The Einstein Polarization Interferometer for Cosmology (*EPIC*)

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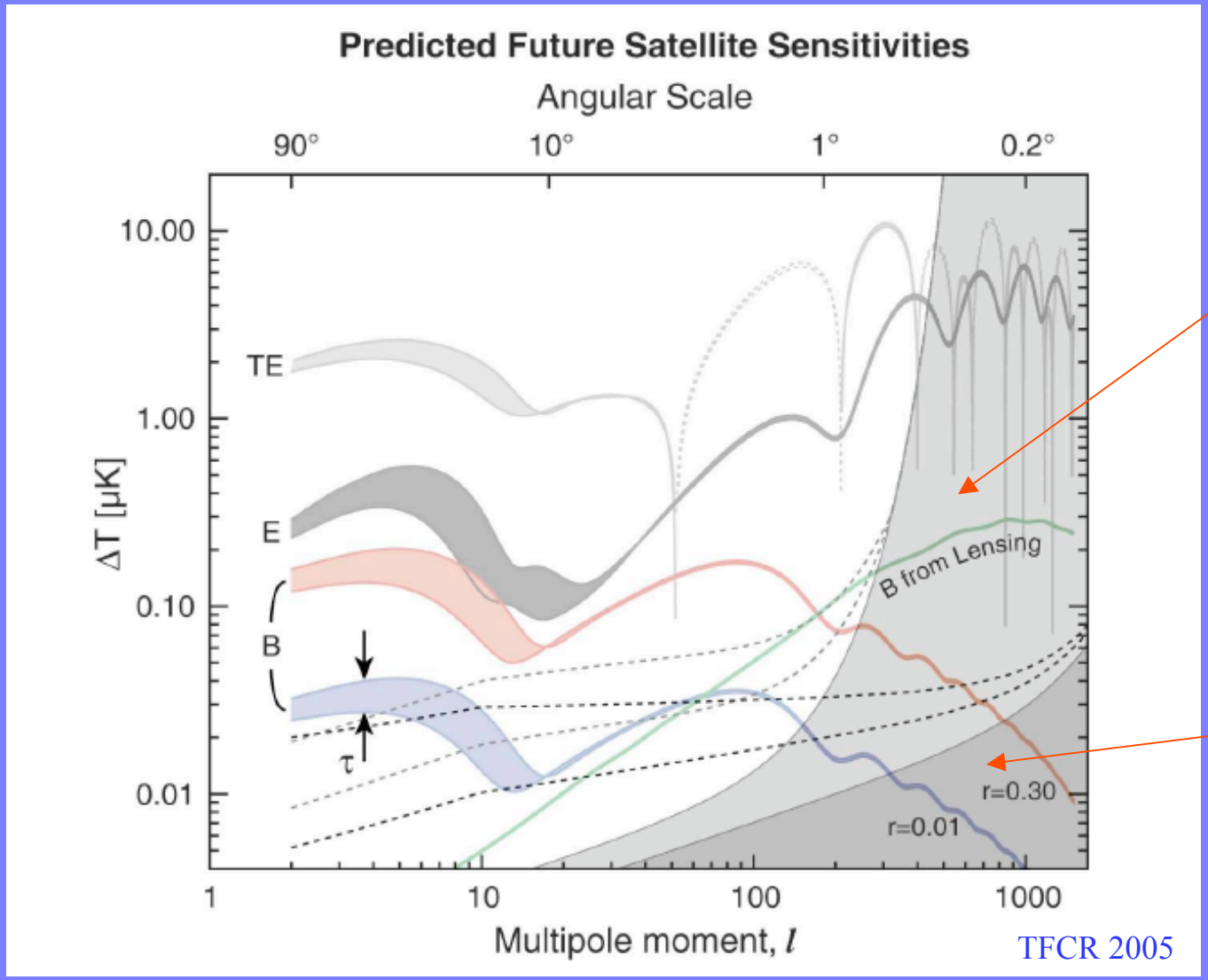
for the *EPIC* collaboration

Brown, Cardiff, Illinois, Ireland-Maynooth, LLNL, Manchester, Richmond, UCSD, Wisconsin, Ball Aerospace, General Dynamics



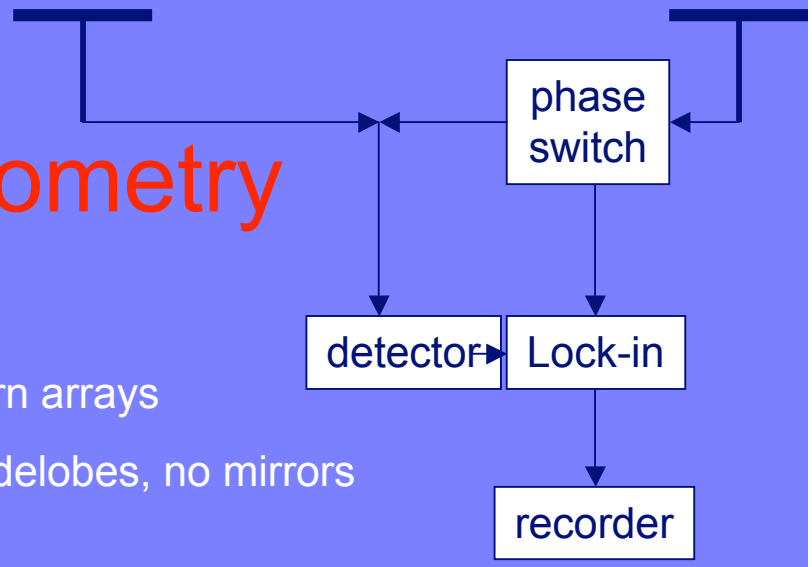
1 year in space
background-limited

1000 pixel instrument
1^0 resolution

2000 pixel instrument
0.1^0 resolution

TFCR 2005

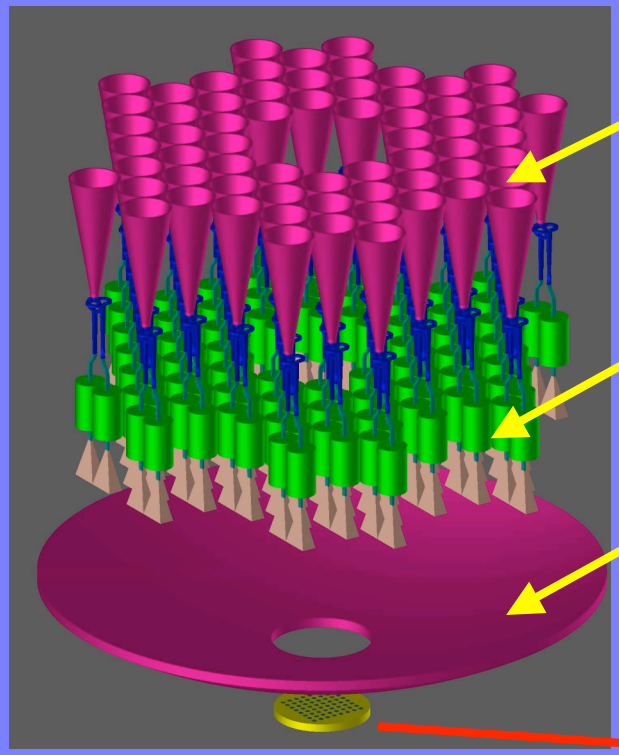
CMB Interferometry



- Simple optics
  - forms beams with corrugated horn arrays
  - symmetric beam patterns, low sidelobes, no mirrors
- No off-axis aberrations
- Stokes U measured by correlation of E_x and E_y on a single detector (no differencing of detectors)
- Differences sky signals without scanning
- Measures power spectrum directly
- Measures both Temp and Polarization anisotropy
- Coherent (HEMTs) or incoherent (bolometers) systems possible
- Angular resolution ~ 2X better than imager of equivalent diameter
- CMB polarization first detected with interferometer (DASI)

EPIC Mission Concept

25 cm at
λ = 0.3 cm

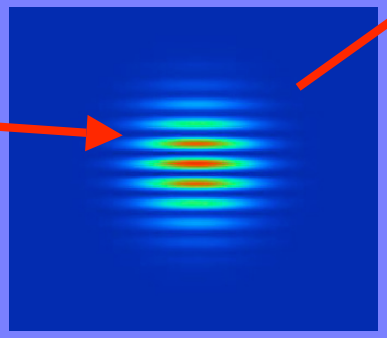


Corrugated horns

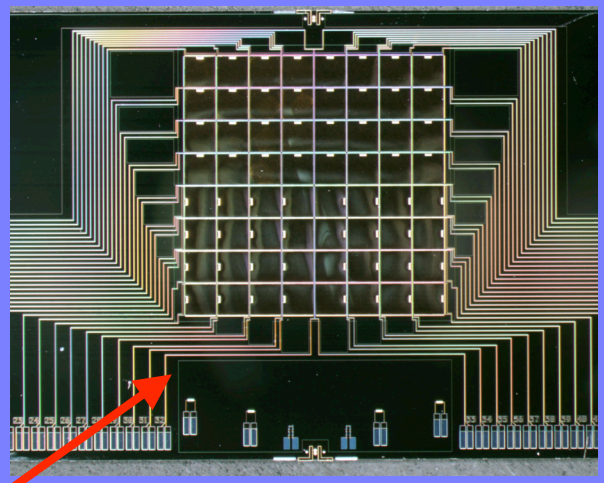
RF phase modulators

Fizeau beam combiner

64-element module
(1 of 16)



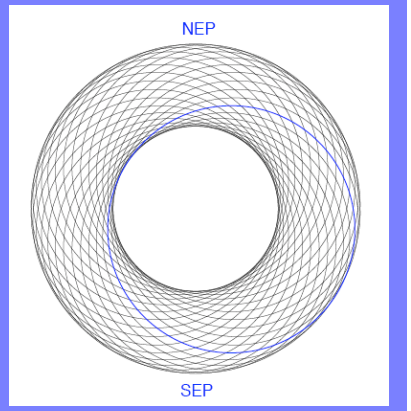
Interference fringes measured in
focal plane by bolometer array

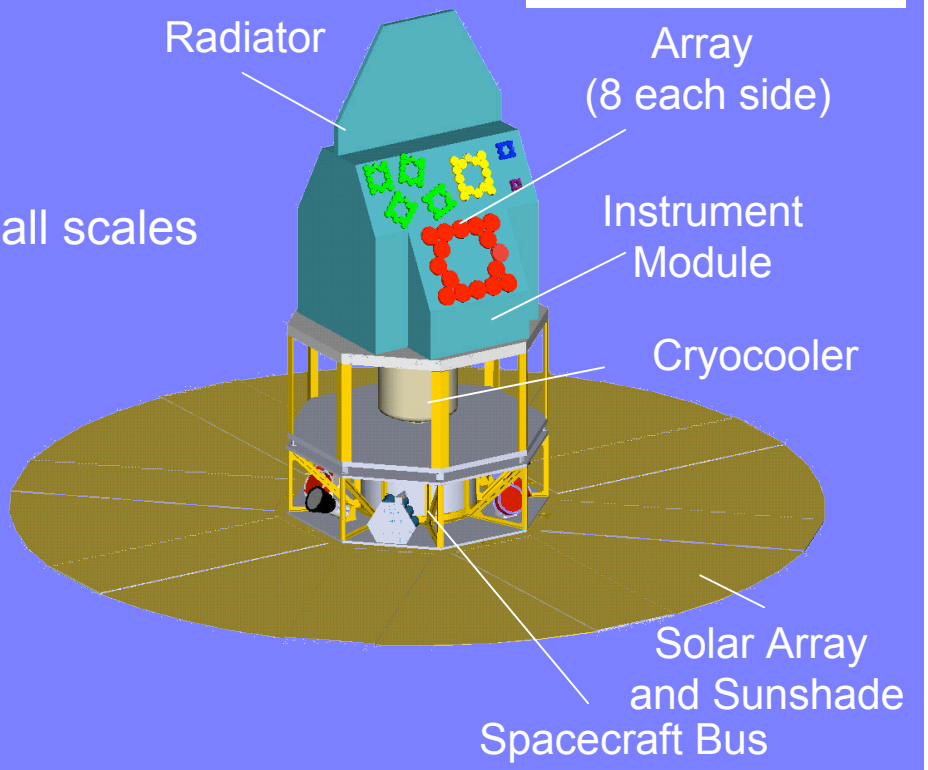


Backshort Under Grid (BUG)
TES array (NASA/GSFC)

EPIC L2 Mission Concept

- Measure CMB *E* and *B* mode polarization over full sky to foreground limit (T/S ~ 0.01)
- Scaled close-packed corrugated horn arrays: 30-300 GHz
- ~15° FOV, ~ 1° synthesized beams
- Total # horns *N* ~ 1024 (= # modes)
- Interferometer: signals cross-correlated
  - between horns: *N(N-1)/2* visibilities for small scales
  - between 2 polarizations for each horn: "correlation polarimetry" for large scales
- Delta II 7925H-10
- Lifetime > 1yr from L2
- Scans like WMAP



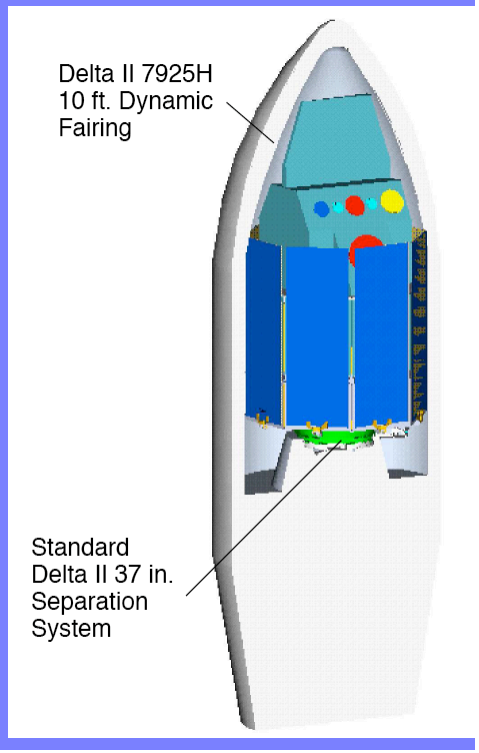


EPIC L2 Instrument Table

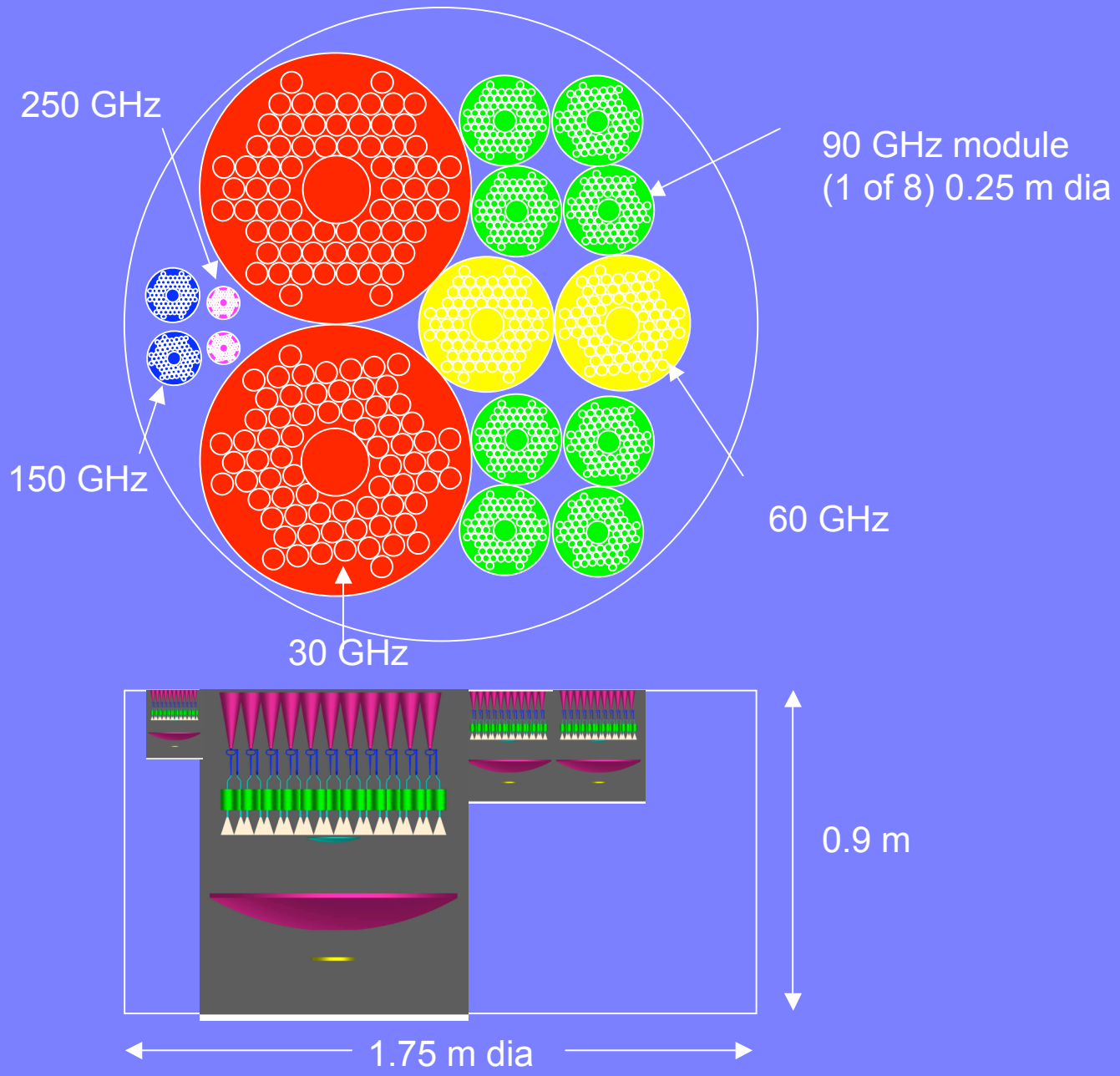
Item	Value/Description
Number and type of instruments	1
Number of channels	16 scaled arrays at 30(2), 60(2), 90(8), 150(2), 250(2) GHz with 20% BW
Size/dimensions (for each instrument)	2 m x 2 m x 5 m
Payload mass with contingency	690 kg, 25%
Average payload power with contingency	450 W, 25%
Average science data rate with contingency	830 Kpbs, 25%
Instrument Fields of View (if appropriate)	arrays view same 15^0 dia FOV
Pointing requirements	3’ knowledge, 6’ control

EPIC L2 Mission Design Table

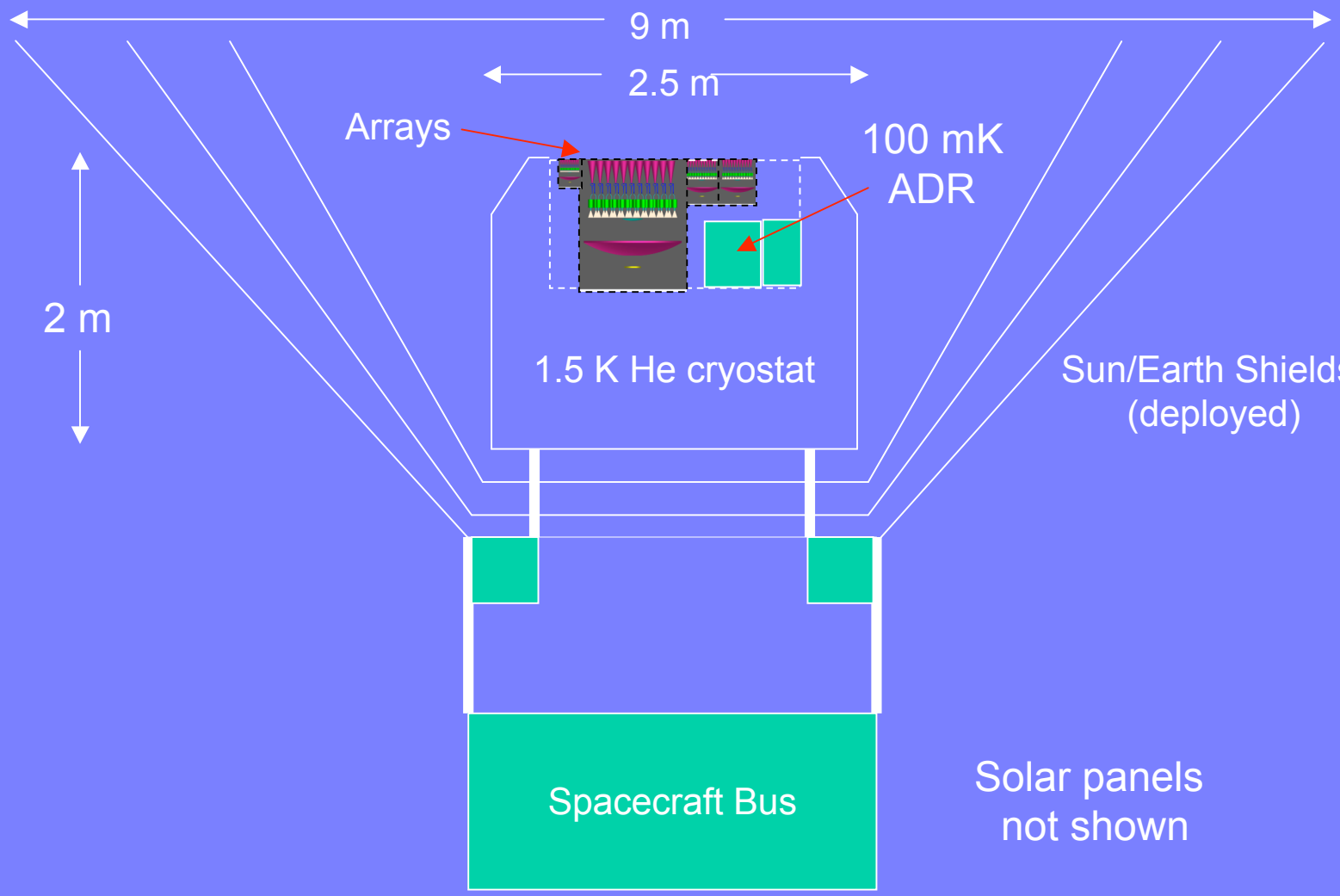
Parameter	Value
Orbit parameters	L2 Lissajous (WMAP) 1rpm spin rate, 1/hr precession rate
Mission lifetime	1 year minimum (2 yr goal)
Maximum eclipse period	TBD
Spacecraft dry bus mass	1120 kg (21%)
Spacecraft propellant mass	96 kg (28%)
Launch vehicle	Delta II
Launch vehicle mass margin	TBD
Spacecraft bus power	908 WOAP (30%)



EPIC LEO Mission Concept



EPIC LEO Mission Concept



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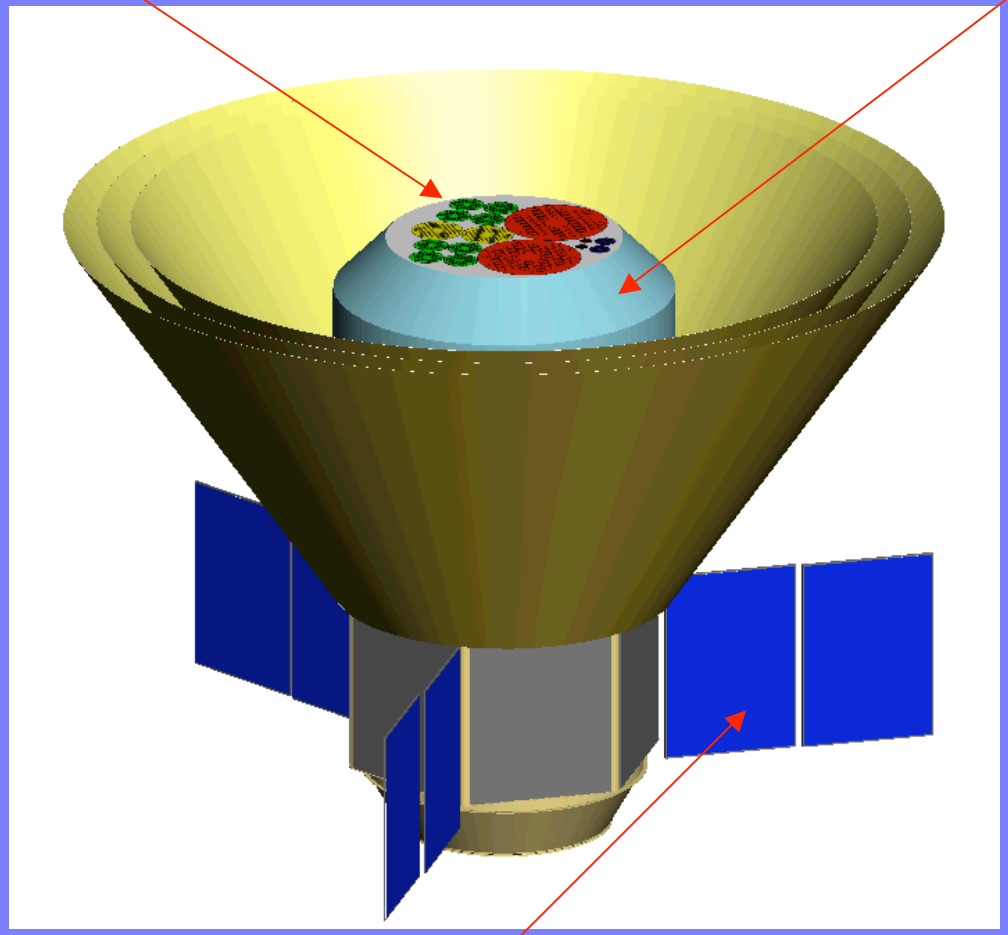
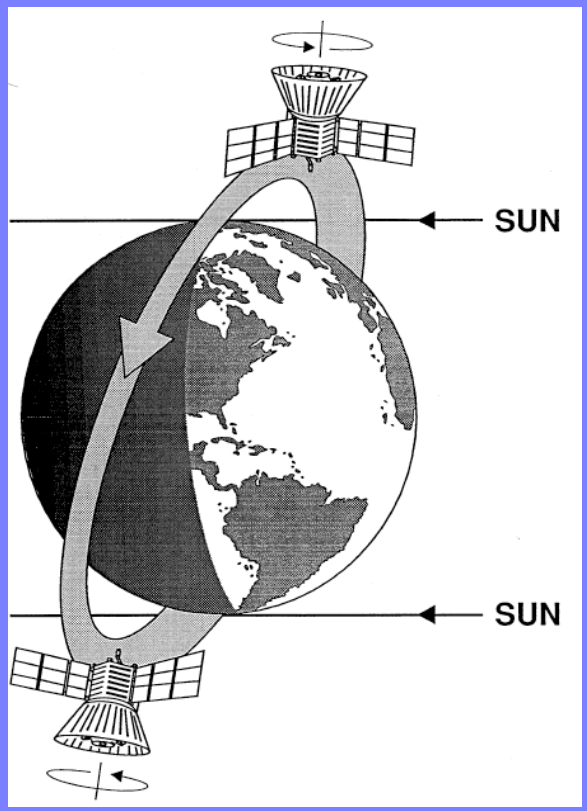
Interferometer arrays

LHe cryostat

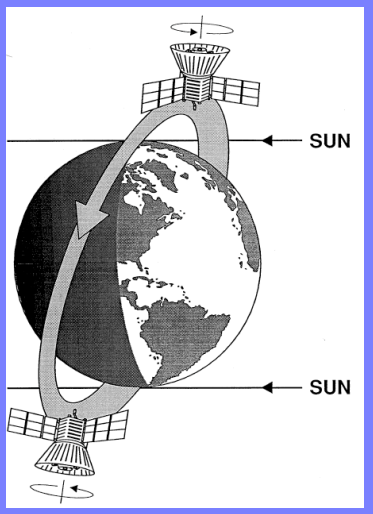


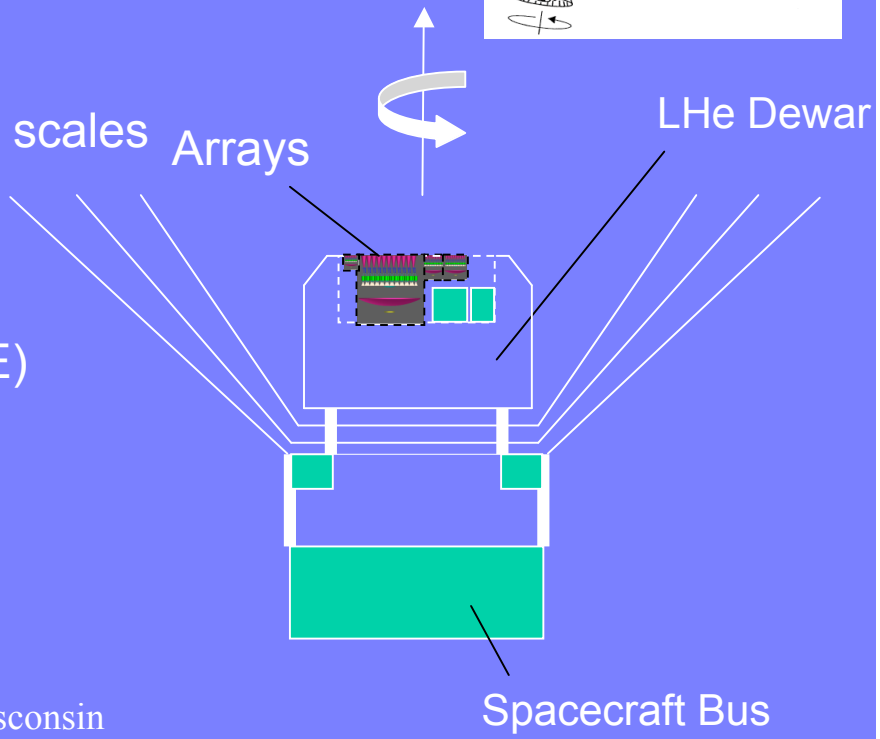


Solar panels

EPIC LEO Mission Concept

- Measure CMB *E* and *B* mode polarization over full sky to foreground limit (T/S ~ 0.01)
- Scaled close-packed corrugated horn arrays: 30-300 GHz
- ~15^{o} FOV, ~ 1^{o} synthesized beams
- Total # horns *N* ~ 1024 (= # modes) x 2 pol'ns
- Interferometer: signals cross-correlated
  - between horns: *N(N-1)/2* visibilities for small scales
  - between 2 polarizations for each horn: "correlation polarimetry" for large scales
- Lifetime > 1yr from 900 km Earth orbit (COBE)





EPIC LEO Instrument Table

Item	Value/Description
Number and type of instruments	1
Number of channels	16 scaled arrays at 30(2), 60(2), 90(8), 150(2), 250(2) GHz with 20% BW
Size/dimensions (for each instrument)	2.5 m dia x 2.7 m
Payload mass with contingency	1590 kg, 25%
Average payload power with contingency	250 W, 25%
Average science data rate with contingency	830 Kbps, 25%
Instrument Fields of View (if appropriate)	arrays view same 15^0 dia FOV
Pointing requirements	3’ knowledge, 6’ control

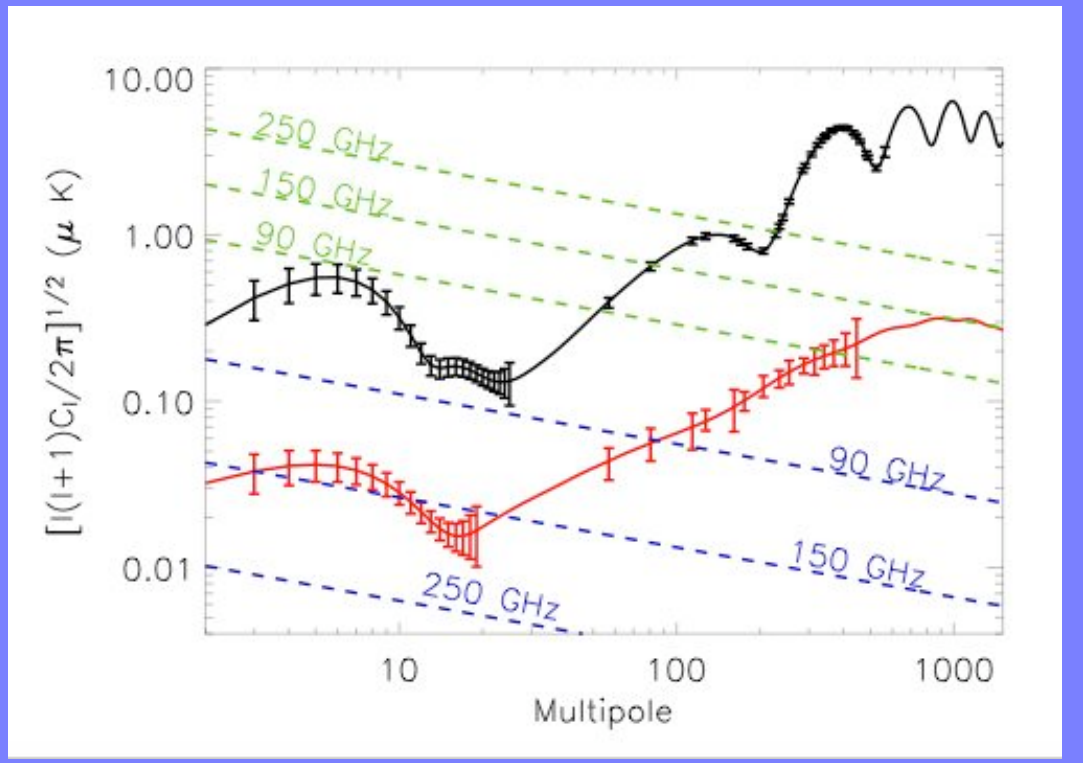
EPIC LEO Mission Design Table

Parameter	Value
Orbit parameters	900 km Sun-synchronous (COBE) 1 rpm spin rate
Mission lifetime	1 year minimum (2 yr goal)
Maximum eclipse period	TBD
Spacecraft dry bus mass with contingency	TBD
Spacecraft propellant mass with contingency	TBD
Launch vehicle	Compatible with Delta II
Launch vehicle mass margin	TBD
Spacecraft bus power and contingency by subsystem	TBD

EPIC sensitivity

- Only 90 GHz channels used in sens. calc.
- Assumes uniform coverage of full sky
- Background-limited detectors, η = 0.5, 20 % BW
- 1 year observation
- Comparable to imager with same # modes
- 2 modes:
  - Inteferometry mode
  - Correlation polarimeter
- T/S = 0.01

End-to-end simulation under development



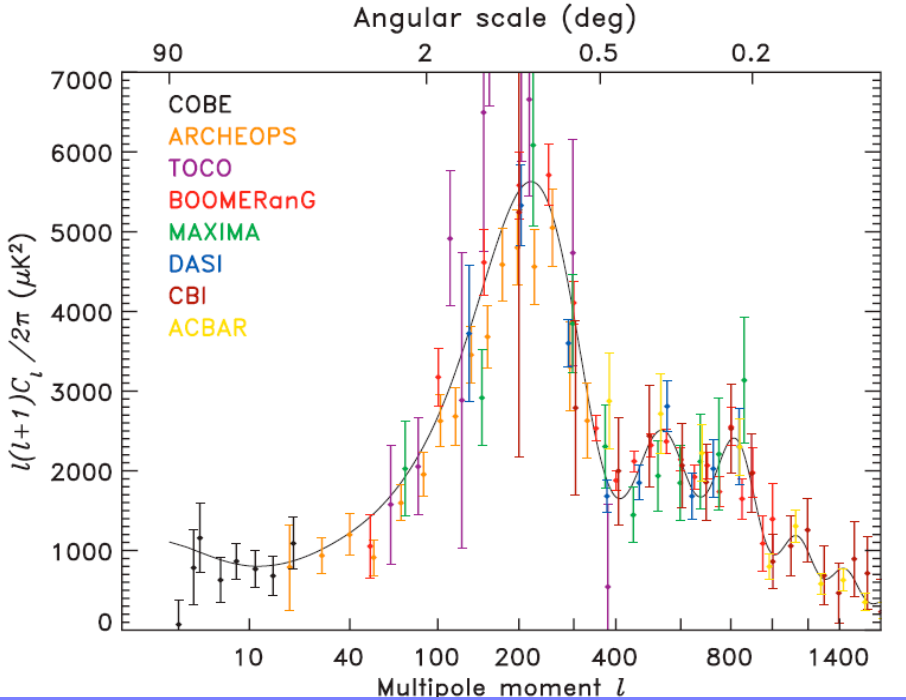
EPIC sensitivity calculation

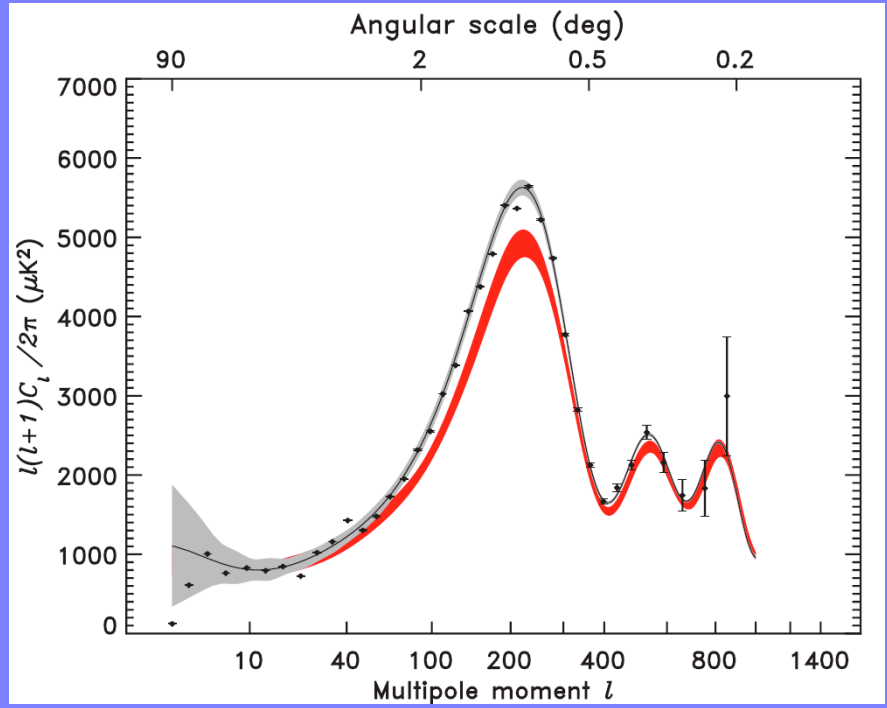
- Each array module has N = 64 antennas, 2 polarizations
- Signal from each antenna spread out over focal plane of
  4N = 256 detectors
- Phase-modulated fringe signal meas'd independently
  by each detector
- Background-limited detectors in focal plane of beam combiner
- η = 0.5, 20 % BW
- 4N demodulated signals are then added in quadrature
  to compute visibility
- Repeat for each of the 2N(2N-2)/2 visibilities (all baselines)
- Add in quadrature signals from other arrays at 90 GHz
- 1 year integration over full sky ("Knox" formula)
- Similar procedure for "correlation polarimeter"

EPIC Challenges

- sensitivity analysis
- data analysis
  - analysis pipeline, simulations
  - mosaicking over full sky
- foreground removal - Fourier vs map space
- phase shifter

CMB Pre- and Post- *WMAP*





Hinshaw et al. 2003