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^{12}CO J=2-1 Map of the Disk of Centaurus A: Evidence for Large Scale Heating in the Dust Lane

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I. Introduction

Centaurus A (NGC 5128) is a nearby (3 Mpc) elliptical galaxy with a prominent dust lane, extensive radio lobes and a compact radio continuum source, suggestive of nuclear activity. As a consequence of its peculiar morphology, this merger candidate has been the subject of much attention, particularly at optical wavelengths. Unfortunately the high and patchy extinction in the disk, aggravated by the warped structure of the dust lane, has severely hindered investigations into the properties of the interstellar medium, particularly with regard to the extent of star formation. Here we present a map of the ^{12}CO J=2-1 line throughout the dust lane which, when combined with a previously measured ^{12}CO J=1-0 map (Eckart *et al.* 1990a) and data on molecular absorption lines observed against the compact non-thermal continuum source (Eckart *et al.* 1990b), offers insight into the excitation conditions of the molecular gas.

II. Results

We mapped the ^{12}CO J=2-1 line with the 15m Swedish-ESO Submillimetre Telescope (SEST) in La Silla, Chile during several observing periods between December 1990 and May 1992. A total of 240 positions, extending over an area of $200'' \times 70''$, were measured with the 230 GHz receiver. The beam FHWM is $22''$ at this frequency. The grid spacing was typically $8''$ in the inner disk and $16''$ at the extremities with total integration times of 30 and 4 minutes respectively.

Our map of the ^{12}CO J=2-1 emission, presented in Figure 1, clearly illustrates that strong emission in this line has been detected over a large area of the dust lane. The emission is generally symmetrical about the nucleus but, as in the case of the J=1-0 and IRAS 50μm maps (Eckart *et al.* 1990a), it is not centrally peaked. The striking similarity in the morphologies of the J=2-1, J=1-0 and 50μm maps suggests that the gas and warm dust ($T_d \sim$40K) are probably well coupled. The good spatial sampling of this map has allowed us to undertake an extensive investigation into the kinematics of the gas, particularly in the nuclear vicinity (Rydbeck *et al.* 1992). Here we restrict discussion to the excitation conditions of the gas.

The excitation conditions in the disk can be probed using the J=2-1/J=1-0 ratio, when the J=2-1 map has been convolved to the resolution of the J=1-0 map. This results in a ratio of close to unity at the position of the nucleus, a value which, rather surprising, is also typical of the gas throughout the whole extent of the disk. The ratio of $\sim$1 outside the nucleus contradicts previous conclusions (Eckart *et al.* 1990a) which had been based on comparison with J=2-1 spectra obtained by Phillips *et al.* (1987). Such a high J=2-1/J=1-0 ratio implies that the bulk of the gas in the dust lane is warm (T>15K), dense ($n_H \sim 2\times10^4 \beta$ cm^{-3}, the critical density required to thermalise the J=2-1 level, where β is the escape probability) and, probably partially, optically thick. This conclusion is supported by a measured J=2-1/J=1-0 ^{13}CO ratio of 0.9 at one position in the disk. That the nucleus of Centaurus A does not dominate the ratio map runs contrary to the trend in active galaxies in which the nuclear vicinity generally harbours warmer and denser gas than the disk (*e.g.* Eckart *et al.* 1991; Henkel *et al.* 1991). On the other hand, in all these galaxies, including Centaurus A, the warm dense molecular gas is enclosed within the nuclear bulges.

Only one other galaxy, M82, claims a J=2-1/J=1-0 ratio significantly higher than that measured for Centaurus A (Wild *et al.* 1992). Although NGC 1808, a nearby (10.9 Mpc) spiral with a peculiar and complex nucleus and numerous 'hotspots', and NGC 4945, a southern edge-on spiral, are characterised by a J=2-1/J=1-0 ratio of $\geq$1 in the nuclear vicinity, this ratio falls to ~0.6 in the disk (Whiteoak *et al.* 1991). In this context, Centaurus A shows excitation characteristics which have more in common with the starburst galaxy IC 342, although even here the J=2-1/J=1-0 ratio falls to ~0.7-0.8 at distances of >500pc from the centre (Eckart *et al.* 1990c). Such a comparison raises the question of the extent of star forming activity in the dust lane. Certainly the dust lane is abundant in HII regions but, on the other hand, the far-IR luminosity and total molecular mass in the central kiloparsec ($1\times10^9 L_\odot$ and $5\times10^7 M_\odot$ respectively) are both a factor of 4 lower than in IC 342. However the star formation efficiencies, $L_{FIR}/M_\odot$, are similar for both galaxies (Eckart *et al.* 1990a) and are comparable to the most active star-forming regions in the disk of the Milky Way.

A more detailed report of this work will be presented elsewhere.

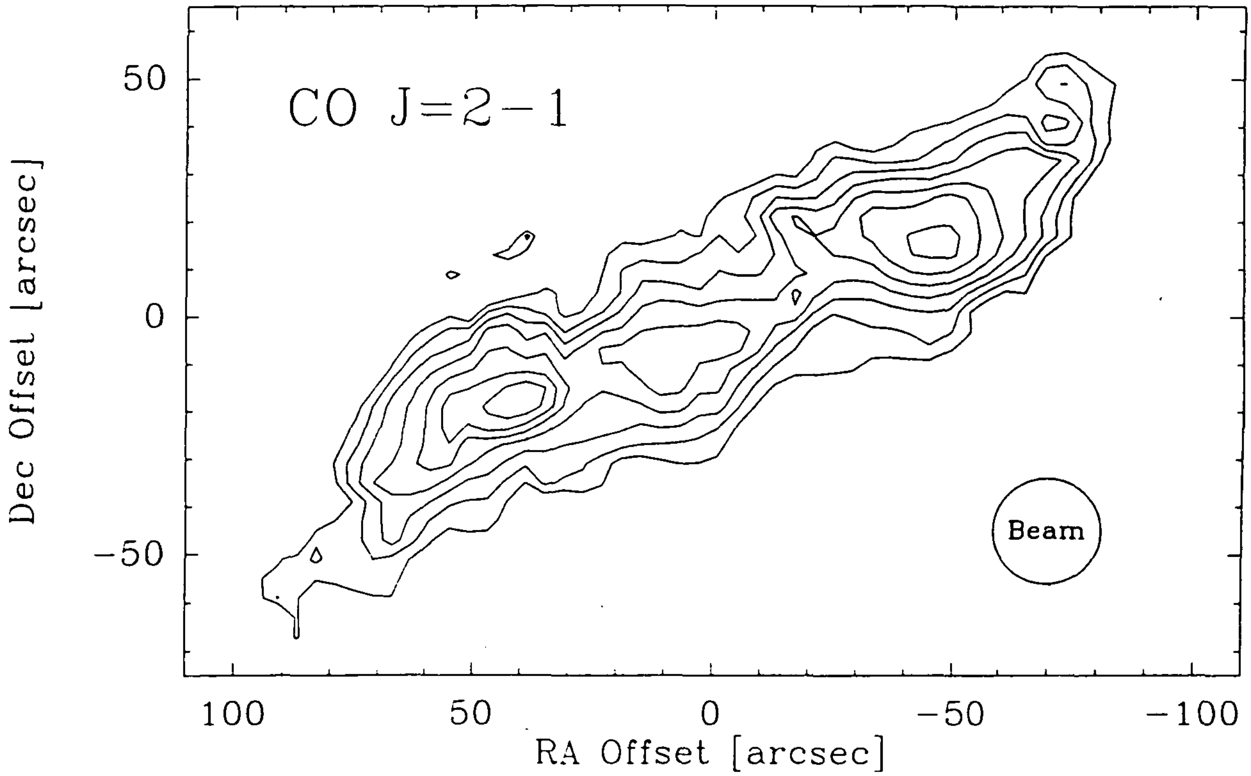

Figure 1: Contour map of the velocity integrated ^{12}CO J=2-1 emission from the dust lane in Centaurus A. Contour levels are 20, 25, ... K kms^{-1} and the peak intensity is 54 K kms^{-1}. Coordinates are offset from the position of the radio continuum source.

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