MuSCAT4 Release Notes

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This document outlines the changes and performance of the MuSCAT4 instrument at LCO's 2-meter telescope at Siding Spring Observatory (COJ). The information herein supplements and supersedes, where applicable, the MuSCAT3 Release Notes.

Users should provide feedback or ask questions via science-support@lco.global.

What's New?

MuSCAT4 at COJ is a copy of MuSCAT3 at OGG (Haleakala Observatory) with the following important modifications:

1. To prevent CCD saturation when observing bright targets, MuSCAT4 has narrow-band filters. MuSCAT3 has photonic diffusers for this same purpose, but the ability to request the diffusers was discontinued on September 20, 2023. MuSCAT3 has an identical set of narrow-band filters since December 2023.
2. The cameras in MuSCAT4 are liquid-cooled to accommodate the higher temperatures at COJ in comparison to OGG.

Submission of Observing Requests

Requests for MuSCAT observations submitted to the portal API must set

```
'Instrument_type': '2M0-SCICAM-MUSCAT'
```

in the `configurations` dictionary. In the portal UI, requests must select "2.0 meter Muscat" from the **Instrument** menu in the Configuration section. (For guidance on composing observation requests for MuSCAT, consult the Getting Started with MUSCAT API & Portal Requests document.) The specific instrument (MuSCAT3 or MuSCAT4) must not be selected. Targets observable from both sites may be scheduled on either of the MuSCAT instruments.

MuSCAT4 Detector Performance

The read noise and full well of the cameras in the different readout modes are given in the table below:

Passband	Camera ID	Read Noise [e-] FAST / SLOW mode	Full well [kADU / ke-]	Gain [e-/ADU]
g’	ep06	15.5 / 4.9	64 / 113	1.75
r’	ep07	12.7 /4.6	64 / 117	1.84
i’	ep08	13.1 / 4.0	46 / 80	1.73
zs	ep09	17.3 / 6.1	64 / 148	2.32

MuSCAT4’s detectors are cooled to -70 deg C due to the higher maximum ambient temperatures at the COJ site. The MuSCAT3 detectors at OGG are cooled to -80 deg C.

Image Quality

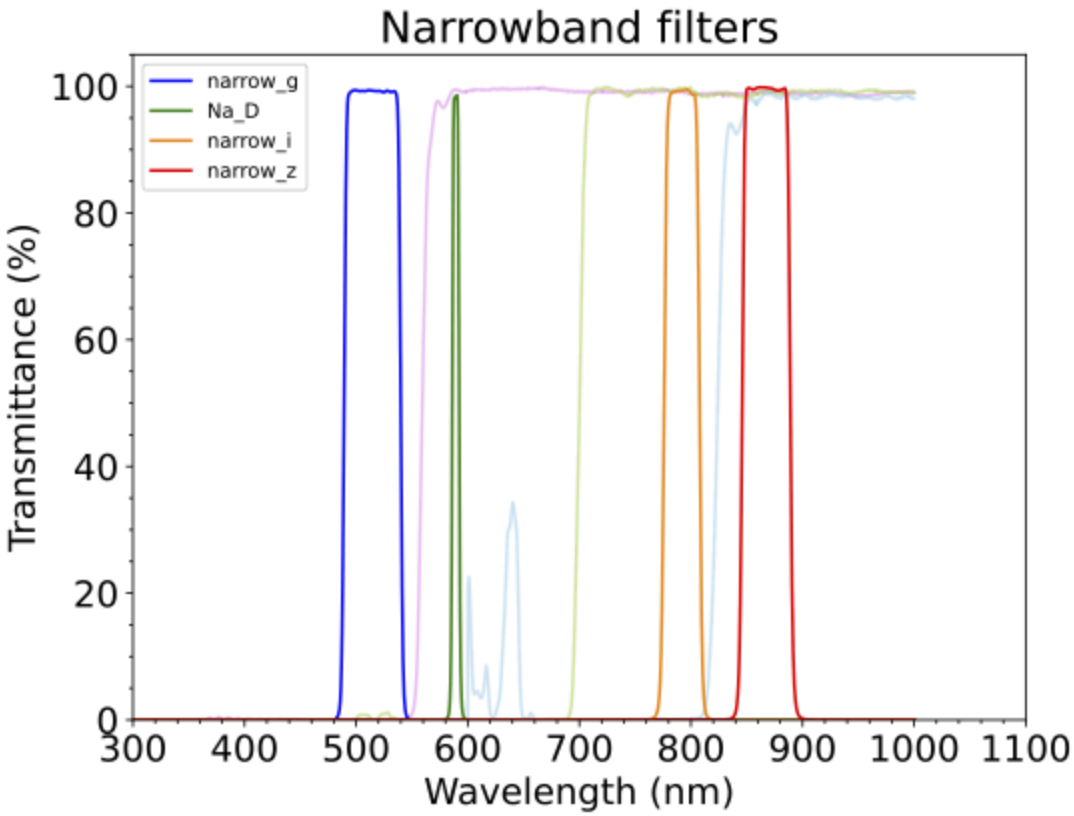
Between the initial camera alignment and the installation on the telescope, the focus of some cameras changed, causing a relative focus offset of the order of 0.5 mm (in the focal plane). During typical seeing conditions at COJ, the relative defocus is not as critical, but it will be improved the next time that MuSCAT4 is removed from the telescope, e.g., when the primary mirror is realuminised.

Narrow-band filters

To observe bright targets, narrow-band filters can be inserted into the beam in place of the broad-band SDSS filters. An identical set of narrow-band filters was installed in MuSCAT3 in December 2023; observation requests for the narrow-band filters are schedulable at either MuSCAT site, depending on target location.

The narrow-band filter specifications are as follows:

Channel	NB filter name	Center / width [nm]
g’	g_narrow	515 / 51
r’	Na_D	589.1 / 6.2
i’	i_narrow	792 / 32
zs	z_narrow	868 / 43



Selecting narrow-band filters:

The portal API and UI have options for placing the narrow-band filters IN or OUT[1] of the optical path. The conventions are:

> Narrow-band filter **IN**: The narrow-band filter is in the beam in lieu of the SDSS filter.
> Narrow-band filter **OUT**: The SDSS filter is in the beam. **This is the default.**

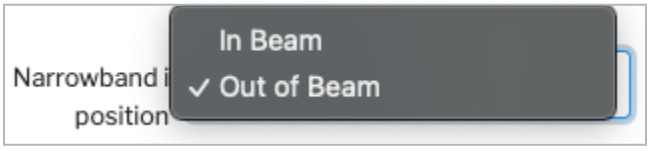
For API observation requests, the narrow-band filter placement is controlled by the `optical_elements` dictionary:

```
'optical_elements': {
          'narrowband_g_position': 'out',
          'narrowband_r_position': 'out',
          'narrowband_i_position': 'out',
          'narrowband_z_position': 'out',
          },
```

[1] This convention is based on MuSCAT3, for which the photonic diffusers were moved into or out of the beam.

This is a change from the API introduced for MuSCAT3; the word “narrowband” has replaced “diffuser”. Users submitting requests to the portal API must update their scripts.

For observation requests composed in the portal UI, “In Beam” must be selected from the appropriate menu in the Instrument Configuration section:



Telescope Guiding

As for MuSCAT3, telescope guiding can be achieved either via the facility guider or via self-guiding by MuSCAT. The guiding selection logic remains the same. From the MuSCAT3 Release Notes: “If Guiding is set to On, then guiding will be attempted using the facility guider. If the attempt fails, the observation will be discontinued. If Guiding is set to Optional, then guiding will also be attempted with the facility guider, but if the attempt fails, the observation will continue without guiding. If Guiding is set to Off, then self-guiding will be used. The channel chosen for guiding will be the one with the shortest exposure time that is greater than 5 seconds.”

Acknowledgement of MuSCAT

All papers based on MuSCAT3 and / or MuSCAT4 data shall contain the following acknowledgement:

“This paper is based on observations made with the MuSCAT instruments, developed by the Astrobiology Center (ABC) in Japan, the University of Tokyo, and Las Cumbres Observatory (LCOGT). MuSCAT3 was developed with financial support by JSPS KAKENHI (JP18H05439) and JST PRESTO (JPMJPR1775), and is located at the Faulkes Telescope North on Maui, HI (USA), operated by LCOGT. MuSCAT4 was developed with financial support provided by the Heising-Simons Foundation (grant 2022-3611), JST grant number JPMJCR1761, and the ABC in Japan, and is located at the Faulkes Telescope South at Siding Spring Observatory (Australia), operated by LCOGT.“

The paper to cite for both the MuSCAT3 and MuSCAT4 instruments is Narita et al. 2020, Proceedings of the SPIE, Volume 11447.

```
@INPROCEEDINGS{Muscat3SPIE,
        author = {{Narita}, Norio and {Fukui}, Akihiko and {Yamamuro}, Tomoyasu and {Harbeck}, Daniel and {Bowman}, Mark and {Elphick}, Mark and {Nation}, Jon and {Armstrong}, J.~D. and {Han}, Jacqueline and {Abe}, Shunichi and {Ikoma}, Masahiro and {Isogai}, Keisuke and {Kawauchi}, Kiyoe and {Kurita}, Seiya and {Kusakabe}, Nobuhiko
```

```
and {de Leon}, Jerome and {Livingston}, John and {Mori}, Mayuko and {Nishiumi}, Taku and {Tamura}, Motohide and {Watanabe}, Noriharu and {Volgenau}, Nikolaus and {Heinrich-Josties}, Elisabeth and {Foale}, Steve and {Daily}, Matt and {McCully}, Curtis and {Kirby}, Annie and {Smith}, Cary and {Haworth}, Brian and {Conway}, Patrick and {Storrie-Lombardi}, Lisa and {Rosing}, Wayne and {Chatelain}, Joey and {Bachelet}, Etienne and {Johnson}, Marshall and {Rabus}, Markus},
         title = "{MuSCAT3: a 4-color simultaneous camera for the 2m Faulkes Telescope North}",
     booktitle = {Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series},
          year = 2020,
        series = {Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series},
       volume = {11447},
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           eid = {114475K},
         pages = {114475K},
           doi = {10.1117/12.2559947},
       adsurl = {https://ui.adsabs.harvard.edu/abs/2020SPIE11447E..5KN},
      adsnote = {Provided by the SAO/NASA Astrophysics Data System}
}
```


Relevant links

- Overview of the MuSCAT3 instrument
- Getting Started with MUSCAT API & Portal Requests