



Higher Structures in M-Theory

LMS/EPSRC Durham Symposium 12 August – 18 August 2018

<http://www.maths.dur.ac.uk/lms/109/index.html>

Abstract

Higher homotopical structures such as L_∞ -algebras, gerbes, and generalised differential cohomologies are at the heart of string and M-theory. This has been recognised in special cases, and there is much evidence for higher structures to play a key role in understanding these theories. In addition, higher structures have been receiving much attention in mathematics and physics independently. This symposium brings together experts in those areas to identify the pertinent open problems and discuss solution strategies. It combines lectures on the foundations, talks on recent advances, and open discussion sessions. There are also going show talks given by PhD students.

Branislav Jurčo (Charles University)

Christian Sämann (Heriot-Watt University)

Urs Schreiber (Čzech Academy of Science and New York University Abu Dhabi)

Martin Wolf (University of Surrey)

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1. Scientific Programme

1.1. Schedule

Each day is devoted to one theme as follows:

Mon Higher differential geometry and higher Lie theory I

Tue Higher structures in M- and F-theory

Wed Higher differential geometry and higher Lie theory II

Thu Double field theory and exceptional field theory and duality symmetric string and M-theory

Fri Further applications: string field theory, higher (pre-)quantisation, and higher spins

	Monday	Tuesday	Wednesday	Thursday	Friday
07:30–08:45	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
09:00–10:30	Schreiber	Lambert	Sati	Berman	Vasiliev
10:30–11:00	Discussion and Coffee Break	Discussion and Coffee Break	Discussion and Coffee Break	Discussion and Coffee Break	Discussion and Coffee Break
11:00–11:40 11:50–12:30	Wolf Ševera	Kim	Fiorenza	Hohm Palmkvist	Sharpe Kupriyanov
12:30–13:00 13:00–14:00	Discussion Lunch	Discussion Lunch	Discussion Lunch	Discussion Lunch	Discussion Lunch
14:30–15:10 15:10–15:50	Monnier Braunack-M.	Chu Tan	Sämman Sachs	Vysoky Samtleben	Grigoriev Schweigert
15:50–16:20	Discussion and Coffee Break	Discussion and Coffee Break	Cathedral Visit	Discussion and Coffee Break	Discussion and Coffee Break
16:20–17:00 17:00–17:40	Voronov Huerta	Sorokin Gukov		Deser Strickland-C.	Schenkel Szabo
17:40–18:00	Discussion and Setting Goals Wine Reception	Gong Show: Bruinsma Peksova		Gong Show: Schmidt Sisca	Gong Show: Raspollini Traube
18:00–18:30		Discussion and Setting Goals		Discussion and Setting Goals	Discussion and Setting Goals
19:00	Dinner	Dinner	Dinner	Conference Dinner	Dinner

1.2. Lectures (90min each)

Speaker: David Berman (Queen Mary University of London)

Slot: Thursday, 09:00–10:30

Title: *Double field theory and exceptional field theory, an overview*

Abstract: This talk will provide an overview of DFT and EFT along with a discussion of open questions and possible future directions.

Speaker: Domenico Fiorenza (Sapienza University of Rome)

Slot: Wednesday, 11:00–12:30

Title: *(super-)Rational T-duality from (super-) L_∞ -algebras*

Abstract: A pair of 2-cocycles on an L_∞ -algebra together with a trivialisation of their product induce a Fourier-type transform between the twisted cohomologies of the central extensions classified by the 2-cocycles themselves. On the one hand, this can be read as the image in rational homotopy theory of topological T-duality for principal $U(1)$ -bundles. On the other hand, the result is completely algebraic and can be easily derived without assuming the existence topological T-duality. In this sense, the algebraic result can be seen to suggest the topological one as the nontrivial globalisation of a simple infinitesimal construction. Even more interestingly, the algebraic construction admits an immediate generalisation to super- L_∞ -algebras and to higher cocycles. This allows for a derivation of Hori's formula and of spherical T-duality for M5-branes directly from the structure of super-Minkowski cocycles occurring in superstring and M-theory. Based on joint work with [Hisham Sati](#) and [Urs Schreiber](#) ([arXiv:1611.06536](#); [arXiv:1803.05634](#)).

Speaker: Seok Kim (Seoul National University)

Slot: Tuesday, 11:00–12:30

Title: *Developments in 6d SCFTs*

Abstract: We review old and new developments in 6d SCFTs. We first briefly discuss the constructions of (2, 0) and (1, 0) SCFTs from string theory, M-theory, F-theory. We then review microscopic methods to describe these QFTs in various set-ups, such as DLCQ, deconstruction, effective field theory methods in various limits. We shall conclude by overviewing interesting open directions.

Speaker: Neil Lambert (King's College London)

Slot: Tuesday, 09:00–10:30

Title: *M-Branes: Lessons from M2's and hopes for M5's.*

Abstract: In this talk we will review the construction of M2-brane SCFTs highlighting some novelties and the role of 3-algebras. Next we will discuss M5-branes: the basics, the obstacles as well as various attempts to construct the associated SCFT and potential relations between M2-branes and M5-branes.

Speaker: Hisham Sati (New York University Abu Dhabi)

Slot: Wednesday, 09:00–10:30

Title: *Geometric and topological aspects of M-branes*

Abstract: Recent investigations of M-branes have revealed how rich in structure they are from both a physical and mathematical points of view. It is hoped that such structures will help us shed light onto the

physical and mathematical nature of M-theory itself. I will survey this area, starting with connections to generalized cohomology and homotopy theory (twisted K-theory, Morava K-theory, elliptic cohomology and the sphere spectrum) and then including higher geometry and higher structures, leading to description of multiple M-branes via String bundles with connections. I will also describe recent work on derivation of twisted K-theory from M-theory via parametrized homotopy theory and the proper topological description of M-branes at ADE singularities. Various aspects of this are part of joint work with other speakers at this meeting (with related talks): [Urs Schreiber](#), [Vincent Braunack-Mayer](#), [Domenico Fiorenza](#), and [John Huerta](#).

Speaker: Urs Schreiber (Čzech Academy of Science and New York University Abu Dhabi)

Slot: Monday, 09:00–10:30

Title: *Introduction to higher supergeometry*

Abstract: Due to the existence of gauge fields and of fermion fields, the geometry of physics is *higher supergeometry*, i.e. *super-geometric homotopy theory*. This is made precise via Grothendieck's functorial geometry implemented in higher topos theory. We give an introduction to the higher topos of higher superspaces and how it accomodates super- L_∞ -algebras and higher gauge fields in the form of twisted differential cohomology. We indicate how geometric homotopy theory reveals that the superpoint emerges 'from nothing', and that core structure of M-theory emerges out of the superpoint, as will be discussed in more detail in talks by [Hisham Sati](#), [Vincent Braunack-Mayer](#), [Domenico Fiorenza](#), and [John Huerta](#). Lecture notes at <https://ncatlab.org/schreiber/show/Introduction+to+Higher+Supergeometry>.

Speaker: Mikhail Vasiliev (Lebedev Physics Institute Moscow)

Slot: Friday, 09:00–10:30

Title: *From higher spin gauge theory to strings*

Abstract: Higher spin gauge theory is a theory exhibiting higher symmetries that can become manifest at ultra high (trans-Planckian) energies. Hence, it is anticipated to be related to quantum gravity. Holographic interpretation of nonlinear higher spin gauge theory will be discussed and its main properties and structures such as unfolded formulation of dynamical equations and non-commutative higher spin algebra in the twistor-like spinor space will be reviewed. The emphasise will be on the peculiarities of the spacetime interpretation of higher spin gauge theory and its potential relation to string and M-theory via a new class of models associated with Coxeter groups and Cherednik algebras.

1.3. Research Talks (40min each)

Speaker: Chong-Sun Chu (National Tsing Hua University)

Slot: Tuesday, 14:30–15:10

Title: *Weyl Anomaly and induced string current in boundary CFT in 6d*

Abstract: In this talk, I will discuss a newly discovered effect in BCFT where a background gauge field strength induces a current in the vicinity of the boundary. In 6d, this give rises to a string current. Its implication will be discussed.

Speaker: Vincent Braunack-Mayer (University of Zurich)

Slot: Monday, 15:10–15:50

Title: *Parametrised homotopy theory and gauge enhancement*

Abstract: According to the Dirac charge quantisation argument, flux forms in a quantum theory lift to define classes in generalised cohomology. The classical example of this is the refinement of the electromagnetic field strength to a class in integral cohomology. Another example is the expected refinement of Ramond–Ramond flux forms to classes in K-theory or, when the background B-field is non-trivial, to classes in twisted K-theory. In this talk, I will provide a broad overview of the true mathematical home of twisted cohomology—parametrised homotopy theory. Following this general overview, I will present recent results, <https://user.math.uzh.ch/cattaneo/Braunack-Mayer.pdf>, in the simplified torsion-free approximation which provide a framework for explicit algebraic computations. Finally, I will explain recent work with Hisham Sati and Urs Schreiber, [arXiv:1806.01115](https://arxiv.org/abs/1806.01115), which applies this general theory to obtain a partial solution to the problem of gauge enhancement in M-theory, which makes M-branes exhibit the twisted K-theory degrees of freedom of D-branes in type IIA string theory.

Speaker: Andreas Deser (INFN Turin)

Slot: Thursday, 16:20–17:00

Title: *Symmetries in field theories from an NQ -manifold perspective*

Abstract: NQ -manifolds and the derived bracket construction give a unified view on (infinitesimal) symmetries in field theory: In degree one these are Lie algebroids and in degree two Courant algebroids. They describe infinitesimal symmetries in Riemannian geometry and generalized geometry (gravity and type II/heterotic supergravity). A modified version of the degree two case gives insight into double field theory. In degree 3 and higher, we get degree- k Vinogradov algebroids governing certain types of exceptional field theories. We will give an overview of these cases emphasizing their relation to finite term strongly homotopy Lie algebras. As a first step towards global questions, we present an NQ -manifold description of three-dimensional nilmanifolds carrying a $U(1)$ -gerbe structure and its implications for the well-studied T-duality in this case.

Speaker: Maxim Grigoriev (Lebedev Physics Institute Moscow)

Slot: Friday, 14:30–15:10

Title: *Gauge PDE, AKSZ sigma models, and higher spin theories*

Abstract: AKSZ sigma models were originally proposed to describe topological systems. In fact, an AKSZ model with finite number of fields and space-time dimension higher than one is necessarily topological. It turns out that AKSZ formalism extends to general gauge theories if one allows for infinite-dimensional target space manifolds. More specifically, a general gauge system can be cast into an AKSZ sigma model whose target space is the BRST-extended equation manifold equipped with the BRST differential and the horizontal differential. The resulting AKSZ formulation can be also considered as a far going generalization of the so-called unfolded formulation known in the context of higher-spin theories. We employ the ambient space version of the approach to (conformal) higher spin theories and their holographic relations. In particular, we show how interacting higher spin theories in anti-de Sitter space can be holographically reconstructed starting from a free CFT on the boundary. We also comment on a possible interpretation of the construction as a higher spin extension of the Fefferman–Graham approach.

Speaker: Sergey Gukov (Caltech)

Slot: Tuesday, 17:00–17:40

Title: *Higher structures and 4-manifolds*

Abstract: In this talk we will discuss three (intimately related) examples of 4-manifold invariants based on higher structures:

- VOA[M4] from transgression of EFTs;
- SW and Donaldson invariants as chiral algebra correlators;
- Massey triple products from trisections.

These topics are based, respectively, on recent work with B. Feigin; paper with M. Dedushenko and P. Putrov; and a solo paper of the speaker.

Speaker: Olaf Hohm (Stony Brook University)

Slot: Thursday, 11:00–12:30

Title: *L_∞ -algebras in double and exceptional field theory*

Abstract: I review L_∞ -algebras and their role in field theories, specifically for duality-covariant formulations of string- and M-theory (double field theory and exceptional field theory).

Speaker: John Huerta (University of Lisbon)

Slot: Monday, 17:00–17:40

Title: *M-theory from the superpoint*

Abstract: We describe how the super Minkowski spacetimes relevant to string theory and M-theory, complete with their Lorentz metrics and spin structures, emerge from a much more elementary object: the superpoint $\mathbb{R}^{0|1}$. In the sense of higher structures, this comes from treating the superpoint as an object in rational homotopy theory, and repeatedly constructing ‘maximal invariant extensions’. We will fit this story into the larger picture of the brane bouquet of Fiorenza–Sati–Schreiber: string theories and membrane theories emerge from super Minkowski spacetimes in precisely the same way as the super Minkowski spacetimes themselves emerge from the superpoint. Based on [arXiv:1702.01774](https://arxiv.org/abs/1702.01774).

Speaker: Vladislav Kupriyanov (Werner Heisenberg Institute)

Slot: Friday, 11:50–12:30

Title: *L_∞ -bootstrap approach to non-commutative gauge theories*

Abstract: Non-commutative gauge theories with a non-constant NC-parameter are investigated. As a novel approach, we propose that such theories should admit an underlying L_∞ -algebra, that governs not only the action of the symmetries but also the dynamics of the theory. Our approach is well motivated from string theory. In this talk I will discuss the L_∞ -bootstrap program: the basic ideas, construction, including the recurrence relations for L_∞^{gauge} -algebra, and uniqueness. As a particular examples we construct the explicit expressions for the non-commutative $\mathfrak{su}(2)$ -like and non-associative octonionic-like deformations of the abelian gauge transformation in slowly varying field approximation. The latter is related to non-geometric backgrounds in string and M-theory.

Speaker: Samuel Monnier (University of Geneva)

Slot: Monday, 14:30–15:10

Title: *A modern point of view on anomalies*

Abstract: We will review the concept of anomaly field theory, which encodes elegantly all the anomalies associated to a given quantum field theory. We will show how the familiar properties of anomalies can be naturally derived in this context and will illustrate the concept with concrete examples. In this framework, Hamiltonian anomalies originate from higher structures, as the shadow of a 2-functor. We will also explain how this framework provides a conceptual picture of the Green–Schwarz mechanism, and its use to study field theories with no single partition function, such as $2d$ chiral conformal field theories or the $6d$ $(2, 0)$ superconformal field theories. We will close the talk with a review of various string theory setups where the checks of anomaly cancellation are still open problems.

Speaker: Jakob Palmkvist (Chalmers University)

Slot: Thursday, 11:50–12:30

Title: *Extended algebras and geometries*

Abstract: For any Kac–Moody algebra \mathfrak{g} and any integrable highest weight representation of it, generalised diffeomorphisms can be defined, including those in ordinary, double, and exceptional geometry when \mathfrak{g} belongs to the A -, D -, or E -series (and the highest weight is the fundamental weight associated to the ‘outermost’ node in the Dynkin diagram). In the cases where they close into themselves, the gauge structure of the transformations can be derived by extending \mathfrak{g} to a Borcherds–Kac–Moody superalgebra. Otherwise, when so called ‘ancillary’ \mathfrak{g} transformations are present (in particular when \mathfrak{g} is infinite-dimensional), the correct structure seems rather to be a tensor hierarchy algebra. Tensor hierarchy algebras include finite-dimensional Lie superalgebras of Cartan type in the A and D cases, and have proven useful in applications to gauged maximal supergravity in the E cases. However, their general structure is still largely unexplored and many questions remain to be answered.

Speaker: Ivo Sachs (Ludwig Maximilian University of Munich)

Slot: Wednesday, 15:10–15:50

Title: *Homotopy algebras in string field theory*

Abstract: Homotopy algebra and its involutive generalisation plays an important role in the construction of string field theory. It ensures consistency and also enters crucially in deformation theory and background independence of string theory. Conversely, world sheet string theory naturally realises a minimal model map. I will review recent progress in these applications of homotopy algebra, their operadic description and its relation to moduli spaces.

Speaker: Christian Sämann (Heriot–Watt University)

Slot: Wednesday, 14:40–15:10

Title: *The non-Abelian self-dual string and a $6d$ superconformal field theory*

Abstract: Self-dual strings are categorified analogues of monopoles. They are expected to arise as BPS states in the long-sought six-dimensional superconformal field theory known as the $(2,0)$ -theory, which describes the effective dynamics of parallel stacks of M5-branes. While the description of abelian self-dual strings is well-known, the non-Abelian generalisation remains somewhat controversial. In this talk, I give a mathematically consistent description of non-Abelian self-dual strings. I also present a six-dimensional

superconformal field theory with many of the properties of the (2,0)-theory which has these self-dual strings as a BPS solution. I conclude by discussing the open problems that need to be solved in order to arrive at a satisfying M5-brane model.

Speaker: Henning Samtleben (ENS Lyon)

Slot: Thursday, 15:10–15:50

Title: *Exceptional field theory for affine algebras*

Abstract: Exceptional field theories are manifestly duality covariant formulations of higher-dimensional supergravity. I will review the recent construction of such theories based on infinite-dimensional affine symmetry algebras, notably the case of the affine algebra E_9 , which is the symmetry of maximal two-dimensional supergravity. I describe the construction of its generalised diffeomorphisms and of its dynamics.

Speaker: Alexander Schenkel (University of Nottingham)

Slot: Friday, 16:20–17:00

Title: *Higher structures in algebraic quantum field theory*

Abstract: AQFT is a well-established rigorous framework to describe quantum field theories on Lorentzian manifolds. Unfortunately, its traditional formulation seems to be too rigid to capture some finer (higher) aspects of quantum gauge theories. In this talk I will provide an overview of our recently initiated homotopical AQFT program whose aim is to address and solve these issues by extending AQFT to a higher categorical/homotopy theoretical framework.

Speaker: Christoph Schweigert (University of Hamburg)

Slot: Friday, 15:10–15:50

Title: *Logarithmic conformal field theory—an attempt to a status report*

Abstract: Logarithmic conformal field theories are based on vertex algebras with non-semisimple representation categories. While examples are known for more than 25 years, some aspects of local logarithmic CFTs have been understood only recently, in a description of conformal blocks by non-semisimple modular functors. We present some results on bulk fields and boundary states in logarithmic theories. We then describe some recent results towards a derived modular functor. This is a summary of work with Jürgen Fuchs, Terry Gannon, Simon Lentner, Svea Mierach, Gregor Schaumann, and Yorck Sommerhäuser.

Speaker: Pavol Ševera (University of Geneva)

Slot: Monday, 12:50–13:30

Title: *Symplectic dg manifolds: integration, differentiation, and boundary field theories*

Abstract: I will review the problem of integration and differentiation in higher Lie theory, i.e. the relation between higher Lie algebroids (dg manifolds) and higher Lie groupoids (simplicial manifolds), and explain, in particular, why integration gives smooth (i.e. Lie) higher groupoids, and why differentiation is inverse to integration (results obtained with Michal Siran). I will then turn to a related, but more speculative topic—why seeing non-topological field theories as living on the boundary of topological ones (of the AKSZ type) is useful for understanding of Poisson–Lie T-duality and (hopefully) of more general dualities.

Speaker: Eric Sharpe (Virginia Tech)

Slot: Friday, 11:00–11:40

Title: *Sigma models on gerbes*

Abstract: In this talk, we will give a short overview of results revolving around sigma models on gerbes and their appearance in string theory. We will briefly review aspects of the corresponding quantum field theories, including 2-group symmetries as well as decomposition. We will also briefly review the appearance of gerbes in moduli spaces of superconformal field theories and supergravity theories, focusing on moduli spaces of elliptic curves. In string theory, the ordinary moduli space of elliptic curves is replaced by a gerbe over that moduli space in order to make Ramond vacua well-defined in families, and we will discuss the implications for string dualities.

Speaker: Dmitri Sorokin (INFN Padua)

Slot: Tuesday, 16:20–17:00

Title: *Higher form gauge fields and membranes in $D = 4$ supergravity*

Abstract: We will review physical effects that three-form gauge fields may produce in four-dimensional field theories and gravity, and discuss possible origin of these fields from Type-II string compactifications on Calabi–Yau manifolds with Ramond–Ramond fluxes. We will also consider coupling of the three-form fields to membranes within $\mathcal{N} = 1$, $D = 4$ supergravity and give examples of BPS domain wall solutions that separate supersymmetric vacua with different values of the cosmological constant.

Speaker: Charles Strickland-Constable (University of Herfordshire)

Slot: Thursday, 17:00–17:40

Title: *Supergravity fluxes and generalised geometries*

Abstract: I will briefly discuss the generalised geometry formulation of supergravity and some of its unresolved issues and major goals, with an emphasis towards its applications to the study of supersymmetric flux backgrounds and dimensional reductions. I will also discuss some recent work on the moduli of $\mathcal{N} = 1$ heterotic geometries, featuring holomorphic generalised geometry structures and associated L_∞ -algebras, and highlight some of the questions that emerge.

Speaker: Richard Szabo (Heriot–Watt University)

Slot: Friday, 17:00–17:40

Title: *Higher quantisation of twisted Poisson structures: a case study*

Abstract: We will overview some approaches to the quantisation of systems whose dynamics are governed by twisted Poisson structures, using the simple model of an electric charge in the background of a smooth monopole distribution (or dually of closed strings in locally non-geometric backgrounds) as an illustrative example. We will compare and contrast approaches to this problem based on deformation quantisation and symplectic realisation, to more geometric constructions based on weak projective 2-representations on the 2-Hilbert space of sections of a suitable gerbe and on the universal enveloping A_∞ -algebra of a twisted Lie algebroid.

Speaker: Meng-Chwan Tan (National University of Singapore)

Slot: Tuesday, 15:10–15:50

Title: *From little strings to M5-branes via a quasi-topological sigma model on loop group*

Abstract: We unravel the ground states and left-excited states of the $A_{k-1} \mathcal{N} = (2, 0)$ little string theory. Via a theorem by Atiyah, these sectors can be captured by a supersymmetric quasi-topological sigma model on $\mathbb{C}P^1$ with target space the based loop group of $SU(k)$. The ground states, described by L^2 -cohomology classes, form modules over an affine Lie algebra, while the left-excited states, described by chiral differential operators, form modules over a toroidal Lie algebra. We also apply our results to unravel the 1/2 and 1/4 BPS sectors of the M5-brane worldvolume theory, whose spectrum we find to be captured by cousins of modular and automorphic forms, respectively.

Speaker: Theodore Voronov (University of Manchester)

Slot: Monday, 16:20–17:00

Title: *Thick morphisms and homotopy bracket structures*

Abstract: As it is known, L_∞ -morphisms of L_∞ -algebras are precisely maps of the corresponding supermanifolds which are in general non-linear. The non-linearity is what is responsible for (higher) homotopies. Therefore, in the situation of homotopy brackets on functions (such as S_∞ or P_∞) one should look for a construction giving non-linear transformations between the spaces of smooth functions. This cannot be pullbacks by smooth maps because those are algebra homomorphisms, so in particular, linear. We shall show that there are ‘non-linear pullbacks’ of functions on supermanifolds induced by ‘thick morphisms’ (or ‘microformal morphisms’), which are not ordinary maps, but rather certain relations. For S_∞ - or P_∞ -manifolds, pullbacks by ‘Poisson thick morphisms’ give L_∞ -morphisms on functions. There are two parallel constructions of thick morphisms (‘bosonic’ and ‘fermionic’). Also, there is a quantum version of thick morphisms (for the bosonic case) given, roughly, by certain type Fourier integral operators. They in particular provide L_∞ -morphisms for ‘homotopy quantum brackets’ generated by higher order Batalin–Vilkovisky type operators.

Speaker: Jan Vysoky (Čzech Academy of the Sciences)

Slot: Thursday, 14:30–15:10

Title: *Courant Algebroid connections: applications in string theory*

Abstract: Courant algebroids generalise quadratic Lie algebras in a natural way and they find their application throughout the mathematical physics. In particular, an analogue of Levi-Civita connections can be used to find a geometrical description for equations of motion of string low-energy effective actions. This observation allows one to employ the tools of geometry to derive some intriguing relations of the effective theories. As an example, the supergravity analogue of Kaluza–Klein reduction and (quasi)-Poisson–Lie T-duality are shown.

Speaker: Martin Wolf (University of Surrey)

Slot: Monday, 11:00–11:40

Title: *Higher gauge theory from twistor space*

Abstract: Recent developments in formulating higher gauge theory with Lie quasi-groupoids as gauge structure will be reviewed. The approach develops higher gauge theory from first principles, and, as such, captures a wide class of theories including ordinary gauge theories and gauged sigma models as well as their categorifications: it will be explained how these ideas can be combined with those of twistor theory to formulate maximally superconformal gauge theories in four and six dimensions by means of quasi-isomorphisms. This is based on joint work with Branislav Jurčo and [Christian Sämann](#).

1.4. Gong Show Talks (10min each)

Speaker: Simen Bruinsma (University of Nottingham)

Slot: Monday, 17:40–17:50

Title: *Using operads to formalise Einstein causality in AQFT*

Abstract: In algebraic quantum field theory we assign to each spacetime an algebra. These algebras are required to behave properly under embeddings into larger spacetimes; specifically, the algebras associated to casually disjoint spacetimes must commute. We use coloured operads to formalise this property.

Speaker: Lada Peksova (Charles University)

Slot: Monday, 17:50–18:00

Title: *Properads and homological differential operators related to surfaces*

Abstract: I will give a biased definition of a properad and recall the construction of the cobar complex and algebra over it. Equivalent description in terms of solutions of generalised master equations, which can be interpreted as homological differential operators, will be explained. This is parallel to the Barannikov's theory for modular operads.

Speaker: Lennart Schmidt (Heriot–Watt University)

Slot: Thursday, 17:40–17:50

Title: *Twisted string algebras and fake flatness*

Abstract: In higher gauge theory one often encounters the fake curvature condition, i.e. the requirement that the fake curvature vanishes. In this talk I will briefly discuss twisted versions of the string algebra and, using the example of the non-Abelian self-dual string, demonstrate how these allow the fake curvature condition to be lifted: under categorical equivalences gauge orbits of solutions are mapped to gauge orbits of solutions even for non-vanishing fake curvature.

Speaker: Lorenzo Raspollini (University of Surrey)

Slot: Friday, 17:40–17:50

Title: *Higher gauge theory and the Batalin–Vilkovisky formalism*

Abstract: We discuss the quantisation of higher gauge theories in the context of Batalin–Vilkovisky formalism which allows for treating the case of gauge theories with an open gauge algebra. In particular, we present the homotopy Maurer–Cartan theory and we discuss how the Batalin–Vilkovisky formalism

applies to it. We argue that any Batalin–Vilkovisky quantisable field theory can be discussed in this setup. This is a joint work with Branislav Jurčo, [Christian Sämann](#), and [Martin Wolf](#).

Speaker: Roberto Sisca (University of Surrey)

Slot: Thursday, 17:50–18:00

Title: *The universal geometry of heterotic vacua*

Abstract: The vacua obtained by compactifying the heterotic string at large radius—while also preserving a certain amount of supersymmetries—can be labelled by parameters that are coordinates for a moduli space of solutions. It is our interest to study this moduli space, both from physics and mathematics perspective. We do this by embedding the heterotic vacua and their moduli space inside a single geometry, that we name ‘universal geometry’, and by appropriately extending the heterotic fields to this space. The deformation theory is then described via differential geometry on a ‘universal bundle’ and we can study natural extensions of some equations. Remarkably, these can incorporate results obtained with more conventional methods in single tensor equations.

Speaker: Matthias Traube (Werner Heisenberg Institute)

Slot: Friday, 17:50–18:00

Title: *Seiberg–Witten maps and L_∞ -quasi-isomorphisms*

Abstract: Gauge theories describing the same physics are supposed to be related by a Seiberg–Witten map. It is shown that this is equivalent to having a specific quasi-isomorphism between the underlying L_∞ -algebras of the gauge theories. In addition, the proof suggests an extension of the definition of a Seiberg–Witten map.

2. Registered Participants

Luigi Alfonsi (Queen Mary University of London)

Saeid Aminian (Charles University)

Alex Arvanitakis (Imperial College London)

Meer Ashwinkumar (National University of Singapore)

David Berman (Queen Mary University of London)

Chris Blair (Vrije Universiteit Brussel)

Peter Bouwknegt (Australian National University)

Simen Bruinsma (University of Nottingham)

Mark Bugden (Australian National University)

Chong-Sun Chu (National Tsing Hua University)

Andreas Deser (INFN Turin)

Domenico Fiorenza (Sapienza University of Rome)

Olga Gelfond (Lebedev Physics Institute Moscow)

Grigorios Giotopoulos (Heriot–Watt University)

Maxim Grigoriev (Lebedev Physics Institute Moscow)

Sergey Gukov (Caltech)

Olaf Hohm (Stony Brook University)

John Huerta (University of Lisbon)

Branislav Jurčo (Charles University)
Seok Kim (Seoul National University)
Vladislav Kupriyanov (Werner Heisenberg Institute)
Neil Lambert (King's College London)
Hai Lin (Tsinghua University)
Vincenzo Marotta (Heriot–Watt University)
Samuel Monnier (University of Geneva)
Jakob Palmkvist (Chalmers University)
Lada Peksova (Charles University)
Marco Perin (University of Nottingham)
Jan Pulmann (University of Geneva)
Lorenzo Raspollini (University of Surrey)
Ivo Sachs (Ludwig Maximilian University of Munich)
Christian Sämman (Heriot–Watt University)
Henning Samtleben (ENS Lyon)
Hisham Sati (New York University Abu Dhabi)
Alexander Schenkel (University of Nottingham)
Vincent Braunack-Mayer (University of Zurich)
Lennart Schmidt (Heriot–Watt University)
Urs Schreiber (Čzech Academy of Science and New York University Abu Dhabi)
Christoph Schweigert (University of Hamburg)
Pavol Ševera (University of Geneva)
Eric Sharpe (Virginia Tech)
Roberto Sisca (University of Surrey)
Paul Skerritt (University of Surrey)
Dmitri Sorokin (INFN Padua)
Charles Strickland-Constable (University of Herfordshire)
Richard Szabo (Heriot–Watt University)
Meng-Chwan Tan (National University of Singapore)
Matthias Traube (Werner Heisenberg Institute)
Mikhail Vasiliev (Lebedev Physics Institute Moscow)
Theodore Voronov (University of Manchester)
Jan Vysoky (Čzech Academy of the Sciences)
Matthew Wheeler (University of Arizona)
Martin Wolf (University of Surrey)
Roberto Zucchini (University of Bologna and INFN Bologna)

3. Funders

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London Mathematical Society

Engineering and Physical Sciences Research Council

Science and Technology Facilities Council

EU COST Action MP1405 Quantum Structure of Space-Time

4. Conference Poster





5. Proceedings/Reviews


Proceedings/Reviews will be published in a special issue of the *Fortschritte der Physik*. All participants who will either give a lecture or a research talk will be informed about the specific details and deadlines after the symposium.

6. Accommodation

Accommodation for all registered participants is in Hatfield College.

Information for participants staying at Hatfield College



Hatfield College dates back to the eighteenth century and is situated in the heart of historic Durham. Hatfield College features a stunning early Georgian Dining Hall alongside many modern amenities and a central location, making it ideal for bed and breakfast.

BEDROOM FACILITIES
Hatfield has 81 ensuite rooms. All bedrooms have the following facilities:

- Tea and coffee making facilities refreshed daily
- Free internet connection Wi-Fi available in the bedrooms
- Hollow fibre filled pillows
- Bathrooms with shaver socket outlets
- Toiletry pack containing Shower gel/Shampoo, Soap, Body Lotion and a vanity kit
- One hand towel and one bath towel per person

CHECK IN
Rooms are guaranteed to be ready by 2pm. The reception will be open from 9am-5pm. Outside of these times, a porter will be available to show you to your room. Please use the internal telephone to call the porter if he is away from his post.

CHECK OUT
Check out is before 10am. Reception is manned 24 hours. If you need to check out during unsociable hours, a Porter should be there to take your room key. If the Porter is not there (possibly on a call out), there is a red telephone on reception. On picking up the telephone you will automatically be directed through to the Porter's mobile number.

BREAKFAST
For participants resident in Hatfield College, breakfast will be served in the Dining Hall. 7.30am onwards – Continental Breakfast; 8.00am onwards – Hot Breakfast.



Guest information

SMOKING
Smoking is prohibited in all enclosed public places in the UK. A designated outdoor smoking area is provided.



BUSINESS AND INTERNET FACILITIES
Free wireless internet access is available in Hatfield College and all University buildings. Login details will be provided at registration.

ELECTRICAL APPLIANCES
Plugs and sockets in the UK have voltage between 220-240V. Please bring appropriate adaptors for your mobile phone recharger and other appliances.


EMERGENCY
In case of an emergency, to report any suspicious behaviour, accidents, if you require any medical attention or any other assistance please contact Reception.

PARKING
Car parking is very limited at Hatfield College and situated in the City centre congestion zone. For more information on available places to park your car in Durham City, please visit:
<http://www.durham.gov.uk/article/4111/Where-can-I-park>



Directions to Hatfield College




Hatfield College
North Bailey,
Durham
University

Set in the centre of the Durham peninsula, Hatfield College is right in the city centre and close to some of the major attractions and the city shops and restaurants.

Transport Directions
Access to Hatfield by car is very limited as the college is situated in the City's congestion zone. However, Durham city offers a variety of parking spaces within easy walking distance. Hatfield College can be easily reached by foot both from the railway station and the bus station (both around 15 minute walk). The Durham Cathedral Bus links the railway station and coach park with Palace Green and runs regularly throughout the day.
For information on this service, visit: <http://www.durham.gov.uk/article/1974/Durham-Cathedral-Bus>

For further information on how to get to Durham, please refer to the Travel section at the end of this brochure.



LOCAL INFORMATION

Railway Timetables:
Available from the Symposium Office, Department of Mathematical Sciences. For Rail enquires telephone 08457 484950 or available from the web, visit: www.nationalrail.co.uk.

Taxis: Paddy's 0191 3866662
Pratts 0191 3860700

Banks: Market Place: Barclays, Lloyds, HSBC, National Westminster.

Travel Agents: Thomson, Market Place 0191 3862335
Thomas Cook, Market Place 0845 3089266

Post Office: Ground floor WHSmith, Market square

Tourist Office: Information 03000 262626

Local Doctor: Claypath Medical Practice, Claypath 0191 3332830

Hospital: University Hospital of North Durham 0191 3332333

7. Department of Mathematical Sciences

Lecture rooms

Main lectures and large seminars will be held in room CG93.

Symposium office

Room CM201 will be used as a symposium office.

Notice board

The notice board is located at the main entrance to the Department of Mathematical Sciences.

Lecture programme

As distributed and also displayed on the notice board. Details of less formal talks will be posted on the notice board.

Tea and coffee

Coffee and biscuits will be served in The Chem Cafe immediately outside CG93 every day as advertised on the lecture programme.

Library facilities

See below.

Xeroxing facilities

Material will be photocopied at 5p per copy (paid in advance). Work left in the symposium office (CM201) before 10:30 am will usually be available for collection in the symposium office before 4:30 pm and work left before 3:00 pm will usually be available the following morning.

Mail

Incoming mail will be delivered to the symposium office (CM201). Should you be expecting any mail during your stay in Durham, please check with symposium office staff. For outgoing mail there is a post box just outside the reception area of the science site. Collections are made at 12:00 noon and 5:15 pm (Monday–Friday), 12:00 noon (Saturday).

Telephone

Maths office.

Computing facilities

See separate sheet.

8. University Library

I am not a member of the University. Can I visit Durham University Library?

If you are not a member of Durham University, you can still visit the Library. Firstly, speak to a member of staff at the visitor window or service desk. You will be asked to produce some personal identification. Identification should be photographic, such as a passport, driving licence or rail card, or an official document or letter bearing your current address. Ensure that you visit during Help

and Information desk opening hours to ensure that staff can assist you. View our opening hours at <https://www.durham.ac.uk/library/using/opening/>.

Can I use Library services and resources?

As a day visitor to the Library, you can use the Library on a reference basis—this means you are welcome to look at, read and photocopy items in the Library collection during your visit.

How do I use the Library photocopiers?

You are welcome to use Library photocopying facilities providing that you are copying material for personal use. Purchase a photocopying card from the the vending machine to use the photocopiers.

Can I use a computer and access electronic resources?

Durham University Library is able to provide limited access to electronic resources for visitors. After entering the Library, speak to a member of staff at the Help and Information desk to register to use our visitor access computer service. Once you have registered, you will be given login details to use a dedicated visitor PC. When you log in, a web browser will open which will allow you access to some of the Library's online resources, where vendor licenses permit. If you have a USB memory drive, you can use this to save files from the internet. As a visitor, you will not be able to print items or access any other software available to full University members (such as Microsoft Office).

Reference access

If you are likely to be a regular visitor to Durham University Library, you may register for a Durham University visitor campus card free of charge, which will allow you reference access to the Library. Inspire passport holders and undergraduates from other UK higher education institutions may also register for reference access.

Borrowing access

Durham University Library is also part of a number of reciprocal schemes, through which we allow some members of other institutions borrowing access to the Library. Visitors with borrowing access are unable to borrow items from the Short Loan Collection. Borrowing access schemes currently in place are:

- SCONUL Access scheme—borrowing access is offered to members of staff, postgraduates and part-time and distance learning students SCONUL Access by email which the visitor prints out and brings to the library
- Teachers of schools in partnership with the School of Education Durham Tees Valley Health Alliance
- To register for borrowing access, fill in a campus card application form, available from the Help and Information desk or on our website: <https://www.durham.ac.uk/library/visitors>.

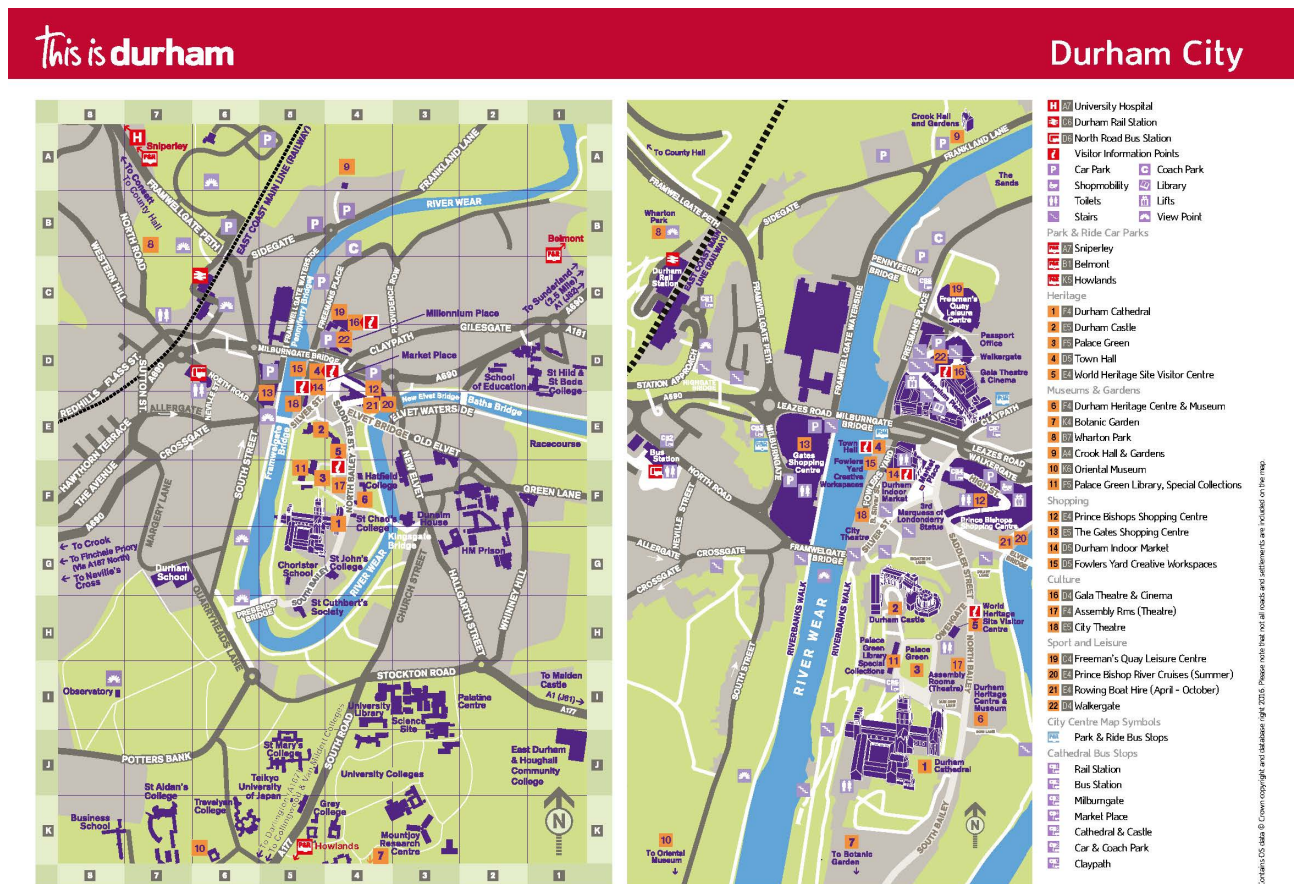
Personal subscriptions and corporate membership

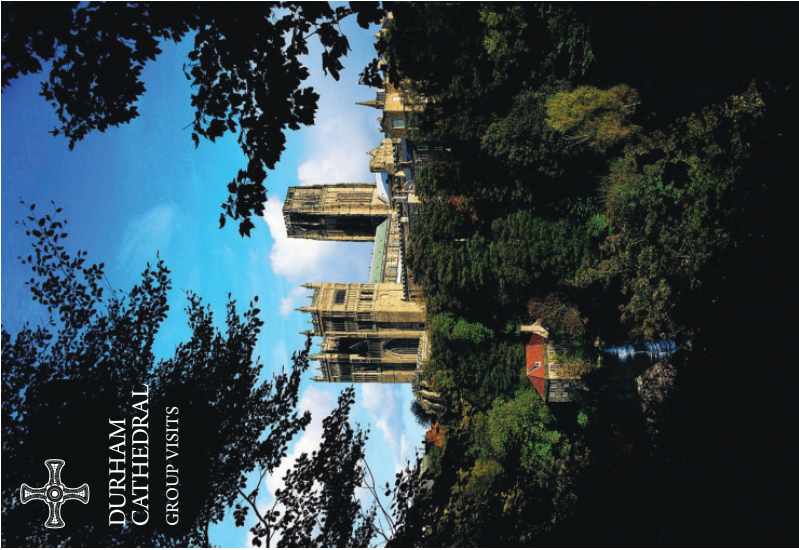
Borrowing access is also available to individuals and organisations by subscription, for which there is a charge. Please see the Library Charges guide for further details. Business, educational or charitable organisations who wish more than one person to become members of the Library can apply for corporate membership by writing to the Librarian, Jon Purcell. Alternatively, you can apply to register as a subscription borrower by speaking to a member of Library staff and filling in a campus card application form.

I've filled in a campus card application form. What happens next?

After your campus card application form is returned to us, it is processed by the Library and Computing and Information Services which may take a few days. You will be contacted when your card is available for collection from the Library.

9. Durham City Map and Durham Cathedral





DURHAM CATHEDRAL
GROUP VISITS

GETTING HERE

Transport
There is free coach parking at the City Centre Coach Park (the Sands). There is no parking at the Cathedral. Durham County Council provides a Durham City Centre Free from 9am to 5pm. An all-day ticket can be purchased on board. For timetable information please see www.durham.gov.uk/bustimetables is DHI 15Q.

Access
Most of the Cathedral and Precinct is accessible, however as an historic building there are some uneven floors and certain areas are not accessible. For wheelchair users access is mostly via ramps; other services include accessible entrance, a stairlift, large print guides, and an induction loop system. Wheelchairs are available on request. Assistance dogs welcome. If you have any access requirements or need any extra help or advice please do let us know in advance.

Further Information & Booking
Durham Cathedral wishes to provide a most enjoyable experience for all visitors, and understands that each group has its individual needs. To discuss your requirements further please contact our Group Visits Office on visits@durhamcathedral.co.uk or 0191 374 4050

DURHAM CATHEDRAL
Durham City
DHI 3EH
0191 386 7266
www.durhamcathedral.co.uk
www.facebook.com/durhamcathedral

TOURS WITH TASTE

For a sumptuous visit why not begin or finish your tour with refreshments served in the medieval Prior's Hall, originally the Prior's Dining Room when the Cathedral was a monastery.
Minimum numbers of 15 apply.

- Morning Coffee & Tour £7.25
- Cream Cake & Tour £10.00
- Lunch & Tour £12.50
- Afternoon Tea & Tour £11.25
- Evening Dinner & Tour £26.00 - optional attendance at the service of Evensong followed by an evening guided tour and fine dining

PHOTOGRAPHY

The Chapter does not permit photography within the Cathedral as it is a sacred place to which people come to pray and visit undisturbed. This includes the use of digital and video cameras and mobile phones. Photographs may be taken within the Precinct area including the Cloisters. There are many postcards and CDs of images available to purchase in the Gift Shop.

EXPERIENCES & PACKAGES

Durham Cathedral and St Chad's College
Residential packages available on selected dates. Guided tour of the Cathedral, optional attendance at the service of Evensong, refreshments and an evening Organ Recital.

Cathedral, Castle & World Heritage Site
Joint ticket for guided tour of the Cathedral, Castle and World Heritage Site on selected dates. Experience the magnificence one of Britain's first World Heritage Sites.

DURHAM CATHEDRAL SHOP

The shop is located off the Cathedral Cloisters close to the Undercroft Restaurant. It is the perfect place to buy souvenirs offering a wide range of postcards, gifts, books and CDs.



Durham has been a place of prayer and pilgrimage for a more than a millennium; the stunning Norman Cathedral was built in 1093 to replace a Saxon monastic church. It houses the shrine of St Cuthbert, the 7th century Bishop of Lindisfarne; and the tomb of the Venerable Bede, who is often called the Father of English History, as author of the early 8th century *The Ecclesiastical History of the English People*.

The Cathedral is one of the finest examples of Norman architecture in Europe, or as American writer Bill Bryson says, "the best Cathedral on planet Earth". The soaring vaulting in the Nave marks a turning point in the history of architecture, as pointed arches were used successfully for the first time instead of Romanesque semi-circular arches. This allowed the building to reach a greater height, paving the way for the Gothic style. Durham Cathedral forms part of a UNESCO World Heritage Site and is a living place for Christian worship. Visitors come from around the world.



Durham Cathedral is open to pre-booked groups on:
Monday – Saturday 9.30am – 5.00pm
Sunday 10pm – 3.00pm

Pre-booked groups of 12 or more people receive a range of exclusive benefits with a group rate of £5.00* per person that includes:

- Private group guided tour available in various languages
- Free place for the group organiser or tour manager
- Free self guide leaflets for unguided tours in various languages

- Free familiarisation visit for organiser ahead of any visit
- Free coach parking at Durham City Centre Coach Park
- Refreshment voucher for the coach driver

Supplementary benefits can be booked subject to an additional charge:

- Special interest talks & behind the scene tours
- Refreshment packages

Evening group visits can also be arranged and can include private dining.

Durham Cathedral is a working Church, booking for groups is essential as special services or other events may be scheduled to take place on the day of your intended visit.

*2011 prices per person for group visits

GUIDED TOURS

General Tour

Trained guides provide a tour which last approximately 1½ hours. It includes the history and development of the Cathedral, the Shrine of St Cuthbert, the Tomb of the Venerable Bede, the Galilee Chapel, the Chapel of the Nine Altars, the Nave and the Quire.

Highlights Tour

For groups that only have a short time to view the Cathedral, a brief 30 minute tour outlines the Cathedral's main points of interest.

BEHIND THE SCENE TOURS & SPECIALIST TALKS

Exclusive behind the scene tours and talks on specialist subjects can be arranged. These may include entry into areas not open to the general public. To ensure availability please book as early as possible.

- Northern Saints
- Pilgrimage Tour
- Architecture
- Stained Glass Windows
- Embroidery & Textiles*
- Cathedral Library & Manuscript Treasures*
- Monastic (Rites of Durham)*
- History of Cathedral Music
- Decorative Art in the Cathedral
- The Art of the Woodcarver
- Other subjects may be available by request.

Durham Cathedral regularly hosts special events and Durham itself has a busy programme of cultural festivals. At the time of your enquiry do ask about upcoming events. There may be something of interest to your group.

*Additional charges apply to some specialist tours.

HOW TO PAY

Payment can be made on arrival at the Information Desk at the back of the Cathedral. It must be made in one payment for the whole group by cash, debit card, credit card or cheque (made payable to Durham Cathedral). Alternatively, by prior arrangement only, the Cathedral can issue an invoice. Minimum numbers apply and will be charged for group bookings.

OPEN TREASURE

Durham Cathedral is reorganising its exhibition space as part of a project called Open Treasure. When complete the Cathedral will be able to display more of its internationally important collections in new exhibition space in some of the Claustral buildings (located off the Cathedral Cloisters). During 2012 the shop will move from the Great Kitchen to the Undercroft. Stunning exhibition space will be developed in the Great Kitchen and in the Monks' Dormitory, linked via a new glazed walkway and gallery. This work should be complete during 2013. At present the Treasures of St Cuthbert are not on display. The relics themselves are in suitable storage ahead of conservation work before they are returned to public view. Some elements of the Cathedral's collections can be seen as part of the specialist talks available to groups listed on this page in particular the Cathedral Library & Manuscript Treasures talk.

