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Gas and Star Formation in Spiral Galaxies: Results for NGC 4736

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ABSTRACT

Interferometric maps of H I and CO emission in the nearby spiral galaxy NGC 4736 are presented. The distributions of atomic and molecular gas are distinctly different, with CO emission peaking near the center and in the star-forming ring while H I is only found at and beyond the ring. Hα emission is well-correlated with the molecular gas on large scales but not on small ($\sim$100 pc) scales. A lack of correlation is also seen when examining the gas consumption time as a function of radius: star formation appears to occur much more efficiently in the ring than in the central region, an effect that does not seem wholly attributable to extinction.

We find some support for the idea that star formation occurs when the gas surface density Σ_g exceeds a threshold density Σ_c expected for gravitational instability: namely, the ratio $Q \equiv \Sigma_c/\Sigma_g$ shows a minimum in the vicinity of the ring. However, this minimum value of Q is $\sim$5 rather than 1–1.5 as expected. A more detailed study of this question, involving a sample from the BIMA Survey of Nearby Galaxies (BIMA SONG), is underway.

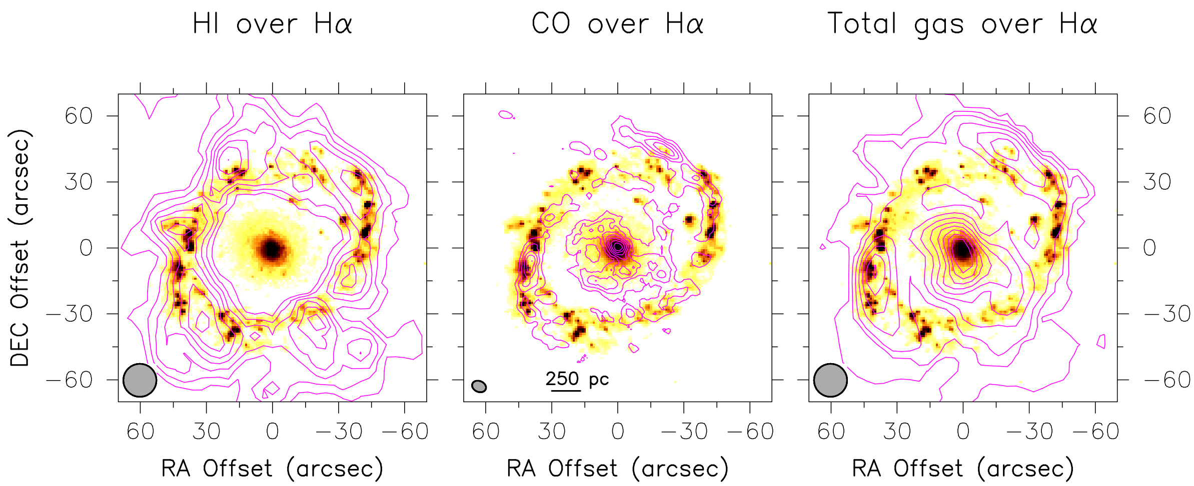
SOFIA's angular resolution in the mid-infrared will be comparable to that achieved by BIMA SONG, and will provide important information on both the interstellar medium and star formation activity in nearby galaxies.

1. Introduction

NGC 4736 (M94) is a nearby ($\approx$6 Mpc) Sab galaxy with a bright ring of H II regions about $50''$ (1.5 kpc) from its center. We have recently imaged the inner $2' \times 2'$ of the galaxy in the λ=2.6 mm CO (1-0) line with the Berkeley-Illinois-Maryland Association (BIMA) interferometer at $6''$ resolution. By making use of VLA H I data previously obtained by Braun (1995), we can investigate the relationship between the atomic and molecular gas and the star formation rate at scales of a few hundred parsecs.

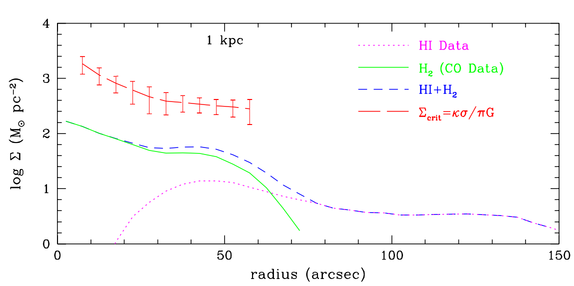
2. Correlations between gas density and star formation

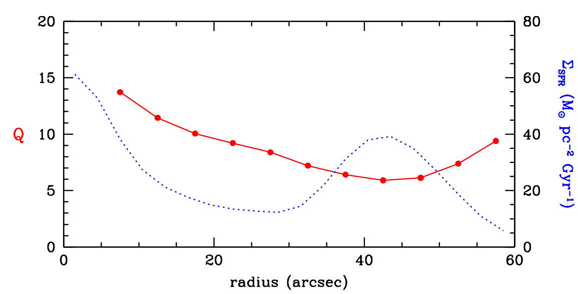
Schmidt (1959) proposed a simple power-law relationship between star formation rate (Ψ) and gas density, $\Psi \propto \rho^n$, while Kennicutt (1989) found that on a global scale, the total gas density and H I density were much better correlated with Ψ than the H_2 density was. For NGC 4736, comparison of the integrated CO intensity with the Hα image of González Delgado *et al.* (1997) shows that CO (which traces H_2) is well-correlated with Ψ on large scales, but rather poorly correlated on small ($\sim$150 pc) scales. A simple explanation for the latter effect is that star-forming molecular clouds in the ring possess too much dust for Hα to be detected, whereas the OB associations which are prominent in the Hα image have dissociated or ionized much of their natal gas. Interior to the ring there is a bright disk of CO emission that is associated with very little Hα emission. Here the lack of correlation may also be due to extinction, although the lack of radio continuum emission (Duric & Dittmar 1988) suggests that star formation is in fact less efficient than in the ring. In a forthcoming paper (Wong & Blitz 2000) we suggest that gas flows towards the ring are responsible for the higher star formation efficiency there. Infrared observations with SOFIA, being less susceptible to extinction, will provide a more robust estimate or current star formation activity.



3. A threshold density for star formation?

Kennicutt (1989) found that Ψ falls sharply below a "threshold" gas surface density which he identified with the Toomre critical density for gravitational instability in a thin disk: $\Sigma_c \sim \kappa\sigma_v/\pi G$, where κ is the epicyclic frequency and σ_v is the velocity dispersion. We find that the ratio $Q \equiv \Sigma_c/\Sigma_g$, where Σ_g is the azimuthally averaged gas density, reaches a minimum at the location of the ring (figure, below right), where star formation is currently most active, but even here Σ_g is well below the critical density (figure, left). Thus, star formation is indeed occurring where Q is small, but at $Q \sim 5$ rather than $Q \sim 1$. A more detailed study of this problem, involving a larger sample of galaxies from BIMA SONG, is in progress.





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