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Lieb-Robinson bound and information propagation in long-range interacting systems TOMOTAKA KUWAHARA, RIKEN Center for Advanced Intelligence Project — A fundamental principle of many-body physics is causality, that is, strict prohibition of information propagation outside the light cone. However, in non-relativistic systems, it is often unclear whether such a light cone can be well-defined. In 1972, this problem was completely solved by Lieb and Robinson in short-range interacting systems. The existence of the effective light-cone was proven; outside of it, the amount of information decays exponentially with the distance. This effective light-cone is characterized in the form of a "Lieb-Robinson bound," and it is linear with respect to time. In the case where the interaction length is short-range, it is quite natural to expect that the information propagation is constrained by a finite velocity. However, beyond short-range interactions, the situation becomes highly non-trivial. In particular, for long-range interactions, information easily propagates to an arbitrarily distant point. Here, long-range interaction indicates that the interaction strength between separated sites demonstrates a power-law decay as $R^{-\alpha}$ for distance R. This intuitively leads to an impression that the linear-light cone can no longer be obtained in long-range interacting systems, as has been shown by Hastings and Koma [1]. Nevertheless, depending on the power-law exponent, it has been numerically [2] and experimentally [3] observed that a linear light cone still remains even under long-range interactions. This motivates the following linear light cone problem: "what is the critical power-law exponent to induce the linear light cone?" Owing to its importance and simplicity, the problem has received significant interest from researchers of various backgrounds. In this talk, we give the solution of the linear light cone problem [4]. Our result provides the complete proof of the linear light cone for $\alpha > 2D + 1$ in generic long-range interacting systems of arbitrary dimensions. The present study proves the optimality of our condition $\alpha > 2D + 1$ by showing an explicit counterexample which violates the linear light cone for $\alpha < 2D + 1$. In addition, we demonstrate that for $\alpha > D$ a polynomial form of the effective light cone still retains as long as if the out-of-time-order correlators are considered [5]. [1] M. B. Hastings and T. Koma, Communications in Mathematical Physics 265, 781 (2006). [2] P. Hauke and L. Tagliacozzo, Phys. Rev. Lett. 111, 207202 (2013). [3] P. Richerme, et al., Nature (London) 511, 198 (2014). [4] T. Kuwahara and K. Saito, Phys. Rev. X 10, 031010 (2020). [5] T. Kuwahara and K. Saito, Phys. Rev. Lett. 126, 030604 (2021).

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