Fundamental Physics Tests with Atomic Interferometry

SLAC Theory

June 2007

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Collaboration

SLAC

Theory

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Theory

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Atomic Experiment

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Atomic Interferometry

Atomic physics has made tremendous progress recently
(cf. Nobel Lectures: 1997, 2001, 2005)

unprecedented precision: 16 digit clock synchronization

many possibilities for improvement

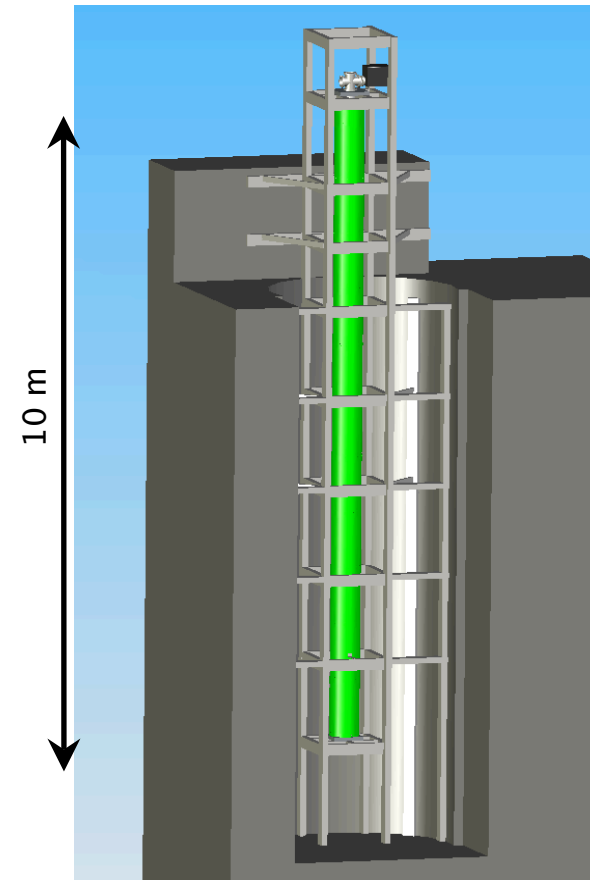
can test e.g. time variation of fundamental constants

How can we use this new tool to test fundamental physics?

Fundamental Physics Tests

Gravitational Waves	$h \sim 10^{-22}$ at frequencies ~ 1 Hz	compact binaries (BH, NS, WD) in local galaxy cluster, cosmological sources (phase transitions, cosmic strings, inflation,...)
Short-Distance Gravity New Forces	$\alpha \geq 10^{-5}$ for $100\ \mu m \leq \lambda \leq 10$ m	extra dimensions, QCD axion, light moduli,...
Atom Neutrality	charge per nucleon $\sim 10^{-30}$	current bound $\sim 10^{-22}$

Stanford 10m Interferometer



10 m atom drop tower.

colocated ^{85}Rb and ^{87}Rb clouds test Principle of Equivalence initially to 10^{-15} in controlled (lab) conditions

Other Prospects

General relativity and extensions (equivalence principle, DGP)

Modifications of quantum mechanics (e.g. Weinberg ’89)?

New ideas?

Gravitational Wave Sensitivity

experimental sensitivity
for continuous sources

L~10 m and LMT	$h \sim 10^{-17}$
L~10 km	$h \sim 10^{-20}$
Heisenberg statistics	$h \sim 10^{-22}$

on earth $\omega \sim 1$ Hz

in space $\omega \sim 10^{-3}$ to 1 Hz

waves from solar mass binaries:

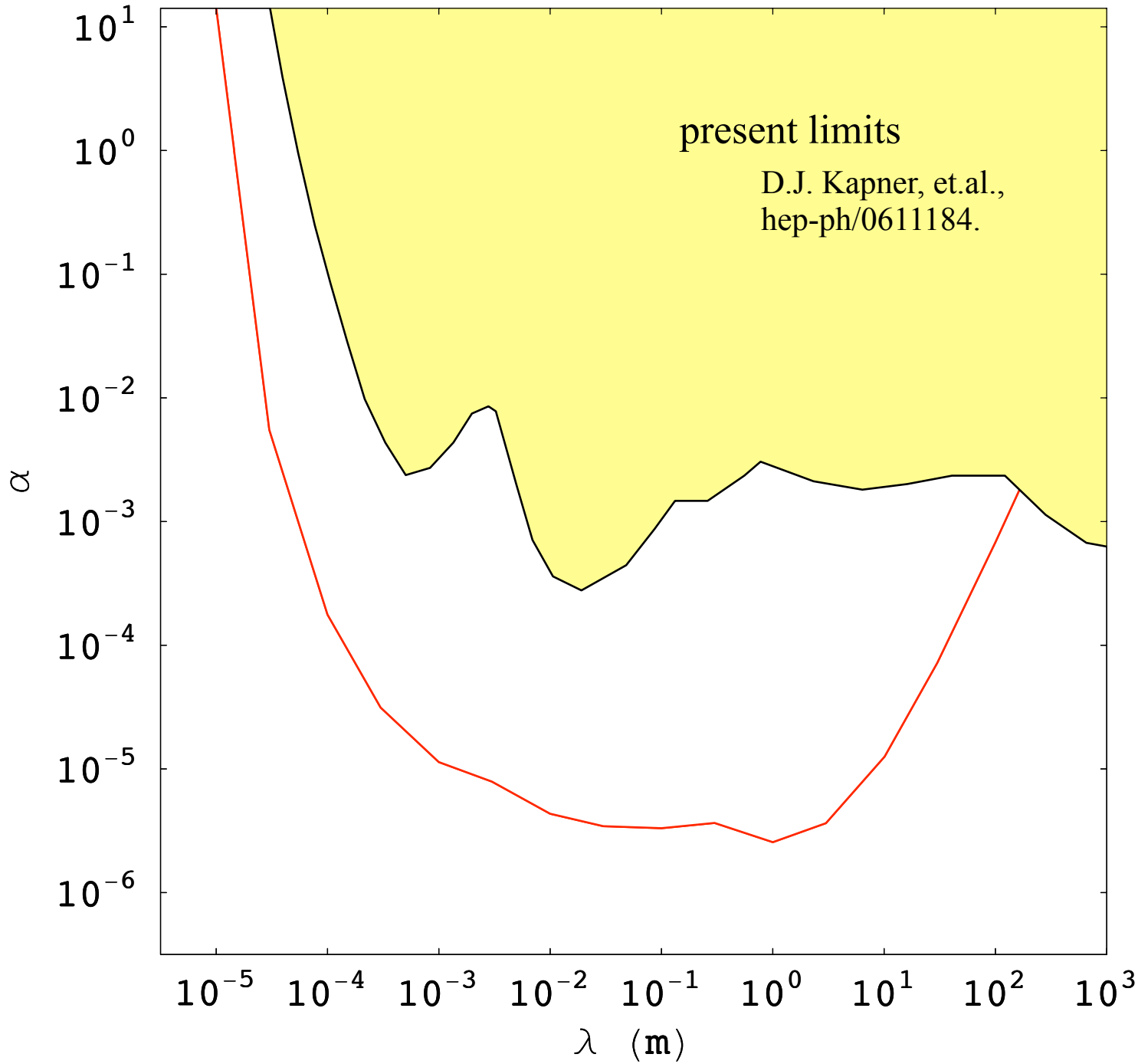
$$h \sim \frac{(GM)^2}{rR}$$

galaxy	$h \sim 10^{-18}$
cluster	$h \sim 10^{-21}$
universe	$h \sim 10^{-23}$

maybe IMBH $\rightarrow$ h up to 10^5 larger

opens a new window for stochastic gravity wave searches
from phase transitions, inflation, cosmic strings...

Short-Range Force Sensitivity



Future Prospects

Experimental Precision for:	Principle of Equivalence	GR effects	
current limits	10^{-13}	10^{-4}-10^{-5}	
AI initial	10^{-15}	10^{-1}	10 m experiment
upgrade	10^{-16}	10^{-2}	$200\hbar k$ beamsplitters
future	10^{-17}	10^{-4}	100 m experiment
far future	10^{-19}	10^{-6}	Heisenberg statistics