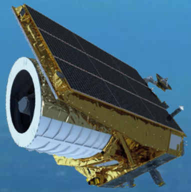
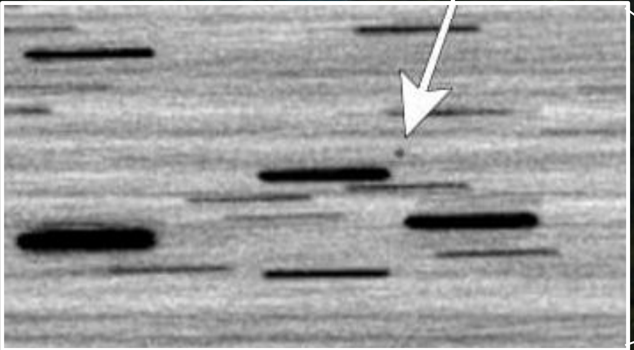
Euclid NISP Signal Estimator

A challenging problem, an analytical solution, and its implications



IRIS26 is somewhere around here



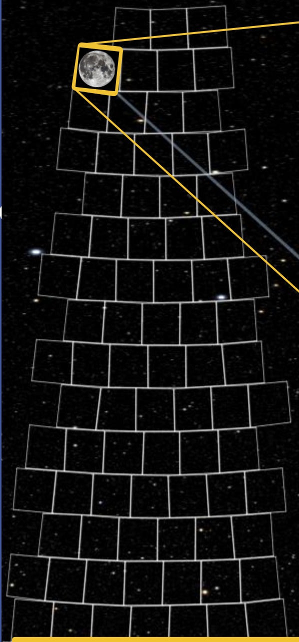
INAF – OAS Bologna, Loiano Observatory
2023-07-09 T 21:30 UT
Credits: Albino Carbognani (INAF)

Presented by Fabrizio Cogato on behalf of *Euclid* Consortium

IRIS workshop 2026 / INAF – OAS Bologna

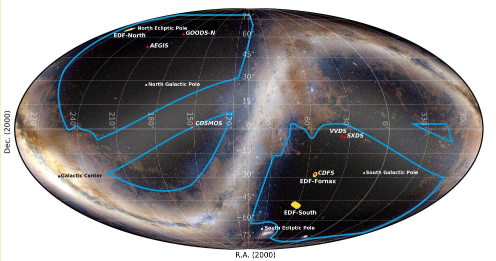
Euclid/NISP Reference Observation Sequence

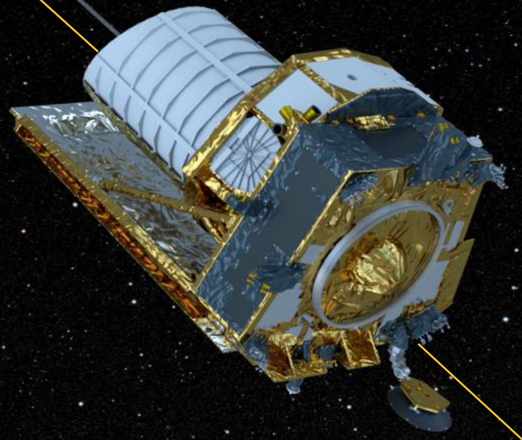
A challenging problem…



Reference Observation Sequence (ROS) // 1.5 h

Region of Interest (>15000 deg^2)





NISP instrument: survey operation (Battaglia+24)

- Spectrometric: 4 × MACC(15,16,11) // 550 s
- Photometric: 12 × MACC(4,16,4) // 87 s

10 deg^2/day = 20 ROS/day → 320 NISP obs/day

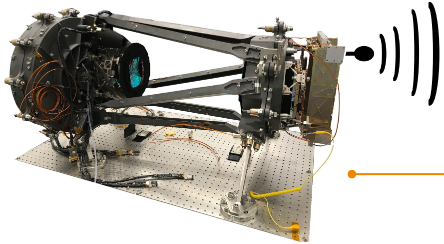
Focal plane: **16 × 2048 × 2048 pixels/obs**
Total data volume: **20000 Gbit/day**
Requirement: **290 Gbit/day**

What should be done?

An analytical solution…

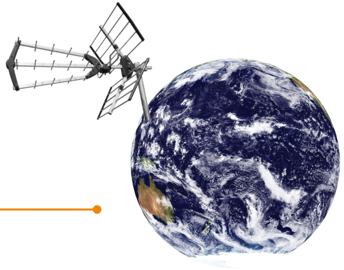
NISP instrument meets the stringent **operational and scientific** requirements thanks to an ad-hoc **hardware-software architecture**.

Near Infrared Spectrometer and Photometer → Mission & Science Operation Centre



Data Transmission

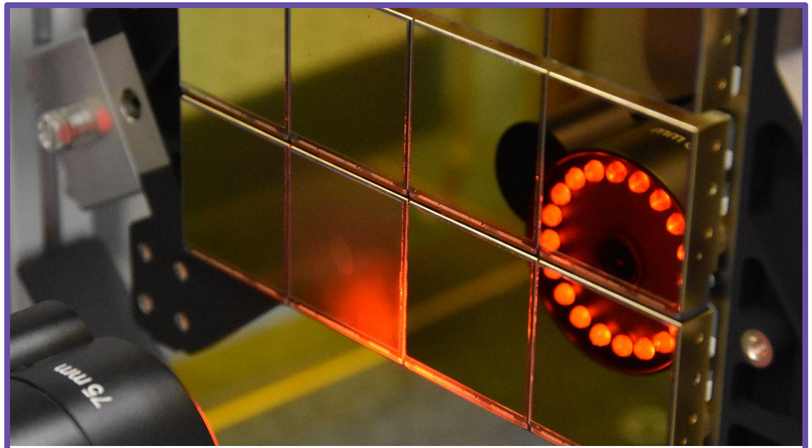
1.5×10^{6} km



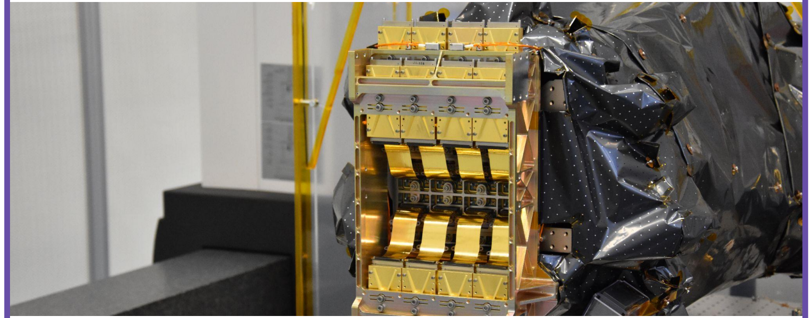
Raw Data Volume	**TM budget**	Downlinked Data Volume
>20000 Gbit/day	**290** Gbit/day	**248** Gbit/day
>2000 frames/day	NISP Signal Detection Chain	640 frames/day

An analytical solution…

NISP Signal Detection Chain: the hardware



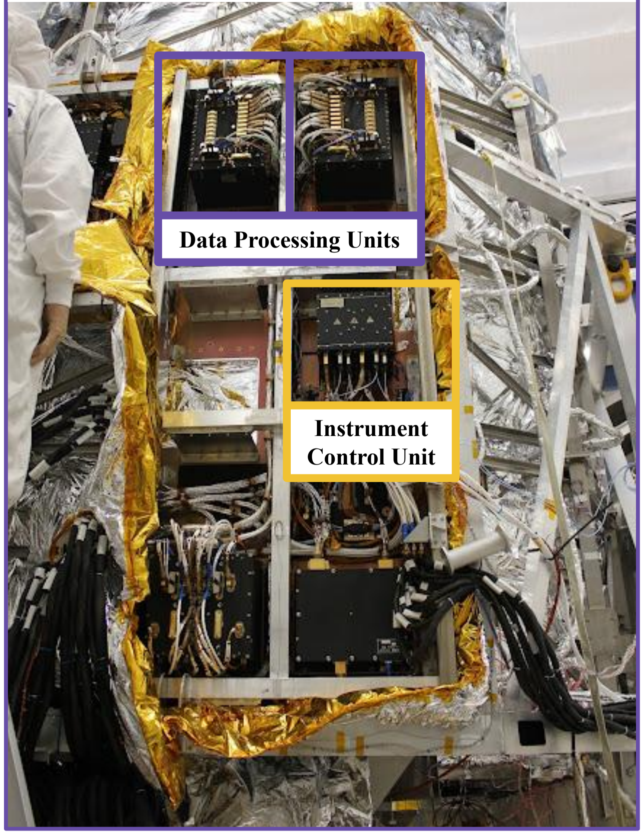
NISP Focal plane (4 x 4 H2RG detectors)



NISP SIDECAR ASIC electronics

Barbier+18

NISP Warm electronics



Medinaceli+20

An analytical solution…

NISP Signal Detection Chain: the software

A New Signal Estimator from the NIR Detectors of the Euclid Mission

Bogna Kubik[1], Remi Barbier[1], Eric Chabanat[1], Arnaud Chapon[2,3], Jean-Claude Clemens[2], Anne Ealet[2], Sylvain Ferriol[1], William Gillard[2], Aurelia Secroun[2], Benoit Serra[2], Gerard Smadja[1], and André Tilquin[2]
[1] University of Lyon, UCB Lyon 1/CNRS/IN2P3, IPN Lyon, Lyon, France; bkubik@ipnl.in2p3.fr
[2] Centre de Physique des Particules de Marseille, Aix-Marseille Université, CNRS/IN2P3, Marseille, France
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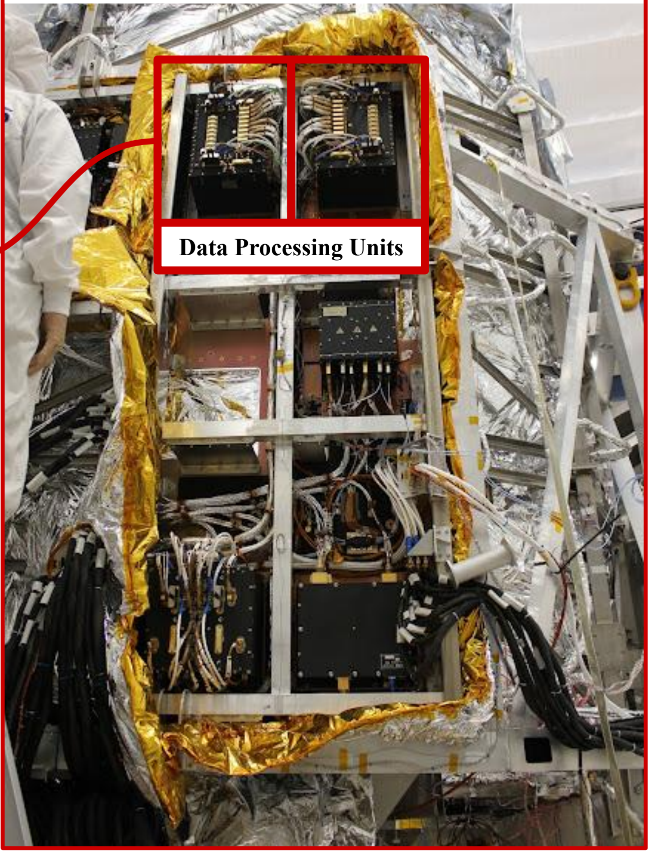
Received 2016 February 12; accepted 2016 May 29; published 2016 September 5

>10 years ago!

Abstract

We describe how the Euclid detectors in the Near Infrared Spectrometer and Photometer (NISP) channel will be read out on board and present an analytic expression for the estimated fluence in each pixel with the associated quality factor of the fit per pixel. The method accounts for the Poisson like distribution of the data and includes the effects of noise correlations that arise after the coadding procedure of frames read non-destructively up the ramp during one exposure. The bias of the flux estimator presented in this paper is kept lower than 0.3% over a wide rang of scientifically interesting fluxes of Euclid. The associated error is by 6% lower than the commonly used formula derived in Rauscher et al. in the context of an equally weighted least squares fit. Moreover, the quality factor follows the very well known $\chi^2_{th}(x; n)$ distribution and thus provides a well behaved statistical tool to check the goodness of the ramp fit. The method is proposed in the context of a large amount of data per exposure, produced by the NISP detectors, that cannot be transferred to the ground for the subsequent processing. The method, which is validated using real and simulated test data, can be safely used by most near-infrared instruments which require very accurate measurements to be performed on board.

NISP Warm electronics



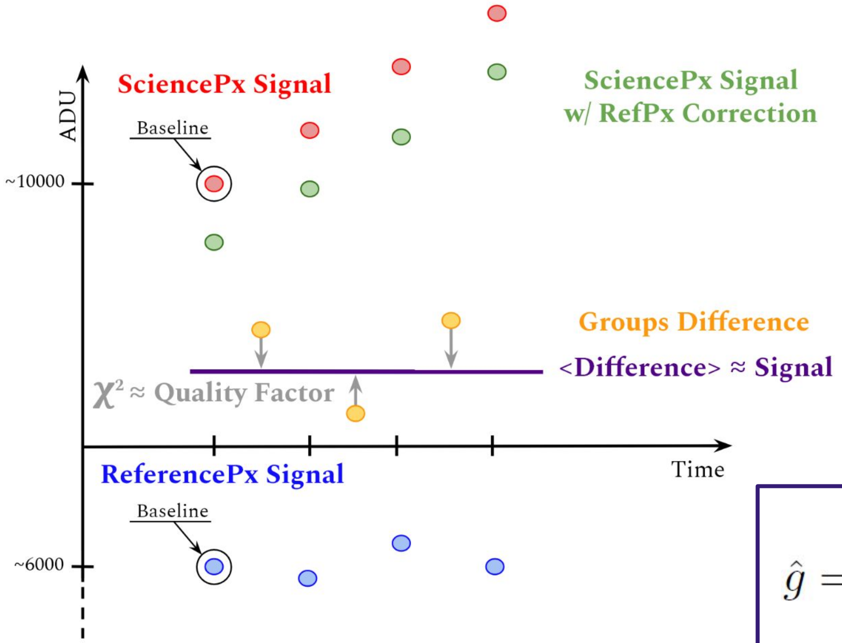
NISP Onboard Data Acquisition and Processing

MACC Sampling ↓	Readout noise attenuation
RefPx Correction ↓	Common mode noise correction
Groups Difference ↓	Signal correlation attenuation
Signal Estimation ↓	Analytical signal measurement
Quality Factor	Analytical goodness-of-fit estimate

Kubik+16

An analytical solution…

"Processing *each* of the 67 × 10^6 NISP px/obs at 1.5 × 10^6 km from Earth, aboard *Euclid*"



NISP Onboard Data Acquisition and Processing

MACC Sampling ↓	Readout noise attenuation
RefPx Correction ↓	Common mode noise correction
Groups Difference ↓	Signal correlation attenuation
Signal Estimation	Analytical signal measurement

$$\hat{g} = \frac{1+\alpha}{2f_e}\left[\sqrt{1+\frac{4f_e^2\sum_{i=1}^{n_g-1}(\Delta G_i+\beta)^2}{(n_g-1)(1+\alpha)^2}}-1\right]-\beta$$

Signal Sampling Properties:

n_g = Number of Groups
n_f = Number of Frames
n_d = Number of Drops

Pixel Properties:

f_e = Conversion Gain [e-/ADU]
σ_R = Readout Noise [e-]

Key Processing Parameters:

$$\alpha = \frac{1-n_f^2}{3n_f(n_f+n_d)} \qquad \beta = \frac{2\sigma_R^2 f_e}{n_f(1+\alpha)}$$

Kubik+16, Cogato+26

And its implications…

"What level of accuracy does the NISP signal estimator achieve?"

To optimize **satellite's resources** NISP onboard processing applies a single **detector-average readout noise** (σ_{DPU}) to each detector array (2040x2040 px)

NISP Signal Estimator $\propto$ Pixel Properties

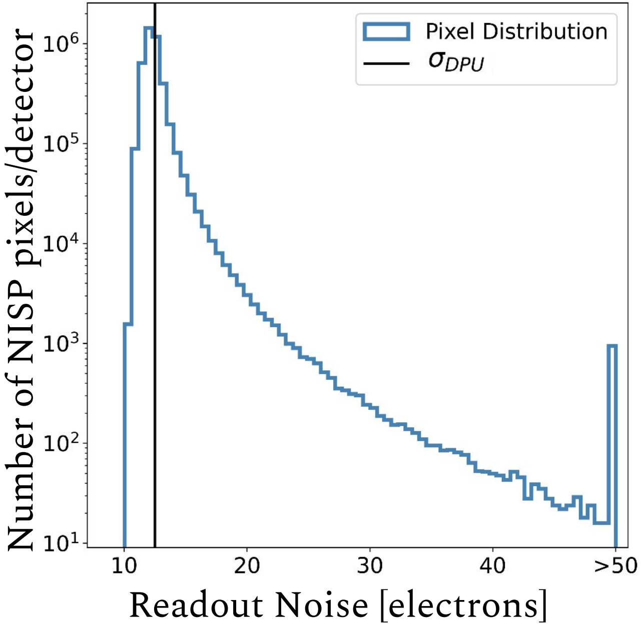
Key Processing Parameter

σ_R = Readout Noise [electrons]

$$\hat{g} = \frac{1+\alpha}{2f_e}\left[\sqrt{1+\frac{4f_e^2\sum_{i=1}^{n_g-1}(\Delta G_i+\beta)^2}{(n_g-1)(1+\alpha)^2}}-1\right]+\beta$$

$$\beta = \frac{2\sigma_R^2 f_e}{n_f(1+\alpha)}$$

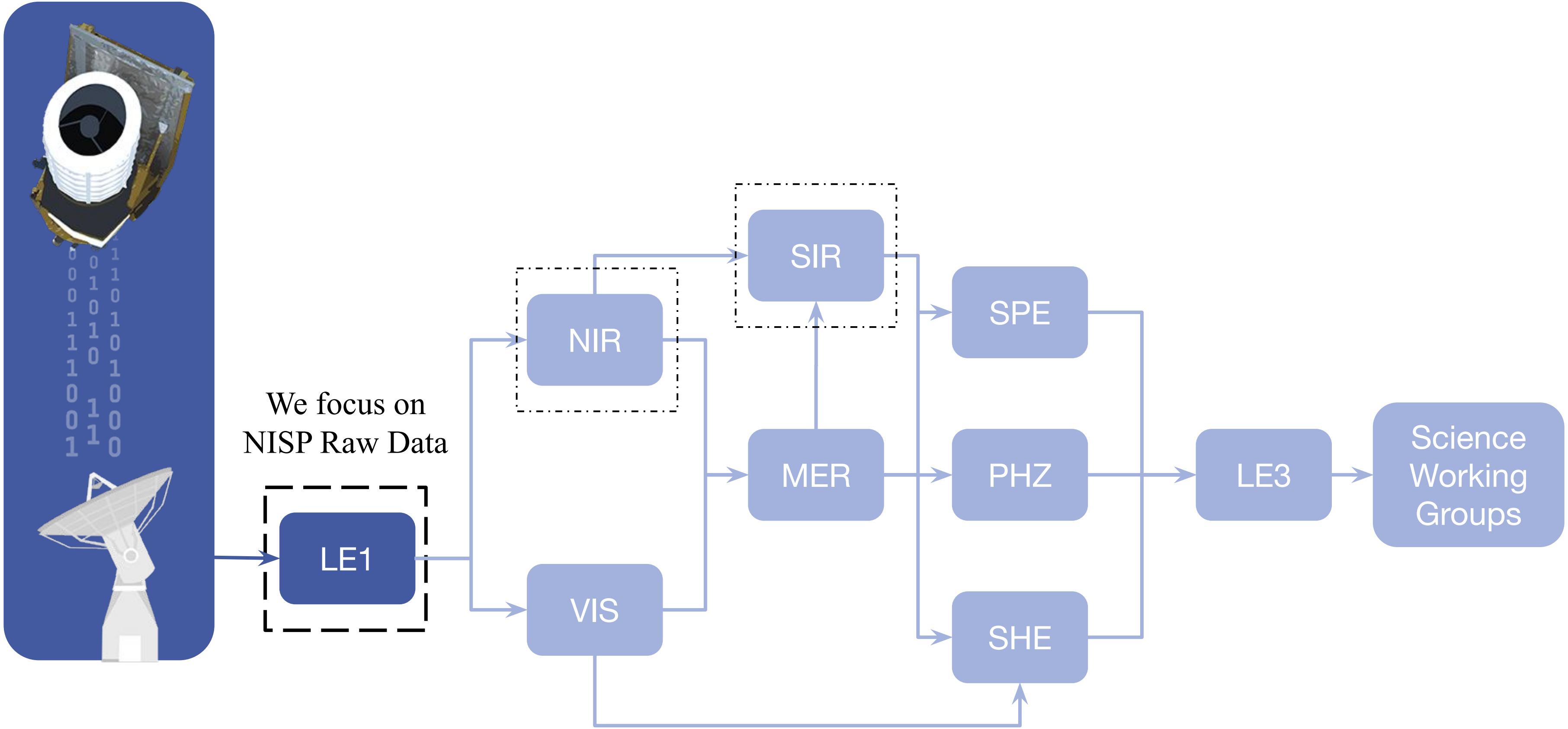
Data Processing Approximation



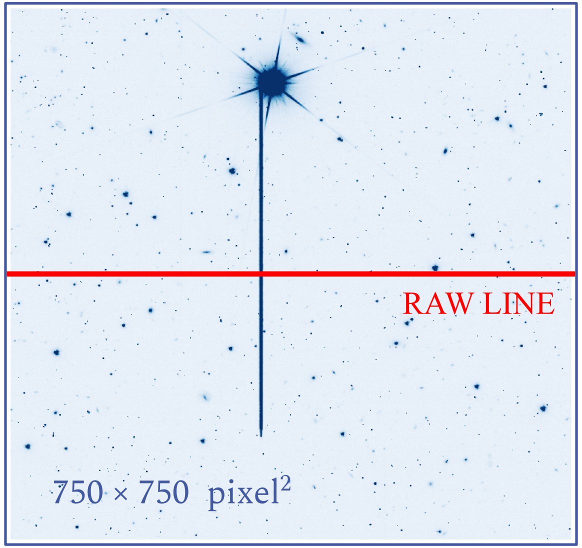
Cogato+26

And its implications…

From Data Stream to Scientific Data



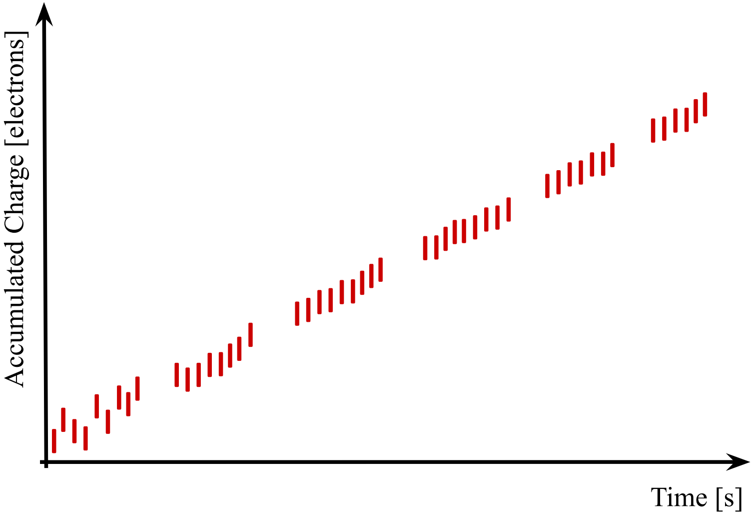
NISP LE1 Raw Data



Onboard Data

NIR SCI

16 × 2048 × 2048 pixels/obs



Control Sample

RAW LINE

16 × 2040 pixels/obs

And its implications…

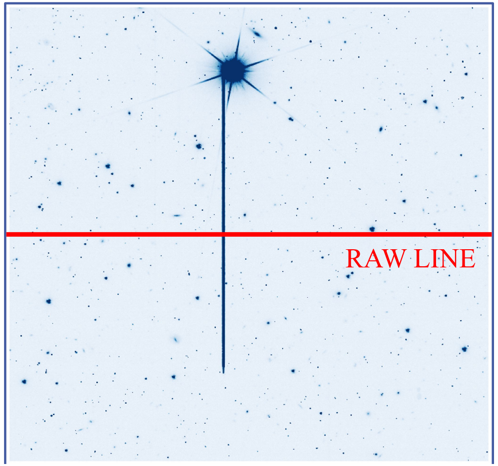
"What level of accuracy does the NISP signal estimator achieve?"

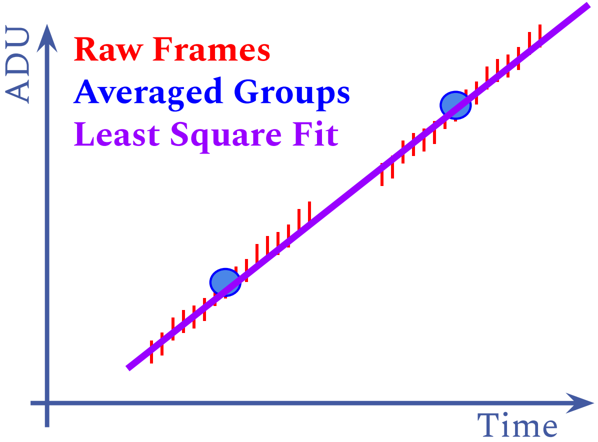
Comparison with un-weighted **Least Square Fit** of UTR frames

In-flight analysis:
NISP Signal Estimator

vs.

On-ground analysis:
Least Square Fitting





$$\hat{g} = \frac{1+\alpha}{2f_e}\left[\sqrt{1+\frac{4f_e^2\sum_{i=1}^{n_g-1}(\Delta G_i+\beta)^2}{(n_g-1)(1+\alpha)^2}}-1\right]-\beta$$

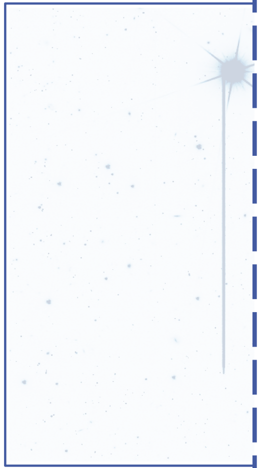
Cogato+26

And its implications…

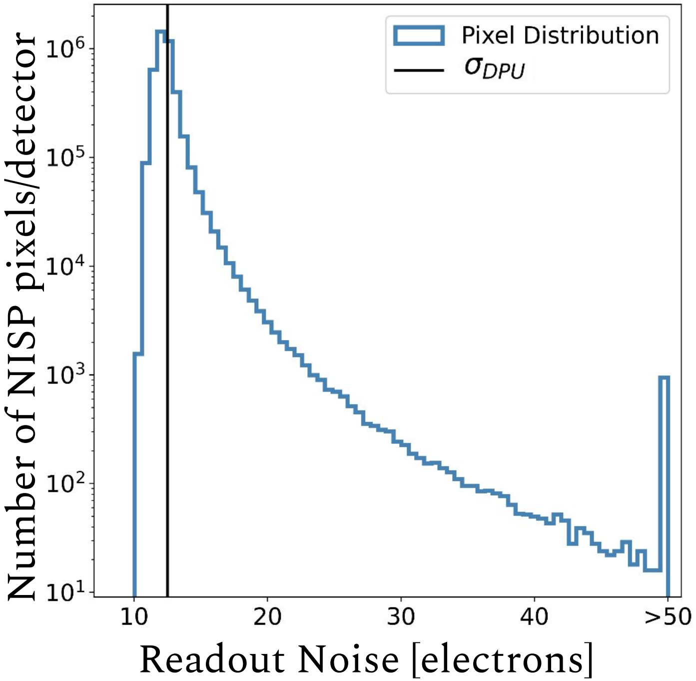
"What level of accuracy does the NISP signal estimator achieve?"

Comparison with un-weighted **Least Square Fit** of UTR frames

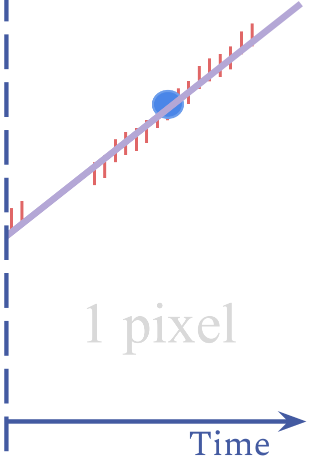
In-flight an
NISP Signal



Data Processing Approximation



und analysis:
are Fitting



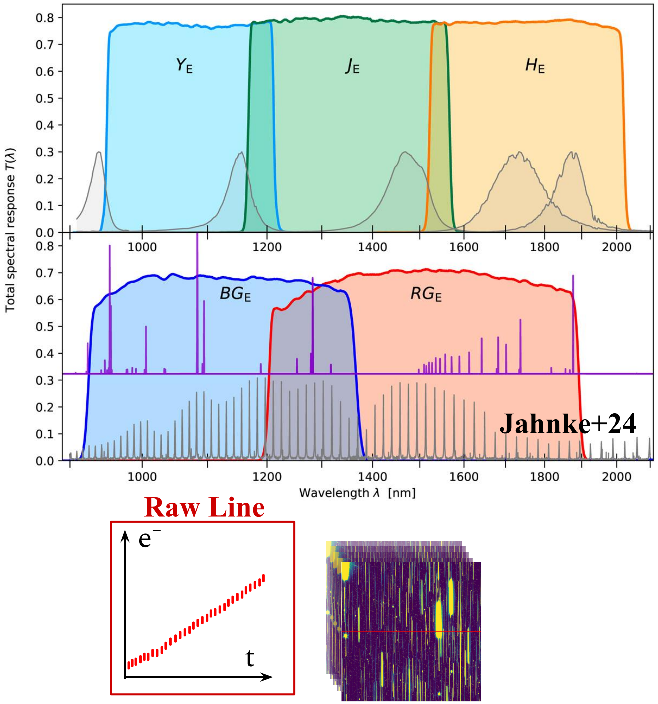
Cogato+26

And its implications…

"What level of accuracy does the NISP signal estimator achieve?"

NISP Flight Data (8 months of Euclid Wide Survey)

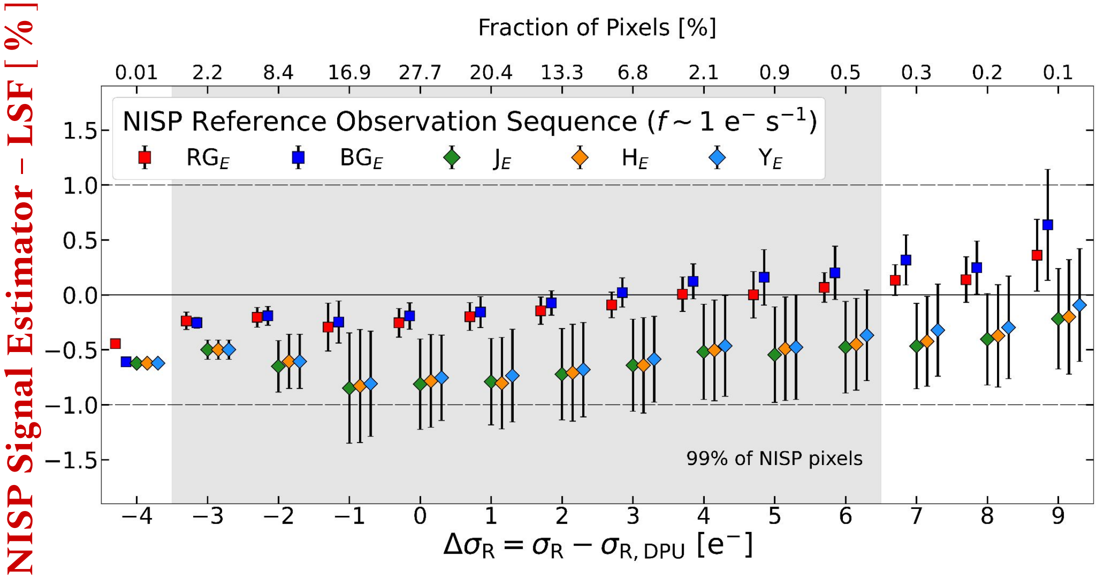
~ 5000 exposures/passsband



Near-infrared zodiacal background

Photo-Spectrometric ~ 1 e⁻/s

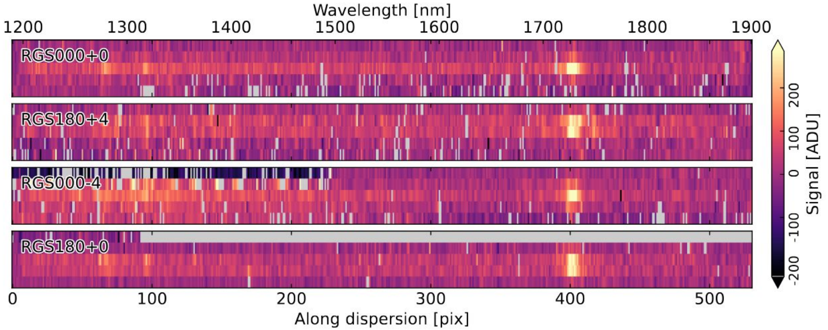
|| **sys-σ_R** || < **0.01 e⁻/s** (99% pixels)

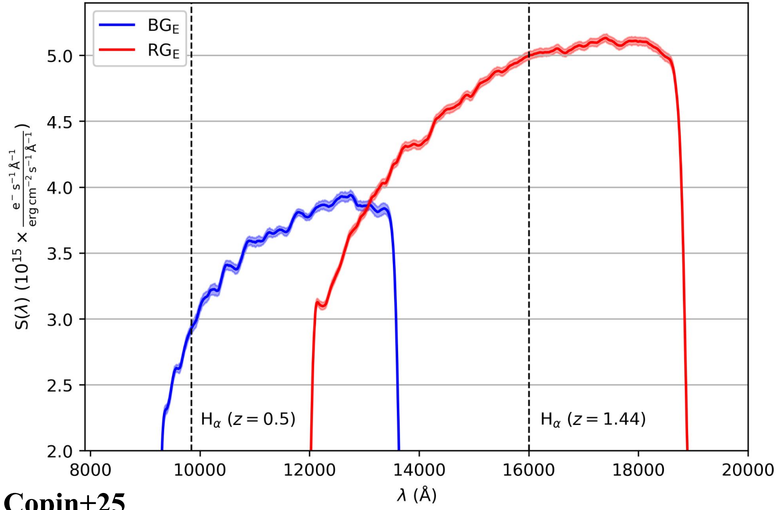


Cogato+26

And its implications…

Impact of the **NISP signal estimator bias** on the accuracy of the **spectroscopic flux calibration**





Copin+25

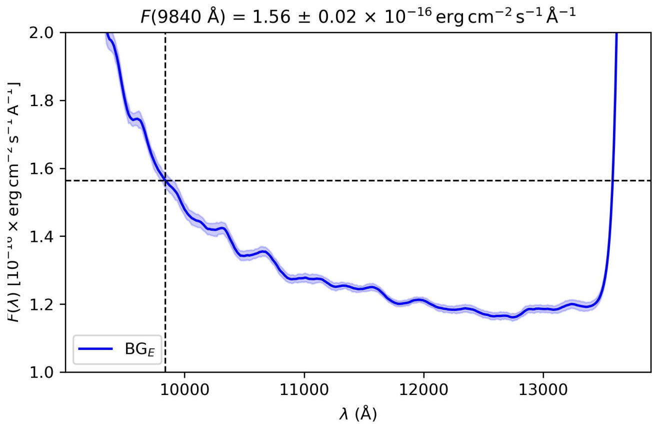
SpectroMACC: $|\delta f| < 0.5\%$

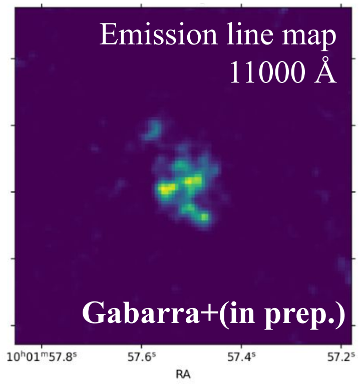
At 1 e/s, the NISP signal estimator bias *increases* the **total uncertainty budget** (RMSE) at the **sub-percent** level:

RG_E: 0.6% → 0.8%

BG_E: 1.4% → 1.5%

NISP spectroscopic scientific performance





Euclid/NISP Signal Estimator

An analytical solution…

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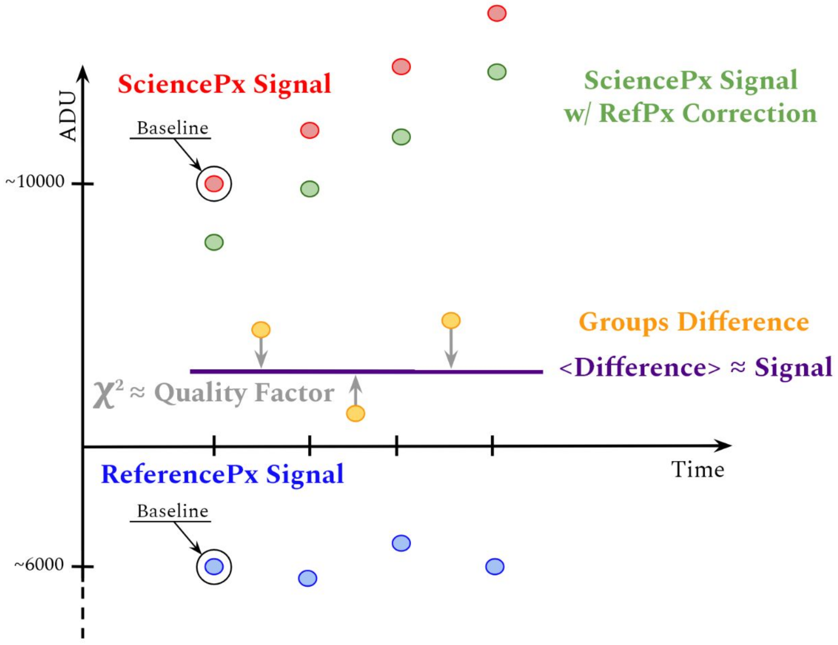

NISP Onboard Data Acquisition and Processing

MACC Sampling	**Readout noise attenuation**
↓	
RefPx Correction	**Common mode noise correction**
↓	
Groups Difference	**Signal correlation attenuation**
↓	
Signal Estimation	**Analytical signal measurement**
↓	
Quality Factor	**Analytical goodness-of-fit estimate**

$$QF = \frac{2f_e}{(1+\alpha)}[(n_g - 1)\hat{g_x} - (G_n - G_1)]$$

Signal Sampling Properties:

n_g = Number of Groups
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Pixel Properties:

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Key Processing Parameters:

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Kubik+16, Cogato+26

And its implications…

"How should the NISP Quality Factor be interpreted?"

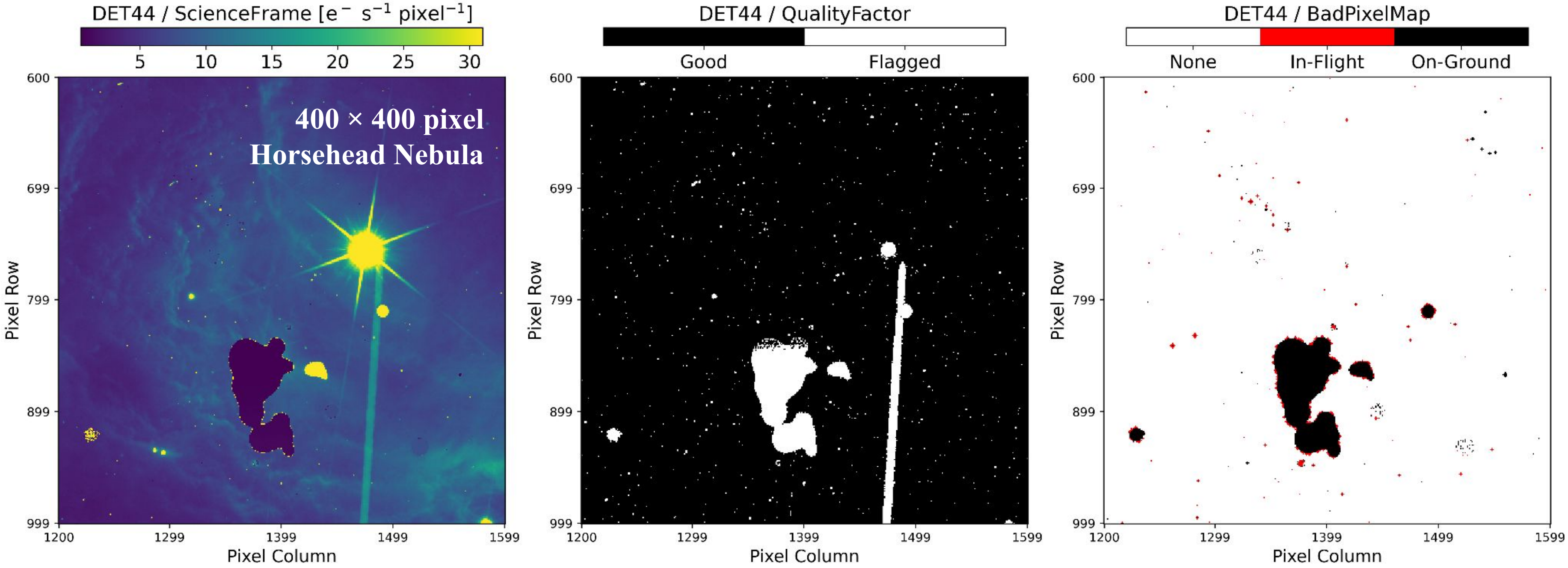
The NISP QF quantifies the *deviation* from *ideal* linear signal integration.

Signal measurement (ΔG_i)

Signal parameter (g)

$$QF = \frac{2 f_e}{(1+\alpha)}\left[(n_g - 1)\hat{g_x} - (G_n - G_1)\right] \sim \chi^2[\mathrm{dof} = (n_g - 1) - 1]$$

- **Persistence signal** and other anomalous behaviours, e.g., bad pixels.



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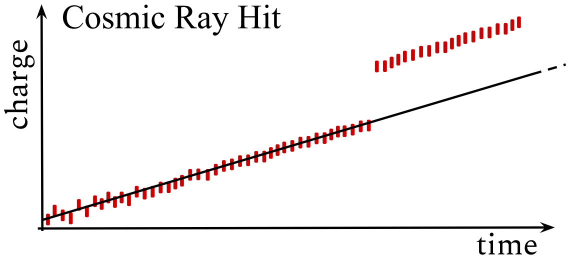
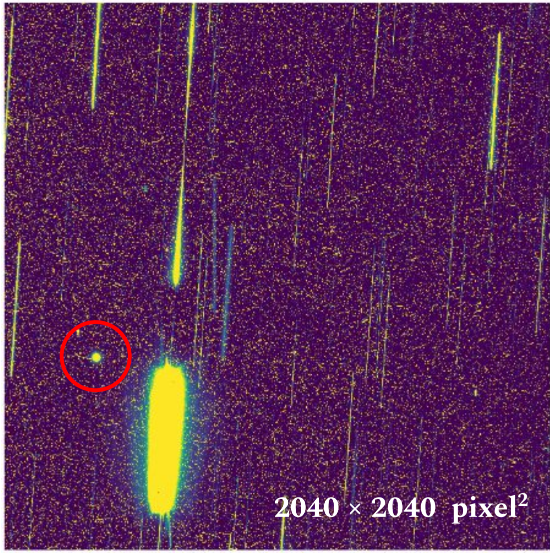
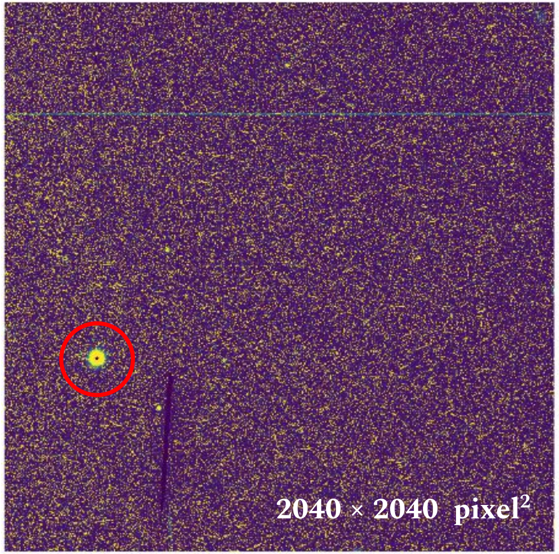
- **Solar energetic particles** and other artefacts



NISP Signal



NISP Quality Factor



And its implications…

"How should the NISP Quality Factor be interpreted?"

A MonteCarlo analysis of NISP QF behaviour

Signal integration variance:

$$D_{kk}(\Delta G_k;\, g) = (1+\alpha)\frac{g}{f_e} + \frac{2\sigma_R^2}{n_f}$$

Input Parameter

- Incident flux [e/s]
- Readout noise [e]
- Conversion gain [e/ADU]

2040 × 2040 px

Acquisition Mode

Photometric MACC(4,16,4)

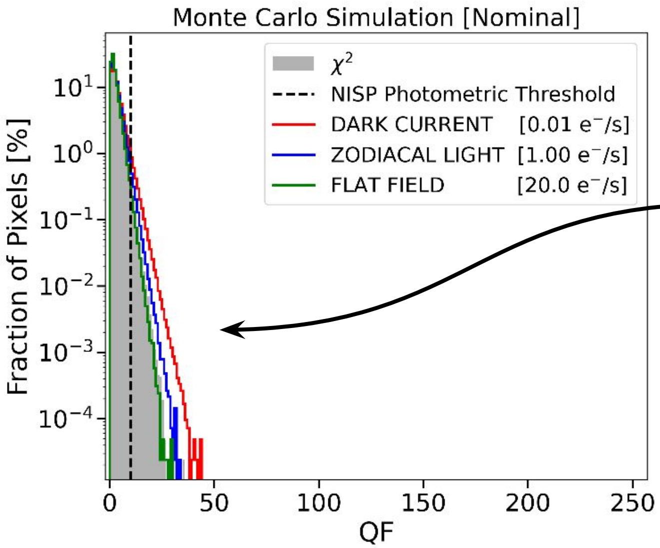
NISP Signal Estimator

NISP Signal + Quality Factor

Nominal

No readout noise approx

Median over
500 synthetic exposures



Cogato+26

And its implications…

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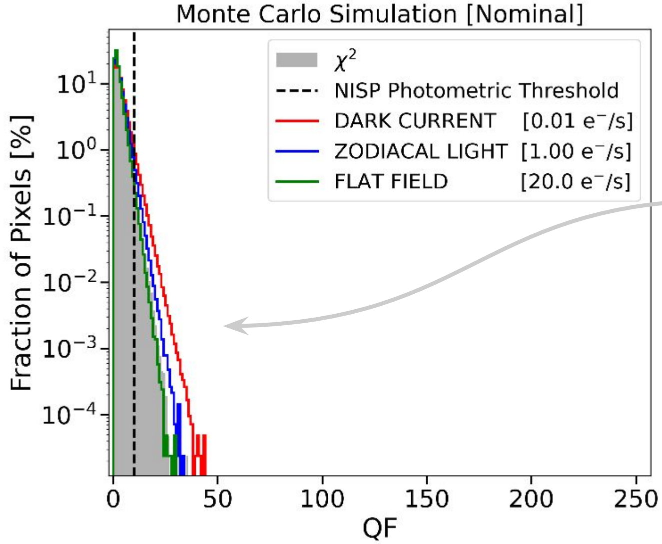
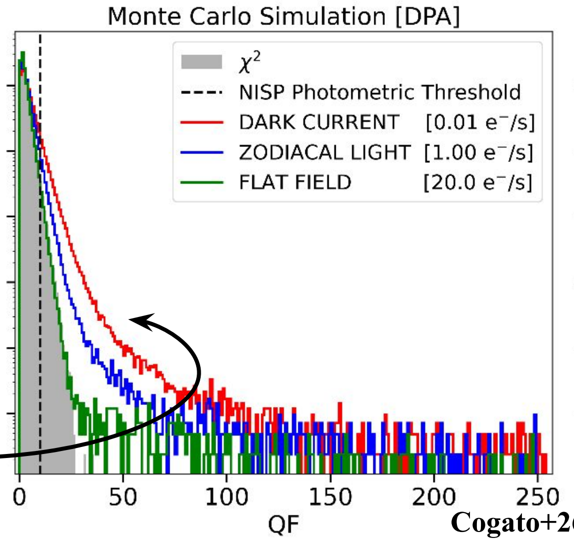


Nominal
No readout noise approx.

Median over
500 synthetic exposures

NISP readout noise approx.
DPA



Cogato+26

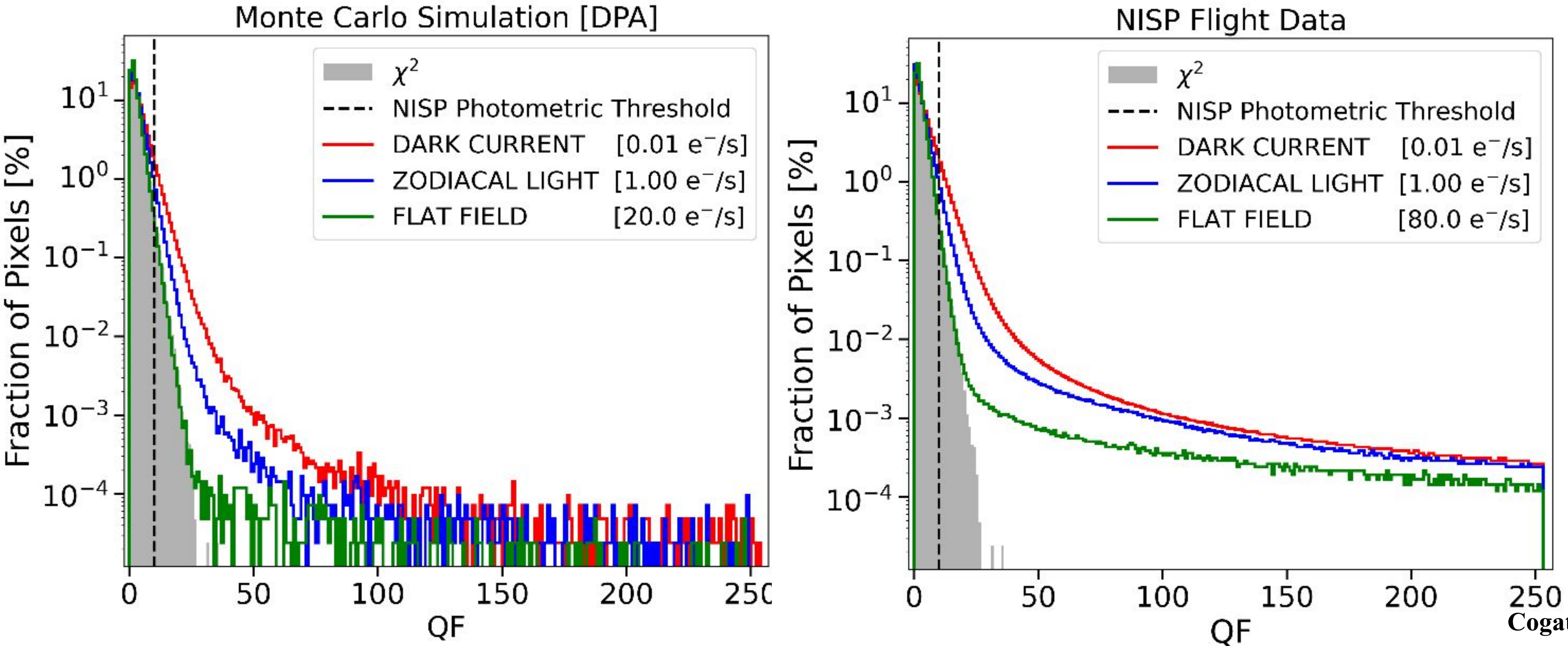
And its implications…

"How should the NISP Quality Factor be interpreted?"

The **NISP QF** marks every pixel whose signal integration deviates from linear behavior.

Expected (MC): QF(10) = 1.31 % of pixels at 1 e/s

NISP Flight Data: QF(10) = 2.59 % of pixels at 1 e/s



Cogato+26

Euclid/NISP Quality Factor

And its implications…

"How should the NISP Quality Factor be interpreted?"

The **NISP QF** marks every pixel whose signal integration deviates from linear behavior.

Photometric MACC(4,16,4) → $\chi^2(2)$

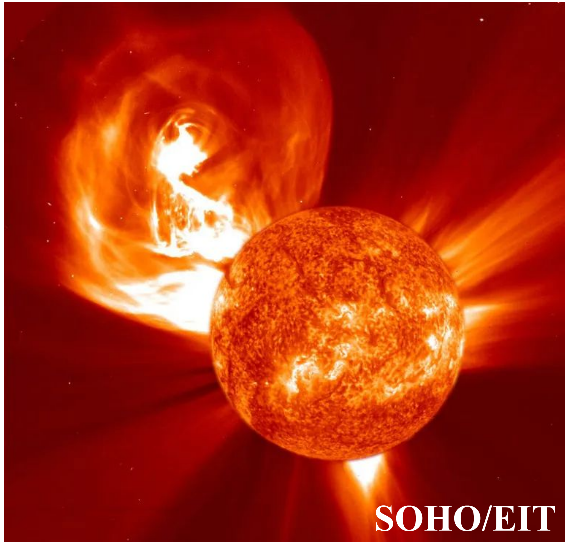
Theoretical (2.7σ clip)**:** $\chi^2(2, 10)$ **= 0.67% of pixels**

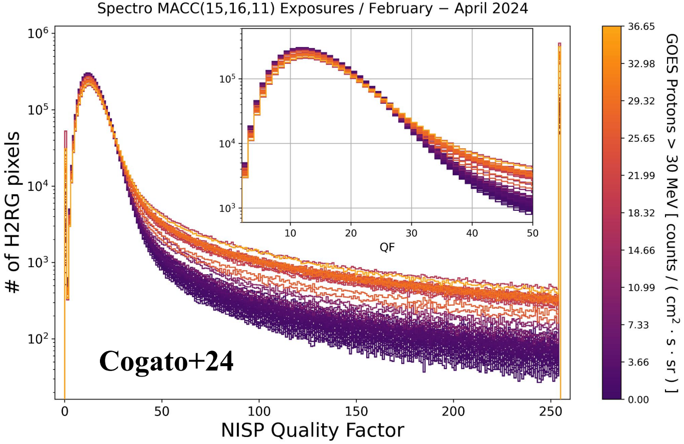
Expected (MC): QF(2, 10) = 1.31 % of pixels

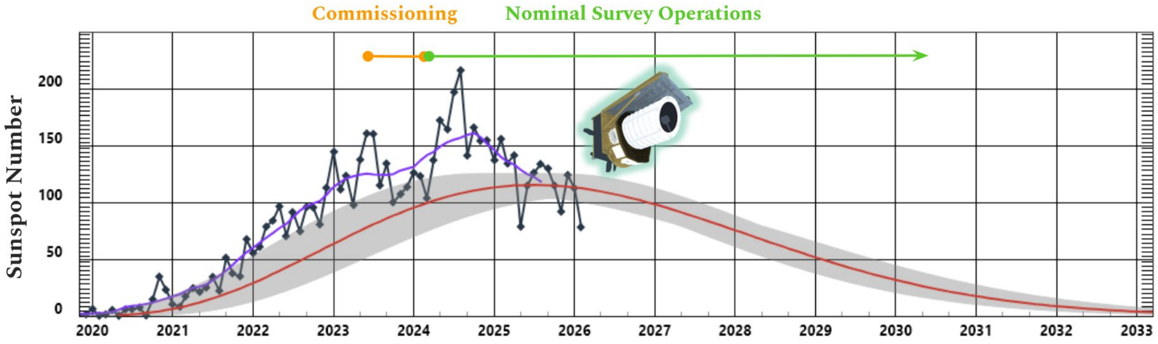
Measured (Flight Data): QF(2, 10) > **3 % of pixels**

space-weather

Solar Coronal Mass Ejection







Lessons Learned on NISP Signal Estimator and Quality Factor

Working in the **ΔG_i space** (Difference of signal groups) reduce signal UTR correlations, resulting in a **three-diagonal covariance matrix**.

<u>However:</u>

- The **analytical solution** for accurate and precise **signal estimation** requires several assumptions/approximations:
  - Diagonal approximation, neglect off-diagonal covariance terms.

Onboard data processing was essential for enabling NISP to observe ⅓ of the sky in 6 years w/ 0.3-arcsec resolution.

<u>However:</u>

- Detector **gain** and **readout noise** must be carefully **characterized on ground** to accurately model the in-flight behavior of **each pixel** in the focal plane.
- The **Data Processing Approximation** (pixel maps → detector-average) is acceptable, provided the appropriate average is selected…

The **NISP Quality Factor** is a powerful tool for **monitoring data quality** and detecting various types of anomalies.

<u>However:</u>

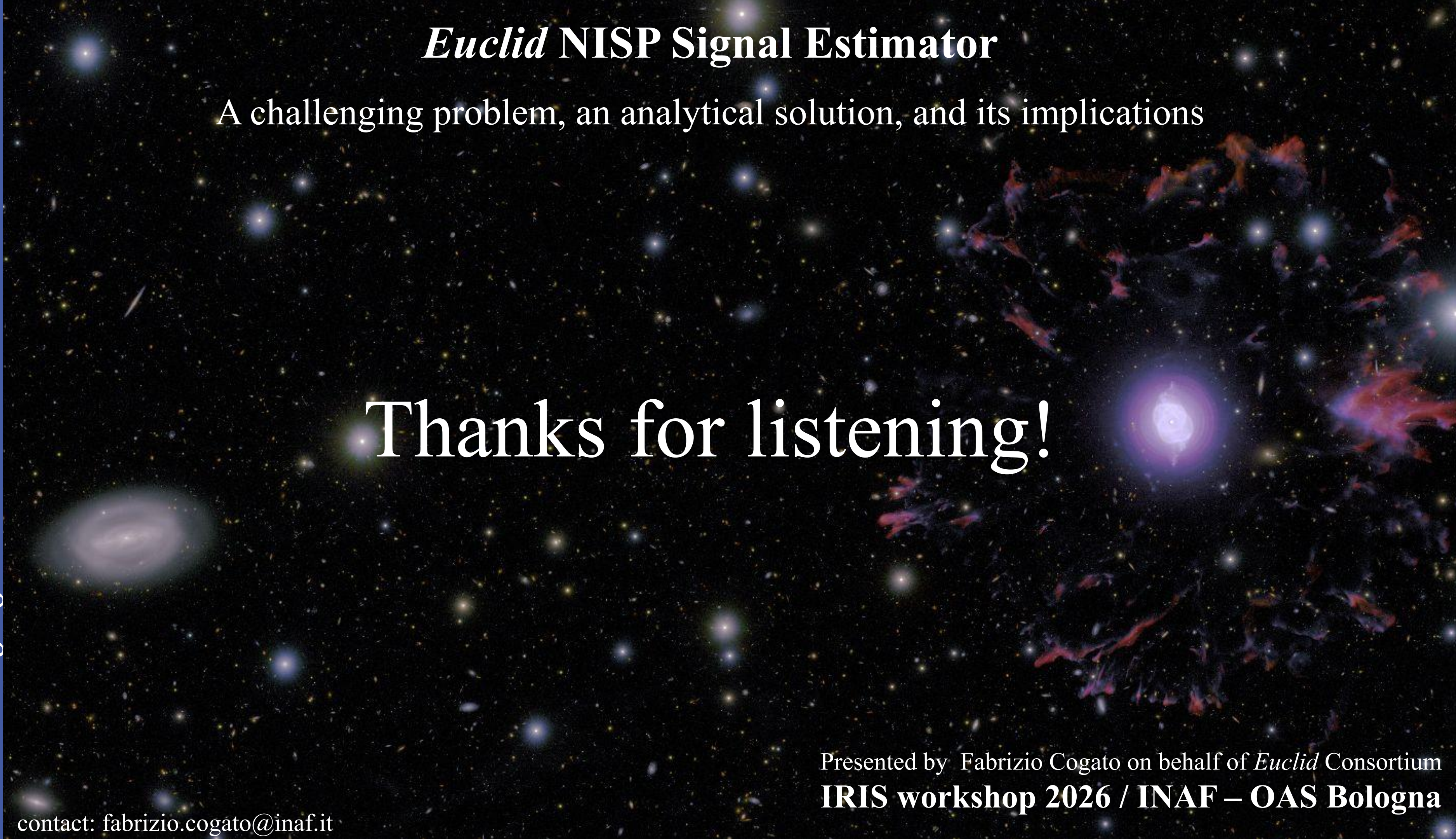
- By construction, it is **affected by the same bias that impacts the NISP signal estimator**, so it must be handled and corrected accordingly.
- Since it flags signal integration anomalies, **recovering the true pixel signal is impossible** (maybe it's "just" difficult and Monte Carlo simulations may help address this).

Advertisement on NISP Signal Estimator and Quality Factor

If you are designing a new **infrared telescope**, there are at least three reasons to integrate the **NISP signal estimator framework** into the data processing chain.

1. **In flight**, it provides **accurate signal estimation** (together with data-quality control) while significantly reducing the total raw data volume.
2. **On the ground**, it accelerates signal processing and provides a robust goodness-of-fit estimator that helps **identify a wide range of anomalies**, which can then be handled later in the processing pipeline.
3. **Looking ahead**, there is always room for improvement – perhaps another paper will join the legacy:

Kubik et al. 2016, Cogato et al. 2026, ??? et al. <2036 ?



Euclid NISP Signal Estimator

A challenging problem, an analytical solution, and its implications

Euclid Imaging Performance

Thanks for listening!

Presented by Fabrizio Cogato on behalf of *Euclid* Consortium

IRIS workshop 2026 / INAF – OAS Bologna

contact: fabrizio.cogato@inaf.it

NISP signal estimator

Lessons learnt on signal estimation

Cogato et al . In prep

$$\mathscr{L}(g \mid \Delta G_i) = \prod_{i=1}^{n_g - 1} \frac{1}{\sqrt{2\pi D_{kk}(g)}} \exp\left[-\frac{(\Delta G_i - g)^2}{2D_{kk}(g)}\right]$$

Less correlations

Reduces bias

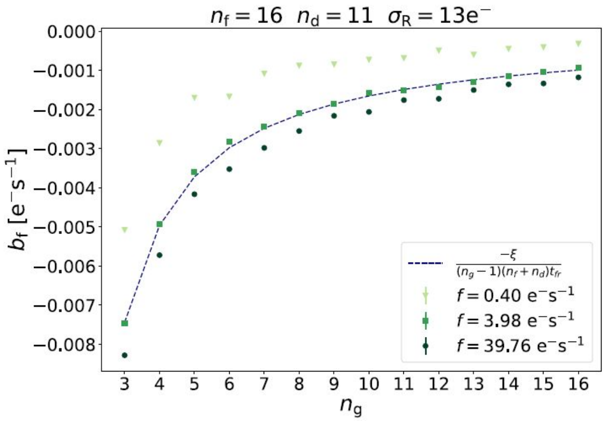
Remaining negligible bias

- Start from $\mathscr{L}(g \mid \Delta G)$ not from $\chi^2 \Rightarrow$ less bias with Poisson noise

- Correct pixel-independent bias (flux-independent in first order approx)

$$b_f = \frac{-\xi}{(n_g - 1)(n_f + n_d)\, t_{fr}}$$

- Remaining deviations: neglected covariance terms



Impact of signal non-linearity on the NISP Quality Factor

QF non–linearity characterization:

$$\log(QF_{NL}) - \log(QF_{LIN}) = \mathrm{Poly(SIGNAL)}$$

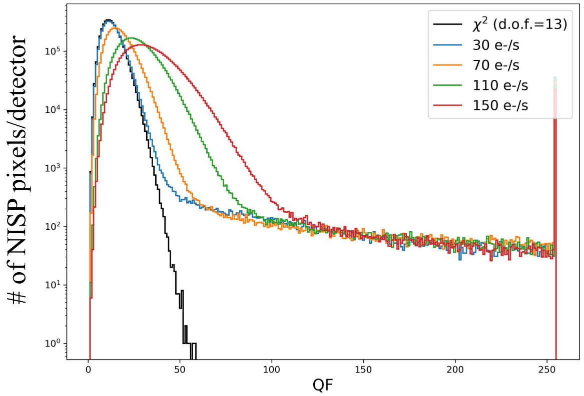
QF non–linearity correction:

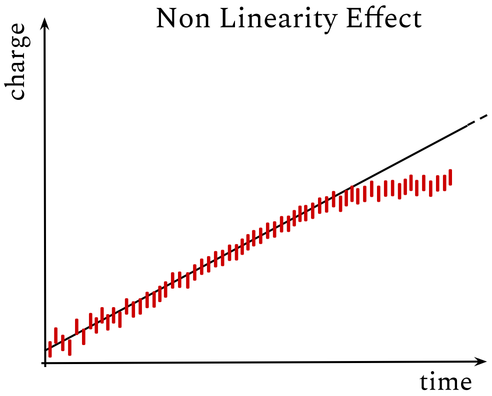
$$QF_{CORR} = QF \cdot 10^{-\mathrm{Poly(SIGNAL)}}$$

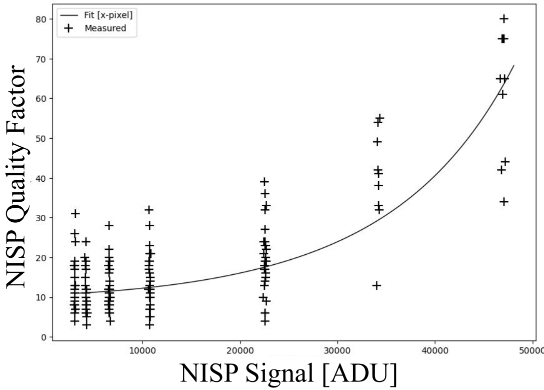
Corrected QF distribution is expected to be:

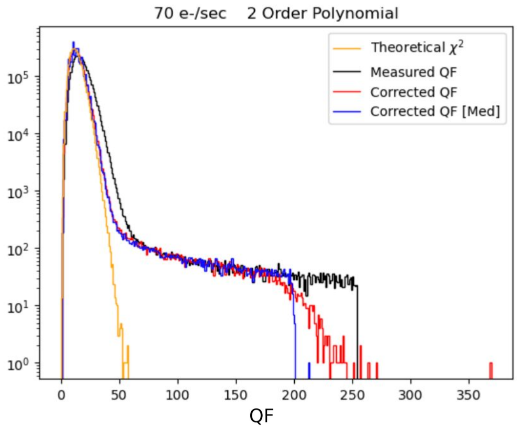
χ^2–like!

Spectroscopic MACC(15,16,11)







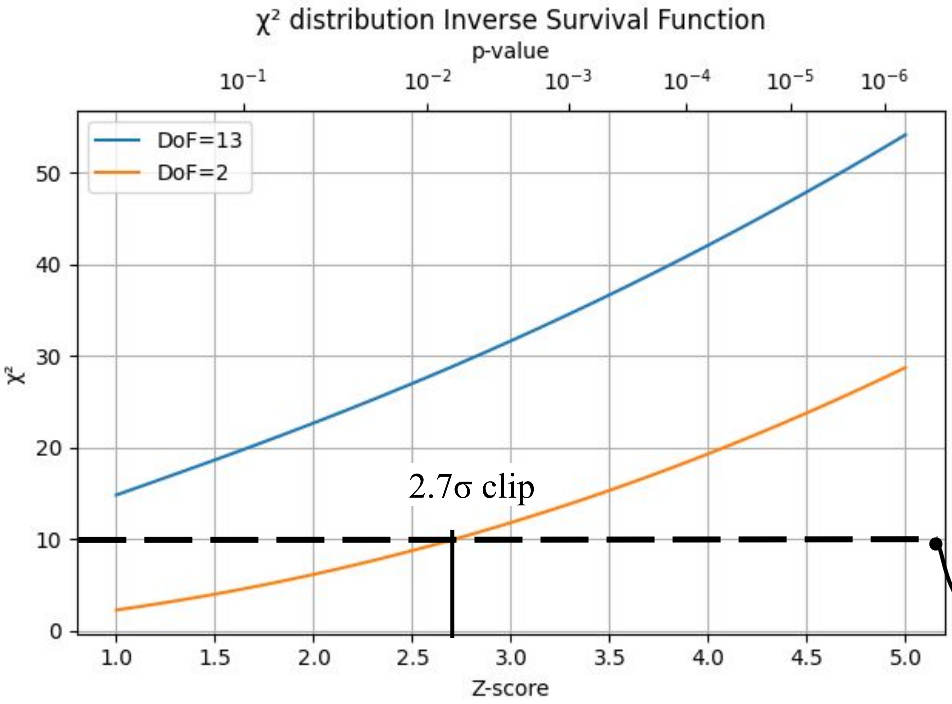


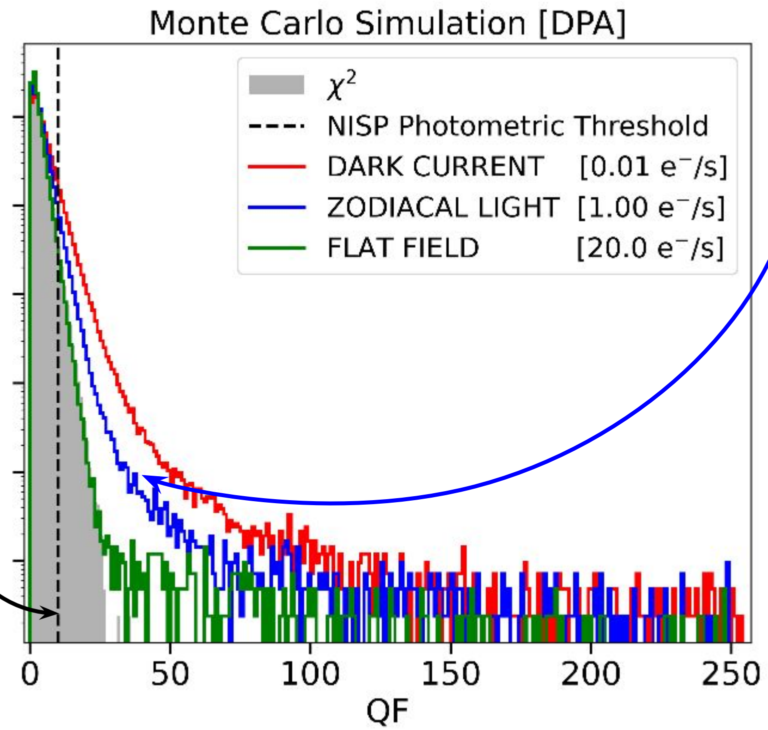
“How should the NISP Quality Factor be interpreted?”

The NISP QF is statistically equivalent to $\chi^2(n_g\text{-}2)$ distribution

χ^2(2, 10) = 0.67% of pixels (2.7σ clip)

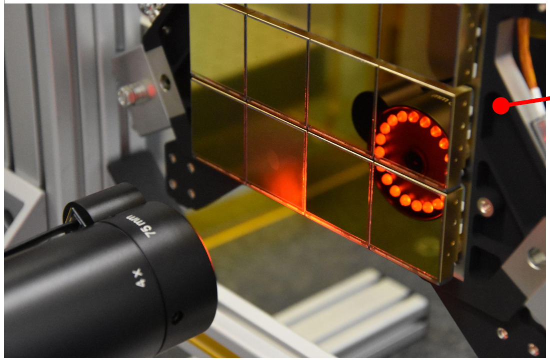
NISP readout noise approx.
1 e/s → QF(10) = 1.31 % of pixels



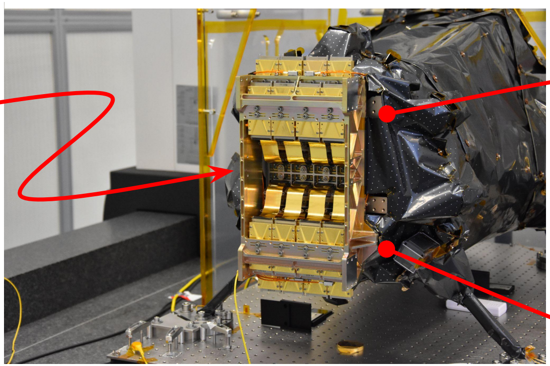


Euclid/NISP Signal Detection Chain

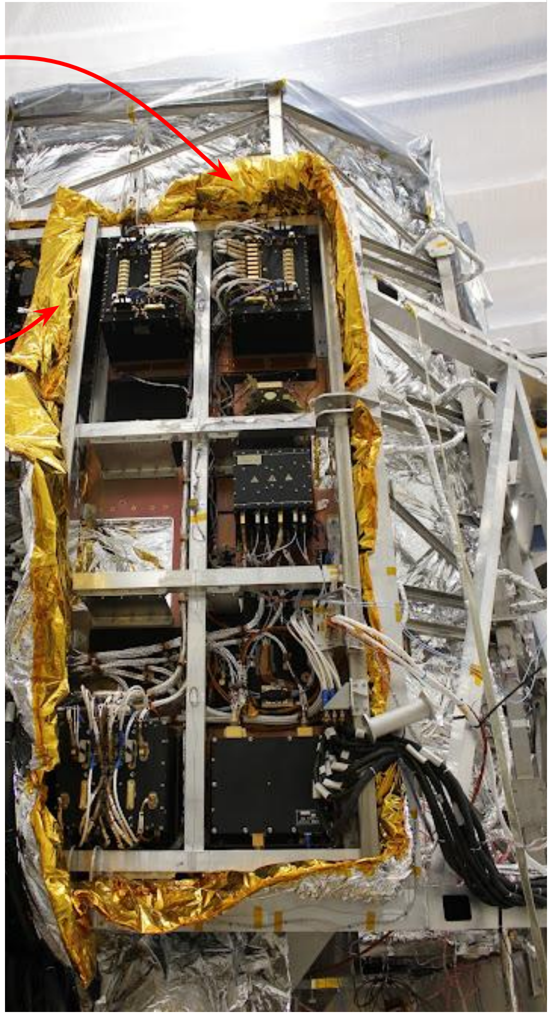
NISP Focal plane (4 x 4 H2RG)

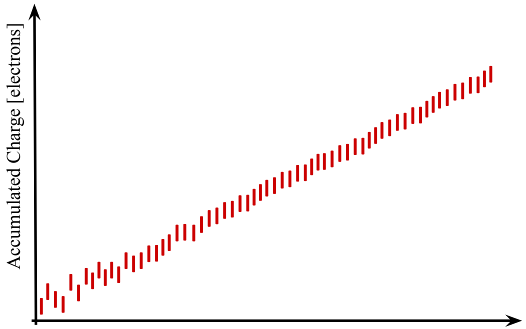


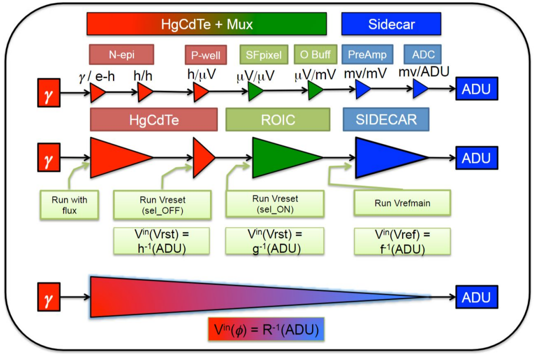
NISP SIDECAR ASIC electronics



NISP Warm electronics



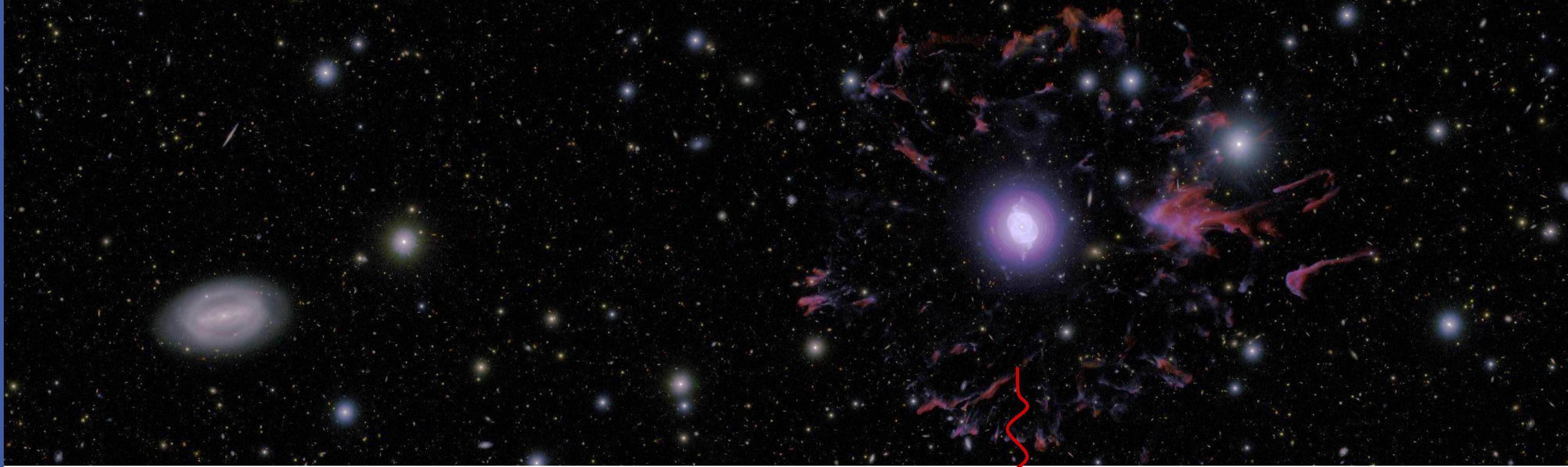




(Barbier+18)

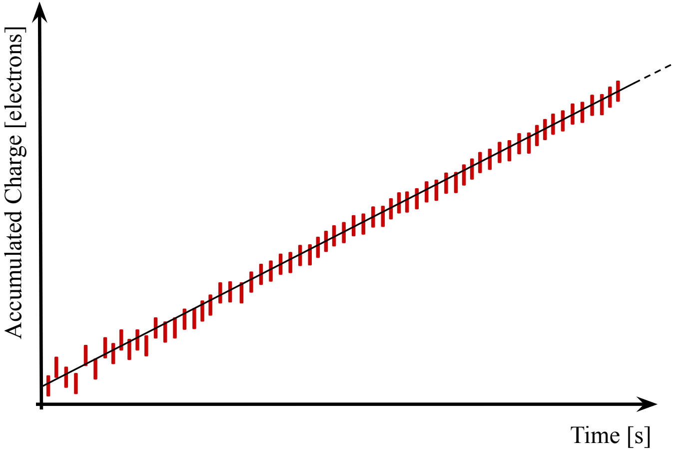
Analogue → Digital

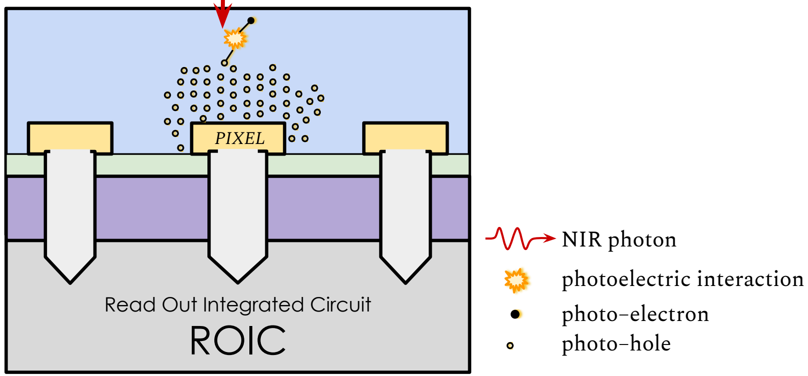
Euclid/NISP Signal Estimator



NGC6543 (Cat's Eye Nebula)
Credits: ESA/NASA/Euclid Consortium

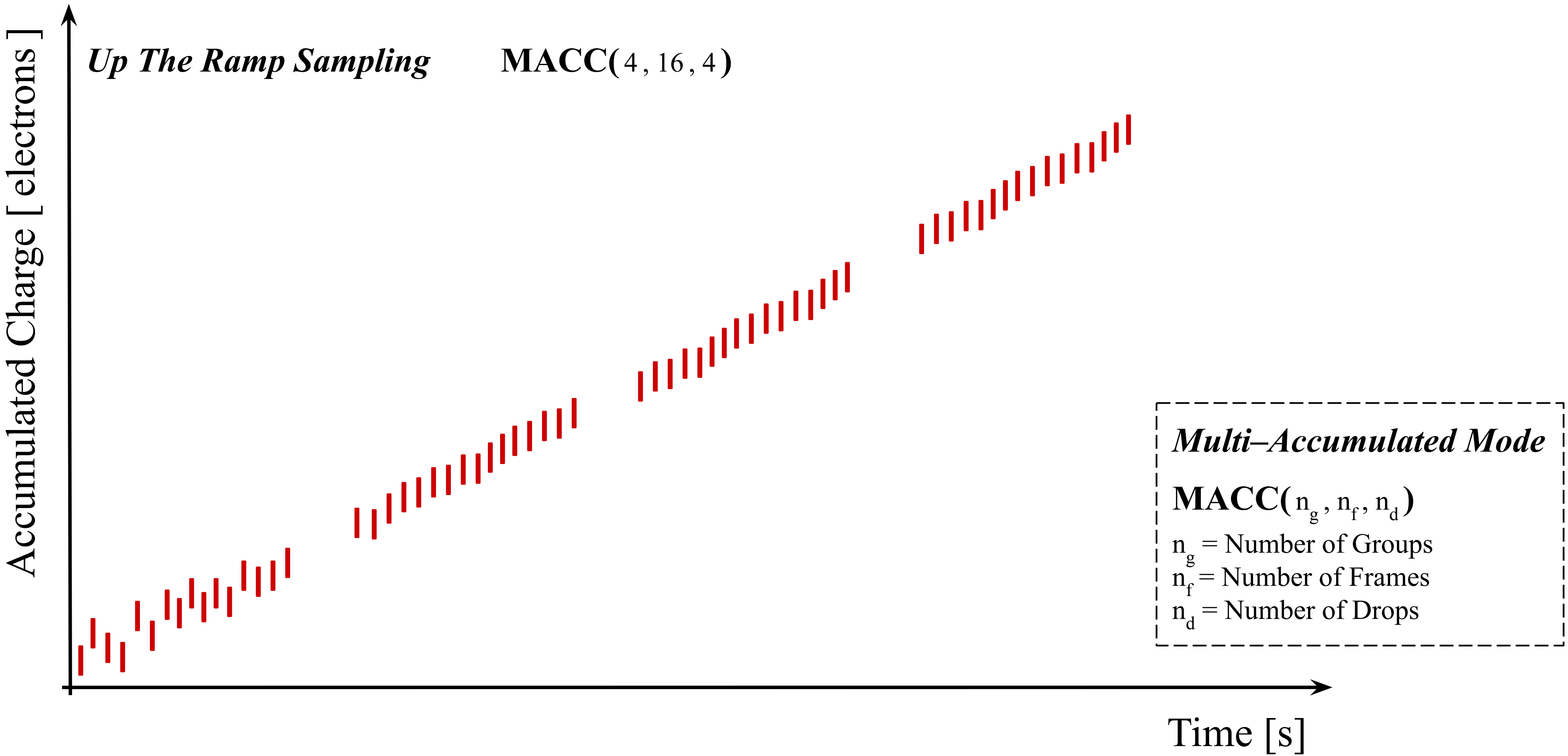
"How should the ramp slope be estimated?"





(Adapted from Mosby+20)

"Well, it's just a straight line!"



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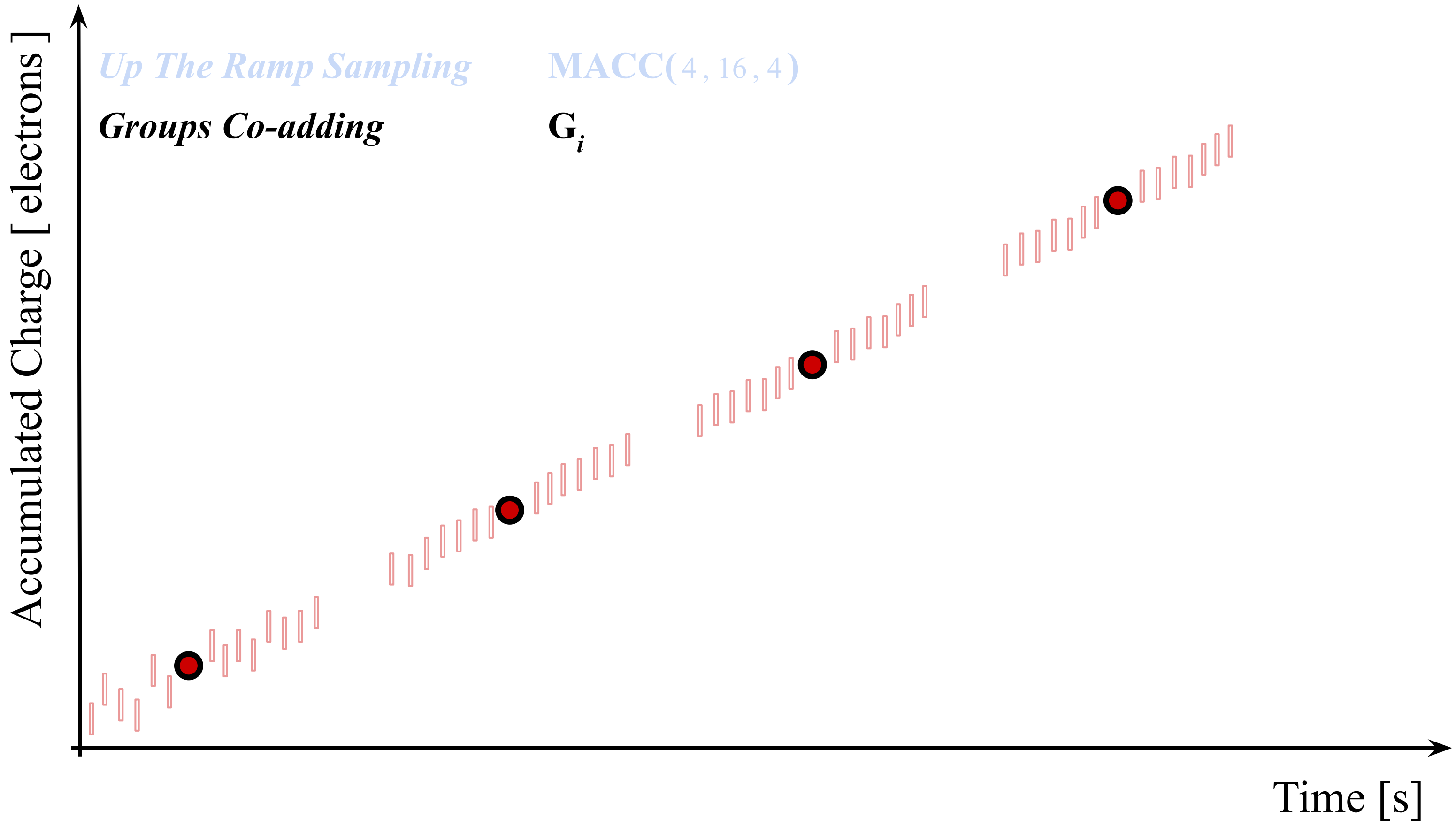
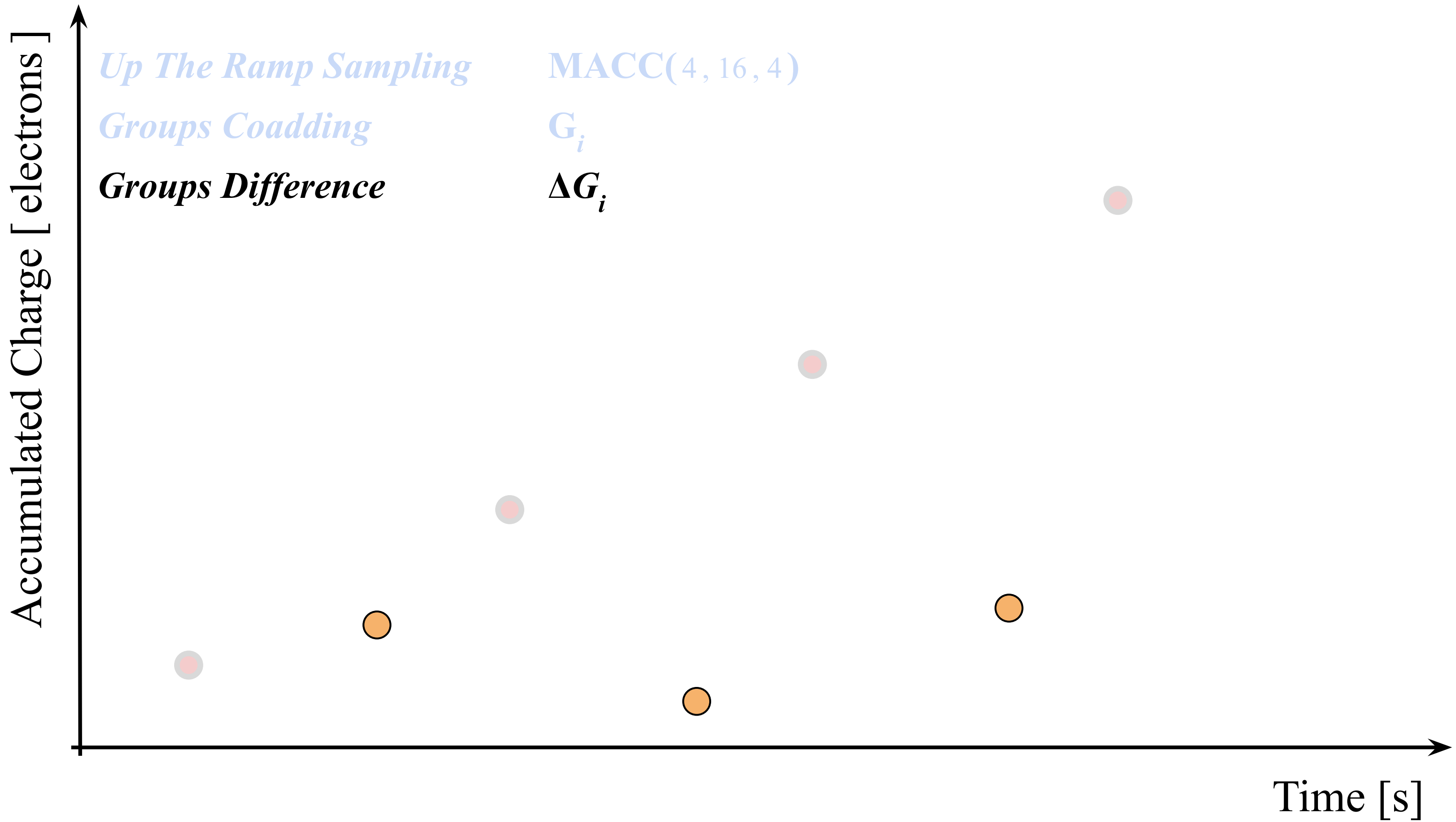


"Perhaps a straight *horizontal* line would be better."



“Perhaps a straight *horizontal* line would be better.”

Euclid’s NISP Signal Estimator

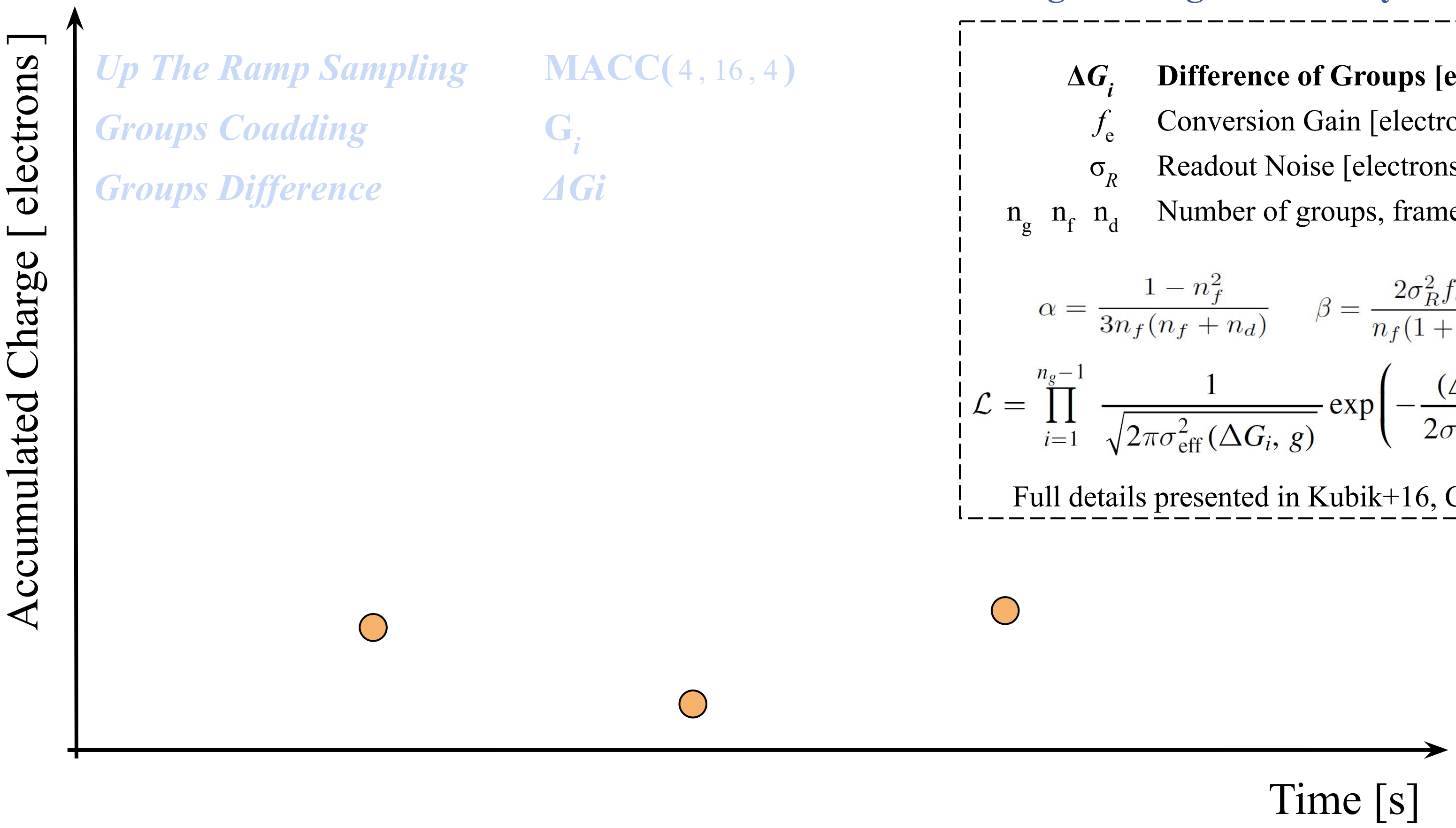
Signal integration analytical model

ΔG_i	**Difference of Groups [electrons]**
f_e	Conversion Gain [electrons/ADU]
σ_R	Readout Noise [electrons]
n_g n_f n_d	Number of groups, frames, drops

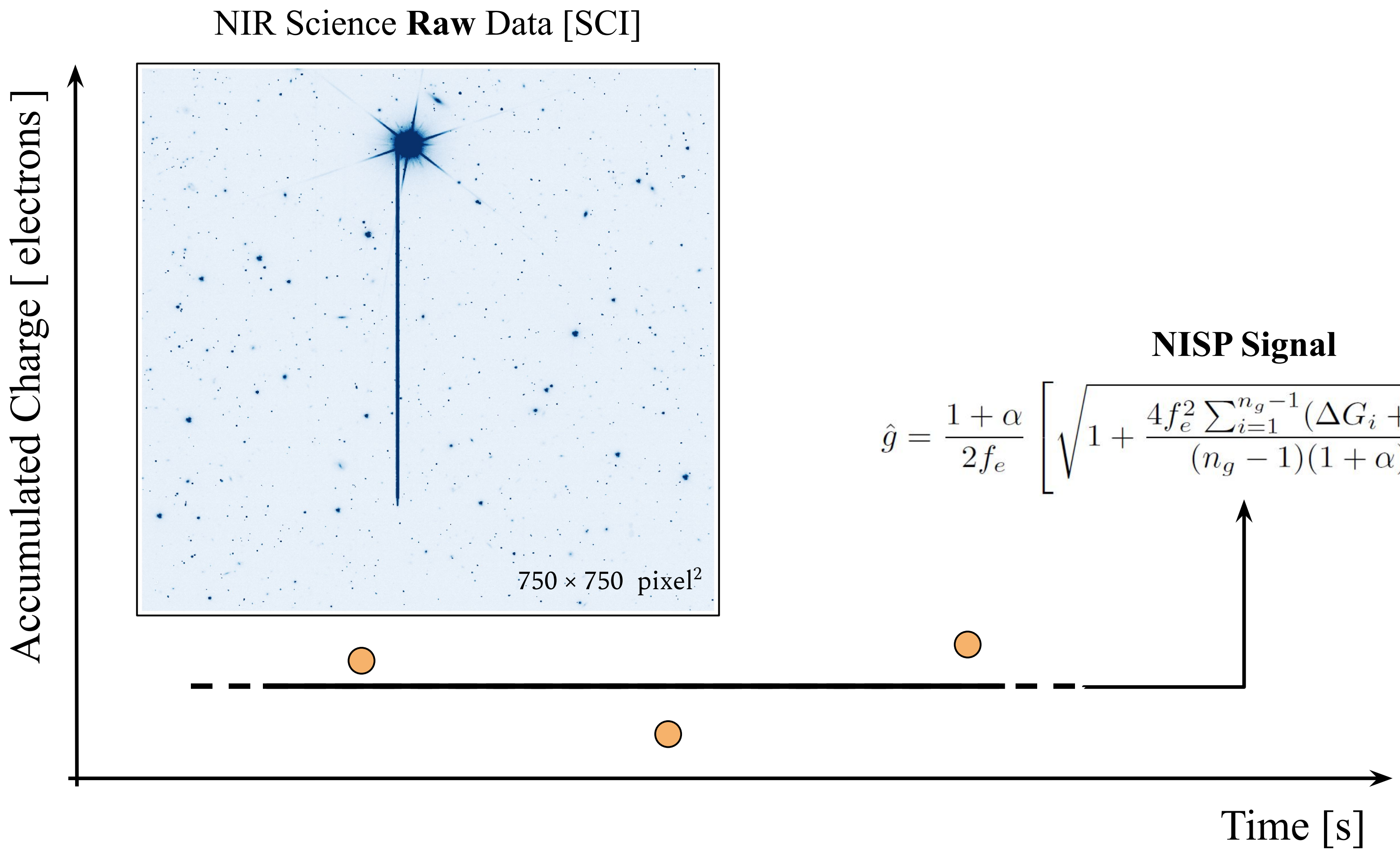
$$\alpha = \frac{1 - n_f^2}{3n_f(n_f + n_d)} \qquad \beta = \frac{2\sigma_R^2 f_e}{n_f(1+\alpha)}$$

$$\mathcal{L} = \prod_{i=1}^{n_g-1} \frac{1}{\sqrt{2\pi\sigma_{\text{eff}}^2(\Delta G_i,\, g)}} \exp\left(-\frac{(\Delta G_i - g)^2}{2\sigma_{\text{eff}}^2(\Delta G_i,\, g)}\right)$$

Full details presented in Kubik+16, Cogato+26



“Ok, now we know how to perform an *analytical* horizontal-line fit…”

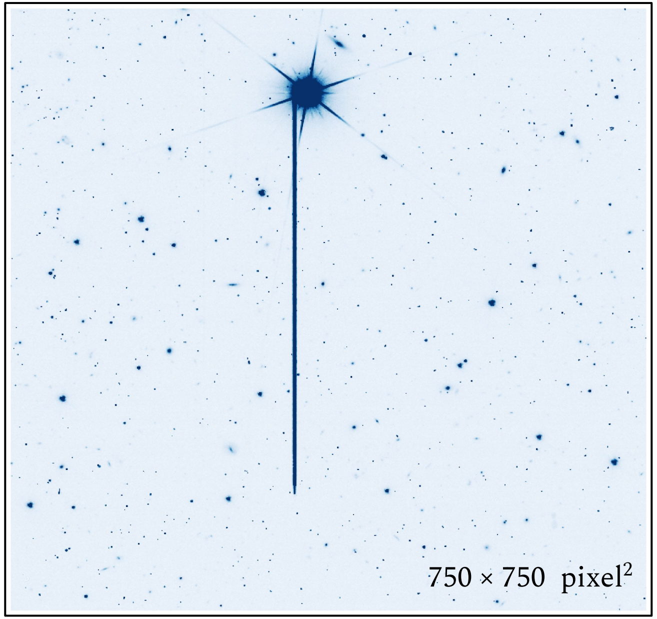


NISP Signal

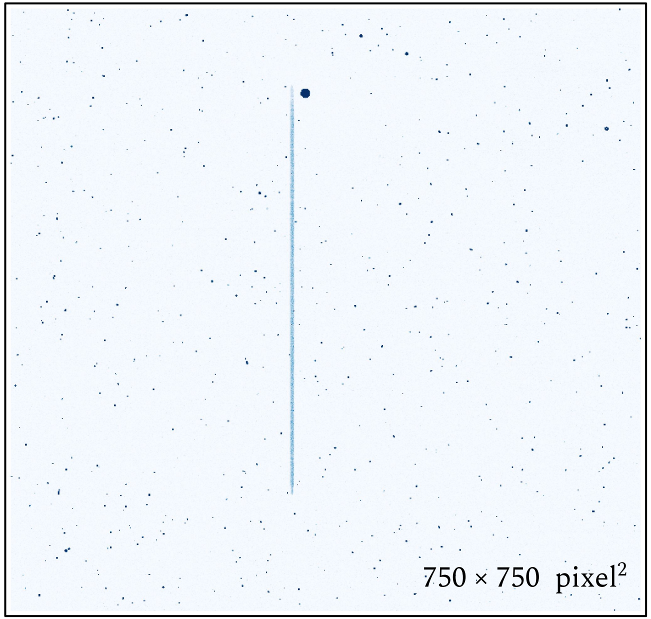
$$\hat{g} = \frac{1+\alpha}{2f_e}\left[\sqrt{1+\frac{4f_e^2\sum_{i=1}^{n_g-1}(\Delta G_i+\beta)^2}{(n_g-1)(1+\alpha)^2}}-1\right]-\beta$$

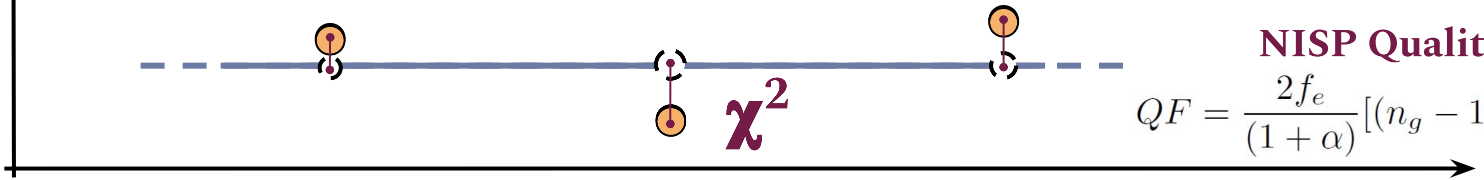
"…and derive an *analytical measure* of the goodness of fit!"

NIR Science **Raw** Data [SCI]



NIR Data Quality [DQ]





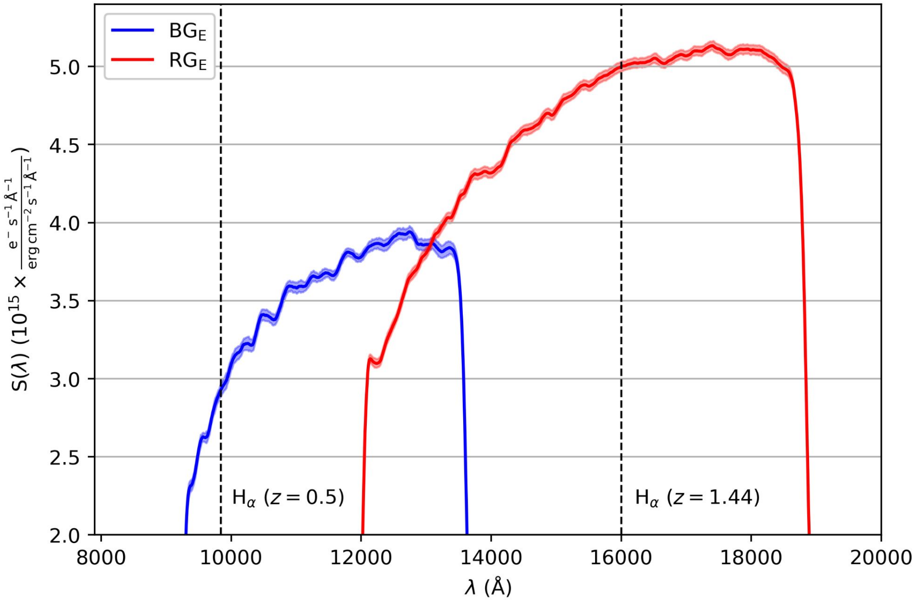
NISP Quality Factor

$$QF = \frac{2f_e}{(1+\alpha)}[(n_g - 1)\hat{g_x} - (G_n - G_1)]$$

"What level of accuracy does the NISP signal estimator achieve?"

Impact of the **NISP signal estimator bias** on the accuracy of the **spectroscopic flux calibration**

NISP Spectroscopic Sensitivity Curve



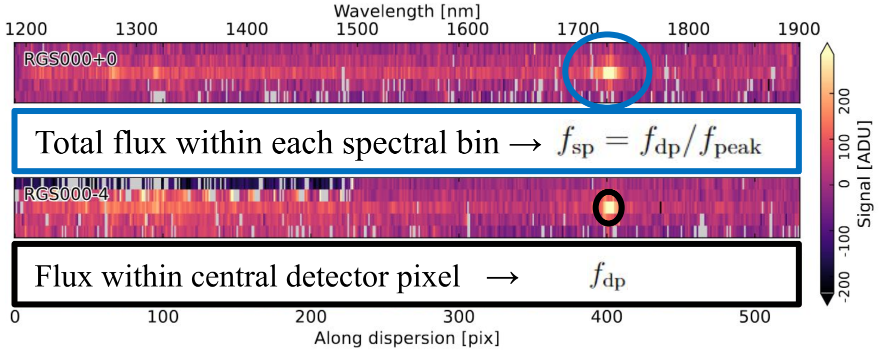
Copin+25

$$\Delta\lambda_{\rm bin}(BG_E) = 12.3\ Å\ {\rm pixel}^{-1}$$

$$\Delta\lambda_{\rm bin}(RG_E) = 13.4\ Å\ {\rm pixel}^{-1}$$

Astrophysical flux density

$$F(\lambda) = \frac{f_{\rm sp}}{S(\lambda)\,\Delta\lambda_{\rm bin}} \quad [{\rm erg\,cm^{-2}\,s^{-1}\,Å^{-1}}]$$



Flux fraction for a 2D Gaussian distribution → $f_{\rm peak} = \left[{\rm erf}\left(\frac{0.5}{\sqrt{2}\,\sigma}\right)\right]^2$

Assuming a **typical galaxy** w/ **angular size** of 0.5 arcsec, σ = 0.9 detector pixels

Impact of the **NISP signal estimator bias** on the accuracy of the **spectroscopic** and photometric flux calibration

Assuming a **typical galaxy** with an angular size of **0.″5**, the spatial profile of the signal can be approximated by a 2D Gaussian with **σ = 0.9 detector pixels** (Copin+25)

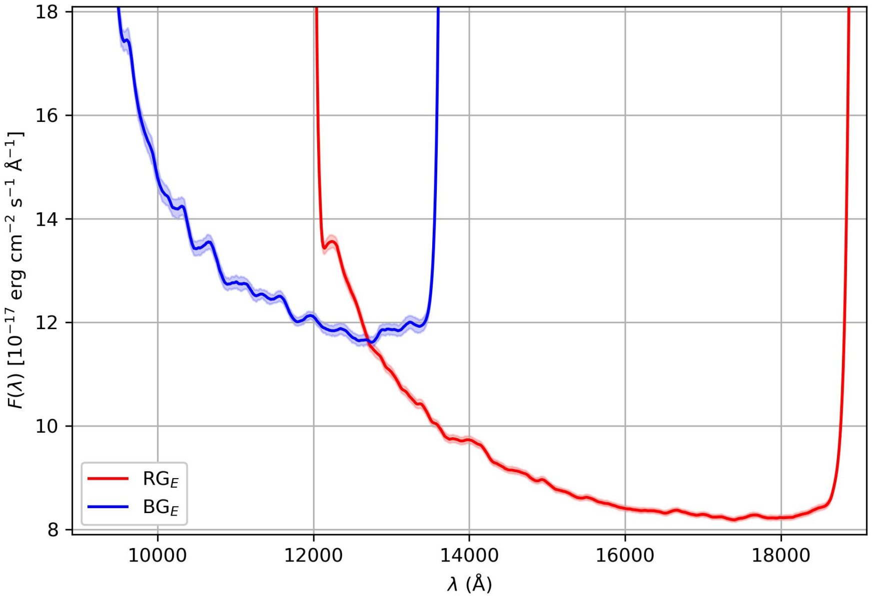
$$f_{\rm peak} = \left[\mathrm{erf}\left(\frac{0.5}{\sqrt{2}\,\sigma}\right)\right]^2 \simeq 0.178$$

$$f_{\rm dp} = 1.00\ \mathrm{e^-\,s^{-1}}$$ = Flux within central detector pixel

$$f_{\rm sp} = f_{\rm dp}/f_{\rm peak} \simeq 5.629\ \mathrm{e^-\,s^{-1}}$$ = Total extracted flux

Astrophysical flux density

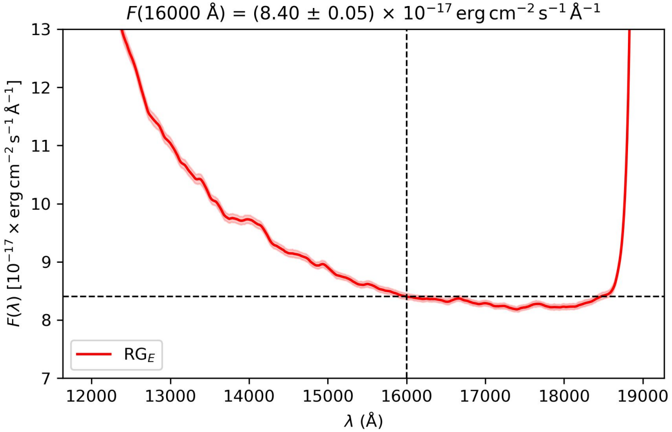
$$F(\lambda) = \frac{f_{\rm sp}}{S(\lambda)\,\Delta\lambda_{\rm bin}} \quad [\mathrm{erg\,cm^{-2}\,s^{-1}\,\AA^{-1}}]$$

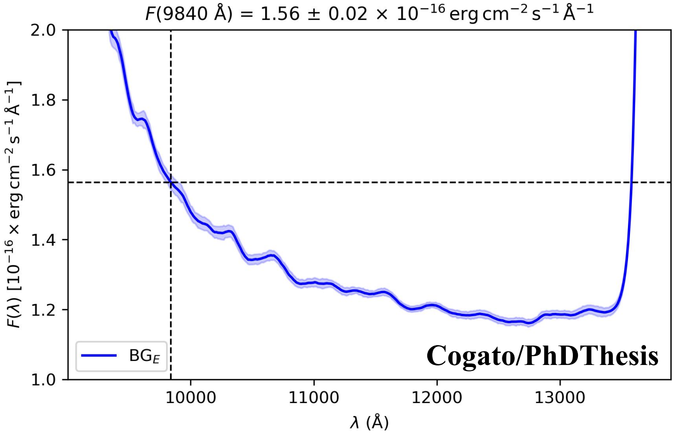


Cogato/PhDThesis

“What level of accuracy does the NISP signal estimator achieve?”

Impact of the **NISP signal estimator bias** on the accuracy of the **spectroscopic** flux calibration



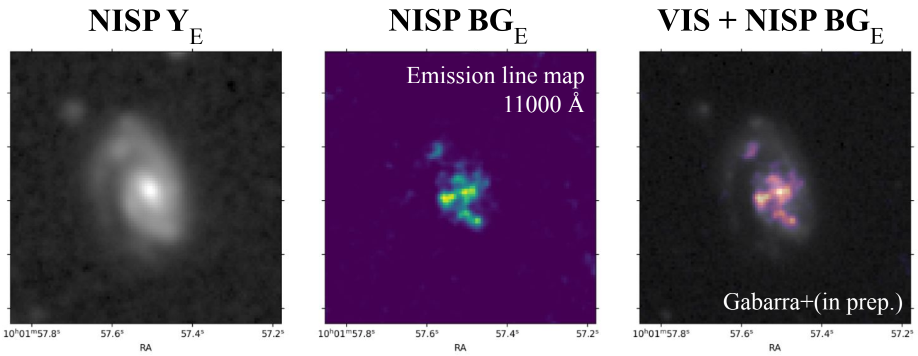


SpectroMACC: $|\delta f| < 0.5\%$

At 1 e/s, the NISP signal estimator bias **increases** the total *uncertainty budget* (RMSE) at the **sub-percent** level:

RG_E: 0.6% → 0.8%

BG_E: 1.4% → 1.5%



Impact of the **NISP signal estimator bias** on the accuracy of the spectroscopic and **photometric** flux calibration

Following **Schirmer+22,** and assuming that the **total source flux is collected within a single detector pixel**, the apparent AB magnitude as a function of the instrumental count rate can be expressed as:

$$m_{\mathrm{AB}}(n_e) = 26.84 + 2.5\log_{10}\left(\int_{\nu_{\mathrm{min}}}^{\nu_{\mathrm{max}}} \frac{T(\nu)}{\nu}\,\mathrm{d}\nu\right) - 2.5\log_{10}(n_e) = \mathrm{ZP} - 2.5\log_{10}(n_e)$$

↓

PhotoMACC: $|\delta n_e| < 1\%$

↓

$$\Delta\mathrm{ZP}_{\mathrm{SE}} = \pm\,|m_{\mathrm{AB}}(1) - m_{\mathrm{AB}}(1.01)| \simeq \pm 0.01\ \mathrm{mag},$$

According to **Schirmer+22**, the dominant contribution to the uncertainty on the NISP photometric zero point arises from uncertainties in the detector quantum efficiency curves, amounting to ± 0.05 mag.
The **total uncertainty on the zero point calibration** can therefore be expressed as:

NISP average zero-point = 25 mag

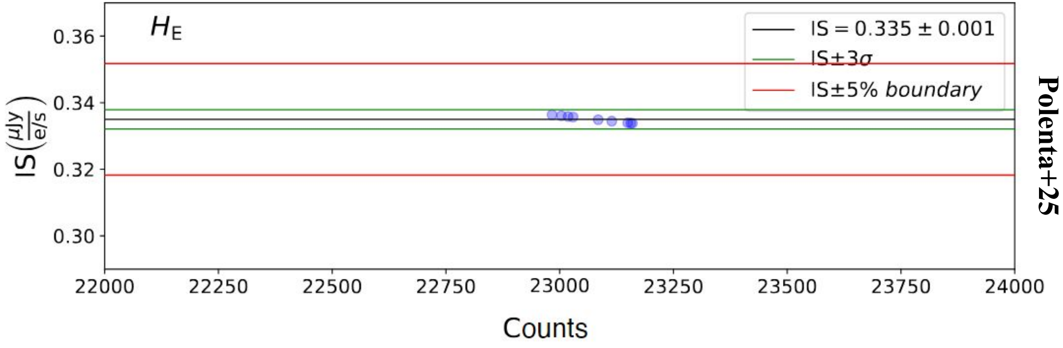
$$\Delta\mathrm{ZP}_{\mathrm{tot}} = \pm\sqrt{\Delta\mathrm{ZP}^2_{\mathrm{QE}} + \Delta\mathrm{ZP}^2_{\mathrm{SE}}} \simeq \pm 0.051\ \mathrm{mag}$$

Impact of the **NISP signal estimator bias** on the accuracy of the spectroscopic and **photometric** flux calibration

The impact of the NISP bias can also be evaluated in terms of the absolute photometric flux calibration. Converting the zero point magnitude into flux units:

$$m_{\mathrm{AB}} = -2.5\ \log_{10}\left(\frac{f_\nu(\nu)}{1\ \mathrm{Jy}}\right) + 8.90. \longrightarrow f(n_e) = 10^{-(\mathrm{ZP}-8.9-2.5\log_{10}(n_e))/2.5)} \times 10^6\ \mu\mathrm{Jy}$$

At 1 e/s, this corresponds to a reference zero point of about 0.3 µJy.
A 1% bias in the measured count rate translates into a variation of 0.003 µJy.



Polenta+25

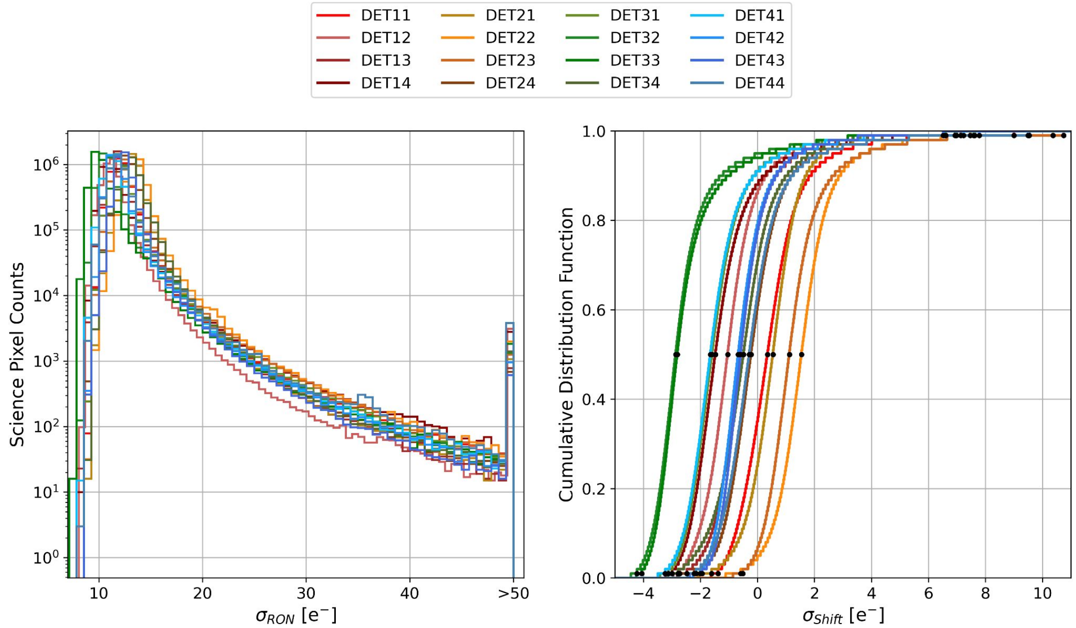
This effect is well below the 5% accuracy requirement on the NISP near-infrared absolute flux calibration.

NISP Signal. Averaged–Parameter (AP) approximation

Reference Signal ⟶ Least Squares Fitting (LSF) of Averaged Groups (16 co-added raw frames)

NISP DPU–measured Signal ⟶ $$\hat{g} = \frac{1+\alpha}{2f_e}\left[\sqrt{1+\frac{4f_e^2\sum_{i=1}^{n_g-1}(\Delta G_i+\beta)^2}{(n_g-1)(1+\alpha)^2}}-1\right]-\beta$$

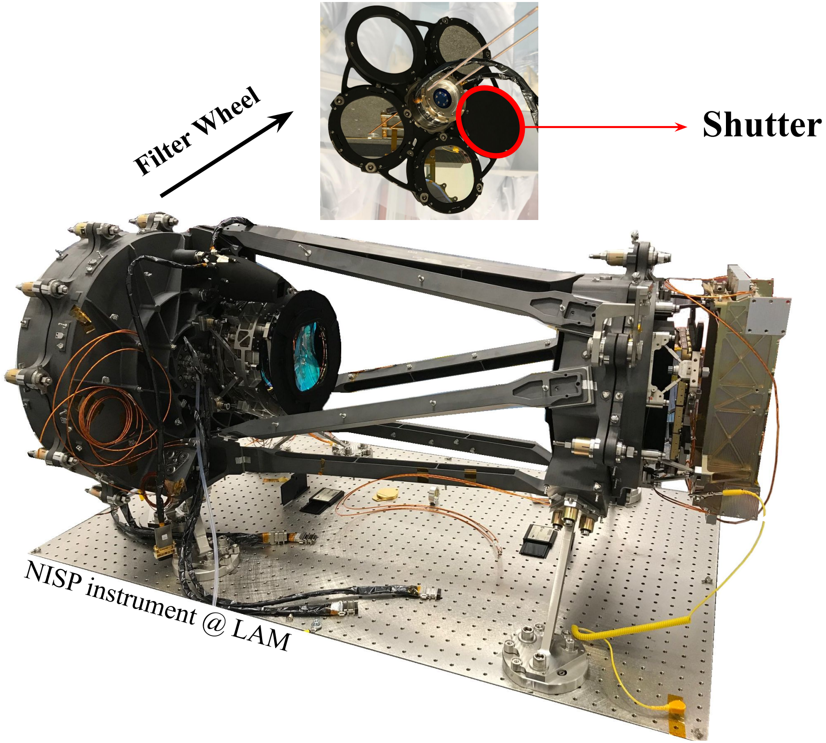
AP approximation Bias ⟶ $S_{BIAS} = \hat{g} - LSF$ vs. $\sigma_{R,\mathrm{Shift}} = \sigma_{R,\mathrm{Map}} - <\sigma_{R,\mathrm{Map}}>$



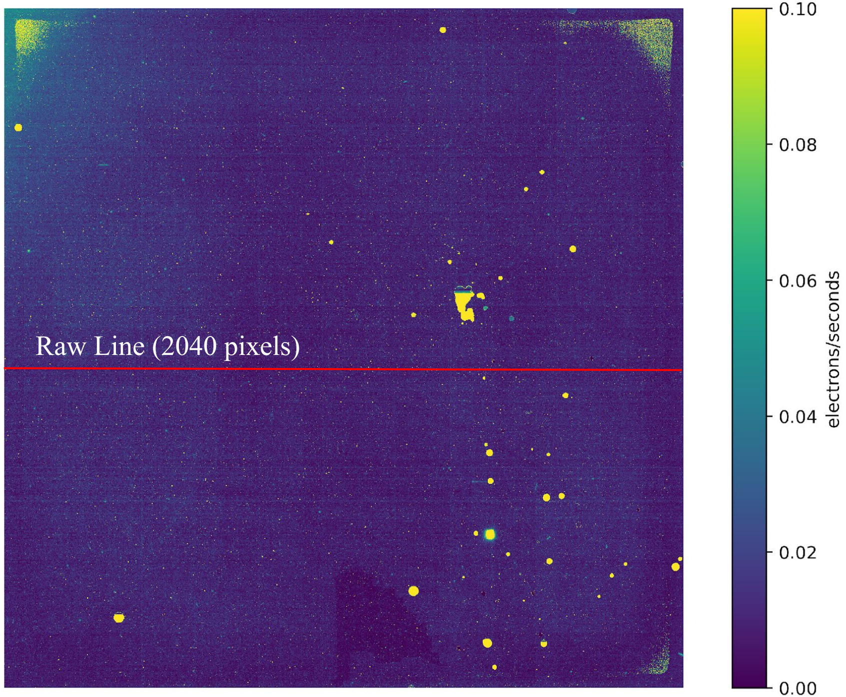
NISP Data Processing: the Averaged–Parameter (AP) approximation

Case Study. Spectroscopic MACC(15,16,11)

- ***DARK CURRENT***



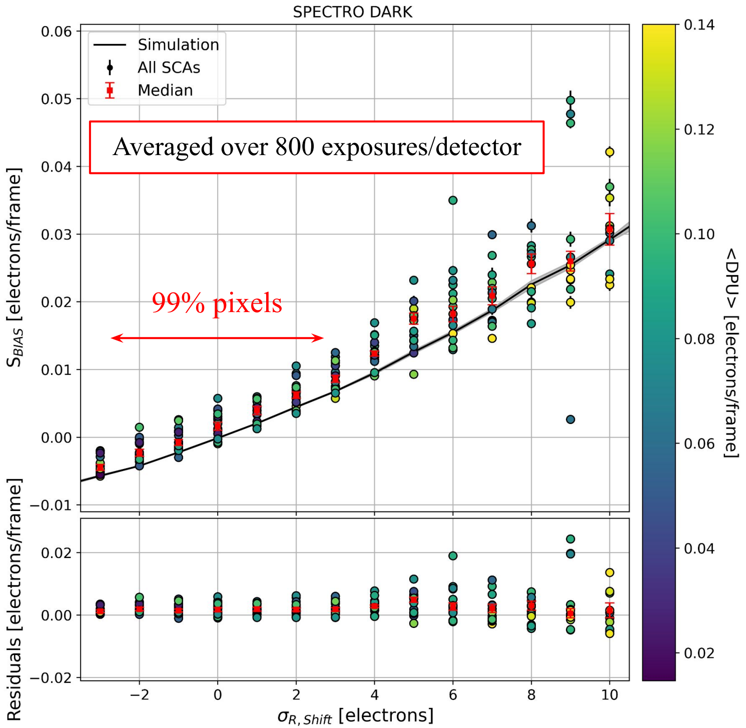
Master Dark (500 images stack)



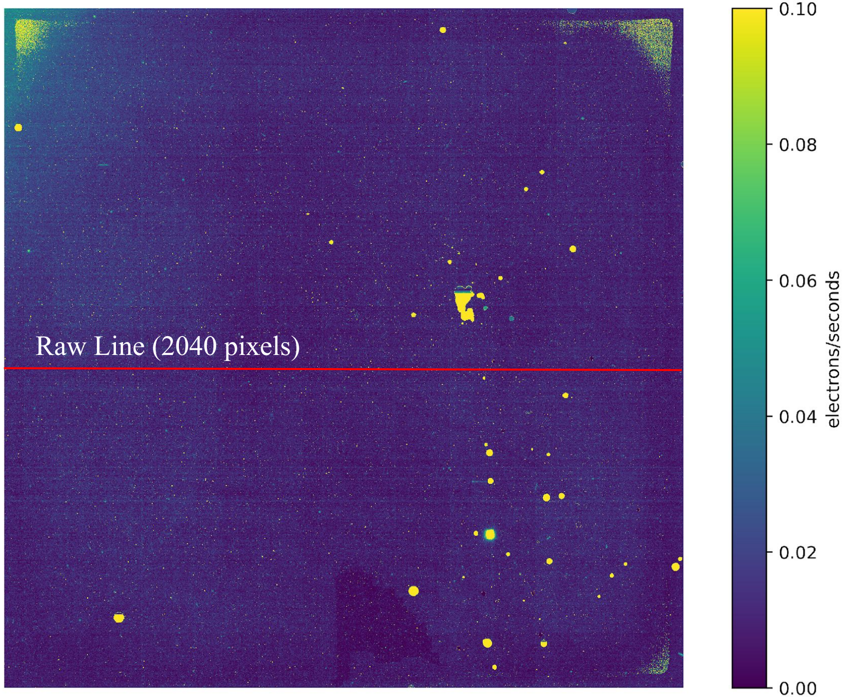
NISP Data Processing: the Averaged–Parameter (AP) approximation

Case Study. Spectroscopic MACC(15,16,11)

- ***DARK CURRENT***



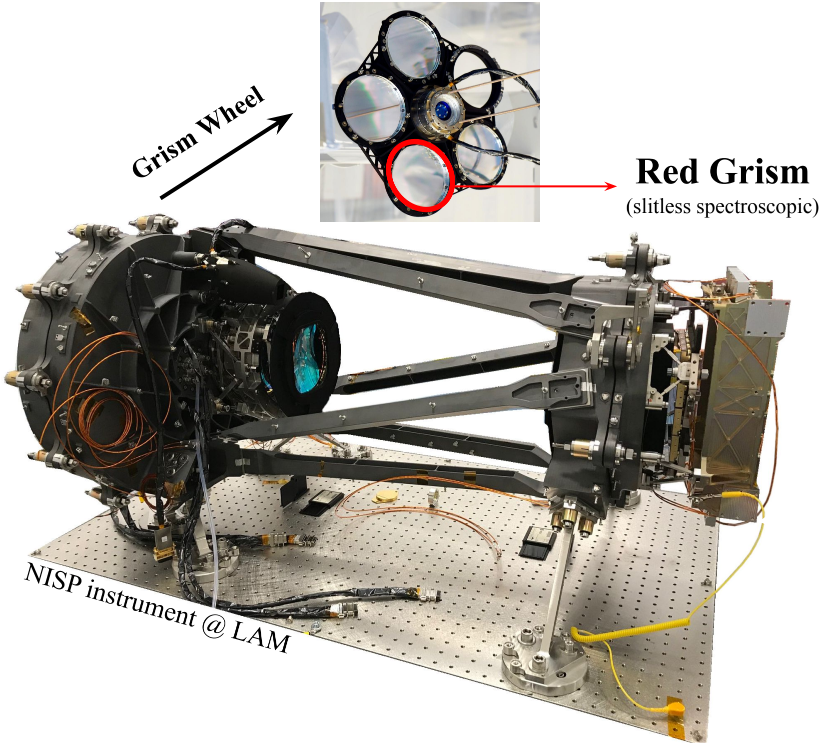
Master Dark (500 images stack)



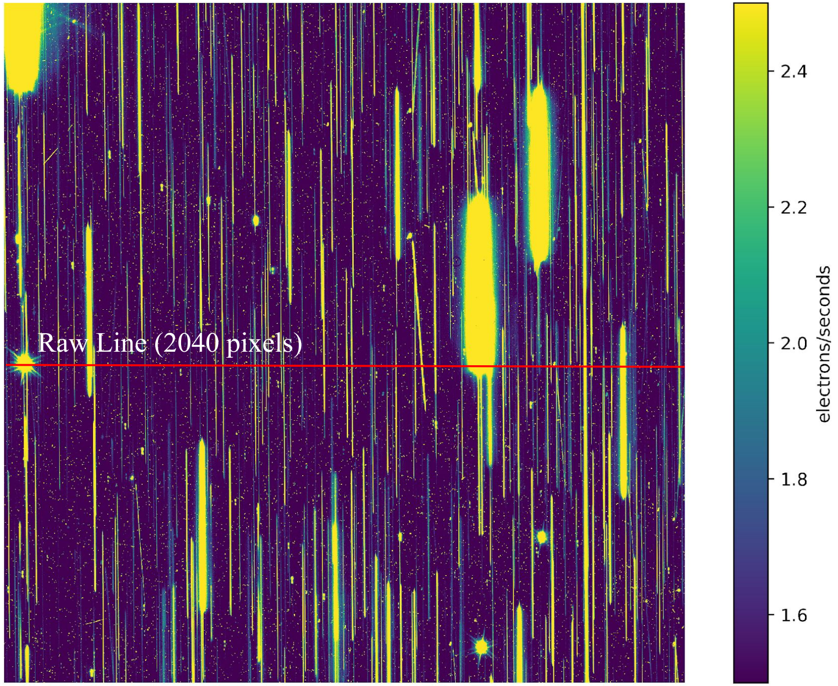
NISP Data Processing: the Averaged–Parameter (AP) approximation

Case Study. Spectroscopic MACC(15,16,11)

- ***ZODIACAL BACKGROUND*** (Scientific Images)



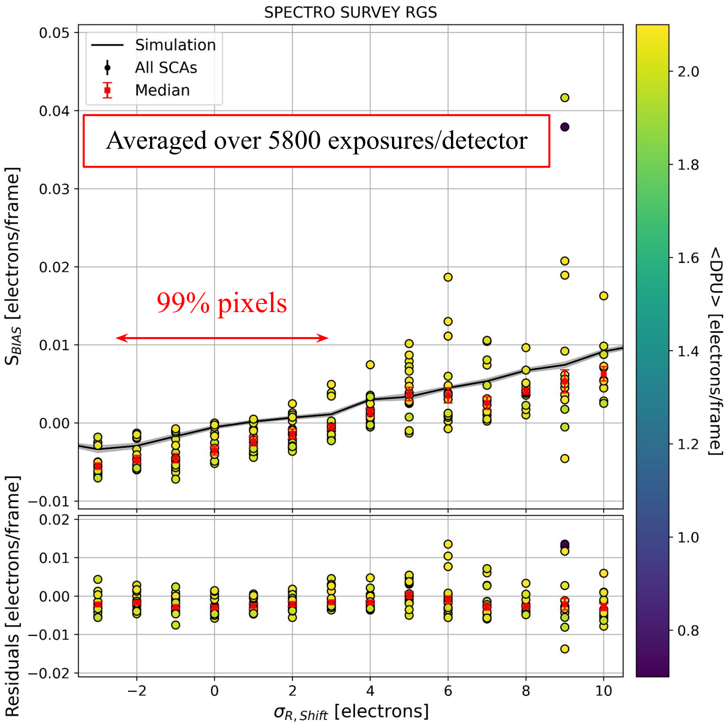
RGS000 exposure (not calibrated)



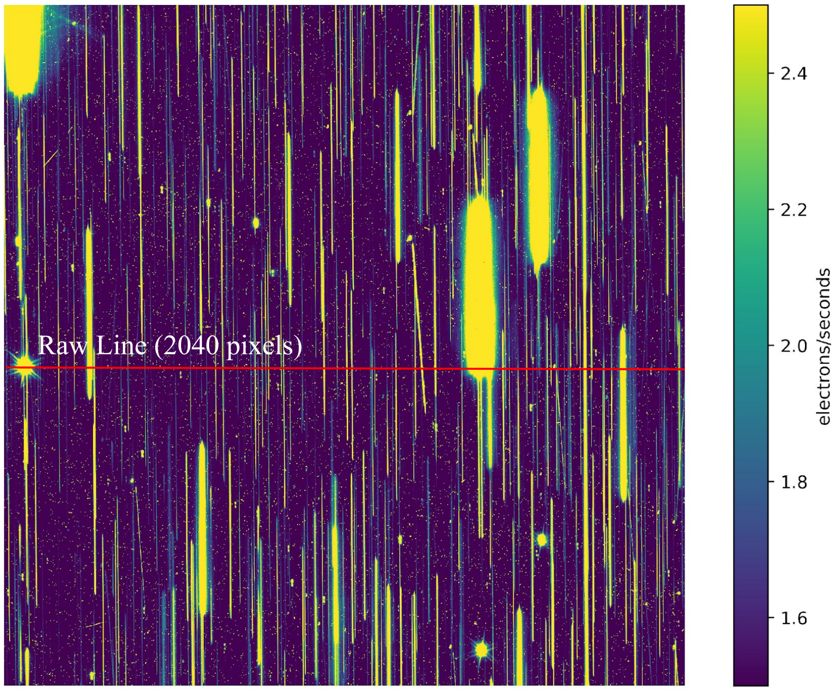
NISP Data Processing: the Averaged–Parameter (AP) approximation

Case Study. Spectroscopic MACC(15,16,11)

- ***ZODIACAL BACKGROUND*** (Scientific Images)

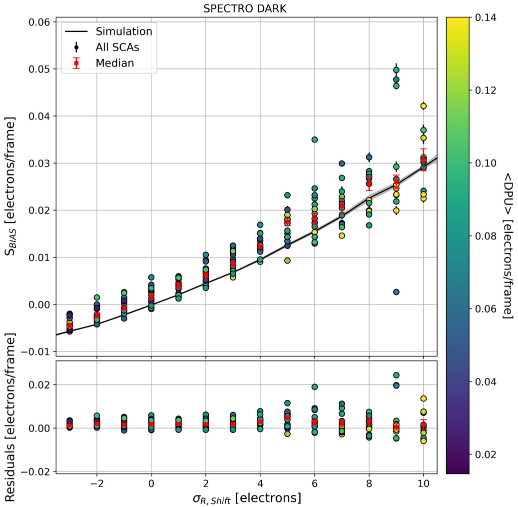


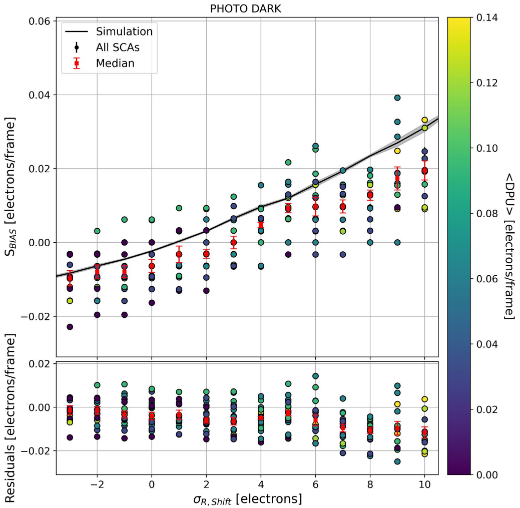
RGS000 exposure (not calibrated)



NISP Data Processing: the Averaged Parameterization approximation

DARK





NISP Data Processing: the Averaged Parameterization approximation

ZODIACAL BACKGROUND