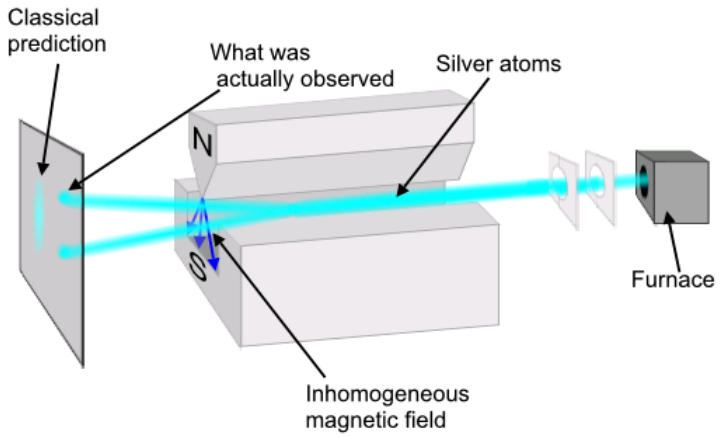
Stern-Gerlach experiment

Stern-Gerlach experiment conceived by O. Stern in 1921 and performed by W. Gerlach in 1922 vividly shows the bizarreness of quantum phenomenon. See the figure. A beam of silver atoms comes out from a furnace and passes through inhomogeneous magnetic field. As silver atoms is like a small magnet (i.e. we say silver atoms possess what is called "magnetic moment") it receives force when passing through the inhomogeneous magnetic field. Think about it this way. If the north pole of a silver atom is directed upward and the south pole of the silver atom downward, the north pole part (i.e. the upper part) of the silver atom will feel the downward force, while the south pole part (i.e. the lower part) will feel the upward force. (See the figure.) However, the downward force will be greater than the upward force, as the magnetic field is stronger at the upper part than the lower part. Therefore, the silver atom will feel a force downward. Similarly, if the north pole of a silver atom is directed downward, it will feel a force upward. By the same token, if the north pole and the south pole of a silver atom is aligned horizontally, it will not receive any net force since the force upward and downward would be the same.

Since there is no reason that the magnetic moment of silver atoms coming out from the furnace would be aligned along a certain direction, it should be reasonable that some would feel a great upward force, or a little bit of upward force, or no force at all, or a little bit of downward force, or a great upward force. After passing through the inhomogeneous magnetic field, the silver atoms should arrive at the whole range of spots on the screen, denoted in the figure as "classical prediction." However, what was actually observed was that there were only two spots on the screen; there is no such thing as the magnetic moment of the silver



atom aligned horizontally, nor slightly askew from horizontal direction. This is strange. It is as if the magnetic moment of the silver atom can be aligned in only two ways from the first place, but not any other ways.

It is actually because the magnetic moment of silver atom is in an "undetermined" state and only in a "determined" state when it is measured. You will learn what it means precisely when we formally introduce quantum mechanics in "A short introduction to quantum mechanics I: observables and eigenvalues."

As an aside, the magnetic moment is proportional to angular momentum, and one can interpret this experiment as measuring the angular momentum.

Summary

- Classically, there is no reason that the magnetic moment of atoms would be aligned along a certain direction.
- However, when it goes through magnetic field, it is aligned along only two certain directions.

(The figure is from `http://commons.wikimedia.org/wiki/File:Stern-Gerlach_experiment.PNG`)