



top view

Let's make your own Milky Way Galaxy model!!

Kumiko S. Usuda
PhD of science, Subaru Telescope



horizontal view

[1] Introduction

Our Earth is a member of the Solar System, and the Solar System is a member of the Milky Way, our Galaxy. The Milky Way is made up of approximately 200 billion stars which have gotten together and have made a large disk whose diameter is 100,000 light years. Our Solar System is located at about 30,000 light years (28,000 light years) away from the Galactic Center (G.C.).

[2] Materials and Tools

1. STURDY BOARD, Black color.
more than 30cm × 30cm (12in × 12in) size, 3mm (0.1 in) thickness. 1
2. Styrofoam ball. 40mm (1.6 in) diameter. 1
(divided into two, colored with a spray or an acrylic paint (in your favorite color))
3. 1/2" Star labels or 1/4" round color dots.
 - (1) The Sun (The Solar System): Red 1
 - (2) Visible nebulae: Yellow 20
 - (3) Invisible (but seen in radio) nebulae: Silver 36
 - (4) Clouds of molecular gas (Molecular clouds): Blue (OPTIONAL) 12
4. Ruler, longer than 30cm (12in).
5. Protractor.
6. Scissors.
7. Color pencils or crayons (your favorite color)
8. Glue (all purpose crafts)

[3] How to make the Galaxy model

1. Draw a 30cm (12in) diameter circle on the STURDY BOARD. The 100,000 light year diameter corresponds to the 30cm (12in) length, and the 1,000 light year width corresponds to 3mm (0.1in). (The width of the disk is 15,000 light years at the center and 5,000 light years at the solar radius.)

2. Write the Solar System (the Sun) 9cm (3.5in) away from the Galactic Center (it corresponds to 30,000 light years). Using the protractor make it graduated from the Solar System. The direction toward the Galactic Center is 0° (See Fig. 1). These angles are called "Galactic longitude (*l*)". You MUST NOT plot angles from the Galactic Center!! The center of angles is the Solar System, the place where we live!

3. Plot visible nebulae (seen in both optical light and radio wavelength) in the Table 1 and place YELLOW star labels there. Plot invisible nebulae (not seen in optical light but observed in radio wavelength) in the Table 2 and place SILVER star labels there. (continues to the next page)

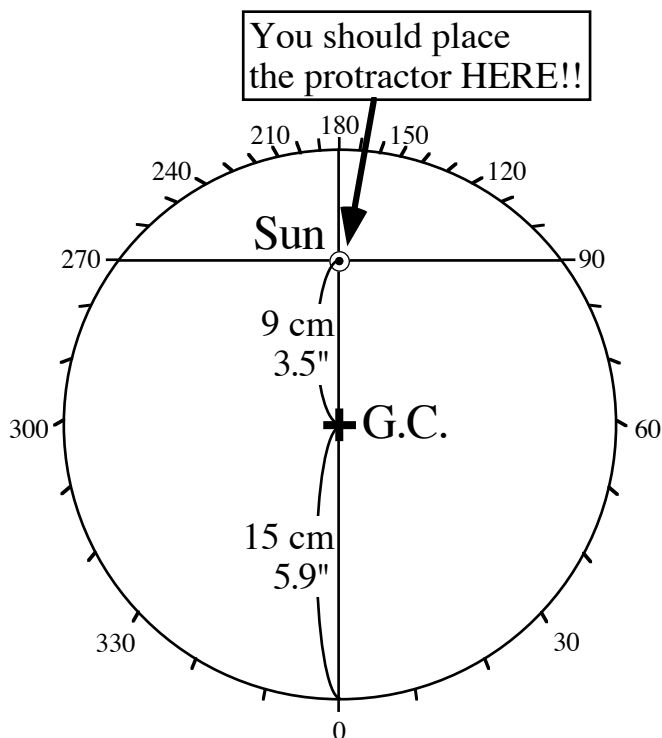


Fig.1: Plotting the Galactic Longitude

If you want, Do for molecular clouds in the same way as nebulae and place BLUE star labels (OPTIONAL). Unfortunately, the data of molecular clouds are only 8° - 90°. Place a RED label for the Sun.

Table 1: Visible Nebulae

<i>l</i> (deg)	distance from Sun (10,000 ly)	distance on the disk (cm)	distance on the disk (inches)
15.1	0.82	2.5	1.0 (1)
18.6	0.72	2.2	0.9 (7/8)
49.2	1.89	5.7	2.2 (2 1/4)
70.3	2.87	8.6	3.4 (3 3/8)
80	0.46	1.4	0.6 (1/2)
102.8	1.17	3.5	1.4 (1 3/8)
111.5	0.91	2.7	1.1 (1)
133.7	0.75	2.3	0.9 (7/8)
173.5	1.11	3.3	1.3 (1 1/4)
282	2.28	6.8	2.7 (2 5/8)
284.3	1.53	4.6	1.8 (1 3/4)
287.6	0.85	2.6	1.0 (1)
289.9	2.58	7.7	3.0 (3)
291.2	0.82	2.5	1.0 (1)
291.6	2.35	7.1	2.8 (2 3/4)
305.3	0.82	2.5	1.0 (1)
316.8	4.08	12.2	4.8 (4 3/4)
328	0.85	2.6	1.0 (1)
332	1.37	4.1	1.6 (1 5/8)
348.8	1.14	3.4	1.3 (1 3/8)

Table2: Invisible Nebulae (seen in radio)

<i>l</i> (deg)	distance from Sun (10,000 ly)	distance on the disk (cm)	distance on the disk (inches)
10.3	6.09	18.3	7.2 (7 1/4)
12.8	1.37	4.1	1.6 (1 5/8)
19.1	4.37	13.1	5.2 (5 1/8)
20.7	4.56	13.7	5.4 (5 3/8)
22.8	4.04	12.1	4.8 (4 3/4)
23.4	2.38	7.1	2.8 (2 3/4)
24.6	2.97	8.9	3.5 (3 1/2)
25.4	4.43	13.3	5.2 (5 1/4)
25.8	2.93	8.8	3.5 (3 1/2)
28	2.25	6.8	2.7 (2 5/8)
29.9	2.28	6.8	2.7 (2 5/8)
30.8	2.15	6.5	2.6 (2 1/2)
37.6	4.04	12.1	4.8 (4 3/4)
43.2	4.6	13.8	5.4 (5 3/8)
48.6	3.88	11.6	4.6 (4 5/8)
51.3	1.43	4.3	1.7 (1 3/4)
79.3	2.48	7.4	2.9 (2 7/8)
79.9	1.86	5.6	2.2 (2 1/4)
289.1	3	9	3.5 (3 1/2)
298.6	3.81	11.4	4.5 (4 1/2)
311.5	2.77	8.3	3.3 (3 1/4)
311.9	3.49	10.5	4.1 (4 1/8)
314.2	3.55	10.7	4.2 (4 1/4)
317.1	3.88	11.6	4.6 (4 5/8)
319.2	4.47	13.4	5.3 (5 1/4)
319.4	4.63	13.9	5.5 (5 1/2)
320.3	4.86	14.6	5.8 (5 3/4)
327.6	3.68	11	4.3 (4 3/8)
328.3	2.77	8.3	3.3 (3 1/4)
331.2	3.94	11.8	4.7 (4 5/8)
331.7	2.54	7.6	3.0 (3)
336.9	2.18	6.5	2.6 (2 1/2)
338	4.6	13.8	5.4 (5 3/8)
338.4	5.87	17.6	6.9 (6 7/8)
338.9	4.82	14.5	5.7 (5 3/4)
340.3	4.69	14.1	5.6 (5 1/2)

Table 3: Molecular Clouds (8° - 90°)
(OPTIONAL)

<i>l</i> (deg)	distance from Sun (10,000 ly)	distance on the disk (cm)	distance on the disk (inches)
8.2	5.18	15.5	6.1 (6 1/8)
11.1	1.56	4.7	1.9 (1 7/8)
17.2	4.86	14.5	5.7 (5 3/4)
18.9	1.83	5.5	2.2 (2 1/8)
23	4.17	12.5	4.9 (4 7/8)
24.5	2.97	8.9	3.5 (3 1/2)
25.7	3.75	11.3	4.5 (4 1/2)
30.8	2.22	6.7	2.6 (2 8/5)
31.4	4.63	13.9	5.5 (5 1/2)
32.6	3.36	10.1	4.0 (4)
39.9	3.68	11	4.3 (4 3/8)
49.5	2.15	6.5	2.6 (2 1/2)

Data in Table 1, 2 are from Geogelin & Geogelin A&A (1976)
Data in Table 3 are from Solomon et al. ApJ (1987)

* " *l* " means the Galactic longitude (the angle from the Galactic Center).

4. When you gaze at the plotted disk, you might notice that objects (nebulae and molecular clouds) are not distributed uniformly but concentrated at specific places. When you trace the specific points, you can draw four (4) "spiral arms" on the disk. Draw spiral arms with color pencil or crayon (See Fig. 2).

5. Cut out the disk from the STURDY BOARD using a cutter.

6. Put half balls of Styrofoam on the center of the disk with glue.

7. Now, you're finished!! YOU DID WELL!!

[4]Watching your Galaxy model...

1. The Milky Way, Our Galaxy, and the Solar System

The shape of the Milky Way Galaxy is a huge disk whose diameter is 100,000 light years. In the model, we reduced the 100,000 light years into 30cm (12in). The distance between the Sun and the Earth (1 AU (Astronomical Unit) = 150,000,000 km (94,000,000 miles)) is 0.000000005 cm (0.000000002 in), so both the Sun and the Earth are in the same tiny dot and we cannot separate them. the 0.000000005 cm (0.000000002 in) is too small to recognize and let's reduce the diameter of our Galaxy into the distance between Honolulu to Santiago, Chile (10,000 km, 6,300 miles). In this scale, the size of the Solar System (diameter of the orbit of the Pluto: 80 AU = 0.001 light year) is as large as a 10 cm (4 in) becomes the size of an earth worm, and the size (diameter) of the Earth (12,700km (8,000 miles) diameter) becomes as small as a virus (1/10 to 1/100 of a plankton). Did you recognize the size of 100,000 light years?

2. Bulge at the Galactic Center

You put the styrofoam ball at the center, didn't you? The name of this "ball" is the Bulge. Old stars get together and make the Bulge. In the *Bulge* there is little gas which is the material of stars. In contrast, there is a lot of gas and many stars are being formed on the *disk* now.

3. Objects you plotted and placed labels

(1) Nebulae (Star Forming Regions)

Bright and heavy stars which are more than 10 times heavier than the Sun emit strong ultraviolet (UV) rays. The UV rays not only burn our skin but also warm and destroy the gas around stars. The warmed gas around the stars (especially hydrogen) emits visible light. This is "*nebula*". We can see red light such as Omega Nebula (M17) at Sagittarius and Orion Nebula (M42).

Visible nebulae that you placed yellow labels are located nearby the Solar System and invisible nebulae (but seen in radio wavelength) that you placed silver labels are located far from our Solar System. Visible light emitted from far nebulae are absorbed by foreground gas and dust in the space and cannot reach to the Solar System. Light emitted from nearby nebulae, where there is not much foreground gas and dust, can reach to the Solar System. Thus visible objects in the Milky Way Galaxy are located near the Sun. Visible stars which can be seen by the naked eye, that make up constellations, are all near our Solar System.

Radio waves are used on TV and radio, cellular, wireless phones on taxi, and so on. When you are at home, you are surrounded by walls and roofs. At this time you cannot watch stars (in visible light) inside your house but you can talk with your friend by cellular (using radio waves). In the same sense, we cannot observe nebulae and stars in visible light behind the foreground gas and dust but we can observe them in radio wavelengths in space.

(2) Molecular clouds (If it is too difficult for you, don't worry. Just skip reading this paragraph.)

Because of molecular foreground gas and dust, we cannot see visible light behind it. In space a lot of molecular hydrogen gathers and makes a "cloud" that is 1,000 to 1,000,000 times heavier than the Sun. In the almost "*empty*" space, there are many dense hydrogen "clouds" (We call those clouds as "*molecular clouds*"). Clouds are denser place in space, however, there are only 100 to 10000 molecules (molecular hydrogen) in one cubic cm (1 cm³). At one atmospheric pressure on the Earth 30,000,000,000,000,000 (3×10¹⁹) molecules (molecular nitrogen, molecular oxygen, and so on) are in one cubic cm (1 cm³). You can recognize that the density of molecular clouds are close to being a vacuum. Yes!! To tell the truth, this density is more vacuous than "laboratory vacuum" using experimental tools (pumps and so on) at a laboratory in the Earth. Furthermore, temperature of molecular clouds is about minus 260°C (minus 440°F) in normal clouds and about minus 240°C (minus 400°F) in warm clouds. Veeeeeeeeeeery Cooooooooold!!!

4. Spiral arms on the Milky Way Galaxy

You drew "spiral arms" on the disk. The arms are places where a lot of stars and molecular gas (material of stars) get together. In the arms many stars are being formed now. Outside of our Galaxy there are many galaxies (disk galaxies) with spiral arms such as M51.

* Spiral arms in the Milky Way Galaxy have names.

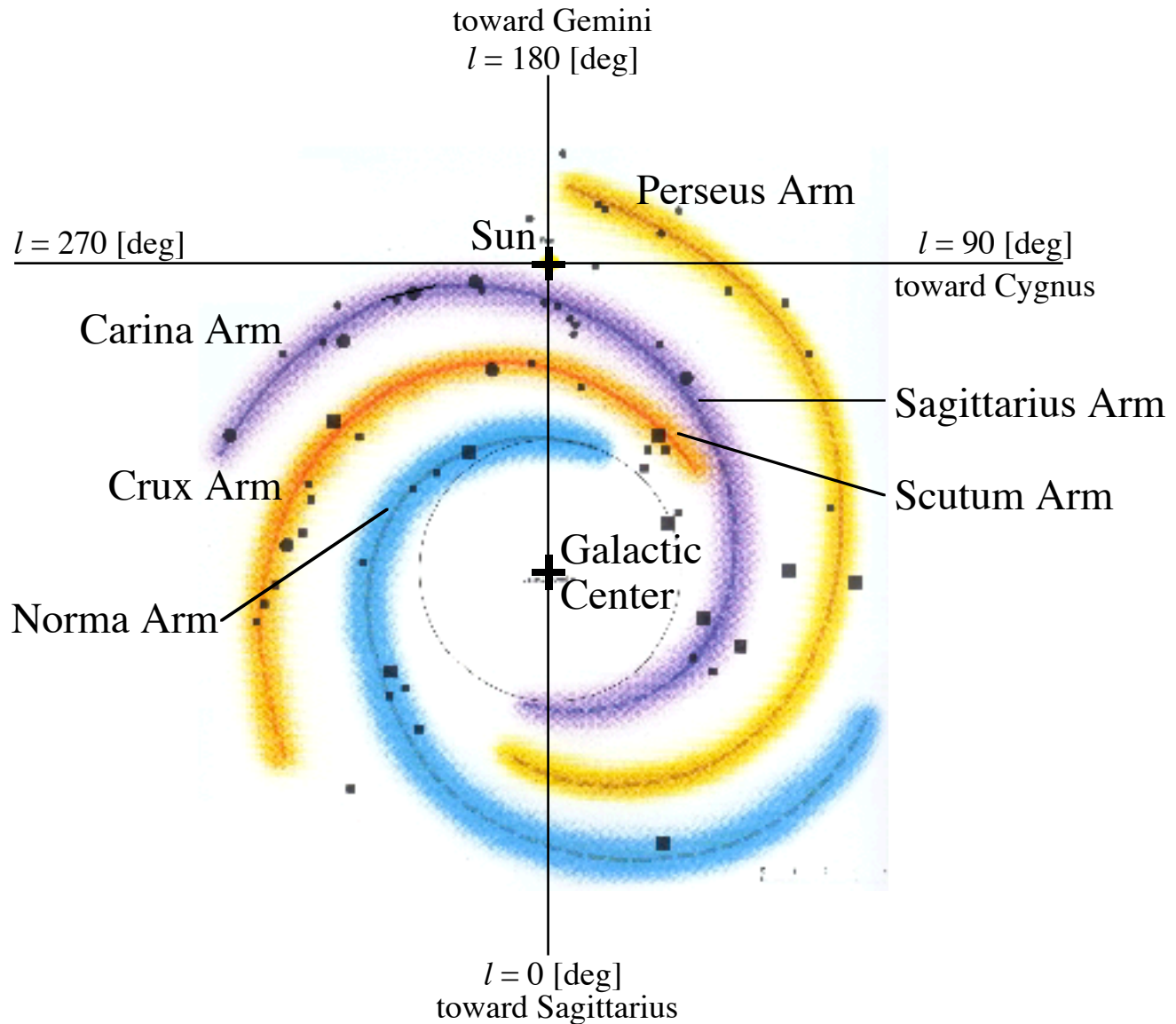


Fig.2: Spiral arms of the Milky Way Galaxy (Georgelin & Georgelin Astronomy&Astrophysics (1976))

5. The Milky Way

There are many many stars in the disk, as I told you above, and we can see many stars in every horizontal direction. This is the Milky Way. We live in the disk, and we watch the star disk inside it. Toward the Galactic Center (the direction of Sagittarius), a largest amount of stars get together. Taking this into consideration, we feel that our Sun is just one of many stars in the Milky Way Galaxy.

6. Outside of Our Galaxy

There are many many galaxies like the Milky Way Galaxy in the universe. The nearest galaxies are Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC). They are seen only in the southern hemisphere. The distance to the LMC is 160,000 light years and that to the SMC is 200,000 light years. The nearest disk galaxy M31 (Andromeda galaxy) is 2,100,000 light years away from the Solar System. How large our universe is!!

* You can download this copy in PDF file at my home page:

<http://www.naoj.org/staff/kumiko/MilkyWay/milkyway.html>

© Kumiko S. Usuda