Noncommutative geometry meets topological recursion

INFORMATION

AND

ABSTRACTS

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General information

Welcome

We are glad to welcome you to NONCOMMUTATIVE GEOMETRY MEETS TOPO-LOGICAL RECURSION, hosted at Mathematics Münster! Due to the pandemic, our conference will take on a hybrid format. This booklet contains information for both online and in person participants of the conference. For further information please visit our web site `https://www.uni-muenster.de/MathematicsMuenster/events/2021/ncg-meets-tr.shtml`.

Overview

The conference takes place August 16–20, 2021. As we expect to have participants joining from many different time zones, we intend – if speakers agree – to record the lectures and make them available on the youtube channel `https://www.youtube.com/c/mathematicsmunster` of Mathematics Münster.

We plan to have:
- Mini courses given by Elba Garcia-Failde, Walter van Suijlekom, Roland Speicher and Bertrand Eynard.
- Ten contributed talks given by participating speakers.
- A gong talk session with 5-minutes talks given by young researchers present in Münster.

The conference is organised by:
- Gaëtan Borot (Institut für Mathematik & Institut für Physik, Humboldt-Universität zu Berlin)
- Masoud Khalkhali (Department of Mathematics, University of Western Ontario)
- Hannah Markwig (Fachbereich Mathematik, Eberhard Karls Universität Tübingen)
- Jörg Schürmann (Mathematisches Institut, WWU Münster)
- Raimar Wulkenhaar (Mathematisches Institut, WWU Münster)

If you have any question or need any help, do not hesitate to contact our secretary Gabi Dierkes at `g.dierkes@uni-muenster.de` or any of the organisers. Contact information can be found on their web pages.

Schedule

The following table gives a detailed schedule. The red coloured cells indicate minicourse sessions, while the green ones indicate contributed talks. The (Z)/(P) next to the speaker's name indicates whether the talk is happening via Zoom or in person.

Time in CEST	Monday 16	Tuesday 17	Wednesday 18	Thursday 19	Friday 20
09:00-10:00	Elba Garcia-Failde (P)	Elba Garcia-Failde (P)	Elba Garcia-Failde (P)	Walter van Suijlekom (Z)	Piotr Śniady (P)
10:00-10:30	tea & coffee	tea & coffee	tea & coffee	tea & coffee	tea & coffee
10:30-11:30	Walter van Suijlekom (Z)	Walter van Suijlekom (Z)	Roland Speicher (P)	Roland Speicher (P)	Séverin Charbonnier (P)
11:30-12:00	break	break	break	break	break
12:00-13:00	Sergey Shadrin (P)	Roberta Iseppi (P)	Camille Male (Z)	Kurush Ebrahimi-Fard (P)	Alexander Hock (P)
13:00-15:00	lunch break	lunch break	lunch break	lunch break	lunch end of conference
15:00-16:00	Roland Speicher (P)	Bertrand Eynard (Z)	Bertrand Eynard (Z)	Bertrand Eynard (Z)	
16:00-16:30	tea & coffee	tea & coffee	tea & coffee	tea & coffee	
16:30-17:30	Gong talks	Lisa Glaser (P)	Yan Soibelman (Z)	James Mingo (Z)	
17:30-18:30	17:30 short break / 17:45 Gong talks	Conference dinner	City tour	Barbecue	
18:30-??:??	Reception	Conference dinner	City tour	Barbecue	

All given times in the schedule are Central European Summer Time (CEST) used in Germany, which is 2 hours ahead of Coordinated Universal Time (UTC), e.g. 9:00 CEST = 7:00 UTC. For instance:

- California = -9h
- Colorado/Saskatchewan = -8h
- Kansas/Texas = -7h
- US East Coast/Ontario = -6h
- UK = -1h
- Israel = +1h
- Chennai = + 3h30
- China = +6h
- Pohang = +7h

Note to online participants

It is unfortunate that we cannot all be together in person. This conference was intended to be a first meeting point for specialists and young researchers active in noncommutative geometry, free probability, and topological recursion. Socialising and connecting people of different mathematical fields is an important aspect. Of course this is easier for participants coming in person to Münster.

If you are participating online, we invite you to be as close as possible to other participants, for instance by keeping webcams on during the event or by engaging in conversations with fellow participants during the breaks.

Zoom coordinates

The platform that is going to be used for virtual participation is Zoom. We ask our remote participants to connect to the conference using the names that they registered with, so that we can prevent any malicious parties from joining. The Zoom coordinates will be announced via email to registered participants. If you wish to receive the coordinates after start of the conference please write to any of the organisers.

Mini courses

The conference features four mini courses, each of which consists of 3 lectures. These will be given by Elba Garcia-Failde (IRIF, Université Paris-Diderot), Walter van Suijlekom (IMAPP, Radboud University Nijmegen), Roland Speicher (Fachrichtung Mathematik, Universität des Saarlandes) and Bertrand Eynard (Institut de Physique Théorique, Paris-Saclay and IHÉS). You can find their abstracts in the following pages.

Elba Garcia-Failde

Introduction to topological recursion

In this mini-course I will introduce the universal procedure of topological recursion, both by treating examples and by presenting the general formalism. We will study the classical case of the Hermitian matrix model in detail, which combinatorially corresponds to ribbon graphs, beginning from the loop equations, which correspond to Tutte's recursion in the combinatorial setting. This will be the starting point to make the connection to free probability, which moreover provides a combinatorial way of exploring the variation of the topological recursion output when applying a symplectic transformation to the input. Apart from the (conjectural) property of symplectic invariance, topological recursion has many other interesting features and, together with its generalizations, has established connections to various domains of mathematics and physics, like intersection theory of the moduli space of curves and integrability. We will explain some of these properties and connections, giving several ideas why this is worth considering, and is the starting or gluing point of an active field of research, and finally hoping to instigate the search of new beautiful connections.

Walter van Suijlekom

Non-commutative geometry and spectral triples

Our starting point is a spectral approach to geometry, starting with the simple question 'can one hear the shape of a drum'. This was phrased by Mark Kac in the 1960s, and led to many developments in spectral geometry. For us, it is the motivation for considering spectral triples, which is the key technical device used to describe noncommutative Riemannian spin manifolds. We will give many motivating examples, and also explain how gauge symmetries naturally arise in this context.

The connection to the other main theme of the workshop is found via the spectral action principle. It allows for a derivation of an action functional from any given spectral triple. This includes the Hermitian matrix model, but more interesting matrix models appear beyond. We will consider some recent developments for such models by deriving a perturbative series expansion for the spectral action.

Roland Speicher

Free probability theory: higher orders and relation to topological recursion

Usual free probability theory was introduced by Voiculescu in the context of operator algebras. It turned out that there exists also a relation to random matrices, namely it describes the leading order of expectation values of the trace for multi-matrix models. Higher order versions of free probability were later introduced by Collins, Mingo, Śniady, Speicher in order to capture in the same way the leading order of correlations of several traces. A prominent role in free probability theory is played by "free cumulants" and "moment-cumulant formulas", and the underlying combinatorial objects are "non-crossing partitions" and, for the higher order versions, "partitioned permutations".

I will give in my talks an introduction to free probability theory, with special emphasis on the higher order versions, and an eye towards possible relations to topological recursion. In particular, it seems that the problem of symplectic invariance in topological recursion has, at least in the planar sector, something to do with the transition between moments and free cumulants.

Bertrand Eynard

(Mixed) topological recursion and the two-matrix model

An issue in non-commutative probabilities, is to compute "mixed traces" of products of random matrices: typically expectation values of the type

$$\mathbb{E}\left(\operatorname{Tr} A^{k_1} B^{l_1} A^{k_2} B^{l_2} \ldots\right)$$

with a joint random matrix measure $P(A, B)$, which we assume to be invariant und er simultaneous unitary conjugation of A and B. The prototype is the 2-matrix model with $A, B \in H_N \times H_N$:

$$P(A, B) = e^{-\operatorname{Tr} V(A)} e^{-\operatorname{Tr} \tilde{V}(B)} e^{\operatorname{Tr} AB} \mathrm{d}A \mathrm{d}B.$$

Another phrasing of this question consists in diagonalizing $A = UXU^\dagger$ and $B = VYU^\dagger$, and calling $W = U^{-1}V$. At fixed spectrum (fixed X and Y), mixed traces amount to computing expectation values of polynomials of W with the Harish-Chandra measure:

$$\int_{W \in G} dW e^{\operatorname{Tr} XWYW^{-1}} W_{i_1,j_1} W^\dagger_{i_2,j_2} W_{i_3,j_3} W^\dagger_{i_4,j_4} \cdots$$

where dW is the Haar measure on the group $G = U(N)$ (can be generalized to other compact Lie groups).

This problem is also closely related to a problem of enumeration of maps in combinatorics: maps with faces of 2 colors, called the "Ising model on random maps". Mixed traces correspond to counting maps with boundaries and with a given sequence of colors along the boundaries. In comparison, non-mixed traces (traces of powers of only A or only B) would count maps with uniformly colored boundaries.

For the 2 matrix model, all these expectation values have been computed, the results involve determinants of some "universal matrices", and yields surprisingly simple answers.

Moreover recursion formulas for their large N expansion are known, and are an extension of the "topological recursion". In the map interpretation, the large N expansion amounts to counting maps of higher topologies, the power

of N being the Euler characteristics of the maps counted. The large N leading order amounts to counting planar maps.

In this series of lecture we will introduce the 2-matrix model and the issue of mixed traces, then we shall give the answers as formulas. Some formulas will be proved during the lectures, but the main goal is to explain how to use the formulas for practical computations.

If times permits, the formulas for all compact Lie groups will be addressed.

We shall largely follow the chapter 8 of the book *Counting surfaces*, B. Eynard, Birkhäuser 2016.

Research talks

In this section you will find the titles and abstracts of the research talks.

Séverin Charbonnier (IRIF, Paris 7)

Topological recursion for fully simple maps

Fully simple maps show strong relations with symplectic invariance of topological recursion and free probabilities. While ordinary maps satisfy topological recursion for a certain spectral curve (x, y), G. Borot and E. Garcia-Failde conjectured in 2017 that fully simple maps satisfy topological recursion for the exchanged spectral curve (y, x). Two proofs of this conjecture were simultaneously released this year (`math-ph/2106.08368` and `math.CO/2106.09002`). I will first define fully simple maps and describe the context of the conjecture; second, I will detail the proof we provided together with G. Borot and E. Garcia-Failde via ciliated maps; last, some connections between this work and free probabilities will be drawn, along with questions left opened.

In collaboration with G. Borot and E. Garcia-Failde (`math.CO/2106.09002`).

Kurusch Ebrahimi-Fard (NTNU Oslo)

An operadic derivation of the twisted factorisation for the operator-valued T-transform

Together with Nicolas Gilliers, we have tried to understand how an operadic perspective might help to formulate a more transparent, i.e., combinatorial derivation of Dykema's twisted factorisation formula for the operator-valued T-transform. In this talk, we will discuss our approach using a diagrammatic presentation.

Lisa Glaser (University of Vienna)

A picture of a spectral triple

A compact manifold can be described through a spectral triple, consisting of a Hilbert space $\mathcal{H}$, an algebra of functions $\mathcal{A}$ and a Dirac operator $\mathcal{D}$. But what if we are given a spectral triple? Then the situation is more complicated, it is not clear how to reconstruct geometry from a spectral triple, in particular one with a non-commutative algebra $\mathcal{A}$, or a finite Hilbert space $\mathcal{H}$. But these are questions one would like to ask if trying to use spectral triples to possibly quantize gravity. In this talk I will show how we recover metric information from a truncation of a spectral triple to make an image, and show some odd shrinking spectral triples.

Alexander Hock (WWU Münster)

From noncommutative quantum field theory to blobbed topological recursion

Scalar quantum field theory on noncommutative Moyal space can be approximated by matrix models with non-trivial covariance. One example is the Kontsevich model, which is governed by topological recursion. We will focus on a slightly different matrix model with the same covariance as the Kontsevich model, but with a quartic interaction, the so-called quartic Kontsevich model. This model does not fit into the class of generalised Kontsevich models (which is also known to satisfy topological recursion). Our loop equations turn out to be of similar structure as the loop equations of the Hermitian 2-matrix model. However, computing the simplest expectation values shows that this model is governed by blobbed topological recursion, an extension of topological recursion. This is proven for genus $g = 0$ and work in progress for higher genera. We will show the explicit recursive structure for these blobs by providing the explicit linear and quadratic loop equations (for $g = 0$).

Roberta Iseppi (Syddansk Universitet, Odense)

The BV-BRST cohomology for $U(n)$-gauge theories induced by finite spectral triples

The Batalin–Vilkovisky (BV) formalism provides a cohomological approach for the study of gauge symmetries: given a gauge theory, by introducing extra (non-existing) fields, we can associate to it two cohomology complexes, the BV and the BRST complex. The relevance of these complexes lies in the fact that their cohomology groups capture interesting physical information on the initial theory. In this talk we describe how both these complexes can be seen as Hochschild complexes of a graded algebra B over a bimodule M. By focusing on $U(n)$-gauge theories induced by a finite spectral triple on $M_n(\mathbb{C})$, we explain how the pair (B, M) is naturally encoded, respectively, in the BV spectral triple associated to the theory for the BV complex and in its gauge - fixed version for the BRST one. This result further reinforces the idea that the BV construction naturally inserts in the framework provided by noncommutative geometry.

Camille Male (Université de Bordeaux)

Freeness over the diagonal and the global fluctuations of Wigner matrices

We characterize the limiting second order distributions of independent complex Wigner and deterministic matrices using Voiculescu's notions of freeness over the diagonal. For unitary invariant random matrices, Mingo and Speicher's notion of second order freeness gives a universal rule to compute the global fluctuation. But this one is in general not valid for non Gaussian Wigner matrices, since the fluctuations are not universal, depending in particular on the moment of order 4 of the matrices. Yet, it is possible to adapt Mingo–Speicher's formulation and reformulate this notion for operator-valued random variables in a second order probability space, and prove a universal rule for more general Wigner matrices (for which the marginal second order distributions are not universal).

James Mingo (Queen's University, Kingston)

The infinitesimal Weingarten calculus

The Weingarten calculus calculates matrix integrals over the unitary and orthogonal groups, in particular their large N behaviour. In this talk we shall look at the Weingarten function on the orthogonal group and the term of subleading order and its relation to infinitesimal freeness. The leading order term was found by Collins and Śniady and governs asymptotic freeness. The subleading term was evaluated by Féray using complete symmetric functions. We will give another interpretation using the planar diagrams of infinitesimal freeness.

Sergey Shadrin (Universiteit van Amsterdam)

Arnold's trinity of algebraic $2d$ gravitation theories

"Arnold's trinities" refers to a metamathematical observation of Vladimir Arnold that many interesting mathematical concepts and theories occur in triples, with some hidden influence of R/C/H hidden in the background. By algebraic $2d$ gravitation theory I mean a very rich system of interrelated algebraic structures surrounding the concept of cohomological field theory in genus 0. It appears that there is an Arnold trinity of algebraic $2d$ gravitation theories (and one of them is a very natural non-commutative version of a CohFT), and I'll try to expose them, with a special focus on new homotopy quotients statements that we discovered last year.

A joint work with Vladimir Dotsenko and Pedro Tamaroff.

Piotr Śniady (Institute of Mathematics, Polish Academy of Science, Warsaw)

Representation theory from the random matrix perspective

In many cases a representation of a group can be viewed as a "random matrix with non-commutative entries". This viewpoint gives a heuristic explanation for many links between the representation theory, the random matrix theory and the free probability theory. This talk is intended to be easy and available to an audience which has no background in representation theory.

Supplementary material (slides, lecture notes, literature) will be available a couple of days before the lecture on the website `psniady.impan.pl/munster`

Yan Soibelman (Kansas State University)

Wall-crossing structures and exponential integrals

The notion of wall-crossing structure was introduced in my joint papers with Maxim Kontsevich for the purposes of Donaldson-Thomas theory (`math.AG/0811.2435`) and complex integrable systems (`math.AG/1303.3253`). In this talk I am going discuss a special case of this notion which appears in the theory of exponential integrals, including a multivalued case (i.e. exponential integral of a holomorphic one-form). This approach gives a conceptual explanation of the resurgence properties of arising perturbative expansions from the point of view of our general conjecture on analytic wall-crossing structures (`math.AG/2005.10651`). It also gives an alternative approach to the problem of counting of saddle connections on a Riemann surface.

Gong talks

In this section you will find the tentative list of the 5 minute "gong talks".

- **Adam Afandi** (WWU Münster)
Hyperelliptic Hodge integrals

- **Nezhla Aghaei** (Syddansk Universitet, Odense)
Combinatorial quantisation of Chern Simons theory

- **Jan Boschheidgen** (Universidad Autónoma de Madrid)
Spectral measures associated to groups

- **Johannes Branahl** (WWU Münster)
Blobbed topological recursion meets quantum field theory

- **Nitin Kumar Chidambaram** (MPIM Bonn)
Topological recursion and Gaiotto vectors

- **Alessandro Giacchetto** (MPIM Bonn)
The Harer–Zagier formula via intersection theory

- **Marvin Hahn** (MPI Leipzig)
Bi-pruned Hurwitz numbers

- **Adrian de Jesus Celestino Rodriguez** (NTNU Oslo)
Semi-multiplicative functions and relations between cumulants

- **Reinier Kramer** (MPIM Bonn)
KP for Hurwitz-type cohomological field theories

- **Danilo Lewański** (IPhT CEA Saclay & IHES)
Topological Renaissance

- **Carlos Perez** (Institute for Theoretical Physics, Warsaw)
On multi-matrix models motivated by random noncommutative geometry

- **Giacomo Umer** (HU Berlin)
Topological recursion in the framework of Whittaker vectors

Information for in person participants

We are very glad to welcome you to the city of Münster! This part of the booklet includes all the information you need to get around. We hope you enjoy your time here!

Locations

NONCOMMUTATIVE GEOMETRY MEETS TOPOLOGICAL RECURSION takes place at the mathematics department of WWU Münster, which is located at Einstein-straße 64. All the lectures will be given in the M1 hall of the old flat building: just enter the main entrance and turn right at the end of the corridor. There will also be signs inside the building to guide you to M1.

Here is a map of the area; the lecture hall is located in the Hörsaalgebäude. Tea and coffee will be served in the 2nd floor of the SRZ building.

Wi-Fi access for guests is possible via eduroam (which you have to configure at your home university) or via the SSID "GuestOnCampus". To use the latter, start any web browser. You will automatically be redirected to the login page. Confirm the terms of use and click on "log in for free". 1 GB data volume

is available per device and day. In contrast to eduroam, GuestOnCampus is not encrypted.

Travel

Participants should consult

`https://www.auswaertiges-amt.de/en/coronavirus/2317268`

on current entry regulations. Participants from "high risk areas" need a complete vaccination to avoid a self-isolation in Germany for 5 days. The list of high risk areas is given at

`https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/`
`Transport/Archiv_Risikogebiete/Risikogebiete_aktuell_en.pdf?__`
`blob=publicationFile.`

In Europe these "high risk areas" are (as of August 12): Andorra, Cyprus, Portugal, Russian Federation, Spain and United Kingdom as well as the regions Provence-Alpes-Côte d'Azur, Occitanie and Corse of France.

Please contact one of the local organisers in case you need an official PCR test for travelling back to your country.

Detailed travel information can be found at `https://www.uni-muenster.`
`de/MathematicsMuenster/aboutmm/directions.shtml`.

Covid restrictions

Due to the pandemic, there are certain rules that we need to follow in order to minimise the risk of covid-19 transmission. In particular:

▶ Participants that are attending the conference in person need to take an antigen rapid test every 48 hours during the conference, *even if they are fully vaccinated/recovered in the last 6 months*.
For rapid tests, one can either have a self-test or a test at one of the public test sites around the city. Self-tests will be provided by the conference. In a break on Monday we will demonstrate how these work. If you wish to have a free official rapid test, *which is necessary for participants staying at Hotel Jellentrup who are not yet fully vaccinated*, you should visit

• ASB Münster, Parkplatz Schlossplatz Nord (Schlossplatz 24),

during 8 am - 8 pm on weekdays and 9 am - 12 pm on weekends. One can make a prior appointment via their web site (which is in German).

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If you visit the test site, make sure to have your ID card or passport with you. It is a 10 minutes walk from the maths department. Here is a map to help you orient:

▶ Inside the university buildings, wearing a surgical or an FFP2 mask is mandatory[1]. When seated in the M1 lecture hall during a talk, participants can take off their masks, since M1 is well ventilated with a certified system and large enough for us to keep a safe distance of 1.5 meters from one another.

▶ Our lecture hall M1 has 50 seats at safe distance from each other. We will mark these preferred seats by painter's tape on the tables. We recommend to take the same seat after the breaks.

▶ If you are experiencing any respiratory symptoms (coughing, sneezing) or fever, please refrain from participation and contact the organisers as soon as possible to discuss how to proceed.
In case of a positive test, the general rules of the health department of the city of Münster apply.

Besides the above rules, we encourage the participants to practice safety measures such as avoiding handshakes, maintaining a minimum distance of 1.5 meters from others and frequently using hand sanitiser.

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[1]You can buy such masks at any drug store, pharmacy or grocery store in Münster.

If you have any question regarding the above rules, please contact either Anja Böckenholt at `anja.boeckenholt@uni-muenster.de` or Carolin Gietz at `carolin.gietz@uni-muenster.de`.

Public transport

▶ Münster is also known as the "bicycle capital of Germany", the reason being that the city is very accessible by bike; everyone uses them around here, so renting a bike is a very convenient option to get around. Here is a list of some bicycle rental stations, the prices vary around 10€ per day.

- Radstation Münster Hundt KG, address: Berliner Platz 27A
- Canu Camp, address: Homannstraße 64
- Hof zur Linde, address: Handorfer Werseufer 1
- Landhaus Eggert, address: Zur Haskenau 81
- Fahrrad Look, address: Dingbängerweg 249

You can find more information about these rental stations, their websites and even more alternatives to these by following this link

```
https://www.stadt-muenster.de/en/tourismus/bike-city/
                    bicycle-rental
```

▶ Münster's main means of public transport is the city bus. There are many frequent bus routes that link the inner part of the city; the maximum waiting time is 10-20 minutes, but a lot of routes are covered by more than one line with alternating schedules.

A single ticket ("Einzelticket") (90 min ride on any bus line in any one direction– no returns) costs about 2.90€ (3.30€ if you buy it from the bus driver), while a short route ticket (distance of 4 further bus stops) costs about 1.90€. There are many alternatives to these like 24hour tickets, or tickets for one whole week. For an interactive overview of all the available tickets and the respective prices, follow this hyperlink.

You can buy tickets for the bus from machines at central bus stops (one is in front of the Mensa), from the Stadtwerke service centers located at BerlinerPlatz 22, Hafenweg 1 and Salzstraße 21 (you might need to check their time schedules though), or using the Deutschebahn App (available in English).

Keep in mind that, due to Covid-19, surgical or FFP2 **masks are mandatory inside the city buses**.

► All around the city, you will see e-scooters belonging to one of several e-scooters rental companies parked on sidewalks. These are available to rent using the company's app (instructions for download are usually found on the scooter). Just download the app, follow the instructions, and you are ready to ride through the city on roads and bike lanes! When you are finished, just end the ride and park it on a sidewalk (out of the way of foot traffic).

For those of you speaking German, you can also install the "Münster:app" on your smartphone; this app helps you choose the most convenient line for your destination, offers information on tickets etc. A non-German alternative to this is Google maps, which offers a good deal of information on how to move around the city.

Hotels

For participants registered early we booked accommodation in Hotel Bakenhof (for most participants) or Hotel Jellentrup.

Jellentrup is less than 10 minutes walk away from the conference site:
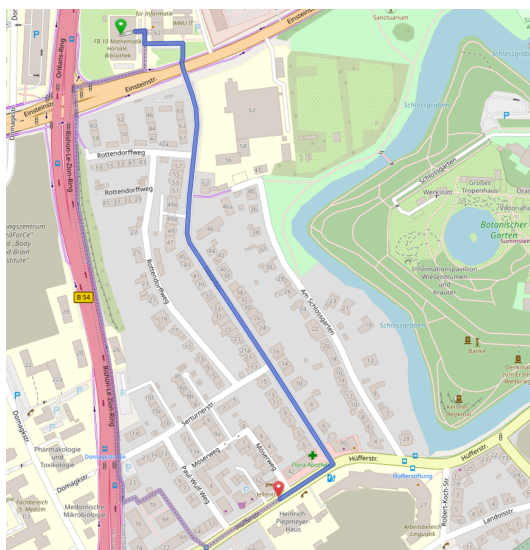
To reach Jellentrup from the train station, use any of the buses 11,12,13,22 (in the right direction: one of the stops must be "Coesfelder Kreuz") and get off at "Hüfferstiftung".

Bakenhof is at 2.5 km distance from the conference site. If you like to walk, here is a map:

Alternatively there is a direct connection via city bus lines 1 or 12 (every 20 minutes) or regional bus R63 or R64. They leave (to Bakenhof) from the bus stop in front of the Mensa ("P+R Coesfelder Kreuz B") to "Gievenbeck Kaserne". It is one stop too many to use the short route ticket, so you might get off at "Deipenfohr" and then walk. The last city bus is at 20:57 from the Mensa. Later there is an R64 at 21:40 and 22:40. Night bus N80 takes a long detour.

The same bus lines 1, 12, R63 and R64 reach Bakenhof from the train station (in the right direction: one of the stops must be "Coesfelder Kreuz").

Tea and coffee; water

Coffee and tea is available during the indicated breaks in the second floor of the SRZ building (see page 16), together with some cookies. Water, orange juice and sparkling fruit juice is available at any time in M1 near the upper entrance. Please put the empty bottles back into the beverage crates under the tables. Tap water in Münster has excellent quality (better than what you get in a bottle).

Lunch

We recommend to have lunch in the Mensa. It is nearby (see the map on page 16); they have a reasonable choice of dishes. Depending on what you take you should expect 5 to 6 € for a main dish. With a valid student's ID card you should get a discount. One can buy aditional drinks. There is no free water.

Other options are given on page 25.

Evening programme

Reception

There will be a reception after the gong talks on Monday outside between M1 and SRZ. We provide beer, wine, water and soft-drinks. There will also be something to eat. It will be rather simple, but you can avoid a restaurant after the reception.

Conference dinner

After the last talk on Tuesday we will have a sort of conference dinner. It will be again between M1 and SRZ, but provided by a real restaurant in Münster. They will also offer wine; beer and soft drinks are provided by us in the same manner as on Monday. For better planning we would like to ask participants who are present in Münster but do not want to take part in this dinner to inform us.

City tour

For Wednesday we organise a walk through the city centre with a possibility to get something to eat and drink (to be paid yourselves) in one of the bars. We will prepare a list on which you can register for the city tour.

Barbecue

We plan to have a barbecue after the last talk on Thursday, again on the campus. Participants who live in Münster have received more information.

Further things one can do in Münster

Of course there are many other things to do besides the above organised activities. We mention only some of the alternatives below:

- The Botanical Garden of the Westfälische Wilhelms-Universität Münster was founded in 1803. As scientific institution it provides resources for scientific research and teaching. Other functions include conservation of species- and genetic diversity and maintenance of scientifically valuable collections. The botanical garden is less than 10 minutes walk from the mathematics department. Opens 8am–7pm every day, admission is free. The entrance is marked with a red 'e' on the map on page 18. It is the ideal place to spend (a part of) the lunch break.

- Friedenssaal (Hall of Peace): The Friedenssaal in Münster's gothic town hall owes its name to the peace treaty between Spain and the Netherlands, which was concluded here under solemn oath on 15 May 1648.

  The Peace of Westphalia is the name given to the totality of the peace treaties that were agreed and signed in Münster and Osnabrück between 15th May and 24th October 1648, which brought an end to the Thirty Years' War in Germany and the eighty-year Dutch War of Independence. The Peace of Westphalia is at the same time a 'confessional peace', a German 'constitutional peace' and a 'peace between states' in Europe. The Peace of Westphalia brought an end to the era of religious confession wars in Central Europe and created the conditions for religious tolerance that had an effect on the whole of Europe.

  The hall originally served as a council chamber, and its fine renaissance wood panelling dates from around 1577. The gallery of portraits, with its pictures of ambassadors, was purchased by the council in 1649. The furnishings of the Peace Hall, which were evacuated during the second world war, have been faithfully restored.

Closed Mondays. Tue–Fri 10am-5pm, Sat+Sun 10am-4pm. A ticket costs 2€.

- City Market: On Wednesdays and Saturdays, from 7 am to 2:30 pm, one can visit the city market of Münster, an open market set up behind St. Paulus dom in the city centre. There you can find a large variety of food products, fabrics, clothes and jewellery, as well as flowers and plants. For more information on the providers and an interactive map of the city market, you can visit the market's web-page:

  `https://www.wochenmarkt-muenster.de/oeffnungszeiten`

- Mühlenhof Open-Air Museum: This outdoor museum is a five-hectare site that preserves the culture and history of the Münsterland region from the 16th to the 19th century. On the site there are 30 buildings, many of which are original structures from that time; on the inside, the buildings are furnished with historical goods so that visitors get a real impression of the Münsterland of days gone by.

  The outdoor museum's address is Theo-Breider-Weg 1 and it is open from 10am to 6pm. An adult ticket costs 6€, while a student ticket costs 4€.

- Pablo Picasso Museum: The Pablo Picasso Münster Art Museum is Germany's first and so far only Picasso museum. The museum shows changing special exhibitions on Pablo Picasso and his fellow classical modern artists such as Georges Braque, Henri Matisse and Marc Chagall. The foundation of Münster's Picasso collection is a globally unique collection of around 800 Picasso lithographs.

  The museum is located at Picassoplatz 1 and is open everyday except Mondays from 10am to 6pm. An adult ticket costs 10€, while a student ticket costs 8€. To visit the museum, it is necessary to book an online ticket, which you can do by following this link:

  `https://kunstmuseum-picasso-muenster.de/home/`

- City Zoo: Münster's "allwetterzoo" is a large zoo that accommodates many animals from different species and different climate zones. The zoo features a 5 km network of trails connecting the large animal houses

and is open every day from 9 am to 7 pm. An adult day ticket costs 18.90€, while a student day ticket costs 12.90€.

The zoo is located at Sentruper Straße 315. The bus line connecting the main station Münster Hbf to the city zoo is line 14. You can find more information on the zoo's website: `https://www.allwetterzoo.de/`

- City Tours: There are plenty of guided/thematic city tours offered in Münster - by foot, by bike or by bus. There are also many creative city games such as murder & mystery events, GPS rallies and much more! Some offers from different guides can be found in the following links:

  `https://k3.de/en/muenster/tours`

  `https://www.stadtlupe-muenster.de/`

  `https://www.stattreisen-muenster.de/`

Places to eat in Münster

There are many places around Münster where you can get something to eat. For lunch, we can recommend the following restaurants:

- Near the campus:

  - Gustav Grün (Wilhelmstraße 5), vegeterian & vegan menu (takeaway).

  - Áro (Neutor 3), fusion restaurant (takeaway)

  - Phoenicia (Steinfurter Str. 37), Lebanese cuisine (dine-in, takeaway)

- Around the city:

  -Meraki (Hansaring 69), Arabic food (dine-in, takeaway)

  - Frauenstraße 24 (the name is also the address), multi-cultural cuisine (dine-in, takeaway)

  - Royals & Rice (Frauenstraße 51), Asian fusion restaurant (dine-in, takeaway)

  - Beetschwester (Tibusstraße 6), vegeterian & vegan menu (dine-in, takeaway)

  - Elbēn am Aasee (Scharnhorststraße 25), Syrian cuisine (dine-in, takeaway)

There are also many German restaurants in Münster that serve traditional food and beer. Here are a few suggestions:

- Pinkulus (Rosenplatz 6), Westfälische cuisine

- Spatzl (Am Stadtgraben 52), Bavarian cuisine

- Altes Gasthaus Leve (Alter Steinweg 37)

- Drübbelken (Buddenstraße 14-15)

All the restaurants in the above lists have updated web-pages and social media that include their menus in detail. Of course, these are only some suggestions and there are plenty of alternatives around Prinzipalmarkt (city-centre) and throughout the city.

As for drinks, there are many bars in the Altstadt or at the Hafen, some of which also feature live music every now and then. A traditional German spot for an afternoon/ evening drink is a Biergarten. There are several around the city. Here are a few.

- Biergarten.ms (Kastellstraße 1)

- Klamm & Heinrich (Breul 9)

- Schloss Biergarten (University of Münster, Schlossgarten 3)

We can also recommend some places for breakfast:

- Backhaus Jankord (Hüfferstraße 26), bakery (takeaway)

- Backhaus Jankord (Gertrudenstraße 22), bakery (takeaway)

- Bäckerei Krimphove (Horstmarer Landweg 101), bakery (takeaway)

- Bäckerei Schrunz (Waldyerstraße 80), bakery (takeaway)

- Essmann's Backstude (Studtstraße 64), bakery (takeaway)

- Herr Hasse Kaffeeröster (Gertrudenstraße 19), coffee place (takeaway, outdoor seating)

- Roestbar (Nordstraße 2), coffee place (takeaway, outdoor seating)

- Bäckerei Wilhelm Middelberg (Wilhelmstraße 1), bakery (takeaway)

Welcome to Mathematics Münster!

We have compiled some general information for planning your stay at Mathematics Münster. For more details and updates on the conference, please visit the conference webpage or www.mathematics-muenster.de.

Your trip to Münster

https://www.uni-muenster.de/MathematicsMuenster/aboutmm/directions.shtml

With public transport to **Münster (Westfalen) train station** it takes about

- 2.5-3.5 hours from Frankfurt Airport (**FRA**). Intercity trains depart every hour,
- 1.5 hours from Düsseldorf Airport (**DUS**). Intercity trains depart every hour,
- 1-1.5 hours from Dortmund Airport (**DTM**) by hourly regional trains,
- 35 minutes from Münster Airport (**FMO**) by shuttle bus.

From the train station to Mathematics Münster
- 15 minutes by bus, busses for "Coesfelder Kreuz" leave every 5 minutes.
- 10-15 minutes by taxi.

Childcare

We gladly support parents by providing child care during conferences and workshops. If you are planning to make use of the child care, please let the organizers know as soon as possible and inform them about the child/children's age.

Our parent-child-rooms at the cluster (Orléans-Ring 10, ground floor) are equipped with toys, books, a baby changing facility, child-beds and for the parents a separate workspace.

Child care is free of charge.

Wi-Fi access for guests

Connect to the SSID **"GuestOnCampus"** and start any web browser. You will automatically be redirected to the login page. Confirm the terms of use and click on "log in for free".

1 GB data volume is available per device and day. Please note that the connection is **not encrypted**.

Willkommen in Münster!

Wir haben einige allgemeine Informationen für die Planung Ihres Aufenthaltes in Münster zusammengestellt. Für Details und Updates zur Konferenz besuchen Sie bitte die Konferenz-Webseite oder www.mathematics-muenster.de.

Anreise nach Münster

https://www.uni-muenster.de/MathematicsMuenster/aboutmm/directions.shtml

Mit öffentlichen Verkehrsmitteln zum **Bahnhof Münster (Westfalen)** dauert es etwa

- 2,5-3,5 Stunden vom Flughafen Frankfurt (**FRA**). Intercity-Züge fahren stündlich,
- 1,5 Stunden vom Flughafen Düsseldorf (**DUS**). Intercity-Züge fahren stündlich,
- 1-1,5 Stunden vom Flughafen Dortmund (**DTM**) mit stündlich verkehrenden Regionalzügen,
- 35 Minuten vom Flughafen Münster (**FMO**) mit dem Shuttlebus.

Vom Bahnhof zum Mathematik Campus:
- 15 Minuten mit dem Bus bis Haltestelle „Coesfelder Kreuz", Abfahrt alle 5 Minuten.
- 10-15 Minuten mit dem Taxi.

Kinderbetreuung

Gerne unterstützen wir Eltern durch Kinderbetreuung bei Tagungen und Workshops. Wenn Sie die Betreuung in Anspruch nehmen möchten, teilen Sie dies und das Alter Ihrer Kinder/Ihres Kindes bitte so bald wie möglich den OrganisatorInnen mit.

Der Eltern-Kind-Räume im Cluster (Orléans-Ring 10, Erdgeschoss) ist mit Spielsachen, Büchern, einem Wickeltisch, Kinderbetten und einem separaten Arbeitsplatz ausgestattet.

Die Kinderbetreuung ist kostenlos.

WiFi Gast-Zugang

Verbinden Sie sich mit der SSID „GuestOnCampus" und starten Sie einen Webbrowser. Sie werden automatisch auf die Anmeldeseite umgeleitet. Bestätigen Sie die Nutzungsbedingungen und klicken Sie auf "kostenlos einloggen". Pro Endgerät und Tag steht Ihnen 1 GB Datenvolumen zur Verfügung. Die Übertragung ist **unverschlüsselt**.

Mathematics Münster Campus
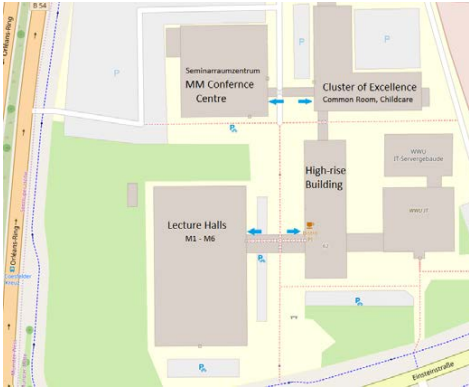
Hochhausgebäude (High-rise)
Einsteinstraße 62
48149 Münster

MM-Conference Centre
Seminarraumzentrum (SRZ)
Orléans-Ring 12
2. Stock/2nd floor

Hörsaalgebäude (Lecture Halls)
Vortragssäle M1 – M6
Einsteinstraße 64

Cluster of Excellence
Orléans-Ring 10
Erdgeschoss/ ground floor

Explore Münster

Münster is a vibrant city. It is a city of science, of learning, the city of the Peace of Westphalia, and Germany's bicycle capital and pioneer in climate protection. The traditional city is also a young city, thanks to its 75,000 students.

If you have some free time during your stay in Münster, we recommend that you discover the city and enjoy its lively atmosphere.

https://www.muenster.de/tourismus.html

Münster offers a wide variety of restaurants, cafés and pubs in every price range. For tips and recommendations visit https://www.muenster-geht-aus.de/

Münster entdecken

Münster ist eine vielseitige Stadt. Es ist eine Stadt der Wissenschaft, des Lernens, die Stadt des West-fälischen Friedens, Fahrradhauptstadt und Deutsch-lands Vorreiter im Klimaschutz. Die traditionsreiche Stadt in Westfalen ist auch eine junge Stadt, nicht zuletzt dank der 75.000 Studierenden.

Wenn Sie ein wenig Freizeit während Ihres Aufenthalts in Münster haben empfehlen wie Ihnen die Stadt zu entdecken und lebendige Atmosphäre zu genießen.
https://www.muenster.de/tourismus.html

Münster bietet eine breite Vielfalt an Restaurants, Cafés und Kneipen in jeder Preisklasse. Für Tipps und Empfehlungen besuchen Sie https://www.muenster-geht-aus.de/

Important Telephone Numbers

Emergency call: 112

Medical emergency service:
Phone: (0049 251) 116117
Raphaelsklinik, Loerstraße 23, 48143 Münster

Wichtige Telefonnummern

Notruf: 112

Hausärztlicher Notdienst:
Tel: (0049 251) 116117
Raphaelsklinik, Loerstraße 23, 48143 Münster