New Insights into Dwarf Galaxy Evolution with LOFAR

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Star-forming dwarf galaxies in the local Universe

- Low mass and luminosity ($10^7 \leq L/L_\odot \leq 10^9$, $M_T \sim 10^8 ... a few 10^9 M_\odot$)
- Holmberg radius: 1-6 kpc
- gas-rich: $M_{\text{gas}}/M_T(R_{H_0}) = 0.3 - 0.8$
- subsolar metallicity; distribution peaking at $12+\log(O/H) = 7.9$
- evolved (a few Gyr old) low-surface brightness (LSB) host galaxy in most dIs and BCDs
Star-forming dwarf galaxies in the local Universe: dIs

- exponential surface brightness profiles with $\mu_0 \sim 23$ mag arcsec$^{-2}$
- weak emission lines on top of a relatively blue stellar continuum with broad Balmer absorption lines
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Star-forming dwarf galaxies in the local Universe: BCDs

Papaderos et al. (2006)
BCDs are in their vast majority (>95%) old gas-rich dwarfs; young galaxy candidates are extremely rare (~1%)

- no evidence for an old host galaxy
- irregular morphology and intense star-forming activity
- extremely metal-deficient ($Z_{\odot}/60 \leq Z \leq Z_{\odot}/15$)
- extremely rare (<1% of the BCD-population; until recently only ~15 such systems known)
I Zw 18: a dwarf galaxy forming within an extended ionized gas envelope
SBS 0335-052: HI cloud with a projected size of 70×20 kpc and a mass of \(\sim 10^9\) M\(_\odot\)

(Pustilnik et al. 2001)
BCDs: starburst-driven mass ejection into halo

NGC 1569

Martin et al. (2001)
Radio continuum observations and magnetic fields in the halos of dIs/BCDs

Chyzy et al. (2000)
Why are we interested in dwarf galaxies?

- most numerous systems in the Universe
- building blocks of normal galaxies
- Origin and implications of starburst activity in low-mass galaxies?
- Star formation and feedback processes under chemical conditions similar to those in young galaxies in the early Universe?
- Evolutionary connections between dIs and BCDs?
Chronology of a starburst in a dI/BCD

Gas cooling/replenishment

Expansion of the hot-gas phase and galact. winds

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The “standard” dI↔BCD evolutionary scenario

Prediction: BCDs spend more than 90% of their lifetimes in a dormant (dI) phase

→ \( \frac{N(\text{dIs})}{N(\text{BCDs})} \sim 10 \)

Problem: identification of this large population of post-BCD systems
Searching for post-BCDs with LOFAR

- **Hα luminosity**
- Optical/NIR colors
- SED modelling

**Problems:**
- Extinction, assumptions on the Star Formation History and the relative amount of young and old stars; absorption-line spectroscopy at faint levels ($\mu_0 \geq 23$ mag arcsec$^{-2}$)

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- **FIR luminosity**
- Radio continuum (4-8 Ghz)
- LOFAR (50 Mhz)

**Time after starburst (Gyr):**

- 0.1
- 0.2
- 0.3
- 0.4
- 0.5
- 0.6
- 0.7
- 0.8
LOFAR:
an efficient tool to search for post-starburst galaxies

\[ t_{\text{syn}} = 1.1 \times 10^9 \text{ yr} \cdot (\nu / \text{Ghz})^{-0.5} \cdot (B/\mu \text{G})^{-1.5} \]

Lifetime of electrons \( t_{\text{syn}} \) observed at cm wavelengths is \( \sim 10^8 \) yr.

At meter wavelengths \( t_{\text{syn}} \) is \( \times 5 \ldots 10 \) times longer

Radio emission at LOFAR wavelengths memorizes starburst activity (the BCD phase) several \( 10^8 \) yr after the termination of the burst
Def. cm/m flux ratio

$$\psi = \frac{f_{\text{cm}}}{f_{\text{m}}}$$

**Case I.** post-starburst phase with $0.1 \leq t \leq \tau$ (1 Gyr)

$$\psi \approx 0$$

**Case II.** continuous star formation over $t \geq 0.1 \ldots$ several Gyr

$$\psi \approx 1$$

If the “standard” dI$\leftrightarrow$BCD evolutionary scenario is correct then $\exists$ large population (surface density: 100 deg$^{-2}$) of nearby ($z<0.2$) dI systems with $\psi \approx 0$
Summary

LOFAR radio observations at m wavelengths

- will allow us to study the low-frequency halos of star-forming galaxies, illuminated by relativistic particles ejected from starburst regions: a new window to study the nature of low-mass galaxies and the starburst-halo interaction

- will provide a new powerful tool for identifying post-starburst (post-BCD) galaxies, selected by their extended low-frequency radio halos in conjunction with their weak (if any) radio emission at cm wavelengths

- A systematic search for dwarf galaxies with \( \psi = f_{cm}/f_{m} \approx 0 \) will allow us to test whether or not the “standard” dI\( \leftrightarrow \)BCD evolutionary scenario for dwarf galaxies is tenable
$dI$ $(\tau \approx 1 \text{ Gyr})$