NIRSpec and MIRI Observations of SN1987A

This article introduces the science justification to observe supernova SN1987A using several instruments onboard JWST.

Introduction

We present a science case of stellar evolution: the study of Supernova 1987A. This example was developed by M. Meixner as a joint GTO Program with the MIRI-EC and her MIRI Science Team. In this example we present the steps that are necessary to design the observations for this plan. In the use case, 3 JWST instruments are involved: MIRI, NIRSpec, and NIRCam. The process includes the creation of a new proposal, the definition of targets, and the design of the observations.

This use case for MIRI and NIRSpec observations of Supernova 1987A was presented and described at the May 2017 JWST Proposal Planning workshop at STScI. The associated webcasts and presentation slides are available at:

- The GTO Science case (M. Meixner): Webcast / Presentation Slides
- The ETC Example (S. Kendrew): Webcast
- The APT Example (Tea Temim): Webcast

From these presentations, we summarize the MIRI Imaging, MIRI MRS Spectroscopy and the NIRSpec IFU observation science case below.

The MIRI and NIRSpec use case on SN 1987A is described in further detail in the sub-pages:

SN 1987A: Step-by-step instructions for the APT

SN 1987A: Step-by-step NIRSpec IFU instructions for the ETC

Science motivation
The main science goals of this project are to understand how massive stars age and explode, how their ejecta form dust and molecules, and how the blast wave from their violent explosion affects their surroundings. JWST MIRI imaging, Medium Resolution Spectroscopy (MRS) and NIRSpec IFU spectroscopy will provide key emission line diagnostics and dust feature and continuum measurements of SN 1987A. The central stellar ejecta of SN 1987A is surrounded by a ring of progenitor gas and dust that is being shocked by the blast wave of the explosion (Figure 1). A large quantity (0.4–0.7 solar masses) of dust (Figure 2) in the stellar ejecta has an unknown composition and these observations may provide the first constraints through imaging and spatially resolved spectroscopy. Both MRS and NIRSpec IFU spectroscopy will measure key shocked line diagnostics that will further constrain the shock physics as well as the elemental abundances in both the ring and the stellar ejecta.

Figure 1. SN 1987A in the Large Magellanic Cloud.

Hubble Space Telescope WFC3 image of SN 1987A and its surrounding in the LMC observed in January 2017. This image was released as STScI-20017-08.

The MIRI observations will be used to investigate the dust morphology, composition and evolution. NIRSpec IFU imaging spectroscopy of the ring and ejecta will be obtained to measure the shocked emission lines.

The main goals of this investigation are:

1. To study the evolution of the interaction of the blast wave with the 2 arcsec diameter equatorial ring and beyond.
2. To determine the nature of the ring’s hot dust component discovered by Spitzer (Bouchet et al. 2006).
3. To search for and confirm mid-IR emission from the 0.5 solar mass of ejecta dust that was discovered at far-IR wavelengths by Herschel.
4. To study the evolution of the dust and molecules in the ejecta (see Figure 3).
5. To look for a remnant neutron star.
Figure 2. SN 1987A in different wavelengths.

Newly formed dust in the center of the supernova remnant as observed by ALMA, combined with emission in the visible by Hubble Space Telescope, and the distribution of the hottest gas as observed by NASA’s Chandra X-ray Observatory.

Figure 3. ALMA reveals dust emission.

Continuum images of SN 1987A in ALMA Bands 3, 6, 7, and 9 (2.8 mm, 1.4 mm, 870 m and 450 m respectively). See Indebetouw et al. (2014) for details.

Observing Strategy
The James Webb Space Telescope is best suited to perform these observations because of the high resolution in the infrared wavelength range from 0.6 to 28 μm. This will allow us to accurately resolve both the ring and the ejecta.

The instruments onboard JWST have a high sensitivity which will allow us to detect faint emission from ejecta and the warm dust emission from the circumstellar ring. These instruments also provide medium and high resolution IFU imaging spectroscopy, which allows for kinematic measurements of gas and continuum measurements of the dust which is interacting with the expanding shock wave.

The environment of SN1987A has significant star formation, which has been studied using HST imaging and spectroscopic observations of SN 1987A. JWST will follow up on those observations using parallel fields when SN 1987A is the prime target. Note that SN 1987A is in the continuous viewing zone of the observatory, which makes it an easy target to schedule in the observing queue.

The proposed observations will be performed in two epochs using the following configurations:

1. **MIRI imaging** with filters $F_{560W}$, $F_{1000W}$, $F_{1800W}$, and $F_{2550W}$ - to study dust continuum shape and morphology in SN 1987A.
2. **MRS IFU** and **NIRSpec IFU** imaging spectroscopy - to determine dust and molecular composition (MIRI MRS) and study shock emission tracers to investigate gas processes (NIRSpec).
3. Parallel observations with the MRS and MIRI simultaneous imaging (when possible).

The expected total observing time including overheads is approximately nine hours.

### Observation design

In order to design the observations of SN1987A, we use the official tools for JWST proposal preparation: the Astronomer's Proposal Tool (APT) and the Exposure Time Calculator (ETC). The links below provide the step-by-step instructions used to demonstrate these tools for this use case.

- Step-by-step instructions for the APT
- Step-by-step instructions for the ETC

### References


Dust production and particle acceleration in Supernova 1987A revealed with ALMA.