III. How can we implement this new safety guideline?

- carbon dioxide monitoring for COVID safety
- COVID Indoor Safety App

Flow (2021), 1:0 1–18
doi:10.1017/flo.2021.1

FLOW CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Monitoring carbon dioxide to quantify the risk of indoor airborne transmission of COVID-19

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Recast safety guideline in terms of carbon dioxide concentration

— Rudnick & Milton (2003), Peng & Jimenez (2021)

Concentration of carbon dioxide $C_2(t)$ evolves as a passive scalar:

$$V\frac{\mathrm{d}C_2}{\mathrm{d}t} = P_2(t) - Q_a(t)C_2$$

where $P_2(t) = N(t)Q_b(t)C_{2,b}$ is the exhaled production rate,

CO_2 removed exclusively by air exchange at a rate $\lambda_a = Q_a(t)/V$

Excess CO_2 evolution: $$\langle C_2 \rangle \approx \frac{\langle P_2 \rangle}{Q_a} - \left(\frac{1-\mathrm{e}^{-\lambda_a \tau}}{\lambda_a \tau}\right)\frac{P_2(\tau)}{Q_a}$$

Relaxes to steady state: $$C_{2,s} = \frac{P_2}{Q} = \frac{Q_b C_{2,b} N}{\lambda_a V}$$ for $\tau \gg \lambda_a^{-1}$

Recast safety guideline in terms of carbon dioxide concentration

$$\langle C_2 \rangle \tau = \int_0^\tau C_2 \, dt < \frac{\epsilon \, C_{2,b}}{\lambda_q s_r \overline{p}_m^2} \cdot \frac{\overline{\lambda}_c}{\lambda_a} \cdot \frac{N}{N_t}$$ ★

where $\lambda_q = Q_b C_q$ is the infection quanta emission rate

Evolving susceptibility of population

N people with probability of being infected, immune or susceptible:

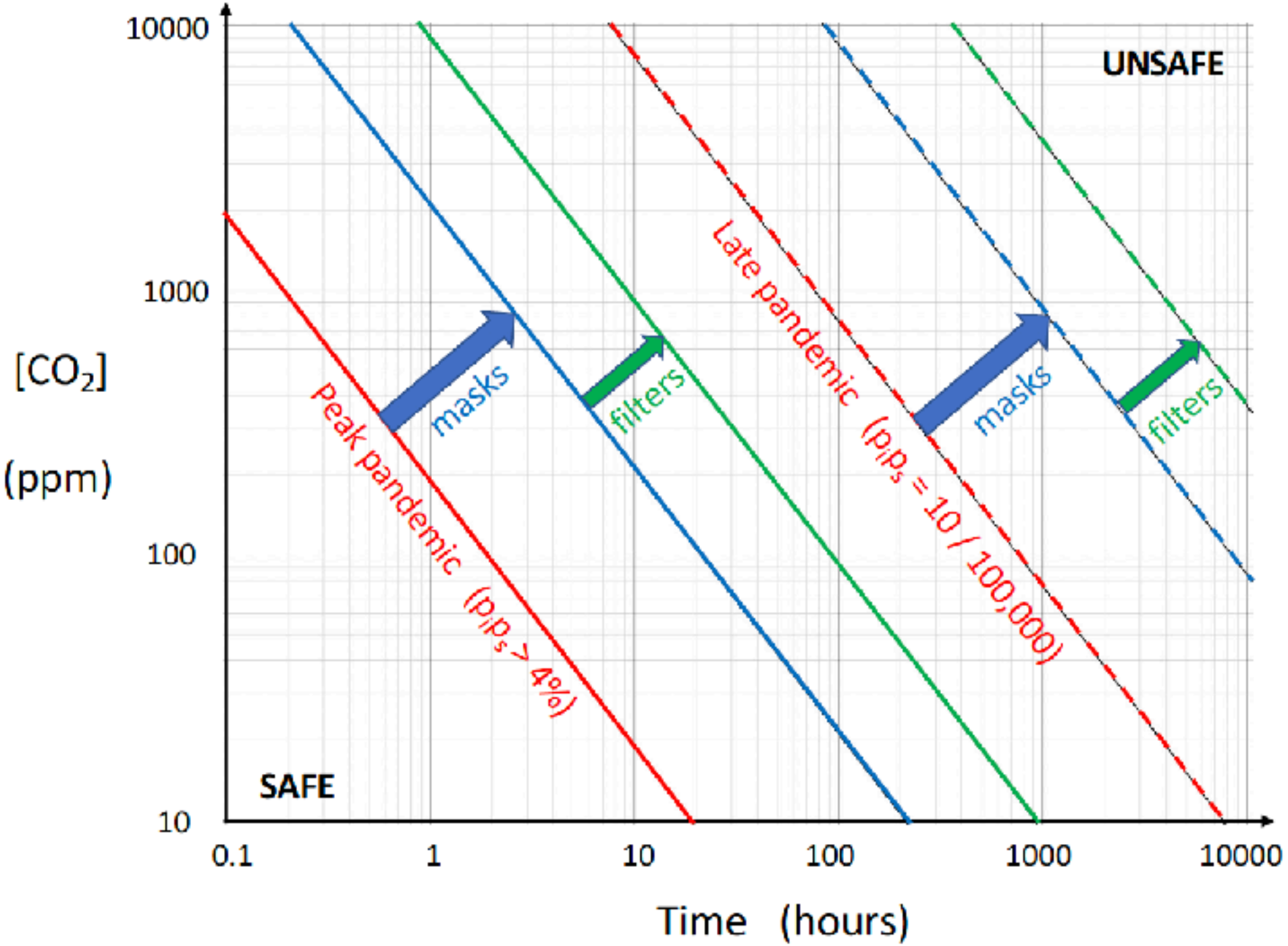
$$p_i, \; p_{im} \; , \; p_s = 1 - p_i - p_{im}$$

Expected number of infected-susceptible pairs: $N_t = N(N-1)p_i p_s$

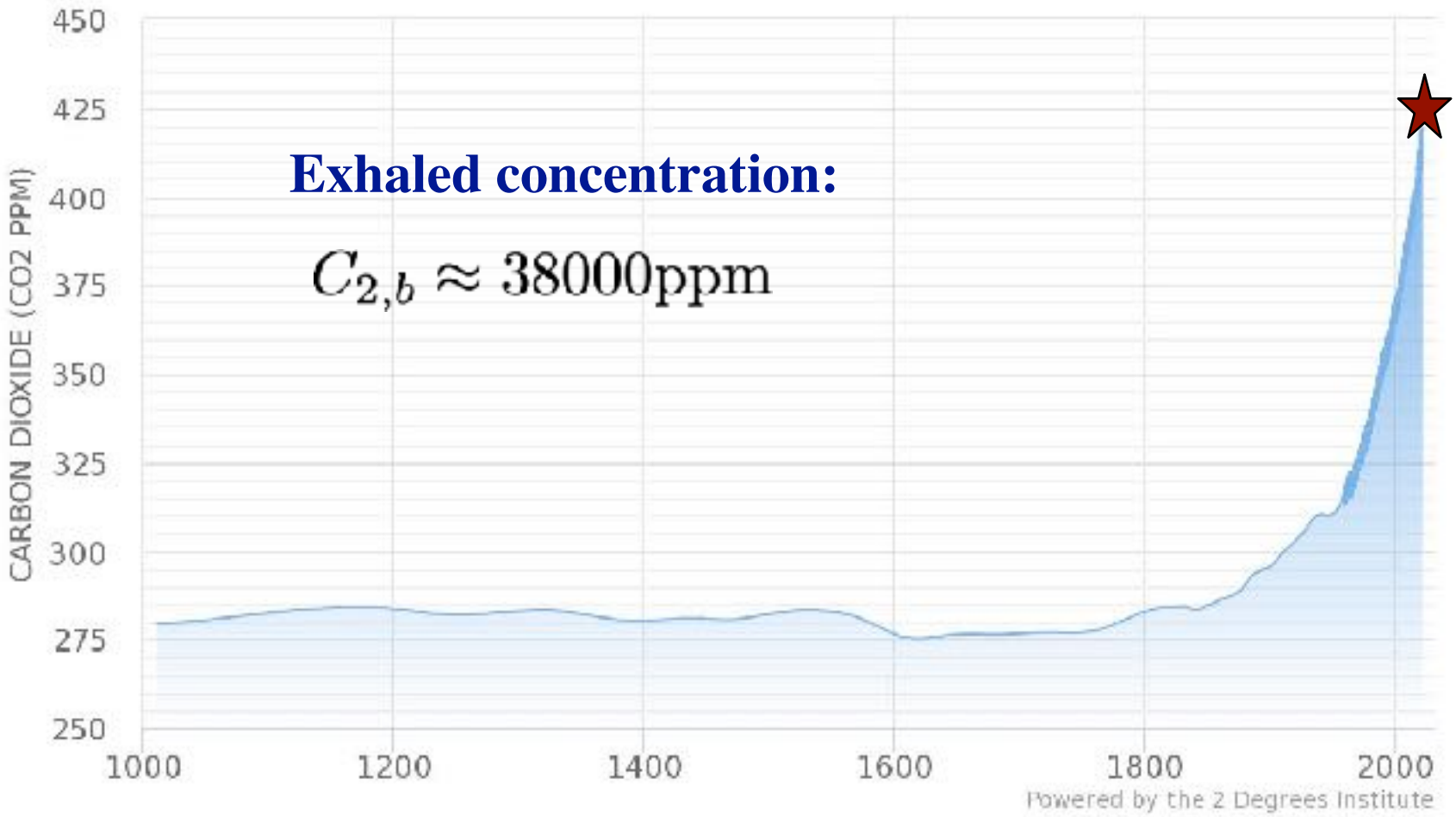
Early pandemic: $N/N_t \approx 1$

Late pandemic: $p_i \to 0 \; , \; p_{im} \to 1 \; , \; N/N_t \to \infty$

★ supplanted by CO_2 safety


10000
1000
100
10
[CO2]
(ppm)
UNSAFE
SAFE
masks
filters
masks
filters
peak pandemic (pipS > 4%)
Late pandemic (pipS = 10 / 100,000)
0.1
1
10
100
1000
10000
Time (hours)

Carbon dioxide levels on Planet Earth



- human occupancy indoors may create levels well above 1000ppm
- drowsiness, decreased decision-making reported at > 1000ppm

Measuring carbon dioxide

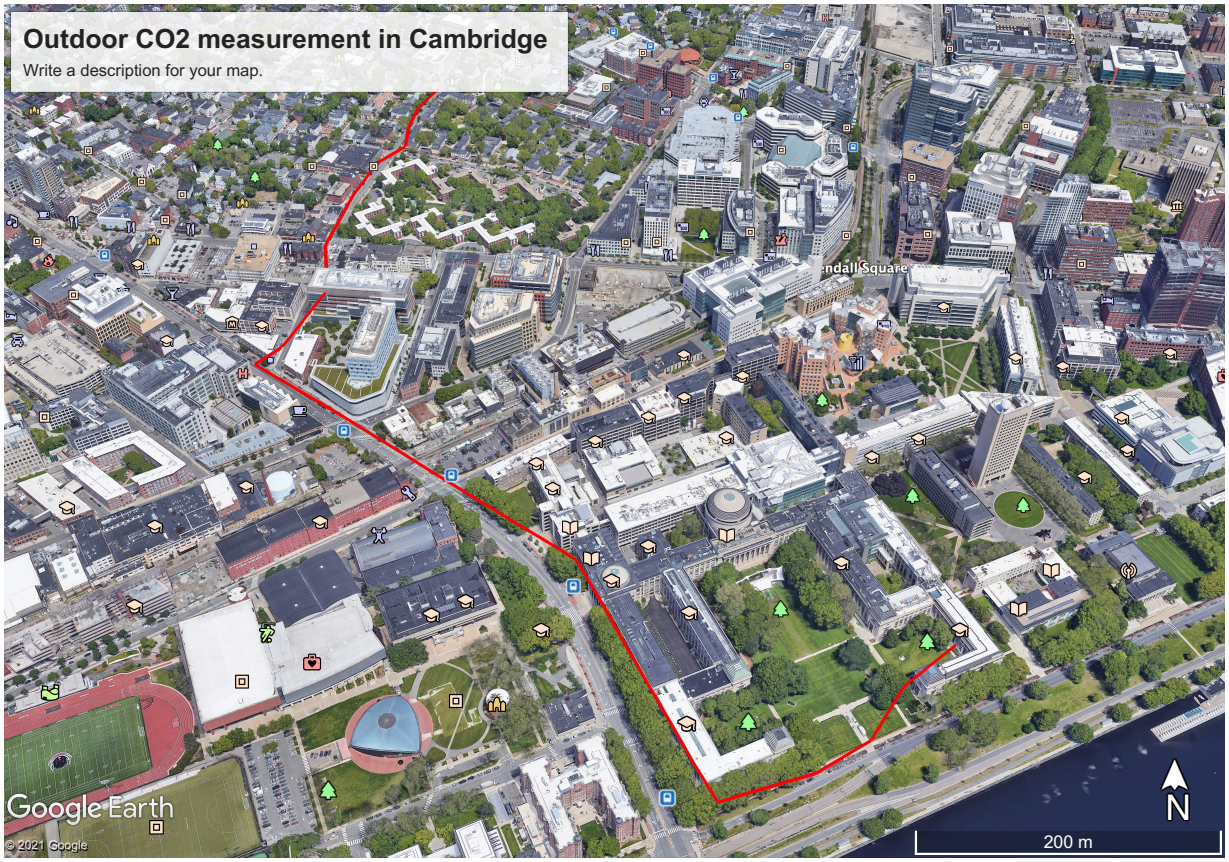
$168

$249

$151

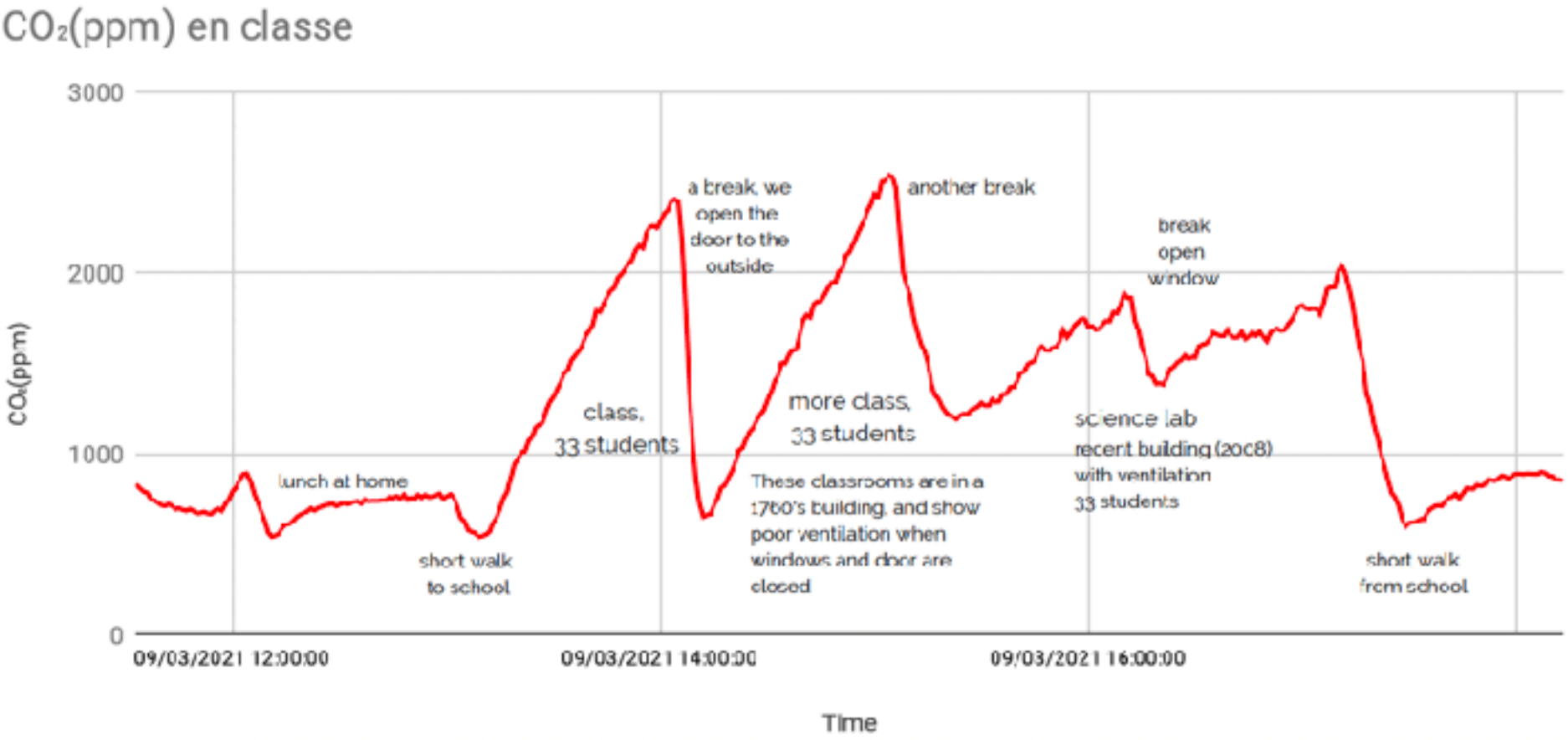
- various inexpensive, readily accessible, easy-to-use options
- widely used to assess indoor air quality in workplace, classroom

Outdoor carbon dioxide measurements at MIT

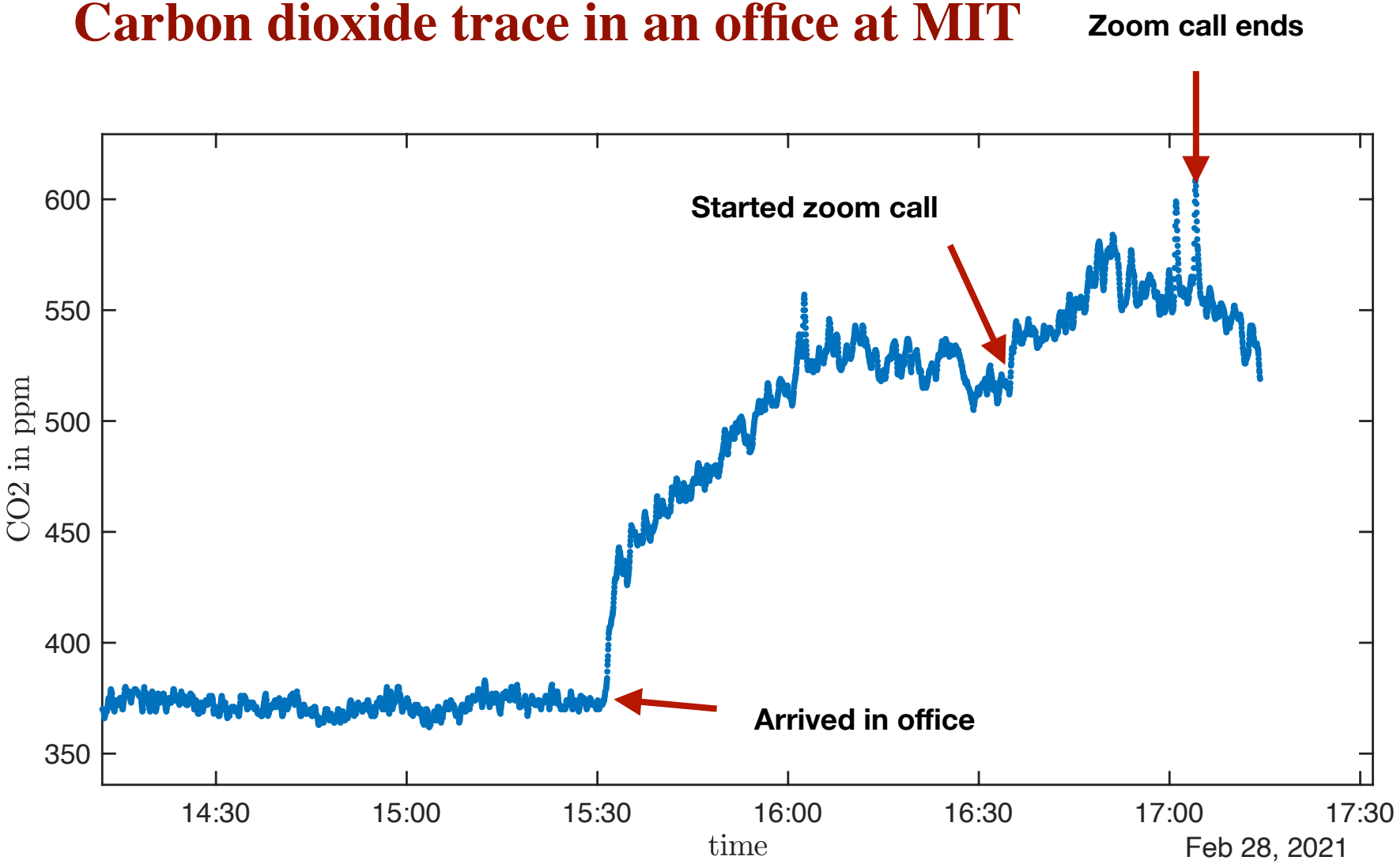


	CO_2(ppm)	Temperature(C)	Humidity(%)	Pressure(hPa)
count	13.000000	13.000000	13.000000	13.0
mean	444.846154	16.338462	15.307692	1024.0
std	8.464102	0.450071	2.897833	0.0
min	431.000000	15.400000	11.000000	1024.0

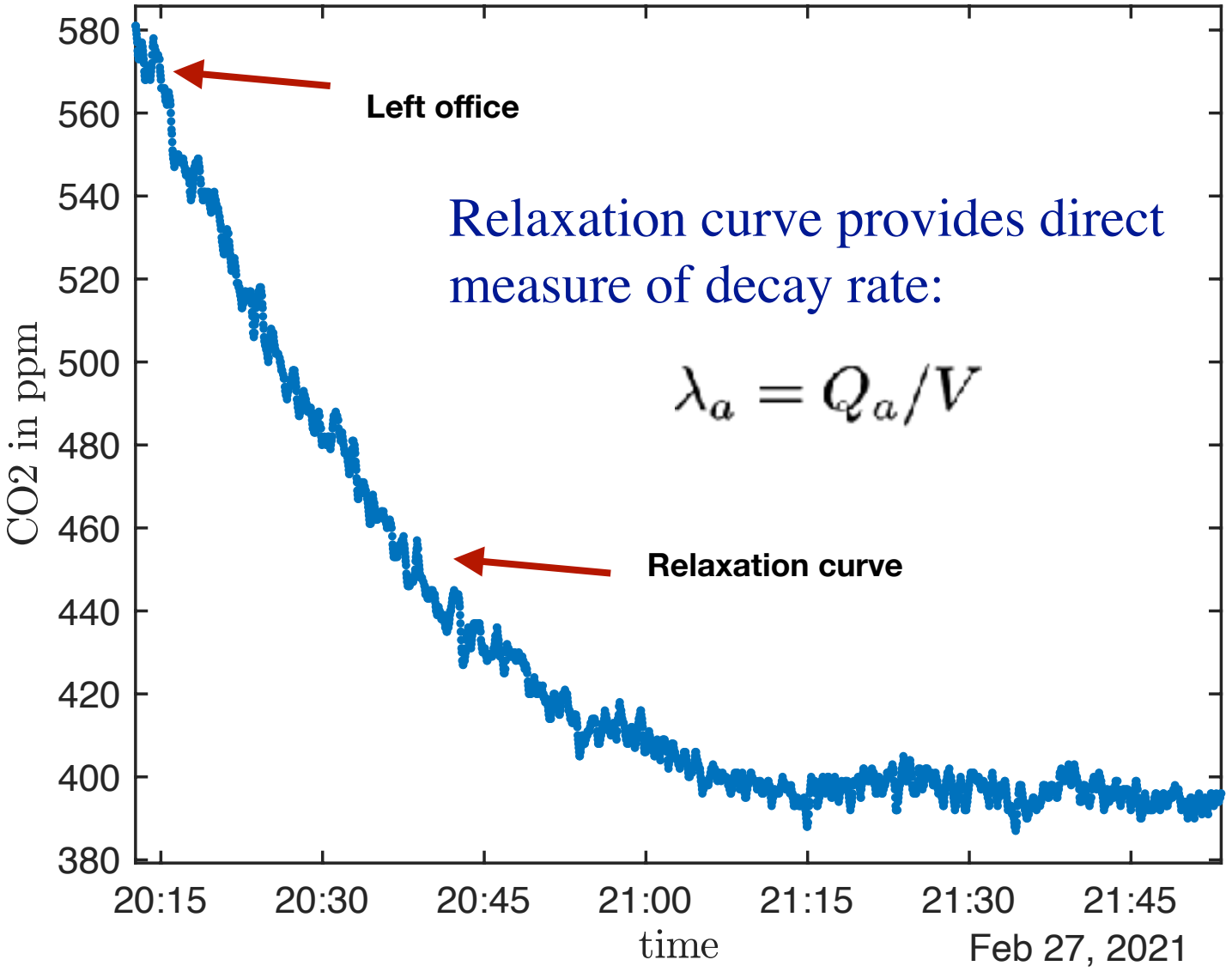
A daily trace of carbon dioxide concentration



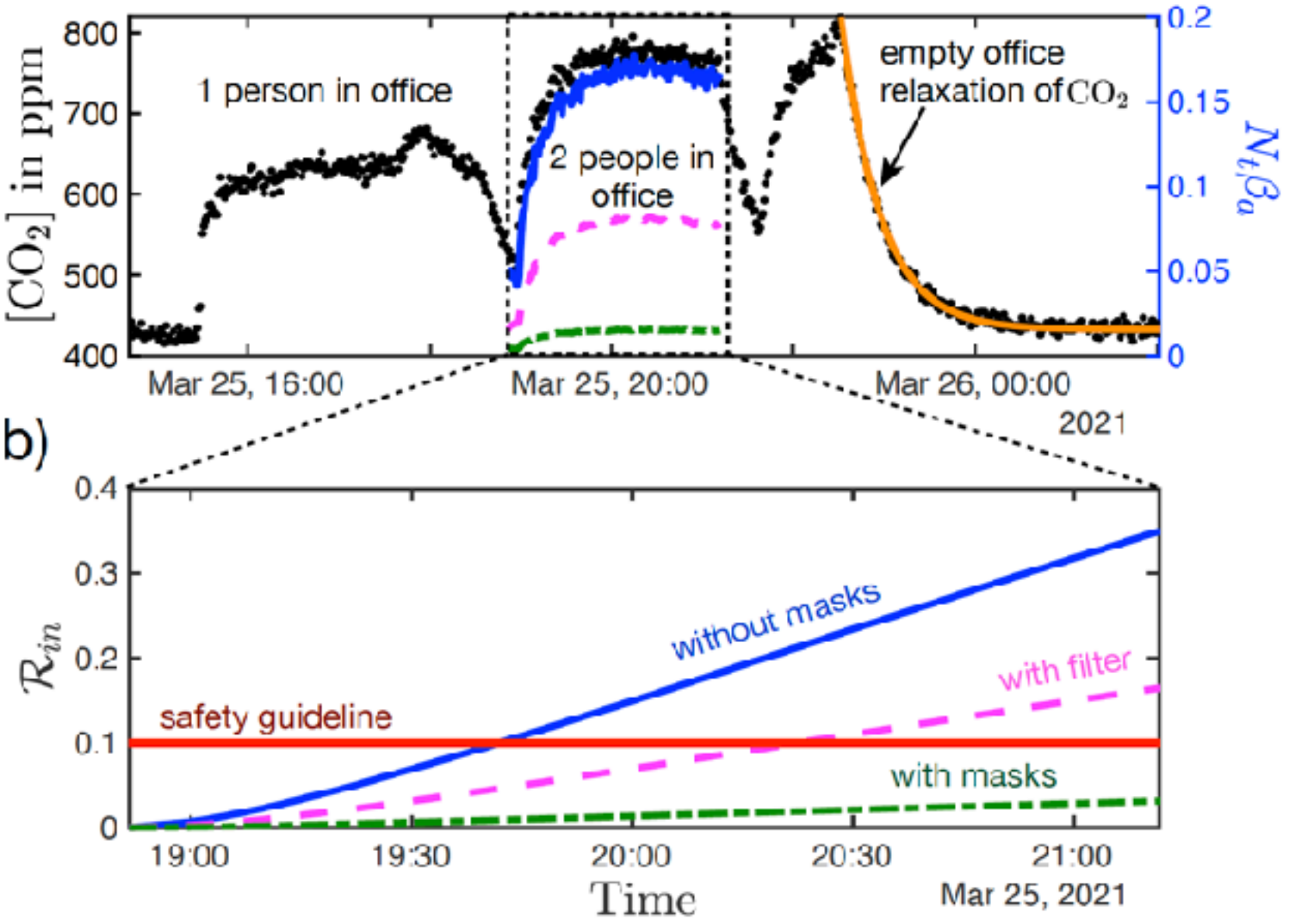
Carbon dioxide trace in an office at MIT



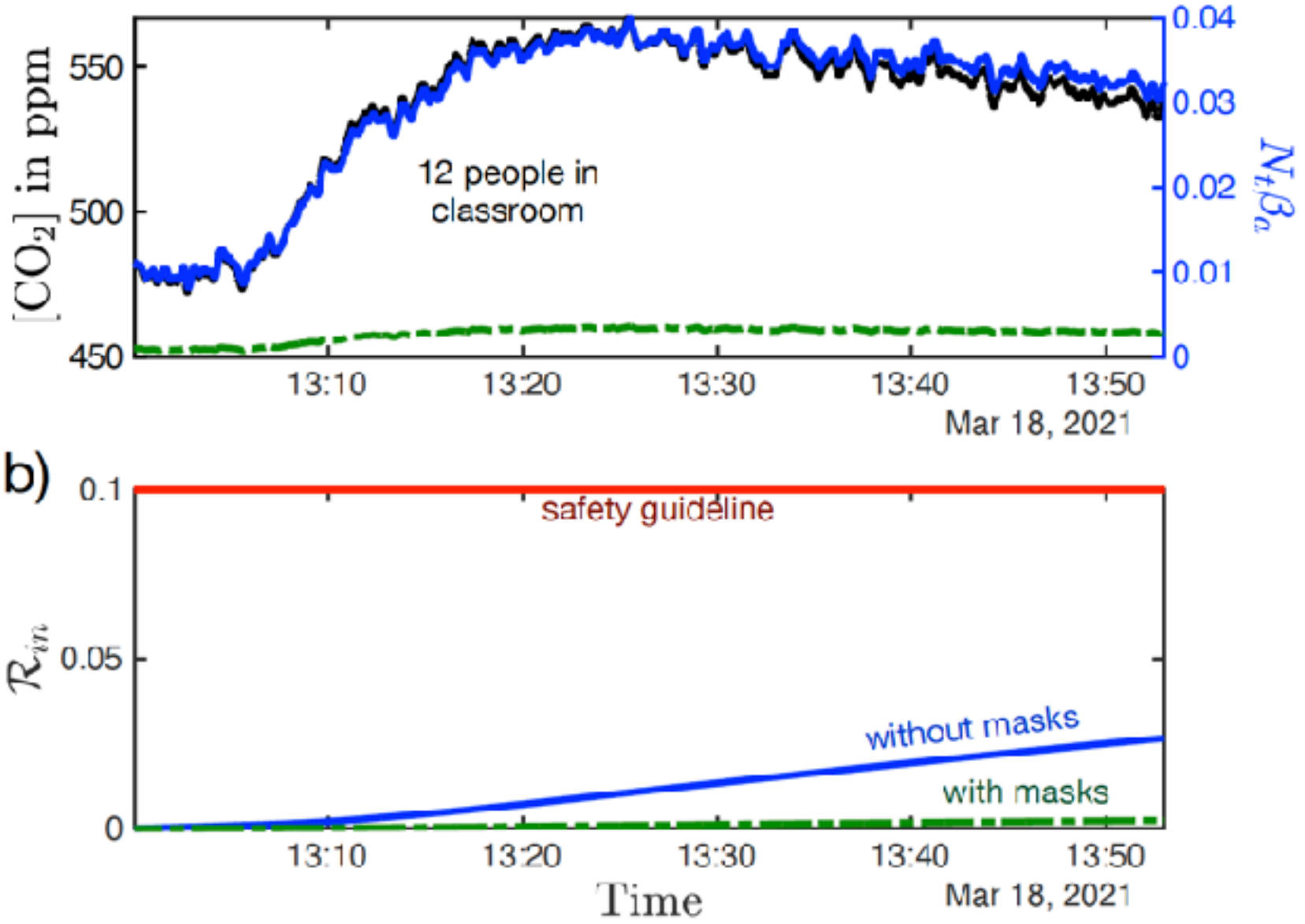
Carbon dioxide trace in an office



Carbon dioxide trace in an office with 2 people



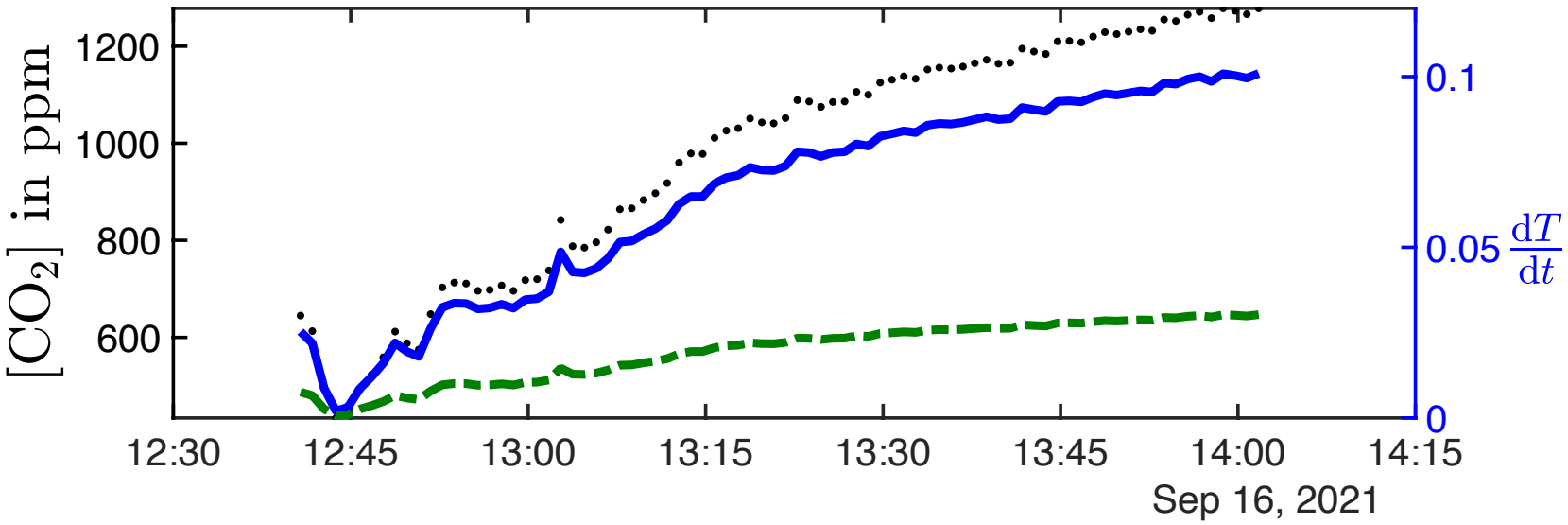
Carbon dioxide trace in a small classroom

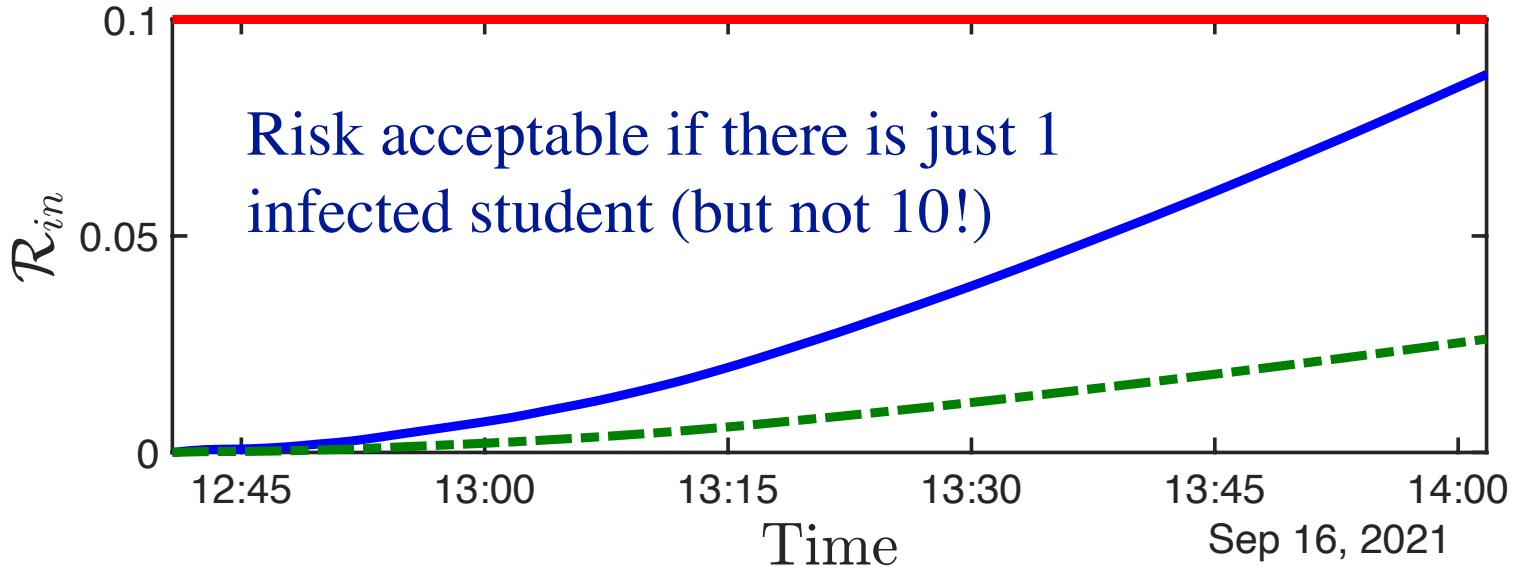


The large classroom where I caught COVID

26-100

300 people

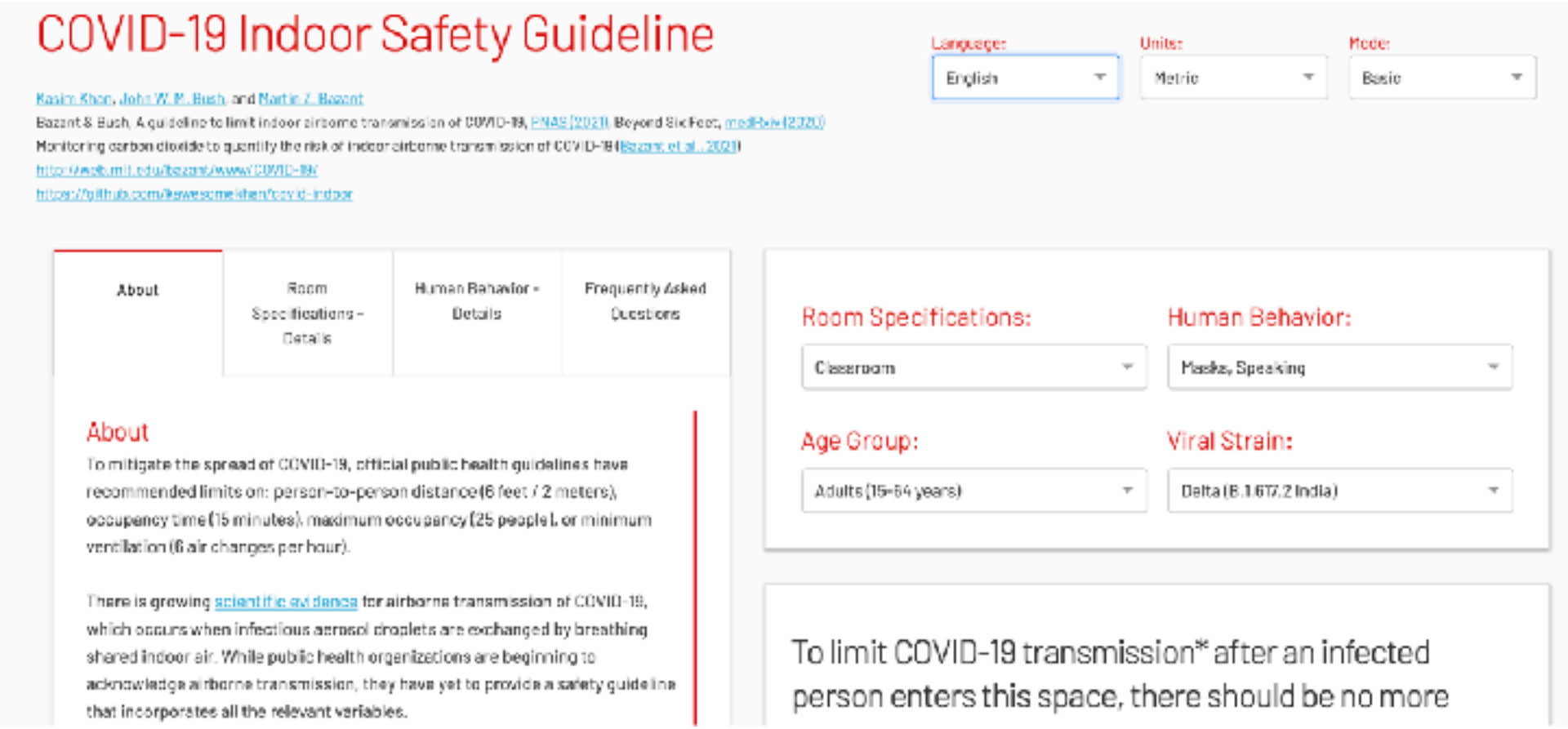




On-line app: **developed with Kasim Khan, Martin Bazant**

— allows for assessment of COVID risk in any indoor setting

— translated into 15 languages; over 1 million users



Conclusions

- gas-phase respiratory flows (jets, puffs) play a critical role in extending the range of pathogen-bearing droplets
- ambient room circulation may suspend aerosols indefinitely
- inferences from best reported super-spreader events implicate airborne transmission as the dominant mode
- relative importance of short- and long-range airborne transmission must be assessed in a case-by-case basis
- inference of infectivity of SARS-Cov2 suggests it is 10 times higher than that of its precursor, SARS-Cov1
- social-distancing guidelines should be augmented by bounds on time spent in indoor spaces
- using CO_2 as a proxy for airborne pathogen concentration allows for real-time assessment of COVID risk in indoor settings

Afterthoughts: When politics meets science

MEDICAL MISINFORMATION WARNING

YouTube doesn't allow content that spreads medical misinformation that contradicts local health authorities or the WHO about COVID-19 on:

- Prevention
- Transmission
- Social distancing guidelines

Note: YouTube's policies on COVID-19 are subject to change in response to changes to global or local health authorities' guidance.

Scientists "Spreading Medical Misinformation"

The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles?

Aerosol Sci Tech, 4/3/2020

Sima Asadi, Nicole Bouvier, Anthony S. Wexler & William D. Ristenpart

Airborne transmission of SARS-CoV-2: The world should face the reality

Environment International, 4/10/2020

Lidia Morawska[a,*], Junji Cao[b]

239 Experts With One Big Claim: The Coronavirus Is Airborne

The W.H.O. has resisted mounting evidence that viral particles floating indoors are infectious, some scientists say. The agency maintains the research is still inconclusive.

New York Times, 7/12/020

CDC reverses itself and says guidelines it posted on coronavirus airborne transmission were wrong

Agency removes statement, claiming website error *Washington Post, 9/21/2020*

Can "local health authorities" *themselves* unwittingly spread medical misinformation?

Coronavirus can be transmitted through the air, CDC confirms *Washington Post, 10/5/2020*

The virus is an airborne threat, the C.D.C. acknowledges. *New York Times, 5/7/2021*


EDITORIAL | ONLINE FIRST

COVID-19 transmission—up in the air

The Lancet Respiratory Medicine

Published: October 29, 2020 - DOI: https://doi.org/10.1016/S2213-2600(20)30514-2

"Public health guidance now needs to advise people how to navigate risk in indoor settings"...

- the truth (airborne transmission) was decried as medical misinformation

The origins of COVID-19


WHOEVER SAID ONE
PERSON CAN'T CHANGE
THE WORLD NEVER ATE
AN UNDERCOOKED BAT

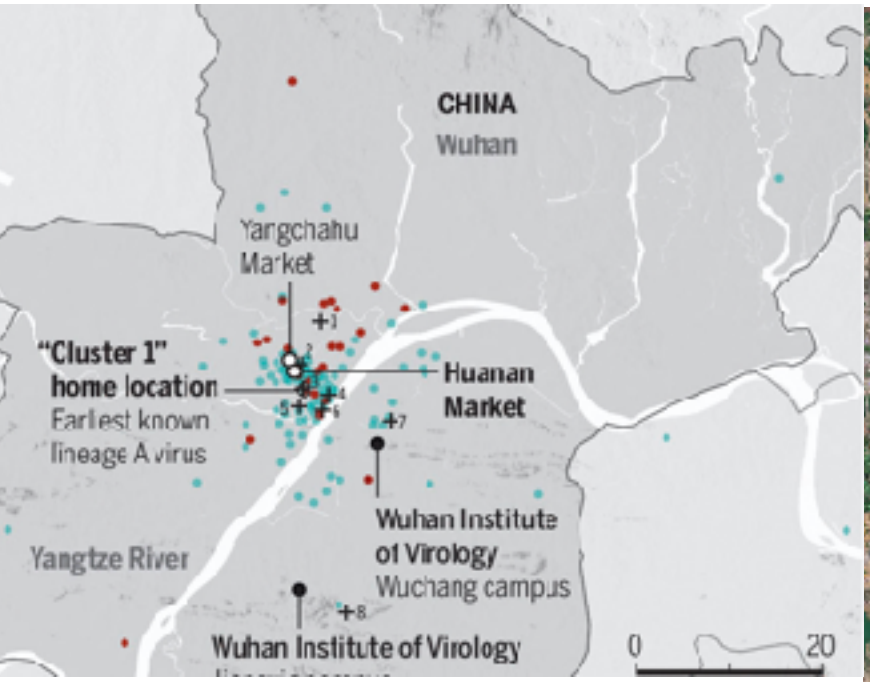
The wrongly accused

Pangolin

Raccoon dog

Why is everybody always picking on me?

The lab leak `*conspiracy*'




WSJ | OPINION
LOCKDOWNS DIDN'T STOP COVID
May 9, 2021
The INDEPENDENT
CLOTH MASKS ARE USELESS IN FIGHT AGAINST OMICRON, EXPERT WARNS
December 22, 2021
CNBC
MIT RESEARCHERS SAY TIME SPENT INDOORS INCREASES RISK OF COVID AT 6 FEET OR 60 FEET IN NEW STUDY CHALLENGING SOCIAL DISTANCING POLICIES
April 23, 2021
FOX NEWS channel
DRACONIAN COVID RESTRICTIONS RUINED LIVES
THE NEXT REVOLUTION w/ STEVE HILTON
JESSE WATTERS PRIMETIME
STARTING TOMORROW 7PM ET

Mini-conclusions

- science imposes a high bar for proof

  — like criminal rather than civil litigation

- scientists must combat intellectual inertia

- scientific credibility suffers when scientists deny things that seem obvious to the nonscientist, or support extravagant, nonsensical theories

- we live in a time when scientific credibility is under fire, so must get our house in order

Thanks for your attention!

For more information, please see my webpage…