ASTR 311 Tutorial 6: The Shape of the Universe

Look at the desk and look around the room. Seems pretty flat, doesn't it? But the Earth isn't flat, so why is the room?

What about the Universe? Is it flat? Does it have positive curvature? Negative? How can we tell?

In this activity, you'll do experiments that explore the effects of curvature. The key to determining the shape is the number of degrees in a triangle.

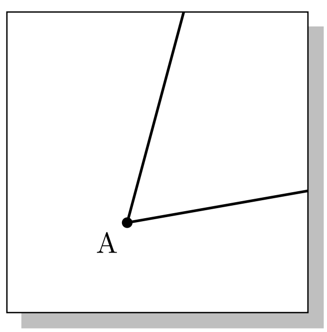
Part 1: A Flat Universe

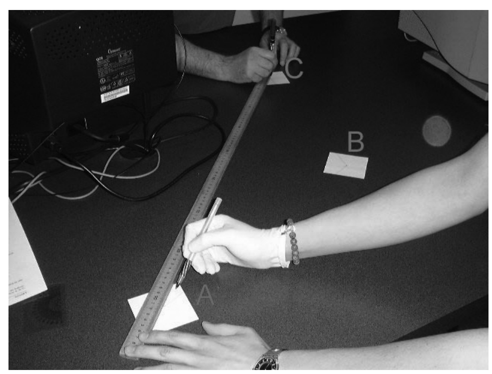
In this Part, you'll use the desktop as a 2-dimensional model of a flat Universe.

1a. Stick the three Post-it notes on your desk, about 1 metre apart, to form the corners of a triangle.

1b. Put a dot on each Post-it note and label them A, B, C.

1c. You want to draw a triangle, but not on the desk! So, put the metre stick between A and B and draw a line along the metre stick, but only on the Post-it! Draw lines along BC and AC. Each Post-it will show one angle of the triangle:





1d. Use the transparent protractor to measure the angle on each Post-it. Record the angles below and then add them up.

corner	**angle**
A	________
B	________
C	________
Sum	________

1e. You should find the angles add up to **180 degrees**. That tells you the desk is **flat**.

Part 2: A Universe with Positive Curvature

Now you'll use the surface of a balloon as a 2-dimensional model of a Universe with positive curvature.

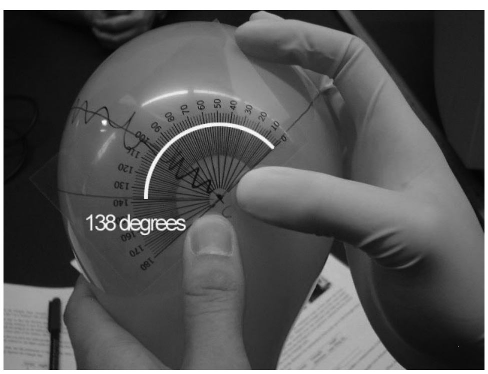
2a. Blow up the balloon about as big as your head and tie it closed. The surface of the balloon is your Universe in this Part.

2b. To draw a triangle on the balloon, first use the overhead marker to draw three dots on the balloon: one at the "North Pole", one near the "equator" and one somewhere in the "Soutern hemisphere". Label the dots A, B, C.

2c. To draw the sides of the triangle, draw "straight lines" on the balloon between the dots. What is a "straight line" on a balloon? The shortest line.

The easiest way to find the shortest path between two points is to use the piece of string. Stretch the string between the points A and B as tight as you can (without making a dent in the balloon.) While the string is on the ballooon, someone trace over the string with the overhead pen. Draw the two other sides of the triangle the same way.

2d. Like you did on the desk, use the protractor to measure the three angles of your "triangle". The picture shows an angle of 138°. Measure your triangle's angles and record them in the table:



corner	angle
A	
B	
C	
Sum	

2e. You should find the angles add up to **more than 180 degrees**. That tells you the balloon has **positive** curvature.

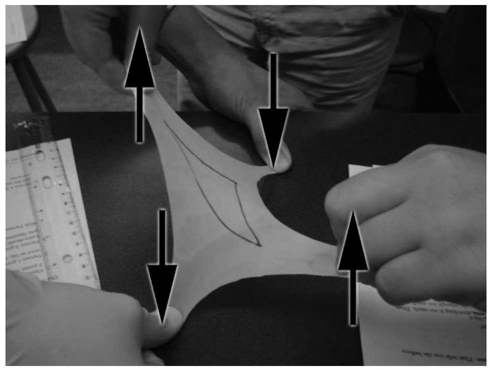
Part 3: A Universe with Negative Curvature

This time, you'll use a piece of stretchy latex rubber to make a "saddle" surface that models a 2-dimensional Universe with negative curvature. This Part requires all three partners to work together!

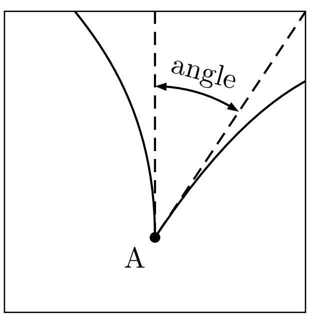
3a. Flatten the rectangle of latex on the desk as best you can without stretching it too much. Draw 3 points A, B, C and connect them to form a triangle. Don't make triangle too small.

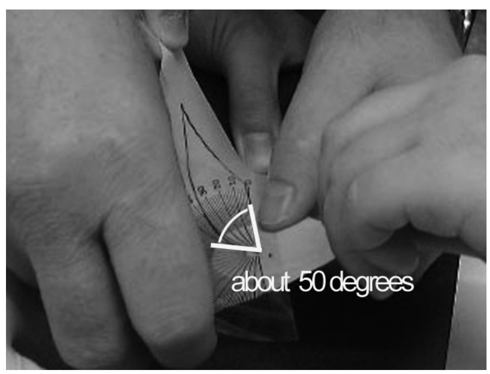
3b. Partner 1 grabs two opposite corners of the latex, stretches them apart until the latex is about twice as big, and holds the corners down on the desk.

3c. Partner 2 grabs the other two corners, pulls them apart and lifts them up off the desk. The latex should form something that looks like a saddle (or a Pringle's potato chip.) The triangle gets distorted in the process.



3d. With Partners 1 and 2 holding the saddle, Partner 3 quickly measures the angles:





corner	**angle**
A	______
B	______
C	______
Sum	______

3e. Partner 1 lets go and snaps Partner 2's finger with the latex. Ha! Ha! Ouch! You should find the angles add up to **less than 180 degrees**. That tells you the balloon has **negative** curvature.

Name ______________________________ ID No. ________________ Tutorial Day/Time ________________

Part 4: Questions Please hand in this worksheet when you are finished.

1. Use the results of your experiments to complete this table.

	degrees in a triangle	curvature	description
Part 1			like a desk
Part 2		positive	
Part 3	less than 180		

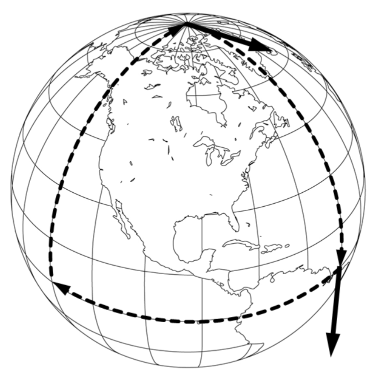
2. If you made a big triangle on the floor of this room, about how many degrees do you think you'd find if you measured the angles? Check one: _____ 180° _____ less than 180° _____ more than 180°

   The Earth is curved, though, and the floor follows the Earth, doesn't it? Why can't you measure the floor's curvature?

3. Do you think astronomers today can use this "triangle method" to measure the curvature of the Universe? If yes, describe the experiment. If no, explain why not.

4. Imagine you're standing at the North Pole. You're carrying a metre stick. You're going to take a long walk, from the North Pole down to the Equator, one quarter of the way around the Earth along the Equator, and then back to the North Pole. The whole time, you've got the metre stick pointing directly South.

   (a) Draw little metre sticks on the diagram, always with the metre stick pointing directly South. The first one is shown. So is the one after the first part of your trip to the Equator.



   (b) When you get back to the North Pole, what is the angle between the metre stick when you left and when you returned?

   (c) You walked the entire trip with the metre stick pointing directly South but when you got back, the metre stick was turned! Where did that happen?

   This effect, that things turn even though they're always pointed in the same direction, is another indicator that the surface is not flat.

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Shopping List

instructions
3 Post-it notes
metre stick
overhead pen
protractor
balloon
piece of string
square of latex

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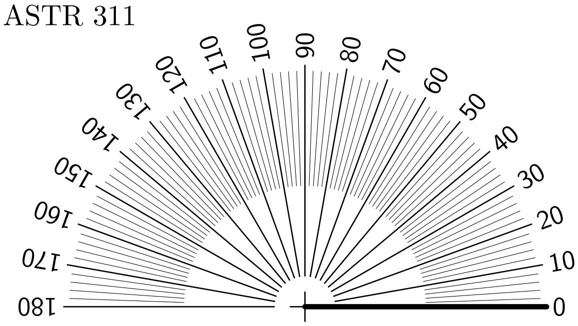

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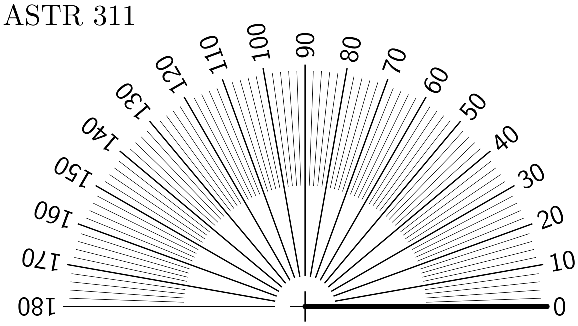

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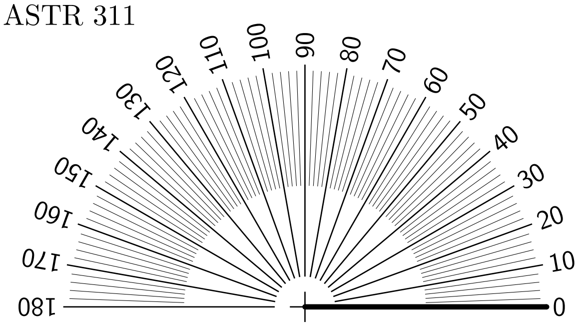

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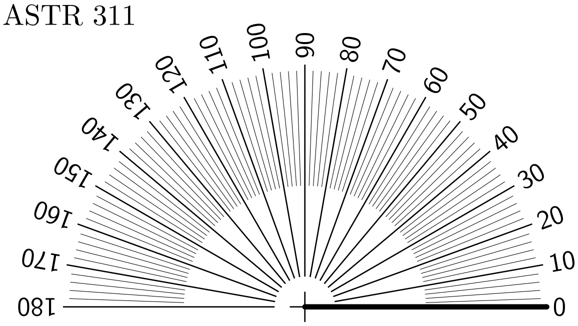

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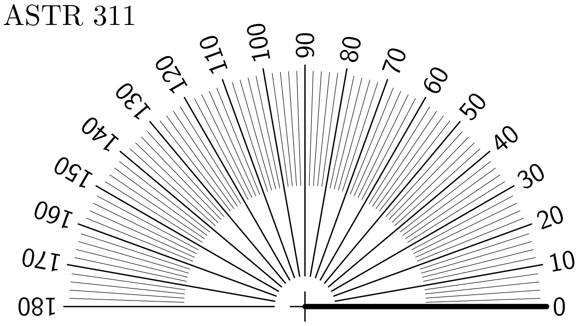

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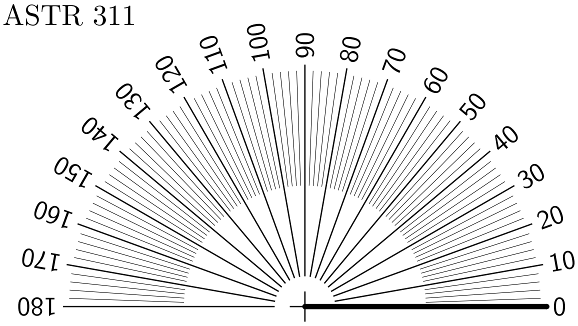

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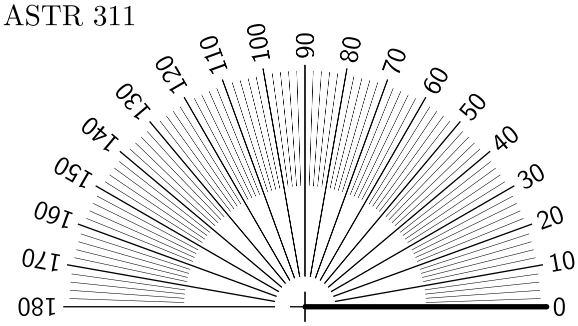

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