2022 CIMPA School Project Proposal

(This fictitious example is freely adapted from schools that have taken place; the French example is distinct)

1 General Information

CIMPA School title: Dynamical Systems and Applications
Official language of the school: English
Country: Benin
Name and address of the host institution (university or equivalent): Institut de Mathématiques et de Sciences Physiques (Dangbo), Université d'Abomey-Calavi
Dates (option A): 18/04/2022 - 29/04/2022
Dates (option B): 09/05/2022 - 20/05/2022

2 Administrative and scientific coordinators

Local coordinator
NAME: MARCOS
Given name (first name): Aboubakar
Gender: Male
Institution and position: Institut de Mathématiques et de Sciences Physiques (IMSP), Professor.
Country: Benin
Email address: ****@yahoo.fr

External coordinator:
NAME: SEARA
Given name: Tere
Gender: Female
Institution and position: Universitat Politecnica de Catalunya, Professor
Country: Spain
Email address: ****@upc.edu

3   Description of the project

Scientific content

The school aims to introduce graduate students and young researchers to the modern theory of dynamical systems and its applications, with a focus on geometric, topological, and numerical methods. The courses will be focused on some key topics in low and high dimensional dynamics, including Hamiltonian systems and Celestial Mechanics. They will also discuss statistical properties of dynamical systems, and their relation with the underlying geometric structures. The participants will be provided with an introduction to the basic material and with the necessary background, before proceeding with the more advanced topics. Geometric and topological methods in dynamics provide a global picture of the structures that organize the dynamics. They are also essential in designing and implementing rigorous numerical experiments. The courses will survey a range of applications including classical mechanics, space mission design, dynamical astronomy, material science and biology.

The introductory lectures will be handled as flipped classes by the students themselves. Advanced lectures, combined with solving exercises and computer experiments, will also be provided. The school participants will be engaged by the instructors through hands-on activities, practical sessions, problem solving, and research projects. They will be organized in study groups, and will be in charge of writing detailed notes.

Host institution and local context in mathematics

The Institut de Mathématiques et de Sciences Physiques (IMSP) is a graduate school of mathematics and physics, located at Dangbo in Benin. The creation of IMSP goes back to 1988, and is a result of the initiative of the late Professor Abdus Salam, Nobel Prize winner and former Director of the International Centre for Theoretical Physics (ICTP), in Trieste (Italy), with the approval of the government of Benin. The fundamental goal of IMSP is to enhance training and research in Mathematics, Physics and Computer Sciences in Africa, mainly in the Sub-Saharan Africa. In this framework, IMSP since 1988, has selected and trained talented students for Master and PhD in PDEs, Control theory, Riemannian, pseudo-Riemannian and Symplectic Geometries, in Physics, in Mathematical Physics and in Computer Science, for 15 countries of Africa. More than 82 PhD have been delivered and all those alumni have obtained a position in their home institutions or in some foreign ones. Many seminars, schools and conferences have been organized by the institution. Many of those activities have been partially funded by the CIMPA, and recently from 7 to 19 July, 2014, IMSP hosted the CIMPA-UNESCO-BENIN research school on Algebraic Number theory and Applications. The Institut de Mathématiques et de sciences Physiques has be recognized by the African Mathematics Union (UMA) as a scientific centre of excellence in 1994 and next, by the DAAD-Germany through his program: Scholarships for postgraduate Training and Research at African Re gional Networks of Centers of Excellence. In 2013, the Institute has been selected and funded as African Centre of Excellence (ACE) by the World bank in order to promote regional specialization in areas that address regional challenges of

development and strengthen its capacity to deliver quality training and applied mathematics.

Prior work related to the project and/or combine with the project

A series of international activities on Dynamical Systems at IMSP has taken place at IMSP since January 2020 under the coordination of Prof. Stefano Luzzatto (ICTP, Trieste, Italy), thanks to the support of ICTP. The objective has been to give a precise and formal mathematical foundation to the Theory of Dynamical Systems and Ergodic Theory, which constitute a really active and vibrant area of mathematical research and have strong interactions with many different areas of research from geometry to functional analysis, from mathematical physics to applications in natural sciences and modeling. The first series of Dynamical Systems courses took place in 2020 and consisted of the following series of courses : " Introduction to Dynamical Systems" by Sergey Tikhomirov (Max Planck Institute for Mathematical Sciences, Leipzig, Germany), "Introduction to Dynamical Systems and Ergodic Theory" by Samuel Senti (Federal University of Rio de Janeiro, Brazil), "Introduction to Complex Dynamics" by Marcos Abate (University of Pisa, Italy) and "Introduction to Ergodic Theory" by Stefano Luzzatto (ICTP, Trieste, Italy). We will have a second series of Dynamical Systems courses in May 2021 involving mainly students from IMSP. It will be about " Introduction to circle maps" with lectures given by the professors Marco Martens (Stony Brook, USA) and Liviana Palmisano (Polish Academy of Sciences, Poland). These series of lectures will help preparing the students to the School.

Expected impact and follow-up of the project

The expected impact is firstly to have IMSP students interested and involved in the Theory of Dynamical Systems and eventually choose a related research problem, and secondly to set up a Master/Doctoral Programme in the Field of Dynamical Systems. We also believe that this school will have a powerful impact on the development of mathematical sciences in the neighboring countries. The course will train students in geometric, topological and numerical aspects of dynamical systems by means of, and in the context of applications. The proposed topics will integrate the knowledge from different areas of mathematics, and will provide a solid basis for scientific computing. The course will outline several new research directions and present the latest developments in the field. The range of applicability of the proposed topics, including particle physics, hydrodynamics, biological and medical sciences, space mission design, computer vision, will very likely motivate the participants to achieve a deeper knowledge and a solid understanding of the dynamical systems phenomena.

The lecturers in the program are planning to give a list of follow-up readings and some concrete problems that the students could try to do, and to organize a reading group which can meet using Skype or social media. The lecturers have also expressed their availability to further mentor and co-advice the participating students and fellows in their future academic endeavors.

Infrastructure

The school will take place on the campus of IMSP at Dangbo. We will use the auditorium, the seminar room and a classroom. Speakers will be accommodated in some hotel close to the campus and a shuttle between the hotel and the campus will be arranged for free. CIMPA participants will share dormitories (double rooms) on the campus. Moreover, all lunches will be taken all together on the campus.

Expected participants

Among participants, we plan to have about about 30 students and researchers from Benin and 20 CIMPA participants from the subsaharian region. We may also have additional foreign participants not covered with CIMPA's support.

4 Scientific committee

Member 1
NAME: SEARA
Given name: Tere
Gender: Female
Institution and position: Universitat Politecnica de Catalunya, professor
Country: Spain
Role: External coordinator and lecturer
Member 2
NAME: DE LA LLAVE
Given name: Rafael
Gender: Male
Institution and position: Georgia Institute of Technology, assistant professor
Country: USA
Role: Instructor
Member 3
NAME: LUZZATTO
Given name: Stefano
Gender: Male
Institution and position: ICTP, professor
Country: Italy
Role: Lecturer and member of the math department of ICTP
Member 4
NAME: SALVO
Given name: Laura
Gender: Female
Institution and position: University Roma 3, professor

Country: Italy
Role: Scientific coordinator of a network between Italy and West Africa
Member 5
NAME: RECHTMAN
Given name: Ana
Gender: Female
Institution and position: France, IRMA Strasbourg, assistant professor
Country: USA
Role: Instructor

Total percentage of women/men : 60% and 40%

5 Organizing committee

Member 1
NAME: MARCOS
Given name: Aboubakar
Gender: Male
Institution and position: IMSP, professor
Country: Benin
Role: Logistics and local support of the School
Member 2
NAME: DEGLA
Given name: Guy
Gender: Male
Institution and position: IMSP, assistant-professor
Country: Benin
Role: Logistics and local support of the School
Member 3
NAME: GANGBO
Given name: Jeanne
Gender: Female
Institution and position: UCLA, professor
Country: USA
Role: International liaison
Member 4
NAME: SEARA
Given name: Tere
Gender: Female
Institution and position: Universitat Politecnica de Catalunya, professor
Country: Spain

Role: Course curriculum, complementary activity (round table on gender issues) and women mentoring

Total percentage of women/men : 50% and 50%

6 Scientific program

Interactive activities

We plan that the three introductory courses below will be handled by flipped classes: PhD students and possible advanced Master students will be divided into three groups and the pdf of each course will be assigned to a group three months before the School starts. During that time the students will study the course with the online help of each instructor. Then they will split the content between them and each will present his/her part of the lecture during the School. Instructors will be in the classroom to correct and answer possible questions from the audience.

Activity 1
Description: Flipped class on Introduction to computation in dynamics
Abstract: The Poincare program for dynamical systems was based on finding invariant objects which acted as landmarks to understand the complicated behavior of systems. For mathematicians finding meant proving theorems of existence that also provided information about location and geometric properties. In modern days, this has also come to mean the use of computers. In this lectures, we plan to present some ideas on how to do computations that go hand in hand with the numerical understanding. Students will be encouraged to carry out some programming tasks in OCTAVE (a public domain computational package, with versions in almost all computer systems). These lectures will be followed by some practical tasks.
Duration: 5h
DE LA LLAVE Rafael (M) Georgia Institute of Technology, Assistant professor

Activity 2
Description: Flipped class on Computational Techniques, Tools and Implementations
Abstract: In this course we present some of the basic techniques that have been used to understand and take profit of the phase space of problems in the field of celestial mechanics and astronomy. Among other topics and extensions, the course includes computation of periodic orbits, and invariant tori using pure numerical or semianalytical approaches. The examples considered are chosen because of their practical interest in science and technology, but the scope of the tools presented are not limited to these particular fields.
Duration: 5h
MIRANDA Josepha (F), IMSP (Benin), Professor

Activity 3
Description: Flipped class on Flows without periodic orbits and plugs
Abstract: The problem of determining when the flow of a non-singular vector field on a closed 3-manifold has a periodic orbit has a long history. We will study examples of vector fields whose flow has no periodic orbits on any closed 3-manifold. These were first constructed by P. A. Schweitzer for C^1 vector fields, and then by K. Kuperberg in the smooth and real analytic categories. Schweitzer's construction was then achieved in the volume preserving category by G. Kuperberg, giving C^1 volume preserving vector fields without periodic orbits. An open question is whether a volume preserving flow on a closed 3-manifold must have periodic orbits. The construction of these flows are all based on the use of plugs: a devise that allows to destroy periodic orbits. The course will present the constructions and main applications.

Duration: 5h
RECHTMAN Ana (F), IRMA Strasbourg France, assistant professor

Introductory and advanced lectures

Course 1
Title: Invariant manifolds, splitting of separatrices and exponentially small phenomena: A Combinatorial/Topological Theory of Nonlinear Dynamics
Duration: 5h
Level: Advanced
Lecturer's NAME: SEARA
Lecturer's given name: Tere
Lecturer's gender: Female
Lecturer's institution and position: Universitat Politecnica de Catalunya, Professor
Lecturer's country: Spain
Abstract of the course: In this course we will talk about invariant manifolds in dynamical systems. We will focus on hyperbolic invariant objects and their stable and unstable manifolds. We will explore the important phenomenum of splitting of separatrices, a problem that Poincare called the "fundamental problem of dynamics". We will present the classical Melnikov method to measure the distance between invariant manifolds in a perturbative setting. Finally we will explain some exponentially small phenomena.

Course 2
Title: A Combinatorial/Topological Theory of Nonlinear Dynamics
Duration: 5h
Level: Advanced
Lecturer's NAME: MISCHAIKOW
Lecturer's given name: Konstantin
Lecturer's gender: Male
Lecturer's institution and position: Rutgers University, professor

Lecturer's country: USA
Abstract of the course: Abstract: It is reasonably safe to assume that much of the work of this century in dynamics will involve the study of multiparameter multiscale systems, will be done using computational methods, and will be based on the analysis of large data sets. In the 70s C. Conley developed a purely topological framework for the study of dynamics. This course will describe this work but from an algorithmic perspective. In particular, it will be shown that the essential ideas of Conley theory can be recast in a combinatorial and algorithmic framework which leads to efficient novel computational methods for nonlinear systems. Furthermore, the use of algebraic topology and new computational topological tools allows one to draw mathematically rigorous conclusions even in the context of finite resolution (measurements) in both phase space and parameter space.

Course 3
Title: Introduction to Differentiable Ergodic Theory
Duration: 5h
Level: Advanced
Lecturer's NAME: LUZZATTO
Lecturer's given name: Stefano
Lecturer's gender: Male
Lecturer's institution and position: ICTP, Professor
Lecturer's country: Italy
Abstract of the course: I will give a brief but precise introduction to the the basic notions of Ergodic Theory, including definitions and examples of invariant and ergodic measures and their main properties. I will prove ergodicity of Lebesgue measure for one-dimensional full branch piecewise linear maps and, depending on the time available, discuss the generalizations to piecewise C^2 maps.

Training sessions

Each course (introductory and advanced) will be combined by 3*1 hour of exercises on paper or with the software OCTAVE. They will be supervised by the instructor or lecturer of each course.

Total percentage of women/men: 50% and 50%

7 Recording or lectures and complementary activities

Recording the lectures (yes/no): Yes. The material and a technician are kindly provided by the university to record the lectures.

Complementary activities

Description: we will organize a round-table on gender issues in mathematics during the free afternoon of the first week. We will take advantage of the presence of Marie-Françoise Roy, president of the IMU committee for women in mathematics who is visiting the university at the same time.

Duration: 1h of discussions conducted by Tere SEARA and Josepha MIRANDA and followed by questions of the audience. Highschool teachers and their classes will also be invited. A small gathering after the meeting is offered by the university.

MIRANDA Josepha, IMSP (Benin), Professor ; SEARA Tere, Universitat Politecnica de Catalunya (Spain), Professor

8   Tentative schedule (to be given as a table)

Week 1

	M	T	W	T	F
AM	Opening ceremony Activity 1 (1h) Activity 2 (1h)	Act 1 (1h) Act 2 (1h) Act 3 (1h)	Act 1 (1h) Act 2 (1h) Act 3 (1h)	Act 1 (1h) Act 2 (1h) Act 3 (1h)	Act 1 (1h) Act 2 (1h) Act 3 (1h)
PM	Activity 3 (1h) Tutorial 1 (1h) Tutorial 2 (1h)	Tut. 3 (1h) Tut. 1 (1h) Tut. 2 (1h)	Free or round table	Tut. 3 (1h) Tut. 1 (1h)	Tut. 2 (1h) Tut. 3 (1h)

An excursion is planned during the week-end.

Week 2

	M	T	W	T	F
AM	Lecture 1 (1h) Lecture 2 (1h) Lecture 3 (1h)	Lec. 1 (1h) Lec. 2 (1h) Lec. 3 (1h)	Lec. 1 (1h) Lec. 2 (1h) Lec. 3 (1h)	Lec. 1 (1h) Lec. 2 (1h) Lec. 3 (1h)	Lec. 1 (1h) Lec. 2 (1h) Lec. 3 (1h)
PM	Tutorial 1 (1h) Tutorial 2 (1h) Tutorial 3 (1h)	Tut. 1 (1h) Tut. 2 (1h)	Free or round table	Tut. 3 (1h) Tut. 1 (1h)	Tut. 2 (1h) Tut. 3 (1h)

9   Provisional budget (expenses)

Transportation costs: 20 K€

- Airfare of 5 foreign speakers: 7 K€

- Transportation of 20 CIMPA students: 8 K€

- Transportation of other foreign students and researchers: 5 K€

- Shuttle from the hotels to the university supported by the university

Lodging: 4,700 €

- Accommodation for speakers (hotel) and CIMPA supervisor: 60 € per night * 6* 13 = 4,680 €

- Accommodation for non-local students supported by the university

Meals: 10,800€

- Midday meals for all participants and speakers (65): 10 € per day* 10 meals* 65 =6,500€

- Dinners for CIMPA participants, speakers and CIMPA supervisor (25): 10 € per dinner *12 dinners * 25= 3 K€

- Coffee-break: 2 €* 10 * 65= 1,300€

Logistics: 1 K€
Opening ceremony, posters, tags, secretary. The recording of the videos is supported by the university.

Others: 1 K€
Excursion

Total expenses: 37,500€

	Nb. pers.	days	price	cost	CIMPA	others
Foreign speakers	5		1,400	7,000		7,000
Tranport Part. CIMPA	20		400	8,000	8,000	
Transport others				5,000		5,000
Transport hotel						offered
Sub-total				20,000	8,000	12,000
Acc. students						offered
Acc. speakers	6	13	60	4,700	0	4,700
Sub-total				4,700		4,700
midday meals	65	10	10	6,500		6,500
dinner CIMPA and speakers	25	12	10	3,000	3,000	
Coffee-break	65	10	2	1,300		1,300
Sub-total				10,800	3,000	7,800
Logistics				1,000		1,000
Other				1,000	1,000	
Sub-total				2,000	1,000	1,000
Total				37,500	12,000 + 25,500 = 37,500	

10 Anticipated funding (resources)

Financial support requested from CIMPA: 12 K€
Local funding: 14 500€

- IMSP: 12,500€ (confirmed)

- Université d'Abomey-Calavi: 2 K€ (expected)

International funding: 4,500€

- AUF: 1,500€ (confirmed)

- IMU: 1,500€ (expected)

- ICTP: 1 K€ (expected)

Costs covered by lecturers: 7 K€ (all speakers will cover their travel expenses with their own grants).

Total ressources: 37,5000€

11 Support and involvement of local institutions

The Institut de Mathématiques et de Sciences Physiques provides accommodation for all CIMPA participants and some other participants. Moreover, the university provides a shuttle for the speakers and material and a technician for recording the lectures. The funding given by IMSP comes from the financial support provided by the World Bank.

12 Additional remarks and comments

None.