4th Joint CAASTRO-CoEPP Workshop: Challenging Dark Matter

Tuesday 21 November 2017, Novotel Barossa Valley Resort

ABSTRACT BOOKLET

Session I

Session Chair:

Elisabetta Barberio
University of Melbourne

Dark matter direct detection: what we cannot see

Gary Hill
University of Adelaide

Dark Matter searches with IceCube

IceCube, constructed in the deep ice at the South Pole, is the world's largest neutrino detector. High energy neutrinos from beyond the Earth have been observed, and this talk will discuss various analyses of these events, testing hypothetical dark matter origins.

Katie Mack

Constraining Dark Matter with Gravitational Waves and Lensing

Some brief thoughts on how future gravitational wave detections can inform our dark matter models, and what we have already learned from them, and how gravitational lensing can give us further insights into dark matter on galactic scales.

Victor Flambaum
University of New South Wales

Enhanced effects of dark matter

Traditional searches for the scattering of dark matter particles off nuclei have not yet produced a strong positive result. The challenge with these traditional searches is that they look for effects that are fourth power in a very small interaction constant. We discuss effects of the first power in the interaction constants, which may give an enormous advantage.

The low mass boson dark matter particles produced after Big Bang form an oscillating classical field and/or topological defects. Interactions with these fields produce a cosmological evolution of the fundamental constants such as the strength of the fundamental forces (including electromagnetism), as well as the masses of the particles. Variations in these physical constants leave characteristic fingerprints on physical processes that take place from as early as a second after the birth of the Universe until the present day.

By studying the effects of dark matter on the primordial abundance of helium produced in the first few minutes of the Universe and on atomic systems in the laboratory, we have derived limits on the interactions of dark matter with photon, electron, quarks and Higgs boson, which improve on existing constraints by up to 15 orders of magnitude, as well as the first ever limits on the interactions of dark matter with the W and Z bosons. Further progress may be achieved with laser interferometry experiments (such LIGO which detected gravitational waves) and pulsar timing.

Other effects of dark matter include oscillating spin-precession and oscillating parity and time reversal violating effect. The results of the recent nEDM collaboration measurements improving limits on the axion interaction with gluons and nucleons up to 3 orders of magnitude will be presented.

Finally, we explore a possibility to explain the DAMA collaboration claim of dark matter detection by the dark matter scattering on electrons. We have shown that the electron relativistic effects increase the ionization differential cross section up to 3 orders of magnitude.

Session II

Session Chair

Chris Power
ICRAR/UWA

Does what we know of galaxy halos tell us anything about what dark matter is?

Any observational test of dark matter in the Local Universe will focus on the regime where it strongly clusters because this is where both analytical reasoning and numerical simulations imply that the signature differences will be found - density cusps and an abundance of substructure. However, the impact of a galaxy's formation on its host halo and the efficiency by which galaxy formation proceeds makes straightforward observational tests challenging. I will discuss how we might go about devising tests that will help us separate the effects of dark matter particle physics from galaxy assembly."

Lister Staveley-Smith
ICRAR/UWA

Galactic Centre Annihilation

Observations of the bulge of the Milky Way show a very significant gamma ray excess which has variously been attributed to positronium (Ps) annihilation, dark matter annihilation, dark matter scattering, and hyperfine transitions of atomic and leptonic dark matter. If Ps decay is involved, an undiscovered source of positrons is needed. Moreover, recombination-line emission should be detectable, with the Rydberg formula implying Ps recombination lines with half the frequency and half the transition probability of hydrogen (H) lines, and thermal linewidths 30 times larger. I will describe some recent attempts with radio telescopes to detect such emission lines in order to elucidate the origin of the gamma ray emission.

Nick Iwanus
University of Sydney

Simulating dark matter annihilation feedback

In this talk I will present results from hydrodynamic simulations that contain a simple implementation of Dark Matter Annihilation Feedback (DMAF). In this model, a particle Dark Matter species self-annihilates and subsequently releases a number of decay products, such positron-electron pairs, gamma rays and quarks. The energy of these products couples to the nearby gas resulting in the heating of galaxies in regions of high dark matter density --the dark matter/baryon fluid is then self-consistently evolved under gravity and hydrodynamics. This heating causes additional pressure forces to develop within galaxies, having strong implications on their mass distributions and star formation rates.

We have run a number of cosmological box simulations which are adiabatic except for the presence of DMAF. For modest annihilation rates we find that DMAF has a stronger effect on galaxies hosted in smaller, more concentrated Dark Matter halos. This suggests that in more advance simulations that contain cooling and thermal feedback effects such as star formation and photo-ionisation, DMAF may imprint signatures onto dwarf galaxies where cooling and heating are already near balanced.

Session III

Session Chair

Christian Reichardt
University of Melbourne

Dark Matter and the CMB

The observed acoustic pattern in the Cosmic Microwave Background (CMB) anisotropy is one of the pieces of evidence supporting the current cold dark matter paradigm. I will review the evidence for dark matter from the CMB, and then talk about how the CDM paradigm is being tested by new, lower-noise CMB experiments. These experiments allow searches for new particles (which would affect the expansion history of the early Universe), searches for the energy injection due to decaying or annihilating dark matter (which would potentially change the ionisation history and distort the black-body spectrum of the CMB), and tests of the predicted large-scale velocity field with the pair-wise kinetic Sunyaev-Zel'dovich effect.

Raymond Volkas
University of Melbourne

Origin of the dark matter mass scale for asymmetric dark matter

The similar mass densities for dark matter and ordinary matter suggest a common origin. Since the ordinary matter mass density in the present-day universe is driven jointly by the baryon asymmetry and the proton mass, this motivates the exploration of composite dark matter originating for a dark QCD-like interaction, with its number density given by a dark matter-antimatter asymmetry that is chemically related to the ordinary baryon asymmetry.

Nicole Bell
University of Melbourne

Direct detection of dark matter via a Two-Higgs-Doublet portal

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Martin White
University of Adelaide

Solving the dark matter problem using many experiments

Solving the dark matter problem will inevitably involve combining positive and negative results from a large range of experiments, including current direct and indirect search results plus collider observations, but also including a large range of other data. I will briefly present a new tool (GAMBIT) for performing global statistical fits of generic dark matter models, and will also summarise recent studies on dark matter phenomenology.

Peter Quinn
ICRAR/University of Western Australia

Axions with radio telescopes

We investigate the use of next generation radio telescopes such as the Square Kilometre Array (SKA) to detect axion two-photon coupling in the astrophysical environment. The uncertainty surrounding astrophysical magnetic fields presents new challenges, but with a frequency range corresponding to axions of mass 1.7 − 57μeV and a spectral profile with a number of distinguishing features, SKA-mid offers a tantalising opportunity to constrain axion dark matter properties. To determine the sensitivity of SKA-mid to an axion signal, we consider observations of the Galactic centre and interstellar medium, and find that this new telescope could allow us to probe axion couplings 10−16GeV−1.

Michael Tobar
University of Western Australia

High Precision Low Energy Experiments to Search for WISP Dark Matter

The explanation of cosmological Dark matter could be the existence of a high density of ultra-light particles with masses as light as 10-21 eV. To search for such low mass particles of an eV or below (including the QCD axions), various high precision low energy experiments are currently proposed world-wide and actively searching for such particles, which are also known as Weakly Interacting Slim Particles (WISPs). Examples of duch particles include Axions or Axion like Particles (spin 0 boson), Dark Photons (spin1 boson) or fields that determine the shape and size of extra dimensions as well as values of fundamental constants.

After a general introduction on these types of precision experiments, we present first results and future plans for the Oscillating Resonant Group AxioN (ORGAN) experiment, a microwave cavity axion haloscope situated in Perth, Western Australia designed to probe for high mass axions motivated by several theoretical models [1]. The first stage focuses around 26.6 GHz in order to directly test a claimed result, which suggests axions exist at the corresponding mass of 110 μeV. Later stages will move to a wider scan range of 15-50 GHz (60 − 210 μeV). We present the results of the path finding run, which sets a limit on g_{aγγ} of 2.02 × 10^{−12} eV^{−1} at 26.531 GHz, or 110 μeV, in a span of 2.5 neV (shaped by the Lorentzian resonance) with 90% confidence. Furthermore, we outline the current design and future strategies to eventually attain the sensitivity to search for well-known axion models over the wider mass range. This includes new designs of tunable microwave cavities based on Bragg modes, with super mode tuning. We will also discuss plans to search for low mass axions below 10-6 eV [2].

We are also undertaking experiments with YIG magnons, and currently have engineered resonant cavities with Ultra-strong and super-strong coupling [3, 4]. Such cavities can be used to search for axions through axion-spin interactions.

[1] Ben T. McAllister, Graeme Flower, Justin Kruger, Eugene N. Ivanov, Maxim Goryachev, Jeremy Bourhill, Michael E. Tobar, arXiv:1706.00209 [physics.ins-det]

[2] Ben T. McAllister, Stephen R. Parker, and Michael E. Tobar, Phys. Rev. D 94, 042001 (2016)

[3] M Goryachev, WG Farr, DL Creedon, Y Fan, M Kostylev, ME Tobar, "High cooperatively cavity QED with Magnons at Microwave Frequencies," Phys. Rev. Applied, vol. 2, 054002, 2014.

[4] N Kostylev, M Goryachev, ME Tobar, "Superstrong Coupling of a Microwave Cavity to YIG Magnons," Appl. Phys. Lett., vol. 108, 062402, 2016.
