The Neutral ISM in Starburst Galaxies
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High resolution observations of neutral gas in the starburst merger NGC 520

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Abstract. Sub-arcsecond angular resolution MERLIN observations of the neutral gas in the nearby starburst galaxy NGC 520 are presented. Against the radio continuum emission of the primary nucleus of this merger induced starburst both neutral hydrogen (HI) and hydroxyl (OH) absorption lines are observed, along with a weak OH maser feature probably related to the star formation activity in this galaxy. The strong HI absorption ($N_H \sim \frac{T_{spin}}{100\,K} 10^{22}$ atoms cm^{-2}) traces a velocity gradient of 0.5 km s^{-1} pc^{-1} across the central kiloparsec of NGC 520 which is consistent with recent CO observations and is attributed to a kiloparsec-scale ring or disk.

1. Introduction

NGC 520 (Arp 157, UGC 966, VV-231) is a nearby (D=30 Mpc; H_0=75 km s^{-1} Mpc^{-1}, 1 arcsec = 145 pc) irregular infrared (L_{fir}=6.3 ×10^{10} $L_\odot$) galaxy. This source is often cited as an example of an ongoing merger event since it is comprised of two optical nuclei, separated by 40 arcsec (∼5.8 kpc) (Hibbard & van Gorkom 1996) and has long tidal arms and plumes stretching from the nuclear region which have been observed in both deep optical images and in arcsecond resolution imaging of HI emission (Hibbard, Vacca & Yun 2000 and refs. therein).

It is widely accepted that NGC 520 contains a central starburst of proportions similar to those found in the nearby starburst galaxy M82, which has probably been induced by the disruptive merger event underway in NGC 520. The central region which dominates the radio emission has been mapped at 15 GHz by Carral, Turner & Ho (1990) and at 5 GHz by Condon et al. (1982) with the Very Large Array (VLA) at sub-arcsecond resolutions. Both Carral et al. and Condon et al. found that at high angular resolution NGC 520 displays an approximately linear east-west central radio structure with multiple compact radio components similar in structure to those found in other infrared galaxies, such as NGC 3628 and Arp 220. Within the central kiloparsec of NGC 520 copious quantities of dust and gas, both molecular (OH, CO) and atomic HI (Baan et al. 1985; Sanders et al. 1988, Yun & Hibbard 2001) have been detected. In the optical the entire central kiloparsec of NGC 520 is heavily obscured by a dust lane with H–K colors indicating a K–band optical extinction of $\sim$1.2–1.6 (Kotilainen et al 2001). Molecular CO (1–0) has been detected and imaged in this central region of NGC 520 at arcsecond resolutions using the Owens Valley Millimeter Array by Sanders et al. (1988) and Yun & Hibbard (2001). Yun & Hibbard found that the CO is solely distributed within a 1.0$\times$0.4 kpc (P.A.=95°) disc surrounding the primary nucleus in NGC 520.

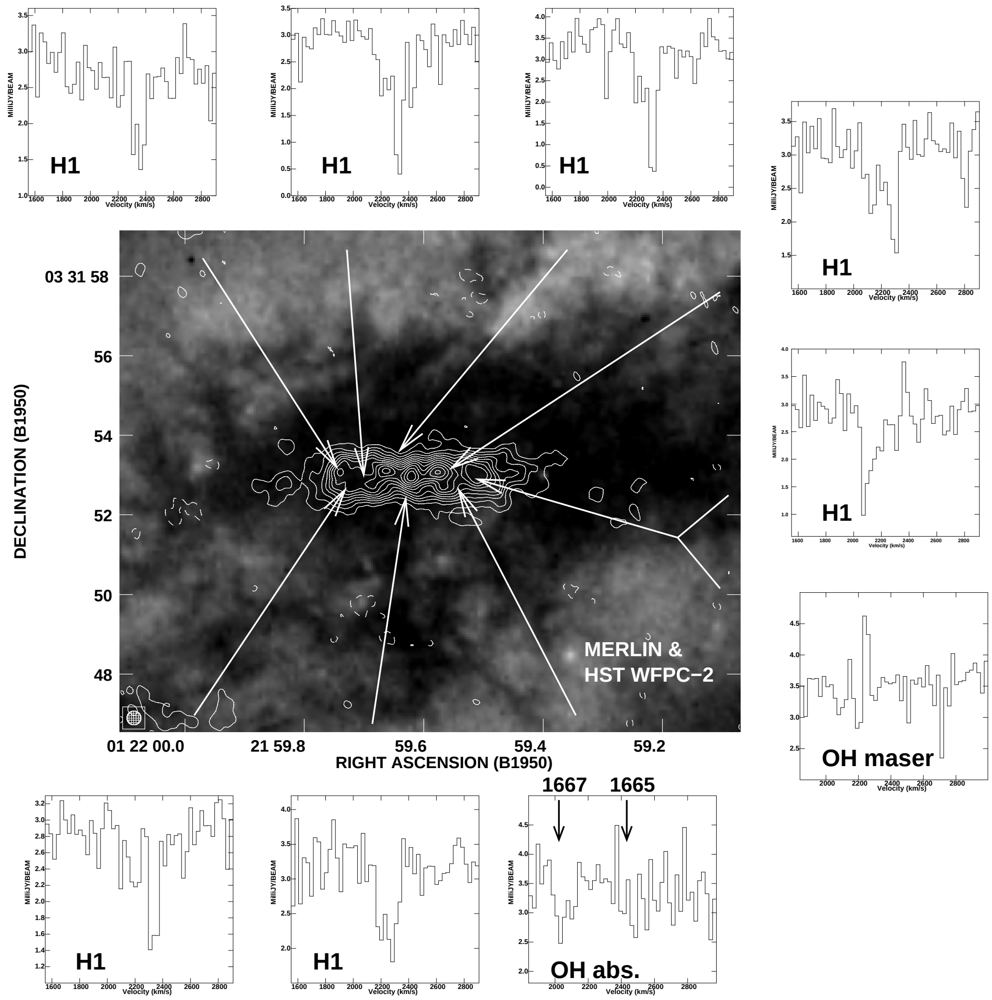

Figure 1. Montage of 1.4-GHz MERLIN radio continuum (contours) overlaying a grey scale *HST* WFPC-2 image of the central region of NGC 520. Radio contour levels are -1, 1, 2, 3, 4, 5, 6, 7, 8, 9 & 10 $\times$0.4 mJy beam^{-1}. Spectra are plotted as flux density versus optical-heliocentric velocity in km s^{-1}. The radio continuum contour image is derived from the line-free channels of the naturally weighted cube and has been convolved with a circular 0.″35 beam.

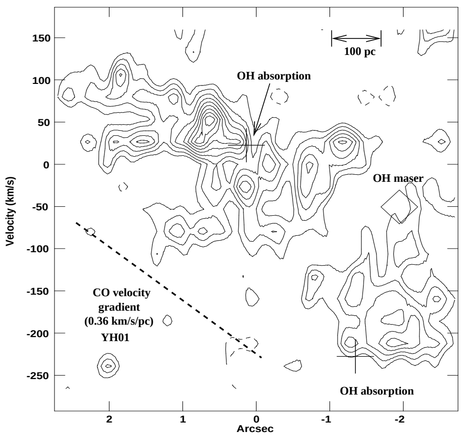

Figure 2. Contours of HI absorption plotted as relative position along the R.A. axis averaged over the $1''.5$ declination range of the source against velocity. Positions along the spatial axis are relative to 01^{h} $21^{m}59.63^{s}$ and are numbered east to west in a positive direction. Velocities are labelled relative to 2282 km s^{-1}. The contour levels are -6.5, -6, -5.5, -5, -4.5, -4, -3.5, -3, -2.5, -2, -1.5, -1 and 2×0.55 mJy beam^{-1}. The positions of the OH absorption and maser emission detected with MERLIN are marked. For comparison the gradient of CO emission (Yun & Hibbard 2001) in the central kiloparsec is also shown, offset from the HI absorption, by the dashed line.

Here we present sub-arcsecond resolution MERLIN observations of the neutral gas distribution and dynamics within the central region of the merger galaxy NGC 520. These results are based upon observations of both HI and OH absorption, and OH maser emission toward the center of NGC 520 on linear scales of ∼50 parsecs with MERLIN. These observations provide approximately a factor of 7 increase in angular resolution compared with previously published studies of the nuclear gas distribution in this source. A more detailed discussion of these results is presented in Beswick et al. (2003).

2. Observations

NGC 520 was observed with the full MERLIN array, including the 76-m Lovell Telescope, on November 4th 2000 at 1653 MHz (redshifted OH) and on December 10th 2000 at 1409 MHz (redshifted HI). In each observation opposite hands of circular polarization were measured with an 8-MHz bandwidth which were correlated into 64 channels resulting in a velocity resolution of $\sim$ 26 km s^{-1}. Preliminary analysis of both data sets were performed using local MERLIN software routines before the data were transfered into the NRAO Astronomical Image Processing System (AIPS). Within AIPS bandpass calibration, phase corrections and some additional editing of the data were achieved using standard tasks. The resulting data were Fourier transformed to produce 512×512×63 spectral line cubes.

2.1. Results & Discussion

The 1.4 GHz radio continuum structure observed with MERLIN is shown in Fig. 1, overlayed upon a similar angular resolution archival *HST* WFPC-2 image (see Beswick et al. 2003 for more details). The radio structure in this central kiloparsec region of the primary nucleus of NGC 520 is approximately east-west in orientation an a composite of numerous low brightness temperature components. This image is consistent with earlier 15 GHz images produced by Carral et al. (1990). Figure 1 also shows a selection of HI absorption spectra as well as two spectra taken from the data set observed at 1.6 GHz. We detect high opacity HI absorption across the majority of the radio continuum structure. At 1.6 GHz we do marginally detect OH absorption from both the 1667 & 1665 MHz transition lines toward part of the radio continuum structure and serendipitously detect weak 1667 MHz maser emission from an unresolved point in the western half of the nucleus (see Fig. 1).

The opacity recorded against the weak and diffuse radio continuum structure ranges between 0.5 and 0.9 with HI column densities against individual radio continuum components of up to $N_H \sim 11.7 \times (\frac{T_{spin}}{100\,K})10^{21}\,atoms\,cm^{-2})$. Figure 2 shows a position (R.A) versus velocity diagram of the HI absorbing structure showing the complex velocity structure observed in the neutral gas at the heart of this galaxy. The velocity structure traces a gradient of $0.5\,km\,s^{-1}\,pc^{-1}$ across the inner kiloparsec. This velocity gradient is consistent, although slightly steeper, than that observed across the same region in CO by Yun & Hibbard (2001) at significantly lower angular resolution. These observations along with those made by Yun & Hibbard trace the neutral gas which most probably lies in a disc rotating about the central starburst region. This disc of neutral gas which is deeply embedded in the within the dusty core of this galaxy and is obscured from being observed in the optical regime. These large quantities of gas and dust observed in the central kiloparsec probably act as fuel for the central starburst activity (Beswick et al. 2003).

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