Weighing the vacuum with Archimedes Experiment Martina De Laurentis Università degli di Napoli "Federico II" - INFN Napoli

on behalf fo ARCHIMEDES collaboration



Vacuum Fluctuation Evidence: Casimir Force

Since the birth of Quantum Mechanics a question rised: Does the vacuum fluctuation weigh or not weigh? (Pauli, Nerst..)



After 100 yr NOT EXPERIMENTAL ANSEWR YET!

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Vacuum Fluctuations Evidence: Casimir Force

Force exerted in the vaccum between two conductive reflective not charged plates at suitable distances a



Attractive force between the plates

First prediction: Casimir 1948 First measure (force): Sparnay 1956 Presently tested (force) with an accuracy of 0.5% (Mohideen: 2005) (No problems in QFT in flat space-time)

Weighing the Vacuum Fluctuations



Total force directed upward = Weigh of the modes removed from the cavity

Analogy with Archimedes Force

It can be interpreted as an Archimedes' buoyancy force in vacuum 1-2 Padova march 2018 Martina De laurentis - Grass2018

Weighing the Vacuum Fluctuations

The IDEA is to weigh a RIGID Casimir Cavity when the plates reflectivity is modulated



Reflectivity very low: no Casimir effect is expected (the modes are inside the cavity like outside). Reflectivity very high: <u>Casimir force pushs up the Cavity</u>

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Experimental Problem: how to modulate the reflectivity



USE MULTICAVITY: like for the multilayer optical reflectors, to use a cascade of cavities enhaces the reflectivity

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Casimir energy for two and three superconducting coupled cavities: Numerical calculations

Authors

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C. Stornaiolo, F. Tafuri, show less

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Modulation of the Casimir Force: Type II superconductors

- 1) Use high-Tc LAYERED superconductors as NATURAL MULTICASIMIR CAVITIES
- Profit of the fact that in normal state the plane (that will become superconducting) is a very poor conductor → high variation of Casimir energy at the transition



 Approximate theory for high_Tc superconductor (plasma sheet no dissipation – zero temperature) – Kempf hypothesis (based on order of magnitude estimation): the contribution to free energy is comparable to condensation energy in particular layered superconductors like YBCO
Result from our analysis (Archimedes R&D in comm II): strong support of Kempf hypothesis -

expected modulation in the regime of $\Delta \eta_E \approx 10^{-4}$ 1-2 Padova march 2018 Martina De laurentis - Grass2018

Proposed measurement





Temperature Modulation screen: Modulate the force by modulating the temperature of the superconductor so that it makes transitions bewteen normal and superconducting state

^{1-2 Padova march 2018} Needed Veryrinigh sentisitivity at low fequencies (<100 mHz)

Expected signal and sensitivity



Sensitivity is for 1 months of integration time (10⁶ s) 1-2 Padova march 2018 Martina De laurentis - Grass2018

Quiet site: No seismic – No antropic noise

Sindaco	Mario Calia (lista civica) dall'11-6-2012				
Territorio					
Coordinate	💜 40°28'N 9°29'E				
Altitudine	521 m s.l.m.				
Superficie	148,72 km²				
Abitanti	1 407^[1] (31-7-2016)				
Densità	9,46 ab./km²				
Comuni confinanti	Bitti, Dorgali, Galtellì, Irgoli, Loculi, Lodè, Onani, Orune, Siniscola				







See Luca Naticchioni's tall Seismic Measurements By Virgo and ET collaborations

The Balance: first prototype realized in Napoli

Within the studies of Archimedes prototype (INFN commission V) we realized a prototype. The design of the joints is very similar to *Tiltemeter of Washington* group but with some differencies to cope with lower momenta of Inertia that are suitable for force measurements



FIG. 9: Torque sensitivity of the rotation sensor. Also shown are the sensor requirements, autocollimator limit and thermal noise limit 10 in torque units.



beam-balance

rferometric read-out



Archimedes' present status



Characteristic of the present balance

- Read-out: Optical lever and quadrant photodiode 3 reflections
- Balance works on closed loop
- Elettrostatic Acutators
- Photodiode follows the beam (repositioning every 1.5 hour)
- Small force power/supply/Actuator to maintain low actuator noise
- Balance lying on a Plinth of about 6 m³ of concrete.



Present tilt sensitivity



Present Torque Sensitivity



We are continuing in trying to improve:

thermally threated joints, lower coupling with seism, suitable feed-back for lower resonance frequency

1)Nonetheless: $4*10^{-12}$ correspond to an integration time of 10^6 s \rightarrow 12 days \rightarrow too long

Seismic Noise on the Napol Plinth





Very next step

Complete redesign of the balance

- Momentum of Inertia 5 times smaller
- Steel supports of the whole balance
- □ Steel support plate
- Interferometric read-out
- □ Steel support of the interferometer reference arm



- Total arm length: 1m
- Base dimensions: 40 cm x 40 cm
- Total height :
 - ~35 cm (~15 cm only the balance)

The interferometer is embedded in a monolithic steel structure



ARCHIMEDES COLLABORATION

experimental	groups	ENRICO CALLON	Ш	
Luciano Errico Saverio Avino <u>Martina De Laurentis</u> Gianluca Gagliardi <u>Optical read-out</u>	Ettore Majorana Paola Puppo Piero Rapagnan	Franco Frasconi Paolo Ruggi Balance (balance-arm, bala	ance suspensions)	
<i>Fulvio Ricci</i> Design and realization of the cry (vacuum chambers, thermal filte		cryogenic sytem ters,thermal_actuators.	theoretic	cal groups Giampiero Esposito Carlo Rovelli
Rosario De Rosa Luciano Di Fiore Electronic and Contro Environmental monito	Fi Di Di Di Di Di Di Di Di Di Di Di Di Di	rancesco Tafuri aniela Stornaiuolo . Piero Pepe ndrea Basti aurang Saini ilvano Petrarca	<i>Marco Grilli Sergio Caprara</i> Superconductors	Luigi Rosa Cosimo Stornaiolo Giuseppe Bimonte Casimir
	Supercondu	uctors Materials		

Conclusions

- We propose an experiment to verify if the Vacuum Fluctuations gravitate by weighing a rigid superonducting multilayer Casimir Cavity when its reflectivty is modulated
- We realized a prototype with a very good sensitivity of 10⁻¹¹ N/sqrt(Hz) @ 0.03 <f <0.1 Hzd
- We expect to have the first results in the next 5-6 years
- It will be the FIRST experiment hosted in the SAR-GRAV laboratory in SOS Enattos, Sardinia

THANK YOU VERY MUCH!

Today

The Dark Components of the Universe Are Slowly Clarified

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<u>Stay on the</u> <u>Main question</u>

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Does vacuum fluctuations gravitate or not? Doesdwacuum2pt@ssure red-s/hifta?De laurentis - Grass2018

Our group versus superconductor/Casimir theory

- 1) First to study Casimir Energy modulation in rigid cavities
- 2) First to study Casimir energy modulation via superconducting plates transitions –
- 3) First to study & measure modulation with thin layer supercondutors
- 4) First group to estimate with detail calculation Casimir energy modulation in layered type II superconductors
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