PROGRAMMA DI RICERCA - MODELLO A
Anno 2004 - prot. 2004023138

1.1 Programma di Ricerca di tipo

Interuniversitario

Area scientifico disciplinare *Scienze fisiche (100%)*

1.2 Titolo del Programma di Ricerca

Testo italiano
Verifica del Principio di Equivalenza con un esperimento di Galileo differenziale in volo parabolico (GATE -"Galileo Airborne Test of Equivalence")

Testo inglese
Test of the Equivalence Principle with a Galileo mass-dropping differential experiment in parabolic flight (GATE -"Galileo Airborne Test of Equivalence")

1.3 Abstract del Programma di Ricerca

Testo italiano
Da tempo viene proposta l' esistenza di nuove forze dipendenti dalla composizione dei corpi, tali quindi da violare il principio di equivalenza. Tuttavia, solo di recente è stato ipotizzato, in lavori pubblicati su riviste prestigiose (Damour, Piazza & Veneziano, PRD D66, 046007, 2002; PRL 89, 081601-1, 2002) che una tale violazione potrebbe avere luogo ad un livello verificabile con esperimenti appena più sensibili di quelli eseguiti finora con bilance di torsione (Braginsky & Panov, Sov. Phys. JEPT 34 463,1972; Baeßler et al. PRL 83 3585,1999) attestatisi alla sensibilità di 10^-12. Poiché l'effetto di violazione del principio di equivalenza è differenziale, i migliori risultati sono stati ottenuti con la bilancia di torsione, poiché è uno strumento per sua natura differenziale. E questo nonostante che, essendo le masse di prova sospese, il segnale disponibile per l'esperimento è solo una piccola componente nel piano orizzontale, molto minore quindi del segnale che interviene nei classici esperimenti di caduta dei gravi alla Galileo. Questi ultimi sono infatti stati abbandonati già da Galileo proprio perché non sono esperimenti differenziali. Tuttavia, nel 1986 alcuni scienziati dell'Università di Pisa hanno proposto un esperimento di caduta dei gravi alla Galileo avente la proprietà di essere differenziale: la massa in caduta è un disco fatto di due mezzi dischi di diversa composizione il cui piano è allineato con la verticale locale; in caso di violazione una delle due metà viene attratta dalla Terra diversamente dall'altra causando una accelerazione angolare del disco attorno al suo asse di simmetria, che viene misurata con un interferometro tipo Michelson. L'esperimento si chiamava GAL (Cavasinni et al., Phys. Lett. A 116 157, 1986) ed è stato completato al CERN nel 1992 (Carusotto et al., PRL 69 1722, 1992). Purtroppo la sensibilità raggiunta è stata soltanto di circa 1 parte in 10^10, limitata, secondo gli stessi autori, dal fatto che il meccanismo di rilascio del disco causa una accelerazione rotazionale spuria del tipo del segnale aspettato. L'esperimento GATE che si propone qui è molto simile a GAL, salvo che viene effettuato all'interno dell'aereo Airbus A300 a zero-g dell'ESA in volo parabolico. Il vantaggio principale (oltre al tempo di caduta più lungo) è il fatto che in questo caso sia il disco che la camera a vuoto che lo racchiude "cadono" insieme; pertanto, è possibile avere un sistema di rilascio a più stadi il cui ultimo stadio può avere una "strength" molto minore di 1-g, tale quindi da causare disturbi molto minori (il disturbo al rilascio è sempre una frazione della forza esercitata dal meccanismo di blocco). Una prima analisi (si veda all'indirizzo http://eotvos.dm.unipi.it/gate) mostra che l'esperimento GATE potrebbe raggiungere una sensibilità di 1 parte in 10^13, permettendo quindi di verificare le indicazioni di una possibile violazione che vengono dalla teoria delle stringhe. Sebbene GATE abbia il vantaggio di partire dai risultati di GAL ci sono alcuni passi da fare per accertarsi che possa riuscire al livello aspettato. Questi sono: a) confermare la validità dell'esperimento attraverso una analisi più dettagliata; b) eseguire esperimenti preliminari a bordo dell'Airbus A300 in modo da verificare la fattibilità della procedura sperimentale prevista; c) eseguire opportune prove di laboratorio a Terra per dimostrare sperimentalmente che meccanismi di rilascio di "strength" ridotta rispetto ad 1-g effettivamente producono disturbi molto piccoli, e comunque accettabili nel caso dell'esperimento GATE. Queste attività, tutte molto ben definite, verranno completate nei 2 anni previsti per questo progetto nel caso esso sia finanziato.

Testo inglese
The existence of new forces which may be composition dependent whereby violating the Equivalence Principle has been hinted since a long time. However, it has been only quite recently (Damour, Piazza & Veneziano, PRD D 66, 046007, 2002; PRL 89, 081601-1, 2002) that a possible violation of Equivalence has been suggested at a level that can be tested with experiments only slightly more sensitive than the best torsion balance experiments performed so far (Braginsky & Panov, Sov. Phys. JEPT 34 463,1972; Baeßler et al. PRL 83 3585,1999) reaching 10^-12. Since a violation of the Equivalence Principle would produce a differential effect, the torsion balance has proved to be a very suitable instrument because it is inherently differential. However, since the test masses are suspended, most of the local gravitational acceleration from the Earth is not available for the experiment, and only its small horizontal component contributes to the test. The famous Galileo-type mass dropping experiments, in which the driving signal is

given by the full local gravitational acceleration, have in fact been abandoned by Galileo himself, in favour of pendula and -ever since the work of Roland von Eötvös - of the torsion balance. This was because they were not differential experiments and couldn't therefore - in spite of the stronger signal- be as sensitive as differential experiments. A differential Galileo-type mass dropping experiment named GAL was devised at the University of Pisa in 1986 (Cavasinni et al., Phys. Lett. A 116 157, 1986) and completed at CERN in 1992 (Carusotto et al., Phys. Rev. Lett. 69 1722, 1992) in order to test the Equivalence Principle by testing the universality of free fall. The free falling mass was a disk made of two half disks of different composition; a violation of Equivalence would produce an angular acceleration of the disk around its symmetry axis, which was measured with a modified Michelson interferometer. The GATE -"Galileo Airborne Test of Equivalence" experiment proposed here is a variant of that experiment to be performed in parabolic flight on-board the "Airbus A300 Zero-g" aircraft of the European Space Agency (see draft online at http://eotvos.dm.unipi.it/gate). The main advantages of GATE with respect to GAL are the longer time of free fall and the absence of weight in the final stage of unlocking. The longer time of fall makes the signal almost 500 times stronger and allows a spurious linear growth of the rotation angle to be separated out. More importantly, unlocking at zero-g can significantly reduce spurious angular accelerations of the disk due to inevitable imperfections in the locking/unlocking mechanism which turned out to be the limiting factor in GAL. A preliminary estimate indicates that GATE should be able to achieve a sensitivity in the fractional relative free fall acceleration of about 10^-13, an improvement by about 3 orders of magnitude with respect to GAL and by about 1 order of magnitude with respect to the best result obtained with a slowly rotating torsion balance (Baeßler et al. Phys. Rev. Lett. 83 3585,1999). For the GATE experiment to be performed successfully it is necessary: a) to confirm the validity of the experiment concept and its expected sensitivity by more detailed analysis; b) to perform appropriate aircraft tests to confirm the in flight experiment procedure and requirements; c) to carry out laboratory tests of the locking/unlocking device to demonstrate that unlocking at reduced strength, as it is possible in parabolic flight and was not possible in the GAL experiment, allows a considerable reduction of the unlocking disturbances which limited the GAL sensitivity. These well defined activities will be carried out in the 2-yr duration of this research project if funded. After that the GATE experiment can be performed with high confidence of achieving its expected sensitivity.

1.4 Durata del Programma di Ricerca

24 Mesi

1.5 Settori scientifico-disciplinari interessati dal Programma di Ricerca

FIS/01 - Fisica sperimentale
FIS/05 - Astronomia e astrofisica
FIS/04 - Fisica nucleare e subnucleare
ING-IND/03 - Meccanica del volo

1.6 Parole chiave

Testo italiano
PRINCIPIO DI EQUIVALENZA ; MISURE DI PICCOLE FORZE ; MISURE DI FORZE DIFFERENZIALI ; CORPO RIGIDO E MECCANICA DI PRECISIONE ; MECCANICA DEL VOLO ; ESPERIMENTI IN ASSENZA DI PESO

Testo inglese
EQUIVALENCE PRINCIPLE ; SMALL FORCE MEASUREMENTS ; MEASUREMENTS OF DIFFERENTIAL FORCES ; RIGID BODY AND HIGH-PRECISION MECHANICS ; FLIGHT MECHANICS ; ESPERIMENTS IN "ZERO-G" ENVIRONMENT

1.7 Coordinatore Scientifico del Programma di Ricerca

NOBILI ***ANNA MARIA***

Professore Associato ***10/09/1949*** ***NBLNMR49P50C969U***

FIS/05 - Astronomia e astrofisica

Università di PISA

Facoltà di SCIENZE MATEMATICHE FISICHE e NATURALI

Dipartimento di MATEMATICA "Leonida Tonelli"

050/2213252	***050/2213224***	***nobili@dm.unipi.it***
(Prefisso e telefono)	*(Numero fax)*	*(Email)*

1.8 Curriculum scientifico

Testo italiano
Nata 10.9.49. Studente della Classe di Scienze della SNS di Pisa per due anni. Laurea in Fisica (110/110 e lode, 1973). Perfezionanda della SN; Titolare di Contratto di Ricerca, Universita' di Bologna; Ricercatore, Universita'di Pisa; Professore Associato Confermato, Università di Pisa (titolare dei Corsi: Elementi di Meccanica Celeste, Meccanica Spaziale, Dinamica del sistema Terra/Luna). Ricerca in: Fisica Fondamentale a terra e nello spazio, Dinamica del Sistema Solare, Geodesia Spaziale. Lavori pubblicati: piu' di cento, su riviste internazionali con referees e nei rendiconti di congressi nazionali e internazionali. Libri: uno in geodesia spaziale in lingua inglese. Ha partecipato a panel ESA/NASA per lo studio di missioni spaziali di fisica fondamentale. E' stata Principal Investigator di una missione considerata per il volo da parte dell'ASI nell'ambito del programma di piccole missioni dell'Agenzia, ora abbandonato. E' responsabile in INFN dell'esperimento GGG per la verifica del principio di equivalenza a terra e nello spazio. Ha lavorato all'estero presso: Cornell University, USA; Glasgow University, UK; Queen Mary College, London; Observatoire de Meudon, Paris, France. Ha sviluppato una pagina web all'indirizzo: http://eotvos.dm.unipi.it/nobili/homenobili.html (circa 350 MB di informazione) che contiene materiale relativo ai progetti di ricerca, articoli scientifici, rapporti di ricerca, testi di conferenze specialistiche e divulgative, foto dell'apparato sperimentale, materiale di convegni promossi (1998 "The Fundamentals of Gravity: Measuring Big G and Testing the Equivalence Principle on Earth and in Space"; 2002 "Experiments on the equivalence principle: from Earth to space probing General Relativity" http://eotvos.dm.unipi.it/nobili/workshop2002). Un CD-Rom della pagina Web e' disponibile e viene largamente diffuso. Svolge attivita' di divulgazione scientifica e di "public outreach" quando richiesta da reti televisive o radiofoniche nazionali.

Testo inglese
Born September 10, 1949. Student at Scuola Normale Superiore in Pisa (Science Class) for 2 years; Laurea degree in Physics (full marks cum laude, 1973). Fellow at Scuola Normale; Reserach fellow at University of Bologna; Researcher at University of Pisa; Associate Professor at University of Pisa (Courses on Celestial Mechanics, Space Mechanics, Dynamics of the Earth/Moon System). Research in: Fundamental Physics on Earth and in Space, Dynamics of the Solar System; Space Geodesy. Published papers: more than one hundred, on international journals with referees and in proceedings of national and international conferences. Books: one, in English. Former member of ESA/NASA science teams of space missions in Fundamental Physics. Principal Investigator (PI) of a small satellite space project investigated by ASI (Agenzia Spaziale Italiana) within its small mission programme. PI within INFN (Istituto Nazionale di Fisica Nucleare) of the GGG experiment to test the equivalence principle on earth and in space Has worked abroad for several years at: Cornell University USA; Glasgow University, UK; Queen Mary College, London; Observatoire de Paris, Meudon France. Has set up a webpage at the address:http://eotvos.dm.unipi.it/nobili/homenobili.html (about 350 MegaByte worth of information) with material on her research projects, publications, description and images of the ongoing GGG experiment for testing the Equivalence Principle, material on Workshops she has organized (1998 "The Fundamentals of Gravity: Measuring Big G and Testing the Equivalence Principle on Earth and in Space"; 2002 "Experiments on the equivalence principle: from Earth to space probing General Relativity" http://eotvos.dm.unipi.it/nobili/workshop2002). The webpage is available on CD for interested scientists. Carries out public outreach activity on request by national TV and radio networks.

1.9 Pubblicazioni scientifiche più significative del Coordinatore del Programma di Ricerca

1. *NOBILI A.M.; BRAMANTI D.; COMANDI G.L.; TONCELLI R.; POLACCO E. (2003).* ***A rotating differential accelerometer for testing the equivalence principle in space: results from laboratory tests of a ground prototype*** *NEW ASTRONOMY. (vol. 8 pp. 371-390) http://eotvos.dm.unipi.it/nobili/ggg/GGG_NA_2003.pdf.*
2. *NOBILI A.M.; D. BRAMANTI; G.L. COMANDI; R. TONCELLI; E. POLACCO; M.L. CHIOFALO (2003).* ***"Galileo Galilei-GG": design, requirements, error budget and significance of the ground prototype*** *PHYSICS LETTERS A. (vol. 318 pp. 172-183)*
3. *G.L. COMANDI; NOBILI A.M.; R. TONCELLI; M.L. CHIOFALO (2003).* ***Tidal effects in space experiments to test the equivalence principle: implications on the experiment design*** *PHYSICS LETTERS A. (vol. 318 pp. 251-269)*
4. *NOBILI A.M.; BRAMANTI D.; COMANDI G.; TONCELLI R.; POLACCO E.; CATASTINI G. (2001).* ***Radiometer effect in space missions to test the equivalence principle*** *PHYSICAL REVIEW D. (vol. 63 pp. 1-3) http://eotvos.dm.unipi.it/nobili/ggweb/radiometer/radiometer.pdf.*
5. *NOBILI A.M. (2001).* ***Precise gravitation measurements on Earth and in space: tests of the Equivalence Principle*** *In T.J. QUINN; S. LESCHIUTTA; P. TAVELLA EDS. Proceedings of the International School of Physics "Enrico Fermi", Course CXLVI: Recent Advances in Metrology and Fundamental Constants. vol. CXLVI pp. 609-652 (http://eotvos.dm.unipi.it/nobili/publications/varenna.pdf). AMSTERDAM: IOS (NETHERLANDS)*

1.10 Elenco delle Unità di Ricerca

nº	Responsabile Scientifico	Qualifica	Settore Disc.	Università	Dipartimento	Mesi Uomo
1.	*NOBILI ANNA MARIA*	*Professore Associato*	*FIS/05*	*PISA*	*MATEMATICA*	*22*
2.	*PALMONARI FEDERICO*	*Professore Ordinario*	*FIS/04*	*BOLOGNA*	*FISICA*	*12*

1.11 Mesi uomo complessivi dedicati al programma

		Numero	Mesi uomo 1° anno	Mesi uomo 2° anno	Totale mesi uomo
Personale universitario dell'Università sede dell'Unità di Ricerca		*8*	*49*	*49*	*98*
Personale universitario di altre Università		*0*	*0*	*0*	*0*
Titolari di assegni di ricerca		*1*	*4*	*0*	*4*
Titolari di borse	*Dottorato*	*0*			
	Post-dottorato	*0*			
	Scuola di Specializzazione	*0*			
Personale a contratto	*Assegnisti*	*1*	*11*	*11*	*22*
	Borsisti	*0*			
	Dottorandi	*0*			
	Altre tipologie	*1*	*11*	*11*	*22*
Personale extrauniversitario		*5*	*28*	*28*	*56*
TOTALE		**16**	**103**	**99**	**202**

2.1 Obiettivo del Programma di Ricerca

Testo italiano
A violation of the equivalence principle, hence of the universality of free fall, would produce a small differential force between two test masses in the gravitational field of a source body. The expected signal being differential, the instrument to detect it should also be differential, namely it should be able to reject as much as possible all forces acting in common mode on both the test masses. This is why the torsion balance, ever since its first use for this purpose by Roland von Eötvös at the end of the 19th century has proved to be the best instrument for equivalence principle tests. The original famous Galileo mass-dropping experiments going back almost 3 centuries before Eötvös, could not possibly compete with torsion balance tests despite the fact that with free falling bodies the force under test is much stronger. The point is that Galileo type mass-dropping experiments were not differential experiments.

This was the case till 1986, when a differential Galileo mass-dropping experiment named GAL was proposed (Cavasinni et al., Phys. Lett. A 116 157, 1986), to be carried out at CERN and completed a few years later (Carusotto et al., Phys. Rev. Lett. 69 1722, 1992). GAL had the advantage of a stronger signal (like any mass-dropping experiments), as well as that of being differential (like the torsion balance) because the dropping mass was a disk made of two half disks of different composition, such that a violation of equivalence would produce an angular acceleration of the disk around its symmetry axis. Unfortunately, the GAL experiment was not as successful as expected (it achieved a sensitivity was about 2 orders of magnitude less good than in the case of torsion balance tests) and the reason, as it was clearly pointed out by the scientists who performed the experiment, was that while unlocking the disk (at 1-g!) it was perturbed by the unlocking itself, thus acquiring a spurious angular acceleration which would mimic the signal. The GATE experiment proposed here, in which a GAL experiment is performed in parabolic flight inside the Airbus A300 zero-g aircraft of ESA (European Space Agency), should be able to overcome this limitation: the disk and the vacuum chamber enclosing it are now both in free fall, thus implying that the final stage of unlocking can be performed at a much reduced level of gravitational acceleration. Since the disturbance of any unlocking mechanism must be a fraction of its strength, the advantage of the GATE experiment is apparent. Moreover, the time of free fall is longer, as compared to GAL, and the signal would grow quadratically with the free falling time duration, which means that the read-out should not be a problem. The free fall time available for the experiment in each parabola is about 20 sec (hence with a signal almost 500 times stronger than in GAL), the number of parabolas each day of flight of the Airbus is about 30 and the number of days in each campaign is typically 3. This means that up to about 90 experiment runs would be possible during one Airbus flight campaign. A preliminary investigation of the GATE experiment indicates that a target sensitivity of 1 part in 10^13 should be attainable (see the draft paper online at the address http://eotvos.dm.unipi.it/nobili/gate).

Such a target is indeed of great at presents, as recent papers published in highly respected Journals (Damour, Piazza and Veneziano, Phys. Rev. D 66, 046007, 2002; Phys. Rev. Lett. 89, 081601-1, 2002) have pointed out, in the framework of string theory, that the equivalence principle might indeed be violated just slightly below the 10^-12 level so far probed by torsion balances. While torsion balances appear to find it difficult to improve on their so far outstanding results, it would be beautiful to gain one order of magnitude with a differential Galileo mass-dropping experiment in parabolic flight. The scientific reward would be enormous, for sure in case of violation, but also in case that no violation is found. It would be the first time since 1972 that 1 order of magnitude in sensitivity is gained; moreover, such an experimental result would serve as a firm reference in string theory.

The two years of the research project proposed here would lay the bases for the success of the GATE experiment, which although very similar to the GAL experiment -whose expertise is available to the GATE proposing scientists- nevertheless needs specific attention. Our goals for this timespan are:

· To publish a detailed high quality paper on the GATE aircraft experiment for testing the equivalence principle (e.g. on Journal such as Review of Scientific Instruments or Physical Review D).

· To perform various tests onboard the Airbus A300 zero-g aircraft allowing us to master all aspects of the actual GATE experiment (see 2.4)

· To design, build and run laboratory tests of an appropriate apparatus whose measurements should demonstrate the advantages of unlocking at a reduced level of gravity, thus showing that the major limitation of the GAL experiment, performed at CERN and of which GATE is a variant in parabolic flight, can indeed be overcome (see 2.4).

The success or failure of the project can be assessed by assessing the achievement of these results. If achieved, the validity of the GATE proposal would be experimentally demonstrated.

Testo inglese
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· To design, build and run laboratory tests of an appropriate apparatus whose measurements should demonstrate the advantages of unlocking at a reduced level of gravity, thus showing that the major limitation of the GAL experiment, performed at CERN and of which GATE is a variant in parabolic flight, can indeed be overcome (see 2.4).

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2.2 Base di partenza scientifica nazionale o internazionale

Testo italiano

Experiments to test the Universality of Free Fall (UFF) -whereby, in a gravitational field, all bodies fall with the same acceleration regardless of their mass and composition- have played a major rôle in the history of experimental gravitation. Indeed, experiments to test the UFF have started even earlier than big G experiments, with Galileo in Pisa already at the end of the 16th century. Newton's formulation of the law of gravitational attraction has related the UFF to the outstanding equivalence of inertial and gravitational. The birth of General Relativity, at the beginning of the 20th century, has put experiments on the UFF in a new perspective: in 1907 Einstein formulates the "hypothesis of complete physical equivalence" between a gravitational field and an accelerated frame on which General Relativity is based. This hypothesis is usually referred to as the Weak Equivalence "Principle" and its experimental consequence is the Universality of Free Fall. Hence, putting to test the UFF amounts to putting to test the hyopthesis on which General Relativity is based, and therefore its foundations.

The best experimental tests of the equivalence principle so far have been performed by the "Eöt-Wash" group at the University of Washington (Seattle, USA) using slowly rotating torsion balances (Baeßler et al. Phys. Rev. Lett. 83 3585,1999) and reaching a sensitivity of 1 part in 10^12. There is general agreement in the community that a sensitivity several orders of magnitude better than that could be obtained were it possible to perform an equivalence principle experiment in a dedicated low Earth orbiting spacecraft. A cryogenic, 1-tonn total mass space experiment named STEP (http://einstein.stanford.edu/STEP) has been proposed with a target sensitivity of 1 part in 10^18, while the smaller "Galileo Galilei"-GG satellite (300 kg total mass) has a target sensitivity of 1 part in 10^17 at room temperature (Nobili et al., Physics Letters A, 318, 172-183, 2003) and is based on a fast rotating differential accelerometer currently under development in Pisa as an INFN approved experiment named GGG-"GG on the Ground" (Comandi et al., Physics Letters A, 318, 213-222, 2003). Aiming at a sensitivity better the one achieved with torsion balances, though not as good as foreseen for the two dedicated space experiments mentioned above, a cryogenic balloon test named GREAT has been proposed and is under investigation (Iafolla et al., Review of Scientific Instruments, 69, no. 12 1998).

The existence of new forces which may be composition dependent whereby violating the Equivalence Principle has been hinted since a long time. However, it has been only quite recently (Damour, Piazza and Veneziano, Phys. Rev. D 66, 046007, 2002; Phys. Rev. Lett. 89, 081601-1, 2002) that a possible violation of Equivalence has been suggested at a level that can be tested with experiments only slightly more sensitive than the best torsion balance experiments performed so far (Roll, Krotkov and Dicke, Ann. Phys. 26 442

1964; Braginsky and Panov, Sov. Phys. JEPT 34 463,1972; Baeßler et al. Phys. Rev. Lett. 83 3585,1999). Since a violation of the equivalence principle would produce a differential effect, the torsion balance has proved to be a very suitable instrument because it is inherently differential. However, since the test masses are suspended, most of the local gravitational acceleration from the Earth is not available for the experiment, and only its small horizontal component contributes to the test. The famous Galileo-type mass dropping experiments, in which the driving signal is given by the full local gravitational acceleration, have in fact been abandoned since Galileo himself, in favour of pendula and -ever since the work of Roland von Eotvos- of the torsion balance. This was because they were not differential experiments and couldn't therefore - in spite of the stronger signal- be as sensitive as differential experiments. A differential Galileo-type mass dropping experiment named GAL was devised at the University of Pisa in 1986 (Cavasinni et al., Phys. Lett. A 116 157, 1986) and completed at CERN in 1992 (Carusotto et al., Phys. Rev. Lett. 69 1722, 1992) in order to test the Equivalence Principle by testing the universality of free fall. The free falling mass was a disk made of two half disks of different composition; a violation of Equivalence would produce an angular acceleration of the disk around its symmetry axis, which was measured with a modified Michelson interferometer. The GATE -"Galileo Airborne Test of Equivalence" experiment proposed here is a variant of that experiment to be performed in parabolic flight on-board the "Airbus A300 Zero-g" aircraft of the European Space Agency (draft online at http://eotvos.dm.unipi.it/nobili/gate). The main advantages of GATE with respect to GAL are the longer time of free fall and the absence of weight in the final stage of unlocking. The longer time of fall makes the signal almost 500 times stronger and allows a spurious linear growth of the rotation angle to be separated out. More importantly, unlocking at zero-g can significantly reduce spurious angular accelerations of the disk due to inevitable imperfections in the locking/unlocking mechanism which turned out to be the limiting factor in GAL. A preliminary estimate indicates that GATE should be able to achieve a sensitivity in the fractional relative free fall acceleration of about 10^-13, an improvement by about 3 orders of magnitude with respect to GAL and by about 1 order of magnitude with respect to the best result obtained with a slowly rotating torsion balance (Baeßler et al. Phys. Rev. Lett. 83 3585,1999).

The GATE experiment proposed here can be viewed as an Equivalence Principle test of intermediate sensitivity between torsion balance ground tests (10^-13), balloon or micro-satellite (150 kg) tests (GREAT and mSCOPE: between 10^-14 to 10^-15), small-satellite (300 kg) room temperature tests (GG: 10^-17), large-satellite (1 ton) cryogenic tests (STEP: 10^-18). In the presence of the possibility, recently published in highly respected Journals, that an equivalence principle violation might show up at a sensitivity no longer out of reach for small research groups and small, very low cost experiments, GATE appears to be a very appropriate addition to the efforts of torsion balance experiments of go beyond the 10^-12 level of sensitivity so hard so improve on.

We regard of great importance for a successful completion of the GATE experiment the fact that it builds up on the results of the GAL experiment (Carusotto et al., Phys. Rev. Lett. 69 1722, 1992), an experiment that has already performed an equivalence principle test to about 1 part in 10^10. Some changes are obviously needed in going from a ground experiment to an experiment in parabolic flight, but the basic features of the experiment (experiment concept, test masses design and read-out) remain the same as in GAL, whose leading scientist (Prof. E. Polacco) is now member of the GATE proposing Pisa group. As for the expertise required in space mechanics, the proposing scientists have a long time acquaintance with small force experiments in space and in addition can count also on the collaboration of the Aerospace Engineering Department of the University of Pisa.

Testo inglese

Experiments to test the Universality of Free Fall (UFF) -whereby, in a gravitational field, all bodies fall with the same acceleration regardless of their mass and composition- have played a major rôle in the history of experimental gravitation. Indeed, experiments to test the UFF have started even earlier than big G experiments, with Galileo in Pisa already at the end of the 16th century. Newton's formulation of the law of gravitational attraction has related the UFF to the outstanding equivalence of inertial and gravitational. The birth of General Relativity, at the beginning of the 20th century, has put experiments on the UFF in a new perspective: in 1907 Einstein formulates the "hypothesis of complete physical equivalence" between a gravitational field and an accelerated frame on which General Relativity is based. This hypothesis is usually referred to as the Weak Equivalence "Principle" and its experimental consequence is the Universality of Free Fall. Hence, putting to test the UFF amounts to putting to test the hyopthesis on which General Relativity is based, and therefore its foundations.

The best experimental tests of the equivalence principle so far have been performed by the "Eöt-Wash" group at the University of Washington (Seattle, USA) using slowly rotating torsion balances (Baeßler et al. Phys. Rev. Lett. 83 3585,1999) and reaching a sensitivity of 1 part in 10^12. There is general agreement in the community that a sensitivity several orders of magnitude better than that could be obtained were it possible to perform an equivalence principle experiment in a dedicated low Earth orbiting spacecraft. A cryogenic, 1-tonn total mass space experiment named STEP (http://einstein.stanford.edu/STEP) has been proposed with a target sensitivity of 1 part in 10^18, while the smaller "Galileo Galilei"-GG satellite (300 kg total mass) has a target sensitivity of 1 part in 10^17 at room temperature (Nobili et al., Physics Letters A, 318, 172-183, 2003) and is based on a fast rotating differential accelerometer currently under development in Pisa as an INFN approved experiment named GGG-"GG on the Ground" (Comandi et al., Physics Letters A, 318, 213-222, 2003). Aiming at a sensitivity better the one achieved with torsion balances, though not as good as foreseen for the two dedicated space experiments mentioned above, a cryogenic balloon test named GREAT has been proposed and is under investigation (Iafolla et al., Review of Scientific Instruments, 69, no. 12 1998).

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2.2.a Riferimenti bibliografici

V.B. Braginsky and V.I. Panov, Sov. Phys. JEPT, Vol. 34, pp. 463-466 (1972)

V. Cavasinni, E. Iacopini, E. Polacco, G. Stefanini, Phys. Lett. A 116, 157 (1986)

V. Iafolla, E.C. Lorenzini, V. Milyukov and S. Nozzoli, Review of Scientific Instruments 69, no. 12 (1998)

S. Carusotto, V. Cavasinni, A. Mordaci, F. Perrone, E. Polacco, E. Iacopini, G. Stefanini, Phys. Rev. Lett. 69 1722-1725 (1992)

S. Baeßler, B.R. Heckel, E.G. Adelberger, J.H. Gundlach, U. Schmidt, H.E. Swanson, Phys. Rev. Lett. 83 3585 (1999)

T. Damour, F. Piazza, G. Veneziano, Phys. Rev. D 66, 046007 (2002)

T. Damour, F. Piazza, G. Veneziano, Phys. Rev. Lett. 89, 081601-1 (2002)

A.M. Nobili et al., "Galileo Airborne Test of Equivalence-GATE", draft, March 2004 (available online at the address http://eotvos.dm.unipi.it/nobili/gate)

2.3 Numero di fasi del Programma di Ricerca:

4

2.4 Descrizione del Programma di Ricerca
Fase 1

Durata e costo previsto

Durata *Mesi 6* **Costo previsto** *Euro 35.000*

Descrizione

Testo italiano
Detailed design of the aircraft experiment [includes: a) selection of the required hardware and assessment of its expected performance; b) preliminary design of the ad hoc hardware that needs to be manufactured in oder to assemble the experimental apparatus to be carried on board the aircraft; c) error budget of the and expected sensitivity]. Purchase and preliminary tests of the read out planned for the aircraft experiment and of the data and command communication system to be used in the aircraft experiment. Preparation of the vacuum chamber to be used in the Pisa lab specifically for ground tests within this project (see below).

Testo inglese
Detailed design of the aircraft experiment [includes: a) selection of the required hardware and assessment of its expected performance; b) preliminary design of the ad hoc hardware that needs to be manufactured in oder to assemble the experimental apparatus to be carried on board the aircraft; c) error budget of the and expected sensitivity]. Purchase and preliminary tests of the read out planned for the aircraft experiment and of the data and command communication system to be used in the aircraft experiment. Preparation of the vacuum chamber to be used in the Pisa lab specifically for ground tests within this project (see below).

Risultati parziali attesi

Testo italiano
We expect to publish a paper on the GATE experiment with details on its design, the instrumentation involved and its performance and a realistic estimate of the expected sensitivity in testing the equivalence principle. Appropriate Journal for this paper could be "Review of Scientific Instruments" or "Physical Review D".

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Unità di Ricerca impegnate

Unità n. 1
Unità n. 2

Fase 2

Durata e costo previsto

Durata *Mesi 6* **Costo previsto** *Euro 65.000*

Descrizione

Testo italiano
Preliminary tests need to be performed onboard the Airbus A300 zero-g aircraft in preparation for the GATE experiment and will be proposed for an Airbus campaign. They are concerned about release and retrieval of a dummy GATE-like chamber and about the measurement of air velocity inside the aircraft during free-fall. One should test: a) a simplified version of a multistage mechanical locking/unlocking device; b) the Airbus free-float procedure whereby during free fall the apparatus is prevented from hitting the aircraft walls thanks to video camera driven pilot manoeuvers; c) the procedure for retrieving the apparatus at the end of free fall and before a new acceleration phase of the aircraft begins; d) the actual free fall time duration available for the experiment; e) the air velocity inside the aircraft relative to the free floating apparatus and possibly also air pressure gradients on the surface of the GATE apparatus which might produce spurious rotations.

It is very unlikely, due to the actual availability of aircraft campaigns, that all these preliminary tests can be performed in 6 months. We shall try however to have all of them completed by the end of June 2006, in the order that will most probably be suggested by the Aircraft staff.

While the Pisa group will be involved mostly in the Airbus tests, the Bologna group will design the locking/unlocking multistage device to be used in the final GATE experiment. It will also design a variant of it in 2-D to be used in laboratory tests with a suspended dummy GATE-like apparatus.

Testo inglese
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While the Pisa group will be involved mostly in the Airbus tests, the Bologna group will design the locking/unlocking multistage device to be used in the final GATE experiment. It will also design a variant of it in 2-D to be used in laboratory tests with a suspended dummy GATE-like apparatus.

Risultati parziali attesi

Testo italiano
We expect to have the results of the Airbus tests performed and the design of the locking/unlocking device both for the final GATE experiment and, more in detail, for the laboratory tests of the disturbances produced by unlocking.

Testo inglese
We expect to have the results of the Airbus tests performed and the design of the locking/unlocking device both for the final GATE experiment and, more in detail, for the laboratory tests of the disturbances produced by unlocking.

Unità di Ricerca impegnate

Unità n. 1
Unità n. 2

Fase 3

Durata e costo previsto

Durata *Mesi 6* **Costo previsto** *Euro 65.000*

Descrizione

Testo italiano
The Pisa group will be involved in completing the aircraft tests which could not be performed in the previous 6 months (see Description of Phase 3). The Bologna group will take care of the construction of a multistage locking/unlocking device (as previously designed) to be used in the laboratory in Pisa, in combination with an appropriate read-out system, to measure the level of disturbances resulting from unlocking the apparatus with various strengths.

Testo inglese
The Pisa group will be involved in completing the aircraft tests which could not be performed in the previous 6 months (see Description of Phase 3). The Bologna group will take care of the construction of a multistage locking/unlocking device (as previously designed) to be used in the laboratory in Pisa, in combination with an appropriate read-out system, to measure the level of disturbances resulting from unlocking the apparatus with various strengths.

Risultati parziali attesi

Testo italiano
We expect to have the results of the remaining Airbus tests and to have constructed all parts of the apparatus to be used for measuring in the laboratory the disturbances caused by unlocking.

Testo inglese
We expect to have the results of the remaining Airbus tests and to have constructed all parts of the apparatus to be used for measuring in the laboratory the disturbances caused by unlocking.

Unità di Ricerca impegnate

Unità n. 1
Unità n. 2

Fase 4

Durata e costo previsto

Durata *Mesi 6* **Costo previsto** *Euro 45.000*

Descrizione

Testo italiano
Both research groups will be involved in assembling the ground testing apparatus in vacuum and in running it in order to obtain experimental evidence of the advantages of unlocking at reduced gravity.

Testo inglese
Both research groups will be involved in assembling the ground testing apparatus in vacuum and in running it in order to obtain experimental evidence of the advantages of unlocking at reduced gravity.

Risultati parziali attesi

Testo italiano
We expect to have experimental results demonstrating that unlocking at reduced gravity will produce small enough disturbances for the GATE experiment in parabolic flight to perform an equivalence principle test a few orders of magnitude better than it was done on Earth by the similar GAL experiment performed at CERN.

Testo inglese
We expect to have experimental results demonstrating that unlocking at reduced gravity will produce small enough disturbances for the GATE experiment in parabolic flight to perform an equivalence principle test a few orders of magnitude better than it was done on Earth by the similar GAL experiment performed at CERN.

Unità di Ricerca impegnate

Unità n. 1
Unità n. 2

2.5 Criteri suggeriti per la valutazione globale e delle singole fasi

Testo italiano
The research programme has been divided in 4 phases and each phase has well defined goals. We therefore suggest that it is evaluated by looking and the fulfilment of these goals. If funded, in 2 years we should be able to obtain the following results:

-To publish a detailed high quality paper on the GATE aircraft experiment for testing the equivalence principle (e.g. on Journal such as Review of Scientific Instruments or Physical Review D).

-To perform various tests onboard the Airbus A300 zero-g aircraft allowing us to master all aspects of the actual GATE experiment (see Phase 2 and 3 for description of the proposed tests and expected results)

-To design, build and run laboratory tests of an appropriate apparatus whose measurements should demonstrate the advantages of unlocking at a reduced level of gravity, thus showing that the major limitation of the GAL experiment, performed at CERN and of which GATE is a variant in parabolic flight, can indeed be overcome.

The success or failure of the project can be assessed by assessing the achievement of these results. If achieved, the validity of the GATE proposal would be experimentally demonstrated.

Testo inglese

The research programme has been divided in 4 phases and each phase has well defined goals. We therefore suggest that it is evaluated by looking and the fulfilment of these goals. If funded, in 2 years we should be able to obtain the following results:

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The success or failure of the project can be assessed by assessing the achievement of these results. If achieved, the validity of the GATE proposal would be experimentally demonstrated.

3.1 Spese delle Unità di Ricerca

Unità di Ricerca	Voce di spesa										TOTALE
	Materiale inventariabile	Grandi Attrezzature	Materiale di consumo e funzionamento	Spese per calcolo ed elaborazione dati	Personale a contratto	Servizi esterni	Missioni	Partecipazione / Organizzazione convegni	Pubblicazioni	Altro	
Unità nº 1	*15.000*	*0*	*13.000*	*5.000*	*50.000*	*27.000*	*17.000*	*8.000*	*0*	*15.000*	150.000
Unità nº 2	*12.000*	*0*	*10.000*	*0*	*36.000*	*0*	*2.000*	*0*	*0*	*0*	60.000
TOTALE	**27.000**	**0**	**23.000**	**5.000**	**86.000**	**27.000**	**19.000**	**8.000**	**0**	**15.000**	**210.000**

3.2 Costo complessivo del Programma di Ricerca

Unità di Ricerca	Voce di spesa					
	RD	RA	RD+RA	Cofinanziamento di altre amministrazioni	Cofinanziamento richiesto al MIUR	Costo totale del programma
Unità n. 1	*0*	*45.000*	*45.000*	*0*	*105.000*	*150.000*
Unità n. 2	*1.000*	*17.000*	*18.000*	*0*	*42.000*	*60.000*
TOTALE	**1.000**	**62.000**	**63.000**	**0**	**147.000**	**210.000**

	Euro
Costo complessivo del Programma	*210.000*
Fondi disponibili (RD)	*1.000*
Fondi acquisibili (RA)	*62.000*
Cofinanziamento di altre amministrazioni	*0*
Cofinanziamento richiesto al MIUR	*147.000*

(per la copia da depositare presso l'Ateneo e per l'assenso alla diffusione via Internet delle informazioni riguardanti i programmi finanziati e la loro elaborazione necessaria alle valutazioni; legge del 31.12.96 n° 675 sulla "Tutela dei dati personali")

Firma _____ Data 31/03/2004 ore 18:55

PROGETTO DI UNA UNITA' DI RICERCA - MODELLO B
Anno 2004 - prot. 2004023138_001

1.1 Tipologia del programma di ricerca

Interuniversitario

Aree scientifico disciplinari

Area 02: Scienze fisiche (%)

1.2 Durata del Programma di Ricerca

24 Mesi

1.3 Coordinatore Scientifico del Programma di Ricerca

NOBILI ***ANNA MARIA*** ***nobili@dm.unipi.it***

FIS/05 - Astronomia e astrofisica

Università di PISA

Facoltà di SCIENZE MATEMATICHE FISICHE e NATURALI

Dipartimento di MATEMATICA

1.4 Responsabile Scientifico dell'Unità di Ricerca

NOBILI ***ANNA MARIA***

Professore Associato ***10/09/1949*** ***NBLNMR49P50C969U***

FIS/05 - Astronomia e astrofisica

Università di PISA

Facoltà di SCIENZE MATEMATICHE FISICHE e NATURALI

Dipartimento di MATEMATICA

050/2213252	***050/2213224***	***nobili@dm.unipi.it***
(Prefisso e telefono)	*(Numero fax)*	*(Email)*

1.5 Curriculum scientifico del Responsabile Scientifico dell'Unità di Ricerca

Testo italiano
Nata 10.9.49. Studente della Classe di Scienze della SNS di Pisa per due anni. Laurea in Fisica (110/110 e lode, 1973). Perfezionanda della SN; Titolare di Contratto di Ricerca, Universita'di Bologna; Ricercatore, Universita'di Pisa; Professore Associato Confermato, Università di Pisa (titolare dei Corsi: Elementi di Meccanica Celeste, Meccanica Spaziale, Dinamica desl sistema Terra/Luna). Ricerca in: Fisica Fondamentale a terra e nello spazio, Dinamica del Sistema Solare, Geodesia Spaziale.

Lavori pubblicati: piu' di cento, su riviste internazionali con referees e nei rendiconti di congressi nazionali e internazionali. Libri: uno in geodesia spaziale in lingua inglese. Ha partecipato a panel ESA/NASA per lo studio di missioni spaziali di fisica fondamentale. E' stata Principal Investigar di una missione considerata per il volo da parte dell'ASI nell'ambito del programma di piccole misisoni dell'Agenzia, ora abbandonato. E' responsabile in INFN dell'esperimento GGG per la verifica del principio di equivalenza a terra e nello spazio. Ha lavorato all'estero presso: Cornell University, USA; Glasgow University, UK; Queen Mary College, London; Observatoire de Meudon, Paris, France. Ha sviluppato una pagina web all'indirizzo: http://eotvos.dm.unipi.it/nobili/homenobili.html (circa 350 MB di informazione) che contiene materiale relativo ai progetti di ricerca, articoli scientifici, rapporti di ricerca, testi di conferenze specialistiche e divulgative, foto dell'apparato sperimentale, materiale di convegni promossi (1998 "The Fundamentals of Gravity: Measuring Big G and Testing the Equivalence Principle on Earth and in Space"; 2002 "Experiments on the equivalence principle: from Earth to space probing General Relativity" http://eotvos.dm.unipi.it/nobili/workshop2002). Un CD-Rom della pagina Web e' disponibile e viene largamente diffuso. Svolge attivita' di divulagazione scientifica e di "public outreach" quando richiesta da reti televisive o radiofoniche nazionali.

Testo inglese
Born September 10, 1949. Student at Scuola Normale Superiore in Pisa (Science Class) for 2 years; Laurea degree in Physics (full marks cum laude, 1973). Fellow at Scuola Normale; Reserach fellow at University of Bologna; Researcher at University of Pisa; Associate Professor at University of Pisa (Courses on Celestial Mechanics, Space Mechanis, Dynamics of the Earth/Moon System). Research in: Fundamental Physics on Earth and in Space, Dynamics of the Solar System; Space Geodesy. Published papers: more than one hundred, on international journals with referees and proceedings of national and international conferences. Books: one, in English. Former member of ESA/NASA science teams of space missions in Fundamental Physics. Principal Investigator (PI) of a small satellite space project investigated by ASI (Agenzia Spaziale Itlaiana) within its small mission programme. PI within INFN (Istituto Nazionale di fisica Nucleare) of the GGG experiment to test the equivalence principle on earth and in space Has worked abroad for several years at: Cornell University USA; Glasgow University, UK; Queen Mary College, London; Observatoire de Paris, Meudon France. Has set up a webpage at the address:http://tycho.dm.unipi.it/nobili/homenobili.html (about 350 MegaByte worth of information) with material on her research projects, publications, description and images of the ongoing GGG experiment for testing the Equivalence Principle, material on Workshops she has organized ((1998 "The Fundamentals of Gravity: Measuring Big G and Testing the Equivalence Principle on Earth and in Space"; 2002 "Experiments on the equivalence principle: from Earth to space probing General Relativity" http://eotvos.dm.unipi.it/nobili/workshop2002). The webpage is available on CD for iunterested scientists. Carryes out public reach activity on request by national TV and radio networks.

1.6 Pubblicazioni scientifiche più significative del Responsabile Scientifico dell'Unità di Ricerca

1. *NOBILI A.M.; BRAMANTI D.; COMANDI G.L.; TONCELLI R.; POLACCO E. (2003).* ***A rotating differential accelerometer for testing the equivalence principle in space: results from laboratory tests of a ground prototype*** *NEW ASTRONOMY. (vol. 8 pp. 371-390) http://eotvos.dm.unipi.it/nobili/ggg/GGG_NA_2003.pdf.*
2. *NOBILI A.M.; D. BRAMANTI; G.L. COMANDI; R. TONCELLI; E. POLACCO; M.L. CHIOFALO (2003).* ***"Galileo Galilei-GG": design, requirements, error budget and significance of the ground prototype*** *PHYSICS LETTERS A. (vol. 318 pp. 172-183)*
3. *G.L. COMANDI; NOBILI A.M.; R. TONCELLI; M.L. CHIOFALO (2003).* ***Tidal effects in space experiments to test the equivalence principle: implications on the experiment design*** *PHYSICS LETTERS A. (vol. 318 pp. 251-269)*
4. *NOBILI A.M.; BRAMANTI D.; COMANDI G.; TONCELLI R.; POLACCO E.; CATASTINI G. (2001).* ***Radiometer effect in space missions to test the equivalence principle*** *PHYSICAL REVIEW D. (vol. 63 pp. 1-3) http://eotvos.dm.unipi.it/nobili/ggweb/radiometer/radiometer.pdf.*
5. *NOBILI A.M. (2001).* ***Precise gravitation measurements on Earth and in space: tests of the Equivalence Principle*** *In T.J. QUINN; S. LESCHIUTTA; P. TAVELLA EDS. Proceedings of the International School of Physics "Enrico Fermi", Course CXLVI: Recent Advances in Metrology and Fundamental Constants. vol. CXLVI pp. 609-652 (http://eotvos.dm.unipi.it/nobili/publications/varenna.pdf). AMSTERDAM: IOS (NETHERLANDS)*

1.7 Risorse umane impegnabili nel Programma dell'Unità di Ricerca

1.7.1 Personale universitario dell'Università sede dell'Unità di Ricerca

Personale docente

nº	Cognome	Nome	Dipartimento	Qualifica	Settore Disc.	Mesi Uomo	
						1° anno	2° anno
1.	*NOBILI*	*Anna Maria*	*Dip. MATEMATICA*	*Prof. Associato*	*FIS/05*	*11*	*11*
2.	*POGGIANI*	*Rosa*	*Dip. FISICA*	*Ricercatore*	*FIS/01*	*11*	*11*

					Universitario			
3.	*MENGALI*	*Giovanni*	*Dip. INGEGNERIA AEROSPAZIALE*		*Prof. Associato*	*ING-IND/03*	*4*	*4*
	TOTALE						**26**	**26**

Altro personale

Nessuno

1.7.2 Personale universitario di altre Università

Personale docente

Nessuno

Altro personale

Nessuno

1.7.3 Titolari di assegni di ricerca

nº	Cognome	Nome	Dipartimento	Data di inizio del contratto	Durata(in anni)	Mesi Uomo	
						1° anno	2° anno
1.	*COMANDI*	*Gian Luca*	*Dip. MATEMATICA*	*01/05/2003*		*4*	
TOTALE						**4**	**0**

1.7.4 Titolari di borse

Nessuno

1.7.5 Personale a contratto da destinare a questo specifico programma

Qualifica	Costo previsto	Mesi Uomo 1° anno	2° anno	Note
Altre tipologie	*50.000*	*11*	*11*	*Si richiede un posto di ricercatore a contratto*
TOTALE	**50.000**	**11**	**11**	

1.7.6 Personale extrauniversitario indipendente o dipendente da altri Enti

nº	Cognome	Nome	Nome dell'ente	Qualifica	Mesi Uomo 1° anno	2° anno
1.	*Polacco*	*Erseo*	*INFN e Ex-Universita' di Pisa (in pensione)*	*Professore ordinario*	*9*	*9*
2.	*Di Virgilio*	*Angela*	*INFN*	*Primo Ricercatore INFN*	*3*	*3*
3.	*Lucchesi*	*David*	*CNR*	*Ricercatore art. 36*	*5*	*5*
4.	*Rossi*	*Alessandro*	*CNR*	*Ricercatore*	*5*	*5*
5.	*Labardi*	*Massimiliano*	*INFM*	*Ricercatore a contratto*	*6*	*6*
	TOTALE				**28**	**28**

2.1 Titolo specifico del programma svolto dall'Unità di Ricerca

Testo italiano
Un esperimento di Galileo differenziale per la verifica del principio di equivalenza: vantaggi del volo parabolico, prove di laboratorio e su Airbus A-300 a "zero-g"

Testo inglese
A differential Galileo mass-dropping experiment to test the Equiavelnce Principle: advantages of parabolic flight, ground tests and flight tests onboard Airbus A-300 "zero-g" aircraft

2.2 Settori scientifico-disciplinari interessati dal Programma di Ricerca

FIS/05 - Astronomia e astrofisica
FIS/01 - Fisica sperimentale
ING-IND/03 - Meccanica del volo

2.3 Parole chiave

Testo italiano
PRINCIPIO DI EQUIVALENZA ; MISURE DI PICCOLE FORZE ; MISURE DIFFERENZIALI ; ESPERIMENTI IN ASSENZA DI PESO ; CORPO RIGIDO E MECCANICA DI PRECISIONE ; MECCANICA DEL VOLO

Testo inglese
EQUIVALENCE PRINCIPLE ; SMALL FORCE MEASUREMENTS ; DIFFERENTIAL MEASUREMENTS ; EXPERIMENTS IN "ZERO-G" ENVIRONMENT ; RIGID BODY AND HIGH-PRECISION MECHANICS ; FLIGHT MECHANICS

2.4 Base di partenza scientifica nazionale o internazionale

Testo italiano
The existence of new forces which may be composition dependent whereby violating the Equivalence Principle has been hinted since a long time. However, it has been only quite recently (Damour, Piazza and Veneziano, Phys. Rev. D 66, 046007, 2002; Phys. Rev. Lett. 89, 081601-1, 2002) that a possible violation of Equivalence has been suggested at a level that can be tested with experiments only slightly more sensitive than the best torsion balance experiments performed so far (Roll, Krotkov and Dicke, Ann. Phys. 26 442 1964; Braginsky and Panov, Sov. Phys. JEPT 34 463,1972; Baeßler et al. Phys. Rev. Lett. 83 3585,1999). Since a violation of the Equivalence Principle would produce a differential effect, the torsion balance has proved to be a very suitable instrument because of being an instrument inherently differential. However its disadvantage is that, the test masses being suspended, most of the local gravitational acceleration from the Earth is not available for the test, but only its small horizontal component. The famous Galileo-type mass dropping experiments, in which the driving signal is given by the full local gravitational acceleration, have in fact been abandoned since Galileo himself, in favor of pendula and -ever since the work of Roland von Eotvos- of the torsion balance, because they were not differential experiments. A differential Galileo-type mass dropping experiment named GAL was devised at the University of Pisa in 1986 (Cavasinni et al., Phys. Lett. A 116 157, 1986) and completed at CERN in 1992 (Carusotto et al., Phys. Rev. Lett. 69 1722, 1992) in order to test the Equivalence Principle by testing the universality of free fall. The free falling mass was a disk made of two half disks of different composition; a violation of Equivalence would produce an angular acceleration of the disk around its symmetry axis, which was measured with a modified Michelson interferometer. The GATE -"Galileo Airborne Test of Equivalence" experiment proposed here is a variant of that experiment to be performed in parabolic flight on-board the "Airbus A300 Zero-g" aircraft of the European Space Agency. The main advantages of GATE with respect to GAL are the longer time of free fall and the absence of weight in the final stage of unlocking. The longer time of fall makes the signal almost 500 times stronger and allows a spurious linear growth of the rotation angle to be separated out. More importantly, unlocking at zero-g can significantly reduce spurious angular accelerations of the disk due to inevitable imperfections in the locking/unlocking mechanism which turned out to be the limiting factor in GAL. A preliminary estimate indicates that GATE should be able to achieve a sensitivity in the fractional relative free fall acceleration of about 10^-13, an improvement by about 3 orders of magnitude with respect to GAL and by about 1 order of magnitude with respect to the best result obtained with a slowly rotating torsion balance (Baeßler et al. Phys. Rev. Lett. 83 3585,1999). Ground tests of the read-out and of the locking/unlocking disturbances can be carried out prior to the aircraft experiment.

Testo inglese
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2.4.a Riferimenti bibliografici

V.B. Braginsky and V.I. Panov, Sov. Phys. JEPT, Vol. 34, pp. 463-466 (1972)

V. Cavasinni, E. Iacopini, E. Polacco, G. Stefanini, Phys. Lett. A 116, 157 (1986)

S. Carusotto, V. Cavasinni, A. Mordaci, F. Perrone, E. Polacco, E. Iacopini, G. Stefanini, Phys. Rev. Lett. 69 1722-1725 (1992)

S. Baeßler, B.R. Heckel, E.G. Adelberger, J.H. Gundlach, U. Schmidt, H.E. Swanson, Phys. Rev. Lett. 83 3585 (1999)

T. Damour, F. Piazza, G. Veneziano, Phys. Rev. D 66, 046007 (2002)

T. Damour, F. Piazza, G. Veneziano, Phys. Rev. Lett. 89, 081601-1 (2002)

A.M. Nobili et al., "Galileo Airborn Test of Equivalence-GATE", draft, March 2003

2.5 Descrizione del programma e dei compiti dell'Unità di Ricerca

Testo italiano

The GATE experiment proposed here is a variant in parabolic flight of the GAL experiment proposed by scientists at the University of Pisa in 1986 and completed at CERN in 1992 (PRL 69 1722-1725, 1992) with a sensitivity of about 10^-10. GATE can therefore fully exploit the considerable expertise gained with the GAL experiment. Moreover, the research unit at the University of Pisa enjoys the collaboration of Professor E. Polacco, who plaid a major role in GAL and has accepted to be part of the unit. Professor Polacco will in particular bring his expertise on the modified Michelson interferometer used to measure the angular acceleration of the disk around its symmetry axis (the expected signal), on the best way to measure rotations of the disk around the other two azes, as well as on the measurements of the absolute rotations of the vacuum chamber with respect to which the rotations of the disk are measured. Professor E. Iacopini, also co-author of the GAL experiment, has accepted to provide all his calcultaions on the dynamic and design of the bi-material disk, as well as on the data analysis of the Michelson interferometer, and to be available for consulation and advice.

Spurious rotations of the disk (relative to the vacuum chamber) around two orthogonal axes in the plane perpendicular to the symmetry axis of the disk can be measured with a position sensitive detector (e.g. like PSD S2044 by Hamamatsu) together with a laser, attached to the chamber, and a small mirror mounted on the plane of the disk. The absolute rotation of the vacuum chamber in all 3 degrees of freedom (relative to inertial space) can be measured with 3 gyroscopes based on the Sagnac effect. The main idea behind GATE is that, since GAL was limited specifically by locking/unlocking disturbances, while in GATE the vacuum chamber is in free fall together with the disk, a final stage of unlocking can take place at a very reduced level of gravity, hence reducing its perturbations on the apparatus considerably. This because it can be convincingly argued that any locking/unlocking device will produce perturbations that are a fraction of its strength.

The problem of residual air inside the cabin needs attention because by acting on the outer surface of the vacuum chamber and not on the disk (the disk is unlocked during measurements), it will cause a relative motion between the two that will affect the read-out laser interferometer system, because part of it is attached to the disk (e.g. the retro-reflectors) and part to the chamber. A crude estimate gives a relative motion of about 1 cm, which would be no problem because the retro-reflectors can be larger than this size. However, a non uniform pressure on the outer surface of the vacuum chamber would produce an angular rotation relative to the disk. The amount of this rotation should be evaluated quantitatively and compared to the angular acceleration in case of a violation of equivalence to the target level. Although any rotation of the chamber is measured, one should consider the possibility of eliminating altogether any disturbance from residual air in the cabin by enclosing the vacuum chamber inside a larger one, just for shielding purposes. In doing this, the read-out being located partly on the disk and partly on the inner chamber, would be totally unaffected by air. An additional locking/unlocking system should be added, similar to the ones used for the inner chamber and the disk.

Prior to performing the experiment on-board the Airbus A300 Zero-g aircraft a GATE-like apparatus is suspended in the laboratory, inside a vacuum chamber, against local gravity and disturbances resulting from the unlocking mechanism in the horizontal plane are directly measured. The total time required for the locking/unlocking procedure onborad the aircraft as well as the effects of residual air inside the cabin can be tested in preliminary parabolic flights. The design, construction and testing of the experimental apparatus can benefit largely from the expertise acquired with the GAL experiment.

The research unit in Pisa will therefore devote its efforts in the 2 years of the project in the following directions:

-To test the perturbations of locking/unlocking dvices of various strengths. This will be done by suspending a dummy body in a vacuum chamber and releasing it in the horizontal plane with a locking/unlocking mechanism similar to the one to be used onboard the aircraft, and measuring the disturbances produced by unlocking at various strengths. A vacuum chamber already exists in the GGG lab at INFN-Pisa, which can be used after new pumps are installed. The advantage of this chamber (originally used for VIRGO tests) is that it was built rigidly connected to a heavy concrete wall in order to reduce vibration seismic noise on apparatus suspended inside the chamber.

-To perform preliminary tests onboard the Airbus A300 zero-g aircraft. The tests will be devoted: A) to measuring the release/catching procedure of the GATE apparatus (to estimate the performance and the required time; B) to measure residual air currents in the aircraft. These tests can be perormed by students at Pisa University, working in collaboration with the GATE scientists, since ESA has an official program for the use of Airbus A300 by European students.

Testo inglese

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2.6 Descrizione delle attrezzature già disponibili ed utilizzabili per la ricerca proposta con valore patrimoniale superiore a 25.000 Euro

Testo italiano

nº	anno di acquisizione	Descrizione
1.	*2003*	*Disponibilita' completa presso i laboratori INFN di Pisa (in San Piero a Grado) di un laboratorio, precedentemente utilizzato dal gruppo di VIRGO, ora dedicato specificatamente alla verifica del Principio di Equivalenza (Laboratorio GGG).*
2.	*2003*	*Disponibilita' nel laboratorio GGG di una grande camera a vuoto costruita ed usata per prove di VIRGO. La camera fu costruita solidale ad una massiccia colonna di cemento, in modo che una massa test sospesa all'interno fosse soggetta ad un basso livello di disturbi sismici. Questa proprieta' e' estremamente utile per i test di GATE. La camera necessita solo di essere rimessa in funzione con pompe appropriate.*

Testo inglese

nº	anno di acquisizione	Descrizione
1.	*2003*	*The proposing scientists have full use of an INFN laboratory in San Piero a Grado-Pisa. It was previously a VIRGO lab, and it is now specifically devoted to testing the Equivalence Principle (GGG Lab).*
2.	*2003*	*A large vacuum chamber is available in the GGG lab which was built and used by the VIRGO group. Next to the chamber and rigidly connected to it was built a very high mass concrete pillar, so that a test mass suspended inside the cahmber would be subjected to a much reduced level of seismic disturbances. This facility is extremely useful for the GATE tests. The chamber and its concrete pillar are there; it only needs to be put back to work witha ppropriate pumps.*

2.7 Descrizione delle Grandi attrezzature da acquisire (GA)

Testo italiano

Nessuna

Testo inglese

Nessuna

2.8 Mesi uomo complessivi dedicati al programma

		Numero	Mesi uomo 1° anno	Mesi uomo 2° anno	Totale mesi uomo
Personale universitario dell'Università sede dell'Unità di Ricerca		*3*	*26*	*26*	*52*
Personale universitario di altre Università		*0*	*0*	*0*	*0*
Titolari di assegni di ricerca		*1*	*4*	*0*	*4*
Titolari di borse	*Dottorato*	*0*			
	Post-dottorato	*0*			
	Scuola di Specializzazione	*0*			
Personale a contratto	*Assegnisti*	*0*			
	Borsisti	*0*			
	Dottorandi	*0*			
	Altre tipologie	*1*	*11*	*11*	*22*
Personale extrauniversitario		*5*	*28*	*28*	*56*
TOTALE		**10**	**69**	**65**	**134**

3.1 Costo complessivo del Programma dell'Unità di Ricerca

Testo italiano

Voce di spesa	Spesa in Euro	Descrizione
Materiale inventariabile	*15.000*	*Componenti meccaniche e strumentazione elettronica*
Grandi Attrezzature		
Materiale di consumo e funzionamento	*13.000*	*Materiale di laboratorio e per ufficio*
Spese per calcolo ed elaborazione dati	*5.000*	*Schede e computers per presa dati*
Personale a contratto	*50.000*	*Fondi per un fisico esperto in gravitazione sperimentale, e specificatamente in esperimenti sul principio di equivalenza. Per l'alto livello richeiste si prevede un posto di ricercatore a contratto.*
Servizi esterni	*27.000*	*Disegni ingegneristici; lavorazioni meccaniche di precisione; elettronica ad hoc*
Missioni	*17.000*	*Viaggi per scopi inerenti a questa ricerca*
Pubblicazioni		
Partecipazione / Organizzazione convegni	*8.000*	*Partecipazione e organizzazione di convegni sulla ricerca in oggetto*
Altro	*15.000*	*"Overhead" obbligatorio del Dipartimento per la gestione dei fondi piu' imprevisti*
TOTALE	**150.000**	

Testo inglese

Voce di spesa	Spesa in Euro	Descrizione
Materiale inventariabile	*15.000*	*Mechanical components and instrumentation*
Grandi Attrezzature		
Materiale di consumo e funzionamento	*13.000*	*Laboratory and office consumable*
Spese per calcolo ed elaborazione dati	*5.000*	*Cards and computers for data acquisition*
Personale a contratto	*50.000*	*Funding for a physicist with expertise in experimental gravity and specifically in tests of the equivalence principle. Due to the high level required, we foresee to open a position as temporary researcher*
Servizi esterni	*27.000*	*Construction drawings; precision mechanics manufacturing; ad hoc electronics*
Missioni	*17.000*	*Travel expenses related to this research project*
Pubblicazioni		
Partecipazione / Organizzazione convegni	*8.000*	*Participation to, and organization of, conferences on topics related to the project*
Altro	*15.000*	*Department overhead for fund managment plus small unexpected expenses*
TOTALE	**150.000**	

3.2 Costo complessivo del Programma di Ricerca

		Descrizione
Costo complessivo del Programma dell'Unità di Ricerca	*150.000*	
Fondi disponibili (RD)		
Fondi acquisibili (RA)	*45.000*	*25000 dall' Ateneo; 5000 dall'Ateneo per la funzione di coordinatore nazionale di A.M. Nobili; 15000 da INFN Sezione di Pisa*

Cofinanziamento di altre amministrazioni		
Cofinanziamento richiesto al MIUR	*105.000*	

3.3.1 Certifico la dichiarata disponibilità e l'utilizzabilità dei fondi di Ateneo (RD e RA)

SI

Occorre precisare che la quota di cofinanziamento MIUR più la quota di cofinanziamento di altre amministrazioni cofinanziatrici del Programma di Ricerca non potrà superare il 70% per programmi Interuniversitari e il 50% per programmi Intrauniversitari del costo totale ammissibile del Programma stesso.

(per la copia da depositare presso l'Ateneo e per l'assenso alla diffusione via Internet delle informazioni riguardanti i programmi finanziati e la loro elaborazione necessaria alle valutazioni; legge del 31.12.96 n° 675 sulla "Tutela dei dati personali")

Firma _____ Data 20/03/2004 ore 12:21

PROGETTO DI UNA UNITA' DI RICERCA - MODELLO B
Anno 2004 - prot. 2004023138_002

1.1 Tipologia del programma di ricerca

Interuniversitario

Aree scientifico disciplinari

Area 02: Scienze fisiche (%)

1.2 Durata del Programma di Ricerca

24 Mesi

1.3 Coordinatore Scientifico del Programma di Ricerca

NOBILI ***ANNA MARIA*** ***nobili@dm.unipi.it***

FIS/05 - Astronomia e astrofisica

Università di PISA

Facoltà di SCIENZE MATEMATICHE FISICHE e NATURALI

Dipartimento di MATEMATICA

1.4 Responsabile Scientifico dell'Unità di Ricerca

PALMONARI ***FEDERICO***

Professore Ordinario ***13/10/1939*** ***PLMFRC39R13E289N***

FIS/04 - Fisica nucleare e subnucleare

Università degli Studi di BOLOGNA

Facoltà di SCIENZE MATEMATICHE FISICHE e NATURALI

Dipartimento di FISICA

051/2095143	***051/252774***	***PALMONARI@BO.INFN.IT***
(Prefisso e telefono)	*(Numero fax)*	*(Email)*

1.5 Curriculum scientifico del Responsabile Scientifico dell'Unità di Ricerca

Testo italiano
Nato il 13.10.39 a Imola (Bo). Laureato in Fisica presso l'Universita' di Bologna il 27.2.64.
Ricercatore dell' INFN, Istituto Nazionale di Fisica Nucleare dal 66 all' 80, ha lavorato presso i Laboratori Nazionali di Frascati fino al 72 con l'anello di accumulazione ADONE, e' stato Staff Member del CERN, Centro Europeo di Ricerche Nucleari dal 73 al 78, dove ha lavorato presso gli anelli di accumulazione per protoni ISR.

Vincitore di concorso a cattedre di Fisica Generale nell'80, e' stato chiamato all'Universita' di Perugia e dall'anno accademico 82/83 all'Universita' di Bologna dove, Professore Ordinario dal 21.2.84, insegna Esperimentazioni di Fisica I.
Ha ricoperto diversi incarichi nell'INFN e nella Facolta' di Scienze. Attualmente e' direttore del Corso di Perfezionamento.
Autore di oltre 200 pubblicazioni nell'ambito della fisica sperimentale delle particelle elementari, dove si e' occupato di interazioni deboli, elettromagnetiche e forti, e' attualmente responsabile per la Sezione INFN di Bologna dell'esperimento per la ricerca di Antimateria nei Raggi Cosmici con lo spettrometro spaziale AMS.
Da dodici anni il suo interesse sperimentale si e' rivolto anche alla quarta interazione fondamentale, l'interazione gravitazionale.

Testo inglese
Federico Palmonari, born on 13.10.39 at Imola, Bologna, Italy, graduated in Physics at the Bologna University on 27.2.64.
Research staff of the Italian Institute of Nuclear Physics (INFN) from 66 to 80, he worked up to 72 at the National Laboratories in Frascati (Rome) on the electron-positron collider ADONE, and from 73 to 78, on leave from INFN, as Staff Member at the European Laboratories of CERN (Geneva) on the proton collider ISR.
Got a Chair as Professor of General Physics at the Perugia University in the academic year 80/81, now is Full Professor at Bologna University from 21.2.84, where is lecturing on Experimentation in Physics I.
Director of the Post-Graduate annual Advanced Course in Physics, he has been in charge of various duties both in INFN and in the Faculty of Sciences.
Author and co-author of more than 200 published papers in the field of experimental physics of elementary particles and their weak, electromagnetic and stong interactions he is now Bologna spoke-person of the experiment for the search of Antimatter in Cosmic Rays with the space spectrometer AMS.
In the last twelve years his interests extended to the experimental study of the gravitational interaction.

1.6 Pubblicazioni scientifiche più significative del Responsabile Scientifico dell'Unità di Ricerca

1. *BALDI P.; CAMPARI E.G.; CASULA G.; FOCARDI S.; PALMONARI F. (2001).* ***Testing Newton's inverse square law at intermediate scales*** *PHYSICAL REVIEW D. (vol. 64 (8) pp. 082001(7)) PACS number(s): 04.80.-y,85.25.-j,94.10.Jd.*
2. *ACHILLI; BALDI; CASULA; FOCARDI; PALMONARI F. (1997).* ***A geophysical experiment on the Newton's inverse square law*** *NUOVO CIMENTO. (vol. 112B pp. 775)*
3. *ACHILLI; BALDI; CASULA; PALMONARI F.; PALMONARI; ERRANI (1995).* ***A calibration system for superconducting gravimeters*** *BULLETTIN GEODESIQUE. (vol. 69 pp. 73)*

1.7 Risorse umane impegnabili nel Programma dell'Unità di Ricerca

1.7.1 Personale universitario dell'Università sede dell'Unità di Ricerca

Personale docente

nº	Cognome	Nome	Dipartimento	Qualifica	Settore Disc.	Mesi Uomo 1° anno	Mesi Uomo 2° anno
1.	*PALMONARI*	*Federico*	*Dip. FISICA*	*Prof. Ordinario*	*FIS/04*	*6*	*6*
2.	*FOCARDI*	*Sergio*	*Dip. FISICA*	*Prof. Ordinario*	*FIS/01*	*7*	*7*
3.	*LEVI*	*Giuseppe*	*Dip. FISICA*	*Ricercatore Universitario*	*FIS/04*	*6*	*6*
4.	*CAPORALONI*	*Marina*	*Dip. FISICA*	*Ricercatore Universitario*	*FIS/01*	*2*	*2*
	TOTALE					**21**	**21**

Altro personale

nº	Cognome	Nome	Dipartimento	Qualifica	Mesi Uomo 1° anno	Mesi Uomo 2° anno
1.	*Lambertini*	*Valerio*	*Dip. FISICA*	*Ass.Tecnico*	*2*	*2*
	TOTALE				**2**	**2**

1.7.2 Personale universitario di altre Università

Personale docente

Nessuno

Altro personale

Nessuno

1.7.3 Titolari di assegni di ricerca

Nessuno

1.7.4 Titolari di borse

Nessuno

1.7.5 Personale a contratto da destinare a questo specifico programma

Qualifica	Costo previsto	Mesi Uomo 1° anno	2° anno	Note
Assegnista	*36.000*	*11*	*11*	*Assegno biennale dedicato*
TOTALE	**36.000**	**11**	**11**	

1.7.6 Personale extrauniversitario indipendente o dipendente da altri Enti

Nessuno

2.1 Titolo specifico del programma svolto dall'Unità di Ricerca

Testo italiano
Verifica del principio di equivalenza debole con un accelerometro differenziale in caduta libera.

Testo inglese
Differential accelerometer test of the weal equivalence principle in a free fall experiment

2.2 Settori scientifico-disciplinari interessati dal Programma di Ricerca

FIS/01 - Fisica sperimentale
FIS/04 - Fisica nucleare e subnucleare

2.3 Parole chiave

Testo italiano
PRINCIPIO DI EQUIVALENZA DEBOLE ; MASSA INERZIALE ; MASSA GRAVITAZIONALE ; CORPO RIGIDO

Testo inglese
WEAK EQUIVALENCE PRINCIPLE ; INERTIAL MASS ; GRAVITATIONAL MASS ; RIGID BODY

2.4 Base di partenza scientifica nazionale o internazionale

Testo italiano
Attualmente il principio di equivalenza debole è verificato a livello di 10^(-12) (1). Recenti articoli teorici (2)(3) avanzano l'ipotesi che possano esistere violazioni del principio appena al di sotto dell'attuale limite sperimentale. Partendo dai risultati di un esperimento gia eseguito (4) è possibile abbassare a 10^(-13) l'attuale limite sperimentale con un esperimento di caduta in condizioni di gravità nulla.

Testo inglese
To-day the experimental tests of the weak equivalence principle set an upper limit for possible violations of the order of 10^-12 (1). Recently, some theoretical papers (2)(3) put forward the ypothesis that violations of equivalence may be present just slightly below the actual experimental limit. Taking advantage of the results obtained and published (4) by a recent free fall experiment, it is possible to build a free-fall apparatus which in zere gravity can reach a 10^-13 sensitivity to violations of the weak equivalence principle.

2.4.a Riferimenti bibliografici

(1) Baessler et al., Phys. Rev. Lett. 83, 3585, (1999).
(2) Damour et al., Phys. Rev. D66, 046007 (2002).
(3) Damour et al., Phys. Rev. Lett. 89, 081601-1 (2002).
(4) Cavasinni et al. Phys. Lett. A 116, 157 (1986) and
S. Carusotto, V. Cavasinni, A. Mordaci, F. Perrone, E.
Polacco, E. Iacopini, G. Stefanini, Phys. Rev. Lett. 69
1722-1725 (1992)

2.5 Descrizione del programma e dei compiti dell'Unità di Ricerca

Testo italiano
L'accelerometro differenziale, cuore dell'apparato sperimentale GATE,
consiste in disco composto di due semidischi di materiali diversi, in caduta libera a gravita' zero.
Il gruppo di Bologna completerà entro il 2005 lo studio della dinamica del disco e il sistema meccanico per il rilascio del disco con il minimo di perturbazioni.
Disegnera' anche un prototipo del meccanismo di sgancio da provare in laboratorio con un disco "dummy" per misurare i disturbi prodotti in
fase di sgancio in condizioni di gravita' ridotta.
Si analizzeranno anche sistemi diversi di misura delle perturbazioni prodotte durante la fase di rilascio del disco.
Entro la prima metà del 2006 verrà costruito il sistema di sgancio ed entro la fine del 2006 saranno effettuate le prove di laboratorio per dimostrare i vantaggi del rilascio del disco a gravita' zero.

Testo inglese

The core of the experimental apparatus is a disk-shaped falling body composed of two halves of different material, acting in zero gravity as a differential accelerometer.
The Bologna group will perform and complete in the year 2005 the study of the disk dynamics and the design of the mechanical system for the release of the disk with minimal perturbations.
It will also design a protoype of the realease mechanism to be tested in the laboratory, with a suspended "dummy" body, in order to measure, though not in all dimensions, the disturbances produced by unlocking in conditions of reduced gravity.
Various read-out solutions will be investigated for the measurement of such release disturbances.
The apparatus for the tests will be built in the first half of year 2006 and laboratory measurements will be performed before the end of the year to demonstrate the advantages of unlocking at "zero-g".

2.6 Descrizione delle attrezzature già disponibili ed utilizzabili per la ricerca proposta con valore patrimoniale superiore a 25.000 Euro

Testo italiano

nº	anno di acquisizione	Descrizione
1.	*1997*	*Simulatore spaziale costituito da una camera a vuoto (vuoto 10-7 mbar) cilindrica con sistema termico da -50 a +80 °C e volume utile di 0,25 metricubi circa. Sara' utilizzata per prove parziali su prototipi. Per i test completi si ricorrera' ad una camera a vuoto esistente a Pisa*

Testo inglese

nº	anno di acquisizione	Descrizione
1.	*1997*	*Thermo-vacuum chamber (about .25 cubic meters useful volume, -60 +80 degrees °C temperature range, 10-7 mbar vacuum range) for space qualification tests. Will be used for testing small prototype mechanics. Complete tests will be done in a vacuum chamber in Pisa*

2.7 Descrizione delle Grandi attrezzature da acquisire (GA)

Testo italiano

Nessuna

Testo inglese

Nessuna

2.8 Mesi uomo complessivi dedicati al programma

		Numero	Mesi uomo 1° anno	Mesi uomo 2° anno	Totale mesi uomo
Personale universitario dell'Università sede dell'Unità di Ricerca		*5*	*23*	*23*	*46*
Personale universitario di altre Università		*0*	*0*	*0*	*0*
Titolari di assegni di ricerca		*0*			
Titolari di borse	*Dottorato*	*0*			
	Post-dottorato	*0*			
	Scuola di Specializzazione	*0*			
Personale a contratto	*Assegnisti*	*1*	*11*	*11*	*22*

	Borsisti	*0*			
	Dottorandi	*0*			
	Altre tipologie	*0*			
Personale extrauniversitario		*0*			
TOTALE		**6**	**34**	**34**	**68**

3.1 Costo complessivo del Programma dell'Unità di Ricerca

Testo italiano

Voce di spesa	Spesa in Euro	Descrizione
Materiale inventariabile	*12.000*	*Acquisto di sensori, quali fotodiodi a quadrante e giroscopi e dell'elettronica associata per le misure di rotazione dei dischi*
Grandi Attrezzature		
Materiale di consumo e funzionamento	*10.000*	*Lavorazioni esterne di parti staccate di meccanica ed elettronica, acquisto di componenti elettroniche e materiale da laboratorio*
Spese per calcolo ed elaborazione dati		
Personale a contratto	*36.000*	*1 assegno di ricerca biennale*
Servizi esterni		
Missioni	*2.000*	*Viaggi e brevi soggiorni Bologna-Pisa per 2 anni*
Pubblicazioni		
Partecipazione / Organizzazione convegni		
Altro		
TOTALE	**60.000**	

Testo inglese

Voce di spesa	Spesa in Euro	Descrizione
Materiale inventariabile	*12.000*	*Sensors and associated electronics (Photodiodes, gyroscopes) for the control of disks rotation*
Grandi Attrezzature		
Materiale di consumo e funzionamento	*10.000*	*Workshop costs for custom mechanical and electrical prts, laboratory consumables and electronic components*
Spese per calcolo ed elaborazione dati		
Personale a contratto	*36.000*	*1 two-years research grant*
Servizi esterni		
Missioni	*2.000*	*Bologna-Pisa travel expenses for 2 years*
Pubblicazioni		
Partecipazione / Organizzazione convegni		
Altro		
TOTALE	**60.000**	

3.2 Costo complessivo del Programma di Ricerca

		Descrizione
Costo complessivo del Programma dell'Unità di Ricerca	*60.000*	
Fondi disponibili (RD)	*1.000*	*Fondi 60% del responsabile F.Palmonari*
Fondi acquisibili (RA)	*17.000*	*Fondi richiesti e acquisibili dall'Ateneo*
Cofinanziamento di altre amministrazioni		
Cofinanziamento richiesto al MIUR	*42.000*	

3.3.1 Certifico la dichiarata disponibilità e l'utilizzabilità dei fondi di Ateneo (RD e RA)

SI

Occorre precisare che la quota di cofinanziamento MIUR più la quota di cofinanziamento di altre amministrazioni cofinanziatrici del Programma di Ricerca non potrà superare il 70% per programmi Interuniversitari e il 50% per programmi Intrauniversitari del costo totale ammissibile del Programma stesso.

(per la copia da depositare presso l'Ateneo e per l'assenso alla diffusione via Internet delle informazioni riguardanti i programmi finanziati e la loro elaborazione necessaria alle valutazioni; legge del 31.12.96 n° 675 sulla "Tutela dei dati personali")

Firma _____ Data *(dal sistema alla chiusura della domanda)*