Instrument Science Report COS 2023-23(v1)

Cycle 29 COS NUV Dark Monitor Summary

Christian I. Johnson[1]

[1] Space Telescope Science Institute, Baltimore, MD

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ABSTRACT

This Instrument Science Report describes the data analysis and results from the Cycle 29 NUV Dark Monitoring Program for the Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope covering dates between November 2021 to October 2022. We present an overview of the calibration plan and summary of the derived NUV MAMA dark rates. We compare the dark rates reported for the Exposure Time Calculator (ETC), which was 1.20×10^{-3} *counts pixel*$^{-1}$ *second*$^{-1}$*, to the final dark rate value measured over the full calibration cycle, which was slightly higher at* 1.24×10^{-3} *counts pixel*$^{-1}$ *second*$^{-1}$*. The full Cycle 29 NUV dark rate increased by about 12% compared to the Cycle 28 NUV dark rate. We measure the magnitude of the increase in the mean NUV dark rate with time, finding a slope of about* 2.55×10^{-5} *counts pixel*$^{-1}$ *second*$^{-1}$ *year*$^{-1}$*. Additionally, we report on the discovery of a repeating sinusoidal pattern in the NUV dark rate with an amplitude of about* 1.38×10^{-4} *counts pixel*$^{-1}$ *second*$^{-1}$ *within each 366 day period.*

Contents

1. Introduction

The COS NUV MAMA dark rate is monitored with a calibration program that takes two 22-minute dark exposures every two weeks, resulting in 52 orbits throughout a typical cycle. The data from this program are used to track changes in the dark rate as a function of time, and also produce the dark rate values adopted by the Exposure Time Calculator (ETC). For Cycle 29, the NUV dark rate was monitored using Program 16535 ("Cycle 29 COS NUV Detector Dark Monitor", PI: Dashtamirova), which ran from November 2021 through October 2022.

2. Analysis and Results

For each exposure of Program 16535, a mean dark rate (counts pixel^{-1} second^{-1}) over the whole detector was calculated in 25 second intervals. Figure 1 shows the resulting dark rate calculations from this program along with those from previous cycles. The figure indicates that the Cycle 29 dark rate values and variations are consistent with those of previous cycles. The NUV dark rate appears to be relatively insensitive to the solar activity level, and instead Cycle 29 continued the long-term trend of a slowly increasing dark rate with time (see also §2.1). Ignoring the dark rate data during the period of rapid increase (2009-2013), including the data from Cycle 29 gives an increase (slope) in the mean NUV dark rate of $\sim 2.55\times10^{-5}$ counts pixel^{-1} second^{-1} year^{-1}.

Figure 2 shows the binned dark rate distribution for the full Cycle 29 dark rate monitoring time frame. We calculate several dark rate thresholds from the binned distributions, but only the upper 95% value is reported for the ETC. This ensures that most users will take NUV observations with dark rates lower than those used by the ETC. For version 29.2 of the ETC, the reporting window included data from March 2021 through March 2022 so the upper 95% dark rate was 1.20×10^{-3} counts pixel^{-1} second^{-1}. This value is similar to the final dark rate from the full Cycle 29 monitoring program of 1.24×10^{-3} counts pixel^{-1} second^{-1}, which includes data from November 2021 through October 2022. However, note that the first 4 visits of Program 16535 failed so the actual data range spans December 3, 2021 through October 17, 2022. The full Cycle 29 NUV dark rate is about 12% higher than the 1.11×10^{-3} counts pixel^{-1} second^{-1} reported for Cycle 28 by Johnson & Dashtamirova (2022).

2.1 Time-Dependent Periodic Dark Rate Variations

As noted in §2, the NUV dark rate trend is characterized by an initial rapid increase in the first few years of COS operation followed by a much more shallow, long-term increase at a rate of about 2.55×10^{-5} counts pixel^{-1} second^{-1} year^{-1}. However, visual inspection of the top panel of Figure 1 shows evidence of a repeating sinusoidal feature having a period of approximately 1 year. To investigate this phenomenon, we

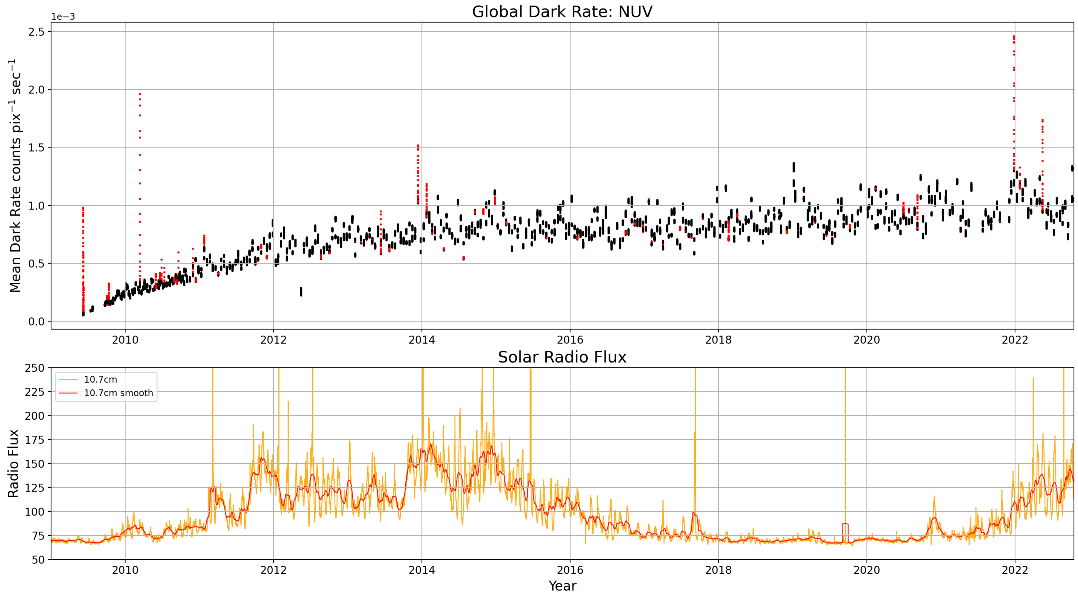

Figure 1. The COS NUV dark rate as a function of time, spanning from the beginning of COS operations through the end of Cycle 29. The dark rate is measured in 25 second intervals, which is then plotted against the time in decimal year (top). Groupings of points occur naturally, as they correspond to the individual exposures, and the dark rates can also vary throughout an exposure. Points in red indicate observations taken near the South Atlantic Anomaly and are not included in the dark rate calculations. The bottom panel shows the 10.7 cm radio flux trend as a tracer of solar activity.

performed a frequency analysis on all of the dark monitor data between fractional years 2013.5 and 2022.794 (end of Program 16535), excluding data near the South Atlantic Anomaly. The resulting periodogram is shown in the bottom panel of Figure 3. While multiple peaks are found near integer multiples of 7-day periods, which are driven by the observing cadence of the dark monitor program, a significant peak is found at 366 days. Combining the long-term linear trend with a sinusoidal function gives the functional form:

$$r_{dark} = m \cdot t + b + Asin(\frac{2\pi}{P} + \phi), \tag{1}$$

where r_{dark} is the NUV MAMA dark rate, m and b are the slope and intercept of the linear portion, t is the time in fractional years, A is the amplitude of the periodic function, P is the period from the frequency analysis, and ϕ is the phase shift. The solid red line in the top panel of Figure 3 shows the resulting fit and indicates that the

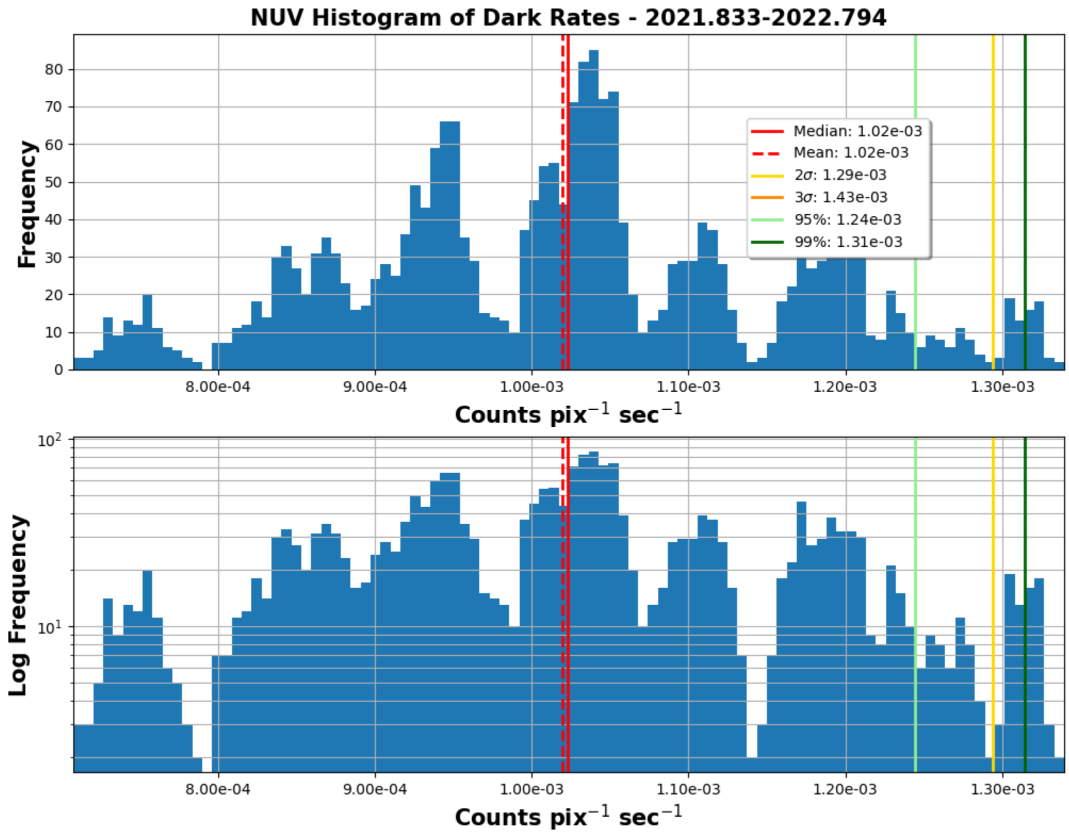

Figure 2. The top panel shows the binned frequency with which various dark rates appeared throughout the Cycle 29 dark monitor calibration program. The solid and dashed red lines indicate the median and mean dark rates while the yellow, orange, light green, and dark green solid lines indicate the 2σ, 3σ, 95%, and 99% values of the binned distribution. For the ETC, the 95% values from the previous 12 months are reported. Note that while the ETC dark rate reported for version 29.2 was 1.20 counts pixel^{-1} second^{-1}, the 95% value over the full cycle was slightly higher at 1.24 counts pixel^{-1} second^{-1}, due to differences in the reporting time frame. The bottom panel shows the same information but using the log of the frequency bins.

NUV MAMA dark rate predictably oscillates with an approximately one year period. The peak-to-trough variation within a given cycle is about 1.38×10^{-4} counts pixel^{-1} second^{-1}.

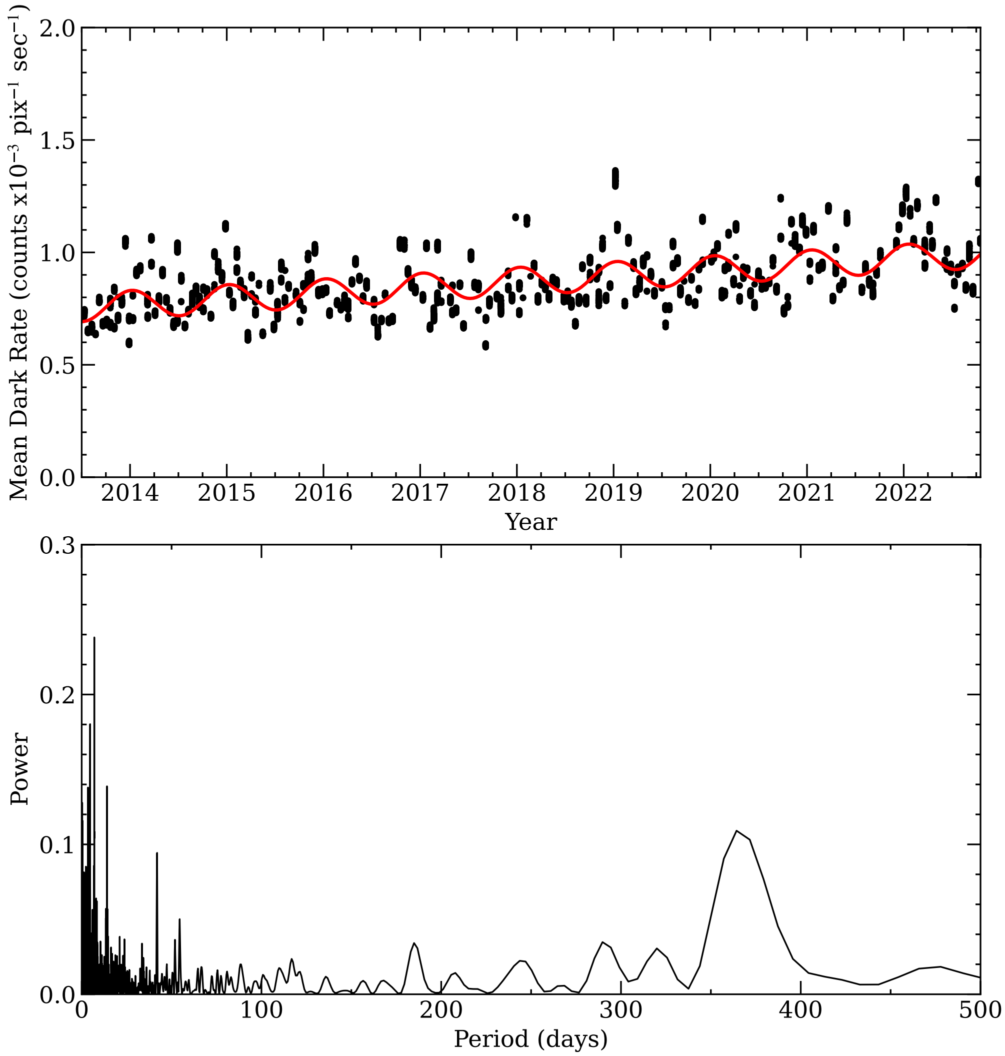

Figure 3. The top panel shows the linear portion of the NUV dark rate monitor, which extends from mid-2013 through the end of the Program 16535. The solid red line is a model fit that includes a linear function to account for the long-term increasing dark rate trend plus a sinusoidal function that models the higher frequency, periodic variations. The filled black data points do not include observations near the South Atlantic Anomaly (red points in Figure 1). The period of the sinusoidal function is ~366 days, which corresponds to a large peak in the periodogram in the bottom panel near log(P) = 2.56 days. Note that the tall, thin features on the left side of the bottom panel tend to fall near integer multiples of 7-day periods, which matches the typical visit schedule.

3. Summary

The COS NUV MAMA detector continues to follow the previously observed trend of a slow increase in dark rate with time. Data covering the period between 2013 and 2022 indicates that the mean dark value increases with a rate of about 2.55×10^{-5} counts pixel^{-1} second^{-1} year^{-1}. For the full Cycle 29 NUV dark calibration program, the 95% dark rate value was 1.24×10^{-3} counts pixel^{-1} second^{-1}, which is slightly higher than the value of 1.20×10^{-3} counts pixel^{-1} second^{-1} reported for the ETC and 12% higher than the Cycle 28 dark rate. However, we discovered a periodic signal in the dark rate monitor indicating that the dark rate varies by $\sim 1.38 \times 10^{-4}$ counts pixel^{-1} second^{-1} over a period of about 1 year. We will continue this monitoring program into future cycles and perform new analyses as necessary.

Change History for COS ISR 2023-23

Version 1: 30 October 2023- Original Document

Johnson, C. I., & Dashtamirova, D., 2022, COS Instrument Science Report COS 2022-07, "Cycle 28 COS NUV Dark Monitor Summary"