# What You Should Know from "Looking Glass Universe"!

1.) One way the Heisenberg's Uncertainty Principle is explained is to say that to see subatomic sized particles, you have to bounce light off them which, in turn, changes their momentum. That change in momentum produces uncertainty. Is the Heisenberg Uncertainty Principle really the consequence of taking measurements?

No!

2.) Does a subatomic particle have just one speed or one place where it is? If the answer is "no," what does a particle have?

As long as the particle's position hasn't been measured, it's speed or position is all the speeds or positions in the superposition that is the wave function. This is why trying to visualize what it is doing is so confusing.

3.) Can you make a measurement of more than one thing about a particle?

No. You can only measure, say, the position or the speed.

4.) When you make a position measurement, does it give you a range of position? If not, what does it give you?

You don't get one range of positions. It just turns up in one, single place, and it will pick which one randomly.

## 5.) Once you've measured once, can you retrieve the superposition?

No! Measuring a second time and the particle will be where it was measured as being in the first time. That is what is meant by "a measurement collapses the state."

## 6.) So what have you done when you've measured the speed of a particle?

You've ruined the real speed, the superposition, by collapsing the wave function.

## 7.) Is the uncertainty in the Heisenberg Uncertainty principle due to disturbing the particle?

No, it has nothing to do with measurement. It has to do with the range of speeds in the superposition. It is the *range* that is being referred to by the principle.

## 8.) Why is "uncertainty" a bad word when talking about, say, speed?

This suggests there is a "correct" speed and we are just uncertain about its value. It suggests a classical particle, which is not what's happening here.

## 9.) What is uncertainty in the Heisenberg's Uncertainty Principle if we are talking about position and momentum?

The HUP is all about the *range* of different speeds (momenta) and positions in the superposition. This range is the uncertainty. It isn't that there is a position we are uncertainty about it. The particle is in a superposition of many places, but it is not equally probable for all of those places. If the likelihood is high that a particle moving along a line will show up in a very small area $\Delta x$, the superposition will be over a very small area. So if we were to measure where it is, we could make a pretty good guess where the particle would turn up. There is also a superposition of speeds (momenta). There will be a range $\Delta p$ over which the momenta will be weighted the most heavily? What HUP says is that $\Delta x$ and $\Delta p$ can't both be as small as you want. If you could, that would allow you to make a particle almost classical in both position and momentum, and that doesn't happen.

10.) So what does Heisenberg's Uncertainty Principle say about the range (uncertainty) of the spatial and momentum wave functions?

$$\Delta x \Delta p \geq \hbar / 2$$

11.) What does Heisenberg's Uncertainty Principle say about the range (uncertainty) of the energy and time?

$$\Delta E \Delta t \geq \hbar / 2$$

12.) Why can we make the uncertainty of both momentum and position super small at the same time?

Because that would make the particle very close to classical and the world isn't classical, it's quantum.

13.) What does this have to do with the Big Bang?