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## Tidal dwarfs in Wolf-Rayet galaxies

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**Abstract.** Wolf-Rayet (WR) galaxies are ideal objects to investigate the triggering mechanisms of star formation. Interactions between dwarf galaxies could explain the triggering in many cases. We present the conclusions about our morphological and spectroscopy analysis of the WR galaxies Mrk 1087 and HCG 31, where interactions between more than two galaxies seem to be operating. We emphasize the nature and probable evolution of the tidal dwarfs found in these particular WR galaxies.

### 1. Introduction

WR galaxies are a subset of emission-line galaxies whose integrated spectra have broad emission features that have been attributed to the presence of a substantial population of WR stars. The WR is a short-lived phase and gives the possibility of studying an approximate coeval sample of starburst galaxies. Making use of population synthesis models it is possible to determine the age of the WR bursts and to study the star formation processes and its causes. Several authors have suggested that interaction between dwarf companion objects is one of the main mechanism of the triggering of these starbursts. Méndez & Esteban (2000) remarked that if an external companion object has induced the star formation their interrelation should be very evident. They performed a systematic study of 13 WR galaxies and found that 7 of them were clearly interacting and other 4 had probable interaction features.

Nowadays, we are extending this study and performing a morphological and spectroscopic analysis of a sample of WR galaxies selected from the latest WR catalogue by Schaerer et al. (1999). We present our results of Mrk 1087 and HCG 31. Intermediate long-slit resolution spectroscopy of both systems were carried out with the ISIS spectrograph at 4.2m William Herschel Telescope (WHT). Optical V imaging of Mrk 1087 was carried out at the 2.2m Calar Alto Observatory, whereas optical U, B and V images of HCG 31 were carried out at 2.56m Nordic Optical Telescope (NOT) with the ALFOSC camera. We used the 1.55m Carlos Sánchez Telescope (CST) to obtain near-infrared images in J (1.2  $\mu\text{m}$ ), H (1.6  $\mu\text{m}$ ) and Ks (2.18 $\mu\text{m}$ ) broad-band filters.

### 2. Mrk 1087

Mrk 1087 is at a distance of 111 Mpc. Our new deep larger-fielded V image (*Figure 1*) shows a new faint companion dwarf galaxy to the north of Mrk 1087

which has a similar radial velocity. It shows nebular emission, indicating that star-formation is ongoing or has been very recent in the object, perhaps due to the interaction. The O/H ratio suggests that objects #1 and #3 are tidal dwarfs originated from material stripped from Mrk 1087. The lower O/H ratio obtained for the north companion suggests that it should be interpreted as an independent nearby dwarf galaxy which is very probably interacting with Mrk 1087. This could explain the presence of the tidal dwarf #1 and its associated bridge, which is almost aligned with the N knot.

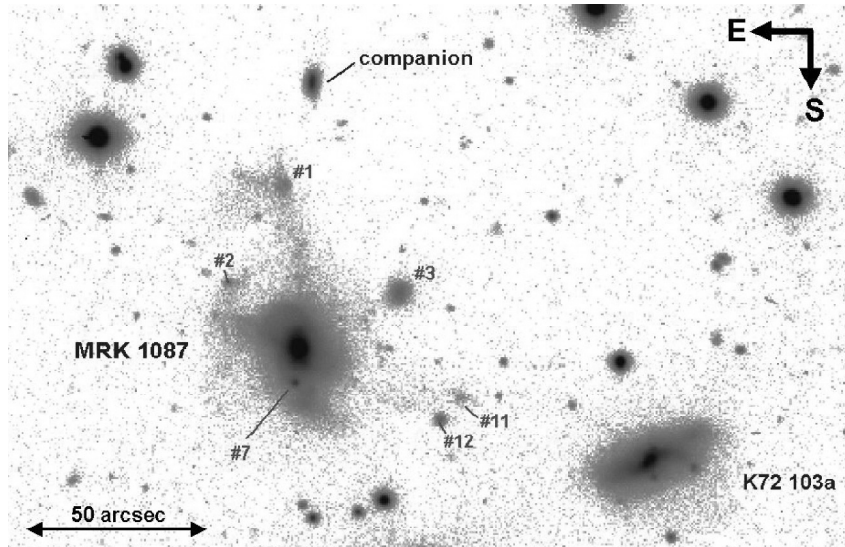


Figure 1. Deep V image of Mrk 1087 and its surrounding.

We have used Leitherer et al. (1999) and Schaerer & Vacca (1998) spectral synthesis models to estimate the age of the bursts. A good agreement in all the age estimations has been obtained. We have found that the burst in the north companion is around 5 Myr old, whereas the main body of Mrk 1087 is around 7 Myr old. The complex geometry of the filamentary structure of Mrk 1087, the existence of several tidal tails, the position-velocity diagrams, the O/H ratios and ages obtained indicate that it is experiencing a strong star formation event due to the interaction with at least two external galaxies: the relatively bright K72 103a at 70 kpc and the new dwarf companion at 60 kpc. We consider that Mrk 1087 and its surroundings can be interpreted as a compact group of galaxies.

Mrk 1087	Centre	North companion	# 1	# 3	# 7
$M_B$	-21.7	-16.2	-16.2	-16.9	-17.3
$12+\log[\text{O}/\text{H}]$	8.70	8.30	8.70	8.70	8.55
Estimated age (in Myr)	7	5	-	6 - 7	5 - 7
Radial velocity ( $\text{km s}^{-1}$ )	0	+117	-63	+10	+144

Table 1.  $M_B$ , O/H ratio,  $\Delta v_r$  and age for Mrk 1087 and surrounding objects.

### 3. Hickson Compact Group 31

The compact group HCG 31, at a distance of around 55 Mpc, is one the best studied compact groups of galaxies because of its peculiar morphology. Members A and C are clearly interacting and form NGC 1741. E and F objects, Mrk 1090 (object G) and the far member Q are also included in HCG 31. We show our V image of the system in *Figure 2 (left)*. The H I map of the group (Williams et al. 1991) shows that all the galaxies are embedded in the same gas cloud. Maxima of H I column density are coincident with the optical galaxies, indicating they are gas rich.

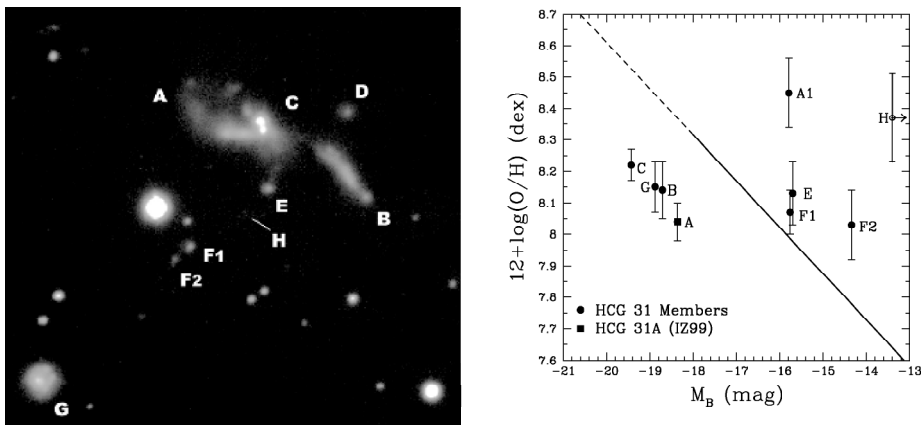


Figure 2. (Left) Deep V image of HCG 31 indicating all its members, except Q. (Right) Luminosity-metallicity relation for bursts in HCG 31. The solid line is the Richer & McCall (1995) relation for dwarf galaxies (extrapolated to non-dwarf galaxies). A is taken from Izotov & Thuan (1999).

HCG 31	A	B	C	E	F1	F2	G	H
$-M_B$	18.4	18.7	19.4	15.8	15.8	14.3	18.9	$>13.1$
$(U-B)$	-0.41	-0.38	-0.66	-0.65	-0.99	-1.01	-0.43	...
$12 + \log(O/H)$	$8.45^a$	8.14	8.22	8.13	8.07	8.03	8.15	$8.37^a$
Est. age (in Myr)	6 - 8	5 - 8	4 - 6	5 - 6	2 - 3	2 - 3	5 - 7	3 - 5

Table 2.  $M_B$ ,  $(U-B)$  color, O/H ratio and age for HCG 31 members.

<sup>a</sup>Calculated by empirical calibrations (see text).

We have analyzed three slit positions observed for intermediate-resolution spectroscopy in order to study the kinematics, physical conditions and chemical abundances of the knots. We have estimated the electron temperature making use both the  $[OIII]$  4363 Å emission line (except for A and H) and empirical methods (Pilyugin 2000, Denicoló et al. 2002). The O/H ratios obtained from direct determination of the electron temperature are rather similar (between 8.0 and 8.2) and are consistent with other previous from the literature. We have obtained the first direct abundance determinations for members E, F2, and G. We have used theoretical models of Leitherer et al. (1999), Stasińska & Leitherer

(1996) and Schaerer & Vacca (1998) to estimate the age of the bursts. Similar values were obtained in each member, indicating that the possible underlying old population seems not to be important, specially in F objects (the youngest members).

The oxygen abundances of the galaxies are unusual taking into account the luminosity-metallicity relation of Richer & McCall (1995). In *Figure 2 (right)* we can see that the four brightest galaxies of HCG 31 (A, B, C and G) show rather similar O/H, about a factor of 2 (0.3 dex) lower than the value expected from this relation. This is a real behaviour because the abundances are well determined, based on direct measurement of the electron temperature for most of the objects. We consider that perhaps the metallicity-luminosity relation of dwarf irregular galaxies is *not appropriate* for interpreting the properties of starburst galaxies because the contribution of the burst dominates the blue luminosity, in contrast to the situation in non-bursting dwarfs.

On the other hand, E and F show the same oxygen abundances as the brightest galaxies of the group, despite the difference of about 5 magnitudes. Furthermore, their position in the O/H vs  $M_B$  diagram seem to be rather consistent with the Richer & McCall (1995) relation. However, it could be fortuitous, because the very blue colors (see *Table 2*) and small sizes derived for E and F may produce that the relative contribution of the young population could be even more important than in the brightest galaxies of the group, as it would be expected following population synthesis models. The future photometric evolution of their starbursts could move their positions away the relation toward lower luminosities after the first 10 Myr. If this prediction were correct, it would favor their tidal dwarf nature as several authors have pointed out previously.

#### 4. WR features and tidal tails in Compact Systems

From 1994, an increasing number of morphological interaction signs, like mergers and tidal tails, has been reported in compact groups of galaxies and similar systems where several interacting galaxies have been discovered. The finding of the WR features in them permits to study the star formation and its triggering mechanism with better detail, as well as a better knowledge of the nature and properties of their tidal dwarves and structures.

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