ACP - NAS

Astroparticle physics Community Planning – Non-Accelerator Subsurface

Presentation of the Initial Draft of the Whitepaper:

IPP TownHall Meeting July 15th, 2020

(Facilitated by the McDonald Institute and SNOLAB)

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Outline:

- The ACP Community Planning Process … and connection to IPP and SAP Long term planning

- Current Status, and next steps

- The White Paper
  - Community aspirations
  - Science Drivers:
    - Dark Matter
    - Neutrino Properties
    - Neutrino Messengers
  - Technology Development
  - Theory in Astroparticle Physics
  - EDI
  - Advantages to Canada
  - 20 year Vision

Rough Plan & Timelines

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Receive (most) community input (briefs)	March 2020
Develop Draft Green Papers	
1st Town Hall Meeting	May 6-7 2020
Update Green Papers. Some new briefs	
Merge Green Papers into White Paper.	
White Paper Draft 1 Submission to IPP	June 30, 2020
2nd Town Hall Meeting	July 20, 2020
Final white paper	July 28, 2020
Final Glossy ACP Report	Late Fall 2020

IPP/CINP

IPP LRP Launch, AGM	June 11-12, 2020
Draft briefs Due to IPP	June 30, 2020
IPP Town Hall ✓	July 15-16, 2020
Final Briefs to IPP	July 28, 2020
IPP submits brief to LRP committee	Dec 1, 2020

NSERC LRP

Inputs to LRP committee	
Town Halls	
Final LRP Report	Sept, 2021
Final Glossy Report	

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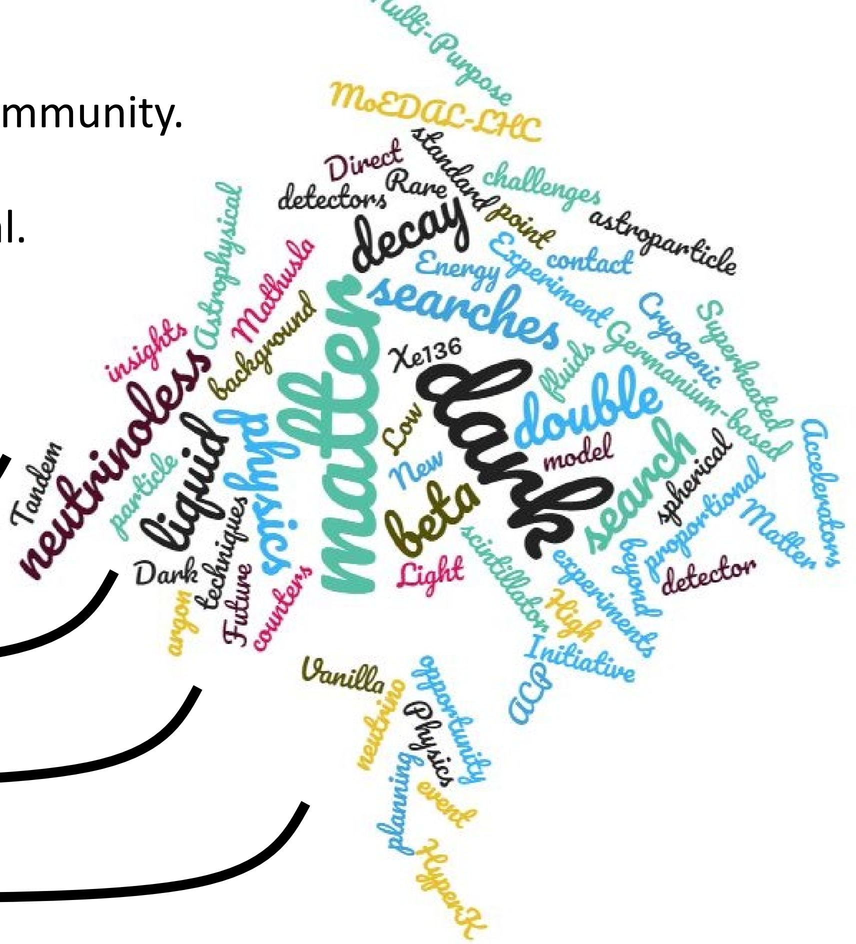
- We originally received 17 briefs from the community.
- Many were cross-disciplinary.
- Some related to theory, others experimental.



Convenor co-chairs digesting briefs according to themes

- Dark Matter
- Neutrino Messenger
- Neutrino Properties
- Technologies

Prepared for the Town Hall meeting of May 6th and 7th

Draft Dark Matter Green Paper

Draft Neutrino Green Paper

Draft Technology Green Paper

Town Hall:

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Green Paper Thematic Discussions		
Wednesday "Morning"	Dark Matter	David Morrissey Simon Viel
Wednesday "Afternoon"	Technology	Fabrice Retiere Silvia Scorza
Thursday "Morning"	Neutrino	Erica Caden, Ken Clark Carsten Krauss, Alex Wright
Community Strategy Discussion		
Thursday "Afternoon"	20 year vision	Panel discussion

- Presentation led by convenors
- Q/A and Input from participants.
- Open Mic discussions

- Opening remarks SNOLAB & McDonald Institute
- Panel Discussion
- Open Mic with participants.

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Final Glossy ACP Report

- A few new briefs received stimulated by the Town Hall
- Convenors continue to update Green Papers: Close to final now but will update based on input from the community through the second townhall. Final versions will be posted on the website*.
- White Paper writing team:
  - Erica Caden
  - Ken Clark
  - Fouad Elgindy
  - David Morrissey
  - Tony Noble
  - Fabrice Retiere
  - Silvia Scorza
  - Nigel Smith

Draft has been submitted and released to the community

On the website:

- White Paper Draft
- Revised drafts of the Green Papers
- Details for the town hall

Community Aspirations

The community aspires to be a global leader in astroparticle physics with a view to the **discovery** of new particles to explain the galactic **dark matter**, an **understanding of the intrinsic properties and nature of the neutrino**, and the **opening-up of new windows** of intersectional astronomy and cosmology studying the **sources of these particles** and their influence on the evolution of the universe.

Fundamental science program focused on high priorities in physics today:

- Origins of dark matter
- Properties of neutrinos
- Understanding of neutrino sources

In the last decade this field has evolved into a major research field. In Canada, increased capacity and capability as a consequence of significant investments:

- **SNOLAB**: Deepest clean International facility for underground science
- **McDonald Institute**: Centre for Astroparticle Physics building intellectual capacity across Canada.

Canada is well placed to capitalise on investments to this research field.

Dark Matter

Recognized globally as one of the highest priorities in physics today

Direct Detection: Main focus in Astroparticle Physics in Canada, largely centred at SNOLAB

DEAP-3600	Currently operational. World leading results with Argon. Single phase, scintillation. Spin-independent WIMP	Future program includes Darkside @ LNGS (funded, in development) and ARGO A global argon consortium considering a 300 tonne scale detector at SNOLAB. SiPM development required.
PICO	Worlds best limits in SD sector with C_3F_8. Currently commissioning upgraded PICO-40 at SNOLAB	Next phase. PICO 500, order of magnitude scale up in physics reach. CFI funded
SuperCDMS	Ge and Si cryogenic semiconductor technology currently focused on lower mass DM detection.	Installation at SNOLAB started. Transition from Sudan, USA.
NEWS-G	Low threshold detector with low A gasses spherical proportional chamber. Very light dark matter	Installation at SNOLAB started. Prototypes at Queen's and Modan, France
SBC	Scintillating Bubble Chamber with argon optimized for very low thresholds and light dark matter.	In development. Planned installation of one detector at SNOLB.

Dark Matter

Under-water neutrino detector in Pacific Ocean off Vancouver Island in collaboration with Ocean Networks. Robust infrastructure already in place.

Synergies:

Indirect Detection: dark matter annihilation → neutrinos SK, HyperK, IceCube, P-ONE

Collider Production: Searches for missing particles at LHC (ATLAS), WIMP-like DM (Belle II), NA62, … planned fixed target "beam-dump" experiments

Taken together, these projects are set to make important and world-leading progress in the search for dark matter over the years to come. They are well poised to discover dark matter and test its properties, and thus help us formulate a much deeper understanding of the universe.

Neutrino Properties

Understanding the nature of neutrinos is recognized globally as one of the highest priorities in physics today

0νββ: Main focus in Astroparticle Physics in Canada, largely centred at SNOLAB
Neutrino Oscillations and mass hierarchy: Good synergies between Astroparticle Physics community and other programs in Canada, for example long baseline oscillations and coherent elastic neutrino-nucleus scattering (CEvNS). Examples include SK, HyperK, IceCube, and the proposed P-ONE, plus other neutrino studies with SNO+

SNO+ — Currently Filling with 780 tonnes LAB scintillator at SNOLAB. Will load to 0.5% tellurium. Projected to have leading sensitivity in the near term. Future programs can include higher Tellerium loading.

nEXO — Extension of very successful Xe based EXO experiment. SNOLAB is location of choice. Requires development of SiPM (Canadian leadership, overlap with Ar dark matter R&D)

Legend — Joining of forces of Majorana and GERDA projects. Based on high purity Ge. Legend-200 under construction at LNGS. The collaboration has indicated that Legend-1000 at SNOLAB would be the preferred choice.

* nEXO and Legend-1000 still await full project approval in the USA. Cryopit at SNOLAB allocated to this activity.

The complementarity between these different experimental techniques using different isotopes to search for 0νββ cannot be overstated and serves the Canadian community well.
Very strong community in Canada with near and long term programs

Neutrino Messengers

The IceCube detector has discovered a sample of very energetic neutrinos likely of extragalactic origin. The origin and acceleration mechanisms for such high energy particles is unknown.

Studying different properties of these neutrinos can illuminate various **aspects of their production**. Studying the energy spectrum may shed light on the **acceleration mechanism** and the **interactions** during propagation. The direction of the neutrinos could indicate the presence of **heavy dark matter** decaying or annihilating.

In Canada, the effort in this area, is through participation on IceCube, as well as the development of P-ONE as a potential future neutrino telescope.

Technology Development

Advances in the development of larger next generation detectors must include advances in reducing all sources of backgrounds, and increasing the sensitivity to the signal. There are several major thrusts in this field with Canadian leadership.

Radiopurity:

- Requires development of radiopure materials (including the production and storage of materials in the underground environment (eg, copper electroforming, etc)
- Requires development of more advanced direct counting techniques with sensitivities improved by a few orders of magnitude.
- Interesting development emerging in Canada is Accelerator Mass Spectrometry (AMS).

Photosensors: (eg for scintillation light from Ar, Xe, Ne, He, …)

- Development of SiPM technology being led by expertise in Canada. Argo, nEXO, SBC are examples of experiments that could benefit from these advances.
    - PDC project (Photon to digital converter) → integrating electronics within the SiPMs
    - dHPD (digital Hybrid Photon Detector) → builds on PDC to produce sensor with excellence performance (sensitivity, timing, radioactivity)

There is an opportunity for Canada to carve one or more commercial niches from a program initially driven by astroparticle physics

Theory in Astroparticle Physics

Astroparticle physics has made enormous progress through a close exchange between theory and experiment. Within the Canadian subatomic theory community, astroparticle physics is a major component of many research programs covering a diverse areas of study.

Theory efforts in Canada contribute in many varied ways, including:

Dark Matter

- Theory is needed to direct laboratory searches for dark matter in the most promising and physically self-consistent way.
- By investigating specific theories of dark matter, theorists have also identified new experimental and detection approaches for the candidates they predict.
- Precision calculations of nuclear and material responses to dark matter scattering are necessary for designing detectors and interpreting the signals they find.
- In the event of a new discovery in a dark matter search, theory will be crucial to understanding the source of the new physics and its relations to other experiments and cosmological observations.

Neutrino

- Investigations of the origin of the observed neutrino masses and mixings help connect experimental measurements to detailed theories of new physics.
- Calculations of nuclear transition matrix elements are essential to connecting the sensitivities of neutrinoless double beta decay searches to the sources of lepton flavour violation that are necessary for this process to take place.
- Work on neutrino production by stellar processes and dark matter connects these two areas of particle astrophysics with each other.

EDI

In the areas of equity, diversity, and inclusion (EDI), **the Canadian Astroparticle Physics community is not representative** of the national demographics across the four designated groups as defined by the Government of Canada to include: women, Aboriginal peoples, persons with disabilities and members of visible minorities.

The community is focused on improving this situation in a number of ways, including:

- Altering the perception of what a “scientist" looks like, in addition to creating **early intervention** programs to increase interest and awareness of maths, science, and physics. These strategies target expanding the diversity of the astroparticle physics pipeline.
- **Addressing common hurdles** such as equity funding (caregivers, accessibility, etc.) for participation in scientific events.
- Piloting a **Diversity and Equity Assessment and Planning** Tool (DEAP), has laid some early groundwork to change the course of the community towards EDI positively.
- Through efforts led by the MI, the community is benefiting from the experience of **direct contact with EDI experts**, additional EDI funding, and connecting community influencers with EDI mentors to lead the conversation of creating inclusive environments.

Canadian Advantages

The Canadian astroparticle physics community has developed unique capabilities and infrastructure that place the community in a strong position globally.

Investments building the capacity within Canada include:
- The development of a deep underground research facility, **SNOLAB**;
- The creation of a CFREF-funded astroparticle physics institute, the **McDonald Institute**;
- **Development of technology Research and Development** at TRIUMF and elsewhere; and
- The development of a **strong academic community**

Demographics:
- Strong existing base in the Universities and National labs, partially an outgrowth of the original SNO program;
- Currently over 100 personnel including scientists, engineers, technicians, postdoctoral fellows and students supported by the McDonald Institute;
- The experimental program at SNOLAB is supported by a staff complement of over 100 personnel.
- The community has been well recognized with 6 Canada Research Chairs a Canada Excellence Research Chair (CERC), and a Nobel prize.

The Canadian astroparticle physics community is well positioned with the critical mass and technical expertise to be leading the next generation astroparticle physics experiments.

Canadian Advantages

SNOLAB:

The competitive advantage that SNOLAB provides to the Canadian astroparticle physics community is **ease of access** to very deep, clean experimental halls capable of hosting kilo-tonne target scale projects, with **expert** scientific, technical and administrative **support and infrastructure** available.

This is a unique combination within the global community of deep underground facilities, as evidenced by the very **strong international demand for space at SNOLAB**.

The McDonald Institute:

The MI provides a **focal point for the Canadian academic community** engaged in astroparticle physics, ensuring dialogue across the community and support to develop these areas of excellence.

There are strong connections across the major research facilities in Canada, including between MI, SNOLAB, TRIUMF, Perimeter Institute and Canadian Nuclear Laboratories.

The continuing development of these capabilities will ensure Canada remains in the vanguard of astroparticle physics.

20 Year Vision

The Canadian astroparticle physics community will play a dominant role in the discovery of new physics, capitalising on;

- The skilled and highly qualified personnel developed over the last decade;
- The investments already made in world-leading infrastructure; and
- the globally competitive capabilities that Canada and our partners possess.

We may expect the **discovery** of new particles to explain the galactic dark matter, greater understanding of the intrinsic properties and nature of the neutrino, and the opening-up of new windows of intersectional astronomy and cosmology studying the sources of these particles and their influence on the evolution of the universe.

Dark Matter:

- An immediate focus is improving the sensitivity of the WIMP searches to reach the level where solar and atmospheric neutrinos become a background.
- To span the natural WIMP mass range, and potential interaction modes with the target nuclei, several detector technologies and target elements are required.

Over the next 20 years as these detectors increase in sensitivity, size and scale, Canadian astroparticle physicists are in an ideal position to ensure leadership and engagement in these experimental endeavours.

20 Year Vision

Neutrino:

- Underground neutrino physics has a strong pedigree in Canada. This will continue with leadership of neutrino projects already hosted at SNOLAB, and engagement with the next generation $0\nu\beta\beta$ detector targeted for SNOLAB.
- With P-ONE, there is a unique opportunity to lead the growing field of multi-messenger astronomy through the exploitation of infrastructure developed initially for use outside of the astroparticle field, by Ocean Networks Canada.

To fully exploit the opportunities over the next 20 years will require the continued development of research and strong engagement from the theory community.

The continued support and development of highly qualified personnel will also be essential, with a strong commitment from the community to develop a diverse and inclusive research environment.

Please have a detailed look at the extensive Green Papers posted on line, which have tried to distill the ~20 briefs, and input from the initial two day townhall meeting into a concise document.

Please also look at the White Paper which has attempted to capture the essence of the Green Papers into a view of the community direction.

It is impossible to capture the depth and thoroughness of these documents in a 15 min overview.

Please join us at our second town hall on July 20th to provide input to the process.

Thank-you