RECOMBINATION-LINE OBSERVATIONS OF THE GALACTIC CENTRE

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ABSTRACT

Aperture-synthesis observations of the H76α and H110α recombination lines are presented for the inner (3pc) region of the Galactic Nucleus. The large line width measured with single dishes (Pauls et al., 1974) is caused by well-ordered large-scale motions of the ionized gas. The velocities of the NeII clumps (Lacy et al., 1980) fit well into our smooth velocity field and smooth intensity distribution. We suggest therefore that the cloud picture of the NeII gas is (at least partly) invalid.

1. INTRODUCTION

The presence of multiple, curved thermal features in the immediate vicinity of the Galactic Centre (Ekers et al., 1983) makes it possible to get kinematical information on the inner part of the Galaxy by recombination-line observations. Already single-dish observations of various recombination lines of hydrogen have shown (cf. Pauls et al., 1974) the lines are unusually wide, reflecting the existence of high velocities.

Fig. 4 in the paper by Oort (1984, this volume) shows the 20-cm continuum observations of Ekers et al. (1983), where one sees the spiral-shaped, thermal feature imbedded in a larger non-thermal shell. We present here results of the H76α line at 2 cm of this thermal 'spiral', observed with the VLA, and the H110α line observed at Westerbork. The results are then compared with the [NeII] observations by Lacy et al. (1980), and we give some contribution to the discussion of possible models to explain the results.

2. THE OBSERVATIONS

The VLA observations at 2 cm of the H76α line were made in January 1982, using the inner 18 antennas in the C configuration (0.1 to 1.7 km baselines). The continuum is shown in Fig. 1 of the preceding paper by Oort (1984). We fitted Gaussians to the spectra at each position in the

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maps, which were smoothed to a 4".5 × 4".5 resolution in order to improve the signal/noise ratio. The peak line intensity and velocity field are shown in Fig. 1a.

The H110α-line observations at 6 cm were made with the WSRT with a 3" × 20" resolution (Bregman and Schwarz, 1982). The spectra were also fitted with Gaussians and the results are shown in Fig. 1b.

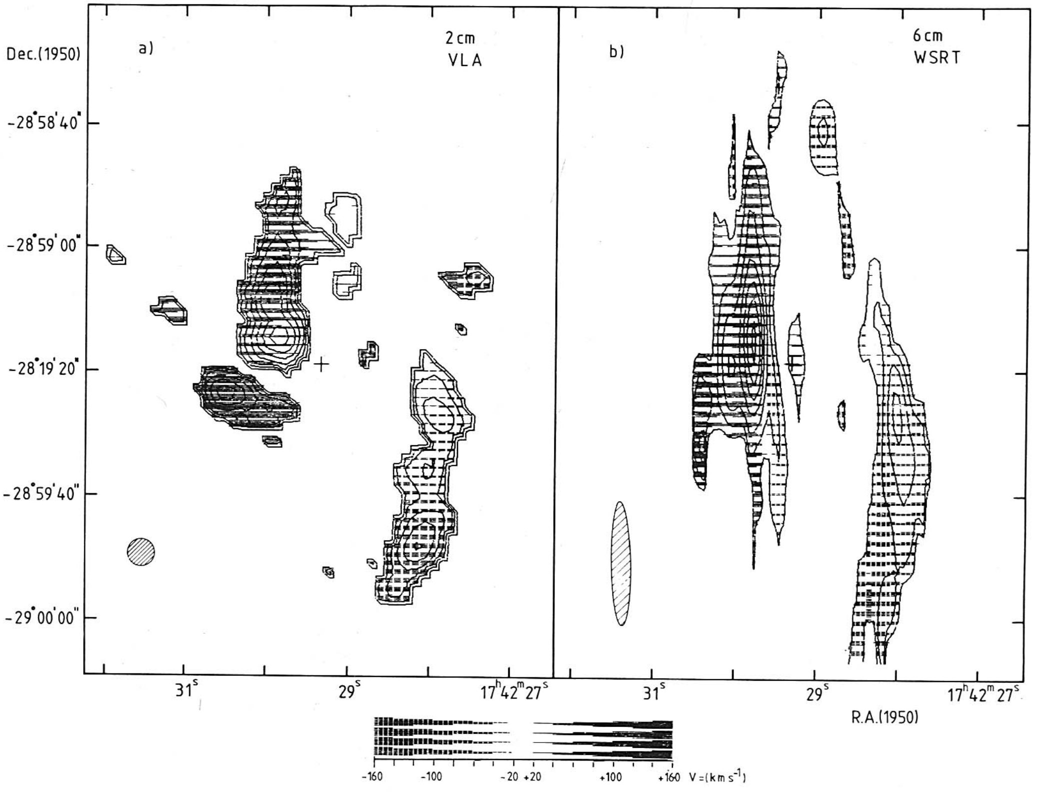

Fig. 1

a. VLA map of the H76α recombination line (2 cm). The contours give the peak intensity of the line (the contours are: 1.3, 2.6, ... K) whereas the raster gives the velocity, cf. the key at the bottom. The beam is 4.5 × 4.5 arcsec (shaded circle), the velocity resolution 32 km/s.

The large-scale structure and the regular velocity field of the main features are clearly seen.

b. WSRT map of the H110α recombination line (6 cm), as Fig. 1a. The contours correspond to 3.3, 5, 6.6, 8.3, 10 K. The beam is 3 × 20 arcsec (shaded ellipse), the velocity resolution 67 km/s.

The three elongated features all show a remarkable degree of coherence in velocity. The NS features appear to rotate around the Centre, with an axis close to that of the general galactic rotation. The EW features suggest that in- or outflow is occurring. The average line width of the H76α line is 40-50 km s^{-1}; at the bend in the N arm it goes up to 100 km s^{-1}, which is probably a blend of 2 features.

The electron temperature (Fig. 2) derived from the H76α results (the assumption of LTE will not affect the numbers significantly) shows the same degree of coherence and seems to go up close to the Centre. The fact that we do not see lines very close to the Centre, combined with the fact that [NeII] lines have been detected there, makes it likely that the electron temperature is greater than 12000K in the Centre.

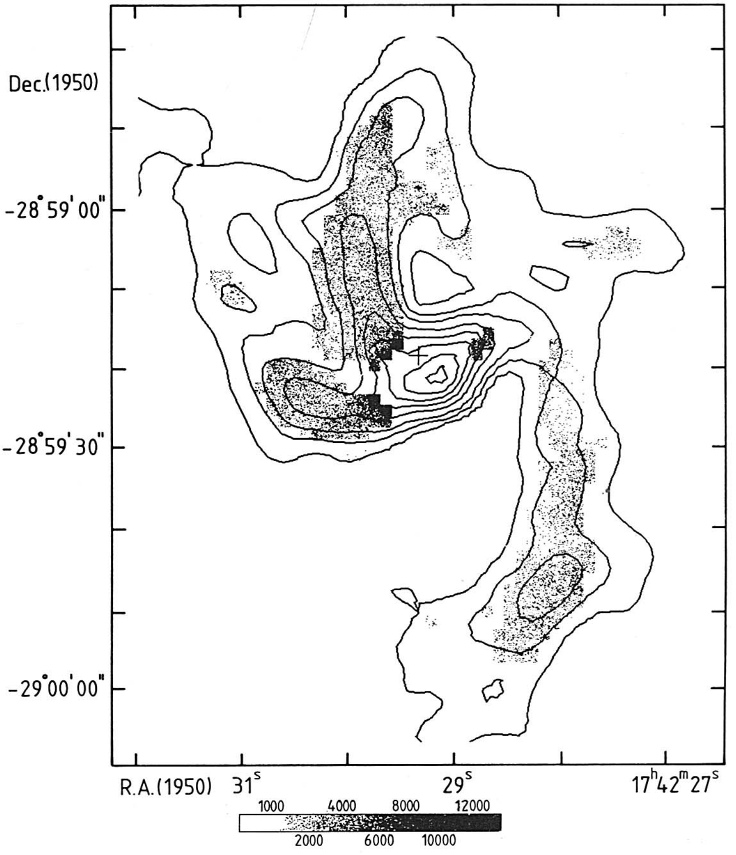

Fig. 2
2-cm continuum map, smoothed to 4.5 × 4.5 arcsec resolution. The contours are at 2.7, 13, 26, 39, ...K. The gray tone gives the electron temperature, derived from the line-to-continuum ratio assuming LTE. The cross gives the position of the non-thermal point-source, which was subtracted. At the centre where we detect no recombination line, the temperatures must be higher than 12000K.

3. COMPARISON WITH [NeII] LINE OBSERVATIONS.

In Fig. 3 we give the H76α results with intensity and velocity contours, together with the [NeII] concentrations as derived by Lacy et al. (1980). There is mostly an excellent agreement. The highest [NeII] velocities are found closest to the centre, where we cannot detect a recombination line.

The excellent agreement between the regular velocity field based on the recombination lines in the spiral features and the velocities of the [NeII] 'clumps' can hardly be fortuitous. Are the 'clumps' imbedded in the large-scale features, or is it possible to interpret the [NeII] results in a different way than in terms of 'clumps'? In any case this apparent morphological difference cannot be an effect of the limited resolution: the 2-cm continuum observations with the original 2 × 3 arcsec resolution, which is superior to the 3 × 3" resolution of the [NeII] observations, do also show the filamentary large-scale structure. In order to answer the above question, we tried to reanalyze the [NeII] data in a similar way as the recombination-line results, by fitting Gaussians to the spectra, within the regularly sampled region. At many positions, mainly in the Centre region, there was more than one Gaussian. But if we exclude components with velocities $|V| > 170$ kms^{-1}, we find one prominent component per position. Amplitude and mean velocity of these components are shown in Fig. 4. Clearly one sees the 'roots' of two of the three spiral features on the E side of the point source; these 'roots' are in perfect agreement with the recombination-line results. Also towards the W of the point source the distributions of [NeII] and its velocity are very smooth.

We therefore conclude that at least part of the [NeII] line originates in the same distributed gas as the recombination lines; possibly there are in addition small [NeII] features. The same conclusion was put forward by Bregman and Schwarz (1982).

4. DISCUSSION

A range of possible interpretations of these data has been discussed by Ekers et al. (1983), who favour tidal distortion of infalling material. We do not want to repeat that discussion here; see also the discussion by Oort in this Volume.

We would like to point out one thing here which is not emphasized by Ekers et al. (1983). The whole complex Sgr A East + West shows a remarkable similarity in the radio continuum to other supernova remnants. The filamentary structure in West and the extension of the N arm outside the shell looks just like the Crab. An obvious difference with other supernova remnants is the large amount of thermal gas and the presence of many infrared sources. A possible alternative interpretation is that a supernova has gone off near a dense, rotating molecular cloud.

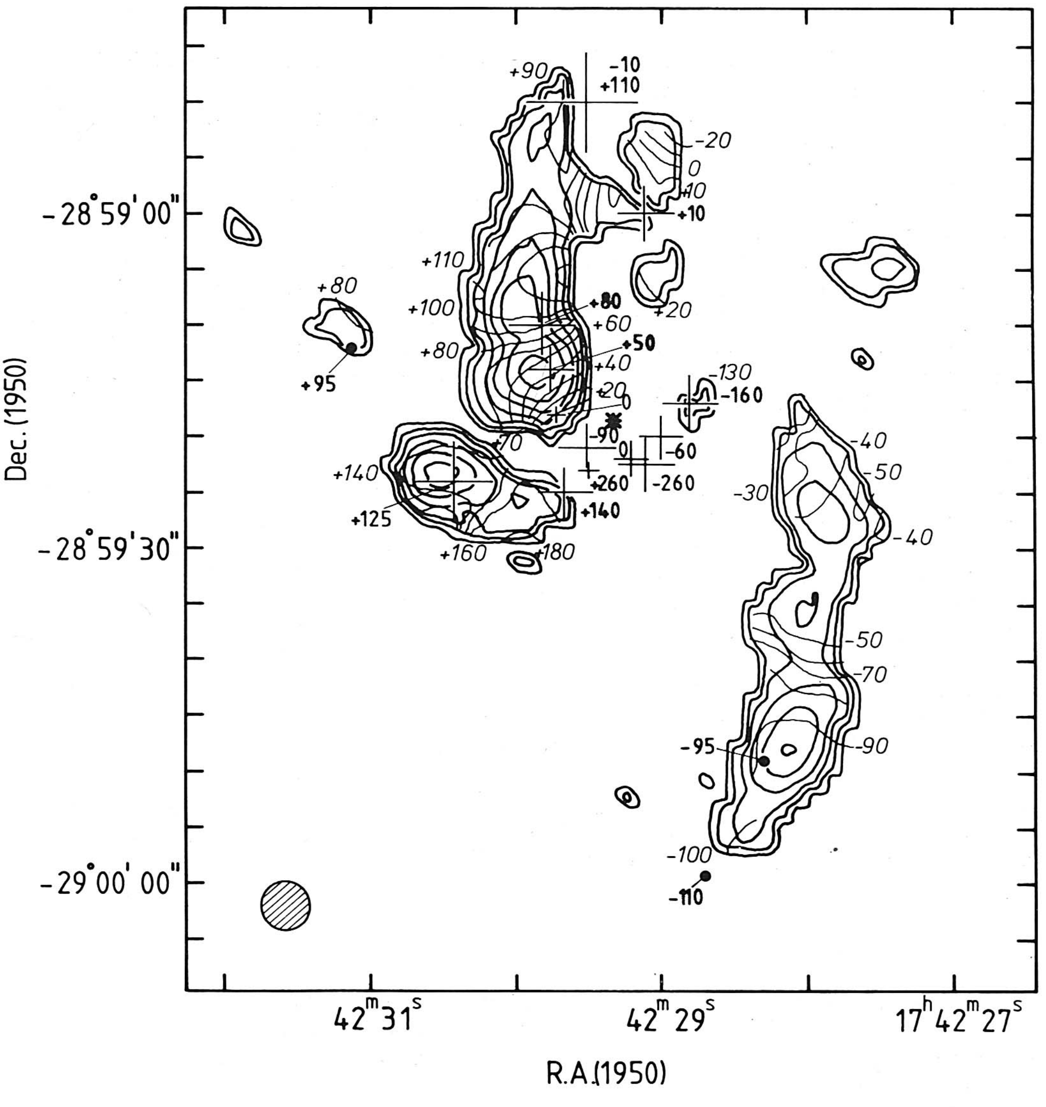

Fig. 3
Comparison of H76α and [NeII] results. Contours show peak intensity and velocity (slanted numbers) of the H76α line (cf. Fig. 1a); the concentration in the NW has a velocity of − 85 km s^{-1}. The crosses indicate positions and sizes of the [NeII] 'clumps', upright numbers (in shaded rectangle) velocities as found by Lacy et al. (1980). A few positions are added with our own estimates of velocities. The agreement between the [NeII] velocities and the recombination-line velocities is very good. The asterisk indicates the position of the point source.

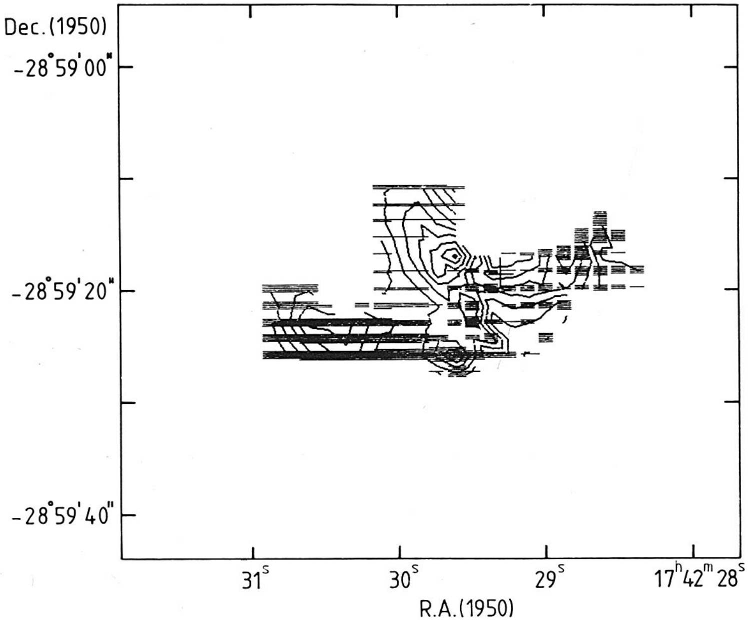

Fig. 4

Peak intensity and velocity of the [NeII] line. A Gaussian fitting was applied to the spectra. Components with velocities $|V| > 170$ km s^{-1} were left out, for key of the velocities see Fig. 1. The scale is the same as for Fig. 3.

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DISCUSSION

R.H. Sanders: This southern arm is quite a bit fainter than the rest of the structure, and it seems to fit rather well into the general shape of the larger shell described by Oort in his review. Do you consider it possible that this southern arm is not connected to the three-armed structure closer to the Centre?

Schwarz: The continuum data may indicate a weak link between the southern arm and the large shell. In the northern arm there is no such relation.