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Molecular spontaneous emission and fluorescence depend strongly on the emitter local environment. Plasmonic nanoparticles provide excellent templates for tailoring fluorophore emission, as they exhibit a potential for both fluorescence enhancement and quenching, depending on emitter positioning in the nanoparticle vicinity. Here we explore the influence of hitherto disregarded nonclassical effects in the description of emitter-plasmon hybrids, focusing on the roles of metal nonlocal response and especially size-dependent plasmon damping. Through extensive modelling of metallic nanospheres and nanoshells coupled to dipole emitters, we show that within a purely classical description a remarkable fluorescence enhancement can be achieved. However, once departing from the local-response approximation, and particularly by implementing the recent generalised nonlocal optical response theory, which provides a more complete physical description combining electron convection and diffusion, we show that not only are fluorescence rates dramatically reduced as compared to the predictions of the local description and the common hydrodynamic Drude model, but the optimum emitter-nanoparticle distance is also strongly affected. In this respect, experimental measurements of fluorescence, the theoretical description of which requires a precise concurrent evaluation of far- and near-field properties of the system, constitute a novel, more sensitive probe for assessing the validity of state-of-the-art nonclassical theories.

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