

Speaker: Viviana Viggiano, University of Bari

Title: Random matrix approach to collective photon emission from disordered cold atomic clouds

Date: Tuesday, January 27, 11:00 am (s.t.)

Place: Seminar room 915

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In a collective spontaneous emission process from an atomic ensemble, the decay rate is modified compared to that of a single isolated atom, yielding subradiance (slower decay) or superradiance (faster decay). In this talk, I will consider a cloud of cold atoms with random positions sampled from a three-dimensional Gaussian distribution and formulate the problem of cooperative photon emission in terms of Euclidean random matrices, whose entries are a function of the distances between pairs of atoms. In particular, I will present a detailed analysis of the Euclidean random matrix S , related to the dissipative dynamics of the atomic cloud induced by photon-mediated interaction, in the asymptotic regime with an infinite number of atoms in the low-density limit.

First, I will analyze the bulk spectral properties of the matrix S , characterizing the microscopic spectral statistics, level spacing, and eigenvectors corresponding to the central part of the spectrum, for different values of the cooperativeness parameter, which quantifies the number of atoms that coherently cooperate in photon emission. I will show that, although S is a Euclidean random matrix, the bulk of its spectrum exhibits the universal behavior of chaotic quantum systems, characterized by level repulsion and delocalized eigenvectors, and can therefore be described using standard random matrix theory [1].

Then, I will focus on the extremely subradiant part of the spectrum of the matrix S and show the occurrence of a phase transition controlled by the cooperativeness parameter. Specifically, there is a critical value of the cooperativeness parameter above which the minimum eigenvalue of S (associated with the most subradiant state) reaches zero, and the spectrum exhibits a condensation of vanishing eigenvalues [2].

[1] V. Viggiano, R. Bachelard, F. D. Cunden, P. Facchi, R. Kaiser, S. Pascazio, and F. V. Pepe, “Cooperative photon emission rates in random atomic clouds”, *Phys. Rev. A* 108, 063701 (2023).

[2] V. Viggiano, R. Bachelard, F. D. Cunden, P. Facchi, R. Kaiser, S. Pascazio, F. V. Pepe, and A. Scardicchio, “Condensation of vanishing photon emission rates in random atomic clouds”, *Phys. Rev. A* 112, 013304 (2025).