IMPERIAL

LIGO

DRAFT

UK ASTROPARTICLE PHYSICS

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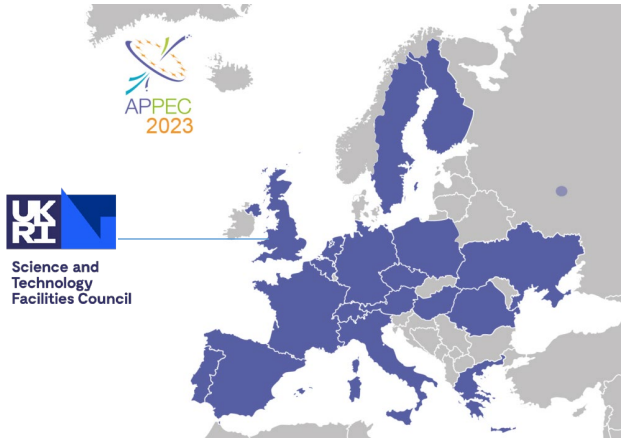
R-ECFA VISIT TO THE UK, SEPTEMBER 2024

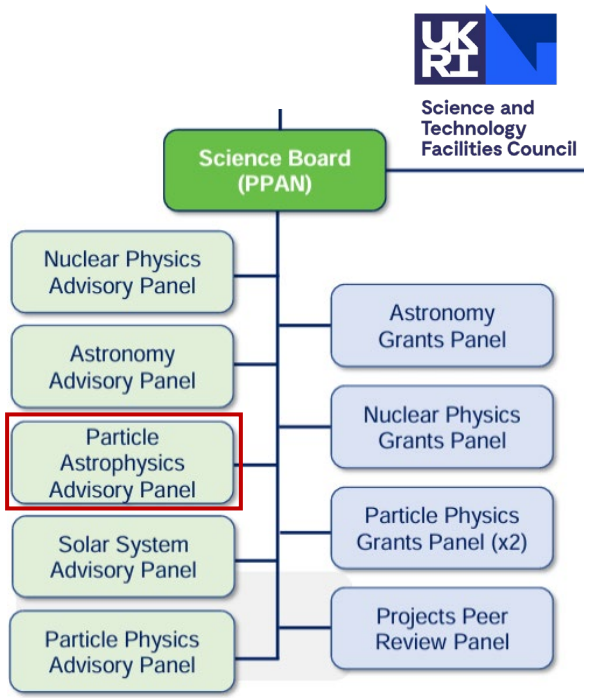
UK ASTROPARTICLE LANDSCAPE

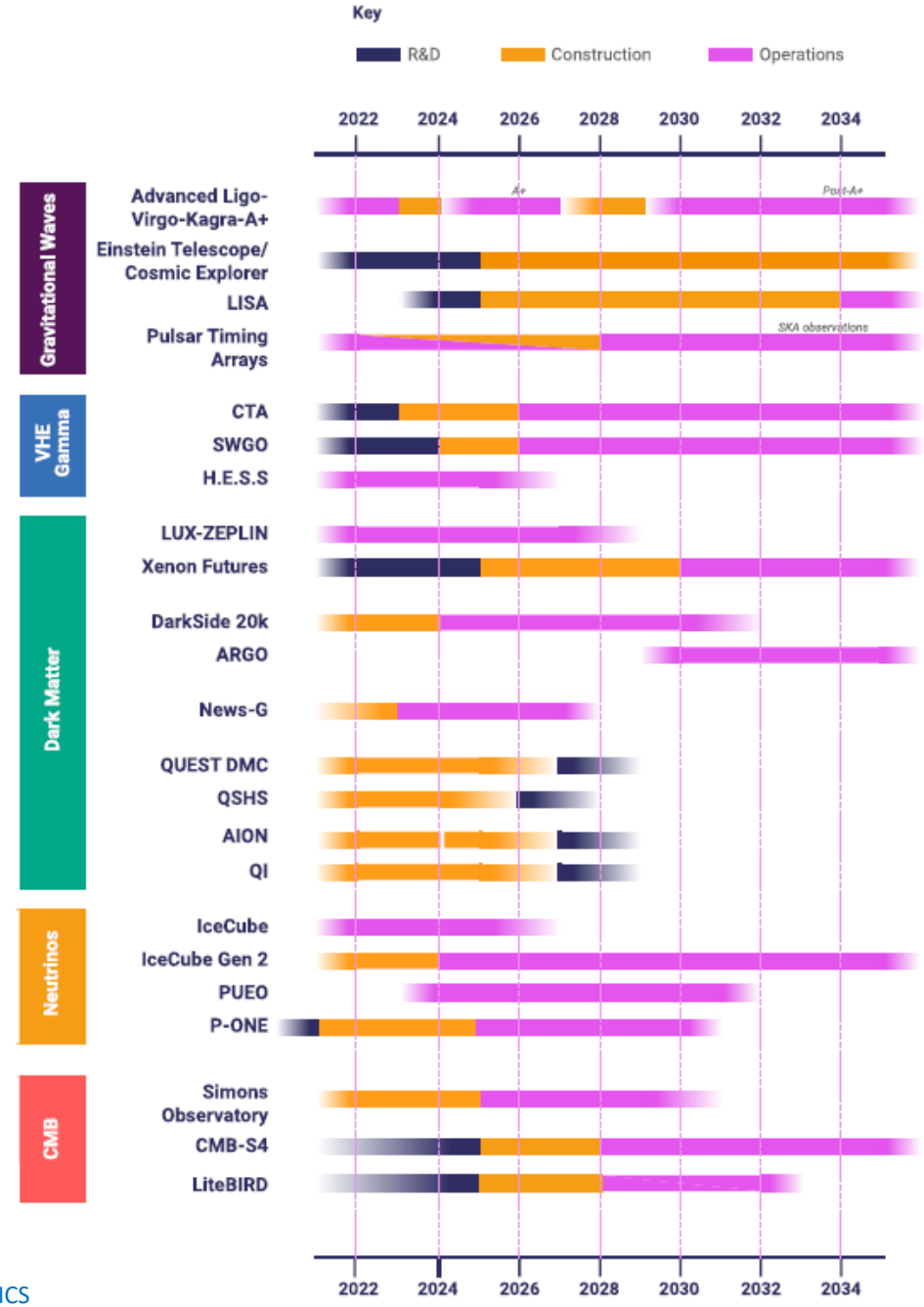
Subject areas

- **Gravitational Waves**
- **VHE Gamma-Ray Astronomy**
- **Direct Dark Matter Searches**
- **Neutrino Astronomy**
- **CMB**
- ***Theory***

Structures: PAAP, APPEC







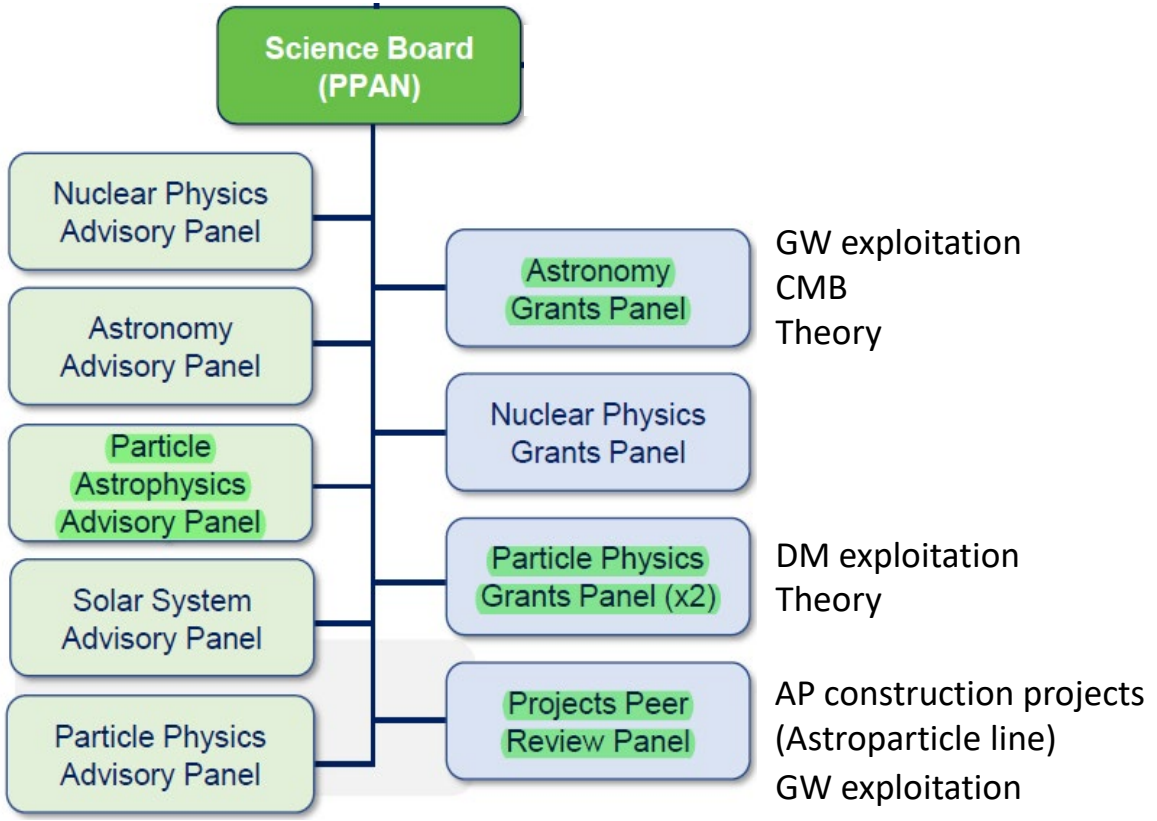
PAAP Roadmap 2022

UK ASTROPARTICLE LANDSCAPE

Groups and demographics – still consulting with various PIs and STFC

- Number of groups and academics & size of teams
- Trend over last decade

ASTROPARTICLE FUNDING SOURCES



STFC

- Construction projects and exploitation
- Double-jeopardy and boundary issues

UK Space Agency

- Space mission hardware
- Boundary issues here too

UKRI Infrastructure Fund

- Major construction/infrastructure projects
- AP quite successful (GW, XLZD, Simons)
- Fund is “oddly shaped”; batteries not included

Other

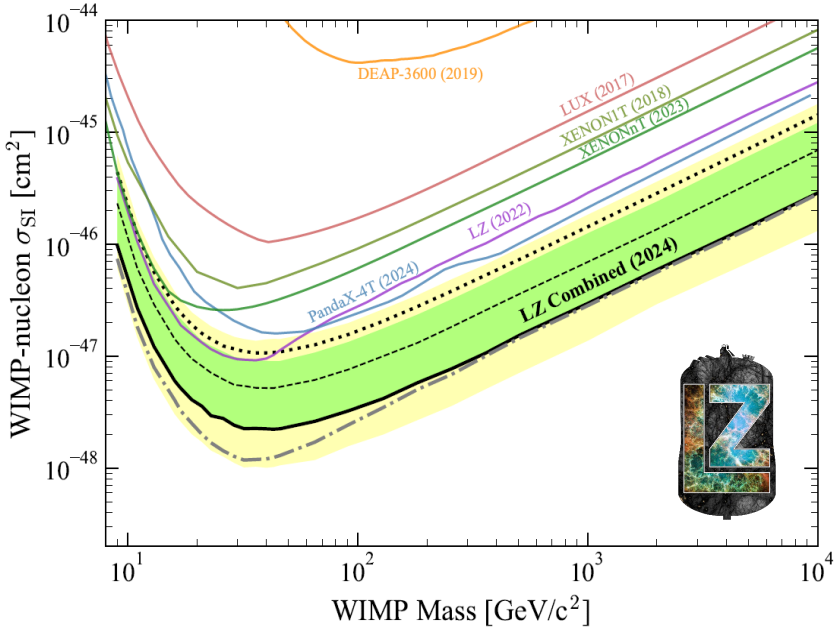
- ERC – not major, Brexit hiatus…

UK ASTROPARTICLE LANDSCAPE

Awaiting data

Area	Institutes #	Academics #	Teams (≥PhD)	Funding (5 yrs, M£)
Dark Matter Searches				
Gravitational Waves				
Gamma-Ray Astronomy				
Neutrino Astronomy				
CMB				
Theory				
TOTAL				

DIRECT DARK MATTER SEARCHES



Main projects (main funded in bold)

- LXe programme: ZEPLIN @Boulby >> LUX @SURF >> **LUX-ZEPLIN (LZ) @SURF**
- LAr programme: DEAP-3600 @SNOLAB >> **DarkSide-20k @LNGS**
- Gas detectors: NEWS-G @SNOLAB; MIGDAL @RAL
- **QTFP programme** (separate talk) – several exciting DM-related projects

Key results & leadership

- LZ leads the field for both spin-independent and spin-dependent interactions: 2022 & 2024 results
  - Major leadership: the "Z" in LZ; current international spokesperson; past physics coordinators
- NEWS-G leading proton-SD interactions in 0.2-1 GeV range
  - Major leadership: current international co-spokesperson

Future

- **Major new underground facility at Boulby** is the paradigm-shifting opportunity
- XENON+LUX-ZEPLIN+DARWIN=XLZD: Rare Event Observatory for DM & ν physics
- **Xenon Futures (R&D)** >> **XLZD@Boulby (UKRI Infrastructure Fund)**
- Further opportunity for mid-class projects under review, including SOLAIRE, DarkSPHERE, QUEST-DMC

BOULBY UNDERGROUND LABORATORY
MAJOR OPPORTUNITY

Major international facility being planned at Boulby, scale £0.5-1B

- Development led by STFC (£3M UKRI funds)

Stage 1: new laboratory at 1,100 m depth by 2028

- XLZD clean manufacture, mid-scale experiment(s), quantum campus; excavations ongoing (~£6M STFC funds)

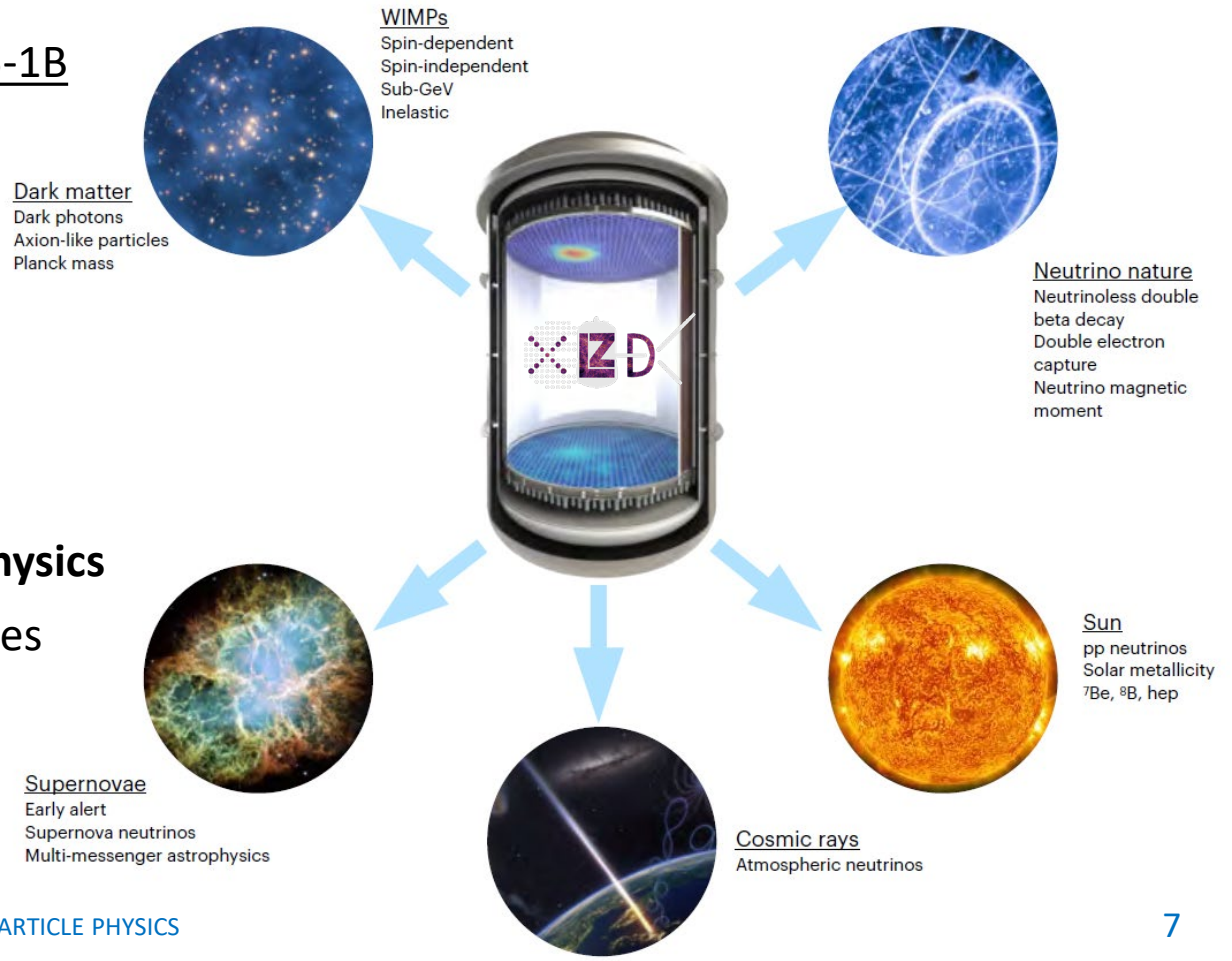
Stage 2: new laboratory at 1,300 m depth by ~2030

- XLZD host facility

XLZD Rare Event Observatory for dark matter and neutrino physics

- Union of main LXe collaborations: 73 institutes in 17 countries
- Supported by >20 UK groups (£8M UKRI funds)

Major opportunity for new "frontier science" complementing the CERN programme



GRAVITATIONAL WAVES

Main projects (main funded in bold)

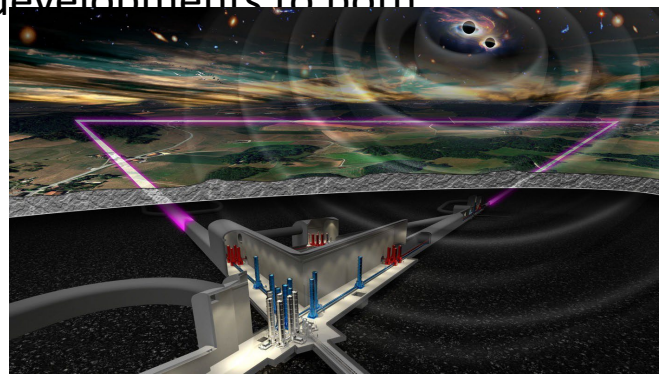
- aLIGO, aLIGO-Virgo-KAGRA network >> **Advanced LIGO plus (A+)**
- LISA Pathfinder >> **LISA, ESA "L-mission" approved (UKSA)**
- Pulsar Timing Arrays – UK played leading role since inception of EPTA and IPTA

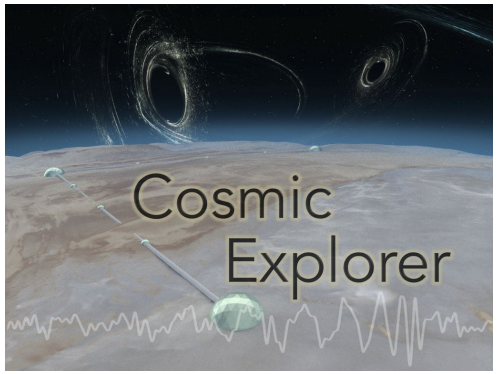
Key results & leadership

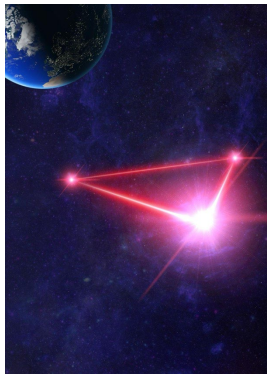
- The observation ~100 GW signals from coalescing binaries comprised of neutron stars and black holes
- aLIGO: UK leadership in operation, upgrade & exploitation
- Major expansion of community since discovery in 2015: "5 to 15 groups"

Future

- Next-gen observatories to realise transformative potential of GW astronomy: Einstein Telescope & Cosmic Explorer: UK scientists are uniquely well placed to deliver developments to both
- UKRI PA now, £100-£200M contribution for FP
- LISA; funded by UK Space Agency (UKSA), ~£40M







VERY-HIGH-ENERGY GAMMA-RAY ASTRONOMY

Main projects (main funded in bold)

- HESS, (MAGIC, VERITAS) >> **CTA design and construction (camera for SSTs @CTA-South) – "final push" needed**
- Limited involvement in Southern Wide-field Gamma-ray Observatory (SWGO)
- Science exploitation from existing observatories (Fermi, HESS), funded mostly from non-STFC sources

Key results & leadership

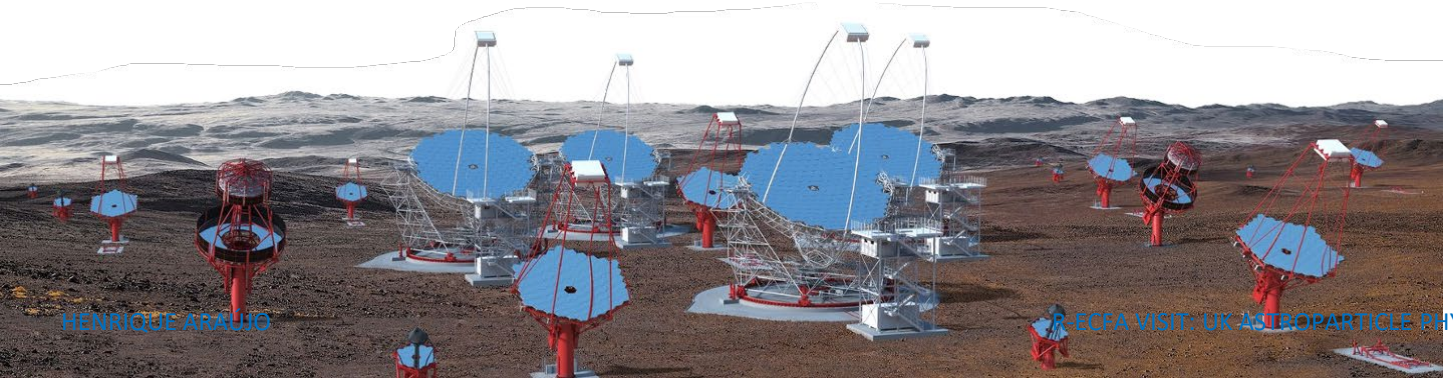
- UK had a founding role in ground-based GRA
- Senior "chair" roles in CTA and HESS
- Successful production/deployment of the first fully-operational camera for SSTs (Sicily, 2019): selected as "the" SST camera

Future

- CTA is the priority for the UK community

Issues

- STFC not prepared to commit significant funding for CTA construction without finalisation of the ERIC: loss of UK "standing army" and leadership



Prototype SST camera in situ on telescope

NEUTRINO ASTRONOMY

Main projects (main funded in bold)

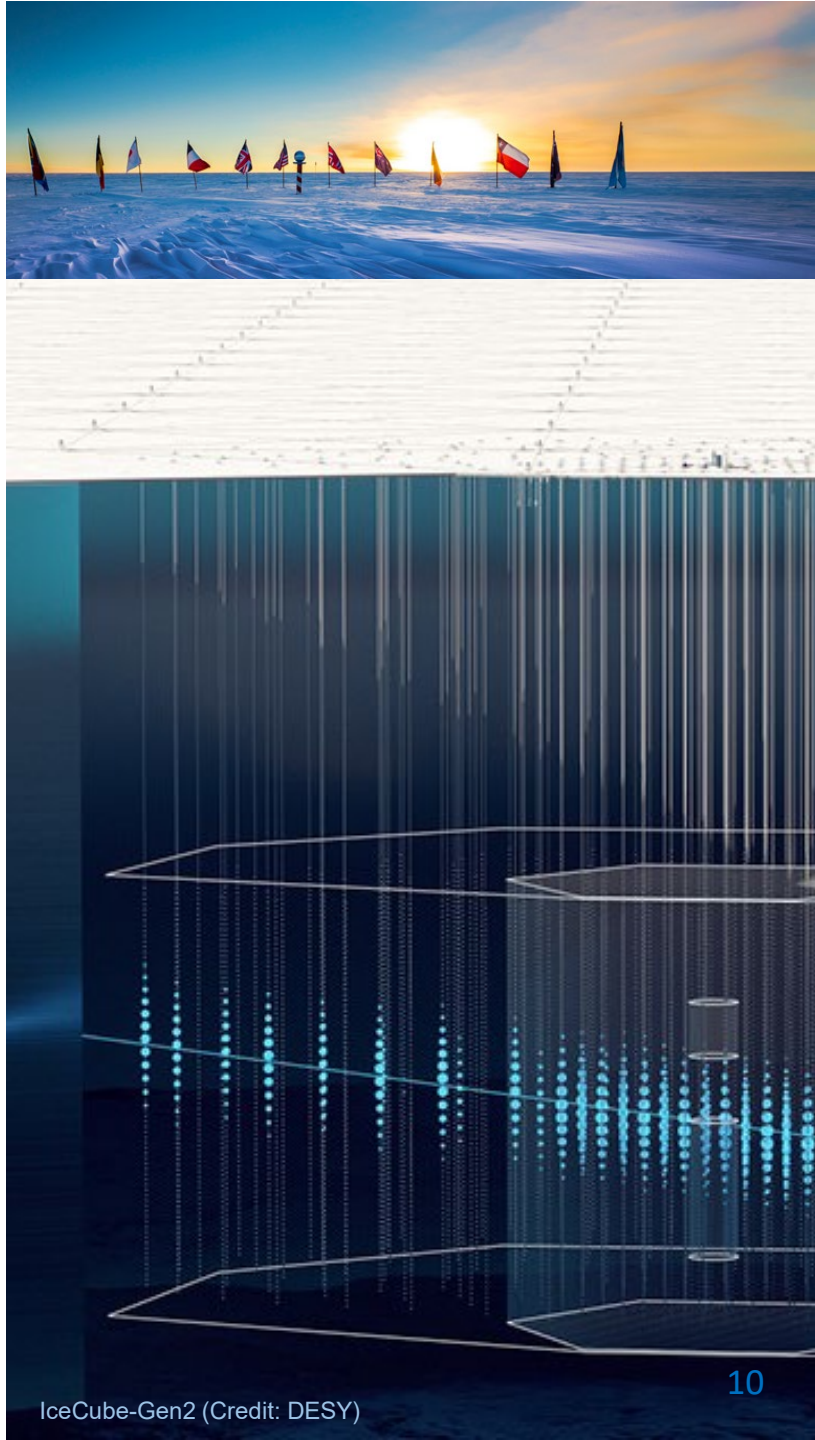
- IceCube/IceCube-Gen2, ANITA/PUEO and P-ONE – mostly non-STFC funding
- UK High-Energy Neutrino (UHEN) consortium is working towards consolidating the UK effort

Key results & leadership

- First high-energy neutrino point source, blazar TXS056+0506

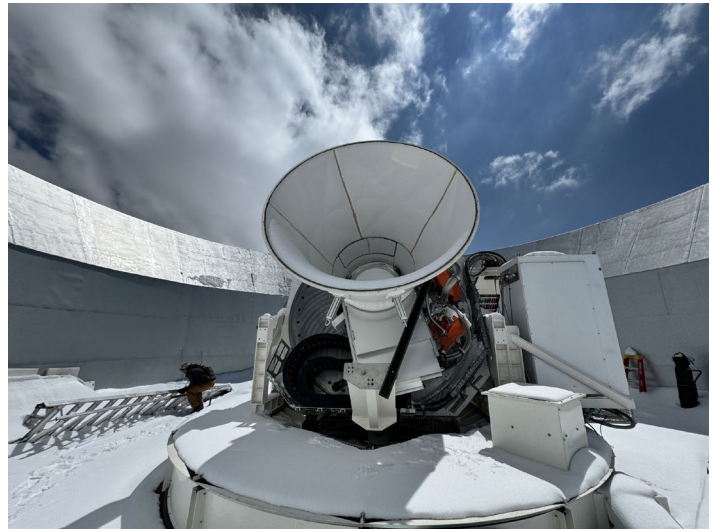
Future

- Community still working on “convergence”, UHEN consortium will keep at it, possibly P-ONE



IceCube-Gen2 (Credit: DESY)

COSMIC MICROWAVE BACKGROUND



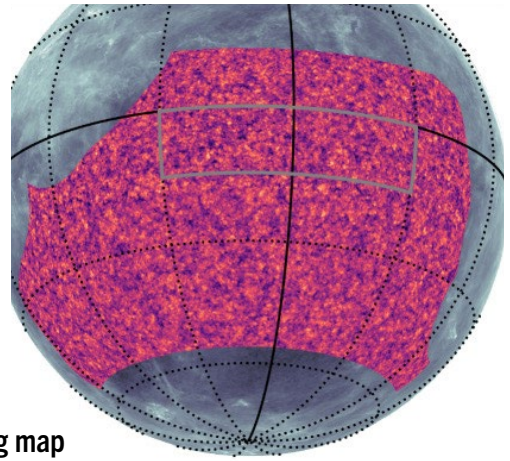
Simons Observatory Small-Aperture Telescope

Main projects (main funded in bold)

- **Simons Observatory:** highest UK priority, significant UK involvement has begun: UKRI Infrastructure Fund (£18M) to provide two small-aperture telescopes (SATs)
- New involvement in Japanese-led **LiteBIRD** satellite, initial funding from UKSA
- Atacama Cosmology Telescope (ATC)

Key results & leadership

- Major role in extracting the most precise measurements of CMB power spectrum and lensing spectrum with Planck and AdvACT: precise tests of Λ-CDM and inflation, tightest bounds on neutrino masses
- UK-led ACT lensing analysis provided high-precision measurements of cosmic structure growth
- Simons Observatory: two SATs are taking data, third due soon, LAT early next year. SO:UK will be leading two additional SATs to come online in 2026



ACT lensing map

Future

- LiteBIRD (inflationary GW): UKSA plans to invest a total £17 million
- CMB-S4: in flux, but the plan has been to seek involvement

THEORY

UK has a large and prominent community in theoretical "Particle Astro" & "Astroparticle"

- One of the largest in Europe – 16 UK institutes in EuCAPT

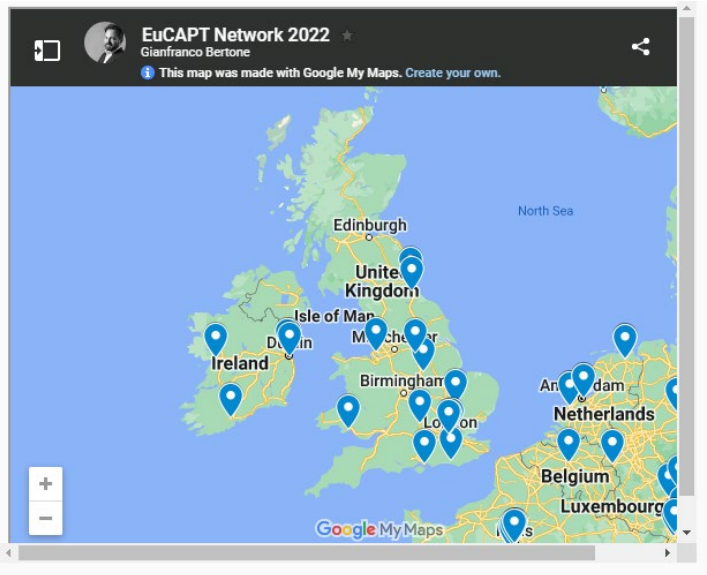
Main areas

- General relativity, particle phenomenology, particle cosmology, cosmic-ray theory, neutrino theory, …
- UK has spearheaded a new theoretical effort to underpin the QTFP programme (DM, GW, …)

EuCAPT: European Consortium for Astroparticle Theory

- Founded by CERN and APPEC in 2019
- Led by UK director (Pascoli)

Challenge: STFC support comes from both Particle Physics and Astronomy grants – "falling between the cracks"; this is a common topic in the wider PA/AP field…



SUMMARY

Astroparticle Physics lies at the intersection of particle physics, astronomy and cosmology.

It is a growing field in the UK and internationally, well poised for discoveries beyond the standard models of Particle Physics and of Cosmology

It complements the (HL-)LHC and is ripe for major investment before the FFC

The UK has a long tradition in this area; the programme is well aligned with APPEC strategy

Opportunities being pursued now, with significant infrastructure funding:

- UK is ready for a step change in leadership in underground science – major plans for Boulby expansion and hosting the XLZD Rare Event Observatory
- Very strong Gravitational Wave community, able to contribute significantly to either next-generation observatory: Einstein Telescope or Cosmic Explorer
- CMB post Planck: significant contributions to the Simons Observatory (& LiteBIRD)

Challenges and limitations:

- Boundaries have consequences: a more strategic approach is needed
- Growth in some areas has not been matched by “people funding” (e.g. GW, Theory)
- The Gamma-Ray Astronomy and Neutrino Astronomy communities need investment