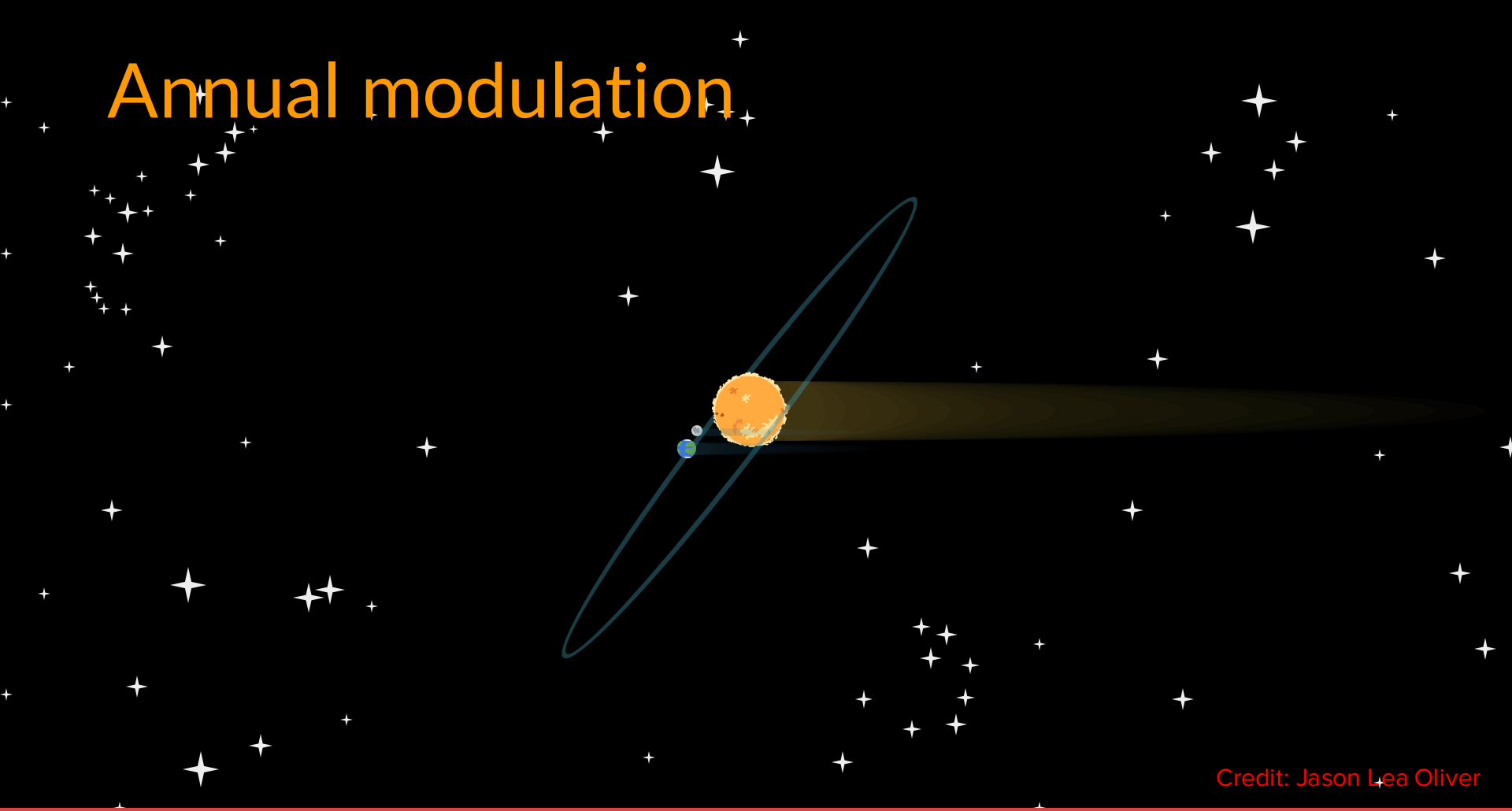
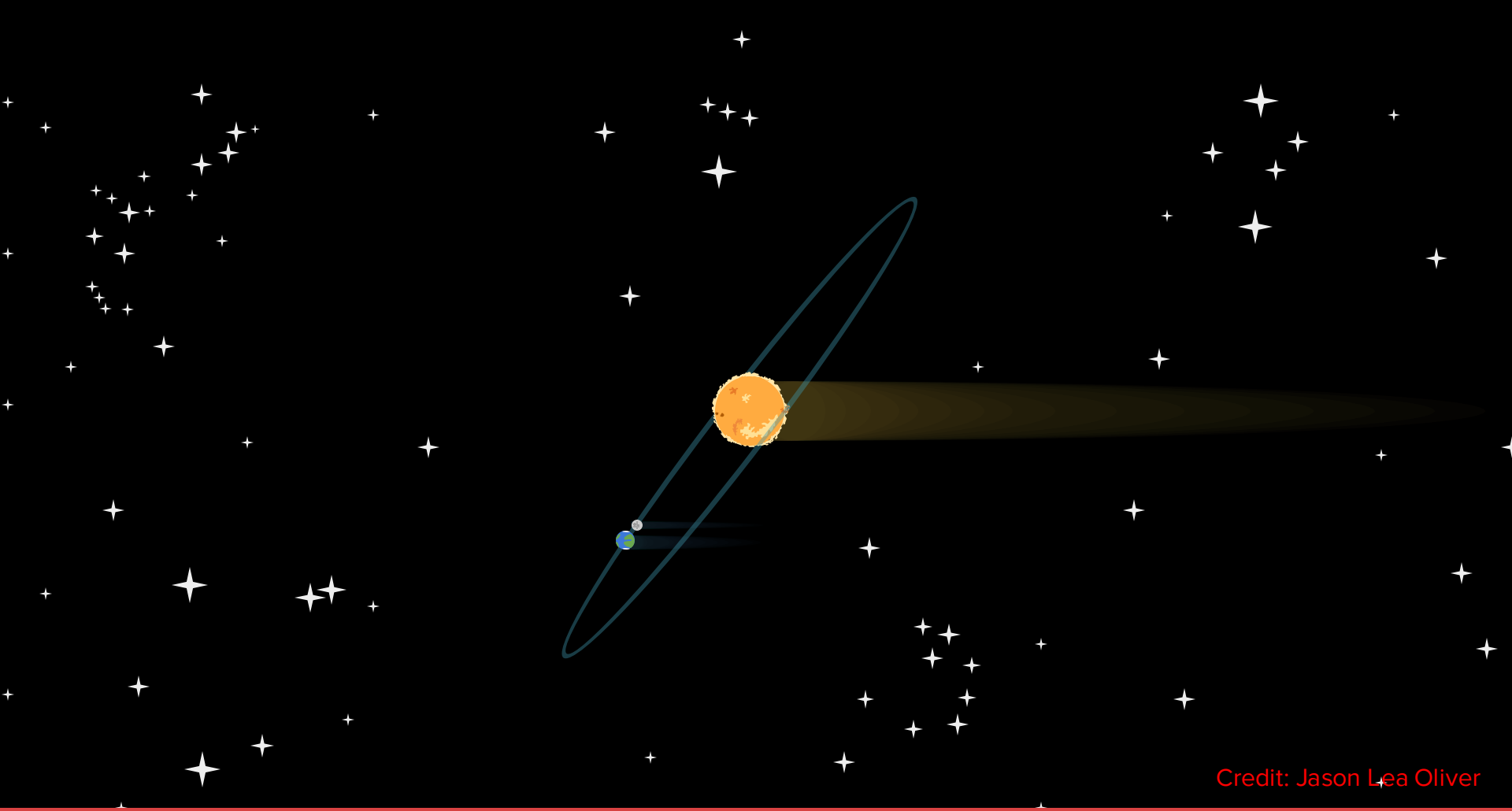
The SABRE South Experiment at the Stawell Underground Physics Laboratory

Sharry Kapoor (On behalf of the SABRE South)
The University of Sydney

Annual modulation



Credit: Jason Lea Oliver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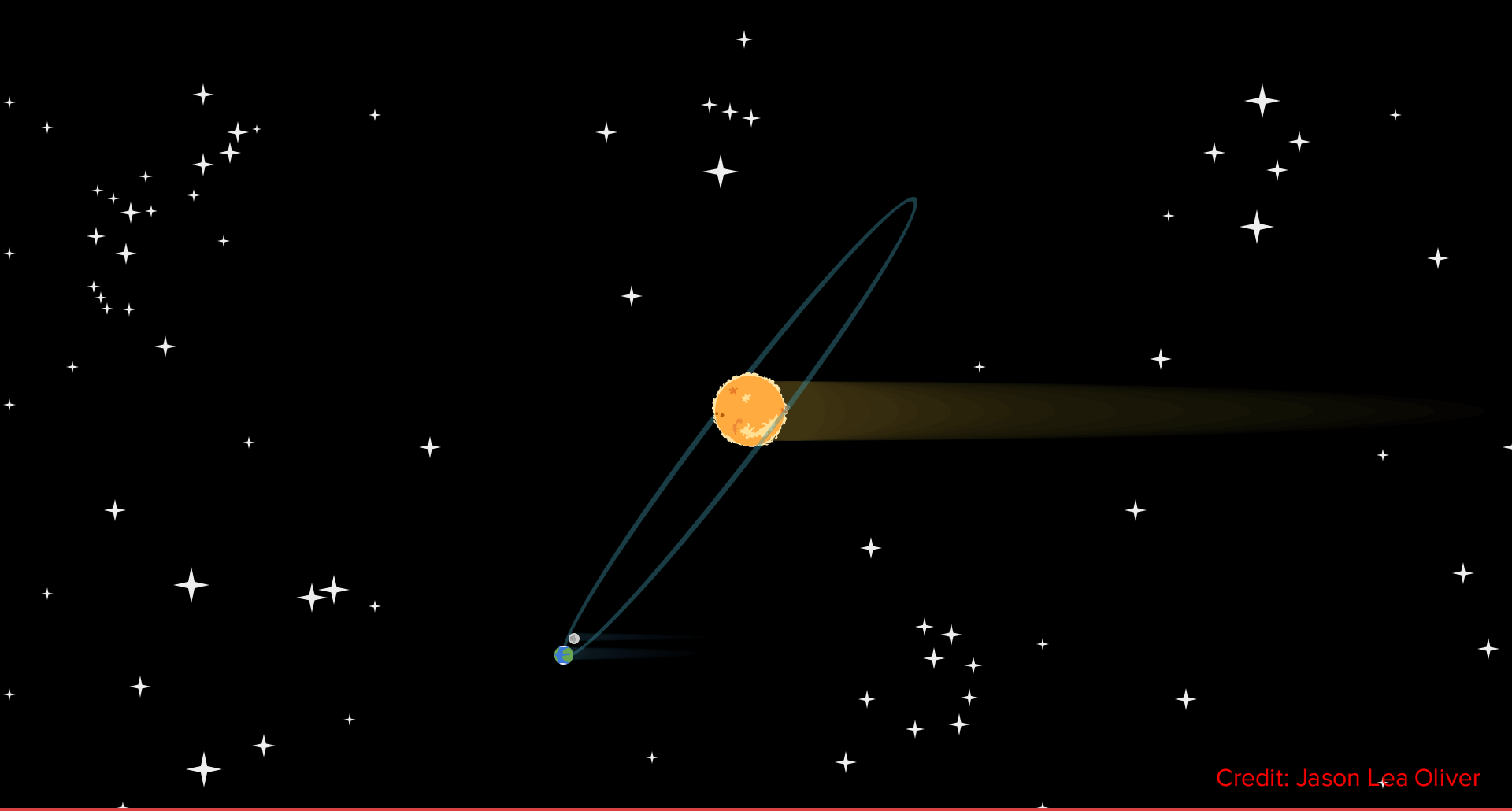
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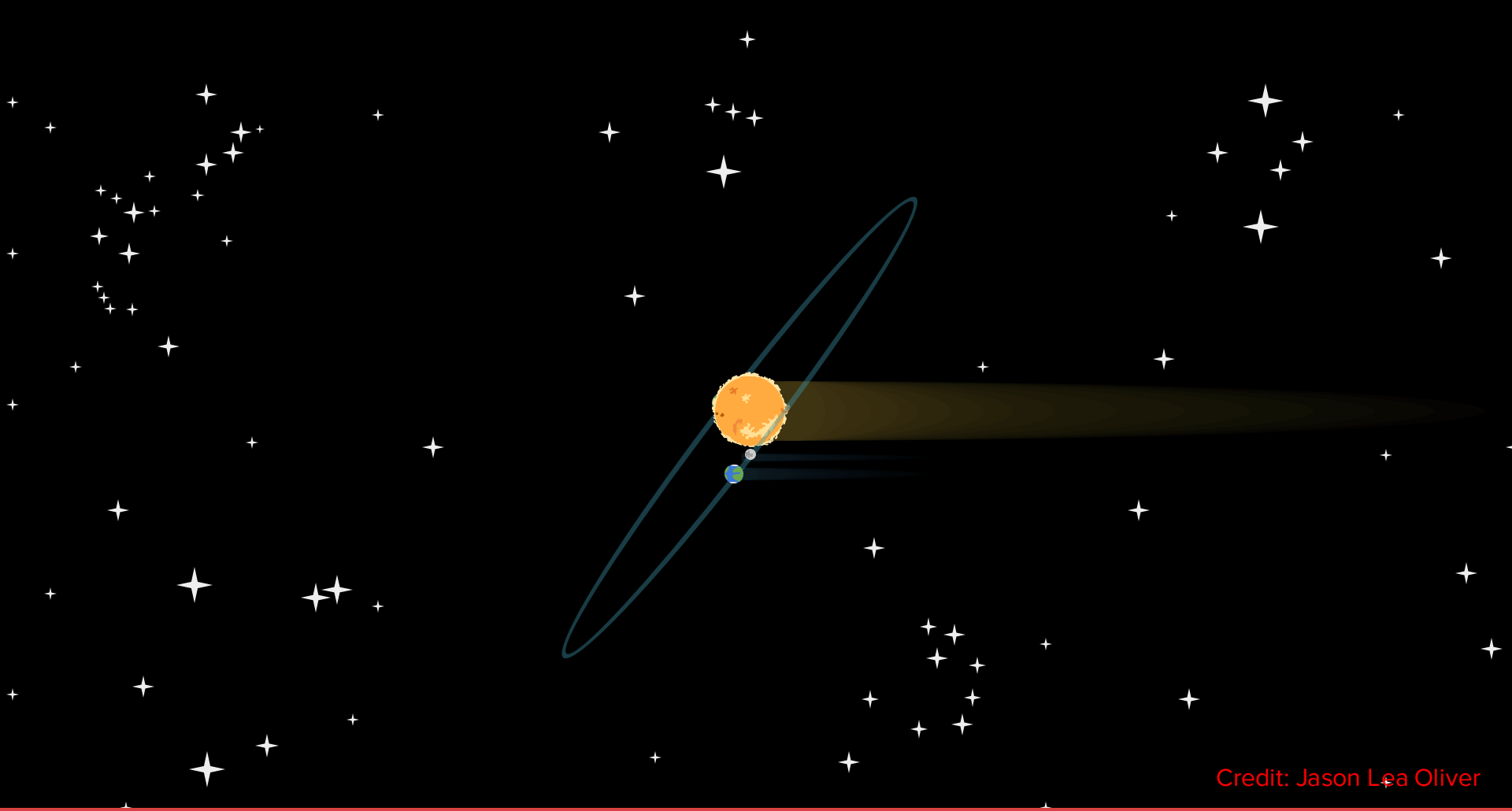
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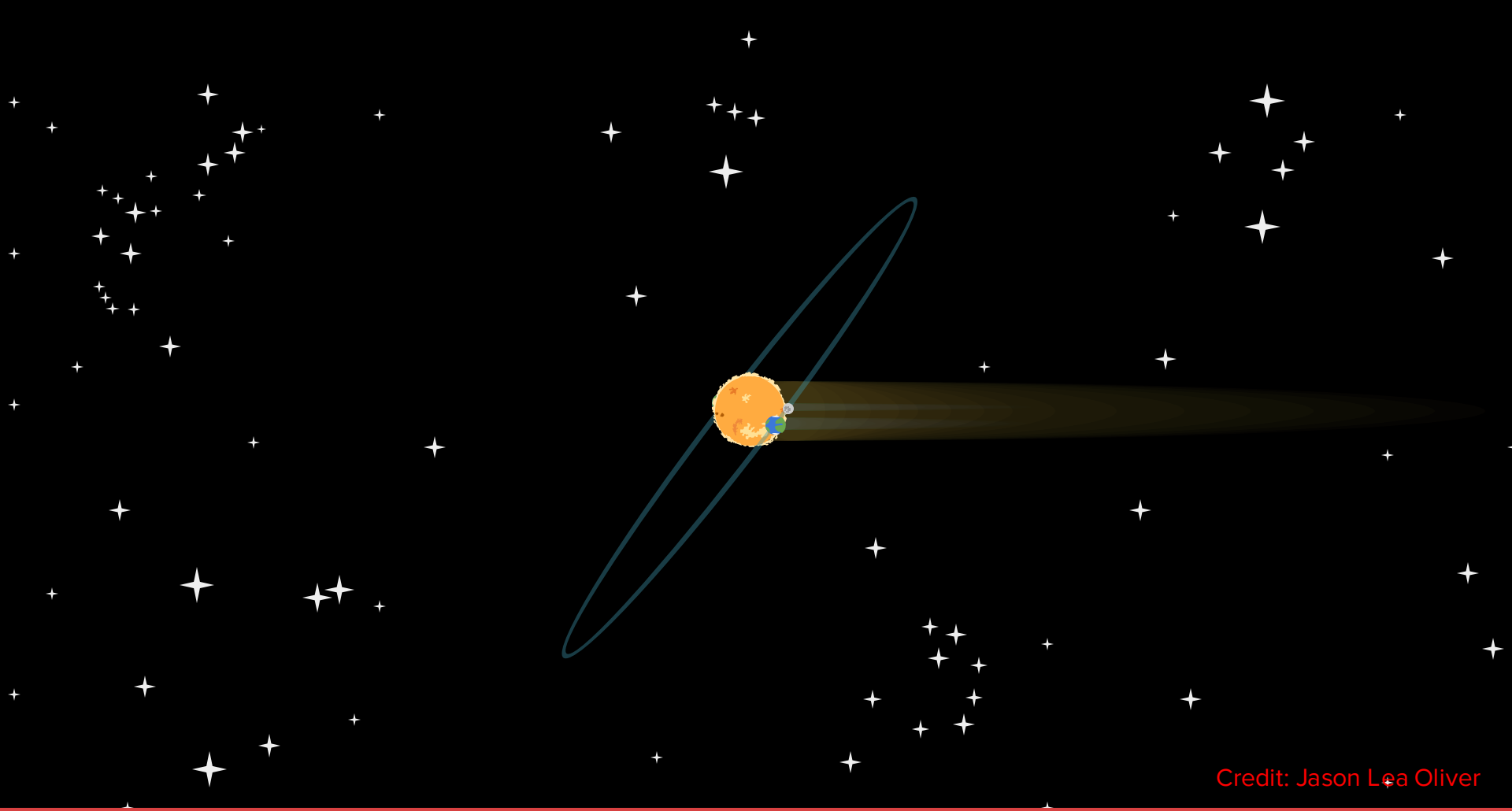
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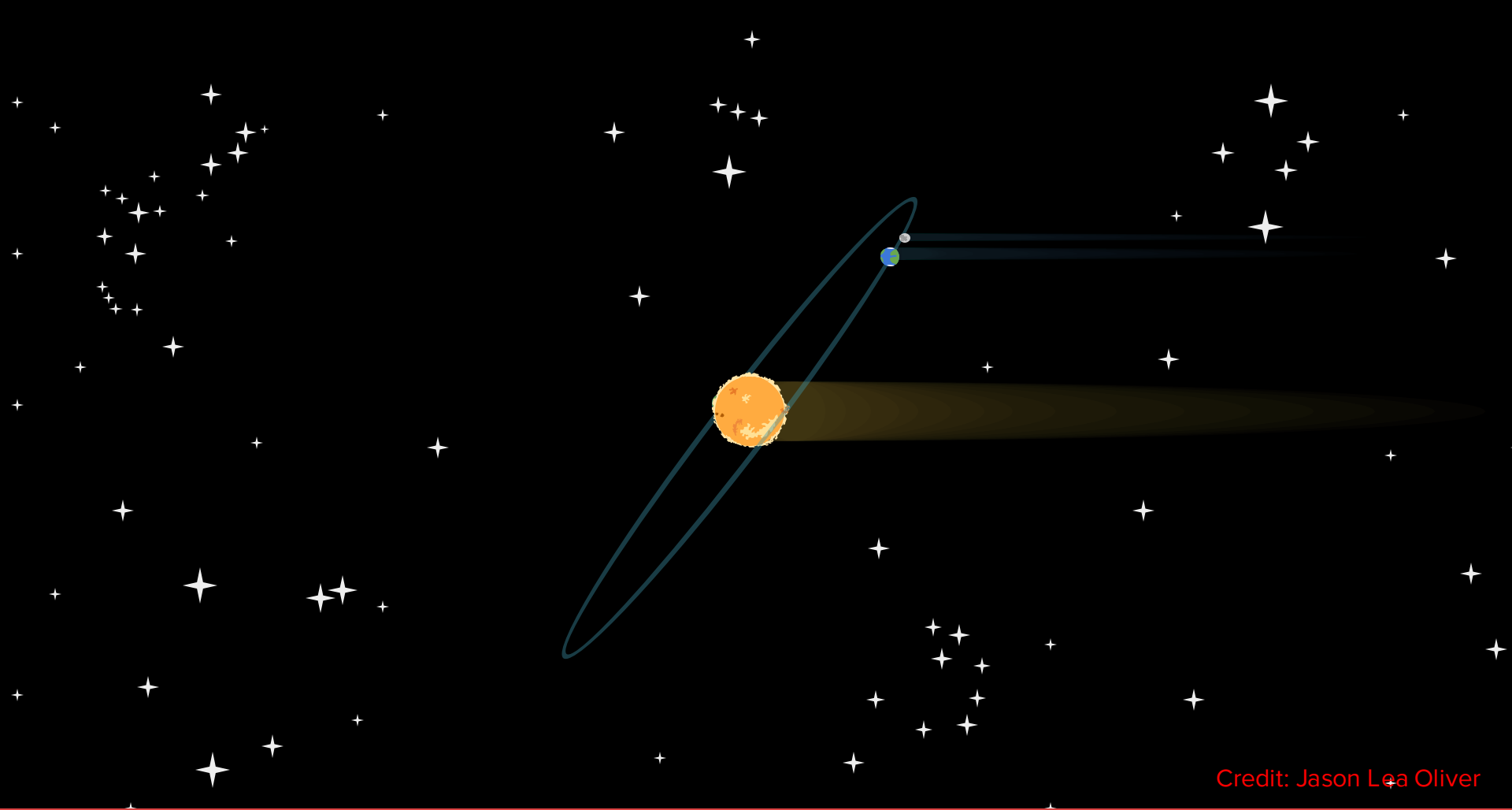
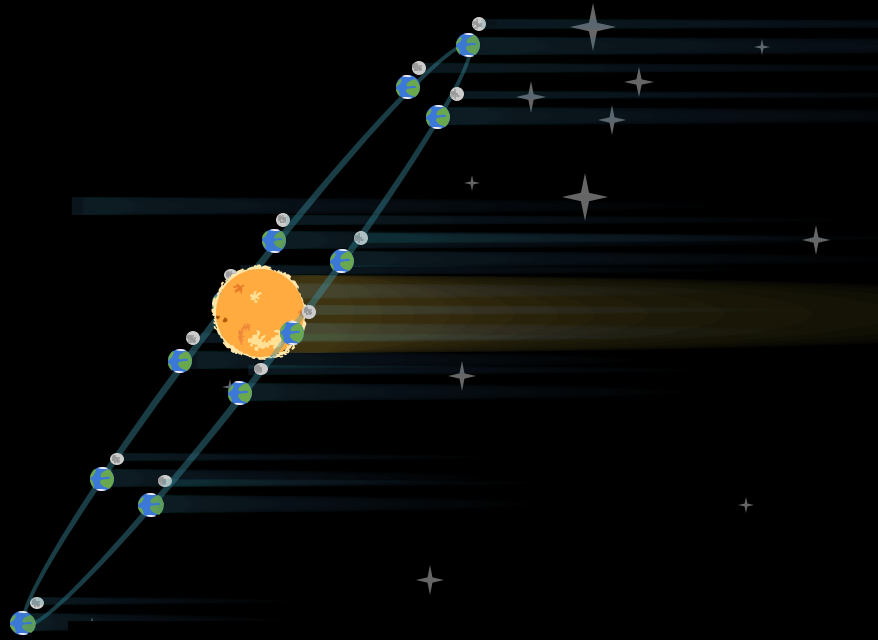

Credit: Jason Lea Oliver

Annual modulation

The Earth's orbit around the Sun causes variations in the relative velocity between the Earth and the dark matter halo, leading to seasonal changes in the interaction rate



Credit: Jason Lea Oliver

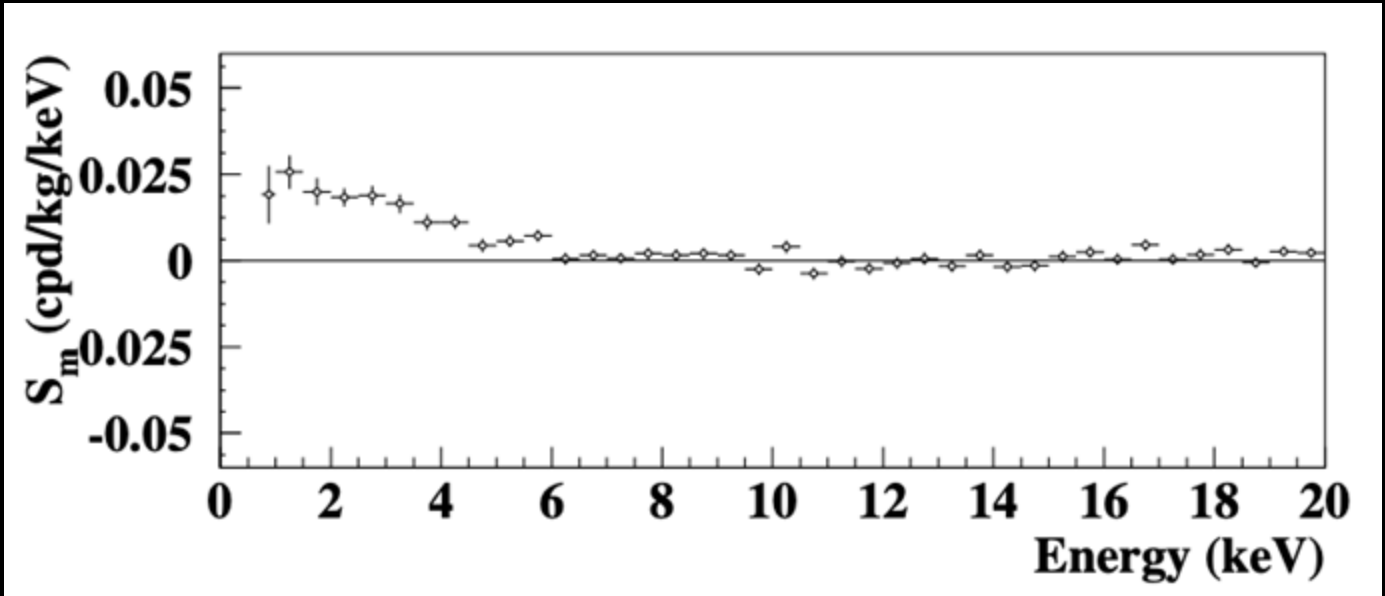
DM interaction rate in the detector

$$\frac{dR}{dE_R}(t) \approx S_0(E_R) + S_m(E_R)\cos\omega(t - t_0)$$

DAMA/LIBRA results

EPJ Web of conferences, p.10001

- 250 kg NaI(Tl) detector based in LNGS consistently observed modulation rate compatible with DM expectations for ~20 years w/ 13.7 σ C.L.
- ΔE= 2-6 keV, Rate= 0.01014±0.00074 cpd/kg/keV, Time= 142.4±4.2 days



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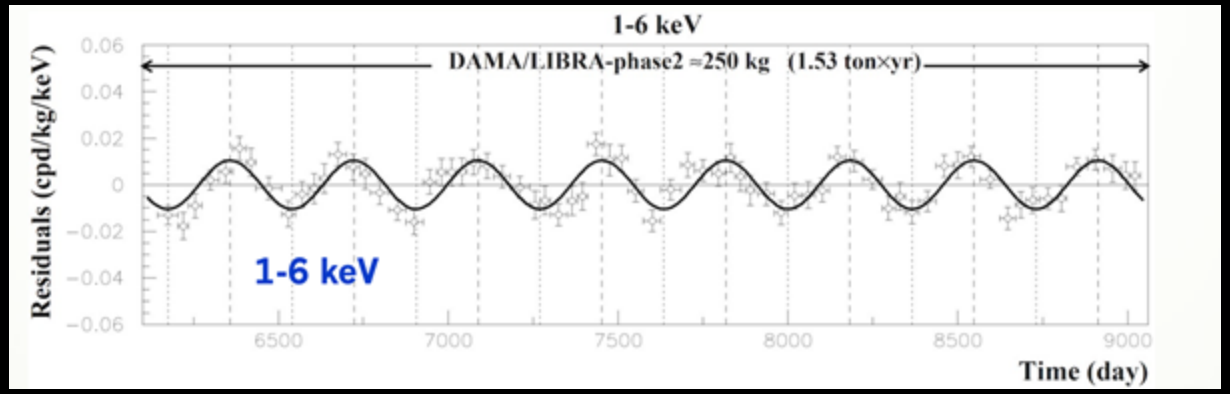
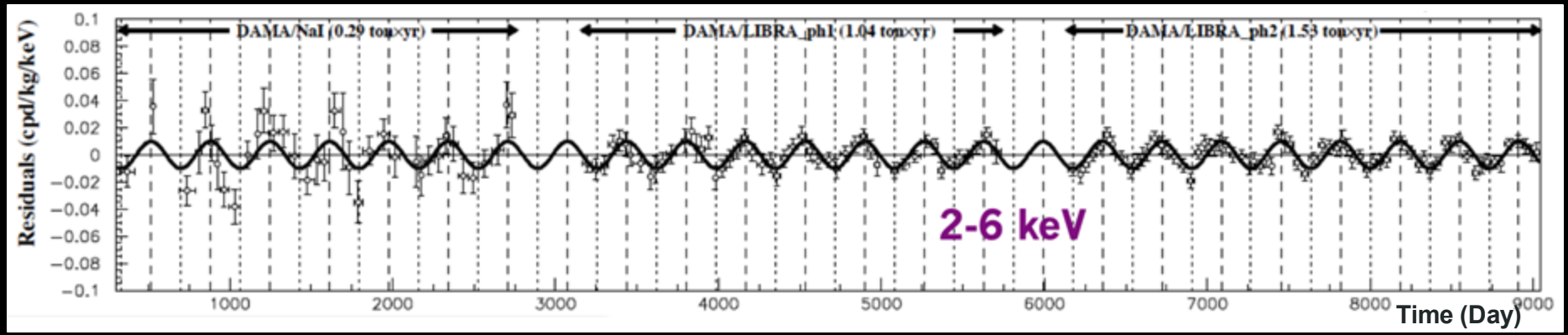
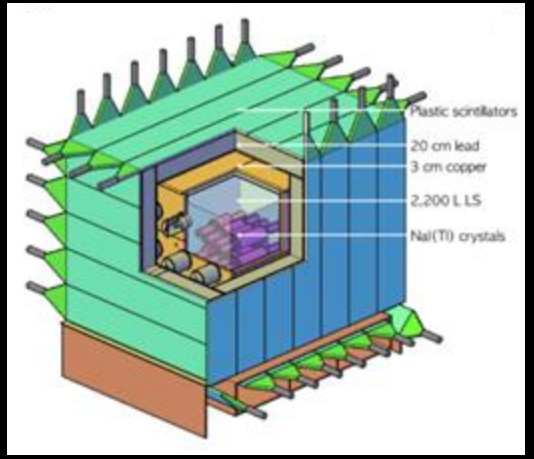




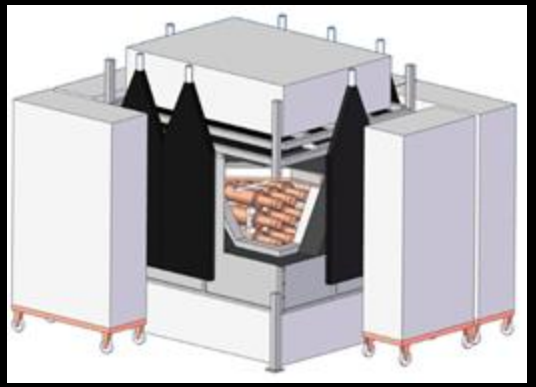
NaI Experiments

Experiment	Mass (kg)	Bkg. (cpd/kg/keVee)
DAMA/LIBRA-phase2	250	0.8
COSINE-100	61.3	2.7
ANAIS-112	112.5	3.2

No DAMA/LIBRA's signal claimed



COSINE

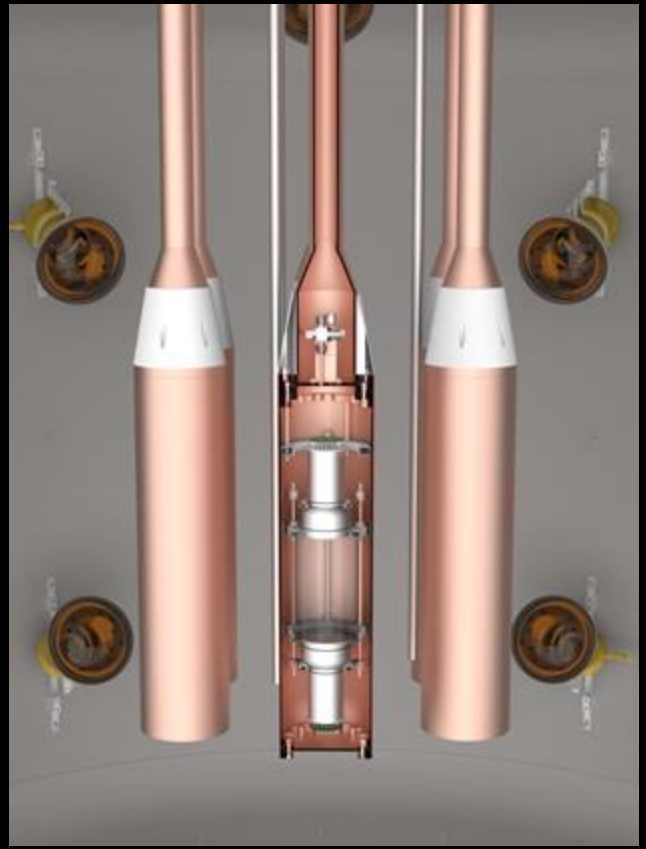


ANAIS

R. Bernabei et al., Annual Modulation results from DAMA/LIBRA, 2023
Carlin, Nelson, et al. *Science advances* 11.36 (2025)

What is SABRE?

- Aim - detect an annual rate modulation from dark matter interactions in ultra-high purity NaI(Tl) crystals

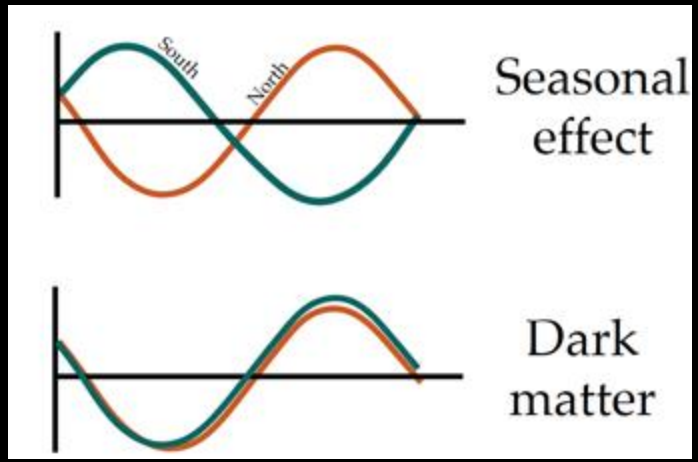


j.nima.2022.167585

What is SABRE?

- Aim - detect an annual rate modulation from dark matter interactions in ultra-high purity NaI(Tl) crystals

- Dual-site design - SABRE South (SUPL, Australia) and SABRE North (LNGS, Italy) - avoids seasonal effects



Credit: Ciaran O'Hare

j.nima.2022.167585

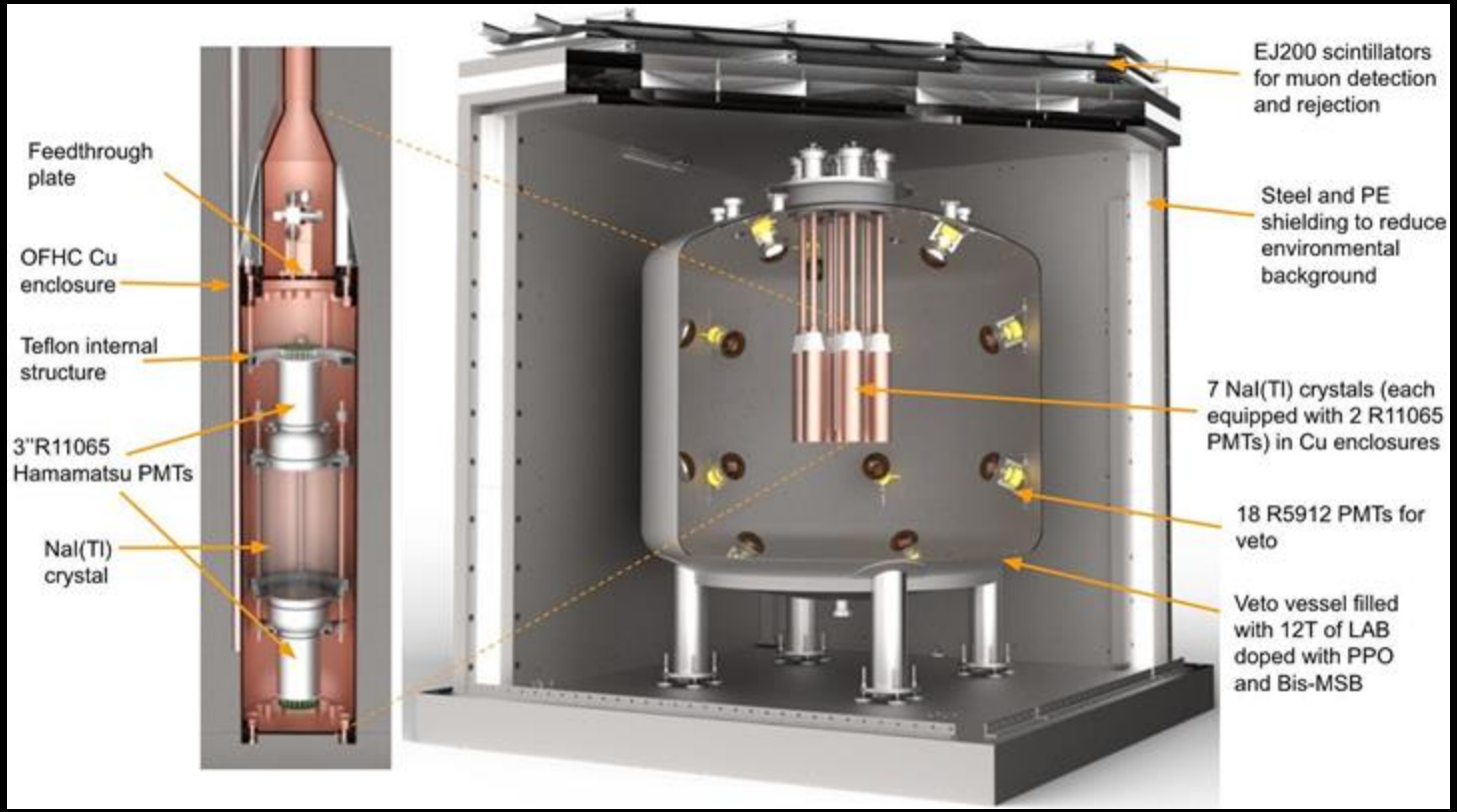
Stawell Underground Physics Lab

First deep underground lab in the southern hemisphere!

Completed in 2023. First access & major detector installation in Jan/Feb 2024

j.nima.2022.167585

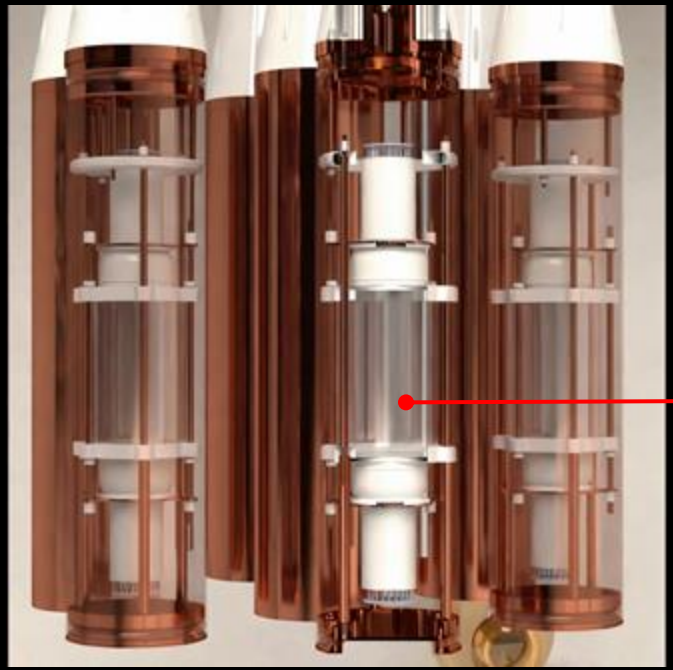
Detector Design



NaI(Tl) crystals

SABRE South, Eur.Phys.J.C 83 (2023) 9, 878

Array of 7 NaI(Tl) crystals (50 kg) doped with thallium and flushed with Nitrogen.



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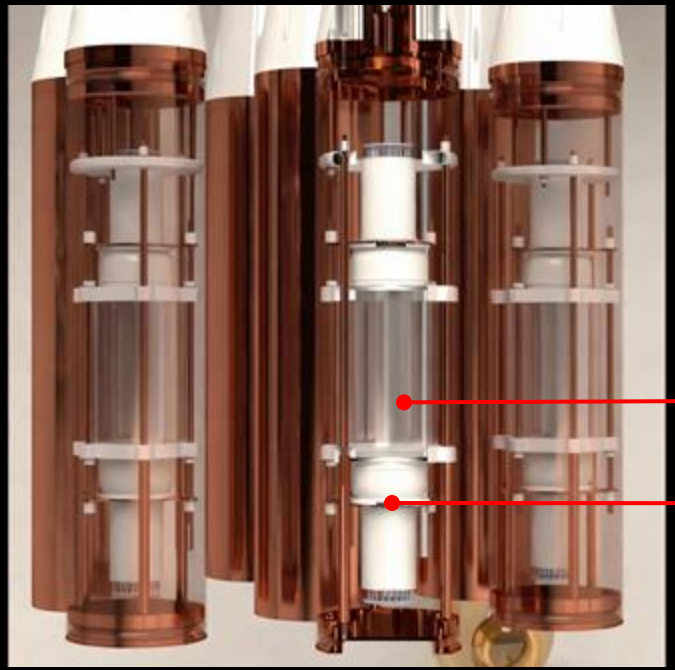

R11065 PMT

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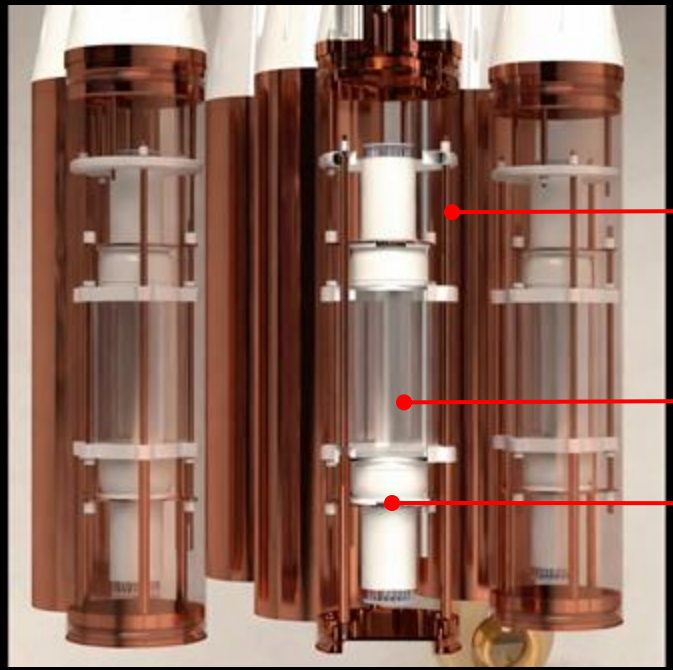

OFHC Copper Enclosure

R11065 PMT

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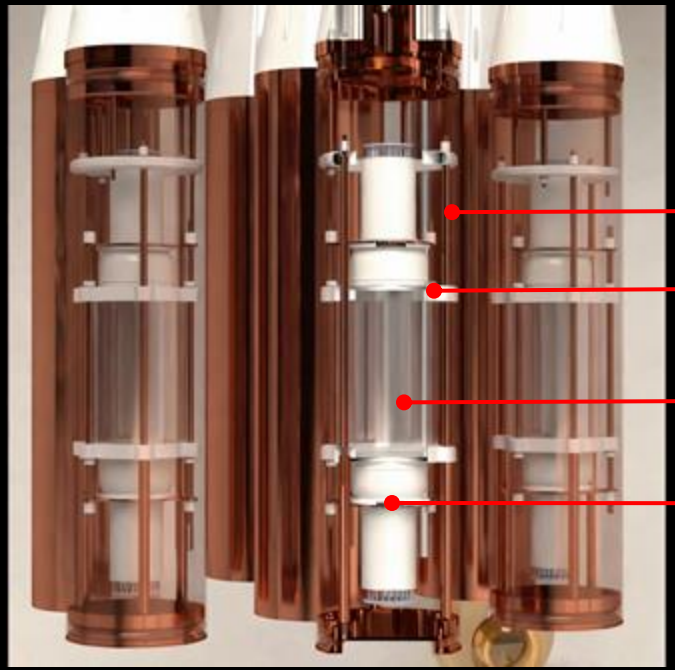

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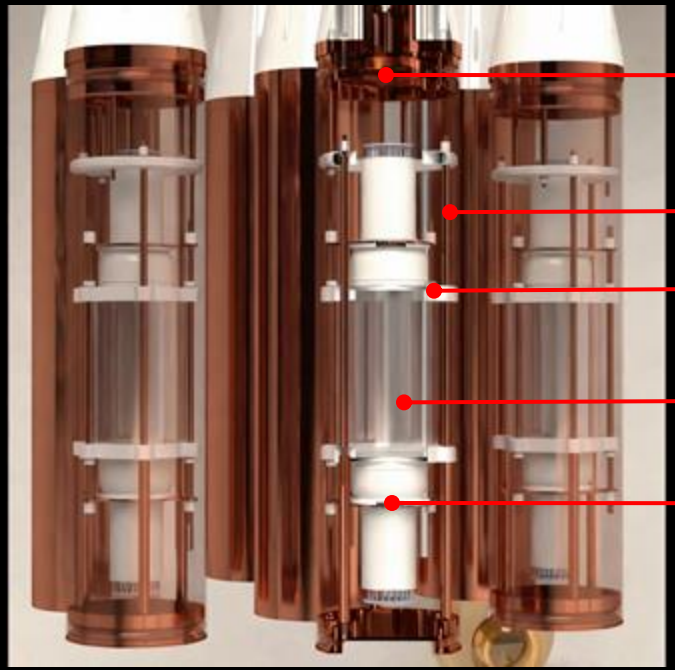

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Active Veto System

SABRE South, Eur.Phys.J.C 83 (2023) 9, 878

~ 12 kL of linear alkyl benzene (LAB) procured from JUNO production line, doped with PPO and bisMSB.

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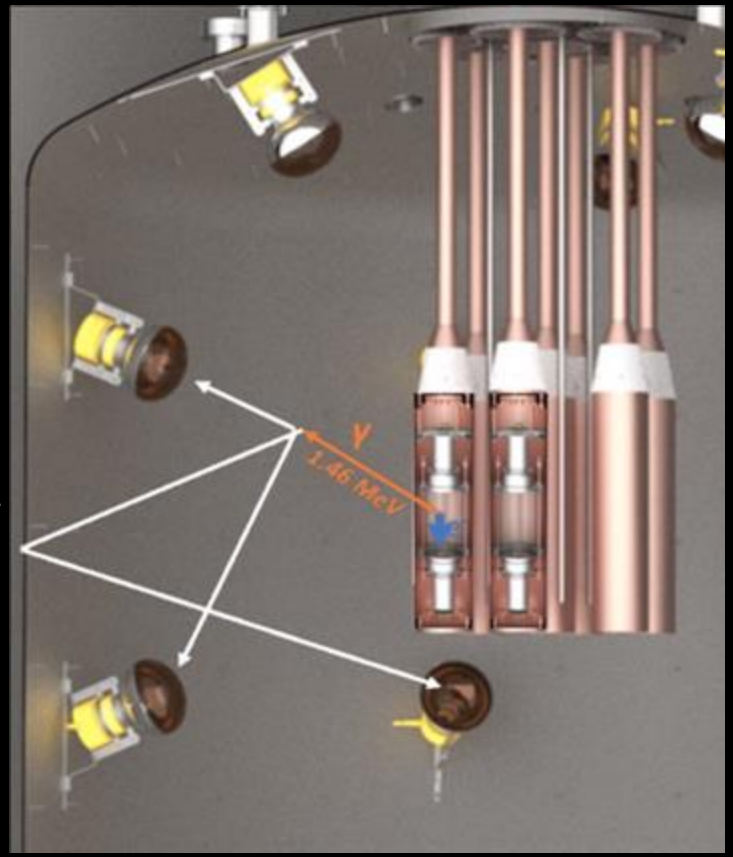

E. Barberio et al 2025 JINST 20 T04001

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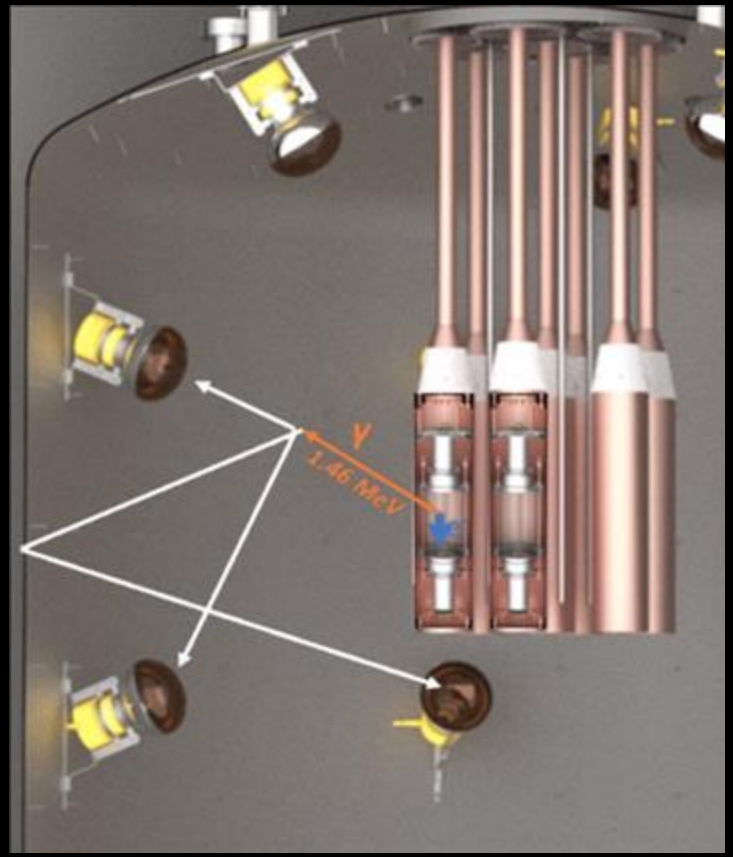

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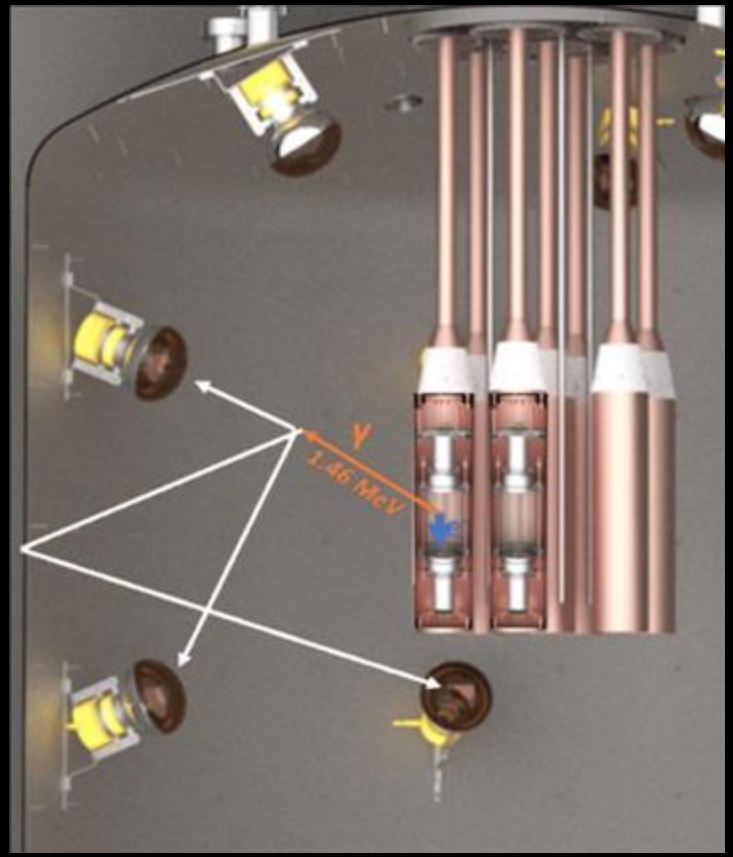
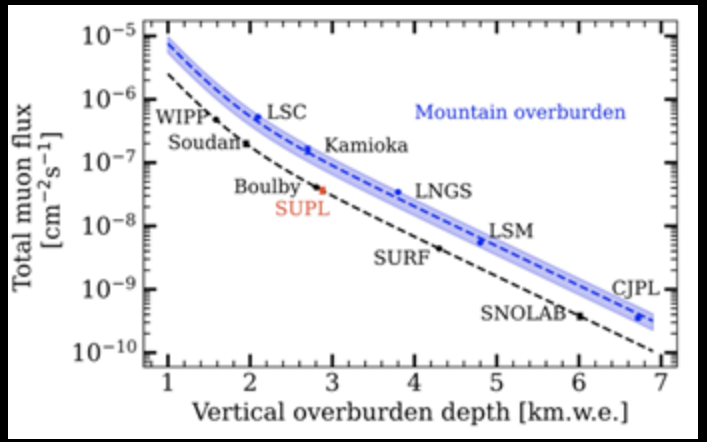
~ 18 R5912 PMTs oil proof, sampled at 500 MS/s +14 from Daya Bay decommissioning



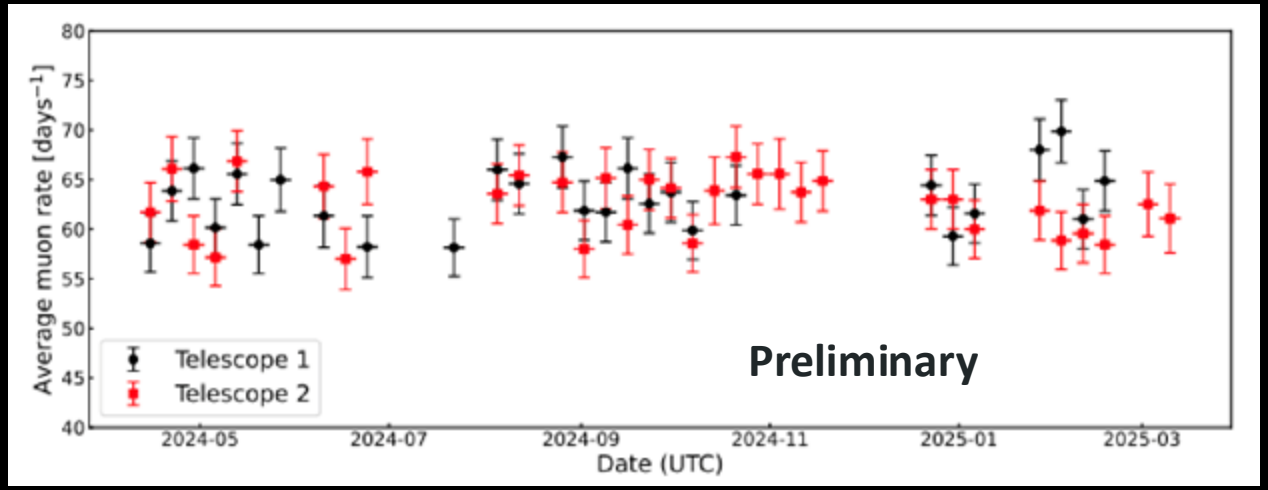
E. Barberio et al 2025 JINST 20 T04001

Muon Veto System

- Provides tagging of Cosmic Muons
- 8 x EJ200 organic scintillator panels (3x 0.4x 0.05 m) with PMTs at opposite ends.
- Total coverage 9.6 m^2 above main vessel.



Muon Flux measurement



$f = f^{raw} / \varepsilon\alpha$,

Where,
ε = detection efficiency of the telescope
α = geometrical acceptance of the telescope

Forthcoming paper:
Measurement of the cosmic muon flux at the Stawell Underground Physics Laboratory

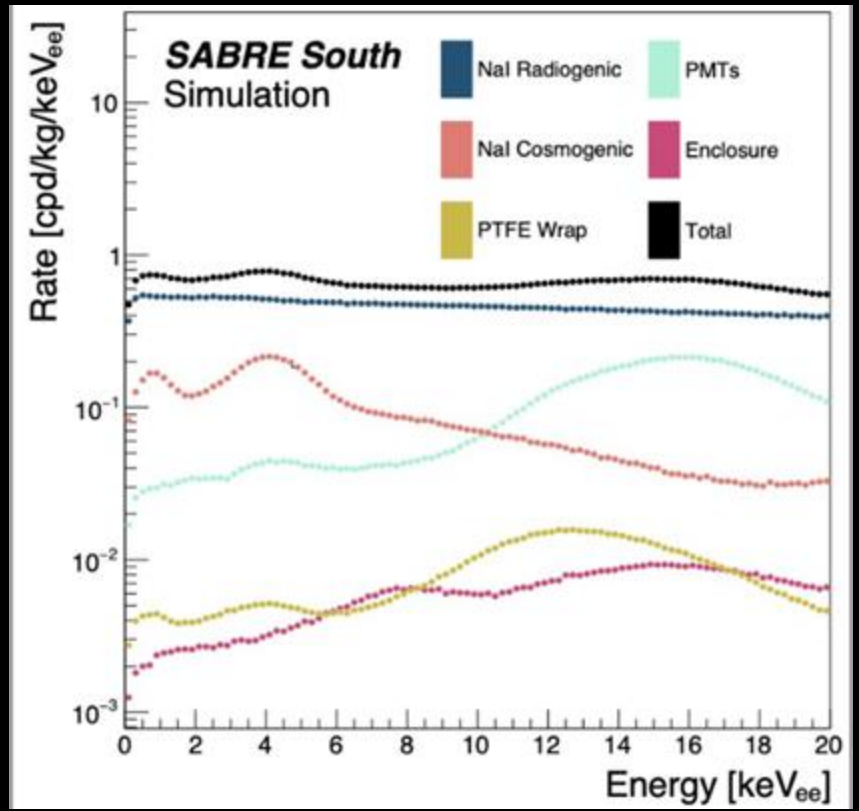
	Nominal value	Uncertainty	
		statistical	systematic
Average f^{raw} [$s^{-1} \times cm^{-2}$]	3.03×10^{-8}	$\pm 0.02 \times 10^{-8}$	
ε	0.989	-	$\pm$ 0.003
α	0.483	-	$\pm$ 0.026
f [$s^{-1} \times cm^{-2}$]	6.33×10^{-8}	$\pm 0.04 \times 10^{-8}$	$\pm 0.35 \times 10^{-8}$

Total Background Model

Zurowski, Barberio Eur.Phys.J.C 82 (2022) 12, 1122

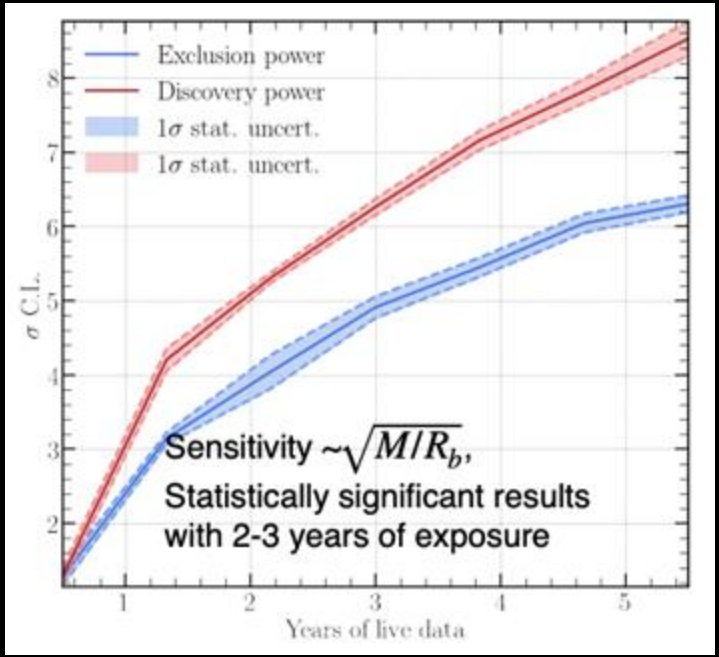
- Less than 10% of experimental background comes from non-crystal sources (detector materials and environmental sources)
- Average background in 1-6 keV RoI is 0.72 cpd/kg/keV for Na-33

Component	Rate (cpd/kg/keV)	Veto efficiency (%)
Crystal intrinsic	$<5.2 \times 10^{-1}$	13
Crystal cosmogenic	1.6×10^{-1}	45
Crystal PMTs	3.8×10^{-2}	57
Crystal wrap	4.5×10^{-3}	11
Enclosures	3.2×10^{-3}	85
Conduits	1.9×10^{-5}	96
Steel vessel	1.4×10^{-5}	>99
Veto PMTs	1.9×10^{-5}	>99
Shielding	3.9×10^{-6}	>99
Liquid scintillator	4.9×10^{-8}	>99
External	5.0×10^{-4}	>93
Total	**0.72**	**27**



SABRE South, Eur.Phys.J.C 83 (2023) 9, 878

Sensitivity of SABRE South



Summary

- Expecting to receive the highest purity crystal that meets our requirement

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- Expecting to receive the highest purity
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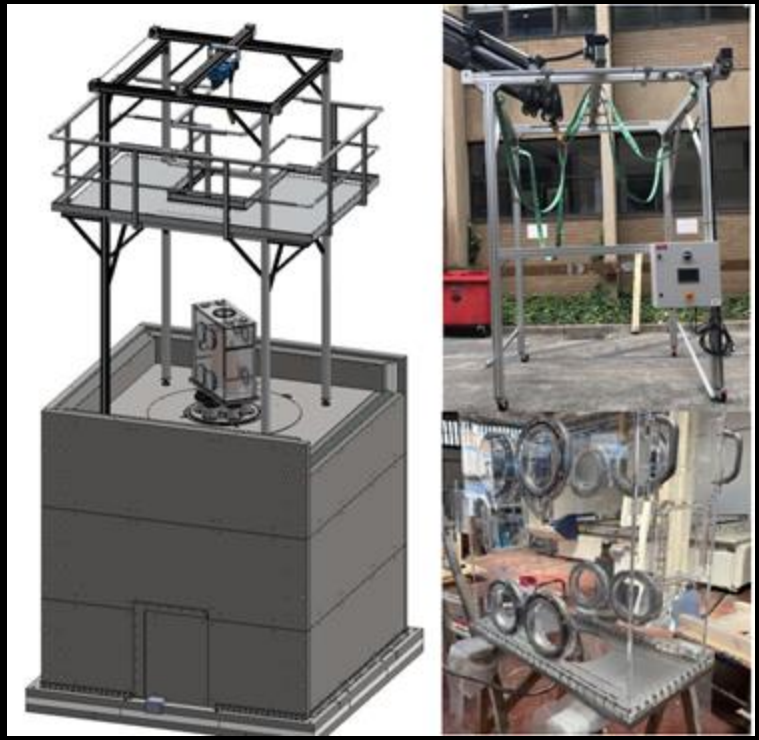
- 4π coverage active background Rejection system
- Targeted to finish installation
  In 2026
- Projected sensitivity of 5σ C.L. in 2 years



Crystal Insertion System

Conclusion:

- **Uniquely positioned** to resolve a 20-year direct dark matter controversy
- **Southern Hemisphere location** enables a decisive cross-check
- **Optimized design and methodology** strengthen sensitivity
- **Final results pending**, but framework supports a definitive test

Thank you!

South

Australian Government
Australian Research Council

KEK-JAPAN

SWINBURNE

THE UNIVERSITY OF SYDNEY

ARC CENTRE OF EXCELLENCE FOR DARK MATTER

THE UNIVERSITY OF MELBOURNE

THE UNIVERSITY of ADELAIDE

Australian National University

North

INFN LNGS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Gran Sasso

SAPIENZA

PRINCETON UNIVERSITY

INFN
Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DEGLI STUDI DI MILANO

UNIVERSITÀ DEL SALENTO

Crystals

RMD
A Dynasil Company

Since 1928
SICCAS

Screening

ANSTO

Science and Technology Facilities Council
Boulby Underground Laboratory

UCL

Veto LS

Institute of High Energy Physics
Chinese Academy of Sciences

8

Back up

SABRE South and North

Common Features:

- Same crystal production and R&D.
- Same detector module concept (Ultra-pure crystals and HPK R11065 PMTs)
- Common simulation, DAQ and data processing frameworks

Different Shielding designs:

- SABRE North has opted for a fully passive shielding due to the phase out of organic scintillators at LNGS.
- For SABRE South, the liquid scintillator will be used for in-situ evaluation and validation of the background in addition to background rejection and particle identification.

Status of SABRE North

SABRE North facilities are now installed in the final site at LNGS