A peculiar feature at l^{II} = 40°.5, b^{II} = - 15°.0

Smith, G.P.

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A PECULIAR FEATURE AT $l^{II} = 40°.5$, $b^{II} = -15°.0$

GAIL P. SMITH*

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A peculiar feature centred at $l^{II} = 40°.5$, $b^{II} = -15°.0$ was found to have a radial velocity of + 89.7 km/sec relative to the local standard of rest. Its density varies between 2 and 25 × 10^{19} hydrogen atoms/cm² and it covers 8° by 3° in the sky. The mean square random radial velocity is 14.8 km/sec. Different parts of the cloud have systematic velocities relative to the average for the whole feature, which may indicate either an expansion or a rotation. The most likely interpretation seems to be that the feature is an extension of the galactic structure.

1. Observations

During an investigation in the 21-cm hydrogen line with the Dwingeloo radio telescope, a peculiar feature centred at $l^{II} = 40°.5$, $b^{II} = -15°.0$, was found clearly separated from the ordinary galactic structure. In order to carry out a detailed study of this feature, a special series of observations was made at 1° intervals. The measurements used in this programme were made with the new eight-channel hydrogen-line receiver mounted in the 25-metre radio telescope of the Netherlands Foundation for Radio Astronomy in Dwingeloo. This receiver will be described in detail by its designer, C. A. Muller, in a forthcoming article. The observing time was 150 hours during the summers of 1961, 1962 and 1963. The bandwidth used was 16 kc/sec or 3.4 km/sec. The profiles were reduced on the X1 electronic computer at the computing centre of the Leiden University; the reduction programme was written by E. Raimond in collaboration with T. Hoekema and J. Hirsch (1961). All velocities are given with respect to the local standard of rest.

Profiles were obtained in a 1° net between $l^{II} = 36°.5$ and $l^{II} = 48°.5$ and between $b^{II} = -11°.0$ and $b^{II} = -21°.0$. Of the 97 profiles obtained, 30 showed traces of the feature. Figure 1 is a representative profile from this region. The initial peak at low positive velocities arises from the ordinary galactic structure. The secondary peak at +103.5 km/sec is the radiation received from the feature. The criterion used to establish the presence of the feature on a profile is also illustrated in figure 1. At some velocity a, the initial intensity has fallen below 1 °K. The feature "existed" on the profile if the intensity then rose above 1 °K at a velocity greater than a; in figure 1, therefore, the region beyond b establishes the presence of the feature. The velocity range of the feature can then be determined as follows: The minimum velocity is b, the point of lowest positive intensity to the left of the feature; the maximum velocity, c, was chosen to be the velocity where the intensity has fallen off to a value of 0.5 °K.

The 29 profiles of the feature are summarized in table 1. The columns represent the following:

Column 1: Galactic longitude and latitude in the new galactic co-ordinate system.

Column 2: The maximum brightness temperature in degrees Kelvin.

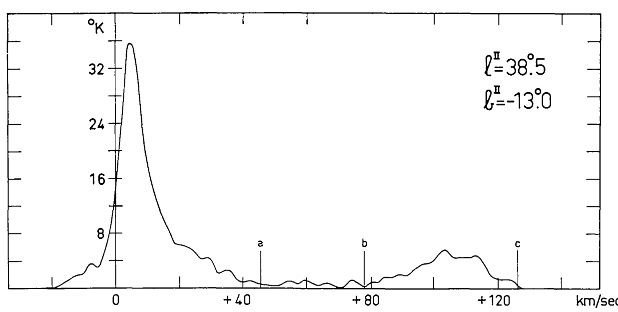

Figure 1. Typical profile from this region. The secondary peak at + 103.5 km/sec arises from the radiation from the feature.

* Present address: Sproul Observatory, Swarthmore, Pa., U.S.A.

Column 3: The velocity range in km/sec.
Column 4: The midpoint of the velocity range.
Column 5: Velocity of the maximum intensity in km/sec.
Column 6: The half-intensity velocities in km/sec.
Column 7: The residual velocity computed from column 4.
Column 8: The velocity dispersion in km/sec computed from the relation

$$D = \sqrt{\{\sum[I_i(v_i - v)^2]\}/\sum I_i}$$

where I_i is the intensity of the point i.

Column 9: N, the number of neutral hydrogen atoms in a column one square centimetre in cross-section.

The number of neutral hydrogen atoms in a column of one square centimetre cross-section was found by counting the number of square millimetres under the profile and applying the relation:

$$N = 1.835 \times 10^{18} \int T_b dv \text{ atoms/cm}^2 .$$

The resulting density distribution is shown in figure 2; the densities given do not include the ordinary galactic structure observed at each point. The density

TABLE 1

l^{II}	b^{II}	T_b max.	Vel. range	Mid. vel.	T_b vel.	Half-int. vel.	Res. vel.	Vel. dis.	$N \times 10^{19}$
38.5	−12.0	2.2	69.7–128.8	99.3	105.6	76.0– 90.0 102.2–124.6	+ 9.6	18.7	10.76
	−13.0	5.6	78.1–126.7	102.4	103.5	94.2–116.8	+12.7	18.0	24.03
39.5	−12.0	2.0	69.7– 92.9	81.3	76.0	70.5– 86.2	− 8.4	12.1	5.24
	−13.0	4.4	66.1–124.6	95.3	91.9	85.3–109.6	+ 5.6	14.3	23.13
	−14.0	3.6	67.2–122.9	95.1	99.3	86.6–106.0	+ 5.4	13.5	16.06
	−15.0	2.0	79.0–114.0	96.1	95.0	86.6–101.4	+ 6.8	12.8	7.10
40.5	−13.0	2.8	61.2–118.3	89.8	104.5	65.0– 89.8	+ 0.1	15.3	17.30
	−14.0	3.8	73.5–133.1	103.5	101.4	79.8–106.4	+13.8	16.4	20.46
	−15.0	3.2	61.2–128.8	95.0	90.8	71.0–109.8	+ 5.3	16.4	21.76
	−16.0	2.2	68.0–115.7	91.9	88.7	80.3–104.3	+ 2.2	11.3	10.97
	−17.0	1.4	71.8– 92.9	82.4	76.0	74.3– 92.1	− 7.3	8.2	3.50
41.5	−13.0	1.4	88.7–107.7	98.2	100.3	90.6–105.0	+ 8.5	27.4	3.26
	−14.0	3.6	52.0–111.9	82.0	90.8	67.6–103.5	− 7.7	15.6	21.95
	−15.0	3.0	63.4–118.3	90.9	101.4	85.7–106.4	+ 1.2	13.1	17.86
	−16.0	2.0	75.6–124.2	99.9	99.9	92.1–109.8	+10.2	13.7	8.74
	−17.0	2.0	65.5–120.4	93.0	76.0	66.7– 83.2 85.7–109.4	+ 3.3	14.3	13.27
42.5	−14.0	2.2	78.1– 99.3	88.7	82.4	79.8– 91.9	− 1.0	6.2	4.34
	−15.0	3.0	67.6–109.8	88.7	92.9	78.1– 98.8	− 1.0	11.0	14.88
	−16.0	2.0	95.9–139.0	117.5	107.7	103.5–135.2	+27.8	30.1	9.95
43.5	−16.0	3.6	73.9–114.0	94.0	97.2	84.3–106.4	+ 4.3	11.1	15.07
	−17.0	2.2	95.5–109.4	102.5	100.3	98.0–108.1	+12.8	10.2	4.47
	−18.0	3.8	83.2–112.1	97.7	103.5	101.0–107.5	+ 8.0	8.6	4.53
44.5	−17.0	2.4	68.2–103.3	85.8	90.6	87.9– 99.1	− 3.9	8.2	5.83
	−18.0	2.0	59.1– 92.9	76.0	88.7	70.8– 90.2	−13.7	17.4	8.40
45.5	−16.0	1.6	66.5– 84.5	75.5	73.9	68.2– 82.4	−14.2	15.2	3.60
	−17.0	2.4	68.6– 94.0	81.3	71.8	70.5– 90.0	− 8.4	11.6	7.07
	−18.0	3.0	61.7–101.6	81.7	75.0	65.0– 78.1	− 8.0	13.3	9.64
	−19.0	2.4	53.0– 82.6	67.8	74.8	63.8– 77.7	−21.9	22.4	7.44
46.5	−18.0	2.0	55.8– 87.2	71.5	80.3	72.4– 85.1	−18.2	19.7	6.79
	−19.0	2.4	61.2– 97.6	79.4	71.8	69.9– 87.2	−10.3	14.1	7.94

was found to vary from 2 to 25 × 10^{19} hydrogen atoms/cm^2. From this diagram, the actual shape of the feature can be seen. The long axis is 8° and the short axis is approximately 3°. The cloud actually seems to consist of two parts joined together at l^{II} = 43°.0.

The average of the midpoints of the velocity range is +89.7 ± 2.0 km/sec; the average of the velocity of the maximum intensity is +90.1 km/sec.

The residual velocities, indicative of the systematic relative motions at various points in the cloud, were computed using column 4 of table 1 and +89.7 km/sec. The results are plotted in figure 3. The arrows are drawn to size; those directed toward the upper right-hand corner indicate a positive residual, while those going in the opposite direction show a negative residual. The average positive residual is 7.8 km/sec; the average negative residual is 9.5 km/sec. Note that the two parts of the cloud mentioned in the preceding paragraph seem to be moving in opposite directions.

In table 2, the values of R_m, the shortest distance to the galactic centre from the line of sight in kiloparsecs and V_{max}, the maximum radial-velocity component along the line of sight due to galactic rotation, are listed. R_m and V_{max} were computed for each longitude using the method described by KWEE, MULLER and WESTERHOUT (1954); the computations were carried out for R_0 = 10 kps and θ_0 = 250 km/sec. R_m and V_{max} are used for comparison purposes only; for this reason, these quantities were determined for b^{II} = 0°.0. Since the region studied lies considerably below the galactic plane, the actual values of these quantities would be

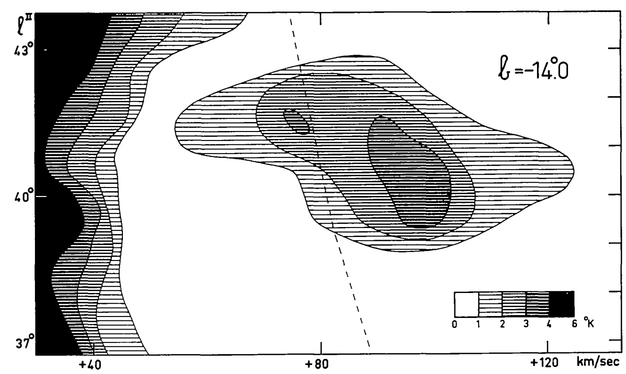

Figure 4. Contour lines of equivalent temperature as a function of galactic longitude and velocity at b^{II} = − 14°.0.

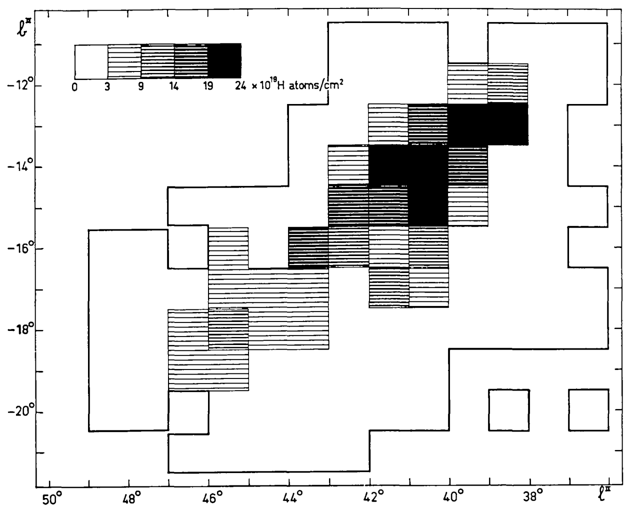

Figure 2. Density distribution within the feature. The region within the heavy line was completely surveyed.

TABLE 2

l^{II}	R_m	V_{max}
38.5	6.23	84.5
39.5	6.36	81.8
40.5	6.49	80.0
41.5	6.63	78.2
42.0	6.69	77.3
43.0	6.82	75.6
44.0	6.95	73.0
45.0	7.07	71.3
46.0	7.19	68.6

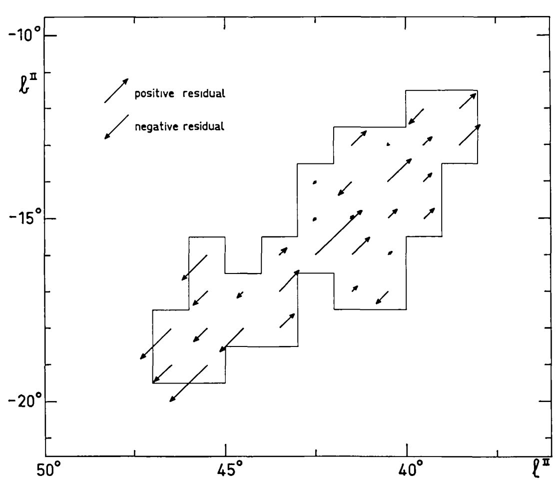

Figure 3. Residual velocities measured at each point within the feature.

somewhat lower. Figure 4 shows the contour lines of equivalent temperature at $b^{II} = -14°.0$ as a function of galactic longitude and velocity. The dotted line through the figure indicates the values of V_{max} listed in table 2. It should be noted that the ordinary galactic structure lies to the left of this line, while the feature is found almost entirely to the right. It was this peculiarity that initiated a study of this feature.

Figure 5 contains six contour diagrams; the contour lines are of equivalent temperature as a function of longitude and latitude. The diagrams are plotted for six velocities: +67.6 km/sec, +76.0 km/sec, +92.9

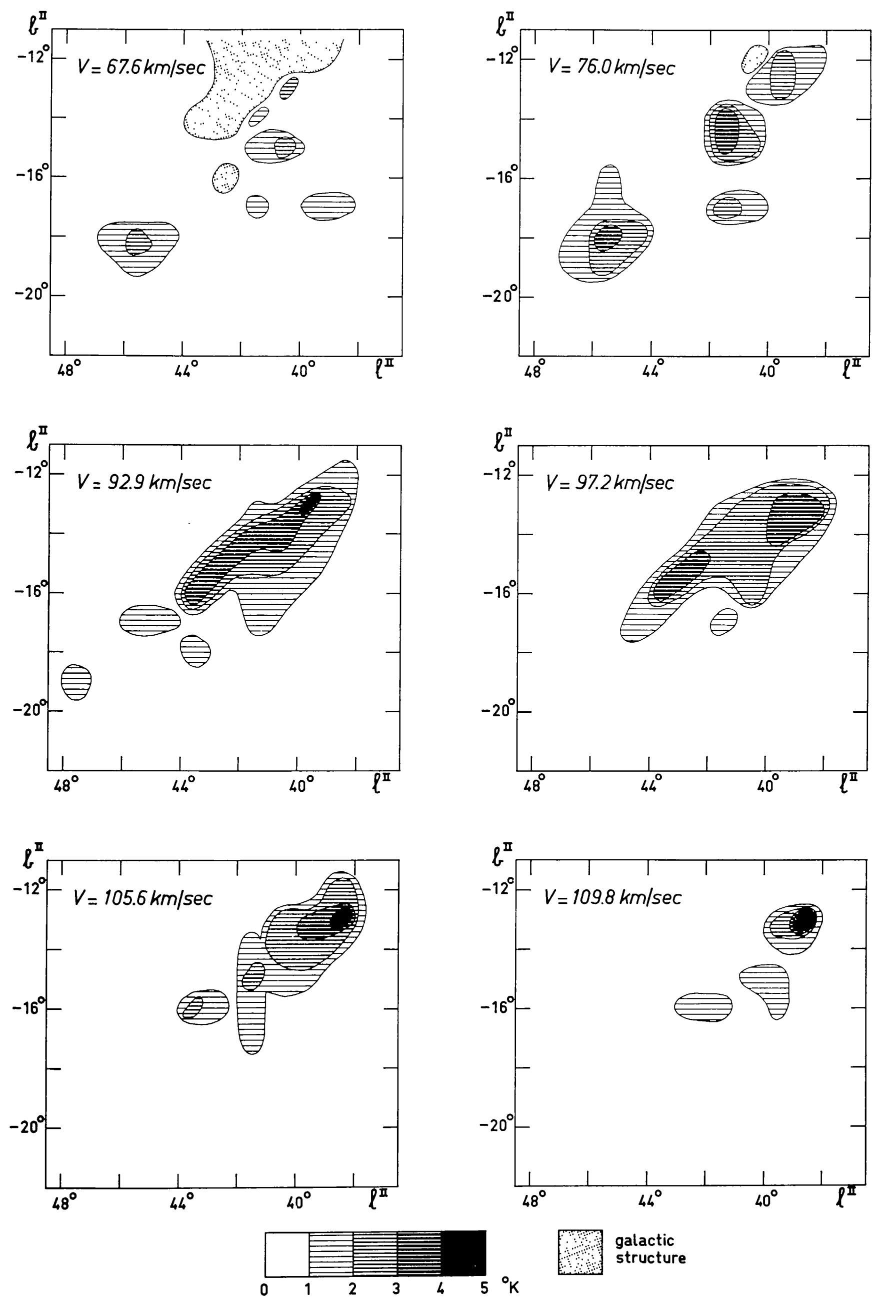

Figure 5. Contour lines of equivalent temperature as a function of longitude and latitude at six different velocities.

km/sec, +97.2 km/sec, +105.6 km/sec, and +109.8 km/sec. It is quite obvious that, even in the first diagram, the feature stands quite apart from the ordinary galactic structure. The extent of the feature is clearly seen in the diagrams for +92.9 km/sec, +97.2 km/sec, and +105.6 km/sec, where the size and brightness temperature remain fairly constant. At +105.6 km/sec, the intensity begins to fall off noticeably; by +126.7 km/sec, it has almost completely disappeared.

2. Interpretation

A study of the Mt Palomar sky charts showed only a faint diffuse reflection nebula in the neighbourhood of theta Aquilae; it does not seem likely that this source coincides with the feature. One very weak radio source (DAVIS, VOLDERS and WESTERHOUT, 1964) is located at $l^{II} = 41°.1$, $b^{II} = -13°.0$; this source is probably not related to the feature. In order to investigate whether the cloud was a part of an expanding shell, 21-cm observations were also carried out in the negative velocity range; no traces of the feature could be found.

The total mass is proportional to R^2, where R is the assumed distance of the cloud in parsecs. The number of neutral hydrogen atoms in the cloud, N_t, is found by summing over N. Table 3 contains the values of N_t and M_H, the total hydrogen mass in solar masses for various values of R. The long and short axes of the cloud are converted to parsecs in column 4.

As to the nature of this object, one finds that there are several possibilities:

1. A part of a supernova shell
2. An entire supernova shell
3. An extension of the galactic structure
4. An extra-galactic object.

When investigating these possibilities, it is necessary to keep in mind data derived in the preceding section concerning the size (8° by 3°), the internal systematic and random motions and the systematic velocity (+89.7 km/sec).

1. If we assume that the observed cloud is a part of a supernova shell moving with a velocity of +89.7 km/sec, then we find that at 500 pc the initial mass must have been greater than 70 ⊙. On the other hand, if the supernova is placed within 300 pc, then a more feasible mass is obtained; however, a more recent explosion is not compatible with the absence of an optical source.

2. If the observed feature is a supernova, expanding with a velocity of 8 km/sec, the initial mass at 500 parsecs must have been 10 ⊙. At this distance, the age of the feature would be several million years, which might explain the absence of an optical source. However, the systematic velocity of 89.7 km/sec can in no way be explained in this theory.

3. In the galactic plane, the material of the Galaxy exhibits an average maximum velocity of +76.5 km/sec for material lying at approximately 6.7 kiloparsecs. The feature, therefore, has a velocity 13.2 km/sec greater than the maximum permitted velocity. It is possible that a piece of the galactic structure has broken off from the ordinary galactic structure and the internal motions can be interpreted as a continued breaking up into even smaller pieces. At a distance of 6.7 kiloparsecs, the mass of the feature is 4×10^5 ⊙ and its area is 1.3 by 0.4 kiloparsecs. This interpretation of the data seems to be quite reasonable.

4. Finally, the possibility should be considered that the feature is an extra-galactic system or a satellite of the galactic system. If it is placed at 50 kpc, the distance of the Magellanic Clouds, then the hydrogen mass would be 2×10^7 ⊙. The fact that this is 20 times less than the hydrogen mass in either of the Magellanic Clouds might explain why the system has not yet been found optically. This hypothesis becomes less attractive when it is noted that the velocity relative to the galactic centre is quite high; the component along the line joining the feature and the sun is about +260 km/sec.

TABLE 3

R (pc)	N_t (atoms)	M_h (in M⊙)	Axes (in pc)	
100	9.6×10^{58}	82.7	5.2	14.0
500	2.4×10^{60}	2070	26.2	70.0
6 700	4.3×10^{62}	3.7×10^5	350.9	1 288.0
50 000	2.4×10^{64}	2.1×10^7	2 619.0	6 993.0

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