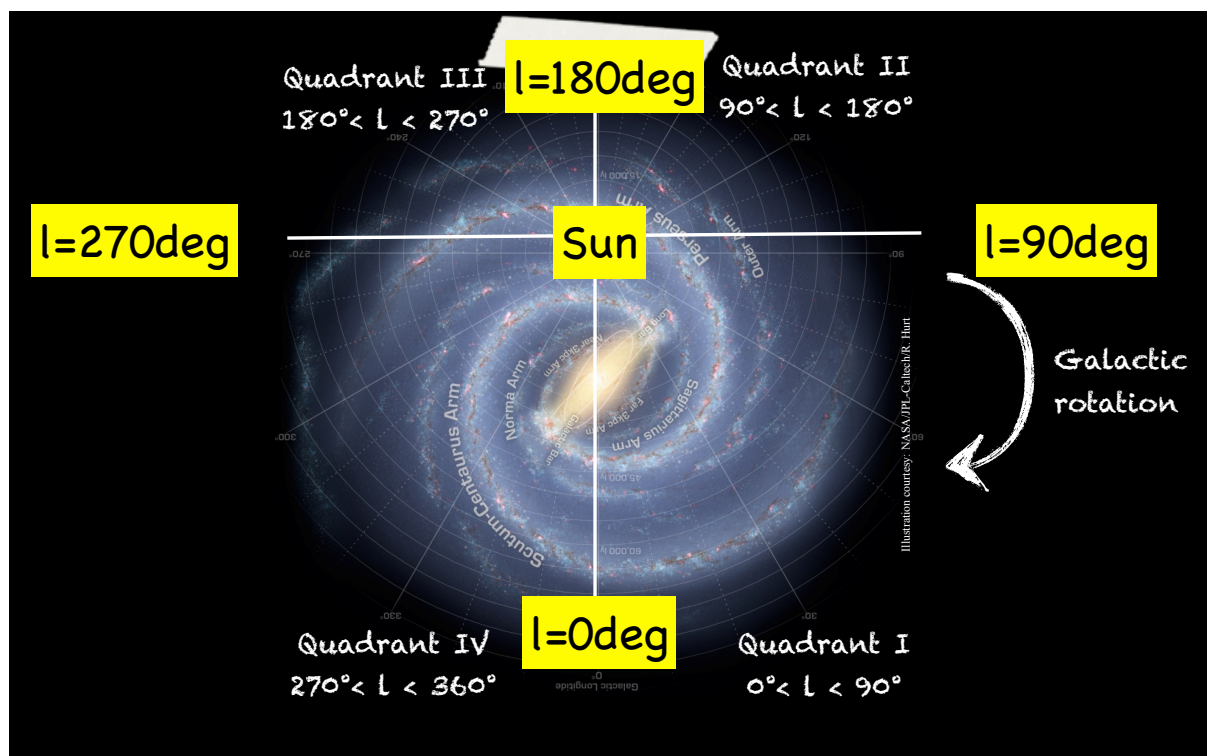


## Rotation of the Milky Way Kinesthetic Activity – Teacher's Guide<sup>1</sup>

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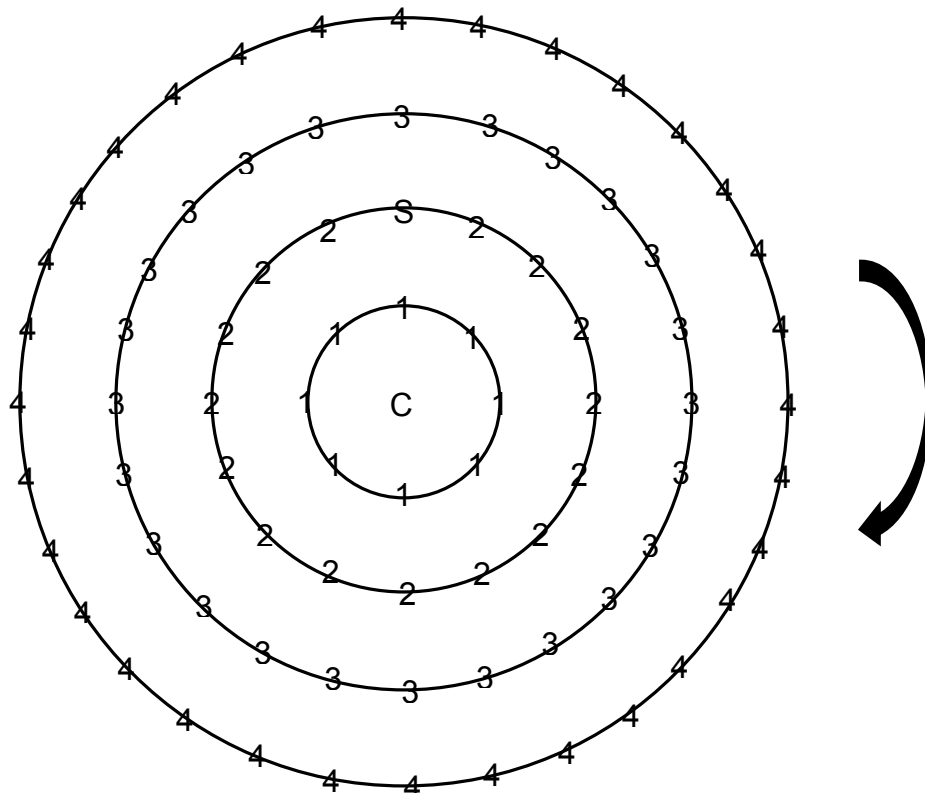


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**1. Draw a series of 4 concentric circles on the ground, using sidewalk chalk, as shown below.**

The radius of circle 2 is twice that of circle 1, the radius of circle 3 is three times that of circle 1 and the radius of circle 4 is four times that of circle 1. The letter C indicates the center of the Galaxy, and the letter S indicates the position of the Sun (solar system), which is about halfway to the edge of the Galaxy.



Note that the numbers on the circles are equally spaced around the circumference of each circle. Thus, since the circumference of a circle is proportional to its radius ( $C = 2\pi r$ ), the number of steps around each circle is proportional to its radius, as shown in the table below.

Radius	Steps around the circumference
1	8
2	16
3	24
4	32

**2. Solid body rotation**

Start by having students stand on the numbers along the cardinal axes (NSEW). Have them rotate so that the axes remained straight. This is a model of *solid body*

*rotation* (like a merry-go-round). Note that the students further away from the center must move *faster* than those closer in. In fact, the speed is directly proportional to radius,  $v \propto r$ . If we define the *angular velocity*  $\omega = v / r$ , then we can note that for solid body rotation,  $\omega = \text{constant}$ .

Now, give two students on different axes a bungee cord to hold. Notice that the cord neither stretches nor droops, meaning that there is *no relative motion* between objects in solid body rotation. This is true no matter which two students you choose.

### 3. Differential rotation

Now have the students rotate at a *constant speed*. This is accomplished by shouting “step” at regular intervals, and having the students move forward *one number* at a time. Do this until the students on circle one have completed one rotation. Note that the relative positions of the students have changed. This is called *differential rotation*, and is what happens in the Milky Way galaxy (and all other spiral galaxies).

### 4. Definition of Galactic longitude and quadrants

Have a student volunteer to be the Sun and have her/him stand on the letter S. Have another student volunteer to be the Black Hole at the center of the Galaxy. Have her/him stand on the C at the center of the circles. Have one student stand along the line between C and S but further out than S, and stretch one bungee cord between this student and C, passing by S. Have two other students hold another bungee cord through S at right angles to the first.

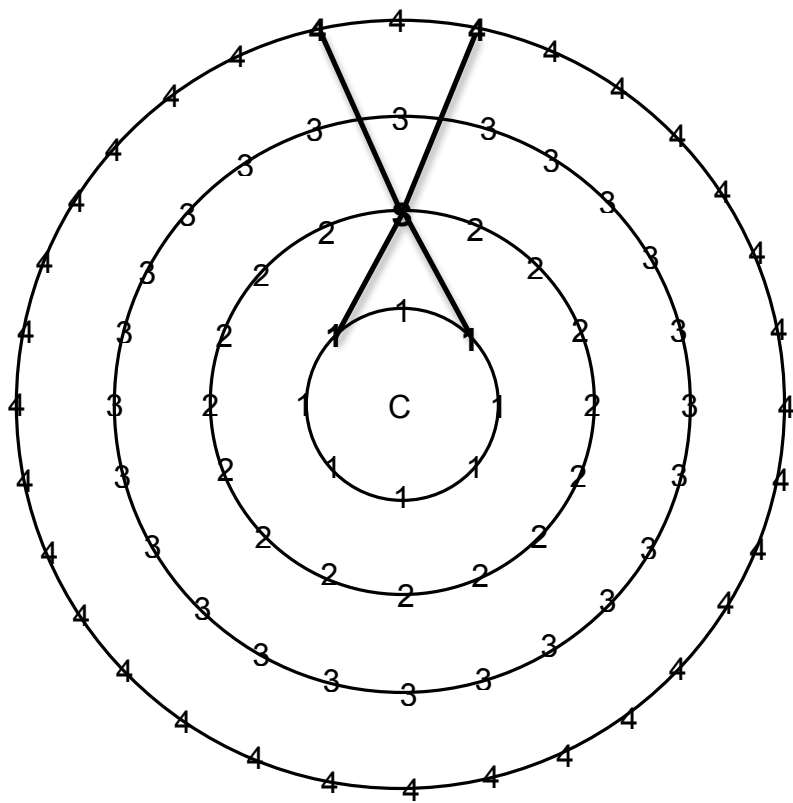
**Galactic longitude** is defined as the angle around a circle *centered on the Sun*, with  $l = 0$  in the direction of the Galactic Center, and increasing in a counter-clockwise sense (opposite to the direction of rotation). The four quadrants of Galactic longitude are defined such that:

- Quadrant I:  $0^\circ < l < 90^\circ$
- Quadrant II:  $90^\circ < l < 180^\circ$
- Quadrant III:  $180^\circ < l < 270^\circ$
- Quadrant IV:  $270^\circ < l < 360^\circ$

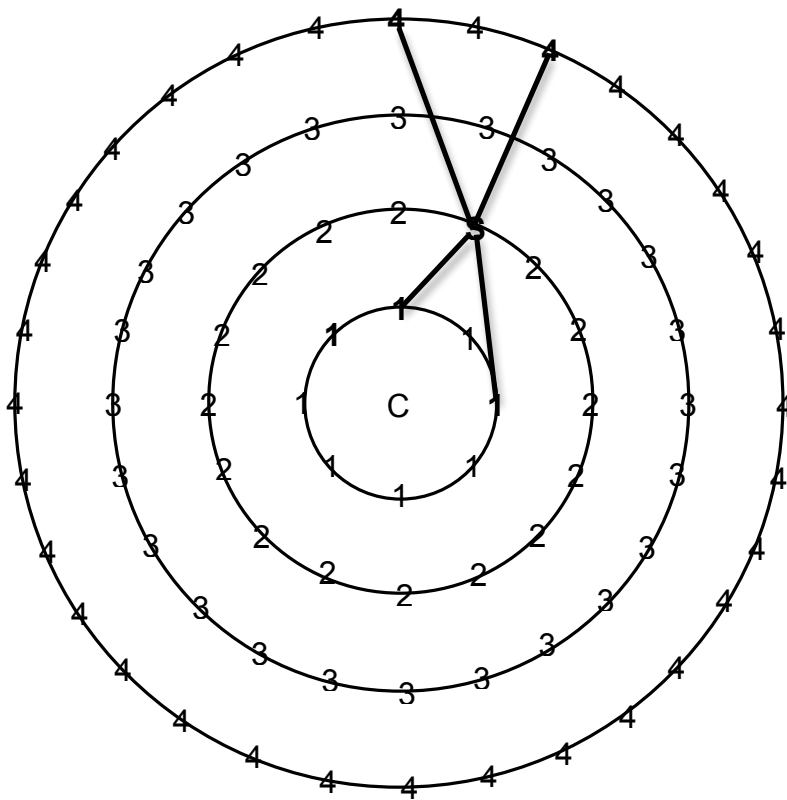
### 5. Pattern of radial velocity in the Galaxy

To determine the pattern of the radial velocity with quadrant, have the student who is the Sun hold a bungee cord with 4 students, one in each quadrant, as indicated by the **bold** numbers in the top figure on the next page (Time Step 0). When you shout “step”, each student (including the Sun!) should step forward one number (see the bottom figure on the next page (Time Step 1). You will find that the radial velocity depends on Galactic quadrant as shown in the table below.

Quadrant	$v_r$
I	+
II	-
III	+
IV	-



**Time step 0**



**Time step 1**

