Effects of radiation damage

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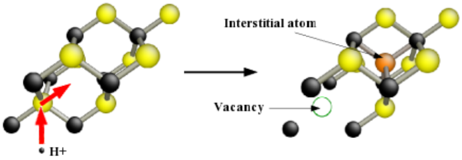
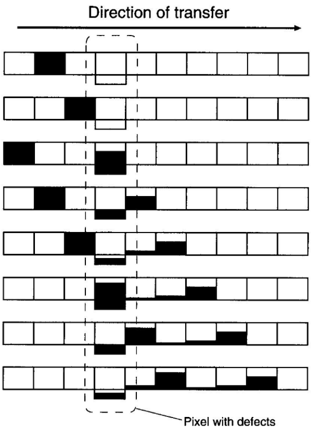
- Radiation damage
- Potential effects on NEAT measurements
- Mitigation strategies

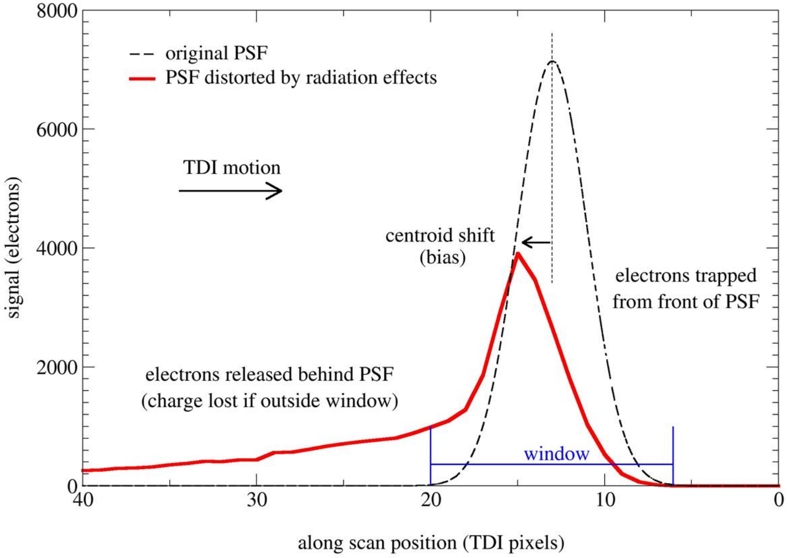
Effects of radiation damage on CCDs





- Solar protons passing through CCDs create traps
- Traps hold and release electrons according to certain time constants
- Charge transfer efficiency of CCD decreases

Effect of radiation damage on PSF (Gaia case)



Effects of radiation damage on astrometry

- Increased image location errors
  - charge loss and distorted PSF shape lead to larger Cramér-Rao bound
    - intrinsic loss of accuracy
  - distorted PSF shape does not match fitting function
- Variable image location shift (bias)
  - distorted PSF (fitted with wrong function) leads to shifted image
  - without any countermeasures the effect is measured to be of order 10 mas (!) for Gaia
- Photometry
  - directly affected by charge loss

All these effects are highly variable with the trap occupancy level

NEAT specifics with respect to CTI

Advantages

- No TDI mode operation
  - no transfer of small signals across CCD
- Smaller CCDs with multiple read-out nodes
  - less transfers during read-out
- CCDs are illuminated by bright stars, higher sky background, and the laser metrology system
  - traps with long release time constants (‘slow’ traps) are inactive
- CCD illumination history is more predictable
  - simplifies modelling CTI effects

Disadvantages

- Less shielding from solar wind protons (?)
- Extreme image location requirements (orders of magnitude beyond Gaia)!!!
  - even tiny CTI effects will count

Mitigation strategies to study

1. Optimize CCD operating temperature so that the activity of traps with time constants of the order of the transfer time between pixels is minimized
   - NEAT transfer period is 10s of μs on average
   - traps at these time constants are known to exist in Gaia CCDs
2. Investigate if 'native CTI' (design traps) is important
   - fast transfers are sensitive to CTI even in absence of radiation damage
   - effect depends on flux level, worse for faint objects
3. Built-in hardware countermeasures
   - charge injection to fill slow traps
   - supplementary buried channel (notch) for low-level signals
   - these may not be necessary for NEAT
4. Investigate effect on astrometry through simulations
   - develop CTI-modelling strategies in order to retrieve bias-free image locations
     - predict the distorted PSF shape before fitting to the data
5. Conduct tests on irradiated CCDs using same setup as during mission
   - this is essential to build confidence in the mission
6. Use pocket-pumping in flight to map trap locations (for each trap species)

Resources available from Gaia heritage

- Detailed electrode level Monte Carlo model of CTI effects
  - see Prod'homme et al., MNRAS 414, 2215 (arXiv:1103.3630)
  - available at
    `http://www.strw.leidenuniv.nl/~prodhomme/cemga.php`
- Forward modelling as part of image location
  - see Prod'homme et al., MNRAS, in press (arXiv:1110.1547)
- Analytical CTI models
  - e.g., Short et al., SPIE conference proceedings, Vol. 7742, 774212
    (`http://dx.doi.org/10.1117/12.856386`)