Dense Molecular Gas in the Tidal Tail of Stephan's Quintet

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Abstract: We present high resolution observations of ^{12}CO *J* =1-0 in the eastern-most tidal of Stephan's Quintet (a.k.a. HCG 92). We detect CO emission that indicates 1 x 10^9 M_{sun} of molecular gas at a location corresponding to a region of active star formation and a dust lane. Comparison of the CO line width with the mass of molecular gas suggests that this region is gravitationally bound and is a real tidal dwarf galaxy and not a transient object.

Introduction: The parallel studies of dwarf galaxies and the outer regions of spiral galaxies have come together as awareness has grown of the apparent formation of new dwarf galaxies in the tidal arms of merging and interacting systems. These galaxies are referred to as "Tidal Dwarf Galaxies" (hereafter TDGs). In the early 1990s, Mirabel and collaborators found patches of enhanced optical emission along the tidal tails of interacting systems and subsequently found that these patches correlate closely with local enhancements in the column density of HI (*e.g.* Mirabel *et al.* 1991; Duc & Mirabel 1994; Duc *et al.* 1997). Some TDGs and candidate TDGs show signs of recent star formation, such as blue colors and H emission (*e.g.* Duc & Mirabel 1994; Iglesias-Paramo & Vilchez 2001) which implies the presence of molecular gas.

Several issues surrounding TDGs remain unresolved, including whether or not they are truly self-gravitating, newly formed galaxies, whether the CO-to-H_2 conversion factor is higher than in dIs and BCDs, and whether their molecular gas is formed *in situ* from atomic gas, or is already in molecular form when expelled from the parent merging system.

To shed some light on these issues, we are undertaking a high resolution study in the ^{12}CO *J* =1-0 line of the Hickson Compact Group 92, also known as Stephan's Quintet. This system has been mapped in CO at low spatial resolution over most of its spatial extent (Lisenfeld *et al.* 2002) or at high spatial resolution in a single field (Gao & Xu 2000). Ours is the first wide-field, multi-pointing, high resolution survey of CO emission in this compact group. We present here first results from selected regions in our study.

Figure 1 (background): Hubble Space Telescope image of Stephan's Quintet taken from the Hubble Heritage website (STScI photo release 2001-22).

Results: Using the CO linewidth of 40 km/s, we can estimate the virial mass of this object using $M_{virial} = 99V^2D_{pc}$ = **7x10⁸ M_sun** assuming a diameter of 10" and a distance of 88 Mpc to HCG 92.

The flux for this region is 7.5 Jy-km/s which we can convert to a molecular mass using $M_{gas} = 1.61\times10^4(\ /\ _{gal})d^2S_{CO}$ = **9×10^8 M_{sun}**

Comparison of the virial mass to the molecular mass suggests that this object is likely gravitationally bound, and represents a true tidal dwarf galaxy, rather than a transient feature.

The fact that $M_{gas} > M_{virial}$ suggests that the CO-to-H2 conversion factor ( ) may be lower than the Galactic value ($_{gal}$) in this low metallicity environment, which is opposite to the normal claims. It is likely that we are not completely resolving this object, so this analysis is not completely valid.

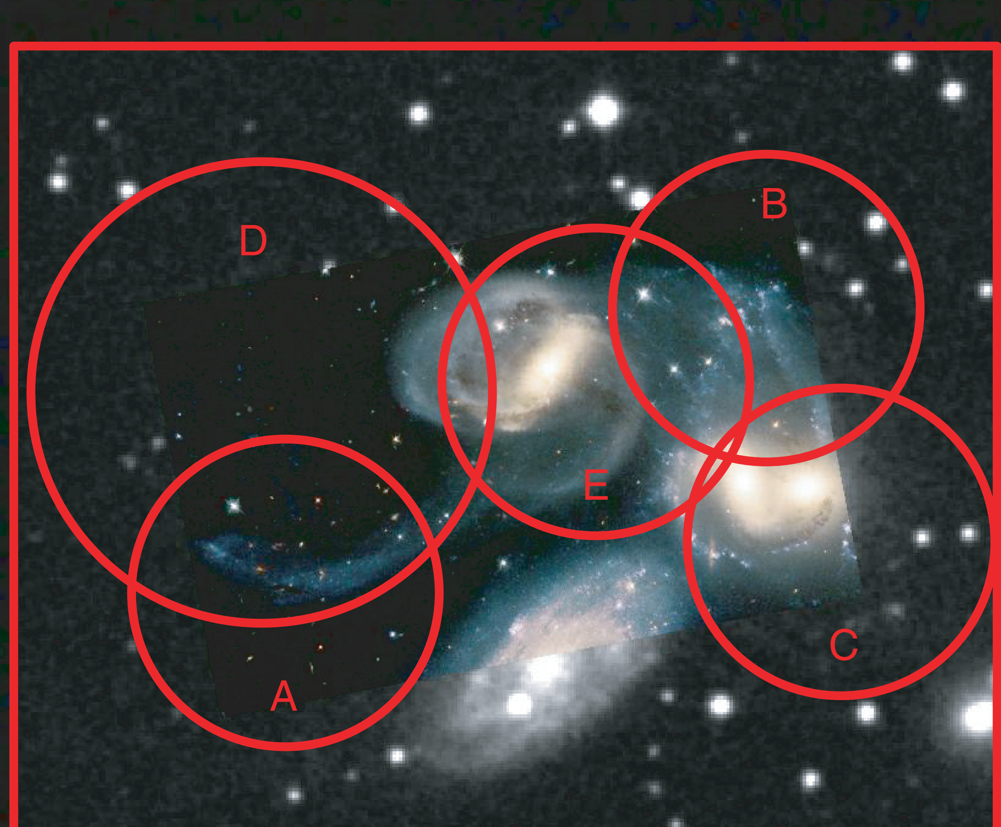

Figure 2: Schematic view of the fields we will be or already have observed with the BIMA interferometer. Field A is presented here. Fields B and C have no detections yet, but more data is incoming. Field D is a 7-field mosaic of the "Arc N" region observed in HI by Williams *et al.* 2002. Field E is from Gao & Xu 2000 and is available in the BIMA archive.

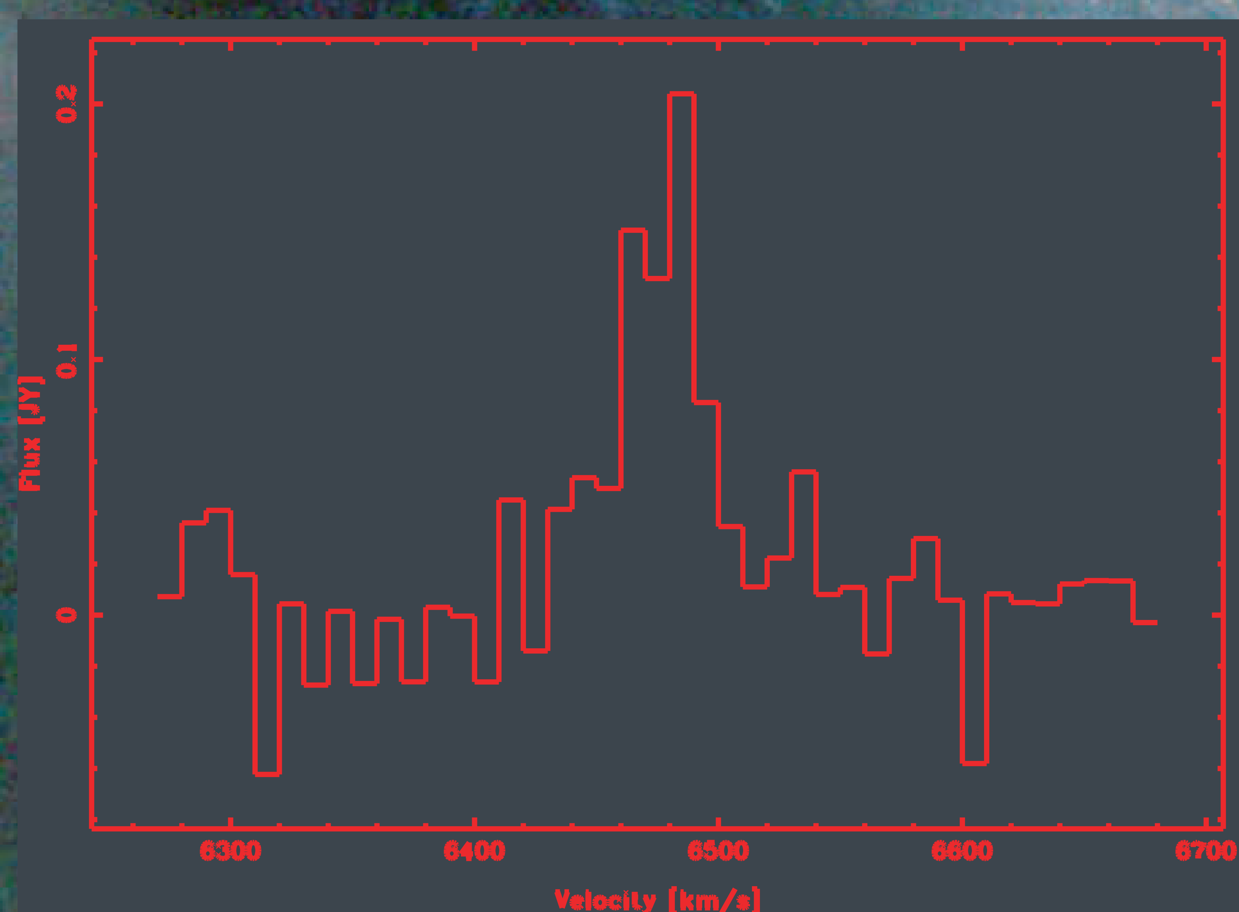

Figure 3: BIMA ^{12}CO *J* =1-0 spectrum for the region shown in Figure 4 (Region A in Figure 2). The total flux is 7.5 +/- 0.7 Jy-km/s which corresponds to a mass of 1 x 10^9 M_{sun} assuming a distance of 88 Mpc. This flux constitutes 100 % of the single dish flux detected with the IRAM 30m by Lisenfeld *et al.* 2002.

Results (cont): We have already observed two other regions without detecting CO emission. Despite evidence of star formation, Region B and Region C (see Figure 2) contain less than 8×10^7 M_{sun} of molecular gas. More data is forthcoming.

Additionally, we have just begun a mosaic of the "Arc N" region, which contains large amounts of HI emission (Williams *et al.* 2002) and contains candidate TDGs (Palma *et al.* 2002).

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Actual Location!

Figure 4: Combined C and D array integrated intensity ^{12}CO J =1-0 map taken with BIMA overlaid on its actual location on the tidal tail. The resolution is 7.5" x 8.5". H maps of this region suggest active star formation is taking place (Duc & Mirabel 1994).