## PROBING THE DARK UNIVERSE WITH THE SKA IN AFRICA



UNIVERSITY of the WESTERN CAPE

Roy Maartens

Department of Physics & Astronomy www.astro.uwc.ac.za



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## Dark Matter

- Galaxies are made of stars, dust and gas
- But when we measure the rotation speeds of stars, we find

not enough baryonic matter to keep the stars in their orbits - by  $\sim 80\%$ !



M109

- We need cold dark matter (CDM) as a 'glue' to stabilise galaxies
- And we need CDM to help galaxies grow under gravity fast enough to match what we observe
- CDM may be a new particle maybe a WIMP.
   Detectors in mines, under the sea, and in CERN.
   So far no sign of CDM



XENON

## The Dark Energy revolution

- Galaxies are moving apart from each other because the Universe is expanding.
- Galaxies attract each other gravitationally so we expect the expansion to slow down.
- In the 1990s, observations showed: the expansion has been accelerating for ~5 billion years



How to explain this? The 'simple' answer:

• The vacuum energy has effectively negative pressure and acts against galactic gravity.

Vacuum energy A is known as Dark Energy



## The crisis of Dark Energy

• Huge clash between prediction and observation:

observed 
$$\Lambda \sim (10^{-3} \text{ eV})^4$$
  
"prediction"  $\Lambda > (10^{12} \text{ eV})^4$  or  $\Lambda \equiv 0$ 

- Attempts to explain Λ=0 or the unbelievably small but nonzero value of Λ – eg the 'Multiverse' and its 'Landscape' in String Theory. So far there is no solution.
- We need consistency checks of DE, DM and Einstein's General Relativity



Dark Matte

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## How to probe DM, DE and GR on cosmic scales?

Need millions and billions of galaxies for statistical power.

By measuring the positions and shapes of galaxies over huge volumes of the Universe, we can detect the signatures of DM, DE and GR.

Can also constrain the sum of neutrino masses – better than terrestrial

Radio telescopes can deliver the largest ever maps of galaxies.

## Why radio telescopes?

Hydrogen gas – the most abundant element in the Universe
 – is invisible in the optical but 'shines' in the radio:



spin-flip transition

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- Hydrogen gas the most abundant element in the Universe
  - is invisible in the optical but 'shines' in the radio:
    - we can 'see' galaxies that contain hydrogen
    - we can 'see' huge clouds of hydrogen that give birth to the first generation of stars in the Universe:

the Cosmic Dawn that lights up the Universe to end the Dark Ages!

## Brief history of the Universe





## Exploring the dark cosmos with the SKA

Square Kilometre Array – the biggest ever radio telescope.

SKA PHASE 1 (~ 2025 –) SKA1-MID: ~200 dishes – in South Africa. SKA1-LOW: ~130,000 dipole antennas – in Australia. SKA PHASE 2 (~ 2030 –)

 $\sim 10 \text{ X SKA1}$ 

Spreads into Africa.







SKA1-LOW: 50 – 350 MHz Phase 1: ~130,000 antennas across 65km



SKA1-MID: 350 MHz – 24 GHz Phase 1: ~200 15m dishes across 150 km

#### SKA site in the Karoo



## SKA in Africa



#### **Partner Countries:**

- Botswana
- Ghana
- Kenya
- Madagascar
- Mauritius
- Mozambique
- Namibia
- Zambia



Ghanain trainees at Kutunse



## MeerKAT – SA's own precursor array

South Africa has built its own radio array – MeerKAT

- 64 x 13.5m dishes
- Science operations from 2019

   will be the world's best!
- Absorbed into SKA1 2023?





# MeerKAT and then SKA will produce 3D maps of galaxies based on detecting the radio waves emitted by galaxies



## SKA science

also tackles other big questions about our Universe:



- Detect more pulsars and also use them to detect gravitational waves
- Understand the super-massive black holes in galaxies
- Scan the Cosmic Dawn when the first stars form
- Search for life in our Galaxy
- Probe the Dark Ages before the first stars formed

## Africa needs more science

- Essential for everyday life
- To help build a society for everyone
- To help protect the environment



- To understand our origins and our place in the Universe
- To help develop a science-based, humanist and internationalist world-view
- Move beyond raw material export a knowledge economy



## SKA spin-offs for Africa

- World-class science will be produced in Africa
- A massive boost for science in general and especially
   Big Data science
- Raising the profile of science
- Increasing the new generation of scientists, engineers and technicians
- Spin-offs for local industry and infrastructure
- For the next 50+ years



## Science belongs to humanity

And it probably started in Southern Africa:



Blombos cave - oldest evidence of abstract thought

### Hunter-gatherers in Africa wondered at the night sky:



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#### The foundation of astronomy and science

## About 200,000 years later ...

