NELSON MANDELA UNIVERSITY

Epidemiological Models for COVID-19

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MANDELA WEBINAR

When is the Peak?
COVID-19 DATA MODELS

Wednesday 24 June 2020 @15:00

COVID-19 Modelling Collaboration

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And many Facebook, LinkedIn and WhatsApp Friends

Outline

- Epidemiological models for COVID-19
- Lessons learns so far
- The South African case
- Beyond modeling COVID-19

Epidemiological models

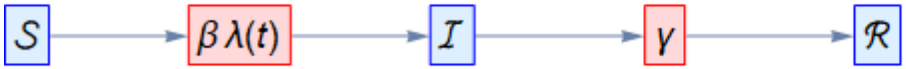
- Infectious diseases are still a more common cause of death in the world
- The transmission interactions in a population are very complex so that it is difficult to comprehend the large scale dynamics of disease spread without the formal structure of a mathematical model
- An epidemiological model uses a microscopic description e.g., the role of an infectious individual, to predict the macroscopic behaviour of disease spread through a population.
- Experiments with infectious disease spread in human populations are often impossible, unethical or expensive.
- Data is sometimes available from naturally occurring epidemics or from the natural incidence of endemic diseases; however, the data is often incomplete due to underreporting

Epidemiological models

- This lack of reliable data makes accurate parameter estimation difficult so that it may only be possible to estimate a range of values for some parameters.
- Since repeatable experiments and accurate data are usually not available in epidemiology, mathematical models and computer simulations can be used to perform needed theoretical experiments.

Epidemiological Models for COVID-19

The SIR Model



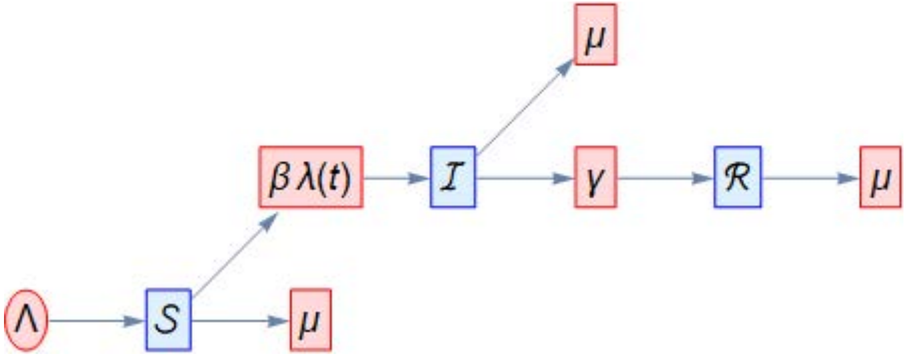
The coefficient β is the *transmission rate constant*, and $\lambda[t]$ is the *force of infection*.

The parameter γ is the *recovery rate constant*, and is defined as $\gamma == \frac{1}{\tau}$, where τ is the average *duration of infection*.

$$\mathcal{S}'[t] == -\beta\,\mathcal{S}[t]\,\lambda[t]$$
$$\mathcal{I}'[t] == -\gamma\,\mathcal{I}[t] + \beta\,\mathcal{S}[t]\,\lambda[t]$$
$$\mathcal{R}'[t] == \gamma\,\mathcal{I}[t]$$

$$\lambda[t] == \mathcal{I}[t]$$

The SIR Model including population demographics



The D Model for COVID-19

The D Model

1. "Global analysis of the COVID-19 pandemic using simple epidemiological models" https://arxiv.org/pdf/2005.06742.pdf
2. "Model studies on the COVID-19 pandemic in Sweden" https://arxiv.org/pdf/2004.01575.pdf

$$
\begin{aligned}
\frac{dS}{dt} &= -\lambda SI, \\
\frac{dI}{dt} &= \lambda SI - \beta I, \\
\frac{dR}{dt} &= \beta I, \\
N &= S(t) + I(t) + R(t),
\end{aligned}
$$

If the recovery rate is very low during the pandemic time interval (as it is indeed the case for COVID-19 up to now), the SIR equations are then reduced to the single equation of the well-known SI model.

This assumption may be reasonable if the spreading time of the pandemic is much faster than the recovery time, i.e. $\lambda \gg \beta$.

Lessons learned

The D Model in China

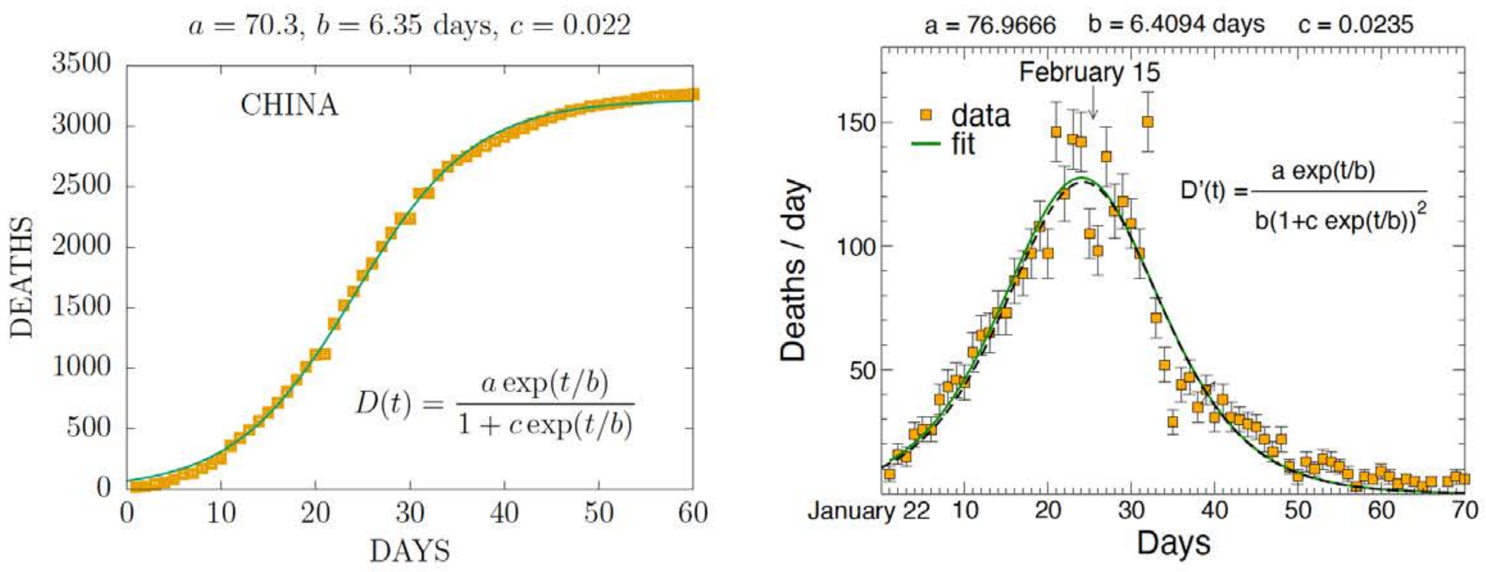


FIG. 1: Fits to total (left panel) and daily (right panel) deaths by COVID-19 in China using the $D(t)$ and D′(t), respectively. The dashed curve shows a fit to the daily deaths using the parameters determined to fit the total deaths (top of left panel), which provides similar results to an independent fit (parameters on the top right), given the statistical fluctuations in the daily rates. Data are taken from [19].

Lessons learned

The D2 vs ESRI Models in different countries

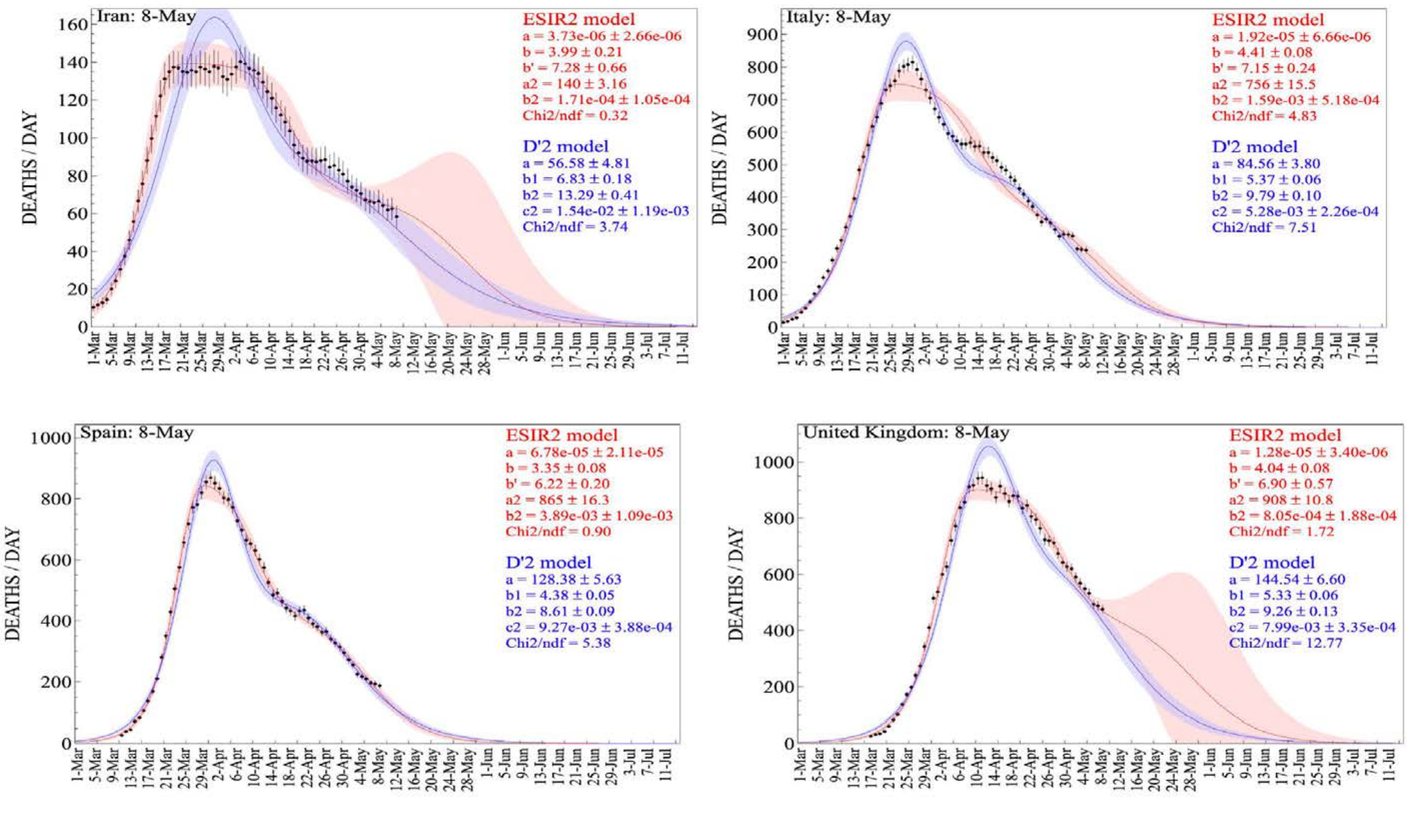
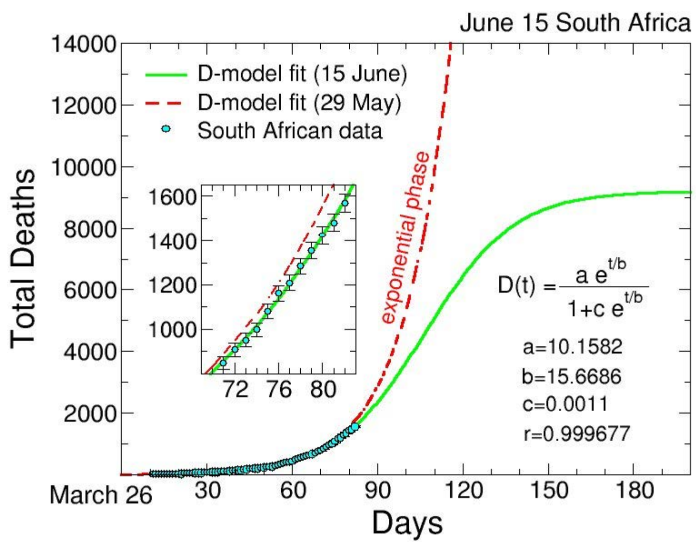
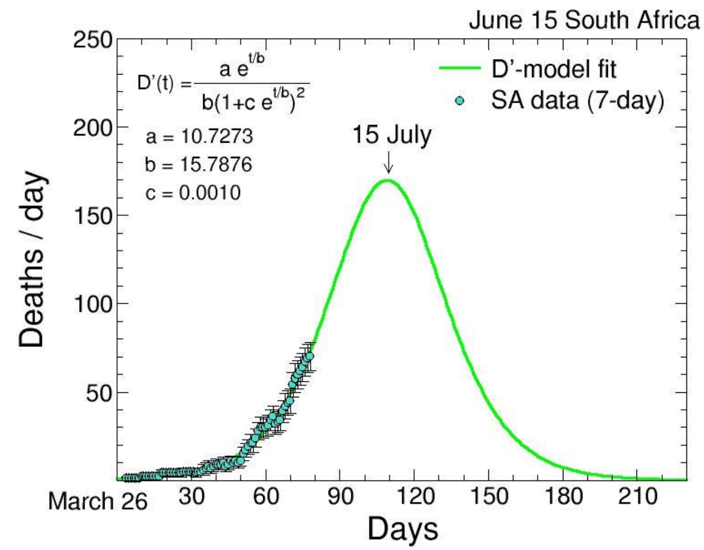


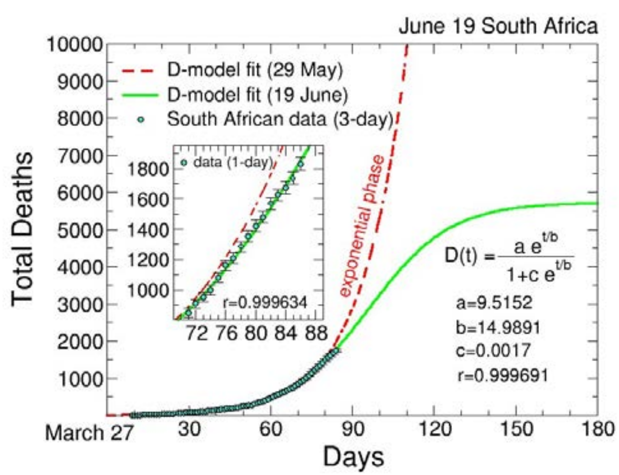
FIG. 11: Daily deaths fitted with the ESIR2 and D'_2 models with a cut off of May 8 2020.

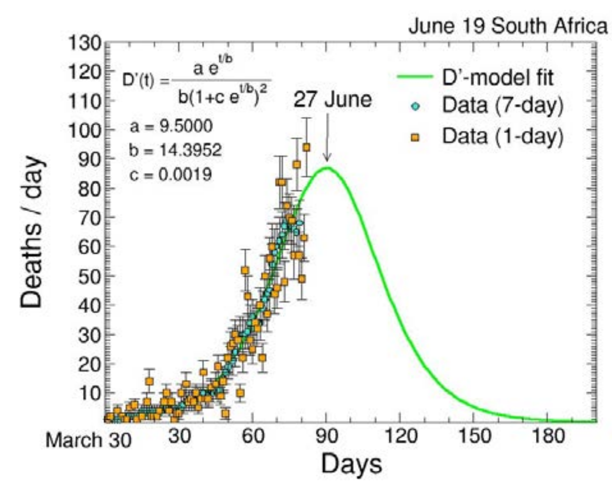
COVID-19 in South Africa

The D Model for South Africa



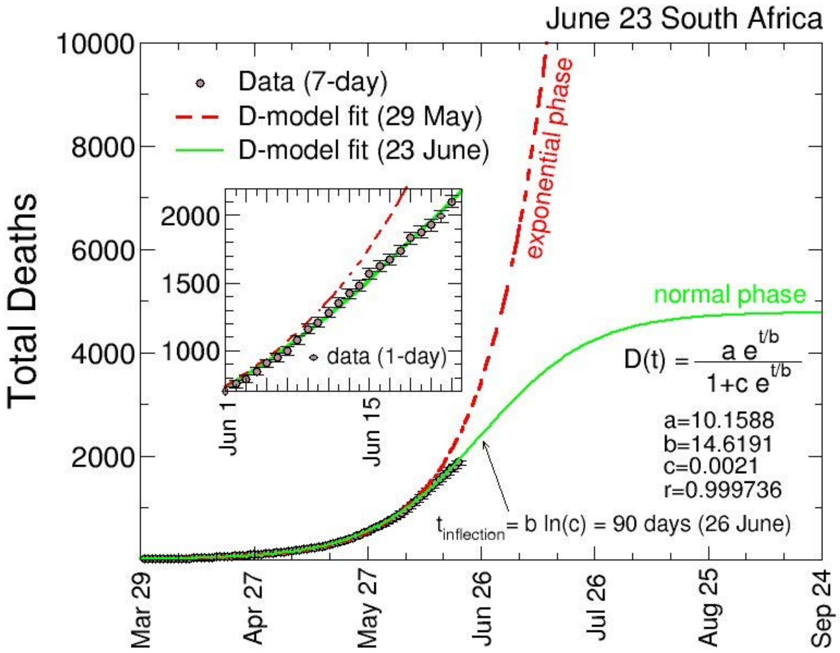


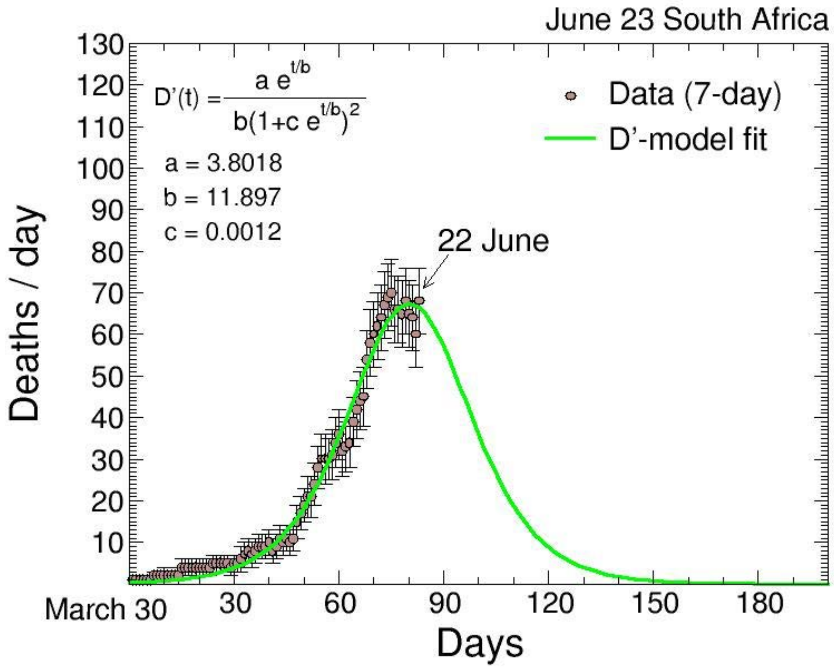




COVID-19 in South Africa

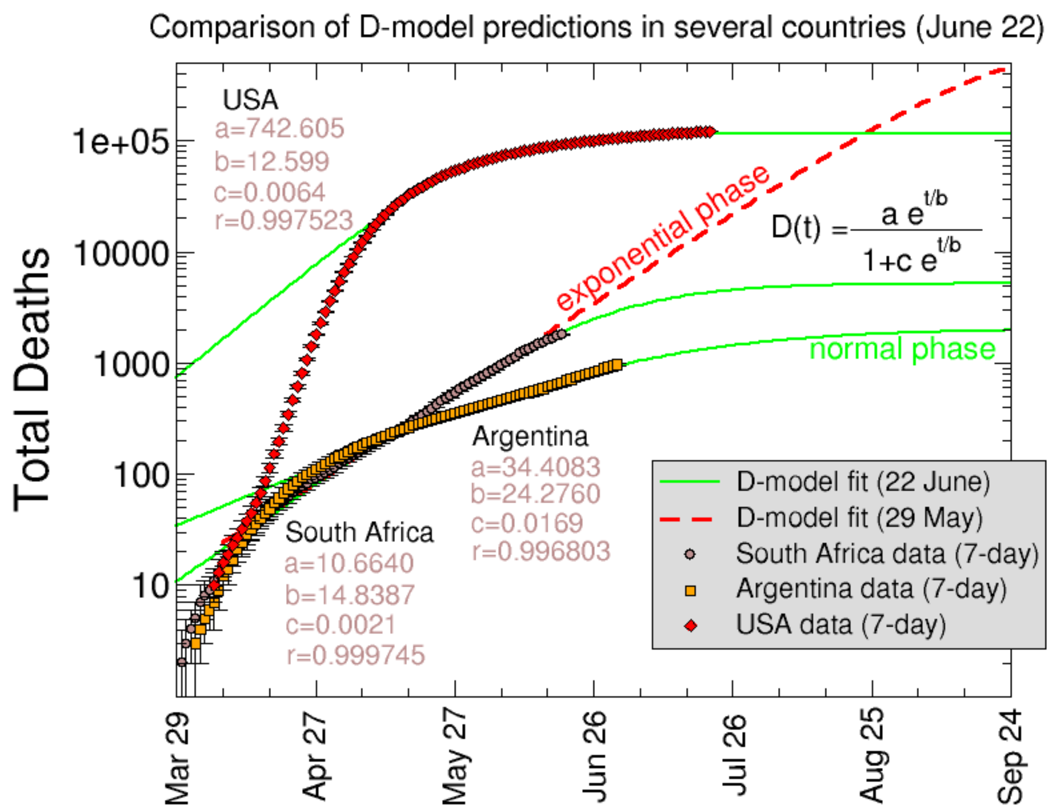
The D Model for South Africa





COVID-19 in South Africa

The D Model for South Africa vs other countries



Lessons from available data

- Challenges in epidemiological modelling remain
- This is a very complex system, which involves many degrees of freedom and millions of people
- Question remain: Can any model predict the evolution of an epidemic from partial data?
- Previous pandemics can help us to understand the current COVID-19 pandemic
- Modelling COVID-19 will help humanity to be better prepared in the future.
- In the end – "It is in your hands" and the fight against COVID-19 continues

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