

Two-minute meeting 2013

Department of Theoretical Particle Physics and Cosmology
The Niels Bohr Institute
University of Copenhagen

September 24th, 2013

New group members since last meeting

- Professor: Subir Sarkar, Oxford University.
- Visiting Professors: Jenni Adams, University of Canterbury, New Zealand.
- Long-term staff: Guido Festuccia (Princeton IAS), Ciaran Williams (Fermilab)
- Postdocs: Assaf Ben-David (Tel-Aviv)
- PhD students: Jeppe Trøst (NBI), Amel Durakovic (NBI)
- Master students: 10 (at least)

Upcoming events

- Nordic Meeting on Strings, Fields and Branes, Nov. 7-9th, NORDITA, Stockholm (Main Speakers: B. Craps, G. Festuccia and S. Rychkov (tbc).)

Scientific Group Activities

- Seminars (Organizers: Tristan Dennen, Jelle Hartong)
- Journal club (Organizer: Troels Harmark)
- PhD meetings (Organizer: Lisa Glaser)

Group secretary:

- Anna Maria Rey (Mo-Thu) in FB8A.
(F-building is the building of the canteen, B first floor, C second floor)

Utility items

- “Lounge” FB6 for discussions, journal club, other social activities, coffee
- Two group bikes (Pick up the key and note your name on the sheet in the kitchen of the FC floor).
- Group homepage, face-book page, mailing lists (—→ Timothy Budd)

Our group website

<http://het.nbi.dk>

- * Event announcements
(new: google calendar!)
- * Personal pages
(Check whether the info is up to date!)

Mailing lists

- * het-seminars@nbi.ku.dk
For all group members and other people interested in the seminars and other events.
- * hetcosmo-all@nbi.ku.dk
All group members (but not MSc students). Any member can post to this list.

NBI-Theoretical Particle Physics and Cosmology

Home People News Research Positions Seminars Journal Club PhD MSc Outreach Links

Welcome to the homepage of the Theoretical Particle Physics and Cosmology group at the Niels Bohr Institute

The theoretical particle physics and cosmology group at the Niels Bohr Institute is involved in a wide scope of research activities centered around quantum theories of gauge fields, gravity and cosmology. Research areas include the Standard Model, Quantum Chromodynamics, Lattice Simulations, Cosmology, Physics of Cosmic Microwave Background, Black Holes, Matrix Theory and String Theory. More specific research interests as well as publications can be found on the individual home pages of the members of the group.

Quick Links

- [nbi.ku.dk](#)
- [SIPRES](#)
- [Map of Copenhagen](#)
- [CERN Portal](#)
- [arXiv](#)
- [Sciencedirect](#)
- [Group Facebook Page](#)

News

New Long-term staff
Guille Ferrellec and Claran Williams have joined our group as long-term staff members.
Posted on 4 Sep 2012

New PhD student
Jesse Thaler has joined our group for his PhD studies under supervision of Susi Teresi.
Posted on 4 Sep 2012

PhD Defense
Ulrich Hansen defended his PhD on Sep. 13 in Aud. A at 10:00.
Posted on 3 Sep 2012

Two minute meeting
Wed. 8. 10:00-10:15
Posted on 4 Sep 2012

Niels Bohr Lecture
Wed. 8. 10:00-10:15
Priyavada Natarajan (Yale University)
From black to white: tracking the formation of supermassive black holes in the universe

HET journal club lunch
Thu. 9. 12:00-12:30
Start-up meeting

Joint DISCOVERY-HET Seminar
Wed. 8. 10:00-10:15
Clausen Fick (CP3-Origins, University of Southern Denmark)
Studies of Minimal Steady Turbulence on the office

Niels Bohr Institute, Copenhagen University, Blegdamsvej 17, 2100 Copenhagen Ø, Denmark

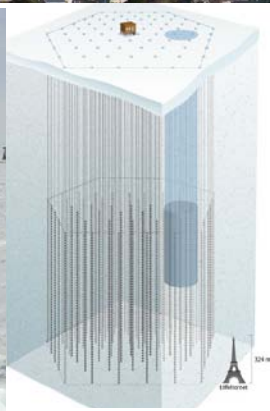
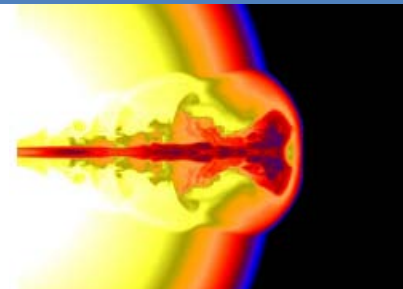
Any updates/suggestions? → Timothy (budd@nbi.dk)



Christchurch, NZ

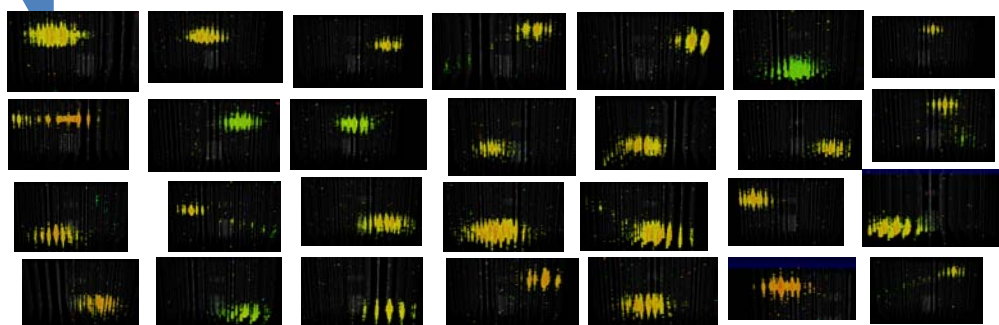
IceCube Neutrino Astrophysics

Jenni Adams University of Canterbury



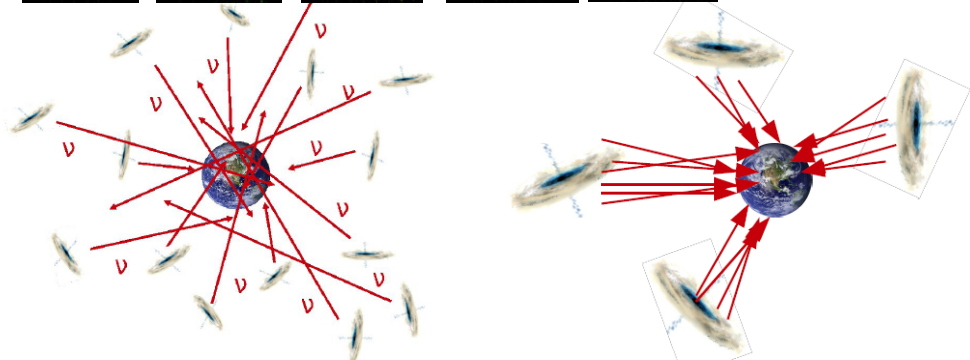
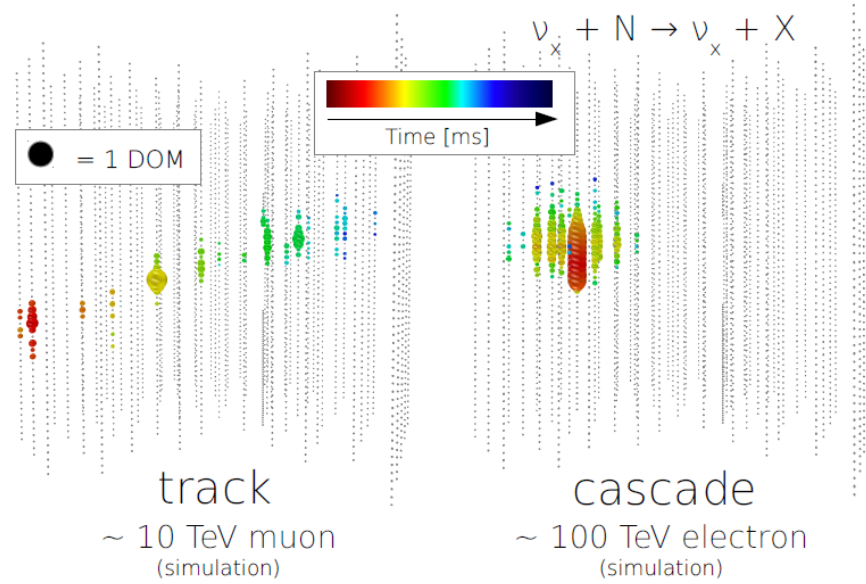
Recent IceCube neutrinos – sampling a diffuse population or can we identify point sources

Cascade Channel



Muon neutrino, CC
 $\nu_{\mu} + N \rightarrow \mu + X$

Electron neutrino, CC
 $\nu_e + N \rightarrow e + X$
All flavors, NC
 $\nu_x + N \rightarrow \nu_x + X$



DT: Dynamical Triangulations. A lattice regularization of the path integral over geometries.

CDT: Causal Dynamical Triangulations. DT with a time foliation.

General present theme:
quantum geometry

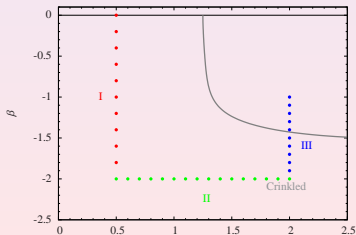
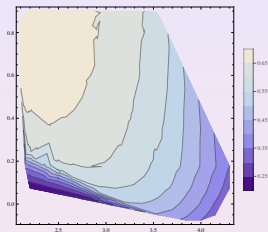
4d CDT renormalization group.

4d DT extended phase diagram.

CDT transfer matrix project

CDT coupled to matter project.

Construction of a measure on 2d geometries



Standard Model Structure from “Small representations”

Why just the Standard Model? We propose that requiring the smallest possible representations, F say, in the sense of maximizing the ratio C_A/C_F or e_A^2/e_F^2 for Abelian part of the gauge group, or rather averaged weighted with the dimension of the invariant subgroups (in a logarithmic way) we are led to the Standard Model!

Novel String Field Theory

Ninomiya and I establish that it indeed gives e.g. the Veneziano model.

Fine Tuning(Multiple Point Principle) Dark Matter and Tunguska Event(s), Kimberlites w. C.D.Froggatt,...

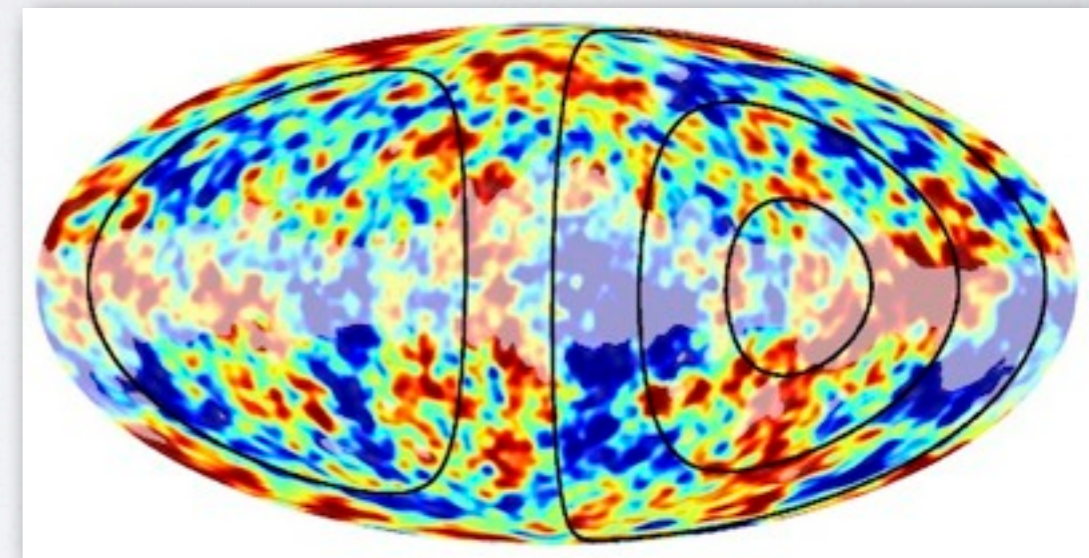
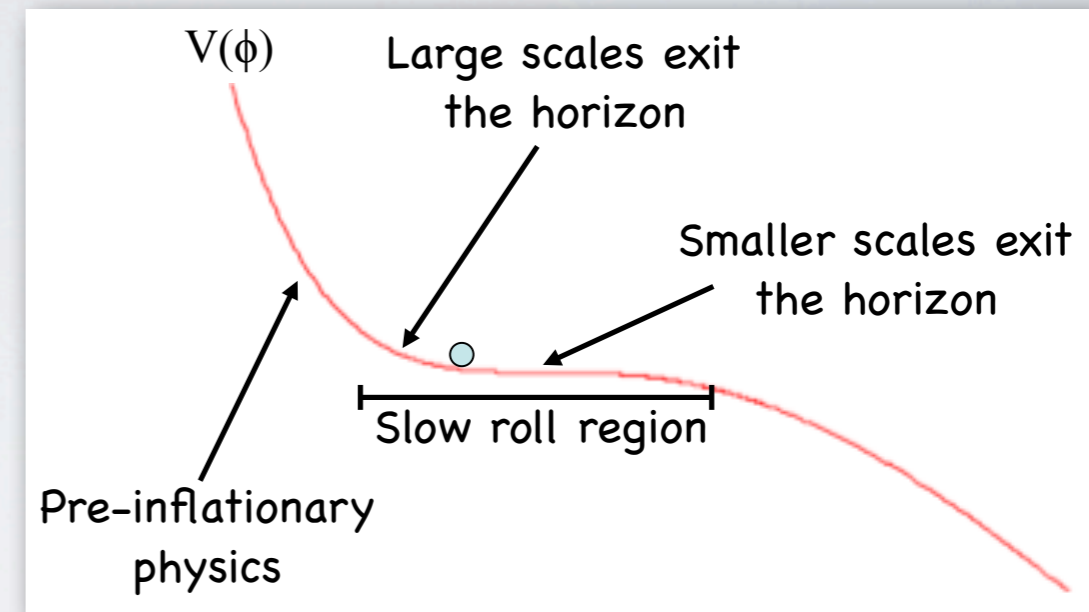
Some other subjects:

Homolumogap, Fermionization, Plebanski gravity and weak unification, Weyl anomaly.

Pre-Inflationary Physics and Large Scale Observations

Assaf Ben-David

- Short inflation is theoretically preferred.
- Pre-inflationary physics affect the largest scales.
- Indeed, there are several large scale anomalies in the CMB ($\sim 3\sigma$).
- Could be foregrounds, systematics, statistical flukes or cosmological.
- Search for imprints of pre-inflationary physics in the data. Can be connected to known anomalies?
- Examples:
 - Pre-inflationary particle.
 - Non-Euclidean topology of the universe.



Kovetz, ABD, Itzhaki (2010)



Emil Bjerrum-Bohr

NBIA & DISCOVERY &
Lundbeck Foundation Junior Group
Leader ~ *Computation of Amplitudes
Group (CAMP)*

Office, Bb.1

Research interests:

Field theory and String Theory ~ Gauge and Gravity theories

- What can we learn about Field Theory in the low energy limit of String Theory.
- Kawai Lewellen Tye relations (KLT), e.g. New KLT forms.
- Monodromy and BCJ relations between gauge amplitudes.

Amplitudes and Spinor-Helicity / Twistor formalism

- New computational methods.
- Amplitudes relevant for LHC using Twistorial/Spinor-Helicity formalism.

Quantum gravity as an Effective Field Theory

- Leading quantum corrections to General Relativity.
- Use of “amplitude inspired techniques” in EFT computations.

Timothy Budd

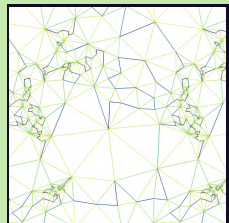
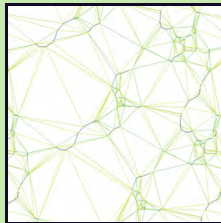
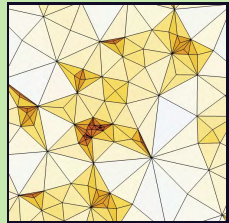
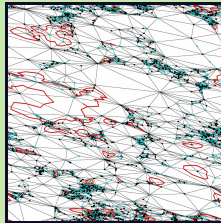
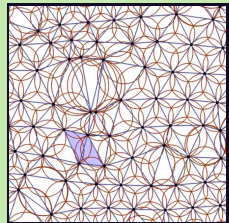
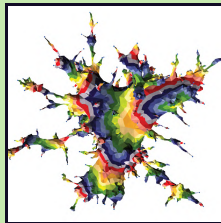
Fb-11, budd@nbi.dk

(Causal) Dynamical triangulations

* Geometry of 2D quantum gravity

- Fractal dimensions
- Matter coupling
- Conformal geometry
- Relation to Liouville gravity & non-critical strings

Both analytical & numerical



Poul Henrik Damgaard

Current research interests:

- QCD amplitude calculations (two loops!)
- Broken conformal invariance and anomalous dimensions
- $\mathcal{N}=4$ Super Yang Mills theory on the lattice
- Fluctuations and statistics of multiplicity distributions in $p - p$ and heavy ion collisions

Interested in moving more towards:

- Astroparticle physics and cosmology
- Particle physics phenomenology (data!)

Tristan Dennen

✧ *UV Divergences in N=4 Supergravity*

helicity	-2	$-\frac{3}{2}$	-1	$-\frac{1}{2}$	0	$+\frac{1}{2}$	+1	$+\frac{3}{2}$	+2
state count	1	4	6	4	2	4	6	4	1

✧ *Global symmetry SU(4)xSU(1,1)*

✧ *Scalars parameterise coset space SU(1,1)/U(1)*

✧ *U(1) is anomalous*

✧ *UV finite through three loops* Bern, Davies, Dennen, Huang (2012)

✧ *UV divergent at four loops* Bern, Davies, Dennen, Smirnov, Smirnov (2013)

$$\mathcal{M}_{\mathcal{N}=4}^{4\text{-loop}} \Big|_{\text{div}} = \frac{1}{(4\pi)^8} st A_{\mathcal{N}=4}^{\text{tree}} \left(\frac{\kappa}{2}\right)^{10} \frac{1 - 264\zeta_3}{288\epsilon} (\mathcal{O}^{--++} + 3\mathcal{O}^{-+++} + 60\mathcal{O}^{++++})$$

✧ *Integration of Feynman integrals*

✧ *Mellin-Barnes techniques*

✧ *Integration-by-parts identities*

Work in progress

Paolo Di Vecchia

- 1 High energy scattering in the Regge limit on a stack of Dp-branes:
derivation of the eikonal operator from string first principles
[G. D'Appollonio, R. Russo and G. Veneziano].
- 2 Study of the dependence on the θ angle useful for physics beyond
the Standard Model
[F. Sannino]

Sonoluminescence:

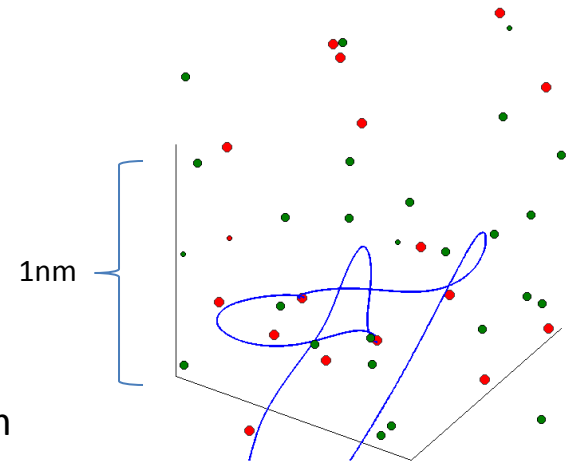
(with Mogens Levinsen)

Investigate competing theories of the emission of light from the compressed heated gas in the collapsed bubble:

bremsstrahlung – bound-free molecular transitions – line broadening – black body radiation

Bremsstrahlung in dilute gas: spectrum is radically different from black-body spectrum.

In dense gas including **coherent multiscattering**: bremsstrahlung and black body spectra become similar.



Phase transitions in excited nuclei (with Sven Åberg et. al)

Comprehensive calculations of nucleon excitations in a well described mean field:

Superfluid -> normal

Loss of orientational correlation

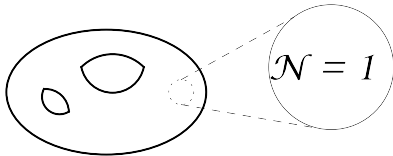
Melting of shell structure

Dynamics of Quantum Field Theories.

- Semiclassical methods
- gauge string duality
- exact methods

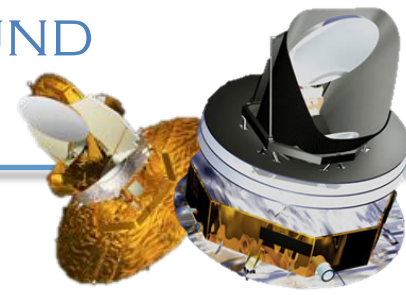
Recently: Understand **SUSY** gauge theories on **curved** manifolds.

- Which manifolds allow SUSY
- How do observables change as geometry is varied
- Applications to QFT in the nonperturbative regime



STUDYING THE COSMIC MICROWAVE BACKGROUND

ANNE METTE FREJSEL, PHD STUDENT

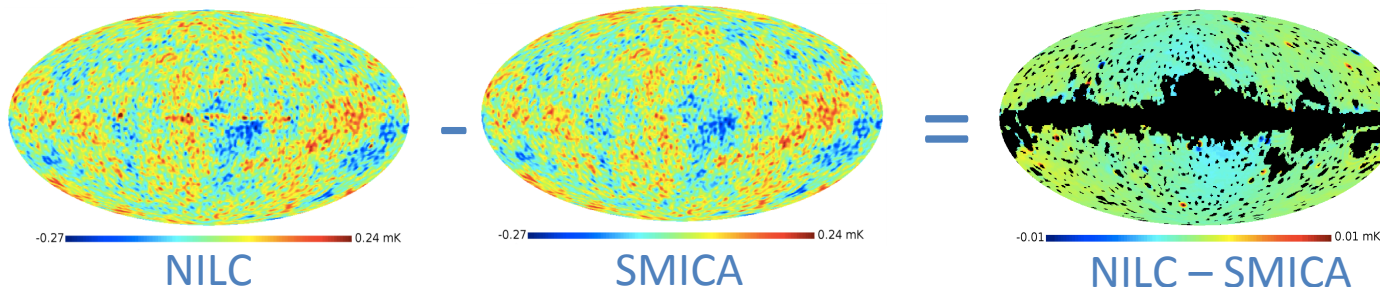
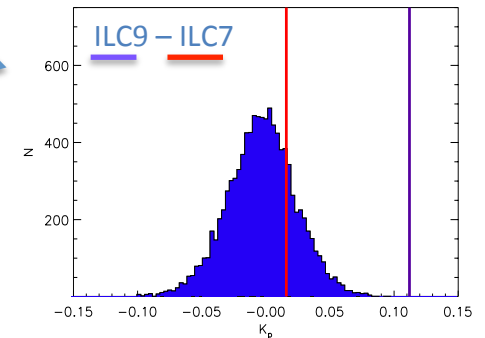
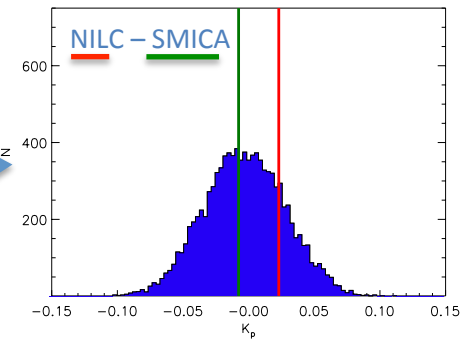


Consistency tests of Planck and WMAP

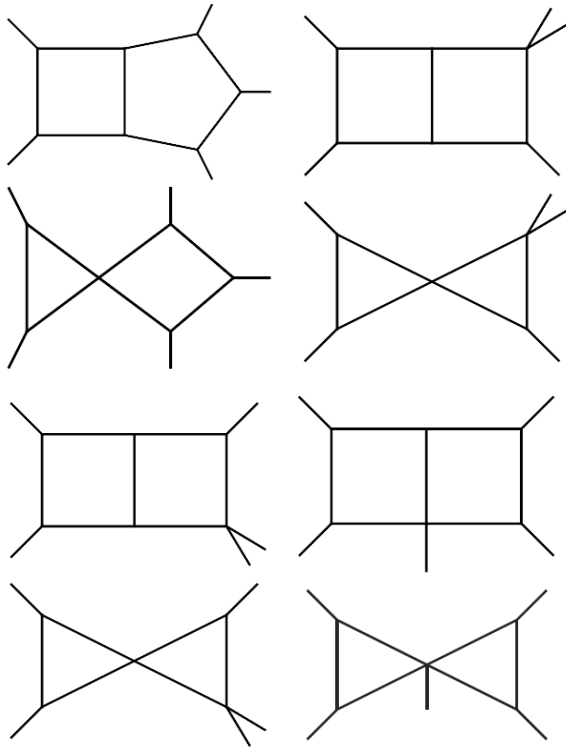
JCAP 06(2013)005, [arXiv:1305.4033](https://arxiv.org/abs/1305.4033)

Conclusions of this work:

- **Planck is very self-consistent**
(this was good to confirm)
- **WMAP has problems with self-consistency**
(this is problematic, some results not expected)
- **Planck is better than WMAP**
(this was also good to confirm)



Hjalte Frellesvig



24 Sept. 2013

Jakob Gath

Ph.D. student, supervisor Niels Obers

Ph.D. Defense Thursday 3. Oct. 2013.

Research:

Effective descriptions of gravity: (Fluid/Solid/Gravity)

Advertisement:

New PhD Meeting Organizer – Lisa Glaser

3rd year Ph.D. student with Jan Ambjørn

■ Causal dynamical triangulations

- worked on: multicritical CDT, simulations of euclidean dynamical triangulations with a measure, **connection to Hořava-Lifshitz**
- collaborated with: Jan Ambjørn, Andrzej Görlich, Yuki Sato, ...

■ Causal sets

- worked on: d'Alembertian operator, **defining locality**
- collaborated with: Fay Dowker, Sumati Surya

■ Quantum Gravity in general, especially

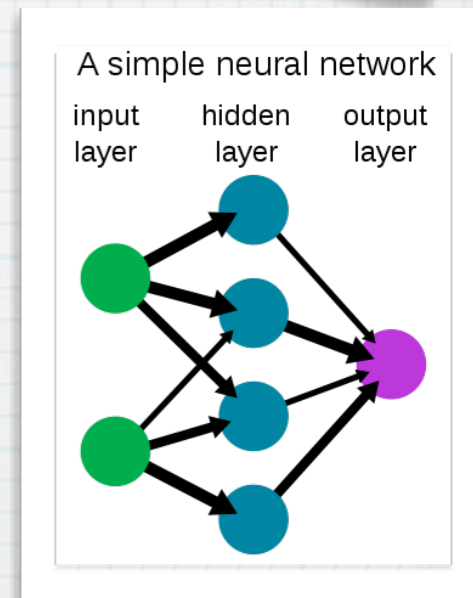
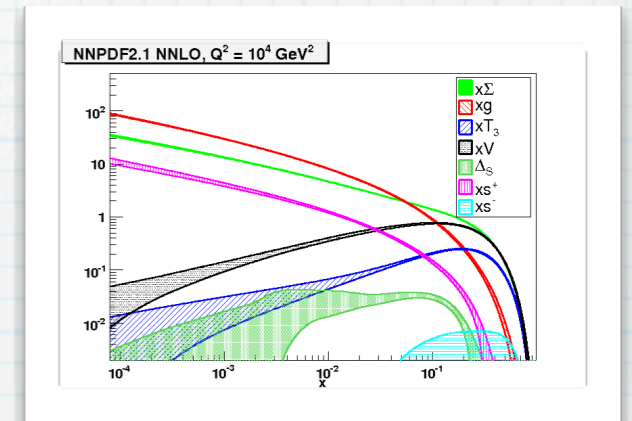
- Tensor models, Shape dynamics
- problem of time, implications of causality, black holes

2-Minute Meeting 2013

A. Guffanti

LHC phenomenology

- 📌 Parton Distribution Functions determination (NNPDF)
- ★ Monte Carlo methods for uncertainties estimation
- ★ Neural Networks as interpolating functions
- 📌 Bayesian Inference techniques for theoretical uncertainties estimation



Cosmology

- 📌 Unbiased determination of cosmological parameters from measurements (recently started collaboration with S. Sarkar)

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$



Troels Harmark

Current research projects:

- Hagedorn temperature in AdS/CFT: w/ Orselli

Confinement/deconfinement temperature
in planar N=4 SYM on $S^1 \times S^3$



Hagedorn temperature of tree-level type
IIB string theory on $AdS_5 \times S^5$

Challenge: Interpolation from weak to strong coupling

Previous work: Successful interpolation near critical point

Current project: Get full interpolating Hagedorn temperature from
TBA equations (Y-systems, T-systems, and all that...)

- Effective description of brane dynamics in gravity/string theory
using blackfold formalism

Compare open sector description (DBI action, gauge theory) to
closed string description (Blackfolds, gravity) for D3-brane with
electromagnetic field

w/ Grignani, Marini & Orselli

→ Leads to a generalized AdS/CFT correspondence

Study effective action for blackfolds at second order

w/ Armas

Review of blackfold formalism

w/ Obers

HET journal club lunch

- Thursdays 12.30 in FB6
- We meet 2-3 times a month
- Send me an email if you like to be on the mailing list
- Topics are tentatively: Black holes, AdS/CFT and Quantum Gravity

First meeting on thursday

HET journal club seminar

- Wednesdays 13.15 in FB6

Seminar next wednesday Oct. 2: G. Grignani

My PhD

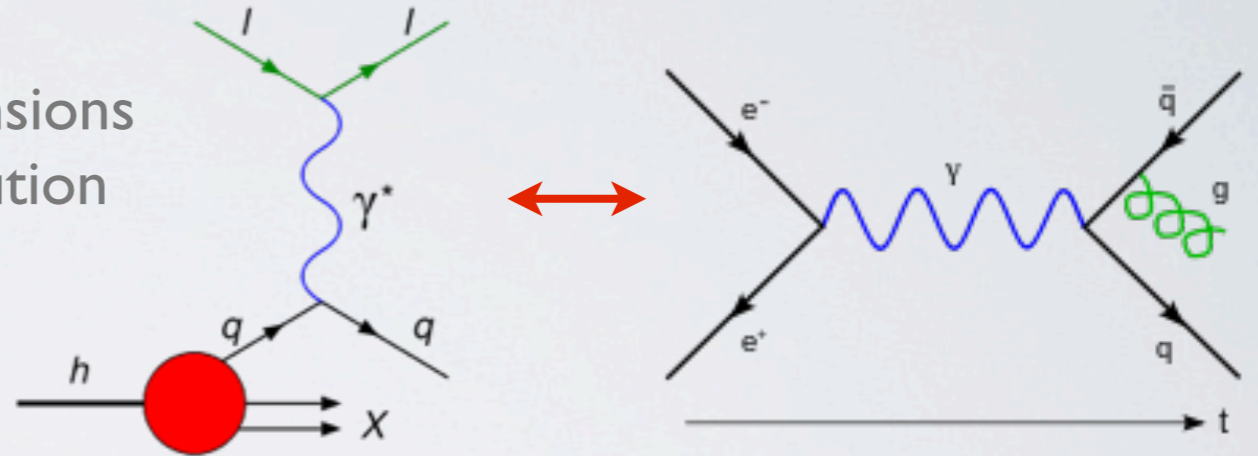
- By Christine Hartmann

I. QCD

Supervision: P.H. Damgaard and R. Ball at NBI:

Generalize relations between anomalous dimensions associated with the evolution of parton distribution and fragmentation functions, respectively.

These are connected with the deep inelastic scattering and annihilation, as seen to the right.

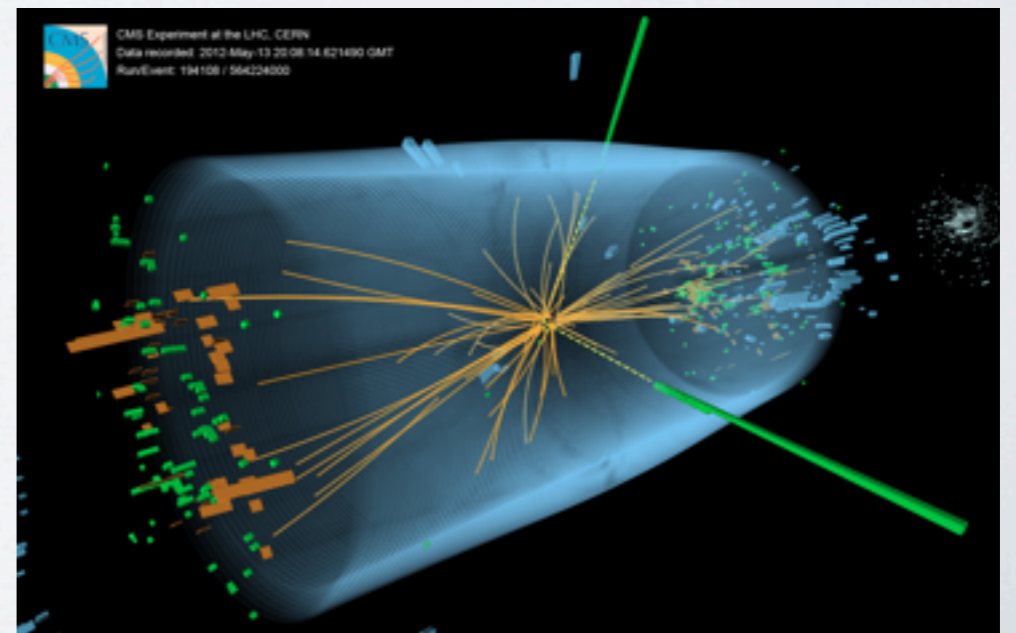


2. Higgs physics beyond the standard model

Supervision: C. Grojean at CERN:

BSM contributions to the renormalization of the $H \rightarrow \gamma\gamma$ decay from dimension 6 scalar operators are found.

Results could help shed light on the compositeness of the Higgs.



- Holography for Lifshitz Space-Times with Morten Christensen, Niels Obers, Blaise Rollier.
- The NSVZ beta function from anomaly matching in an $\mathcal{N} = 1$ effective field theory with field dependent couplings, together with Jean–Pierre Derendinger.

Future:

- AdS/CMT: Lifshitz hydrodynamics, holographic zero temperature ground states for finite density systems.
- Subtracted geometry: putting black holes in a ‘box’ (AdS type confining potential) and hidden conformal symmetry, Kerr/CFT.
- Seminar organizer together with Tristan Dennen.

Matti Herranen

Background

- PhD at the University of Jyväskylä, Finland, 2006 - 2009
- Postdoc at the RWTH Aachen University, Germany, 2009 - 2012
- Postdoc at the NBIA since October 2012

Research Interests

- Particle physics of the early Universe:
 - Baryogenesis and Leptogenesis (origin for the observed baryon asymmetry of the Universe)

$$\frac{n_B}{n_\gamma} = (6.19 \pm 0.15) \times 10^{-10}$$

- Quantum dynamics of cosmological inflation
- Quantum field theory...
 - In and out of thermal equilibrium
 - In curved spacetime
 - Schwinger-Keldysh formalism - 2PI
 - Quantum transport



Rijun Huang

PhD student
huang@nbi.dk

Supervisor:
Poul Henrik Damgaard
Emil Bjerrum-Bohr

Research Interests:

-) Loop amplitude calculation with modern methods
-) Gravity Amplitude & Yang-Mills Amplitude
-) Maybe...more phenomenological problems
-) Mathematical description



Asger C. Ipsen

PhD student (since July 2012), advisor Jan Ambjørn.

Interests (physics related, in arbitrary order)

- Quantum gravity: CDT, DT (so far in 2D)

- Solvable models

- Foundations of QFT

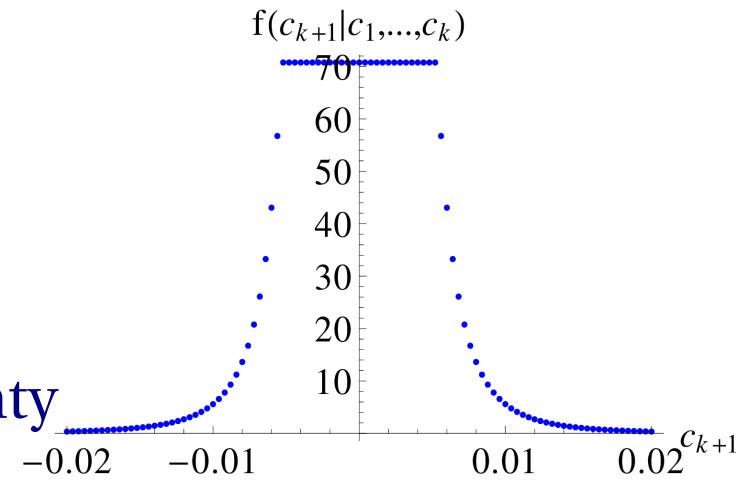
- Quantum information theory

I have previously worked on random matrix theory in the context of QCD with imaginary isospin chemical potential.

Laura Jenniches – two-minute-meeting 2013

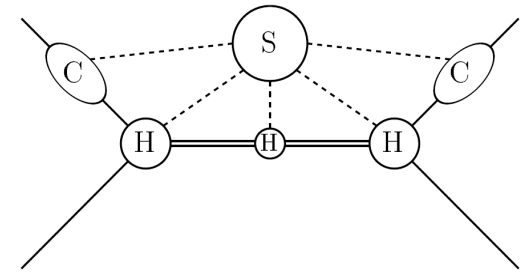
Perturbative QCD

- ✗ Theoretical uncertainty estimates with Bayesian statistics for observables both with and without initial-state hadrons
- ✗ Result: assign degree of belief to uncertainty intervals, posterior distributions



Soft collinear effective theory & Supersymmetry

- ✗ Distinguish hard, collinear & soft contributions
- ✗ Identification of resonant & non-resonant regions
- ✗ 4-point function at NLO



Anomalous couplings in diboson physics

- ✗ Effective Field Theory approach

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{c_i}{\Lambda^2} \mathcal{O}_i + \dots$$

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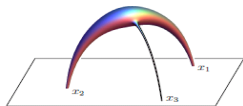
Integrability in the AdS/CFT correspondence:

The spectral problem of $\mathcal{N} = 4$ SYM, ABJM and ABJ theory, integrable spin chains and their Bethe equations, Wilson loops, giant gravitons, amplitudes



Beyond integrability of the AdS/CFT correspondence:

Nonplanar effects, three-point functions, one point functions in defect conformal field theories.



Quantum Holography

A holographic model of graphene, holographic quantum Hall effect.

- Hao Liu, Post Doctor, Planck data analysis, Room FB4
- Working on:
 - Curvaton field & large scale anomalies (JCAP, arxiv:1302.6080).
 - Ecliptic emission in the Planck sky maps, the relation to odd-even parity asymmetry (Paper done, waiting for co-authors).
 - Ecliptic emission in the Planck sky maps, detailed emission type and spectrum analysis and removal.
 - The impact of the ecliptic emission on the polarization data.
- Working with: Pavel Naselsky, Anne Mette Frejsel, Martin Kirstejn Hansen.



Symmetries in Gauge Theories

4d $\mathcal{N} = 4$ super Yang–Mills theory

3d $\mathcal{N} = 6$ super Chern–Simons theory

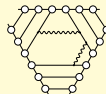
Scattering Amplitudes

- How to use integrability efficiently?



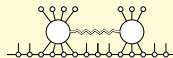
Conformal Structure Constants

- What can we learn from the spectral problem?
- Recursion relations in the loop order?



Gauge Theory Integrability

- Underlying mathematical structure?
- Relation to condensed matter models?



Yuri Makeenko

(ITEP, Moscow)

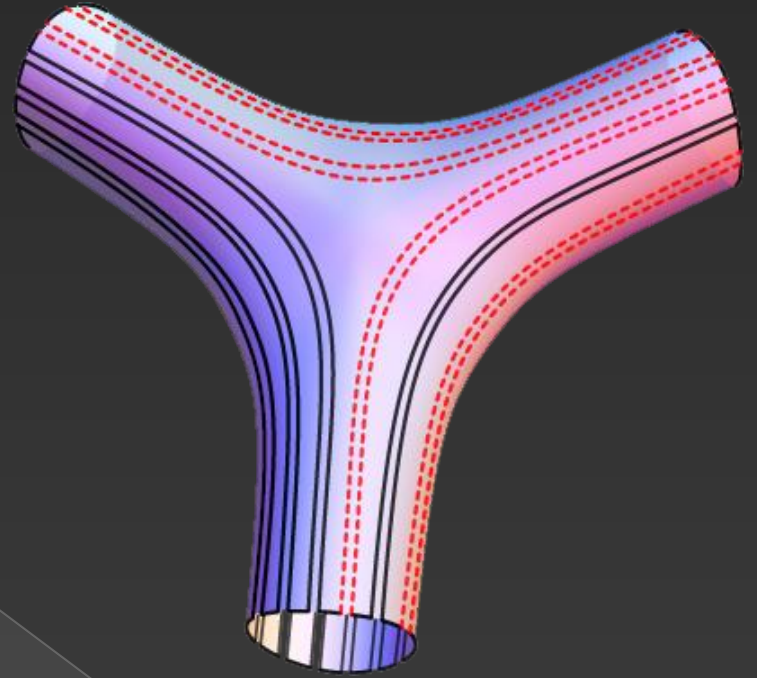
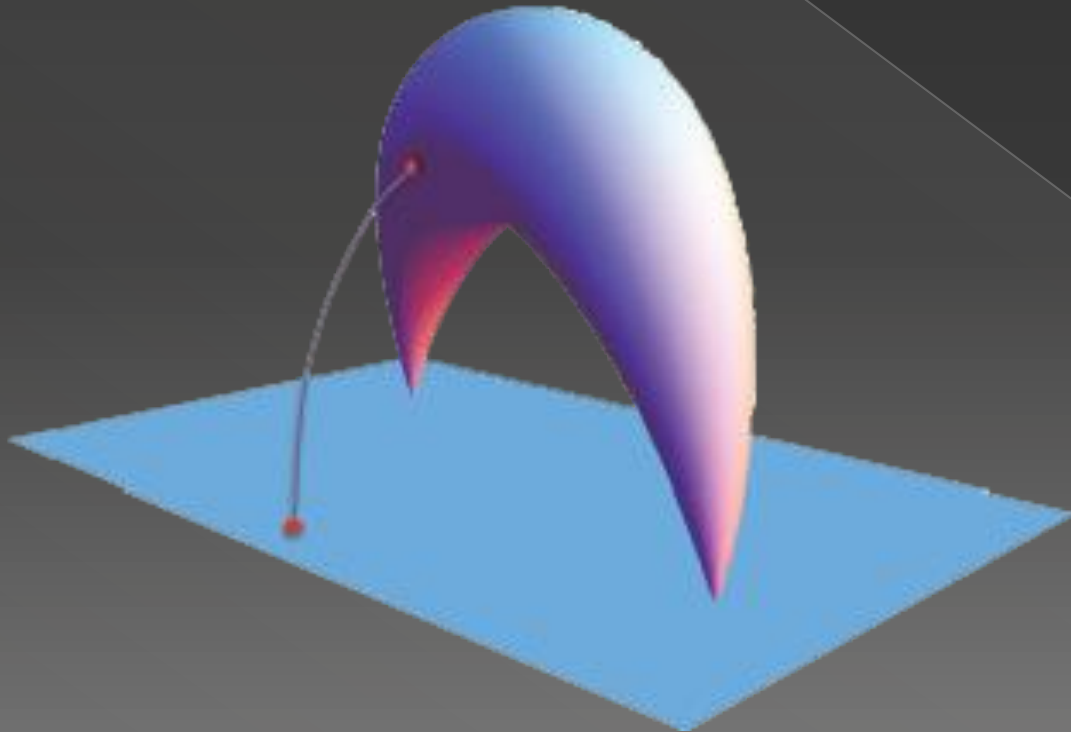


Current research interest:

- Large N QCD
- QCD string
- fundamental string

Recent progress due to

- inspiration from $\mathcal{N} = 4$ SYM
- effective string at large distances
- Liouville modes make string consistent



Problems of QCD with $\mu \neq 0$

- No conventional lattice simulations (sign problem)
- No conventional perturbation theory unless $T \rightarrow \infty$ or $\mu \rightarrow \infty$

Possible ways to calculate

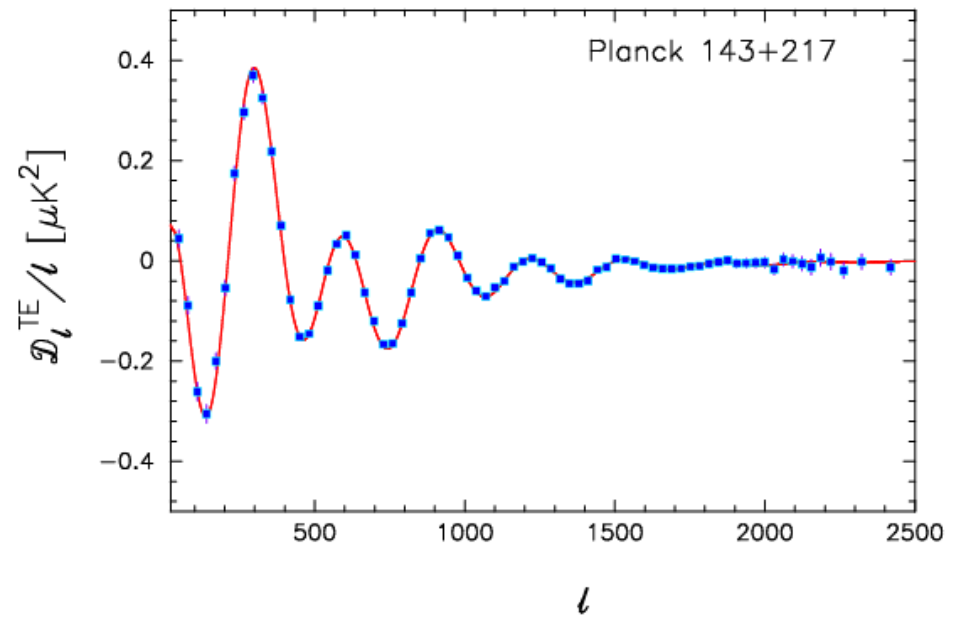
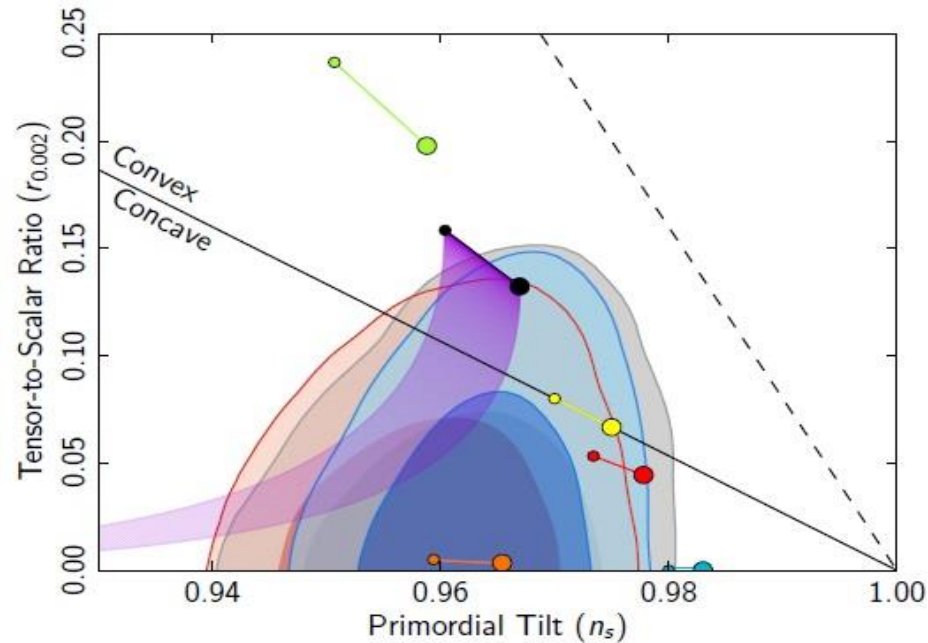
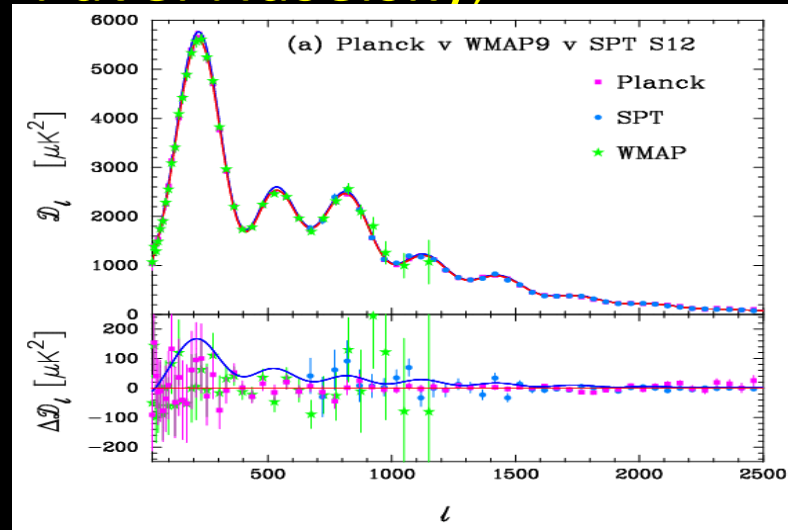
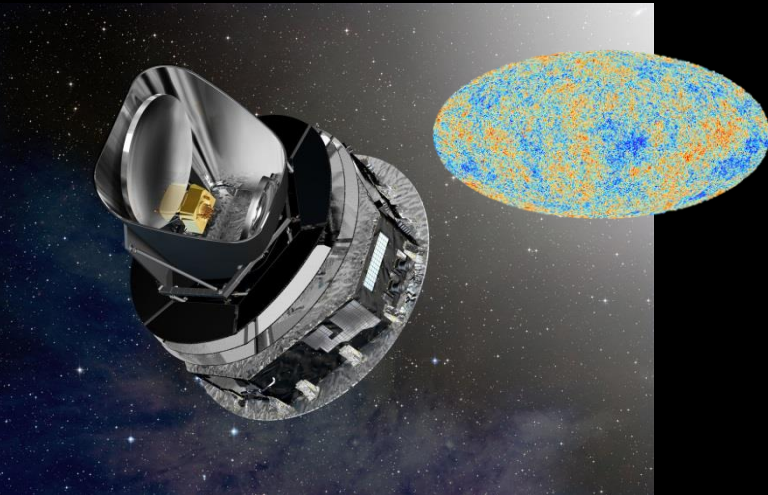
- Hadron resonance gas model, lattice strong coupling expansion (with Kim Splittorff and Jeff Greensite)
- At large N_c , lattice QCD with heavy quarks from the strong coupling expansion related to continuum QCD on $S^1 \times S^3$ with $S^3 \ll \Lambda_{QCD}^{-1}$ (with Tim Hollowood, Alex Christensen, and Pete Pedersen).

Future

- Formulation of other non-abelian gauge theories from the lattice strong coupling expansion?

PLANCK view at the inflationary Universe

Pavel Naselsky,



Research interests, Niels Obers (2 min. meeting 2013)

Blackfolds: dynamics of black holes in gravity and string theory

- black holes as “fluids” and “materials”
- transport and response coefficients for charged branes
- time-dependence + stability
- flux backgrounds and cosmology



Aspects of the holography

- Lifshitz holography and applications (e.g. AdS/CMT)
- Lifshitz black holes/branes in string theory/supergravity
- thermal Giant Gravitons and bubbling black holes
- fluid/gravity correspondence
- subtracted black hole geometries



Wishlist

- entanglement entropy and AdS/CFT
- Partition functions and localization techniques in QFT/ST

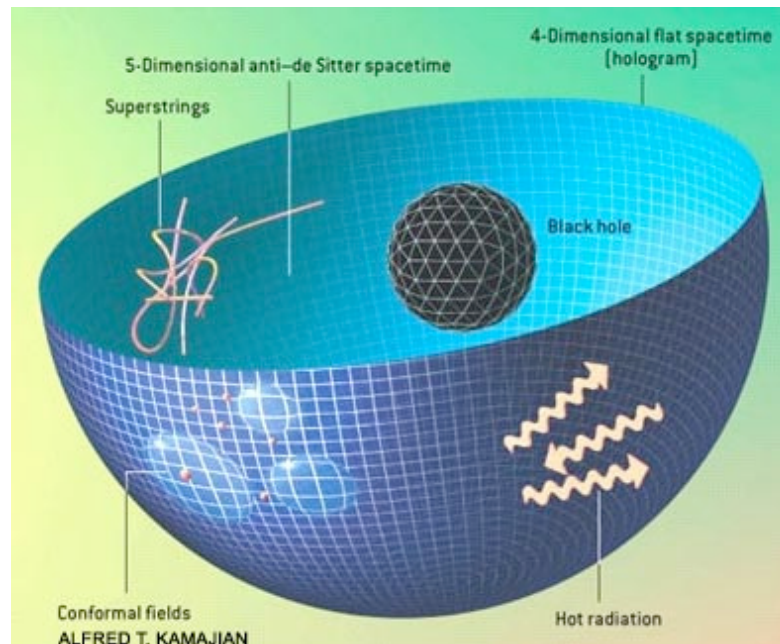


With:

Jay Armas (Bern), Troels Harmark, Jelle Hartong,
Jan de Boer (Amsterdam), Elias Kiritsis (Crete), Vasilis Niarchos (Crete),
Blaise Rollier (Amsterdam), Kostas Siampos (Mons)

Jakob Gath (soon: Ecole Polytechnique), Andreas Vigand Pedersen (PhDs):
Marco Sanchioni (new PhD from SISSA)

Morten Holm Christensen (finished MSc),
Isak Buhl-Mortensen, Svavar Gunnar Gunnarsson (MSc)



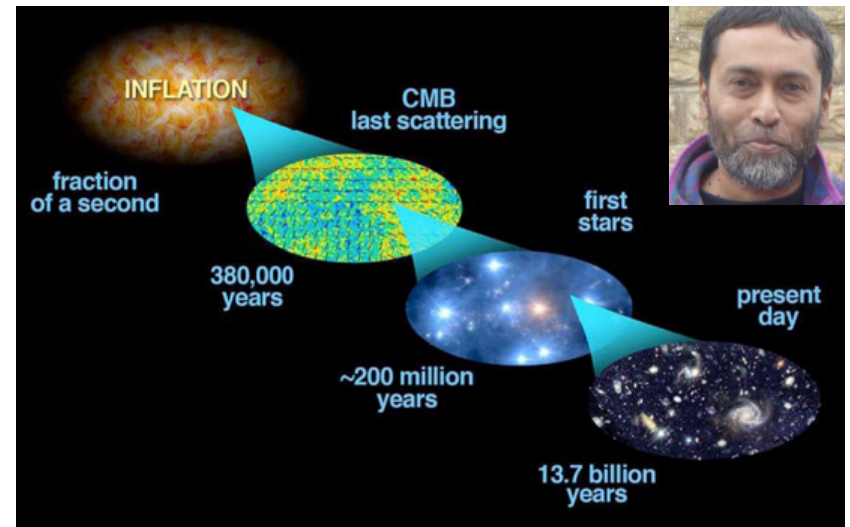
Chris Pethick

(Nordita and NBIA)

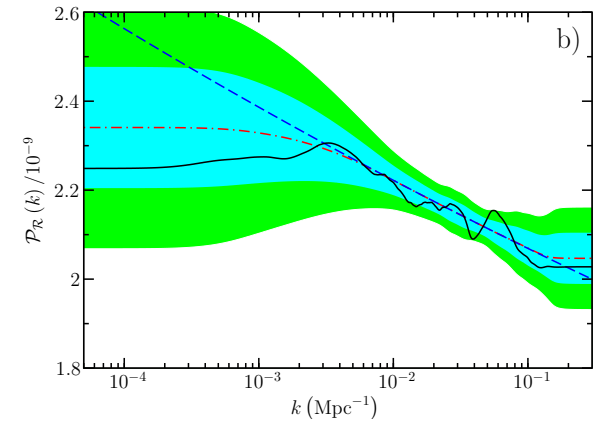
- Properties of crusts of neutron stars
(Important for neutron star cooling and oscillations)
Neutrons between nuclei can make crystal lattice unstable
With Dmitry Kobyakov (Ph. D. student in Umeaa)
- Neutrino processes in stellar collapse
With A. Schwenk and A. Bartl (Darmstadt) and P. Saugmann (master student in Copenhagen)
- Neutron star models
With A. Schwenk, J. Lattimer (Stony Brook) and K. Hebeler (Ohio State)

Subir Sarkar

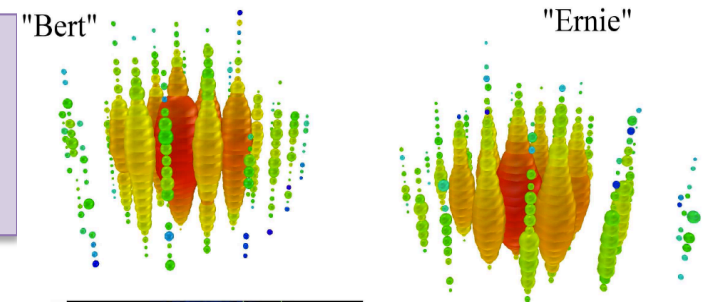
50% at NBIA (2013-18) + 50% at Oxford Univ.
where I am head of the Particle Theory Group
... setting up astroparticle physics group @ NBI
(in collaboration with DISCOVERY & DARK Centres)
Students: Jeppe Trøst Nielsen (PhD) + Amel Durakovic (PhD) + Rasmus Rasmussen (MSc)



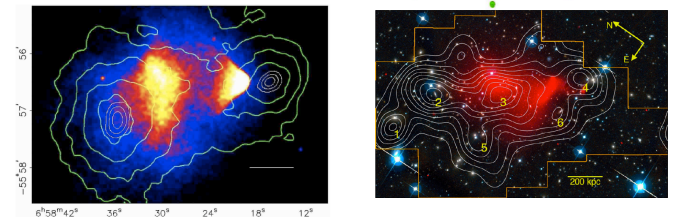
Early universe: Reconstructing the primordial spectrum of density fluctuations ([arXiv:1308.2317](#))
... we find possible features suggestive of non-trivial dynamics during 'inflation' ➔ now testing with *Planck* data to check if the features are real



High energy neutrinos: Participation in *IceCube* expt: seen events of cosmic origin ([PRL 111:021103,2013](#)) + neutrino oscillations ([PRL 111:081801,2013](#)) ➔ *PINGU*



Dark matter: Testing for self-interactions using observations of colliding clusters ([arXiv:1308.3419](#))



MADS SØGAARD

Position and affiliation

PhD student at NBIA/Discovery Center

Scientific trajectory

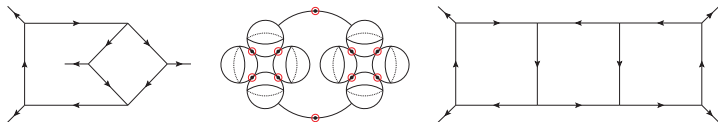
B.Sc. '09, NBIA/HET; M.Sc. '12, NBIA/Discovery; Visitor '13, UCLA.

Academic advisors

Emil Bjerrum-Bohr, Poul Henrik Damgaard

Research interests

Computation of multiloop scattering amplitudes in gauge theories by means of multivariate complex analysis and algebraic geometry; Bern-Carrasco-Johansson color-kinematics duality between gauge and gravity theories.



“One of the most remarkable discoveries of elementary particle physics has been that of the existence of the complex plane,”
– Julian Schwinger

[Who] Kim Splittorff

Master Students 2013-2014

Master Students 2012-2013

Peter Pedersen and Alexander Simon Christensen

Anders Møllgaard: PhD Complex Systems NBI

Christian Marboe: PhD Trinity College Dublin

Therkel Zøllner Olesen: Defense 4/10

[What] $V \rightarrow \infty$, $m_q \rightarrow 0$ and $a \rightarrow 0$, in lattice QCD at nonzero μ_q

[Why] Understand dense strongly interacting matter

[How] Chiral Perturbation Theory

Random Matrix Theory

Strong coupling

Spin models

AdS/CFT

[Who] Kim Splittorff

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Spin models

AdS/CFT

[Where]

Fc5


$$ds^2 = -dt^2 + a^2(dr^2 + r^2d\Omega^2)$$

Andreas Vigand Pedersen

vigand@nbi.dk

PhD student (@ Niels Obers)

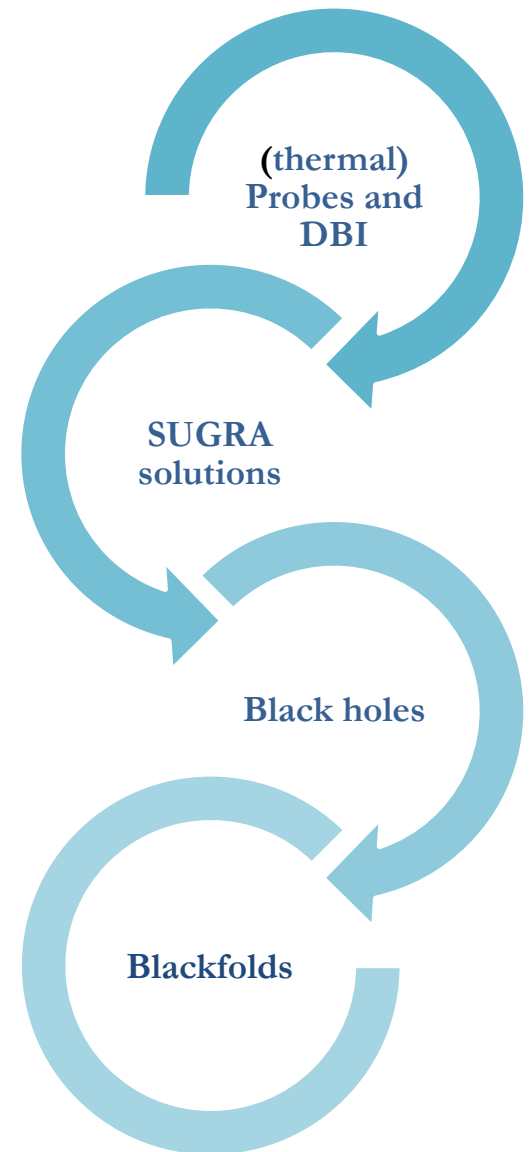
Background: Master from NBI.

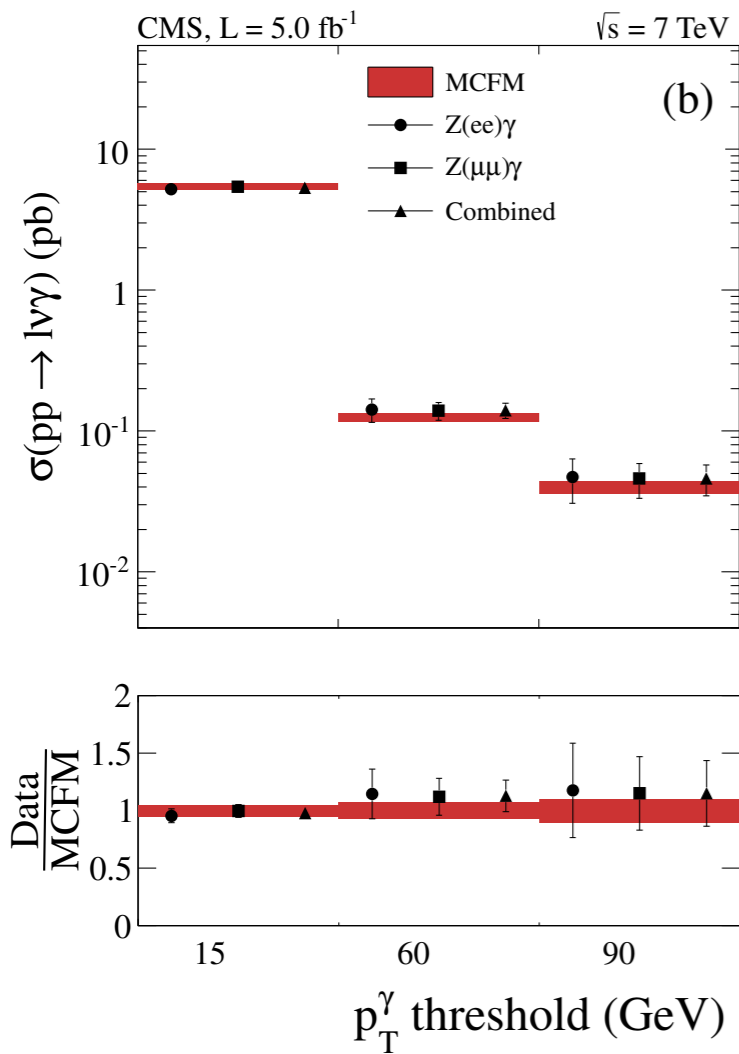
Interests:

- Physics.
- Gravity theories.
- Higher dimensional gravity and Fluid/gravity.
- AdS/CFT and applied AdS/CFT.

Currently investigating:

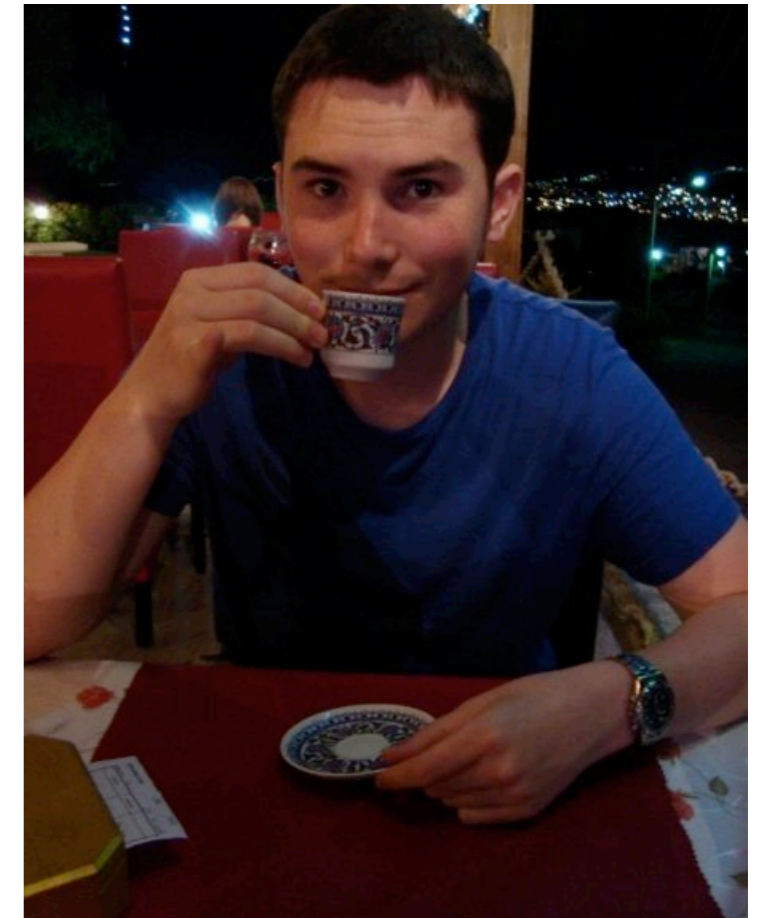
- New aspects of Fluid/gravity.
- New methods for understanding brane physics via effective approaches (\sim blackfolds).





Ciaran Williams

me



I am interested in LHC phenomenology, Higgs, Dark Matter, and SM measurements.

I am an author of MCFM, a code for NLO phenomenology. Lots of projects, so feel free to get in touch if you're interested in LHC physics!



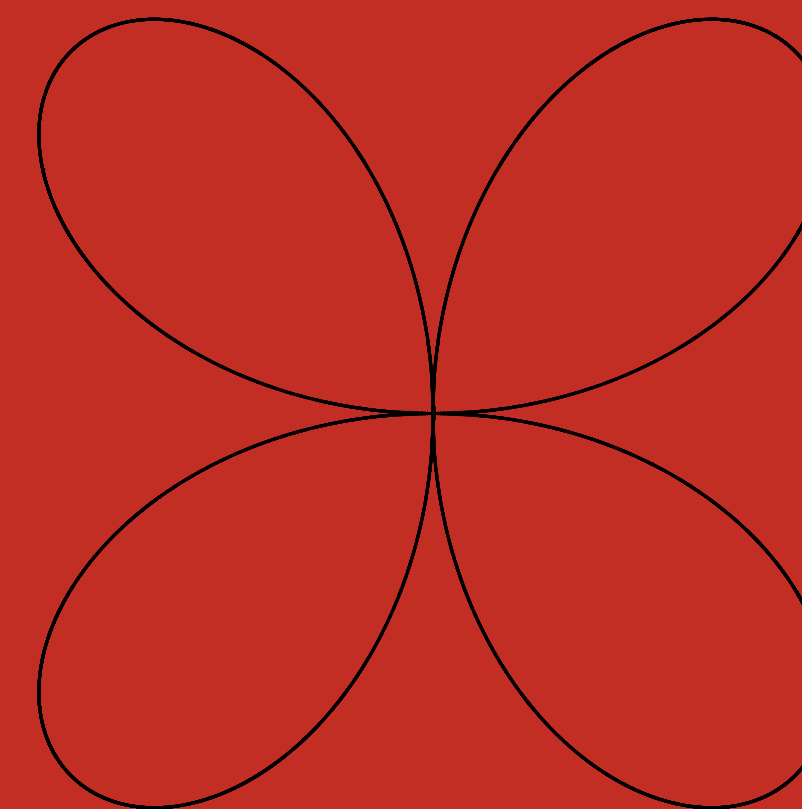
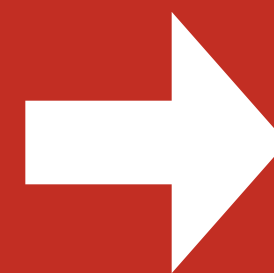
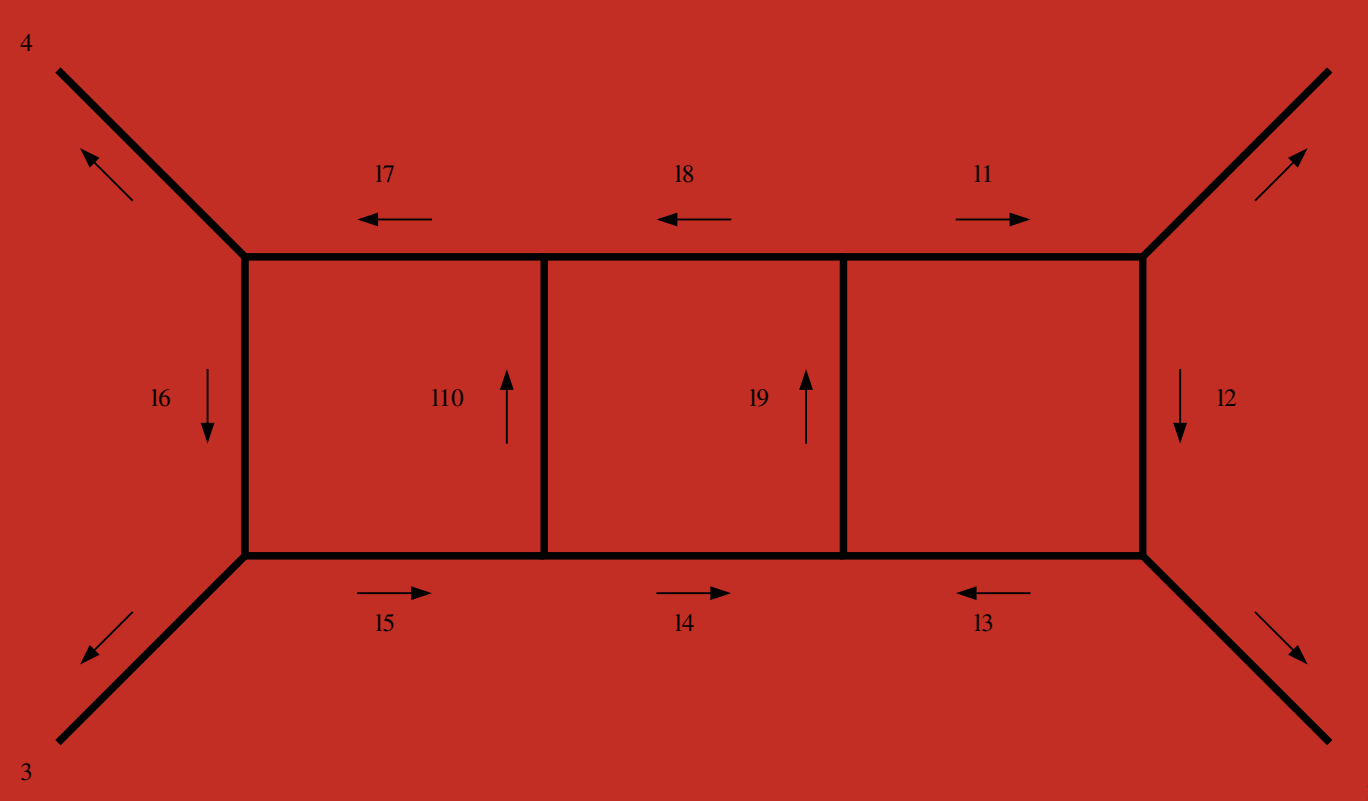
Yang Zhang



NBIA & Discovery Center

Ph.D. 2011, Cornell University

working on two and three-loop amplitudes via **generalized unitarity** and **computational algebraic geometry**



Primary Decomposition

$$I = \cap_i I_i$$

Groebner Basis

$$N = \sum_j f_j g_j + r$$

Integrand $\int \frac{d^D l_1}{(2\pi)^D} \cdots \int \frac{d^D l_L}{(2\pi)^D} \frac{N}{D_1 \dots D_k}$