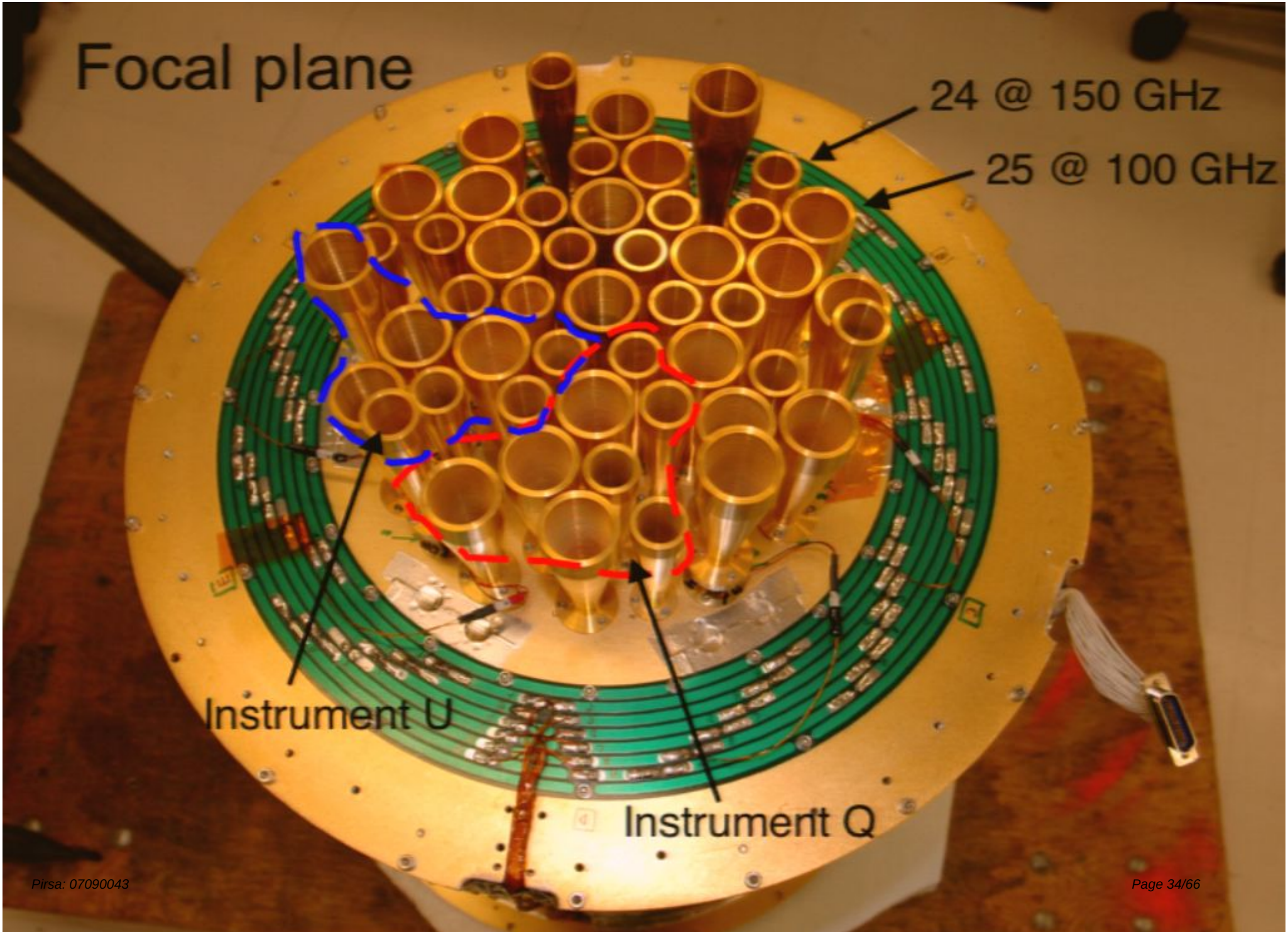
JPL

NASA

BICEP:

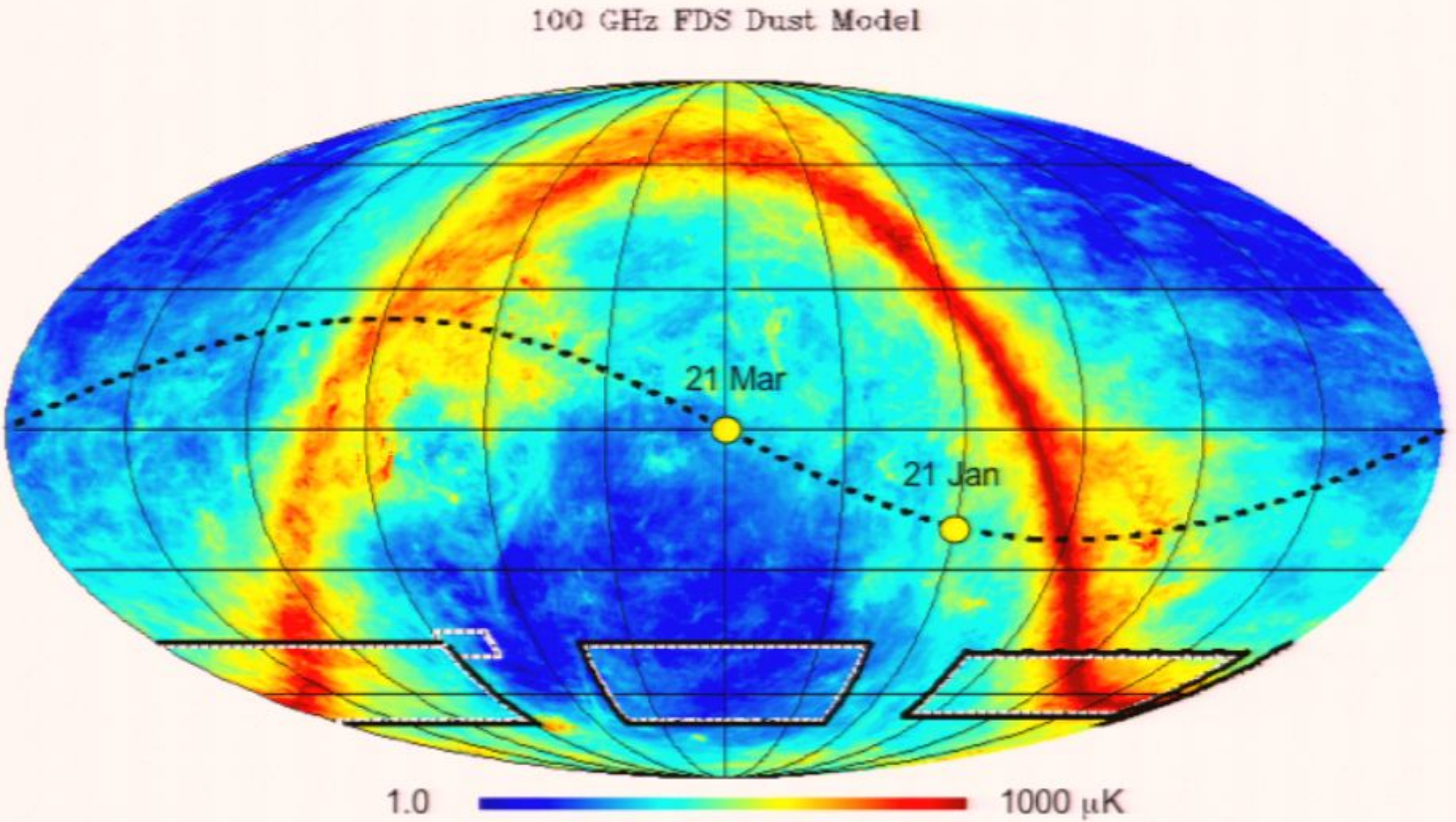


BICEP1


Focal plane
24 @ 150 GHz
25 @ 100 GHz
Instrument U
Instrument Q

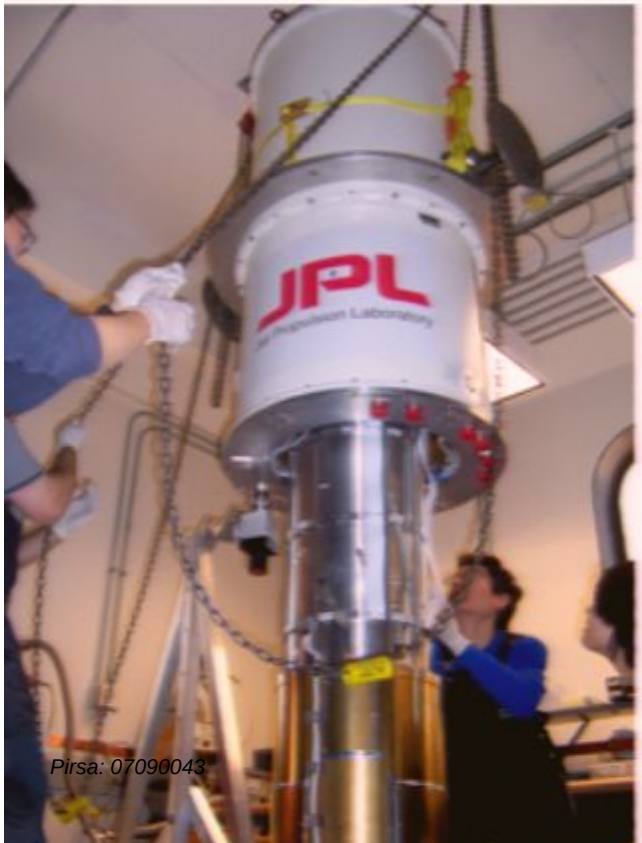
29 Nov 2005: BICEP installed in DSL

BICEP field selection



> 3000 hours on CMB target in first season!

From empty room to working observatory in 2 months….



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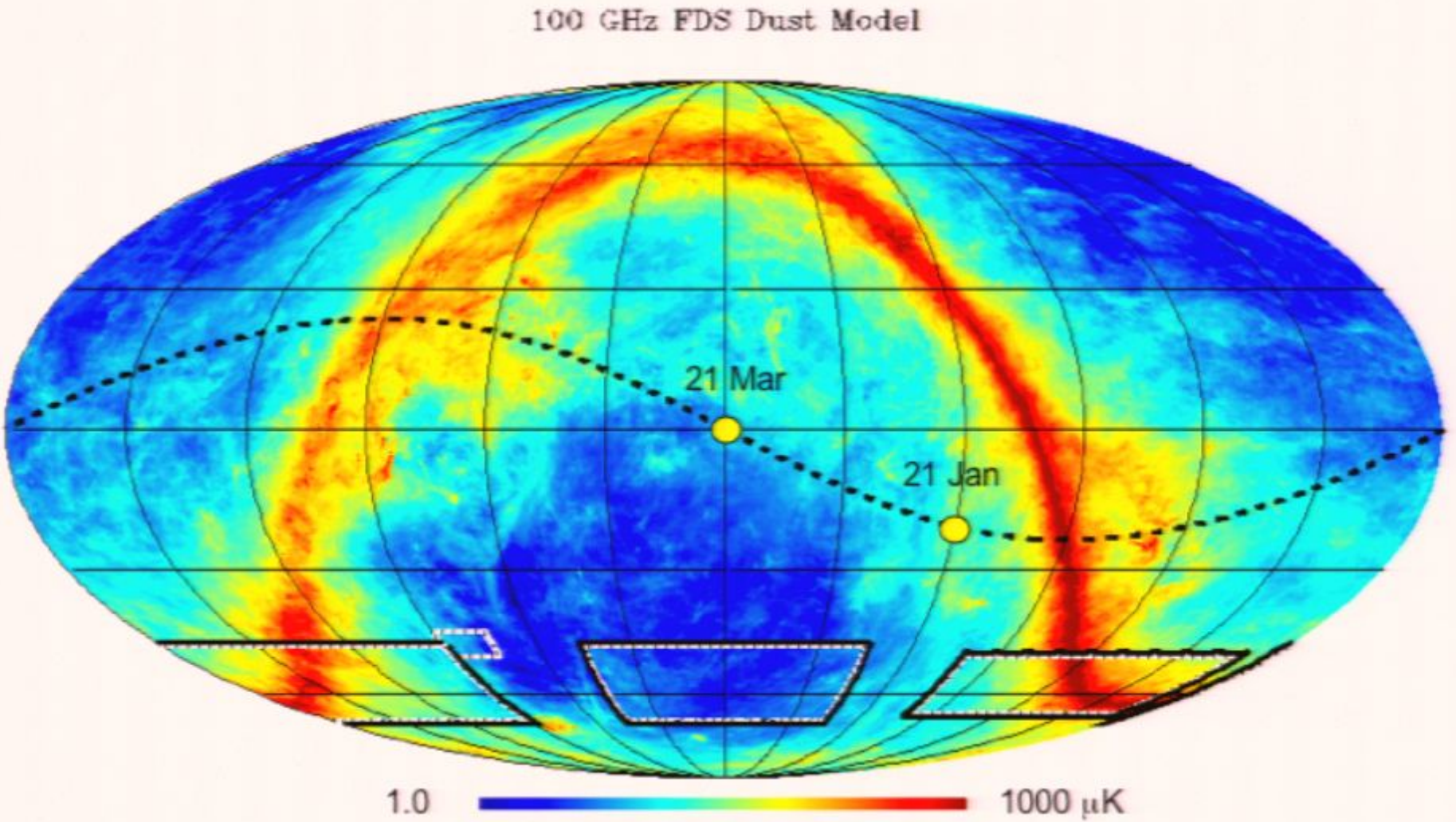

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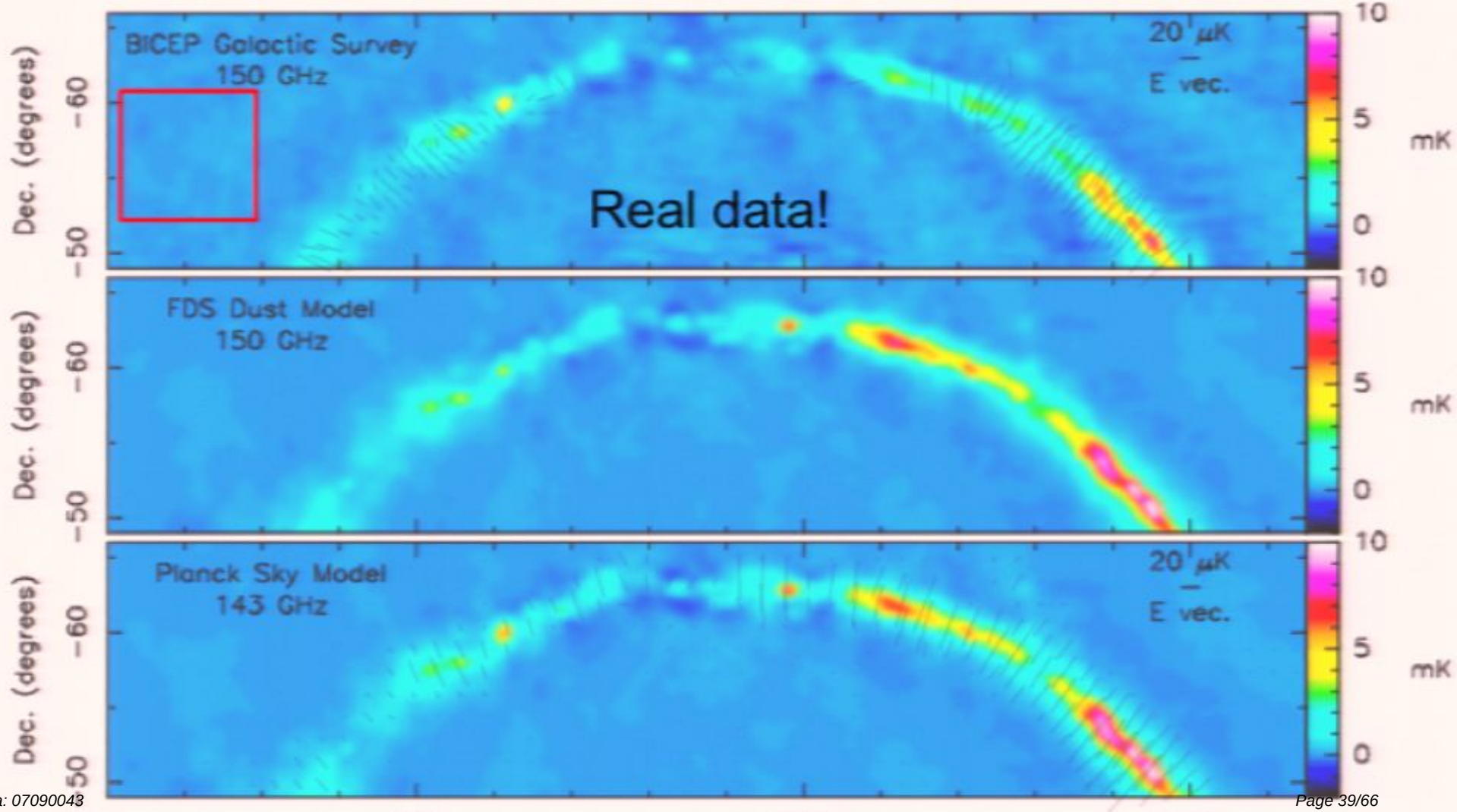
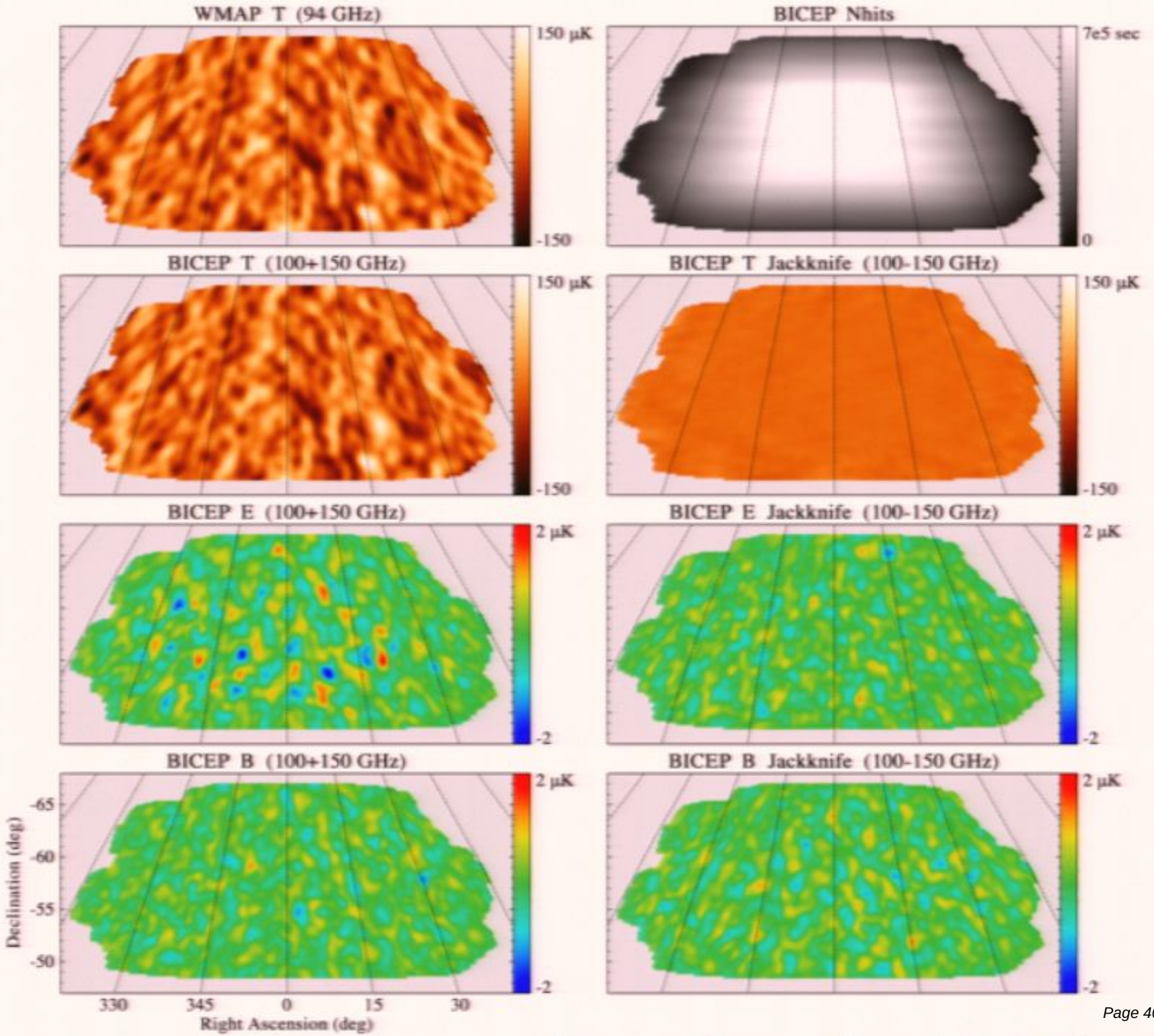
Polarization in the plane of the Galaxy at </= expected levels

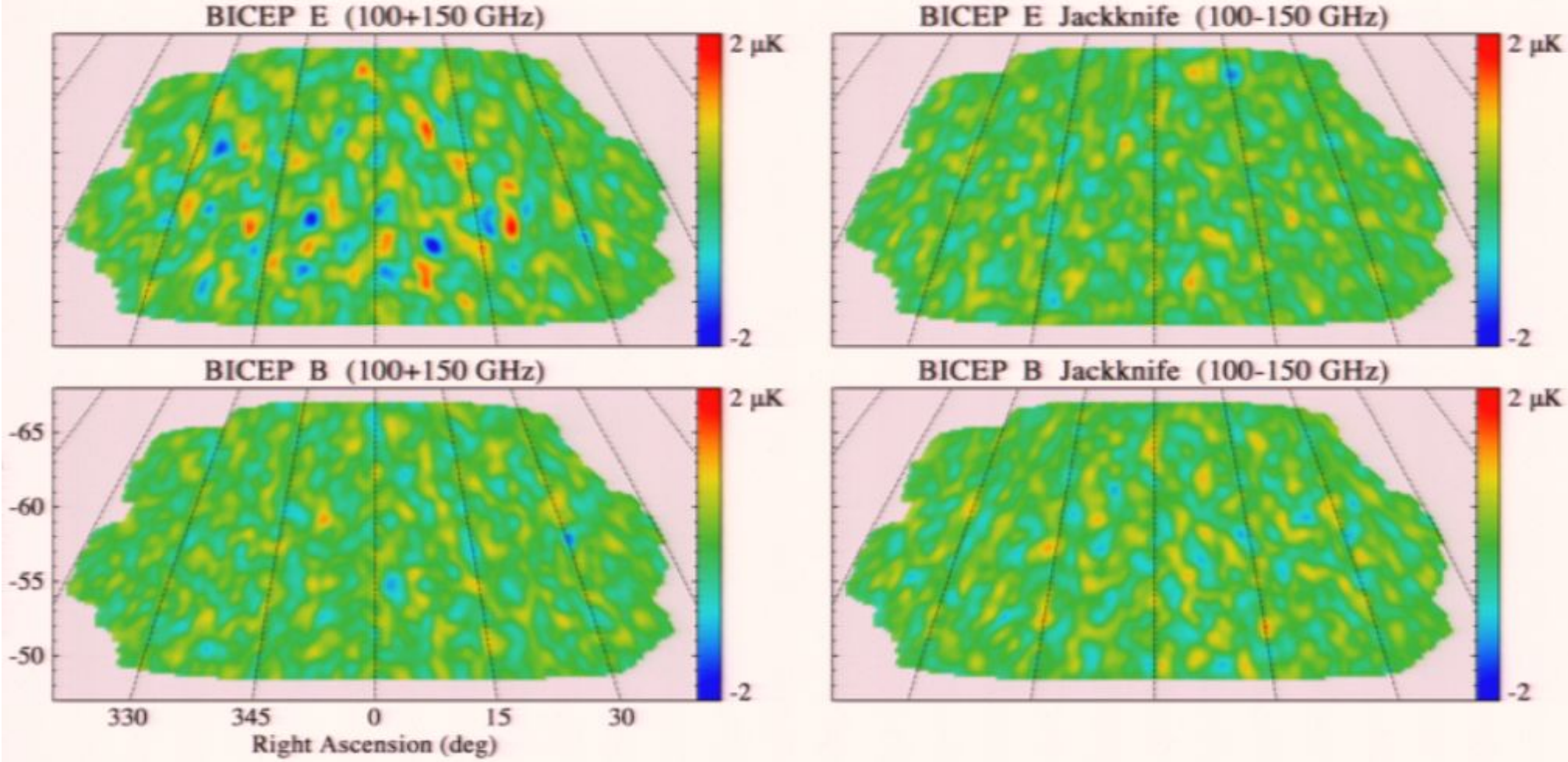


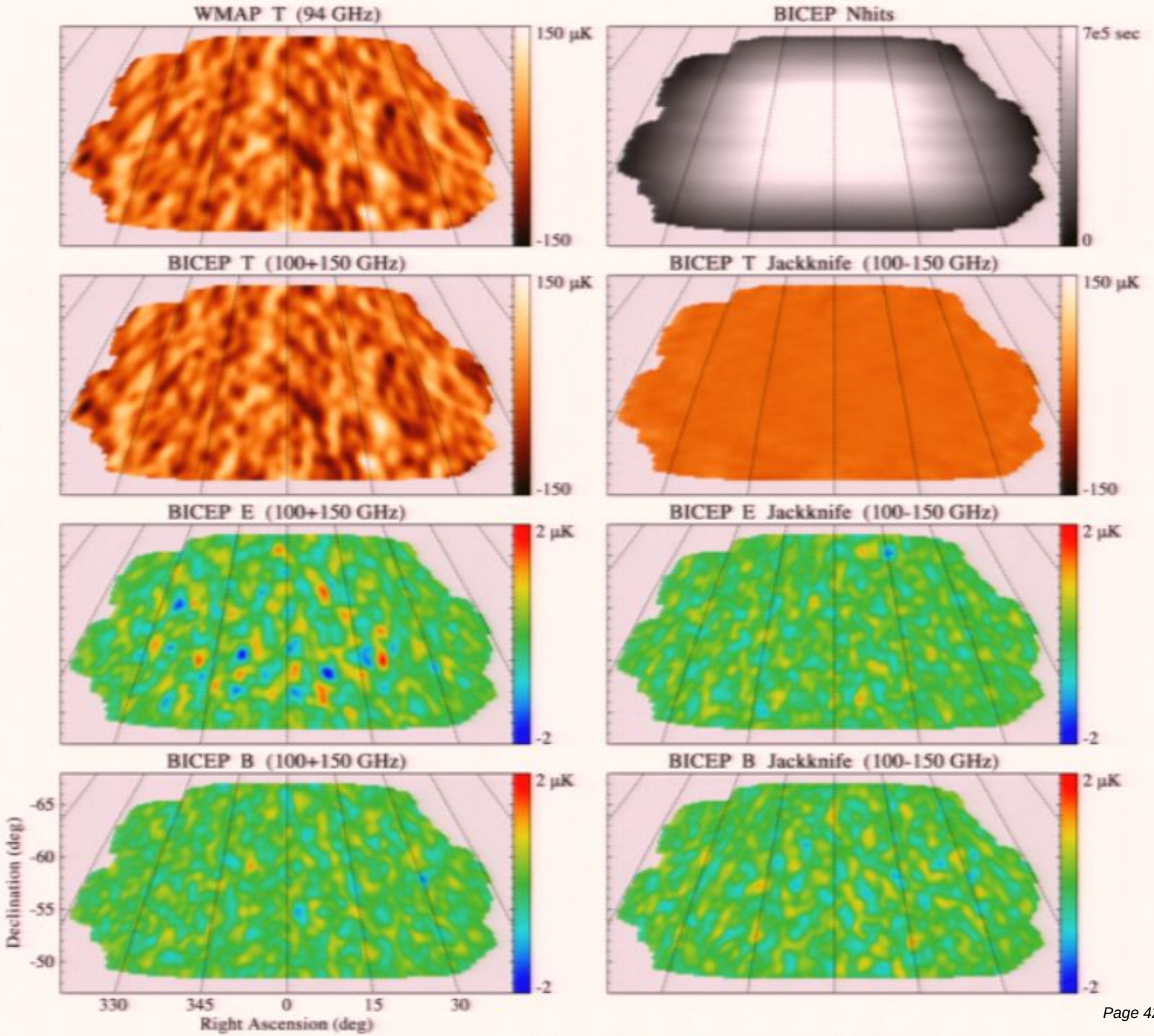
Darren Dowell



Kiwon Yoon, Cynthia Chiang

There are no enormous geese





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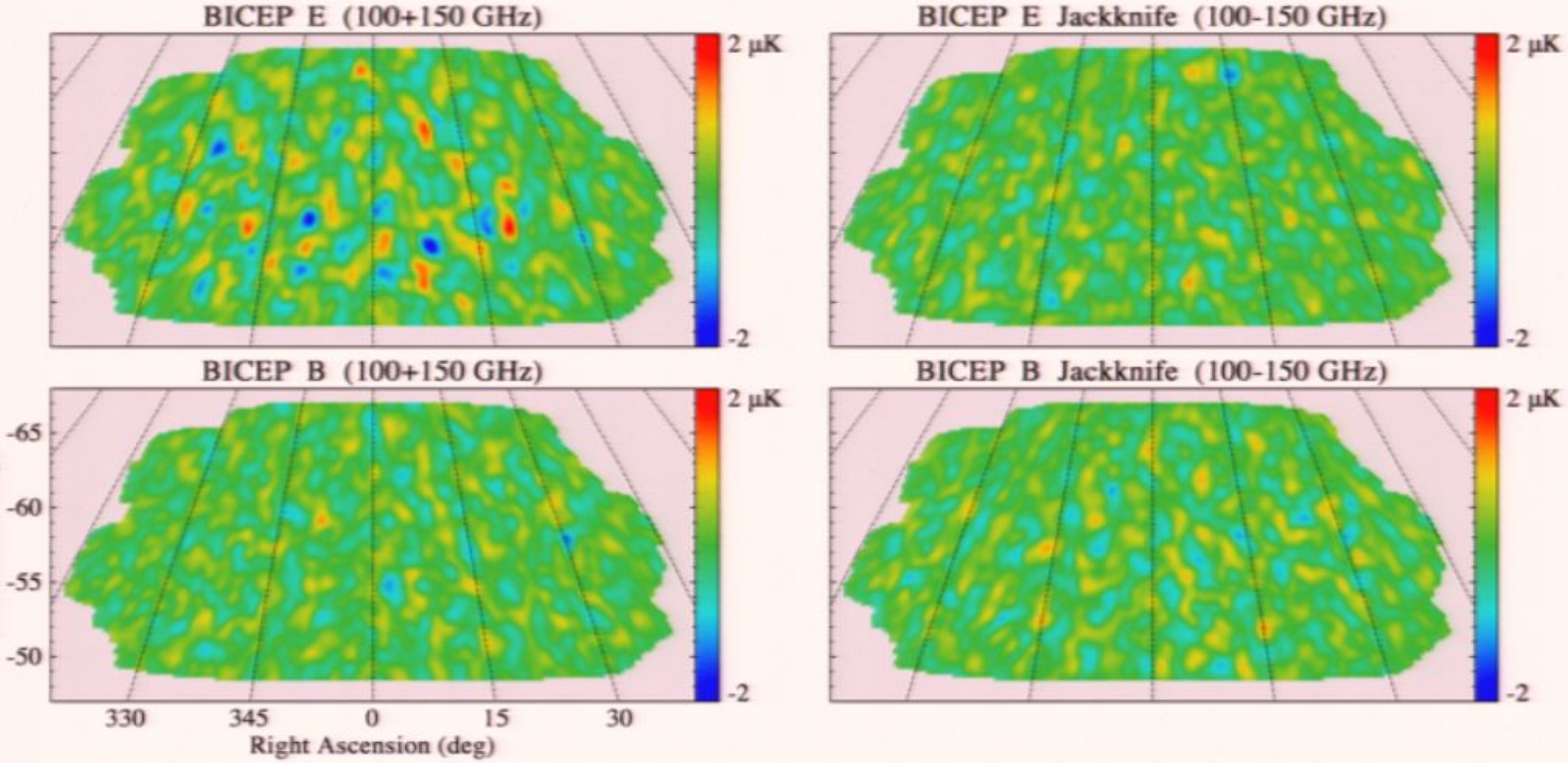
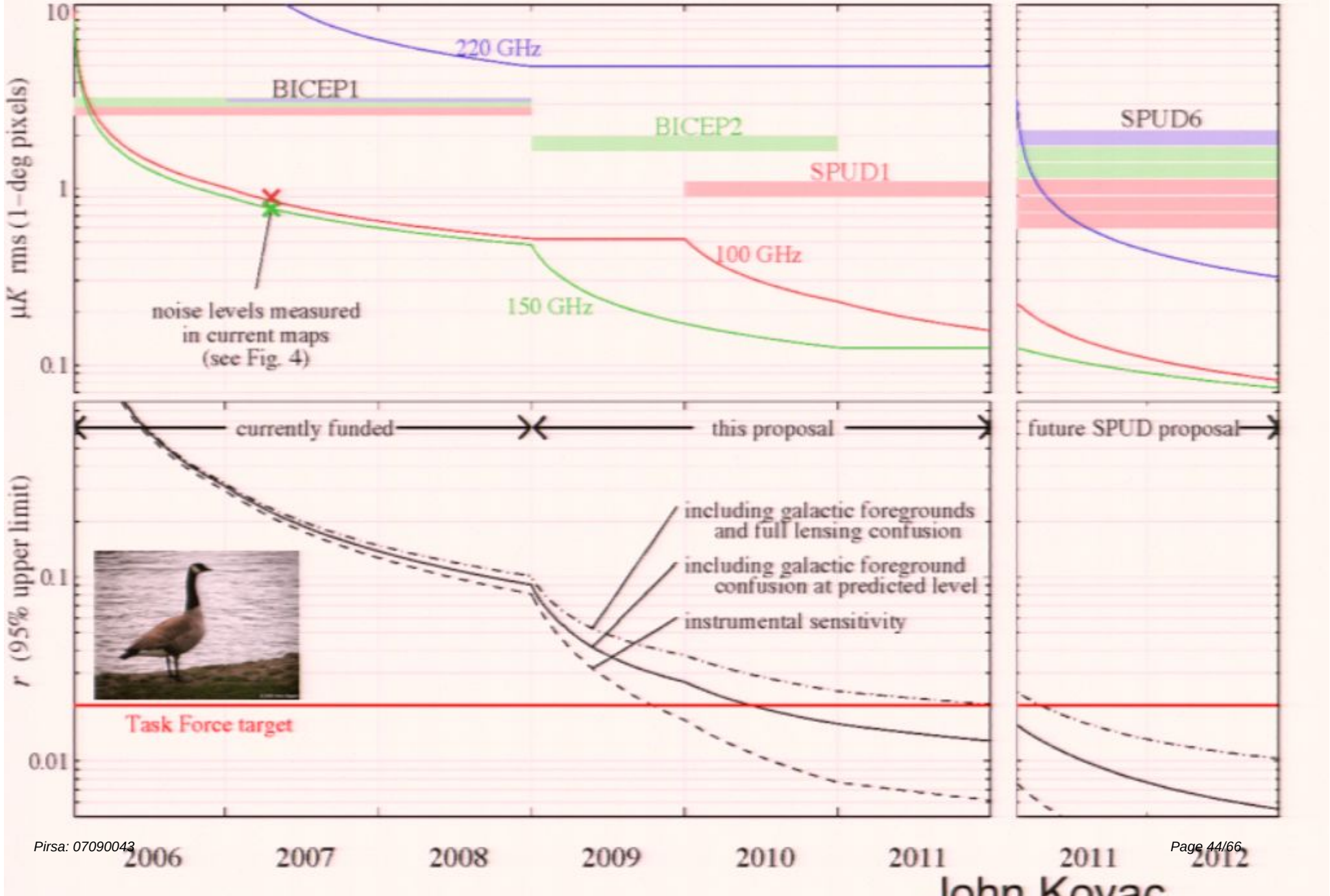
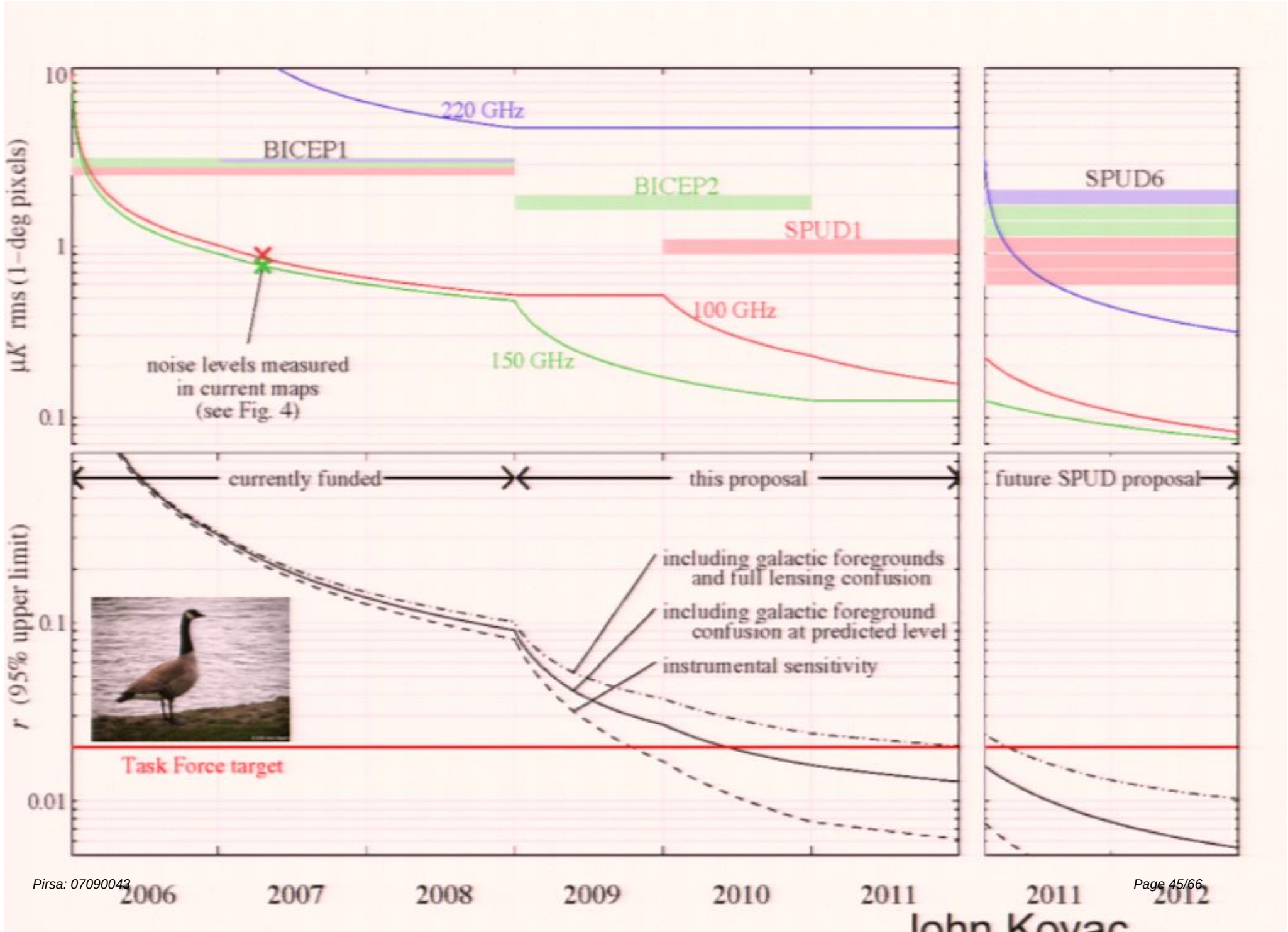



10
1
0.1
μK rms (1-deg pixels)
220 GHz
BICEP1
BICEP2
SPUD1
SPUD6
100 GHz
150 GHz
noise levels measured
in current maps
(see Fig. 4)
currently funded
this proposal
future SPUD proposal
r (95% upper limit)
0.1
0.01
including galactic foregrounds
and full lensing confusion
including galactic foreground
confusion at predicted level
instrumental sensitivity
Task Force target
2006
2007
2008
2009
2010
2011
2011
2012

John Kovac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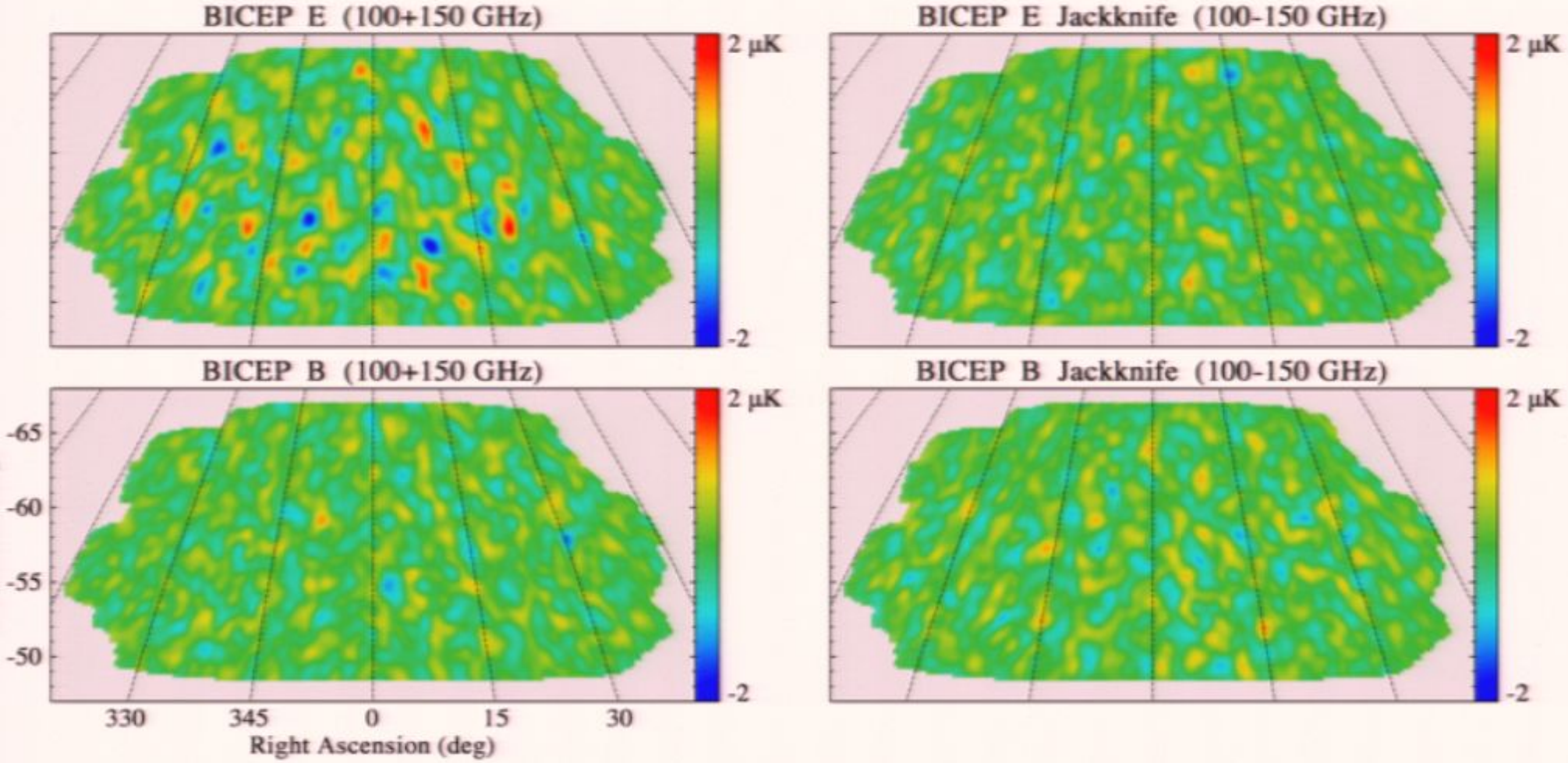

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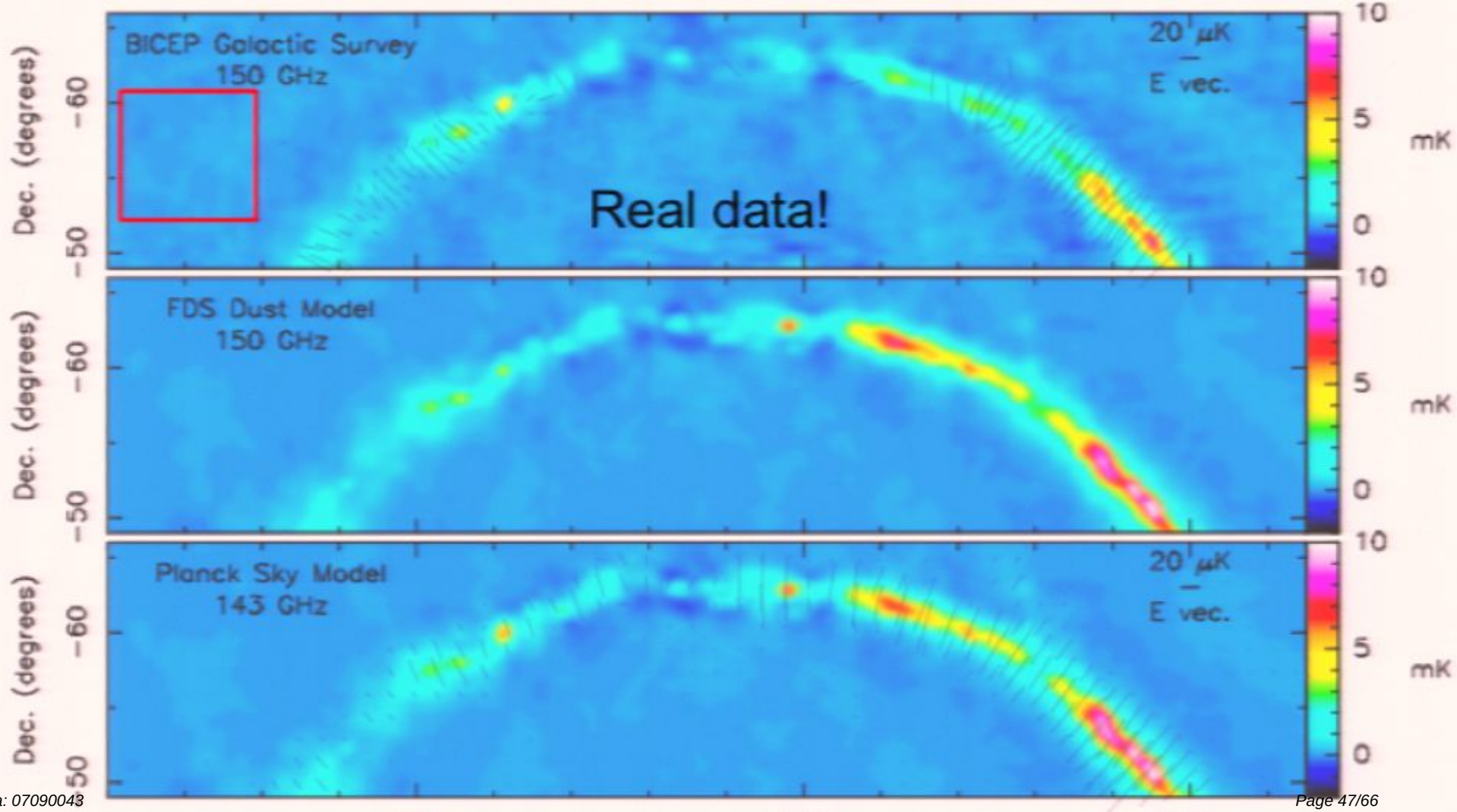
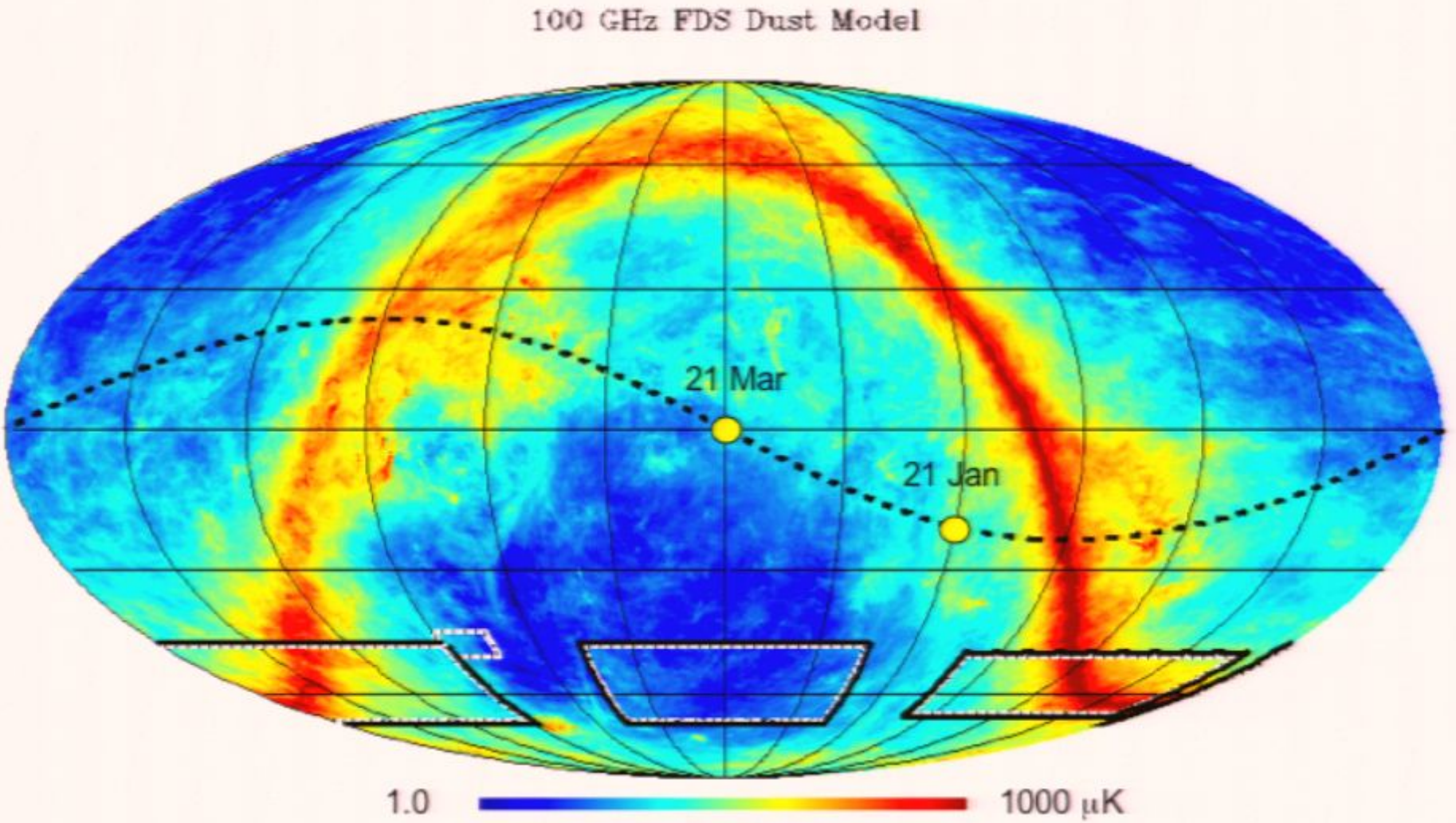


Darren Dowell

BICEP field selection



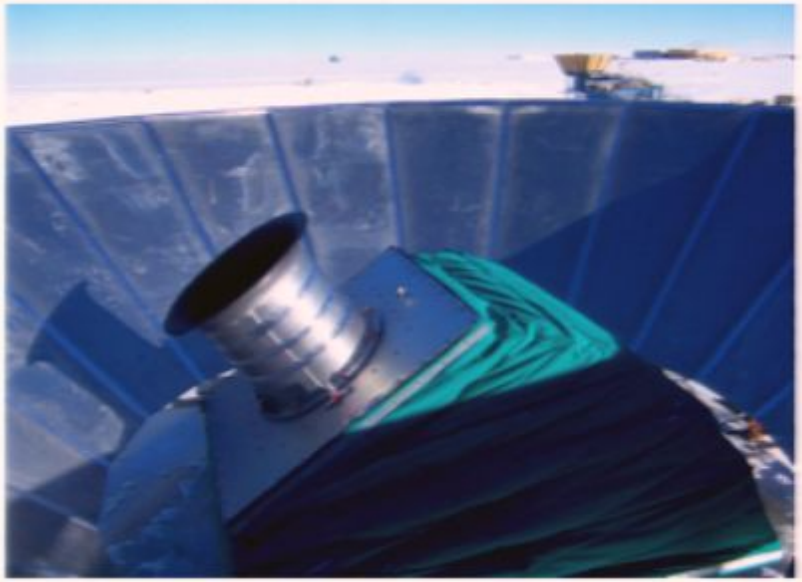
> 3000 hours on CMB target in first season!

29 Nov 2005: BICEP installed in DSL

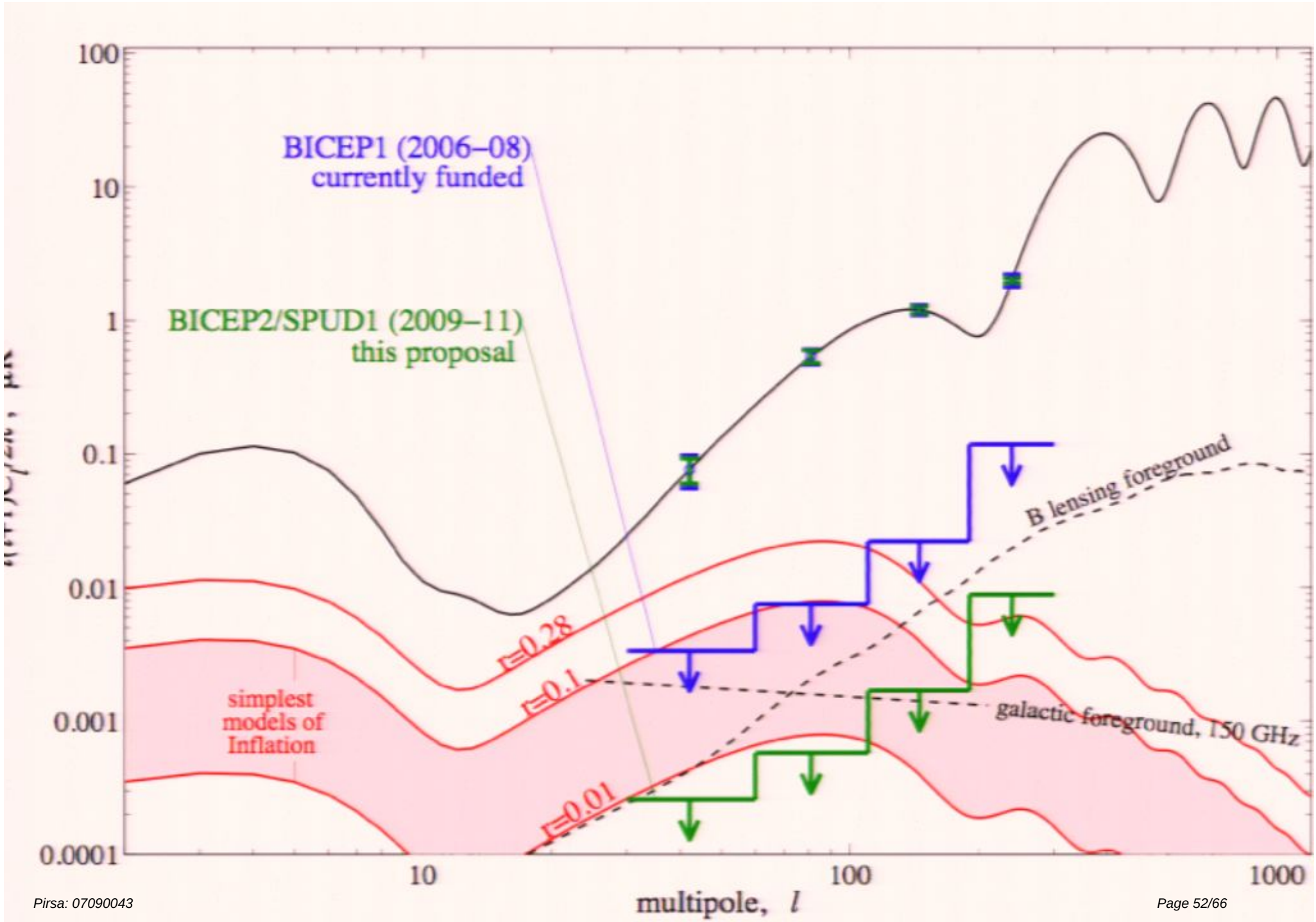
Why the South Pole?

- Best target region observable 24/7, 10 months per year.
- Altitude ~ 10,500 feet.
- Sun below horizon for 6 months
- Extremely stable, dry atmosphere
- Easy access to telescope (!?)
- Simple, low-cost logistics (!?)

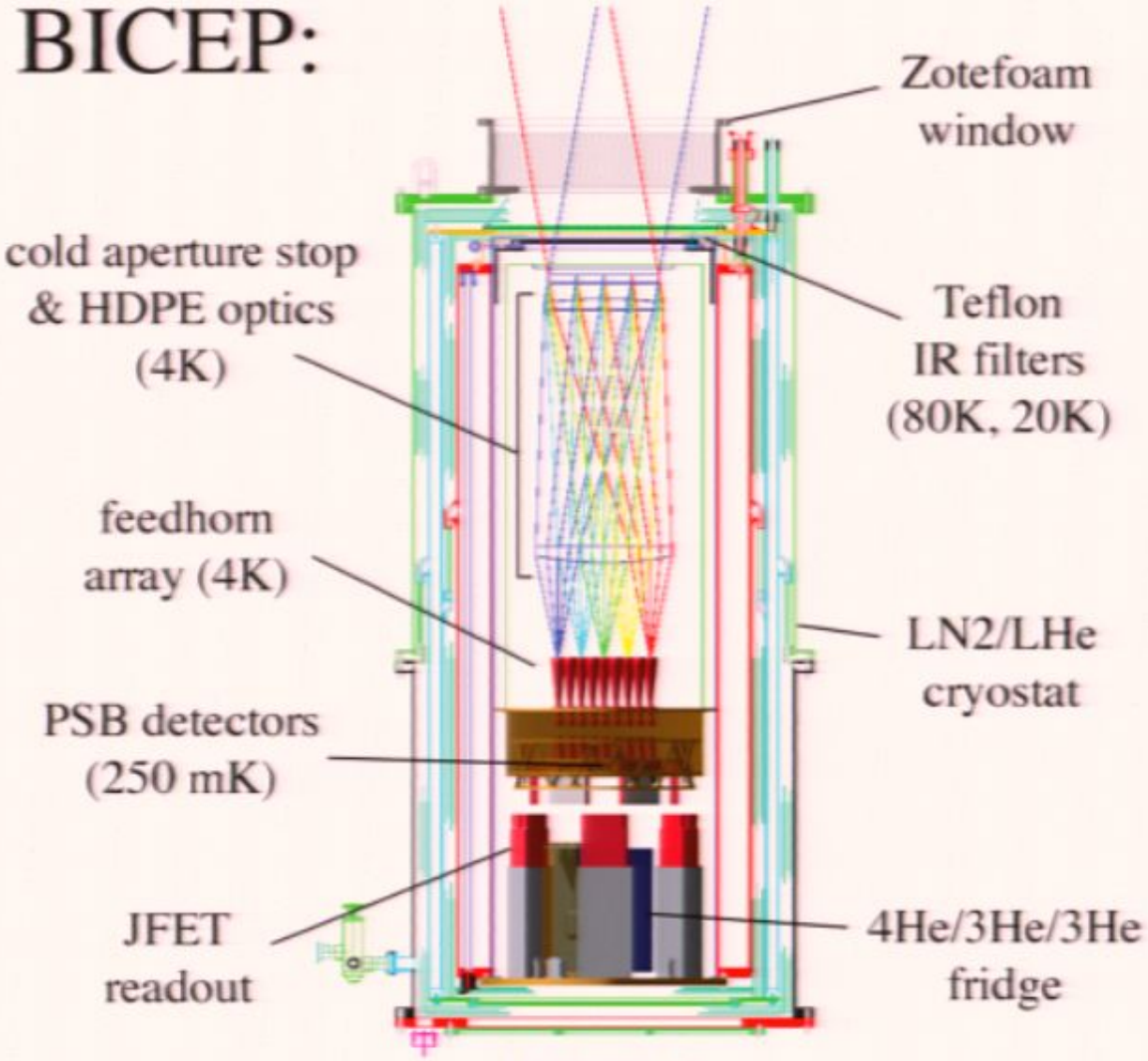
Why a small aperture?



- Aperture filling waveplate
- Aperture filling calibration
- Stability of (4K) telescope & beams
- Superior sidelobe suppression


BICEP1 (2006–08)
currently funded
BICEP2/SPUD1 (2009–11)
this proposal
B lensing foreground
galactic foreground, 150 GHz
r=0.28
r=0.1
r=0.01
simplest
models of
Inflation
100
10
1
0.1
0.01
0.001
0.0001
10
100
1000
multipole, l

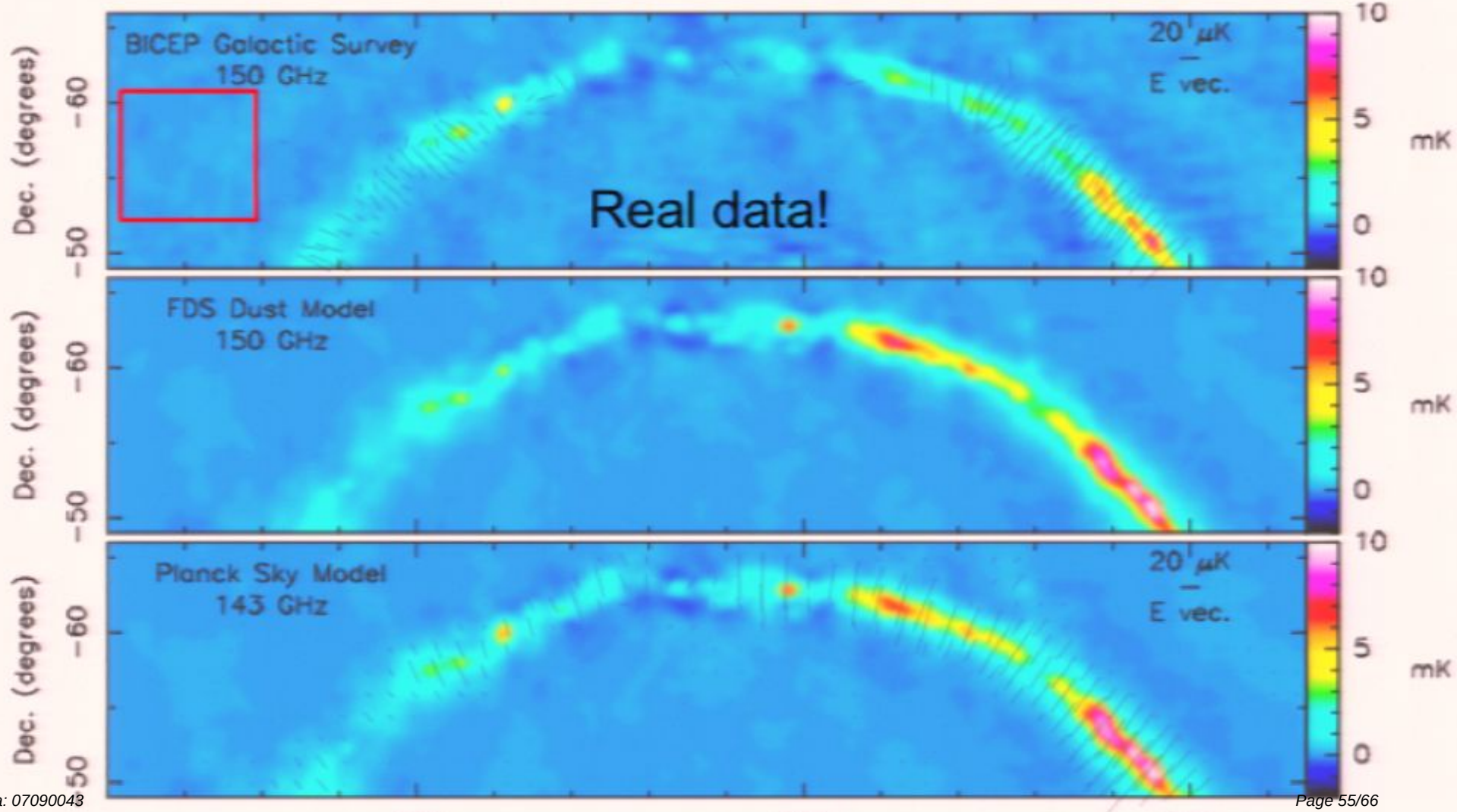
BICEP:



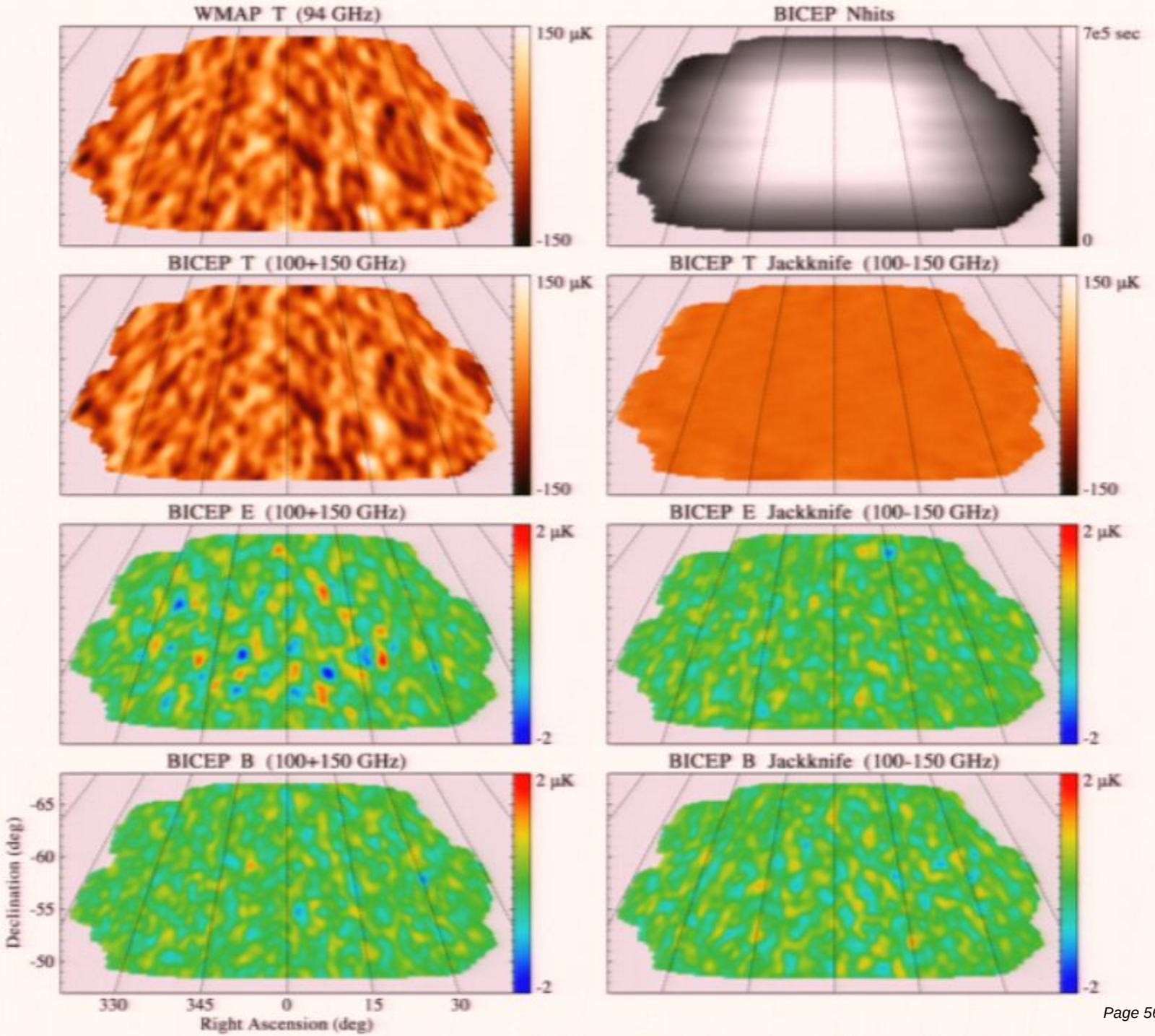
BICEP1

29 Nov 2005: BICEP installed in DSL

Polarization in the plane of the Galaxy at </= expected levels



Darren Dowell



Kiwon Yoon, Cynthia Chiang

What comes next?

What comes next?

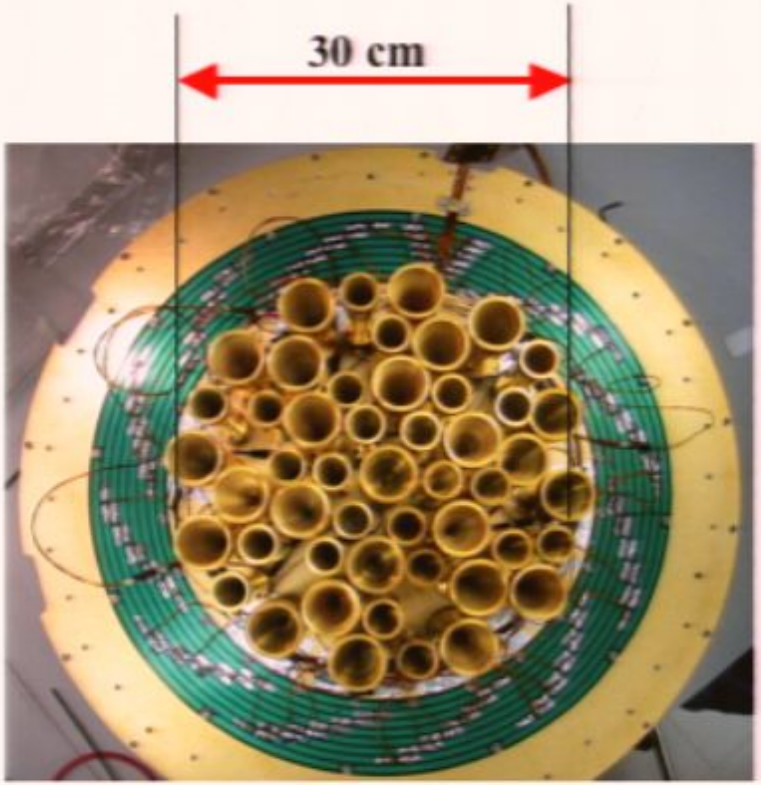
Bolometric Polarimeters

The state-of-the-art:

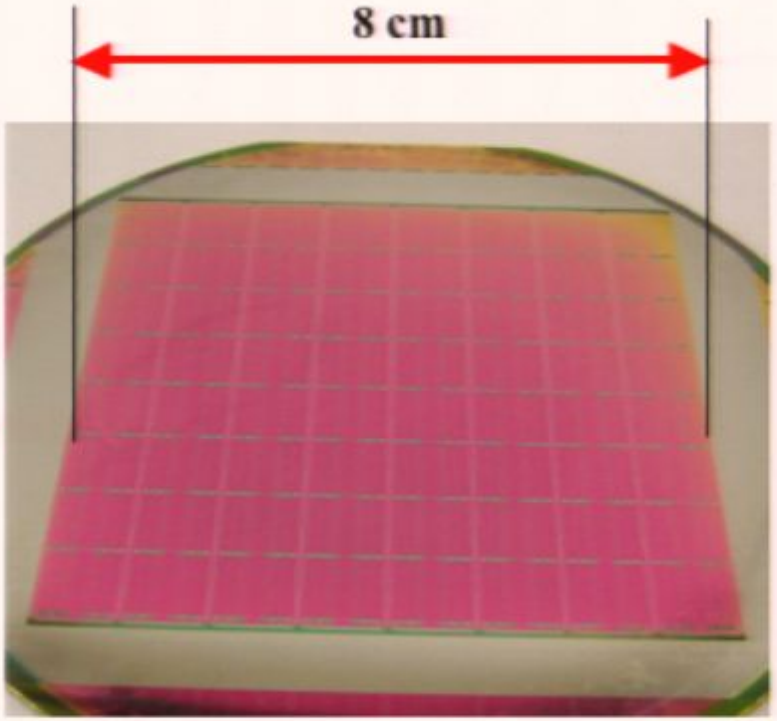
- Co-locating dual-polarization polarimeter
- High optical efficiency, wide band
- Extremely stable
- Nice beam/band
- Low polarization artifacts
- Discrete elements: feeds, filters, detectors

The future:

- To integrate all these components on a Si wafer → mass production
- Higher packing density
- TES enables SQUID multiplexed read-out



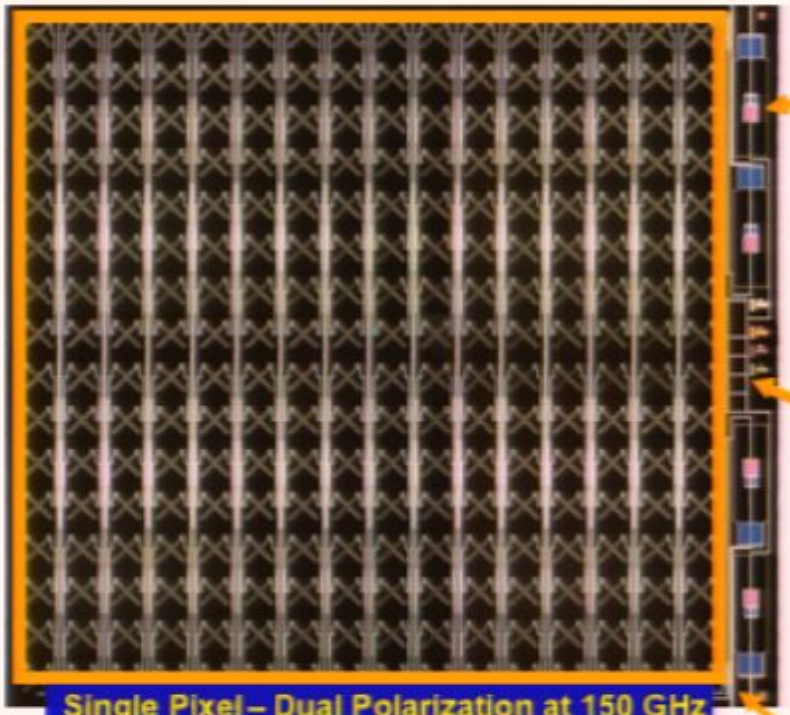
BICEP focal plane (98 detectors)



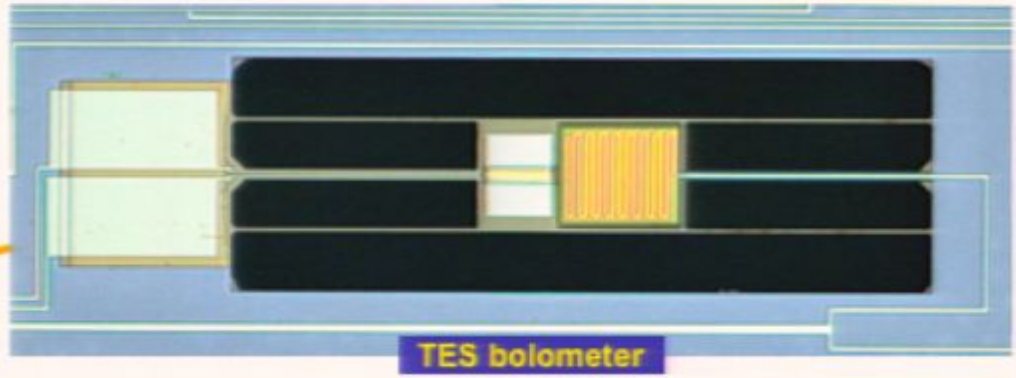
Antenna-coupled TES array
(256 Q/U detectors)

The components of a "pixel" (Bock, Jones, Kuo)

Beam synthesizing antennas w/ low loss Nb microstrips

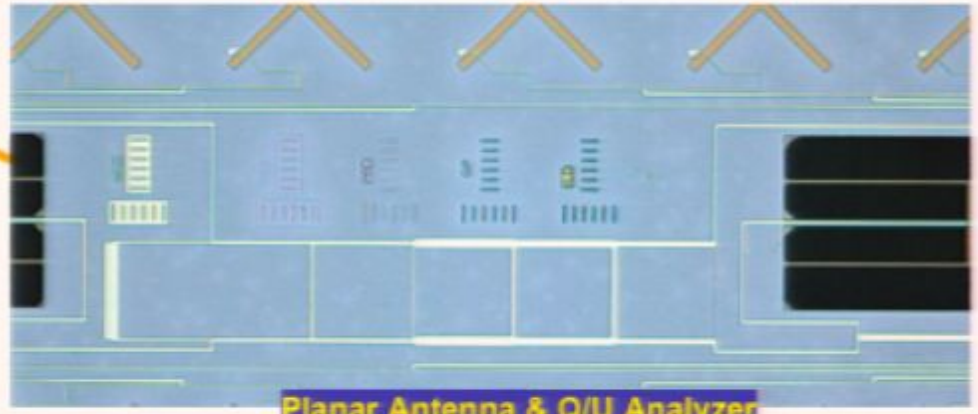


Single Pixel – Dual Polarization at 150 GHz



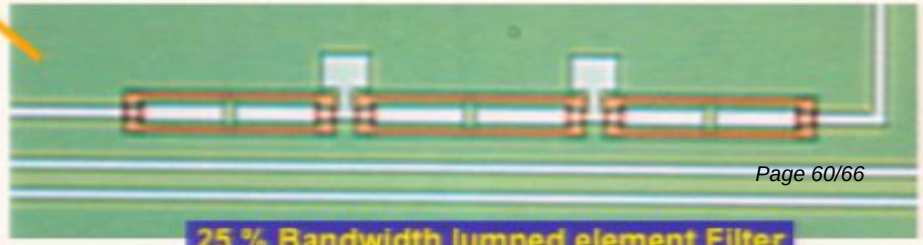
TES bolometer

Superconducting Transition Edge Sensors



Planar Antenna & Q/U Analyzer

Simultaneous Q/U measurements can be done with 180° hybrids (pre-detection)



25 % Bandwidth lumped element Filter

Advantages for CMBPOL

- TES detectors ..... CMBPOL sensitivities *already demonstrated*
- SQUID multiplexing ..... Large formats ≥ 10^4 elements
- Small active volume ..... Operates from 30 – 500 GHz
- Beam collimation ..... Eliminates discrete feeds
- Intrinsic filters ..... No discrete components

The next step requires a larger team….

Caltech (PI Kovac)

Chicago (Pryke)

CWRU (Ruhl)

JPL(Bock)

NIST (Irwin)

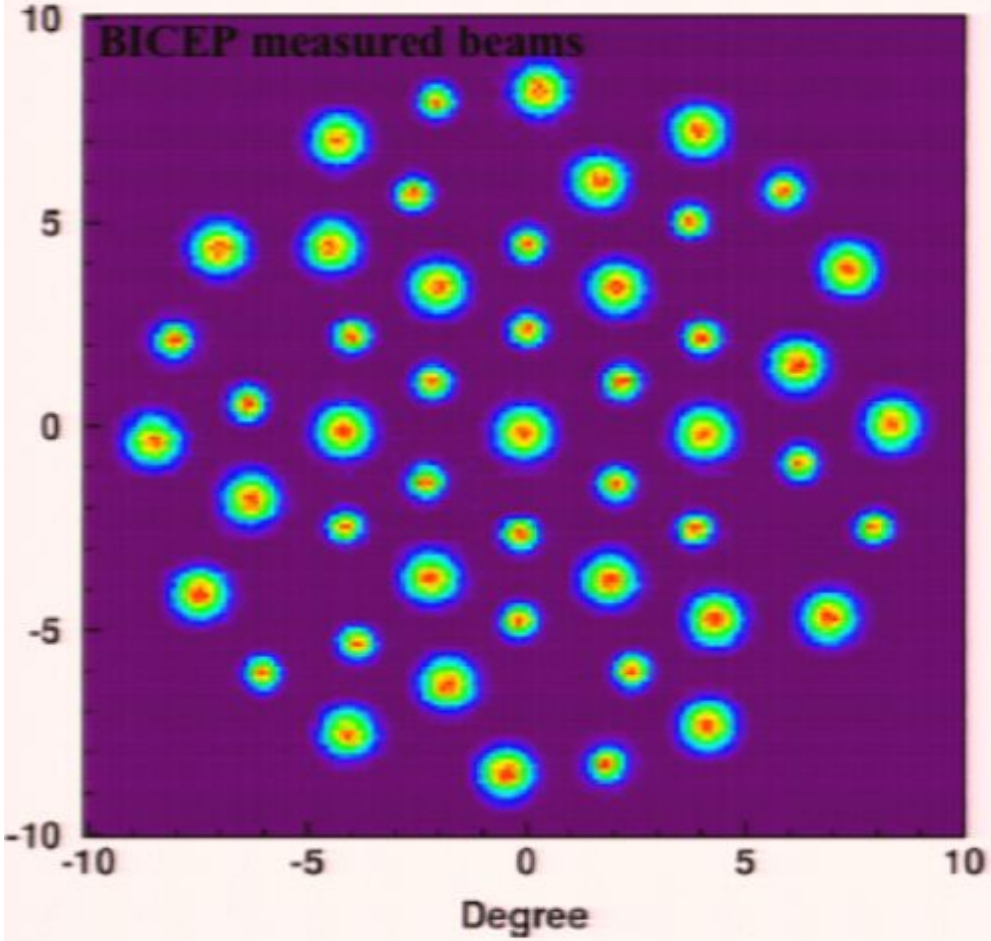
Stanford (Kuo)

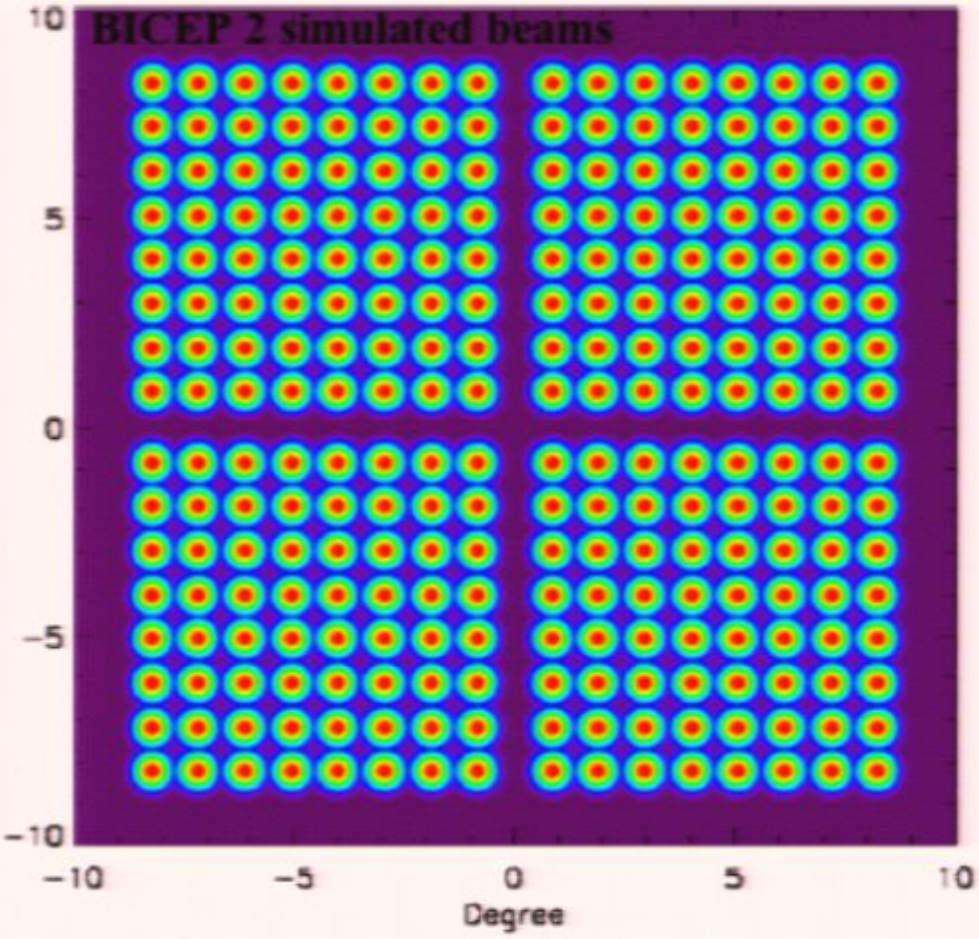
UBC (Halpern)

UCSD (Keating)

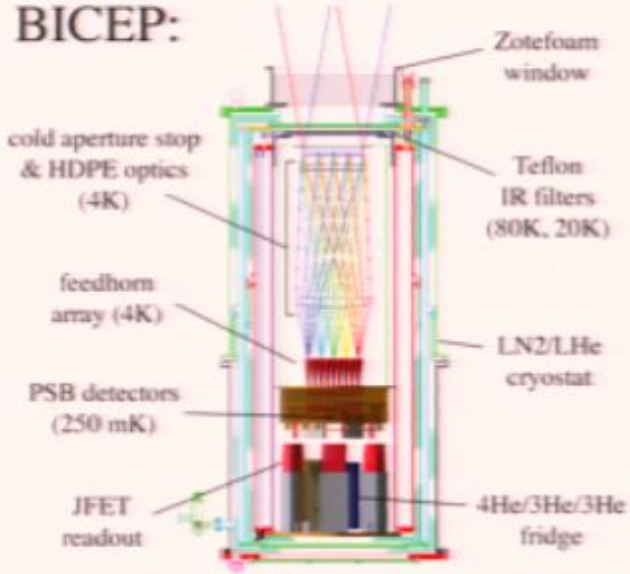
UT (Netterfield)

Getting more pixels on the sky …

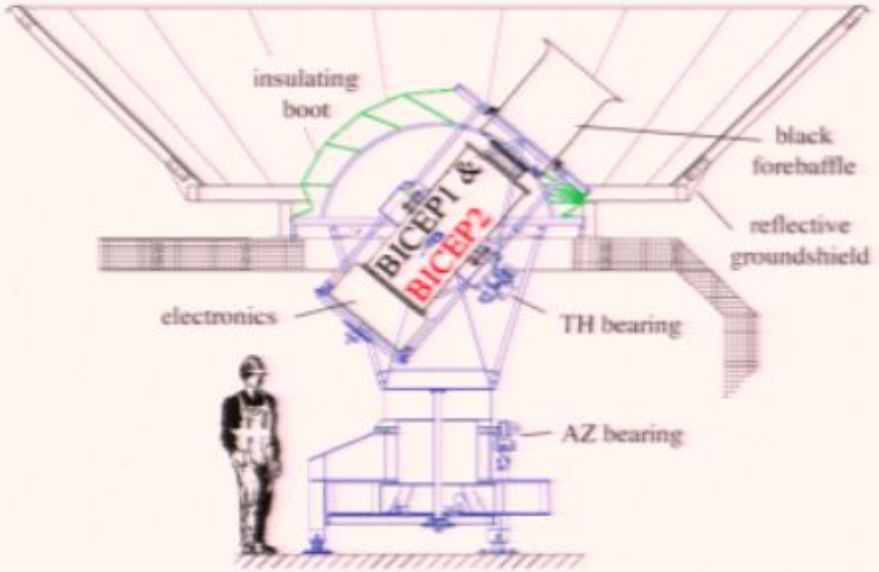




BICEP:

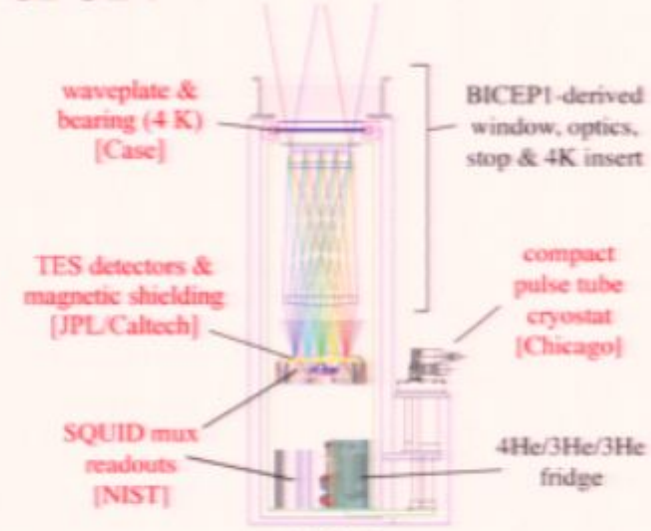


BICEP1

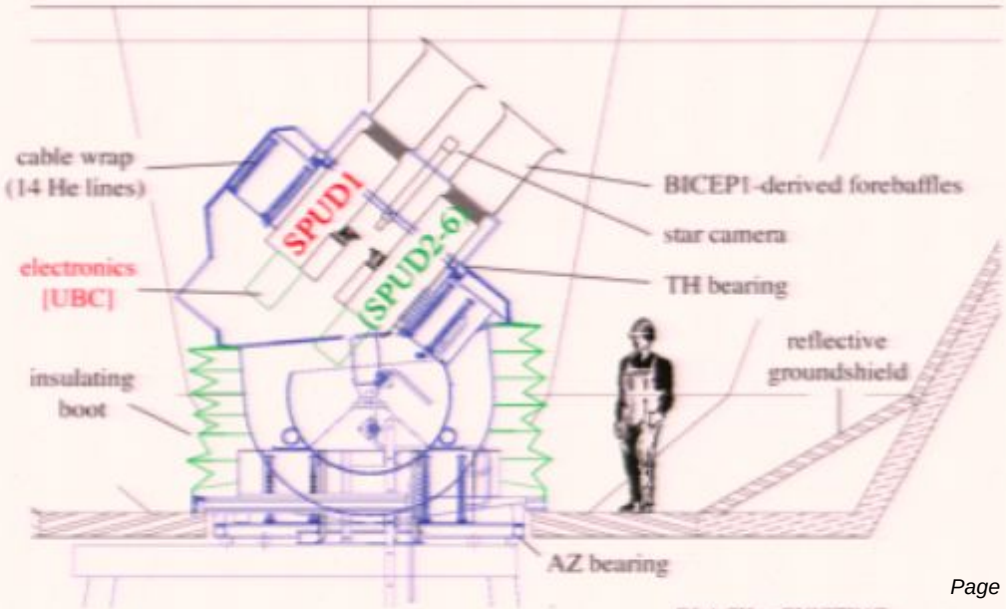


DSL BICEP platform (7500 lbs cap)

SPUD:



SPUD1



DASI tower (100,000 lbs cap)

BLACK = EXISTING
RED = FOR THIS PROPOSAL

The gory details in controlling systematics ….

Parameter	Definition	BICEP1 Req't (r=0.1)	BICEP1 Meas.[1]	BICEP2/SPUD Req't (r=0.01) w/o HWP	BICEP2/SPUD Req't (r=0.01) w/ HWP	BICEP2/SPUD Calculated[2]
Gain mismatch (I-pol)	$(g_1 - g_2)/g$	$< 1.5 \times 10^{-2}$	$< 5 \times 10^{-3}$	$< 2.5 \times 10^{-3}$	negl.	4×10^{-4}
Differential FWHM	$(\sigma_1 - \sigma_2)/\sigma$	$< 4 \times 10^{-2}$	$< 2 \times 10^{-3}$	$< 7 \times 10^{-3}$	negl.	2×10^{-4}
Differential pointing	$\Delta\theta/\sigma$	$< 3 \times 10^{-2}$	1×10^{-2}	$< 5 \times 10^{-3}$	negl.	9×10^{-5}
Differential ellipticity	$(e_1 - e_2)/2$	$< 9 \times 10^{-2}$	$< 1 \times 10^{-3}$	$< 1.6 \times 10^{-2}$	negl.	7×10^{-5}
Cross-polarization	$\Delta\phi$ (rad)	$< 1.4 \times 10^{-1}$	5×10^{-3}	$< 2.4 \times 10^{-2}$	negl.	5×10^{-6}
Pol. sidelobes to Galaxy[3]	(dBi)	< -13	< -38	< -18		< -38
Pol. sidelobes to ground[3]	(dBi)	< -24	< -38	< -29		< -38
Optics temperature[4]	ΔT_{RJ} (μK)	<3.5	<0.7	<1	<3	<0.7
Cold-stage temperature[4]	ΔT (nK)	<3	<2.7	<1	<3	<1

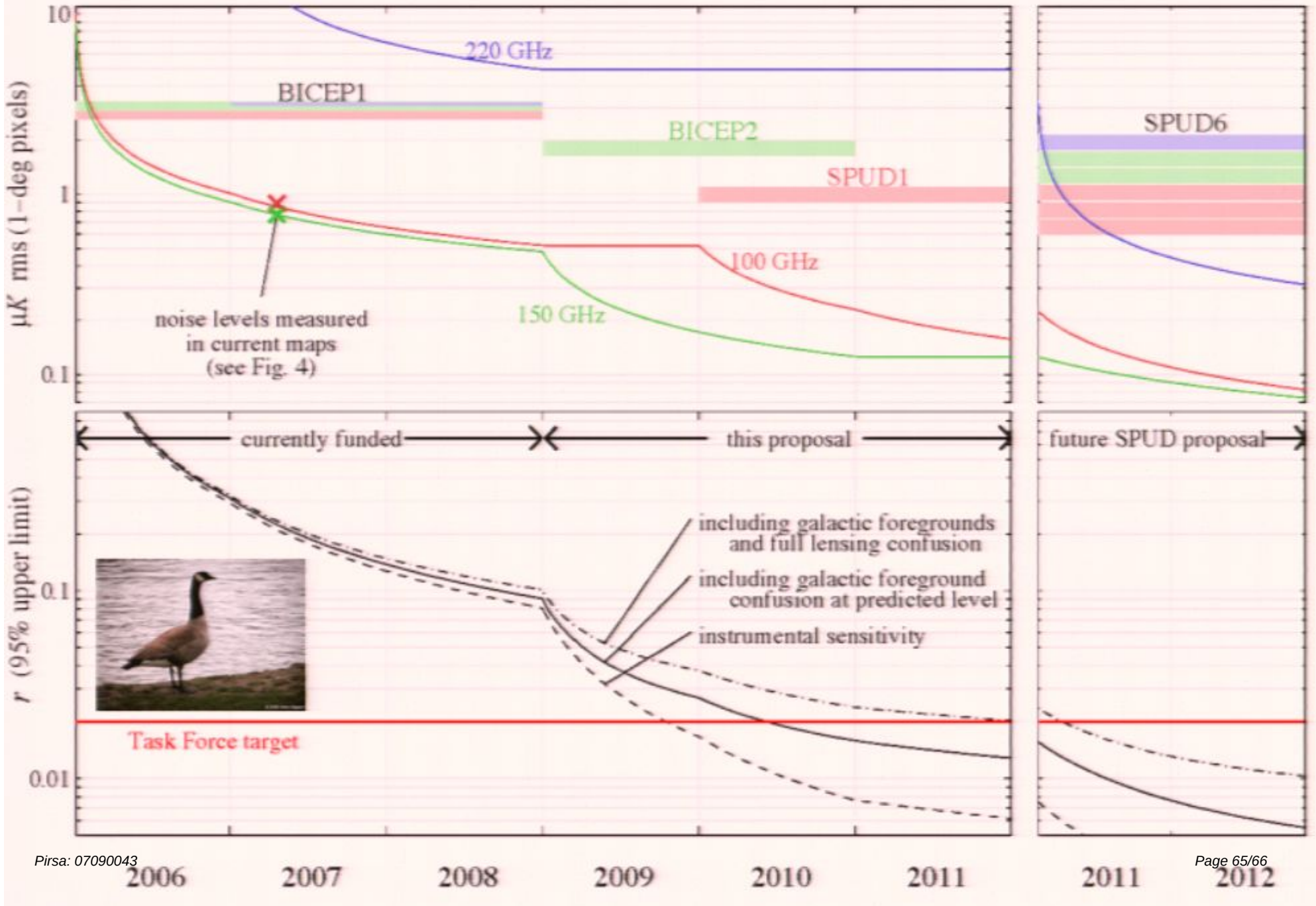
[1] Typical value measured from an end-to-end beam test of the entire BICEP1 optics.

[2] BICEP2/SPUD estimates for main beam effects based on a physical optics calculation of the refracting optics (worst case over the entire FOV), sidelobe and temperature levels based on BICEP1 performance.

[3] Following Page et al. (2003), defined here as $G_0(\theta,\phi) = (4\pi/\Omega)Pg(\theta,\phi)$, where P is the polarization.

[4] Scan-synchronous, over $\ell = 30 - 300$, assuming no reduction from varying the scan pattern.

Table 2: Potential Systematic Errors for BICEP and SPUD.


10
1
0.1
μK rms (1–deg pixels)
220 GHz
BICEP1
BICEP2
SPUD1
SPUD6
100 GHz
150 GHz
noise levels measured
in current maps
(see Fig. 4)
currently funded
this proposal
future SPUD proposal
including galactic foregrounds
and full lensing confusion
including galactic foreground
confusion at predicted level
instrumental sensitivity
r (95% upper limit)
0.1
0.01
Task Force target
2006
2007
2008
2009
2010
2011
2011
2012

What if there is a goose?

- Higher frequency coverage (SPIDER)
- Lower frequency coverage (QUIET)
- Confirmation (CLOVER, etc.)
- Higher angular resolution (SPT / ACT)
- Job security (a future satellite)