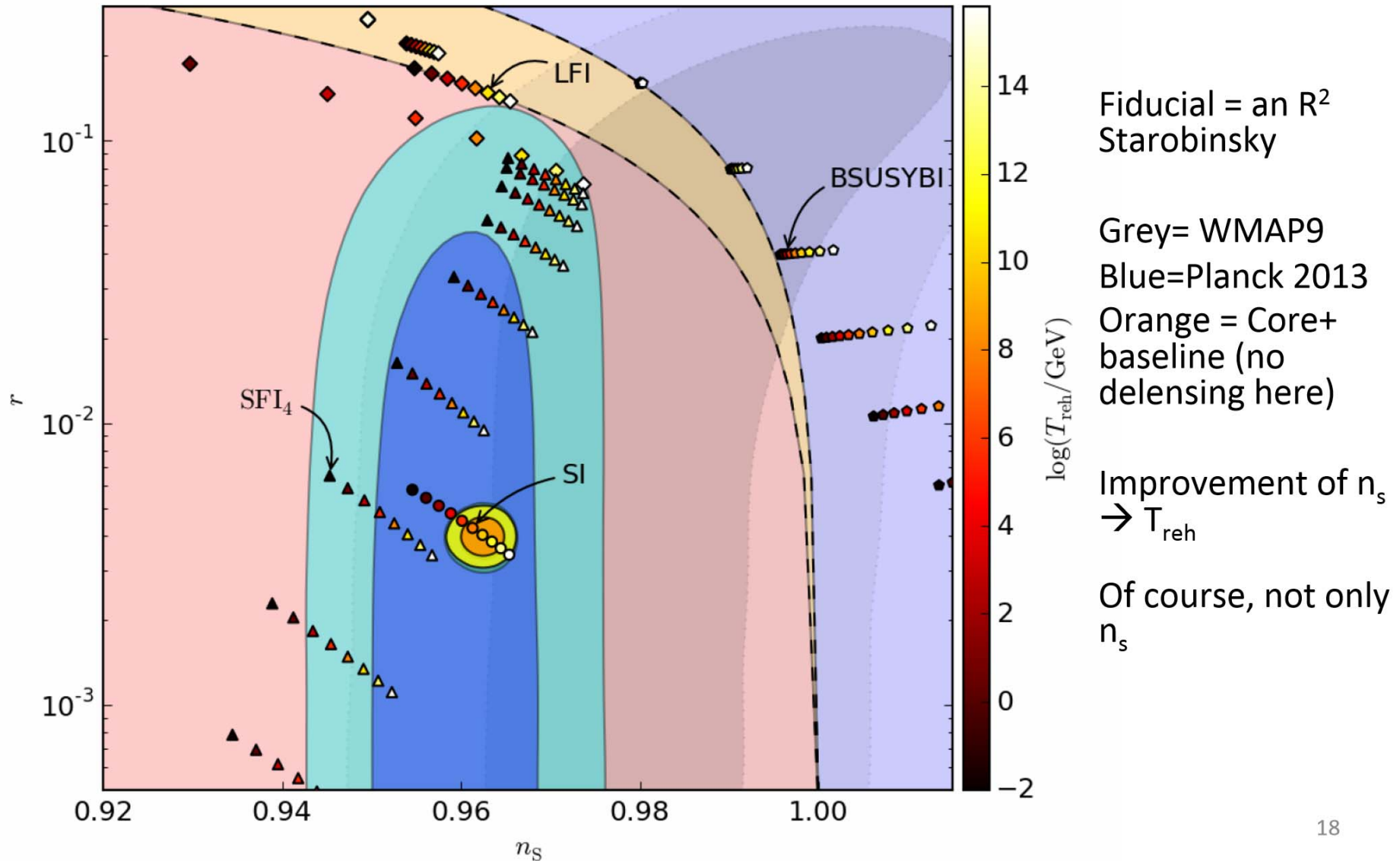


Cosmic Microwave Background Polarization

- B-modes polarization of the CMB:
 - produced by *dark matter* structures (lensing) crossed by CMB photons
 - Produced by the *inflation* process in the very early universe ($E=10^{16}$ GeV ??) and its *tensor* fluctuations.
- Measurement method:
 - Accurate maps of the Stokes parameters of the CMB
 - Exquisite control of systematic effects in polarimeters
 - Wide frequency range for accurate monitoring of locally produced polarization
- Current limits:
 - Ratio tensor/scalar fluctuations : $r < 0.1$ @ 95% C.L. (Planck, Keck, BICEP)
 - For single-field, slow-roll inflation:
$$V^{1/4} = 1.06 \times 10^{16} \text{ GeV} \left(\frac{r}{0.01} \right)^{1/4}$$
 - Not only r , but also n_s , n_T , and possibly the full inflaton potential V .

Inflation model testing



Forthcoming B-modes experiments

- Planck flown, preliminary results published, legacy analysis by 2016. Best limits in synergy with Keck & BICEP
- EBEX balloon flown
- SPIDER balloon flown 1/2 (95 & 145 GHz)
- Keck array, BICEP2 published (95 & 140 GHz, south pole)
- ABS done (145 GHz, Atacama)
- CLASS in preparation (38, 93, 148, 217 GHz, Atacama)
- ACTpol (90 & 146 GHz, Atacama) taking data
- PolarBEAR publishing and taking data (95 & 150 GHz, Atacama)
- SPTpol publishing and taking data
- Plan-B balloon with KIDs under discussion in France
- LSPE being prepared (140, 220, 240 GHz, arctic balloon flight)
- QUBIC being prepared (140 & 220 GHz, Dome-C)
- Stage 4 at the horizon
- LiteBIRD satellite in phase A
- M5 – ESA call for medium mission coming in spring 2016 (CORe++)

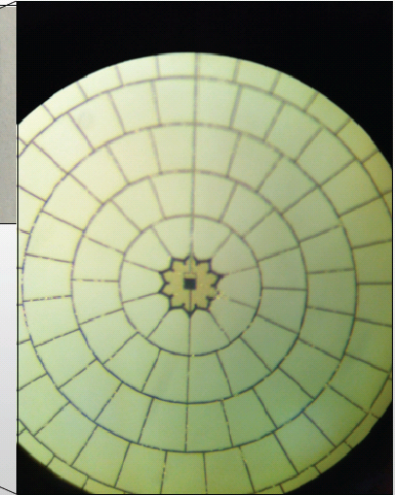
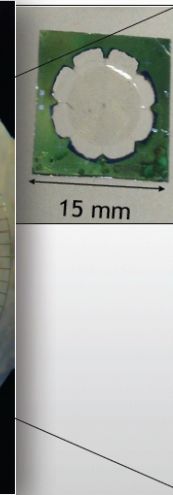
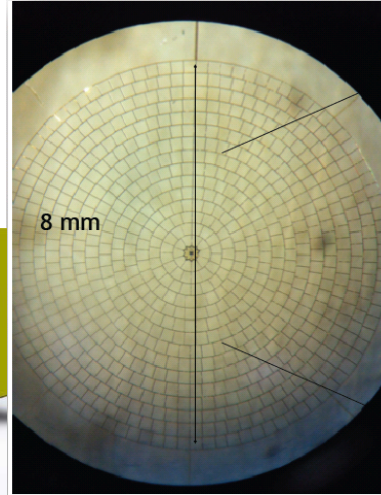
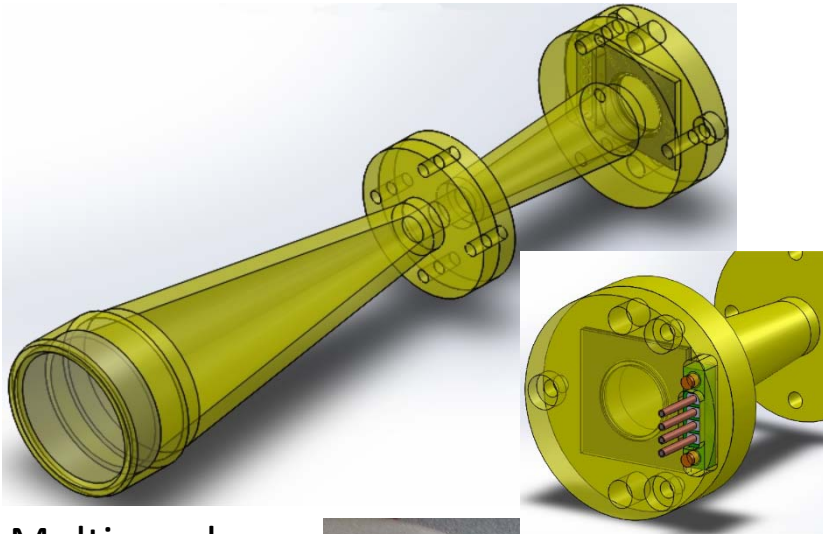
Many!

Many!

LSPE in a nutshell

- The Large-Scale Polarization Explorer is :
 - an instrument to measure the polarization of the Cosmic Microwave Background at large angular scales
 - using *a spinning stratospheric balloon payload* to avoid atmospheric noise
 - flying *long-duration, in the polar night*
 - using a *polarization modulator* to achieve high stability
- Frequency coverage: 40 – 250 GHz (5 channels, 2 instruments: **STRIP** & **SWIPE**)
- Angular resolution: 1.3° FWHM
- Sky coverage: 20-25% of the sky per flight
- Combined sensitivity: $10 \mu\text{K arcmin}$ per flight
- Current collaboration: Sapienza, UNIMI, UNIMIB, IASFBO-INAF, IFAC-CNR, Uni.Cardiff, Uni.Manchester. INFN-GE, INFN-PI, INFN-RM1, INFN-RM2, INFN-FE
- See [astro-ph/1208.0298](#), [1208.0281](#), [1208.0164](#) and forthcoming updates

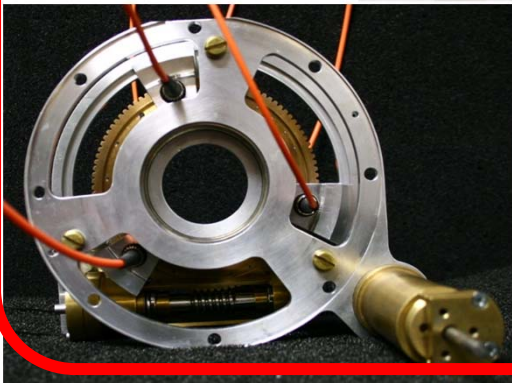
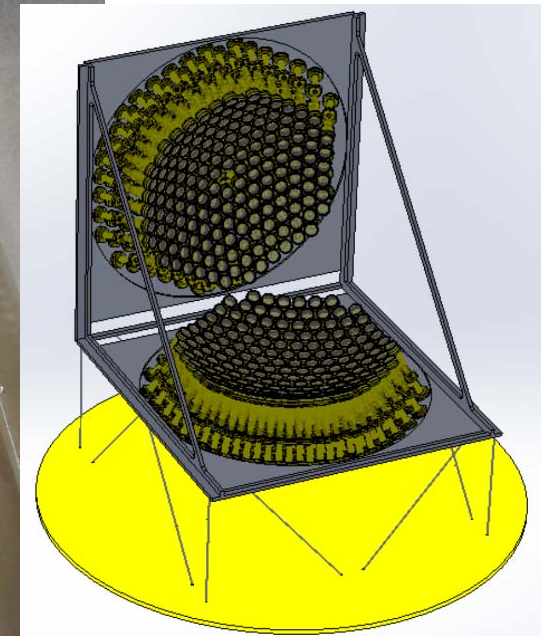
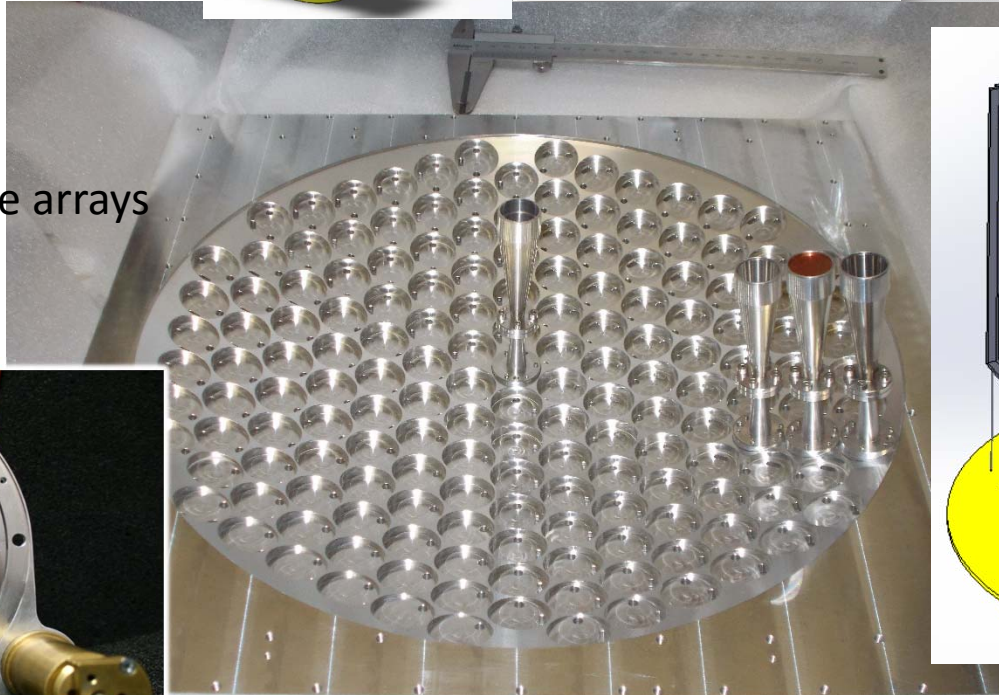
LSPE: enabling technologies



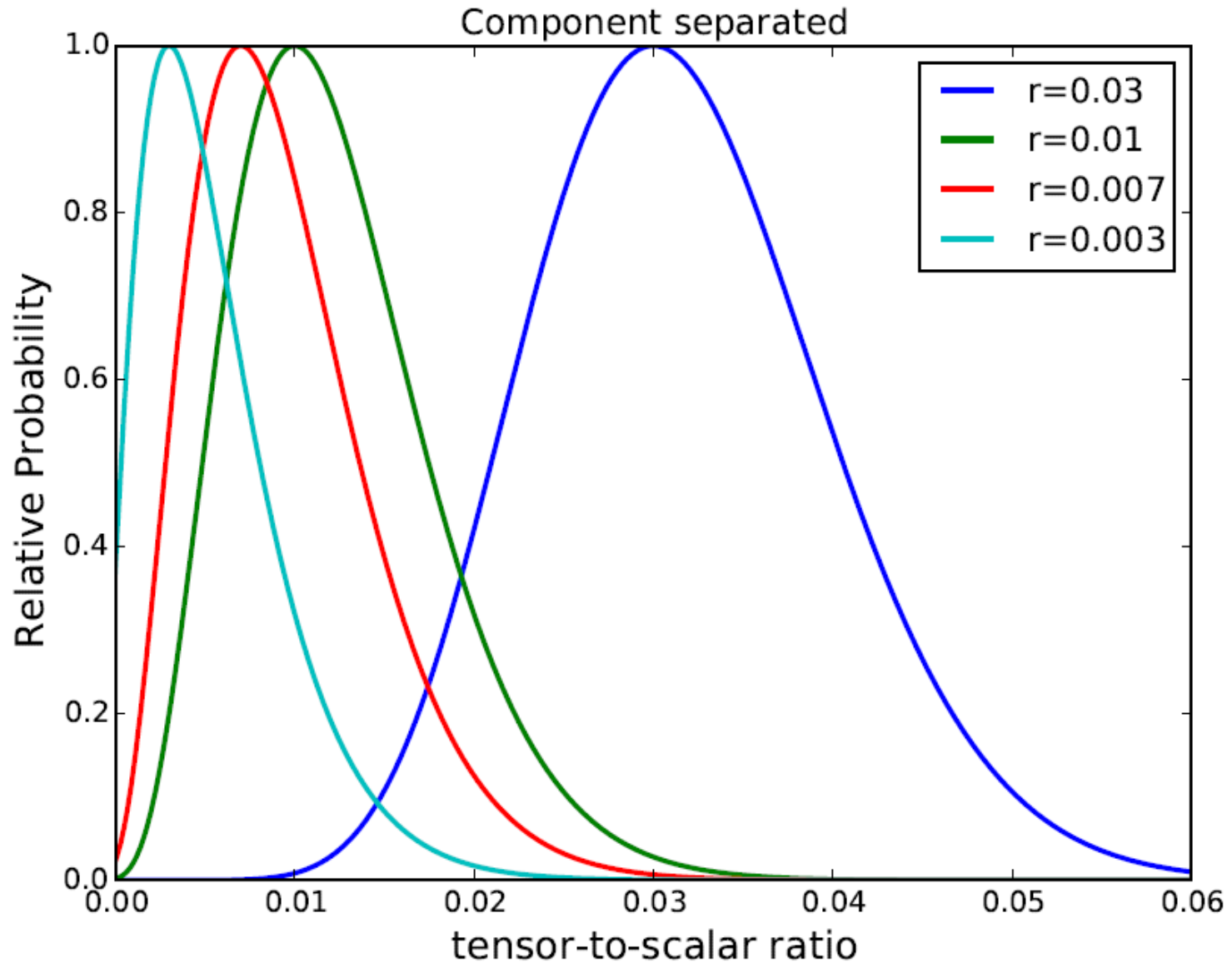
Multi-mode
TES detectors

Large focal plane arrays

Rotating HWP



SWIPE Performance Forecast (1st flight)



Not just inflationary B-modes

- A very active community is interested to Cosmic Polarization Rotation
- The orientation of polarization appears to be the most stable property of photons.
- However, changes in the polarization angle of photons traveling over cosmological distances are foreseen, for example, if fundamental physical principles, such as the Einstein Equivalence Principle, are violated, or if there is a Faraday rotation.
- A very difficult measurement. Usually based on non-zero $\langle TB \rangle$ & $\langle EB \rangle$

See presentations/papers at <http://www.arcetri.astro.it/cpr/>



**Cosmic Polarization Rotation
from Galilean Principles to
Cosmology**

International Workshop
September, 7-8 2015
Villa il Gioiello - Firenze - ITALY

... and the spectrum of the CMB !

- COBE-FIRAS demonstrated that the spectrum of the CMB is a high accuracy blackbody.
- However, several processes lead to inevitable distortions ! New trend (PIXIE et al.): ultra-high precision measurements of the spectrum
- Comptonization & free-free distortion associated with reionization / structure formation & hot galaxy clusters
- Dissipation of acoustic modes at small scales:
 - complementary probe of inflation over additional ~ 10 e-folds!
 - signal for standard power spectrum
- Hydrogen and Helium recombination lines from $z \simeq 1000$
 - HI Balmer & Paschen- α lines
 - additional anisotropic signals
- Resonant scattering signals of “metals” during the dark ages