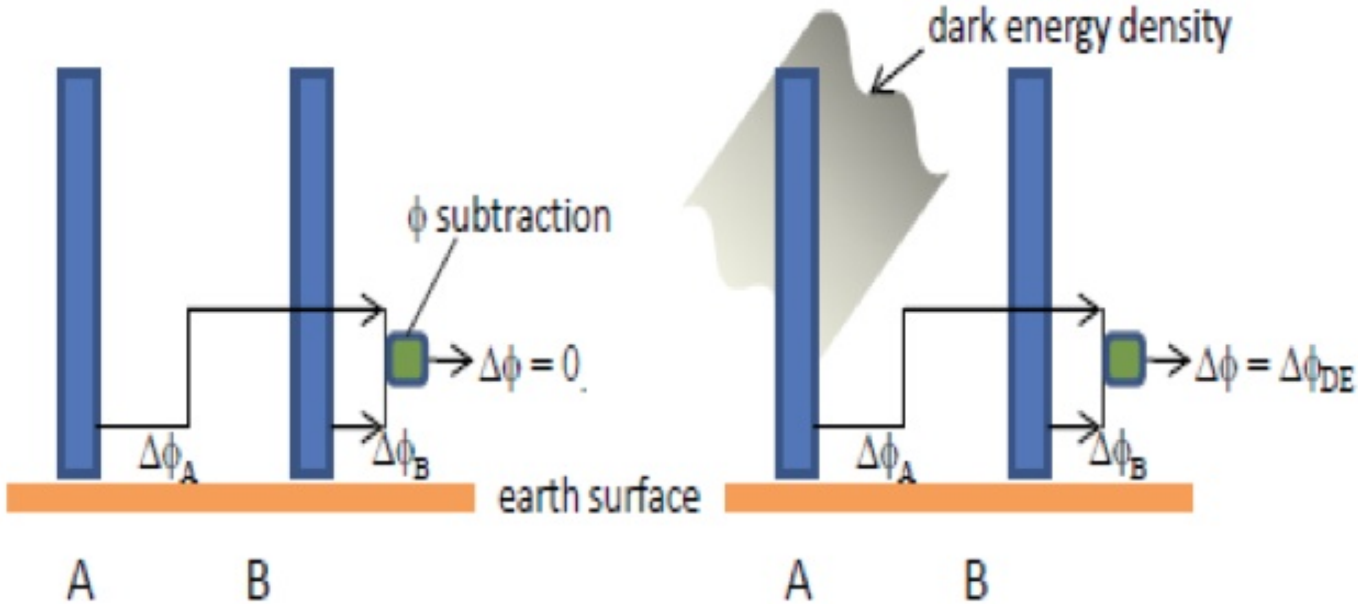
THE DARK ENERGY ATOM-INTERFEROMETER EXPERIMENT



Martin Perl
Kavli Institute For Particle Astrophysics And Cosmology
SLAC Linear Accelerator Laboratory
Stanford University

Presented by Josh Francis, 28 Oct 2011

THE DARK ENERGY ATOM-INTERFEROMETER EXPERIMENT

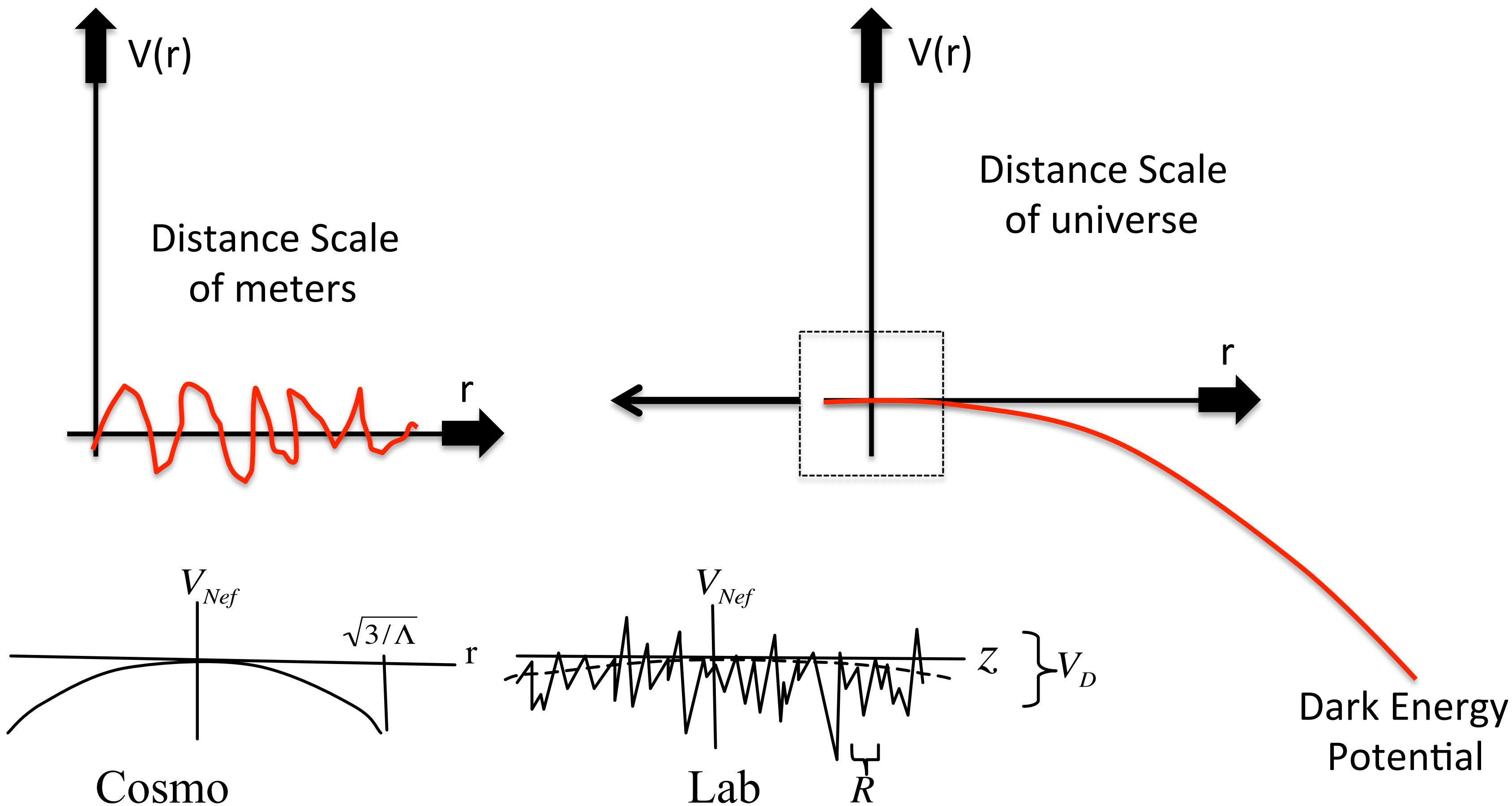
Ronald Adler
Physics Department, Stanford University
SLAC Linear Accelerator Laboratory
Gregory Bernard
SLAC Linear Accelerator Laboratory
Ryan Coffee
SLAC Linear Accelerator Laboratory
Jonathan Coleman
Physics Department, University of Liverpool
Joshua Francis
Physics Department, Stanford University
Eric Lee
Physics Department, University of New Mexico
Dinesh Loomba
Physics Department, University of New Mexico
Ziba Mahdavi, Administrator
Kavli Institute for Particle Astrophysics and Cosmology
Martin Perl
Kavli Institute for Particle Astrophysics and Cosmology
SLAC Linear Accelerator Laboratory
Dennis Ugolini
Physics Department, Trinity University

The assumptions about dark energy underlying our experiment:

1. Dark energy exerts a small, but not zero, force on matter; not the direct gravitational force on energy.

2. The distribution of dark energy density is not uniform

Theory with Caveats:



Maybe more accurate to say we are looking for any gravitating background energy density and not necessarily "Dark Energy"

Light-pulse atom interferometry
Department of Physics, Stanford University, Stanford, California 94305
arXiv:0806.3261v1[physics.atom-ph]

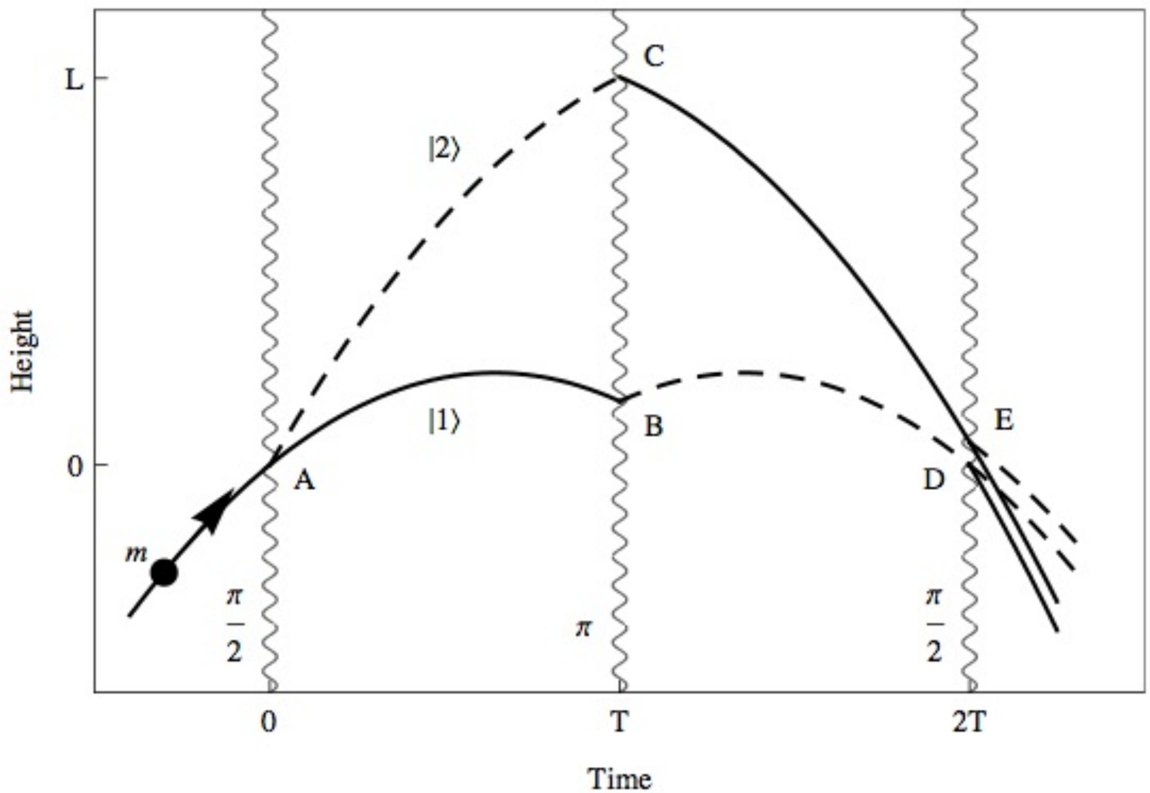


Fig. 10. – Space–time diagram for a single atom of mass m during the interferometer pulse sequence. The atom is launched with velocity v_z from the bottom of the vacuum system. At time $t = 0$, a $\frac{\pi}{2}$ (beamsplitter) pulse is applied to coherently divide the atom wavefunction. After a time T, a π (mirror) pulse is applied that reverses the relative velocity between the wavefunction components. A final $\frac{\pi}{2}$ (beamsplitter) pulse at time $2T$ results in interference between the two space–time paths. The interferometer phase shift is inferred by measuring the probability of detecting the atom in either state $|1\rangle$ (solid line) or state $|2\rangle$ (dashed line). Note that points D and E are in general spatially separated in the presence of non-uniform forces, leading to a separation phase shift.

Error Model

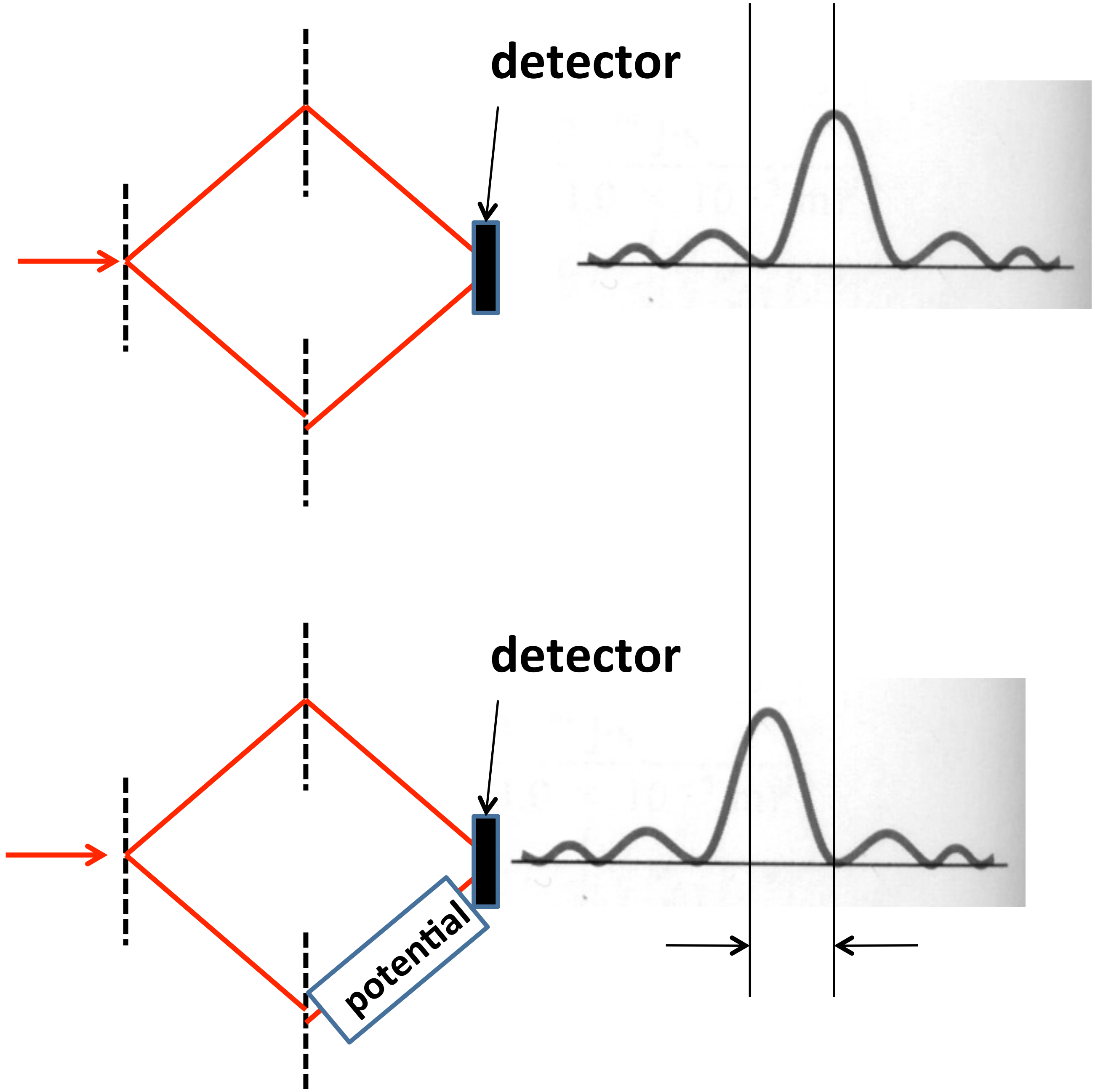
Use standard methods to analyze spurious phase shifts from uncontrolled:

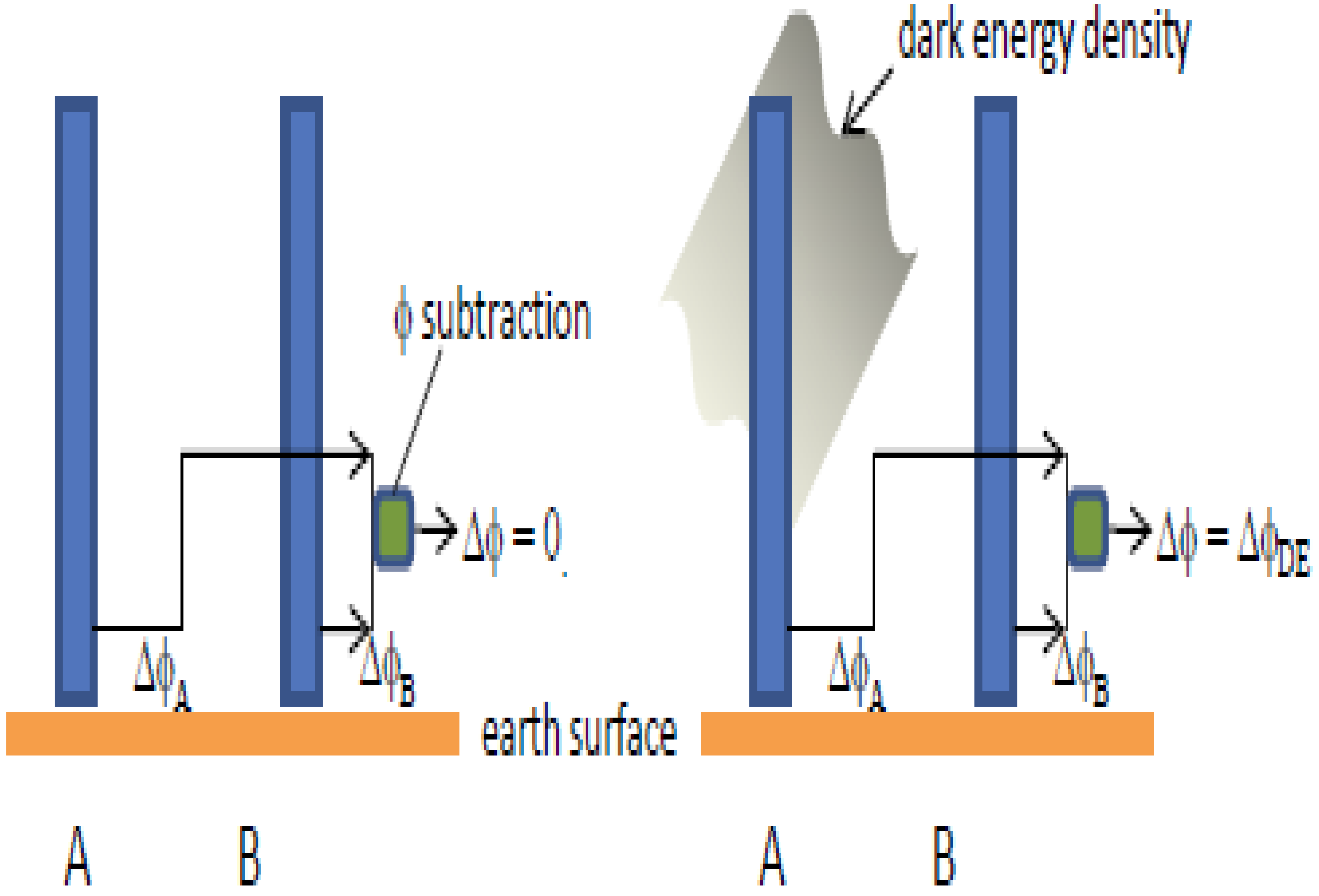
- Rotations
- Gravity anomalies/gradients
- Magnetic fields
- Proof-mass overlap
- Misalignments
- Finite pulse effects

Known systematic effects appear controllable at the $\delta g \sim 10^{-16}$ level.

[$\delta G/G \sim 10^{-5}$ is feasible (limited by test mass)]

$-k_{eff}\, g\, T^2$	-2.84724×10^{8}	1.
$k_{eff}\, R_E\, \Omega_y^2\, T^2$	6.21045×10^{5}	2.18122×10^{-3}
$k_{eff}\, T_{zz}\, V_L\, T^3$	1.57836×10^{3}	5.54347×10^{-6}
$-\frac{7}{12}\, k_{eff}\, T_{zz}\, g\, T^4$	-9.20709×10^{2}	3.23369×10^{-6}
$2\, k_{eff}\, v_{x0}\, \Omega_y\, T^2$	1.97884×10^{1}	6.95002×10^{-8}
$-3\, k_{eff}\, V_L\, \Omega_y^2\, T^3$	-5.16411	1.81373×10^{-8}
$\frac{7}{4}\, k_{eff}\, \Omega_y^2\, g\, T^4$	3.0124	1.05801×10^{-8}
$\frac{7}{12}\, k_{eff}\, R_E\, T_{zz}\, \Omega_y^2\, T^4$	2.00827	7.05338×10^{-9}
$\frac{k_{eff}^2\, T_{zz}\, \hbar\, T^3}{2m}$	7.05401×10^{-1}	2.47749×10^{-9}
$k_{eff}\, T_{zz}\, v_{x0}\, T^3$	7.05401×10^{-1}	2.47749×10^{-9}
$k_{eff}\, T_{zz}\, T^2\, z_0$	8.92817×10^{-2}	3.13573×10^{-10}
$-\frac{7}{4}\, k_{eff}\, R_E\, \Omega_y^4\, T^4$	-6.57069×10^{-3}	2.30774×10^{-11}
$-\frac{7}{4}\, k_{eff}\, R_E\, \Omega_y^2\, \Omega_x^2\, T^4$	-3.84744×10^{-3}	1.35129×10^{-11}
$-\frac{3 k_{eff}^2\, \Omega_y^2\, \hbar\, T^3}{2m}$	-2.30795×10^{-3}	8.10592×10^{-12}
$-3\, k_{eff}\, v_{x0}\, \Omega_y^2\, T^3$	-2.30795×10^{-3}	8.10592×10^{-12}
$\frac{1}{4}\, k_{eff}\, T_{zz}^2\, V_L\, T^5$	2.18739×10^{-3}	7.68251×10^{-12}
$3\, k_{eff}\, v_{y0}\, \Omega_y\, \Omega_x\, T^3$	1.76607×10^{-3}	6.20273×10^{-12}
$-\frac{31}{360}\, k_{eff}\, T_{zz}^2\, g\, T^6$	-7.53436×10^{-4}	2.6462×10^{-12}
$4\, B_0\, V_L\, T^2\, \alpha\, b_{z1}$	5.14655×10^{-4}	1.80756×10^{-12}
$-4\, B_0\, g\, T^3\, \alpha\, b_{z1}$	-5.14655×10^{-4}	1.80756×10^{-12}
$k_{eff}\, \Omega_y^2\, T^2\, z_0$	9.73714×10^{-5}	3.41985×10^{-13}
$-k_{eff}\, \Omega_y\, \Omega_x\, T^2\, y_0$	-7.45096×10^{-5}	2.61691×10^{-13}
$\frac{7}{4}\, k_{eff}\, T_{zz}\, v_{x0}\, \Omega_y\, T^4$	6.39894×10^{-5}	2.24742×10^{-13}
$-7\, V_L\, g\, T^4\, \alpha\, b_{z1}^2$	-4.7766×10^{-5}	1.67762×10^{-13}
$\frac{7}{4}\, k_{eff}\, T_{zz}\, v_{x0}\, \Omega_y\, T^4$	-3.19947×10^{-5}	1.12371×10^{-13}
$4\, V_L^2\, T^3\, \alpha\, b_{z1}^2$	2.72948×10^{-5}	9.58642×10^{-14}
$3\, g^2\, T^5\, \alpha\, b_{z1}^2$	2.04711×10^{-5}	7.18982×10^{-14}
...	.	..


detector
detector
potential


dark energy density
φ subtraction
Δφ = 0
Δφ = Δφ_DE
Δφ_A
Δφ_B
Δφ_A
Δφ_B
earth surface
A
B
A
B

Progress at Stanford