Spectrophotometric Investigation of a Sample of Tidal Dwarf Galaxies

Peter M. Weilbacher[1], Pierre-Alain Duc[2]

[1]Universitäts-Sternwarte Göttingen, Geismarlandstr. 11, 37083 Göttingen, Germany
[2]CNRS and CEA/DSM/DAPNIA/SAp, Saclay, 91191 Gif sur Yvette cedex, France

Abstract

We summarize our findings on broad-band imaging and spectroscopy of a sample of Tidal Dwarf Galaxies candidates in a sequence of interacting systems. Evidence for decoupled kinematics in the ionized gas have been found in several objects. This could indicate that they are bound galaxies and therefore genuine TDGs. As a detailed example we analyze the system AM 1159-530, where surprisingly high velocity gradients have been measured.

1 Introduction

In the past several authors have used the term "Tidal Dwarf Galaxy" to describe everything from faint knots with dubious association to the interacting system and luminous H II regions to massive knots embedded in tidal tails. We would now like to give a more restrictive

> Definition
>
> A Tidal Dwarf Galaxy (**TDG**) is a bound condensation of dwarf-galaxy mass built from tidal material.

This kind of *true TDG* is difficult to prove observationally, so that in most of the real cases one is restricted to observing *decoupled kinematics* (as a hint to dynamical stability) of a condensation in or at the end of a tidal tail. Systems where this has been accomplished up to now are Arp 105, NGC 7252, NGC 5291, and Arp 245 (Duc et al., 1997; Hibbard et al., 1994; Duc & Mirabel, 1998; Duc et al., 2000, resp.).

From today's observational evidence and dynamical and photometric modelling, a formation sequence for TDGs can be drafted:
An interaction between two giant galaxies occurs; at least one has to be gas rich to account for the star-formation observed in TDGs. Due to gravitational forces and depending on the encounter geometry tidal tails form out of the disk material. One or more condensations may appear in the gaseous and/or stellar component of the tail. Other material is then pulled into this gravitational potential well. Collapsing gas may then initiate a starburst on top of the old stellar population inherited from the parent galaxy. After a long time tidal features disappear, while the condensations may survive as "normal" dwarf galaxies.

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2 Imaging Results

Weilbacher et al. (2000) performed a photometric investigation of TDGs in 10 interacting systems using broad-band B,V,R imaging. Using two-color plots (see Weilbacher & Fritze-v.Alvensleben, this volume) probable TDGs were identified using their distinct color range (which differs from that of background galaxies) in comparison with photometric evolutionary synthesis models. Finally *36 candidates for TDGs* were selected from about 100 knots in the tidal tails. It was found that these TDG candidates are brighter than normal H II regions in spiral galaxies, and are experiencing *strong starbursts*. Therefore a *strong fading* is expected, if/after the current burst stops.

3 Spectroscopic Sample Overview

To be able to confirm the photometric results of our TDG candidate selection we conducted spectroscopic observations of the sample of interacting systems listed in Table 1. We used the EFOSC2 instrument on the ESO-3.6m telescope. The table lists the spectroscopic observing mode (multi-object or long-slit spectroscopy) for each system. The last four columns give the number of photometrically selected TDG candidates, the number of condensations that we could detect (restrictions were brightness and positioning of MOS slits), the number of objects with emission lines, and finally the number of objects where kinematical signatures are visible on the 2D spectrum.

System name	Observ. mode	TDG-Candidates total	detected	w. emiss. lines	kinematics vis.
AM 0529-565	MOS	4	2		
AM 0537-292	2 MOS	5	5	4	2
AM 0547-244	MOS	3	2	2	1(2)
AM 0547-474	LS	2	2		
AM 0607-444	MOS	1	1	1	
AM 0642-645	LS				
AM 0748-665	MOS	3	1	1	
AM 1054-325	MOS+LS	6	5	5	2
AM 1159-530	MOS	1	1	1	1
AM 1208-273	MOS				
AM 1237-364	MOS	4	4	4	2
AM 1324-431	MOS	4	2	2	(1)
AM 1325-292	LS	2	2	(2)	
AM 1353-272	MOS	12	4	4	

Table 1: Spectroscopic observations summary

To illustrate how we will analyze the data of these systems, we present one of our sample systems as an example.

4 The system AM 1159-530

This is a strongly disturbed system with two tidal tails but without a clearly identified interacting companion, which might have caused this disturbed appearance. The luminosity of the nucleus is $M_B = -18.4$ mag, the central receding velocity $V_{\rm nucl} = 4530$ km s^{-1}, corresponding to a distance of $D = 60$ Mpc when using a Hubble constant of $H_0 = 75$ km s^{-1} Mpc^{-1}. The tidal tails of the

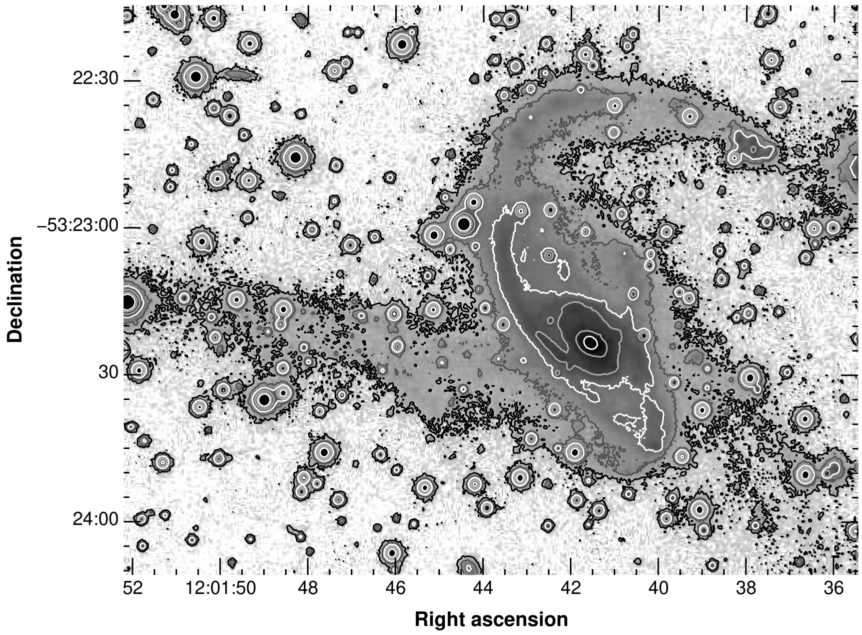

Figure 1: The disturbed system AM 1159-530. Surface brightness contours from 20 to 25 mag/□″ are indicated. The scale is $10'' = 3$ kpc.

system have projected lengths of 38 and 29 kpc (western and northern tail, resp.). In Fig. 1 a logarithmic intensity image of the system is shown.

At the end of the northern tail a bright ($M_B = -16.3$ mag) condensation is visible, which we selected as a TDG candidate. The optical extent of this object amounts to 3.6 kpc $\times$ 2.1 kpc, and it has a knotty appearance. It also has blue colors of $B - V = 0.18$ and $B - R = 0.30$ mag and hosts a H II region. Its spectrum exhibits a weak continuum and strong emission lines. From the Balmer line fluxes we derive a star formation rate of $\sim$1 $M_\odot$ yr^{-1} (from the calibration of Kennicutt et al., 1994), and using the Balmer and oxygen lines we estimate an oxygen abundance of $12 + \log(O/H) = 8.4 \pm 0.1$, shifting the object from the luminosity-metallicity relation of normal dwarf galaxies into the region where most TDGs are located (see contribution by P.-A. Duc in *this volume*).

The ionized gas in this object has a strong velocity gradient which is clearly visible in the 2D spectra shown in Fig. 2**(a)**. The corresponding velocity curve is plotted in Fig. 2**(b)**. We measure a peak to peak gradient as large as $\sim$500 km s^{-1} within a diameter of only 1.7 kpc. For reference, the mean velocity of the tail itself varies by less than 80 km s^{-1} from its base to its tip. Pure streaming motions can therefore only account for a few percent within the small region of the TDG. Such a velocity gradient could, in principle, trace the re-accretion of tidal material or be interpreted in terms of rotation. If the latter were the case, one would derive from it a virial mass $M_{\rm dyn}$ as large as $10^{10} M_\odot$. This is of course much higher than the stellar mass, which is estimated to be $M_{\rm stars} = 10^8 M_\odot$ from the optical luminosity. But given the errors in both of these estimates and the fact that the dynamical state of the object is largely unknown, we do not think that dark matter is needed to fill the gap. The gas mass, which is usually high in TDGs (e.g. Duc et al., 1997) but currently unknown in AM 1159-530, might account for the missing mass.

In any case, the condensation at the end of the northern tail of AM 1159-530 appears to be kinematically decoupled from the tidal tail and thus is a *true* TDG.

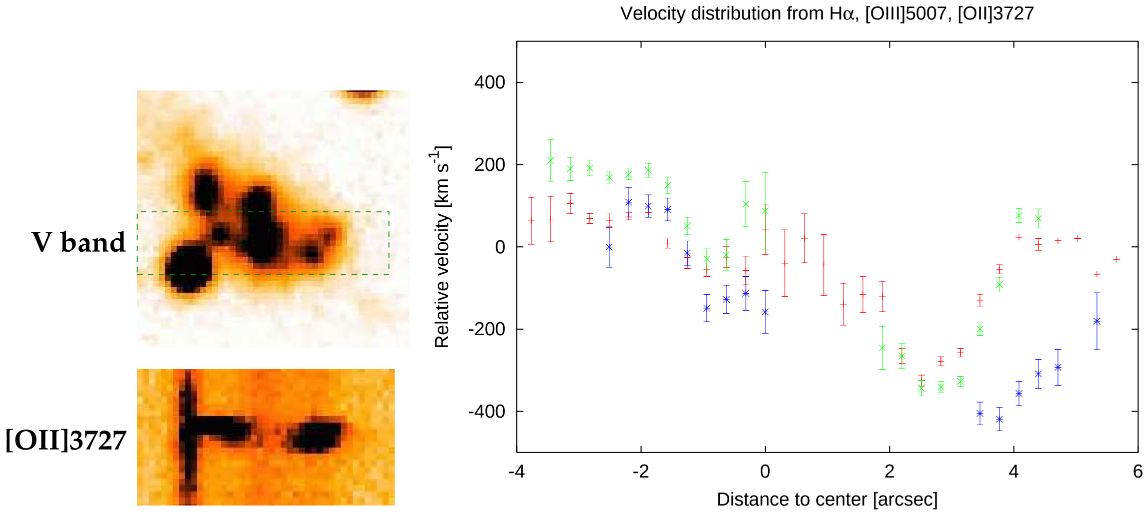

Figure 2: **(a)** V-band image of the TDG with the position of the slit marked and the position-velocity distribution as extracted from the 2D spectrum from the region around the [O II]3727 line. **(b)** Velocity distribution as derived from the three lines Hα, [O III]5007, and [O II]3727.

5 Conclusions

We have found one more system with a bright TDG kinematically decoupled from the tidal tail. It exhibits a strikingly strong velocity gradient the origin of which could be multifold, including rotation. The TDG is currently experiencing a strong starburst.

We have a wealth of spectrophotometric data which we still have to analyze in detail,in particular to derive reddening, star-formation rate, and metal abundance. Several more TDG candidates with kinematical signatures are visible on 2D spectra (see Tab. 1); we can therefore expect to find a few more true TDGs in our sample.

Comparison with photometry and spectra from evolutionary synthesis models (see Weilbacher & Fritze-v.Alvensleben, this volume) will allow to reasonably constrain the burst parameters and provide clues to the future evolution of our TDG candidates.

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