Interactions and starburst activity in galaxy groups

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ABSTRACT

We present some results of the **multiwavelength analysis** (*optical, NIR and radio observations*) of some **galaxy groups hosting starburst galaxies** in order to understand their general properties, environment and star formation history and the importance of the interactions and mergers between galaxies in their evolution. Concerning the galaxy groups **HCG 31** and **Mkn 1087**, interactions involving more than two objects are needed to explain all the detected features. We also present our new puzzling radio data about the starburst galaxy **Tol 9** within the **Klemola 13 group**.

THE HICKSON COMPACT GROUP 31

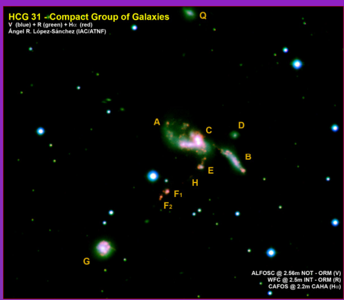


Figure 1. Color image of HCG 31 combining B, R & Hα data obtained using different telescopes.

HCG 31, at 54.8 Mpc, is one the best studied **compact groups** because of its peculiar morphology (**Figure 1**). Members A and C are clearly interacting and constitute NGC 1741. The H I map of the group (Williams et al. 1991; Verdes-Montenegro et al. 2005) shows that all the galaxies, except D (a background galaxy), are embedded in the same neutral gas cloud. A detailed analysis is found in **López-Sánchez et al. (2004a)** and **López-Sánchez (2006).**

Optical and NIR imaging

Deep imaging in optical and NIR filters was used to study the morphology of the galaxies, as well as their stellar populations comparing with theoretical models. F is the youngest member (2.5 Ma) and hosts a substantial population of WR stars.

Optical spectroscopy

Our deep spectra let a direct determination of both electron temperature and chemical abundances in almost all members. The O/H and N/O ratios are rather similar despite their very different absolute magnitudes and range between 12+log (O/H) = 8.0 and 8.2 and log (N/O) = –1.4 and –1.2.

The **kinematics of the ionized gas** (**Figure 2**) indicate that the velocities of **F1 and F2** are similar to that of **E and G**, which coincides with the radial velocity of the HI cloud in this zone. The H I extension has a rather constant radial velocity but the optical tidal tail shows a clear streaming motion Thus, we are observing two spatially coincident kinematical structures:

1. An **arm-like HI structure** that extends from A+C in direction to member G, from which **objects E and F may be formed** (*yellow-pale* in **Figure 3**), and

2. An **optical tidal tail that emerges from the southwest of the A+C complex**, which consist of a curved string of faint star-forming regions that ends at the position of object H (*blue and violet* in **Figure 3**).

Conclusions

E, F1, and **F2 are TDG candidates** made by material from the southern **arm-like HI extension,** which was stripped **from the A+C complex** due to **a fly-by encounter with G**. The **merging process of A and C** could be the origin of the **two optical tidal tails** that extend towards the northeast and southwest

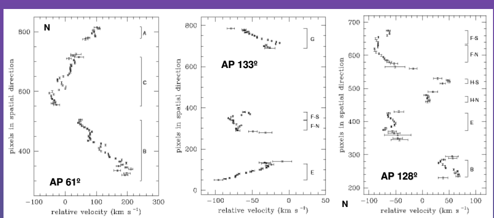


Figure 2. Position-velocity diagrams obtained for the 3 slit positions observed in HCG 31 using the ISIS spectrograph at 4.2m WHT.

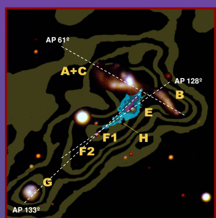


Figure 3. Deep image including the H I map (grey-black contours, Williams et al. 1991) and the southern optical Hα tail (blue-violet contour, Iglesias-Páramo & Vílchez 2001). The slit positions are also shown.

THE GALAXY GROUP OF MKN 1087

Mkn 1087, at 111 Mpc, is the main member of a group of three systems (**KPG 103a, Mkn 1087** itself and a **dwarf galaxy at the north**) and several diffuse dwarf objects (**Figure 4**). A detailed analysis is found in **López-Sánchez et al. (2004b)** and **López-Sánchez (2006).**

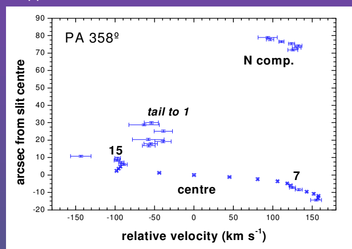
Optical and NIR imaging

Our new deep images revealed the existence of the **north companion galaxy** at 41 kpc from Mkn 1087. Some of the **non-stellar objects** surrounding Mkn 1087 are **connected by bridges** with the main body and host star-formation events. The age of the last star-formation burst was also determined for each knot.

Optical spectroscopy

We observed 5 slit positions in Mkn 1087 in order to obtain spectra of the main objects. Chemical abundances were derived using empirical calibrations. The **external nature of the dwarf companion** at the north is confirmed by its low metallicity [12+log(O/H) = 8.24] with respect to the one derived for Mkn 1087 [12+log(O/H) = 8.57] and because its kinematics is detached of the rotation pattern of the main galaxy (see **Figure 5**). It seems to have a sort of small rotation pattern; we estimate a mass of 2.2 × 10⁸ M⊙, two orders of magnitude lower than Mkn 1087 (~5.6 × 10¹⁰ M⊙).

The rest of the dwarf objects (**#1, #3, #11** and **#12**) show similar abundances despite their different angular distances from Mkn 1087. This fact, together their kinematics, suggest that they are **tidal dwarf galaxies** formed from material stripped from Mkn 1087.



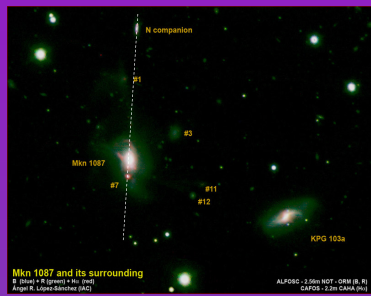


Figure 4. Color image of Mkn 1087 and its surrounding combining B, R & Hα data. The slit position used at 4.2m WHT is also shown.

Mkn 1087: A Luminous Compact Blue Galaxy

Mkn 1087 can be classified as a low-z **Luminous Compact Blue Galaxy** (LCBG), rare objects in the local Universe but common at high redshift. LCBGs are especially interesting for studies of galaxies evolution and formation because they could be the equivalent of the high-z Lyman-break galaxies in the local universe (Erb et al. 2003).

Conclusions

The complex geometry of the filamentary structure of Mkn 1087 and all the photometric, chemical and kinematical results can be explained assuming that **it is in interaction with two external galaxies**:

1. the relatively bright **KPG 103a**, that could explain the bridges, the non-stellar objects located between both galaxies (#11 and #12), and the tidal dwarf galaxy #3;

2. and the new **dwarf north companion**, that could originate the tidal features at the east, the bridge between Mkn 1087 and knot #1, and produce the star formation triggering in the knots found in them.

Figure 5. Position-velocity diagram obtained for the slit position observed in Mkn 1087 using the ISIS spectrograph at 4.2m WHT. Notice the apparent rotation pattern in the inner part of Mkn 1087 and the position of objects #1, #3 and #15 (candidates to TDGs). Knot #7 shows no important deviation of the main rotation pattern. The north companion object is kinematically detached of the of the main galaxy and shows a sort of small rotation pattern.

THE KLEMOLA 13 GROUP

The **Klemola 13 group** (HIPASS J1034-28), located at 43.3 Mpc, contains at least 7 galaxies with different morphological types (see **Figure 6**). Klemola 13 possesses a intense starburst galaxy, **Tol 9** (ESO 436-42), that seems to host an important population of Wolf-Rayet stars indicating both the youth and the strength of the starburst (**López-Sánchez 2006**). Several independent objects are found in the neighbourhood of Tol 9, being the more important the **nearby spiral galaxy ESO 436-46** (at 20.2 kpc).

Optical and NIR results

The analysis of the optical, NIR and Hα images and the optical spectroscopy of Tol 9 is presented in **López-Sánchez (2006)** and in poster *Interactions and star formation activity in Wolf-Rayet galaxies* (**López-Sánchez & Esteban, 2007**). Our images reveal an old stellar population bridge from Tol 9 towards a **dwarf companion object** located 10 kpc at SW, indicating probable **interaction phenomena**. The continuum-subtracted Hα emission map of Tol 9 and the kinematics of the ionized gas suggest that an **outflow of material or a galactic wind** exists in the starburst. The estimated oxygen abundance in Tol 9 is **12+log (O/H) = 8.57** and their nitrogen to oxygen ratio is **log (N/O) = –0.81**.

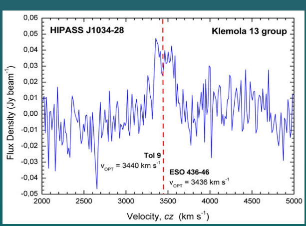


Figure 7. HIPASS spectrum of Klemola 13. The radial velocities derived from optical data for Tol 9 and ESO 436-46 are shown with a dotted line.

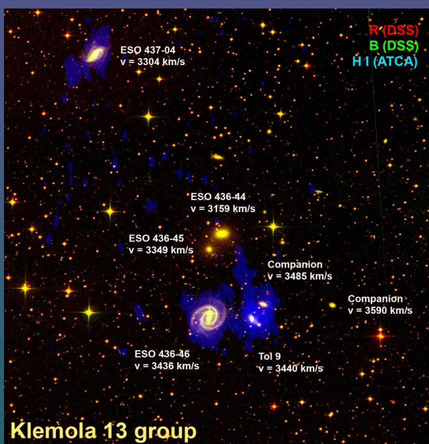


Figure 6. DSS image of Klemola 13 group combining B (green) and R (red) filters. The H I map obtained using ATCA data is shown in blue.

H I previous results

The **HIPASS HI spectrum** of the area (**Figure 7**) reveals a considerable amount of atomic gas, therefore we carried out **H I ATCA observations** of the group. They were performed on 28 and 30 January 2007 using the 1.500 and 750 arrays. The data were reduced using **MIRIAD software** and without considering long baselines (i.e., rejecting data from ATCA antenna 6).

The **H I intensity map** (**Figure 8a**) shows that the neutral gas is mainly found in two regions: the first is located around the spiral galaxy ESO 436-46 (***E Cloud***) whereas the second is embedding Tol 9 and 2 nearby galaxy objects (***W Cloud***). We also detect H I emission in the far object ESO 437-04.

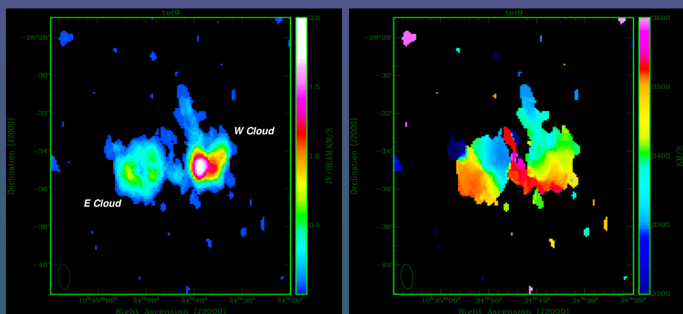


Figure 8. Results of the ATCA H I observations of the Klemola 13 group: (a, left) H I distribution and (b, right) velocity field. The beam size is 78'' x 32'', with a PA= 4.6º, obtaining 50 channels with 12 km/s resolution.

Although we should expect that the neutral gas is mostly associated with ESO 436-46, **the maximum of H I column density is actually found in Tol 9**. Our H I map also reveals a long H I structure at the north of the W cloud and in direction of ESO 436-44 and ESO 436-45. These two galaxies, that are composed by and old stellar population, do not show H I emission.

The **H I kinematics** are also intriguing (**Figure 8b**). The H I cloud around ESO 436-46 reveals the **rotation pattern** expected for a spiral galaxy. But **this characteristic is also found in the H I cloud embedding Tol 9 and its surrounding dwarf galaxies**. Indeed, only seeing the H I velocity field it seems that they constitute one single object. The kinematics of the long tail at the north of the *W cloud* suggest that it is a **tidal tail** formed from material striped from this cloud. A **peculiar structure** is connecting the NW area of the *E cloud* with the SE region of the *W cloud.*

Conclusions

Klemola 13 is a very interesting group of galaxies hosting a powerful starburst, Tol 9. The **peculiar H I morphology and kinematics** observed in the group need a **further analysis** in order to understand their characteristics and evolution.

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