ASP STUDY OF COVID-19 DATA FROM AFRICAN COUNTRIES

Dr. Ann Njeri

7th Biennial ASP, Nelson Mandela University.

7th December 2022

Outline:

- Global COVID-19 Situation
- COVID-19 Situation in Africa
- ASP COVID-19 Study
- Conclusions

❑ Global COVID-19 Situation:

WHO Coronavirus (COVID-19) Dashboard   Back to t

Name	Cases - cumulative total	Cases - newly reported in last 7 days	Deaths - cumulative total	Deaths - newly reported in last 7 days	doses administered per 100 population	primary series per 100 population	Persons Boosted per 100 population
Global	**640,395,651**	**2,819,661**	**6,618,579**	**6,971**	**167.32**	**64.34**	**29.9**
+ By WHO Region							
+ By World Bank Income Group							
United States of America	97,618,392	288,901	1,071,245	1,488	195.04	68.16	33.98
India	44,672,913	2,083	530,624	20	159.36	68.9	16.04
France	36,837,205	370,785	155,407	454	227.4	77.48	60.47
Germany	36,530,020	170,922	158,109	74	226.9	78.04	62.46
Brazil	35,266,159	184,123	689,801	529	231.79	79.18	49.88
Republic of Korea	27,208,800	370,960	30,621	343	257.01	87.17	65.63
Japan	24,911,367	782,453	49,826	1,054	271.49	81.42	66.47
Italy	24,260,660		181,098		248.9	82.95	75.04

❑ COVID-19 Situation in Africa:

WHO prediction 2020:

- 29-44m Africans could be infected
- 83-190000 Africans could die
- Suggests Africa has lower transmission rates
- Prolong outbreak for several years
- Pressure on economic resources
- Containment measures challenge: 60% living below poverty line

Current Situation:

- 9.4m infected
- <180,000 dead
- Millions rendered jobless, increased poverty & insecurity
- A number of studies conducted

ASP COVID-19 Study: Contribute to understanding & containment

❑ ASP COVID-19 Study:

Call:

- **March 2020**
- **Dr. Kétévi A. Assamagan**
- **ASP alumni**
- **Study COVID-19 data from their country (birth/resident)**
- **Permission from academic supervisor(s) sought**
- **A number of ASP alumni responded: <u>April 2020</u>**

1st Publication:

- **July 2020**

https://arxiv.org/pdf/2007.10927.pdf

2nd Publication:

Elsevier Scientific African

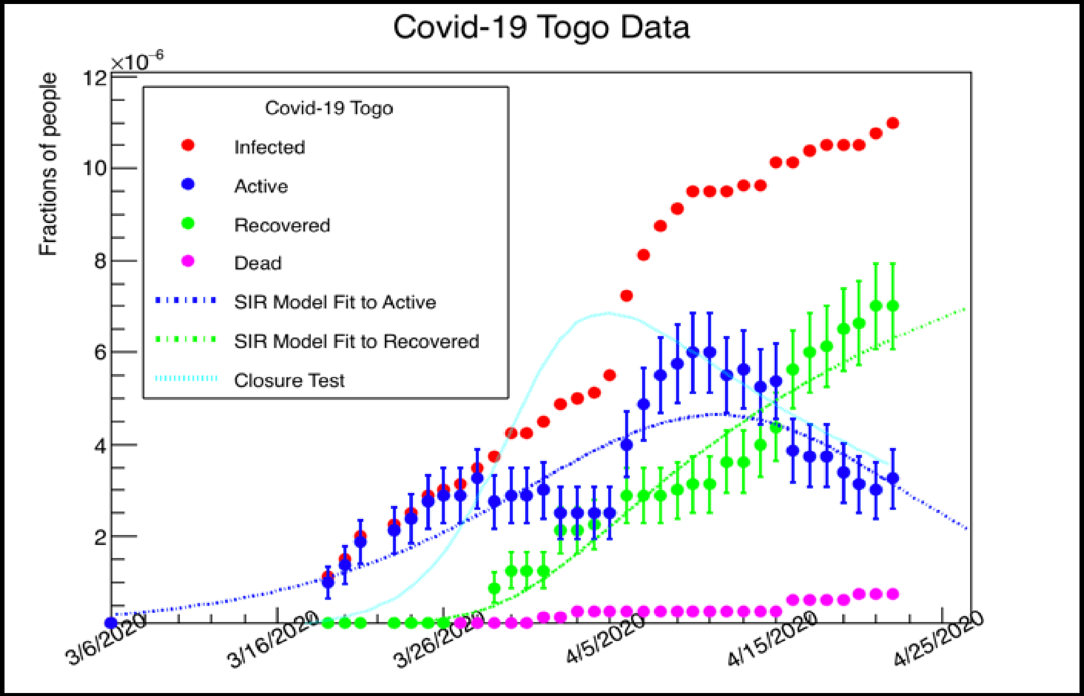
3rd Publication:

https://arxiv.org/pdf/2209.08694.pdf

SIR Model

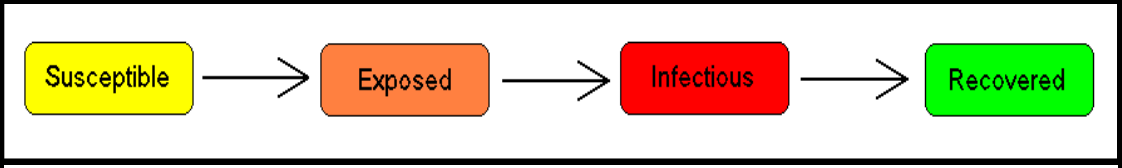
Simplest Model:

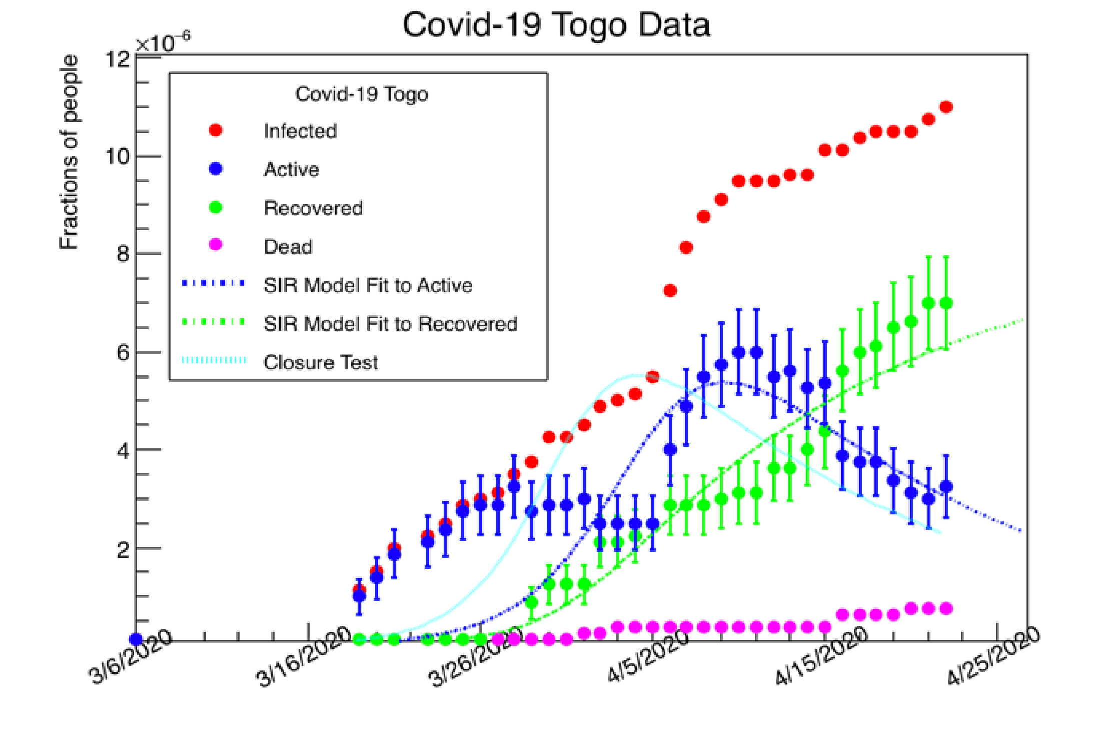
- **A good Model should successfully fit all the 3 datasets (Active, Recovered & Dead) simultaneously**
- **SIR unsuccessful in fitting the 3 curves simultaneously**



- **Fitting the recovered and the active independently also gives 2 different model parameters from fits to 2 independent datasets.**
- **Closure Test: using the 2 model parameters obtained by fitting the recovered to test for the active dataset, gives light blue curve, instead of the blue curve.**
- **Fitting only 1 dataset does not result in a good modeling on the other dataset.**

SEIR Model

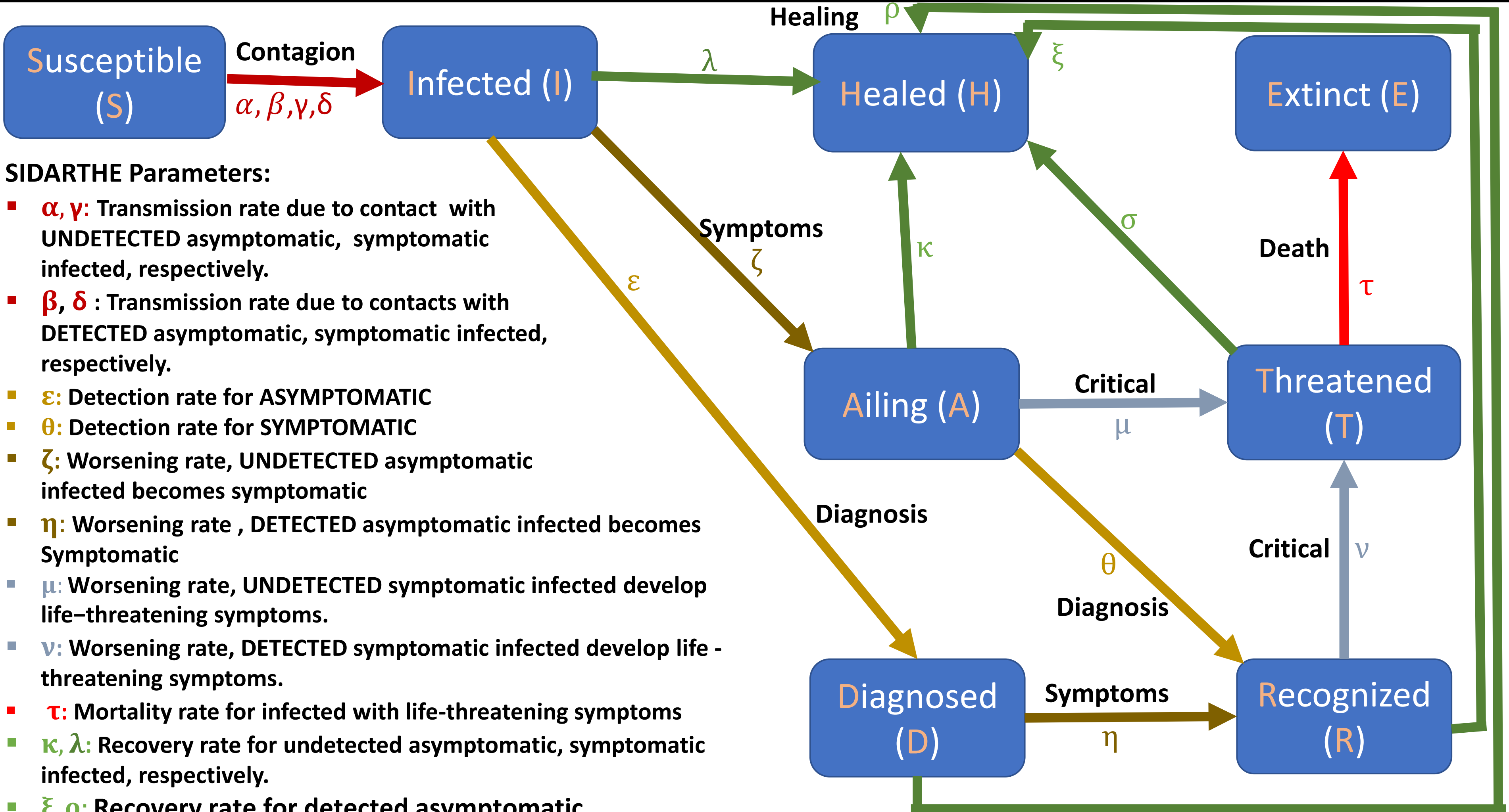




- **Mis-modelling did not improve**
- **Closure test: still poor – significant difference between the blue curve (active cases) & light blue curve**

➢ **Conclusion: we need a model that can fit all the 3 datasets: active, recovered & dead simultaneously.**

SIDARTHE Model



SIDARTHE Parameters:

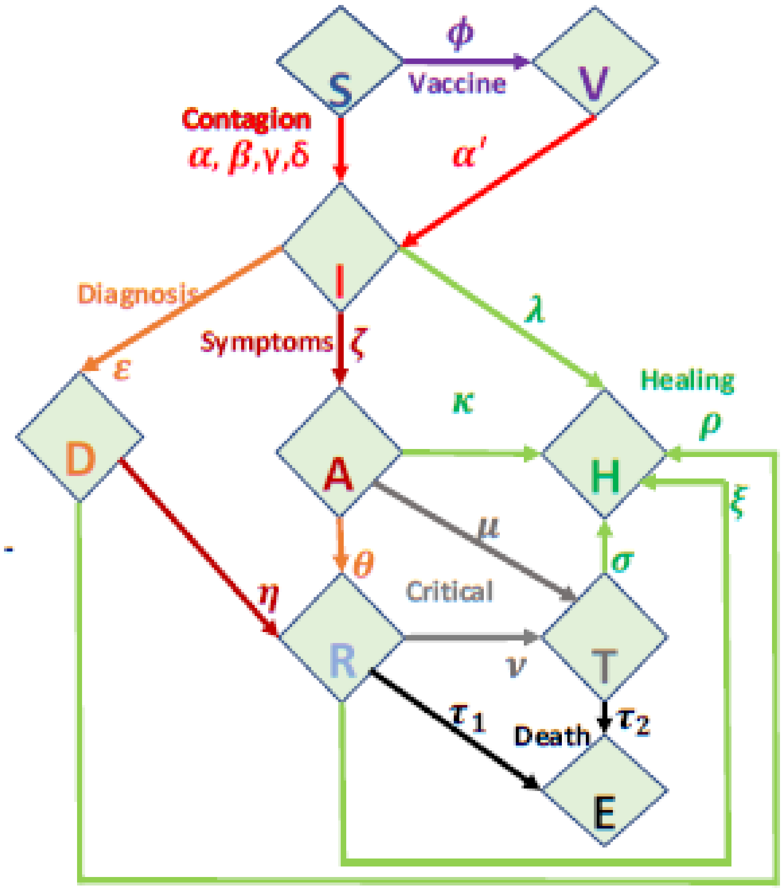
- **α, γ: Transmission rate due to contact with UNDETECTED asymptomatic, symptomatic infected, respectively.**
- **β, δ : Transmission rate due to contacts with DETECTED asymptomatic, symptomatic infected, respectively.**
- **ε: Detection rate for ASYMPTOMATIC**
- **θ: Detection rate for SYMPTOMATIC**
- **ζ: Worsening rate, UNDETECTED asymptomatic infected becomes symptomatic**
- **η: Worsening rate , DETECTED asymptomatic infected becomes Symptomatic**
- **μ: Worsening rate, UNDETECTED symptomatic infected develop life–threatening symptoms.**
- **ν: Worsening rate, DETECTED symptomatic infected develop life - threatening symptoms.**
- **τ: Mortality rate for infected with life-threatening symptoms**
- **κ, λ: Recovery rate for undetected asymptomatic, symptomatic infected, respectively.**
- **ξ, ρ: Recovery rate for detected asymptomatic, symptomatic infected, respectively.**

SIDARTHE-V Model: PaperII

Susceptible–Infected-Diagnosed-Ailing-Recognized-Threatened-Healed-Extinct-Vaccinated_Infected (SIDARTHE-VI)

Parameters:

- α, γ: Transmission rate due to contact with UNDETECTED asymptomatic, symptomatic infected, respectively.
- β, δ : Transmission rate due to contacts with DETECTED asymptomatic, symptomatic infected, respectively.
- ε: Detection rate for ASYMPTOMATIC
- θ: Detection rate for SYMPTOMATIC
- ζ: Worsening rate, UNDETECTED asymptomatic infected becomes symptomatic
- η: Worsening rate , DETECTED asymptomatic infected becomes Symptomatic
- μ: Worsening rate, UNDETECTED symptomatic infected develop life–threatening symptoms.
- ν: Worsening rate, DETECTED symptomatic infected develop life - threatening symptoms.
- κ, λ: Recovery rate for undetected asymptomatic, symptomatic infected, respectively.
- ξ, ρ: Recovery rate for detected asymptomatic, symptomatic infected, respectively.
- ϕ: vaccination rate
- α': Reinfection rate of vaccinated
- τ_1, τ_2: Mortality rate for recognized infected and for infected with life-threatening symptoms



Methods

SIDARTHE mathematical model. The SIDARTHE dynamical system consists of eight ordinary differential equations, describing the evolution of the population in each stage over time: $\dot{V} = -\alpha' IV + \phi S$ → (9)

$$\dot{S}(t) = -S(t)(\alpha I(t) + \beta D(t) + \gamma A(t) + \delta R(t)) \tag{1}$$

$$\dot{I}(t) = S(t)(\alpha I(t) + \beta D(t) + \gamma A(t) + \delta R(t)) - (\varepsilon + \zeta + \lambda)I(t) \tag{2}$$

$$\dot{D}(t) = \varepsilon I(t) - (\eta + \rho)D(t) \tag{3}$$

$$\dot{A}(t) = \zeta I(t) - (\theta + \mu + \kappa)A(t) \tag{4}$$

$$\dot{R}(t) = \eta D(t) + \theta A(t) - (\nu + \xi)R(t) \tag{5}$$

$$\dot{T}(t) = \mu A(t) + \nu R(t) - (\sigma + \tau)T(t) \tag{6}$$

$$\dot{H}(t) = \lambda I(t) + \rho D(t) + \kappa A(t) + \xi R(t) + \sigma T(t) \tag{7}$$

$$\dot{E}(t) = \tau T(t) \tag{8}$$

- **Solved equations for modelling**
- **16(17) parameters**

https://www.nature.com/articles/s41591-020-0883-7.pdf

The Basic Reproduction Number R_0

- R_0 = **expected number of secondary cases produced by a single (typical) infection in a completely susceptible population**
- R_0 is one of the quantities used to parametrize the beginning of an epidemic **~ to understand if epidemic is growing = Appropriate containment measures**
- R_0 is dimensionless and is NOT a rate
- R_0 is model dependent

SIR Model:

- In an epidemic, we require *$di/dt > 0$, i.e $\beta si - \gamma i > 0$*
- At the outset of the epidemic, assuming everyone is susceptible, s=1 therefore:

$$\beta/\gamma = R_0 > 1$$

- R_0 = probability of infection (given contacts) x average rate of contacts x duration of infectiousness

SIDARTHE Model:

$$R_0 = \frac{\alpha}{r_1} + \frac{\beta \times \epsilon}{r_1 \times r_2} + \frac{\gamma \times \zeta}{r_1 \times r_3} + \frac{\delta \times \eta \times \epsilon}{r_1 \times r_2 \times r_4} + \frac{\delta \times \zeta \times \theta}{r_1 \times r_3 \times r_4}$$

$r_1 = \varepsilon + \zeta + \lambda$
$r_2 = \eta + \rho$
$r_3 = \theta + \mu + \kappa$
$r_4 = \nu + \chi$
$r_5 = \sigma + \tau$

Calculating for the initial R_0:

$R_0 = \alpha/r_1 + \beta \times \varepsilon/(r_1 \times r_2) + \gamma \times \zeta/(r_1 \times r_3) + \delta \times \eta \times \varepsilon/(r_1 \times r_2 \times r_4) + \delta \times \zeta \times \theta/(r_1 \times r_3 \times r_4) + r_5$

- **All 16(17) parameters are solved for in the SIDARTHE-V differential equations**

- $R_0 > 1$: epidemic continues
- $R_0 < 1$: outbreak ends
- R_0 can be used to estimate the fraction of people to vaccinate.
- R_0 must be applied with caution due to model dependency

What is an R value in an epidemic?

In an epidemic, one of the most important numbers is R - the reproduction number. If this is below one, then on average each infected person will infect fewer than one other person; the number of new infections will fall over time.

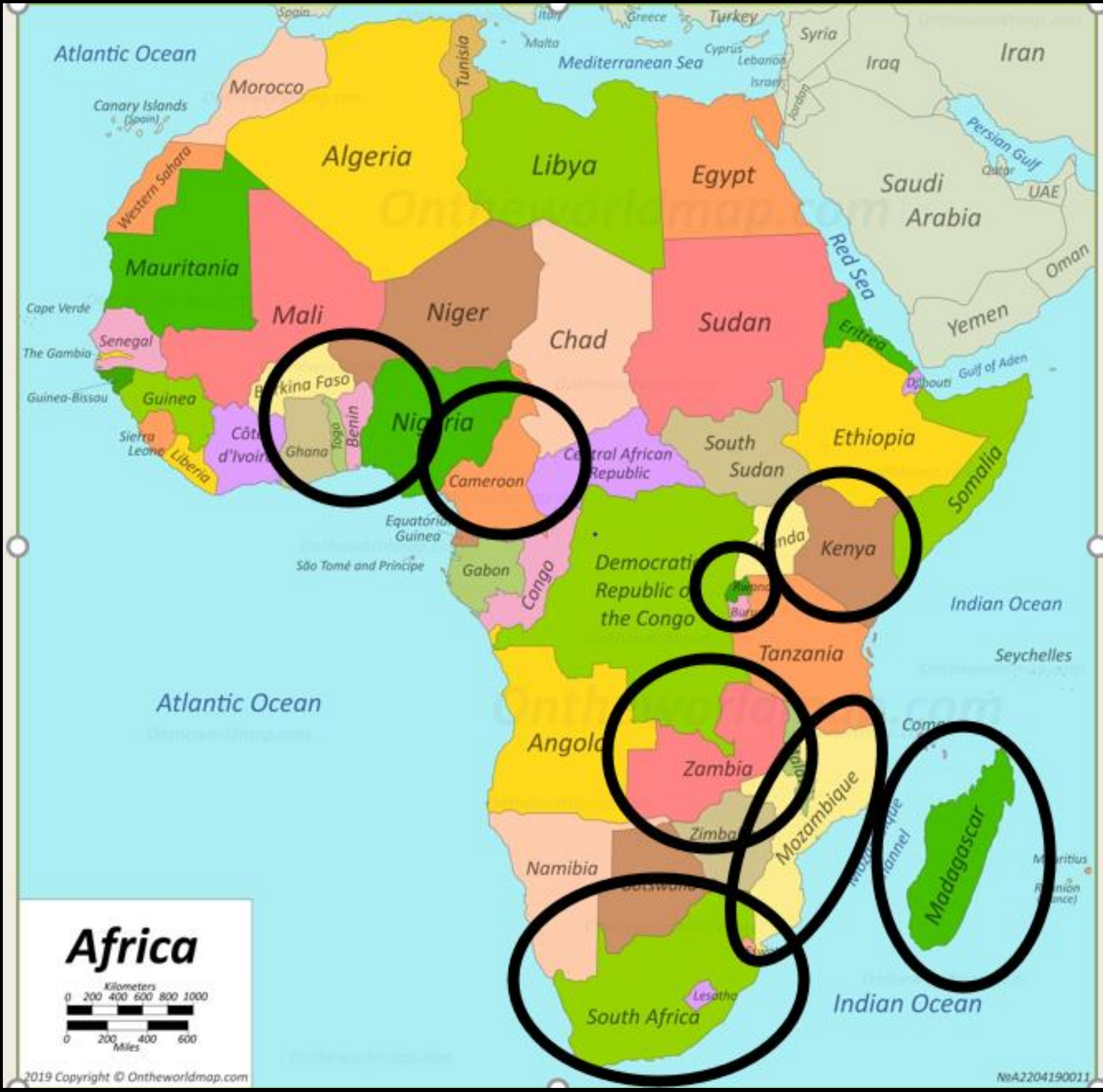
The lower the number, the faster the number of new infections will fall. When R is above one, the number of new infections is accelerating; the higher the number the faster the virus spreads through the population.

24 Jul 2020

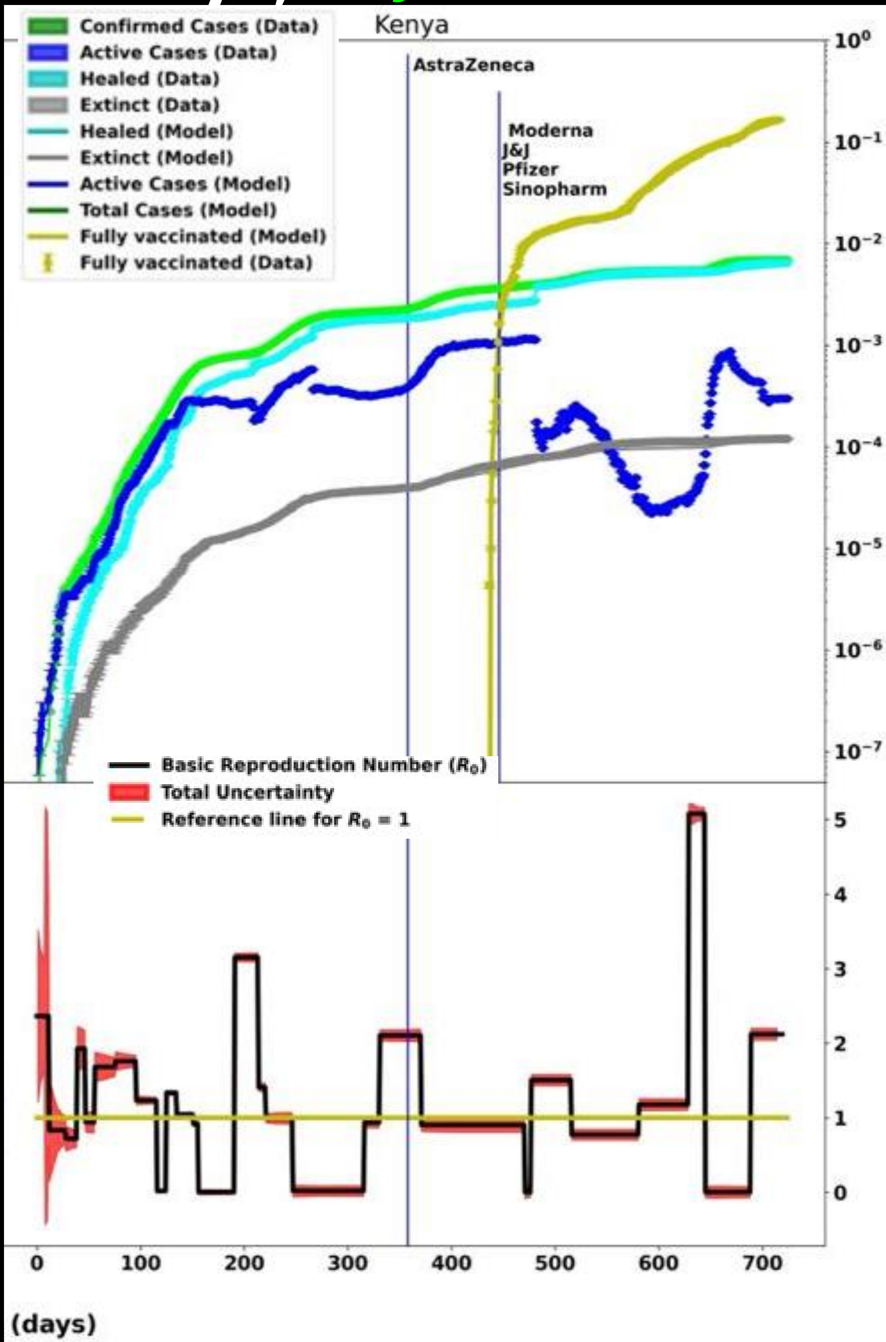
www.gov.uk › publications › our-pl...

Our plan to rebuild: The UK Government's COVID-19 recovery ...

- Benin
- Cameroon
- Ghana
- Kenya
- Madagascar
- Mozambique
- Nigeria
- Rwanda
- South Africa
- Togo
- Zambia



Kenya, *A. Njeri*



Population = 46m

1st Case: 13th March-Travelled from US via London

Attended party: 2nd case friend of 1st case

Testing capacity increased ~April

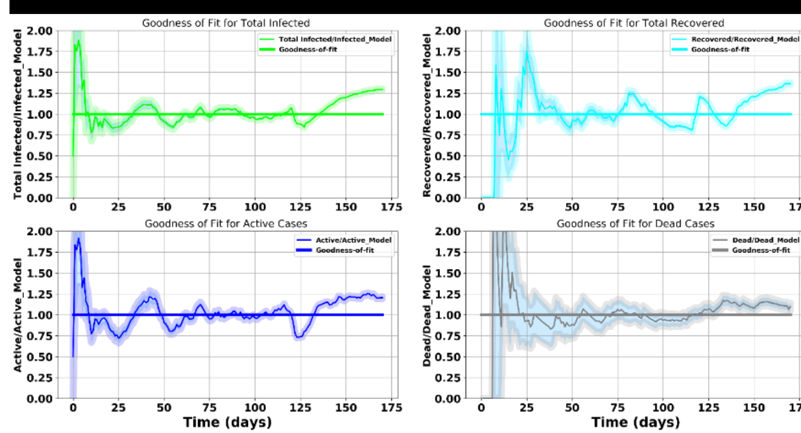
Cessation of Movement in 2 major cities: Nairobi & Mombasa

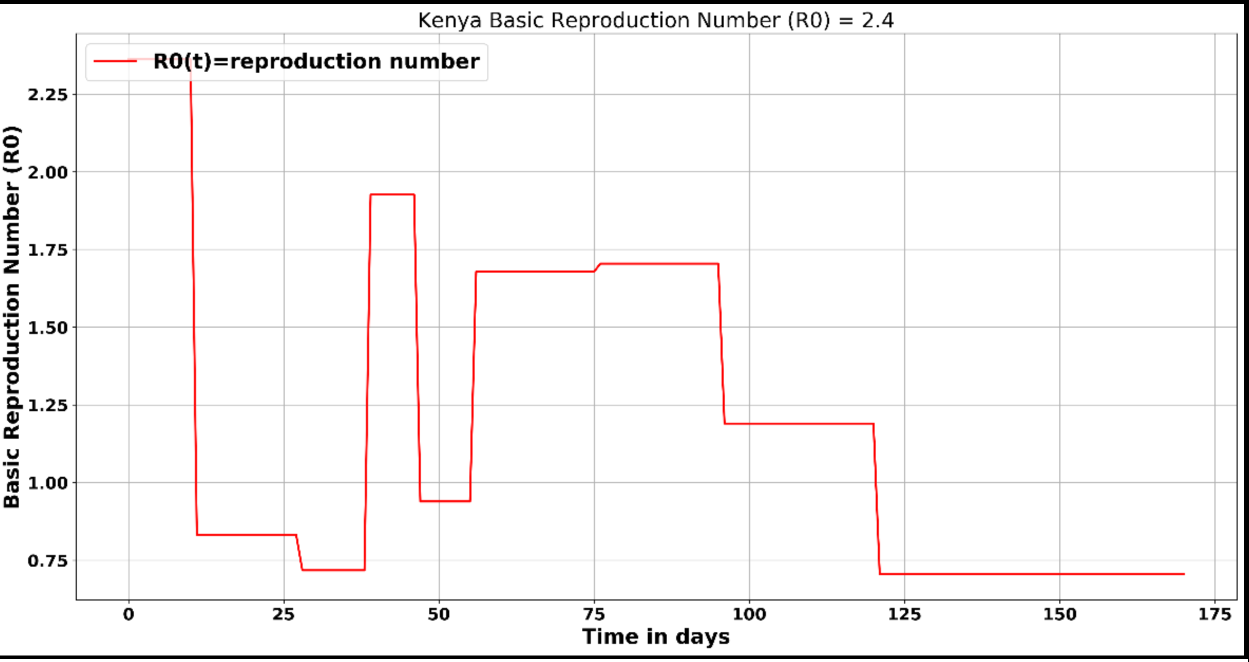
Flights suspended, Partial country lockdown, Night Curfews

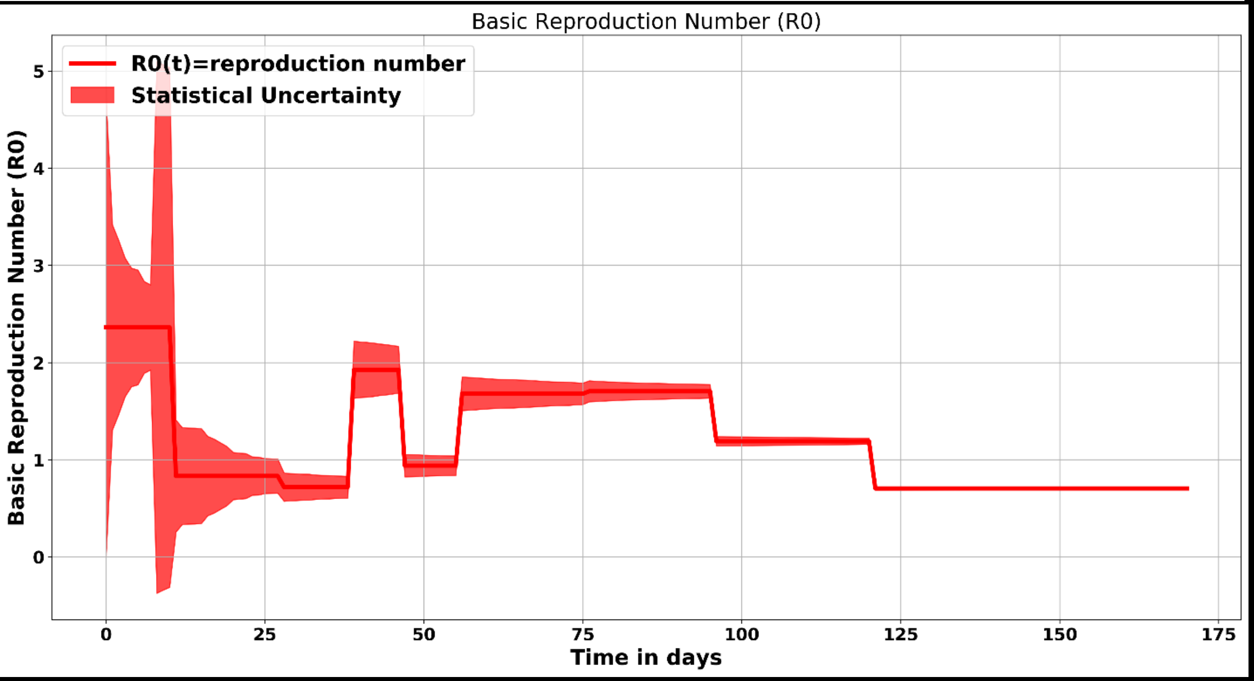
Social distancing in restaurants

50 people maximum

Curve slowed down(4th month), Flattening of a curve(Jul): Fatality rate ~1.57%







- Large $R_0>1$ at the beginning
- No control measures in place yet
- Closure of points of entry eliminated the imported cases
- Decline in R_0 implying that the control measures were effective
- R_0 rise and fall periodically due to a number of reasons

  e.g increased testing capacity, relapses in control measures, etc
- Months later $R_0<1$

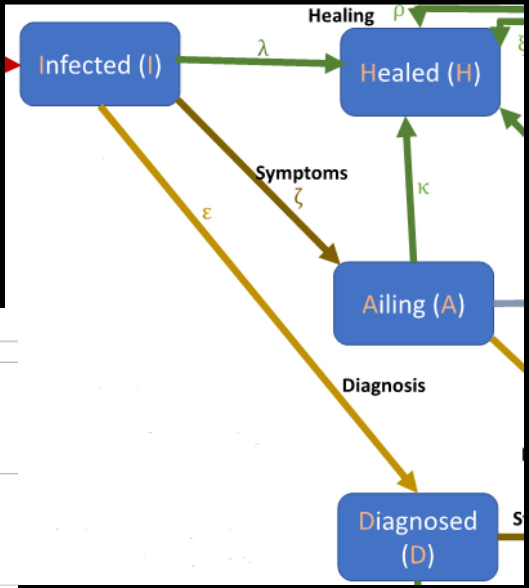
Systematic Uncertainties on R_0

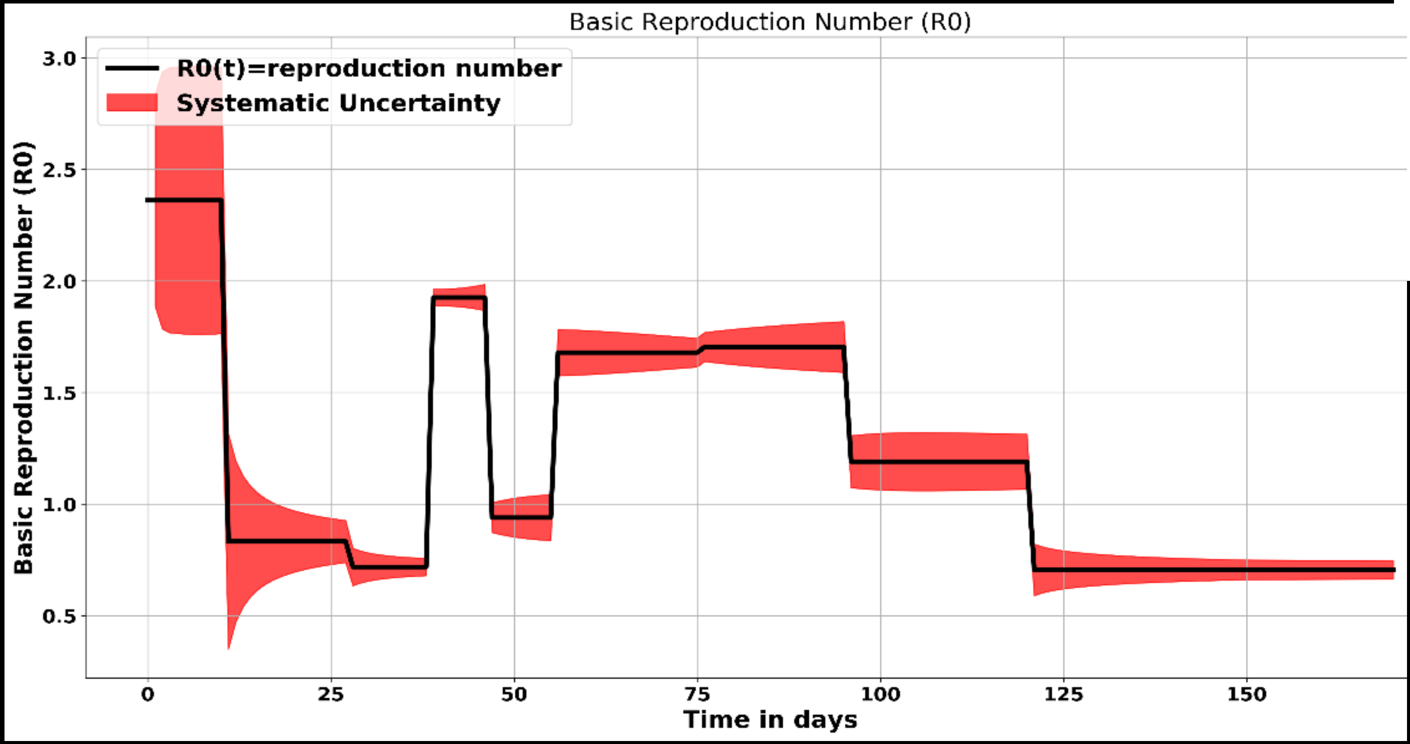
SIDARTHE Model:

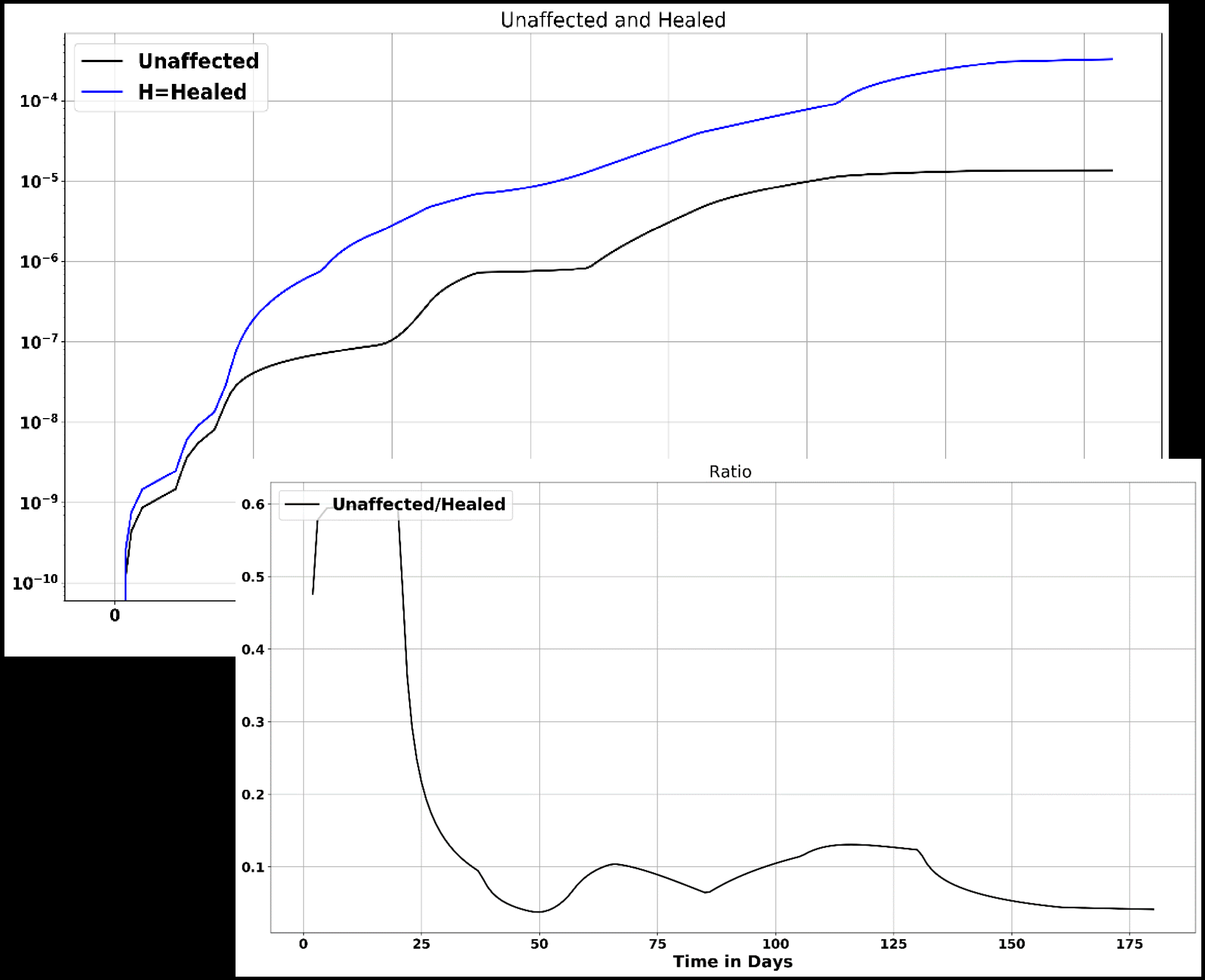
H= Healed ***λ not included in the data, yet it is included in the model.***

= Systematic error on the modeling

$$\dot{H}(t) = \lambda I(t) + \rho D(t) + \kappa A(t) + \xi R(t) + \sigma T(t)$$

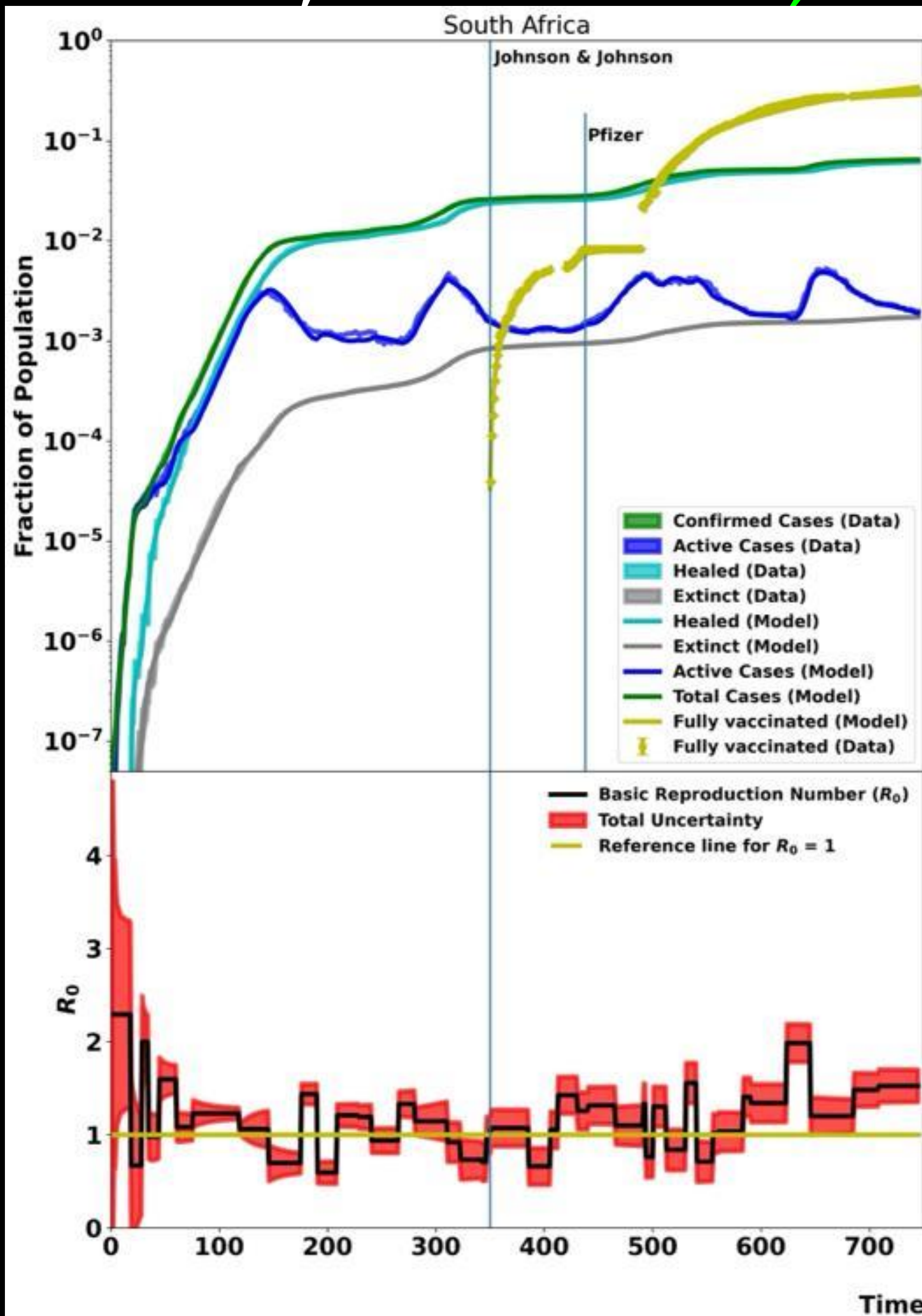






Unaffected and Healed
Unaffected
H=Healed
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0
Ratio
Unaffected/Healed
0.6
0.5
0.4
0.3
0.2
0.1
0
25
50
75
100
125
150
175
Time in Days

South Africa, *Dr. D. Mathebula , F. Macucule & A. Guga*

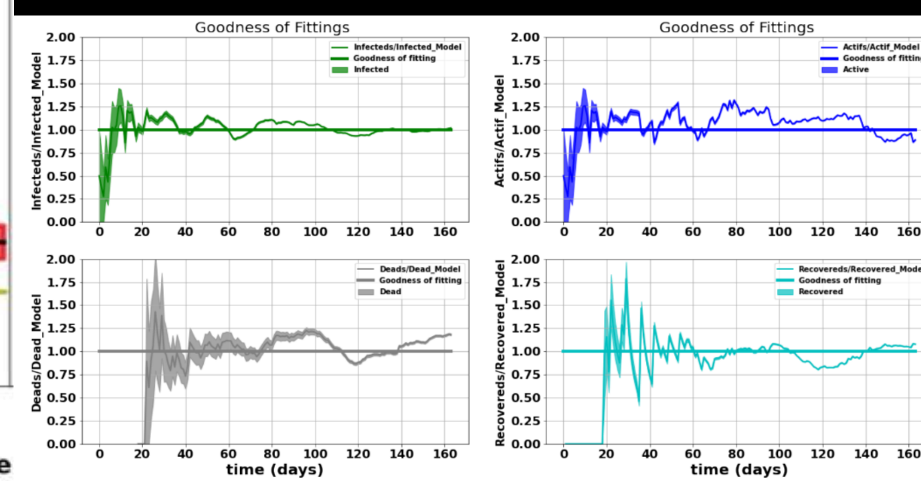


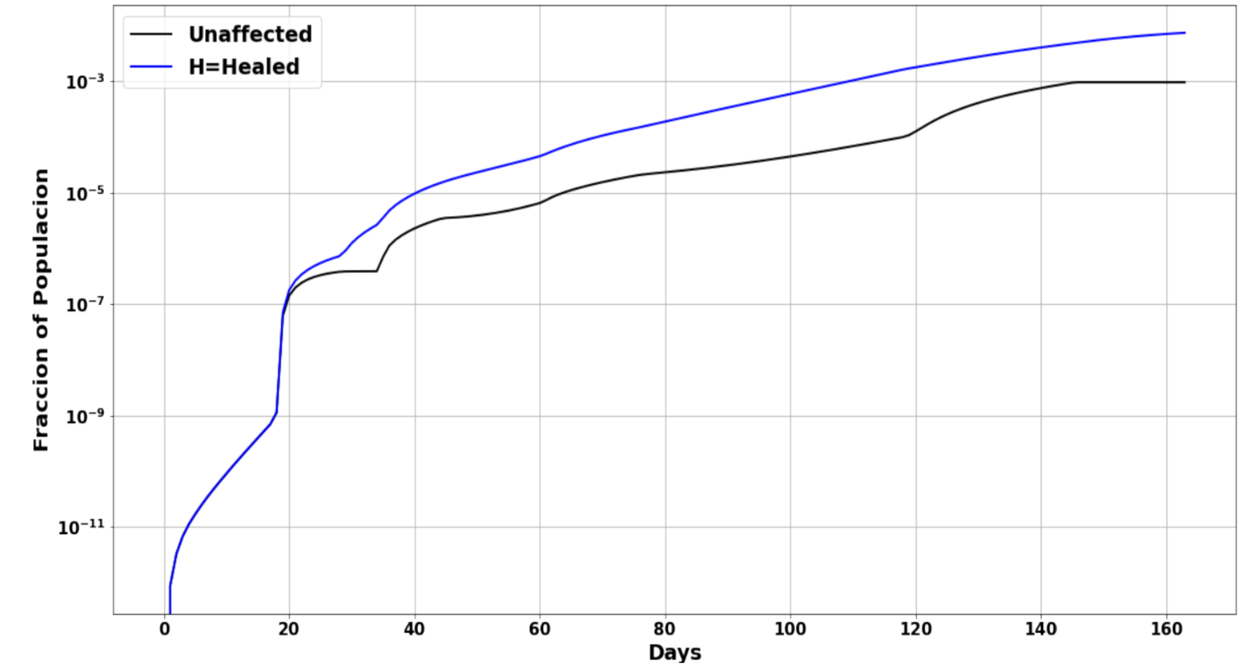
1[st] Case : 03 March
Case travelled from Italy

National lockdown
24/03/2020: borders, schools, flights suspended

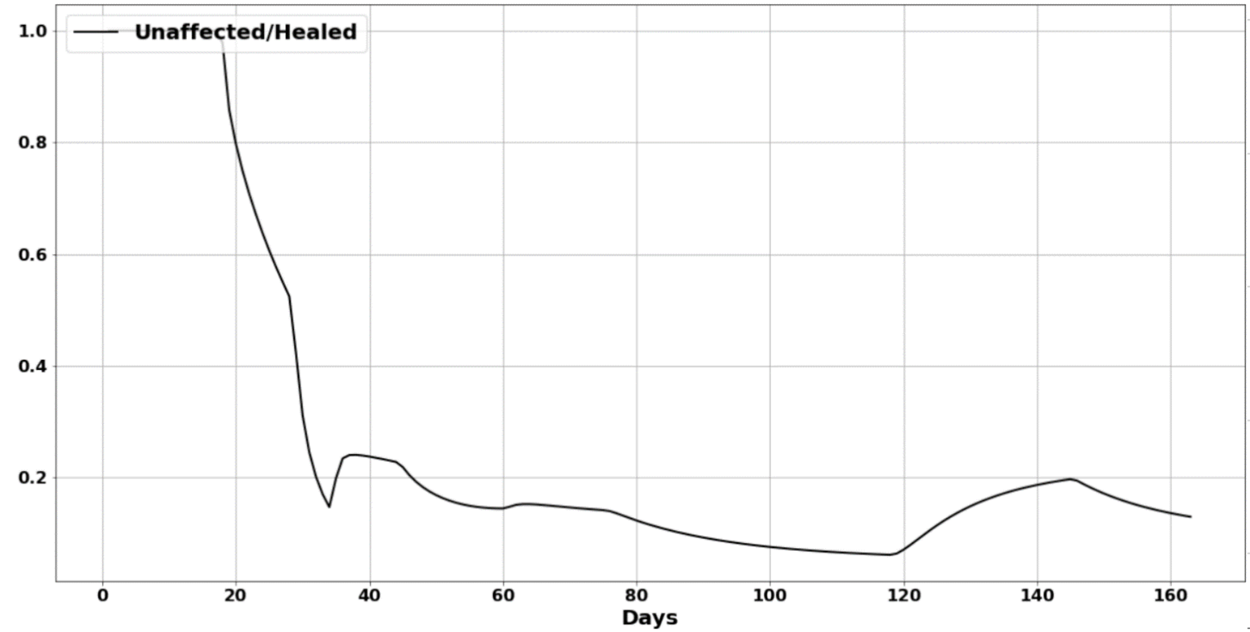
Lockdown Levels 5-1

↓Level 1 Lockdown level
21/09: Low covid spread & high health system preparedness

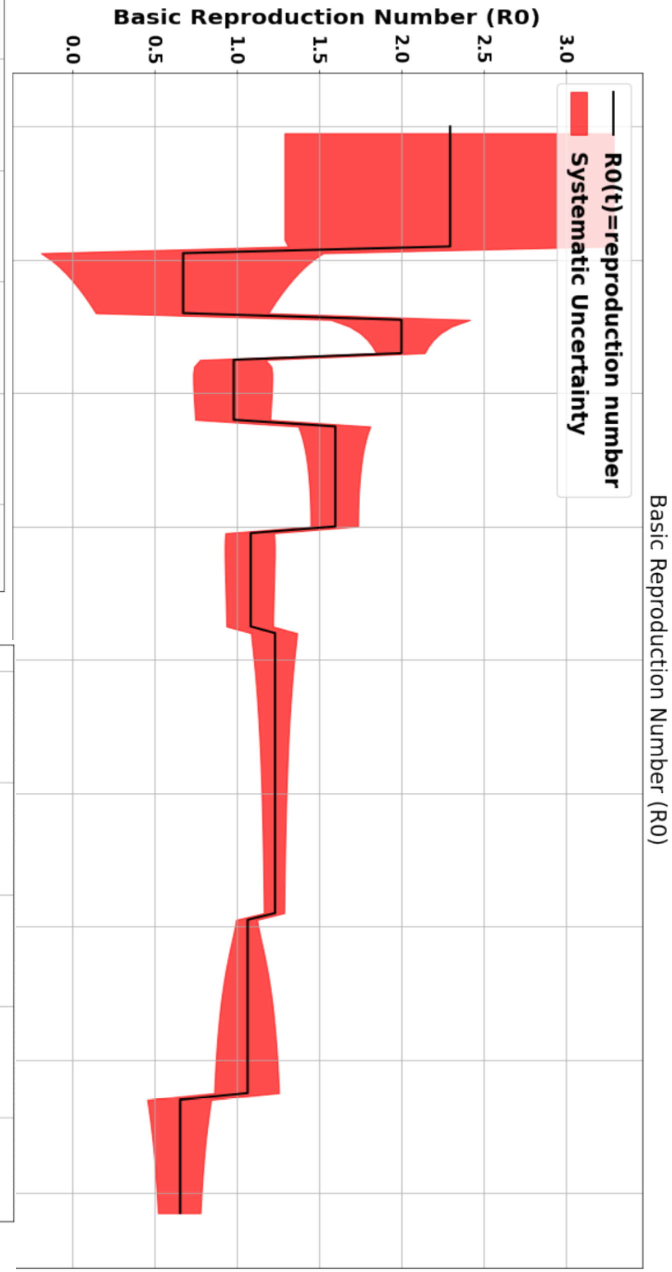




Unaffected
H=Healed
Fraccion of Populacion
Days

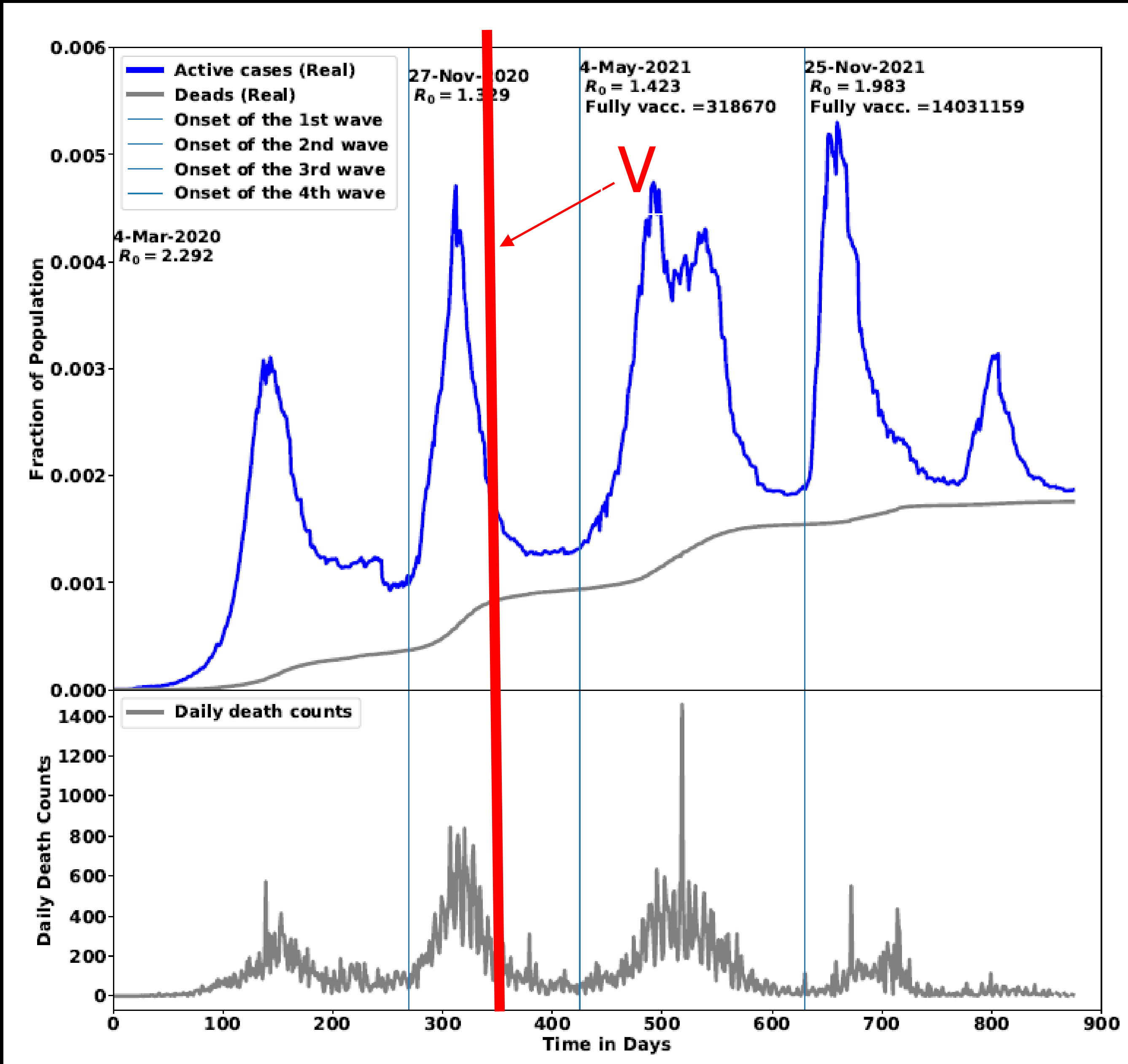


Unaffected/Healed
Days



Basic Reproduction Number (R0)
R0(t)=reproduction number
Systematic Uncertainty
Basic Reproduction Number (R0)

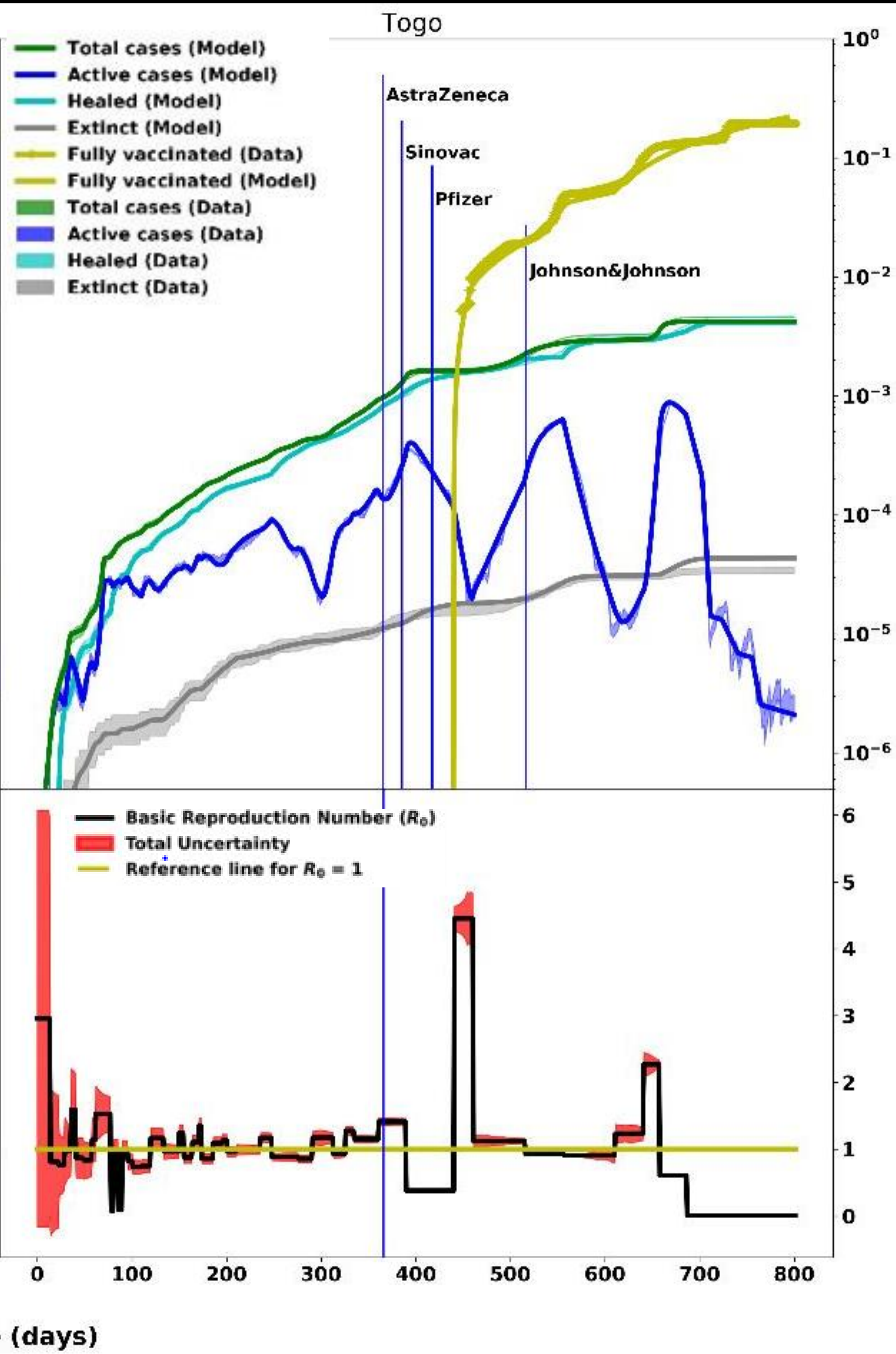
Waves vs. Daily Deaths:



-Vaccination impact ~1 year later (1/3 pop=vaccinated)

- **Reduced daily death rates/ Cumulative deaths plateau**
- **Relaxation of control = no resurgence/ peaks**

Togo, Dr. S. Azote



1st Case: 6 March: Case travelled to Germany, France, Turkey & Benin

Surveillance at PoEs

Flights to Europe suspended ~10 days

Borders closed 2 weeks later

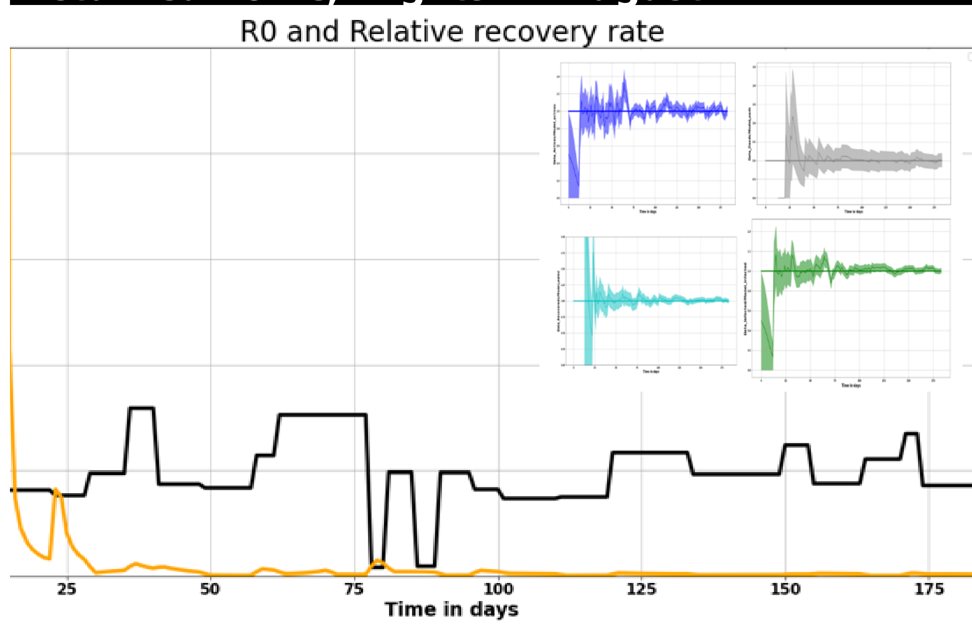
Curfew introduced

Public places e.g schools closed

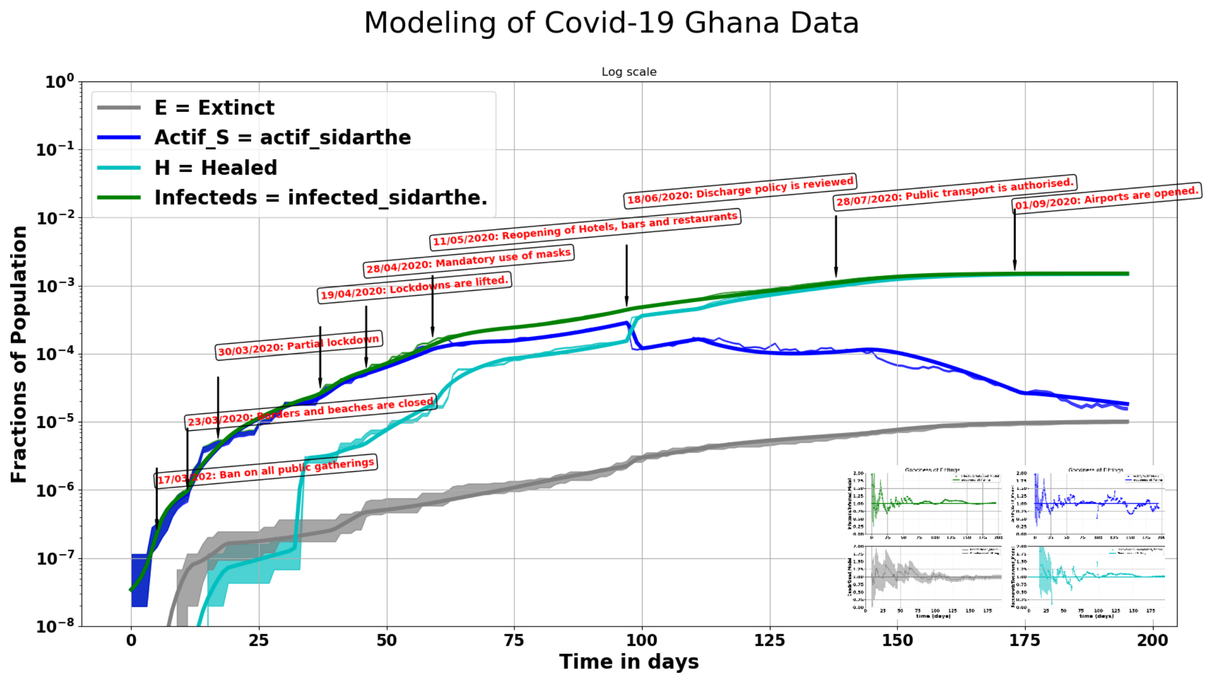
Social gatherings restricted

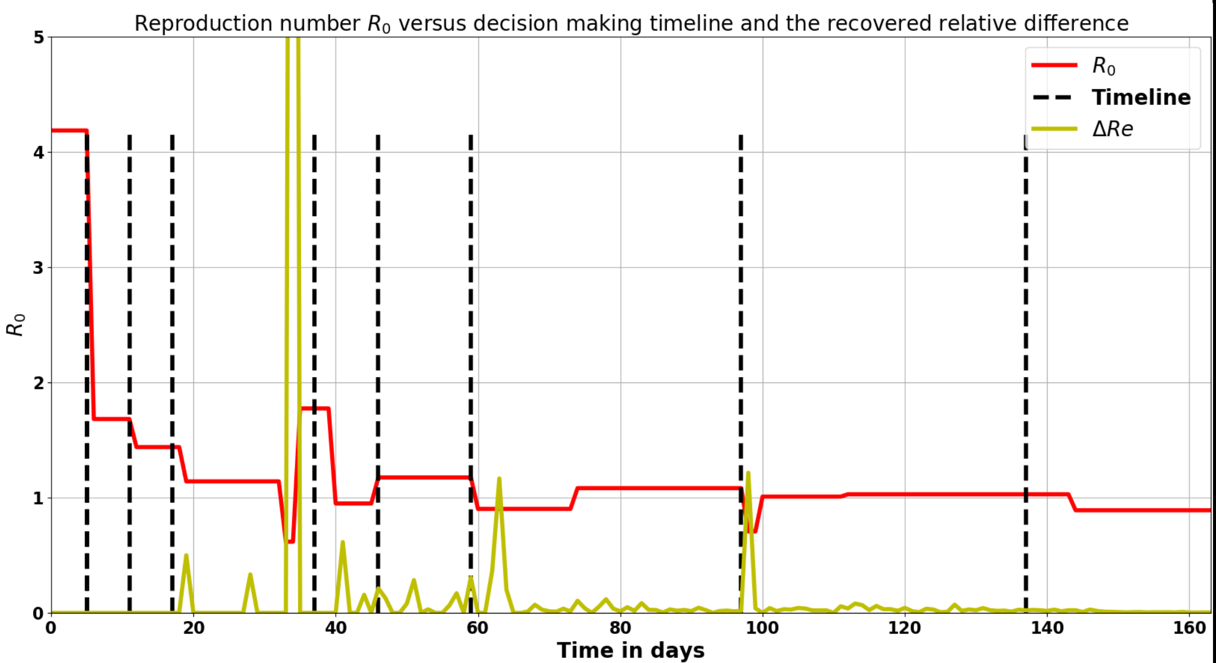
Massive test drive form 07 April

5-20 May cases increased: neighboring countries reopened borders-Togolese returned home, Flights 1st August



Ghana, *Dr. K. Amouzouvi*

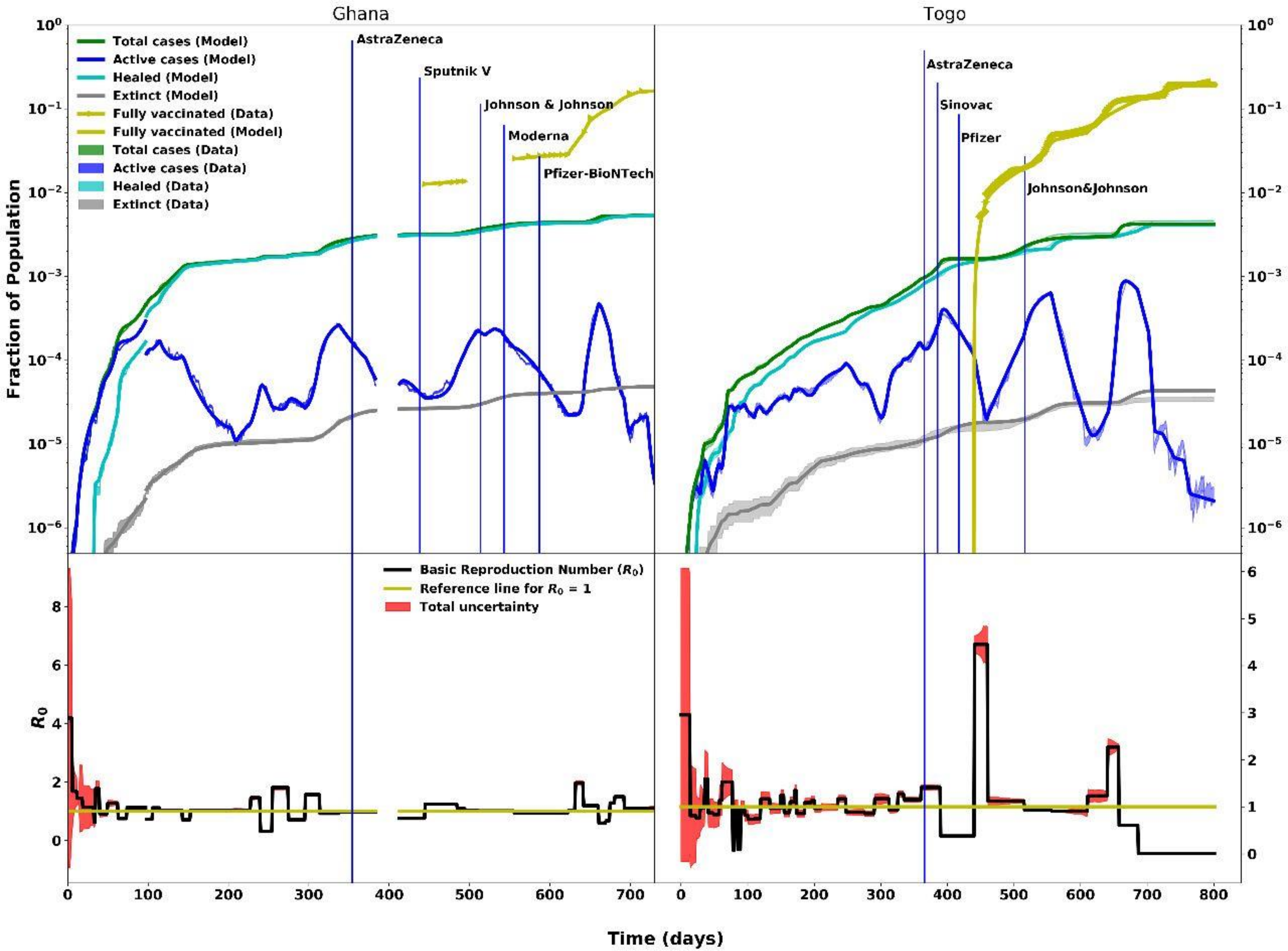




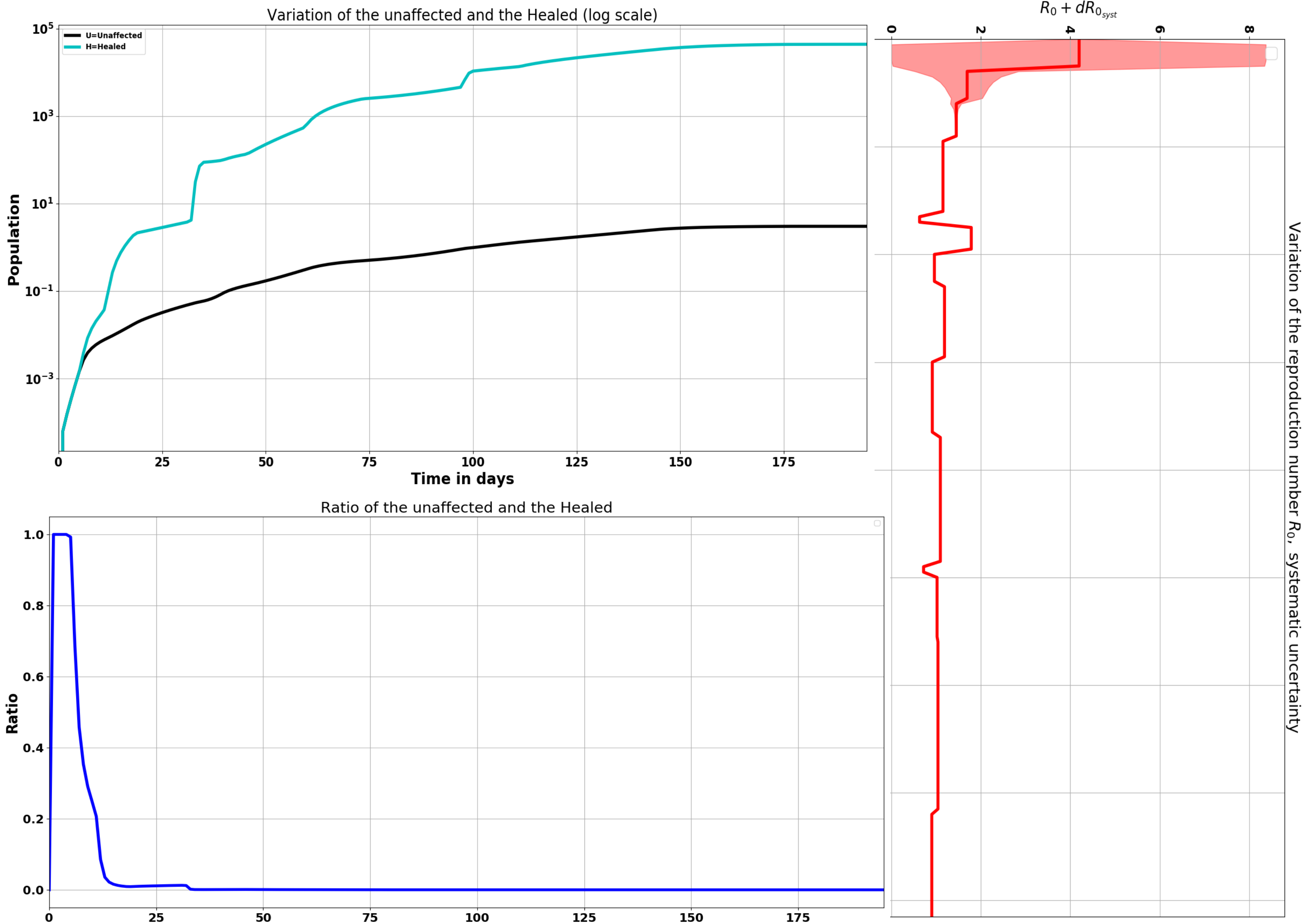
1st Case: 12 March

Day 6: Ban on all public gatherings
Day 12: Borders & beaches closed
Day 18: Partial lockdown
Day 38: Lockdown lifted
Day 47: Mandatory use of masks
Day 60: Reopening of Hotels, bars and restaurants
Day 98: Discharge policy is reviewed: Instead of following the two negative tests protocols, the infected who did not show any symptoms or whose symptoms disappeared during treatment
Day 138: Public transport is allowed
Day 173: Airports are opened.'

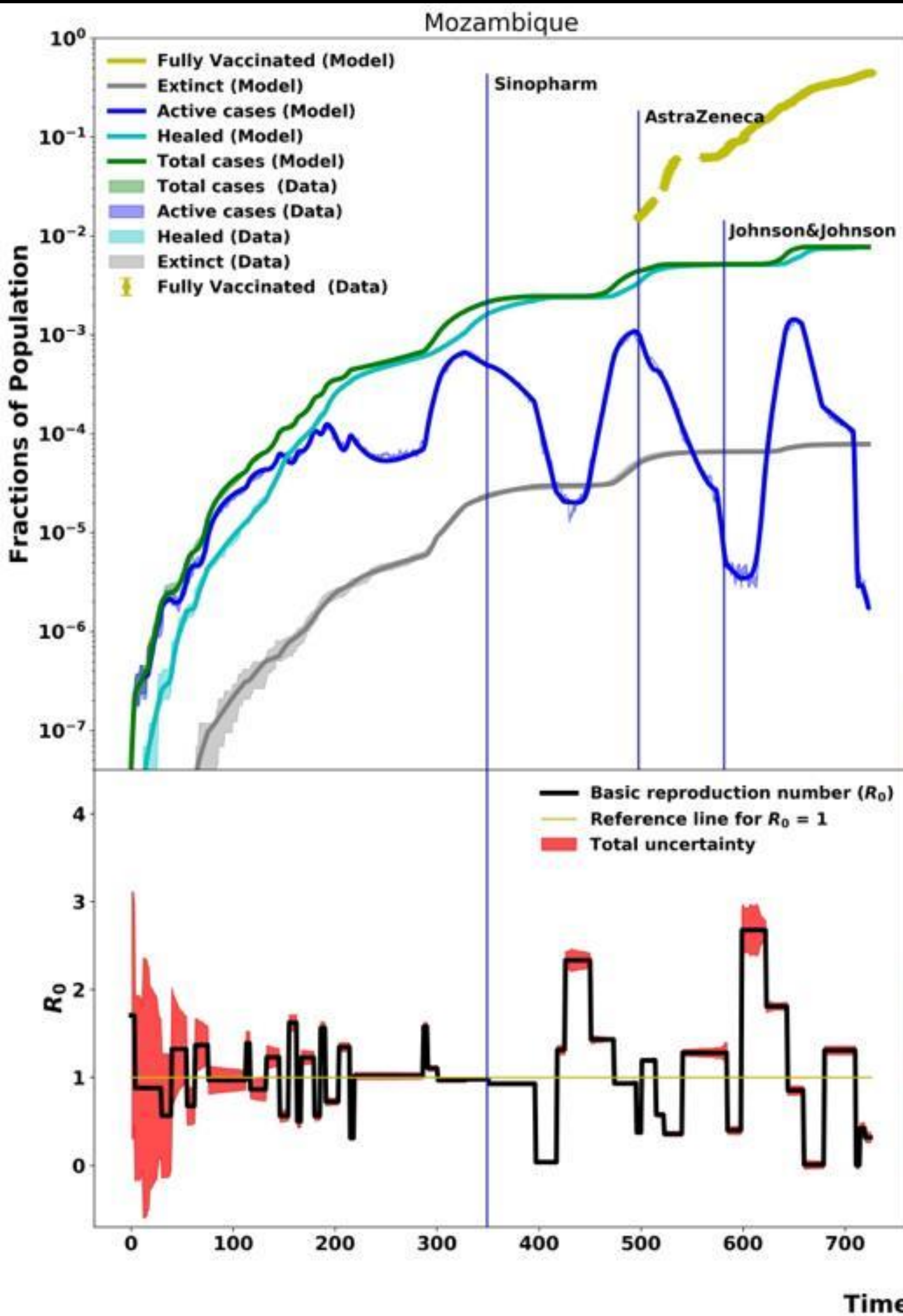
ΔRe[i] = (Re[i]-Re[i-1])/Re[i-1] at Day i
Ro rapid drop at ~Day 33
Highest peak in ΔRe
Ro drops & ΔRe peaks 63 & 98



Ghana
Togo
Total cases (Model)
Active cases (Model)
Healed (Model)
Extinct (Model)
Fully vaccinated (Data)
Fully vaccinated (Model)
Total cases (Data)
Active cases (Data)
Healed (Data)
Extinct (Data)
AstraZeneca
Sputnik V
Johnson & Johnson
Moderna
Pfizer-BioNTech
Sinovac
Pfizer
Johnson&Johnson
Fraction of Population
Basic Reproduction Number (R_0)
Reference line for R_0 = 1
Total uncertainty
R_0
Time (days)


Variation of the unaffected and the Healed (log scale)
U=Unaffected
H=Healed
Population
Time in days
10^5
10^3
10^1
10^{-1}
10^{-3}
0
25
50
75
100
125
150
175
Ratio of the unaffected and the Healed
Ratio
1.0
0.8
0.6
0.4
0.2
0.0
$R_0 + dR_{0_{syst}}$
Variation of the reproduction number R_0, systematic uncertainty
0
2
4
6
8

Mozambique, *T. Mabote, Claudio M. Paulo*



1st Case : 22nd March

Case had travelled from the UK

Schools closed immediately

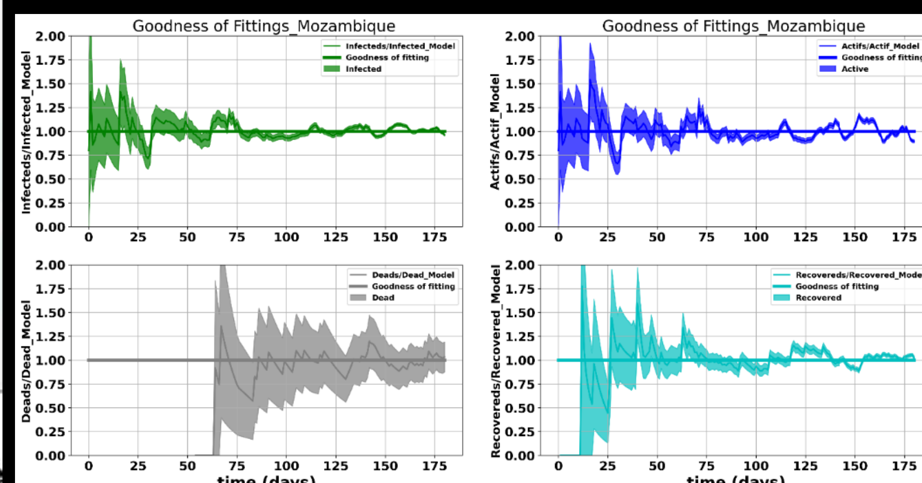
Social gatherings restricted

State of emergency declared 01/04-29/07

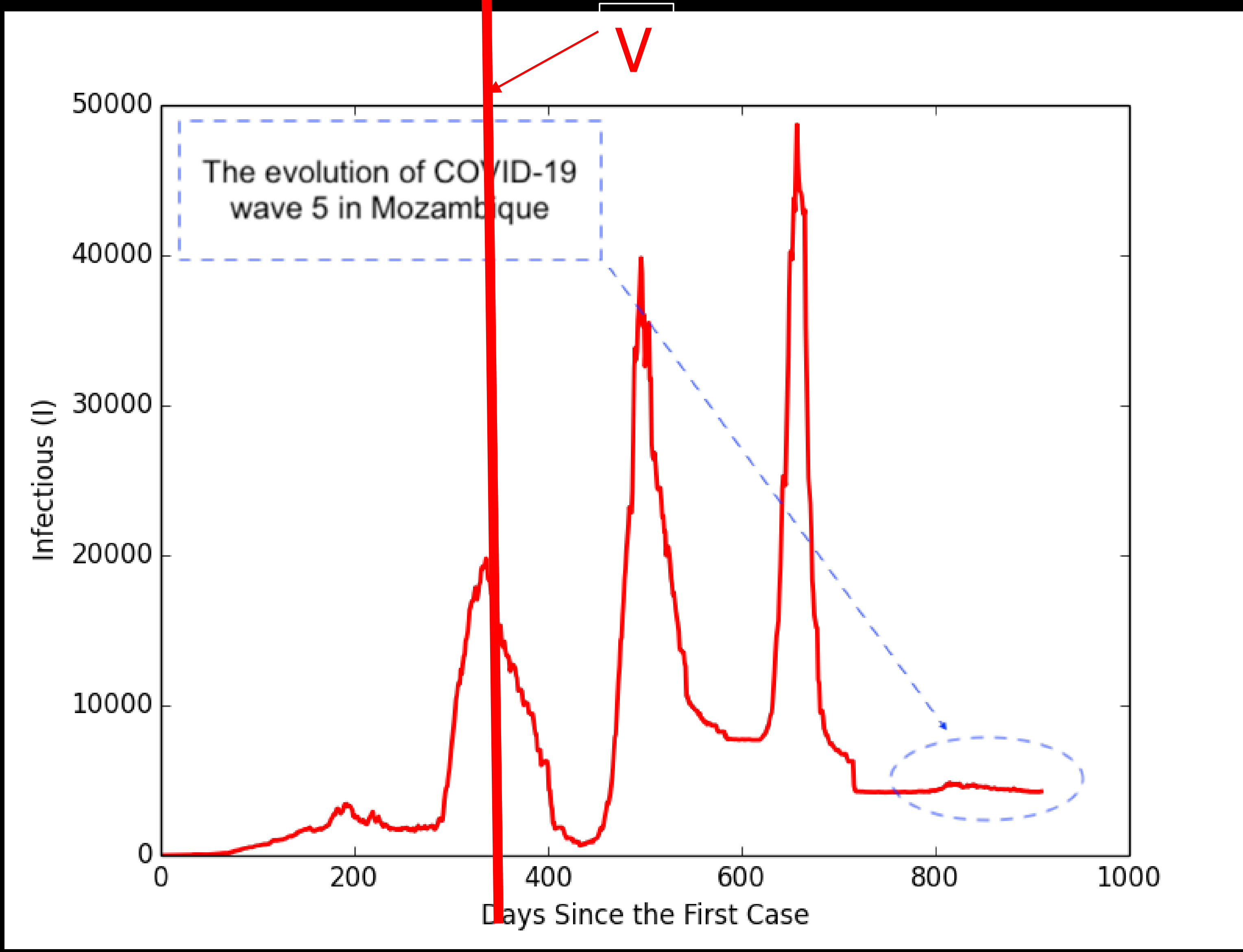
Flights suspended on 12/05

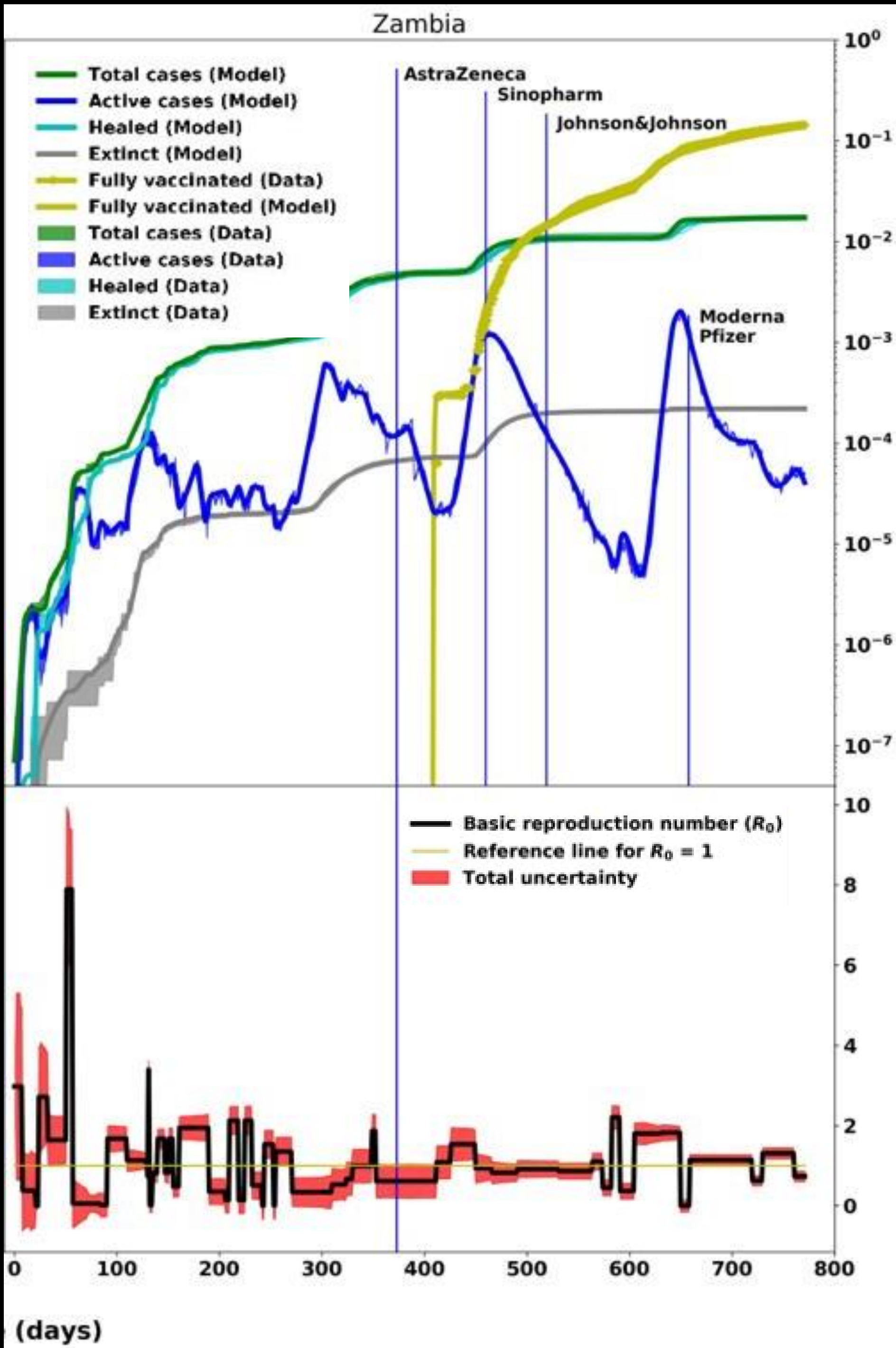
No country lockdown

Country slowly reopening with social distancing measures in place



Waves vs. Time:



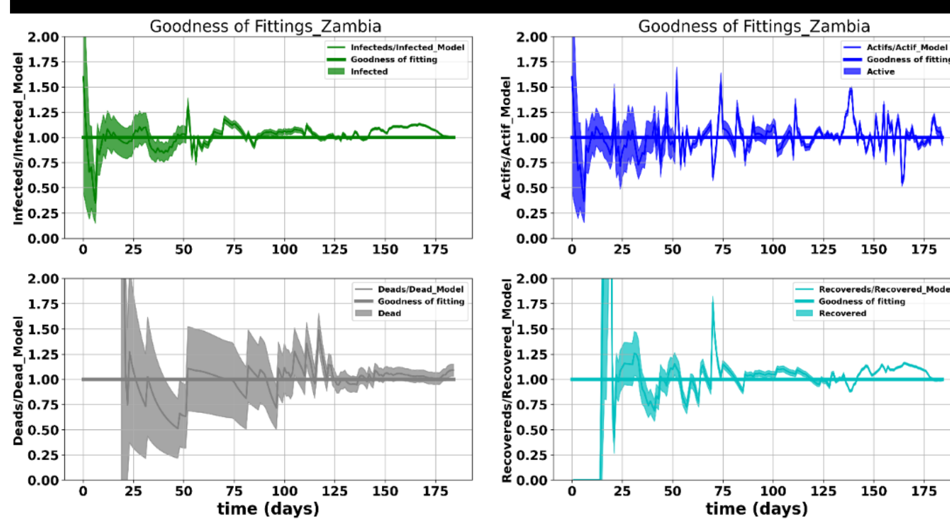


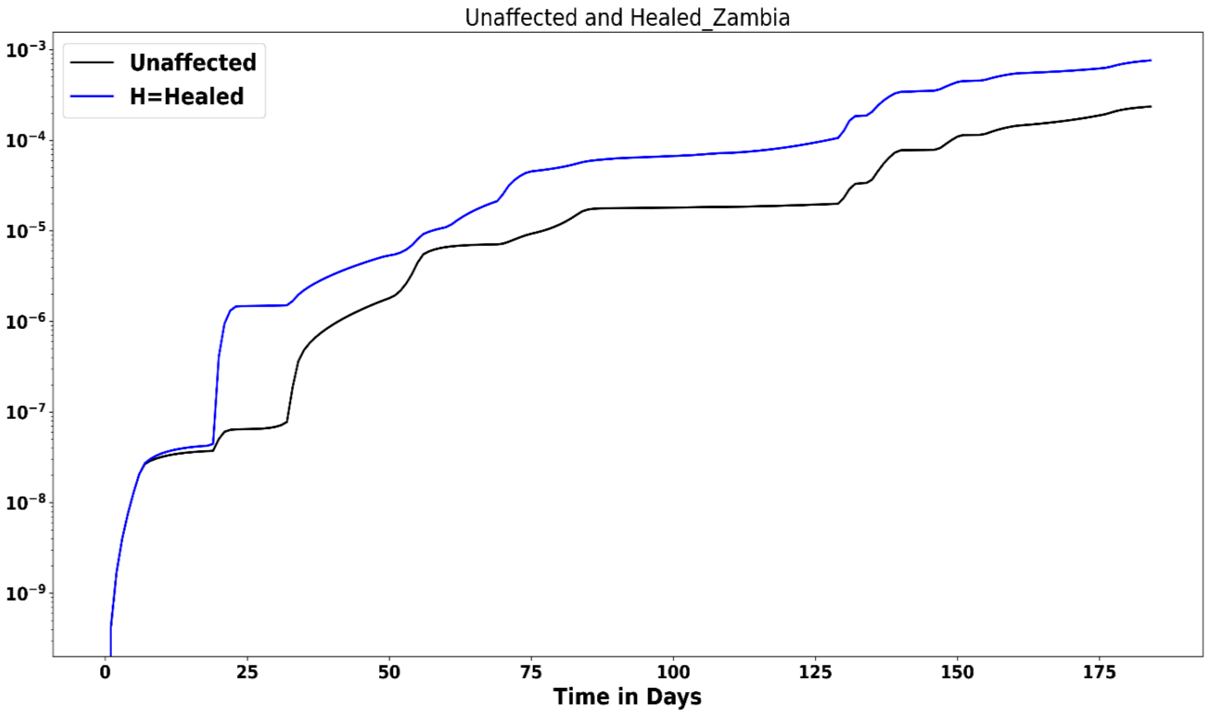
Zambia, *G. Zimba, T. Mabote*

1st Case: 13th March

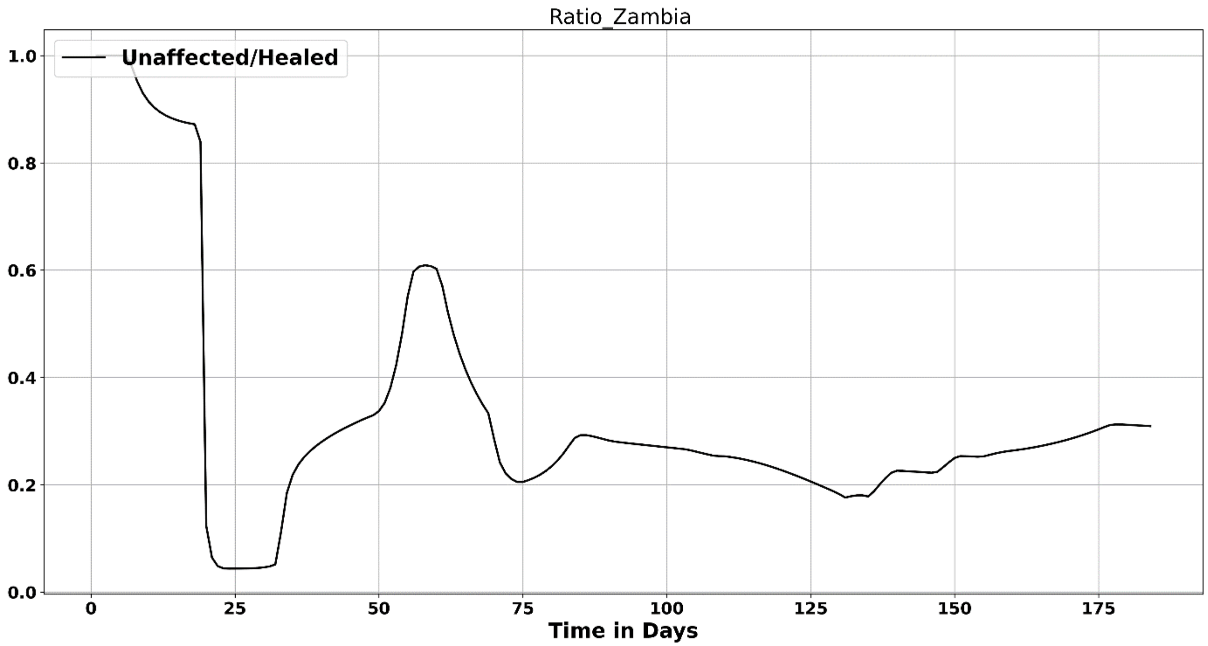
Presidential Directive -26/03: Measures to control spread of COVID-19

Peak around day 60 truck driver crossing over from Tanzania in the northern region

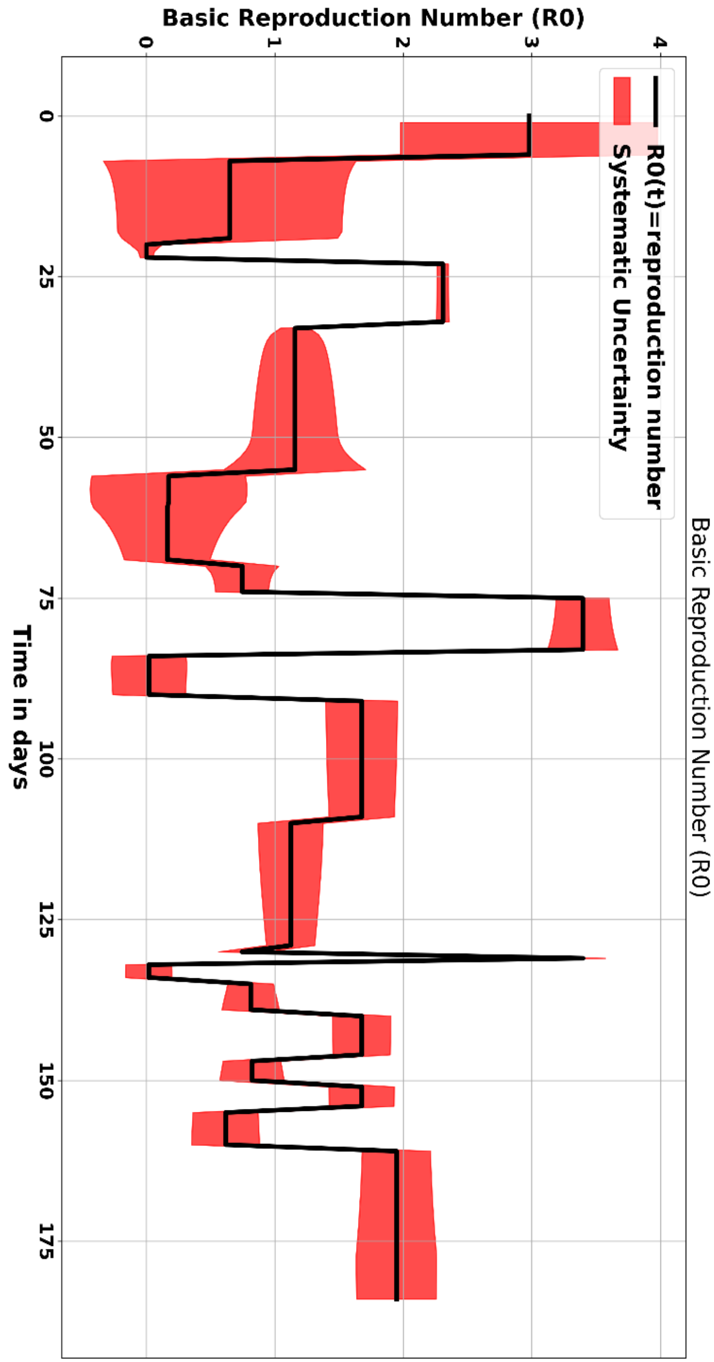




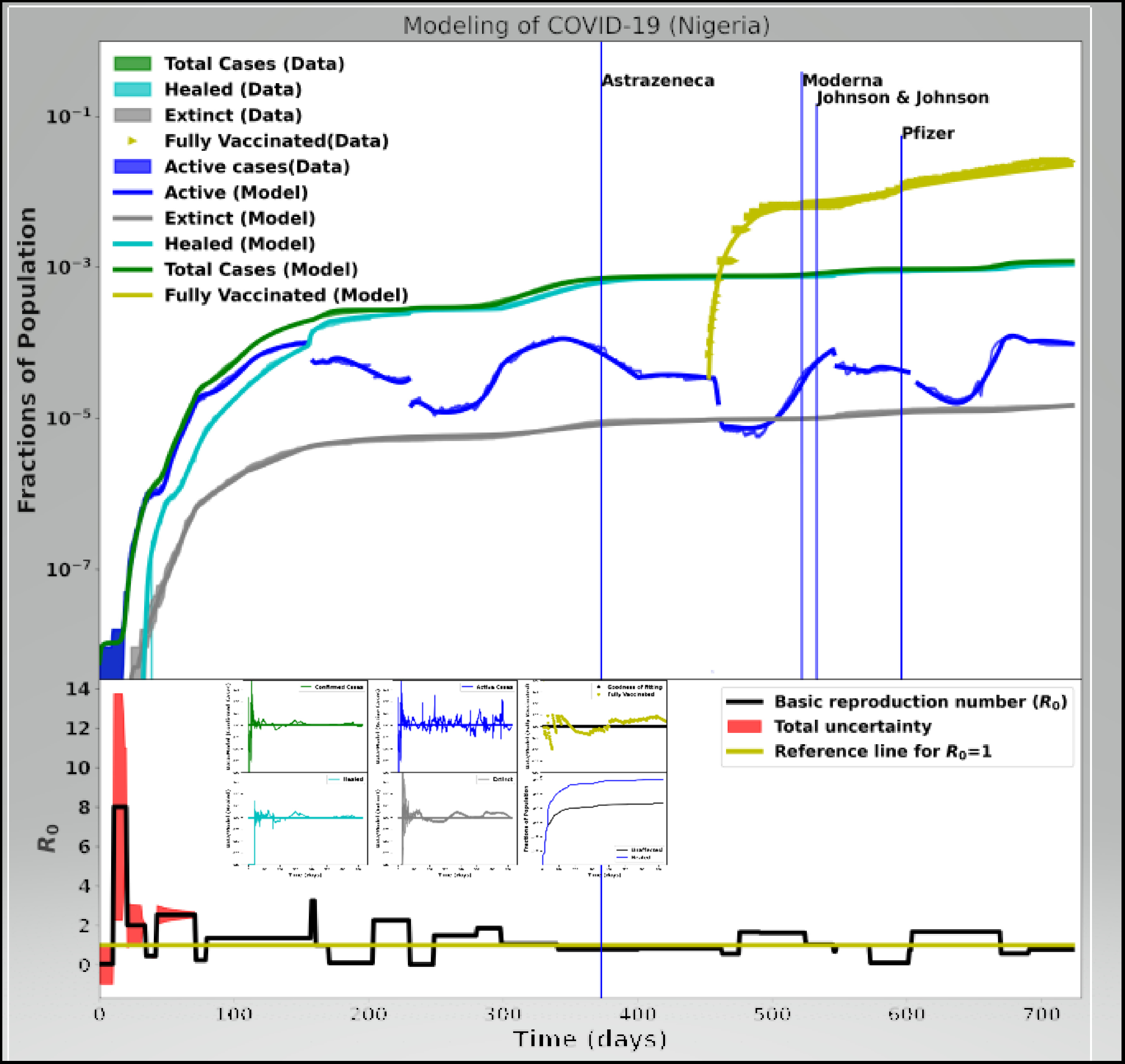
Unaffected and Healed_Zambia
Unaffected
H=Healed
Time in Days



Ratio_Zambia
Unaffected/Healed
Time in Days

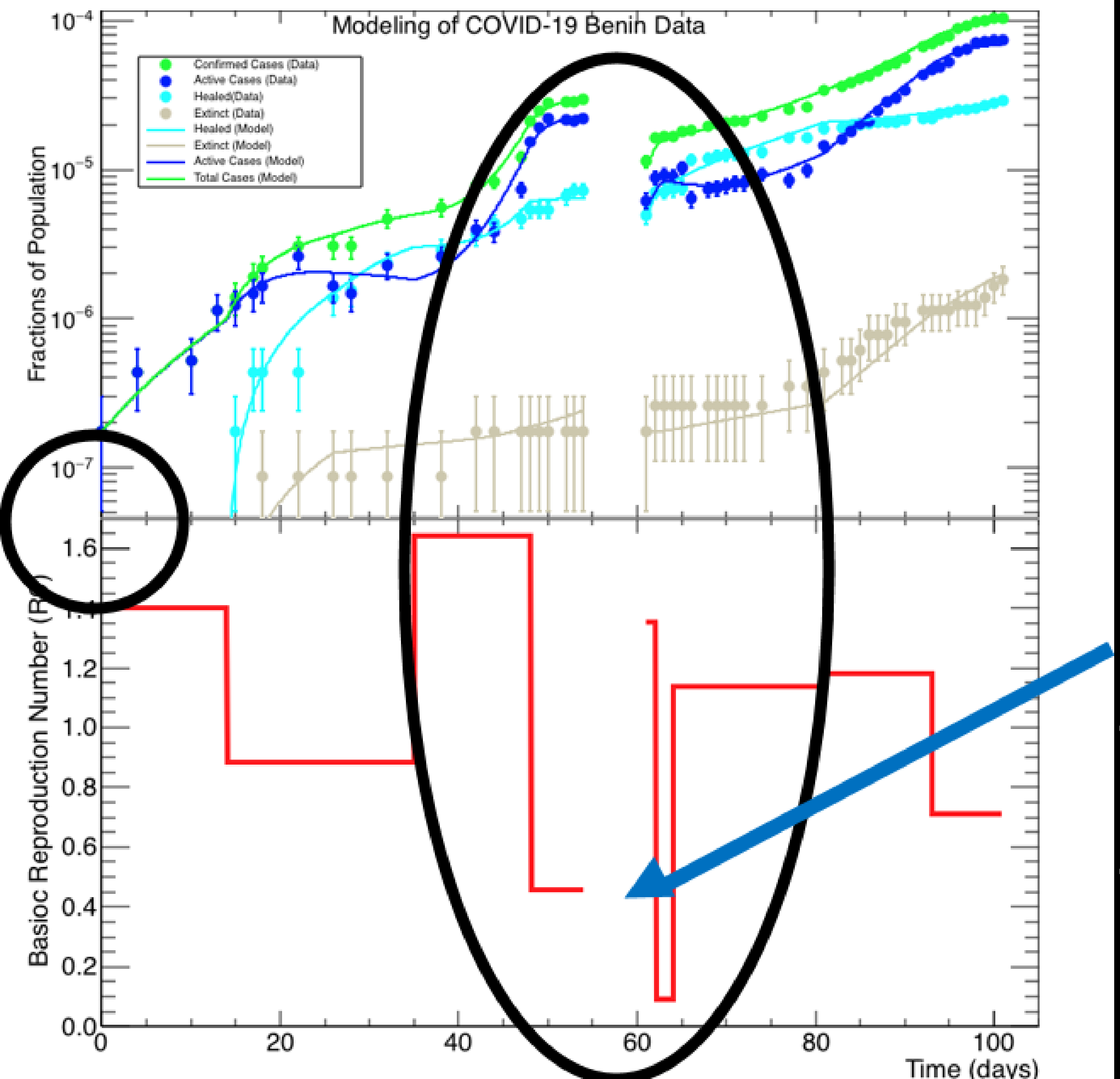


Basic Reproduction Number (R0)
R0(t)=reproduction number
Systematic Uncertainty
Time in days
Basic Reproduction Number (R0)



Nigeria

In PIII



Benin, *A. Guga*

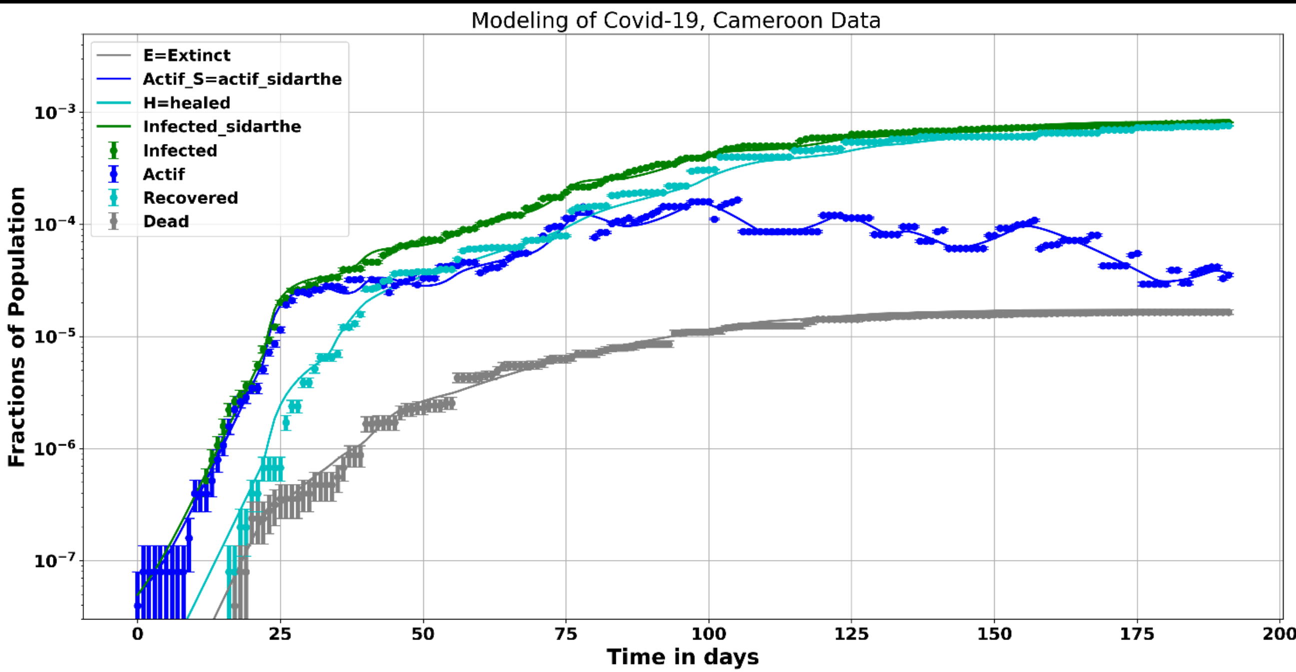
Gov't measures to curb spread

Gap on the data on days 55-60: change in data reporting

Systematic difference before (PCR + RD test) & after the gap (PCR test only)

RD tests used only for contact tracing

Cameroon, *T. Mabote & F. Onyie*



1st Case : 06 March

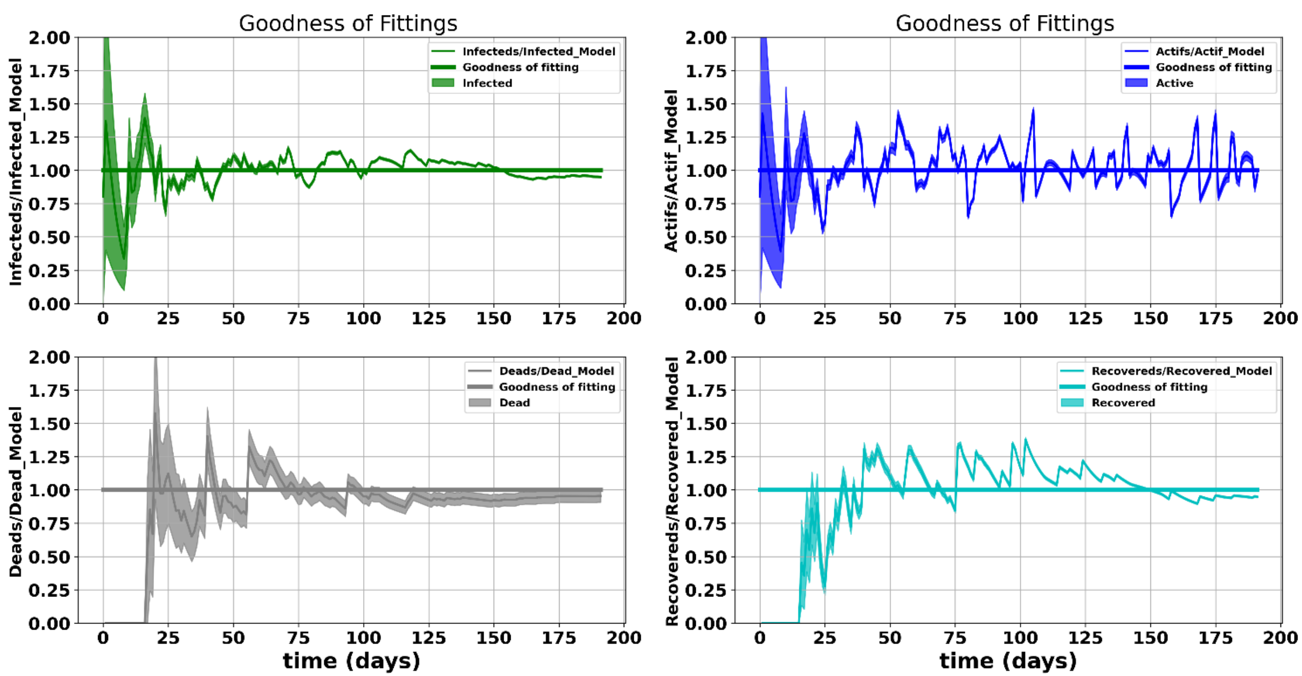
Closed borders on 18/03

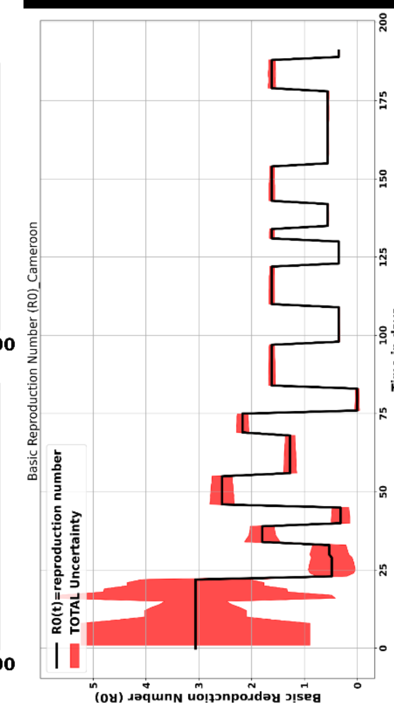
Screening & quarantine measures for returnees

Schools closed

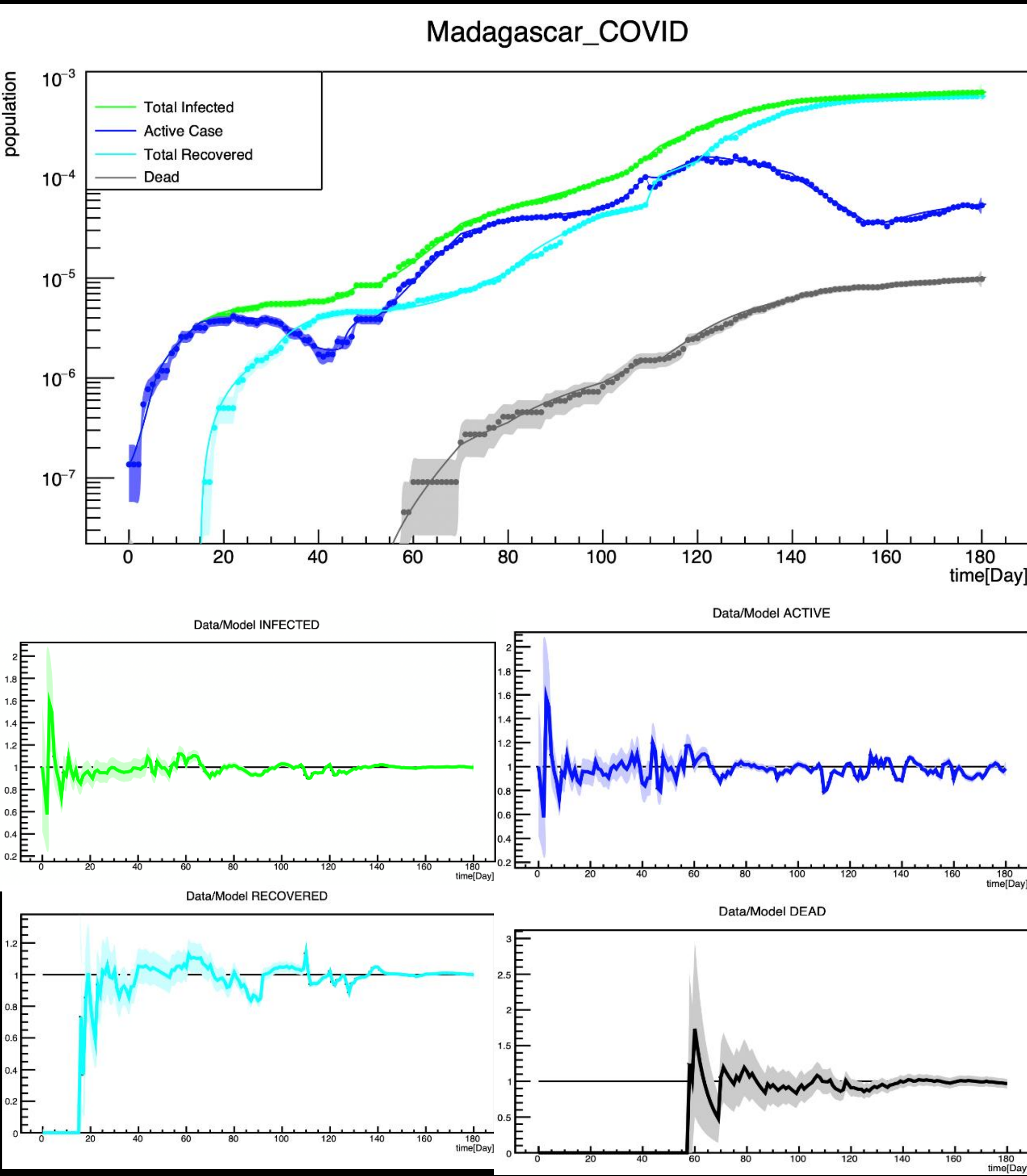
6pm curfew

gatherings restricted





Madagascar, *Dr. L. Rakotondravohitra & Dr. F. Fanomezana*



1st 3 Cases: 20 March

57 cases at end of March

High recovery end of April & dip in Active cases

Increased testing capacity

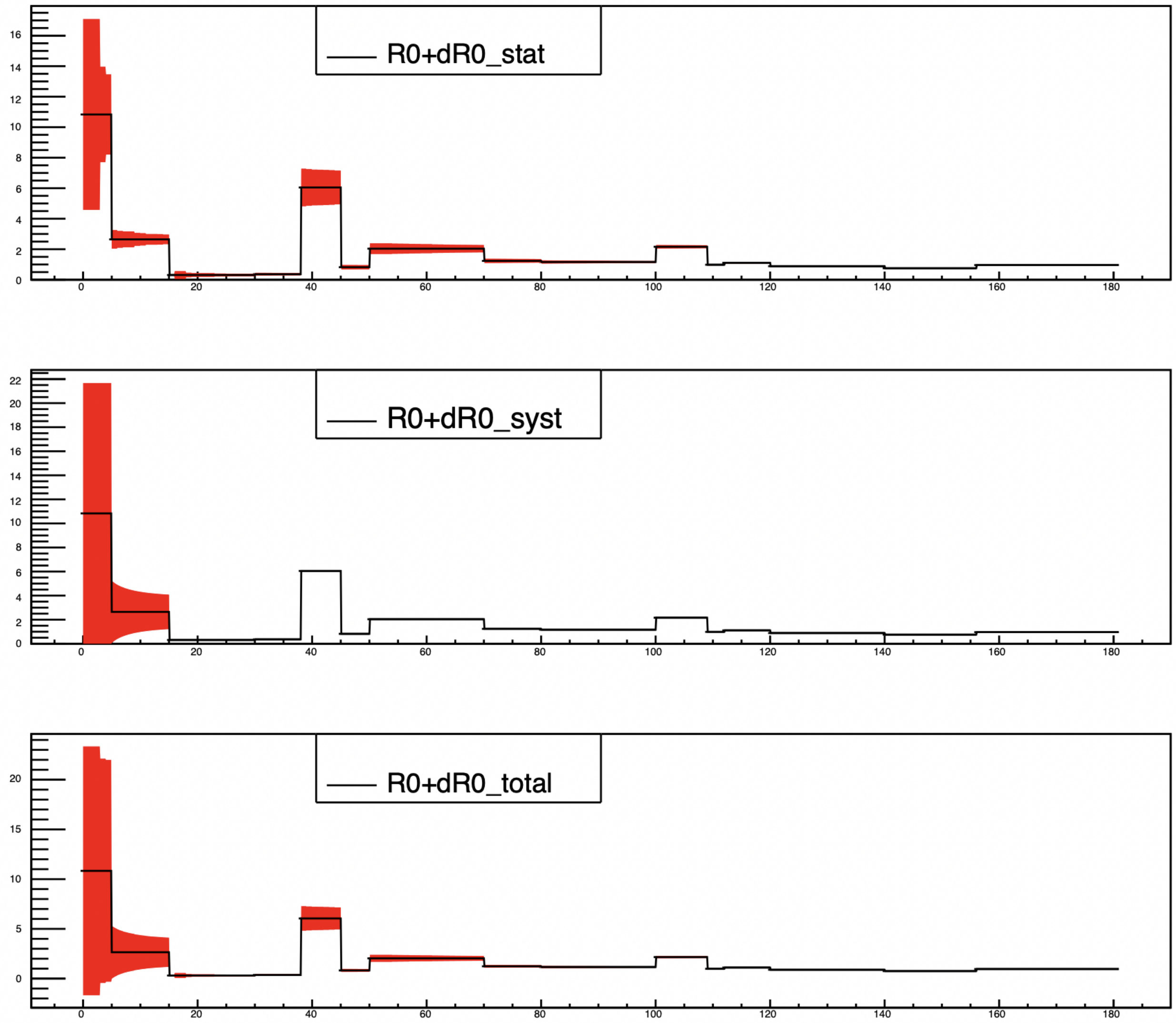
Infection/Active peaked from May-July. Maximum peak in July

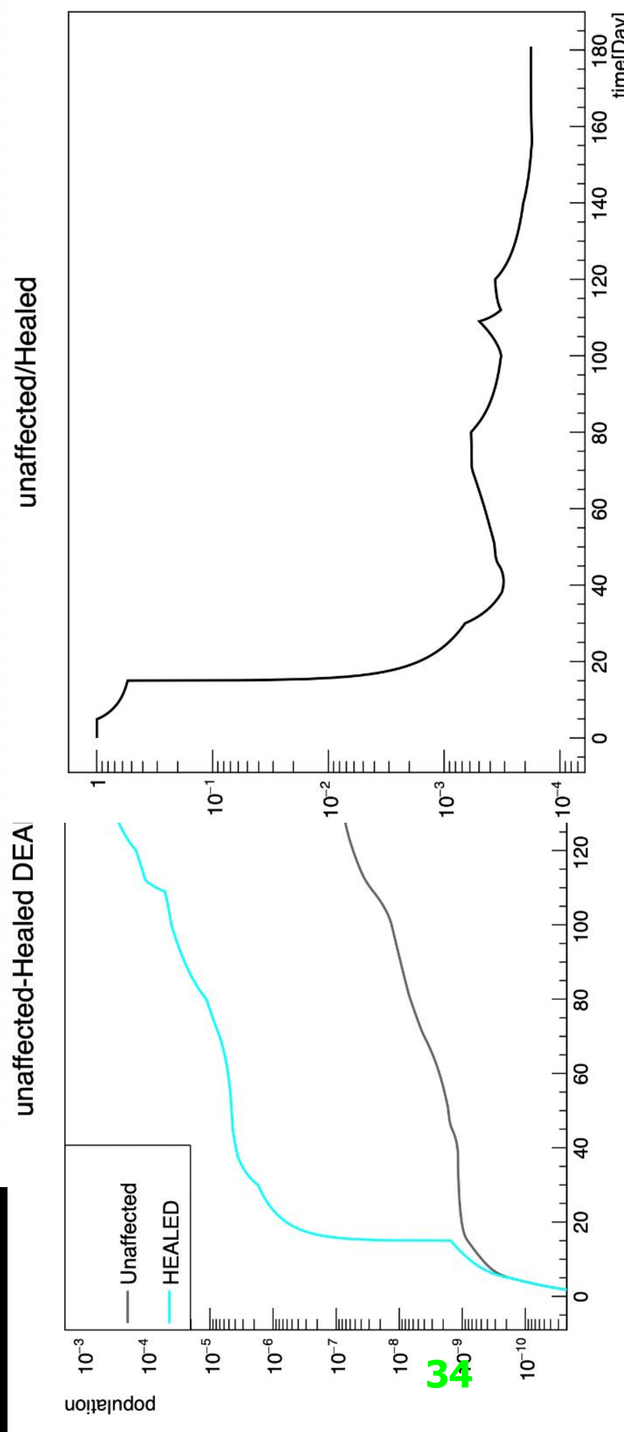
Infection slowed down from August

Flattening of the curve towards end of August

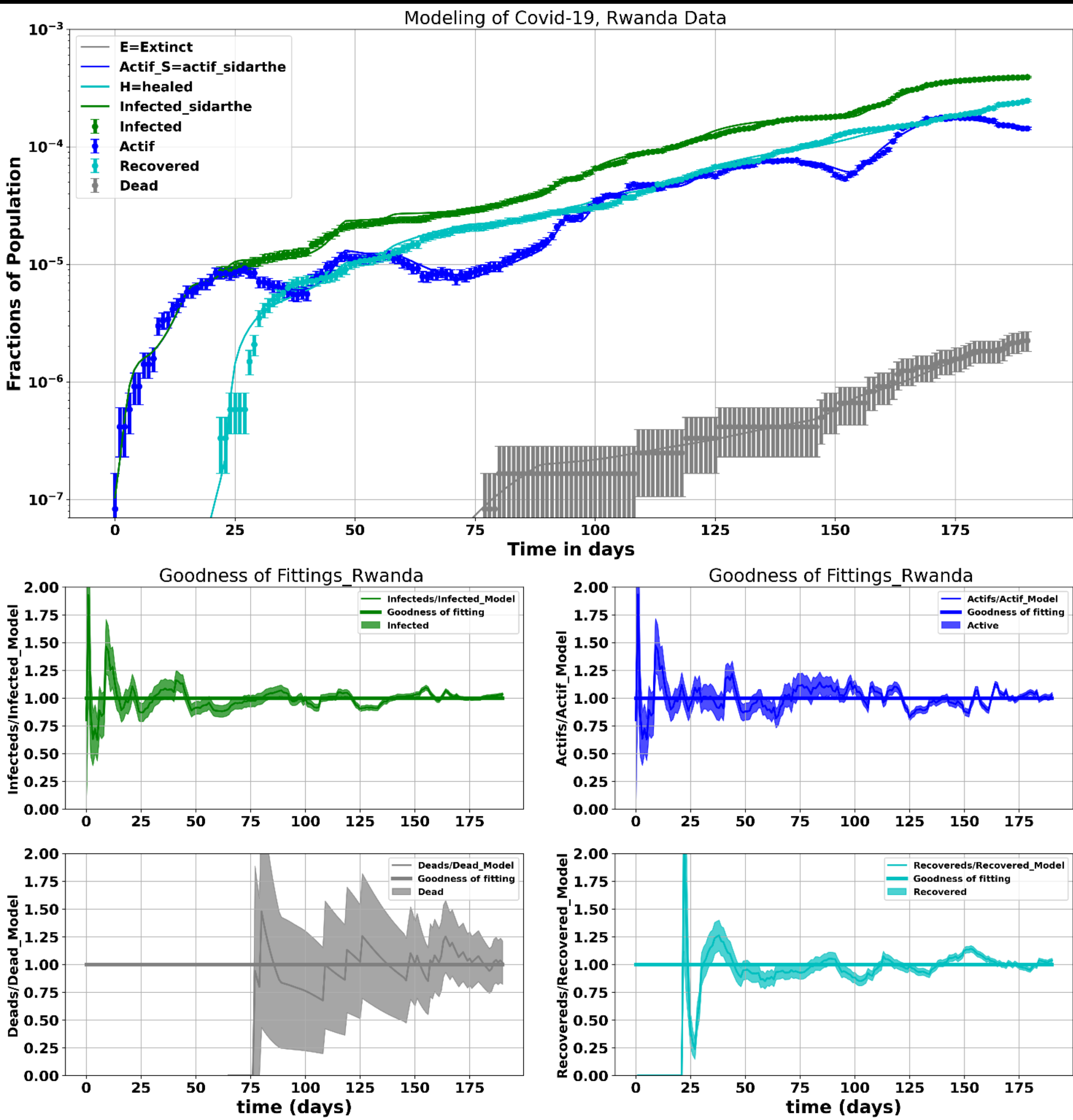
Country is currently closed off to international flights

25-45 cases per week


R0+dR0_stat
R0+dR0_syst
R0+dR0_total


unaffected/Healed
time[Day]
unaffected-Healed DEA
Unaffected
HEALED
population

Rwanda, *T. Mabote & K. Mwale*



1st Case : 14th March

Foreigner

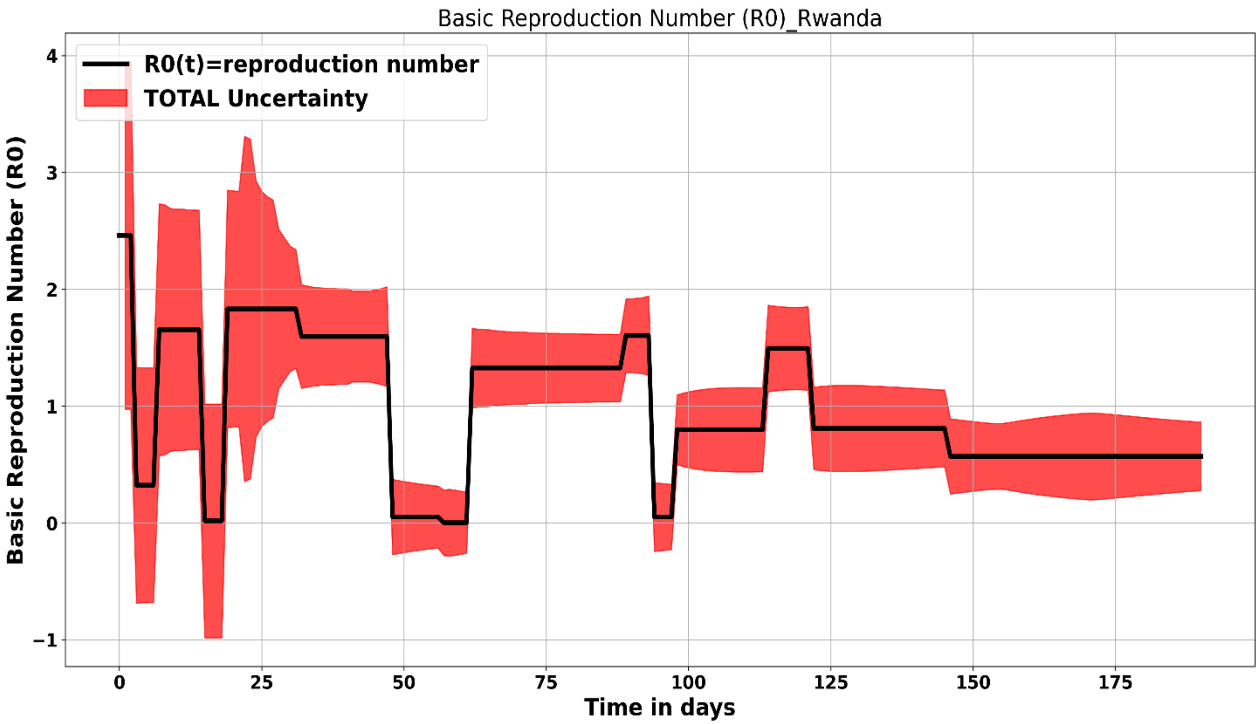
Schools closed immediately

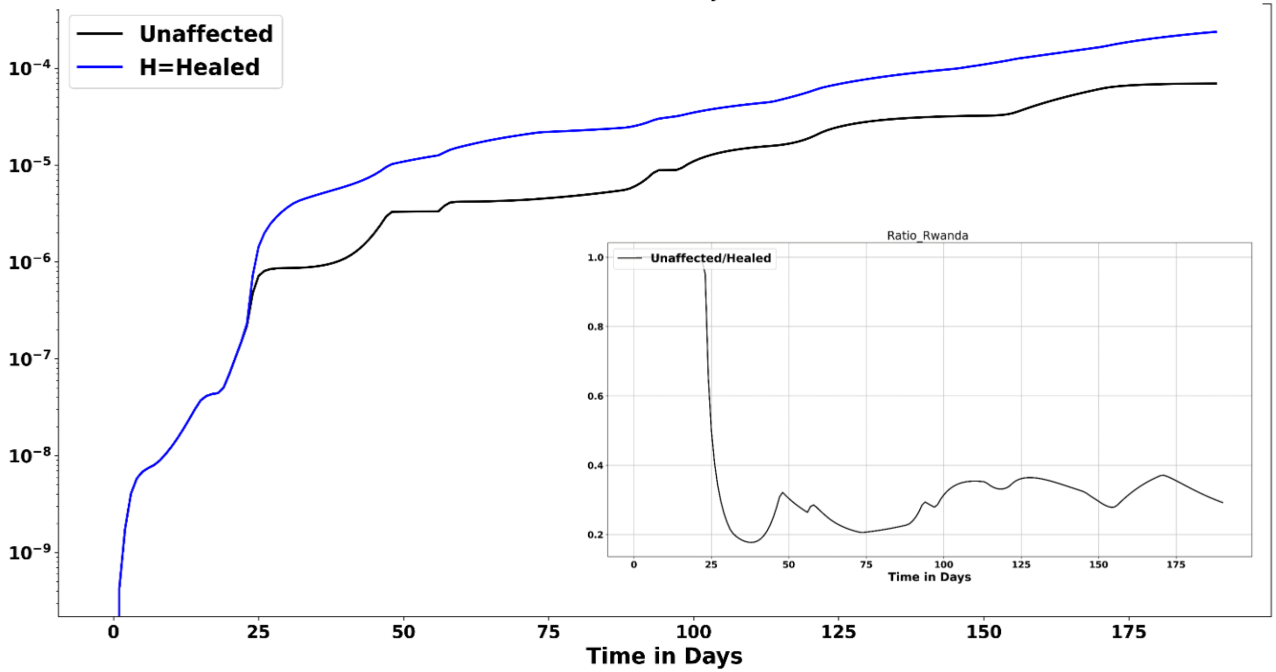
Testing of symptomatic cases & contact tracing

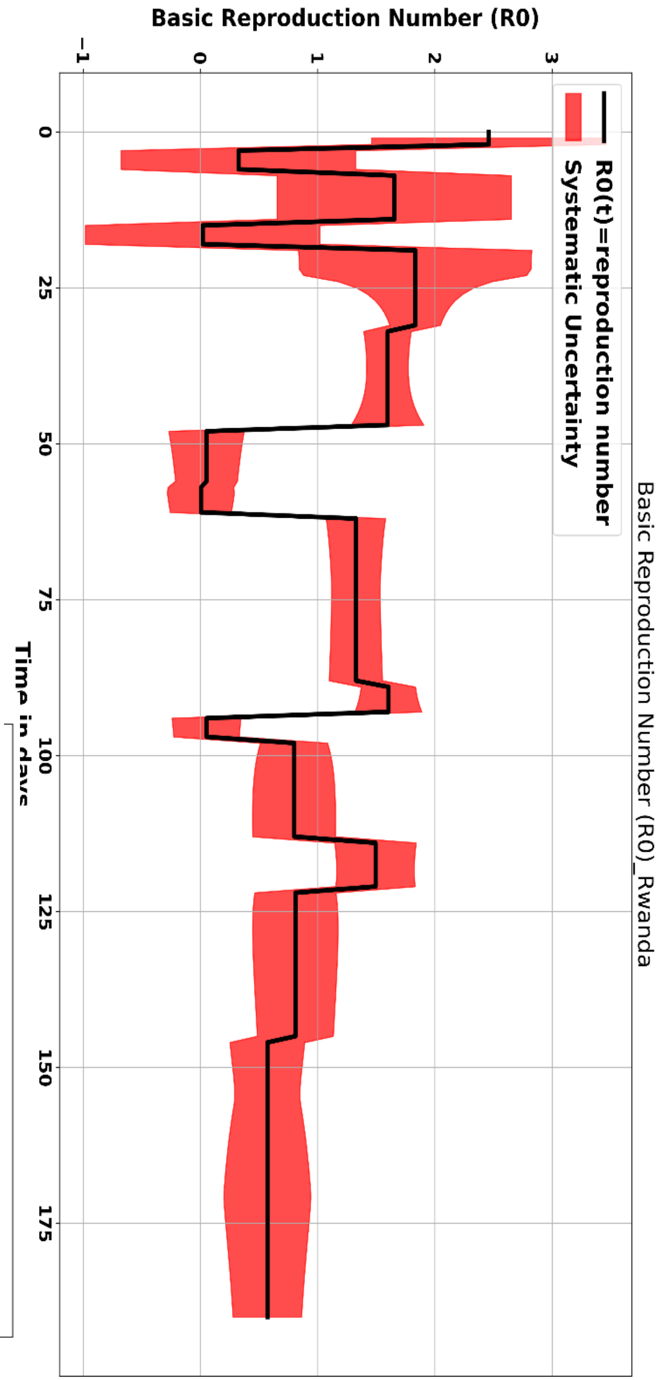
21/03 National lockdown

- **Contact tracing one of the most effective measure used by the Rwandan Govt to test asymptomatic individuals who came into contact with the infected persons.**

Lowers the active cases after just the 1st month of pandemic outbreak


Basic Reproduction Number (R0)_Rwanda
R0(t)=reproduction number
TOTAL Uncertainty
Basic Reproduction Number (R0)
Time in days


Unaffected
H=Healed
Time in Days
Ratio_Rwanda
Unaffected/Healed
Time in Days


Basic Reproduction Number (R0)
R0(t)=reproduction number
Systematic Uncertainty
Basic Reproduction Number (R0)_Rwanda

❑ Conclusion:

- **We model the COVID-19 data using the SIDARTHE(+V), and extracted a time-dependent basic reproduction number (R_0) for each country studied**

- **Our study indicates that the initial measures taken by the African Govts were effective in curbing the spread of the virus (R_0<1): PII**

- **Relaxation and difficulties to maintain the control measures over time drive the R_0 in a time-dependent cyclic pattern of rises and falls**

In most countries, e.g. South Africa, after the initial growth, the epidemic has slowed and the R_0 has fallen below 1

- **Impact of vaccination ~1 year later, no R_0 peaks: PIII**

- **The African Puzzle? The Low transmission rates: Youthful population? Low testing capacity? BCG vaccine? High Disease burden? Unreported deaths(2.4%)? Early preparedness? Experience from other epidemics? Worth investigating: OVERALL**

The ‘A’ Team

?

COLLABORATORS:

Dr. Kétévi A. Assamagan
Togo & USA

Team Leader

Experimental Physicist
Brookhaven National Laboratory
Fellow, African Academy for Sciences

Research Interests: Search for new physics beyond the Standard Model of particle physics

Alma Mater: University of Lomé
Co-founder, ASP

Passionate: Physics Education,
Communication &
Outreach

Prof. Simon Connell
South Africa
Professor of Physics
University of Johannesburg

Research Interests: nuclear & particle physics

Alma Mater: University of Witswaterand
Passionate: Technology & Innovation

SAIP former president

Prof. Azwinndini Muronga
South Africa

Executive Dean of Science
Nelson Mandela University

Interests: Research, Training & Innovation in Science

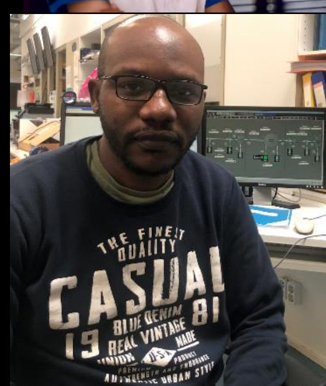
Assoc. Prof. Dephney Mathebula
South Africa
Snr Lecturer,Biomathematic
UNISA

Dr. Somiealo Azote
Togo
Postdoc, Italy
ASP 2016

Dr. Kossi Amouzouvi
Togo
Lecturer
KNUST, Ghana
TU Dresden, Germany
APS2014

Dr. Laza Rakotondravohitra
Madagascar
Resident
Duke University Medical Center, USA

Dr. Fenosoa Fanomezana
Madagascar
PostDoc
University of Antananarivo



George Zimba
Zambia
PhD
University of Jyväskylä, Finland
ASP2016

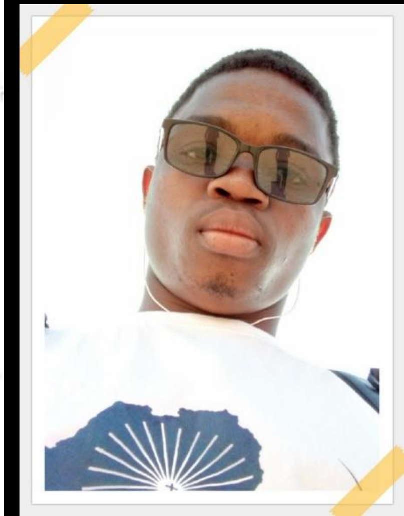
Ebode Fabien Onyie
Cameroon
PhD
University of Yaounde
ASP2016

Kondwani C. Mwale
Malawi
Masters of Physics
University of Rwanda, Rwanda
ASP2020

Aluwani Guga
South Africa
PhD Physics
Nelson Mandela University
ASP2022

Essossolim C. Haliya
Togo
PhD
University of Abomey-Calavi, Benin
ASP2018

Toivo S. Mabote
Mozambique
MSc Astronomy, UP
ASP2020



Francisco Macucule
Mozambique
MSc Astronomy

Moses Kamwela
Lecturer & HoD
Pharmacology
Lusaka Apex
Medical Uni.

Jesutofunmi A. Fajemisin
Nigeria
Un. Of South Florida
ASP2018

Dr. Jean
Baptiste
Fankam Fankam
Postdoc, Wits
South Africa

Abigail Amankwah
Ghana
MSc Maths,
AIMS Ghana

Prof. Claudio Moises Paulo
Mozambique
Coordinator
Astro & Space
Universidade Eduardo Mondlane

Mulape Kanduza
Zambia
Cancer Diseases Hospital
Lusaka, Zambia

PDRA, Newcastle University
PhD, Jodrell Bank Centre for Astrophysics
University of Manchester

PhD Supervisor: Dr. Robert Beswick
Research Interests: Extragalactic radio sources: AGNs + SFGs, VLBI

Kenyan

Alma Mater: University of Nairobi, University of Manchester

Passionate:
STEM Mentorship for Schoolgirls

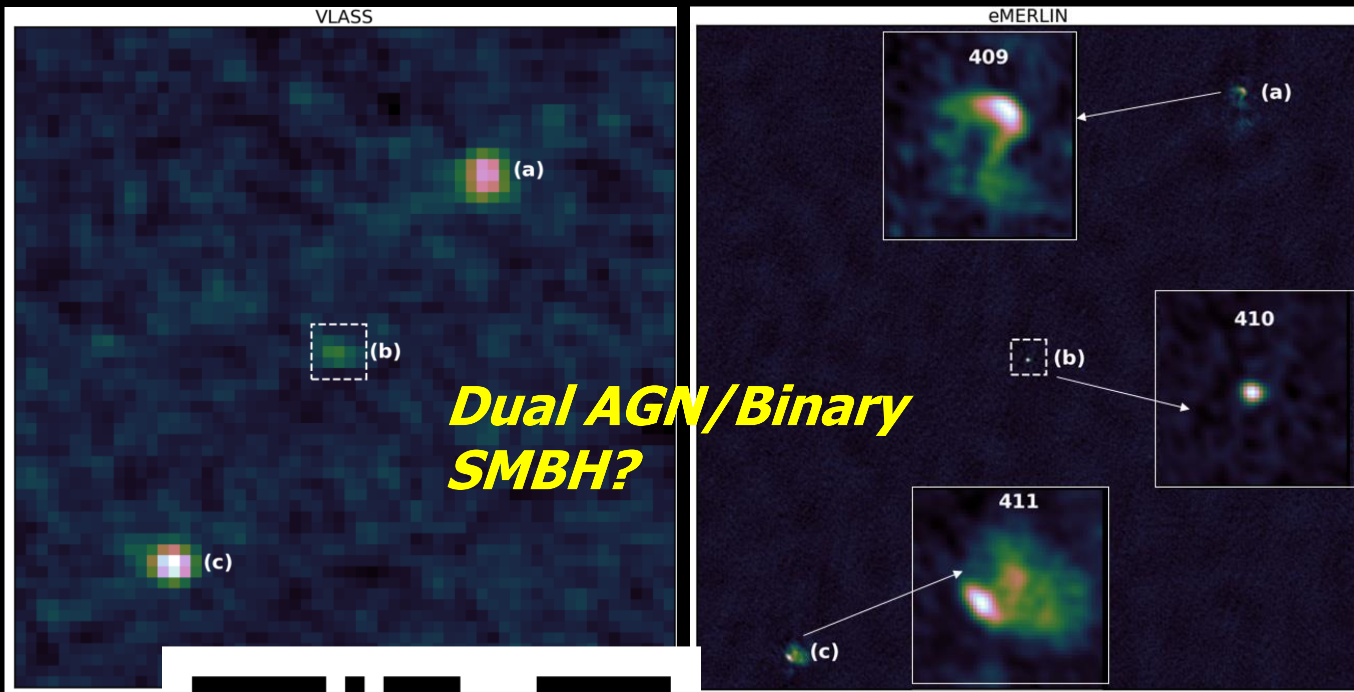
100% Primary-Secondary Education Transition

IAU-OAD UoM JIVE UoN

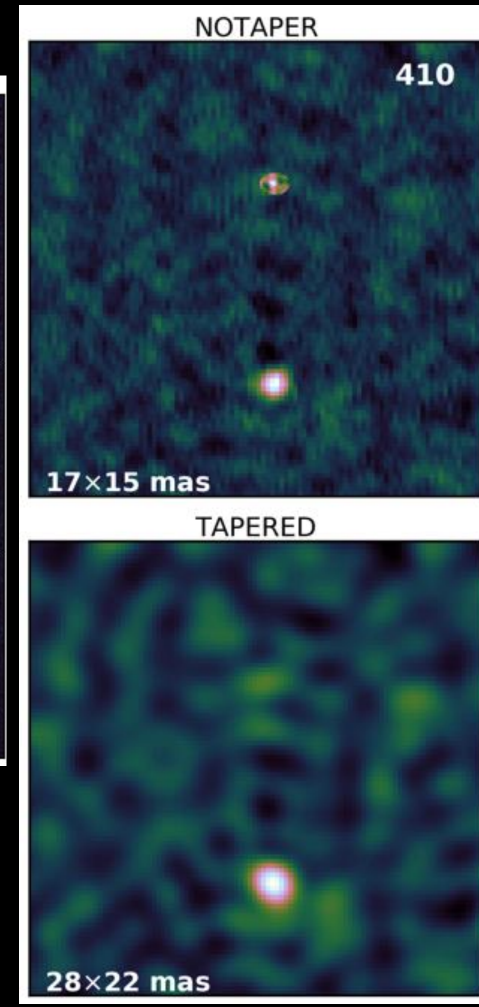
http://arxiv.org/abs/2212.01874

Njeri et al. 2022, MNRAS, Accepted

Serendipitous discovery?

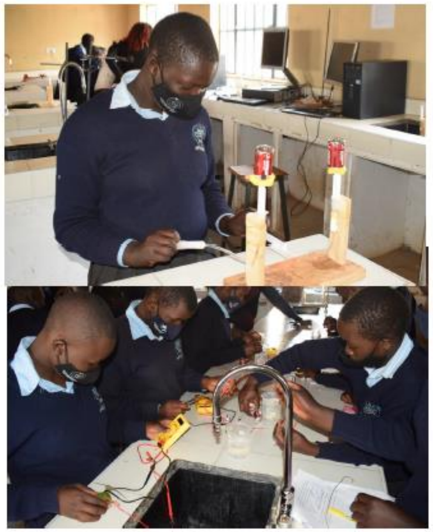


Dual AGN/Binary SMBH?



Elimisha Msichana Elimisha Jamii

III. Astro-STEM Workshops & Mentorship

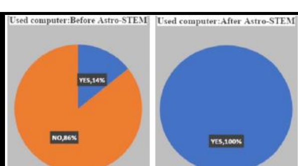


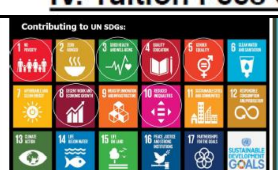
- Facilitate early participation of girls in Sciences
- Change misconceptions about STEM (e.g. Physics) subjects among schoolgirls
- Increase No.of girls selecting Physics in Year 3-4 & sitting for the Physics National exam

IV. Computer Literacy

- Computer Literacy non-existent
- Introduction to computer Astro-STEM
- Provided 7 computers so far

IV. Tuition Fees Scholarship





EMEJ/

- Overarching
secondary (
- Address these socio-economic issues via **Astronomy Outreach**, **mentorship programmes**, targeted **STEM Workshops** & **Scholarship** opportunities
- Demography: **schoolgirls,12-20 yrs**.

I. Mentorship & Outreach:

1. Engage the local communities (girls, parents, teachers, education stakeholders)- discuss ways to positively tackle above socio-economic issues.
2. Pair each teen girl with a life-long mentor
3. Leadership & mentorship programme.

~5000 schoolgirls in Kenya

Tracking & Monitoring:

- Mentorship throughout high school, long-term tracking & monitoring.
- Phone calls, one-on-one.

Can you be a mentor????

GET IN TOUCH!!!!!

4th Biennial ASP, Kigali Rwanda 2016!!!