# A coded aperture approach for particle measurements in space plasmas

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# Space plasma particle instruments



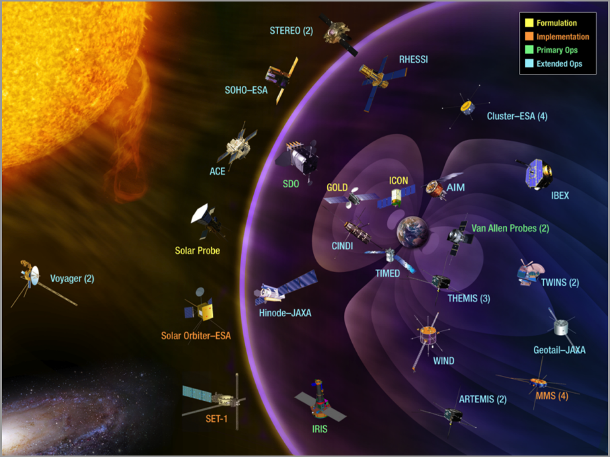


Figure 1 : http://science.nasa.gov/media/medialibrary/2014/04/10/SateliteImage.png

# Space weather



Key data:

- Fields (electric and magnetic)
- Particles
  - Electrons, ions and neutrals
  - Trapped particles

# Energetic electron flux



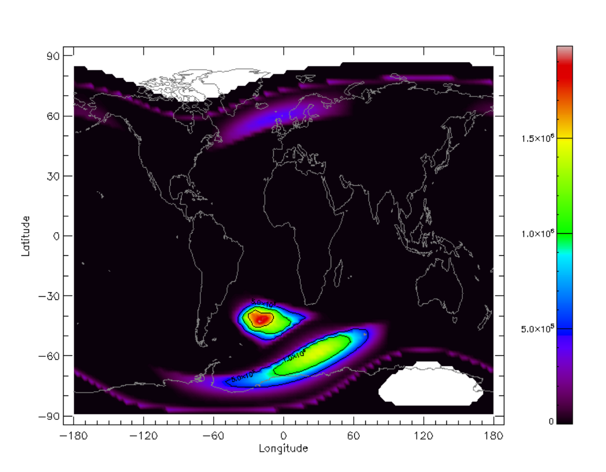


Figure 2 : >40 keV flux at 300 km altitude at 00:00 UTC during a solar maximum in $cm^{-2}s^{-1}$ from the AE-8 model via SPENVIS

# Research aims

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To develop a concept for a charged particle detection system suitable for small satellites which can be simulated, prototyped and characterised

# Proposed instrument concept

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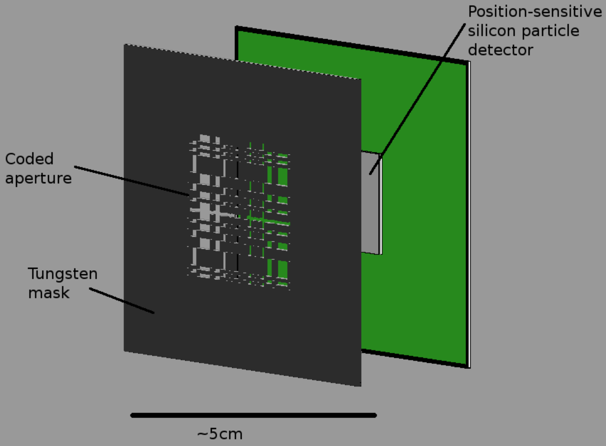



Figure 3 : Mask and detector geometry

# Coded aperture imaging



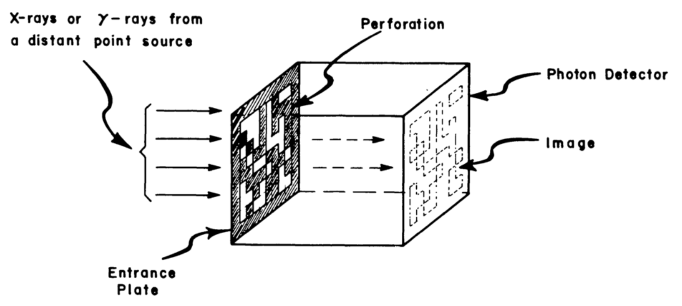


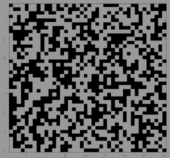
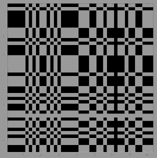
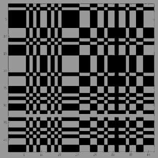
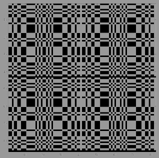

Figure 4 : Original 'scatter-hole camera' concept for X-rays or gamma rays by Dicke (1968)

# Mask shapes



Parameters include

- Mask shape
- Deconvoloution algorithm
- Geometry and materials
- Type of detector

# The simulation setup



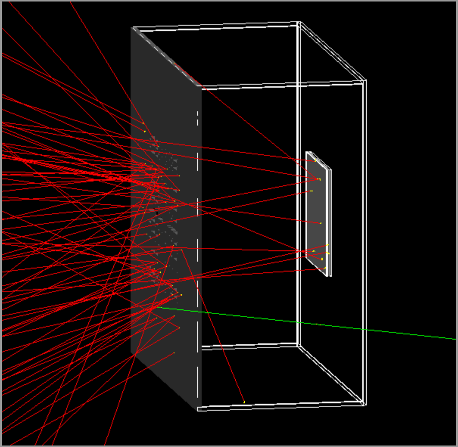


Figure 5 : Mask and detector irradiated with protons

# Simulation output



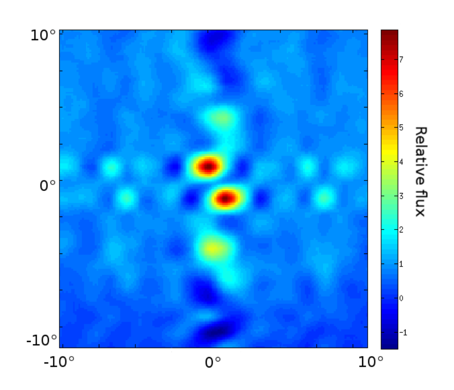



Figure 6 : Reconstructed point sources, 3° separation

# The lab setup

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Prototype instrument:

- Requires vacuum for particle propagation
- Perfect Binary Array mask of tungsten-copper pseudo-alloy (470 $\mu$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

# The lab setup



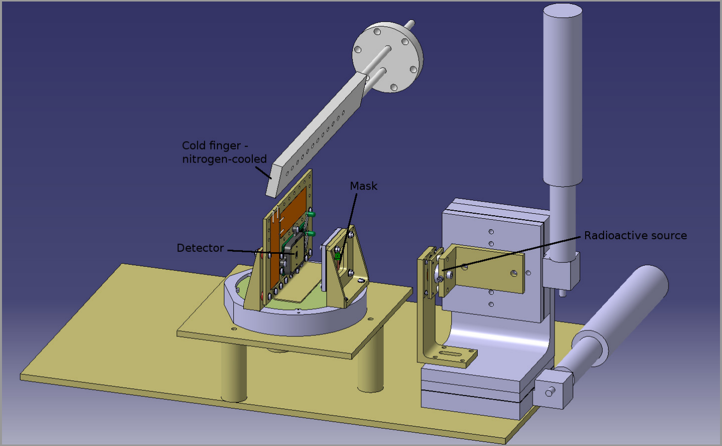



Figure 7 : CAD of the vacuum chamber setup

# The lab setup



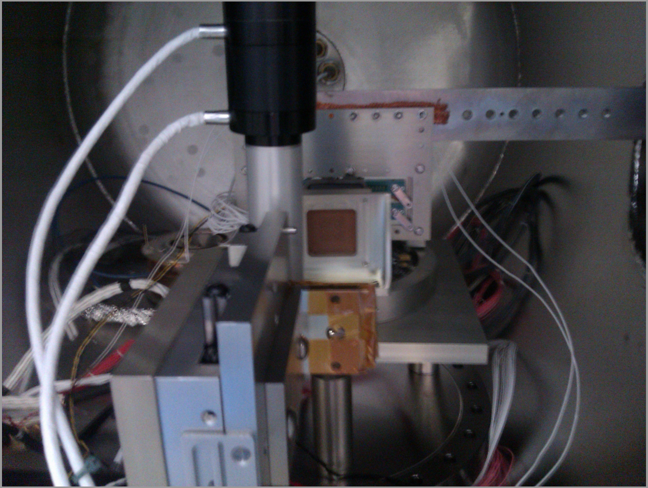
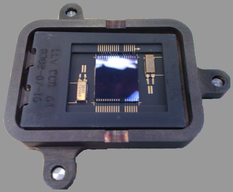


Figure 8 : The vacuum chamber setup

# 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 [1]



[1] Bedington 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

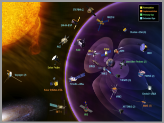
# Acknowledgements

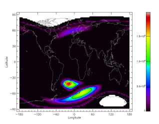


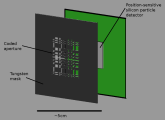
Science & Technology Facilities Council

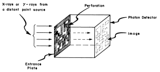
# Figures

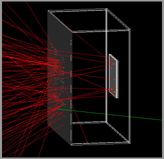


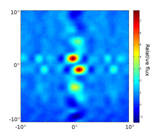


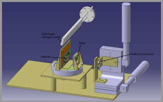


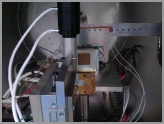

Position-sensitive silicon particle detector
Coded aperture
Tungsten mask
~5cm

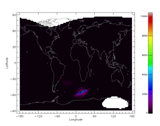

Perforation
Photon Detector
Image
Entrance Plate

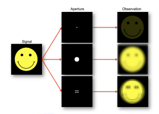


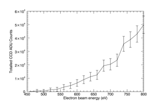

Relative flux
10°
0°
-10°
-10°
0°
10°

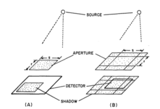







Aperture
Observation
Signal


Totalled CCD ADU Counts
Electron beam energy (eV)


SOURCE
APERTURE
DETECTOR
SHADOW
(A)
(B)

# Protons



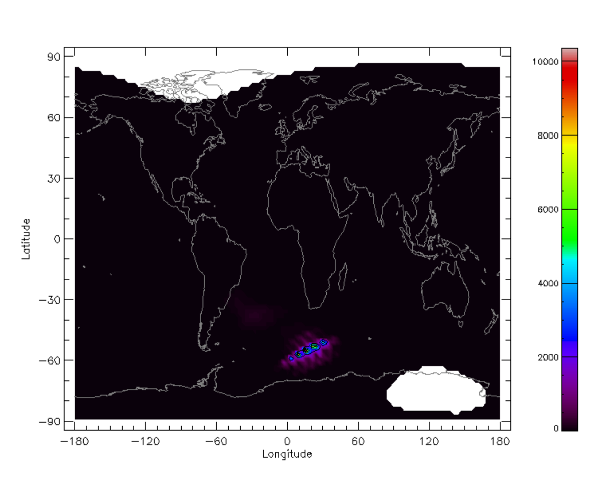



Figure 9 : >40 keV flux at 300 km altitude at 00:00 UTC during a solar maximum in $cm^{-2}s^{-1}$ from the AP-8 model via SPENVIS

# Aperture shapes



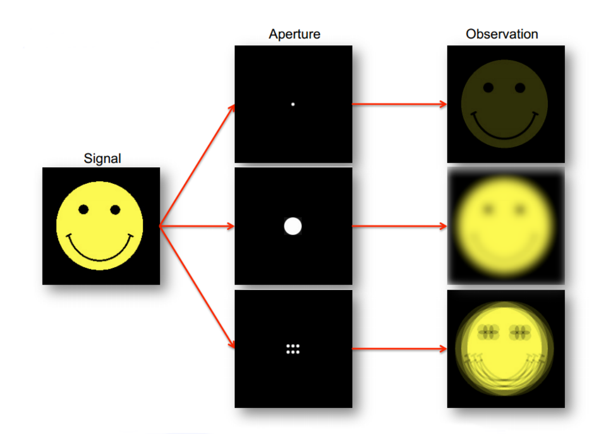



Figure 10 : Slide from Rebecca Willett explaining coded aperture principles

# CCD response



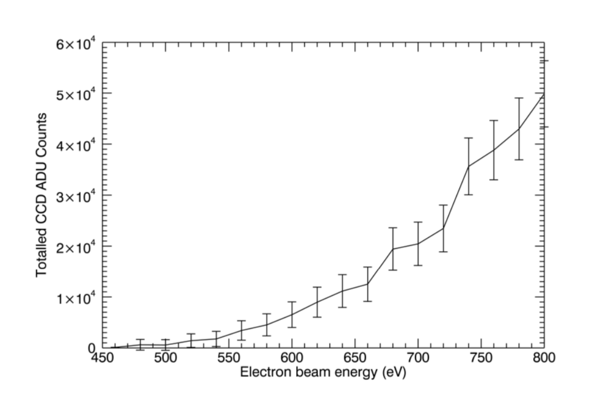



Figure 11 : CCD measured response from Bedington et al 2012

# Repeated URAs



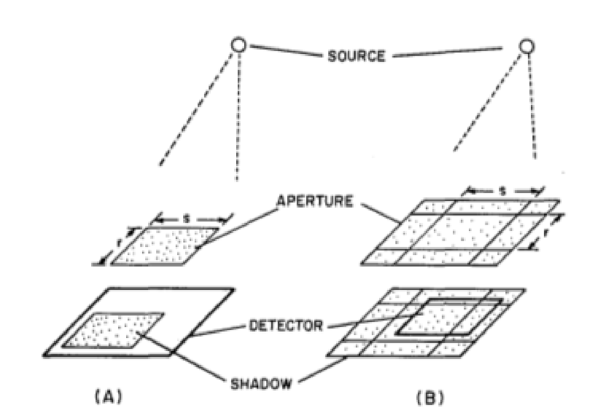



Figure 12 : Improved field of view using a repeated array from Fenimore (1978)