Non-obvious controls:

- In **Experiment** mode, a single Hydrogen atom is hidden behind the black box. In **Prediction** mode, the atom is visible. Students should be able to discover that only the predictions of the Schrodinger model match the results of an experiment.
- Select **Transitions** in the **Help** menu to show the wavelengths needed for transitions in the Bohr, deBroglie, and Schrodinger models. If **Light** is set to **Monochromatic**, the wavelength slider flashes white when it is over a wavelength that could excite the electron from the ground state.
- Use the camera icon (📷) to take a snapshot of the Spectrometer so that you can compare the patterns for different models.
- Set the slider at the bottom to **fast** to build up the Spectrometer pattern quickly.
- You can **Pause** the sim and then use **Step** to incrementally analyze.
- If you are doing a lecture demonstration, set your screen resolution to 1024x768 so the simulation will fill the screen and be seen easily.

Important modeling notes / simplifications:

- These atoms are not to scale!
- In the **Schrodinger** model, transitions obey the selection rules $\Delta l = \pm 1$, $\Delta m = 0, \pm 1$. Because of these selection rules, the state 2,0,0 is a metastable state from which the electron cannot spontaneously emit a photon. If **Light** is set to **White**, whenever the electron falls into this state, the gun will soon emit a photon of exactly the right energy to excite it. If **Light** is set to **Monochromatic**, the electron will remain stuck in this state unless you select a wavelength that can excite it out of this state.
- In the **Bohr** and **deBroglie** models, transitions between any two levels are equally probable. In the Schrodinger model, the probability of a transition is based on the overlap between the wave functions, and some transitions are forbidden or highly improbable. Thus, there are fewer spectral lines in the Schrodinger model than in the Bohr or deBroglie model.
- In the **Plum Pudding** model, we assume the electron can absorb any frequency of light, but always emits light with frequency equal to its oscillation frequency.¹

Insights into student use / thinking:

- Students may not realize that UV photons can have different wavelengths, since they all look the same.
- If **Light** is set to **Monochromatic**, students may not realize that they need to move the slider into the UV region to excite the atoms.
- Students many have trouble identifying the red goo in the Plum Pudding model as positive charge. In interviews, we see that some students describe the Plum Pudding model as a cloud of negative charged filled with little specks of positive charge, rather than the other way around. The word “cloud” suggests that they are mixing up the Plum Pudding model with the Schrodinger model, in which the electrons are often described as a cloud of negative charge. These students initially thought that the electron in the simulation was a proton, but were eventually able to identify it correctly by using the legend or by comparing it to the electrons in other models.

Suggestions for sim use:

- For tips on using PhET sims with your students see: [Guidelines for Inquiry Contributions](#) and [Using PhET Sims](#)
- The simulations have been used successfully with homework, lectures, in-class activities, or lab activities. Use them for introduction to concepts, learning new concepts, reinforcement of concepts, as visual aids for interactive demonstrations, or with in-class clicker questions. To read more, see [Teaching Physics using PhET Simulations](#)
- For activities and lesson plans written by the PhET team and other teachers, see: [Teacher Ideas & Activities](#)
- Ask students to determine which model most closely matches the experimental observations.
- Ask students to explain the reasons that people believed in each model, as well as the reasons they discarded each model in favor of a new model. This sim can be used in conjunction with the [Rutherford Scattering sim](#), which illustrates the reasons for moving from the plum pudding model to the solar system model.