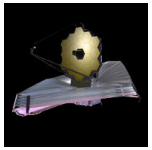

1250 - Probing the sub-surface oceans of Europa and Enceladus with JWST

Cycle: 1, Proposal Category: GTO

INVESTIGATORS

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OBSERVATIONS

Folder	*Observation*	*Label*	*Observing Template*	*Science Target*
Observation Folder				
	1	NIRCam Europa	NIRCam Imaging	(1) EUROPA
	2	NIRSpec Europa	NIRSpec IFU Spectroscopy	(1) EUROPA
	3	MIRI Europa	MIRI Medium Resolution Spectroscopy	(1) EUROPA
	9	MIRI Europa-BKG	MIRI Medium Resolution Spectroscopy	(3) EUROPA-BKG
	4	MIRI/Img Europa	MIRI Imaging	(1) EUROPA
Observation Folder				
	5	NIRCam Enceladus	NIRCam Imaging	(2) ENCELADUS
	6	NIRSpec Enceladus	NIRSpec IFU Spectroscopy	(2) ENCELADUS
	7	MIRI Enceladus	MIRI Medium Resolution Spectroscopy	(2) ENCELADUS
	8	MIRI/Img Enceladus	MIRI Imaging	(2) ENCELADUS

ABSTRACT

Do the icy moons, Europa and Enceladus, host habitable conditions at submerged hydrothermal vents? We propose to perform high spatial and spectral resolution observations of the jets emanating from these moons, measuring volatile abundances and isotopic ratios. Such measurements will reveal unprecedented information regarding the processes acting beneath the moons' thick ice crusts, and the potential for habitability of the sub-surface oceans.

OBSERVING DESCRIPTION

Introduction and Background: Do the icy moons, Europa and Enceladus, host habitable conditions at submerged hydrothermal vents? The right balance of energy sources, temperature, pressure and chemical diversity leads to prosperous environments for life on Earth. Thanks to the plentitude of recent discoveries of extremophile organisms, the limits for such conditions have greatly expanded, and the hypothesized sub-surface oceans on these moons represent one of the most habitable niches in our Solar System. Observations with JWST will permit to probe these habitats with unprecedented sensitivity and spatial resolution, revealing unique information regarding the processes acting beneath the moons' thick ice crusts, and the potential for habitability of the sub-surface oceans.

Europa: The surface of this moon of Jupiter is surprisingly young, as revealed by a crater retention age of only 10-100 Myr (1), suggestive of ongoing resurfacing. Furthermore, ice fractures and moving lineae are indicative of underlying tectonic activity and/or volcanic eruptions. By integrating this morphological information with that obtained by radio-tracking from the Galileo spacecraft, a possible ocean (or a low-density convective ice layer) of 80-170 km thickness is inferred to be present below Europa's icy crust (2, 3). More recently, water vapor plumes were observed above the frigid south polar regions (4), and linked to the previously identified fractures or lineae. Particularly interesting was the fact that the intensity of the plumes varied according to its distance from Jupiter, a strong indicator of tidal heating and flexing in Europa. Such tidal energy could provide enough heat to generate a liquid ocean underneath the ice, further establishing the sub-surface of Europa as an astrobiologically relevant site, with a potential for habitability. The presence of liquid water and of possible volcanic/hydrothermal sub-surface activity would resemble ecosystems on Earth, but no markers suggesting these processes are active in Europa have been detected.

Enceladus: As with Europa, Saturn's moon Enceladus shows a relatively young surface, linear fractures with enhanced temperatures - termed "tiger stripes" (5), and collimated plumes of water (6, 7). However, unlike Europa, the presence of a global sub-surface ocean is not suggested for Enceladus. Instead, smaller non-continguous reservoirs containing pressurized liquid water beneath its southern pole have been suggested. Using gravitational studies, Iess et al. (8) established the depth of this reservoir to be 30-40 kilometers, and to extend to south latitudes of ~50 degrees. The presence of natural radioactivity, together with an active surface could suggest a long-term water cycle. This would move material (as well as any organic compounds deposited on the surface) deep into these liquid-water reservoirs, thus providing a potential for habitability. Little is known about

the chemical composition of the plumes, with the first in-situ measurements (9) revealing comet-life abundances. However, more detailed studies indicated that abundances appeared correlated with spacecraft velocity, a suspicious result suggesting that formation of most species occurred within the instrument itself (10).
1

The true composition of these habitats and that of the encompassing torus are still unknown, and key compositional studies can provide key insights into the processes sustaining the activity on these bodies and the potential habitability of their sub-surface.
Proposed Investigation: we propose to perform high spatial and spectral resolution observations of the jets emanating from these moons, measuring volatile abundances and isotopic ratios. Specifically, we propose to map these moons with NIRSpec in the whole 1-5 microns spectral range and with NIRCam with several filters, allowing us to address the following science goals:
1) Habitability of the sub-surface oceans: Measuring the composition of the plumes will test for chemical diversity of these “oceans,” perhaps indicative of geological activity. For instance, sensitive searches for volatile organics (e.g., CH3OH, H2CO) and sulfur species (e.g., SO2) would establish a rich chemical environment, representing a key parameter in the origin and development of life. In particular, clay-minerals (phyllosilicates) were recently discovered on the surface of Europa (11), suggesting an icy crust rich in meteoritic material delivered by asteroids and comets, known to be rich in organic material. The potential for such material reaching the sub-surface ocean (through a recycling icy crust) further enhances the possibility for habitability.
2) Stability, location and composition of the active regions: by performing high-resolution mapping, we will be able to identify the regions of active release, and the processes responsible for the activity.
Why JWST? JWST is uniquely favored among ground-based and spaceborne observatories to address these questions, because the moons are relatively small, the emanating material is modest and the emitting fluxes are heavily diluted by their large geocentric distances, ultimately requiring unprecedented sensitivities and high spatial resolutions. In addition, without the telluric extinction that affects ground-based observations, we can probe the strong fundamentals, leading to orders of magnitude improvements in sensitivity to what is currently possible

Proposal 1250 - Targets - Probing the sub-surface oceans of Europa and Enceladus with JWST

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(1)	EUROPA	STD=JUPITER	STD=EUROPA	
Comments: Extended=YES				
(2)	ENCELADUS	STD=SATURN	STD=ENCELADUS	
Comments: Extended=YES				
(3)	EUROPA-BKG	STD=JUPITER	STD=EUROPA	TYPE=POS_ANGLE,RAD=300,ANG=0,REF=NORTH
Comments: Extended=YES				

Observation

Proposal 1250, Observation 1: NIRCam Europa

Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Comments: Because the observations with NIRCam,NIRSpec and MIRI are used to derive common properties of the surface and jets of Europa, they need to be done in a non-interruptible sequence. This will allow us to accurately sample the same lats/lons/time on the moon and to get better inter-image calibration and photometry, which we need for quantifying weak ice/molecular features.

Diagnostics

(NIRCam Europa (Obs 1)) Warning (Form): Pointing performance insufficient

(NIRCam Europa (Obs 1)) Warning (Form): Pointing performance insufficient

(NIRCam Europa (Obs 1)) Warning (Form): Pointing performance insufficient

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(1)	EUROPA	STD=JUPITER	STD=EUROPA	

Comments: Extended=YES

Template

Module	Subarray
B	SUB64P

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	SUBARRAY_DITHER	3	STANDARD		1

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F212N	F460M	RAPID	5	10	30	3	9.106	
2	F140M	F335M	RAPID	5	10	30	3	9.106	
3	F070W	F250M	RAPID	5	10	30	3	9.106	

Special Requirements

Group Observations 1, 2, 4, Non-interruptible

DEFAULT WINDOW: ANGULAR RATE EUROPA FROM JWST LESS THAN 0.03
DEFAULT WINDOW: NOT OCCULTATION OF EUROPA BY JUPITER FROM JWST
CENTRAL MERIDIAN LONGITUDE OF EUROPA FROM JWST BETWEEN 80 110

Observation

Proposal 1250, Observation 2: NIRSpec Europa Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: NIRSpec IFU Spectroscopy

Diagnostics

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(1)	EUROPA	STD=JUPITER	STD=EUROPA	

Comments: Extended=YES

Template

TA Method
NONE

Dithers

#	Dither Type	Size	Starting Point	Number of Points	Points
1	CYCLING	SMALL	1	2	

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	G140H/F100LP	NRSRAPID	2	10	false	true	NONE	2	20	644.206	
2	G235H/F170LP	NRSRAPID	5	5	false	true	NONE	2	10	644.206	
3	G395H/F290LP	NRSRAPID	5	5	false	true	NONE	2	10	644.206	

Special Requirements

Group Observations 1, 2, 4, Non-interruptible

DEFAULT WINDOW: ANGULAR RATE EUROPA FROM JWST LESS THAN 0.03
DEFAULT WINDOW: NOT OCCULTATION OF EUROPA BY JUPITER FROM JWST

Observation

Proposal 1250, Observation 3: MIRI Europa

Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: MIRI Medium Resolution Spectroscopy

Diagnostics

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(1)	EUROPA	STD=JUPITER	STD=EUROPA	

Comments: Extended=YES

Acquisition

#	Target
1	NONE

Template

AcqFilter	Primary Channel	Simultaneous Imaging	Imager Subarray
F560W	ALL	NO	FULL

Dithers

#	Dither Type	Optimized For	Direction
1	4-Point	EXTENDED SOURCE	NEGATIVE

Spectral Elements

#	Wavelength Range	Detector	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	LONG(C)	MRSLONG		FASTR1	22	2	1	Dither 1	4	8	499.507	
1	LONG(C)	MRSSHORT		FASTR1	22	2	1	Dither 1	4	8	499.507	
2	MEDIUM(B)	MRSLONG		FASTR1	22	2	1	Dither 1	4	8	499.507	
2	MEDIUM(B)	MRSSHORT		FASTR1	22	2	1	Dither 1	4	8	499.507	
3	SHORT(A)	MRSLONG		FASTR1	22	2	1	Dither 1	4	8	499.507	
3	SHORT(A)	MRSSHORT		FASTR1	22	2	1	Dither 1	4	8	499.507	

Special Requirements	
	3 After 9 DEFAULT WINDOW: ANGULAR RATE EUROPA FROM JWST LESS THAN 0.03 DEFAULT WINDOW: NOT OCCULTATION OF EUROPA BY JUPITER FROM JWST

Observation

Proposal 1250, Observation 9: MIRI Europa-BKG Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: MIRI Medium Resolution Spectroscopy

Diagnostics

(Visit 9:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(3)	EUROPA-BKG	STD=JUPITER	STD=EUROPA	TYPE=POS_ANGLE,RAD=300,ANG=0,REF=NORTH

Comments: Extended=YES

Acquisition

#	Target
1	NONE

Template

AcqFilter	Primary Channel	Simultaneous Imaging	Imager Subarray
F560W	ALL	NO	FULL

Spectral Elements

#	Wavelength Range	Detector	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	LONG(C)	MRSLONG		FASTR1	22	1	1	None	1	1	61.051	
1	LONG(C)	MRSSHORT		FASTR1	22	1	1	None	1	1	61.051	
2	MEDIUM(B)	MRSLONG		FASTR1	22	1	1	None	1	1	61.051	
2	MEDIUM(B)	MRSSHORT		FASTR1	22	1	1	None	1	1	61.051	
3	SHORT(A)	MRSLONG		FASTR1	22	1	1	None	1	1	61.051	
3	SHORT(A)	MRSSHORT		FASTR1	22	1	1	None	1	1	61.051	

Special Requirements	
	3 After 9 DEFAULT WINDOW: NOT OCCULTATION OF EUROPA-BKG BY JUPITER FROM JWST DEFAULT WINDOW: SEPARATION OF EUROPA-BKG IO FROM JWST GREATER THAN 10" DEFAULT WINDOW: SEPARATION OF EUROPA-BKG GANYMEDE FROM JWST GREATER THAN 10" DEFAULT WINDOW: SEPARATION OF EUROPA-BKG CALLISTO FROM JWST GREATER THAN 10" DEFAULT WINDOW: ANGULAR RATE EUROPA-BKG FROM JWST LESS THAN 0.03

Observation

Proposal 1250, Observation 4: MIRI/Img Europa Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: MIRI Imaging

Diagnostics

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(1)	EUROPA	STD=JUPITER	STD=EUROPA	

Comments: Extended=YES

Template

Subarray
SUB64

Dithers

#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size
1	4-Point-Sets				1	1	POINT SOURCE	NEGATIVE	DEFAULT

Spectral Elements

#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	F1280W	FASTR1	5	20	1	Dither 1	4	80	40.517	

Special Requirements

No Parallel Attachments

Group Observations 1, 2, 4, Non-interruptible

DEFAULT WINDOW: ANGULAR RATE EUROPA FROM JWST LESS THAN 0.03
DEFAULT WINDOW: NOT OCCULTATION OF EUROPA BY JUPITER FROM JWST

Observation

Proposal 1250, Observation 5: NIRCam Enceladus Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: NIRCam Imaging

Comments: Because the observations with NIRCam,NIRSpec and MIRI are used to derive common properties of the surface and jets of Enceladus, they need to be done in a non-interruptible sequence. This will allow us to accurately sample the same lats/lons/time on the moon and to get better inter-image calibration and photometry, which we need for quantifying weak ice/molecular features.

Diagnostics

(NIRCam Enceladus (Obs 5)) Warning (Form): Pointing performance insufficient

(NIRCam Enceladus (Obs 5)) Warning (Form): Pointing performance insufficient

(NIRCam Enceladus (Obs 5)) Warning (Form): Pointing performance insufficient

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(2)	ENCELADUS	STD=SATURN	STD=ENCELADUS	

Comments: Extended=YES

Template

Module	Subarray
B	SUB64P

Dithers

#	Primary Dither Type	Primary Dithers	Subpixel Dither Type	Dither Size	Subpixel Positions
1	SUBARRAY_DITHER	3	STANDARD		1

Spectral Elements

#	Short Filter	Long Filter	Readout Pattern	Groups/Int	Integrations/Exp	Total Integrations	Total Dithers	Total Exposure Time	ETC Wkbk.Calc ID
1	F212N	F460M	RAPID	5	10	30	3	9.106	
2	F140M	F335M	RAPID	5	10	30	3	9.106	
3	F070W	F250M	RAPID	5	10	30	3	9.106	

Special Requirements

Group Observations 5, 6, 8, Non-interruptible

DEFAULT WINDOW: ANGULAR RATE ENCELADUS FROM JWST LESS THAN 0.03
SEPARATION OF ENCELADUS SATURN FROM JWST GREATER THAN 20"
DEFAULT WINDOW: NOT OCCULTATION OF ENCELADUS BY SATURN FROM JWST

Observation

Proposal 1250, Observation 6: NIRSpec Enceladus Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: NIRSpec IFU Spectroscopy

Diagnostics

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(2)	ENCELADUS	STD=SATURN	STD=ENCELADUS	

Comments: Extended=YES

Template

TA Method
NONE

Dithers

#	Dither Type	Size	Starting Point	Number of Points	Points
1	CYCLING	SMALL	1	2	

Spectral Elements

#	Grating/Filter	Readout Pattern	Groups/Int	Integrations/Exp	Leakcal	Dither	Autocal	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	G140H/F100LP	NRSRAPID	2	10	false	true	NONE	2	20	644.206	
2	G235H/F170LP	NRSRAPID	5	5	false	true	NONE	2	10	644.206	
3	G395H/F290LP	NRSRAPID	5	5	false	true	NONE	2	10	644.206	

Special Requirements

Group Observations 5, 6, 8, Non-interruptible

DEFAULT WINDOW: ANGULAR RATE ENCELADUS FROM JWST LESS THAN 0.03
DEFAULT WINDOW: NOT OCCULTATION OF ENCELADUS BY SATURN FROM JWST
CENTRAL MERIDIAN LONGITUDE OF ENCELADUS FROM JWST BETWEEN 255 285

Observation

Proposal 1250, Observation 7: MIRI Enceladus Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: MIRI Medium Resolution Spectroscopy

Diagnostics

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

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(2)	ENCELADUS	STD=SATURN	STD=ENCELADUS	

Comments: Extended=YES

Acquisition

#	Target
1	NONE

Template

AcqFilter	Primary Channel	Simultaneous Imaging	Imager Subarray
F560W	ALL	NO	FULL

Dithers

#	Dither Type	Optimized For	Direction
1	4-Point	EXTENDED SOURCE	NEGATIVE

Spectral Elements

#	Wavelength Range	Detector	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	LONG(C)	MRSLONG		FASTR1	22	2	1	Dither 1	4	8	499.507	
1	LONG(C)	MRSSHORT		FASTR1	22	2	1	Dither 1	4	8	499.507	
2	MEDIUM(B)	MRSLONG		FASTR1	22	2	1	Dither 1	4	8	499.507	
2	MEDIUM(B)	MRSSHORT		FASTR1	22	2	1	Dither 1	4	8	499.507	
3	SHORT(A)	MRSLONG		FASTR1	22	2	1	Dither 1	4	8	499.507	
3	SHORT(A)	MRSSHORT		FASTR1	22	2	1	Dither 1	4	8	499.507	

Special Requirements	DEFAULT WINDOW: ANGULAR RATE ENCELADUS FROM JWST LESS THAN 0.03 DEFAULT WINDOW: NOT OCCULTATION OF ENCELADUS BY SATURN FROM JWST

Observation

Proposal 1250, Observation 8: MIRI/Img Enceladus Wed Dec 14 22:00:52 GMT 2022

Diagnostic Status: Warning

Observing Template: MIRI Imaging

Diagnostics

(Visit 8:1) Warning (Form): Overheads are provisional until the Visit Planner has been run.

Solar System Targets

#	Name	Level 1	Level 2	Level 3
(2)	ENCELADUS	STD=SATURN	STD=ENCELADUS	

Comments: Extended=YES

Template

Subarray
SUB64

Dithers

#	Dither Type	Starting Point	Number of Points	Points	Starting Set	Number of Sets	Optimized For	Direction	Pattern Size
1	4-Point-Sets				1	1	POINT SOURCE	NEGATIVE	DEFAULT

Spectral Elements

#	Filter	Readout Pattern	Groups/Int	Integrations/Exp	Exposures/Dith	Dither	Total Dithers	Total Integrations	Total Exposure Time	ETC Wkbk.Calc ID
1	F1280W	FASTR1	5	20	1	Dither 1	4	80	40.517	

Special Requirements

No Parallel Attachments

Group Observations 5, 6, 8, Non-interruptible

DEFAULT WINDOW: ANGULAR RATE ENCELADUS FROM JWST LESS THAN 0.03
DEFAULT WINDOW: NOT OCCULTATION OF ENCELADUS BY SATURN FROM JWST