State of Physics in South Africa

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South Africa at a glance

- ## Facts/Trivia

⇨25th Largest in the world (in size)

⇨Pop: 52 m; “rainbow” nation of 9 African, 3 Asian, and 6 European cultures.

⇨Has an entire floral kingdom within borders (>23,000 plant species) and home to:

  - The Worlds Largest land mammal (the elephant)
  - The tallest (Giraffe), and fastest (Cheetah) mammals
  - The Largest antelope (eland) and bird (Ostrich)

⇨GDP 2nd largest, and most sophisticated in Africa.

  - Upper Middle income economy
  - Largest deposits of minerals in the world

⇨20 universities and technical universities

  - 4 ranked in Shanghai Top 500
  - The only Cyclotron facility in Southern Hemisphere
  - Has the largest optical telescope in the Southern Hemisphere
  - Leader in Fischer-Tropp technology (Oil from Coal)

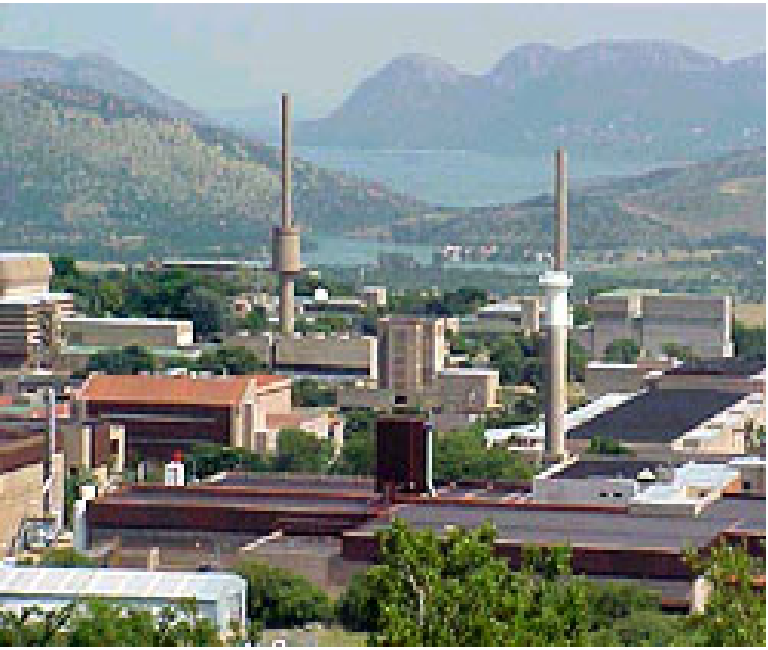
⇨Ch. Barnard : World’s first Heart Transplant

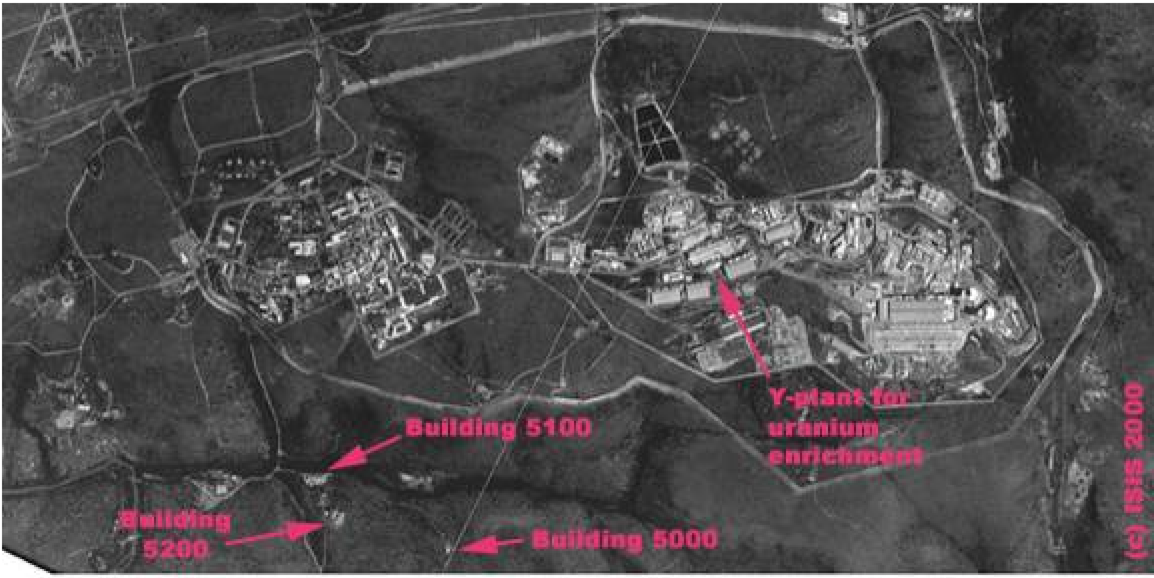
⇨Has produced 4 Nobel Laureates in Science & Medicine

⇨First Country in Africa to poses Nuclear Weapons and the first to in the world to “voluntarily “disarm.

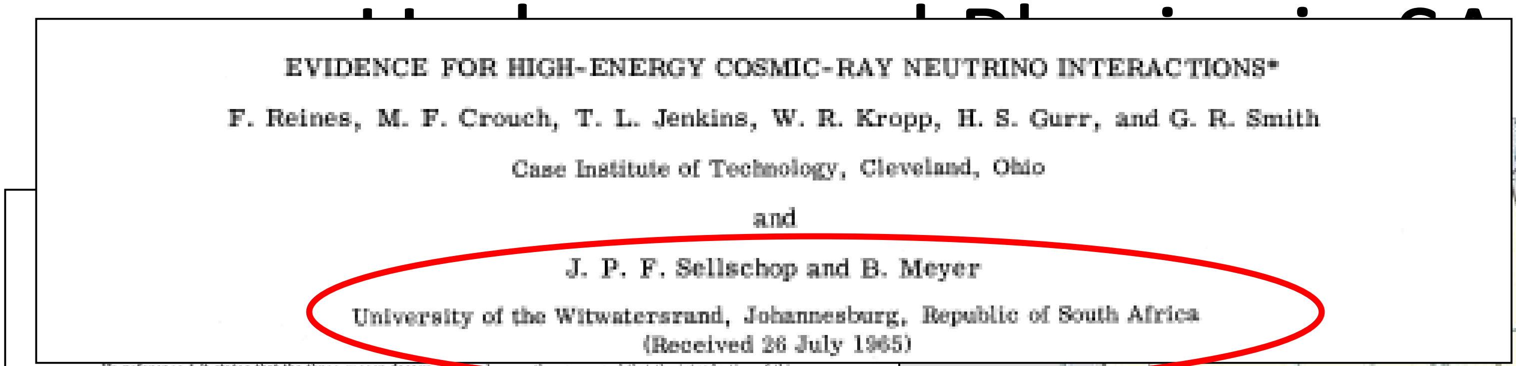
Early Physics in SA

- The first Universities were established in the late 1800’s.
- The Council for Scientific and Industrial Research established in 1945
- The Atomic Energy Board was established in 1950 – Nuclear weapons programme.
- **The South African Institute of Physics was established in 1955**.



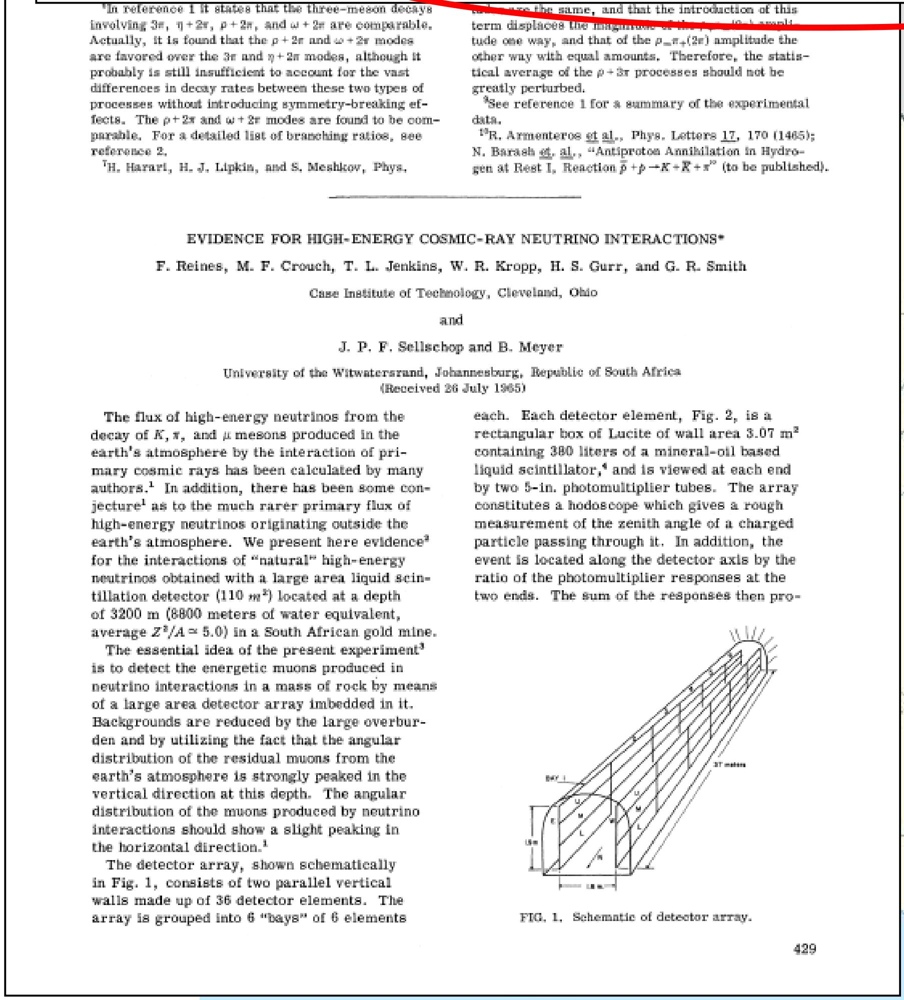


Significant former nuclear weapons related facilities at the Pelindaba-Valindaba Complex, near Pretoria, South Africa. December 1991 KVR-1000 image from www.terraserver.com.



EVIDENCE FOR HIGH-ENERGY COSMIC-RAY NEUTRINO INTERACTIONS*

F. Reines, M. F. Crouch, T. L. Jenkins, W. R. Kropp, H. S. Gurr, and G. R. Smith
Case Institute of Technology, Cleveland, Ohio
and
J. P. F. Sellschop and B. Meyer
University of the Witwatersrand, Johannesburg, Republic of South Africa
(Received 26 July 1965)



[6] In reference 1 it states that the three-meson decays involving 3π, $\eta+2\pi$, $\rho+2\pi$, and $\omega+2\pi$ are comparable. Actually, it is found that the $\rho+2\pi$ and $\omega+2\pi$ modes are favored over the 3π and $\eta+2\pi$ modes, although it probably is still insufficient to account for the vast differences in decay rates between these two types of processes without introducing symmetry-breaking effects. The $\rho+2\pi$ and $\omega+2\pi$ modes are found to be comparable. For a detailed list of branching ratios, see reference 2.

[7] H. Harari, H. J. Lipkin, and S. Meshkov, Phys.

[illegible] are the same, and that the introduction of this term displaces the magnitude [illegible] amplitude one way, and that of the $\rho_-\pi_+(2\pi)$ amplitude the other way with equal amounts. Therefore, the statistical average of the $\rho+3\pi$ processes should not be greatly perturbed.

[8] See reference 1 for a summary of the experimental data.

[9] R. Armenteros et al., Phys. Letters 17, 170 (1465); N. Barash et. al., "Antiproton Annihilation in Hydrogen at Rest I, Reaction $\bar{p}+p\to K+\bar{K}+\pi$" (to be published).

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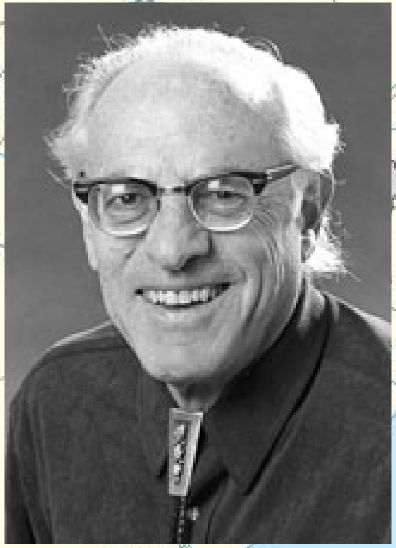
The flux of high-energy neutrinos from the decay of K, π, and μ mesons produced in the earth's atmosphere by the interaction of primary cosmic rays has been calculated by many authors.[1] In addition, there has been some conjecture[1] as to the much rarer primary flux of high-energy neutrinos originating outside the earth's atmosphere. We present here evidence[2] for the interactions of "natural" high-energy neutrinos obtained with a large area liquid scintillation detector (110 m^2) located at a depth of 3200 m (8800 meters of water equivalent, average $Z^2/A\simeq 5.0$) in a South African gold mine.

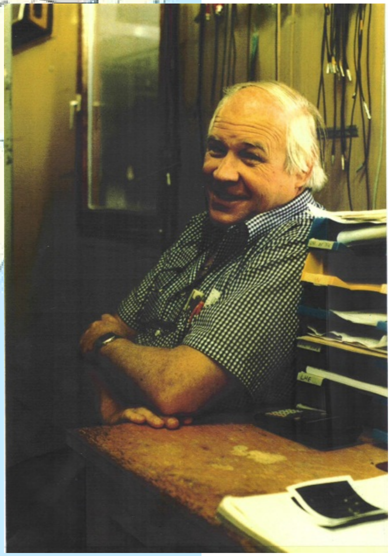
The essential idea of the present experiment[3] is to detect the energetic muons produced in neutrino interactions in a mass of rock by means of a large area detector array imbedded in it. Backgrounds are reduced by the large overburden and by utilizing the fact that the angular distribution of the residual muons from the earth's atmosphere is strongly peaked in the vertical direction at this depth. The angular distribution of the muons produced by neutrino interactions should show a slight peaking in the horizontal direction.[1]

The detector array, shown schematically in Fig. 1, consists of two parallel vertical walls made up of 36 detector elements. The array is grouped into 6 "bays" of 6 elements each. Each detector element, Fig. 2, is a rectangular box of Lucite of wall area 3.07 m^2 containing 380 liters of a mineral-oil based liquid scintillator,[4] and is viewed at each end by two 5-in. photomultiplier tubes. The array constitutes a hodoscope which gives a rough measurement of the zenith angle of a charged particle passing through it. In addition, the event is located along the detector axis by the ratio of the photomultiplier responses at the two ends. The sum of the responses then pro-

FIG. 1. Schematic of detector array.



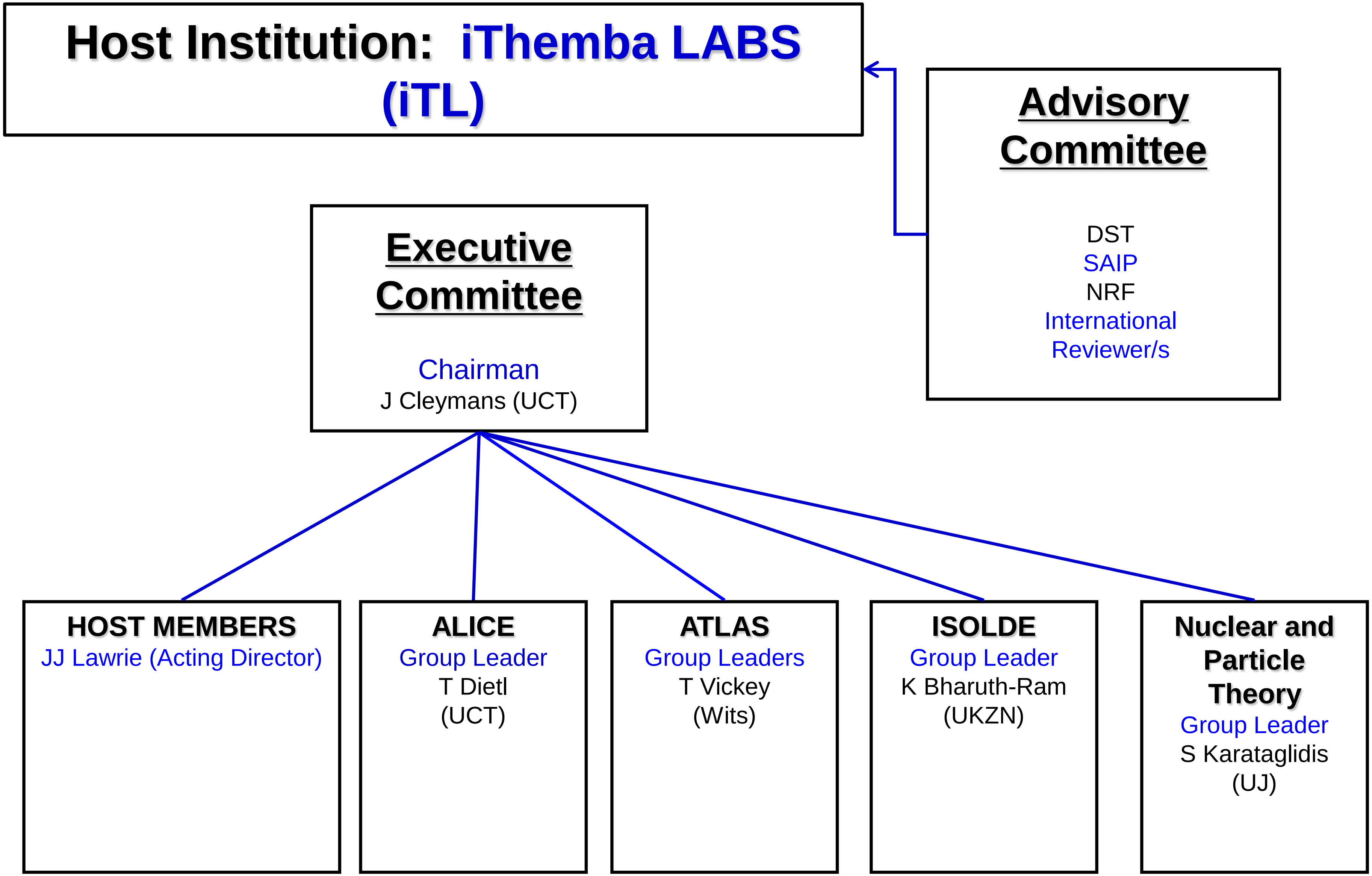
Frederick Reines



Friedel Shellschop

Phys Rev Lett, 15, 429 (1965)

High Energy Physics → SA-CERN Program



Host Institution: iThemba LABS (iTL)

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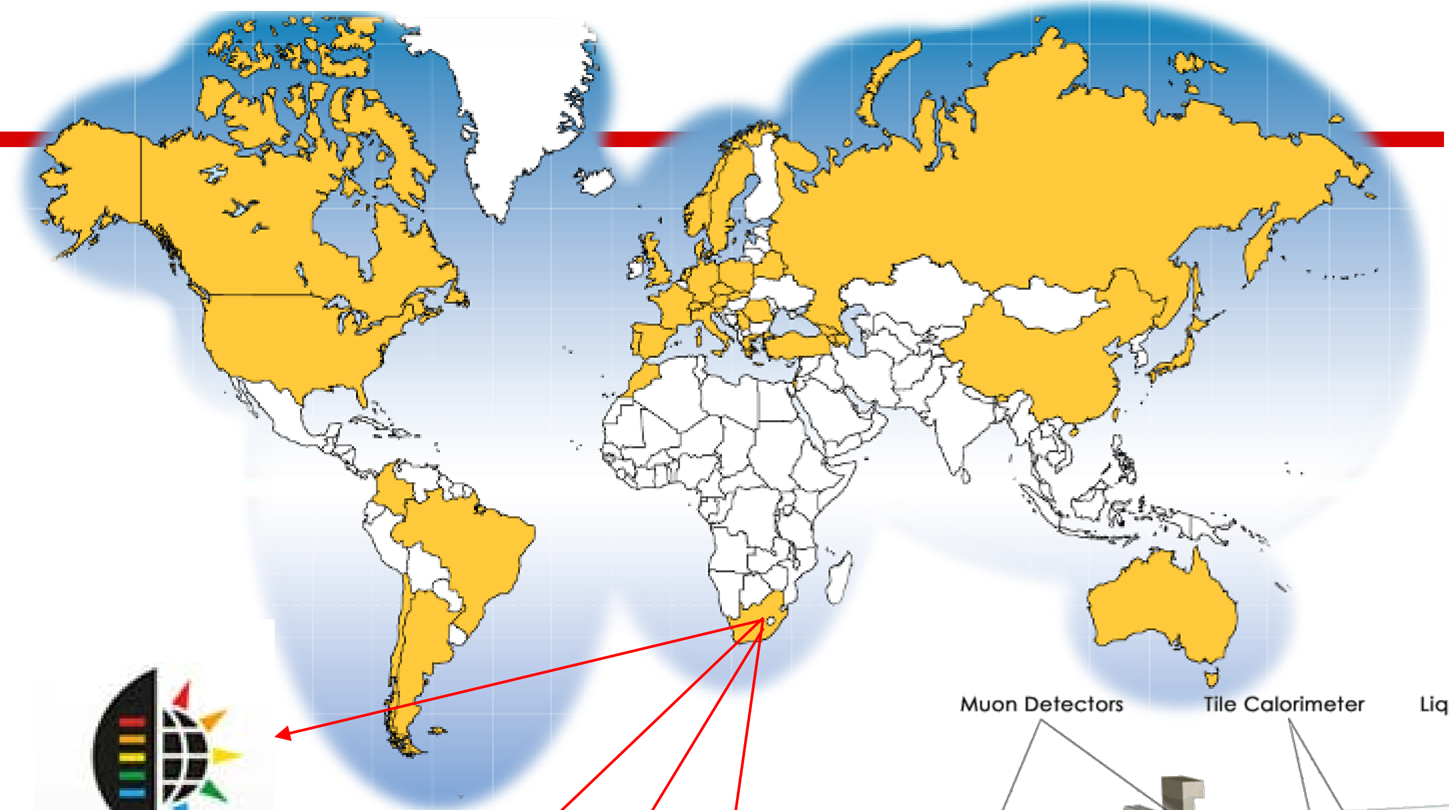

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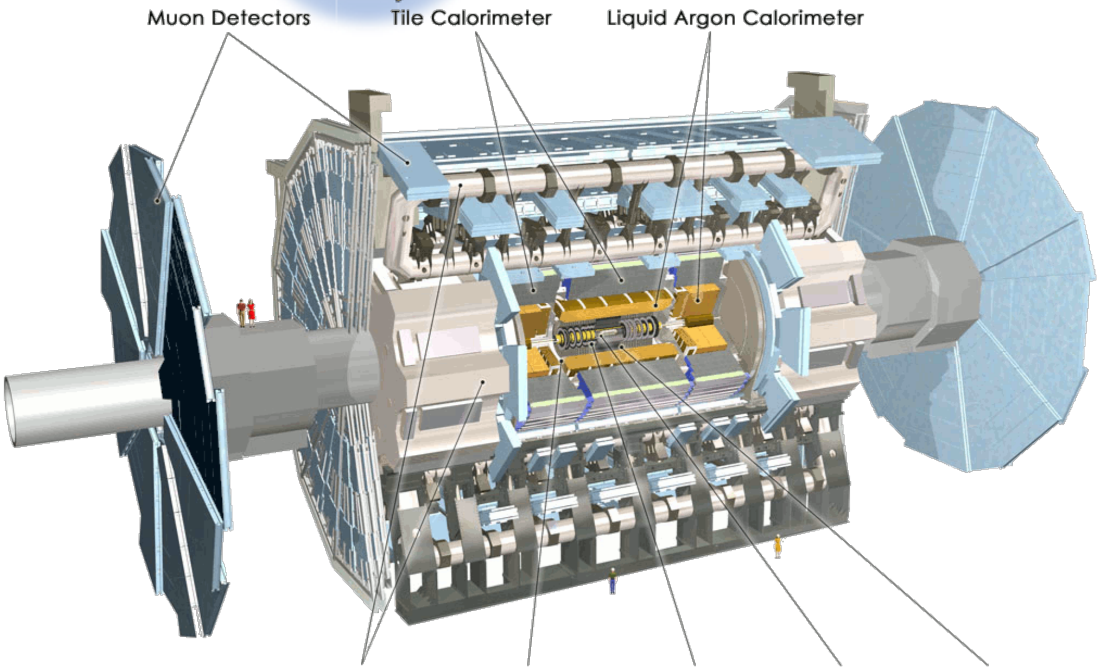
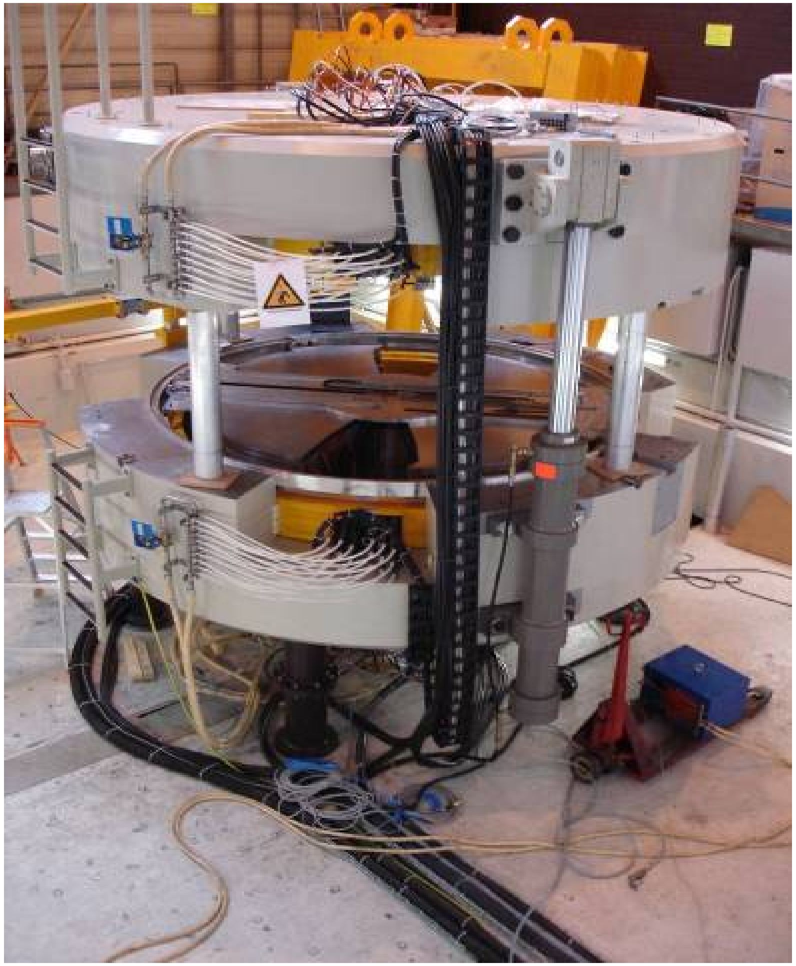
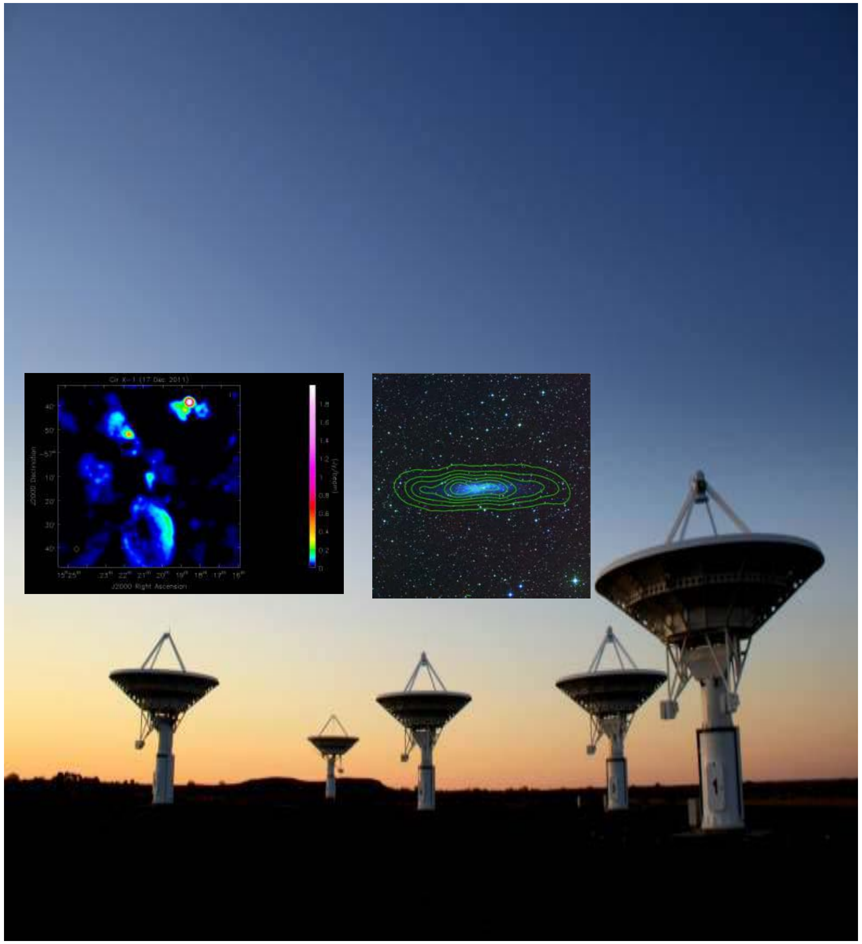


SA-CERN Officially Launched at iThemba in 2008

Other Physics Initiatives

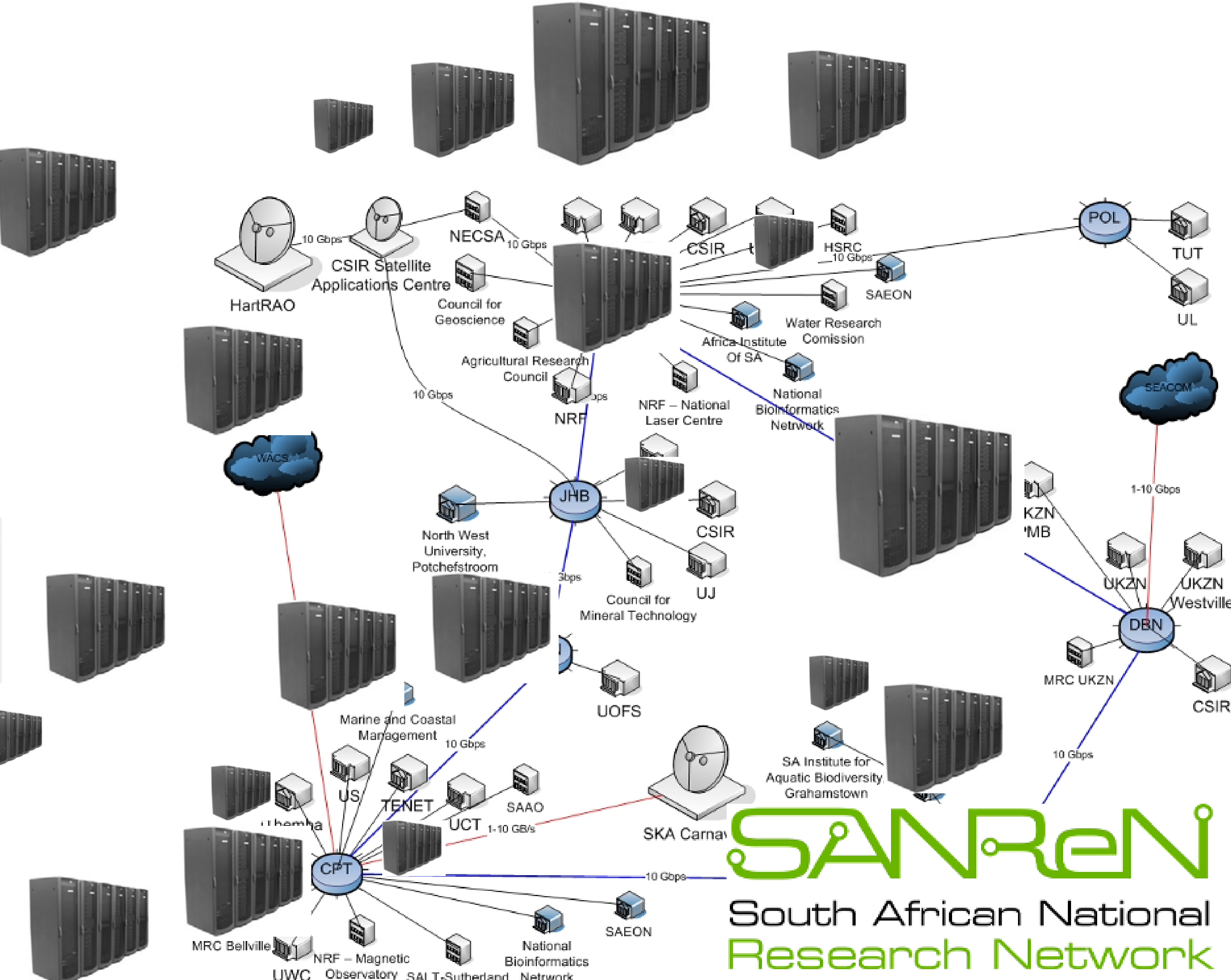


Radio Active Beams at iThemba LABS



Square Kilometre Array

Scientific Computing in South Africa



CHPC
CENTRE FOR HIGH PERFORMANCE COMPUTING

SANReN
South African National Research Network

Case for U/ground Facility in the South

COMMENT

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CRYPTOGRAPHY Chinese blockbuster novel on code-breaking reviewed p.36

HOMININS Human-origins exhibition probes history of immigration p.38

CONSERVATION Preserving concrete, from dams to Fallingwater p.39

The proposed Cherenkov Telescope Array (artist's impression) might detect light flashes from γ-rays produced when dark-matter particles interact.

Broaden the search for dark matter

Bold strategies are needed to identify the elusive particles that should make up most of the Universe's mass, say **Mario Livio and Joe Silk.**

Dark matter is living up to its name. In spite of decades of compelling evidence from astronomical observations showing the existence of matter that neither emits nor absorbs electromagnetic radiation, all attempts to detect dark matter's constituents have failed.

The presence of dark matter is inferred from its gravitational effects. Stars and gas clouds in galaxies and galaxies in clusters move faster than can be explained by the pull of visible matter alone. Light from distant objects may be distorted by the gravity of intervening dark material. The pattern of large-scale structures across the Universe is largely dictated by dark matter. In fact, about 85% of the Universe's mass is dark, accounting for about one-quarter of the total cosmic energy budget.

Despite its ubiquity, the nature of dark matter eludes us. Negative results have flowed from searches for candidate particles to explain it. In 2013, the Large Underground Xenon (LUX) experiment — the most sensitive detector of its kind — in the Homestake Mine in Lead, South Dakota, reported no signs of dark matter in its first three months of operation[1]. The Large Hadron Collider (LHC) at CERN, Europe's particle-physics laboratory near Geneva, Switzerland, has found no evidence for the existence of what some think are the most likely culprits: supersymmetric particles, theoretically predicted partners to the known elementary particles.

Is there light at the end of this dark tunnel? Possibly — but only if searches become bolder and broader. More varied particle types should be sought. Definitive tests need to be devised to rule out some classes of ▶

The LUX experiment detects photons produced when dark-matter particles interact with liquid xenon.

excess could indicate dark-matter-particle annihilations or decays. But a similar line from Earth's atmospheric limb implies that at least part of the signal must be instrumental in origin. A conclusive test may come in the next couple of years from the HESS (High Energy Stereoscopic System) γ-ray telescope in Namibia, which is observing the inner Galaxy in the 100 GeV to 1 TeV energy range.

The null results from LUX, the LHC and many other experiments are narrowing the range of possible particles that could explain dark matter. As claimed detections pop up only to disappear, physicists are becoming justifiably sceptical about every announcement of a discovery.

Some theorists have even started to wonder whether dark matter exists. Since the 1980s, a few have proposed modifying the theory of general relativity to do away with the need for dark matter. Such radical ideas are increasingly invoked to address another grave problem in astrophysics: the origin of the 'dark energy' that accelerates the expansion of the Universe. Most researchers think that we are far from needing new physical laws, especially because experimental avenues are still open. But unpleasant surprises are always possible.

There are two worst-case scenarios. First, dark matter may not comprise one type of particle — as many current searches assume — but many. Second, the particles might interact only gravitationally, and could be practically invisible to conventional detectors.

NEW DIRECTIONS

Existing experiments should run their course. But new approaches are needed to tease out dark-matter particles in the next decade.

A dark-matter modulation experiment, such as DAMA/LIBRA or CoGeNT, in the Southern Hemisphere would gauge the extent of Earth's seasonal effects, which would be out of phase relative to the north.

Clumps or streams of dark matter moving through the Milky Way, distorting the rate at which particles hit detectors, should be visible as disturbances in the motions of the roughly one billion nearby stars that will be tracked by the European Space Agency's newly launched GAIA satellite during its five-year mission.

At the LHC and other next-generation accelerators, particle collisions with missing energy — drawn by an unknown particle — or other unexpected signatures could illuminate the dark sector.

We must also broaden directed searches and exploit astrophysical methods. First, we should look towards more massive particles, such as the SUSY particles. It will be difficult to detect heavy particles directly because there will be fewer of them. But γ-ray astronomy may help. The Cherenkov Telescope Array — an international project to build more than 100 ground-based telescopes to capture light flashes from γ-rays scattered by the atmosphere — should after 2015 open the window to 100-TeV energies. This energy coincides nicely with the highest limit on the WIMP mass expected from fundamental physics arguments. Such particles would generate TeV γ-rays when they annihilate or decay.

Second, broader categories of dark-matter particles should be sought. Like ordinary matter, dark matter could be complex, perhaps carrying a small charge, or having internal states akin to the electron levels of an atom. Changes in the Sun's oscillations as clouds of 'millicharged' particles scatter off electrons in the solar plasma might be detectable through helioseismology. Gravitational lensing could measure the more-spherical dark haloes of distant galaxies, which are expected if dark-matter particles interact electromagnetically, albeit feebly.

Third is the axion. Predicted to explain an anomaly in quantum chromodynamics, the theory of the strong force, the electromagnetic signatures of axions have been long sought in the lab without success. String theory suggests types of ultralight axion that would be slightly more 'warm' than cold dark matter. Mixes of cold and warm dark matter, perhaps also including neutrinos[10], might explain, for example, why there are fewer dwarf galaxies than cold-dark-matter scenarios predict.

Astrophysicists should look for unusual signals in old stars, such as neutron stars and white dwarfs. As stars orbit their galaxy, they accumulate WIMPs. Collected in the core of a neutron star, WIMPs might form a tiny black hole that could eventually devour the star, causing a violent explosion — an event that has yet to be seen. Helioseismology could also probe the effect of WIMPs on the Sun's temperature profile.

To refine theoretical and experimental strategies, particle physicists and astrophysicists need to communicate better. The number of dark-matter-candidate particles to be explored is limited, bounded at low masses by our failure to see anything and at high masses by the constraints of theory. A multidisciplinary approach to explore the 1–100 TeV mass–energy range should be the next frontier for the dark-matter community. ■

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Can South Africa become the Centre of Southern Hemisphere Neutrino Physics?

- **South Africa was active in this area of research in the 1960's through pioneering experiments done at ERPM gold mine the where the late Nobel Laureate F. Reines (including the late JPF Sellschop)**
  - **observed (in 1965) the first natural neutrinos** along with the Indian team led by Goku Menon and colleagues in Kolar Gold fields in India, **setting first astrophysical limits**!
- Some of the World's deepest mines are in SA:
  - Tau Tona 3,900 m (12,800 ft) – 50 C
  - Plans to extend Mponeng mine, a sister mine to TauTona, down to 4,500 m (14,800 ft) in the coming years
  - World Leading Mining engineering and Geo seismology schools
  - Geographical Location of SA places it closest to the heart of our galaxy

The SAUL Collaboration

Shaun Wyngaardt (Stellenbosch University)
Richard Newman (Stellenbosch University)
Robbie Lindsay (University of the Western Cape)
Andy Buffler (University of Cape Town)
Jacques Bezuidenhout (Saldanha Military Academy)
Rob de Meijer (EARTH Foundation)
Peane Maleka (iThemba LABS)
Ricky Smit (iThemba LABS)
Rudolph Nchodu (iThemba LABS)
Milton van Rooy Stellenbosch University)
Zikona Ndlovu (Stellenbosch University)
Zeblon Vilakazi (University of the Witwatersrand)
Sergio Collafrancesco(University of the Witwatersrand)

Special mention: Kai Zuber (TU Dresden, Germany)

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Laboratory for Accelerator Based Sciences

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