A coded aperture approach for particle measurements in space plasmas

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Space plasma particle instruments

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Space particle environment

Research aims

Concept

Coded-aperture instruments

Simulations

Current tests

Future work

Figures

Figure 1: http://science.nasa.gov/media/medialibrary/2014/04/10/SatelliteImage.png
Space weather

Key data:
- Fields (electric and magnetic)
- Particles
  - Electrons, ions and neutrals
  - Trapped particles
Figure 2: >40 keV flux at 300 km altitude at 00:00 UTC during a solar maximum in cm$^{-2}$s$^{-1}$ from the AE-8 model via SPENVIS.
To develop a concept for a charged particle detection system suitable for small satellites which can be simulated, prototyped and characterised
Proposed instrument concept

Figure 3: Mask and detector geometry
Figure 4: Original ‘scatter-hole camera’ concept for X-rays or gamma rays by Dicke (1968)
Parameters include
- Mask shape
- Deconvolution algorithm
- Geometry and materials
- Type of detector
The simulation setup

Figure 5: Mask and detector irradiated with protons
Figure 6: Reconstructed point sources, 3° separation
Prototype instrument:

- Requires vacuum for particle propagation
- Perfect Binary Array mask of tungsten-copper pseudo-alloy (470 \( \mu \text{m} \))
- Back-illuminated CCD64 from e2v (nitrogen cooling)

Test setup:

- Radioactive \( \beta \) sources: Samarium-151, Carbon-14
- X-Y table for control of source position
Figure 7: CAD of the vacuum chamber setup
Figure 8: The vacuum chamber setup
The CCD

- Back-illuminated CCD64 from e2v
- Custom design for the SXI x-ray telescope on GOES satellites
- Used for previous lab and rocket based electron detection at MSSL

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1Bedington et al., Using a CCD for the direct detection of electrons in a low energy space plasma spectrometer, *Journal of Instrumentation*, 7(1), 2012
Results

Prototype analysis currently acquiring data

- Preliminary results visually match simulations
- Need longer times to match trapped particle fluxes

Differences between space and lab analysis

- Mask pattern needs to be scaled
- Lab electronics allow 100 s integration times
- Noise levels require individual particle identification and summing
Future work

- Use of the concept with other suitable detectors, for example Medipix
- Further simulations of designs in realistic space-like environments
- Use of other particle sources
Acknowledgements
Figure 9: >40 keV flux at 300 km altitude at 00:00 UTC during a solar maximum in cm$^{-2}$s$^{-1}$ from the AP-8 model via SPENVIS
Figure 10: Slide from Rebecca Willett explaining coded aperture principles
Figure 11: CCD measured response from Bedington et al 2012
Repeated URAs

Figure 12: Improved field of view using a repeated array from Fenimore (1978)