The Draco Nebula, a Molecular Cloud Associated with a High Velocity Cloud?

U. Mebold and P.W.M. Kalberla

Radioastronomisches Institut der Universität Bonn,
Auf dem Hügel 71, 5300 Bonn 1, Fed. Rep. Germany

Extended and very faint bright nebulae are found in high ($b \gtrsim 30^{o}$) galactic latitudes at the Palomar Observatory Sky Survey (POSS) (Lynds, 1965) and even more pronounced at a very sensitive photographic survey of the galactic polar caps by Sandage (1976). Such a nebula, located in the constellation Draco and called "Draco Nebula" or "Dracula", was found to be in detailed positional coincidence with a 21-cm emission line feature at a LSR velocity of VLSR $\approx$ -22 km s^{-1} by Goerigk et al. (1983). Estimates of the minimum visual extinction, $AV \gtrsim 1$ mag, from star counts ON and OFF Dracula (Goerigk et al., 1983) and an estimated visual surface brightness of

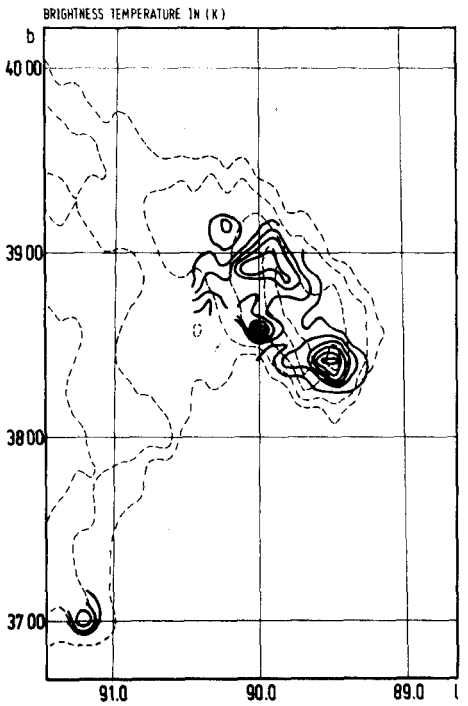

Fig. 1
Isophotes of integrated ^{12}CO brightness temperatures (full lines) superimposed on the distribution of the maximum 21-cm line brightness temperature (broken lines) for the Draco cloud. ^{12}CO-contours are at intervals of 1.5 K·km s^{-1} starting at 1.5 K km s^{-1}, HI contours at 1.5, 5, 10, 15 and 20 K.

https://doi.org/10.1017/S0252921100098298 Published online by Cambridge University Press

SBV $\simeq$ 24 mag (arc sec)$^{-2}$ (Lynds 1965) indicate that Dracula fits the relation

$$SBV = 24.2 - 2.5 \log AV$$

for dust clouds located above the galactic plane and reflecting the integrated starlight of the galactic disk (Sandage 1976). Hence Dracula is probably a reflection nebula. The quoted observations gave a ratio NHI/E(B-V) of atomic neutral hydrogen column density and colour excess that is about a factor of 10 smaller than the standard ratio NH/E(B-V) of hydrogen nuclei and colour excess.

This lead us to search for indicators of molecular hydrogen, H2, like the CO molecule. We used the 2.5-m mm-Telescope of the University of Bordeaux (Baudry et al., 1980) for observations of the λ 2.6-mm and λ 2.7-mm transitions of the ^{12}CO and the ^{13}CO molecule. The ^{12}CO results are presented in Fig. 1 as isophotes of integrated brightness temperature (full lines) superimposed on the distribution of the maximum 21-cm line brightness temperature (broken lines). We see at Fig. 1 and by inspection of the POSS that ^{12}CO is brightest where HI and - even more pronounced - where the dust is brightest. ^{13}CO-lines were measured only at the positions of the peaks of the two CO-clumps with lowest latitudes, called Drac 1 and Drac 2.

The results of the CO observations at these positions are summarized in Table 1. From the top to the bottom we give for these clumps the galactic longitude, ℓ, and latitude, b, of the centre of the clumps, the amplitudes, T_L, the half power line widths, ΔV, and the LSR centre velocities of the ^{12}CO and ^{13}CO lines, VLSR, the LTE excitation temperature of the CO molecules, T_{EX}, the optical depth, τ^{13}, and the column density, $N^{13}CO$, (cf. Dickman 1978) of the ^{13}CO molecules.

We have estimated molecular hydrogen column densities, NH2, first from a direct observational correlation of CO column densities, NCO, with NH2 (Federman et al., 1980) adopting a CO- isotopic ratio of $N^{12}CO/N^{13}CO = 50$, and second from observational correlations of $N^{13}CO$ and AV and the "standard" ratio NH2/AV = $0.94 \cdot 10^{21}$ molecules cm^{-2} mag^{-1} (Frerking et al., 1982).

https://doi.org/10.1017/S0252921100098298 Published online by Cambridge University Press

These two estimates of NH2 called NH2(UV) and NH2(AV), the total column density of hydrogen nuclei,

$$NT = NHI + 2\ NH2,$$

derived from the average of NH2(UV) and NH2(AV) and the 21 cm lines, and the extinction, AV, derived from the "standard" ratio of NH2/AV are also listed in Table 1.

In order to be able to study the dynamics of our CO-clumps we have attempted to determine the distance of Dracula in two ways: First we have conducted a UBV photo electric photometry with the 1 m telescope of the Calar Alto Observatory in Spain of about 60 stars in the brightest part of Dracula. With some uncertainty due to the unknown metallicity of possible halo stars we found only unreddened stars up to a distance of about 800 pc. Also from the extinction given in Table 1, from a relative star count defizit of 11 percent ON and OFF Dracula and from models of the stellar distribution perpendicular to the galactic plane (Scheffler, 1982) we derive a distance of about 800 pc. Adopting a distance of 800 pc and the apparent sizes of our CO-clumps we estimate the densities, n, and total masses, M, given in Table 1. The virial theorem was applied to test whether or not the CO- clumps are gravitationally bound systems. From the velocity dispersions $\sigma = \Delta V/2.355$ of the ^{13}CO lines, the total masses M and the linear diameters, d, we have (κ = gravitational constant)

$$\sigma^2 < 2\kappa M/d,$$

i.e. both clumps appear to be gravitationally bound systems.

Finally we like to point out that Dracula has a close positional and possibly even astrophysical relationship to the high velocity cloud (HVC) phenomenon. Dracula is located at the low latitude end of Hulsbosch's (1979) HVC complex CI; indeed high negative velocity HI-gas is observed over most of the region covered by Dracula. Further, Dracula is positionally coincident with a C-band x-ray emission feature in the SAS- satellite sky maps (Clark, private communication, see also the C-, M- and J-band maps of McCammon

https://doi.org/10.1017/S0252921100098298 Published online by Cambridge University Press

et al., 1982). It is therefore suggestive that the x-ray emission is thermal bremsstrahlung produced by electrons and ions in HVC CI and the galactic gas and that Dracula is a part of a decelerated high velocity cloud.

Summary

An extended and faint bright nebula at $\ell \approx 91^{\circ}$, $b \approx 38^{\circ}$ exhibits HI λ21-cm, ^{12}CO λ2.6-mm and ^{13}CO λ2.7-mm emission lines in detailed positional agreement with the brightness distribution at the Palomar Observatory Sky Survey. Three colour UBV photometry of ∿ 60 stars in the field of the bright nebula indicates a distance of ∿ 800 pc. With this distance the total mass of two molecular clumps in the nebula is 27 and 219 $M_{\odot}$ and they appear to be gravitationally bound systems. A possible astrophysical relation to the high velocity HI- cloud phenomenon is pointed out.

References

Baudry, A., Brillet, J., Desbats, J.M., Lacroix, J., Montignac, G., Encrenaz, P., Lucas, R., Beaudin, G., Dierich, P., Germont, A., Landry, P., Rerat, G.: 1980, J. Astron. Astrophys. 1, 193

Dickman, R.L.: 1978, Astrophys. J. Suppl. 37, 407

Federman, S.R., Glassgold, A.E., Jenkins, E.B., Shaya, E.J.: 1980, Astrophys. J. 242, 545

Frerking, M.A., Langer, W.D., Wilson, R.W.: 1982, Astrophys. J. 262, 590

Goerigk, W., Mebold, U., Reif, K., Kalberla, P.M.W., Velden, L.: 1983, Astron. Astrophys. 120, 63

Hulsbosch, A.: 1979, in IAU Symp. 84, 525

Lynds, B.T.: 1965, Astrophys. J. Suppl. 12, 163

McCammon, D., Burrows, D.N., Sanders, W.T., Kraushaar, W.L.: 1982, Astrophys. J. 269 No 1, 107

Sandage, A.: 1976, Astron. J. 81, 954

Scheffler, H.: 1982, in Landolt-Börnstein, Vol. 2, Astron. Astrophys., Subvol. c, p. 175

Table 1

	Drac 1		Drac 2	
gal. long	91^{o} 11'		89^{o} 32'	
gal. lat.	36^{o} 59'		38^{o} 24'	
	^{12}CO	^{13}CO	^{12}CO	^{13}CO
T_L/K	4.2	0.5	5.5	0.7
$\Delta V/km\ s^{-1}$	1.3	0.8	2.0	1.4
$V_{LSR}/km\ s^{-1}$	-25.2	-25.1	-23.7	-23.3
T_{EX}/K	7.4		8.8	
τ^{13}	0.12		0.13	
$N^{13}CO/cm^{-2}$	$3.4\ 10^{14}$		$8.6\ 10^{14}$	
$NH2(UV)/cm^{-2}$	$1.6\ 10^{21}$		$2.6\ 10^{21}$	
$NH2(AV)/cm^{-2}$	$1.2\ 10^{21}$		$1.6\ 10^{21}$	
NT/cm^{-2}	$2.9\ 10^{21}$		$4.3\ 10^{21}$	
AV/mg	1.6		2.3	
n/cm^{-3}	620		400	
$M/M_{\odot}$	27		219	
$\sigma^2(2\kappa M/d)^{-1}$	0.74		0.69	

https://doi.org/10.1017/S0252921100098298 Published online by Cambridge University Press