

## 10.6: Wrapping It Up 10 - Curved Spacetime Around Astronomical Objects

Imagine you are studying a binary system in which a pulsing neutron star is orbiting a supermassive black hole and you are viewing the system from the direction of the black hole. Over time you have detected that the time interval between the pulses from the pulsar is changing. Intrigued, you set about to discover what is happening by studying a graph of the pulsar's periods.

The *Binary Pulsar Simulation* contains four pieces:

- The Options box allows you to select up to two different effects: the Doppler Shift and Gravitational Redshift .
- The Observer View section shows you what the observer is seeing from the binary pulsar system.
- The Simulation View section shows the orbit of the pulsar around its black hole companion and has a button for you to start the simulation.
- The last section is the Graph, which displays the light intensity of the pulsar over time. After running the simulation, you can use your mouse to hover over points on the graph to read off intensities and times for individual data points.

The big arrow near the point marked “A” points in the direction of you, the observer.

When you first start up the activity, the default setting has no options selected.

### Play Activity

#### 10.6.1: Part I: The Period of the Pulsar

In this part of the activity, you will measure the period between pulses emitted by the pulsar with no options selected. This will give you the “rest” or “laboratory” period of the pulsar.

Click the Start button to run the simulation for one orbit and examine the graph of the pulses. The letters A, B, C, and D describe different pulsar locations as it orbits around the black hole.

1.



2.

3.

4.

5.

### 10.6.2: Part II. Doppler Shift

Now select the Doppler Shift box and run the simulation again.

1.

2.

3.

4.

5.

Now convert your results from period to frequency:

6.

7.

### 10.6.3: Part III: Gravitational Redshift

Next, select the gravitational redshift box (and de-select the Doppler shift box) and run the simulation again.

1.

2.

3.

4.



#### 10.6.4: Part IV: Doppler Shift and the Gravitational Redshift

So far in our simulations, we have been looking at the two effects on a pulsar's period individually. But in the real world, both the Doppler shift and gravitational redshift occur simultaneously. In this part of the activity, we will see what happens when we include both effects.

1.

2.

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