A kinematic study of the neutral and ionized gas in the irregular dwarf galaxies

van Eymeren et al. (2009a, b, 2010)
Abstract

• The feedback between massive stars and the interstellar medium is one of the most important processes in the evolution of dwarf galaxies.

• The main aim is to study the kinematics of the neutral and ionized gas components in order to search for outflowing gas structures and to make predictions about their fate.

• They detect outflows in the Hα spectra of galaxies, but their expansion velocities are too low to allow the gas to escape from the gravitational potential.
Introduction

• Numerous ionized gas structures such as supergiant shells or filaments close to the galactic disc of dwarf galaxies have been detected on deep Hα images.

• Spectroscopic observations of the Hα line revealed that most of the ionized gas structures expand from the disc into the halo of their host galaxies.

• There are two scenarios about the fate of the gas.
  • Outflow (galactic fountain)—the gas cools down and falls back on to the disc.
  • Galactic wind—the gas escapes from the gravitational potential.

• In order to understand the processes happening in dwarf galaxies, they performed a multi wavelength study of altogether four irregular dwarf galaxies.
Observations

• Irregular dwarf galaxies;
  • NGC 2366, NGC 4861, NGC 5408, and IC 4662

• The deep R-band, Hα, and HI images, and the spectroscopy centered at the Hα line ($\lambda = 6565$ Å) for each sample are obtained.
  • R-band images $\Rightarrow$ global morphology
  • Hα images $\Rightarrow$ HII regions, ionized gas shell and filamentary structures
  • HI images $\Rightarrow$ neutral gas morphology and velocity
  • Hα line spectroscopy $\Rightarrow$ ionized gas velocity
NGC 2366 — Morphology

R-band image
- stellar disc

Hα image
- shells
- filaments

HI intensity
- pachy structure

HI velocity
- rotation
- line of sight velocity
NGC 2366 — Kinematics

• The Hα velocity field shows two major deviations from the overall rotation velocity (two black circles in left figure).

• Left figure is the residual map after subtracting the HI velocity field from the Hα velocity field.

• A large red-shifted outflow with an expansion velocity of up to 50 km/s, and a faint blue-shifted component with an offset of 30 km/s are shown.
NGC 4861 — Morphology

R-band image

- shells
- ring-like structure (SGS5)

Hα image

- symmetrically distributed
- more extended than optical content

HI intensity

HI velocity

- rotation
NGC 4861 — Kinematics

- The Hα velocity field shows several deviations from the overall rotation (four black circles in left figure).

- The residual map subtracting the HI velocity field from the Hα one.
  - a: blue-shifted with about 25 km/s
  - b, c: red-shifted with about 30 km/s
  - d: blue-shifted with about 20 km/s
NGC 5408 — Morphology

**R-band image**
- slightly elongated stellar disc

**Ha image**
- shells
- filaments

**HI intensity**
- smooth
- warped

**HI velocity**
- rotation
NGC 5408 — Kinematics

Comparison of the Hα velocity and the HI velocity

The + symbols represent the Hα velocities obtained from the spectra; the solid line the HI velocities obtained from the high-resolution velocity map of the main component.

- **blue-shifted component**
- **red-shifted component**

An expanding superbubble in the north-east of NGC5408 is detected.
IC 4662 — Morphology

R-band image
- slightly elongated box-like shape

Ha image
- shells
- filaments

HI intensity
- inner system is perpendicular to the outer system

HI velocity
- twisted
IC 4662 — Kinematics

Comparison of the Hα velocity and the HI velocity

The + symbols represent the Hα velocities obtained from the spectra; the solid line the HI velocities obtained from the high-resolution velocity map of the main component.

There are a few obvious discrepancies, which might indicate outflowing ionized gas.
Discussion

• Since the dwarf galaxies are considered as dark matter dominated systems, they calculate the escape velocities from dark matter halo models and compare them with the expanding velocities of ionized gas.

• They model the escape velocities by using the pseudo-isothermal (ISO) halo (Binney & Tremaine 1987); its density profile and the derived escape velocity are

\[ \rho_{ISO}(r) = \rho_0 \left(1 + \left(\frac{r}{r_c}\right)^2\right)^{-1} \]

and

\[ v_{esc}(r) = \sqrt{2 v_c^2 \left(1 + \log\left(\frac{r_{max}}{r}\right)\right)} \]

where \( v_c \) is the circular velocity and \( r_{max} \) is the maximum radius of the dark matter halo.
Outflow or galactic wind?

- Escape velocities for large $r_{\text{max}}$ (solid lines) and small $r_{\text{max}}$ (dotted lines), the observed rotation curves (small triangles with error bars), and the expanding gas structures (large triangles).

- Since the HI velocity field of IC 4662 is twisted, it is impossible to derive the rotation curve and the escape velocity.

- As can be seen, the expansion velocities of the outflows, although partially quite significant, stay far below the escape velocity, even for the lower limit case. This is mainly due to the fact that they were found close to the dynamic centre where the escape velocities are high.

NGC 2366  NGC 4861  NGC 5408
Summary

• In order to search for outflowing gas structures and to make predictions about their fate, they study the kinematics of the neutral and ionized gas components of irregular dwarf galaxies.

• They perform a multi wavelength study of four irregular dwarf galaxies (NGC 2366, NGC 4861, NGC5408, IC 4662).

• They detects outflows in Hα in all sample dwarf galaxies, which show expansion velocities of 20-60 km/s.

• They compare the expansion velocities with the escape velocities derived from the dark matter halo models, and conclude that it is very unlikely that the gas will be blown away.