Star Formation
Toward the “Quiescent” Core NGC 6334 I(N)

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At the time of their birth, young massive stars are deeply embedded in the dense molecular cores from which they form, thus making it impossible for us to observe them directly. The very early stages of massive star formation can therefore only be detected indirectly through the effects they have on the surrounding cloud via massive bipolar outflows, enhancements of certain molecular species, or infrared emission from heated dust grains.

At a distance of 1.7 kpc, NGC 6334 is one of the nearest and most prominent regions of ongoing high-mass star formation (Neckel, 1978), but because of its southerly location, it is not well studied. The nebula is associated with a remarkable, filament-like giant molecular cloud (GMC) which contains a chain of 6 distinct sites of recent high-mass star formation (McBreen et al., 1979). Additional evidence for star formation is the emission of vibrationally excited H₂ detected in a large, 20″ resolution map by Straw & Hyland (1989). This map shows bright emission in the H₂ 1-0 S(1) line extended over several square parsecs toward the GMC.

In July 1998, we mapped the H₂ 1-0 S(1) and Brγ lines toward a significant fraction of the molecular cloud using the Fabry-Perot on IRAC2 at the 2.2-m. This provided a factor 400 improvement in spatial resolution over the previous H₂ 1-0 S(1) maps of Straw & Hyland (1989). Furthermore, using the SEST in June 1998, we conducted a multi-frequency study of the molecular gas in the NGC 6334 cloud. From these data we find that the NGC 6334 I & I(N) molecular cores, shown in Figure 1, probably contain the youngest sites of high-mass star formation within the NGC 6334 GMC. NGC 6334 I incorporates an ultracompact H II region, two mid-IR sources, a young stellar cluster, a plethora of masers, and at least one (probably two) bipolar outflow(s). The shock
excited H$_2$ 1-0 S(1) emission we detected in bow-shock shaped emission knots toward the NH$_3$ masers detected by Kraemer & Jackson (1995) (cf. Fig. 2), and the broad non-Gaussian line wings detected in the molecular line emission, impressively display these outflows toward NGC 6334 I. In contrast, I(N), a cooler source has only been detected at submillimetre or millimetre wavelengths. Interestingly, I(N) contains several masers whose presence, far from any known site of active star formation, has been an enigma.

From our SEST data, we confirm that the NGC 6334 I(N) core is chemically quiescent and much cooler when compared to its southernly neighbour NGC 6334 I. Considering the apparent cluster embedded within the NGC 6334 I core, this is not surprising as much of the molecular material within this core must have been heated and processed by the embedded young stars. However, NGC 6334 I(N) shows some very surprising peculiarities: bright emission lines of sulfur-bearing molecules and SiO line emission with broad line wings. These strong lines and their attendant line wings are clear evidence for a molecular outflow and shock chemistry in this seemingly quiescent molecular core.

Maps of the blue and red line wings in the observed transitions of SiO indicate a bipolar flow (cf. Fig. 3). The near-infrared maps obtained with the 2.2-m provide further evidence for outflows in I(N) through the detection of vibrationally ex-
Molecular Gas in 30 Doradus

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Introduction

The Large Magellanic Cloud (LMC) contains numerous star-forming regions (SFRs) in an environment considerably different from the Galaxy. As in our Milky Way, SFRs in the LMC include complexes of ionised gas, patches of dust, and clusters of young stars and share the same markers of star formation: protostellar objects (Jones et al. 1986; Hyland et al. 1992), compact infrared sources (Schwering & Israel 1990; Rubio et al. 1992), OH and H\textsubscript{2}O masers (Whiteoak & Schwering 1990; Rubio et al. 1992) and substantial infrared flux (Cohen et al. 1988; Israel et al. 1993; Kutner et al. 1997; Johansson et al. 1998). The SFRs in the LMC should be important stepping stones between Galactic SFRs and those in more distant galaxies. In particular, the giant H II region 30 Doradus is thought to be a keystone object for understanding the "starburst" phenomenon in active galaxies (cf. Walborn 1991). Much larger than any Galactic SFR, the 30 Doradus region contains luminous clusters of massive young stars emitting intense UV radiation and powerful stellar winds which have created loops and shells of ionised gas, and shows evidence for a highly efficient formation mechanism unmatched in Galactic molecular clouds (Massey and Hunter 1998). We summarise here the results of an ongoing investigation of the characteristics of the highly excited molecular gas and cold molecular gas towards the centre of the 30 Doradus region, made through observations of H\textsubscript{2} and CO(2\textrightarrow{}1) line emission, respectively.

Cold Molecular Gas

CO emission from the 30 Doradus region was first detected, using the Columbia millimetre radio telescope, by Melnick & Rubio (1985). Their pointed, low angular resolution (8.8') observations showed a weak CO line emission with several velocity components. Higher sensitivity CO mapping of a region of ~ 1° centred near the exciting cluster of the H II region (hereafter the R136 cluster), made with the same instrument, were reported by Garay et al. (1993). They suggested that the CO emission from the 30 Doradus region arises from small, dense molecular clumps that are embedded in a mainly atomic but partly molecular interclump medium where CO has been destroyed by photodissociation due to the strong UV radiation field present in the area.

As part of the ESO-SEST Key Programme: CO in the Magellanic Clouds, Johansson et al. (1998) mapped the CO(1\textrightarrow{}0) line emission from the 30 Doradus region with a tenfold higher angular resolution (45") than in previous works. They identified more than 30 molecular clouds within a region of 24' x 24', having typically sizes of 10 pc and masses of ~ 2 x 10\textsuperscript{4} M\textsubscript{\odot}, confirming the suggestion made by Garay et al. (1993). In particular, close to the R136 cluster, Johansson et al. (1998) detected two CO clouds located toward the north-east and west of R136 (clouds # 10 and 13, respectively) and which lie close to the edg-

References


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Figure 4: H\textsubscript{2}1-0 S(1) emission toward NGC 6334 I and I(N) from our Fabry-Perot imaging with the 2.2-m in July 1998. The lower part of this figure shows the same H\textsubscript{2} emission knots as Figure 2, but with higher dynamic range. Relative offsets are given in arcseconds from an arbitrary off-position, chosen to align the two FP-fields. We caution the reader that the registration of the data in this figure is preliminary and may have absolute errors of several arcseconds. Note that no continuum and no Br\gamma emission could be detected toward the shock-excited H\textsubscript{2} emission knots.