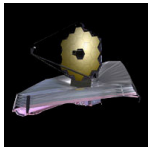

5502 - Probing the existence of dark matter halos at parsec scale with JWST

Cycle: 3, Proposal Category: GO

INVESTIGATORS

Name	*Institution*
Prof. Francesco R. Ferraro (PI) (ESA Member)	**Universita di Bologna**
Prof. Barbara Lanzoni (CoI) (ESA Member)	Universita di Bologna
Dr. Livia Origlia (CoI) (ESA Member)	INAF - Osservatorio di Astrofisica e Scienza dello Spazio
Dr. Cristina Pallanca (CoI) (ESA Member)	Universita di Bologna
Dr. Mario Cadelano (CoI) (ESA Member)	Universita di Bologna
Mrs. Chiara Crociati (CoI) (ESA Member)	Universita di Bologna
Mrs. Silvia Leanza (CoI) (ESA Member)	Universita di Bologna
Mr. Lanfranco Chiappino (CoI) (ESA Member)	Universita di Bologna
Dr. Cristiano Fanelli (CoI) (ESA Member)	Universita di Bologna
Martina Loriga (CoI) (ESA Member)	Universita di Bologna
Dr. Emanuele Dalessandro (CoI) (ESA Member)	INAF - Osservatorio di Astrofisica e Scienza dello Spazio
Dr. R. Michael Rich (CoI) (US Admin CoI)	University of California - Los Angeles
Dr. Enrico Vesperini (CoI)	Indiana University System
Alex Billi (CoI) (ESA Member)	Universita di Bologna
Camilla Giusti (CoI) (ESA Member)	Universita di Bologna
Dr. Davide Massari (CoI) (ESA Member)	INAF - Osservatorio di Astrofisica e Scienza dello Spazio

OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
CENTRAL_POINTING				
	1	CP_F115_1	NIRCam Imaging	(1) CENTRALPOINTING
	2	CP_F115_2	NIRCam Imaging	(1) CENTRALPOINTING
	3	CP_F200	NIRCam Imaging	(1) CENTRALPOINTING

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
	4	short	NIRCam Imaging	(1) CENTRALPOINTING
OFFSET_POINTING				
	5	OP_F115_1	NIRCam Imaging	(2) OFFSETPOINTING
	6	OP_F115_2	NIRCam Imaging	(2) OFFSETPOINTING
	7	OP_F200	NIRCam Imaging	(2) OFFSETPOINTING

ABSTRACT

Terzan5 is a stellar system in the Galactic bulge that, despite its globular cluster appearance, harbors sub-populations with huge differences in age (7.5 Gyr) and in iron content (1 dex). Its chemical abundance pattern is strikingly similar to that of the bulge, strongly suggesting that Terzan5 could be the relic of a primordial structure, possibly embedded in a dark matter (DM) halo that contributed to form the bulge. Its velocity dispersion remains constant out to more than 20 core radii, at odds with the luminosity that rapidly decreases with radius. This suggests either an anomalously large amount (~8 times larger than expected) of very low-mass stars in its outer regions, or the presence of a DM halo.We propose ultra-deep NIRCam observations in F115W and F200W to probe the stellar mass function of Terzan5 down to 0.2 Msol and distinguish between the two possibilities. If no excess of low-mass stars is found, the velocity dispersion profile of Terzan5 would be the first evidence of a DM halo at sub-galactic scale (~5 pc). For decontamination purposes we plan an offset NIRCam pointing properly sampling the bulge population, thus also providing the community with the deepest color-magnitude diagram of the Galactic bulge ever obtained. This program can be done only with JWST and NIRCam offers the unique opportunity to sample the core and the periphery of this extincted object in just one pointing, with the needed angular resolution and at near-IR wavelengths. With a modest investment of observing time, this program promises a huge scientific pay-back: proving the existence of DM halos at parsec scales would represent a revolution in the field of observational cosmology.

OBSERVING DESCRIPTION

We propose ultra-deep observations with NIRCam to probe, for the very first time, the possible existence of dark matter (DM) halos at sub-galactic scale (a few parsecs). To this aim, NIRCam will be pointed on Terzan 5, a stellar system in the Galactic bulge recently recognized to be the survived remnant of a massive stellar structure, possibly embedded in a DM halo, which possibly contributed to form the Milky Way bulge.

The velocity dispersion profile of Terzan 5 remains constant out to ~200" from the center (corresponding to a physical scale of ~5 pc) and is totally inconsistent with the density distribution of the stars brighter than the main sequence turnoff (with masses of ~0.8 Msol) that, instead, rapidly decreases already at r~10". This indicates that in Terzan 5 the mass does not follow the light!

To verify whether this behavior is due to a parsec-scale DM halo, or an anomalous excess of low-mass stars (with masses 0.2 Msol<M<0.5 Msol) in the outskirts of the system, we plan to determine the stellar mass function of Terzan 5 down to 0.2 Msol, at different distances from the center, by

using ultra-deep observations with NIRCam in the F115W (J) and F200W (K) filters.
The observations are organized in two pointings:
(1) CENTRAL Pointing -- the two eyes of NIRCam will sample Terzan 5, from its core to its periphery (r~200''), thus providing the required radial coverage in just one shot.
(2) OFFSET Pointing -- NIRCam will sample the bulge population well beyond the tidal radius of Terzan 5 (in a field at r~10' from the center, affected by comparable extinction and at the same Galactic latitude), by using the same filters and the same exposure times adopted for the CENTRAL Pointing. This is crucial to allow an accurate statistical decontamination of Terzan 5 members from Galactic field stars.
To accurately distinguish the multi-iron sub-populations hosted in Terzan 5 (and thus measuring their mass functions), we need to reach S/N>50 (i.e., photometric errors <0.02 mag) at M=0.2 Msol, corresponding to m_F115W=25.2, m_F200W=23. To avoid heavy saturation of giant stars, all the observations will be split in a series of sub-exposures, which will be opportunely dithered to allow an optimal sampling of the PSF.

By using the ETC and the APT version 2023.5.2, we find that the most suited setup both to maximize the SNR of the observations and to avoid severe saturation of the brightest sources is to adopt BRIGHT2 detector readout pattern. Moreover, in order to maximize the observed area at full depth, we adopted Primary Dither Type = “INTRAMODULEBOX”. This pattern has been designed to yield the coverage of 2 square regions (one for each module) without gaps when performing 4 dither positions. Thus, we propose the following strategy. To reduce the data flow excess, in the filter F115W the observations for each pointing are split in two visits: CP_F115_1 and CP_F155_2 for the CENTRAL pointing, and OP_F115_1 and OP_F115_2 for the OFFSET pointing. Each visit consists in 8 dithered exposures using Primary Dither Type = “INTRAMODULEBOX”; Primary Dithers = 4 and a STANDARD Subpixel Dither Type with 2 Subpixel Positions, acquired with the BRIGHT2 detector readout pattern (5 groups and 9 integrations). For the filter F200W, we plan only one visit for each pointing: CP_F200 and OP_F200, for the CENTRAL and the OFFSET pointing, respectively. Each visit consists in 8 dithered exposures using Primary Dither Type = “INTRAMODULEBOX”; Primary Dithers = 4 and a STANDARD Subpixel Dither Type with 2 Subpixel Positions, acquired with the BRIGHT2 detector readout pattern (5 groups and 7 integrations). In addition we request a short exposure (in the CENTRAL pointing only) in both filters (readout=RAPID, groups=2, integration=1). This will be combined with previous HST data as third-epoch images for measuring the proper motion of giant and turnoff stars, thus allowing a solid (PM-based) field decontamination of the turnoff region, with the aim to firmly assess the age of the multi-iron sub-populations hosted in the system. Thus, the requested total time amounts to 19 hours.
According to the warning generated by the APT, this strategy generates Data Excess above the MIDDLE threshold. However, this is indeed unavoidable since all the possible strategies to reduce the Data Excess would invalidate the proposed science because of saturation issues.

With no additional cost in terms of time, we also plan to take advantage of the NIRCam long wavelength channel to secure simultaneous

observations in the F277W and F356W filters. This will provide us with a photometric characterization of the surveyed stars from the near-IR to the mid-IR, which is optimal for the estimates of their stellar parameters (temperature, metallicity etc.) and bolometric luminosity.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	CENTRALPOINTING	RA: 17 48 3.0000 (267.0125000d) Dec: -24 46 55.00 (-24.78194d) Equinox: J2000		
Comments: *Category=Stellar Cluster* *Description=[Globular star clusters]*				
(2)	OFFSETPOINTING	RA: 17 47 37.7450 (266.9072708d) Dec: -24 56 21.00 (-24.93917d) Equinox: J2000		
Comments: *Category=Stellar Cluster* *Description=[Globular star clusters]*				

Observation

Proposal 5502, Observation 1: CP_F115_1

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 1:1) Warning (Form): Data Excess over middle threshold

(Visit 1:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	CENTRALPOINTING	RA: 17 48 3.0000 (267.0125000d) Dec: -24 46 55.00 (-24.78194d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F115W	F277W	BRIGHT2	5	9	72	8	8417.628	

Special Requirements

Fiducial Point Override NRCBS_FULL

Observation

Proposal 5502, Observation 2: CP_F115_2

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 2:1) Warning (Form): Data Excess over middle threshold

(Visit 2:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	CENTRALPOINTING	RA: 17 48 3.0000 (267.0125000d) Dec: -24 46 55.00 (-24.78194d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F115W	F277W	BRIGHT2	5	9	72	8	8417.628	

Special Requirements

Fiducial Point Override NRCBS_FULL

Observation

Proposal 5502, Observation 3: CP_F200

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 3:1) Warning (Form): Data Excess over middle threshold

(Visit 3:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	CENTRALPOINTING	RA: 17 48 3.0000 (267.0125000d) Dec: -24 46 55.00 (-24.78194d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F200W	F356W	BRIGHT2	5	7	56	8	6527.956	

Special Requirements

Fiducial Point Override NRCBS_FULL

Observation

Proposal 5502, Observation 4: short

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 4:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(1)	CENTRALPOINTING	RA: 17 48 3.0000 (267.0125000d) Dec: -24 46 55.00 (-24.78194d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F115W	F277W	RAPID	2	1	8	8	171.788	
2	F200W	F356W	RAPID	2	1	8	8	171.788	

Special Requirements

Aperture PA Range 65 to 74 Degrees (V3 64.94737309 to 73.94737309)
Aperture PA Range 86 to 95 Degrees (V3 85.94737309 to 94.94737309)
Aperture PA Range 98 to 170 Degrees (V3 97.94737309 to 169.94737309)
Aperture PA Range 206 to 214 Degrees (V3 205.94737309 to 213.94737309)
Aperture PA Range 220 to 24 Degrees (V3 219.94737309 to 23.94737309)
Fiducial Point Override NRCBS_FULL

Observation

Proposal 5502, Observation 5: OP_F115_1

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 5:1) Warning (Form): Data Excess over middle threshold

(Visit 5:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(2)	OFFSETPOINTING	RA: 17 47 37.7450 (266.9072708d) Dec: -24 56 21.00 (-24.93917d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F115W	F277W	BRIGHT2	5	9	72	8	8417.628	

Special Requirements

Fiducial Point Override NRCBS_FULL

Observation

Proposal 5502, Observation 6: OP_F115_2

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 6:1) Warning (Form): Data Excess over middle threshold

(Visit 6:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(2)	OFFSETPOINTING	RA: 17 47 37.7450 (266.9072708d) Dec: -24 56 21.00 (-24.93917d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F115W	F277W	BRIGHT2	5	9	72	8	8417.628	

Special Requirements

Fiducial Point Override NRCBS_FULL

Observation

Proposal 5502, Observation 7: OP_F200

Wed Sep 04 14:00:20 GMT 2024

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Diagnostics

(Visit 7:1) Warning (Form): Data Excess over middle threshold

(Visit 7:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Fixed Targets

#	Name	Target Coordinates	Targ. Coord. Corrections	Miscellaneous
(2)	OFFSETPOINTING	RA: 17 47 37.7450 (266.9072708d) Dec: -24 56 21.00 (-24.93917d) Equinox: J2000		

Comments:
Category=Stellar Cluster
Description=[Globular star clusters]

Template

Module	Subarray	Target Placement
ALL	FULL	Module B (B4 corner)

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	INTRAMODULEBOX	4	STANDARD		2

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F200W	F356W	BRIGHT2	5	7	56	8	6527.956	

Special Requirements

Fiducial Point Override NRCBS_FULL