HOW TO CREATE A SKY MAP STEP BY STEP

DOINA VASILCA

Technical University of Civil Engineering,
Faculty of Geodesy Bd. Lacul Tei 124, Bucharest, Romania
Email: doinavasilca@yahoo.com

Abstract. This article aims to show, in detail, the main steps towards creating a sky map. It describes the problem of choosing a map projection depending of the intended purpose of the final map and its target users. After that, all of the steps necessary for creating complete maps in specific projections are explained and exemplified.

Key words: Astronomy–Sky map–Map projection–Perspective azimuthal projections.

1. INTRODUCTION

The creation of a sky map implies a strong collaboration between cartographers and astronomers. This is due to the fact that the former need to know exactly what the latter want to find on the projected map. If a representation of the sky as it is seen from a particular point on the Earth's surface is desired, then depending on its position on the globe one can choose an azimuthal projection. If a singular constellation is to be represented, then a conformal cylindrical or conical map projection could be chosen instead. In most cases, the astronomers will be the ones to inform the cartographers that the map should be made in a projection that preserves the similarity of shapes and thus to aid the users of the map in recognising the depicted constellations. Thus, cartographers must consider adopting a conformal projection that will meet the requirements of the map at hand.

Once the extent of the depicted area and the projection have been established, the cartographers will need to know the coordinates (*i.e.* right ascension and declination) of the represented celestial objects (i.e. stars), which can usually be found in Fundamental Catalogues (*e.g.* FK5). Following that, the equatorial coordinates are correlated to the geographical ones - more specifically, right ascension to latitude and declination to longitude. This way, the position of celestial objects at any given moment may be represented on a projected grid of meridians and parallels.

To this end, several of the map projections used in the creation of celestial maps will be presented as following.

Romanian Astron. J. , Vol. **26**, No. 3, p. 199–214, Bucharest, 2016

2. MAP PROJECTIONS FOR SKY MAPS

In principle, any map projection used to represent the Earth as a whole can also be applied to the representation of the entire celestial sphere (*e.g.* the Hammer, Aitoff-Hammer, pseudo-cylindrical Sanson, pseudo-cylindrical Eckert, pseudo-cylindrical Mollweide equal-area projections). Unfortunately, these projections share the disadvantage of not being conformal, meaning that they distort the shape of the depicted objects, resulting in final maps that are harder to follow by layman users.

Representing one hemisphere is easier in this regard, since using a conformal perspective azimuthal projection will result in very suggestive maps that can be easily compared with the real image of the sky as it is seen from the Earth's surface. These map projections are therefore most suitable for showcasing regions with circular boundaries (Bugayevskiy, Snyder, 1995). In order to create a star map as would be seen from the North or South Pole, a polar perspective azimuthal projection can be used. Alternatively, if the observer is situated at a medium latitude, then an oblique perspective azimuthal projection would be preferred. Similarly, should the central point of a projection be located on the Equator, a transversal perspective azimuthal projection will work best. The only disadvantage of any of the above map projections is that only one hemisphere can be represented at a time.

When creating maps of constellations and given the relative extent of the represented area, any conformal map projection can be used (*e.g.* a conical or a cylindrical conformal one).

Further on, the most commonly used map projections for hemispheres and constellations will be presented.

3. THE STEREOGRAPHIC AZIMUTHAL PROJECTIONS

From the category of perspective azimuthal projections, only the stereographic ones will correctly preserve shapes, or in other words the angles will be represented onto a plane without deformation. This type of map projections are also known as conformal or orthomorphic projections.

The rectangular coordinates are calculated based on latitude and longitude using the following formulae (Soloviev, 1955):

$$x = \frac{2R(\cos\phi_o sin\phi - \sin\phi_o cos\phi cos\lambda)}{1 + (\sin\phi_o sin\phi + \cos\phi_o cos\phi cos\lambda)} \tag{1}$$

$$y = \frac{2Rcos\phi sin\lambda}{1 + (\sin\phi_o sin\phi + \cos\phi_o cos\phi cos\lambda)} \tag{2}$$

Where φ_o and λ_o are the geographic coordinates of the map projection pole.

The above formulae represent the general case of the oblique stereographic projection. They can be used in specific scenarios where $\phi_o = 90^o$ and $\phi_o = 0^o$, namely in the polar and equatorial azimuthal projections, respectively. Therefore, the polar azimuthal projection formulae for rectangular coordinates are:

$$x = \frac{-2Rcos\phi cos\lambda}{1 + sin\phi} \tag{3}$$

$$y = \frac{2Rcos\phi sin\lambda}{1 + sin\phi} \tag{4}$$

In the equatorial projection, formulae (1) become:

$$x = \frac{2Rsin\phi}{1 + cos\phi cos\lambda} y = \frac{2Rcos\phi sin\lambda}{1 + cos\phi cos\lambda} \tag{5}$$

With stereographic projections, any circle shown on the spherical surface is represented by a circle in plane, as a consequence of their orthomorphic characteristics. Thus, both meridian and parallel images will appear as circles in plane, this being supported through their equations, as demonstrated by Soloviev (1955).

In the oblique stereographic map projection, the meridian equation takes the following form:

$$(x + 2Rtg\phi_o)^2 + (y + 2Rctg\lambda sec\phi_o)^2 = (2Rsec\phi_o cos\lambda)^2 \tag{6}$$

meaning that meridians become eccentric circles of radius $2Rsec\phi_o cos\lambda$, with centres in the points with coordinates $x_m = -2Rtg\phi_o$ and $y_m = 2Rctg\lambda sec\phi_o$.

The parallel equation is:

$$\left(x - \frac{2Rcos\phi_o}{\sin\phi_o + sin\phi}\right)^2 + y^2 = \left(\frac{2Rcos\phi}{\sin\phi_o + sin\phi}\right)^2 \tag{7}$$

As it can be deduced, their radius is $\frac{2Rcos\phi}{\sin\phi_o + sin\phi}$ and their centres are situated on the polar axis image in those points of coordinates $x_p = \frac{2Rcos\phi_o}{\sin\phi_o + sin\phi}$ and $y_p = 0$. The aspect of the meridian and parallel grid is shown in Figure 3.

In the polar stereographic projection, parallels appear as concentric circles whose formula is:

$$x^2 + y^2 = \left[2Rtg\left(45^o - \frac{\phi}{2}\right)\right]^2 \tag{8}$$

As it can be seen, their radius is $2Rtg\left(45^o - \frac{\phi}{2}\right)$.

Meridians, on the other hand, are represented by lines that intersect in the centre of the parallels. Their equation is:

$$\frac{y}{x} = -tg\lambda \tag{9}$$

The aspect of the meridian and parallel grid for one hemisphere is represented in Figure 6.

In the last analysed case, that of the transversal stereographic projection, the images of meridians become eccentric circles governed by the equation:

$$x^2 + (y + 2Rctg\lambda)^2 = (2Rcosec\lambda)^2 \tag{10}$$

Their radii become equal to $2Rcosec\lambda$ and their centres are situated on the OY axis in the points with the coordinates $x_m = 0$ and $y_m = -2Rctg\lambda$. Parallels are also shown as eccentric circles using the equation:

$$(x - 2Rcosec\phi)^2 + y^2 = (2Rctg\phi)^2 \tag{11}$$

Their centres have the coordinates $x_m = 2Rcosec\phi$ and $y_m = 0$, situated on the OX axis. Their radii are $2Rctg\phi$. The meridian and parallel grid for one hemisphere extending on latitude from $\phi = -90^o$ to $\phi = +90^o$ and on longitude from $\lambda_o - 90^o$ to $\lambda_0 + 90^o$ is shown in Figure 9.

4. STEPS FOR CREATING A CELESTIAL MAP

In order to create a sky map, the very first step is establishing which object is intended to be represented. The map projection can then be chosen according to its extension, as shown above.

The next step is extracting the equatorial coordinates of the stars – the right ascension (α) and declination (δ) – from a star catalogue. These coordinates are preferred because they are analogous with the longitude (λ) and latitude (φ) used in cartography. Declination is defined as the angle between the star direction and the celestial equator and can therefore be related to latitude. Right ascension is defined as the angular distance measured on the celestial equator from the vernal equinox point (Bădescu, 2004) and can thus be assimilated with longitude, since the celestial equator is in the same plane with Earth's equator. Only two differences exist between them: their units of measurement and their origin. Right ascension is expressed in time units (*i.e.* hours) and its origin is the Vernal Equinox Point (*i.e.* the First Point of Aries), while longitude is expressed in degrees and is measured from the Greenwich

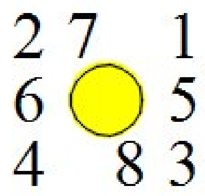

Fig. 1 – The Yoeli order of selecting the position of point feature labels (adapted from Dent, 1999).

meridian. Therefore, these coordinate systems are slightly rotated one after the other. Bearing this in mind, in order to derive longitude from right ascension, hours must be converted to degrees knowing that $1^h = 15^o$. It is not necessary to change the origin, however, because maps will also feature hour circles ($\delta = const$) and diurnal circles ($\alpha = const$).

The third step is calculating the Cartesian coordinates (x, y) of the grid nodes and of the visible stars using the forward mapping equation. Considering that the celestial sphere is infinite, any value may be used for its radius. For this reason, unlike terrestrial ones, sky maps do not come with scales.

The fourth step is representing the calculated coordinates on the projection plane.

The fifth step is adding symbols and inscriptions on the map. In order to create an attractive map, its symbols, typefaces and colours must be chosen very carefully. It is the author's personal consideration that many of the principles applied for terrestrial maps, as thoroughly analysed by Dent *et al.* (1999), can also be used for sky maps as well, so further on the most important ones will be described.

1. A good colour contrast should be used to emphasise the most important elements of the map, namely the celestial bodies themselves.

2. All of the represented elements must be readily visible.

3. Map lettering should be readable and respect some conventions regarding its positioning and orientation as pertaining to other elements of the map. For instance, the labels for point elements – stars, in the case of sky map – should be placed close to the designated positions in a certain order, as presented in Figure 1.

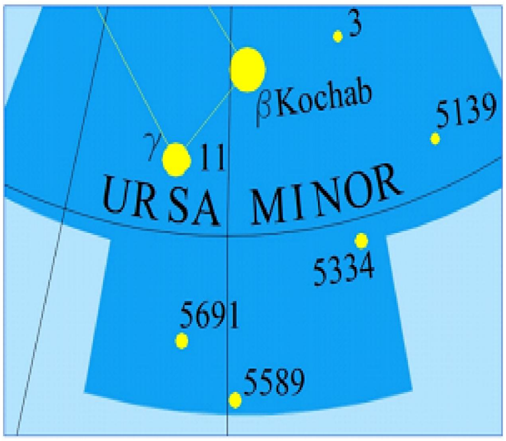

Fig. 2 – Positioning and orientation of the map lettering.

1. Names should be oriented so as to follow the depiction of parallels.

2. For denominating various celestial bodies and constellations, different typefaces, fonts, sizes and weights should be used.

3. The names of area features (*e.g.* a constellation) should be placed within it.

All of these outlined principles are exemplified in Figure 2.

Once all of the above steps have been completed, the newly-created map should be checked for errors and can afterwards be published.

In order to exemplify the described stages, we have designed several maps of the Ursa Major and Ursa Minor constellations and hemisphere maps centred at points of coordinates ($\alpha = 15^h, \delta = 45^o$), ($\alpha = 15^h, \delta = 90^o$), ($\alpha = 15^h, \delta = 0^o$). These maps are presented here below. Equatorial coordinates of the stars used for calculating their positions in the projection plane (from Table 1 to Table 6) were extracted from the FK5 Catalogue.

Tables 1 and 2 list the stars' coordinates for the oblique stereographic map projection, while tables 3 and 4 list the stars' coordinates for the plar stereographic map projection and tables 5 and 6 content the stars' coordinates for the polar stereographic map projection.

Table 1

Coordinates for stars from the constellation Ursa Minor in the oblique stereographic projection (Coordinates of the pole projection: $\alpha = 15^h$, $\delta = 45^o$)

Bayer designation	Right ascension [h m s]	Declination [o ‘ “]	Apparent magnitude	X	Y
α UMi	2 31 48.70	89 15 51.00	2.02	8433.99	-18.56
β UMi	14 50 42.30	74 09 20.00	2.08	5203.46	118.20
γ UMi	15 20 43.70	71 50 02.00	3.05	4782.72	-297.76
θ UMi	15 31 24.90	77 20 58.00	4.96	5821.30	-324.69
ζ UMi	15 44 03.50	77 47 40.00	4.32	5924.05	-439.57
η UMi	16 17 30.30	75 45 19.00	4.95	5636.40	-882.80
ε UMi	16 45 58.10	82 02 14.00	4.23	6852.72	-691.23
δ UMi	17 32 12.90	86 35 11.00	4.36	7736.59	-422.11
λ UMi	17 16 56.80	89 02 16.00	6.38	8121.86	-110.06

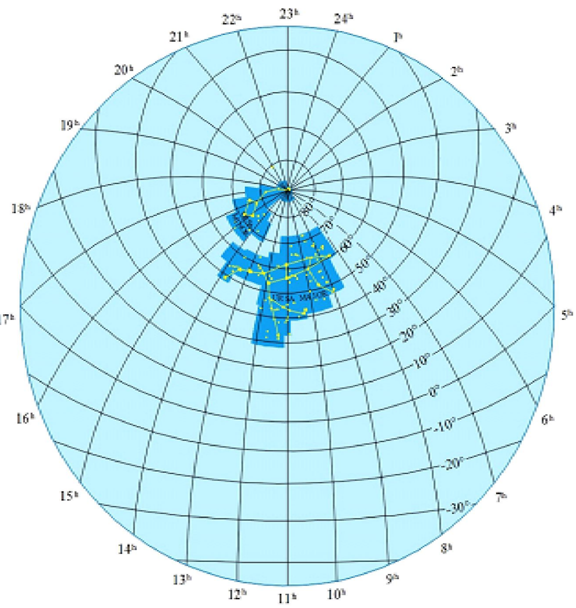

Fig. 3 – Hour and diurnal circles represented in the oblique stereographic map projection (central point: α=11^h, δ=45^o)

Table 2

Coordinates for stars from the constellation Ursa Major in the oblique stereographic projection (Coordinates of the pole projection: $\alpha = 11^h$, $\delta = 45^o$)

Bayer designation	Right ascension [h m s]	Declination [o ‘ “]	Apparent magnitude	X	Y
o UMa	8 30 15.90	60 43 05.00	3.36	3617.78	3143.75
π1UMa	8 39 11.70	65 01 15.00	5.64	4211.93	2582.84
π2 UMa	8 40 12.80	64 19 40.00	4.60	4090.32	2628.20
I UMa	8 59 12.40	48 02 30.00	3.14	1211.95	3476.96
ρ UMa	9 02 32.70	67 37 47.00	4.76	4441.24	1976.49
K UMa	9 03 37.50	47 09 24.00	3.60	1014.13	3411.09
σ1 UMa	9 08 23.60	66 52 24.00	5.14	4271.10	1939.06
σ2 UMa	9 10 23.20	67 08 05.00	4.80	4300.96	1887.00
τ UMa	9 10 55.10	63 30 49.00	4.67	3685.78	2136.18
θ UMa	9 32 51.40	51 40 38.00	3.17	1504.59	2346.09
υ UMa	9 50 59.40	59 02 19.00	3.80	2650.71	1561.91
φ UMa	9 52 06.40	54 03 52.00	4.59	1783.47	1739.83
λ UMa	10 17 05.80	42 54 52.00	3.45	-274.78	1369.66
μ UMa	10 22 19.70	41 29 58.00	3.05	-541.64	1231.10
ω UMa	10 53 58.70	43 11 24.00	4.71	-314.18	191.61
β UMa	11 01 50.50	56 22 57.00	2.37	1993.32	-44.93
α UMa	11 03 43.70	61 45 03.00	1.79	2945.09	-78.66
ψ UMa	11 09 39.80	44 29 55.00	3.01	-83.05	-300.73
ξ UMa	11 18 10.90	31 31 45.00	4.87	-2345.03	-685.58
ξ UMa	11 18 11.00	31 31 45.00	4.41	-2345.02	-685.64
ν UMa	11 18 28.70	33 05 39.00	3.48	-2068.03	-682.74
χ UMa	11 46 03.00	47 46 46.00	3.71	583.65	-1348.40
γ UMa	11 53 49.80	53 41 41.00	2.44	1645.57	-1393.95
δ UMa	12 15 25.60	57 01 57.00	3.31	2341.07	-1797.04
ε UMa	12 54 01.70	55 57 35.00	1.77	2462.64	-2763.13
ζ UMa	13 23 55.50	54 55 31.00	2.27	2620.05	-3539.86
ζ UMa	13 23 56.40	54 55 18.00	3.95	2619.65	-3540.51
η UMa	13 47 32.40	49 18 48.00	1.86	2053.84	-4631.82

Table 3

Coordinates for stars from the constellation Ursa Minor in the polar stereographic projection (Coordinates of the pole projection: $\delta = 90^o$)

Bayer designation	Right ascension [h m s]	Declination [o ‘ “]	Apparent magnitude	X	Y
β UMi	14 50 42.30	74 09 20.00	2.08	15116.36	173.95
γ UMi	15 20 43.70	71 50 02.00	3.05	14500.69	-429.76
θ UMi	15 31 24.90	77 20 58.00	4.96	16035.56	-491.82
ζ UMi	15 44 03.50	77 47 40.00	4.32	16188.41	-669.03
η UMi	16 17 30.30	75 45 19.00	4.95	15733.01	-1325.13
ε UMi	16 45 58.10	82 02 14.00	4.23	17622.29	-1099.56
δ UMi	17 32 12.90	86 35 11.00	4.36	19070.37	-701.18
λ UMi	17 16 56.80	89 02 16.00	6.38	19723.36	-186.37

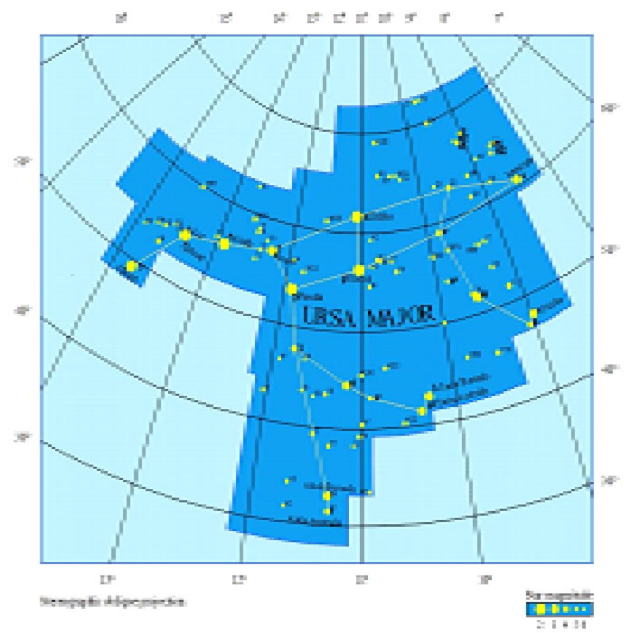

Fig. 4 – Ursa Major represented in the oblique stereographic map projection (central point: α=11^h, δ=45^o).

Table 4

Coordinates for stars from the constellation Ursa Major in the polar stereographic projection
(Coordinates of the pole projection: $\delta = 90^o$)

Bayer designation	Right ascension [h m s]	Declination [o ‘ “]	Apparent magnitude	X	Y
ο UMa	8 30 15.90	60 43 05.00	3.36	-4148.86	3175.91
π1UMa	8 39 11.70	65 01 15.00	5.64	-3619.96	2553.72
π2 UMa	8 40 12.80	64 19 40.00	4.60	-3735.43	2610.40
I UMa	8 59 12.40	48 02 30.00	3.14	-6628.18	3857.44
ρ UMa	9 02 32.70	67 37 47.00	4.76	-3446.63	1939.20
K UMa	9 03 37.50	47 09 24.00	3.60	-6856.59	3815.35
σ1 UMa	9 08 23.60	66 52 24.00	5.14	-3616.38	1914.91
σ2 UMa	9 10 23.20	67 08 05.00	4.80	-3590.72	1861.52
τ UMa	9 10 55.10	63 30 49.00	4.67	-4183.72	2156.64
θ UMa	9 32 51.40	51 40 38.00	3.17	-6453.27	2579.27
υ UMa	9 50 59.40	59 02 19.00	3.80	-5290.01	1642.84
φ UMa	9 52 06.40	54 03 52.00	4.59	-6203.44	1893.42
λ UMa	10 17 05.80	42 54 52.00	3.45	-8561.77	1621.76
μ UMa	10 22 19.70	41 29 58.00	3.05	-8888.02	1474.26
ω UMa	10 53 58.70	43 11 24.00	4.71	-8653.86	227.43
β UMa	11 01 50.50	56 22 57.00	2.37	-6041.49	-48.55
α UMa	11 03 43.70	61 45 03.00	1.79	-5032.11	-81.87
ψ UMa	11 09 39.80	44 29 55.00	3.01	-8379.53	-353.53
ξ UMa	11 18 10.90	31 31 45.00	4.87	-11158.65	-887.10
ξ UMa	11 18 11.00	31 31 45.00	4.41	-11158.64	-887.19
ν UMa	11 18 28.70	33 05 39.00	3.48	-10802.64	-872.88
χ UMa	11 46 03.00	47 46 46.00	3.71	-7566.13	-1541.07
γ UMa	11 53 49.80	53 41 41.00	2.44	-6377.30	-1526.05
δ UMa	12 15 25.60	57 01 57.00	3.31	-5600.48	-1912.74
ε UMa	12 54 01.70	55 57 35.00	1.77	-5380.02	-2921.97
ζ UMa	13 23 55.50	54 55 31.00	2.27	-5114.46	-3713.32
ζ UMa	13 23 56.40	54 55 18.00	3.95	-5114.78	-3714.06
η UMa	13 47 32.40	49 18 48.00	1.86	-5520.68	-4950.82

Table 5

Coordinates for stars from the constellation Ursa Minor in the equatorial stereographic projection (Coordinates of the pole projection: $\alpha = 15^h$, $\delta = 0^o$)

Bayer designation	Right ascension [h m s]	Declination [o ‘ “]	Apparent magnitude	X	Y
β UMi	14 50 42.30	74 09 20.00	2.08	15116.36	173.95
γ UMi	15 20 43.70	71 50 02.00	3.05	14500.69	-429.76
θ UMi	15 31 24.90	77 20 58.00	4.96	16035.56	-491.82
ζ UMi	15 44 03.50	77 47 40.00	4.32	16188.41	-669.03
η UMi	16 17 30.30	75 45 19.00	4.95	15733.01	-1325.13
ε UMi	16 45 58.10	82 02 14.00	4.23	17622.29	-1099.56
δ UMi	17 32 12.90	86 35 11.00	4.36	19070.37	-701.18
λ UMi	17 16 56.80	89 02 16.00	6.38	19723.36	-186.37

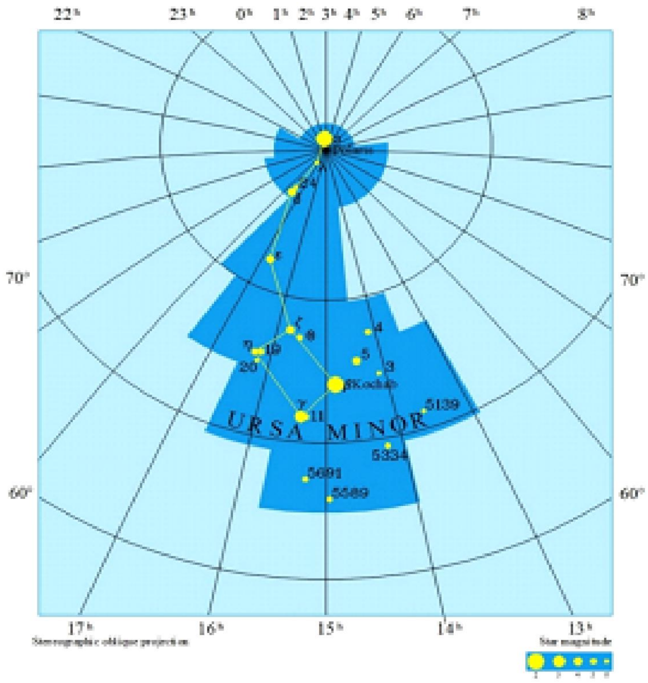

Fig. 5 – Ursa Minor represented in the oblique stereographic map projection (central point: α=15^h, δ=45^o).

Table 6

Coordinates for stars from the constellation Ursa Major in the equatorial stereographic projection (Coordinates of the pole projection: $\alpha = 11^h$, $\delta = 0^o$)

Bayer designation	Right ascension [h m s]	Declination [o ‘ “]	Apparent magnitude	X	Y
ο UMa	8 30 15.90	60 43 05.00	3.36	12564.63	4282.71
π1UMa	8 39 11.70	65 01 15.00	5.64	13478.32	3619.58
π2 UMa	8 40 12.80	64 19 40.00	4.60	13302.09	3662.53
I UMa	8 59 12.40	48 02 30.00	3.14	9425.85	4262.71
ρ UMa	9 02 32.70	67 37 47.00	4.76	13888.23	2802.80
K UMa	9 03 37.50	47 09 24.00	3.60	9198.56	4148.06
σ1 UMa	9 08 23.60	66 52 24.00	5.14	13653.54	2728.76
σ2 UMa	9 10 23.20	67 08 05.00	4.80	13701.79	2659.37
τ UMa	9 10 55.10	63 30 49.00	4.67	12819.11	2926.73
θ UMa	9 32 51.40	51 40 38.00	3.17	9957.21	2920.92
υ UMa	9 50 59.40	59 02 19.00	3.80	11500.12	2046.25
φ UMa	9 52 06.40	54 03 52.00	4.59	10371.77	2194.62
λ UMa	10 17 05.80	42 54 52.00	3.45	7919.46	1585.29
μ UMa	10 22 19.70	41 29 58.00	3.05	7621.20	1409.61
ω UMa	10 53 58.70	43 11 24.00	4.71	7917.69	221.58
β UMa	11 01 50.50	56 22 57.00	2.37	10720.10	-57.27
α UMa	11 03 43.70	61 45 03.00	1.79	11958.61	-104.52
ψ UMa	11 09 39.80	44 29 55.00	3.01	8184.96	-351.10
ξ UMa	11 18 10.90	31 31 45.00	4.87	5654.26	-730.39
ξ UMa	11 18 11.00	31 31 45.00	4.41	5654.26	-730.46
ν UMa	11 18 28.70	33 05 39.00	3.48	5950.96	-735.39
χ UMa	11 46 03.00	47 46 46.00	3.71	8930.70	-1617.35
γ UMa	11 53 49.80	53 41 41.00	2.44	10227.93	-1748.83
δ UMa	12 15 25.60	57 01 57.00	3.31	11075.94	-2321.84
ε UMa	12 54 01.70	55 57 35.00	1.77	11108.52	-3581.49
ζ UMa	13 23 55.50	54 55 31.00	2.27	11172.68	-4609.06
ζ UMa	13 23 56.40	54 55 18.00	3.95	11172.04	-4609.83
η UMa	13 47 32.40	49 18 48.00	1.86	10210.22	-5860.55

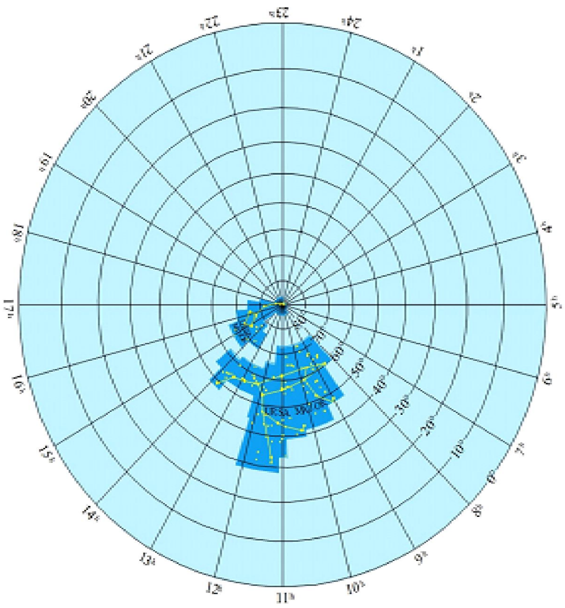

Fig. 6 – Hour and diurnal circles represented in the polar stereographic map projection (central point at $\delta=90^o$).

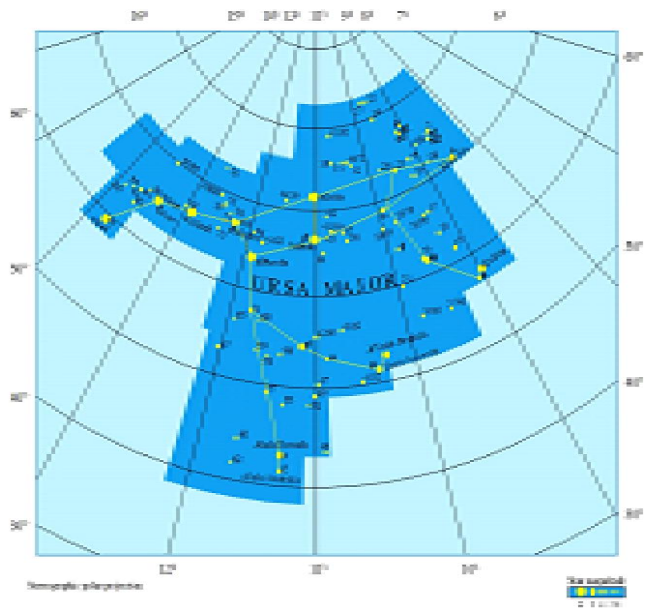

Fig. 7 – Ursa Major represented in the polar stereographic map projection (central point: $\delta=90^o$)

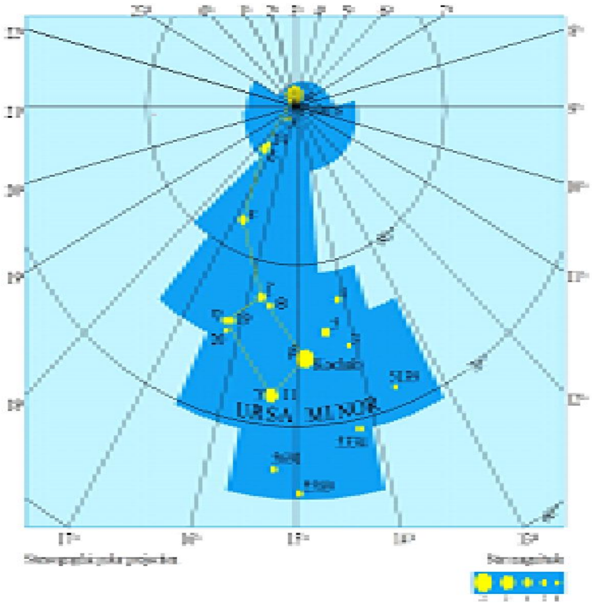

Fig. 8 – Ursa Minor represented in the polar stereographic map projection (central point: δ=90^o)

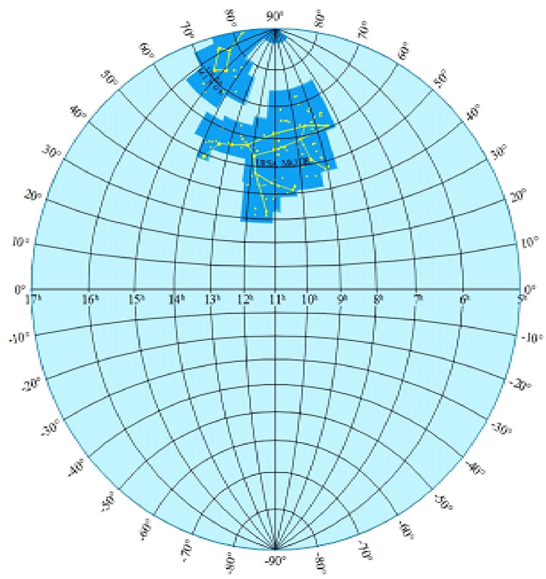

Fig. 9 – Hour and diurnal circles represented in the equatorial stereographic map projection (central point at α=11^h δ=0^o).

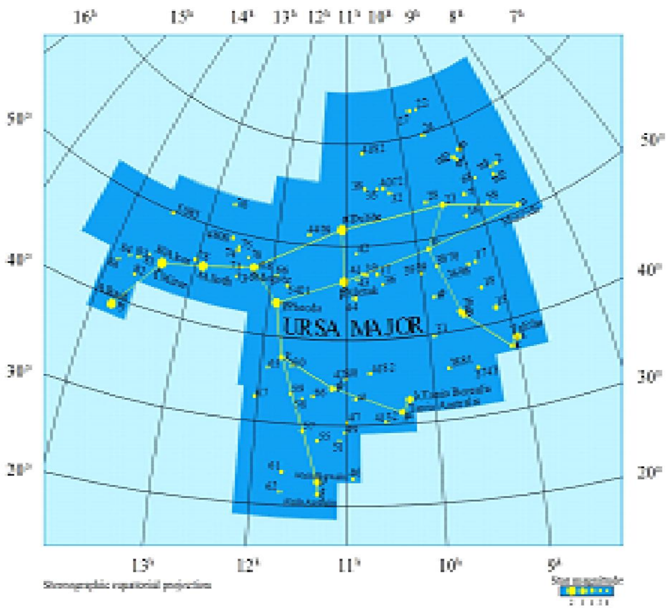

Fig. 10 – Ursa Major represented in the equatorial stereographic map projection (central point at $\alpha=11^h$ $\delta=0^o$)

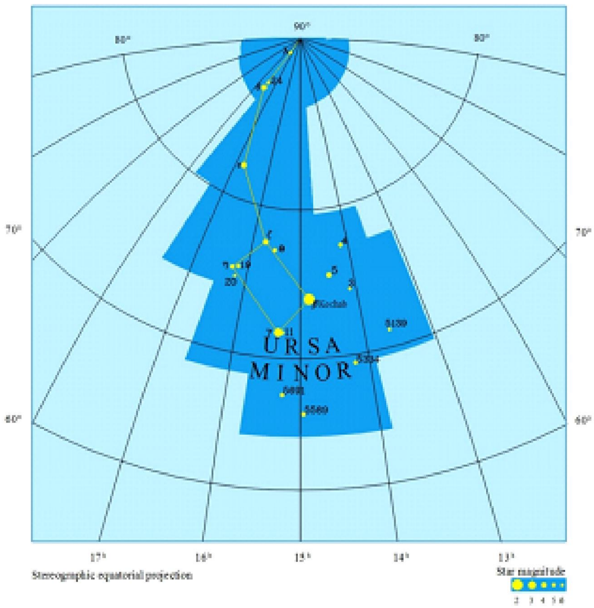

Fig. 11 – Ursa Minor represented in the equatorial stereographic map projection (central point at $\alpha=11^h$ $\delta=0^o$)

5. CONCLUSIONS

In order to create a sky map, one should follow approximately the same steps as for creating a terrestrial map. The map projection needs to be chosen according to the represented area (e.g. one constellation, one hemisphere or the entire celestial sphere). The degree of detail is established according the map's intended users. The Cartesian coordinates of the grid nodes and of the celestial bodies are calculated from the equatorial coordinates using the forward equation of the map projection, after which they are represented in plane.

For sky maps in particular, stereographic azimuthal projections are preferred for their ortomorphic property and for the shape of the grids. Their major disadvantage is that only one hemisphere can be represented on a single map.

In order to exemplify all of the concepts described within, several hemisphere maps of the constellations Ursa Major and Ursa Minor were created using the stereographic perspective azimuthal projection, in the polar, oblique and equatorial aspects.

The current paper aims to be used as a guide by those who want to create sky maps themselves.

REFERENCES

Bădescu, O.: 2004, *Elemente de astronomie fundamentală*, Conspress, Bucureşti.
Bugayevskiy, L. M., Snyder, J. P.: 1995, *Map Projections. A Reference Manual*, Taylor & Francis.
Dent, B. D., Torguson, J.S., Hodler, T. W.: 2009, *Cartography. Thematic Map Design*, McGraw-Hill, New York.
Soloviev, M.D.: 1955, *Proiecţii cartografice*, Editura Militară, Bucureţti.

Received on 13 December 2016