BIRS proposal text field entries.

1 Title of Proposal

GAMBIT
Towards a Global And Modular Beyond-the-Standard-Model Inference Tool

2 Overview

A short overview of the subject area of your workshop

The two most pressing and fundamental issues in modern physics are the identity of dark matter (DM) and the nature of physics at the TeV energy scale. A wealth of theories has been proposed for each, and an enormous amount of experimental data has been collected to test those theories. Unfortunatley 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. Our Workshop aims to remedy this situation.

DM constitutes 80% of the matter in the Universe and was discovered 80 years ago, but its composition remains a mystery. With the impending activation of the 14 TeV Large Hadron Collider (LHC), discovery of the Higgs boson and construction of high-energy astrophysics experiments like the *Fermi*-LAT, HESS-II, IceCube and SuperCDMS, we now stand on the doorstep of the TeV scale. Many popular DM candidates are intrinsically linked to the appearance of new physics beyond the Standard Model (BSM) at precisely this scale [1]. The mass of the newly-discovered Higgs itself even compels us to move beyond the Standard Model [2, 3]. We also know that the Standard Model is incomplete because it does not include gravity, nor explain the excess of matter over antimatter in our Universe, nor the fact that neutrinos have mass.

Many different experimental probes of BSM physics exist: direct and indirect searches for DM, accelerator searches, and neutrino experiments. Experiments such as CRESST [4], *Fermi*-LAT [5] and PAMELA [6] may even already show tantalizing hints of DM. 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. This global fit approach is the one we will discuss and develop at BIRS in 2015. Such holistic analyses exploit the synergy between different experimental approaches to its maximum potential, squeezing every last statistical drop of information possible from each experiment. Robust analysis of correlated signals, 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. This 'win-win' situation is a particular feature of a global fit analysis, as even non-detections provide crucial physical insight into which theories and parameter regions are disfavoured.

3 Objectives

A statement of the objectives of the workshop and an indication of its relevance, importance, and timeliness

Statement of objectives

The primary goals of this BIRS 5-day Half Workshop will be

1. To re-evaluate the computational and statistical techniques used to carry out global fits in particle and astroparticle physics.

2. To develop a second generation global-fitting package for particle and astroparticle physics: GAMBIT, the Global And Modular Beyond-the-Standard-Model Inference Tool.

3. To determine the statistical approach(es) to be supported by GAMBIT.

4. To identify new computational strategies that optimize the efficiency and accuracy of GAMBIT relative to first-generation codes.

5. To prioritize and discuss different physics analyses to be carried out with GAMBIT.

Relevance, importance and timeliness

Existing global fits [7–11] cover only a very small subset of interesting particle models; most have dealt with only the very simplest versions of supersymmetry. This is partly for computational reasons, as efficiently exploring the parameter spaces of more complicated models is extremely time consuming. Existing optimization and inference techniques are barely capable of dealing with even the models that have been considered so far [12, 13]. Efforts to date have rarely been truly 'global', as the full range of possible observables and datasets (e.g. indirect searches for dark matter) have not been included in a detailed way. The present generation of global analysis suites will all hit a brick wall 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.

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. Our BIRS Workshop will do exactly this.

By rewriting the computational and statistical bedrock of BSM global fits, we will be in a position to discuss and develop a new, second-generation global fitting suite for particle and astroparticle physics: GAMBIT. GAMBIT will transform the budding field of global fits, by providing a framework in which new theories, observables, likelihoods and scanning algorithms can be quickly, easily and consistently combined in order to completely and rigorously test essentially *any* proposed extension of particle physics beyond the Standard Model.

Attendees

Creating a tool such as GAMBIT is an extremely demanding problem in applied statistics and applied 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. Researchers from such leading institutes as the Oskar Klein Centre for Cosmoparticle Physics (Stockholm), the Imperial Centre for Inference and Cosmology (London) and the Centre of Excellence for Particle Physics at the Terascale (Adelaide, Melbourne, Sydney) have all already expressed their extremely strong interest in taking part in the Workshop. The combination of guests we envisage for this Workshop is unique, bringing together the broad range of expertise in astrophysics and particle physics, theory and experiment, DM phenomenology, statistical and numerical methods required to make our ambitious vision a reality.

By collecting world experts in all these areas for an intensive, focused week on the problems, strategy and first attempted implementation of a second-generation global-fitting code, the BIRS GAMBIT Workshop will provide new opportunities for exchange of ideas between members of all these fields. This will drive the field of BSM global fits forward by enabling new collaborations. The Workshop we hold at BIRS will form the basis for what we hope will be an ongoing formal consortium of experts in the BSM global fitting arena, dedicated to the development and usage of the GAMBIT global-fitting framework. If this proposal is successful, given the long lead-time for holding a Workshop at BIRS and the urgency of the problem, we will attempt to begin preliminary discussions by email before even arriving at BIRS. This will ensure that we hit the ground running in Banff, and come away from the Workshop having achieved the maximum progress possible towards our Objectives.

The GAMBIT BIRS Workshop, and the consortium that we hope will

rise from it, will also prove a fertile training ground for upcoming talent in the field. We have identified a number of extremely promising doctoral students and postdoctoral researchers with an interest in BSM global fitting; their involvement in the Workshop and consortium will give them unrivalled experience in the ingredients of BSM global fits, and an excellent opportunity to influence the future directions of the field, all but ensuring that they become its future leaders.

Timetable

The first 2 days of the Workshop will consist of presentations. Some of these will evaluate existing statistical frameworks (e.g. the composite profile likelihood and Bayesian posterior), computational methods (e.g. nested sampling) and overall code structures used in BSM global fits. We will encourage those presenters to approach their subject matter with a critical, idealistic eye, with the goal of identifying how a global-fitting framework should be designed so as to reflect best practices in these areas – rather than just the 'simplest thing to get running'. This will address Objective 1. Other presentations will give proposals for using new methods in BSM global fits, like Hamiltonian sampling, random forests and differential evolution. This will address Objectives 3 and 4. A third set of presentations will focus on specific aspects of the physics that should be addressed by future BSM global fits: dark matter, collider and flavour physics. This will address Objective 5.

The latter 3 days of the Workshop will be devoted almost entirely to collaborative development of the GAMBIT suite, including group coding sessions and code design mini-workshops. Towards the end of the week, we also envisage some code presentations and tutorials, where a small number of attendees show the group as a whole the progress they have made, and how others can use or expand on it. These will address Objective 2.

References

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[3] G. Degrassi, S. Di Vita, *et. al.*, *Higgs mass and vacuum stability in the Standard Model at NNLO*, *JHEP* **8** (2012) 98, [`arXiv:1205.6497`].

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CRESST-II Dark Matter search, Eur. Phys. J. C **72** (2012) 1971, [`arXiv:1109.0702`].

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[7] P. Scott, C. Savage, J. Edsjö, and the IceCube Collaboration: R. Abbasi et al., *Use of event-level neutrino telescope data in global fits for theories of new physics, JCAP* **11** (2012) 57, [`arXiv:1207.0810`].

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[12] Y. Akrami, P. Scott, J. Edsjö, J. Conrad, and L. Bergström, *A profile likelihood analysis of the Constrained MSSM with genetic algorithms, JHEP* **4** (2010) 57, [`arXiv:0910.3950`].

[13] F. Feroz, K. Cranmer, M. Hobson, R. Ruiz de Austri, and R. Trotta, *Challenges of profile likelihood evaluation in multi-dimensional SUSY scans, JHEP* **6** (2011) 42, [`arXiv:1101.3296`].

4 Press Release

Please provide 1-2 paragraphs for a press release for your workshop. It should be understandable by the general public

Imagine living in a house where you don't even know the names or faces of your four housemates. This is where astronomers and particle physicists

find themselves right now with the matter in our own Milky Way Galaxy. Dark matter makes up over 80% of the Milky Way, and the Universe as a whole, but we still don't know what it actually is. Many theories predict that this mystery is somehow related to the Higgs boson, the origin of mass, and some as-yet-uncovered symmetry about to be discovered at the Large Hadron Collider (LHC).

A group of twenty particle physicists, astronomers, statisticians and computational scientists is meeting at the Banff International Research Station to create the computational tools of the future in the search for dark matter, and the broader particle theory it belongs to. Using cutting-edge statistical and computational techniques only developed in the last few years, their plan is to combine the results of searches for dark matter and new symmetries from a huge number of different experiments. These range from the LHC to smaller particle colliders, gamma-ray telescopes, cosmic antimatter probes, ultra-clean experiments in the world's deepest mines, and a neutrino telescope embedded in the Antarctic ice at the South Pole. The result will be the first truly comprehensive analysis of theories for dark matter and new physics, painting a much clearer picture of what dark matter is, and what it isn't.

5 Participants

A list of potential participants and their affiliations is important to the review process, but you will not be bound by it. The Programme Committee looks favourably on participant lists where there is an indication that the participants have been contacted and have expressed interest in the proposal.

Enter the participants one per line using the following format: Family name, Given name, affiliation - department

For example: Smith, Sam, Institute of Generic Names - Generic Department

The following participants have been contacted and expressed **very strong interest** in participating. Students are indicated with asterisks (*) and post-doctoral researchers with daggers (†), indicating the potential for training young talent at this Workshop.

1. **Andreev**, Andrij, Stockholm University – Department of Statistics
2. **Balazs**, Csaba, Monash University – School of Physics
3. **Bringmann**, Torsten, University of Oslo – Department of Physics
4. **Buckley**, Andy, University of Edinburgh – School of Physics and Astronomy
5. ***Cornell**, Jonathan M., University of California Santa Cruz – Santa Cruz Institute for Particle Physics
6. ***Dal**, Lars A., University of Oslo – Department of Physics

7. **Jackson**, Paul, University of Adelaide – School of Chemistry and Physics

8. **Edsjö**, Joakim, Stockholm University – Oskar Klein Centre and Department of Physics

9. ***Farmer**, Benjamin, Monash University – School of Physics

10. [†]**Krislock**, Abram, Stockholm University – Oskar Klein Centre and Department of Physics

11. ***Kvellestad**, Anders, University of Oslo – Department of Physics

12. **Mahmoudi**, Farvah Nazila, LPC Clermont-Ferrand and CERN – Theory Division

13. [†]**Martinez**, Gregory, Stockholm University – Oskar Klein Centre and Department of Physics

14. [†]**Putze**, Antje, Aachen University – Department of Physics IB

15. **Raklev**, Are, University of Oslo – Department of Physics

16. [†]**Rogan**, Christopher, Harvard University – Laboratory for Particle Physics and Cosmology

17. [†]**Saavedra**, Aldo, University of Sydney – Department of Physics

18. **Serra**, Nicola, University of Zurich – Physik-Insitut der Universität Zürich

19. [†]**Savage**, Christopher, University of Utah – Department of Physics and Astronomy

20. **van Dyk**, David A., Imperial College London – Chair in Statistics, Department of Mathematics

21. [†]**Weniger**, Christoph, University of Amsterdam – GRAPPA Institute

We also expect that

22. **Meinshausen**, Nicolai, ETH Zürich – Department of Statistics

will have an interest in attending, although we have not explicitly contacted him about this Workshop as yet.