A dynamic sky simulation for the Scanning Sky Monitor on ASTROSAT.

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April 30, 2003

Abstract

We have developed a software for computation and dynamic display of x-ray source locations in the field of view of continuously scanning coded mask cameras of the Scanning Sky Monitor (SSM) aboard ASTROSAT. This software reads a database of known X-ray source locations and strengths (such as the UHURU catalog) and as a function of time computes the location of sources in the field of view of each of the three SSM cameras in the local camera coordinates. We have applied this in the visualization of the operation of the SSM cameras, their background modelling and the refinement of source location using multiple cameras with crossed fields of view.

0.1 Introduction

About half of the x-ray sources in our galaxy are transient in nature. They brighten by a factor of more than 10 and at times even by a factor of as much as a million within a few days. These transient sources can occur anywhere in the sky, and are scientifically very important since they provide information on a large dynamical scale on the processes leading to this increase in brightness. Hence it is necessary to continously monitor the sky in order to detect, locate and study these transients. This function is achieved by an x-ray sky monitor. This monitor will also periodically study the known bright x-ray sources and indicate the level of flux emitted by them. This also enables searching for long-term periods in these sources.

The proposed x-ray monitor will be a position sensitive proportional counter with one dimensional coded mask very similar in design to the ASM or RXTE, the specipications of which are shown in table 1

Table 1: SSM Specifications

Energy range	2 - 10 kev
Position resolution	< 0.5 mm
Field of view	$5^o \times 90^o$
Sensitivity	$\sim$10 mCrab (1 day integration)
Best time resolution	1ms
Angular resolution	$\sim$5 - 10 arcmin

In order to cover as much of the sky as possible and also to precisely locate the transients in two dimensions it is necessary to have at least three such monitors. The monitors will have to continously scan the sky irrespective of the functions of the other instruments on the satellite. It is therefore necessary to mount two monitors with their field of view forming an 'X' in the sky and the third monitor perpendicular to these two. All three monitors are proposed to be mounted on a boom, which will have rotation capability to scan the sky.

0.1.1 Camera Projection

To start with consider a single camera :

Given the position of the center co-ordinates, the orientation of the camera (ϕ) and its field of view along y-direction is 107.74^o and along x-direction is 22.26^o as shown in Fig: 1

To find the range of RA and DEC when camera projected anywhere on the sky i.e. to convert camera co-ordinates (θ_x and θ_y) in terms of sky co-ordinates (RA and DEC).

$\phi \Longrightarrow$ The angle between the great circle and the principal axis of the camera as shown in Fig: 2

Concept of rotational co-ordiante transformations was used to convert camera co-ordinates to sky co-ordinates.

Consider the celestial sphere as shown in Fig. 3. Consider a arbitrary source with coordinate (α, δ) on the celestial sphere, the corresponding camera coordinates (x, y, z) along X, Y and Z-axis are determined (Z-axis represents the pole) using the transformations discussed below, refer figure 4,

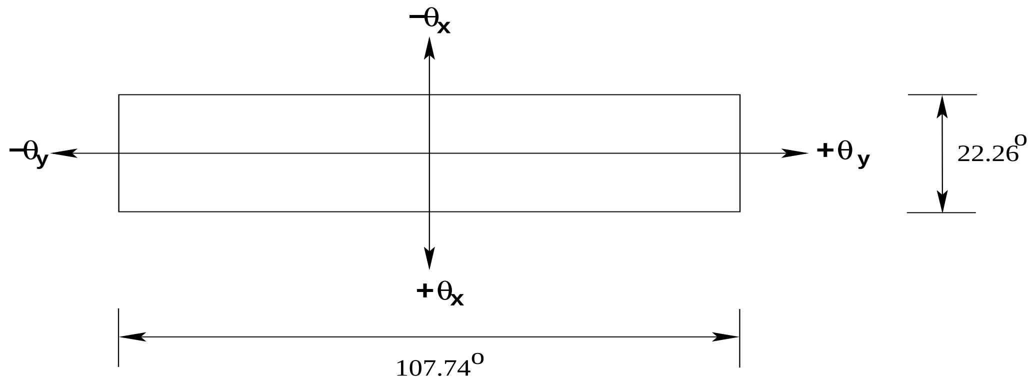

Figure 1: Field of view of the single camera

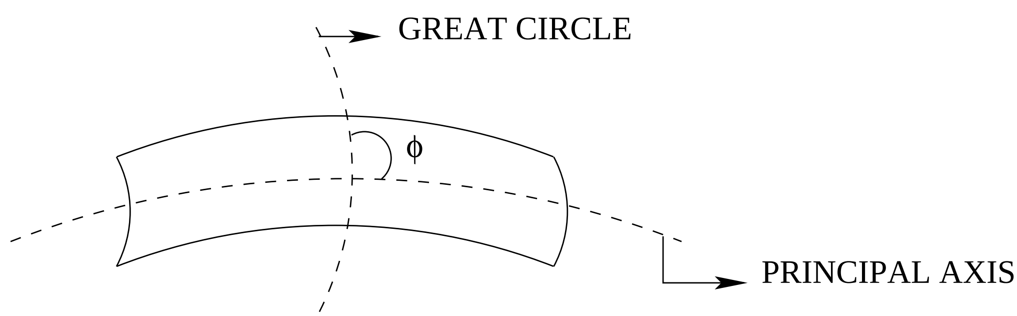

Figure 2: Camera projection

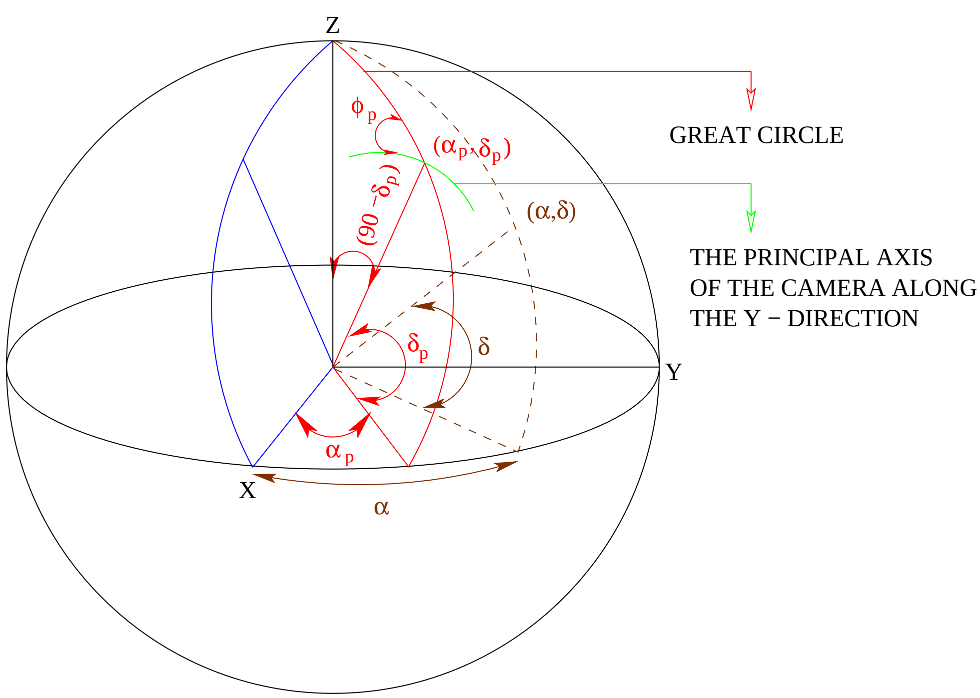

Figure 3:

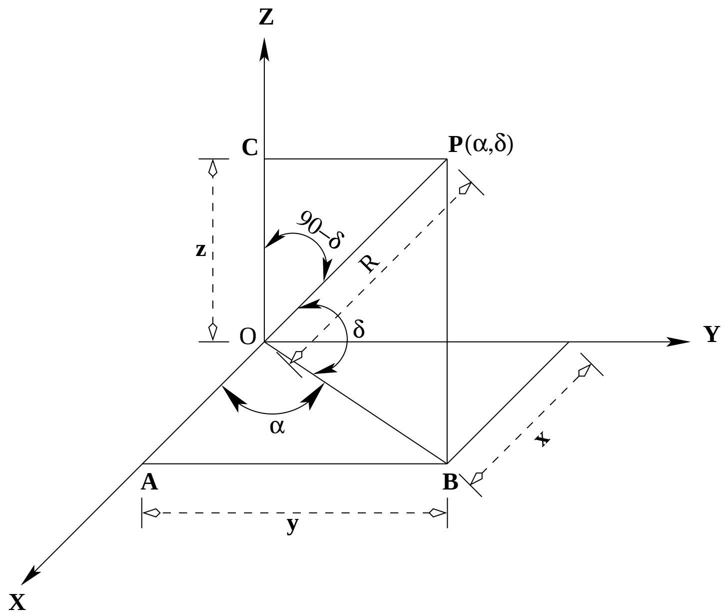

Figure 4:

Consider △OPB,

$$\cos\delta = \frac{OB}{OP} = \frac{a}{R} \tag{1}$$

Where R is the distance from the origin to the point P(α, δ).

$$\Rightarrow a = Rcos\delta \tag{2}$$

Now, consider △OZP, we get

$$\cos(90-\delta) = \frac{z}{R} \tag{3}$$

$$\Rightarrow z = R\sin\delta \tag{4}$$

Consider △OAB,

$$\cos\alpha = \frac{OA}{OB} = \frac{x}{a} = \frac{x}{R\cos\delta} \tag{5}$$

$$\Rightarrow x = R\cos\delta\cos\alpha \tag{6}$$

$$\sin\alpha = \frac{AB}{OB} = \frac{y}{a} = \frac{y}{R\cos\delta} \tag{7}$$

$$\Rightarrow y = R\cos\delta\sin\alpha \tag{8}$$

Hence the camera co-ordinates along corresponding axis are

$$x = R\cos\delta\cos\alpha = \cos\delta\cos\alpha \tag{9}$$

$$y = R\cos\delta\sin\alpha = \cos\delta\sin\alpha \tag{10}$$

$$z = R\sin\delta = \sin\delta \tag{11}$$

Set the radius of the sphere, R to unity. Let (α_p, δ_p) be the centre co-ordinates of the camera and ϕ_p, the inclination angle as shown in figure 3. Rotating the old co-ordinates x,

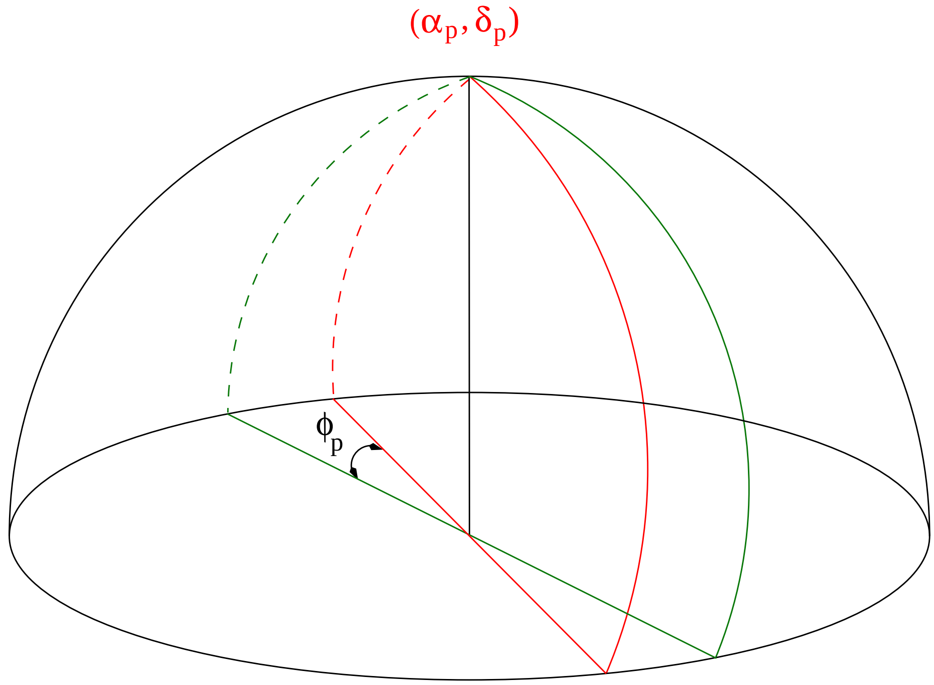

Figure 5:

y, z in terms of new co-ordinates $\overline{x}, \overline{y}, \overline{z}$ by using the rotational co-ordinate transformations.

$$\begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} = ((\mathbf{AB})\mathbf{C}) \begin{pmatrix} x \\ y \\ z \end{pmatrix} \tag{12}$$

To find matrix **C**, the X-axis is rotated by an angle α_p keeping Z-axis fixed (The rotation is done in the XY plane).

$$\mathbf{C} = \begin{pmatrix} \cos\theta_{\overline{z}} & \sin\theta_{\overline{z}} & 0 \\ -\sin\theta_{\overline{z}} & \cos\theta_{\overline{z}} & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \cos\alpha_p & \sin\alpha_p & 0 \\ -\sin\alpha_p & \cos\alpha_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{13}$$

To find matrix **B**, the X-axis is rotated by an angle ($\pi/2$ - δ_p) keeping the Y-axis fixed (The rotation is done in the XZ plane).

$$\mathbf{B} = \begin{pmatrix} \cos\theta_{\overline{y}} & 0 & -\sin\theta_{\overline{y}} \\ 0 & 1 & 0 \\ \sin\theta_{\overline{y}} & 0 & \cos\theta_{\overline{y}} \end{pmatrix} = \begin{pmatrix} \sin\delta_p & 0 & -\cos\delta_p \\ 0 & 1 & 0 \\ \cos\delta_p & 0 & \sin\delta_p \end{pmatrix} \tag{14}$$

To find matrix **A**,the Y-axis is rotated by an angle $\theta_{\overline{z},2} = (\phi_p - \pi/2)$ in the XY plane (Z axis is constant). The result of the transformations lead the center coordinates of the camera (α_p, δ_p) to coincide with the pole. The two meridians passing through the point. One the principal axis of the camera along θ_y direction and the other a great circle. The angle between the meridians is ϕ_p. (refer Fig. 3 and Fig. 5)

$$\mathbf{A} = \begin{pmatrix} \cos\theta_{\overline{z},2} & \sin\theta_{\overline{z},2} & 0 \\ -\sin\theta_{\overline{z},2} & \cos\theta_{\overline{z},2} & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \sin\phi_p & -\cos\phi_p & 0 \\ \cos\phi_p & \sin\phi_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{15}$$

Using equations (13), (14) and (15) in equation (12) leads to

$$\begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} = \begin{pmatrix} \sin\phi_p & -\cos\phi_p & 0 \\ \cos\phi_p & \sin\phi_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \sin\delta_p & 0 & -\cos\delta_p \\ 0 & 1 & 0 \\ \cos\delta_p & 0 & \sin\delta_p \end{pmatrix} \begin{pmatrix} \cos\alpha_p & \sin\alpha_p & 0 \\ -\sin\alpha_p & \cos\alpha_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} \tag{16}$$

Substituting the values of x, y and z from equations (9), (10) and (11) in equation (16) results in

$$\begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} = \begin{pmatrix} \sin\phi_p & -\cos\phi_p & 0 \\ \cos\phi_p & \sin\phi_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \sin\delta_p & 0 & -\cos\delta_p \\ 0 & 1 & 0 \\ \cos\delta_p & 0 & \sin\delta_p \end{pmatrix} \begin{pmatrix} \cos\alpha_p & \sin\alpha_p & 0 \\ -\sin\alpha_p & \cos\alpha_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\delta\cos\alpha \\ \cos\delta\sin\alpha \\ \sin\delta \end{pmatrix} \tag{17}$$

Solving the above matrix equation the corresponding body coordinates are obtained.

$$\overline{x} = \sin\phi_p \sin\delta_p \cos\delta\cos(\alpha_p - \alpha) + \cos\phi_p \cos\delta\sin(\alpha_p - \alpha) - \sin\phi_p \cos\delta_p \sin\delta \tag{18}$$

$$\overline{y} = \cos\phi_p \sin\delta_p \cos\delta\cos(\alpha_p - \alpha) - \sin\phi_p \cos\delta\sin(\alpha_p - \alpha) - \cos\phi_p \cos\delta_p \sin\delta \tag{19}$$

$$\overline{z} = \cos\delta_p \cos\delta\cos(\alpha_p - \alpha) + \sin\delta_p \sin\delta \tag{20}$$

Substuting the body coordinates in the following equations we obtain θ_x and θ_y. From figure 1,

$$\sin\theta_x = \frac{\overline{x}}{\sqrt{\overline{x}^2 + \overline{z}^2}} \tag{21}$$

$$\cos\theta_x = \frac{\overline{z}}{\sqrt{\overline{x}^2 + \overline{z}^2}} \tag{22}$$

$$\sin\theta_y = \frac{\overline{y}}{\sqrt{\overline{y}^2 + \overline{z}^2}} \tag{23}$$

$$\cos\theta_y = \frac{\overline{z}}{\sqrt{\overline{y}^2 + \overline{z}^2}} \tag{24}$$

The above set of equations will result in two values for θ_x and θ_y which correspond to different quadrants, therefore to find in which quadrant θ_x and θ_y falls, $\tan^{-1}()$ function was used.

$$\theta_x = \tan^{-1}\left(\frac{\sin\theta_x}{\cos\theta_x}\right) \tag{25}$$

$$\theta_y = \tan^{-1}\left(\frac{\sin\theta_y}{\cos\theta_y}\right) \tag{26}$$

NOTE : The C math library function atan2() was used to evaluate θ_x and θ_y in the program code. The atan2() function calculates the arc tangent of $\sin\theta_x/\cos\theta_x$, the signs of $\sin\theta_x$ and $\cos\theta_x$ are used to determine the quadrant in which θ_x falls.

Hence, from the given center co-ordinate of the camera (α_p, δ_p) at any position and its inclination angle ϕ_p. θ_x and θ_y can be calculated for any source i.e. (α, δ) from the above transformation equations i.e. given ϕ_p, α_p, δ_p and (α, δ) from the file uhuru.dat

(UHURU sources) its θ_x and θ_y co-ordiantes are obtained.
The program zlist1.c [PATH : /misc/sat2/astrosat/SUSHILA/zlist1.c], reads the data from the file uhuru.dat and transforms the camera co-ordinate to body coordinate, results of which are written into a new file uhuru1.dat in the following format (Object Name, Right Acension of the Source, Declination of the Source, θ_x, θ_y, counts). The program converts (α, δ) to (θ_x, θ_y) for any position of α_p, δ_p and ϕ_p provided by the user.
The program zlist2.c [PATH : /misc/sat2/astrosat/SUSHILA/zlist2.c], reads the data from the file uhuru.dat. In this case α_p, δ_p, ϕ_p are defined inside the program itself instead of accepting the values from the user. α_p was changed from 0^o to 360^o in steps of 45^o, ϕ_p was changed from 0^o to 180^o in steps of 10^o and δ_p equal to zero degree. For each set of α_p and δ_p, one full rotation of ϕ_p from 0^o to 180^o was done. For each set, the total number of sources inside the field of view of the camera, maximum counts divide by the crab counts(947) and total counts divided by the crab counts was found. These information was stored in the file called u2.dat in the following format (α_p, δ_p, ϕ_p, number of source, Maxcnts/947, totalcounts/947).

INVERSE TRANSFORMATION :
From the given α_p, δ_p, ϕ_p, θ_x and θ_y to obtain source coordinate α and δ

$$R^{-1} = R(-\theta) \tag{27}$$

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = ((\mathbf{C^{-1}B^{-1}})\mathbf{A^{-1}}) \begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} \tag{28}$$

Also from spherical geometry we know,

$$\overline{x}^2 + \overline{y}^2 + \overline{z}^2 = 1 \tag{29}$$

Using equation (29) and rearranging (21), (22), (23) and (24)

$$\overline{x}^2 = \frac{\sin^2\theta_x \cos^2\theta_y}{1 - \sin^2\theta_y \sin^2\theta_x} \tag{30}$$

$$\overline{y}^2 = \frac{\sin^2\theta_y \cos^2\theta_x}{1 - \sin^2\theta_x \sin^2\theta_y} \tag{31}$$

$$\overline{z}^2 = \frac{\cos^2\theta_y \cos^2\theta_x}{1 - \sin^2\theta_x \sin^2\theta_y} \tag{32}$$

From equation (27) and (15)

$$\mathbf{A}^{-1} = \begin{pmatrix} \cos(-\theta_{\overline{z},2}) & \sin(-\theta_{\overline{z},2}) & 0 \\ -\sin(-\theta_{\overline{z},2}) & \cos(-\theta_{\overline{z},2}) & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\overline{z},2} & -\sin\theta_{\overline{z},2} & 0 \\ \sin\theta_{\overline{z},2} & \cos\theta_{\overline{z},2} & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \sin\phi_p & \cos\phi_p & 0 \\ -\cos\phi_p & \sin\phi_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{33}$$

since, $\theta_{\overline{z},2} = (\phi_p - \pi/2)$

From equation (27) and (14)

$$
\mathbf{B}^{-1} = \begin{pmatrix} \cos(-\theta_{\overline{y}}) & 0 & -\sin(-\theta_{\overline{y}}) \\ 0 & 1 & 0 \\ \sin(-\theta_{\overline{y}}) & 0 & \cos(-\theta_{\overline{y}}) \end{pmatrix} = \begin{pmatrix} \cos\theta_{\overline{y}} & 0 & \sin\theta_{\overline{y}} \\ 0 & 1 & 0 \\ -\sin\theta_{\overline{y}} & 0 & \cos\theta_{\overline{y}} \end{pmatrix} = \begin{pmatrix} \sin\delta_p & 0 & \cos\delta_p \\ 0 & 1 & 0 \\ -\cos\delta_p & 0 & \sin\delta_p \end{pmatrix} \tag{34}
$$

since, $\theta_{\overline{y}} = (\pi/2 \text{ - } \delta_P)$

From equation (27) and (13)

$$
\mathbf{C}^{-1} = \begin{pmatrix} \cos(-\theta_{\overline{z}}) & \sin(-\theta_{\overline{z}}) & 0 \\ -\sin(-\theta_{\overline{z}}) & \cos(-\theta_{\overline{z}}) & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\overline{z}} & -\sin\theta_{\overline{z}} & 0 \\ \sin\theta_{\overline{z}} & \cos\theta_{\overline{z}} & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} \cos\alpha_p & -\sin\alpha_p & 0 \\ \sin\alpha_p & \cos\alpha_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{35}
$$

since, $\theta_z = \alpha_p$

Substituting the value of equations (33), (34) and (35) in equation (28) leads to the camera coordinates

$$
\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \cos\alpha_p & -\sin\alpha_p & 0 \\ \sin\alpha_p & \cos\alpha_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \sin\delta_p & 0 & \cos\delta_p \\ 0 & 1 & 0 \\ -\cos\delta_p & 0 & \sin\delta_p \end{pmatrix} \begin{pmatrix} \sin\phi_p & \cos\phi_p & 0 \\ -\cos\phi_p & \sin\phi_p & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} \tag{36}
$$

By taking the square root of equation (30), (31) and (32) $\overline{x}$, $\overline{y}$ and $\overline{z}$ are obtained. Substituting the values of $\overline{x}$, $\overline{y}$ and $\overline{z}$ in equation (36) and simplyfying we obtain

$$
\begin{aligned}
x = {} & (\cos\alpha_p \sin\delta_p \sin\phi_p + \sin\alpha_p \cos\phi_p) \left(\frac{\sin\theta_x \cos\theta_y}{\sqrt{1 - \sin^2\theta_y \sin^2\theta_x}} \right) \\
& + (\cos\alpha_p \sin\delta_p \cos\phi_p - \sin\alpha_p \sin\phi_p) \left(\frac{\sin\theta_y \cos\theta_x}{\sqrt{1 - \sin^2\theta_y \sin^2\theta_x}} \right) \\
& + \cos\alpha_p \cos\delta_p \left(\sqrt{1 - \overline{x}^2} \; \cos\theta_y \right)
\end{aligned} \tag{37}
$$

$$
\begin{aligned}
y = {} & (\sin\alpha_p \sin\delta_p \sin\phi_p - \cos\alpha_p \cos\phi_p) \left(\frac{\sin\theta_x \cos\theta_y}{\sqrt{1 - \sin^2\theta_y \sin^2\theta_x}} \right) \\
& + (\sin\alpha_p \sin\delta_p \cos\phi_p + \cos\alpha_p \sin\phi_p) \left(\frac{\sin\theta_y \cos\theta_x}{\sqrt{1 - \sin^2\theta_y \sin^2\theta_x}} \right) \\
& + \sin\alpha_p \cos\delta_p \left(\sqrt{1 - \overline{x}^2} \; \cos\theta_y \right)
\end{aligned} \tag{38}
$$

$$
\begin{aligned}
z = {} & (-\cos\delta_p \sin\phi_p) \left(\frac{\sin\theta_x \cos\theta_y}{\sqrt{1 - \sin^2\theta_y \sin^2\theta_x}} \right) + (-\cos\delta_p \cos\phi_p) \left(\frac{\sin\theta_y \cos\theta_x}{\sqrt{1 - \sin^2\theta_y \sin^2\theta_x}} \right) \\
& + \sin\delta_p \left(\sqrt{1 - \overline{x}^2} \; \cos\theta_y \right)
\end{aligned} \tag{39}
$$

Also from equation (9), (10) and (11) x = $\cos\delta\cos\alpha$, y = $\cos\delta\sin\alpha$, z = $\sin\delta$. Hence,

$$\delta = \sin^{-1}(z) \tag{40}$$

and

$$\alpha = \tan^{-1}\left(\frac{y}{x}\right) \tag{41}$$

Hence from the given α_p, δ_p, ϕ_p and the field of view of the camera (θ_x and θ_y), (α and δ) are evaluated by inverse transformation equations i.e. for any source in the local camera co-ordinate(θ_x, θ_y) the corresponding value of (α, δ) are obtained, this helps in drawing the camera projection.

HAMMER - AITOFF PROJECTION :

This map projection is an equal area map projection which displays the world on the ellipse. The coordinates to plot the aitoff are generated using the relations

$$d = \sqrt{1 + \cos\delta\cos(\alpha/2)} \tag{42}$$

$$x = \frac{2\cos\delta\sin(\alpha/2)}{d} \tag{43}$$

$$y = \left(\frac{\sin\delta}{d}\right) \tag{44}$$

The x and y coordinates which are the results of the transformation of α and δ values ranging from 180^o to -180^o and 90^o to -90^o respectively. The values obtained are fed to the pgplot device to generate the aitoff projection. 5 Horizontal lines are drawn on the aitoff (δ range divided in steps of 30^o). 9 vertical lines are similarly drawn (α range divided in steps of 45^o). The result of the plot is as shown in Fig. 6. The α values of the UHURU Sources read from the catalog are normalised from (0^o to 360^o) range to (180^o to -180^o). The δ values remain the same. The x and y coordinates of the UHURU Sources are obtained from the relation and the UHURU Sources are plotted on the aitoff projection as shown in Fig. 7.

PROJECTING MULTIPLE CAMERAS ON THE AITOFF :

To facilitate maximum coverage the slanted cameras (camera 1 and 2) are placed at position such that the difference in the angle of their axis is 24^o and the BOOM camera (camera 3) is perpendicular to the slanted cameras. All the three cameras have identical field of view.
To obtain the common center coordinate and the inclination angles of the slanted cameras in terms of the body coordinates, given the field of view of all the three cameras, the center coordinate of the BOOM camera and its inclination angle, the transformations discussed below are followed.
The position of camera 3 before the transformations is as shown in the Fig. 8. The center coordinate of the camera 3 are (α_B, δ_B) . The inclination angle ϕ_B (a function of time, as the cameras are rotating). Initially to point the boom camera to the pole position the center coordinate of camera 3 are shifted from δ_B to -(90^o - δ_B) = (δ_B - 90^o) as shown in Fig. 9. The point "a" in the Fig. 9 is the common center coordinate (α_s, δ_s)

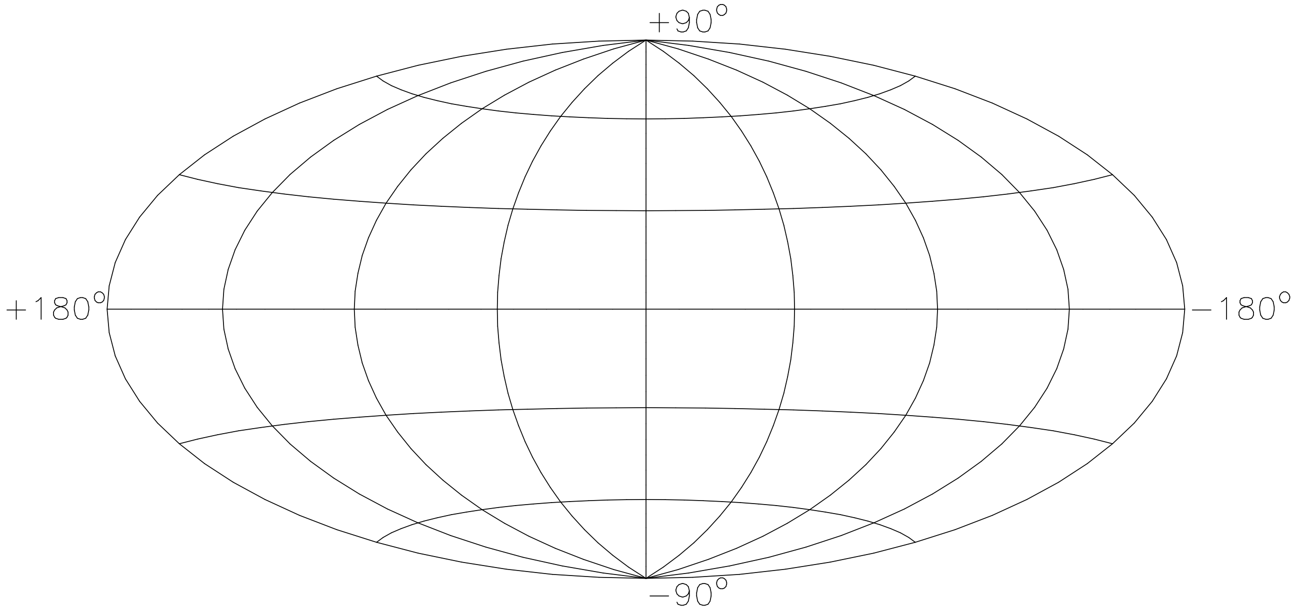

Figure 6: HAMMER - AITOFF PROJECTION

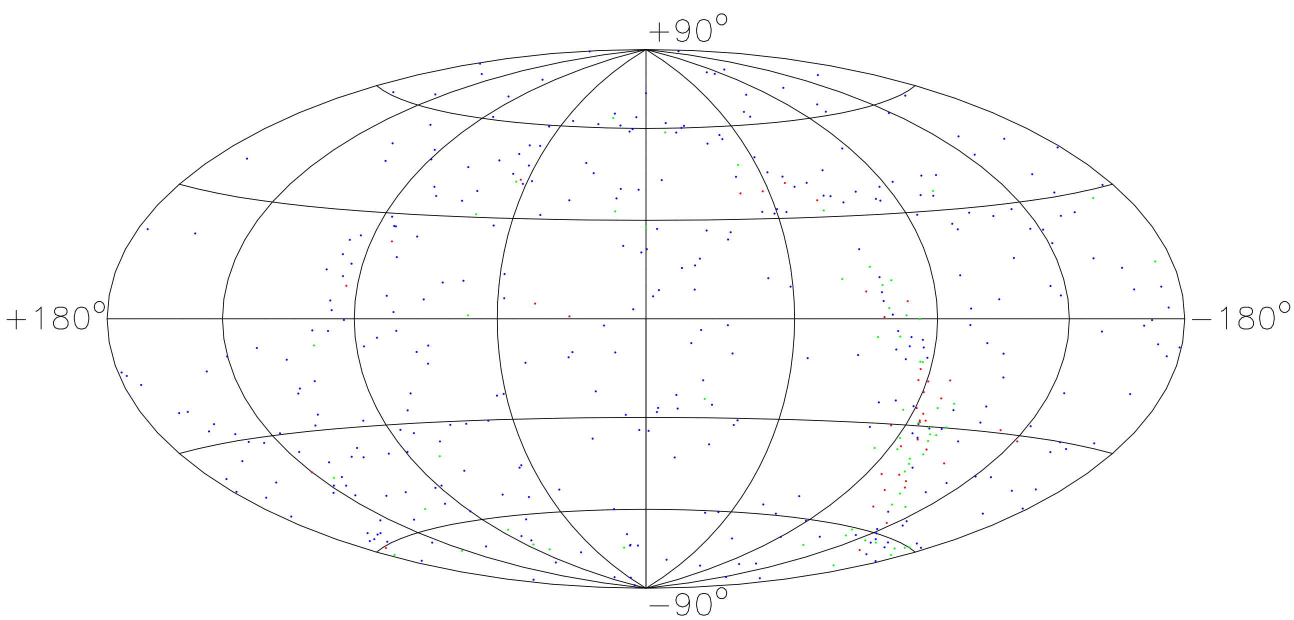

Figure 7: HAMMER - AITOFF PROJECTION WITH UHURU SOURCES

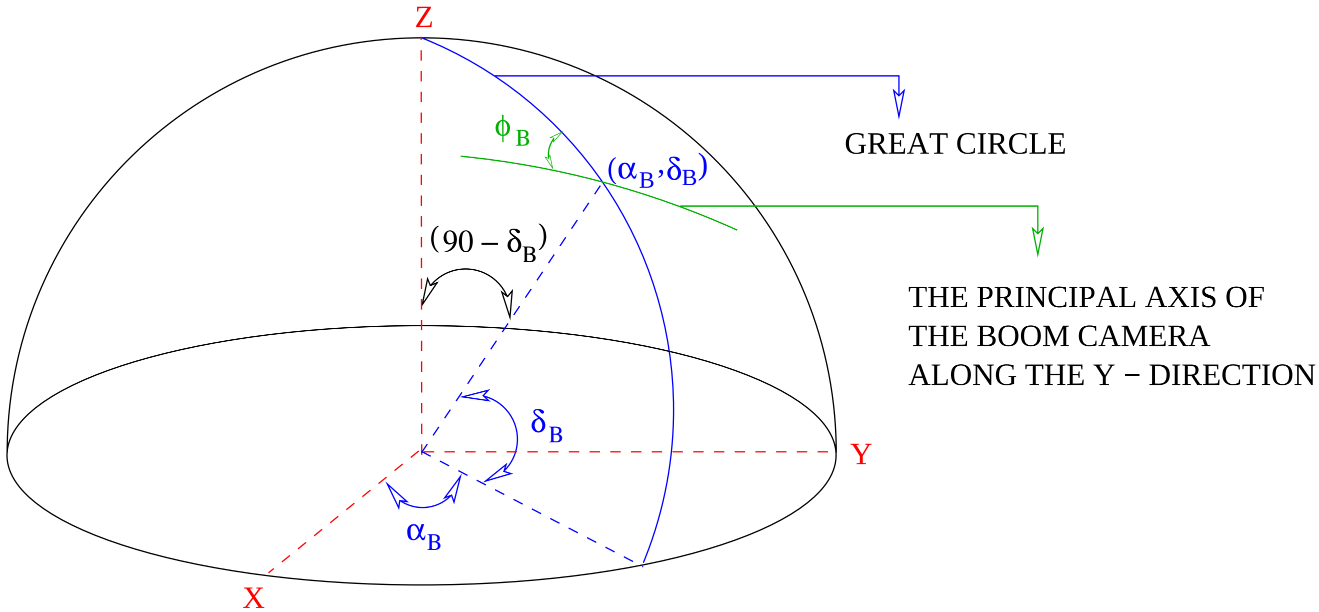

Figure 8:

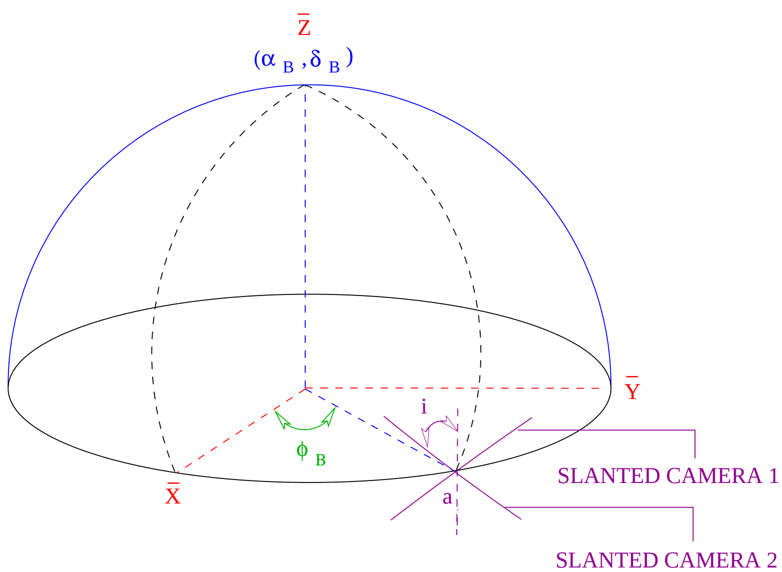

Figure 9:

for the slanted cameras while their inclination angles are ϕ_{s1} and ϕ_{s2} respectively. The coordinates of point "a" obtained are,

$$a = \begin{pmatrix} \overline{x} \\ \overline{y} \\ 0 \end{pmatrix} = \begin{pmatrix} \cos\phi_B \\ \sin\phi_B \\ 0 \end{pmatrix} \tag{45}$$

The slanted cameras are inclined at an angle of i = 12^o as shown in Fig. 9. To obtain "x","y","z" in terms of "$\overline{x}$", "$\overline{y}$", "$\overline{z}$" the cameras are initially rotated along the $\overline{XZ}$ - Plane keeping $\overline{Y}$ constant by an angle (90^o - δ_B) and later rotated along the $\overline{XY}$ - Plane keeping $\overline{Z}$ constant by an angle α_B. The result of the rotations lead to the following matrix equations,

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \cos\alpha_B & -\sin\alpha_B & 0 \\ \sin\alpha_B & \cos\alpha_B & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \sin\delta_B & 0 & \cos\delta_B \\ 0 & 1 & 0 \\ -\cos\delta_B & 0 & \sin\delta_B \end{pmatrix} \begin{pmatrix} \overline{x} \\ \overline{y} \\ \overline{z} \end{pmatrix} \tag{46}$$

Solving equation (46) using (45) we obtain,

$$x = \cos\alpha_B \sin\alpha_B \cos\phi_B - \sin\alpha_B \sin\phi_B \tag{47}$$

$$y = \sin\alpha_B \sin\delta_B \cos\phi_B + \cos\alpha_B \sin\phi_B \tag{48}$$

$$z = -\cos\alpha_B \cos\phi_B \tag{49}$$

The transformations to the body coordinates "x", "y" and "z" are obtained by following the procedure as described for the single camera case (refer Fig. 4)

$$x = \cos\delta_s \cos\alpha_s \tag{50}$$

$$y = \cos\delta_s \sin\alpha_s \tag{51}$$

$$z = \sin\delta_s \tag{52}$$

Equating equations (47) (48) and (49) with (50) (51) and (52) α_s and δ_s are obtained.

The positions of the cameras 1 2 and 3 in terms of the body coordinates are known and are shown in Fig.10. The inclination angles ϕ_{s1} and ϕ_{s2} are calculated by taking the dot product of the components along the plane of the meridian passing through the common center coordinate of the slanted cameras and its normal (α, δ).The first step involves calculation of θ, the angle between the meridian and the locus of the slanted cameras. The body coordinates for the BOOM camera are generated by following the transformations as described for the slanted cameras and the coordinates of the normal to the plane of the meridian. To obtain the components the following transformations are used,

Component along the normal

$$x = \cos\delta_B \cos\alpha_B \tag{53}$$

$$y = \cos\delta_B \sin\alpha_B \tag{54}$$

$$z = \sin\delta_B \tag{55}$$

and component along the meridian

$$x = \cos(90^o + \alpha_s) = -\sin\alpha_s \tag{56}$$

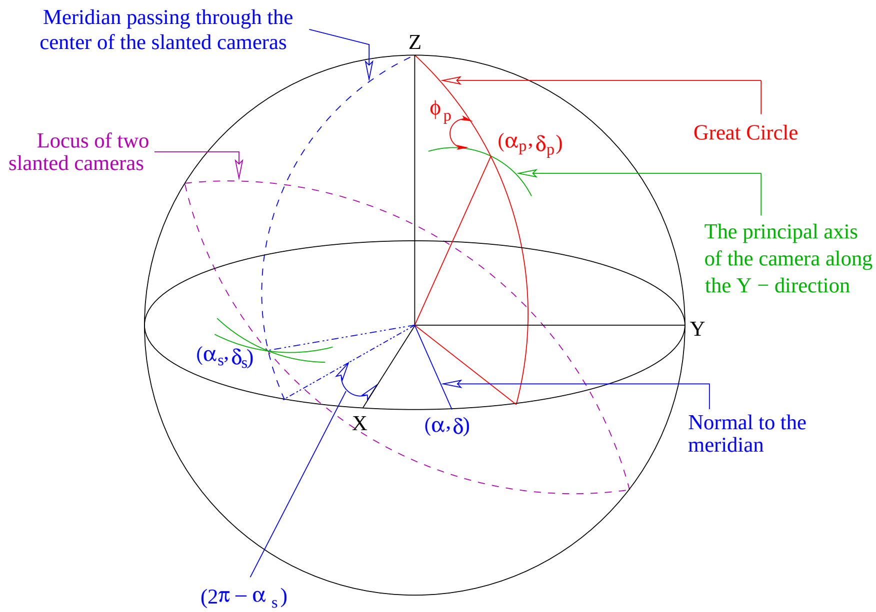

Figure 10:

$$y = \sin(90^o + \alpha_s) = \cos\alpha_s \tag{57}$$

$$z = \delta = 0 \tag{58}$$

The dot product of the above components yields

$$\cos\theta = -\cos\delta_B \cos\alpha_B \sin\alpha_s + \cos\delta_B \sin\alpha_B \cos\alpha_s \tag{59}$$

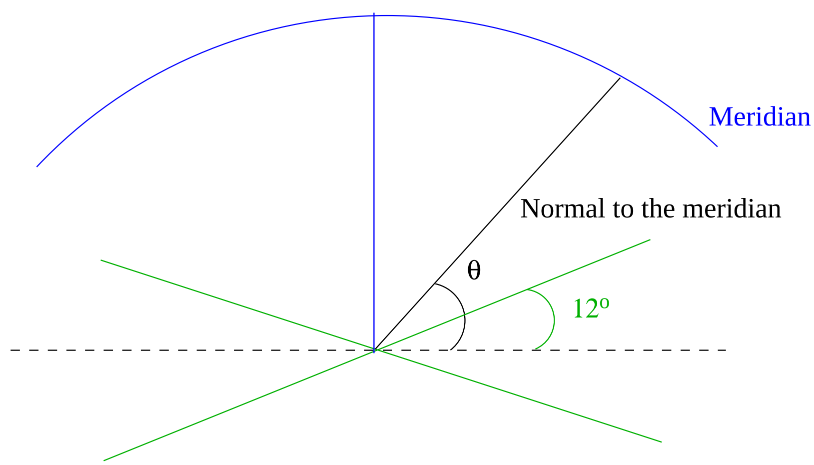

Figure 11:

From the Fig. 11
ϕ_{s1} = 90^o - θ + i and ϕ_{s2} = 90^o - θ - i the inclination angles for the slanted cameras are obtained. The results of the transformations lead to the final projection of all the three cameras on the aitoff.

RESULTS

The program "plotaitoff15.c" [/sat2/astrosat/SUSHILA/STAGE1/plotaitoff15.c] accepts a given value for center coordinate of the boom camera and plots the projection of all the three cameras on the aitoff along with the histograms of the source count in the field of view. Results of the program for α_B = -99^o, δ_B = -36^o and ϕ_B = 320^o (the position for which there is maximum number of sources in the field of the BOOM camera) are shown in Fig. 12.

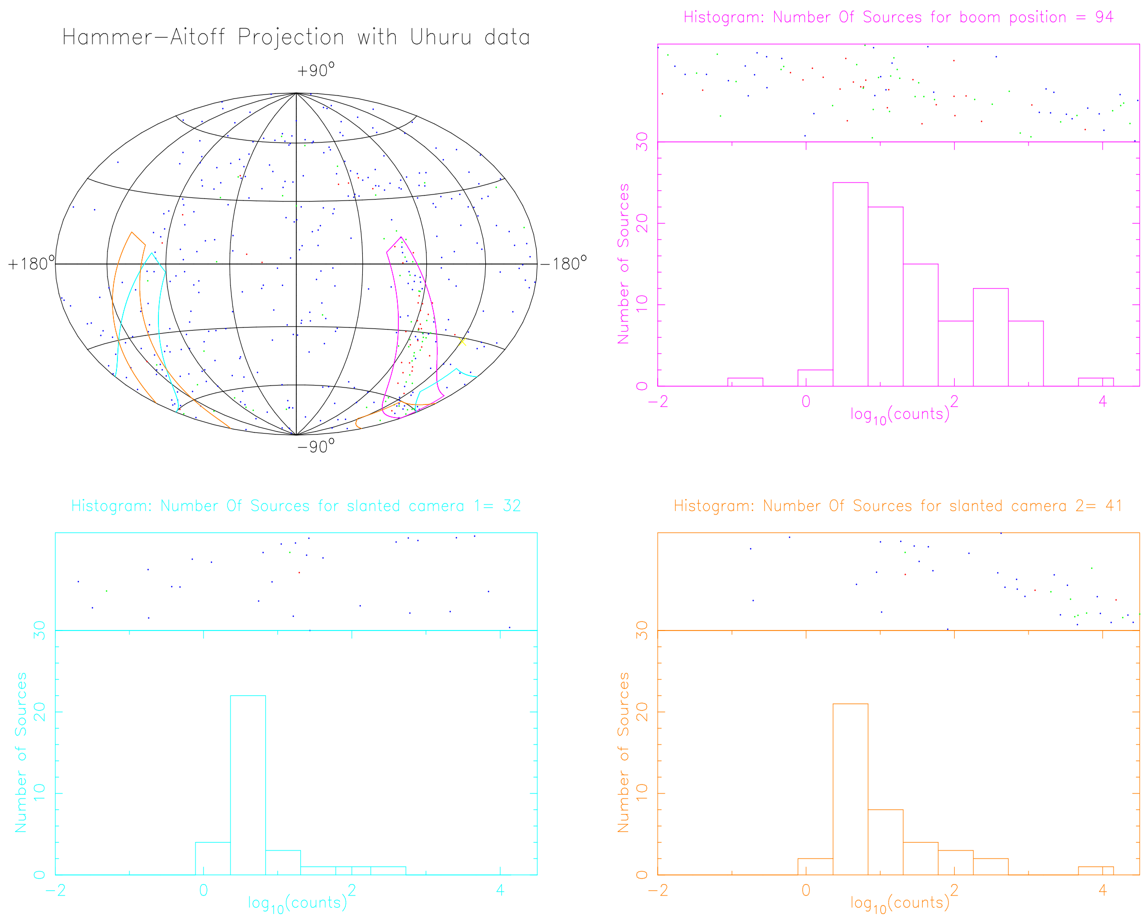

Figure 12: