Formation and Evolution of Galaxy Outskirts
Proceedings IAU Symposium No. 321, 2016
A. Gil de Paz, J.H. Knapen & J.C. Lee, eds.

doi:10.1017/S1743921316009066

The frequency and properties of young tidal dwarf galaxies in nearby groups

K. Lee-Waddell[1], K. Spekkens[2], P. Chandra[3], N. Patra[3], J.-C. Cuillandre[4], J. Wang[1], M. P. Haynes[5], J. Cannon[6], S. Stierwalt[7], J. Sick[8] and R. Giovanelli[5]

[1]CSIRO Astronomy and Space Science, Australia Telescope National Facility, PO Box 76 Epping, NSW 1710, Australia
email: Karen.Lee-Waddell@csiro.au

[2]Department of Physics, Royal Military College of Canada, PO Box 17000, Station Forces Kingston, ON K7K 7B4, Canada

[3]National Centre for Radio Astrophysics, Tata Institute of Fundamental Research Pune 411 007, India

[4]CEA/IRFU/SAp, Laboratoire AIM Paris-Saclay, CNRS/INSU, Université Paris Diderot Observatoire de Paris, PSL Research University F-91191 Gif-sur-Yvette Cedex, France

[5]Cornell Center for Astrophysics and Planetary Science, Cornell University Ithaca, NY 14853, USA

[6]Department of Physics and Astronomy, Macalester College, 1600 Grand Avenue Saint Paul, MN 55105, USA

[7]Department of Astronomy, University of Virginia, 530 McCormick Road Charlottesville, VA 22904, USA

[8]Department of Physics, Engineering Physics and Astronomy, Queen's University Kingston, ON K7L 3N6, Canada

Abstract. We present the results of a multi-wavelength investigation of the dwarf galaxy populations in three interacting galaxy groups: NGC 871/6/7, NGC 3166/9, NGC 4725/47. Using degree-scale Giant Metrewave Radio Telescope HI mosaics and deep optical photometry from the Canada-France-Hawaii Telescope, we measured the HI and stellar properties of the gas-rich low-mass group members to classify each one as a classical dwarf galaxy, a short-lived tidal knot or a tidal dwarf galaxy (TDG). Our observations detect several dwarf irregulars and various tidal knots. We identify four potentially long-lived tidal objects in the three groups, implying that TDGs are not readily produced. The tidal objects examined in this small survey also appear to have a wider variety of properties than TDGs formed in current simulations.

Keywords. galaxies: dwarf, galaxies: interactions, galaxies: groups: individual (NGC 871/6/7, NGC 3166/9, NGC 4725/47)

1. Introduction

Many present-day galaxies reside in group environments (Tago *et al.* 2008), where tidal interactions dominate the dynamics of the contained members. Gaseous material pulled from the outer disks of interacting spirals can produce second-generation tidal dwarf galaxies (TDGs), which differ from first-generation 'classical' dwarfs by their higher metal content and lack of dark matter (Hunter *et al.* 2000). The formation of any tidal feature greatly constrains the interaction properties of the host galaxies and enables in depth study of this evolutionary process.

The significance of dark matter poor TDGs is a topic of recent debate (e.g. Kroupa 2012, Duc *et al.* 2014), which has resulted in contentious conclusions about the validity of the standard ΛCDM model. Hierarchical formation simulations imply that very few TDGs should be expected at the current epoch (Sheen *et al.* 2009); whereas, numerical modelling by Dabringhausen & Kroupa (2013) conclude that the majority of galaxies should be tidal. Sample size is one source of discrepancy between the studies. Few TDGs are widely considered authentic due to the variety of corroborating observations required to confirm tidal origins (e.g. Lelli *et al.* 2015). Therefore, the robust identification of additional TDGs is critical for expanding our understanding of these objects.

2. Multi-wavelength survey

We have conducted a detailed investigation of three nearby gas-rich interacting galaxy groups to study the properties and frequency of TDGs in these environments. The groups were selected from the blind Arecibo Legacy Fast ALFA (ALFALFA) survey (Giovanelli *et al.* 2005) and show signs of recent tidal interaction events, which optimizes the likelihood of detecting young TDGs.

High-resolution HI maps from the Giant Metrewave Radio Telescope (GMRT) enabled gas and dynamical mass (M_{gas} and M_{dyn}) measurements for the identified gas-rich dwarfs. Deep optical photometry from the Canada-France-Hawaii Telescope (CFHT) MegaCam was used to distinguish and characterize putative low surface brightness optical counterparts to the low-mass HI features. The combination of our HI and optical observations provided dynamical to baryonic mass ratios and stellar population estimates that were used to classify TDG candidates, short-lived tidal knots and classical gas-rich dwarf irregular galaxies (dIrrs).

3. Results and implications

We identify a total of four potentially long-lived tidal objects in the three groups. The NGC 3166/9 group contains an HI knot, AGC 208457 (Fig. 1a), which has the hallmarks of a genuine TDG (Lee-Waddell *et al.* 2012, 2016). AGC 749170 is a large ($M_{gas} = 2 \times 10^9$ $M_\odot$) HI feature located in the NGC 871/6/7 group that has an extremely faint stellar counterpart (Fig.1b), implying a dynamical mass to stellar light ratio > 1000 $M_\odot/L_\odot$. This feature appears to lack dark matter and is likely fairly young (Lee-Waddell *et al.* 2014). The NGC 4725/47 group hosts two tidal knots located within a prominent HI tidal tail extending out of NGC 4747 (Fig.1c). These knots appear to have sufficient mass ($M_{gas} = 1 \times 10^8$ $M_\odot$) to decouple from the tail and eventually evolve into long-lived TDGs (Lee-Waddell *et al.* 2016).

The three groups in our study contain a total of at least eight dIrrs, four short-lived tidal knots and four potentially long-lived tidal objects. M_{dyn}/M_{gas} is a clear distinguishing property as shown in Fig. 2. AGC 208457 and AGC 749170 appear distinct from both the tidal knots that are currently not self-gravitating and other dwarf galaxies. Additionally, these two knots occupy the same lower portion of the plots as other observed TDGs found in the literature. Nevertheless, the tidal objects examined in this survey appear to have a wider variety of properties than TDGs of similar mass formed in current simulations – a possible result of environmental influences – which requires further investigation (Lee-Waddell *et al.* 2016).

The extensive capabilities of the Australian Square Kilometre Array Pathfinder (ASKAP) will provide wide-field observations with the sensitivity and resolution required to trace extended tidal features and resolve the HI properties of individual tidal knots in nearby

https://doi.org/10.1017/S1743921316009066 Published online by Cambridge University Press

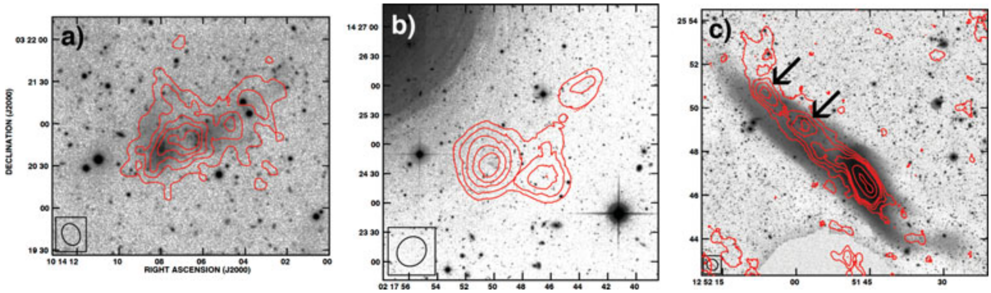

Figure 1. GMRT HI contours of the potentially long-lived tidal knots superimposed on CFHT g'-band images. a) TDG candidate AGC 208457. b) extremely optically dim HI feature AGC 749170. c) NGC 4747 and its tidal tail containing two large HI knots.

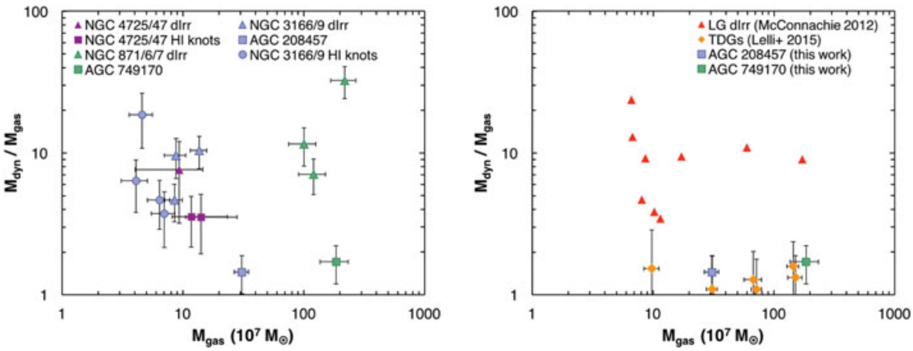

Figure 2. Mass ratios for various low-mass objects. Left panel: dIrrs (triangles), potentially long-lived tidal features (squares) and short-lived HI knots (circles) detected in this study. Right panel: dIrrs in the Local Group (as classified by McConnachie 2012), TDGs reported by Lelli *et al.* (2015) and likely TDGs: AGC 208457 and AGC 749170.

groups. The ASKAP's WALLABY survey will cover 75% of the sky ($-90° <$ dec $< +30°$; Koribalski 2012) and will target a range of interacting systems during early science starting in late 2016. ASKAP commissioning data has been able to map previously unresolved tidal objects (see Serra *et al.* 2015); WALLABY is therefore poised to revolutionize our understanding of TDGs and their surrounding environments.

References

Dabringhausen, J. & Kroupa, P., 2013, *MNRAS*, 429, 1858
Duc, P.-A., Paudel, S., McDermid, R. M., *et al.*, 2014, *MNRAS*, 440, 1458
Giovanelli, R., Haynes, M. P., Kent, B., *et al.*, 2005, *AJ*, 130, 2598
Hunter, D. A., Hunsberger, S. D., & Roye, E. W., 2000, *ApJ*, 542, 137
Koribalski, B., 2012, *PASA* 29, 359
Kroupa, P., 2012, *PASA*, 29, 395
Lee-Waddell, K., Spekkens, K., Haynes, M. P., *et al.*, 2012, *MNRAS*, 427, 2314
Lee-Waddell, K., Spekkens, K., Cuillandre, J.-C., *et al.*, 2014, *MNRAS*, 443, 3601
Lee-Waddell, K., Spekkens, K., Chandra, P., *et al.*, 2016, *MNRAS*, accepted
Lelli, F., Duc, P.-A., Brinks, E., *et al.*, 2015, *A&A*, 584, 113
McConnachie, A. W., 2012, *AJ*, 144, 4
Serra, P., Koribalski, B., Kilborn, V., *et al.*, 2015, *MNRAS*, 452, 2680
Sheen, Y.-K., Jeong, H, Yi, S., *et al.*, *AJ*, 138 1911
Tago, E., Einasto, J., Saar, E., *et al.*, 2008, *A&A*, 479, 927

https://doi.org/10.1017/S1743921316009066 Published online by Cambridge University Press