FORCAST Instrument Status and Science

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Instrument Overview

- FORCAST - **F**aint **O**bject infra**R**ed **CA**mera for the **S**OFIA **T**elescope

- P.I.: Terry Herter (Cornell)

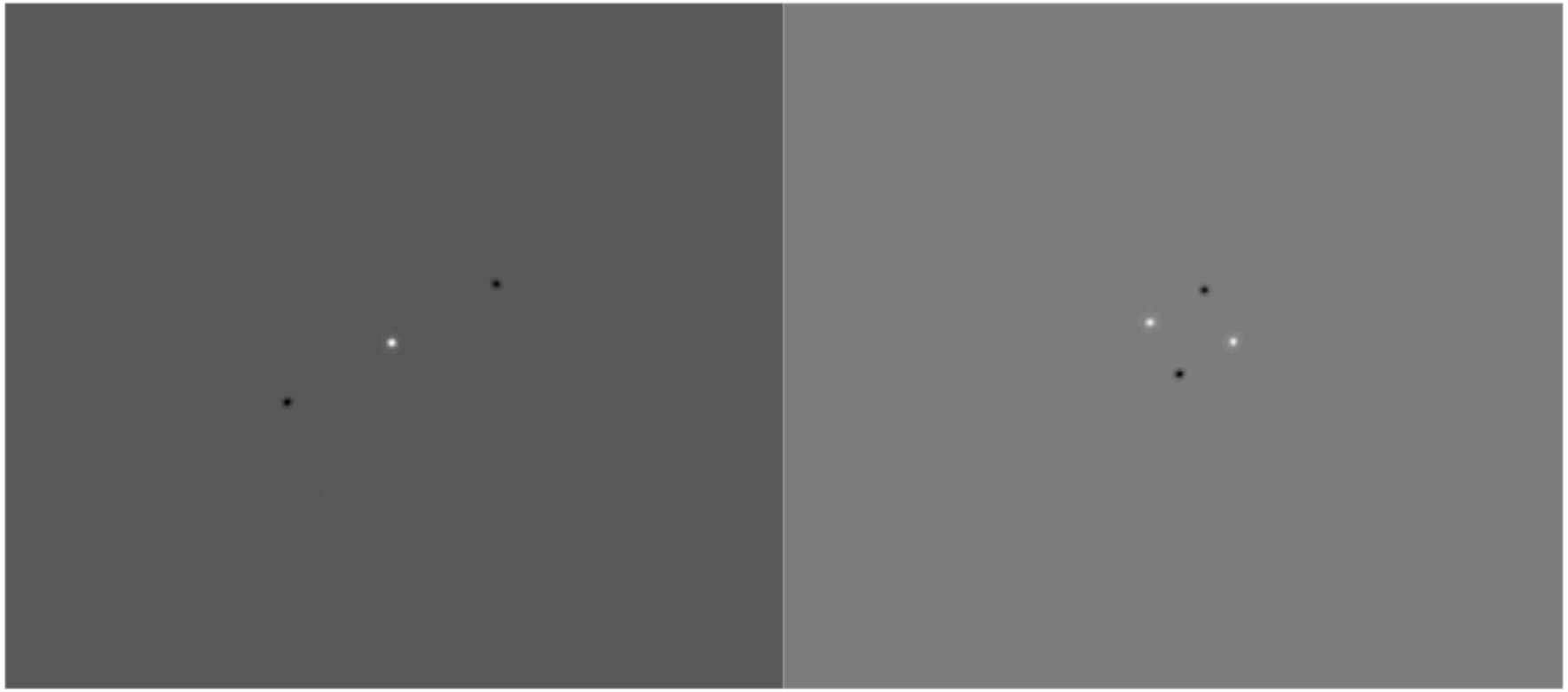
- Dual Channel, mid-IR (5-40 µm) camera
  - Short Wave Camera (SWC) – Si:As BiB Array – $\lambda < 25$ µm
  - Long Wave Camera (LWC) – Si:Sb BiB Array – $\lambda > 25$ µm
  - 3.4’ x 3.2’ FOV with 0.768’’ square pixels

- Grism Spectroscopy
  - Low Resolution from 5-40 µm at R ~ 200
  - High Resolution from 5-14 µm at R ~ 800-1200

Basic Observing Modes

2-Position Chop with Nod (C2N)

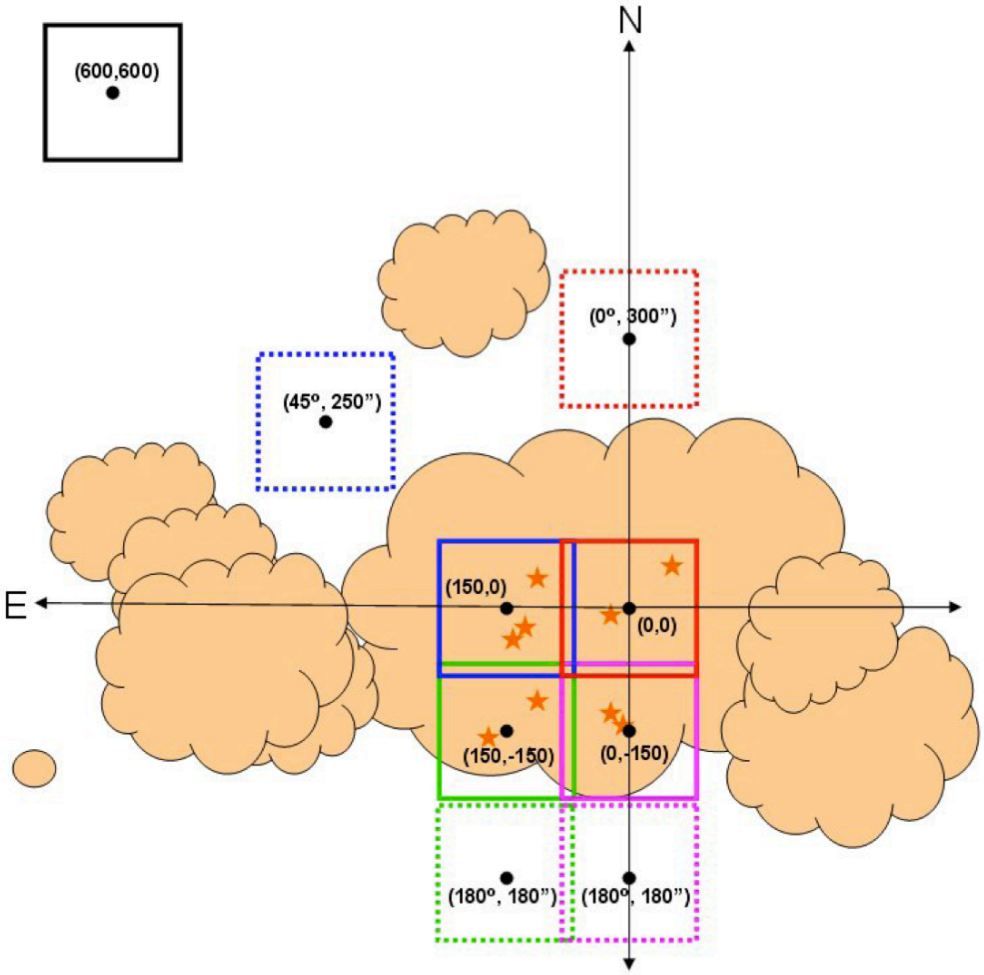
- Nod-Match-Chop (NMC)
- Nod-Perp-Chop (NPC)



Novel Observing Modes

2-Position Chop with Offset Nod (C2NC2)

- Advantages
  - Allows extreme chop amplitudes up to 7’
  - Allows extreme offset nods
  - Coma free
- Disadvantages
  - Low observing efficiency of ~25%

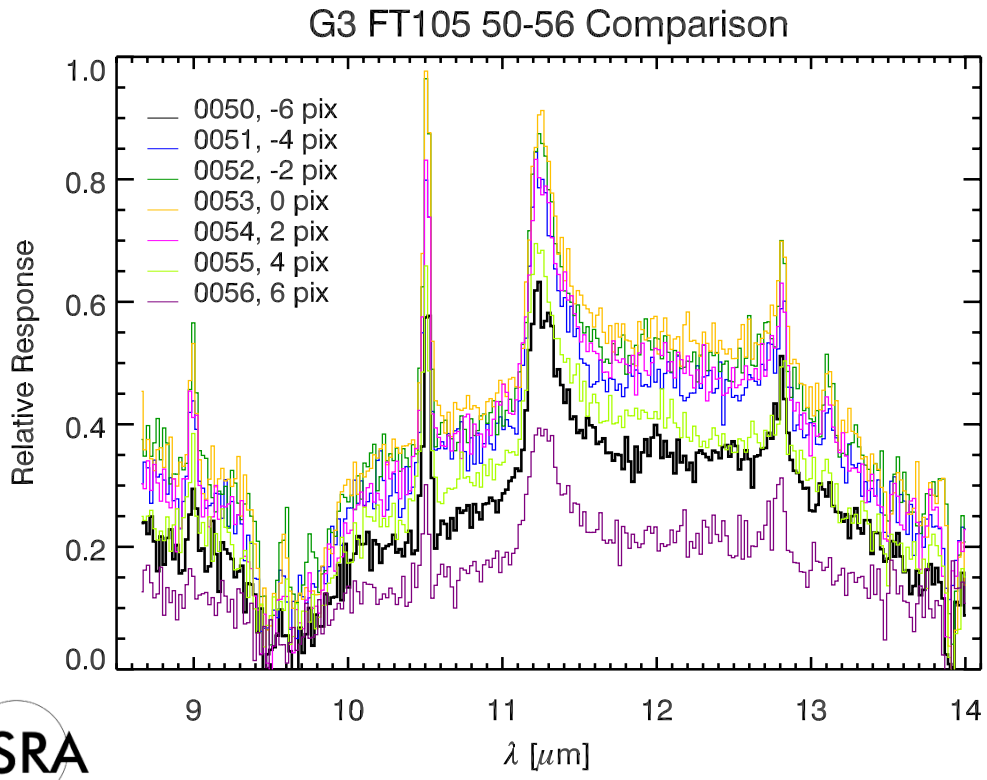


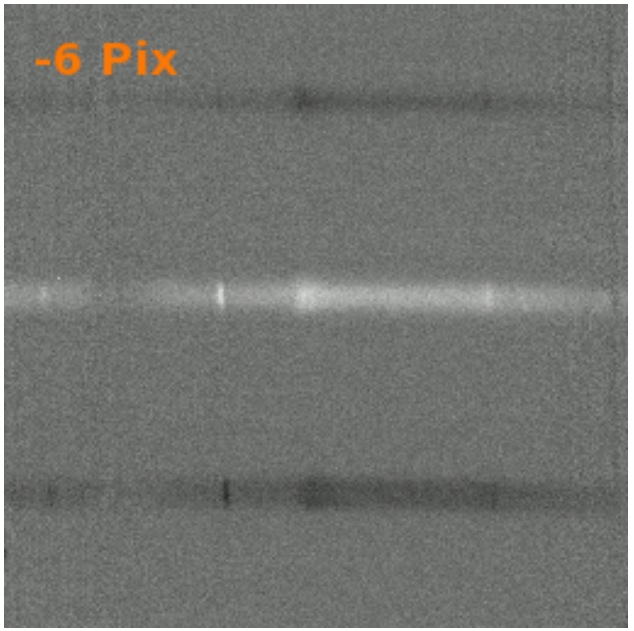
Novel Observing Modes

Slit Scanning

- Slit Scan across NGC 7027
- 2.4'' slit
- 7 positions w/ 2 pix offsets

HST; Delio Tolivia Cadrecha





FORCAST Commissioning Results

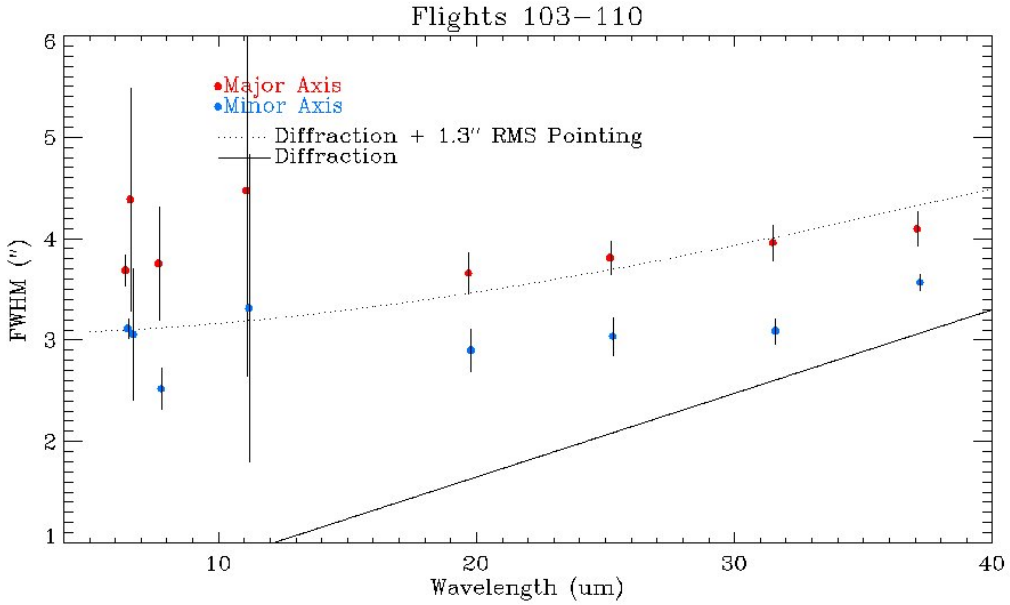
Instrument Commissioning

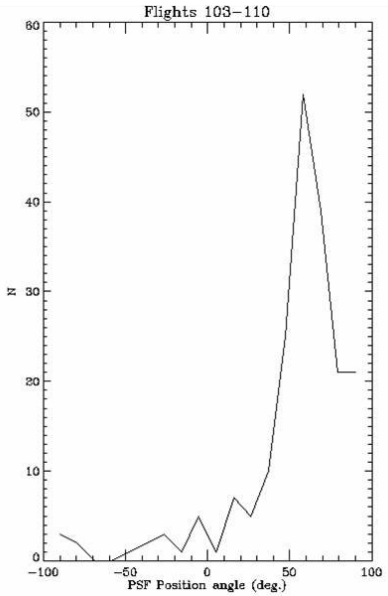
- Timeline
  - Phase I:
    - SOFIA Flights #98, 99
    - March/April 2013
  - Phase II:
    - SOFIA Flights #103-110; #128
    - May/July 2013; September 2013

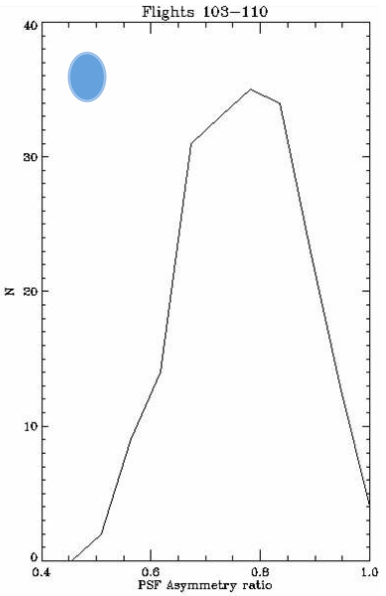
- Results of Interest
  - Pointing Stability & Image Quality
  - Imaging Sensitivities
  - Slit Positioning & Stability
  - Grism Sensitivities

Pointing Stability & Image Quality

- Bore-Sight Positioning
  - x: +/- 0.1 pix (0.08’’)
  - y: +/- 0.65 pix (0.49’’)
- Image Quality
  - PSF consistent with Diffraction Limit + 1.3’’ rms jitter
  - Typical axial ratio of 0.78 at angle of 55˚

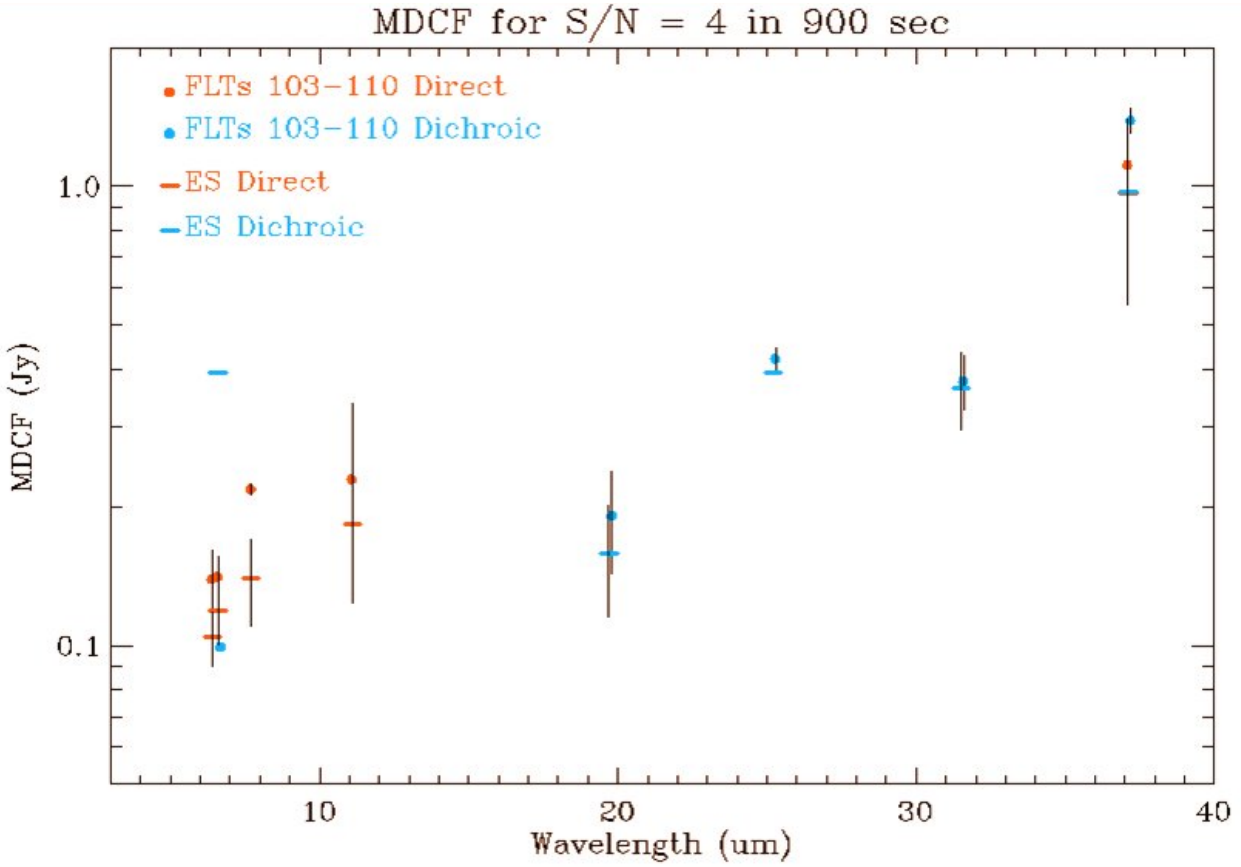






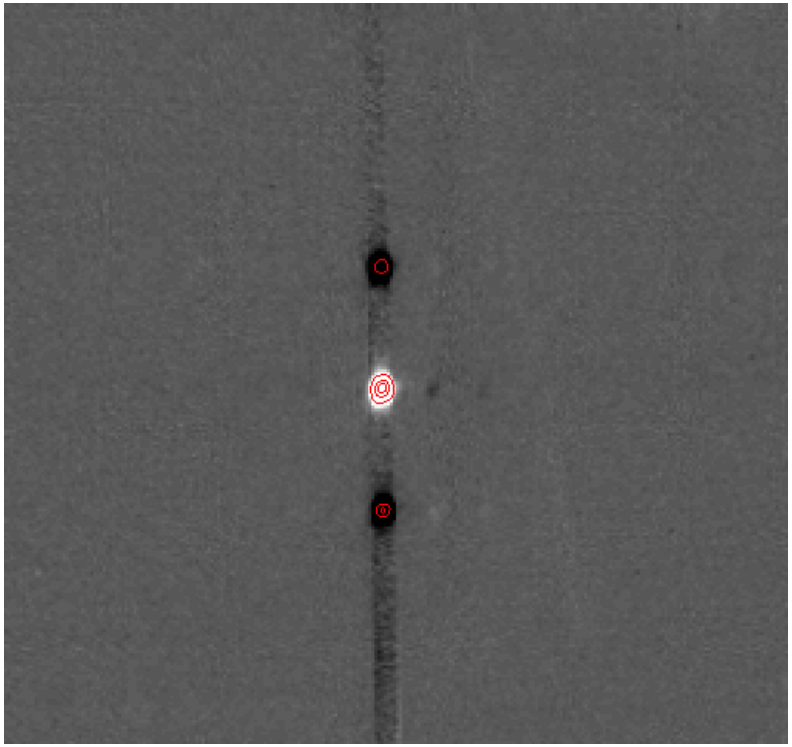
Imaging Sensitivities

- Changes affecting sensitivities
  - Added blocking filters
  - Improved cold strapping of detectors
  - Changed the preferred well depth at readout
  - Determined the optimal detector bias level



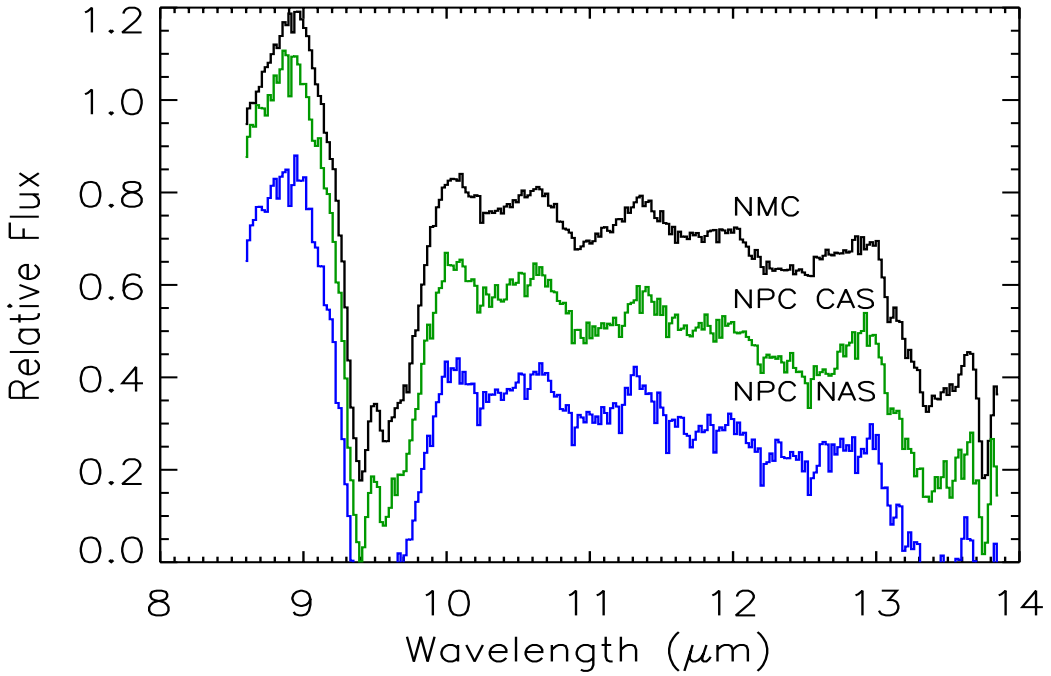
Slit Positioning & Stability

- Dual SWC slit-imaging with LWC grism spectroscopy
- NMC with 4.7’’ slit
- 10 images, including 5 LOS rewinds
- Elapsed time ~ 10 min



Grism Sensitivities

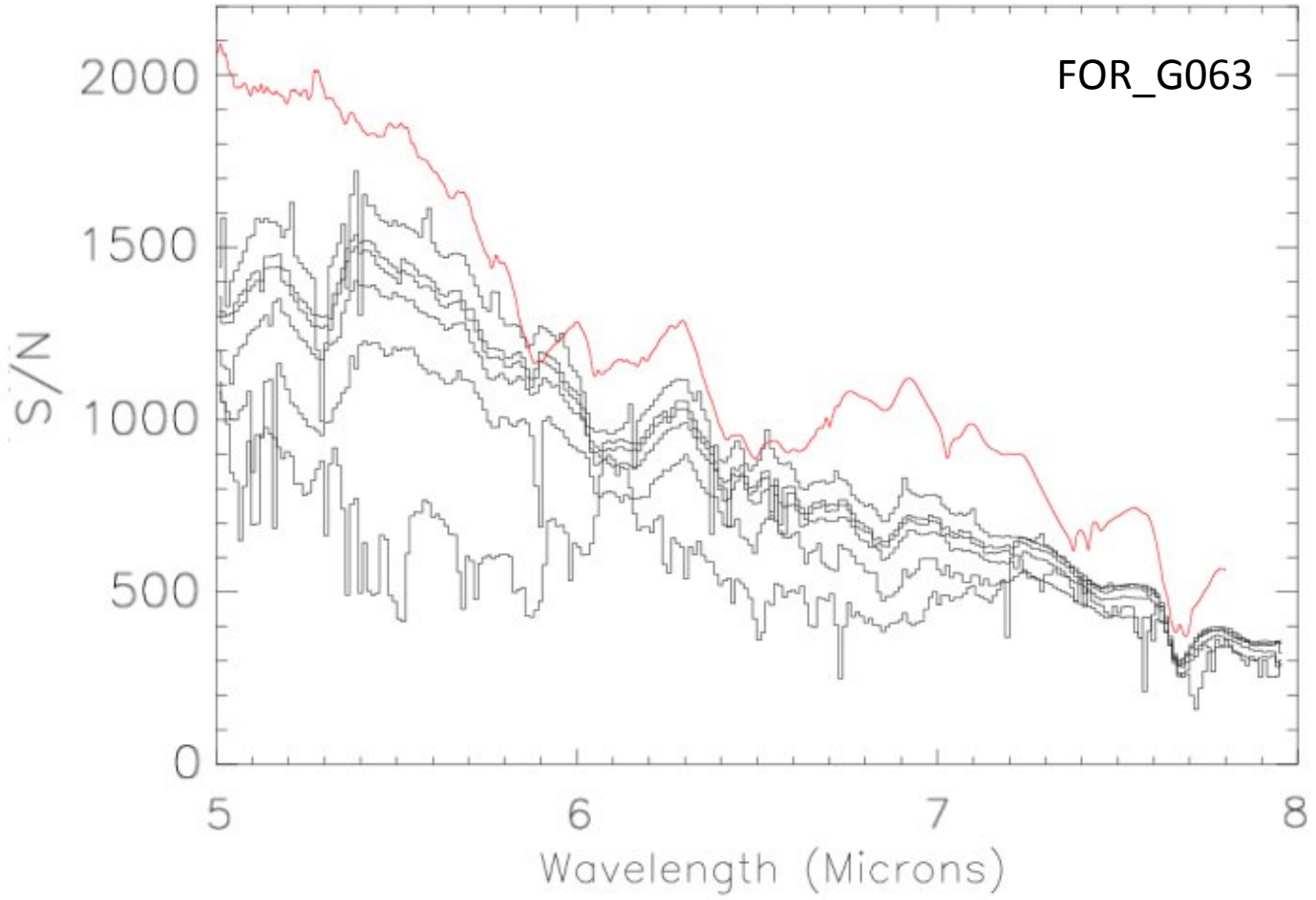
- Determined optimal chop/nod setup for grism observations to be Nod-Match-Chop (along slit)



- NMC: S/N = 75
- NPC-CAS: S/N = 42
- NPC-NAS: S/N = 31

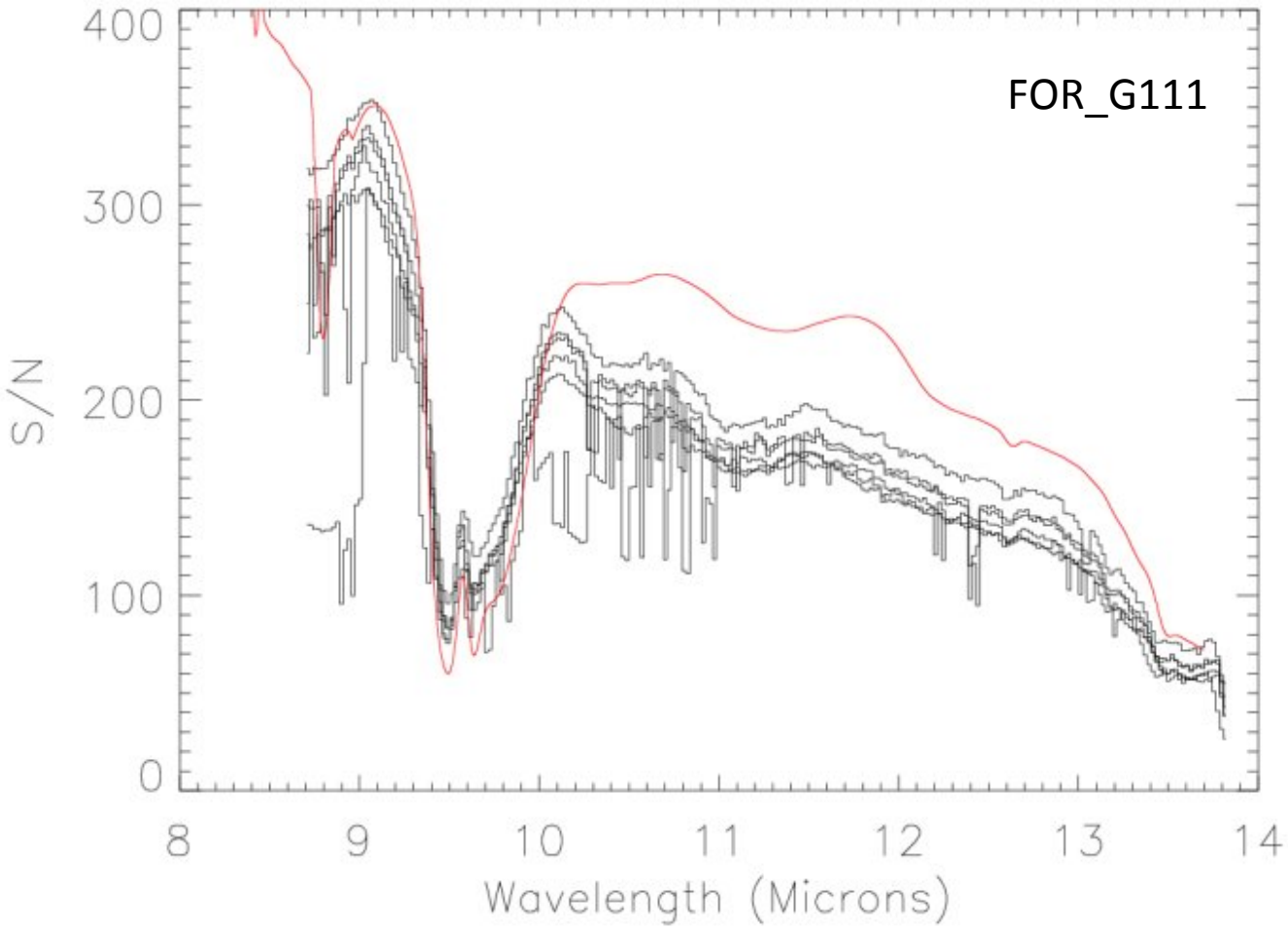
Grism Sensitivities

Measured grism sensitivities relative to advertised sensitivities using the on-line grism exposure time calculator.



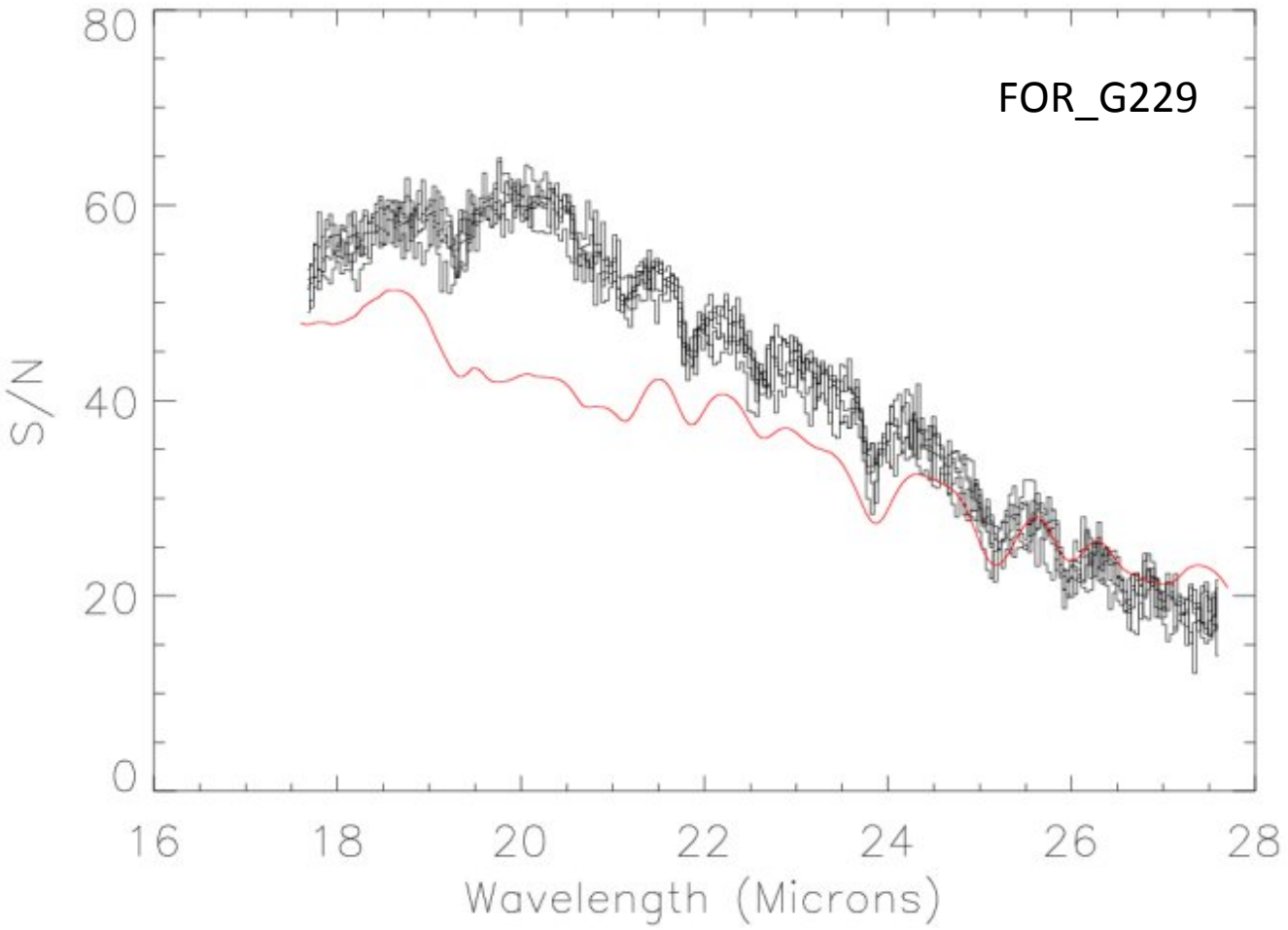
Grism Sensitivities

Measured grism sensitivities relative to advertised sensitivities



Grism Sensitivities

Measured grism sensitivities relative to advertised sensitivities



Grism Sensitivities

Comparison of Grism S/N Observed vs. Advertised

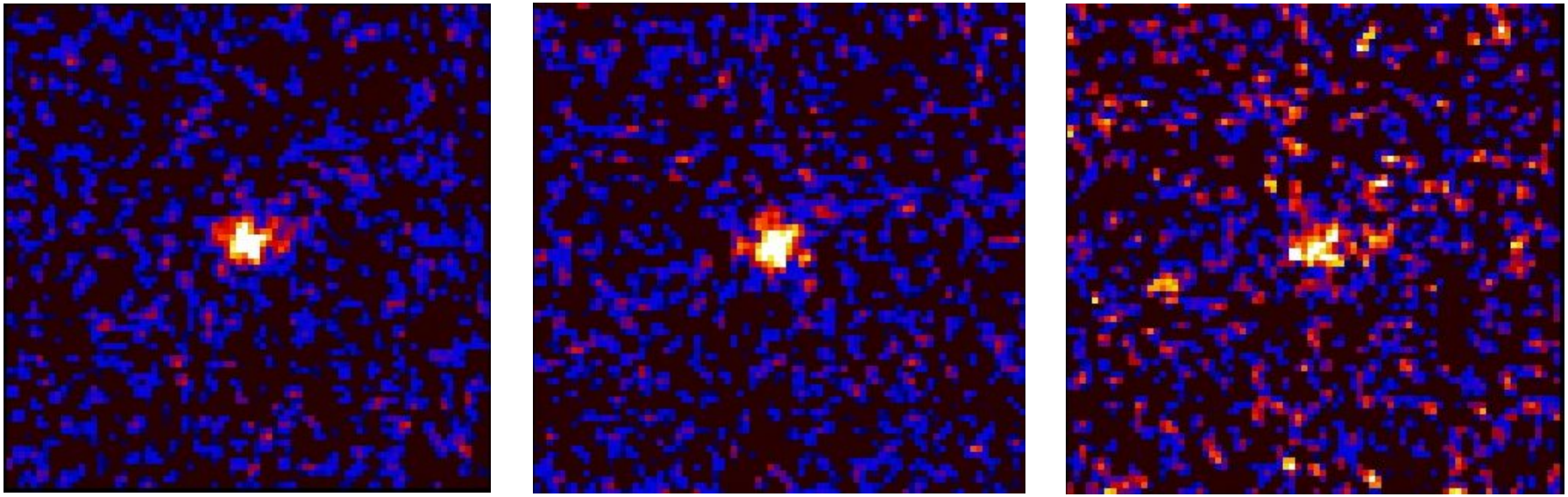
Grism	Wavelength	Average Observed S/N	Advertised S/N	Ratio of S/N (Obser/Advert)
G1 (FOR_G063)	5.1	1245	1956	0.64
	6.4	840	981	0.86
	7.7	301	393	0.77
G3 (FOR_G111)	8.7	280	319	0.88
	11	179	248	0.72
	13.2	101	139	0.73
G5 (FOR_G229)	17.8	55	48	1.15
	22.8	43	37	1.16
	27.2	19	22	0.86

- S/N achieved is within 30-50% that advertised to Cy 1 and Cy 2 GIs.
- Worst performance seen in FOR_G063, with sensitivities as low as 50% than expected in some bands
- Best performance seen in FOR_G229, with sensitivities as high as 50% greater than expected in some bands

FORCAST Early Science Results

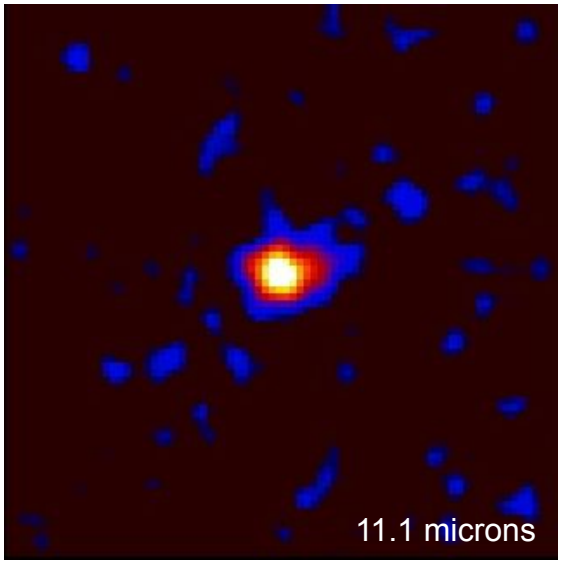
Comet ISON

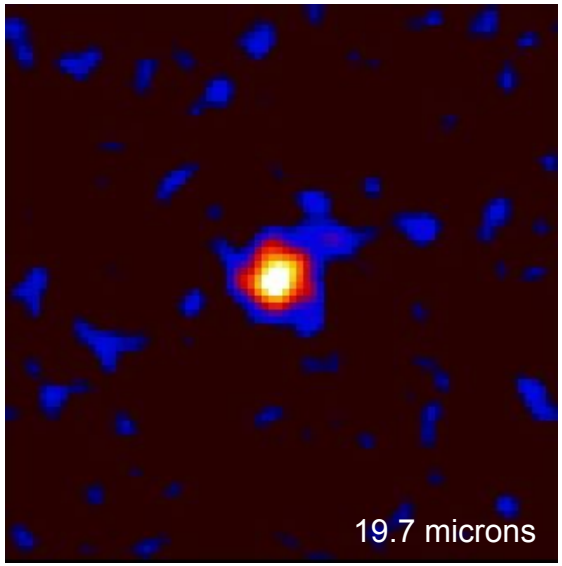
- P.I. Diane Wooden
- Target-of-Opportunity program - PID #01_0074
- Observed on Oct 15, 2013 11:30 UT
- SOFIA Flight #135

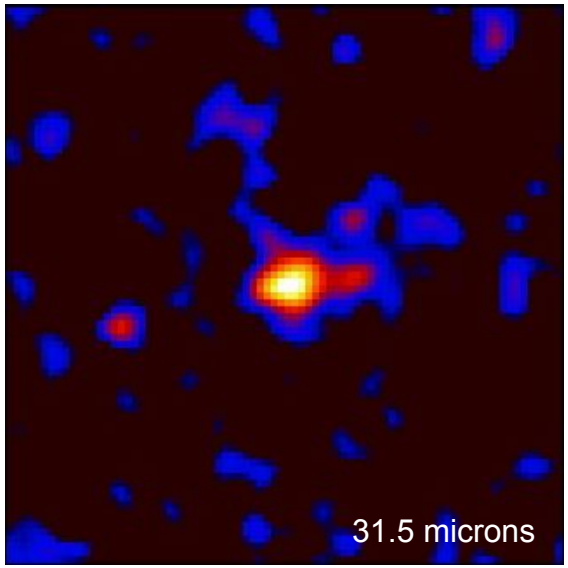


“Raw” FORCAST Images of Comet ISON

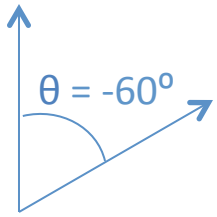
Comet ISON





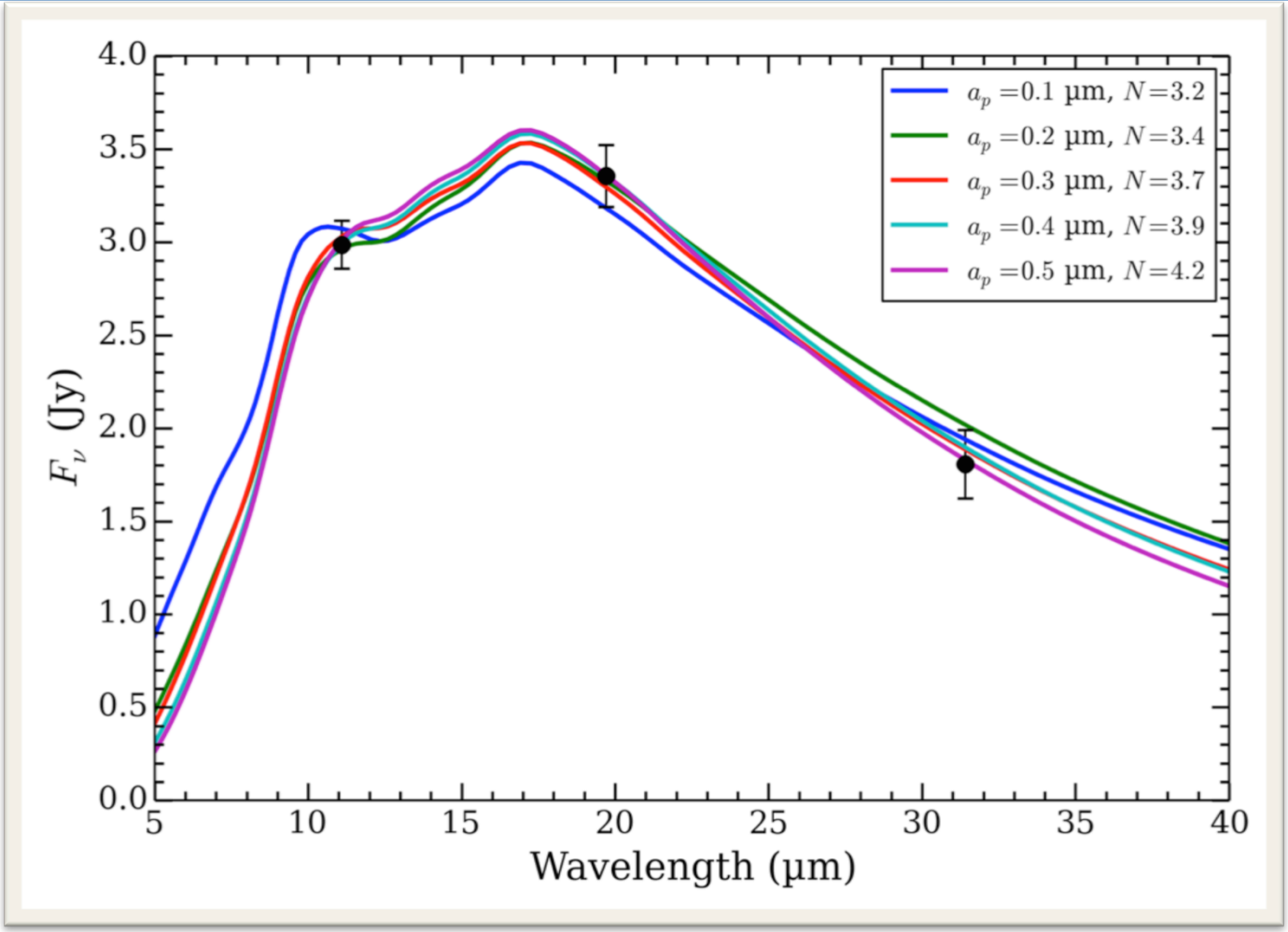


3-pixel Gaussian smooth applied



Comet ISON had a tail in mid-Oct that extended at position angle of -60°

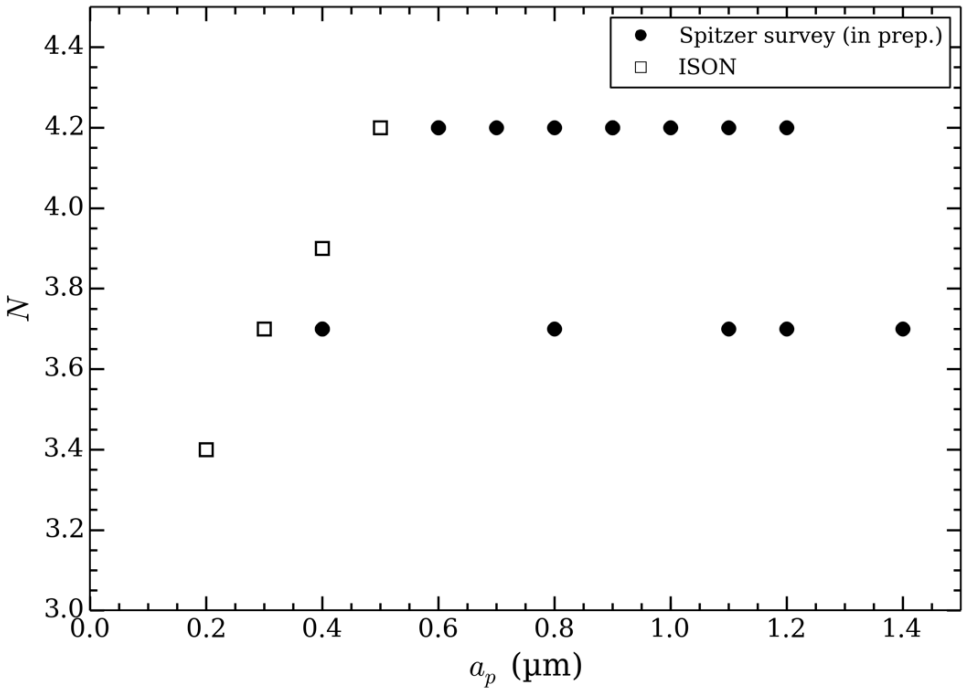
Comet ISON



- Model indicates a steep grain size distribution with moderately porous to solid grains
- Low silicate strength (~10%) indicates high carbon fraction

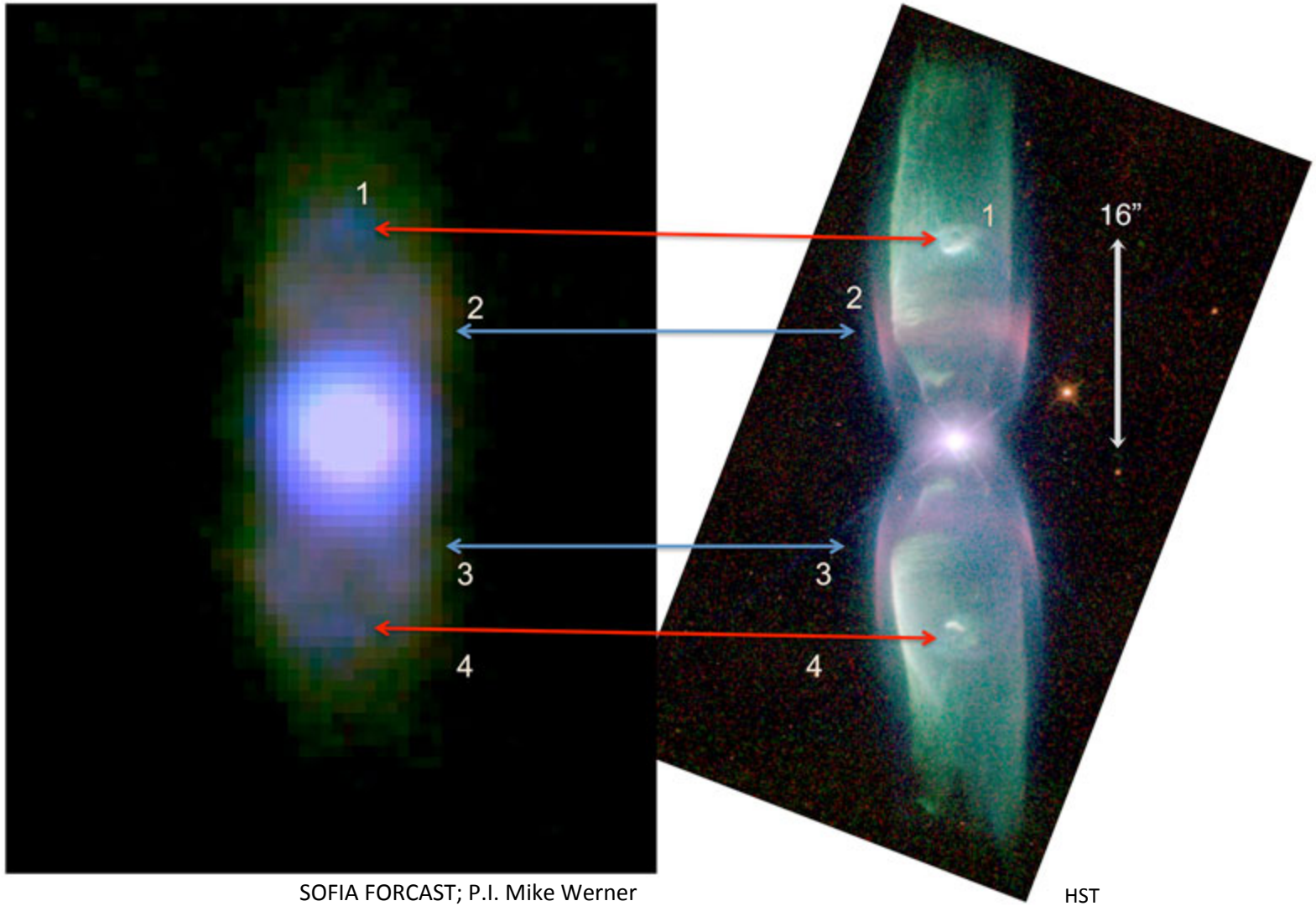
Comet ISON

- One of only 5 Oort family comets observed and analyzed in this manner
- Grain size distribution moderately steep
- Peak grain sizes consistent with Jupiter family, but on the small end



For additional details, see posters by
Mike Sitko – AAS #247.12
Mike Kelley – AAS #247.15

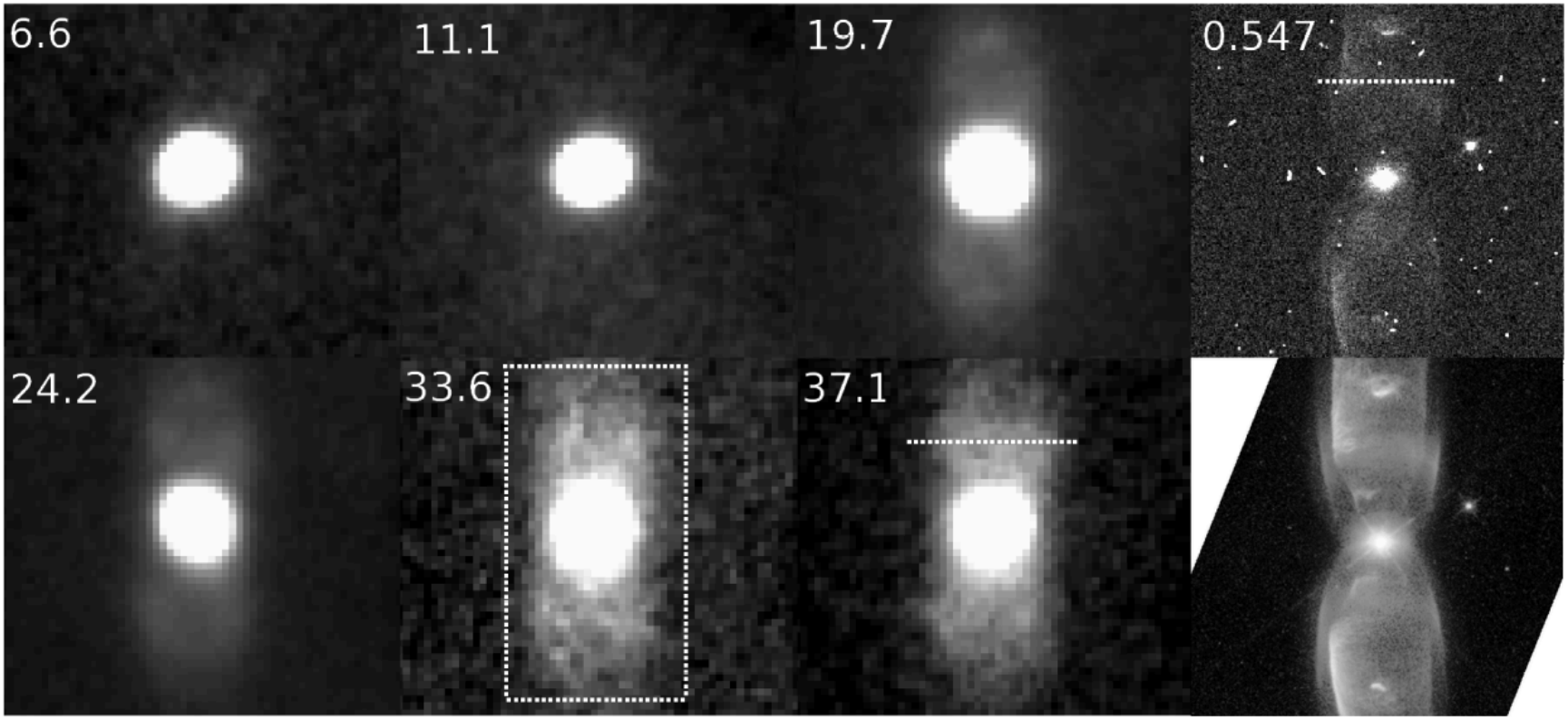
M2-9

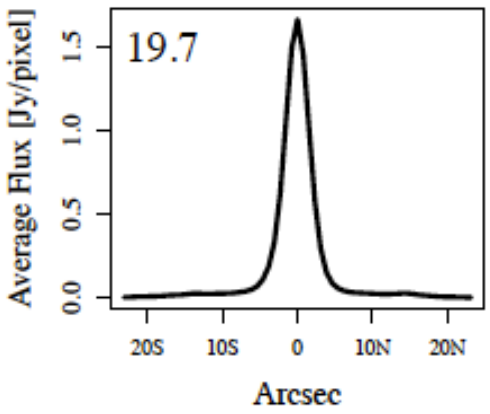


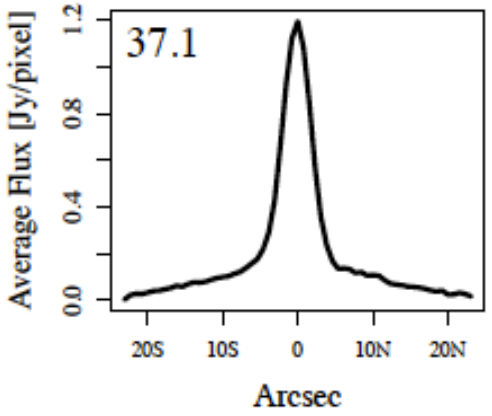
SOFIA FORCAST; P.I. Mike Werner

HST

M2-9


6.6
11.1
19.7
0.547
24.2
33.6
37.1

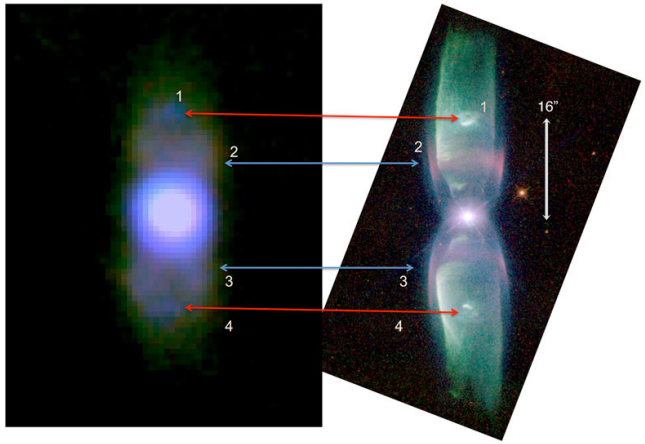

19.7
Average Flux [Jy/pixel]
0.0
0.5
1.0
1.5
20S
10S
0
10N
20N
Arcsec


37.1
Average Flux [Jy/pixel]
0.0
0.4
0.8
1.2
20S
10S
0
10N
20N
Arcsec

M2-9

- Dust is well mixed within the lobes of the outflow
- Asymmetry observed in HST images not seen in SOFIA data
- Total 2.5-40 µm luminosity found to be 840 L_{sol} for the central source and 390 L_{sol} for the lobes
- Additional information in:

  Werner et al. 2014, ApJ, 780, 156

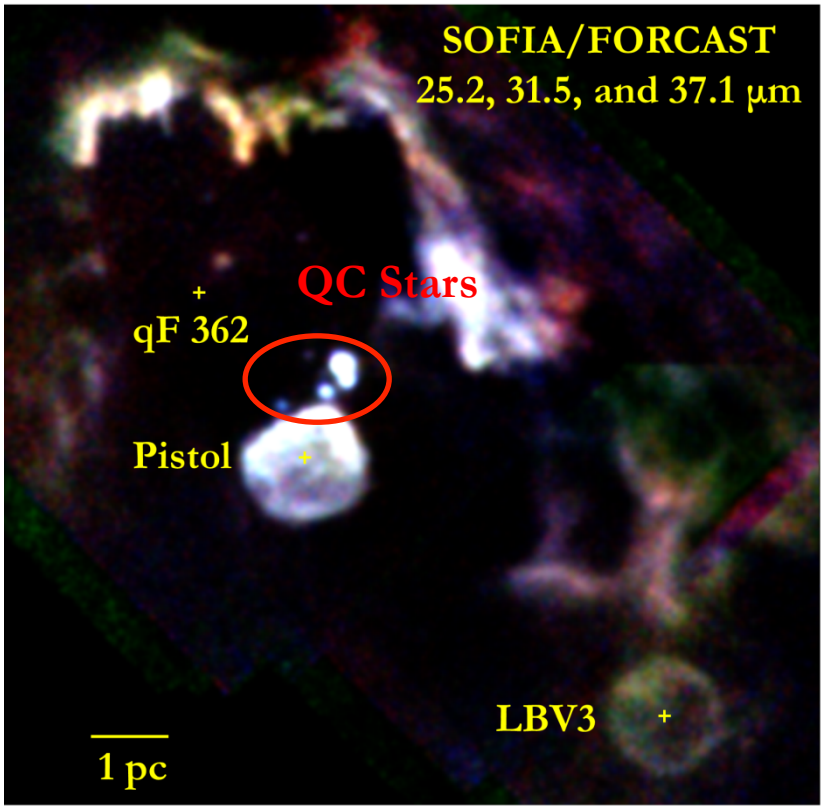


LBVs in & near the Quintuplet Cluster

- GTO PID #70_0001; P.I. Terry Herter
- Ryan Lau, et al. 2014
  - AAS Poster #346.32

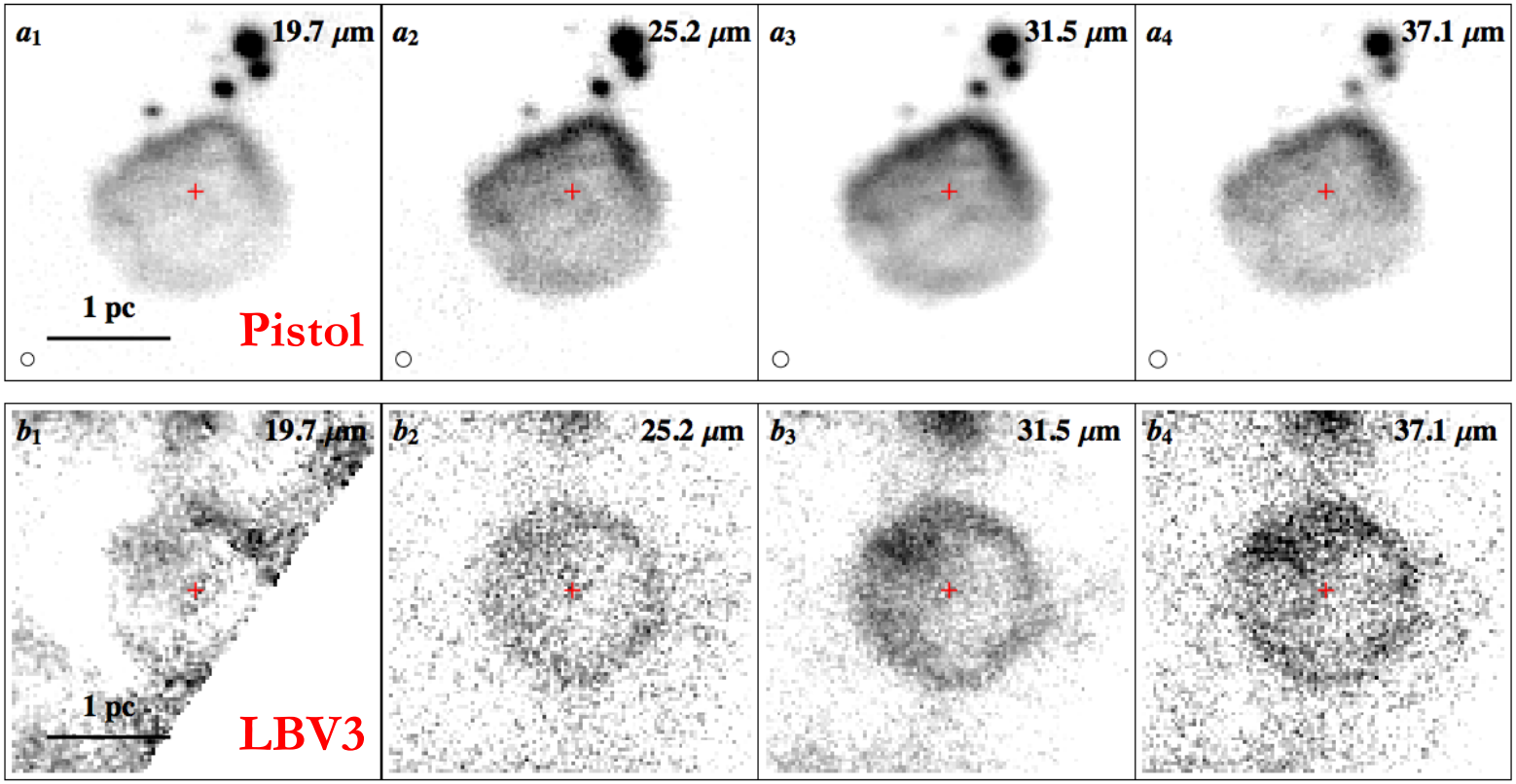
- 3 LBVs are known in and near the Quintuplet Cluster at the Galactic Center: qF 362, the Pistol star, and G0.120-0.048 (LBV3)

- *First detection of the dust emission surrounding LBV3*



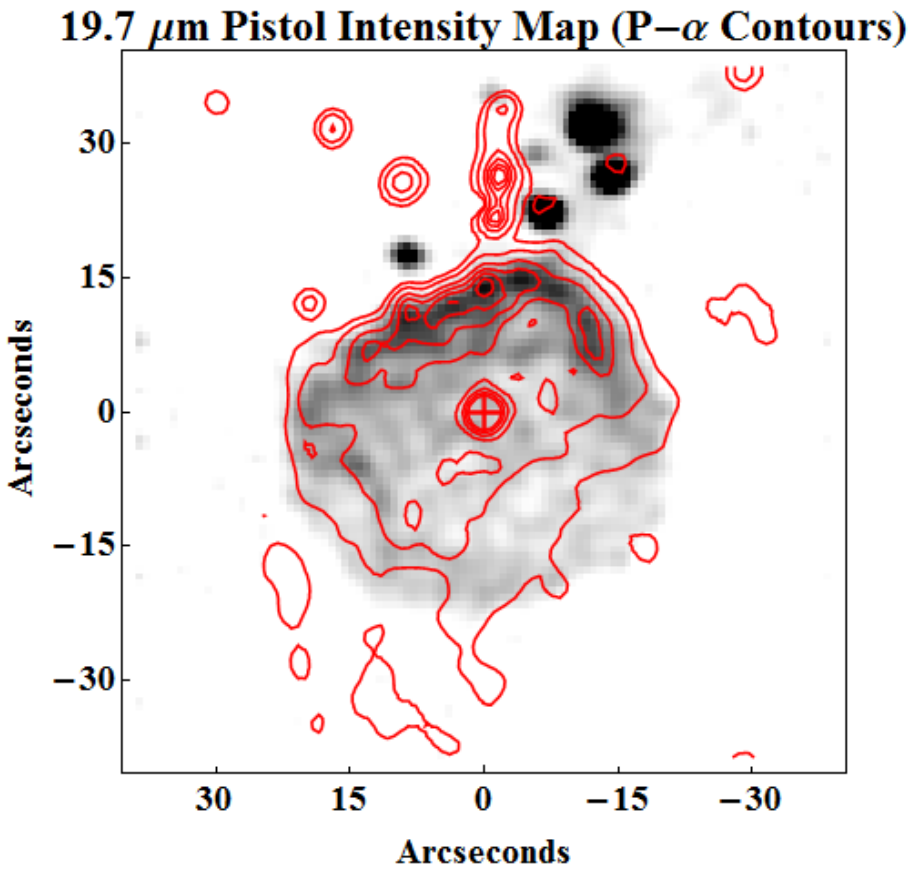
SOFIA/FORCAST false color image of the 3 LBVs in and near the Quintuplet Cluster at 25.2 (blue), 31.5 (green), 37.1 (red) μm

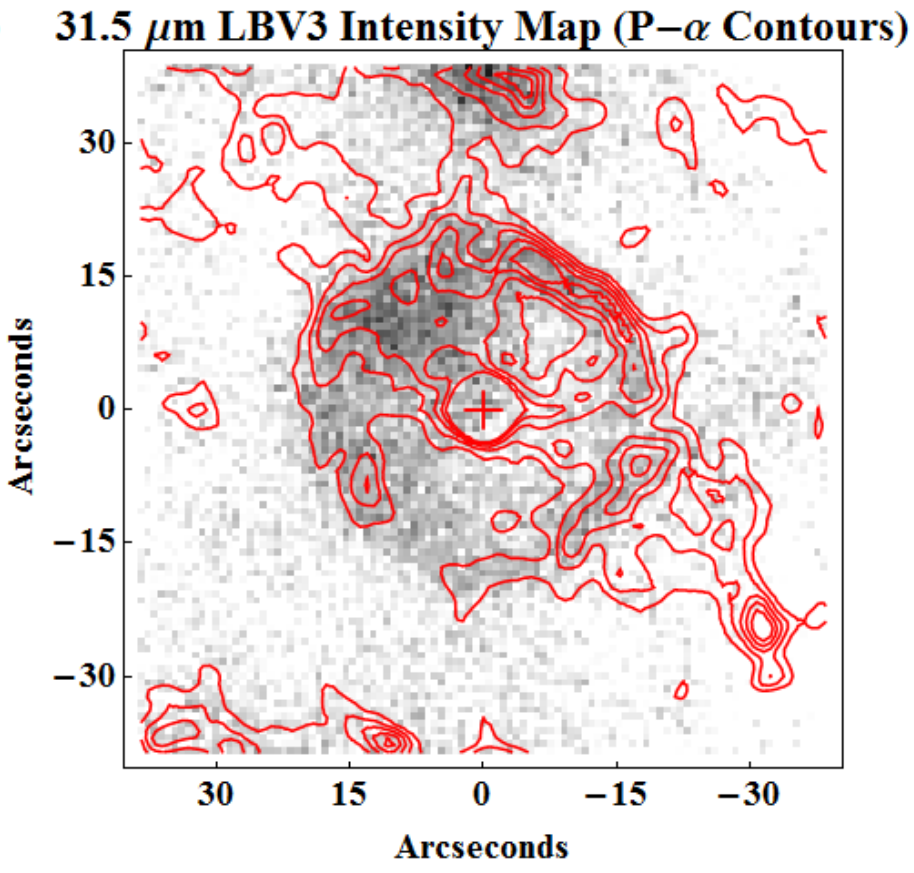
LBVs in & near the Quintuplet Cluster



Argue that the Pistol and LBV3 are identical "twins" that exhibit contrasting nebulae due to the external influence of their different environments

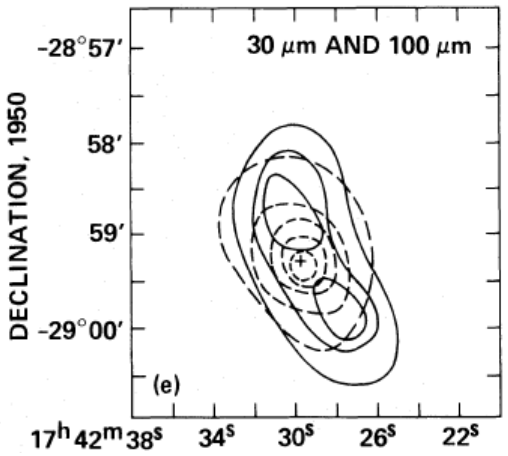
LBVs in & near the Quintuplet Cluster



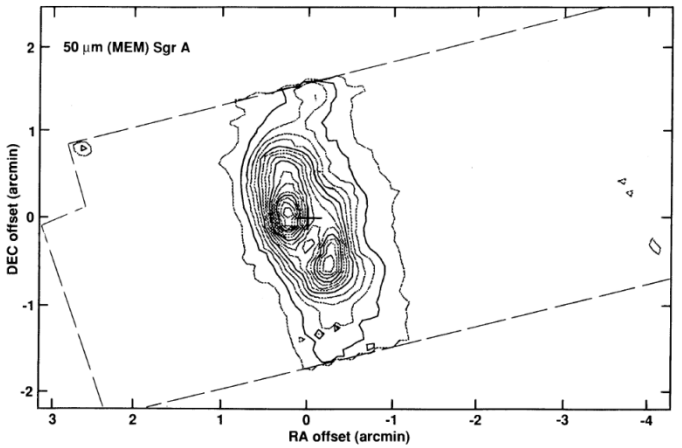


The Paschen-α contours closely trace the dust emission from both nebulae suggesting they are fully ionized. *The LBVs do not produce enough Lyman-cont photons to ionize the nebulae… How are the nebulae ionized?*

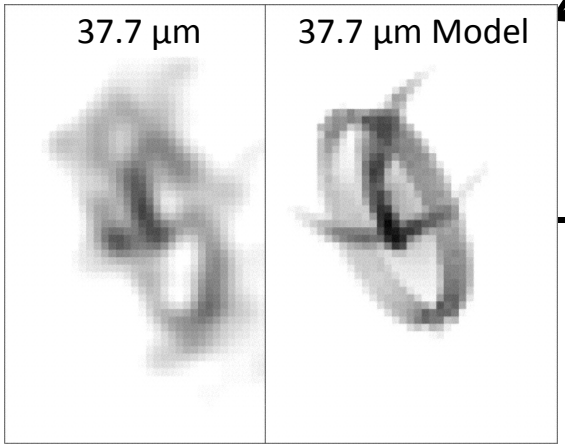
Circumnuclear Ring Around Sgr A*



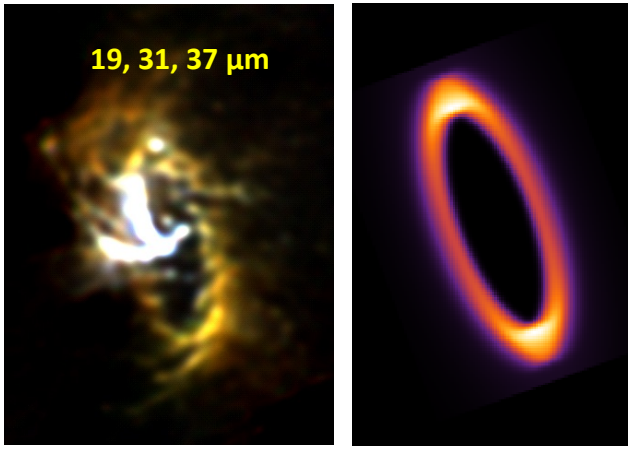
Becklin, Gatley & Werner (1982)



Davidson et al. (1992)



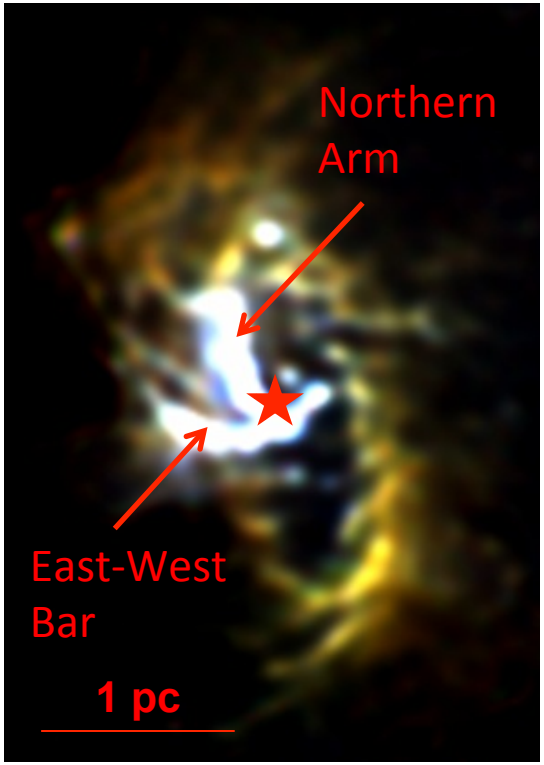
Latvakoski et al. (1999)



Lau et al. (2013)

Circumnuclear Ring Around Sgr A*

SOFIA/FORCAST



Face on View

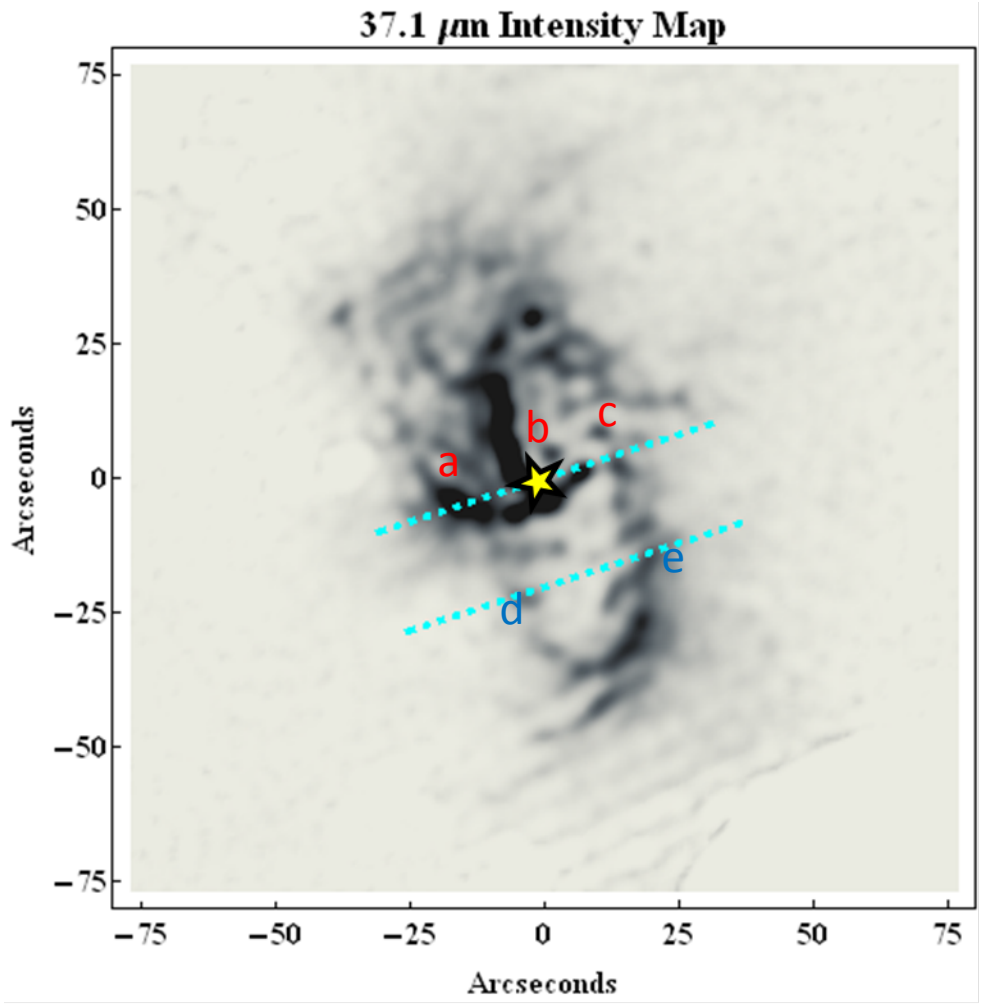
Face-on view of CNR model

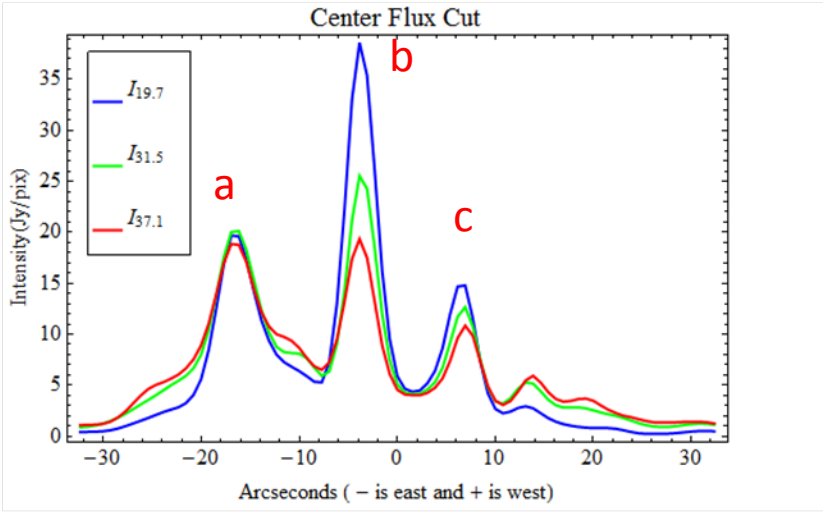
Observed View

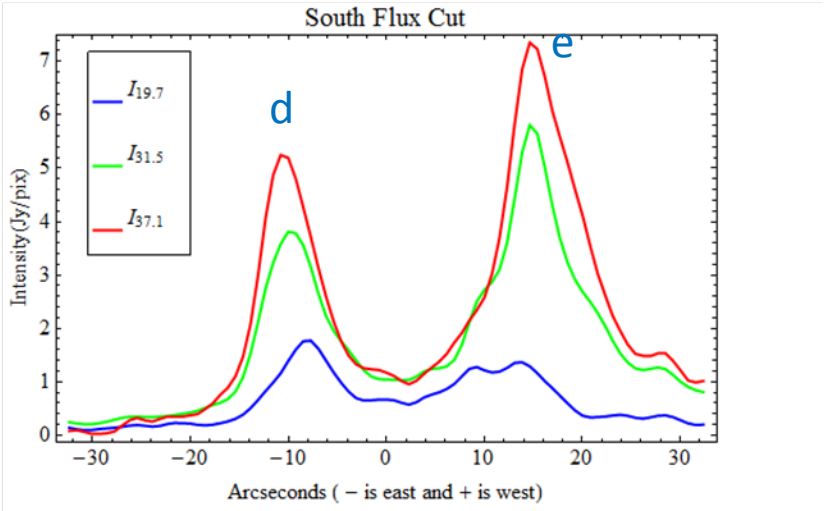
Observed view of CNR model

CNR inclined by ~67 degrees and has a radius of 1.4 pc

Circumnuclear Ring Around Sgr A*

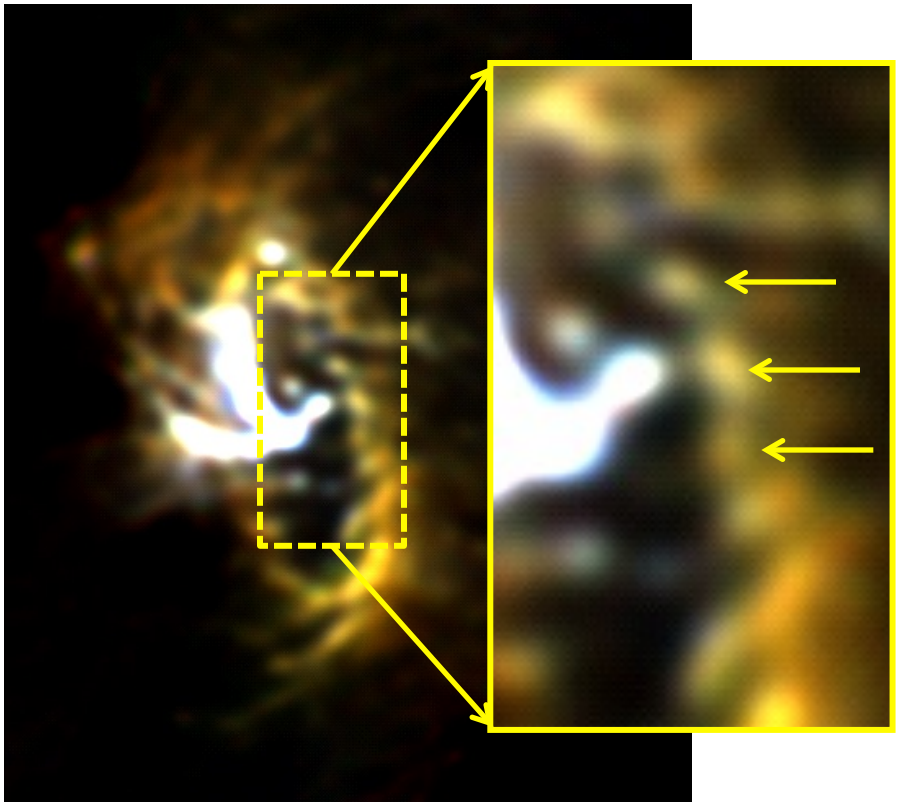






Upper Right: Intensity cut through ring center
Lower Right: Intensity cut through south ring

Circumnuclear Ring Around Sgr A*



SOFIA/FORCAST false color image of the inner 6 pc of the GC at 19.7 (blue), 31.5 (green), 37.1 (red) μm. Inset shows zoom of inner edge "clumps"

- Resolve "clumps" at the inner edge of the CNR
  - r ~ 0.15 pc
- "Clumps" due to density enhancements (not embedded sources)
  - $n \sim 5 - 9 \times 10^4\ cm^{-3}$
- "Clumps" not tidally stable!
  - Should shear out in an orbital period

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