School of Mathematics, Statistics and Physics
Vision Statement

The School will conduct world-class research in mathematics, statistics and physics evidenced by being ranked in the top ten in future UK Research Excellence Framework for Mathematics and top twenty for Physics. The School will seek opportunities to broaden its research to enable it to work on societal problems, nationally and globally. All students in the School will be supported to reach their full educational potential. They will develop strong disciplinary based skills, together with the awareness and ability to deploy them in a wide range of careers. Diversity and inclusivity will become embedded in how the School is run, creating an environment that is caring and supportive.
To conduct world-leading research in mathematics, statistics and physics and to seek opportunities to use our research expertise in support of business, industry and the development of evidence-based policies for UK government departments and agencies.

To deliver a portfolio of Undergraduate and Postgraduate degree programmes in mathematics, statistics and physics that address the needs of local, national and international student populations, and which provide an outstanding educational experience for all. The School will enhance the degree programmes across the University through the provision of high-quality service teaching.
Investing in our People

Our staff are at the core of what we do in delivering excellent teaching and research in mathematics, statistics and physics. Most of our staff are in the first half of their career, as we have expanded the School rapidly by appointing rising stars over the last 10 years. We encourage new staff to build their research portfolio and play a central role in working with senior academics in running the School. Equality and diversity is at the centre of the School’s policies in addressing the needs of its staff.

Equality and Diversity

The School has been recognised by the University for its advertising campaigns to promote diversity. Our goal is to continue to promote and increase staff diversity and gender equality through diversity design, training and other initiatives. The School is flexible in addressing the needs of its staff, providing specific policies for maternity/paternity leave, flexible working, unpaid leave and Sabbaticals. We are working to secure the Athena Swan Silver award by embedding good practice and developing an inclusive culture that values all staff.

Restart Fellowship

For staff and research students who have taken career breaks we are proud of our Restart Fellowship, which enables them to continue their exciting career paths at Newcastle University.
Our strategic educational objectives are:

1. Develop an outreach and recruitment programme that addresses the needs of local, national and international populations.
2. Provide a portfolio of degree programmes to enable overall growth in student numbers, alongside improving entry grades.
3. Ensure an inclusive and excellent student experience for all.
4. Enhance degree programmes across the Faculty and University through the provision of high quality service teaching.
5. Provide all students with the opportunity to develop their skills to enable them to fulfil their potential.

Undergraduate Education

Our degree programmes are accessible for all backgrounds. We provide excellent core knowledge in the curriculum, we focus on an inclusive and excellent student experience and provide students with opportunities to develop their skills (e.g. problem solving). We are accredited by the IMA (maths programmes) and IOP (physics programmes).

Undergraduate for Life Strategy

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I enjoyed every minute of my work placement and it’s really shaped my future, giving me lots to talk about in interviews and helping me to secure a fantastic job once I graduate.

Danni Martin

Danni Martin accepting her Pride of Newcastle University Award for Outstanding Contribution to the Workplace.
Postgraduate Education

We have a thriving multi-national community of over 80 postgraduate research students, across our PhD, MPhil and MRes programmes. These students work on topics which range from the fundamental and theoretical to the applied and interdisciplinary. A significant role is played by our Centre for Doctoral Training in Cloud Computing for Big Data, which is training the next generation of data scientists with the School of Computing. We have a history of success in running collaborative postgraduate projects with external partners from industry, government and overseas universities.

All of our postgraduates are supported by expert supervision, advanced technical training and state-of-the-art facilities, such as our high-performance computers and clean rooms. Our postgraduates also benefit from tailored professional development to equip them with a broader range of high-level skills for their future, for example, management, outreach, teaching and entrepreneurship.

Our strategic postgraduate objectives are:

1. Expand postgraduate research across disciplinary themes and inter-disciplinary challenges.
2. Develop a portfolio of Masters programmes providing in-demand high-level skills and knowledge.
3. Grow our collaborative postgraduate research with external partners.
4. Offer an outstanding research training and environment, with access to state-of-the-art facilities.
5. Ensure a supportive and inclusive student experience, with broad development opportunities.

The EPSRC Centre for Doctoral Training in Cloud Computing for Big Data is an innovative and highly prestigious programme, offering the opportunity to study for a PhD in an exciting, new area in which there is an acute skills shortage.
Our research is divided into the following groups:

- **Pure Mathematics**
  - Analysis
  - Algebra

- **Applied Mathematics**
  - Geophysical and Atmospheric Fluid Dynamics
  - Quantum Matter
  - Relativity and Cosmology
  - Mathematical Biology

- **Statistics**
  - Bayesian
  - Spatial

- **Physics**
  - Emerging Technology and Materials
  - Quantum Matter Relativity and Cosmology
  - Geophysical and Spatial Astrophysical Fluid Dynamics
  - Mathematical Biology
  - Applied Mathematics
  - Pure Mathematics
  - Statistics
  - Physics
Geophysical and Spatial Astrophysical Fluid Dynamics

What we do
Research on fluid and gas dynamics across a range of geophysical and astrophysical topics including the Earth’s atmosphere and oceans, planets, stars, galaxies and galactic plasmas. An astrophysical and geophysical plasma and fluids are affected by magnetic fields, which research revolves around studies of magnetic hydrodynamics (MHD). We carry out both analytically and numerically involving high-performance computing with sophisticated numerical codes.

Research priorities
Our present research priorities are listed below, although we welcome research students and fellows to work on topics that align with our overall interests:

- Atmospheric and oceanic dynamics
- Fluid dynamics of planetary interiors
- Solar magnetohydrodynamics
- Solar tides
- Stellar and planetary interiors
- Galaxies and interstellar mediums

Quantum Matter

What we do
This research group is concerned with the theoretical study and modelling of the quantum properties of matter and light, from the fundamental to the technological. We live in a quantum era, where the quantum mechanical properties of matter and light are being probed and tested to unprecedented levels, and exploited into quantum technologies such as precision clocks and quantum computers.

Research priorities
The Quantum Matter research group covers a range of different topics:

- Bose-Einstein condensation
- Quantum fluids
- Ultra cold gases
- Superfluid liquid helium
- Exciton-polariton condensates
- Solitons, vortices and turbulence
- Light-matter interaction
- Quantum optics
- Fundamentals of quantum mechanics
- Quantum transport

We have a strong international reputation in this area of research. We collaborate with leading experimental and theoretical experts worldwide (including at Athens, Helsinki, Lancaster, Melbourne, New York, Osaka, Prague, Sao Paulo, Trento and Tubingen).

Relativity and Cosmology

What we do
This research group focuses on the Big Bang and fundamental physics. In recent years, astronomical observations and particle physics experiments have shown that very large scales and very small scales are ruled by the same physical theories. This exemplifies the interdisciplinary nature of the very early universe. Relativity has helped to form a new branch of physics, known as Particle Astrophysics, which is becoming increasingly recognised as a key research area.

Research priorities
The Particle Astrophysics group aims to use the early universe to test the consistency of new developments in particle physics and quantum gravity. An example is the five dimensional brane-world theory that has arisen from superstring models. We are also investigating the effects of quantum gravity on particle physics experiments.

Our work links directly to satellite observations of the universe today. This enables us to explain the properties of the universe before microwave radiation, and also provides a set of initial conditions for galaxy formation, linking it with research areas in astrophysical fluid dynamics.

Mathematical Biology and Archaeology

What we do
The work done by this interdisciplinary group uses mathematics to model, understand and interpret biological and archaeological systems. This group works in collaboration with cell and animal biologists, astronomers, climate scientists and environmental scientists.

Research priorities
- Biological fluid dynamics
- Biomechanics
- Cell biology
- Social dynamics
- Natural and engineered ecological systems
- Modelling of prehistoric systems

Mathematical Biology

Research priorities
- Very early universe
- Dark matter and dark energy
- Universe in the lab
- Origin of large-scale structure
- Quantum theories of gravity
What we do

The beautiful and far-reaching theory of functions of a complex variable is one of the great achievements of mathematicians of the late 19th and early 20th centuries. We are interested both in the application of complex analysis to operators and in the use of operator theory to prove results in complex analysis.

Linear operators, mainly on Hilbert space, have a highly developed theory, arising partly from classical mathematical physics. More recently, there have been many applications to engineering.

Algebraic properties of collections of operators have come to be important in quantum theory. Questions about them have come to play a fundamental role in several branches of mathematics, particularly where there is a need to analyse non-commutative generalisations of classical objects of study.

Topological homology concerns questions on the structure and properties of Banach and C*-algebras. Mostly it describes their properties from the viewpoint of homological algebra.

Our research priorities

•  Complex Analysis
•  Operator Theory and Operator Algebras
•  Topological Homology

What we do

Homological algebra was invented to formalise aspects of algebraic topology, but has developed into something far more ambitious. With the advent of triangulated categories and, more generally, model categories, it can be seen as a unifying theory of many areas of mathematics, stretching from topology over algebra to analysis.

An association between geometry and group theory was first formalised in the late 19th century, that geometric constructions can be understood in terms of their symmetry groups. Notable successes are applications in 3-manifold theory, complex dynamics, first order logic, the theory of formal languages, Riemannian geometry and representation theory.

Representation theory is a study of symmetry. It is concerned with understanding all possible ways in which some algebraic structure (a group, an associative algebra, a Lie algebra) can be represented as linear operators on some vector space. In some ways it is linear algebra for groups.

Our research priorities

•  Homological Algebra
•  Geometric Group Theory
•  Representation Theory
What we do
We have long had interests in the use of modern computationally intensive Bayesian methods for solving difficult statistical inference problems involving complex data.

Our research covers many areas of application and in recent years, has focused increasingly in the application areas of biostatistics and stochastic systems biology. There is considerable overlap between the work of this group and that undertaken in the Electronic Biometrics and Electronic Systems Biology group.

Our research priorities:
- Analysis of high dimensional data sets in stochastic and deterministic models using partially observed experimental data, particularly biological and environmental
- Data integration in biostatistics
- Development of methods of quantification of uncertainty in the scientific process
- Phylogenetics, particularly the origin of the eukaryotes
- Bayesian approaches to functional genomics analysis
- Bayesian linear methods
- Multiscale time series and forecasting
- Representation of subjective prior information for covariance matrices
- Spatial and temporal modeling of real data
- Environmental design
- Environmental informatics
Emerging Technologies and Materials

What we do
The group has an encompassing research programme with an emphasis on applications approach. Our research covers all aspects of the technology development cycle - from computational materials discovery, through materials development and characterisation, to optical and electrical devices.

We are home to:
- Two clean rooms with start-to-finish fabrication capability
- Labs with a full complement of characterisation tools
- The Photon Science Laboratory
- AIMPRO and FALCON ab-initio materials modelling

Our research priorities
The Emerging Technologies and Materials group covers a range of different research topics, including, but not limited to:
- Quantum mechanics
- Low-dimensional materials
- Gallium arsenide
- Semiconductors for extreme environments
- Photonics
- Energy materials
- Optogenetic devices
- Nanotechnology

We have a global reputation with major collaborations spanning 25 countries and covering five continents.

Physics
The large scale structure of the universe is formed by the gravitational interaction of large masses as in this computer simulation from the Relativity and Cosmology group.

Ab initio quantum mechanical simulation of a silicon quantum dot

Density snapshots (incoherent and coherent parts) of an ultracold atomic gas in a harmonic trap

Quantum turbulence in an ultracold ferrofluid
Researchers from the Industrial Statistics Research Unit have developed a Bayesian forecasting tool for Northern Gas Networks that provides them with accurate gas demand forecasts for the UK’s gas network. The system ensures the efficiency and reliability of the Northern UK gas distribution network and provides a more accurate prediction of how much gas they will need from the national network. The long-term gas demand forecasting tool predicts demand daily for North East and Northern regions of the UK. It accounts for large-scale variations in annual gas demand, that include effects of seasons and times when demand is expected to fluctuate, such as during bank holidays.

Business and Engagement

Our School has a strong track record in working with business, industry and research, informing evidence-based policy for government departments, agencies and devolved assemblies.

Industrial Statistics Research Unit (ISRU)

ISRU seeks collaborative research opportunities between the statisticians in the School and a wide range of external stakeholders. The unit anticipates statistical projects with a number of external partners including:

Business and Engagement Advisory Board (BEAB)

The School has established a BEAB to help expand our collaborative research in mathematics, statistics and physics with external stakeholders. The BEAB will take part in a range of seminars, workshops and events. The School will be working closely with the BEAB to identify potential research projects and opportunities.

Engagement between Enzen and Newcastle University achieved the desired business outcomes. The relationship with the University has been taken to the next level through multiple initiatives.

Subramani Venkatachalam, Account Manager, Enzen.
Advanced clinical diagnostics and monitoring of cornea damage

Thermal and chemical burns of the eye are a serious injury that result in chronic eye pain, poor vision, and frequent blindness. Monitoring the cornea post-surgery has proven difficult for ophthalmologists as subtle, gradual changes are challenging to identify without dedicated quantum analysis. Researchers in applied mathematics and physics have developed advanced, computer-aided methods to analyse microscopic cornea photographs to facilitate diagnostics and monitoring of cornea damage. The project will provide a suitably accurate and reproducible diagnostic and monitoring method to assist in day-to-day medical decision making.

Software tools for road safety hotspot prediction

Vision Zero is a multi-national road safety project that aims to achieve a highway system with no fatalities or serious injuries involving road traffic. This project, in conjunction with PTV Group, feeds into this vision. The statistical models enable a proactive approach to the treatment of road safety hotspots, with road safety schemes deployed based on predicted accident counts, as opposed to reactive treatment strategies based on observed accident counts. The software tools developed as part of the project are used by around 20 road safety organizations worldwide, including local authorities in the UK, Lisbon municipality, and New York City Department of Transportation.
Collaborations with non-academic partners:

- Modelling tree epiphytotics in the UK. Department for Environment, Food & Rural Affairs
- Modelling anoxic water in the Clyde estuary. Scottish Environmental Protection Agency
- Analysis of leakage within pipeline systems at medium pressure. Northern Gas Networks Ltd, Cadent Gas Ltd, Scottish Gas Networks, Wales & West Utilities Ltd
- Keeping track of nuclear fuel in reprocessing. Sellafield Ltd
- Preventing blood clots in children undergoing kidney dialysis. NHS
- Data analytics and data mining in the utilities sector. Green Global & the utilities sector
- Statistical research for pipeline defect detection and sizing. Advanced Engineering Solutions
- Development of analytical methods for flexible integrated circuits. Prognostic
- Statistical methods to develop a verification and validation strategy for product design. Orange Safety UK Ltd
- Statistical techniques for engineering with advanced materials. The Alan Turing Institute. M*ASMO
- Quantifying functional co-variation in calcium handling proteins in cardiac myocytes. The Alan Turing Institute. British Heart Foundation
- Economic evaluation and adoption plan for the HeadStart test for patients with COPD. Hologic
- Simulated spread of tree disease through the UK tree distribution

Key Facts:

Graduates in work, or further study 6 months after graduating: 90%

- Postgraduate Research Associates/KTPs: 19
- Undergraduates: 175
- Academic Staff: 70
- Professional Services Staff: 15
- Maths & Stats Students: 750
- Physics Students: 16
- Grant Award: £1.10m in 2018
- Total of Research Associates/KTPs: 19
- Total of Maths & Stats Students: 750
- Total of Professional Services Staff: 15
- Total of Academic Staff: 70
- Total of Undergraduates: 175
- Percentage of Maths & Stats Students: 83%
- Percentage of Physics Students: 19%
- Percentage of Undergraduates: 16%
- Percentage of Grant Award: 15%