Continuum observations of Sgr A at mm/submm wavelengths

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We have mapped the source complex Sgr A (containing Sgr A West and East) at λ2.8mm, 1.3mm and 350μm using the IRAM 30m MRT (Pico Veleta, Spain) and the 3m IRTF (Mauna Kea, Hawaii) telescopes. Detailed results have been published or will be published elsewhere (Mezger et al., 1986, Paper I; Zylka and Mezger, 1988, Paper II; Mezger et al., 1988, Paper III).

The following results were obtained :

1) The flux density of Sgr A* increases from ~1Jy at λ2cm to ~2.5Jy at λ1.3mm. Between epoch 1981.3 and 1986/87 the spectrum of Sgr A* appears to have steepened (Paper II, see also Fig.1b, this paper). A secular variation at decimeter wavelengths resulting in a steepening of the spectrum has been observed previously (Brown and Lo, 1982) and was then accompanied by emission of the positronium annihilation line. But for the last few years the radio spectrum of Sgr A* was stationary and the gamma ray line has been absent (This correlation has been pointed out to us by R.L. Brown, priv.comm.).

2) Between λ2cm and 1.3mm the spectrum of Sgr A West is that of optically thin free-free emission. Significant optical thickness sets in at λ≥6cm, while dust emission becomes noticeable at λ≤1.3mm (Paper III; see also Fig.1c, this paper).

3) The circum-nuclear disk (CND) which surrounds Sgr A West and extends at least ~8pc to the north and south of Sgr A*, contains $\sim 10^4 m_\odot$ of hydrogen. It consists of clumps of a few hundred $m_\odot$ with typical densities of $\sim 10^5 cm^{-3}$ (Paper III). This picture is in general agreement with the model suggested by Genzel and co-workers (e.g. Genzel et al., 1985; Genzel, 1986).

4) We have detected a dust ring surrounding the synchrotron shell source Sgr A East, whose eastern rim coincides with the region of highest hydrogen column density in the GMC M-0.02-0.07 and whose western rim coincides with the CND surrounding Sgr A West. This ring, which we

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interpret as a partial shell surrounding Sgr A East, is elliptical with an inner major diameter of ~10pc along the galactic plane. It has been previously observed in OH and H_2CO absorption and has a total gas mass of ~6 $10^4 m_\odot$. The synchrotron shell source and the associated shell of dust and gas appear to be the result of an explosive event which occurred inside a GMC of density ~$10^4 cm^{-3}$. A "normal" supernova explosion with a typical energy input of ~10^{51} erg is ruled out. Four alternatives are discussed, two of which are found to be consistent with observations: a) We follow the suggestion by Yusef-Zadeh and Morris (1987) that Sgr A East with its surrounding shell of dust and gas is due to an explosive event which occurred close to Sgr A*. In this case an energy input of >4 10^{52} erg is required. This energy could be considerably lower, if the shell was created by a wind from the galactic center prior to the explosion. b) The dust shell is due to a stellar wind from a massive star which later exploded. The synchrotron source Sgr A East would then result from the interaction between supernova ejecta and this "progenitor bubble" (Paper III). We prefer the first alternative. This dust ring is also visible in molecular line absorption (Sandqvist, 1974; Whiteoak et al, 1974; Sandqvist et al, 1987) and emission (our observations with the MRT; in prep.; see also Fig.2a,c, this paper).

5) We suggest that the CND surrounding Sgr A West is a transient feature, which was formed when the swept-up material of the dust shell interacted with the mass concentration of stars near the galactic center. The CND is an inconspicuous feature when compared to the masses of both the dust ring surrounding Sgr A East (~$6 \cdot 10^4 m_\odot$) and the GMCs M-0.02-0.07 and M-0.13-0.08 (~5 $10^5 m_\odot$ per cloud) (Paper I and III; see also Fig.2b, this paper).

6) Putting together recent continuum and line data the following geometry of the source complex Sgr A emerges: Sgr A West is located in front of or close to the surface of Sgr A East. The explosive event which created Sgr A East occurred inside a giant molecular cloud but close to both its surface facing the sun and its western edge. It appears to have dispersed most of the gas in front of Sgr A West and thus could explain the remarkably low and uniform extinction across Sgr A West. Towards the east and south the expanding shell hit the bulk of the mass of the GMCs M-0.02-0.07 and M-0.13-0.08, while towards the west it may have disrupted the cloud. It could not disperse, however, the back part of the cloud in which it exploded and which is seen as a smooth gas layer of column density ~4.5 $10^{22} cm^{-2}$. The CND is inclined by an angle i~50°-70° (i=90°:edge-on) towards the line-of-sight. It appears that the front face of the GMC, where it intersects with the cavity containing Sgr A East, is similarly inclined (Paper III).

7) Although gas density and gas mass integrated over the inner 10pc are high the gas-to total mass-ratio is less than 1% due to the high stellar concentration in this region.

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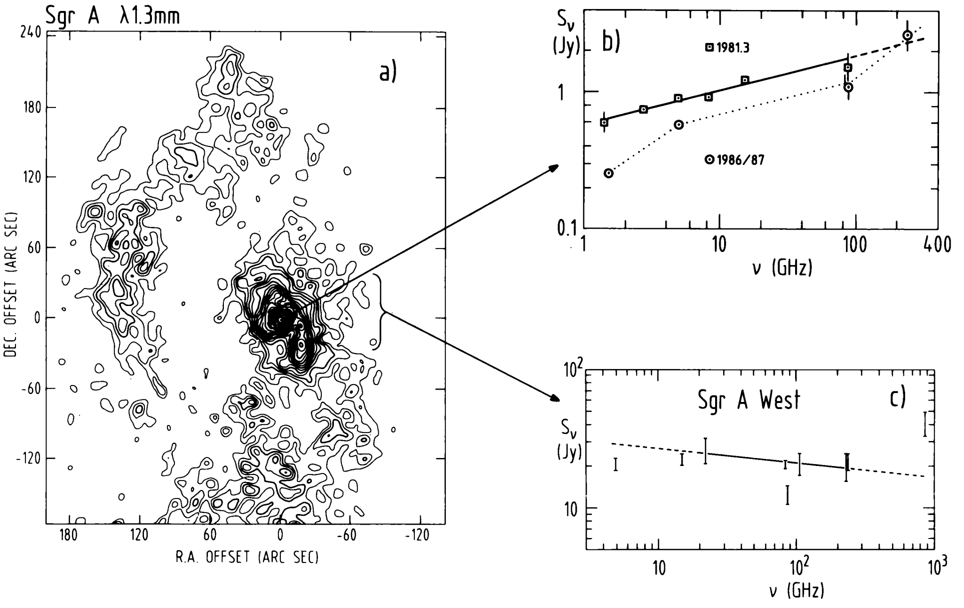

Fig. 1a: λ1.3mm, θ_A=11" map of the Sgr A complex made with the 30m MRT on Pico Veleta, southern Spain. Contours are at 90, 160...930, 1230, 1530...3330mJy (11"-beam)$^{-1}$ (Paper III). 1b: The spectrum of Sgr A as derived by Backer (1982) for the epoch 1981.3 (open squares and solid/dashed curve). A possible steepened spectrum for the epoch 1986/87 (open circles and dotted curve) based on flux density measurements of 0.25Jy at 1.5GHz, 0.55Jy at 5GHz (Lo, priv.comm.) 1.05Jy at 86GHz (Wright et al., 1987) and 2.5Jy at 230GHz. 1c: The spectrum of Sgr A West, corrected for the contributions from Sgr A*. Flux densities are from Paper III, Table 2. The superposed line indicates the spectrum of optically thin free-free emission ($S_\nu \propto \nu^{-0.1}$).*

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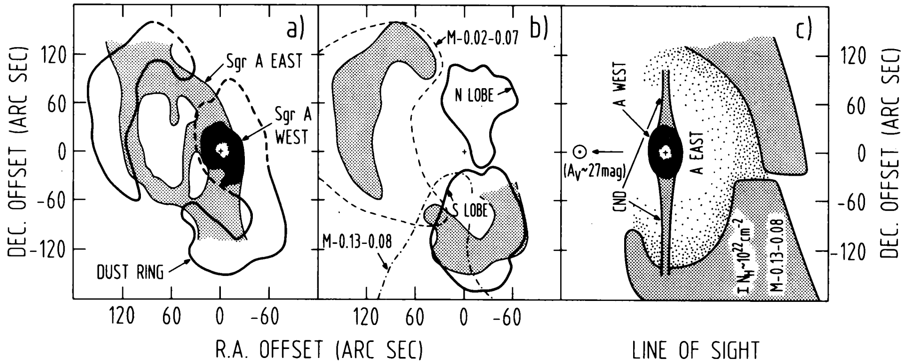

Fig. 2: Illustration of the spatial arrangement of the various features of the Sgr A complex. Crosses indicate the position of Sgr A. a) Spatial coincidence perpendicular to the line-of-sight of the dust ring, the synchrotron source Sgr A East and the HII region Sgr A West; and b) of the GMCs M-0.02-0.07 and M-0.13-0.08, dust ring (shaded area) and of the northern and southern lobes of the circumnuclear disk (CND) c) A simplified possible spatial arrangement in the line-of-sight direction drawn as a cross section in declination through the position of Sgr A*. The thickness of the neutral gas components is an indication of the hydrogen column density observed in this direction. Note that the CND, and possibly also the cavity, are actually not seen edge-on (inclination angle i=90°) but at an angle of i~70° (see text).*

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