DM in PAAP Roadmap 2021

S.Burdin for PAAP

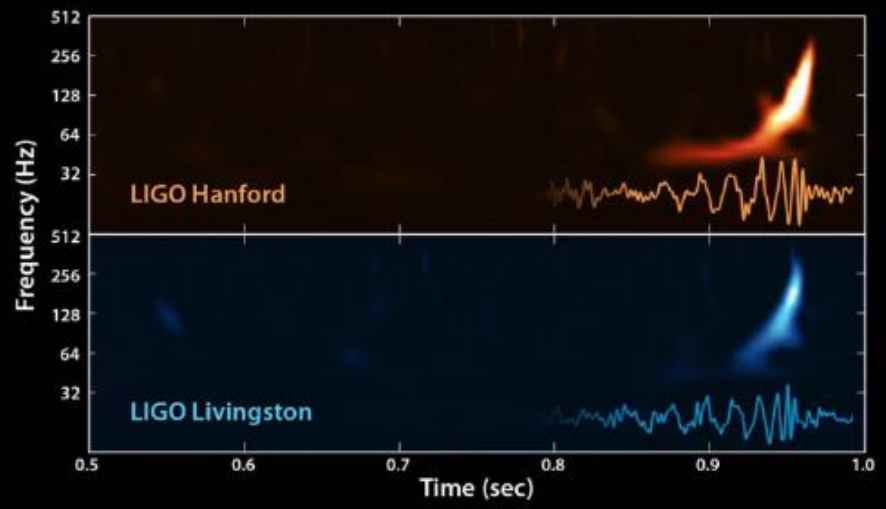
DMUK @ RAL

16/11/2021

Roadmap for UK Particle Astrophysics

STFC Particle Astrophysics Advisory Panel Report - 2016

Chamkaur Ghag, Ruth Gregory, Julian Osborne, Patrick Sutton, Lee Thompson



PAAP Roadmap 2021

Sergey Burdin, Ed Daw, Stephen Fairhurst, Laura Kormos,
Jon Lapington, Christopher McCabe, Blake Sherwin

November 2021

Highlights

- The observation of close to 100 gravitational wave signals from coalescing binaries comprised of neutron stars and black holes. This includes the first multi-messenger observation of a neutron star merger (also observed as a gamma ray burst and subsequently seen across the electromagnetic spectrum), the first observation of neutron star--black hole binaries, and a population of black hole binaries.
- Ground-based VHE gamma-ray instruments make crucial contributions to multi-messenger astronomy. These include the first detections of TeV photons from gamma-ray bursts. The identification of the gamma-ray blazar TXS056+0506 as the first high-probability PeV neutrino source was secured by IACT imaging of the associated TeV flare.
- Achieving the best sensitivity to WIMPs in 2016 with the LUX detector in strong competition with PandaX and XENON collaborations. The next generation detector LUX-ZEPLIN (LZ) was built and starts taking data in 2021. Searches for wave-like dark matter such as axions have been supported through the Quantum Technologies for Fundamental Physics programme, specifically QSHS and AION.
- The first-ever identification of a likely point source of extragalactic high-energy neutrinos and cosmic rays (blazar TXS056+0506) using multi-messenger astronomy, with follow-up observation by gamma-ray, X-ray and optical telecopes. The addition of Gd to the world's largest underground neutrino detector, Super-Kamiokande, which allows it to aim for the first observation of Diffuse Supernova Neutrino Backgrounds.
- Extracting most precise measurements to date, with both Planck and AdvACT experiments, of the CMB power spectrum and lensing spectrum. This has allowed us to test LCDM and inflation predictions at unprecedented accuracy; it has also provided the tightest bounds on neutrino masses and new light particles in the early universe.

Particle Astrophysics Science Questions

	A1	A2	A3	A4	A5	A6	A7	A8	B2	C1	C2	C3	C4	C6	C7	C8
Grav Wave	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	
VHE γ-ray	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Neutrino	✓	✓		✓	✓			✓		✓			✓			
Direct DM	✓	✓	✓	✓	✓			✓		✓	✓		✓			✓
CMB	✓	✓	✓	✓				✓		✓			✓			

- A:1 What are the laws of physics operating in the early Universe?
- A:2 How did the initial structure in the universe form?
- A:3. How is the universe evolving and what roles do dark matter and dark energy play?
- A:4. When and how were the rst stars, black holes and galaxies born?
- A:5. How do stars and galaxies evolve?
- A:6. How Do Nuclear Reactions Power Astrophysical Processes and Create the Chemical Elements?
- A:7. What is the True Nature of Gravity?
- A:8. What can gravitational waves and high-energy particles from space tell us about the universe?

Particle Astrophysics Science Questions

	A1	A2	A3	A4	A5	A6	A7	A8	B2	C1	C2	C3	C4	C6	C7	C8
Grav Wave	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	
VHE γ-ray	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Neutrino	✓	✓		✓	✓			✓		✓			✓			
Direct DM	✓	✓	✓	✓	✓			✓		✓	✓		✓			✓
CMB	✓	✓	✓	✓				✓		✓			✓			

- C:1. What are the fundamental particles and fields?
- C:2. What are the fundamental laws and symmetries of physics?
- C:3. What is the nature of space-time?
- C:4. What is the nature of dark matter and dark energy?
- C:6. What is the nature of nuclear matter?
- C:7. Are there new phases of strongly interacting matter?
- C:8. Why is there more matter than antimatter?

International Context and other reviews

- 2016 Particle Astrophysics Roadmap
- 2019 Particle Astrophysics Programme Evaluation
- 2020 STFC Balance of Programmes
- 2020 Dark Matter Strategic Review
- 2021 PPAP Roadmap
- Boulby Feasibility Study
- APPEC Dark Matter Report
- USA P5 report 2014
- Snowmass 2021 in progress

General Recommendations

- **2.1** We recommend increased levels of funding for particle astrophysics to ensure continuing UK roles within existing experiments, as well as increasing the breadth and depth of particle astrophysics research in the UK.
- **2.2** We recommend that STFC should provide large, strategic investment in future particle astrophysics observatories and experiments to ensure continuing UK leadership into the long term.
- **2.3** Ensure a clear career path for Particle Astrophysics researchers with better job prospects and job security. This would required a move away from short term contracts towards more longer term contracts and permanent positions, but would enable the retention of the best early career post-docs. This is particularly important for Instrument Scientists and Research Software Engineers. We should also ensure that more early-career fellowships are available, targeted at these under-funded areas.
- **2.4** STFC should ensure that Particle Astrophysics expertise is well represented on funding panels, particularly the PPGP Experimental and Theory and AGP Observation grant rounds. Make sure that PA priorities, as laid out in this roadmap, are clearly communicated to the panel members.
- **2.5** Provide a mechanism to fund exploratory research on new projects. Ensure that successful projects can then be funded in the long term.
- **2.6** Coordinated funding of space missions. Cooperation between agencies is fostered through cross-representation on relevant committees, and funding mechanisms and processes underlying the dual-key approach be made more transparent via monitoring and evaluation of regular published reports.

Dark Matter Recommendations

- **5.1** Support LZ operations/exploitation as the highest priority. Support DarkSide-20k operation/exploitation upon successful completion of the construction phase.

- **5.2** Support the UK participation with significant leadership role in design, construction and operation of at least one large-scale direct dark matter search experiment. STFC should ensure that decisions are made in a timely manner that ensures full participation from the beginning with leadership roles is possible. In a limited funding scenario, the experiment which is able to reach the ``neutrino floor'' on the shortest timescale should be prioritised.

- **5.3** STFC should develop a clear strategy for supporting R&D efforts aimed at widening the accessible range of masses and interactions of particle dark matter, which would include low-level seed-corn funding and mechanisms to transition to larger-scale experiments.

- **5.4** Continue to support hidden sector direct dark matter research and grow the new research community in this area through further funding calls beyond the initial QTFP call, to sustain this research in the longer term.

Theory Recommendations

- **8.1** STFC and the particle and astrophysics panels should acknowledge that not all areas of PA theory can be neatly classified as either astrophysics or particle physics and that there will be core areas of PA theory that will necessarily appear to be on the borderline of the panel's remit. Furthermore, we would encourage STFC and the panels to consider mechanisms that could be put in place to prevent world-leading areas of PA theory from falling between the cracks of the two panels.

- **8.2** The STFC should ensure that follow-on funding for the theoretical activities in the QTFP area is available. We also recommend that fellowship panels (including Ernest Rutherford, Future Leaders and Stephen Hawking fellowships) recognise that theoretical research in the QTFP area falls within their remit and ensure that they include panel members with the expertise to judge proposals from this area.

Infrastructure, Technologies, Computing

- Infrastructure Requirements, Boulby, no recommendations yet…
- **9.1** Fund a new mode of large scale technology programmes to develop high impact technologies with application across multiple projects and over several fields. Provide enhanced funding opportunities and fellowships for experimentalists and instrument specialists to stem the declining numbers in the UK.
- **9.2** Given the near-certainty of increased complexity, channel count and miniaturisation of future PA experiments, the concept of a central UK design and fabrication facility serving all STFC communities for electronics design and construction should be reconsidered.
- **9.3** To exploit the synergies in sensors, electronics, and associated technologies between particle and astroparticle physics we recommend that the Particle Physics Technology Advisory Panel (PPTAP) be expanded to include a proportionate number of members to represent particle astrophysics interests, and possibly renamed to reflect its extended remit.
- **9.4** Large-scale computing for simulations and data analysis is critical for all areas of Particle Astrophysics. STFC must ensure that adequate computing resources continue to be made available to enable full exploitation of observational and experimental data.
- **9.5** STFC should provide a greater level of support for specialist computing staff, particularly Research Software Engineers, within Particle Astrophysics. Furthermore, it is important to establish a viable career path for computing specialists; STFC should consider initiatives that provide incentives for Universities to retain such academics.

Outreach and Impact

- **10.1** Outreach activities are essential for broader societal appreciation of science and for attracting the next generation of talented researchers, regardless of their background. Particle astrophysics research is particularly suitable for outreach, as it focuses on some of the most extreme environments and on some of the most profound open questions in science. Outreach activities from the particle astrophysics community should therefore be strongly supported.

Comments and Feedback

Please send written comments **by Friday 26th November** to Ailsa Johnstone at ailsa.johnstone@stfc.ukri.org.

We will be holding two open Zoom sessions to receive input from the community. They will be held at:

10am on Thursday 18th November. Zoom link: https://cardiff.zoom.us/j/81350450992?pwd=U29uSVMvTzNBYnYrRGVDaFJvWGI1QT09

3pm on Monday 22nd November. Zoom link: https://cardiff.zoom.us/j/84864344504?pwd=SmtkMFpxUlVRQ0RLVm4wV05pQS85QT09