New insights to the photometric structure of Blue Compact Dwarf Galaxies from deep Near−Infrared studies

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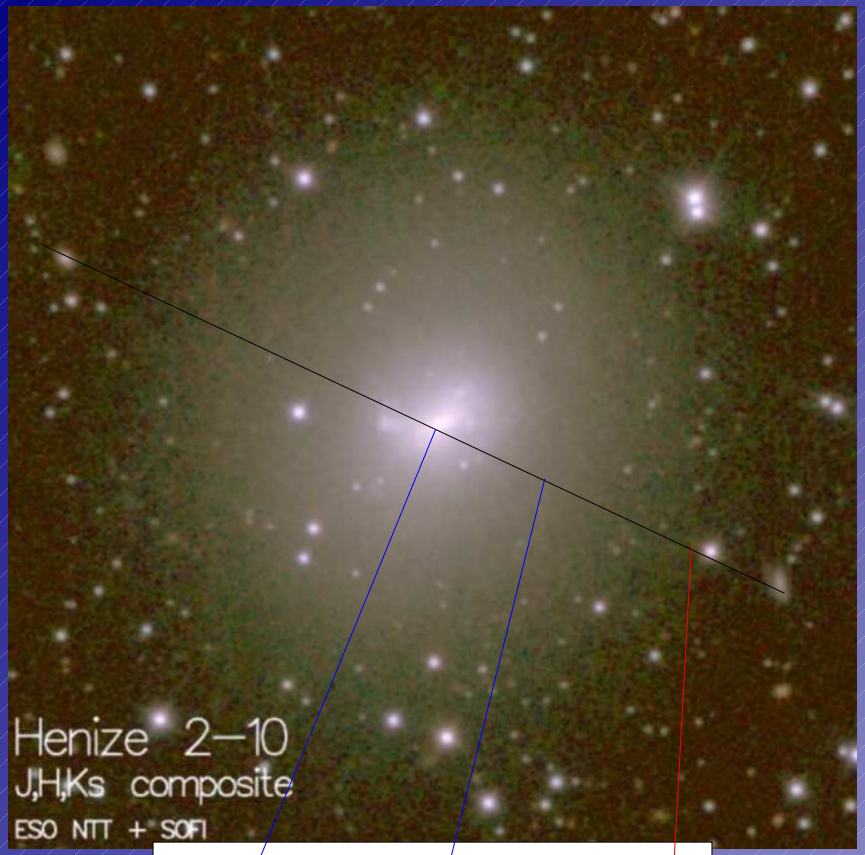
Madrid 2003

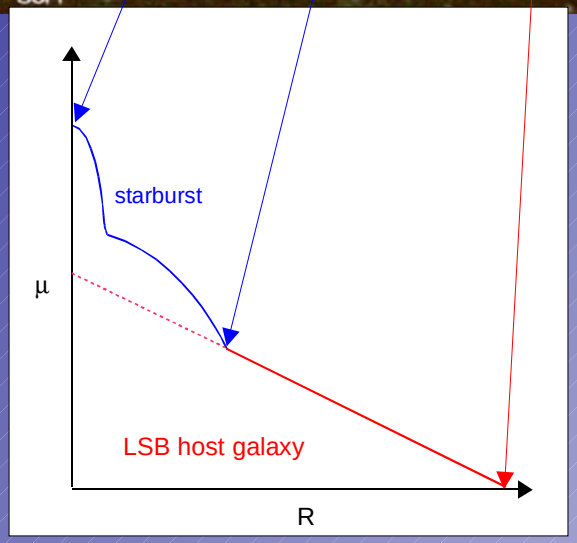
For a detailed description of this work,
see Noeske et al. (2003) and Cairós et al. (2003)



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Superposition of young and old stellar components in BCDs





- Old stellar LSB host galaxy (high *M/L*, contains practically all stellar mass): dynamically important, precise studies to constrain radial stellar mass distribution
  → clues to starburst activity & evolutionary scenarios
  → crucial input to models of starburst−driven evolution of dwarf galaxies

- Central luminosity excess, due to recent/ongoing SF activity (stellar and ionized gas emission) (‘‘starburst component’’)

⇒ Decomposition required: fit to the LSB component at large radii (negligible contribution by starburst)

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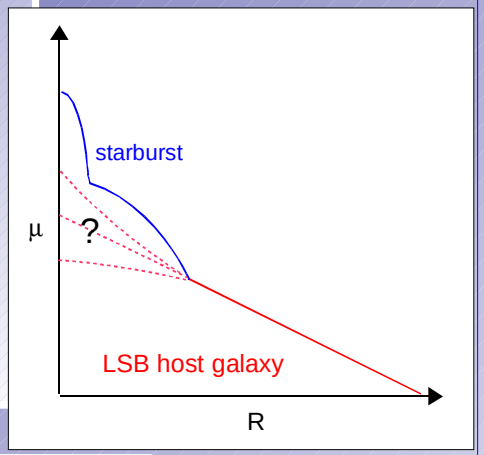
Problem at optical wavelengths:

Starburst emission, superposed on host galaxy, is important down to ~24 B mag arcsec^{-2}: studies of the host galaxy are restricted to large photometric radii

⇒ does the exponential slope of the LSB host continue to R=0?

⇒ reliability of decomposition?

$(L_{starburst}, L_{hostgalaxy}, M_*, \rho_*(r),...)$



Deep NIR data could provide a solution:

$$\frac{(L_{starburst}/L_{tot})_B}{(L_{starburst}/L_{tot})_K} \geq 4$$

- dust extinction ($A_V/A_K \approx 9$)
- optical − NIR colors are better suited to constrain stellar population age than optical colors alone

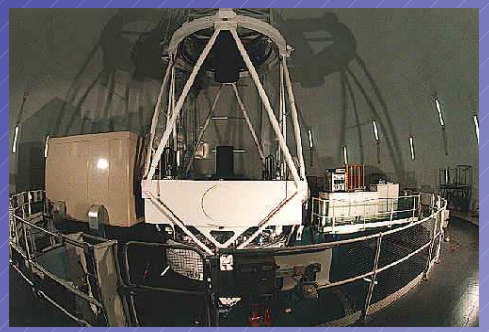


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NIR imaging of large samples of BCDs,
sufficiently deep (μ_j>23 mag arcsec^{-2}) to study their stellar host galaxy,
has only recently become possible (1kx1k NIR detectors)







Observations:

3.6m ESO NTT + SOFI,
3.6m Calar Alto + OMEGA PRIME,
4.2m WHT + INGRID

typical on−object exposure times:
J: 20 min, H: 25 min, K'/Ks: >30 min

> 40 objects, covering all morphological subclasses of BCDs; ≈35 now analyzed

Chosen BCDs for which deep optical data (broad & narrow band images, spectra) obtained by our collaboration, to perform multiwavelength study

Data reduction:

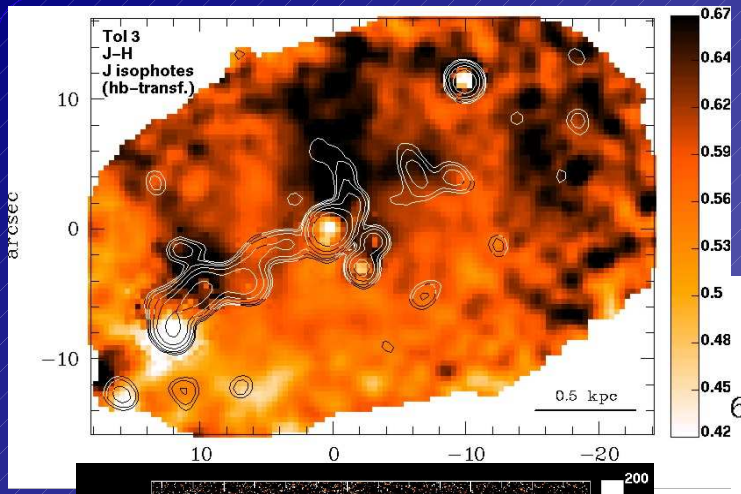
Surface photometry requires very homogeneous background on all scales:

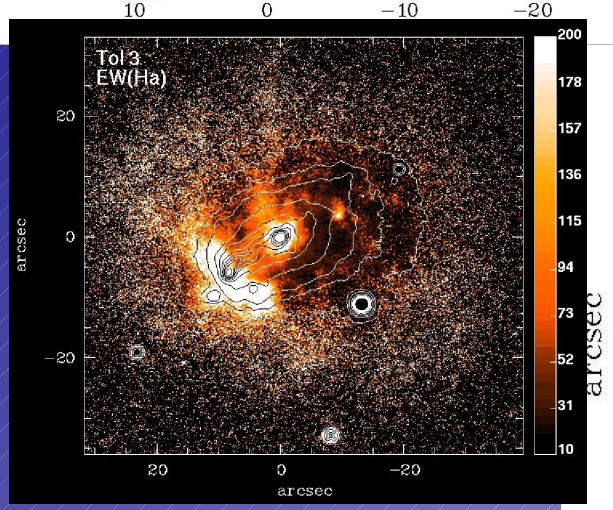
→ developed own software (set of ESO MIDAS modules), extending standard reduction recipes by new correction steps

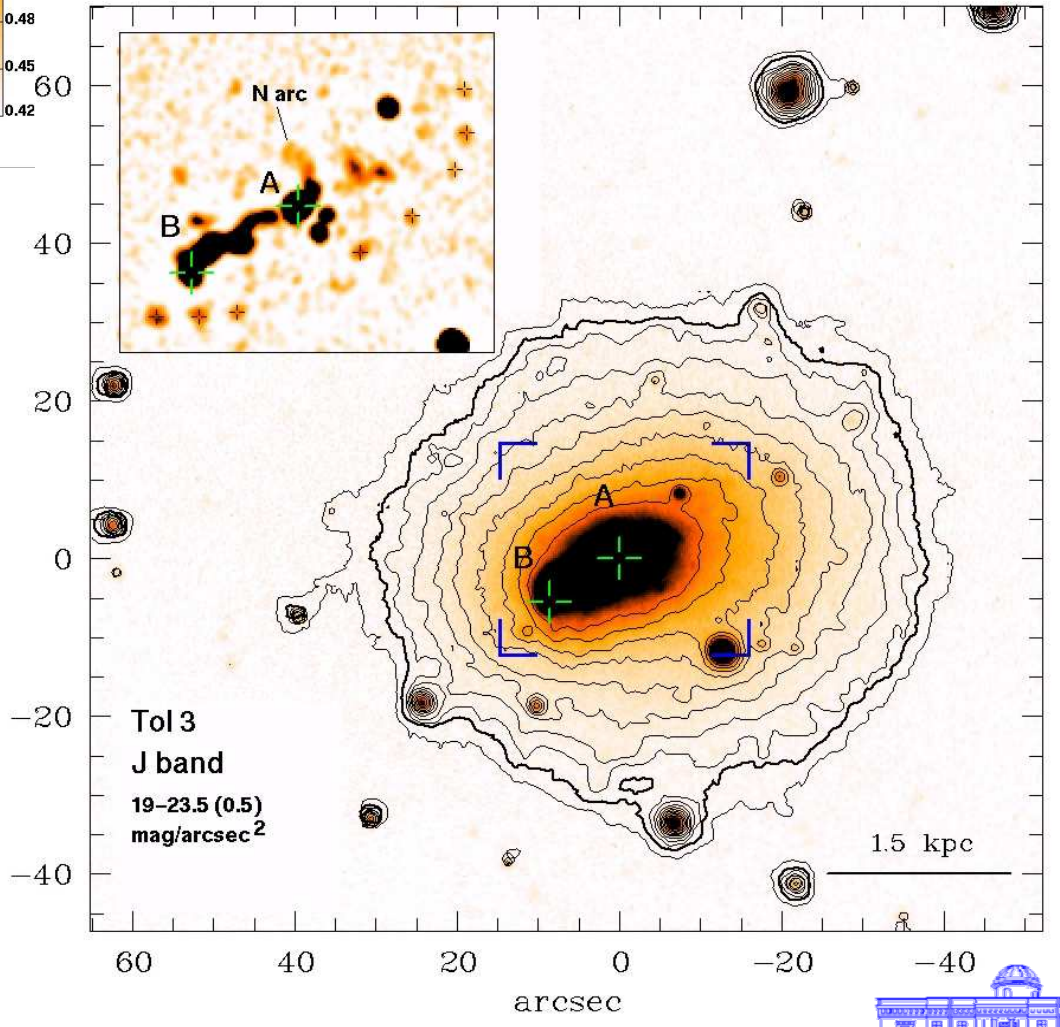
→S/N weighted coaddition,
→interactive alignment control,
→1st order background residual correction,
→improved background level determination and subtraction,
→replacement of fore−/background sources



Example Results: Tol 3 (NGC 3125)







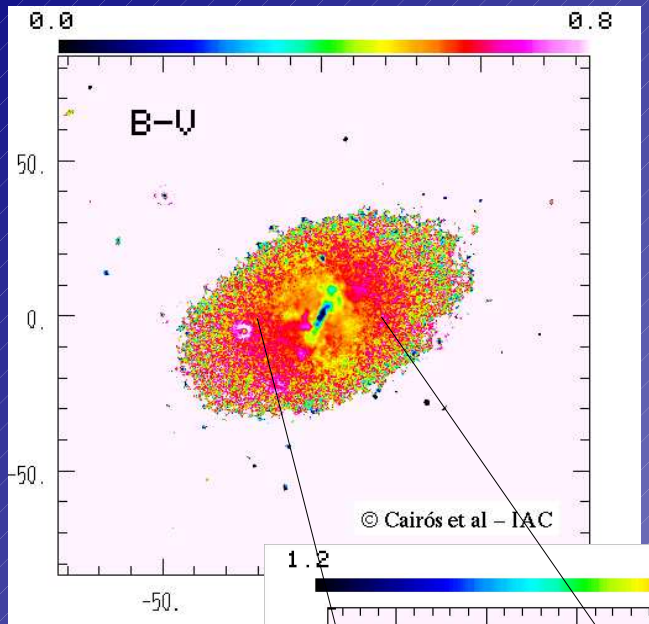
D=13.8 Mpc; M_B = −18.0 mag (Marlowe et al. 1999)

Z≈1/4 Z_{sun} (Masegosa et al. 1994)

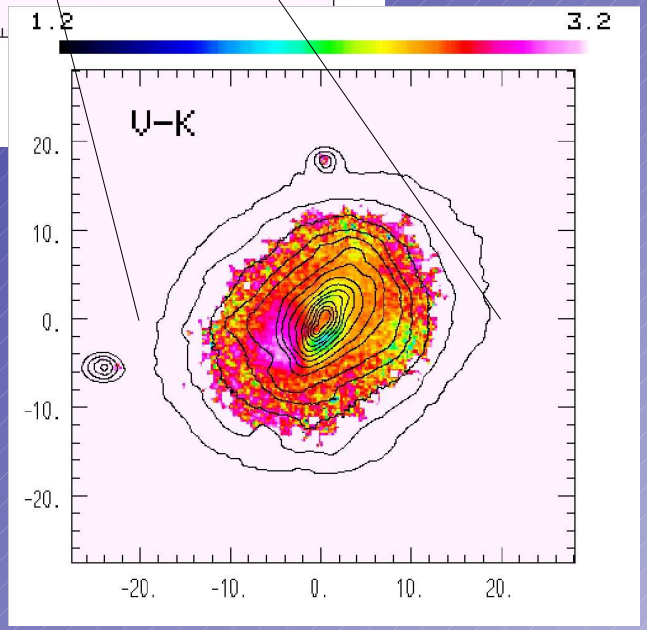
morphology: iE (Loose & Thuan 1986)

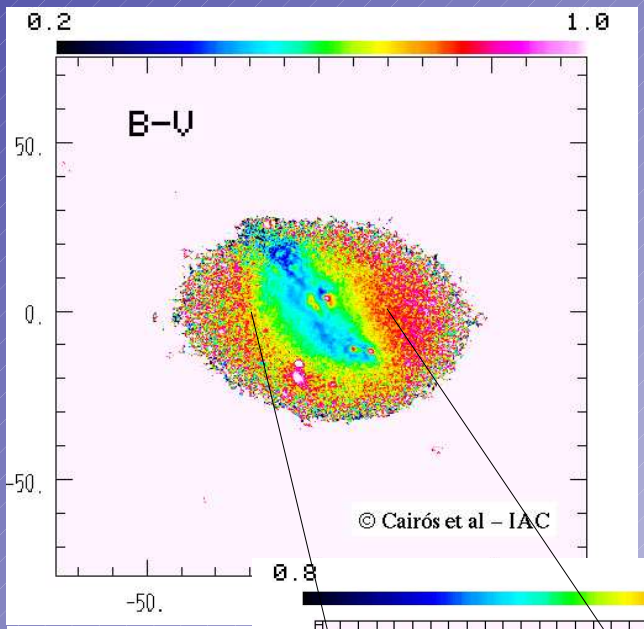
bi−polar reflection nebula out to 20'' from nucleus 'A', ≈4.5x10^5 M_{sun} of cold dust (Alton et al. 1994)

Non−uniform dust in and around the star−forming regions of BCDs from NIR−optical comparisons

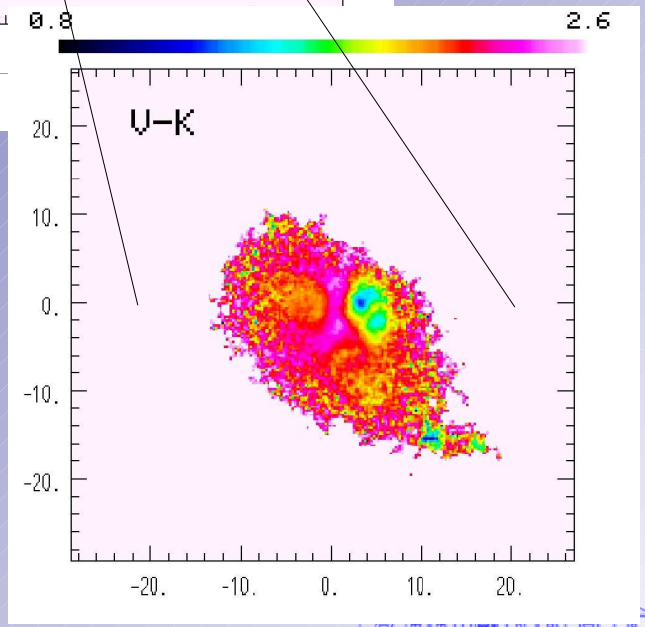


Mrk 33





Mrk 35



Cairós et al. 2001b, 2002b

Surface photometry analysis:

Derivation of surface brightness profiles (SBPs) using different methods , intercomparison of results

Limiting surface brightness:

$\mu_{J,lim}$: 23.5 – 25.5 mag arcsec^{-2}

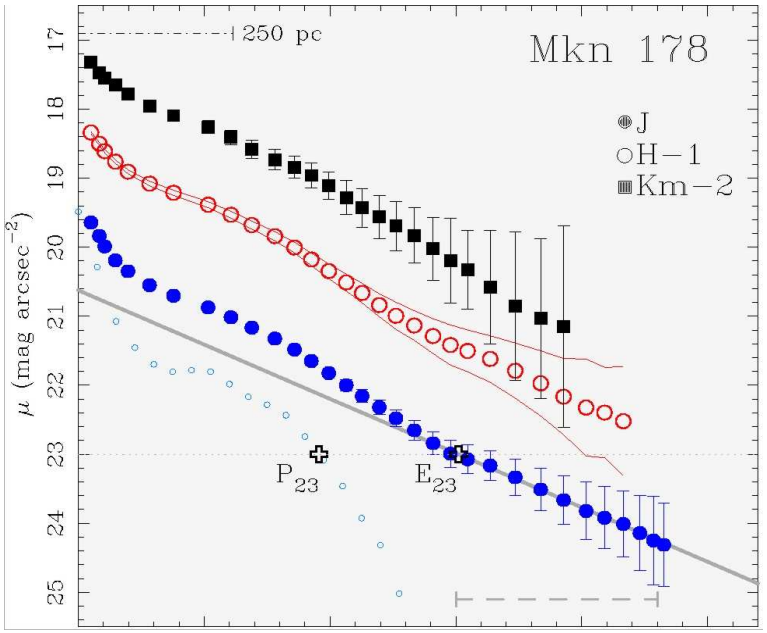
($\Leftrightarrow \approx$25.5 – 27 B mag arcsec^{-2})

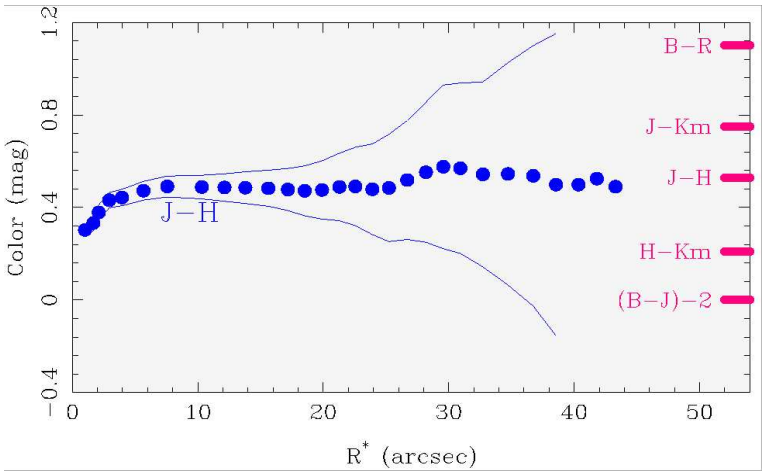
$\mu_{H,lim}$: 22 – 24.5 mag arcsec^{-2}

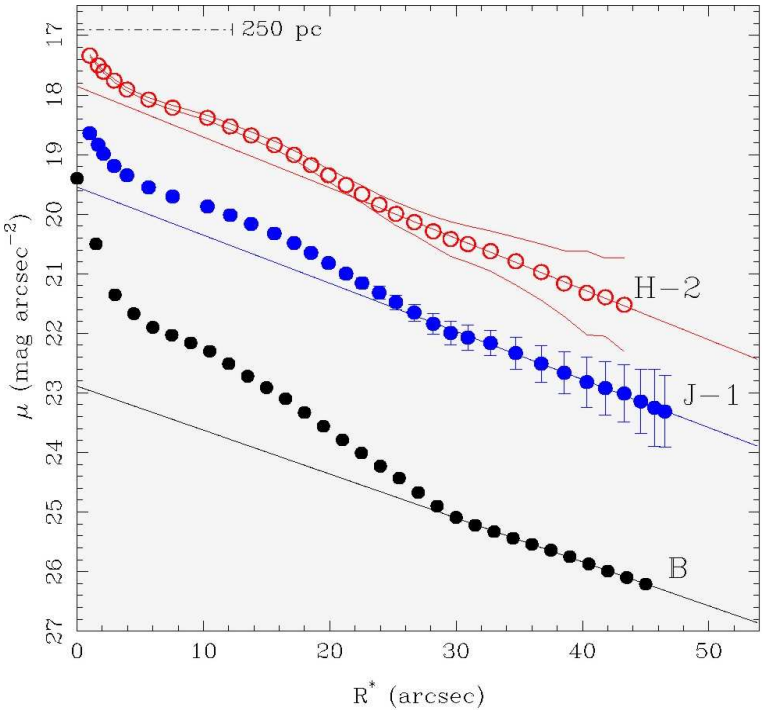
$\mu_{K,lim}$: 22 – 24 mag arcsec^{-2}



Example Results: The BCD Mkn 178



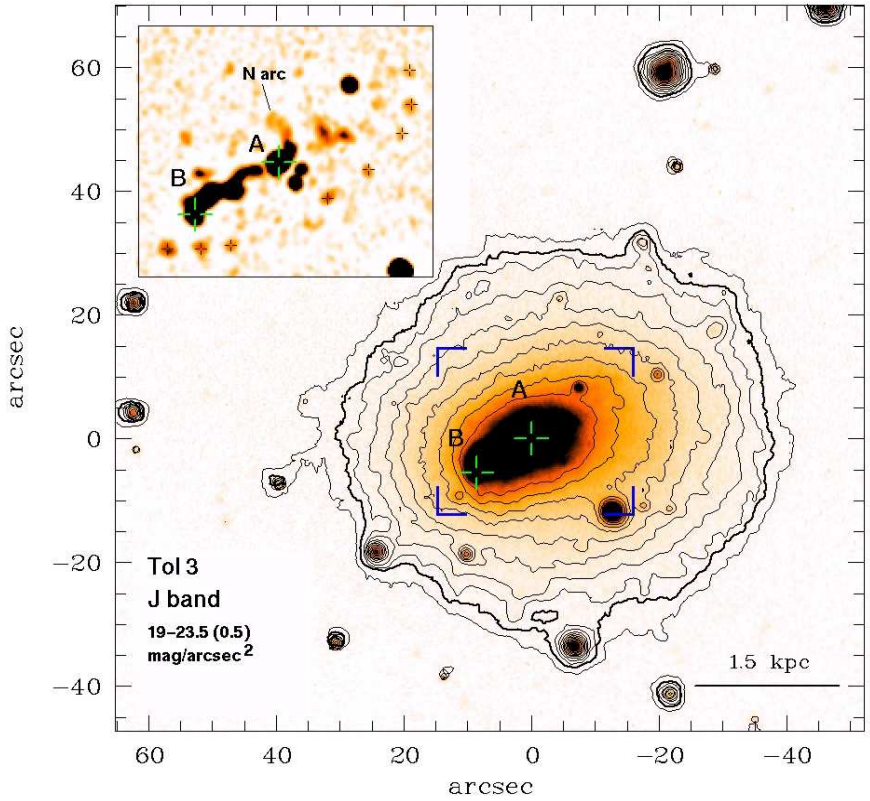


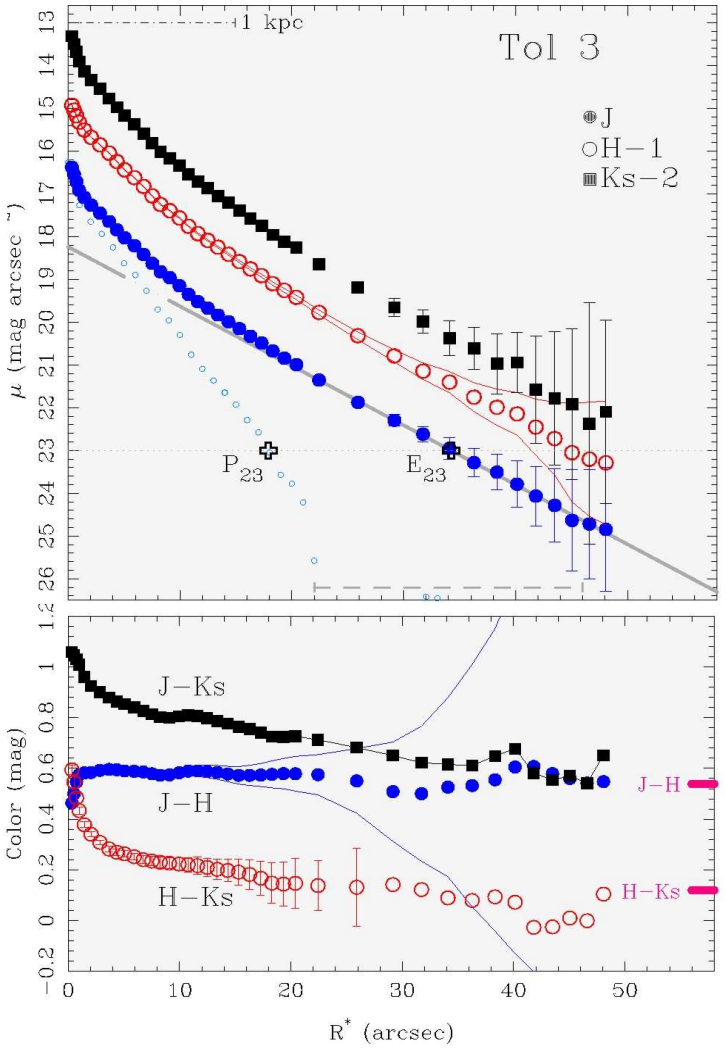


Line−of−sight contribution of the starburst component at the B band effective radius (280 pc) decreases from 67% in B, to 36% in J and only 26% in H.

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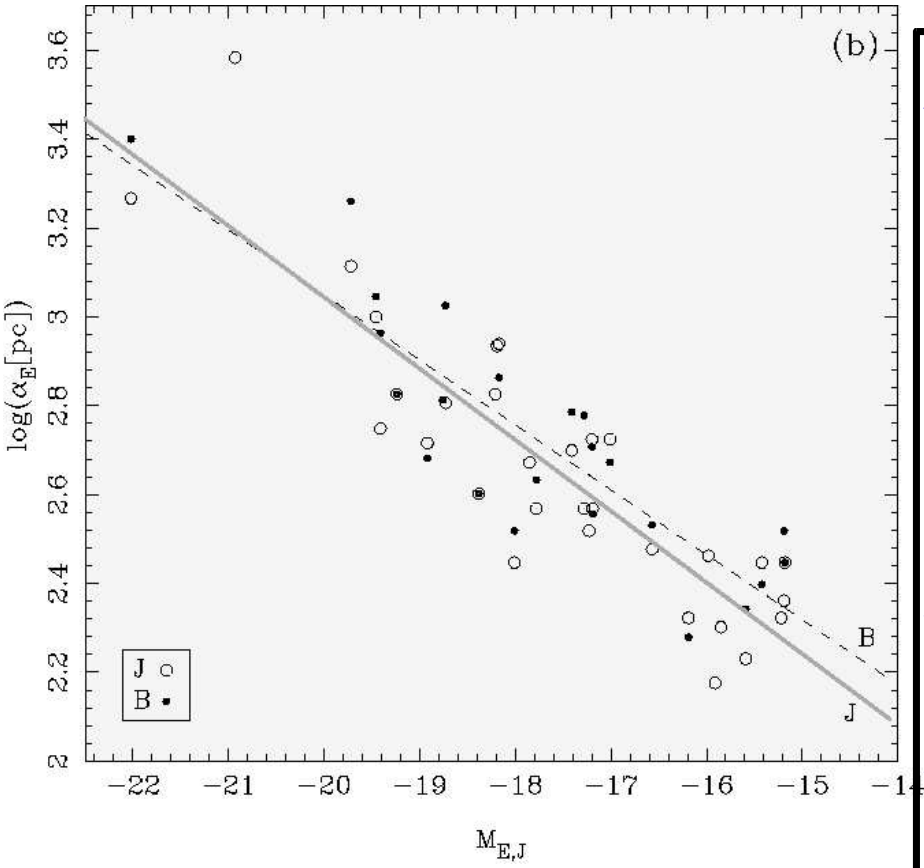
Example Results : Tol 3 (NGC 3125)





exponential stellar host galaxy; superposition of central starburst micmicks *overall* curved surface brightness profile (cf. Cairós et al. 2003)

Structural properties of the stellar LSB host galaxy in the optical and NIR



General agreement between B and NIR bands within the uncertainties for:

- $\mu_{E,0}$ (assuming similar LSB host colors)
- α_E
- relations $\mu_{E,0}$,α_E vs. M_E

Comparison optical−NIR suggests systematic overestimation of α_E , $\mu_{E,0}$ in the optical in cases of

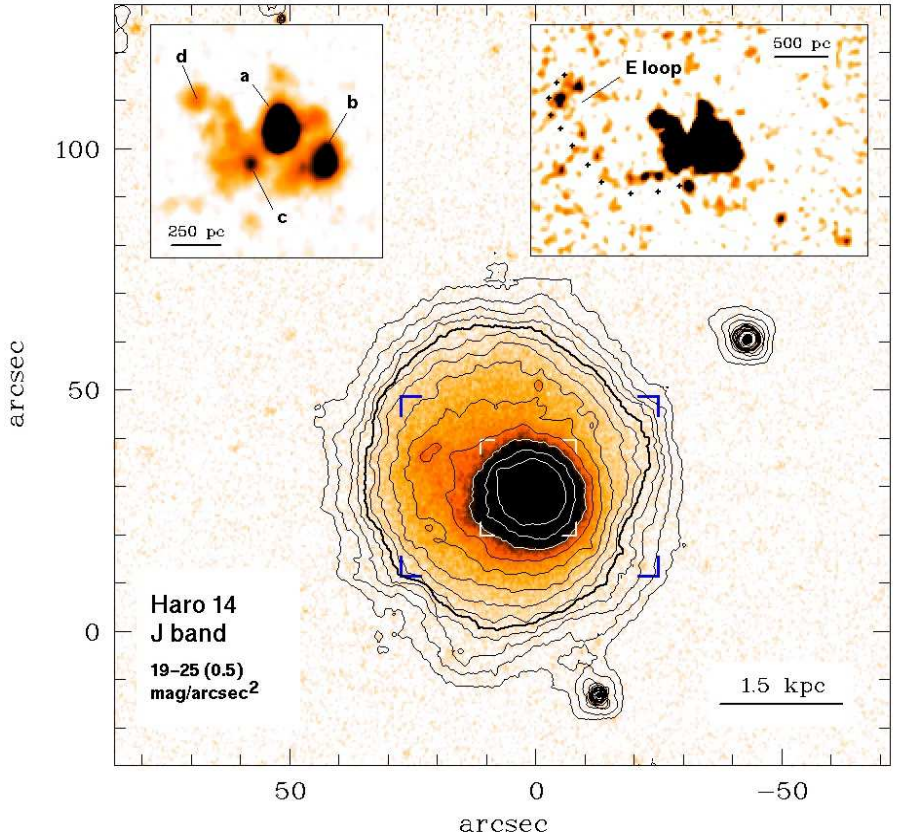
- wide−spread extranuclear SF activity
- undetected centrally flattening LSB host

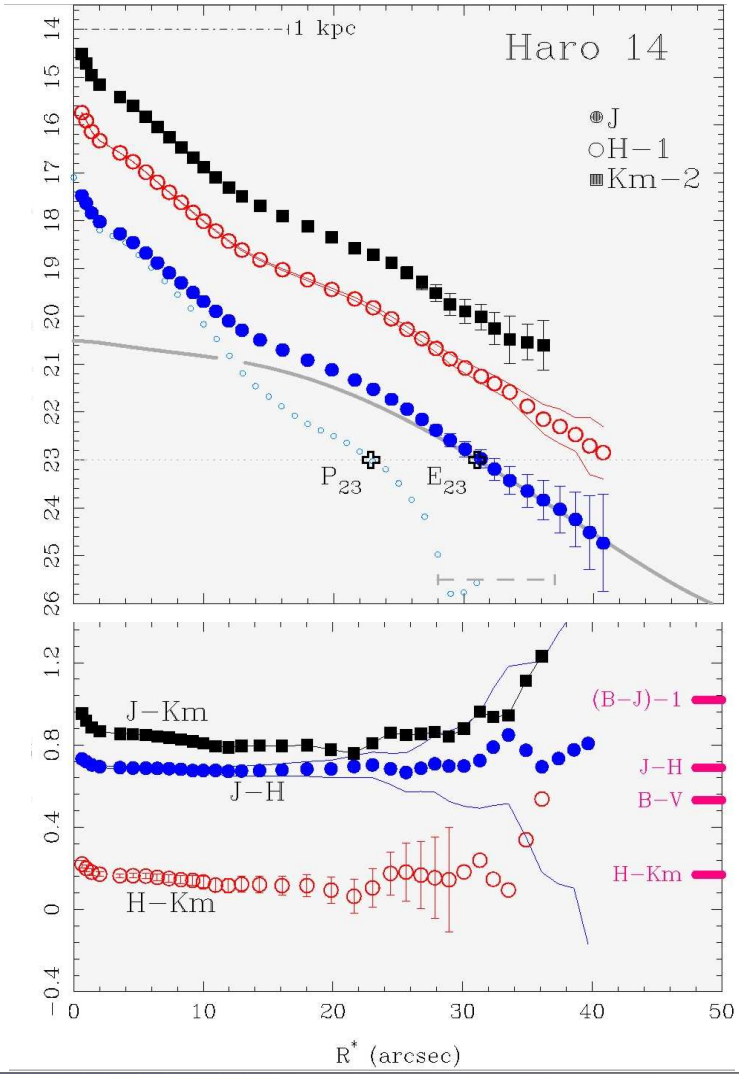
→ NIR data confirm compact structure of the stellar host of BCDs



Centrally flattened SBP of the host galaxy: examples

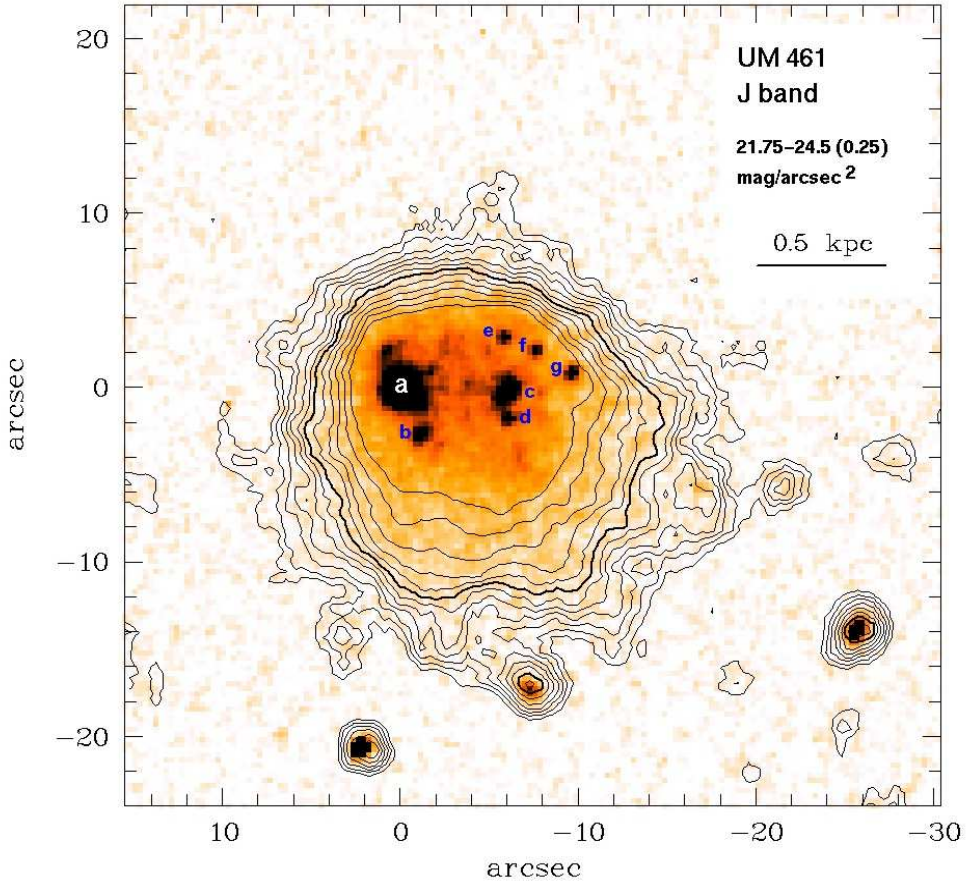
Haro 14
strong flattening: (b,q) = 3.6,0.94



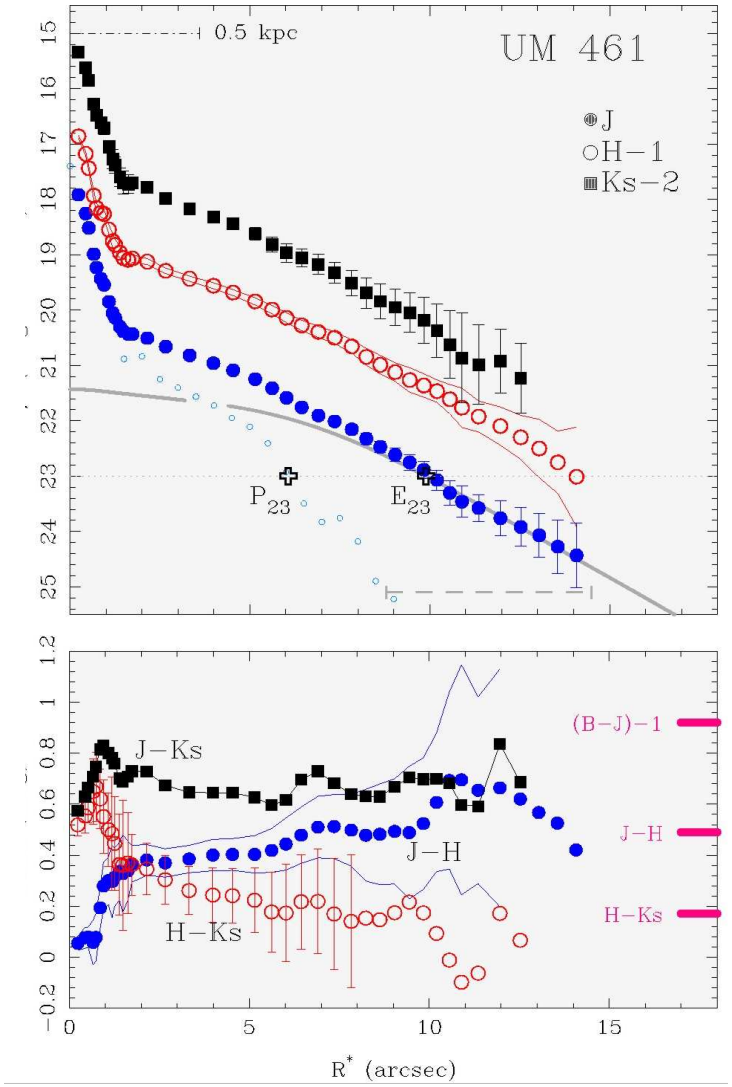


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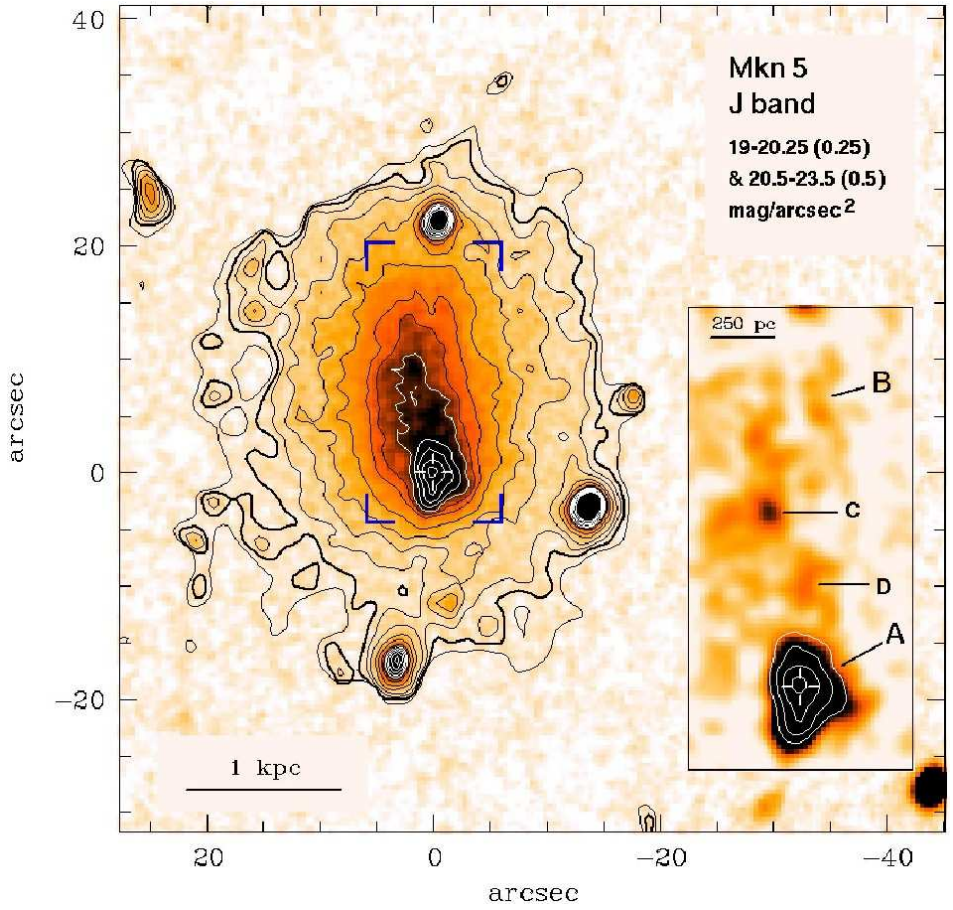
Centrally flattened SBP of the host galaxy: examples

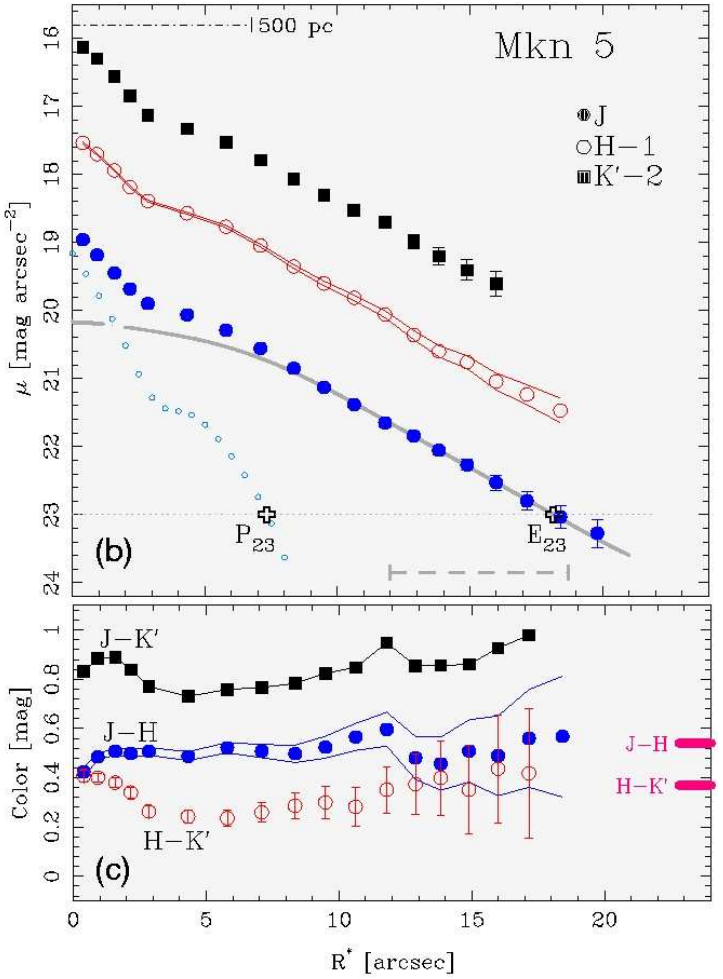


Flattened exponential fit
(b,q)=2.3,0.85



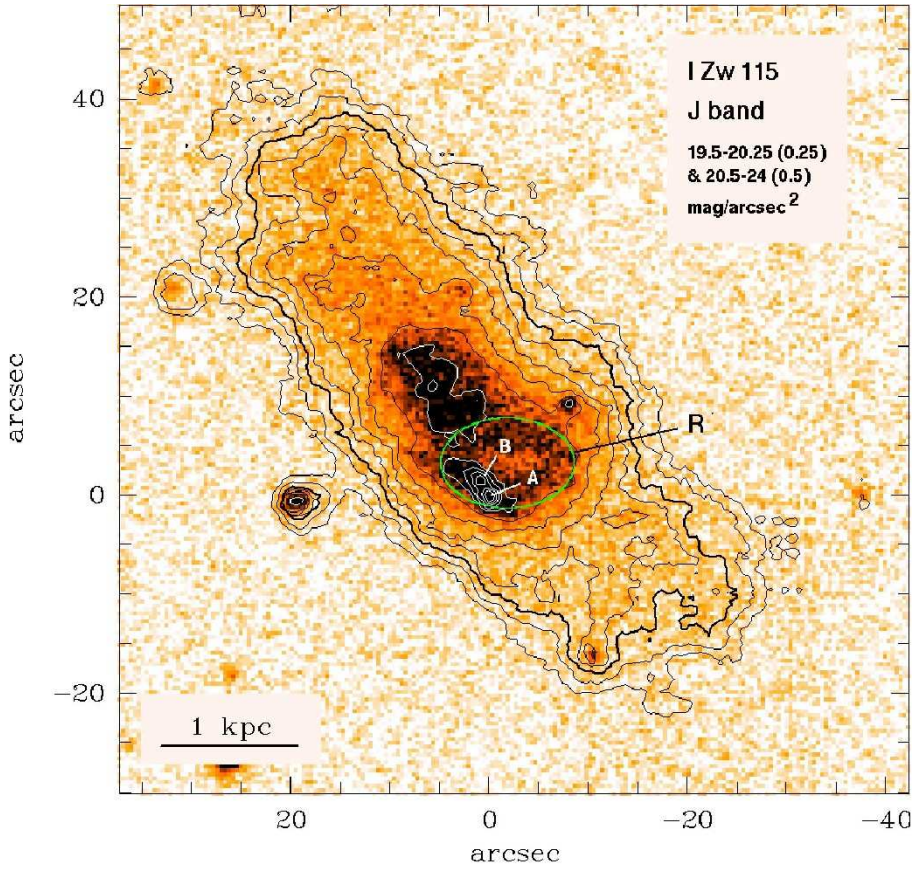
Centrally flattened SBP of the host galaxy: examples

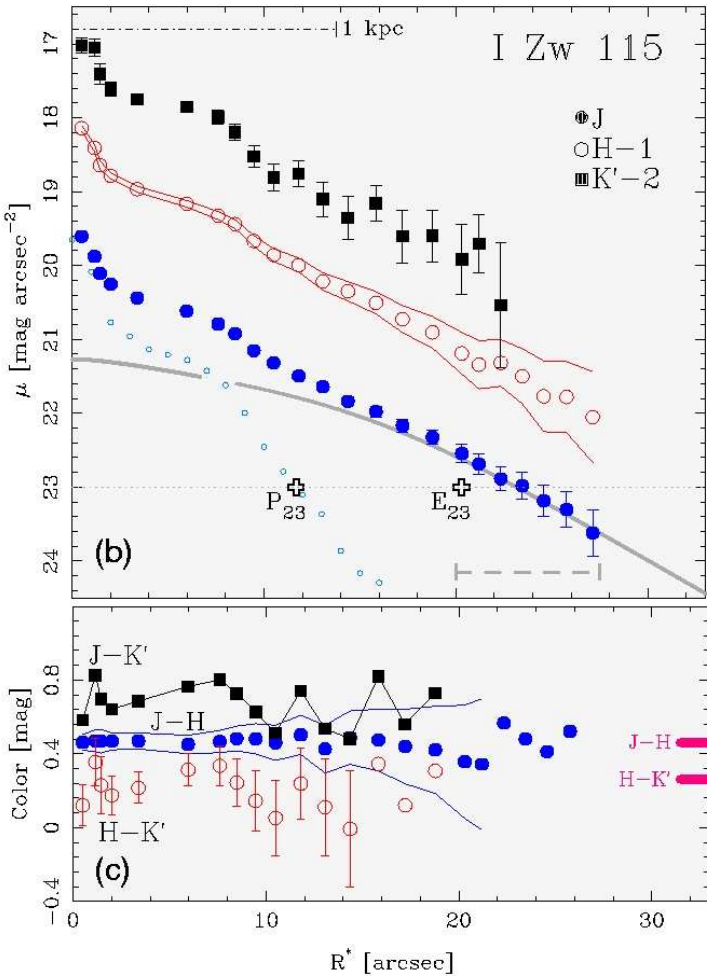




Flattened exponential fit
(b,q)=1.4,0.65

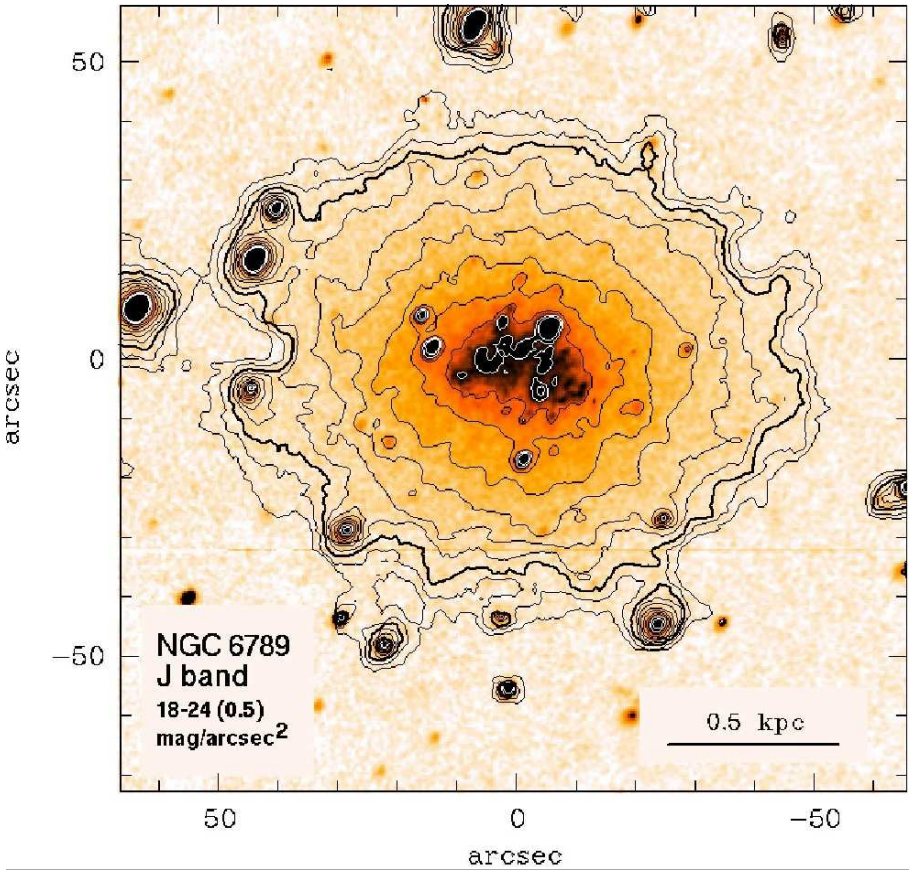
Centrally flattened SBP of the host galaxy: examples

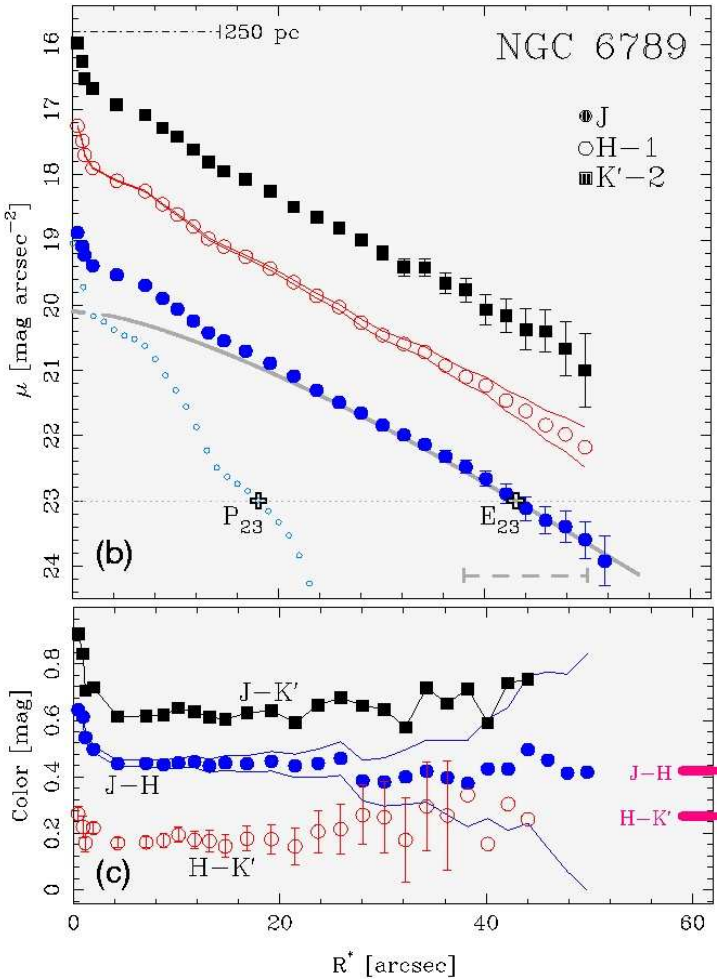




Flattened exponential fit
(b,q)=2.4,0.8

Centrally flattened SBP of the host galaxy: examples





Flattened exponential fit
(b,q)=3.3,0.70

Centrally flattened SBP of the host galaxy

Outer parts of the host galaxy are well fitted by an exponential law
BUT
profile extrapolation to the center results in a higher intensity than is observed at small radii (~1...3 scale lengths) → central flattening

''*type V SBPs*'' (Binggeli & Cameron 1991)
2 *empirical* fitting laws, approximating such SBPs:

Modified exponential (Papaderos et al. 1996):

$$I(R) = I_0 \exp\left(-\frac{R}{\alpha}\right)\left[1 - q \exp\left(-P_3(R)\right)\right]$$

$$P_3(R) = \left(\frac{R}{b\,\alpha}\right)^3 + \left(\frac{R}{\alpha}\cdot\frac{1-q}{q}\right)$$

bα : cutoff radius, α : exponential scale length

$q = \Delta I / I_0$: relative intensity depression at R=0

4 parameters; method of choice

Sérsic law (Sérsic 1968):

$$I(R) = I_0 \exp\left(-\frac{R}{\beta}\right)^{\eta}$$

3 parameters;
alternatively used for comparison for SBPs of type V ;
method of choice for profiles steeper than an exponential (η>1) (e.g. Cairós et al. 2003 for BCDs)



SBPs of the host galaxy: sample summary

Results from the NIR sample analyzed so far:

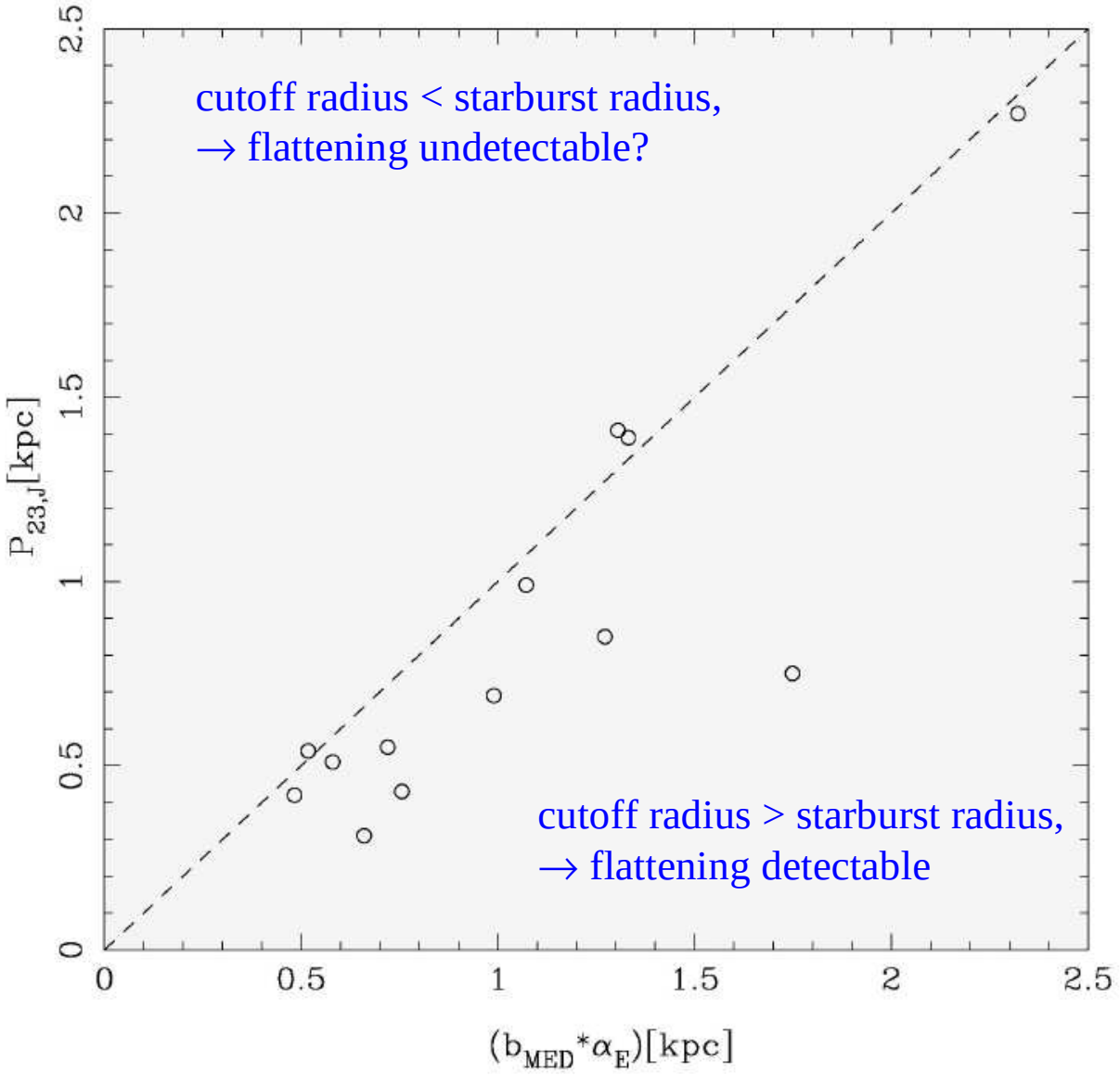
- > 50 % show a centrally flattened / *type V* LSB host
- many ambiguous cases (insufficiently deep data/extended starbursts also in the NIR), probably more *type V* LSB hosts (→next page)
- <25% are non−ambiguous cases which suggest pure exponential
- 1 case of a LSB host steeper than an exponential (Mrk 33)

Current picture of the host galaxy from optical studies:

SBPs of BCD host galaxies can generally be approximated by a pure exponential law.
Centrally flattened SBPs are relatively rare

(Loose & Thuan 1986, Kunth et al. 1988, Papaderos et al. 1996, Telles et al. 1997, Marlowe et al. 1997, Doublier et al. 1997, Salzer & Norton 1999, Vennik et al. 2000, Cairós et al. 2001a,...)

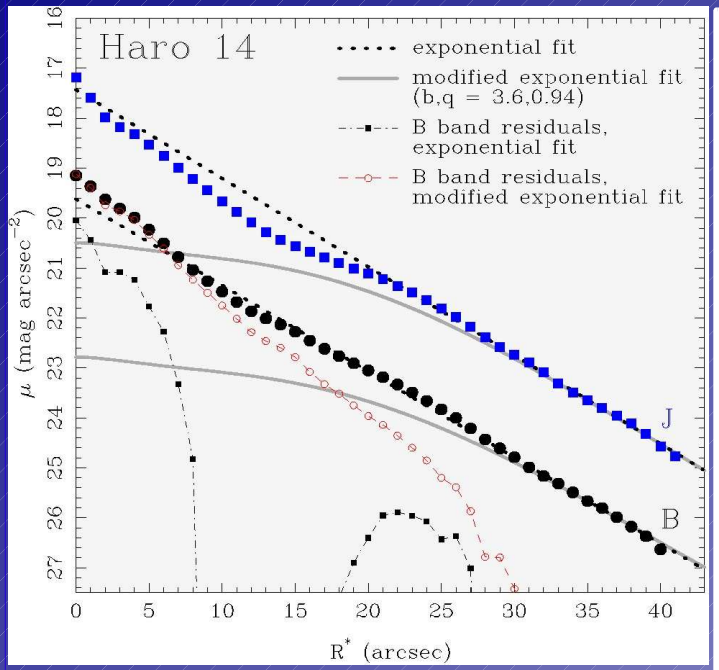




The cutoff (flattening) radii of detected inwards−flattening (type V) surface brightness profiles of the LSB host galaxies are typically ≤ the plateau radius of the starburst component:

→ observational bias against type V profiles with smaller cutoff radii, hidden below the starburst emission also in NIR wavelengths?

Flattening of the host galaxy SBP: implications on current understanding of BCDs from optical studies



Where a central flattening/type V of the host galaxy SBP ist present, but undetected:

- decomposition by means of an exponential fit overestimates the luminosity of the host galaxy (and hence M_*!) (our sample: factor 1.5 ... ~2); correspondingly underestimates the luminosity of the starburst component
- The stellar density distributions, corresponding to a pure exponential and a flattened SBP, differ:
- (cf. Papaderos et al. 1996, Mazure & Capelato 2002) : → $\phi_{grav}(r)$

M_*, ϕ_{grav}, $L_{starburst}/L_{host}$: prime parameters for understanding:

- evolutionary links between dwarf galaxies and starbursts in BCDs
- photometric fading of compact, star−forming galaxies after end of SF activity:

→ $z = 0$ descendants of high−redshift blue compact objects (FBGs/CNELGs)?

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Summary

- Studies of the stellar host galaxies of BCDs
  - give important clues to the origin of their star−forming activity
  - necessary for advancing our understanding of dwarf galaxy evolution
  - difficulties in the optical, due to superposition of starburst: →step to the NIR
- First large, deep NIR data set
  - 40 BCDs, JHK
  - 4 m telescopes, 1kx1k detectors → quality of 2m telescope optical data (25 J mag arcsec^{-2})



- Signatures of non−uniform dust extinction; discovery of morphological details hidden in the optical → more complete view of star−formation processes
- >50% of the stellar host galaxy SBPs show a central flattening with respect to the exponential law (*type V profile*, found for various luminosities / morphologies)
  - → often barely/not disclosable in the optical
  - → important observational constraint to scenarios of dwarf galaxy evolution (gravitational potential, burst strength, SF history...)
  - → After termination of star−forming activities, BCDs (and more luminous BCGs/FBGs/CNELGs?) may fade more strongly than previously thought



The NIR BCD project: an outlook

- Existing tools for data reduction and analysis
- $\Rightarrow$ Extend studies to larger samples and deeper data for BCDs

- Part of a multiwavelength study of BCDs, studying various aspects of their star formation and evolution (P. Papaderos, L.M. Cairós, I. Delgado, N. Caon, J.M. Vílchez, J. Iglesias−Páramo, C. Muñoz−Tuñón, B. García Lorenzo...)
  - optical broad and narrow band images, high and low resolution spectroscopy
  - combined interpretation of multiwavelength information (spectrophotometry, structure, kinematics, chemistry)



The NIR BCD project: an outlook

- future plans {and dreams}?
  - detailed mass−/dynamical modelling of BCDs, including results for HI, and deep spectroscopic data of stellar kinematics (now ongoing projects using big telescopes!)
  - application of the techniques and results obtained for local BCDs to compact, star−forming objects at intermediate redshifts (rest−frame optical, rest−frame NIR:10m class ground based telescopes/AO, space observatories)
    (collaboration with R. Guzmán et al., Univ. of Florida)



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