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Research Note

Synthesis Observations of the Region near the Proposed New Milky Way Companion at 0.610 GHz

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Summary. We have observed the field around the proposed core of Simonson's dwarf companion galaxy at 0.610 GHz with the Westerbork Radio Telescope. We find no evidence in the radio data for a companion galaxy. The H I features may be associated with high or intermediate velocity cloud or a proposed SNR. A source list is presented to aid identification of the nearby γ-ray source.

Key words: galaxies — radio sources — γ-ray source — galactic clouds — SNR

I. Introduction

Based on studies of galactic 21 cm. line survey data (Weaver and Williams, 1974), Simonson (1975) proposed the presence of a nearby companion dwarf galaxy. He found two features in the H I data: a compact feature, *A*, which he associates with the core of the galaxy and an extended feature, *B*, which he associates with a stream of high velocity gas bridging the dwarf and our own galaxy. The stream having been caused by tidal interaction.

In the same region of the sky, a strong γ-ray source has been detected (Kniffen et al., 1975). While the position of the γ-ray source and the proposed galaxy nucleus are not exactly coincident, the agreement is not unreasonable considering the uncertainty in the γ-ray source's position. To date, no clear identification of the γ-ray source has been made.

The possibility of the γ-ray source being explainable by the 21 cm feature has been discussed by Bignami et al. (1976) and by Cesarsky et al. (1976) using the mass and distance parameters derived by Simonson (1975). The main argument against such an explanation in both works is the uncommonly strong γ-luminosity required. It had been remarked by Simonson (1975) that sensitive radio and infrared (see Bignami et al. 1976) observations would be needed to determine if the object was a galaxy. To help solve this problem, we made observations at 0.610 GHz of a field centered on the proposed galaxy with the Westerbork radiotelescope. At this frequency, we could expect to see any continuum radiation coming from the galaxy or from the γ-ray source with reasonably high sensitivity. To avoid confusion as to which object (H I or γ-ray) we are discussing we shall refer to the field of the radio observation as the Geminga field.

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II. Observations and Reduction

A 12 h observation of the Geminga field centred at R.A. $= 6^h27^m20^s$; Dec. $= +15°1'25''$ ($l^{II} = 197.2$, $b^{II} = +2.2$) was made on 30 January, 1976 with the Westerbork synthesis radiotelescope at the frequency of 0.610 GHz. The telescope consists of twenty interferometers spaced over a 1.5 km baseline. A detailed description of the telescope is given by Högbom and Brouw (1974). The observations were reduced using the standard WSRT reduction programs (Someren Grève, 1974). The reduction was done in two stages. An initial map of the region was made and the location of the strong sources were determined. The 7 strongest sources ($S_{610} > 0.050$ Jy) were substracted from the input data and a new map was made of the region. This allowed us to reach an effective noise limit of approximately 0.003 Jy (1σ). The synthesized beam size was $56 \times 216''$. The useful field of view was $2.°8 \times 2.°8$.

Figure 1 shows a contour diagram of the radio emission in the field. The effects of the grating rings and sidelobes of the strongest sources have been removed by "cleaning" for display purposes. Table 1 lists all sources found in the field to a limiting flux level of 0.015 Jy. The parameters of the strongest 7 sources were determined from the original map and the remaining source parameters were determined from the map where the 7

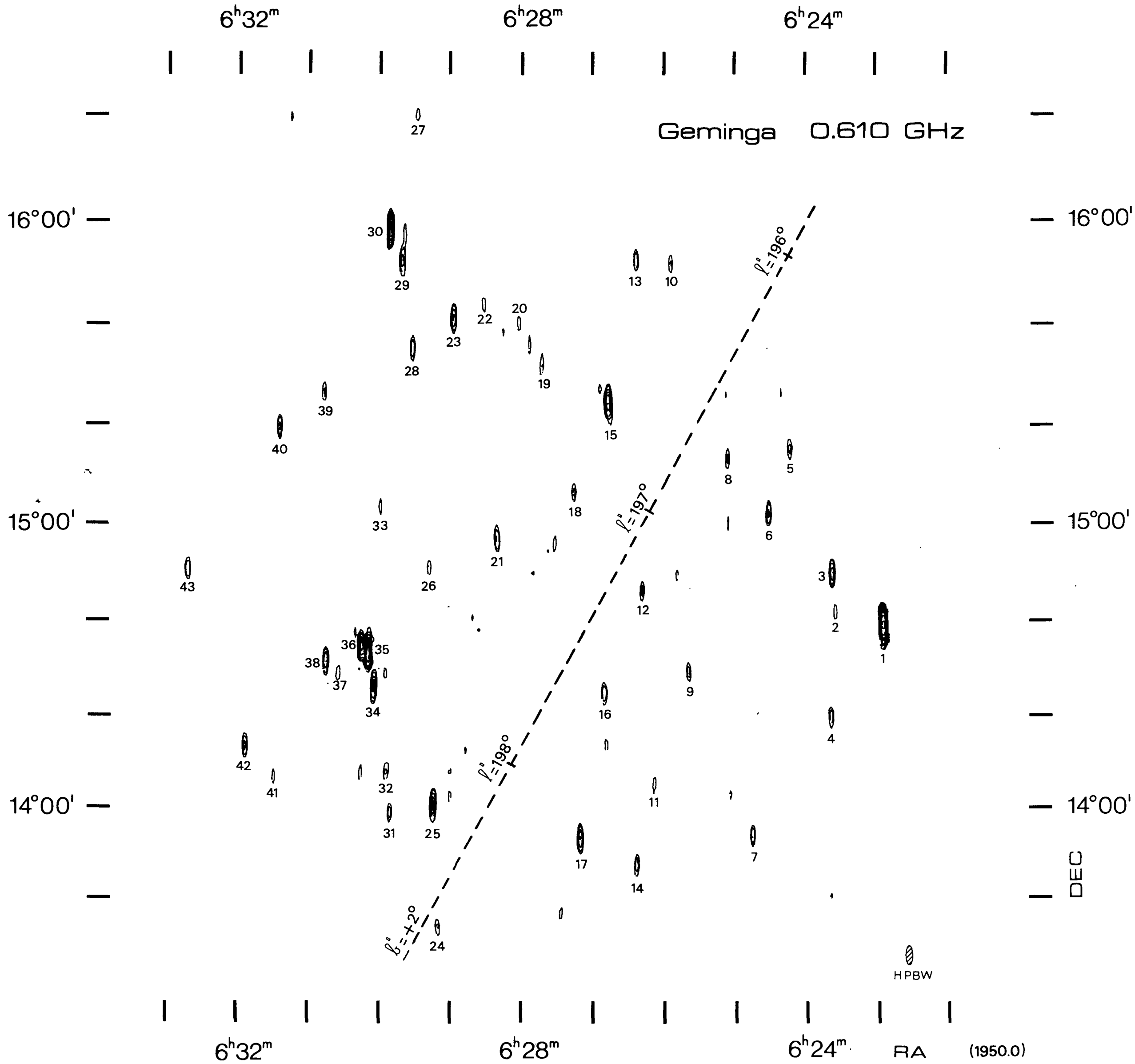

Fig. 1. Contour diagram of the 0.610 GHz. flux density distribution. The contour levels indicated are: 0.010, 0.015, 0.025, 0.040, 0.055, 0.080, 0.110, 0.150, 0.250, 0.400, 0.600 Jy. The displayed data is uncorrected for primary beam attenuation. The source numbers correspond to the numbers in Column 1 of Table 1

strongest sources were subtracted. The information listed in Table 1 is as follows:

Column 1: Source number (Correspond to source numbers in Figure 1).

Column 2, 3: Source Celestial (1950.0) position with uncertainty listed below.

Column 4: Source peak flux density with its uncertainty listed below.

Column 5, 6: Source galactic coordinates.

Column 7: Comments on individual sources.

The flux density parameter is obtained dividing the map flux density by the primary beam attenuation which is a function of the source distance with respect to the field centre given by the equation:

$$1/(0.997+0.21r-2.2928r^2+1.1635r^3+0.6776r^4-0.69r^5+0.154r^6)$$

where r is the distance from the map centre in degrees.

The flux and positional errors are calculated via the formulae given by Willis et al. (1976).

III. Discussion

To check for any correlation between the continuum sources in the field and the H I features, we have plotted the position of the four strongest sources on top of

TABLE 1

(1) N	(2) RA H M S	(3) DEC D M S	(4) FLUX Jy	(5) l^{II} Deg.	(6) b^{II} Deg.	(7) COMMENTS
1	6 22 54.69	14 42 02.1	3.665	196.984	1.102	4C 14.18 subtracted
	.03	2.0	.180			
2	6 23 34.90	14 45 39.3	0.064	197.007	1.274	
	.34	19.8	.004			
3	6 23 37.91	14 53 29.2	0.145	196.897	1.346	
	.12	7.0	.008			
4	6 23 39.18	14 23 35.0	0.147	197.340	1.116	
	.22	13.0	.011			
5	6 24 12.74	15 19 10.7	0.057	196.585	1.671	
	.25	14.6	.004			
6	6 24 30.96	15 06 29.4	0.063	196.806	1.636	
	.16	9.5	.003			
7	6 24 45.61	13 58 52.4	0.260	197.829	1.160	
	.20	11.7	.014			
8	6 25 05.48	15 17 48.7	0.034	196.604	1.847	
	.27	15.9	.003			
9	6 25 39.19	14 34 31.3	0.035	197.406	1.629	
	.27	15.6	.003			
10	6 25 53.54	15 56 31.1	0.080	196.224	2.320	
	.30	17.4	.004			
11	6 26 08.63	14 10 48.0	0.051	197.811	1.549	
	.39	22.3	.004			
12	6 26 18.69	14 51 34.3	0.022	197.229	1.903	
	.27	15.9	.003			
13	6 26 22.97	15 57 20.0	0.102	196.267	2.430	
	.21	12.0	.006			
14	6 26 23.70	13 53 04.9	0.190	198.100	1.465	
	.23	13.0	.011			
15	6 26 47.13	15 29 54.9	0.173	196.717	2.303	subtracted
	.05	3.1	.005			
16	6 26 50.64	14 30 19.0	0.040	197.603	1.851	
	.19	11.3	.003			
17	6 27 11.12	13 58 51.1	0.160	198.105	1.679	
	.17	9.8	.009			
18	6 27 16.18	15 11 47.7	0.020	197.039	2.265	
	.28	16.3	.003			
19	6 27 42.71	15 37 09.4	0.030	196.714	2.556	
	.32	18.3	.003			
20	6 28 01.99	15 45 07.7	0.038	196.633	2.686	
	.34	19.8	.003			
21	6 28 20.58	15 02 12.6	0.034	197.301	2.420	
	.16	9.4	.003			
22	6 28 31.38	15 48 48.5	0.046	196.633	2.819	
	.36	20.6	.004			

TABLE 1 (continued)

(1) N	(2) RA H M S	(3) DEC D M S	(4) FLUX Jy	(5) l^{II} Deg.	(6) b^{II} Deg.	(7) COMMENTS
23	6 28 56.77	15 45 50.0	0.093	196.725	2.886	
	.16	9.0	.005			
24	6 29 10.78	13 39 07.4	0.561	198.622	1.954	
	.30	17.3	.060			
25	6 29 14.48	14 06 01.7	0.418	198.232	2.176	subtracted
	.07	4.0	.022			
26	6 29 17.99	14 56 07.2	0.023	197.499	2.577	
	.34	19.7	.003			
27	6 29 27.44	16.24 32.7	0.541	196.209	3.295	
	.39	22.5	.065			
28	6 29 31.83	15 39 48.7	0.076	196.879	2.964	
	.19	11.1	.004			
29	6 29 40.57	15 56 41.2	0.223	196.646	3.126	
	.14	7.9	.012			
30	6 29 50.32	16 02 17.9	1.564	196.581	3.204	subtracted
	.04	2.6	.074			
31	6 29 51.50	14 04 05.6	0.155	198.330	2.294	
	.25	14.6	.085			
32	6 29 54.32	14 12 59.5	0.097	198.204	2.373	
	.27	15.8	.008			
33	6 29 59.32	15 07 59.7	0.028	197.401	2.816	
	.39	22.8	.003			
34	6 30 04.86	14 31 53.2	0.334	197.945	2.557	subtracted
	.05	3.1	.014			
35	6 30 09.87	14 38 06.4	0.440	197.862	2.623	subtracted
	.04	2.6	.016			
36	6 30 15.23	14 39 12.5	0.193	197.856	2.650	subtracted
	.07	4.3	.007			
37	6 30 35.09	14 33 19.5	0.058	197.980	2.676	
	.35	20.2	.005			
38	6 30 45.73	14 35 54.9	0.108	197.962	2.734	
	.17	10.1	.006			
39	6 30 46.72	15 30 31.7	0.078	197.156	3.159	
	.29	16.6	.004			
40	6 31 24.74	15 22 58.9	0.079	197.338	3.236	
	.40	22.9	.008			
41	6 31 29.80	14 10 30.0	0.237	198.420	2.695	
	.39	22.8	.020			
42	6 31 53.99	14 16 39.8	0.550	198.374	2.829	
	.16	9.2	.040			
43	6 32 42.95	14 52 50.6	0.424	197.930	3.283	
	.18	10.7	.040			

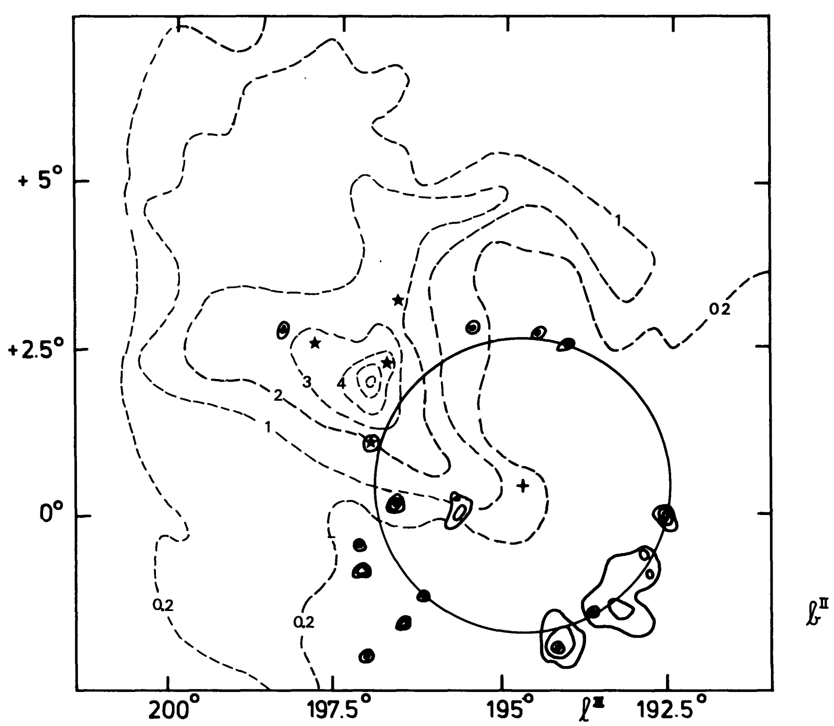

Fig. 2. Superposition of contours of H I column density, in units of 3.6 10^{19} cm^{-2} as given by Simonson (1975), dashed lines; the location of the Origem loop (circle with cross at the centre) and associated strong sources as given by Berkhuijsen (1974), solid lines; and the location of the four strongest sources in the Geminga field (sources 1, 15, 30, 35 in Table 1 and Figure 1 are indicated by stars)

Simonson's (b^{II}, l^{II}) contours (Fig. 2). There does not ppear to be any obvious correlation between the sources and the H I structure. If the galaxy were similar to the LMC and SMC systems, we would expect to see considerable extended continuum emission. We find no evidence for any extended emission associated with the proposed galaxy to a limit of approximately 1 K in the brightness temperature. To check if there might by an excess of sources in the region, we compared our source flux density distribution with the extensive

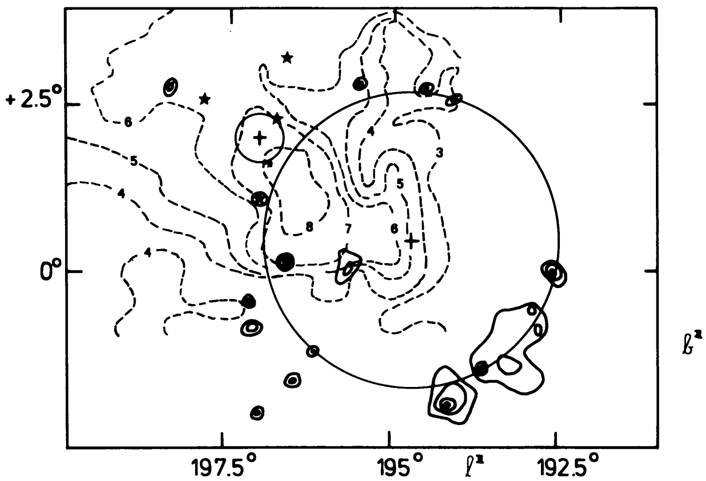

Fig. 3. Superposition of the extreme velocity in units of $-10\ \text{km s}^{-1}$ as given by Simonson (1975), dashed lines; the location of the Origem loop (large circle with cross at the centre) and associated strong sources as given by Berkhuijsen (1974), solid lines; and the location of the four strongest sources in our field (sources 1, 15, 30, 35 in Table 1 and Figure 1 are indicated by stars). The small circle with a cross at its centre indicates the location of the peak of the total hydrogen column density

study of background source distribution at 21 cm and 50 cm by Willis et al. (1976), (private communication). We found no evidence for an excess number of sources at any flux level. Finally, the lack of noticeable optical, radio or infrared features associated with the proposed galaxy leads us to believe that the H I features noted by Simonson are probably not due to a satellite galaxy. Most likely, they are related to objects in our own galaxy.

There are several possible explanation for the H I features. Simonson's features *A* and *B* could be intermediate velocity clouds similar to those reported e.g. by Wesselius (1973). Their surface brightness distributions and velocity dispersions are not exceptional for this class of objects. Another possibility is that the H I features are related to a proposed SNR shell referred as the Origem loop by Berkhuijsen (1974). If we compare the location of the loop with the neutral hydrogen contours shown in Figure 2, we see that the peak of the H I lies just outside the loop. This would be expected if the SNR were expanding into the denser cloud, as, for instance, is the case for IC 443 (Duin, 1974). If we compare the location of the loop with respect to the velocity contours (as, in Figure 3), we see that the peak velocity lies well inside the loop and that this gas is approaching us at a velocity $20\ \text{km s}^{-1}$ faster than the gas at the edge of the loop. Berkhuijsen (1974) quoted an expansion velocity of the loop of $20\ \text{km s}^{-1}$, in good agreement with the observed velocity difference, if the cloud was on the near side of the SNR. Of course, this new interpretation would require a value of the distance to the H I feature coincident with that to the Origem loop, i.e. 1000 ± 500 pc. This is much smaller than the value of 17 ± 4 kpc quoted by Simonson (1975) and may introduce new possibilities in the search for correlation between the unexplained γ-ray source and other optical or radio features.

There are several possible interpretations of the H I features discussed by Simonson. We feel that there is insufficient evidence to support the idea of a companion galaxy and that the features are heigher intermediate or high velocity clouds and some may be related to an old SNR shell. Any positive identification of the γ-ray source will have to await a better determination of its position.

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