A14.1 Localized perception from a spread-out wave function.

Quantum mechanics implies perception of localized results.

In the half-silvered mirror experiment of Ch. 6, the results exactly imitate what we would expect if there really were an objectively existing, particulate photon. The versions of the observer see either |Det H,yes⟩|Det V,no⟩, as if the alleged photon had traveled on the H path, or |Det H,no⟩|Det V,yes⟩, as if the photon had traveled on the V path; and no version ever perceives |Det H,yes⟩|Det V,yes⟩. What we will show here is that this imitation of the particle-like property of localization—that there is perceived detection in one and only one localized place, either at the V detector or the H detector in the half-silvered mirror case—holds in all cases.

Scattering experiment.

We use a scattering experiment to illustrate. A single electron (electron-like wave function) scatters off a proton (proton-like wave function) and hits a screen coated with N grains of film. Experimentally we know that if the grains are analyzed, only one will be found to be exposed, even though the wave function hits them all. We will show that quantum mechanics implies only one grain will be *perceived* as exposed. Neither the existence of particles nor collapse is necessary to obtain this perceptual result.

After the slit but before detection, the state vector of the electron is (A6.2)

$$\int d^3x\, \psi(\mathrm{x})|\mathrm{x}\rangle \tag{1}$$

where ψ is the wave function. And the state vector of the N grains is

$$\prod_{j=1}^{N} |gr\ j\rangle \tag{2}$$

As the electron wave function passes through the layer of grains, one can divide the integral of Eq. (1) into a sum, with one term for each grain. We suppose grain j has frontal area ΔA_j and take z_j as the direction perpendicular to ΔA_j. Then

$$\int d^3x\, \psi(\mathrm{x})|\mathrm{x}\rangle = \sum_j \int dz_j \int dA_j\, \psi(x)|x\rangle \tag{3}$$

For each grain *j*, there is an interaction term H_j such that if the electron hits that grain, it gets changed from non-exposed to exposed. Thus the j^{th} term in Eq. (3) will expose grain *j* and only grain *j*. This implies that after the electron wave function passes through the crystals, the full wave function, electron plus grains, will be a sum of N terms,

$$|\Psi\rangle = \sum_{j=1}^{N} |gr\ 1\rangle \ldots |gr\ j^*\rangle \int dz_j \Delta A_j \psi(x)|x\rangle \ldots |gr\ N\rangle \tag{4}$$

with one and only one exposed grain, indicated by the asterisk, in each term.

Each of these N terms corresponds to a separate version of reality (because a grain is effectively a macroscopic system). If we now include an observer who looks at the state of each grain, there will be a different version of the observer for each of the N versions of reality. And in accord with the principle of the isolation of branches (Ch. 10), the version of the observer on branch *j* can perceive only the state of the grains on that branch. Thus when the observer is included, the state vector becomes

$$\sum_{j=1}^{N} |gr\ 1\rangle \ldots |gr\ j^*\rangle \int dz_j \Delta A_j \psi(x)|x\rangle \ldots |gr\ N\rangle |\text{Obs sees only grain } j \text{ exposed}\rangle \qquad (5)$$

So we see that, in spite of the fact that the electron wave function is spread out over all the grains, there will never be **perception** of more than one exposed grain. (Note: The small amount of the wave function that hits each grain carries the full energy of the electron (Ch. 13) so that it has sufficient energy to expose the grain.)

Summary.

The result is that it is not necessary to assume either *collapse* or *the existence of particles* to explain why only one **localized** grain is perceived as exposed. The mathematics of quantum mechanics—by itself, with only wave functions existing, and no collapse—is sufficient to explain why the observer perceives a localized effect from a spread-out wave function.