Oxford Particle Theory Group

Founded in 1963 by **Dick Dalitz** (dec.)
Emeriti: **Jack Paton, Ian Aitchison, John Taylor, Chris Llewellyn-Smith, Frank Close, Graham Ross*, Mike Teper***

John Wheater 1986-

Conformal field theory and quantum gravity

Andrei Starinets 2008-

Gauge-string duality, holography, AdS-CFT

Supported by: STFC, EU, Royal Society …

+ presently 10 postdocs & 20 DPhil students

http://www2.physics.ox.ac.uk/research/particle-theory

Andre Lukas 2004-

String theory and phenomenology

* => regularly in the department
Visitors: Alon Faraggi (Liverpool)
Juan Rojo (Amsterdam)
Gavin Salam (CERN)
Stephen West (RHUL)

Jorge Casalderrey-Solana
RSURF 2014-

+ Many associates in Astro, PP & Maths Inst

Giulia Zanderighi 2007-

Uli Haisch 2011/16-

Joe Conlon 2008/14-

John March-Russell 2002-

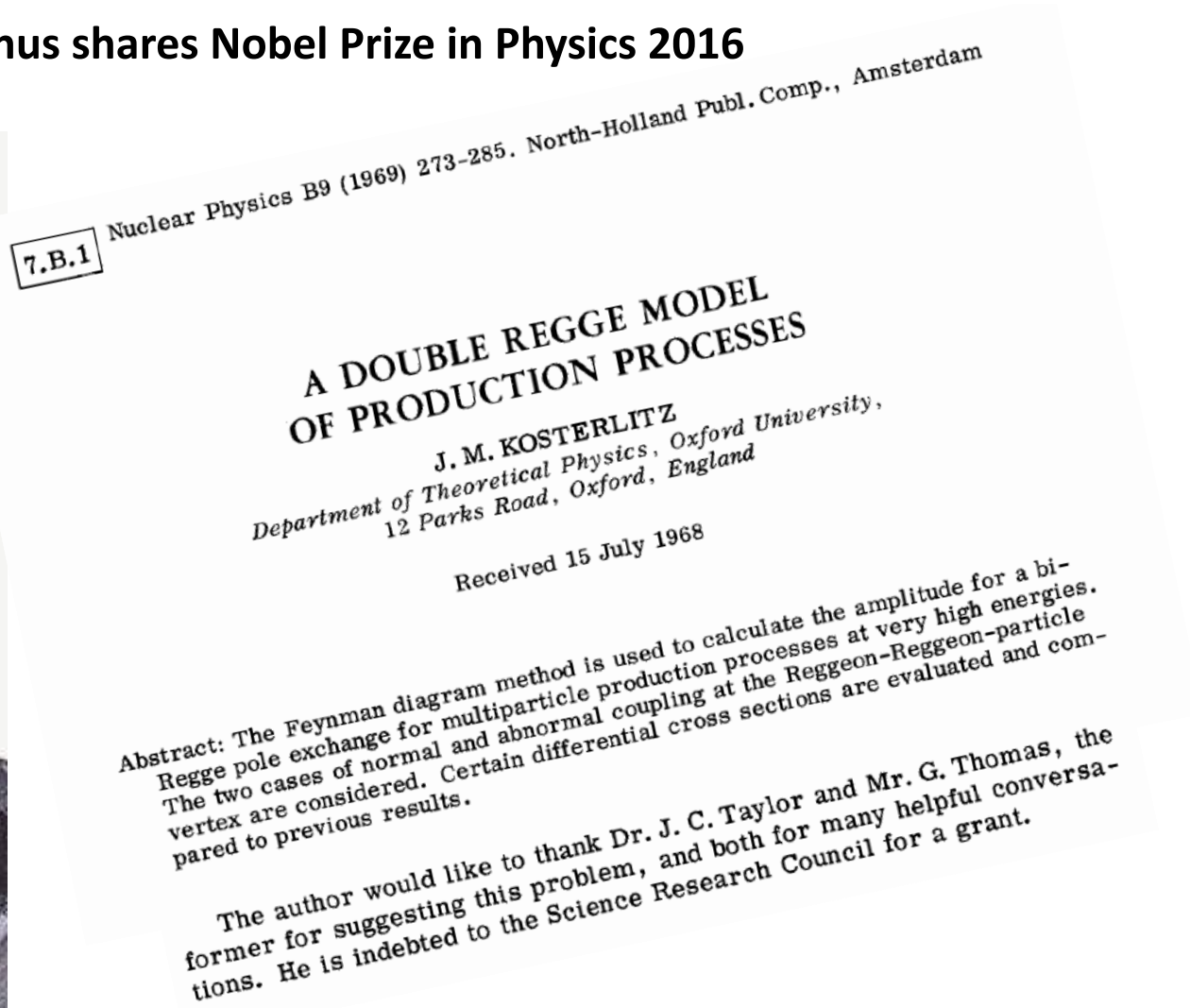
Subir Sarkar 1990/98-

Phenomenology of electroweak and strong interactions

Physics beyond the Standard Model

Particle astrophysics and cosmology

Oxford alumnus shares Nobel Prize in Physics 2016



7.B.1 Nuclear Physics B9 (1969) 273–285. North-Holland Publ. Comp., Amsterdam

A DOUBLE REGGE MODEL OF PRODUCTION PROCESSES

J. M. KOSTERLITZ

Department of Theoretical Physics, Oxford University, 12 Parks Road, Oxford, England

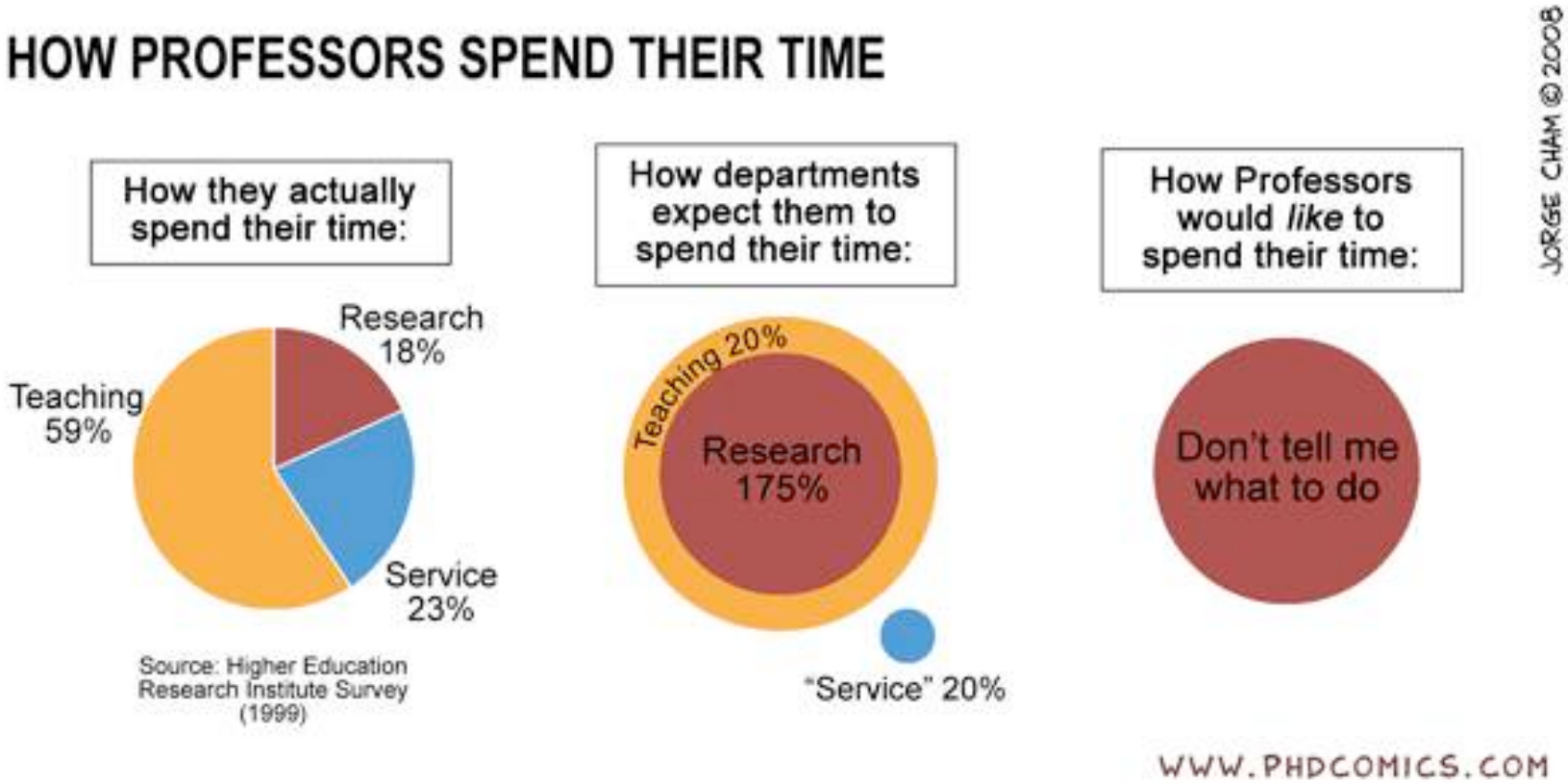
Received 15 July 1968

Abstract: The Feynman diagram method is used to calculate the amplitude for a bi-Regge pole exchange for multiparticle production processes at very high energies. The two cases of normal and abnormal coupling at the Reggeon-Reggeon-particle vertex are considered. Certain differential cross sections are evaluated and compared to previous results.

The author would like to thank Dr. J. C. Taylor and Mr. G. Thomas, the former for suggesting this problem, and both for many helpful conversations. He is indebted to the Science Research Council for a grant.

Theoretical Physics Theses					
PARRY, David Emsley.	Nucleon Resonance Production at High Energies: A Quark-Model Calculation.	DPhil	1971	Dalitz, R H	PT
MOTLEY, C. J.	Matrix Elements of the Nucleon-Nucleon Interaction.	DPhil	1970	Brink, D M	PT
KOSTERLITZ, J M	Problems in strong interaction physics	DPhil	1969	Taylor, J C	PT
HOLDSWORTH, D.	Numerical Calculations of Quark-Antiquark Bound State Masses, Using the Bethe-Salpeter Equation.	DPhil	1968	Dalitz, R H	PT
KEAM, R. F.	Some Properties of the Ladder Approximation Bethe-Saltpeter Equation	DPhil	1968	Not stated	PT
PEREZ, S. M.	Inelastic Scattering and the Nuclear Shell Model.	DPhil	1968	Hodgson, P E	PT
BARNETT, A. R.	Research in Nuclear Structure.	DPhil	1965	Tanner, N W	PT
FRAMPTON, Paul Howard.	Strong Interactions of Elementary Particles: Regge Theory and Sum Rules.	DPhil		Taylor, J C	PT
LONDERGAN, J. Timothy.	Hypernuclear Decay Spectra.	DPhil		Dalitz, R H	PT

Staff


HOW PROFESSORS SPEND THEIR TIME
How they actually spend their time:
Research 18%
Teaching 59%
Service 23%
Source: Higher Education Research Institute Survey (1999)
How departments expect them to spend their time:
Teaching 20%
Research 175%
"Service" 20%
How Professors would *like* to spend their time:
Don't tell me what to do
JORGE CHAM © 2008
WWW.PHDCOMICS.COM

Heavy Ion Collisions, Holography and Jets

- Extremely high temperatures

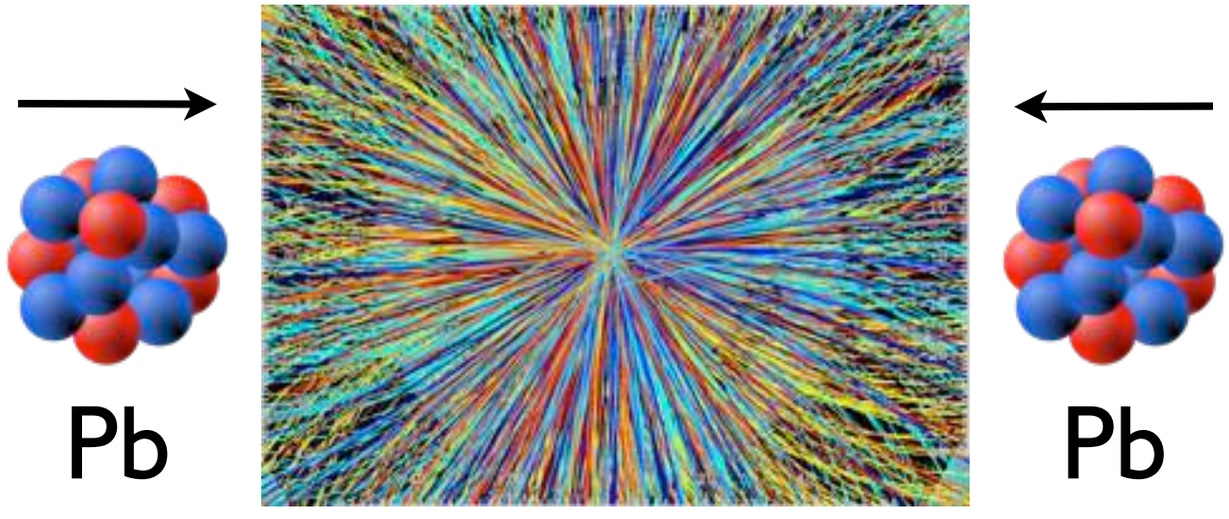
  $T > 2\times10^{12}$ K = 170 MeV

- A new state of matter

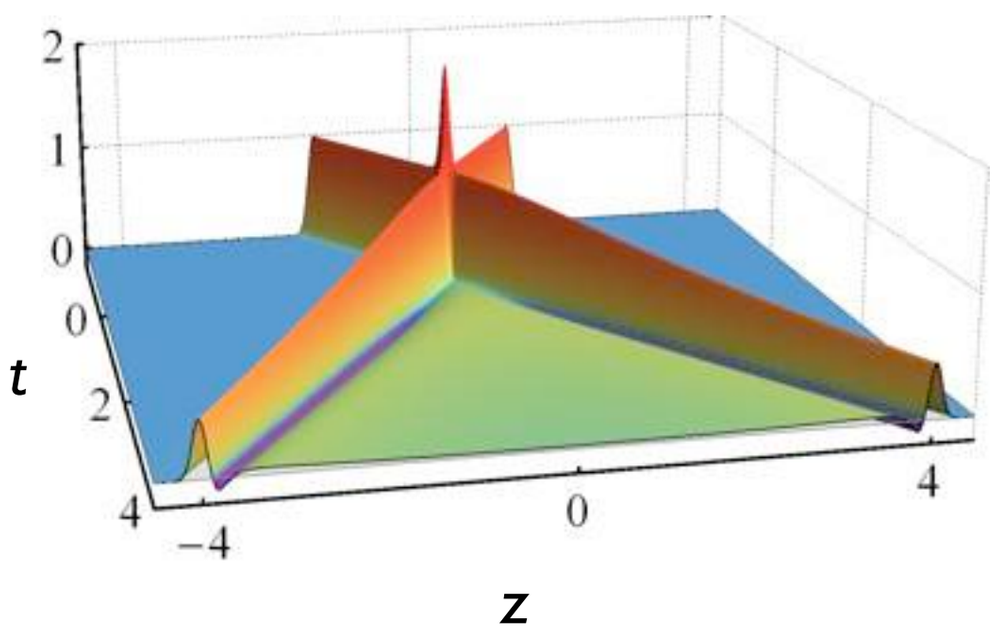
  Quark Gluon Plasma

- The most perfect fluid

- LHC: Pb-Pb @ $\sqrt{s}$= 2.76 TeV



Energy Density



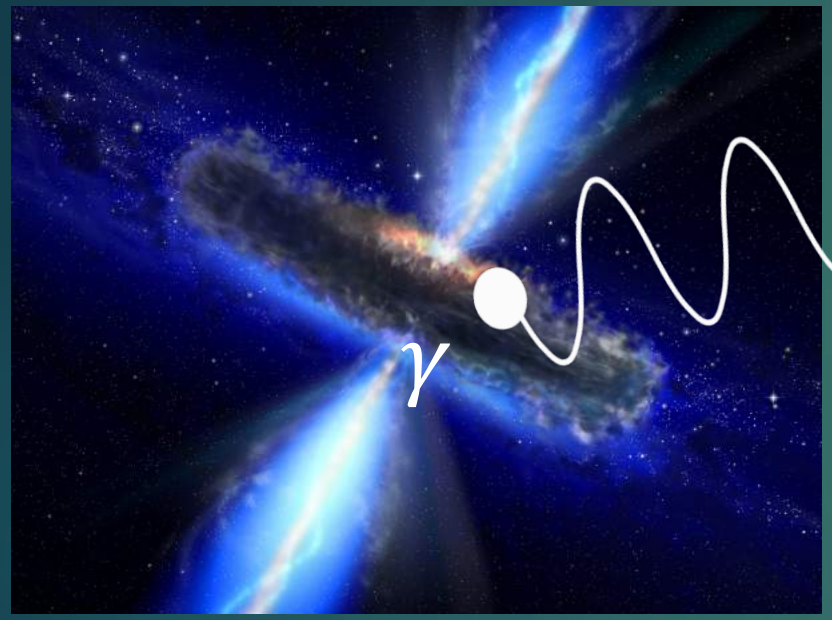
- What are the properties of QGP?
  - How is it generated?
  - What are its transport coefficients?
  - How does it interact with probes?

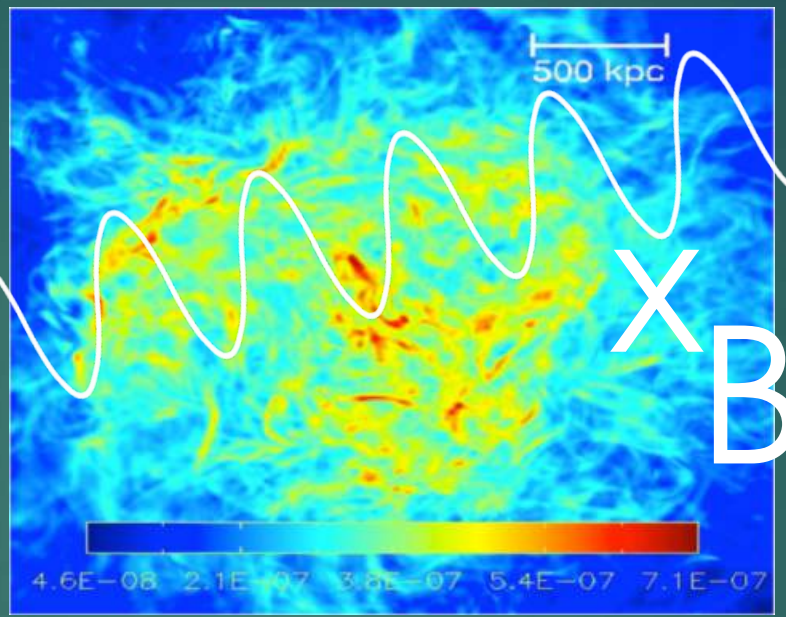
- Techniques that we use
  - Numerical GR (Holography)
  - pQCD
  - Effective field theory methods

Jorge Casalderrey-Solana | Royal Society Fellow | jorge.casalderreysolana@physics.ox.ac.uk

Dark matter or ALPs can produce features in this spectrum

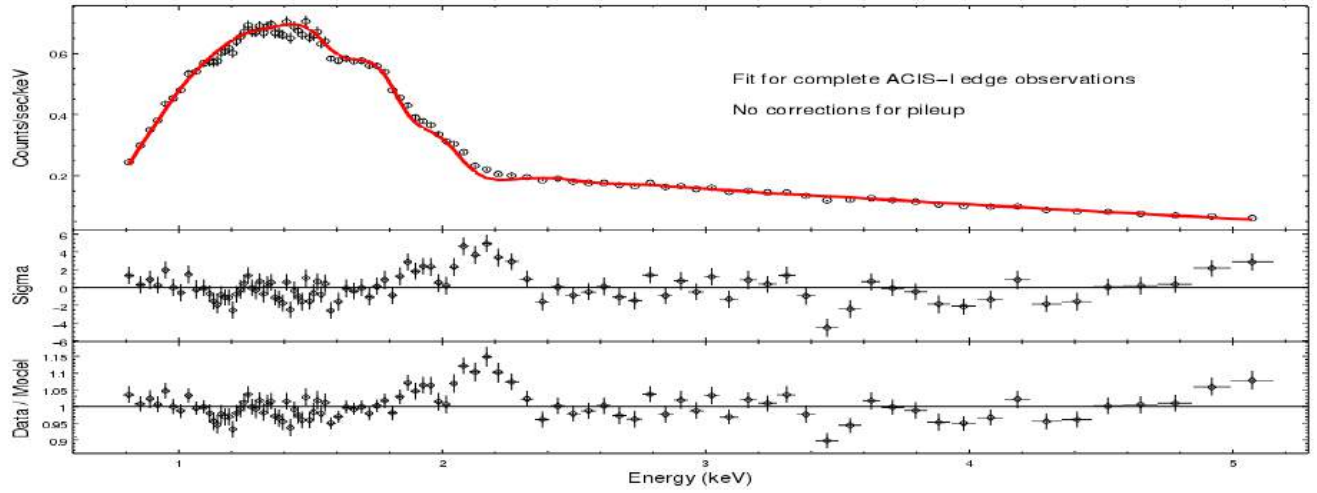
AGNs are bright point sources of photons

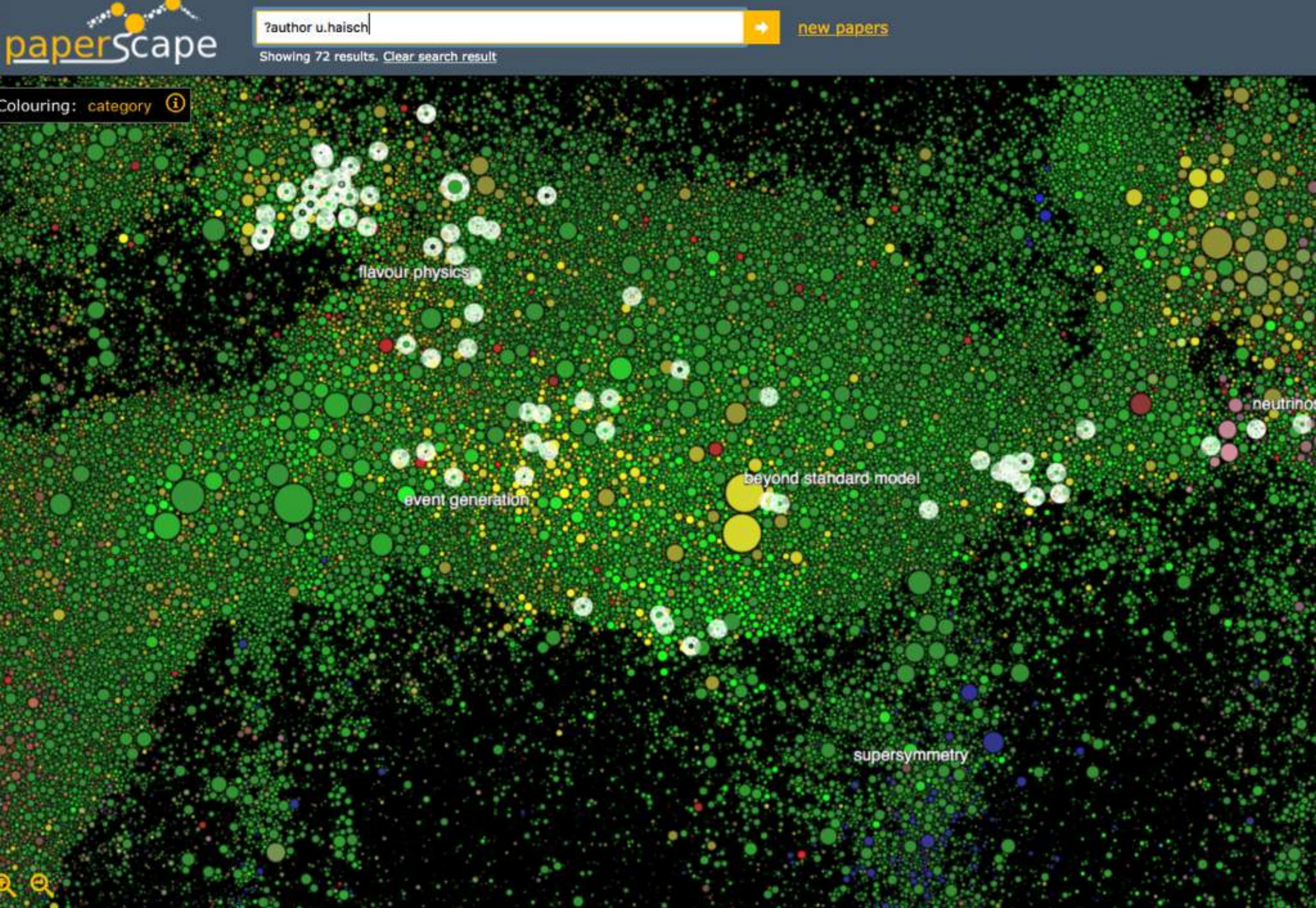




We have looked at NGC1275 – central AGN of Perseus cluster – notable feature at 3.54 keV

JOSEPH CONLON – string theory, cosmology, BSM, astroparticle physics, particle astrophysics……





ULI HAISCH DALITZ 2

Andre Lukas

Main interest: string theory, with emphasis on compactifications, model building and phenomenology.

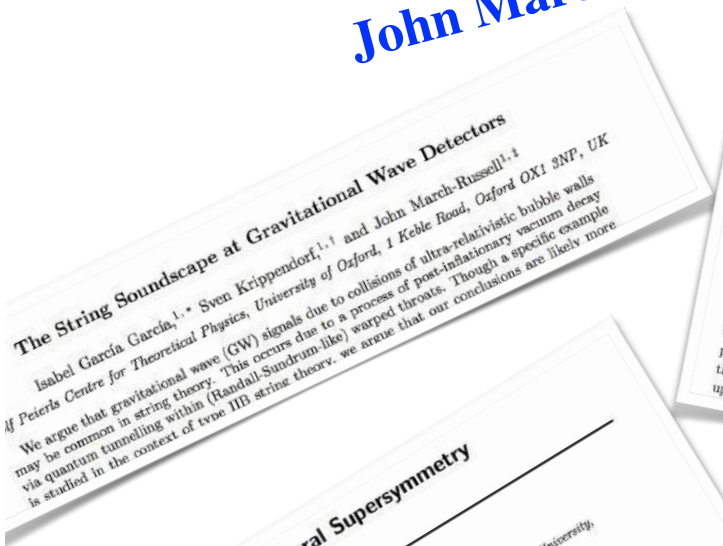
More specifically:

- Calabi-Yau manifolds, vector bundles and heterotic model building
- Flux compactifications and non-CY manifolds
- (Computational) algebraic geometry and string theory
- M-theory compactifications and F-theory
- String cosmology

Major theme: "Getting the standard model from string theory"

Current students: (Challenger Mishra, Chuang Sun,) Stefan Blasneag, Callum Brodie. Capacity for one new student this year.

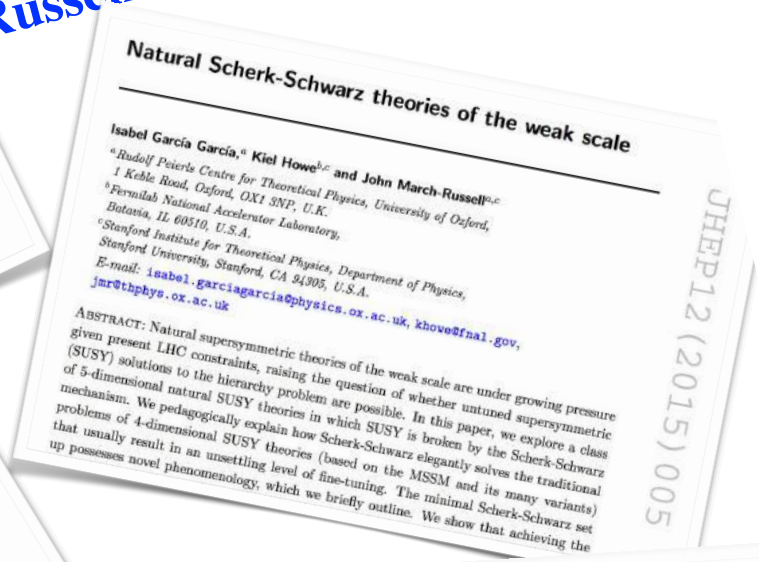
John March-Russell


The String Soundscape at Gravitational Wave Detectors

Isabel García García,[1,*] Sven Krippendorf,[1,†] and John March-Russell[1,‡]

[1] Rudolf Peierls Centre for Theoretical Physics, University of Oxford, 1 Keble Road, Oxford OX1 3NP, UK

We argue that gravitational wave (GW) signals due to collisions of ultra-relativistic bubble walls may be common in string theory. This occurs due to a process of post-inflationary vacuum decay via quantum tunnelling within (Randall-Sundrum-like) warped throats. Though a specific example is studied in the context of type IIB string theory, we argue that our conclusions are likely more


Natural Scherk-Schwarz theories of the weak scale

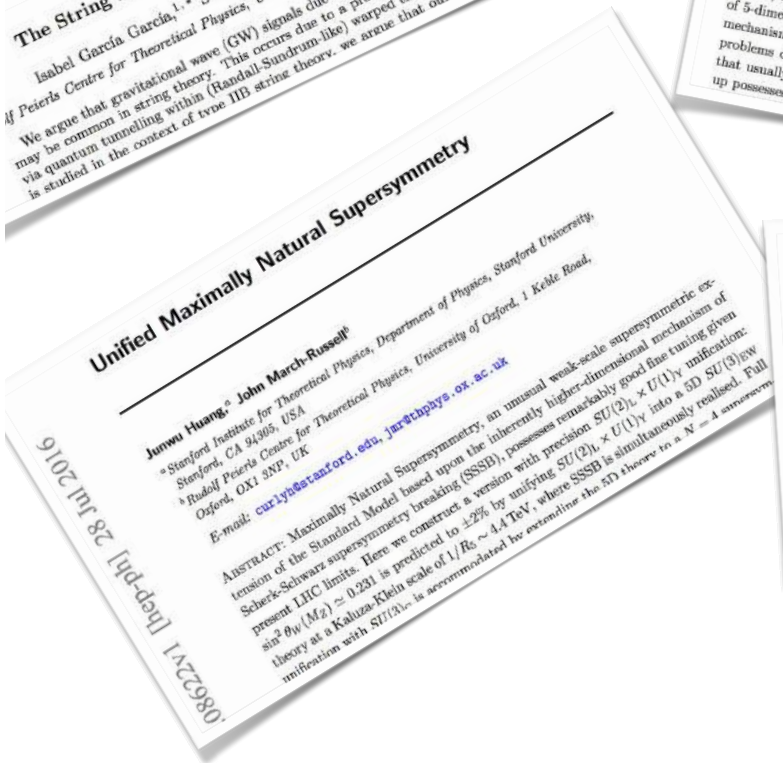
Isabel García García,[a] Kiel Howe[b,c] and John March-Russell[a,c]

[a] Rudolf Peierls Centre for Theoretical Physics, University of Oxford, 1 Keble Road, Oxford, OX1 3NP, U.K.
[b] Fermilab National Accelerator Laboratory, Batavia, IL 60510, U.S.A.
[c] Stanford Institute for Theoretical Physics, Department of Physics, Stanford University, Stanford, CA 94305, U.S.A.

E-mail: isabel.garciagarcia@physics.ox.ac.uk, khowe@fnal.gov, jmr@thphys.ox.ac.uk

Abstract: Natural supersymmetric theories of the weak scale are under growing pressure given present LHC constraints, raising the question of whether untuned supersymmetric (SUSY) solutions to the hierarchy problem are possible. In this paper, we explore a class of 5-dimensional natural SUSY theories in which SUSY is broken by the Scherk-Schwarz mechanism. We pedagogically explain how Scherk-Schwarz elegantly solves the traditional problems of 4-dimensional SUSY theories (based on the MSSM and its many variants) that usually result in an unsettling level of fine-tuning. The minimal Scherk-Schwarz set up possesses novel phenomenology, which we briefly outline. We show that achieving the

JHEP12(2015)005


Unified Maximally Natural Supersymmetry

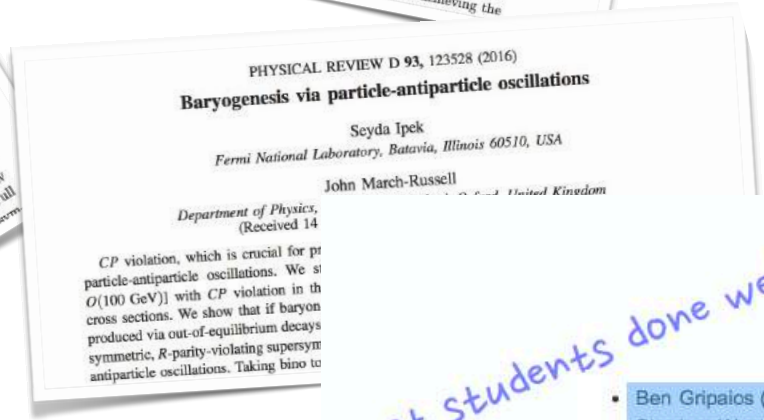
Junwu Huang,[a] John March-Russell[b]

[a] Stanford Institute for Theoretical Physics, Department of Physics, Stanford University, Stanford, CA 94305, USA
[b] Rudolf Peierls Centre for Theoretical Physics, University of Oxford, 1 Keble Road, Oxford, OX1 3NP, UK

E-mail: curly@stanford.edu, jmr@thphys.ox.ac.uk

Abstract: Maximally Natural Supersymmetry, an unusual weak-scale supersymmetric extension of the Standard Model based upon the inherently higher-dimensional mechanism of Scherk-Schwarz supersymmetry breaking (SSSB), possesses remarkably good fine tuning given present LHC limits. Here we construct a version with precision $SU(2)_L \times U(1)_Y$ unification: $\sin^2\theta_W(M_Z) \simeq 0.231$ is predicted to $\pm 2\%$ by unifying $SU(2)_L \times U(1)_Y$ into a 5D $SU(3)_{EW}$ theory at a Kaluza-Klein scale of $1/R_5 \sim 4.4$ TeV, where SSSB is simultaneously realised. Full unification with $SU(3)_c$ is accommodated by extending the 5D theory to a $\mathcal{N} = 4$ supersym

arXiv:1608.06224v1 [hep-ph] 28 Jul 2016


PHYSICAL REVIEW D 93, 123528 (2016)

Baryogenesis via particle-antiparticle oscillations

Seyda Ipek
Fermi National Laboratory, Batavia, Illinois 60510, USA

John March-Russell
Department of Physics, ... United Kingdom

(Received 14

CP violation, which is crucial for pr
particle-antiparticle oscillations. We st
O(100 GeV)] with CP violation in th
cross sections. We show that if baryon
produced via out-of-equilibrium decays
symmetric, R-parity-violating supersym
antiparticle oscillations. Taking bino to

Past students done well...!

tenured/long-term
postdoc

- Ben Gripaios (University Lecturer, Cambridge)
- Stephen West (University Lecturer, Royal Holloway, London)
- Thomas Flacke (Postdoc, Korea University)
- Babiker Hassanain (Finance)
- Francesco Riva (Postdoc, CERN)
- Joao Rosa (Postdoc, Aveiro University)
- Matthew McCullough (Staff Member, CERN)
- Chris McCabe (Postdoc, GRAPPA Institute, Amsterdam)
- David "Doddy" Marsh (Postdoc, Kings College, London)
- Mathew Bullimore (Postdoc, IAS Princeton)
- James Unwin (Postdoc, University of Illinois Chicago)
- Nana Liu (Postdoc, Singapore National University)
- Edward Hardy (Postdoc, ICTP, Trieste)
- Robert Lasenby (Postdoc, Perimeter Institute)
- James Scoville (Major, USAF)
- James Scargill (Postdoc, UC Davis)

Subir Sarkar: *Particle astrophysics & cosmology*

I am at Oxford only *during* term - rest of the time at NBI Copenhagen

Students: *Finishing*: David Kraljic (viva: 21 Oct), Jim Talbert (viva: 19 Sept);
Continuing: George Johnson (with John March-Russell),
Starting: Augustinas Malinauskas (with Uli Haisch)

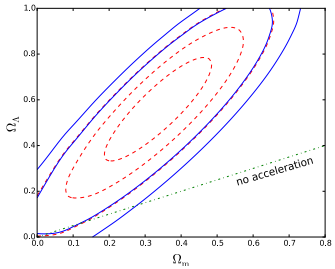
Late universe: *Marginal* evidence (< 3σ) for cosmic acceleration from the Hubble diagram of 740 SN Ia!

+ < 0.1 Bullet Cluster-like systems are expected in the standard ΛCDM cosmology up to $z \sim 0.3$ (whereas > 10 are seen)

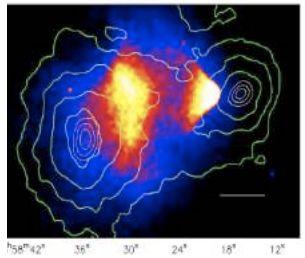
Early universe: Reconstruction of the primordial spectrum of scalar fluctuations from *Planck* data => features may be evidence for multiple inflation (associated non-Gaussianity) … also BICEP2 gravitational wave spectrum has *wrong* sign

High energy neutrinos: I participate in the *IceCube* expt. which discovered cosmic high energy neutrinos … now determining flavour composition + background from atmospheric charm + ruled out ~eV mass sterile neutrino

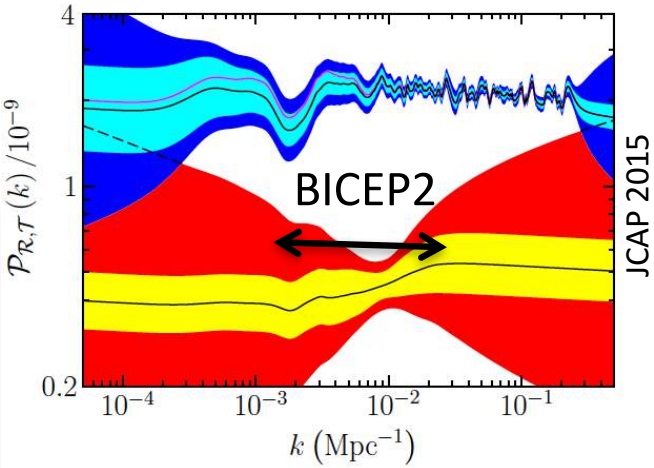
Dark matter: Particularly interested in *asymmetric* relic particles and their phenomenology – and attempts at detection by both terrestrial and cosmic experiments … Ruled out MSSM DM in Sun + Self-interactions in A3827?



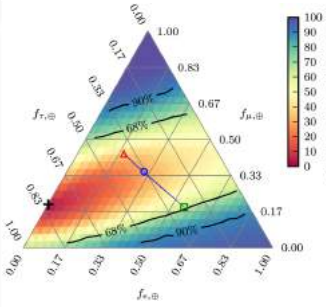
Nat. Sci. Rep. 2016



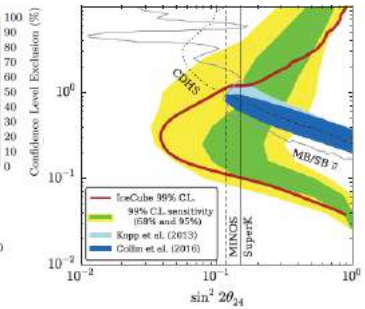
JCAP 2015



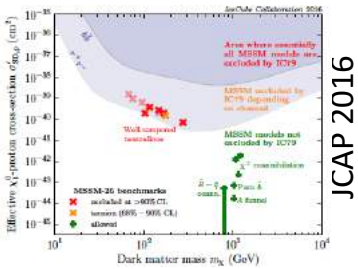
JCAP 2015



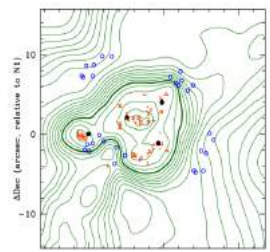
PRL 2015



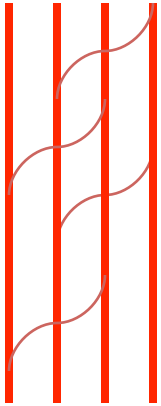
PRL 2016



JCAP 2016



MNRAS 2015



conjectured
exact equivalence

Open strings picture: dynamics of strings & branes at low energy is desribed by a quantum field theory without gravity

STRONG COUPLING

Closed strings picture: dynamics of strings & branes at low energy is described by string theory in curved space in higher dim.

WEAK COUPLING

Allows study of correlation functions, Wilson loops, thermodynamics, transport, non-equilibrium behavior, turbulence, quantum quenches etc in STRONGLY interacting systems (of some class) by using their DUAL weak gravity description

Oxford Holography Group: J. Casalderrey Solana (RSURF), T.Andrade, C.Eling, A.Ficnar, P.Kleinert, J.Probst, N.Gushterov, B.Meiring, A.Starinets

John Wheater

Discretized models of Quantum Gravity & Quantum Geometry

Manifolds ⟷ Graphs

Quantum Field Theory ⟷ Statistical Mechanics

Matrix Models | Rigorous Combinatorics | Numerical Simulation

JW, Ben Niedner graduated 2016, collaborators in Copenhagen & Reykjavik

Giulia Zanderighi

currently on a 5y leave at CERN

My research focuses on LHC phenomenology

Recent/ongoing work includes

- NLO calculations
- NNLO+Parton Shower for Higgs, Drell Yan, associated Higgs production
- resummation of soft/collinear logs in Higgs production with a jet-veto
- finite mass effects in Higgs production
- electroweak ZZ production & application to anomalous couplings
- fully differential calculation of VBF Higgs production at NNLO
- precise determination of the photon PDF

I will be in Oxford all day tomorrow and give the Theory Colloquium on *Precision Higgs study at the LHC*

Emeriti & Visitors

G. Ross - Physics Beyond the Standard Model?

- Has low-scale SUSY been fully tested by the LHC? $M_{W,Z} \ll M_{GUT}, M_{Planck}$?

  ...No, not even the MSSM!

- Scale invariant theories (including gravity) +Pedro, Chris Hill

- Inflation & Black Hole production +Subir, Gabriel German

- Fermion masses and mixings

$e.g. \quad SU(5) \times \Delta(27) \times U(1)$

(1,1) texture zero in $M^D_{q,l,\nu}, M^M_{\nu_R}$

$$\sin\theta_C = \sqrt{\frac{m_d}{m_s}} - e^{i\delta}\sqrt{\frac{m_u}{m_c}}$$

$$m_b \simeq 3m_\tau, m_s \simeq m_\mu, m_d \simeq 9m_e$$

$$\sin\theta_{13} \simeq \sqrt{\frac{m_\odot}{3m_@}} - \sqrt{\frac{m_e}{3m_\mu}}, \sin\theta_{12} = \sqrt{\tfrac{1}{3}}, \sin\theta_{23} \simeq \sqrt{\frac{1}{2}}$$

Michael Teper

Research: non-perturbative properties of field theories -

main tool: lattice field theory

Current topics:

- $SU(N)$ gauge theories and large-N, e.g. arXiv:1609.03873
- $SO(N)$ gauge theories and large-N, e.g. arXiv:1510.07841
- Confining lux tubes and string theory, e.g. arXiv:1602.07634

Nikhef

PDF4BSM
Parton Distributions in the Higgs Boson Era

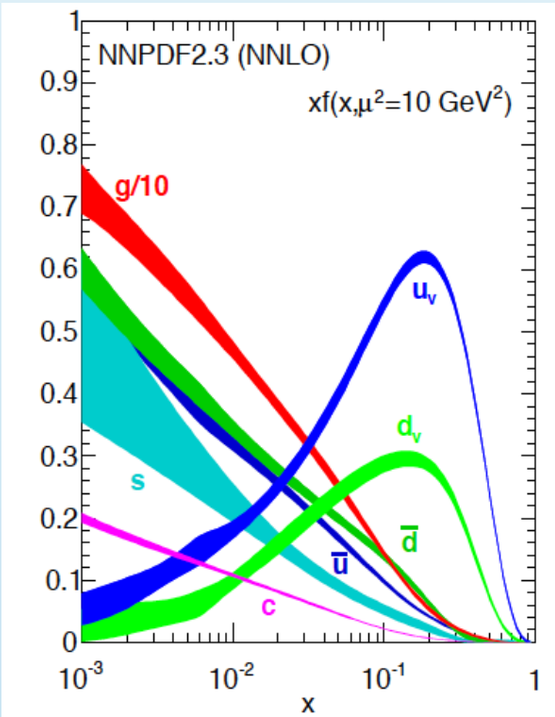
erc
European Research Council
Established by the European Commission

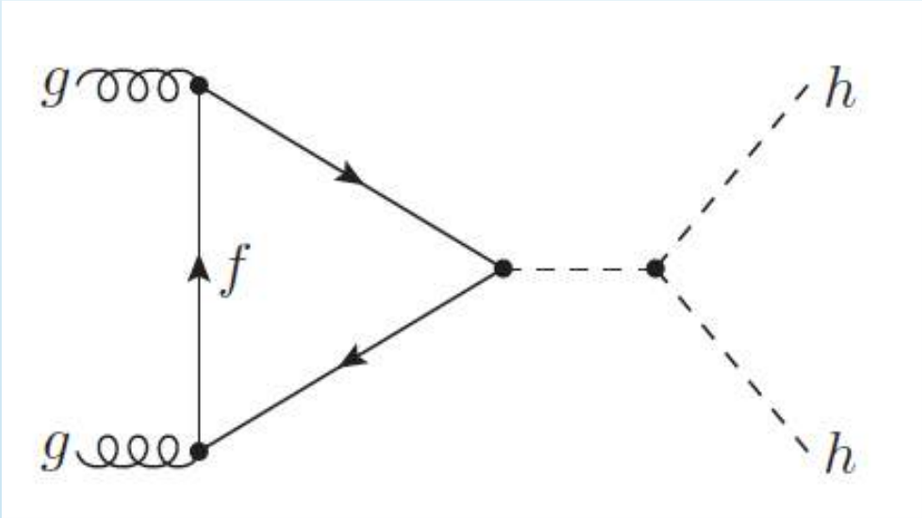
VU VRIJE UNIVERSITEIT AMSTERDAM

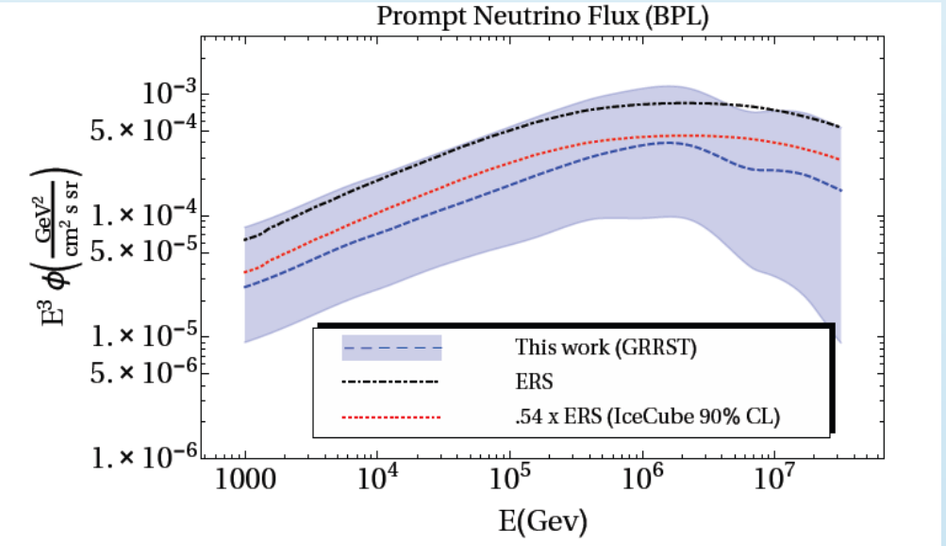
Juan Rojo

VU Amsterdam & Theory group, Nikhef

- ☑ **Parton Distribution Functions (NNPDF)**
- ☑ **QCD phenomenology at the LHC**
- ☑ **Higgs pair production and jet substructure**
- ☑ **Interplay collider/astroparticle physics**





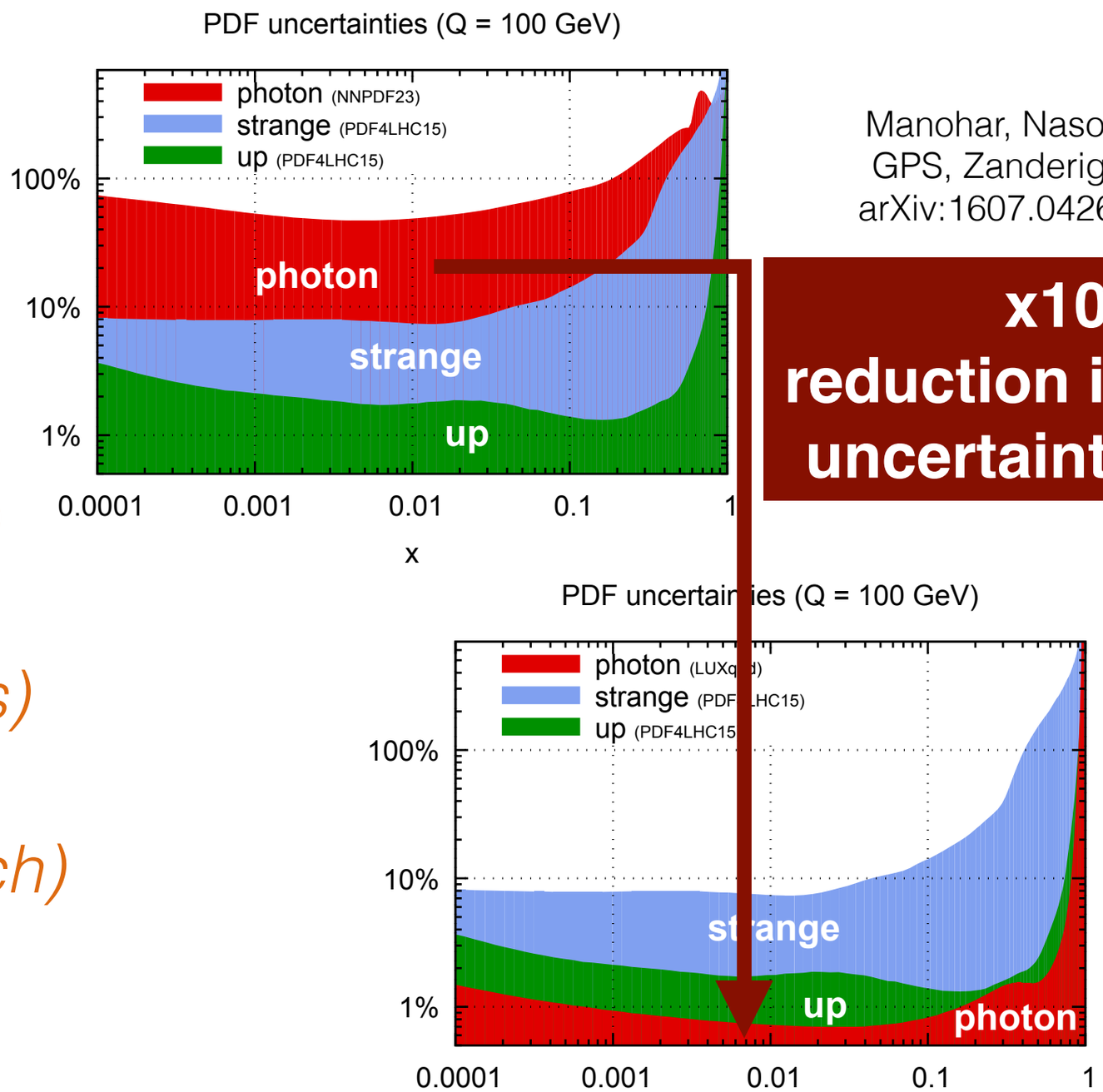


Gavin P. Salam

CERN–TH (also on leave from CNRS, Paris)
& frequent visitor to Oxford

Main interest: LHC physics
mostly from a QCD point of view

- Jet-physics
  (anti-kt algorithm, FastJet)
- Higgs studies
  (e.g. VBF @ NNLO, jet vetoes)
- Parton Distribution Functions
  (e.g. hoppet, LUXqed photons)
- BSM searches
  (jet substructure, ColliderReach)
- heavy-ion collisions



Manohar, Nason, GPS, Zanderighi
arXiv:1607.04266

x100 reduction in uncertainty

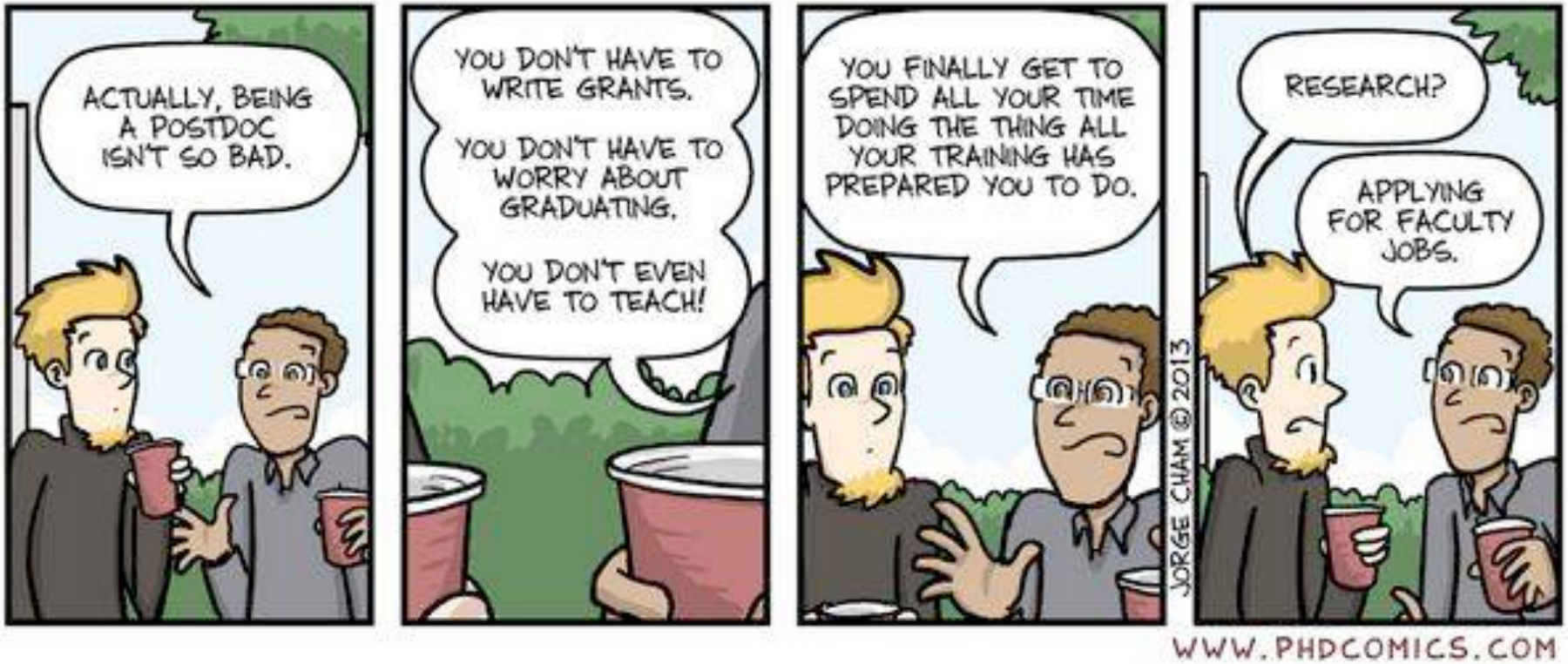
Stephen West

Astro-Particle Physics

ROYAL HOLLOWAY UNIVERSITY OF LONDON

- Dark Matter and Hidden sectors
  - Beyond WIMP DM - freeze-in, Nuclear Dark matter…
  - Link to matter-antimatter asymmetry - asymmetric dark matter
  - Dark matter consequences for stars
  - Dark matter direct and indirect detection
  - How do we probe more complicated hidden sectors?
- BSM physics at the Colliders
  - Long lived states
  - Anything BSM including SUSY
- Electroweak Symmetry breaking
  - Extended Higgs sectors
- Neutrino Physics
- Black Holes
  - Colliding particles in the fields of…
- Early Universe Cosmology
  - Phase Transitions
  - Topological Defects

Postdocs


ACTUALLY, BEING A POSTDOC ISN'T SO BAD.
YOU DON'T HAVE TO WRITE GRANTS.
YOU DON'T HAVE TO WORRY ABOUT GRADUATING.
YOU DON'T EVEN HAVE TO TEACH!
YOU FINALLY GET TO SPEND ALL YOUR TIME DOING THE THING ALL YOUR TRAINING HAS PREPARED YOU TO DO.
RESEARCH?
APPLYING FOR FACULTY JOBS.
JORGE CHAM © 2013
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Tomas Andrade (postdoc at Holography group)

Holography: gravities $\Leftrightarrow$ field theories

From the gravity side: use classical GR to understand strongly coupled field theories

- **Applications to condensed matter:** holographic lattices, transport, metal/insulator transitions
- **Non-relativistic holography:** generalize AdS/CFT to theories with Galilean symmetry
- **Numerical GR in AdS**: time evolution, non-homogeneous solutions (PDE's)

Fady Bishara (Dalitz 4)

Research Interests

- Dark matter model building; rich dark sectors (e.g. flavour structure, compositeness)
- Higgs physics: how to constrain/measure light Yukawas? Minimal or non-minimal EWSB? (Students: let me know if interested, there are suitable LHC pheno. follow up ideas)
- Physics beyond the SM in general

Currently working on/thinking about

- Theo. tools for DM dir. det.: RG effects, HBχPT, HDMET
- Topo./non-topo. solitons (as DM, e.g.) w/IGG, JG, OL, & JMR
- Flavoured DM annihilating into pNGBs of broken flav. symm.

Andreas Braun

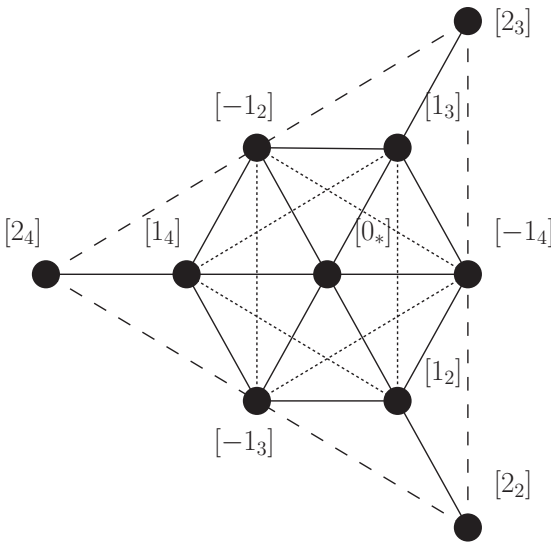
I work on the relation of string theory to established physics

- How can we build the standard model ?
- Are there generic features/correlations ?

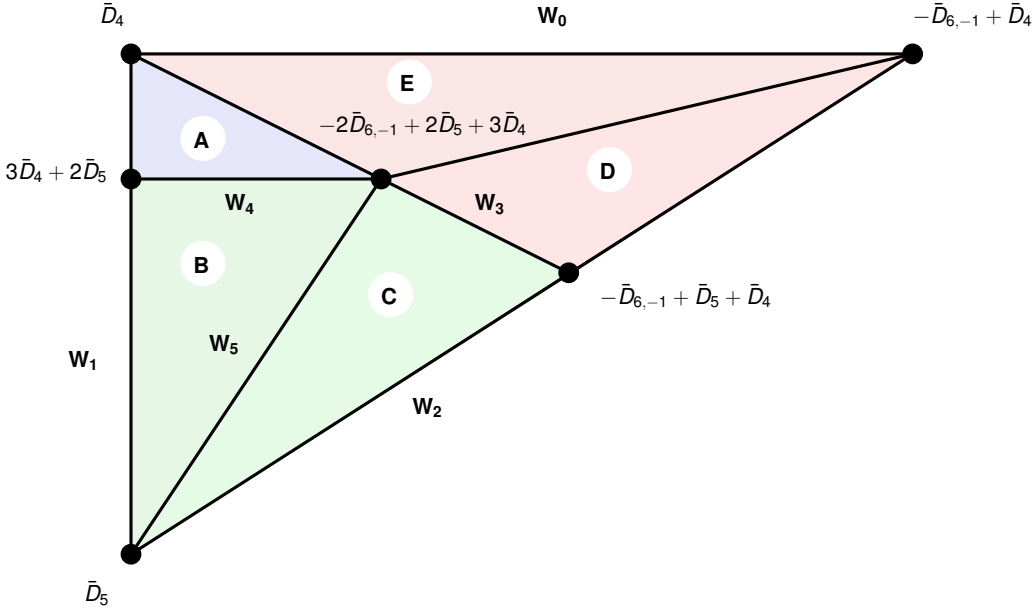
This involves lots of geometry and arithmetic, in particular

- Special holonomy manifolds, polyhedra, ...
- Vector bundles, flux vacua, lattices, ...

Different $K3$ fibred Calabi-Yau 3folds

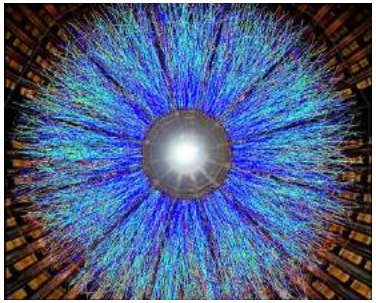


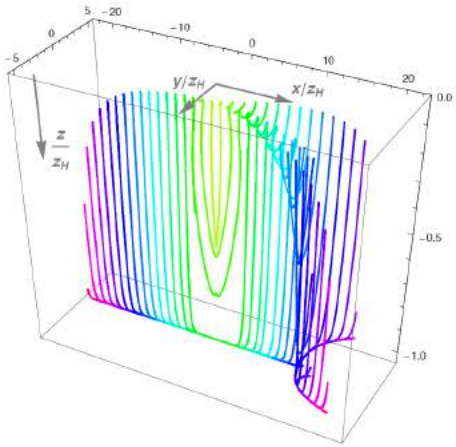
The extended Kähler cone of a Calabi-Yau

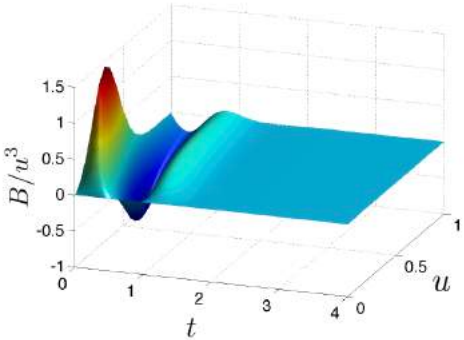


Andrej Ficnar

- Postdoc in Andrei Starinets' holography group
  - PhD in 2014, Columbia University
- Main interest: applications of gauge/gravity duality to QCD and quark-gluon plasma
  - Unique insight into (non-equilibrium) physics of strongly coupled systems
- Recent projects and interests:
  - Holographic jet quenching
    - Holographic 3-jet events
    - Energy loss and equilibration of a baryon-rich QGP
  - Numerical holography
    - Isotropization at finite coupling







Work: String Phenomenology

General: working on connecting string theory with the real world.

Past:
~~SUSY~~, D-brane model building, global string models with moduli stabilisation + local D-brane configurations

Last year and current:
- Constraints on large field inflation in string theory (e.g. 1601.00647)
- Axions, 3.5 keV line and X-ray astronomy (Joe's talk)
- Gravity waves as a probe of string theory (JMR's talk)

Francesco Muia

1st postdoc after my PhD in Bologna

Supervisor: Dr. Michele Cicoli

Dalitz Institute, Room 9b

Research interests: **getting phenomenology from strings**.

String-Pheno

Model building ⟷ **Look for signatures**

Past topics:

1. **Low-energy SUSY** models from string compactifications.
2. String **inflation**.
3. **Baryogenesis** from strings.
4. **Dark matter** in string models.
5. **Dark radiation** in string models.

} **non-thermal cosmology**

Current projects and ideas:

- Axion string inflation (GWs?). ⟶ In collaboration with people based at the PCCP in Paris.
- GWs from string models. ⟶ In collaboration with Dr. S. Krippendorf, Dalitz Institute, Room 9b.
- Non-thermal dark matter. ⟶ In collaboration with Dr. M. Cicoli, Bologna University and ICTP.
- Global string models. ⟶ In collaboration with Dr. M. Cicoli and Dr. P. Shukla, ICTP.

Emanuele R. Nocera, Dalitz 8a

Research interests & activity

1. Parton distributions functions for LHC phenomenology and beyond

   I work as a member of the `NNPDF` collaboration

2. Spin physics and 3D-imaging of the proton

   how do quarks and gluons contribute to the proton spin?

3. The hadronization of partons

   how do quarks and gluons fragment into final-state particles?

4. Nonperturbative models of nucleon structure and their interplay with perturbative QCD

   can we learn something about the nucleon structure from nuclear models?

Personal path

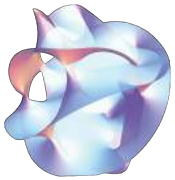
1. born in Aosta, Italy
2. Ms.Sc.[1], Ph.D.[2], PD[3]
3. PDRA since 10/2015

Fabian Ruehle

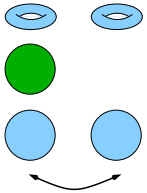
2010: Master at University of Heidelberg
2010 – 2013: PhD at University of Bonn
2013 – 2016: Postdoc at DESY Hamburg
2016 – : Postdoc at Oxford

Physics

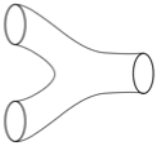
String Theory/Pheno
Particle Physics



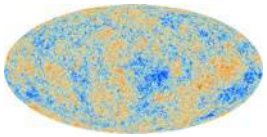
Dualities
Heterotic/F-Theory



Gauged Linear Sigma Models
Worldsheet theories

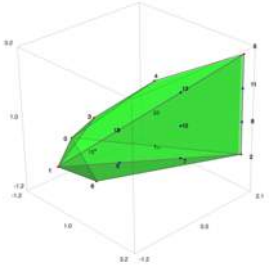


Cosmology
Moduli Stabilization, de Sitter, DM

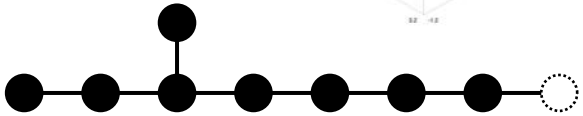


Mathematics

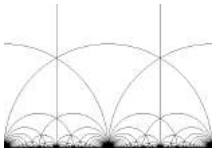
Algebraic / Toric Geometry



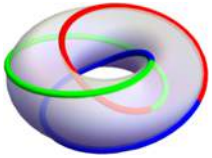
Group Theory



Conformal Field Theory



Knot Theory



Associates

Particle physics

Research themes

High-energy frontier physics

Exploring fundamental physics with high-energy colliders

ATLAS Oxford Group
LHCb Neville Harnew, Guy Wilkinson, Malcolm John

Neutrinos

The group studies the properties of neutrinos, one of the most abundant particles in the Universe.

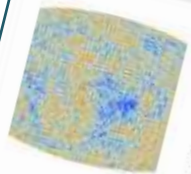
Group Leaders Giles Barr, Steve Biller, Alfons Weber

Liquid Argon Neutrino Experiments
MINOS / MINOS+ Alfons Weber
SNO+ Steve Biller
SoLid Antonin Vacheret
T2K Giles Barr, Alfons Weber

Dark matter and Precision measurements

Particle physics is not just huge detectors and collaborations. We study fundamental particles from a different perspective, with small high precision experiments.

Group Leaders Samuel Henry, Hans Kraus



Cosmology

We lead observational and theoretical work to determine what the dark matter is, what is the dark energy, why they behave the way they do and how did the Universe start off this way.

C-Band All Sky Survey
Cosmic Microwave Background
Cosmological Gravity
Dark Matter & Dark Energy
Euclid Lance Miller, Matt Jarvis
Large-Scale Structure
Supernova Cosmology
Weak Lensing

Mathematical Physics Group

Welcome to the web pages of the Mathematical Physics Group. We are part of the Mathematical Institute at the University of Oxford, and are located on the first floor of the north wing of the Andrew Wiles Building on Woodstock Road: click here for a map.

The group's research is centred around gauge and gravity theories with an emphasis on their quantum field theories. There is also a subgroup working on quantum computation and cryptography. Much of our research is connected in one way or another with string theory; see the string theory pages for a unified view of this group, which includes people in the Theoretical Physics Group in the Department of Physics in addition to the Mathematical Institute. This includes Calabi–Yau manifolds and related heterotic geometry, AdS/CFT and twistor theory & scattering amplitudes. Much of the work of the group impacts on mathematics as well as physics, and we enjoy close relations with the Geometry Group in the Mathematical Institute. More detailed descriptions of our Research Areas may be found by exploring the panel on the left. The specific research interests of individual members are contained in their department profiles, which can be accessed from our Members page.

Astrophysics

- Circa 29 faculty
- Head of sub-dept: Prof Steve Balbus
- Areas
  - Instrumentation (ELT,SKA,CBASS,WEAVE, ...)
  - Observations (CMB, Optical, Radio, IR. Xray)
  - Theory (compact objects, galaxies, large scale structure, early universe)

Surveys

- CMB: Planck and ACTPol, AdvACT, Simons Array, CBASS
- Radio: LOFAR, MeerKat and SKA
- Optical/infrared: Weave, Euclid, LSST but also KIDS, RCSlens, LSST
- ELT

i.e. Oxford Astro is involved most big surveys.

Cosmology

- Erminia Calabrese (CMB)- Planck, ACTs
- Julien Devriendt (Galaxy evolution and formation)- computational and analytical techniques
- Pedro G Ferreira (Cosmology theory)- Early universe, general relativity, large scale structure
- Lance Miller (Weak Lensing)- CFHTLenS, Euclid, KIDS
- Joe Silk (Astroparticle and Galaxies)- dark matter, large scale structure, CMB
- Adrianne Slyz (Galaxy evolution and formation)- computational and analytical techniques

Beecroft Institute

- David Alonso (LSS)
- Emilio Bellini (GR, Early Universe)
- Tessa Baker (GR, LSS)
- Rafael Alves Batista (Astroparticle)
- Elisa Chisari (WL)
- Clotilde Laigle (LSS, Galaxies
- Julian Mertens (WL)
- Johannes Noller (GR, Early Universe)
- Mark Richardson (LSS, Galaxies)
- David Sloan (Inflation, Early Universe)

String Theory Group (Maths Branch)

* James Sparks ; AdS/CFT
* Chris Beem ; N=4 SYM, conformal field theories
* Fernando Alday ; integrability, strong coupling limit of N=4 SYM
* Lionel Mason and Andrew Hodges ; twistor string theory, amplitudes of N=4 SYM
* Sakura Schafer-Nameki ; F-theory, heterotic string theory
* Xenia de la Ossa and PC ; CY manifolds and heterotic string theory, non-Kähler manifolds