PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Nicola Isernia

XXXIV Cycle

Training and Research Activities Report – Third Year

Tutor: Fabio Villone

1. Information
    a. Nicola Isernia, M.Sc. in Electrical Engineering, Università degli Studi di Napoli Federico II
    b. XXXIV Cycle - ITEE Doctoral School, Università degli Studi di Napoli Federico II
    c. Athenaeum fellowship
    d. Tutor: Prof. Fabio Villone
2. Study and Training activities
    a. Courses [9]
    Introduzione ai Circuiti Quantistici (28/09/2020 – 22/12/2020, Esame sostenuto in data 28/05/21) [9]
    b. Seminars [2.1]
        - "Science, Reality and Credibility. Il ruolo del pensiero scientifico per contrastare la disinformazione e affrontare le grandi sfide del futuro.", Prof. Saul Perlmutter (Physics Nobel Prize 2011), 24/11/2020 in the framework of the scientific festival "Futuro Remoto" [0.3]
        - "At the Nexus of Big Data, Machine Intelligence and Human Cognition", Prof. George Djorgovski, 02/12/20 in the framework of Antonio Picariello Lectures [0.2]
        - "Force and Visual Control for Safe Human−Robot Interaction", Prof. Bruno Siciliano, 03/12/20 for the Department of Electrical Engineering and Information Technology at The Chinese University of Hong Kong [0.4]
        - "Realistic global simulations of stellar interiors", Prof. Jane Pratt (Georgia State University), 03/12/2020 for the JOREK Team [0.2]
        - "Probing gravitational field: a fundamental viewpoint.", Prof. Lorenzo Fatibene, 21/01/2021 in the framework of the SSM scientific colloquia [0.2]
        - "Machine Learning: causality lost in translation" – Prof. E. A. Valentijn, 10/02/21 in the framework of Antonio Picariello Lectures on Data Science [0.2]
        - "The coming revolution of Data driven Discovery (a fourth Methodological Paradigm of Science)" – Prof. Giuseppe Longo in the framework of Antonio Picariello Lectures on Data Science (25/03/21) [0.2]
        - "Material-Independent Modes for the Electromagnetic Scattering" – Mariano Pascale (29/06/21) [0.2]
        - "Turbulent dynamics in viscous fluids: a complex phenomenon ubiquitous in nature", Prof. Vincenzo Carbone (18/11/21 for the Scuola Superiore Meridionale Scientifc Colloquia) [0.2]
        - "Relatività Speciale: storia e ruolo nella fisica" (16/12/21 delivered as internal Seminar for several research groups in the field of Electrical, Structural and Fluid Dynamics engineering) [-]
    c. External courses (attended as Seminars) [1]
        - Advanced Course on Plasma Physics and Diagnostics delivered by the international PhD Programme in Fusion Science and Technology, with special emphasis on the lectures
            - Non-linear MHD Theory and HPC physics – Marco Veranda – 09/03/21 [0.2]
            - SOL & divertor physics – N. Vianello – 10/03/21 [0.2]
        - Advanced Plasma Control Course for the International PhD in Fusion Science and Technology, with special emphasis on lectures:
            - "Design plasma magnetic control, Matlab hands-on session" – Ph.D. Adriano Mele (15/06/21, in the frame of Advanced Plasma Control Course for the International PhD in Fusion Science and Technology) [0.3]
            - "Plasma scenario design & optimization" – Prof. Roberto Ambrosino (16/06/21, in the frame of Advanced Plasma Control Course for the International PhD in Fusion Science and Technology) [0.3]
3. Research activity
    a. Title

        The plasma – structures electromagnetic interaction in Tokamaks

b. Study

Magneto-Hydro-Dynamic plasma models in interaction with surrounding currents, including evolutionary equilibrium simulations.

c. Research description

The research focus of this year was mainly devoted to three correlated but distinct topics:

- Finalization of **thermodynamic framing of *Magneto-Hydro-Dynamics***, with focus on chemically reacting fluid mixtures. The description of partially ionised gases in the framework of extended-MHD models is an important step in the understanding of tokamak operational regimes with significant plasma-wall contact. Ultimately, we dedicated some efforts to the study of the sheath region, which is typically not in conditions local thermodynamic equilibrium. This study is fundamental in the understanding of halo currents, and in the future self-consistent description of such electromagnetic phenomena.
- Implementation of the **JOREK-CARIDDI coupling** via the ***Virtual Casing Principle***. This activity is in collaboration with the *fast particles and MHD unit* at the *Max Planck Institute for Plasma Physics* of Garching. We extended the capabilities of the CARIDDI code to include a description of the JOREK boundary. First equivalent currents to the plasma where tested successfully for the axisymmetric case. The calculation of magnetic fields due to equivalent currents at the JOREK boundary seems also promising.
- **Alternative formulations** for the **JOREK-CARIDDI coupling**. This activity is in collaboration with the *fast particles and MHD unit* at the *Max Planck Institute for Plasma Physics* of Garching. We are investigating other possible Coupling schemes for the self consistent interaction of the two models, which however is applicable in many other contexts. We postulated some possible *direct* Boundary Element Methods formulation. Preliminary tests internal to the JOREK group show the viability of such approaches to our case
- **Simulation** of **real Tokamak experiments** by the evolutionary equilibrium model *CarMa0NL*. We dedicated some efforts in fitting our simulations to real experimental data available from JET and TCV magnetic diagnostics. We find a reasonable agreement of the dynamic simulation of JET shot #71985, which highlights the importance of the proper set up of the width of the halo layer. Moreover, we dedicated a simulation campaign to the study of disruption trajectories in TCV. This is the companion activity to a recent experimental campaign taking place at the TCV tokamak. We found good qualitative, and sometimes quantitative, agreement. We are developing dedicated analytical models to explain some of the observed correlations between pre-disruption position and plasma displacement during the disruption.
- **Simulation** of **COMPASS** experiments and **COMPASS-U** planned experiments. This activity is in collaboration with Ph.D. Vadim Yanovskiy, which lead most of the simulations. In the former case we are interested to the study of halo currents, and the activity is still very preliminary. In the second case we were motivated by the necessity of estimating forces on the for the COMPASS-U tokamak which is being built at *Institute of Plasma Physics of Prague*.

d. Collaborations

- PhD Vadim Yanovskiy – Design of COMPASS-U and modelling of COMPASS experiments.
- Joint European Torus (JET) Work Package T17-13 “Disruption and runaways” – Coupled plasma-structure models for JET experiments.
- *Fast particles and MHD unit* at the *Max Planck Institute of Plasma Physics (Garching, DE),* in particular: Ph.D. Mathias Hoelzl (Head of the research unit), Ph.D. F.J. Artola, Ph.D. student N.Schwarz – Implementation of the coupling of the extended-MHD code JOREK and the eddy current code CARIDDI

4. Products

a. Journal Publications

i. "Global forces on the COMPASS-U wall during plasma disruptions", Yanovskiy, V.; Isernia, N.; Pustovitov, V. D.; Scalera, V.; Villone, F.; Hromadka, J.; Imrisek, M.; Havlicek, J.; Hron, M. & Panek, R., Nuclear Fusion, Vol. 61, 096016

ii. P. Vondracek, R. Panek, M. Hron, J. Havlicek, V. Weinzettl, T. Todd, D. Tskhakaya, G. Cunningham, P. Hacek, J. Hromadka, P. Junek, J. Krbec, N. Patel, D. Sestak, J. Varju, J. Adamek, M. Balazsova, V. Balner, P. Barton, J. Bielecki, P. Bilkova, J. Błocki, D. Bocian, K. Bogar, O. Bogar, P. Boocz, I. Borodkina, A. Brooks, P. Bohm, J. Burant, A. Casolari, J. Cavalier, P. Chappuis, R. Dejarnac, M. Dimitrova, M. Dudak, I. Duran, R. Ellis, S. Entler, J. Fang, M. Farnik, O. Ficker, D. Fridrich, S. Fukova, J. Gerardin, I. Hanak, A. Havranek, A. Herrmann, J. Horacek, O. Hronova, M. Imrisek, N. Isernia, F. Jaulmes, M. Jerab, V. Kindl, M. Komm, K. Kovarik, M. Kral, L. Kripner, E. Macusova, T. Majer, T. Markovic, E. Matveeva, K. Mikszuta-Michalik, M. Mohelnik, I. Mysiura, D. Naydenkova, I. Nemec, R. Ortwein, K. Patocka, M. Peterka, A. Podolnik, F. Prochazka, J. Prevratil, J. Reboun, V. Scalera, M. Scholz, J. Svoboda, J. Swierblewski, M. Sos, M. Tadros, P. Titus, M. Tomes, A. Torres, G. Tracz, P. Turjanica, M. Varavin, V. Veselovsky, F. Villone, P. Wąchal, V. Yanovskiy, G. Zadvitskiy, J. Zajac, A. Zak, D. Zaloga, J. Zelda, H. Zhang,
"*Preliminary design of the COMPASS upgrade tokamak*", Fusion Engineering and Design, Volume 169, 2021,112490, ISSN 0920-3796, DOI: 10.1016/j.fusengdes.2021.112490

iii. S. Perna, V. Scalera, M. d'Aquino, N. Isernia, F. Villone and C. Serpico, "*Magnetostatic Field Computation in Thin Films Based on k-Space Fast Convolution With Truncated Green's Function*" in IEEE Transactions on Magnetics, vol. 58, no. 2, pp. 1-6, Feb. 2022, Art no. 7000106, doi: 10.1109/TMAG.2021.3079474.

b. Conference Publications

i. M. Cianciosa, N. Isernia, G. Rubinacci, D. Terranova, F. Villone, "*Coupled Modeling for Self Consistent Equilibrium Evolution Using the IPS Framework*", 47th Plasma Physics Conference of the European Physical Society, online, 2021, (OCS: P1.1038)

ii. F. Villone, S. Coda, N. Isernia, G. Rubinacci, the TCV and EUROFusion MST1 Team, "*Disruption trajectory studies on TCV: experiments and modelling*", 47th EPS Conference on Plasma Physics, online, 2021 (P4.1029)

c. Submitted/in preparation:

i. "*Magneto-Hydro-Dynamics as Non-Equilibrium Thermodynamics application*", N. Isernia, F. Villone, C. Serpico (internal revision concluded, ready for submission)

ii. "*Sideways forces on asymmetric tokamak wall during plasma disruptions*", Yanovskiy, Vadim; Isernia, Nicola; Pustovitov, Vladimir; Villone, Fabio. (submitted to Nuclear Fusion and in advanced peer-review phase)

iii. "*Effects of plasma mass on axisymmetric plasma evolution in tokamaks*", F. Villone, A. De Pasquale, N. Isernia (in preparation)

iv. "*CarMa0NL modelling of COMPASS halo currents*", V.V. Yanovskiy, A. Casolari, J. Havlicek, A. Iaiunese, N. Isernia, E. Matveeva, V.D. Pustovitov, F. Villone (in preparation)

v. "*The JOREK-CARIDDI Coupling via the Virtual Casing Principle*", N. Isernia, N. Schwarz, F.J. Artola, M. Hoelzl, G. Rubinacci, S. Ventre, F. Villone (planned for 48th EPS Conference on Plasma Physics)

5. Conferences and Seminars
   a. 47th EPS Conference on Plasma Physics (21-25/06/21 – Online).
   b. Delivering Seminar "Magneto-Hydro-Dynamics as a Continuum Theory" for the course Electrodynamics of Continuous Media (Mathematical Engineering – Federico II), 20/04/2021
   c. Delivering Seminar "Energy balance during disruptions" in the framework of Fusion EP Webinars, 27/04/2021
6. Activity abroad
   Max Planck Institute for Plasma Physics (Garching, DE) 01/07/21 – 30/09/21
   Contact person: Ph.D. Matthias Hoelzl (Head of the *fast particles and MHD* research unit)

The activity was dedicated mainly to the coupling of the electromagnetic model for tokamak conductors CARIDDI to the extended-MHD model for the plasma JOREK, as detailed in previous points.

30/01/22

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Cycle XXXIV

	Credits year 1								Credits year 2								Credits year 3								
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6		
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth + ext	Summary	Total
Modules	23	9	9.4		9			**27.4**	15		3			8.4	4	**15.4**	20				9			**9**	**51.8**
Seminars	7	0	0.6	0.7	1	0	3	**5.3**	3	1.4		0.8	0.5		1.5	**4.2**	5	1.1	0.4	0.6	0.8		0.2	**3**	**12.6**
Research	34	2	1	6.3	5	8	6	**28.3**	42	8.6	7	9.2	9.5	1.6	4.5	**40.4**	34	8.6	8.6	8	4	8.7	24	**62**	**130.6**
	64	11	11	7	15	8	9	**61**	60	10	10	10	10	10	10	**60**	59	9.7	9	8.6	14	8.7	24	**74**	**195**

Check
30-70
10-30
80-140
180

Year	Lecture/Activity	Type	Credits	Certification	Notes
1	Elettromagnetismo e Relatività	Ad hoc module	5	x	
1	Mathematical Physics Model	MS module	9	x	
1	A leap into functional data analysis	Ad hoc module	2	x	
1	MHD Equilibrium and Stability	Ad hoc module	2.4	x	
1	Meccanica Statistica	MS module	9	x	
1	Author Seminar: How to publish a scientific paper	Seminar	/	x	
1	Computational And Machine Learning for Complex Ecosystems	Seminar	0.2	x	
1	Chaos in Magnetizationd Dynamics	Seminar	0.4	x	
1	Spin-orbit optical phenomena	Seminar	0.2	x	
1	IEEEXplore Training and Authorship Workshop	Seminar	0.5	x	
1	Medical Thermal Therapy and Monitoring using Microwave Inverse Scattering	Seminar	0.2	x	
1	Scuola F. Gasparini - Viterbo	PhD School	0.8	x	
1	Scuola F. Gasparini - Napoli	PhD School	3	x	
2	Scientific Programming and Visualization with Python	Ad hoc module	3	x	
2	Analisi Funzionale	MS module	6	x	
2	Machine Learning	Ad hoc module	2.4	x	
2	Mathematics of the Finite Element Method	Ad hoc module	4	x	
2	Seminar Cycle "Intelligenza Artificiale ed Etica"	Seminar	1.4	x	
2	Formulation of the magneto-mechanical problem by using the principle of ene	Seminar	/	/	
2	Derivation of Balance Equations of Electrodynamics Materials based on Avera	Seminar	/	/	

2	How to get published with IEEE?	Seminar		0.4	x
2	Elettromagnetismo e Salute	Seminar		0.4	/
2	Premixed model for interactions of a plasma with the injection of atoms	Seminar		0.1	/
2	Asymmetric wall force and thermal quench in JET disruptions	Seminar		0.1	/
2	Noninvasive mapping of electrical properties using MRI	Seminar		0.3	x
2	Maximum Likelihood Tomography on JET: an overview with focus on bolomet	Seminar	/		/
2	How to publish Open access with IEEE to increase the exposure and the impa	Seminar	/		/
2	We are at a cross-roads (digital humanism)	Seminar		0.2	x
2	IBM Quantum: i primi computer quantistici per la ricerca e la didattica	Seminar		0.2	/
2	On Dead-Time Compensation in Repetitive Control	Seminar		0.2	x
2	Valutazione dei livelli di esposizione e del rispetto dei limiti Antenne e 5G	Seminar		0.3	/
2	Cybersecurity nella fabbrica intelligente	Seminar		0.4	x
2	Nonintrusive reduced order models using physics informed neural networks	Seminar		0.2	x
3	Science, Reality and Credibility. Il ruolo del pensiero scientifico per contrastare	Seminar		0.3	x
3	At the Nexus of Big Data, Machine Intelligence and Human Cognition	Seminar		0.2	/
3	Force and Visual Control for Safe Human−Robot Interaction	Seminar		0.4	x
3	Realistic global simulations of stellar interiors	Seminar		0.2	/
3	Probing gravitational field: a fundamental viewpoint	Seminar		0.2	/
3	Machine Learning: causality lost in translation	Seminar		0.2	/
3	The coming revolution of Data driven Discovery (a fourth Methodological Para	Seminar		0.2	/
3	Non-linear MHD Theory and HPC physics	Adv. Lecture		0.2	x
3	SOL & divertor physics	Adv. Lecture		0.2	x
3	Material-Independent Modes for the Electromagnetic Scattering	Seminar		0.2	x
3	Design plasma magnetic control, Matlab hands-on session	Workshop		0.3	x
3	Plasma scenario design & optimization	Seminar		0.3	x
3	Turbulent dynamics in viscous fluids: a complex phenomenon ubiquitous in na	Seminar		0.2	x
3	Relatività Speciale: storia e ruolo nella fisica	Seminar	/		/