Chapter 14
Vacuum Fluctuations

As stated by Milonni [370, p. xiii] and emphasized by others [174, 195], "*. . . there is no vacuum in the ordinary sense of tranquil nothingness. There is instead a fluctuating quantum vacuum."* One of the observable vacuum effects is the *spontaneous emission of radiation* [565]: "*. . . the process of spontaneous emission of radiation is one in which "particles" are actually created. Before the event, it consists of an excited atom, whereas after the event, it consists of an atom in a state of lower energy, plus a photon."*

Recent experiments achieve single photon production by spontaneous emission [87, 308, 322, 441, 486], for instance by electroluminescence. Indeed, most of the visible light emitted by the sun or other sources of blackbody radiation, including incandescent bulbs, is due to spontaneous emissions [370, p. 78].

Just as in the beam splitter case discussed earlier the quantum (field theoretic) formalism can be used to compute (scattering) probabilities – that is, expectations for occurrences of individual events, or mean frequencies for large groups of quanta – but remains silent for single outcomes.

Alas, also in the quantum field theoretic case, unitarity, and thus permutations, govern the state evolution. Thus, for similar reasons mentioned earlier – mainly the uniformity of the validity of unitary quantum evolutions – the ontological status of indeterminism remains uncertain.

If we follow the quantum canon, any such emission is an irreducible, genuine instance of creation coming from nothing (ex nihilo); more precisely, in theological terms, the spontaneous emission of light and other particles amounts to an instance of *creatio continua*. (This is also true for the stimulated emission of a quantum.)

A (fapp postulated) gap of determinism based on vacuum fluctuations is schematically depicted in Fig. 14.1. It consists of an atom in an excited state, which transits into a state of lower energy, thereby producing a photon. The photon (non-)creation can be coded by the symbols 0 and 1, respectively.

K. Svozil, *Physical (A)Causality*, Fundamental Theories of Physics 192,
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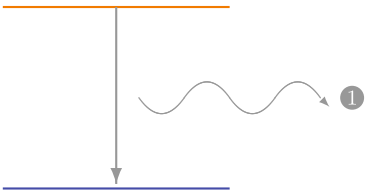

Fig. 14.1 A gap created by the spontaneous creation of a photon

It might not be too unreasonable to speculate that all gap scenarios, including spontaneous symmetry breaking and quantum oracles, are ultimately based on vacuum fluctuations.