Centre for Research in String Theory:

David Berman
Andreas Brandhuber
Sanjaye Ramgoolam
Rodolfo Russo
Bill Spence
Steven Thomas
Gabriele Travaglini
Brian Wecht (new faculty arriving in October)
+2 postdocs + 10 graduate students.
String Theory and hidden geometries

Sanjaye Ramgoolam

Queen Mary, Univ. of London
From falling apples to orbiting planets, Newton explained that there is one underlying equation:

\[ F = \frac{GMm}{r^2} \]
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\[ F = \frac{GMm}{r^2} \]
FORCE of gravity ↔ CURVATURE of Spacetime
Now the key player is the metric $g_{\mu\nu}(t = x_0, x_1, x_2, x_3)$ which describes the curvature of space-time. For each point in spacetime $g_{\mu\nu}$ is a matrix with $\mu, \nu \in 0, 1, 2, 3$.

And the equation is

$$\delta S = 0$$

where

$$S = \int dt dx_1 dx_2 dx_3 R \sqrt{g}$$
There are three other fundamental forces, e.g. electromagnetic forces.

These are described with Quantum Electrodynamics - QED - Quantum → uncertainty principle

\[ \Delta x \Delta p \geq \hbar \]

The better we know where an electron is, the less we know where it is going.
The other deep wisdom of QED is that electric force only exists because light exists.
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Force is exchange of photons (particles of light).
String theory shows that QED and gravity can be unified if different particles are different vibration modes of strings.
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Different vibration modes → different energies and spins.
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Different vibration modes $\rightarrow$ different energies and spins.

different particles.
Feynman diagram becomes a string interaction diagram
Another example of Hidden geometry:

Unification is possible if:
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Unification is possible if:

Point $\rightarrow$ circle

line $\rightarrow$ cylinder

Feynman diagram $\rightarrow$ string diagram
80’s : This only works if the space-time is **ten-dimensional**, i.e in addition to the four we know, there are another **six dimensions**.
90’s : Three major discoveries in string theory.

All three challenging how we think about space-time.

And we are still trying to work through the implications.
Eleventh dimension : M-theory

Build a string universe : 10 spacetime dimensions, and one variable coupling constant.
Eleventh dimension: M-theory

Build a string universe: 10 spacetime dimensions, and one variable coupling constant.

It turns out that this string universe is an 11 dimensional universe (with an extra space dimensions) with no adjustable coupling constant.
Branes: Alternatively, the world can be a 3-dimensional brane living in ten dimensional universe.
Gauge-String duality.

It was discovered that a 3+1 dimensional world without gravity: a MATRIX generalization of photon theory can be physically equivalent to a theory with strings, branes and gravitons in 10 dimensions.
Generalized geometry in string and M-theory: Berman + student Musaev

Electrons are charged under the 4-vector potential $A_\mu$. Strings: $B_{\mu\nu}$. Membranes of M-theory: $B_{\mu\nu\lambda}$
Some recent themes at QMUL

Generalized geometry in string and M-theory: Berman + student Musaev

Electrons are charged under the 4-vector potential $A_\mu$. Strings: $B_{\mu\nu}$. Membranes of of M-theory: $B_{\mu\nu\lambda}$

The metric $g_{\mu\nu}$ which describes curvature of space-time, is generalized to a metric in a doubled space – which includes these potentials.

This allows generalizations of the geometries that the six “small dimensions” of string theory can form.
Fuzzy geometry of branes:

\[ \Delta X \Delta P > \hbar \]

\[ \downarrow \]

\[ \Delta X \Delta Y > \Theta \]

(Ramgoolam, Spence, Thomas + students Papageorgakis, Mc Namara)
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(Ramgoolam, Spence, Thomas + students Papageorgakis, McNamara)

Fuzzy branes in inflationary models of cosmology
(Thomas, Ward + collaborators in Astro Unit.)
Gauge-string duality: Quantum states to geometries

( Ramgoolam, Russo + students and postdocs Pasukonis, Brown, Turton, Gili, Georgiou, Heslop, Kimura. )

Use the large $N$ Matrix photon theory in four dimensions, to construct the quantum states of branes and strings in the dual spacetime in ten dimensions.
Simple mathematical models of gauge-string duality can be found using classical mathematics such as Riemann existence theorem and Schur-Weyl duality which can be used to relate the combinatorics of matrix models (zero dimensions) to that of string worldsheets (in two dimensions).

(Ramgoolam + postdocs/students Jejjala, Rodriguez-Gomez, Pasukonis, Garner and external collaborators Robert de Mello Koch. )
Directions towards particle physics:

Rodolfo Russo: **high energy string scattering** (with Will Black and external collaborators e.g. Veneziano)

**Supersymmetry breaking** (Rodolfo Russo, Steven Thomas, with students Mc Garrie, Koschade)

**Amplitudes**: Brandhuber, Spence, Travaglini + postdocs Heslop, Gang Yang, Congkao Wen.
A unification of surprises?

String theory has given us many surprises:

- Ten dimensions is secretly eleven.
- A 3+1 dimension world can be a brane in 10 dimensions.
- A theory of Matrix photons in 4 dimensions can encode gravity in 10 dimensions.
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What is it really telling us about space-time?