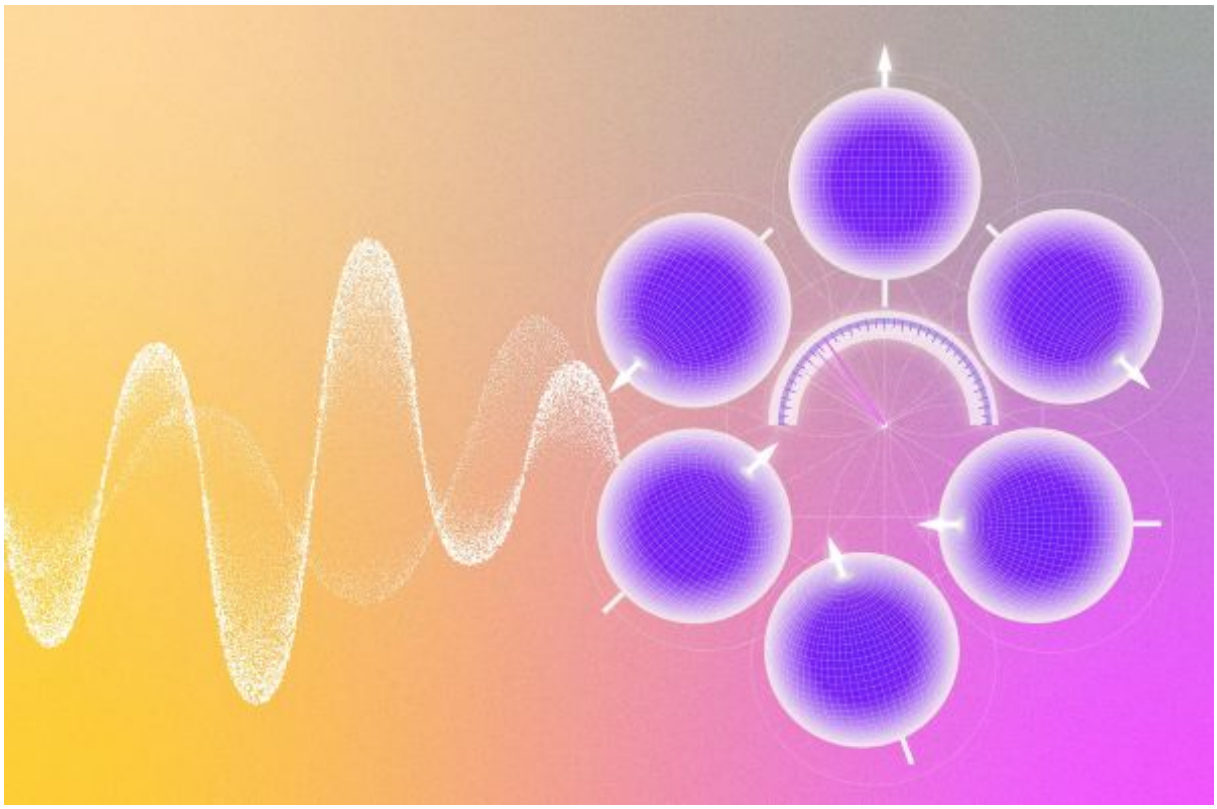

Quantum backaction: from obstacle to resource

In a recent Physical Review X study, ICFO researchers challenge the conventional view in quantum machine learning that quantum backaction (the disruptive effect measurement has on quantum systems) is purely detrimental. They demonstrate that, instead, it is a valuable resource when properly controlled. In particular, the team shows how tuning the measurement strength can enhance the memory and predictive capabilities of the quantum reservoir computing algorithm.

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One of the most counter-intuitive features of quantum physics is the influence of measurement on the system under study. It is typically said that measuring a quantum system substantially disturbs it, collapsing its quantum wavefunction and instantly erasing its initial superposition. This extreme backaction effect, however, occurs with so-called projective measurements. But one can perform softer measurements that extract less information about the system without fully collapsing its wavefunction. These measurements

rely on an indirect interaction between the system and the measurement apparatus; they are thus known as **indirect measurements**.

In a Physical Review X publication, ICFO researchers, **Giacomo Franceschetto**, **Dr. Marcin P?odzien**, **Prof. Maciej Lewenstein**, **ICREA Prof. Antonio Acin**, and **Dr. Pere Mujal**, have now demonstrated the **advantage of indirect measurements for quantum machine learning tasks**. By carefully **adjusting the measurement strength**, the researchers **optimized the amount of backaction** introduced into the quantum system, significantly **enhancing the performance of** an algorithm called **quantum reservoir computing (QRC)**.

Until recently, many approaches to QRC either tried to avoid the disturbances induced by measurements by effectively resetting the system after each processing step, or attempted to compensate for it using classical feedback. In both cases, measurement backaction was treated as a limitation to be minimized or corrected, rather than assource.

In 2021, researchers at the Institute for Cross-Disciplinary Physics and Complex Systems (IFISC) in Mallorca, including Dr. Pere Mujal, proposed an alternative: an online protocol in which the same quantum reservoir processes a sequence of inputs without being reset between steps, making it more efficient.

In this approach, each data point from a time series is injected sequentially into the same quantum reservoir. The system evolves, spreading the information through its internal interactions, and the resulting signals are read out using indirect measurements. Crucially, the next input is introduced without resetting the system, so the backaction from previous measurements remains embedded in the system dynamics. Repeating this cycle for all elements of the series generates a dataset of measured features, which is subsequently used to train a classical model to, for instance, forecast a chaotic time series.

In the present study, the ICFO team adopts this online protocol and systematically explores how the strength of the measurements shapes the system's behavior. They show that when the disturbance introduced by measurement is carefully controlled, it reshapes the reservoir's internal dynamics in a way that enhances its memory and improves the prediction of complex, chaotic signals. This control allows the algorithm to operate effectively in regimes where it would otherwise struggle, turning measurement backaction from a source of degradation into a useful feature.

i¿½While backaction was typically thought to degrade the reservoir's memory and predicti e capacity, we now show it can provide a positive contribution by using the Mallorcan onli e protocoli¿½ explains Dr. Pere Mujal, lead researcher of the study. i¿½This repres nts a conceptual turnover in the field, from viewing quantum backaction as an unavo dable limitation to recognizing it as a purely quantum tool with great potential,i¿½ e adds. Now the team aims to investigate the role of backaction in other scenarios and to col aborate with experimental groups to implement their proposal. Giacomo Franceschetto, firs author of the article, shares: i¿½We would be thrilled to see concrete implementations of he online protocol with tunable indirect measurements, especially in platfor

s such as superconducting and photonic systems where such control is feasible, and to d monstrate the enhancement effect reported in thi

Reference:

Giacomo Franceschetto, Marcin P?odzien, Maciej Lewenstein, Antonio Acin, Pere Mujal, Harnessing quantum back-action for time-series processing, Phys. Rev. X, (2026).
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