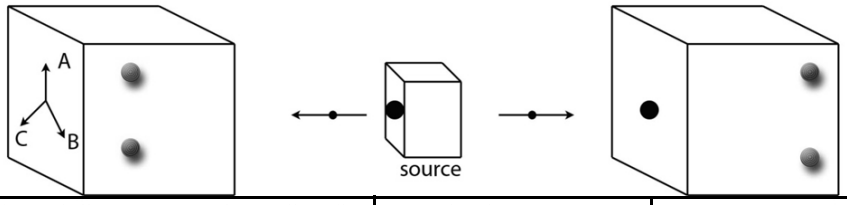
EPR Correlations/Entanglement

- A source produces atom pairs in an entangled state (e.g. state of zero total angular momentum).
- Each analyzer can be set to one of three settings, and lights either green or red with each measurement.
- Suppose each atom pair has some **predetermined** quality (an instruction set) that causes the devices to light either green or red (a realist perspective).
- There are then eight different types of atom pairs, and nine combinations of device settings.



TYPE OF ATOM	RESULT FOR EACH RUN, IF SWITCH IS SET TO: A	B	C
I	RED	RED	RED
II	RED	RED	GREEN
III	RED	GREEN	RED
IV	RED	GREEN	GREEN
V	GREEN	RED	RED
VI	GREEN	RED	GREEN
VII	GREEN	GREEN	RED
VIII	GREEN	GREEN	GREEN

ANALYZER SETTING LEFT	RIGHT	TYPE OF ATOM-PAIR I	II	III	IV
A	A	R/R	R/R	R/R	R/R
A	B	R/R	R/R	R/G	R/G
A	C	R/R	R/G	R/R	R/G
B	A	R/R	R/R	G/R	G/R
B	B	R/R	R/R	G/G	G/G
B	C	R/R	R/G	G/R	G/G
C	A	R/R	G/R	R/R	G/R
C	B	R/R	G/R	R/G	G/G
C	C	R/R	G/G	R/R	G/G
# OF SETTINGS FLASHING SAME COLOR		**9**	**5**	**5**	**5**

REALIST EXPECTATION: Devices should flash the same color at least 5/9 of the time. →

OBSERVATION:

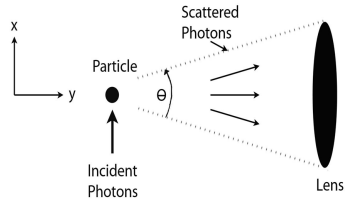
When the settings on both devices are the same (A, B or C) they always flash the same color.
If the (random) settings are ignored, the devices flash the same color 1/2 of the time.

CONCLUSION:

NO (LOCAL) DERMINISTIC SCHEME CAN REPRODUCE ALL THE PREDICTIONS OF QUANTUM MECHANICS!

The Uncertainty Principle

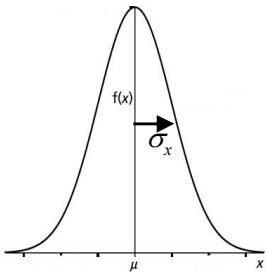
Realist Interpretation



$$\Delta x = \frac{\lambda}{\theta} \qquad \Delta p_x = \left(\frac{h}{\lambda}\right)\left(\frac{\theta}{2}\right) \qquad \Delta x \Delta p_x = \frac{h}{2}$$

- Photons are scattered by localized particles.
- The lens' resolving power introduces an uncertainty in the position.
- The size of the lens introduces an uncertainty in the momentum transferred .

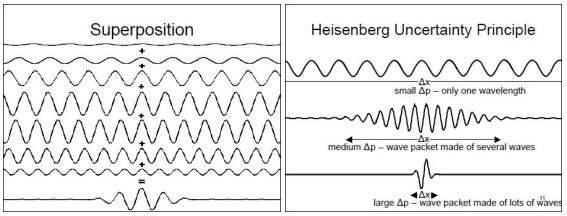
Statistical Interpretation



$$\sigma_x^2 = \frac{1}{N}\sum_{i=1}^{N}(\mu - x_i)^2 \qquad \sigma_x \sigma_p \geq \frac{\hbar}{2}$$

- Measurements are performed on an ensemble of similarly prepared systems.
- Distributions of position and momentum values are obtained.
- Uncertainties in position and momentum are defined in terms of the variance.

Wave Interpretation



$$f(x) = \int_{-\infty}^{+\infty} p(k) e^{2\pi i k x} dk \qquad p(k) = \int_{-\infty}^{+\infty} f(x) e^{-2\pi i k x} dx$$

- Wave packets are constructed from a series of plane waves.
- The more spatially localized the wave packet, the less uncertainty in position.
- With less uncertainty in position comes a greater uncertainty in momentum.