Kick-Off Meeting

Indo-French Center for Applied Mathematics

2012

PROGRAM and ABSTRACTS

Université de Nice Sophia Antipolis

Laboratoire J. A. Dieudonné – Parc Valrose

November 19-21

Nice, France

IFCAM is a joint Indo-French center for Applied Mathematics supported by

Department of Science and Technology, India
Indian Institute of Science, Bangalore, India
Centre National de la Recherche Scientifique, France
INRIA, France
École Normale Supérieure de Paris, France
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Université de Nice Sophia-Antipolis, France
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The workshop is supported by

CNRS, European Research and International Cooperation Office
Université de Nice
Institut de Mathématiques de Toulouse
Université Paul Sabatier

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Talks

Master in Scientific Computing

Round Table
Visio-conference with TIFR-CAM

With the support of IFCAM the colleagues from Bangalore would like to develop an option of `Modeling and Scientific Computing' in the existing masters in applied mathematics. It has been proposed in January 2012 that this option will be first developed at TIFR-CAM. A 2-credit course on `Mathematical Modeling' has been introduced for M.Sc students at CAM from August to December 2012. There are plans to offer an advanced version of this as an optional course in the 4th and final semester of the Masters program at CAM. Depending on the feedback on these courses, a new stream in `Modeling and Scientific computing' could be planned. The Round Table discussion is aimed to generate ideas towards this course as well as the option of Masters in `Modeling and Scientific Computing'.

The topics of the round table will be:
- What can be the syllabus of such an option, what topics have to be addressed in modeling, what skills has to be developed in the field of computing, what training in Mathematics....

- How to attract students, what are the links with industries and services ...

- What can be the specific relation of such an option to training in engineering.

This round table is open to all the participants interested in this matter. The involvement of those who have experience in this field is required. The round table will be organized as follows. Some speakers will present their experiences and views on these matters (about 5-10 mns by speakers, depending on the numbers of people who would like to intervene). After that the discussion will be opened between the audience and the panelists and managed by a moderator. Those who would like to intervene can send a message before the workshop to the organizing committee. Colleagues from TIFR-CAM will be connected by visio-conference with Nice.

The Fattorini Criterion for the Stabilizability of Parabolic Systems and its Application to MHD flow and fluid-rigid body interaction systems

Mehdi Badra
Université de Pau (Pau, France)

In this talk we present a general methodology to study the feedback stabilizability of an infinite dimensional parabolic system of type:

$$y' = Ay + Bu + N(y,u). \tag{1}$$

Here, u is a finite dimensional feedback control of the form:

$$u(t) = \sum_{j=1}^{K} (y(t)|\varepsilon_j)v_j, \tag{2}$$

A is a linear operator with compact resolvent and generating an analytic semigroup, B is a linear and possibly unbounded input operator and $N(\cdot)$ is a superlinear nonlinear mapping. For instance, the Navier-Stokes equations with Dirichlet boundary control can be stated in the form (1).
The stabilizability of (1) by means of the finite dimensional feedback control (2) is obtained from the stabilizability of the linear system $y' = Ay + Bu$ and is reduced to the following infinite dimensional Hautus-Fattorini test:

$$\lambda \in \mathbb{C} \quad \lambda\varepsilon = A^*\varepsilon \quad \text{and} \quad B^*\varepsilon = 0 \quad \Longrightarrow \quad \varepsilon \equiv 0. \tag{3}$$

The above test is a criterion for approximate controllability of infinite dimensional system that has been first proved by Fattorini in [1] in the case of a bounded input B.
When considering systems discribed by partial differential equations the criterion (3) is simply a unique continuation property for an eigenvalue problem. In particular, it can be used to prove the feedback stabilizability of some coupled Navier-Stokes type equations and some fluid-structure systems. We give examples of applications for a magnetohydrodynamic flow system and for a fluid-rigid body interaction system.

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Modeling the dynamics of Hepatitis C Virus with combined antiviral drug therapy: Interferon and Ribavirin

Sandip Banerjee
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A mathematical modeling of Hepatitis C Virus (HCV) dynamics will be the highlight of this talk. The proposed model, which involves four coupled ordinary differential equations, describes the interaction of target cells (hepatocytes), infected cells, infectious virions and non-infectious virions. The model takes into consideration the addition of ribavirin to interferon therapy and explains the dynamics regarding the biphasic and triphasic decline of viral load in the model. A critical drug efficiency parameter has been defined and it is shown that for efficiencies above this critical value, HCV is eradicated whereas for efficiencies lower this critical value, a new steady state for infectious virions is reached, which is lower than the previous steady state.

Dissipationless Turbulence in the Fourier-Truncated Gross-Pitaevskii Turbulence in Two Dimensions

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We carry out extensive direct numerical simulations of Gross-Pitaevskii turbulence in the unforced, dissipationless, two-dimensional (2D) case. In particular, we explore the time evolution of different initial conditions (or initial states) to examine which statistical properties, e.g., energy and occupation spectra and order-parameter correlation functions, of the resulting solutions of the 2D GP equation show universal features. We divide the temporal evolution into the following regimes: (a) an initial-transient state, which is characterized by the formation, annihilation, and chaotic movement of vortex-antivortex pairs such that the overall pair density diminishes with time; (b) a regime in which the system approaches a thermalized state; (c) the thermalized, Kosterlitz-Thouless state. We elucidate the crossovers between these states and the self-truncation of the energy spectrum as the system moves towards thermalization. We compare our results with earlier studies of 2D GP turbulence.

Composites with unexpected effective properties

Marc Briane
INSA Rennes, France

A composite may have effective properties which differ notably from the properties of its homogeneous constituents. Pathological effects are due to the geometrical arrangement of the constituents combined the high contrast between them. The metamaterials belong to this class. For example Lakes (1996) and Sigmund and Torquato (1996-97) showed that one can build a composite that contracts when heated, although the three constituent materials all expand when heated. Here we present two other examples of composites with unexpected effective properties, obtained with G.W. Milton in the framework of Electrophysics. First a three-dimensional high conductive chain mail like a Middleage armor allows us to change the sign of the Hall coefficient. Second a columnar structure the section of which is composed of four high conductive arms permits to align the Hall electric field with the prescribed magnetic field, while they are orthogonal in a homogenous conductor. Finally we present a project with M. Vanninathan in the context of IFCAM. The aim is to derive a metamaterial which induces a change of sign of the effective Burnett tensor. Such a composite could have interesting applications in Acoustics.

Nonlinear hyperbolic systems and related scientific computing issues

Frédéric Coquel
Ecole Polytechnique, Palaiseau, France

On the controllability of a simplified model of fluid-structure interaction

Sylvain Ervedoza
CNRS – IMT, Toulouse

In this talk, I will present and discuss the controllability properties of a simplified model of fluid-structure interaction. In this model, the fluid evolves according to the linear wave equation, whereas the structure is an oscillator inside the fluid and submitted to the force exerted by the fluid. Our main goal is to discuss the exact controllability property of such model depending on the location of the control set and the shape of the rigid body. In particular, we provide another proof of the results in Tucsnak Vanninathan 2009 and give a more precise estimate on the time of controllability in the case in which the control set contains a neighborhood of the structure and of the external boundary of the fluid. We also study the case of a control exerted only in a neighborhood of the external boundary of the fluid when the structure is a disk, using strongly that, in that case, the coupling between the structure and the fluid only involves the first mode in the spherical harmonic decomposition, the other modes being completely decoupled from the rigid structure. This is a joint work with M. Vanninathan (TIFR, Bangalore).

A mixed Eulerian-Lagrangian approach to hydrodynamic simulations

Uriel Frisch
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I shall report some recent results obtained in collaboration with colleagues from India, Italy, Japan and Russia which could lead to an international project to tackle the thorny issue of finite-time blow of solutions to the 3D incompressible Euler equations.
As is well known, Eulerian simulations with a very small spatial mesh using an explicit scheme also require very small time steps, because the latter must be smaller than the time required to travel accross the mesh at the maximum flow velocity (mesh sweeping condition, also frequently - but somewhat improperly - called Courant-Friedrichs-Lewy condition).
In Lagrangian coordinates, fluid particles are labelled by their initial positions. The standard way of writing the equations in Lagrangian coordinates makes them very unappealing for numerical simulation. A new form has been discovered which involves only Lagrangian gradients of the Lagragian map that relates initial and current fluid particle positions. This form, which is closely related to one discovered by P. Constantin in 2000, makes it very easy to generate time Taylor series for the Lagrangian map. Combined with a new way of generating numerically the inverse Lagrangian map, this allows a temporal updating in which the time step is only constrained to be small compared to the nonlinear time (roughly the inverse of the largest velocity gradient). This should sharply reduce the algorithmic complexity of doing high-resolution simulations for the Cauchy problem.
The method is fairly general and can be applied to both incompressible and compressible flow. Actually, the idea is an outgrowth of the Lagrangian perturbation method developed by cosmologists in the 90s to tackle the compressible Euler-Poisson equations in connection with the dynamics of large-scale structures in the Universe.

Structure of the entropy solution of a scalar conservation law with strict convex flux

Shyam Ghoshal
Laboratoire de Mathématiques
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Joint work with Adimurthi and Gowda

We prove the structure Theorem of the entropy solution. Furthermore we obtain the shock regions each of which represents a single shock at infinity. Using the structure Theorem we construct a initial data $u_0 \in C_c^\infty$ for which the solution exhibits infinitely many shocks as $t \to \infty$. Also we have generalized the asymptotic behavior (the work of Dafermos, Liu, Kim) of the solution and obtain the rate of decay of the solution with respect to the N-wave. Basic ingredients in the proof of these results are Lax-Oleinik explicit formula and generalized characteristics which was introduced by Dafermos.

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Existence of singular solutions to semilinear critical problems in $\mathbb{R}^2$

Jacques Giacomoni
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Joint work with R. Dhanya and S.K. Prashanth

We study the existence of singular solutions for the following semilinear problem involving nonlinearities with super exponential growth:

$$(P_\lambda) \qquad \begin{cases} -\Delta u = \lambda(h(u)e^{u^\alpha}) & \text{in } \Omega, \\ u > 0 \quad \text{in } \Omega, & u|_{\partial\Omega} = 0. \end{cases}$$

where $\Omega \subset \mathbb{R}^2$ is a bounded domain with smooth boundary, $\lambda > 0$, $1 \leq \alpha \leq 2$ and h is a smooth "perturbation" of e^{t^α} as $t \to +\infty$. Next, we focus on the critical case, i.e. $\alpha = 2$ and discuss the properties of singular solutions (regularity, Morse index). We exploit these results to prove the existence of many turning points in the continua of solutions to the related bifurcation problem.

Nonlinear hyperbolic systems and related mathematical modeling issues

Edwige Godlewski
UPMC, Paris, France

For nonlinear infinite dimensional equations, which to begin with: linearization or discretization?

Laurence Grammont
Université de Lyon, Laboratoire de Mathématiques de l'Université de Saint-Étienne, France

To tackle a nonlinear equation in a functional space, two numerical processes are involved: discretization and linearization. In this paper we study the differences between applying them in one or in the other order.
As linearization scheme we consider the Newton-Kantorovich method.
Linearize first and discretize the linear problem is called Option A. Discretize first and linearize the discret problem is called Option B.
It appears that Option A converges to the exact solution, contrarily to Option B which converges to a finite dimensional solution.
We will present two examples: As example 1, the discretization scheme is chosen to be the Kantorovich projection approximation and as example 2, the discretization scheme is chosen to be the Nyström method.
Numerical evidence is provided with a nonlinear integral equation.
An application is presented where a combination of both options is proposed for solving a differential spectral problem.

Homogenization of linear adsorption in porous media

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Solute transport through porous media finds applications in wide ranging areas from Chermical engineering to Soil sciences. We consider an ε-periodic infinite porous medium, Ω_ε, typically built out of $\mathbb{R}^d$ by removing a periodic distribution of solid obstacles. A coupled convection-diffusion system, in Ω_ε and on $\partial\Omega_\varepsilon$, is considered with a reaction term acting as a coupling term on the pore boundaries.

$$\begin{aligned} &\partial u_\varepsilon/\partial t + \varepsilon^{-1} b_\varepsilon \cdot \nabla u_\varepsilon - \nabla \cdot (D_\varepsilon \nabla u_\varepsilon) = 0 \quad \text{in } (0,T)\times\Omega_\varepsilon, \\ &-\varepsilon^{-1} D_\varepsilon \nabla u_\varepsilon \cdot n = \partial v_\varepsilon/\partial t + \varepsilon^{-1} b^S_\varepsilon \cdot \nabla^S v_\varepsilon - \nabla^S \cdot \left(D^S_\varepsilon \nabla^S v_\varepsilon\right) \\ &\qquad = \varepsilon^{-2}\kappa\left(u_\varepsilon - (v_\varepsilon/K)\right) \qquad \text{on } (0,T)\times\partial\Omega_\varepsilon, \\ &u_\varepsilon(0,x) = u^0(x) \text{ in } \Omega_\varepsilon,\ v_\varepsilon(0,x) = v^0(x) \text{ on } \partial\Omega_\varepsilon, \end{aligned} \tag{4}$$

where b_ε (resp. b^S_ε) on Ω_ε (resp. on $\partial\Omega_\varepsilon$) are the ε-periodic velocity fields, D_ε (resp. D^S_ε) on Ω_ε (resp. on $\partial\Omega_\varepsilon$) are the ε-periodic diffusion tensors. κ is the reaction rate and K the adsorption equilibrium constant. The method of *Two-scale convergence with drift*[2] is employed in arriving at a homogenized equation. The sequences $\{u_\varepsilon\}$, $\{v_\varepsilon\}$ two-scale converge with drift b^* to u_0, Ku_0 respectively. u_0 satisfies the homogenized equation, a diffusion equation.

$$\begin{cases} K_d \dfrac{\partial u_0}{\partial t} - \div_x \left(A^* \nabla_x u_0\right) = 0 \ \text{ in } (0,T)\times\mathbb{R}^d \\ K_d\, u_0(0,x) = |Y^0| u^0(x) + |\partial\Sigma^0|_{d-1} v^0(x), \quad x \in \mathbb{R}^d \end{cases} \tag{5}$$

where $K_d = |Y^0| + K|\partial\Sigma^0|_{d-1}$ is the effective porosity with Y^0 the fluid part, Σ^0 the solid part in the unit cell $[0,1]^d$ which repeats itself in $\mathbb{R}^d$ upon rescaling. The dispersion tensor A^* is given by

$$\begin{aligned} A^*_{ij} = &\int_{Y^0} D(y)\left(\nabla_y \chi_i + e_i\right)\cdot\left(\nabla_y \chi_j + e_j\right) dy + \kappa \int_{\partial\Sigma^0} \left(\chi_i - \tfrac{\omega_i}{K}\right)\left(\chi_j - \tfrac{\omega_j}{K}\right) d\sigma(y) \\ &+ K^{-1} \int_{\partial\Sigma^0} D^S(y)\left(K e_i + \nabla^S_y \omega_i\right)\cdot\left(K e_j + \nabla^S_y \omega_j\right) d\sigma(y) \end{aligned} \tag{6}$$

with $(\chi,\omega) = (\chi_i,\omega_i)_{1\le i\le d}$ being the solution of the so-called cell problem. The effective drift b^* is given by

$$b^* = \frac{1}{K_d}\Big(\int_{Y^0} b(y)\,dy + K \int_{\partial\Sigma^0} b^S(y)\,d\sigma(y)\Big) \tag{7}$$

Some $2D$ numerical simulations were done using the FreeFem++ package. We have assumed in our work[1] that the velocity fields are purely periodic, functions depending only on the fast variable $y = x/\varepsilon$ and not on the slow variable x. The main technical reason is that the homogenized drift b^* would then depend on x which cannot be handled by our method. We are lacking the adequate tools (even formal ones) to guess the correct effective limit. This handicap of the theory of homogenization to address general flow fields highlights a need for the development of new tools in the theory of homogenization. Currently, we are working on a similar model with a nonlinear coupling term $\varepsilon^{-2}\kappa\left(\{\alpha u_\varepsilon/(1+\beta u_\varepsilon)\} - v_\varepsilon\right)$ involving *langmuir isotherm*.

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A Multiserver Queueing System with Multiclass Customers: Optimal Load Distribution via Admission Prices

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We consider a multiserver system serving a multiclass population. All classes have identical service time requirements but have different arrival rates and different costs per unit waiting time. An arriving customer of class i is routed to queue j with probability $p_{i,j}$ independent of other customers. Each queue has a delay function that is determined by the total arrival rate of customers to that queue. The routing objective is to minimise the delay cost in the system. The structure of the $p_{i,j}$ at optimal allocation is determined. Next, we consider a system in which an admission price of c_j is charged to a customer that joins queue j. Here the total cost for customer is the sum of the admission price to the queue that it joins and the expected cost of the delay in that queue. There is no central router and each customer chooses the queue to minimise its total cost. The load distribution here will achieve a Wardrop equilibrium. We characterise the structure of the load distribution at Wasrdrop equilibrium. We then determine the admission prices such that the load distribution at the Wardrop equilibrium is the same as that of the optimal allocation.

TBA

Alain Pumir
ENS Lyon

Control of the compressible Navier-Stokes system

Mythily Ramaswamy
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For the one dimensional Navier-Stokes system linearized around constant steady states, controllability and stabilizability aspects will be discussed. Local stabilization of full nonlinear system will be also presented.

Effects of Galerkin-truncation on Inviscid Equations of Hydrodynamics

Samriddhi Sankar Ray
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It is shown that the solutions of inviscid hydrodynamical equations with suppression of all spatial Fourier modes having wavenumbers in excess of a threshold K_G exhibit unexpected features. The study is carried out for both the one-dimensional Burgers equation and the two-dimensional incompressible Euler equation. At large K_G, for smooth initial conditions, the first symptom of truncation, a localized short-wavelength oscillation which we call a ”tyger”, is caused by a resonant interaction between fluid particle motion and truncation waves generated by small-scale features. These tygers appear when complex-space singularities come within one Galerkin wavelength $\lambda_G = 2\pi/K_G$ from the real domain and typically arise far away from preexisting small-scale structures at locations whose velocities match that of such structures. Tygers are weak and strongly localized at first but grow and eventually invade the whole flow. They are thus the first manifestations of the thermalization predicted by T.D. Lee in 1952.
An obvious consequence of such effects of truncation is the uncertainty in numerically estimating the time-decay of the width of the analyticity strip $\delta(t)$ which is related to the issue of finite-time singularity (see, e.g, Bustamante and Brachet, arXiv:1112.1571, 2012). We discuss possible ways of a more precise determination of $\delta(t)$, taking into account the effect of truncation, by using high-precision numerical simulations coupled with a semi-numerical procedure, called asymptotic extrapolation, developed recently by Joris van der Hoeven, to obtain accurate exponents from numerical data.

Patterns of life and death: Complex spatio-temporal dynamics in heterogeneous biological systems

Sitabhra Sinha
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Spatially coherent waves of activity are critical for the proper functioning of different biological organs, in particular, the heart and the pregnant uterus. In the uterine system, physiological changes that are not yet well-understood take place through the course of pregnancy that eventually lead initially transient excitations to give way to system-wide macroscopic contractions immediately preceding birth. Using models that include excitable and passive cells, we are trying to understand the mechanism that results in these dynamical transitions. Another vital organ of the human body, the heart exhibits regular contractions under normal circumstances and any disruption of the natural rhythm can lead to one of several types of arrhythmia, some of which can be potentially fatal. Spiral waves and their subsequent breakup into spatiotemporal chaos have been associated with certain life-threatening arrhythmia, such as ventricular tachycardia and fibrillation. Currently most effective therapies for such cardiac disorders involve applying large electrical shocks that have damaging side-effects. We are trying to develop more efficient chaos-control based strategies for terminating arrhythmia by studying the role of sub-threshold stimulation and tissue heterogeneities (such as inexcitable obstacles and excitability gradients) on the dynamics of spiral waves and spiral chaos states.

Multicasting in a Random Network

Rajesh Sundaresan
ECE Department, Indian Institute of Science

The talk will be on multicast information flow over a random network. A subset of the nodes in the network are in a communication session (for example, a video multicast). Traffic from source node of the session has to be sent to every other node in the session, with the remaining nodes acting as relays. The nodes are connected by undirected links whose capacities are modeled as random quantities. The talk will discuss the asymptotics of the maximum possible rate (with network coding) in the limit of a large number of nodes, with the fraction of nodes in session approaching a constant. A simple, decentralized, ”push-pull” algorithm (without network coding) and its asymptotic optimality will then be discussed.

Biography: Rajesh Sundaresan is currently a visiting scholar at the Coordinated Science Laboratory, University of Illinois at Urbana-Champaign. He is an associate professor at the ECE department of the Indian Institute of Science, Bangalore. He is visiting the Coordinated Science Laboratory on an Indo-US Science and Technology Forum Fellowship. He received his Ph.D. in Electrical Engineering from Princeton University in 1999, designed wireless modems at Qualcomm Incorporated from 1999 to 2005, and joined the faculty of the Indian Institute of Science in 2005. His research interests are in the areas of information theory and networks.

Linearisable mapping and their explicit integration

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Linearisable systems are omnipresent in the domain of integrable differential equations. In the Painlevé-Gambier classification of integrable second-order differential equations one encounters Painlevé equations and also linearisable systems. They can be divided into two main families: projective systems (which can be linearised through a Cole-Hopf transformation) and systems which can be represented as two Riccati equations coupled in cascade. All of the above notions extend to the discrete domain. The study of discrete linearisable second-order mapping revealed the existence of three main families of such systems. The first one are the the projective mappings, the second group are the linearisable mappings of Gambier type and their various degenerate forms and third family is called linearisable mappings of third kind. We shall present the linearisable mappings belonging to these families, derive their nonautonomous forms and give their explicit integrations.

On the Kirschner-Panetta dynamics in cancer modeling: from theory to practice

Alexei Tsygvintsev
UMPA, ENS de Lyon, France

The equations of Kirschner-Panetta describe the important features of dynamics and interaction between human host immune system and cancer cells. They are proven to represent and to capture in the more simple form the essential qualitative properties and at the same time are based on solid experimental data. In this talk we describe these equations and make a brief review of recent progress in both theoretical and applied directions.

On stochastic conservation laws

Guy Vallet
Université de Pau, France

In this talk, we are interested in the formal nonlinear stochastic conservation law of type:

$$du - div(f(u))dt = h(u)dw \quad \text{in } \Omega \times \mathbb{R}^d \times]0, T[,$$

with an initial condition $u_0 \in L^2(\mathbb{R}^d)$ and $d \geq 1$.

After a brief reminder on conservation laws and stochastic problems, we propose to prove the existence and the uniqueness of the entropy solution. The result is based on Kruzhkov's doubling-variable method and the convergence in the sense of Young measures.

Higher order Homogenized Coefficients: Their signs and Estimates

M. Vanninathan
TIFR-CAM, Bangalore, India

We consider a higher order homogenized tensor which arises in the homogenization process of elliptic operators.We present results concerning their signs and estimates.Microstructures behind these estimates are also obtained.Some conjectures in this direction are proposed.

Kick-Off Meeting

Monday, November 19	Tuesday, November 20	Wednesday, November 21
9h30 – Opening – Short Presentation of IFCAM 10h30 - Coffee Break 11h – 11h 45 Uriel Frisch 11h45 – 12h30 Munirathinam Tamizhmani	8h30 – 9h30 Round Table 'Master in Scientific Computing' Visio with TIFR-CAM 9h30 – 10h15 Dharmaiah Manjunath 10h15 – 11h Rajesh Sundaresan Coffee break 11h30 – 12h15 Marc Brachet 12h15 – 13h Samridhi Sankar Ray	9h – 9h45 M. Vanninathan 9h45 – 10h30 Harsha Hutridurga Coffee break 11h – 11h45 Laurence Grammont 11h45 – 12h30 Mehdi Badra
Lunch at Parc Valrose	Lunch at Parc Valrose	Lunch at Parc Valrose
14h – 14h45 Edwidge Godlewski 14h45 – 15h30 Frédéric Coquel Coffee break 16h – 16h45 Ghoshal Shyam 16h45 – 17h30 Guy Vallet	14h30 – 15h15 Sitabhra Sinha 15h15 – 16h Alain Pumir Coffee break 16h30 – 17h15 Sandip Banerjee 17h15 – 18h Alexei Tsygvintev Dinner at 'Le Méridien'	14h – 14h45 Mythily Ramaswamy 14h45 – 15h30 Jacques Giacomoni Coffee break 16h – 17h30 – Discussions about IFCAM