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Young Galaxies and Stellar Nurseries Born when Galaxies Collide

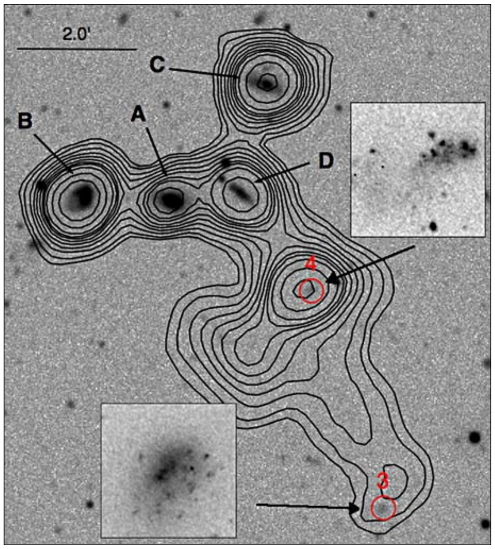
Gemini Multi-Object Spectrograph observations lead to a better understanding of how tidal tails of galaxy mergers may not only pollute their intergalactic environment but also form young galaxies and stellar nurseries when galaxies collide.

When galaxies collide they go through dramatic transformations leaving behind debris in the intergalactic medium. In the past few years we've developed a method using multi-wavelength data that has proven quite successful in identifying newly formed objects within this tidal debris. First, we searched the literature for cases of interacting galaxies with extended neutral hydrogen (HI) tidal tails. We then used a source-finder algorithm on ultraviolet (UV) images taken with the Galaxy Evolution Explorer Satellite (GALEX) to identify sources that coincided with the HI tails.

To date, we've detected 263 such UV objects in 33 interacting systems. In all cases, these UV sources lie outside large galaxies and may be associated with debris of previous galaxy collisions.

Our next main goal was to establish the physical properties of these UV sources; all belong to low-density environments where the physical processes might differ from those in star-forming regions in disks of spiral galaxies. However, GALEX data alone could not provide enough information and multi-wavelength data, in particular spectroscopy, to verify their nature and whether these sources are part of the interacting system.

Figure 1.
GALEX NUV image 10′ × 10′ with H I contours. Four HCG 100 members are marked as "A, B, C, and D". Intragroup objects are circled (radius = 8 arcseconds) and numbered. VLA NH I contours are 0.6, 1.2, 2.1, 3.6, 4.4, 5.1, 5.9, 6.6, 7.4 × 10^{20} cm^{-2} (Verdes Montenegro et al. *2006). North is to the top and east to the left. Objects 3 and 4 from de Mello* et al. *(2008) are the "Baby Galaxies" identified in the NUV image and for the first time seen in the optical r-Band with Gemini.*



In 2008 we started a pilot project with Gemini to explore the nature of a dozen UV sources found in the HI tidal tail of a group of galaxies known as Hickson Compact Group 100 (HCG 100). Located 249 million light-years away, this group is formed by a bright central spiral galaxy (HCG 100a), an irregular galaxy with an optical tidal tail (HCG 100b), a late-type barred spiral (HCG 100c), a late-type edge-on spiral (HCG 100d), and a really long HI tidal tail extending more than 424,000 light-years from the interacting galaxies. In de Mello *et al.* (2008), we present GALEX images of this group, where we identified a dozen UV sources located in the vicinity of the HI tail. When we compared their UV light to the ones of stellar populations from theoretical models, we estimated that they are only a few million years old.

Gemini Baby Galaxies

With the Gemini Multi-Object Spectrograph (GMOS), we confirmed that two of the largest UV sources lie at the same distance as the Hickson group and therefore they may belong to this interacting system. With Gemini optical (r) images, we discovered the knotty morphology of these objects (Figure 1), just like one would expect from young galaxies. But GMOS data provided us with one more piece of information that helped us understand better the nature of these "baby galaxies." From Gemini spectroscopy, we were able to detect the chemical elements already present in these galaxies and determined they are more metal-rich than typical dwarf galaxies (de Mello *et al.*, 2012).

Therefore, due to their morphology and chemical composition, we suggested calling them tidal dwarf galaxies (TDGs), *i.e.* "baby galaxies" born from gas that has already been enriched by chemical elements formed by previous generations of stars in the colliding galaxies. The pre-enriched gas has been thrown out from the colliding galaxies during the interaction and is now forming new generations of stars within the TDGs, which have masses equivalent to 100,000 times that of the Sun.

Gemini Stellar Nurseries

We have also used Gemini to investigate the tidal tails of colliding galaxies in the process of becoming one single galaxy, also known as mergers. We chose NGC 2782 (Arp 215), which lies 110 million light-years distant and has two tails. One is a prominent tidal tail detected in HI, located to the western side of the object, and the other is a tidal tail formed by a stellar component seen to the east side of the galaxy.

GALEX images reveal seven UV sources in the region where the HI tail is, which Gemini superb quality images is able to resolve in several individual clusters (Figure 2). With GMOS we found that these clusters are also as metal-rich as the TDGs in HCG 100 (Torres-Flores *et al.*, 2012; Werk *et al.*, 2011). But stellar clusters are not as massive as TDGs, having masses equivalent to 10,000 times the mass of the Sun. These stellar clusters may have formed out of highly enriched gas once expelled from the center of the merging galaxies. An additional possibility is that the tail has nursed a few generations of young stellar systems, which ultimately polluted this medium with metals, further enriching the already pre-enriched gas ejected to the tail when the galaxies collided.

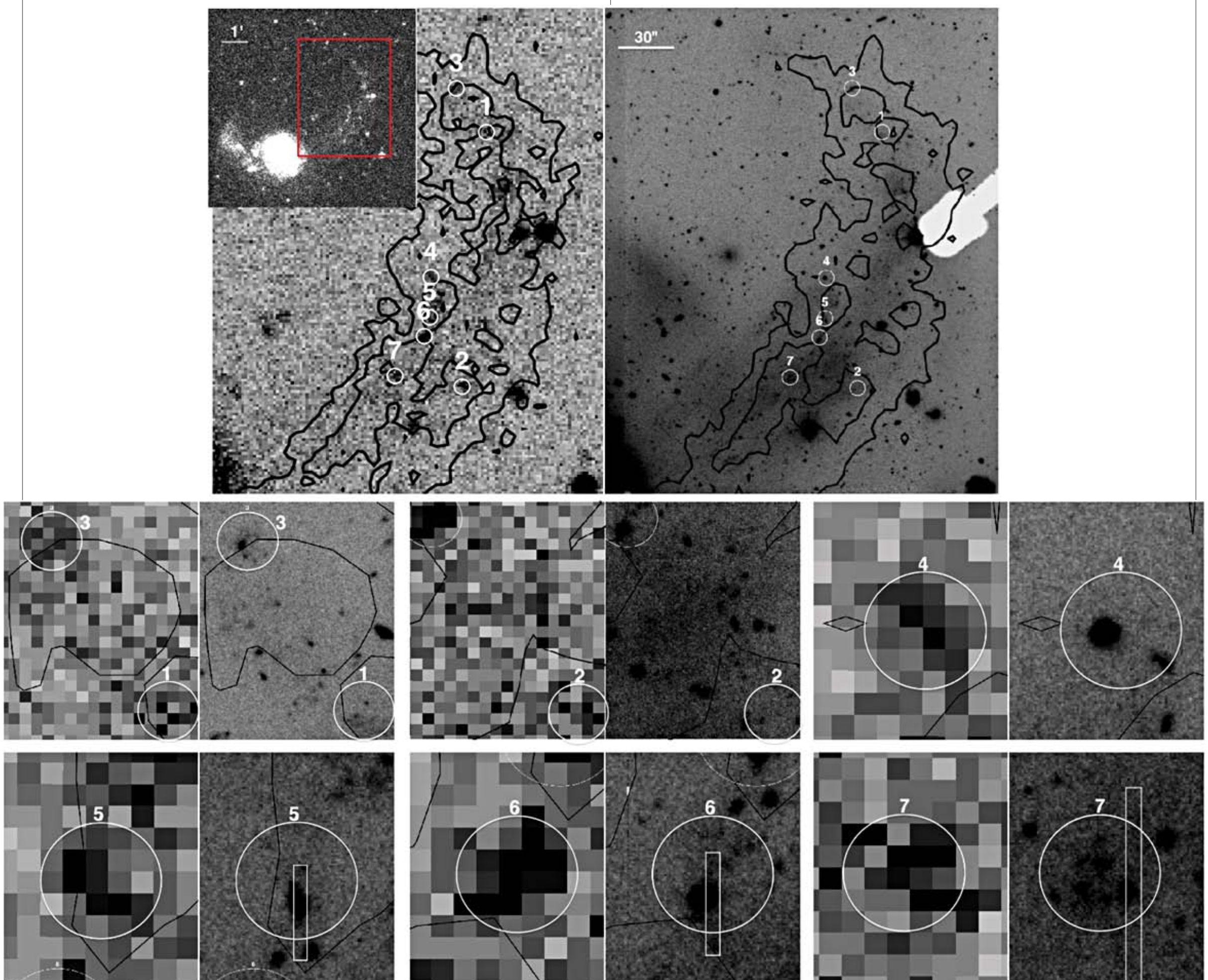


Figure 2.

GALEX NUV-band image of the HI tidal tail of NGC 2782. NUV-band image of the entire target is shown in the upper-left corner. Top-right: Gemini r-band image of the tail. The numbered circles (4 arcsecond radius) show the detected regions. The contours represent the HI distribution taken from Smith (1994). Bottom images: close-up of the detected regions (left-hand side: NUV-band image; right-hand side: r-band image). The Gemini r-band image resolved the UV detections in several smaller stellar clusters, as exemplified in the lowest six panels. The white rectangles over regions 5, 6 and 7 indicate, approximately, the position of the slit in the spectroscopic observation.

Environmental Effect?

We are currently working on more Gemini data of other UV sources in HI tails of several interacting systems –– searching for any environmental evidence that may be decisive factors in the formation of TDGs or/and stellar clusters. Some preliminary results show that compact groups of galaxies may be more conducive to TDG formation (or better said, TDG survival) than pairs and mergers. This argument agrees with the simulations by Bournaud and Duc (2006) where specific conditions, such as low impact velocity (v < 250 kilometers per second), prograde encounters and mass ratio up to 4:1 may lead to TDG formation. Compact groups might harbor these conditions besides the possibility that group potential may be able to drive TDGs away from the nearby proximity of their progenitor galaxies.

The Importance of Our Results

The fate of these newly discovered objects is still unknown. Whether these systems will become independent entities is not clear. It will depend on several parameters, such as the distance to the parent galaxies and total masses. TDGs, for instance, might grow into dwarf galaxies and become part of the interacting system. But they might also fall into bigger galaxies and be torn apart.

Stellar clusters may also be tidally shredded and become sparse stars in the intergalactic medium; they might also become the progenitors of globular clusters and stay as part of the final merging system. Independently of what the future holds for these systems, when they are young, they contain massive stars which will explode as supernovae as they evolve. Because the masses of these systems are low, the escape velocity is low, and therefore more material is ejected from them, polluting the surroundings. We suggest that these objects may be active polluters of the intergalactic medium where they were formed.

For more information:

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