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Unbound Molecular Complexes in M33

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The HI content of the nearby spiral galaxy M33 (d$\sim$0.8 Mpc) has been the subject of many detailed studies (most recently Deul and van der Hulst 1987), but similar data on the molecular gas component has been lacking. This galaxy is currently undergoing vigorous high-mass star formation, as evidenced by the many OB associations and HII regions, and so is expected to possess at least some molecular gas. Interferometric studies ~~at OVRO~~ have detected molecular clouds similar to Galactic Giant Molecular Clouds (GMCs) (Boulanger *et al.* 1988; Wilson *et al.* 1988). We have recently mapped the nuclear region of M33 in the CO J=1-0 line with the NRAO 12 m telescope (half power beam width 55″ $\sim$ 210 pc) out to a radius of 3.5′ in order to trace the detailed distribution of the molecular gas.

The resulting map (~~Figure 1~~) reveals six large complexes with diameters of 200-400 pc, fully contained within ~~our~~ map. Interferometer observations of these regions have resolved them into individual molecular clouds similar to Galactic GMCs (Wilson *et al.* 1988). The complexes ~~in Figure 1~~ are much larger than individual Galactic GMCs (Sanders, Scoville, and Solomon 1985), but are somewhat smaller on average than the large associations seen in the grand-design spiral galaxy M51 (Rand and Kulkarni 1989). If we extend the velocity-diameter relation observed for Galactic GMCs to these larger structures, the predicted velocity widths are a factor of 1.5-3 times greater than the observed full-width half-maximum velocities (13-29 km s^{-1}). The peak brightness temperatures are $\sim$0.2 K, at least a factor of 10 lower than what is observed for Galactic GMCs. If these large structures are made up of objects similar to Galactic GMCs, the area filling factor of the small clouds is roughly 10%. These results suggest that these complexes are not very large GMCs, but rather are associations of many individual GMCs or GMCs embedded in a diffuse gas component.

We have calculated both virial and molecular masses for the complexes, adopting the Galactic value $\alpha = 3 \times 10^{20}$ cm^{-2} (K km s^{-1})$^{-1}$ for the ratio of H_2 column density to integrated CO flux. The value of α in M33 is unlikely to be much different from the Galactic value, since this nuclear region has roughly solar metallicity (Pagel 1985) and for the individual clouds resolved by the interferometer observations the CO flux-based mass is in rough agreement with the virial mass (Wilson *et al.* 1988). For all but one of these complexes the virial mass is a factor of 5-8 larger than the molecular mass, implying that they are not virially bound. The uncertainties of $\pm$40% in these mass estimates are insufficient to resolve this discrepancy. Since the complexes lie within 1.3 kpc of the nucleus of M33, it is important to consider the effects of tidal forces. We have estimated the minimum mass required for tidal stability and find that the molecular masses all fail by factors of 3-8 to bind the complexes against tidal disruption. Thus both the discrepancy between the virial and molecular masses and the tidal stability analysis imply that these molecular complexes are not themselves gravitationally bound, but instead are transient associations of individual bound objects.

We can calculate the lifetimes of the complexes, assuming them to be made up of roughly 20 individual GMCs with a Galactic mass distribution. If the complexes are unbound, the individual clouds will escape from the complex in roughly the crossing time, $t_{cross} = R/v$, where R is the radius of the complex and v is the 3-dimensional velocity dispersion, $v = 1.36 V_{FWHM}$. The crossing times are 1-2$\times 10^7$ yr, comparable to the lifetime of a 15 $M_\odot$ star and roughly 10-20% of the time required to complete one orbit around M33. If we model the disruption of a complex as a simple expansion in radius to twice the initial radius over one crossing time, the resulting collision timescale indicates that roughly 10% of the clouds in the complex will suffer a collision during this time. Thus we might expect to see enhanced star formation efficiencies in these large complexes if the collisions of individual clouds promote high-mass star formation.

Deconvolved IRAS maps show considerable structure within this region, with a mean dust temperature derived from the 60/100 μm flux ratio of 33 K. The total mass of molecular gas derived from the 100 μm flux (cf. Thronson and Telesco 1986) is in reasonable agreement with the mass derived from the integrated CO flux, suggesting that we are unlikely to be significantly underestimating the molecular hydrogen mass by using the Galactic value of α. The ratio of the far-infrared luminosity to the molecular hydrogen mass is 3.8 $L_\odot/M_\odot$, typical for regions with low levels of star-forming activity.

The total H_α flux is proportional to the high-mass star formation rate and the ratio of the H_α flux to the molecular gas mass traces the high-mass star formation efficiency. Both the high-mass star formation rates and efficiencies in the different complexes vary by a factor of 7. The average star formation efficiency does not appear to be enhanced in regions with large amounts of molecular gas, while the star formation rate per unit area is three times higher in regions with high molecular gas densities. These preliminary results suggest that, at least in M33, regions with high star formation rates are primarily due to an overabundance of molecular gas, not to a higher than average star formation efficiency.

References

Boulanger, F., Vogel, S. N., Viallefond, and F., Ball, R. 1988, in *Molecular Clouds in the Milky Way and External Galaxies*, eds. R. Dickman, R. Snell, and J. Young, (Springer-Verlag: New York), 401.

Deul, E. R. and van der Hulst, J. M. 1987, *Astr. Ap. Suppl.* **67**, 509.

Pagel, B. E. P. 1985, in *Production and Distribution of C, N, O Elements* (ESO workshop), eds. I. J. Danziger, F. Matteucci, and K. Kjär, 155.

Rand, R. J. and Kulkarni, S. R. 1989, these proceedings.

Sanders, D. B., Scoville, N. Z., and Solomon, P. M. 1985, *Ap. J.* **289**, 373.

Thronson, H. A. and Telesco, C. M. 1986, *Ap. J.* **311**, 98.

Wilson, C. D., Scoville, N. Z., Freedman, W. L., Madore, B. F., and Sanders, D. B. 1988, *Ap. J.* **333**, 611.

Fig. 1 – The map of the integrated CO emission is shown for the inner region of M33. The lowest contour is at 1.1 K km s^{-1} and the contours increase by 0.4 K km s^{-1}. The (0,0) position corresponds to $\alpha(1950) = 01^h31^m03.0^s$, $\delta(1950) = +30°23'54''$ and the optical nucleus is indicated by the cross at ($\Delta\alpha = -0.3, \Delta\delta = 0.35$). The two inner spiral arms are indicated by the dashed lines.