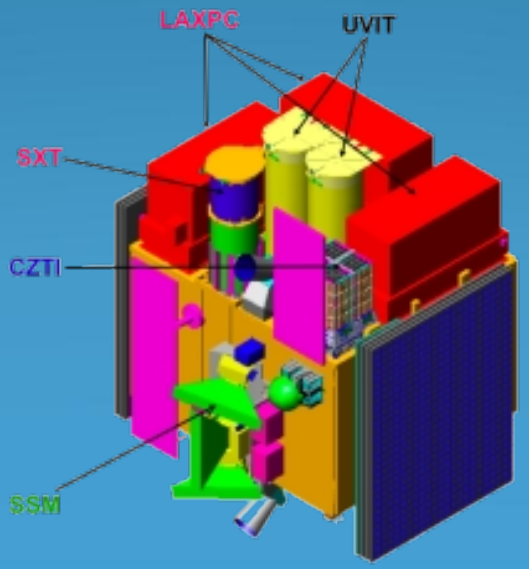
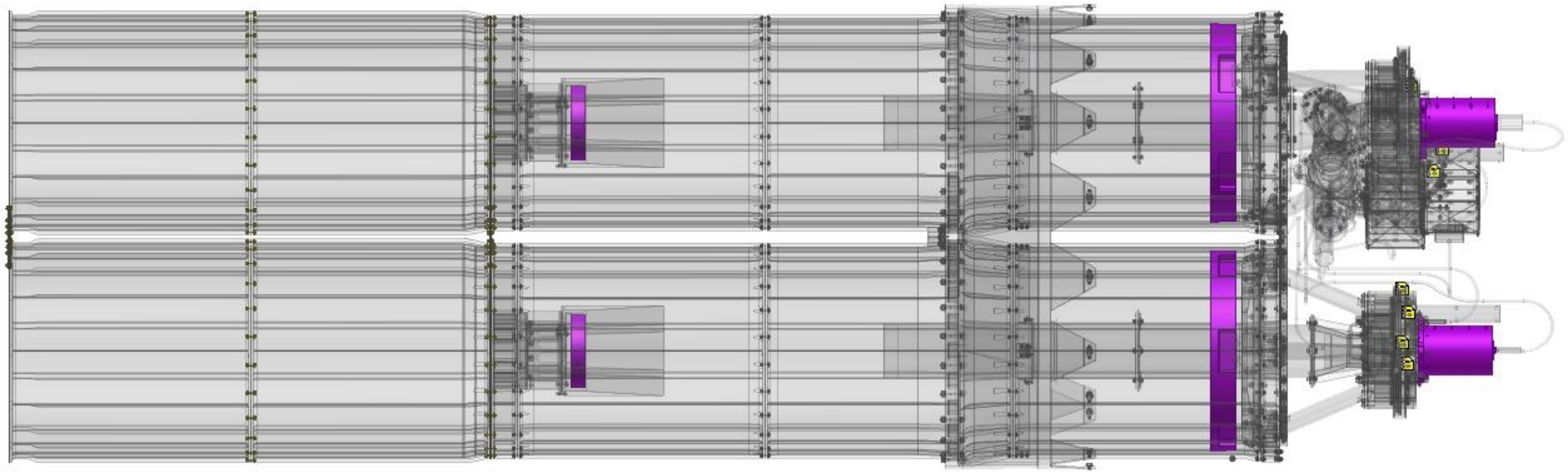
UVIT – IN ORBIT CALIBRATIONS

Annapurni Subramaniam
IIA

UVIT-PMB Meeting – 08 June 2012



UVIT Telescope – various components



Calibrations

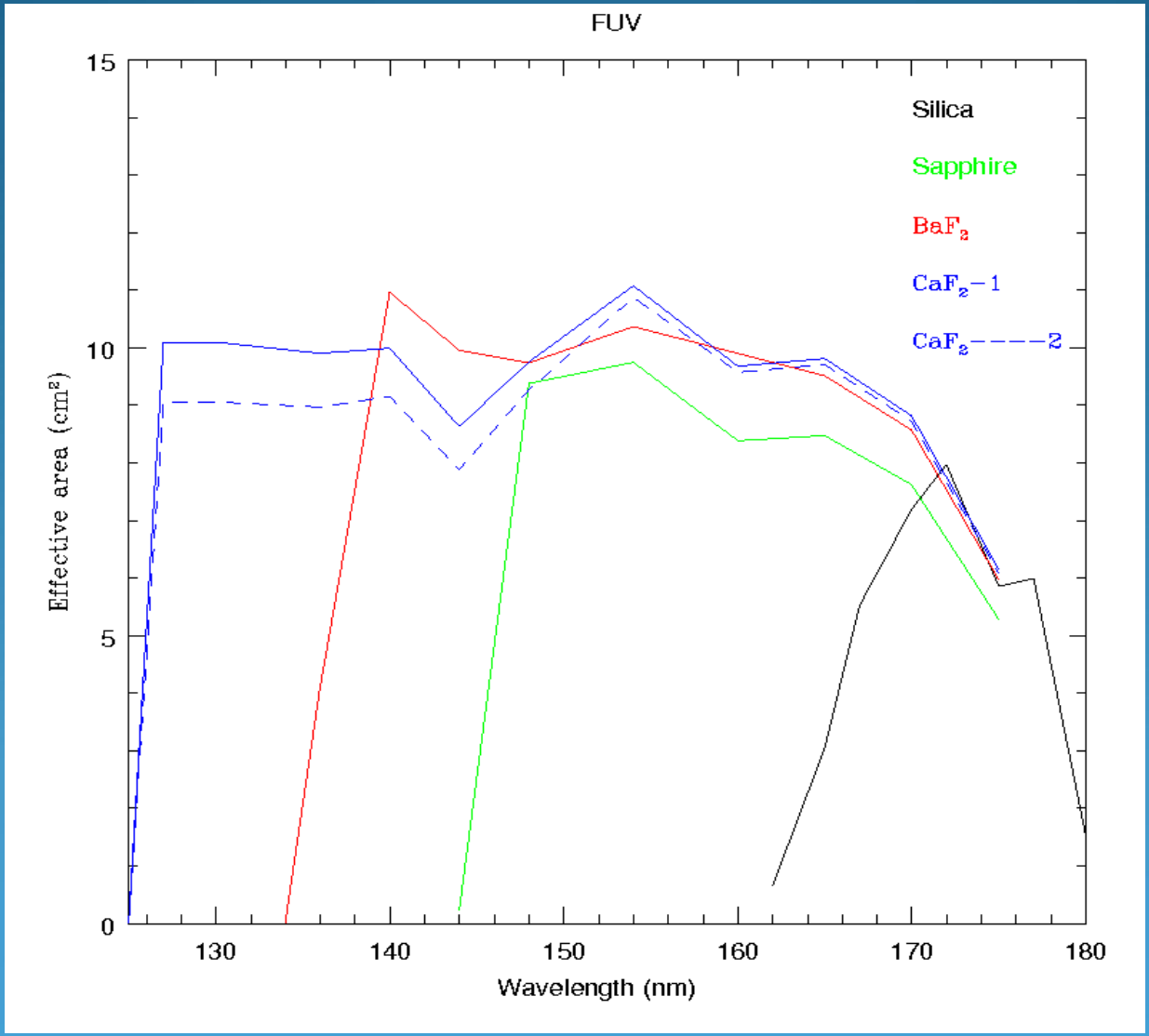
Calibrations are of two types:
1. Ground calibrations
2. In orbit calibrations

In general,
calibration deliverables = ground/orbit/(ground+in orbit)

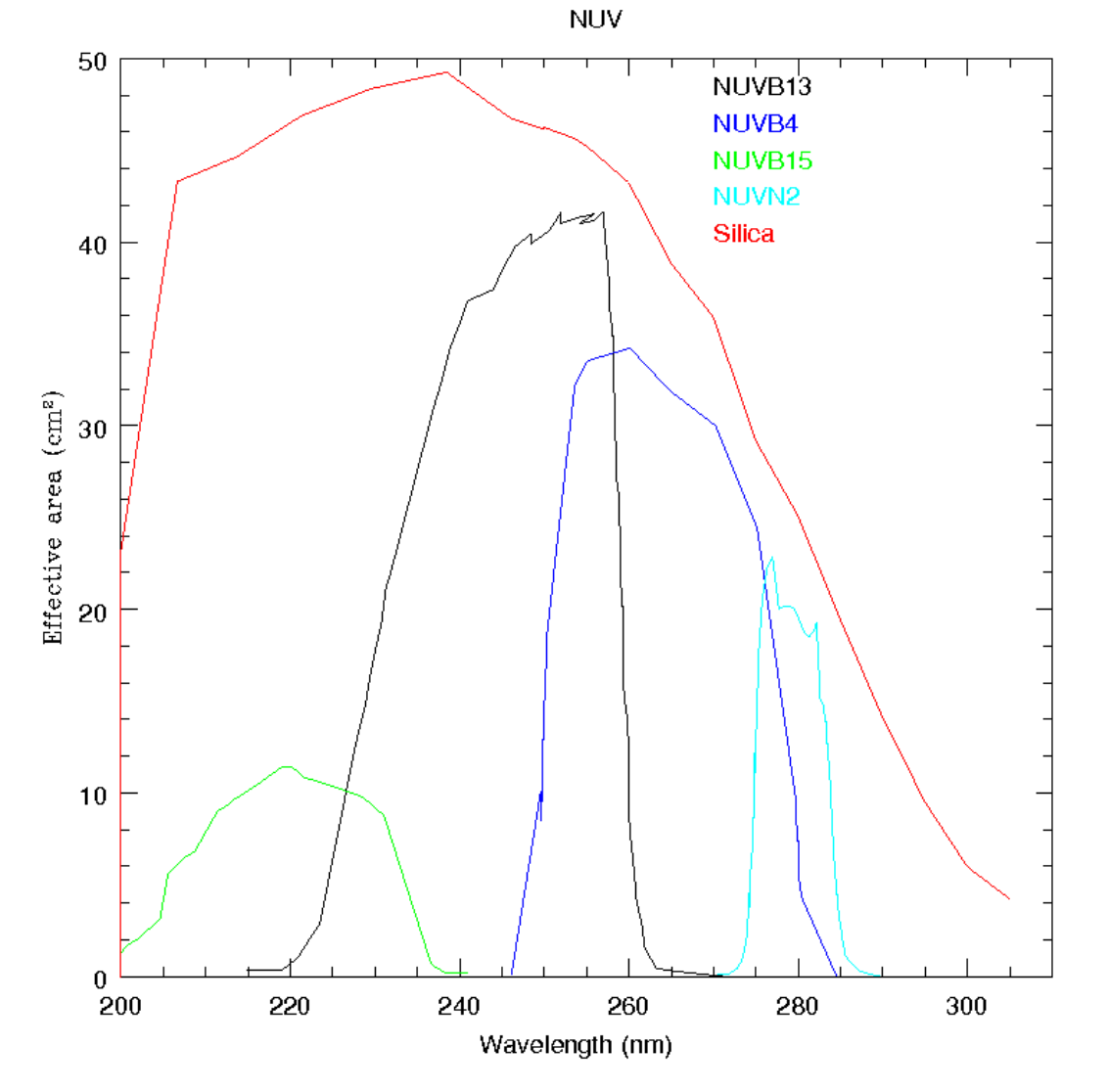
Estimations:
Reflectivity, Transmission, detection efficiency, spectral and spatial response of various components

- Integration of individual estimations

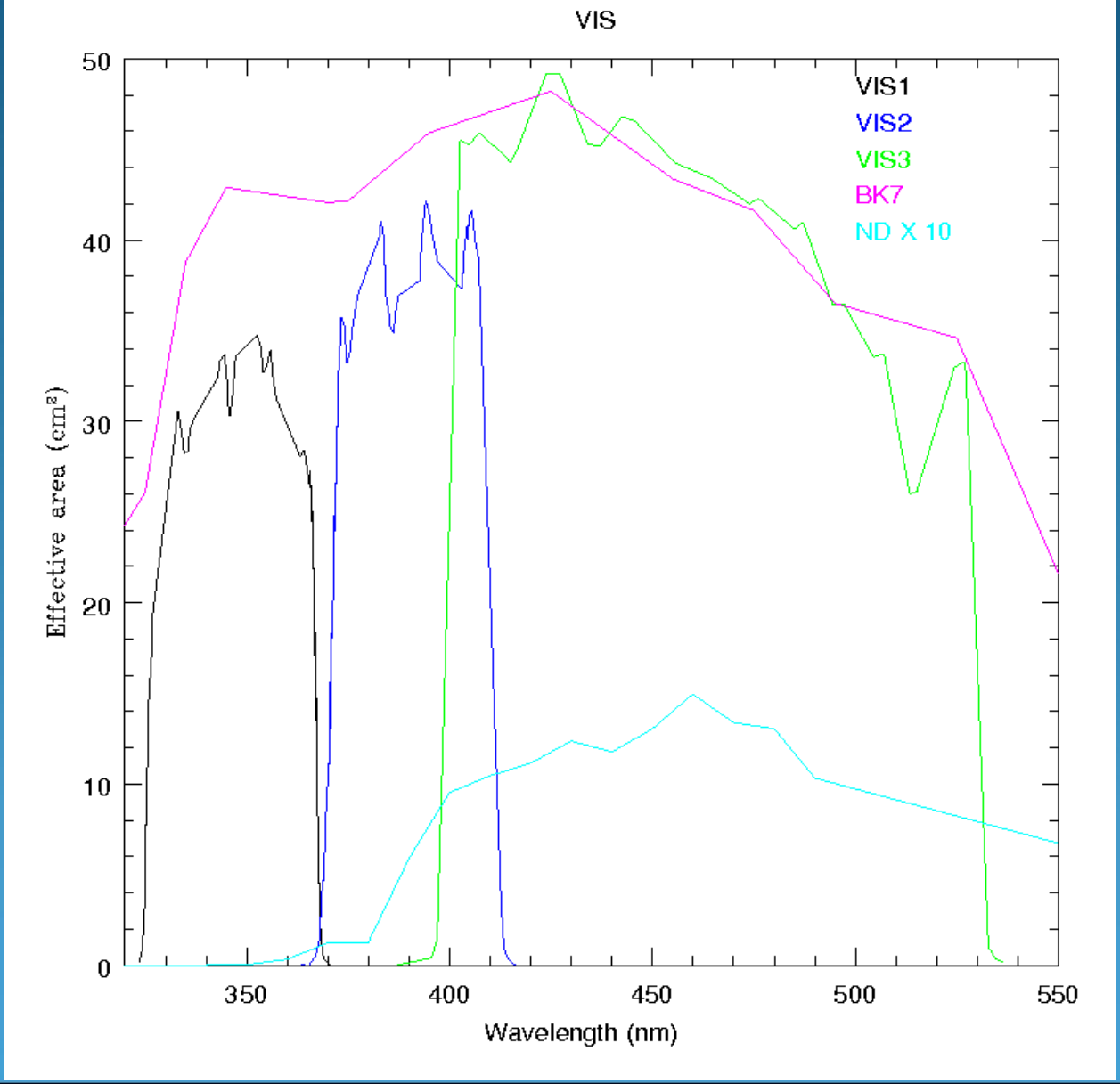
Effective area of the FUV Telescope



Effective area of the NUV Telescope



Effective area of the Visual Telescope



$$\lambda_0 = \frac{\int \lambda A(\lambda) d\lambda}{\int A(\lambda) d\lambda},$$

$$\lambda_{eff} = \frac{\int \lambda A(\lambda) F(\lambda) d\lambda}{\int A(\lambda) F(\lambda) d\lambda},$$

Filter parameters

1. FUV Filter parameters:

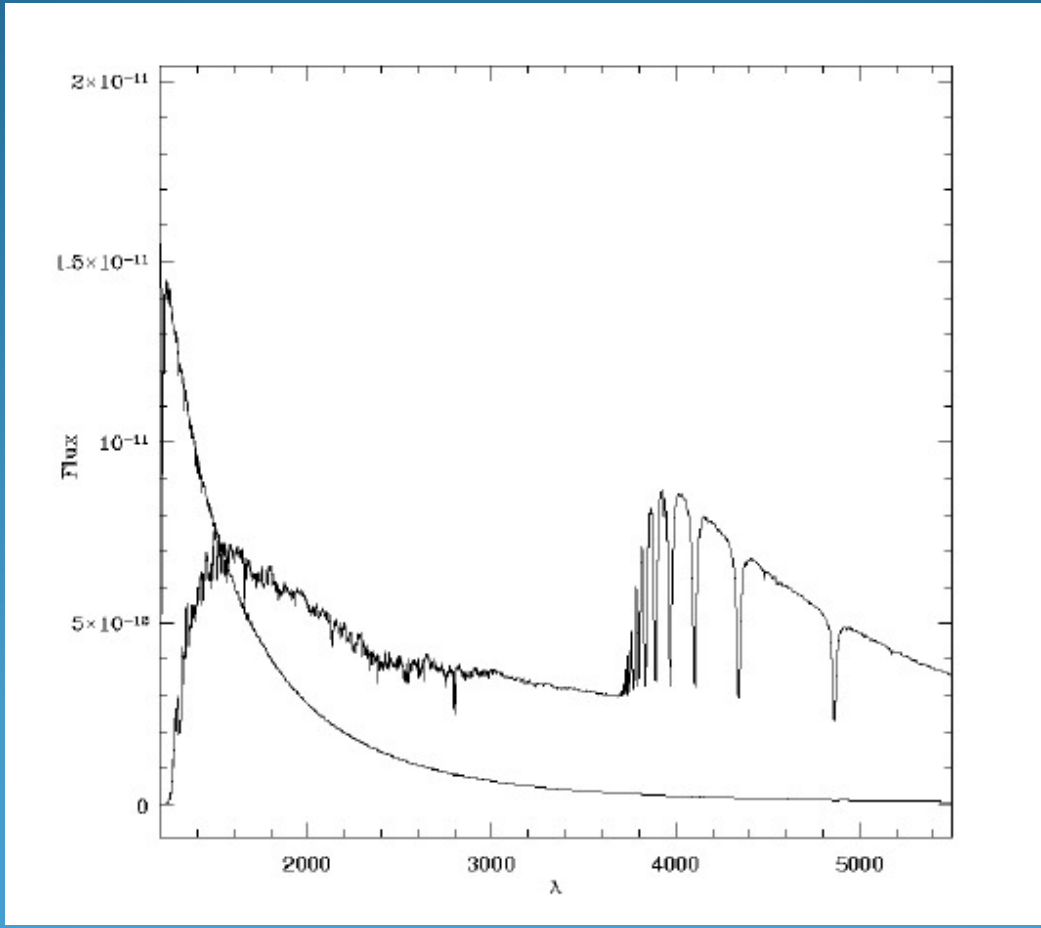
	mean	mean	eff_lambda	eff_lambda	Bandpass
	(filter)	(filter+det)	(Vega)	(G191b2b)	(filter+detector)
BaF2	1593	1537	1544	1504	380 (1370-1750)
Sapphire	1631	1605	1604	1587	290 (1460- 1750)
Silica	1730	1717	1717	1714	125 (1660- 1785)
CaF2-1	1571	1488	1529	1438	500 (1250- 1750)
CaF2-2	1575	1493	1533	1444	500 (1250- 1750)

2. NUV Filter Parameters:
(For silica, the region within the NUV is considered (200-305)

Filter	mean (filter)	mean (filter+det)	eff_lambda (Vega)	eff_lambda (G191b2b)	Bandpass (Filter+detector)
Silica	2480	2473	2440	2371	785(2015- 2800)
NUBV13	2485	2506	2502	2491	280 (2310- 2590)
NUVB15	2175	2178	2173	2166	270 (2060- 2330)
NUVB4	2663	2620	2612	2603	275 (2505- 2780)
NUVN2	2798	2791	2792	2790	90 (2750- 2840)

3. VISUAL Filter parameters:
BK7 (only the visual range is considered)

Filter	mean (filter)	mean (fil+det)	eff_lambda (Vega)	eff_lambda (G191b2b)	Bandpass (Filter+Detector)
VIS1	3469	3492	3489	3469	400 (3265- 3665)
VIS2	3906	3867	3908	3853	400 (3720- 4120)
VIS3	4650	4580	4486	4455	1300 (4000- 5300)
BK7	4207	4217	4204	3737	2200 (3240- 5440)


2×10⁻¹¹
1.5×10⁻¹¹
10⁻¹¹
5×10⁻¹²
0
Flux
2000
3000
4000
5000
λ

Photometric calibration:

Measure flux of a spectro-photometric standard and obtain zero point at the center for:

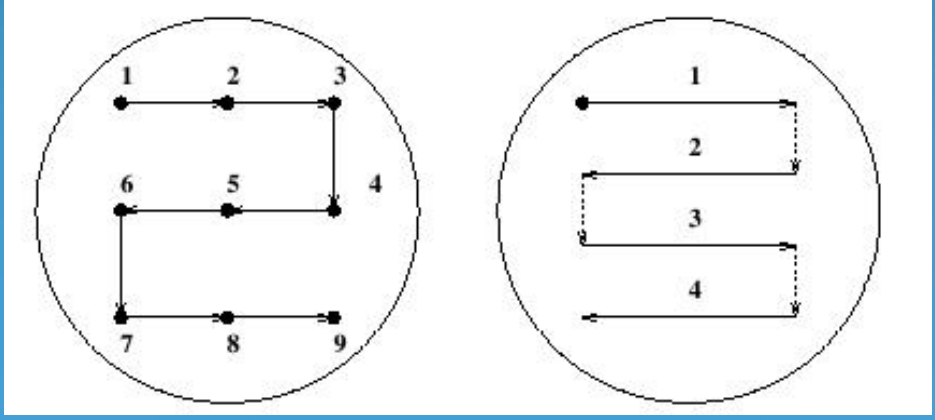
each filter, full detector (512X512), windows of two sizes (250X250, 125X125), three centroiding algorithms (3X3, 3 Sq, 5Sq).

Estimation of variation of zero point across the detector – 9 point cluster

FUV and NUV will use White dwarfs as standards. VIS channel will use Landolt standards.

Track photometric stability during the lifetime of the mission.

Aim for an accuracy of better than 10% for faint stars and 1-2% for bright stars.



Notation:
Like in GALEX, UVIT magnitudes and fluxes will be expressed in the AB system (Oke 1974), based on spectrum with a constant flux per unit frequency and a zero-point approximately based on the V magnitude of Alpha Lyrea (Vega) at 5480.

m(UVIT, filter) = -2.5 log (cps/rr) = -2.5 log (f UVIT)
where cps is the counts per second, and rr is the relative response at the position of the object.

UVIT calibrated magnitudes are converted to a system with AB zero-point:
m(AB, filter) = m(UVIT, filter) +m0(AB)

Spectral calibration of grating:

1. Wavelength coverage in FUV and NUV
2. Dispersion
3. Spectral sensitivity - flux calibration
4. Wolf-Rayet stars and planetary nebulae will be used for the above tasks.
5. The stability of the above parameters as a function of time will be monitored

Astrometric calibration:

Pointing accuracy: Nearby stars with accurate astrometry will be used to track the pointing accuracy, this will be monitored.

The positional accuracy of < 0.5 arcsec between the channels within the full field is required.

Estimation of Field of view: Old Open clusters (M67, NGC 188), globular clusters with good astrometry will be used to estimate the coverage.

Estimation of PSF

1. Observations of photometric standards at the centre and at 9 positions will be used to estimate the average PSF as well as its variation across the field.
2. Observations of open cluster/globular cluster will be used to find the variation of the PSF across the field.
3. The above tasks will be repeated to monitor the stability of the system

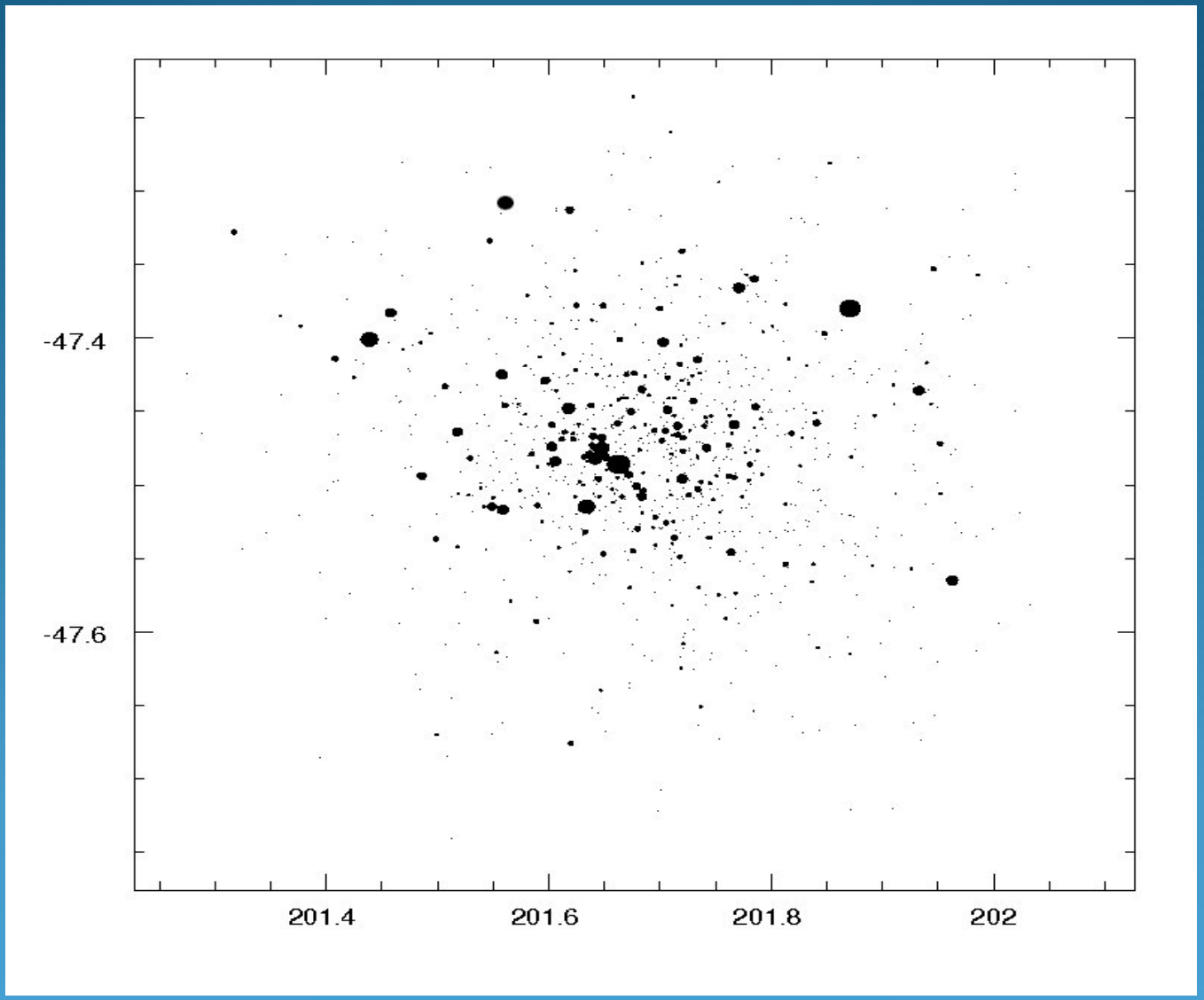
Field distortion:

1. Detailed estimation of distortion due to the detector done in **ground calibration**
2. Will be checked in orbit – using globular clusters with good astrometry and large number of stars across the field.

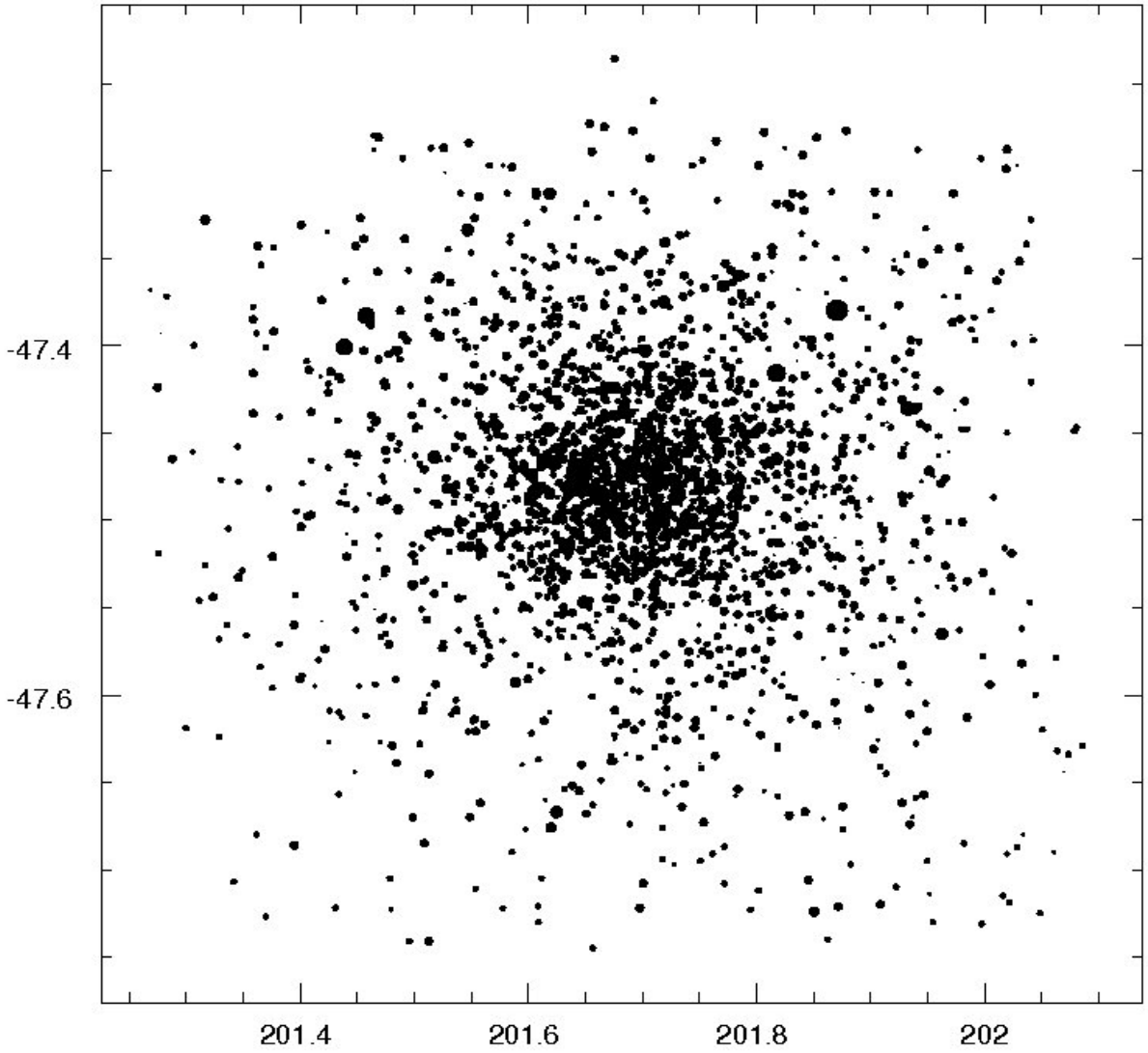
Possible target – Omega Centauri, NGC 362, NGC 6752, Omega Cen was simulated for this purpose.

It has a bright core a few bright stars – can be used with caution

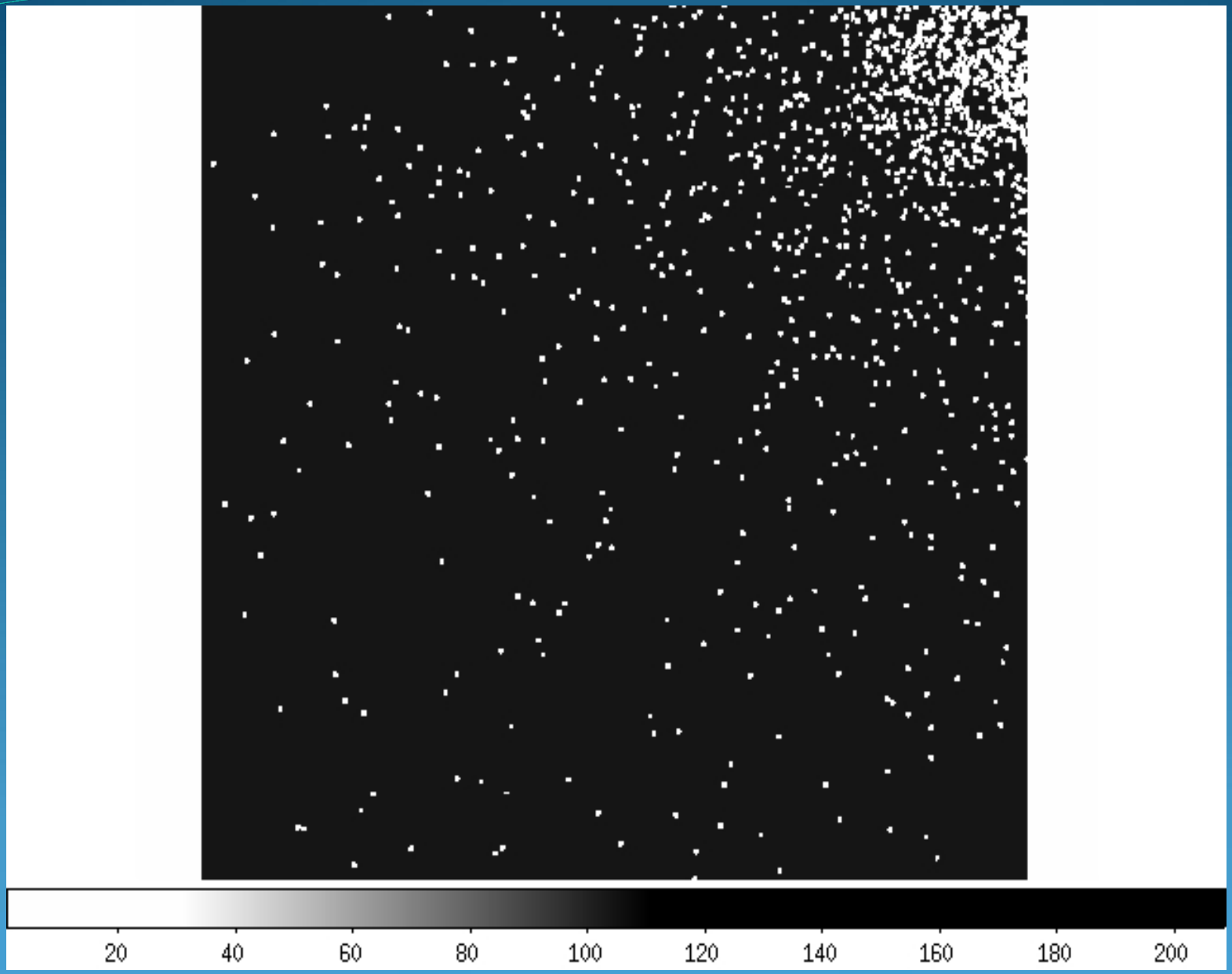
Omega Centauri in FUV



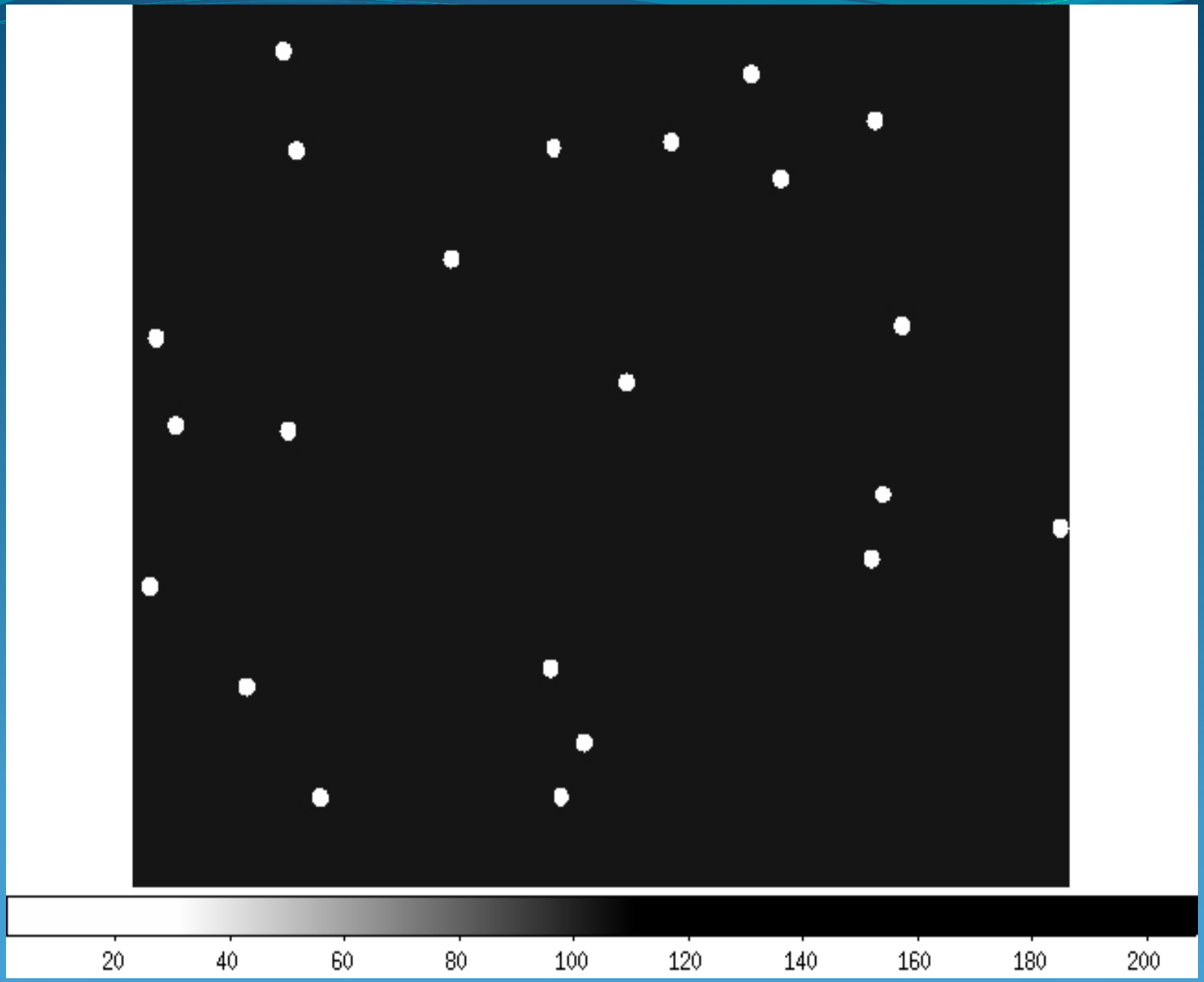
Omega Centauri in NUV



Input Image of Omega Centauri (1/4) in NUV

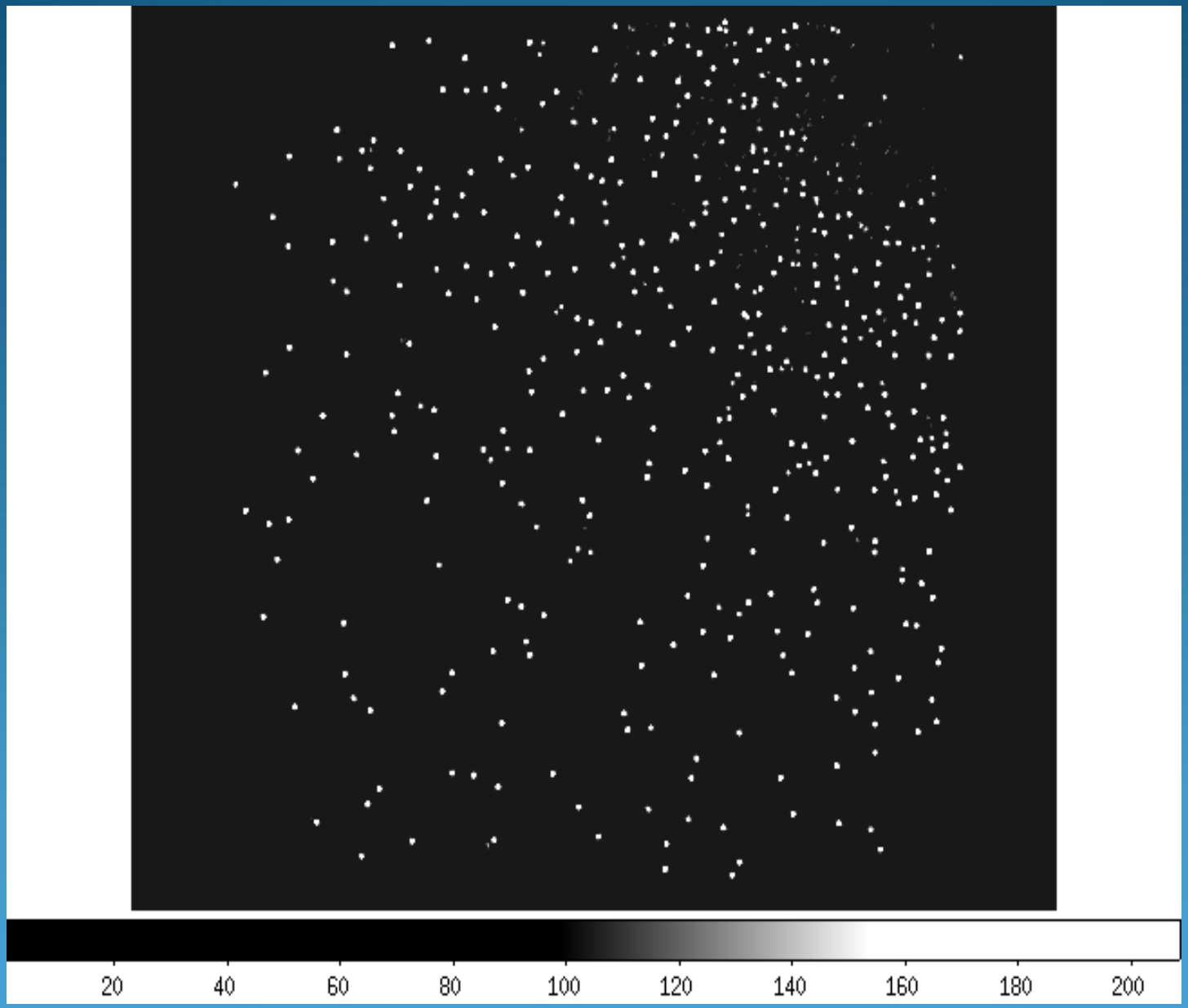


Close up of the input image

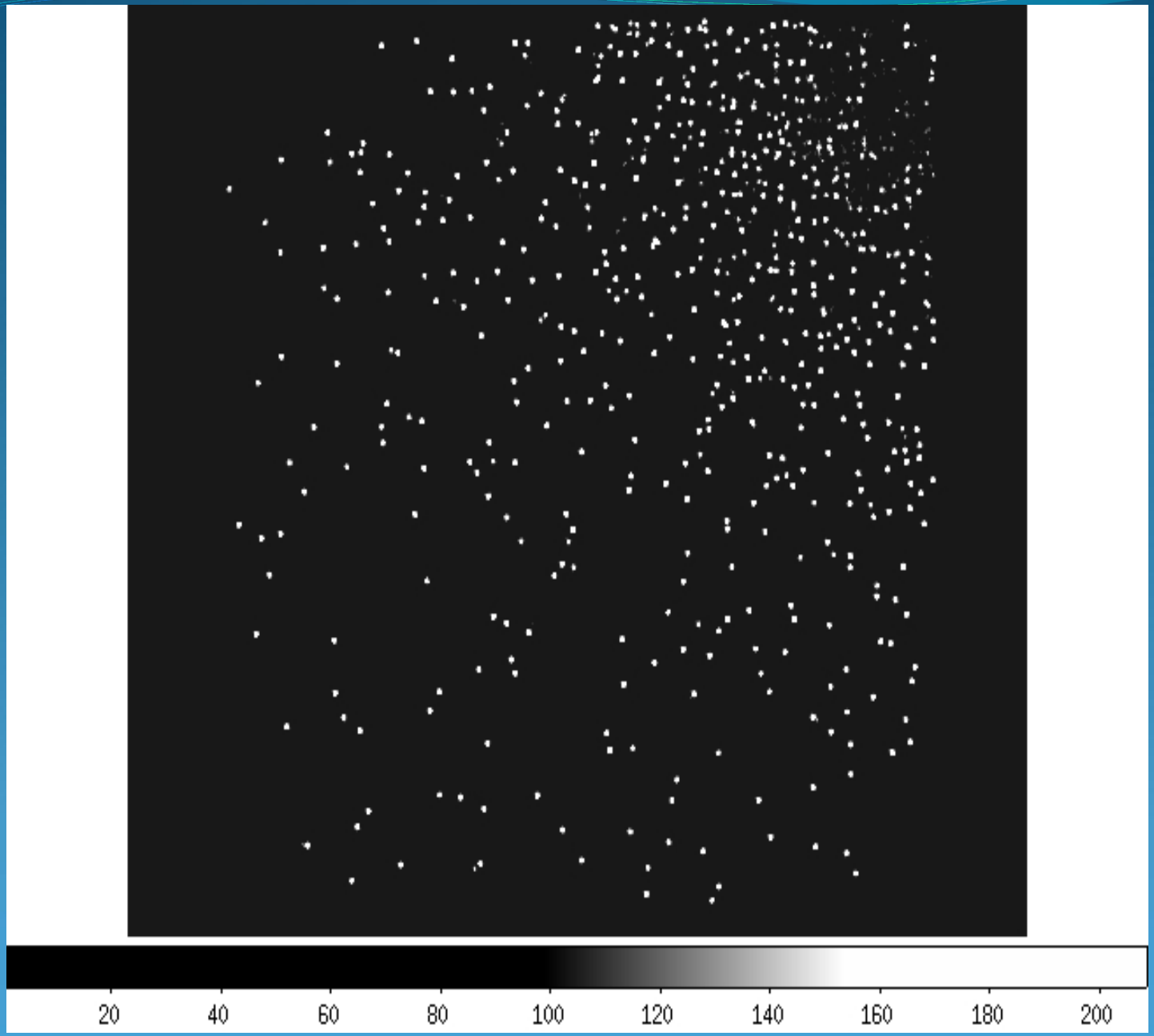


Simulated image in NUV using UVIT simulator

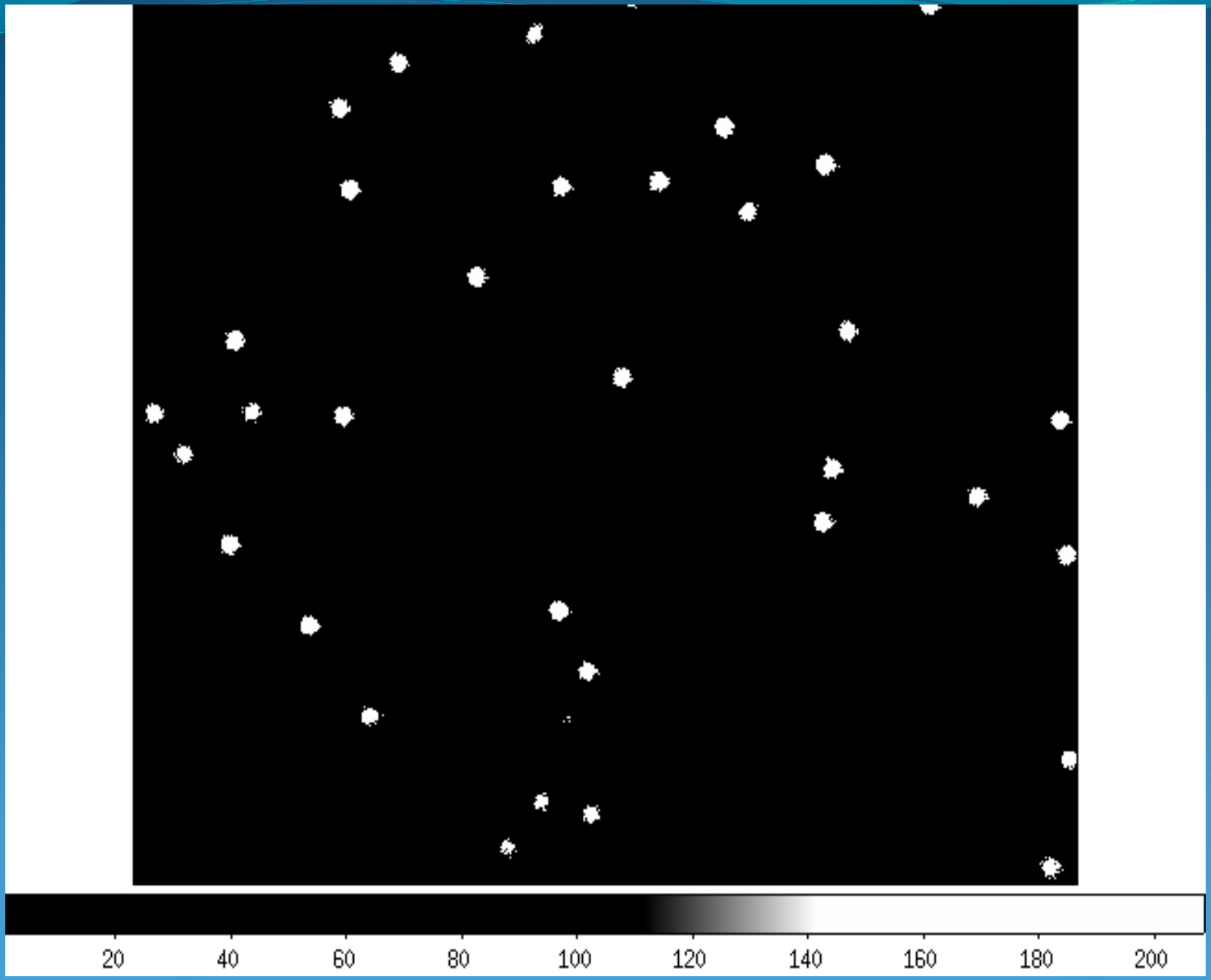
(Rejection threshold – more than one photon/frame)



Simulated image – rejection threshold increased



Close up of the simulated image



Timing Calibration

Temporal resolution:

The read rate of the detector for full field: 30 frames/sec = 34ms exposure time

A 6'X6' field can be read at:

500 frames/sec= 2ms exposure time (pointing accuracy ~ 3 arcmin)

It is possible to record absolute time for each photon event.

Calibrations : Need to choose an appropriate source for calibration in orbit (UVIT/+Other payloads)

Estimation of Background:

Background at the beginning and end of an orbit: First and last images taken in an orbit will be used to estimate the background as a function of Sun & Moon location.

Estimation of scattered light due to a bright object in the field or nearby – a few test cases will be observed with varying proximity

Name	RA (2000)	Dec (2000)	Sp.Type	V	(B-V)
G158-100	00 33 54.32	-12 07 57.1	DK-G	14.89	0.69
BPM 16274	00 50 03.18	-52 08 17.4	DA2	14.2	-0.02
Fiege 11	01 04 21.64	04 13 37.7	sdB	12.07	-0.23
Fiege 16	01 54 08.03	-06 42 53.6	A0	12.41	-0.02
Fiege 22	02 30 16.55	05 15 51.6	DA3	12.80	-0.07
Fiege 24	02 35 07.51	03 43 56.6	DA1	12.42	-0.19
GD50	03 48 50.06	-00 58 30.4	DA2	14.05	-0.28
HZ 4	03 55 21.70	09 47 18.7	DA4	14.47	0.08
LB227	04 09 28.76	17 07 54.4	DA4	15.35	0.05
HZ 2	04 12 43.51	11 51 50.4	DA3	13.86	-0.05
G191-B2B	05 05 30.62	52 49 54.0	DA0	11.78	-0.34

The following table summarises various calibration tasks and the time involved ***during the PV phase***:

Task	*Exposure time*	*Number of orbits "*" = once/week others ~ once/month*
Photometric zero-point (FUV and NUV):	388 min	16 orbits*
Photometric zero-point (FUV):	116 min	6 orbits*
Photometric zero-point (VIS):	71 min	2 orbits*
Secondary photometric cal. (FUV, NUV):	103 min	3 orbits*
Secondary photometric cal. (FUV):	51 min	1.5 orbits*
Secondary photometric cal. (VIS):	38 min	1.1 orbits*
Flux calibration of grism:	108 min	3.1 orbits*
Wavelength calibration of grism:	90 min	2.5 orbits
Astrometric position calibration:	100 min	2.8 orbits
Astrometric angular separation:	40 min	1.2 orbits
Bright star and linearity checks:	35 min	1 orbit
Background estimation:	35 min	1 orbit
Timing calibration:	35 min	1 orbit
PSF estimation:	40 min	1.2 orbit

FUV Channel

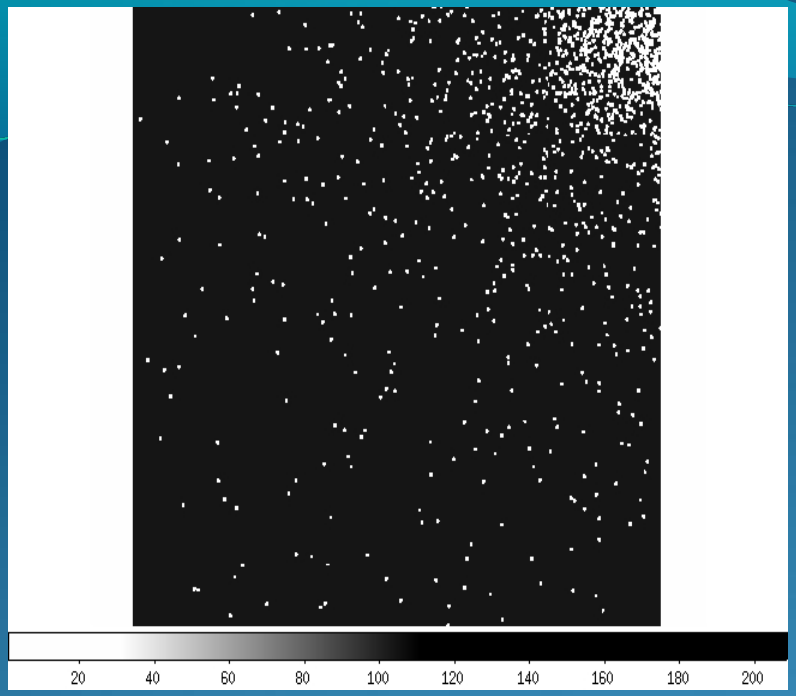
Time sec.	Action	Remark	Time (sec)
0	Filter Block position	Detector covered	0
0	Slew to object 1	Reach Target 1, P1 (center);	0
60	Filter Block position	Detector covered	60
60	Start Imaging:NO HV	Dark frame HV off; exposure time 20s	60
80	Stop Imaging	Dark frame, NO HV	80
80	Stand By	HVs OFF	80
80	Filter FUV 1 – start of set S1	Go to filter FUV 1; 20s to move to FUV1	80
100	Start Imaging	filter settles, exposure time 400s	100
500	Stop Imaging	end of exposure	300
500	Filter FUV 2	Go to filter FUV 2; 20s to move	300
520	Start Imaging	filter settles; exposure time 400s	320
920	Stop Imaging	end of exposure	520
920	Filter FUV 3	Go to filter FUV 3; 20s to move	520
940	Start Imaging	filter settles; exposure time 400s	540
1340	Stop Imaging -end of set S1	end of exposure	740
1360	Filter Block position	Detector covered, move to block filter, 20s	740
1360	Stand By		760
1360			960
1360			960
1360			980
1360			1180
1360			1200
1380			1200
1380	**Slew to next position**	filter settles, and Slew begins with Detector blocked, new position with offsets RA = +7 arcmin, Dec = +7 arcmin	1380
2640	execute set S1	Imaging in 3 FUV filters as above	2500
2660	Stand By	Detector covered, filter blocked	2520
2660	**Slew to next position**	filter settles, and Slew begins with Detector blocked, new position with offsets RA = -7 arcmin, Dec = +7 arcmin	2660
3920	execute set S1	Imaging in 3 FUV filters as above	3780
3940	Stand By	Detector covered, filter blocked	3780
3940	**Slew to next position**	filter settles, and Slew begins with Detector blocked, new position with offsets RA = -7 arcmin, Dec = -7 arcmin	3940
5200	execute set S1	Imaging in 3 FUV filters as above	5060
5220	Stand By	Detector covered, filter blocked	5080

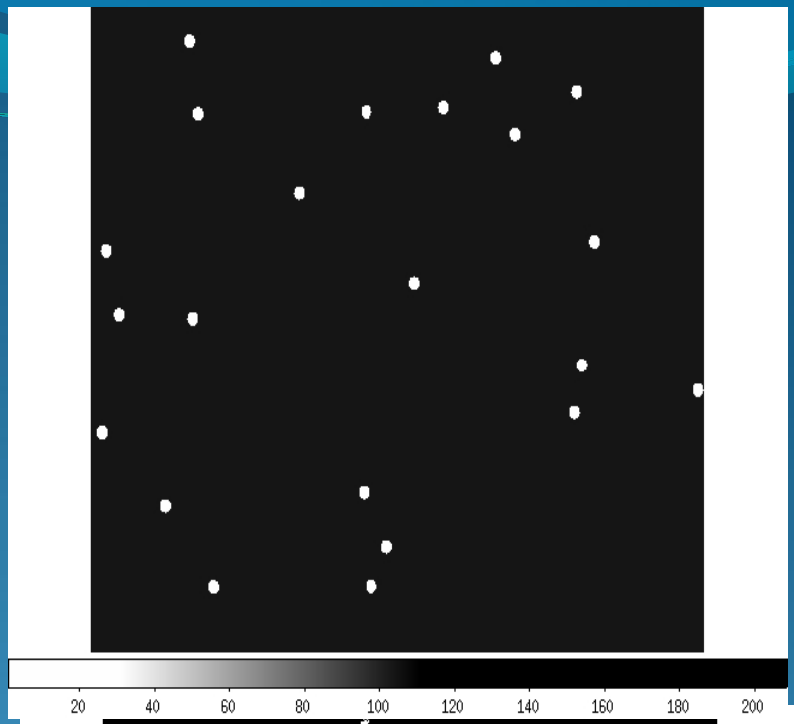
List of objects for calibration presented in the PV phase calibration plan document.

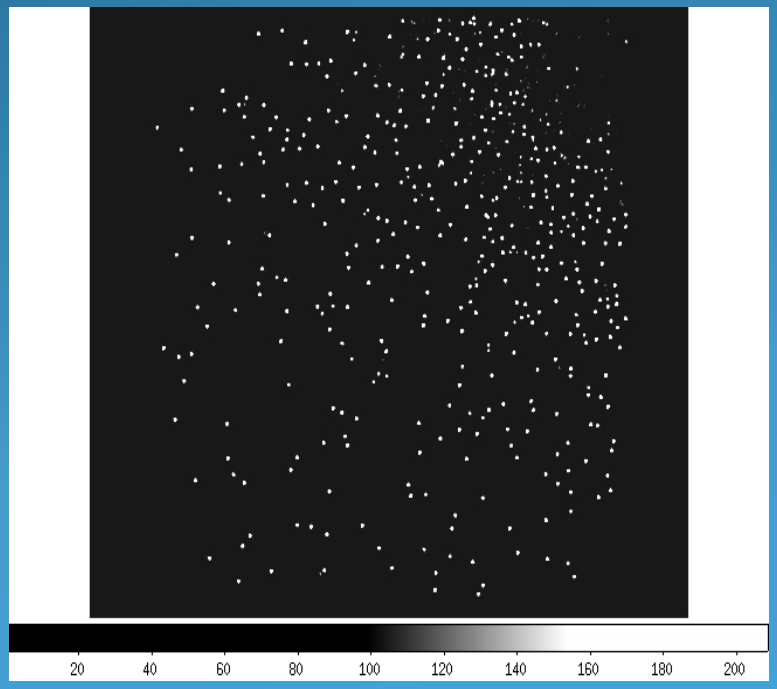
Details of observation for various tasks are also presented.

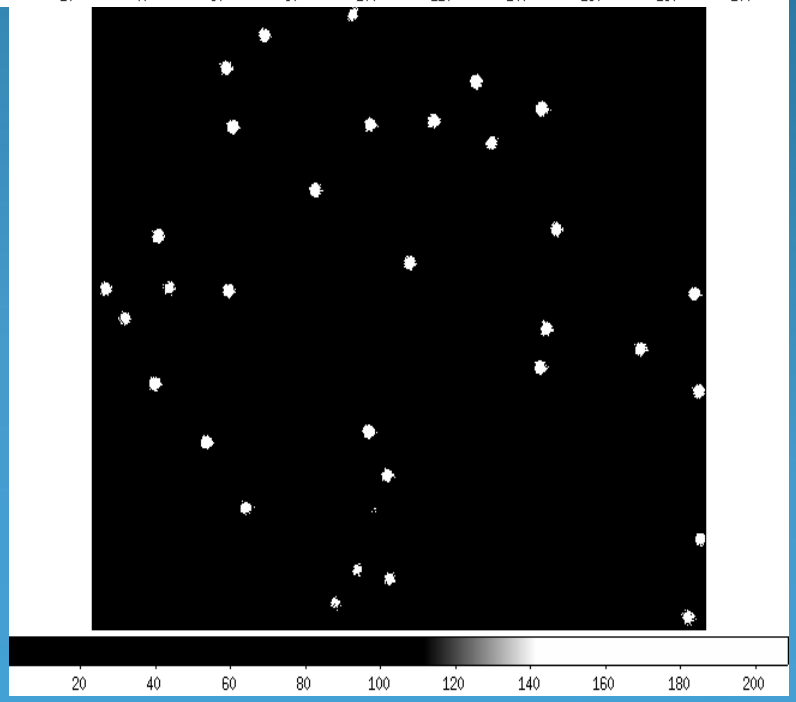
The PV phase calibration plan is integrated into the ASTROSAT PV phase calibration plan.

Thank You


20
40
60
80
100
120
140
160
180
200


20
40
60
80
100
120
140
160
180
200


20
40
60
80
100
120
140
160
180
200


20
40
60
80
100
120
140
160
180
200

Effective area of the Telescope:

Primary Mirror: 880 sq.cm

Mirror reflectivity: (fuv-70%, nuv-80%, vis-80%)

Number of mirrors

Filters (fuv-4, nuv – 4, vis – 4)

Dichroic reflectivity

Detector

The following table summarises various calibration tasks and the time involved ***during the PV phase***:

Task	*Exposure time*	*Number of orbits* *"*" = once/week* *others ~ once/month*
Photometric zero-point (FUV and NUV):	388 min	16 orbits*
Photometric zero-point (FUV):	116 min	6 orbits*
Photometric zero-point (VIS):	71 min	2 orbits*
Secondary photometric cal. (FUV, NUV):	103 min	3 orbits*
Secondary photometric cal. (FUV):	51 min	1.5 orbits*
Secondary photometric cal. (VIS):	38 min	1.1 orbits*
Flux calibration of grism:	108 min	3.1 orbits*
Wavelength calibration of grism:	90 min	2.5 orbits
Astrometric position calibration:	100 min	2.8 orbits
Astrometric angular separation:	40 min	1.2 orbits
Bright star and linearity checks:	35 min	1 orbit
Background estimation:	35 min	1 orbit
Timing calibration:	35 min	1 orbit
PSF estimation:	40 min	1.2 orbit