STATUS REPORT OF THE CMB TASK FORCE

Rainer Weiss, MIT
on behalf of the Task Force

HEPAP meeting February 15, 2005
Washington DC
AAAC meeting February 16, 2005
Arlington, Virginia

MEMBERS OF THE CMB TASK FORCE

James Bock	Caltech / JPL
Sarah Church	Stanford University
Mark Devlin	University of Pennsylvania
Gary Hinshaw	NASA / GSFC
Andrew Lange	Caltech
Adrian Lee	University of California at Berkeley / LBNL
Lyman Page	Princeton University
Bruce Partridge	Haverford College
John Ruhl	Case Western Reserve University
Max Tegmark	University of Pennsylvania / MIT
Peter Timbie	University of Wisconsin
Rainer Weiss (chair)	MIT
Bruce Winstein	University of Chicago
Matias Zaldarriaga	Harvard University

AGENCY OBSERVERS

Beverley Berger	National Science Foundation
Vladimir Papitashvili	National Science Foundation
Michael Salamon	NASA/HDQTS
Nigel Sharp	National Science Foundation
Kathy Turner	US Department of Energy

Charter of CMB Task Force

- OSTP response to Turner Panel “From Quarks to Cosmos” sponsored by DOE,NASA and NSF.
- Recommend a program of research of CMB observations to understand the properties of the inflationary epoch of cosmology
- Primary objective to present plan to measure CMB polarization
- HEPAP and AAAC Committees to receive report
- Full report available mid March 2005

THE BASIC QUESTIONS

- How did the universe begin

  Is inflation correct and how can it be tested

- What is the fundamental physics

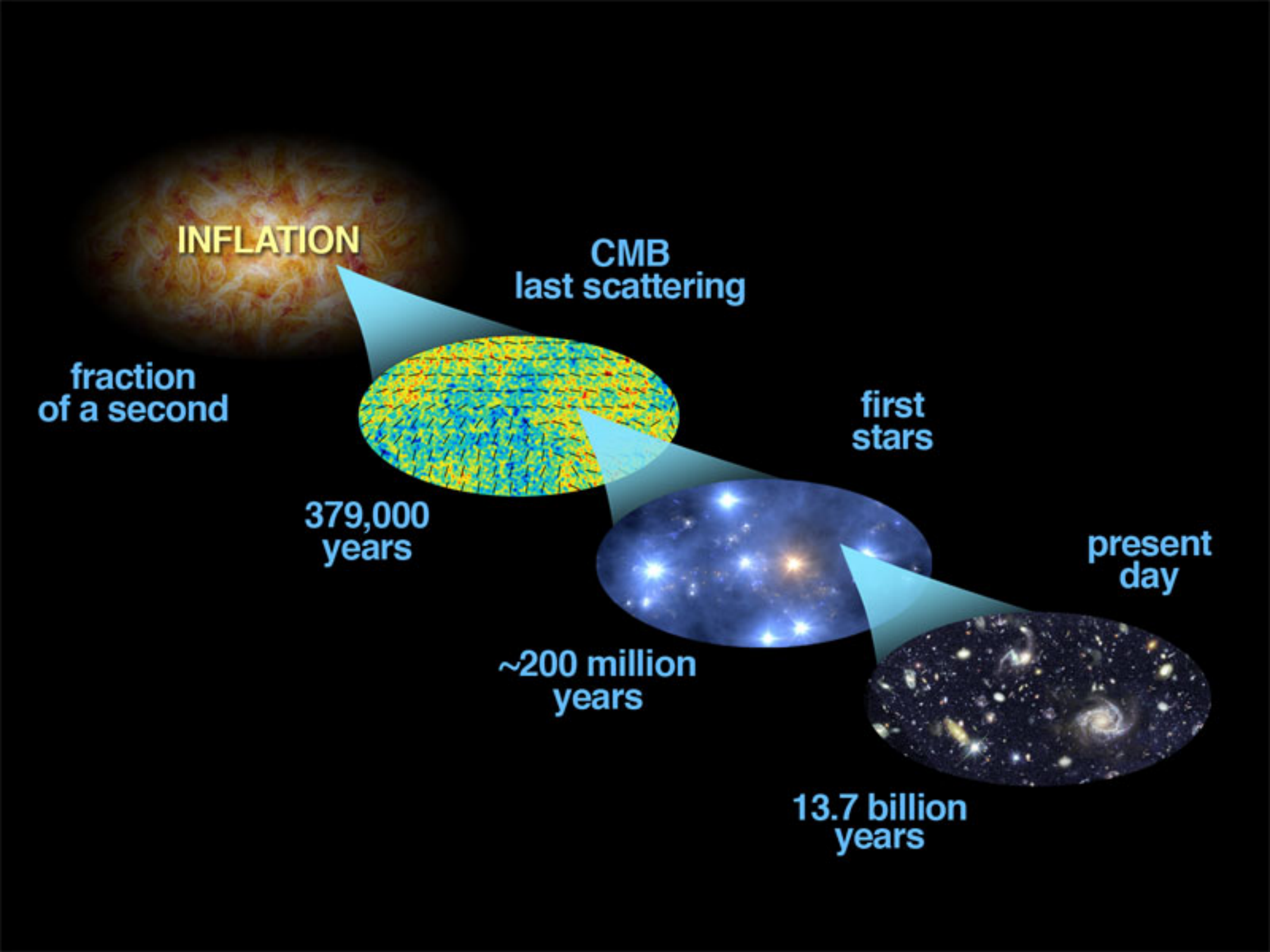
  What is the energy scale and the interaction

  What are the constituents of the primeval universe

- How did the universe evolve

  What is the nature of the dark energy

  What is the geometry of the universe


INFLATION
CMB
last scattering
fraction
of a second
379,000
years
first
stars
~200 million
years
present
day
13.7 billion
years

Properties of "standard “ inflation measurable with the CMB

- Spectrum of spatial temperature fluctuations
  - Intrinsic quantum fluctuations both scalar and tensor
  - Scale invariant spectrum k^n, n = 0.96+/-0.02
- Gaussian probability distribution of fluctuations
- Tensor gravitational waves generated due to acceleration during inflation, related to energy scale of inflation

$$r = \frac{\Delta T_{tensor}}{\Delta T_{scalar}} \leq 0.3$$

  - cause quadrupolar density and temperature fluctuations in the primeval plasmas
  - uniquely measurable in the patterns of the CMB polarization due to Thomson scattering of the CMB by electrons (B modes)

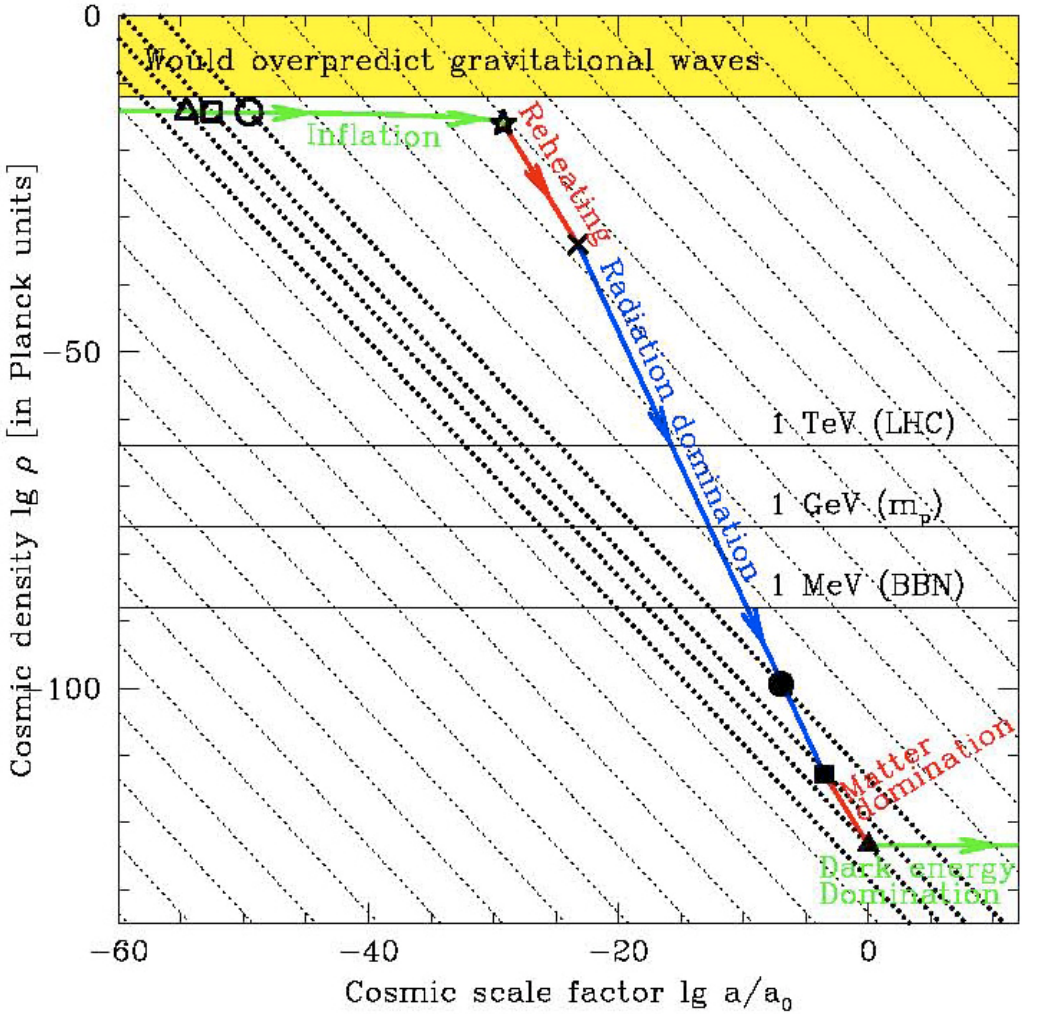
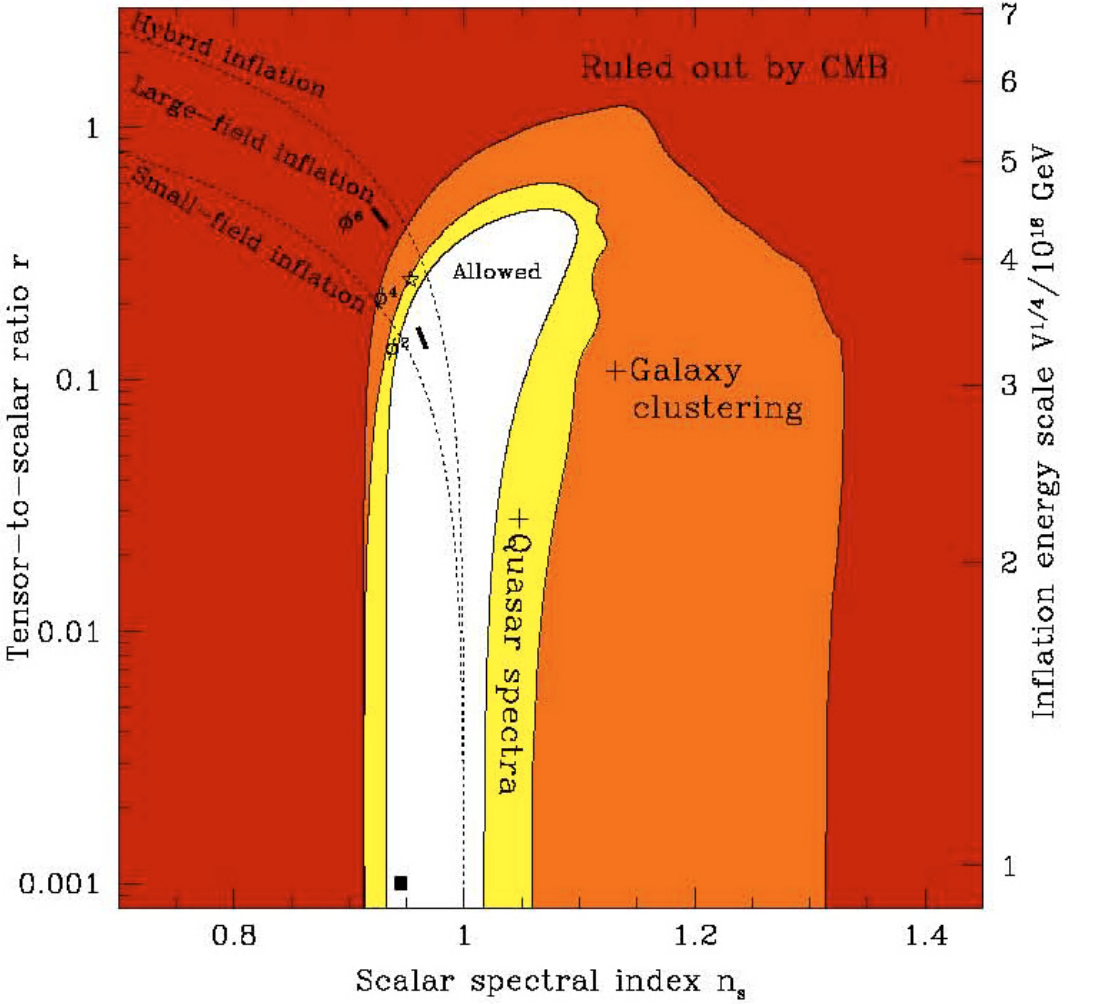
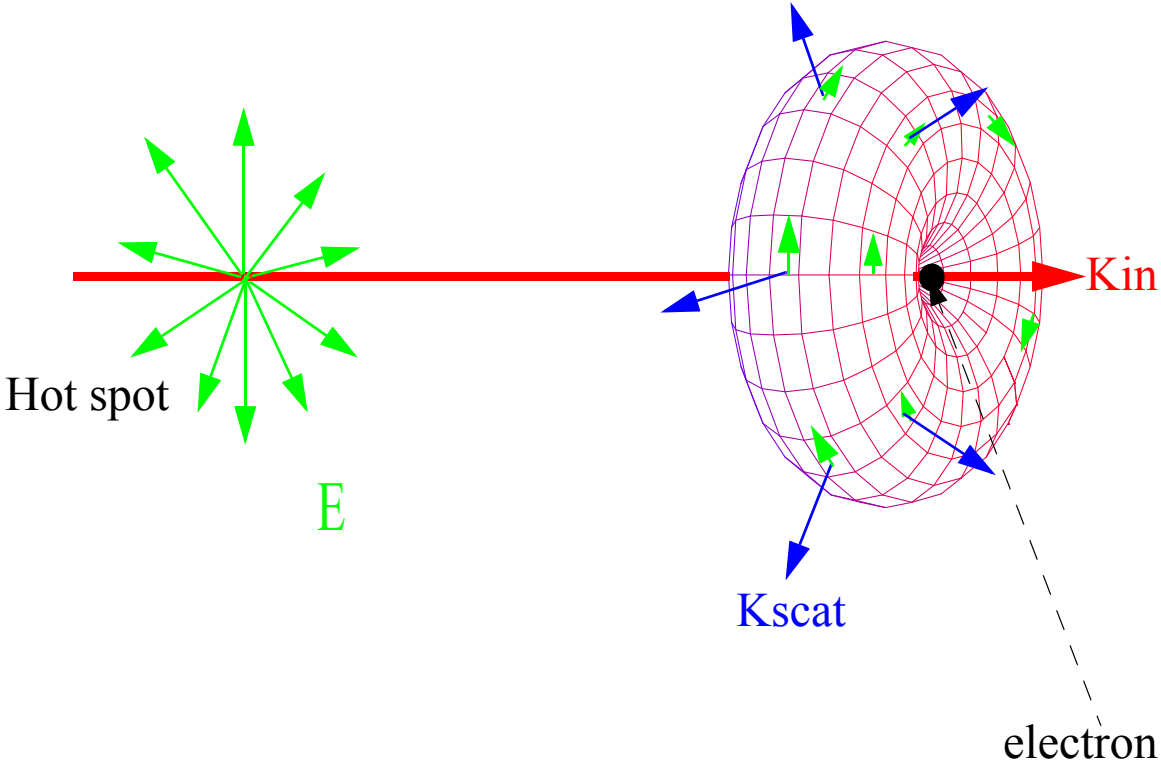


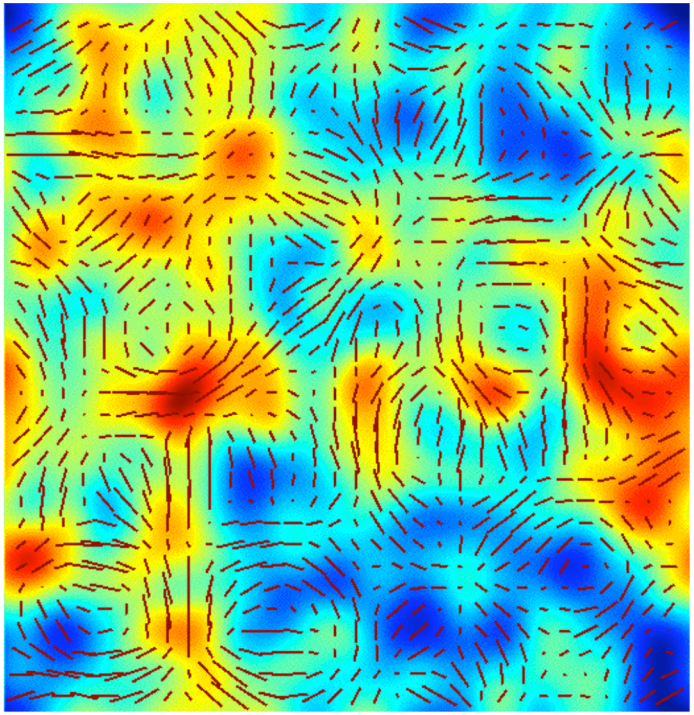
Figure 1: The cosmic mean density (solid curve) is diluted as the Universe expands. Inflation is a period when there is almost no dilution, causing the expansion to accelerate. The result is that the curve decreases slower than the dotted diagonal lines of slope −2. The two triangles lie on the same diagonal, which means that quantum fluctuations generated during inflation at the open triangle have been stretched into the horizon-scale fluctuations that we observe today at the filled triangle in the CMB. Detecting inflationary gravitational waves with CMB polarization would directly measure the shape of this cosmic density curve in the upper left corner of the plot, just as the proposed Joint Dark Energy mission would directly measure the same curve in the lower right corner.

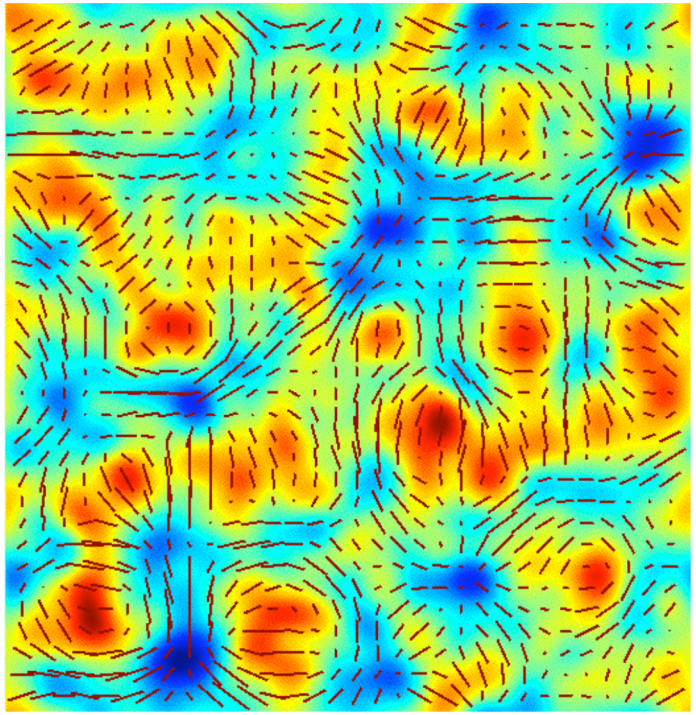
M. Tegmark & M. Zaldarriaga

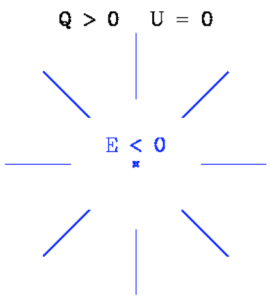


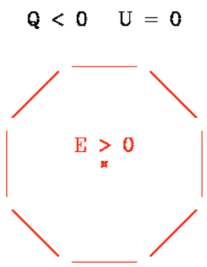

Hot spot
E
Kin
Kscat
electron

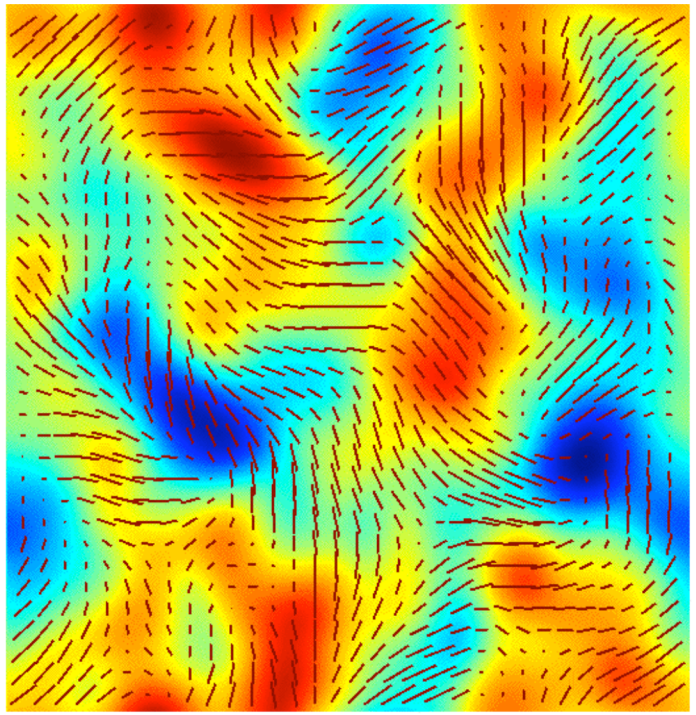
H. Edens

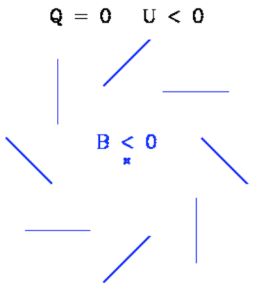


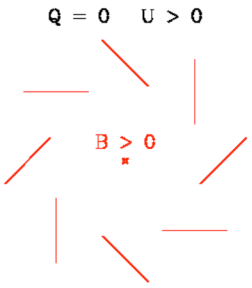




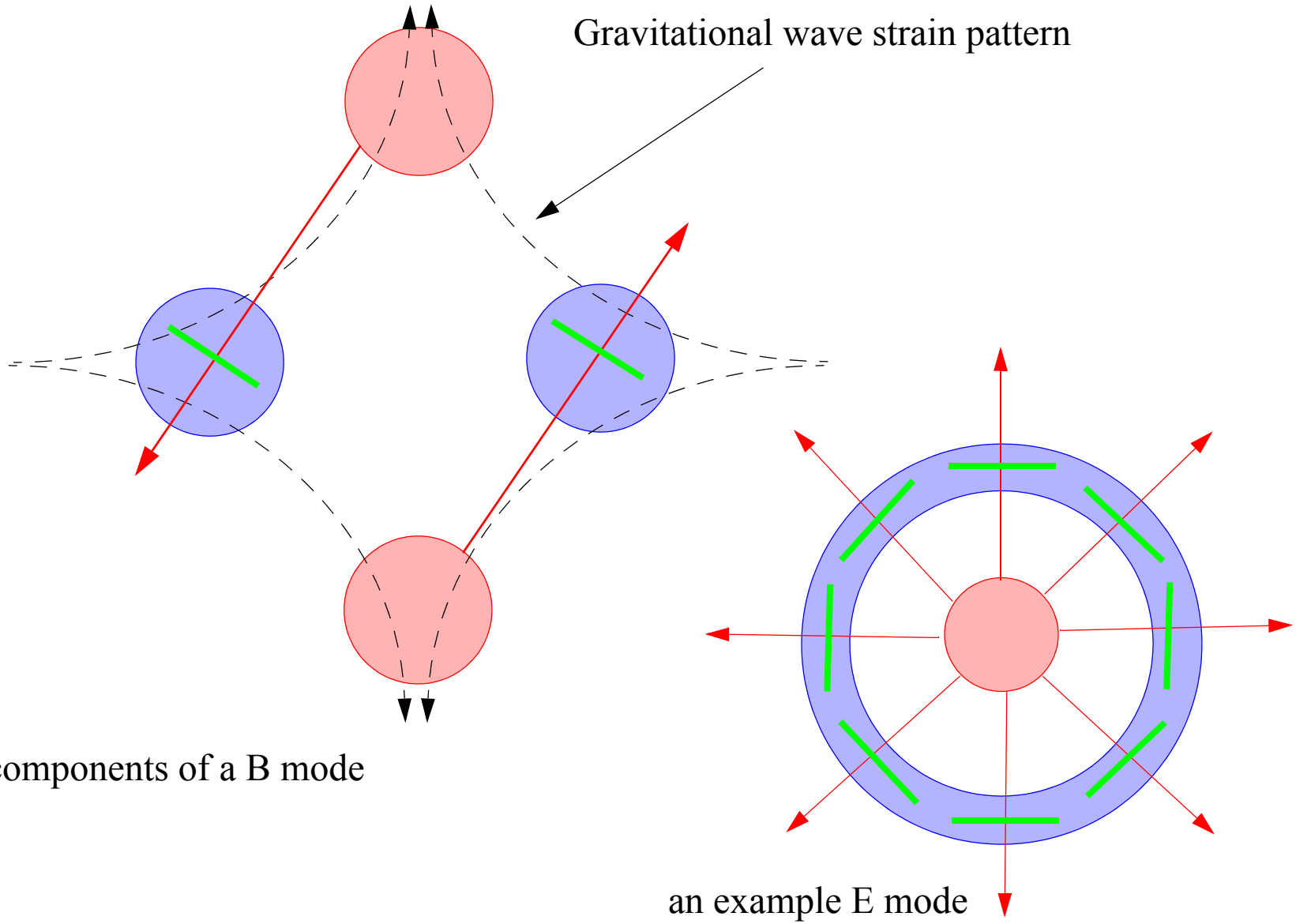


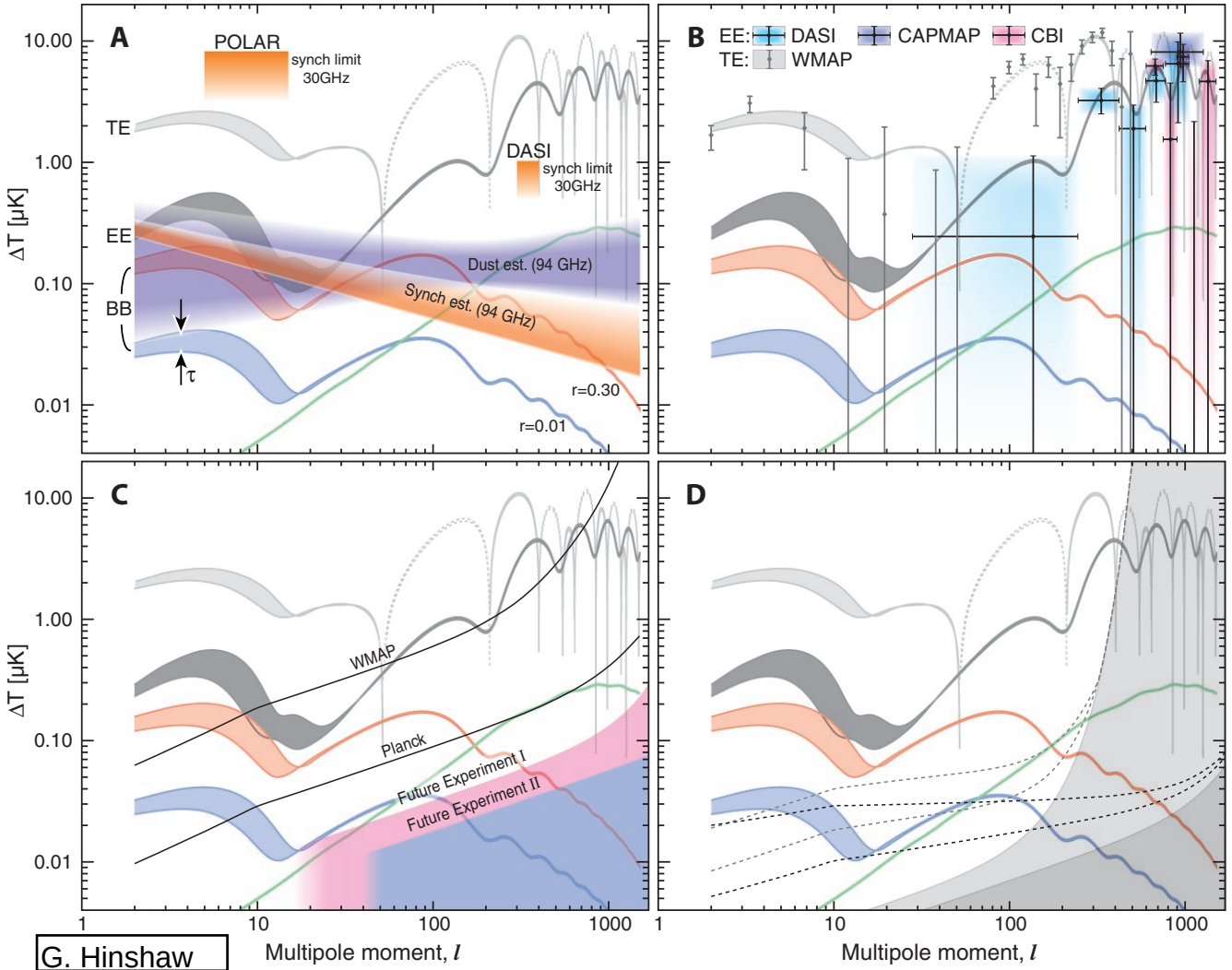






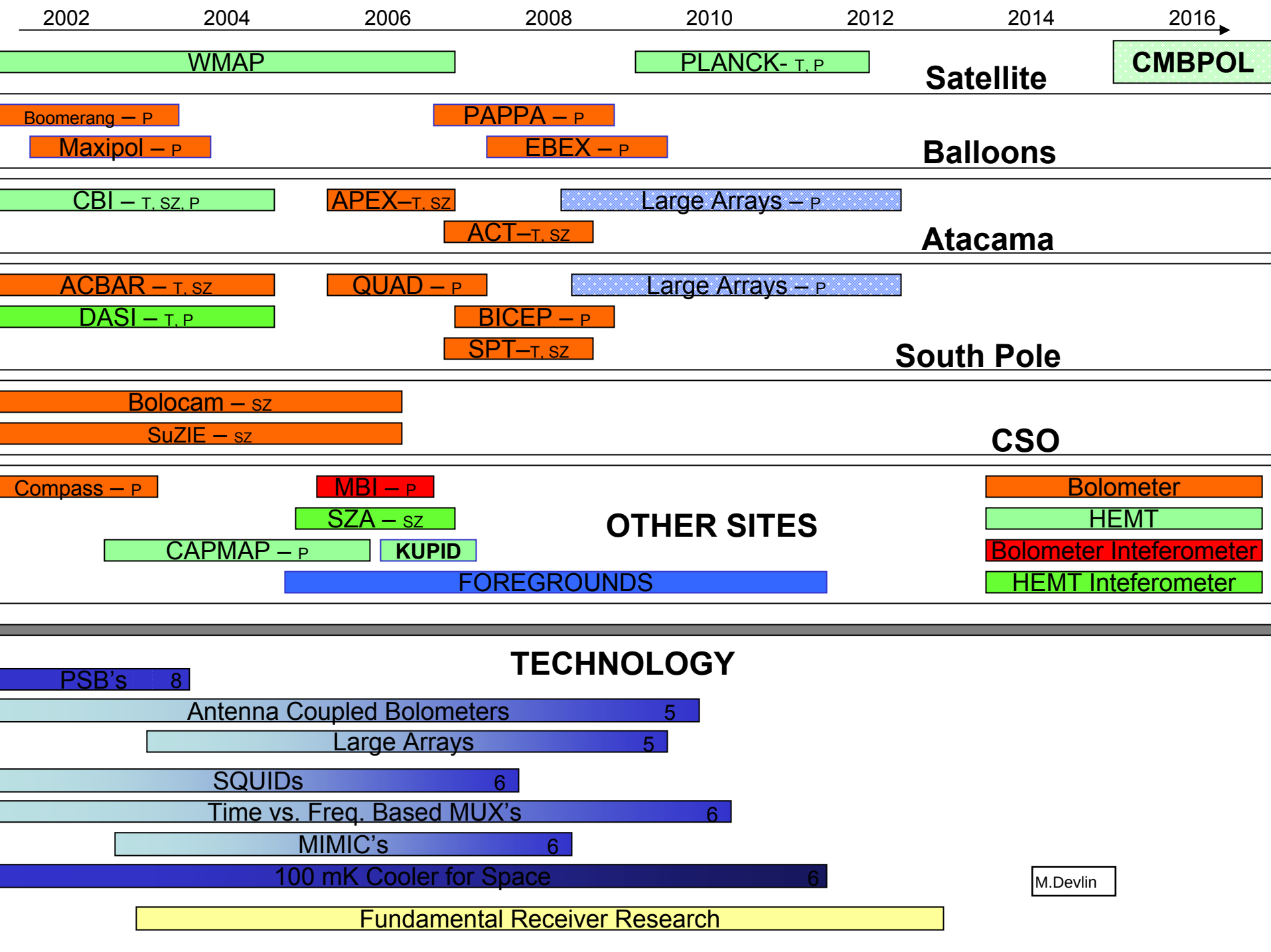
M. Zaldarriaga

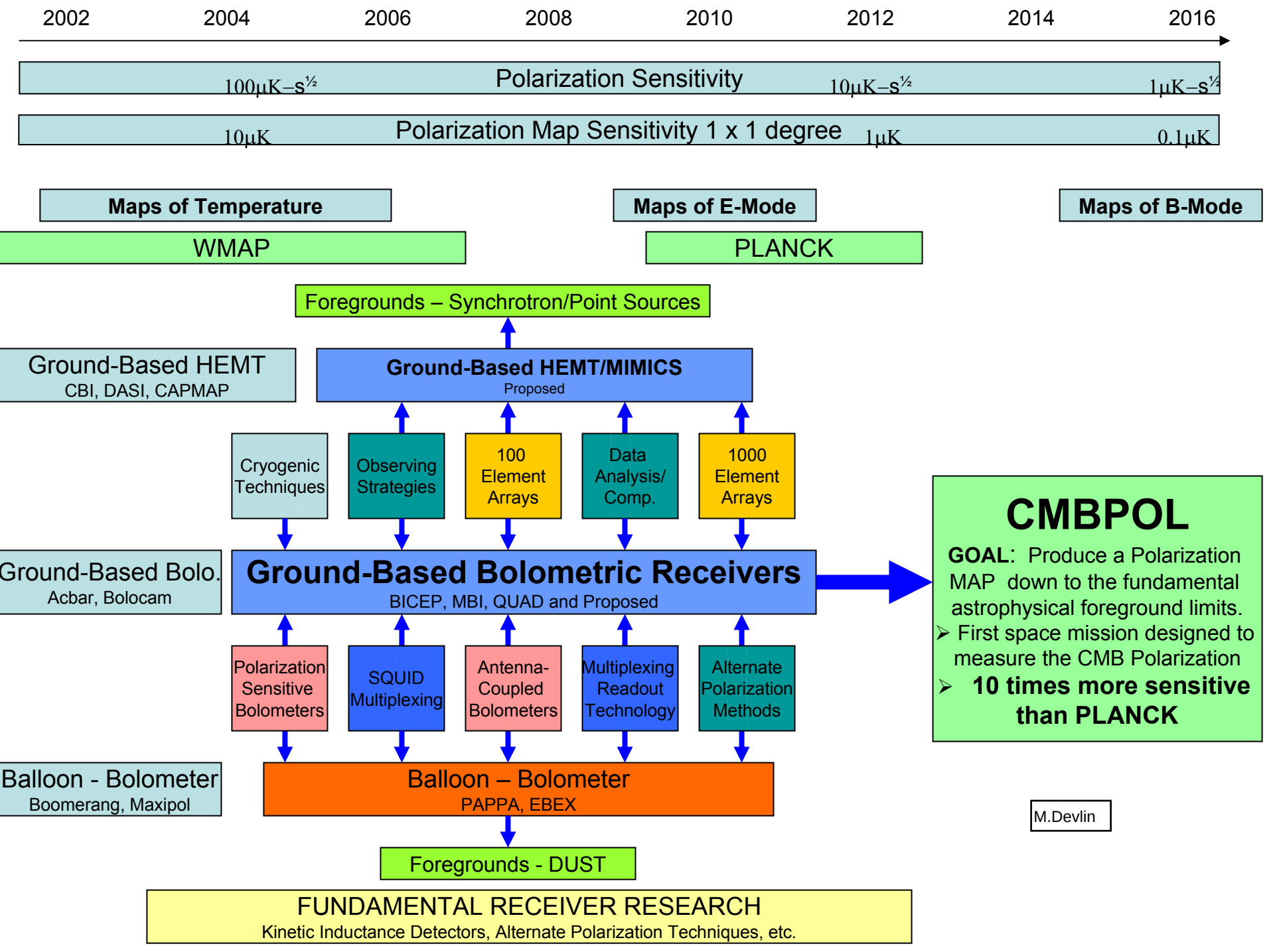

Gravitational wave strain pattern
components of a B mode
an example E mode

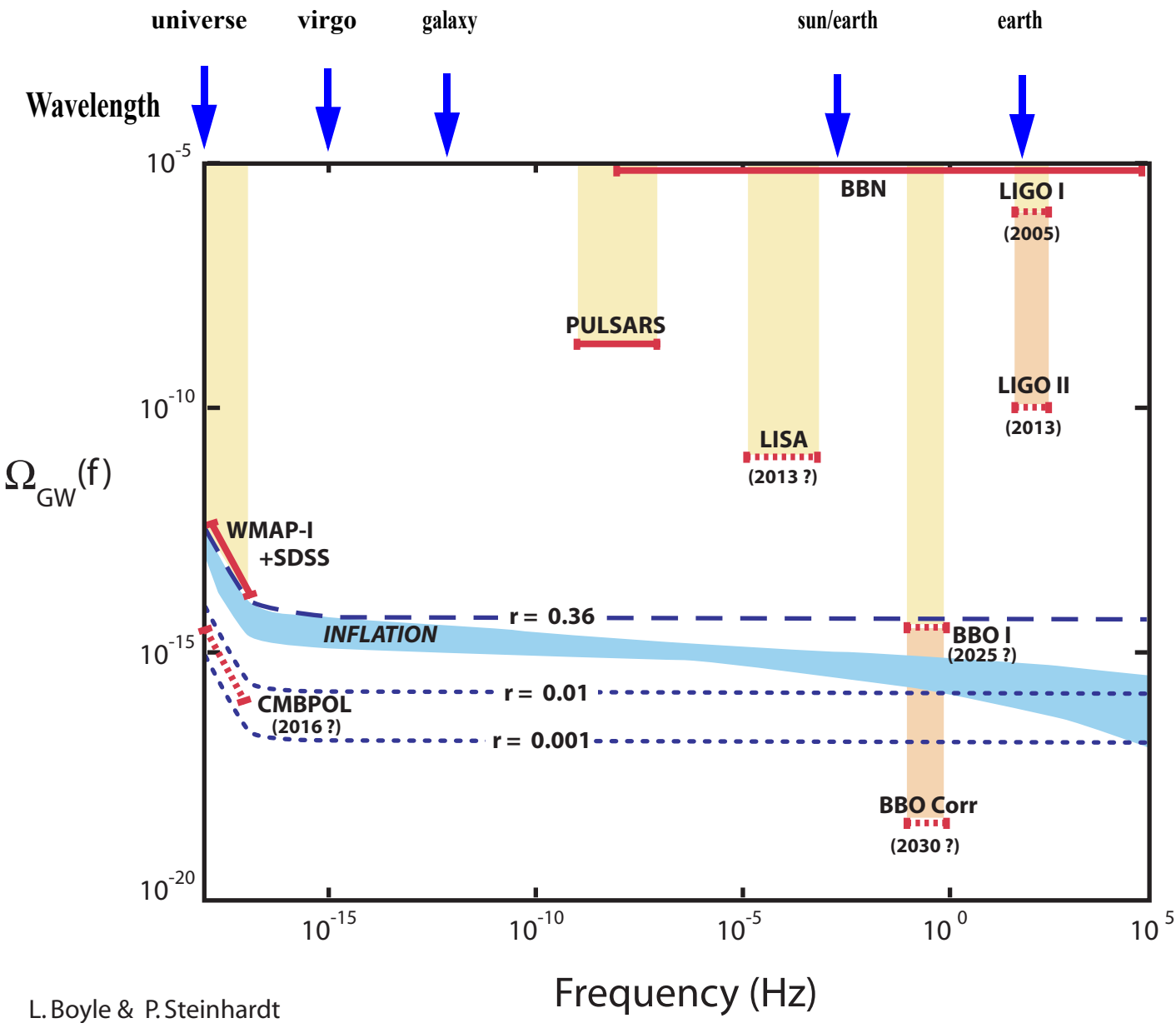

A
POLAR
synch limit
30GHz
TE
DASI
synch limit
30GHz
EE
BB
τ
Dust est. (94 GHz)
Synch est. (94 GHz)
r=0.30
r=0.01
B
EE:
TE:
DASI
WMAP
CAPMAP
CBI
C
WMAP
Planck
Future Experiment I
Future Experiment II
D
ΔT [μK]
10.00
1.00
0.10
0.01
1
10
100
1000
Multipole moment, l
G. Hinshaw

Major components of the program

- Completion of WMAP and successful launch and operation of PLANCK (TE, EE and foregrounds)
- Ground based and balloon borne observations of small angular scale temperature variations (n and SZ effect)
- Ground based and balloon borne program to measure polarization of the CMB and develop techniques and technology for a space mission (CMBPOL) in the next decade designed to measure the B modes to a level limited by the ability to model foregrounds.
  - Program to measure polarized foregrounds
  - Program to develop polarization sensitive receivers incorporating arrays of 1000s of detectors operating at the background limit of the CMB
- Cooperative interagency program of research supported by DOE, NASA, NSF, NIST makes good sense.


2002
2004
2006
2008
2010
2012
2014
2016
WMAP
PLANCK- T, P
CMBPOL
Satellite
Boomerang – P
PAPPA – P
Maxipol – P
EBEX – P
Balloons
CBI – T, SZ, P
APEX–T, SZ
Large Arrays – P
ACT–T, SZ
Atacama
ACBAR – T, SZ
QUAD – P
Large Arrays – P
DASI – T, P
BICEP – P
SPT–T, SZ
South Pole
Bolocam – SZ
SuZIE – SZ
CSO
Compass – P
MBI – P
SZA – SZ
CAPMAP – P
KUPID
FOREGROUNDS
OTHER SITES
Bolometer
HEMT
Bolometer Inteferometer
HEMT Inteferometer
TECHNOLOGY
PSB's 8
Antenna Coupled Bolometers 5
Large Arrays 5
SQUIDs 6
Time vs. Freq. Based MUX's 6
MIMIC's 6
100 mK Cooler for Space 6
M.Devlin
Fundamental Receiver Research


2002
2004
2006
2008
2010
2012
2014
2016
Polarization Sensitivity
100μK–s½
10μK–s½
1μK–s½
Polarization Map Sensitivity 1 x 1 degree
10μK
1μK
0.1μK
Maps of Temperature
Maps of E-Mode
Maps of B-Mode
WMAP
PLANCK
Foregrounds – Synchrotron/Point Sources
Ground-Based HEMT
CBI, DASI, CAPMAP
Ground-Based HEMT/MIMICS
Proposed
Cryogenic Techniques
Observing Strategies
100 Element Arrays
Data Analysis/ Comp.
1000 Element Arrays
Ground-Based Bolo.
Acbar, Bolocam
Ground-Based Bolometric Receivers
BICEP, MBI, QUAD and Proposed
Polarization Sensitive Bolometers
SQUID Multiplexing
Antenna-Coupled Bolometers
Multiplexing Readout Technology
Alternate Polarization Methods
Balloon - Bolometer
Boomerang, Maxipol
Balloon – Bolometer
PAPPA, EBEX
Foregrounds - DUST
FUNDAMENTAL RECEIVER RESEARCH
Kinetic Inductance Detectors, Alternate Polarization Techniques, etc.
CMBPOL
GOAL: Produce a Polarization MAP down to the fundamental astrophysical foreground limits.
First space mission designed to measure the CMB Polarization
10 times more sensitive than PLANCK
M.Devlin



L. Boyle & P. Steinhardt