Establishing Extreme Dynamic Range with JWST: Decoding Smoke Signals in the Glare of a Wolf-Rayet Binary

Scientific Category:	<SCIENTIFIC CATEGORY>
Scientific Keywords:	Circumstellar Matter, Dust, Hot Stars, Interstellar Medium, Massive Stars
Instruments:	MIRI, NIRISS
Proposal Size:	SMALL
Exclusive Access Period:	0 months
Allocation Information (in hours):	
Science Time:	7.0
Charged Time:	19.1

Abstract

Dust is a key ingredient in the formation of stars and planets. However, the dominant channels of dust production throughout cosmic time are still unclear. With its unprecedented sensitivity and spatial resolution in the mid-IR, the James Webb Space Telescope (JWST) is the ideal platform to address this issue by investigating the dust abundance, composition, and production rates of various dusty sources. In particular, colliding-wind Wolf-Rayet (WR) binaries are efficient dust producers in the local Universe, and likely existed in the earliest galaxies. We purpose JWST observations of the colliding-wind binaries WR 140 and WR 137 to investigate dust composition, abundance, and formation mechanisms in this dust-forming colliding-wind process. We will utilize three key JWST observing modes with the medium-resolution spectrometer (MRS) and imager on the Mid-Infrared Instrument (MIRI) and the Aperture Masking Interferometry (AMI) mode with the Near Infrared Imager and Slitless Spectrograph (NIRISS).

Our proposed observations will yield high impact scientific results on the dust forming properties WR binaries, and establish a benchmark for key observing modes for imaging bright sources with faint extended emission. This will be valuable in various astrophysical contexts including mass-loss from evolved stars, dusty tori around active galactic nuclei, and protoplanetary disks. We are committed to designing and delivering science-enabling products for the JWST community that address technical issues such as bright source artifacts that will limit the maximum achievable image contrast.

(NoI Ref. #180)

Target Summary:

Target	RA	Dec
WR140	20 20 27.9761	+43 51 16.28
WR140-OFFSET-1	20 20 27.9851	+43 51 15.90
WR140-OFFSET-2	20 20 28.0553	+43 51 13.74
WR140MRSCAL	20 16 35.9811	+45 20 20.87
WR137	20 14 31.7632	+36 39 39.51
WR137AMIREFPSF	20 12 57.8919	+35 45 46.45

Observing Summary:

Target	Observing Template	Flags	Allocation *
WR140-OFFSET-1	MIRI Medium Resolution Spectroscopy *F560W, F1000W, F2100W*		9,492 / 15,995
WR140-OFFSET-2	MIRI Medium Resolution Spectroscopy *F560W, F1000W, F2100W*		9,492 / 15,622
WR140MRSCAL	MIRI Medium Resolution Spectroscopy *F560W, F1000W, F2100W*		1,500 / 6,724
WR140	MIRI Imaging *F1500W, F2100W, F2550W*		1,008 / 7,931
WR137	NIRISS Aperture Masking Interferometry *F480M, F380M*		896 / 5,745
WR137AMIREFPSF	NIRISS Aperture Masking Interferometry *F480M, F380M*		956 / 5,736
WR137AMIREFPSF	NIRISS Aperture Masking Interferometry *F480M, F380M*		955 / 5,103
WR137	NIRISS Aperture Masking Interferometry *F480M, F380M*		954 / 6,048

* Science duration / charged duration (sec)

Total Prime Science Time in Hours: 7.0

Total Charged Time in Hours: 19.1

Observing Description

We will perform a total of 15.9 hours of MIRI MRS and Imager observations of the dust-forming Wolf-Rayet (WR) binary WR 140 and NIRISS/AMI observations of the dust-forming WR binary WR 137. These observations include two calibrators for each instrument mode: HD 193090 and HD 228337.

In the MIRI MRS mode, we will obtain the full 5 - 28 micron spectral coverage (Ch1 - Ch4) of WR 140 out to 3 fossil dust arcs. We will perform MRS observations at two pointings: one offset from WR 140 by 0.4 arcseconds, and one offset by 2.7 arcseconds to cover the bright regions in the 1st, 2nd, and 3rd fossil dust arcs. Both MRS pointings will utlize the 4-point dither pattern optimzed for extended sources.

We will observe a mid-IR PSF reference star selected from the JMMC stellar diameter catalog (Bourges et al. 2017) with a nearly identical 12 micron flux as WR 140. Comparing the spectra from the reference star and WR 140 will allow us to differentiate the artifacts and the bright source from faint extended emission around WR 140. Importantly, HD 193090 is located within 2 degrees of WR 140, which requires only a ~5 min JWST slew overhead. We will perform the same dither pattern as our central WR 140 pointing but with a shorter exposure time per dither position.

In the MIRI Imager mode, we will perform short, several minute-long exposures with the F1500W, F2100W, and F2550W filters centered on WR 140 using the 4-point dither strategy optimized for extended sources. Although the bright central source of WR 140 and possibly the 1st and 2nd dust arcs will saturate the Imager, we will be able to probe out to 7 or more fossil dust arcs with the Imager sensitivity and field of view in the "FULL" subarray mode.

In the NIRISS/AMI mode, we propose F380M and F480M observations of WR 137 in a 4-point dither and undithered mode. At the anticipated timing of Cycle 1 ERS, WR 137 will be exhibiting enhanced dust-formation due to the orbital confirguration of the central binary system and thus provides an ideal target for NIRISS/AMI to achieve our science and technical goals. The goal of performing the two different observations will be to investigate and attempt to mitigate the NIRISS/AMI persistence effects from bright sources. We will perform dithered and undithered ("stare" mode) with the same on-source exposure time. Both modes have advantages and disadvantages for imaging the faint emission around WR 137. With no dithers, WR 137 will remain in the same position on the detector and persistence will therefore not significantly affect the resulting data. However, bad pixels on the detector cannot be corrected. The 4-point primary dither mode will allow us to remove the bad pixels but persistent images from the bright central source of WR 137 will affect the image reconstruction. One of our goals in this proposal is to determine which method is best suited for performing observations of faint extended emission around bright sources. Additionally, we will investigate how to calibrate for the persistence in the dithered observations. After the last "stare"observation, we will take two short exposure direct images with the F380M and F480M filters.

We will observe a PSF calibrator of similar 3.8 and 4.8 micron flux as the bright central core of WR 137 with NIRISS/AMI in order to characterize the interferometric transfer function and ultimately for the reconstruction of WR 137. Our PSF calibrator, HD 228337, will be observed in the same dither and no-dither observations that we plan for WR 137 with the same exposure depth to compare the persistence effects.

Investigators:

Investigators and Team Expertise are included in this preview for your team to review. These will not appear in the version of the proposal given to the TAC, to allow for a dual anonymous review.

	Investigator	Institution	Country
	M Hankins	Arkansas Tech University	USA/AR
	M Kasliwal	California Institute of Technology	USA/CA
*	A Lamberts	Observatoire de la Cote d'Azur	FRA
	R Lau	ISAS, Japan Aerospace Exploration Agency	JPN
	C Russell	Catholic University of America	USA/DC
*	J Sanchez-Bermudez	European Southern Observatory - Chile	CHL
	A Sivaramakrishnan	Space Telescope Science Institute	USA/MD
	D Thatte	Space Telescope Science Institute	USA/MD

Number of investigators: 8

* ESA investigators: 2

Team Expertise: