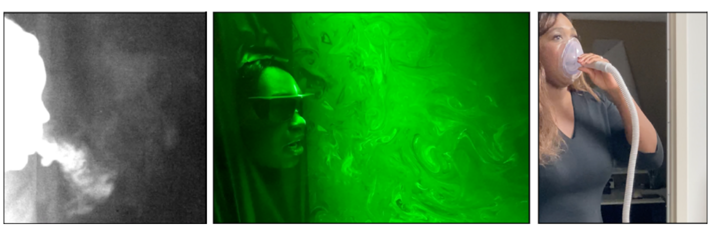
Singers, Oboists, and Physicists Orchestrate a COVID-19 Strategy

In an unlikely collaboration, physicists and professional musicians studied how to limit COVID-19's spread during operatic performances. Hint: It involves instruments wearing masks.

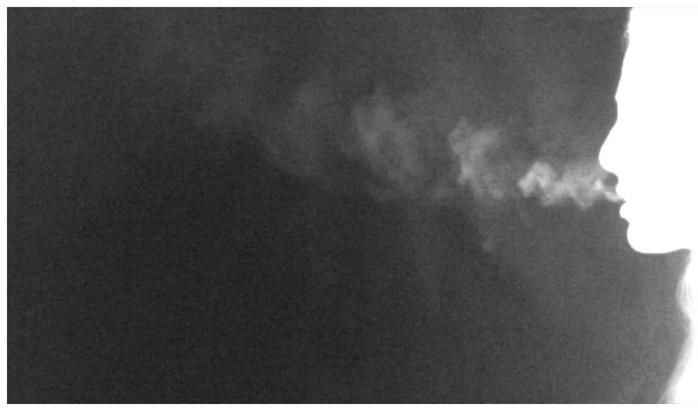
By **Katherine Wright**

An opera aficionado, Philippe Bourrianne's regular visits to New York's Metropolitan Opera House (colloquially known as the Met) came to an abrupt halt in March 2020 when COVID-19 hit the city, shutting down its theaters. But the Princeton University physicist was in luck: during the Met's 18-month shutdown he was repeatedly serenaded—in his laboratory—by some of the Met's best singers and instrumentalists, including mezzo-soprano Isabel Leonard, who Bourrianne had heard perform in Debussy's *Pelléas et Mélisande* just before the pandemic struck.

The private concerts at the Princeton lab were part of a study, initiated by the Met's orchestra, to gain scientific understanding of how the Met could resume performances without the cast and orchestra members all falling sick [**1**]. They turned to



Experimental setups used to measure the airflows during singer Angel Blue's performance of "Casta Diva." (Left) An infrared high-speed camera was used to track the warm CO_2 exhaled by the soprano. (Middle) Flows were also visualized using a fog chamber illuminated by a green laser sheet. (Right) Blue performed into a flowmeter so that the physicists could measure flow rates of her exhalations.
Credit: P. Bourrianne/Princeton University



Mezzo-soprano Isabel Leonard performing the Armenian lullaby "Oror" while Bourrianne and his colleagues take measurements of her exhalations using infrared light.
Credit: P. Bourrianne *et al.* [1]

Bourrianne and his colleagues after learning that the team were already looking into the spread of COVID-19 by airflows produced from speaking (see **Synopsis: Altering Airflows and Stopping Drops**).

"It was clear that the orchestra was struggling to find ways to play together," says Elizabeth Bowman, who at the height of the pandemic worked as the publicist for the Met's orchestral musicians. She says that the best way forward was for the group to enlist the help of researchers. The situation was unusual, Bourrianne says, as having the subjects pose the questions "is not standard for most research projects, which typically involve scientists coming up with the questions they want to explore."

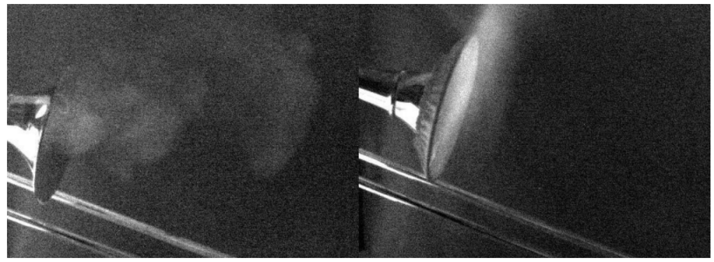
To sing or to play a wind instrument requires sustained exhalation. This air—as with all air we breathe out—is loaded with droplets, which, if we are sick, can carry pathogens. If breathed in by someone else, these pathogens can infect that person, leading to person-to-person transmission of an illness. Scientists realized early on that COVID-19 can spread through the air, with dramatic evidence coming from “super-spreader” events in which whole choirs came down with the disease after practicing together.

The choirs in those cases were made up of amateur singers, who stood shoulder-to-shoulder during practices. That proximity made it highly likely that they would breathe in a neighbor’s air. Studies also suggested that the air emitted by amateur singers contained more droplets—and thus potentially more pathogens—than it did for people speaking the same words, but quantitative evidence remained absent. “The news was labeling singers as super-spreaders with little information to back up the statement,” Bowman says.

At the time, for example, it remained unclear whether any of these qualitative results for amateur singers were relevant to highly trained opera singers, who often sing individually or in small groups. World class soloists also have such control over their breath that they can resonate the top notes of *The Magic Flute*’s “Queen of the Night” or *Turandot*’s “Nessun Dorma” without blowing out a lit candle placed inches from their face. “They are amazingly good at limiting airflow,” Bourrianne says.

In the study, Bourrianne and his colleagues set the performers up in the center of the lab. The researchers then took various measurements of the air the performers exhaled as they iteratively performed their designated pieces. The artists included three singers, an oboist, a trombonist, and four other wind-instrument players.

When the singers performed, the team found that the properties of the exhalations depended on the letter being sung. For vowels—the most commonly voiced sound for opera singers—the exhaled air moved at around half the speed during singing than it did during speaking, but it contained more droplets. These droplets rose as they exited the mouth, carried upward by the warm, exhaled air, forming a roughly 10-cm-wide buoyant cloud around the singer’s head. (For context, speaking and breathing led to clouds wider than 1 m.) In contrast, for consonants, the droplet-laden air traveled approximately 4 times faster during singing than speaking, moving in jet structures that extended for more than a meter.



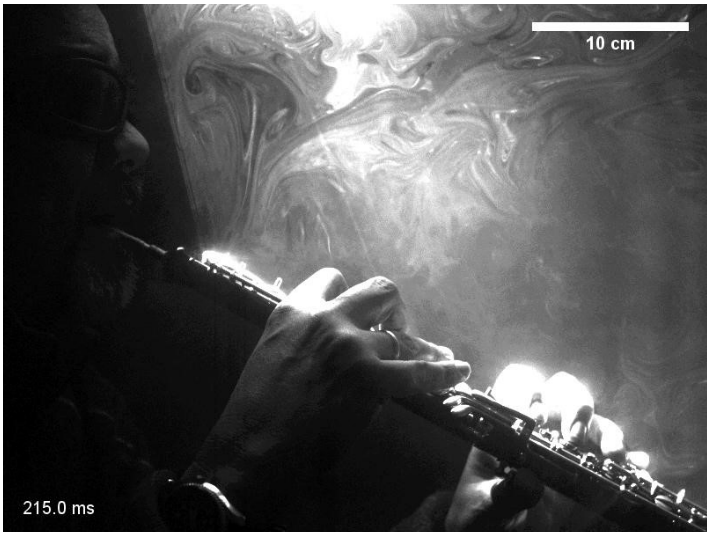
The playing of a trombone by Demian Austin without (left) and with (right) a mask over the bell.
Credit: P. Bourrianne/Princeton University

Since opera singers largely voice vowels, keeping consonants very short, Bourrianne says that singing can be practiced safely in well-ventilated spaces when it comes to COVID-19 transmission. “Even though the [exhaled] air contains more drops, it’s rising rapidly, very close to the singer,” he says. Wearing a mask reduces the risk even more by further slowing the outward expansion of exhaled air.

The team found similar speed reductions for the air and droplets emanating from the ends of wind instruments while they were being played. But this air traveled farther—60 cm in just 3 s for a trombone—because of the funneling effects of the wind instruments’ bells. Placing masks over the bells cut the distance down to just 10 cm.

Air also exited directly from the instrumentalists’ mouths, showing up in the experiments as bursts of fast-moving air. The feature was most pronounced for the oboist. Playing the oboe requires slow, sustained exhalations. But, at the end of a musical phrase, Bourrianne and colleagues observed that the oboist rapidly expelled the air that remained in his lungs before taking his next breath. That rapid exhalation produced a forceful jet of drops that moved nearly 50 times faster than the air exiting the oboe’s bell.

The results suggest that—when it comes to infection risk for orchestra players—the oboist is probably the most “dangerous” person to be placed next to, Bourriane says. “You definitely



Musician Pedro Díaz makes a rapid exhalation during this high-speed video of him playing Ennio Morricone's "Gabriel's Oboe." In this video, airflow is visualized by the motion of laser-illuminated fog that surrounds Díaz.
Credit: P. Bourrianne *et al.* [**1**]

want to sit oboists farther apart, while trombonists can be closer together."

Katherine Wright is Deputy Editor of ***Physics Magazine***.

REFERENCES

1. P. Bourrianne *et al.*, "Air flows in opera," **Phys. Rev. Appl. 18, 024042 (2022).**