



**SEDUTA DEL COLLEGIO DEI DOCENTI DEL 39°-40°-41°-42° CICLO
06 ottobre 2026**

Il Collegio dei Docenti del Dottorato di Ricerca in Scienze Fisiche e Chimiche dell'Università di Palermo, dei cicli 39, 40, 41 e 42, regolarmente convocato dal Coordinatore Prof. Marco Cannas, si riunisce alle ore 14:30 del giorno 06.10.2026 con il seguente ordine del giorno:

- 1) Esame finale di conseguimento del titolo di Dottore di Ricerca del 39° ciclo (I° sessione)**
- 2) Cotutela Università degli Studi di Palermo/Université Paris Cité: proposta per la composizione della commissione dell'esame finale dell'allievo Andrea DAMONTE**
- 3) Riconoscimento titolo di Dottorato conseguito all'estero**
- 4) Provvedimenti allievi: autorizzazione periodi all'estero**
- 5) Ratifica decreti**

Presiede il Coordinatore Prof. M Cannas, svolge le funzioni di segretario il Prof. Simonpietro Agnello.

Sono presenti

Marco Cannas, Simonpietro Agnello, Fabio Bagarello, Gianpiero Buscarino, Angelo Carolo, Maria Rita Calvino, Giuseppe Cavallaro, Francesco Ciccarello, Umberto De Giovannini, Tiziana Di Salvo, Francesco Ferrante, Francesco Giannici, Giuseppe Lazzara, Lorenzo Lisuzzo, Fabrizio Lo Celso, Gabriele Lo Monaco, Salvatore Lorenzo, Manuela Mallamaci, Giovanni Marsella, Fabrizio Messina, Marco Miceli, Loreta Angela Muscarella, Gioacchino Massimo Palma, Mauro Paternostro, Alberto Pettignano, Fabio Reale, Lucia Rizzuto, Alice Sciortino, Davide Valenti, Serena Benatti, Giuseppina Micela, Ciro Pinto, Antonino D'Ai, Melania Del Santo.

Sono assenti giustificati

Leonardo Abbene, Luciano Burderi, Antonino Buttacavoli, Dario Duca, Claudio Fazio, Rosario Iaria, Luca Innocenti, Salvatore Miccichè, Stefana Milioto, Paolo Pagano, Roberto Passante, Michelangelo Scopelliti

Sono inoltre presenti

Elena Ambrosi, Antonino Petralia, Salvatore Colombo

in qualità di cotutor.

Il Presidente, prof. M. Cannas, verificato il numero legale, dichiara aperta la seduta

1) Esame finale di conseguimento del titolo di Dottore di Ricerca del 39° ciclo (I° sessione)

Il presidente illustra gli adempimenti necessari per il conseguimento del titolo di dottore di ricerca per gli allievi del 39° ciclo che intendono sostenere l'esame finale nella prima sessione (15 Novembre – 19 Dicembre 2026).

In accordo al cronoprogramma, il presente collegio dei docenti dovrà occuparsi dei seguenti punti:
- formulazione della relazione del dottorando sulle attività svolte



- formulazione del parere per il titolo di Doctor Europaeus
- proposta di formazione delle commissioni giudicatrici
- nomina dei valutatori esterni

Simone ARTINI

(Tutor: Prof. Salvatore Lorenzo; Co-Tutor: Prof. Mauro Paternostro)

Il collegio prende visione della relazione dell'allievo (**allegato 1 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

- | | |
|----------------------------|-----------------------------------|
| 1) Prof. Angelo Carollo | Università degli Studi di Palermo |
| 2) Prof. Andrea Smirne | Università degli Studi di Milano |
| 3) Prof. Giacomo Guarnieri | Università degli Studi di Pavia |

Membri supplenti

- | | |
|----------------------------|-----------------------------------|
| Prof. Francesco Ciccarello | Università degli Studi di Palermo |
| Prof. Bassano Vacchini | Università degli Studi di Milano |

Il collegio nomina i **valutatori esterni**:

- 1) Alessio Serafini, University College London
email: a.serafini@ucl.ac.uk
- 2) Stefano Gherardini, CNR-INO Firenze e LENS-Università degli Studi di Firenze
email: stefano.gherardini@cnr.it; stefanogherardini@gmail.com



UNIVERSITÀ DEGLI STUDI DI PALERMO
DOTTORATO DI RICERCA IN SCIENZE FISICHE E CHIMICHE

Alessandro ROMANCINO

(Tutor: Prof. Gioacchino Massimo Palma)

Il collegio prende visione della relazione dell'allievo (**allegato 2 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

- | | |
|----------------------------|-----------------------------------|
| 1) Prof. Angelo Carollo | Università degli Studi di Palermo |
| 2) Prof. Andra Smirne | Università degli Studi di Milano |
| 3) Prof. Giacomo Guarnieri | Università degli Studi di Pavia |

Membri supplenti

- | | |
|----------------------------|-----------------------------------|
| Prof. Francesco Ciccarello | Università degli Studi di Palermo |
| Prof. Bassano Vacchini | Università degli Studi di Milano |

Il collegio nomina i **valutatori esterni**:

- 1) Prof.ssa Chiara Macchiavello, Università di Pavia
email: chiara.macchiavello@unipv.it
- 2) Prof.ssa Maria Luisa Chiofalo, Università di Pisa
email: marilu.chiofalo@unipi.it



UNIVERSITÀ DEGLI STUDI DI PALERMO
DOTTORATO DI RICERCA IN SCIENZE FISICHE E CHIMICHE

Valerio FARDELLA

(Tutor: Dott.ssa Serena Benatti, Cotutor: Dott. Antonino Petralia)

Il collegio prende visione della relazione dell'allievo (**allegato 3 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

- | | |
|-----------------------------------|--|
| 1) Prof. Marco Miceli | Università degli Studi di Palermo |
| 2) Dott.ssa Loredana Prisinzano | INAF – Osservatorio Astronomico di Palermo |
| 3) Dott. Antonino Francesco Lanza | INAF – Osservatorio Astrofisico di Catania |

Membri supplenti

- | | |
|--------------------------|--|
| Prof. Fabio Reale | Università degli Studi di Palermo |
| Dott. Ignazio Pillitteri | INAF – Osservatorio Astronomico di Palermo |

Il collegio nomina i **valutatori esterni**:

- 1) Dott.ssa Monica Rainer, INAF - Osservatorio Astronomico di Merate
email: monica.rainer@inaf.it
- 2) Dott. Gaetano Scandariato, INAF - Osservatorio Astrofisico di Catania.
email: gaetano.scandariato@inaf.it



UNIVERSITÀ DEGLI STUDI DI PALERMO
DOTTORATO DI RICERCA IN SCIENZE FISICHE E CHIMICHE

Gabriele GALLETTA

(Tutor: Dott.ssa Giuseppina Micela, Cotutor: Dott. Salvatore Colombo)

Il collegio prende visione della relazione dell'allievo (**allegato 4 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

- | | |
|-----------------------------------|--|
| 1) Prof. Marco Miceli | Università degli Studi di Palermo |
| 2) Dott.ssa Loredana Prisinzano | INAF – Osservatorio Astronomico di Palermo |
| 3) Dott. Antonino Francesco Lanza | INAF – Osservatorio Astrofisico di Catania |

Membri supplenti

- | | |
|--------------------------|--|
| Prof. Fabio Reale | Università degli Studi di Palermo |
| Dott. Ignazio Pillitteri | INAF – Osservatorio Astronomico di Palermo |

Il collegio nomina i **valutatori esterni**:

- 1) Dott. Jorge Sanz Forcada, Centro de Astrobiología (CSIC-INTA), Madrid, Spagna
email: jsanz@cab.inta-csic.es
- 2) Prof. Ignasi Ribas: Institute of Space Sciences of the Spanish Research Council, Barcellona, Spagna
email: iribas@ice.csic.es; iribas@ice.cat



UNIVERSITÀ DEGLI STUDI DI PALERMO
DOTTORATO DI RICERCA IN SCIENZE FISICHE E CHIMICHE

Alessandro LO BIANCO

(Tutor: Prof. Giuseppe Cavallaro, Cotutor: Prof. Giuseppe Lazzara, Prof.ssa Magdalena Broda)

Il collegio prende visione della relazione dell'allievo (**allegato 5 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

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|--------------------------------|-----------------------------------|
| 1) Prof. Francesco Ferrante | Università degli Studi di Palermo |
| 2) Prof.ssa Daniela Meroni | Università degli Studi di Milano |
| 3) Prof.ssa Kinga Pielichowska | University of Krakow |

Membri supplenti

- | | |
|----------------------------------|-----------------------------------|
| Prof. Giuseppe Domenico Arrabito | Università degli Studi di Palermo |
| Prof. Alberto Pettignano | Università degli Studi di Palermo |

Il collegio nomina i **valutatori esterni**:

- 1) Prof. Arnon Chaipanich, Chiang Mai University, Department of Physics and Materials Science, Thailand
email: arnon.chaipanich@cmu.ac.th
- 2) Prof.ssa Giuliana Gorrasi, Università degli Studi di Salerno, Dipartimento di Ingegneria Industriale.
email: ggorrasi@unisa.it



Dimitrios Kostantinos MANIADAKIS

(Tutor: Dott. Antonino D'Ai, Cotutor: Dott.ssa Elena Ambrosi)

Il collegio prende visione della relazione dell'allievo (**allegato 6 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

- | | |
|------------------------|--|
| 1) Prof. Rosario Iaria | Università degli Studi di Palermo |
| 2) Prof. Andrea Sanna | Università degli Studi di Cagliari |
| 3) Prof. Andrea Tiengo | Istituto Universitario di Studi Superiori di Pavia |

Membri supplenti

- | | |
|--------------------------|---|
| Dott. Ciro Pinto | INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo |
| Dott. Giancarlo Cusumano | INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo |

Il collegio nomina i **valutatori esterni**:

- 1) Dott.ssa Domitilla De Martino, Osservatorio di Napoli
email: domitilla.demartino@inaf.it
- 2) Dott. Gianluca Israel, Osservatorio di Roma
email: gianluca.israel@inaf.it



UNIVERSITÀ DEGLI STUDI DI PALERMO
DOTTORATO DI RICERCA IN SCIENZE FISICHE E CHIMICHE

Claudia MARAVENTANO

(Tutor: Prof.ssa Tiziana Di Salvo, Cotutor: Dott. Giancarlo Ghirlanda, Dott.ssa Lara Nava)

Il collegio prende visione della relazione dell'allievo (**allegato 7 al verbale**).

Il collegio propone che la commissione giudicatrice per l'esame finale sia composta da:

Membri effettivi

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|---------------------------------|--|
| 1) Prof. Rosario Iaria | Università degli Studi di Palermo |
| 2) Prof.ssa Elisabetta Bissaldi | Politecnico di Bari – INFN |
| 3) Dott. Fabrizio Fiore | INAF – Osservatorio Astronomico di Trieste |

Membri supplenti

- | | |
|------------------------|--|
| Prof. Marco Miceli | Università degli Studi di Palermo |
| Dott. Ruben Salvaterra | INAF – Istituto di Astrofisica Spaziale e Fisica Cosmica di Milano |

Il collegio nomina i **valutatori esterni**:

- 1) Prof.ssa Annalisa Celotti, Scuola Internazionale Superiore di Studi Avanzati, Trieste (Italy),
email: annalisa.celotti@sissa.it
- 2) Diego Gotz, Service d'Astrophysique (AIM) – CEA/DSM/Irfu, Saclay (France)
email: diego.gotz@cea.fr



2) Cotutela Università degli Studi di Palermo / Université Paris Cité:

proposta per la composizione della commissione dell'esame finale dell'allievo Andrea DAMONTE

Il coordinatore comunica che l'allievo **Andrea DAMONTE** ha completato il percorso di dottorato in cotutela fra Università degli Studi di Palermo / Université Paris Cité, svolgendo una tesi dal titolo "*M-dwarf XUV flares and their impact on hydrogen-water exoplanet atmospheres. The Proxima Centauri system*" sotto la supervisione di Prof. Antonio Garcia Muñoz (Université Paris Cité) e Dott.ssa Giuseppina Micela (INAF – Osservatorio Astronomico di Palermo)

L'esame finale si svolgerà presso Ormes des Merisiers, CEA Saclay - Gif sur Yvett (France), entro la fine del 2026. La proposta di composizione della commissione giudicatrice segue l'accordo di cotutela siglato fra le due Università

Membri effettivi

- 1) **Prof. Fabio Reale**, Università degli Studi di Palermo
- 2) **Prof. Antoine Strugarek**, Université Paris Cité
- 3) **Dott.ssa Sandrine Vinatier**, Université PSL
- 4) **Dott. Pierre Drossart**, Sorbonne Université
- 5) **Prof. Antonio Garcia Muñoz**, Université Paris Cité
- 6) **Dott.ssa Giuseppina Micela**, INAF – Osservatorio Astronomico di Palermo
- 7) **Prof. Beate Stelzer**, University of Tübingen
- 8) **Prof. ssa Antonija Oklopčič**, University of Amsterdam

Il collegio, **all'unanimità, approva** la proposta di commissione

3) Riconoscimento titolo di dottorato conseguito all'estero (Dott. Oleh Petruk)

Il presidente comunica di avere ricevuto una nota da

U.O. Foreign students and qualification recognition – Immatricolazione studenti e verifica titoli accademici stranieri

per il riconoscimento accademico del titolo di Dottore di Ricerca conseguito all'estero.

Tale nota invita il Collegio dei Docenti a stabilire se i documenti del **Dott. Oleh Petruk**, nato a Lviv (Ucraina) il 02/02/1971, siano ritenuti corrispondenti al Dottorato in Scienze Fisiche e Chimiche dell'Università degli Studi di Palermo.

A tale fine, il presidente riassume i requisiti previsti dalle "Linee Guida per il riconoscimento accademico dei titoli esteri di Dottorato di Ricerca in Italia", emanate dal CIMEA nel mese di Luglio 2022.

"Ai fini della valutazione del titolo estero di dottorato per il rilascio diretto del titolo italiano



di Dottorato di Ricerca (i), il titolo estero dovrà sempre rispettare tutte le seguenti caratteristiche:

- (i) essere titolo ufficiale di terzo ciclo di dottorato del sistema estero di riferimento, rilasciato da una istituzione ufficiale del sistema estero;
- (ii) conferire i medesimi diritti accademici nel sistema estero di riferimento;
- (iii) presentare i medesimi elementi di natura e disciplinari del titolo italiano corrispondente in termini di durata, natura di ricerca e modalità di ottenimento;
- (iv) deve esistere un titolo di Dottorato di Ricerca nel medesimo settore con cui si possa comparare il titolo estero, sia per tipologia che per ambito disciplinare.”

Il presidente espone la documentazione presentata dal Dott. Oleh Petruk, che è in possesso dei seguenti titoli accademici:

- Laurea Specialistica in Fisica, conseguita il 28/06/1993, presso l'Università Statale di Lviv (Ucraina)
- Dottorato di Ricerca in Scienze Fisico-Matematiche (specializzazione in Astrofisica, Radioastronomia) conseguito in data 27/06/2000 presso Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv (Ucraina) presentando una tesi dal titolo «*Hydrodynamic simulations of supernova remnant evolution in non-uniform medium* »

Il collegio dei docenti,

- vista la nota inviata da U.O. Foreign students and qualification recognition – Immatricolazione studenti e verifica titoli accademici stranieri

per il riconoscimento accademico del titolo di Dottore di Ricerca conseguito all'estero;

- esaminata la documentazione presentata dal Dott. **Dott. Oleh Petruk**, nato a Lviv (Ucraina) il 02/02/1971, in possesso del titolo di Dottorato di Ricerca in Scienze Fisico-Matematiche (specializzazione in Astrofisica, Radioastronomia) conseguito in data 27/06/2000 presso Main Astronomical Observatory, National Academy of Sciences of Ukraine, Kyiv (Ucraina) presentando una tesi dal titolo *Hydrodynamic simulations of supernova remnant evolution in non-uniform medium*;

accerta la coerenza sotto il profilo scientifico-disciplinare del percorso di formazione e di ricerca del titolo estero con il Dottorato di Ricerca in Scienze Fisiche e Chimiche;

pertanto, **delibera all'unanimità** il riconoscimento e il rilascio diretto del Dottorato di Ricerca estero conseguito dal Dott. **Oleh Petruk**.

4) Provvedimenti Studenti: Autorizzazione di permanenza all'estero per un periodo non inferiore a 6 mesi dell'allieva Marta Giuseppina EBBREO

Il presidente comunica di aver ricevuto da parte dell'allieva Marta Giuseppina EBBREO (XL ciclo) la richiesta di autorizzazione per recarsi in missione presso:

Istituto di Scienza e Nanomateriali dell'Università di Zaragoza – Spagna

dal 19 ottobre 2026 al 19 aprile 2027, per un periodo complessivo non inferiore a 6 mesi (180 giorni).

Durante il periodo all'estero, l'allieva Marta Giuseppina EBBREO svolgerà attività di ricerca inerente al suo progetto di ricerca.

Il collegio approva all'unanimità



5) Ratifica decreti

Il coordinatore comunica che per motivi di urgenza, ha emanato i seguenti decreti:

Decreto del 17/09/2026

Oggetto: Ciclo di lezioni dal titolo “Advanced Soft Matter”; CoRI 2026 (Azione D1)

Proponente: Prof. Emanuele Marino

Studioso straniero: Prof. KODGER Thomas Edward

Decreto del 17/09/2026

Oggetto: Ciclo di lezioni dal titolo “Quantum chaos in non-Hermitian systems»; CoRI 2026 (Azione D3)

Proponente: Dott. Federico Roccati

Studioso straniero: Prof. Shinsei Ryu

Il Collegio dei Docenti, **all'unanimità, approva** la ratifica dei decreti.

Il verbale è approvato seduta stante. La seduta si chiude alle ore 15:50.

Il Presidente

Prof. Marco Cannas

Il Segretario

Prof. Simopietro Agnello



Allegato 1

PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Simone Artini

Transcript of Records

Tutor: Prof. Salvatore Lorenzo

Cotutor: Prof. Mauro Paternostro

Courses/school/exam scores:

- Agent-based models – Prof. Micciché
- Quantum Information Theory – Prof. Paternostro
- Open Quantum Systems and Quantum Machine Learning – Prof. Lorenzo, Dr. Innocenti

Research and training periods abroad

Research visit at ITP Ulm, from 20/04/2026 to 26/08/2026, supervised by Prof. Susana F. Huelga

Papers published:

- Simone Artini and Mauro Paternostro. "Characterizing the spontaneous collapse of a wavefunction through entropy production." *New Journal of Physics* 25, 123047 (2023). DOI: 10.1088/1367-2630/ad153a. arXiv: 2310.12675 [cond-mat.stat-mech].
- Simone Artini, Gabriele Lo Monaco, Sandro Donadi and Mauro Paternostro. "Non-equilibrium thermodynamics of gravitational objective-collapse models." *Physical Review Research* 7 (4), 043017 (2025). DOI: 10.1103/7hqd-zf96. arXiv: 2502.03173 [quant-ph].
- Simone Artini, Mauro Paternostro and Salvatore Lorenzo. "Coherent heat exchange in a prethermalizing open quantum system." *Physical Review A* 113 (5), 052203 (2025). DOI: 10.1103/q5vb-dfgj. arXiv: 2508.03193 [quant-ph].
- Steve Campbell et al. "Roadmap on quantum thermodynamics." *Quantum Science and Technology* 11 (1), 012501 (2026). DOI: 10.1088/2058-9565/ae1e27. arXiv: 2504.20145 [quant-ph].
- Simone Artini, Gabriele Lo Monaco, Alberto Imparato, Mauro Paternostro and Sandro Donadi. "Broken Detailed Balance and Entropy Production in CPTP Quantum Brownian Motion." *Physical Review Research* 8 (3), 033216 (2026). DOI: 10.1103/qqxn-qc4g. arXiv: 2507.23322 [quant-ph].
- Pedro B. Melo et al. "Non-equilibrium thermodynamics of collapse models in the strongly non-Gaussian regime." arXiv: 2606.06259 [quant-ph] (2026).
- Luca Innocenti et al. "A general estimation framework for continuous-variable systems." arXiv: 2607.19287 [quant-ph] (2026).



Conferences/workshop attended:

- **Talks:**

- "Non-equilibrium thermodynamics of the quantum brownian motion" — Nonequilibrium Quantum and Statistical Thermodynamics Workshop, Edinburgh, UK (2026).
- "Non-equilibrium thermodynamics of gravitational objective-collapse models" — Workshop Fundamental Problems in Quantum Physics, Trieste, Italy (2025).
- "Coherent heat exchange in a prethermalizing open quantum system" — Annual Congress of the Società Italiana di Fisica (SIF), Palermo, Italy (2025).
- "Characterizing the spontaneous collapse of a wavefunction through entropy production" — Workshop Exploring the Quantum Boundaries: an Odyssey into the gravity related collapse models, INFN Sezione di Frascati, Italy (2024).
- "Characterizing the spontaneous collapse of a wavefunction through entropy production" — A look at the interface between gravity and quantum theory-2024 edition, San Vito di Cadore, Italy (2024).

- **Posters:**

- "Non-equilibrium thermodynamics of collapse models in the strongly non-Gaussian regime." - Midsummer Conference on Open Quantum Systems, Decoherence, and the Quantum-to-Classical Crossover, Helsinki, 2026;
- "Non-equilibrium thermodynamics of collapse models in the strongly non-Gaussian regime." - Mini.workshop on Thermodynamics, Measurement and Classicality, Vienna, 2026.

Thesis title: Nonequilibrium thermodynamics of open quantum systems

Abstract:

In this Thesis, we investigate key aspects of the non-equilibrium thermodynamics of open quantum systems, highlighting the implications of genuinely quantum features and characterizing the thermodynamic properties of spontaneous wave-function collapse models. Quantum thermodynamics is a fast-developing field, crucial both for assessing the energetic cost of microscopic operations—made accessible by recent technological advancements—and for providing fundamental insights into the emergence of microscopic irreversibility. Furthermore, the non-equilibrium thermodynamic framework serves as a powerful tool to probe foundational, phenomenological models such as spontaneous collapse theories. Originally introduced to resolve the quantum measurement problem, these models have only recently



UNIVERSITÀ DEGLI STUDI DI PALERMO
DOTTORATO DI RICERCA IN SCIENZE FISICHE E CHIMICHE

been examined through a thermodynamic lens, opening novel physical interpretations and new avenues for experimental testing.

Specifically, we first analyze the non-equilibrium relaxation of a prethermalizing system, where a long-lived metastable state precedes full asymptotic thermalization, induced by two qubits interacting with a spatially correlated bosonic bath. The extended lifetime of this phase, which preserves information about initial quantum coherences, allows us to formulate a modified Fluctuation Theorem within the end-point measurement scheme.

We then analyze quantum Brownian motion models using their Wigner representation. This phase-space approach allows us to adapt the framework of classical stochastic thermodynamics to examine the non-equilibrium properties arising from symmetry and complete positivity requirements, revealing a pairwise incompatibility among these properties and asymptotic equilibrium. Finally, we turn our attention to the Continuous Spontaneous Localization and Di'osi-Penrose models, as well as their dissipative extensions, characterizing the entropy production driven by the collapse mechanism and evaluating their asymptotic steady-state properties.

The PhD Board Dean

Prof. Marco Cannas



Allegato 2

PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Alessandro Romancino

Transcript of Records

Tutor: Prof. G. Massimo Pima

Courses/school/exam scores:

- Quantum Information Theory and Quantum Computing
- Open Quantum Systems and Quantum Machine Learning
- Quantum Optics & Topology in Photonic Lattices

Research and training periods abroad

February 2025 – July 2025

During the second year I've spent 6 months at the Universitat de les Illes Balears (UIB), Palma de Mallorca, Spain. This research period abroad has been done from February to July 2025, financed by the PhD fund increase for periods abroad.

During the stay I've been supervised by Prof. Roberta Zambrini in UIB and I've spent my stay in the IFISC (Institute for Cross-Disciplinary Physics and Complex Systems) research institute in UIB. The research has been developed around the study of Quantum Machine Learning, with the focus of Quantum Reservoir Computing.

Papers published:

1. J. Romero-Pallejà, J. Añibal, A. Romancino, C. Marconi, and A. Sanpera, "Multipartite Entanglement in the Diagonal Symmetric Subspace," *J. Math. Phys.* **66**, 022203 (2025). DOI: 10.1063/5.0240964. arXiv:2403.05244
2. A. Romancino, J. Romero-Pallejà, G. M. Palma, and A. Sanpera, "Entanglement Percolation in Random Quantum Networks," *Quantum Sci. Technol.* **11**, 025044 (2026). DOI: 10.1088/2058-9565/ae5fca arXiv:2602.10189
3. A. Romancino, "Random Entanglement Percolation on Realistic Quantum Networks," *Il Nuovo Cimento C* **49**, 1-4 (2026). DOI: 10.1393/ncc/i2026-26176-2. arXiv:2604.21967
4. J. Romero-Pallejà, J. Añibal, A. Romancino, C. Marconi, and A. Sanpera, "Erratum: 'Multipartite Entanglement in the Diagonal Symmetric Subspace' [*J. Math. Phys.* **66**, 022203 (2025)]," *J. Math. Phys.* **67**, 059902 (2026). DOI: 10.1063/5.0324633

Conferences/workshop attended:

- Talks:
 - October 2024 – **Invited talk:** Entanglement Percolation in Random Quantum Networks, Working Party on Quantum Reservoir Computing, Erice.
 - September 2025 – **Oral presentation:** Entanglement Percolation in Random Quantum Networks, 111th Congress of the Italian Physical Society (SIF), Palermo. Won the **Best Communication Award**.
- Posters:
 - September 2024 – **Poster presentation:** Entanglement Percolation in Random Quantum Networks, 16th Italian Quantum Information Science Conference, Pizzo Calabro. Won the **Honorable Mention** from the journal Entropy.



Thesis title:

Graphs and Complex Networks in Quantum Information Theory
Realistic and resource-aware quantum information processing

Abstract:

This thesis studies how graphs and complex-network methods can be used to understand realistic and resource-aware problems in quantum information. The first part focuses on entanglement distribution in quantum networks. After introducing percolation theory, I generalize entanglement percolation to heterogeneous networks in which the entanglement shared across the edges is randomly distributed. I show that classical entanglement percolation depends only on the average singlet-conversion probability, while quantum preprocessing based on entanglement swapping becomes sensitive to the full distribution and can lose its advantage as the heterogeneity increases. I also connect this framework to polarization-dependent loss in photonic quantum networks.

The second part turns to quantum machine learning, with particular attention to quantum reservoir computing and quantum extreme learning machines under limited measurement resources. I introduce an online training strategy inspired by shadow tomography and designed for finite measurement statistics. Finally, I return to complex networks by representing quantum correlations inside a reservoir as weighted networks and studying how their structure relates to machine-learning performance. Together, these results show how network methods can provide a common language for both entanglement distribution and the analysis of quantum learning systems.

DIAGRAM 111-AD-IT
ALFREDINO ROMANO

The PhD Board Dean

Prof. Marco Cannas

Firmato digitalmente da:
Marco Cannas

Data: 01/10/2026 12:33:48

DIPARTIMENTO DI FISICA E CHIMICA

Via Archirafi 36, 90123 Palermo, Italy



Allegato 3

PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Valerio Fardella

Transcript of Records

Tutor: Dr. Serena Benatti

Cotutor: Dr. Antonino Petralia

Courses/school/exam scores:

- School: *Spectroscopic data analysis with iSpec - International Summer School*, Wrocław, Poland, from September 2nd to 5th 2025
- School: *The Bianca Garilli School - Scientific Communication in Astronomy 3rd edition*, Bertinoro, Italy, from October 12th to 17th 2025
- School: *INAF PhD School Francesco Lucchin - Spring 2026*, Nicolosi, Italy, from May 24th to 29th 2026.
- Course and exam score: *Project Management in the Scientific-Spatial Context*, by G. Micela, Score "A".
- Course and exam score: *Astrophysics Laboratory of Thermal X-ray plasmas*, by C. Pinto, Score: "A".
- Course and exam score: *Exoplanets course*, by G. Micela, Score "A".

Research and training periods abroad

Comparative analysis of the HARPS-N pipelines according with the stellar spectral types, from May 24th 2025 to August 14th 2025.

I provided support at the Telescopio Nazionale Galileo (TNG) located at the Roque de los Muchachos Observatory on the island of La Palma in the Canary Islands, Spain, learning how to operate the instruments and collecting data for the observational program. I performed a comparative analysis between the old and the new data reduction software pipelines of HARPS-N Instrument at the TNG, investigating the origins of their differences.

Papers published:

- V. Fardella, S. Benatti, R. Spinelli, D. Locci, G. King et al., under second revision, *Astronomy & Astrophysics*, "Characterisation of the 400 Myr old multi-planet system K2-233".
- G. Guilluy, M. C. D'Arpa, A. S. Bonomo, R. Spinelli, F. Biondi, L. Fossati, A. Maggio, P. Giacobbe, A. F. Lanza, A. Sozzetti, F. Borsa, M. Rainer, G. Micela, L. Affer, G. Andreauzzi, A. Bignamini, W. Boschin, I. Carleo, M. Ceconi, S. Desidera, V. Fardella, et al., 2024, *Astronomy & Astrophysics*, "The GAPS Programme at TNG. LIV. A He I survey of close-in giant planets hosted by M-K dwarf stars with GIANO-B".



- M. C. D'Arpa, A. Saba, F. Borsa, L. Fossati, G. Micela, C. Di Maio, M. Stangret, G. Tripodo, L. Affer, A. S. Bonomo, S. Benatti, M. Brogi, **V. Fardella**, et al., 2024 *Astronomy & Astrophysics*, "The GAPS programme at TNG. LX. Atmospheric characterisation of KELT-9 b via single-line analysis: Detection of six H I Balmer lines, Na I, Ca I, Ca II, Fe I, Fe II, Mg I, Ti II, Sc II, and Cr II".
- A. S. Bonomo, L. Naponiello, A. Sozzetti, S. Benatti, I. Carleo, K. Biazzo, P. E. Cubillos, M. Damasso, C. Di Maio, C. Dorn, N. Hara, D. Polychroni, M.-L. Steinmeyer, K. A. Collins, S. Desidera, X. Dumusque, A. F. Lanza, B. S. Safonov, C. Stodolale, D. Turrini, C. Ziegler, L. Affer, M. D'Arpa, **V. Fardella**, et al., 2026, *Astronomy & Astrophysics*, "The GAPS programme at TNG. LXXI. A sub-Neptune suitable for atmospheric characterization in a multiplanet and mutually inclined system orbiting the bright K dwarf TOI-5789 (HIP 99452)".
- C. Di Maio, S. Benatti, D. Locci, R. Spinelli, M. Baratella, K. Biazzo, J. Maldonado, A. F. Lanza, C. Dorn, P. E. Cubillos, A. Salmi, A. Maggio, L. Naponiello, F. Marzari, G. Micela, **V. Fardella**, et al., 2026, *Astronomy & Astrophysics*, "The GAPS Programme at TNG. LXXXIII. Confirmation of the hot sub-Neptune TOI-4602 b (HD 25295 b), a key target for future atmospheric characterization".
- C. Di Maio, S. Benatti, S. Colombo, G. Piccinini, R. Spinelli, **V. Fardella**, et al., under second revision, *Astronomy & Astrophysics*, "Minimum observations for accurate Exoplanetary mass estimation with Radial Velocity Analysis (MINERVA)".
- M. C. D'Arpa, F. Biassoni, F. Borsa, V. Singh, G. Micela, S. Benatti, L. Malavolta, A. F. Lanza, S. Desidera, E. Herrero-Alonso, A. S. Bonomo, M. Brogi, G. Guilluy, L. Fossati, L. Mancini, G. Mantovan, **V. Fardella**, et al., submitted, *Astronomy & Astrophysics*, "The GAPS programme at TNG. TBD. Orbital refinement and atmospheric investigation of TOI-1518 b".
- D. Sicilia, M. Basilicata, G. Guilluy, G. Scandariato, F. Borsa, C. Di Maio, M. Brogi, A. Chiavassa, L. Fossati, F. Amadori, P. Giacobbe, A. S. Bonomo, A. Sozzetti, L. Mancini, G. Andreuzzi, S. Colombo, **V. Fardella**, et al., under revision, *Monthly Notices of the Royal Astronomical Society*, "The GAPS programme at TNG. TBD. The first atmospheric investigation of the gas giant WASP-13 b at high resolution with GIARPS".

Conferences/workshop attended:

- Talks:
 - May 25th 2024: "MINERVA: MINimum observations for Exoplanetary mass estimation with Radial Velocity Analysis", Ariel-IT, Palermo, Italy.
 - October 24th 2024: "Understanding the planets composition from the Radial Velocity and Transit Photometry measures", Chianti Topics 7th, Florence, Italy.
 - November 28th 2024: "Status of AMS01 & AMS18", 21st GAPS Progress Meeting, Milan, Italy.
 - May 15th 2025: "AMS01 (TOI-2411) a multi-planetary system?", 22nd GAPS Progress Meeting, Palermo, Italy.
 - October 29th 2025: "Status of AMS18 (K2-233)", 23rd GAPS Progress Meeting, Catania, Italy.
 - April 26th 2026: "AMS01 (TOI-2411). Always more planets", 24th GAPS Progress Meeting, Rome, Italy.

- Posters:



- February 26th 2025: "Ariel Masses Survey (ArMS) Large Programme", V. Fardella, S. Benatti & ArMS collaborators, ExolItaly, Rome, Italy.
- June 30th – July 3rd 2025: "Two Low-Mass Planets Orbiting the Late G-type Star TOI-214", S. Benatti, V. Fardella, D. Bossini, F. Bouchy, N. Buschacher, et al., EPRV6 Conference, Porto (Portugal).

Thesis title: "Characterisation of low-mass multi-planet systems around late-type stars with varying activity"

Abstract:

Over the past few decades, exoplanetary science has transitioned from the mere detection of new worlds to the detailed characterisation of their physical and orbital properties. The deployment of highly productive space-based missions, such as Kepler, K2, and the Transiting Exoplanet Survey Satellite (TESS), has led to the discovery of thousands of transiting exoplanets. However, understanding the true nature of small exoplanets –specifically those bridging the "radius valley" that separates rocky super-Earths from volatile-rich sub-Neptunes – requires precise mass determinations. These masses are typically obtained through ground-based high-resolution Radial Velocity (RV) spectroscopy, which, when combined with transit photometry, allows us to constrain planetary bulk densities and infer internal compositions. The primary challenge in measuring the subtle Doppler shifts induced by low-mass planets stems from the intrinsic magnetic activity of their host stars, which can easily mask or mimic genuine planetary signals.

This thesis is focused on the comprehensive characterisation of multi-planetary systems hosting low-mass planets, using both transit photometry and high-precision RV observations. A significant portion of the research presented in this thesis, conducted within the Global Architecture of Planetary Systems (GAPS) collaboration and the Ariel Masses Survey (ArMS) programme with the HARPS-N high-precision spectrograph at the Telescopio Nazionale Galileo (TNG), pertains to the application of advanced statistical tools and Multi-Dimensional Gaussian Process (Multi-GP) frameworks to mitigate stellar jitter and robustly extract planetary masses.

I will begin by discussing a methodological investigation into spectroscopic Data Reduction Software (DRS). Specifically, I will compare the two available HARPS-N pipelines to demonstrate how optimised data extraction significantly reduces RV dispersion for active stars and impacts the detectability of low-mass planets. Following this, I will introduce PANELLA, a custom-built Bayesian framework to model planetary interiors. I will detail its application to a demographic sample of 129 radius valley planets, revealing that planets with radii lower than 1.9 $R_{\oplus}$ show a clear Earth-like internal composition and providing strong empirical evidence for environment-driven evolutionary pathways, such as atmospheric photoevaporation.

Furthermore, I will detail the in-depth analysis of two highly contrasting multi-planetary systems that serve as keystone laboratories for planetary evolution: the young (400 Myr), highly active star K2-233, and the mature (5 Gyr), magnetically quiescent star TOI-2411. I will present the complex Multi-GP RV analysis required to characterise the three transiting planets of K2-233, alongside X-ray-driven photoevaporation simulations that reveal the system's ongoing atmospheric escape. In stark contrast, I will present the discovery of a remarkably compact, six-planet architecture in the TOI-2411 system, demonstrating how the star's magnetic quiescence allowed for the detection of three additional non-transiting companions purely from their Doppler signals. Notably, TOI-2411 exhibits a highly intriguing dynamical configuration, where some planets share an orbital plane aligned with the stellar equator while others reside on inclined orbits, strongly suggesting a peculiar and complex evolutionary history.



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The core part of my work is the in-depth analysis of these two systems to illustrate how intense stellar activity severely biases observational detections, and how the mature TOI-2411 architecture can be interpreted as the long-term evolutionary outcome of young systems like K2-233. Ultimately, the precise planetary masses and structural characterisations derived in this work lay a crucial foundation for the next generation of atmospheric studies with the James Webb Space Telescope (JWST) and the upcoming ESA-Ariel space mission.

The PhD Board Dean

Prof. Marco Cannas
Marco Cannas



Allegato 4

PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Gabriele Galletta.....

Transcript of Records

Tutor: Giuseppina Micela

Cotutor: Salvatore Colombo

Courses/school/exam scores:

- Workshop on Astrostatistics by Eric D. Feigelson
- PLATO GOP Workshop 24-25/02/2026
- Course and exam: Project Management in the Scientific-Spatial Context by G. Micela. Score A
- Course and exam: Astrophysics laboratory of thermal X-ray plasmas by C. Pinto. Score A
- Course and exam: Exoplanets course by G. Micela. Score A

Research and training periods abroad

6 months in London in Blue Skies Space Ltd. contributing to the satellite MAUVE

Papers published:

- Galletta et. al published the 13/06/2025: Exploring short-term stellar activity in M dwarfs: A volume-limited perspective, *Astronomy & Astrophysics*, 698:A180
- Galletta et. al published the 20/08/2026: Characterizing stellar flares in Ariel targets: activity analysis and transit contamination. *RAS Techniques and Instruments*, rzag062.
- Galletta et. al submitted the 10/06/2026 on *RAS Techniques and Instruments*: PHOTO-CAT - Photometric Contamination Analyzer Tool: A High-Performance Framework for Photometric Contamination Assessment (R2 submitted on 21/09/2026)
- Micela et. al submitted the 29/07/2026 on *RAS Techniques and Instruments*: An Ariel end-to-end experiment on a small sample of targets: Target selection and characterization.

Conferences/workshop attended:

- Talks:
 - o IT Science Ariel Meeting, Palermo, 20-22 May 2024, Short-term stellar activity analysis of the Ariel dry run's targets
 - o VIII Congresso Nazionale della Società Italiana di Astrobiologia, Messina, 11-13 June 2025, Exploring short-term stellar activity in M dwarfs: A volume limited perspective
 - o 111° Congresso Nazionale Società italiana di Fisica, Palermo, 22-26 September 2025, Exploring short-term stellar activity in M dwarfs: A volume limited perspective
 - o MAUVE Members Meeting, London, 24-26 November 2025, Contamination Analyzer Tool



- Ariel-IT: 5th national meeting on Ariel science, Firenze, 04-06 May 2026, Characterizing Stellar Flares in the ARIEL Targets: Activity Analysis and Transit Probabilities
- Ariel Consortium Meeting, Wien, 15-18 September 2026, Characterizing stellar flares in Ariel targets: activity analysis and transit contamination
- Posters:
 - Exoplanets in Italy: status and perspectives, Rome, 26-28 February 2025, Exploring Short-Term Stellar Activity in dM Stars
 - Ariel Open Conference, London, 17-19 March 2026, Characterizing Stellar Flares in Ariel Targets: Activity Analysis and Transit Contamination

Thesis title: Stellar Activity and contamination analysis: Analysis Techniques and Software Optimization with Applications to Spatial Missions.

Abstract:

The characterization of exoplanetary systems relies increasingly on high-precision photometric observations, whose interpretation can be strongly affected by stellar activity, star-planet interactions, and flux contamination from unresolved or nearby sources. This thesis investigates these effects across different observational and physical scales, combining the analysis of stellar flares, the study of activity-planet connections, and the development of scalable tools for photometric contamination assessment.

The first part of the thesis focuses on stellar flaring activity in low-mass stars. A homogeneous volume-limited sample of M dwarfs within 10 pc was analysed using Transiting Exoplanet Survey Satellite (TESS) light curves. An iterative Gaussian-process detrending procedure was adopted to remove long-term stellar variability while preserving short impulsive events, which were subsequently identified and characterized in terms of amplitude, duration, and energy. Injection-recovery experiments were used to validate the detection pipeline and quantify its completeness and biases. The resulting flare frequency distributions were described using power-law models, and the Flare Energy Index, GE01, was introduced as a normalized activity metric that enables comparisons among stars with different bolometric luminosities. The analysis revealed a broad diversity in flare activity and identified distinct activity regimes within the nearby M-dwarf population.

The same methodology was subsequently applied to the Ariel Mission Candidate Sample to quantify the potential impact of stellar flares on observations of exoplanetary transits and atmospheres. Using TESS observations of 290 Ariel targets, more than 15,000 flares were identified and characterized. The resulting flare distributions show that relative flare activity increases towards lower stellar luminosities, while a 3% of targets exhibits enhanced activity. The analysis also provides a statistical estimate of the probability that a flare occurs during a transit observation, demonstrating that stellar variability can represent a significant source of contamination for the most active Ariel targets.

A complementary analysis investigates possible signatures of star-planet magnetic interaction in the active planetary systems of Proxima Centauri and AU Microscopii. The flare occurrence time series were analysed through periodicity searches and phase-folding techniques, with particular attention to stellar rotation, planetary orbital periods, and the corresponding synodic periods for different orbital configurations. Periodogram analysis, including CLEAN deconvolution, was used to distinguish candidate periodic signals from sampling-related effects.

The final part of the thesis addresses a different but complementary observational challenge: photometric contamination produced by neighboring sources in wide-field surveys. To this purpose, the tool PHOTO-CAT was developed. The tool constructs a three-dimensional representation of the sky from large astrometric catalogues, performs rapid spatial neighbour searches using a memory-optimized KDTree, and derives target-by-target contamination metrics from source separations and relative fluxes.



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Both geometrical aperture models and a Gaussian PSF-based model are supported, together with optional conversion to arbitrary instrumental bandpasses using empirical photometric relations or stellar-atmosphere models. PHOTO-CAT was benchmarked on large Gaia datasets and applied to the Ariel Mission Candidate Sample, demonstrating how contamination can vary with wavelength and observing geometry and how such information can support target selection and observation planning.

The results presented in this thesis have been partially published in the following works: Galletta et al. (2025), *Exploring Short-Term Stellar Activity in dM Stars: A Volume-Limited Perspective*; Galletta et al. (2026), *Characterizing Stellar Flares in Ariel Targets: Activity Analysis and Transit Contamination*; and Galletta et al. (2026 submitted), *The Contamination Analyzer Tool: A High-Performance Framework for Photometric Contamination Assessment*.

The PhD Board Dean

Prof. Marco Cannas



Allegato 5

PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Alessandro Lo Bianco

Transcript of Records

Tutor: Prof. Giuseppe Cavallaro

Cotutor: Prof. Giuseppe Lazzara, Prof.ssa Magdalena Broda

Courses/school/exam scores:

Courses:

- "Advanced microscopy and spectroscopy techniques applied to nanomaterials", S. Agnello and G. Buscarino, University of Palermo (20 hours)
- "Organic/Inorganic Nanocomposites: thermodynamics, structure, and applications", G. Cavallaro, University of Palermo (20 hours)
- "Heterogeneous Catalysis: Computational and Experimental Perspectives" L. Lisuzzo, University of Palermo (20 hours)
- "Soft Matter course 2024" T. E. Kodger and E. Marino (18 hours)

School:

July 1-3, 2025

Soft Matter Summer School

Grenoble, France.

February 9-11, 2025

VI Scuola AIAA "I relitti del mondo antico: dal recupero alla conservazione"

Marsala, Italy.

June 29-July 5, 2024

NATO ASI Summer School "Nanomaterials and Nanoarchitectures II"

Smolenice Castle, Bratislava, Slovakia.

Research and training periods abroad

- Brno University of Technology, Brno, Czech Republic, October 3rd – November 5th 2025
- University of Melbourne, Melbourne, Australia, February 16th – July 21st 2026

Papers published:

1. Armetta, F.; Lo Bianco, A.; Boiko, V.; Hreniak, D.; Saladino, M. L. Ancient Blue, Modern Speed: Microwave-Assisted Synthesis and the Role of Structural Evolution in Han Blue Luminescence. *J. Mater. Chem. C* 2026. <https://doi.org/10.1039/d6cc02111e>
2. Lo Bianco, A.; Ebbreo, M. G.; Cavallaro, G.; Carino, M. M.; Zhao, Y.; Agnello, S.; Lazzara, G. Adsorbent Materials for Hydrocarbons Removal by Geopolymerization of Halloysite Clay Nanotubes Filled Within Chitosan Matrix. *Adv. Mater. Interfaces* 2026. <https://doi.org/10.1002/admi.70568>



3. Lo Bianco, A.; Calvino, M. M.; Fiorilla, S.; Březina, M.; Hajzler, J.; Lisuzzo, L.; Cavallaro, G.; Šiler, P.; Lazzara, G. Wood Ash Lye as a Sustainable Alkaline Activator for Halloysite Nanotube-Based Geopolymers with Improved Performance and Durability. *ACS Appl. Mater. Interfaces* **2026**, *18* (34), 46691–46704. <https://doi.org/10.1021/acsaami.6c14048>
4. Lo Bianco, A.; Armetta, F.; Boiko, V.; Hreniak, D.; Saladino, M. L. What If the Ancient Egyptians Had Microwaves? Modern Chemistry Refines the Process Behind the Oldest Synthetic Pigment in Human History. *Inorg. Chem.* **2026**, *65* (15), 8422–8430. <https://doi.org/10.1021/acs.inorgchem.5c05969>
5. Lo Bianco, A.; Calvino, M. M.; Cavallaro, G.; Liu, M.; Milioto, S.; Lazzara, G. Sustainable Food Packaging Films by Methylcellulose Enriched with Spent Coffee Grounds Extract. *International Journal of Biological Macromolecules* **2026**, *359*, 151852. <https://doi.org/10.1016/j.ijbiomac.2026.151852>
6. Lo Bianco, A.; Calvino, M. M.; Cavallaro, G.; Milioto, S.; Lazzara, G.; Broda, M. Halloysite-Based Geopolymerization for the Mineralization and Stabilization of Porous Wood. *Ceramics International* **2026**. <https://doi.org/10.1016/j.ceramint.2026.04.047>
7. Lo Bianco, A.; Armetta, F.; Calvino, M. M.; Gagliardo Briuccia, G. E.; Macalik, B.; Hreniak, D.; Saladino, M. L.; Lazzara, G.; Cavallaro, G. Invisible Near-Infrared Luminescent Marker Incorporating Egyptian Blue in Halloysite-Based Geopolymer Mortars: Applications in Covert Tagging. *Journal of Alloys and Compounds* **2026**, *1050*, 185458. <https://doi.org/10.1016/j.jallcom.2025.185458>
8. Lo Bianco, A.; Calvino, M. M.; Lazzara, G.; Milioto, S.; Cavallaro, G. Geopolymerization of Halloysite Clay Nanotubes Mixed with Hydroxypropyl Cellulose for Development of Composite Films with Flame Resistance Properties. *Ceramics International* **2026**, *52* (10, Part B), 15130–15138. <https://doi.org/10.1016/j.ceramint.2025.06.260>
9. Lo Bianco, A.; Calvino, M. M.; Cavallaro, G.; Šiler, P.; Wasserbauer, J.; Milioto, S.; Lazzara, G. Hollow Spherical Capsules From Geopolymerized Gel Beads With Halloysite Nanotubes for Pollutants Removal and CO₂ Capture. *Small* **2025**, *21* (33), 2504306. <https://doi.org/10.1002/smll.202504306>
10. Lo Bianco, A.; Calvino, M. M.; Cavallaro, G.; Lisuzzo, L.; Pasbakhsh, P.; Milioto, S.; Lazzara, G.; Lvov, Y. Flame-Resistant Inorganic Films by Self-Assembly of Clay Nanotubes and Their Conversion to Geopolymer for CO₂ Capture. *Small* **2024**, *20* (51), 2406812. <https://doi.org/10.1002/smll.202406812>
11. Armetta, F.; Lo Bianco, A.; Boiko, V.; Hreniak, D.; Saladino, M. L. Multimodal Anti-Counterfeiting Inks: Modern Use of an Ancient Pigment in Synergy with a Persistent Phosphor. *J. Mater. Chem. C* **2025**, *13* (3), 1188–1197. <https://doi.org/10.1039/d4tc04228j>

Conferences/workshop attended:

Talks:

September 16-19, 2025

8th Central and Eastern European Conference on Thermal Analysis and Calorimetry (CEE-C-TAC8), Mostar, Bosnia and Herzegovina.

Lo Bianco A., Calvino M.M., Cavallaro G., Milioto S., Hreniak D., Boiko V., Armetta F., Saladino M.L., Giuseppe Lazzara; *From Flame-Retardant Films to Luminescent Mortars: Multifunctional Geopolymer Systems Across Scales.*

July 13-18, 2025

ICC 2025 – XVIII International Clay Conferences, Dublin, Ireland.

Lo Bianco A., Calvino M.M., Cavallaro G., Šiler P., Milioto S., Lazzara G.; *Tailoring Functional Properties in Hybrid Composites through Geopolymerization: From Fire Resistance to Pollutant Capture.*



December 9-11, 2024

AICAT 2024 - XLV National Conference on Calorimetry, Thermal Analysis and Applied Thermodynamics, Caserta, Italy.

Lo Bianco A., Calvino M. M., Cavallaro G., Pasbakhsh P., Lazzara G., Milioto S.; *Enhancing Functional Properties of different Materials through Geopolymerization: "Improved Flame-Retardancy and Pollutant Adsorption"*.

September 1-4, 2024

MoDeSt 2024 11th conference of the Modification, Degradation, Stabilization of Polymers Society, Palermo, Italy.

Lo Bianco A., Calvino M. M., Cavallaro G., Pasbakhsh P., Lazzara G., Milioto S.; *"Geopolymers Beyond Construction: Enhanced Adsorption and Flame Retardancy in Nanocomposite Systems"*.

Posters:

July 1-3, 2025

Soft Matter Summer School, Grenoble, France.

Lo Bianco A., Calvino M. M., Cavallaro G., Siler P., Wasserbauer J., Milioto S., Lazzara G.; *"Hollow Spherical Capsules From Geopolymerized Gel Beads With Halloysite Nanotubes for Pollutants Removal and CO₂ Capture"*.

February 12-14, 2025

XIII Congresso Nazionale ALAr, Palermo, Italy.

Lo Bianco A., Calvino M. M., Cavallaro G., Broda M., Lazzara G., Milioto S.; *"Geopolymers: An Innovative Resource for Cultural Heritage Conservation"*.

June 29-July 5, 2024

NATO ASI Summer School "Nanomaterials and Nanoarchitectures II", Bratislava, Slovakia.

Lo Bianco A., Calvino M. M., Cavallaro G., Pasbakhsh P., Lazzara G., Milioto S.; *"Development and Characterization of Free-Standing Halloysite-Based Inorganic Films and Their Transformation into Geopolymers and Ceramics"*.

Thesis title: ADVANCED GEOPOLYMER-BASED MATERIALS FOR STRUCTURAL AND FUNCTIONAL APPLICATIONS

Abstract:

This Ph.D. thesis presents the development and comprehensive characterization of innovative, eco-friendly materials based on the alkaline activation (geopolymerization) of halloysite clay nanotubes (HNTs), evaluated both as pristine inorganic networks and as biopolymer-geopolymer hybrid architectures. In the first part of the research, the unique long morphology of Patch halloysite nanotubes enables the fabrication of self-standing inorganic films without organic binders. Driven by physical nanotube entanglement into a "bird's nest" structure, these binder-free films exhibit notable flexibility, superior thermal shielding properties, and intrinsic flame resistance. Subsequent alkaline activation converts the inorganic precursors into highly porous geopolymers that double the carbon dioxide (CO₂) capture capacity relative to unreacted clay films.

The second part explores hybrid composite systems across two- and three-dimensional geometries. The alkaline activation of chitosan/halloysite composite films converts the clay component into an amorphous geopolymer while preserving the cationic biopolymeric matrix. This structural transformation generates



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and significantly elevates porosity from 2% up to 49%, resulting in a ~220% increase in dodecane vapor uptake and a ~50% enhancement in aqueous phenol adsorption. Similarly, the geopolymerization of ionically cross-linked alginate/HNT gel beads converts compact composite spheres into hollow geopolymeric capsules with an internal macroscopic cavity of approximately 950 μm . These hollow capsules display increased compressive flexibility, enhanced water retention, and doubled CO_2 sequestration efficiency. Furthermore, the geopolymerization of hydroxypropyl cellulose nanocomposite films forms a protective inorganic coating around the biopolymeric fibers, substantially increasing the Young's modulus up to 4101 MPa and imparting immediate flame-extinguishing capability within 0.53 seconds. Finally, these geopolymeric platforms are extended to complex substrates, smart tagging, and circular chemistry. Vacuum impregnation of halloysite into waterlogged archaeological wood, followed by in situ geopolymerization, reduces volumetric drying shrinkage from 70% to 27–30% while enhancing mechanical strength and buffering against acid decay. Incorporating trace amounts of ancient Egyptian blue pigment (0.2–0.6 wt.%) into halloysite geopolymer mortars yields covert, near-infrared luminescent markers (910–950 nm) for optically invisible QR codes used in anti-counterfeiting. Finally, biomass waste-derived wood ash lye was successfully validated as a sustainable alternative to industrial sodium hydroxide, yielding halloysite geopolymers with a dense microstructure, superior water durability, and a reduced environmental footprint.

Overall, this work demonstrates that halloysite geopolymerization represents a versatile, sustainable platform for engineering multifunctional materials tailored for environmental remediation, greenhouse gas capture, and thermal protection.

The PhD Board Dean

Prof. Marco Cannas

Marco Cannas



Allegato 6

PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Maniadakis Dimitrios Kostantinos

Transcript of Records

Tutor: Antonino D'Ai

Cotutor: Elena Ambrosi

Courses/school/exam scores:

- Courses

- Millisecond Pulsars — Prof. Rosario Iaria — Maximum score
- Astrophysics Laboratory of Thermal X-ray Plasmas — Dr. Ciro Pinto — Maximum score
- Magnetohydrodynamics in Astrophysical Processes — Dr. Salvatore Colombo — Maximum score

- Schools

- Computing and High Performance Computing — 24 June 2024 - 5 July 2024

Programming and optimization skills tailored for parallel computers. The course provided theoretical and hands-on training.

Research and training periods abroad:

- ESA Archival Research Visitor Programme, European Space Astronomy Centre (ESAC), Madrid, Spain — January 2025 to April 2025.

Development of a pipeline for energy-resolved pulse-profile and pulsed-fraction analysis with XMM-Newton, applied to simultaneous XMM-Newton and NuSTAR observations of Vela X-1. Advisor: Dr. Felix Fürst.

- Visiting Research Stay, Dr. Karl Remeis Observatory, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Bamberg, Germany — January 2026 to April 2026.

Collaboration with Dr. Ekaterina Sokolova-Lapa and Prof. Jörn Wilms on Monte Carlo simulations of cyclotron-line formation in accreting X-ray pulsars and theoretical predictions of their energy-dependent variability.

- Observational Shift at the Large-Sized Telescope 1 (LST-1), Roque de los Muchachos Observatory, La Palma, Spain — 2 September 2026 to 24 September 2026.



Papers published:

- D. K. Maniadakis et al., "Energy-resolved pulse profiles of Vela X-1: Cross-calibrating XMM-Newton and NuSTAR to trace spectral features," *Astronomy & Astrophysics*, 710, A357 (2026). DOI: 10.1051/0004-6361/202659954.
- D. K. Maniadakis et al., "How the spin-phase variability of cyclotron lines shapes the pulsed fraction spectra: Insights from 4U 1538-52," *Astronomy & Astrophysics*, 700, A70 (2025). DOI: 10.1051/0004-6361/202555112.
- A. D'Ai, D. K. Maniadakis et al., "Energy-resolved pulse profile changes in V 0332+53: Indications of wings in the cyclotron absorption line profile," *Astronomy & Astrophysics*, 694, A316 (2025). DOI: 10.1051/0004-6361/202451469.
- E. Sokolova-Lapa, D. K. Maniadakis et al., "Fingerprints of thermal Comptonization in accreting neutron stars: Plasma-vacuum interplay in cyclotron lines and polarisation," *arXiv e-prints*, arXiv:2608.24396 (2026). DOI: 10.48550/arXiv.2608.24396. (Submitted - under peer review)
- E. Ambrosi et al., "The elusive cyclotron line in 4U 1901+03: Hidden, yet present," *Astronomy & Astrophysics*, 709, A42 (2026). DOI: 10.1051/0004-6361/202557808.
- C. Malacaria et al., "Double-hump spectrum, pulse profile dip, and pulsed fraction spectra from the low-accretion regime in the X-ray pulsar MAXI J0655-013," *Astronomy & Astrophysics*, 706, A321 (2026). DOI: 10.1051/0004-6361/202557862.

CTAO/LST collaboration papers:

- K. Abe et al., "Constraints on the VHE Counterpart of Two Binary Black Hole Mergers Observed by the MAGIC and CTAO LST-1 Telescopes," *Publications of the Astronomical Society of the Pacific*, 138, 084101 (2026). DOI: 10.1088/1538-3873/ae8a7e.
- K. Abe et al., "Detection of the distant quasar OP 313 with the first Large-Sized Telescope of CTAO," *Astronomy & Astrophysics*, 712, A91 (2026). DOI: 10.1051/0004-6361/202558646. • K. Abe et al., "CTAO LST-1 observations of magnetar SGR 1935+2154: Deep limits on sub-second bursts and persistent tera-electronvolt emission," *Astronomy & Astrophysics*, 706, A25 (2026). DOI: 10.1051/0004-6361/202555431.
- K. Abe et al., "VHE γ -ray observations of bright BL Lacs with the Large-Sized Telescope prototype (LST-1) of the CTAO," *Monthly Notices of the Royal Astronomical Society*, 544, 669–686 (2025). DOI: 10.1093/mnras/staf1728.
- K. Abe et al., "Constraining the TeV gamma-ray emission of SN 2024bch, a possible type II_n-L from a red supergiant progenitor: Multiwavelength observations and analysis of the progenitor," *Astronomy & Astrophysics*, 702, A125 (2025). DOI: 10.1051/0004-6361/202554721.
- K. Abe et al., "GRB 221009A: Observations with LST-1 of CTAO and implications for structured jets in long gamma-ray bursts," *The Astrophysical Journal Letters*, 988, L42 (2025). DOI: 10.3847/2041-8213/ade4cf.
- K. Abe et al., "Detection of the Geminga pulsar at energies down to 20 GeV with the LST-1 of CTAO," *Astronomy & Astrophysics*, 698, A283 (2025). DOI: 10.1051/0004-6361/202554350.



Conferences/workshop attended:

- Talks:

- Italian National Conference of Compact Objects, Alghero, Italy — 24 September 2024. "Revealing complex cyclotron line shapes in X-ray pulsars through pulsed fraction spectra."
- Feeding the Spinning Top, Santander, Spain — 4 March 2025. "The extremely variable cyclotron line of 4U 1538-52 and its effect on the energy-dependent pulse profiles."
- Accretion Meeting, Vasto, Italy — 26 June 2025. "How the spin-phase variability of cyclotron lines shapes the pulsed fraction spectra: Insights from 4U 1538-52."
- 18th IACHEC Meeting, Seeblick Pelham, Germany — 20 April 2026. "Energy-resolved pulse profiles of Vela X-1: Cross-calibrating XMM-Newton and NuSTAR to trace spectral features."
- NewAthena Rising: SWG4, Barcelona, Spain — 2 June 2026. "Energy-resolved pulse profiles of Vela X-1: Cross-calibrating XMM-Newton and NuSTAR to trace spectral features."
- Super-Eddington Accretion onto Compact Objects, Cagliari, Italy — 25 June 2026. "Broadband pulsed fraction spectroscopy of Vela X-1: Cross-calibration and modelling with simultaneous XMM-Newton and NuSTAR observations."

- Posters:

- Microquasar Workshop, Cefalù, Italy — 15 September 2025. "How the spin-phase variability of cyclotron lines shapes the pulsed fraction spectra: Insights from 4U 1538-52."

Thesis title: Timing signatures of spectral features in strongly magnetized X-ray pulsars

Abstract:

This thesis investigates the pulsed fraction spectrum of strongly magnetized X-ray pulsars. The pulsed fraction measures how strongly the observed emission changes during one rotation of the neutron star, while the pulsed fraction spectrum describes how this variability changes with energy. By analyzing different sources, I show that structures in the pulsed fraction spectrum are produced by spectral variability throughout the pulse cycle, and that the signatures associated with cyclotron resonant scattering features can be used to constrain the geometry of the system. Pulsed fraction spectra can also reveal spectral features that are difficult to identify in phase-averaged spectroscopy, provide a tool for cross-calibration between X-ray instruments, and reveal the timing signatures of soft X-ray emission lines. Finally, Monte Carlo simulations of cyclotron-line formation are used to generate simulated pulsed fraction spectra and investigate how these signatures depend on the magnetic geometry and viewing angle.

The PhD Board Dean

Prof. Marco Cannas
Marco Cannas



PHD IN PHYSICAL AND CHEMICAL SCIENCES, XXXIX COURSE

PhD Candidate: Claudia Maraventano

Transcript of Records

Tutor: Prof. Tiziana di Salvo (University of Palermo)

Co-tutors: Dr. Giancarlo Ghirlanda, Dr. Lara Nava, (INAF Brera)

Courses/school/exam scores:

- *Astrophysics laboratory of thermal X-ray plasmas*
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Exam score: A = ottimo
- *Millisecond Pulsars: Theory and Observations*
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- *Quantum field theory in a curved spacetime or in non-inertial frames*
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Exam score: A = ottimo

Research and training periods abroad

Institut d'Astrophysique de Paris (IAP), Paris - France

Visiting student, April 2025 - October 2025

Research project: Studying the nature of the emission process in gamma-ray bursts

Supervisors: Prof. F. Daigne (IAP, Sorbonne Université), Prof. R. Mochkovitch (IAP)

Papers published (chronological order, as of September 2026)

- *The puzzling orbital residuals of XTE J1710-281: Is a Jovian planet orbiting the binary system?*
Iaria, R., Di Salvo, T., Anitra, A., Miceli, C., Leone, W., Maraventano, C., ... & Burderi, L., 2024, A&A.
<https://doi.org/10.1051/0004-6361/202449299>
- *High energy time lags of gamma-ray bursts*
Maraventano, C., Ghirlanda, G., Nava, L., Di Salvo, T., Leone, W., Iaria, R., ... & Tsvetkova, A., 2025, A&A.
<https://doi.org/10.1051/0004-6361/202554053>
- *Time domain astrophysics with transient sources Delay estimate via Cross Correlation Function techniques*
Leone, W., Burderi, L., Di Salvo, T., Anitra, A., Sanna, A., Riggio, A., Maraventano C., ... & Miceli, C., 2025, A&A.
<https://doi.org/10.1051/0004-6361/202453054>



• *A Mysterious Feature in the NICER Spectrum of 4U 1820-30: A Gravitationally Redshifted Absorption Line?*
Iaria, R., Di Salvo, T., Anitra, A., Barra, F., Sanna, A., Maraventano, C., ... & Burderi, L., 2026, ApJ.

<https://doi.org/10.3847/1538-4357/ae2758>

• *Time lags as a proxy of the spectral evolution in gamma-ray bursts*

Maraventano, C., Daigne, F., Mochkovitch, R., Nava, L., Ghirlanda, G., & Di Salvo, T., 2026, A&A.

<https://doi.org/10.1051/0004-6361/202660232>

• *4U 1624-490 as a possible intermediate-mass X-ray binary: constraints from XRISM and NuSTAR spectroscopy*

Iaria, R., Anitra, A., Di Salvo, T., Sanna, A., Barra, F., Burderi, L., Maraventano, C., Caserta, S., Leone, W., Miceli, C., 2026, accepted for publication in A&A.

• *On the origin of negative spectral lags in gamma-ray bursts*

Maraventano, C. and Mochkovitch, R., 2026, in preparation.

• *Time lags in gamma-ray bursts with Swift*

Maraventano, C. et al., 2026, in preparation

Conferences/workshop attended:

- Talks:

- Speaker at First CTAO Summer School (2024): "Time Delays Between LLE and GBM light curves of GRBs"
- Supplementary teaching activity (docenza integrativa), 62 hours, "Laboratorio di Fisica I: Statistical Data Analysis with Laboratory", BSc in Physics (L-30), Department of Physics and Chemistry - Emilio Segrè, University of Palermo, A.Y. 2025/2026 (02/03/2026 - 05/06/2026).

- Posters:

- Poster presentation at International Conference "Celebrating 20 years of Swift Discoveries (2025)": "Investigating High-Energy Time Lags in Gamma-Ray Bursts with Fermi-LAT and GBM"

Thesis title: *Spectral lags as a probe of the prompt emission physics in Gamma-Ray Bursts*

Abstract:

Gamma-Ray Bursts (GRBs) are the most luminous transient phenomena in the observable Universe: brief flashes of gamma-ray radiation, released at cosmological distances (up to $z \sim 9.4$) with isotropic-equivalent energies from $\sim 10^{42}$ to a few 10^{54} erg. Their bimodal duration distribution motivates the classification into short GRBs (< 2 s), associated with the coalescence of compact objects, and long GRBs (> 2 s), produced by the core collapse of massive stars. GRBs display a highly variable prompt



emission (keV–MeV), followed by a long-lasting broadband afterglow. In the standard fireball model both phases are powered by an ultra-relativistic collimated outflow, with bulk Lorentz factor $\Gamma \sim 100$ –1000: the prompt emission arises from internal dissipation within the jet, the afterglow from the shock that the outflow drives into the circumburst medium.

Despite five decades of observations, the physical origin of the prompt emission remains an open question: how the jet energy is dissipated, and which radiative process converts it into the observed photons. A powerful observable in this context is the spectral lag, the time delay τ between the light curves of the same burst in two different energy bands, whose measurement requires far fewer photons than a full spectral characterization and does not rely on any assumed spectral model. The lag is defined as positive when the hard photons arrive before the soft ones, and negative in the opposite case. Long GRBs systematically show positive lags in the keV–MeV range, while at GeV energies negative lags have been reported in a few bright bursts. Short GRBs, on the other hand, are consistently found to have lags compatible with zero. The interpretation of these delays is not yet settled: they may reflect the way the spectrum of a single component evolves in time, or the coexistence of distinct emission processes contributing to the observed radiation, such as the prompt emission and the afterglow. The spectral lag can therefore tell us what happens at the spectral level during the emission of the burst, and which components are at play.

In order to understand the link between time lags and spectral evolution in GRBs, during my PhD I computed spectral lags over the widest energy baseline considered so far, from the soft X-rays to 100 MeV, and combined them with time-resolved spectral analysis.

I performed a systematic study of GRB spectral lags, extending for the first time the analysis into the 30–100 MeV domain by exploiting Fermi LAT Low-Energy (LLE) data jointly with Fermi/GBM data for a sample of 70 GRBs. Cross-correlating the light curves in four energy bands, I found that the lags measured within the GBM range (10 keV – 1 MeV) are predominantly positive, with no significantly negative case. The lag between the lowest GBM band and the LLE band, instead, splits the sample almost evenly between significantly positive (40%) and negative (37%) values. A positive lag would be consistent with a single component, softening in time, that dominates across the whole energy range, whereas a negative lag might suggest that a distinct and harder component emerges in the LLE band while the prompt emission is fading.

To clarify the spectral origin of this behavior, I performed a time-integrated spectral analysis of the LLE data, comparing the spectral slope measured in the LLE band with the extrapolation of the keV–MeV spectrum. Bursts with a positive high-energy lag tend to show a softer LLE spectrum, consistent with a single component softening in time, whereas bursts with a negative lag tend to show a harder one. These results led me to propose a phenomenological scenario in which the sign of the high-energy lag reflects the origin of the observed emission: two components can dominate the 30–100 MeV band, the high-energy tail of the prompt emission and the onset of the afterglow, and a negative lag marks the delayed emergence of the latter.

To test this scenario, I performed a time-resolved spectral analysis and, in parallel, a time-resolved measurement of the lags, following the evolution of the spectral parameters and of the time delays across the same time intervals. I applied this analysis to GRB 160625B and GRB 190114C, two of the



brightest bursts of the sample, having a positive and a negative lag respectively, and whose photon statistics allow the spectrum to be constrained interval by interval.

In GRB 160625B a single spectral component softens continuously in time and all lags remain positive; interpreting its high-energy cutoff as due to pair-production opacity, I derived $\Gamma \sim 120\text{--}260$ and an emission radius $R \sim 10^{14}$ cm, well above the photosphere. In GRB 190114C an additional power-law component emerges at ~ 2.5 s after trigger and dominates in the LLE band, thus determining

a negative lag all over the burst duration. The flux of this power-law component is broadly consistent with the early afterglow, although its steep rise (faster than t') leaves an internal origin equally viable. The measurement of the lag thus provides an indication of which component dominates the LLE band, at a much lower cost than the time-resolved spectral analysis that would otherwise be required.

I explored with numerical simulations a third scenario for the origin of negative lags. When the high-energy emission is initially suppressed by $\gamma\gamma$ pair-production opacity and is progressively released as the outflow expands and becomes transparent, the high-energy photons reach the observer later than the soft ones, even when the underlying spectrum does not evolve at all. I found that this process should happen in sufficiently compact sources, having a low bulk Lorentz factor Γ combined with a high luminosity L . However, since Γ is observed to correlate with L , the two conditions lie at opposite ends of the population, and the mechanism is confined to the outliers of this correlation, whose low Γ makes them intrinsically faint at high energies: their absence in LLE-selected samples is thus a selection effect rather than evidence against the mechanism.

The proposed scenario also makes a prediction at the opposite end of the energy range: where no additional hard component is expected to contribute, the lag should always be positive, since it would be driven solely by the spectral evolution of the prompt emission. To test this prediction, I computed for the first time the spectral lags of the prompt emission between the XRT (0.3–10 keV) and BAT (15–150 keV) detectors onboard Swift, for 33 GRBs with simultaneous detections of the prompt emission. For the 19 bursts with a measured redshift I adopted fixed rest-frame energy bands. I found that 26 out of 33 lags are significantly positive and that none is significantly negative, in agreement with the expectation for an energy range where a single prompt component dominates. A time-resolved XRT+BAT spectral analysis of four bursts spanning the extremes of the lag distribution (~ 0.6 to ~ 15.5 s) revealed what the lag magnitude reflects. The lag is null or very small when E_{peak} stays constant, or varies too little to cross the observing bands; it becomes sizeable when E_{peak} migrates from one band to the other, as in GRB 100906A, and in that case is larger the more slowly the spectral evolution proceeds.

This thesis thus builds a coherent and predictive framework, tested from 0.3 keV to 100 MeV, in which the lag sign is a proxy of the nature of the emission components at play and the lag magnitude measures the amplitude of their spectral evolution. Spectral lags can be robustly computed with far fewer photon counts than a full spectral characterization requires.

Identifying the number of components also matters for the applications of time lags for fundamental physics. Tests of Lorentz Invariance Violation exploit the fact that, if the speed of light depended on photon energy, photons of different energies emitted simultaneously at cosmological distances would accumulate a measurable delay along their path. Any observed lag is therefore the sum of two terms: an extrinsic one, due to propagation, and an intrinsic one, imprinted at the source by the physics of the



emission. Constraining the former requires the latter to be understood, and these tests implicitly assume that the photons of the two bands are produced by the same component and are thus co-spatial, which is not always the case.

Spectral lags have long been regarded as a by-product of the spectral evolution. This thesis shows that they are a diagnostic in their own right, one that reads the physics of the emission from the arrival times of the photons alone. With the larger and better characterized samples that the coming missions will provide, what is here a framework tested on a handful of bursts can become a standard tool for probing the physics of GRBs.

The PhD Board Dean

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