

GIULIANA INDELICATO

PhD in Mathematics, obtained at the Department of Mathematics of the **University of Torino** (viva: Feb. 25 2008);

PhD in Mechanics and Energetics, issued by the **Institut National Polytechnique de Lorraine** (viva: Feb. 25 2008).

The above PhD degrees have been obtained in a joint PhD program between the Department of Mathematics of the University of Torino (Italy) and the Institut National Polytechnique de Lorraine (Ecole doctorale: EMMA - Laboratoire: LEMTA Mécanique et Energétique - Nancy, France) from Nov. 1 2003 until Oct. 31 2007 with extensive research periods spent in both Universities.

Topic of PhD Thesis: "Mechanical Models for 2D fiber networks and textiles", advisors Prof. F. Pastrone and Prof. J.F. Ganghoffer.

Degree in Mathematics 110/110 cum laude, at the Department of Mathematics of the University of Torino (Jul. 7 2003).

Research experience:

Research contract at the Department of General Psychology of the **University of Padova** for the project: "Study of problems of comparative choice via game theory techniques". Jan-Apr. 2015.

Research contract at the Department of Mathematics of the **Politecnico di Milano** for the project: "Diffuse interface models of Austenite/Martensite transitions". July-Sept. 2013.

Research contract at the Department of Mathematics of the **University of Torino** for the project: "Mathematical Models of conformational changes in viral capsids", May-Oct. 2013.

Postdoctoral Research Associate at the Department of Mathematics of the **University of York**, from May 1 2012 until Apr. 30 2013.

Marie Curie Research Fellow, at the Department of Mathematics of the **University of York**, from May 1 2010 until Apr. 30 2012.

PostDoc at the Department Metodi e Modelli Matematici per le Scienze Applicate of the **University of Padova**, from Nov. 2 2009 until Apr. 30 2010 on the project "Crystallographic problems in Mathematical Virology".

PostDoc at the Department of Mathematics of the **University of Torino**, from Nov. 1 2007 until Oct. 31 2009, on the project "Complex structures and fiber reinforced materials".

Devised, funded and managed projects

Marie Curie Actions – Intra-European Fellowships (FP7-MC-IEF2009) awarded for the project: MATVIR - Mathematical Virology: A classification of virus architecture and the structural transitions important for maturation and infection.

Scholarship from the **Università Italo Francese / Université Franco Italienne** (UIF/UFI) (Bando Vinci 2004) awarded for the research project "Elaboration of Mechanical Models for microstructured solids".

Description of my major research achievements

During my PhD I have focused on the constitutive characterization of the energy functional and stress-deformation curves of fiber-reinforced materials, in particular textiles. It is in this context that I became interested in the theory of symmetry groups and their invariants. In [12] I have applied the theory of group invariants to textiles, characterizing the deformation energy as a function of invariants that depend in a special manner on the geometrical characteristics of the warp and the weft: these results allow to distinguish the mechanical behaviour of textiles in dependence of the weave pattern and its symmetry properties. In the existing literature, the usual characterizations of the energy functional of textiles either take into account the geometry of the weave pattern but neglect bending stiffness, or account for bending effects as in shell theory but completely ignore the characteristics of the weave. In this context, my results constitute a substantial improvement that will allow a more precise analysis of the mechanical behaviour of tissues via, for instance, finite element methods. To perform the calculation of the invariants I have used the group theoretical computational package 'Singular'.

Later, during my Post Doc, I have begun working on the applications of the theory of symmetry groups to multilattices, i.e., structures corresponding to the union of simple lattices. In this context, I have developed an algorithm for the derivation and the classification of multilattices in arbitrary dimension [3].

The algorithm allows to determine explicitly the locations of the points of a multilattice given its space group, and to determine whether two multilattices are arithmetically equivalent. The algorithm is based on ideas from integer matrix theory, and can be easily coded in classical mathematical software packages such as Matlab and Maple. This algorithm substantially improves on the only other approach to this problem existing in the literature, proposed by M. Hosoya in 1986 (Hosoya M., Group theoretical definition of crystal-structure types, Bull. Coll. Sci. Univ. Ryukyus 41, 31-48, 1986), which is based on a completely different principle. The approach proposed in [3] has different potential applications, the first of which is a software that somewhat generalizes the International Tables of Crystallography, allowing the classification of complex crystalline structures and the determination of their space groups. Not last, it can be used to determine the symmetry of regular systems of points in 6D, with applications to the study of capsid structures.

I have worked on a research project on Mathematical Virology in collaboration with the group supervised by Prof. Twarock at YCCSA (York). The project is twofold: as a first

approach, we are using techniques of high-dimensional mathematical crystallography and group theory to study the structural transitions of viral capsids with icosahedral symmetry[1-2-8-9]. In fact, icosahedral symmetry is non-crystallographic in three dimensions, and the idea is to use methods developed in the theory of quasicrystals to describe and study the transformations of sets of points approximating the viral capsid. The theory naturally lends itself to a treatment of the structural transformations of two and three-dimensional quasicrystals, and we have applied it to study transformations of Penrose tilings of the plane [7]. As a further approach, we are also exploring the possibility of describing the configurational changes of the viral capsid through a coarse-grained model, that accounts for the behaviour of the proteins and their links [5] or using a Ginzburg-Landau approach based on the representation of the energy of the capsid in polynomials invariant under the icosahedral group [6].

I have also worked with a group of researchers at SISSA on a project for the identification of mechanical and assembly units of viral capsids via quasi-rigid domain decomposition. We develop and apply a general and efficient computational scheme for identification of the stable domains of a given viral capsid. The method is based on elastic network models and optimal quasi-rigid domain decomposition [4]. The paper [4] was the cover article of the November 2013 issue of Plos Computational Biology and has been recommended by F1000.

Recently I started a collaboration with the group supervised by Prof. Biscari at Politecnico of Milano on a joint project on Shape Memory Alloys, together with the research and development laboratories of SAES Getters (Saes Group). Work is in progress.

I got involved in a collaboration with Prof. Twarock at University of York and Prof. Burkhard at the University of Connecticut, where he is leading a group of researchers that design small proteins capable to self-assemble into nanoparticles with icosahedral symmetry. They also study medical applications of such nanoparticles, for instance as synthetic vaccines or as drug targeting and delivery systems.

Publications

- [1] Salthouse DG, Indelicato G., Cermelli P., Keef T., Twarock R., *Approximation of virus structure by icosahedral tilings*, Acta Crystallographica A71 (4), 410-422 (2015)
- [2] Cermelli P., Indelicato G., Twarock R., *The role of symmetry in conformational changes of viral capsids: a mathematical approach*, Discrete and Topological Models in Molecular Biology, Eds. Jonoska N., Saito M., Natural Computing book series, Springer, 217-240 (2014)
- [3] Indelicato G., *An algorithm for the arithmetic classification of multilattices*, Acta Crystallographica A69, 63-74 (2013)
- [4] Polles G., Indelicato G., Potestio R., Cermelli P., Twarock R., Micheletti C., *Mechanical and assembly units of viral capsids identified via quasi-rigid domain decomposition* Plos Computational Biology, Vol.9, No11, e1003331 (2013). Cover article for the November 2013 issue of PLoS Comput Biol - F1000Prime recommended
- [5] Cermelli P., Indelicato G., Twarock R., *Non icosahedral pathways for viral capsid expansion*. Physical Review E, Vol.88, No.3 , 032710 (2013)
- [6] Zappa E., Indelicato G., Albano A, Cermelli P., *A Ginzburg-Landau model for the expansion of a dodecahedral viral capsid*, International Journal of Non-Linear Mechanics 56, 71-78 (2013)

- [7] Indelicato G, Keef T, Cermelli P, Salthouse D G, Twarock R, Zanzotto G. *Structural transformations in quasicrystals induced by higher-dimensional lattice transitions*. Proceedings of the Royal Society of London. Series A, 468, 1452-1471, (2012)
- [8] Indelicato G., Twarock R. *A Mathematical Approach To Structural Transitions In Viral Capsids*. International Journal of Modern Physics Conference Series, vol. 9, 11-23, (2012)
- [9] Indelicato G, Cermelli P, Salthouse D G, Racca S, Zanzotto G, Twarock R. *A crystallographic approach to structural transitions in icosahedral viruses*. Journal of Mathematical Biology, vol. 64, 745-773, (2012)
- [10] Indelicato G., *Material symmetry and invariants for a 2D fiber-reinforced network*. Applied and Industrial Mathematics in Italy III (AIMI III), Series on advances in mathematics for applied sciences 82, 401-412, World Scientific, (2009)
- [11] Indelicato G., *The influence of the twist of individual fibers in 2D fibered networks*. International Journal of Solids and Structures 46 (3-4), 912-922 (2009)
- [12] Indelicato G., Albano A., *Symmetry properties of the elastic energy of a woven fabric with bending and twisting resistance*. Journal of Elasticity 94(1), 33-54 (2009)
- [13] Indelicato G., *Inextensible networks with bending and twisting effects*. Rendiconti del Seminario Matematico 65(2) 261-268 (2007)

Publications in preparation or submitted

Indelicato G., Wahome N., Ringler P., Müller S. A., Mu-Ping Nieh, Burkhard P., Twarock R. *Principles Governing the Self-assembly of Coiled-Coil Protein Nanoparticles*

Zappa E., Indelicato G., Cermelli P., Twarock R, *The influence of random perturbation on conformational changes of viral capsids*

Scientific Collaborations

- Prof. R. Twarock, Department of Mathematics and Department of Biology, **University of York** (UK) - research topics: mathematical models for viral transitions, quasicrystals.
- Prof. C. Micheletti, **SISSA** Trieste (Italy)- project on the identification of mechanical and assembly units of viral capsids via quasi-rigid domain decomposition.
- Prof. P. Burkhard, Institute of Materials Science and Department of Molecular and Cell Biology, **University of Connecticut** (USA) project on the structure of nanoparticles.
- Prof. P. Cermelli **University of Torino** - research topics: conformational changes in viruses.
- Prof. A. Albano **University of Torino** - research topics: theory of invariants.
- Prof. G. Zanzotto **University of Padova** - research topics: multilattices.
- Prof. P. Biscari **Politecnico di Milano** and M. Urbano **SAES Getters (Lainate)** - research topics: shape memory alloys

Research visits at:

- SISSA**-Trieste (several visits in 2010-2013);
- University of Padova** (several visits in 2008-2012);

- University of Kentucky** (USA). May 3-10 2008 /Apr. 16 - May 11 2009, visit to Prof. M. Jabbour;
- Mathematisches Forschungsinstitut Oberwolfach** (Germany). Dec. 16-22 2007. Week on "Material Theories" collaboration with Prof. G. Zanzotto and Prof. P. Cermelli;
- Institut National Polytechnique de Lorraine** - Laboratoire: LEMTA Mécanique et Energétique (extensive periods 2005/2007)

Invited talks at international meetings

- "A mathematical toolkit for the prediction of the geometry of self-assembling nanoparticles", **4th Mathematical Virology Workshop**, York (UK), Aug.18-22, 2014
Plenary talk
- "A coarse grained model of structural transitions of viral capsids", **Mathematics and Mechanics of Biological Assemblies and Soft Tissue Workshop**, Roma (Italy), Feb. 13-15 2013
- "Expansion of icosahedral viral capsids via non-icosahedral pathways: a coarse grained model" **Northern Regional Meeting of the London Mathematical Society & Workshop on Mathematics of Human Biology**, Newcastle (UK), June 6-8 2012
- "Non-icosahedral pathways for the expansion of icosahedral viral capsids: a coarse grained model", **American Mathematical Society Special Session & Workshop on Discrete Models in Molecular Biology**, Tampa (USA) Mar.10-14 2012
- "Mathematical problems in the description of structural transitions of viral capsids", **Mathematics and Mechanics of Biological Assemblies and Soft Tissue Workshop**, Milano (Italy), Feb. 20-22 2012
- "An example of Marie Curie project: MATVIR" welcome home workshop University of Torino (Italy), Dec. 17-21 2012
- "The dynamic behaviour of viral capsids under structural transitions important for infection", **SMB 2011/ECMTB 2011 Conference**, Krakow (Poland), June 28 - July 2 2011
- "Crystallography of structural transitions in viral capsids", **3rd Mathematical Virology Workshop**, Ambleside (UK), Aug.16-20, 2010
- "Structural transitions in viruses", **SMB / BIOMAT 2010**, Rio de Janeiro (Brasil), July 24-29 2010
- "Bending and twisting effects in inextensible networks", **Symposium on Mathematical Modeling, Mechanics & Materials**, Bressanone (Italy) Mar. 17-21 2007
- "Inextensible networks with bending and twisting effects", **Intensive seminar on Nonlinear Waves, Generalized Continua and Complex Structures**, Torino (Italy), May 4-6 2005

Contributed talks at international meetings

- "Non-icosahedral pathways for the expansion of icosahedral viral capsids: a coarse grained model" Congress of the Italian Society for Industrial and Applied Mathematics (**SIMAI 2012**) Torino (Italy), June 25-28 2012
- "A mathematical approach to structural transitions in viral capsid International", **International Conference on Mathematical and Computational Biology**, Melaka (Malaysia), Apr. 12-14 2011
- "Symmetry Properties of the Elastic Energy of a woven fabric with bending and twisting resistance", Congress of the Italian Society for Industrial and Applied Mathematics (**SIMAI 2010**) Roma (Italy), Sept. 15-19 2008

- "Symmetry Properties of the Elastic and Bending Energy of a 2Dimensional Fibered Network, with Applications to Soft Materials and Bio-Materials", **SIAM Conference on Mathematical Aspects of Materials Science**, Philadelphia (USA) May 11-14 2008

Participation in research projects

- "Mathematical virology: A novel approach to the structure and assembly of viruses" **Research Leadership Award 2007** (PI: Prof. R. Twarock, The University of York)

- "Mathematical virology: a classification of virus architecture and the structural transitions important for maturation and infection" **Marie Curie Actions – Intra-European Fellowships** FP7-MC-IEF 2009 (Named Researcher, PI Prof. R. Twarock, The University of York)

- "Mathematics and mechanics of biological systems and soft tissues" **PRIN 2009-2013** (PI: Prof. G. Saccomandi, University of Perugia)

- "Mathematical models for materials science and complex systems" Progetto di Ateneo 2008 (PI: Prof. Cermelli, University of Torino)

- "Mathematical models for materials science" **PRIN 2005-2007** (PI: Prof. A. Di Carlo, University of Roma 3);

- "Multiscale problems in solids" Progetto di Ateneo 2007 (PI: Prof. P. Cermelli, University of Torino)

- "Does noise simplify or complicate the dynamics of nonlinear systems?" INDAM Project 2004 (PI: Prof. L. Sacerdote, University of Torino)

Participation in schools

- "Mathematical problems in the physics of crystals and quasicrystals", Prof. P. Cermelli, Brescia, Feb. 2-4 2009

- "Mathematical models in continuum mechanics", Prof. P. Podio-Guidugli, Brescia, Feb. 25-27 2008;

- "Fundamental mathematical structures in neo-classical continuum mechanics", Prof. A. Di Carlo, Brescia, Jan. 29-31 2007;

- Meeting: "Nonlinear dynamics and noise in biological systems", Torino, Apr. 19–21 2004;

- "Does noise simplify or complicate the dynamics of nonlinear systems?", Prof. F. Flandoli, B. Gentz, P. Kloeden, Torino, Apr. 13–17 2004;

- "Introduction to wavelets and some application", Prof. Sablonnière, Torino, Jan. 27-30 2004.

Member of the local organizing committee of the following conferences and events:

- "3rd Mathematical Virology Workshop", Ambleside (UK), Aug. 16-20, 2010;

- 11th Euromech-Mecatmat conference "Mechanics of microstructured solids: cellular materials, fiber reinforced solids and soft tissues", Torino (Italy), Mar. 10-14 2008;

- "Intensive seminar on Nonlinear Waves, Generalized Continua and Complex Structures", INPL, Nancy (France), Apr. 3-7 2006;

- "Intensive seminar on Nonlinear Waves, Generalized Continua and Complex Structures", Department of Mathematics University of Torino, May. 4-6 2005.

Teaching

Teaching experience as assistant professor at the University of Torino and Politecnico of Torino from 2004 to 2008.

Dissemination activities

I have organized activities aimed to increase the impact of mathematical research in everyday's life, and to disseminate aspects of the mathematical research to non-specialists such as:

- Focus for maddmaths: <http://maddmaths.simai.eu/divulgazione/i-virus-conoscono-la-matematica/>

I contributed to the following events:

- "Florence Nightingale Day" - Maths Gallery at Lancaster University Apr 17 2013
- "Cambridge Science Festival 2011" at Newton Institute Cambridge, dissemination activities related to the talk 'Viruses under the Mathematical Microscope: Deciphering the Code of Viral Geometry'
- "Researcher's Night" Torino Sep. 26 2008;
- "Accademia della matematica: L'uomo che fece l'uovo" (funded by Fondazione per la Scuola Compagnia di San Paolo) Apr. 10-12, Nov. 27-29 2008, Feb.12-14, Nov. 18-21 2009, Feb. 14-17, Dec. 16-19 2010, Mar. 4-7 2011;

In this last case, I have contributed to the development of a training curriculum for Italian high-school teachers, with the goal of providing guidance and inspiration in improving teaching. This work also implied coordinating and supervising the residential visits of groups of teachers with mathematical "laboratory work" for periods as long as three days. Moreover I have been a Tutor in the following events aimed to high-school students

- "Snowmath-Matematica sulla neve" (Department of Mathematics University of Torino) Torino 15–18 Nov.2005.
- "Progetto Elites - Tre mattine all'Università" Department of Mathematics University of Torino a.y. 2005/2006 a.y. 2006/2007.

Torino, 10/07/2015