

Common sense science for epidemics

Sourendu Gupta

TIFR Colloquium
09 September, 2020

Discussions, corrections, and lessons from/with DTP, TIFR, and ISRC. RPG and her network of microbiologists and virologists across the world.

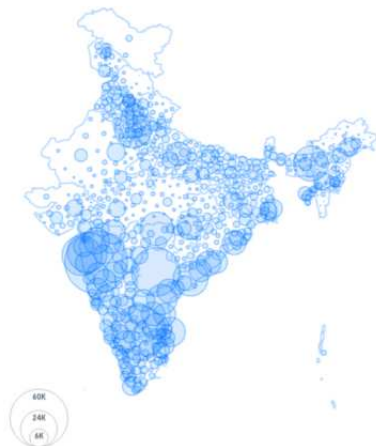
Outline

- 1 Measurements and errors
- 2 Dimensional analysis and classical mechanics
- 3 Characterising COVID-19

Gloom and doom?



State/UT	Confirmed	Active	Recovered	Deceased	Tested
Maharashtra	8,63,062	2,10,978	6,28,773	25,964	†90.4K 45.7L
Andhra Pradesh	4,76,806	1,02,067	3,70,163	4,276	39.7L
Tamil Nadu	4,51,827	51,633	3,92,507	7,687	51.3L
Karnataka	3,79,486	99,101	2,74,196	6,170	32L
Uttar Pradesh	2,53,175	58,595	1,90,818	3,762	62L
Delhi	1,85,220	18,842	1,61,865	4,513	17.1L
West Bengal	1,74,659	23,654	1,47,553	3,452	20.7L
Bihar	1,44,134	16,981	1,26,411	741	37.2L
Telangana	†2,511 1,38,395	32,915	†2,579 1,04,603	†11 877	†62.1K 16.7L



Credulity about numbers

Coronavirus growth rate declines 40% post lockdown, giving India hope

Country's average growth of between March 15 and 31 was 2 per cent. Post lockdown, in the last two weeks the growth rate has come down to 1.2 per cent.

Topics

Coronavirus | Health Ministry

Ruchika Chitravanshi | New Delhi
Last Updated at April 18, 2020 01:49 IST

Business Standard, 18 April 2020



Times of India, 21 April 2020

[Home](#) / [Cities](#) / [Mumbai](#) / Maharashtra's Covid growth rate falls below India's for the first time

Maharashtra's Covid growth rate falls below India's for the first time

The seven-day compounded daily growth rate (CDGR) for Maharashtra has remained below the national average for three consecutive days now.

Indian Express, 3 June 2020

Science from Data

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Natural sciences study objects and phenomena; what to ask in order to understand what we see; what to measure in order to answer a question.

Most TIFR seminars and questions are about not about the numbers, but about how you get to the numbers. Perhaps the most important step in experimental sciences is to understand errors; before you make a measurement you study the measuring instrument. Data is the last step.

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Richard Hamming

The purpose of computing is insight, not numbers.

Public health versus science

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Examples of bad science

When will the COVID-19 crisis end? Until now, many predictions: ranging from April 3 to September 10.

Some even continually updated, so that model predictions have changed by several months over several months!

Incorrect understanding of input data. Insufficient attention to the meaning of models.

Precise is not accurate

Number of detected infections on day t is $I(t)$. Suppose this is growing exponentially: $I \sim 2^{t/T}$.

Then doubling time is

$$\frac{1}{T} = \frac{1}{\log 2} \times \log \left[\frac{I(t+1)}{I(t)} \right]$$

One day the doubling time is 5 days, the next day it is 8 days.
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Scientific skepticism: can you distinguish a growth period of 5 from 8 days with one day's data? What accuracy do you need?

$$100 \times 2^{1/5} = 114.9 \quad 100 \times 2^{1/8} = 109.0$$

Require errors in $I(t)$ to be less than 5%. Does I have this accuracy?

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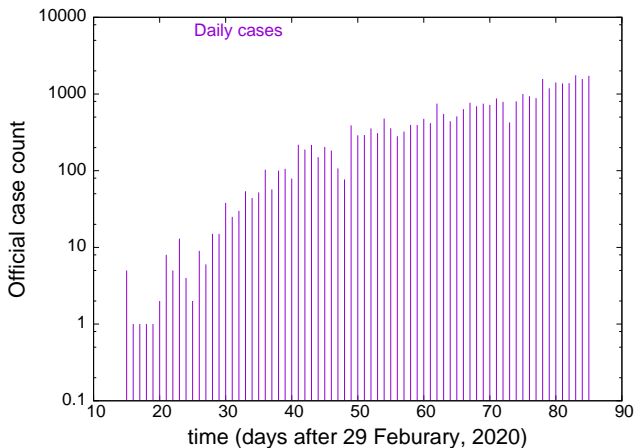
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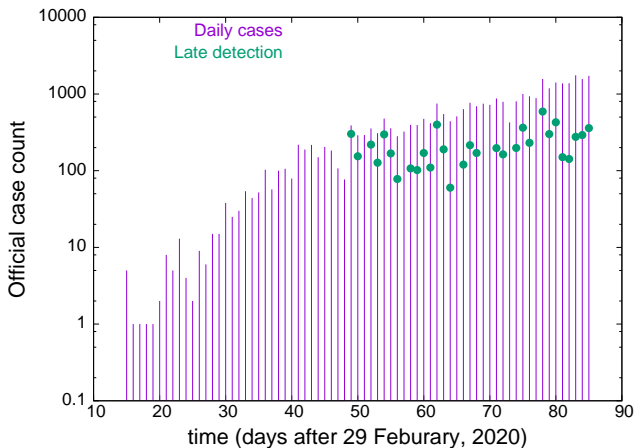
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As the number of cases increases, the number of samples to be tested also increases? Is the testing process scaling up with perfect efficiency?

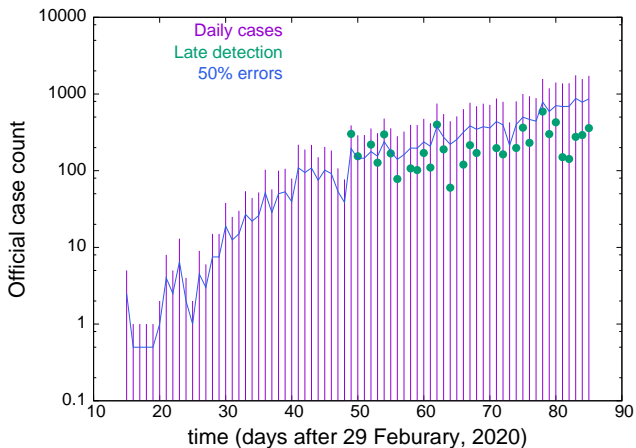
MCGM self-correction



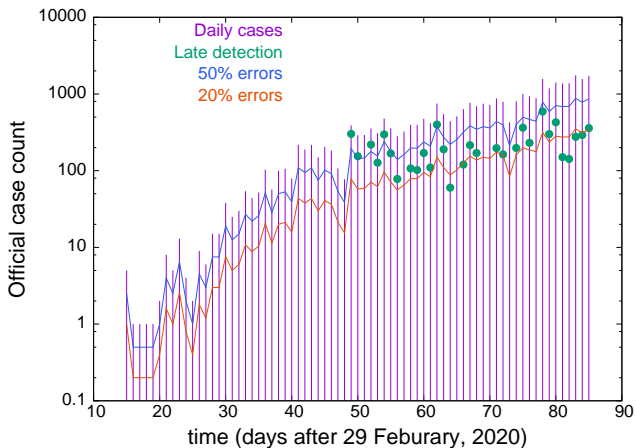
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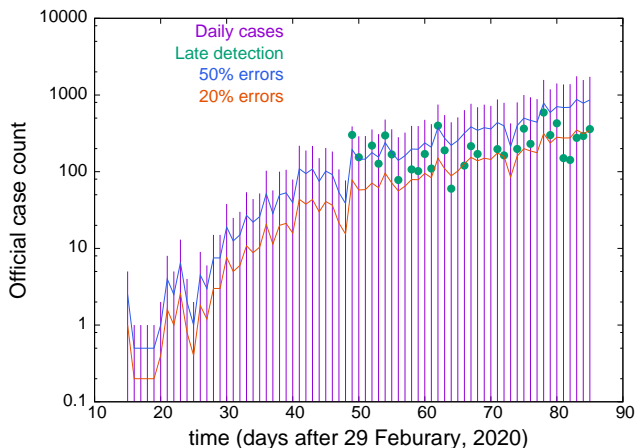
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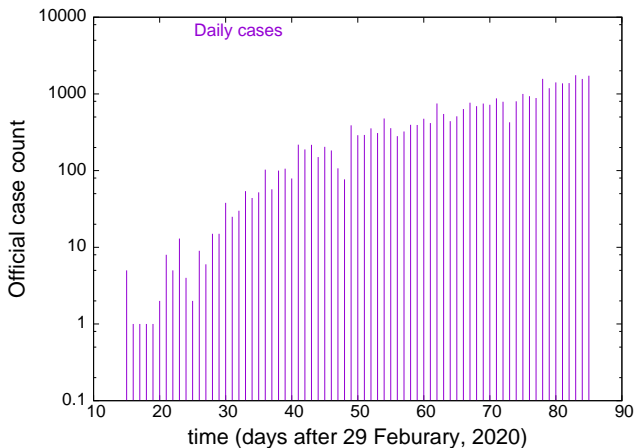


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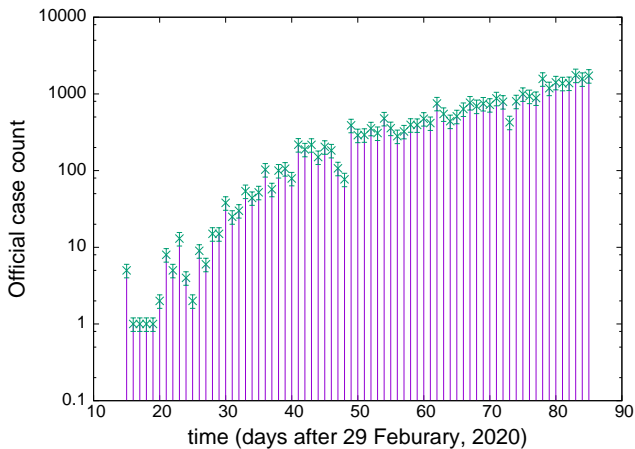


Errors due to delays, about 20–25% of the case numbers. Errors due to detection?

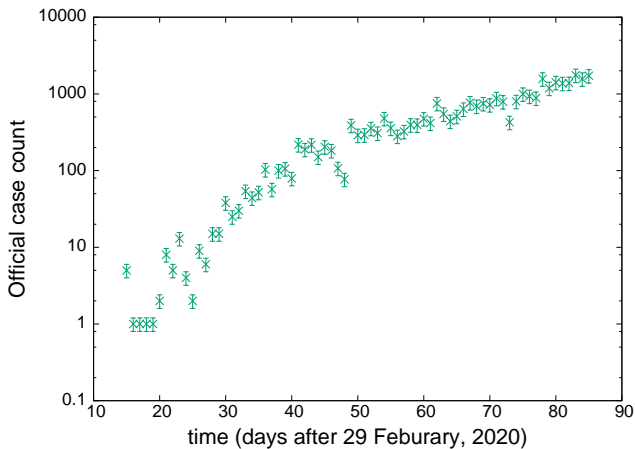
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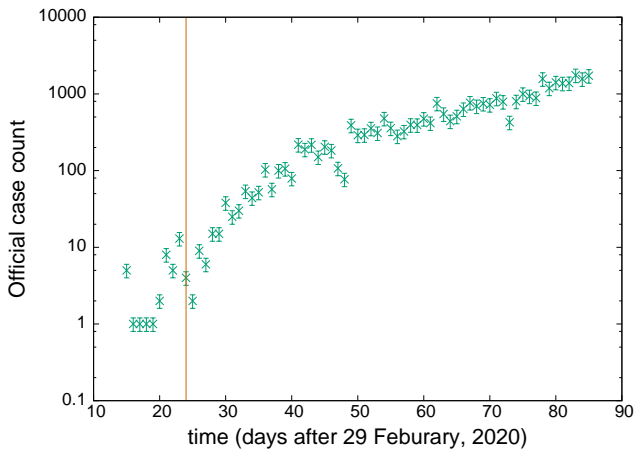
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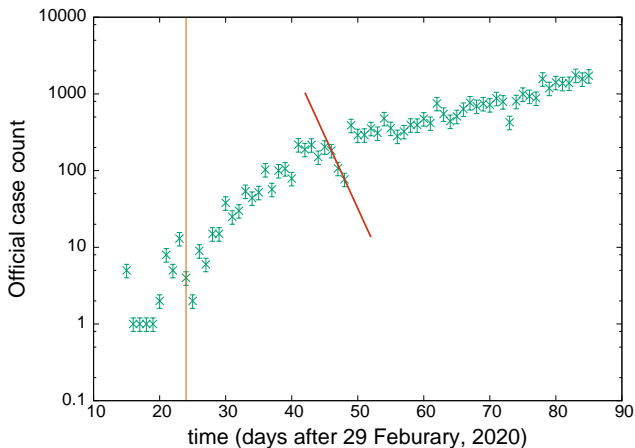
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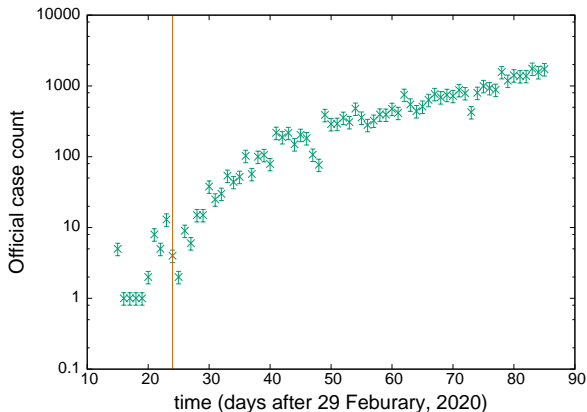


Errors and early history



Odd behaviour

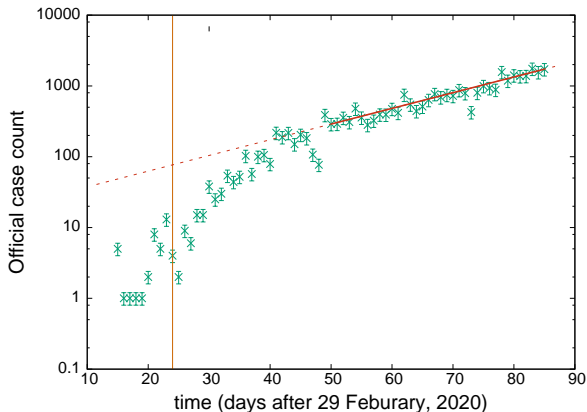
If lockdown causes flattening, then why does it come into play after 25 days? COVID-19 **serial time** is 3–5 days*. Why flattening after 6–8 generations of infections?



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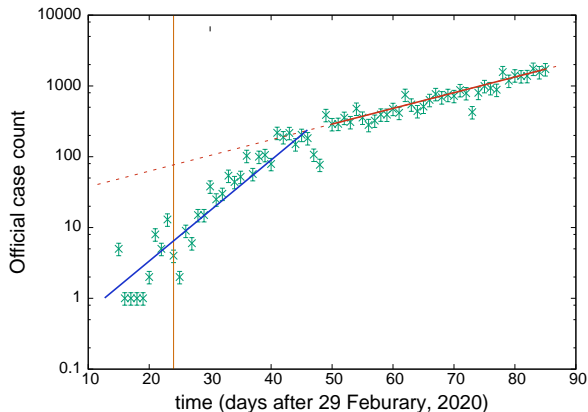
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Resolving the puzzle

Compared 6 cities till mid-April: Ahmedabad, Chennai, Delhi, Indore, Mumbai, Pune. Cases rose in all cities with steadily changing doubling time:

$$I(t) \sim 2^{t/(T_0+tT_1)}$$

In all cases $T_0 \sim 1$ day, and $T_1 \sim 0.15\text{--}0.20$ days. Why this adaptation?

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Another oddity: in the early days, Pune epidemic seeded by Mumbai. Most cases traced to contact in Mumbai or travel from Mumbai. Still cases rose faster in Pune than Mumbai.

Very likely to be a systematic error in the measurement. I attributed it to **disease surveillance network being built up**.

SG, [arxiv:2005.08499](https://arxiv.org/abs/2005.08499)

Alternative explanations, with this change fitted to epidemic models gave predictions which were proved wrong by the end of May.

Remaining unknowns

- 1 Sero-prevalence of antibodies (TIFR study + others) show that official disease surveillance catches one or two orders of magnitude less of infected than actual. Why?
- 2 CFR (**case fatality ratio**) is the ratio of deaths due to COVID-19 and the number of detected cases. Observed CFR is currently around 5.8%. IFR (**infection fatality ratio**) is the ratio of deaths and the actual number of actual infections. Using official figure for deaths, and sero-data for infections, IFR is less than 0.1%.
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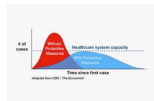
There are possible autocorrelations in the data of 3–4 days. Is this due to delays in the detection of new clusters of infections? Or is it due to clusters of infections in health workers?

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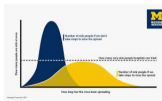
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Puzzles

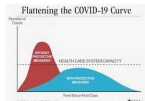
How should we maximize our own chances of survival?



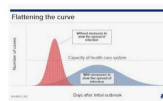
How to Flatten the Curve on Coronavirus ...
nytimes.com



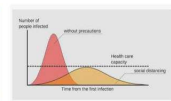
Flattening the Curve for COVID-19: What ...
healthing.usfmhealth.org



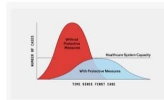
Flattening the coronavirus curve: It's ...
abcnews.go.com



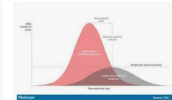
Coronavirus: What does flattening the ...
cbc.com



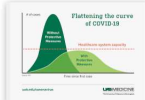
What does "flattening the curve" really ...
wslw.com



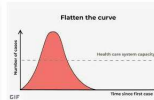
How Long Does the Coronavirus Live on ...
wired.com



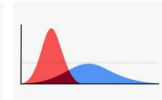
Flattening the Curve: Graphic Shows ...
medscape.com



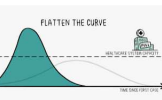
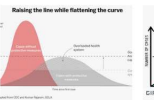
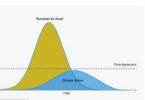
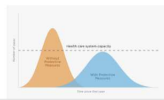
To stop spread of COVID-19, flattening ...
wslw.com



This One Graph Shows Why Flattening ...
sciencelife.com

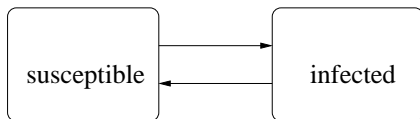


We can "shrink" the COVID-19 curve ...
newsroom.unsw.edu.au

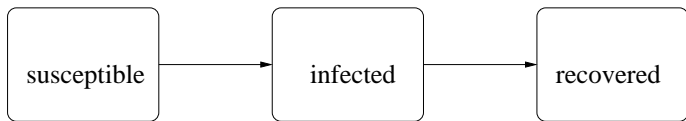


What are these curves? What remains fixed, what is changed?

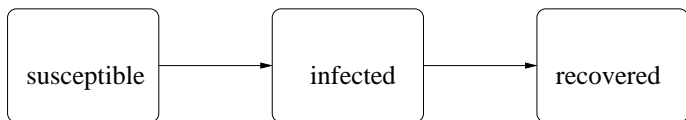
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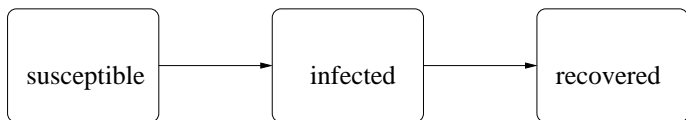
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$$\frac{dS}{dt} = -\alpha SI, \quad \frac{dI}{dt} = \alpha SI - \beta I, \quad S + I + R = P$$

α is the rate of infections, $1/\beta$ is the mean time of recovery. For COVID-19 $1/\beta \simeq 2$ weeks.

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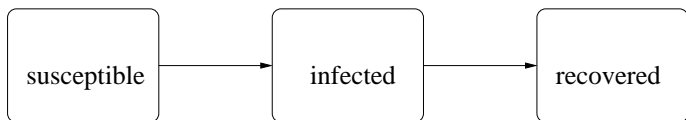


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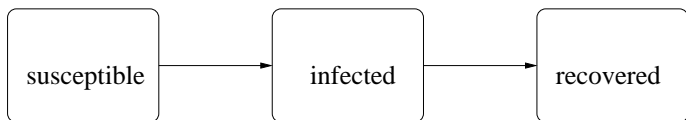


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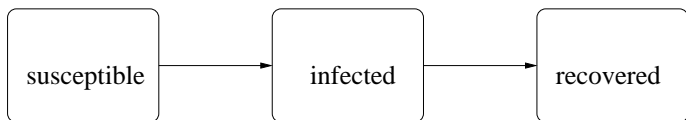
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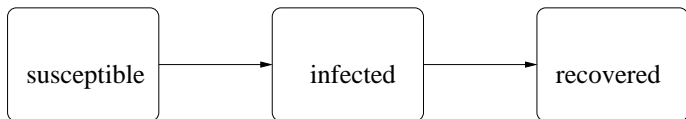
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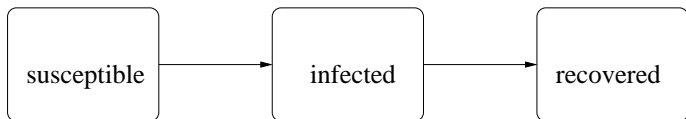
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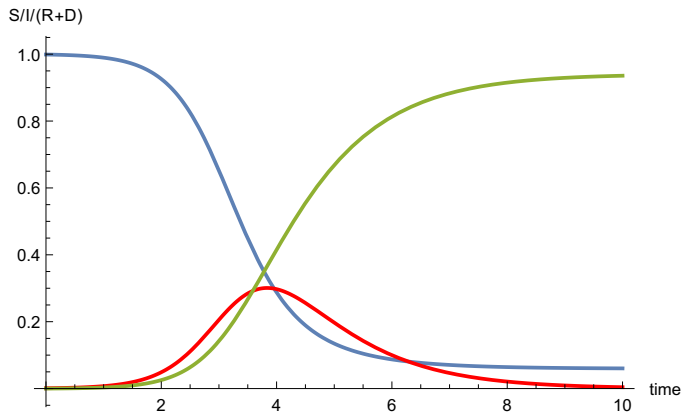
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Terminology: R_0 is the **basic reproduction rate**. Sometimes $1/\beta$ is called the **recovery time**.

Numerical solution



Phase space picture

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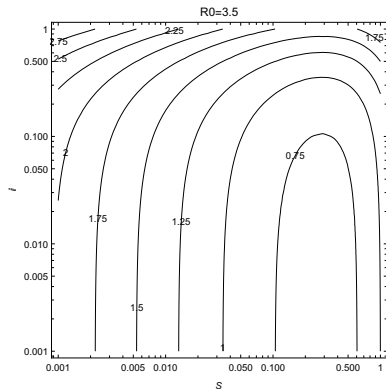
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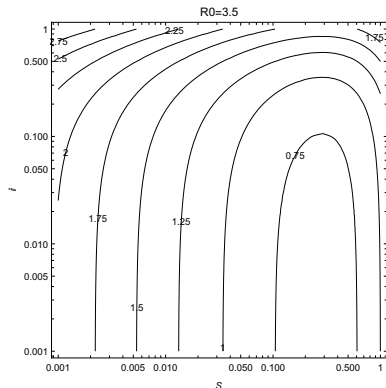
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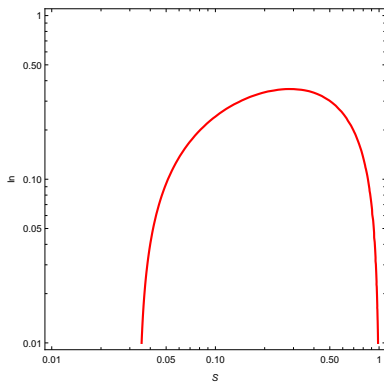
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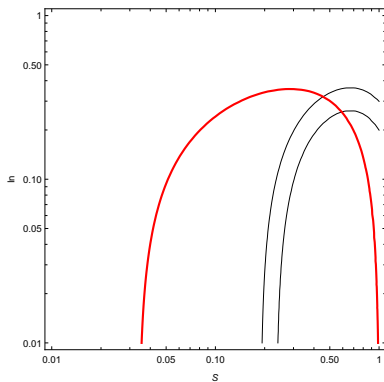


The epidemic equations can be derived from a Lagrangian: classical mechanics. Go to Hamiltonian: symplectic structure, KAM tori. Many new and interesting questions, not asked before.

The logic of a lockdown

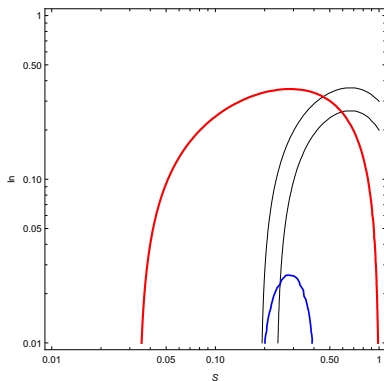


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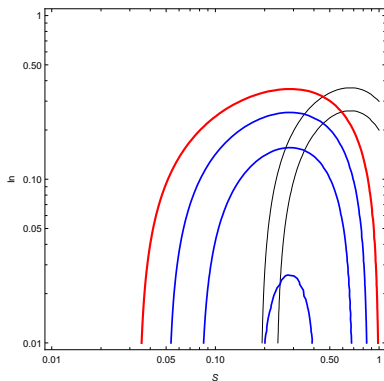
Your conceptual framework determines imaginable solutions

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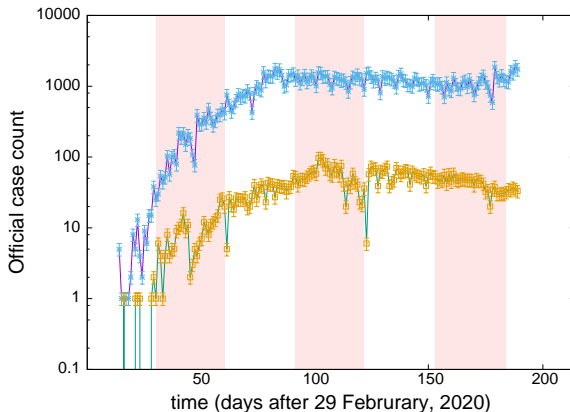
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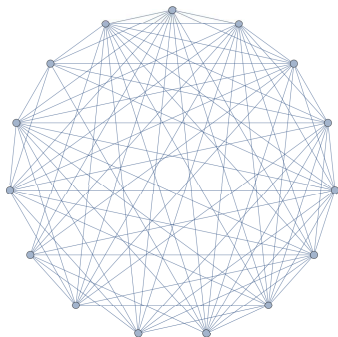
Something unexpected



Three month long plateau. Serial time is 3–4 days, recovery time is 10–20 days. So major mismatch of scales. Dynamics at work, but plateau not expected in compartmental models.

Networks: ami tomake Barabasi

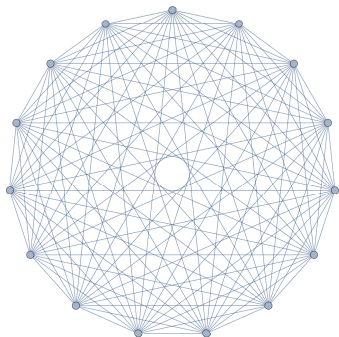
Mumbai in partial lockdown now: many housing complexes gate off visitors, meetings between people in different complexes restricted. Model this by incomplete mixing in the reaction equations. Difference from physical sciences: non-local interactions allowed. Resembles reaction-diffusion equations on a network.



Erdős-Rényi graph

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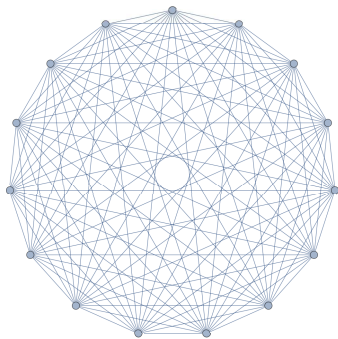
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Complete graph

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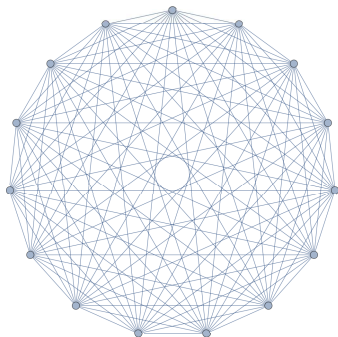
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Fixed points remain as before: $I = 0$.

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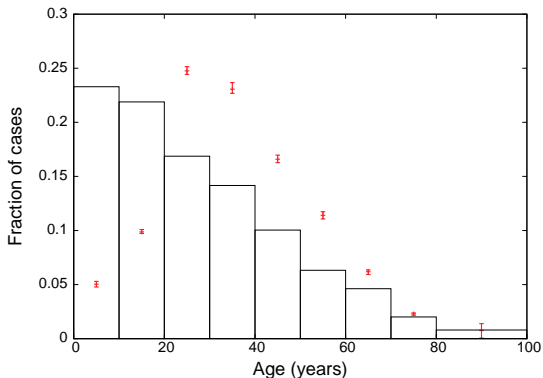
Robust construction; describes Mumbai's plateau with 2 parameters.

SG TIFR/TH/20-34

Outline

- 1 Measurements and errors
- 2 Dimensional analysis and classical mechanics
- 3 Characterising COVID-19**

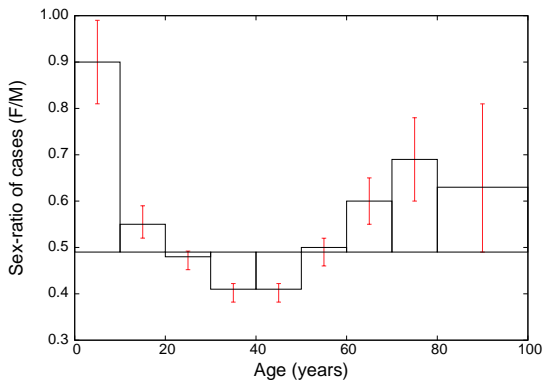
Age distribution of infections



Difference between population age structure and infections age structure: possibly due to different exposure rates, different infection rates, and different testing rates.

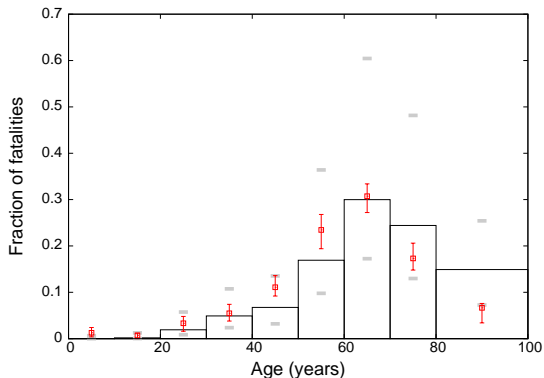
SG, MedRxiv-2020-153957

Sex and age distribution of infections



Women half as likely to be infected as men? Drop in infection rates of women between puberty and menopause! Not seen elsewhere in the world. Special Indian genetics, or differential access to health care?

Fatalities due to COVID-19



Observed age distribution of deaths due to infections from COVID-19 agrees with the rest of the world. This predicts IFR of 0.4%, and implies unidentified deaths.

SG, MedRxiv-2020-153957

Morbidity

Death is one of the outcomes of COVID-19 in the short term.
Complete recovery is another. There is a spectrum in between.

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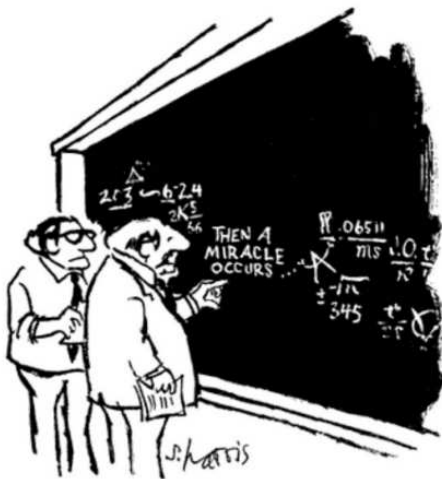
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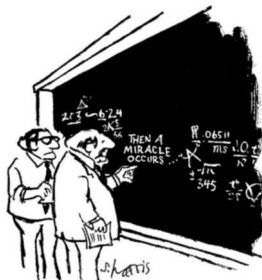
Damage to other organ systems reported.

A vaccine will solve everything



"I think you should be more explicit here in step two."

A vaccine will solve everything



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India and the GAVI Foundation is betting heavily on the Oxford/AstraZeneca vaccine. The Serum Institute has stockpiled 10^6 doses, and can convert facilities to produce 60×10^6 doses a month, 50% for India. Funding from GAVI Foundation.

Nature, news item 03 September, 2020

Numbers! Numbers!

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How effective is the vaccine? Is immunity life long?

Long term solutions

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