The Gaia CCD radiation damage

Marco Delbo

DPAC Radiation Task Force

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Outline

- CCD radiation damage: the problem
- The problem for GAIA and its TDI observations
  - Astrometry, Photometry, RVS spectroscopy
- How big these effects are going to be?
- Experiments
- Modeling
- Cure
- Where we are now

Gaia: Spacecraft and Focal Plane Assembly

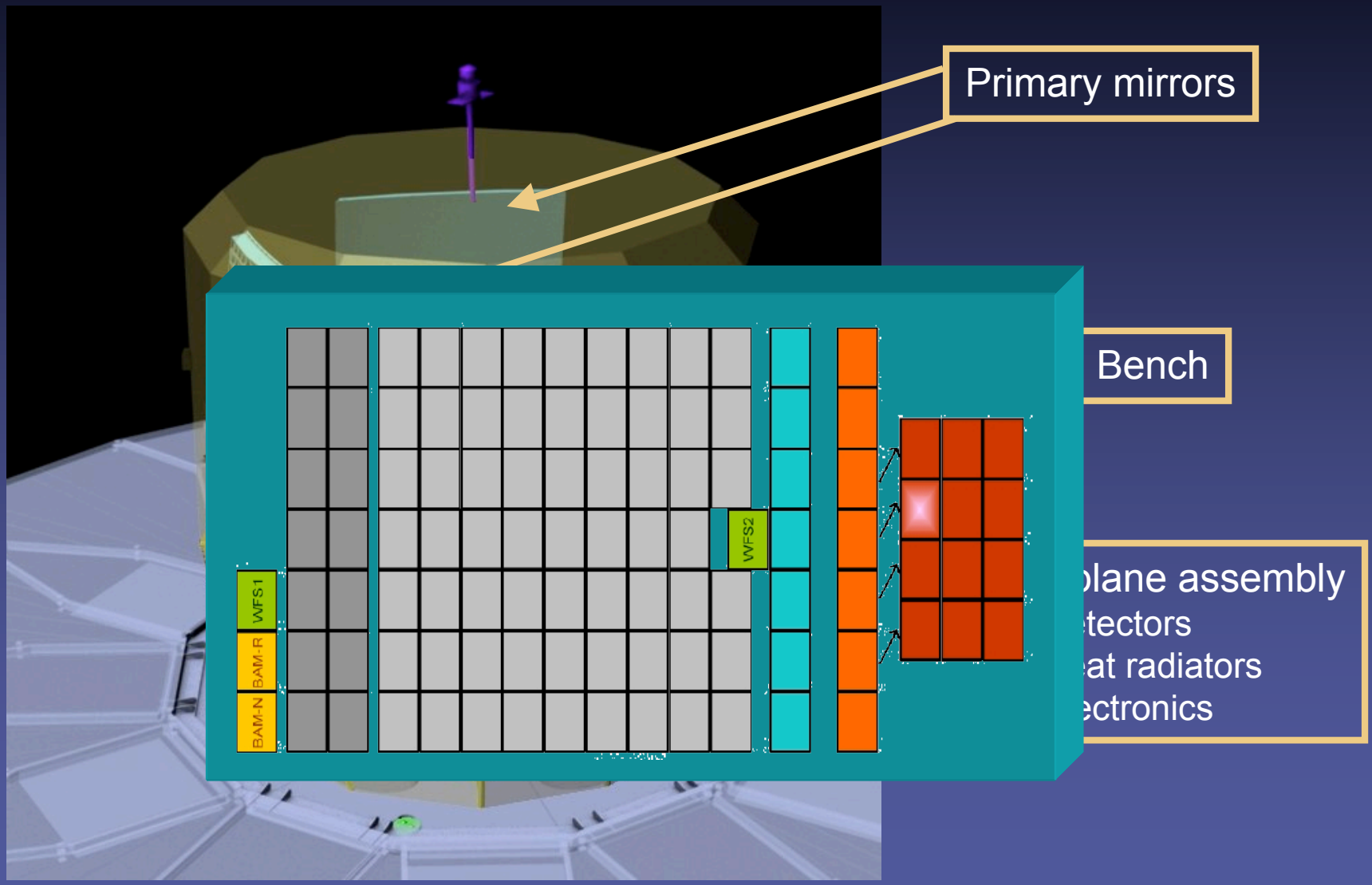
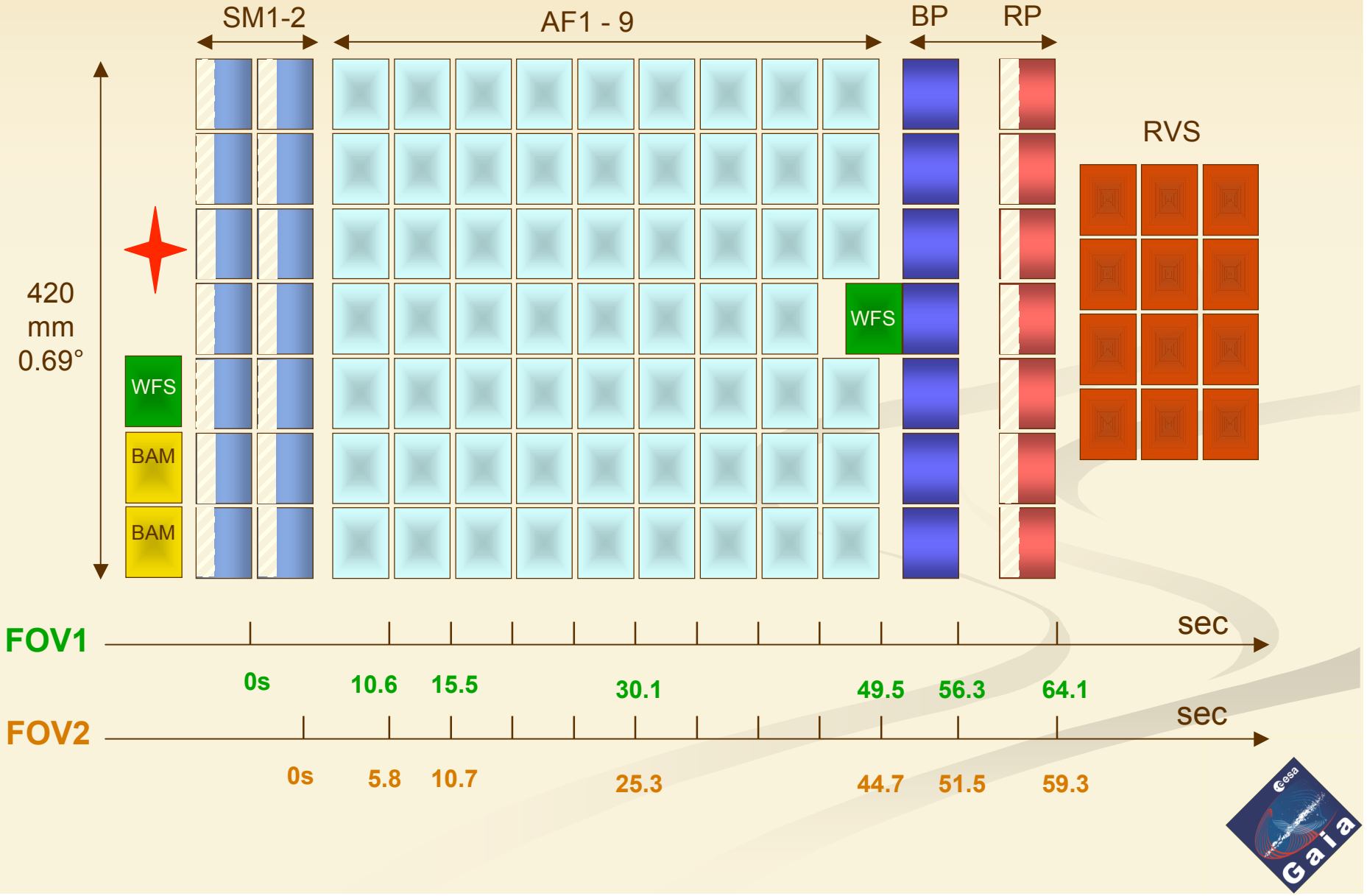


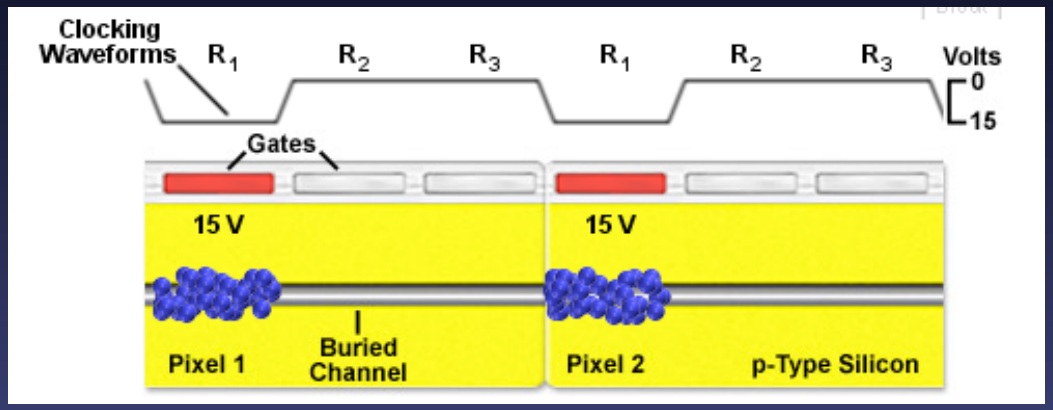
Image credits: ESA

Focal Plane – TDI mode

106 CCDs (4.5 x 2 kpix), 1 pixel 60 x 180 mas

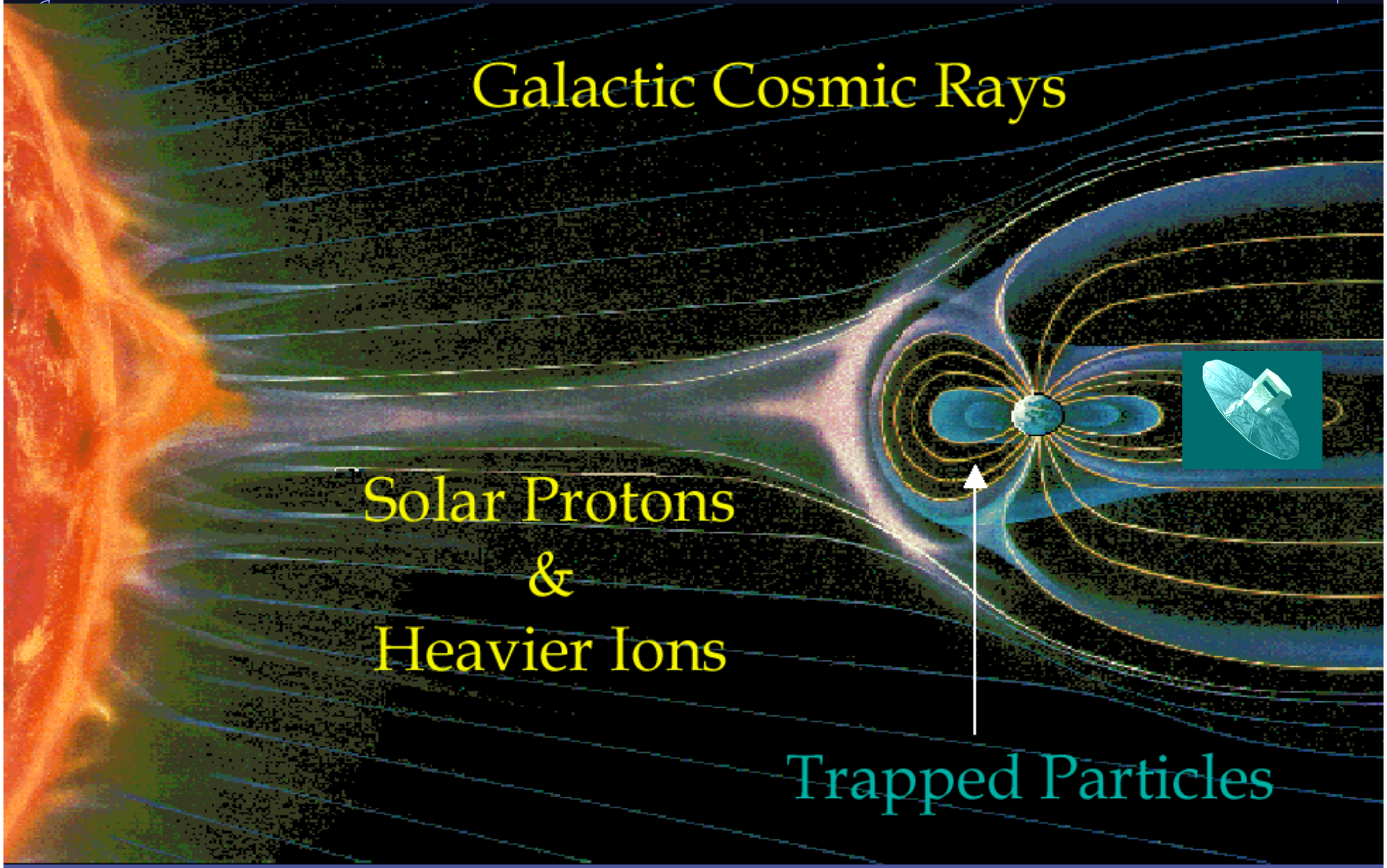


CCD clocking and charge transfer



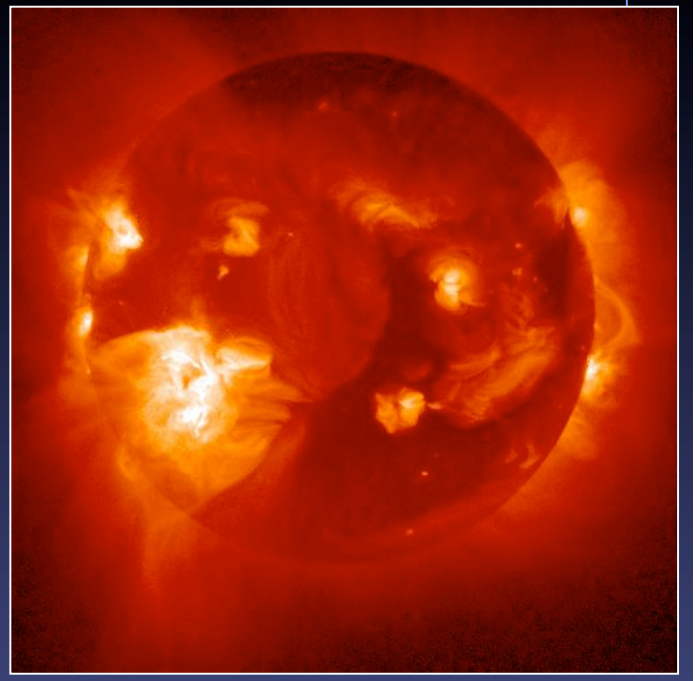
http://learn.hamamatsu.com/tutorials/threephase/

Space Environment:



CCD radiation damage

- Solar radiation
  - Protons, heavy ions, electrons, neutrons, gamma rays, X-rays…
  - Event driven – occasional high fluxes over short periods.
- Cosmic rays
  - Continuous low intensity
  - Heavy ions

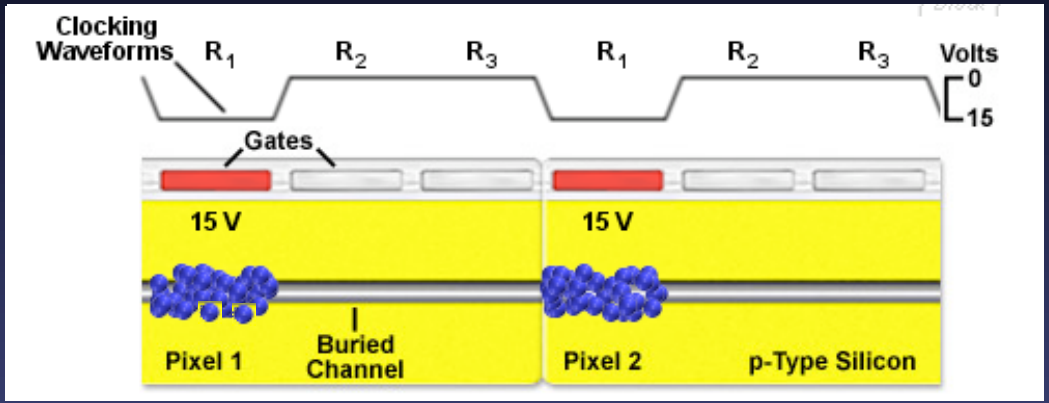


- Ionization damage
- Bulk or displacement damage

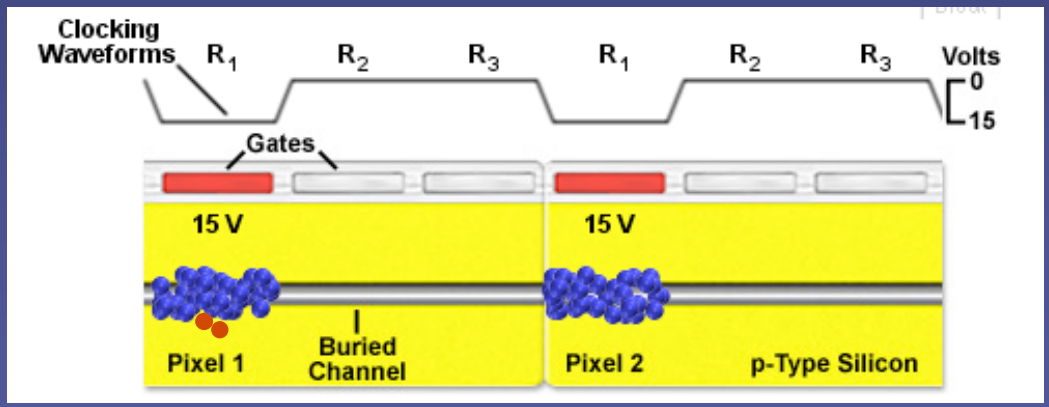
- J. Janesic Scientific Charged Coupled Devices (§8)
- Documents on livelink

Charge traps and transfer inefficiency (CTI)

Trapping Charges

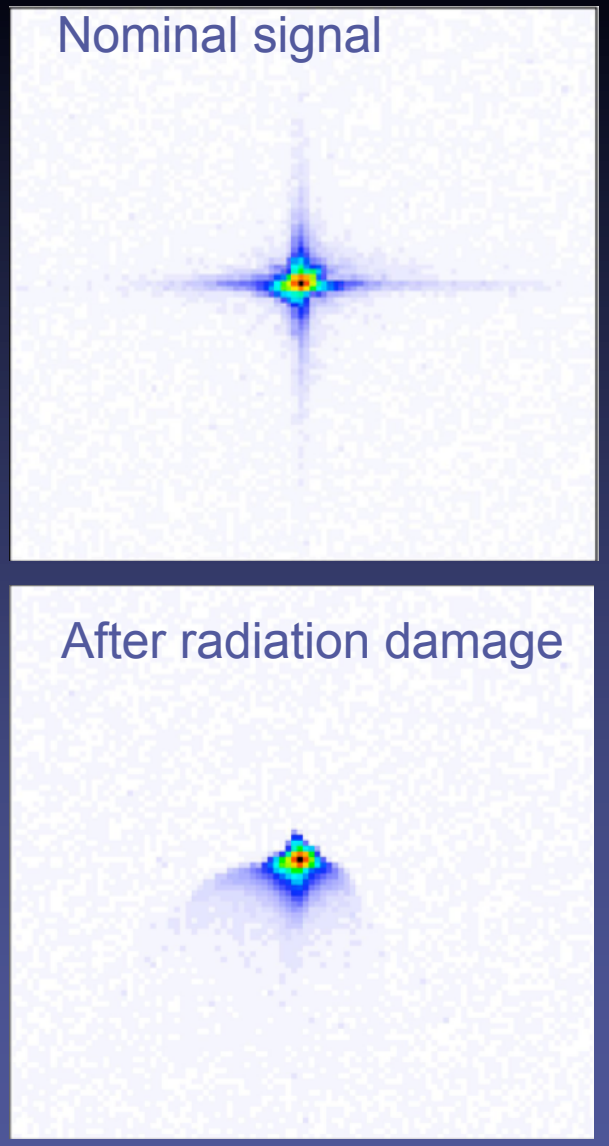


Releasing Charges



CTI effects in Gaia

- Mission critical issue
- The effect of radiation damage is a combination of traps and releases (fast trapping and slow release, temperature dependent)
  - Function of amplitude of the signal
  - Radiation history of each pixel (including the background) gate activation etc.
  - Possible charge injection
- Shape, amplitude, position of the signals
- Astrometry, Photometry, Spectroscopy

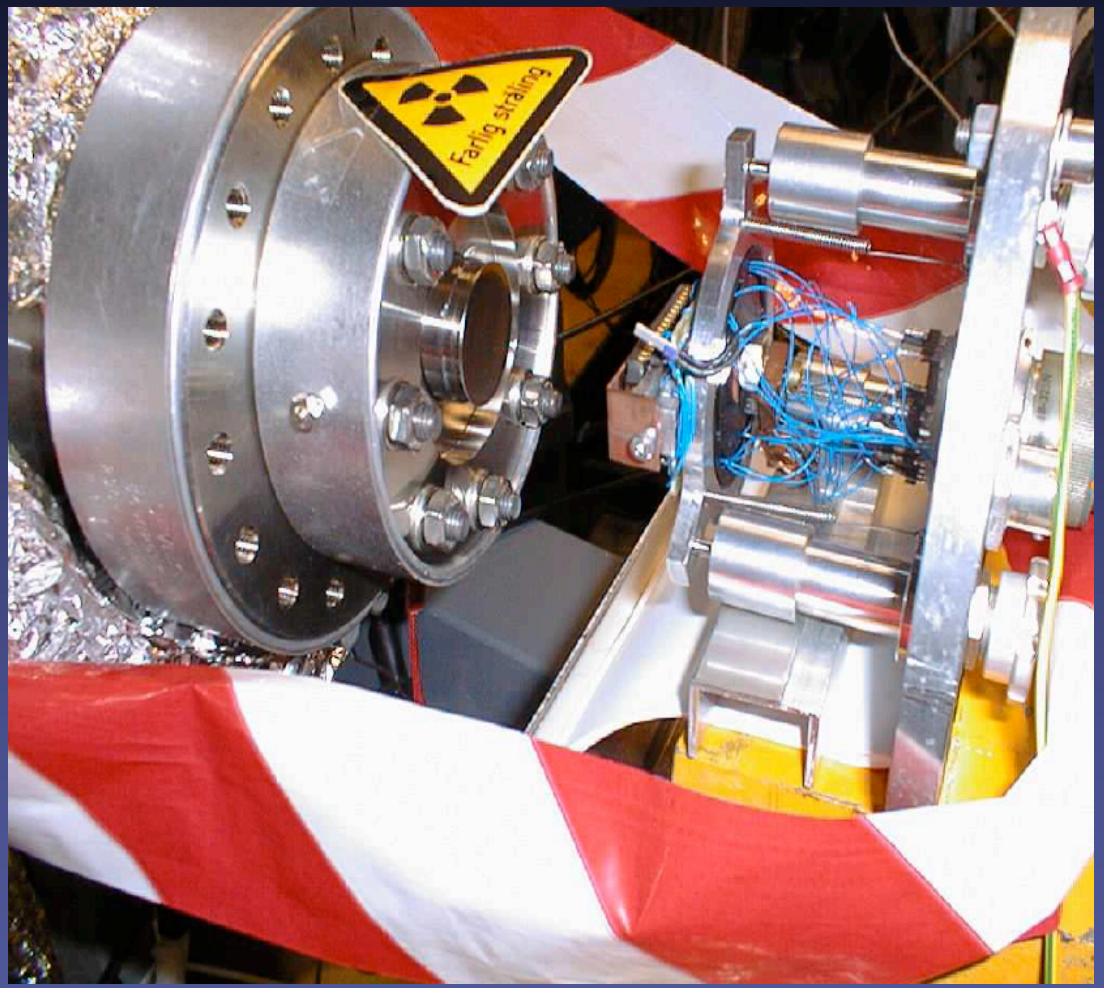


13th mag G2V

Simulations by Alexander Short ESAC

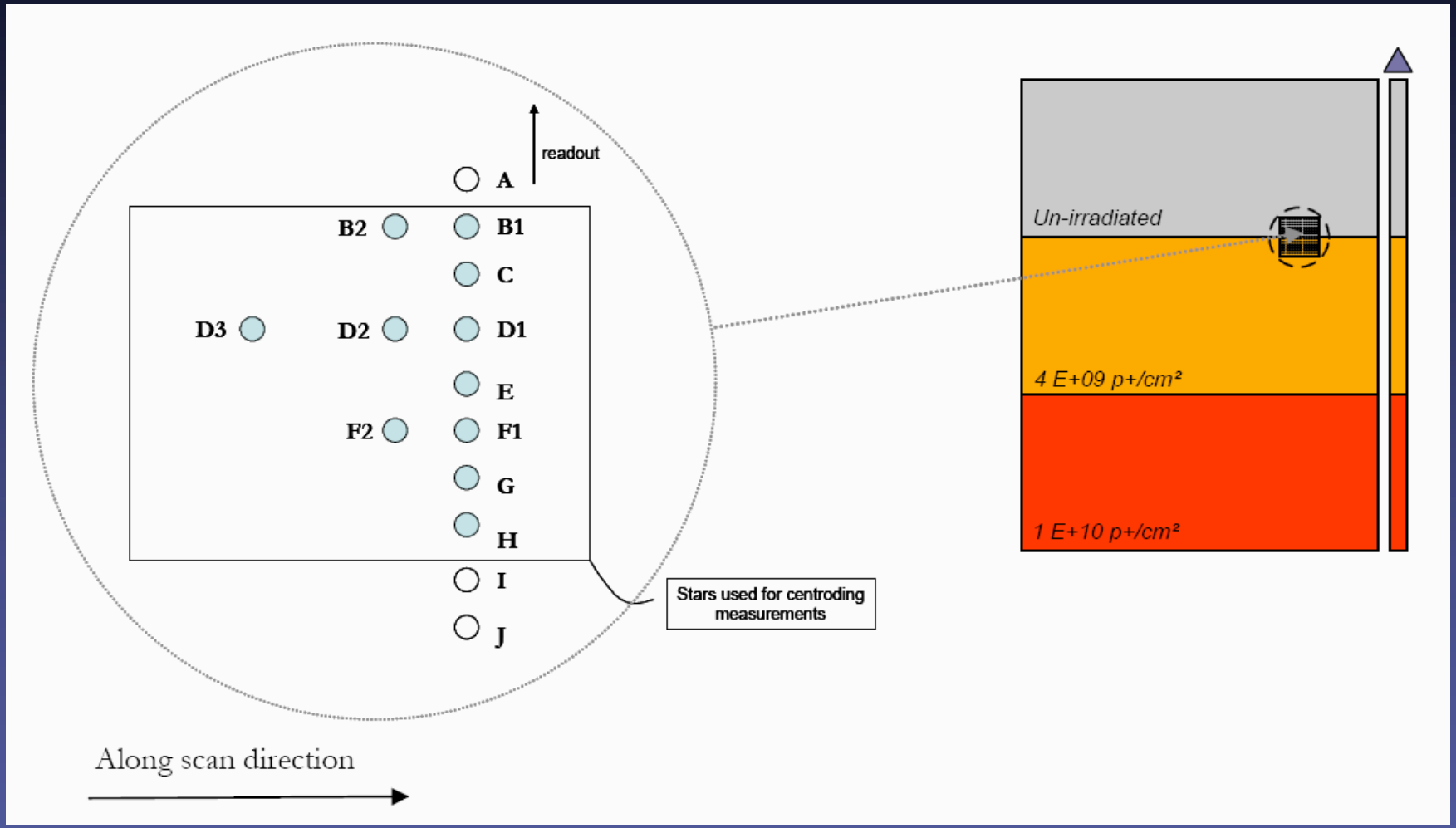
CCD Radiation Testing

- Astrium has carried out some CCD radiation tests:



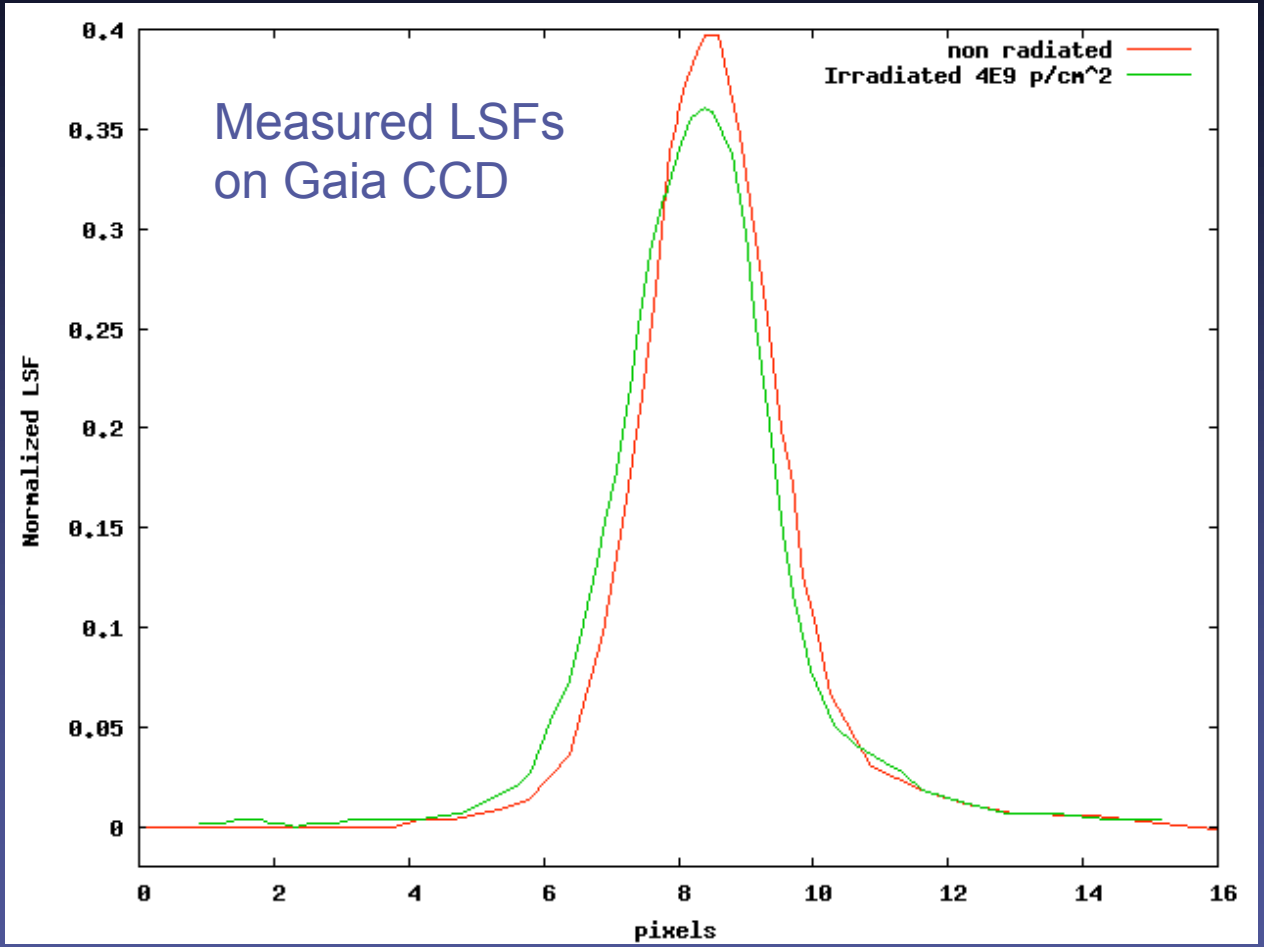
A proton irradiation setup

Astrium CCD radiation tests



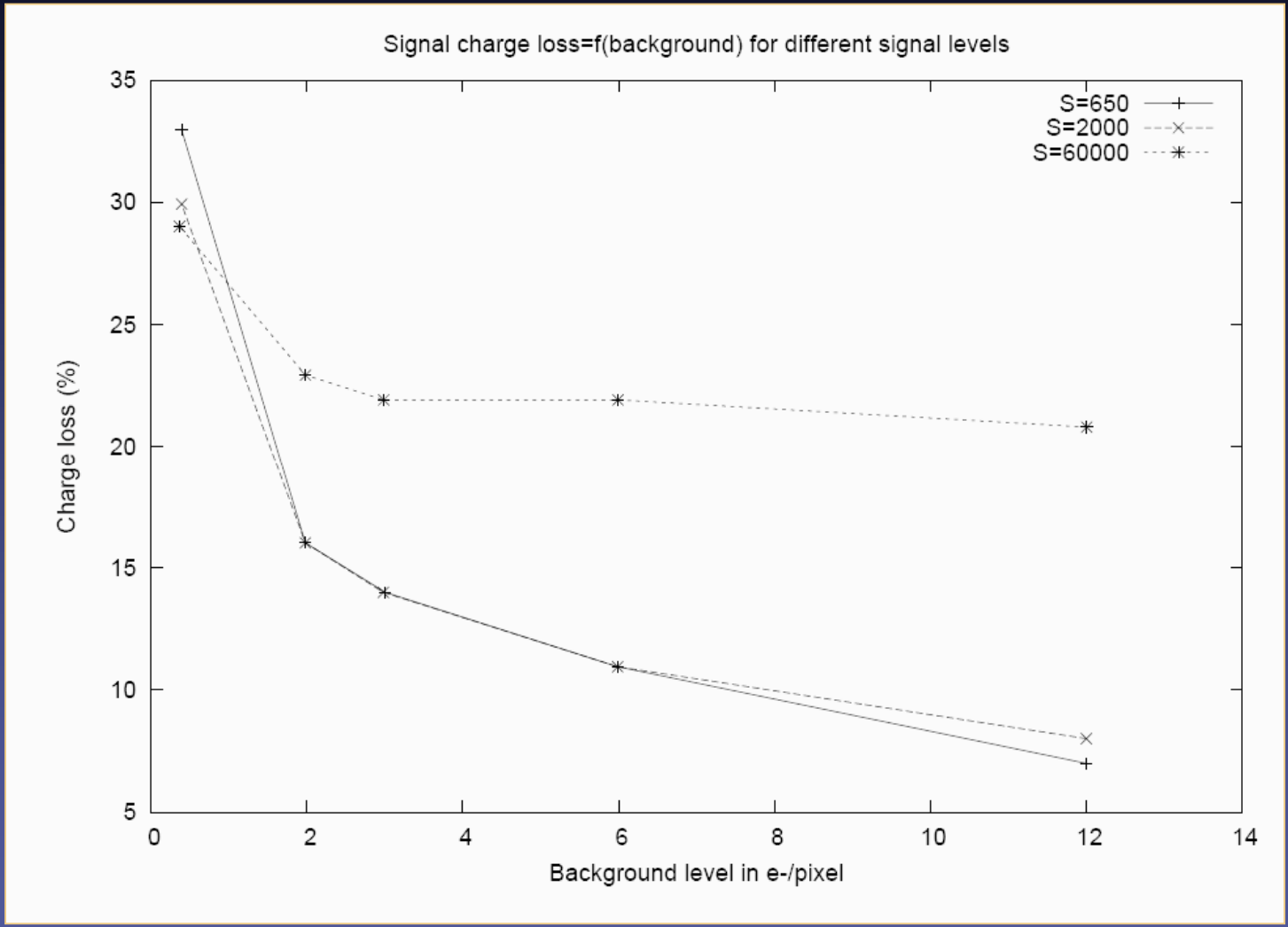
Results from Gaia CCD radiation tests

Even though the difference between the two LSFs appears small, it is a big effect with respect to centroiding accuracy.



Adapted from "Status at PDR on Radiation Recovery activities"(GAIA.ASF.TCN.PLM.00071) Safa & Marchais (2007)

Charge loss



Astrium models of he charge loss as function of star magnitude and the background level
Results obtained from the Astrium CCD radiation experiments.
Source Astrium

Calibration of Radiation damage at IDT level

- The idea is that the calibration of the radiation damage effects is at the Immediate Data Treatment level → CUs will receive "undamaged" data.
- Model to calibrate the data based on a small set of parameters: flux, radiation history, age of CCD, local transit history incl. back ground and non observed objects.
  - Correction at image level
  - Big change in the IDT pipeline
  - CUs must understand the model
- Current models based on a statistical macroscopic level
  - Safa & Marchais (2007), Brown (2007), GBIS
  - A. Short just came up with a 0.0.0 version of a physical model that reproduce ASTRIUM data.
- Astrium analysis of CCD radiation tests still in progress

Gaia Radiation Task Force (GDRTF@ast.cam.ac.uk)

Floor van Leeuwen
Institute of Astronomy, Cambridge

Lennart Lindegren
Lund Observatory

Anthony Brown
Leiden Observatory

Stefan Jordan
Zentrum fuer Astr. der Universitaet Heidelberg

Marco Delbo
Obs. Cote d'Azur

CU6
No image

Mark Cropper
MSSL

CU1
No image

Frederic Raison
ESAC

CU2
No image

Michael Weiler
Obs. Paris Meudon

CTI implementation in GBIS

by Michael Weiler, Carine Babusiaux GAIA-C2-SP-OPM-MW-002-D

- A very basic CTI simulation tool is available in GIBIS from cycle 4 on.
- This tool is based on the CTI model by Safa & Marchais (2007) and its implementation by Brown (2007).

What is good:

- CUs have now and handy model to work with

What is not yet good:

- The CTI model is by now not available for the SM and the RVS.
- AC movements of sources cannot be taken into consideration.
- Model not reliable for faint sources (<300e^-)

Conclusions

- The CTI effects is an important source of uncertainty for GAIA astrometry and photometry.
- We lack a full understanding of the CTI effects.
- First CCD irradiation experiments performed by Astrium
- Full analysis of the experiments is underway.
- Models are being developed
- Gaia DPAC radiation task force.