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Standard PROPOSAL

Document Status: With Owner
STFC Reference:

Ernest Rutherford Grants 2014

Organisation where the Grant would be held

Organisation	Imperial College London	Research Organisation Reference:	P53869
Division or Department	Dept of Physics		

Project Title [up to 150 chars]

Global searches for new Higgs physics with GAMBIT

Start Date and Duration

a. Proposed start date	31 March 2015	b. Duration of the grant (months)	36

Applicants

Role	Name	Organisation	Division or Department	How many hours a week will the investigator work on the project?
Principal Investigator	Dr Pat Scott	Imperial College London	Dept of Physics	7.5

Proposal Classifications

Classification Areas:

Research Areas are the subject areas in which you may have expertise and you should select at least one of these.

To add or remove Research Areas use the relevant link below.

Subject	Topic	Indicator %	Keyword
Particle astrophysics	Cosmology	5	
Particle astrophysics	Direct Dark Matter Detection	15	
Particle astrophysics	Gamma Ray Astronomy	15	
Particle physics - theory	Phenomenology	50	
Particle physics - theory	Quantum Field Theory	15	

Qualifiers:

Qualifiers are terms that further describe the area of research. Please ensure you complete this section if relevant. To add or remove Qualifiers use the links below.

Type	Name
Approach	Exploitation of existing datasets
Approach	Large new datasets
Approach	Quantitative

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Approach	Technique/Method Development
Approach	Theory Development
Collaboration location region	England
Collaboration location region	Mediterranean
Collaboration location region	North America
Collaboration location region	Oceania
Collaboration location region	Scandinavia
Collaboration location region	Scotland
Collaboration location region	Western Europe
Project Engagement by Sector	Academic Users
Theoretical Methods	T&M ab initio approaches
Theoretical Methods	T&M Correlation Analysis
Theoretical Methods	T&M Modelling
Theoretical Methods	T&M Monte Carlo
Theoretical Methods	T&M Numerical Analysis
Theoretical Methods	T&M Probabilistic Modelling
Theoretical Methods	T&M Semi-empirical Methods
Theoretical Methods	T&M Simulation
Theoretical Methods	T&M Stochastic Modelling
Use of Facilities	National Grid Service (NGS)

Keywords:

Free-text keywords may be used to describe your area of expertise in more detail if appropriate. To add or remove those previously added use the links below.
Free-text Keywords
beyond the standard model
dark matter
extended Higgs sectors
global fits
Higgs physics
Higgs portal
statistical methods (Bayesian)
statistical methods (frequentist)

Objectives

List the main objectives of the proposed research in order of priority [up to 4000 chars]

The GAMBIT Project is an international collaboration of 25 leading theorists and experimentalists, which I lead. Its mission is to carry out extensive combined statistical analyses of a broad range of astronomical and particle physics datasets, in the context of different theories for physics beyond the Standard Model of particle physics. Such analyses are known as 'global fits,' and are the topic of the Ernest Rutherford Fellowship that I have been awarded.

This ERG deals with an important and timely expansion of the GAMBIT program, based around the combination of the physics of dark matter and the recently-discovered Higgs boson. This research will produce the most comprehensive analysis to date of theories for new particles related to the Higgs boson, including models where Higgs and dark matter are intimately connected. These are the models most likely to be found or tested in the next round of LHC and dark matter experiments.

Scientific Objectives

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1. To constrain or discover physics beyond the Standard Model in the Higgs sector by combining accelerator measurements with dark matter searches
2. To determine which Higgs-portal dark matter and non-Standard Model Higgs sector theories are preferred by data
3. To determine if the observed Higgs boson shows any evidency of non-Standard Model behaviour

Summary

Describe the proposed research in simple terms in a way that could be publicised to a general audience [up to 4000 chars]. Note that this summary will be automatically published on STFC's website in the event that a grant is awarded.

Higgs and dark matter are hot stuff in particle physics right now: we have found a new particle, it has a mass of 125 GeV, and it looks and acts pretty much how a Higgs should. But is it the only Higgs boson out there? Does it interact with all the other known particles in exactly the way we expect, or are there some important deviations? Are there other particles we haven't found yet, that interact with the Higgs, and that the Higgs might be able to lead us to -- like dark matter?

Many theories for physics beyond our Standard Model predict new particles, to explain things like the existence of dark matter and the mass we measure for the Higgs boson. Very many of these theories involve one or more new particles that interact in some way with the Higgs boson. A lot of those theories actually involve dark matter interacting with no other known particles apart from the Higgs -- which would explain why it is so dark!

The research funded by this Ernest Rutherford Grant will allow me to test models where dark matter and the Higgs are related, by comparing everything we know about the Higgs to all the other tests we have of physics beyond the Standard Model, in an extremely detailed way. This will involve myriad measurements of Higgs production and decay at the Large Hadron Collider, direct searches for dark matter with ultra-clean detectors deep underground, indirect searches with cosmic ray detectors in space, precision tests of rare particle processes, and cosmological observations of the Universe on extremely large scales. This combined information will allow me to test and compare theories for new Higgs physics in a far more complete and statistically rigorous way than has been done before.

Academic Beneficiaries

Describe who will benefit from the research [up to 4000 chars]

The extensions included in this ERG will enhance the academic benefits of my ERF in 5 key ways:

1. Improved state of knowledge about physics Beyond the Standard Model

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By performing extensive global fits to Higgs-portal and non-standard Higgs theories, this grant will significantly increase the

number of theories that can be analysed in the GAMBIT Project. Including all LHC Higgs channels and additional tools to allow loop-corrected Standard Model processes to be taken into account (via an interface to MadGraph5_aMC@NLO) will allow global fits to be done much more accurately, as the fits will contain additional specialised information that would otherwise be unavailable. Overall, this means that I can provide a far larger volume of more accurate information to the academic community on the relative viability of different theories beyond the Standard Model, and the preferred areas of their parameter spaces.

2. Availability of second-generation global fitting software
--
GAMBIT Project software will be open source; the Data Management Plan facilitating this is attached. GAMBIT software will become the default for careful analyses of theories beyond the Standard Model, by phenomenologists, experimentalists and theorists alike. Individual modules will also be available as stand-alone downloads, providing direct access to observable and likelihood calculations. This will give theorists and phenomenologists a versatile toolkit for quickly checking new ideas in model-building, before launching into full statistical analyses.

3. Centralised availability of results from experiments and GAMBIT scans
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The GAMBIT Repository will contain all the input data required by the physics modules for calculating likelihoods. The Repository will become a de facto centralised store for all the most constraining reduced data in particle and astroparticle physics, which will save researchers the effort of harvesting and collating data from experiments and/or extracting data from publications. This grant will add new data on all Higgs channels probed at the LHC, and full GAMBIT definitions for a range of Higgs-portal and non-standard Higgs sector theoretical models. Results of all GAMBIT global fits will also be made available, so experimentalists can quickly compare sensitivities of experiments with the current state of knowledge about different theories.

4. Increased ease for theorists
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The interface to MadGraph5 that will be developed in the course of this ERG will reduce the amount of time and effort required to implement new models by roughly a factor of 5--10. This will make the GAMBIT software far more useful to theorists interested in using it to quickly test and compare different versions of new models that they are in the process of developing.

5. Increased cross-disciplinary interaction and awareness between astronomers, experimentalists and particle theorists
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GAMBIT establishes strong multidisciplinary links between experts in particle theory, particle experiment, astronomy and statistics. This allows each member to learn from members in other fields, and to spread that experience within their home institute and 'home field'. This will enhance cross-disciplinary interactions and collaboration between the fields beyond the borders of GAMBIT.

Impact Summary

Impact Summary (please refer to the help for guidance on what to consider when completing this section) [up to 4000 chars]

Apart from academics within astrophysics and particle physics, there are three groups that have the potential to benefit from the research in this grant:

1. Workers and firms in other quantitative fields

In the course of developing GAMBIT, I will create a number of novel scanning and optimisation software packages, extend existing optimisation methods, and develop new data-mining strategies. These new computational techniques will be useful to workers in quantitative sectors such as finance, engineering and information technology, who are required to

solve optimisation problems and/or extract meaningful conclusions from so-called 'Big Data' on a regular basis. Some examples might include:

* A stockbroker modelling billions of share-price movements, needing to find the best-fit parameters of a market model in order to maximise his/her trading returns,
* An engineer designing an infrastructure project like a transport network, trying to maximise the overall cost-benefit ratio of the project whilst simultaneously fulfilling a number of complicated external design constraints, or
* A software engineer designing an application like Google Maps to find the fastest route from Point A to Point B.

2. Policy Makers and Research Councils

The GAMBIT Project will not only determine the current state of agreement between different theories and all current data, but will also quantify how effectively proposed experiments can probe theories of new physics. This will provide a means of quantifying and comparing the expected performance of new experimental proposals. Given that policy makers and Research Councils must decide which future experiments to fund, this information will provide them an additional concrete means by which to rank different scientific proposals against each other.

3. The general public

The general public has an enduring interest in astrophysics, cosmology and the latest energy frontier in the search for new particles. In providing funding for a PDRA and Project Student on GAMBIT, this grant will give the UK public two more young, enthusiastic, communicative scientists to take part in the extensive public outreach program of my ERF. That program involves developing an interactive computer program to be used by school children in connection with school visits carried out by the Imperial College Astrophysics group; see the Pathways to Impact document and p 17 of the attached copy of my 2012 ERF application for more details. This will increase enthusiasm for physics amongst the young, and (one hopes) ultimately help increase tertiary enrolments in science and technology subjects.

At a more abstract level, this grant will provide a public benefit by concretely increasing the sum total of human knowledge about the most fundamental physical laws governing the behaviour of our Universe. By characterising Higgs physics in the most complete and detailed way possible, I will increase this understanding significantly, regardless of whether deviations from the Standard Model prediction for the Higgs are observed or not.

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Summary of Resources Required for Project

Financial resources

Summary fund heading	Fund heading	Full economic Cost	STFC contribution	% STFC contribution
Directly Incurred	Staff	129856.00	103884.80	80
	Travel & Subsistence	23490.00	18792.00	80
	Other Costs	17200.00	13760.00	80
	Sub-total	**170546.00**	**136436.80**	
Directly Allocated	Investigators	0.00	0.00	80
	Estates Costs	50508.00	40406.40	80
	Other Directly Allocated	3741.00	2992.80	80
	Sub-total	**54249.00**	**43399.20**	
Indirect Costs	Indirect Costs	126159.00	100927.20	80
Exceptions	Staff	47589.00	47589.00	100
	Other Costs	11988.00	11988.00	100
	Sub-total	**59577.00**	**59577.00**	
	Total	**410531.00**	**340340.20**	

Summary of staff effort requested

	Months
Investigator	0
Researcher	36
Technician	0
Other	0
Visiting Researcher	0
Student	36
Total	72

Research Council Facilities
£ 0

Other Support

Details of support sought or received from any other source for this or other research in the same field.

Awarding Organisation	Awarding Organisation's Reference	Title of project	Decision Made (Y/N)	Award Made (Y/N)	Start Date	End Date	Amount Sought / Awarded (£)
National Research Council Canada	The Banting Fellowship BPDF-424460-2012	Discovery and discrimination of models for new physics with combined terrestrial and astrophysical data	Y	Y	01/10/2012	30/03/2014	88400
Royal Society of New Zealand	The Marsden Fund, Application 12-UOC-098	A Neutrino Net for Dark Matter	Y	N	01/01/2013	31/12/2015	475800
University of Sydney	IRCA-G162448	Enhancing the search for physics beyond the Standard Model by combining terrestrial and astrophysical measurements	Y	Y	28/01/2014	21/03/2014	8500
Australian Research Council	DP150100963	Data Mining for the Particle Physics of Dark Matter	N	N	01/01/2015	31/12/2019	524000
Fonds de recherche du Québec (FQRNT)	2015-PR-180742	The Cosmic String/Dark Matter Connection	Y	Y	01/09/2014	31/08/2017	175000

Related Proposals

Proposal is related to a previous proposal to STFC

Reference Number	How related?
ST/K00414X/1	Invited resubmission
ST/L002876/1	Invited resubmission

Staff

Directly Incurred Posts

			EFFORT ON PROJECT							
Role	**Name /Post Identifier**	**Start Date**	**Period on Project (months)**	**% of Full Time**	**Scale**	**Increment Date**	**Basic Starting Salary**	**London Allowance (£)**	**Super-annuation and NI (£)**	**Total cost on grant (£)**
Researcher	Researcher	31/03/2015	36	100	A&R LB p28	01/10/2015	33590	0	7966	129856
									Total	129856

Applicants

Role	Name	Post will outlast project (Y/N)	Contracted working week as a % of full time work	Total number of hours to be **charged** to the grant over the duration of the grant	Average number of hours per week **charged** to the grant	Rate of Salary pool/banding	Cost estimate
Principal Investigator	Dr Pat Scott	Y	100	0	0	45040	0
						Total	0

Students

Role	**Name /Post Identifier /Institution**	**Start Date**	**London Allowance (£)**	**Fees**	**Estimated Cost**
Project Student	PhD Student in Theoretical Physics / Imperial College London	31/03/2015	Yes	11988.00	47589.00

Travel and Subsistence

Destination and purpose		Total £
Outside UK	2-week collaborative visits to other GAMBIT institutes, to progress Higgs activities with ATLAS GAMBIT members and Higgs-portal work with GAMBIT theorists. Travel to be undertaken by PDRA, student or myself. (£1500 x 4)	6000
Outside UK	An additional overseas conference presentation, per year. These will be additional talks that I would not have otherwise given, on the results of the GAMBIT BSM Higgs and Higgs-portal analyses. (£1000 x 3)	3000
Outside UK	Travel for Postdoctoral Research Assistant to GAMBIT Collaboration meetings (£1800 x 3).	5400
Outside UK	Travel for Project Student to GAMBIT Collaboration meetings (£1800 x 3)	5400
Outside UK	Travel for Postdoctoral Research Assistant to give one international conference presentation per year (£1000 x 3)	3000
Within UK	Standard STFC student conference travel support for Project Student, to give three domestic conference presentations (£230 x 3)	690
	Total £	23490

Other Directly Incurred Costs

Description	Total £
2-week visit by GAMBIT Higgs specialist C. Rogan (Harvard) to Imperial, to collaborate on LHC Higgs combination.	2000
High-end laptop and peripherals (screen, keyboard, mouse, etc) for Postdoctoral Research Assistant, to be used for developing GAMBIT global fit code.	2500
Standard STFC Research Training Support Grant for Project Studentship. Most of this will be put towards the purchase of a laptop for developing Lagrangian-level global fit code. (£1000 x 3 years)	3000
Enterprise-level desktop server and peripherals, to be used for hosting and managing GAMBIT Collaboration data, policy and code repository.	3700
Funds to organise one GAMBIT Collaboration meeting in the UK during the course of the Fellowship: venue hire, refreshment costs, partial travel support for attendees (to be awarded preferentially to the most needy students).	5000
Recruitment costs for PDRA.	1000
Total £	17200

Other Directly Allocated Costs

Description	Total £
Infrastructure Technicians	3741
Total £	3741

Research Council Facilities

details of any proposed usage of national facilities

Name of Facility	Units	Cost £	Proposed Usage
Other	0	0	I will apply for HECToR time separately, to run GAMBIT scans; if unsuccessful, I will use Imperial facilities.
	Total £	0	

Classification of Proposal

(a) Peer Review Preferences

Tick one of the following boxes to indicate the STFC peer review panel you consider most appropriate to review this proposal.

Astronomy Grants Panel: Astronomy Observation	
Astronomy Grants Panel: Astronomy Theory	
Astronomy Grants Panel: Solar Studies	
Astronomy Grants Panel: Planetary	
Other	x
Particle Astrophysics	
PPGP (Experiment)	
PPGP (HPC)	
PPGP (Theory)	
Science Board	
Space Missions/Ground Based Facilities	
Nuclear Physics Panel	
Nuclear Physics Project Peer Review Panel	
Particle Physics IPPP Panel	
Strategic HPC Panel	
Accelerator Peer Review Panel	
Project Peer review Panel (PP)	

For astronomy consolidated grants please indicate whether any of the other AGP panels are relevant and at what percentage.

(b) Types of Activity (mandatory)

Assign % relevance(in multiples of 5) to the activities listed, totalling 100%

Type of Activity	**Broad Indication of Category**	**%**
Exploitation and experiment	Data collection, data analysis, experimental research	50
Investment in new instrumentation, facilities or techniques	For example, design and construction of new facilities and instruments, instruments and technique development and research on underpinning technology	
Operation and maintenance of facilities	The recurrent cost of providing facilities	
Theory	Theoretical research including modelling	50
		Total = 100%

(c) Facilities

Please indicate which facilities, if any, apply to this application. Please provide further details if necessary.

AAO		ALMA		Apex		Athena	
Bepi-Colombo		Boulby	x	Cassini Huygens		CERN LHC	x
CERN Other		Cheops		CLF		CLUSTER	
CoRoT		Diamond		EcHO		E-ELT	
e-MERLIN		ESRF		Euclid		ExoMars	
FMOS		FNAL	x	GAIA		Ganil	

Gemini		GSI / FAIR		Herschel		Hinode	
HPC	x	HST		ILL		INT	
IRIS		ISIS		JCMT		JLAB	x
JPARC		JUICE		JWST		Jyvaskyla	
KARI		KECK		KEK		Keplar	
Kua Fu		La Silla		LIGO		LISA / Pathfinder	
Liverpool Telescope		LOFAR		LSST		MICE	
Newton XMM		NGTS		Other	x	Planck	x
PLATO		Rosetta		SDO		SKA	
SLAC		Soho		Solar Orbiter		Spitzer	
STEREO		SuperWasp		SWARM		SWIFT	
UKCAN		UKIRT		UKST		VISTA	
VLBI		VLT		VST		WHT	

Other

Fermi-LAT, AMS-02, GAPS, VERITAS, HESS, MAGIC, CTA, LUX/LZ, ZEPLIN-III

(d) Space or Ground Based (mandatory)

Please assign relevance (in multiples of 5%) to Ground or Space based activities, entering "0" where there is none.

Ground or Space	**%**
Ground-based	60
Space-based	40
	Total <= 100%

OTHER INFORMATION

Reviewers

1	**Name**	**Organisation**	**Division or Department**	**Email Address**
Professor Benjamin Allanach		University of Cambridge	Applied Maths and Theoretical Physics	b.c.allanach@damtp.cam.ac.uk

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