

Neutron Stars

•Materials

Iron filing demonstration

•Introduction

In this lab, you will explore the properties of several types of neutron stars. First, your lab instructor will introduce the concept of **magnetic field** using a bar magnet and iron filings. Study the chart below for an understanding of magnetic field strengths.

Magnetic Field magnitude (Gauss)	Object
0.6	Earth's field
100	common hand held magnets
4000	strong sunspots
4.5×10^5	strongest sustained magnets*
1×10^8	strongest non-neutron star fields
$10^{12} - 10^{13}$	radio pulsars
$10^{14} - 10^{15}$	magnetars

*If made any stronger, the magnet would exceed the tensile strength of the material, and it will blow apart!

Gamma-ray bursts (GRBs) were first detected in the late 1960s by U.S. satellites designed to look for space-based nuclear weapons testing. GRBs are characterized by a short burst of gamma rays (from milliseconds in duration to a few minutes), and rarely have an easily detectable glow more than a few minutes after the event. GRBs are flashes-in-the-pan: they explode once, never to return.

GRBs were a big mystery to astronomers when they were first seen (and in fact, they still are). The situation became worse when, on March 5th, 1979, intense flashes of gamma rays were detected coming from the direction of the Large Magellanic Cloud, a companion galaxy to the Milky Way. Then, over the next few months, more

flashes of gamma rays were detected coming from the same region of the sky. For a while, the idea that GRBs only flashed once was in doubt, but then it was realized that the repeating sources were a totally different class of object. Dubbed **Soft Gamma Ray Repeaters** (SGRs), because they peak at a slightly lower (also called "softer") energy of gamma ray than GRBs, these were found to be neutron stars - incredibly dense remnants of supernova explosions - which have extremely strong magnetic fields, far stronger than typical neutron stars. For reasons still unknown, the super-magnetic field can cause the crust of the neutron star to slip, much like an earthquake. The intense gravity of the neutron star makes such a slip a dramatic event indeed; the energies can be enough to generate huge bursts of gamma rays which typically last for less than a second. Over time, the pressure builds up again, and another flash is seen. This is how gamma rays are seen from the same object more than once.

Also in the mid-1970s, different kinds of high-energy events were starting to be identified. The so-called **X-Ray Bursters** (XRBs) were discovered. Like SGRs, they were neutron stars with repeating bursts, but their magnetic fields, while strong, were not at the level of the SGRs' strength. And unlike SGRs, which are isolated, individual neutrons stars, XRBs are caused by neutron stars in binary systems. The neutron star in such a system can accrete, or draw in, matter from a normal companion star. The matter builds up on the surface of the neutron star, and then suddenly explodes in a thermonuclear blast. It is this explosion which creates the burst of X-rays, which lasts for roughly 20 to 100 seconds. After the matter burns up in the blast, the accretion starts again and the pattern repeats. This causes repeated XRBs from the same object.

During the 1970s through the 1990s, much confusion arose because it was not clear at first that there were actually three different types of physical mechanisms that were producing the bursts of energy. Placing something in its correct category is half the battle in understanding it. It took 30 years for astronomers to sort out these different types of phenomena, and in fact they are still working on classifying and understanding them. You will do the same, but in just 45 minutes or so!

•Procedure

1) You will use the data given in the table on the following page to make deductions about any trends in the objects and determine how many categories (based on common properties) there are from those trends. You need to decide which objects belong to which categories.

Data types:

Object name. The name of the object is based on its coordinates on the sky. The sky is mapped by astronomers using a coordinate system similar to longitude and latitude, but the axes are called Right Ascension (or RA) and declination. RA is measured in the direction of East-West on the sky, and goes from 0 to 24 hours (each further divided into 60 minutes). Declination is measured in North-South on the sky, and goes from -90 to 90 degrees. An object's name on the card is its RA (a four digit number where the first two digits are the hours, and the second two are the minutes) and its declination in degrees, including the plus or minus sign. An object at an RA of 5 hours 30 minutes and a declination of -20 degrees would have the name 0530-20.

Location. Latitude (b) and longitude (l) in Galactic coordinates of each burst.

Energy Peak. The energy where the burst has the maximum number of photons.

Optical Counterpart. What is seen in visible light at the position of the burst.

Distance. The distance from the Earth to the burst in light years.

Burst Repetition. How often the bursts are seen to recur, if they do recur. "None" means that no repetition has been detected, and "N/A" means no information is available.

Spin or Orbital Period. Either the spin period of the burster, or its binary orbital period if it is in a binary system.

2) Using the location data (galactic coordinates), plot the distribution of the mystery objects in the sky. Make a copy or trace the projection map at the end of the lab, then plot each of the objects on that separate page. Use a different symbol for each group from part 1.

•Questions

1) How many groups do you think there are? What properties do you think are the most useful for separating the groups?

2) What can you say about the distribution of each group on the map? Are the bursts in each group randomly located, or do they fall into a pattern on the sky?

3) What is the average peak energy of the bursts in each group?

4) What is the average distance from the Earth of the bursts in each group? Is there a lot of variation in the distances of the objects in each group, or are they all about the same distance?

5) What other properties do the members of each group have in common?

For credit, turn in your map and answers to the questions above and below.

•Further investigation (required)

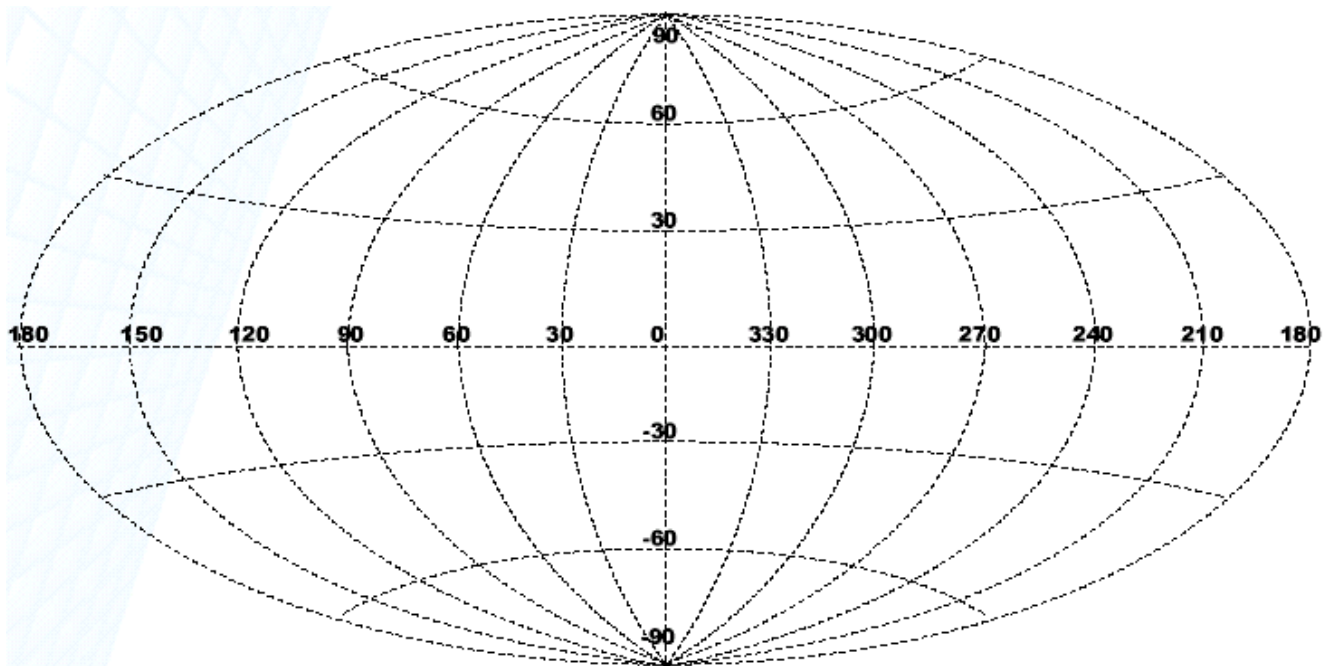
www.nasa.gov/vision/universe/watchtheskies/swift_nsu_0205.html

Explore the December 27, 2004 event on the website above and answer these questions:

1) According to your work in part 1 of the lab, what type of burst was this? What caused the burst? How far away was it? What special name is given to this type of neutron star?

2) How much more powerful was it than previous record holders? How long would it take the sun to produce this much energy?

Name	Location (l,b)	Energy Peak (keV)	Optical Counterpart	Distance (light years)	Burst Repetition	Spin or Orbital Period
0501+11	189, -18	175	Mag 25 host galaxy	5.7 billion	none	none
0526-66	276, -33	30	Super nova remnant	180,000	<1/month	8 sec
0656+79	135, 27	370	Mag 25 host galaxy	6.4 billion	none	none
2232-73	315, -40	175	Mag 23 host galaxy	4.2 billion	none	none
2359+08	101, -52	175	Mag 23 host galaxy	6.9 billion	none	none
1627-41	337, 0	20	Super nova remnant	36,000	every 1.7 hrs	N/A
1636-53	333, -5	2.3	Mag 17 star	21,000	every 7.7 hrs	3.8 hrs
1659-29	354, 7	2.5	Mag 18 star	48,000	every 9 hrs	3.4 days
0748-67	280, -20	2.2	Mag 17 star	33,000	every 10 hrs	3.8 hrs
1156+65	132, 51	370	Mag 26 host galaxy	10.5 billion	none	none
1338-80	305, -18	370	Mag 26 host galaxy	8.6 billion	none	none
1525+44	73, 55	1500	Mag 24 host galaxy	9.5 billion	none	none
1728-34	354, 0	2.8	N/A	33,000	every 7.1 hrs	N/A
1735-44	346, -7	2.3	Mag 17 star	37,000	every 5 hrs	4.65 hrs
1820-30	3, -8	2.2	Mag 19 star	21,000	every 3.3 hrs	11.4 min
1900+14	43, 1	30	Super nova remnant	23,000	every 0.14 hr	5.16 sec
1935-52	345, -28	175	Mag 24 host galaxy	.11 billion	none	none
1806-20	10, 0	25	Super nova remnant	47,000	every 1.1 hrs	7.5 sec
1837+05	36.5	2.4	Mag 18 star	23,000	every 0.3 hr	N/A
1850-08	25, -4	2.7	Mag 20 star	22,000	N/A	N/A



View where the galaxy is centered at 0,0. Use the data from "location" to plot.