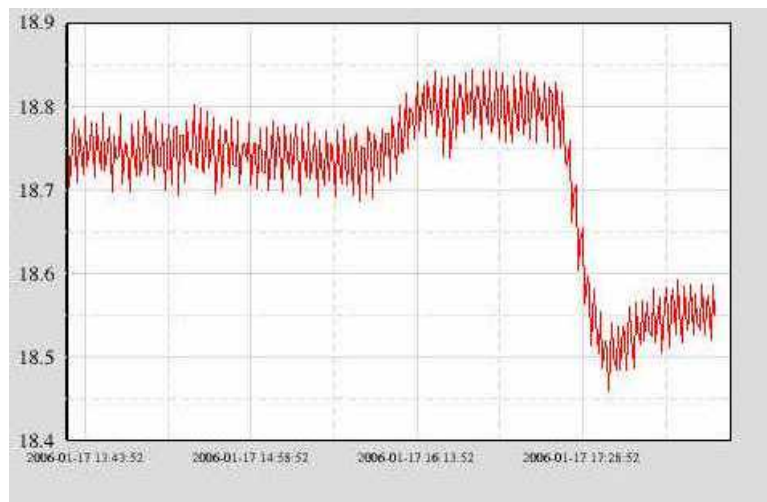


Searching for Gravitational Waves in Noisy Data

Student Activity Worksheet

Introduction

You have probably done science experiments in which you measured a small handful of variables a small number of times. Using computers for help, gravitational wave detectors like LIGO measure and record thousands of different variables at the same time, all of the time. Some of these measurements occur once a second; others occur over 16,000 times per second. Scientists then search for patterns in these data by making plots such as the one shown here. Notice that the trace is not smooth but that it constantly jiggles up and down by about 20% of the span of the vertical axis. Scientists call this jiggle *noise*, and it shows up at some level in almost all real data that is measured through time. To a scientist, the term *noise* means more than sound. Noise represents all the vibrations in the data, often coming from a variety of sources, that make it harder to see the pattern of interest or *signal*.



On this plot the main features of the pattern (the signal) are easy to distinguish from the noise, especially the sharp drop on the right. In this activity you will search for the evidence of gravitational waves in noisy data. Although the data you will use are simulated and not actual detector data, the exercise will give you a good look at the strategies that scientists of all types use to hunt for real signals.

Instructions

In the activity your teacher will provide four plots of simulated data, labeled Signal 1 through Signal 4. These are printed on transparency sheets. You will notice that each plot shows the presence of a signal plus a lot of noise. Your job is to characterize the signal in each data plot by finding the best match between the data and a signal *template*. There are four sets of templates; M, C, P and X. Each set contains six individual templates; M1, M2 ... M6 and so on. The templates are graphs of mathematical equations. These equations and their graphs are *models*. They represent scientists' expectations of what gravitational waves will look like in the data.

Compare the noisy data plots to the signal templates (models) by laying the data transparencies over the templates. Find what you feel is the best match for each data plot. Record your results in the table below

Characterization of Gravitational Wave Signals

Data set	Signal 1	Signal 2	Signal 3	Signal 4
Label of template that gives the best match				

Questions

1. Did you always agree with your classmates as you chose what you thought were the best matches? Can you see how scientists could disagree with each other as they try to match models to signals in their data? Explain.
2. Scientists use models to help them understand the behavior of real systems. One purpose of models is to simplify the system under study. In this activity how do the models (the templates) simplify the real systems (the data sets)? Do the templates help you understand the data sets better? Explain.
3. You may have made a model of the solar system in school. Astronomers now use computers to make models of the solar system, stars, galaxies and clusters of galaxies. Why are these models necessary, or in what ways are they helpful? Why don't the astronomers just study the galaxies themselves? (Think about how the models (templates) helped you in this activity.)
4. Write a short paragraph summarizing what you have learned in this activity. Use the following terms in your paragraph (not necessarily in this order): *data, signal, noise, template, model*.