Observations of M 32 at 21 cm

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These low-intensity observations were possible because of the highly sensitive and stable receiver, designed by Ir C. A. MULLER, and maintained in an excellent condition by him and his staff.

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OBSERVATIONS OF M32 AT 21 CM

BY D. G. WENTZEL[1]) AND H. VAN WOERDEN[2])

Measurements of the 21-cm line at the position of M32 and at velocities spread about the optical velocity show that probably the neutral hydrogen mass is smaller than 25×10^6 solar masses, its ratio to the total mass smaller than 4%. No lower limit can be set.

The elliptical nebula M32 ($\alpha = 10^\circ.102, \delta = 40^\circ.635$, 1958.0) was observed for possible emission in the 21-cm line by the same methods as M31 (VAN DE HULST, RAIMOND, VAN WOERDEN 1957; further called I). Since, on the sky, M32 lies within M31, the profile due to M31 was calculated at the position of M32 according to the model in I. Table 1 shows the average beam brightness temperatures [3]) T observed with the antenna pointed at M32, together with their theoretical mean errors (I, p. 4) and the T predicted from the M31 model. Velocities are with respect to the local standard of rest. In the upper four lines the comparison band fell at a velocity, V_1, where galactic radiation might be present. This necessitated a second comparison, between V_1 and V_2; the results of these separate measurements are given in column 4 of Table 1 in the order

$$[T(V_{obs}) - T(V_1)] + [T(V_1) - T(V_2)] = \\ = T(V_{obs}) - T(V_2).$$

The mean error of the combined result is correspondingly increased. The measurements were made in December, 1957, and took 12 observing hours. The comparison field was located at $\alpha = 15^\circ.00$, $\delta = 41^\circ.00$.

TABLE 1

V_{obs} (km/sec)	V_1 (km/sec)	V_2 (km/sec)	T_{obs} (°K)	m.e. (°K)	T(M31) (°K)
− 274	− 46	+ 182	− 0.20 + 0.75 = + 0.55	0.36	0.95
− 253	− 25	+ 203	− 0.87 + 0.63 = − 0.24	0.36	0.32
− 232	− 4	+ 224	− 0.58 + 0.58 = 0.00	0.36	0.12
− 211	+ 17	+ 245	− 0.34 + 0.26 = − 0.08	0.36	0.05
− 190	+ 38		+ 0.29	0.25	0.03
− 169	+ 59		+ 0.02	0.25	0.01
− 148	+ 80		+ 0.14	0.25	0.00

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[3]) This is the same quantity which in I was incorrectly called the antenna temperature. See page 328 in the preceding paper (VOLDERS 1959).

We wish to derive from these data an upper limit on the mass of neutral hydrogen in M32. The visual diameters of M32 are 12′ × 8′ (Holmberg 1958), so it is expected to be a point source for the Dwingeloo antenna (half-power beamwidth 34′). From I (eqs. 5 and 7) we have, for a very small area of the nebula,

$$\int_{0}^{+\infty} n_{\mathrm{H}}\, dl = 5.91 \times 10^{-4} \int_{-\infty}^{+\infty} T_b\, dV, \qquad (1)$$

with n_{H} = number of atoms per cm³, dl = element of line of sight in kpc, T_b = brightness temperature in °K, V = velocity in km/sec. The numerical factor in (1), and the notation in what follows, have been brought into agreement with the preceding paper (Volders 1959). We introduce the antenna pattern by multiplying both sides by $\frac{2\pi\theta f(\theta)\, d\theta}{\Omega'}$ and integrating over θ from 0 to ∞. At the left-hand side we may approximate $f(\theta) = 1$ (this is an overestimate by a few per cent). Hence

$$\frac{1}{\Omega'}\int\!\!\int\!\!\int n_{\mathrm{H}}\, dl\, dx\, dy = 5.91 \times 10^{-4} \int_{-\infty}^{+\infty} T dV.$$

Here x and y are rectangular co-ordinates on the sky expressed in units of 0°.25 = 1/229 radian. So the integral at the left-hand side multiplied by $\left(\frac{s}{229}\right)^2 \left(\frac{1\ \mathrm{kpc}}{1\ \mathrm{cm}}\right)^3$ is the total number of neutral hydrogen atoms in the nebula, where s = the distance in kiloparsecs. Introducing $\Omega' = 5.50$ (I, eq. 8) and $m_{\mathrm{H}}/M_{\odot} = 8.40 \times 10^{-58}$, we finally obtain the total mass of neutral atomic hydrogen in the nebula, expressed in solar masses:

$$M_{\mathrm{H}} = 1.53\, s^2 \int_{-\infty}^{+\infty} T\, dV. \qquad (2)$$

This formula is correct for any point nebula observed with the present Dwingeloo beam and showing no self-absorption.

We shall estimate the velocity width and an upper limit for T separately. Since the model of M31 is quite uncertain, we shall neglect the first two values in Table 1, where T(M31) is appreciable. The average of the remaining 5 values is

$$T_{obs} = +0.07 \pm 0.13\ (\mathrm{m.e.})\ {}^{\circ}\mathrm{K},$$

so that 0.2 °K may be taken as the upper limit for T(M32).

According to optical observations, the radial velocity of M32 is −210 ± 10 (p.e.) km/sec when reduced to the local standard of rest (Humason, Mayall and Sandage 1956).

In averaging the 5 values for T_{obs} quoted above, a velocity interval of about 100 km/sec was used. Minkowski has observed a velocity dispersion of 100 km/sec for the stars in the nucleus of M32 (Bowen 1954). A similar velocity dispersion may be assumed for possible gas present in the system. A velocity dispersion of about 200 km/sec and rotational velocities up to about 500 km/sec occur in the E7 nebula NGC 3115 (Minkowski, *unpublished*), but the diameter of this system is about 10 times larger and its total luminosity about 50 times that of M32. We will assume a velocity width of 200 km/sec.

Taking s = 630 kpc (Baade 1955, 1956; Schmidt 1957) we get as upper limit on the neutral atomic hydrogen mass in M32:

$$M_{\mathrm{H}} \leq 25 \times 10^6\ M_{\odot}.$$

The data are also consistent with a lower limit of zero radiation received. Our results do not confirm those by Heeschen (1957), who found $M_{\mathrm{H}} = (8 \text{ to } 40) \times 10^6\ M_{\odot}$, and $T = 0.6$ °K at a velocity of −214 km/sec. It is easy to prove that, for the Harvard 60-foot antenna, radiation of M31 at this velocity would be non-negligible.

The total mass M of M32 is not very well determined. Holmberg (1952) has estimated $M = 1.3 \times 10^9\ M_{\odot}$ from the luminosity L and the proportion M/L derived from the colour. A revision of his estimate, based on the new distance scale, would give $M = 8 \times 10^9\ M_{\odot}$. Schwarzschild (1954) has found $M = 25 \times 10^9\ M_{\odot}$, but his analysis was based on a supposed asymmetry in the rotation curve of M31 which has since been disproved (I, Section 6). Poveda (1958), using Minkowski's velocity dispersion of 100 km/sec (Bowen 1954) and the virial theorem, finds $M = 0.5 \times 10^9\ M_{\odot}$, or $0.6 \times 10^9\ M_{\odot}$ if using our distance s = 630 kpc; his value results in $\left(\frac{M}{L}\right)_{pg} = 5$. He assumed purely radial motions. If the velocity distribution in the nuclear part is isotropic, the mass and the value of M/L would be three times higher.

Using Poveda's mass, the neutral hydrogen fraction in M32 would be

$$\frac{M_{\mathrm{H}}}{M} \leq 0.04;$$

this upper limit, however, is too high to have much significance.

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