FORCAST DATA PRODUCTS BASIC SCIENCE

SOFIA WORKSHOP

November 7th 2011

USRA Data Reduction Team: Miguel Charcos Llorens, William Vacca, Andrew Helton, Li Sun and Ralph Shuping

FORCAST DRIP Team: Luke Keller (Ithaca College), Marc Berthoud (U. Chicago), Terry Herter (Cornell U.),Joe Adams (Cornell U.)

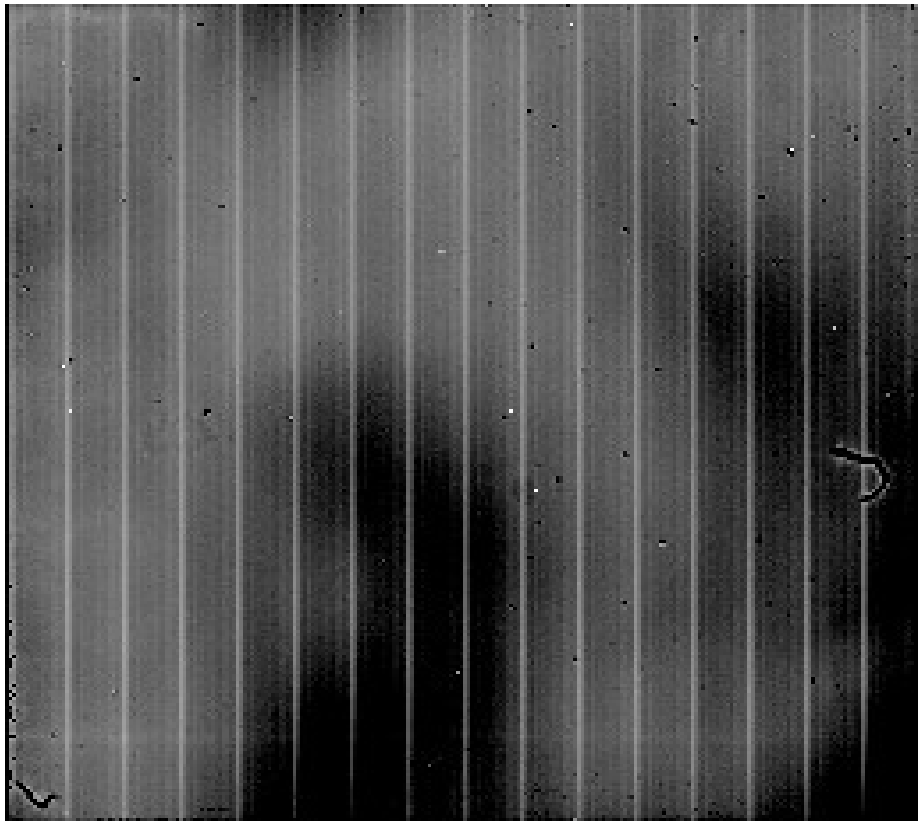
Outline

- Observed Data
- Data Reduction Process
- Data Products
- Final Results

Observed Data

OBSERVATIONAL ARTIFACTS IN MID-IR

- Bad Pixels and cosmic rays
- Electronic Noise:
  - Droop
  - Jailbar (Vertical bars)
  - Non-linearity
  - Gain differences
- Optical Path Differences
- Optical Distortion
- Sky and Telescope Background



Observed Data

OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

- Observing modes:
  - C2
    - Symmetric and Asymmetric chop
  - C2N
    - Nod-Match-Chop (NMC)
    - Nod-Perp-Chop (NPC)
  - C2NC2
  - Dithering
- Flat fields
- Darks

Observed Data

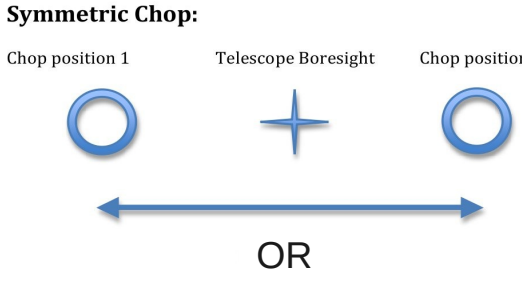
OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

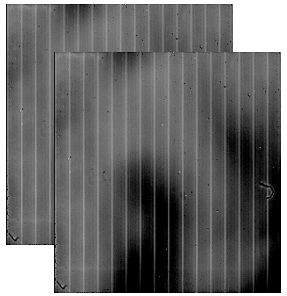
- Observing modes:
  - C2
    - Symmetric and Asymmetric chop
  - C2N
    - Nod-Match-Chop (NMC)
    - Nod-Perp-Chop (NPC)
  - C2NC2
  - Dithering
- ~~Flat fields~~
- ~~Darks~~ Add noise

Observed Data

OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

- Observing modes:
  - C2
  - C2N
  - C2NC2
  - Dithering





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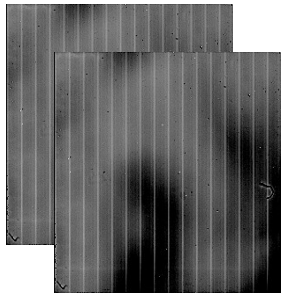

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rFT062_0006.fits
= Array[256,256,2]

Observed Data

OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

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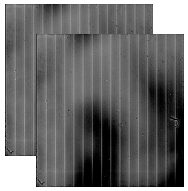

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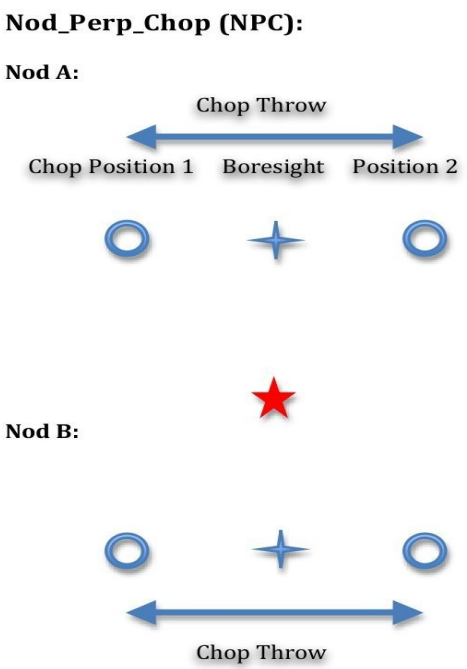
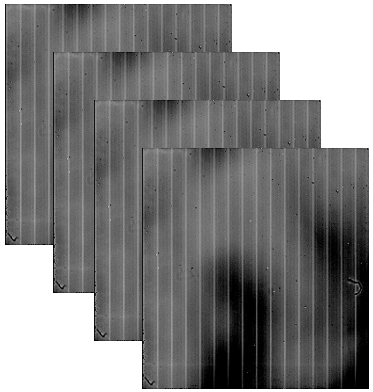
  - C2N





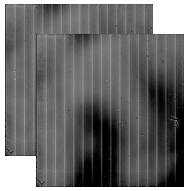
= bFT061_0287.fits
rFT061_0287.fits
= Array[256,256,4]

  - C2NC2
  - Dithering

Observed Data

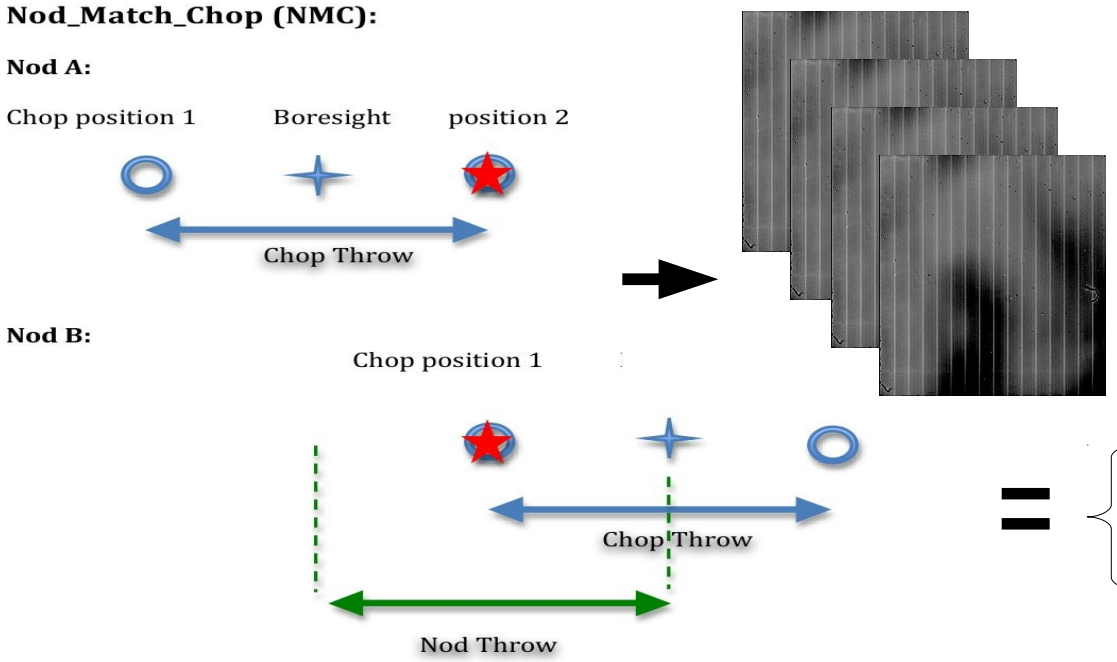
OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

- Observing modes:
  - C2



= bFT062_0006.fits
rFT062_0006.fits
= Array[256,256,2]

  - C2N
  - C2NC2
  - Dithering



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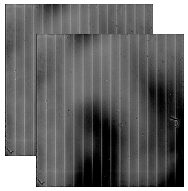
rFT061_0287.fits
= Array[256,256,4]

Observed Data

OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

- Observing modes:
  - C2



= bFT062_0006.fits
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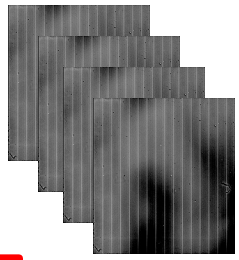
  - C2N



= bFT061_0287.fits
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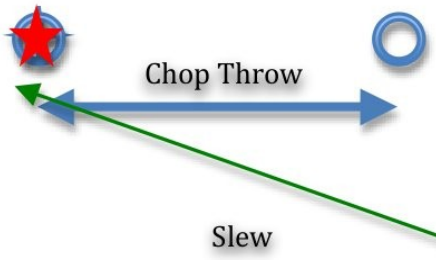
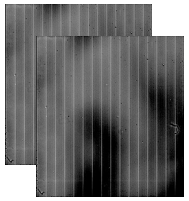
  - C2NC2



ABAABAAB



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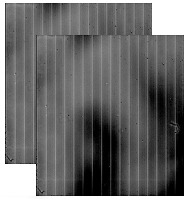
x8



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rFT063_0110.fits
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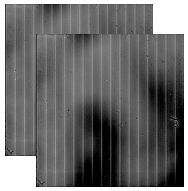
  - Dithering

Observed Data

OBSERVATIONAL TECHNIQUES AND LEVEL_1 (RAW)

- Observing modes:
  - C2



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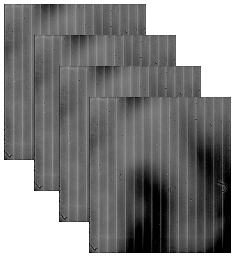
  - C2N



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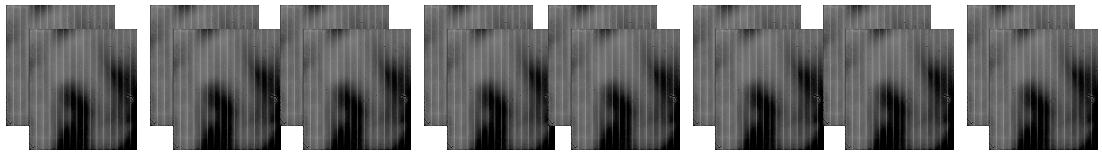
rFT061_0287.fits
= Array[256,256,4]

  - C2NC2



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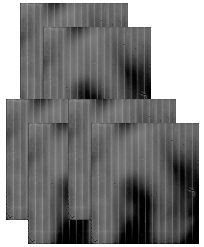
rFT063_0104-110.fits
= 8xArray[256,256,2]

  - Dithering

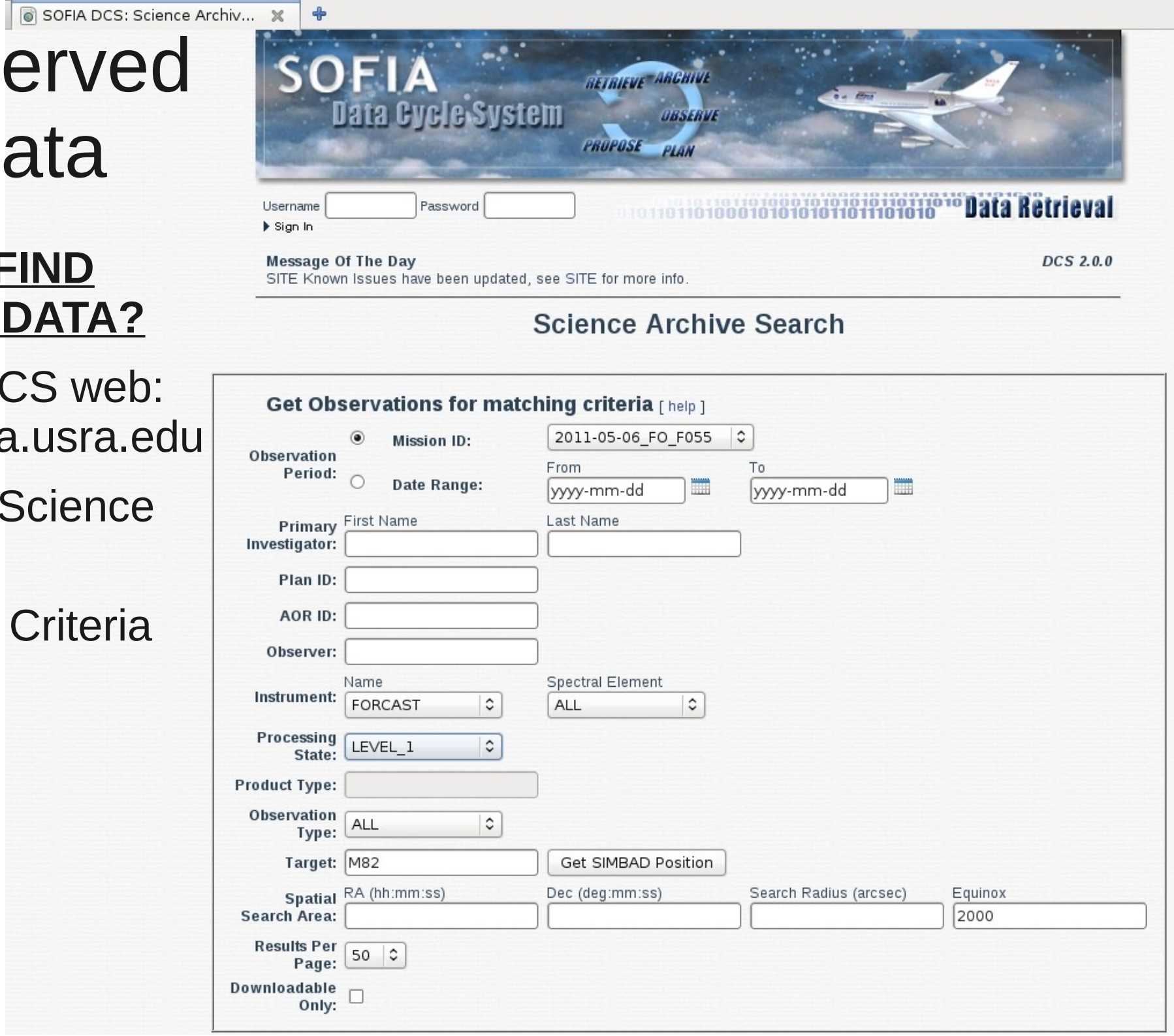


= NxArray[256,256,2 or 4]

Observed Data

HOW TO FIND LEVEL_1 DATA?

- Go to DCS web: dcs.sofia.usra.edu
- Search Science Archive
- Choose Criteria



Observed Data

HOW TO FIND LEVEL_1 DATA?

- Select data + push “Get Selected Data” + Confirm selection
- Click email link + download zip file + unzip
- Verify hash

Get Selected Data

All ☐	Mission ID	Processing	AOR	Primary Investigator	Observer	Target	Observation Type	RA - Dec (J2000)	Obs Date (UTC)	Start - End (UTC)	Exp. Time (sec)	Instrument	Spectral Element	Release Date (UTC)	File Size (MB)
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.36 - +28:04:43.9	2011-05-06	11:43:33 - 11:43:38	4.7068	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.73 - +28:05:15.16	2011-05-06	11:43:56 - 11:44:01	4.6943	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.37 - +28:04:45.29	2011-05-06	11:44:27 - 11:44:32	4.6943	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.86 - +28:05:13.83	2011-05-06	11:44:50 - 11:44:55	4.794	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.37 - +28:04:45.49	2011-05-06	11:45:13 - 11:45:18	4.794	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.68 - +28:05:15.73	2011-05-06	11:45:36 - 11:45:42	4.8811	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02
☐	2011-05-06_FO_F055	LEVEL_1	UNKNOWN Get Data Products		?	Beta Peg	standard	23:03:46.35 -	2011-05-06	11:46:41 -	4.6943	FORCAST	N.I.	2011-10-05 00:00:00.0	1.02

Observed Data

DATA PROPERTIES (LEVEL_1)

- Name convention:
  - Name = b/r + FT0 + flight# + _ + file# + .fits
    ex: bFT062_0001.fits
  - Archive names have unique stamp
    ex: bFT062_0001_*1319575990644*.fits
- Header Keywords
  - *OBSTYPE* (object or standard)
  - *INSTMODE* = C2, C2N (+ C2nc2 keyword)
  - *PROCSTAT* = Level_1, Level_2
  - *WAVELNTH* for filter

Data Reduction Process

REDUCTION ALGORITHMS AND LEVEL_2 DATA

- Remove instrument artifacts and sky
- Data Reduction Steps
  - Select Data Groups
  - Identify and clean bad pixels
  - Droop correction
  - Non-linearity correction
  - Stack planes
  - Distortion correction
  - Merge peaks
  - Coadd merged images

Data Reduction Process

- Select Data Groups
- Clean Bad Pixels
- Droop Correction
- Non-linearity Correction
- Stack Planes
- Distortion Correction
- Merge Peaks
- Coadd Merged images

Flight ID: 2011-05-06_FO_F055 Date: 5May2011 7:45 PM TO Local

Science Team: Terry Herter, Joe Adams, Justin Schoenwald, Chuck Henderson, George Gull, Jim DeBuizer, Bob Gehrz

Object	Time	AOR ID#	Frame #	λ(μ) short	λ(μ) long	t(int) (sec)	Chop Type	Data Mode	FR Short	FR Long	Pres. Altitude	SM Temp	Comments
α Boo	01:11		188	11.3	—	55		C2N	113L	—	41K	+31.35	w/o Dich
			189	11.1	37	55			73H	70L			w/ Dich
	01:12		190	11.3	37	55			85H	70L			w/ Dich

#	INSTMODE	OBJNAME	OBJECT	FILTER	C2NC2	DATATYPE	PROCSTAT	DICHROIC	DATASRC	OBSTYPE	CHOPMNOD	DITHERS	NDITHERS	NFILES
0	C2N	x	Gamma Dra	11.1um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	5
1	C2N	x	Gamma Dra	19.7um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	5
2	C2N	x	Gamma Dra	24.2um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	9
3	C2N	x	Alpha Boo	24.2um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	2
4	C2N	x	Alpha Boo	19.7um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	2
5	C2N	x	Alpha Boo	11.1um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	9
6	C2N	x	Beta And	19.7um		IMAGE	LEVEL_1	Open (lwc)	astro	standard	CMN		x	8
7	C2N	x	Beta And	11.1um		IMAGE	LEVEL_1	Dichroic	astro	standard	CMN		x	14
8	C2N	x	Gamma Dra	31.4um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	5
9	C2N	x	Gamma Dra	34.8um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	5
10	C2N	x	Gamma Dra	37.1um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	9
11	C2N	x	Alpha Boo	34.8um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	2
12	C2N	x	Alpha Boo	37.1um		IMAGE	LEVEL_1	Dichroic	astro	standard	CPN		x	2
13								Dichroic	astro					
14								pen (lwc)	astro					
15								pen (lwc)	astro					
								Dichroic	astro					

Visual Inspection:
- S/N
- Background
- Instrument/telescope issues

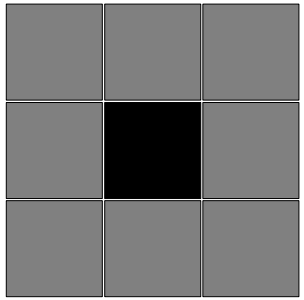
2 FILES in GROUP 3

bFT061_0164_1306520758894.fits

bFT061_0167_1306520746984.fits

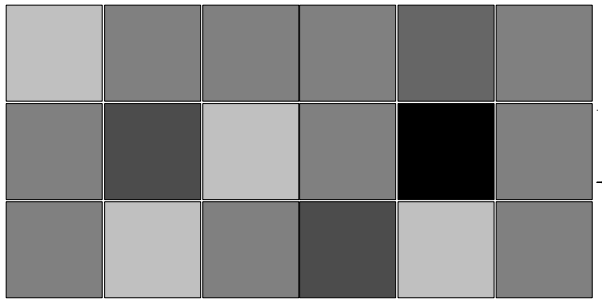
Data Reduction Process

- Select Data Groups
- Clean Bad Pixels
- Droop Correction
- Non-linearity Correction
- Stack Planes
- Distortion Correction
- Merge Peaks
- Coadd Merged images



BadPixel Mask from Instrument Team

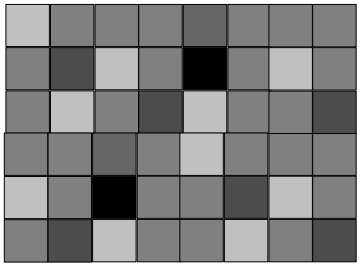
Correct using planar interpolation



+mean_signal_row*factor

Characterized by Herter, T

Correct using correction coeff



Characterized by Vacca, W

Correct using correction background level, scale and signal reference

Data Reduction Process

- Select Data Groups
- Clean Bad Pixels
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- Non-linearity Correction
- Stack Planes
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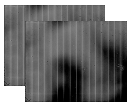
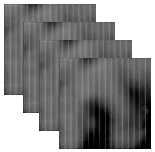
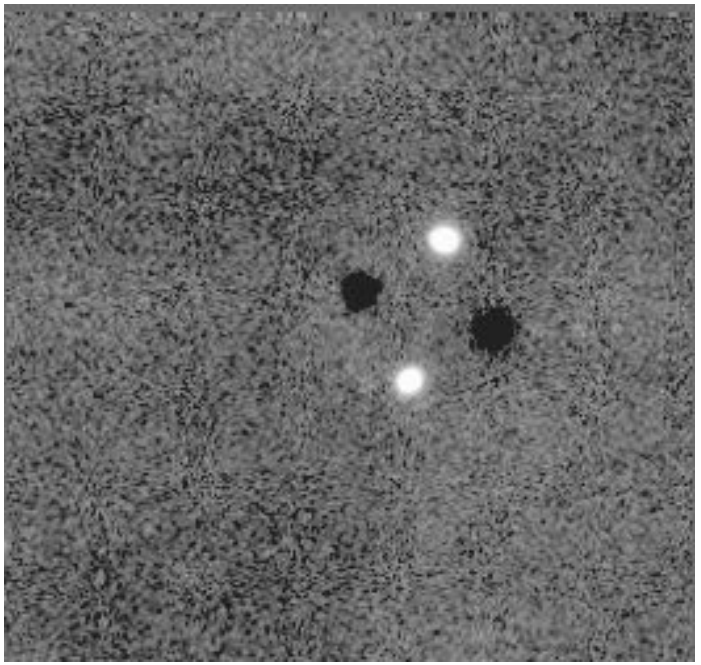
C2



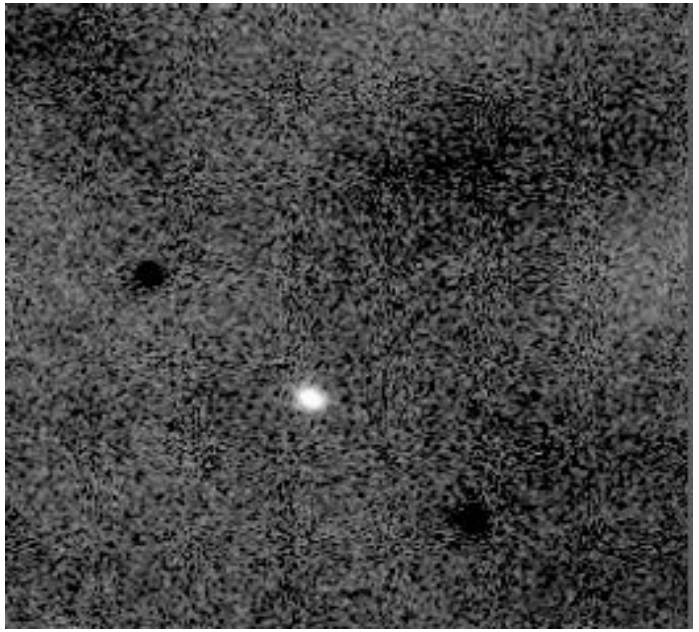
C2N



C2N - NPC



C2N - NMC



Data Reduction Process

- Select Data Groups
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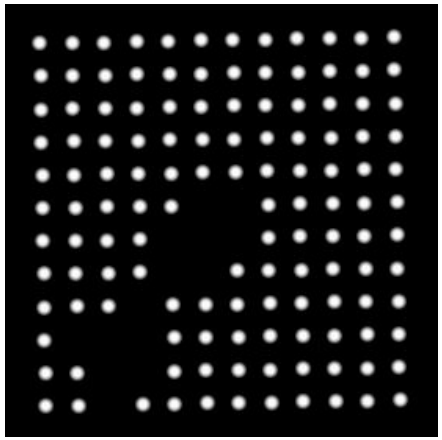
- Non-linearity Correction
- Stack Planes
- Distortion Correction
- Merge Peaks
- Coadd Merged images



Distortion correction characterized by Vacca, W

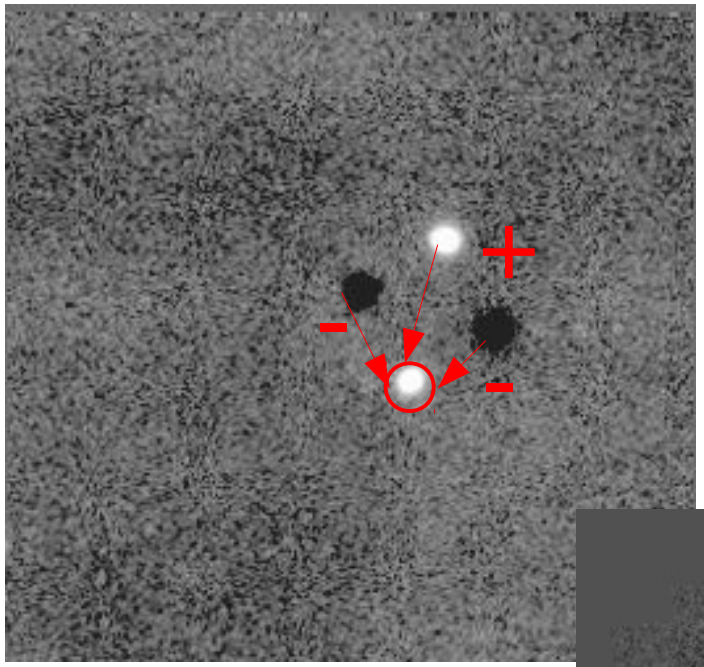
Find peaks

Create Model

Perform Distortion correction

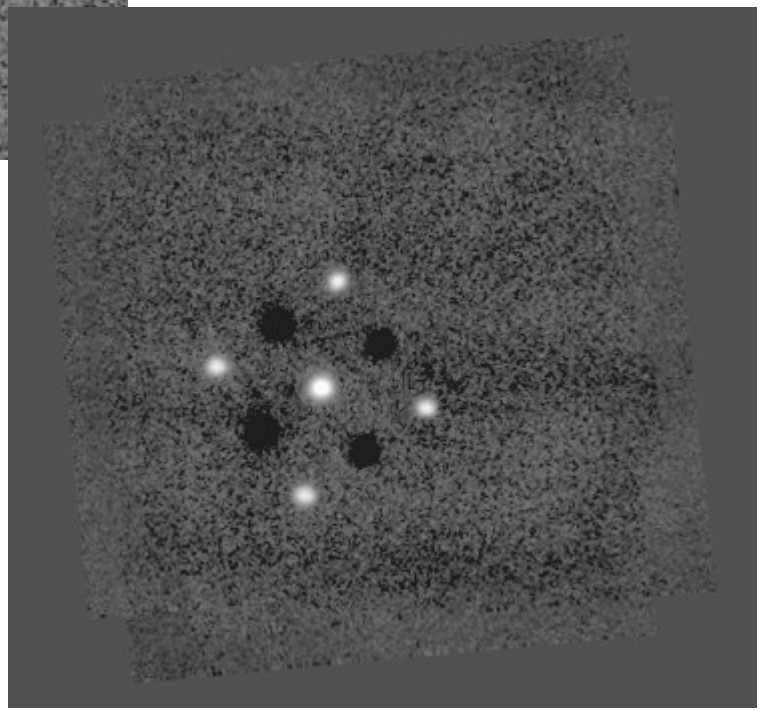
Data Reduction Process

- Select Data Groups
- Clean Bad Pixels
- Droop Correction
- Non-linearity Correction
- Stack Planes
- Distortion Correction
- Merge Peaks
- Coadd Merged images

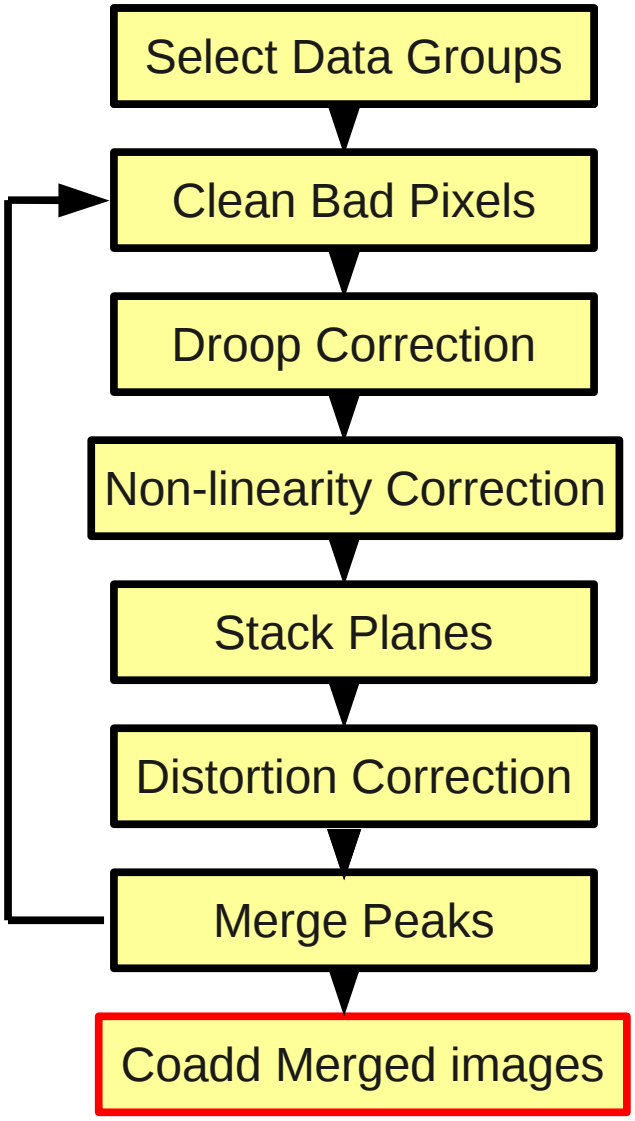


Shift 3 times

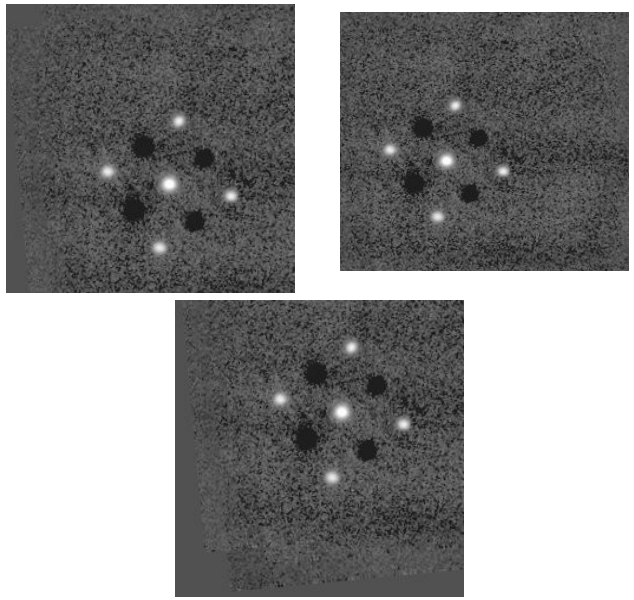
Rotate to sky coordinates (=180-SKYANGL)

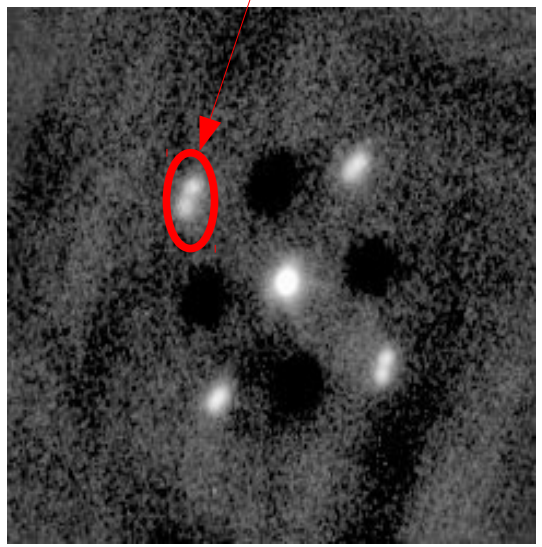


Data Reduction Process

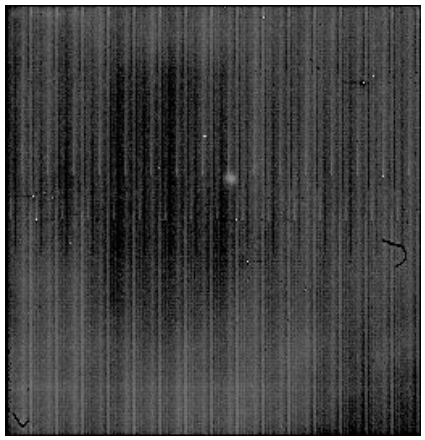


C2N - NPC

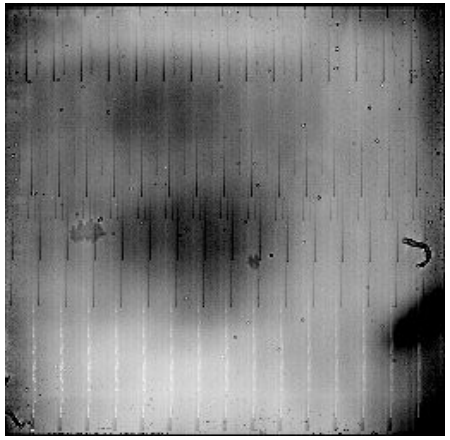




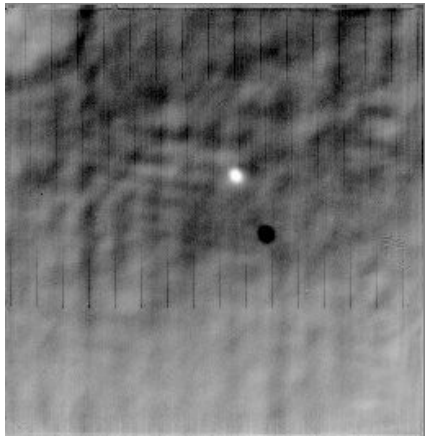
Data Reduction Process



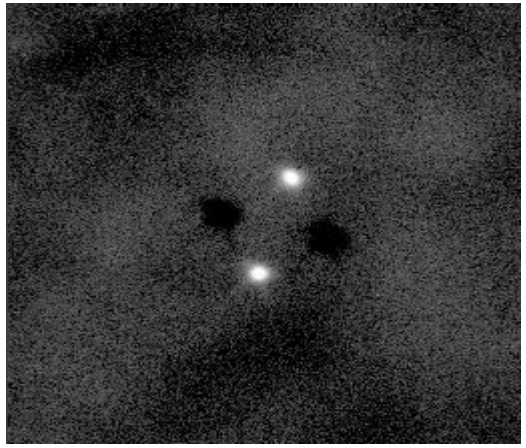
Raw Data



Corrected Data
(Bad Pix, droop and non-lin)



Chop subtracted

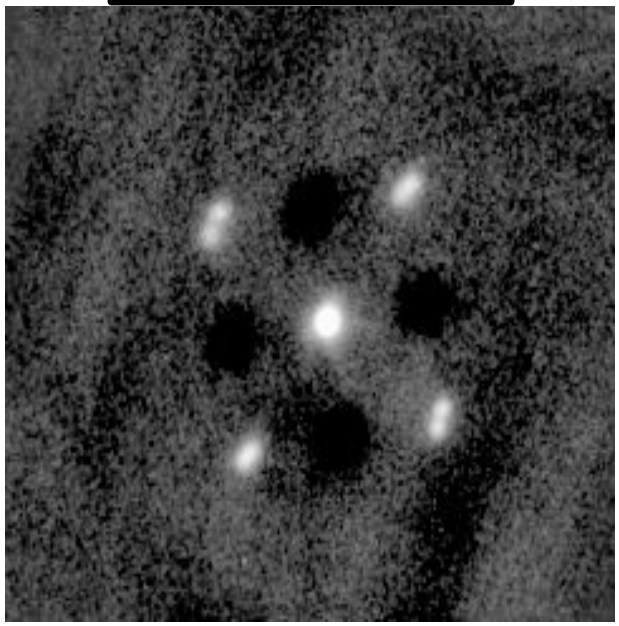


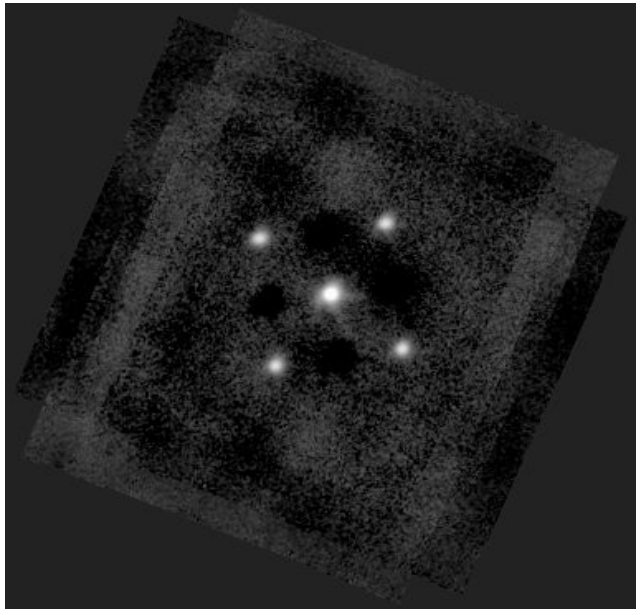
Stacked

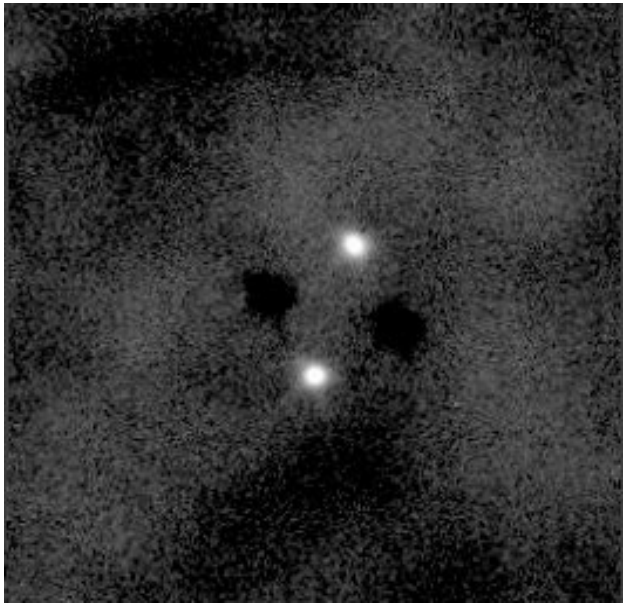
Distortion Corrected

Merged

Coadded







Data Products

Level_1 image: bFT055_0169.fits

Level_2 image: bFT055_0169_[PRODTYPE].fits

Select Data Groups

Clean Bad Pixels

Droop Correction

Non-linearity Correction

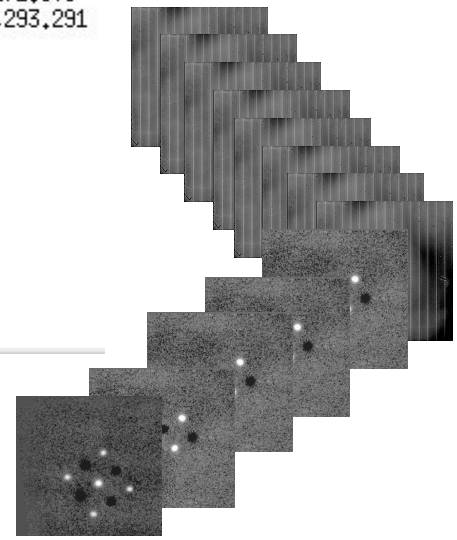
Stack Planes

Distortion Correction

Merge Peaks

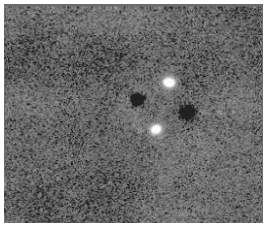
Coadd Merged images

```
HISTORY Merge: algorithm used for shift is CENT
HISTORY Merge: X, Y shifts are 0.00000,0.00000 for peak 259.899,238.205
HISTORY Merge: X, Y shifts are -35.0684,-21.2699 for peak 294.968,259.474
HISTORY Merge: X, Y shifts are 19.3484,-34.0981 for peak 240.551,272.303
HISTORY Merge: X, Y shifts are -15.9698,-55.0869 for peak 275.869,293.291
HISTORY Coadd: X,Y shift of image is -0.0197067,
PARENT12= '2011-05-27_FO_F061B0176' /
PL0-3   = 'CLEANED '           /
PL4-7   = 'DROOPED '           /
PL8-11  = 'IMGLINEARIZED'      /
PL12-15 = 'LINEARIZED'         /
PL16-19 = 'FLATTED '           /
PL20    = 'STACKED '           /
PL21    = 'UNDISTORTED'        /
PL22    = 'MERGED  '           /
PRODTYPE= 'ALLRED  '           /
ecl> []
```

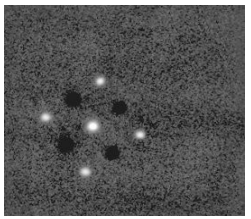


bFT055_0169_allred.fits

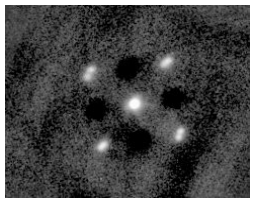
bFT055_0169_undistorted.fits



bFT055_0169_merged.fits



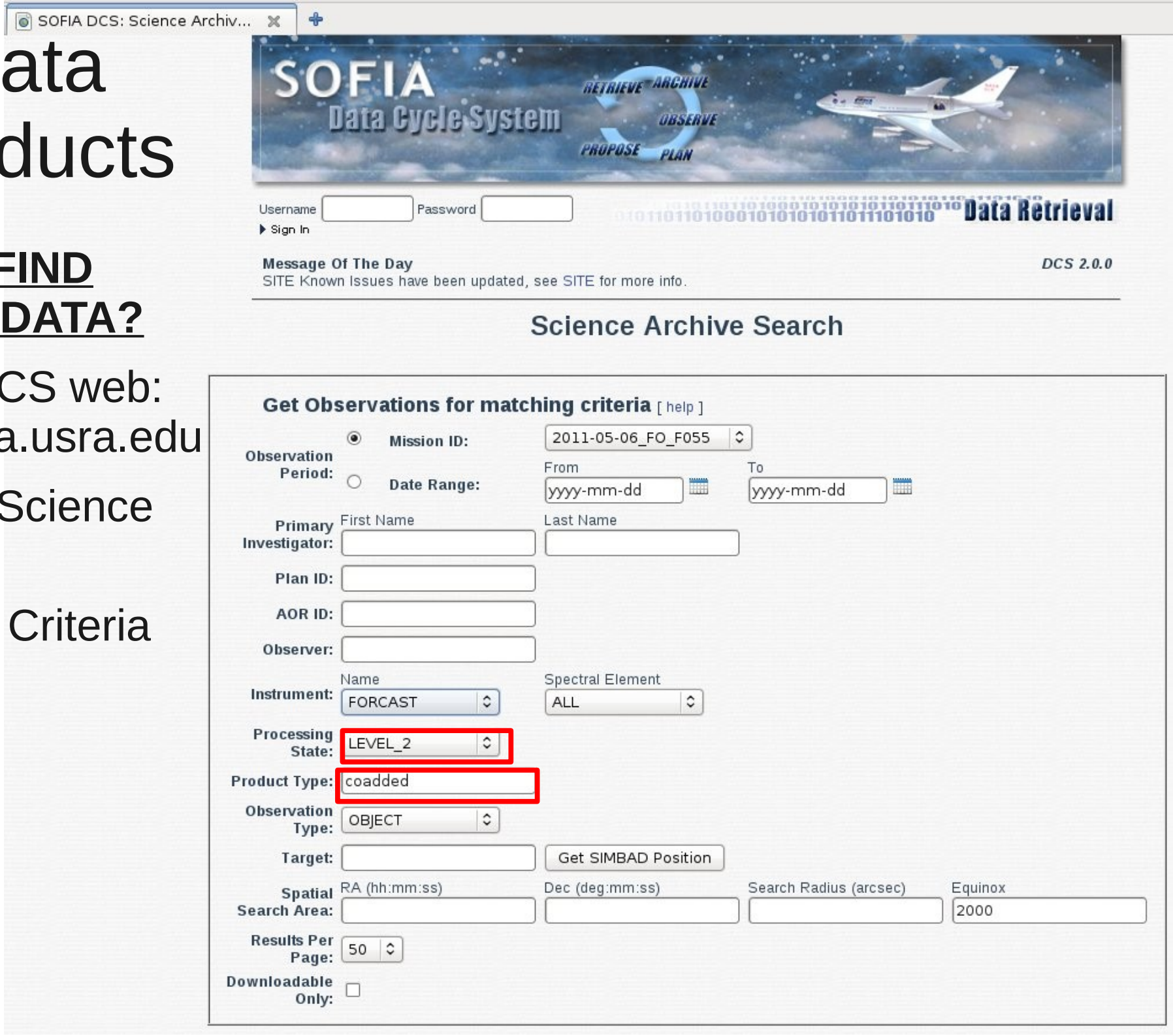
bFT055_0169_coadded.fits



Data Products

HOW TO FIND LEVEL_2 DATA?

- Go to DCS web: dcs.sofia.usra.edu
- Search Science Archive
- Choose Criteria



Data Products

DATA PROPERTIES (LEVEL_2)

- Name convention:
  - Name = b/r + FT0 + flight# + _ + file# + _ + prodtype .fits
    ex: bFT062_0001_coadded.fits
  - Archive names have unique stamp
    ex: bFT062_0001_coadded_*2359585900341*.fits
- Header Keywords
  - *HISTORY* gives information about the reduction (ex: shifts)
  - *CHPAMP*/*CHPANG* – *NODAMP*/*NODANG* for manually perform or double-check shifts
  - *TELRA* and *TELDEC* for checking final combination
  - *PRODTYPE*: drip-undistorted, drip-coadded,...

Final Results...

- Images in Mega-electrons per second
- For **high S/N:** Use coadded images and calibrators for science
- For **low S/N:**
  - No cadded images because:
    - Dither keywords are not precise
    - Centroid and correlation algorithms are inefficient due to high and uneven background
  - Manually combine merged images
- **Special cases**:
  - Need accurate merged images
    - Verify shifts in merged header history
    - If required, manually combine undistorted images
    - Rotate image by 180-*SKYANGL*
  - Need accurate coadded images
    - Verify shifts in coadded header history
    - If required, manually combine merged images
  - Need to lower the S/R by combining various coadded files
    - Multiply each coadded image by the number of merged files
    - Combine the scaled merged files
    - Divide by the total number of merged files for all the combined coadded

QUESTIONS?