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Using Atomic Gas as a Critical Test of Galaxy Evolution in Cosmological Simulations + 1

Prof Lerothodi L Leeuw ([UWC, SA](#))

Prof Maarten Baes (U Ghent, Belgium, SKIRT PI)

Prof Erwin de Block (ASTRON, Holland, MHONGOOSE PI)

Ms Omphile Rabyang and Ms Mpendulo Sibiya (Atomic Gas); Dr Gauri Sharma, Ms Refilwe Mmekwe and Mr Sabelo Kunene (Dark Matter) and Mr Mekuanint Kifle (HERA)

Unsolved Problems in Astrophysics and Cosmology

08 December 2022

The 21st Jerusalem Winter School in Theoretical Physics: The Origin of Galaxies

Mon, 29/12/2003 to Thu, 08/01/2004

The Origin of Galaxies

The Victor Rothschild Memorial Symposia

All lectures will take place at the Israel Institute for Advanced Studies,
at the Edmond J. Safra, Givat Ram Campus

General Director: David Gross, University of California at Santa Barbara

Directors:

Sandra M. Faber, University of California, Santa Cruz

Avishai Dekel, The Hebrew University of Jerusalem

Contact

Israel Institute for
Advanced Studies (IIAS)
The Hebrew University of
Jerusalem, Feldman
bldg, Edmond J. Safra
Campus, Givat Ram,
Jerusalem, Israel

The 21st Jerusalem Winter School in Theoretical Physics: The Origin of Galaxies

versus **Unsolved Problems in Astrophysics and Cosmology 2022**

2002 versus 2022

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The Origin of Galaxies

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General Director: David Gross, University of California at Santa Barbara

Directors: **What is the source of the submm and radio emission in galaxies ... et al. 2002**

Sandra M. Faber, University of California, Santa Cruz

Avishai Dekel, The Hebrew University of Jerusalem

New SCUBA and submm detections now common ALMA
Protoplanetary Disks to High-z Galaxies

New clues on planet formations? (Greaves et al. 2005)

What is the source of **submm emission** in Galaxies? (Leeuw et al. 2002)

New IRAS versus JWST Near and Mid-infrared Detections

Dust and Gas Emission and High-z and High-star-forming Galaxies

New clues on planet formations from ALMA et al. 2022

MeerKAT, ASKAP, nVLA, LOFAR, HERA, HIRAX, SKA!

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Overview of Two Problems

- **Unsolved Problem**
 - Using Atomic Gas as a Test for Galaxy Formation Simulations
 - *Ongoing Project* (Credit to Baes, Leeuw and Collaborators)
- **Little Explored Problem** (Correlates with Difficult, Prof O. Lahav)
 - Exploring Boundaries of Science, a base for Approaching Science and Religion in Outreach
 - Proposed IAU GA 2024 Focus Meeting in Cape Town, due Dec 01, 2022
 - (Credit to the SOC [... Leeuw ...])



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Little Explored Problem

(Credit to the SOC)

- Approaching Science and Religion in Outreach (e.g. Guy Consolmagno 2008)
- Proposed IAU GA 2024 Focus Meeting in Cape Town. Engage - Vote - Attend
- **Scientists, including you perhaps**, are often approached on the issue of **science and religion**, when dealing with general audiences or non-scientists either in the media, public outreach or the classroom.
- It is therefore important they have some thought-out **framework or references for handling the issue**
- That it is important to know your audience, underpins communication



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Little Explored Problem (Credit to the SOC)

- **Approaching Science and Religion in Outreach** (e.g. Lerothodi Leeuw et al. 2007, 2019)
- Proposed IAU GA 2024 Focus Meeting in Cape Town. Engage - Vote - Attend
- **How to approach or present the topic of science and religion** to general audiences, of whatever religious persuasion, who may have questions about the relation between the two
- As a base of above, **explore boundaries of what science can and cannot say** about astronomy and cosmology and with what degrees of certainty
- Noting **opportunities and risks**, both of and not tacking the above.

Enhancing and sharing humanity's scientific understanding of the universe since 1899.

[→ Learn more about the American Astronomical Society](#)

Is this done inclusively to all people, of all backgrounds?
Is it inclusive of people interested in different religions?
Any missed-opportunities and at what price?



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Little Explored Problem (Credit to the SOC)

- **Exploring Boundaries of Science** (e.g. George Ellis 2017)
- *Proposed IAU GA 2024 Focus Meeting in Cape Town. Engage - Vote - Attend*
- What are the **boundaries** of what **science can and cannot** say about astronomy and cosmology
- What **can** be said or settled scientifically and with what **degrees of certainty** in these domains, **such as** the birth and evolution of planets, stars and galaxies and age of the universe,
- On the other hand, **what questions cannot**, **such as** why the universe exists, how it was created, and what there was before it came into being



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Little Explored Problem (Credit to the SOC)

- **Exploring Boundaries of Science** (e.g. Piero Benvenuti 2022)
- *Proposed IAU GA 2024 Focus Meeting in Cape Town. Engage - Vote - Attend*
- What are the risks of not addressing these issues in a meaningful and respectful way and propose ways for mitigating those risks
- Are there any scholarly updates of the history of science and religion, science and religion in society and intersections of the topic
- The meeting will deal with science and religion in their higher-level principles, being nonsectarian and not pretending to be representative of the individual and diverse religions and faiths of the globe
- The meeting itself is not the solution but a platform and forum!



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Little Explored Problem (s)

Topics / Sub-problems

1. Approaching **Science and Religion in Outreach** (Guy Consolmagno 2008)
2. **Limitations of Science** (George Ellis, Cambridge University Press, 2017)
3. **Intersections of Science and Religion** (Andrew Briggs, Oxford U P, 2018)
4. Scholarly Update of the history of Science and Religion
5. **Science and Religion in Society** with Africa as a Focus (Templeton F.)
6. Interweaving of the Above Topics



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Unsolved Problem

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- Unsolved Problem(s)
- Why Atomic Gas and Galaxy Formation Simulations
- **Project Science Goals**
- Why TNG50 (TNG100, TNG300) SIMBA and EAGLE **Simulations**
- Why SKIRT (**Mpendulo Sibiya's work**), MHONGOOSE, MIGHTEE (**Omphile Rabyang's work**) and Higher-redshift
- **Status and Future**
 - **Status and Opportunities** of Atomic Gas Comparisons

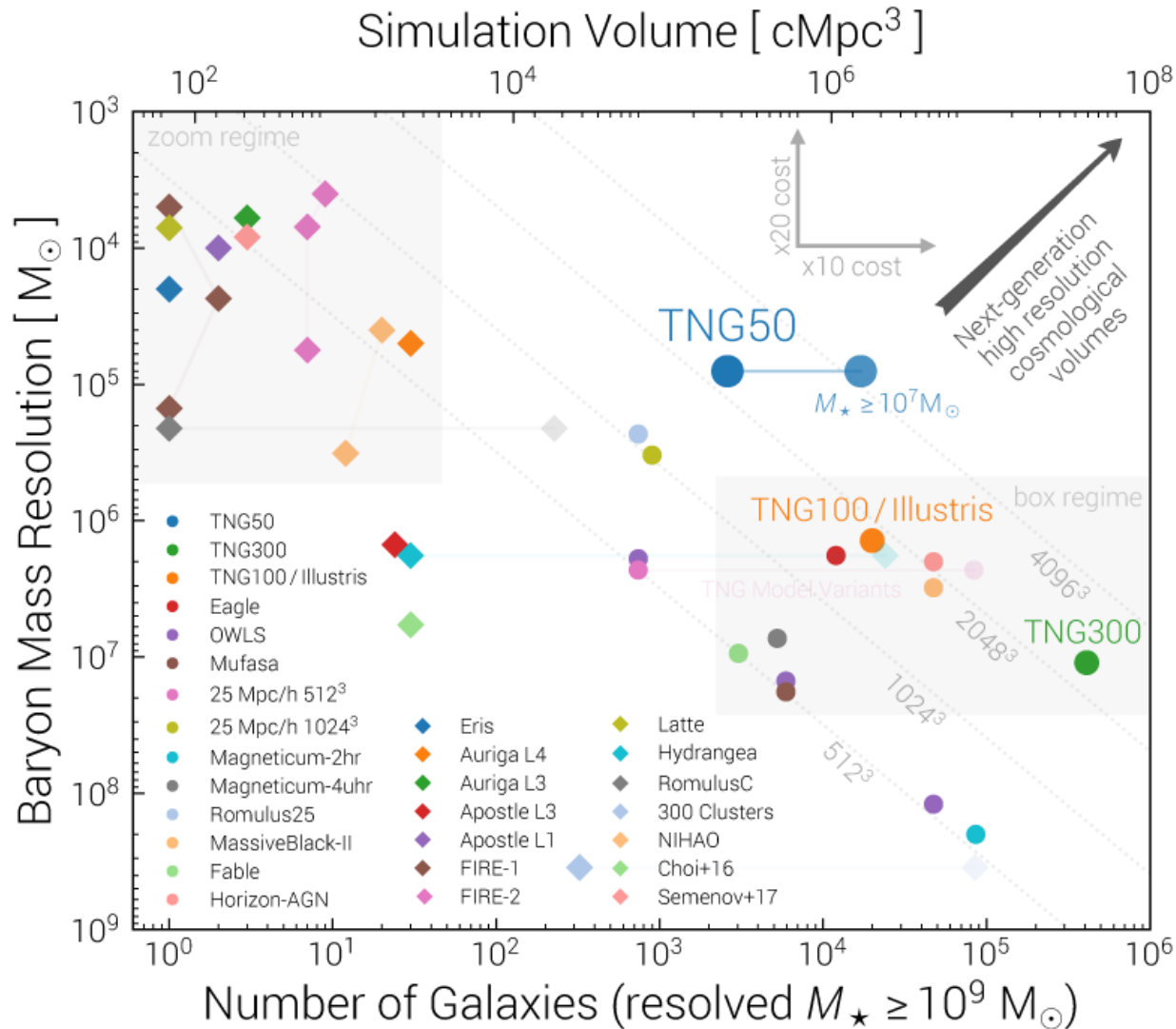
Science Goal of this Project, exploiting two independent opportunities

- **The main goal** of our project is to critically test the TNG50 and SIMBA cosmological hydrodynamical simulation of galaxy formation through the galaxy atomic gas properties in a UV field, that is normally included through sub-grid prescriptions.
- **On the one hand**, progress has been made in 3D radiative transfer codes allowing **SKIRT**, a 3D radiative transfer code developed by our team (Baes et al. 2011; Camps & Baes 2015) and procedures (Camps et al. 2016) to perform radiative transfer for simulated galaxies from **state-of-the-art cosmological hydro-dynamical simulations** and calculate the UV radiation field at every position of a simulated galaxy for comparison with observations.
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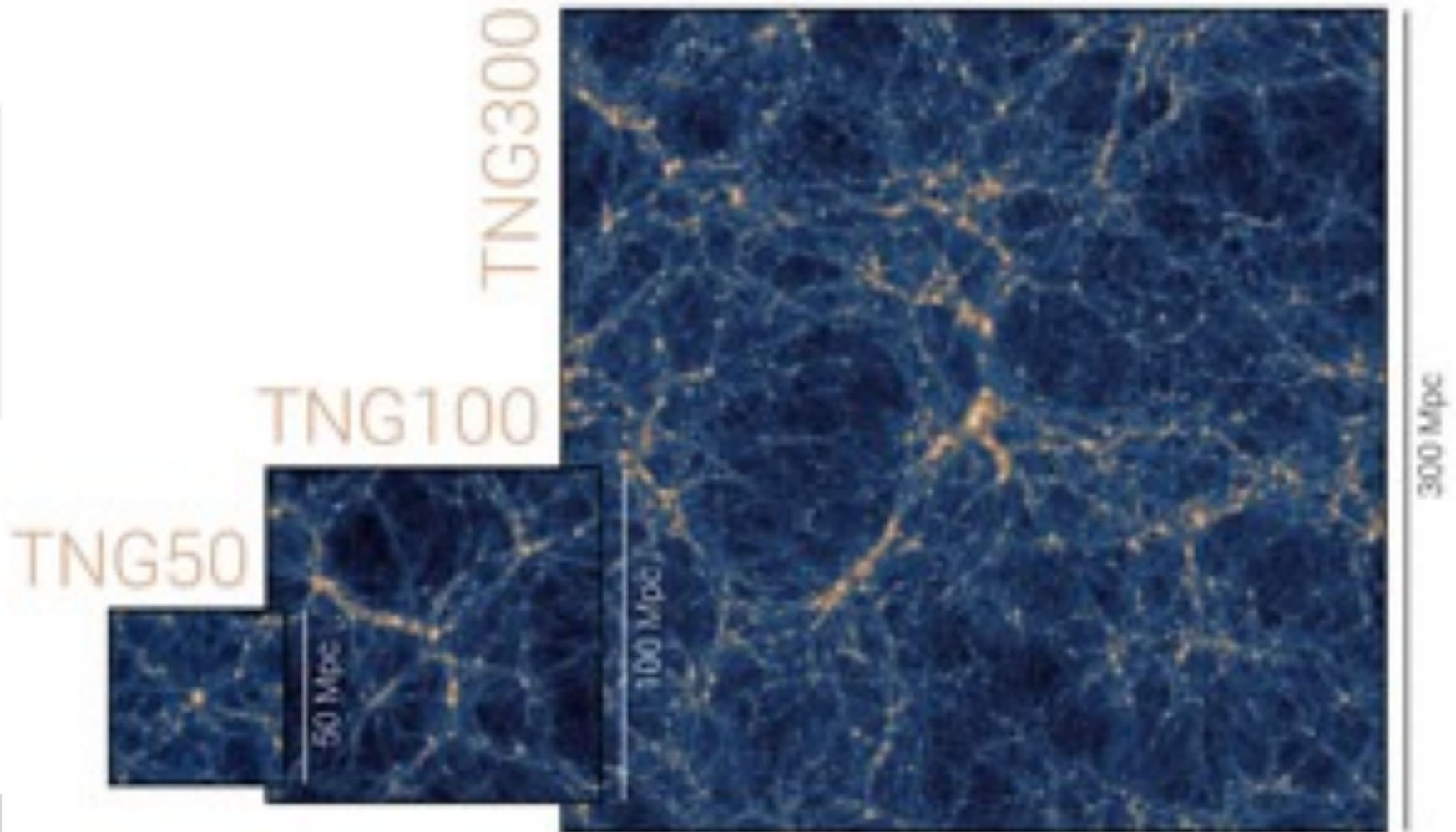
Science Goal of this Project, exploiting two independent opportunities

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- **On the other hand**, new observational HI data is becoming available, such as the **MHONGOOSE** survey, a 1500-hr **MeerKAT** Large Survey Project with the main scientific goals of imaging the HI distribution of 30 nearby galaxies at high angular resolution and to very low HI column densities, thus providing crucial tests for the simulation predictions. **Mightee** is now also available and in use. **Laduma?**
- **Mpendulo (MSc) and Omphile (PhD)**

TING50 (dark blue circle) in comparison to other cosmological volumes (circles) and zoom simulation projects (diamonds) at $z \sim 0$



The TNG50 volume enables a detailed look at the structural properties of galaxies and gas around them, and physics of the simulation; while TNG300 enables the study of galaxy clustering and TNG100 is in between.





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legacy products for the community:

SKIRT HI tools (Mpendulo, 2021) and images from TNG simulations (Andre PhD at U Ghent, 2022) to compare with observations (Mightee, Omphile, 2022 at UWC)

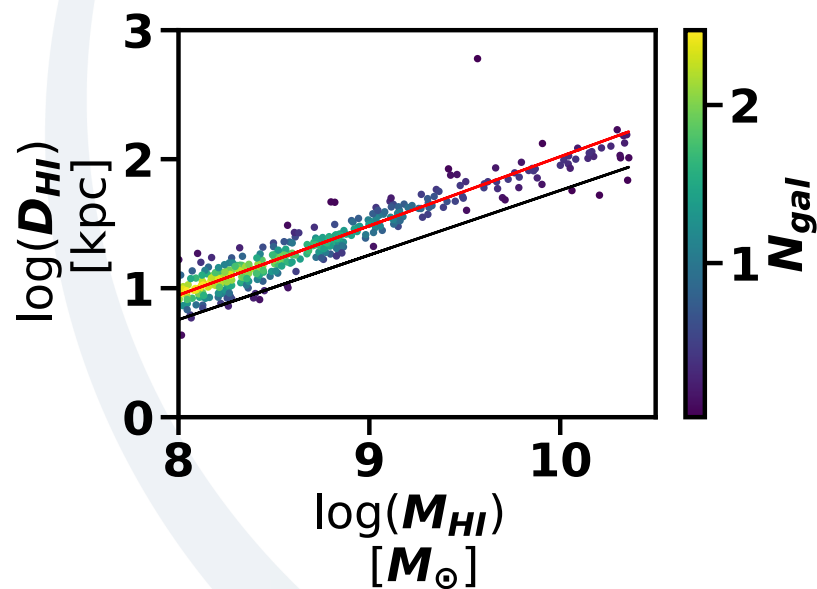
TNG50

HI mass-size relation

Number of galaxies = 586

$z = 0$

$$y = 0.537 \pm 0.008 x + -3.349 \pm 0.066$$



Fitted function

— scatter = 0.13 dex

$$\log(D_{HI}) = 0.537 \log(M_{HI}) - 3.349$$

Rajohnson et al 2022

— scatter = 0.057 dex

$$\log(D_{HI}) = 0.501 \log(M_{HI}) - 3.252$$

Investigating Temporal Structures in HERA Observations



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by
Mekuanint Kifle
University of the Western Cape (UWC)

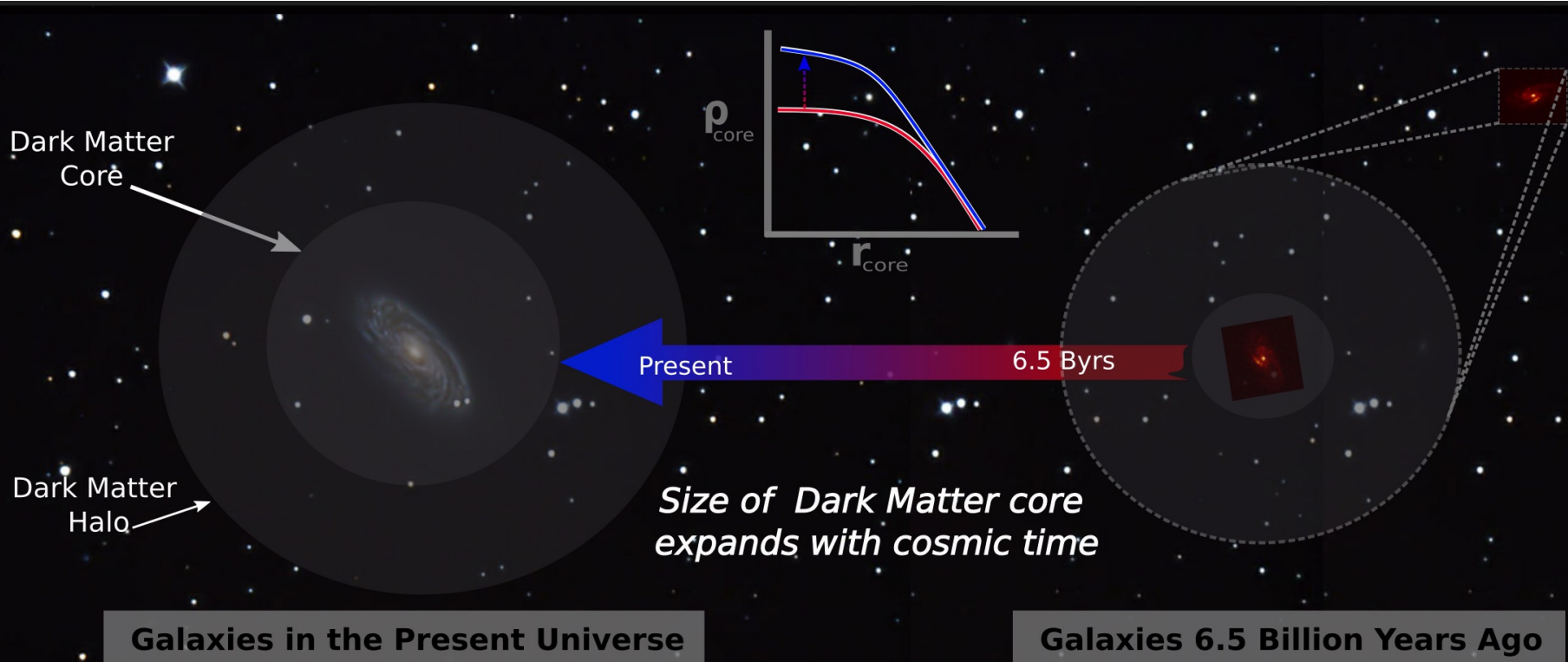


Supervisor: Prof. Lerothodi Leeuw (UWC, SA)

Co-supervisors: Prof. Miguel Morales (UW, USA)
Dr. David DeBoer (UC, USA)

2022-11-09

Dr Gauri Sharma's work on dark matter:





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Summary

Two Problems

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- **History of Visits at Hebrew University of Jerusalem**
- **Unsolved Problem**
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