Adapted by Kelly Bollman from an activity submitted by Chris Lind - Lakes Middle School, Coeur d'Alene, ID

Activity Title: **Mapping a Radio Source**
Curriculum Area: Astronomy, Earth Science
Appropriate for grades: 7-12

Overview:
Students will be analyzing the relative signal strength (flux) data and map a portion of the radio sky from data collected by the VLA (very large array) using constructed and computer generated two and three-dimensional representations.

Purpose:
1. Make an iso-concentration contour radio map, to
2. Understand the nature of the radio source, to
3. Be introduced to synchrotron radiation, and to
4. Use Excel to represent a set of data

Required background knowledge:
Drawing contour lines (topographic mapping experience helps)
Electromagnetic spectrum
Magnetism and magnetic lines of force

Students will be able to:
Identify regions of equal signal strength (flux)
Draw a smooth line around regions of equal value
Construct meaning by making a concrete model of an abstract concept
Use a computer program to model a set of data

From the National Science Education Standards:
As a result of activities in grades 5-8 and 9-12, all students should develop an understanding of science as a human endeavor, nature of science, abilities of technological design, and understandings about science and technology.

Resources/Materials needed:
Colored pencils
Signal strength raw data representing a radio source (provided)
Computer with Microsoft Excel®
For 3-dimensional aspect:
Straws
Clear tape
Crayola® white Modeling Clay
Plastic surface or container

Teacher notes:

Activity One:

The student activity pages have the procedures and the Radio Map Values matrix for hand drawn contouring. The 50 Kelvin contour has already been drawn as an example. The data matrix is in Kelvin. The Kelvin unit was selected to be more easily understood by a wider spectrum of students, rather than Jansky units or microwatts. The data was taken at 1400 megahertz. This frequency shows synchrotron in a similar way to the 2295-megahertz frequency that the GAVRT antenna uses. The data set was collected in May 1997and provided courtesy of Jet Propulsion Laboratory.

Activity Two:

This activity assumes that the students have been provided an electronic file containing the matrix information. If you do not have the radio map values matrix in electronic format from the training, you can easily make the file. Using the values from the handout in Activity One, type the values into a blank Excel spreadsheet. You should have 17 rows and 17 columns.

1. Select all the typed values. You are going to format the cells so that they are spaced equally. After you have selected the 17 columns and rows, they should all be black.
2. Go to Format. Select Row and then Height. Type in 25 and select OK.
3. With all the values selected, again, go to Format, Column and then Width. Type in 4.71 and select OK.
4. With all the values selected, go to Format, then Cells. Select the alignment tab. For horizontal, select center, and for vertical, select center. Say OK.
5. Save the file. It is now properly formatted for student use.

Students can follow the directions given to produce a basic two-dimensional map that can serve as a key for the contouring exercise in Activity One. After that basic map is produced students should save the file and then experiment with other representations.

Activity Three:

3-Dimensional Extension:

Cut plastic straws, to a scaled length (1mm = 1 Kelvin) and push into a modeling compound base. (Leave a few mm that will be "buried" in the block. We recommend Crayola® white Model Magic. This substance can be written on with pencil to guide the placement of rows of straws, and it hardens to solid foam over time that holds the straws well.

Tips for the Classroom:

For younger students, the teacher may want to pre-cut the straws and store them in separate containers for each length.

The teacher may have the students pre-cut the straws and put the lengths in separate containers according to length.

This is a time-consuming activity. Different parts of the map can be assigned to lab groups so that the class assembles one model (quadrants, for example).

Student Activity One: Making a 2-Dimensional Iso-Concentration Contour Map of a Radio Source

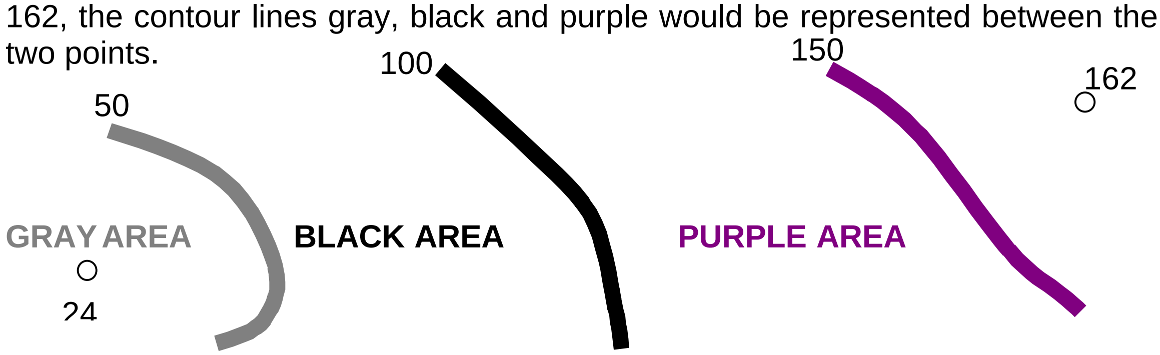
Procedures:

1. Use the colored pencils to draw a smooth line around regions of equal value on the Radio Map Values page provided. Use the color guide provided below:

Synchrotron Emission at 1400 MHz	**Pencil Color**
0-**50**	Gray
51-**100**	Black
101-**150**	Purple
151-**200**	Dark Blue
201-**250**	Light Blue
251-**300**	Green
301-**350**	Yellow
351-**400**	Orange
401-**450**	Red

2. Use a contour interval of 50 as indicated by the chart above. The lines that you draw will represent the bolded values. You will have a line for 50, a line for 100, 150, 200, 250, 300, 350, and 400. All the space between the 50 line and the 100 line will be colored Black. All the space between the 100 line and the 150 line will be colored purple, etc.

<u>Contouring Rules</u>:
All values in a range are represented. For instance, if you have two points 24 and 162, the contour lines gray, black and purple would be represented between the two points.



Contour lines do not cross over themselves like a figure eight. They are open loops of varying shapes.

You may mathematically interpolate between points or "guess-timate" where the values lie in multiples of fifty for this exercise.

Radio Map Values – Student Activity One

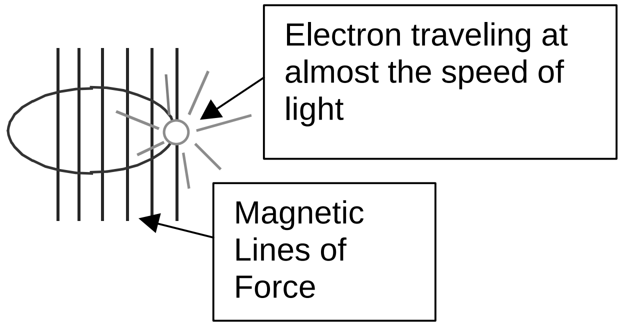
This matrix is in Kelvin at 1400 megahertz and was collected in May 1997 with the Very Large Array (VLA), provided courtesy of Jet Propulsion Laboratory. For further information contact Dr. Scott Bolton or Dr. Steve Levin at JPL. The right ascension and declination values have not been provided on this chart.

0	5	0	5	10	5	5	5	5	5	5	5	5	10	5	5	10
0	5	0	5	5	5	5	0	5	5	10	10	5	5	0	5	0
5	20	15	0	10	5	10	5	5	5	0	5	0	5	5	5	5
5	5	5	10	10	10	10	10	5	10	5	10	10	5	5	10	5
5	10	20	15	15	20	10	10	10	15	15	20	30	20	15	15	10
20	25	30	35	45	45	25	15	15	30	70	75	60	50	40	25	20
15	30	55	60	100	125	70	5	10	20	150	165	110	80	65	50	25
40	65	80	85	130	145	35	40	45	45	65	190	155	115	100	85	45
65	90	115	135	185	160	70	95	105	110	125	415	255	190	155	105	60
55	105	130	160	260	205	95	90	90	80	75	180	135	100	95	70	40
30	65	75	85	110	135	65	30	30	15	170	150	100	70	60	30	20
20	35	50	60	75	100	60	20	20	20	65	70	55	40	30	30	20
15	20	25	35	35	30	15	10	15	10	10	20	25	30	20	10	15
10	10	10	15	20	10	10	5	0	5	5	15	10	5	0	5	5
10	5	10	10	5	10	0	0	5	10	10	5	5	5	5	5	5
5	5	5	5	0	10	10	5	5	5	5	5	5	5	5	5	5
10	0	0	10	5	5	0	5	5	5	5	5	5	5	5	10	0

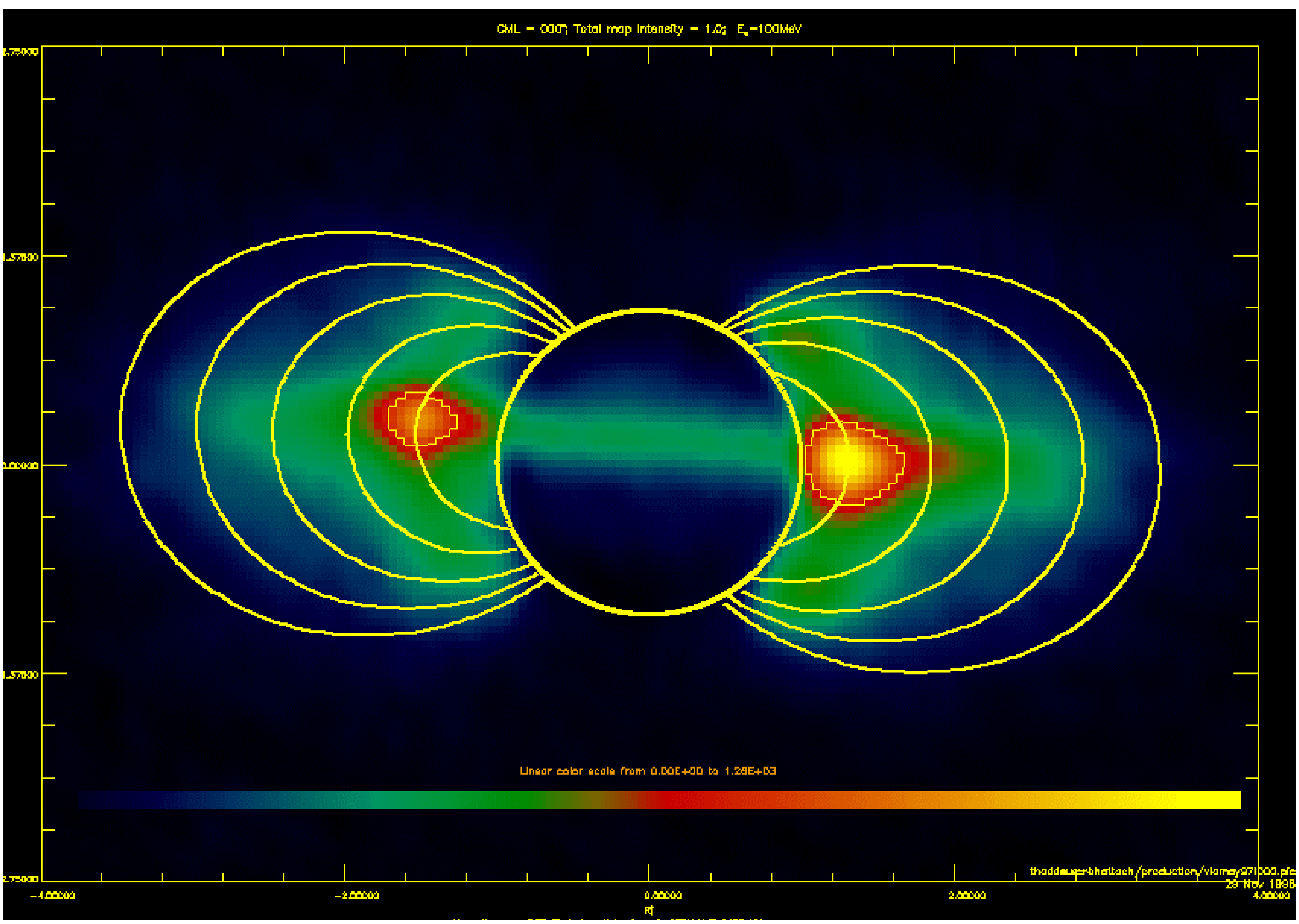
50

Synchrotron Emission from Jupiter

In Jupiter's magnetosphere, electrons enter the magnetic field across the magnetic lines of force. The electrons gyrate around the field lines almost at the speed of light. When this happens, photons of energy are released as synchrotron emission. See the diagram below.



When this synchrotron emission is viewed perpendicular to the magnetic lines of force, it is seen at its greatest intensity. When viewed at an angle, above or below perpendicular, the intensity is apparently less. As Jupiter's rotation causes the magnetic field to wobble, the apparent brightness of the synchrotron emission in radio brightens and dims. The image below is a cross-section of the synchrotron emission. The circle represents Jupiter.



Questions:

1. Compare and contrast your hand-drawn contour map with the image produced by the very large array in May 1997.

2. What you have drawn/contoured is a cross-section of the synchrotron emission of Jupiter. What does “cross-section” mean?

3. Why do you think there is a green “shadow” across the middle of the cross section in the VLA image?

For more information on synchrotron radiation and emission, the following resources may be helpful.

Lewis, J. (1997) Physics and chemistry of the solar system. (Rev. Ed.). San Diego, CA: Academic Press.

Fisher Miller, D. (April 1998) Basics of Radio Astronomy [online] , JPL d-13835, http://www.avstc.org/gavrt/frameset.htm OR http://www.jpl.nasa.gov/radioastronomy/

Activity Two: Making a 2-Dimensional Iso-Concentration Contour Map of a Radio Source, Using a Spreadsheet Program

Your teacher will provide you with a data file on disk called **radio_map_matrix.**

1. Put your diskette in the A: drive.

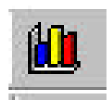
2. Open Excel by selecting **Start -Programs -Microsoft Excel.**

3. Once Excel is open select **File –Open.**

4. Look at the A drive and select **radio_map_matrix.**

5. Hi-light /select all the data so that it turns black. There are 17 rows and 17 columns of numbers. Make sure you have selected them all.

6. Click on the chart wizard button. This button is located on the Standard tool bar a little left of center and looks like this.



7. In the chart wizard, select **Surface** on the left side of the screen.
You will also need to pick a type of surface map on the right side of the screen.

8. Select the color, two-dimensional option on the lower left.

9. Click **next**.

11. Click **next** again**.**

12. Titles Tab
You will need to type in the chart labels on this screen. The x-axis is right ascension (in degrees, minutes and seconds). The y-axis is declination (in hours, minutes and seconds). The chart needs a title. If you use the three-dimensional settings later, the z- axis could be brightness or radio intensity in Kelvin.
Axes Tab
Select Categories and Series. Leave Value unselected because this is a two-dimensional map. You can go back later and select it if you switch to a three-dimensional map representation.
Gridlines Tab
Leave all boxes unselected.
Legend Tab
Select the Left option.
Select **Next** at the bottom of the window.

13. Click **finish.**

14. You now need to modify the chart you have made so that the intervals will match your hand-drawn contour map.

15. Double-click on a white interior part of the legend of the chart. You should get a window called Format Legend with four tabs in it.

16. Select the scale tab and change the major unit to 50 (the same as the contour interval for the drawing).

17. When you close the scale window look at your chart.

18. To change the individual map colors, select one of the small colored boxes and then double click on it. You can then choose the color you want each one to be. Please use the directions to Activity One as a guideline for the colors so that the computer generated map will match the one you made by hand in class.

19. Save your file as **radio_map_yourname**.

Note:

Now that you have saved your master file, you can experiment with different chart options.

You can select your chart by clicking on it and hitting the chart wizard button again. By changing the major unit on the scale tab, you can display the map information in different contour intervals.

You can also select other types of surface maps, 3d for instance. Spend some time tinkering with this program so that you can see what it does.

Student Activity Three: Making a 3-Dimensional Iso-Concentration Contour Map of a Radio Source Using Straws

Procedures

1. Using the Radio Map Values from Activity One, cut a straw for each numerical value. One Kelvin is equal to one millimeter in straw length. Some of the values are high and you may need to tape two straws together to achieve the proper length.

2. After all the straw lengths have been cut and are ready to be used (either sorted by length into marked containers or lined up in rows as they appear in the Radio Map Values matrix), prepare the modeling compound. Use one package of Crayola® , white Modeling Clay per set of straws. Roll the compound out so that it is even in thickness and about half a centimeter thick. Make sure that you have at least a 14cm by 14 cm square. (Each straw is about 8 mm wide.)

   It is easier if the rows are marked in using a straw to press straw-sized circles into the compound to mark columns and rows. Another effective method for marking the columns and rows is to draw a grid for the placement of the straws using a pencil and ruler.

3. Place the straws into the compound at the proper locations. Wait for the compound to set. This compound will adhere to paper. It is best not to have it sitting on a paper-covered surface. Keeping it in a plastic container or on a plastic surface works best. The compound also begins to dry fairly quickly. Do not prepare it until the straws are ready to be placed.

You now have a three-dimensional representation of the synchrotron emission around Jupiter. Compare this model with a computer-generated model produced in Activity Two. Which type of chart shows a key for the straw activity?

Additional Teacher Notes

Activity Two

If you prefer the x and y axes to have the proper right ascension and declination values, please refer to the chart below when making your student disks. To incorporate these column and row labels into your chart, hi-light this information as well in step five of the directions.

When you are on step 6, you will see a Series tab at the top of the window. If you click on this tab, you will see that the new information has already been incorporated. Select next and follow the direction as stated in the activity.

An example of the finished product has been superimposed on the matrix below so that you can see what the end product should look like.

	21h 30m 49s	21h 30m 49.5s	21h 30m 50s	21h 30m 50.5s	21h 30m 51s	21h 30m 51.5s	21h 30m 52s	21h 30m 52.5s	21h 30m 53s	21h 30m 53.5s	21h 30m 54s	21h 30m 54.5s	21h 30m 55s	21h 30m 55.5s	21h 30m 56s	21h 30m 56.5s	21h 30m 57s
-15d 21m 00s	0	5	0	5	10	5	5	5	5	5	5	5	5	10	5	5	10
-15d 21m 07.5s	0	5	0	5	5	5	5	0	5	5	10	10	5	5	0	5	0
-15d 21m 15s	5	20	15														
-15d 21m 22.5s	5	5	5														
-15d 21m 30s	5	10	20														
-15d 21m 37.5s	20	25	30														
-15d 21m 45s	15	30	55														
-15d 21m 52.5s	40	65	80														
-15d 22m 00s	65	90	115														
-15d 22m 07.5s	55	105	130														
-15d 22m 15s	30	65	75														
-15d 22m 22.5s	20	35	50														
-15d 22m 30s	15	20	25														
-15d 22m 37.5s	10	10	10														
-15d 22m 45s	10	5	10														
-15d 22m 52.5s	5	5	5														
-15d 23m 00s	10	0	0	10	5	5	0	5	5	5	5	5	5	5	5	10	0