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Tidally compressed molecular gas in ultraluminous and early type galaxies

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Abstract. The effect of the galactic tidal field is usually considered disruptive in the literature. However, in some cases its effect can become compressive. Using the virial theorem, we have determined the minimum density for a cloud to be stable and gravitationally bound within the tidally compressive region of a galaxy. We have applied our results to a sample of early type and ultraluminous galaxies observed in the literature. For early type galaxies with a core-type luminosity profile, the molecular gas is compressed to high densities of at least $10^4 \mathrm{cm}^{-3}$ within the inner 50 pc where the field is compressive. For ultraluminous galaxies our treatment predicts molecular gas densities of $10^2 - 10^4 \mathrm{cm}^{-3}$ within the central few 100 pc. These values agree well with gas densities observed in the centers of these galaxies.

Key words : galaxies : kinematics and dynamics - galaxies : ISM

1. Introduction

In the paper we study the effect of the compressive tidal field on gas in the centers of early type and ultraluminous galaxies. We first describe the equilibrium of gravitationally bound cloud in such a field and then we apply the model to an observed sample of galaxies.

2. Cloud equilibrium in the tidal field of a galaxy

For a molecular cloud in virial equilibrium in a galactic tidal field, the equation of cloud equilibrium is,

$$v^2 = \frac{2}{3}\frac{GM_c}{R_c} - \frac{1}{2}T_o R_c^2 \tag{1}$$

where M_c is the mass of a cloud, R_c is the cloud radius, v is the 3-D velocity dispersion in a cloud and T_0 is the tidal field per unit distance across a cloud (i.e. $T_0 = -\frac{\partial^2 \Phi}{\partial r^2}$). We have assumed that the density within a cloud is universely proportional to radius. For a tidally compressive field $T_0 = -|T_0|$ and so using the fact that the cloud is gravitationally bound, we obtain the minimum cloud density in a compressive tidal field to be,

$$\langle \rho_m \rangle = \frac{9}{16\pi G} |T_o| \tag{2}$$

Physically this denotes the minimum density for a gravitationally bound cloud to exist within the compressive core of a galaxy. For lower densities, the gas within that region will be diffuse and gravitationally unbound. Such gas will not lead to star formation.

3. Application to early type and ultraluminous Galaxies

We have used the Tremaine et al. (1994) family of potentials to determine the tidal field in a sample of early type galaxies. We applied the results to determine the mean gas densities in the compressive core of a sample of flat core early type galaxies observed by Faber et al. (1997). The results are shown in Table 1. Our results show that gas densities depend on core size and the distance from the galaxy center. We then used the Downes & Solomon (1998) CO observations of the molecular disks in a sample of ultraluminous galaxies, to determine the compressive tidal field in these galaxies. Our result are shown in Table 2. The particle number density ⟨n⟩ lies in the range 10^2 to $10^4 cm^{-3}$. The range in gas densities agrees well with those observed by Downes & Solomon (1998).

Table 1. Model cloud densities for early type galaxies.

Galaxy Name	Galaxy Type	Core/Power Law Type	Break Radius R_0 (pc)	Galaxy Mass ($M_\odot$)	Predicted H_2. Number Density (cm^3). at R'=0.4
NGC 4594	Sa/Sb	Power Law	3.6	1.1×10^{11}	. . .
NGC 4697	E6	Power Law	240.d0	1.5×10^{11}	. . .
NGC 4472	E/SO	Flat Core	177.8d0	8.4×10^{11}	10^4
NGC 4649	E1-2	Flat Core	263.d0	9.9×10^{11}	5.10^3
NGC 1400	E1/SO	Flat Core	34.7d0	2.4×10^{11}	5.10^6
NGC 1316	SO	Flat Core	35.5d0	2.9×10^{11}	5.10^5
NGC 1600	E	Flat Core	758.6d0	1.5×10^{12}	300
NGC 3379	E	Flat Core	83.2d0	9.8×10^{10}	10^4
NGC 4486	E	Flat Core	562.3d0	9×10^{11}	420

Table 2. Model cloud densities for ultraluminous galaxies.

Galaxy Name	Rotation Curve Turnover Radius (pc)	Rotation Curve Turnover Velocity (kms–1)	Predicted H2 Number Density (cm3)
00057+4021	240	250	7×10^2
02483+4302	270	270	6×10^2
VIIZw31	290	290	6×10^2
10565+2448	230	220	6×10^2
Mkr231	75	345	10^4
Arp193-disk	220	230	7×10^2
Mkr273-disk	70	280	10^4
Arp220-disk	200	330	2×10^3
Arp220-west	35	300	5×10^4
Arp220-east	50	350	3×10^4
17208-0014	310	260	4.5×10^2
23365+3604	340	260	4×10^2

References

Das M., Jog C.J., 1999 (in preparation)

Downes D., Solomon P.M., 1998, ApJ, 507, 615

Faber S.M., et al. 1997, AJ, 114(5), 1771

Tremaine S. et al. 1994, AJ, 107(2), 634