Resolving the Rise and Fall of Star Formation in Galaxies
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The curious case of NGC 5068 and its neutral hydrogen fingers

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Abstract. How galaxies replenish their gas supply in order to sustain star formation, is a research topic of many of the new and upcoming neutral atomic hydrogen (H I) surveys on the SKA precursor instruments. This replenishment, or accretion, of gas in the form of H I is likely to occur at column densities one or two orders of magnitude below previous observational limits and it has, so far, not been unambiguously detected. We present recent deep H I observations of NGC 5068, an isolated nearby star-forming galaxy observed by MeerKAT as part of the MHONGOOSE survey. This survey is the deepest H I survey of nearby galaxies until the advent of the SKA and is reaching column densities of $N_{\rm H\,I} \sim 2 \times 10^{18}\,{\rm cm}^{-2}$ at $30''$ resolution. The combination of the resolution and sensitivity of the MeerKAT HI data have revealed “fingers” of low column density gas extending out from the main H I disk of the galaxy. While the origin of these fingers remains a mystery for now, the dynamics of the main galaxy disk and the outer disk in which the fingers are located, as well as the morphology of the fingers, does not seem to suggest a previous merger event.

Keywords. ISM, galaxies, NGC 5068

1. Introduction

Studies of the gas and star formation in galaxies have shown that the observed amount of neutral gas, in particular the neutral atomic hydrogen (H I), is insufficient to sustain the observed star formation (Larson 1972; Sancisi et al. 2008). One of the goals of the MeerKAT HI Observations of Nearby Galactic Objects - Observing Southern Emitters (MHONGOOSE; de Blok et al. 2016, 2020), a large survey project using the MeerKAT Radio Telescope (Jonas & MeerKAT Team 2016), is to observe the low column density H I gas in 30 nearby galaxies to uncover how galaxies sustain their ongoing star formation. In this work, we present deep and detailed new high sensitivity H I observations of one of the MHONGOOSE galaxies, NGC 5068. This galaxy is a nearby ($d = 5.2 \pm 0.22$ Mpc, Anand et al. 2021), face-on spiral galaxy of moderate mass and star formation ($M_\star = 2.57 \times 10^9\,M_\odot$ and SFR $= 0.288\,M_\odot\,{\rm yr}^{-1}$, Leroy et al. 2019, 2021).

2. What the H I reveals about NGC 5068

The deep, high resolution H I data observed by MeerKAT reveals a complex picture of the H I reservoir of NGC 5068. Fig. 1 shows NGC 5068 in gray scale as observed

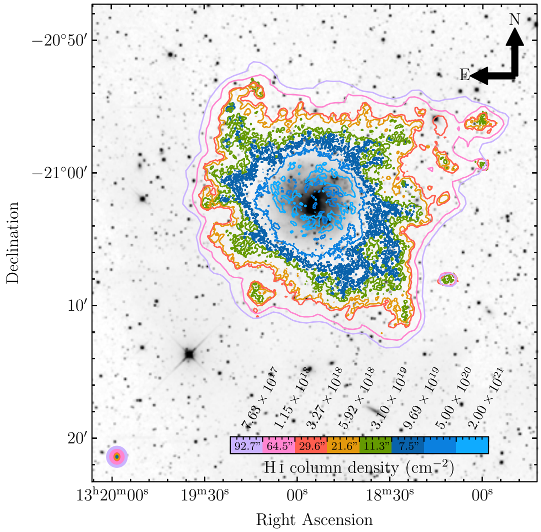

Figure 1. Optical MeerLICHT q-band image of NGC 5068 with 3σ H I column density contours from the different resolutions overlaid.

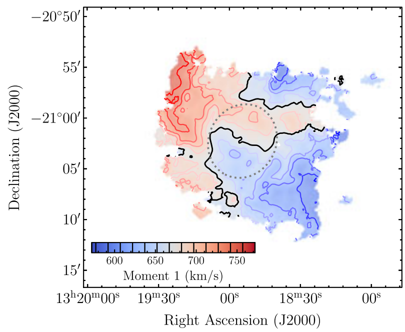

Figure 2. Velocity field (moment 1) for NGC 5068. Contours are spaced at $15\,\mathrm{km\,s^{-1}}$, with the black contour representing the systemic velocity of the galaxy.

by MeerLICHT† in the optical q-band with the overlaid contours indicating the 3σ H I column density ($N_{\mathrm{H\,I}}$) of at the six different resolutions ($N_{\mathrm{H\,I},3\sigma} = 7.76 \times 10^{17}\,\mathrm{cm^{-2}}$ at $90''$ to $N_{\mathrm{H\,I},3\sigma} = 9.6 \times 10^{19}\,\mathrm{cm^{-2}}$ at $7.5''$) of the MeerKAT data. On the edge of the star forming (SF) disk, Fig. 1 shows clumpy "fingers" of low-column density gas extending outwards, as well as low column density clumps to the north west of the galaxy.

The velocity field (Fig. 2) reveals a regular rotating inner disk coincident with the SF disk (indicated by the dotted grey ellipse), suggesting that the inner disk is largely unaffected by whatever is driving complex motion of the outer disk. The velocity dispersion map (Fig. 3) also shows a region of high dispersion gas encircling the SF disk, further suggestion activity affecting gas is in the outskirts. It is clear from the position velocity slice, shown in Fig. 4, extracted from the high dispersion regions (indicated by the black line in Fig. 3) that the high velocity dispersion is in fact driven the presence of clumpy low column density gas.

† MeerLICHT (`http://www.meerlicht.uct.ac.za`) is the 0.6 m optical telescope located in South Africa that is tied to MeerKAT and has the same field of view.

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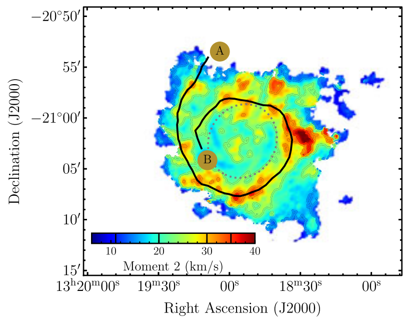

Figure 3. Moment 2 map for NGC 5068. The black line indicates the path over which the position-velocity (PV) slice shown in Fig. 4 is extracted. The "A" and "B" markers correspond to the same markers in the PV diagram.

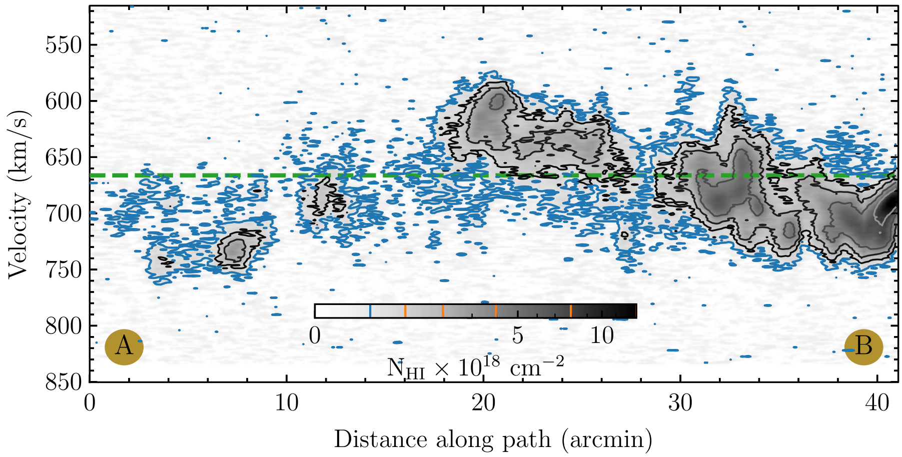

Figure 4. Position velocity slice extracted along the path indicated in Fig. 3. "A" and "B" match the corresponding markers in the moment 2 map indicating the start and end of the PV slice.

3. Conclusions

There are a number of possible origins of the "fingers" and clumpy gas on the north western side of the galaxy. Below, we discuss three possible scenarios:

Previous interaction with a neighbour: despite NGC 5068 being a member of a loose group of galaxies (Pisano et al. 2011; Kourkchi & Tully 2017), a recent ($t < 1$ Gyr) interaction is unlikely as the closest neighbouring galaxy has a projected separation of > 400 kpc. For an imprint of such an interaction to remain in the H I of NGC 5068, the neighbour would need to moving at $v \gtrsim 390\,\mathrm{km\,s^{-1}}$.

Outer gas from a minor merger: this is unlikely as we find low column density gas throughout the H I disk.

Accretion of cold gas: this is a likely scenario as the gas in the outskirts of the H I disk is very clumpy (see the clouds particularly in the north west region of the galaxy in Fig. 1). More evidence to support this scenario is that the high velocity dispersion gas (Fig. 3) is driven by low column density component outside of the SF region. The clumps of gas to the north west of the galaxy are also not rotating with the general rotation of the outer disk or the main SF disk.

Despite the last scenario being the most likely, it is not possible given the currently available data to completely rule out the first two scenarios. Moreover, accretion of gas

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can also come in two forms: re-accretion of previously expelled gas or accretion of fresh gas from the cosmic web. Disentangling these two requires further modelling and will be an interesting challenge.

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