

Gruppo IV di Bologna

Coordinatore (03/2020, rinnovato 03/2023): [Roberto Casadio \(UniBO\)](#)

Totale associati: 101 (88 $\Rightarrow$ 90 FTE + nuovi dottorandi in selezione)

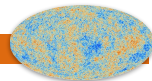
- Tutte le 6 linee di ricerca sono rappresentate nella Sezione di Bologna:
 - ① Teoria dei Campi e di Stringa: FLAG, GAST, ST&FI
 - ② Fenomenologia: Amplitudes, QFT@Collider
 - ③ Fisica Nucleare e Adronica: MONSTRE
 - ④ Metodi Matematici: Quantum
 - ⑤ Fisica Astro-Particellare: InDark, TaSP
 - ⑥ Fisica Statistica e Teoria di Campo Applicata: LINCOLN
- Ricercatori afferenti ad IS su altra sezione o non afferenti a IS
- Ricercatori con parziale afferenza ad esperimenti di altri gruppi:
 - ATLAS: Alberghi
 - RD-FCC/MUCOL: Maltoni
 - ET-Italia INFN: Casadio, Pedro, Pesci, Tronconi, Giusti

- *Responsabile nazionale:* Alessandro Tronconi (INFN)
- *Sedi partecipanti:* Bologna, Catania, Milano, Pisa, Trento, Trieste
- *Responsabile locale:* Alessandro Tronconi (INFN)
- *Personale ricercatore ed associato afferente:*
Roberto Casadio (UniBO 80%), Gabriele Gionti (esterno), **Andrea Giusti (UniBO YR24 80%)**, Alexander Kamenshchik (UniBO), Andrea Mentrelli (UniBO), Alessandro Pesci (INFN 80%), Gianmassimo Tasinato (UniBO 50%) Alessandro Tronconi (INFN 80%), Gian Paolo Vacca (INFN 20%)
Assegnista: Riccardo Martini, Max Fahn
Dottorandi: Tommaso Bambagiotti, **Polina Petriakova**
- *Attività scientifica:* Gravità quantistica, cosmologia e buchi neri
 - Teoria quantistica dei campi e gravitazione quantistica
 - Aspetti quantistici e semiclassici del collasso gravitazionale e buchi neri
 - Modelli di inflazione cosmologica, buchi neri primordiali, materia oscura, energia oscura
 - Sorgenti compatte e cosmologiche di onde gravitazionali
 - Gruppo di rinormalizzazione e sicurezza asintotica

BO members: 14 (10.6 FTE)
Tot. Papers 07/2024-25: 28
Preprints 07/2024-25: 16

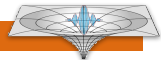
Responsabile Nazionale e locale: **Alessandro Tronconi (INFN BO)**

Cosmology and Black holes



- ▶ **R. Casadio**, R. da Rocha, **A. Giusti**, P. Meert, "Thermodynamic and configurational entropy of quantum Schwarzschild geometries", Phys.Lett.B 849 (2024) 138466
- ▶ **R. Casadio**, **A. Kamenshchik**, J. Ovalle, "From black hole mimickers to black holes", Phys.Rev.D 109 (2024) 2, 024042
- ▶ L. Gallerani, M. Miranda, **A. Giusti**, **A. Mentrelli**, "On Alternative Formulations of the Thermodynamics of Scalar-Tensor Theories", Phys. Rev. D 110, 064087 (2024)
- ▶ **G. Gionti S. J.**, M. Galaverni, "On the canonical equivalence between Jordan and Einstein frames", Eur.Phys.J.C 84 (2024) 3, 265
- ▶ **A. Tronconi**, **G. Venturi**, "An Effective Theory for Higgs Inflation", 2505.06197 [hep-ph]

Theoretical/formal aspects of (quantum) gravity

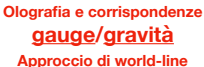


- ▶ **A. Kamenshchik** and **P. Petriakova**, "IR finite correlation functions in de Sitter space, a smooth massless limit, and an autonomous equation", JHEP 04 (2025) 127
- ▶ **R. Martini**, G. Paci, D. Sauro, **G.P. Vacca**, O. Zanusso, "Substructures of the Weyl group and their physical applications", JHEP 07 (2024) 191
- ▶ J.M. Isidro, C.F. Paganini, **A. Pesci**, "Gravitation as a statistical theory on the light cone", Class. Quantum Grav. 42 (2025) 065007

GAST - Gauge and String Theories

- *Responsabile nazionale:* Domenico Seminara (UniFI)
- *Sedi partecipanti:* Bologna, Firenze, Milano Bicocca, Parma, Perugia, Pisa, Trieste
- *Responsabile locale:* Davide Fioravanti (INFN Bologna)
- *Personale ricercatore ed associato afferente:*
 Simonetta Abenda (UniBO 50%), Fiorenzo Bastianelli (UniBO), Olindo Corradini (UniMORE), Davide Fioravanti (INFN), Rita Fioresi (UniBO), Rouven Frassek (UniMORE), Emanuele Latini (UniBO), Francesco Ravanini (UniBO), Marco Rossi (UniCa), Diego Trancanelli (UniMORE), Roberto Zucchini (UniBO)
 Assegnisti: Istavan Mate Szecsenyi
 Dottorandi: Filippo Fecit, Michela Lapenna, Francesco Olivi, Riccardo Giordana Pozzi, Thomas Martin Weber
- *Attività scientifica:*
 - Aspetti fondamentali delle Teorie di Campo Quantum, Statistiche e Particelle
 - Risultati esatti, non perturbativi e perturbativi (in esse)
 - Dualità ed equivalenze tra teorie di gauge e gravità (AdS/CFT)
 - Quantum Information theory: entanglement ed entropia
 - Teorie integrabili, di gauge e gravità (classiche e quantistiche) e loro aspetti matematici.
 - Approccio di world-line, ampiezze e anomalie quantistiche
 - Higher gauge theories
 - Olografia, loops di Wilson, istantoni, confinamento
- *External Grants:* EC Network Gatis, MIUR-PRIN contract 2017CC72MK_003, COST Action CaLISTA CA21109, CaLIGOLA MSCA-2021-SE- 01-101086123

GAuge and STring (the inner spirit of theories)



Aspetti fondamentali con svariati collegamenti fisici e metodologici: **filone di ricerca unitario, anche fuori Bologna!**
Modello Standard (teorie di gauge)+ **Gravità: metodi esatti (o quasi)**. Produttiva: circa 20+10 articoli+preprint/anno.

- **Olografia/corrispondenze tra teorie di Gauge/Gravità/Integrabilità+Integrability exact methods in physics and mathematics**: Abenda, Fioravanti, Fiorese, Frassek, Lapenna, Olivi, Rossi, Trancanelli, Weber; *Integrability, susy SU(2) matter gauge theories and black holes*; *From Painlevé equations to N=2 susy gauge theories: prolegomena*; *Conformal defects and RG flows in ABJM*.
- **Approccio di world-line a teorie di campo gravità**: Bastianelli, Corradini, Fecit, Latini; *Unified worldline treatment of Yukawa and axial couplings*.
- **Entanglement, entropia, Quantum Computation**: Ravanini, Zucchini; *Spin-s Dicke states and their preparation*; *Calibrated hypergraph states: I calibrated hypergraph and multi qudit state monads*.

ST&FI - String Theory and Fundamental Interactions

- *Responsabile nazionale:* Marialuisa Frau (UniTO)
- *Sedi partecipanti:* Bologna, Napoli, Padova, Roma 2, Torino, Trieste
- *Responsabile locale:* Michele Cicoli (UniBO)
- *Personale ricercatore ed associato afferente:*
Michele Cicoli (UniBO), Ling Lin (UniBO), Antonella Grassi (UniBO) Francisco Gil Pedro (UniBO 80%), Gianmassimo Tasinato (UniBO 50%)
Dottorandi: Luca Brunelli, Luca Caraffi, Vittorio Larotonda
- *Attività scientifica:* Fenomenologia e cosmologia di stringa
 - Compattificazioni di stringa
 - Modelli con D-brane
 - Stabilizzazione dei moduli
 - Applicazioni alla cosmologia: inflazione, dark matter e dark energy
 - Applicazioni alla fisica delle particelle: assioni e rottura della supersimmetria

ST&FI

String theory and Fundamental Interactions

Members: Michele Cicoli (PO and local coordinator)

Francisco Pedro (PA)

Ling Lin (RTDb)

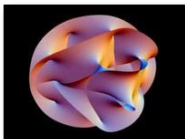
Antonella Grassi (PO Dip. Mat.)

Gianmassimo Tasinato (PA) – 50%

Luca Brunelli, Vittorio Larotonda, Luca Caraffi (PhD)

Close collaborator: Federico Carta (RTD INFN)

Research: String Phenomenology
String Cosmology



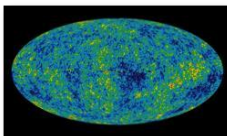
Explicit string compactifications

Chiral global embedding of Fibre Inflation with anti-D3 uplift

Cicoli, Grassi, Lacombe, Pedro
JHEP 06 (2025) 090

Deep observations of the type IIB flux landscape

Chauan, Cicoli, Krippendorff, Maharana, Piantadosi, Schachner - **Accepted by JHEP**



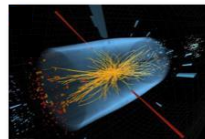
Applications to Cosmology

Loop blow-up inflation

Bansal, Brunelli, Cicoli, Hebecker, Kuespert
JHEP 07 (2024) 289

From inflation to quintessence: a history of the universe in string theory

Cicoli, Padilla, Pedro
JHEP 10 (2024) 141



Applications to Particle Physics

Phenomenology of superheavy decaying dark matter from string theory

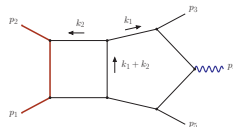
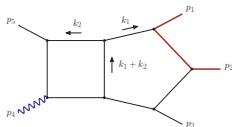
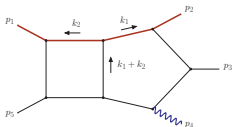
Allahverdi, Arina, Cicoli, Chianese, Maltoni, Massaro, Osinski
JHEP 02 (2024) 192

Amplitudes

- *Responsabile nazionale:* Vittorio del Duca (LNF)
- *Sedi partecipanti:* Bologna, LNF, Napoli, Padova, Roma 1, Torino
- *Responsabile locale:* Tiziano Peraro (UniBO)
- *Altri membri locali:*
 - Assegnisti: Matteo Becchetti (50%), Dhimiter Canko (50%), Vsevolod Chestnov (50%)
 - Dottorandi: Alessandro Porcari (50%), Mattia Pozzoli (50%)
- *Attività scientifica:*
 - Gauge theories
 - mathematical methods in QFT and gravity
 - multi-loop amplitudes
 - on-shell techniques

Amplitudes Highlights (sezione di Bologna)

- Computation of **two-loop integrals** for **top-pair+W boson production**
M. Becchetti, D. Canko, V. Chestnov, T. Peraro, M. Pozzoli, S. Zoia (2025)



- **Amplitudes and loop integrals** for LHC phenomenology
M. Becchetti, D. Canko, M. Pozzoli, L. Tancredi, S. Zoia et al. (2025)
 - Canonical differential equations for loop integrals in top-pair + jet production
 - One-loop corrections to top-pair + W production @ $\mathcal{O}(\epsilon^2)$
 - Two-loop amplitudes for di-photon production mediated by heavy quark loops
 - Three-loop master integrals for the production of vector bosons with different masses
- **Algebraic/Analytic** relations of Feynman integrals and multi-loop automation:
V. Chestnov, P. Mastrolia, T. Peraro et al. (2024-2025)
 - Intersection Numbers from Companion Tensor Algebra
 - Reduction to master integrals and transverse integration identities
 - Differential Space of Feynman Integrals: Annihilators and D-module
 - CALICO: Computing Annihilators from Linear Identities Constraining (differential) Operators

QFT@Collider- Teoria di Campo delle Interazioni Fondamentali e fenomenologia

- *Responsabile nazionale:* Gian Paolo Vacca (INFN Bologna)
- *Sedi partecipanti:* Bologna, Cosenza, Firenze, Milano Bicocca, Pavia
- *Responsabile locale:* Gian Paolo Vacca (INFN)
- *Personale ricercatore ed associato afferente:*
 Gian Luigi Alberghi (INFN 20%), Ilaria Brivio (UniBO 80%), Fabio Maltoni (UniBO 75%), Davide Pagani (INFN), Tiziano Peraro (UniBO,50%), Filippo Sala (UniBO 20%), Gian Paolo Vacca (INFN 80%)
 Assegnisti: **Matteo Becchetti (50%), Dhimiter Canko (50%), Vsevolod Chestnov (50%),** Lambda Pryianka
 Dottorandi: Luca Beccatini, Simone Meoni, Olimpia Miniati (80%), Alessandro Porcari (50%), Mattia Pozzoli (50%),
- *Attività scientifica:* QFT for collider Physics
 - SM and BSM phenomenology
 - Effective field theories and SMEFT
 - Higher perturbative computations and Precision Physics
 - Physics in future particle colliders (Muon, FCC, ...)
 - Small x QCD
 - RG flows and critical theories

QFT@Colliders

TEORIA DI CAMPO DELLE INTERAZIONI FONDAMENTALI
E FENOMENOLOGIA DELLA FISICA NEI COLLIDER

Staff (7), Postdocs (5), Ph.D. (5)

Papers: published (17) and preprints (19)

Multiloop
techniques and
computations

Reduction of master integrals and transverse integration identities

V. Chestnov, G. Fontana and T. Peraro, JHEP 03 (2025) 113, arXiv:2409.04783

Two loop Feynman integrals for leading color $t\bar{t}W$ production at hadron colliders

M. Becchetti, D. Canko, V. Chestnov, T. Peraro, M. Pozzoli et al., arXiv:2504.13011

Lepton/muon
colliders

Double neutral-current corrections to NLO electroweak leptonic cross sections

S. Frixione, F. Maltoni, D. Pagani, M. Zaro, arXiv:2506.10732

Precision phenomenology at multi-TeV muon colliders

S. Frixione, F. Maltoni, D. Pagani, M. Zaro, arXiv:2506.10733

EW corrections and heavy boson radiation at a high-energy muon collider

Y. Ma, D. Pagani, M. Zaro, Phys. Rev D11 (2025) 053002

EFT

Jet bundle geometry of scalar field theories

M. Alminawi, I. Brivio, J. Davighi, J. Phys. A 57 (2024) 435401

Electroweak corrections in the SMEFT: four fermion operators at high energies

H. El Faham, K. Mimasu, D. Pagani, C. Severi, E. Vryunidou, JHEP 06 (2025) 241, arXiv:2412.16076

BSM probes

Top-quark pair production as a probe of light top-philic scalars and anomalous Higgs interactions

F. Maltoni, D. Pagani, S. Tentori, JHEP 09 (2024) 098, arXiv: 2406.06670

Quantum
information
at collidersQuantum properties of $H \rightarrow VV^*$: precise predictions in the SM and sensitivity to new physics

M. Del Gratta, F. Fabbri, P. Lamba, F. Maltoni, D. Pagani, arXiv: 2504.03841

Quantum tops at circular lepton colliders

F. Maltoni, C. Severi, S. Tentori, E. Vryunidou, JHEP 09 (2024) 001, arXiv: 2404.08049

MONSTRE - Teorie microscopiche di sistemi a molti corpi fortemente interagenti

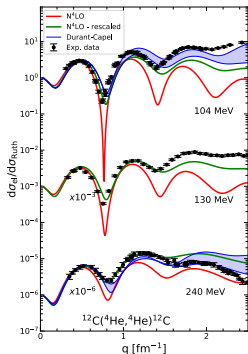
- *Responsabile nazionale:* Danilo Gambacurta (LNS)
- *Sedi partecipanti:* Bologna, Catania, Milano, Napoli, Padova, Trento
- *Responsabile locale:* Paolo Finelli (UniBo)
- *Personale ricercatore ed associato afferente:* Paolo Finelli (UniBo)
- *Attività scientifica:* Fisica nucleare (struttura e reazioni)
 - QCD a bassa energia ed interazioni nucleari
 - Struttura nucleare ed eccitazioni collettive dei nuclei
 - applicazioni nel settore astrofisica (stelle neutroni)

Iniziativa Specifica **MONSTRE**

Paolo Finelli (local coordinator)

**Modeling Nuclear
Structure and Reactions**

Long-term strategy: **Ab-initio** Nuclear Reactions



to be submitted to PRL (2004)

Inelastic Nucleon-Nucleus scattering ◀

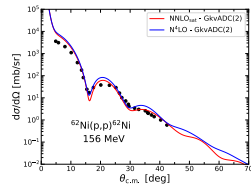
(Work in progress)

Nucleus-Nucleus scattering ◀

(Work in progress)

Transfer reactions ✗

FRAGMENTATION



PRC (2004), Editor's suggestion

Quantum

- *Responsabile nazionale:* Stefano Mancini (UniCAM)
- *Sedi partecipanti:* Bari, Bologna, Camerino, Catania, Milano-Como, Napoli-Salerno, Padova, Palermo, Trento TIPFA, Trieste.
- *Responsabile locale:* Elisa Ercolessi (UniBo)
- *Personale ricercatore ed associato afferente:*
 Staff: Cristian Degli Esposti Boschi (CNR 50%), Elisa Ercolessi (UniBo), Pierbiagio Pieri (UniBo), Lorenzo Piroli (UniBo)
 Assegnisti: David Gyorgy Szasz-Schagrin, Leonardo Pisani (UniBo)
 Dottorandi: Pietro Bovini, Marko Brnovic, **Riccardo Cioli**, David Aram Korbany, Matteo Grotti, Francesco Pirolo
- *Attività scientifica:* Progetti principali su Teoria Quantistica dei Molti Corpi
 - QUANTHEM - ERC Starting Grant 2023 (Lorenzo Piroli)
 - Quantum Computing Solutions for High Energy Physics (QUANTERA)
 - Quantum Computing for Data Analysis (Int. Foundation Big Data and Artificial Intelligence)
 - Hamiltonian evolution of the dynamics of QCD-inspired field theory models (INFN-CERN-IBMQ)

IS QUANTUM - Sezione di Bologna**QUANTUM MANY BODY THEORIES, QUANTUM COMPUTATION and INFORMATION THEORY**

- Effetti quantistici macroscopici: transizioni di fase quantistiche (miscele bosoniche/fermioniche; fasi topologiche)
- Simulazioni quantistiche di sistemi fuori dall'equilibrio; Circuiti quantistici e automi cellulari quantistici
- Simulazioni quantistiche di teorie di campo su reticolo; algoritmi quantistici e ibridi per problemi di ottimizzazione

PUBBLICAZIONI

B.Vermersch et al., PRX 14, 031035 (2024)

E.Vernier et al., PRL133, 050606 (2024)

M. Fava et al., PR Res. 6, 043246 (2024)

J. D'Alberto et al., PRA **109**, 053302 (2024)V. Piselli et al., Condensed Matter **9**, 41 (2024)

C. Sanavio et al., Entropy 26, 345 (2024)

C. Sanavio et al., IEEE Trans. Quantum Eng. 5, 2500712 (2024)

D. Pomarico et al., Entropy 27, 427 (2025)

R. Cioli et al., Quantum 9, 1698 (2025).

F.Ares et al., PRD 110, L061901 (2024)

L. Piroli et al., PRL133, 230401 (2024)

L. Pisani et al., Results in Physics **57**, 107358 (2024)L. Pisani et al., PRB **110**, L100506 (2024)

S. Pradhan et al., PRB 108, 064410 (2024)

E. Ercolessi et al., IJGMMP 21, 2440011 (2024).

F. Caleca et al., Entropy 27, 199 (2025)

L. Pisani et al., SciPost Physics **18**, 076 (2025)

F. Hübner et al., SciPost Physics 18, 135 (2025)

InDark - Inflazione, Materia Oscura e Strutture su Grandi Scale dell'Universo

- *Responsabile nazionale:* Massimiliano Lattanzi (UniFE)
- *Sedi partecipanti:* Bologna, Ferrara, Genova, Laboratorio Nazionale del Gran Sasso, Milano, Padova, Roma II, Torino, Trieste, Parma
- *Responsabile locale:* Marco Baldi
- *Personale ricercatore ed associato afferente:*
Marco Baldi (UniBO 80%), Carlo Burigana (INAF 50%), Giulia Despali (UniBO), Stefano Ettori (INAF 50%), Fabio Finelli (INAF 40%), Carlo Giocoli (INAF 50%), Federico Marulli (UniBO), Massimo Meneghetti (INAF 50%), Lauro Moscardini (UniBO), Daniela Paoletti (INAF 50%), Mauro Sereno (INAF 50%) Tiziana Trombetti (INAF 50%)

Assegnisti:

Giovanni Aricò (Assegno INFN-InDark), Adam Bengt Johansson Andrews

All members involved in the ESA mission **Euclid**, partial participation to **LiteBIRD** Joint Study Group, partial participation to **Einstein Telescope** Cosmology Division.



INDARK

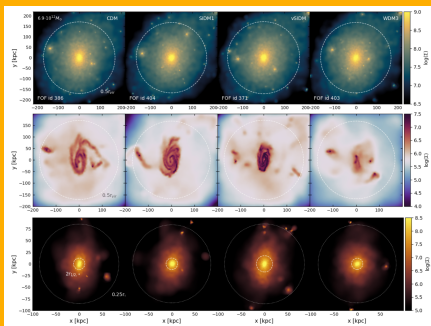
Inflation, Dark Matter, and the LSS of the Universe



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



G.Despali et al. (incl. L. Moscardini): "Introducing the AIDA-TNG project: Galaxy formation in alternative dark matter models"

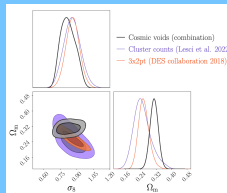


Mass, gas, and stellar distributions in simulated Milky-Way size halos for standard CDM and different alternative DM particle candidates

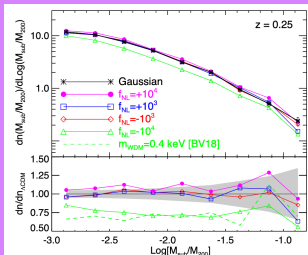
M. Baldi et al. (incl. L. Moscardini), "Cosmological simulations of scale-dependent primordial non-Gaussianity"

The variation of the abundance of Dark Matter satellite halos for different models of scale-dependent primordial non-Gaussianity

S.Contarini et al. (incl. F. Marulli, L. Moscardini, M. Baldi)
"The perspective of voids on rising cosmology tensions"



Constraints on cosmological parameters using cosmic voids in the BOSS DR12 release



TAsP - Theoretical Astroparticle Physics

- *Responsabile nazionale:* Eligio Lisi (BA)
- *Sedi partecipanti:* Bari, Bologna, Ferrara, Lecce, LNF, LNGS, Napoli, Padova, Pisa, Pavia, Roma I, Torino, Trieste
- *Responsabile locale:* Silvia Pascoli (UniBO)
- *Personale ricercatore ed associato afferente:*
Enrico Bertuzzo (UniMORE), Ilaria Brivio (UniBO 20%), Michele Lucente (UniBO), Silvia Pascoli (UniBO 90%), Filippo Sala (UniBO 80%), **Xabier Marcano (UniBO YR24)**
Assegnista: Alessandro Granelli, Salvador Rosauo Alcaraz (INFN)
Dottorandi: Giovanni De Marchi, Elina Merkel, **Jacopo Nava**
- *Attività scientifica:*
 - Fisica dei neutrini
 - Fisica astroparticellare oltre il Modello Standard

TASP: Neutrino and astroparticle theory and pheno

From low energies (dark sectors)

to GUT scales

eV keV MeV GeV TeV Intermediate scale GUT scale

1. Rich dark sectors,
HNL searches, DM

2. Baryon asymmetry and GW at
multiple scales

1. **Dark sectors:** subGeV DM as an explanation of 511 keV line (2410.16379) and of HE neutrino events due to DM scattering around blazars (2412.07861, 2506.06416) in coll. with students A. De Marchi and J. Nava; DM tests in white dwarfs (2410.13908) by student J. Hoefken Zink; signals at NA62 (2406.17599); MicroBooNE first search of rich dark sectors via mono-photons (2502.10900); dark photon DM EFT (2406.14437).
2. **Neutrinos:** COSMOLOGY: Impact of massive neutrinos on large scale structure formation and its interplay with dark energy in collaboration with ICC (2403.12967, 2407.10965); interplay between DM and see-saw (2503.20017); sterile neutrino portals (2412.10101); modular symmetry protected see-saw (2505.21405).
3. **Baryogenesis and leptogenesis:** ALP induced leptogenesis via NR from ALP decays (2407.01667); leptogenesis scale from neutrino masses and neutrino less double beta decay (2502.10093).
4. **Phase transitions:** Explanation of NANOGrav via a GeV scale supercooled phase transition (2501.15649).
5. **GUTs and GW:** Connection between domain walls and GW signals (2409.16359).
6. multiple **DUNE papers** as members of the DUNE collaboration.

- 4 seniors, 1 ricercatore TASP, Salvador Rosauero-Alcaraz, 4 PhD students (A. De Marchi, J. Hoefken Zink, E. Merkel, J. Nava).
- 1 PhD thesis: Dark sectors as an approach to BSM searches. From terrestrial experiments to astrophysical ones, by J. Hoefken Zink.
- EuCAPT Director (S. Pascoli).
- Coordination of Horizon2020 ITN HIDDEN with over 200 scientists (S. Pascoli, coordinator).
- Horizon Europe Staff Exchange ASYMMETRY (S. Pascoli, Local PI).
- Collaboration/discussions with DUNE/ICARUS experimental team at Bologna and with KM3Net, NA64 and MicroBooNE.

LINCOLN - Statistica e Dinamica su Reti Complesse

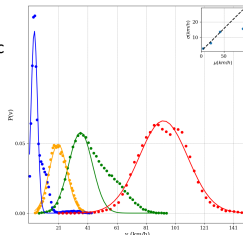
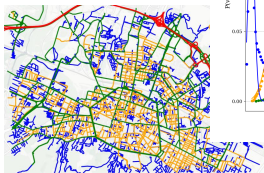
- *Responsabile nazionale:* Enzo Orlandini (UniPD)
- *Sedi partecipanti:* Bologna, Cosenza, Firenze, Padova, Perugia, Catania
- *Responsabile locale:* Armando Bazzani (UniBO)
- *Personale ricercatore ed associato afferente:*
 Armando Bazzani (UniBo), Mirko Degli Esposti (uniBO), Marco Lenci (UniBO),
 Daniel Remondini (UniBO 20%)
 Assegnisti: Mattia Radice
 Federico Capoani (ATLAS)
 Dottorandi: Gregorio Berselli, Aldo Canfora, **Giulio Colombini**, Filippo Dalla,
Lorenzo di Meco, Tommaso Rondini
- *Attività scientifica:*
 - The aim of this project is to develop theoretical tools (i.e. stochastic dynamical systems, spectral methods, inhomogeneous mean-field approaches, topological methods, renormalization group ideas) for Complex Systems Physics and Non-equilibrium Statistical Physics.
 - Bologna group: Applying non-linear dynamical theory to complex systems and developing dynamical models on graphs for transport and neural systems. Extending the Entropy concept to explain biological and social systems

Connection with PNRR and Bologna Digital Twins projects and third mission activities of Theoretical Physics

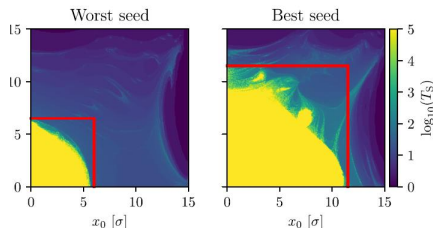
Lincoln project: dynamical and complex systems

resp. A. Bazzani

Multilayer structure of traffic
in Bologna (TIM dataset)



Chaos indicator for LHC magnetic lattices



- 1) Chaos indicators for nonlinear dynamics in circular particle accelerators CE Montanari, RB Appleby, A Bazzani, A Fornara, M Giovannozzi, ... The European Physical Journal Plus 140 (6), 1-23 2025
- 2) Measurement of the nonlinear diffusion of the proton beam halo at the CERN LHC CE Montanari, RB Appleby, A Bazzani, M Giovannozzi, P Hermes, ... The European Physical Journal Plus 140 (1), 86 2025
- 3) A probabilistic phenotype dynamical model for sympatric speciation: some properties and numerical results A Bazzani, R D'Ambrosio, P Freguglia, E Venturino Journal of Biological Systems 32 (04), 1427-1439, 2024
- 4) Congestion transition on random walks on graphs L Di Meco, M Degli Esposti, F Bellisardi, A Bazzani Entropy 26 (8), 632 2024

Altre attività di ricerca

- *Membri afferenti a IS in altra sezione*

Roberto Balbinot (UniBO) **QUAGRAP-TS**

Si è studiata l'emissione di radiazione di Hawking in buchi neri acustici formati da condensati di Bose-Einstein nel caso in cui ci sia una regione sonica estesa che divide quella supersonica da quella sonica. Questo "allargamento" dell'orizzonte produce un'attenuazione del segnale che risulta inoltre modulato.

D. Penalver, M. De Vito, R. Balbinot and A. Fabbri, "Acoustic black holes in BECs with an extended sonic region", Phys. Rev. D (2025) in stampa.

- *Personale ricercatore associato non afferente a IS:*

Paolo Pasini (INFN senior)

Marco Carta (PNRR YR24 Carta)

Attività affine alla IS ST&FI.

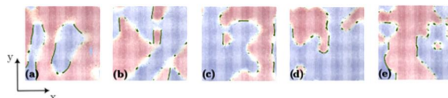
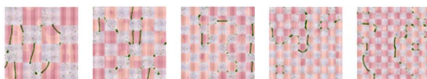
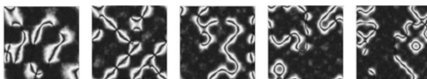
Personale affiliato scientificamente attivo:

Cesare Chiccoli, Giovanni Venturi

Computer simulations of anisotropic systems (C. Chiccoli and P. Pasini)

We considered a nematic liquid crystal film confined to a flat cell with homeotropic and planar-patterned hybrid anchoring, similar to a chessboard pattern, with alternating square domains featuring uniform and random anchoring, respectively. By employing Monte Carlo simulations, we have been able to demonstrate the system's capability to stabilize line and point defects. We have observed that the interplay between domain size, anchoring conditions, and system size plays a crucial role in determining the types of defects that emerge. For smaller domain sizes (up to 40×40 spins), point defects with $\pm 1/2$ topological charge can be observed alongside line defects, while for larger domains, we only observe line defects at the domain corners. Point defects tend to annihilate in pairs or move towards regions with uniform alignment anchoring. Line defects, on the other hand, tend to persist for longer simulation times and can even close themselves to annihilation. Anchoring strength at the bottom surface has a significant influence on defect behavior. Stronger anchoring leads to the formation of defect lines deeper in the bulk of the system rather than just at the surface. These deeper defects are characterized by being located several layers above the surface and can be connected to surface-aligned domains.

In conclusion, our extensive simulations of liquid crystal systems within different domain sizes and anchoring strengths have provided valuable insights into the formation and behavior of topological defects. In particular, our findings give us a clear picture of how defects form and behave in liquid crystal systems, helping us understand how different factors influence defect behavior. These findings should be valuable for designing and manipulating liquid crystal systems for various applications from displays to advanced materials.



An example of the effects of size domain on defect line position for $\tau=4$ (a), 6 (b), 8 (c), 10 (d), and 12 (e), with different coupling at the bottom (0.7) and at the top (0.5). Defects completely placed on the surface as, for instance, those marked in last line, are observed in (d) and (e), although in all values, the small line in the domain corner are also placed in surface. Defects placed above the surface, in the bulk, are observed in all values of τ .

C. Chiccoli et al., Point and Line Defects in Checkerboard Patterned Hybrid Nematic Films. A Computer Simulation Investigation
(DOI: <https://doi.org/10.1103/PhysRevE.110.014704>)

Collaborations:

Universities of Maringà and Apucarana (Brazil)

University of Ljubljana (Slovenia)

Gruppo IV in Sezione

Necessità del Gruppo Teorico: stesse degli anni passati (ma stiamo ancora aumentando...).

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grazie a [Antonella Aiello](#) e [Elisa Zini](#)
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 - 2) post-doc stranieri in convenzione con UniBO (2026 ?)
 - 3) supporto organizzazione eventi.