Queen's University Belfast

HORIZON 2020

Horizon 2020 Marie Skłodowska-Curie Actions
Individual Fellowships Call 2017 – Expression of Interest

Contact Person	**Dr Ioannis Kourakis**

Research Field(s)

☐Chemistry CHE	☐Environment and Geosciences ENV
☐Social and Human Sciences SOC	☐Life Sciences LIF
☐Economic Sciences ECO	☒Mathematics MAT
☐Information Science and Engineering ENG	☒Physics PHY

Keywords:

Physics: Nonlinear Physics; Plasma Physics; plasmonics; wave propagation in dispersive media; instabilities, shocks, nonlinear structures related to electrostatic and electromagnetic waves, laser plasma interactions (theoretical).
Mathematics: Nonlinear Dynamics; Solitons; Nonlinear Partial Differential Equations (PDEs).

Short description of the Faculty/Dept./School/Centre:

The Centre for Plasma Physics (CPP) is part of School for Mathematics and Physics at Queen's University Belfast. CPP has long experience in both experimental and theoretical plasma physics. It hosts a world-class laser facility (TARANIS) which allows for cutting edge experiments on laser-plasma interactions, along with the associated theoretical research, performed by the theory group.

Short Description of the research project

The dynamics of coherent large-amplitude nonlinear excitations is a frontier topic in modern plasma science [1], among other physical contexts [2]. Such excitations are efficiently modelled as solitons [2], i.e. pulse- or kink- shaped structures which preserve their shape during propagation, thanks to a mutual balance between dispersion and nonlinearity, amidst a plethora of other mechanisms affecting their dynamics (ponderomotive effects, collisions, dissipation, turbulence, mode coupling). Typical representatives of the nonlinear structure family include solitons and double layers (or shocks), along with more recent paradigms, such as rogue waves (freak waves) [3] and supersolitons [4]. Thanks to their remarkable stability properties, solitons arise as ideal carriers of localised lumps of energy in various physical contexts where energy transport mechanisms are of relevance. In the framework of laser-beam-plasma interactions, these include inertial confinement fusion (ICF) energy production schemes, where a fuel pellet is ignited by an incident "shock". Furthermore, *particle acceleration* by shock structures is a mechanism of importance in astrophysics [5], as well as in ion acceleration schemes in the laboratory [6], but also in innovative theoretical ion acceleration schemes for overdense plasmas [7].

In this proposal, we envisage a comprehensive investigation of the dynamical characteristics of structures arising as numerical solutions of a hybrid fluid-plasma/Maxwell model. We plan to build up on existing studies, based on purpose-built fluid-plasma codes, in view of a detailed comparison

Queen's University Belfast

HORIZON 2020

with analytical theories, on one hand, and also with recent results from particle-in-cell (PIC) simulations, on the other. Structures covered will include mainly solitons (pulses) and double layers (kinks, shocks), but may also be extended to more sophisticated waveforms, such as freak waves [3] and supersolitons [4] in various plasma configurations.

Extensive use of computational plasma research techniques will be made, in combination with theoretical investigations, meant to provide insight in possible initial conditions for the simulation. Some experience in numerical modelling (e.g. Matlab) and, ideally, in symbolic computation (Maple, Mathematica) is thus indispensable. Numerical work will either reply on existing codes, or to be developed.

References:

[1] *Nonlinear Waves, Solitons & Chaos*, E.Infeld & G.Rowlands, Cambridge U. Press, 2000.
[2] *Physics of Solitons*, Thierry Dauxois & Michel Peyrard, Cambridge Univ. Press, 2006.
[3] *Electromagnetic Rogue Waves in Beam-Plasma Interactions*, G.P. Veldes, J. Borhanian, M. McKerr, V. Saxena, D.J. Frantzeskakis and I. Kourakis , *J. Optics* **15**, 064003 (2013).
[4] *Electrostatic supersolitons in three-species plasmas*, F. Verheest, M.A. Hellberg and I. Kourakis, *Phys. Plasmas* **20**, 012302 (2013).
[5] Holland Publ. Co. Elsevier Sci. Publ. Amsterdam, 1990);
[6] D. Haberberger *et al,* Nat. Phys. **8**, 95 (2012).
[7] A. Macchi, *et al*, Phys. Rev. E, **85**, 046402 (2012).

Expertise required by the applicant

The applicant should have a solid background in either theoretical physics (plasma physics or/and materials or/and nonlinear optics) or applied mathematics (nonlinear dynamics, preferably), in addition to a good knowledge of computational techniques. The project will include a series of computational tasks, in parallel with developing techniques of nonlinear analysis for physical systems off-equilibrium. Our focus will be either beam-plasma interactions, or nonlinear dispersive media.

Application procedure

The projects relies on external funding, via the H2020 Marie Skłodowska-Curie/Individual Fellowships 2017 scheme, to be applied for. This is a competitive scheme, and success depends on the candidate profile. Highly qualified candidates interested in the project should contact Dr Yannis Kourakis (i.kourakis@qub.ac.uk) for a preliminary discussion. Project details, both in actual content (problems to be investigated) and in methodological approach (computation versus theory) will be determined and will be fine-tuned and optimised, depending on the applicant background and skills.