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^{12}CO(J=3→2) detections in bulges of low surface brightness galaxies with APEX

Gaspar Galaz[1], Paulo Cortes[2], Leonardo Bronfman[2] and Monica Rubio[2]

[1]Departamento de Astronomia y Astrofisica, Pontificia Universidad Catolica de Chile, Casilla 306, Santiago 22, Santiago, Chile
email: ggalaz@astro.puc.cl

[2]Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Santiago, Chile
emails: pcortes@das.uchile.cl, leo@das.uchile.cl, monica@das.uchile.cl

Abstract. Using the APEX sub-millimeter telescope we have detected for the first time the CO rotational transition ^{12}CO(J=3→2) in two of five low surface brightness galaxies. For galaxies with positive detection, the emission is detected in their bulges, with measured gas velocity dispersion of about 80 km/s and observed main-beam brightness temperature $T_{MB} \sim 10$ mK. Using a standard CO to H_2 conversion factor, we are able to estimate molecular gas masses for LSBs with positive detections, and upper limits for those LSBs with negative detections. Assuming a higher gas temperature for the generation of the ^{12}CO(J=3→2) line compared to that for the ^{12}CO(J=1→0) one, results suggest that a warm molecular gas component is present in bulges, indicating a radiation field preventing the formation of large cooler amounts of molecular gas, compared to high surface brightness galaxies with higher metallicity and likely more dust.

1. Background

Spiral low surface brightness galaxies (LSBs) are galaxies with disk surface brightnesses $\mu_0(B) > 22.0$ mag arcsec^{-2}. They typically have low stellar formation rates (SFRs < 1 $M_\odot$ yr^{-1}), sub-solar metallicities, large atomic gas fractions (H), small amounts of dust and, then, small amounts of molecular gas (H_2). Normally, the CO is used as tracer of the H_2. Yet, it has been detected for only a small number of LSBs (ONeil *et al.* 2000, ApJ, 545, L99, Matthews et al. 2001, ApJ, 549, L191). These authors detect the transition ^{12}CO(J=1→0) and few ^{12}CO(J=2→1), in less than 5 LSBs. Here we report for the first time positive detections of the ^{12}CO(J=3→2) transition in LSBs, occurring at higher frequency (345.8 GHz, 867 μm) compared to other ^{12}CO transitions. The emission is detected in the bulges of two of a total of five face-on LSBs: NGC0521 and PGC070519 (Galaz *et al.* 2006, AJ, 131, 2035). Using a canonical conversion factor CO to H_2, we estimate the total amount of H_2 in LSBs with detections, and to suggest upper limits for those galaxies with negative detections.

2. Sample and Observations

Observations were carried out with the Atacama Pathfinder EXperiment (APEX) sub-millimeter telescope, between October 2006 and January 2007. We have used the APEX-2A spectrograph, which was centered in the rest-frame of each galaxy (see Table 1), and tuned onto the ^{12}CO(J=3→2) rest frequency. Total exposure times were about 3 hours

Table 1. Intrisic features and derived parameters for the observed galaxies with APEX. We have $> 1\sigma$ detections only for NGC0521 and PGC070519.

Name	cz (km/s)	$\mu_0(B)$ (mag arcsec^{-2})	T_{MB} (mK)	$\int T_{MB}dv$ (K km s^{-1})	M$_{HI}$ ($\times 10^8 M_\odot$)	M$_{H_2}$ ($\times 10^8 M_\odot$)	M$_{H_2}$/M$_{HI}$	Width (km s^{-1})	D$_{27}$ (arcsec)	$B-R$ (mag)	$J-K_s$ (mag)
NGC0521	5028	22.1	12.7	1.20(0.12)	2.2	2.01	0.91	88.7	80	1.64	0.74
PGC070519	5244	22.3	9.8	0.76(0.94)	16.5	1.39	0.08	72.8	27	0.99	0.62
NGC7589	8938	21.5	< 5	< 0.03	26.6	< 0.170	< 0.006	~ 80	25	2.00	0.81
UGC02081	2615	22.4	< 5	< 0.03	1.1	< 0.015	< 0.014	~ 80	47	1.11	0.63
UGC02921	3695	23.6	< 5	< 0.03	13.4	< 0.028	< 0.002	~ 80	23	....	....

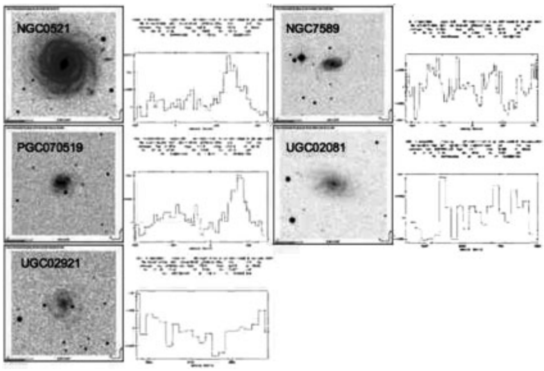

Figure 1. B band DSS images of NGC0521 and PGC070519, and ^{12}CO(J=3→2) APEX detections. A Gaussian fit to the main brightness temperature as a function of the gas velocity in km/s is indicated for detections.

per galaxy. Beam size was $\sim$ 18 arcsec, covering most of the bulges in all cases. Galaxies are part of the LSB sample studied in Galaz et al. (2006), and were selected taking into account similar masses of H, (see Table 1), and face-on orientation, to see clearly the bulge and to compare directly gas and stellar velocity dispersions. All galaxies are located at low redshifts (cz<9000 km/s) and are not part of known clusters. All APEX spectra were smoothed to 16 km/s, yielding a typical main-beam brightness temperature of about 10 mK for detections.

3. Results

As shown in Figure 1, only two of five galaxies present significant ^{12}CO(J=3→2) emission in their bulges, shown by Gaussian fits: NGC0521 and PGC070519. Table 1 shows relevant information derived from the observations, as well as intrinsic properties of galaxies. In particular, we derived H_2 masses as $M(H_2) = 5.82[(\pi/4)d_b^2 T_{MB}]$ (Sanders *et al.* 1986, ApJ, 305, L45), which assumes a conversion factor $X = N(H_2)/\int T(CO)dv = 3.6 \times 10^{20}\,\mathrm{cm}^2/(K\,\mathrm{km\,s}^{-1})$. The higher excitation temperature of the ^{12}CO(J=3→2) transition suggests us that little amount of dust is present in bulges and also that estimated H_2 masses are in fact upper limits, expecting H_2 masses about 4 times larger than those obtained (de Blok & van der Hulst 1998, A&A, 336, 49). If our computations are correct, we obtain that NGC0521 has a large fraction of molecular gas in its bulge, due to its small HI mass. More observations will take place this year with APEX for these galaxies, both spectroscopic and bolometric, to better study their gas emission and dust distribution.

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