Nature of the unusual transient AT 2018cow from HI observations of its host galaxy

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On the nature of the unusual transient AT 2018cow from H I observations of its host galaxy


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ABSTRACT

Context. Unusual stellar explosions represent an opportunity to learn about both stellar and galaxy evolution. Mapping the atomic gas in host galaxies of such transients can lead to an understanding of the conditions triggering them.

Aims. We provide resolved atomic gas observations of the host galaxy, CGCG137-068, of the unusual, poorly-understood transient AT 2018cow searching for clues to understand its nature. We test whether it is consistent with a recent inflow of atomic gas from the intergalactic medium, as suggested for host galaxies of gamma-ray bursts (GRBs) and some supernovae (SNe).

Methods. We observed the H I hyperfine structure line of the AT 2018cow host with the Giant Metrewave Radio Telescope.

Results. There is no unusual atomic gas concentration near the position of AT 2018cow. The gas distribution is much more regular than those of GRB/SN hosts. The AT 2018cow host has an atomic gas mass lower by 0.24 dex than predicted from its star formation rate (SFR) and is at the lower edge of the galaxy main sequence. In the continuum we detected the emission of AT 2018cow and of a star-forming region in the north-eastern part of the bar (away from AT 2018cow). This region hosts a third of the galaxy’s SFR.

Conclusions. The absence of atomic gas concentration close to AT 2018cow, along with a normal SFR and regular H I velocity field, sets CGCG137-068 apart from GRB/SN hosts studied in H I. The environment of AT 2018cow therefore suggests that its progenitor may not have been a massive star. Our findings are consistent with an origin of the transient that does not require a connection between its progenitor and gas concentration or inflow: an exploding low-mass star, a tidal disruption event, a merger of white dwarfs, or a merger between a neutron star and a giant star. We interpret the recently reported atomic gas ring in CGCG 137-068 as a result of internal processes connected with gravitational resonances caused by the bar.

Key words. dust, extinction – galaxies: individual: CGCG 137-068 – galaxies: ISM – galaxies: star formation – supernovae: individual: AT 2018cow – radio lines: galaxies

1 Introduction

Unusual, luminous, and rare stellar explosions provide an opportunity to learn about stellar evolution and also about galaxy evolution in a broader context. An example of the latter approach is the possibility to select galaxies that experience a recent inflow of gas from the intergalactic medium (IGM) using host galaxies of long gamma-ray bursts (GRBs) and some types of supernovae (SN). Atomic gas concentrations away from the galaxy centres towards GRB/SN positions suggest an external origin of the gas (Michałowski et al. 2013, 2016, 2018a), and a potential deficiency in molecular gas (Hatsukade et al. 2013; Stanway et al. 2013; Michałowski et al. 2016, 2018b). Studying gas inflows in such a direct way is important because they are required to fuel star formation in all galaxies, as implied from observations (Sancisi et al. 2008; Sánchez Almeida et al. 2014; Spring & Michałowski 2017; Elmegreen et al. 2018; Combes 2018) and simulations (Schaye et al. 2010; van de Voort et al. 2012; Narayanan et al. 2015). Recently Thöne et al. (2019) also suggested that in GRB hosts gas outflows are very common.

Observations of atomic gas in host galaxies of unusual and/or unclassified transients can therefore bring us closer to understanding the nature of these events. Similar atomic gas properties around the position of a transient to those of GRBs would suggest that the explosion mechanism is similar, i.e., an explosion of a massive star.

With this in mind, we report an analysis of gas properties in the host galaxy of the unusual and poorly-understood transient AT 2018cow1. The transient was discovered on 16 June 2018 by the Asteroid Terrestrial-impact Last Alert System (ATLAS; Tonry et al. 2018) surveying the entire visible sky every two nights (Smartt et al. 2018; Prentice et al. 2018). It was classified as a broad-lined type Ic (Izzo et al. 2018; Xu et al. 2018), type Ib (Benetti et al. 2018), or interacting type Ibn (Fox & Smith 2019) supernova and given the designation SN 2018cow. However, it is unclear whether this really was a supernova (see below). It has been detected at (sub)millimetre (de Ugarte Postigo et al. 2018; Smith et al. 2018; Ho et al. 2019) and radio (Dobie et al. 2018; Bright et al. 2018).

1 It was initially designated ATLAS18qqn by the ATLAS discovery team.
Navana & Chandra 2018 wave-lengths, including very long-baseline interferometry (VLBI) from which the most precise position has been derived: RA (J2000) = 16:16:00.2243, Dec. (J2000) = +22:16:04.893 with a \( \sim 1 \) mas uncertainty (An 2018 Bietenholz et al. 2018 Horesh et al. 2018). AT 2018cow had several unusual characteristics: high peak luminosity, blue colour/high temperature even a month after the explosion, very fast initial flux rise (Prentice et al.2018 Perley et al. 2019), high decline rate, no spectral features up to four days after the explosion, very broad short-lived absorption and emission spectral features (Perley et al. 2019), variability of the X-ray light curve (Rivera Sandooval et al. 2018), a month-long plateau at millimetre wavelengths (see Michalowski et al. 2018c for another example), as well as high radio flux (Ho et al. 2019).

It has been shown that it could not have been powered by radioactive decay (Prentice et al. 2018 Margutti et al. 2019). Several models have been proposed to explain the observed properties: a stellar collapse leading to the formation of a magnetar (Prentice et al. 2018 Margutti et al. 2019), a luminous blue variable exploding in a non-uniform circum-stellar medium (Rivera Sandooval et al. 2018), a SN from a low-mass hydrogen-rich star, a failed SN from a blue supergiant (Margutti et al. 2019), a tidal disruption event (TDE: Liu et al. 2018 Kuin et al. 2018 Perley et al. 2019), a jet driven by an accreting neutron star colliding with a giant star (Soker et al. 2019), or a merger of white dwarfs (Lyutikov & Toonen 2018). However, the constraints on the nature of this explosion set by the host galaxy properties have not been explored thoroughly.

AT 2018cow exploded within a spiral galaxy of type Sc (Willett et al. 2013, CGCG 137-068, at a redshift of \( z = 0.014 \) (Perley et al. 2019). It has an inclination from the line of sight of 24.4° (Makarov et al. 2014) \( ^2 \) It has a bar and weak spiral arms (Perley et al. 2019). Its stellar mass and SFR are \( 1.42^{+0.17}_{-0.10} \times 10^9 M_\odot \) and \( 0.22_{-0.04}^{+0.03} M_\odot \ yr^{-1} \) respectively (Perley et al. 2019). The galaxy was claimed to be asymmetric with more near-IR emission in the south-west, i.e., in the part of the galaxy where AT 2018cow exploded (Kuin et al. 2018), \( \sim 1.7 \) kpc from the galaxy centre (Kuin et al. 2018 Perley et al. 2019).

The objectives of this paper are: i) to provide a resolved measurement of the atomic gas properties of the host galaxy of AT 2018cow in order to learn about its nature, and ii) to test whether these properties are consistent with a recent inflow of atomic gas from the intergalactic medium.

We use a cosmological model with \( H_0 = 70 \) km s\(^{-1}\) Mpc\(^{-1}\), \( \Omega_m = 0.7 \), and \( \Omega_\Lambda = 0.3 \), implying that AT 2018cow, at \( z = 0.014 \), is at a luminosity distance of 60.6 Mpc and 1" corresponds to 286 pc at its redshift. We also assume the (Chabrier 2003) initial mass function (IMF).

2. Data

On 8 and 9 February 2019 the field of AT 2018cow was observed for 14 hrs with the Giant Metrewave Radio Telescope (GMRT) \(^3\). For calibration of the flux and the bandpass 3C286 was observed for 15 min at the start and the end of the run. For the phase calibration 1609+266 was observed every 40 min. The correlator was setup with 33 Mhz bandwidth and 512 channels centred around 1400 MHz.

After the submission of this paper, additional GMRT data were reported by Roychowdhury et al (2019). Hence, for the H\(\alpha\) analysis we also included these archival data. As part of that program 7 hrs of data were obtained on 27 August 2018. The channel width was half as wide as for our observations. The same calibrators were observed.

The data were reduced with a range of data reduction packages. We downloaded the FITS files with the raw data from the GMRT archive. These FITS files were then loaded into the Common Astronomy Software Applications (CASA) package (McMullin et al. 2007) with the IMPORT-GMRT task without applying the online flags. Further data reduction was done with the MEERKATH\(^4\) pipeline which is being developed for H\(\alpha\) data reduction of MeerKAT data. The pipeline is setup in a modular fashion using the platform-independent radio interferometry scripting framework STIMELA\(^5\). In practice this means that the calibrator data are initially flagged with AOFLAGGER\(^6\) (Offringa et al. 2018) and calibrated and transferred to the target with CASA. For the data in this paper the phase calibrator was used as a bandpass calibrator, as the GMRT bandpass clearly fluctuated over the time of the observations. As the phase calibrator was bright (4.8 Jy), this leads to an improved bandpass calibration over the course of the observations.

After the initial calibration the target was split out of the measurement set, further flagged with AOFLAGGER, imaged with WSCLEAN (Offringa et al. 2014) in Stokes I, then the sources in the field were extracted and modeled with pyBDSF\(^7\), after which this model was used in Cubical\(^8\) for the self-calibration. This step was repeated until a phase-only self-calibration no longer improved the extracted models.

After the calibration, the three separate days were mapped on to the same channel grid with the CASA task MTRANSFORM and the modelled continuum was subtracted from the data. Any residual continuum was subtracted with UVLIN. At this stage the data were also doppler-corrected and projected onto a barycentric velocity frame.

The visibilities were weighted according to a Briggs weighting scheme with Robust = 0.0 and uv-tapers of 4, 6, 8 and 20 k\(\lambda\) were applied to attain cubes with varying spatial resolution. The cubes were inverted and cleaned with the CASA task TCLEAN. The cleaning was performed in an iterative process where we first clean the full cube to a 10\(\sigma\) threshold then create a mask with SOFIA (Serra et al. 2013), and then clean within this mask to 0.5\(\sigma\). This last step was done outside the pipeline as currently it can not deal with the frequency increments of opposite sign in the different datasets.

The final cubes have a resolution of FWHM = 28.9′ × 26.2′, 19.2′ × 18.1′, 13.12′ × 12.79′, and 5.5′ × 4.6′ and a channel width of 65.1 kHz. The frequency axis was converted into a velocity axis using the relativistic definition which results in a velocity of 1700 \( km \ s^{-1} \) inside the 1 mas uncertainty (An 2018 Bietenholz et al. 2018 Horesh et al. 2018).

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2 Project no. DDTC022, PI: M. Arabsalmani
3 Project no. 35J21, PI: M. Michalowski
4 Project no. 35J22, PI: M. Arabsalmani
5 https://github.com/ska-sa/meerkathi a private repository for the time of development
6 https://github.com/SpeMakh/Stimela/wiki
7 https://github.com/lofar-astron/PyBDSF
8 https://github.com/ratt-ru/CubiCal/
in a channel width of 13.9 km s\(^{-1}\) with an error of \(\sim 0.01\) km s\(^{-1}\) on the outermost channels of the cube.

For our data from February 2019 (excluding those from August 2018, due to the variability of AT 2018cow) we also imaged together all channels of the entire 33 MHz bandwidth (before continuum subtraction) to produce a continuum image at an observed frequency of 1.397667 GHz. The beam size is 2.0\(''\) \(\times\) 1.8\(''\) and the noise is 17.5 \(\mu\)Jy beam\(^{-1}\). The \(\text{H}_\text{i}\) line spans \(\sim 0.6\) MHz, so it should not affect this continuum image based on the 33 MHz bandwidth. Indeed, when we exclude the channels with the line emission we obtain an almost identical map.

In order to correct the astrometry we identified 16 sources in the Faint Images of the Radio Sky at Twenty-Centimeters (FIRST) survey \cite{Becker1995,White1997} that are point-like in our continuum map. On average these sources were found to be shifted on our map with respect to the FIRST position by \((+1.30 \pm 0.14)''\) in right ascension and \((+0.51 \pm 0.14)''\) in declination. We shifted our continuum and \(\text{H}_\text{i}\) maps by this offset. This has very little effect on \(\text{H}_\text{i}\) maps, as their beam sizes are much larger. This offset also implies that the positional uncertainty in our continuum map is \(0.14''\) in both directions.

### 3. Results

The \(\text{H}_\text{i}\) fluxes at each frequency element were determined by aperture photometry with an aperture radius of 45\(''\). The spectra are shown in Fig. 1. The \(\text{H}_\text{i}\) emission maps derived from the collapsed cubes within the dotted lines in Fig. 1 are shown in Fig. 2. This range was selected to encompass the full velocity width of the line. It was also used to obtain integrated \(\text{H}_\text{i}\) emission \(\left(F_{\text{int}}\right)\) in Jy km s\(^{-1}\)) directly from the spectra. The line luminosity \(\left(L_{\text{HI}}\right)\) in K km s\(^{-1}\) pc\(^2\) was calculated using Eq. 3 in \cite{Solomon1997} and transformed to \(M_{\text{HI}}\) using Eq. 2 in \cite{Devereux1990}. The \(\text{H}_\text{i}\) zeroth and first moment maps (integrated emission and velocity field) are also shown on Fig. 2.

We detected and resolved the \(\text{H}_\text{i}\) emission of the host of AT 2018cow. The atomic gas disk is larger than the stellar disk with a centre (moment 0 ‘centre of mass’) offset from the optical centre by \(\sim 1.2''\) (\(\sim 0.3-0.6\) kpc in projection), and \(\sim 5''-6''\) or \(\sim 1.4-1.7\) kpc from the position of AT 2018cow. Using the formula of \cite{Ivison2007} the positional uncertainty is \(\sim 0.5-1.5''\), so the offset to the

\[ r = 0.6 \times \text{FWHM}_{\text{beam}} / (S/N), \] where FWHM\(_{\text{beam}}\) is the FWHM of the beam and S/N is the signal-to-noise ratio.
Fig. 2. Top: H\textsubscript{i} contours (red; collapsed H\textsubscript{i} cube) of CGCG 137-068 overlayed on the Gran Telescopio Canarias optical \textit{i'}-band image (Kann et al., in prep.). The contours are 3, 4, 6, 7, and 9\(\sigma\), where \(\sigma = 0.031, 0.029, 0.027\), and 0.019 Jy beam\(^{-1}\) km s\(^{-1}\) for the data at the resolution of 28\"', 19\"', 13\"', and 5\"', respectively (corresponding to a neutral hydrogen column density of \(\sim 0.5, 0.9, 1.8, \) and \(8.4 \times 10^{20} \) cm\(^{-2}\), respectively). Second row: the H\textsubscript{i} data cube collapsed within the dotted lines given in Fig. 1. Third row: The first moment map (velocity field) of the H\textsubscript{i} line with the same contours as in the top panel. The velocities are relative to the systemic velocity of 4197 km s\(^{-1}\) derived from the optical spectrum (Perley et al. 2019). Columns are for the resolution as marked on the panels. The VLBI position of AT 2018cow is indicated by the blue or grey circles. The green dotted circle has a radius of 45\" and corresponds to the aperture within which the total H\textsubscript{i} emission was measured. The beam size of the H\textsubscript{i} data is shown as the grey ellipses. The images are 120\" \times 120\" and the scale is indicated by the ruler. North is up and East is to the left.

galaxy centre is at most 2\(\sigma\), but to the AT 2018cow position it is significant at \(\sim 5\sigma\).

The H\textsubscript{i} maps (Fig. 2) do not show strong evidence of recent gas inflows. The gas distribution is much more regular than those of the hosts of GRB 980425 (Arabsalmani et al. 2015), GRB 060505 (Micha/lski et al. 2015), and SN 2009bb (Micha/lski et al. 2018a), which ex-
Table 1. HI properties of CGCG 137-068.

<table>
<thead>
<tr>
<th>Beam</th>
<th>$z_{HI}$</th>
<th>$W_{50}$</th>
<th>$W_{10}$</th>
<th>$F_{int}$</th>
<th>log($L_{HI}$)</th>
<th>log($M_{HI}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(°)</td>
<td>(2)</td>
<td>(km s$^{-1}$)</td>
<td>(km s$^{-1}$)</td>
<td>(Jy km s$^{-1}$)</td>
<td>(K km s$^{-1}$ pc$^2$)</td>
<td>(M$_{⊙}$)</td>
</tr>
<tr>
<td>28</td>
<td>0.013972 ± 0.000014</td>
<td>50 ± 30</td>
<td>127 ± 9</td>
<td>0.94 ± 0.09</td>
<td>10.738 ± 0.038</td>
<td>8.909 ± 0.038</td>
</tr>
<tr>
<td>19</td>
<td>0.013976 ± 0.000014</td>
<td>48 ± 22</td>
<td>127 ± 18</td>
<td>1.02 ± 0.12</td>
<td>10.772 ± 0.048</td>
<td>8.944 ± 0.048</td>
</tr>
<tr>
<td>13</td>
<td>0.013983 ± 0.000017</td>
<td>47 ± 22</td>
<td>126 ± 26</td>
<td>1.17 ± 0.15</td>
<td>10.832 ± 0.051</td>
<td>9.004 ± 0.051</td>
</tr>
<tr>
<td>5</td>
<td>0.013988 ± 0.000022</td>
<td>33 ± 14</td>
<td>126 ± 34</td>
<td>1.49 ± 0.23</td>
<td>10.939 ± 0.063</td>
<td>9.111 ± 0.063</td>
</tr>
</tbody>
</table>

Notes. (1) Beam size of the HI cube (the global estimates are the most reliable for the coarsest resolution). (2) Redshift determined from the emission-weighted frequency of the HI line. (3) HI linewidth at the 50% of the maximum. (4) Width at the 10% of the maximum. (5) Integrated flux within the dotted lines on Fig. 1. (6) HI line luminosity using equation 3 in Solomon et al. (1977). (7) Neutral hydrogen mass using equation 2 in Devereux & Young (1990).

Table 2. Properties of the continuum 1.397667GHz sources within CGCG 137-068.

<table>
<thead>
<tr>
<th>RA</th>
<th>Dec</th>
<th>$F_{1.4}$ GHz</th>
<th>SFR$_{radio}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(h m s)</td>
<td>(d m s)</td>
<td>(mJy)</td>
<td>(M$_{⊙}$ yr$^{-1}$)</td>
</tr>
<tr>
<td>16 10 00.209</td>
<td>+22 10 04.18</td>
<td>1.239 ± 0.018</td>
<td>&lt; 0.565</td>
</tr>
<tr>
<td>16 10 00.729</td>
<td>+22 10 09.52</td>
<td>0.101 ± 0.018</td>
<td>0.081 ± 0.011</td>
</tr>
</tbody>
</table>

Notes. The first object corresponds to AT 2018cow. We treated its radio SFR estimate (using the conversion of Bell (2003)) as an upper limit because AT 2018cow has a significant contribution to the radio flux. The mean time of the observations is 2019-02-08-17.41667 UT (237.28470 days after the optical discovery).

Fig. 3. Continuum GMRT 1.4GHz contours (red) of CGCG 137-068 on the Gran Telescopio Canarias optical $i$'-band image of the galaxy (Kann et al., in prep.). The lowest contour is at 2 mJy beam$^{-1}$ and the steps are in factors of $\sqrt{2}$. The VLBI position of AT 2018cow is indicated by the white circle. We detected the emission of AT 2018cow at this position and an additional object in the north-eastern part of the galaxy. The beam size of the radio data is shown as the grey circle. The image is $30'' \times 30''$ and the scale is indicated by the ruler. North is up and East is to the left.

hbit strong gas concentrations close to the GRB/SN positions, away from the galaxy centres.

On the two zeroth moment maps with the highest resolutions we see the ring-like structure reported by Roychowdhury et al. (2019). In Sect. 4 we provide evidence that this structure is of internal origin.

On the outskirts of CGCG 137-068 there are gas plumes in both the zeroth moment and the collapsed maps (Fig. 2), but they are of low signal-to-noise, so they cannot be interpreted as real structures with confidence. Moreover, they can be spiral structures.

Moreover, from one resolution to another the ‘centre of mass’ of the zeroth moment maps moves only by $\sim 1''$ ($\sim 3''$ for the $28''$ map with the worst positional uncertainty). This suggests that the distribution is symmetric. The velocity fields (bottom row of Fig. 2) and the double-horn profiles of the HI spectra (Fig. 1) are consistent with a rotating disk.

The SFR-$M_{HI}$ relation (Eq. 1 in Michalowski et al. 2013), predicts log($M_{HI}/M_{⊙}$) = 9.14$^{+0.04}_{-0.07}$ for SFR = 0.22 $M_{⊙}$ yr$^{-1}$ of CGCG 137-068 (the errors include both the uncertainty in the SFR and in the parameters of the relation). This is 0.24 dex, i.e. $\sim 3\sigma$, higher than the measured value (Table 1), which is within the scatter of this relation (0.38 dex at 1$\sigma$). Hence CGCG 137-068 has a normal atomic gas content for its SFR and is located close to most gas-poor galaxies within this relation. The relation has been established using over 1500 galaxies, also covering the SFR range relevant here.

We present the continuum map at an observed frequency of 1.397667GHz in Fig. 3. We detected two point sources within CGCG 137-068: AT 2018cow in the southwest and a second source at the north-eastern part of the bar, just outside the bulge. The positions, fluxes, and SFRs using the conversion of Bell (2003) are listed in Table 2. For the first source we show the SFR as an upper limit, as it is dominated by AT 2018cow. This is motivated by a small offset (0.24") of this source to the VLBI position of AT 2018cow and the fact that a variable 1.4GHz flux at this level has been reported by Margutti et al. (2019).

The SFR of the second source (0.081 $M_{⊙}$ yr$^{-1}$) is $37^{+7}_{-8}$% of the total SFR of the galaxy as measured from the spectral energy distribution modelling (0.22 $M_{⊙}$ yr$^{-1}$; Perley et al. 2019). This source is coincident with one of the peaks of the HI maps. The analogous continuum source is not present in
Moreover, barred spirals always exhibit significant star formation along the bar and differences between the two halves of the bar are common among local spirals, but regions inside bars do not dominate the total SFR (Regan et al. 1996; Sheth et al. 2000, 2002; Koda & Sofue 2002; Momose et al. 2013; Hirota et al. 2014; Yajima et al. 2019). Moreover, barred spirals always exhibit significant star formation in the galaxy centre, which is not evident for CGCG 137-068.

The SFR and stellar mass of CGCG 137-068 (Perley et al. 2019) imply a specific SFR (sSFR ≡ SFR/M$_*$) of ≈ 0.15 Gyr$^{-1}$. At this stellar mass, the sSFR of a main-sequence galaxy is ≈ 0.2 Gyr$^{-1}$ (Speagle et al. 2014). Hence, CGCG 137-068 is a main-sequence galaxy at the bottom of the scatter of this relation with no enhancement or strong suppression of star formation.

The atomic gas and star formation properties of CGCG 137-068 are summarised in Fig. 4 and compared with GRB/SN hosts with H$_i$ measurements (Michalowski et al. 2013, 2018a). For each galaxy we also show the predicted gas depletion time from the M$_{HI}$-SFR relation (Michalowski et al. 2013). GRB/SN hosts occupy two regions of this diagram: either on/below the main-sequence and abundant with atomic gas (high gas depletion timescale well above the prediction), or above the main-sequence with low gas depletion timescale, due to elevated SFR. In contrast, CGCG 137-068 is below the main-sequence, but it has lower gas content than predicted from the M$_{HI}$-SFR relation. In particular it is different than the hosts of GRB 060505 and 111005A, which have a fainter gas than predicted from their SFR. In terms of the M$_{HI}$/SFR ratio, the AT 2018cow host is most similar to the GRB 980425 host, which is, however, at the upper boundary of the main sequence and exhibits a strong gas concentration close to the GRB position, unlike the AT 2018cow host.

4. Discussion

The atomic gas distribution of CGCG 137-068 does not show strong unusual features (especially not at the
AT 2018cow position), in contrast to the off-centre gas concentrations and irregular velocity fields of the host galaxies of GRBs or relativistic SNe (Arabsalmani et al. 2013; Michalowski et al. 2014, 2015, 2016, 2018a). Moreover, there is no enhancement of the SFR, which could be a signature of a gas inflow. The environment of AT 2018cow therefore suggests that its progenitor may not have been a massive star (Prentice et al. 2018; Margutti et al. 2019; Rasmussen et al. 2006). Hence, to investigate this further we analysed the large-scale environment of CGCG 137-068 using the NASA/IPAC Extragalactic Database (NED) of CGCG 137-068. It seems fairly isolated, with no other galaxies within 500 kpc projected distance and 1000 km s⁻¹ velocity. The nearest galaxy is UGC 10322, more than 500 kpc away in projected distance. Hence, in the current catalogues there is no galaxy which is close enough to significantly influence the properties of CGCG 137-068. We found that CGCG 137-068 is ~ 700 kpc to the west of a possible galaxy group extending several hundred kpc across and containing six galaxies. Similar to the host of SN 2009bb (Michalowski et al. 2018a), this could mean that there is a supply of intergalactic gas available for inflow onto CGCG 137-068, but we did not find any evidence of such process.

On the other hand, all other proposed explosion mechanisms of AT 2018cow, apart from massive-star core-collapse, should not result in a connection between its progenitor and gas concentration or inflow: an exploding low-mass hydrogen-rich star (Margutti et al. 2019), a TDE (Liu et al. 2018; Kuin et al. 2018; Perley et al. 2019), and a merger of white dwarfs or a neutron star and a giant star (Lyutikov & Toonen 2018; Soker et al. 2019). Hence, the normal atomic gas distribution of CGCG 137-068 is consistent with these mechanisms.

After the submission of this paper, the results of Roychowdhury et al. (2019) on the atomic gas distribution in the host galaxy of AT 2018cow were published. They found a ring of gas, also visible in our combined dataset (Fig. 5). As claimed by Roychowdhury et al. (2019), such a gas ring could be the result of a minor merger. However, most rings in galaxies has been shown to be the result of resonances caused by the presence of a bar (gravitational torques; see the review by Buta & Combes (1996) and other internal mechanisms, like viscous torques (Jerkstrand et al. 2013), Buta (1986), Lesch et al. (1996), Combes & Gerin (1985), Armillotta et al. (2019)). Similarly, Díaz-García et al. (2019) found an increasing fraction of ringed galaxies with increasing bar Fourier density amplitude (also for galaxies with stellar masses similar to that of CGCG 137-068) exhibit central depressions of atomic gas (likely due to the molecular phase) or enhancement at the location of the spiral arms (Leroy et al. 2008; Bigiel & Blitz 2012, Martinsson et al. 2016). This feature, combined with low sensitivity (as in the highest-resolution map of Roychowdhury et al. 2019) would give rise to a ring-like structure in the data, which would have a purely internal origin. Hence, the presence of the gas ring in CGCG 137-068 without any sign of disturbance is not strong evidence of a recent merger.

5. Conclusions

We observed the H i atomic hydrogen line emission of the AT 2018cow host galaxy with the Giant Metrewave Radio Telescope. There is no unusual atomic gas concentration near the position of AT 2018cow. The gas distribution is much more regular than those of the hosts of GRBs and SNe. The AT 2018cow host has an atomic gas mass lower by 0.24 dex than the prediction from its SFR and is at the lower edge of the galaxy main sequence. In the continuum we detected the emission of AT 2018cow and of a star-forming region in the north-eastern part of the bar (away from AT 2018cow). This region hosts a third of the galaxy star formation rate (SFR).

The absence of atomic gas concentration close to AT 2018cow, along with a normal SFR and regular H i velocity field sets CGCG137-068 apart from GRB/SN hosts studied in H i. The environment of AT 2018cow therefore suggests that its progenitor may not have been a massive star. Our findings are consistent with an origin of the transient that does not require a connection between its progenitor and gas concentration or inflow: an exploding low-mass star, a tidal disruption event, or a merger of white dwarfs or of a neutron star and a giant star. We interpret the recently reported atomic gas ring in CGCG 137-068 as a result of internal processes connected with gravitational resonances caused by the bar.

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