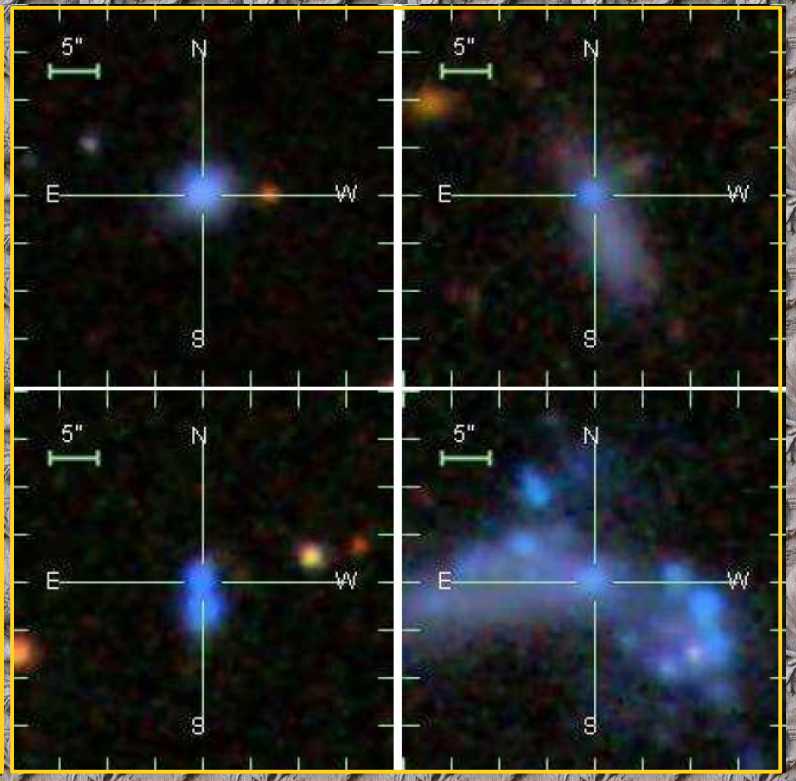




Blue Compact Dwarf Galaxies: born to be wild

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Centro de Astrofísica da Universidade do Porto & Instituto de Astrofísica e Ciências do Espaço

Estallidos Workshop 2015 • Granada • May 2015

POPH QUALIFICAR É CRESCER.

QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007.2013

GOVERNO DA REPÚBLICA PORTUGUESA

UNIÃO EUROPEIA Fundo Social Europeu

Dwarf Galaxies in the nearby Universe

gas content ↑

oxygen abundance ↓

color: rel. blue



\+

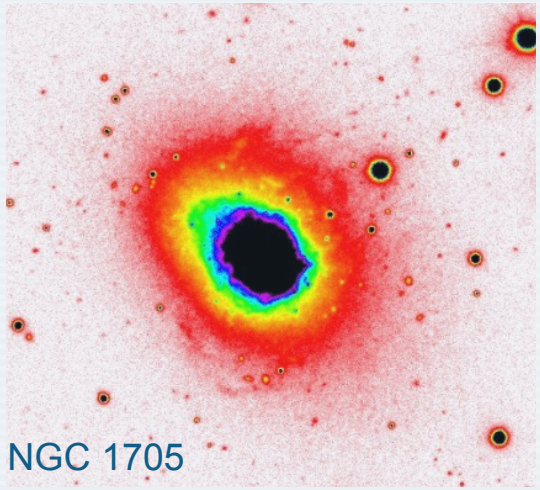
dSph

Dwarf Irregular (dI)

gas content ↑

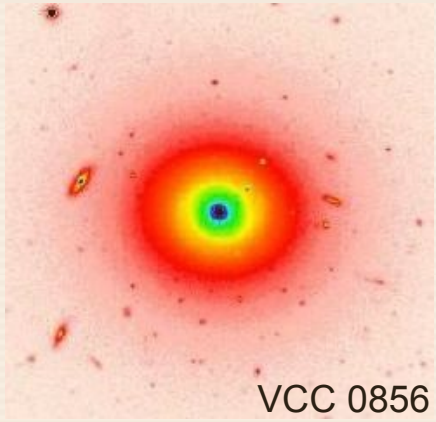
oxygen abundance ↓

color: blue



Blue Compact Dwarf (BCD)

Late-type



gas content ↓

metallicity ↑

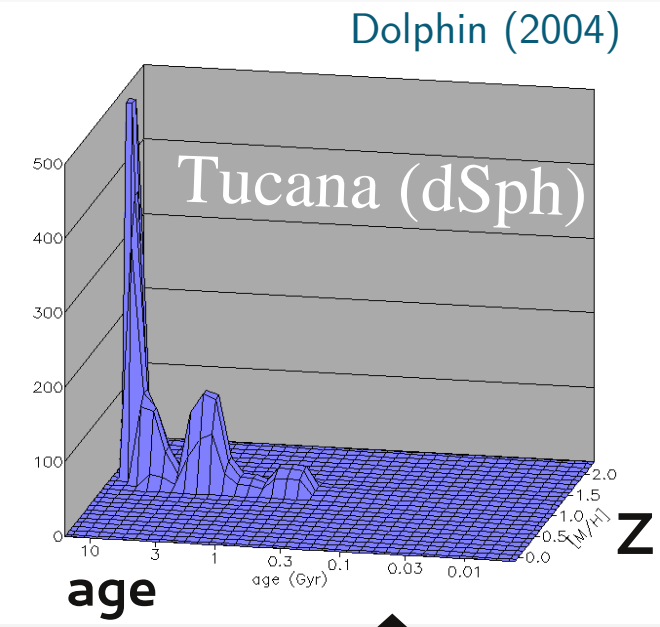
color: red

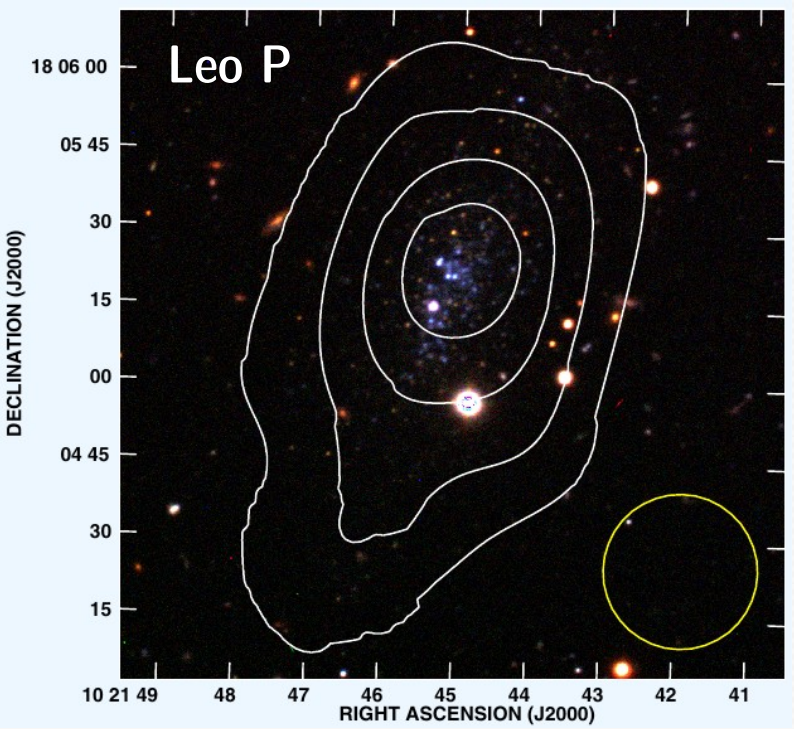
Dwarf Elliptical (dE)

Early-type

Low-surface brightness, low-sSFR metal poor galaxies

sSFR
ΣSFR
<μ>



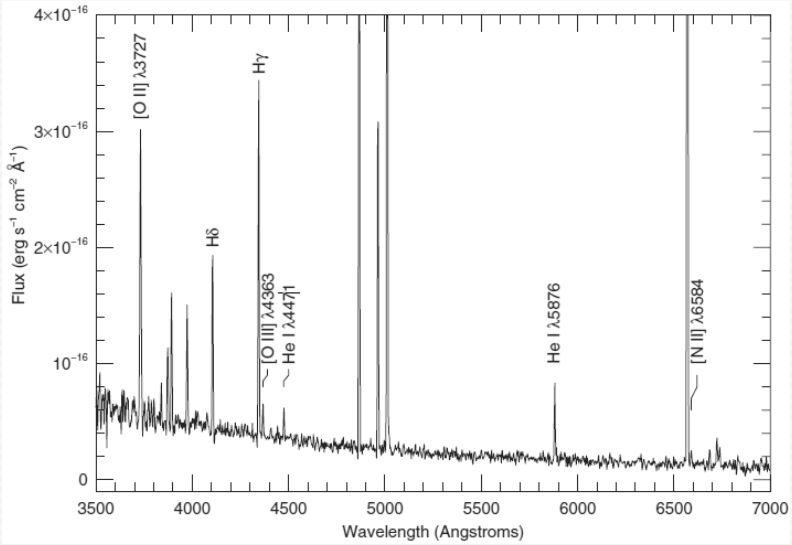


Giovanneli et al. (2013)

- Dwarf spheroidals (dSph) and *transition galaxies*
- a few nearby dwarf irregulars with a very low <μ> and large $M(HI)/L_B$ ratio

(*retarded, slowly-cooking, dark*)

- Blue low-surface brightness (LSB) galaxies (and the outskirts of late-type disks)

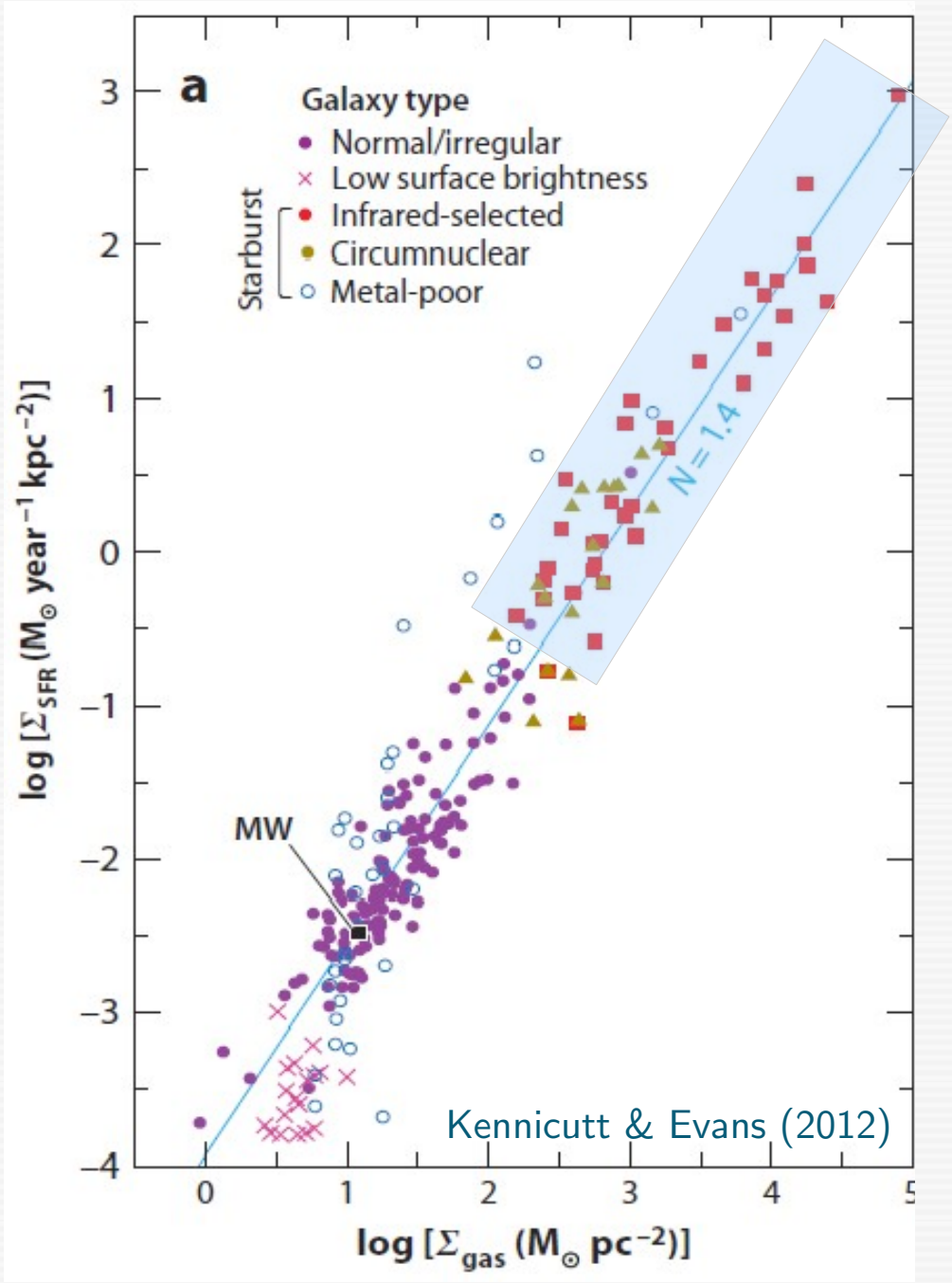


Skillman et al. (2013)

see, e.g. Mateo (1998), McConnachie (2012), Bergvall (2012)

High-surface brightness, high-sSFR metal poor galaxies

sSFR
ΣSFR
<μ>



High-surface brightness, high-sSFR metal poor galaxies

L'SFR
sSFR
<μ>

$\precsim 10^{-8}$ yr^{-1}

- Blue compact dwarf (BCD) galaxies (low-mass & high-compactness subset of HII galaxies)

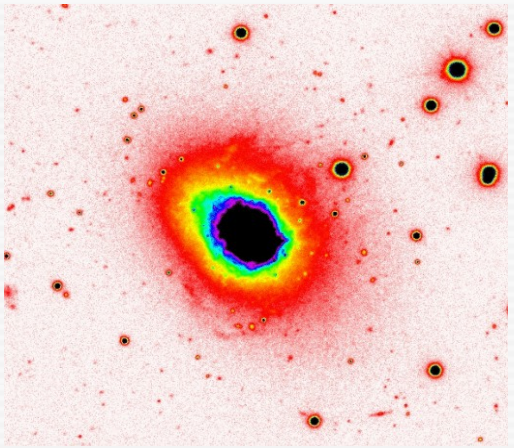
  $M_* \approx$ a few 10^8 $M_\odot$; $Z_O \simeq 8.1$

- Luminous blue compact galaxies (BCGs)
  - LBCGs
  - CNELGs
  - green peas

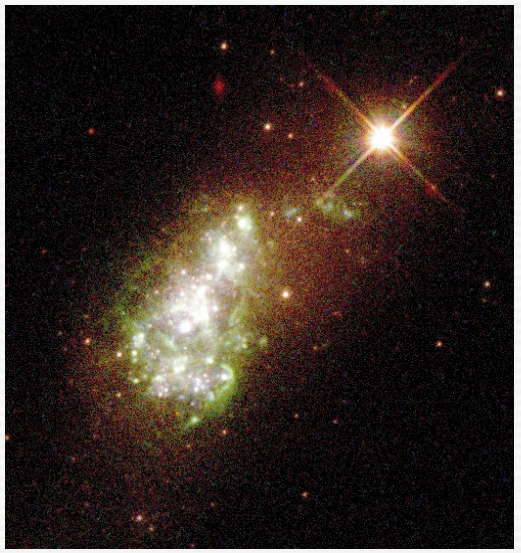
  $M_* \approx$ a few 10^9 $M_\odot$; $Z_O \precsim 8.5$

- XMP BCDs (XBCDs)

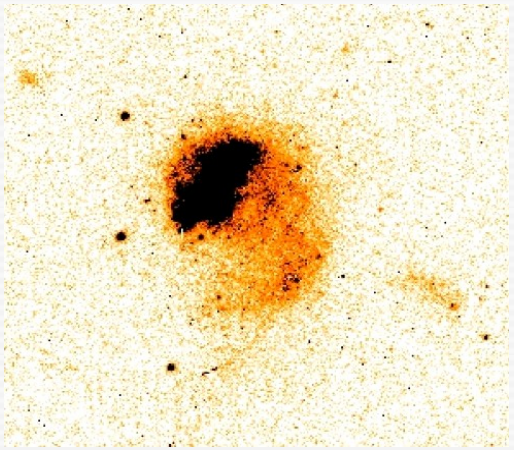
  $M_* \approx 10^7$ $M_\odot$; $Z_O \precsim 7.6$



Papaderos et al. (1996)



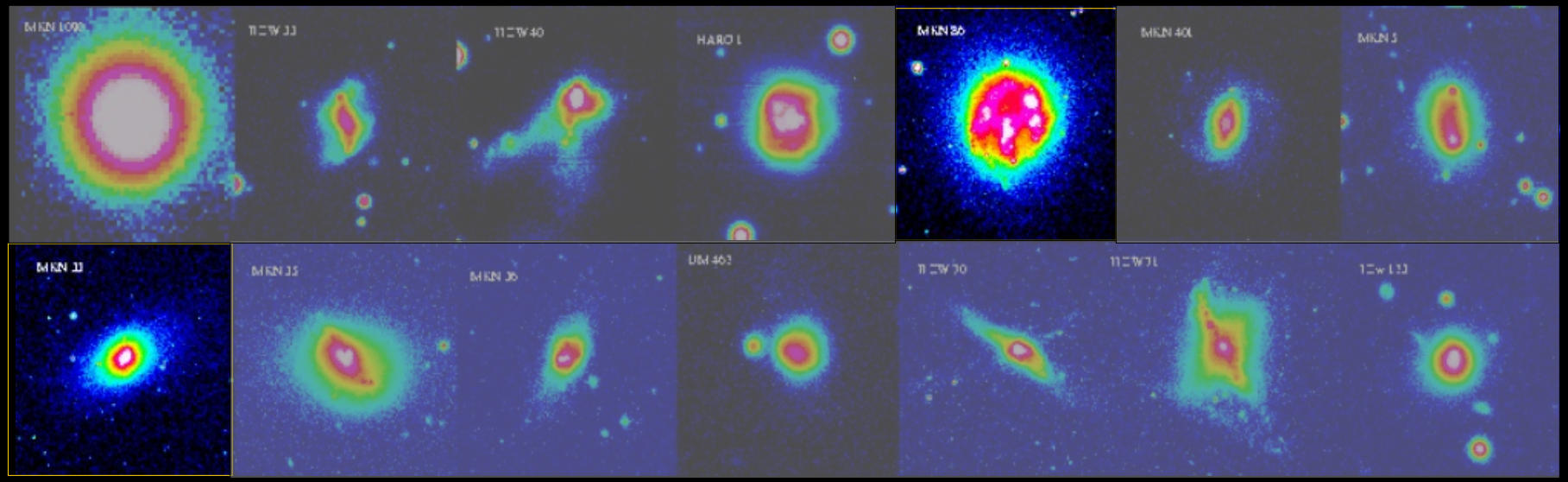
Östlin et al. (2003)



Papaderos et al. (1999)

Blue Compact Dwarf (BCD) galaxies: a mixed bag

iE
(irregular elliptical)

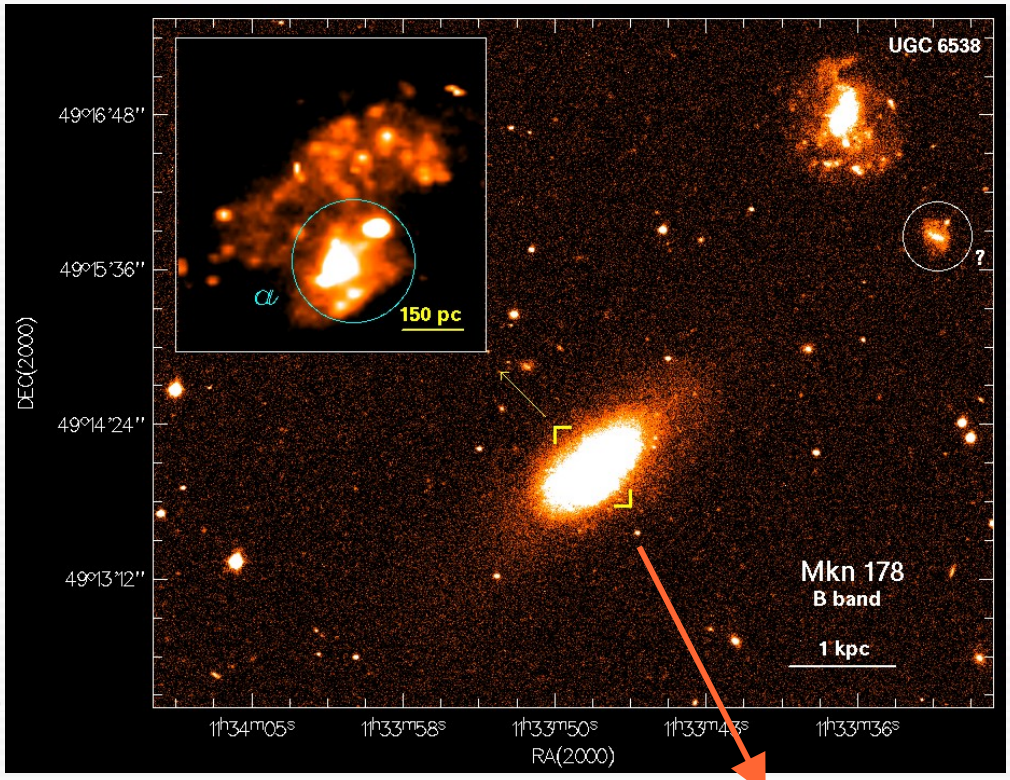


nE
(nuclear elliptical)

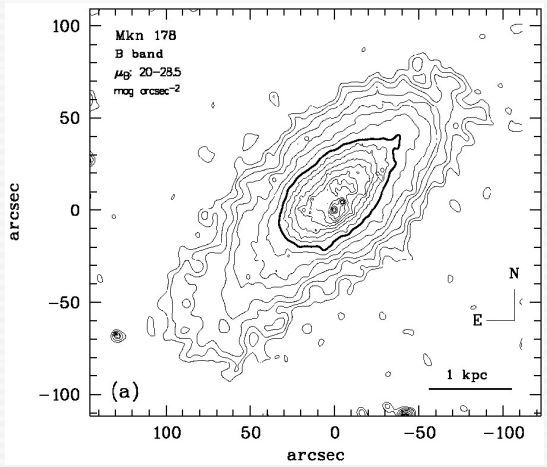
Cairós et al. (2001)

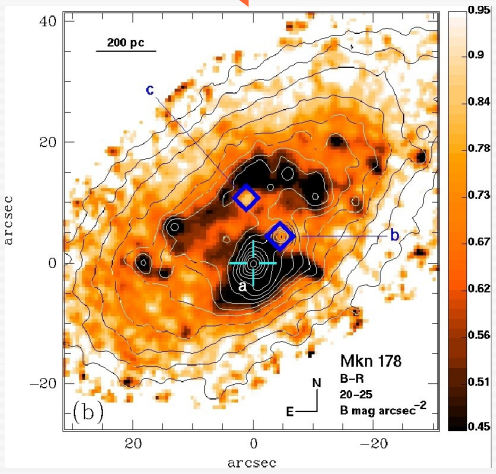
- dwarf galaxies ($10^7 \leq L/L_\odot \leq 10^9$, $M_B > -18$ mag; $M^* \sim 10^7 \ldots 10^9\ M_\odot$)
- intense star-forming activity on a spatial scale ≃1 kpc
- evolved low-surface brightness host galaxy in most (>95%) BCDs
- not strongly interacting
- compact (effective radius: 0.1 – 0.6 kpc)

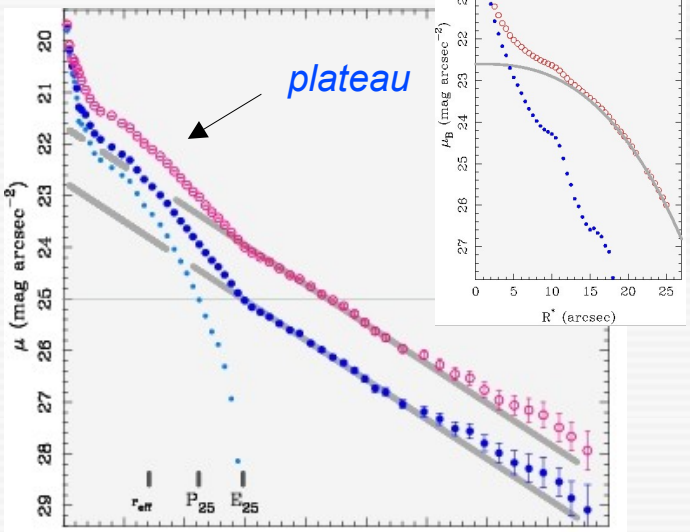
Structural properties of BCDs & BCGs

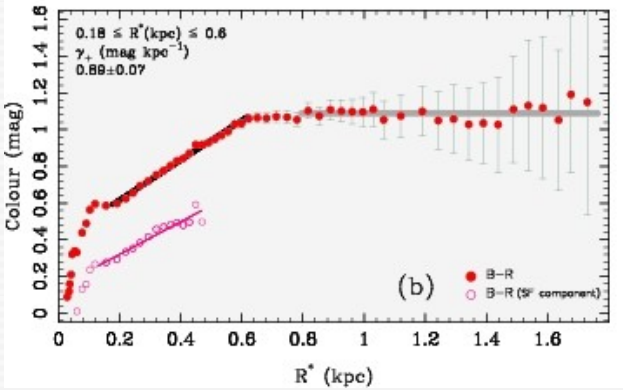


Papaderos et al. (2002)









P_{25}, E_{25}: isophotal radius of the star-forming and LSB component

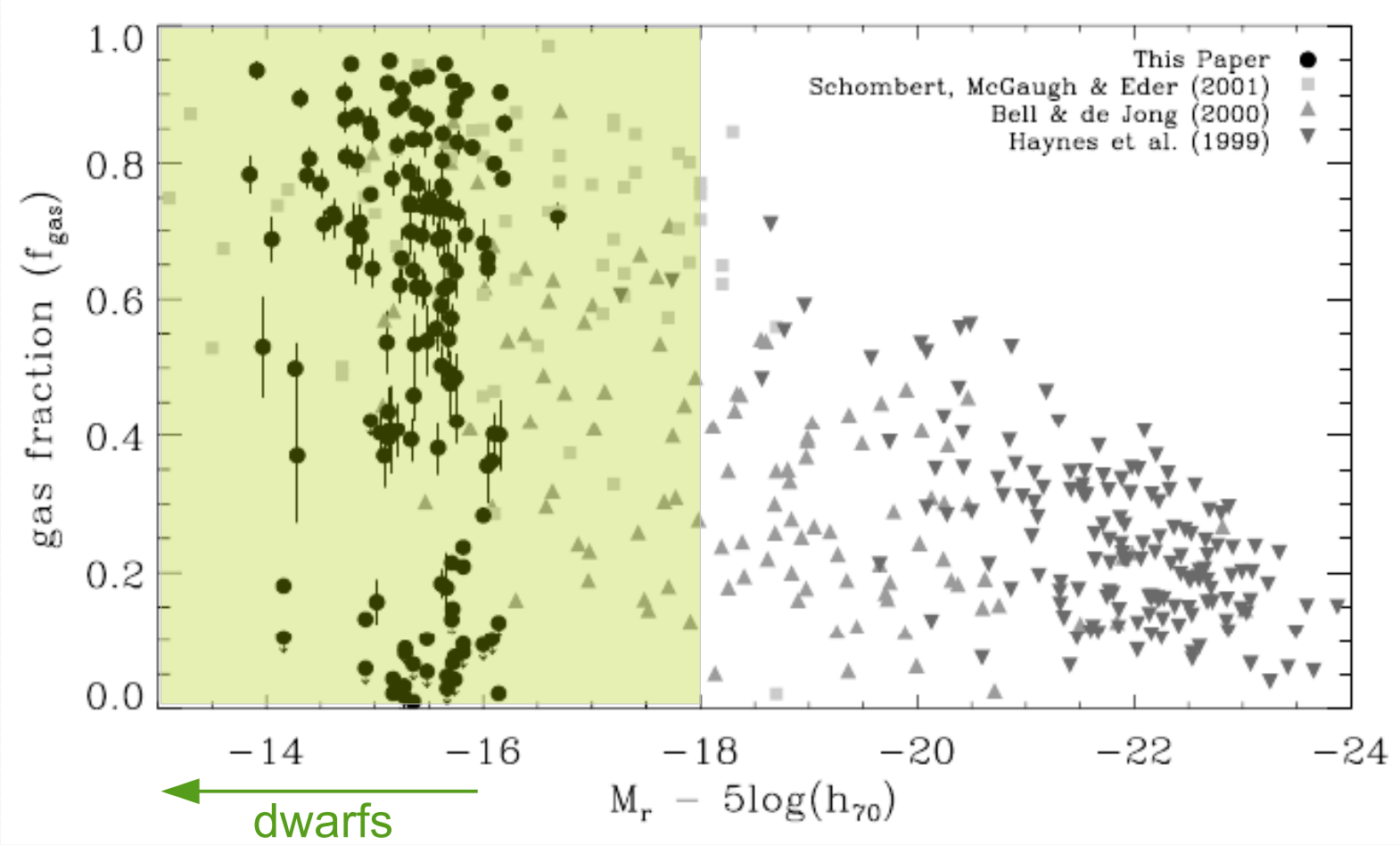
line-of-sight intensity contribution of the SF component: <40% at **P_{25}**, 4% at **E_{25}**

D = 4 Mpc
M_B=-13.9 mag

Mkn 178

Gas fraction as a function of absolute magnitude

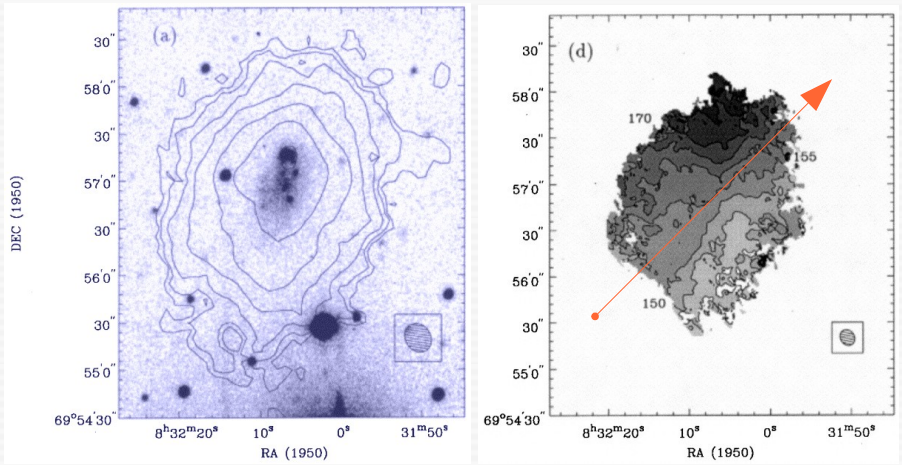
typically $M(HI+He)/M(\star+gas) > 0.4$

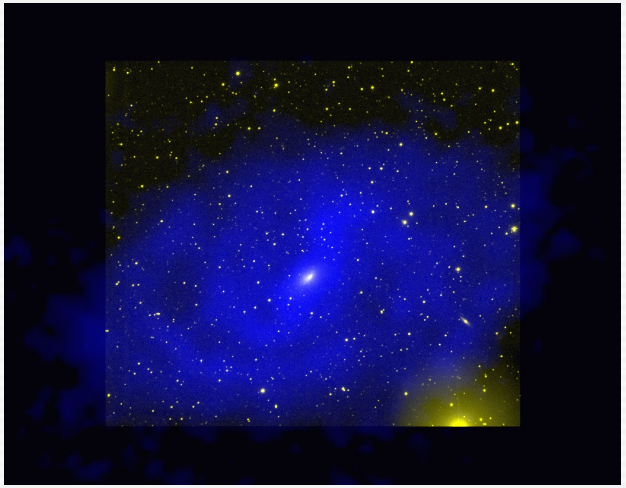


Geha et al. (2006)

Properties of the HI component in BCDs

UGC 4483

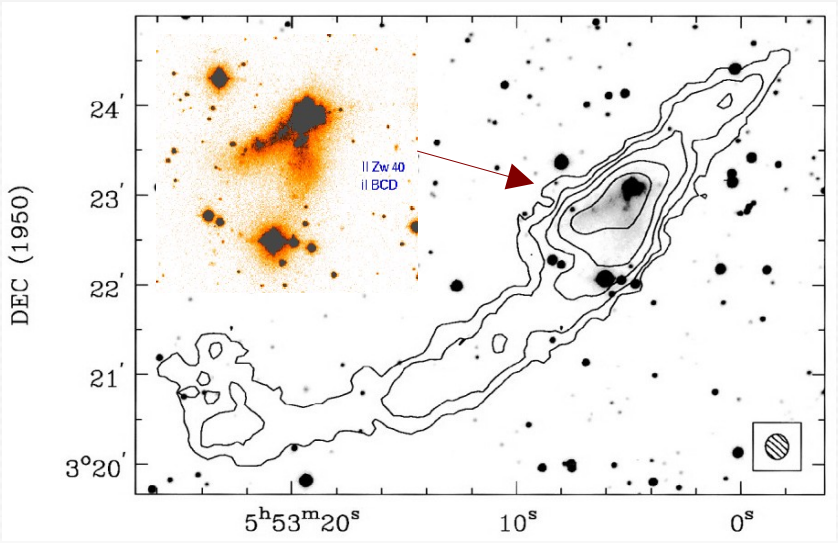


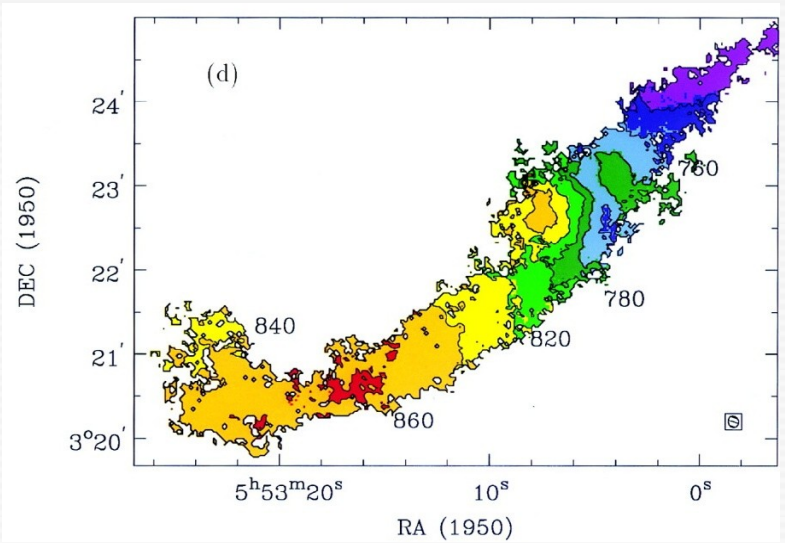


NGC 2915

van Zee et al. (1998)

II Zw 40

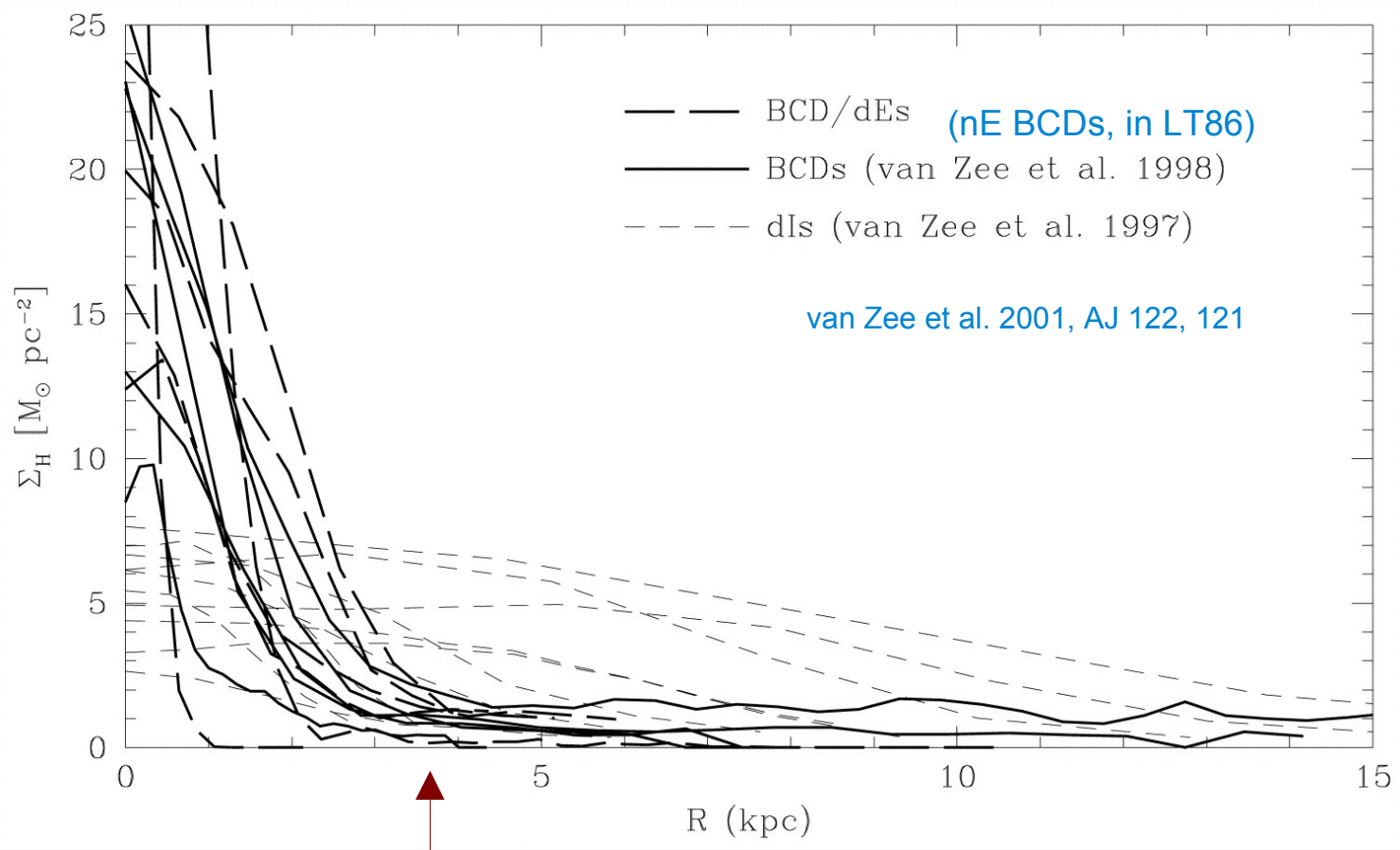




mass ratio: typically $M_{HI}=(0.1\text{-}1)\times10^9\ M\odot$, M_{Gas}/M_T: 0.3-0.9, M_T/L_B=2-6

$$\frac{\text{HI radius}}{\text{optical radius}} \sim 3\ldots10$$

Comparison of the radial HI surface density distribution in BCDs and quiescent (low-SFR, low-sSFR) late-type dwarfs (dwarf irregulars - dIs)



Optical Radius

BCDs are more compact than dIs with respect to their HI distribution

$$\Sigma_{\rm HI}({\rm BCDs}) \sim 5 \times \Sigma_{\rm HI}({\rm dIs})$$

See also Taylor et al. (1995), Simpson & Gottesmann (2003)

Questions

i) what triggers starbursts in BCDs?

ii) evolutionary links between BCDs and dIs

iii) mechanisms controlling star-forming activity in BCDs?

v) spatial progression of star-forming activity

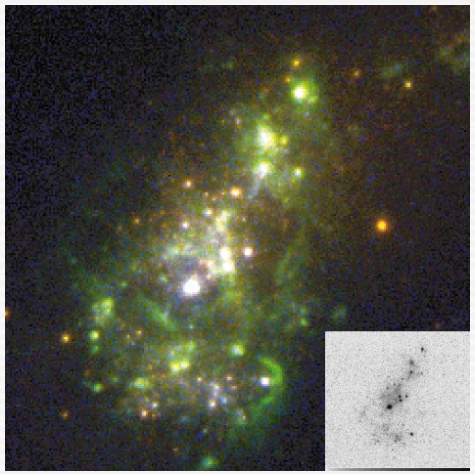
vi) feedback, chemical and kinematical evolution of the ISM

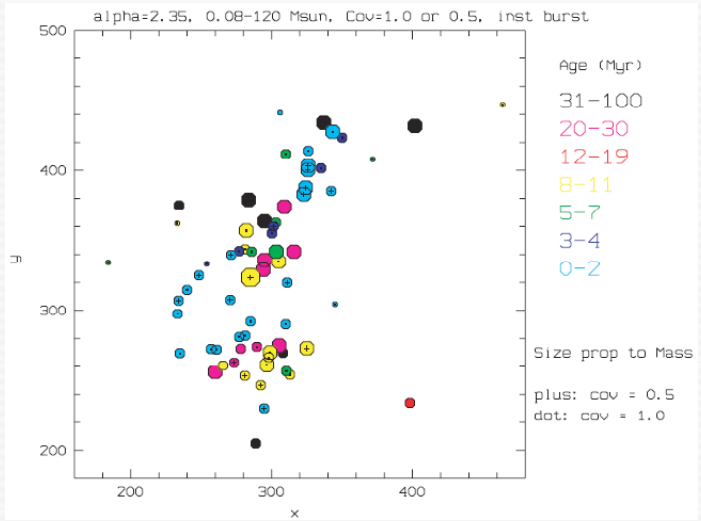
Possible starburst triggering mechanisms ...

- stochastic self-propagating star formation (Gerola & Seiden 1981)
- self-gravitating gas halo → gas collapse → straburst (e.g. Davis & Phillipps 1988)
- capture of a gas-rich companion (e.g. Bergvall & Östlin 2002)
- weak interactions with optically faint companions (e.g. Noeske et al. 2001, Pustilnik et al. 2001) via the Icke (1985) mechanism

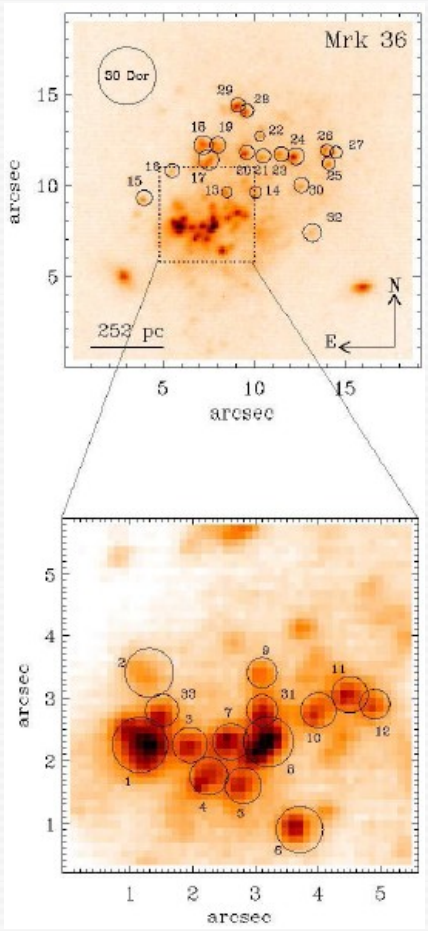
Questions

Coeval star formation? Spatial progression of star-forming activity … ?

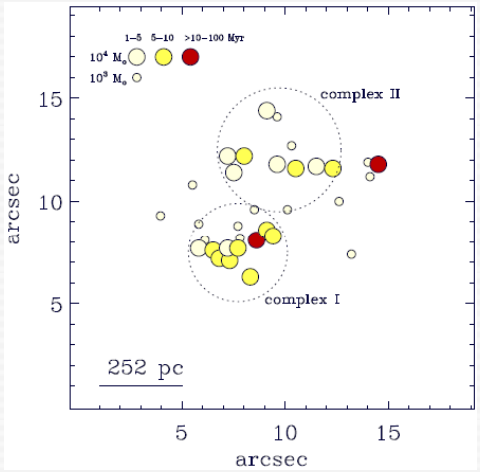




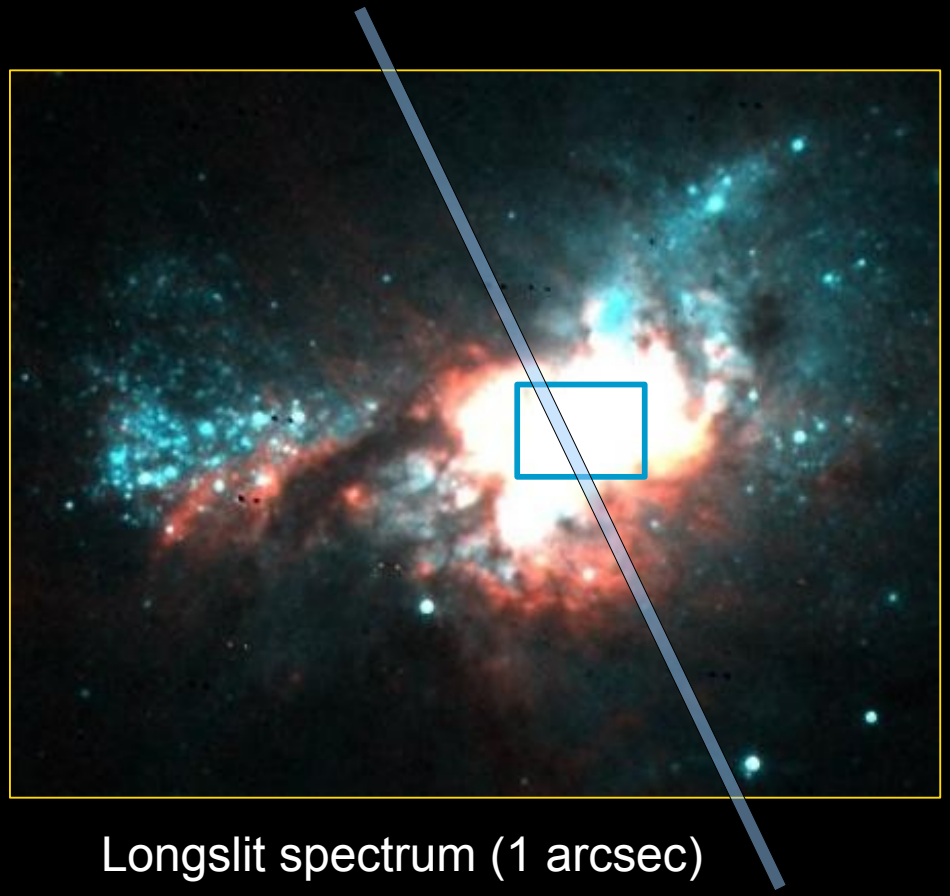
Östlin et al. (2003)



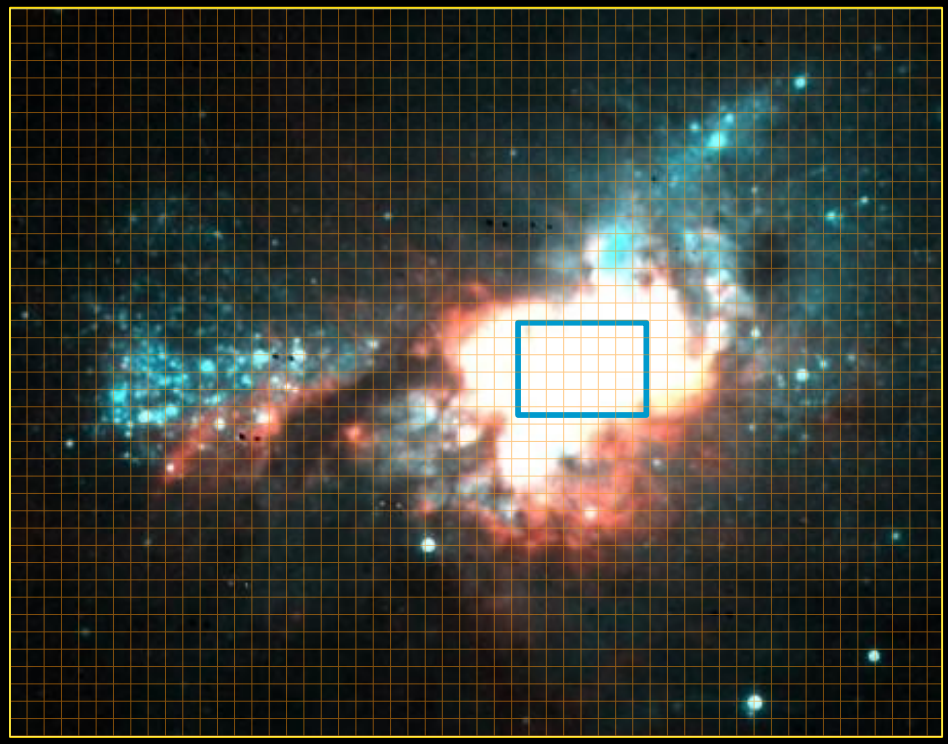
Lagos et al. (2011)



Integral Field Unit (IFU) spectroscopy



Longslit spectrum (1 arcsec)



IFU array (0.2 arcsec/spaxel)

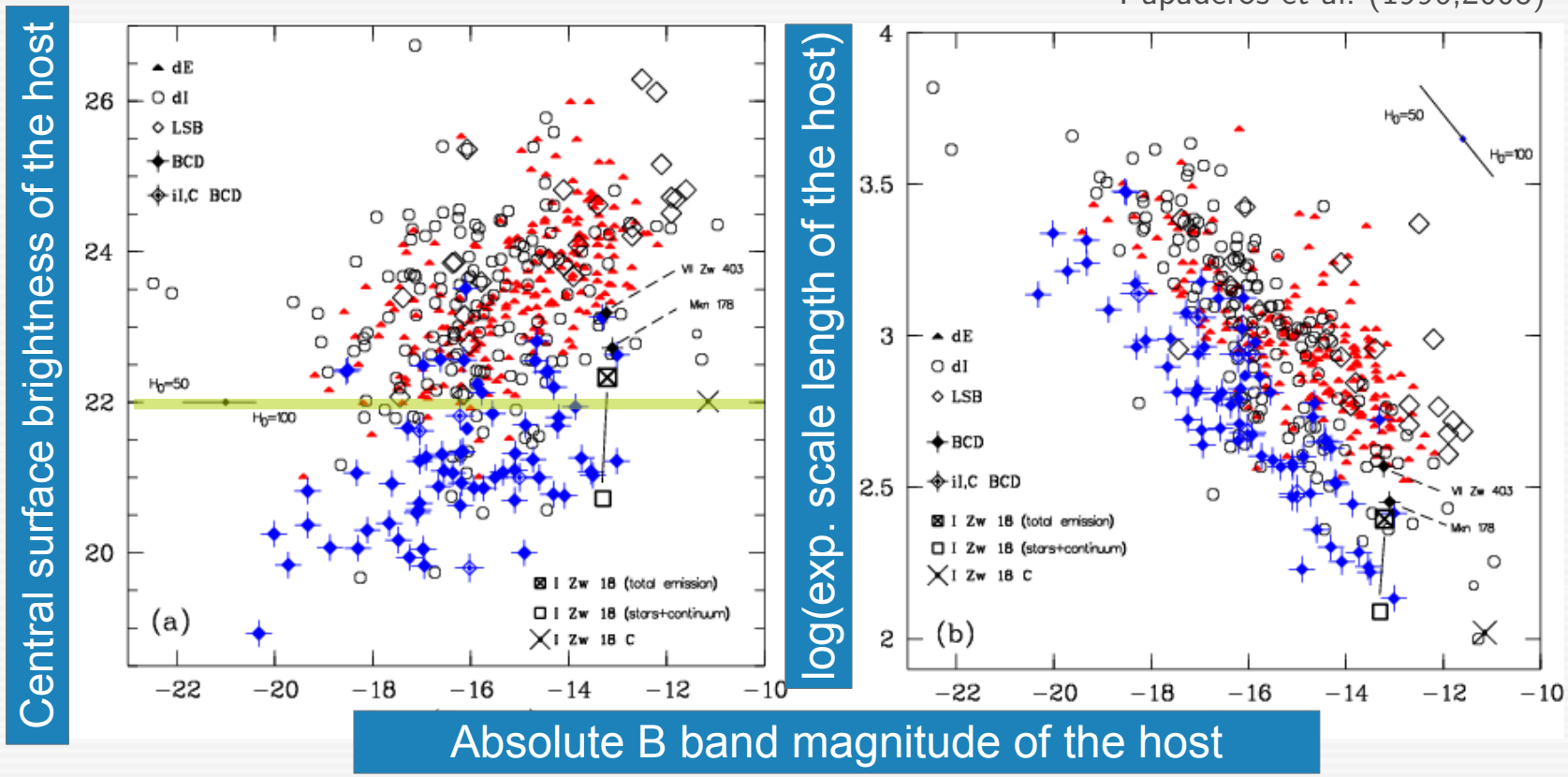
Spatially resolved analysis of BCDs and BCGs out to z~1
(e.g. with VLT/MUSE 9×10^4 spectra + large field of view)

Starburst activity in low-mass galaxies occurs preferentially in compact, high-stellar density (ρ_*) hosts

Papaderos et al. (1996,2008)

low-sSFR (dIs)

high-sSFR (BCDs)



- The central ρ_* of the BCD host galaxy is $\sim$10 $\times$ higher than that in a (low-sSFR) dI
- The $\rho_*(R)$ of the underlying higher-M/L host (consequently, the form of the gravitational potential) is one of the key parameters regulating star-forming activity in triaxial low-mass galaxies (i.e. the Schmidt-Kennicutt law provides an incomplete parametrization of the SFR).

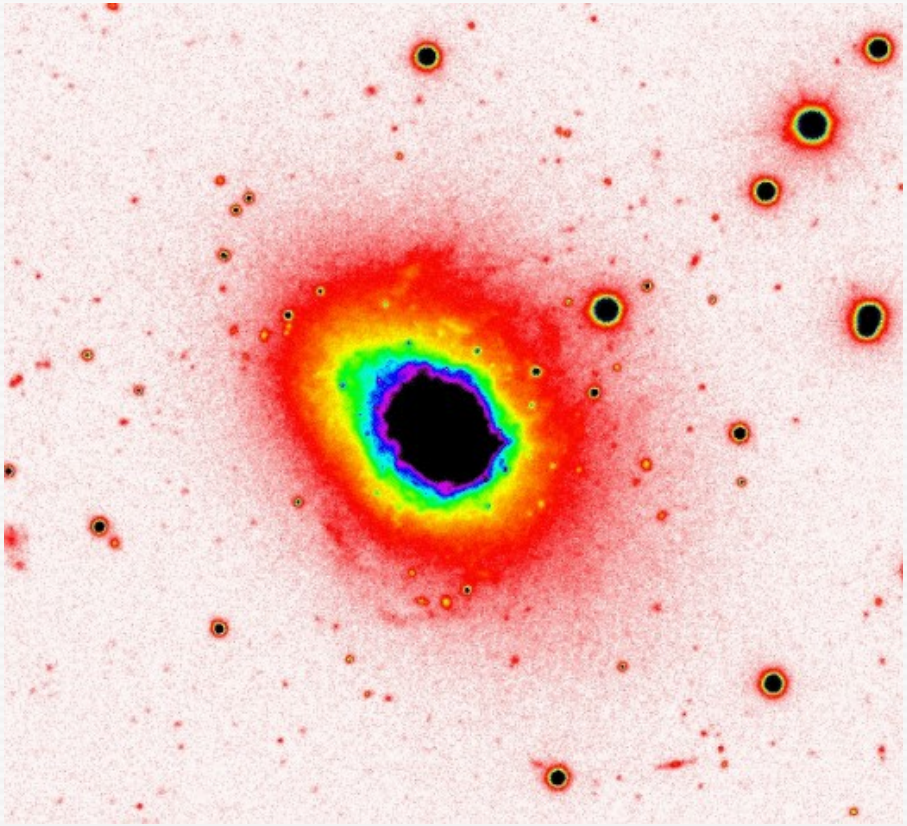
Is there a structural and evolutionary dichotomy between diffuse low-sSFR (dIs) and compact high-sSFR (BCD) late-type dwarfs?

possible interpretations ...

- Adiabatic contraction of the LSB host of a pre-BCD (dI) in response to gas inflow from the halo & subsequent adiabatic expansion of the BCD in response to mass loss (Papaderos et al. 1996).
  - possible only if DM does not dominate within the Holmber radius of a dI/BCD
  - homologous (?) change of the surface brightness profile of the LSB host

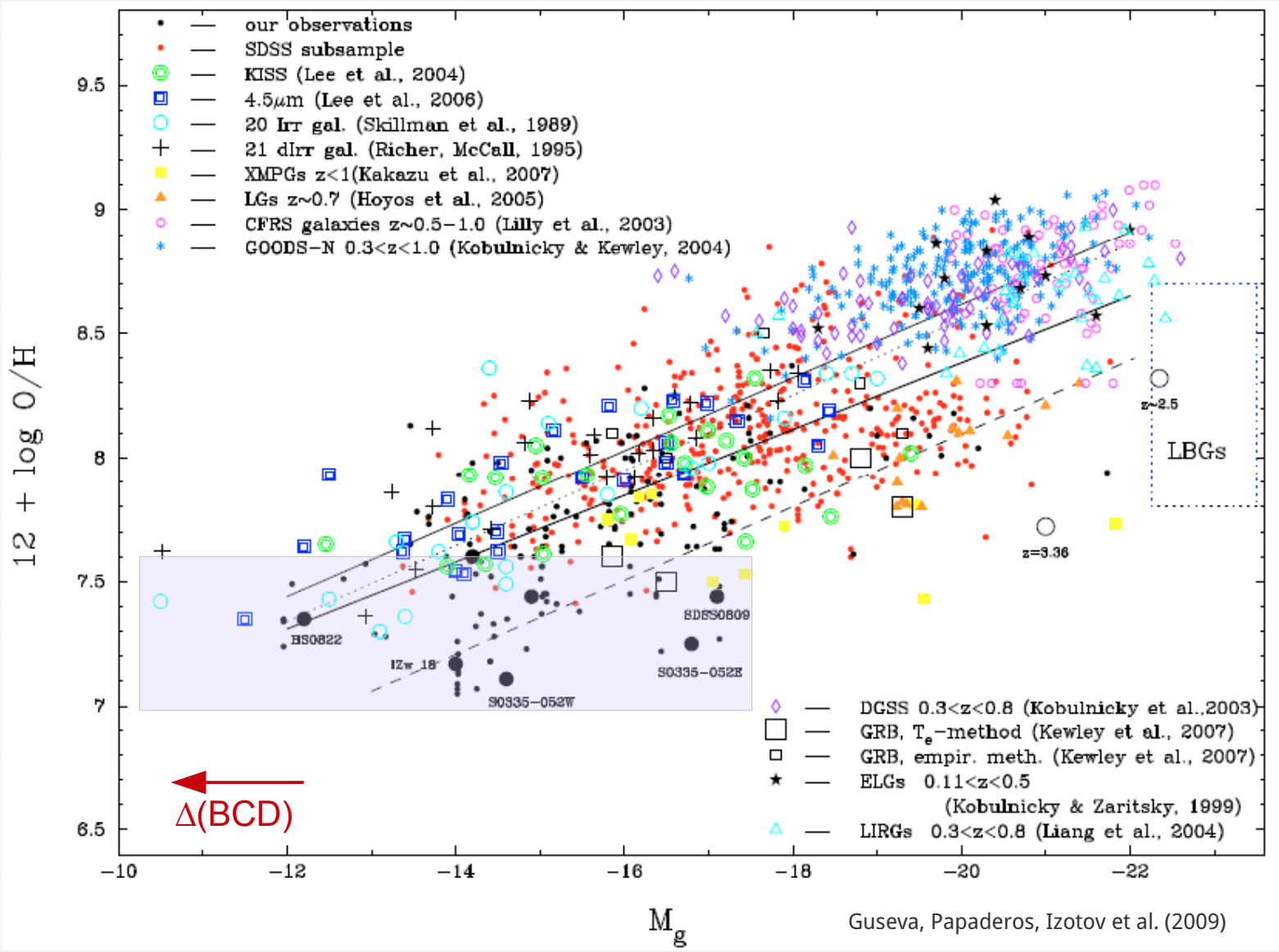
- Bimodality: Low-sSFR late-type dwarfs (dI) differ from high-sSFR late-type dwarfs (BCDs) in the structural properties of their evolved host (and, perhaps, in their angular momentum?) ... Why?

In >95% of the BCD population in the local Universe
starburst activity takes place
within an old extended LSB host galaxy



There are very few exceptions!

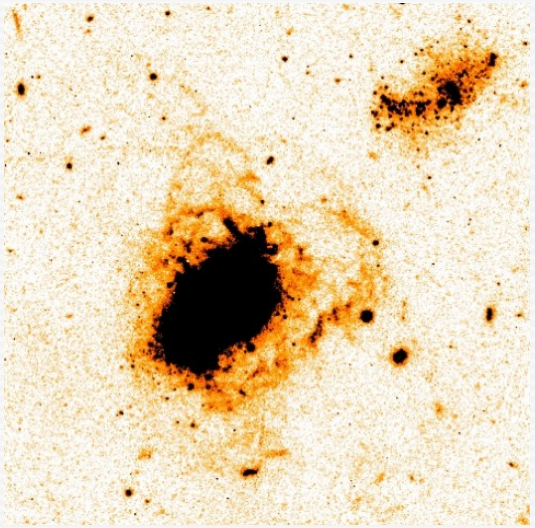
Luminosity vs (gas-phase) metallicity :: L-Z relation



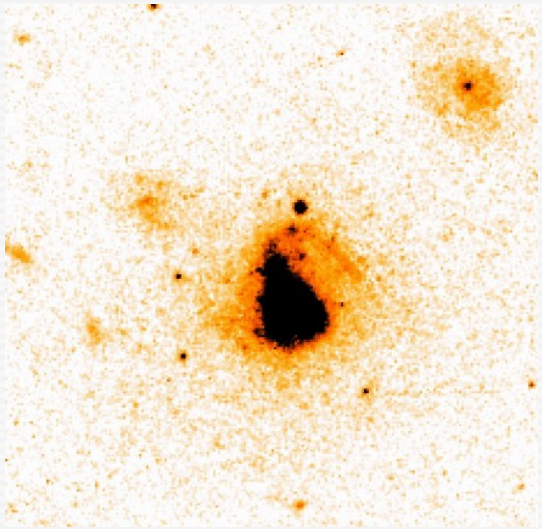
Guseva, Papaderos, Izotov et al. (2009)

Extremely metal-poor (XMP) BCDs: XBCDs

Young galaxy candidates in the nearby universe?

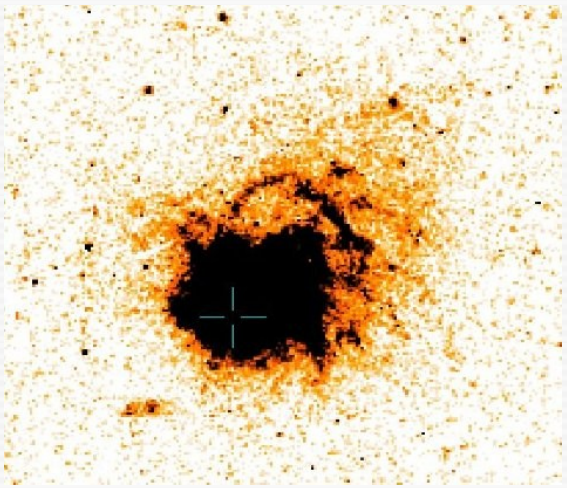


Papaderos et al. (2002)

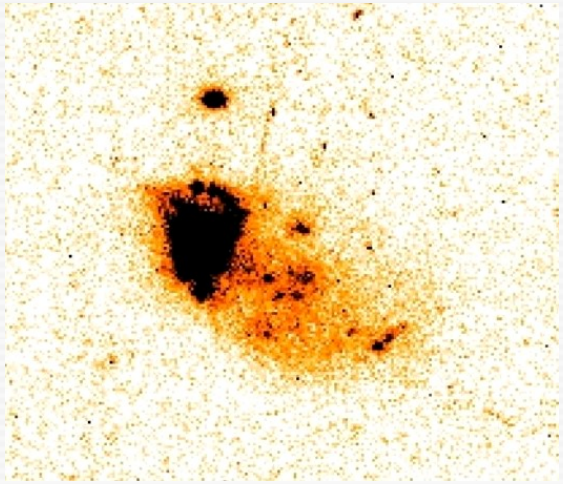


Guseva, Papaderos, Izotov et al. (2004)

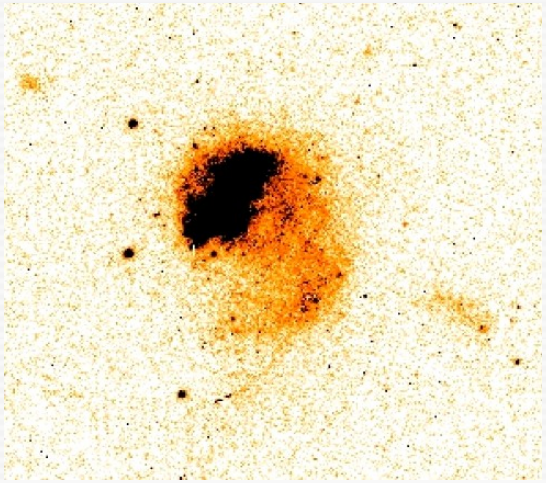
- Gas-phase metallicity: $7.0 \lesssim 12+\log(O/H) \lesssim 7.6$
- No evidence for a dominant old stellar population (>50% of M_* formed in the past 1-3 Gyr)
- Irregular morphology, with a a remarkably large fraction of **cometary** systems



Thuan et al. (1997), Papaderos et al. (1998)



Fricke et al. (2001)



Papaderos et al. (1999,2007)

Pairwise XMP/XBCD formation at a late cosmic epoch (?)

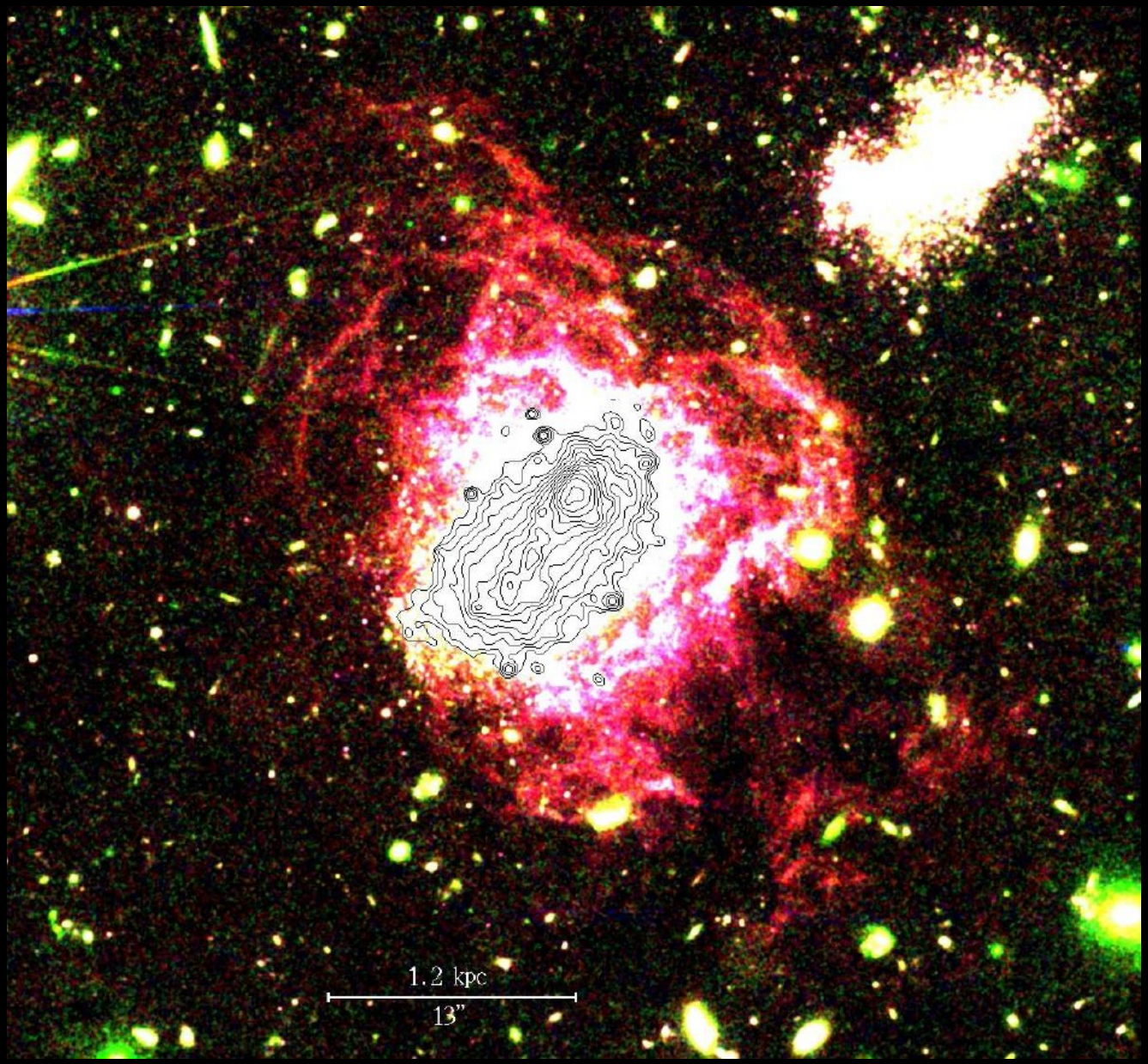
Strong & extended nebular emission in XBCDs

- 2D subtraction of nebular line emission using HST WFPC2 [OIII]5007 and Hα narrow band images (Papaderos et al. 2002) leads to complete removal of the lower-surface brightness (LSB) envelope of I Zw 18

The LSB envelope of
I Zw 18 is entirely due to
extended nebular emission

- Very deep HST ACS imaging down to $\mu \simeq 30$ mag/arcsec^2 (Papaderos & Östlin 2012) shows that the nebular envelope of I Zw 18 reaches out to R $\simeq$ 2.6 kpc

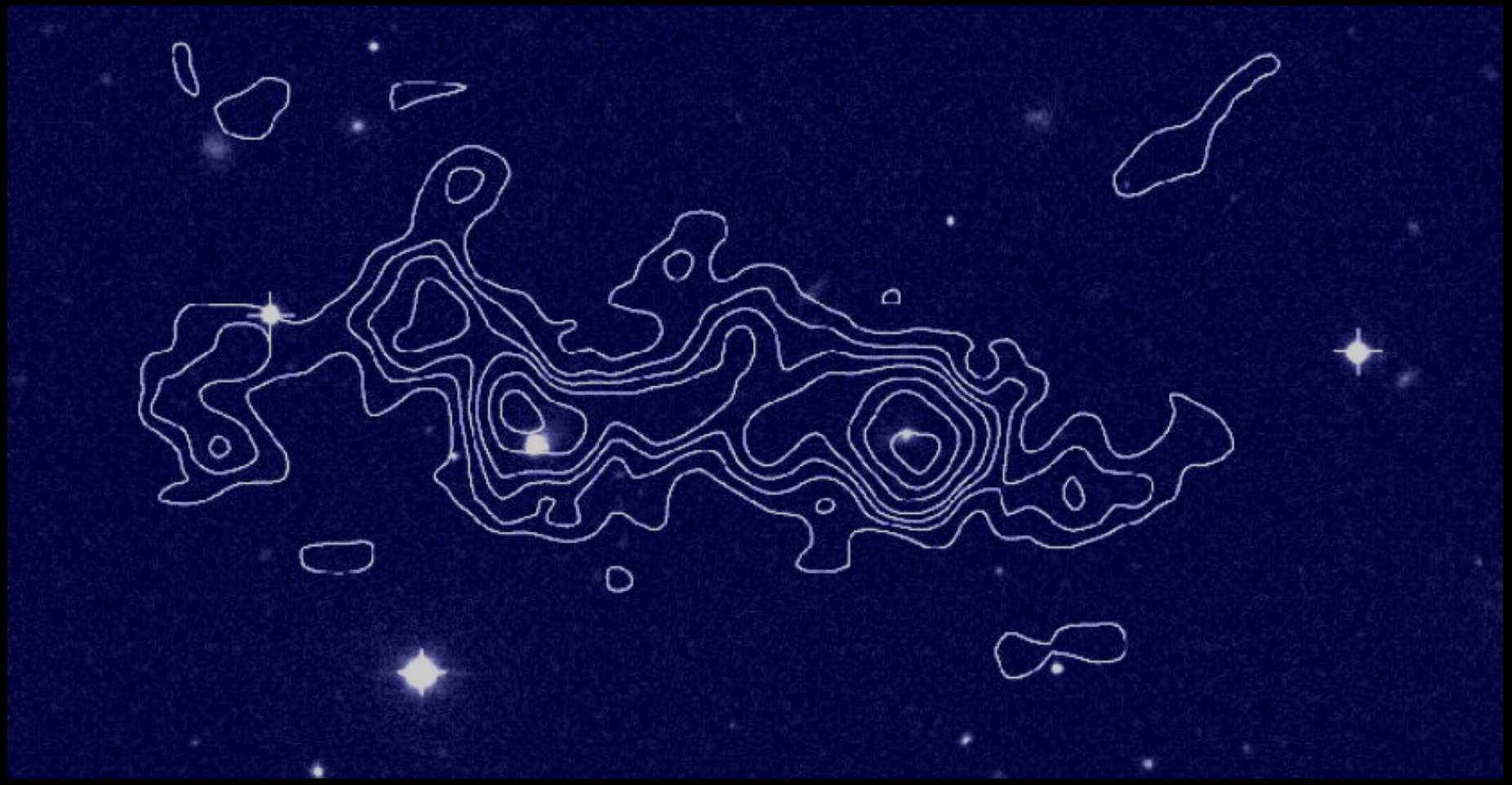
The nebular halo of I Zw 18
extends out to
16 exponential scale lengths
of the stellar component
and
contributes $\geq 1/3$
of the total R band luminosity



Papaderos & Östlin (2012)

Pairwise XBCD formation

Example: the XBCD pair SBS 0335-052 E&W



Pustilnik et al. (2001)

SBS 0335-052: HI cloud with a projected size of 70×20 kpc; mass of $\sim 10^9$ $M_\odot$

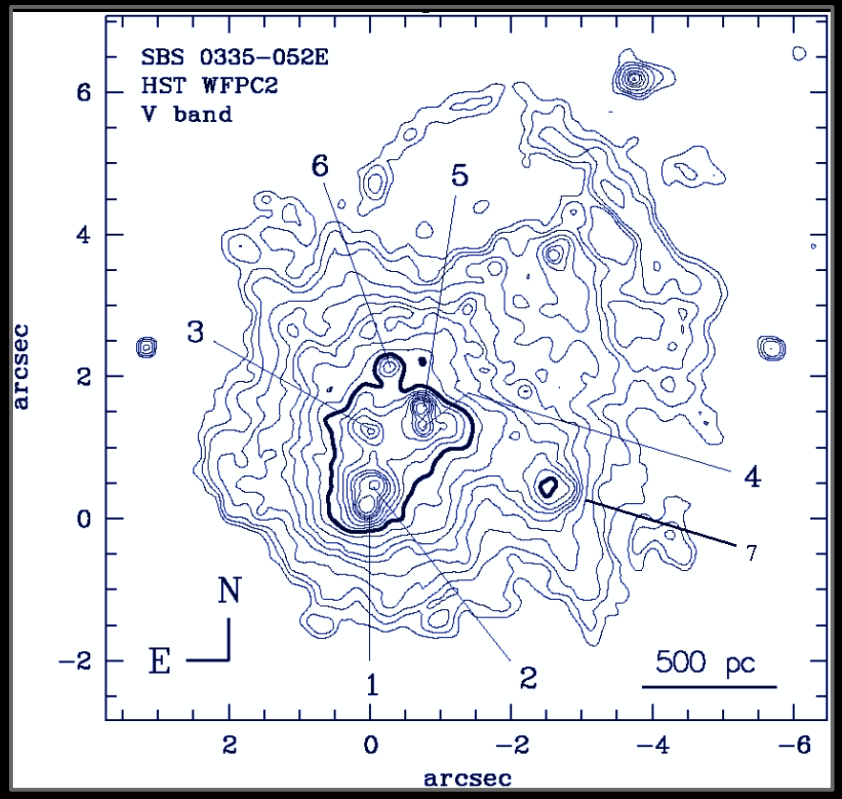
SBS 0335-052 E: formation through propagating star formation



- Study of the V-I color and spatial distribution of stellar clusters using HST data

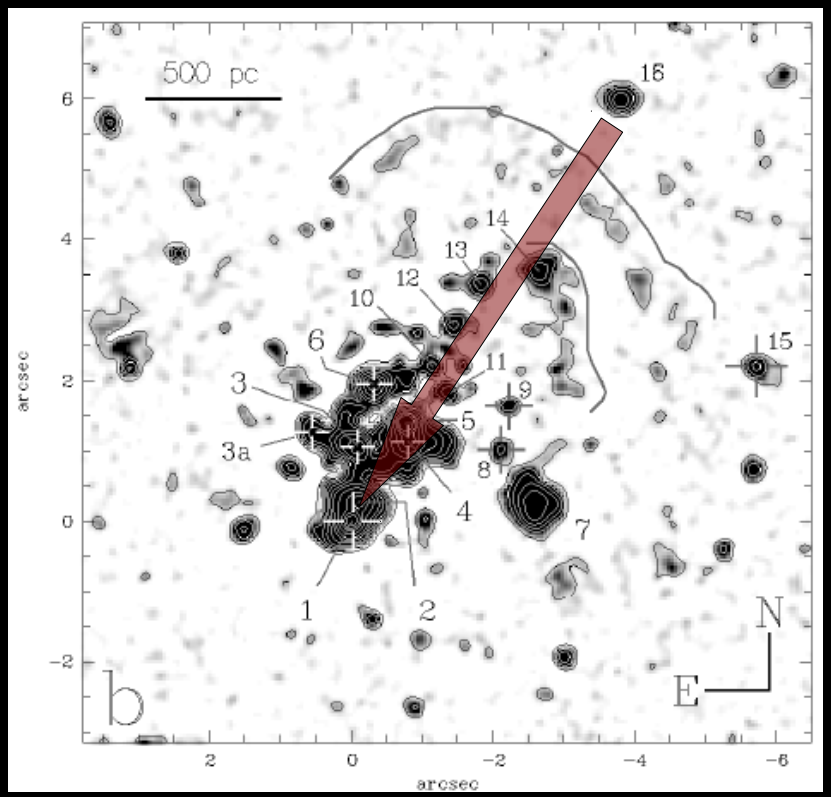
→

- galaxy formation in a propagating mode from NW to SE with a mean velocity of ∼20 km/s.



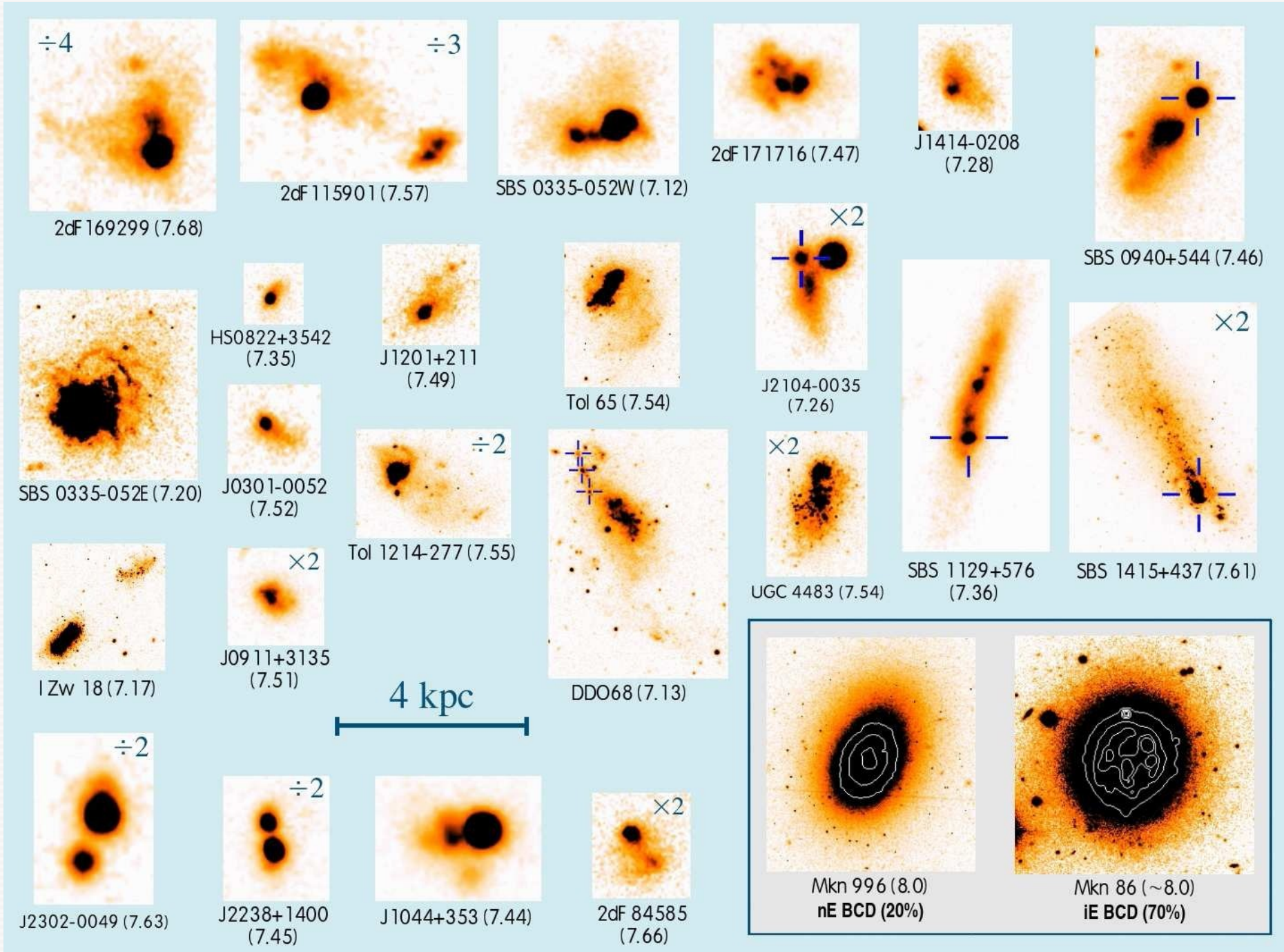
Papaderos et al. (1998)

HST/WFPC2, V band



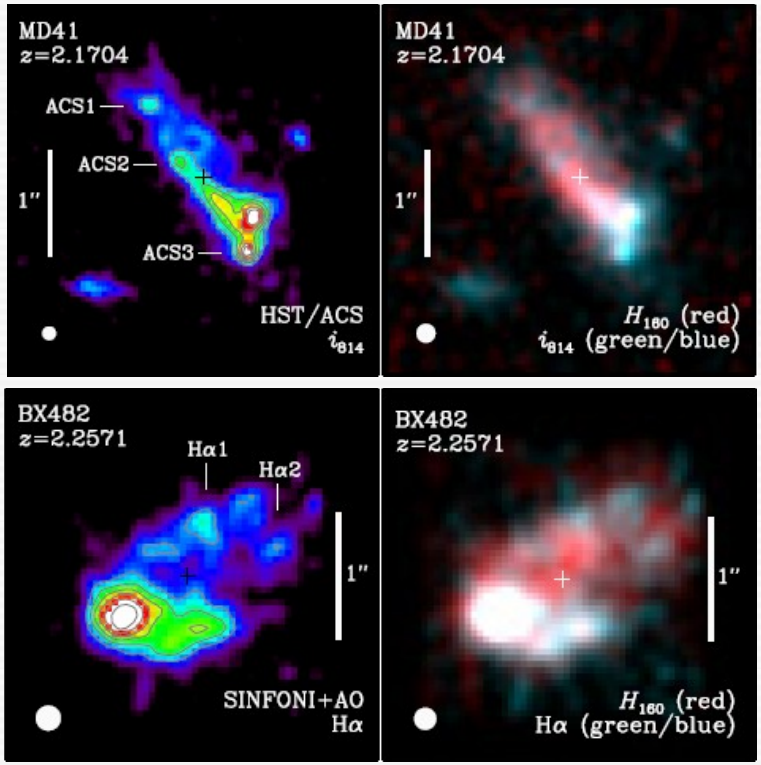
HST/WFPC2, I band, unsharp masked

Morphological comparison of BCDs and XBCDs



Papaderos et al. (2008)

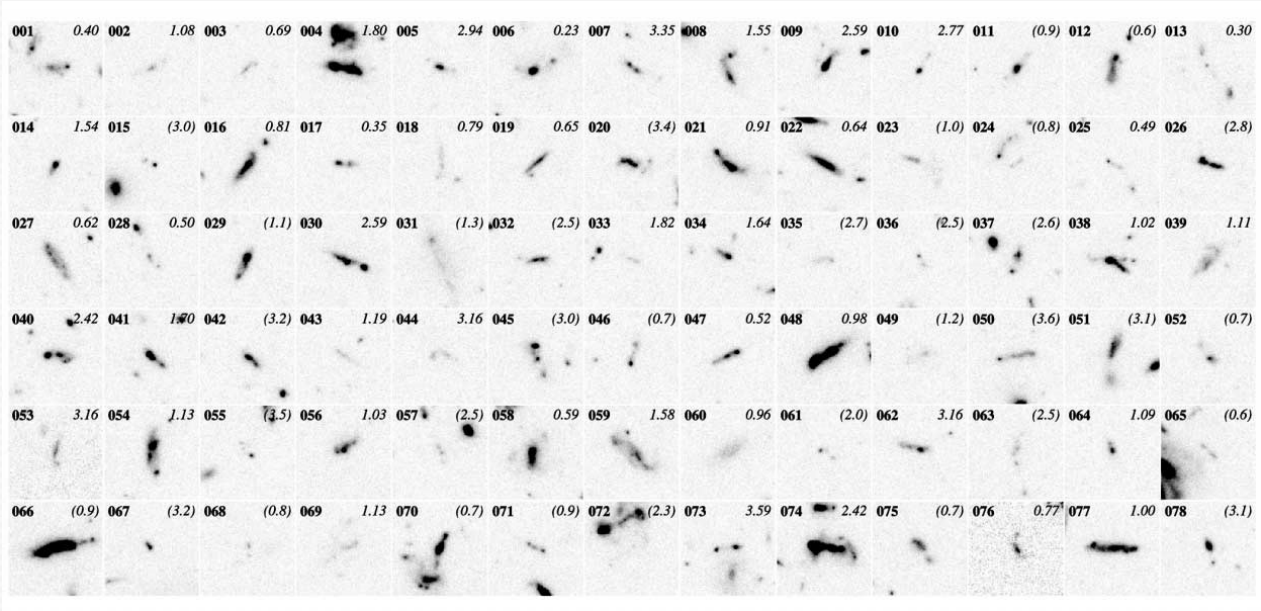
Cometary (or tadpole) massive galaxies at high redshift



Förster-Schreiber et al. (2011)



HUDF: Elmegreen et al. (2005)



Hubble Ultra Deep Field (HUDF): Straughn et al. (2006)

Possible formation mechanisms

- propagating star formation (Papaderos etal. 1998)
  l = 10 kpc * (v/10 km/s) * (t/1 Gyr)
- weak tidal interactions (Straughn et al. 2006)
- turbulent clumpy galactic disks in formation at high redshift (cf Bournaud et al. 2009)
- stream-driven accretion of metal-poor gas from the cosmic web (Dekel & Birnboim 2006, Dekel et al. 2009; see Sanchez-Almeida et al. 2014 for a recent review)

Summary

- Star-forming activities in evolved low-mass starburst galaxies (BCDs) are not entirely regulated by stochastic processes; the gravitational potential of their host galaxy plays an important role.

- Some of the (very few) extremely metal-poor BCDs known (XBCDs with $7.0 \leq 12+\log(O/H) \leq 7.6$) are cosmologically young objects ($M_{\star,old}/M_{\star,1\text{-}3\ Gyr} \leqslant 1/3...1/2$)
$\longrightarrow$ important laboratories of extragalactic astronomy

- Connection between BCD/XBCD evolutionary status, gas-phase metallicity and morphology. The nature of cometary (or tadpole) galaxies in the local universe and at higher z's is enigmatic ...