THE DISC OF THE MILKY WAY

G. Iafrate, M. Ramella
INAF - Astronomical Observatory of Trieste

Information and contacts: **http://vo-for-education.oats.inaf.it** - **iafrate@oats.inaf.it**

Within this use case you discover the shape and thickness of the disc of our own Galaxy by counting stars within and around the Milky Way. With the use of both Aladin and Stellarium you draw the line corresponding to the disc of the Milky Way in a coordinate diagram.

If used in the classroom this is an intermediate use case. Pupils will be able to discover the Galaxy disc by themselves, simply starting from the text of the use case.
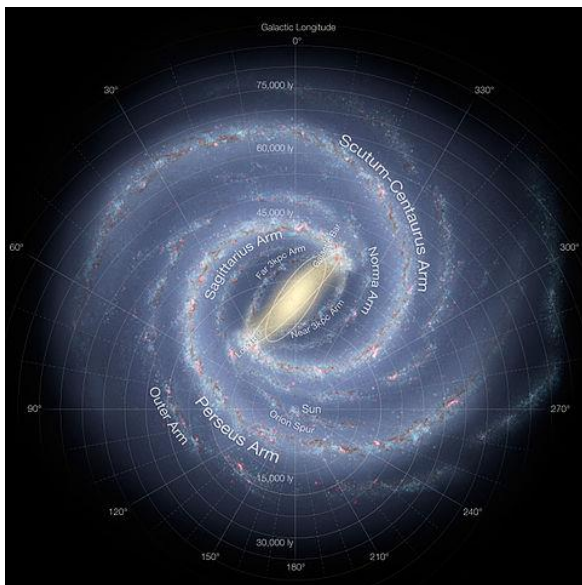
Fig. 1: picture representing our galaxy as it would appear if seen from outside.

1 Introduction

In 1609 Galileo Galilei was the first scientist to observe the sky with the telescope (and an open mind). He understood that the Milky Way, the luminescent cloud that crosses the night-sky, is produced by a large number of stars so distant from us to be unresolved by naked eye. Recent estimates indicate that in our MW there might be as many as 400 billion stars, a staggering number indeed. The great astronomer William Herschel in 1781 was the first to understand that the Milky Way is a rather thin disc of stars and that we live inside it. Herschel erroneously thought that we were at the center of the Milky Way, his mistake being justified because he did not know the distances of the stars. In fact, the disc of the Milky Way also contains clouds of gas and dust. These clouds dim and redden stars hiding the true shape of

the Milky Way. It is only during the XX century that astronomers were finally able to map the shape of the Milky Way, a barred spiral galaxy that, seen from outside, would look approximately like the galaxy in Figure 1. Radiation bands other than visible light were the key to the structure of the disc, most notably the radio band. In this use case we will (re)discover the Milky Way using the powerful tools of the Virtual Observatory.

2 Stellarium

Stellarium is a free software that transforms a home computer in a planetarium. It calculates the positions of Sun and Moon, planets and stars, and draws the sky how it would be seen from an observer anywhere on the Earth and at any epoch. Stellarium can also draw the constellations and simulate astronomical phenomena such as meteor showers and solar or lunar eclipses.

Stellarium may be used as an educational tool for kids of all ages, as an observational aid for amateur astronomers wishing to plan an observing night, or simply to explore the sky (it is fun!). Stellarium shows a realistic sky, very close to what you see with naked eye, binoculars or telescope. Stellarium gives astronomical data (coordinates, magnitude, distance, etc.) of most of the celestial objects visualized on the screen. You can freely download Stellarium from our site http://vo-for-education.oats.inaf.it or from http://www.stellarium.org.

3 Aladin

Aladin is an interactive sky atlas developed and maintained by the Centre de Donnèes astronomiques de Strasbourg (CDS) for the identification of astronomical sources through visual analysis of reference sky images.

Aladin allows the user to visualize digitized images of any part of the sky, to superimpose entries from the CDS astronomical catalogues and tables, and to interactively access related data and information from various data servers (like SIMBAD, NED, VizieR). In this tutorial we use the standalone version of Aladin, because this is the only version allowing us to load a local astronomical image. In this usecase we use Aladin in the *undergraduate* mode (developed in the framework of the EuroVO-AIDA European project).

4 Find the MW in Stellarium

The Milky Way (MW from now on) can be easily spotted on the virtual sky of Stellarium. Open Stellarium and select the sky and viewing options [F4] and increase the brightness of the MW to level 4. Select, for example, the location Trieste in Italy [F6] and the day September 21, 2015 at 10PM [F5].

Fig.2: Milky Way in Stellarium.

The MW runs in the middle of the sky from SW to NE (fig. 2) passing close to

your zenith (the point above your head where your vertical meets the celestial sphere). The wider part, or more precisely the bulge of the MW is toward the SW horizon in the region of the constellation Sagittarius. In order to see the constellations and their names type [c] and [v]. This region is actually the center of our galaxy. When we look 180° away from Sagittarius along the MW, we look at the anti-center. The anti-center is not far from the NE direction where the MW disappears under the horizon. In Table 1 you find the main reference points of the MW.

In order to have a full view of the MW, turn off the ground [g], the atmosphere [s], and the fog [f]. Open the window of the viewing options and set the luminosity of the MW to a level higher than the default level 1, for example set it to level 4. It is now easy to explore the extent and geometry of the MW.

	RA	DEC	constellation
North galactic pole (+90° lat.)	$12^h\,51^m.4$	+27° 13'	Coma Berenices
South galactic pole (-90° lat.)	$0^h\,51^m.4$	-27° 13'	Sculptor
galactic center (0° long.)	$17^h\,45^m.6$	-28° 94'	Sagittarius
anti-center (180° long.)	$5^h\,45^m.6$	+28° 94'	Auriga

Tab. 1: Main reference points of the Milky Way.

5 Resolve the MW stars with the Virtual Telescope (Aladin)

In order to explore the nature of the MW. we select a few directions inside and outside the MW. In practice any direction you select will coincide with a star whose equatorial coordinates RA/Dec will appear in the left upper corner of Stellarium. Select the first two stars in the MW: the first toward the anti-center (*1) and the second next to the center but away from the big dark clouds (*2). Example: *1 = (5h, 43°); *2 = (20h, 31°). Select the next two stars away from the MW and on the same side, approximately at the same distance along the MW. Example: *3 = (3h, 9°); *4 = (22h, 0°). Select the last 2 stars in the same positions as *3 and *4 relative to the MW but on the other side. Example: *5 = (9h,50°); *6 = (17h,40°).

Launch Aladin and insert the coordinates of *1 in the location bar (e.g. 5 0 0 +43 0 0). Select the infrared (IR) view of the sky. Adjust the size of the window and use the zoom slider in order to have a window that is close to or slightly larger than 1°. The angular size of the window appears in the tiny navigation box in the right bottom corner.
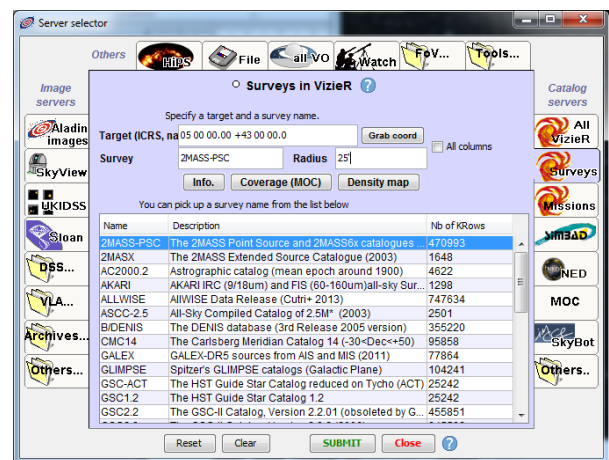

Fig. 3: server selector window.

The field of view is amazingly crowded with many stars. In order to have a more quantitative idea of their number, open the server selector (fig. 3) and select the 2MASS-PSC (2 Micron All Sky Survey – Point Sources Catalog) with a radius r = 25' (fig. 4). In the window of the stack go with the mouse over the label 2MASS-PSC: a box with the number of sources

will pop up. In the case of *1 (anti-center of the MW) the number of sources is 13164.
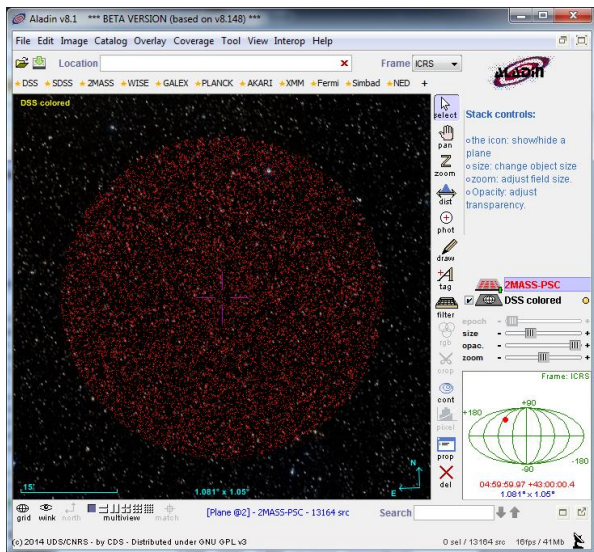

Fig. 4: 2MASS-PSC survey with a radius of 25'.

You may mark this number on a note pad. Then delete all the planes in the stack and proceed to the next star, *2. The field is even more crowded. In fact, in the 2MASS-PSC catalog there are 46379 sources within a circle of radius 25'. The view of the sky around *3 is dramatically different: it seems almost empty! In fact there are only 1072 sources, 43 times fewer than toward the bulge of the MW. The fields around *4, *5, and *6 are comparable to that of *3 with 1729, 1021, 1785 sources respectively. We have (re)discovered what already Galileo Galilei had found: the glow of the Milky Way is produced by a multitude of stars that we have separated and counted and thanks to our virtual telescope.

6 The galactic poles

The fact that we see the MW crossing the sky from any location on Earth (as you can verify by changing your location in Stellarium), means that the MW circles the Earth. Stellarium can display the MW over the whole sky. Turn off the ground [g], the atmosphere [s], and the fog [f] and set the luminosity of the MW to level 4. Turn the wheel of the mouse zooming out until you can see the whole MW. Center it and shift it using the keyboard arrows until it has a nearly circular shape (fig. 5).

Fig. 5: Milky Way displayed over the whole sky in Stellarium.

The center of the circle approximately indicates the direction of a galactic pole. More precisely, the galactic poles are defined as the directions of the perpendicular to the MW disc through the Earth. Astronomers have chosen the North Galactic Pole (NGP) in the constellation Coma Berenices and the South Galactic Pole (SGP) in the constellation Sculptor. You find their coordinates in Table 1. Once the MW appears as a full circle around one of the two galactic poles, you have only to change direction with the keyboard arrows until you see the MW circling the other side of the sky in order to find the other galactic pole (in order to recognize the poles it helps to display constellation names and lines).

To point Aladin toward the NGP and the SGP (type their coordinates in the location bar) and to count sources in the 2MASS-SPC yields, not surprisingly, rather empty images of the sky and low star counts: 602 and 618 stars toward the SGP and NGP respectively.

7 The coordinates of the MW disc

Using more Aladin pointings, and more patience, in order to count stars from the MW disc to the poles you could obtain a rather accurate map of the position on the sky of our galactic disc. In the exercises we suggest how to do it. You should not be surprised to find out that in your diagram the Milky Way is not a circle nor a straight line: in order to plot on a flat surface a 3D curve you have to distort it. Just imagine what happens if you flatten the skin of an orange on the table.

8 The thickness of the galactic disc

How thick is the disc of the MW? In order to answer to this question it is not enough to count stars as we did to find out the position on the sky of the MW disc. The reason is that we can see luminous stars to very large distances and faint stars mostly in the neighbourhood of the Sun. Faint stars are plentiful while luminous stars are relatively rare. For this reason without knowing distances to the stars we mix local stars in our neighborhood with distant stars in the disc. Local stars surround us, they are those we count toward the galactic poles. However, even without individual measurements of distance we can find out more of the structure of the MW by considering only the hottest blue stars (O-type stars). These stars are very luminous and can be seen from very large distances. Very few of them are in our neighbourhood.

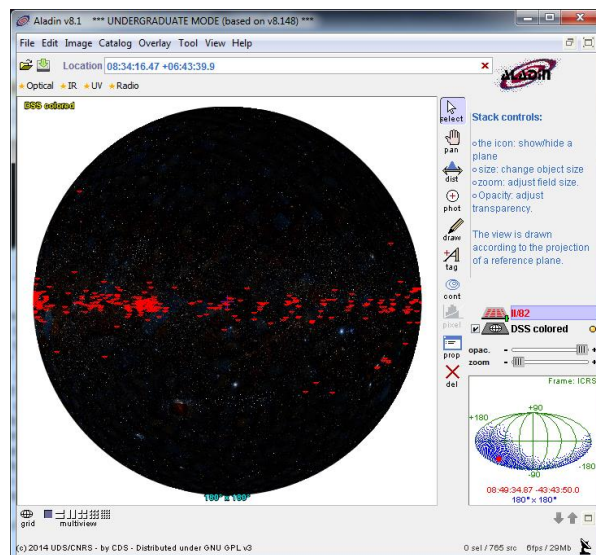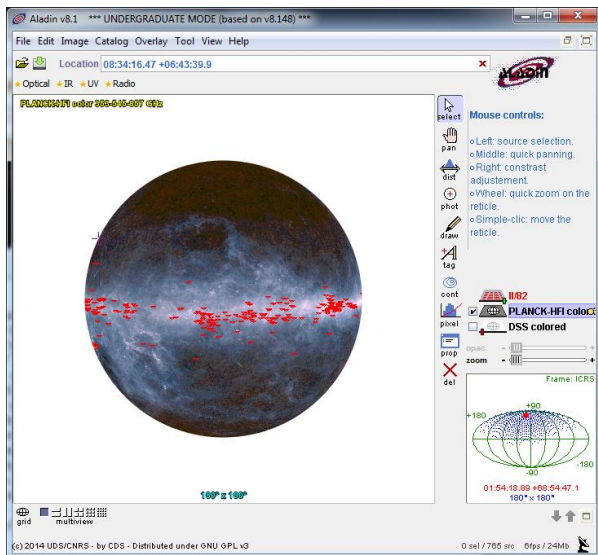In Aladin, click the button "optical" under the location input bar.

Fig. 6: optical view of the sky with O-Type stars in the Milky Way (red symbols).

Then, if needed, zoom out with the slider until you can see a disc corresponding to the projection of the sky that you can explore and rotate, just press the "pan" button and then click and drag the mouse.

Now open the server selector in Aladin and click the All Vizier tab. Select the optical wavelength and type "O-type" in the "Author, free text" search bar. Submit your query and once you have the oputput list, select the catalog II/82 of galactic O-type stars by Garmany+ (1982). Submit it for plotting. The points marking the position of the O-type stars will track a thinner disc of the MW of constant width (fig. 6). By selecting the radio view of the sky the amazing image of the hydrogen map produced by the planck satellite will give you an even more defined view of the MW disc (fig. 7).

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Fig 7: radio view of the sky with O-Type stars
in the Milky Way (red symbols
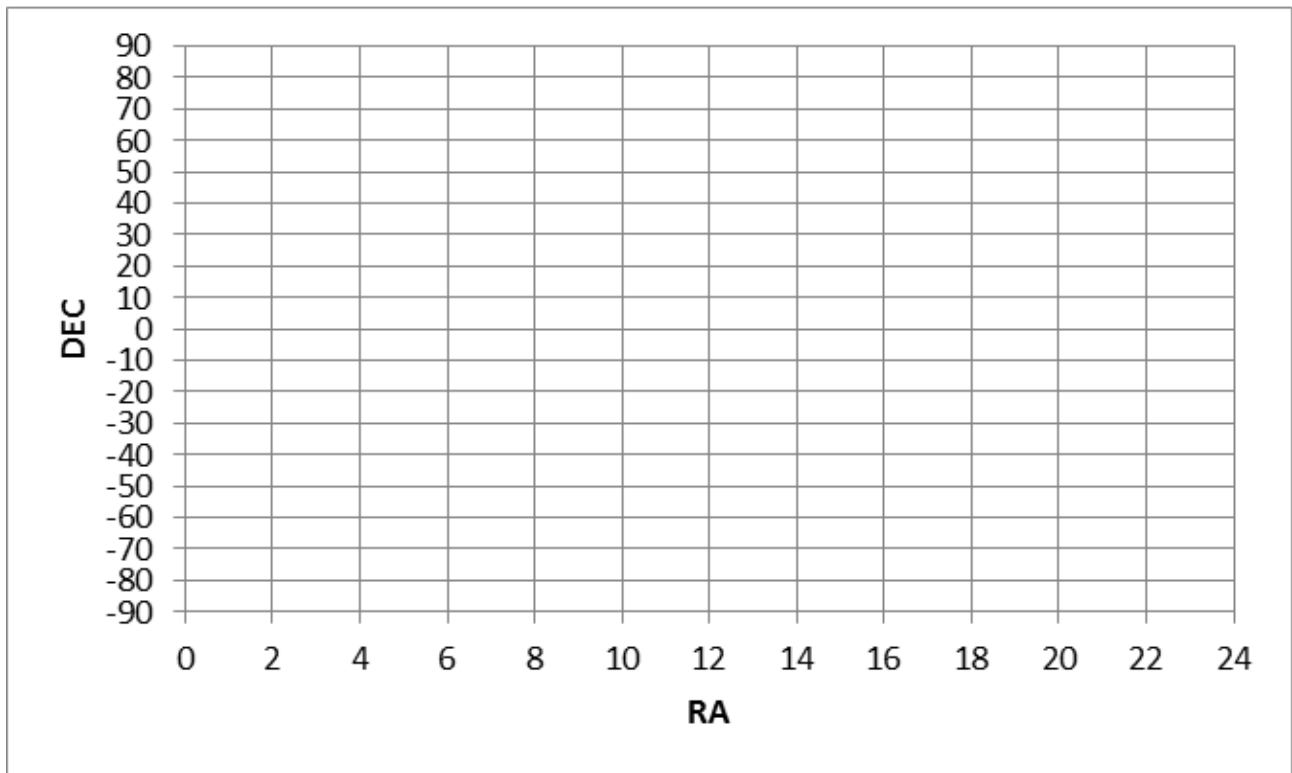
EXERCISES

Exercise 1

Look up in Aladin how much crowded are the following directions in the sky. As described in section 5, insert the coordinates in the Aladin location bar and then load the 2MASS-PSC catalog with a radius of 14' and note how many stars it contains. Fill the table with the star counts and then mark the more crowded directions (> 2000 counts): they belong to the Milky Way.

RA	DEC	Star counts	Milky Way?
0h 0m 0s	60° 0' 0''		
0h 0m 0s	-60° 0' 0''		
2h 0m 0s	55° 0' 0''		
2h 0m 0s	-50° 0' 0''		
4h 0m 0s	45° 0' 0''		
4h 0m 0s	-20° 0' 0''		
6h 0m 0s	15° 0' 0''		
6h 0m 0s	-30° 0' 0''		
7h 0m 0s	0° 0' 0''		
8h 0m 0s	-25° 0' 0''		
8h 0m 0s	60° 0' 0''		
10h 0m 0s	-50° 0' 0''		
10h 0m 0s	30° 0' 0''		
12h 0m 0s	-60° 0' 0''		
12h 0m 0s	0° 0' 0''		
14h 0m 0s	-60° 0' 0''		
14h 0m 0s	-10° 0' 0''		
16h 0m 0s	-60° 0' 0''		
16h 0m 0s	50° 0' 0''		
18h 0m 0s	-30° 0' 0''		
18h 0m 0s	70° 0' 0''		
19h 0m 0s	0° 0' 0''		
20h 0m 0s	20° 0' 0''		
22h 0m 0s	50° 0' 0''		
22h 0m 0s	10° 0' 0''		

Exercise 2

Plot the directions belonging to the Milky Way found in the previous exercise in the equatorial coordinates grid: the result will be how the Milky Way appears in a RA-DEC plot (see section 7).

SOLUTION

Exercise 1

Look up in Aladin how much crowded are the following directions in the sky. As described in section 5, insert the coordinates in the Aladin location bar and then load the 2MASS-PSC catalog with a radius of 14' and note how many stars it contains. Fill the table with the star counts and then mark the more crowded directions (> 2000 counts): they belong to the Milky Way.

RA	DEC	Star counts	Milky Way?
0h 0m 0s	60° 0' 0''	5478	X
0h 0m 0s	-60° 0' 0''	407	
2h 0m 0s	55° 0' 0''	3244	X
2h 0m 0s	-50° 0' 0''	281	
4h 0m 0s	45° 0' 0''	2414	X
4h 0m 0s	-20° 0' 0''	325	
6h 0m 0s	15° 0' 0''	3116	X
6h 0m 0s	-30° 0' 0''	771	
7h 0m 0s	0° 0' 0''	3910	X
8h 0m 0s	-25° 0' 0''	5076	X
8h 0m 0s	60° 0' 0''	493	
10h 0m 0s	-50° 0' 0''	6477	X
10h 0m 0s	30° 0' 0''	275	
12h 0m 0s	-60° 0' 0''	11004	X
12h 0m 0s	0° 0' 0''	344	
14h 0m 0s	-60° 0' 0''	15392	X
14h 0m 0s	-10° 0' 0''	391	
16h 0m 0s	-60° 0' 0''	12337	X
16h 0m 0s	50° 0' 0''	378	
18h 0m 0s	-30° 0' 0''	20567	X
18h 0m 0s	70° 0' 0''	603	
19h 0m 0s	0° 0' 0''	15928	X
20h 0m 0s	20° 0' 0''	8436	X
22h 0m 0s	50° 0' 0''	5960	X
22h 0m 0s	10° 0' 0''	676	

Exercise 2

Plot the directions belonging to the Milky Way found in the previous exercise in the equatorial coordinates grid: the result will be how the Milky Way appears in a RA-DEC plot (see section 7).