



# QUANTUM MECHANICS

*James Freericks, Department of Physics  
Georgetown University  
Work funded by the NSF and Georgetown*

*Please join in a moment of silence in solidarity with the citizens of Ukraine*



# *Asher Peres tells us to focus on the real world*



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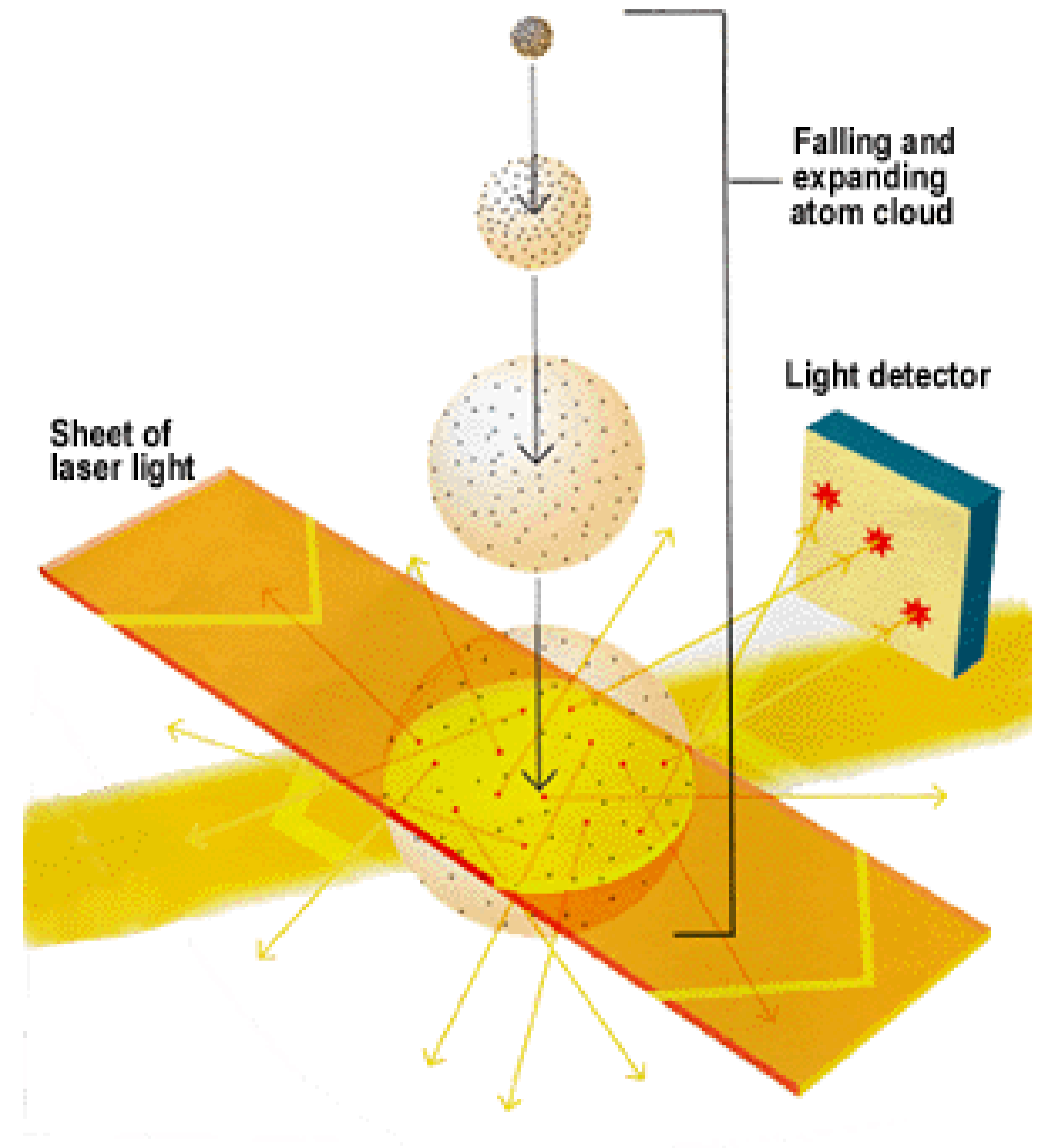


*Quantum phenomena do not occur in a Hilbert space. They occur in a laboratory.*

*Perhaps you have said in class that we  
cannot measure position and momentum at  
the same time*

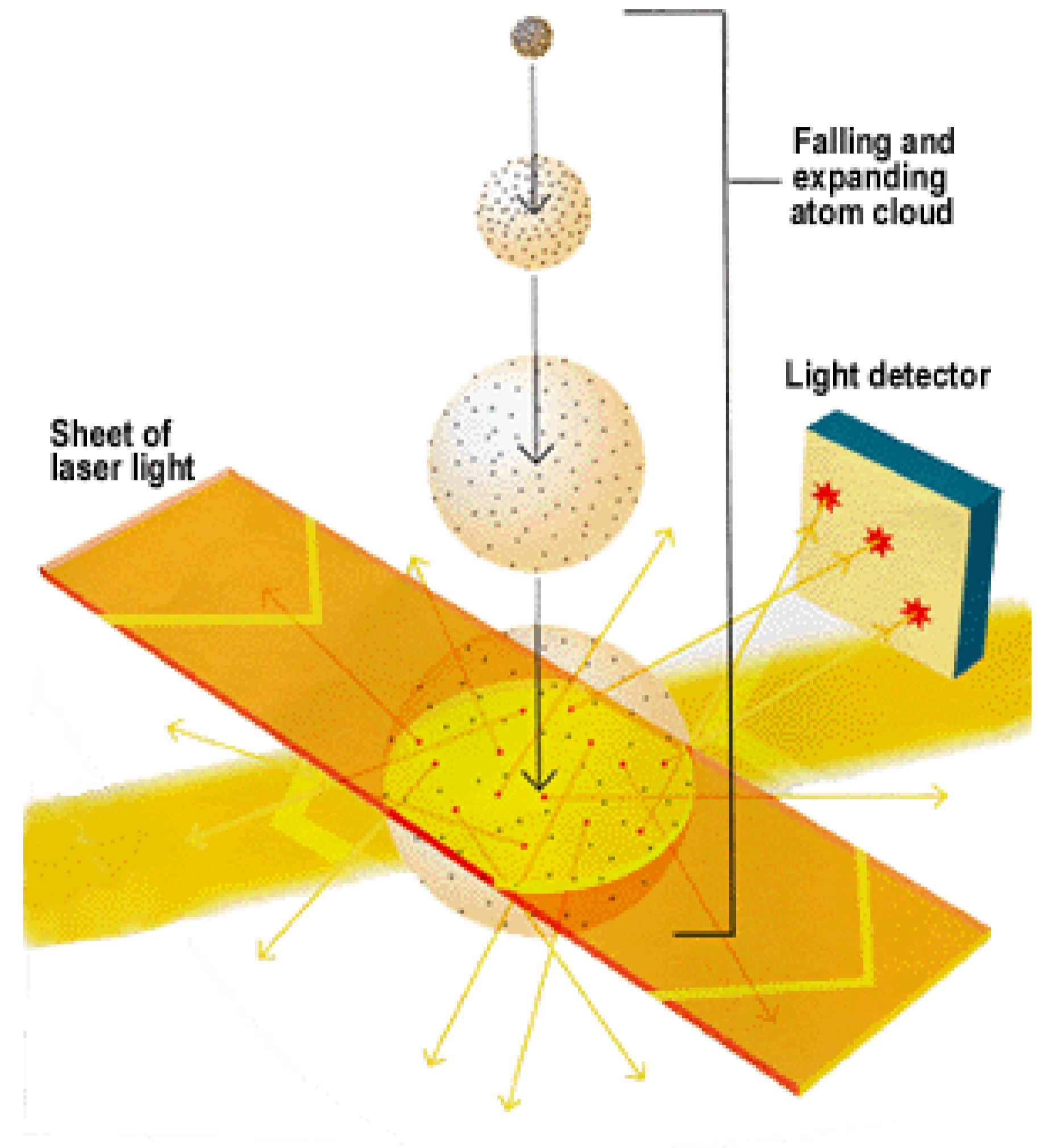
*But then how do we measure momentum?*

# *Time of flight*



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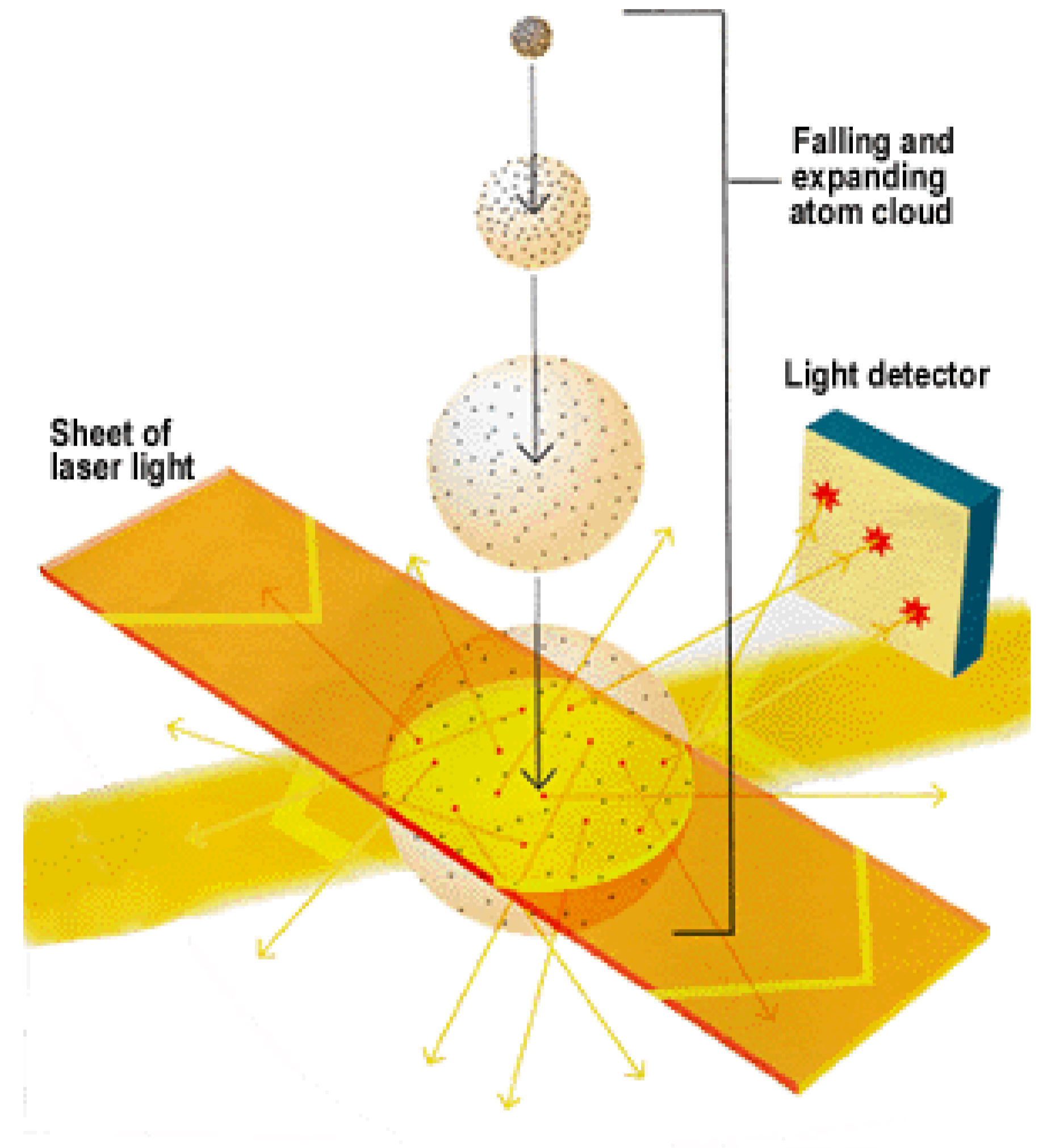
1. An event starts a clock





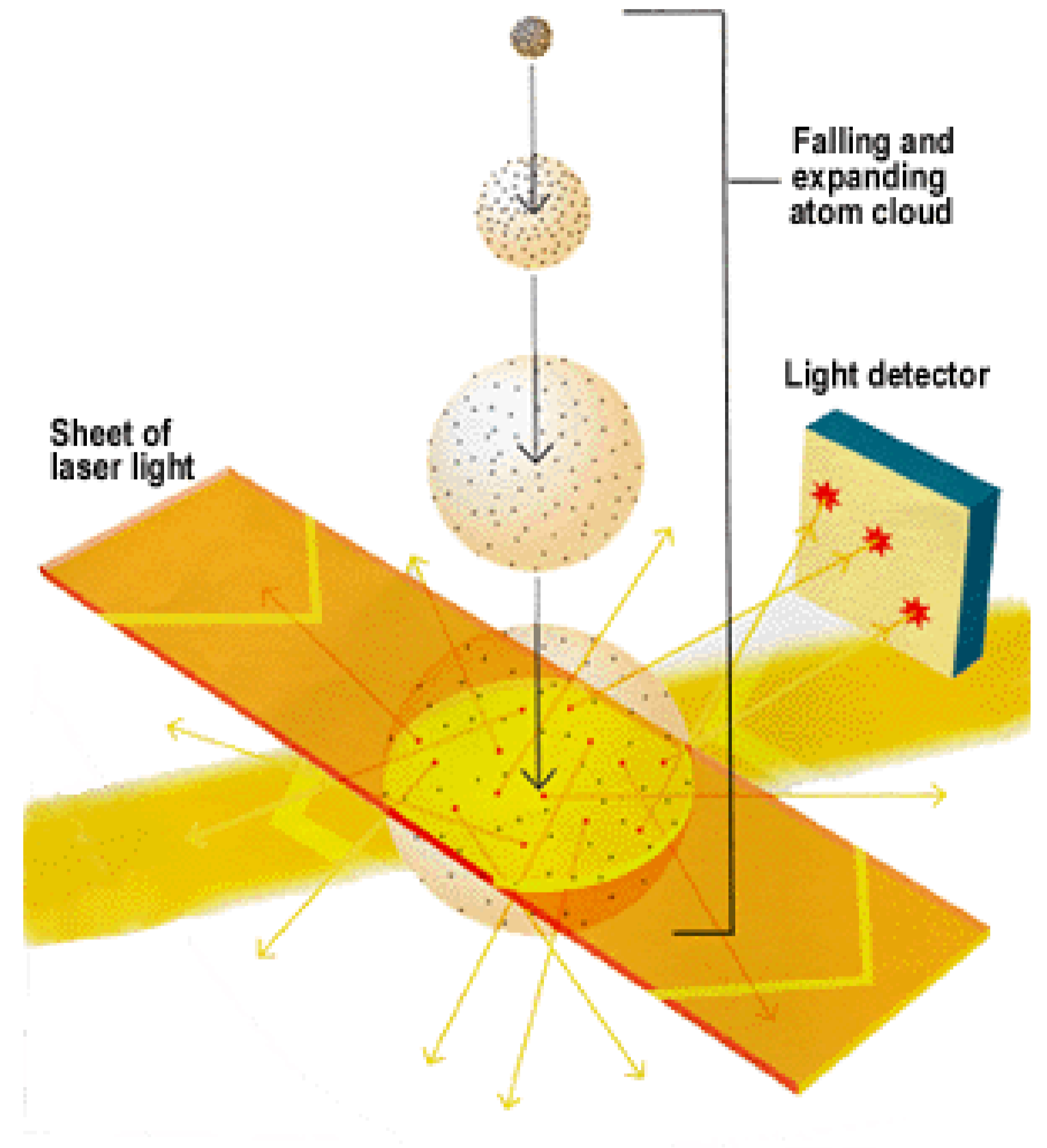
# *Time of flight*

1. An event starts a clock
2. The particle travels through free space to the detector where it is detected



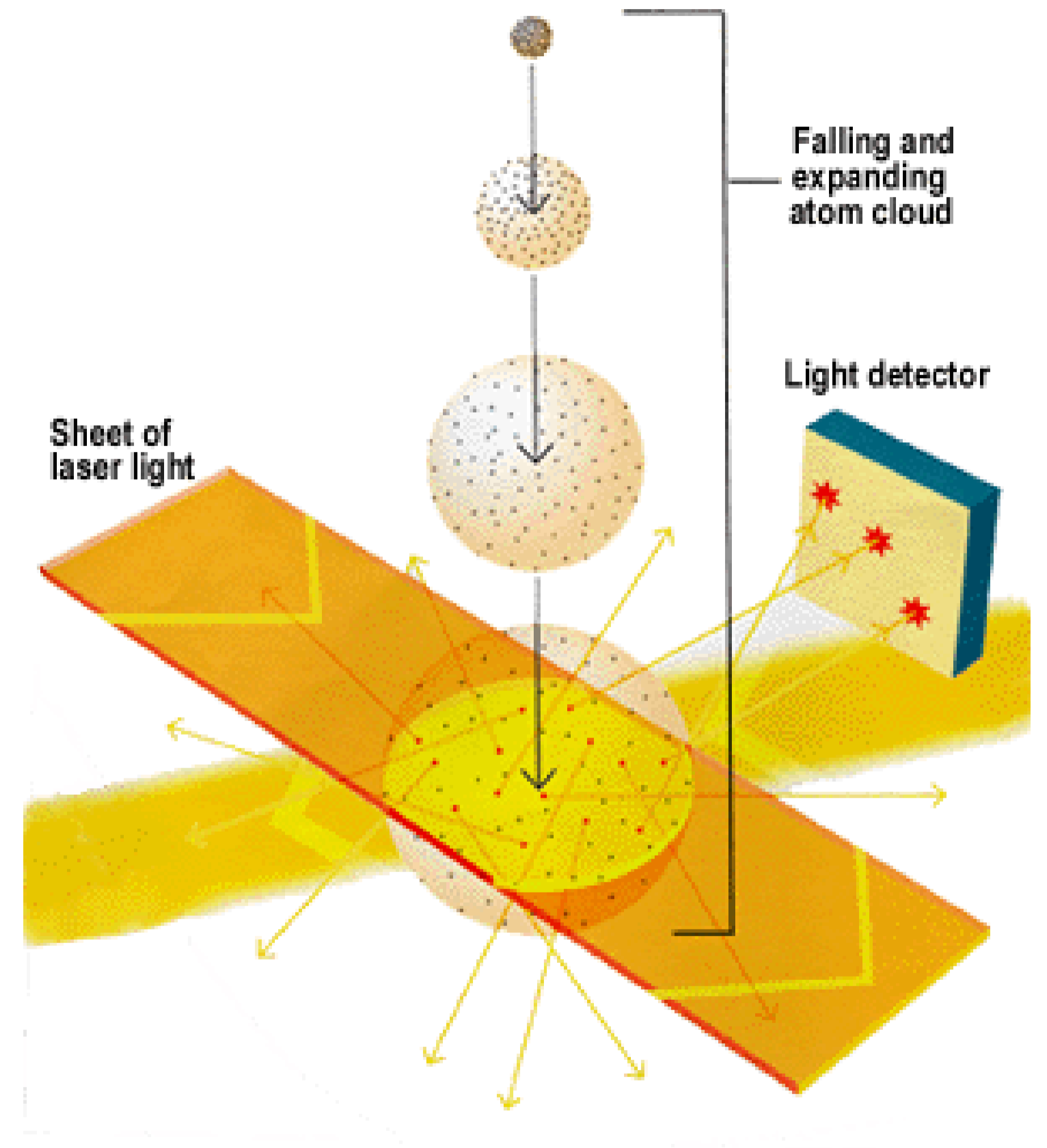
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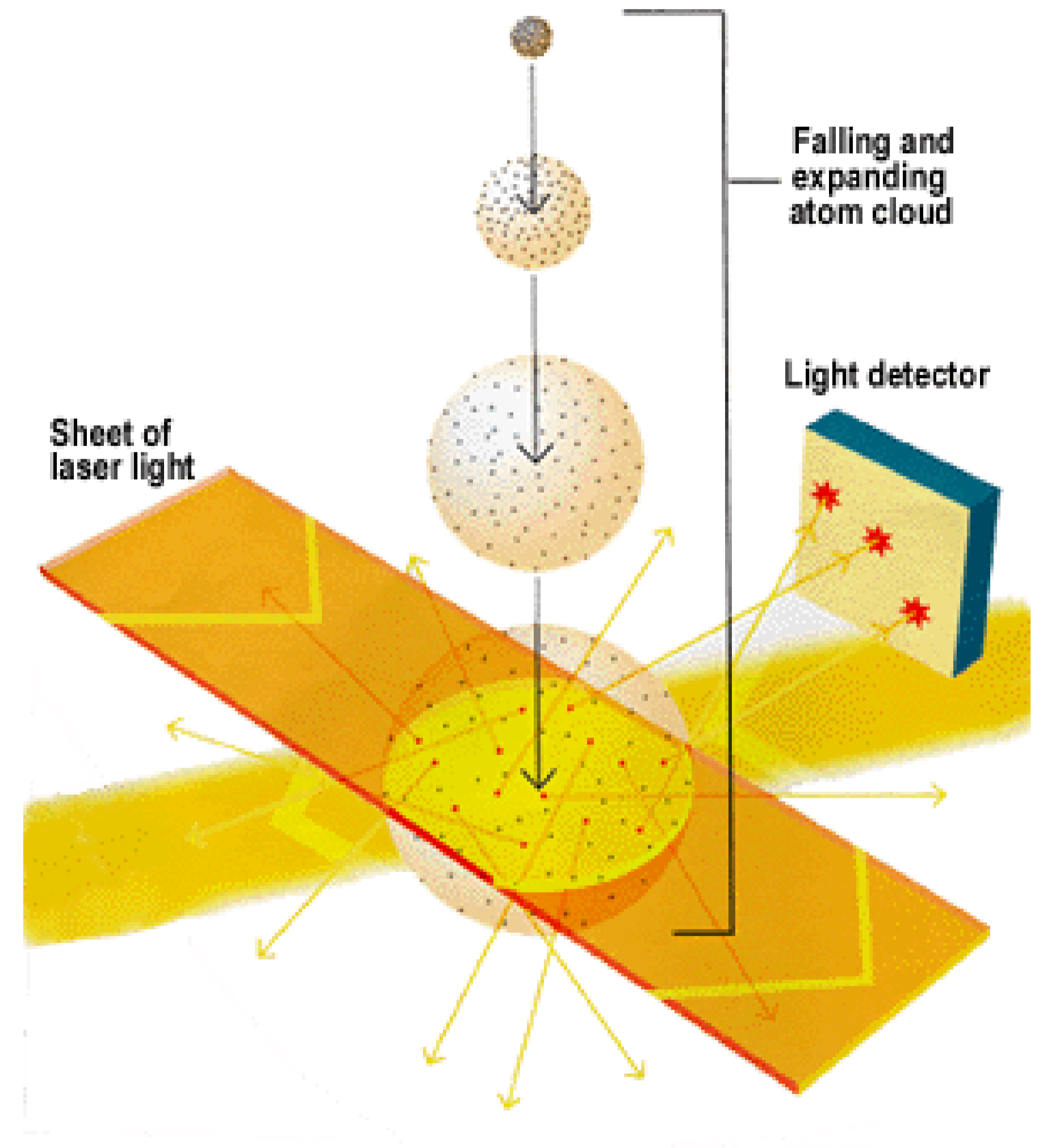
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4. From the speed we get the momentum
5. At the instant of measurement, we know the position and the momentum of the particle at the same time.



*It is simply not true that one cannot measure position and momentum at the same time!  
Please don't tell your students this.*

*We cannot prepare a quantum state with definite position and momentum, but we can measure position and infer momentum as accurately as you want.*

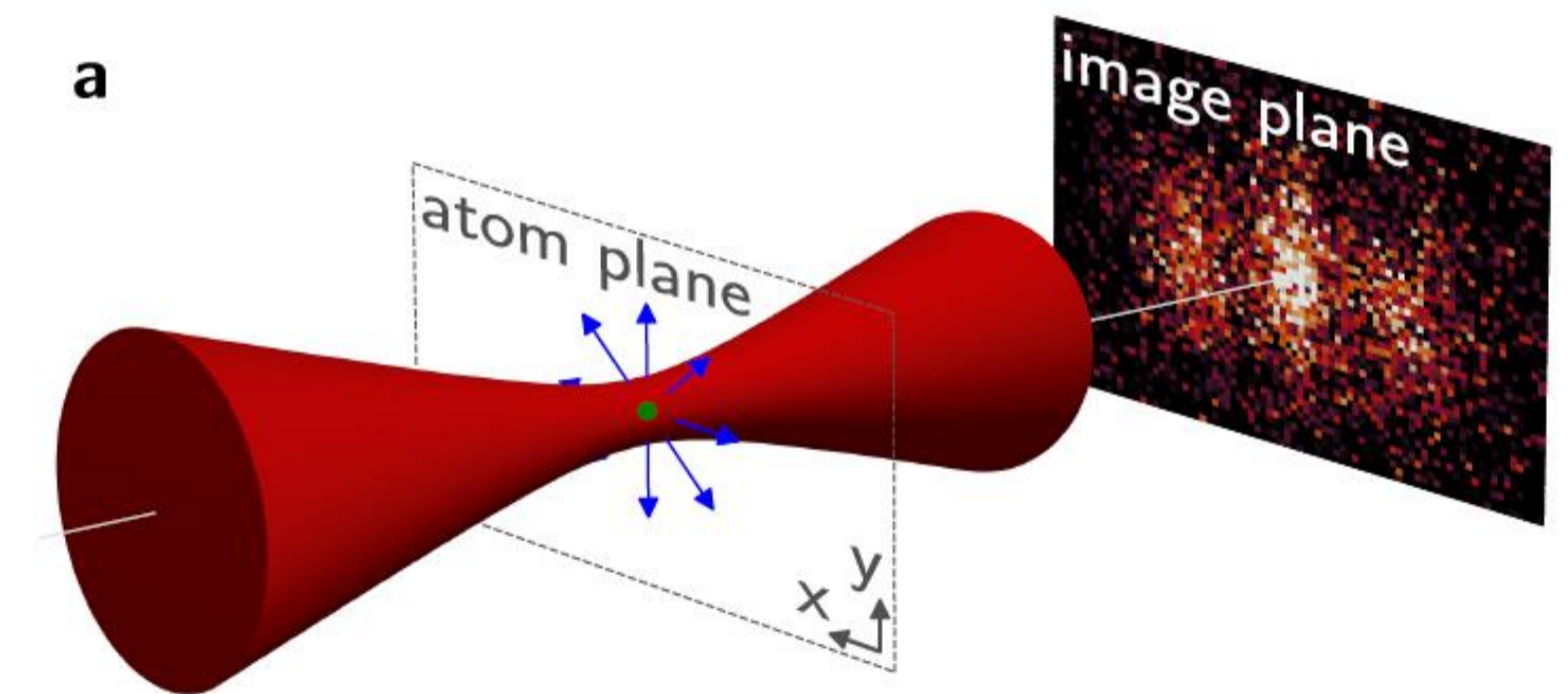
*Time of flight gives a great opportunity to talk about real experiments and the relationship between collapse and what is actually measured.*

*Cindy Regal shows us how  
to do this with harmonic  
oscillator wavefunctions.*

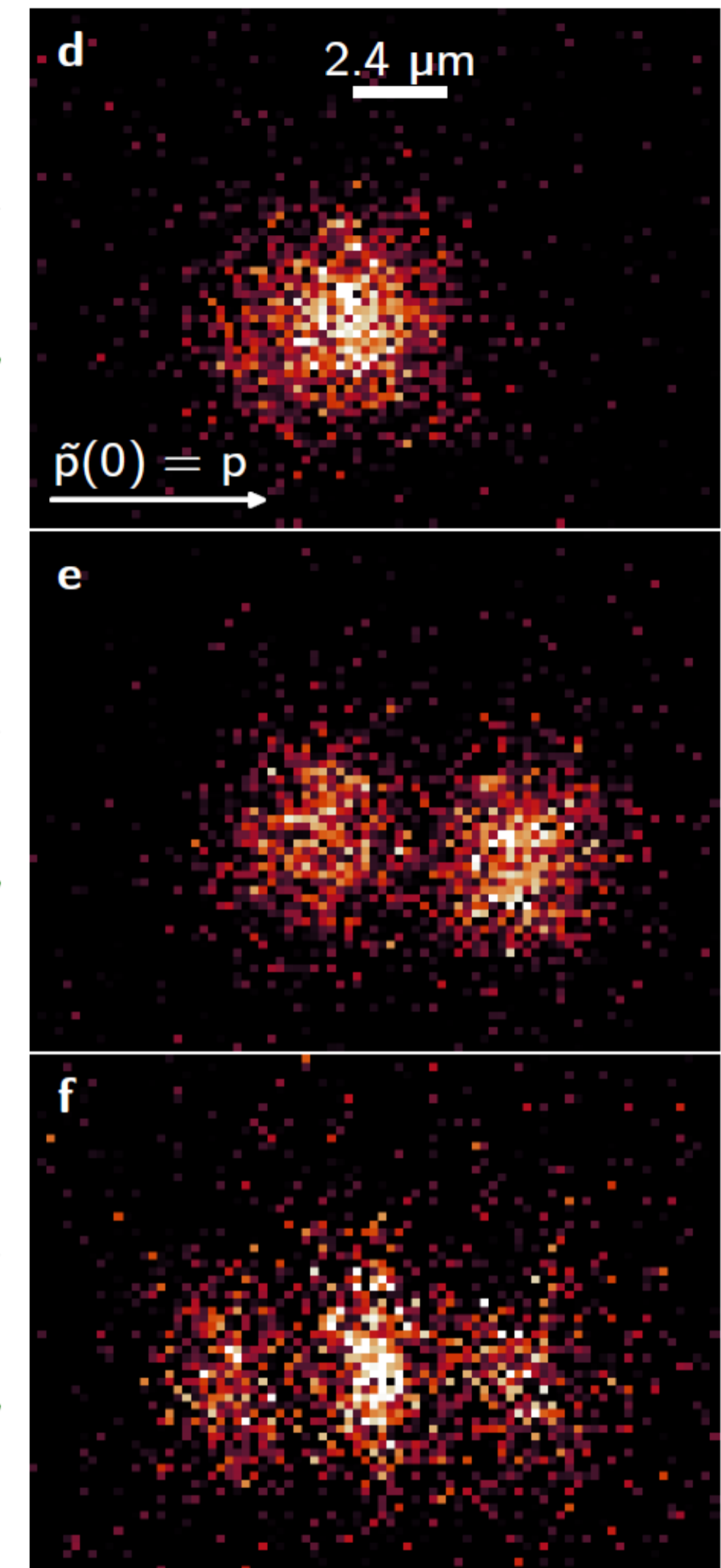
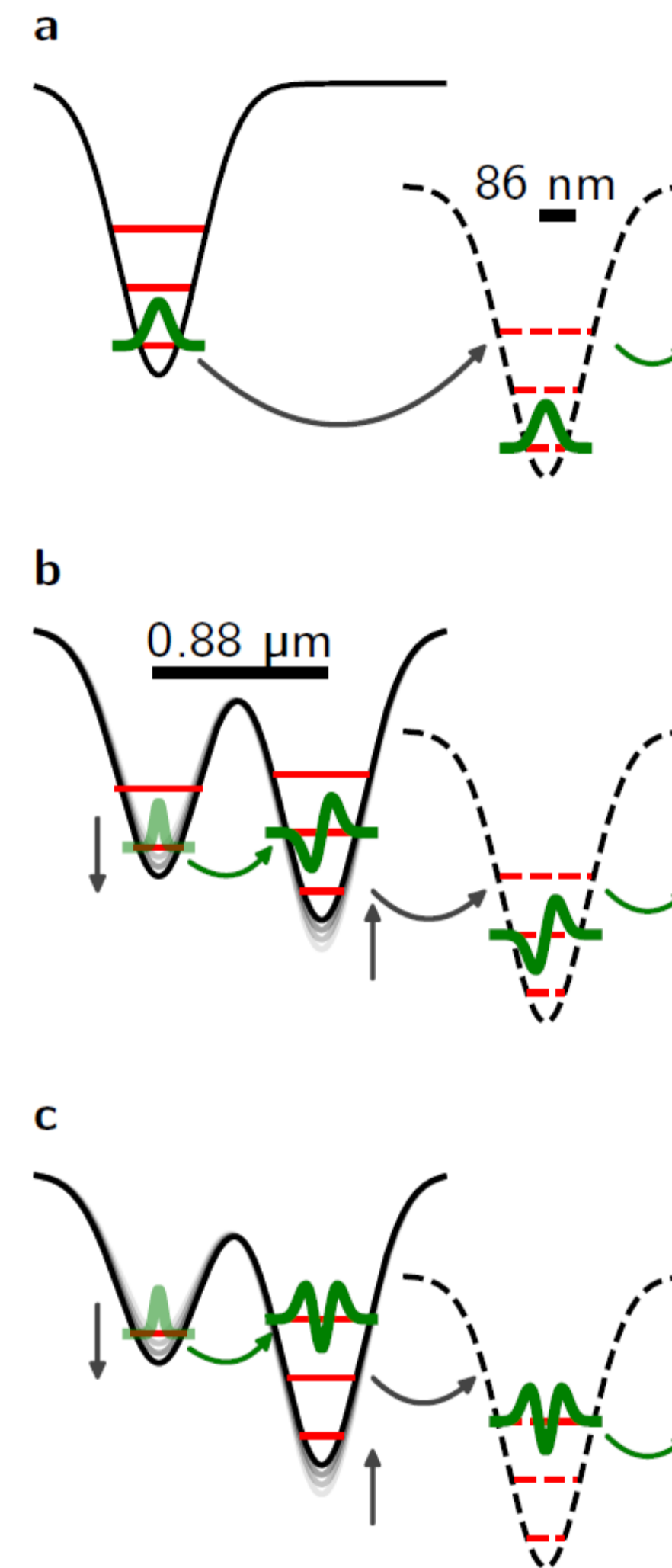
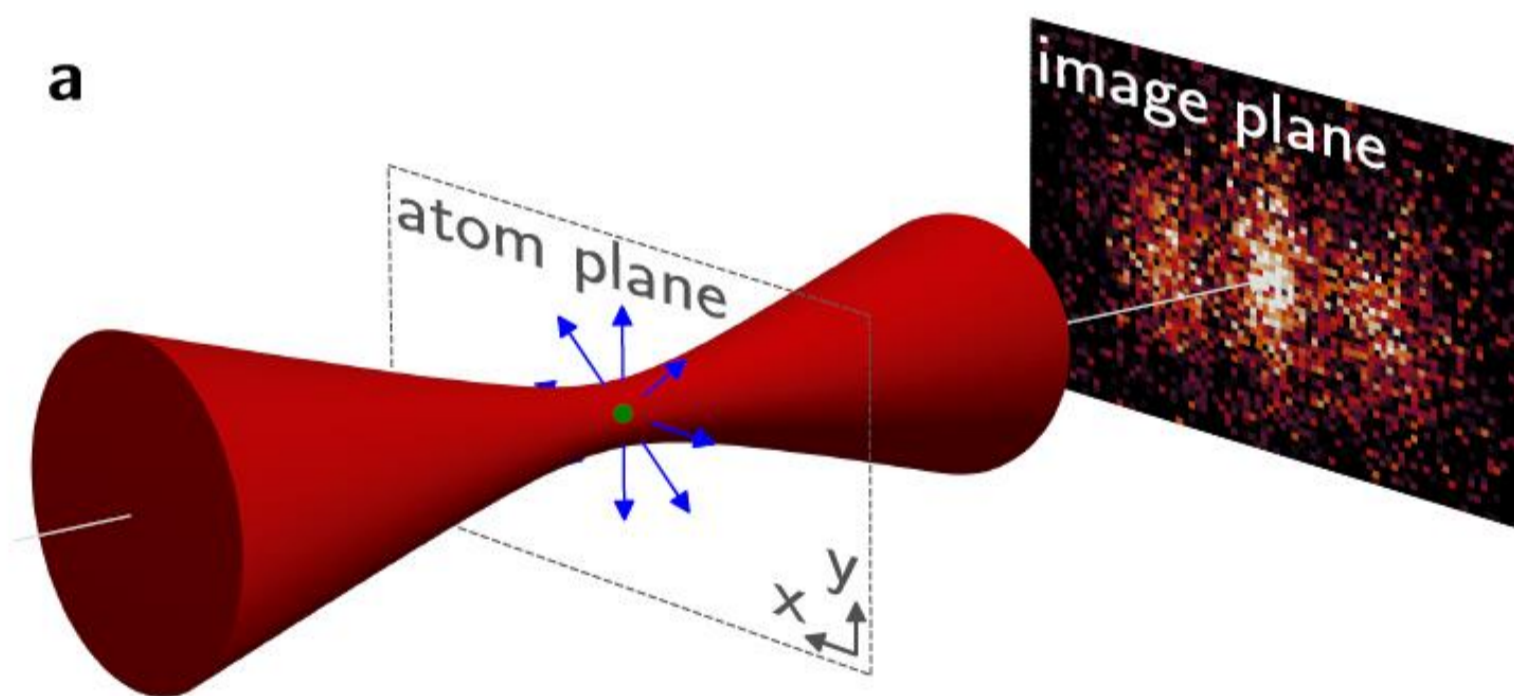




*Prepare the ground state by cooling. Use a double-well structure to transfer to a low excited state. Then release the trap and use time of flight to measure the momentum distribution.*

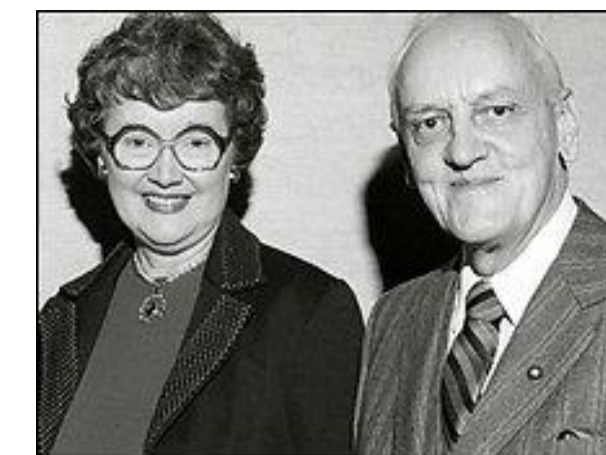


# Harmonic oscillator wavefunctions measured by time of flight (Regal)



*This is a great example of a second quantum revolution experiment that can be understood even at the high school level!*

*Thanks to*

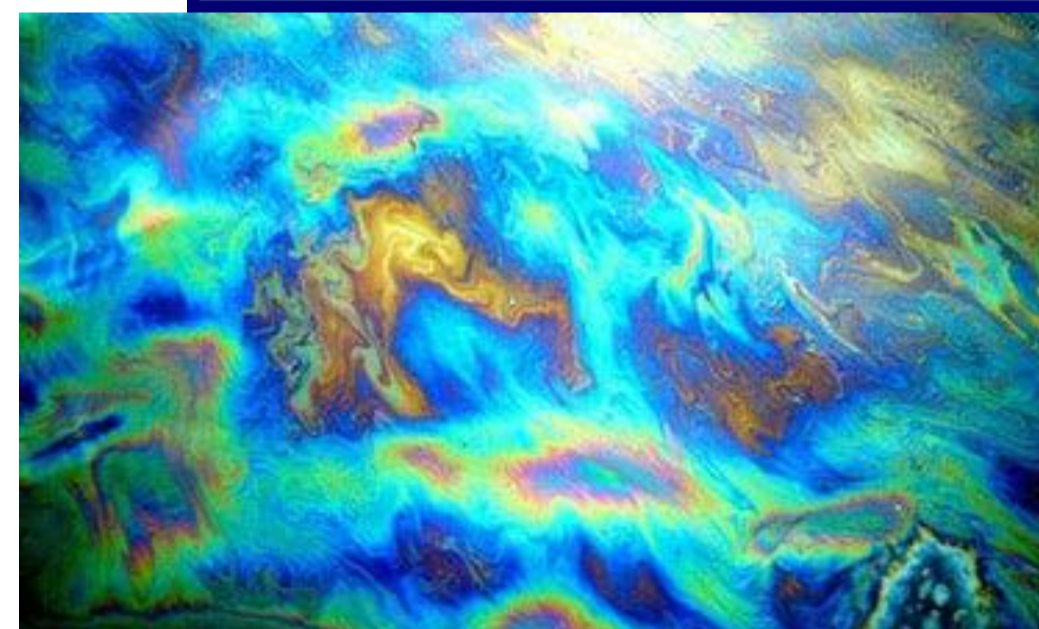


*Resources*

<https://quantum.georgetown.domains>



<https://www.edx.org/course/quantum-mechanics>



<https://www.edx.org/course/quantum-mechanics-for-everyone>



*Directly measuring the harmonic oscillator wavefunction*

CSAAPT Fall meeting, October 22, 2022

