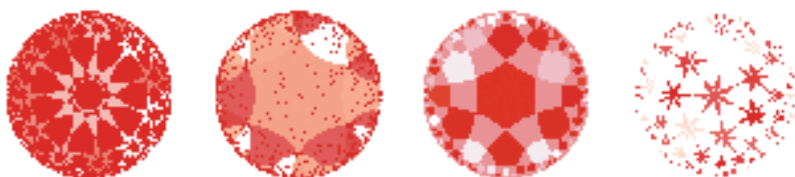# Master Class
2008 / 2009

ASPECTS OF CALABI-YAU GEOMETRIES

FINITE AND INFINITE DIMENSIONAL DYNAMICAL SYSTEMS

International Master Semester
FEBRUARY – MAY 2009

GEOMETRY IN THE SCIENCES

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The Netherlands

MATHEMATICAL RESEARCH INSTITUTE

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There is something paradoxical about mathematical research. Unraveling a mathematical problem is a highly individual activity, but it is precisely in discussion with colleagues that questions and problems emerge. Interaction is crucial.

In 1992, four of the leading mathematics departments of universities in the Netherlands joined forces to form an inspiring platform for interaction by founding the Mathematical Research Institute (MRI). In doing so, the universities of Groningen, Nijmegen, Twente and Utrecht have further reinforced the position of Dutch mathematical research, the quality and productivity of which is ranked in the European top. The MRI covers a broad range of specializations, with emphasis on five central areas in mathematics: algebra and geometry, analysis, stochastics and operations research. Research at the MRI is characterized by its attention to the dynamic relationship between fundamental and applied aspects of mathematics. In order to stimulate the quality and the development of its research, the MRI pays a great deal of attention to education and training of researchers.

All partners of the MRI are directly involved in its programmes – this guarantees a high level of quality. The MRI also has excellent connections in The Netherlands and abroad and regularly invites guest lecturers. This multi-faceted and international atmosphere allows students to get the most out of different visions: an inspiring and challenging situation.

MRI ACTIVITIES

The Master Class (one year) and International Master Semester (4 months) occupy an important place in the MRI's programme of studies. **They are open to anyone in the final years of their undergraduate studies, and also to graduate students.** The courses offered vary annually and offer a unique opportunity for mathematical talent to develop in the context of current topics. The language of instruction is English and both programmes are aimed at an international audience. In the past this has proved to be successful in bringing together Dutch and foreign students. Recently, these activities have become affiliated to one of the national research programmes (``clusters'') supported by the Dutch Science Foundation (NWO), or are organized in collaboration with the Thomas Stieltjes Institute for Mathematics.
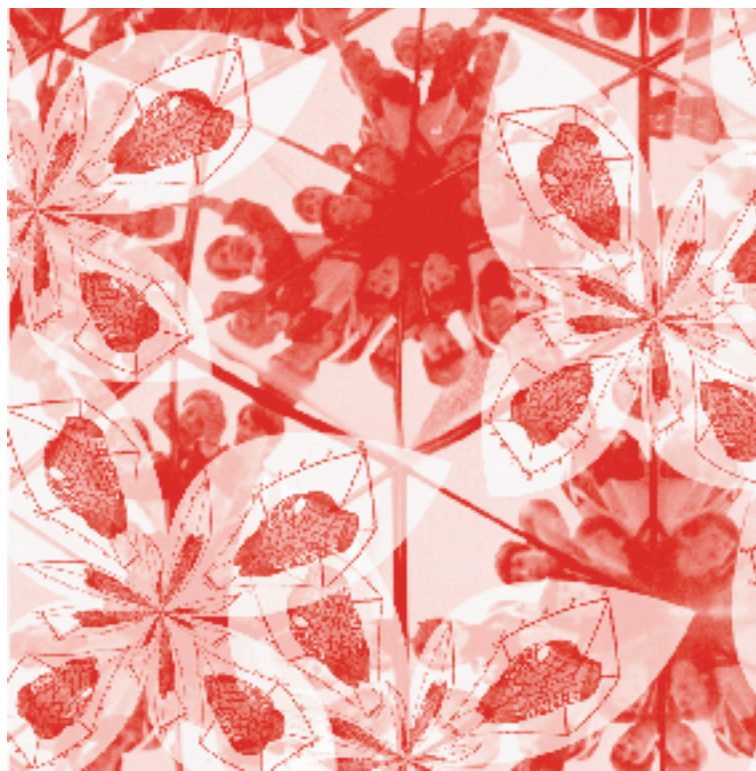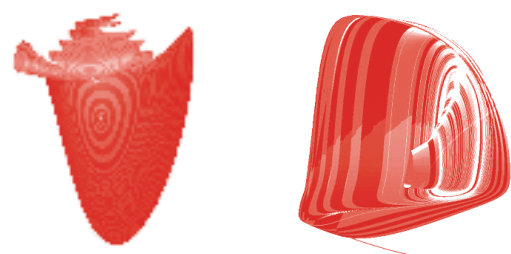
MASTER CLASS

In the one-year-long Master Class, a current topic is studied intensively and profoundly at an advanced level. The Master Class can form a significant contribution to a PhD programme or preparation for one.

The programme runs from September through June and includes two full days of lectures and seminars per week and individual work on a test problem. The emphasis is on an independent, individual effort, but includes personal and intensive contact with lecturers. Lecturers provide extensive exercise material based on which they give the participants feedback. There is a weekly consultation hour for individual questions. Regular evaluation and testing guarantees the quality of the programme. Students who complete the courses successfully will be awarded a Master Class Certificate.
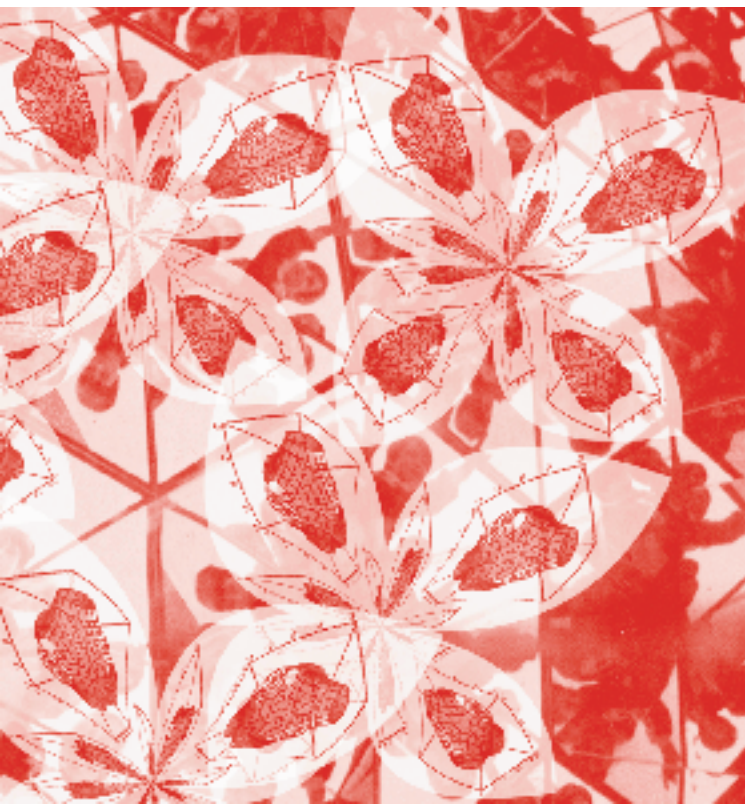
The final application deadline for the 2008/2009 Master Class is DECEMBER 1st, 2007. The applications and ALL the necessary documents must have been received by the MRI secretariat by this date. Candidates will be selected on the basis of previous academic achievement and references from their home universities.

Admission and tuition fees for the Master Class are 2269 euro. The cost of a modest but pleasant stay in the Netherlands, including residence and insurance, is approximately 850 – 1000 euro per month. In addition to the cost of travel to and from The Netherlands, an extra amount of 300 euro will be needed to cover travel expenses in The Netherlands to and from the locations of supplemental educational activities.

Participants needing financial support are encouraged to approach potential sponsors individually, through their own universities or international institutions. See also: www.nuffic.nl/huygens .

In a few cases, the MRI may be able to help with applications for a stipend. The MRI itself only offers a limited number of stipends.

INTERNATIONAL MASTER SEMESTER

This programme is a new initiative of the MRI. The aims are similar to those of the Master Class, the main difference being that the International Master Semester is shorter and more intensive. In this way the Master Semester is more suitable as an activity complementary to ongoing studies at the home university.

The final date for applications to the International Master Semester 2009 is September 15th, 2008. Applications and the necessary documents must have been received by the MRI secretariat by this date. Candidates will be selected on the basis of previous academic achievement and references from the home university. Admission and tuition fees together for the International Master Semester is 908 euro. Living expenses in the Netherlands will cost participants approximately 850 – 1000 euro, including residence and insurance. In addition to the cost of travel to and from The Netherlands, an extra amount of 300 euro will be needed to cover travel expenses in The Netherlands to and from the locations of supplemental educational activities. Participants needing financial support are encouraged to approach potential sponsors individually, through their own universities or international institutions, for example. In a few cases, the MRI may be able to help with applications for a stipend. The MRI also offers a limited number of stipends of its own.
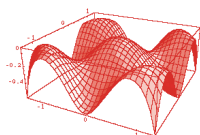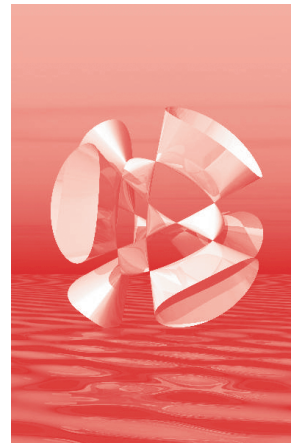
ASPECTS OF CALABI-YAU GEOMETRIES

The name Calabi-Yau manifold refers to the solution by S-T. Yau in 1977 of a conjecture of E. Calabi. The result describes one aspect of these remarkable geometric objects. The objects themselves, however, can be looked upon from many different view-points and for some the origins go back long before CY. Those of complex dimension 1 are elliptic curves and have been studied since the 18th century. Those of complex dimension 2 are K3-surfaces, which appeared in the 19th century as Kummer surfaces. Calabi-Yau threefolds did not attract much interest until in the 1980's when physicists realized that these could be used to bridge the gap between the 10 real dimensions needed for string theory and the 4-dimensional space-time we live in. Since then there has been an explosive growth of our understanding of Calabi-Yau threefolds, thanks to the joint research activities of many physicists and mathematicians.

In this Master Class we want to look at Calabi-Yau manifolds from a number of different view-points. The course on **Elliptic Curves** will present the classical theory of complex elliptic curves and their moduli. The courses on Toric Geometry, Riemannian Geometry, Hodge Theory and Special Lagrangian Fibrations will present different geometric scenarios, starting with general structure and focusing later on particularities of Calabi-Yau manifolds. The course on Frobenius Manifolds and Gromov-Witten Invariants deals with the geometry of moduli spaces of Calabi-Yau manifolds. In the two seminars students and guest speakers will discuss the connections between the ways in which Calabi-Yau manifolds appear in thelecture series as well as new developments in this fast growing field.

This Master Class is affiliated to the research cluster GQT (Geometry and Quantum Theory) between the University of Amsterdam, the University of Utrecht and the Radboud University Nijmegen, which is supported by NWO (Netherlands Organisation of Scientific Research).

The Master Class runs from September 1st, 2008 until June 30th, 2009

For more information see: http://www.math.uu.nl/people/stien/mc2008-2009.html

FIRST SEMESTER

> **Elliptic Curves and their moduli**
  lecturer: G. Cornelissen (Utrecht)
> **Toric Geometry**
  lecturer: J. Stienstra (Utrecht)
> **Riemannian Geometry**
  lecturers: E. van den Ban, S.Vandoren (Utrecht)
> **Hodge Theory**
  lecturer: J. Steenbrink (RU Nijmegen)

SECOND SEMESTER

> **Frobenius Manifolds and Gromov-Witten invariants**
  lecturer: E. Looijenga (Utrecht)
> **Special Langrangian Fibrations on Calabi-Yau Varieties** lecturers: t.b.a
> **Seminar on Calabi-Yau varieties** (guest speakers and students)
> **Seminar on Mirror Symmetry** (guest speakers and students)

PREREQUISITES

Applicants should have completed at least three years of undergraduate studies in pure mathematics or theoretical and mathematical physics

FINITE AND INFINITE DIMENSIONAL DYNAMICAL SYSTEMS

The research area `nonlinear dynamical systems' covers all aspects of the evolution of systems that may, or may not, be spatially extended. The solar system, the joint atmospheric and oceanic circulation, the world economy, the spread of diseases, etcetera, can all be viewed and modeled as dynamical systems. Therefore, this research area is intimately connected with physics, chemistry, economics, and the earth and life sciences. As a mathematical discipline, it interacts with many subfields, such as analysis, topology, measure theory, probability theory and functional analysis.

This Master Class aims at presenting a unified viewpoint for the study of finite and infinite dimensional systems, including maps, ordinary and partial differential equations and functional differential equations. Apart from developing the mathematical theory, significant attention will be paid to the interactions between the theory and applications.

In the Netherlands, the various research groups working in the broad area of dynamical systems and their various applications, have joined forces in a research cluster `Nonlinear Dynamics of Natural Systems' that is funded by NWO (Netherlands Organization for Scientific Research). This Master Class is affiliated to this cluster.

The Master Class runs from September 1st, 2008 until June 30th, 2009

For more information see: http://homepages.cwi.nl/~doelman/mc2008-2009.html

FIRST SEMESTER

> **Partial Differential Equations**
  lecturer: R. van der Vorst (VU Amsterdam)
> **Conservative Dynamical Systems**
  lecturers: H. Broer (Groningen),
  H.Hanssmann (Utrecht)
> **Asymptotic Analysis and Bifurcation Theory**
  lecturers: A. J. Homburg (U Amsterdam),
  J. Rademacher (CWI Amsterdam),
  V. Rottschafer (Leiden)
> **Neural Networks**
  lecturers: A. Doelman (CWI/U Amsterdam),
  S. A. van Gils (Twente), G. M. Hek
  (U Amsterdam)

SECOND SEMESTER

> **Geometric Mechanics**
  lecturers: H. Hanssmann (Utrecht), B. Rink
  (VU Amsterdam), H. Waalkens (Groningen)
> **Advanced Dynamical Systems:
  Ergodicity & Stochasticity**
  lecturers: D. Crommelin (CWI, Amsterdam),
  A.J. Homburg (U Amsterdam),
  C. Kuelske (Groningen)
> **Advanced PDE's**
  lecturers: J. B. van den Berg (VU Amsterdam),
  J. Hulshof (VU Amsterdam), M. A. Peletier
  (Eindhoven)
> **Seminar**
  Lecturers: H. Broer (Groningen), A. Doelman
  (CWI/U Amsterdam), H. Hanssmann (Utrecht),
  V. Rottschafer (Leiden)

PREREQUISITES

Applicants should have completed at least three years of undergraduate studies in pure mathematics or theoretical and mathematical physics.

GEOMETRY IN THE SCIENCES

Non-trivial techniques from Geometry and Topology are frequently applied in disciplines like Physics, Astrophysics, Computer Vision and Shape Analysis, Computer Graphics, Geometric Modeling, Bio-molecular Modeling and Robotics. Issues here are modeling phenomena in nature at very small or very large scale, modeling geometric objects or the extraction and reconstruction of such objects from large data sets. Objects are subject to motion and deformation in which not only their geometry, but also their topology can change.

A key role is played by concepts and results from Differential Geometry (like curvature in General Relativity), from Differential Topology (like Morse Theory in the evolution of shapes), from Singularity Theory (e.g., for the description of the Medial Axis and other skeletal structures), from Homology Theory (e.g., for the computation of Betti numbers for the classification of objects and patterns in spatial data), and from Mechanics and kinematics (e.g., for modeling and planning of motion and deformation). More and more, these topics are subject of multidisciplinary research, in which input from mathematics is steadily becoming more important.

**The International Master Semester runs from February 1st, 2009 until May 31st, 2009.**

For more information see: http://www.cs.rug.nl/~gert/mri/

PREREQUISITES

Linear Algebra, Introduction to Differential Manifolds, Ordinary Differential Equations, Basic Topology, Basic Algebra.

COURSES

> **Geometry and Physics**
  Lecturer: H.W. Broer
> **Singularity Theory and its Applications**
  Lecturer: D. Siersma
> **Discrete and Computational Geometry**
  Lecturers: G. Vegter, M. de Berg
> **Student Seminar** Various speakers
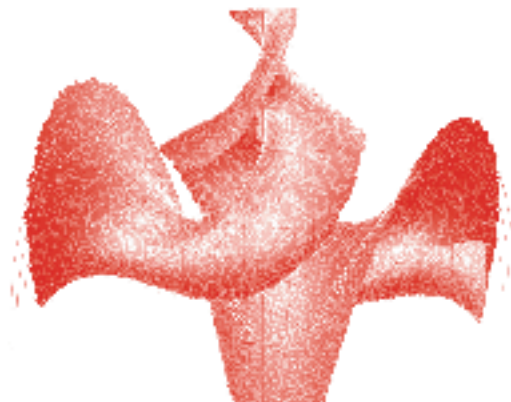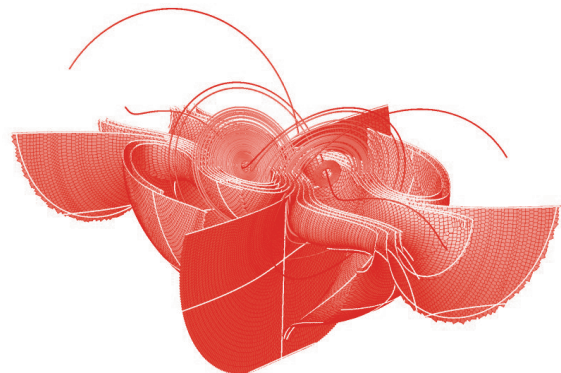
STUDYING AT THE MRI

The participating universities are located in Groningen, Nijmegen, Twente and Utrecht, each with its own special attractions. Often the courses take place in two of these four universities.
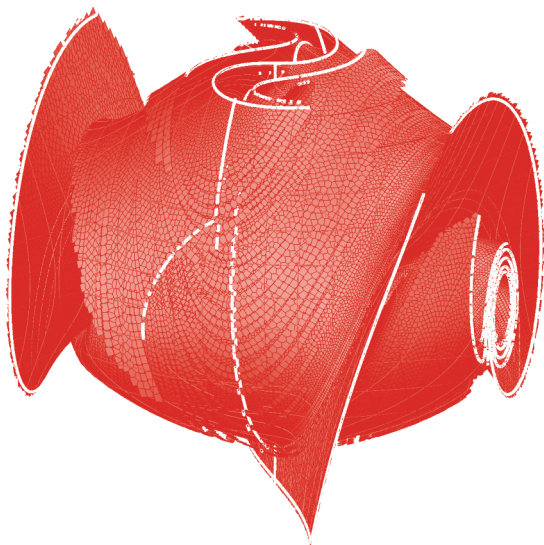
The MRI helps students find housing in one of the four cities, on campus or in a student house. Participants in the Master Class and International Master Semester have full use of the university facilities, such as excellent libraries and computers with Internet connection (e-mail).

Camilo Arias Abad (Colombia), participant in the 2003-2004 Master Class, PhD student in Utrecht

I truly enjoyed the Master Class in Non Commutative Geometry held in Utrecht/ Amsterdam in 2003-2004. Since the beginning it was clear that the lecturers would be of the highest level, that courses would be difficult and that we were expected to work a lot. I also realized soon that my classmates were all (as I am) genuinely interested in mathematics, this resulted in many useful discussions and made my stay in Utrecht much more interesting and pleasant. It was very easy to talk to the professors and ask them very frequently questions, I learned a lot from close contact with them. Also, people at the department were kind and helpful. After the Master Class, I came back to Utrecht as a PhD student. Now I have even closer contact with professors and fellow students, enjoy the mathematical discussions, questions and seminars and also, non-mathematical discussions, chess and football games. This is really the kind of environment I like to study in.

Marius Crainic (Romanian), Master Class coordinator (researcher at Utrecht University), former student in the 1995-1996 Master Class, former PhD student Utrecht

My decision to come to The Netherlands to take part in the Master Class (1995-1996) was one of the most inspired (and difficult) decisions I ever took. It was totally new for me, and later it became part of my normal life. Mathematically (and not only), a new world opened in front of me. Having around excellent mathematicians which are at the same time excellent teachers and friendly persons, is indeed a very good environment for studying and for research.

In the last few years I had the opportunity to see many of the students that took part in the Master Classes, and several of them are now colleagues or (and) friends. Probably the most appropriate label that one can attach with the Master Class is ``diversity''. Students come from all over the world, backgrounds are very different, culturally and mathematically, and the paths that the students take after the Master Class are quite various: some go back to their own country, some continue with a PhD project (in The Netherlands or elsewhere), some decide to go and work in industry, etc, etc. But, for one year, they all come here driven by their passion for mathematics, they often spend (working or partying) nights together, become friends.

The life in Holland is itself pleasant and interesting. The people are friendly, life is very well organized, and the country is so small that in less than one hour by train you can move between most of the big cities (Amsterdam, Den Hague, Nijmegen, Rotterdam, Utrecht, etc), while in two-three hours you can be in Koln (Germany), Brussels (Belgium), Paris (France), etc.

Javier Fernandez de Bobadilla de Olazabal (Spain), participant in the 1996-1997 Master Class, former PhD student in Nijmegen/Utrecht, former PostDoc in Utrecht:

I participated in 1996/1997 Master Class in Complex Geometry and Topology. The quality of the programme was very good. The courses were well selected, broad and deep. The lecturers knew how to go direct to the heart of the matter in each course. Moreover, I found the test problem an excellent way to get immersed into a research topic and make a first contribution. In fact, my current research interests are more related with my test problem than with the topic of my PhD thesis.

Besides the Master Class itself one can benefit very much from the scientific environment of the MRI. There are leading experts in many fields of mathematics, and interesting courses, seminars and talks are organized on a regular basis. Actually, like many other Master Class students, I continued my stay in MRI until I finished my PhD, and I further continued my stay in The Netherlands on a PostDoc position. I have no doubt that Master Class has been a corner-stone of my career.

I have experience with the Master Class of the MRI since the beginning (around 1990). I have been teaching several courses and was very often impressed by the efforts from the students. Master Class students come from all over the world. They have different cultural background, which makes teaching in the master class very interesting.
Also the mathematical background is different in most cases. First we have to make some efforts to introduce all students to the common prerequisites of the subject. This is mostly done in the first semester. An important ingredient is also the weekly seminar, where the students talk by themselves about mathematics.

During the second semester the lectures discuss new developments. Some of courses are especially designed for this part of the master class. Moreover there is the `research problem'. During this period there is a very near contact between student and supervisor and it mostly takes a lot of work to finish the paper in time.

The end of June closes with examinations and graduation. This is mostly the end of a successful year.

The International Master Semester is a new initiative of the MRI. It has many properties in common with the Master Class, but is shorter: only one semester. It focuses on a special topic of interest and can also be used for student exchanges as part of a Master degree and is a good start or preparation for a Ph.D. programmes.
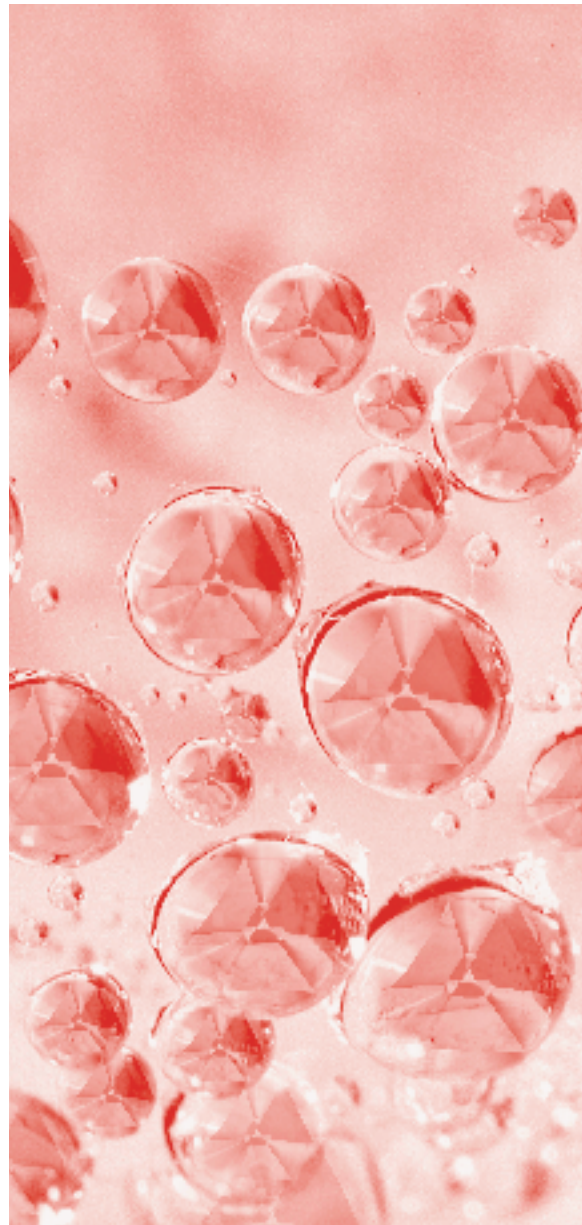
APPLICATION DEADLINES

MASTER CLASS: DECEMBER 1, 2007

MASTER SEMESTER: SEPTEMBER 15, 2008

To apply for the Master Class or International Master Semester send the following documents to the secretariat of the MRI:

> curriculum vitae (including the following details: first name, surname, date of birth, nationality, address, postal code, city, country, phone number, fax, email address)

> academic record: list of subjects/classes/marks taken at university, subjects for degree examination, photocopy of diploma (if available).

> recommendations from members of the academic staff of the home university (at least one)

> a summary of financial circumstances.

Applications for the Master Class and the International Master Semester should be sent to

Jean Arthur & Hans Gooszen
Utrecht University
P.O. Box 80010
3508 TA Utrecht
The Netherlands
email **mri@math.uu.nl**
tel **+31-30-2531472**
fax **+31-30-2518394**

MRI website **http://mri.math.uu.nl**

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