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From: N. R. Izenberg

Subject: Bandpasses for CONTOUR imagers

References: (1) N. R. Izenberg, Master Calibration Record Parts 1-4

(2) M. R. Keller, B. Gotwols, Imagers Report SRO-02M-30

Summary

Bandpasses for spectral filters of Comet Nucleus Tour (CONTOUR) imagers: CONOUR Remote Imager/Spectrometer (CRISP) and CONTOUR Forward Imager (CFI). Both imagers had 9 narrow band "spectral" filters covering wavelengths of science interest and one broadband "clear" filter. Each spectral filter was characterized using monochromatic scans across its bandpass. The spectral bandpasses for all filters were within desired specifications.

Introduction

CONTOUR's CFI and CRISP Imager are the two CCD-camera instruments on the CONTOUR spacecraft. Each imager has a 10-filter filter wheel in between the telescope optics and the CCD. Nine of the filters are "spectral" and one is a "clear" or wide-bandpass filter. Accurate knowledge of the bandpasses of the imager filters is required for analysis of the flight data. The bandpass is defined as wavelength range of light allowed through the filter at high transmission levels (Transmission >0.5). CRISP spectral filters were predominantly for geological study of the comet targets and were relatively broadband (~ 40 nm across), while CFI filters were for coma studies and approach imaging, with narrower filters (5-15 nm), the narrowest being UV filters primarily for coma emission features.

To support this bandpass analysis, a series of monochromator scan images were collected during the calibration of the instruments. The various light wavelengths were generated in the APL Optical Calibration Facility (OCF) using the facility monochromator and exit pinholes. A high-resolution calibration of this test equipment was completed in summer '01 and supplemented during CONTOUR calibration.

In addition to computing the bandpass, the monochromator wavelength scans have been used to estimate the out of band light sensitivity within the filters of CRISP Imager and CFI sensor.

Filter Specifications

All CRISP and CFI filters were built and initially tested by Barr. Figures 1 and 2 show the transmission of all the filters in both CFI and CRISP determined by Barr.

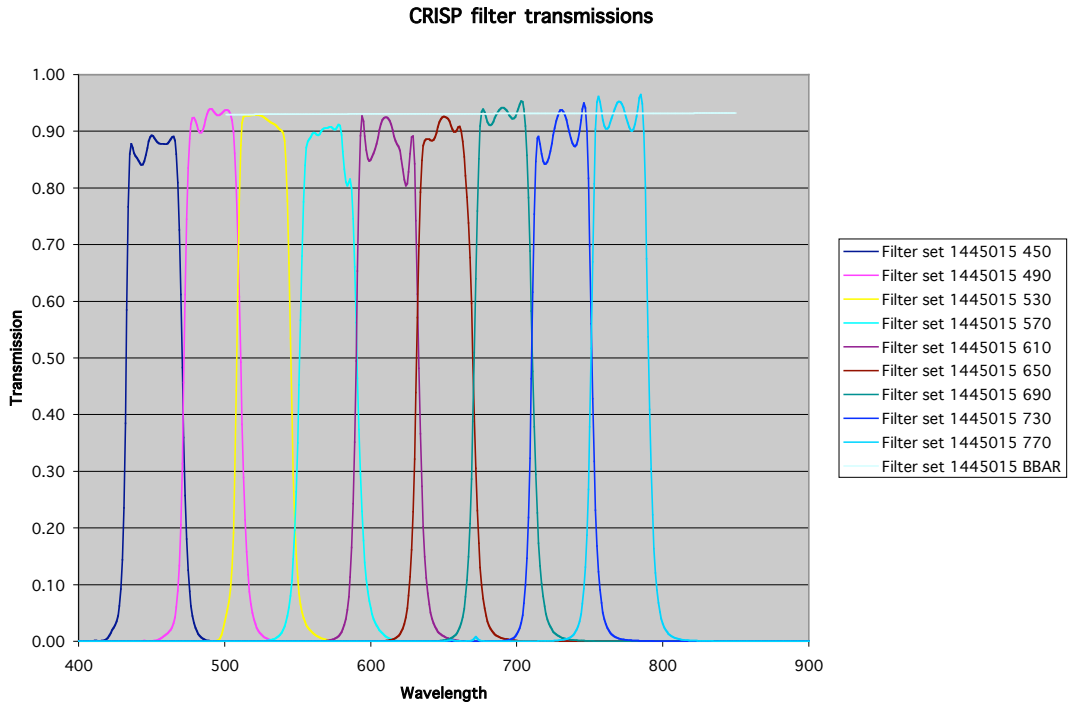


Figure 1. CRISP Filter Transmission. The broad horizontal light blue line indicates the bandpass of the "clear" filter.

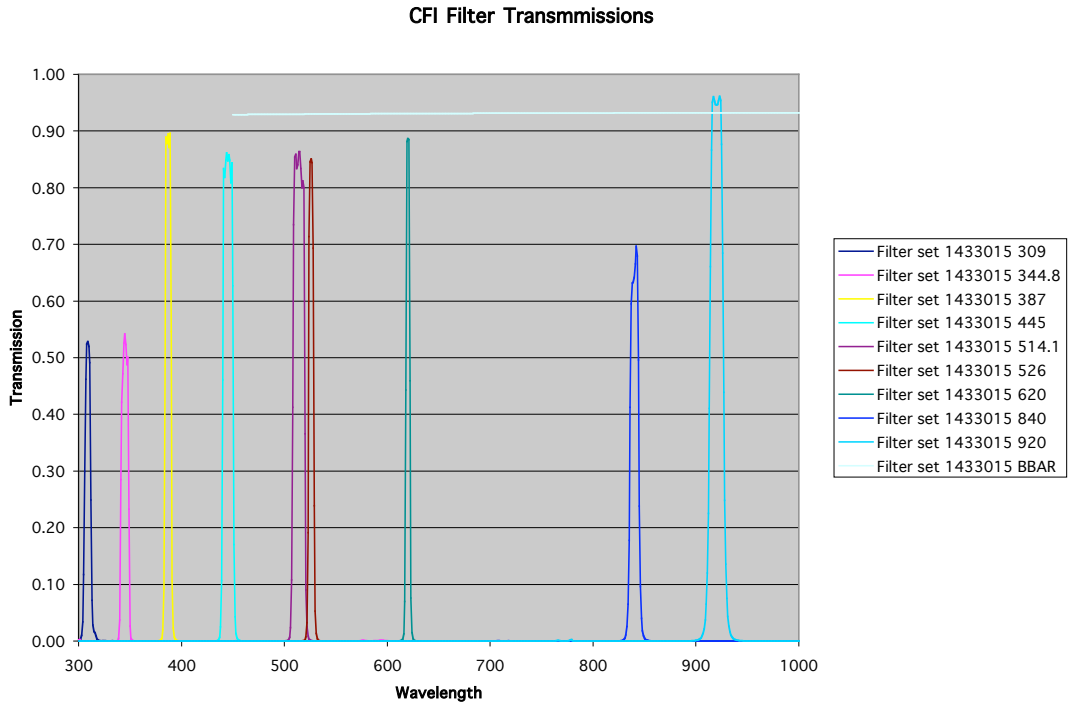


Figure 2. CFI Filter Transmission. The broad horizontal light blue line indicates the bandpass of the "clear" filter.

Monochromator Test Conditions

The test setup for bandpass determination utilized the OCF monochromator, fed by a small, extended light source. The monochromator narrowed the light incoming to the instrument to a near-pinpoint with restricted (~ 1nm FHWM) wavelength. For each imager filter a series of dark images was taken followed by wavelength scans. For each image of the wavelength scan, the Monochromator wavelength changed, going from 10-20 nm out of expected bandpass on one side, to 10-20 nm out of the band pass on the other side. Each filter was tested for its own wavelength range. Narrow Band CFI filters were additionally tested with out-of-band rejection filters added to the light path.

Images were analyzed after subtracting background, dark current, and subtracting frame transfer smear (Ref. 2). Additional dark correction was provided by averaging pixels to either side of the point source in illuminated images. Relative response for a given monochromator wavelength was determined by integrating light over a box of imager pixels centered on the brightest pixel of a given image. The box was centered on the centroid of the spot of a given filter's nominal central wavelength. A series of increasing-size boxes were examined until the signal in the image was maximized for the nominal central wavelength, then the same box size was used for all monochromator wavelengths across that filter. Resulting response was normalized to unity for maximum integrated signal from all wavelengths across a given filter, to give relative response across the filter's spectral ranges.

The data for imager filter bandpasses were taken during calibration runs CIBMA_PW2 for CRISP and CFCCC_FWV for CFI. Master Calibration Record (MCR) entries (Ref. 1) for the runs used is presented below in the MCR format.

CIBMA_PW2 – Post-environmental CRISP Wavelength scan

CI	B	M	A	_	P	W2
CRISP Imager	Post-Env	Medium (-30 C) Chamber	Ambient Detector		M/C Point Source	Wavelength Scan 2

Date of Test	Logbook Page(s)	Operator(s)
12/25/01	CRISP II: 41-42	NI

Wavelength scan across spectral filters - ~ 4 nm bandwidth monochromator settings. Script error recorded 90 darks instead of 10 at start of script.

Run 02:

Number of images: 289
Filts: 2-10, Exp time: 980 ms
Darks (Images 1-100)
Filt 2, 1640 nm-1960 nm scan in 16 nm steps (4^{th} Order) (91-111)
Filt 3, 1800 nm-2120 nm scan in 16 nm steps (4^{th} Order) (112-132)
Filt 4, 1960 nm-2280 nm scan in 16 nm steps (4^{th} Order) (133-153)
Filt 5, 2120 nm-2440 nm scan in 16 nm steps (4^{th} Order) (154-174)
Filt 6, 2280 nm-2600 nm scan in 16 nm steps (4^{th} Order) (175-195)
Filt 7, 2440 nm-2760 nm scan in 16 nm steps (4^{th} Order) (196-216)
Filt 8, 2600 nm-2920 nm scan in 16 nm steps (4^{th} Order) (217-237)
Filt 9, 2680 nm-3160 nm scan in 16 nm steps (4^{th} Order) (238-268)
Filt 10, 2920 nm-3240 nm scan in 16 nm steps (4^{th} Order) (269-289)
History File: Yes
Notes from History file: n/a
Notes from Logbook:
Test performed after fiddling with MC setup to get bright spot in decent focus.

CFCCC_FWV - Wavelength Scan

CF	C	C	C	_	F	WV
CFI	"Final" Cal	Cold (-30 C) Chamber	Cold Detector		"Fat" M/C Point Source	Wavelength Scan

Date of Test	Logbook Page(s)	Operator(s)
02/21/02-02/22/02	CFI I: 99-101	NI, PT, DH, KH, JW

BASELINE SCRIPT
Spectral filters only, fixed exp time for each.
4 Darks
Spectral scan across the filter region. Form 25 nm below center to 25 above.
UV filters (8-10) have extra scan across OOB rejection filters in the M/C setup

Runs executed:
Run 01:

Number of images: 0
Bad Run - script problems
Notes from History file: n/a
Notes from Logbook: n/a

Run 02:

Number of images: 546
Filters: Spectral
Filt 2: 4 Darks, then 1 nm step scan across filter (Images 1-54)
Filts 3-7 (55-324)
Filt 8: 4 darks, 1 nm step scan across filter + repeat across filter w. OOB in place (325-398)
Filts 9 and 10 same as 8 (399-546)
History File: Yes
Notes from History file: n/a
Notes from Logbook:
3936 counts at 527 nm - saturated. Prediction was ~3000 DN at this point.
UV filters showed low/no signal.
Exposure times set for 0 order monochromator, not 1st order

Run 03:
Number of images: 324 GOOD DATA
Filters: 2-7
History File: Yes
Notes from History file: n/a
Notes from Logbook:
Script rewritten as in Logbook
Filt 2: 4 Darks, then 1 nm step scan across filter (Images 1-54)
Filts 3-7 (55-324)
Aborted during Filter 8 Record 4 command, which choked on a 60 second record.
1st Order Monochromator exposure time

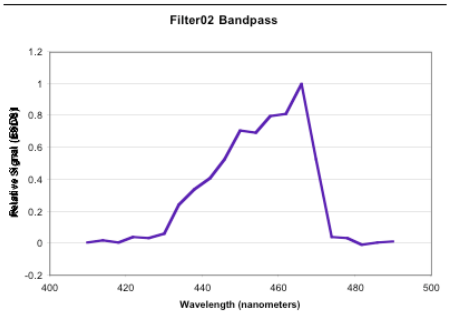
Run 07:
Number of images: 172 GOOD DATA
Filters: 8, 9, 10
Same as run 5. The only problem here is that the command to move the open filter into position after the darks for filter 10 was, for some reason, skipped - even though it was in the script. Filter 10 data is all dark.
History File: Yes
Notes from History file: n/a
Notes from Logbook: n/a

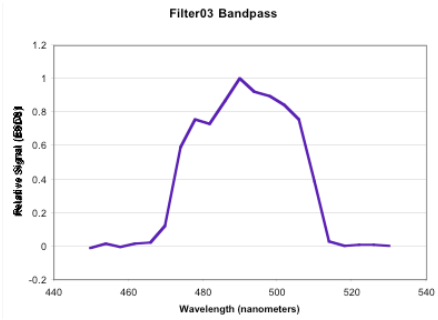
Run 08:
Number of images: 74 GOOD DATA
Filters: 10
CFCCC_WFV2 script hacked to CFCCC_WFV3_script. This contains *only* filter 10 data acquisition. Problem was in script where "CF" was used in place of "OCF"
Only problem here is that the bandpass filter did not go in, so we have 2 scans of the filter itself.
Despite this gross incompetence in script coding, we are *not* going to do another run.
History File: Yes
Notes from History file: n/a
Notes from Logbook: n/a

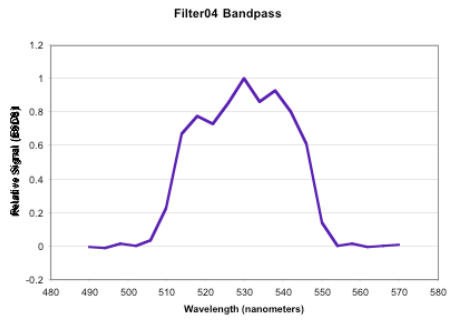
Bandpass Results

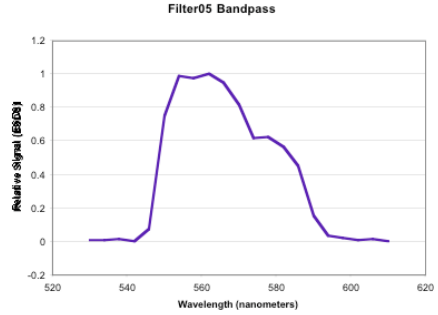
Data tables of results are appended as the PDF files CRISP_Bandpass_Data.pdf and CFI_Bandpass_Data.pdf. Results for spectral bandpasses are shown in Figure 3 for CRISP and Figure 4 for CFI.

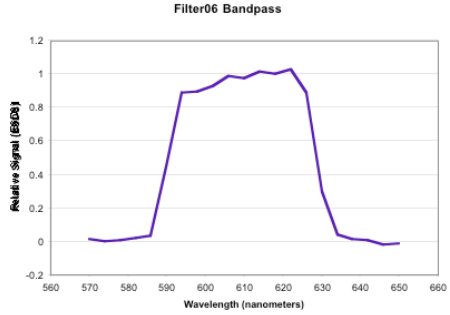
CRISP Spectral Filter Bandpasses: Relative Signal vs. Monochromator Wavelength.

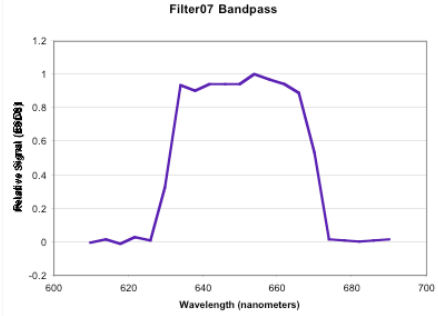


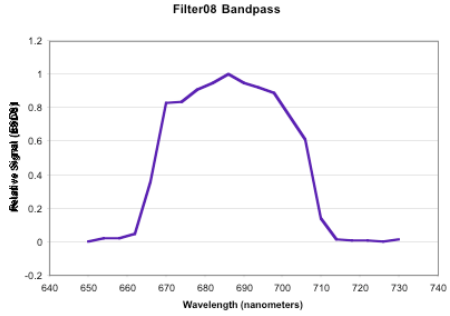


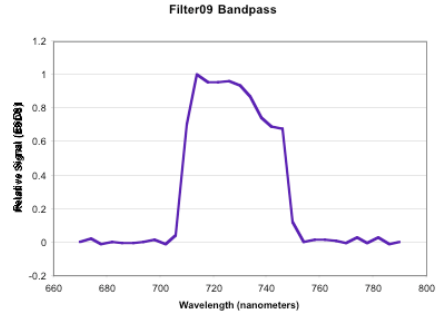


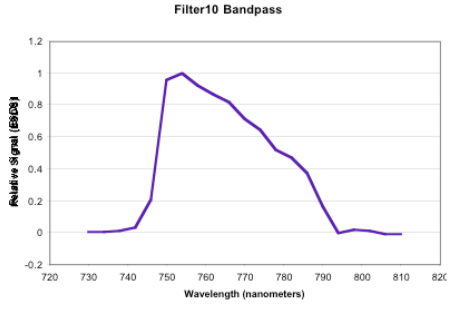












CFI Spectral Filter Bandpasses: Relative Signal vs. Monochromator Wavelength.

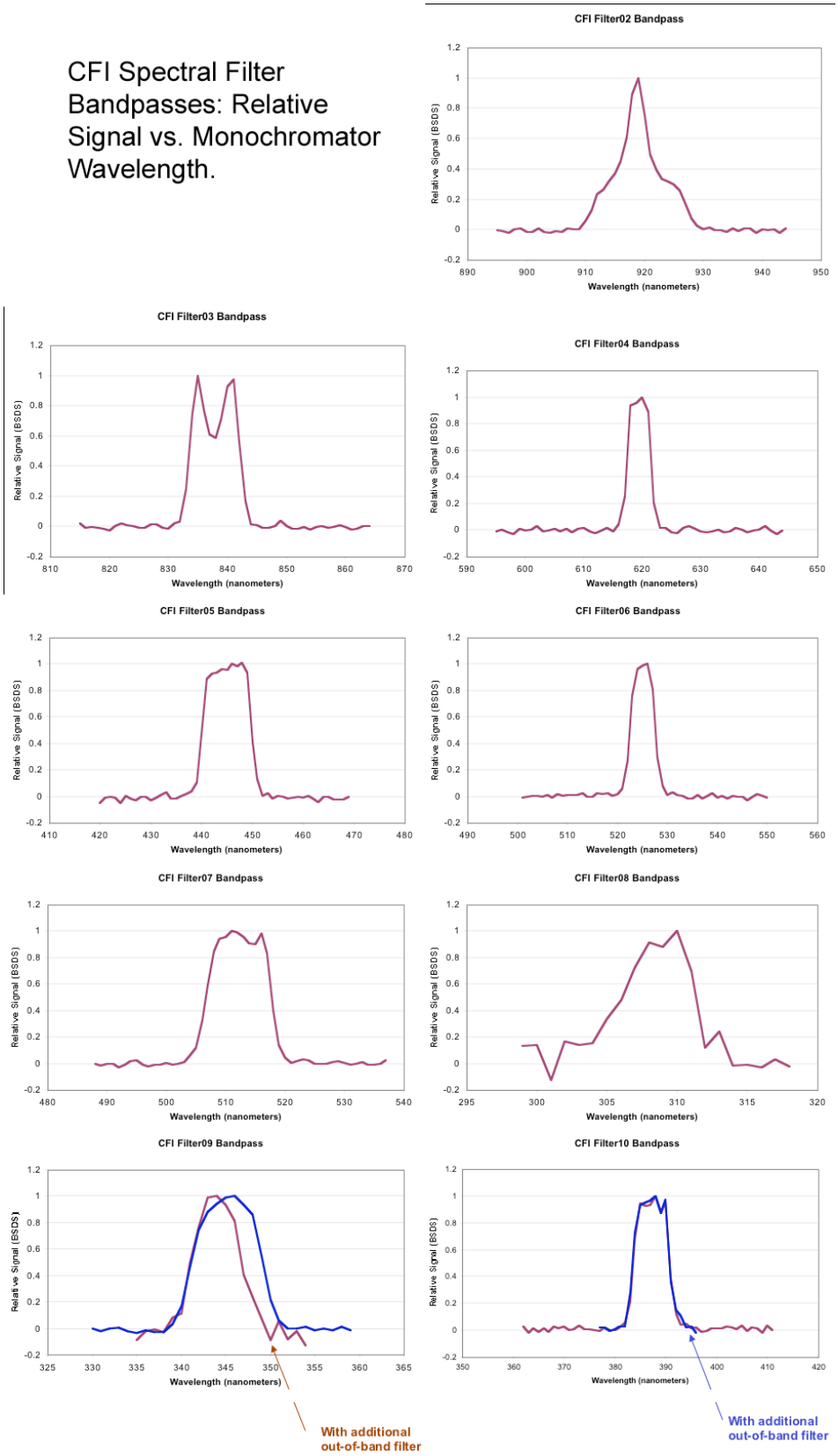


Figure 3. Relative response for CRISP spectral filters.
Figure 4. Relative response for CFI spectral filters. Filters 9 and 10 also have relative response thtough 10-nm band out-of-band rejection (OOB) filters. The Filter 9 OOB filter cut off inside the filter bandpass.

The CRISP_Bandpass_Data.pdf table shows, for each filter, the wavelength of monochromator light (4th order, in Angstroms), the effective wavelength for CRISP (in nm), the raw DN received by the instrument, the relative response (normalized to the wavelength of maximum response), and a wavelength weighting factor (relative response * wavelength). Band center is determined by summing the total relative response across the wavalangth scan and dividing by the total wavelength weight. Spectral width of the filter is determined by the full width half maximum (the wavelength range where the relative response is greater than 50% of maximum). The CFI_Bandpass_Data.pdf table shows effective wavelength from the monochromator (in Angstroms), and the raw DN response for each filter. Table 1 shows derived bandpass information for all spectral filters including effective center wavelength and band width.

TABLE1.

Summary Bandpass Information

CRISP		
Filter	Effective center	Effective width
2	454.9	24.96
3	491.4	31.68
4	529.9	30.44
5	566.2	32.12
6	609.8	37.72
7	650.5	37.44
8	685.4	34.00
9	727.6	34.76
10	764.6	30.72

CFI		
Filter	Effective center	Effective width
2	919.2	7.29
3	837.7	7.27
4	619.4	4.21
5	445.4	8.93
6	524.7	5.37
7	512.4	11.01
8	308.4	5.31
9	345.3	7.62
10	387.4	7.57

The relative response of the filters has obvious differences from the transmission specifications from Barr. The transmission results are direct measurements of only the filters themselves. The relative responses from the wavelength scans include effects of the camera optics and CCD Quantum Efficency. Sloped relative response functions at the shortest and longest wavelengths of CRISP, for example, are in part due to the falling off of the CRISP CCD QE.

Conclusions

Bandpasses for all filters of both CRISP and CFI imagers were acceptable.

Appendix - Supplements

Tables of Barr filter transmission and OCF wavelength scan response.

Table 1: CRISP Transmissivity is in the PDF file CRISP_filter_transmission_Barr.pdf
Table 2: CFI Transmissivity is in the PDF file CFI_filter_transmission_Barr.pdf

Tables 1 and table 2 list transmission of each spectral and "clear" filter for the two imagers at a given set of wavelengths. In both tables, Column 1 is wavelength in nanometers, columns 2-10 are the transmissions of each spectral filter in order of ascending center wavelength, and column 11 is the transmission of the broadband "clear" filter.

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