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PRELIMINARY RESULTS ON JWST CYCLE 1 GO #2180: THE CIRCUMGALACTIC MEDIUM OF NGC 891

J. Chastenet[1], I. Looze[1,], M. Relaño[2,3], T. Williams[4], E. Xilouris[5] and the proposing team

Abstract. We present the latest maps of the edge-on galaxy NGC 891 observed by JWST, and preliminary results. The NIRCam instrument observed the northern half of the disk in the F150W and F277W filters, while MIRI observed a portion of the circum-galactic medium (CGM) in F770W. The mid-infrared image at 7.7 μm tracing aromatic-rich grains shows filamentary structures, expanding as far as $\sim$ 4 kpc, together with a large number of small clumps, also visible in the image. These dust-rich structures give us insights to identify the feedback processes responsible for the ejection of mid-plane material out to the CGM.

Keywords: Dust composition, Polycyclic aromatic hydrocarbons, Galactic and extragalactic astronomy, Circumgalactic medium

1 Introduction & Presentation of the proposal

The focus of this proceeding is the JWST Cycle 1 GO #2180 program (PI De Looze), entitled "Structure formation and baryonic cycling in the edge-on galaxy NGC891".

1.1 Introduction

The circum-galactic medium (CGM) is the interface between the large halo and the main disk of spiral galaxies. That is where in- and outflows happen, and the recycling of baryonic material that fuels galaxies takes place. Understanding these exchanges also requires to understand the stratification of disks, at various wavelengths. The determination of disks of various sizes (thin to thick, and even extra-thin disks) can only be done unambiguously in edge-on galaxies. This eventually can help understanding the inflow and outflow processes, making edge-on galaxies the best laboratories to study how feedback processes shape galaxy evolution.

These processes appear to be somewhat insufficiently understood, since the simulations often show discrepancies when compared to observational data. In particular, an overestimation of feedback processes in cosmological simulations tend to overestimate the scale-heights of galactic disks (Governato et al. 2004; Grand et al. 2016; Trayford et al. 2017). With numerous recent observations of these outflows, their importance is no longer questioned, but their exact nature and efficiency need to be refined. What drives these mechanisms, e.g., supernovae, stellar winds, ionizing radiation, cosmic rays, is not well understood.

This study focuses on the disk and CGM of NGC 891, a nearly perfectly edge-on galaxy ($i \sim 89.7°$; Xilouris et al. 1999), located at $\sim$ 9.6 kpc (Strickland et al. 2004). Its proximity and inclination, combined with the high-sensitivity and spatial resolution of JWST, this target is an excellent choice to investigate the main issues related to the feedback processes in spiral galaxies.

[1] Sterrenkundig Observatorium, Ghent University, Krijgslaan 281-S9, B9000 Gent, Belgium
[2] Departamento Física Teórica y del Cosmos, Universidad de Granada, E-18071 Granada, Spain
[3] Instituto Universitario Carlos I de Física Teórica y Computacional, Universidad de Granada, E-18071 Granada, Spain
[4] Sub-department of Astrophysics, Department of Physics, University of Oxford, Keble Road, Oxford OX1 3RH, UK
[5] Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing, National Observatory of Athens, P. Penteli, 15236 Athens, Greece

1.2 Data

We present the first data taken as part of the proposal. The NIRCam F150W and F277W observations were taken on August, 15$^{\rm th}$ 2022, and MIRI F770W observation were taken on December, 23$^{\rm rd}$ 2022. Figure 1 shows these observations. Additionally, we collected parallel NIRCam observations during the MIRI pointings, not shown here.

The NIRCam data cover the northern half of the disk, out to $\sim$ 3 kpc on both sides. We can notice visible absorption features in the mid-plane at both wavelengths, more prominent at 1.5 μm (top left panel of Figure 1). The data was reduced using the modified pipeline from the PHANGS Team (Lee et al. 2023, Williams et al., in prep). The short- and long-wavelength arrays do show conspicuous differences. While the background appears relatively smooth in F277W, the F150W image shows visible large structures, stripes and offsets between dithers that we have not yet corrected. Note that the small squares in F150W are due to a lack of overlap in the short-wavelength sub-array mode.

The MIRI F770W observations cover a strip off the main disk from $\sim$ 1 to $\sim$ 10 kpc (thus not covering the disk directly), to trace the 7.7 μm mid-IR emission feature from large aromatic molecules (Polycyclic Aromatic Hydrocarbons, PAHs, or Hydrogenatic Amorphous Hydrocarbons Jones et al. 2013; Li 2020, for a review). We mark the distances at 1, 2, 3, 5, and 10 kpc in the MIRI panel of Figure 1. With the high sensitivity and spatial resolution of JWST, bright, fine structures are visible. The presence of arcs, filaments, and potential galactic fountains are detected at reasonable signal-to-noise ratio.

2 Early analysis

This section presents preliminary results from a first analysis of the data products.

2.1 Mid-IR radial profiles

We use literature driven assumptions to estimate the scale-height of the dust distribution as seen in the MIRI image. In earlier work, a dust scale-height of $\sim$ 0.10 kpc was found using a single exponential disk or $\sim$ $0.13 - 0.6$ kpc with a double-exponential disk in the *Spitzer*/IRAC 8 μm image (e.g., Bocchio et al. 2016). Our analysis reveals a scale-height of $z_{\rm d} \sim 0.4 - 0.5$ kpc using a single disk. Since we do not cover the mid-plane, our estimate is closer to the thick disk that was found in other studies.

2.2 Clumps

The insets in Figure 1 show zoom-ins on a few regions, to highlight the presence of small bright clumps. Cold, dense gas clumps have been predicted in simulations (e.g., Lan & Fukugita 2017; Hirashita & Lan 2021; Farber & Gronke 2022).

We focus on these clumps throughout the image in a preliminary analysis. To identify them, we use the ASTRODENDRO package. However, as visible in Figure 1, there is a strong gradient close to the disk out to further distances. This gradient makes it difficult to adjust the parameters of ASTRODENDRO to conservatively, but accurately detect the right sources. To alleviate that effect, we use an unsharp-masked version of the MIRI image. Unsharp-masking is an edge enhancement technique. This allows us to focus on bright clumps and remove the more diffuse filaments and the gradient. The bulk of the detected clumps has a radius ranging between $\sim$ 10 and $\sim$ 30 pc, slightly smaller than what is predicted in simulations. The number of clumps peaks around 1 kpc from the disk, with a rapid decrease in number to further distances.

2.3 Filaments

Multiple filaments are visible in the first $\sim 2 - 2.5$ kpc. Filaments have been identified in the CGM of other edge-on galaxies, at different wavelengths (e.g., Rand et al. 1990; Howk & Savage 1997; Rossa et al. 2004; Irwin et al. 2007), showing that they exist in several phases of the gas component.

Unfortunately, since our observations do not cover the main disk, we cannot directly connect these filaments to the mid-plane of NGC 891. Instead, we combine our new data with the *Spitzer*/IRAC 8 μm image. We apply unsharp-masking to that image, and enhance dusty filaments and the disk. We compare these IRAC filaments with the ones identified in the (convolved) MIRI image using FILFINDER (Koch & Rosolowsky 2015). The agreement is very good, and we can connect these MIRI structures all the way back to the disk. Using

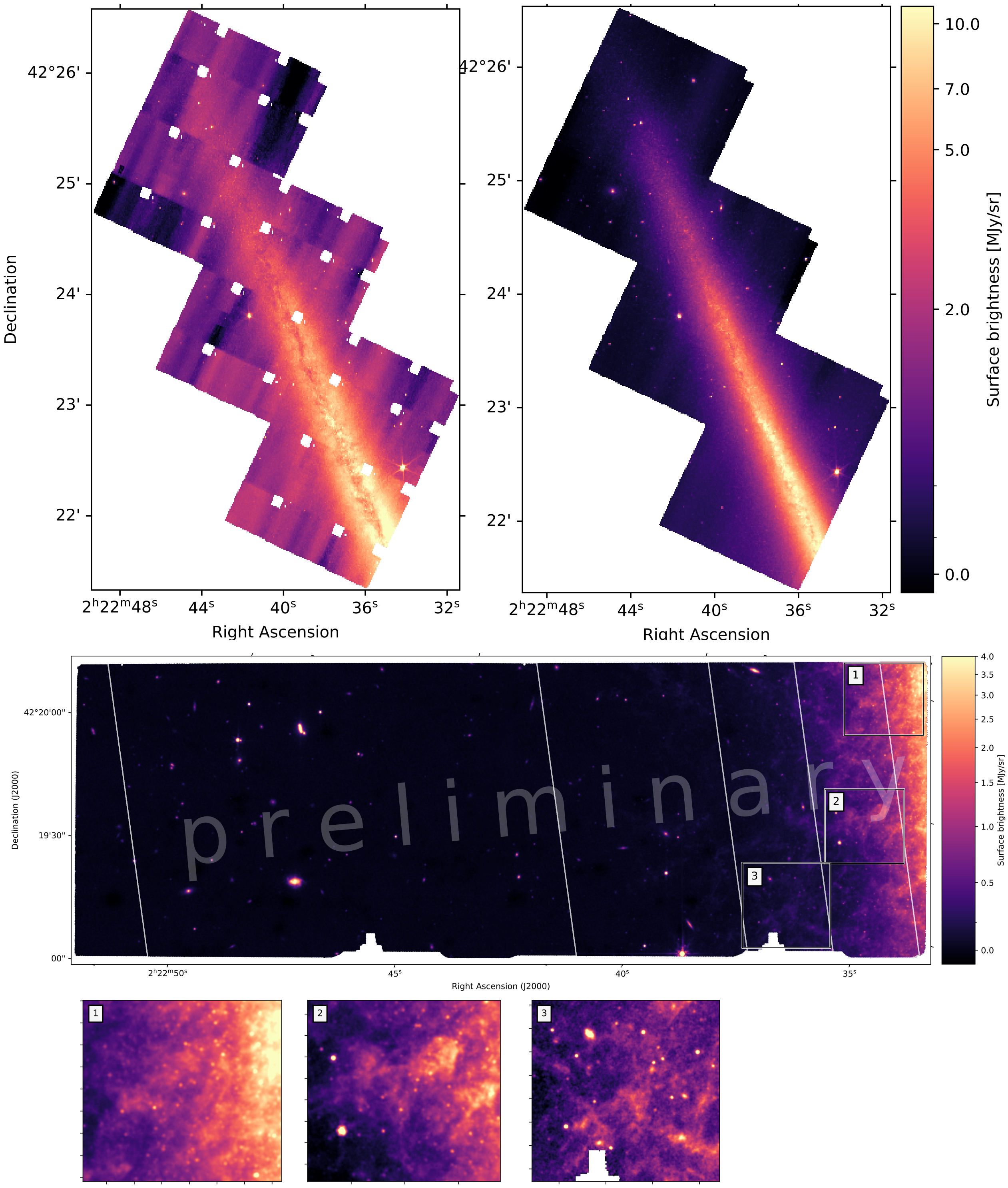

Fig. 1. *Top panels:* NIRCam F150W (left) and F277W (right) of the northern half of the disk. Conspicuous absorption structures are visible in both images. *Bottom panel:* MIRI F770W image, with distance marks at 1, 2, 3, 5, and 10 kpc from the mid-plane. The three insets (shown with a different color-stretch show detailed filaments and clumps.

mid-IR data to derive star formation rates (SFRs; e.g., Leroy et al. 2019), we find that these filaments are often linked to high SFRs. This has been studied in several works as well (e.g., Heckman 2002; Yoon et al. 2021). Additional work will attempt to precisely estimate the lower-limit on SFR that can birth extensive filaments.

3 Conclusions

We present new observations of NGC 891, a nearby edge-on galaxy. NIRCam data in the F150W and F277W filters trace the stellar content in the northern half. MIRI/F770W data shows the distribution of PAHs in the CGM of NGC 891, out to 4 kpc away from the mid-plane. We focus our early analysis on prominent filaments and small dense clumps, visible at 7.7 μm. Identifying the properties of these structures will allow us to estimate the amount of mid-IR features carriers (PAHs) in the CGM, put constrains on their formation outside of the mid-plane, and/or the stellar/supernova processes responsible for their ejection in the CGM through galactic outflows.

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