NGC 6552 is a galaxy at z = 0.02656 ± 0.00042 classified as an active galactic nucleus (AGN) Seyfert 2 in the optical (Moran et al. 1996; Bower et al. 1996; Falco et al. 1999; Paturel et al. 2002; Gioia et al. 2003; Shu et al. 2007), and as a Compton-thick AGN (CT-AGN), with a derived column density of log(N_H) = 24.05 cm^{-2}, in X-rays (Ricci et al. 2015). Most recent X-ray studies with XMM-Newton (Jansen et al. 2001), comple-
Table 1. Summary of MIRI commissioning observations for NGC6552

| Visit | Imager target | MRS target | Imager Filter | MRS band | Groups | Int | Exp. | Dithers | Exp. time(\textsec) |
|-------|---------------|------------|---------------|----------|--------|-----|------|---------|---------------------|
| 1     | Back.         | Star       | F560W         | SHORT    | 25     | 1   | 1    | 4       | 277.5               |
| 2     | Back.         | NGC 6552   | F560W         | SHORT    | 200    | 1   | 1    | no dither | 555                 |
| 3     | NGC 6552      | Back.      | F560W         | MEDIUM   | 25     | 8   | 1    | no dither | 574                 |
| 4     | NGC 6552      | Back.      | F560W         | LONG     | 25     | 1   | 1    | 8       | 555                 |
| 5     | Back. + Persistence | NGC 6552 | F560W       | ALL      | 182    | 1   | 1    | no dither | 3 \times 505        |
| 6.1   | Back. + Persistence | Back.       | F560W         | SHORT    | 25     | 1   | 1    | 4       | 277.5               |
| 6.2   | Back. + Persistence | Back.       | F56550W      | SHORT    | 25     | 1   | 1    | 4       | 277.5               |
| 6.3   | Back. + Persistence | Back.       | F560W         | SHORT    | 25     | 20  | 1    | no dither | 1440.2              |

Consult PID1039 for details. (* Exposure time are in seconds.

mended with NuSTAR (Harrison et al. 2013) observations sensitive to hard X-rays in the 3 to 78 keV range, confirm the classification of NGC 6552 as a CT-AGN (Torres-Albá et al. 2021). The X-ray model predicts the presence of a CT-AGN within a Compton-thin torus oriented almost edge-on (75 degrees with respect to our line of sight). NGC 6552 has also been observed in imaging and spectroscopy at mid-infrared (mid-IR) wavelengths with Spitzer and WISE. These observations have been used to cross-calibrate the long-wavelength band of WISE (W4) with the Spitzer InfraRed Spectrograph long-low module (IRS-LL) and MIPS 24 μm channel (Jarrett et al. 2011).

The Mid-Infrared Instrument (MIRI, Rieke et al. 2015b; Wright et al. 2015) onboard the James Webb Space Telescope (JWST) includes imaging and medium resolution integral field spectroscopy (IFS) observing modes from 4.9 to 28.1 μm. The MIRI Imager provides high resolution images in nine filters, with a clear field of view (FoV) up to 2.3 square arcmin (Bouchet et al. 2015). The Medium Resolution Spectrometer (MRS) provides IFS in twelve individual spectral bands, organized in four channels (SHORT, MEDIUM, and LONG). The MRS provides a factor of x10-100 increased sensitivity from previous mid-IR telescopes, combined with a sub-arcsec resolution in a FoV ranging from ~13 to ~56 square arcsec, and a spectral resolution of 75 to 200 km s⁻¹ (Wells et al. 2015; Glasse et al. 2015; Labiano et al. 2021, Argiriou et al. in prep.). Due to the low central extinction in the mid-IR spectral range, similar to that in the several keV X-ray range (Corrales et al. 2016a), and the improvements in the spatial and spectral resolution from previous mid-IR instruments, MIRI will be a key instrument to peer into the inner dust-enshrouded nuclear regions of nearby galaxies giving the possibility to separate the nucleus from its circumnuclear environment, and study both components with unprecedented detail and sensitivity.

Galactic winds and outflows are a universal phenomenon associated with AGNs and star-forming galaxies (Veilleux et al. 2005; Fabian 2012; King & Pounds 2015; Veilleux et al. 2020). They have been detected in different phases of the gas, from highly ionized to neutral, and molecular gas, and at both low-z and high-z (Rodríguez-Ardila et al. 2006; Guillard et al. 2012; Veilleux et al. 2013; Arribas et al. 2014; Harrison et al. 2016; Emonts et al. 2017; Pereira-Santaella et al. 2018; Davies et al. 2020; Spilker et al. 2020; Álvarez-Márquez et al. 2021). The mid-IR wavelength range is very rich in coronal emission lines, i.e. lines with ionization potential (Eₚ) close or above 100 eV, of different elements (sulfur, neon, iron, argon, magnesium, among others). These lines, together with the low extinction in this spectral range relative to the optical, provide a unique opportunity to probe the gas close to the AGN, and therefore to establish the physical conditions and kinematics of the outflows in the inner regions close to the black-hole and accreting torus (e.g., Pereira-Santaella et al. 2010; Fischer et al. 2011).

In this paper we demonstrate the MIRI capabilities to study the physical conditions and kinematics of the nuclear regions in nearby galaxies. The paper is structured as follows: Section 2 describes the MIRI Imager and MRS observations of NGC 6552. Sections 3 and 4.1 explains the calibration of the MIRI Imager and MRS data. Section 4.2 shows the final calibrated spectra of NGC 6552. Section 5 presents the fluxes and kinematics measurements of all detected emission lines, the properties of the ionized outflowing gas and the warm molecular Hydrogen, and the Seyfert nature of the AGN and black hole mass of NGC 6552. Finally, Section 6 summarize and conclude the paper. We have adopted H₀ = 67.7 km s⁻¹ Mpc⁻¹ and Ωₘ = 0.307 (Planck Collaboration et al. 2016) as cosmological parameters. The corresponding luminosity distance (D_L) and physical scale used in this paper for z=0.02656 are 120Mpc and 0.552 kpc/arcsec⁻¹, respectively.

2. Observations

MIRI data of NGC 6552 was obtained on May 7th, 2022, during the commissioning of JWST, as part of the persistence characterization of the MIRI detectors (PID 1039, P.I. D. Dicken). The magnitude of the detector persistence is a function of flux of the source of origin, as well as the time spent observing that source on the same detector pixel (Rieke et al. 2015a). The persistence behaviour has been first measured during MIRI ground testing, so this commissioning activity aimed at verifying that the memory effect seen in the detectors after observing a bright source was as expected.

The aim of this program was to investigate the presence of persistence after long observations of NGC 6552 on the MIRI Imager and MRS detectors, and analyze any artefacts and their decay for up to 25 minutes. The program began by taking a background observation with the filter F560W of the MIRI Imager, and the MRS observing a star (TYC-4213-1049-1) using the SHORT band (visit 1). The aim of this observation was to gauge the state of the detectors (i.e. to look for any existing artefacts) before the program started, as well as to use it for background subtraction in the MIRI imager calibration process. A carefully designed sequence of observations followed, using both the MIRI Imager and the MRS simultaneously observing adjacent FoV (see Table 1 for a summary). Visits 2, 3 and 4 were relatively long (555 seconds) on-target exposures with the MIRI imager in order to put a large amount of signal on the detector, to see if this imprints a persistence signature in the data. The nucleus of NGC 6552 was able to saturate the imaging data in the third detector readout. Visit 5 was on-target MRS observations with exposure times of 505 seconds in each of the MRS bands.

| Visit | Imager target | MRS target | Imager Filter | MRS band | Groups | Int | Exp. | Dithers | Exp. time(\textsec) |
|-------|---------------|------------|---------------|----------|--------|-----|------|---------|---------------------|
| 1     | Back.         | Star       | F560W         | SHORT    | 25     | 1   | 1    | 4       | 277.5               |
| 2     | Back.         | NGC 6552   | F560W         | SHORT    | 200    | 1   | 1    | no dither | 555                 |
| 3     | NGC 6552      | Back.      | F560W         | MEDIUM   | 25     | 8   | 1    | no dither | 574                 |
| 4     | NGC 6552      | Back.      | F560W         | LONG     | 25     | 1   | 1    | 8       | 555                 |
| 5     | Back. + Persistence | NGC 6552 | F560W       | ALL      | 182    | 1   | 1    | no dither | 3 \times 505        |
| 6.1   | Back. + Persistence | Back.       | F560W         | SHORT    | 25     | 1   | 1    | 4       | 277.5               |
| 6.2   | Back. + Persistence | Back.       | F56550W      | SHORT    | 25     | 1   | 1    | 4       | 277.5               |
| 6.3   | Back. + Persistence | Back.       | F560W         | SHORT    | 25     | 20  | 1    | no dither | 1440.2              |
The MRS observations did not saturate. Visit 6 was used as a reference image and to study persistence decay in the MIRI Imager detector, if any. Finally, MRS observations from visits 2, 3, and 4 have been used for background characterizations purposes.

Since the MRS is spatially undersampled, the MIRI Instrument Team recommends using dithering on every MIRI observation to maximize the spatial and spectral sampling and the scientific return of the MIRI observations. Due to the nature of this program, the MRS on-target observations did not use dithers, as the program was designed to investigate artefacts in the detector image rather than on sky. The MIRI Imager visits 2 and 3 used offsets instead of dithers to make sure any persistence artefacts were well separated from one image to another. The MIRI Imager visit 4 uses two 4-point, extended dither patterns. The MRS background simultaneous observations, visits 2, 3, and 4, follow the MIRI Imager dither pattern strategies. For additional information on dithers and exposure times see Table 1.

The results of the commissioning investigation demonstrated that the impact of persistence artefacts was very low, where persistence was seen at a level $<0.01\%$ of the source flux. Such levels of persistence are easily calibrated using standard MIRI dither patterns and the JWST calibration pipeline. In the case of NGC 6552, the saturating nucleus had no impact on the imaging or subsequent exposures, as the MIRI Imager proved to work extremely well in this relatively high contrast observation (see Section 3).

3. MIRI image

The MIRI imaging data were reprocessed with the v1.6.3 JWST pipeline, using the latest reference files available. After the level 1 detector processing, we applied a fix to the pipeline to re-create rate images from the rateints files after averaging valid data, as a bug in the pipeline affected the pixels that are saturating in after the third group, which is the case for some of the central pixels. For those pixels, only the first 3 frames were used. Note that this fix will be implemented in a future version of the pipeline. Then, the level 2 pipeline was run with the default parameters and using the sky flats computed from the LMC data taken during commissioning (PID 1040). These preliminary flats contain image artifacts caused by MIRI reset anomaly (see Ressler et al. 2015, for a discussion of this effects), like for example tree-ring shaped structures. However, most of these image artifacts are removed by the master background subtraction (explained below), as the features are stable. Since the calibration of the image is still preliminary, the MIRI Imager data is only used in this paper to illustrate the MRS pointings, crossmatch the MIRI Imager and the MRS photometry, and illustrate the optical quality (in particular the low persistence) and dynamical range of the imager.

A master sky background image was created from the first visit file and subtracted from all the images. This sky image was created by sigma clipping all the images from the visit 1 aligned in instrument coordinates. We note that this injects residual small scale variations at a percent level in the background, which are not critical for our analysis. The left panel Fig. 1 shows on the the entire galaxy, highlighting the low surface brightness emission in the dusty ring around the barred galaxy. Clumps of star formation are resolved in the bar, the spiral arms and the ring.

Fig. 1. MIRI background-subtracted images of NGC 6552 in the F560W filter: the left panel shows the entire galaxy and the right panel a zoom on the central region observed with the MRS. The rectangles show an overlay of the four MRS channels (from the short to long wavelengths: CH1 in blue, CH2 in green, CH3 in red, and CH4 in black). Both images are shown on a log-scale, but with different stretches and contrasts to highlight the extended faint ring structure in the left panel, and the point-like central active nuclei in the right panel. The dynamical range in flux between the central pixels and the extended ring is about 20000, showing the exquisite imaging capabilities of the MIRI detectors.

1 the version of CRDS was 11.16.6, and CRDS context "jwst_0942.pmap"
The right panel shows the central nucleus with the footprints of the four MRS channels. The MRS footprints are not perfectly centered onto the nucleus because we did not use target acquisition, and because those observations were done before updating the flight distortion model to the observatory. The nucleus image exhibits the bright central cross-shaped PSF, characteristic of the cruciform pattern at this wavelength (Gáspár et al. 2021), which shows that the AGN is dominating the central point-like emission. This illustrates how both the dynamical range and the spatial resolution of the MIRI IFU can help separating the nuclear region from the circum-nuclear emission.

4. MIRI Spectroscopy

4.1. MRS Data Calibration

The MRS observations were processed with the JWST calibration pipeline (release 1.5.3). This release uses build 8.0.1 of the Data Management System (DMS) and context 0913 of the Calibration References Data System (CRDS). It compiles the best understanding of the MIRI in-flight performance, based on the MIRI ground test campaigns and the JWST commissioning (Rigby et al. 2022). The Cycle 1 calibration plan will keep reviewing and updating the CRDS files and the JWST calibration pipeline. The MRS pipeline is divided into three different processing stages (Labiano et al. 2016; Bushouse et al. 2022). The first stage performs the detector-level corrections, identification and correction of the cosmic ray (CR) impacts, and transforms the ramps into slope detector products (Morrison et al. in prep). The second stage assigns the coordinate system, performs the straylight, fringe flat, and photometric calibrations, to generate fully calibrated individual exposures. The third stage combines the different dithered exposures to create 3D spectral cubes (Law et al. in prep) and 1D extracted spectra, in the process it allows to perform an outlier rejection and a background matching. The background could be subtracted in stage 2 or 3 of the pipeline depending of the methodology selected by the user.  

Third stage was not used in this work as the MIRI data was not dithered, and the 1D spectral extraction, background subtraction, and residual fringe correction were performed outside of the JWST calibration pipeline.

We found that the standard pipeline identifies and corrects most of the CR events, but the so-called CR showers and/or high energetic CRs still leave some relevant residual effects. Also, the current in-flight darks and reset anomaly corrections are injecting a vertical stripping pattern in the slope detector data (see Footnote 2 and MIRI Feature and Caveats webpage for examples). Their strength depends on the length of the ramp, where long ramps (> 150-200 groups in FASTR1 readout mode, ~500s) minimize this effect. These effects, plus others like hot/bad detector pixels, are vastly reduced in 4-point dithered observations allowing to obtain the optimal MRS spatial and spectral resolution. The MRS observations of NGC 6552 were taken with no dithers, as the goal of this commissioning activity was not to obtain a final optimized cube. To minimize the sampling effect and reduce the number of empty spaxels in the 3D cubes, we have selected a cube spaxel size equal to the MRS slice width (Wells et al. 2015). We have generated twelve 3D cubes, one for each of the MRS sub-channels, with spatial and spectral sampling of 0.176" × 0.176" × 0.001 μm, 0.277" × 0.277" × 0.002 μm, 0.387" × 0.387" × 0.003 μm, and 0.645" × 0.645" × 0.006 μm for channels 1, 2, 3, and 4, respectively. However, the 3D cubes still have a small number of spaxels affected by the lack of data due to bad/hot pixels in the detector. These have been identified, masked and interpolated in the 1d extracted spectra presented in Sec. 4.2.

Background observations have a different setup than on-target observations for NGC 6552. The majority of the MRS background observations were carried out using short ramps (25 frames in FASTR1 read-out mode = 69.5s), except for the MRS SHORT band (visit 2, see Table 1). Short integrations are affected by the striping effect. The impact of this effect is different in each channel, as they present different background levels: the striping effect is large in channels 1 and 2 where the background is low, but it is highly minimized in channels 3 and 4 where the background is higher (see Footnote 2 and MIRI Feature and Caveats webpage for examples). We therefore used different strategies to subtract the background depending of the channel. For channels 1 and 2, which are dominated by the zodiacal light, we subtracted the background provided by the JWST background tool. We found that the background model is consistent with the channels 1 and 2 SHORT, which have ramp lengths similar to the on-target observations. For channels 3 and 4, which are dominated by the thermal self-emission, we used the background observations that were less affected by detector effects. We subtracted a background level calculated as the median value of all the spaxels in each slice of the background 3D cubes.

We extracted the 1D spectra using the background subtracted cubes and following the standard aperture or annulus photometry (Bradley et al. 2022). We generated three 1D spectra from: (i) a nuclear region, (ii) a circumnuclear region, and (iii) a larger aperture that include both the nuclear and circumnuclear regions (see Section 4.2 for details). All the 1D spectra were derived individually for each of the 12 MRS sub-bands. The extracted 1D spectra still contain fringes, periodic features coming from interference effects in the detector and filters (Argyriou et al. 2020, Mueller et al. in prep). The flat fringe correction of the JWST calibration pipeline produces residuals fringes in the MRS detector products. A residual fringe step, that performs an additional fringe correction is already implemented in the JWST calibration pipeline, but not running by default (Kavanagh et al. in prep., Gasman et al. in prep.). We ran the residual fringe correction in all the extracted 1D spectra of NGC 6552. The correction reduced the final fringe residuals to levels lower than 6%, and a median level of 2-4% (Rigby et al. 2022). To remove the (minor) flux discontinuities between channels, we stitched the 12 sub-channels together, using the 1SHORT band flux level as reference for the others. We found that the multiplicative stitching factors needed for each individual channel was lower than ±5% in all sub-channels.

4.2. Spectral Extraction

As we commented in Section 4.1, the calibrated 3D cubes of NGC6552 are non-optimal sampled, and could contain spaxels affected by detector features. The analysis of this paper has been focus in the characterization of different areas of the central region of NGC 6552, rather than a more complex 2D analysis as already performed in Pereira-Santaella et al. (2022) for NGC 7319 using an optimal MRS dataset. Even so, the MRS provides angular resolution to separate the nuclear and circumnuclear regions in NGC 6552. Assuming a $D_L = 120$Mpc, the MRS point spread function (PSF) full width at half maximum (FWHM) correspond...
to physical scales of 170 pc for channel 1 evolving up to maximums of 580 pc for channel 4LONG.

We have performed three different 1D spectral extraction of the central region of NGC6552. First, we extracted a spectrum of the nuclear region using a circular aperture of radius equal to $1.5 \times FWHM(\lambda)$, where $FWHM(\lambda) = 0.31 \times \lambda [\mu m]/8$ arcsec. The nuclear spectrum was corrected for aperture losses taking into account that the nuclear emission is a point-like source. We use the MRS PSF models from webbPSF (Perrin et al. 2014)\(^3\). The percentage of flux that losses out of the selected aperture is 30% for channel 1 and evolves up to 20% in channel 4. WebbPSF models were compared with bright point-like source observations during JWST commissioning, and we found that their curve of growth at radius equal to $1 \times FWHM(\lambda)$ differs by 6% in channel 1 and 2, by 4% in channel 3, and by 3% in channel 4 (Álvarez-Márquez et al. in prep). Second, we extracted a spec-

\(^3\)webbPSF does not currently support the MIRI MRS mode, but the feature is under development by the MIRI team.
Fig. 3. As Fig. 2, for MRS channels 3 and 4. The MRS channel 4 spectra is shown up to 27 µm due to uncertainties in the photometrical calibrations for λ > 27 µm. The comparison with the Spitzer IRS Long Low spectrum (red line, from Jarrett et al. 2011) shows excellent photometric agreement from 14.5 to 22 µm (see text for details) and illustrates how the gain in spectral resolution provided by the MRS helps to detect weak PAH features and weak lines (compared to the continuum), in particular the high-excitation [NeV] lines.

trum of the circumnuclear region in an annulus with an inner radius equal to 1 arcsec (∼0.55 kpc) and an outer radius of 1.6 arcsec (∼0.88 kpc). Based on the WebbPSF models and assuming the nucleus as a point-like source, the circumnuclear region is contaminated by a 2.5%, in channel 1, and up to 12.5%, in channel 4, of flux coming from the nucleus. We correct the circumnuclear spectrum from the nuclear contamination by subtracting the percentage of the nuclear emission enclosed in the selected annulus aperture using the nuclear spectrum. However, we found that the circumnuclear spectrum could still be affected by a residual nuclear emission in channels 3 and 4. This residual effect is less than 12% based on the relative nuclear to circumnuclear flux of the coronal emission lines associated with the AGN (see Table 2). Third, we extracted a spectrum, named central, in a circular aperture with a constant radius of 1.6 arcsec (∼0.88 kpc) for all MRS channels. Assuming a nuclear emission as a point-like source, a fraction of the nuclear emission will be extended outside of the selected aperture. The percentage of nuclear flux that is loss out of the selected aperture ranges from 6%, in channel 1, to 30%, in channel 4, using the PSF models from webbPSF.
We corrected the central spectrum by these flux percentages using the nuclear spectrum. Note that the central spectrum includes the emission of the nuclear and circumnuclear regions, but it is not the sum of both of them.²

Figures 2 and 3 show the nuclear, circumnuclear, and central MRS spectra of NGC 6552, and the identification of all emission lines and polycyclic aromatic hydrocarbon (PAH) features. The nuclear and central spectra are dominated by the central AGN emission, which is mainly composed by a steeply rising continuum due to warm dust emission and a large number of high-excitation and coronal emission lines. The spectra also show low-excitation emission lines, warm hydrogen molecular lines, and PAH features from the interplay between the star-formation and the AGN components of NGC 6552. The presence of PAHs indicate that the AGN radiation field has not depleted or destroyed them like seen in other high-luminosity Seyferts (e.g., Alonso-Herrero et al. 2020; García-Bernete et al. 2022). The spectra of the circumnuclear region is mainly dominated by the star-formation component of the galaxy showing low-excitation emission lines, hydrogen molecular lines, and PAH features. Channel 3 and 4 of the circumnuclear spectrum could be contaminated up to 12% by the AGN emission. Therefore, coronal emission lines and some contribution from the continuum are still present in these channels.

The MRS central spectrum and the Spitzer IRS-LL low resolution spectrum (Jarrett et al. 2011) of NGC 6552 agree within ~3% in channels 3 and 4SHORT (see Figure 3). Similar results are found in the MIRI commissioning observation of the planetary nebula SMP-LMC-058 for the full MRS wavelength coverage (Jones et al. in prep.). The central NGC 6552 spectrum shows mean deviations of ~10% and ~25% in channels 4 MEDIUM and LONG with respect to the Spitzer IRS-LL low resolution spectrum. These deviations could be associated with residuals due to the background subtraction, as the background observations were not setup for this propose in the program (see Sections 2 and 4.1 for details). The MIRI Imager F560W photometry, derived from the unsaturated part of the ramps, of the central region agree within 10% for the MIRI Imager F560W image and the MRS channel 1SHORT spectrum. As a summary, the MRS absolute flux uncertainty, based on commissioning data, is ≤10% (Rigby et al. 2022). The NGC 6552 calibrated data agree with this statement in channels 1SHORT to 4MEDIUM, but we suggest to use a ~25% in channel 4LONG for the special case of NGC 6552. We assume these absolute errors in deriving line ratios and analysis that follows.

5. Results and Discussion

5.1. Emission Lines Fluxes and Kinematics

The NGC 6552 shows a considerable number of emission lines with high signal-to-noise ratios (SNR) in the nuclear spectrum. We detect all Neon lines present in the mid-IR wavelength range, from [NII] to [NeVI], with SNRs between 18 to 75. The presence of coronal atomic lines is evident, going from the brightest ones with SNRs>50, [NeVI]7.65µm and [NeV]14.32µm, to shallower ones with SNRs between 20 to 50, i.e. [MgVII]5.50µm, [MgV]5.61µm, [FeVIII]5.45µm, or [FeVII]7.82-9.53µm.

The same happens with high-excitation atomic lines, i.e. [ArIII]8.99µm, [SIV]10.51µm, [OIV]25.89µm, and low-excitation atomic lines, i.e. [FeII]5.34µm, [ArII]6.99µm, [NeII]12.81µm, [NeIII]15.56µm and [SIII]18.71µm, all of them detected with SNRs between 30 to 100. The rotational molecular hydrogen lines from the H2(0-0)S(1) to H2(0-0)S(8) transitions are detected with SNR between 30 to 60, except for H2(0-0)S(7) line that is blended [MgVII]5.50µm and its SNR drops to 5. We also detect additional emission lines with lower SNRs, the most relevant one is Pfund-α with SNR≈10.

We identified and analyzed all detected emission lines with SNR higher than 3 in the NGC 6552 1D extracted spectra. Depending on the line profiles, we performed one-component and two-component Gaussian fit, plus a second order polynomial to fit the continuum and emission line (Markwardt 2009).³ The MRS resolving power ranges from 4000, in channel 1, to 1500, in channel 4, corresponding to line FWHM from 75km s⁻¹ to 200km s⁻¹ (Labiano et al. 2021). The instrumental line broadening was included in the line profile fitting algorithm. The uncertainties on the derived emission line parameters, like the line FWHM, flux, central wavelength, etc, were estimated using a Monte Carlo simulation. The noise of the spectrum was measured as the root mean square (rms) of the continuum surrounding the emission line. This noise was used to generate new spectra (n=500), where a random Gaussian noise with a sigma equal to the rms was added to the original spectrum before the lines were fitted again. The final uncertainty is the standard deviation of the n individual measurements. Table 2 presents the fluxes of all emission lines detected in the nuclear, circumnuclear, and central spectra of NGC 6552.

The central wavelengths of the systemic components of all emission lines detected in the nuclear spectra give a median redshift of 0.02652±0.00088, in agreement with previous estimates (Paturel et al. 2002). We found that the current MRS wavelength calibration is, in general, better than the FWHM of the MRS line spread function (LSF, Labiano et al. 2021). However, channel 2 presents offsets of up to 0.01µm. The [NeV]14.32µm emission line shows an offset of 0.04µm, and the emission lines in 3LONG are double peaks around 17.3µm due to offsets in the wavelength calibration across different slices. These are known issues, and do not effect the analysis presented in this paper.

All the emission lines in the NGC 6552 spectra are spectrally resolved. Molecular hydrogen lines present one-component Gaussian profiles, with intrinsic line FWHMs of 295±36km s⁻¹. In contrast, the high signal-to-noise (SNR) atomic forbidden lines (high- or low-excitation ones) have asymmetric profiles, with blue wings. Pfund-α, the only hydrogen atomic line detected in the NGC 6552 spectra, presents an intrinsic line FWHM of 415±41km s⁻¹, larger than the average widths of the atomic forbidden and molecular Hydrogen lines, and with no evidence of asymmetries.

The atomic lines show a combination of a systemic and a blue-shifted velocity components, and we have characterized them by a two-component Gaussian fit. Figure 4 illustrates the analyses of high-excitation and coronal atomic lines (Eα ≥ 30 eV). We found that the systemic and blue-shifted velocity components of these emission lines are consistent within the given error bars, independent of their ionization potentials or critical densities. The average systemic line FWHM, 280±50 km s⁻¹,

³ We used the MPFIT Python routine to perform the fits. The version used is available here: https://github.com/segasai/astrolibpy/tree/master/mpfit
Table 2. Fluxes of all detected emission lines in the nuclear, circumnuclear, and central spectra of NGC 6552.

| Line            | \( \lambda_{\text{lab}} \) [\( \mu \text{m} \)] | \( F_{\text{Nuclear}} \) \left[ 10^{-15} \text{ erg/s/cm}^2 \right] | \( F_{\text{Circum.}} \) \left[ 10^{-15} \text{ erg/s/cm}^2 \right] | \( F_{\text{Central}} \) \left[ 10^{-15} \text{ erg/s/cm}^2 \right] |
|-----------------|---------------------------------|-------------------------------------------------|-------------------------------------------------|
| H\(_z\) (1-1)S(9)\(f^1\) | 4.954                            | 0.17±0.03                                       | 0.9±0.2                                         |
| H\(_z\) (0-0)S(8)\(f^1\) | 5.053                            | 1.16±0.04                                       | 0.8±0.1                                         |
| [FeII]\(f^1\)       | 5.340                            | 6.0±0.2                                         | 2.7±0.2                                         |
| [FeVII]\(\alpha\) \(2\) | 5.447                            | 5.4±0.2                                         | 9.9±0.6                                         |
| [MgVII]\(f^2\)        | 5.503                            | 8.2±0.4                                         | 12±1                                            |
| H\(_z\) (0-0)S(7)\(f^1\) | 5.511                            | 4.3±0.8                                         | 1.74±0.09                                       |
| [MgV]\(f^2\)          | 5.610                            | 10.8±0.2                                        | 18.1±0.4                                        |
| [FeII]\(f^1\)         | 5.674                            | 0.5±0.1                                         | 0.50±0.04                                       |
| [KIV]\(f^1\)          | 5.982                            | 0.56±0.4                                        | 0.6±0.2                                         |
| H\(_z\) (0-0)S(6)\(f^1\) | 6.109                            | 2.50±0.8                                        | 0.7±0.1                                         |
| [SiVII]\(f^1\)        | 6.492                            | 0.68±0.09                                       | 0.8±0.2                                         |
| [NII]\(f^1\)          | 6.636                            | 0.9±0.3                                         | 1.5±0.5                                         |
| H\(_z\) (0-0)S(5)\(f^1\) | 6.910                            | 11.4±0.3                                        | 3.8±0.08                                        |
| [ArII]\(f^2\)        | 7.985                            | 30.4±0.8                                        | 2.98±0.08                                       |
| [NaIII]\(f^1\)        | 7.318                            | 2.4±0.2                                         | 3.6±0.3                                         |
| Pfund-\(\alpha\) \(2\) | 7.460                            | 1.9±0.2                                         | 0.3±0.08                                        |
| [NeVII]\(\alpha\) \(2\) | 7.652                            | 52.5±0.7                                        | 2.4±0.2                                         |
| [FeVII]\(\alpha\) \(2\) | 7.815                            | 3.3±0.2                                         | 5.1±0.4                                         |
| [ArV]\(f^2\)          | 7.902                            | 2.6±0.2                                         | 3.9±0.3                                         |
| H\(_z\) (0-0)S(4)\(f^1\) | 8.025                            | 6.8±0.2                                         | 2.39±0.06                                       |
| [ArII]\(\alpha\) \(2\) | 8.991                            | 17.8±0.3                                        | 2.2±0.2                                         |
| [FeVII]\(\alpha\) \(2\) | 9.527                            | 4.9±0.2                                         | 0.4±0.1                                         |
| H\(_z\) (0-0)S(3)\(f^1\) | 9.66                             | 12.2±0.2                                        | 7.8±0.2                                         |
| [SIV]\(\alpha\) \(2\) | 10.51                            | 40.3±0.4                                        | 9.1±0.2                                         |
| H\(_z\) (0-0)S(2)\(f^1\) | 12.28                            | 9.0±0.3                                         | 5.6±0.2                                         |
| [NeIII]\(\alpha\) \(2\) | 12.81                            | 12±3                                            | 20.1±0.4                                        |
| [NeV]\(\alpha\) \(2\)  | 14.32                            | 55±1                                            | 6.9±0.2                                         |
| [NeII]\(\alpha\) \(2\)  | 15.56                            | 14±2                                            | 20.3±0.2                                        |
| H\(_z\) (0-0)S(1)\(f^1\) | 17.03                            | 20.4±0.5                                        | 11.1±0.9                                        |
| [SiII]\(\alpha\) \(2\)  | 18.71                            | 64±2                                            | 7.2±0.2                                         |
| [NeV]\(\alpha\) \(2\)   | 24.32                            | 35±2                                            | 6.9±0.6                                         |
| [OIV]\(\alpha\) \(2\)   | 25.89                            | 167±6                                           | 14.8±0.5                                        |

(1) Line fit with one Gaussian component. (2) Line fit with two Gaussian components. Additional uncertainties in the absolute flux of 10% for channels 1SHORT to 4MEDIUM and 25% for 4LONG should be considered.

5.2. Highly Ionized Nuclear Outflow. Kinematics and Physical Properties.

The blue-shifted velocity components identified in all atomic emission lines are interpreted as being due to the presence of outflowing material close to the AGN. This is the first clear observational evidence for a nuclear outflow in NGC 6552. The outflow share the same kinematics and fraction of the total flux in all high-excitation and coronal emission. This clearly indicates that, independent of the ionization state (from about 28 to 187 eV, see Table 3) the lines are tracing the same regions of the nuclear outflow. This is fully ionized, with no evidence of any stratification in its ionization structure. Moreover, the outflowing gas is characterized by a blue-shifted velocity offset of -126±44 km s\(^{-1}\) on average, with outflow maximal velocities (V\(_{\text{peak}}\) + 2\(\sigma_{\text{blue}}\), where \(\sigma_{\text{blue}}\) is the sigma of the Gaussian component fit) of 689±37 km s\(^{-1}\) (see Table 3). This implies that, assuming a bi-conical structure centered on the AGN, we are predominantly seeing the outflowing gas coming towards us. The opacity of the interstellar medium in the mid-IR is significantly smaller (factors 30 to 100) than that in the optical. However for the large column densities measured towards the AGN in NGC6552, i.e. log(N\(_\text{H}\)) = 24.05 cm\(^{-2}\) (Ricci et al. 2015), a large optical depth between 3.3 and 10 is expected in the 5 to 25 \(\mu\text{m}\) MRS spectral range (e.g. Corrales et al. 2016b). Therefore the lack of a red velocity component in the emission line profile is interpreted as emitting outflowing gas moving away from us (i.e. receding direction) but obscured from our line of sight, even at these wavelengths, by the torus around the AGN, and/or the dense medium in its vicinity.

The ratio of the [NeV]14.32\(\mu\text{m}\) to [NeV]24.32\(\mu\text{m}\) emission lines gives an estimation of the electron density in the highly ionized coronal emission gas. Independent of the unknown electron temperature, the low ratio measured in NGC 6552 (1.6±0.8, using absolute flux errors), indicates that the coronal gas is in the low density regime, i.e. less than 10\(^{5.5}\) cm\(^{-3}\) for temperatures less than 10\(^{4}\) K (Dudik et al. 2007). However, the kinematics of the high-excitation and coronal gas (27.6 < E\(_{\text{ion}}\)[eV] < 186.5) are very similar, while the critical electron densities cover a wide range from log(n\(_{\text{crit}}\)[cm\(^{-3}\)]) equal to 4 to 6.6 (see Figure 4 and Table 3). This indicates that the physical conditions of the ionized gas in the outflow must be closer to the lower densities (i.e. less than a few 10\(^{3}\) cm\(^{-3}\)) and temperatures (i.e. less than few 10\(^{4}\) K). Otherwise, lines such as [NeV]14.3\(\mu\text{m}\) and [OIV]25.9\(\mu\text{m}\) would not be detected as strong as presented in the NGC 6552 nuclear spectrum (Pereira-Santaela et al. 2010). The lack of [FeII]4.89\(\mu\text{m}\) emission is also consistent with low densities (< 10\(^{3}\) cm\(^{-3}\)) Pereira-Santaela et al. 2022).

The outflowing material appears only in the ionized gas, with no evidence of the outflow in any of the molecular rotational lines present in the nuclear spectrum. In fact, the average line FWHMs (295±36 km s\(^{-1}\)) of the molecular lines agrees with the systemic velocity component of the ionized gas (280 ± 50 km s\(^{-1}\)). This could indicate that: (i) the molecular gas in the nuclear region is not directly facing the radiation coming out of the AGN and its velocity field is determined by the dynamical mass in the nuclear region, or (ii) when the molecular hydrogen becomes part of the outflow gets quickly dissociated contributing to widen the Pfund-\(\alpha\) hydrogen line.
5.3. Warm Molecular Hydrogen

The JWST, and in particular the MRS, will revolutionize our ability to observe the infrared lines of molecular hydrogen (Guillard et al. 2015). In NGC 6552 we have detected a suite of pure rotational lines, from the brightest 0–0 S(1) 17 μm transition up to the 1–1 S(9) 4.9 μm line, at remarkable high signal-to-noise for each of the three spectral extractions (central, nuclear and circumnuclear). Those lines arise from warm (≈ 100 – 20000 K) molecular gas (Habart et al. 2005). We have used these observed line fluxes (Table 2) to derive the column densities and masses of warm H₂ for each of the three regions, assuming a 10% absolute flux uncertainty, by fitting the H₂ excitation diagrams (see Wakelam et al. 2017, for a review).

We emphasize that the warm (≈ 100 K) gas is only a fraction of the total molecular mass. Most of the cold molecular gas cannot be traced by the mid-infrared H₂ lines. If the 0–0 S(0) line at λ = 28.2 μm, which is located at the far end of the MRS-covered wavelength range and currently not properly calibrated, were available, it would provide access to the lower temperature gas and a better constraint on the total warm H₂ mass. Hence, the numbers derived here can be viewed as lower limits (see Guillard et al. 2012, for a discussion). The highly excited 1–1 S(9) line has not been included in the fits as it is only detected in the nuclear extraction and (tracing only a tiny fraction of the H₂ mass) it does not affect our derived column densities and mass estimates.

Figure 5 shows the excitation diagrams for the three spectral extractions, where the logarithm of the column densities of the upper H₂ levels divided by their statistical weights, ln(N_u/g_u), are plotted against their excitation energies, E_u/k_B, expressed in K. For a single uniform temperature ln(N_u/g_u) ∝ T_{exc}, where T_{exc} is the excitation temperature. The plotted values of ln(N_u/g_u) have been constructed in two ways: first, in a situation of local thermal equilibrium (LTE), where the excitation temperature equals that of the gas, and where the ortho-to-para ratio (OPR) is assumed to be OPR = 3. Those values, shown as the blue circles on Figure 5, exhibit a classical curvature, which indicates that multiple temperatures are present, and we get good agreement with a two-temperature fit that invokes a warm component (typically ≈ 300 K here) and a hot component (≈ 1200 K). We note that the spectral extraction in the nucleus shows the highest excitation. It is expected because of the stronger radiation field, and possibly stronger cosmic ray ionization rate, or enhanced dissipation of turbulent energy close to the central nuclei (Ogle et al. 2010). The distribution of the ln(N_u/g_u) values also exhibits a “zigzag” pattern which shows that the ortho-to-para ratio is smaller than 3 for all the regions. This indicates that the H₂ gas is thermalized to lower temperatures (Flagey et al. 2013), or that its chemistry is out of equilibrium, because the time spent hot for the gas is shorter than the ortho-to-para conversion time, as it is the case in molecular shocks for instance (e.g. Neufeld et al. 1998; Wilgenbus et al. 2000). We therefore constructed the excitation diagram in a second way, by fitting the OPR in addition to the two temperatures. Those column densities are displayed as the black triangles, and shows a smoother fit to the data. We used those fits to estimate the physical parameters of the warm H₂ gas.

The legends of each panel of Figure 5 shows the results of the temperature and OPR fits, as well as the total column densities. Additionally, all the physical parameters derived from the fits of the excitation diagrams are gathered in Table 4. The warm H₂ masses are derived assuming an angular distance of 120 Mpc and solid angles corresponding to the extracted regions as stated in Sect. 4.2. A mass of warm H₂ of at least 1.7 ± 1.1 × 10^7 M_☉ is present in the central region (1.8 kpc in diameter), with almost 20% of that mass in the circum-nuclear region. The masses quoted in Table 4 are typical of what is detected at these temperatures in nearby radio galaxies or infrared galaxies (e.g. Guillard et al. 2012; Pétrit et al. 2018). Again, if we had access to the 0–0 S(0) line, which is sensitive to cooler gas, or if we had performed a more sophisticated modelling taking into account a distribution of temperatures, as in Togi & Smith (2016) for instance, our derived H₂ masses would be a factor 2-10 larger. We defer to a future paper the line maps fitting with detailed physical models.

5.4. Seyfert Nature of the AGN and Black Hole Mass

The mid-IR emission lines of ionised gas have been used to disentangle the AGN and stellar emission in nearby galaxies, in particular, the sequence of different ionization levels of neon ([NeII]12.82μm, [NeIII]15.56μm to [NeV]14.32,24.32μm) and the [OIV]25.89μm line (Pereira-Santaella et al. 2010). Table 5 shows the Neon and Oxygen line ratios for NGC 6552. They
confirm that the nuclear, circumnuclear and central spectra of NGC 6552 are close to the median values of Seyfert 1 and 2, indicating that the ionization of the interstellar medium in NGC 6552 at distances up to a radius of 0.88kpc from the nucleus is dominated by the AGN radiation field. However, in Section 4.2, we have concluded that the channels 3 and 4 spectra of the circumnuclear region could contain up to 12% of the nuclear AGN emission which make it difficult to disentangle if the circumnuclear region is dominated by the radiation field of the AGN or the star-formation.

Black hole (BH) mass based on the line FWHM of the high-excitation emission line has been obtained using Spitzer high resolution spectroscopy in nearby galaxies (e.g. Dasyra et al. 2008). Taking the line FWHM of the systemic component in the nuclear spectrum of [NeV]14.3 µm (215±15 km s⁻¹), we derive a NGC 6552 BH mass, log(MBH[M☉]), of 6.4±0.5. This gives a
mass range of 0.8 to 8 million solar masses, which is in average the mass of the Milky Way BH (4.1×10⁶M☉, Ghez et al. 2008; Event Horizon Telescope Collaboration et al. 2022). As the MRS has a spectral resolution 5 times higher than the Spitzer high resolution mode, and a sub-arcsec angular resolution at all wavelengths, the line profiles of the high-excitation and coronal lines with MIRI will provide far better and more accurate measurements of the BH mass than the initial estimates based on previous mid-IR spectroscopy.

The only Hydrogen recombination line detected in the mid-IR spectral range of NGC 6552 is Pfund-α with a line FWHM of 415 ± 39 km s⁻¹, a factor 1.4-1.9 larger than the ionized and molecular lines, and shows no evidence of outflowing gas. This result can be interpreted in two different ways. On the one hand, the broader Pfund-α line could be tracing the inner broad line region (BLR) in this galaxy. There is already some evidence of a hidden BLR based on polarized light measurement (Tran 2001). However, the SNR of Pfund-α is not good enough to trace a very broad weak line as expected if the BLR is mostly obscured in this CT-AGN. On the other hand, the line FWHM could represent the dynamical mass of the host galaxy contained within the aperture while the width of the molecular and ionized gas would be tracing the dynamical mass in smaller regions, closer to the AGN.

Table 4. Physical parameters derived from the two-temperatures fitting of the H₂ excitation diagrams for the three spectral extractions.

| Parameter        | Nuclear | Circum. | Central |
|------------------|---------|---------|---------|
| T(cold) [K]      | 326 ± 66 | 382 ± 51 | 322 ± 52 |
| T(hot) [K]      | 1238 ± 97 | 1488 ± 397 | 1120 ± 108 |
| N(cold) [10²⁰ cm⁻²] | 7.2 ± 5.9 | 1.31 ± 0.99 | 3.9 ± 2.9 |
| N(hot) [10²⁰ cm⁻²] | 2.6 ± 1.1 | 0.03 ± 0.02 | 0.5 ± 0.3 |
| N(total) [10²⁰ cm⁻²] | 7.5 ± 6.0 | 1.31 ± 0.99 | 3.9 ± 3.0 |
| Ortho-to-para ratio | 2.1 ± 0.4 | 2.5 ± 0.8 | 2.2 ± 0.5 |
| M(H₂) [10⁷ M☉] | 1.25 ± 0.78 | 0.35 ± 0.21 | 1.7 ± 1.1 |

Table 5. Observed line ratios for NGC 6552 regions

| Line ratio | Nuclear | Circum. | Central |
|------------|---------|---------|---------|
| [OIV]25.89 /[NeV]24.32 | 4.8±2.4 | 2.1±1.1 | 4.7±2.4 |
| [OIV]25.89 /[NeV]14.32 | 3.0±1.1 | 2.1±1.1 | 2.6±0.9 |
| [NeV]24.32 /[NeV]14.32 | 0.6±0.3 | 1.0±0.4 | 0.6±0.2 |
| [NeIII]15.56 /[NeV]14.32 | 2.6±0.6 | 2.9±0.6 | 2.6±0.5 |
| [NeII]12.81 /[NeV]14.32 | 2.2±0.5 | 2.9±0.6 | 2.5±0.5 |
| [NeIII]15.56 /[OIV]25.89 | 0.8±0.3 | 1.4±0.5 | 1.0±0.4 |
| [NeII]12.81 /[OIV]25.89 | 0.7±0.3 | 1.4±0.5 | 0.9±0.4 |
| [NeIII]15.56 /[NeII]12.81 | 1.4±0.3 | 1.0±0.2 | 1.0±0.4 |

6. Summary and Conclusions

The galaxy NGC 6552 with an already identified Compton-thick AGN in its center, was observed with the MIRI Imager and Medium Resolution Spectrometer during the JWST commissioning to characterize the persistence of the MIRI detectors. We present the calibrated NGC 6552 MIRI image and MRS spectra, including an extensive and detailed explanation of the MIRI data and calibration process.

We obtain the nuclear, circumnuclear, and central mid-IR spectra of NGC 6552. The nuclear and central spectra are dominated by the AGN emission, with steeply rising continuum and a large number of high- and low-excitation emission lines, warm molecular Hydrogen lines, and PAH features from the interplay between the star-formation and AGN components. The spectra
of the circumnuclear region is mainly dominated by the star-formation, with low excitation lines, molecular hydrogen lines, and PAH features, but it is contaminated by ≤ 12% of the nuclear AGN emission. The central MRS spectra of NGC 6552 is consistent with previous Spitzer low-resolution observations, and with the MIRI F560W Imager photometry.

The MIRI IFS provides the first clear observational evidence for a nuclear outflow in NGC 6552. The nuclear AGN is ionizing the surrounding regions, and producing a blueshifted, high-speed outflow with offset velocities of -126±44 km s⁻¹ and maximum velocities of 689±37 km s⁻¹. The outflow is not spatially resolved, and represents the 68±6% of the total emission of high-excitation and coronal emission lines. The analysis suggests a scenario where the outflow is fully ionized, with no evidence of stratification in its ionized structure, and produced in a low density (<10³ cm⁻³) environment. The lack of the red component in the spectra suggests that the receding side of the outflow is obscured by material around the nucleus of the galaxy. Additionally, we confirm that NGC 6552 is a Seyfert galaxy and contains an active black hole with a low-intermediate mass ranging from 0.8 to 8 million M☉.

From two-temperature fits of the H₂ excitation diagrams constructed for the three regions, we derived a warm H₂ mass of at least 1.7 ± 1.1 x 10⁷ M☉ in the central region (1.8 kpc in diameter) of the galaxy, with 20% of that mass in the circun-nuclear region (in an annulus between 0.55 and 0.88 kpc in radius). The H₂ excitation is significantly stronger in the nuclear region. The warm H₂ lines are spectrally resolved, exhibit Gaussian profiles and show no evidence of outflowing gas. The FWHM of the lines is consistent with the systemic component in the high excitation lines, suggesting that the warm molecular gas is somehow shielded from (or not aligned with) the AGN radiation, and its kinematics are determined by the BH and stellar dynamical mass.

This early commissioning paper already demonstrates the huge gain in the scientific performance that JWST/MIRI provides over previous ground- and space-based infrared observatories. With respect to the study of AGNs, the high angular resolution of the MIRI IFS allows one to spatially separate the central regions of active galaxies; the high spectral resolution of MIRI enables kinematic studies, almost unaffected by dust extinction. Most importantly, the high sensitivity provided by the 6.5 m aperture of the JWST, offers for the first time full access to the zoo of important diagnostic lines, covering a wide range in ionization states, and offering redundant spectral information for cross-checks. Although the data for NGC6552 are non-optimally sampled these advantages are realised and used to provide new constraints on the nature of the nucleus and circumnuclear regions. Altogether, we expect that JWST-MIRI will revolutionize the field of AGN research over the coming years.

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References

Alonso-Herrero, A., Pereira-Santaella, M., Rigopoulou, D., et al. 2020, A&A, 639, A43
Álvarez-Márquez, J., Marques-Chaves, R., Colina, L., & Pérez-Fournon, I. 2021, A&A, 647, A133
Argyrou, I., Wells, M., Glasse, A., et al. 2020, arXiv e-prints, arXiv:2007.16143
Arribas, S., Colina, L., Bellocli, E., Maíz-Apellániz, R., & Villar-Márquez, M. 2014, A&A, 568, A14
Bouchet, P., García-Marin, M., Lagage, P.-O., et al. 2015, PASP, 127, 612
Bower, R. G., Hasinger, G., Castander, F. J., et al. 1996, MNRAS, 281, 59
Bradley, L., Sipocz, B., Robitaille, T., et al. 2022, arXiv e-prints, arXiv:2007.16143
Brown, H., Eisenhamer, J., Doncheva, N., et al., 2022, spacetelecom/jwst: JWST 1.6.2
Corrales, L. R., García, J., Wilms, J., & Baganoff, F. 2016a, MNRAS, 458, 1345
Corrales, L. R., García, J., Wilms, J., & Baganoff, F. 2016b, MNRAS, 458, 1345
Dasyra, K. M., Ho, L. C., Apponi, A., et al. 2008, ApJ, 674, 104
Davies, R. L., Förster Schreiber, N. M., Lutz, D., et al., 2020, ApJ, 894, 28
Dudik, R. P., Weingartner, J. C., Satyapal, S., et al. 2007, ApJ, 664, 71
Ennotts, B. H. C., Colina, L., Piqueras-López, J., et al. 2017, A&A, 607, A116
Event Horizon Telescope Collaboration, Akiyama, K., Alberdi, A., et al., 2022,
A&A, 650, L12
Fabian, A. C., 2012, ARA&A, 50, 455
Falco, E. E., Kurtz, M. J., Geller, M. J., et al. 1999, PASP, 111, 438
Fischer, T. C., Crenshaw, D. M., Kraemer, S. B., et al. 2011, ApJ, 727, 71
Flagay, N., Goldsmith, P. F., Liu, D. C., et al., 2013, ApJ, 762, 11
García-Bernete, I., Rigopoulou, D., Alonso-Herrero, A., et al. 2022, MNRAS, 509, 4526
Gáspár, A., Rieke, G. H., Guillard, P., et al. 2021, PASP, 133, 04504
Ghez, A. M., Salim, S., Weinberg, N. N., et al. 2008, ApJ, 689, 1044
Gioia, I. M., Henry, J. P., Mullis, C. R., et al. 2003, ApJS, 149, 29
Glasse, A., Rieke, G. H., Bauwens, E., et al. 2015, PASP, 127, 686
Guillard, P., Boulanger, F., Lehmann, M. D., Appleton, P. N., & Pineau des Forêts, G. 2015, in SF2A-2015: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics, 81–85
Guillard, P., Ogée, P. M., Ennotts, B. H. C., et al. 2012, ApJ, 747, 95
Habart, E., Walmsley, M., Verstraete, L., et al. 2005, Space Sci. Rev., 119, 71
Harrison, C. M., Alexander, D. M., Mullaney, J. R., et al. 2016, MNRAS, 456, 1195
Harries, T. J., Craig, W. W., Christensen, F. E., et al. 2013, ApJ, 770, 103
Jansen, F., Lumb, D., Altieri, B., et al. 2001, A&A, 365, L1
Jarrett, T. H., Cohen, M., Masri, F., et al. 2011, ApJ, 735, 112

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King, A. & Pounds, K. 2015, ARA&A, 53, 115
Labiano, A., Argyriou, I., Álvarez-Márquez, J., et al. 2021, A&A, 656, A57
Labiano, A., Azzollini, R., Bailey, J., et al. 2016, in SPIE Conf. Series, Vol. 9940, Markwardt, C. B. 2009, in Astronomical Society of the Pacific Conference Series, Vol. 411, Astronomical Data Analysis Software and Systems XVIII, ed. D. A. Bohlender, D. Durand, & P. Dowler, 251
Moran, E. C., Halpern, J. P., & Helfand, D. J. 1996, ApJS, 106, 341
Neufeld, D. A., Melnick, G. J., & Harwit, M. 1998, ApJ, 506, L75
Ogle, P., Boulanger, F., Guillard, P., et al. 2010, ApJ, 724, 1193
Patat, G., Dubois, P., Petit, C., & Woelfel, F. 2002, LEDA, 0
Pereira-Santaella, M., Álvarez-Márquez, J., García-Bernete, I., et al. 2022, arXiv e-prints, arXiv:2208.04835
Pereira-Santaella, M., Colina, L., García-Burillo, S., et al. 2018, A&A, 616, A171
Pereira-Santaella, M., Diamond-Stanic, A. M., Alonso-Herrero, A., & Rieke, G. H. 2010, ApJ, 725, 2270
Perrin, M. D., Sivaramakrishnan, A., Lajoie, C.-P., et al. 2014, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 9143, Space Telescopes and Instrumentation 2014: Optical, Infrared, and Millimeter Wave, ed. J. Oschmann, Jacobus M., M. Clampin, G. G. Fazio, & H. A. MacEwen, 91433X
Petric, A. O., Armus, L., Flagay, N., et al. 2018, AJ, 156, 295
Planck Collaboration, Ade, P. A. R., Aghanim, N., et al. 2016, A&A, 594, A13
Ressler, M. E., Sukhatme, K. G., Franklin, B. R., et al. 2015, PASP, 127, 675
Ricci, C., Ueda, Y., Koss, M. J., et al. 2015, ApJ, 815, L13
Rieke, G. H., Ressler, M. E., Morrison, J. E., et al. 2015a, PASP, 127, 665
Rieke, G. H., Wright, G. S., Böker, T., et al. 2015b, PASP, 127, 584
Rigby, J., Perrin, M., McElwain, M., et al. 2022, arXiv e-prints, arXiv:2207.05632
Rodríguez-Ardila, A., Prieto, M. A., Viegas, S., & Gruenwald, R. 2006, ApJ, 653, 1098
Shu, X. W., Wang, J. X., Jiang, P., Fan, L. L., & Wang, T. G. 2007, ApJ, 657, 167
Spilker, J. S., Aravena, M., Phadke, K. A., et al. 2020, ApJ, 905, 86
Togi, A. & Smith, J. D. T. 2016, ApJ, 830, 18
Torres-Albà, N., Marchesi, S., Zhao, X., et al. 2021, ApJ, 922, 252
Tran, H. D. 2001, ApJ, 554, L19
Veilleux, S., Cecil, G., & Bland-Hawthorn, J. 2005, ARA&A, 43, 769
Veilleux, S., Maolino, R., Bolatto, A. D., & Aalto, S. 2020, A&A Rev., 28, 2
Veilleux, S., Meléndez, M., Sturm, E., et al. 2013, ApJ, 776, 27
Wakelam, V., Bron, E., Cazaux, S., et al. 2017, Molecular Astrophysics, 9, 1
Wells, M., Pei, J.-W., Glass, A., et al. 2015, PASP, 127, 646–664
Wilgenbus, D., Cabrit, S., Pineau des Forêts, G., & Flower, D. R. 2000, A&A, 356, 1010
Wright, G. S., Wright, D., Goodson, G. B., et al. 2015, PASP, 127, 595