

Particle Astrophysics Advisory Panel Update @ IOP Town Hall Meeting

10/4/2024

• PAAP:

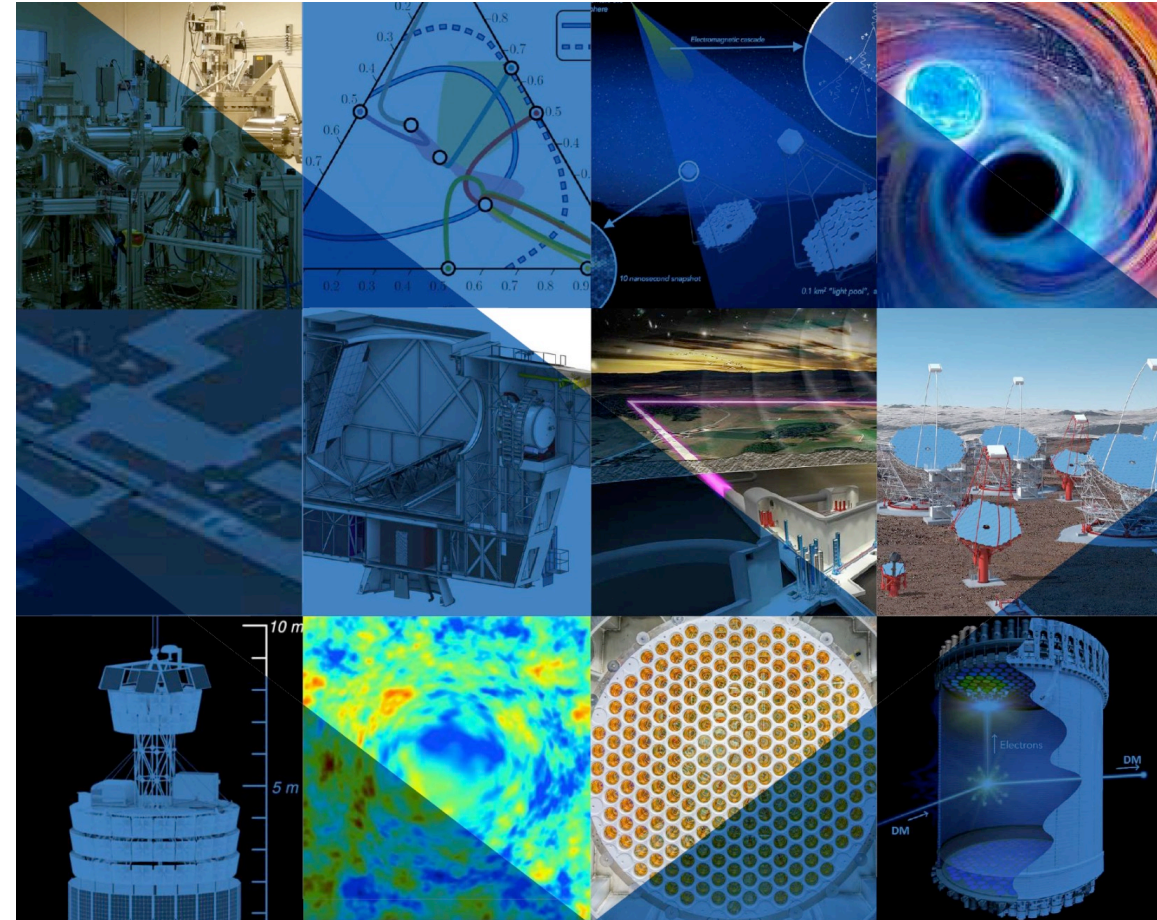
- *Sergey Burdin (Chair, Liverpool)* - Direct (particle-like) Dark Matter searches
- *Garret Cotter (Oxford)* - Gamma-ray Astronomy
- *Djuna Croon (Durham)* - Theory
- *Ed Daw (Sheffield)* - Direct (wave-like) Dark Matter searches & Quantum Technology for Fundamental Physics
- *Teppei Katori (KCL)* - Neutrino Astronomy
- *Laura Nuttall (Portsmouth)* - Gravitational Waves
- *Blake Sherwin (Cambridge)* - Cosmic Microwave Background

• Science Board representatives:

- *Francesca Di Lodovico (KCL)*, *Anne Green (Nottingham)*,
Patrick Sutton (Cardiff)

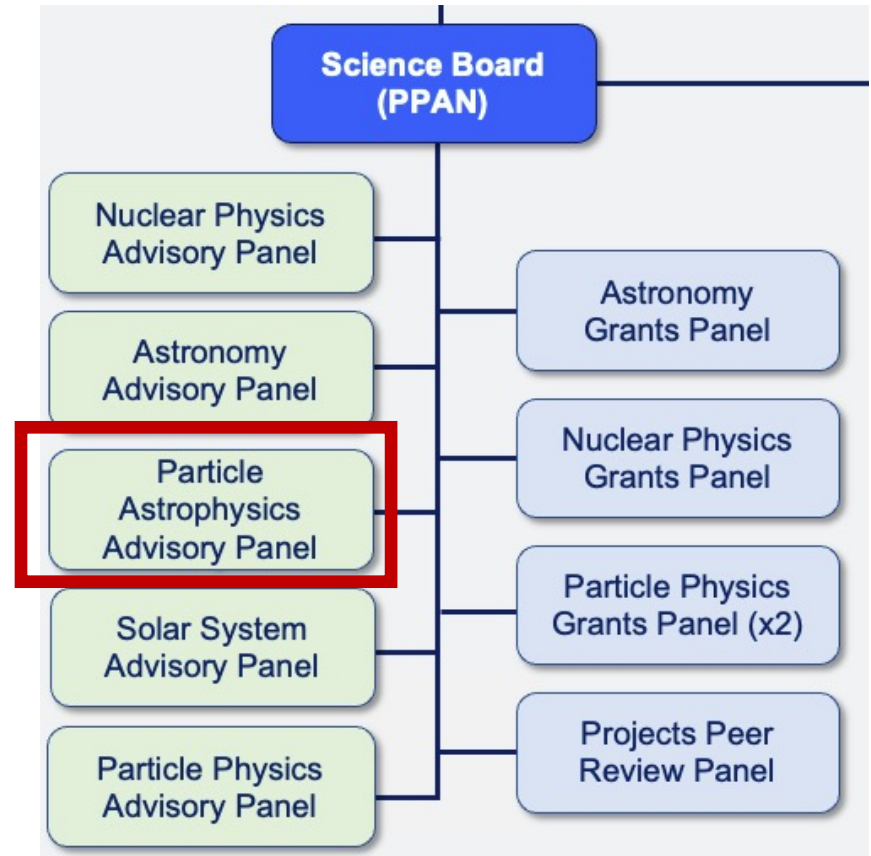
• STFC:

- *Thomas Gray*, *Georgina Freeman (currently on maternity leave)*,
Melanie Kidd, *Jamie Parkin*



PAAP role

- One of the 5 Advisory Panels for the Science Board (PPAN)
- Link between SB and the community
 - Establishment of effective route for communication with SB (PPAN) and STFC on strategic programmatic issues
- Overview of activities within Particle Astrophysics
- A science vision and long-term strategy
 - Roadmap
 - Current and future science opportunities
- Technology roadmap for Particle Astrophysics
- Advice to the SB on specific questions as requested
- Links to other advisory panels



PAAP Activities 2023-24

- In-person meeting in June 2023 in Sheffield
- Presentation to the Science Board in July 2023
- Wave 4 Infrastructure Fund Preliminary Activities Review
 - 4 projects considered
 - 3 projects endorsed
 - 2 projects recommended by SB
 - XLZD
 - AION
- Input to STFC on APPEC and P5 reports
- Continued working on the PAAP Roadmap update
 - This activity has been paused to redefine the process and make the update and information we are collecting better suitable for the PPAN Roadmap



Inputs to the PPAN Roadmap

- [Particle Astrophysics Roadmap published in August 2022](#)
 - It will be a basis for the input from Particle Astrophysics AP to PPAN Roadmap
 - An update has been initiated in April 2023 but there was a very limited interest from the community
 - Up-to-date, correct and detailed information is important as it will be used for the PPAN Roadmap
- Questions for the update
 - Are the recommendations up-to-date?
 - Have there been any major scientific developments that should affect future support of relevant UK research
 - Have there been any significant updates to relevant international roadmaps?
 - Any new opportunities or risks?
 - Any external drivers and key decision dates?
- Inputs will be needed to SB in early September → inputs from the community should be finalised by mid-July
 - Questionnaires will be distributed in ~May
 - Please don't ignore. Single PPAN programme approach removing funding silos within core programme represents opportunities but also challenges, and correct up-to-date inputs will be even more important
- **Any questions e-mail: [Particle.Astro AT STFC.ukri.org](mailto:Particle.Astro@STFC.ukri.org)**

Subject Areas

Gravitational Waves

LIGO-Virgo-KAGRA:

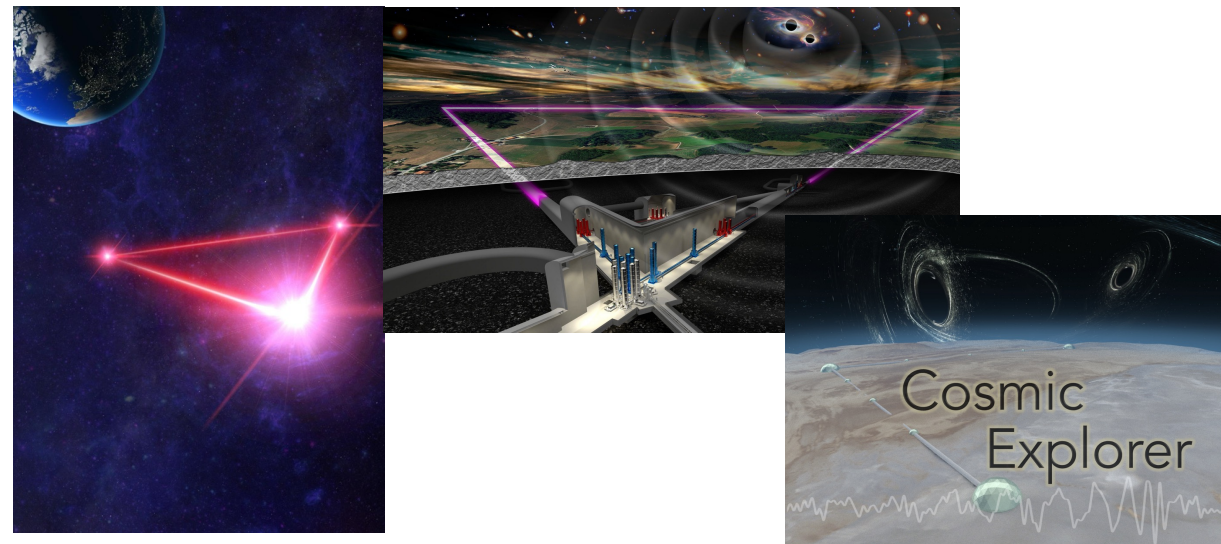
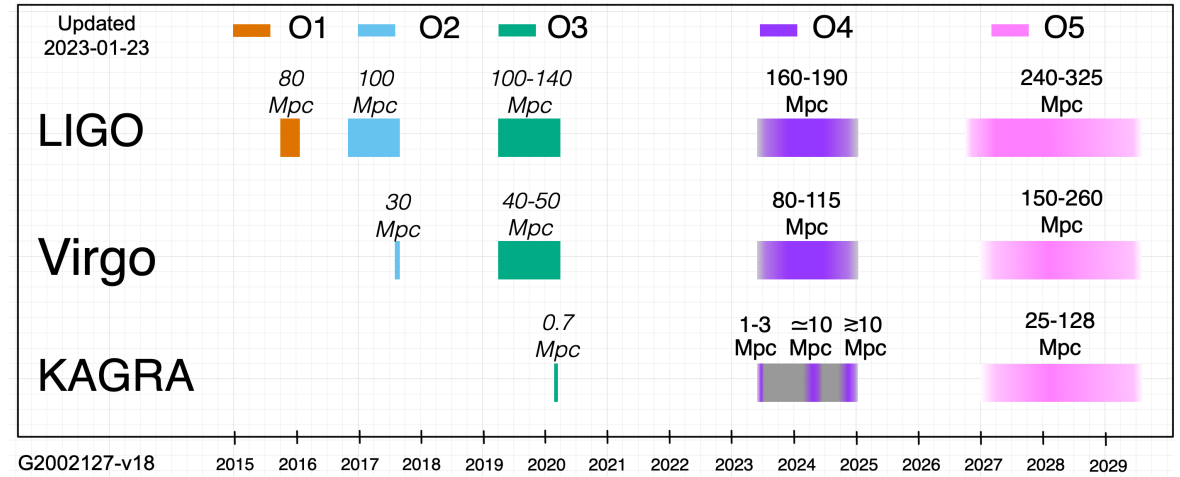
- O4 commenced in May 2023. The O4a science run was completed successfully with 81 public gravitational-wave alerts <https://gracedb.ligo.org/superevents/public/O4/>.
- The second half of O4 (O4b) is due to start on 10th April. Virgo is expected to join science data taking.

Future detectors:

- **LISA** has been adopted – this was announced a few weeks ago
- The next GW grant round has been announced, with a submission deadline of August 2024.
- Preliminary infrastructure proposal was approved by UKRI with £8M funding over 3 years starting in October 2023.

Pulsar Timing Arrays:

- The **European Pulsar Timing Array** had its second data released, and announced evidence for discovery of a gravitational wave background based on its analysis. <https://arxiv.org/abs/2306.16214>.



Neutrino Astronomy

Neutrinos are only high-energy particles to explore the deep universe

- TXS0506+056: a nearby blazar
- NGC1068: a nearby galaxy
- Galactic plane: the nearest high-energy neutrino source

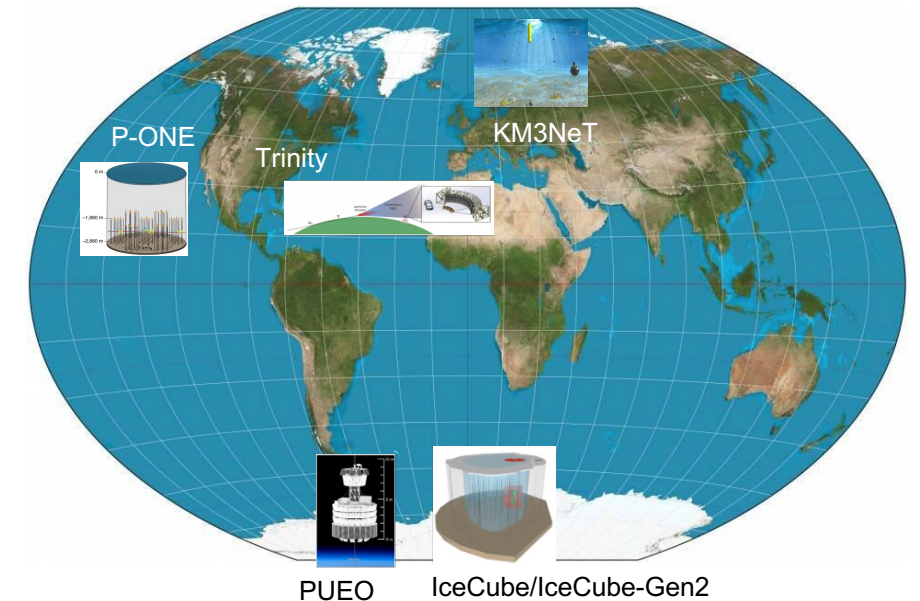
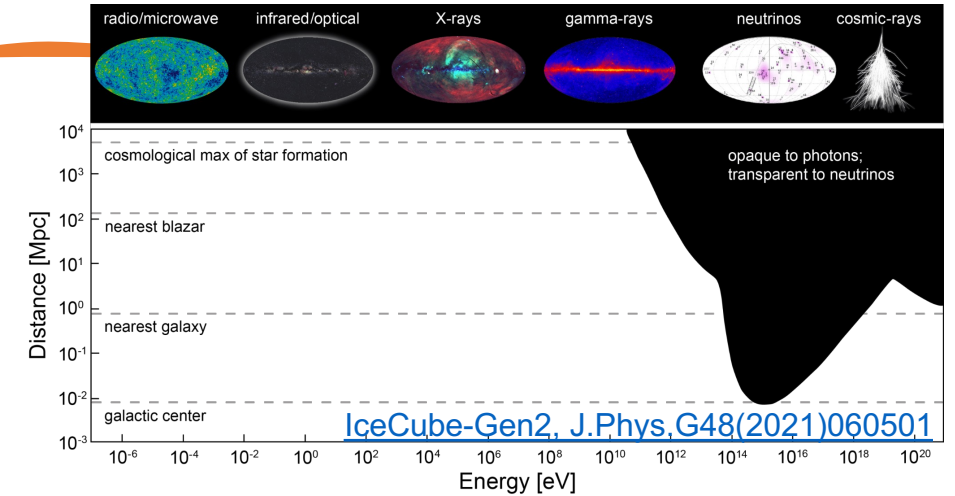
[IceCube, Science380\(2023\)1338](#)

All of these give new physics opportunities!

UK High-Energy Astrophysical Neutrino consortium

- **IceCube, PUEO, P-ONE, KM3NeT, Trinity**
- Experimental submission to PPGP (**IceCube, PUEO, P-ONE**)
Near term plan: Exploit science from **IceCube** and **PUEO**
Long term plan: **P-ONE** as a baseline UK project
- Community building workshops are planned (TBA)

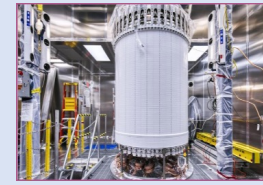
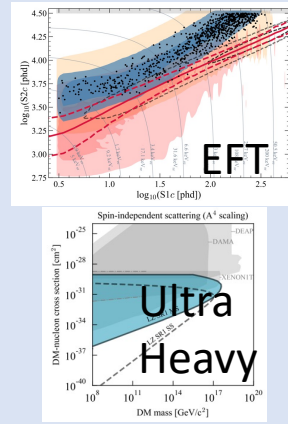
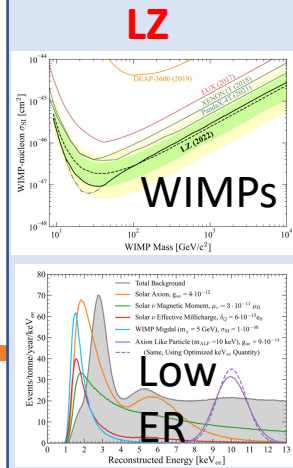
Universe is opaque to high-energy gamma rays



Dark Matter

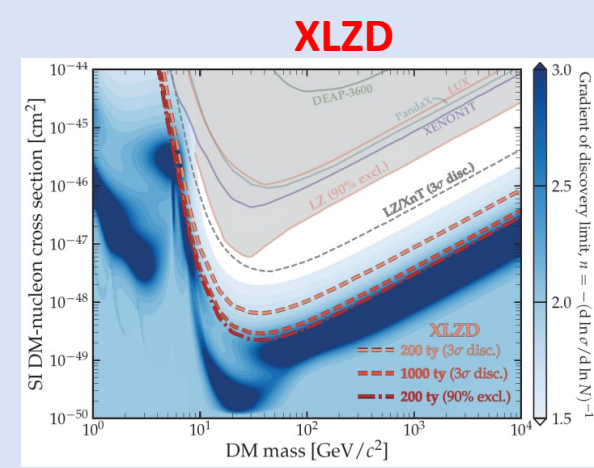
(Particle-like)

- **Direct Dark Matter search experiments with strong contributions from UK groups produce world leading results**
- **Strong motivation and well-developed ideas for future experiments**
 - **Utilising Boulby Underground Laboratory in particular**



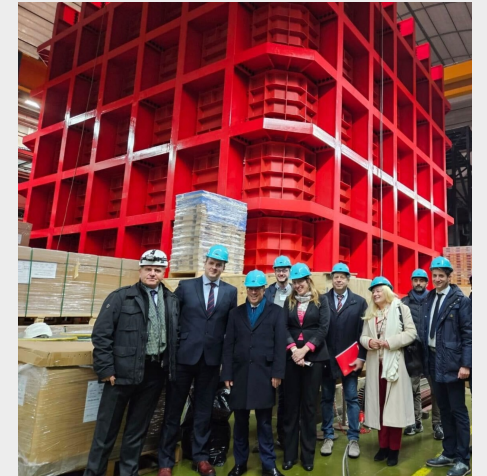
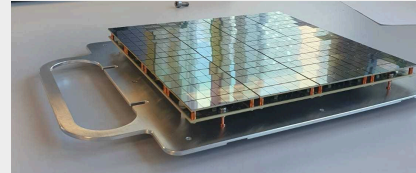
Case to host in Boulby

Successful operation and publication of results in progress



DarkSide-20k

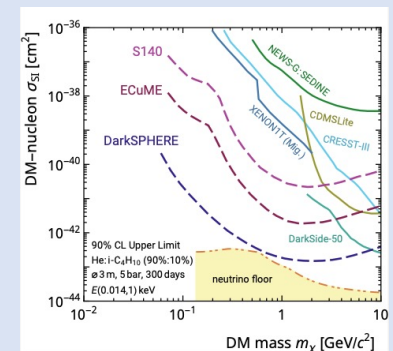
- Construction at Gran Sasso Laboratory (LNGS) advanced
 - cryostat and infrastructures in LNGS Hall C complete!
 - TPC components in production
 - Installation of UK photodetectors starting 2025, Ar fill 2026.
- DarkSide-UK project delivering 7 m² of SiPM array detectors
 - Production ~15% complete as of today, and on schedule.



UK ambassador to Italy visits DarkSide-20k, 12/23

DarkSPHERE

- New result on proton-DM spin-dependent interaction cross-section to be published imminently using a 140cm in diameter detector constructed with 4N copper, featuring an electroformed inner shield of 0.5mm
- Conceptual design of DarkSPHERE published [PhysRevD.108.112006].
- High radiopurity electroforming facility at Boulby being commissioned.
 - Electroformation of 30cm in diameter spherical proportional counter in 2023.
- Collaboration with BUTTON-30 for commissioning/physics exploitation.
- Detector instrumentation development for DarkSPHERE completed, individual read-out of anode signals demonstrated.
- Invited to submit full proposal in the UKRI-STFC Future Underground Dark Matter Science Experiments call.

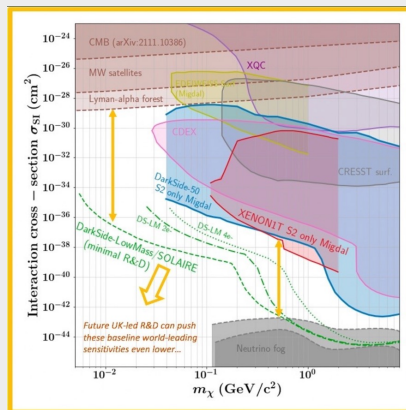


SOLAIRE

The science goals are unprecedented sensitivity to low mass dark matter in the keV to GeV range, and solar neutrino sources using liquid argon as a target

The ambition is to site this experiment at Boulby.

The scale is about 2.0 m high in internal TPC volume, and 2.5 m internal diameter, with external dimensions 4.2 m high and 4.7 m diameter.



SOLAIRE has been invited to submit a full proposal to the UKRI-STFC Future Underground Dark Matter Science Experiments call

Quantum Technologies for Fundamental Physics

AION – atom beam interferometry for ultra-light axion / mid band gravitational waves.

QSHS – ultra-low-noise search for QCD axion / wave-like dark matter.

QTNM – ultra-low-noise tritium endpoint neutrino mass by sensing cyclotron radiation.

QUEST-DMC – superfluid ^3He particle-like dark matter detector, nanowire readout.

QI – precision optical and squeezed light interferometry for ultra-light halo or produced axions/ALPS, probes of semiclassical gravity and quantum gravity.

QSIMFP – superfluid helium simulators of general relativity, fundamental theory.

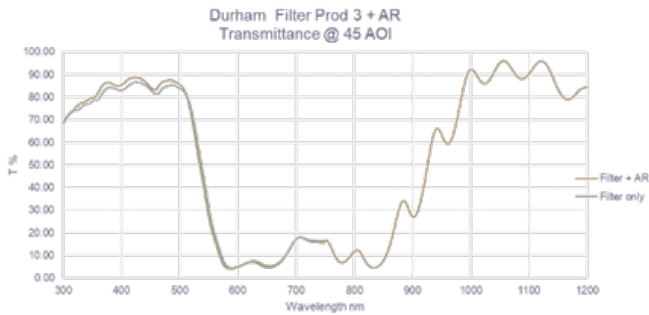
QSNET – precision network of atomic clocks used to test for beyond-standard-model behaviour of fundamental constants.

Plus, 17 other smaller QTFP-supported projects developing novel physics and devices.

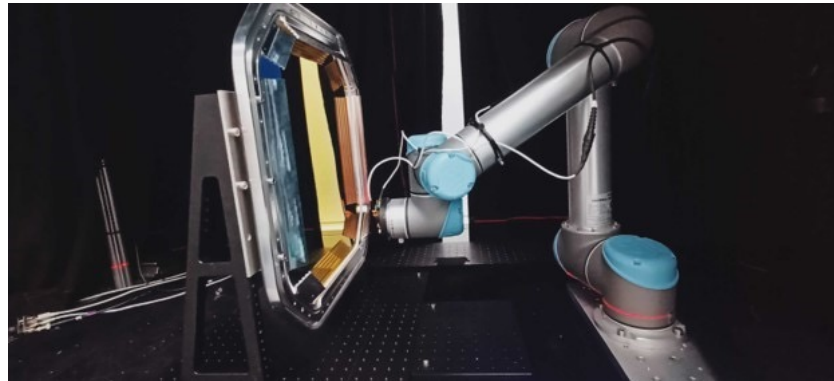
- Several new publications and preprints from the groups about new devices developed and physics results.
- Currently QTFP is undergoing a light touch STFC review.
- ***See talk by Chris Parks on Detector R&D (under DRD5) for more details.***

Gamma Ray Astronomy

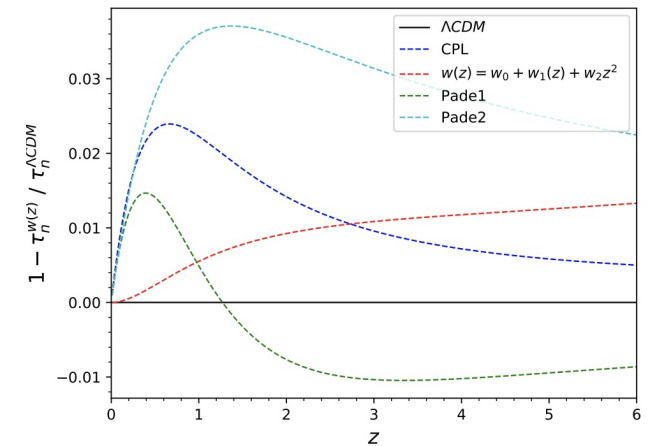
- VHE gamma rays probe extreme environments, AGN and high-energy particle acceleration, and BSM physics.
- **Cherenkov Telescope Array Observatory (CTAO)** is beginning construction. UK leadership in CTAO:
 - Prototype and pre-production camera FEE electronics, software (funded by STFC, complete), camera windows (funded).
 - Astrophysical transients, AGN, BSM physics (ALPs, LIV, DM)



Transmittance spectrum of camera window coating produced by TMF in Basingstoke, with and without an antireflective (AR) coating.



UK funded for production of 50 windows in the UK - covers all SST cameras (plus spares).

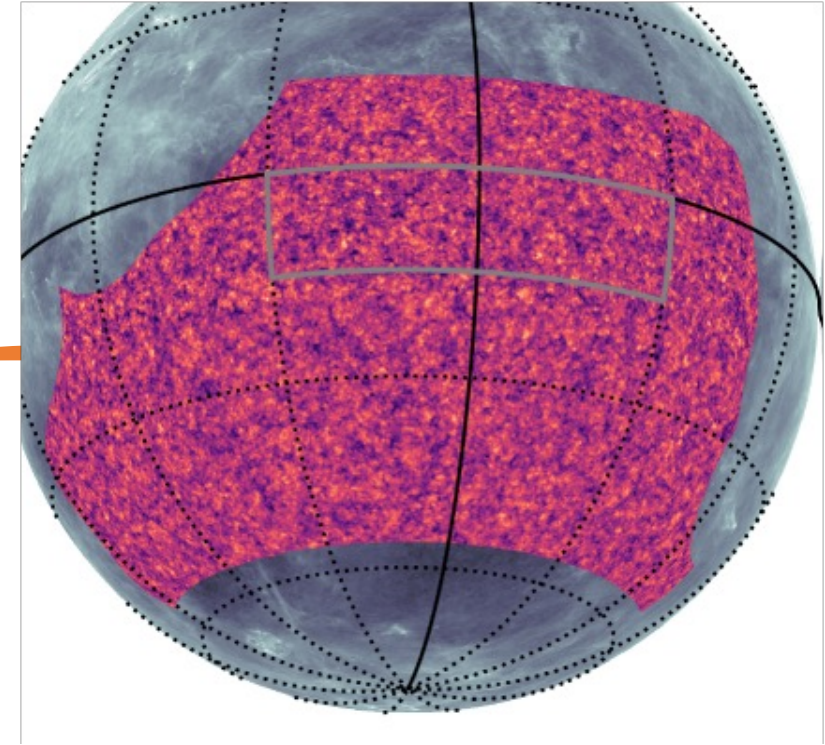


- New calculations for LIV time delays in Universes with different Dark Energy EoS.
Abdalla, H., Cotter, G., et al., 2024, Class Quantum Grav, 41 015033

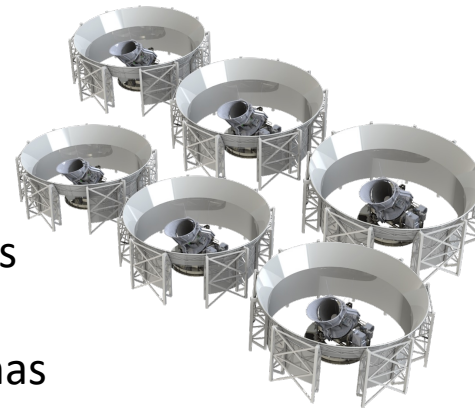
- **To maintain UK leadership in VHE gamma-ray astronomy, and secure ROI, participation in CTAO is essential.**

Cosmic Microwave Background

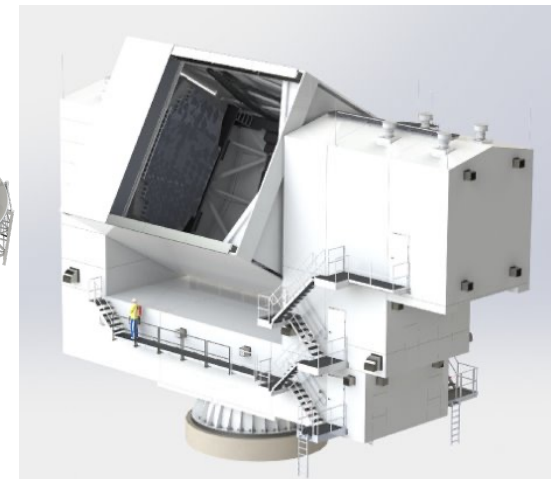
- Broad scientific programme targeting constraints on the early universe, new light particles, neutrinos, cosmic tensions, and astrophysics.
- Extensive UK involvement and leadership in both analysis and experiment.
- Current and near-future surveys:
 - Ongoing ground-based experiments: **ACT** and **SPT** imminently finalizing major power spectrum analyses going beyond Planck constraints. ACT lensing analysis (w. UK leadership) recently provided high-precision measurements of cosmic structure growth.
 - **Simons Observatory** has had first light with the Small Aperture Telescopes. SO:UK project, major UK involvement in SO has begun.
 - US funding for further expansion, **Advanced SO**, was confirmed.
- Upcoming experiments
 - **CMB-S4** ranked very highly by US P5; will allow for continued progress despite constraints on South Pole operations
 - UK involvement in **LiteBIRD** satellite collaboration, funded by UKSA, has started



ACT lensing map

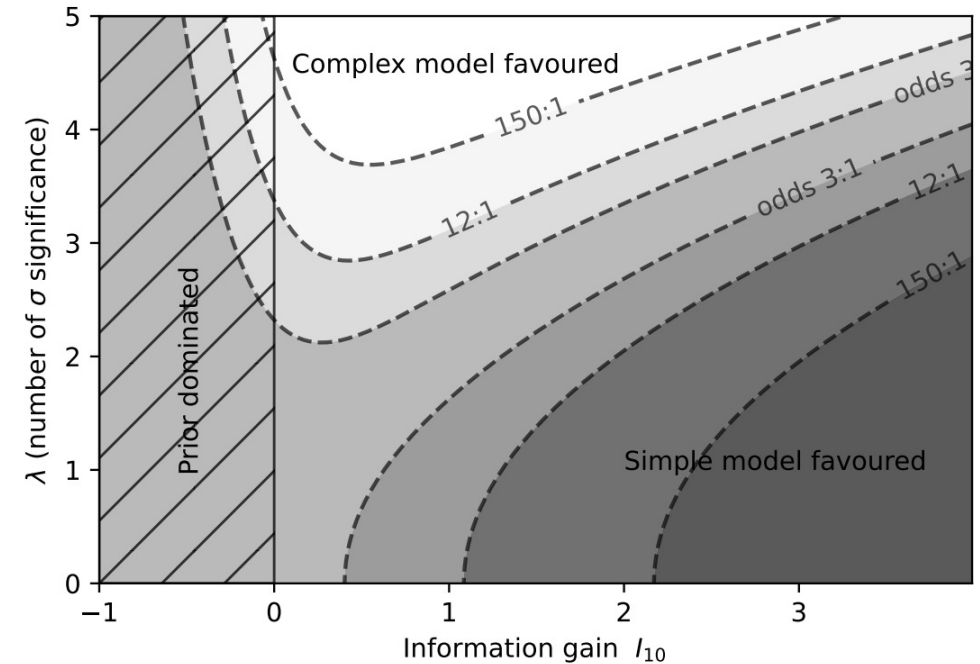


Simons Observatory



Theory

- Results in astroparticle theory, cosmology and fundamental physics inform and support experimental efforts. **Key research lies at the borderline of funding remits.**
- **Progress in modelling** of binary waveforms, cosmological gravitational wave sources, CMB spectral distortions, particles in extreme astrophysical environments (supernovae, stellar cores, compact objects), (ultralight) dark matter, gravitational probes of DM (lensing, accretion, dynamical heating), modified gravity
- **Model building efforts to resolve tensions with concordance cosmology:** Hubble constant (H_0), structure growth σ_8 , dark matter, dark energy and modified gravity
- **Challenge: evaluating model merit.** Occam's razor, Bayesian evidence
- **STFC should consider mechanisms ensuring that world-leading areas of PA theory receive appropriate funding**



In a Bayesian framework, complex models are favored for tensions of high significance, from arXiv:2203.06142

Conclusion

- Particle Astrophysics is experiencing active growth.
- UK groups play leading roles in Particle Astrophysics experiments producing world leading results.
- Development of the Boulby Underground Laboratory has a strong potential to boost Particle Astrophysics and provides an opportunity to host world leading experiments in UK.
- PAAP roadmap and information being collected in the next ~3 months will be used as inputs to PPAN Roadmap
- **E-mail: [Particle.Astro AT STFC.ukri.org](mailto:Particle.Astro@STFC.ukri.org)**

