The Einstein Polarization Interferometer for Cosmology (EPIC)

Peter Timbie

University of Wisconsin - Madison

EPIC Mission Concept Study Team

University of Wisconsin - Madison	Peter Timbie, Amanda Gault *Peter Hyland, Siddharth Malu*
Brown University	Greg Tucker, Andrei Korotkov *Jaiseung Kim*
University of Richmond	Ted Bunn
Cardiff University	Lucio Piccirillo, *Carolina Calderon*
National University of Ireland - Maynooth	Creidhe O'Sullivan
UW Space Science and Engineering Center	Fred Best
Spectrum Astro	Dominic Conte
Ball Aerospace	Rod Oonk
Lawrence Livermore NL	Shafinaz Ali

History of planning for CMBPol in the US

3 mission concept studies selected for the Einstein Inflation Probe
NASA Beyond Einstein program 2003
"CMBPol" - centered at NASA/Goddard
"EPIC imager" - centered at JPL
"EPIC interferometer" - centered at Wisconsin

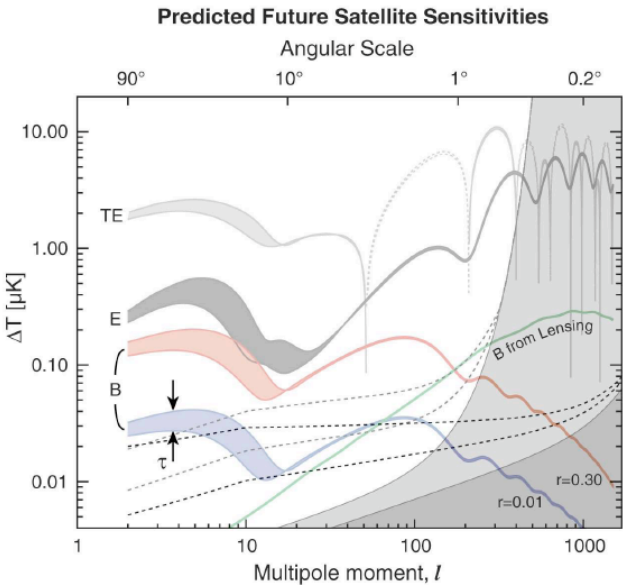
Joint Task Force on CMB Research (TFCR)
(Weiss Committee) - report 2006

Beyond Einstein Program Assessment Committee (BEPAC)
(NRC) 2006 - 2007

Decadal Review Panel (NRC) 2009 -
3 workshops this summer to prepare the case for CMBPol
-inflation, systematic effects, technology readiness

If B-modes are seen …
(by Planck or suborbital missions)

- If seen, most likely will be at recombination “bump” at l ~ 80.
- Recombination bump may be confused with lensing.
- Low l hard to get (foregrounds, sky coverage) except in space. Planck can reach ~ T/S ~ 0.1.
- Need full B spectrum (including reionization bump at l ~ 5) tomeasure tensor spectral index n_T.
- CMBPol will still need to do its own for
  removal to improve spectrum measure

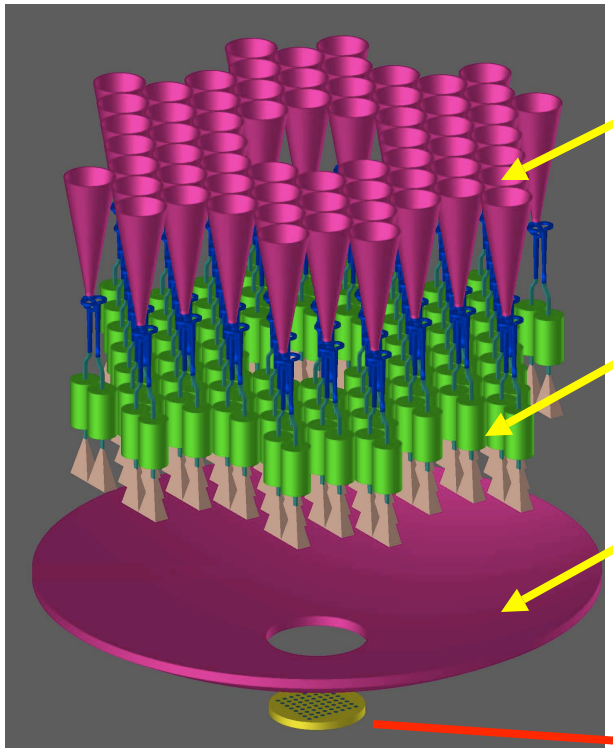


If B-modes are *not* seen…
(by Planck or suborbital missions)

May still be visible through reionization bump, which will be hard to see pre-CMBPol

EPIC Mission Concept

25 cm at
λ = 0.3 cm

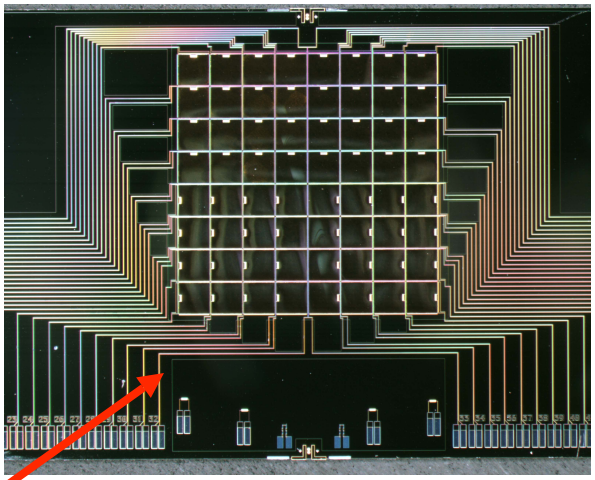


Corrugated horns

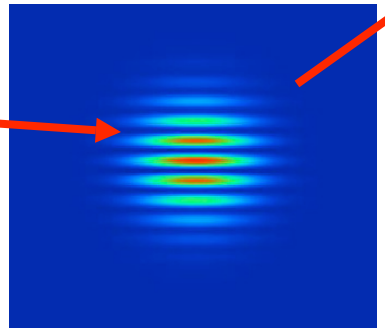
RF phase modulators

Fizeau beam combiner

64-element module
(1 of 16)

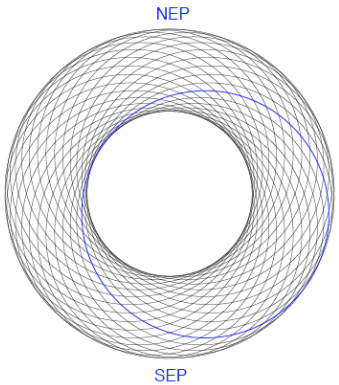


Backshort Under Grid (BUG)
TES array (NASA/GSFC)

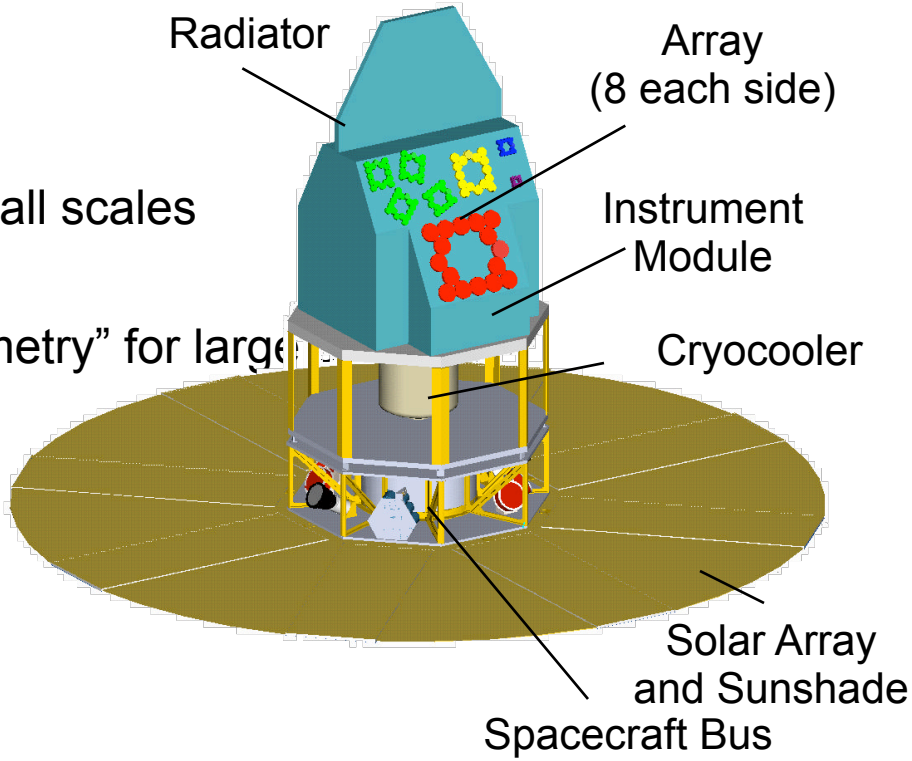


Interference fringes measured in
focal plane by bolometer array

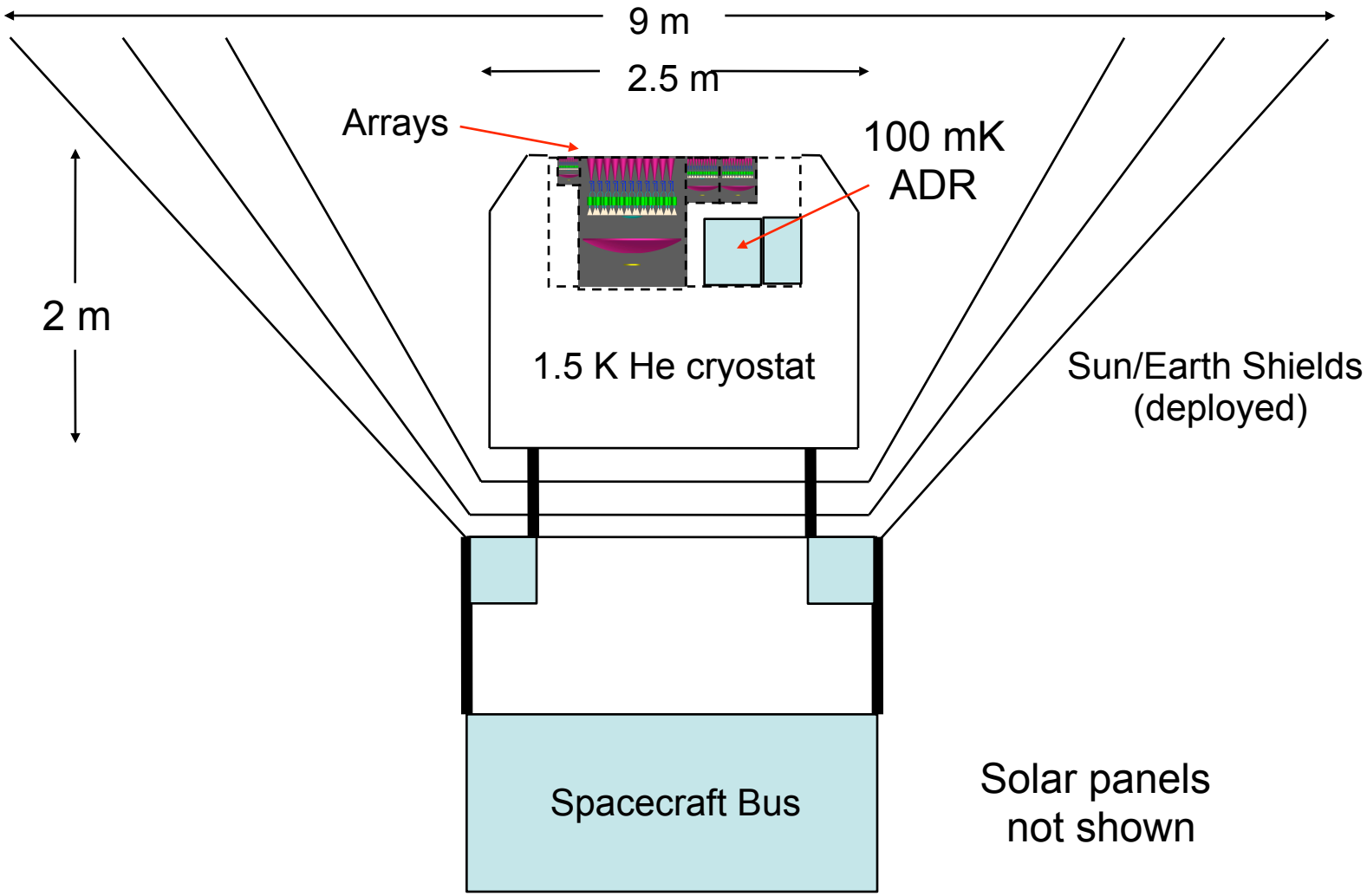
EPIC L2 Mission Concept



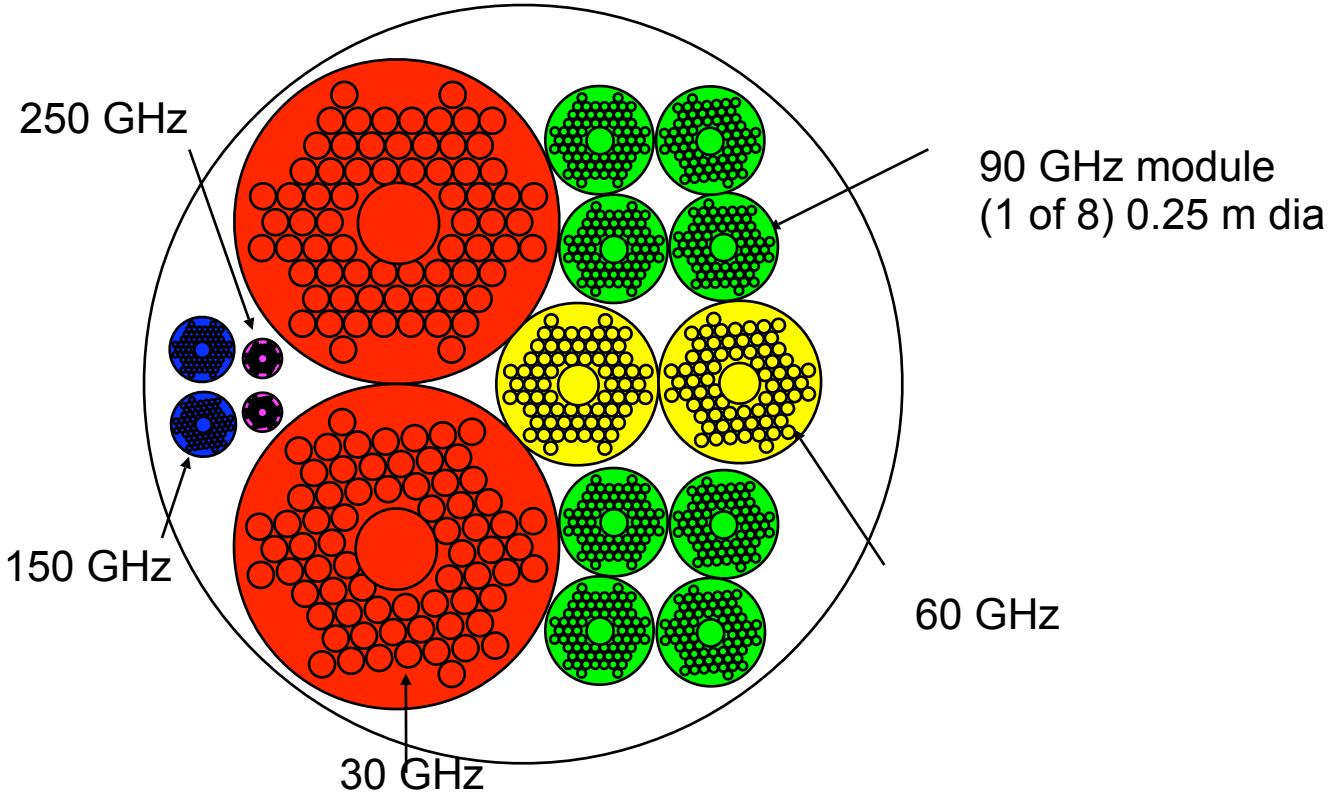
- Measure CMB *E* and *B* mode polarization over full sky to foreground limit (T/S ~ 0.01)
- Scaled close-packed corrugated horn arrays: 30-300 GHz
- ~15° FOV, ~ 1° synthesized beams
- Total # horns *N* ~ 1024 (= # modes)
- Interferometer: signals cross-correlated
  - between horns: *N(N-1)/2* visibilities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

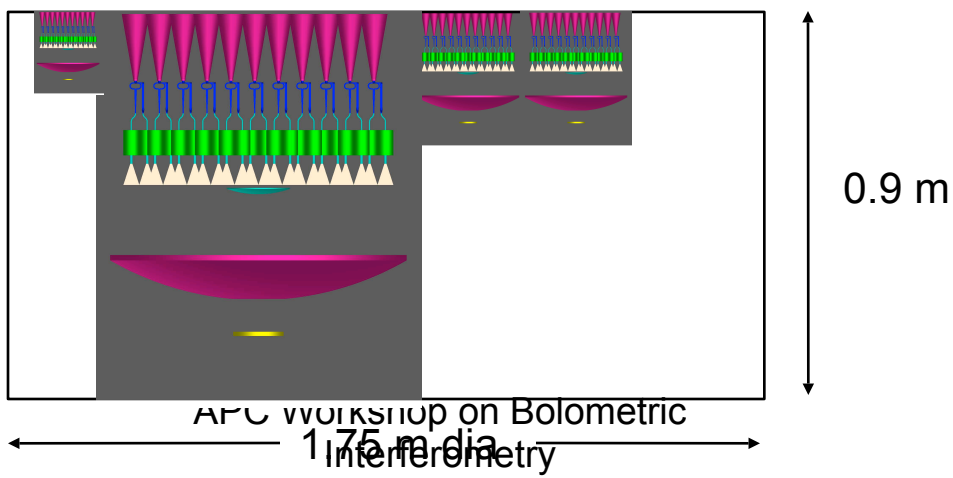


EPIC LEO Mission Concept



EPIC LEO Mission Concept

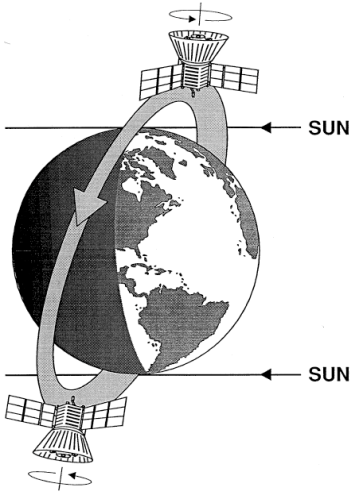


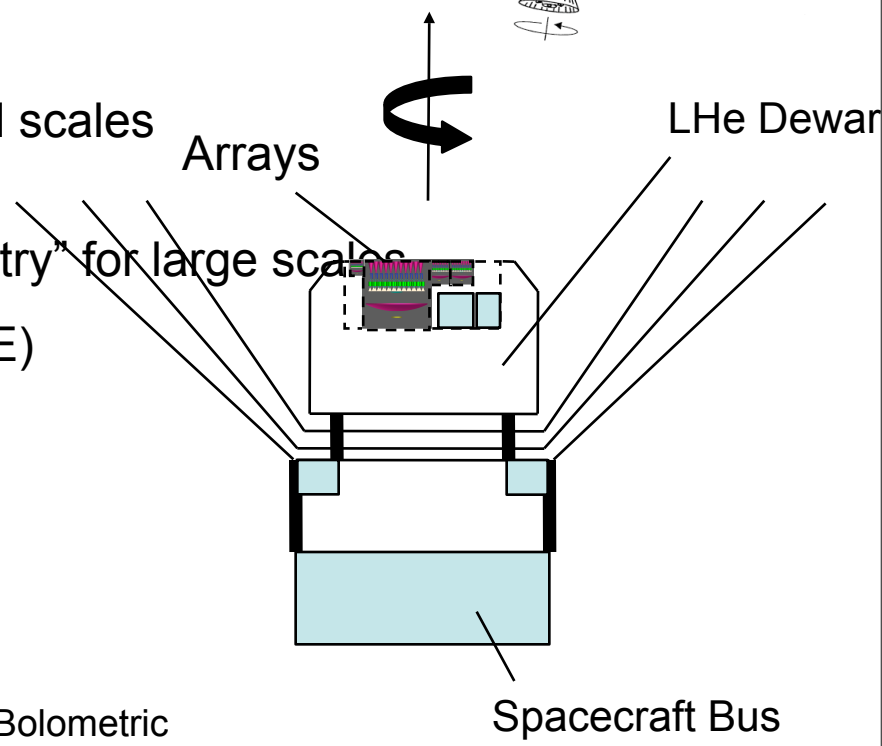


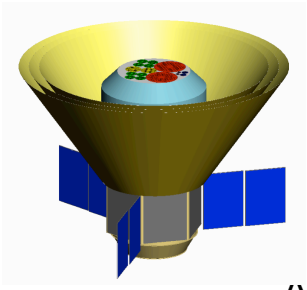
EPIC LEO Mission Concept

- Measure CMB *E* and *B* mode polarization over full sky to foreground limit (T/S ~ 0.01)

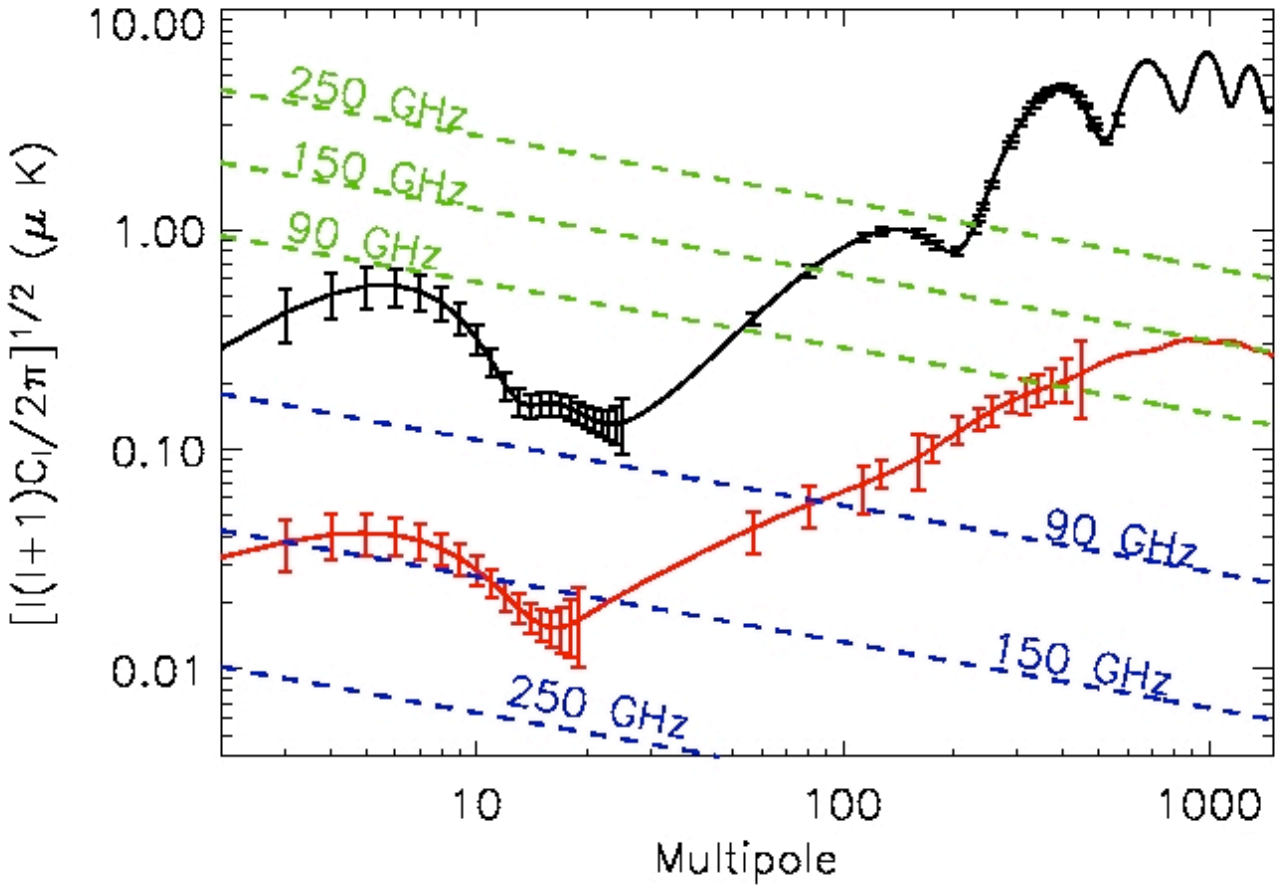
- Scaled close-packed corrugated horn arrays: 30-300 GHz
- ~15° FOV, ~ 1° synthesized beams
- Total # horns *N* ~ 1024 (= # modes) x 2 pol'ns
- Interferometer: signals cross-correlated
  - between horns: *N(N-1)/2* visibilities for small scales
  - between 2 polarizations for each horn: "correlation polarimetry" for large scales
- Lifetime > 1yr from 900 km Earth orbit (COBE)







EPIC sensitivity



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)

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	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	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

Technology Readiness

Technology	TRL	Heritage
Corrugated horn antennas	9	WMAP & COBE
OMT	9 (<100 GHz)	WMAP
Phase modulator	6 (<100 GHz)	BICEP & MBI
Fizeau combiner	5	MBI
Focal Plane Arrays		
NTD Ge bolometers	8	Planck & Herschel
TES bolometers	6	SCUBA, GBT
LHe Cryostat	9	Spitzer, ISO, Herschel, COBE
Sub-K Cooler: Single-shot ADR	9	ASTRO-E2

Sensitivity analysis: recovery of source intensity distribution

218 J. Opt. Soc. Am. A/Vol. 20, No. 2/February 2003 Jonas Zmuidzinas

Cramér–Rao sensitivity limits for astronomical instruments: implications for interferometer design

Jonas Zmuidzinas

Division of Physics, Mathematics, and Astronomy, California Institute Institute of Technology, 320-47 Pasadena, California 91125

Received April 24, 2002; revised manuscript received July 23, 2002; accepted September 25, 2002

Multiple-telescope interferometry for high-angular-resolution astronomical imaging in the optical–IR–far-IR bands is currently a topic of great scientific interest. The fundamentals that govern the sensitivity of direct-detection instruments and interferometers are reviewed, and the rigorous sensitivity limits imposed by the Cramér–Rao theorem are discussed. Numerical calculations of the Cramér–Rao limit are carried out for a simple example, and the results are used to support the argument that interferometers that have more compact instantaneous beam patterns are more sensitive, since they extract more spatial information from each detected photon. This argument favors arrays with a larger number of telescopes, and it favors all-on-one beam-combining methods as compared with pairwise combination. © 2003 Optical Society of America

OCIS codes: 030.4280, 030.5260, 030.5290, 110.4280, 120.6200, 270.5290, 350.1270.