Update from the PAAP

Particle Astrophysics Advisory Panel

Philip Mauskopf, Cardiff University

Giles Hammond, University of Glasgow

Jim Hinton: University of Leicester

Alex Murphy: University of Edinburgh

Silvia Pascoli: Durham University

https://paap.astro.cf.ac.uk/doku.php

ASPERA

SIXTH FRAMEWORK PROGRAMME

Science & Technology Facilities Council

Particle Astrophysics

- The field of particle astrophysics encompasses projects measuring and characterising the properties of *particles and radiation from space* apart from standard electromagnetic radiation. These projects often lie at the intersection between Cosmology, Astrophysics and Nuclear and Particle physics.
- Internationally, particle astrophysics is defined by *technique*
- Two ways to measure particles from space:
- Direct detection - Gravity wave telescopes, Neutrino detectors and telescopes, Cosmic ray telescopes, Gamma ray telescopes, Dark matter detectors and telescopes, Other exotic particle searches – e.g. axions, magnetic monopoles, etc.
- Indirect detection – pulsar timing, CMB, weak lensing, LSS, etc.
- Thus there is an overlap between the activities of PAAP and FUAP / PPAP / NPAP (science and technology overlap)

Particle Astrophysics: The European Strategy

- Reviews relevant to UK strategy;

  2010 STFC programmatic review

  ASPERA (http://www.aspera-eu.org)

ASPERA

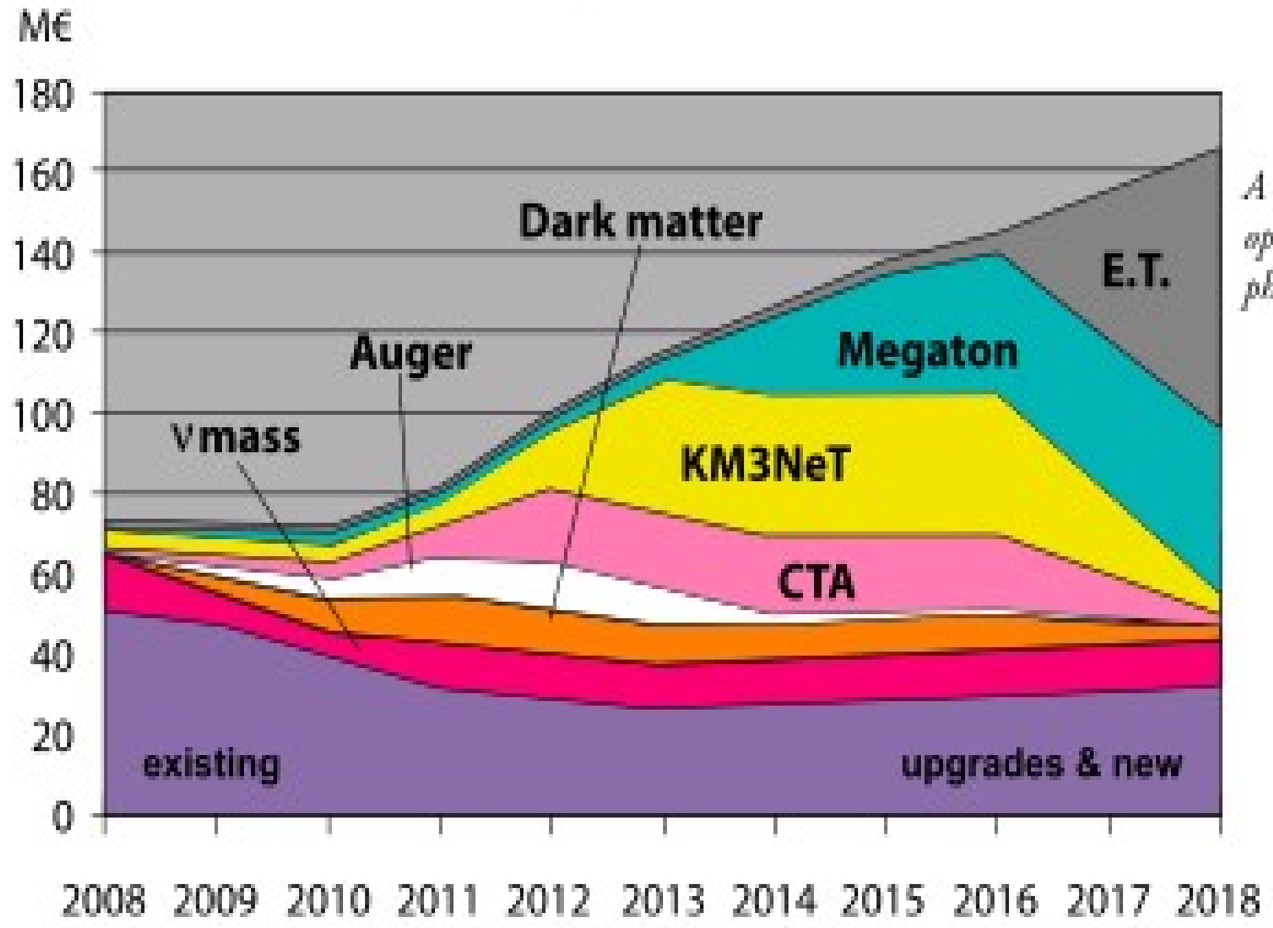
– is a network of national government agencies responsible for coordinating and funding national research efforts in Particle Astrophysics

– has identified the development of a roadmap for Particle Astrophysics in Europe as one of its main deliverables

ASPERA Magnificent Seven (Sep 2008)

- Ton-scale detectors for dark matter search
- A ton-scale detector for the determination of the fundamental nature and mass of neutrinos
- A megaton-scale detector for the search for proton decay, for neutrino astrophysics and for the investigation of neutrino properties
- A large array of Cherenkov Telescopes for detection of cosmic high energy gamma-rays
- A cubic kilometre-scale neutrino telescope in the Mediterranean Sea
- A large array for the detection of charged cosmic rays
- A third-generation underground gravitational antenna

ASPERA – European review of particle astrophysics



A scenario for investment and operation cost of astroparticle physics in the ASPERA countries.

UK PA areas

The techniques used in Particle Astrophysics can be divided into the following broad areas (with examples of projects that have received UK support indicated in brackets):

- Particle astrophysics theory (cosmology, DM, GW's, neutrino's and particle accel.)
- Gamma ray astronomy (CTA, HESS, VERITAS)
- Direct dark matter detection (EURECA/CRESST/EDELWEISS, ZEPLIN/LUX-ZEPLIN, DRIFT, ArDM, etc.)
- Gravitational wave detection (LIGO, Advanced-LIGO, LISA)
- Neutrino astronomy (SNO+, LAGUNA)
- Cosmic rays (AUGER South, ANITA, ACORNE)
- CMB polarisation studies (PLANCK, EBEX, POLARBEAR, SPIDER, ACT-POL, etc.)

Mixture of large facilities and smaller scale experiments

Internationally growing field

STFC support for PA projects except GW ended in 2010 SR

Gamma Ray Astronomy

Science areas:

Fundamental physics:

Lorentz invariance – quantum gravity

Dark matter annihilation signature

High energy universe (extragalactic):

Gamma ray bursts

Emission from AGN

Starburst galaxies

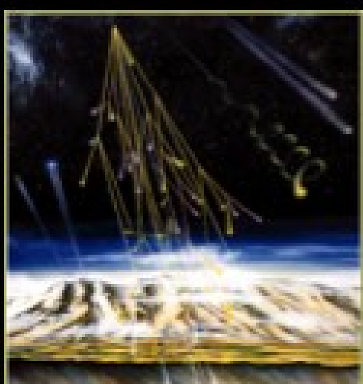
High energy universe (galactic):

Binaries

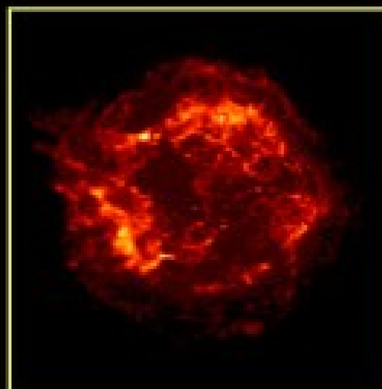
Pulsar wind nebulae

Gamma ray pulsars

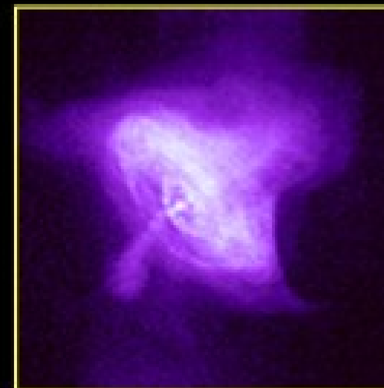
Science with VHE Gamma Rays



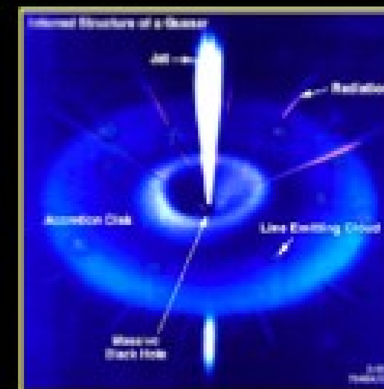
Origin of cosmic rays



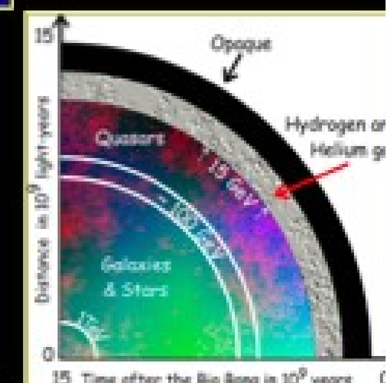
SNRs



Pulsars and PWN

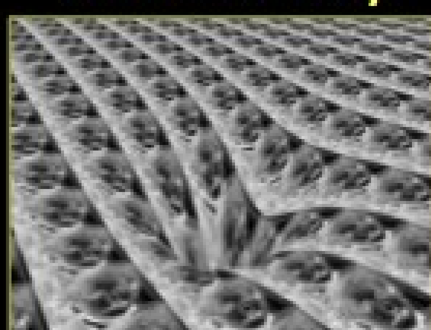


AGNs

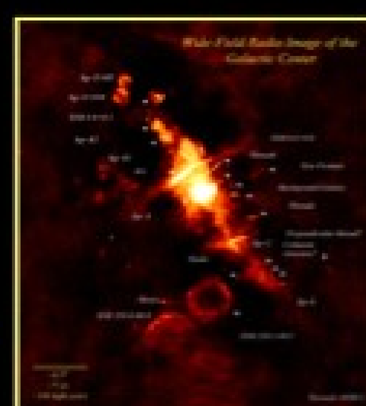


Cosmology

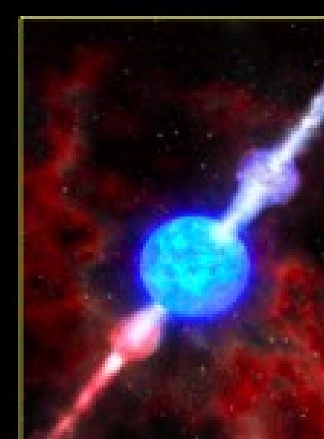
Space-time & relativity



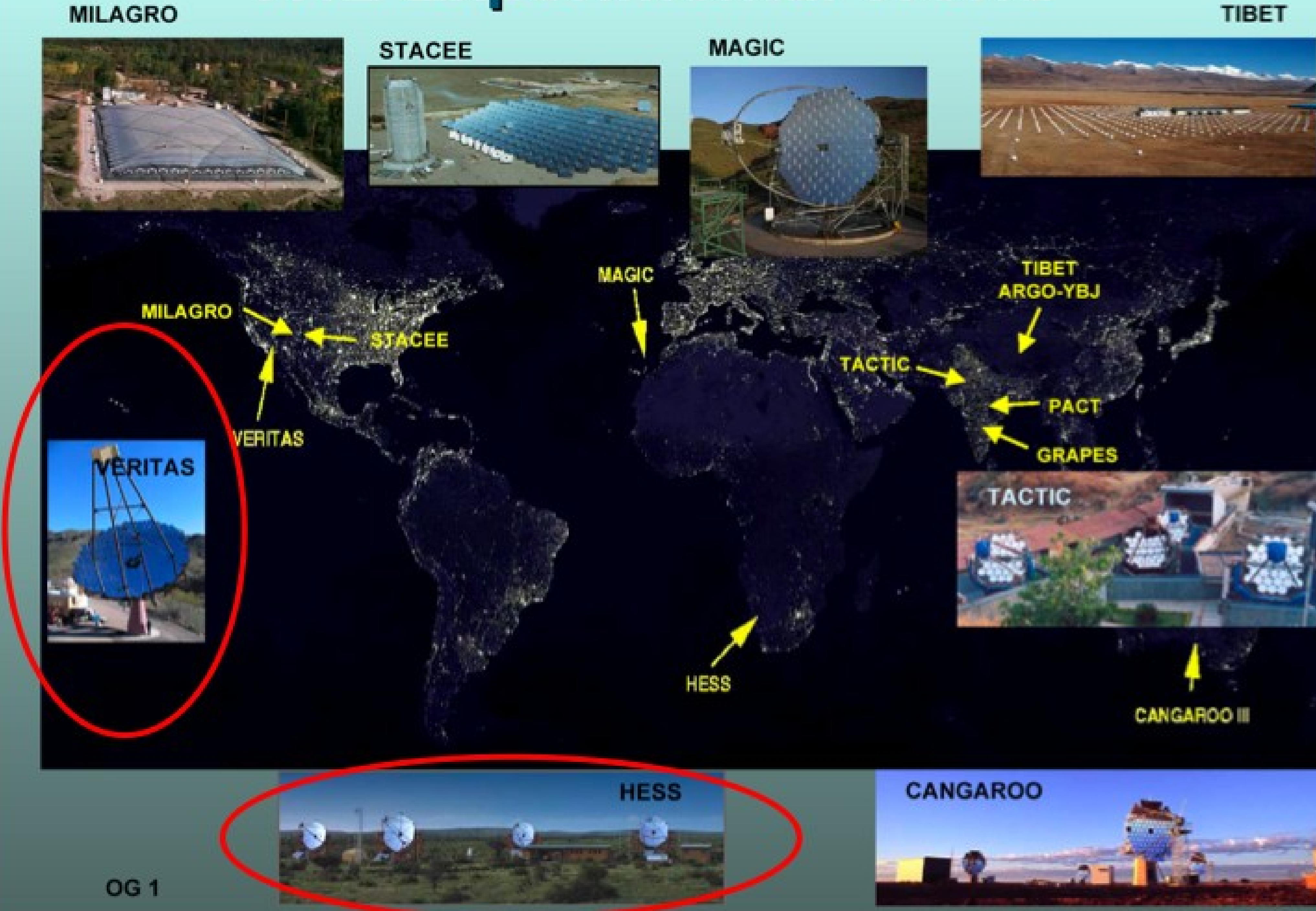
Dark matter



GRBs



VHE Experimental World



OG 1

Gamma Ray Astronomy
Next Generation: CTA

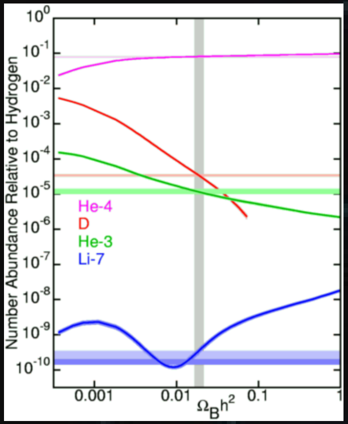
CTA is the successor to the current arrays of imaging atmospheric Cherenkov telescopes (IACTs), such as HESS and VERITAS, which over the last decade have helped revolutionise our understanding of many of the highest energy phenomena in the Universe.

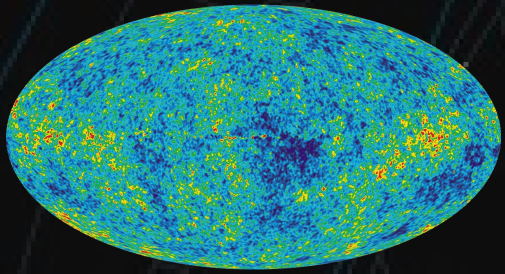
2011: STFC solicited a SOI for CTA

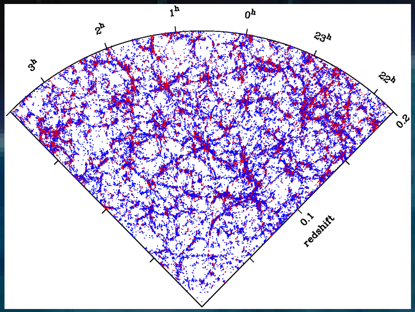
2011: SOI has been reviewed and full proposal has now been requested

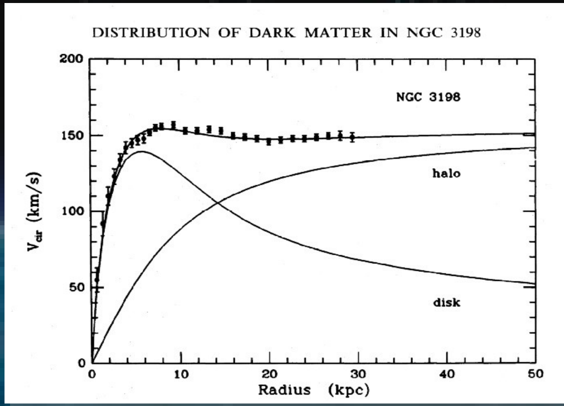
Direct Dark Matter Searches

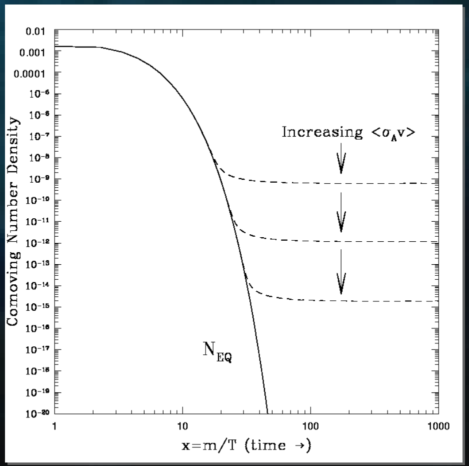
All the astronomical data consistently point to the existence of dark matter



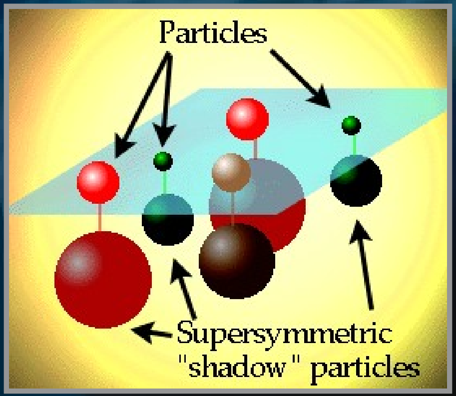








Lightest supersymmetric particle forms a very good WIMP candidate

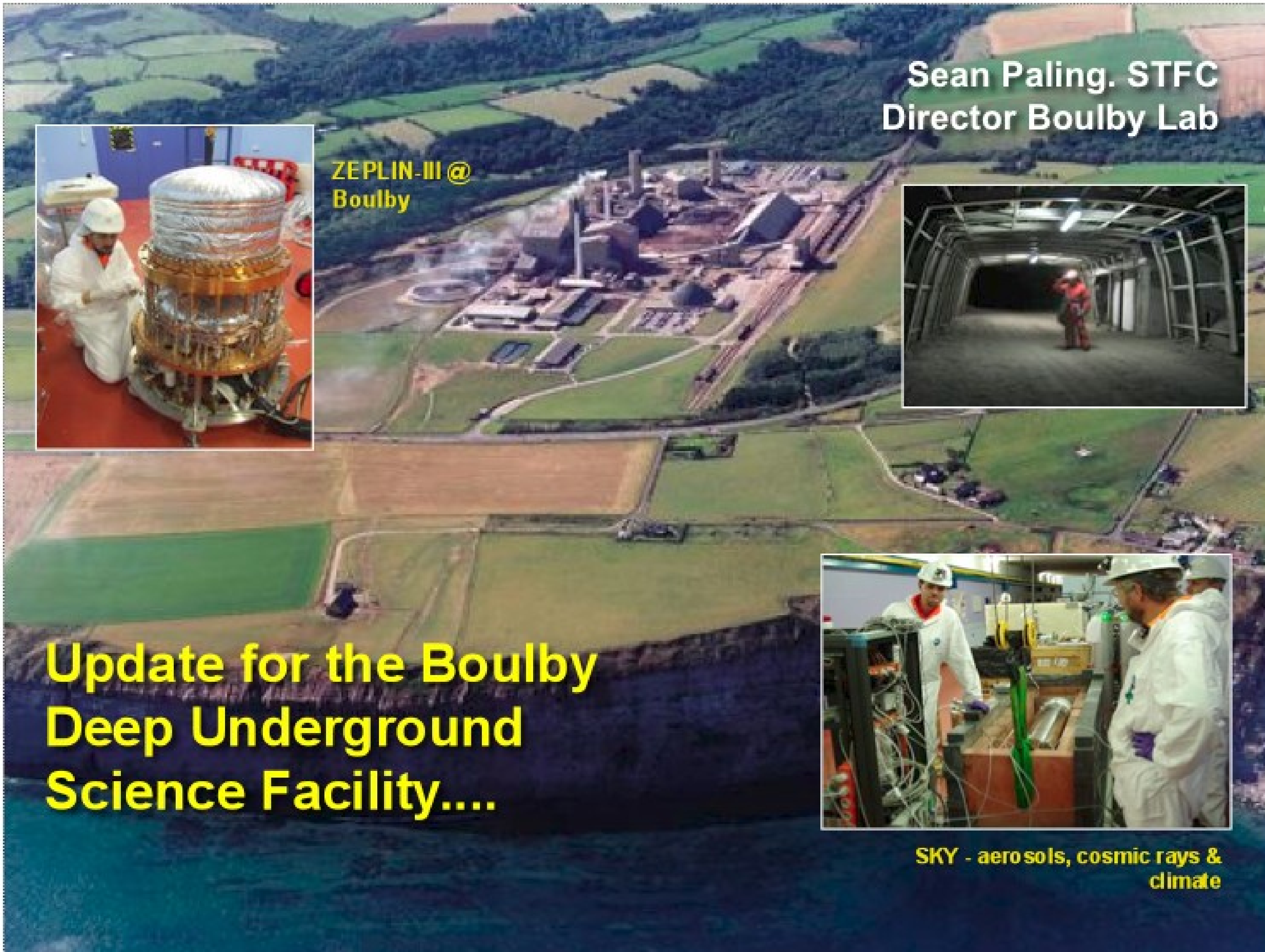


Direct Dark Matter Searches

LUX-ZEPLIN is the successor to the current ZEPLIN experiment led by the UK and EURECA is the successor to the current CRESST and EDELWEISS experiments with UK spokesperson. DRIFT and ArDM are important for future dark matter characterisation experiments.

2011: STFC requested SOI for dark matter

2011: SOI approved and now full proposal requested


Sean Paling. STFC
Director Boulby Lab
ZEPLIN-III @
Boulby
Update for the Boulby
Deep Underground
Science Facility....
SKY - aerosols, cosmic rays &
climate

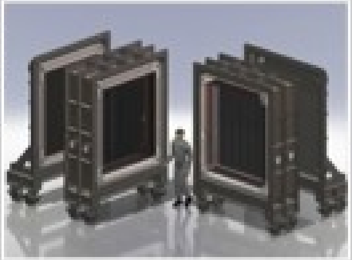
Future Science @ Boulby

- **NEW - €850k over 3 years (2011-2014) funding secured specifically to develop inter-disciplinary science at Boulby.**

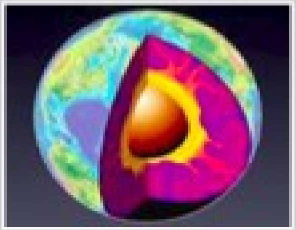
- 'Low- background' projects...
  - SKY Cosmo-climatology project:
  - Ultra-low Background Gamma Spectroscopy:

- 'Other' deep underground projects...
  - Extremophiles, geomicrobiology and astrobiology.
  - Carbon Capture & Storage
  - Muon tomography for geological survey.
  - Etc etc etc...

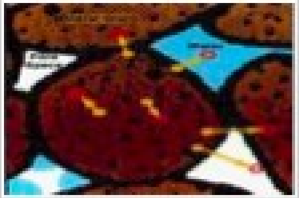
Astro-particle Physics and BEYOND...



DRIFT-III directional Dark Matter search

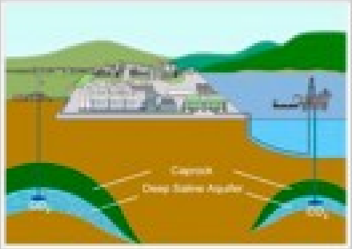


Large-scale rare-event studies?

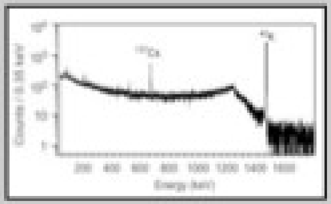


Geology, Geochemistry, Geo-microbiology

Climatology, atmospheric physics



Carbon Capture



Low back-ground counting

Boulby Mine

A working potash and rock-salt mine on the North East of England.

Operated by **Cleveland Potash Ltd**.

Major local employer ~1000 direct and 4000 indirect employment.

Deepest mine in Britain – 1100m deep (2805mwe) – **Cosmic ray muon flux reduced by 10^6**

Potash

`View from Staithes

Dark Matter Experiments – April 2011

ZEPLIN-III

Imperial College, Edinburgh, RAL, LIP-Coimbra, ITEP-Moscow

2 phase (liquid/gas) high field Xenon WIMP dark matter detector. 31 PMTs immersed in ~8.5kg liquid target. High purity Cu construction. Pb shielding & active veto. Installed 2008. FSR (3months – 847kg.d). Running until May2011.

2nd science run completed (>300 day) giving world-class sensitivity. Results out (very) soon

DRIFT-II

Sheffield, Edinburgh, Occidental College, New Mexico, Colorado State

Low pressure gaseous TPC directional WIMP dark matter detector.
1m^3 (fiducial) negative ion drift TPC, 167g CS_2 target. Dual 0.5m^3 drift vols with MWPC readout. Installed – 2005. US (NSF) funded to end 2011. 3 year extension bid now in to NSF – **DRIFT-III**

Now running with CS_2/CF_4 mix - allowing world-class WIMP-proton SD limit setting

LAGUNA

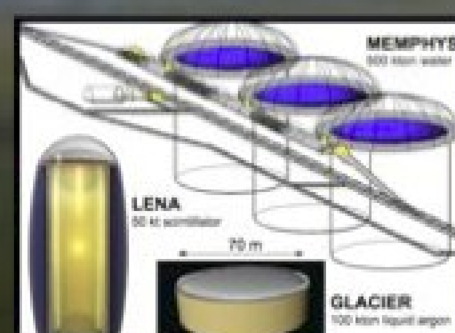
Large Apparatus for Grand Unification and Neutrino Astrophysics

FP7 (& beyond) funded design study for infrastructure to house a MEGATON 'rare event' observatory

BIG QUESTIONS:

- Proton decay
- Supernova neutrinos
- Diffuse SN neutrinos
- Solar neutrinos
- Atmospheric neutrinos
- Geo-neutrinos
- Reactor neutrinos
- Neutrino beams
- Indirect dark matter (direct DM and DBD)

Boulby is one of 7 potential sites



Gravitational Waves

Science areas:

Fundamental physics:

Extreme gravity - quantum gravity

Cosmology:

Early universe phase transitions

History of acceleration

High energy universe:

Gamma ray bursts

Black holes

Supernovae

Binary mergers

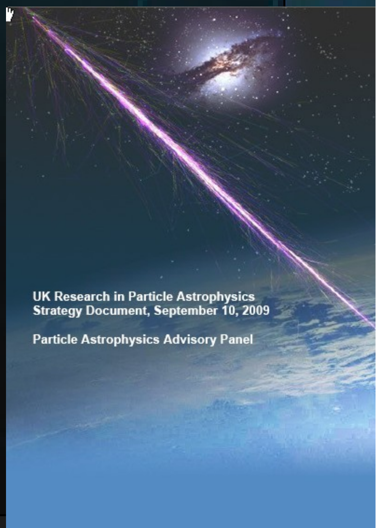
High energy universe:

Pulsar glitches

Magnetar flares

Other:

Helioseismology

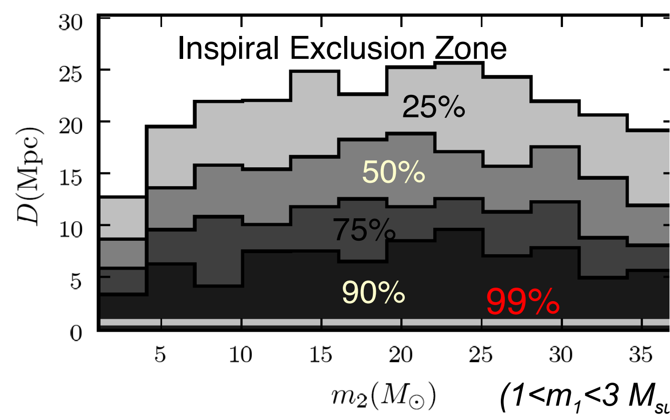


Gravitational Waves

Crab Pulsar

- observed luminosity of the Crab nebula accounts for < 1/2 spin down power
- spin down due to: electromagnetic braking/particle acceleration/*GW emission?*
- LIGO s5 result:
  - ellipticity upper limit: $\varepsilon < 2.1 \times 10^{-4}$
  - GW energy upper limit < 6% of radiated energy is in GWs

Abbott, et al., *"Beating the spin-down limit on gravitational wave emission from the Crab pulsar,"* Ap. J. Lett. **683**, L45-L49, (2008).



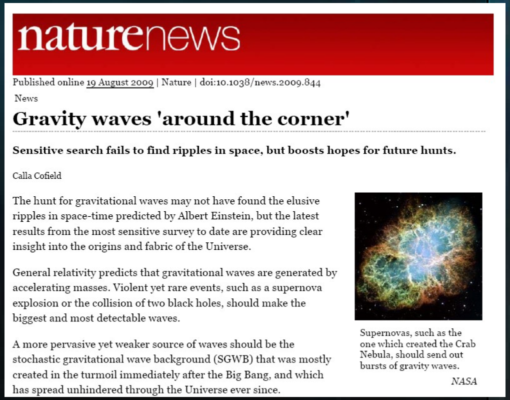
GRB 070201

- GRB observed in direction of M31 during s5 science run
- Binary merger in M31 scenario excluded at >99% level
- Cannot exclude an SGR in M31.

Abbott, et al. *"Implications for the Origin of GRB 070201 from LIGO Observations"*, Ap. J., 681:1419–1430 (2008).

The Stochastic GW Background: *Beating BBN!*

- An isotropic stochastic GW background could come from:
  - the primordial universe (inflation)
  - an incoherent sum of point emitters isotropically distributed over the sky
- Preliminary LIGO s5/VSR1 result: $\Omega_{0,\ \mathrm{LIGO}} < 9.0 \times 10^{-6}$


naturenews

Published online 19 August 2009 | Nature | doi:10.1038/news.2009.844

News

Gravity waves 'around the corner'

Sensitive search fails to find ripples in space, but boosts hopes for future hunts.

Calla Cofield

The hunt for gravitational waves may not have found the elusive ripples in space-time predicted by Albert Einstein, but the latest results from the most sensitive survey to date are providing clear insight into the origins and fabric of the Universe.

General relativity predicts that gravitational waves are generated by accelerating masses. Violent yet rare events, such as a supernova explosion or the collision of two black holes, should make the biggest and most detectable waves.

A more pervasive yet weaker source of waves should be the stochastic gravitational wave background (SGWB) that was mostly created in the turmoil immediately after the Big Bang, and which has spread unhindered through the Universe ever since.

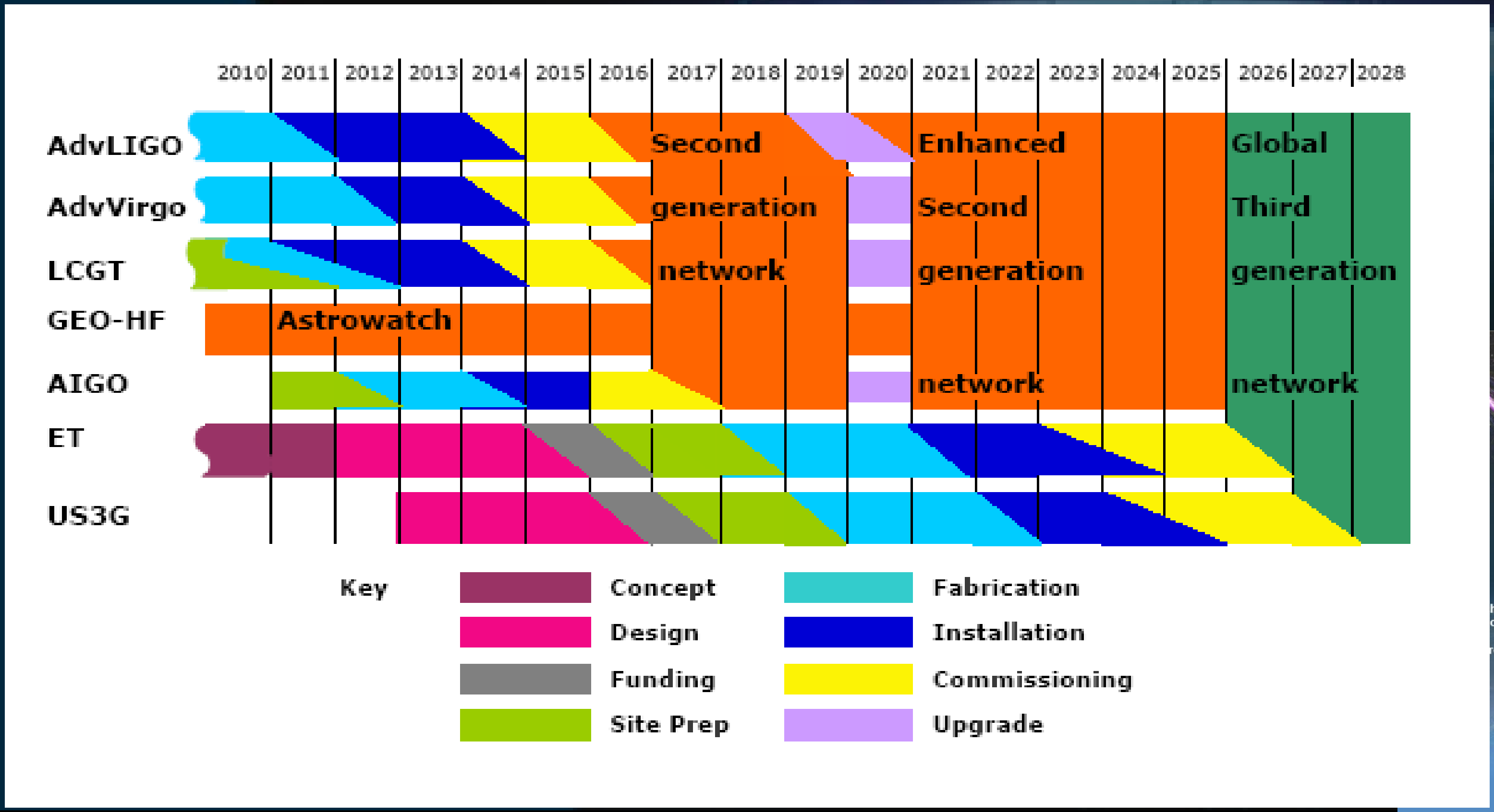
Supernovas, such as the one which created the Crab Nebula, should send out bursts of gravity waves.

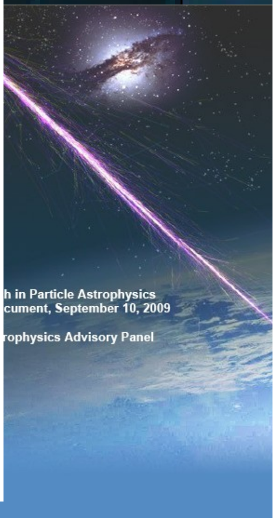
NASA

Gravitational waves

The two main future projects are Advanced LIGO and LISApf/LISA

2011: Cardiff hosting international conference on GW (Amaldi)





Neutrino Astronomy

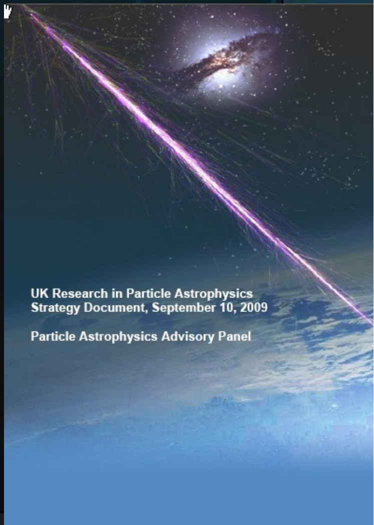
Science areas:

Cosmology:
Supernova background
Cosmological neutrinos

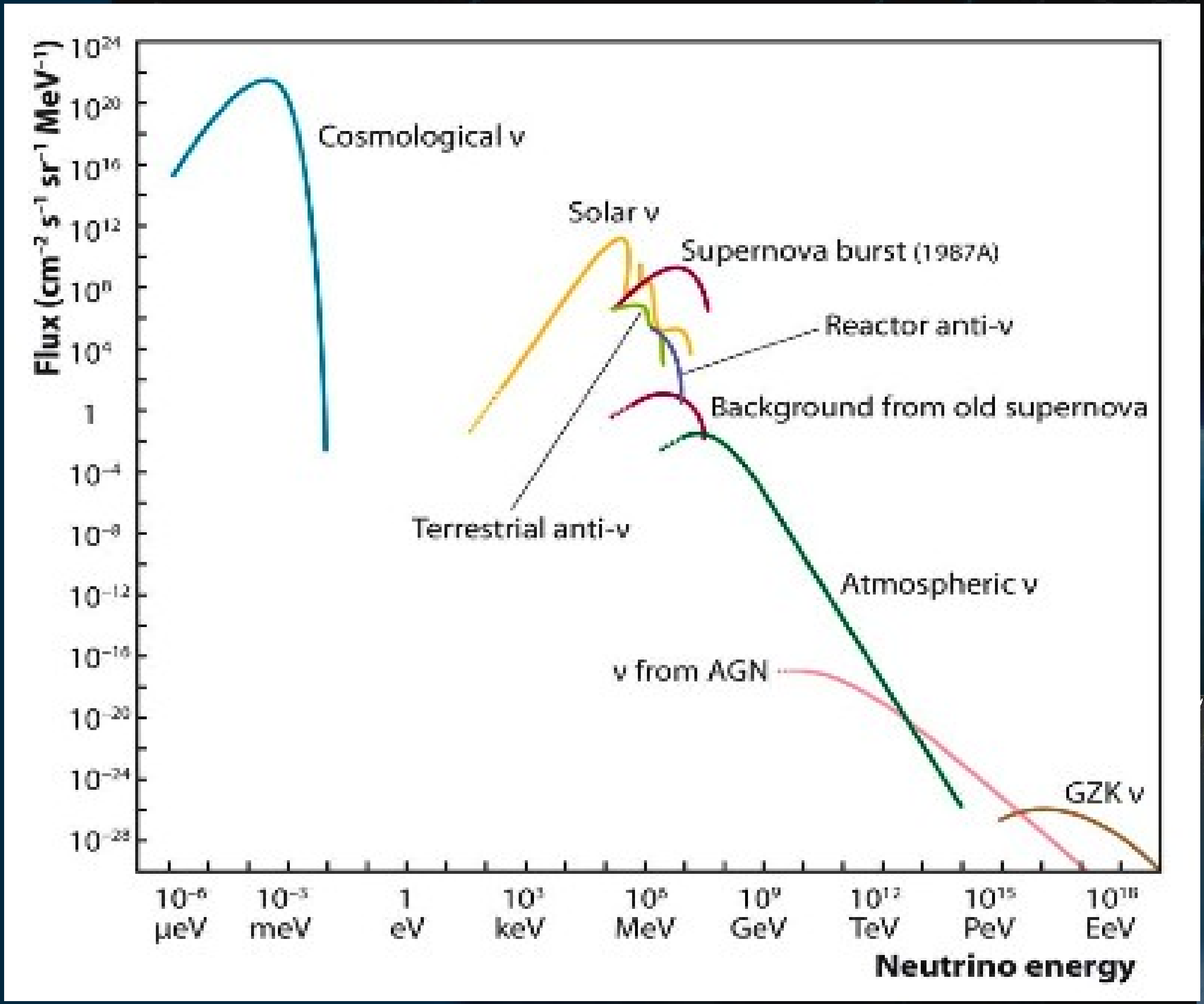
High Energy Universe:
Emission from AGN
GZK neutrinos
Supernovae

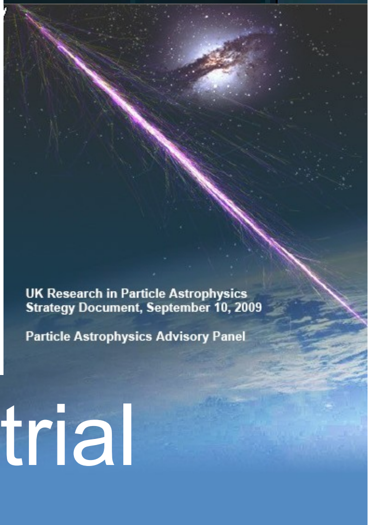
Other:
Solar physics
Geophysics/Atmospheric

Fundamental particles:
Neutrino mixing angles
Neutrino mass hierarchy
CP violation



Neutrino Astronomy





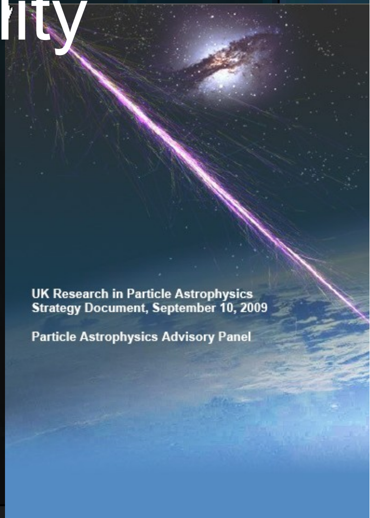
So far: Limited to Solar, SN1987A, terrestrial

Cosmic Rays

Auger South construction is completed and has begun science operations. These are expected to last > 10 years. The UK has a leading role in science from Auger. Precision measurements of cosmic ray spectrum up to > 100 EeV (10^{20} eV)

STFC has not funded further UK contribution to GZK neutrino experiments other than general radio facilities (LOFAR, SKA)

STFC has not funded UK participation in construction or operation of a next generation cosmic ray facility



CMB general

With CMB(+LSS,SNIa,etc.) you can detect everything indirectly:

- Dark matter
- Gravity waves
- Neutrinos
- Exotic particles

UK participating in PLANCK science and other projects such as SPT, ACT, EBEX, SPIDER, etc.

- Detection of CMB lensing signal

- Constraints on neutrino masses

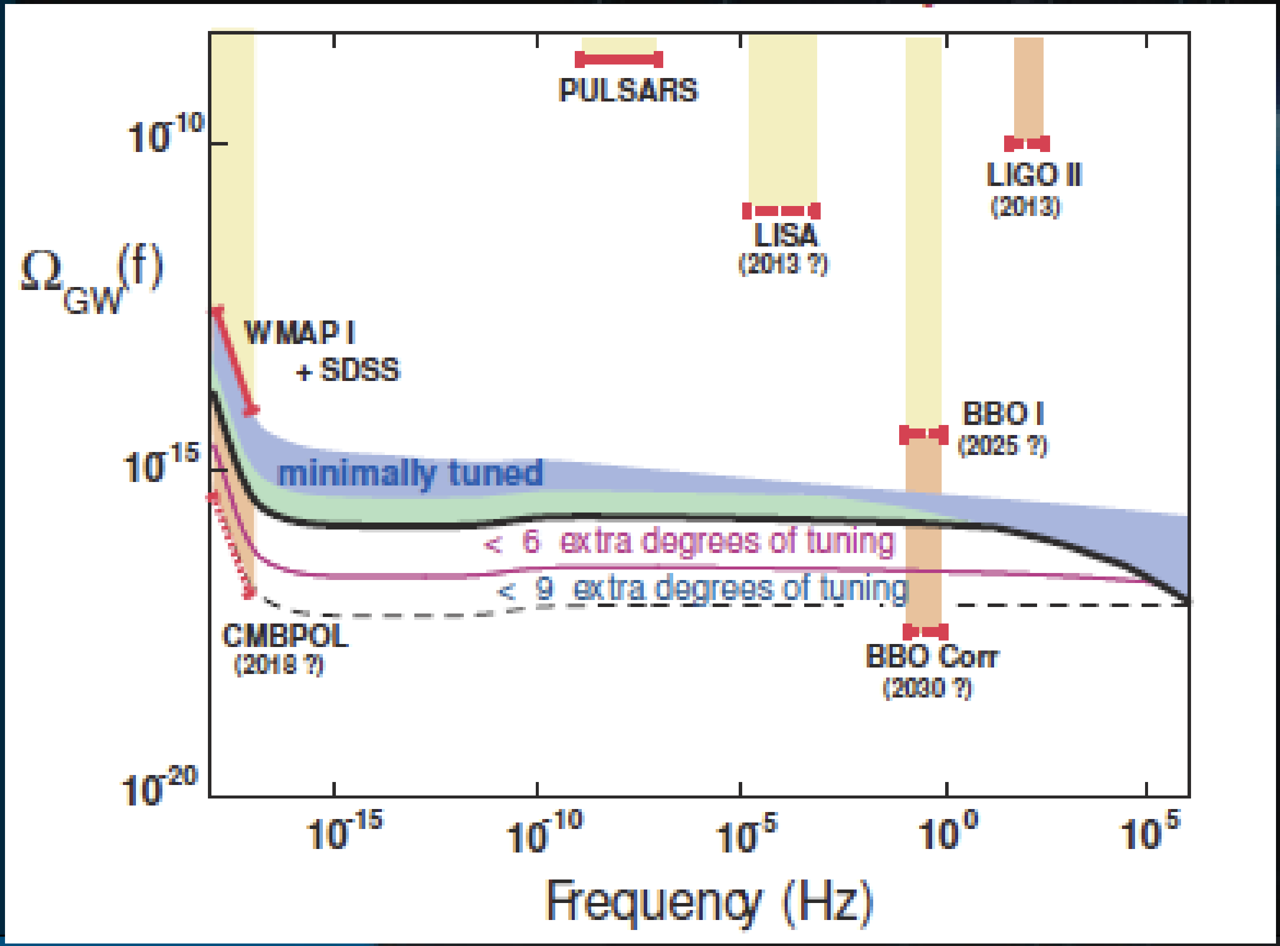
- Constraints on primordial power spectrum

- Searches for exotic particles/phenomena (cosmic strings, monopoles, etc.)

CMB polarisation

Detection of the imprint of gravitational waves on the CMB polarisation would give unique information on the initial seeds of structure in the universe.

Uses the surface of last scattering as a gravitational wave detector.



Summary

Large discovery potential in PA experiments

e.g. Dark matter, gravity waves

Large potential for new windows on the universe

- Gravity waves
- Neutrino astronomy
- CMB polarisation
- Gamma rays
- Cosmic rays