

# Curriculum Vitæ of Leonardo Gualtieri

## Personal Data:

Address: Università “Sapienza”, Dipartimento di Fisica,  
Piazzale A.Moro 2, 00185 Roma, Italy  
E-mail: leonardo.gualtieri@roma1.infn.it  
Telephone/Fax: +390649694247/+39064957697  
Birth: Rome, 9/10/1971  
Military Service: Civilian service (substitutive of military service) Oct. 1995 - Sept. 1996

## Research Interests:

Varios aspects of gravitational theory:  
General Relativity and Gravitational Waves (presently my main interest),  
Supergravity and String Theory, Gravity as a Gauge Theory

## Education and Research:

From Nov 2015 Associate Professor at “La Sapienza” University of Rome  
Mar 2006 - Oct 2015 Researcher at “La Sapienza” University of Rome  
Oct 2005 - Feb 2006 Enrico Fermi fellowship at “La Sapienza” University of Rome  
Jun 2005 - Sep 2005 Postdoc position (Contratto di Collaborazione Coordinata e Continuativa)  
at “La Sapienza” University of Rome  
Jun 2003 - May 2005 Postdoc position (Assegno di Ricerca) at “La Sapienza” University of Rome  
May 2001 - Apr 2003 Postdoc position (Assegno di Ricerca) at “La Sapienza” University of Rome  
Nov. 1999 - Apr. 2001 Postdoc position (Assegno di Ricerca) at Université Libre de Bruxelles  
Mar. 1997 - Oct. 1999 Ph.D. studies in Theoretical Physics at University of Turin  
Title of the Thesis: “Harmonic Analysis and Superconformal  
Gauge Theories in Three Dimensions from AdS/CFT Correspondence”  
Dec. 1995 Laurea degree in Physics (110/110 cum laude)  
at “La Sapienza” University of Rome  
Title of the Thesis: “Effetti Gravitomagnetici su Particelle Cariche”

## Teaching:

2011/2012: Undergraduate course “Fisica” for Natural Science students  
2009/2010: Undergraduate course “Relatività Generale”  
From 2007: Phd course “Buchi Neri in Relatività Generale”  
From 2003: Support teaching to various undergraduate courses  
2001/2003 Support teaching to the PhD course “Relatività Generale”

**Computing experience:**

Linux, Windows and MacOS environments, Fortran, Mathematica, Maple

**Languages spoken:**

English (fluent), French (good knowledge), Italian (mother language)

**Awards and Grants:**

From 2014:	National Coordinator of the TEONGRAV Specific Initiative of INFN
2013	National Habilitation in Theoretical Physics (Full Professor) and Astrophysics (Associate Professor)
2012	Research Grant from “Sapienza” University
2011	IRSES Grant from European Commission, within the FP7 Program
2007	“Honorable Mention” from the Gravity Research Foundation
2003	Research Grant “Progetto Giovani Ricercatori” from Italian University Ministry
1996	“Luca Branca” fellowship for recent graduates in Astrophysics
1992	“Persico” fellowship for Physics students from Accademia Nazionale dei Lincei

**Member of the organizing  
committee of the  
following Conferences:**

2013	Strong Gravity Beyond GR: from Theory to Observations Lisbon (Portugal)
2012	Problemi Attuali di Fisica Teorica Vietri sul Mare, Salerno (Italy)
2011	Numerical Relativity and High Energy Physics Madeira (Portugal)
2010	Neutron Stars as Gravitational Wave Sources Monte Porzio, Rome (Italy)

**International  
Collaborations  
Presently Active:**

Departament de Fisica Aplicada, Universitat d'Alacant (Spain)  
Department of Cosmology and Gravitation, University of Portsmouth (UK)  
Centro Multidisciplinar de Astrofisica, Universidade de Lisboa (Portugal)  
Department of Physics and Astronomy, University of Mississippi, MS (USA)  
Max Planck Institut fur Gravitaionsphysik, Potsdam (Germany)  
IOFFE Institute, St. Petersburg (Russia)

## Publication List

### Articles in refereed journals:

- R85 “Evolution of a proto-neutron star with a nuclear many-body equation of state: Neutrino luminosity and gravitational wave frequencies”  
G. Camelió, A. Lovato, L. Gualtieri, O. Benhar, J.A. Pons, V. Ferrari  
arxiv:1704.01923, Phys. Rev. D96 (2017) 043015
- R84 “Geodesic Models of Quasi-periodic-oscillations as Probes of Quadratic Gravity”  
A. Maselli, P. Pani, R. Cotesta, L. Gualtieri, V. Ferrari, L. Stella  
arXiv:1703.01472, Astrophys. J. 843 (2017) 25
- R83 “Costraining black holes with light boson hair and boson stars using epicyclic frequencies and quasiperiodic oscillations”  
N. Franchini, P. Pani, A. Maselli, L. Gualtieri, C.A.R. Herdeiro, E. Radu, V. Ferrari  
arxiv:1612.00038, Phys. Rev. D95 (2017) 124025
- R82 “Perturbed black holes in Einstein-dilaton-Gauss-Bonnet gravity: stability, ringdown, and gravitational-wave emission”  
J.L. Blázquez-Salcedo, C.F.B. Macedo, V. Cardoso, V. Ferrari, L. Gualtieri, F.S. Koo, J. Kunz, P. Pani  
arxiv:1609.01286, Phys. Rev. D94 (2016) 104024
- R81 “Testing the black hole ‘no-hair’ hypothesis”  
V. Cardoso, L. Gualtieri  
arXiv:1607.03133, Class. Quant. Grav. 33 (2016) 174001
- R80 “Spin evolution of a proto-neutron star”  
G. Camelió, L. Gualtieri, J.A. Pons, V. Ferrari  
arXiv:1601.02945, Phys. Rev. D94 (2016) 024008
- R79 “Tidal Love numbers of a slowly-spinning neutron star”  
P. Pani, L. Gualtieri, V. Ferrari  
arXiv:1509.02171, Phys. Rev. D92 (2015) 124003
- R78 “Testing general relativity with present and future astrophysical observations”  
E. Berti, E. Barausse, V. Cardoso, L. Gualtieri, *et al.*  
arXiv:1501.07274, Class. Quant. Grav. 32 (2015) 243001
- R77 “Rotating black holes in Einstein-Dilaton-Gauss-Bonnet gravity with finite coupling”  
A. Maselli, P. Pani, L. Gualtieri, V. Ferrari  
arXiv:1507.07079, Phys. Rev. D92 (2015) 083014
- R76 “Superradiant instability of the Kerr brane”  
A. Ishibashi, P. Pani, L. Gualtieri, V. Cardoso  
arXiv:1507.07079, J.H.E.P. 209 (2015) 1
- R75 “Tensor-multi-scalar theories: relativistic stars and 3+1 decomposition”  
M. Horbatsch, H.O. Silva, D. Gerosa, P. Pani, E. Berti, L. Gualtieri, U. Sperhake  
arXiv:1505.17462, Class. Quant. Grav. 32 (2015) 204001
- R74 “Exploring New Physics Frontiers Through Numerical Relativity”  
V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake  
arXiv:1409.0014, Liv. Rev. Rel. 18 (2015) 1

- R73 “Tidal deformations of a spinning compact object”  
P. Pani, L. Gualtieri, A. Maselli, V. Ferrari”  
arXiv:1503.07365, Phys. Rev. D92 (2015) 024010
- R72 “Testing gravity with quasi-periodic oscillations from accreting black holes:  
the case of the Einstein-Dilaton-Gauss-Bonnet theory”  
A. Maselli, L. Gualtieri, P. Pani, L. Stella, V. Ferrari  
arXiv:1412.3473, Astrophys. J. 810 (2015) 115
- R71 “Higher dimensional Numerical Relativity: code comparison”  
H. Witek, H. Okawa, V. Cardoso, L. Gualtieri, C. Herdeiro, M. Shibata, U. Sperhake, M. Zilhao  
arXiv:1406.2703, Phys. Rev. D90 (2014) 084014
- R70 “Rotating proto-neutron stars: spin evolution, maximum mass and I-Love-Q relations”  
G. Martinon, A. Maselli, L. Gualtieri, V. Ferrari  
arXiv:1406.7661, Phys. Rev. D90 (2014) 064026
- R69 “Quasinormal modes of superfluid neutron stars”  
L. Gualtieri, E.M. Kantor, M.E. Gusakov, A.I. Chugunov  
arXiv:1404.7512, Phys. Rev. D90 (2014) 204010
- R68 “Constraining the equation of state of nuclear matter with gravitational  
wave observations: Tidal deformability and Tidal disruption”  
A. Maselli, L. Gualtieri, V. Ferrari  
arXiv:1310.5381, Phys. Rev. D88 (2013) 104040
- R67 “Scalar, electromagnetic, and gravitational perturbations of  
Kerr-Newman black holes in the slow-rotation limit”  
P. Pani, E. Berti, L. Gualtieri  
arXiv:1304.1160, Phys. Rev. D88 (2013) 064048
- R66 “Equation-of-state-independent relations in neutron stars”  
A. Maselli, V. Cardoso, V. Ferrari, L. Gualtieri, P. Pani  
arXiv:1304.2052, Phys. Rev. D88 (2013) 023007
- R65 “Gravito-Electromagnetic Perturbations of Kerr-Newman  
Black Holes: Stability and Isospectrality in the Slow-Rotation Limit”  
P. Pani, E. Berti, L. Gualtieri  
arXiv:1304.1160, Phys. Rev. Lett. 110 (2013) 241103
- R64 “Numerical simulations of single and binary black holes in  
scalar-tensor theories: circumventing the no-hair theorem”  
E. Berti, V. Cardoso, L. Gualtieri, M. Horbatsch, U. Sperhake  
arXiv:1304.2836, Phys. Rev. D87 (2013) 124020
- R63 “Dissipation in relativistic superfluid neutron stars”  
M.E. Gusakov, E.M. Kantor, A.I. Chugunov, L. Gualtieri  
arXiv:1211.2452, Mon. Not. Roy. Astron. Soc. 428 (2013) 1518
- R62 “NR/HEP: roadmap to the future”  
V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake, *et al.*  
arXiv:1201.5118, Class. Quant. Grav. 29 (2012) 24401

- R61 “Perturbations of slowly rotating black holes: massive vector fields in the Kerr metric”  
P. Pani, V. Cardoso, L. Gualtieri, E. Berti, A. Ishibashi  
arXiv:1209.0773, Phys. Rev. D86 (2012) 104017
- R60 “Black hole bombs and photon mass bounds”  
P. Pani, V. Cardoso, L. Gualtieri, E. Berti, A. Ishibashi  
arXiv:1209.0465, Phys. Rev. Lett. 109 (2012) 131102
- R59 “On the validity of the adiabatic approximation in compact binary inspirals”  
A. Maselli, L. Gualtieri, F. Panarale, V. Ferrari  
arXiv:1205.7006, Phys. Rev. D86 (2012) 044032
- R58 “Light scalar field constraints from gravitational-wave observations of compact binaries”  
E. Berti, L. Gualtieri, M. Horbatsch, J. Alsing  
arXiv:1204.4340, Phys. Rev. D85 (2012) 122005
- R57 “Dynamics of black holes in de Sitter spacetimes”  
M. Zilhao, V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake, H. Witek  
arXiv:1204.2019, Phys. Rev. D85 (2012) 104039
- R56 “Tidal interaction in compact binaries: A post-Newtonian affine framework”  
V. Ferrari, L. Gualtieri, A. Maselli  
arXiv:1111.6607, Phys. Rev. D85 (2012) 044045
- R55 “Floating and sinking: the imprint of massive scalars around rotating black holes”  
V. Cardoso, S. Chakrabarti, P. Pani, E. Berti, L. Gualtieri  
arXiv:1109.6021, Phys. Rev. Lett. 107 (2011) 241101
- R54 “Higher-dimensional puncture initial data”  
M. Zilhao, M. Ansorg, V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake, H. Witek  
arXiv:1109.2149, Phys. Rev. D84 (2011) 084039
- R53 “Oscillations of hot, young neutron stars: Gravitational wave frequencies and damping times”  
F. Burgio, V. Ferrari, L. Gualtieri, H.-J. Schultze  
arXiv:1106.2736, Phys. Rev. D84 (2011) 044017
- R52 “Gravitational waves from extreme mass-ratio inspirals in Dynamical Chern-Simons gravity”  
P. Pani, V. Cardoso, L. Gualtieri  
arXiv:1104.1183, Phys. Rev. D83 (2011) 104048
- R51 “Structure, Deformations and Gravitational Wave Emission of Magnetars”  
L. Gualtieri, R. Ciolfi, V. Ferrari  
arXiv:1011.2778, Class. Quant. Grav. 28 (2011) 114014
- R50 “Head-on collisions of unequal mass black holes in D=5 dimensions”  
H. Witek, V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake, M. Zilhao  
arXiv:1011.0742, Phys. Rev. D83 (2011) 044017

- R49 “Black hole-neutron star coalescing binaries”  
V. Ferrari, L. Gualtieri, F. Pannarale  
Int. J. Mod. Phys. D19 (2010) 1241
- R48 “Numerical relativity for D dimensional space-times: head-on collisions of black holes and gravitational wave extraction”  
H. Witek, M. Zilhao, L. Gualtieri, V. Cardoso, C. Herdeiro, A. Nerozzi, U. Sperhake  
arXiv:1006.3081, Phys. Rev. D82 (2010) 104014
- R47 “Gravitational signature of Schwarzschild black holes in dynamical Chern-Simons gravity”  
C. Molina, P. Pani, V. Cardoso, L. Gualtieri  
arXiv:1004.4007, Phys. Rev. D81 (2010) 124021
- R46 “Structure and deformations of strongly magnetized neutron stars with twisted torus configurations”  
R. Ciolfi, V. Ferrari, L. Gualtieri  
arXiv:1003.2148, Mon. Not. Roy. Astron. Soc. 406 (2010) 2540
- R45 “Numerical relativity for D dimensional axially symmetric space-times: formalism and code tests”  
M. Zilhao, H. Witek, U. Sperhake, V. Cardoso, L. Gualtieri, C. Herdeiro, A. Nerozzi  
arXiv:1001.2302, Phys. Rev. D81 (2010) 084052
- R44 “Neutron star tidal disruption in mixed binaries: the imprint of the equation of state”  
V. Ferrari, L. Gualtieri, F. Pannarale  
arXiv:0912.3692, Phys. Rev. D81 (2010) 064026
- R43 “Threshold anomalies in Horava-Lifshitz-type theories”  
G. Amelino-Camelia, L. Gualtieri, F. Mercati  
arXiv:0911.5360, Phys. Lett. B686 (2010) 283
- R42 “Comment on ‘Kerr Black Holes as Particle Accelerators to Arbitrarily High Energy’ ”  
E. Berti, V. Cardoso, L. Gualtieri, F. Pretorius, U. Sperhake  
arXiv:0911.2243, Phys. Rev. Lett. 103 (2009) 239001
- R41 “Perturbations of Schwarzschild black holes in Dynamical Chern-Simons modified gravity”  
V. Cardoso, L. Gualtieri  
arXiv:0907.5008, Phys. Rev. D80 (2009) 064008
- R40 “Relativistic models of magnetars: the twisted-torus magnetic field configuration”  
R. Ciolfi, V. Ferrari, L. Gualtieri, J.A. Pons  
arXiv:0903.0556, Mon. Not. Roy. Astron. Soc. 397 (2009) 913
- R39 “A Semi-relativistic Model for Tidal Interactions in BH-NS Coalescing Binaries”  
V. Ferrari, L. Gualtieri, F. Pannarale  
arXiv:0801.2911, Class. Quant. Grav. 26 (2009) 125004
- R38 “ Transformation of the multipolar components of gravitational radiation under rotations and boosts”  
L. Gualtieri, E. Berti, V. Cardoso, U. Sperhake  
arXiv:0805.1017, Phys. Rev. D78 (2008) 044024

- R37 “The Return of the membrane paradigm? Black holes and strings in the water tap”  
V. Cardoso, O.J.C. Dias, L. Gualtieri  
arXiv:0705.2777, Int. J. Mod. Phys. D17, (2008) 505
- R36 “Relativistic models of magnetars: structure and deformations”  
A. Colaiuda, V. Ferrari, L. Gualtieri, J. A. Pons  
arXiv:0712.2162, Mon. Not. Roy. Astron. Soc. 385, 2080 (2008)
- R35 “Quasi-normal modes and gravitational wave astronomy”  
V. Ferrari, L. Gualtieri  
arXiv:0709.0657, Gen. Rel. Grav. 40, 945 (2008)
- R34 “New approach to the study of quasinormal modes of rotating stars”  
V. Ferrari, L. Gualtieri, S. Marassi  
arXiv:0709.2925, Phys. Rev. D76 (2007) 104033
- R33 “Unstable  $g$ -modes in proto-neutron stars”  
V. Ferrari, L. Gualtieri, J. A. Pons  
arXiv:0709:0403, Class. Quant. Grav. 24 (2007) 5093
- R32 “Quark matter imprint on gravitational waves from oscillating stars”  
O. Benhar, V. Ferrari, L. Gualtieri, S. Marassi  
astro-ph/0603464, Gen. Rel. Grav. 39 (2007) 1323
- R31 “Equilibrium configurations of fluids and their stability in higher dimensions”  
V. Cardoso, L. Gualtieri  
gr-qc/0610004, Class. Quant. Grav. 23 (2006) 7151
- R30 “Hybrid approach to black hole perturbations from extended matter sources”  
V. Ferrari, L. Gualtieri, L. Rezzolla  
gr-qc/0606059, Phys. Rev. D73 (2006) 124028
- R29 “Coupling of radial and axial non-radial oscillations of compact stars: gravitational waves from first-order differential rotation”  
A. Passamonti, M. Bruni, L. Gualtieri, A. Nagar, C. F. Sopuerta  
gr-qc/0601001, Phys. Rev. D73 (2006) 084010
- R28 “Hawking emission of gravitons in higher dimensions: non-rotating black holes”  
V. Cardoso, M. Cavaglià, L. Gualtieri  
hep-th/0512116, J.H.E.P. 0602 (2006) 021
- R27 “Black hole particle emission in higher dimensional spacetimes”  
V. Cardoso, M. Cavaglià, L. Gualtieri  
hep-th/0512002, Phys. Rev. Lett. 96 (2006) 071301
- R26 “Perturbative approach to the structure of rapidly rotating neutron stars”  
O. Benhar, V. Ferrari, L. Gualtieri, S. Marassi  
gr-qc/0504068, Phys. Rev. D72 (2005) 044028
- R25 “Relativistic  $r$ -modes and shear viscosity: regularizing the continuum spectrum”  
J.A. Pons, L. Gualtieri, J.A. Miralles, V. Ferrari  
astro-ph/0504062, Mon. Not. Roy. Astron. Soc. 363 (2005) 121

- R24 “Coupling of radial and non-radial oscillations of relativistic stars: gauge-invariant formalism”  
A. Passamonti, M. Bruni, L. Gualtieri, C. Sopena  
gr-qc/0407108, Phys. Rev. D71 (2005) 024022
- R23 “Gravitational Wave asteroseismology reexamined”  
O. Benhar, V. Ferrari, L. Gualtieri  
astro-ph/0407529, Phys. Rev. D70 (2004) 124015
- R22 “Non-adiabatic oscillations of compact stars in general relativity”  
L. Gualtieri, J.A. Pons, G. Miniutti  
gr-qc/0405063, Phys. Rev. D70 (2004) 084009
- R21 “Nonlinear  $N$ -parameter spacetime perturbations: gauge transformations”  
C. Sopena, M. Bruni, L. Gualtieri  
gr-qc/0306027, Phys.Rev. D70 (2004) 064002
- R20 “Gravitational waves from rotating proto-neutron stars”  
V. Ferrari, L. Gualtieri, J.A. Pons, A. Stavridis  
astro-ph/0409578, Class. Quant. Grav. 21 (2004) S515
- R19 “Rotational effects on the oscillation frequencies of newly born proto-neutron stars”  
V. Ferrari, L. Gualtieri, J.A. Pons, A. Stavridis  
astro-ph/0310896, Mon. Not. Roy. Astron. Soc. 350 (2004) 763
- R18 “Gravitational energy loss in high-energy particle collisions: ultrarelativistic plunge into a multidimensional black hole”  
E. Berti, M. Cavaglia, L. Gualtieri  
hep-th/0309203, Phys. Rev. D69 (2004) 124011
- R17 “Two-parameter non-linear spacetime perturbations: gauge transformations and gauge invariance”  
M. Bruni, L. Gualtieri, C. Sopena  
gr-qc/0207105, Class. Quant. Grav. 20 (2003) 535
- R16 “Non-radial oscillation modes as a probe of density discontinuities in neutron stars”  
G. Miniutti, J.A. Pons, E. Berti, L. Gualtieri, V. Ferrari  
astro-ph/0206142, Mon. Not. Roy. Astron. Soc. 338 (2003) 389
- R15 “Are Post-Newtonian templates faithful and effectual in detecting gravitational signals from neutron star binaries?”  
E. Berti, J.A. Pons, G. Miniutti, L. Gualtieri, V. Ferrari  
gr-qc/0208011, Phys. Rev. D66 (2002) 064013
- R14 “Gravitational signals emitted by a point mass orbiting a neutron star: effects of stellar structure”  
J.A. Pons, E. Berti, L. Gualtieri, G. Miniutti, V. Ferrari  
gr-qc/0111104, Phys. Rev. D65 (2002) 104021
- R13 “Gravitational signals emitted by a point mass orbiting a neutron star: a perturbative approach”  
L. Gualtieri, E. Berti, J. A. Pons, G. Miniutti, V. Ferrari  
gr-qc/0107046, Phys. Rev. D64 (2001) 104007



- R12 “Non-semisimple gaugings of  $D = 5$   $\mathcal{N} = 8$  supergravity”  
L. Andrianopoli, F. Cordaro, P. Frè, L. Gualtieri  
hep-th/0012203, Fortsch.Phys. 49, 511 (2001)
- R11 “An exotic theory of massless spin-two fields in three dimensions”  
N. Boulanger, L. Gualtieri  
hep-th/0012003, Class. Quant. Grav. 18 (2001) 1485
- R10 “Non-Semisimple Gaugings of  $D = 5$   $\mathcal{N} = 8$  Supergravity and FDA.s”  
L. Andrianopoli, F. Cordaro, P. Frè, L. Gualtieri  
hep-th/0009048, Class. Quant. Grav. 18 (2001) 395
- R9 “Inconsistency of interacting, multi-graviton theories”  
N. Boulanger, T. Damour, L. Gualtieri, M. Henneaux  
hep-th/0007220, Nucl. Phys. B597 (2001) 127
- R8 “The structure of  $\mathcal{N} = 3$  multiplets in  $AdS_4$  and the complete  $Osp(3|4) \times SU(3)$  spectrum of  $M$ -theory on  $AdS_4 \times N^{010}$ ”  
P.Frè, L.Gualtieri, P.Termonia  
hep-th/9909188, Phys. Lett. B471 (1999) 27
- R7 “ $3D$  superconformal theories from Sasakian seven-manifolds:  
new nontrivial evidences for  $AdS_4/CFT_3$ ”  
D.Fabbri, P.Frè, L.Gualtieri, C.Reina, A.Tomasiello, A.Zaffaroni, A.Zampa  
hep-th/9907219, Nucl. Phys. B577 (2000) 547
- R6 “ $Osp(\mathcal{N}|4)$  supermultiplets as conformal superfields on  $\partial AdS_4$  and the generic form of  $\mathcal{N} = \epsilon$ ,  $d = 3$  gauge theories”  
D.Fabbri, P.Frè, L.Gualtieri, P.Termonia  
hep-th/9905134, Class. Quant. Grav. 17 (2000) 55
- R5 “ $M$ -theory on  $AdS_4 \times M^{111}$ : the complete  $Osp(2|4) \times SU(3) \times SU(2)$  spectrum from harmonic analysis”  
D.Fabbri, P.Frè, L.Gualtieri, P.Termonia  
hep-th/9903036, Nucl. Phys. B560 (1999) 617
- R4 “Stellar Pulsations excited by a scattered mass”  
A.Borrelli, V.Ferrari, L.Gualtieri  
gr-qc/9901060, Phys. Rev. D59 (1999) 124020
- R3 “ $N = 8$  BPS Black Holes with  $1/2$  or  $1/4$  Supersymmetry  
and Solvable Lie Algebra Decomposition”  
G.Arcioni, A.Ceresole, F.Cordaro, R.D’Auria, P.Frè, L.Gualtieri, M.Trigiantè  
hep-th/9807136, Nucl. Phys. B542 (1999) 273
- R2 “ $N = 8$  Gauging Revisited: an Exhaustive Classification”  
F.Cordaro, P.Frè, L.Gualtieri, P.Termonia, M.Trigiantè  
hep-th/9804056, Nucl. Phys. B532 (1998) 245
- R1 “On the Perturbations of a Nonrotating Star Excited by a Massive Source.  
*I. The Matching Conditions at the Surface of the Star*”  
V.Ferrari, L.Gualtieri  
Int. J. Mod. Phys. D6, 3 (1997) 323

**Contributions to conference proceedings:**

- C19 “Black holes in Einstein-Gauss-Bonnet-dilaton theory”  
J.L.B. Salcedo *et al.*  
Ljubljana, Slovenia, September 2016  
Published in: Proceedings IAU Symposium 324, 265, 2017
- C18 “Preface by the editors”  
C. Herdeiro, E. Berti, V. Cardoso, L.C.B. Crispino, L. Gualtieri, U. Sperhake  
Belem, Brazil, September-October 2015  
Published in: Int. Journ. Mod. Phys. D25, 1602002, 2016
- C17 “Recent developments in the tidal deformability of spinning compact objects”  
P. Pani, L. Gualtieri, A. Maselli, V. Ferrari  
Belem, Brazil, September-October 2015  
Published in: Int. Journ. Mod. Phys. D25, 1641001, 2016
- C16 “Numerical Relativity and High Energy Physics: Recent Developments”  
E. Berti, V. Cardoso, L.C.B. Crispino, L. Gualtieri, C. Herdeiro, U. Sperhake  
Belem, Brazil, September-October 2015  
Published in: Int. Journ. Mod. Phys. D25, 1641022, 2016
- C15 “The Large Observatory for x-ray timing”  
M. Feroci *et al.*  
Montreal, Canada, June 2014  
Published in Proc. SPIE 9144, 91442T, 2014
- C14 “Black Hole Collisions in Asymptotically de Sitter Spacetimes”  
M. Zilhao, V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake, H. Witek  
Prague, June 2012’  
Published in Springer Proc. Phys. 157, 247, 2014
- C13 “Relativistic astrophysics at GR20”  
I. Mandel, M. Coleman Miller, *et al.*  
Warsaw, Poland, July 2013  
Published in: Gen. Rel. Grav. 46, 1688, 2014
- C12 “Spring School on Numerical Relativity and High Energy Physics (NR/HEP2)”  
V. Cardoso (ed.), L. Gualtieri (ed.), C. Herdeiro (ed.), U. Sperhake (ed.)  
Lisbon, Portugal, March 2013  
Published in: Int. Journ. Mod. Phys. A28, 22, 2013
- C11 “On the validity of the adiabatic approximation in compact binary inspirals”  
A. Maselli, L. Gualtieri, V. Ferrari  
Proceedings of the 13th Marcel Grossman Meeting (MG13), arxiv:1302.5249  
Stockholm, Sweden, July 2012
- C10 “Numerical relativity in D dimensional space-times: collisions of unequal mass black holes”  
H. Witek, V. Cardoso, L. Gualtieri, C. Herdeiro, U. Sperhake, M. Zilhao  
Proceedings of the Spanish Relativity Meeting (ERE 2010)  
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- C9 “Simulations of black holes in compactified spacetimes”  
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- C8 “Black holes in a box”  
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- C7 “Numerical relativity in higher dimensions”  
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- C6 “Relativistic  $r$ -modes and shear viscosity”  
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- C4 “Gravitational waves from neutron stars described by modern EOS”  
O. Benhar, V. Ferrari, L. Gualtieri, gr-qc/0410140  
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“Spring School in QFT and Hamiltonian Systems” Calimanesti, Romania, May 2000,  
“Quantization, Gauge Theory and Strings” Moscow, Russia, June 2000
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### **Presentations at conferences:**

- Sep 2016 22<sup>th</sup> SIGRAV Conference on General Relativity and Gravitational Waves  
Cefalù, Palermo (Italy)  
“Testing general relativity with gravitational waves and electromagnetic waves”
- Mar 2016 Problemi Attuali di Fisica Teorica  
Vietri sul Mare, Salerno (Italy)  
“Testing gravity with gravitational-wave observations”
- Feb 2016 What Next 2016  
Rome (Italy)  
“Fundamental physics with gravitational waves”
- Jun 2015 Annual NewCompStar Conference 2015  
Budapest (Hungary)  
“On the tidal Love numbers of rotating neutron stars”
- Jun 2015 One Hundred Years of Strong Gravity  
Lisbon (Portugal)  
“Accreting black holes as probes of strong-field gravity”
- Nov 2014 NewCompstar WG3 Meeting  
Lyon (France)  
“Gravitational wave emission from individual stars”
- Sep 2014 21<sup>th</sup> SIGRAV Conference on General Relativity and Gravitational Waves  
Alessandria (Italy)  
“Oscillations of neutron star and black holes in the eve of the advanced gravitational wave detectors”
- Apr 2014 Problemi Attuali di Fisica Teorica  
Vietri sul Mare, Salerno (Italy)  
“Quasi-normal modes of a relativistic superfluid neutron star”
- Apr 2014 Gravitational Physics in the Next 20 Years  
Napoli (Italy)  
“Open questions in gravitational physics”
- Mar 2014 The Structure and Signals of Neutron Stars  
Firenze (Italy)  
“On the gravitational signal from tidally deformed neutron stars in coalescing binaries”
- Jul 2013 20<sup>th</sup> International Conference of General Relativity and Gravitation (GR20)  
Warsaw (Poland)  
“Black hole motion on a non-uniform scalar field in scalar-tensor theories”
- Jul 2013 20<sup>th</sup> International Conference of General Relativity and Gravitation (GR20)  
Warsaw (Poland)  
“Quasi-normal modes of a relativistic superfluid neutron star”

- Apr 2013 VESF school on gravitational waves, neutrinos and multiwavelength electromagnetic observations: the new frontier of Astronomy  
Monte Porzio Catone, Roma (Italy)  
“Gravitational waves from neutron stars: rotation and oscillations”
- Jun 2012 Compstar 2012: the Physics and Astrophysics of Compact Stars  
Tahiti (French Polynesia)  
“Gravitational waves from compact binary inspirals and neutron star EOS: Love numbers or Love functions?”
- Apr 2012 Problemi Attuali di Fisica Teorica  
Vietri sul Mare, Salerno (Italy)  
“Stellar Oscillations of Newly Born Neutron Stars”
- Dec 2011 IV Workshop on Black Holes  
Aveiro (Portugal)  
“Gravitational wave sources in dynamical Chern-Simons gravity”
- Sep 2011 Parma Workshop on Numerical Relativity and Gravitational Waves  
Parma (Italy)  
“Tidal interaction in compact binaries: a post-Newtonian affine framework”
- May 2011 Compstar 2011: Gravitational waves and electromagnetic radiation from compact stars  
Catania (Italy)  
“Stellar oscillations of hot, young neutron stars”
- Mar 2011 Rencontres de Moriond 2011  
La Thuile, Aosta (Italy)  
“Neutron stars as gravitational wave sources”
- Sep 2010 19<sup>th</sup> SIGRAV Conference on General Relativity and Gravitational Waves  
Pisa (Italy)  
“Neutron star equation of state and gravitational wave emission: magnetars, tidal disruption, stellar oscillations”
- Jul 2010 19<sup>th</sup> International Conference of General Relativity and Gravitation (GR19)  
Mexico City (Mexico)  
“Structure and deformations of magnetars with twisted torus fields”
- Jul 2010 19<sup>th</sup> International Conference of General Relativity and Gravitation (GR19)  
Mexico City (Mexico)  
“Black hole oscillations in dynamical Chern-Simons gravity”
- Mar 2010 Problemi Attuali di Fisica Teorica  
Vietri sul Mare, Salerno (Italy)  
“Structure and deformations of magnetars with twisted torus fields”

- Jan 2010 14<sup>th</sup> Gravitational Wave Data Analysis Workshop  
 Roma (Italy)  
 “Structure and deformations of magnetars with twisted torus fields”
- Dec 2009 2<sup>nd</sup> Workshop on Black Holes  
 Lisbon (Portugal)  
 “Oscillations and stability of black holes in dynamical Chern-Simons gravity”
- Feb 2008 Neutron Star Dynamics Meeting  
 Gregynog (UK)  
 “Relativistic models of magnetars”
- Oct 2007 4<sup>th</sup> ILIAS Meeting  
 Tubinga (Germany)  
 “Stable and unstable  $g$ -modes in proto-neutron stars”
- Sep 2007 Matter at Extreme Densities and Gravitational Waves from Compact Objects  
 Trento (Italy)  
 “Relativistic models of magnetars”
- Apr 2007 Problemi Attuali di Fisica Teorica  
 Vietri sul Mare, Salerno (Italy)  
 “Unstable  $g$ -modes in proto-neutron stars”
- Dec 2006 3<sup>rd</sup> ILIAS/N6-ENTApP Meeting  
 Paris (France)  
 “Unstable  $g$ -modes in proto-neutron stars”
- Sep 2006 17<sup>th</sup> SIGRAV Conference on General Relativity and Gravitational Waves  
 Turin (Italy)  
 “Gravitational waves from oscillations of relativistic stars”
- Sep 2006 Mini-workshop “Understanding Neutron Stars”  
 Alicante (Spain)  
 “Unstable  $g$ -modes in proto-neutron stars”
- Feb 2006 3<sup>rd</sup> ILIAS Meeting  
 LNGS, Assergi (Italy)  
 “Gravitational wave asteroseismology with strange stars”
- Aug 2005 International School of Subnuclear Physics, 43<sup>th</sup> Course  
 Erice (Italy)  
 “Gravitational waves from rotating compact stars”
- Jul 2005 Albert Einstein Century International Conference  
 Paris (France)  
 “Relativistic  $r$ -modes and shear viscosity”

- Jun 2005 Hydro-MiniWorkshop of the SFB/TR7  
Tübingen (Germany)  
“Relativistic  $r$ -modes and shear viscosity”
- Apr 2005 1<sup>th</sup> Virgo-EGO Scientific Forum Meeting  
Pisa (Italy)  
“Study of the  $r$ -modes instabilities in rotating neutron stars”
- Sep 2004 16<sup>th</sup> SIGRAV Conference on General Relativity and Gravitational Waves  
Vietri sul Mare, Salerno (Italy)  
“Gravitational waves from neutron stars described by modern EOS”
- Jul 2004 17<sup>th</sup> International Conference of General Relativity and Gravitation (GR17)  
Dublin (Ireland)  
“Gravitational waves from non-adiabatic stellar oscillations”
- Apr 2004 Problemi Attuali di Fisica Teorica  
Vietri sul Mare, Salerno (Italy)  
“Gravitational waves from non-adiabatic oscillations of relativistic stars”
- Sep 2003 Advanced School and Conference on Sources of Gravitational Waves  
S.I.S.S.A., Miramare, Trieste (Italy)  
“Neutrino-transport effects on proto-NSs oscillations and on GW frequencies”
- Jul 2003 “5th Edoardo Amaldi Conference on Gravitational Waves”  
University of Pisa, Tirrenia, Pisa (Italy)  
“Gravitational waves from rotating proto-neutron stars”
- Sep. 2002 Theoretical Foundations of Sources for Gravitational Wave Astronomy of the Next Century  
University of Palma, Palma de Mallorca (Spain)  
“Gauge issues in non-linear relativistic perturbation theory with two parameters”
- Oct. 2000 The Quantum structure of Spacetime and the Geometric nature of Fundamental Interactions  
Humboldt University, Berlin (Germany)  
“Non-semisimple gaugings of  $D = 5$   $\mathcal{N} = 8$  supergravity”
- Apr. 1997 Problemi Attuali di Fisica Teorica  
Vietri sul Mare, Salerno (Italy)  
“Perturbations of a non-rotating star excited by a massive source”

## Past and Present Research Activity

My research field is gravitational theory, in its different aspects: classical general relativity (presently my main research interest), superstring theory, gravity as a gauge theory.

### Classical general relativity and gravitational waves

In the last years, I focused onto the problem of understanding gravitational wave emission from astrophysical objects. My experience in the field has mainly developed working in the group of prof. V.Ferrari. The main lines of research I have investigated in this field are the following.

- One of the most promising sources of gravitational waves is the coalescence of neutron stars, but a complete description of this process is still far from reaching. Some interesting information, however, can be derived using a perturbative approach that we have applied to study the gravitational signals emitted when a mass  $m_0$  is orbiting around a neutron star of mass  $M \gg m_0$  [R1], [R4], [C1], [R13], [R14]. This study has been carried out by assuming that the perturbations of the gravitational field and of the fluid composing the star are excited by the stress-energy tensor of a pointlike mass, solving the equations of stellar structure in general relativity perturbed to first order. This approach constitutes a progress with respect to the commonly used assumption that both stars are point-like masses, since we treat at least one of the two stars as an extended object with internal dynamics. We found that the quasi-normal modes of the star can be excited during the latest phases of the coalescence.

In [R15], by comparing the signal derived in [R13], [R14] with the postnewtonian templates commonly used in the data analysis of interferometric antennas, we have shown that when 3<sup>rd</sup> generation interferometers, very sensitive in the kHz frequency band will be available, the effects of stellar structure will need to be taken into account in the data analysis if we want to efficiently extract the signal from noise.

In [R39], [R44], [R49] we have studied the coalescence of black hole-neutron star binary systems. We have modeled such systems using a semi-analytic approach, called affine approximation, in which the star is treated as an ellipsoid, deformed by the tidal field of the black hole. In its original formulation, this approach describes the stellar orbit as a geodesic of the black hole metric, the tidal field in terms of the Riemann tensor of the black hole metric, and the internal structure of the star using Newtonian gravity. We have improved this approach by including relativistic corrections in the treatment of the stellar structure, and by describing the orbital motion with a post-Newtonian framework. With our model, we have been able to study the conditions under which the star is disrupted by the black hole tidal field before falling into the black hole; in this case, a short gamma-ray burst may form. Furthermore, we have shown that the emitted gravitational wave signal would be characterized by a cut-off frequency; if the gravitational signal is detected, the measure of the cut-off frequency would allow to estimate the neutron star radius with great accuracy, providing valuable information on the equation of state of the matter composing the star. In [R56] we have improved the model, merging in a consistent framework the post-Newtonian and the affine approaches. Our equations describe, in a unified framework, both the system orbital evolution, and the neutron star deformations. The deformations are driven by the tidal tensor, which we have expand at 1.5 post-Newtonian order. In [R59] we have applied this approach to study the dynamical evolution of the tidal tensor, assessing the validity of the widely used “adiabatic approximation”, in which it is assumed that the quadrupole tensor and the tidal tensor are proportional. We find that this approximation does not give an accurate description of the coalescence, but it allows to compute the emitted gravitational waveform with the accuracy required for present and upcoming gravitational detectors. In [R66] we found that our approach allow to determine universal relations relating the deformability of the star with its momentum of inertia, which are valid during the entire inspiral process. In [R68] we have determined how to extract information on the neutron star equation of state taking into account both the cut-off frequency in the signal from black hole-neutron star binary coalescences, and the stellar deformability.

In [R73], [R79] we have studied how the so-called “Love numbers”, which encode the deformability properties of neutron stars (or black holes), are affected by the rotation of the compact object. As a first step to compute the tidal Love numbers of a spinning compact star, we have computed the



exterior geometry of a spinning object distorted by an axisymmetric tidal field to second order in the angular momentum, finding that, in the case of black holes, the Love numbers identically vanish. We have then computed, to second order in the angular momentum, the Love numbers of neutron stars, finding that spin-tidal couplings can introduce important corrections to the gravitational waveforms of neutron star binaries approaching the merger.

- A very interesting line of research in gravitational astrophysics is the so-called “gravitational wave asteroseismology”. Compact stars like neutron stars are expected to pulsate in damped oscillations (quasi-normal modes), which are associated to the emission of gravitational waves. The detection of these signals will allow to measure the frequencies and damping times of such oscillations, which carry information on the structure of the star and on the equation of state of matter in its core. This would offer a unique opportunity to study the behaviour of matter at supranuclear density, in such extreme conditions that cannot be reproduced in a laboratory. Our uncertainty on the equation of state in neutron star interiors reflects the present lack of knowledge on the interactions among hadrons. Therefore, the detection of gravitational waves from neutron star oscillations could shed light also on the nature of hadronic interactions.

In [R16] we have studied how the quasi-normal modes of a neutron star are affected by a phase transition occurring in its core, which may occur due to pion/kaon condensation or to quark deconfinement. We found that there exists a class of gravity-modes associated with that transition, whose frequency depends on the amplitude of the density discontinuity.

A systematic study has been carried out in [R23], [C4], where several possible equations of state of nuclear matter have been considered, and the frequencies and damping times of the most relevant quasi-normal modes have been computed. We have used the most recent equations of state proposed to model matter at supranuclear densities, involving alternatively only nucleons, nucleons and hyperons, nucleons and quarks, or only quarks. We show that the identification in the spectrum of a detected gravitational signal of a sharp pulse corresponding to the excitation of the fundamental mode or of the first pressure-mode, combined with the knowledge of the mass of the star - the only observable on which we may have reliable information - would allow to gain interesting information on the composition of the inner core.

This study has been extended in [R32], by considering in more detail the possibility that what are believed to be neutron stars are instead quark stars, that is, stars constituted by deconfined quark matter. The present knowledge of the equation of state of quark matter is much smaller than that of the equation of state of nuclear matter. In [R32] we have studied systematically the parameter space of the quark star equation of state, computing the frequencies and damping times of the quasi-normal modes. We have found that a GW-detection from a candidate neutron star/quark star oscillating in its quasi-normal modes will enable us both to discriminate if it is a neutron star or a quark star, and to constrain the quark matter equation of state.

In [R53], [R85] we have studied the quasi-normal modes of hot, young neutron stars. We have employed an equation of state recently developed to describe the neutron star matter in presence of high temperature and neutrino diffusion. We have determined how the mode frequency depends on the entropy profile and the lepton composition, finding that, in the very early stages, gravitational wave emission efficiently competes with neutrino processes in dissipating the star mechanical energy residual of the gravitational collapse. In the first work, [R53], done in collaboration with F. Burgio and H.-J. Schultze, of INFN (Catania), we have employed profiles of entropy and lepton fraction at the different stages of the early neutron star evolution, which are qualitatively similar to those obtained from previous numerical simulations. In [R85] we have performed a fully consistent simulation of the neutron star evolution in the first minute after birth, solving the transport equation, and using a consistent computation of the equation of state and of the transport coefficients.

We have written a review [R35] on quasi-normal modes in stars and black holes and gravitational wave astronomy.

- Another line of research we are developing regards the perturbations of rotating stars, which are a promising source of gravitational waves. In particular, in [R19], [R20] we have studied how the frequencies and damping times of the oscillation modes of a hot, lepton-rich, rotating proto-neutron

star born in a gravitational collapse change during the first minute of life, and their dependency on the rotation rate. We have studied the secular instability of the gravity-modes, that appear in the oscillation spectrum because of the intense entropy and composition gradients that develop in the stellar interior, finding that such modes are unstable; however, the growth time of the modes is very large, and the instability is more likely to be damped by internal viscous processes rather than by gravitational wave emission. In [R70] we have studied how the rotation rate and the mass of a proto-neutron star evolve during the first minute of its life, finding that an isolated neutron star cannot reach, at the end of the evolution, the maximum values of mass and rotation rate allowed by the zero-temperature equation of state. We have also found that the universal relations among deformability, momentum of inertia and rotation-induced quadrupole moment, valid for cold, old neutron stars, are violated in hot, newly born proto-neutron stars. This work has been extended in [R80], where we have solved numerically the neutrino transport equations and, at each timestep, the structure equation of the proto-neutron star, determining the evolution of the rotation rate of the proto-neutron star during the first minute after its birth.

In [R26] we have studied, using a perturbative approach developed to third order in the angular velocity, the equilibrium structure of rapidly rotating neutron stars. As we show, our perturbative approach is as good as the numerical integration of the exact Einstein's equations, but it is much simpler, and gives a better physical insight. We have studied various astrophysically relevant quantities, like the maximum allowed rotation rate of the star, and the momentum of inertia, considering the most recent equations of state which have been proposed for neutron stars. These equilibrium structures can be taken as a starting point to study oscillations of rotating stars.

In [R34] we have developed a new method to study the oscillation modes of rapidly rotating neutron star. Indeed, all approaches present in the literature have serious problems, and such oscillations are still poorly understood. In our approach the oscillations are treated as perturbations in the frequency domain of the stationary, axisymmetric background describing a rotating star. The perturbed equations are integrated using spectral methods in the  $(r, \theta)$ -plane. We have tested our approach in the case of slowly rotating stars. Using a similar approach, in [R65,R67] we have determined, for the first time, the quasi-normal modes of a Kerr-Newman black hole (i.e., a stationary electrically charged, rotating black hole), in the limit of small rotation.

- In collaboration with the Departament de Física Aplicada, Universitat d'Alacant (Spain), we are studying the structure and oscillations of neutron stars, including more and more physical effects in our models to make them as realistic as possible.

In particular, we have been studying how dissipative effects modify the oscillation properties of a relativistic star and the corresponding gravitational wave emission. Up to now, dissipative effects have been taken into account in the relativistic theory of stellar perturbations only "a posteriori", by solving the equations for the perturbations of a perfect fluid, and then deriving the dissipative quantities in terms of such perturbations. In this way, only qualitative estimates can be given on the gravitational wave emission. To overcome this problem, we have been considering directly the equations for perturbations of a dissipative fluid. In our approach, the perturbed Einstein + hydrodynamical equations around a stationary background are studied, and the perturbed stress-energy tensor appearing in these equations describes a dissipative fluid. This approach can be applied to various physical contexts.

In [R22] we have studied non-adiabatic, non-radial perturbations of relativistic stars, by including the effects on thermal and chemical diffusion. Our results show that the frequencies and damping times of the quasi-normal modes can be substantially altered with respect to the standard, adiabatic case. These effects can have implications on the gravitational emission of newly born neutron stars and of strange stars with a superconducting core.

In [R25], [C6] we have studied the effects of viscosity to the instability of quasi-normal modes of rotating stars (in particular, the so-called  $r$ -modes), by including the effects of viscosity in the equations describing stellar perturbations. We computed the viscous damping time of the  $r$ -mode oscillations, more accurately than in previous works published in the literature. Furthermore, we found that a small amount of viscosity can regularize the equations for the  $r$ -modes, avoiding

unphysical divergences which appears using perturbation theory.

The unstable  $g$ -modes in proto-neutron stars, and their coupling with oscillatory  $g$ -modes, have been studied in [R33], where their role in supernova explosions has been analyzed.

In [R63], [R69] we have studied the effects of superfluidity on stellar oscillations. We have found a new class of modes associated with superfluidity, computing their frequencies and damping times, and we have studied under which conditions they are potentially detectable by gravitational wave interferometers.

In [R36] we have developed a relativistic model of strongly magnetized neutron stars (“magnetars”), including poloidal and toroidal magnetic fields, different possible field structures, different equations of state and masses. We have considered stationary, axisymmetric configurations, and we have determined the stellar deformation produced by the magnetic field. The solution we find crucially depends on a parameter, which represents the relative strength of toroidal and poloidal magnetic fields; for some ranges of such parameter, the interior field can be much larger than the exterior field, thus the stellar deformation (and the consequent gravitational emission) can be larger than previously expected. We have then further developed the study of stationary configurations of magnetars in [R40,R46,R51], where we have considered more realistic magnetic field configurations, with the so-called twisted-torus shape. In this configuration, the poloidal field extends throughout the entire star and in the exterior, whereas the poloidal field is confined in a torus-shaped region inside the star. There is growing evidence that this is indeed the actual configuration of magnetic field in young magnetars. We have determined the stellar deformation induced by the twisted-torus magnetic field, and estimated the corresponding gravitational wave emission.

- In collaboration with the Department of Cosmology and Gravitation of the University of Portsmouth (UK), we have been studying the fundamenta of perturbation theory in general relativity (and more generally in spacetime theories). A better understanding of perturbation theory is crucial in order to predict the features of gravitational waves emitted by astrophysical sources. In particular, we have studied  $N$ -parameter non-linear perturbation theory in general relativity [R17], [C3], [R21]. We found the general expression for gauge transformations, and a characterization for gauge invariance, at any perturbative order.

This approach can be very useful in the study of non-linear phenomena in relativistic astrophysics. We have applied it to study the coupling between radial and non-radial oscillations of a compact star, which could be very relevant for the emission of gravitational waves, due to resonance effects between these different kinds of oscillations. In [R24], [C5] we have derived the equations which describe such non-linear oscillating system, and in [R29] we have numerically integrated such equations, in the case where the non-radial oscillations are axially symmetric. We have found that this coupling can strongly enhance the emitted gravitational signal when the frequency associated to the radial oscillation is close to the frequency of one of the axial non-radial quasi-normal modes of the star.

- Another line of research is the study of the general features of Einstein’s general relativity, such as the properties of gravitational radiation or of black holes. In [R38] we have derived the transformation properties of the multipolar decomposition of gravitational radiation under rotations and boosts. Our result allows a more complete interpretation of the outcome of fully relativistic simulations of gravitational wave sources, like the simulations of black hole-black hole coalescences. We have also written a review [R81] on the no-hair hypothesis, discussing how general is the Kerr solution to describe black holes in the universe.

## Superstring Theory

During my Ph.D. studies in Turin, working in the group of prof. P.Frè. I mainly studied superstring theory.

The most promising candidate for the unification of all the fundamental interactions is the string theory, and a fundamental ingredient in string theory is supersymmetry. String theory includes supergravity, that is the supersymmetric extension of general relativity, as low energy limit. Therefore string theory (or, more precisely, the still misterious eleven dimensional  $M$ -theory, whose different perturbative limits are the string theories), inherits and incorporates all the deeper successes, problems and issues of the

theory of general relativity and of its quantization. This  $M$ -theory includes not only strings, but also extended objects of diverse dimensions, called  $p$ -branes, that play a crucial role in the understanding and in the developing of this theory.

In the first part of my Ph.D. studies, I focused on four dimensional maximal supergravity, studying its possible gaugings [R2], and its  $BPS$  saturated black hole solutions [R3]. We found the complete classification of the gauged maximally supersymmetric supergravities in four dimensions, and of the black hole solutions preserving  $1/2$  and  $1/4$  of the maximal supersymmetry in four dimensions. Afterwards, we have been studying the possible gaugings of five dimensional supergravity [R10] [R12], in the perspective of brane world theories (see below). We have found a new gauged supergravity.

It is particularly relevant the conjectured, and partially proved,  $AdS/CFT$  correspondence. According to this correspondence, there is the possibility of describing the quantum nonperturbative regime of a conformal field theory living on the worldvolume of a  $p$ -brane by means of a classical supergravity on anti De-Sitter space  $AdS_{p+2}$  in  $p+2$  dimensions. These correspondences are not only at a pure calculational level, they are correspondences between entire conceptual categories. This new field of inquiry promises to conjugate problems of nongravitational quantum field theory with problems typically gravitational, with profit of both disciplines.

My last Ph.D. year (and my Ph.D. thesis) has been devoted to an exhaustive analysis of a particular version of  $AdS/CFT$  correspondence, from the derivation of the supergravity spectrum to the construction of the dual conformal theory [R5], [R6], [R7], [R8]. In this way, we found new nontrivial evidences for the validity of the  $AdS/CFT$  correspondence.

In [R76] we have studied a new kind of instability of the Kerr brane, i.e., of the direct product between the Kerr spacetime and an  $n$ -dimensional Ricci-flat space.

### String-Inspired approaches to Gravity

In recent years, an exciting perspective has been opened by the so-called Brane World scenario, which states that we live in a four dimensional brane in a higher dimensional universe. In this model, the standard model fields live on the brane, while gravity lives in the higher dimensional space. This scenario, which is inspired from string theory and hopefully can be found to arise as an  $M$ -theory solution (the works [R10], [R12] are also in this perspective), may solve the problem of the mass hierarchy, and leads to sensible phenomenological consequences.

In the context of the Brane-World scenario, it has been suggested that, if the true energy scale for gravity is  $\sim TeV$ , it could be possible the formation of mini-black holes in high energy particle colliders. Recently I have been studying the gravitational wave emission that would arise in such an event, in which the black hole can be treated, with good approximation, as a multi-dimensional black hole, since it lives in the higher dimensional space; a first estimate is given by the gravitational emission due to a particle plunging into a multi-dimensional black hole [R18]. Furthermore, in [R27], [R28] we have studied Hawking emission in multi-dimensional black holes, computing the absorption cross-sections for gravitons and the relative emissivities and power output. In [R31], [R37] we have studied the possible analogy between black objects and fluids with surface tension in more than four dimension.

In [R45] we have developed a framework to model processes involving black holes in higher dimensions using numerical relativity, i.e. by numerical integration of the fully non-linear Einstein's equations. Using this formalism, in [R48, R50, R54, R71] we have studied head-on collision of black holes in five and six dimensional spacetimes, determining the emitted gravitational energy. Using a similar formalism, in [R57, C14] we have studied head-on collisions of black holes in an asymptotically De Sitter spacetime, in four spacetime dimensions. We have been the coordinators of a white paper on the use of numerical relativity to problems related to high energy physics [R62]. We have written a review [R74] about the use of numerical relativity beyond astrophysics (high-energy physics, tests of general relativity, etc.).

Other possible extensions of General Relativity, inspired by string theory and by other quantum theories of gravity, are Chern-Simons gravity and scalar-tensor gravity. In [R41], [R47]; we have proven the stability of spherically symmetric black holes in Chern-Simons gravity, and we have determined their

quasi-normal modes. As we have shown, detection of black hole quasi-normal modes may allow to set strong limits on the parameters which characterize Chern-Simons gravity. In [R52], we studied how the signal from an extreme mass-ratio inspiral in Chern-Simons gravity differs from the signal of the same process in General Relativity, showing that detection of such signal in the space-based gravitational detector LISA could discriminate between General Relativity and Chern-Simons gravity in a wide region of the parameter space. In [R55] we have studied how massive scalar fields couple to matter in orbit around black holes; we found that such coupling would lead to the appearance of “floating orbits”, in which an orbiting body would remain without inspiralling, extracting rotational energy from the black hole. This effect would allow to perform accurate tests of modified general relativity using space-based detectors of gravitational waves. In [R58] we have studied how gravitational wave observation could constrain the parameter space of massive scalar-tensor theory. In [R60,R61] we have studied how the existence of massive vector fields would affect astrophysical black holes. We have found that massive vector perturbations of rotating black holes are unstable; therefore, present observational data from rotating black holes exclude a wide range of possible massive vector particles. This result allowed us to set limits to the photon mass much stronger than the previously known bounds. In [R64] we have studied how single and binary black hole behave in scalar-tensor theory, assuming a non-uniform scalar field profile; we have solved numerically the fully non-linear equations describing spacetime and the scalar field, finding that in the case of a binary coalescence, a scalar field emission is present. In [R75] we have studied the behaviour of neutron stars in scalar-tensor theories with more than one scalar field. In [R72] we have studied another possible extension of General Relativity, Einstein-Dilaton-Gauss-Bonnet gravity, showing that future measurement of the quasi-periodic oscillations in the X-ray flux emitted by accreting stellar mass black holes could allow to discriminate between this theory and General Relativity. In [R77,R82] we have extended this work, finding the solution of the field equations of Einstein-Dilaton-Gauss-Bonnet (EDGB) gravity which describes black holes up to second order in the rotation rate, and to seventh order in the coupling parameter, and computing how this effect can be observed in near-future X-ray experiments. In [R83] we have studied how this astrophysical probe (quasi-periodic oscillations in the X-ray flux emitted by accreting stellar mass) can be used to discriminate Kerr black holes from “hairy” black holes, a recently discovered solution of Einstein’s equations describing stationary black holes surrounded by a light massive scalar field. In [R82,C19] we determined a subset of the quasi-normal modes of black holes in this theory, finding evidence that such black holes are linearly stable, and showing that EDGB gravity can be constrained by gravitational wave observations.

In [R43] we have studied a model of quantum gravity recently proposed by Horava, in which Lorentz invariance is broken by an anisotropic scaling, and is restored in the infrared limit. We have investigated the phenomenological consequences of this scenario, related to modifications in the dispersion relation.

We have written an extensive review [R78] on astrophysical tests of general relativity against modified theories of gravity.

### **Gravity as a gauge theory**

During my first postdoc experience, in Brussels, working in the group of prof. M.Hennaux, I mainly studied gravitational theory as a spin-two field theory.

Gauge theory techniques like BRST formulation and Batalin-Vilkovisky approach can be useful to investigate several aspects of spin-two theories, and of higher spin theories. With these techniques it is possible to work out all the possible consistent interactions among massless fields in arbitrary dimensions.

We found that, restricting ourselves to interactions with at most two derivatives and without ghosts, general relativity is the only consistent interaction of massless spin-two fields, and that cross-interactions for a collection of such fields are not allowed [R9], [C2]. However, there is an exception in  $D = 2 + 1$  case, where an “exotic” theory is allowed [R11].