PLATO instrument performance

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STESCI Workshop II

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Instrument performance

- Thank you to: Alan, Bart, Carsten, Dave, Demetrio, Denis, Gisbert, Jason, Joris, Juan, Jürgen, Martin, Mattheo, Matthias, Peter, Reza, Stefanie 1, Stefanie 2, Steve, Thibaut, Tomasz, Valerio, Valery … from the entire team
- Motivation
  - NSR is PLATO's key performance parameter
  - NSR estimation is needed for
    - requirement definition and justification (PURD, TRD, URD, …)
    - Sensitivity analysis
    - Optimization, mitigation and trade-off analysis
    - Input and cross validation to other simulation tools, e.g. PLATOSim
    - Input for data processing chains
- How?
  - Physical models
  - Spatially distributed maps

Performance impactors

Aberration

Jitter

Stray light

Vignetting

Radiation

Polarization

Temperature

Transmissivity

Contamination

Distortion

Thermo-elastic distortions

Point spread function

Gain stability

Quantum efficiency

Analogue-digital conversion

Charge transfer efficiency

Offset stability

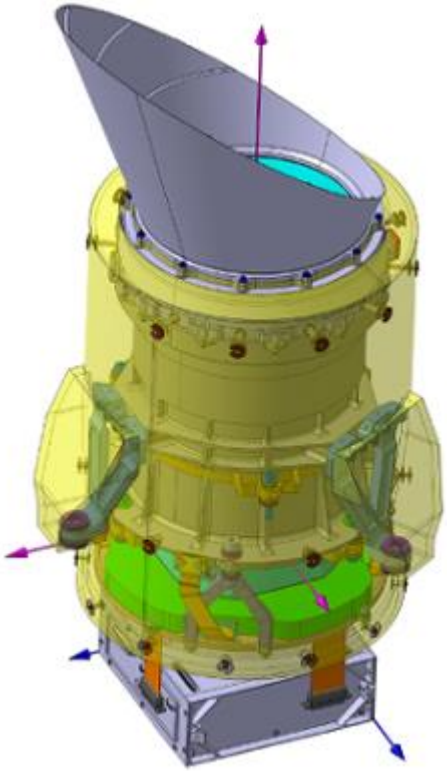
Photo-resonse non-uniformity

Bias voltage stability

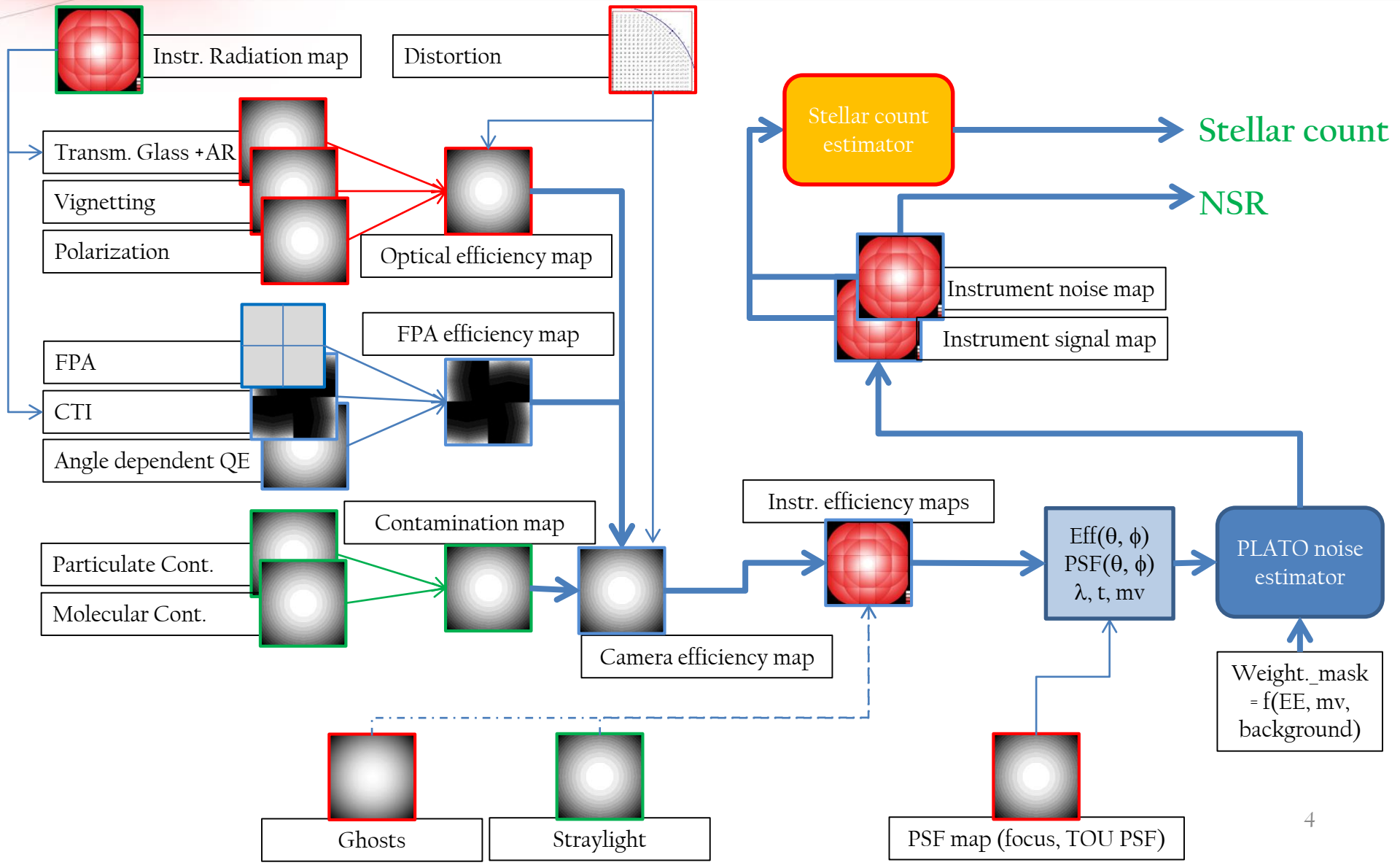
Dark signal

Masking

Read-out noise

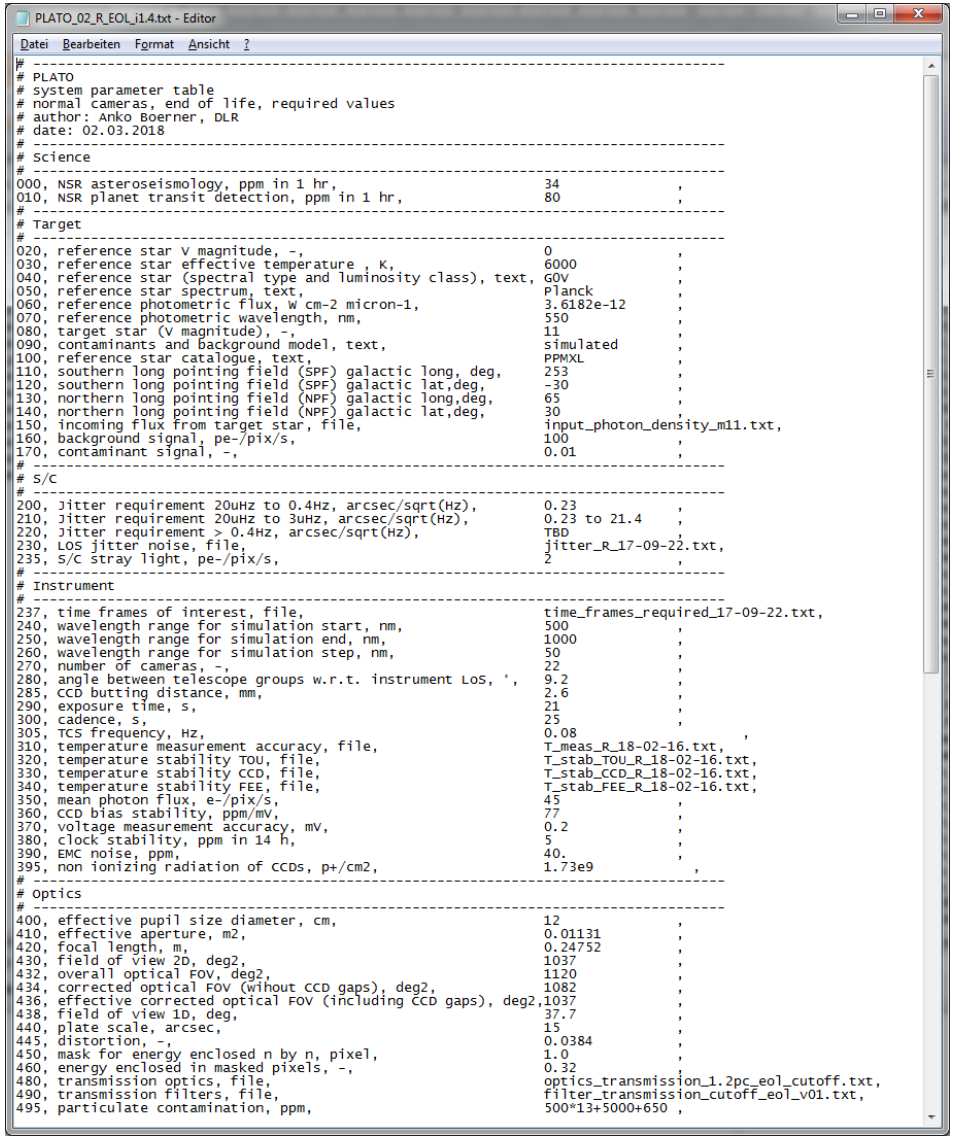


Spatially resolved maps



Simulations

- Models
  - Photons from target star to photoelectrons to digital values
  - Photons from elsewhere
  - Several other noise sources
- Software
  - IDL program Noise estimator 6.8
  - Two modes
    - Single pixel (run time < 1s)
    - Map (~1h per star field)
- Parameters
  - See https://teamsites-extranet.dlr.de/pf/PLATO-Office/
  - PPT -> Simulation parameter -> issue_1.4



PLATO_02_R_EOL_i1.4.txt - Editor

Datei Bearbeiten Format Ansicht ?

```
# ------------------------------------------------------------------------------
# PLATO
# system parameter table
# normal cameras, end of life, required values
# author: Anko Boerner, DLR
# date: 02.03.2018
# ------------------------------------------------------------------------------
# Science
# ------------------------------------------------------------------------------
000, NSR asteroseismology, ppm in 1 hr,                          34              ,
010, NSR planet transit detection, ppm in 1 hr,                  80              ,
# ------------------------------------------------------------------------------
# Target
# ------------------------------------------------------------------------------
020, reference star V magnitude, -,                              0               ,
030, reference star effective temperature , K,                   6000            ,
040, reference star (spectral type and luminosity class), text, G0V             ,
050, reference star spectrum, text,                              Planck          ,
060, reference photometric flux, W cm-2 micron-1,                3.6182e-12      ,
070, reference photometric wavelength, nm,                       550             ,
080, target star (V magnitude), -,                               11              ,
090, contaminants and background model, text,                    simulated       ,
100, reference star catalogue, text,                             PPMXL           ,
110, southern long pointing field (SPF) galactic long, deg,      253             ,
120, southern long pointing field (SPF) galactic lat,deg,        -30             ,
130, northern long pointing field (NPF) galactic long,deg,       65              ,
140, northern long pointing field (NPF) galactic lat,deg,        30              ,
150, incoming flux from target star, file,                       input_photon_density_m11.txt,
160, background signal, pe-/pix/s,                               100             ,
170, contaminant signal, -,                                      0.01            ,
# ------------------------------------------------------------------------------
# S/C
# ------------------------------------------------------------------------------
200, jitter requirement 20uHz to 0.4Hz, arcsec/sqrt(Hz),         0.23            ,
210, jitter requirement 20uHz to 3uHz, arcsec/sqrt(Hz),          0.23 to 21.4    ,
220, jitter requirement > 0.4Hz, arcsec/sqrt(Hz),                TBD             ,
230, LOS jitter noise, file,                                     jitter_R_17-09-22.txt,
235, S/C stray light, pe-/pix/s,                                 2               ,
# ------------------------------------------------------------------------------
# Instrument
# ------------------------------------------------------------------------------
237, time frames of interest, file,                              time_frames_required_17-09-22.txt,
240, wavelength range for simulation start, nm,                  500             ,
250, wavelength range for simulation end, nm,                    1000            ,
260, wavelength range for simulation step, nm,                   50              ,
270, number of cameras, -,                                       22              ,
280, angle between telescope groups w.r.t. instrument LoS, ',    9.2             ,
285, CCD butting distance, mm,                                   2.6             ,
290, exposure time, s,                                           21              ,
300, cadence, s,                                                 25              ,
305, TCS frequency, Hz,                                          0.08            ,
310, temperature measurement accuracy, file,                     T_meas_R_18-02-16.txt,
320, temperature stability TOU, file,                            T_stab_TOU_R_18-02-16.txt,
330, temperature stability CCD, file,                            T_stab_CCD_R_18-02-16.txt,
340, temperature stability FEE, file,                            T_stab_FEE_R_18-02-16.txt,
350, mean photon flux, e-/pix/s,                                 45              ,
360, CCD bias stability, ppm/mV,                                 77              ,
370, voltage measurement accuracy, mV,                           0.2             ,
380, clock stability, ppm in 14 h,                               5               ,
390, EMC noise, ppm,                                             40.             ,
395, non ionizing radiation of CCDs, p+/cm2,                     1.73e9          ,
# ------------------------------------------------------------------------------
# Optics
# ------------------------------------------------------------------------------
400, effective pupil size diameter, cm,                          12              ,
410, effective aperture, m2,                                     0.01131         ,
420, focal length, m,                                            0.24752         ,
430, field of view 2D, deg2,                                     1037            ,
432, overall optical FOV, deg2,                                  1120            ,
434, corrected optical FOV (wihout CCD gaps), deg2,              1082            ,
436, effective corrected optical FOV (including CCD gaps), deg2,1037             ,
438, field of view 1D, deg,                                      37.7            ,
440, plate scale, arcsec,                                        15              ,
445, distortion, -,                                              0.0384          ,
450, mask for energy enclosed n by n, pixel,                     1.0             ,
460, energy enclosed in masked pixels, -,                        0.32            ,
480, transmission optics, file,                                  optics_transmission_1.2pc_eol_cutoff.txt,
490, transmission filters, file,                                 filter_transmission_cutoff_eol_v01.txt,
495, particulate contamination, ppm,                             500*13+5000+650 ,
```

Use cases

- For two star catalogues: PIC 0.2 and PIC 0.3
- Use cases
  - Standard
    - Beginning of life, required
    - End of life, required
    - Beginning of life, typical (e.g. CCD's QE can be 3% better than required)
    - End of life, typical
  - Padua cases
    - Changed exposure times
    - NPF + SPF
    - Evolution over life time
  - Extra
    - Changed divergence angle: 9.2° ... 0°

Results

- Enriched star catalogues contain NSR (random and random + systematic in 1hr) per star on instrument level (considering all cameras which see this star)

N:_backup\HD_D_Projects\PLATO\Engineering\Noise\Simulations_Support_and_Results\13_starcatalogue\padua_02\log_18-05-07\pic0_3_PLATO_Padua_001.txt - Notepad++

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

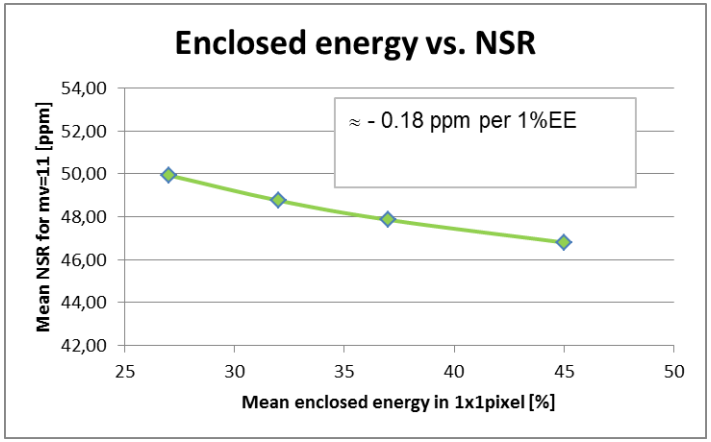
pic0_3_PLATO_Padua_001.txt

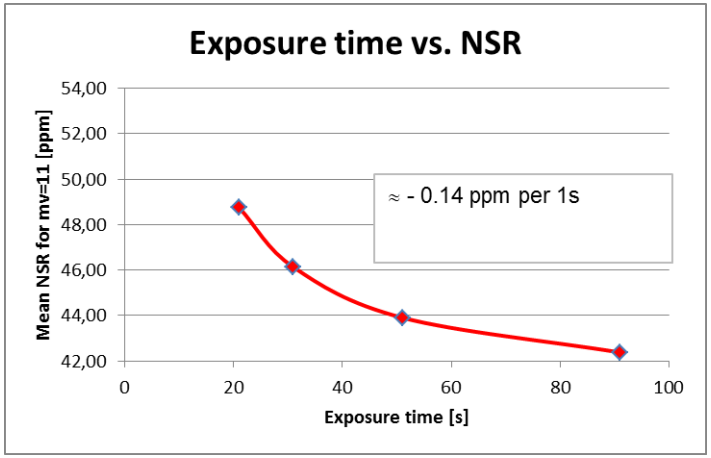
```
# PLATO
# ------------------------------------------------------------------------------
#  1. Column = Magnitude [-]
#  2. Column = Longitude in S/C coordinate system [deg]
#  3. Column = Latitude in S/C coordinate system [deg]
#  4. Column = random NSR [ppm]
#  5. Column = random + systematic NSR [ppm]
#  6. Column = number of cameras seeing the star
#  7. Column = number of cameras getting saturated
#  8. Column = sigma of cameras PSF
#  9. Column = DEBUG_p_target
# 10. Column = DEBUG_opt_trans
# 11. Column = DEBUG_add_efficiency
# 12. Column = DEBUG_overall_eff_wo_cti
# 13. Column = DEBUG_e_target
# 14. Column = DEBUG_overall_eff
# 15. Column = DEBUG_eff_CTI
# 16. Column = DEBUG_e_target_cti
# 17. Column = DEBUG_signal_spread
# 18. Column = DEBUG_external_eff
# 19. Column = star ID
# ------------------------------------------------------------------------------
# Simulation coverage [%]:       100.000
# ------------------------------------------------------------------------------
   10.27  -12.97   24.21 7.369976e+001 7.428741e+001      5      0  0.640       920341.  0.798  0.838  0.366    90881.  0.341  0.933    84780.  0.270  0.583     3597046
   10.28  -13.07   24.17 7.380794e+001 7.439474e+001      5      0  0.640       914006.  0.798  0.838  0.366    90441.  0.342  0.933    84404.  0.270  0.584     3597486
   10.28  -14.85   23.56 7.317720e+001 7.376900e+001      5      0  0.640       918310.  0.798  0.838  0.365    90454.  0.344  0.943    85266.  0.270  0.581     3599886
    9.99  -13.01   24.04 6.275879e+001 6.344756e+001      5      0  0.640      1190335.  0.798  0.838  0.368   118424.  0.348  0.943   111690.  0.270  0.587     3602944
   10.80  -15.83   23.15 9.819982e+001 9.864218e+001      5      0  0.640       566121.  0.798  0.838  0.363    55539.  0.338  0.930    51660.  0.270  0.579     3603278
   10.47  -12.13   24.25 8.188943e+001 8.241890e+001      5      0  0.640       769394.  0.798  0.838  0.369    76630.  0.340  0.921    70557.  0.270  0.588     3604560
   10.00  -15.53   23.21 6.294257e+001 6.362936e+001      5      0  0.640      1182032.  0.798  0.838  0.365   116378.  0.348  0.954   111042.  0.270  0.581     3604898
   10.94  -15.72   23.14 1.072480e+002 1.076534e+002      5      0  0.640       498413.  0.798  0.838  0.364    49036.  0.337  0.924    45309.  0.270  0.581     3605308
   10.97  -14.30   23.56 1.080995e+002 1.085017e+002      5      0  0.640       485276.  0.798  0.838  0.368    48277.  0.336  0.912    44007.  0.270  0.587     3606502
   10.01  -16.85   22.70 6.325337e+001 6.393683e+001      5      0  0.640      1175626.  0.798  0.838  0.361   114665.  0.347  0.960   110079.  0.270  0.576     3607278
   10.65  -11.76   24.28 9.093893e+001 9.141621e+001      5      0  0.640       652693.  0.798  0.838  0.370    65213.  0.337  0.910    59361.  0.270  0.590     3607352
   10.97  -12.07   24.17 1.086988e+002 1.090989e+002      5      0  0.640       486798.  0.798  0.838  0.372    48884.  0.333  0.896    43777.  0.270  0.593     3608151
   10.78  -12.58   24.02 9.729052e+001 9.773695e+001      5      0  0.640       575373.  0.798  0.838  0.372    57771.  0.338  0.909    52503.  0.270  0.593     3608270
   10.50  -14.57   23.40 8.386893e+001 8.438599e+001      5      0  0.640       750912.  0.798  0.838  0.369    74835.  0.345  0.935    69949.  0.270  0.588     3609210
   10.78  -13.04   23.86 9.675403e+001 9.720291e+001      5      0  0.640       579094.  0.798  0.838  0.372    58108.  0.339  0.912    53018.  0.270  0.592     3609251
```

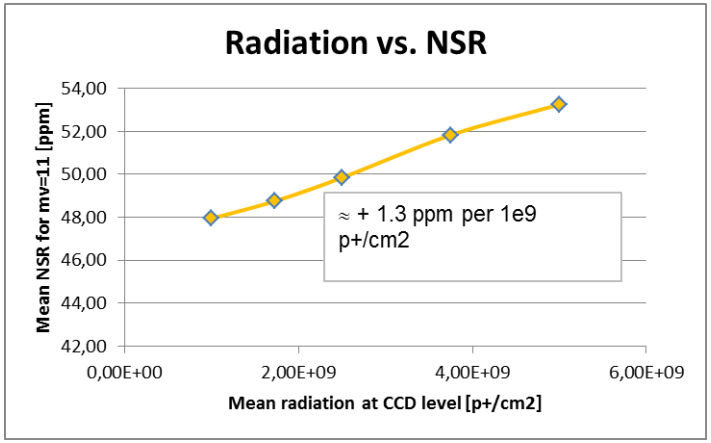
Normal text file | length : 25.091.457 | lines : 140.195 | Ln : 2 | Col : 1 | Sel : 9 | 2 | Windows (CR LF) | UTF-8 | INS

Results

- Sensitivity analysis (single pixel mode)
  - Fast but average value only
  - To understand dependencies and impacts of single parameters to NSR

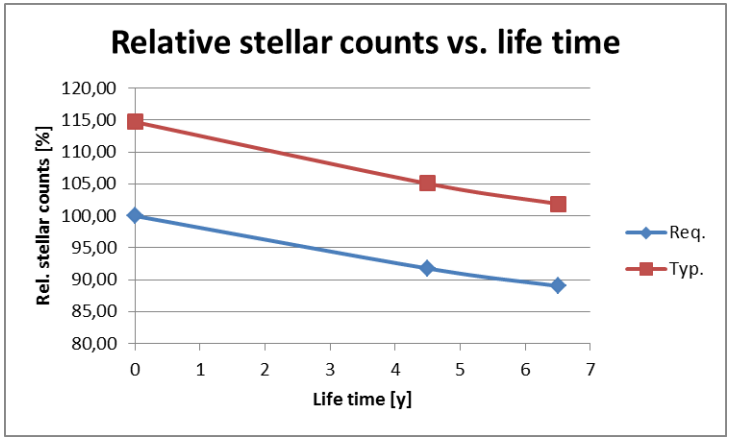


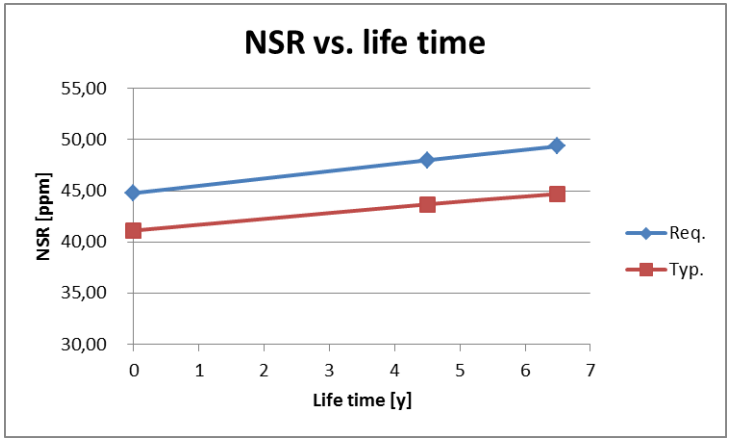


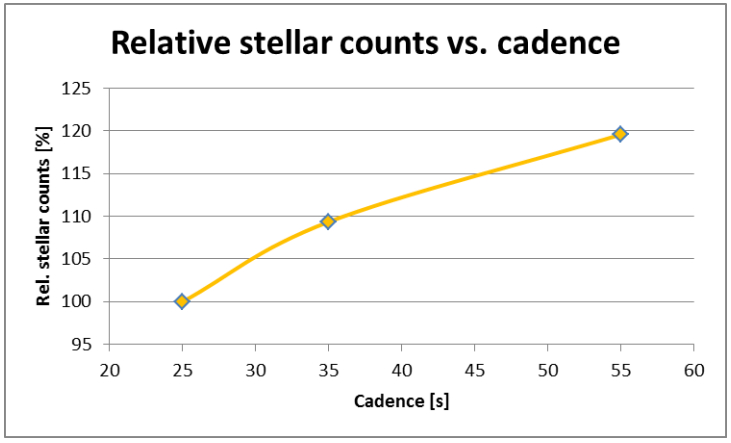


Results

- Sensitivity analysis (map mode)
  - Slow but accurate
  - Each star is assigned to NSR
  - Stellar counts can be predicted







Next steps

- Support of several requirement activities
- Support of signal/ noise modelling activities, e.g. transient simulations, FCam science
- Stellar counts, planet yields can be estimated based on the enriched star catalogues, update of the star catalogue expected (PIC0.4)