

Evaluation of satellite orientation and direction of energetic radiation in LEO orbit

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Overview

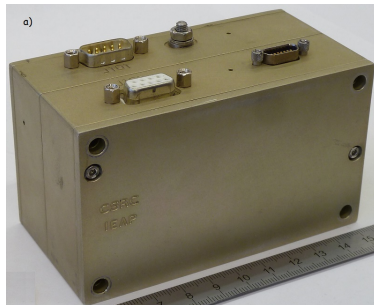
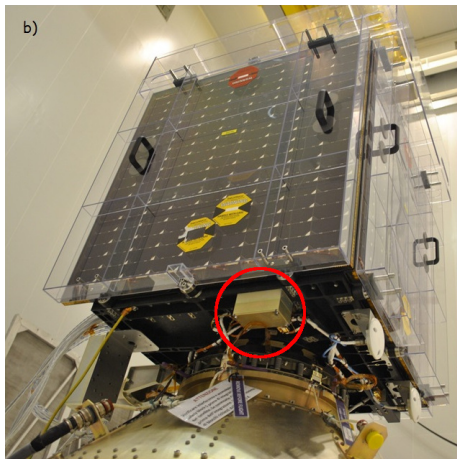
Angle distribution of incoming particles to earth

- Evaluation of Space Application of Timepix RAdiation Monitor (SATRAM) data (attached to Proba-V satellite)
- Determination of satellite orientation relatively to earth
- Determination of particle angles in Timepix detector (track processing)

Express data in (L,B) coordinate system

- L = McIlwain parameter
- distance from earth of the magnetic field lines of a dipole in earth radii above earth equator
- B = B-field strength

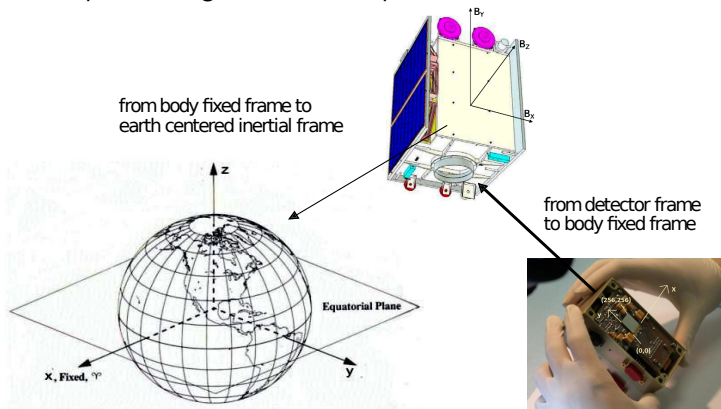
Proba-V and SATRAM



- Altitude = 820 km
- Inclination = 98.8°
- Sun-synchronous orbit
- in orbit since May 2013

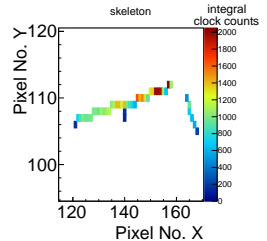
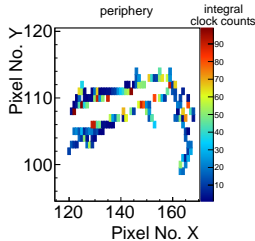
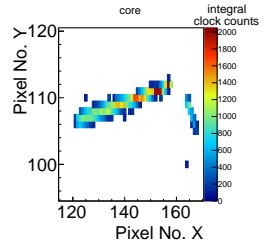
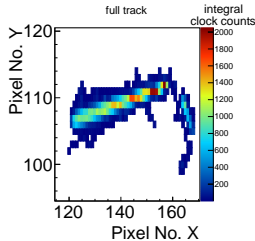
Satellite orientation

Obtain particle angles in the Timepix detector and then:

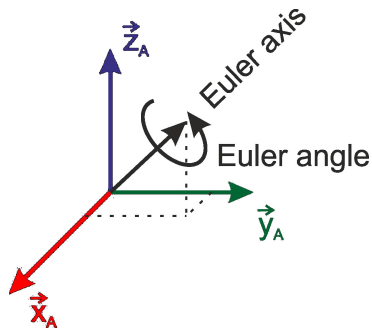


Track processing

- Obtain particle angles by extracting skeleton from track
- Skeleton is the actual path of the particle within the silicon layer
- polar angle = angle in the plane of detector
- azimuth angle = angle between detector plane and particle elevation



Coordinate transformation



based on: Quaternions - a 4x1 matrix with scalar part s and vector part \vec{r} (Euler axis)

$$q = \begin{bmatrix} s \\ \vec{r} \end{bmatrix} = \begin{bmatrix} s \\ r_x \\ r_y \\ r_z \end{bmatrix} = \begin{bmatrix} \cos \frac{\Theta}{2} \\ \|\vec{e}\| \cdot \sin \frac{\Theta}{2} \end{bmatrix}$$

with $\Theta =$ Euler angle

Figure : Taken from: [1]

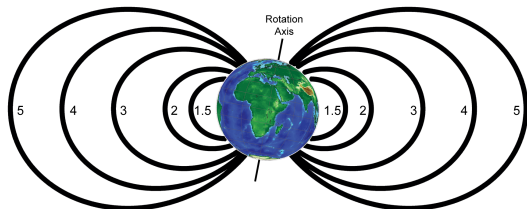
transformation of \vec{r} from coordinate system A to B:

$$\begin{bmatrix} 0 \\ \vec{r}_B \end{bmatrix} = q_{B \leftarrow A} \otimes \begin{bmatrix} 0 \\ \vec{r}_A \end{bmatrix} \otimes q_{B \leftarrow A}^{-1}$$



Mcllwain parameter

- L = magnetic shell parameter or Mcllwain parameter
- distance from earth of the magnetic field lines of a dipole in earth radii above earth equator
- movement of particles trapped in the magnetosphere is described in (L,B) coordinate system
- simplifies system to 2 coordinates



L-Shell map

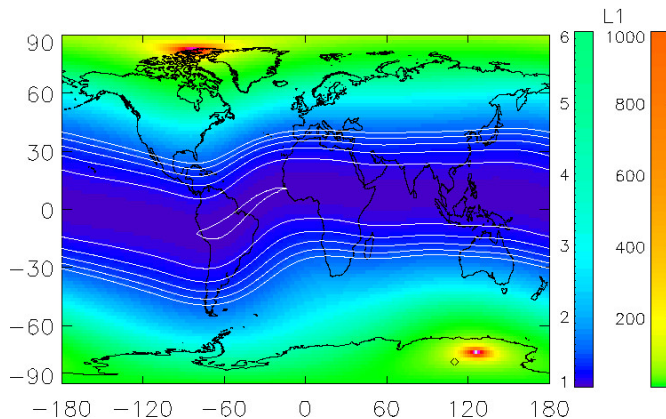


Figure : Mapped L parameter. Taken from: [2]

B-field strength

SATRAM data from March 2015:

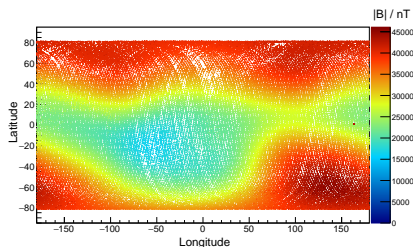


Figure : Measured B-field strength
820 km above earth surface

Theoretical data from 2010:

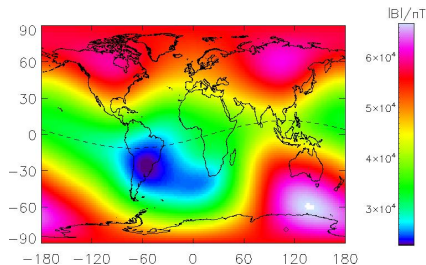


Figure : Calculated B-field strength on
earth surface. Taken from: [2]

References

- [1] K. Großekatthöfer et al., “Introduction into quaternions for spacecraft attitude representation”, Technical University of Berlin, Department of Astronautics and Aeronautics, 2012
- [2] J Pilchowski et al. “On the definition and calculation of a generalised McIlwain parameter”, Astrophys. Space Sci. Trans., 6, 9-17, 2010
- [3] C. E. McIlwain “Magnetic Coordinates”, University of California, Department of Physics, 1965