Bpol

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Why do we want to measure polarization?

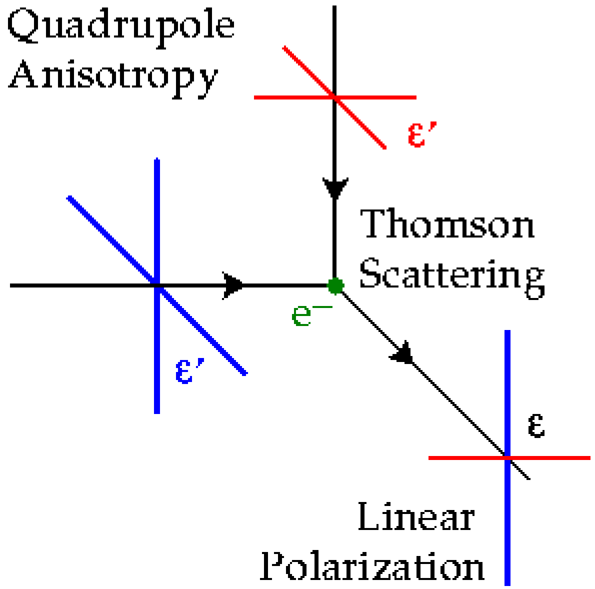
- **Because CMB anisotropies are polarized**!

- Thomsom scattering cross-section depends on polarization as

$$\frac{d\sigma_T}{d\Omega} \propto |\epsilon \cdot \epsilon'|^2 ,$$

- A net polarization is generated during recombination if there is a quadrupole anisotropy in the radiation field.

- The net polarization generated via scattering is **linear** (i.e. the CMB will have non-zero Stokes parameters Q and U, but V=0).

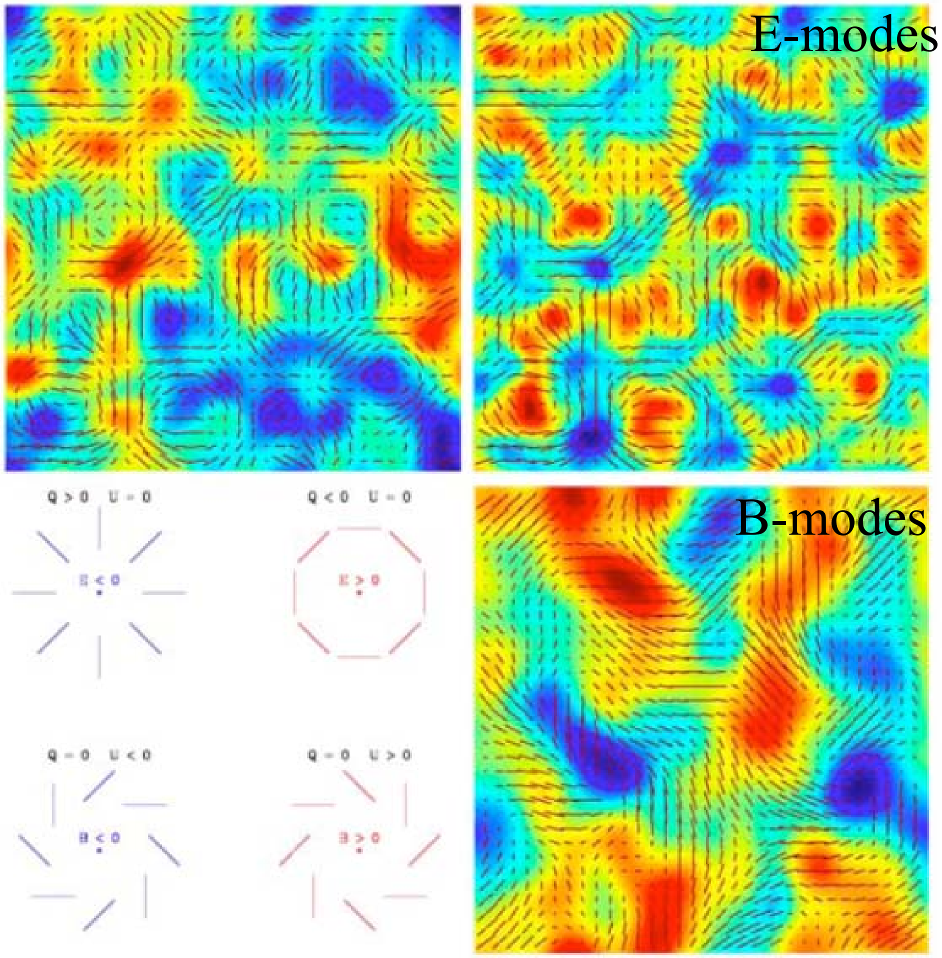


Why do we want to measure polarization? (II)

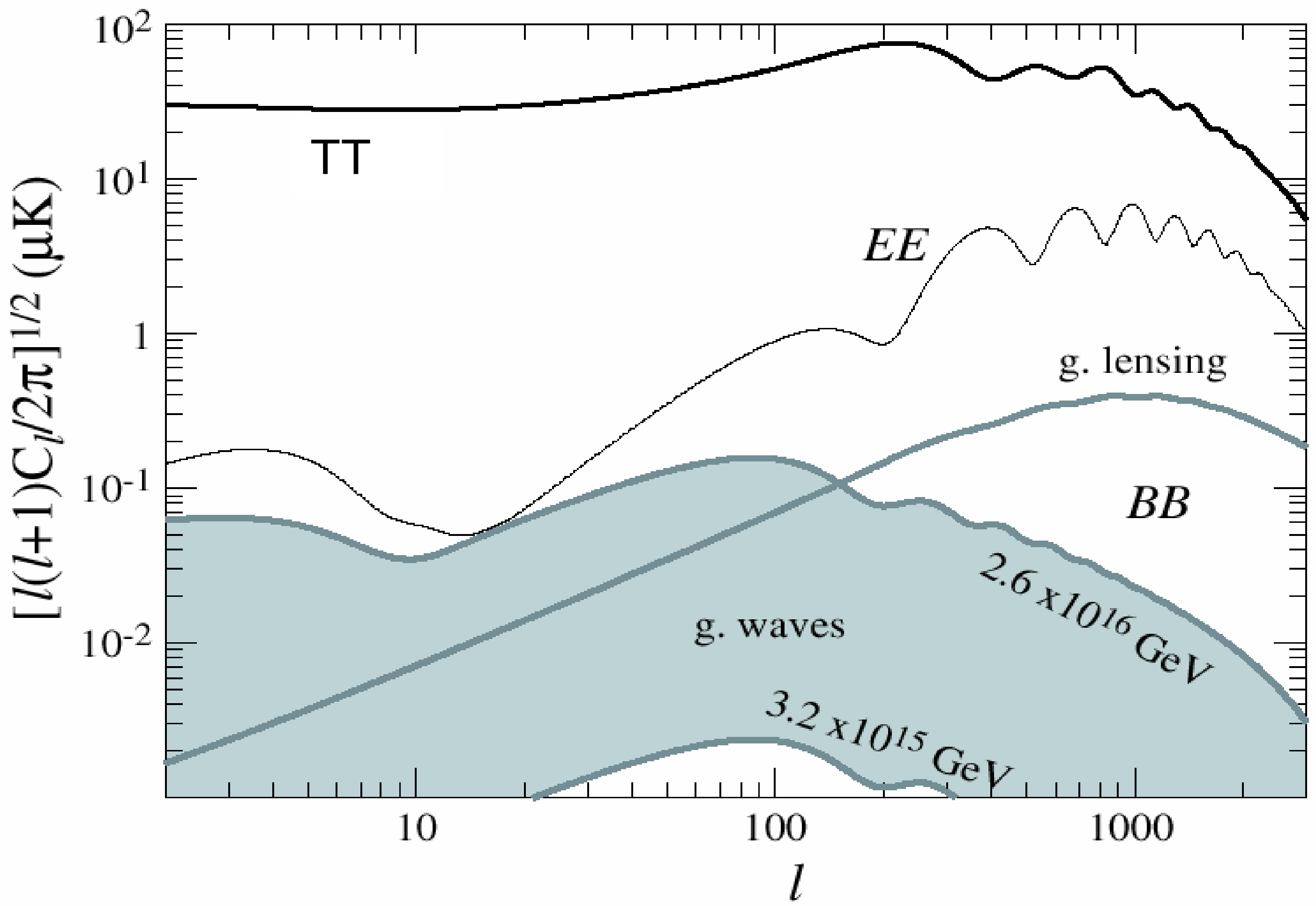
- Polarization maps can be decomposed into two components usually called **E-modes** (analog of the gradient component) and **B-modes** (analog of the curl component).

- **Physics of generation of the Polarization.** Different sources of anisotropies generate different types of modes.

	E-modes	B-modes
Scalar (density perturbations)	Yes	No
Tensor (gravity waves)	Yes	Yes

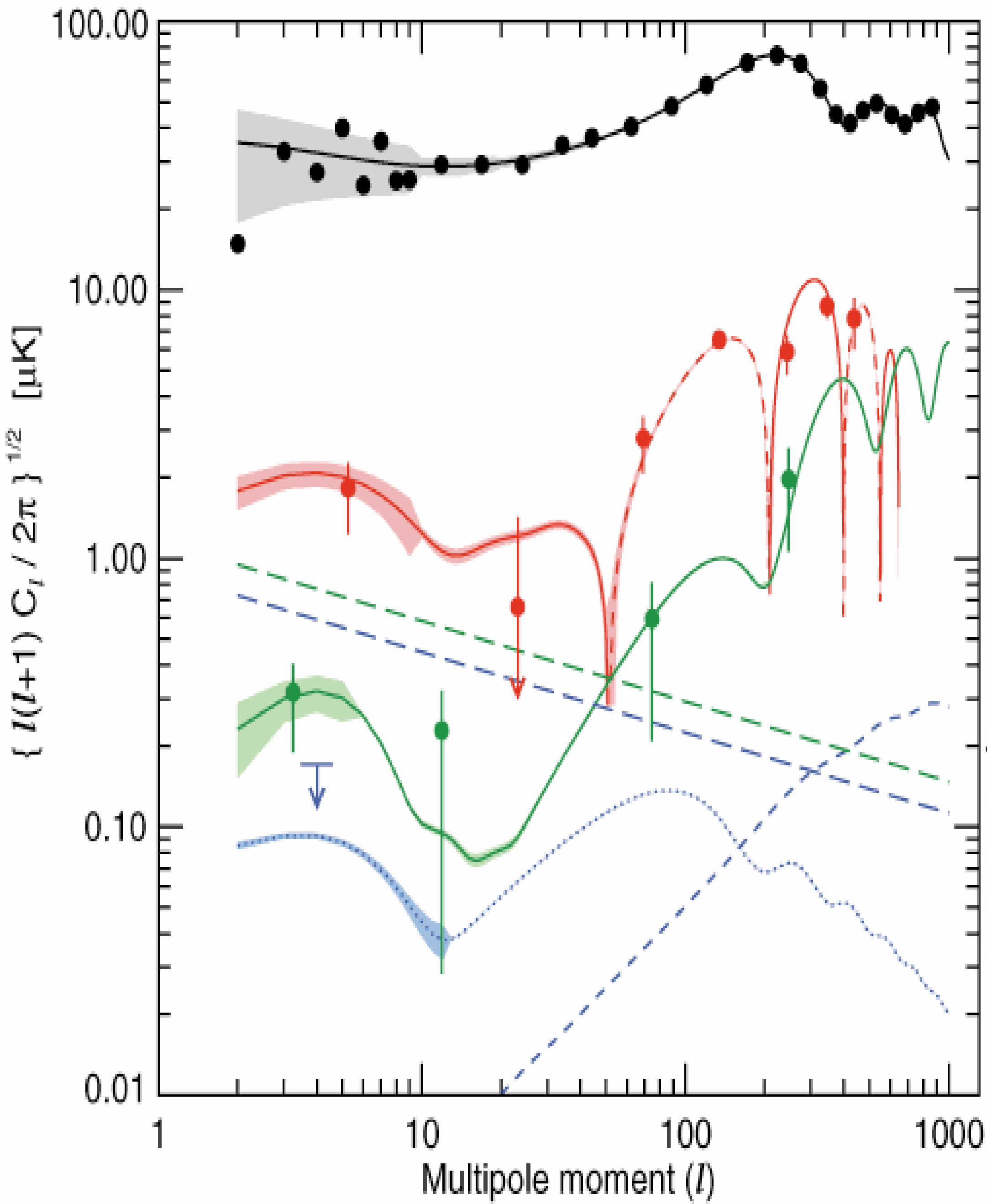


Primordial gravity waves and B-modes



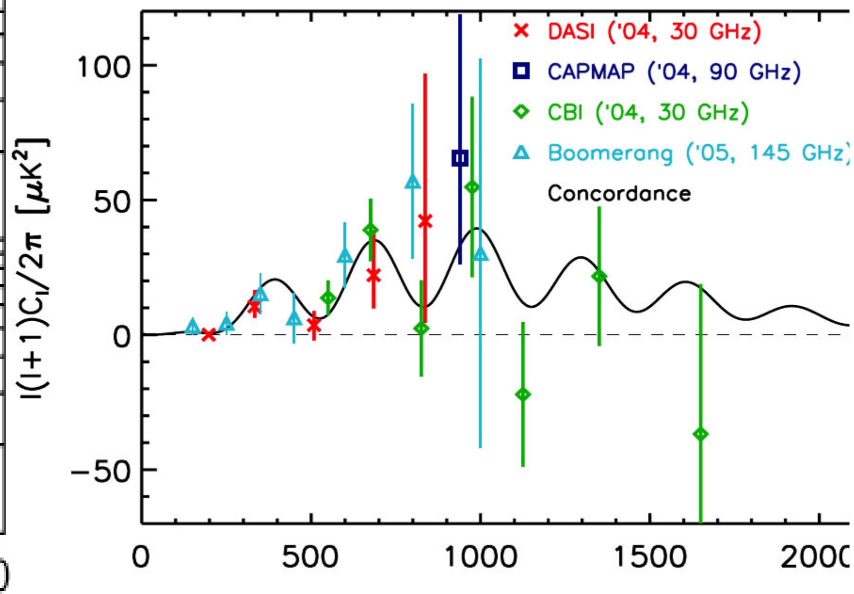
- **r=T/S** is proportional to the fourth power of the energy scale of inflation.
- **r**=0.1 corresponds to an energy scale of inflation around the expected GUT scale.

Current observational status



* E-mode detections: DASI, WMAP, CAPMAP, CBI, Boomerang, QUAD.

* Current upper limits from WMAP are r<0.65 (Spergel et al. 2006).



Observability of B-modes

- **Critical issues**:
  - Signals are extremely small. Large number of receivers. Large bandwidths.
  - Control on systematics (spillover, cross-pol, etc).
  - Foregrounds. B-modes are never dominant over galactic foregrounds.

- **Planck** (launch 2008; frequency range 30-800GHz) will reach r~0.05.

- Next generation missions: **EPIC** (NASA Beyond Einstein Program), **BPOL** (ESA Cosmic Visions). 2015-2020. Planned sensitivities between r=0.01-0.001.

Observability of B-modes (II)

- **Systematic program to study polarized astrophysical foreground signals is needed** (see NASA-NSF report "Task Force on CMB research" and ESA-ESO report on "Fundamental cosmology").
- **Exploration/development of modulation techniques to measure polarization needed.**
- **Exploration of arrays of (~1000) new sensitive and small detectors (antenna-coupled bolometers).**
- Ground-based polarization experiments: (mainly small scales and high frequencies)
  - Correlation receivers (QUIET)
  - Bolometers (B2K, SPTpol, ACT, CLOVER, QUAD).

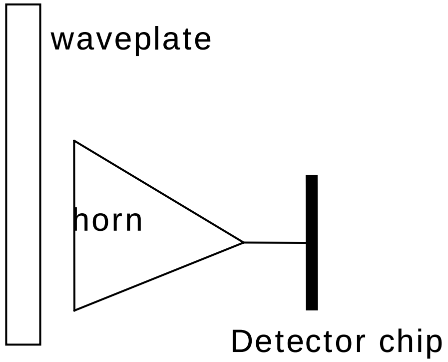
Detector characteristics

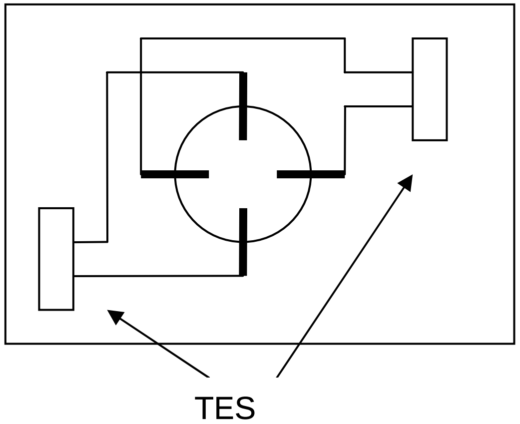
	SAMPAN				BPol					
Freq bands (GHz)	100 35%	143 35%	217 35%	353 35%	45 ?	70 35%	100 35%	143 35%	217 35%	353 35%
Ang. Res. FWHM arcmin	40	30	20	20	15^0	68	47	47	40	59
# detectors	20,000				2012 (1006 horns)					
# horns	N/A				2	7	108	127	398	364
Secs/pixel (2 yrs mission)					?	1954	957	957	961	1499
Det noise Q&U(reqs) μK√s						50	46.5	50	72	240
Q&U Sens (reqs) μK arcmin						15	7	7	7	20
Horns required						28	104	120	249	339
Focal plane weight (@ 0.1K) (kg)						10		3.5	3.2	0.5
Telescope weight (lenses + supports) (kg)						10		4	3	2
WP & Mechanisms (kg)						4		1.5	1.5	2
Telescope diameter (mm)					45 Bare horn	265		185	143	60

DETECTOR

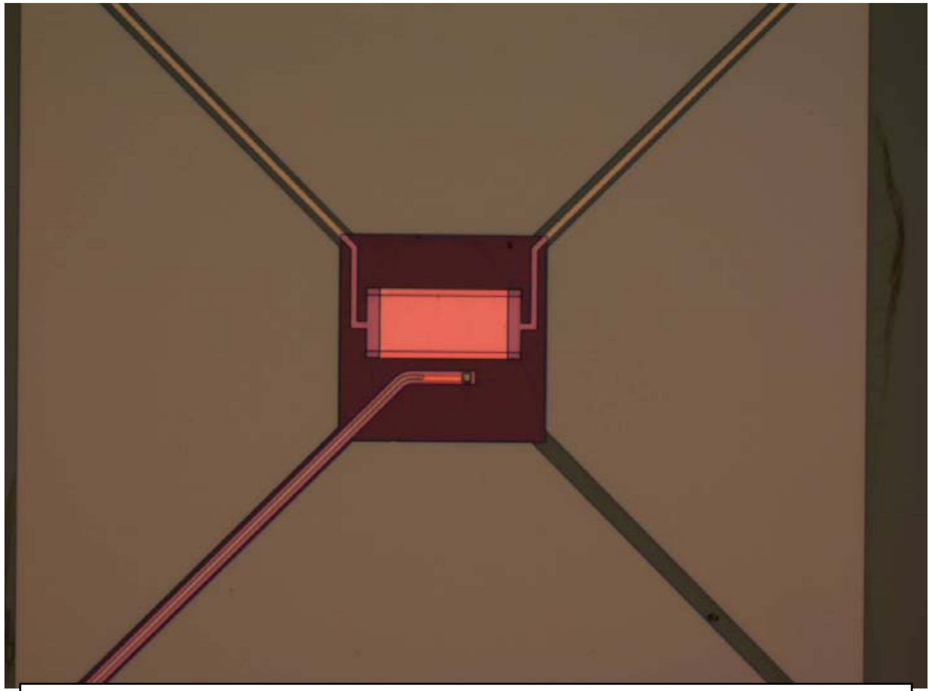
• TES bolometers

M_{45}= 1.5 Kg, N_{det}= 2
$M_{70/100}$ = 10 Kg, N_{det}= 7+108=115
M_{143} = 3.5 Kg, N_{det}= 127
M_{217} = 1.6 x 2 = 3.2 Kg, N_{det}= 398
M_{353} = 0.12 x 4 = 0.5 Kg, N_{det}= 364





Microstrip Coupled Transition Edge Sensors 100-300GHz



- A microstrip coupled, MoCu TES detector for 100GHz. The microstrip line enters bottom left.

A superconducting bolometer utilizes the tremendous change in resistance that occurs in the transition of certain metals and semiconductors from their normal to the superconducting state.

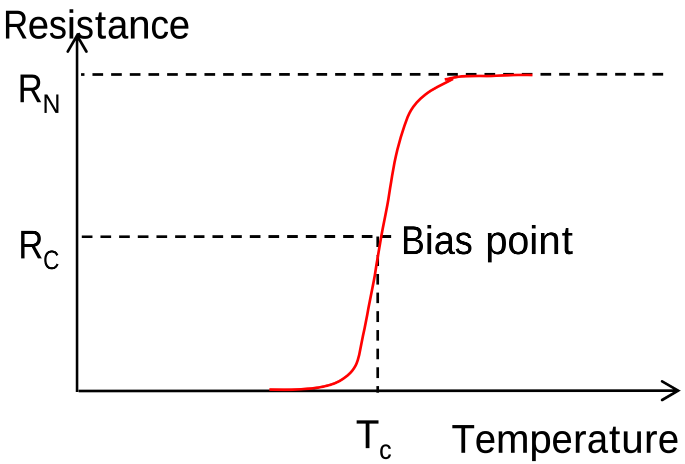
Voltage-biased, the electrical power is given by

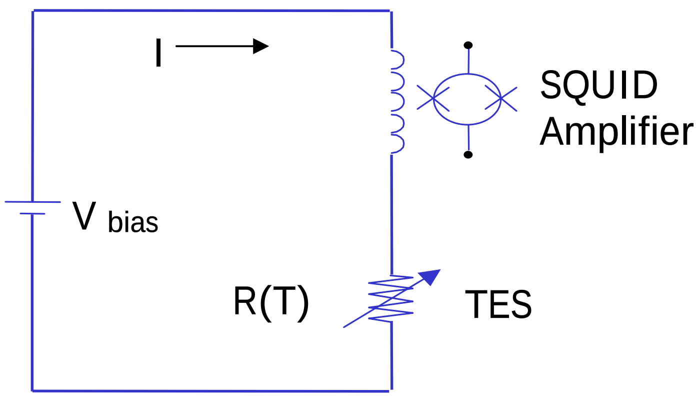
Pbias=Vo^2 / R

Ptotal=Psignal+Pbias

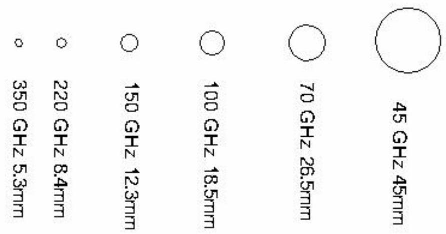
Tc remains constant.

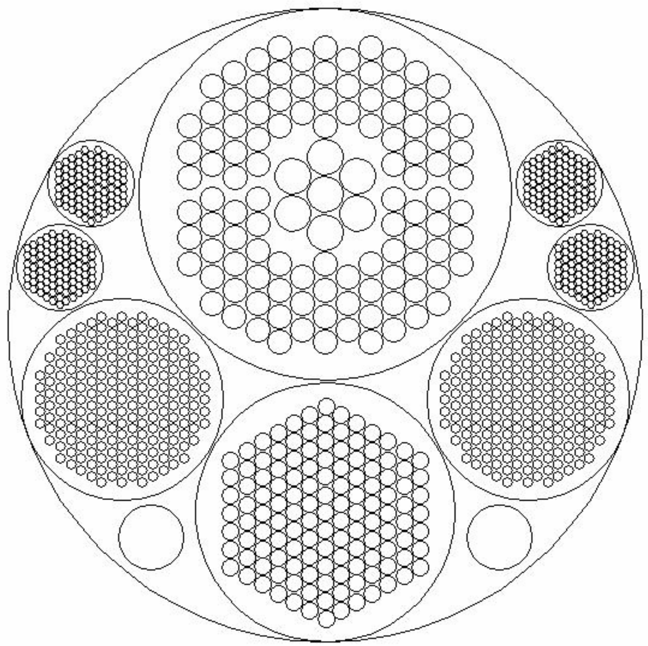
This effect is called "Strong electrothermal feedback"
Adrian T. Lee et al. (1996)





FOCAL PLANE LAYOUT



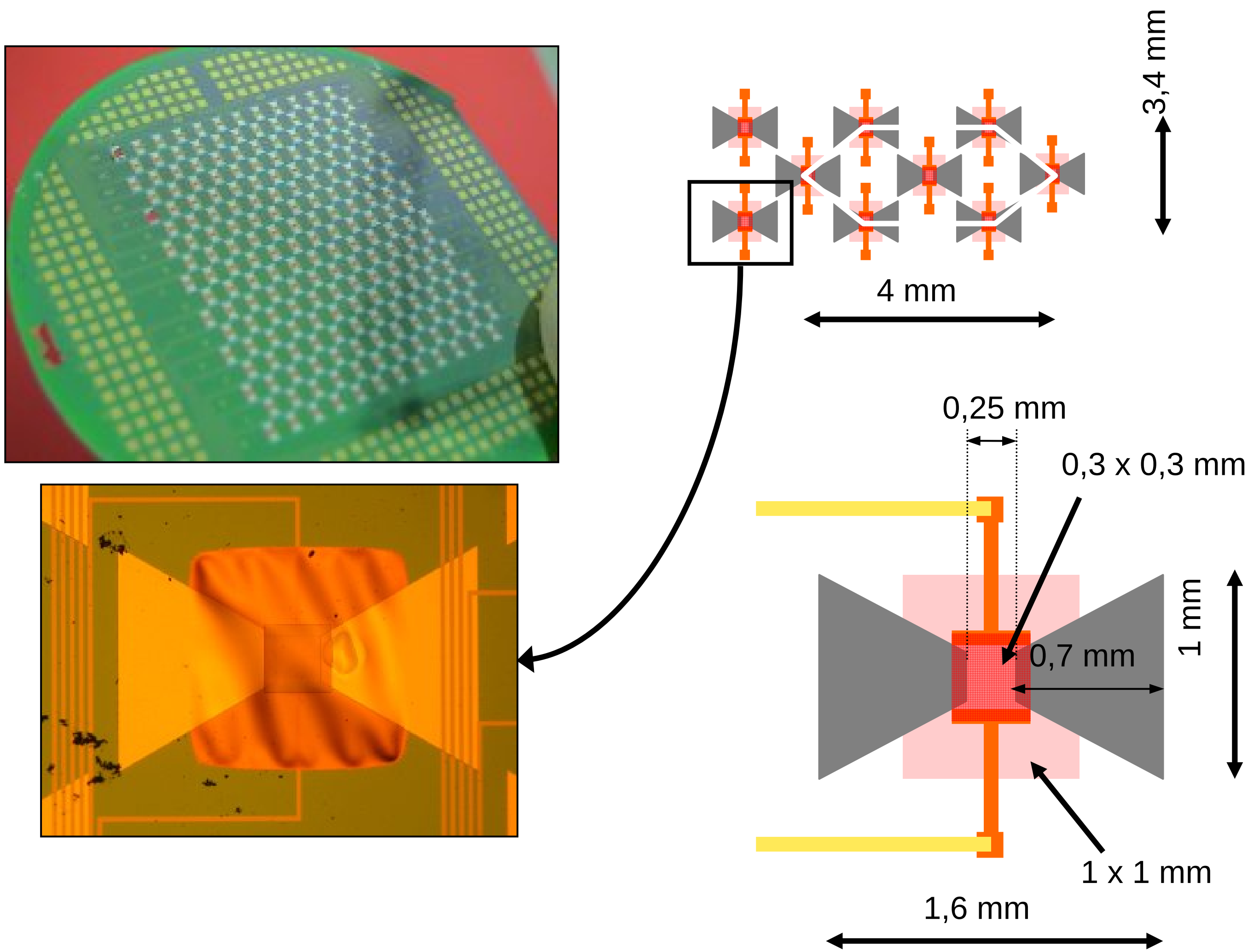


TECHNOLOGY READINESS LEVELS

Subsystem	TRL	used in
Horns	9	COBE etc.
WG OMT	9	WMAP
Planar OMT	6(?)	PAPPA, CLOVER
Waveplate	6	SCUBA, MAXIPOL
TES + Readout	6	SCUBA, GBT, CLOVER
Superfluid cryostat	9	ISO, COBE, SPITZER
Single shot ADR	9	XRS on ASTRO-E2
Planck dilutor	8(?)	Archeops, Planck HFI

Antenna-coupled TES Bolometer, 0.1 K, (204 pixels)

HFSS modelling in collaboration with CRTBT Group in Grenoble (A. Benoit et al.).



RESUMEN

- Cubrimiento del cielo mediante giro desde el punto L2.
- Duración de 2 años.
- Sensibilidad en polarización de 10nK (rms) en escalas angulares de 1 grado
- Detectores: 2000 bolómetros TES, 50-350 GHz, criogenia 100 mK
- Líderes: Paolo de Bernardis (U. Roma), F. Bouchet (IAP; X. Dessert, M. Piat), L. Piccirillo (U. Manchester), R. Rebolo (IAC), E. Martínez-González (IFCA)
- Carga útil: eléctronica (IAC), detectores (IFCA)
- Interés de otras instituciones: ICE/IEEC, U. Oviedo, U. Valencia