

THE STELLAR HOST IN BLUE COMPACT DWARF GALAXIES: The need of a 2D fit

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OUTLINE

1- Introduction

2- Determination of structural parameters on BCDs

3- 2D Simulations

4- 2D Fitting of a sample of galaxies

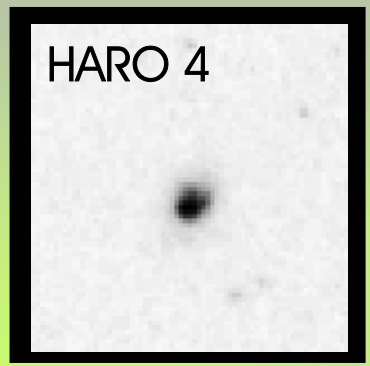
5- Discussion

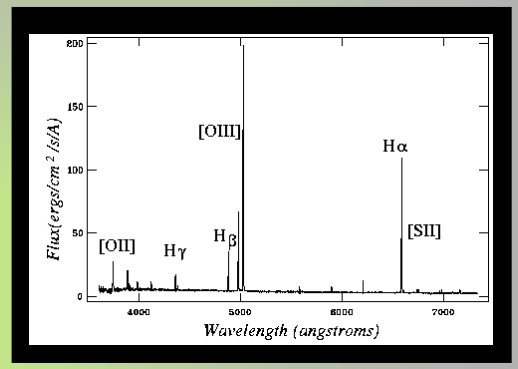
6- Conclussions and future projects

What are BCDs?

Why to study them?

- Low luminosity ($M_B > -18$)
- Compact (D < 1 kpc)
- H_{II} regions spectra
- Gas-rich (Thuan & Martin 1981)





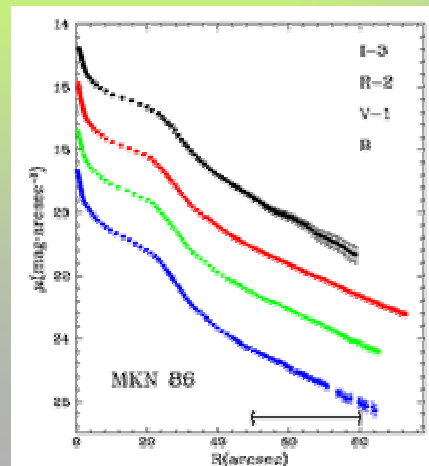
- Metal-deficient ($Z_\odot/50 < Z < Z_\odot/3$; Kunth & Sargent 1986)
- High star-forming rates (0.1-10 $M_\odot$/yr; Fanelli et al. 1988)

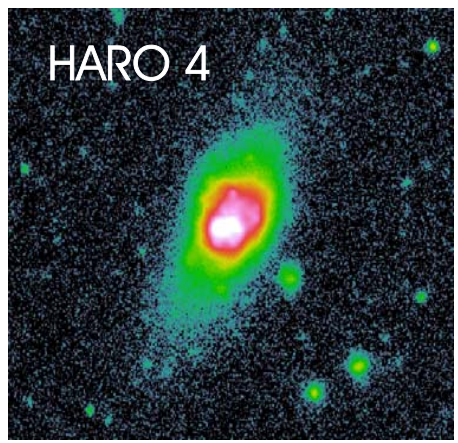
Stellar Populations:

The BCD light distributions show, at least, two components:

★ *The starburst (SB):*

★ *The low-surface brightness (LSB) host galaxy*





What are BCDs? | **Why to study them?**

Star Formation

BCDs are low mass galaxies, with no density waves, undergoing vigorous star-formation. They result ideal laboratories in order to study possible triggering mechanisms of starburst and their evolution.

Evolutive connections between dwarf galaxies

The comparison of structural properties between BCDs and other dwarf galaxies could show evolutive links.

BCDs in a cosmological context and the evolution of galaxies

The extremely metal-deficient BCDs are ideal laboratories to study physical processes and measure abundances in a nearly primordial environment.

Could Compact Blue galaxies at z ~ 1 be progenitors of local BCDs/HII **?** (Koo et al. 1995).

Properties of nearby BCDs could provide a *template* in the Local Universe to interpret the results at higher redshifts.

Interaction between galaxies and its medium

Low mass galaxies ➡ Small escape velocities ➡ Mass ejection

Super-winds and feedback mechanisms



Unanswered questions

• Do all BCDs have an underlying stellar component? What are the structural parameters of the hosts? espheroids and/or disks?

Are there any young BCDs ?

• Are there evolutionary links between BCDs and other types of dwarfs ?

• What mechanisms originate and propagate the star-formation activity in BCDs ?

Interactions ?

• What are the star-formation histories of these galaxies ?

What are BCDs? | **Why to study them? Motivations**

Comprehensive analysis of the starburst:

Constrain its IMF, star-formation history, ages and metallicities.
Analyse the gas morphology: super-winds. Stellar morphology (i.e. Super Stellar Clusters, SSCs)

Unveiling the properties of the LSB stellar host: WHY?

1. Deriving ages and chemical abundances of the stellar component hosting the SB is the first step in order to establish the evolutionary status and the star-forming history of the galaxy
2. Comparison of the host structural properties with those of dEs and dIs and investigate evolutionary links
3. LSB contains most of the stellar mass
4. Its morphology holds clues to the evolutionary status of the galaxies and to the Star Formation processes

ONLY WITH AN ACCURATE MODEL OF THE LSB CAN WE:

– Determine the total magnitude of the starburst (=galaxy-model), and its average colors.

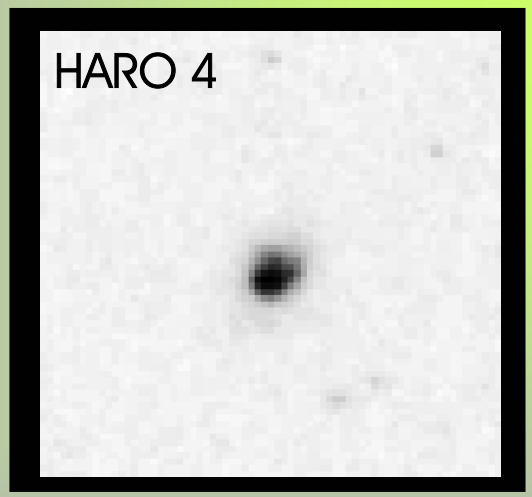
– Determine the magnitude and colors of the individual star-forming knots, by subtracting out the LSB host flux.

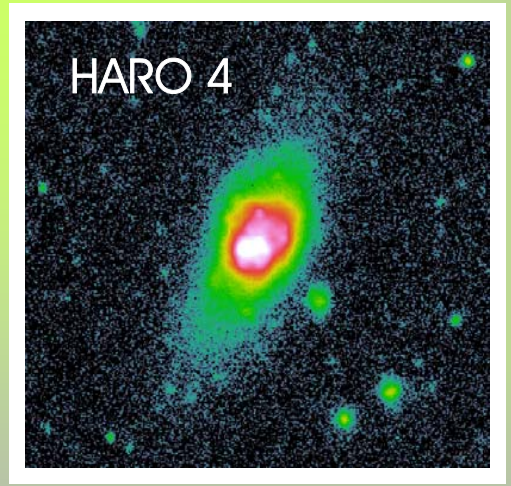
– Compute the correct emission-line equivalent widths by subtracting the LSB host continuum.

UNVEILING THE NATURE OF THE LSB STELLAR HOST IN BCDs

However, not much deep in-depth work has been done so far, because:

It is a very difficult task, which require a great deal of observational and analysis effort. We require high quality data at very low surface brightness levels (from 23-24 to 27-28 mag arcsec^{-2} in B)





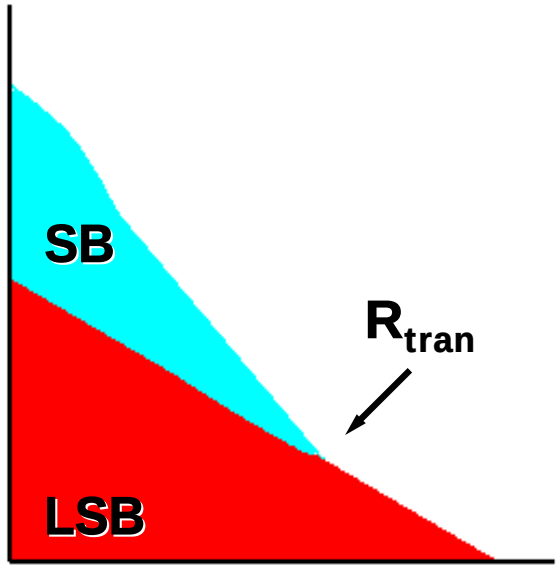
On fitting galaxy components

2D Techniques

The problem:

The surface brightness profile of BCDs is the superposition of at least two component:

1. *The Starburst (SB)* is made up of the emission from young massive stars, and dominates the light at high and intermediate intensity levels
2. *The LSB stellar host* dominates at larger radii and contains most of the galaxy´s stellar mass

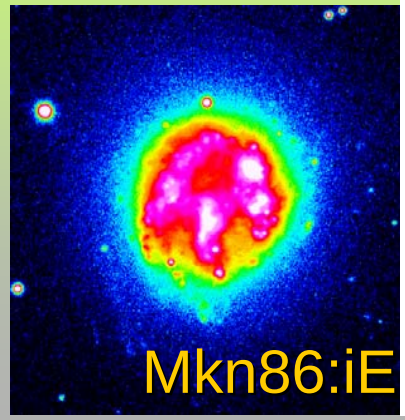


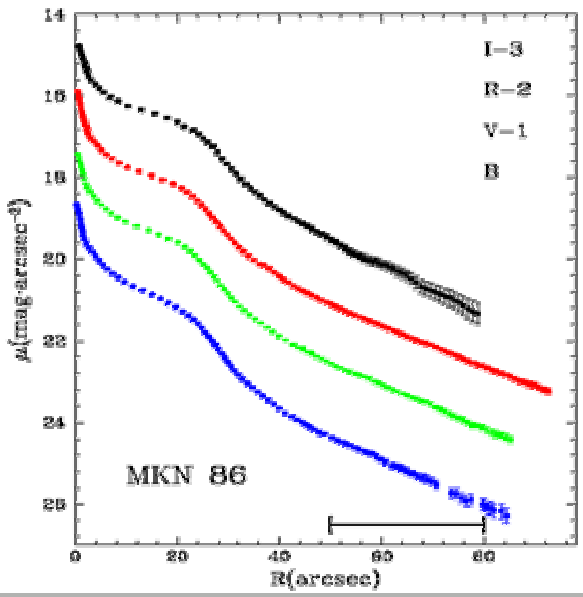
Characterization of the underlying component: Requirements

Proper determination of the fitted region: R_{tran}

Deep, extended profiles

Use of a suitable analytical model for the light distribution: Sérsic ?





On fitting a Sérsic law to the SBP of the host

Sérsic law

$$I(r) = I_e \exp\left\{-b_n\left[\left(\frac{r}{r_e}\right)^{1/n} - 1\right]\right\}$$

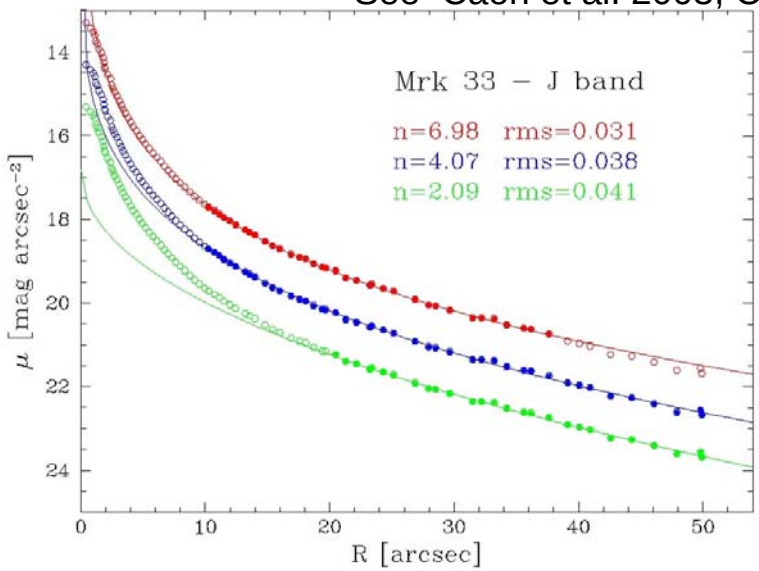
Successfully applied to ellipticals (Caon et al. 1993), brightest cluster members (Graham et al. 1996), bulges of spirals (Andredakis et al.1995), dwarf ellipticals (Young & Curie 1994)

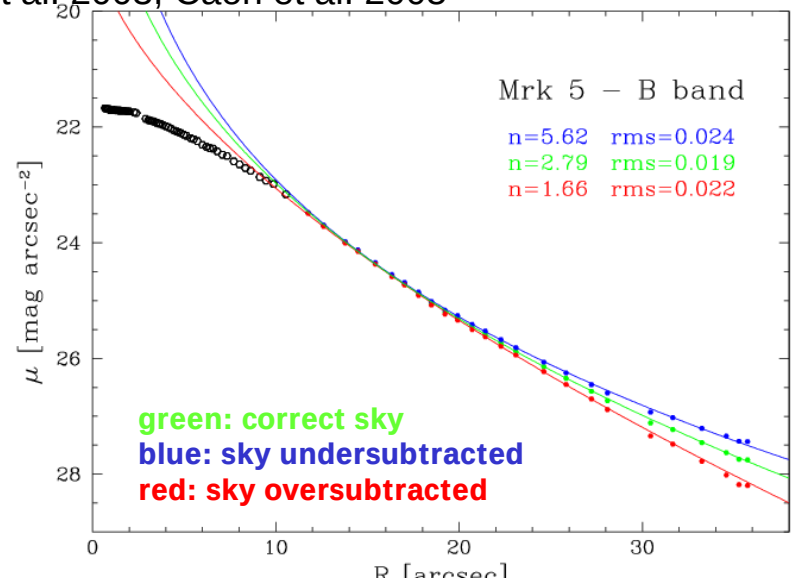
The Sérsic model provides a more precise and physically meaningful description of the SBP, but the fitted parameters depend on:

1. The radial range

2. Sky subtraction errors

See Caon et al. 2003, Cairós et al. 2003, Caon et al. 2005





On fitting galaxy components

2D Techniques

In general, the previous work (e.g. Papaderos et al. 1996a,b; Doublier et al. (1997, 1999), Telles (1995); Östlin (1998); Marlowe et al. (1997, 1999); Cairós et al. 2001a,b), mainly in the optical range, have provided unreliable or discrepant results, as the structural parameters turned out to be strongly dependent on:

1 - the quality of the analyzed dataset;

2 - what way and how well the SB emission has been excluded when modelling the host;

3 - the specific method used to derive the profile

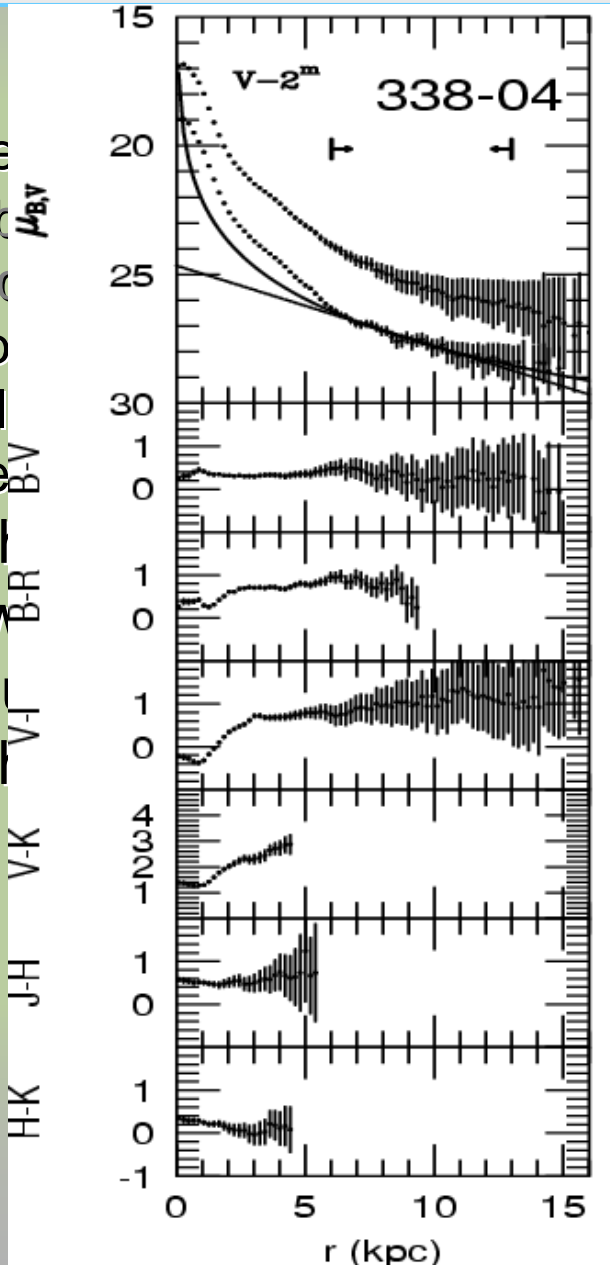
Example : Bergvall & Östlin (20

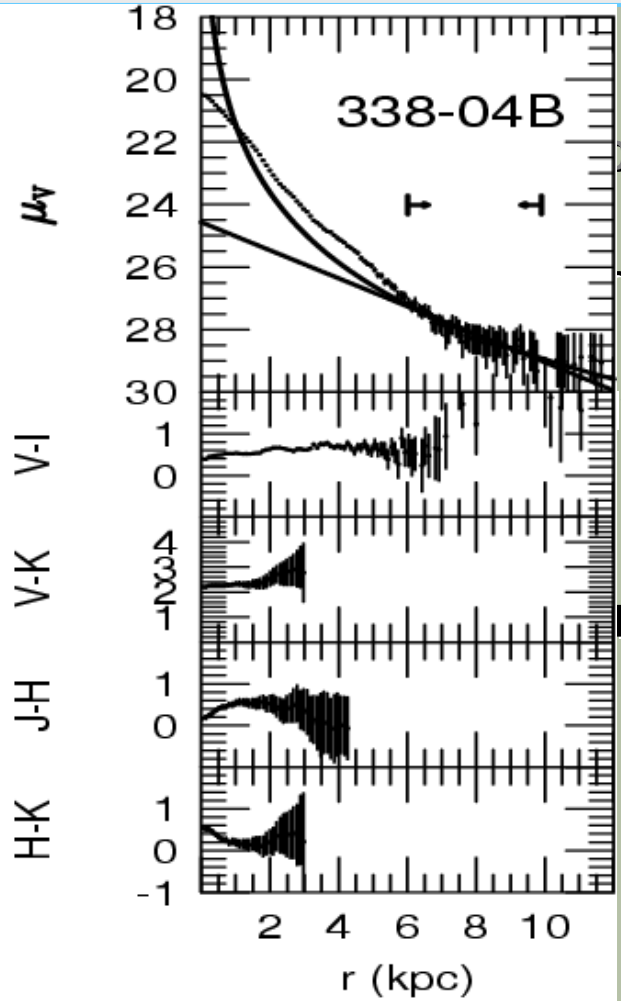
In 4 of 6 BCDs they found n >1

On fitting galaxy components

2D Techniques

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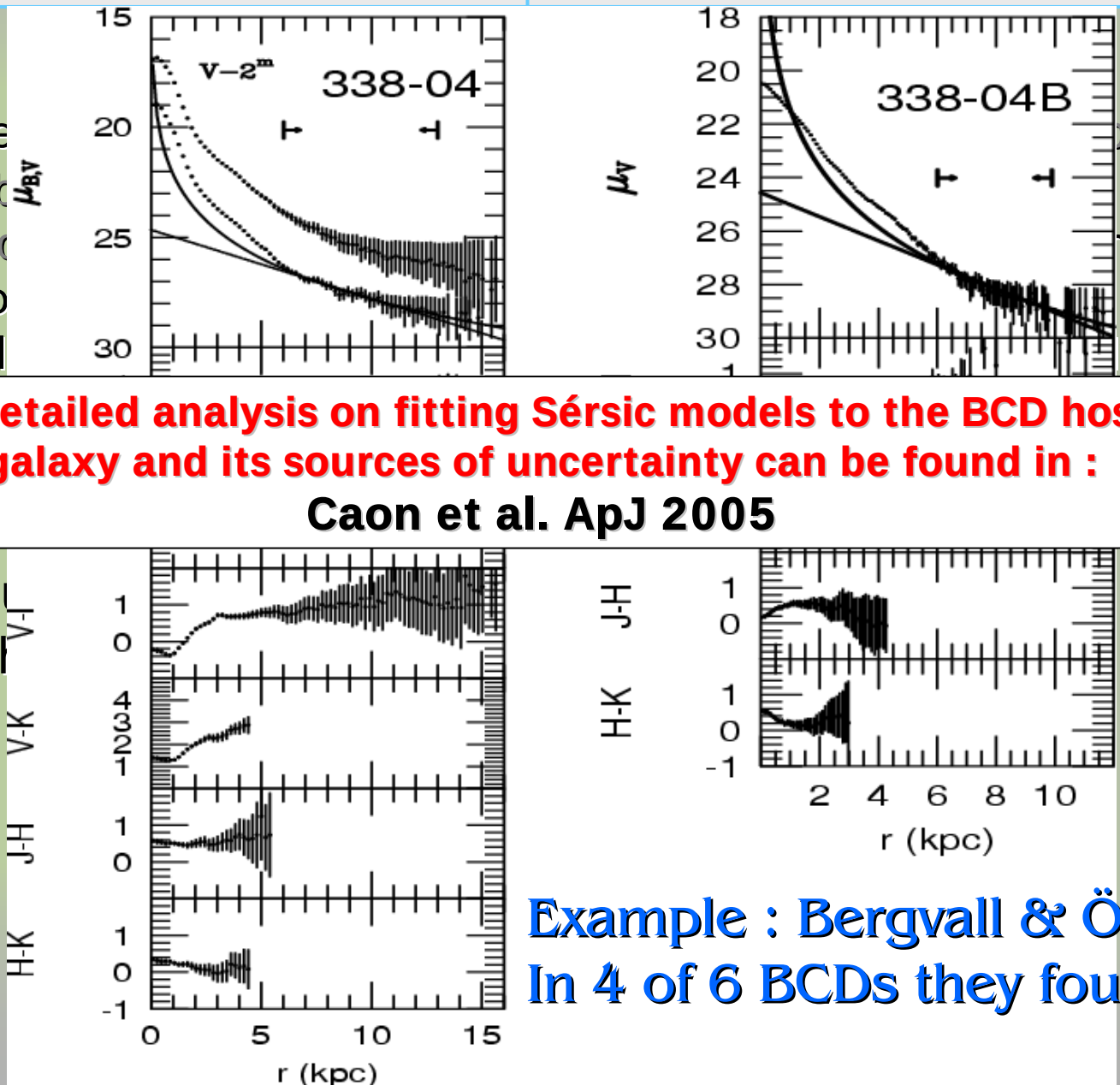
Example : Bergvall & Östlin (20

In 4 of 6 BCDs they found n >1

On fitting galaxy components

2D Techniques

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A detailed analysis on fitting Sérsic models to the BCD host galaxy and its sources of uncertainty can be found in :
Caon et al. ApJ 2005

Example : Bergvall & Östlin (20
In 4 of 6 BCDs they found n >1

On fitting galaxy components | **2D Techniques**

2D fits, a better tool for analyzing BCD´s ?

2D fitting allow us to use all the image information, pixel to pixel, without using average isophotes. For B/D decomposition, ideal simulations have shown that 2D modelling can better recover the true parameter values (Byun & Freeman 1995, Wadadekar et al. 1999)

Especially in BCDs, because their :

- Large SB contamination
- Low surface brightness of the host
- Complex morphology
- Twisted isophotes, ellipticity changes, etc..

For the very first time, we have developed and applied in BCDs a 2D fitting methodology, based on a 2D fitting algorithm called GALFIT. This allowed us to fit the LSB component by using detailed masks in order to achieve a more accurate characterization of the stellar host using a larger effective area

2D Fitting with GALFIT (Peng et. al., 2002, AJ, 124)

✓ Wrote in C, GALFIT is a galaxy/point source fitting algorithm that fits 2D parameterized, axisymmetric functions directly to images

✓ Allow us to adjust a set of parameters that is tuned to match the light profile and morphology of the object

✓ Allow us to introduce masks

✓ Allow us to fit a sky level

✓ Allow us to take into account the seeing. The models can be convolved with the PSF using FFT

✓ To optimize the fit, i.e. To minimize the χ^2 residual between the data image and the model, the best parameters are found by using a Levenberg-Marquardt algorithm modified

Free download from: http://zwicky.as.arizona.edu/cyp/work/galfit/galfit.html

Which is the expected error, induced by the limited fitted area of a galaxy light distribution, in recovering the 2D Sérsic parameters?

→ Simulations with simplified synthetic galaxies

Hypothesis:

a) Galaxy: 2D Sérsic model with two possible *n* values: 1(disk-like) and 4 (spheroid)
b) Starburst: Gaussian distribution, axially symmetric and concentric with the Sérsic profile, which contaminate between 20 and 50%, by varying their width.
c) L_{tot} (SB + LSB) – L_{LSB} was typically between 0.5 and 1 mag
d) Poissonian noise to the images and background pedestal (*MKNOISE/IRAF*) with (*GAIN; RDNOISE*). Resulting μ_{sky} ~26, 27 and 28 mag arcsec^{-2} (typical for deep optical images as our)

Relative percentage area:

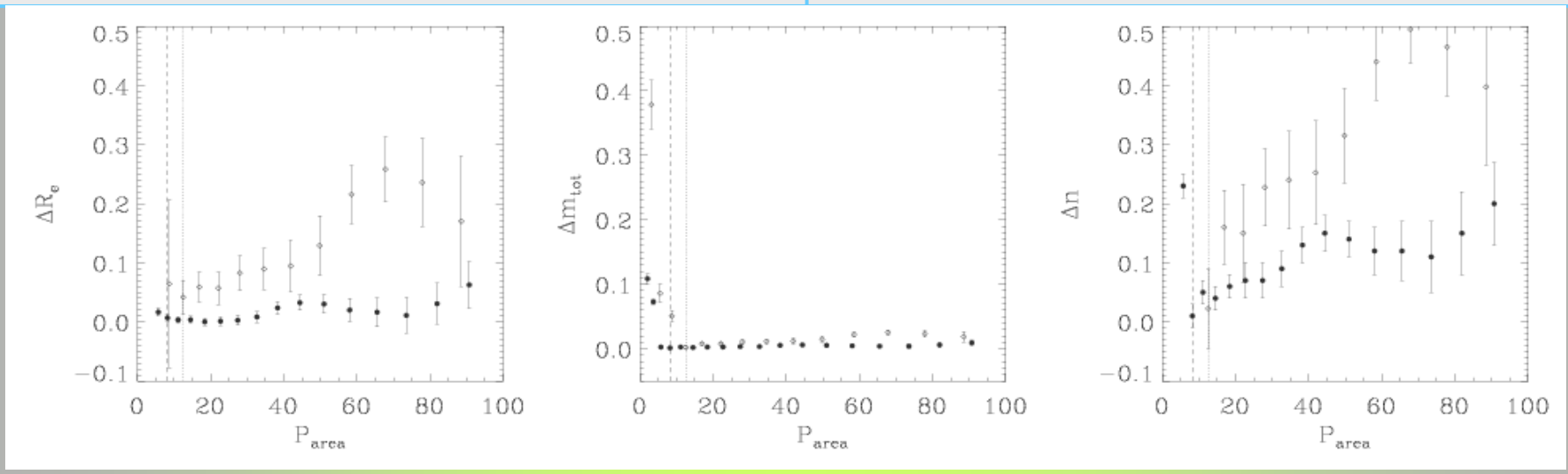
$$P_{area} = 100\left(\frac{N_{mask}}{N_{gal}}\right)$$

N_{mask}: number of de pixels masked out of the fit

N_{gal} : number of pixels with S/N >1

Methodology

Results



	n=1 cases	*n*=4 cases
Contamination > 5%:	GALFIT converge with large errors in *n,* up to 20%	GALFIT could not converge Errors in *n* too large (>50%)
Without contamination:	More robust and stable fits Small errors, < 20% in *n*	Slow convergence. Small stability range. Large errors,<50%

Sérsic models with a central knot covering the 10-20% above S/N=1 (30-40% of the radial profile) recover their structural parameters with errors in *n* < 10%, fitting at least, the 60% of the galaxy, if *n*=1. If *n*=4 then the errors grows a factor of two at the same fitted area; n=4 are more affected by random uncertainties (poissonian)

4. 2D FITTING OF A SAMPLE OF GALAXIES

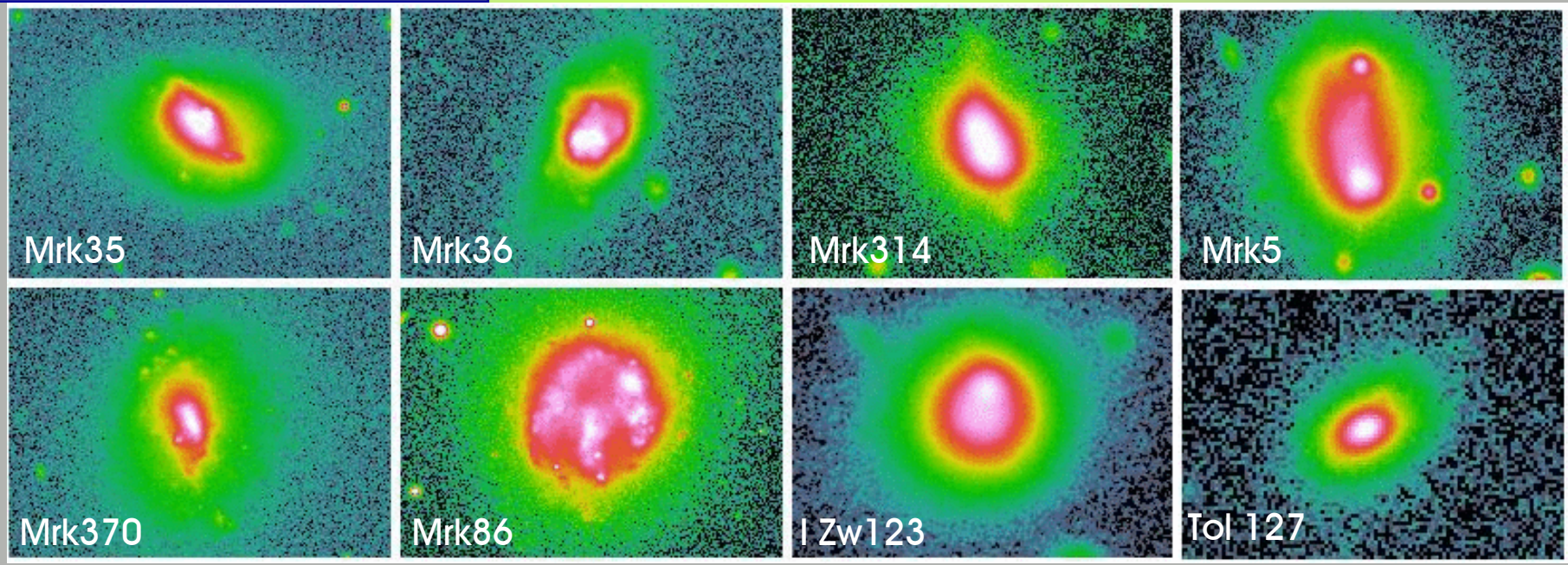
The galaxies:

Cairós et al. 2001b
Caon et al. 2005

- 2.5m NOT
- 3.5m Calar Alto
- 1m JKT y 1.5m (ESO) La Silla

Muestra de Galaxias

Galaxia (1)	Otros nombres (2)	R.A.(J2000) (3)	Dec.(J2000) (4)	D (Mpc) (5)	A_B (mag) (6)	M_B (mag) (7)
Tololo 0127-397		01 29 15.8	−39 30 37	61.0	0.067	−17.75
Mrk 370	NGC 1036, UGC 02160	02 40 29.0	19 17 50	10.9	0.399	−16.99
Mrk 5	UGCA 130	06 42 15.5	75 37 33	14.0	0.364	−15.51
Mrk 86	NGC 2537, UGC 04274	08 13 14.7	45 59 26	8.1	0.232	−17.37
Mrk 35	Haro 3, NGC 3353	10 45 22.4	55 57 37	15.6	0.031	−17.79
Mrk 36	Haro 4, UGCA 225	11 04 58.5	29 08 22	10.4	0.131	−14.84
I Zw 123	UGCA 410, Mrk 487	15 37 04.2	55 15 48	12.5	0.062	−15.09
Mrk 314	NGC 7468, UGC 12329	23 02 59.2	16 36 19	28.9	0.383	−18.53



Preparation of images and masks

- Elimination of artifacts
  Elaboration of masks
  Preparation of the PSF
- Edition of the header image
  and/or noise maps
  Preparation of the input file

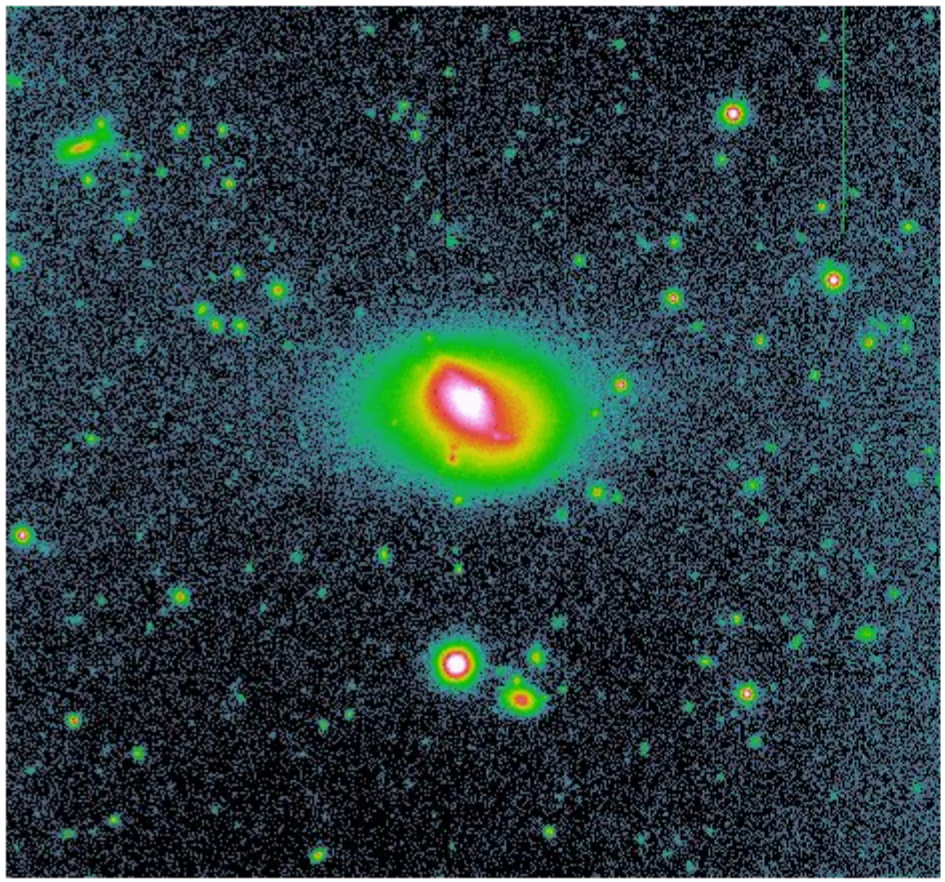
Successive fits and definition of the ***Stability Region***

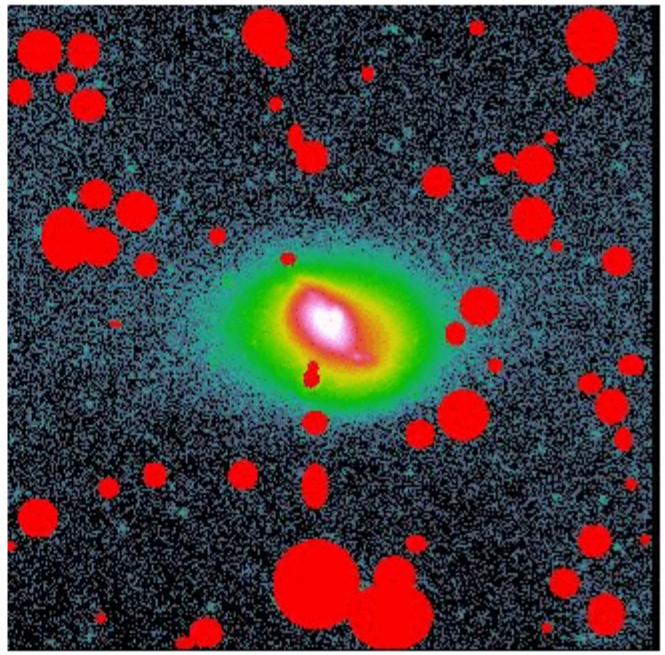
- Analysis of stability in parameter plots
- Control of residuals

Possible refinements

Preparation of

Elimination of artifacts
Elaboration of masks
Preparation of the PSF

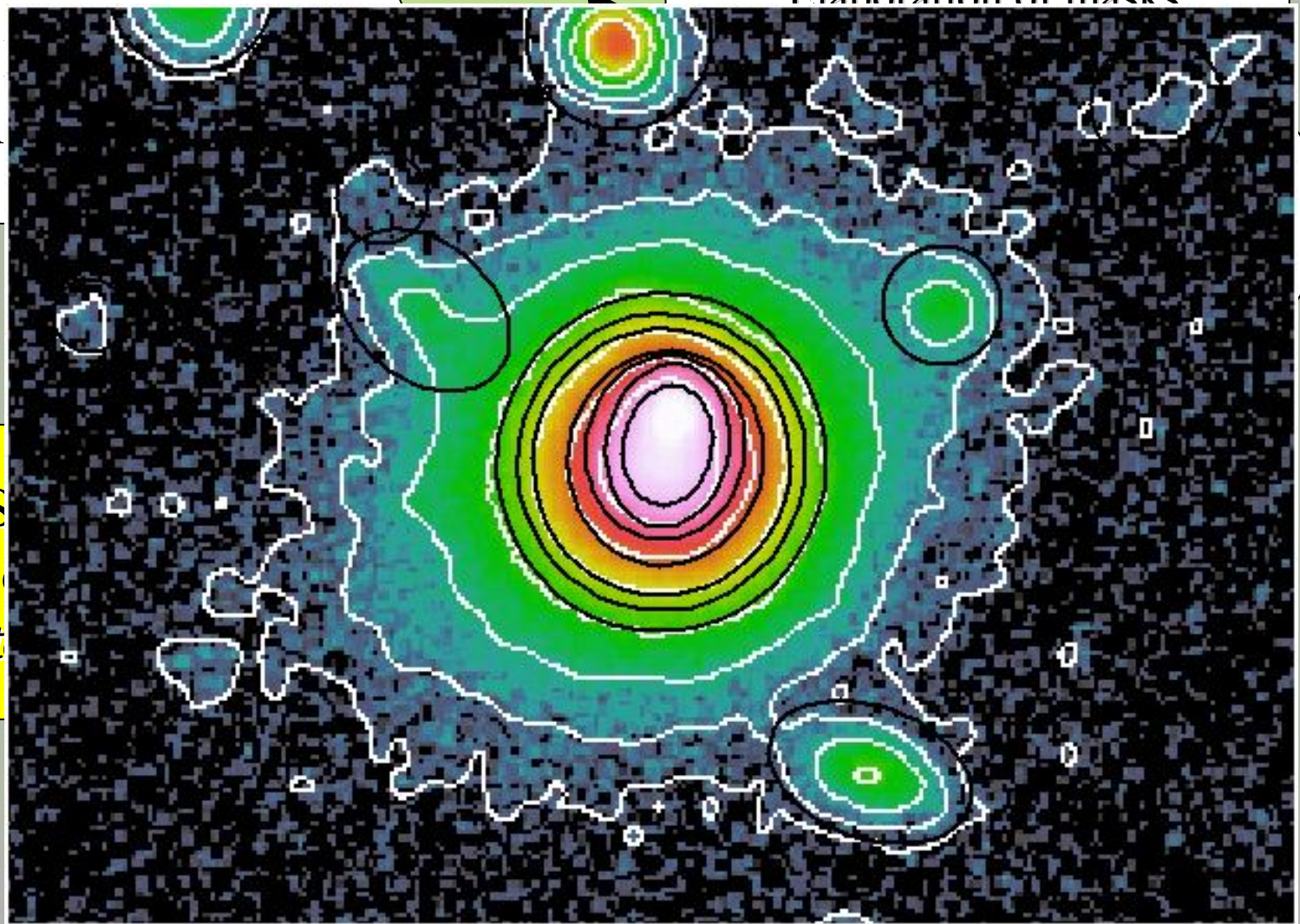


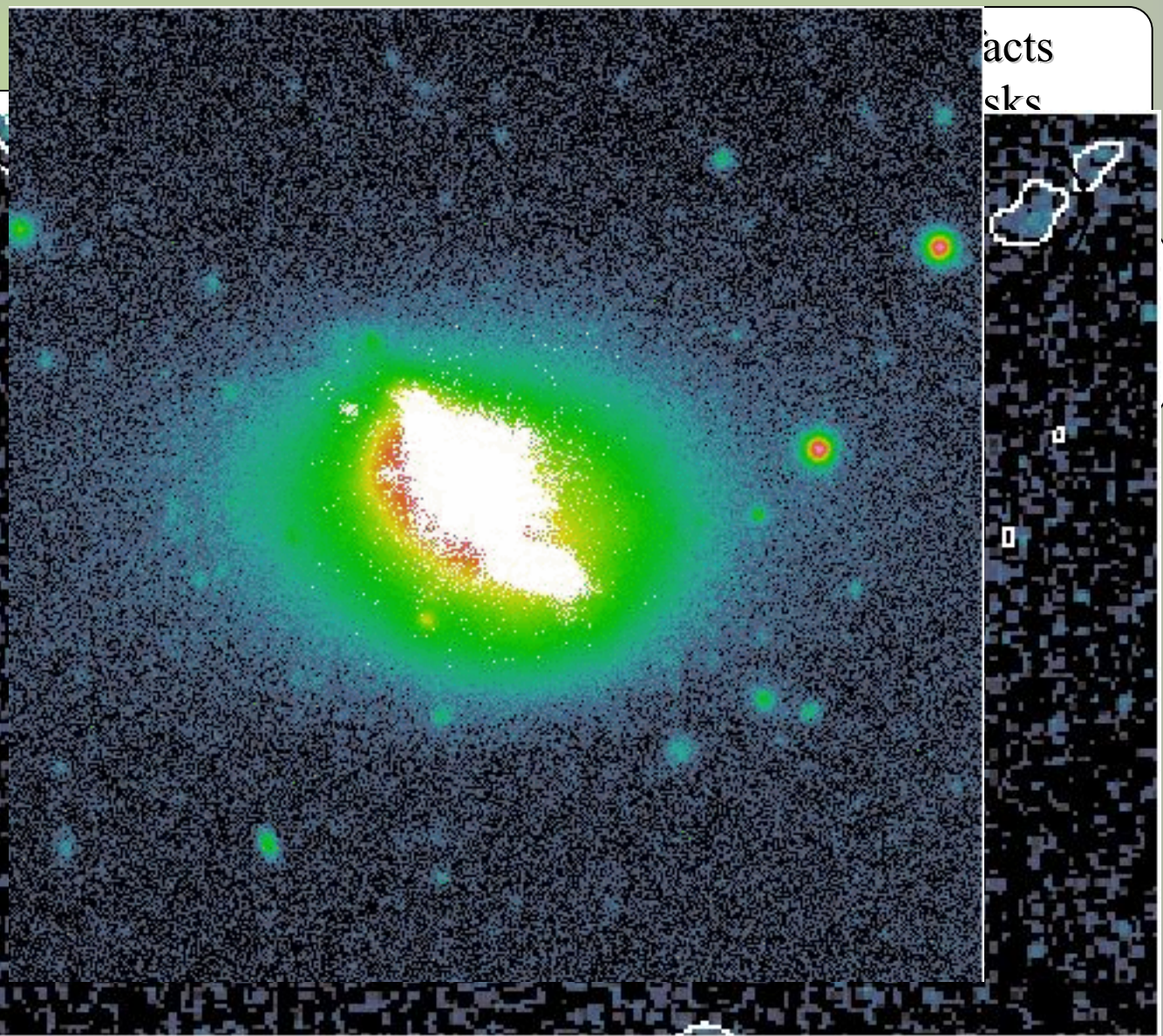


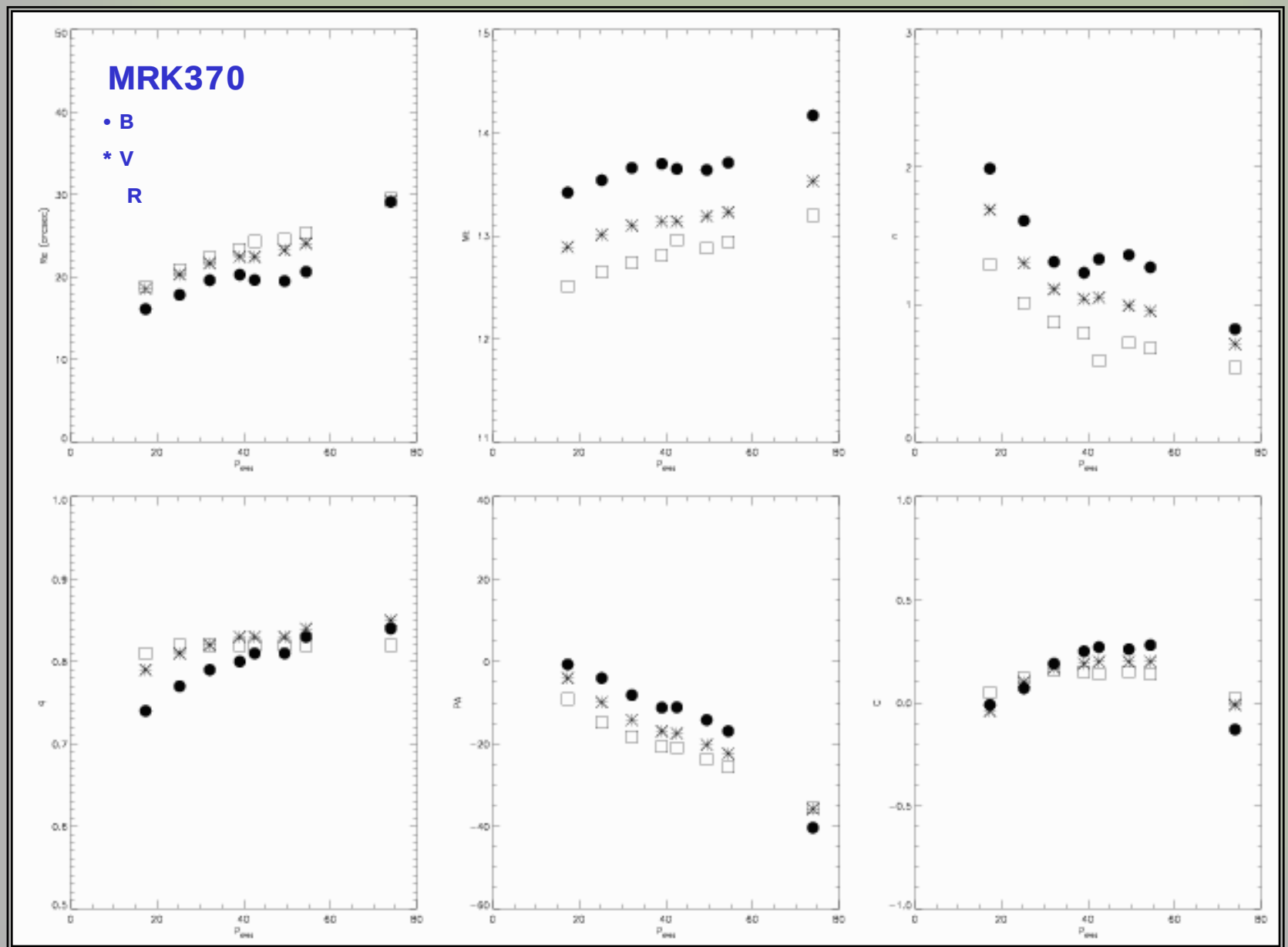
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Elaboration of masks

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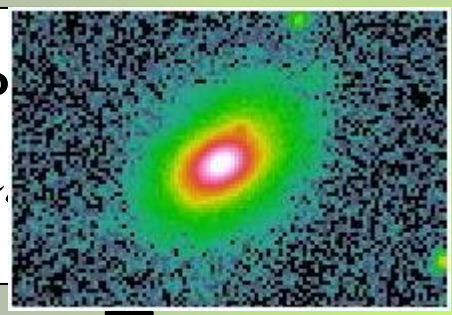
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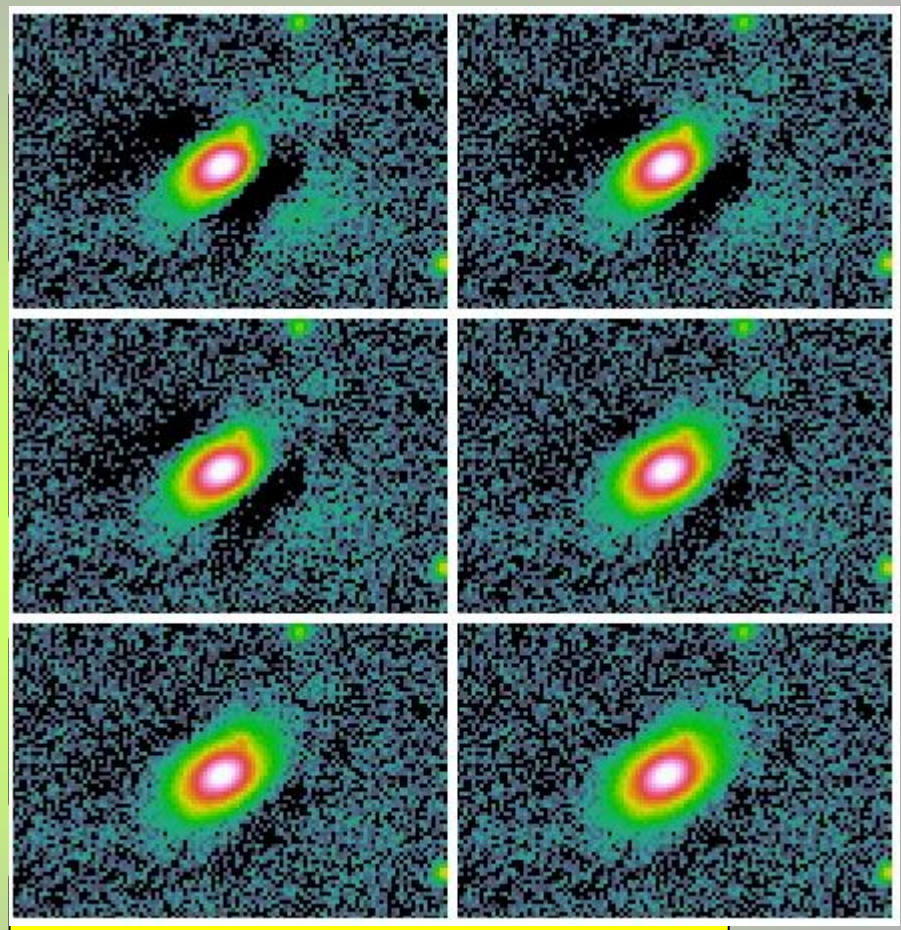





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Successive fits
and definition of the
Stability Region

Control of residuals

Possible refinements

Galaxy	Filter	R_{tran}	$\sim P_{area}(\%)$	n	r_e	μ_e	m_{LSB}	$P.A.$	$q(=b/a)$	c
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Tol 127	*B*	4.97	9.6	1.02±0.03	4.29±0.01	23.35±	17.49±0.02	-54.3	0.69	0.22
	V	5.88	24.0	0.74±0.06	5.39±0.06	22.52±	16.30±0.06	-49.9	0.67	0.02
	R	4.97	10.9	1.16±0.04	4.47±0.01	21.98±	15.96±0.03	-51.7	0.67	0.10
Mrk 370	*B*	23.80	24.1	1.33±0.11	19.50±0.21	22.92±	13.64±0.05	-14.2	0.80	0.26
	V	18.83	15.2	1.01±0.05	22.33±0.14	22.60±	13.16±0.03	-18.1	0.83	0.18
	R	23.80	24.1	0.74±0.06	24.53±0.26	22.39±	12.88±0.05	-23.7	0.82	0.15
Mrk 5	*B*	10.97	10.9	0.99±0.04	9.62±0.09	23.63±	16.02±0.04	13.1	0.76	0.10
	V	10.97	9.6	1.05±0.04	9.53±0.08	23.15±	15.54±0.03	13.2	0.75	0.07
	R	10.61	9.0	1.04±0.03	10.17±0.08	22.96±	15.21±0.02	12.5	0.78	-0.01
Mrk 86	*B*	31.11	26.0	0.82±0.07	25.80±0.29	22.86±	13.20±0.05	-21.3	0.90	0.00
	V	31.11	16.0	1.33±0.08	22.26±0.15	21.67±	12.10±0.03	-19.7	0.91	0.00
	R	37.92	18.5	1.21±0.08	30.47±0.25	22.08±	11.88±0.04	-21.0	0.90	0.00
Mrk 35	*B*	20.80	20.2	0.98±0.07	15.04±0.13	22.68±	14.11±0.05	74.0	0.72	-0.02
	V	19.45	17.6	1.01±0.06	14.72±0.11	21.95±	13.41±0.04	77.3	0.71	0.03
	R	19.45	16.0	0.97±0.05	14.94±0.10	21.66±	13.11±0.03	77.7	0.70	-0.01
Mrk 36	*B*	9.02	26.0	1.23±0.11	6.93±0.08	23.46±	16.46±0.06	-26.5	0.56	-0.17
	V	9.02	22.1	1.28±0.10	7.08±0.07	23.15±	16.09±0.06	-26.1	0.51	-0.21
	R	8.46	18.5	0.99±0.07	7.92±0.06	23.00±	15.82±0.05	-25.8	0.56	-0.26
I Zw 123	*B*	6.95	16.0	1.66±0.11	4.18±0.07	21.97±	15.93±0.05	-47.3	0.93	-0.23
	V	8.08	22.1	2.21±0.23	3.80±0.10	21.41±	15.43±0.07	-48.5	0.86	0.03
Mrk 314	*B*	12.33	16.8	1.26±0.08	11.88±0.09	22.91±	14.73±0.04	14.8	0.77	-0.46

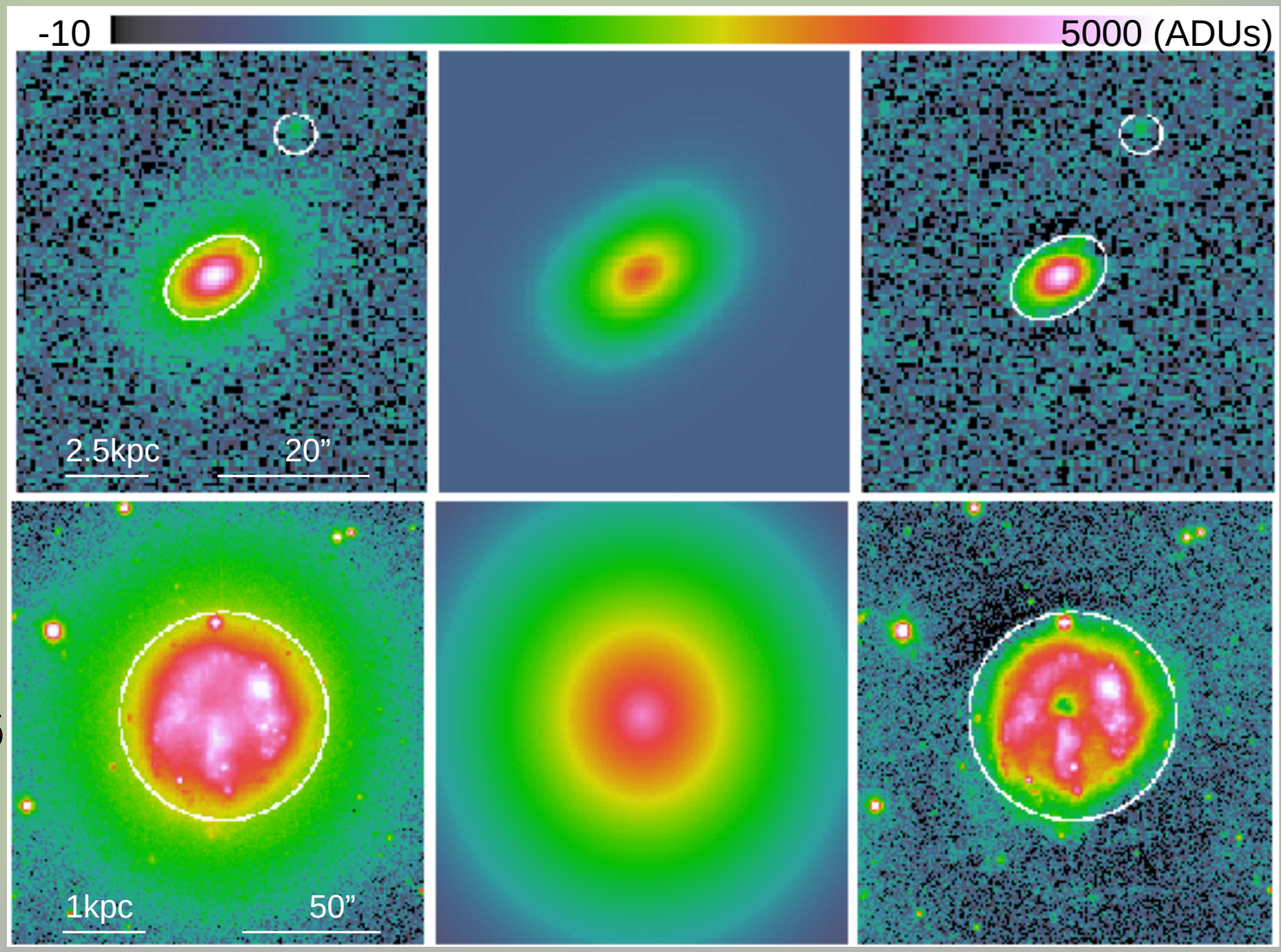
[a] Notes.– Columns (1): n ... ed area relative to $1\sigma_{sky}$ of the galaxy; (5) n shape parameter; (6) eff ... $^{-2}$); (8) total magnitude of the LSB component derived form the fit (mag); (9) position angle; (10) ellipticity; (11) boxy/disky shape parameter

Majority of DISK-LIKE objects ($n \sim 1$)

EXAMPLE

TOL127

MRK 86



Error sources

Sensibility to the fitted area of the galaxy & contamination

Sensibility to the sky-subtraction errors

Other error sources: isophote twist of a single component, inadecuate model...etc

Consistency checks

Searching for stability: Plots *Parameter vs.* P_{area}

Assuming that the LSB has no color gradients, n and Re should be the same in all filters.

Old population: *M_{tot} should be smaller toward red filters*

The variation of the Sersic parameters with the fitted area (simulations), and the scatter among the different filters, all provide a practical estimate of their uncertainties

2D-1D Comparison | Mrk 5...a special case?

R_{tran} (2D) ≤ R_{tran} (1D) → Smaller masks
Larger fitted area

- Large stability with R_{tran} in 2D parameters
- Larger control in the sky-subtraction sensibility problem
- Good control in components with twisted isophotes
- Poissonian weight ($1/\sigma^2_{x,y}$) *vs* constant weight

In 6 of the 8 galaxies: parameters in good agreement with Caon et al. 2005 → DISKS (*n* ~ 1)

2 EXCEPTIONS

I Zw 123	m_{LSB}	n	Re (")
B	15.93 (15.19)	1,66 (2.61)	4.18 (2.07)
V	15.43 (14.84)	2,21 (3.01)	3.80 (2.74)

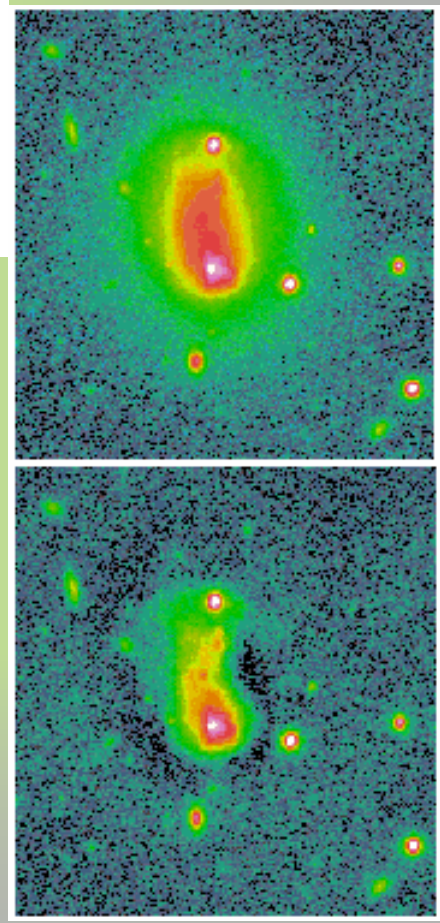
Mrk 5	m_{LSB}	n	Re (")
B	16.02 (14.39)	0.99 (2.83)	9.62 (3.35)
V	15.54 (14.38)	1.05 (2.46)	9.53 (4.89)
R	15.21 (13.96)	1.04 (2.70)	10.17 (4.60)

2D-1D Comparison

Mrk 5...an special case?

Sensitivity of Sérsic parameters of Mrk 5 (B) to changes in the sky background

Sky background	R_{tran}	P_{area} (%)	n	r_e	μ_e	m_{tot}	χ^2_ν
Correct sky	**10.97**	**~ 10.9**	**0.99**	**9.62**	**23.63**	**16.02**	**2.232**
	13.54	~ 16.8	1.57	6.75	22.59	15.54	2.592
Sky oversubtracted	10.97	~ 10.9	0.88	9.23	23.54	16.08	3.093
	13.54	~ 16.8	1.07	8.5	23.24	15.87	2.692
Sky undersusbtracted	10.97	~ 10.9	1.17	10.47	23.83	15.97	3.013
	13.54	~ 16.8	4.07	1.99	19.15	14.26	2.564



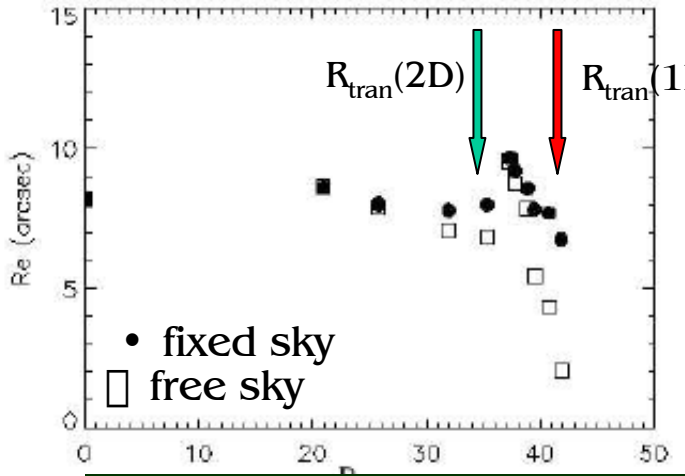
residual = ima - mo

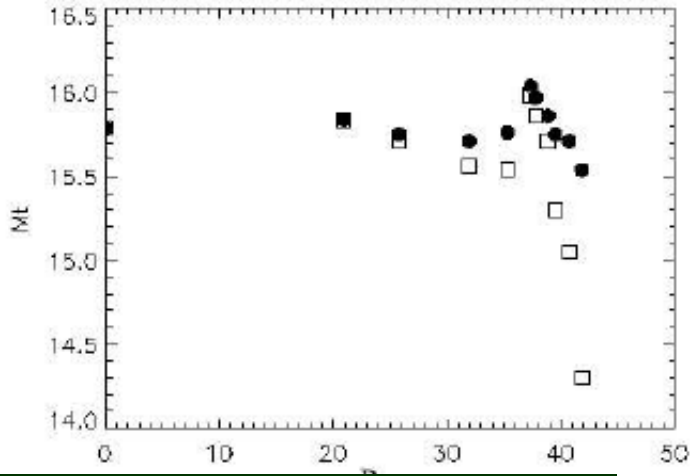
2D-1D Comparison

Mrk 5...an special case?

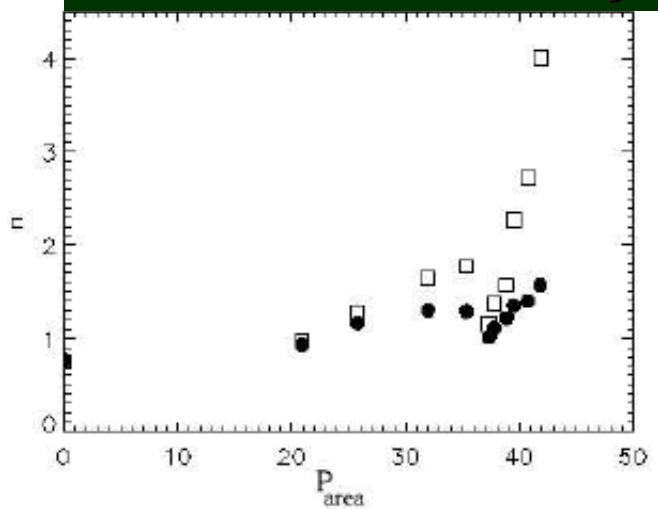
Sensitivity of Sérsic parameters of Mrk 5 (B) to changes in the sky background

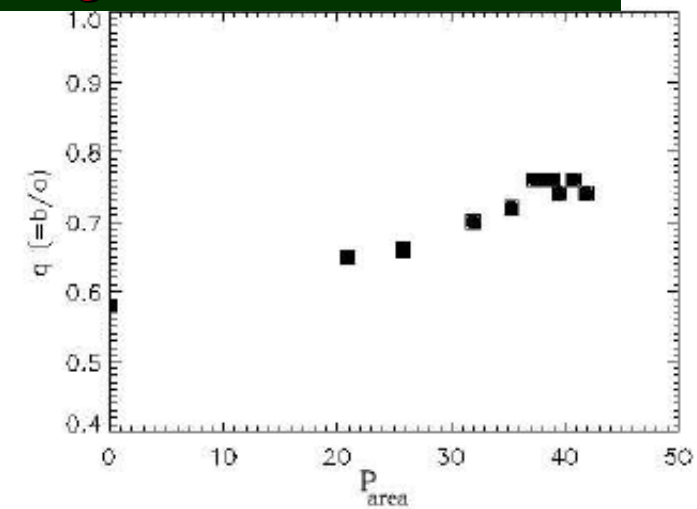
Sky background	R_{tran}	P_{area} (%)	n	r_e	μ_e	m_{tot}	χ^2_ν

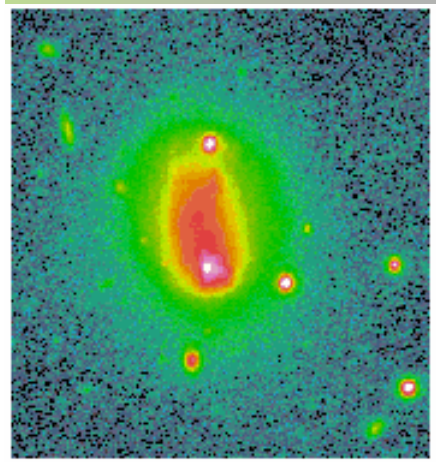


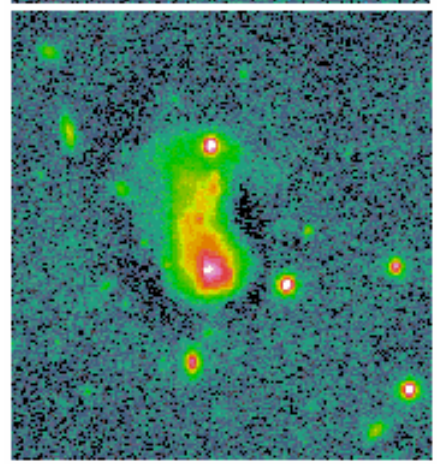


We can check the sky-background uncertainties





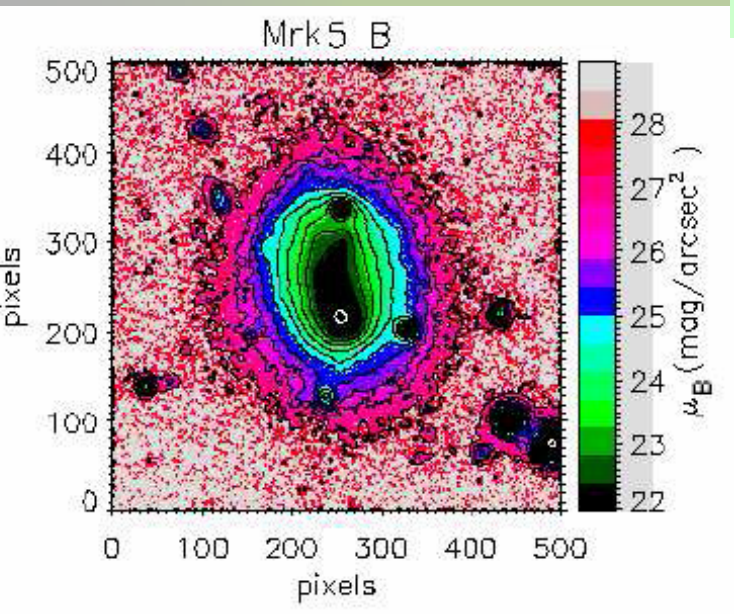




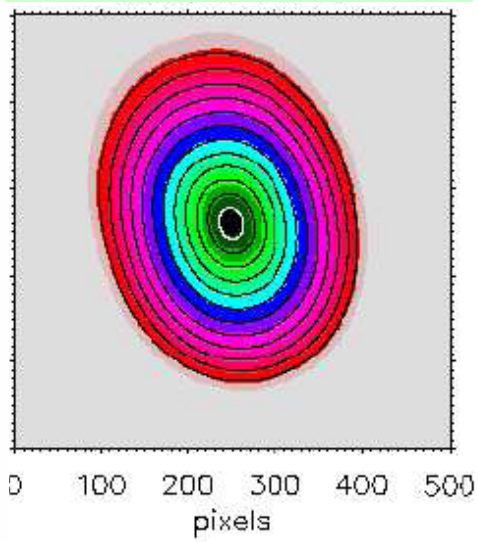
residual = ima - mo

2D-1D Comparison

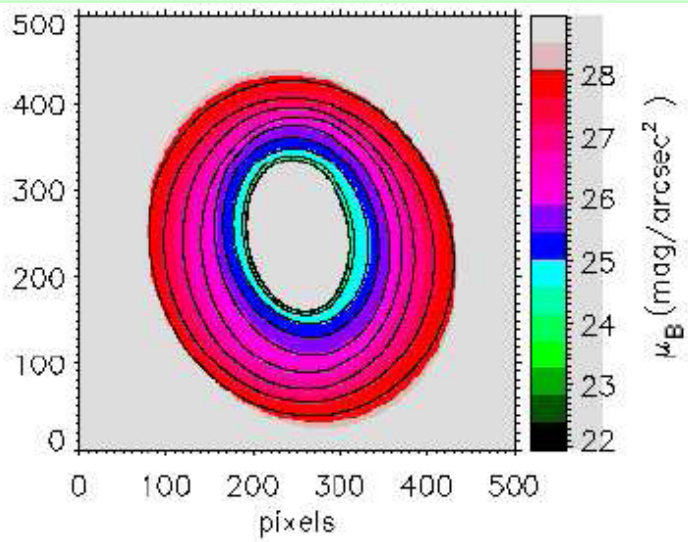
Mrk 5...an special case?

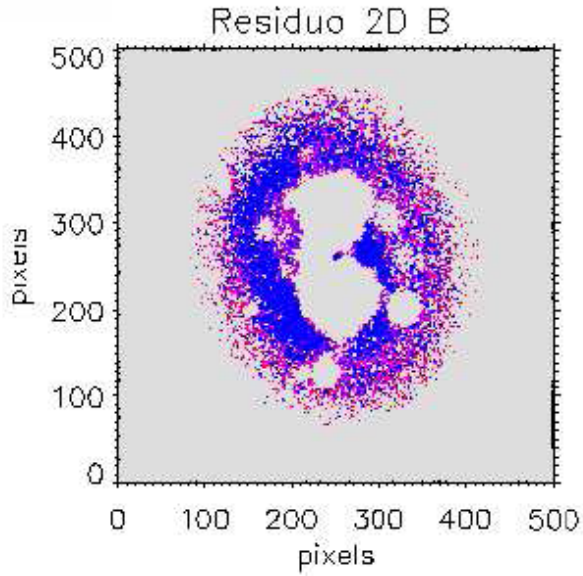


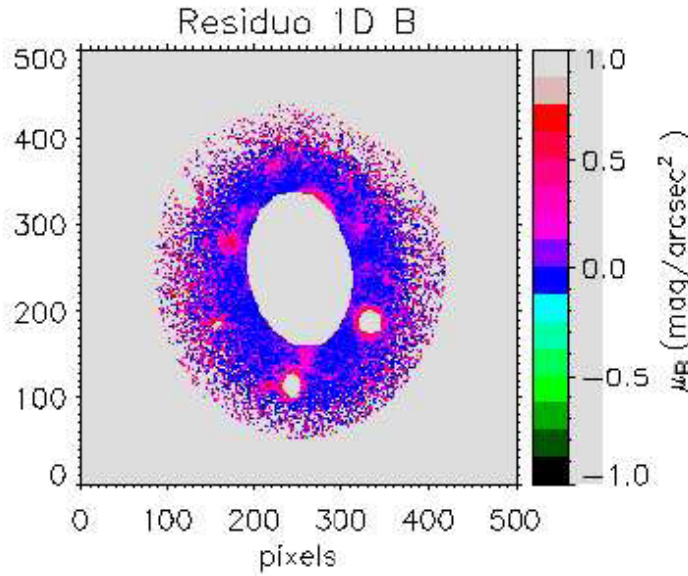
MODEL 2D FROM GALFIT



MODEL 2D FROM A 1D FIT (BMODEL / IRAF)

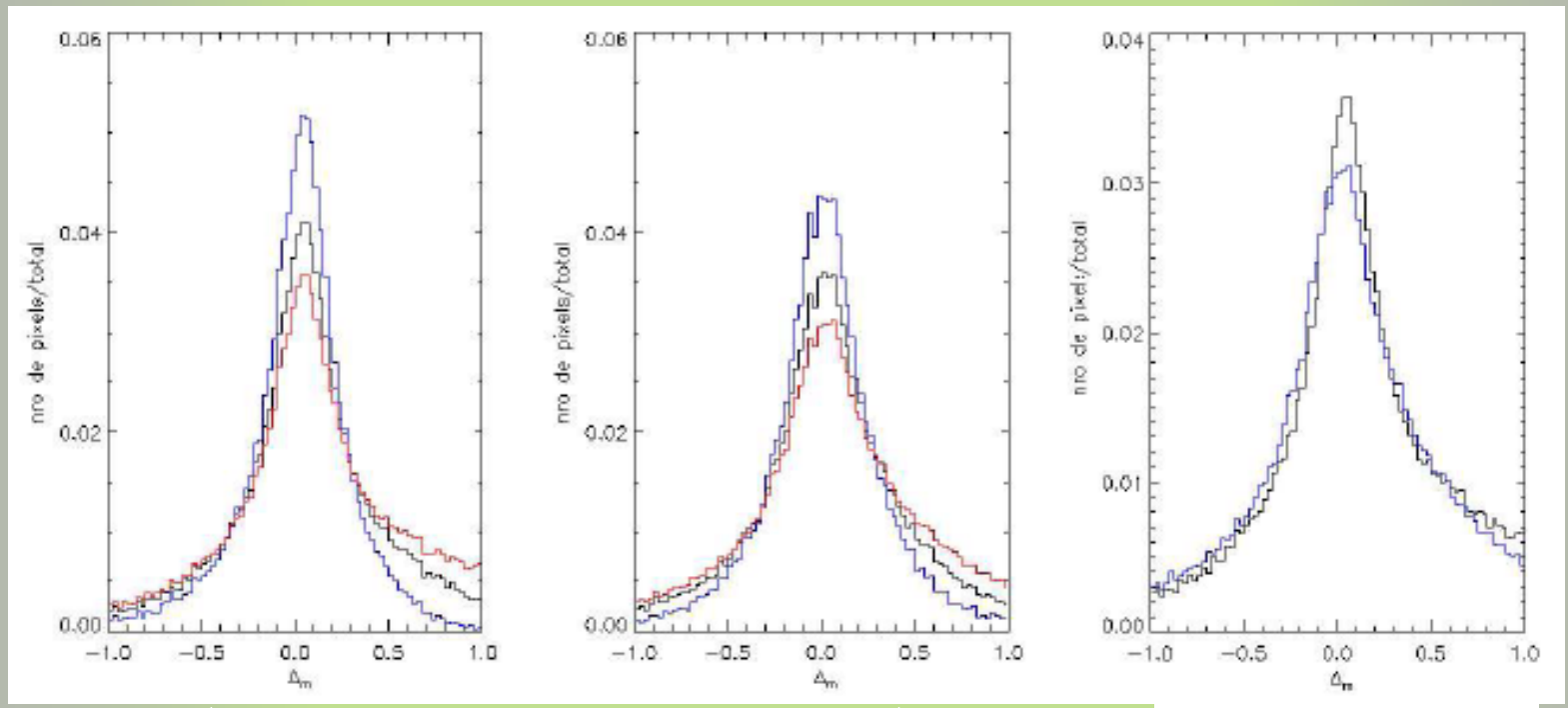






2D-1D Comparison | **Mrk 5...an special case?**

Residuals in the fitted regions:



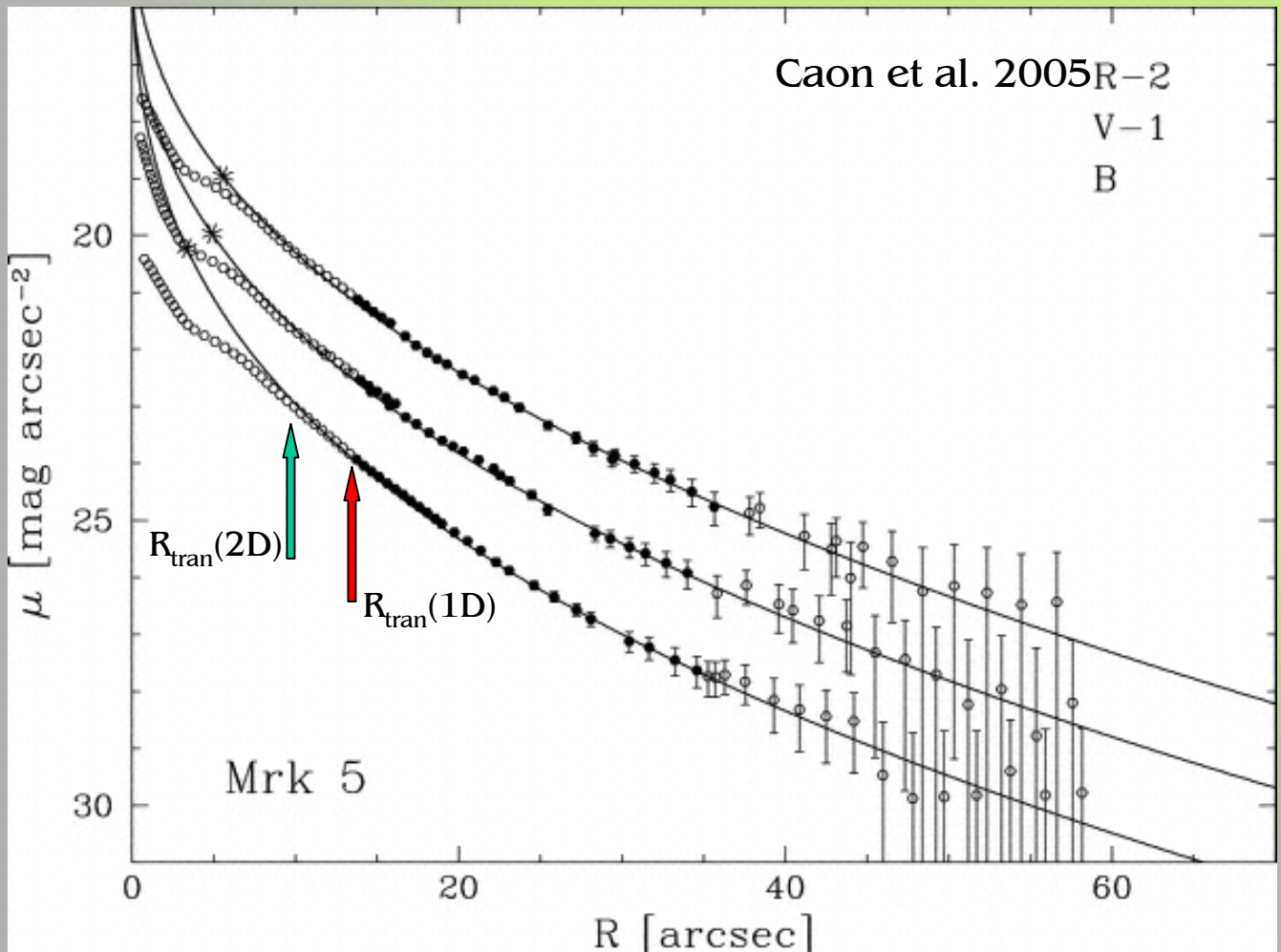
Red: until R_{max}(1D)
Black: until 1σ
Bluel: until 2σ

Black: 2D Fit
Blue: 1D Fit
Both until R_{max}(1D)

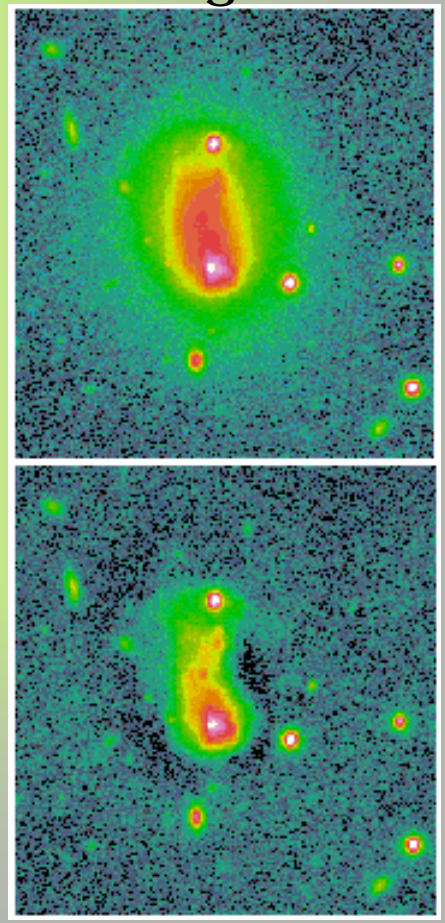
NO CONSIDERABLE DIFFERENCE

2D-1D Comparison | **Mrk 5...an special case?**

Residuals in the masked regions:



image



residual = ima - mod

2D-1D Comparison | **Mrk 5...an special case?**

So, the differences come from....

is the radial profile toward the center failing? difficult to reproduce them?

is the Sérsic model inadecuate toward the center?, and it is, why only in Mrk 5?

the adopted weights in the fits, specially in those more external regions?

We have shown that 1D fits in Mrk5 are affected by a mix of errors: sensibility to the sky-subtraction in a galaxy where the transition radius is on the limit of the errors by an insuficient fitted area.

2D models give us more confident result

6. CONCLUSIONS AND FUTURE WORK

We have developed and applied for the very first time in BCDs a new methodology based on a 2D algorithm. We have fitted the LSB component, with a Sérsic law.

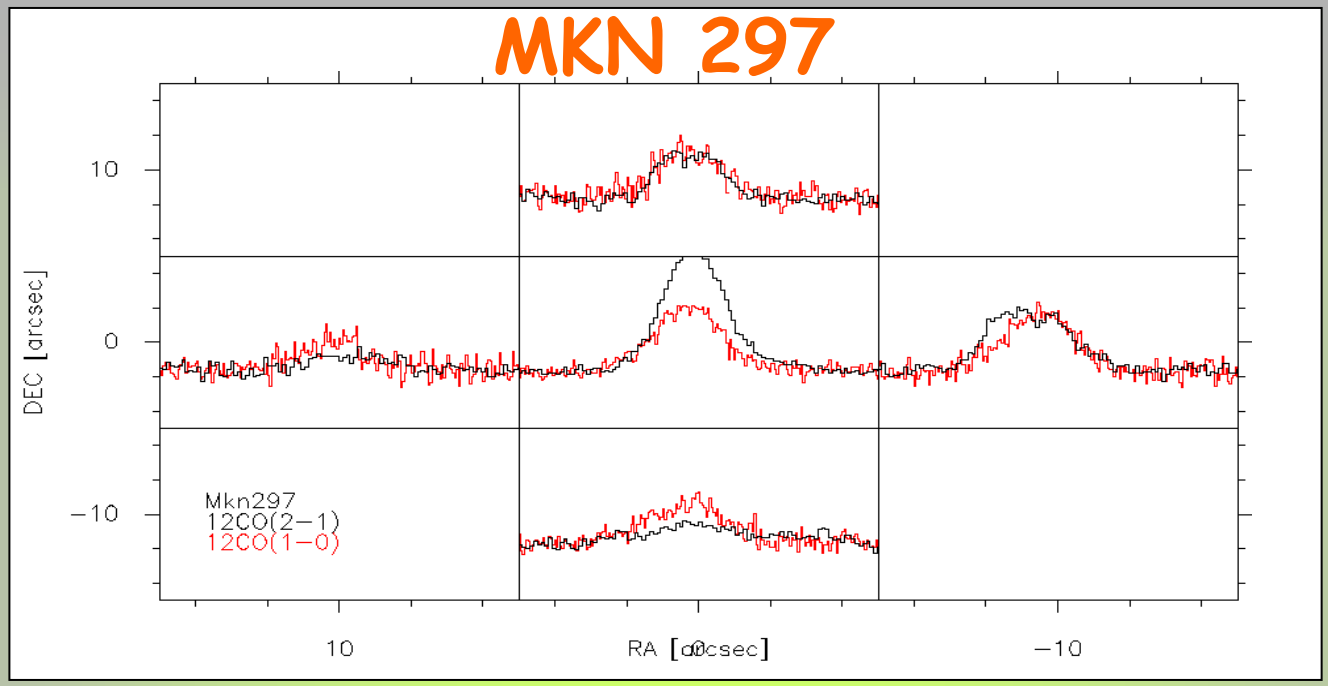
The outer regions of this sample of BCDs can be accurately fitted by a Sérsic model. We found in 7 of 8 galaxies a $n \sim 1$ Sérsic LSB component, and effective radius in agreement with a color gradient close to zero

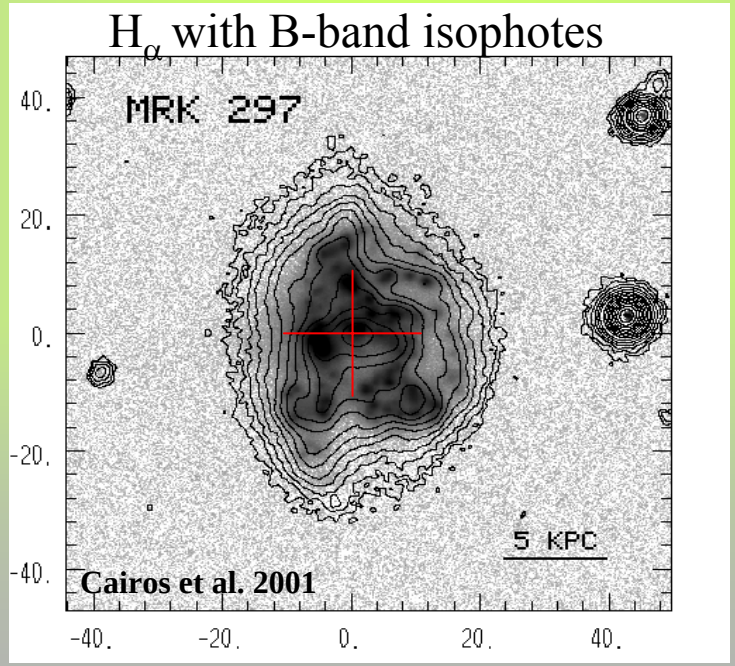
In general our results are in good agreement with Caon et al. 2005 with two exceptions: I Zw123 y Mrk5, for which we have made an extensive study, founding a plausible explanation to this problem.

Our results and analiysis encourage us to enlarge the study to a larger sample of 28, statistically more significative.

Amorin et al. A&A 2006 coming soon...

Thank you!


MKN 297
10
0
−10
DEC [arcsec]
Mkn297
12CO(2−1)
12CO(1−0)
10
RA [arcsec]
−10


H$_\alpha$ with B-band isophotes
MRK 297
40.
20.
0.
-20.
-40.
5 KPC
Cairos et al. 2001
-40.
-20.
0.
20.
40.

Fitting the LSB host: exponential *vs* Sérsic models

1. Exponential model

Currently used in the optical (Papaderos et al. 1996; Östlin 1998; Gil de Paz 2000; Cairós 2000; Cairós et al. 2001a, 2002) .

Also applied to NIR data (Cairós et al. 2003; Noeske et al. 2003a, b)

- In objects with extended starburst, NIR scale parameters show larger discrepancies with the values found in the optical
- Many galaxies are found to display systematic deviations from the exponential behavior

Ajustes de componentes galácticas | Algoritmos bidimensionales

La ley de Sérsic

$$I(r) = I_e \exp\left\{-b_n\left[\left(\frac{r}{r_e}\right)^{1/n} - 1\right]\right\}$$

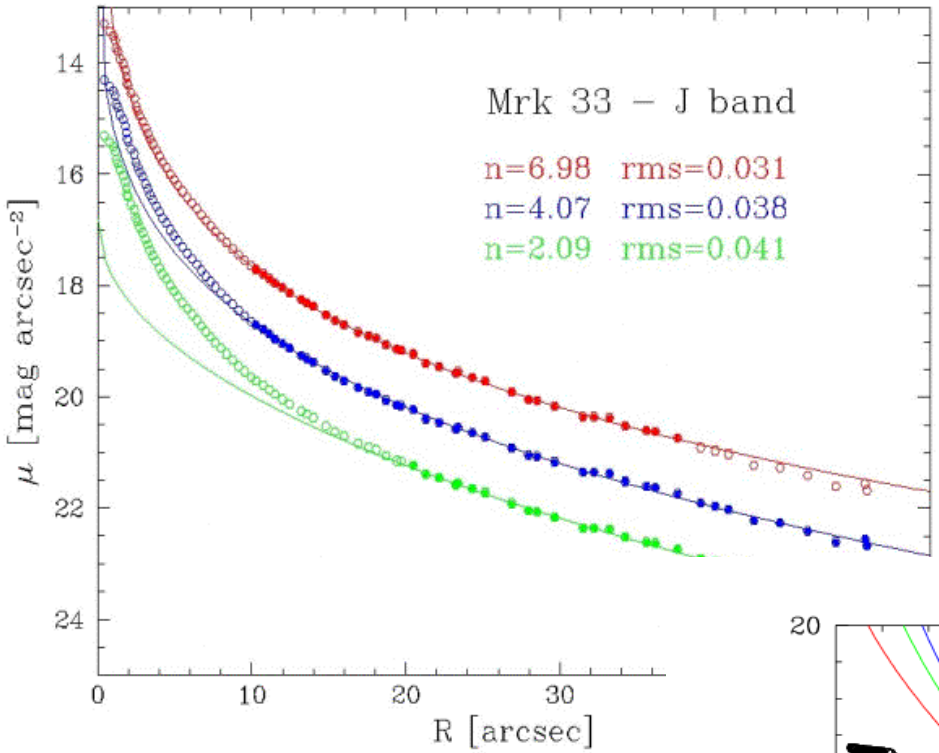
Aplicada satisfactoriamente a elípticas (Caon et al. 1993), miembros brillantes de cúmulos (Graham et al. 1996), bulbos de espirales (Andredakis et al.1995), enanas elípticas (Young & Curie 1994)

Los modelos de Sérsic proveen una descripción más precisa y con mayor significado físico de el perfil de brillo superficial, pero los parámetros a ajustar dependen de:

1. El rango radial

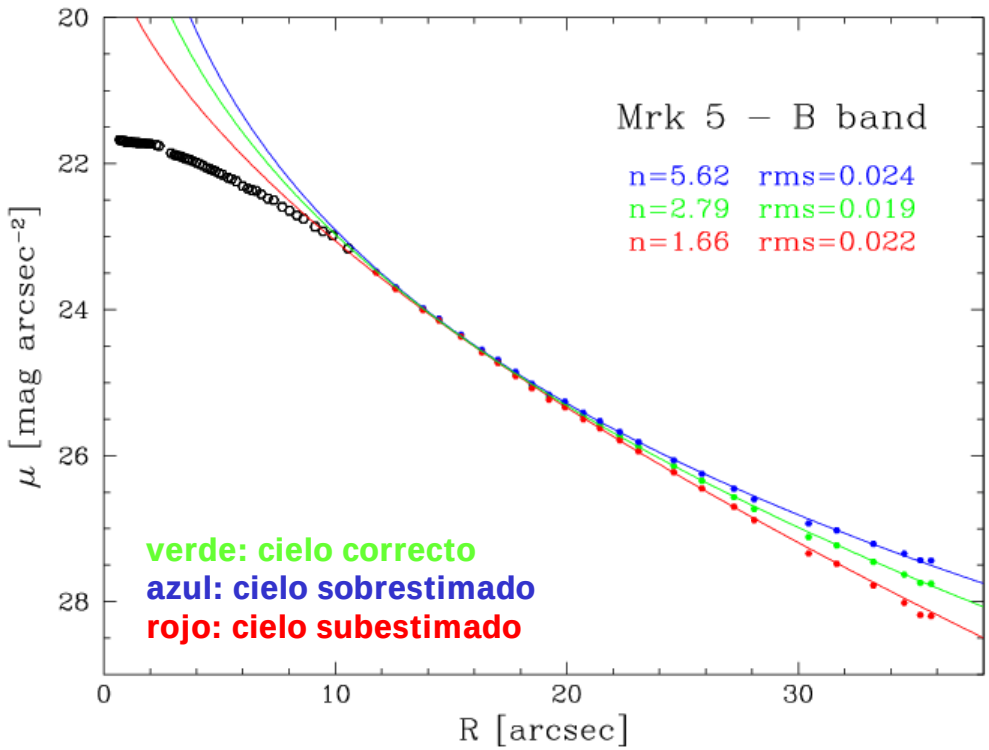
2. Los errores de substracción de cielo

Ver Caon et al. 2003, Cairós et al. 2003, Caon et al. 2005



ritmos bidimensionales

satisfactoriamente a elípticas
al. 1993), miembros brillantes
os (Graham et al. 1996),
espirales (Andredakis et



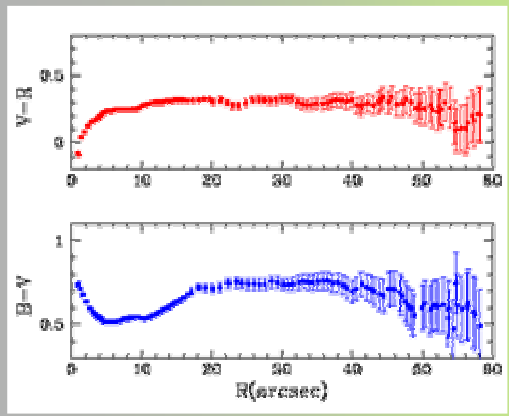
Los modelos de Sérsic p
mayor significado físico d
parámetros a ajustar depe

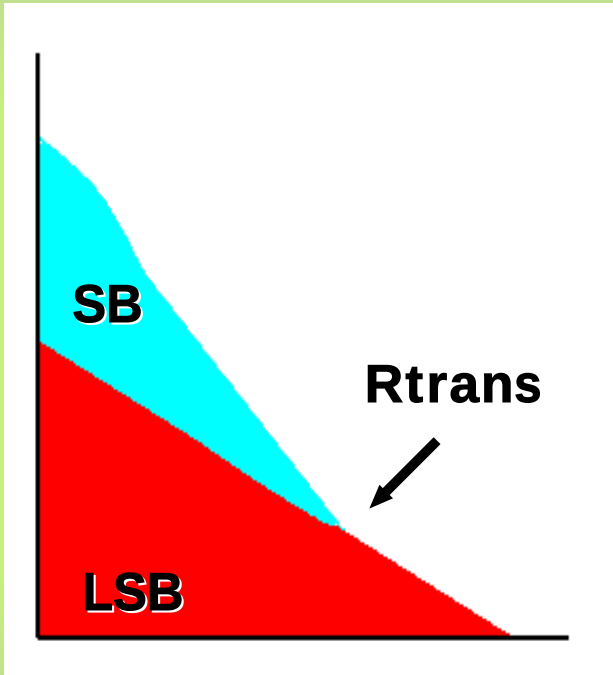
1. El rango radial

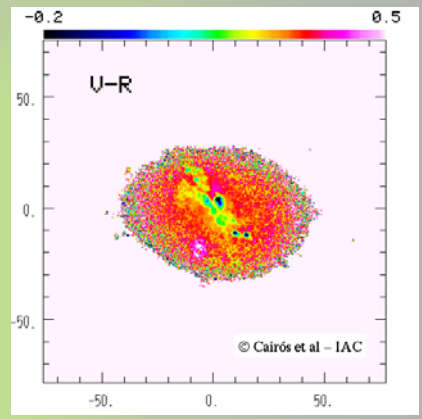
2. Los errores de substrac

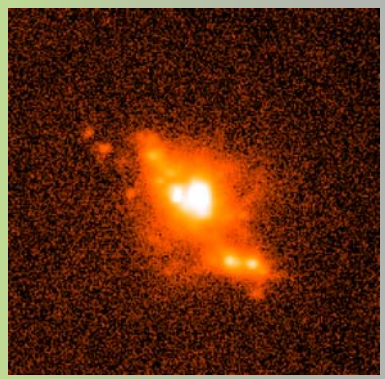
Ver Caon et al. 2003, Ca

SBP decomposition. Fit to the LSB component at large radii (outside the starburst region)









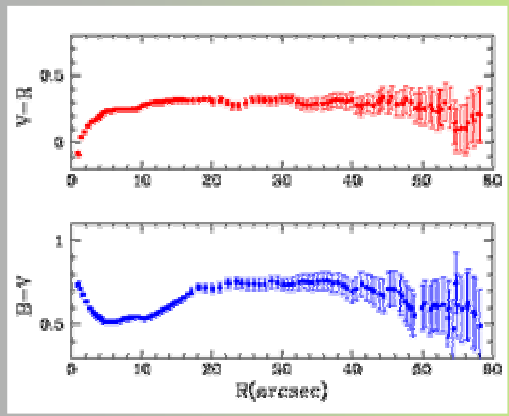
Exponential fit (α,μ) → (Flux, L, colors) HOST

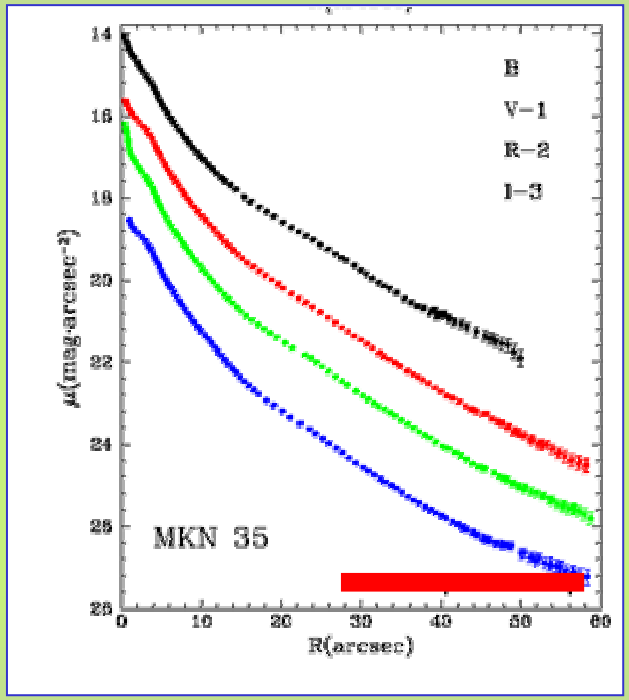
Subtract → (Flux, L, colors) STARBURST

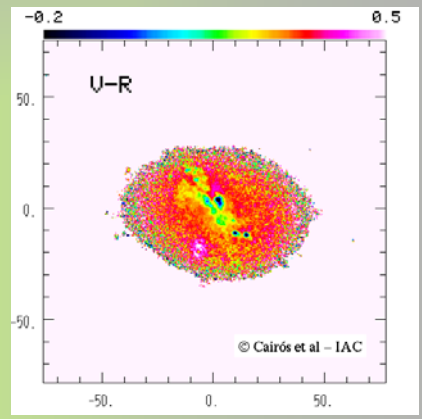
Cairós et al. 2001, 02

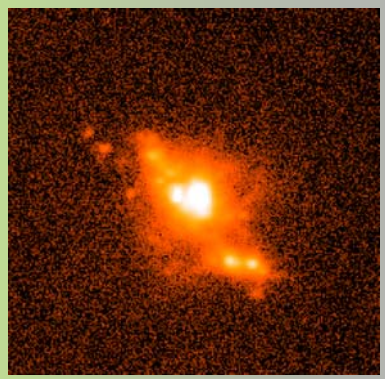
Cairós et al. in prep.

SBP decomposition. Fit to the LSB component at large radii (outside the starburst region)









Exponential fit (α,μ) ➔ (Flux, L, colors) HOST

Subtract ➔ (Flux, L, colors) STARBURST

Cairós et al. 2001, 02

Cairós et al. in prep.