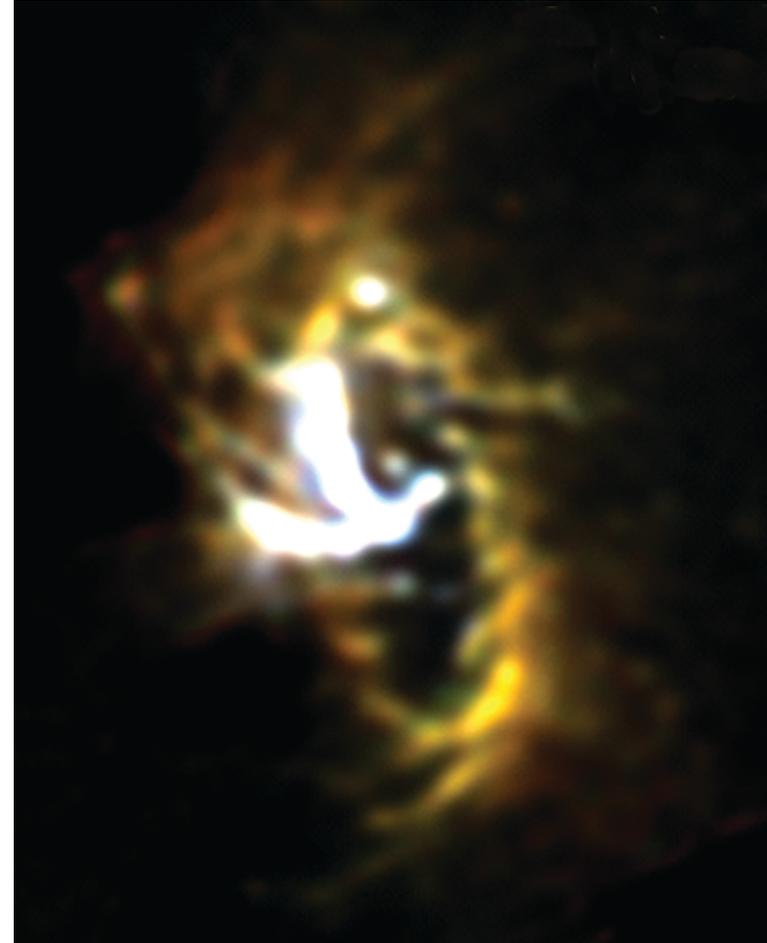


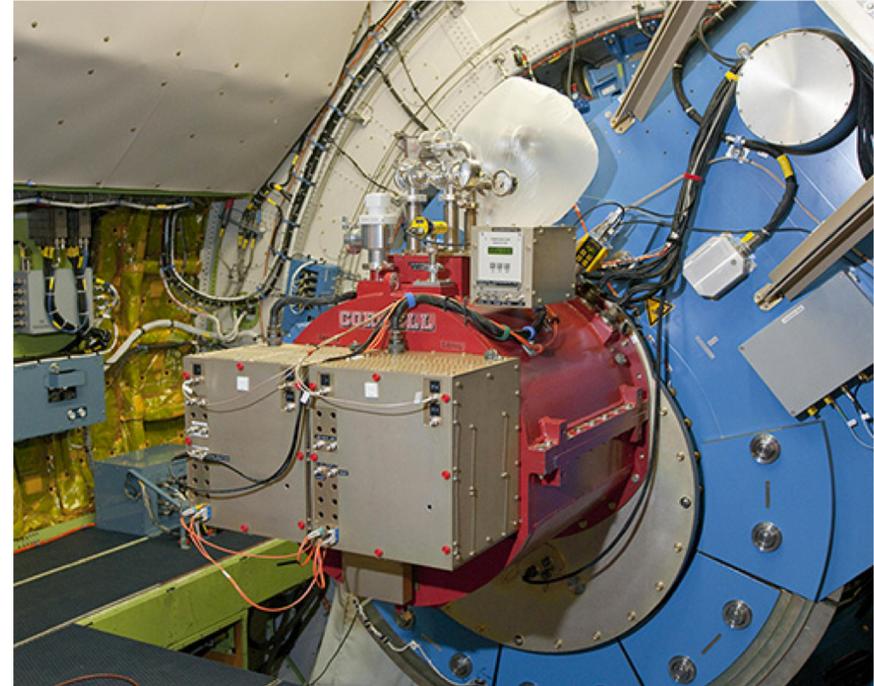
Mid-IR imaging and spectroscopy with FORCAST



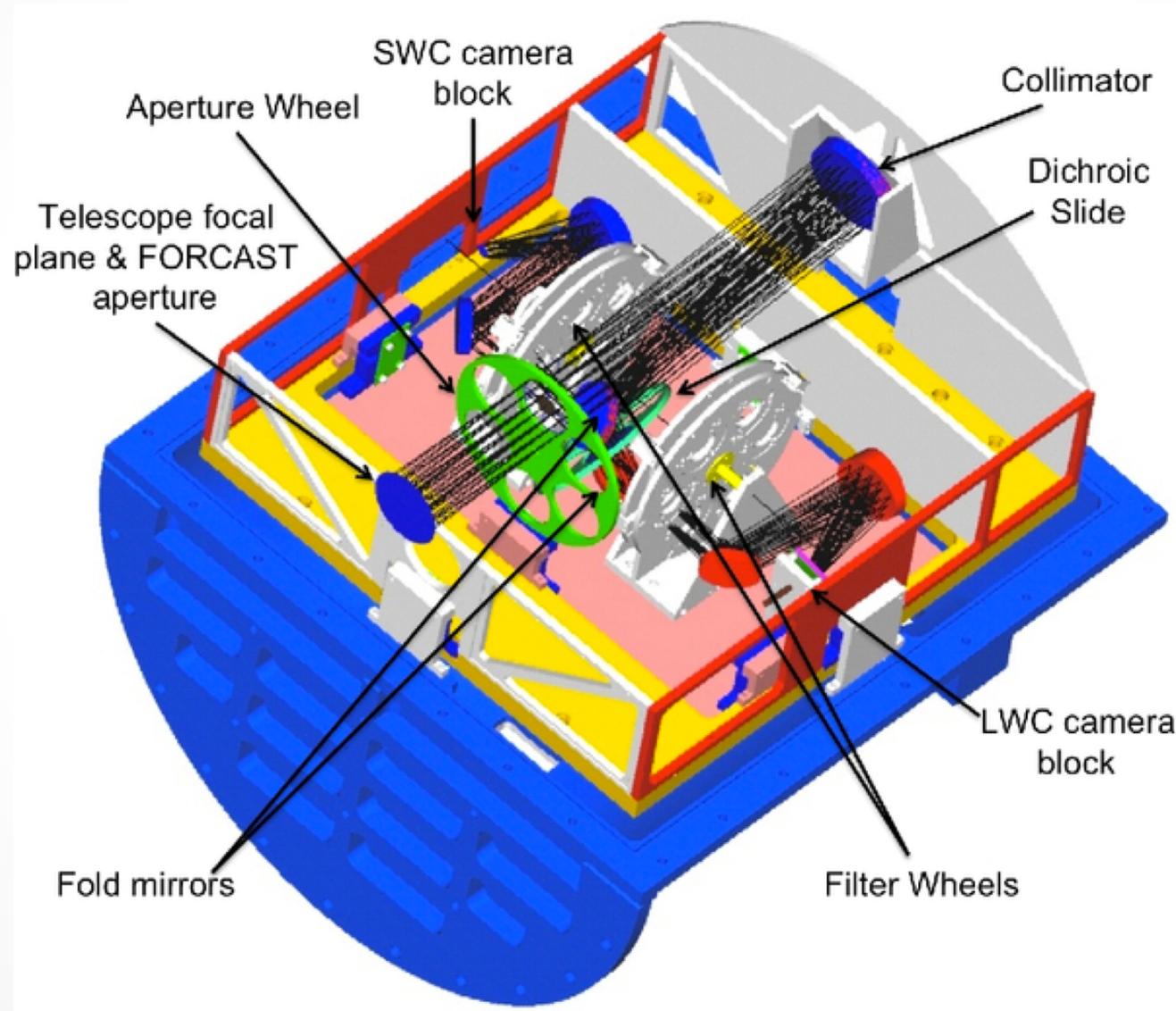
The galactic center with FORCAST
(NASA/DLR/USRA/DSI/FORCAST Team/Lau et al. 2013)

Faint Object infraRed CAmera for the SOFIA Telescope

- 2-channel mid-IR camera and grism spectrometer
- 1st Gen Instrument
- PI T. Herter (Cornell)
- Wide field (3.4' x 3.2' FOV) dual channel 5-40 μm camera and spectrograph
- SWC – Si:As BIB 256x256 array for 5-25 μm , 0.79"x0.75"pix, rebinned to 0.768" square
- LWC – Si:Sb BIB 256x256 array for 25-40 μm , 0.79"x0.75"pix, rebinned to 0.768" square
- 4 Grisms + 2 long slits provide low resolution ($R \sim 70-300$) spectroscopy over 5-40 μm



Schematics



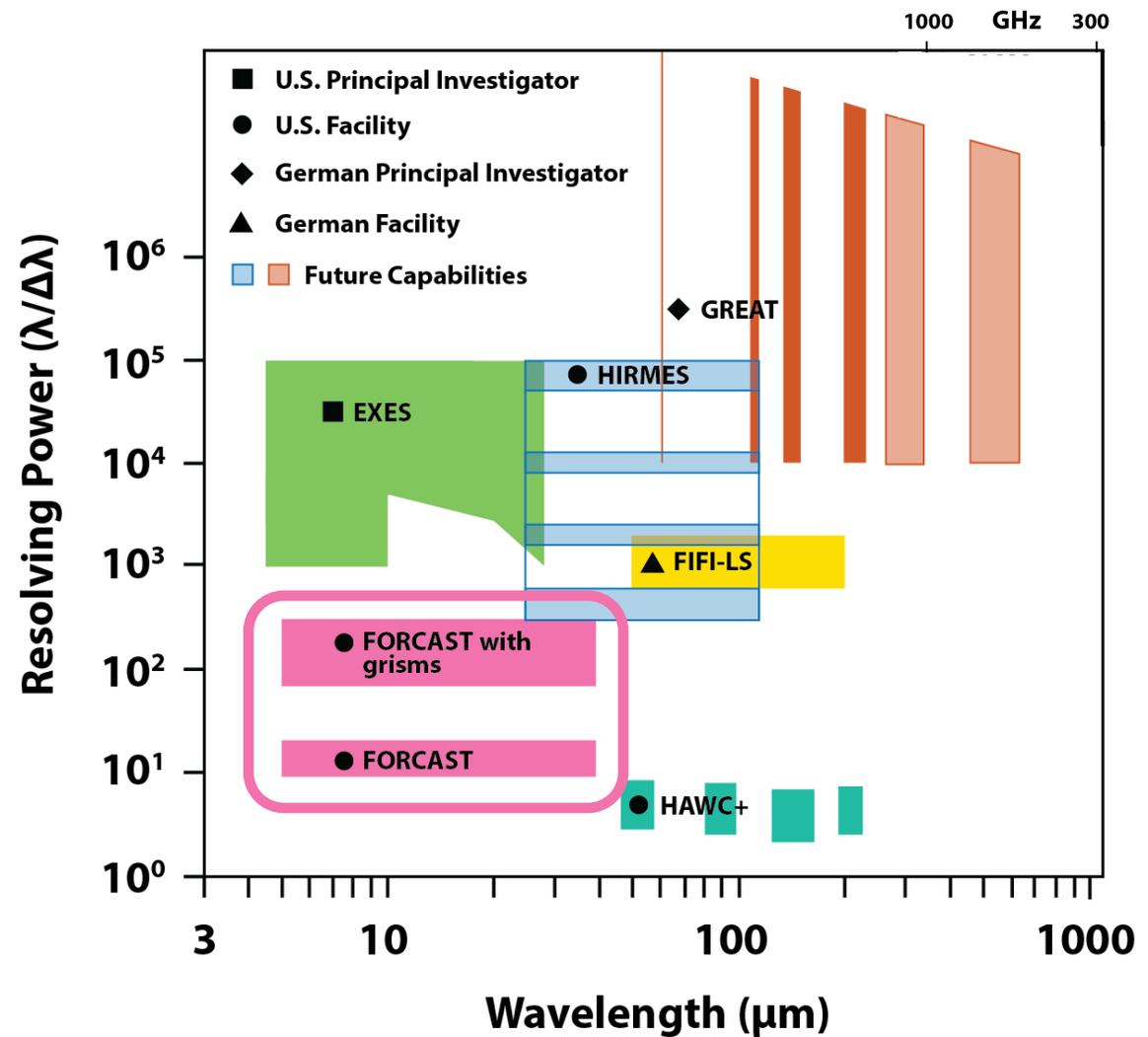
Filters and grisms

Filter Parameters

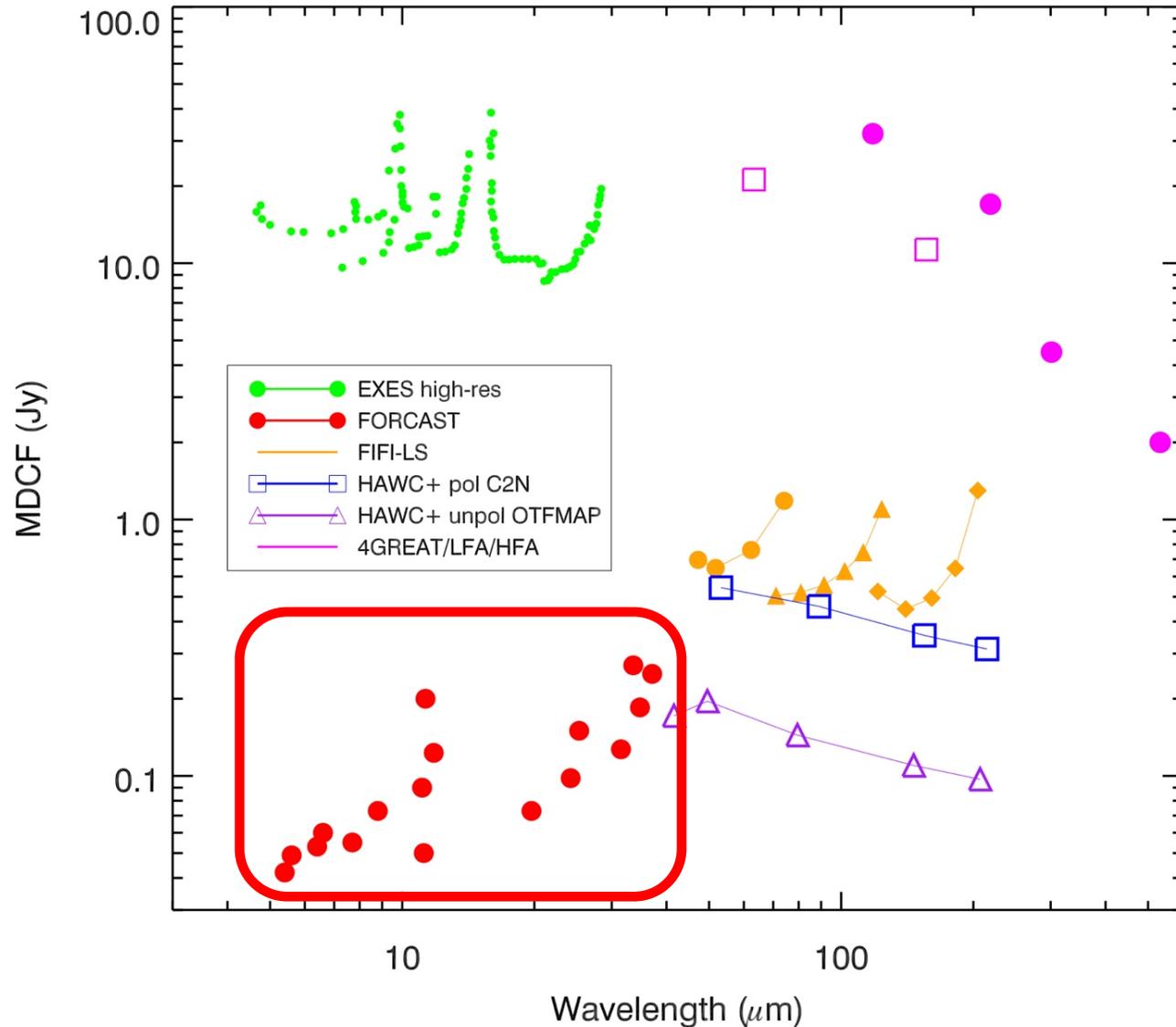
SWC Filters		LWC Filters	
λ_{eff} (μm)	$\Delta\lambda$ (μm)	λ_{eff} (μm)	$\Delta\lambda$ (μm)
5.4	0.16	24.2	2.9
5.6	0.08	31.5	5.7
6.4	0.14	33.6	1.9
6.6	0.24	34.8	3.8
7.7	0.47	37.1	3.3
8.8	0.41	A subset of these will be chosen each cycle as the nominal set.	
11.1	0.95		
11.2	2.7		
11.3	0.24		
11.8	0.74		
19.7	5.5		
25.4	1.86		

Grism Details

Grism	Coverage (μm)	$R (\lambda/\Delta\lambda)^a$
G063	4.9–8.0	120 ^c /180
G111	8.4–13.7	130 ^c /260
G227	17.6–27.7	110/120
G329	28.7–37.1	160/170 ^b



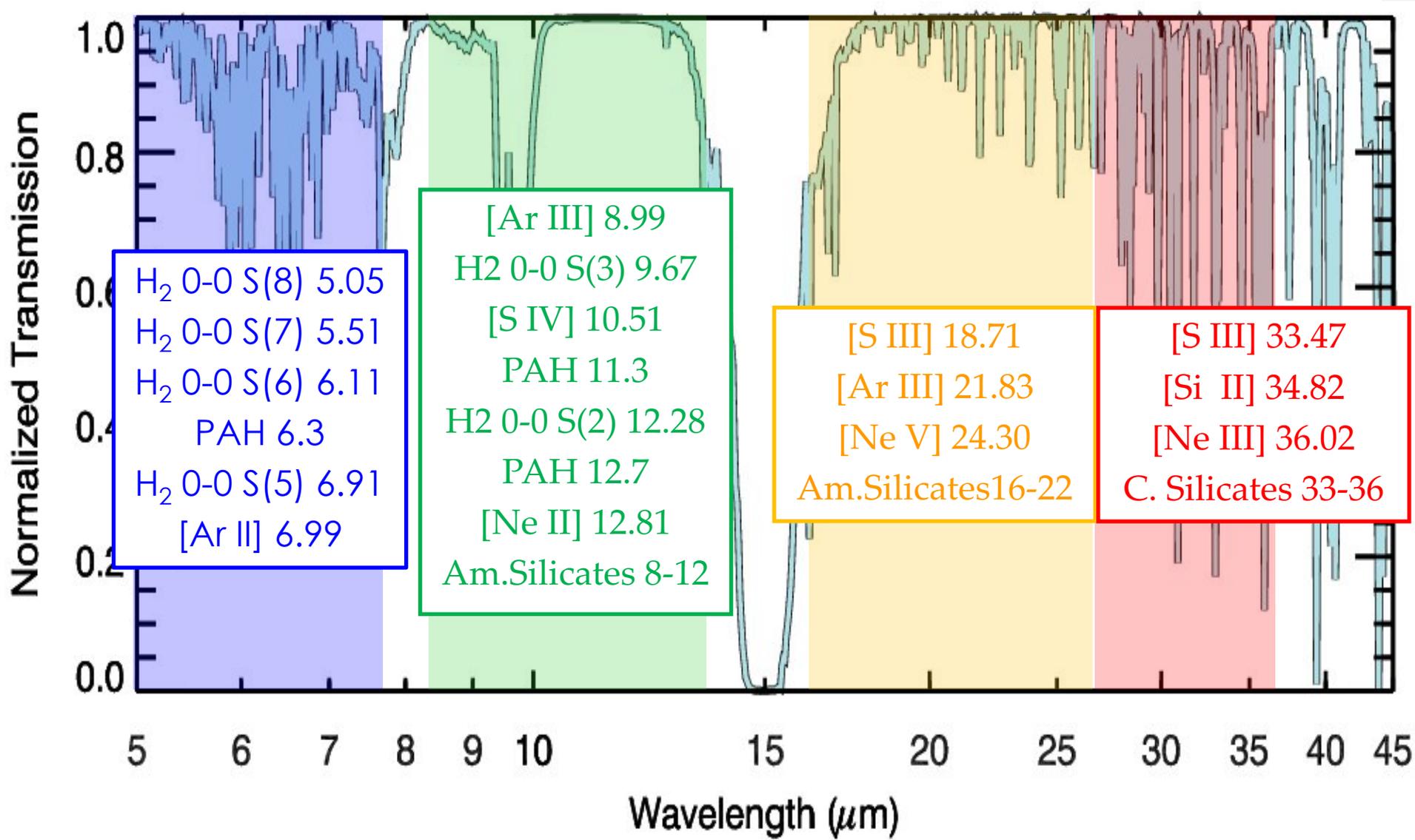
Range and continuum sensitivity



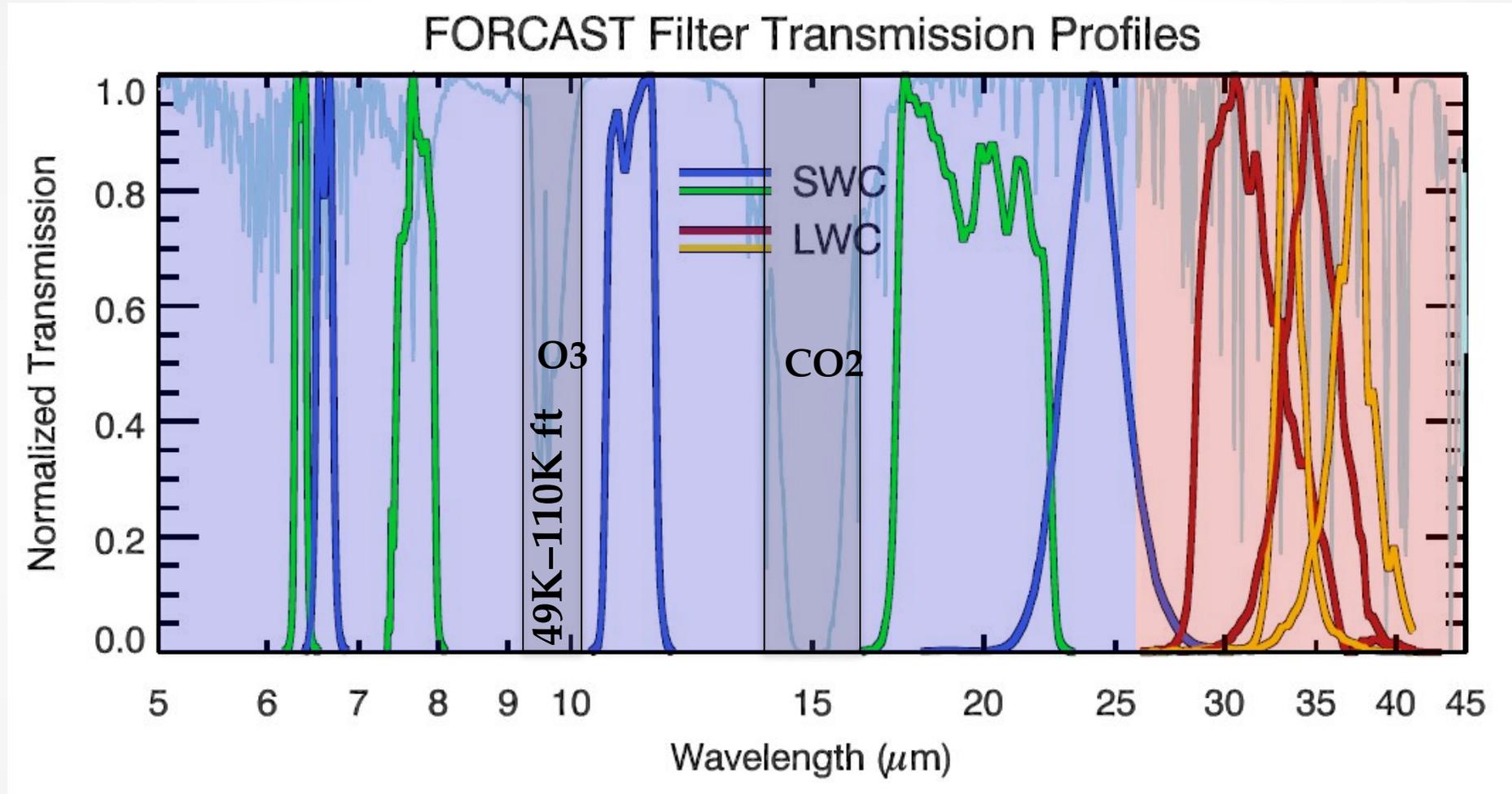
4- σ MDCF for point sources (Jy) for 900 s of integration time.

“Review: Far-Infrared Instrumentation and Technology Development for the Next Decade”
Farrah, D. et al, 2017, JAI

Spectral features of interest

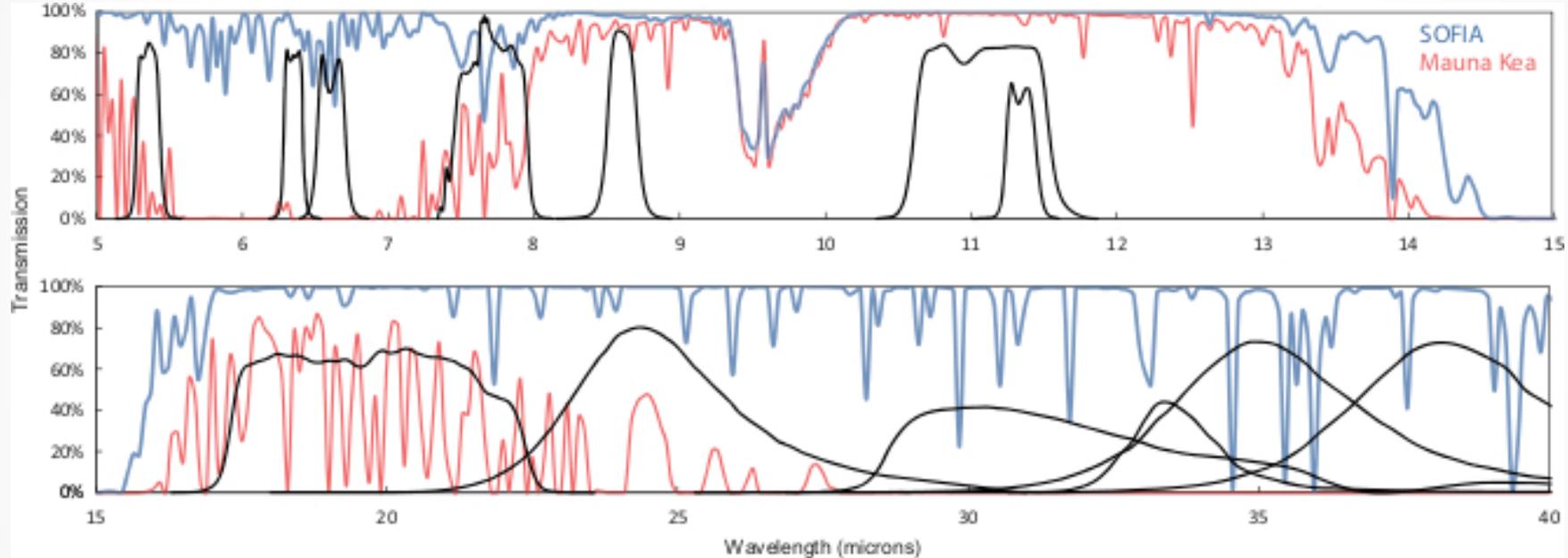


Filters



The dichroic is designed to transmit light at wavelengths greater than 25 μm , and reflect light less than 25 μm .

FORCAST Filter Profiles



SOFIA : 41000 ft, 7.3 μm PWV, 45° ZA

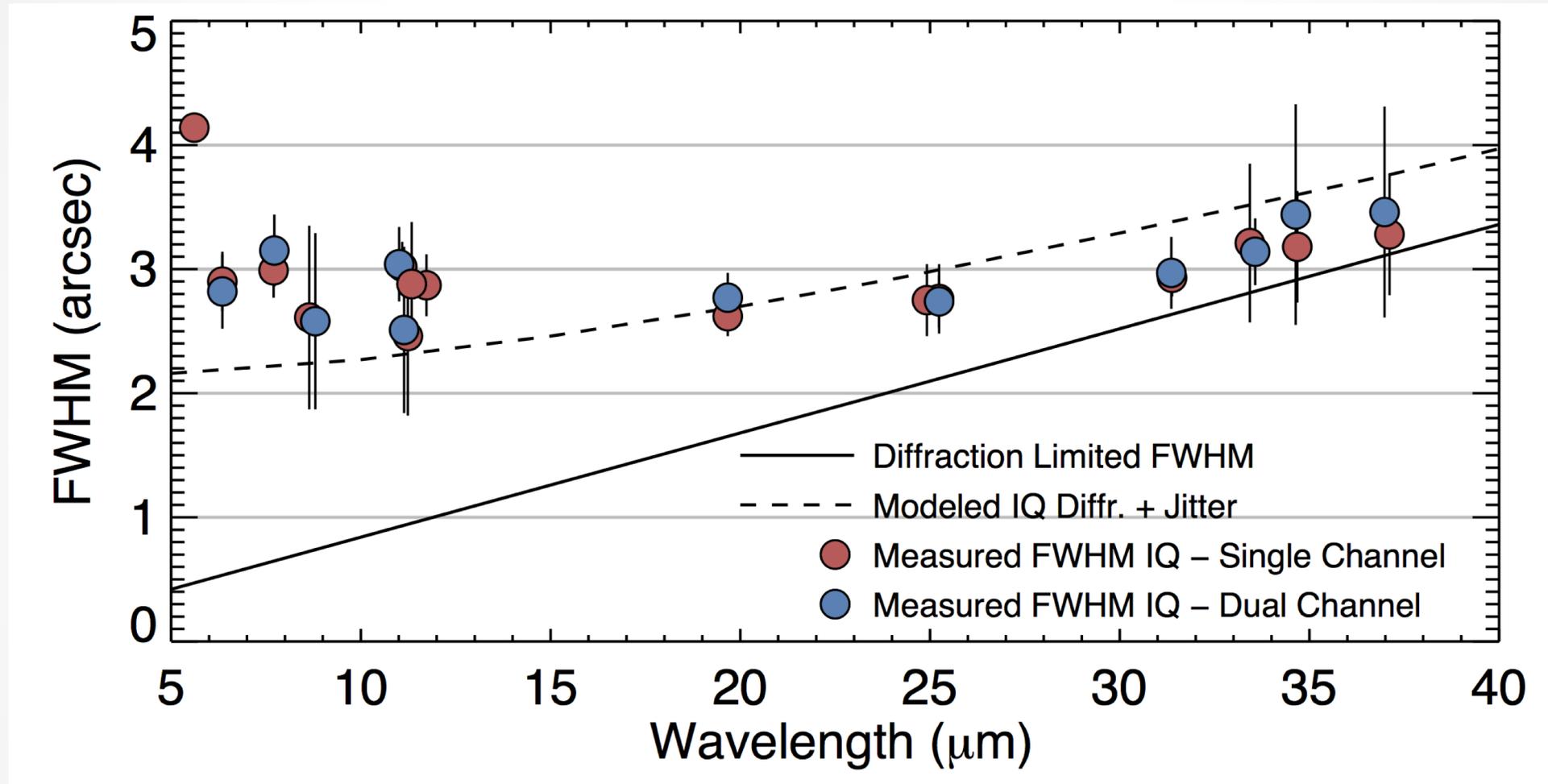
Mauna Kea: 13800 ft, 3.4 mm PWV, 45° ZA

Filters and dichroic

Channel	λ_{eff} (μm)	$\Delta\lambda$ (μm)	
SWC	6.4	0.14	
	6.6	0.24	~60%
	7.7	0.47	
	11.1	0.95	
	19.7	5.5	~85%
	24.2	2.9	
LWC	31.5	5.7	
	33.6	1.9	~40%
	34.8	3.8	
	37.1	3.3	

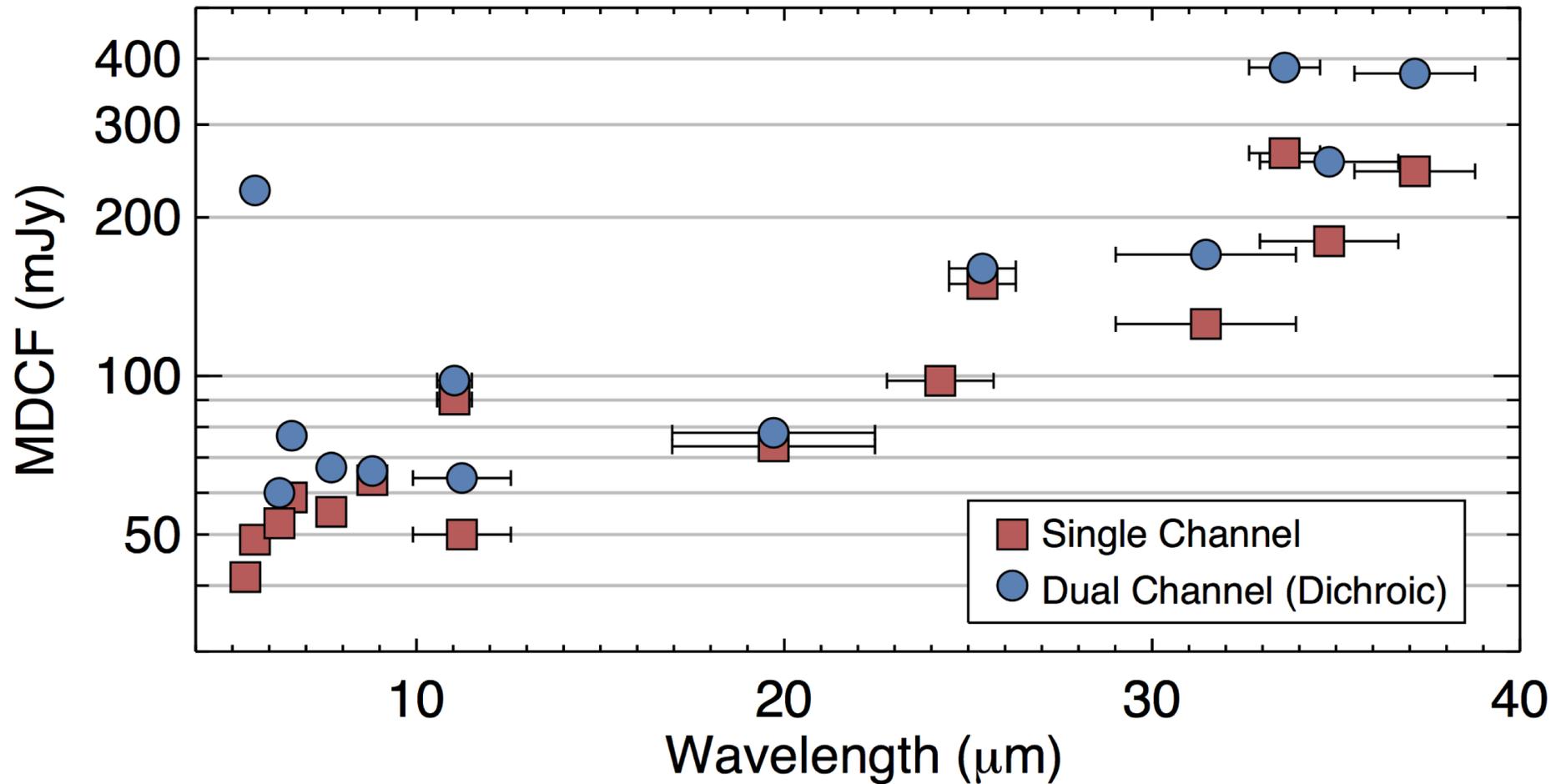
- Dual channel mode allows simultaneous imaging at two wavelengths
- *However, there is decreased throughput compared to single channel mode*

FORCAST Imaging Resolution



For comparison, Spitzer resolution of ~ 6" @ 24μm

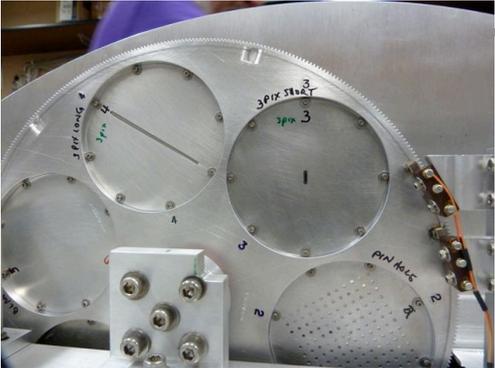
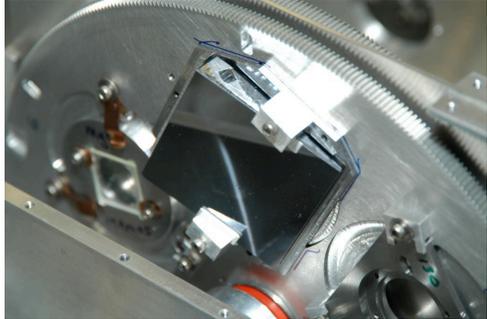
Imaging Sensitivity



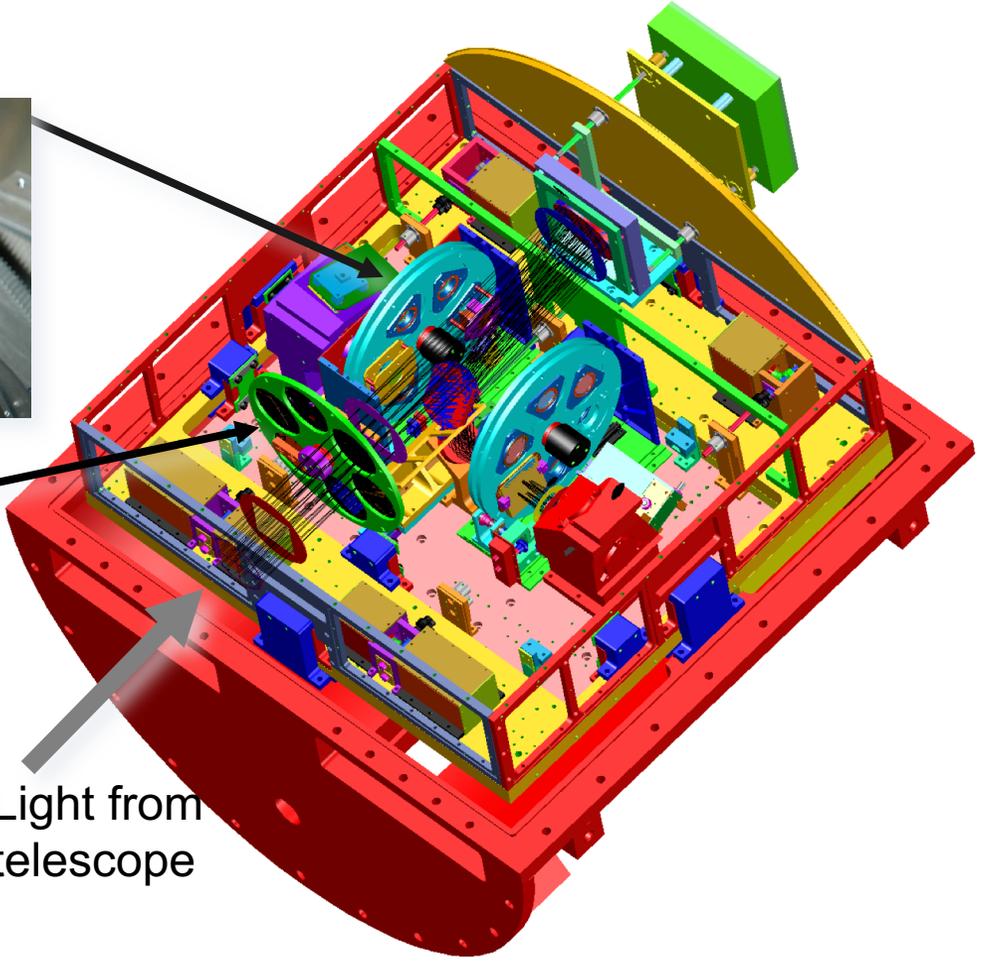
- S/N=4 in 900s, 41000 feet, single channel mode; larger limiting fluxes with dichroic
- Altitude/water vapor affect sensitivity more in the LWC
- In preparing your FORCAST observations, you can use SITE, the online integration time estimator

FORCAST grism design overview: layout

Grisms in existing imaging filter wheels

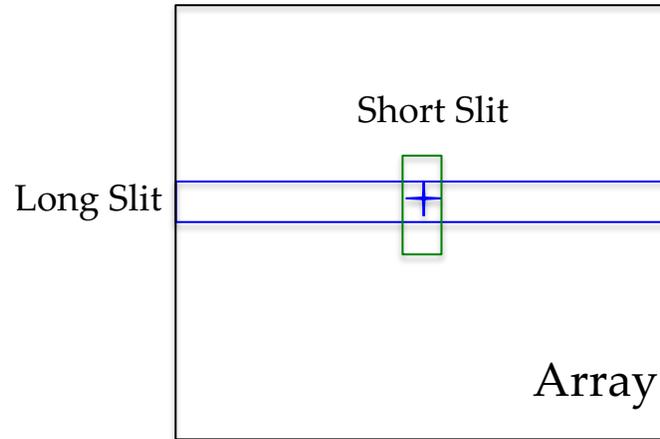


Slits in existing aperture wheel

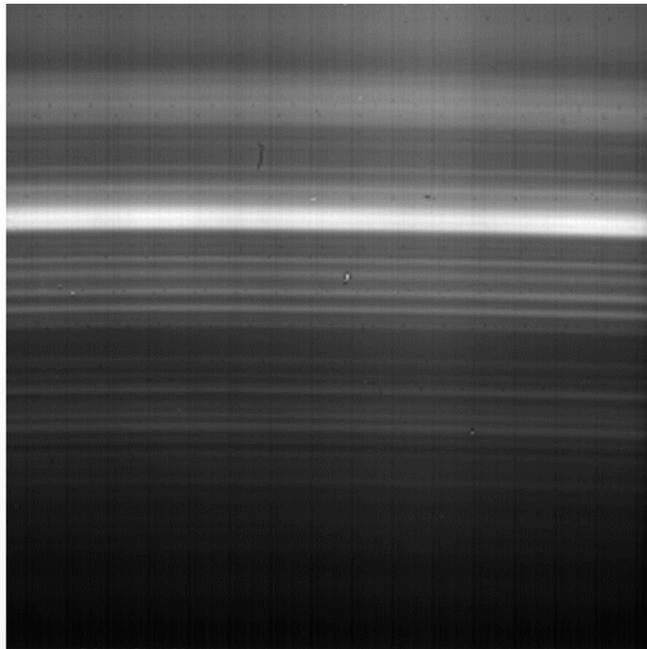


Light from telescope

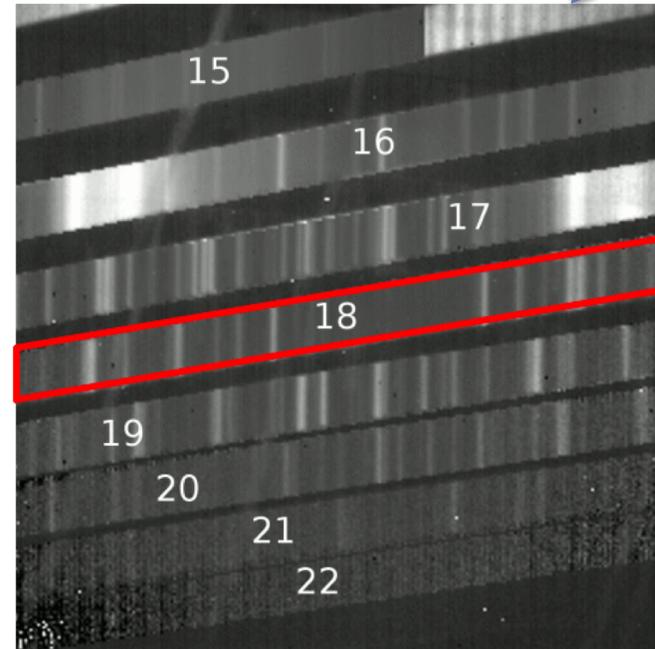
Grism spectral formats



Long slit modes

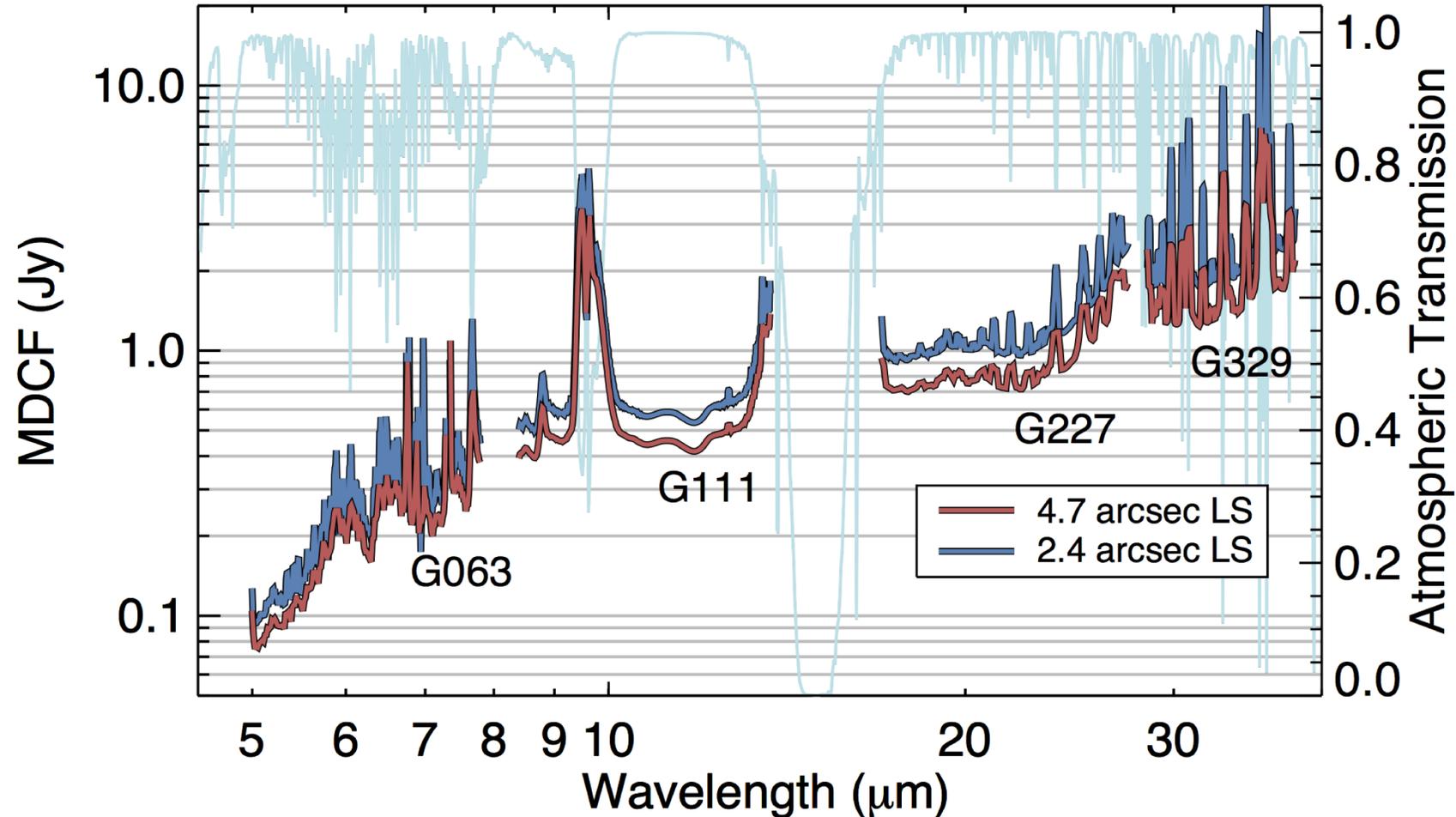


Short slit (XD) modes



interference fringes

Spectroscopic Sensitivity

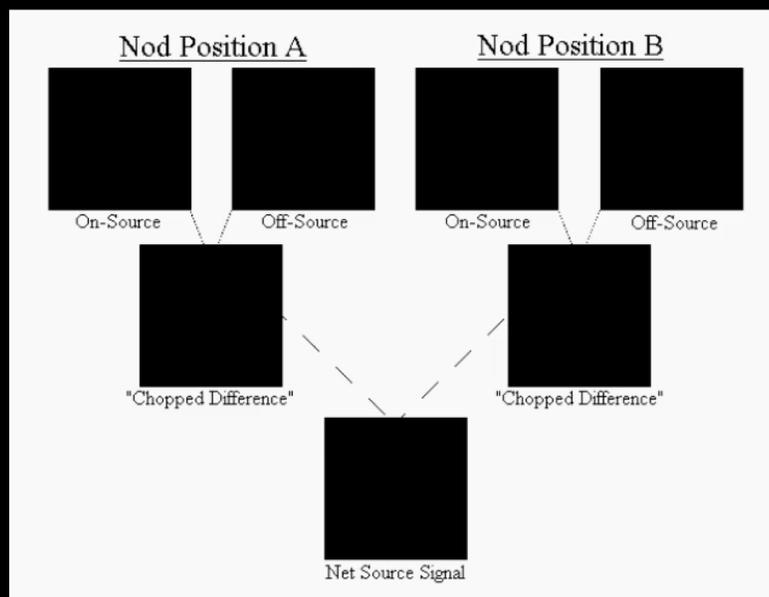
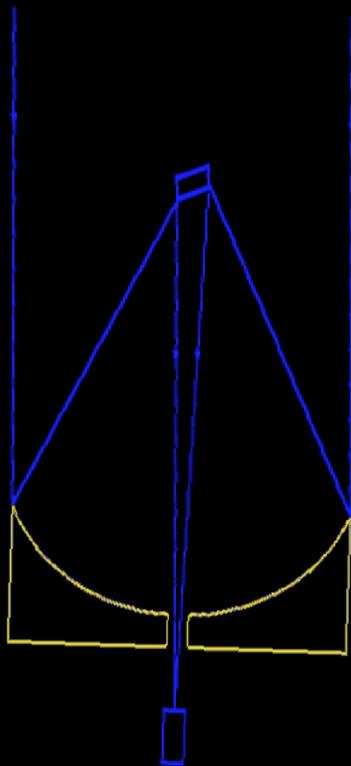


- S/N=4 in 900s, 41000 feet, single channel mode **only**
- Altitude/water vapor affect sensitivity more in the LWC
- In preparing your FORCAST observations, you can use SITE, the online integration time estimator

Chop/Nod Technique

- MIR observations are completely background (sky+telescope+instrument) limited
 - Background can be $>10^6$ times brighter than most sources
 - Detector wells can fill in 1-100 msec
- MIR background varies rapidly (order of less than a few sec)
- To subtract majority of the background the secondary is tilted between on-source and off-source positions (chopping) at a rapid rate (~few Hz)
- However, chopping introduces small additional offsets due to the different optical paths for the beams in the two chop positions
- To remove background offset, telescope is moved to another position (nodding) and the chop is repeated
 - Nods on a timescale of ~30 sec,
- The two images from the chop positions are subtracted, and the two resulting chop-subtracted images from the two nod positions are subtracted
 - This double-differencing removes all background contributions
- One must ALWAYS chop and nod for FORCAST observations

Chopping & Nodding



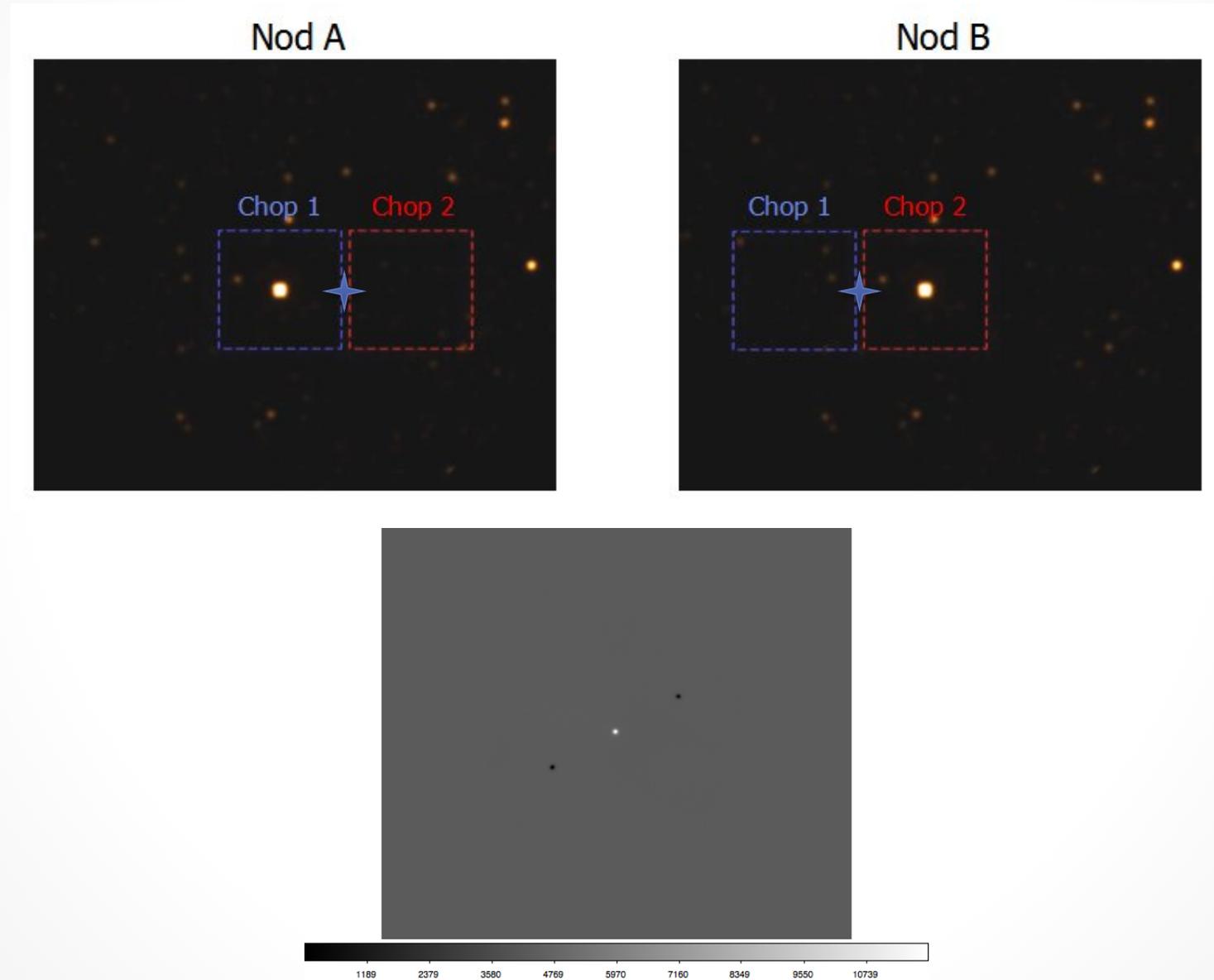
Chop Nod Animation

Nod Position A

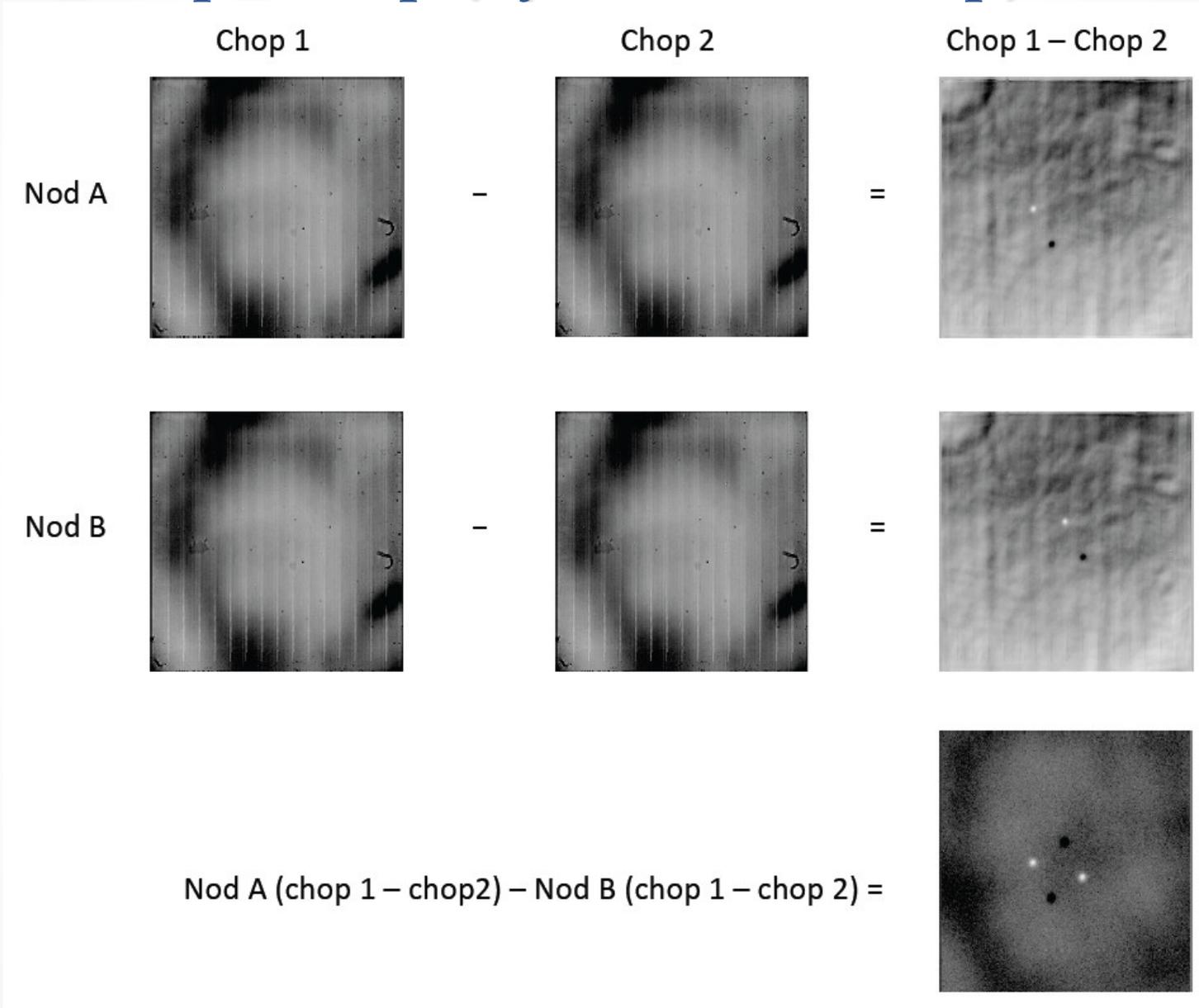
Plus Beam

$$\text{Source+Sky+Tel}_+ - (\text{Sky+Tel}_-)$$

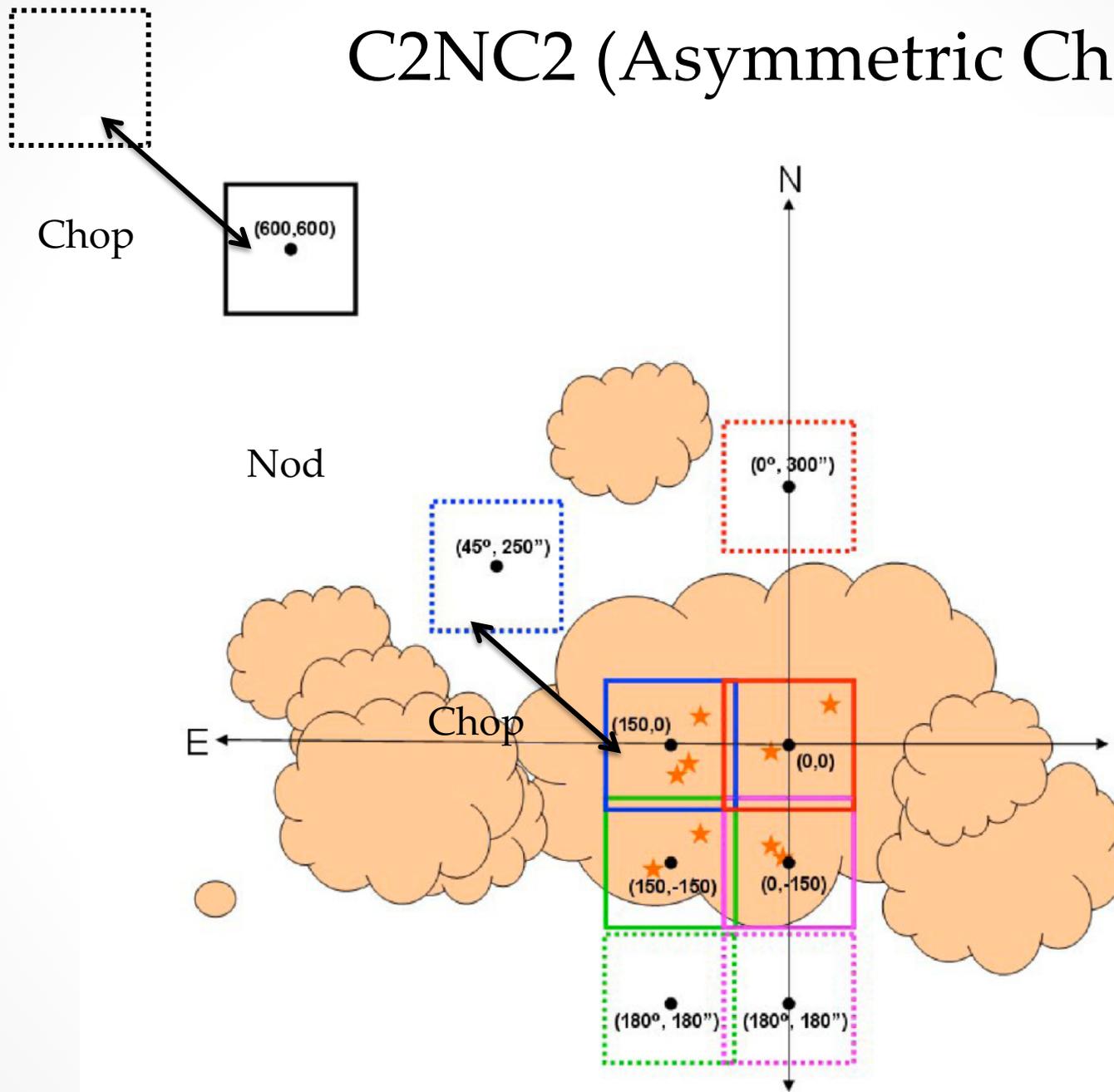
Nod_Match_Chop (Symmetric Chop) Mode:



Nod_Perp_Chop (Symmetric Chop) Mode:

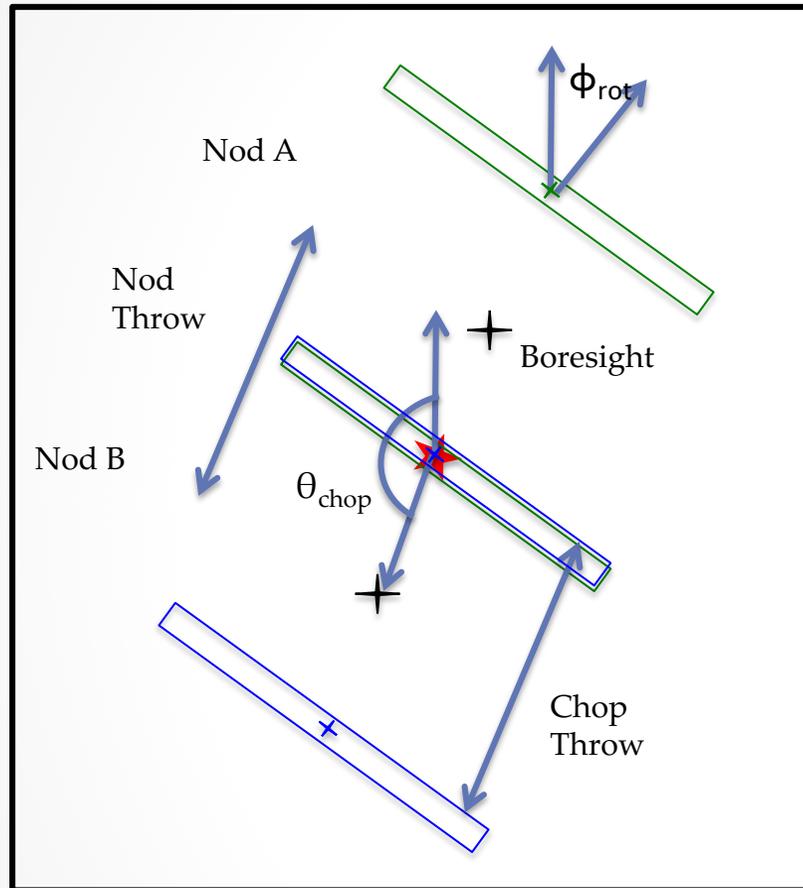


C2NC2 (Asymmetric Chop) Mode:

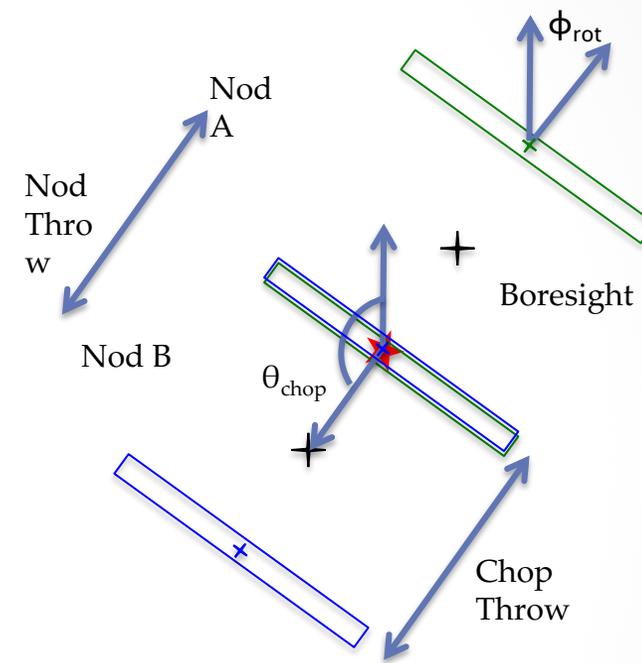


Grism Observing Modes: NMC

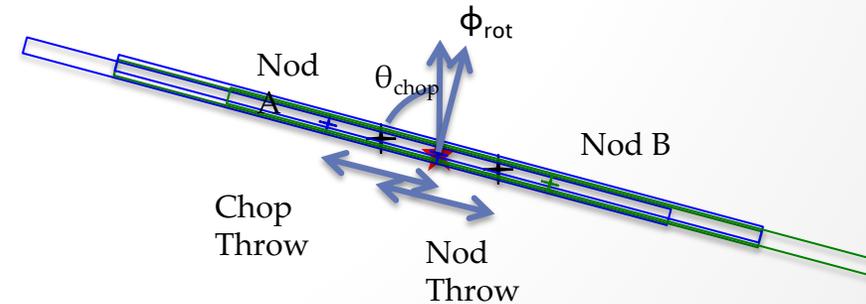
General



Perpendicular

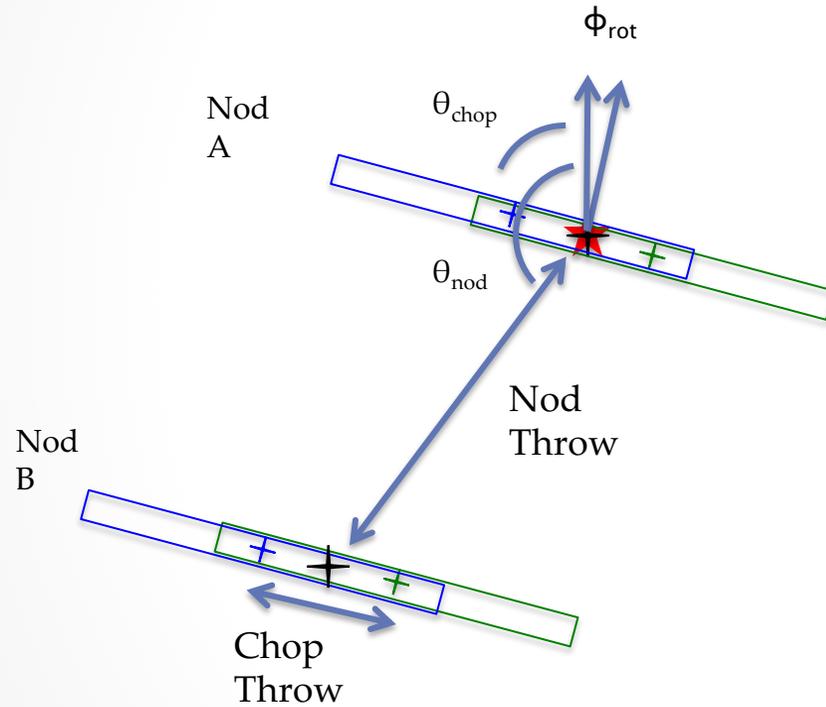


Parallel

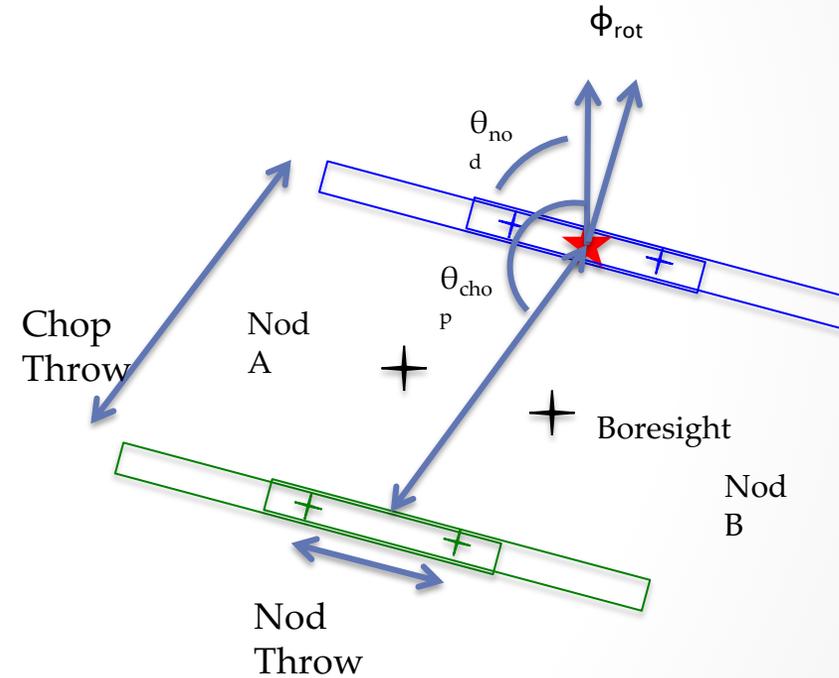


Grism Observing Modes: CAS, NAS

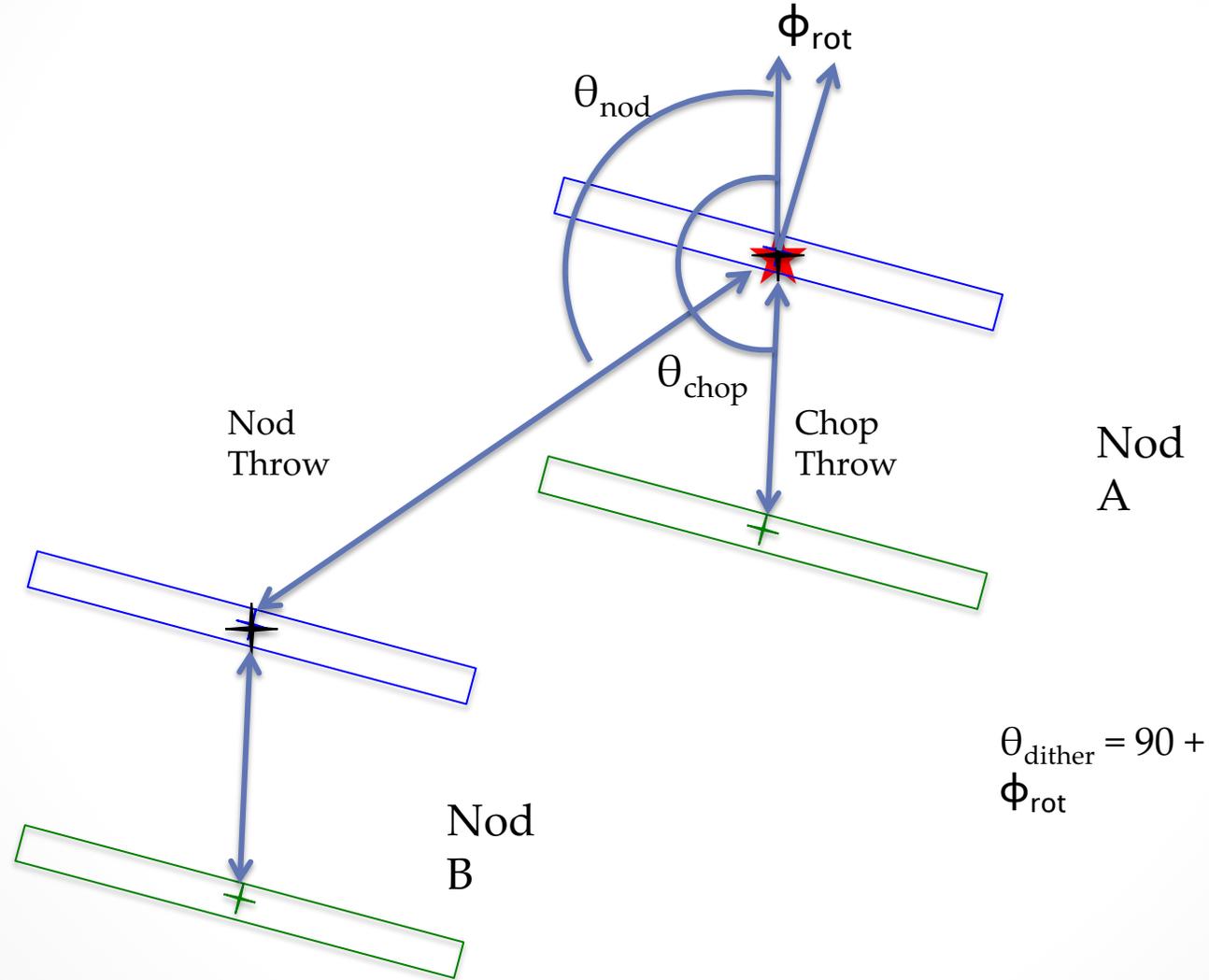
Chop_Along_Slit



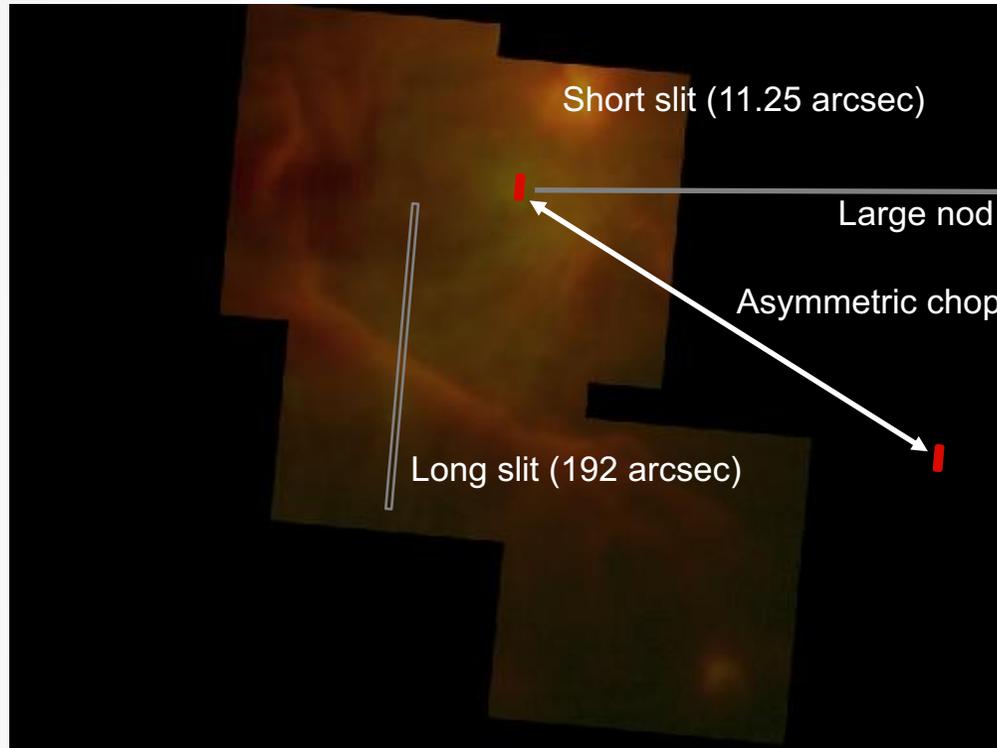
Nod_Along_Slit



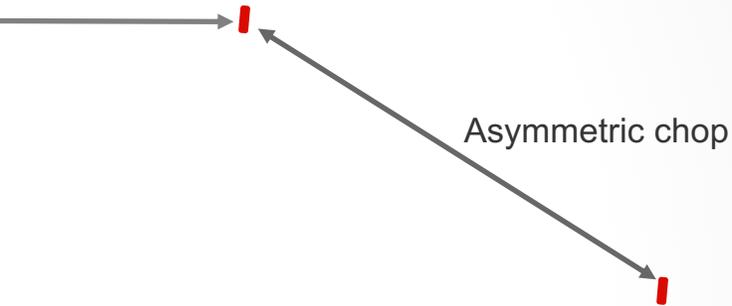
Grism Observing Modes: C2NC2



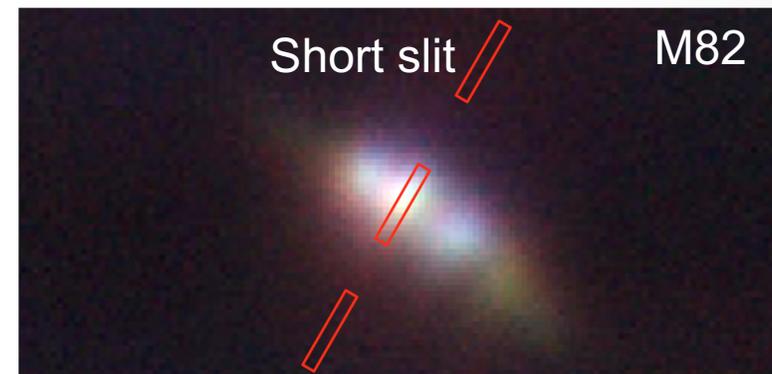
Pointed observations & mapping in extended sources



Large HII region example C2NC2 mode



Galaxy example NMC



FORCAST Exposure Time Calculator

FORCAST ETC found on the DCS web pages:

Imaging: <https://dcs.sofia.usra.edu/proposalDevelopment/SITE/index.jsp>

Grisms: https://forcast.sofia.usra.edu/cgi-bin/forcast/forcast_grisms_calc.cgi

Input Observing Parameters

Select the quantity to be estimated:
Choose a grism:
Choose a slit size (arcsec):
Required Signal-to-Noise ratio:
Total on-source integration time (sec):
Source type:
Source Flux:
Source spectral shape:
Source blackbody temperature (K) or Power Law Index:

Limiting Flux
FOR_G063
2.4
Point Source
Blackbody
W/m²/micron at 10 microns

- Limiting Flux
- Total Integration Time
- Signal-to-Noise
- 2.4"
- 4.7"
- Point Source
- Extended Source
- Blackbody
- Power Law

FOR_G063
FOR_XG063
FOR_G111
FOR_XG111
FOR_G227
FOR_G329

Submit Form Clear Form

FORCAST Exposure Time Calculator

FORCAST Grism Calculator Output

Input Parameters

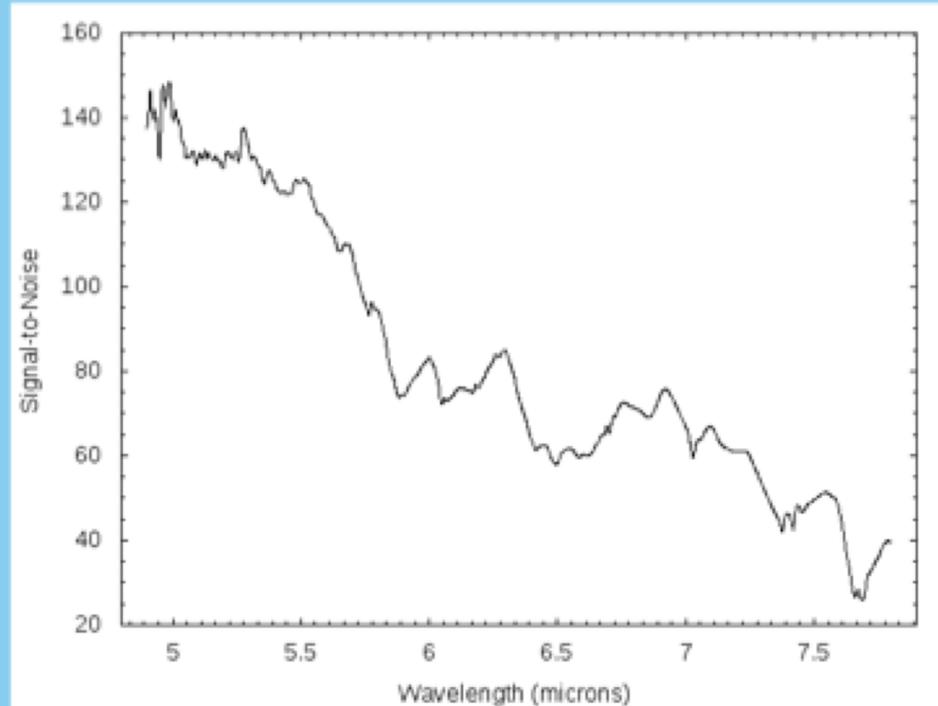
Mode: Signal-to-Noise
Grism: 1
Slit: 4.7 arcsec
Source flux : 1.499e-13 W/m²/micron at 10 microns
Source blackbody temperature: 1500 K
Total exposure time: 60 sec

[View output data file](#)

Slit size = 4.700 arcsec
 Resolution = 90.0
 Single frame exposure time = 0.059570 sec
 Frame Rate = 16.787 Hz
 Number of Coadds = 1007.00000
 Total Exposure Time = 60.0000000 sec
 Input flux : 0.1499E-12 W/m²/micron at 10.000 microns

Wavelength (microns)	FWHM (arcsec)	Fractional Slit Transmission
5.000	3.51	0.75
6.350	3.53	0.74
7.700	3.54	0.74

Plot of Signal-to-Noise as a function of Wavelength



FORCAST in USPOT

FORCAST_Imaging [AOR ID: N/A]

Unique AOR Label: FORCAST_Imaging-0000

Target: None Specified

New Target Modify Target Target List...

Observing Condition & Acquisition / Tracking

* Exposure Time (sec) 60.000

Cycles 1

Min Contiguous Exp Time (sec) 0.000

Observation Order 1

Dither Patt...
 None
 3 point
 5 point
 9 point
 custom

Dither Offset
Dither Coordinate Sky
DitherOffset (arcsec) 10.000
ExpTimePerDither (sec) 21.000

Chop / Nod
* Chop/Nod Style Nod Match Chop
Chop Type Sym
Chop Throw (arcsec) 60.000
Chop Angle Coordinate Array
Set Chop Angle Ranges
Chop Angle (deg) 30.000
Nod Throw (arcsec) 60.000
Nod Angle Coordinate Array
Nod Angle (deg) 210.000
Example Rotation Angle (deg) 0.000

(** = Advanced) (* = required for Phase I)

Observation Est... Comments... Proposal Info...

Cancel Apply OK

FORCAST Imaging

IMAGING_DUAL
IMAGING_SWC
IMAGING_LWC

Nod Match Chop
Nod Perp Chop
C2NC2

Array
Sky

- ETC provided on-source integration time to achieve a specific S/N.
- Enter on-source integration time in USPOT. Then USPOT will add overheads.



2018
Community Days
Workshops



FORCAST in USPOT



2018
Community Days
Workshops



USRA



FORCAST Grism Spectroscopy

FORCAST_Grism [AOR ID: N/A]

Unique AOR Label:

Target: None Specified

Observing Condition & Acquisition / Tracking

* Exposure Time (sec)
 Cycles
 Min Contiguous Exp Time (sec)
 Observation Order
 IR Source Type

* Instrument Configuration

* SWC * LWC * Slit

Chop / Nod

Example Rotation Angle (deg)

* Chop/Nod Style

Chop Type
 Chop Throw (arcsec)
 Chop Angle Coordinate

Chop Angle (deg)

Nod Throw (arcsec)
 Nod Angle Coordinate
 Nod Angle (deg)

(** = Advanced) (* = required for Phase I)

GRISM_SWC
GRISM_LWC

Nod Match Chop
Nod Perp Chop CAS
Nod Perp Chop NAS
NXCAC
SLITSCAN

Array
Sky

FORCAST in USPOT

FORCAST Grism Acquisition

Match Grism Configuration

IMAGING_SWC
IMAGING_LWC

Include two acquisition AORs, each of which will achieve $S/N > 5$. Integration time for most observations < 60 s. Details can be worked out in Phase II, but it is important to create AORs in Phase I to reserve time for it, typically a total of 3 minutes per acquisition.

The screenshot shows the 'FORCAST Acquisition [AOR ID: N/A]' window. The 'Unique AOR Label' is 'FORCAST_Acquisition-0000'. The 'Target' is 'None Specified'. The 'Observing Condition & Acquisition / Tracking' section is active. The 'Import Config from AORID' is 'NONE'. The 'Exposure Set-Up' section includes: Exposure Time (sec) 10.000, Observation Order 0, Config IMAGING_SWC, SWC FOR_F054, LWC NONE, and Slit FOR_LS24. The 'Chop / Nod' section includes: Chop/Nod Style Nod_Match_Chop, Chop Type Sym, Chop Throw (arcsec) 60.000, Chop Angle Coordinate Array, Chop Angle (deg) 30.000, Nod Throw (arcsec) 60.000, Nod Angle Coordinate Array, and Nod Angle (deg) 210.000. A legend at the bottom indicates that fields with a double asterisk (**) are advanced and fields with a single asterisk (*) are required for Phase I.

FORCAST Data Products

- Once flight series is complete, data are pipelined, flux calibrated, and archived in the SOFIA Data Cycle System (<https://dcs.sofia.usra.edu>), usually within a month.
- GOs are then notified via email and provided links for data retrieval.
- **Proprietary period is typically 1 year from completion of pipeline processing and calibration.**
- Pipeline processing removes instrumental artifacts and sky/telescope background.
- Telluric correction is applied using a grid of ATRAN models.
- Flux calibration is applied using response tables/curves derived from observations of standard sources (stars/asteroids).
 - **Flux calibration uncertainty: 5 – 10%**
- See **FORCAST Data Handbook** and Cookbook Recipes for more information:
 - <https://sofia.usra.edu/science/proposing-and-observing/data-products>



Resources online

- FORCAST observer manual

<https://www.sofia.usra.edu/science/proposing-and-observing/sofia-observers-handbook-cycle-6/5-forcast>

- FORCAST time estimator (grisms)

https://forcast.sofia.usra.edu/cgi-bin/forcast/forcast_grisms_calc.cgi

- FORCAST time estimator (imaging)

<https://dcs.sofia.usra.edu/proposalDevelopment/SITE/index.jsp>

