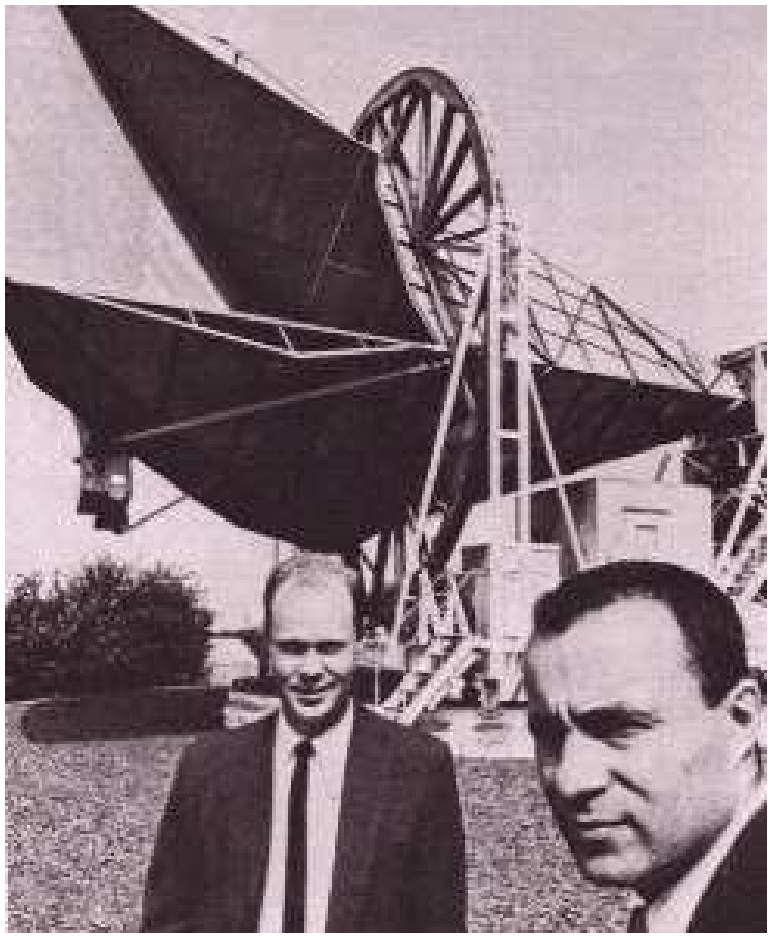
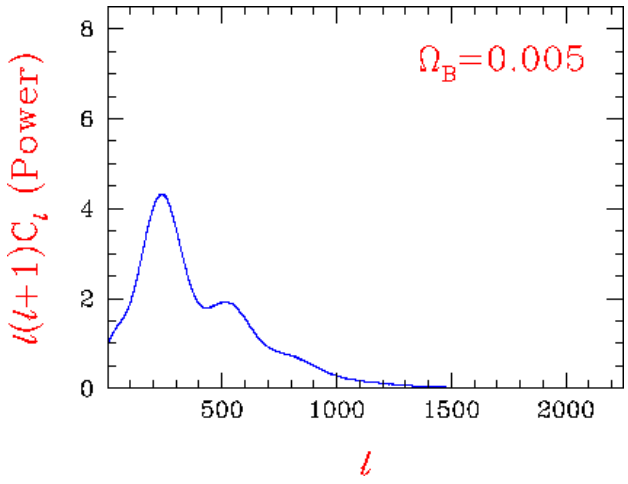
CMB observations

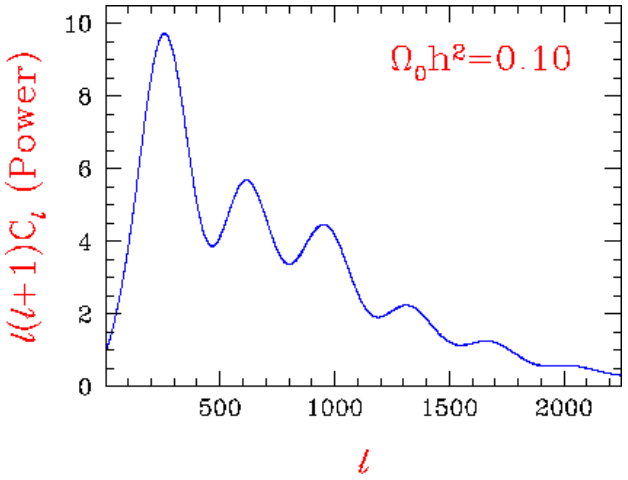


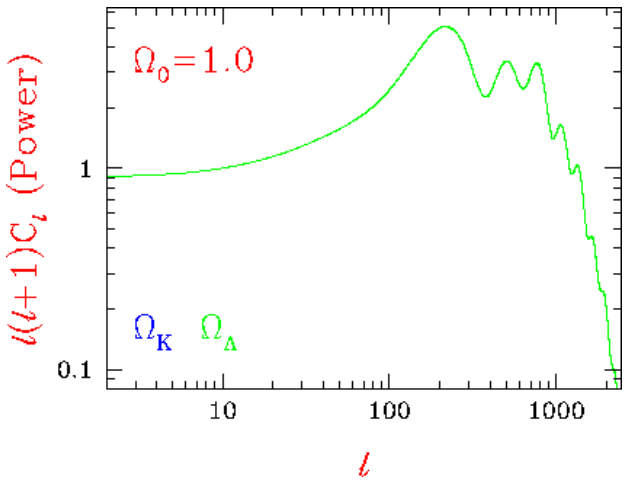
Penzias & Wilson (1965)

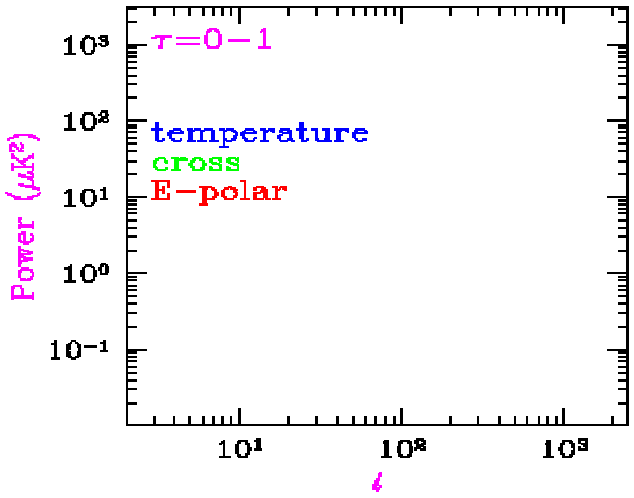
(2007)

CMB temperature fluctuations -> cosmological parameters



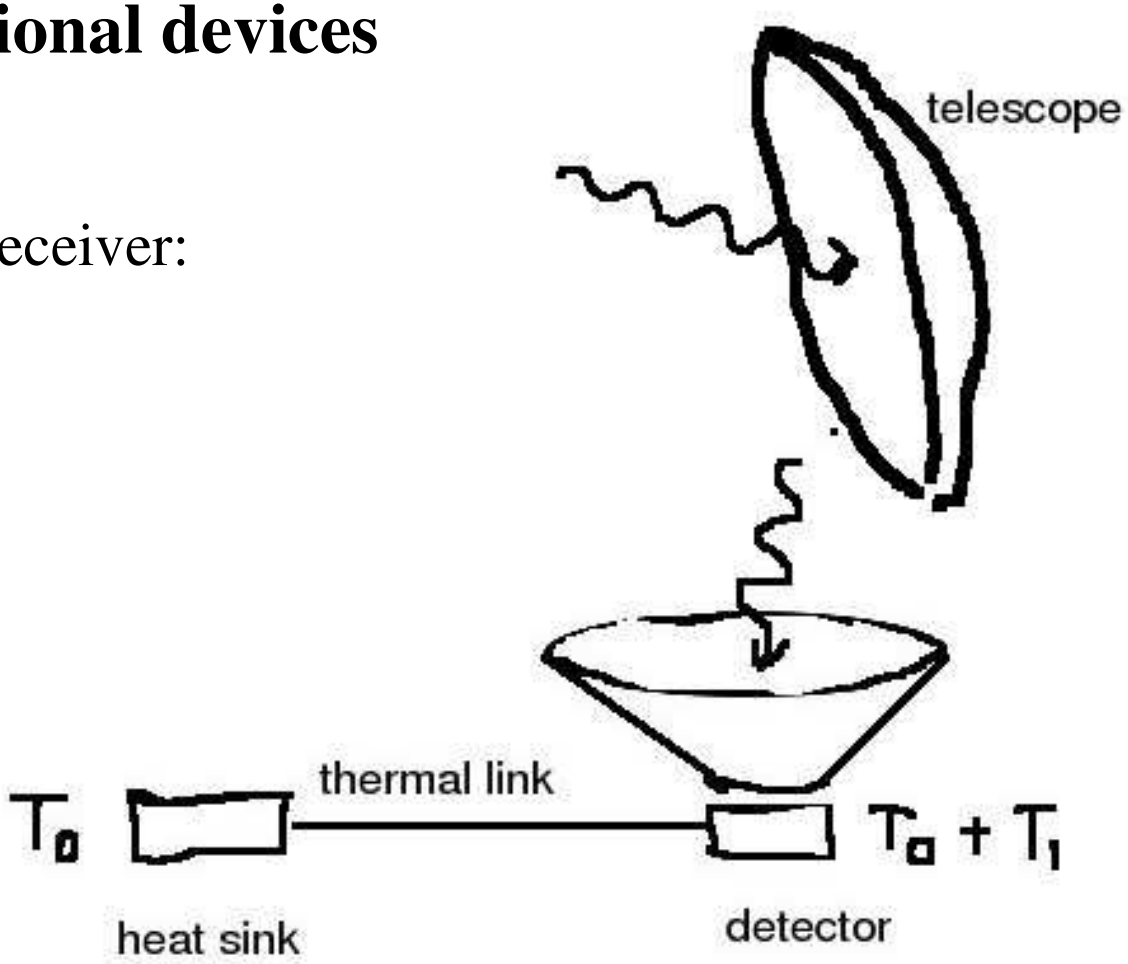






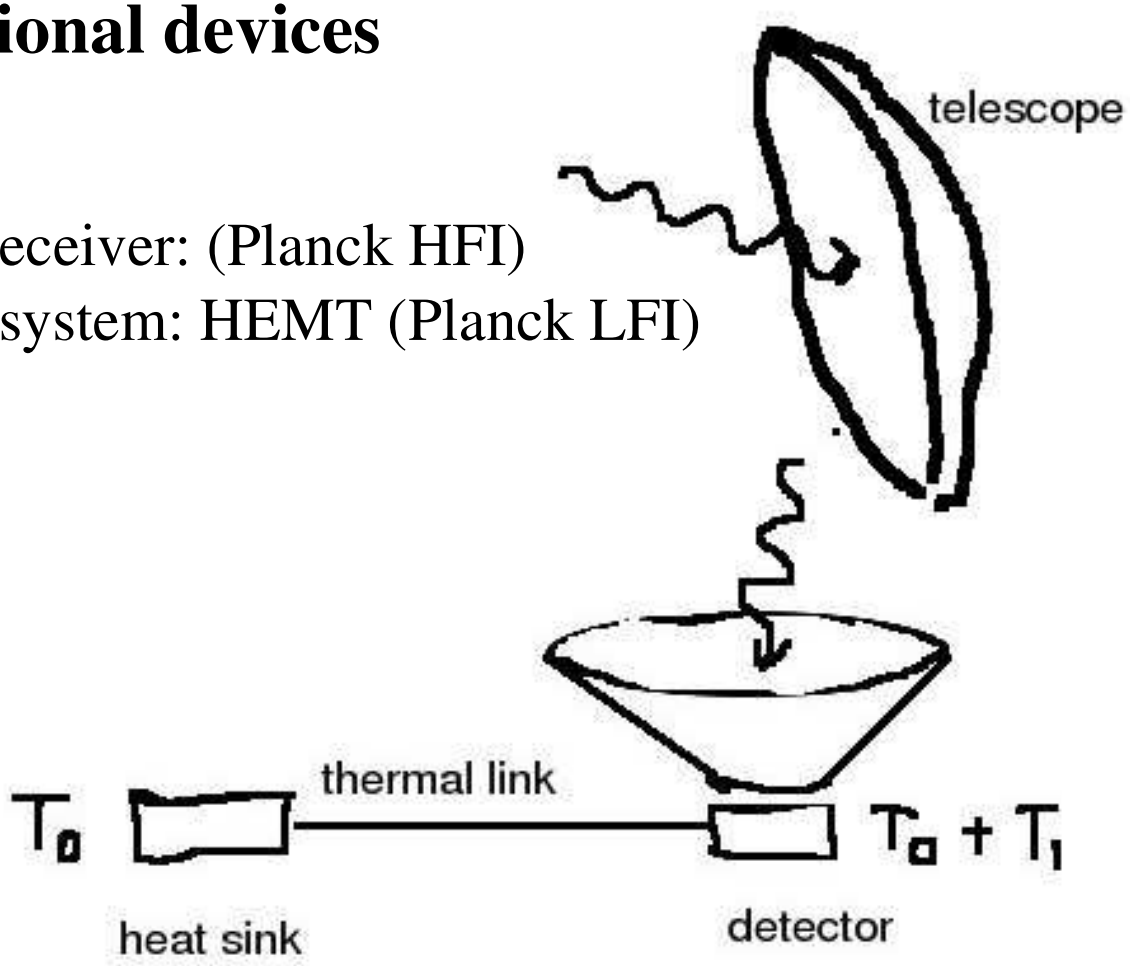
Observational devices

Bolometric receiver:



Observational devices

Bolometric receiver: (Planck HFI)
2nd common system: HEMT (Planck LFI)



Sky coverage ($A = d\theta_1 \; x \; d\theta_2$)

Small field -> large sample variance $\sigma^2_{\rm sam} \simeq (4\pi/A)\sigma^2_{\rm cos}$

Narrow field -> spectral resolution $\Delta \ell < 1/d\theta_1$

Resolution & sensitivity

Angular resolution $\theta \propto 1/\ell$
5′-10′ resolution -> $\ell \sim 2000$

$\Delta T/T \sim 10^{-6}$
important in polarization studies

Scanning strategy

Optimal scanning:
- simple connected pattern -> easy computationally
- complex repeated scan -> diminishes systematic errors

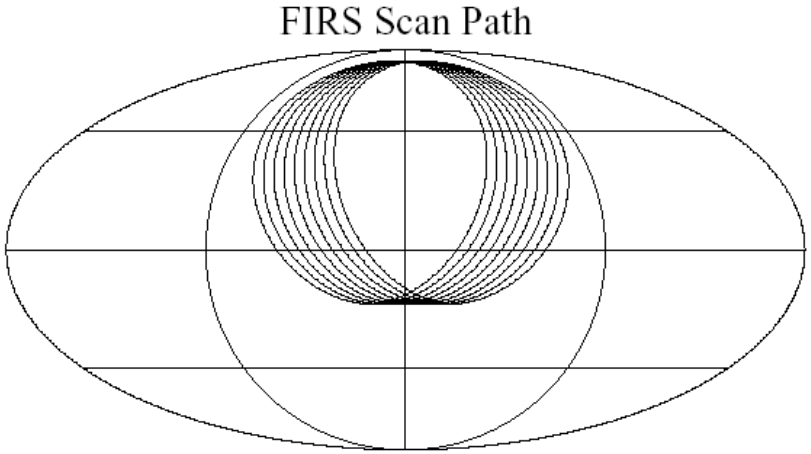
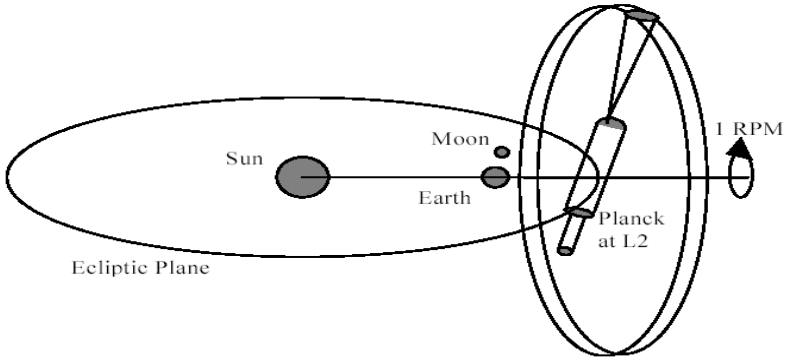


Fig. 4.— A simple scan pattern generated by rotation around the zenith and the diurnal rate.

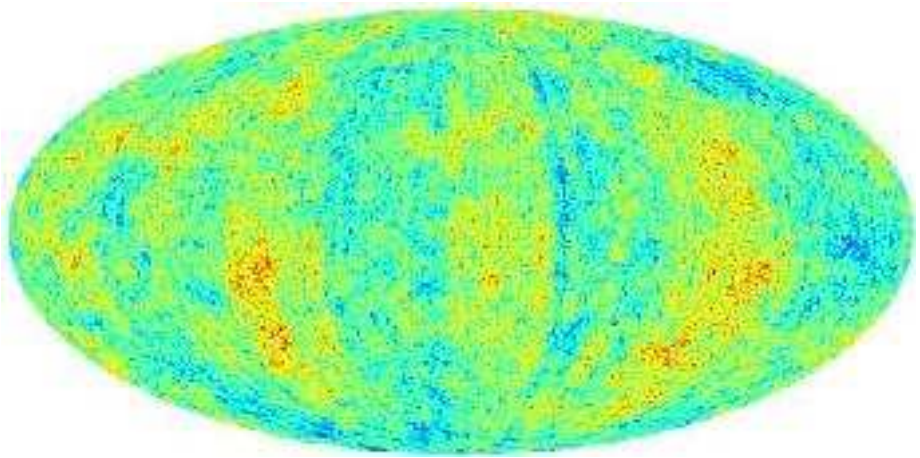
E.g. noise in the Planck temperature map



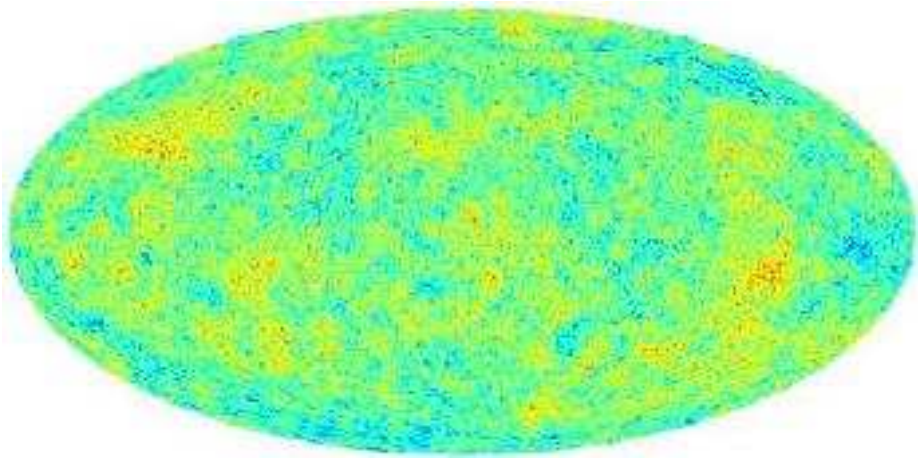
Planck scan pattern

Noise in Planck temperature map

One whole sky scan:
stripy artefacts



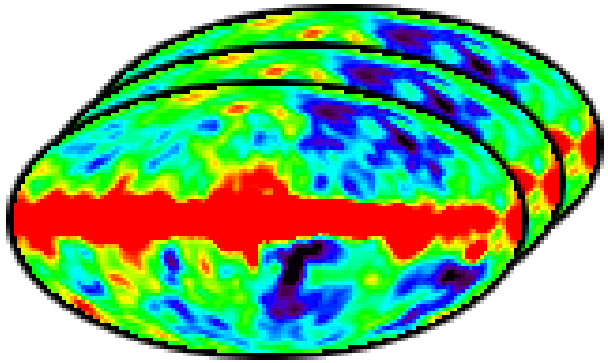
After second scan
stripes vanish



Raw data to map

Pixel 1	Pixel 2	ΔT
6422947	6443428	-454.841
3141592	2718281	141.421
8454543	9345593	654.766
1004356	8345388	-305.567
...	...	...

TOD=time ordered data



Temperature maps

y = a x + n

y = TOD, **x** = map, **n** = noise

- 'COBE' method
- Wiener Filter method

Choice of frequencies & foreground removal

Dust

Free-free

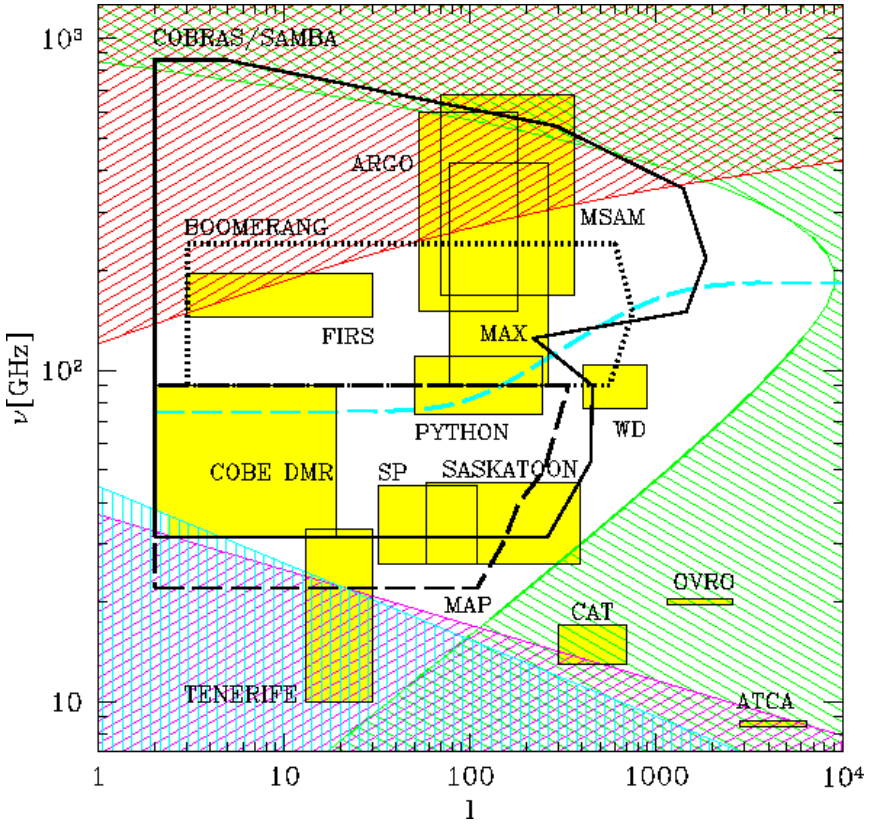
Syncrotron

Point sources

small ℓ : dust at high freq.

large ℓ : point sources at low frequencies

Non-Gaussian sources easily filtered



Low weight for contaminated regions

CMB experiments:

Max Tegmark's cosmic microwave background data analysis center: experiments - Mozilla

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http://www.hep.upenn.edu/~max/cmb/experiments.html

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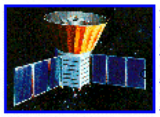
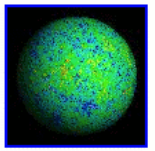
Links to CMB Experiments

- Satellites



WMAP (data here)
COBE
Planck (formerly called COBRAS/SAMBA)
DIMES



- Balloon-borne

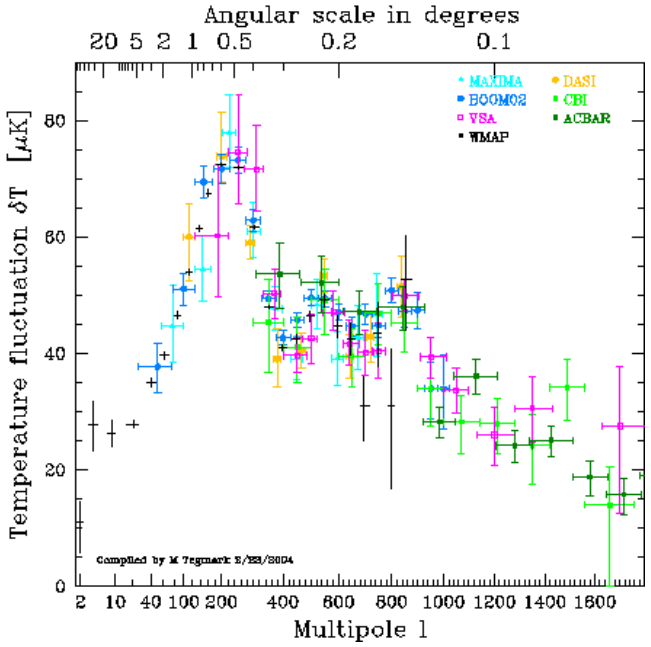
FIRS
ARGO
MAX
MSAM

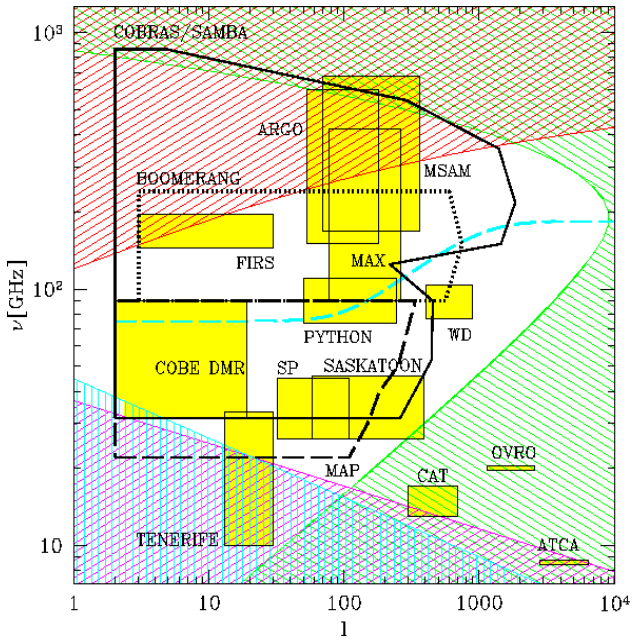
  - BAM
  - QMAP (Princeton, Penn, QMASK data)
  - BOOMERanG
  - MAXIMA
  - Top Hat
  - HACME
  - ACE
  - Archeops
  - BEAST

- Ground-based

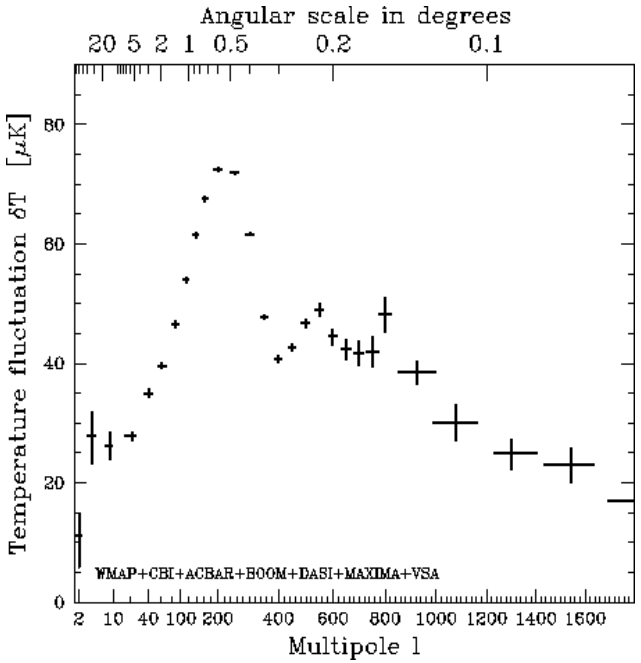
Tenerife
South Pole
Saskatoon
Python

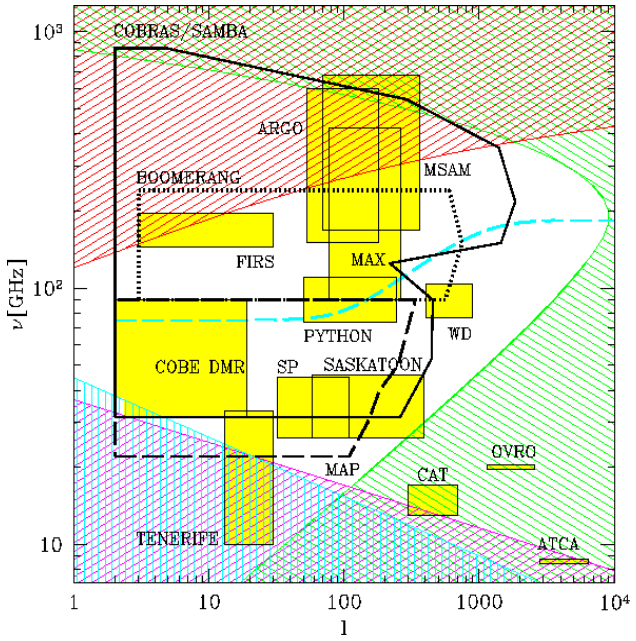
  - IAC/Bartol
  - White Dish
  - CAT
  - OVRO
  - ATCA
  - SuZIE
  - COLD
  - CG
  - Viper
  - COBRA
  - Jodrell Bank
  - Ryle
  - Brown/Wisc Polarization
  - MAT/TOCO (Princeton, Penn)
  - DASI
  - VSA





Project	Frequency (GHz)	scale (l)	location
WMAP	22 – 90	2 – 1000	satellite
(PLANCK	30 – 857	2 – 2000	satellite)
MAXIMA	150 – 420	50 – 600	balloon
BOOMERANG	90 – 420	10 - 700	balloon
CBI	26 – 36	300 – 3000	Chile
ACBAR	150 – 450	60 – 2500	Antarctica
DASI	26 – 36	125 – 700	Antarctica
VSA	26 – 36	130 – 1800	Tenerife





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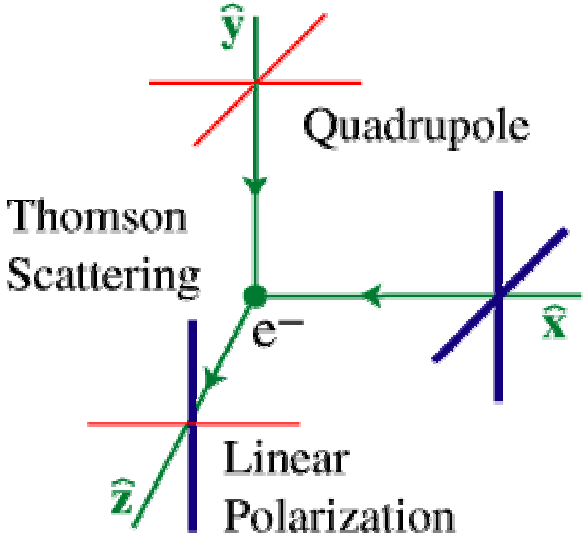
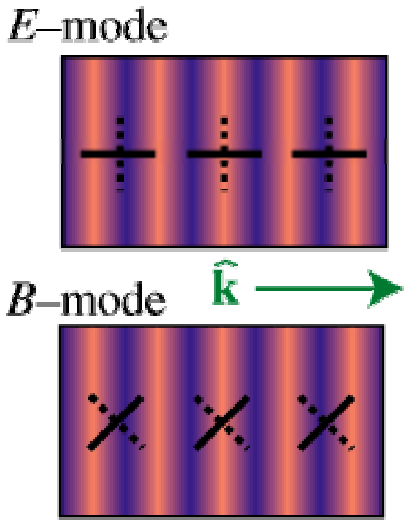
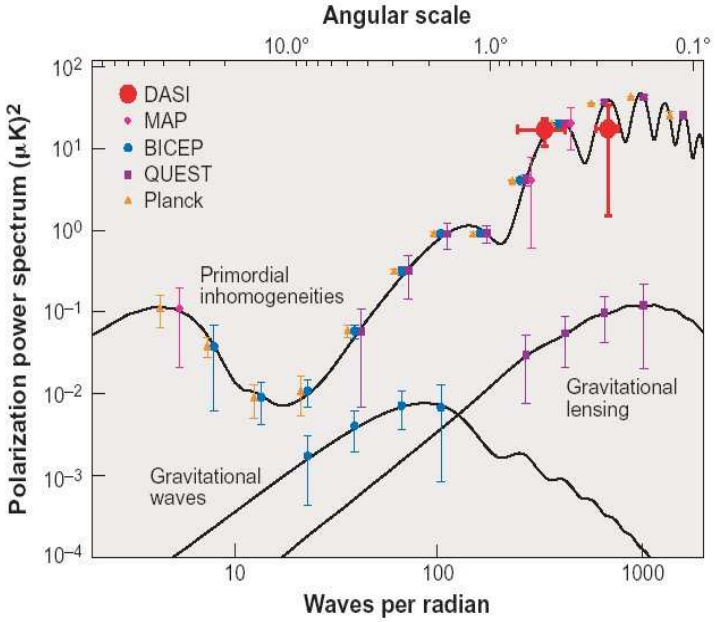
ACBAR	150 – 450	60 – 2500	Antarctica
DASI	26 – 36	125 – 700	Antarctica
VSA	26 – 36	130 – 1800	Tenerife

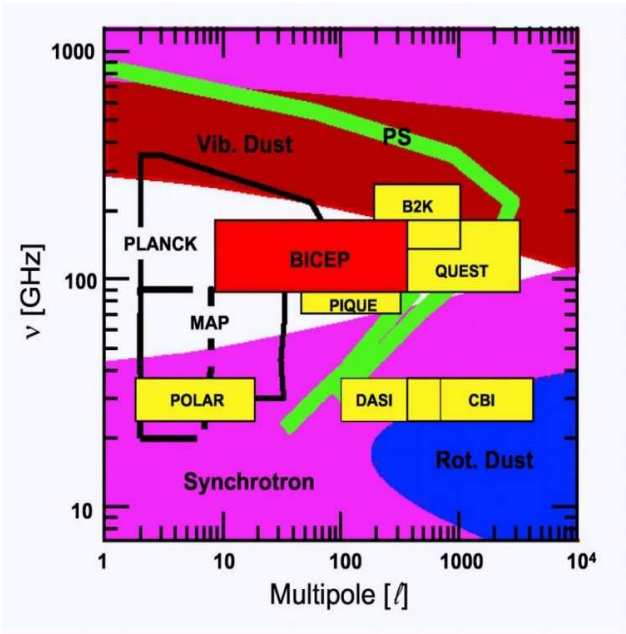
Polarization



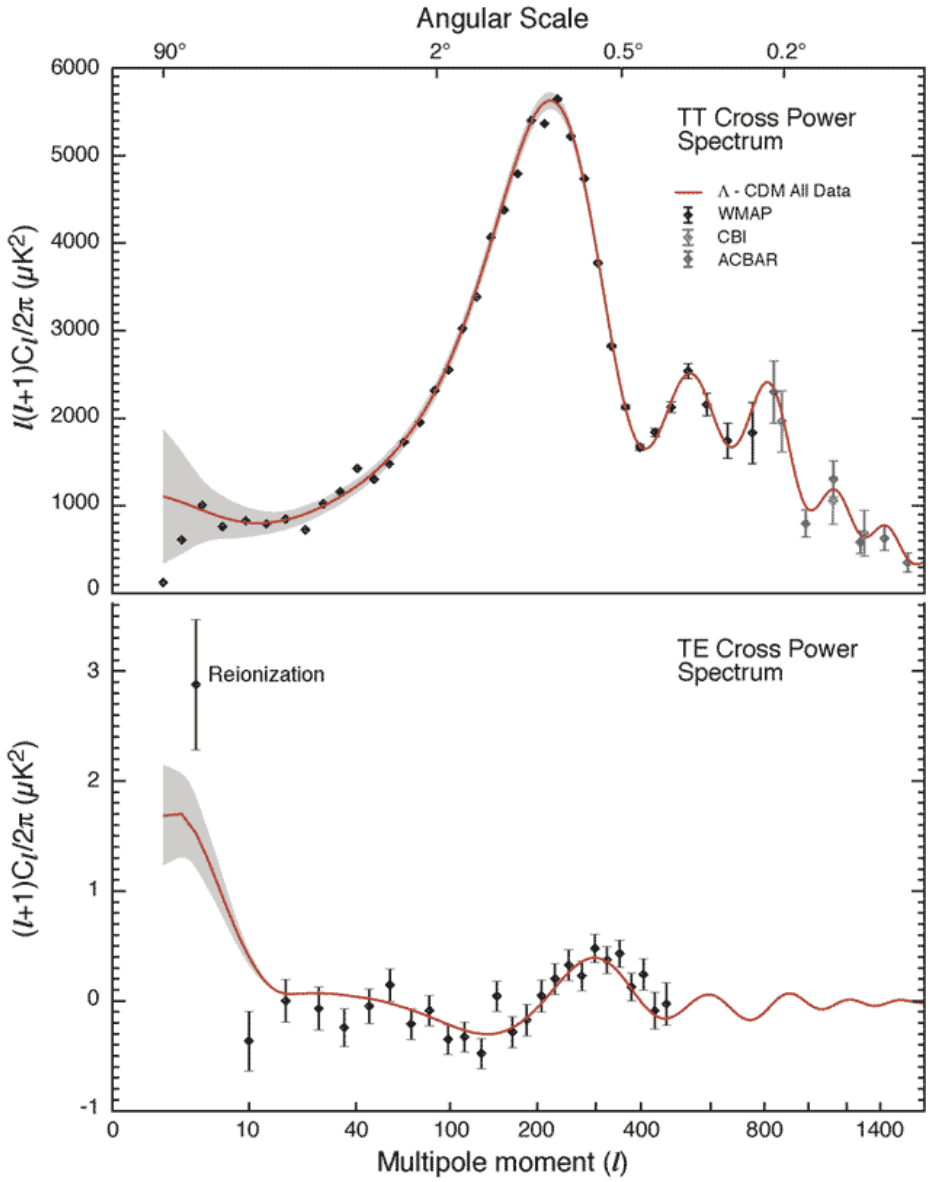


- polarization fraction ~10 %
- reionization, gravity waves, diminished degeneracy in cosmological parameter estimation





project	Frequency (GHz)	scale (l)	location
WMAP	22 – 90	2 – 1000	satellite
MAXIPOL	150 – 420	50 – 600	balloon
Boomerang/B2K	150 – 345	200 - 700	balloon
CBI	26 – 36	300 – 3000	Chile
DASI	26 – 36	125 – 700	Antarctica
QUEST	100 – 150	25 – 2500	- " -
POLAR	26 – 36	2 – 20	USA
BICEP	90 – 150	10 – 300	Antarctica


Angular Scale
90°
2°
0.5°
0.2°
TT Cross Power Spectrum
Λ - CDM All Data
WMAP
CBI
ACBAR
l(l+1)C_l/2π (μK^2)
6000
5000
4000
3000
2000
1000
0
TE Cross Power Spectrum
Reionization
(l+1)C_l/2π (μK^2)
3
2
1
0
-1
0
10
40
100
200
400
800
1400
Multipole moment (l)

DASI Home Page - Mozilla

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http://astro.uchicago.edu/dasi/

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DASI

DEGREE ANGULAR SCALE INTERFEROMETER

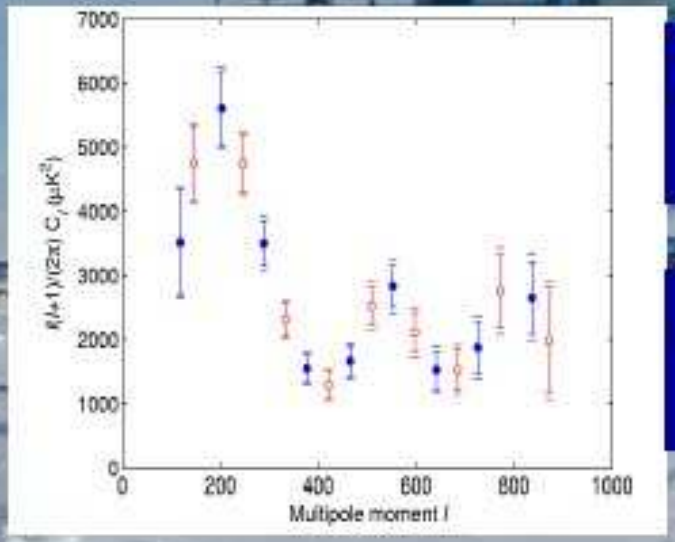
DASI is a 13-element interferometer designed to measure temperature and polarization anisotropy of the Cosmic Microwave Background (CMB) Radiation over a large range of scales with high sensitivity. The instrument uses cooled HEMT amplifiers running between 26-36GHz, in ten 1 GHz channels and operates from the NSF Amundsen-Scott South Pole station. Funding for DASI comes from the NSF Office of Polar Programs initially via the Center for Astrophysical Research in Antarctica, CARA, a NSF Science and Technology Center, and currently through a grant directly from the Office of Polar Programs. The Center for Cosmological Physics (CfCP) provides additional support at Chicago.

h = 2800 m
700 m from South Pole

MAPO January 2001
fully equipped modern lab
at South Pole station

DASI w/ deployable ground shields

Viper/ACBAR

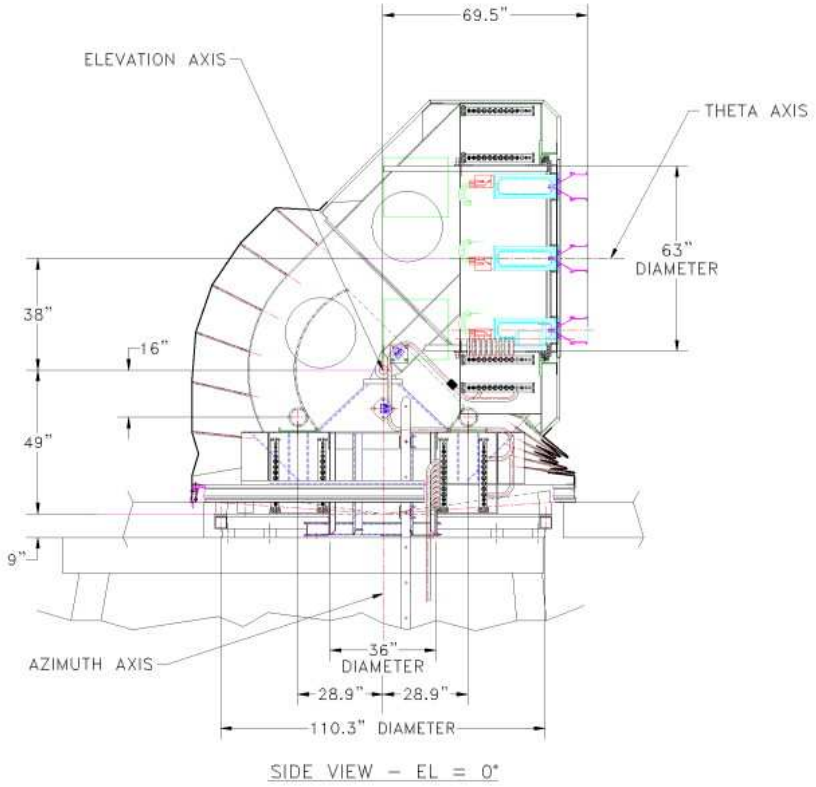


DASI Year 1: 92 days, 16 hours/day
32 fields, released April 2001

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

10.4.--27.10. 2001 & 14.2.--11.7.2002, C2&C3

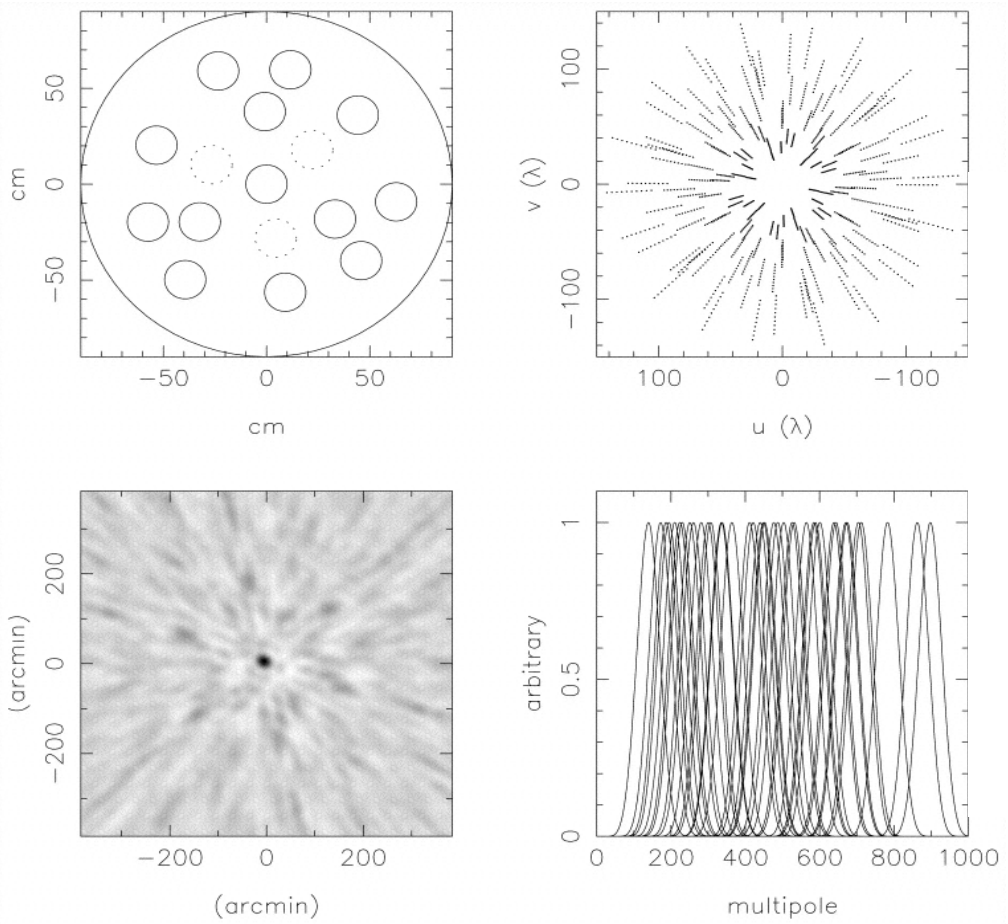

DASI, March 2000



SUMMARY OF ARRAY PARAMETERS

Parameter	Value
Primary antenna elements	13
Aperture diameter (cm)	20
Beamwidth of 30 GHz (deg)	3.4 ± 0.07
Aperture efficiency	0.835 ± 0.033
Gain (μ K Jy^{-1})	9.5 ± 0.4
Band (GHz)	26–36
Correlator IFs (GHz)	10×1
rms sensitivity of 1 GHz band (Jy s$^{1/2}$)	$\sim$60
$B_{\rm min}$ (cm)	25.1
$B_{\rm max}$ (cm)	120.73

10 frequencies: 26 – 36 GHz



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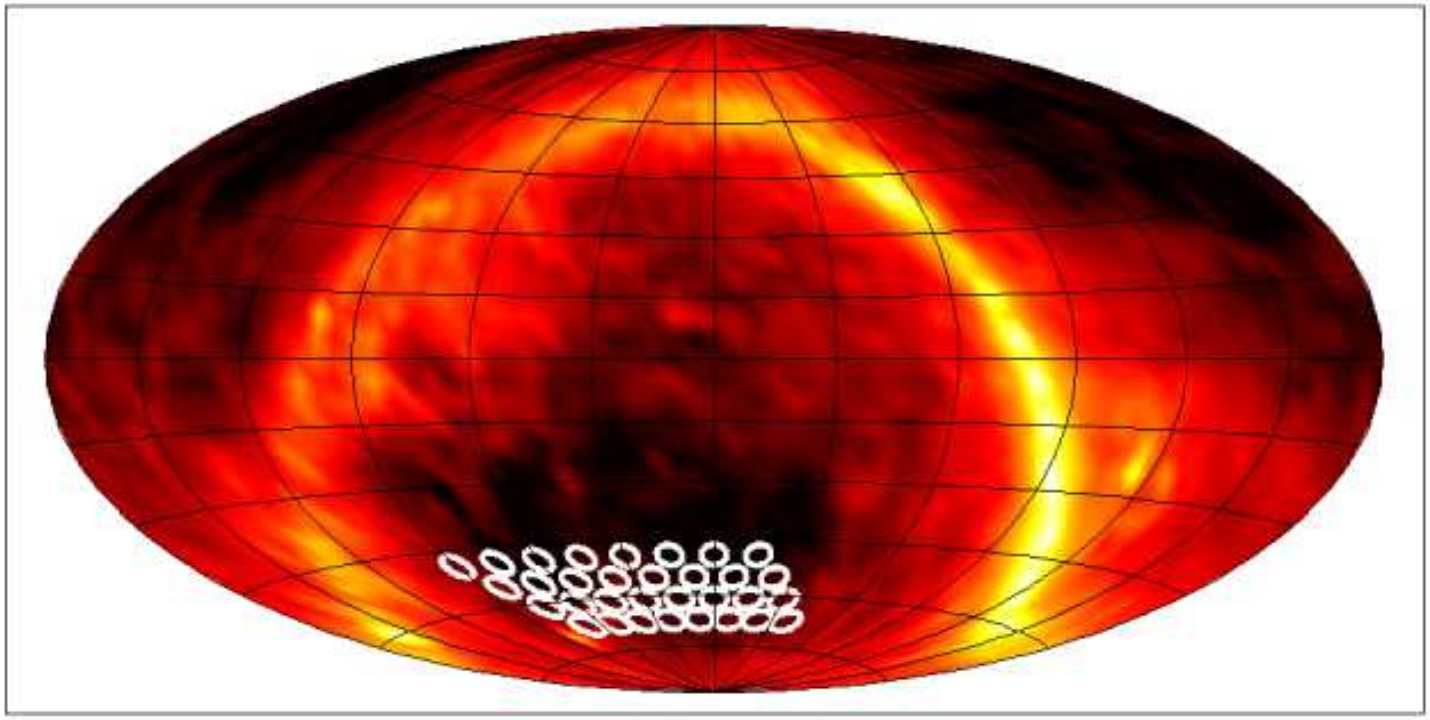
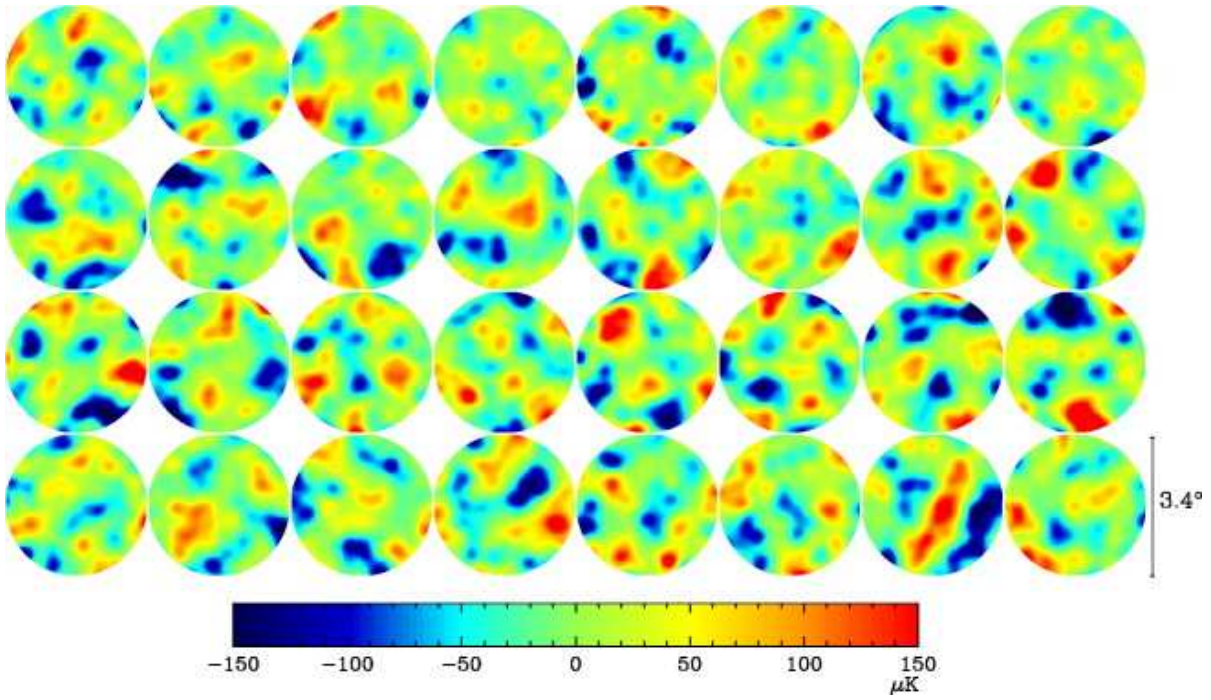
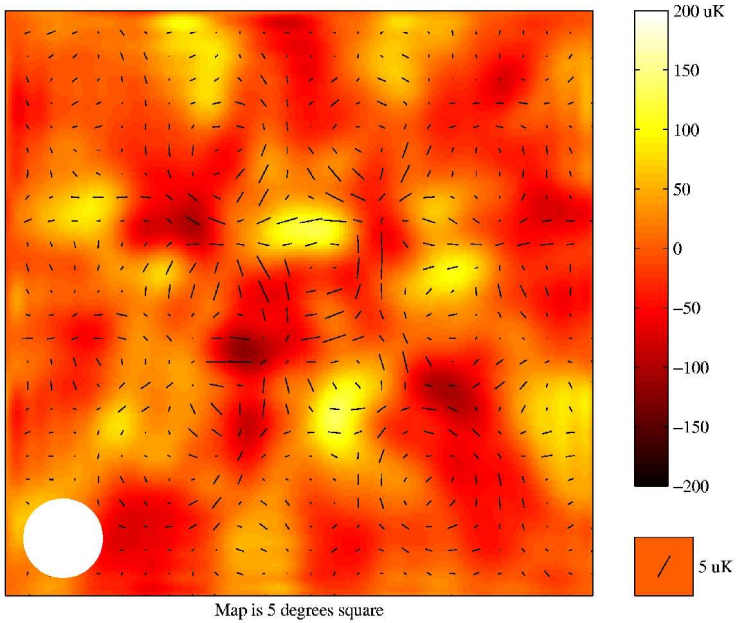
DASI observed fields



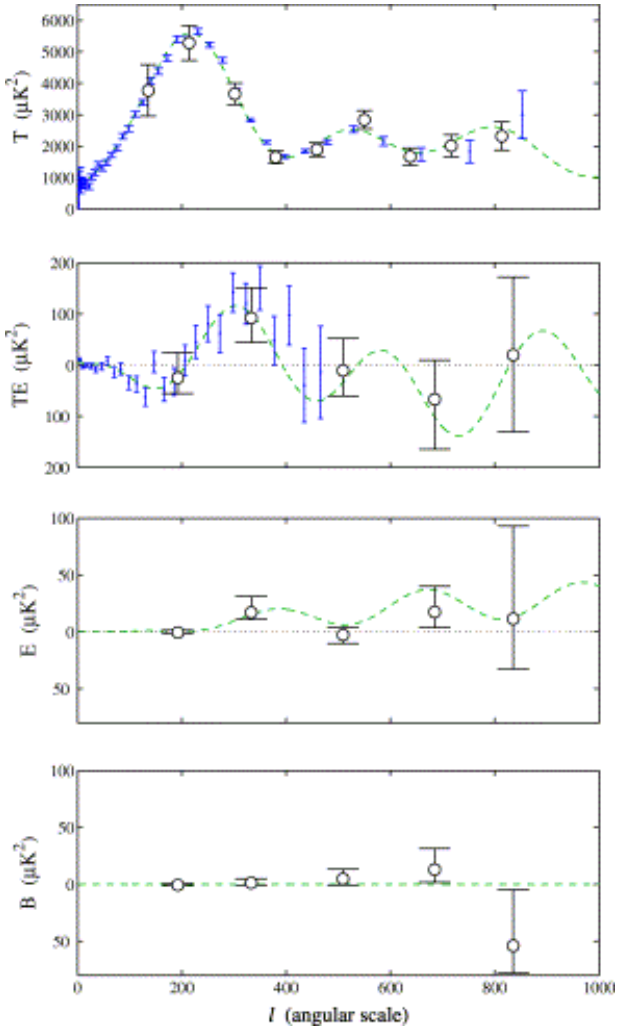
DASI temperature maps



DASI polarization map



Map is 5 degrees square



DASI recent news

QUEST (Q and U Extra-galactic Survey Telescope) will be mounted to DASI, observations start 2005. -> QUAD (QUEST and DASI)

- $100 < l < 2000$
- sensitivity good enough for E-mode spectrum and grav.lensed B-mode
- 2.6 m Cassegrain focus telescope
- 12 polarization-sensitive bolometer (PSB) pairs at 100 GHz and 19 pairs at 150 GHz
- 4' beam

Archeops Main Page - Mozilla

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L'EXPÉRIENCE ARCHEOPS

Les résultats d'Archeops !!!!

Cliquez ici pour en savoir plus!

Mise à disposition des données



version anglaise

L'expérience ARCHEOPS a pour but la mesure du rayonnement fossile émis par l'univers, peu de temps après le Big Bang. L'étude de ce rayonnement est essentielle pour obtenir des informations très précises sur l'évolution de l'univers : densité, constante de Hubble, âge de l'univers, etc La réalisation de cette expérience se fait grâce à des mesures très sensibles, à des températures proches du zéro absolu, effectuées au foyer d'un télescope. Ce télescope est suspendu sous un ballon stratosphérique permettant de s'affranchir de l'effet de l'atmosphère.

Présentation générale

- Le rayonnement fossile
- Les différentes expériences
- L'instrument Archéops
- La collaboration
- Liens sur le CMB (anglais)

Dernières nouvelles

Journal de bord

Lettre hebdomadaire

- Le vol de test en Sicile (1999)
- Vol test à Kiruna
- Vols scientifiques Kiruna 2000-2001

Archeops instrument:

- 1.5 m telescope, tilted 41 deg
- spin 2 rpm
- 30% sky coverage on 12 h mission
- pointing accuracy < 1'
- 21 focal plane bolometers ~ Planck-HFI: 6x 143 GHz, 8x 217 GHz (CMB), 6x 353 GHz (Pol), and 1x 545 GHz (dust)
- lobe size: 10'
- cooling to 100 mK by 3He/4He dilution fridge

Flights:

- test flight from Sicily
- two missions from Kiruna

Telescope

Table 1. Design and construction parameters for the Archeops telescope

Parameter	Value
f#[a]	1.7
Plate scale[a]	35 mm/deg
Primary mirror	
Conic constant	−1
Radius of curvature of paraboloid	160 cm
Major axis of mirror	177 cm
Minor axis of mirror	150 cm
Weight	45 kg
Secondary mirror	
Conic constant	−0.18
Radius of curvature	53 cm
Tilt of major axis[a]	15°
Major axis of ellipsoid	130 cm
Axial magnification of ellipsoid	2.5
Major axis of mirror	84 cm
Minor axis of mirror	79 cm
Weight	10 kg
Image Surface	
Conic constant	0 (=spherical)
Radius of curvature	101 cm

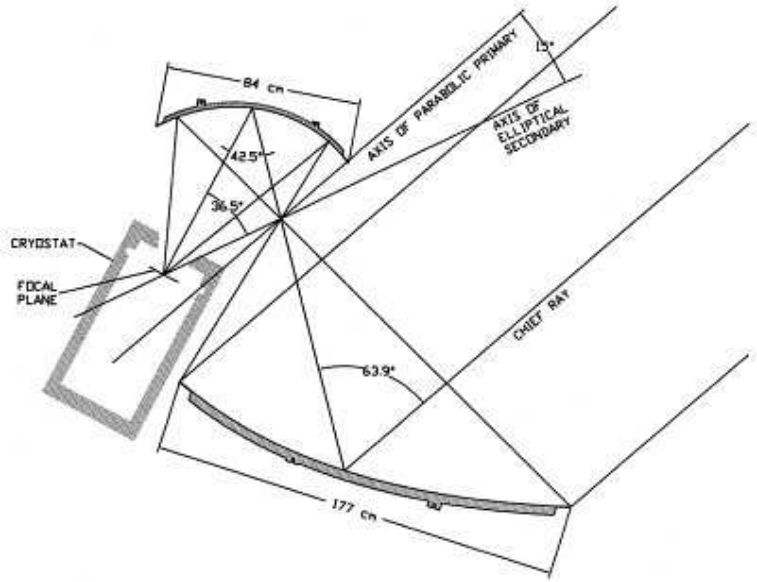

Fig. 2. A side view of the Archeops telescope and cryostat. The telescope is a tilted Gregorian system consisting of a parabolic primary and elliptic secondary. The primary axis of the ellipse is tilted with respect to the axis of the parabola such that the system satisfies the Dragone condition. The system provides an RMS wave-front error of less than 6% at wavelengths between 2 and 0.85 mm, for beam sizes between 8′ and 5′, respectively.

Telescope

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Minor axis of mirror	79 cm
Weight	10 kg
Image Surface	
Conic constant	0 (=spherical)
Radius of curvature	101 cm

Focal plane

- triple horn guide system for each bolometer
- thermal breaks reduce background power falling onto bolometer

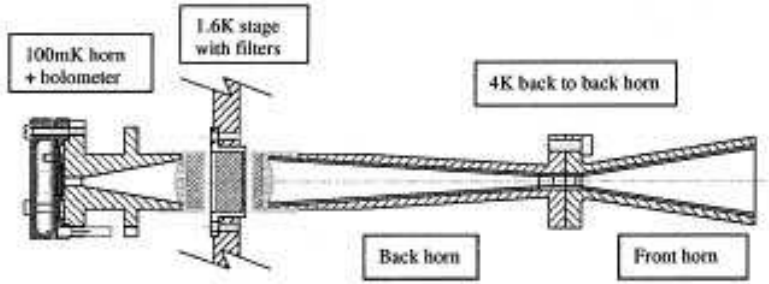
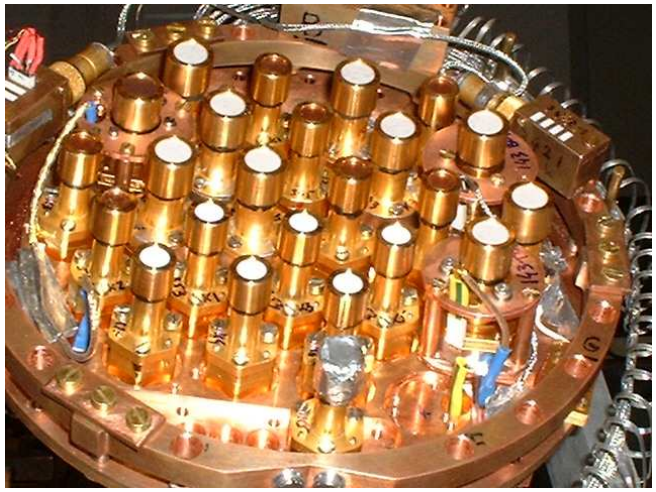
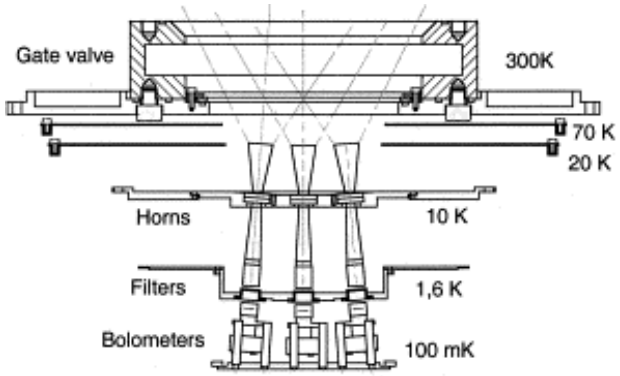
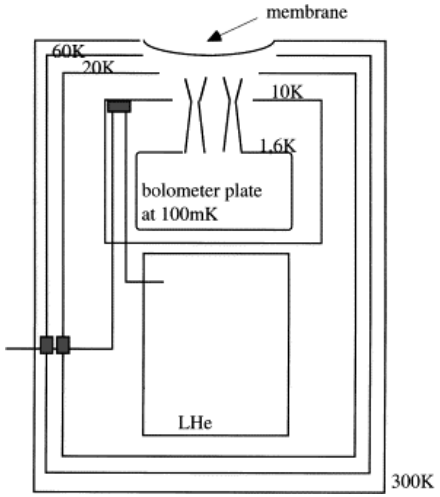


Fig. 4. Optical configuration for a single photometric pixel.



Cryostat





Open cycle dilution refrigerator
- liquid He reservoir 4.2 K -> Joule-Thompson expansion cooling to 1.6 K and 0.1 K
- NbSi metal insulation transition thermometers
similar design as in Planck HFI

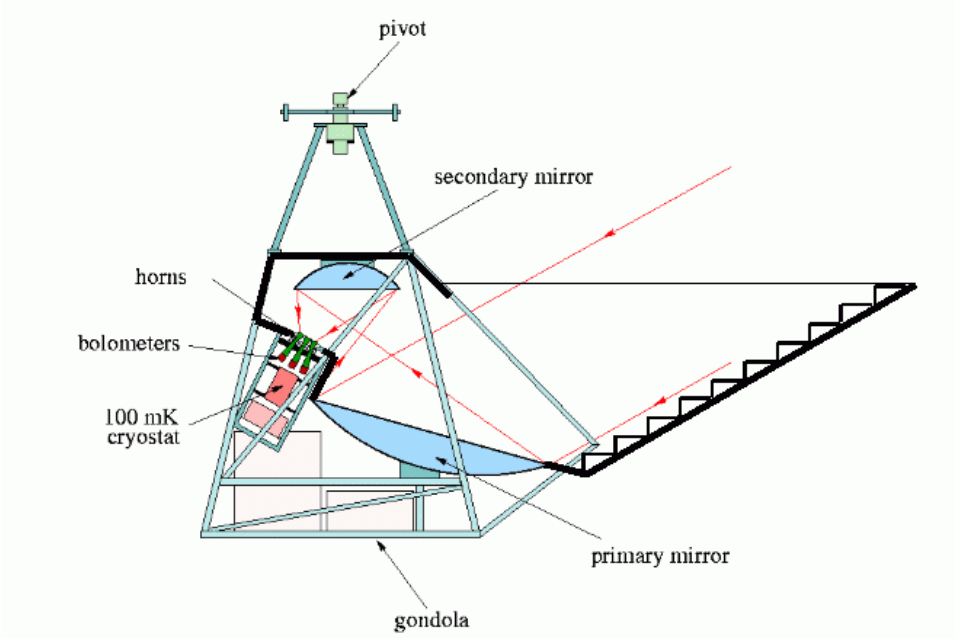
Pointing

3 gyroscopes (sampling rate 171 Hz)

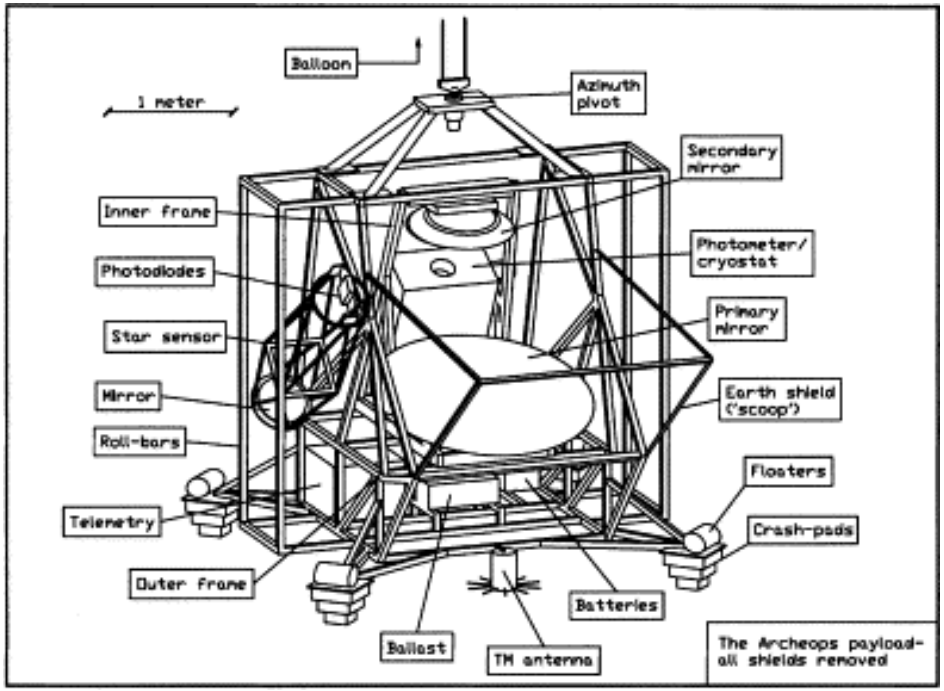
GPS (sampling rate 0.5 Hz)

Stellar sensor; during one rotation of the payload (spin rate 2 rpm) star sensor scans full circle 1.4 deg wide. On average 50 – 100 stars with m<7 on this circle.
46 photodiodes on focal plane for collecting stellar data
Time lag for detection: ~ 5 ms after integration.
(sampling rate 171 Hz)

Gondola


pivot
secondary mirror
horns
bolometers
100 mK
cryostat
primary mirror
gondola

Gondola



Mass : 1000 kg
(500 kg scientific payload,
250 kg lead ballast)
Azimuth pivot mount, motor with 0.24 Nm/A torque (2A average current)
Flight chain: 10 m steel cable ladder
Electronics:
- modulation control for bolometers & thermom.
- focal plane heater
- rotation control
- main gate valve
- photometer heaters

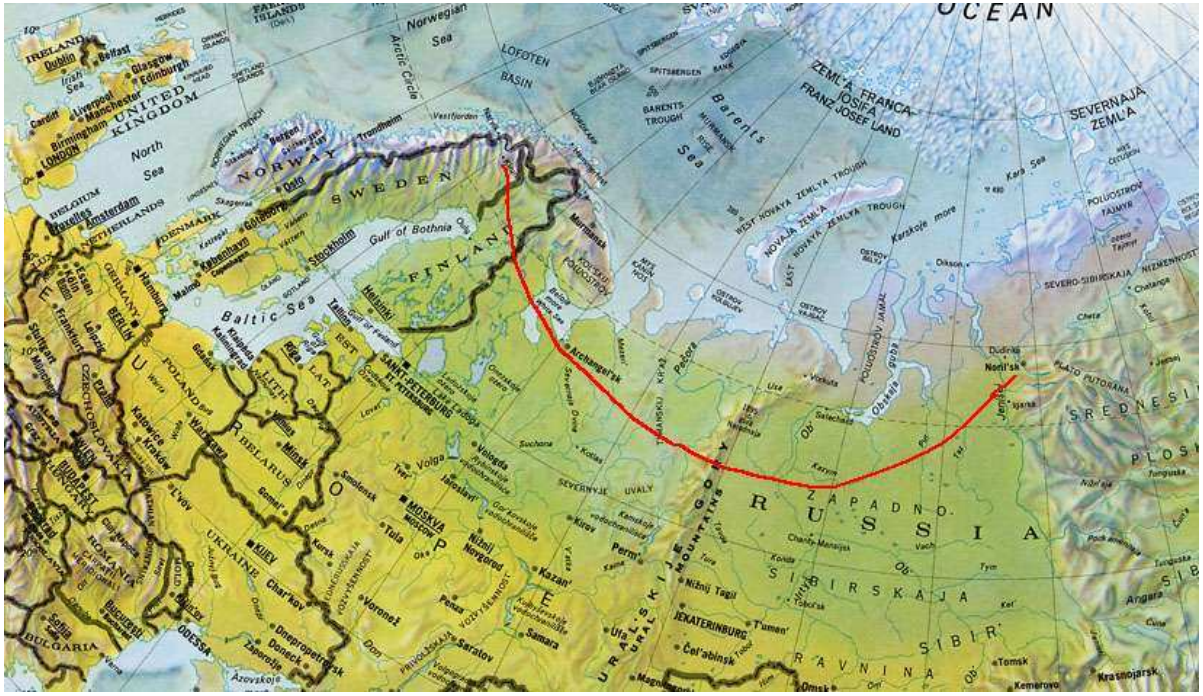
On-board computer
EPLD Altera 9400 card.
Dilution card, stellar sensor card,
2 Gb data storage module
Batteries: 48x 3V, 36Ah Li-batt. -> 60 – 100 W

Test flight, Trapani, Sicily, 17.-18.7.1999

21:22 launch
23:55 spinning starts
01:00 first light (the Galaxy)
01:27 standard altitude (40 km) achieved,
cryostat stabilizes at 112 mK,
final polarization adjustments
06:00 sunrise
09:52 automatic shutdown (Sun heat)
14:22 gondola separates from balloon
15:23 landing in Spain

Scientific flights, Kiruna, Sweden, 2001-2002

1st flight Jan 01
2nd on Jan 02 unsuccesful (balloon problem)
3rd on Feb 02:



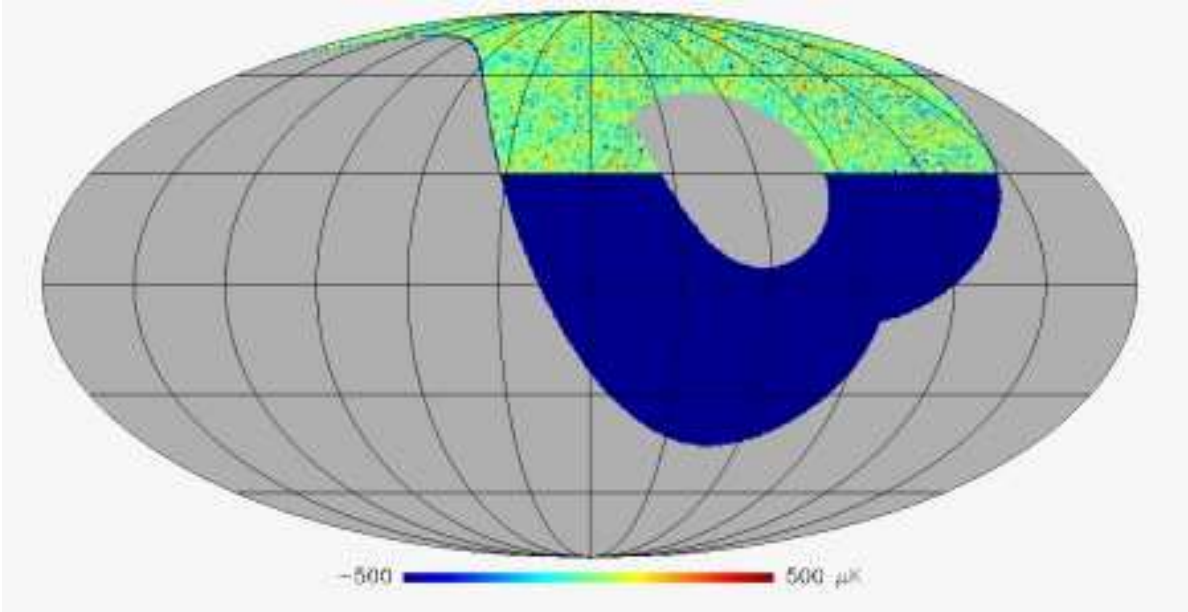
Launch at 13:44

Launch at 13:44

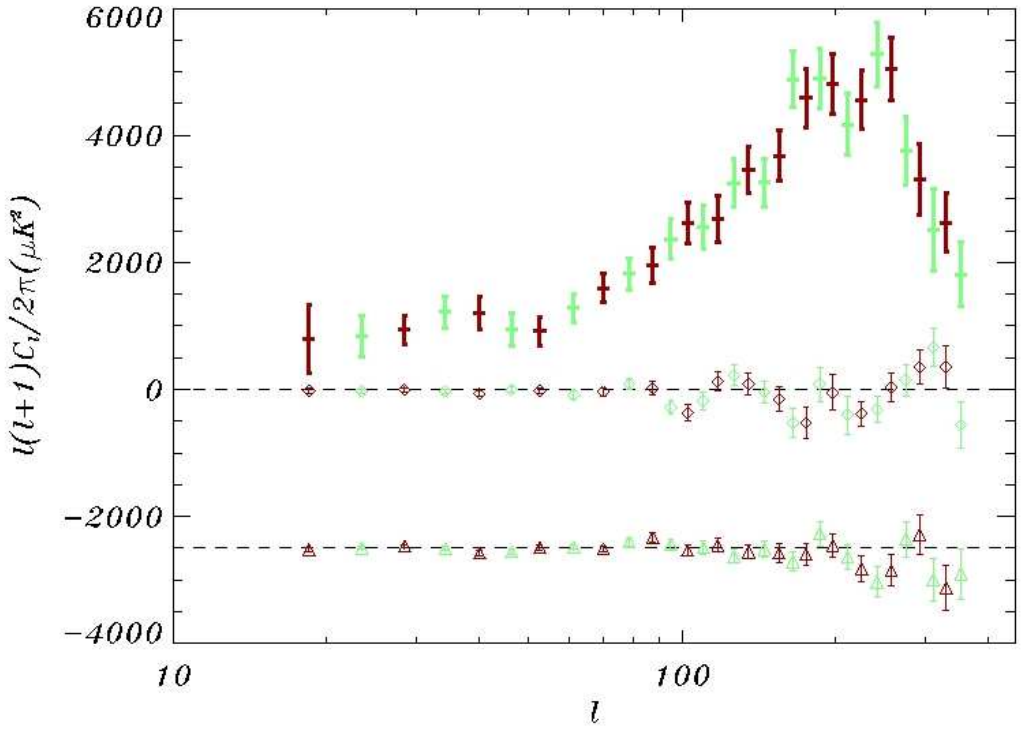
Nominal altitude of
34 km reached in 2 hours.

Landing in Siberia 19 h
later..

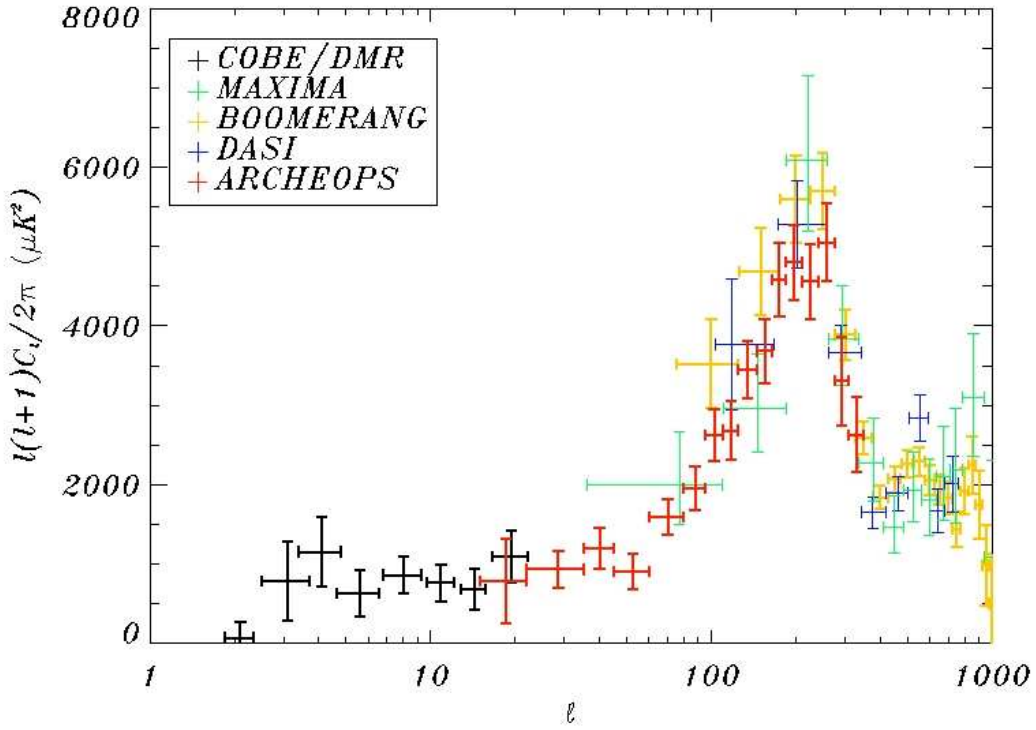
Temperature map:



Anisotropy spectrum



Anisotropy spectrum



CMB OBSERVATIONS, CONCLUSION

A good CMB experiment has
- high sensitivity (dT/T ~ 10E-6)
- high resolution (l ~ 1/theta)
- large sky coverage (dl ~ 1/dtheta)
- good scanning strategy (stripes)
- many frequencies (foreground removal)
- polarimeters (more info)

3 types of experiments:
- ground
- balloon
- space

Future: high-sensitivity polarization studies.