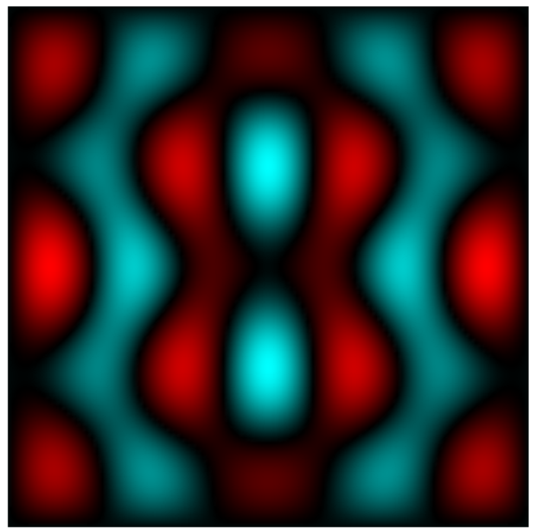
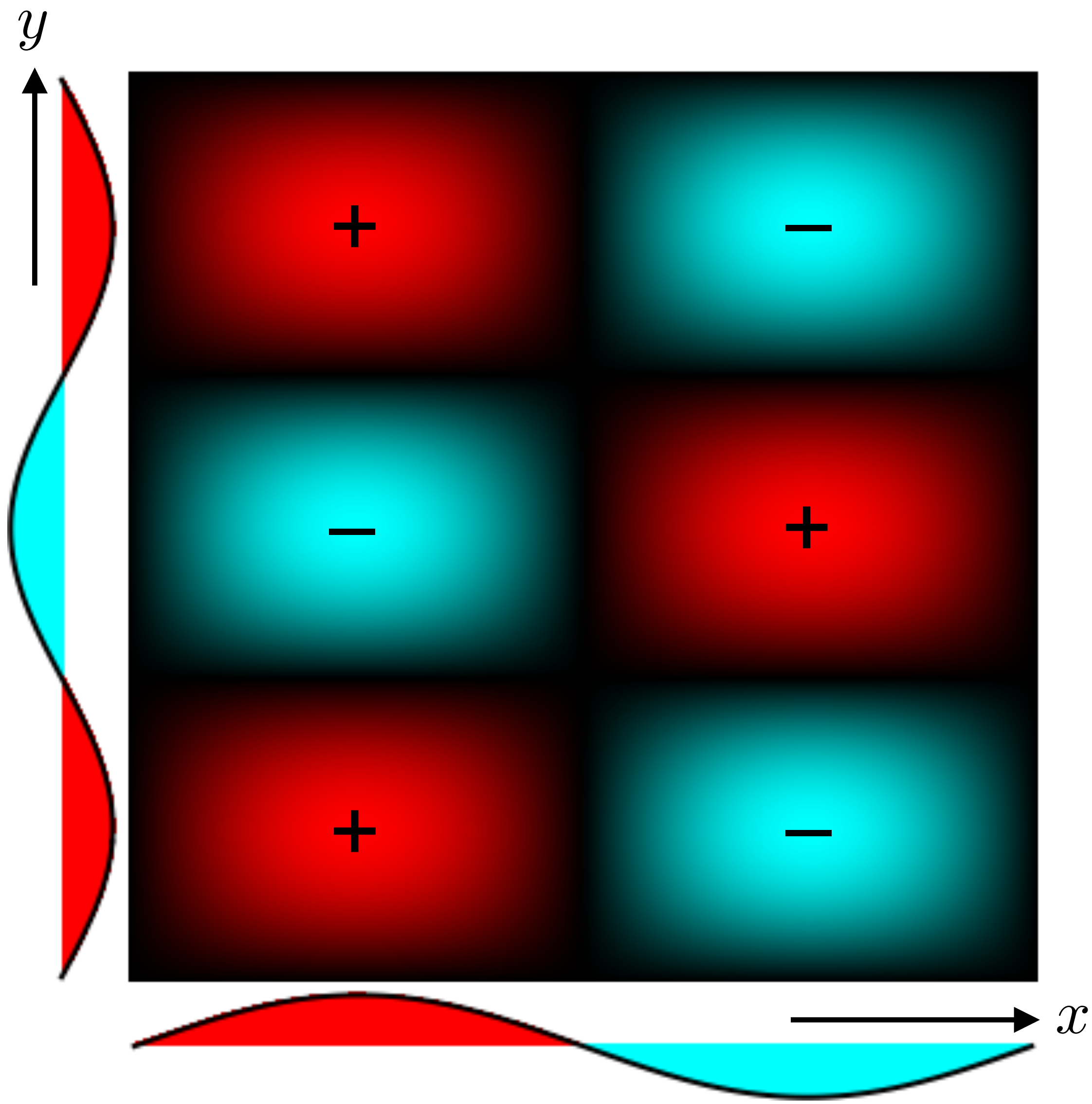
Entanglement Isn't Just Spin

Dan Schroeder, Weber State University, 19 July 2016



Context: First example of a QM problem in more than one dimension, e.g., 2-D square infinite square well...

A separable wave function

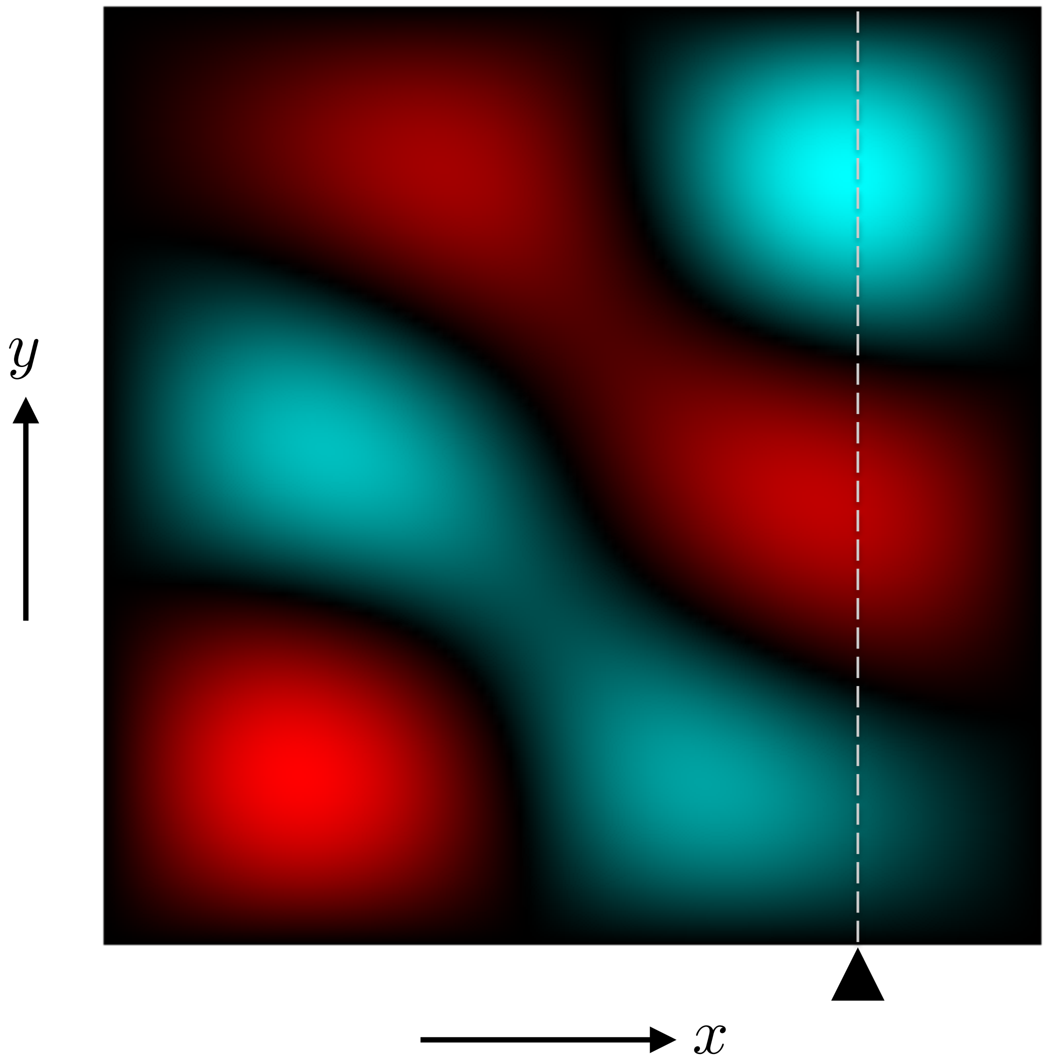


$$\psi(x,y) = \sin(2\pi x)\sin(3\pi y)$$

Misconception #1:

All multidimensional wave functions are separable.
(At least when the potential energy is symmetric.)

Another solution to the TISE

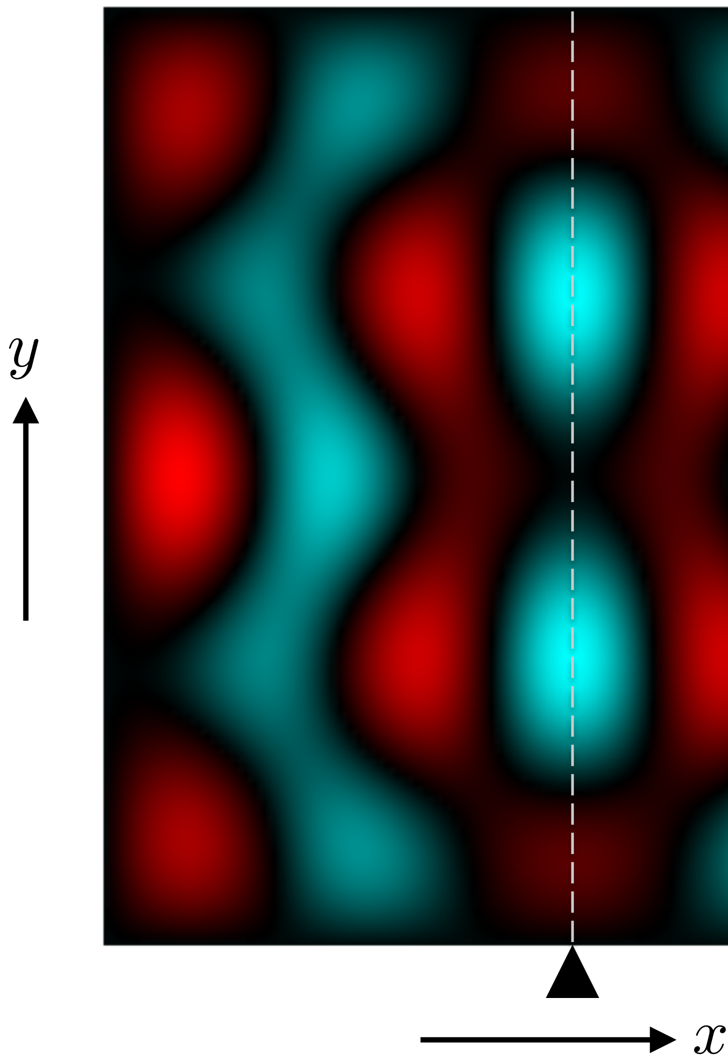


$$\psi(x, y) = \sin(2\pi x)\sin(3\pi y) + \frac{1}{2}\sin(3\pi x)\sin(2\pi y)$$

Measuring *x* tells you something new about *y*

➔ **Entanglement!**

Another entangled solution to the TISE



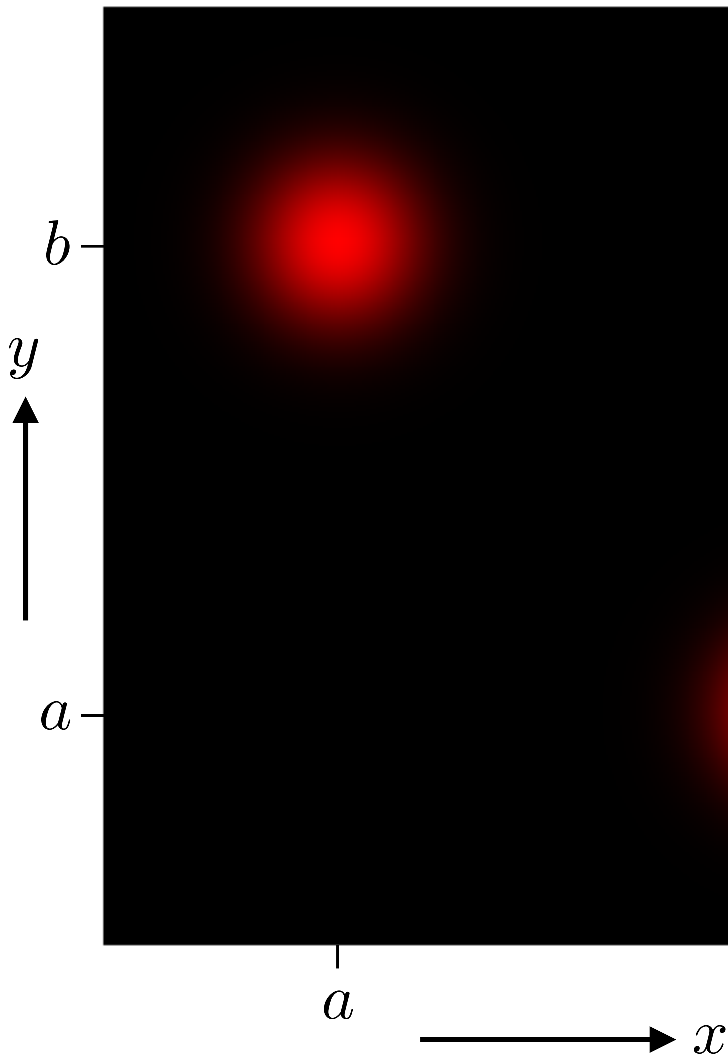
$$\psi(x, y) = \sin(7\pi x)\sin(1\pi y) + \sin(5\pi x)\sin(5\pi y)$$

Misconception #2:

Every wave function is a solution of the time-independent Schrödinger equation.

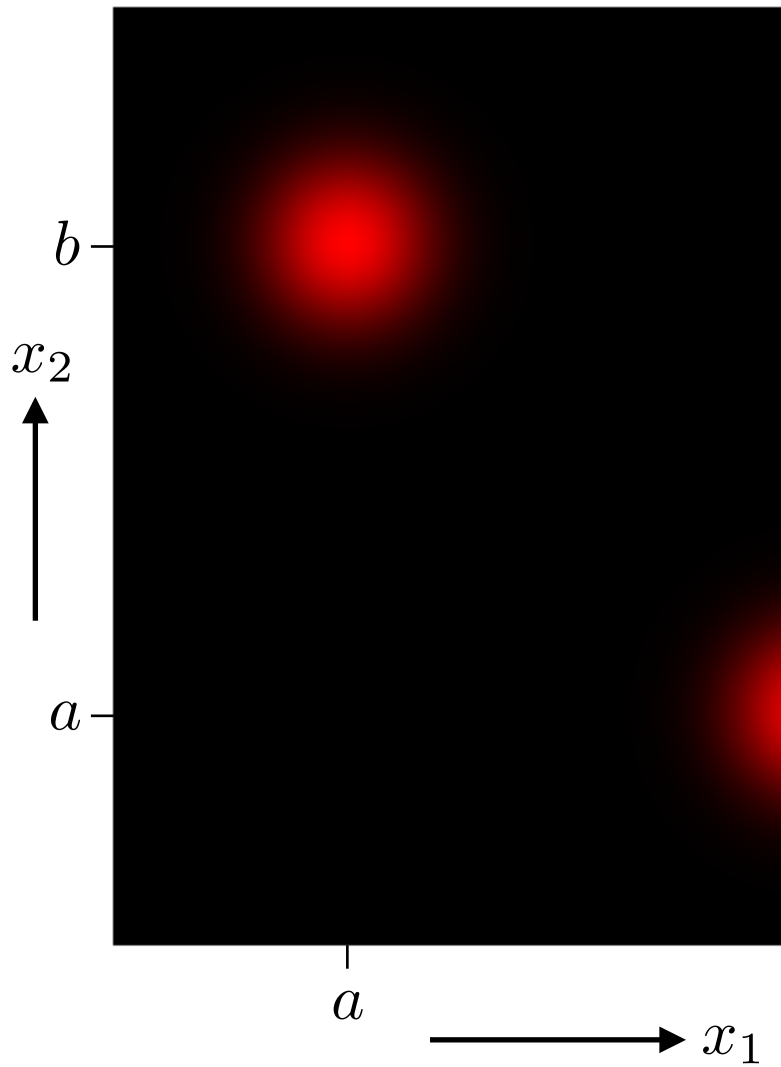
(see, e.g., work of C. Singh)

Another perfectly valid wave function



$$\psi(x,y) = e^{-(x-a)^2} e^{-(y-b)^2} + e^{-(x-b)^2} e^{-(y-a)^2}$$

Two particles in *one* dimension



$$\psi(x_1, x_2) = e^{-(x_1-a)^2} e^{-(x_2-b)^2} + e^{-(x_1-b)^2} e^{-(x_2-b)^2}$$

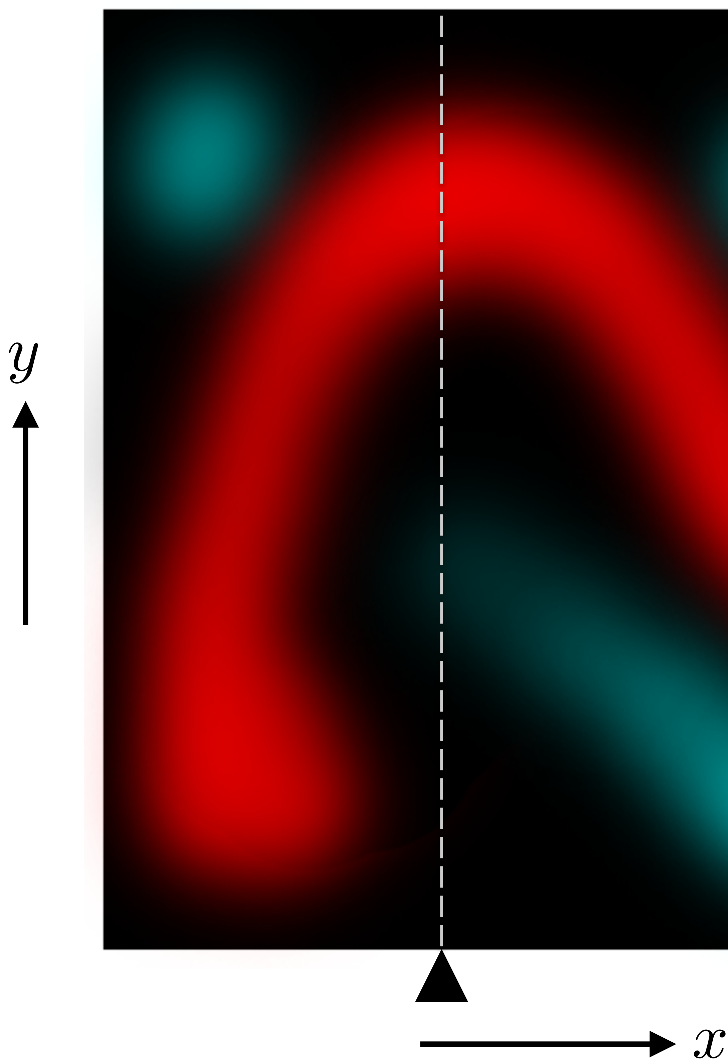
Measuring x_1 tells you something new about x_2

➔ **Entanglement!**

Misconception #3:

Every particle has its own wave function.

Yet another perfectly valid wave function

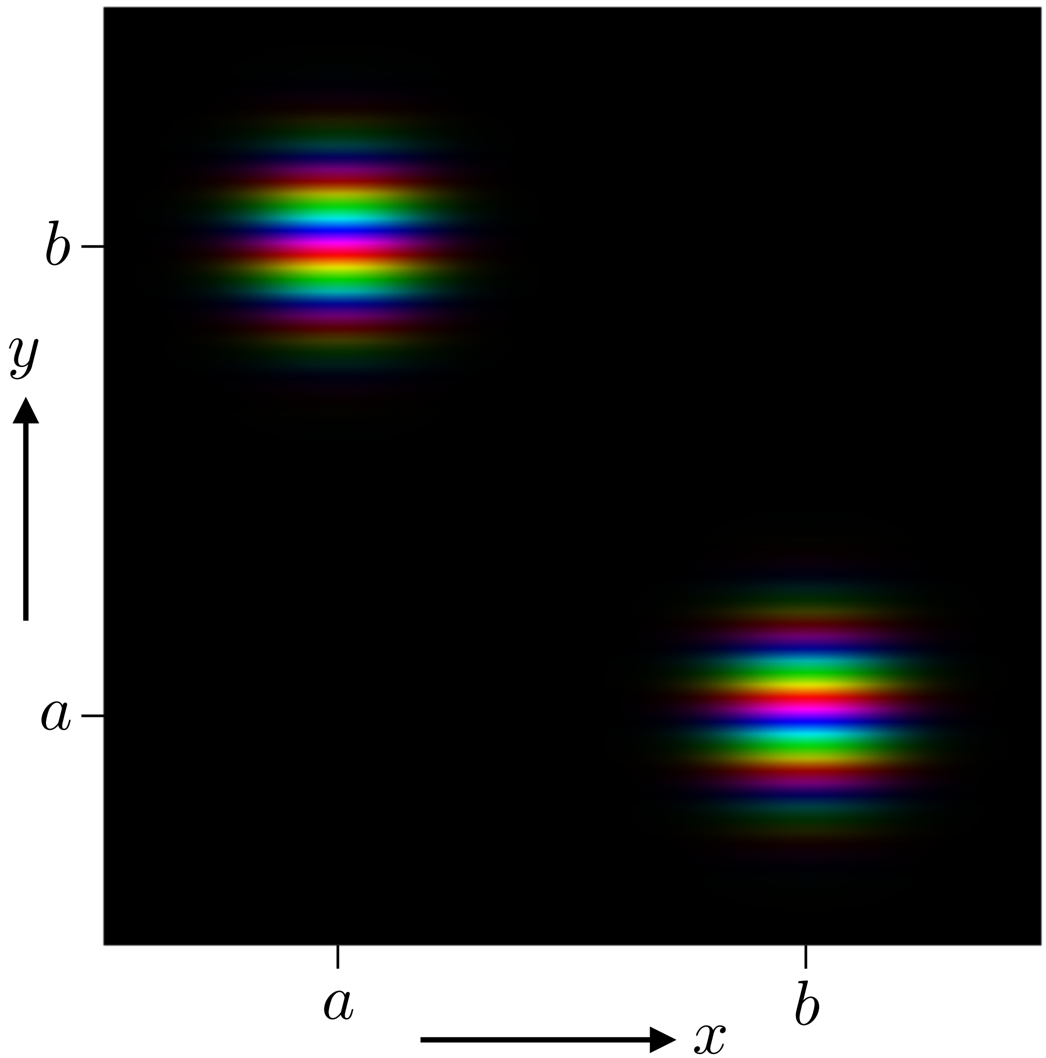


$$\psi(x, y) = ???$$

Feel free to replace:

$$(x, y) \longrightarrow (x_1, x_2)$$

Yet another perfectly valid wave function

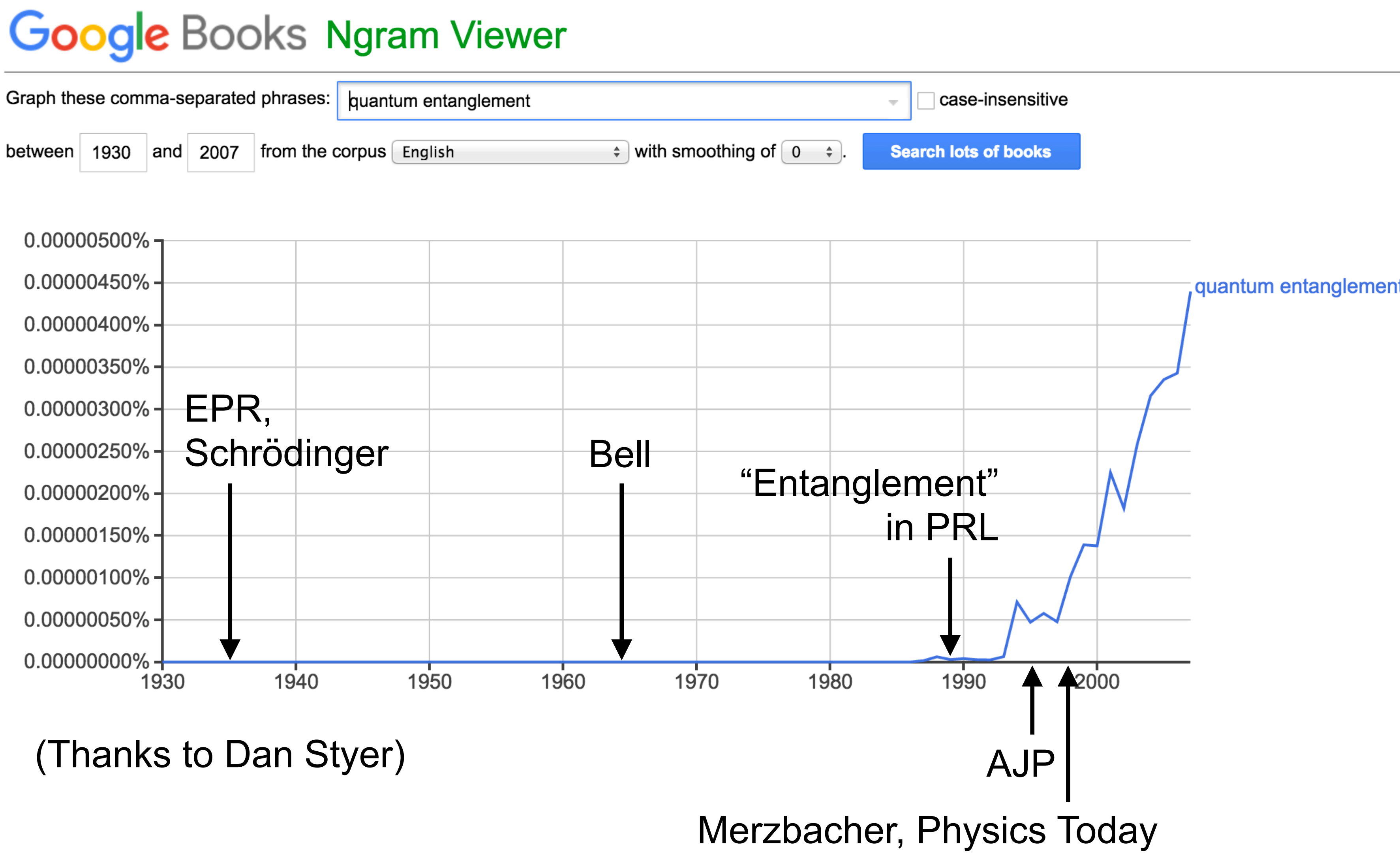


$$\psi(x,y) =$$
$$e^{-(x-a)^2} e^{-(y-b)^2} e^{-iky}$$
$$+\ e^{-(x-b)^2} e^{-(y-a)^2} e^{+iky}$$

Feel free to replace:

$$(x,y) \longrightarrow (x_1, x_2)$$

Why teach entanglement?



(Thanks to Dan Styer)

Why teach entanglement?

- Explosive growth of quantum information science.
- Today’s students have already heard the term and are naturally curious.
- Probably essential for understanding the meaning of “measurement”.

My suggestions:

- **Put some entangled wave functions into your quantum course!**

- **Use the word “entanglement” early and often!**