# THE INFLUENCE OF THE ENVIRONMENT ON THE EVOLUTION OF DWARF GALAXIES

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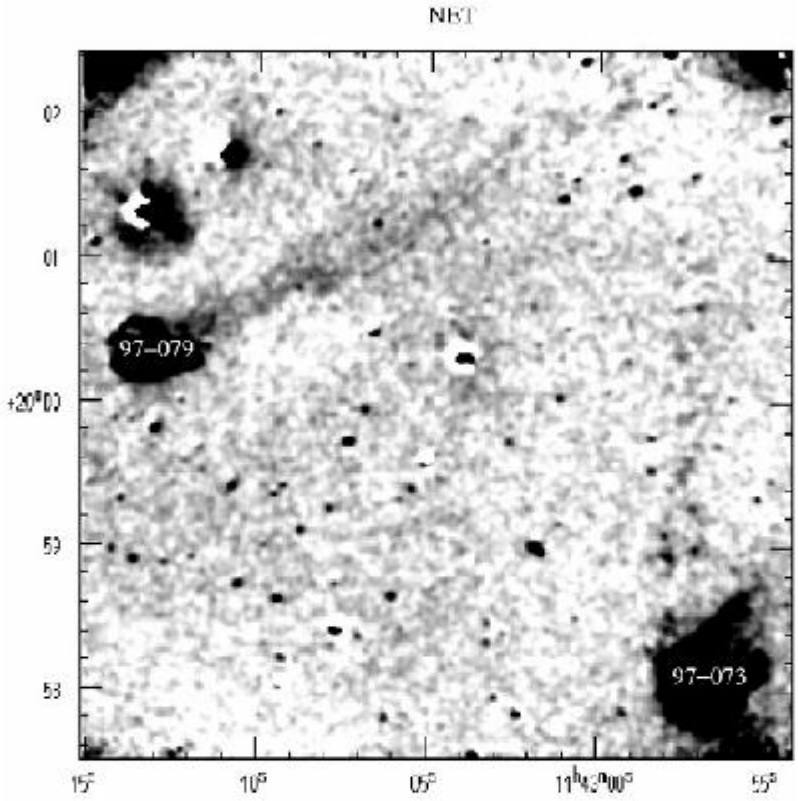
Several statistical studies on some properties of dwarf galaxies show that:

Global environment

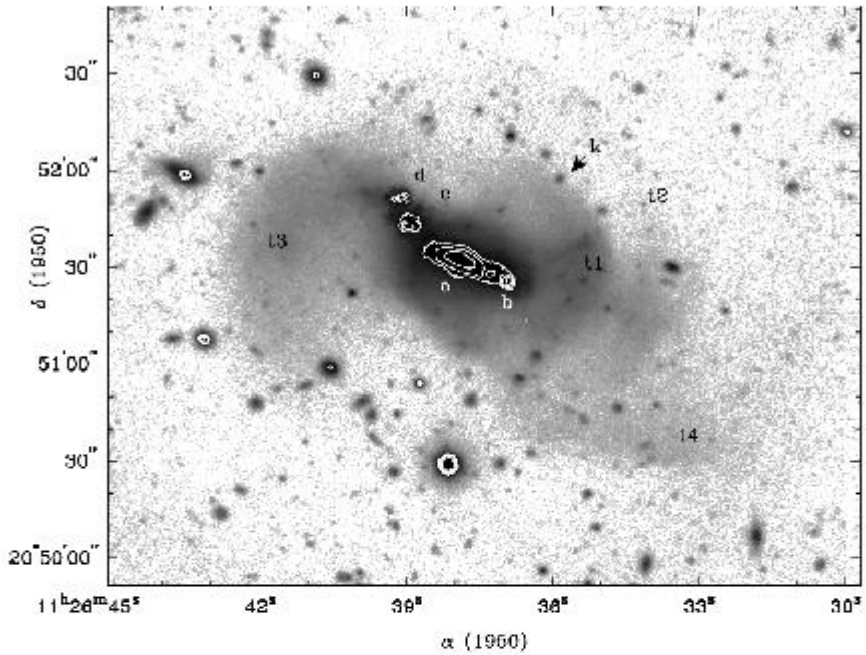
- $M(\mathrm{HI})/L_B$ for a sample of LSB SFDGs is higher in low density regions. SF indicators do not change with ambience density (Karatchenseva 1990)
- SFDGs in low ensity regions present higher H$\beta$ EWs for a given $L_B$ (Vílchez 1995).
- SFDGs in voids show higher $M(\mathrm{HI})/L_B$ than field ones (Huchtmeier et al. 1997) but similar star formation properties (Popescu et al. 1999).

Local environment

- SFDGs with close companions show star formation properties similar to those of isolated ones (Campos-Aguilar & Moles 1991; Noeske et al. 2001).
- SF bursts of MOT BCDs are triggered by idal interactions or mergers of low mass galaxies (Pustilnik et al. 2001).



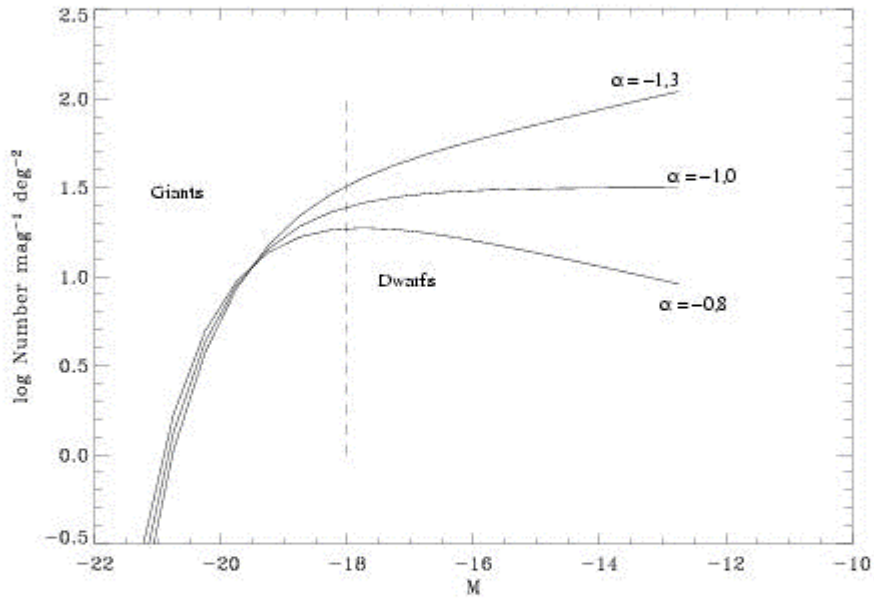

H$\alpha$ image of two irregular galaxies in the cluster Abell 1367 from Gavazzi et al. (2001). Two 75 kpc long tails of ionized gas are apparent.




Disrupted morphology of the compact group of dwarf galaxies HCG54, $R$ image from Verdes-Montenegro et al. (2001), with a bar-like centered on the system structure and shells of stellar material surrounding the galaxies.

# Dwarf Galaxies in clusters:

# How many... ?



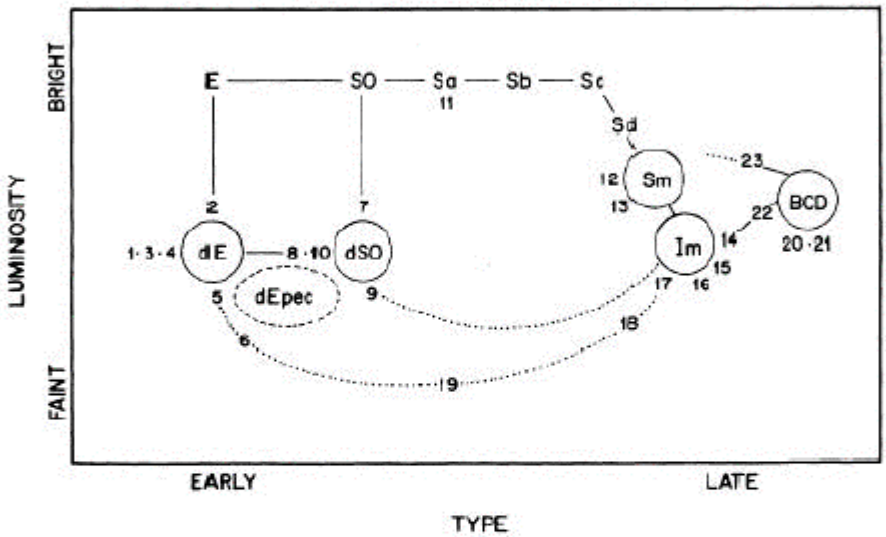

The Luminosity Function (LF):

$$\phi(L) \propto (L/L*)^{\alpha} \exp^{-(L/L*)}$$

Cluster LFs are steeper than field LFs $\longrightarrow$ More dwarfs per giant in clusters.

# Dwarf Galaxies in clusters:

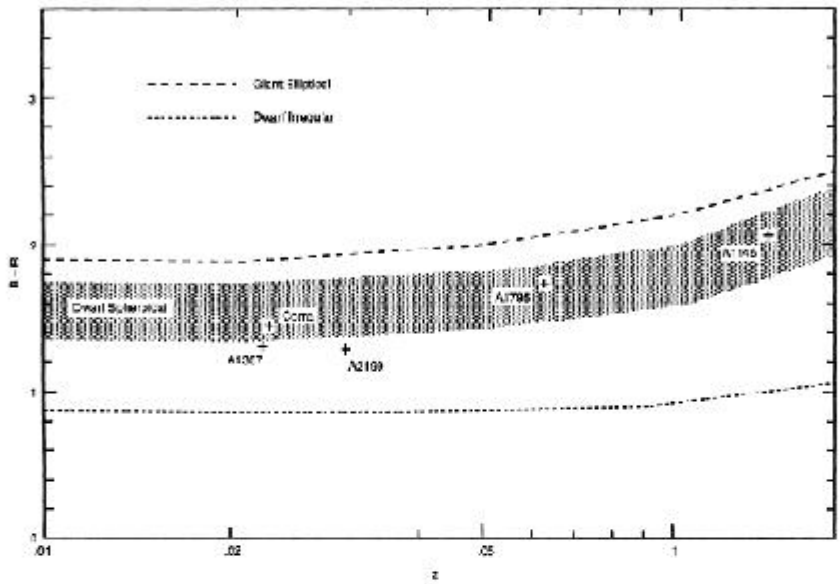
# What kind... ?




Sandage & Binggeli (1984)

- Early-type: dE, dS0
- Late-type: Sdm, Sm, Im, BCD
- Ultracompact early-type (Phillipps et al. 2001, Mieske et al. 2002) and late-type (Drinkwater & Hardy 1991).

Evolutionary connection between early and late type dwarfs?

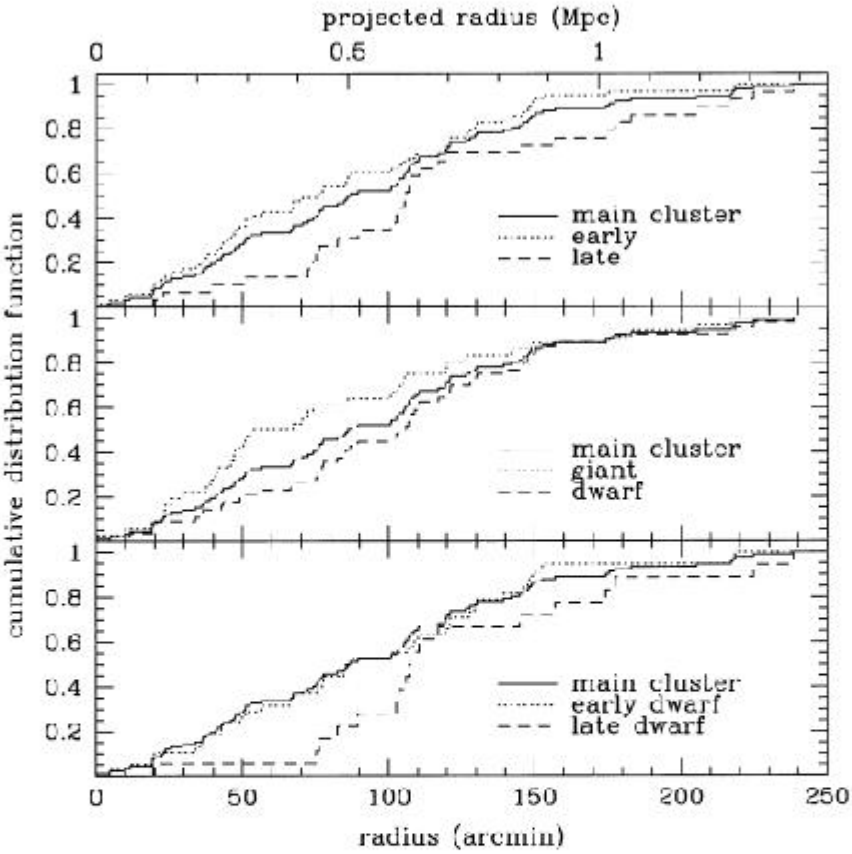



Most of dwarfs in clusters show colors typical of dEs (Trentham 1997).

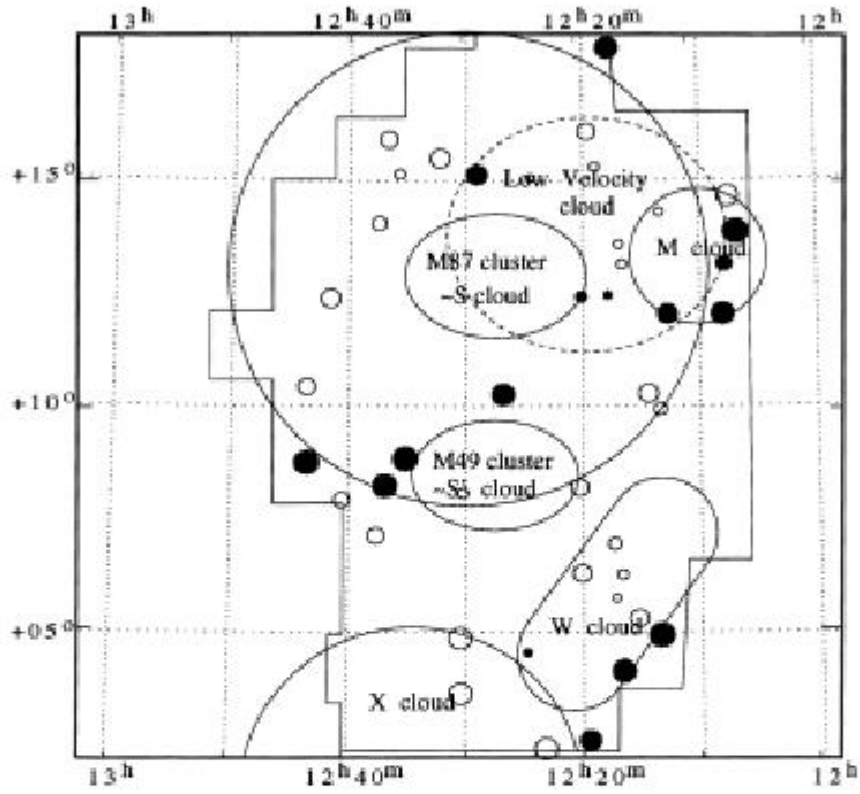
## Dwarf Galaxies in clusters:

## Where... ?

- Dwarf galaxies always follow giant galaxies $\longleftrightarrow$ no segregation of faint and dwarf galaxies on large scales.
- Dwarfs in clusters are less concentrated that giants: Population - density relationship? (Phillipps et al. 1998)
- But, strong morphological segregation among the dwarfs:
  Early dwarfs are concentrated in higher density regions (Binggeli et al. 1990).




Cumulative distribution of galaxies in the Fornax cluster (Drinkwater et al. 2001). The bottom pannel shows the difference between the early and late type distribution of dwarfs.




Projected spatial distribution of a sample of dwarf galaxies in Virgo (Heller et al. 1999). Filled circles correspond to BCDs. Open circles correspond to LSB SFDGs.

# Properties of SFDGs in clusters...

(There is not an homogeneous sample to compare with the field: different selection criteria in the literature!!!)

- **SFRs**
  - Lower H$\beta$ EW for a given $L_B$ (Vílchez 1995, Virgo; Duc et al. 2001, Hydra).
  - No correlation between Virgocentric distance and the SFR (Almoznino & Brosch 1998, Gavazzi et al. 2002)
- **Stellar populations**
  - Composite stellar populations in Virgo (Almoznino & Brosch 1998)
  - SEDS fit well a monotonically increasing SFH (Gavazzi et al. 2002)
- **Structural parameters**
  - No strong color gradients (Heller & Brosch 2001, Virgo; Duc et al. 1999, Hydra).
  - Structural parameters similar to those of field SFDGs (Heller & Brosch 2001, Virgo; Duc et al. 1999, Hydra).
- **Metallicity**
  - Several galaxies not following the $Z$ vs. $L_B$ relationship in Hydra (Duc et al. 2001) and Virgo (Vílchez & Iglesias-Páramo 2003).
- **Dynamics**
  - SFDGS shows evidence on infall towards the cluster centers (Biviano et al. 1997, Drinkwater et al. 2001).

# Evolution of DGs in clusters...

Evolutionary link between dIs, BCDs and dEs in clusters?

- An increase of the density of SFDGs falling to the cluster center is found at intermediate radii for different clusters.
- Gas depletion timescales are found to be of the order of the Hubble time, so that an external mechanism is required to exhaust the gas content.

Thus...

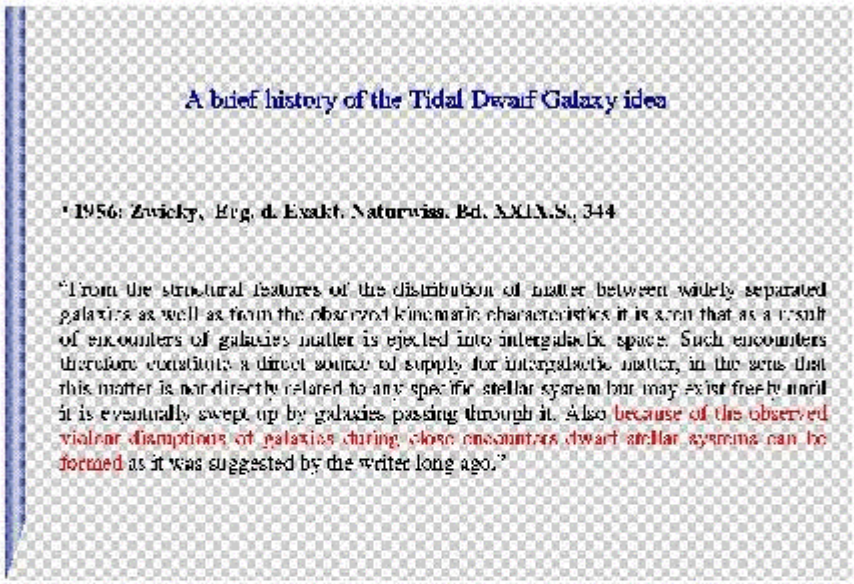
- Environmentally induced evolution is expected to occur in SFDGs in clusters.
  - At intermediate radii

    Interactions can produce bursts of star formation as SFDGs begin to fall towards the cluster center.
  - At inner radii

    Tidal stripping (interaction galaxy-intergalactic medium) could remove the outer gas of DGs in rich clusters.

    Tidal stirring (interaction galaxy-gravitational potential) could produce morphological evolution of dwarfs in poor clusters.

# Tidal Dwarf Galaxies




Courtesy P.A. Duc

# Theories of TDG formation

- Barnes & Hernquist (1992)

  *"...It is found that dwarf systems form in material drawn out during the encounter; these objects can capture large amounts of moderately enriched gas but retain little dark matter from their parents' haloes. They should therefore have lower mass-to-light ratios than galaxies formed directly by the collapse of primordial matter."*

- Elmegreen et al. (1993)

  *"Galaxy interactions that agitate the interstellar medium by increasing the gas velocity dispersion and removing the peripheral gas in tidal arms should lead to the formation and possible ejection of self-gravitationally bound cloud complexes with masses in excess of* $10^8$ $M_\odot$. *Some of these complexes may eventually appear as independent dwarf galaxies."*

# Searching for TDG candidates

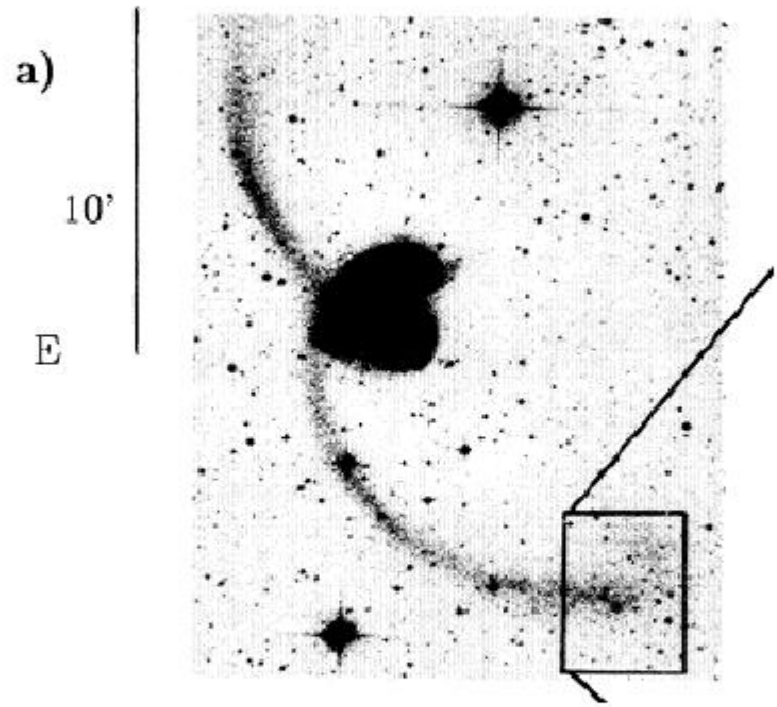
- Statistical approach: Around HCGs and interacting pairs of galaxies.

  Controversial!

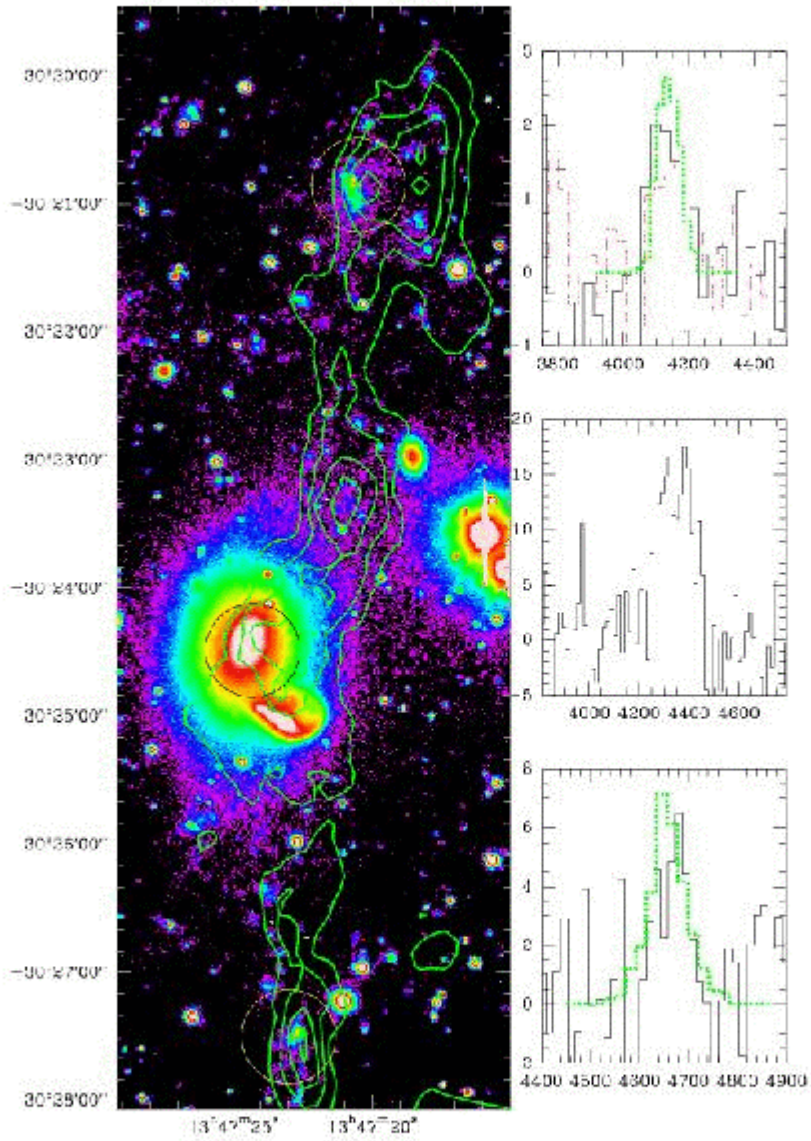
  - Hunsberger et al. (1998): Need for a double Schechter function to fit the HCGs LF.
  - Delgado et al. (2003): No significant enhancement of the number counts.

- Along tidal tails of interacting pairs of galaxies.
- But ALSO in clusters and interacting pairs without tails.
- Requirements for TDG candidates (Weilbacher et al. 2000,2002; Iglesias-Páramo & Vílchez 2001):

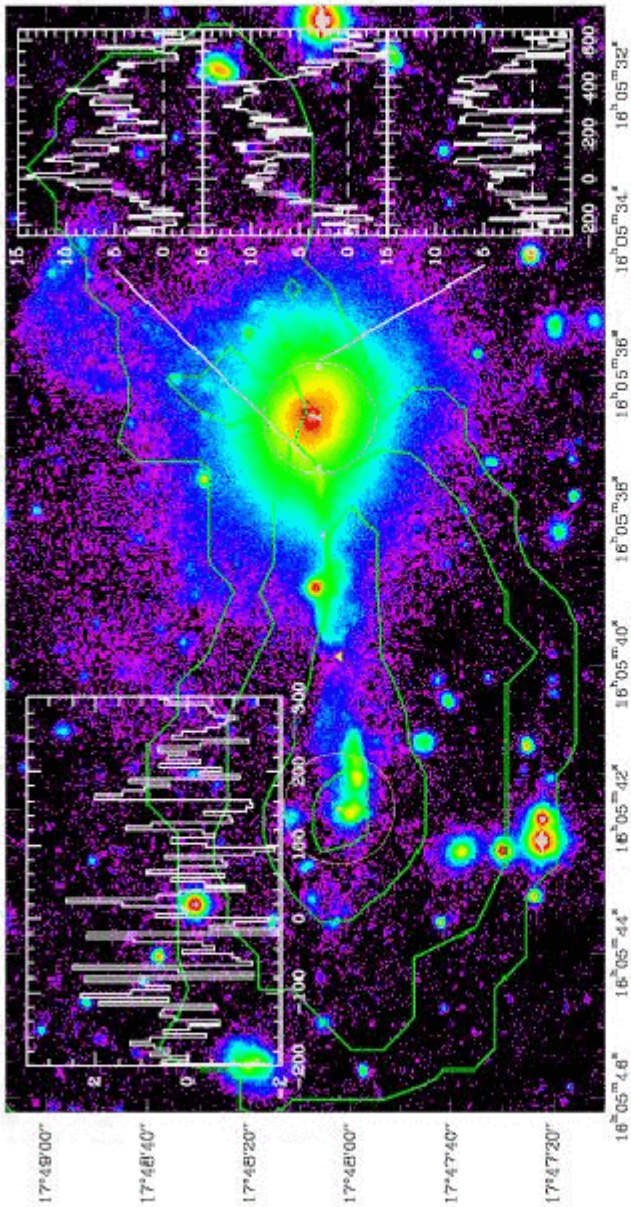
  - Blue colors, H$\alpha$ emission: to ensure recent SF activity.
  - Limiting magnitude/H$\alpha$ luminosity: to eliminate HII regions.
  - Minimum distance to the parent galaxy nucleus: to favour escape from the parent galaxy.
  - Dynamical information: to ensure detachment from the parent galaxy and self-gravitation.



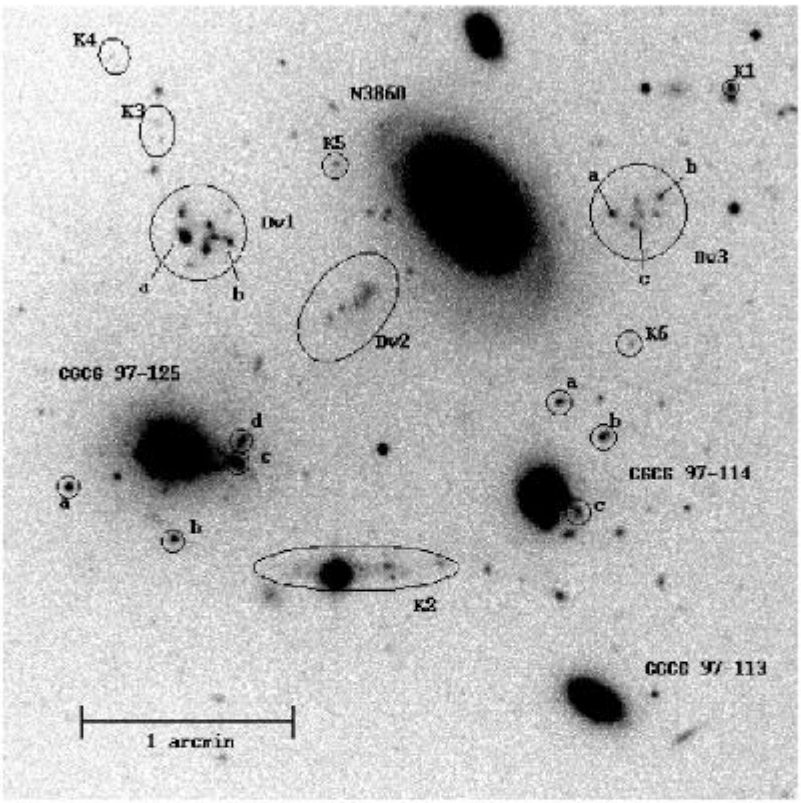

At the tip of a tidal tail in the Antenna (Mirabel et al. 1992).




Around NGC 5291 (Braine et al. 2001)




Around IC 1182 in Hercules cluster (Braine et al. 2001)




Around a group of galaxies in Abell 1367 (Sakai et al. 2002)

# Properties of TDG candidates

From a sample of several TDGs found in interacting pairs of galaxies (Mirabel et al. 1992; Duc & Mirabel 1998; Braine et al. 2001; etc):

- Luminosity range comparable to *normal* dwarfs
- Metallicity higher than normal dwarfs

  $\longrightarrow$ TDGs do not follow the normal Luminosity *vs* Metallicity relationship found for *normal* dwarfs
- HI masses of the order of $10^9$ $M_\odot$.
- CO content larger than for *normal* dwarfs.

  $M_{mol}$/SFR similar to spirals but not to *normal* dwarfs.
- No dark matter is required to explain the CO line widths!

# Old TDGs, do they exist?

Trying to identify them by their...

- Metallicity
- Structure
- Stellar population
- Dark matter content

(Hunter et al. 2000)