NETHERLANDS ORGANISATION FOR SCIENTIFIC RESEARCH

Physical Sciences Division

APPLICATION FORM FOR COMPUTING TIME

The application must always be submitted via the main applicant's Iris account.

GENERAL INFORMATION

Project name	Pilot for: First GAMBIT search for new physics
Scientific Area*	Physics
Relevance to the Top Sectors**	N/A

* choose from: *Earth Sciences & Climate, Astronomy, Biosciences, Chemistry and Materials Science, Medical Sciences, Physics, Linguistics, Technical Sciences and Engineering, Mathematical Sciences, Informatics, Genomics, Other*

** The Dutch government has designated nine 'top sectors': areas of economic activity to which extra attention is to be devoted. They are: Agrifood, Chemicals, the Creative Industry, Energy, High-tech Systems and Materials, Life Sciences, Logistics, Horticulture and Water. For further information, see www.top-sectoren.nl.
State (where applicable) if and how your project proposal is relevant to one or more of the designated top sectors. You should also include details of any proposed collaboration with the private sector if applicable.
This section will not affect the assessment but gives the GBE a better understanding of the manner in which proposals are relevant to the top sectors and the national economy."

APPLICATION TYPE

1st application request or continuation	1st application request (Request for pilot)
Continuation application of a project with the same title (Note that a continuation application cannot be processed if the report of the previous granted application has not been submitted via IRIS)	No
Project number previous grant with the same title:	0
Submission date of the report of this previous grant:	N/A
Institute request	No
Program request	No
Dutch Computing Challenge Project (Scientifically high-profile and computationally large-scale projects requiring a significant part of Huygens. Think of one week or up to a couple of months of a significant part of the Huygens capacity.)	No

1. Main applicant (the principal investigator, having a permanent position at the organisation)

Main applicant- name	Weniger
First name	Christoph
Initials	C
Gender	Male
Date of birth	5 June 1980
Title(s)	Dr.
Job title	Junior Faculty
Organisation	University of Amsterdam
Faculty/department	Institute of Physics
Group/Subgroup ('leerstoelgroep')	GRAPPA
Address or P.O. Box	Science Park 904
Postal code and city	1098XH, Amsterdam
Telephone	+31(0)20525 6294
e-mail	c.weniger@uva.nl

2. Co-applicant (if applicable)

Co-applicant- name	Scott
First name	Pat
Initials	P
Gender	Male
Date of birth	June 21 1982
Title(s)	Dr.
Job title	STFC Rutherford fellow / Junior Faculty

Organisation	Imperial College London
Faculty/department	Department of Physics
Group/subgroup (‘leerstoelgroep’)	Astrophysics
Address or P.O. Box	Blackett Laborator, Prince Consort Rd
Postal code and city	London SW7 2AZ
Telephone	+44 (0)20 7584 5968
e-mail	p.scott@imperial.ac.uk

In case of more co-applicants, please copy this table and fill it out.

3. Project leader (actual person responsible for the computations)

Main applicant – name	Weniger
First name	Christoph
Initials	C
Gender	Male
Date of birth	5 June 1980
Title(s)	Dr.
Job title	Junior Faculty
Organisation	University of Amsterdam
Faculty/department	Institute of Physics
Group/subgroup (‘leerstoelgroep’)	GRAPPA
Address or P.O. Box	Science Park 904
Postal code and city	1098XH, Amsterdam
Telephone	+31(0)20525 6294
e-mail	c.weniger@uva.nl

Point of contact for NWO Physical Sciences (*)

	Mark
Main applicant	X
Co-applicant	
Project leader	

*The granting letter will always be sent to the main applicant. If you wish that NWO Physical Sciences will contact either the co-applicant or the project leader for any other matters, please mark here.

4. Type of institute/organisation

	Mark
University	X
NWO-Institute	
Other (please indicate which)	

5. System preference

	Mark all that apply
Bull bullx system (Cartesius) regular CPU nodes	X
Bull bullx system (Cartesius) GPU	
Dell National Computing Cluster (Lisa)	

6. Amount of computing time requested

The unit of computing time used is SBU (System Billing Unit)

Cartesius: one SBU corresponds to the usage of one core of the system for one hour. Cartesius batch nodes either have 24 cores (thin nodes, the majority), 32 cores (fat nodes), or 16 cores + 2 GPUs (GPU nodes). For the GPU nodes we do not charge the number of CPU cores but we charge the number of CPU cores times three. Consequently: using a thin node for one hour costs 24 SBU: using a fat node for one hour costs 32 SBU: using a GPU node for one hour costs 48 SBU. Lisa:one SBU corresponds to the usage of eight cores of the system for one hour. Lisa nodes have 8, 12 or 16 cores.

Project Type	Requested amount (SBU)
1st application request $\leq$ 100.000 System Billing Units	100.000
1st application request $\geq$ 100.000 System Billing Units	

7. Amount of enabling effort requested

This section only applies to Dutch Computing Challenge Projects, for all other projects please proceed with Section 8.

a. Describe what work has already been done to develop the codes.

This should include the following: description of the main algorithms, how they have been implemented and parallelized, and their main performance bottlenecks and the solutions to the performance issues you have considered. Please provide the name and version of all codes to be used in the project. For each code that needs to be optimized, please provide the details listed below.

1. Name and version.
2. Webpage and other references.
3. Licensing model.
4. Contact information of the code developers.
5. Your relationship to the code (developer, collaborator to main developers, end user, etc.).

b. Describe what enabling work will need to be completed before production runs can begin.

c. Please make it clear what work will need to be done by your own group and what you are requesting to be done by SURFsara staff.

d. Please make clear if any enabling work can be done in parallel with production runs.

e. Please indicate how many months of SURFsara FTE will be required (we strongly suggest to contact SURFsara before submitting your application).

8. Scientific aspects

a. Scientific problem

1. Describe the complete project in the context of your research group, including the relation between subprojects (if any) in your application. Mention the scientific question(s) you want to answer. Use a maximum of 1000 words for your description;

Introduction

The two most pressing and key issues in fundamental and astroparticle physics today are the identity of dark matter (DM) and the nature of physics at the TeV energy scale. A wealth of beyond the Standard Model (BSM) theories has been proposed for each, and an enormous amount of experimental data has been collected to test those theories [1]. Unfortunately though, when it comes to comparing all these theories with all the relevant data, existing computational and statistical tools in particle and astroparticle physics are woefully inadequate. The goal of this pilot project is to demonstrate conclusively that we can remedy this situation with a new computational system that we developed in a large international collaboration of theoretical and experimental physicists, and that will serve the community for years to come: GAMBIT (The Global And Modular BSM Inference Tool).

Many different experimental probes of BSM physics exist: direct and indirect searches for DM, accelerator searches, neutrino experiments and cosmological and astrophysical probes. To make robust conclusions about the overall level of support for different BSM scenarios from such varied sources, a simultaneous statistical fit of all the data, fully taking into account all relevant uncertainties, assumptions, and correlations is an absolute necessity. Robust analysis of correlated signals in a `global analysis`, in a range of complementary experiments, is essential for claiming a credible discovery of DM or new physics at the TeV scale - and indeed, even for definitively excluding theories.

Existing global fits [2-6] cover only a very small subset of interesting particle models; most have dealt with only the very simplest versions of supersymmetry. Existing optimization and inference techniques are barely capable of dealing with even the models that have been considered so far [7, 8]. The present generation of global analysis suites will all reach their limits within the next year in their abilities to deal with alternative theories, additional observables and the advanced numerical and statistical algorithms required for producing genuinely robust results.

GAMBIT and scientific goals

We have developed the new global analysis suite GAMBIT, which will overcome the glaring shortcomings of the existing codes for BSM physics analysis. The key scientific problems that we plan to address with GAMBIT are:

1. What is the correct model to describe new physics at the TeV scale, in light of all existing and upcoming observational data?
2. What constitutes the dark matter of the Universe? What are its couplings, its mass and its spin?
3. What are the most promising ways forward in the search for new physics at the TeV scale?

The development of GAMBIT started 2.5 years ago, and was and is an extremely demanding problem in applied statistics and computer science, requiring the use of many specialized statistical techniques and computer codes. It is also a highly interdisciplinary physics problem, straddling the theoretical and experimental branches of both astronomy and particle physics. GAMBIT was written by a collaboration of about 26 researches from all relevant branches of physics. Researchers from such leading institutes as the Oskar Klein Centre for Cosmoparticle Physics (Stockholm), the Imperial Centre for Inference and Cosmology (London), the Centre of Excellence for Particle Physics at the Terascale (Adelaide, Melbourne, Sydney) and the Centre of Excellence for Gravitation and Astroparticle Physics (Amsterdam) are heavily involved in the development of GAMBIT.

The central criteria during code development were:

1. Keeping the code general enough to allow a fast definition of new datasets, theoretical models and statistical algorithms.
2. An extensive database of BSM models (not just the common supersymmetric scenarios), and of observables (precision likelihood modules).
3. Many statistical options – Bayesian/Frequentist, likelihood definitions, scanning algorithms.
4. Massively parallelized codes.

Goals of this pilot project

The goals of this pilot project are to finalize the development of GAMBIT and validate it for the use in a first large-scale full physics global analysis. In particular:

A) To ensure the stability and efficiency of all theory and observational codes for individual points in the scan.

We will perform runs using a small sample of benchmark points in the MSSM-25 to ensure that the full likelihood routines are running properly on the Cartesius installation of the GAMBIT code. We will use these runs to check whether all critical code components properly scale up to a 32 Core system, and take countermeasures if required. Furthermore, we will confirm that there are no remaining problems with memory leakage and thread safety issues (this was already tested on smaller systems). The main result will be a realistic time estimate for the runtime of the full likelihoods for a single typical point.

We will finally show that production runs work as expected by performing a full scan over the scalar singlet DM model.

B) To test the scalability of all code components for scanning over high dimensional parameters spaces.

Given the high dimensionality of the MSSM-25 parameter space, it is vital to obtain a realistic and accurate estimate for the conversion time of scans. To this end, we will set up a 25 dimensional toy-likelihood function with a similar complexity as expected for the MSSM-25 scans, including e.g. intersecting hyper-surfaces of different dimensionality, isolated poles and regions with high parameter degeneracies. We will explore with test runs how many likelihood evaluations are typically required to obtain convergent results. Running these toy likelihood functions on the Cartesius cluster will allow us rapidly test a large number of different possible configurations and hence the stability of our convergence estimate.

The results from both point one and point two of the pilot will allow us to validate all codes for a full physics analysis of the MSSM-25 in a subsequent project and provide us with a realistic estimate for the required computing time.

Once we have successfully completed the pilot and evaluated the results, we will apply for time on the Cartesius cluster to perform an exhaustive analysis of the MSSM-25.

2. Please explain the relation between the amount of requested computing time and the research within your subgroup and/or faculty/department. This research may be theoretical, observational and/or experimental. Please indicate the importance of the computing facilities and the amount of requested computing time for your scientific research and its impact;

As discussed above, the goal of the this pilot project is to pave the way for an extensive global analysis of the MSSM-25 model, which will require of the order of 4 million core hours (as a very preliminary estimate). This is well beyond the scope of local computing facilities like the Lisa cluster in Amsterdam. The completion of this project hence hinges on high-performance computing facilities, and the Cartesius cluster would be an excellent choice for that.

The main applicant and PI of this project is staff member of GRAPPA (Gravitation and Astroparticle Physics Amsterdam) at the UvA, and plays a leading role in the development or the GAMBIT tool itself as well as all DM-related observables and theory codes. GRAPPA has a tradition in the global analysis of supersymmetric models (Prof. G. Bertone). With GAMBIT we introduce now a revolutionary new framework for these global scans, which will in the very near future supersede all existing codes and efforts and establish a new standard in global scans. Performing the first full-scale analysis with GAMBIT at a Dutch computing facility would help to establish GRAPPA at UvA as the world-leading institution for BSM analyses with global scans.

We expect that the outcome of this project will have a significant and lasting impact on the field of astroparticle and high energy physics. In fact, future progress in understanding which BSM models are favoured by experimental data will be contingent upon massively expanding the range of theories to which global fits have been applied, and the number of experimental results included in them. The only way to do this is to reconsider the computational and statistical tools used to carry them out, from the ground up. With our first MSSM-25 scan, we will realize exactly this and pave the way for many future analyses of non-supersymmetric models.

3. Please explain how the research in this project will be financed. In the case of subprojects, please indicate it for each subproject. If your project (or subprojects) is financed through 2nd or 3rd channels ("2^{e} en 3^{e} geldstroom"), please mention the overall project and its registration number (if available).

Several grants contribute to finance this project. CW was awarded a NWO VIDI grant (2nd channel) that started Oct 2014, which will finance one postdoc and one PhD student that will work on long-term development of GAMBIT. PS won a STFC (Science and Technology Facilities Council) research grant and has access to PhD students at Imperial College London that will work on implementing the actual scan. The major parts of the code development is financed by personal grants and permanent positions of the various members of the GAMBIT collaboration.

b. Numerical methods and implementation aspects

1. Which numerical methods will be used in your project? Please give details on discretisation and numerical methods;

The project requires large-scale, statistically-driven parameter scans of models for new physics. These will draw on a wide range of different observables, likelihoods and theoretical calculations. The overarching numerical methods are therefore optimisation and search algorithms. Each observable calculation however also employs further specific numerical methods. Below we give some detail about each in turn.

The natural basis for discretisation in the GAMBIT code is evaluation of likelihoods and observables at different parameter combinations. We parallelise calculations both at the scanner level, via MPI, and at the individual sample level, via OpenMP. A typical run has the sampler send a single parameter point to each node, and for the likelihoods and observables at that point to be evaluated using all cores of a single node. The primary bottleneck is the collider likelihood calculation, which we have extensively optimised and parallelised with OpenMP.

Scanning algorithms

Our strategy for sampling parameter spaces has two parts. The first is to dynamically optimise the actual likelihood calculations to be done for each sample. We do this using graph theoretic methods, identifying the slowest likelihood components on the fly, and arranging them to run last for each sample, subject to constraints imposed by the dependencies of each part of the calculation on other parts. This speeds up the sampling significantly, because some samples can be discarded already without bothering to evaluate the most expensive likelihoods.

The second part of our sampling strategy is to employ sophisticated statistical sampling algorithms. We employ two main complementary techniques, motivated by our goal of producing both Bayesian and frequentist inferences on the detection or exclusion of new physics.

The first method is nested sampling (NS; [9]). NS samples the Bayesian posterior probability distribution in progressively smaller shells of probability, beginning with a widely dispersed population of samples that gradually converges towards regions of highest posterior probability. This method is specifically optimised for obtaining samples from the Bayesian posterior probability distribution, and for eventually calculating the Bayesian evidence.

The second method is differential evolution (DE; [10]). DE is a heuristic evolutionary optimisation method. It also employs a population of samples, but interbreeds them using various vector addition operations, in order to find new samples that exhibit a better value of the objective function than their parents.

Nested sampling provides samples with a density that is proportional to the Bayesian posterior, so is very good at mapping the regions of highest posterior probability. Differential evolution, when employed with the raw likelihood value of each point as its objective function, is an efficient method for finding the best-fit set of parameters. This makes it the sampling method of choice for producing results based in the frequentist profile likelihood.

Dark matter calculations

Dark matter observables typically require the integration of dark matter density and velocity distributions, and differential cross-sections, to produce predictions for total rates. For these integrals we employ different integration methods depending upon the dimensionality and locality of the integrand. These range from simple routines based on Simpson's method to sophisticated globally adaptive codes such as CUBPACK [11]. Many of the functions used to build the integrands must also be accurately interpolated; we do this with either simple linear or cubic spline interpolation, or in more poorly-sampled cases, tensioned splines via TSPACK [12].

Particle decays, electroweak precision observables and flavour physics

Many cross-section calculations in particle physics require complicated integrals over phase space distributions of virtual particles and hadronic parton distribution functions. In many cases the integration methods mentioned above are too slow for these applications. In these cases we use adaptive Monte Carlo integration techniques, largely based on the venerable VEGAS algorithm [13].

LHC and other collider physics observables

Making accurate predictions for signals of new particles at colliders requires extensive Monte Carlo simulation of the collision process, the ensuing hadronisation and particle showering, and the subsequent appearance of collision products in detectors. We use well-tested standard tools for simulating the hadronisation and showering (Phythia 8 [14]), then parallelise them using OpenMP and apply further optimisations to ensure that they run quickly enough for large-scale scans. For the detector simulation, we take public parameterisations of the LHC experiments' detector responses, and use these to perform simple event-level smearing in order to quickly simulate how our predicted signals would appear in the real detectors. We calibrate the results of this exercise against more extensive, standard detector simulations (Delphes [15]).

Particle mass calculations

Due to quantum corrections, particle rest masses actually depend on the energy of the experiment in which they are tested. To make accurate predictions of observable quantities, like the rates of particle production in LHC experiments, one therefore needs to know what the masses of new particles are expected to be at different energy scales. The masses at different scales are related by a system of coupled ordinary differential equations (ODEs), with boundary conditions typically given by previous measurements at low scales and theoretical arguments at high scales. We use the standard shooting method for solving boundary value problems in ODEs to convert the problem to a multi-dimensional root-finding problem, and then employ a fixed-point iteration scheme to obtain the final solution at any given energy.

2. Which codes (specify names of programs / packages) will be used in your project?

The project will be the first large-scale production run of the GAMBIT package [16]. GAMBIT has been extensively developed over the last 2.5 yr by a collaboration of some 26 people, led by the applicants. It draws on a number of existing codes for different parts of its calculation:

Scanning/Optimization: MultiNest [17], Diver (forthcoming differential evolution sampler by Scott et al), GreAT

[18], twalk (forthcoming sampler by Martinez et al)

Dark Matter: DarkSUSY [19], MicrOmegas [20], nulike (forthcoming neutrino likelihood package by Scott et al), gamlike (forthcoming gamma-ray likelihood package by Weniger et al), DDCalc (forthcoming direct detection likelihood package by Savage et al).

Particle decays: SUSY-HIT [21], FeynHiggs [22]

Electroweak precision observables: FeynHiggs [22]

Flavour observables: SuperIso [25], EOS [26]

LHC and other collider observables: Pythia 8 [14], Delphes [15], HiggsBounds [23], HiggsSignals [24], Buckfast (forthcoming fast LHC detector simulation by White et al)

Particle mass calculations: FlexibleSUSY [27], SoftSUSY [28]

These packages have only quite common library dependencies (cmake 2.6 or later, Boost, gcc/gfortran 4.7 or later, GSL 1.10 or later, ROOT).

The code packages listed above as 'forthcoming' are all written by GAMBIT members. These all are finished and only awaiting paper writeups before public release.

3. (Only for projects requesting more than 100.000 SBU):

Describe the implementation details of your numerical approach for the preferred system (MPI, OpenMP, hybrid, CUDA, OpenCL, OpenACC, ….);
Which standard package(s) (application software, if any) and which libraries will be used ?
Indicate the parallel performance of the code(s) you plan to use;
Indicate how much memory and how much I/O (volume and bandwidth) will be needed.

N/A

4. Indicate why the system you prefer is indeed the right system for your application. Please indicate why other systems (e.g. your local facilities or other national facilities) cannot be used.

Scanning the MSSM-25 in particular will require roughly a billion samples, at 0.5 s per sample on a 24-core node = approximately 400 core years. To be able to achieve this sort of compute time in a reasonable wall time, we must run on hundreds or thousands of nodes in parallel, utilising all cores on each node. We therefore require a facility where it is possible to run massively parallelised CPU jobs (our code is not written to make use of GPUs), without queuing for weeks at a time. The current request is for a pilot study to illustrate the feasibility of GAMBIT for such a large-scale run on the Cartesius cluster.

c. Feasibility

1. Explain the amount of requested computing time. This can be done by using the table below, but also other ways are possible. In any case, explain how your planned runs add up to the requested amount of computing time. (The accounting weight "a" for Cartesius CPU nodes is 1; for Cartesius GPU nodes is 3; for LISA nodes is 1.).

The following table provides an overview of the computing time requirements for this pilot project.

Type Run	# Runs	# Steps/Run	Wall time/Step	# CPU cores	accounting weight	Total SBUs/Type Run
SubA	20	1	1	3500	1	70.000
SubB	10	1	1	3000	1	30.000
….	….	….	….	….	….	….
TOTAL						100.000

SubA (See Sec 8.a.1.A): We will make a number of runs to establish that all likelihood functions that are relevant for the MSSM-25 scan are working properly and scale well up to a system with 32 Cores and O(100) nodes. We will test this in various configurations to estimate the typical runtime for individual points in the full scan.

SubB (See Sec 8.a.1.B): Using toy-likelihood functions, we will study the convergence behavior of different scanning algorithms with the goal of estimating the runtime and computing requirements for a full scan of the MSSM-25.

2. Describe both the total memory requirements of the full job and the memory requirements per core or MPI process. Do the same for data storage and for I/O. Distinguish between permanent data storage and scratch storage space during the job;

Memory requirement per MPI process (in the case of GAMBIT per node): < 4 GB.
Scratch space per MPI process: < 1 GB.
Data storage during the job: up to 100 GB.

3. (Only project requesting more than 1.000.000 SBU) Provide scaling graphs of the numerical methods used in the proposal on the selected or a similar system. NWO will provide links to scaling benchmarks for commonly used numerical methods. Links to these scaling benchmarks can be found on http://www.nwo.nl/onderzoek-en-resultaten/programmas/rekentjd+nationale+computersystemen;

N/A

4. Indicate the names of the persons who will be performing the actual computations. Full details of these persons need to be given in section 9 below;

Christoph Weniger, Pat Scott, Richard Bartels, Ben Farmer

5. Indicate the required post processing work and the necessary computing systems.

Since this is a pilot project, the actually required post processing of the results is minimal. It will mostly entail a statistical analysis of the chains that were generated during the model parameter scan in terms of Bayesian quantities (credible regions, best-fit points, mean values, parameter correlations and higher moments). The post processing will be done on local machines or on the LISA cluster.

9. Available human resources for the project

This section will need to contain the information on all persons involved in the computational work of the project. If more persons are involved in the project, please copy the table and fill it out for each person involved.

Name	Weniger
First name	Christoph
Initials	C
Gender	Male
Date of birth	5 June 1980
Title(s)	Dr.
Job title*	Junior Faculty
Organisation	University of Amsterdam
Faculty/department	Institute of Physics
Group/subgroup ('leerstoelgroep')	GRAPPA
Address or P.O. Box	Science Park 904
Postal code and city	1098XH Amsterdam
Telephone	+31(0)20525 6294
e-mail	c.weniger@uva.nl
Number of working hours per week	6
Period	1st June 2015 – 31st July 2015
1st 2nd or 3rd channel ('geldstroom')	2nd channel: NWO VIDI Grant & D-ITP

NETHERLANDS ORGANISATION FOR SCIENTIFIC RESEARCH

Physical Sciences Division

APPLICATION FORM FOR COMPUTING TIME

Name	Scott
First name	Pat
Initials	P
Gender	male
Date of birth	June 21 1982
Title(s)	Dr.
Job title*	STFC Rutherford Fellow / Junior Faculty
Organisation	Imperial College London
Faculty/department	Department of Physics
Group/subgroup ('leerstoelgroep')	Astrophysics
Address or P.O. Box	Blackett Laborator, Prince Consort Rd
Postal code and city	London SW7 2AZ
Telephone	+44 (0)20 7584 5968
e-mail	p.scott@imperial.ac.uk
Number of working hours per week	6
Period	1st June 2015 – 31st July 2015
1st 2nd or 3rd channel ('geldstroom')	STFC Ernest Rutherford Fellowship (UK) (2^{nd} channel)

Name	Bartels
First name	Richard
Initials	R
Gender	Male
Date of birth	
Title(s)	MSc Physics
Job title*	PhD student
Organisation	University of Amsterdam
Faculty/department	Institute of Physics
Group/subgroup ('leerstoelgroep')	GRAPPA
Address or P.O. Box	Science Park 904
Postal code and city	1098XH
Telephone	
e-mail	richard.t.bartels@gmail.com
Number of working hours per week	3
Period	1st June 2015 – 31st July 2015
1st 2nd or 3rd channel ('geldstroom')	GRAPPA PhD school (2^{nd} channel)

Name	Farmer
First name	Ben
Initials	
Gender	
Date of birth	
Title(s)	
Job title*	
Organisation	
Faculty/department	
Group/subgroup ('leerstoelgroep')	
Address or P.O. Box	
Postal code and city	
Telephone	
e-mail	
Number of working hours per week	
Period	1st June 2015 – 31st July 2015
1st 2nd or 3rd channel ('geldstroom')	

** Also indicate if AIO's and OIO's are involved.*

10. Expertise with respect to supercomputer usage

a. For each person referred to in section 9, please indicate his/her experience with supercomputers (which, where, for how long).

Christoph Weniger: Regular use of the LISA computing cluster (e.g. cosmological parameter scans, analysis of gamma-ray data), since 2013. This includes running MPI parallelized codes.

Pat Scott:

Richard Bartels: Limited experience with LISA cluster since start of PhD (Sep 2014).

Ben Farmer:

b. Please indicate which local computing facilities are available to the research group.

Research at GRAPPA usually makes use of the LISA computing cluster.

11. Project plan

Desired start date	1st June 2015 (or as soon as possible)
Please note that projects for computing time always run for one year. After one year, the account is closed and submission of the report to NWO Physical Sciences is mandatory. Three months before the end of the project, you will receive a notification from SURFsara by email. If you want to apply for a continuation project, you need to submit the report of your just finished project via Iris before submitting the continuation application. For administrative reasons, the remaining SBUs will not be added to the continuation project.	

The goals of this pilot project are described in section 8.a.1, section “Goals of the pilot project”. We plan to study both the stability and runtime characteristics of our codes, and the scalability, and to use this information to set up a realistic plan for the full physics run of GAMBIT in the main project.

12. Publicity

Requests for funding and/or computing time will be published on the NWO website automatically, unless the project includes confidential matter.

	Mark: Yes/no
Is (part of) the information in this application confidential and as such cannot be published on the NWO website?	Yes
If yes, indicate the reasons why	The GAMBIT code is a completely new approach to global scans and not released to the public yet. It is hence a competitive advantage to keep, for the time being, technical details about the implementation and the testing strategies internal to the collaboration.

13. Remarks, references and relevant publications

References for section 8

[1] G. Bertone, D. Hooper, and J. Silk, Phys. Rep. 405 (2005) 279–390
[2] P. Scott, C. Savage, J. Edsjö, and the IceCube Collaboration, JCAP 11 (2012) 57
[3] P. Bechtle, T. Bringmann, et. al., JHEP 6 (2012) 98
[4] O. Buchmueller, R. Cavanaugh, et. al., Eur. Phys. J. C 72 (2012) 2243
[5] L. Roszkowski, E. M. Sessolo, and Y.-L. S. Tsai, Phys. Rev. D 86 (2012) 095005
[6] C. Strege, G. Bertone, et. al., JCAP 4 (2013) 13
[7] Y. Akrami, P. Scott, J. Edsjö, J. Conrad, and L. Bergström, JHEP 4 (2010) 57
[8] F. Feroz, K. Cranmer, M. Hobson, R. Ruiz de Austri, and R. Trotta, JHEP 6 (2011) 42

[9] Skilling J, 2004, AIP Conf. Series 735:395
[10] Storn R & Price K, 1997, J. Global Optimization 11:341
[11] Cools R & Haegemans A, 2003, ACM Transactions on Mathematical Software 29:287
[12] Renka RJ, 1993, ACM Transactions on Mathematical Software 19:81
[13] Lepage GP, 1978, J. Comp. Phys. 27:192
[14] Sjostrand T et al, 2006, JHEP 05:026
[15] Favereau et al, 2014, JHEP 02:057
[16] gambit.hepforge.org
[17] Feroz et al, 2009, MNRAS 398:1601
[18] Putze A & Derome L, 2014, Phys. Dark Universe 5:29.
[19] Gondolo P et al, 2004, JCAP 07:008
[20] Belanger G et al, 2014, Computer Phys. Comm. 185:960
[21] Djouadi A et al, 2007, Acta Phys. Polon. B38:635
[22] Heinemeyer S et al, 2000, Computer Phys. Comm. 124:76
[23] Bechtle et al, 2014, Eur. Phys. J. C 74:2693
[24] Bechtle et al, 2014, Eur. Phys. J. C 74:2711
[25] Mahmoudi F, 2009, Computer Phys. Comm. 180:1579
[26] Bobeth et al, 2010, JHEP 07:098
[27] Athron P et al, 2015, Computer Phys. Comm. 190:139
[28] Allanach BC, 2002, Computer Phys. Comm. 143:305

D. DATE

Submission date	
By (main applicant, co-applicant or project leader)	Christoph Weniger

This application form must be submitted in pdf-format via the NWO IRIS system. Follow the link here *(NWO Iris)*