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*

Conformal field theory and quantum gravity

Supported by: STFC, EU, Royal Society...

Gauge-string duality, holography, AdS-CFT

+ presently 10 postdocs & 20 DPhil students

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

---

**Andrei Starinets** 2008-

String theory and phenomenology

**Giulia Zanderighi** 2007-

Phenomenology of electroweak and strong interactions

**Uli Haisch** 2011/16-

**Joe Conlon** 2008/14-

Physics beyond the Standard Model

**John March-Russell** 2002-

Particle astrophysics and cosmology

**Subir Sarkar** 1990/98-

---

* => 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

---

* Jack Paton, Ian Aitchison, John Taylor, Chris Llewellyn-Smith, Frank Close, Graham Ross, Mike Teper

**Andre Lukas** 2004-

Emeriti: Jack Paton, Ian Aitchison, John Taylor, Chris Llewellyn-Smith, Frank Close, Graham Ross*, Mike Teper*

---

Supported by:

STFC, EU, Royal Society...

---

**John Wheater** 1986-

---

**Supported by:**

STFC, EU, Royal Society...

+ presently 10 postdocs & 20 DPhil students

---

**http://www2.physics.ox.ac.uk/research/particle-theory**
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.
HOW PROFESSORS SPEND THEIR TIME

How they actually spend their time:
- Teaching: 59%
- Research: 18%
- Service: 23%

Source: Higher Education Research Institute Survey (1999)

How departments expect them to spend their time:
- Research: 175%
- Teaching: 20%
- "Service": 20%

How Professors would like to spend their time:
- Don't tell me what to do

WWW.PHDCOMICS.COM
Heavy Ion Collisions, Holography and Jets

- Extremely high temperatures
  \[ T > 2 \times 10^{12} \text{ K} = 170 \text{ MeV} \]
- A new state of matter
  Quark Gluon Plasma
- The most perfect fluid

LHC: Pb-Pb @ \( \sqrt{s} = 2.76 \text{ TeV} \)

- 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

Energy Density

![Graph showing energy density with axes t and z]
AGNs are bright point sources of photons

Dark matter or ALPs can produce features in this spectrum

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……
Apart from heavy-ions
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.
**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

**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 \(\Lambda\)CDM cosmology up to \(z \sim 0.3\) (whereas > 10 are seen)

**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 \(\sim\)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?

---

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

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

STRONG 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

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
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 SUSY been fully tested by the LHC? 
  \[ M_{W,Z} \ll M_{GUT}, M_{Planck} \]
  \[ \wedge \]
  \[ \text{...No, not even the MSSM!} \]

- Scale invariant theories (including gravity) 
  \[ + \text{Pedro, Chris Hill} \]

- Inflation & Black Hole production 
  \[ + \text{Subir, Gabriel German} \]

- Fermion masses and mixings 
  \[ e.g. \ SU(5) \times \Delta(27) \times U(1) \]
  \[ (1,1) \text{ texture zero in } M_{\Delta, L}, M_{\nu} \]
  \[ \sin \theta_C = \sqrt{m_\mu/m_\tau} - e^{i \delta} \sqrt{m_\tau/ m_\mu} \]
  \[ m_b = 3m_\tau, m_s = m_\mu, m_d = 9m_e \]
  \[ \sin \theta_{13} = \sqrt{m_\mu/m_\tau}, \sin \theta_{12} = \sqrt{3}, \sin \theta_{23} = \sqrt{1/2} \]
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
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
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
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

Black Holes
- Colliding particles in the fields of…

Electroweak Symmetry breaking
- Extended Higgs sectors

Early Universe Cosmology
- Phase Transitions
- Topological Defects

Neutrino Physics
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.
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

Research interests: getting phenomenology from strings.

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.

Current projects and ideas:
- Axion string inflation (GWs?).
- GWs from string models.
- Non-thermal dark matter.
- Global string models.

In collaboration with people based at the PCCP in Paris.
In collaboration with Dr. S. Krippendorf, Dalitz Institute, Room 9b.
In collaboration with Dr. M. Cicoli, Bologna University and ICTP.
In collaboration with Dr. M. Cicoli and Dr. P. Shukla, ICTP.
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, PD³
3. PDRA since 10/2015
2010: Master at University of Heidelberg
2010 – 2013: PhD at University of Bonn
2013 – 2016: Postdoc at DESY Hamburg
2016 – : Postdoc at Oxford

Fabian Ruehle

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 Neillie Harrow, 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, Aliona Weber

Liquid Argon Neutrino Experiments
MINOS / MINOS: Aliona Weber
SNOLab Steve Biller
SNO+ Anahita Vachher
T2K Giles Barr, Aliona 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 Harpy, 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 departmental 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