Kinematics of the Molecular Gas in Centaurus A

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We report on observations of Cen A using the SEST telescope (Swedish-ESO Submillimeter Telescope). In a previous paper (Eckart *et al.* 1990a, hereafter Paper I) we presented a fully sampled map of the ^{12}CO(1-0) distribution in the disk which complements the ^{12}CO(2-1) cuts obtained by Phillips *et al.* (1987, 1989). From these data we determined that the ISM in the disk of Centaurus A is cold (T<10 K), with densities of the order of the ^{12}CO critical density ($\sim 2 \times 10^4$ cm^{-3}). Absorption against the nuclear continuum source has been reported for HI (van Gorkom 1987, van der Hulst *et al.* 1983, Whiteoak and Gardner 1971) and a number of molecular species, such as OH, H_2CO, C_3H_2, ^{12}CO, and ^{13}CO (Whiteoak and Gardner 1971, Gardner and Whiteoak 1976, Bell and Seaquist 1988, Phillips et al. 1987, Israel et al. 1990). Here we summarize measurements of absorption in the lines of ^{12}CO, ^{13}CO, HCO^+, HCN, CN and CS (see Eckart *et al.* 1990b ; hereafter Paper II).

Kinematics and Distribution of the Emitting Gas: Fig.1 shows the velocity-position diagram along a position angle of 125°. At our spatial resolution the data show signature of solid body rotation for the inner 180″. The rotation is centered on the IR/radio nucleus (Giles 1986) of Centaurus A. Under the assumption of constant emissivity in the ^{12}CO(1–0) line, the position velocity diagram cannot be explained by a rotating ring of molecular gas. In this case one would expect the diagram to show a minimum at the central position. If, on the other hand, the warping or thickness of an optically thick disk is on the order of its diameter times the cosine of its inclination or if the emissivity is a function of position a ring cannot be excluded from our data. Convolving the optical rotation curve given by Bland (1985) to a resolution of 45″ we find that a velocity dispersion of approximately 60 km s^{-1} (FWHM 150 km s^{-1}) is required to produce a velocity-position diagram like the measured one shown in Fig.1. This is in good agreement with the Hα velocity dispersion maps presented by Bland *et al.* (1987) and about a factor of two smaller than the value of 140 km s^{-1} reported by Bertola *et al.* (1985) for the stellar component along a position angle of 35° perpendicular to the dust lane. The line width along the dust lane is approximately constant and we find no evidence for enhanced turbulent motion at the nucleus. At velocities of about 300 and 800 km s^{-1} there is a sharp transition between the rising and the flat part of the rotation curve. The latter is better sampled by the HI data of van Gorkom (1987). In the south east strong HI emission also extends into the inner 180″. Fig.2 shows the velocity-position diagram perpendicular to the dust lane at a position angle of 35° along with the velocity measurements for the stellar component by Bertola *et al.* (1985). Our CO data exhibits a gradient which is consistent with the velocity gradient indicated by the stellar data. This implies that the CO disk is not decoupled from the motion of the stellar, elliptical component about the projected minor axis of the light distribution (see also Wilkinson *et al.* 1986), underlining the complexity of the kinematics in Centaurus A.

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Kinematics and Distribution of the Absorbing Gas: In Fig.3 we show the HCO^+ spectrum in which the different absorption features are most easily discussed. Most prominent are three narrow features A,B, and C at v_{LSR}=550±1 kms^{-1}, 540±1 kms^{-1}, 544±1 kms^{-1}, respectively. The HCO^+(1-0) spectrum also reveals two broad troughs centered at about 580 kms^{-1} and 604 kms^{-1} probably corresponding to the HI absorptions at 576 and 595.5 km s^{-1} which have been attributed to infalling gas within 500 pc of the nucleus (van der Hulst *et al.* 1983). The spatially unresolved line features are most probably due to absorption of the continuum emission by molecular clouds in our line-of-sight to the compact, nuclear continuum source. From our data there is no indication that these clouds have to be particularly close to the nucleus. The observed velocity differences between individual absorption line features do not appear to be peculiar compared to the velocity dispersion of 60 km s^{-1} in the molecular disk (Paper I). The central HI absorption feature shows a frequency shift as a function of position against the jet components that is consistent with the rotation curve (van der Hulst *et al.* 1983). This indicates that the absorption takes place in clouds all along the line of sight through the galaxy. Assuming that the absorbing atomic and molecular gas components are well "mixed" along this line we estimate a **mean distance** of the absorbing material from the nucleus of the order of **1 kpc** (the diameter of the molecular disk is about 2.6 kpc; Paper I). The (FWHM) line widths of the different ^{12}CO(1-0) absorption features close to the systemic velocity of Centaurus A are well within the range of line widths measured for single molecular clouds in our Galaxy (Solomon *et al.* 1987).

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Fig.1

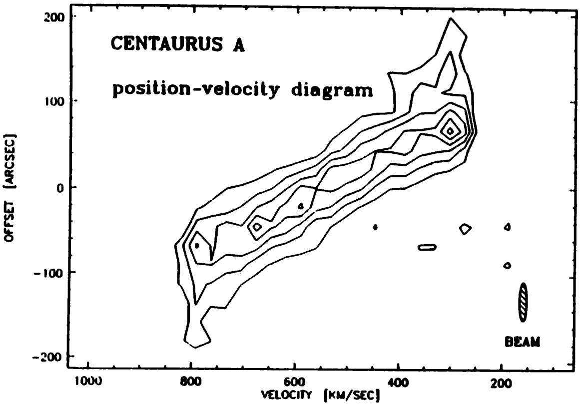
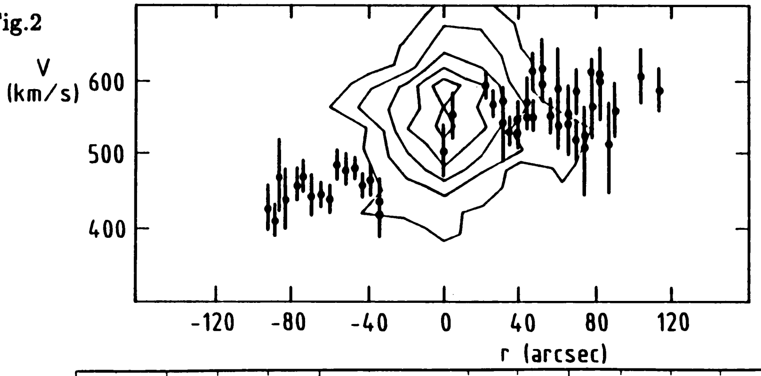


Fig.2



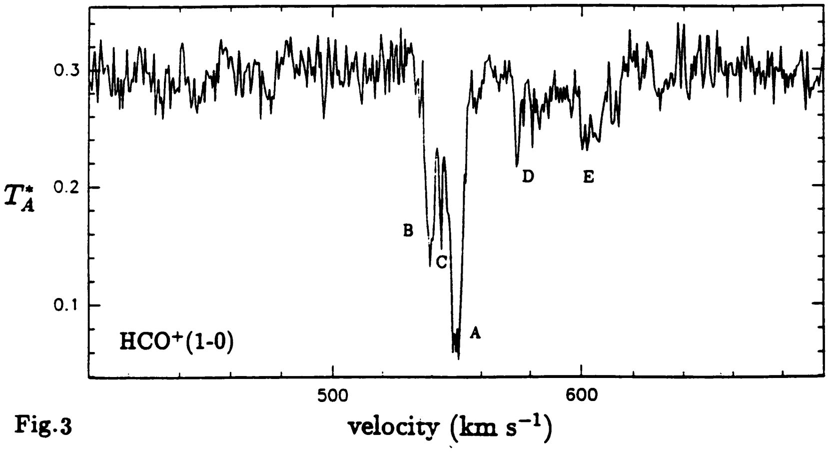


Fig.3