2022/2023 Theoretical and Computational Sciences Summer Study & Research Programme @NMU

Connecting Quarks with the Cosmos – connecting people with the Universe

Azwinndini Muronga

Nelson Mandela University, Gqeberha, South Africa

NELSON MANDELA UNIVERSITY

NITheCS
National Institute for Theoretical and Computational Sciences

Change the World

From NITheP to NITheCS Internship Programme

- NITheCS Associates are requested to provide internship topics
- A call to eligible students is sent out for applicants to choose the topics of their interest
- Potential hosts (the Associates) will select best suitable candidates to do internships with them overs recess period
- It is advisable not to do an internship at your home institution
- It is a fully funded programme – transport, accommodation and meals.

Now, how did I get involved?

The Research Experience for Undergraduates

- Back at UCT between 2005 -2010
- 3rd year physics students conducted research projects using Thermal Model and UrQMD model, also Neutron Star EoS
- They presented their results at SAIP Conferences

About 7 UG students have marched on to complete their PhDs locally and abroad

NITheP Internship Programme

- 2010 Internship Programme
  - Mr Fhumulani Nemulodi
  - Mr Tshifhiwa Ravhengani
  - Ms Rachel Makua
- 3 interns

- 2011 Internship Programme
  - Mr Mlungisi Alex Doctor Ntshangase
  - Ms Phindile Felicia Magagula

2 interns

NITheP Internship Programme

- 2012 Winter Internship Programme
  - Mr Thendo Emmanuel Nemakhavhini
  - Ms Rotondwa Mudau
  - Mr Moabi George Matsidisi
  - Mr Dumisane Albert Maretele
  - Mr Erasmus du Toit

- 2012 Summer Internship Programme
  - Mr Thando Timax Khedzi
  - Mr Rendani Lukhwa
  - Ms Londiwe Ndlangamandla
  - Mr Azwidovhiwi Emmanuel Nengudza
  - Mr Seanego Billy Mokgadi
  - Mr Lufuno Takalani
  - Mr Bongani Amos Baloyi

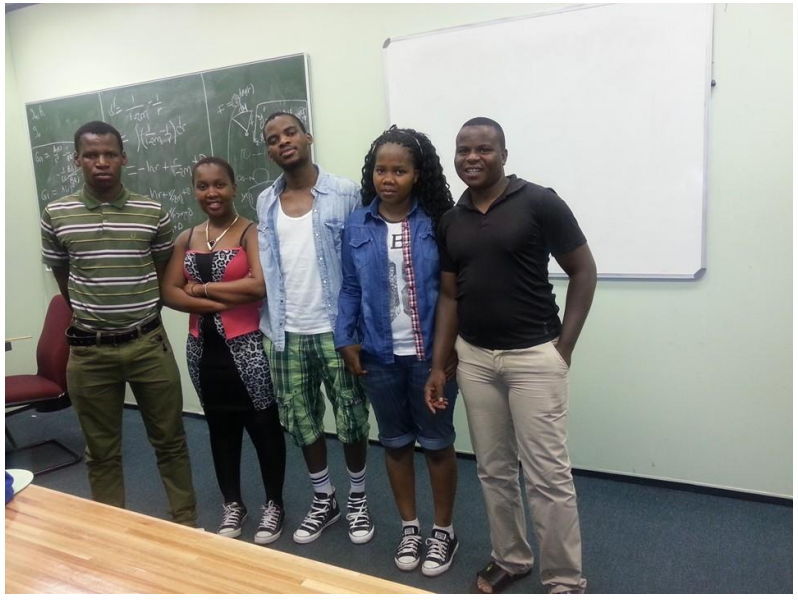
  - Tutors – R Mudau and E Maluta

12 interns

NIThePInternship Programme

- 2013 Internship Programme
  - Mr Mulalo Rollet Mudau
  - Mr Lutendo Phuthu
  - Ms Portia Gezekile Nyalunga
  - Ms Octovia Thusini
  - 4 interns

- 2014 Internship Programme
  - Ms Thobeka Lamula
  - Mr Jerry Mokgolobotho
  - Ms Phumzile Zandile Mabika
  - Ms Thulani Shiluvani
  - Mr Bonginkosi Zikhali
  - 5 interns



NITheP Internship Programme

- 2015 Internship Programme
  - Mr Eugine Thato
  - Mr Thabe Maha
  - Ms Sinegugu Mthembu (now one of the tutors)
  - Ms Ndina Mukwevho
  - Mr Thembinkosi Msibi
  - Ms Khanyisa Sowazi
  - Mr Thembalethu N
  - Mr Alex Ngomane

8 interns

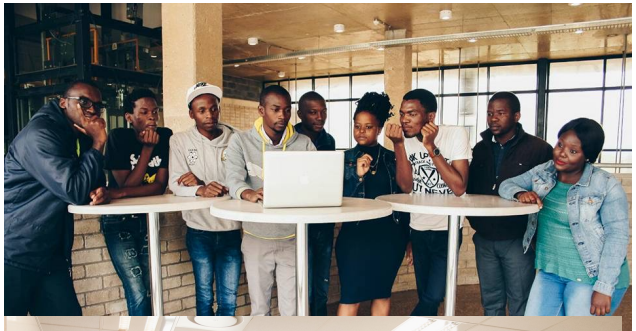
- 2016 Internship Programme

- Did not happen! Due to administration challenges at NITheP.

0 interns

NIThePInternship Programme

- 2017 Internship Programme



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Page: 9

THEY DID IT: Final-year BSc and maths and physics postgraduate students on the National Institute of Theoretical Physics Internship Programme last month, photographed in the New Science Building at Nelson Mandela University. Like these students, matriculants who achieve in maths and science have the opportunity to pursue undergraduate and postgraduate degrees and join the global science community.
BACK, FROM LEFT: Mphamela Enos Baloyi (University of Limpopo), Precious Matodzi Mabidi (University of Limpopo), Sindisiwe Xhakaza (University of Johannesburg), Ndivhuwo Ndou (University of Venda)
COUCH FROM LEFT TO RIGHT: Thabani Ngcobo (University of KZN), Shiffhiwa Khorommbi (University of Limpopo), John Tshegofatso Tshipi (University of Pretoria)
FRONT: Rudzani Foster Nemusunda (University of Venda), Tsebo Kibe (University of Stellenbosch)

From the Star Newspaper

Far more can excel in maths, science

9 interns

NITheP Internship Programme

- 2018 Internship Programme

10 interns

Aluwani and Thuthukile are now tutors

NIThePInternship Programme

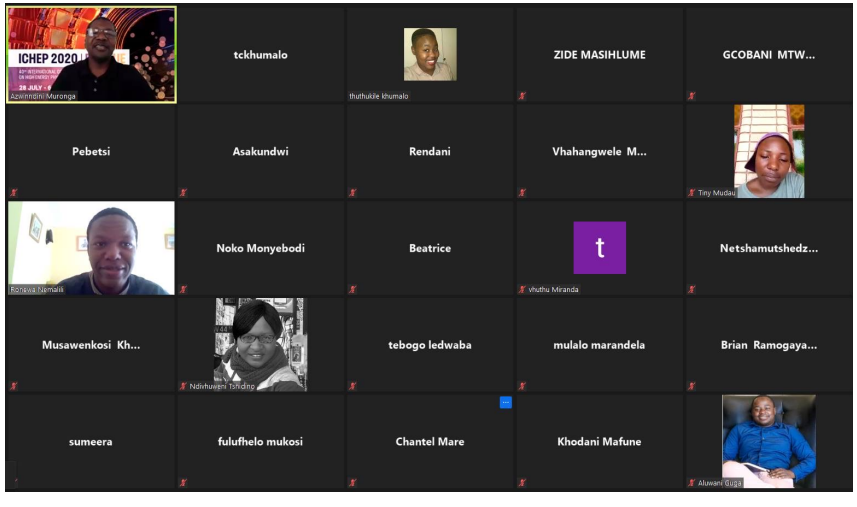
- 2019 Internship Programme

Vhahangwele is now one of the tutors

6 interns

NITheCS Internship Programme

- 2020 Internship Programme



26 Interns online during Covid-19

- A dramatic increase compared to in-person programme

NMU-NITheCS Internship 2020/2021

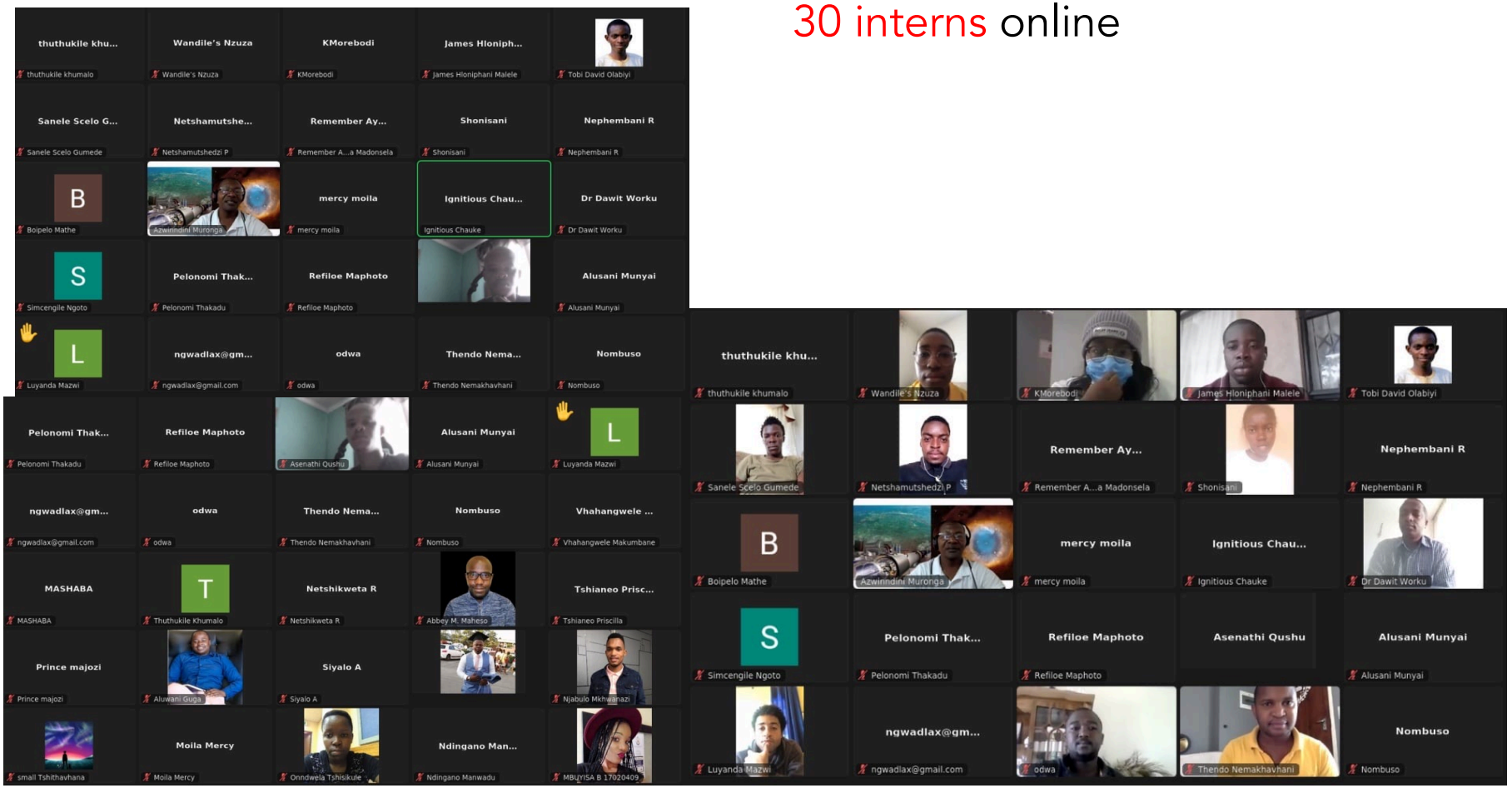
Name	Surname	Title	Affliation	Title	Name	Surname	Affliation
Vhuthu Muiranda	Tshilengo	Ms	UNIVEN	Ms	Thuthukile	Khumalo	WITS
Thembeka	Ntombela	Ms	UNIZUL	Mr	Aluwani	Guga	NMU
Tebogo	Motsei	Ms	UFS	Ms	Vhahangwele	Makumbani	UFS
Summera	Gopal	Ms	UWC	Ms	Mercy	Moila	UL
Phathutshedzo Tiny	Mudau	Ms	NMU	Mr	Thendo	Nemakhavhani	UJ
Pebetsi	Thokwane	Ms	UNIVEN	Dr	Rendani	Netshikweta	UNIVEN
Noko Cedric	Monyebodi	Mr	WITS	Dr	Dawit	Worku	CPUT
Ndivhuwo	Netshamutshedzi	Mr	NMU	Prof	Dephney	Mathebula	UNIVEN
Ndivho	Mukwevho	Mr	SPU	Dr	Paradza	Masimba	CPUT
Musawenkosi	Khulu	Mr	UNIZUL				
Mulalo Valencia	Marandela	Ms	UNIVEN				
Mpho	Phakoe	Ms	UWC				
Masihlume	Zide	Mr	UWC				
Mankele Comfort	Makofane	Ms	UNIVEN				
Koketso	Mohale	Mr	WITS				
Khodani Angel	Mafune	Ms	UNIVEN				
Gcobani	Mtawazana	Mr	NMU				
Fulufhelo	Mukwevho	Ms	UNIVEN				
Fulufhelo	Mukosi	Ms	UNIVEN				
Chantel	Mare	Ms	UP				
Brian	Ramoayana	Mr	UL				
Bradley	Nemutudi	Mr	UL				
Bonange George	Mbewe	Mr	NMU				
Ronewa	Nemalili	Mr	UNIVEN				
Beatrice	Mamorobela	Ms	NMU				
Asakundwi Praisethelord	Dzhivhuho	Ms	UNIVEN				

Diversity & inclusion – 15 F &11 M

NITheCS Internship Programme

- 2021 Internship Programme

30 interns online



NMU-NITheCS Internship 2021/2022

Title	Name	Surname	Affliation		Title	Name	Surname	Affliation 2021/2
Mr	Ignitious	Chauke	UNIVEN	Mr	Ms	Thuthukile	Khumalo	WITS
Mr	Kyle	Groenewald	SPU		Mr	Aluwani	Guga	UCT
Mr	Sanele Scelo	Gumede	UNIZUL	Mr	Ms	Vhahangwele	Makumbani	UFS
Miss	MICHEALA TATUM	HOENSELAAR	UJ	Ms	Ms	Mercy	Moila	UL
Mr	PIERRE DAMIEN GANINSHUTI	KABYARE	UWC	Mr	Mr	Thendo	Nemakhavhani	UJ
Mr	REMEMBER AYANDA	MADONSELA	UWC	Mr	Dr	Rendani	Netshikweta	UNIVEN
Mr	ABBEY MATIMBA	MAHESO	SUN	Mr	Dr	Dawit	Worku	CPUT
Mr.	Prince Phathizwe	Majozi	UNIZUL	Mr	Prof	Dephney	Mathebula	UNISA
MR	JAMES HLONIPHANI	MALELE	UJ	Mr	Dr	Paradza	Masimba	CPUT
Mr	Ndingano	Manwadu	UNIVEN	Mr				
Ms	REFILOE INNOCENCIA	MAPHOTO	UL	Ms				
Ms	Lwazikazi	Maqungo	UWC					
Mr	Sipho Victor	Mashaba	UNIVEN	Mr				
Mr	VINCENT	MASILELA	UJ	Mr				
Ms	Boipelo Nicholette	Mathe	WITS	Ms				
Mr	Luyanda	Mazwi	UJ					
Ms	Busisiwe	Mbuyisa	UNIVEN	Ms				
Mr	Njabulo Ndumiso	Mkhwanazi	UNIZUL	Mr				
Ms	NOMBUSO NONKULULEKO	MSIZA	UP	Ms				
Ms	Alusani	Munyai	UNIVEN	Ms				
Mr	Rapula Ephraim	Ndaba		Mr				
Ms	Resign	Nephembani	UNIVEN	Ms				
Mr	PFANO	NETSHAMUTSHEDZI	UNIVEN	Mr				
Ms	SHONISANI EDNAH	NETSHIHENI	UNIVEN	Ms				
Ms	Tshianeo Priscilla	Nevhufumba	UNIVEN	Ms				
Mr	XOLISANI ENKOSI	NGWADLA	UWC					
Miss	Wandile Siyamthanda	Nzuza	WITS	Mr				
Mr	Tobi David	OLABIYI	SUN	Mr				
Ms	Onkabetse Felicia	Olehile	SPU	Ms				
Mr	ASENATHI	QUSHU	UWC	Mr				
Ms	Boineelo Lovedelia	Sekori	SPU	Ms				
Mr	KUDZAI EMMANUEL	SITHOLE	UWC	Mr				
Mr	ATHENKOSI	SIYALO	UWC	Mr				
Mr	Small	Tshithavhana	WITS	Mr				
Mr	Odwa Azizipho	Tyuka						

Diversity & inclusion – 11 F & 19 M

NMU-NITheCS Internship 2022

A special year – 12 years on

NELSON MANDELA UNIVERSITY

The 7th Biennial African School of Fundamental Physics and Applications

28 November - 9 December 2022

Largest in-person since 2010

33 interns in-person
10 tutors
10 visitors from India and Russia

It is always intensive!

Introductory lectures, group discussions, calculating, computing, presenting, scientific report/paper writing

NMU-NITheCS Internship 2022/2023

Title	Name	Surname	Affliation		Title	Name	Surname	Affliation
Mr	Nkonzo	Xulu	UNIZUL		Prof	Dephney	Mathebula	UNISA
Ms	Khethiwe	Cele	UKZN		Ms	Vhangwele	Makumbane	UFS
Ms	Dimakatso J	Maheso	UJ		Dr	Dawit	Worku	CPUT
Mr	Ntokozo God-knowledge	Cebekhulu	UNIZUL		Dr	Rendani	Netshikweta	UNIVEN
Miss	Asakundwi Praisethelord	Dzhivhuho	UNIVEN		Mr	Aluwani	Guga	UCT
Miss	Dineo Patience	Motjope	UNIZUL		Mr	Thendo	Nemakhavhani	UJ
Mr	FUNANANI	RAPHULU	UNIVEN		Ms	Thuthukile	Khumalo	WITS
Miss	Fundile Sindy	Nyaweni	NMU		Ms	Mercy	Moila	UL
Mr	Busani	Bhengu	UNIZUL		Ms	Tebogo	Ledwaba	UL
Miss	Shonisani	Netshiheni	UNIVEN		Ms	Lerato	Seabi	UWC
Mr	Shandukani	Muronga	UNIVEN		Ms	Sinegugu	Mthembu	UWC
Miss	Vhuhwavho	Phophi	UNIVEN					
Ms	Yondela	Mdlatu	WUSU					
Mr	Sunday	Ogundipe	UNIZUL					
Mr	Thuthukani N	Nyawo	UNIZUL					
Miss	Lebogang Olga	Mongale	NWU					
Mr	Simamkele	Xipu	UJ					
Miss	Pusheletso	Mmatladi	UWC					
Ms	Marry	Thekwe	UNIVEN					
Mr	Ndivhuwo Theophilus	Netshiavha	UCT					
Miss	Maria Mankone	Ramaoka	UNIVEN					
Mr	Samuel	Mnisi	UL					
Ms	Siphe	Somathube	WUSU					
Mr	Mziwandile	Sibiya	UNIZUL					
Miss	Amogelang Malebo Antoinnete	Moeng	UJ					
Mr	Nkosikhona Terrence	Gabela	UNIZUL					
Mr	Tshimangadzo	Mbabala	UNIVEN					
Miss	Constance Maleboea	Machema	NWU					
Mr	Matsobane Alex	Mothibi	UJ					
Mr	Tshepo	Mahura	SUN					
Mr	Pfano	Netshamutshedzi	UNIVEN					
Ms	Brayne Vanessa	Kagma Matoukam	SUN					
Miss	Amahle	Mtuti	WUSU					

Diversity and inclusion – 17F & 16M

2022 NMU-NITheCS Internship Programme was unique

- **Activity Report on the Seventh African School of Fundamental Physics and Applications (ASP2022)**
- Kétévi A. Assamagan, Bobby Acharya, Kenneth Cecire, Christine Darve, Fernando Ferroni, Julia Ann Gray, Azwinndini Muronga – https://arxiv.org/pdf/2302.13940.pdf

NELSON MANDELA UNIVERSITY
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University World News
Africa Edition

IUPAP Centenary YEARS 1922 - 2022

UNESCO United Nations Educational, Scientific and Cultural Organization

IYBSSD2022 International Year Basic Sciences for Sustainable Development

al Edition Africa Edition Asia Hub SDGs Hub Transformative Leadership Special Reports Partner

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llow us on **Twitter**

SOUTH AFRICA

Institute focuses on training high-level problem solvers

Heather Dugmore 13 June 2023

LinkedIn Tweet Share

A total of 36 interns, the largest-ever number of final-year BSc, honours and masters students from South Africa's rural areas and historically disadvantaged universities, have submitted projects for

2023/2024 Programme

Lookout for:

1. NITheCS Internship call
2. NMU-NITheCS Summer Study & Research Pogramme call – applied through NITheCS call
3. SA-JINR Theory Workshop call – integration with the summer study & research programme in Gqeberha, Nov/Dec 2023

The Projects

Theory and Phenomenology of Relativistic Heavy Ion Collisions.

Group members

Amogelang Moeng (UJ)

Siphe Somathube (WSU)

Mziwandile Sibiya (UWC)

Nkosikhona Gabela (UniZulu)

Tutors

Makumbane Vhahangwele (UFS)

Dawit Worku (CPUT)

NELSON MANDELA UNIVERSITY

NITheCS National Institute for Theoretical and Computational Sciences

Stages of RHIC

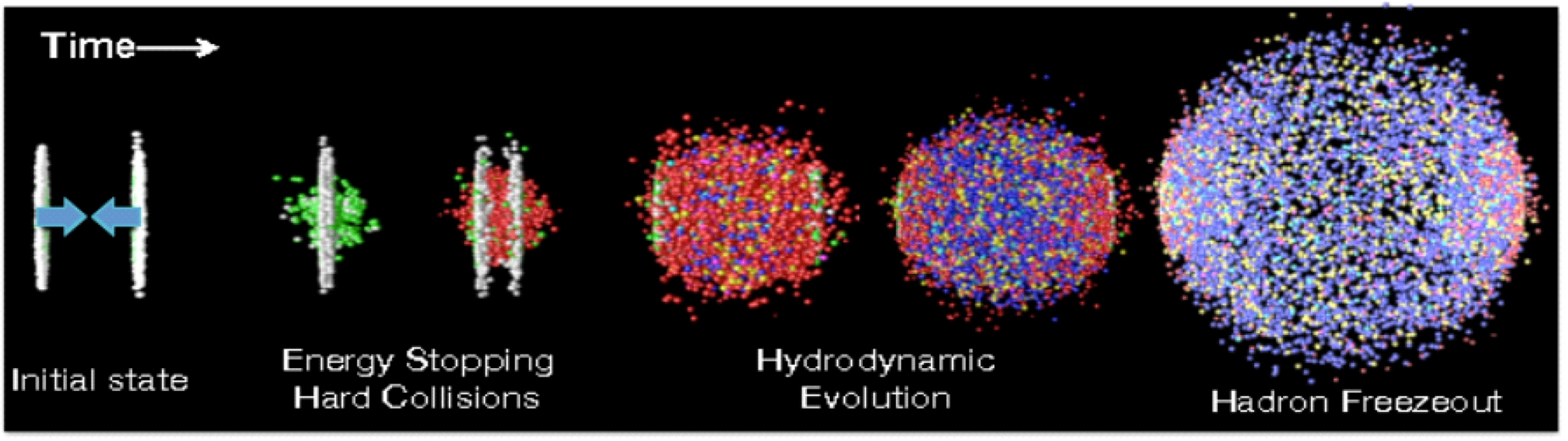


Figure 1: Stages of relativistic heavy ion collision (RHIC).

Models Related to the stages of RHIC

Fluid Dynamics Model

- Aims to describe physical phenomena of liquid droplet formed with a set of partial differential equations
- Energy-momentum tensors (Magneto-hydrodynamics model)

Kinetic Theory Model (Ultra-relativistic Quantum Molecular Dynamics)

- UrQMD is used to investigate hadron interactions during heavy-ion collisions
- It is a transport model used to project the heavy-ion reaction's whole evolution

Thermal and statistical Model

- Accounts for quantitative features of hadron production in heavy-ion collisions
- Reproduces the particle multiplicities with fewer parameters
- Thermal-statistical model - Boltzmann, Fermi-Dirac and Bose-Einstein distribution framework are employed.

Experiments

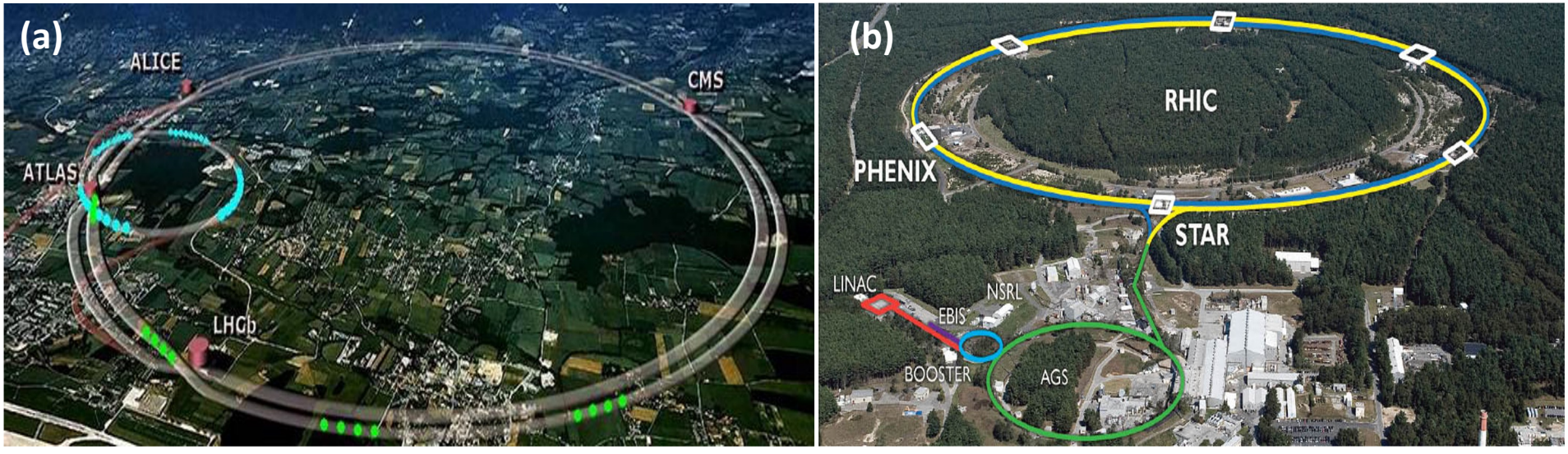


Figure 2: **(a)** LHC- border of France and Switzerland (CERN laboratory) and **(b)** RHIC – Brookhaven National Laboratory, USA.

Quark-gluon plasma (QGP) signatures

J/ψ suppression

- The J/ψ particle is a bound state consisting of charm and anti-charm quark ($c\bar{c}$).
- The production of this resonance will be suppressed in a QGP, where $c\bar{c}$ **pair is separated due to Debye screening of the colour changes**. $V(r) = \frac{q}{4\pi r} + \mathrm{kr}$
- When the plasma hadronizes, the separated will likely combine with other quarks to open charm rather than J/ψ.
- The production of J/ψ is suppressed because the c and $\bar{c}$ quarks produced would be separated by many quarks of other flavours, leading instead to the production of charmed mesons, D mesons

Figure 3: Illustration of Debye screening and production of mesons.

QGP Signatures Cont'd

Strangeness enhancement

- The strangeness content in QGP is believed to be enhanced from that of normal hadronic matter as the temperature increases. As the strangeness content is greatly enhanced, the probability for the production of multistrange hyperons will also be greatly enhanced in a QGP.
- In a recent measurement of the WA97 Collaboration, the production of multistrange hyperons is found to be substantially enhanced. In particular, the production of $\Omega^- + \bar{\Omega}^+$ in Pb+Pb collisions at 158A GeV is enhanced by up to a factor of 15 relative to that of p+Be.
- Multistrange hyperons can also be produced by secondary collisions of hadrons. It is known that the collision of the produced pions with nucleons leads to the enhancement of kaons and Λ particles.

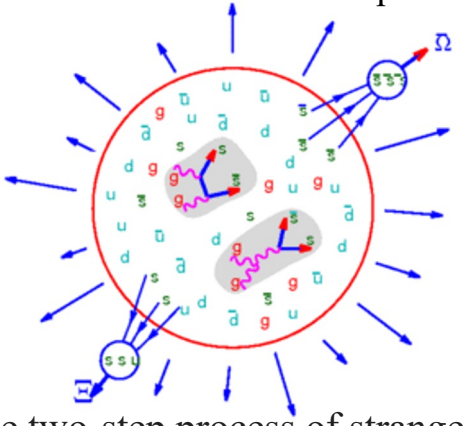


Figure 4 :Illustration of the two-step process of strange antibaryon production.

The Projects

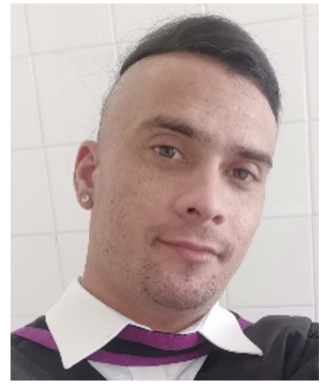
The Physics and Evolution of the Early Universe

Group members: Shonisani Netshiheni (*Univen*), Ron-Ryan Baatjes (*UWC*) and Busani Bhengu (*Unizulu*)

Tutors: Ms Sinegugu Mthembu (*UWC*) and Dr. Masimba Paradza (*CPUT*)

Host: Prof. Azwindini Muronga (*NMU*)




COSMOLOGICAL SOLUTIONS FOR SINGLE COMPONENT UNIVERSE

Matter dominated		
k	$a(t)$	t
$k=0$	$a_0\left(\frac{t}{t_0}\right)^{\frac{2}{3}}$	$\frac{2}{3H_0}$
$k=1$	$\frac{a_0}{2}\frac{\Omega_{m0}}{(\Omega_{m0}-1)}\left(1-\cos\psi\right)$	$\frac{\Omega_{m0}}{2H_0(\Omega_{m0}-1)^{\frac{3}{2}}}(\psi-\sin\psi)$
$k=-1$	$\frac{a_0}{2}\frac{\Omega_{m0}}{(1-\Omega_{m0})}(\cosh u-1)$	$\frac{\Omega_{m0}}{2H_0(1+\Omega_{m0})^{\frac{3}{2}}}(\sinh u-u)$
Radiation dominated		
k	$a(t)$	t
$k=0$	$a_0(\frac{t}{t_0})^{\frac{1}{2}}$	$\frac{1}{2H_0}$
$k=1$	$\sqrt{\frac{2\Omega_{m_{r0}}}{2\Omega_{m_{r0}}}}sin(\eta)a_0$	$\sqrt{\frac{2\Omega_{m_{r0}}}{2\Omega_{m_{r0}}}}(1-cos(\eta))t_0$
$k=-1$	$\sqrt{\frac{2\Omega_{m_{r0}}}{1-2\Omega_{m_{r0}}}}sinh(\eta)a_0$	$\sqrt{\frac{2\Omega_{m_{r0}}}{1-2\Omega_{m_{r0}}}}(cosh(\eta)-1)t_0$
Λ dominated		
k	$a(t)$	
$k=0$	$a_0e^{H_0(t-t_0)}$	
$k=1$	$\frac{c}{\sqrt{4\pi G\rho_0}}=\frac{c}{\sqrt{\Lambda}}$	
$k=-1$	$\frac{c}{\sqrt{4\pi G\rho_0}}=\frac{c}{\sqrt{\Lambda}}$	

Figure 3: Matter, Radiation and Dark energy dominated universes.

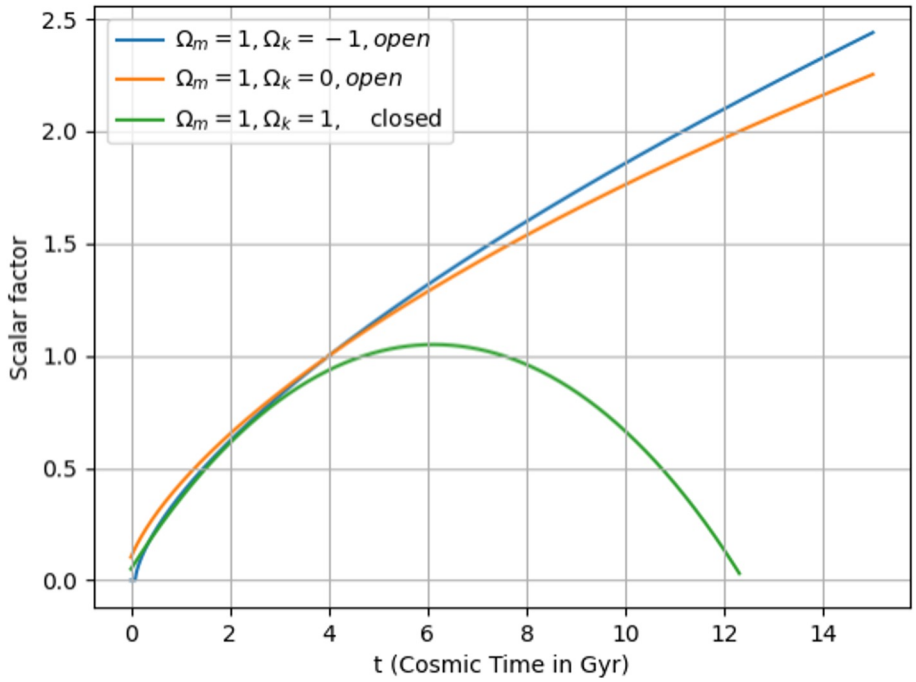


Figure 4: Graphical solutions of the Friedmann equations for each curvature parameter k.

TEMPERATURE OF THE UNIVERSE

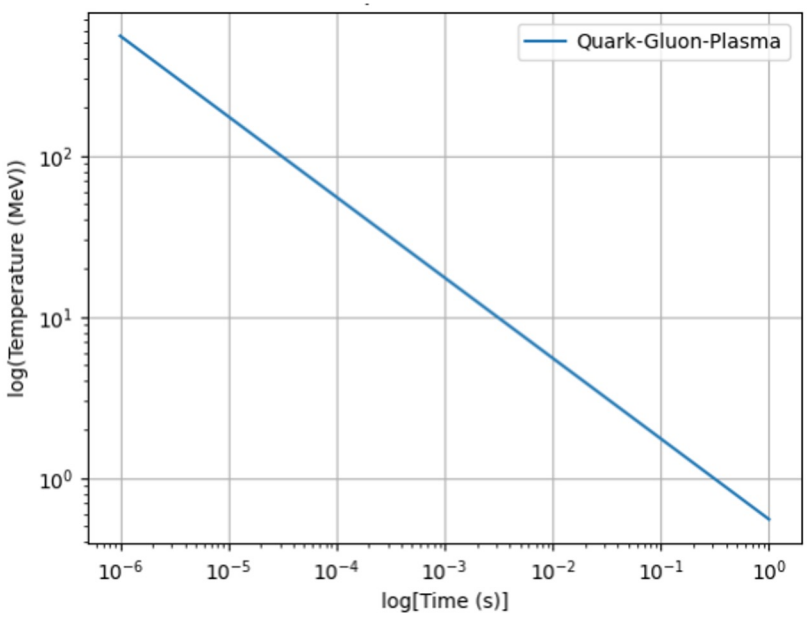


Figure 5 : Temperature and time

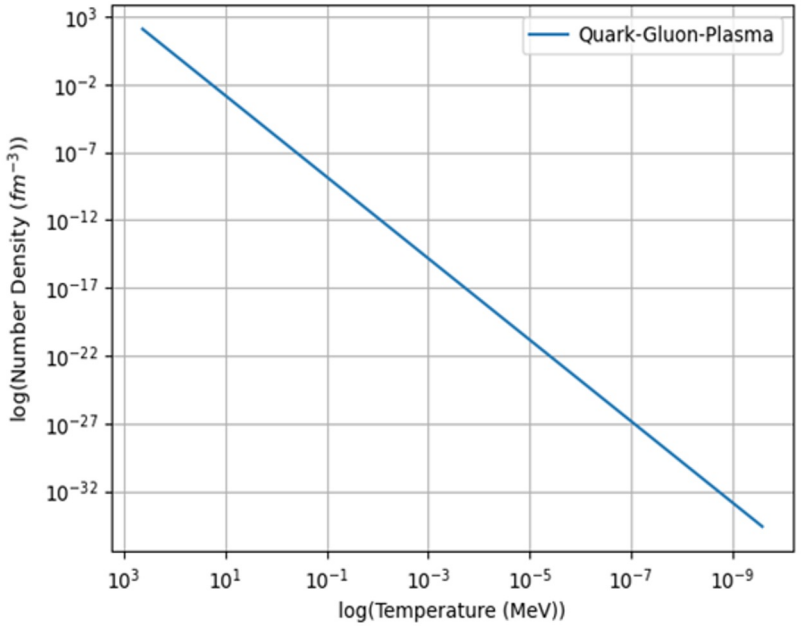


Figure 6 : Number density Vs. Temperature

```python
import plotly.graph_objects as go
import matplotlib.pyplot as plt
import numpy as np


tH = 12
a_0 = tH

a = np.linspace(0.5, 1.6) #

density_matter = 1.0/(a**3)
density_radiation = 1.0/(a**4)

plt.plot(a, density_matter, label='Matter Density')
plt.plot(a, density_radiation, label='Radiation Density')
plt.title('Energy Density vs Scalar factor')
plt.yscale("log")
plt.xscale("log")

plt.legend(loc='upper right', borderaxespad=0.6, handletextpad=0.5)
plt.grid(linestyle = '-')
plt.xlabel('Scalar factor (a)')
plt.ylabel('Energy Density (eV $m^{-3}$)')
plt.show()
```

Code : Energy density of matter and radiation vs. scalar factor

```python
import plotly.graph_objects as go
import matplotlib.pyplot as plt
import numpy as np
import math
import pylab

#g_boson = 106.75 # T >> 100 GeV
g_boson = 61.75  # T > 200 MeV
#g_boson = 10.75  # T > 1 MeV
#g_boson = 3.91   # T << MeV
#g_boson = 3.36   # T << MeV neutrinos


plt.xlim = [0, 1]  # time in seconds
plt.ylim = [0, 10e3] # temperature in MeV

t = np.linspace(0, 1, int(10e5)) # sec

y1 = np.sqrt(2.42 /(np.sqrt(g_boson)*(t))) # MeV

plt.plot(t, y1, label='Quark-Gluon-Plasma')
plt.title('Temperature vs Time ')
plt.yscale("log")
plt.xscale("log")

plt.legend(loc='upper right', borderaxespad=0.6, handletextpad=0.5)
plt.grid(linestyle = '-')
plt.xlabel('log[Time (s)]')
plt.ylabel('log(Temperature (MeV))')
plt.show()
```

Code : Temperature vs time for quark-gluon plasma

```python
import plotly.graph_objects as go
import matplotlib.pyplot as plt
import numpy as np

kB = 8.616*10**-11 # MeV/ K
T = np.linspace(3, 500) # MeV

g_gluon = 61.75
density_gloun = (g_gluon*(np.pi**2)/30)*kB*(T)**4

plt.plot(T, density_gloun, label='Quark-Gluon plasma')

plt.title('Energy Density vs Temperature')
plt.gca().invert_xaxis()

plt.legend(loc='upper right', borderaxespad=0.6, handletextpad=0.5)
plt.grid(linestyle = '-')

plt.xlabel('Temperature (MeV)')
plt.ylabel('Energy Density (MeV $m^{-3}$)')

plt.show()
```

Code : Energy density vs Temperature for quark-gluon plasma

The Projects

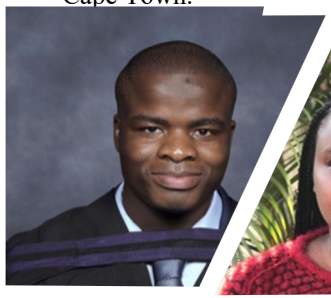
Relativistic Fluid Dynamics for Heavy-Ion Physics and Astrophysics

Ramaoka Maria-
AIMS-University of
Cape Town.

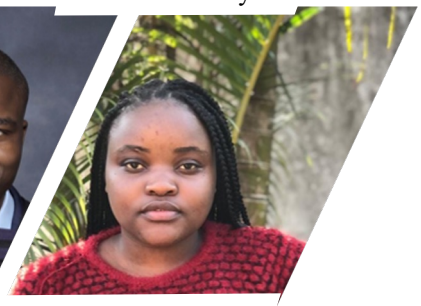
Seabi Magdeline. M
Nelson Mandela
University

Netshikweta Rendani
University of Venda

Mnisi Samuel
University of Limpopo



Ndivhuwo
Netshiavha T.
University of
Cape Town



Merry Thekwe-AIMS-
University of Cape Town

Participants

Results

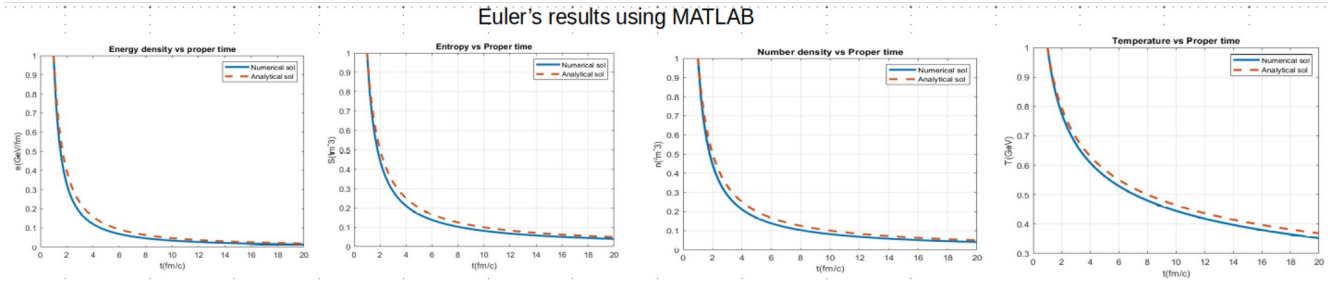


Figure 1: Hydrodynamic analysis of an evolving HIC system using MATLAB.

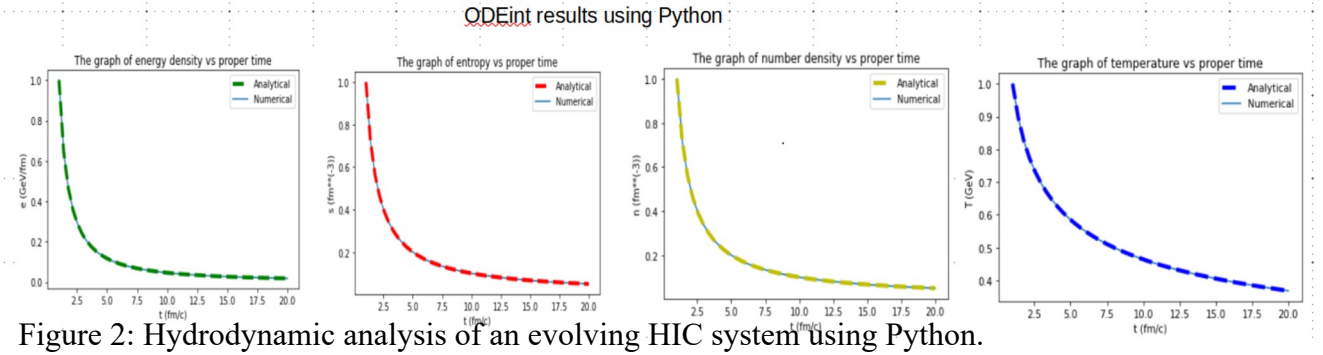


Figure 2: Hydrodynamic analysis of an evolving HIC system using Python.

The Projects

Physics of Core-Collapse Supernovae

Simamkele Xipu
University of Johannesburg

Rendani Netshikweta
University of Venda

Pusheletso Mmatladi University of Cape Town

Seabi Magdeline M.
Nelson Mandela University

Lebogang Mongale- North-West University.

Participants

Methodology and Results

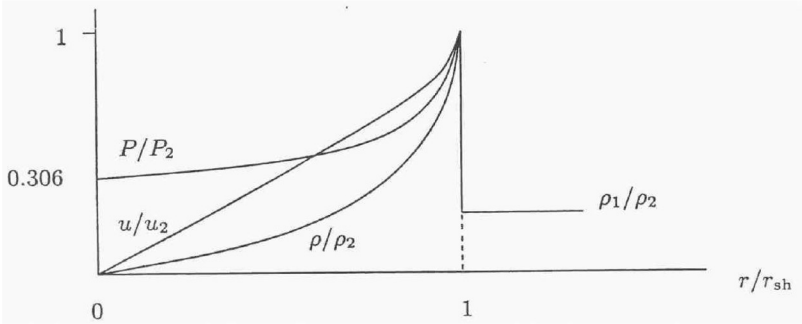


Figure 1: The Sedov solution for a spherical blastwave with γ = 5/3, in units of the immediate post-shock values. [Shu, The Physics of Astrophysics, Volume II, Figure 17.3]

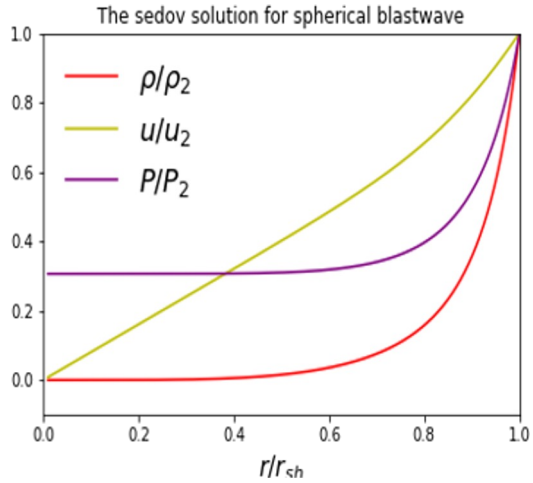


Figure 2: The numerical solution for the spherical blastwave .

The Projects

A.M Mothibi

NELSON MANDELA UNIVERSITY

T.E Nemakhavhani

Relativistic Kinetic Theory in Heavy-Ion Collisions and Particle & Astrophysics

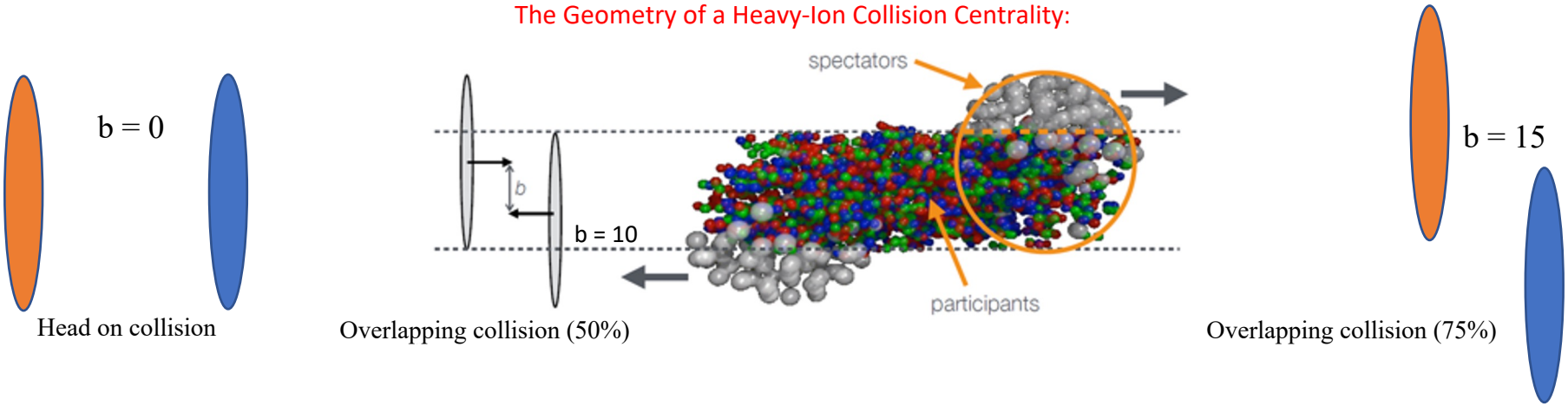
Studying the dependence of observables on the impact parameter (b) in Pb+Pb High Energy Heavy-Ion collision particle multiplicity from the microscopic model (UrQMD) at Elab = 300 AGeV

Group members: A.M Mothibi(UJ)
M.C Machema(NWU), and T Mbabala(WITS)
Tutors: T.E Nemakhavhani (UJ),
Host: Azwinndini Muronga (NMU)

Aim

Abstract: The impact parameter dependence (b = 0 – 19%) of different meson and baryon species at central rapidity and particle ratios in Pb+Pb was studied employing High Energy Heavy-Ion collisions at an incident kinetic beam energy (lab frame) of E_{elb} = 300 AGeV for a duration of t = 400 fm/c. The Pb+Pb reaction was simulated from the Ultra-relativistic Quantum Molecular Dynamics model (UrQMD). We employed the particle ratios technique to distinguish between hadronic cascade and hydrodynamical models, incorporating a QGP phase transition. The study will give an insight into the behaviors of particle production at different impact parameters leading to chemical freezeout and thermal equilibrium. This will open more windows when it comes to a better understanding of the phase transition of the hadron gas for different High Energy Heavy-ion collision systems. We report here on the results at central rapidity and above the saturation time, at a randomly chosen time of t = 380 fm/c, and also the particle ratio as a function of impact parameter at a different time t for both meson and baryon species.

The Geometry of a Heavy-Ion Collision Centrality:



UrQMD Model simulation

UrQMD (Ultra-relativistic Quantum Molecular Dynamics) is a fully integrated Monte Carlo simulation package for nucleus+nucleus, p+p, p+N, and N+N interactionIt is a microscopic model used to simulate (ultra)relativistic heavy ion collisions in the energy range from MeV to up to 14 TeV Large Hadron Collider (LHC) energies.

The Input File of the UrQMD Model

```
pro 208 82
tar 208 82

nev 200
imp 0

elb 300.
tim 400 20

eos 0



f13
#f14
f15
f16
f19
f20

xxx
```

Calculating rapidity distribution from the UrQMD Output results file after simulation

$$y = \frac{1}{2}\ln\left[\frac{p^0 + p_z}{p^0 - p_z}\right]$$

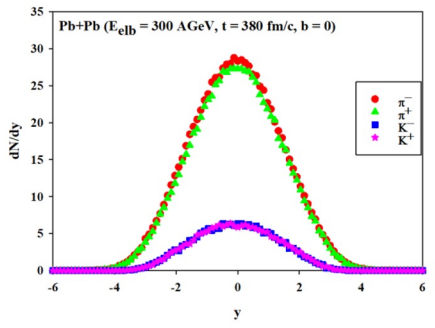
The Output File of UrQMD Model

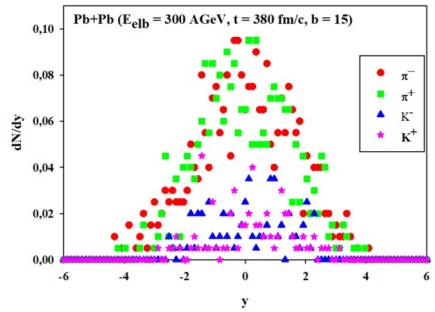
```
 GNU nano 6.2                                                    test.f14
UQMD   version:       20030   1000  20030  output_file  14
projectile:  (mass, char)  208  82   target:  (mass, char)  208  82
transformation betas (NN,lab,pro)      0.0000000  0.9176243 -0.9176243
impact_parameter_real/min/max(fm):     0.00  0.00  0.00  total_cross_section(mbarn):       0.00
equation_of_state:    0  E_lab(GeV/u): 0.1000E+02  sqrt(s)(GeV): 0.4720E+01  p_lab(GeV/u): 0.1090E+02
event#          1 random seed:  1671093572 (auto)   total_time(fm/c):       20 Delta(t)_O(fm/c):       20.000
op  0    0    0    0    0    0    0    0    0    0    0    0    0
op  0    0    0    0    0    0    1    0    1    0    0    0    2    1
op  0    0    0    1    1    0    0    0    0    0    0    0    1    0
pa 0.1000E+01   0.5200E+00   0.2000E+01   0.3000E+00   0.0000E+00   0.3700E+00   0.0000E+00   0.9300E-01   0.3500E+00   0.2500E+00   0.0000E+00   0.5000E+00
pa 0.2700E+00   0.4900E+00   0.2700E+00   0.1000E+01   0.1600E+01   0.8500E+00   0.1550E+01   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
pa 0.9000E+00   0.5000E+02   0.1000E+01   0.1000E+01   0.1000E+01   0.1500E+01   0.1600E+01   0.0000E+00   0.2500E+01   0.1000E+00   0.3000E+01   0.2750E+00
pa 0.4200E+00   0.1080E+01   0.8000E+00   0.5000E+00   0.0000E+00   0.5500E+00   0.5000E+01   0.8000E+00   0.5000E+00   0.8000E+06   0.1000E+01   0.2000E+01
pvec: r0             rx             ry             rz             p0             px             py             pz             m          ityp 2i3 chg lcl#  nc>
         1016          20
    4450    1291    3158       1    1389    4269       0       0
  0.20000000E+02  0.33418554E+01  0.36284065E+01  0.14350657E+02  0.18129023E+01 -0.18080603E+00  0.17749442E+00  0.15305475E+01  0.93800002E+00          1  1  1     >
  0.20000000E+02 -0.48555301E+01 -0.33614695E+01 -0.24216277E+01  0.11912576E+01 -0.67566687E+00 -0.24454009E+00 -0.15141053E+00  0.93800002E+00          1 -1  0     >
  0.20000000E+02  0.16809273E+01  0.39715774E+01 -0.16846221E+02  0.31827494E+01 -0.10933928E+00  0.30081790E+00 -0.30245005E+01  0.93800002E+00          1 -1  0     >
  0.20000000E+02  0.29711382E+01  0.38090525E+00 -0.48836326E+01  0.11891112E+01  0.68461510E+00 -0.15305960E+00 -0.20497863E+00  0.93800002E+00          1 -1  0     >
  0.20000000E+02  0.78474877E+01 -0.89394127E+01  0.90678194E+01  0.16336009E+01  0.63073127E+00 -0.51860632E+00  0.86972483E+00  0.11160001E+01         27  0  0     >
  0.20000000E+02  0.43627440E+01  0.60291083E+01 -0.11756532E+02  0.29853564E+01  0.38754054E+00  0.85178451E+00 -0.26752167E+01  0.93800002E+00          1 -1  0     >
  0.20000000E+02 -0.12424556E+02 -0.85582261E+01 -0.39830185E+01  0.21092646E+01 -0.15067606E+01 -0.95718999E+00 -0.61855699E+00  0.93800002E+00          1 -1  0     >
  0.20000000E+02 -0.83228081E+01  0.39148238E+00  0.14374633E+02  0.16280349E+01 -0.15684938E+00  0.41958877E-01  0.13207162E+01  0.93800002E+00          1 -1  0     >
  0.20000000E+02 -0.83023322E+00 -0.22913806E+01 -0.50188885E+00  0.10586487E+01 -0.37175947E-01  0.31848257E+00  0.37159103E+00  0.93800002E+00          1 -1  0     >
  0.20000000E+02 -0.11834652E+02  0.20257069E+01  0.92727959E+01  0.22862952E+01 -0.14068974E+01  0.44321276E+00  0.14736023E+01  0.93800002E+00          1 -1  0     >
```

Results & Discussion

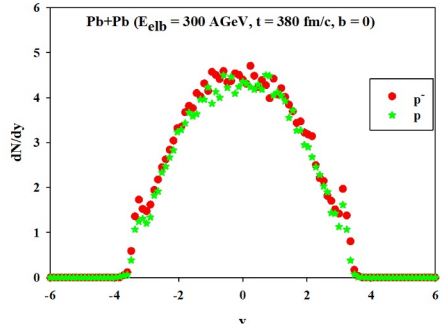
looking for physics further away from the central collision

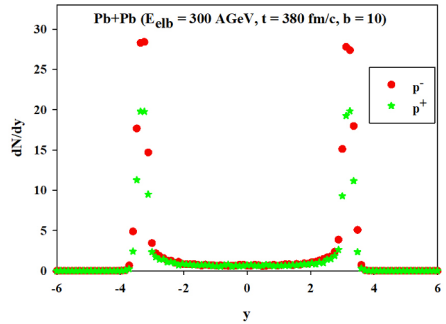
Rapidity distribution: Meson



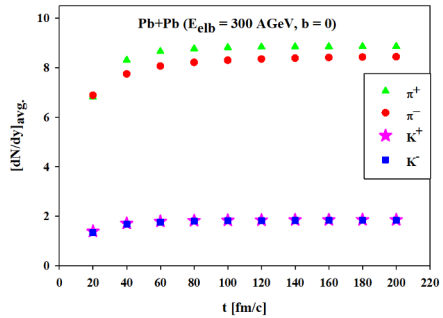


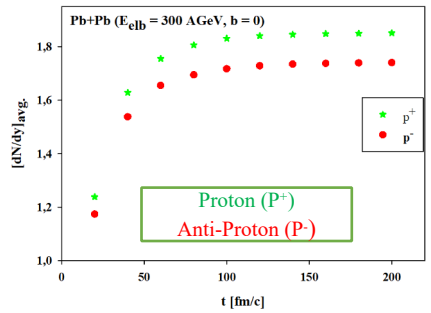
Rapidity distribution: Baryon



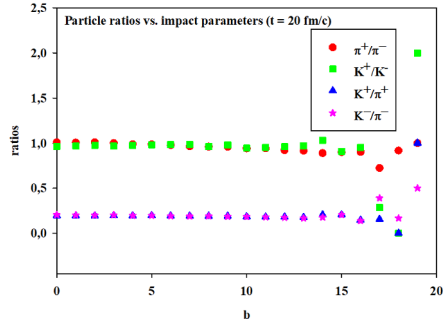


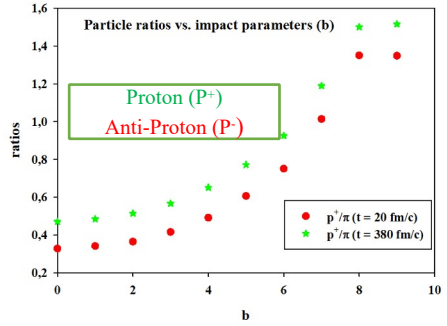
Time evolution: saturation time is the same for different (b)





Particle ratios





See Thendo Nemakhavhani's presentation for detailed discussion

The Projects

Statistical and Thermal Physics in Heavy-Ion Collision and particle & Nuclear Astrophysics

Group members: Amahle Mtuti (Walter Sisulu University), Bralyne Vanessa Matoukam (University of Stellenbosch), Pfano Netshamutshedzi (University of Venda)

Facilitator: Dr Dawit Worku (*CPUT*)

Host: Prof. Azwinndini Muronga (*NMU*)

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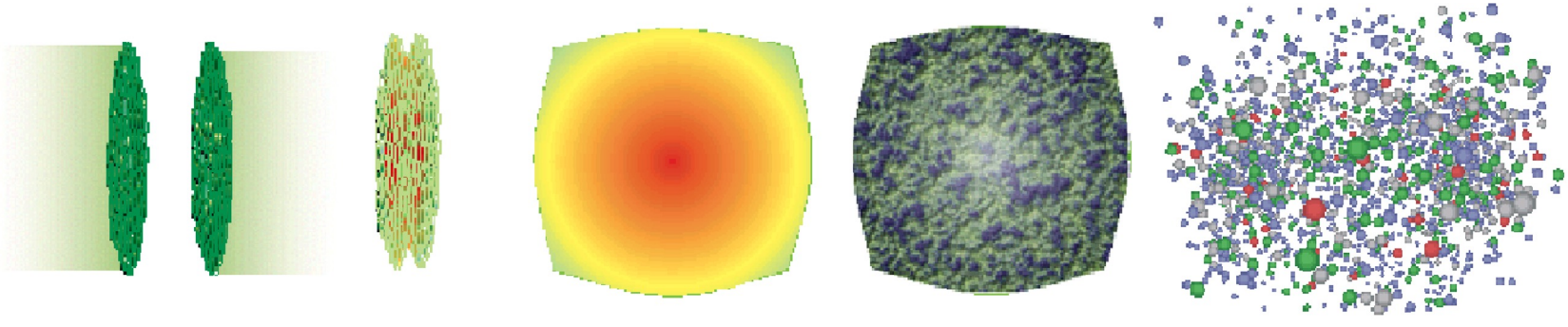
National Institute for Theoretical and Computational Sciences

Stat-Mech group photos while analysing their results

Stages of Heavy-Ion Collision



The aim of this project is to study the last stage which is to study the formation of hadron gases through particle production, particle ratios, and transverse momentum distributions can shed light on the dynamics of the collision and the properties of the matter produced.

The Projects

Compact Stars as Laboratories for Matter at Extremes and Fundamental Physics

Group members: Khethiwe Cele (UKZN), Nkonzo Xulu (UNIZULU), Dimakatso Maheso (UJ)

Facilitator: Ms Thuthukile Khumalo (*Wits*)

Host: Prof. Azwinndini Muronga (*NMU*)

This project focuses on the

- structure of compact stars
- exploration of the4 forces of nature
- EoS of dense/compact matter – connections with heavy-ion collisions
- use GWs to constrain the EoS in heavy-ion collisions
- effect of the extreme gravitation, magnetic fields, and spin
- connections between particle physics, nuclear physics, and astrophysics

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NITheCS National Institute for Theoretical and Computational Sciences

The Projects

The IYBSSD and the IUPAP centenary

100 years of physics in Africa - the past, present and future

Visit the poster for more details

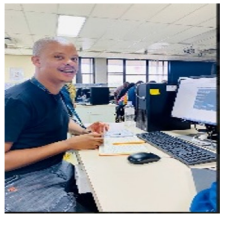
Group members

Yondela Mdlatu (*WSU*)

Shandukani Muronga (*UNIVEN*)

Sunday Ogundipe (*UNIZULU*)

Vhuhwavho Phophi (*UNIVEN*)



Asenathi Qushu (*UWC*)

Tutor(s)

Aluwani Guga (*UCT*)

Dephney Mathebula (*UNISA*)

Vhahangwele Makumbane (*UFS*)

NELSON MANDELA UNIVERSITY

05 July 2023

NITheCS
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Theoretical and Computational Sciences

Results and discussion

Physics Discoveries that Contribute to sustainable development

Allan Cormack of Cape Town and his colleague Godfrey Hounsfield invented the computed axial tomography scan, or CAT, in 1972. He developed the mathematical method for the CAT scan, in which an X-ray source and electronic detectors are rotated about the body, and the generated data is analyzed by a computer to provide a crisp map of the tissues inside a cross-section of the body.

History of Physics in Africa

Deborah Enilo Ajakaiye, the first female Professor in physics in Africa was born in 1940 in Northern Nigeria and is a Nigerian geophysicist. Her work with geo-visualization has been used to locate both mineral deposits and groundwater in Nigeria.

Inventions in Africa

African scientist	Invention	Application
Ferdinand Chauvier	Kreepy Krauly (1974)	For removing biological and fine particles in pools
Sandile Ngcobo	Digital laser (2013)	For on-demand laser modes

Innovations Resulting From The Study Of Physics In Africa

Innovation refers to a new or better way of executing a project or carrying out a task. Discussed below are some innovations credited to the study of physics in Africa.

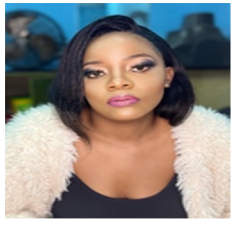
The Projects

Theoretical & Computational Biophysics

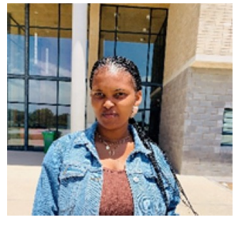
Visit the poster for more details

Group members

Ntokozo G Cebekhulu(UNIZULU)*)*



Asakundi Dzhivhuho (UNIVEN)

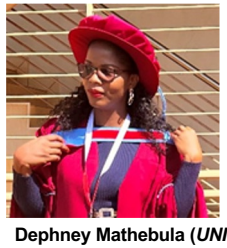


Dineo Motjope (UNIZULU))

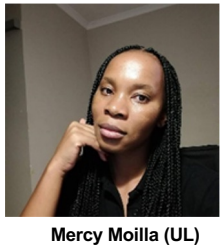
Fundile Nyaweni *(NMU)*

Funanani Raphulu (UNIVEN)

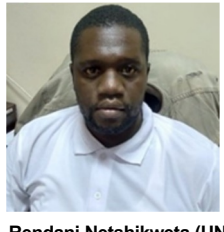
Tutor(s)



Dephney Mathebula (*UNISA*)



Mercy Moilla (UL)



Rendani Netshikweta (UNIVEN)

Aluwani Guga (UCT)

NELSON MANDELA UNIVERSITY

05 July 2023

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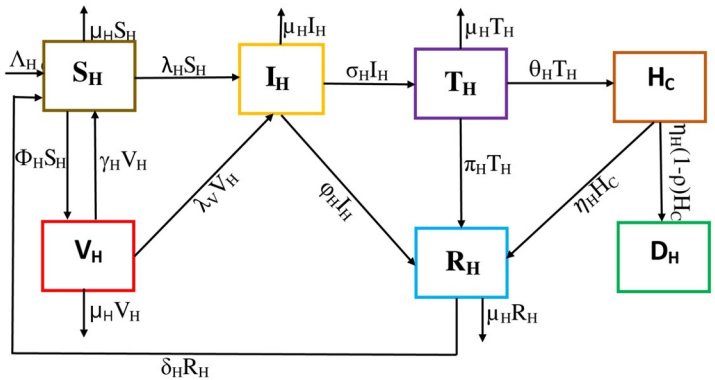
Results and discussion

The system's behaviour was numerically examined using MATLAB, with the parameter values taken from the literature. To model the data from the World Health Organization on COVID-19 cases in South Africa from 2020-2022, the data was fitted within due to the difficulty in accurately measuring the size of the asymptomatically infectious group, which makes up the majority of cases. Figures 1 and 2 display the model's predictions for infected and recovered individuals respectively. The fit shown in Figure 1 is not a good fit, while that in Figure 3 is a good fit. Sensitivity analysis was also conducted for some scenarios.

Mathematical Formulations

we develop a compartments model that comprises seven compartments which are susceptible S, infected I, recovered R, vaccinated V , tested T, hospitalised H, and deceased D. A set of ordinary d
(ODE ' s) is used to formulate the equations for the model.



Model system

Based on the above schematical diagram, we have the following system of differential equations:

$$
\begin{cases}
\dot{S_H} = \Lambda_H - \lambda_H S_H - (\mu_H + \phi_H)S_H + \gamma_H V_H + \delta_H R_H \\
\dot{I_H} = \lambda_H S_H + \lambda_V V_H - (\mu_H + \sigma_H + \Psi_H)I_H \\
\dot{R_H} = \Psi_H I_H + \eta_H \rho H_C + \pi_H T_H - (\mu_H + \delta_H)R_H \\
\dot{T_H} = \sigma_H I_H - (\mu_H + \theta_H + \pi_H)T_H \\
\dot{H_C} = \theta_H T_H - \eta_H H_C \\
\dot{V_H} = \phi_H S_H - \lambda_V V_H - (\mu_H + \gamma_H)V_H \\
\dot{D_H} = (1-\rho)\eta_H H_C
\end{cases} \quad (1)
$$

where $S = S_0 \geq 0$, $I = I_0 \geq 0$, $R = R_0 \geq 0$, $V = V_0 \geq 0$, $T = T_0 \geq 0$, and $D = D_0 \geq 0$ with $\lambda_H = \frac{B_H I_H}{N}$, $\lambda_V = \frac{B_V I_H}{N}$ and $N = S_H + I_H + R_H + T_H + H_C + V_H + D_H$.

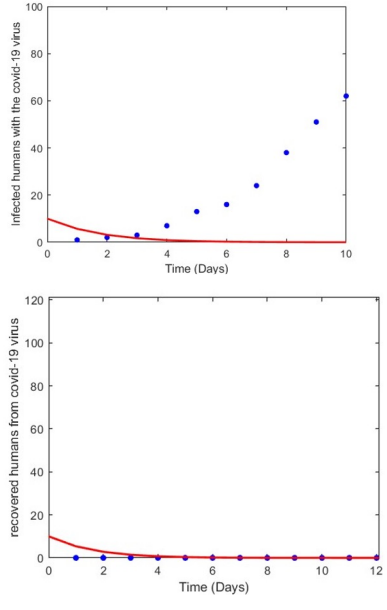


Figure1: (A) Data fitting for infected groups, (B) Data fitting for recovered groups.

Take home message

The NMU-NITheCS Summer Study & Research Programme

- It is not an internship – it is a summer study & research programme
- It is a multi-/inter-/cross-/trans-disciplinary programme
- It equips students with skills to become research scholars and problem solvers, encourages students to pursue postgraduate studies and increases enrolment of previously marginalized (female and black) PG students in physics, mathematics, statistics, and computer science at institutions across SA and abroad
- It is a vehicle for capacity development in the basic sciences
- It leverages resources from other programs – SAIP, ASP, SA-CERN, NITheCS, SA-JINR Theory, Kruger, NRF/DSI, ICTP
- It looks to SADC for expansion, and it will benefit from a strong and sustainable HDM program
- The science case is clear – Q2CAfrica, but we still must work on connecting people