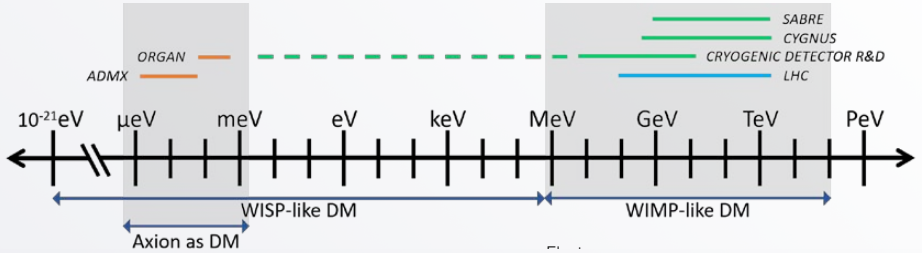
ARC CENTRE OF EXCELLENCE FOR DARK MATTER PARTICLE PHYSICS

Australian Government

The University of Melbourne | The University of Adelaide | The University of Sydney | The University of Western Australia | The Australian National University | Swinburne University

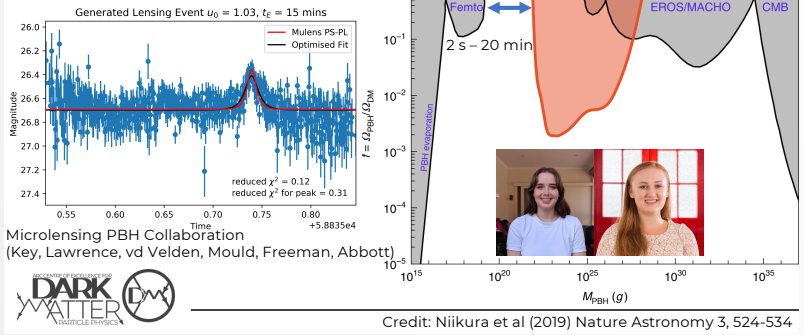
MASS RANGE



NEW MASS RANGE

2020

Nowhere for PBH to hide (soon)



Microlensing PBH Collaboration
(Key, Lawrence, vd Velden, Mould, Freeman, Abbott)

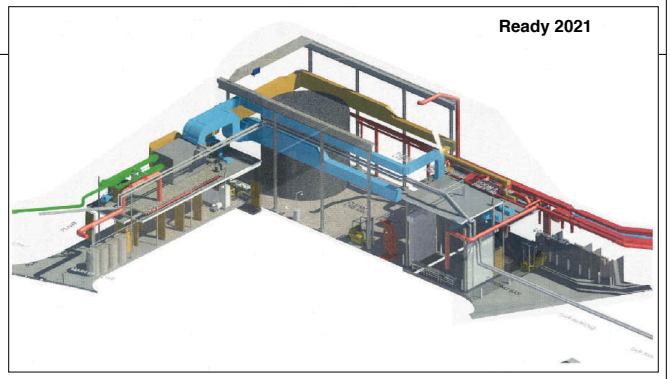
Credit: Niikura et al (2019) Nature Astronomy 3, 524-534

EXPERIMENTAL PROGRAM TIMELINE

Program		2019	2020	2021	2022	2023	2024	2025	2026	2027
WIMP Direct Detection	SABRE proof-of-principle (Italy)									
	SABRE South									
	Cryogenic Detector									
	CYGNUS small prototype									
	CYGNUS 1m^3 prototype									
WISP Direct Detection	ADMX Run 1b and Run 1c									
	ADMX Upgrade, 8-16 μeV			Design/Proto		Construct				
	ORGAN									
	ORGAN Upgrade									
R&D for WIMP & WISP Searches (including Precision Metrology)	Room temp. NaI and veto systems									
	Cryogenic bolometer/phonon sensors									
	TPC large scale									
	Precision frequency schemes									
Nuclear Metrology	ICPMS – Develop native capability									
	HPGe – Rationalise native capability									
	AMS Improve ToF system									
	AMS Improve resolution of ion chamber									
	AMS Integrate electrostatic analyzer									

Blue: R&D and new experiments, Orange: construction and commissioning, Green: detector operation

SUPL STATUS



First deep underground laboratory in Australia

1. **Southern hemispheres location:** pin down any season-related background

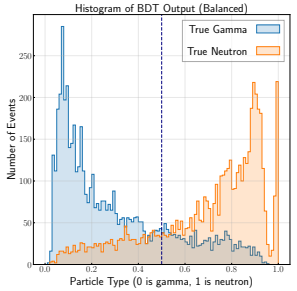
2. **Active veto:** 10 time less background of DAMA/ LIBRA

3. **Development of ultra-high purity NaI(Tl) crystals**
   - Ultra high purity NaI powder
   - Ultra clean crystal growth method:almost as clean as DAMA/LIBRA

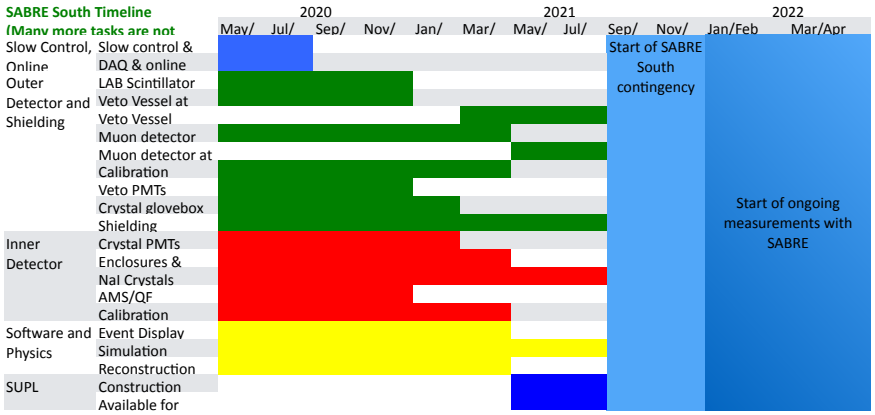
4. Particle ID
- New techniques are being developed, discrimination between electron vs nuclear recoil

(Adelaide, ANU, Uni Melbourne, Swinburne, ANSTO)

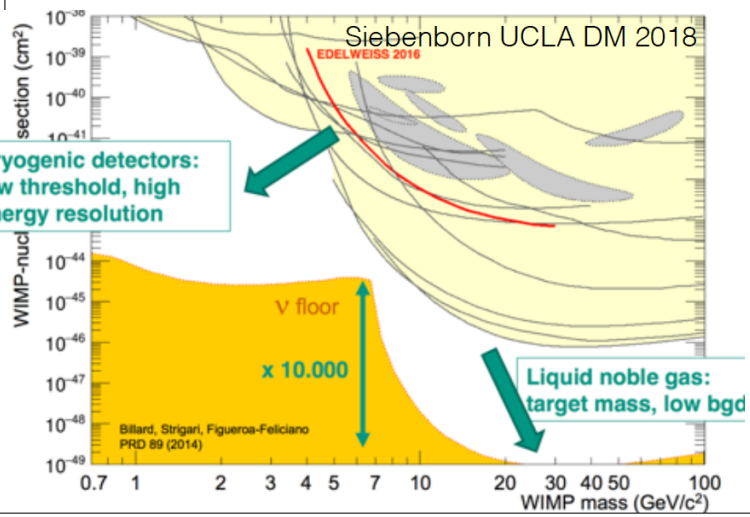
SABRE



SABRE



NEXT?



METROLOGY

Advanced Metrology

Developing methods to measure contamination in detector materials

Immediate focus on ^{40}K, ^{129}I, ^{210}Pb

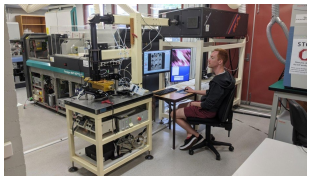
Survey relevant, existing capabilities of ultra-sensitive techniques/laboratories

e.g. ICP-MS:

- PNNL (USA) – ^{40}K
- Developing local capability: collaboration with ANU Research School of Earth Science
  - Laser ablation, Quadrupole, Sector field ICP-MS, etc

see Z. Slavkovská later today

Also TIMS, AAS, …



CYGNUS

Driving part of the physics program:
ANU, UoM. Claran O'Hare, N Bell, Jay Newstead, Peter McNamara,

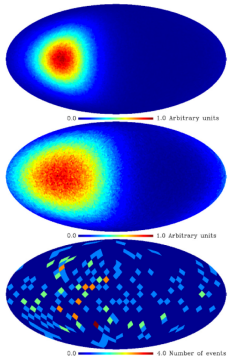
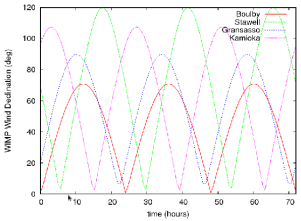


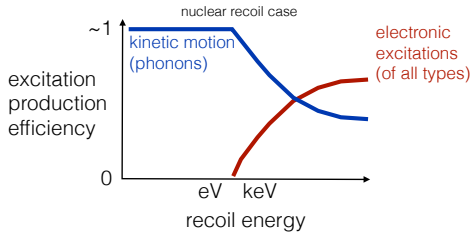
Figure from J. Billard *et al.* 2010

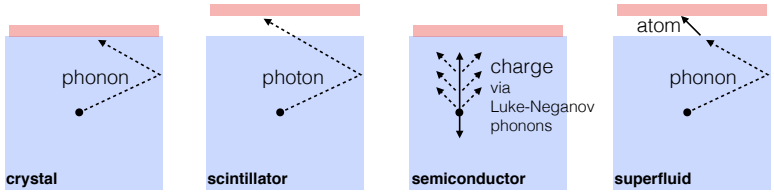
- WIMP flux in the case of an isothermal spherical halo
- WIMP-induced recoil distribution
- A typical simulated measurement:
  100 WIMP recoils and
  100 background events
  (low angular resolution)

Lyndsey Bignel



LOW MASS



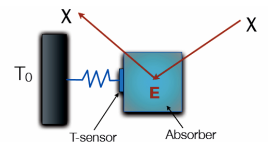


Very Cryogenic Solid State

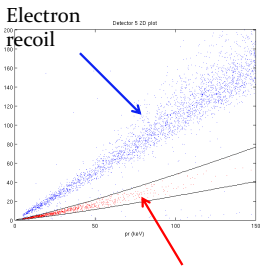
Big Advance = Distinguish ER from NR on an event by event basis

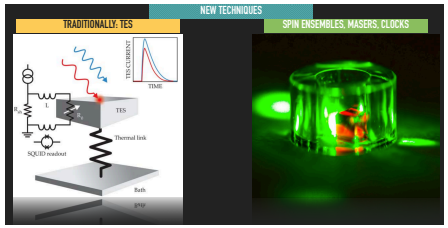
Need sensitivity (big ΔT) for small ΔE

50 mK



$$C(T) = \frac{\Delta E}{\Delta T} \propto T^3$$





Maxim Goryachev

LOW MASS

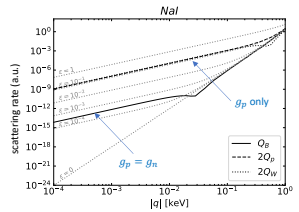
Peter Cox

1) DM-optical phonon scattering

[PC, Melia, Rajendran 1905.05574]

Scattering rate suppressed for DM that couples equally to protons and neutrons.

"coupling-to-mass" effect

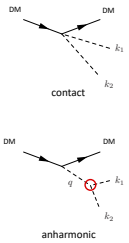


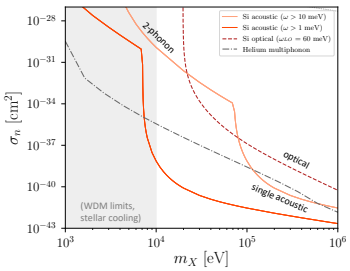
2) Multi-phonon scattering

[Campbell-Deem, PC, Lin, Melia, Knapen 1911.03482]

Single acoustic mode requires very low energy threshold.

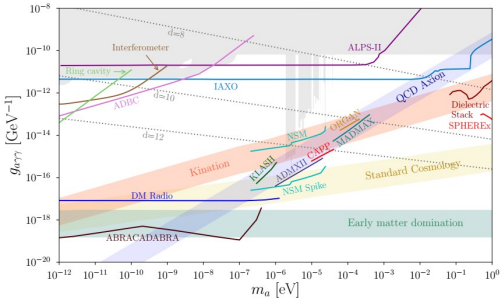
2-phonon processes can be relevant for low masses.





AXIONS/ALPS

Axions: Letters of Interest: SNOWMASS



ALP Dark Matter: Misalignment

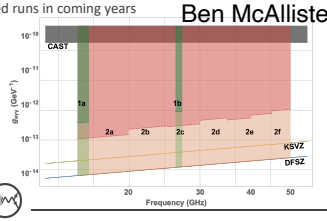
Matt Dolan

- The axion/ALP is not a thermal relic (i.e. not a WIMP)
- Field displaced from origin in early universe
- Starts to oscillate around origin when $m_a \sim H(T_{osc})$
- The ALP field evolves as $a \sim a_i \left(\frac{R_i}{R(t)}\right)^{3/2} \cos m_a t$
- R(t) is the scale factor of the FRW cosmology.

Axions - ORGAN

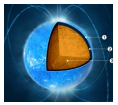
- Planned runs in coming years

Ben McAllister



Plenty of room to get involved!

Cross-node theory highlight: Dark Matter Capture in Neutron Stars



Melbourne: Nicole Bell, Sandra Robles, Michael Virgato
Adelaide: Anthony Thomas, Theo Motta
ANU: Giorgio Busoni

Dark Matter Capture in Stars
→ complementary approach to DM-nucleon recoil experiments

- Due to their extreme density, ***neutron stars*** capture dark matter very efficiently.
- ***Capture probability is of order unity*** when $\sigma_{n\chi} > \sigma_{th} \sim 10^{-45}\text{cm}^2$

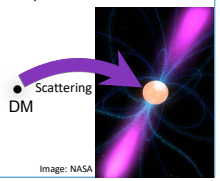


Image: NASA

Cedric Simenel and Tony Thomas

Outline

I. Nuclei from Quarks
- **start from a QCD-inspired model of *hadron* structure**
- **develop a quantitative theory of nuclear structure**

II. Neutron Stars
- **role of hyperons and insights from GW170817**

III. Dark Matter:
Use insights from I and II to investigate and constrain properties of Dark Matter and its interactions
- **proposed explanation for neutron lifetime anomaly**
- **capture of DM by neutron stars**
- **effects of captured DM on neutron stars**
- **scattering of DM from nuclei (eg. in SABRE)**

LHC

Paul Jackson, Geoff Taylor

Recent work

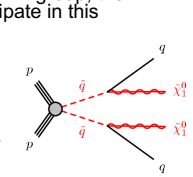
- Flagship DM searches at the LHC are under the remit of the combined DM group, the search groups each participate in this

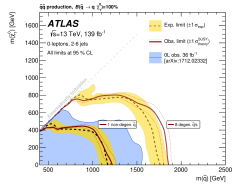
Recently submitted updated search for jets and missing energy using full Run2 data
https://arxiv.org/abs/2010.14293

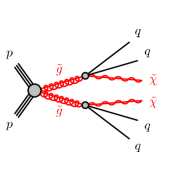
No excesses observed

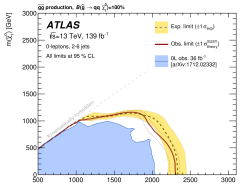
Place stringent limits on squark and gluino production.

More canonically, limits on invisible objects produced in association with jets.



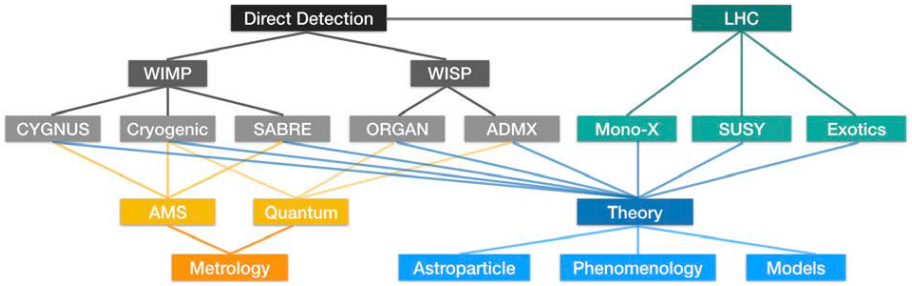






THE UNIVERSITY of ADELAIDE

RESEARCH



FUTURE **IMPORTANT DATES**

- 2 days ECR workshop (all centre researchers are invited) end of January:
  - ECR presenting there research (1.5 days)
  - ECR discussion on centre committees participation (0.5 days)
- Special Initiative:
  - Two stags: EOI and final round.
  - Process and selection criteria by the end of the year
- Calls for topical workshops in February (tbd)
- Annual report 31 March 2021

THANKS

Amanda (UoM), Martina(UoM), Paddy (UoA), Luana (Swinburne), Mary (UoM), Petra (ANU), Linda (UWA), Danae (Sydney), Sharon (UoA) and Fleur (UoM) for media stories.

Please fill the survey: https://www.surveymonkey.com/r/QJBRW78