



# *QuITE* Quantum Interferometer Test of Equivalence Principle

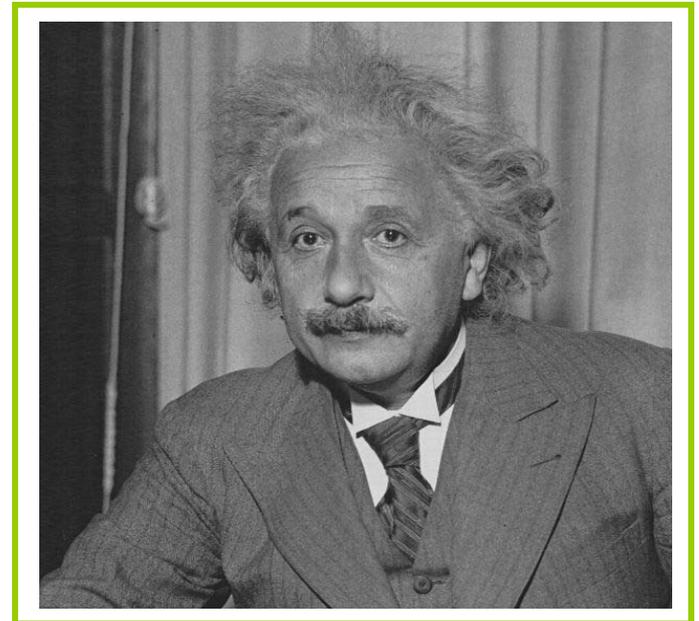


## Science Objective:

Seeking a violation of Einstein's Equivalence Principle (EEP) by improving the test limit by three orders of magnitude.

### *What's EEP?*

- a) all bodies fall identically;
- b) all local free fall frames are equivalent.



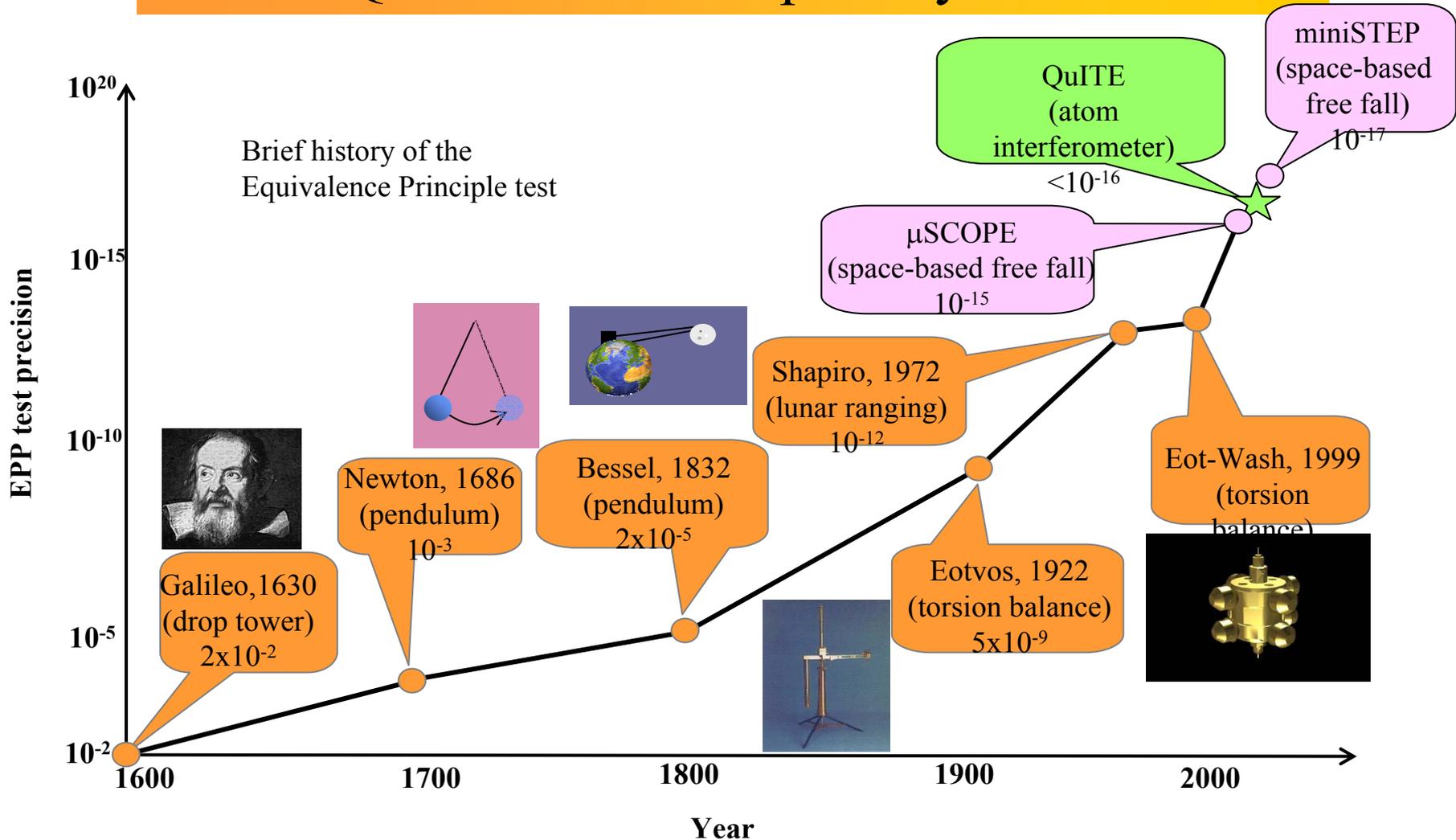


# QuITE Quantum Interferometer Test of Equivalence Principle



## What's QuITE mission capability for EEP test ?

Brief history of the  
Equivalence Principle test





# *QuITE* Quantum Interferometer Test of Equivalence Principle



**PI: Mark A. Kasevich, Yale University**  
**Co-I: Lute Maleki, Jet Propulsion Laboratory**

*Quantum particle-wave duality*





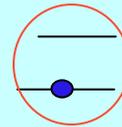
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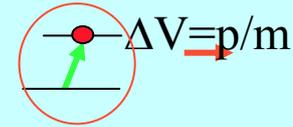
## Understanding Atom-Wave Interferometer Using Light Pulses

Photon absorption process  $p=hk$   
( $\pi$  pulse)

light  $\rightarrow$



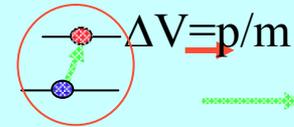
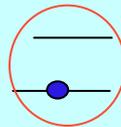
atom



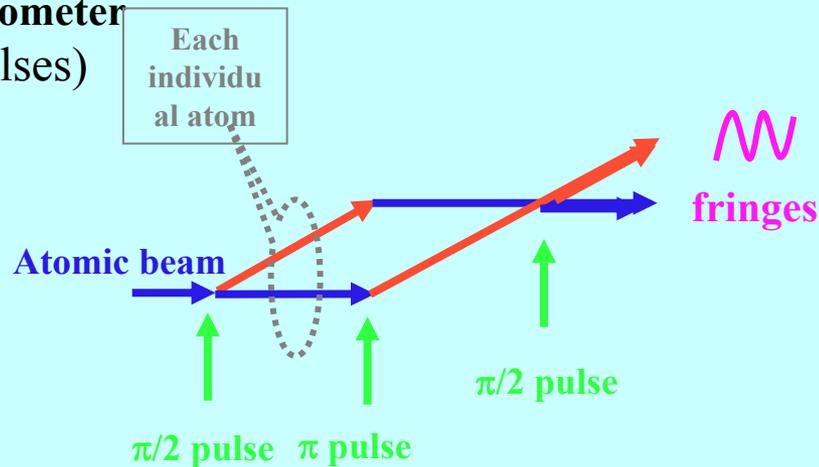
After absorption

Superposition state  
( $\pi/2$  pulse)

$p=hk$   
light  $\rightarrow$



**Atom Interferometer**  
( $\pi/2$ - $\pi$ - $\pi/2$  pulses)





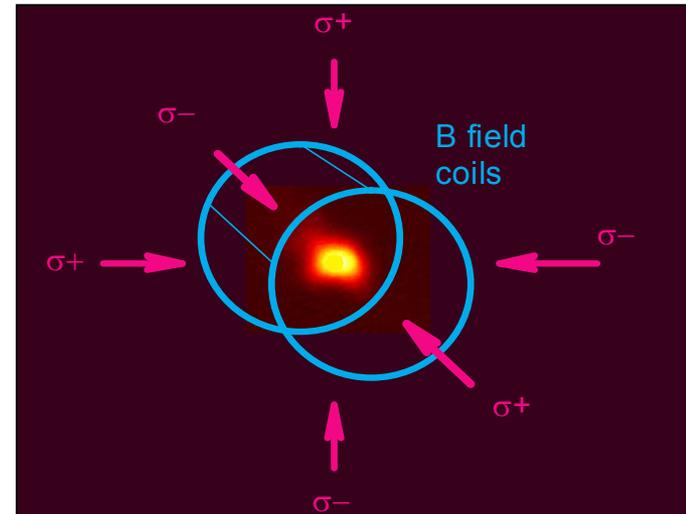
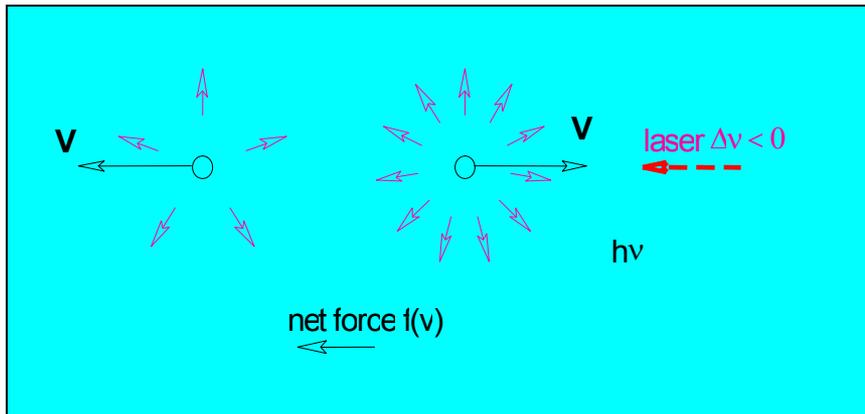
# QuITE Quantum Interferometer Test of Equivalence Principle



## Laser cooling and trapping technology

### Cooling force:

velocity-dependent viscous force via Doppler shifts of negatively detuned laser.





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# Quantum Interferometer Test of Equivalence Principle



## Technology Goal:

<b>Differential Accelerometer Attribute</b>	<b>Existing Laboratory Gravity Gradiometer</b>	<b>Proposed Ground</b>	<b>Space-Borne</b>
<b>Sensitivity</b>	$1 \times 10^{-9} \text{ g/Hz}^{1/2}$	$1 \times 10^{-11} \text{ g/Hz}^{1/2}$	$1 \times 10^{-13} \text{ g/Hz}^{1/2}$
<b>Accuracy for 6 months of data collection</b>	NA	$3 \times 10^{-15} \text{ g}$	$< 1 \times 10^{-16} \text{ g}$



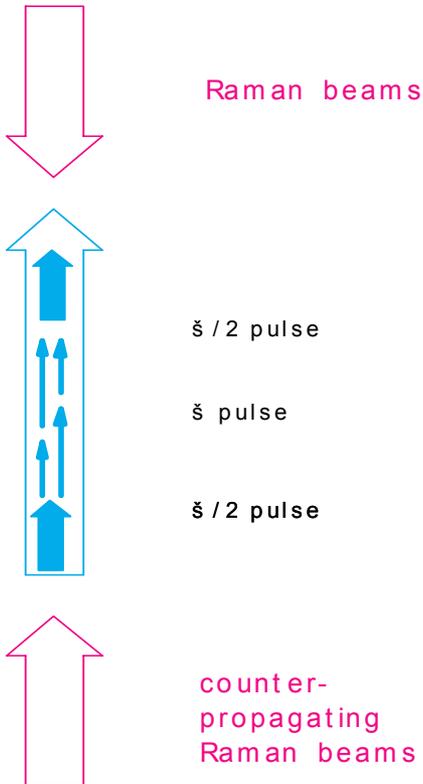
# QuITE Quantum Interferometer Test of Equivalence Principle



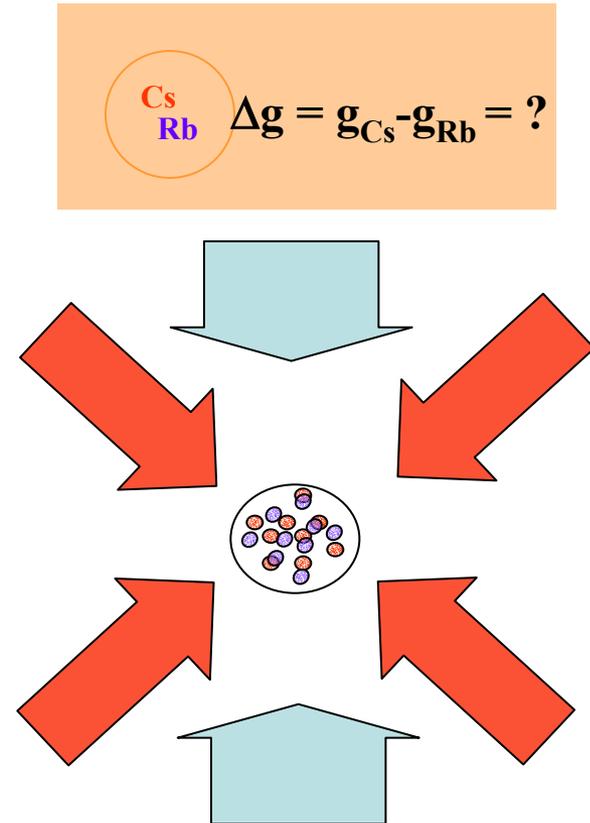
## Concept of QuITE experiment:

Using atom-interferometer-based differential accelerometer with Cs and Rb atoms to test the composition dependence of local acceleration as well as local Lorentz invariance and position invariance.

Atom interferometer accelerometer



Two species differential accelerometer





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# Quantum Interferometer Test of Equivalence Principle



Atom  
Test  
Mass

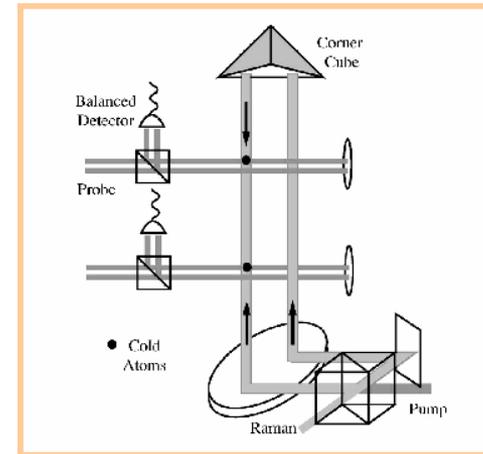
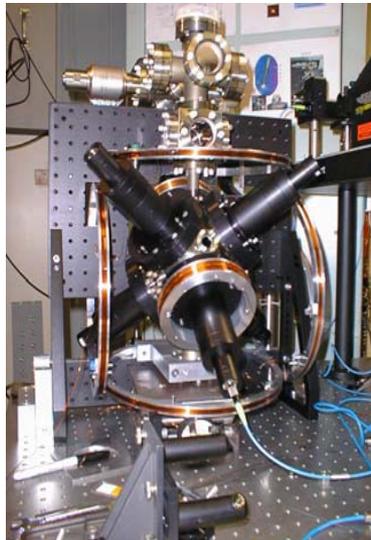
All  
Laser  
manipulation

~~Cryogen  
(LN<sub>2</sub>)~~

~~Mechanical  
Moving  
parts~~

## Yale University:

- 1) Demonstrated gravity gradiometer with  $10^{-9}$  g/Hz<sup>1/2</sup> differential acceleration sensitivity;
- 2) Demonstrated vibration common mode suppression by 7 orders of magnitude.



Yale experiment scheme

## JPL and LCAP facility:

- 1) Experimental demonstration of atom interferometer;
- 2) Technology synergy and heritage from other LCAP projects such as PARCS and RACE
- 3) Synergy with gravity gradiometer development for Earth Science applications.



# *QuITE* Quantum Interferometer Test of Equivalence Principle



## *QuITE* mission promises

### exciting scientific and technology returns:

- 1) Improving the test of Einstein's Equivalence Principle
  - Searching for a new limit of validity improved by three orders of magnitude
  - Provide new way of testing with individual atoms
- 2) First space-borne atom interferometer technology demonstration for future fundamental physics experiments (atom gyroscope, ...)
- 3) Technology development for space-borne quantum gravity gradiometer for other NASA applications (Earth Science gravity mapping code Y, Space Science planetary exploration code S, ....)