THE GALACTIC CENTRE

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I would like to start by bringing the good wishes of Australian radio astronomers to this new group which is joining us in the radio study of the southern sky.

The nuclear regions of galaxies are generally considered as regions of high density, with population II stars in a "nuclear bulge". In some galaxies, the presence of gas in the nucleus is shown by the appearance of the OII 3727 doublet, sometimes with a high velocity dispersion. Some nearby galaxies (e.g. M 31, M 33, M 51) show a small very bright spot, right at the nucleus, of the order of 10 pc in diameter. Non-circular velocities have been found near the centre in some galaxies.

Optical observations of our own galactic nucleus are very difficult, as there is at least 9^m of absorption between us and the centre. Baade has studied a star cluster near the centre (in the bulge), and Courtes has observed ionized hydrogen patches with high velocities, which are presumably in the nucleus. But there are very few optical observations, and the main study must be done by radio. We in the south are very well placed for work on the central region.

There are several radio approaches, involving the continuum and various radio lines. The region is found to be very complex, and many problems remain.

THE CONTINUUM

The most interesting (that is the most informative) region of the continuum is 1-100 cm in wavelength. Over all of this range, the main radiation is from the Milky Way belt, with a concentration in the region of the centre.

The first striking conclusion about the central part is the small angular width of the emitting layer, which must be quite thin, with no relation to the stellar bulge.

Two types of continuum emission processes take place in the Galaxy: (i) thermal emission from HII regions, through free-free transitions, and (ii) non-thermal emission from the synchrotron process, from electrons spiralling in a magnetic field. The two types can be best distinguished by their spectra. The thermal component becomes relatively more important as the wavelength is reduced.

The strong central source is known as Sagittarius A. The central complex was first resolved into separate components by Drake (1960). Subsequently the details of the regions have been studied in the following published surveys:

Authors	Wavelength cm	Beamwidth
Cooper and Price (1964)	11	6.7
Broten et al (1965)	6	4.0
Downes, Maxwell and Meeks (1965)	3.6	4.2
Hollinger (1965)	2.1	5.9
Downes, Maxwell and Meeks (1965)	1.9	2.2

These surveys all show a number of components, one to the south, and three to the north of the central peak. (The papers should be consulted for details). Spectral studies have been carried out by Cooper and Price (1964), Burke (1965), and Downes (1965). By separating the components as well as possible, and then comparing the data at different wavelengths all agree that the main Sgr-A component is non-thermal in origin, whereas the other components all appear to be thermal.

There is no direct evidence from the continuum observations themselves that all the components are actually located in the vicinity of the centre; however our hydrogen-line absorption observations indicate that the three strongest components, and probably the whole complex, are physically associated, and located at the centre.

The angular size of the strong central component is 4 min arc, equivalent to 12 pc at the distance of the galactic centre. The best position for Sgr A, from all the available observations, is:

$$\alpha = 17^h\ 42^m\ 28^s \quad \text{(1950)} \qquad l^{II} = 359^\circ\ 58'$$
$$\delta = -28^\circ\ 58'.5 \qquad\qquad b^{II} = -0^\circ\ 03'$$

We have surveyed a larger area of 60 square degrees around the galactic centre (Kerr and Sinclair, in preparation). The results for the whole region are not yet available, but the pattern of the "ridgelines" shows some interesting features (Figure 1). This pattern is extremely symmetrical about the position of Sgr A, and in fact shows a higher degree of symmetry than any other aspect of the galactic centre observations. It also includes features which are steeply inclined to the galactic equator and strongly suggest ejection of material. The main galactic ridge shows a pronounced tilt over several degrees of longitude, which is in the same sense as that found for high-velocity neutral hydrogen.

21-cm HYDROGEN LINE

Very strong absorption effects are found in the spectrum of Sagittarius A in the frequency range of the 21-cm hydrogen line (Figure 2). There are deep absorption components associated with hydrogen in the nearby spiral arms (near zero velocity) and in the "3-kpc" arm (near -50 km sec). Absorption is found over a wide range of negative and positive velocity.

In the vicinity of the centre, both absorption and emission show considerable fine structure (Rougoor 1964, Kerr 1964, Kerr and Vallak 1966). Large outward motions are indicated for much of the hydrogen. An example of the detail available is shown in Figure 3, which gives the hydrogen distribution along the equator in the longitude range 355º-5º.

One of the most interesting features in the central region is the way that the high velocity meterial is inclined to the galactic plane.

Figure 4 shows the latitude of the high velocity ($|v| > 100$ km/sec) peak as a function of longitude; the diagram is based on positive-velocity material for $\ell^{II} > 360º$, and negative-velocity gas for $\ell^{II} < 360º$. The pattern is roughly symmetrical, with a long extension out of the galactic plane on each side. The southern feature probably joins on to the 3-kpc arm, which is itself well north of the plane over a considerable range of longitude; however the northern section appears to fade out at the northernmost longitudes.

The major "expanding" arm, usually known as the 3-kpc arm, can be followed from ℓ^{II} = 4º to 336º, but it is not clear whether it is a single continuous feature. There is a major complexity at 348º, and another at about 342º, and the overall arrangement is not clear. There are probably several branches, and also cross-links to other parts of the spiral pattern.

A possible structure for the whole central region is shown in Figure 5. In the centre is a rapidly-rotating feature, possibly a disk as proposed by the Dutch, with some expansion motion in its outer parts. From this disk there may be a rudimentary bar, inclined to the galactic plane, which contains much of the high-velocity material. Further out, and possibly connected to the bar, is the "3 kpc arm", with a less regular counterpart on the opposite side. Minor features are certainly present, but cannot be located in space. There is a general appearance of quadrantal symmetry. The picture proposed here is consistent with the observations, but cannot be regarded as well established, as there is no way of establishing distances for most of the hydrogen in the central regions.

OH LINES

The OH group of lines near 18 cm has been observed in the galactic nucleus by the Australian group (Robinson et al 1964; Bolton et al 1964). The OH abundance in some parts of this region is 100 times that observed near the Sun. The relative strengths of the various lines are quite different from those expected theoretically and the ratios vary greatly from point to point. The OH observations in this region have all been in absorption so far, except for a small component of emission at one point.

The OH absorption spectrum for Sgr A is shown in Figure 6 for the 1667 Mc/s line. The two strongest components are at velocities around + 40 and -120 km/sec. The great strength of the former component indicated that a considerable proportion of the OH has a component of motion towards the Sgr-A source, i.e. presumably towards the "centre". Components at the OH velocities can be seen in the hydrogen absorption profile (Figure 2), but they are much less important in the hydrogen pattern.

In discussing the distribution and motions of the OH sources, Bolton et al (1964) stress some minor features which appear to have a constant velocity over a few degrees of longitude. However, the greatest kinetic energy appears to be associated with a slow rotational motion.

The present author considers that the OH is located in the outer part of the nuclear "disk", because it extends over several degrees in longitude, and also it exhibits a low rotational velocity. Rougoor (1964) has already suggested that the rotational velocity of the hydrogen falls off in this region.

HYDROGEN RECOMBINATION LINE

Mezger (1966) has recently detected a hydrogen line near 6 cm, which corresponds to the transition from $n = 109$ to 108, in two components of the galactic centre source. The line was not observable in the main Sgr-A component. As this line is only emitted in H II regions, this results supports the view that the central component is nonthermal in origin, while the other components are thermal.

X-RAYS

A number of X-ray sources have recently been found in observations from rockets. The only one identified so far is associated with the Crab nebula. There is a cluster of other sources in Sagittarius and Scorpius. None of these coincides with the radio source Sgr A, but the clustering in this direction suggests a relation with the nuclear disk (Johnson 1966). However it should be emphazized that no individual correlations have been found with nuclear objects and it should be noted that the X-ray sources show a greater apread in latitude than the radio-emitting region in the nucleus.

CONCLUSION

The central region has many complexities. We have some idea of its structure, but our interpretation must still be inconclusive. There is a forthcoming series of lunar occultations of the galactic centre, from 1967 to 1970, which should yield more information on the fine structure of the region. Unfortunately, parallax moves the apparent position of the Moon northwards for a southern observatory, and consequently Parkes and Pereyra will not see any occultations of Sgr A. In this case, we must leave the main work to northern observatories.

I conclude this review about one part of the galaxy by saying that there is still plenty to be discovered, as in fact there is in the whole Galaxy. I am sure that this new telescope, which is so well placed geographically for galactic studies, will play an important part in attacking the many problems that are to be found in the Galaxy.

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LEGENDS TO FIGURES

Fig. 1 Location of 20-cm continuum "ridge lines" in the galactic centre region.

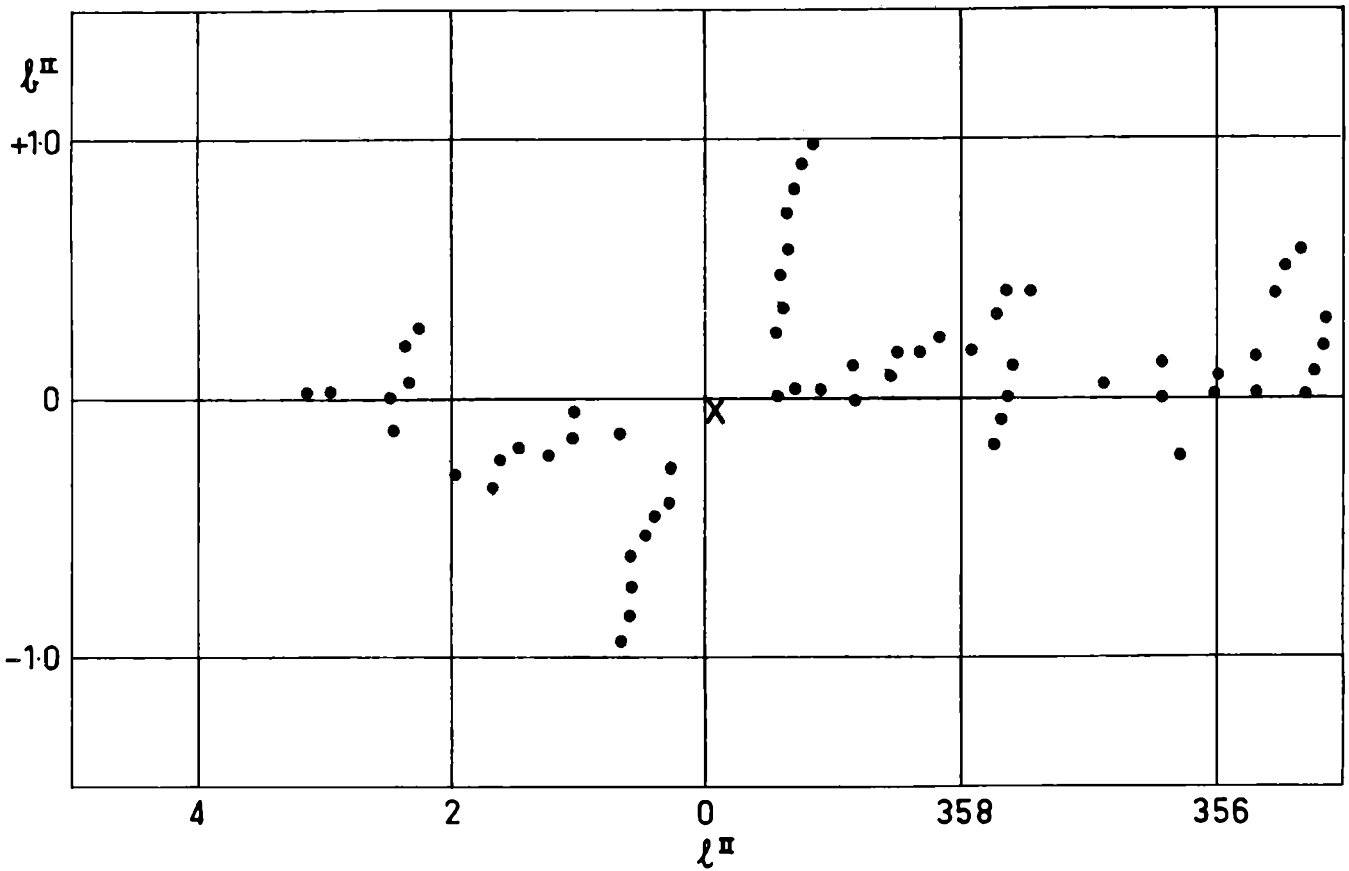
Fig. 2 21-cm absorption profile for Sgr A, together with the estimated emission profile in the absence of absorption.

Fig. 3 Hydrogen contour diagram along galactic equator (scale unit = 1.4°K in T_A).

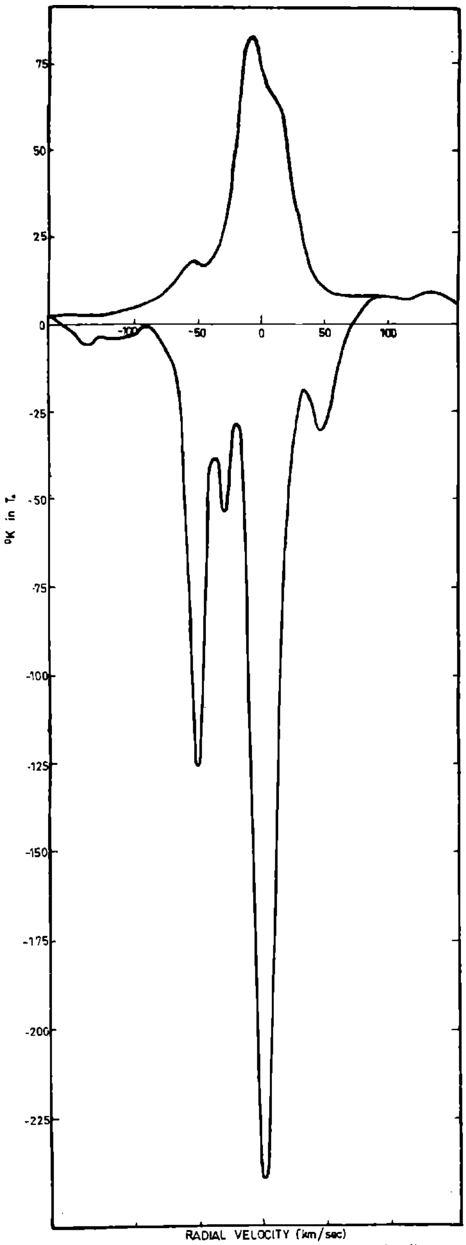
Fig. 4 Latitude of high-velocity hydrogen peak.

Fig. 5 A possible structure for the galactic centre region.

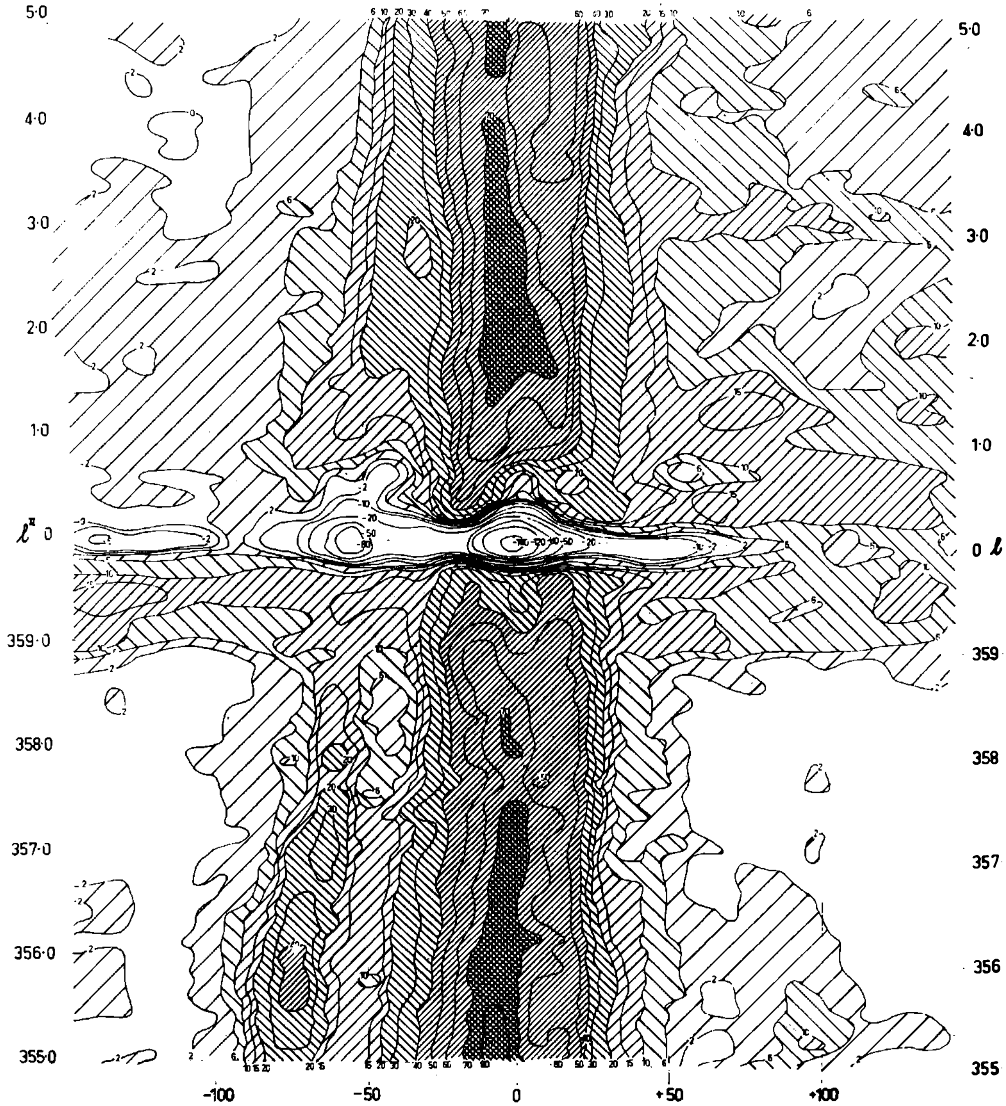
Fig. 6 OH absorption profile for Sgr A (1667 Mc/s). The 21-cm profile is drawn as a dashed line, on an arbitrary scale. (Robinson *et al*. 1964).



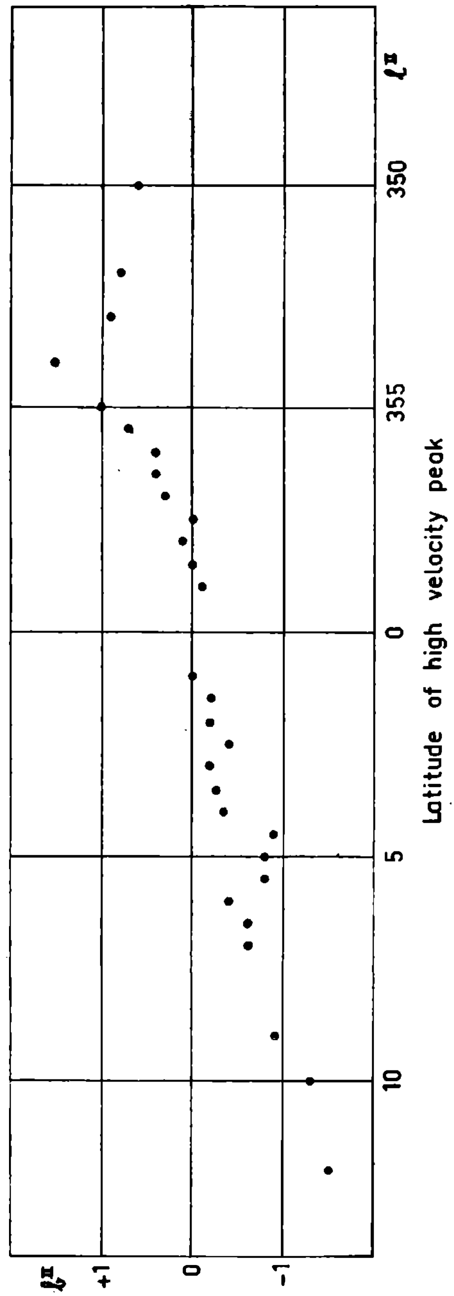
20cm continuum ridge lines



GALACTIC CENTRE - Assumed emission & observed absorption profiles.



CONTOUR DIAGRAM ALONG GALACTIC EQUATOR (Scale unit = 1·2 °K in T_A)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5
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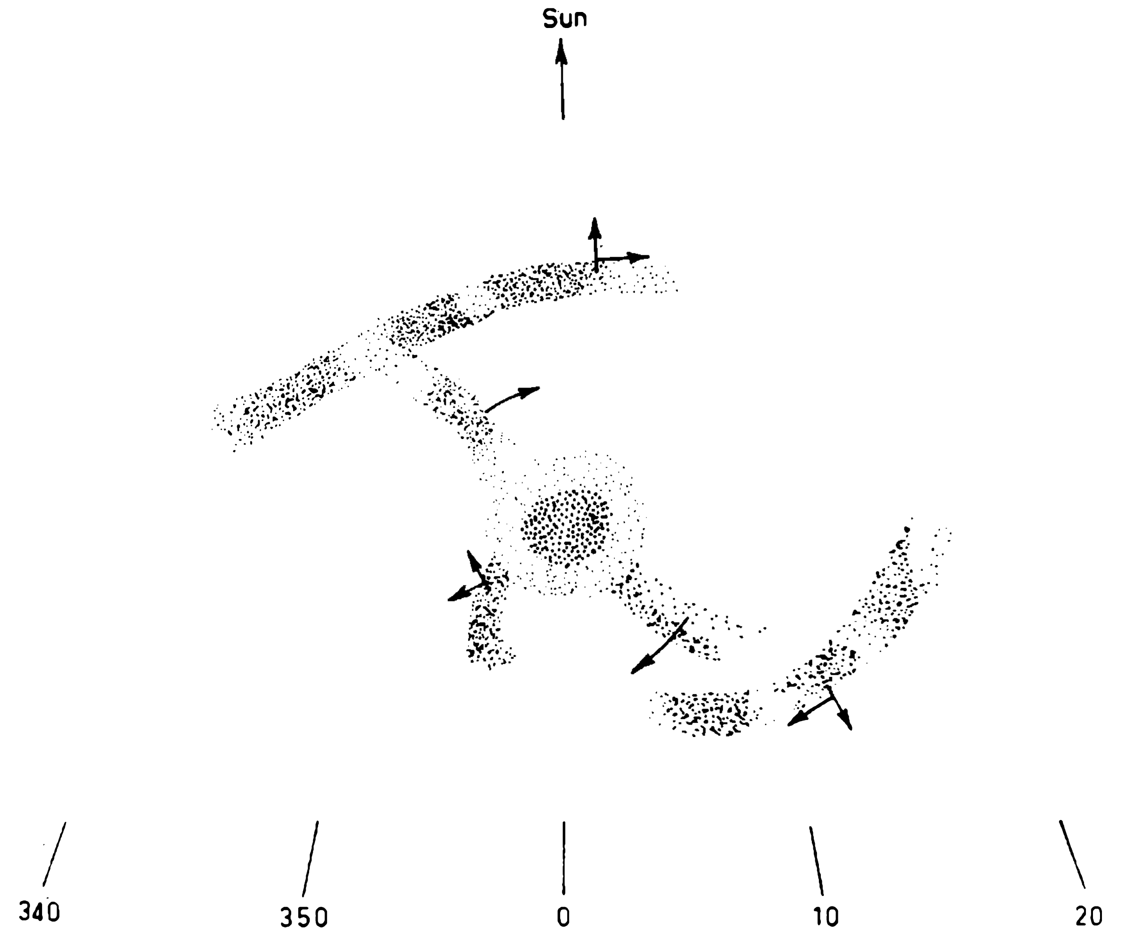
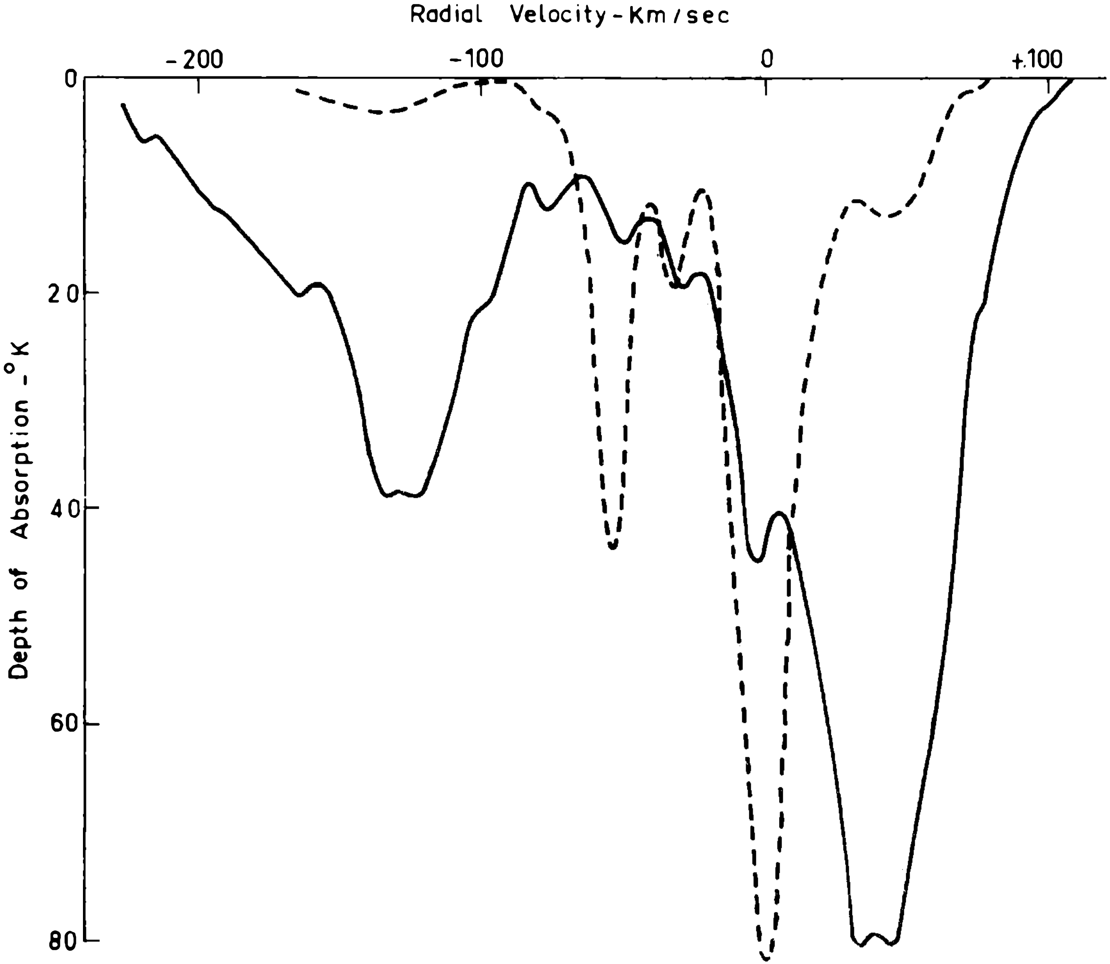
ℓII
bII
+1
0
-1



A possible structure for the galactic centre region


Radial Velocity - Km / sec
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-100
0
+100
Depth of Absorption - °K
0
20
40
60
80