Nom et prénom du coordinateur / coordinator's name	**DUBOULOZ Adrien**		
Acronyme / Acronym	**BirPol**		
Titre de la proposition de projet	Automorphismes Polynomiaux et Transformations Birationnelles		
Proposal title	Polynomial Automorphisms and Birational Transformations		
Comité d'évaluation / Evaluation committee	**SIMI 1** – Mathématiques et interactions		
Type de recherche / Type of research	✙ Recherche Fondamentale / Basic Research ☐ Recherche Industrielle / Industrial Research ☐ Développement Expérimental / Experimental Development		
Aide totale demandée / Grant requested	124 664,00 €	**Durée de la proposition de projet / Proposal duration**	48 mois

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1. RÉSUME DE LA PROPOSITION DE PROJET / PROPOSAL ABSTRACT

The project BirPol concerns the interaction of algebraic geometry, commutative algebra, holomorphic dynamics and geometric group theory. The aim is to study the groups of polynomial automorphisms of affine spaces and Cremona groups, that is, birational transformations of projective spaces. These groups have already been extensively studied since the 19th century in classical algebraic geometry, however there are many questions concerning their structure which are still open for dimension three and higher. The study of these two groups has long been conducted separately, guided by varying interests and approaches. However, many recent results, both in algebraic geometry, group theory and holomorphic dynamics reveal a profound analogy between the two subjects both at the levels of known results essentially in dimension two, as in the conceptual and technical difficulties encountered in addressing their study in higher dimension.

The main scientific objective is to develop common techniques and approaches allowing us on the one hand to reinterpret and improve the existing results in dimension 2 and secondly to make significant progress in the study of polynomial automorphisms and birational automorphisms in dimension 3. The project team consists therefore of experts from various complementary aspects of these questions (birational projective geometry, affine algebraic geometry, holomorphic dynamics, real algebraic geometry, commutative algebra, invariant theory, geometric group theory), who will collaborate on different aspects to develop new approaches in this research area.

The activities planned in this project (quarterly mini-workshops, thematic conferences, and an international congress) have two complementary objectives: first to create an environment which encourages new collaborations between the various domains of the experts of the team which could lead to new results, and secondly to develop and promote the following directions of research :

1) the use and adaptation of the tools of Mori theory to the studies of polynomial and birational automorphisms; and

2) the development of a new approach to the moduli space of infinite dimensional groups based on the existing theory of ind-varieties and algebraic ind-schemes.

This project also aims to contribute to the establishment of a network of French researchers around the themes of affine geometry and birational transformations. At this time, such a network exists, but it is only structured around an informal Inter-University Franco-Swiss workshop group created in 2006 on the theme of automorphisms of affine spaces. This project will develop the group's activities, promote and distribute its interests and increase its visibility both nationally and internationally.

2. CONTEXTE, POSITIONNEMENT ET OBJECTIFS DE LA PROPOSITION / CONTEXT, POSITIONNING AND OBJECTIVES OF THE PROPOSAL

2.1. CONTEXTE DE LA PROPOSITION DE PROJET / CONTEXT OF THE PROPOSAL

2.1.1. AUTOMORPHISMS AND BIRATIONAL TRANSFORMATIONS

The complex affine space $\mathbf{A}^n$ and projective space $\mathbf{P}^n$ are basic objects in algebraic geometry. A natural and classical question is to describe the automorphism group Aut($\mathbf{A}^n$) and the group of birational transformations Bir($\mathbf{P}^n$). Birational transformations are self-maps, defined only on a dense open subset, determined by a collection of n homogeneous polynomials and admitting an inverse of the same type. More generally, two groups are attached to each affine or projective algebraic variety **M**: its automorphism group Aut(**M**) and its group of birational transformations Bir(**M**). Our project concerns the study of such groups, and the interplay between their structure and the geometry of **M**.

Recent results shed a new light on this classical nineteenth century topic. Different techniques, viewpoints and questions are now available. Algebraic geometry provides new tools to describe **M**, Aut(**M**), and Bir(**M**): Minimal model program and Mori techniques, Sarkisov program and the method of maximal singularity, intermediate Jacobians and Hodge theory, etc. These tools have been mainly developed in the context of projective varieties, but they are in principle also adapted to handle the affine case, usually at the cost of additional technical difficulties coming from the non compact nature of these varieties. Holomorphic dynamics in several variables have been successfully used to describe both the dynamics and the algebraic properties of birational transformations and automorphisms. Meanwhile, in the affine context, new promising tools and notions to understand the link between the geometry of **M** and the structure of the groups Aut(**M**) have been introduced, borrowing both from commutative algebra and complex analysis : algebraic density and flexibility, infinite dimensional algebraic groups, stabilization techniques, etc. It is progressively realized that certain of these tools can be also adapted to the projective context.

Thus, during the past few years, new approaches have been developed for treating groups of the form Aut(**M**) and Bir(**M**), where **M** is either affine or projective, with tools from commutative algebra, algebraic geometry, complex analysis, dynamical systems, geometric group theory. New viewpoints emerged at the same time, with questions coming from these new techniques rather than just algebraic geometry.

Our project has three main goals:

- Develop the study of such groups by a systematic and simultaneous use of these different techniques: In particular, geometric group theory, dynamical systems and commutative algebra.
- Understand the link between the geometry of **M** and the structure of groups like Aut(**M**) and Bir(**M**), where **M** can be a real or complex, affine or projective, variety.
- Develop analogies for affine algebraic geometry to known results in projective geometry.

The members of the project obtained important results in this field of research when **M** has dimension 2, and, building on these, progressively started to explore certain aspects of the 3-dimensional case. One of the challenges is thus to make progress in general in higher dimensions.

Precise problems and activities are described in the following sections. We now describe some of the activities which have been already organized by several members of the project.

2.1.2. EXISTING STRUCTURES AND INTERNATIONAL RELATIONS

French Workgroup on Automorphisms of Affine Spaces.- Most of the participants of our project are members of a workgroup organized by A. Dubouloz since 2006. The initial aim was to regroup French researchers, from different fields of algebraic geometry and commutative algebra, interested in understanding breakthroughs in the 3-dimensional theory of polynomial automorphisms. The group progressively grew and broadened its interests to all subjects related with affine and birational geometry. The members of this workgroup meet each other regularly at the occasions of mini-workshops organized in the different laboratories involved. On the downside, since this workgroup does not have a dedicated funding, several potential participants cannot attend as often as they would like, and there is almost never any possibility to invite exterior speakers.

French-Swiss joint seminar on Affine Geometry.- The Mathematic Institute of Basel is a most valuable partner of our project, in particular in the persons of Hanspeter Kraft and Jérémy Blanc. J. Blanc is a young researcher, expert in the Cremona group Bir($\mathbf{P}^2$) , who moved to Basel in 2010 after being awarded a Research Professorship from the Swiss National Fund. He has ongoing collaborations with several members of the french team of the project. In this context, many joint activities with the Swiss team in Basel have been developed :

- A joint seminar on affine geometry between Dijon and Basel started in 2010, initially funded by a one-year grant from Université de Bourgogne.
- Julie Déserti is on leave from her position at Paris 7 to be a visiting researcher in Basel for 18 months, starting January 2011.
- H. Kraft, A. Dubouloz and H. Flenner (Bochum) will organize an Oberwolfach Seminar (school aimed at PhD students) on affine geometry in November 2011.
- S. Lamy and J. Déserti will be the speakers of a winter school on birational geometry in January 2011, organized by J. Blanc.

The presences of J. Blanc and H. Kraft attract many post-doctorants and assistant lecturers in the field of (affine) algebraic geometry: P.-M. Poloni, S. Vénéreau, H. Ahmadinezhad, E. Dufresne, A. Liendo. One aim of the project is to create a similar dynamics in Dijon.

French-Dutch PHC Grant Van Gogh "Polynomial Automorphisms: Between Algebra and Geometry".- During 2008 and 2009, A. Dubouloz and S. Maubach (Nijmegen) coordinated a project aimed at developing the relations between french researchers in affine geometry and the dutch leading experts in the algebraic theory of polynomials automorphisms in Nijmegen. Joint conferences have been organized in Dijon(2008) and Nijmegen(2009) and the participants of the project met regularly in France and in the Netherlands. New collaborations between the french participants J.-P. Furter, P.-M. Poloni, A. Dubouloz and the dutch young researchers S. Maubach and J. Berson were initiated during this project. There are still some ongoing collaborations between certain participants, and the project helped to set up perennial relations between the two teams.

2.2. ÉTAT DE L'ART ET POSITION DE LA PROPOSITION DE PROJET / STATE OF THE ART AND POSITIONNING OF THE PROPOSAL

2.2.a.- The groups Bir(P^2) and Aut(A^2).-

The group Bir($\mathbf{P}^2$) of birational transformations of the projective plane, also called « Cremona group of rank 2 », has been a classical object of study since the late 19th (see [Hud27] for an account of the huge classical litterature on the subject -a new edition is in project, with a preface by M. Reid and S. Lamy- and [Car02] for a modern account). A basic result attributed to M. Noether says that Bir($\mathbf{P}^2(\mathbf{C})$) is generated by the projective linear group and a single quadratic birational transformation, which we can choose equal to the standard involution (x,y) → (1/x, 1/y). The relations between these generators have been described by Gizatullin, and then by Iskovskikh [Giz82, Isk85].

For the group Aut($\mathbf{A}^2$), a presentation by generators and relations is known since the pioneer works Jung [Ju42] and van der Kulk [vdK53] : it is the amalgamated product of the affine group and the elementary (or triangular) group along their intersection. This algebraic structure is quite strong and gives an efficient tool to describe Aut($\mathbf{A}^2$) via the Bass-Serre Theory, which provides a natural simplicial metric tree on which Aut($\mathbf{A}^2$) acts by isometries. For instance every algebraic subgroup is conjugated to a subgroup of the affine or the triangular group. In his PhD thesis S. Lamy gave a classification of solvable subgroups of Aut($\mathbf{A}^2$), and obtained a Tits alternative for this group [Lam01]. As observed first by Danilov [Dan74] with a recent refinement by S. Lamy and J.-P. Furter [FL09], the Bass-Serre Theory also enables the application of the theory of small cancellations to show that the unimodular subgroup of Aut($\mathbf{A}^2$) is not simple. In a slightly different direction, J. Déserti [Des06] described the automorphism group of Aut($\mathbf{A}^2$) as an abstract group. All these results served as precious examples for a parallel study of Bir($\mathbf{P}^2$).

The description of Bir($\mathbf{P}^2$) in terms of generators and relations has been used by J. Déserti to describe automorphisms of Bir($\mathbf{P}^2(\mathbf{C})$) as an abstract group. One can study algebraic subgroups of the Cremona group by tools from algebraic geometry. This is a classical topic for finite or connected subgroups of Bir($\mathbf{P}^2$). Using an equivariant version of the Sarkisov program, J. Blanc [Bla08] obtained a classification of all maximal algebraic (possibly non-connected) subgroups of Bir($\mathbf{P}^2$). This is also one of the few directions for which interesting results have been obtain in higher dimension : Umemura [Ume82, Ume85] gave a description of maximal connected algebraic subgroups of Bir($\mathbf{P}^3$) and Prokhorov [Pro09a, Pro09b] began the study of finite subgroups of Bir($\mathbf{P}^3$). Recently, it has been realized that the group Bir($\mathbf{P}^2$) acts faithfully by isometries on a hyperbolic space of infinite dimension, with a nice interplay between basic properties of isometries and basic dynamical properties of the birational transformations. This fact turned to be useful to find new properties of this group : For instance, S. Cantat [Can10] proved that it satisfies the Tits Alternative, and S. Cantat and S. Lamy [CL10] established that Bir($\mathbf{P}^2$) is not a simple group: it contains numerous proper normal subgroups.

Thus, one can say that we now have a good understanding of Aut($\mathbf{A}^2$) and Bir($\mathbf{P}^2$) and their subgroups. In another direction, it is an old problem to define good topologies and further natural algebraic structures on these groups. In the words of Mumford [Brow76]: *Let* G = $\mathrm{Aut}_{\mathbf{C}}(\mathbf{C}(x_0, x_1))$ *be the Cremona group [...]. The problem is to topologize* G *and associate to it a Lie algebra consisting, roughly, of those meromorphic vector fields* D *on* $\mathbf{P}^2(\mathbf{C})$ *which "integrate" into an analytic family of Cremona transformations*. Shafarevich [Sha66, Sha95] equipped Aut($\mathbf{A}^2$) (and more generally Aut($\mathbf{A}^n$)) with a natural structure of infinite dimensional algebraic variety obtained as an inductive limit of a system of closed immersions of finite dimensional varieties. However, this approach lacked good theoretical foundations until the recent work of T. Kambayashi [Ka96, Ka03] who precisely defined the appropriate notions of ind-schemes and pro-affine algebras needed to tackle this kind of questions.

Recently, Serre [Se08] introduced a Zariski topology on Bir($\mathbf{P}^2$), but it is still unknown whether Bir($\mathbf{P}^2$) can be further equipped with a natural structure of infinite dimensional algebraic variety or ind-scheme.

2.2.b.- Automorphisms of rational surfaces.- Another circle of questions with recent progresses in dimension two concerns the classification of biregular automorphisms f of rational surfaces, either affine or projective. These results give new insights on the structure of Bir($\mathbf{P}^2$).

On the projective side, S. Cantat [Can99] observed that the only compact complex surfaces with biregular automorphisms with positive entropy are (a blow-up of) certain tori, K3 or Enriques surfaces, and rational surfaces. Only few examples were known in the latter class. Since then the situation changed quite dramatically, but a complete classification is still elusive. Many examples have now been constructed by Bedford and Kim, by McMullen [McM07] and by Uehara. Bedford and Kim produced explicit constructions of such automorphisms, including continuous families of pairs (S,f) with parameter space of arbitrary large dimension. Recently, J. Déserti and J. Grivaux [DG10] gave another way of constructing examples and initiate the study of their deformations.

On the affine side, for many rational affine surfaces the richness of the "continuous" part of the automorphism group depends on the geometry of algebraic 1-parameter flows on it. The existence and the geometry of these flows is intimately related to birational properties of suitable projective models of these surfaces thanks to pioneer work of Danilov and Gizatullin [Giz71, DG75, DG77]. J. Blanc and A. Dubouloz [BD10] developed effective descriptions which helped to clarify the structure of automorphism groups with respect to algebraic 1-parameter flows and associated foliations.

In a distinct, but parallel spirit, F. Mangolte and his coauthors (J. Blanc, J. Huisman, J. Kollar) realized that most real algebraic surfaces S have a large group of birational transformations that act by smooth diffeomorphisms on the real part of the surface $S(\mathbf{R})$ (see [HM09, KM09, BM10]); for example, the group generated by such diffeomorphisms is dense in Diff(S($\mathbf{R}$)) when S=$\mathbf{P}^2$. This provides a new bridge between groups of birational transformations and classical groups like Diff(M), where M is a compact manifold, which seems to be extremely interesting in higher dimension.

2.2.c.- Higher dimensions.- Most of the above results concern the two-dimensional case, that is groups of birational or regular transformations of projective and affine surfaces. As we shall see in Section 2.3, one of our goal is to develop the study of such groups in higher dimensions.

The right framework to study projective birational geometry in higher dimension, usually referred to as the Minimal Model Program, emerged in the 1980s after works by Mori, Reid, Shokurov, Kawamata, Kollár, etc. It has been intensively developed during the last decades, and the existence of minimal models in arbitrary dimension is now established [BCHM10]. One of the consequences of this theory, called the Sarkisov Program, provides an algorithm for factorizing any birational transformation between a certain class of projective varieties (Mori fiber spaces, which include projective spaces) into a sequence of elementary transformations [BM97, Cor95, HM^{c}K10]. It works well for obtaining rigidity results, that is to prove that certain varieties have a finite group of birational self maps. A first instance of such a result concerned the smooth quartic 3-fold in $\mathbf{P}^4$, whose non-rationality was proved by Iskovskikh and Manin in a landmark paper [IM71]). A long collection of other examples of rigid varieties has been studied (see for instance [CPR00]). It would be interesting to mix these ideas with the viewpoints of geometric group theory, and dynamical systems : This is precisely one of our goals.

In contrast, one of the most central notion in the past and recent study of higher dimensional polynomial automorphisms is the algebraic notion of tameness : One says that a polynomial automorphism is tame if it belongs to the group generated by the affine group and the triangular group. In view of the Jung theorem one can wonder if any polynomial automorphism of $\mathbf{A}^3$ is tame. The most striking result in the field is probably the proof by Shestakov-Umirbaev [SU04] that a large class of automorphisms of $\mathbf{A}^3$ is non tame: for instance the famous Nagata automorphism belongs to this class. Unfortunately their proof is based on clever and tricky calculations and lacks conceptuality; the same might be said of the recent reworked proof by Kuroda [Kur10]. An important consequence of this result is that no reasonable set of generators is known for the group Aut($\mathbf{A}^3$). For the moment, only few attempts [Kis05] have been made to try to find alternative and complementary interpretations in the framework of logarithmic Minimal Model Program. This seems however to be an important and promising direction : it is one of our other goals to study it in details.

Very recently, the successive work of Kaliman, Kutzschebauch, Flenner, Arzhantsev, Zaidenberg [KaKu08] [AFKKZ10] led to the emergence of new more geometric notions in the affine context : Algebraic density property and flexibility. The latter are again deeply related with the geometry and dynamics of algebraic 1-parameter flows. In particular, the results in *loc.cit.* imply that the automorphism group of a smooth affine variety **M** acts *n*-transitively on **M** for every *n* provided that its subgroup generated by 1-parameter algebraic flows acts transitively on **M**. In a complementary direction, L. Moser-Jauslin, P.-M. Poloni and A. Dubouloz [DMP09, M09] developed new algebro-geometric techniques exploiting foliations invariant under 1-parameters flows which enabled to completely describe the automorphism groups of certain affine threefolds close to $\mathbf{A}^3$. These new born theories need to be developed further and put together with complementary viewpoints from birational geometry and geometric group theory.

2.3. OBJECTIFS ET CARACTÈRE AMBITIEUX ET/OU NOVATEUR DE LA PROPOSITION DE PROJET / OBJECTIVES, ORIGINALITY AND/ OR NOVELTY OF THE PROPOSAL

Our main objective is to progress in the understanding of groups of transformations on surfaces and higher dimensional algebraic varieties, both affine or projective. The originality of our approach is that it includes the use of geometric group theory and dynamics. Below, we present two complementary main frameworks of research (2.3.a and 2.3.b) that we consider particularly relevant to our project and list some important open problems in these that seem feasible to us. Subsections 2.3.c and 2.3.d present some more specific problems that we plan to treat in relation with these main directions.

2.3.a.- Topologies, algebraic structures and subgroups.- A natural question concerning the groups Aut($\mathbf{A}^n$), Bir($\mathbf{P}^n$), and more generally the groups Aut($\mathbf{M}$) and Bir($\mathbf{M}$) for an affine of projective variety $\mathbf{M}$, is to define good topologies on them. One can for instance try to compare these groups to complex linear groups, or try to mimic the Zariski or the transcendent topology.

As mentioned before, some results in this direction exist for the case of Aut($\mathbf{A}^n$) after the work of Shafarevich but one of the main issue is to give precise definitions of what should be the "infinite dimensional scheme of automorphisms of $\mathbf{A}^n$". This object should represent in the best possible sense the functor of polynomial automorphisms. The preliminary foundational work of Kambayashi is a good starting point, but is has to be reworked to handle this natural functorial point of view. J.-P. Furter and A. Dubouloz started in 2009 to develop this strategy which does eventually provide the expected universal objects parametrizing the transformations at hand. *Furthermore, the methods are now general enough to tackle the case of the group Aut(**M**) of an arbitrary affine variety.*

But basic questions are still open in this theory, for instance, a striking example of B. Totaro shows that we do not have a satisfactory notion of smooth point on an ind-scheme. *We plan to study these foundational questions in detail.* Also, some of the "theorems" stated by Shafarevich must be examined with care. In particular, contrary to what is claimed in [Sha66], we now have strong evidence that the group of tame automorphisms is *not* dense in the whole group Aut($\mathbf{A}^n$). Thus, one can ask instead: *Is the group of tame automorphisms a closed subgroup of Aut(A^3) ?* One of the main advantage of this formalism it that, by construction, it enables in particular to interpret actions of algebraic groups $\mathbf{G}$ on $\mathbf{A}^n$ as homomorphisms of ind-algebraic groups from $\mathbf{G}$ to Aut($\mathbf{A}^n$). This is the source of many natural new concrete questions, for instance, *if the conjugacy class in* Aut($\mathbf{A}^n$) *of the homomorphism from G to Aut($\mathbf{A}^n$) is closed, does it follow that the corresponding action of $\mathbf{G}$ on $\mathbf{A}^n$ is linearizable provided it has a fixed point ?* The study of many analogous intermediate questions related to classical invariant theory will help to orient further developments.

The search for natural topologies and algebraic structures on Bir($\mathbf{P}^n$) seems much more complicated. For example, *is it possible to endow the Cremona group with a structure of topological group such that the induced topology on biregular automorphim groups of rational surfaces is the usual compact-open topology ?* In the affirmative, it would be natural to try to understand the discrete subgroups, and to see if the notion of continuous subgroup is related to a suitable notion of Lie algebra. Concerning the Zariski topology, *one has to understand the topology introduced by Serre better*, as well as the kind of structures of ind-scheme that can be put on groups of birational transformations. For example, similarly to the affine case, the Cremona group of rank *n* should possess a structure of ind-scheme, obtained by gluing together some natural local affine ind-scheme structures. Such a result, which seems reachable in the context of our project, would answer a question of Shafarevich.

2.3.b.- Sarkisov program and algebraic subgroups.- The Sarkisov program (see Section 2.2.c.) is a nice theoretical framework which gives indications on the structure of Bir($\mathbf{P}^n$).

However, it is not obvious how to obtain a similar factorization process in an *affine* setting, where we want each elementary link to induce an isomorphism between the affine varieties at hand. This problem is raised and partially solved in dimension 2 by A. Dubouloz and S. Lamy in [DL08] using ad hoc methods, but remains open in dimension 3. This is a very important question, and we plan to study it in detail. *As a first step, we have to rework the factorization process obtained in dimension 2 in the most recent framework [Hm^{c}K10] :* We expect that our existing factorization algorithm reflects a polytopal decomposition of a suitable cone of effective divisors on an appropriate projective model of the surface, for which the elementary links correspond to points on the boundary contained in more than two polytopes.

In parallel, we will continue the study of the "behaviour at infinity" of families of interesting examples of automorphisms of $\boldsymbol{A}^3$. In particular, we would like to *reinterpret in a geometric framework the algebraic algorithms for recognizing tame automorphisms given in [SU04, Kur10]*. We also expect to derive from this study new examples of completions of $\boldsymbol{A}^3$ into log-Fano threefolds.

In an other direction, we expect to produce interesting new examples of automorphisms of affine varieties by studying particular classes of Sarkisov links : for instance, it is not known *whether the complement of a smooth cubic surface in* $\boldsymbol{P}^3$ *admits any automorphism* (beside a finite group of linear ones).

The Sarkisov program will be useful for another aim : C*lassify maximal algebraic subgroups of* Bir($\mathbf{M}$) *when* $\mathbf{M}$ *is* $\mathbf{P}^3$ *or, for example, a smooth cubic hypersurface in* $\mathbf{P}^4$. To start, one should rework Umemura's classification of maximal connected subgroups of Bir($\mathbf{P}^3$), and, as done by J. Blanc in dimension 2 and by Prokhorov to describe finite subgroups of Bir($\mathbf{P}^3$), apply new techniques to include the case of non-connected groups.

More generally, some 2-dimensional results based on general facts from the birational classification of surfaces should extend in higher dimension. For instance, if f is an automorphism (resp. a birational transformation) of the affine space $\mathbf{A}^3$ (resp. of a projective 3-fold), then, typically, the sequence of degrees of its iterates f^n, $n>0$ grows exponentially fast. As in dimension 2, we expect that *if the growth is not exponential, then it is polynomial and there exists an f-invariant fibration on the variety.*

2.3.c.- Continuous families: Four examples.- Most of the aforementioned problems concern transformation groups which are either continuous, or at least possess strong constraints on the degrees of their elements. We now describe four specific problems about groups of this type :

Abstract morphisms between complex linear algebraic groups are well understood. Is such a description possible for groups of biregular of birational transformations in small dimension ? For example, *can we describe all morphisms from classical Lie groups, like* SL(2,**C**), *to* Bir($\mathbf{P}^2$) *? Can we describe all morphisms from* Aut($\mathbf{A}^2$) *to* Aut($\mathbf{A}^3$) *?*

As explained in 2.2.b., the group of real birational transformations of $\mathbf{P}^2(\mathbf{R})$ with no real indeterminacy point is a dense subgroup of Diff($\mathbf{P}^2(\mathbf{R})$) which acts *n*-transitively on $\mathbf{P}^2(\mathbf{R})$ for all *n*. Similar results hold for real rational surfaces and higher dimensional projective spaces. *What can be said in the case of cubic hypersurfaces in* $\mathbf{P}^4(\mathbf{R})$? They have richer geometry and their groups of birational transformations are still infinite dimensional but smaller than Bir($\mathbf{P}^3(\mathbf{R})$).

A reasonable intermediate question to classify biregular automorphisms with positive entropy of rational surfaces is to study deformations of pairs (X_t, f_t) where for each t, X_t is a rational surface, and f_t is an automorphism of X_t with positive entropy. One problem is to *decide whether automorphisms of rational surfaces are more likely to be rigid or to have a non trivial deformation space*.

As mentioned in 2.2.b the existence on an affine surface of "many" algebraic 1-parameter flows depends on birational properties of suitable projective models. It is natural to ask if the existing descriptions can be refined to obtain *a characterization of affine surfaces* $\boldsymbol{S}$ *for which the subgroup of Aut(*$\boldsymbol{S}$*) generated by 1-parameter algebraic flows acts transitively on* $\boldsymbol{S}$.

2.3.d.- Symmetric spaces and geometric group theory.- Recent breakthrough in the study of birational transformations of surfaces (e.g. [CL10]) uses the action of Bir(*S*) on the injective limit of Picard groups of all possible blow-ups of the surface *S*. This limit is endowed with an intersection form of signature $(1,\infty)$ and one can then naturally construct a symmetric space of infinite dimension but with rank 1 on which Bir(S) acts by isometries. Interesting results are then deduced from the interplay between algebraic geometry, dynamical systems, and this action by isometries.

For the study of Bir($\boldsymbol{M}$) with dim($\boldsymbol{M}$)=3, we expect that the limit of all Chow groups of blow ups of **M** should give rise to an infinite dimensional space with rank 2 properties. Thus, *we ask for the description of such an action and a dictionary between properties of an element of Bir(*M*) as an isometry of such a space, and its properties as a transformation of* **M**. This type of infinite dimensional metric spaces have been the subject of recent works in geometric group theory (Caprace and Monod [CM09]), which might be a source of inspiration to understand properties of subgroups of Bir($\mathbf{P}^3$), or more generally Bir($\boldsymbol{M}$) where **M** is a projective threefold. There is no doubt that a systematic use of these techniques will give a grasp on questions which were previously out of reach.

A usual approach to check whether a conjecture in algebraic geometry is sensible or not is to consider it first in the setting of toric geometry. We propose as a possible guideline for research that some properties of Bir($\mathbf{P}^n$) might be well reflected and captured by the behaviour of the group of monomial transformations, which is isomorphic to GL(n,**Z**). A basic test would be to *interpret some group theoretic features of* GL(n,**Z**), n > 2 *(for instance bounded generation) in the context of Sarkisov program and the action of* Bir($\mathbf{P}^n$) *on the above mentioned infinite dimensional "symmetric" space*. This kind of questions is already in germs in the recent preprints by Lin [Li10] and Favre and Wulcan about the degree growth of monomial maps.

3. PROGRAMME SCIENTIFIQUE ET TECHNIQUE, ORGANISATION DE LA PROPOSITION DE PROJET / SCIENTIFIC AND TECHNICAL PROGRAMME, PROPOSAL ORGANISATION

3.1. PROGRAMME SCIENTIFIQUE ET STRUCTURATION DE LA PROPOSITION DE PROJET/ SCIENTIFIC PROGRAMME, PROPOSAL STRUCTURE

As detailed above, our scientific aims are the following: Extend and reinterpret known results on automorphisms and birational transformations of affine and projective varieties of dimensions 2 and 3; study new questions in higher dimension and more specifically in dimension 3 by mixing algebraic geometry with techniques from dynamics and geometric group theory. A second goal is to pursue and reinforce the activities organized around Dijon in the area of birational geometry, complex analytic geometry and their applications to affine algebraic geometry.

To achieve these goals, we shall organize research meetings of different sizes, and increase the number of short time visits in the universities of our team.

3.1.a.- Quarterly workshops.- We plan to regularly organize research meetings or mini-workshops during the four years of the project. For this, we shall exploit and develop the structure of the existing workgroup on Automorphisms of Affine Spaces. Based on the fruitful experience of four previous years of existence of this workgroup, these meetings of 2 or 3 days each will be organized each trimester, alternatively in the different home universities of the participants to the project (Angers, Dijon, La Rochelle, Lyon, Paris, Marseille, Rennes,).

With such workshops, we shall learn new results and techniques together, so as to increase our common knowledge of the main tools and problems concerning polynomial automorphisms and birational transformations. The idea is to maintain the initial philosophy of this workgroup, allowing ourselves to occasionally concentrate our efforts to understand a very specific result in the recent literature, as it has been the case, for example, with the intensive study of the breakthrough on 3-dimensional polynomial automorphisms due to Shestakov and Umirbaev [SU04,Um06].

Each of these meetings will include research expositions, open problem sessions and time for free discussions among the participants. The themes will be chosen after discussion between the members of the project but the precise programs will be decided each time as one goes along, in order to include the latest results and orientations of the project. These meetings will not be reserved only to the members of the project; we shall encourage participation of the usual audience of the existing workgroup and try to attract new people from other connected fields of interest in algebraic and complex geometry.

These workshops will constitute a very important part of our activity. We now list several of the themes we have in mind to give precise examples.

- **Dynamics and geometry of automorphisms.-** This first workshop will be the occasion to acquire a common knowledge on the dynamics of (birational transformations and) automorphisms of surfaces. Two main examples are the dynamics of automorphisms of the plane (Hénon mappings) and the geometry/dynamics of actions of additive groups (the group $(\mathbf{C},+)$). Possible speakers are S. Cantat, J. Deserti, A. Dubouloz, R. Dujardin (Ecole Polytechnique), and V. Guedj (Toulouse).

- **Automorphisms in real algebraic geometry.-** This mini-workshop will be the occasion to explain what are the recent results on the groups of real birational transformations of $\mathbf{P}^2(\mathbf{R})$ or real surfaces $S(\mathbf{R})$ without real indeterminacy points: Density in Diff($S(\mathbf{R})$), isotopy classes of such transformations, etc. The second goal is to present open questions that could be studied by all the participants to our project. Possible speakers are S. Cantat, J. Huisman (Brest), F. Mangolte.

- **Topology and geometry of ind-schemes and ind-groups.-** The aim of this mini-workshop is to present to all the participants of the project the basic notions and recent developments of the theory of ind-varieties and ind-groups and their applications to the study of polynomial automorphisms and algebraic group actions on affine spaces. This will be also the occasion to present and discuss the open problems concerning the study of topologies and further algebraic structures on the Cremona groups. Possible speakers are A. Dubouloz, J.-P. Furter, H. Kraft, I. Stampfli (Basel).

- **Groups of transformations: Two examples.-** The idea is to put together people from algebraic geometry and geometric group theory together during a short meeting. On one side, we shall organize a series of survey talks on Bir($\mathbf{P}^2$) and Aut($\mathbf{A}^2$); on the other side, we shall invite people like F. Dahmani (Grenoble) or V. Guirardel (Rennes) to describe ideas from geometric group theory in the case of the group of interval exchanges and the mapping class group.

3.1.b.- Annual research meetings.- Every year, one of these regular meetings will be extended to a one-week research meeting organized in Dijon. These longer meetings will be an opportunity to invite French and international experts to give mini-courses and research surveys centered on one or two particular themes of affine or birational geometry in relationship with our main concern. As an example, we propose the following topic for our first annual meeting.

- **Maximal singularities of rational maps.-** The goal would be to understand several viewpoints on the notion of (maximal) singularities (or center) for birational maps. This is a central object for the study of birational rigidity. The relevant notions require a good understanding of singularities and multiplicities, and can be analyzed with tools from commutative algebra (including valuations), algebraic geometry, and pluripotential theory (Lelong numbers and such). This workshop will be the occasion to put these ideas together. Possible speakers include: A. Corti (Londres), C. Favre (Ecole Polytechnique), M. Reid (Warwick), S. Boucksom (Paris VI), S. Lamy, , etc.

3.1.c.- International Congress.- The third year of the project, we want to organize a more important international congress, for example at the CIRM. This congress will be more focused on classical subject in affine algebraic geometry and their interactions with birational geometry. The last important congress organized in Europe around these themes took place in Oberwolfach in January 2007. It was attended by about fifty participants, among them most of the important senior researchers in the field and many young mathematicians. Overview talks given at this occasion by leading experts contributed to disseminate important new ideas and perspectives in the field, and, four years afterward, one should observe that many recent progresses emerged from these ideas and from the cooperations and discussions between the participants during the congress. Since then, we had no other opportunities to meet our foreign colleagues except sometimes for short sectional meetings of the AMS in North America, or at the occasion of individual stays.

We strongly believe that it is time to organize a new international congress in the field and that this project gives us the best possible context to organize it in France. In view of the dynamics initiated around the workgroup on Automorphisms of affine spaces since 2006, we think that organizing such a congress will contribute to promote this area of research in France and attract new PhD students.

Of particular importance for us is the fact that it will help to continue developing the existing connections with the groups of affine geometry in

- North America : A. Crachiola, D. Daigle, D. Finston, G. Freudenburg, S. Kaliman, L. Makar-Limanov, U. Umirbaev, P. Russell, D. Wright, W. Zhao.
- Japan : M. Miyanishi, K. Masuda, H. Kojima, S. Kuroda, T. Kishimoto
- The Russian teams on invariant theory and projective birational geometry : I. Arzhantsev, Y. Prokhorov, V. Popov, K. Shramov,

and, closer to us :

- The group on affine geometry, algebraic groups and invariant theory in Basel :J. Blanc, H. Kraft, S. Vénéreau, P.-M. Poloni, A. Liendo and the dutch team around A. van den Essen in Nijmegen : J. Berson, S. Maubach, R. Willems.

Thus, a reason to plan this event on the third year of the project is to be able to have some follow-up collaborations, either by inviting a foreign researcher for a short research stay in France, or by a member of the project visiting a collaborator abroad. In both situations these collaborations would be partially supported by the project.

3.1.d.- Missions.- Besides the meetings, we shall also encourage and support missions. They could be of different types :

- One of us visiting another member of the project for a collaboration.
- Participation to a congress of algebraic or complex geometry.
- One of us attending regularly a seminar in another university or institute than his own.
- Mission abroad for collaborations linked to the themes of the project.
- Invitation of foreign collaborators for short stays in France in the context of the project.

We insist on the fact that the financial support for these kinds of missions is absolutely essential for the success of the project: we want to integrate the participants, who are dispersed on the French territory, into a perennial network.

3.1.e.- Discharges of Teaching Duties. - In order to facilitate the participation to these various activities and to promote additional punctual visits between the applicants, the projects includes some fundind for a discharge of 96 hours from the teaching duties of J. Déserti and S. Lamy.

3.2. DESCRIPTION DES TRAVAUX PAR TÂCHE / DESCRIPTION BY TASK

3.2.1 TÂCHE 1 / TASK 1 : COORDINATION

Except for the punctual needs of organization for the different meetings and conferences detailed in 3.3 below, our project will not require any specific management. Being a project of fundamental research in mathematics, we think it would be counterproductive and unrealistic to ask the participants to collaborate on imposed problems, to impose strict milestones or deadlines for finding and publishing new results. On the contrary, our plan is to encourage the participants to exchange regularly with each others, to develop their own networks of collaborators inside and outside the strict context of the project. We strongly believe that it is the best possible way to develop the already existing collaborations between the participants of the project and to initiate new ones on sub-problems of common interest which will progressively emerge during the project. Since the main activities will take place in Dijon, the project will be coordinated from Dijon by A. Dubouloz and L. Moser-Jauslin.

3.2.2 TÂCHE 2 / TASK 2 : ORGANIZATION OF WORKSHOPS AND ANNUAL RESEARCH MEETINGS

Our experience with the meetings of the workgroup Automorphisms of Affine Spaces, as well as with former ANR projects (“Symplexe” and “Complexe”), show that these mini-workshops do not require heavy organization. The local organization will be each time taken in charge by the participant of the project present in the chosen hosting laboratory.

The themes will be in general chosen in advance after discussion between the members of the project but the programs of these meetings will be decided as one goes along, in order to include the latest results and orientations of the project. These meetings will not be reserved to the members of the project : we shall encourage participation of the usual audience of the existing workgroup and try to attract new people from other connected fields of interest in algebraic and complex geometry.

The annual research meeting in Dijon will require a little more organization. We plan to decide the main themes of each meeting at least six months in advance to have enough time to contact the speakers and make announcements. We already have a reasonable experience of the organizational needs for such meeting, since A. Dubouloz and L. Moser-Jauslin organized one in Dijon in 2008.

3.2.3 TÂCHE 3 / TASK 3 : ORGANIZATION OF THE INTERNATIONAL CONGRESS

The organization of the international congress during the third year of the project, probably in CIRM in Luminy, should be started at least two years in advance. We will benefit from the experience of the closing conference of ANR Project “Complexe” coordinated by L. Meersseman which will be organized in CIRM in fall 2011.

3.3. CALENDRIER DES TÂCHES, LIVRABLES ET JALONS / TASKS SCHEDULE, DELIVERABLES AND MILESTONES

Year 1 :

Task	1st trimester	2nd trimester	3rd trimester	4th trimester
Mini-workshop	**Session 1: La Rochelle** Organiser: Furter	**Session 2: Rennes** Organiser: Cantat		**Session 3: Basel** Organisers: Déserti / Blanc
Research Meeting			**Dijon** Organisers: Dubouloz Moser-Jauslin	

Year 2 :

Task	1st trimester	2nd trimester	3rd trimester	4th trimester
Mini-workshop	**Session 4: Angers** Organiser: Mangolte		**Session 5: Marseille** Organiser: Grivaux	**Session 6: Lyon** Organiser: Lamy
Research Meeting		**Dijon** Organisation : Dubouloz Moser-Jauslin		

Year 3 :

Task	1st trimester	2nd trimester	3rd trimester	4th trimester
Mini-workshop	**Session 7: La Rochelle** Organiser: Furter		**Session 8: Grenoble** Organisers: Dubouloz / Zaidenberg	**Session 9: Rennes** Organiser: Cantat
International Congress		**CIRM-Luminy** Organisers: Dubouloz Moser-Jauslin		

Year 4 :

Task	1st trimester	2nd trimester	3rd trimester	4th trimester
Mini-workshop	**Session** 10: **Reims** Organisers : Dubouloz / Alev	**Session** 11: **Lyon** Organiser: Lamy	**Session** 12: **Paris** Organiser: Déserti	
Research Meeting				**Dijon** Organisers: Dubouloz Moser-Jauslin

4. STRATÉGIE DE VALORISATION, DE PROTECTION ET D'EXPLOITATION DES RÉSULTATS / DISSEMINATION AND EXPLOITATION OF RESULTS, INTELLECTUAL PROPERTY

As explained above, the activities of our project mainly consist of conferences and workshops. This will give us the opportunity to promote our area of research, to attract other researchers to our field and to disseminate our results to the larger community of algebraic geometers. Also, the new results that will be obtained as consequences of the existing collaborations between the participants of the project and the new ones which will be initiated in the context of the project will give rise to publication in scientific journals.

The fact that the quarterly workshops will be organized in the different laboratories hosting the participants of the project (Dijon, Lyon, Paris, Rennes, Marseille, La Rochelle, Angers, Basel) and possibly in other French or European laboratories hosting researchers interested in our main concern (for instance Reims, Grenoble) will give us the opportunity to reach a wider audience. In particular, the experience of the workgroup on Automorphism of Affine Space shows that these meetings usually attract other researchers from the hosting laboratories.

Of course, the international congress will give the opportunity to disseminate the results obtained during the first two years of the project. But, as already explained in 3.1.c, the congress will serve the broader purposes to discuss their interactions with other main trends in affine algebraic geometry, to take the necessary time to discuss new perspectives and problems for the next years with our foreign colleagues, to continue developing the existing connections with other international teams and to initiate new ones.

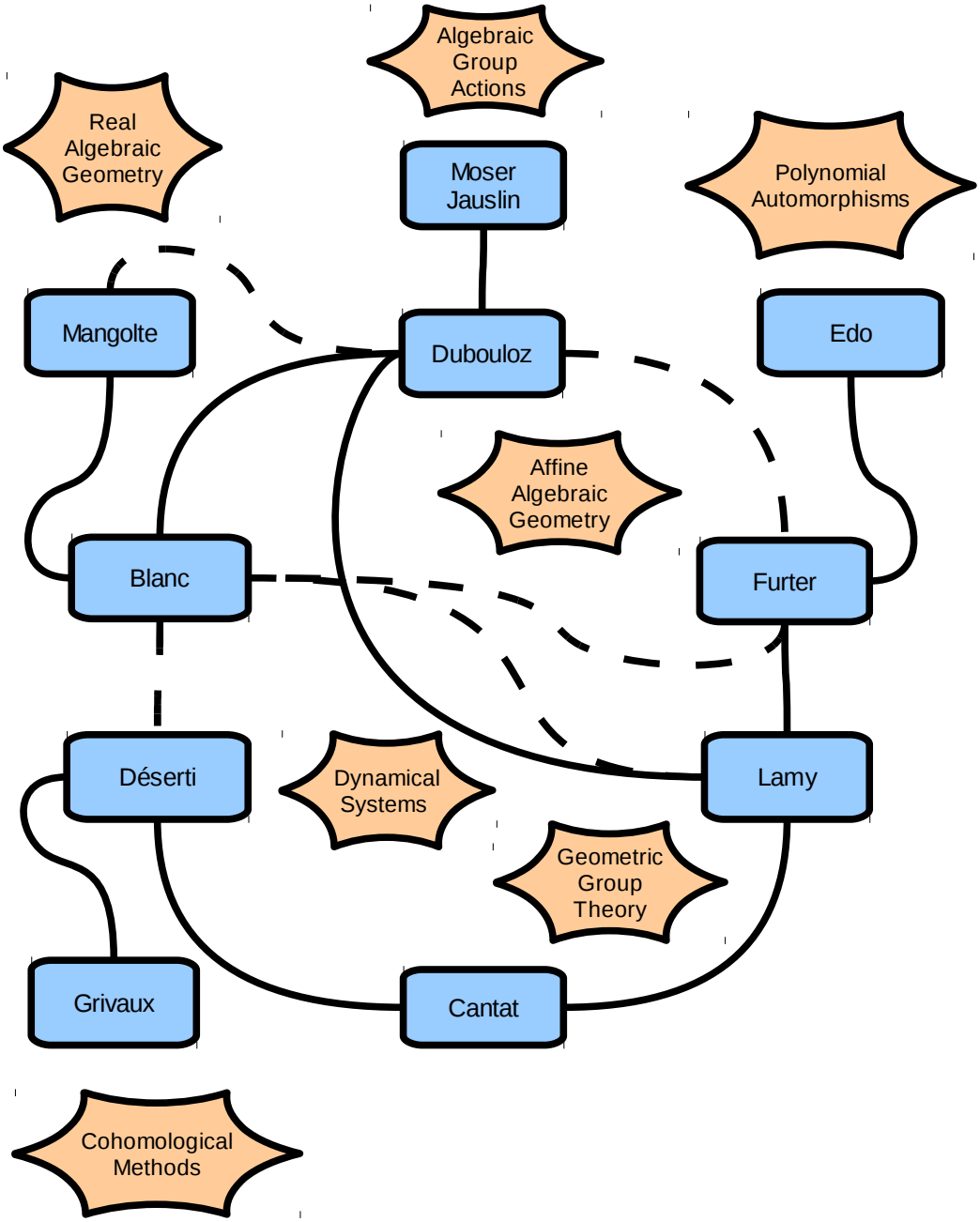
Finally, we would like to insist on the fact that a large community of french researchers will indirectly benefit from this project. This includes in particular :

- The members of the team participating since 2006 to the workgroup on Automorphisms of Affine Space, for instance M. Zaidenberg and his PhD students A. Perepechko and K. Kuyumzhiyan in Grenoble, J. Alev in Reims, P. Cassou-Noguès in Bordeaux.
- The french young researchers and post-docs in Basel : P.-M. Poloni, A. Liendo and S. Vénéreau.

This will encourage a wider diffusion in all of France of the themes related to affine and birational geometry. Also, the project will contribute to maintain and to develop the existing relations with other European teams on closely related questions.

5. DESCRIPTION DU PARTENARIAT / CONSORTIUM DESCRIPTION

5.1. DESCRIPTION, ADÉQUATION ET COMPLÉMENTARITÉ DES PARTICIPANTS / PARTNERS DESCRIPTION AND RELEVANCE, COMPLEMENTARITY



Team of the project

- Plain lines indicate past collaborations.
- Dotted lines indicate ongoing collaborations.

The team of the project consists of :

- Three young researchers : J. Grivaux, J. Déserti and A. Dubouloz.
- A Chargé de Recherche and two Maîtres de Conférence with an Habilitation à Diriger des Recherches : S. Cantat, J.-P. Furter and S. Lamy.
- An experimented Maitres de Conférence : E. Edo.
- Two Professors : L. Moser Jauslin and F. Mangolte.
- A swiss young professor : J. Blanc.

Dubouloz (coordinator), Cantat, Deserti, Furter, Lamy are each involved up to 38,4 PM in this project, and form a coherent scientific team together with J. Blanc (Basel). They are experts in adjacent and complementary fields in algebraic geometry, holomorphic dynamics and commutative algebra. Each other member is partially involved in the project, and bring a specific complementary competence.

As mentioned above, most of the participants to the present project are active members of the workgroup Automorphisms of Affine Spaces. They meet each other regularly at the occasions of the workshops organized in the context of this workgroup. Many of the existing collaborations between the participants to the project have been initiated during the meetings of the workgroup. We should in particular mention the following ones :

- **A. Dubouloz and S. Lamy** started in 2007 to apply and adapt the tools of birational geometry and Mori Theory to the study of questions in the field of affine geometry. They described a logarithmic variant of the Sarkisov Program for surfaces [DL08] and, as a preliminary to an higher dimensional theory, they worked out many explicit calculations for automorphisms of $\mathbf{A}^3$. They are now working to develop a suitable logarithmic version of Sarkisov Program adapted to the study of polynomial automorphisms in dimension 3.

- **S. Lamy and J.-P. Furter** used tools from combinatorial group theory to improve a result of Danilov [Dan74] concerning normal subgroups of the group of plane polynomial automorphisms [FL09].

- **S. Cantat and S. Lamy** recently obtained a generalization of the previous result, using geometric group theory to prove the non-simplicity of the Cremona group Bir($\mathbf{P}^2$).

- **J.-P. Furter and E. Edo** studied in 2004 certains properties of families of polynomial automorphisms [EF04]. In 2010 J.-P. Furter visited E. Edo in Nouméa for an ongoing collaboration. It was continued during a one month stay of E. Edo in France during fall 2010.

- **A. Dubouloz and J.-P. Furter** started in september 2009 a collaboration aimed at constructing moduli spaces for automorphisms in the framework ind-affine schemes. They are currently developing some of the necessary additional theoretical foundations.

- **L. Moser-Jauslin, A. Dubouloz** and P.-M. Poloni (Basel) study since 2008 certain families of rational affine surfaces, their embeddings in affine spaces, with a particular focus on the obstructions to lift their automorphisms to automorphisms of the ambient spaces [MP06, DP09, DMP09].

Several ongoing collaborations involve french members of the project and Jérémy Blanc :

- **A. Dubouloz and J. Blanc** studied automorphism groups of rational affine surface in relation with the birational geometry of their projective models. They obtained effective methods to describe these groups in terms of combinatorial invariants [BD10]. They have ongoing collaborations to understand better the influence of certain rational foliations on the structure of these groups.

- **F. Mangolte and J. Blanc** studied very transitive automorphism groups of real geometrically rational algebraic varieties [BM10]. They have ongoing collaboration on other related projects.

- **J. Déserti and J. Blanc** : Ongoing collaboration on representations of SL(2,**Z**) in Bir($\mathbf{P}^2$).

- **S. Lamy and J. Blanc** : Ongoing collaboration on construction of automorphisms on some affine 3-folds.

- **J.-P Furter and J. Blanc** : Ongoing collaboration on the potential structures of ind-scheme on Bir($\mathbf{P}^2$).

5.2. QUALIFICATION DU COORDINATEUR DE LA PROPOSITION DE PROJET/ QUALIFICATION OF THE PROPOSAL COORDINATOR

Adrien Dubouloz coordinates the activities of the workgroup Automorphisms of Affines Spaces since its creation in 2006. During the years 2008 and 2009, he has been the French coordinator of the French-dutch PHC Project Van Gogh « Polynomial automorphisms : between algebra and geometry ». In this context, he organized together with L. Moser-Jauslin an international conference on Polynomial Automorphisms in Dijon in February 2008. He participates since 2009 to the organization of the activities of ANR Project “Complexe” coordinated by L. Meersseman in Dijon, and, as such, has the experience of the organizational needs to run this kind of project.

He has close scientific contacts and ongoing collaborations with different leading teams on affine algebraic geometry in North America (D. Finston, G. Freudenburg, D. Daigle …) and Japan (M. Miyanishi, T. Kishimoto). During 2010, he spent one month in Japan (Saitama, Osaka) and one month in USA (Las Cruces) to develop these ongoing collaborations. In November 2011, he will give a mini-course in an Oberwolfach Seminar on Affine Geometry co-organized with H. Kraft and H. Flenner.

A. Dubouloz holds several responsibilities in his institute that illustrate his skills in organization and coordinations tasks. He organizes since 2008 the weekly seminar Algebra-Geometry-Topology and he is also a member of the laboratory council.

5.3. QUALIFICATION, RÔLE ET IMPLICATION DES PARTICIPANTS / QUALIFICATION AND CONTRIBUTION OF EACH PARTNER

	Nom / Name	Prénom / First name	Emploi actuel	Discipline	Personne.mois * / PM	Rôle/Responsabilité dans la proposition de projet 4 lignes max
Coordinateur	DUBOULOZ	Adrien	CR	Maths	**38,4** (80 %)	Affine algebraic geometry, birational geometry, Mori theory,ind-schemes
Autres membres						
	CANTAT	Serge	CR	Maths	**38,4**	Dynamical systems, groups of automorphisms and birational transformations.
	DESERTI	Julie	MCF	Maths	**38,4**	Birational transformations, complex geometry, folliations, dynamic
	EDO	Éric	MCF	Maths	**28,8** (60%)	Algebraic theory of polynomial automorphisms
	FURTER	Jean-Philippe	MCF	Maths	**38,4**	Algebraic theory of polynomial automorphisms, infinite dimensional algebraic varieties
	GRIVAUX	Julien	CR	Maths	**19,2** (40%)	Complex geometry
	LAMY	Stéphane	MCF	Maths	**38,4**	Birational geometry, Mori Theory, geometric group theory, dynamic
	MANGOLTE	Frédéric	PR	Maths	**20** (45%)	Birational geometry, real algebraic geometry
	MOSER-JAUSLIN	Lucy	PR	Maths	**24** (50%)	Invariant theory, affine geometry
Participant étranger						
	BLANC	Jérémy	PR	Maths	**24**	Birational geometry, Cremona group

- à renseigner par rapport à la durée totale du projet

6. JUSTIFICATION SCIENTIFIQUE DES MOYENS DEMANDÉS / SCIENTIFIC JUSTIFICATION OF REQUESTED RESSOURCES

- *Équipement / Equipment*

No large equipment is needed for this project (however, see below for small equipment such as books and laptops)

- *Personnel / Staff*

All the participants to the project have permanent position in France. Our project does not involve any hiring of additional staff on temporary positions.

- *Prestation de service externe / Subcontracting*

As detailed in 3.1, one of the the main activities of the group will be the organization of meetings. In this context, the expenses for external services concern :

- **15 000 € : Organization of the three annual research meetings in Dijon.** This includes transport and living expenses of the invited speakers not members of the project. This also includes the possibility to take in charge the living expenses of a limited number of other participants not member of the project. Moreover, this includes possible additional living expenses for certain invited speakers to stay for a second week in Dijon, especially in case of invited speakers from USA, Canada or Japan. Indeed, it will very interesting for us that they stay two weeks in Dijon: one for the research meeting to give their mini-course and another one for further discussions. We evaluate the cost of these meetings and extended stays of foreign speakers to 6000 € each, not including the transport and living expenses of the participant to the project which we consider as missions below. The additional financial support will be provided by the mathematical institute of Dijon.

- **12 000 € : Organization of the 9 quarterly mini-workshops.** This includes the transport and living expenses of external speakers, as well as the travel and living expenses of a (very) limited number of other participants not member of the project. This does not include the transport and living expenses of the participants to the project, which are again considered as missions. Based on the experience of the workgroup on Automorphisms of Affine Spaces, the cost of these workshops is 2000 € each. As we already do since 2006, we will ask each time the hosting laboratory or university for auxiliary financial support.

- **10 000 €: Organisation of the International Congress.** It will certainly take place at the CIRM in Luminy. We expect around fifty participants. We plan to pay the living expenses of all participants, as well as the travel expenses of the invited speakers not members of the project. We evaluate the total cost of the Congress to 20 000 €, but in case our application is accepted, the CIRM should totally cover the living expenses for up to forty participants.

TOTAL FOR EXTERNAL SERVICES : 37 000 €

- *Missions / Travel*

Most of the financial support we ask for is dedicated to missions. It should be emphasized that one guiding principle of this project is to encourage the mixing of areas for a better understanding of polynomial automorphisms and birational transformations. This supposes to be able to support every initiative coming from members of the group. Besides the transport and living expenses of the french participants for the meetings that will be organized during the project, we ask for support of other type of missions as :

- One of us visiting another member of the project for a collaboration.
- Participation to a conference on a relevant topic for the evolution of the project.
- One of us attending to a seminar in another university or institute than his own one.
- Mission abroad for collaborations if it is linked to the themes of the project.

We insist on the fact that the financial support for these kinds of missions is really essential for the success of the project : we want to integrate the participants, who are dispersed on the French territory, to a perennial network. The remaining credits, if any, will be re-affected to support these types of missions.

- **34 000 € : Participation to the 9 workshops and 3 research meetings.** For the french members of the project, we evaluate this cost on the average basis of 150 € for transport expenses and 80€/day for living expenses. Taking into account the fact for each session, we will not have to support travel and living expenses of the participants to the project hosted in the laboratory organizing the meeting, the estimated cost is the following :

	Mini-worshops	Research meetings
Average unit cost by participant	310,00 €	550,00 €
Average total cost by participant	2 500,00 €	1 650,00 €
Total cost	22 500,00 €	11 550,00 €
TOTAL	**34 050,00 €**	

- **20 000 € : Support for other type of missions as detailed above.** Financial support for these missions will be divided between the french members following roughly their percentage of implication in the project. They could be used in complement to other financial support. The amount given corresponds to approximatively 700 € per year for a member of the project with the maximal percentage of implication.

TOTAL FOR MISSIONS : 54 000 €

- *Dépenses justifiées sur une procédure de facturation interne / Costs justified by internal invoicies*

- **20 000 € : Compensation of 192h of teaching duties.** This concerns Julie Déserti and Stéphane Lamy who ask each for a compensation of 96h of teaching duties.

- *Autres dépenses de fonctionnement / Other expenses*

- **7500 € (8870 € TTC) for equipment.** This includes the possibility to buy laptops. We find important for any mathematician to have a computer in his office and also a laptop to work at home or when traveling. Usually, the laboratory offers one computer, but not two. This support will allow any french member of the project who needs it to have a laptop.
  This also includes buying books for the mathematical research library of Dijon. The mathematical library at Dijon has limited funds and, due to the history of the laboratory, we lack basic and more specialized books in algebraic geometry.

7. ANNEXES / ANNEXES

7.1. RÉFÉRENCES BIBLIOGRAPHIQUES / REFERENCES

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[FL09] J.-P. Furter and S. Lamy, *Normal subgroup generated by a plane polynomial automorphism*, Transformation Groups 15, no. 3, p. 577-610, (2010).

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[Pro09b] Y. Prokhorov, *Simple finite subgroups of the Cremona group of rank 3*, preprint arXiv:0908.0678 (2009).

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[Um06] U. U. Umirbaev, *Defining relations of the tame automorphism group of polynomial rings, and wild automorphisms of free associative algebras*, Dokl. Akad. Nauk 407 (2006), no. 3, 319-324.

7.2. BIOGRAPHIES / CV, RESUME

Adrien DUBOULOZ

32 ans
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Cursus :

- 2001-04 : **Doctorat** *Sur une classe de schémas avec actions de fibrés en droites*, Directeur M. Zaidenberg, Université de Grenoble I
- 2001-04 : Allocataire-Moniteur, Université de Grenoble I.
- 2004-06 : ATER, Université Grenoble I
- 2006-.. : **Chargé de recherches CNRS** 2nd classe, Université de Bourgogne

Publications (extraits):

[1] J. Blanc, A. Dubouloz, *Automorphisms of $\mathbb{A}^1$-fibered surfaces*, e-print arXiv:0906.3623v1, to appear in Trans. of AMS.

[2] A. Dubouloz, L. Moser-Jauslin, P.-M. Poloni, Non cancellation for smooth contractible threefolds, arXiv 1004.4723, to appear in Proc. Amer. Maths. Soc.

[3] A. Dubouloz, L. Moser-Jauslin, P.-M. Poloni, *Inequivalent embeddings of the Koras-Russel cubic threefold*, Michigan Maths. J. 59 (2010), 679-694.

[4] A. Dubouloz, *The cylinder over the Koras-Russell cubic threefold has a trivial Makar-Limanov invariant*, Transformation Groups vol 14, no 3 (2009), p. 531-539.

[5] A. Dubouloz, *Additive group actions on Danielewski varieties and the Cancellation Problem*, Math. Z. 255 (2007), no. 1, p. 77-93 .

Nombre de publications dans les revues internationales à comité de lecture : **9**

Prix/Distinctions :

- 2007-09 : Contrat d'étude FABER n° 07-512-AA-010-S-179 de la région Bourgogne (40k€).

Divers :

- 2006- .. : Organisateur du Groupe de Travail inter-universitaire tournant « Automorphismes des Espaces Affines » http://math.u-bourgogne.fr/topo/dubouloz/GdTAutos/gdt2.html
- 2007-09 : Coordinateur français du projet PHC Van Gogh franco-néerlandais n° 18153NA « Polynomial Automorphisms : between algebra and geometry »
- Membre des GDR CNRS 2945 « Singularités et Applications » et 3064 « Géométrie Algébrique et Géométrie Complexe »

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Cursus :

- 2002-06 : Doctorat en mathématiques, sous la direction de T. Vust, Université de Genève.
- 2006-07 : Post-doc (avec A. Beauville), Laboratoire J.A. Dieudonné, Université de Nice.
- 2007-08 : Post-doc (avec M. Brion), Institut Fourier, Université de Grenoble.
- 2008-09 : Post-doc (avec T. Vust) et assistanat (Exercices), Université de Genève. 2009 : 6 mois de service civil (remplacement du service militaire obligatoire) EMS Franchises, Genève.
- 2010-.. : Professeur boursier (financé par le FNS), Université de Bâle.

Encadrement doctoral :
- 2010-.. : Directeur de thèse de Maria Fernanda Robayo.

Publications (extraits):

[1] Blanc, Jérémy *The correspondence between a plane curve and its complement.* J. Reine Angew. Math. 633 (2009), 1–10.

[2] Blanc, Jérémy *Sous-groupes algébriques du groupe de Cremona.* Transform. Groups 14 (2009), no. 2, 249–285.

[3] Blanc, Jérémy *Groupes de Cremona, connexité et simplicité.* Ann. Sci. Éc. Norm. Supér. (4) 43 (2010), no. 2, 357–364,

[4] Blanc, Jérémy et Dubouloz, Adrien *Automorphisms of A1-fibered affine surfaces.* Trans. Amer. Math. Soc. (à paraître)

[5] Blanc, Jérémy et Mangolte, Frédéric. *Geometrically rational real conic bundles and very transitive actions.* Compos. Math. (à paraître)

Nombre de publications dans les revues internationales à comité de lecture : **15**

Prix/Distinction :

-Prix Vacheron Constantin 2008 (Prix de la meilleure thèse 2004-08 en Mathématiques - Genève)
-Prix Enriques 2009

Serge CANTAT

37 ans
Chargé de Recherche 1ère classe - Habilité à diriger des recherches (2006).
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Cursus :

- 1996-1999 : **Doctorat** *Dynamique des Automorphismes des surfaces K3*, (directeur E. Ghys, ENS-Lyon).
- 1999-2000 : Post-doctorat Ruhr Universität Bochum (Allemagne)
- 2000-2006 : Maître de conférences Rennes 1 (délégation en 2001)
- 2006- .. : **Chargé de Recherche** CR1 CNRS
- 2006-2007 : En mission à l'université Cornell (New York State, USA)

Publications (extrait) :

[1] S. Cantat and S. Lamy : *Normal subgroups of the Cremona group*, arXiv:1007.0895 manuscript soumis.
[2] S. Cantat and A. Zeghib : *Holomorphic Actions, Kummer Examples, and Zimmer Program*, manuscript soumis.
[3] S. Cantat : *Sur les groupes de transformations birationnelles des surfaces*; Annals of Math., to appear
[4] S. Cantat : *Bers and Hénon, Painlevé and Schroedinger*; Duke Math. Journal, vol 149 (2009), no. 3, pp. 411-460
[5] S. Cantat : *Caractérisation des exemples de Lattès et de Kummer*; Compos. Math. 144 (2008), no. 5, 1235--1270.

Nombre de publications dans les revues internationales à comité de lecture : **20**

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30 ans
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Cursus :

- 2004-06 : **Doctorat** *Sur le groupe de CREMONA : aspects algébriques et dynamiques*, Université de Rennes 1
- 2004-07 : Allocataire-Monitrice à l'Université de Rennes 1
- 2007- .. : Maître de conférences à l'Université Denis Diderot-Paris 7
- 2009 : Délégation CNRS Université Denis Diderot-Paris 7 [6mois]
- 2010 : Délégation CNRS Université Denis Diderot-Paris 7 [6mois]

Publications (extraits):

[1] J. Déserti. *Expériences sur certaines transformations birationnelles quadratiques*. Nonlinearity, 21 (2008), no. 6, 1367--1383.
[2] D. Cerveau, J. Déserti, D. Garba Belko, R. Meziani, *Géométrie classique des feuilletages quadratiques*, Bull. Braz. Math. Soc. (N.S.), 41 (2010), no. 2, 161--198.
[3] D. Cerveau, J. Déserti, *Feuilletages et transformations périodiques*, Experiment. Math., 19 (2010), no. 3, 447--464.
[4] J. Déserti, J. Grivaux, *Automorphisms of rational surfaces with positive topological entropy*, to appear in Indiana Univ. Math. J.
[5] J Déserti, D. Cerveau, *Transformations birationnelles de petit degré*, à paraître dans la série « Cours Spécialisés », Société Mathématique de France.

Nombre de publications dans les revues internationales à comité de lecture : **13**

Prix/Distinctions :

-2007 : Lauréate de l'Institut Post-Doctoral Européen.
-2007: Mention Spéciale dans la catégorie Systèmes en évolution, Prix Bretagne Jeune Chercheur.
-2007: Prix de la meilleure thèse 2007 en Mathématiques et leurs interactions de la Fondation d'entreprise EADS.

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35 ans
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Cursus :

- 1998-02 : **Doctorat** *Automorphismes Polynomiaux*, Directrice P. Cassou-Noguès, Université Bordeaux I
- 2001-02 : ATER, Université Bordeaux I
- 2003-04 : PRAG, Université de Nouvelle-Calédonie
- 2005- .. : **Maître de Conférence**, Université de Nouvelle-Calédonie.

Publications (extraits):

[1] E. Edo, A. van den Essen, S. Maubach, *A note on k[z]-automorphismes in two variables*, J. Pure Appl. Algebra 213 (2009), no. 6, 1197-1200.
[2] E. Edo, *Some famillies of polynomial automorphisms* II, Acta Math. Vietnam. 32 (2007), no. 2-3, 155-168.
[3] E. Edo, *Totally stably tame variables*, J. Algebra 287 (2005), no. 1 15-31.
[4] E. Edo, J.-P. Furter, *Some famillies of polynomial automorphisms*, J. Pure Appl. Algebra 194 (2004), no. 3, 263-271.

Nombre de publications dans les revues internationales à comité de lecture : **7**

Jean-Philippe FURTER

42 ans
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Cursus :

- 1990-95 : **Doctorat** *Sur les automorphismes quadratiques de l'espace affine*, Directeur J. Bertin, Université Grenoble I
- 1995-96 : ATER, ENS Lyon
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- 1998- .. : **Maître de Conférence**, Université de La Rochelle
- 2008 : **Habilitation à Diriger des Recherches** *Sur les automorphismes polynomiaux de l'espace affine,* Université de La Rochelle
- 2007-08 : CRCT [6mois] MIA Université La Rochelle.

Publications (extraits):

[1] J.-P. Furter, *Quasi-locally finite polynomial endomorphisms*, Math. Z. 263, no. 2, 473-479 (2009).

[2] J.-P. Furter, *Plane polynomial automorphisms of fixed multidegree*, Math. Ann. 343, 901-920 (2009).

[3] J.-P. Furter, *Fat points embeddings in affine space*, Journal of Pure and Applied Algebra 212, 1583-1593 (2008).

[4] J.-P. Furter, *Jet groups*, J. Algebra 315, no. 2, 720-737 (2007).

[5] J.-P. Furter et S. Maubach, *Locally finite polynomial endomorphisms*, Journal of Pure and Applied Algebra 211, no. 2, 445-458 (2007).

Nombre de publications dans les revues internationales à comité de lecture : **12**

Prix/Distinction :

- PEDR (2008-2012)

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Chargé de recherche CNRS 2ème classe
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Cursus:

- 2006-2009 : Doctorat *Quelques problèmes de géométrie complexe et presque complexe*, Institut de Mathématiques de Jussieu, sous la direction de Claire Voisin.
- 2007-2010 : Allocation couplée, monitorat à l'université Pierre et Marie Curie
- 2009 : Invité deux mois à Imperial College, Londres
- 2010- : Chargé de recherche CNRS, Université de Provence

Publications:

[1] J. Grivaux, *Tian's invariant of the Grassmann manifold,*Journal of Geometric Analysis 16 (3), 2006, p.523-533.

[2] J. Grivaux, *Chern classes for coherent analytic sheaves in Deligne cohomology*, Mathematische Annalen 347 (2), 2010, p. 249-284.

[3] J. Grivaux, *Topological properties of punctual Hilbert schemes of almost-complex fourfolds (I)* à paraître dans Manuscripta Mathematica.

[4] J. Grivaux, *Topological properties of punctual Hilbert schemes of almost-complex fourfolds (II)* à paraître dans Geometry&Topology.

[5] J. Déserti et J. Grivaux, *Automorphisms of rational surfaces with positive topological entropy*, à paraître dans Indiana Univ. Math. Journal.

Nombre de publications dans des revues internationales à comité de lecture: **5**

Prix/Distinctions:

2005 Prix Fermat junior de mathématiques

Divers:

Membre du GDR CNRS 3064 (Géométrie algébrique et géométrie complexe)

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Cursus :

- 1997-99 : **Doctorat** *Automorphismes polynomiaux du plan complexe : étude algébrique et dynamique*, Directeur Dominique Cerveau, Université Paul Sabatier, Toulouse
- 1999-00 : Post-Doctorat CRM Barcelona (Espagne).
- 2000-01 : ATER, ENS Lyon
- 2001-02 : ATER, Université Rennes I
- 2002-.. : **Maître de Conférence**, Université Lyon I
- 2010 : **Habilitation à Diriger des Recherches** *Groupes de transformations birationnelles de surfaces*, Lyon.
- 2009-11 : **Marie Curie Research Fellow** IEF, University of Warwick (UK).

Publications (extraits):

[1] S. Cantat and S. Lamy : *Normal subgroups of the Cremona group*, arXiv:1007.0895 manuscript soumis.

[2] A. Dubouloz, S. Lamy, *Variation on the log Sarkisov program for surfaces*, arXiv:0802.2441, soumis, (2009).

[3] J.-P. Furter, S. Lamy, *Normal subgroup generated by a plane polynomial automorphism*, Transformation Groups 15, no. 3, p. 577-610, 2010.

[4] S. Cantat, S. Lamy, *Groupes d'automorphismes polynomiaux du plan*, Geom. Dedicata 123, p. 201-221, 2006.

[5] S. Lamy, *Sur la structure du groupe d'automorphismes de certaines surfaces affines*, Publ. Mat. 49, no. 1, p. 320, 2005.

Nombre de publications dans des revues internationales à comité de lecture : **8**

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- **Cursus :**
- 1994 : **Doctorat** *Cycles algébriques réels sur les surfaces*, Université de Montepellier II.
- 1994-95 : Boursier Post-Doctoral CEE Pise (Italie) [6 mois]. Assistant EPFL Lausanne (Suisse) [3 mois]
- 1996-2010 : **Maître de Conférence** LAMA UMR5127 CNRS – Université de Savoie
- 2002-03 : Délégation CNRS [1 an], Laboratoire IM3, UMR 5030 CNRS-Université Montpellier II
- 2004 : **Habilitation à Diriger des Recherches** *Géométrie algébrique réelle de certaines variétés de dimension 2 et 3*, Université de Savoie
- 2007-08 : CRCT [6mois], puis Délégation CNRS LAMA UMR5127 CNRS [6 mois].
- 2010-.. : **Professeur**, Université d'Angers.

Encadrement doctoral :

- 2001-05 : Directeur de Thèse Mouadh Akriche (Allocataire) : *Nombres de Betti des surfaces elliptiques réelles.* Soutenue le lundi 12 décembre 2005.
- 2010-.. : Directeur de thèse de Samir Moulahi, en co-tutelle avec l'université du 7 Novembre à Carthage (Tunisie)

Publications (extraits):

[1] F. Catanese, F. Mangolte, *Real singular Del Pezzo surfaces and threefolds fibred by rational curves, II*, Annales Scientifiques de l'Ecole Normale Supérieure 42, 531-557 (2009).

[2] J. Huisman, F. Mangolte, *The group of automorphisms of a real rational surface is n-transitive*, Bulletin of the London Mathematical Society 41, 563-568 (2009).

[3] J. Kollár, F. Mangolte, *Cremona transformations and diffeomorphisms of surfaces*, Advances in Mathematics 222, 44-61 (2009).

[4] J. Blanc, F. Mangolte, Geometrically rational real conic bundles and very transitive actions, Compositio Mathematica, arXiv:0903.3101[math.AG], sous presse (2010).

[5] F. Mangolte, J.-Y. Welschinger, Do uniruled six-manifolds contain Sol Lagrangian submanifolds?, International Mathematics Research Notices, arXiv:1001.2927 [math.SG] en cours de révision (2011).

Nombre de publications dans les revues internationales à comité de lecture : **18**

Prix/Distinction :

- PEDR (1998-2002), (2002-2006) et (2006-2010)

Divers : Membre des GDR CNRS 2945 « Singularité et Applications » et 3064 « Géométrie Algébrique et Géométrie Complexe »

Lucy MOSER-JAUSLIN

52 ans
Professeur 1ère classe
IMB UMR 5584 CNRS - Université de Bourgogne
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Cursus :

- 1983-87 : **Doctorat** *Plongements normaux de SL(2)/Γ*, Université de Genève.
- 1987-89 : Assistant docteur à l'université de Genève.
- 1990-91 : Chercheur avancé du Fonds National Suisse de la Recherche Scientifique à l'Université de Rutgers, USA.
- 1991-92 : Chercheur avancé du Fonds National Suisse de la Recherche Scientifique à l'Université de Bourgogne.
- 1992-98 : **Maître de Conférences** à l'Université de Bourgogne.
- 1995 : **Habilitation à Diriger des Recherches** *Actions algébriques des groupes réductifs sur les variétés complexes*, Université de Bourgogne.
- 1998- .. : **Professeur**, Université de Bourgogne.
- 2007- .. : Directrice de l'IMB UMR 5584 CNRS – Université de Bourgogne

Encadrement doctoral :
- 1996-00 : Directrice de thèse de Gilles Bousquet.
- 1997-00 : Co-directrice de thèse (avec Robert Moussu) de Philippe Bonnet (Allocataire normalien).
- 2003-07 : Directrice de thèse de Pierre-Marie Poloni (Allocataire).

Publications (extraits):

[1] L. Moser-Jauslin, *Automorphism group of Koras-Russell threefolds of the first kind* , to appear in Proceedings of "Affine Algebraic Geometry : A conference in Honour of Peter Russell", Montreal 1-5 june, 2009 , CRM Proceedings Lecture Notes

[2] A. Dubouloz, L. Moser-Jauslin, P.-M. Poloni, *Inequivalent embeddings of the Koras-Russel cubic threefold*, Michigan Maths. J. 59 (2010), 679-694.

[3] L. Moser-Jauslin, P.-M. Poloni, *Embeddings of a family of Danielewski surfaces and certain* $\mathbf{C}^+$*-actions on* $\mathbf{C}^3$, Annales de l'Institut Fourier, 56, no. 5 (2006), 1567-1581.

[4] G. Bousquet, L. Moser-Jauslin, *A local study of embeddings of complexity one* , CRM Proceedings and Lecture Notes, 35 (2004), AMS, p. 1-10.

[5] G. Freudenburg, L. Moser-Jauslin, *Real and rational forms of certain* $O_2(\mathbf{C})$*-actions, and a solution to the weak complexification problem*, Transformation Groups, 9, no. 3 (2004), p. 257-272.

Nombre de publications dans les revues internationales à comité de lecture : **18**

7.3. IMPLICATION DES PERSONNES DANS D'AUTRES CONTRATS / INVOLVEMENT OF PROJECT PARTICIPANTS TO OTHER CONTRACTS

	Nom de la personne participant au projet / name	Personne . Mois / PM	Intitulé de l'appel à projets, source de financement, montant attribué / Project name, financing institution, grant allocated	Titre du projet : Project title	Nom du coordinateur / coordinator name	Date début & Date fin / Start and end dates
N°	A. Dubouloz	6,1pm (20%)	Projet ANR jeunes chercheurs 150 000 €	Uniformization of families of complex manifolds	L. Meersseman	2009-2012
N°	L. Moser-Jauslin	18pm (50%)	Projet ANR jeunes chercheurs 150 000 €	Uniformization of families of complex manifolds	L.Meersseman	2009-2012