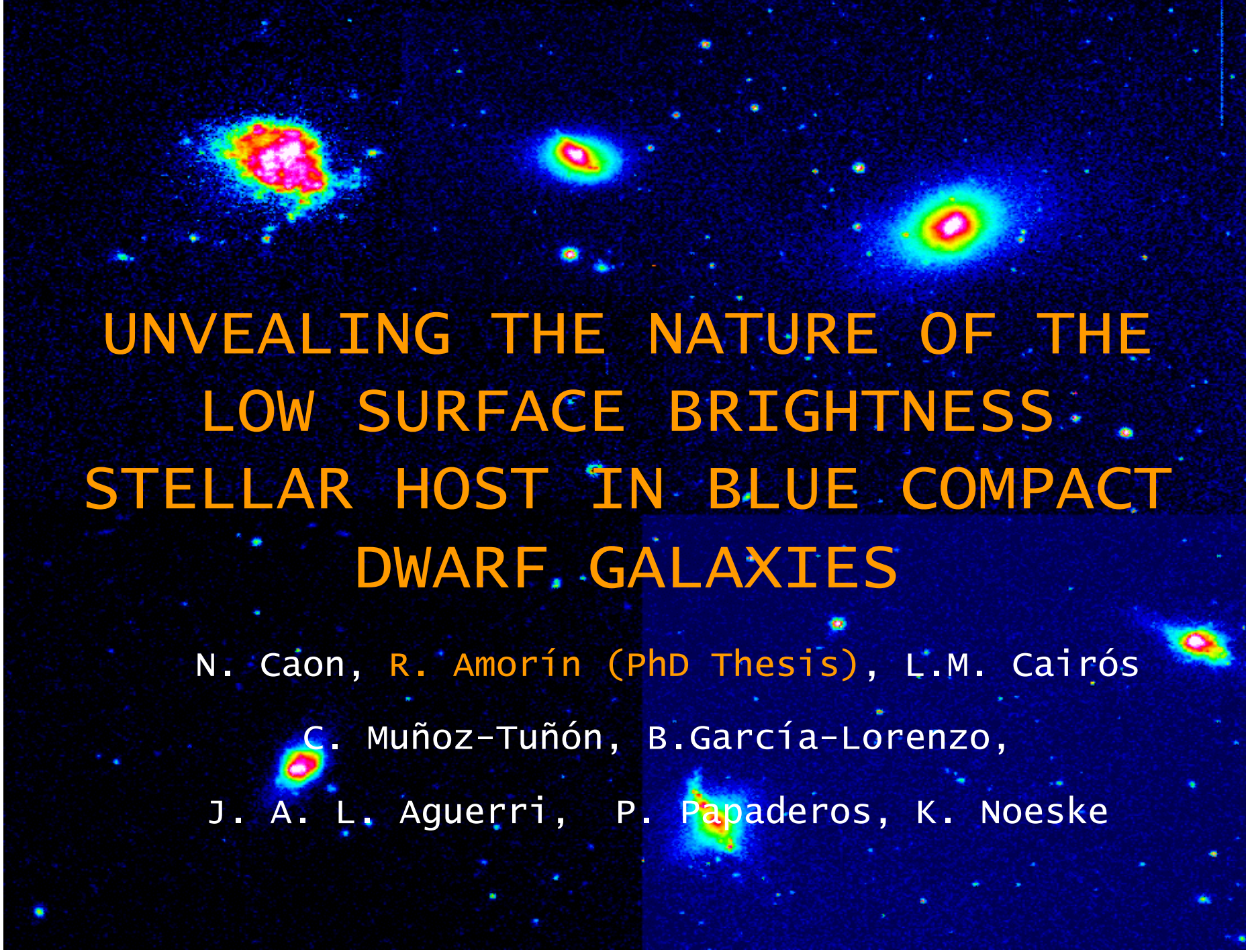


UNVEALING THE NATURE OF THE LOW SURFACE BRIGHTNESS STELLAR HOST IN BLUE COMPACT DWARF GALAXIES

N. Caon, R. Amorín (PhD Thesis), L.M. Cairós

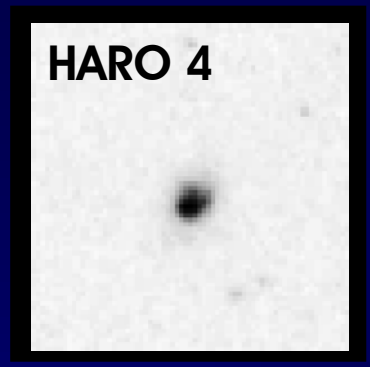
C. Muñoz-Tuñón, B.García-Lorenzo,

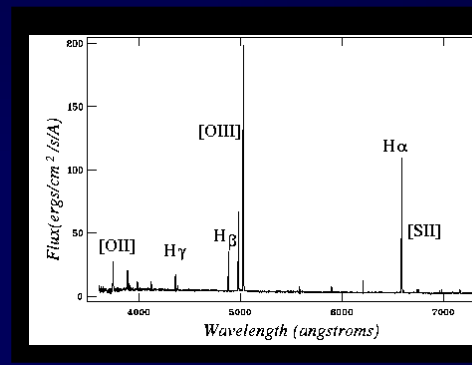
J. A. L. Aguerri, P. Papaderos, K. Noeske

AGENDA

- Introduction
- Why fit the LSB host?
- Fitting issues and techniques
- Deep Near-Infrared investigations
- Results
- Work in progress and future projects

Blue Compact Dwarf Galaxies





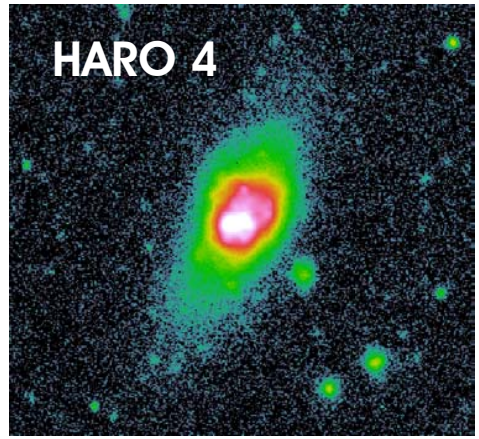
- Low luminosity ($M_B > -18$)
- Compact (D < 1 kpc)
- H_{II} regions spectra
- Gas-rich (Thuan & Martin 1981)
- Metal-deficient ($Z_\odot/50 < Z < Z_\odot/3$; Kunth & Sargent 1986)
- High star-forming rates (0.1-10 $M_\odot$/yr; Fanelli et al. 1988)

YOUNG GALAXIES?

(Sargent & Searle 1970; Kunth & Sargent 1986; Kunth, Maurogordato,& Vigroux 1988).

Deep photometric analysis in the optical reveal a low surface brightness regular envelope (Loose & Thuan 1986).

Colors are indicative of an evolved population of stars (Doublier 1997, 1999; Cairós et al. 2001a,b, 2002).



Why do we study BCDs ?

- Opportunity to study physical processes and determine abundances in a *nearly primordial environment*
- Laboratories to study the *star formation* process: low mass galaxies, no density waves
- *Cosmology:* BCDs could be the local counterparts of the faint blue galaxies at z ~ 1

Unanswered questions

- Do all BCDs have an underlying stellar component? What are the structural parameters of the hosts ?

  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 ?

- Comprehensive analysis of the starburst:

  Constrain its IMF, star-formation history, ages and metallicities

  Analyze the gas morphology: superwinds

  Stellar morphology (i.e. Super Stellar Clusters, SSCs)

- Assessment of the properties of the LSB stellar host

UNVEILING THE NATURE OF THE LSB STELLAR HOST IN BCDs

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

UNVEILING THE NATURE OF THE LSB STELLAR HOST IN BCDs

MODEL THE LSB TO DETERMINE THE STARBURST PROPERTIES

ONLY WITH AN ACCURATE MODEL OF THE LSB CAN WE:

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

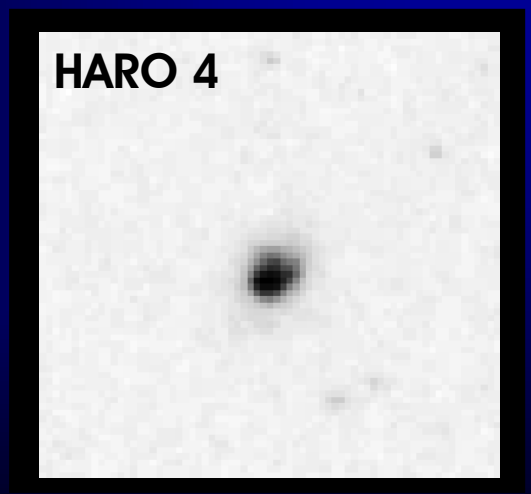
2 – Determine the magnitude and colors of the individual star-forming knots, by subtracting out the LSB host flux.

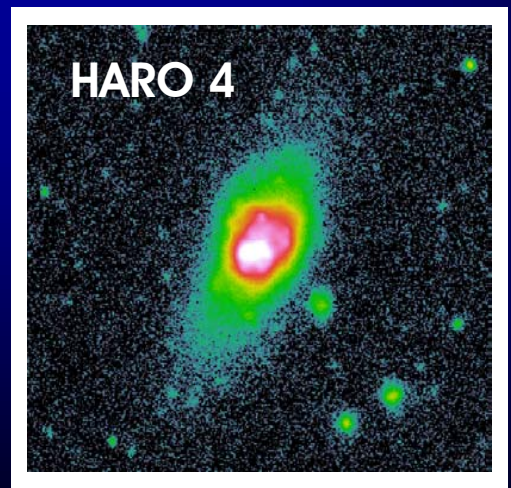
3 – Compute the correct emission-line equivalent widths by subtracting the LSB host continuum.

UNVEILING THE NATURE OF THE LSB STELLAR HOST IN BCDs

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

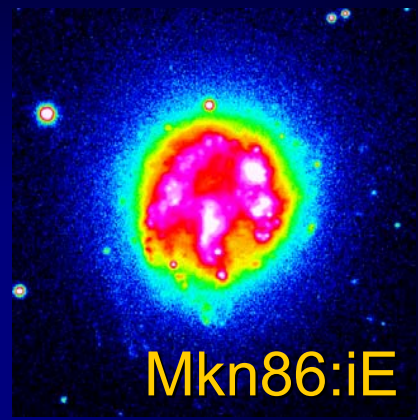
It is a very difficult task, which require a great deal of observational and analysis effort. We require high quality data at very low surface brightness levels (24 mag arcsec^{-2} in B)





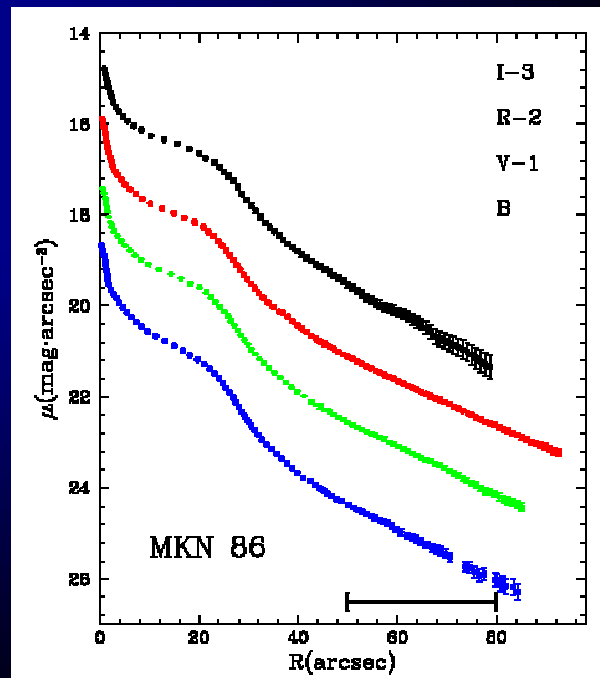
On fitting the LSB host in BCDs

I. The problem



The SBP of BCDs is the superposition of at least two component:

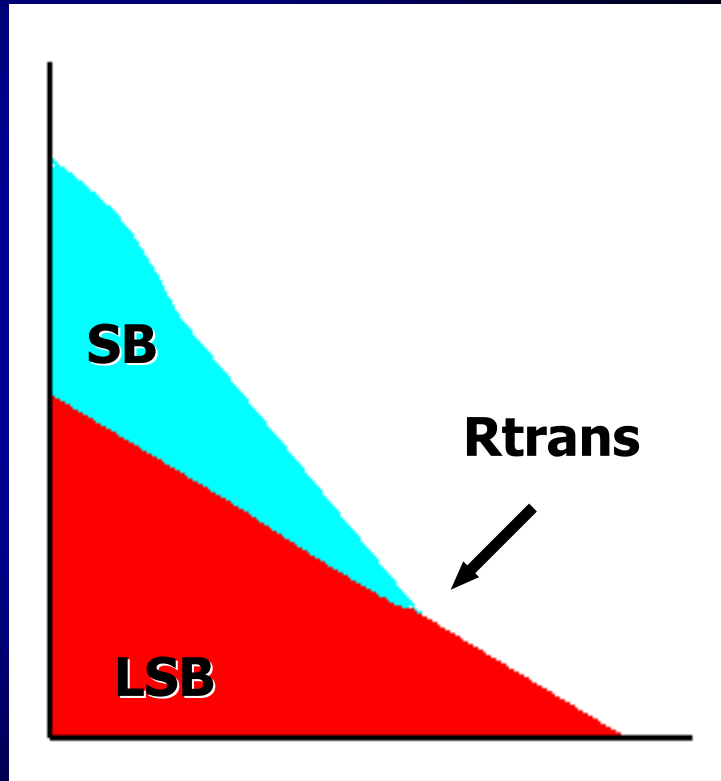
1. *The Starburst* is made up of the emission from young massive stars, and dominates the light at high and intermediate intensity levels
2. *The LSB stellar host* dominates at larger radii and contains most of the galaxy´s stellar mass



On fitting the LSB host in BCDs

II. Methodological issues

1. Proper determination of the fitted radial range
2. Deep, extended profiles
3. Use of a suitable analytical model for the light distribution



On fitting the LSB host in BCDs - Optical

1. Previous work

Papaderos et al. 1996a,b; Doublier et al. (1997, 1999), Telles (1995); Östlin (1998); Marlowe et al. (1997, 1999); Cairós et al. 2001a,b

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

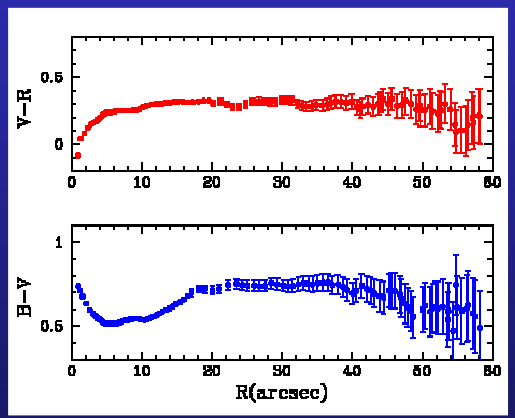
On fitting the LSB host in BCDs -NIR

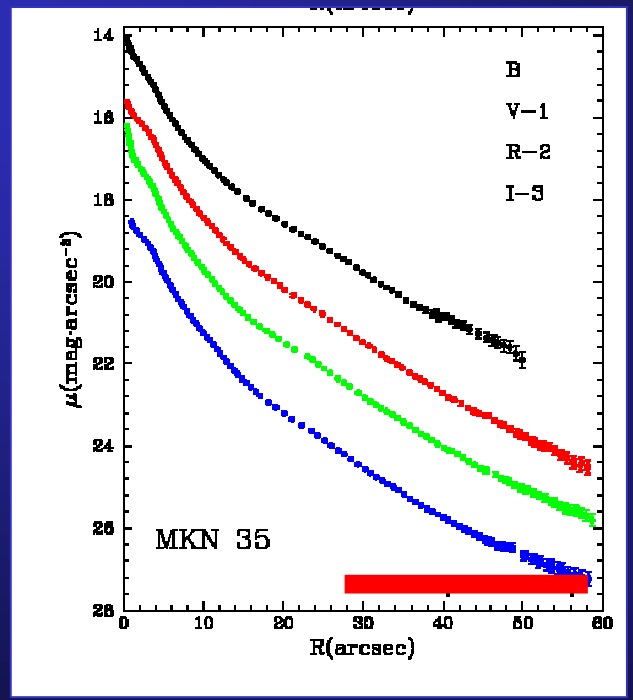
Advantages

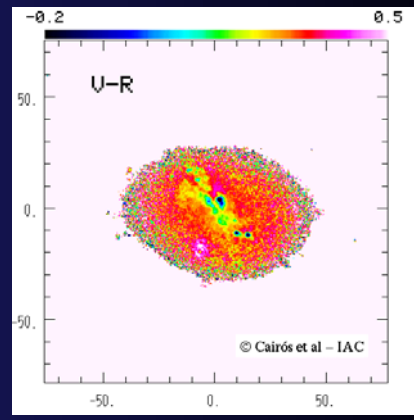
- Smaller contribution of young stars / nebular emission lines to the galaxy flux;
- The starburst fades away at smaller galactocentric distance;
- Extinction is much lower; $A_V / A_K \sim 9$;
- Optical-NIR colors are better suited to constrain stellar population ages;
- Spectral features as CO λ1.63-2.3μ are powerful tools to trace the properties of the stellar populations;
- NIR allows to identify optical obscured SSCs;

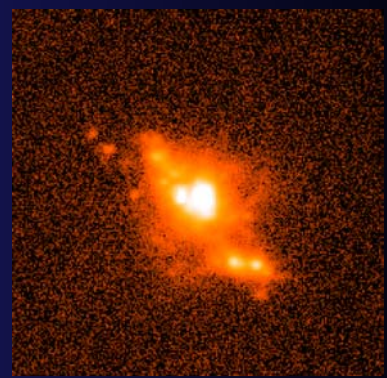
But: it costs much more in telescope time to reach the same depth as in the optical ...

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, 0

Cairós et al. in prep

OPTICAL & NIR OBSERVATIONS: ~ 60 BCDs, **U, B, V, R, I, J, H, K**

- 2.5m NOT
- 2.2m Calar Alto
- 3.6m Calar Alto

μ_{LIM} **~ 27 - 28 B-mag arcsec^{-2}**

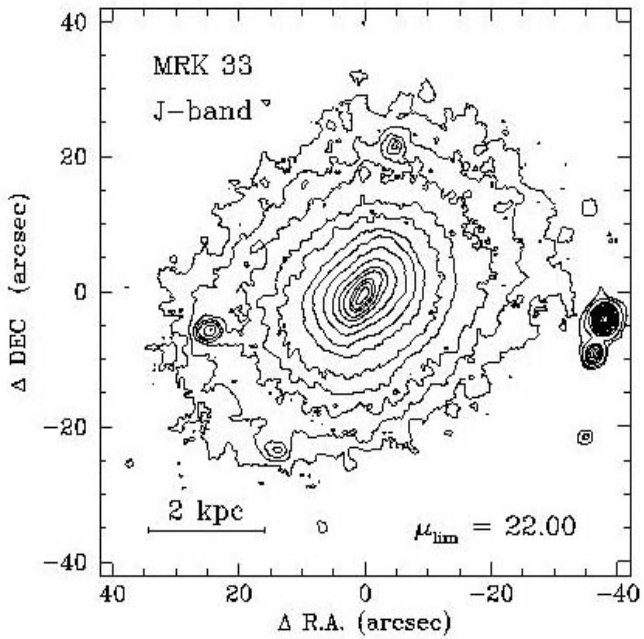
First NIR Study of a large sample of BCDs in the NIR

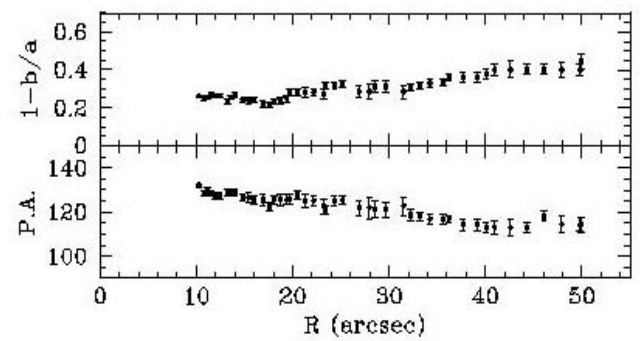
- 3.6m ESO NTT + SOFI
- 4.2m WHT + INGRID
- 3.6m CAHA + OMEGA PRIME

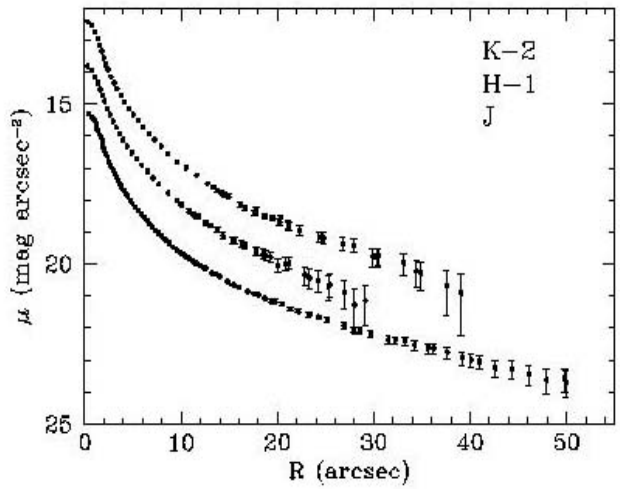
$\mu_{J,LIM}$ **~ 22.5-24 mag arcsec^{-2}**

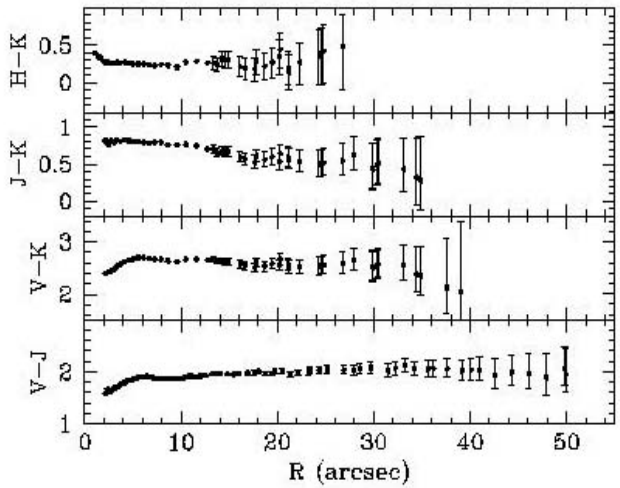
$\mu_{K,LIM}$ **~ 21.5-23 mag arcsec^{-2}**

SURFACE PHOTOMETRY









MKN 33

J-band

$\mu_{J,LIM}$ ~ 24 mag arcsec^{-2}

LSB colors

J - K = 0.51

V - J = 2.01

V - K = 2.52

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

On fitting a Sérsic law to the SBP of the host

2. 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

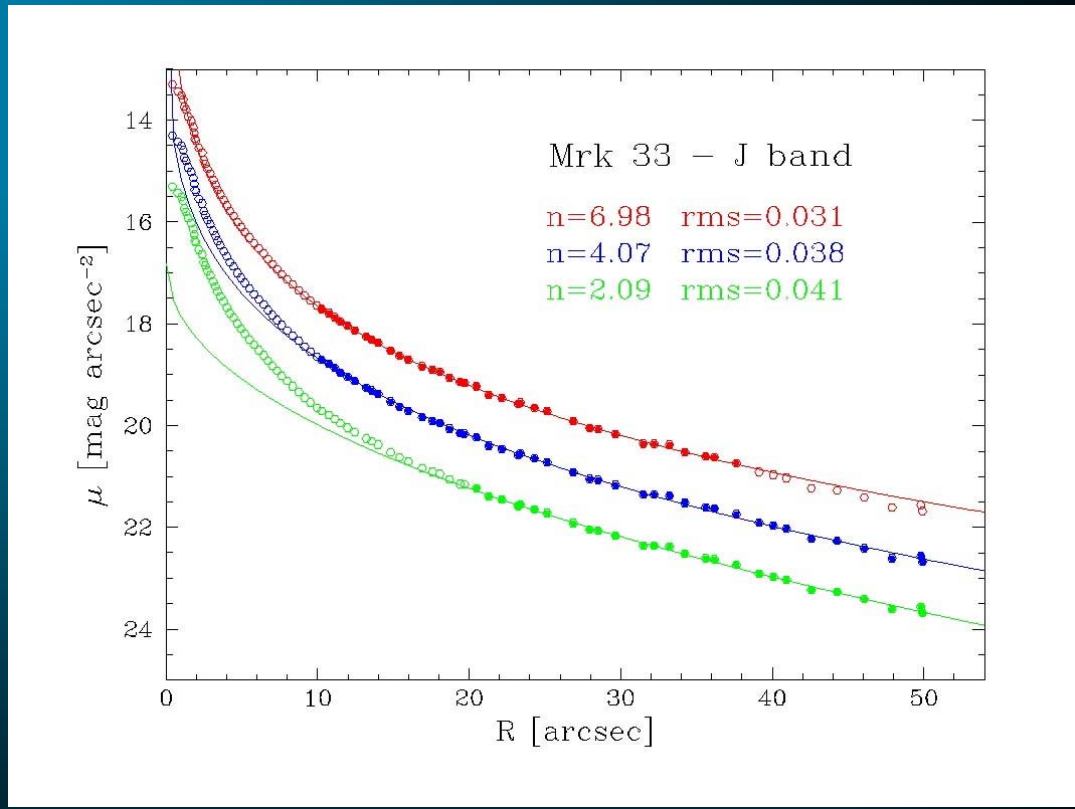
See Caon et al. 2003, Cairós et al. 2003, Caon et al. in prep.

Sensitivity to radial range

The Sersic parameters may strongly depend on the exact radial range used.

This effect is exhacerbated if part of the starburst region is included in the fit.

1 – green: “conservative” fit
2 – blue: SB region included
3 – red: short radial interval

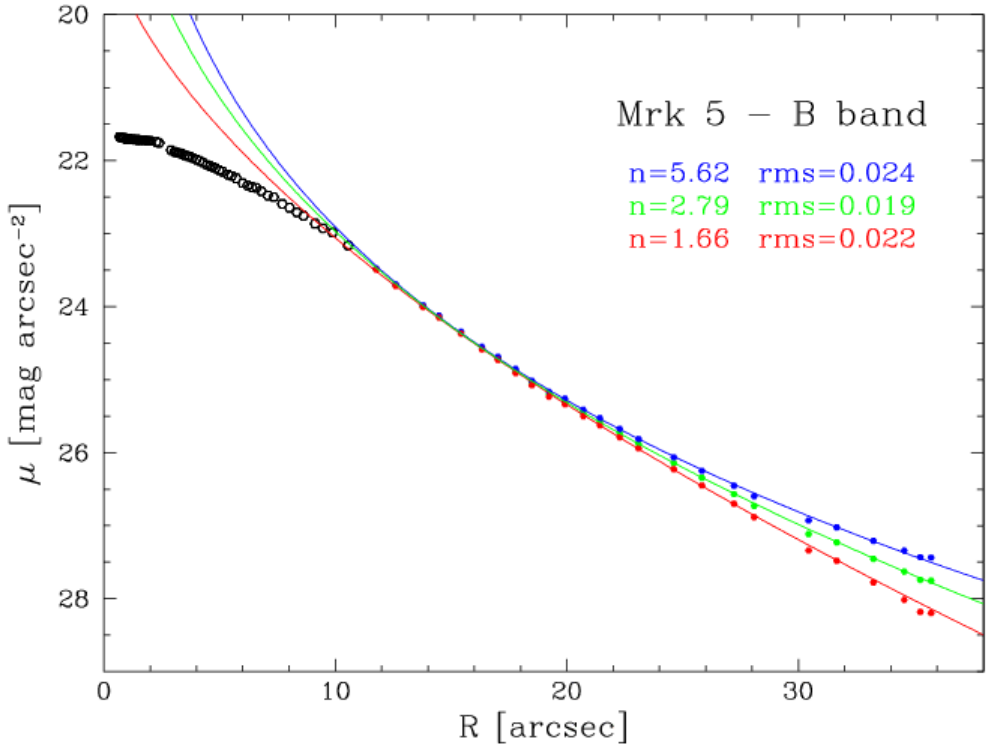


Sensitivity to sky background subtraction errors

The Sersic parameters are also affected by sky-background uncertainties.

green: correct sky
blue: sky undersubtracted
red: sky oversubtracted

(last datapoint changes by +/- 0.30 mag)



Consistency checks

How can we estimate the reliability and accuracy of the fitted Sersic parameters?

1 - We explore their dependency on the exact value of Rtran and Rmax.

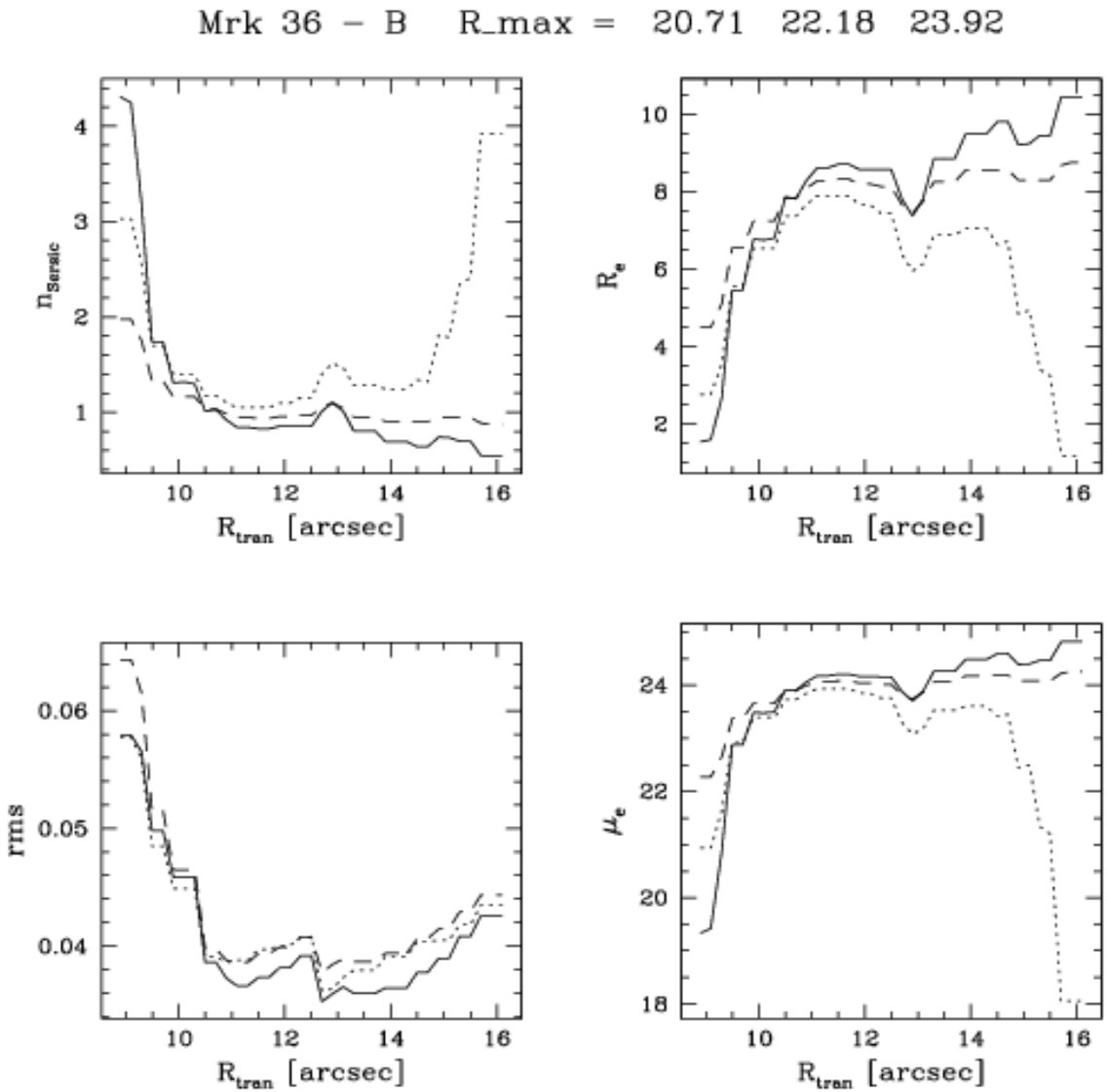
2 – Assuming that the LSB has no color gradients, n and Re should be the same in all filters.

The fit is repeated by varying Rtran within a reasonable interval, and by setting different values for Rmax.

The variation of the Sersic parameters with the fitted radial interval, and the scatter among the different filters, all provide a practical estimate of their uncertainties

In the interval 11 < R < 14 parameters are quite stable.

Also, plots with the fits in V and R show consistent behaviors.



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..

2D techniques will allow us to fit the LSB by using detailed masks in order to achieve a more accurate characterization of the stellar host using a larger effective area

And we have the software....

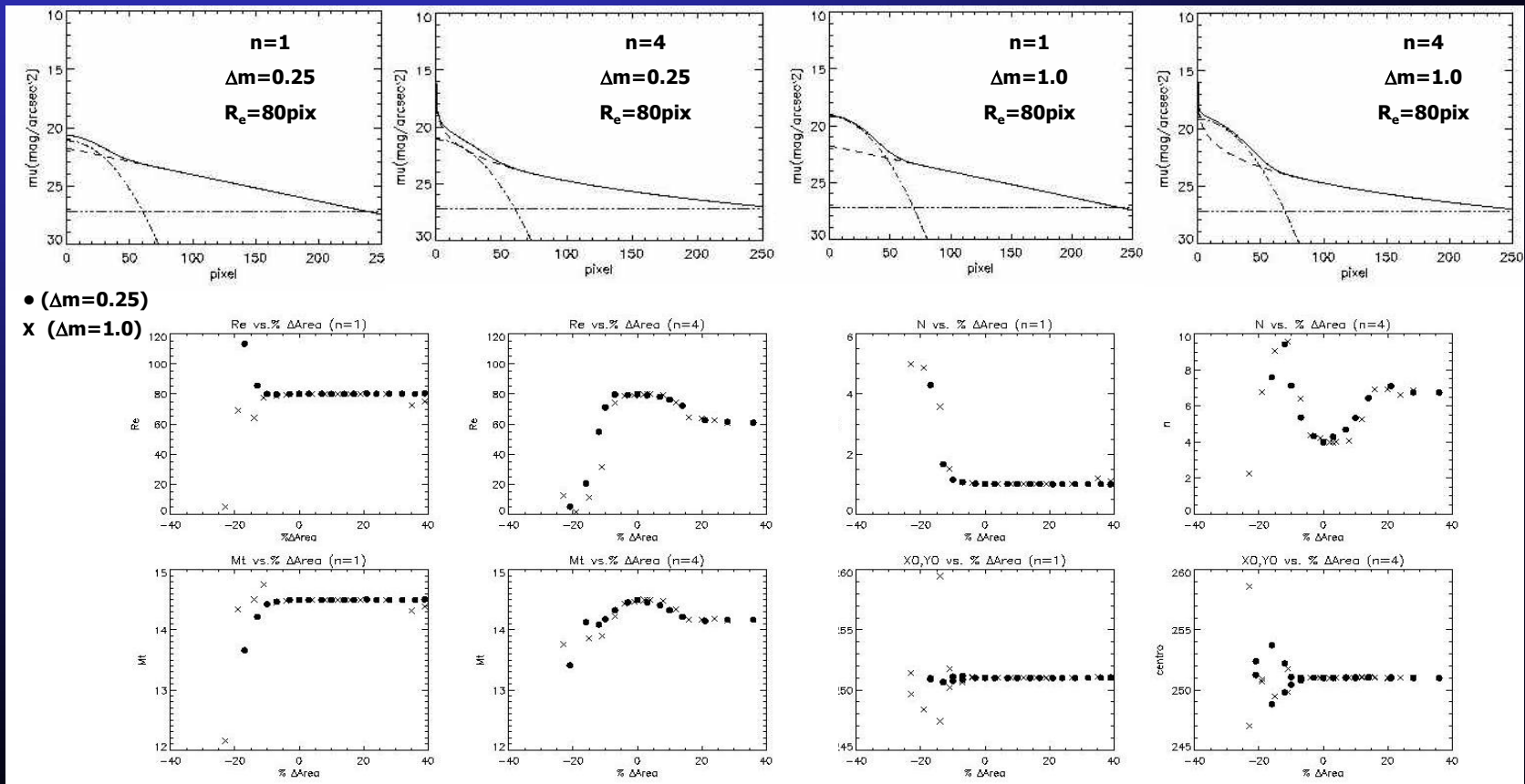
2D Fitting with GALFIT (Peng et. al., 2002, AJ, 124)

- 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
- GALFIT is conductive for analyses that involves trial-and-error manual fitting, in addition to large statistical studies
- The models are 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-Masquardt algorithm modified

2D Fitting with GALFIT

Very simple simulations

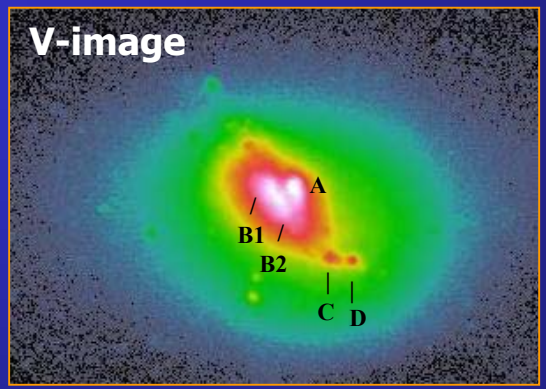
- Pure 2D Sérsic (n=1 & n=4) with a central gaussian knot profiles were fitted in order to check the algorithm robustness



2D Fitting with GALFIT

Real cases: 1) **Mrk35**

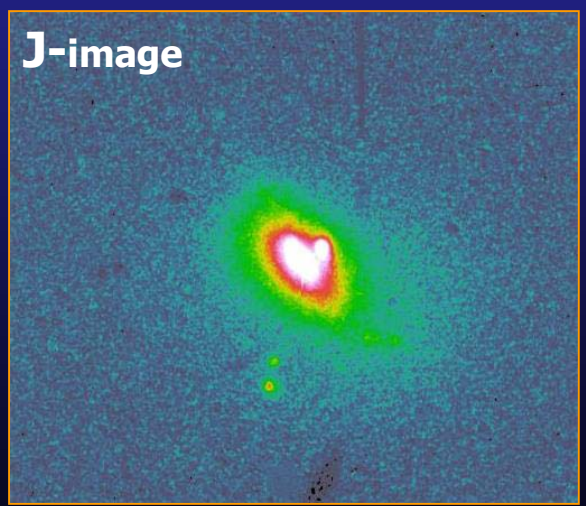




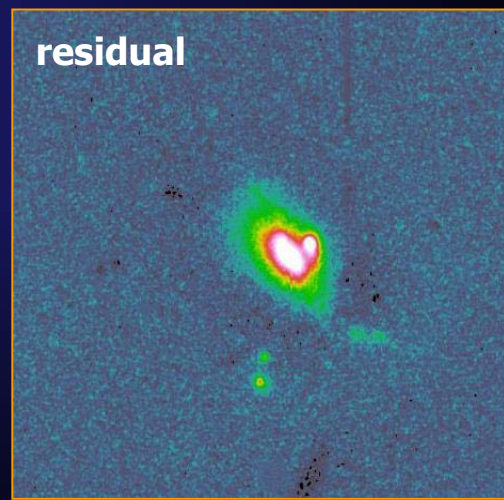
	m_{HOST}	n	Re (")
B	14.55	0.96	19.49
V	13.66	1.00	20.22
R	13.13	0.95	20.46
J	14.65	1.18	17.77
H	14.55	0.70	18.36
K	15.76	1.05	18.07

For each band, the best-fit 2D model was substracted out from the broad-band image

Very good agreement with 1D parameters

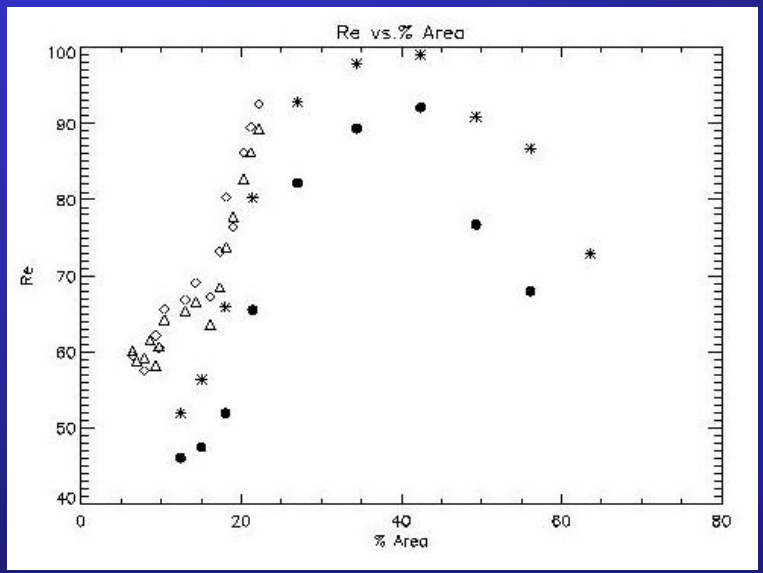


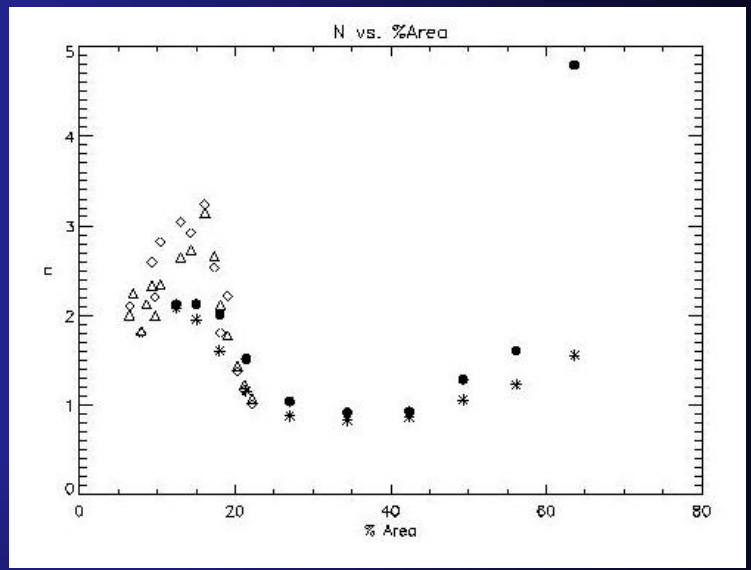


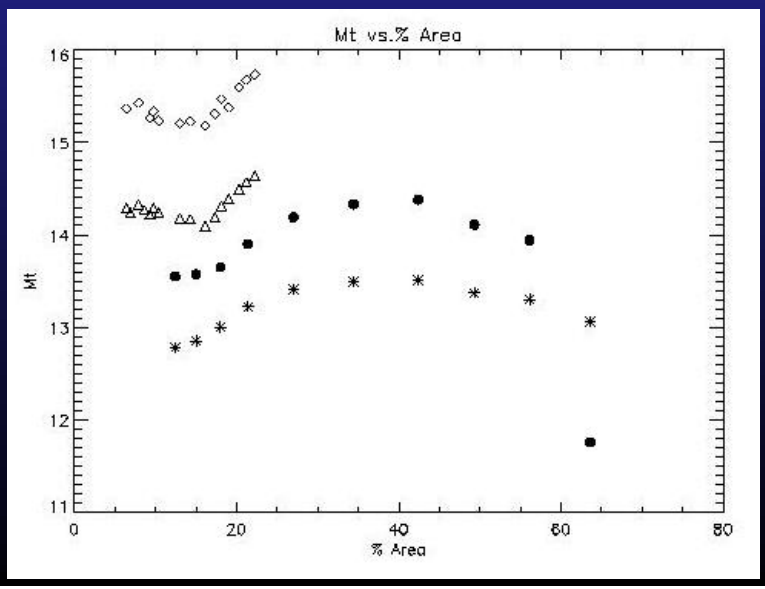


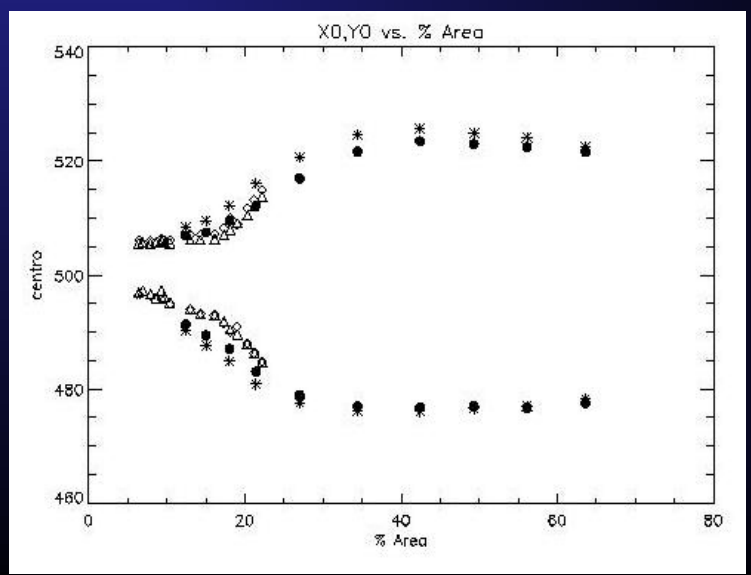
2D Fitting with GALFIT

Stability of parameters







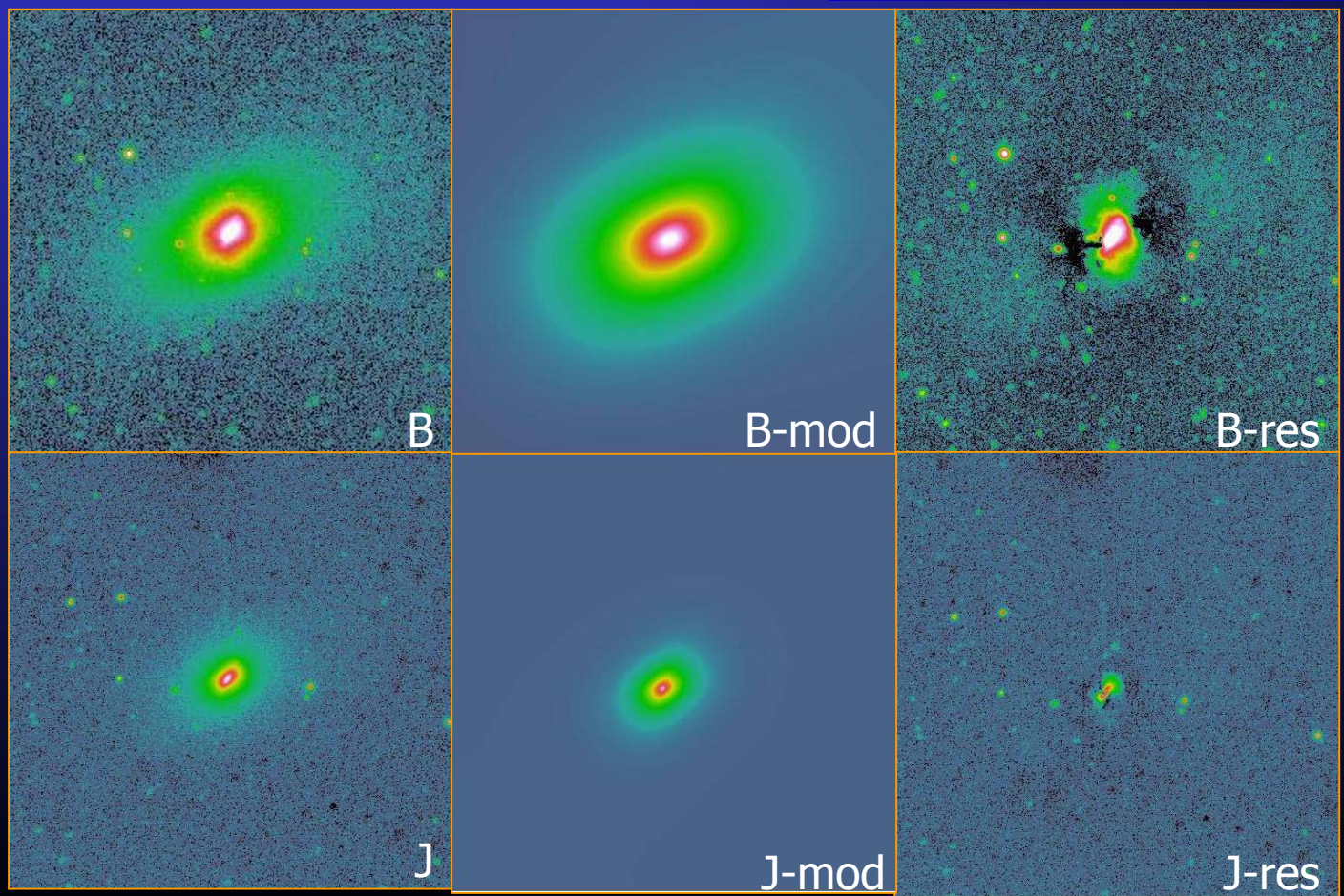


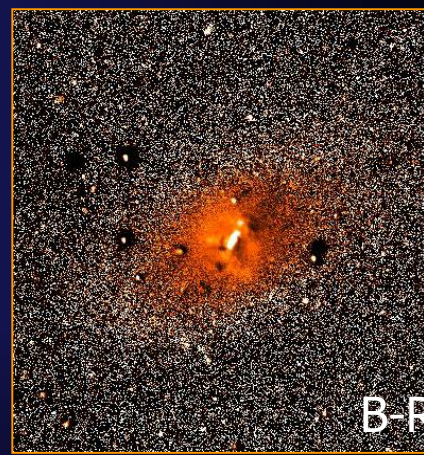
2D Fitting with GALFIT

Real cases: **1) Mrk33**

(Preliminary)

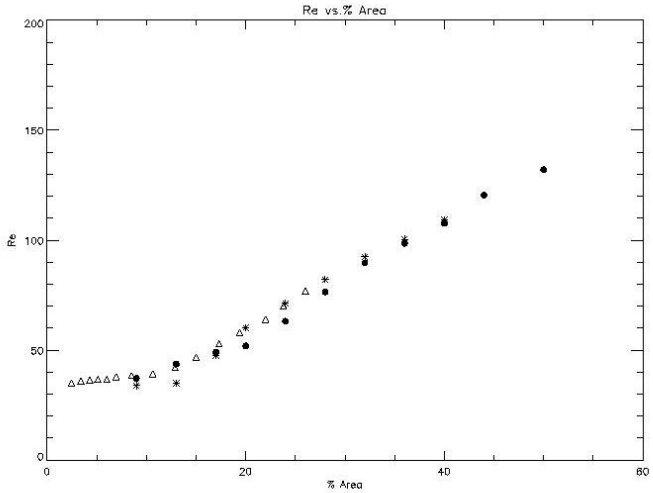
	m_{HOST}	n	Re (")
B	14.12	3.55	15.48
V	13.33	4.03	10.54
J	15.04	4.40	12.35
K	16.1	3.5	8.0

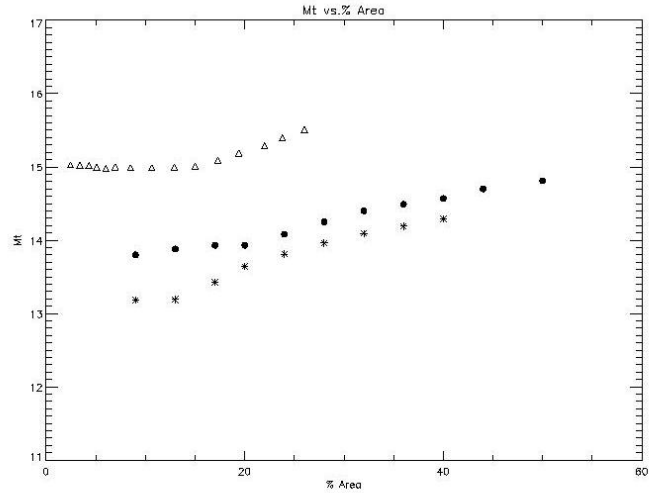


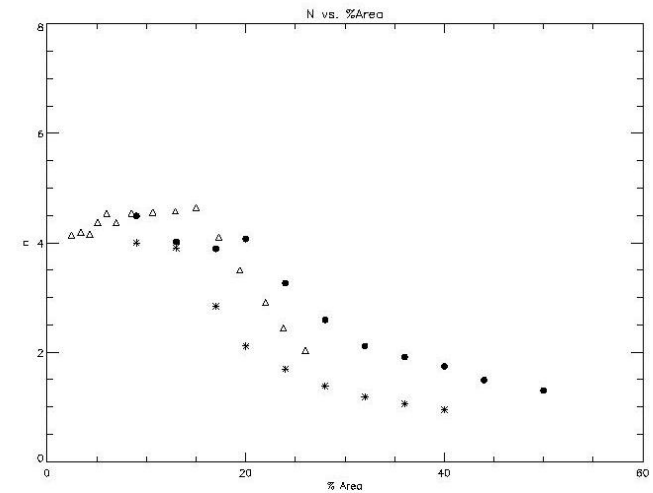


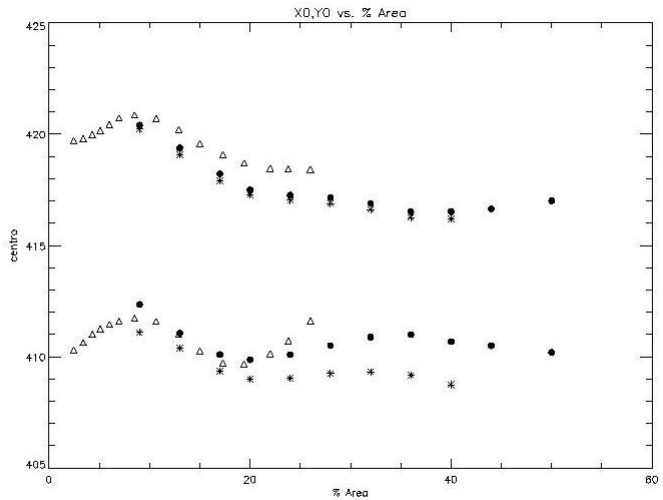
2D Fitting with GALFIT

Stability of parameters







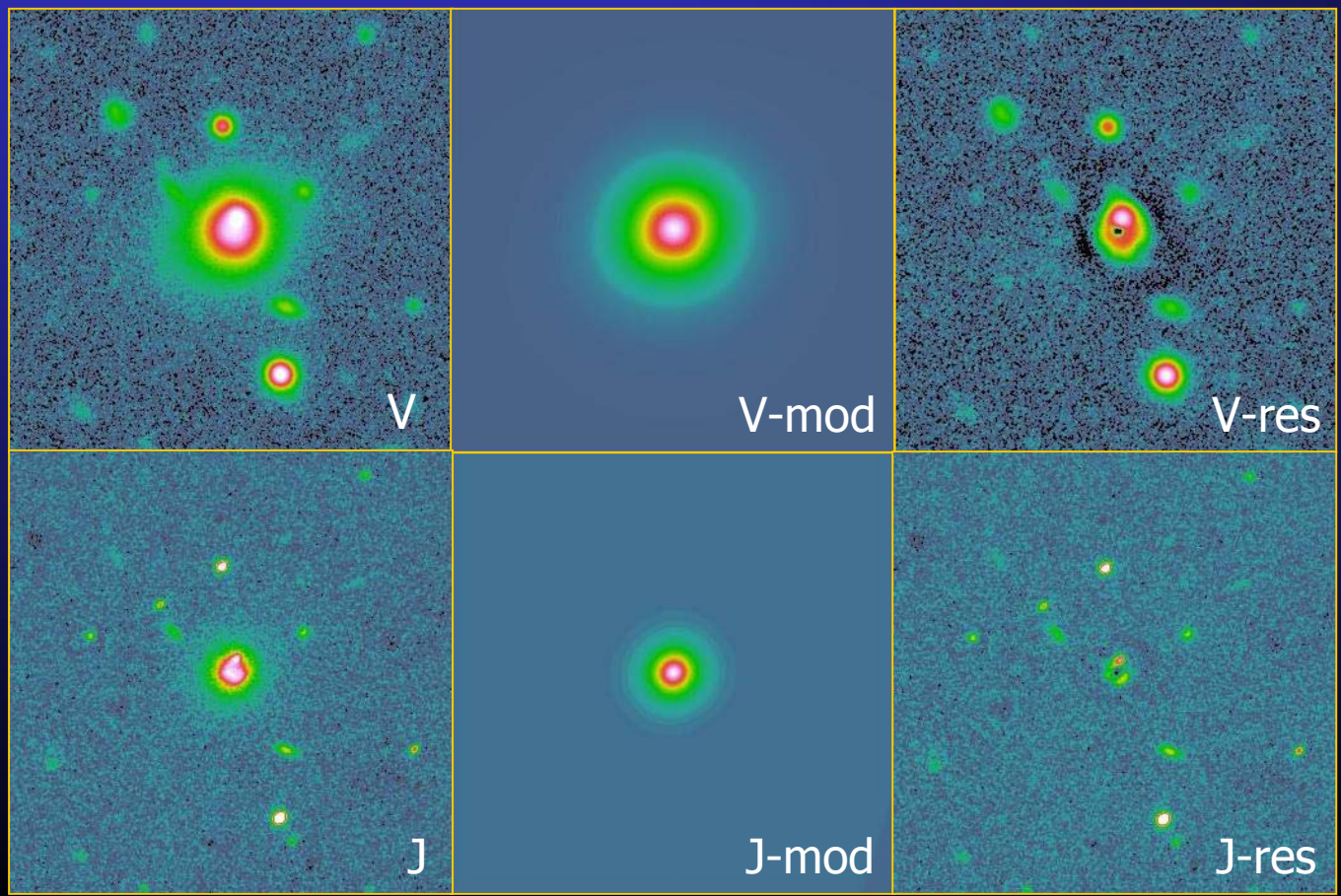


2D Fitting with GALFIT

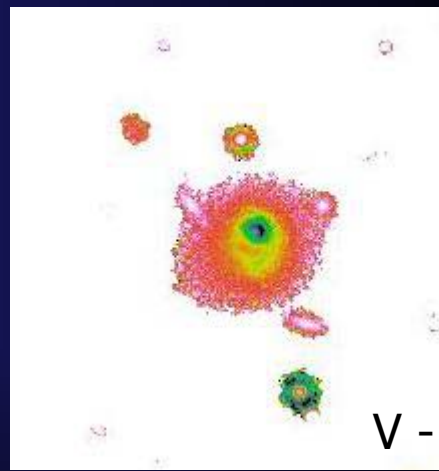
Real cases: **1) I zw123**

(Preliminary)

	m_{HOST}	n	Re (")
B	15.75	2.06	3.22
V	15.25	2.07	3.58
J	17.36	1.20	3.87
H	17.52	1.00	3.30
K	18.11	1.13	3.51

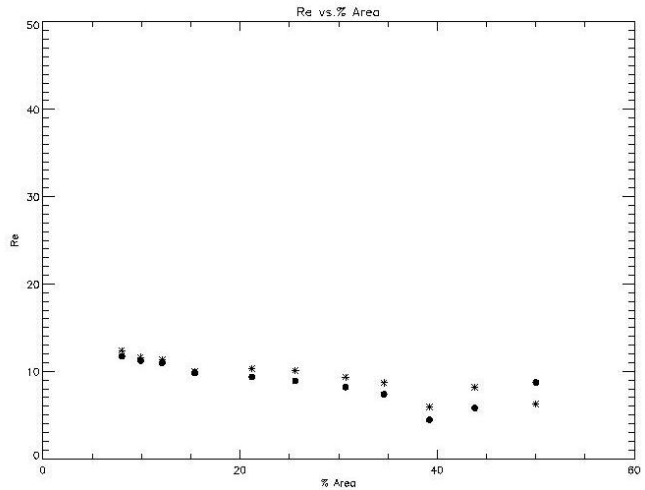


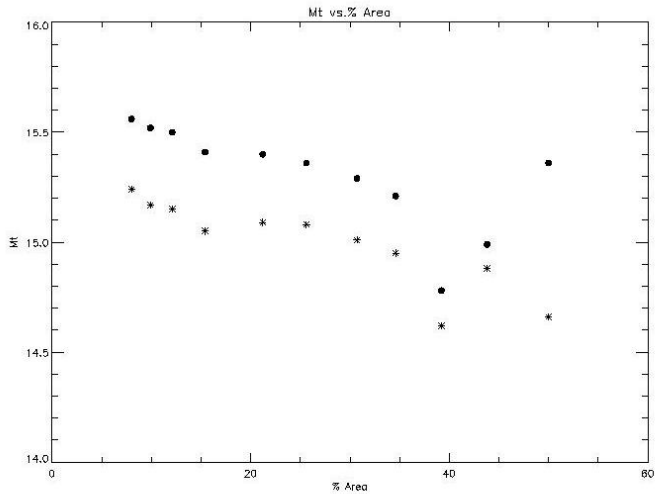
Good agreement with 1D parameters in the optical

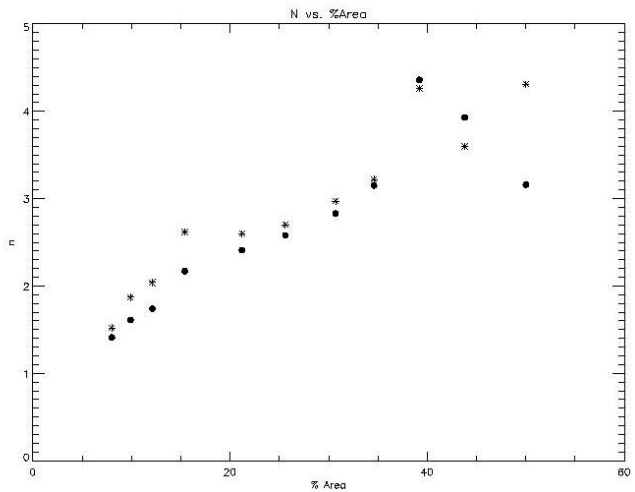


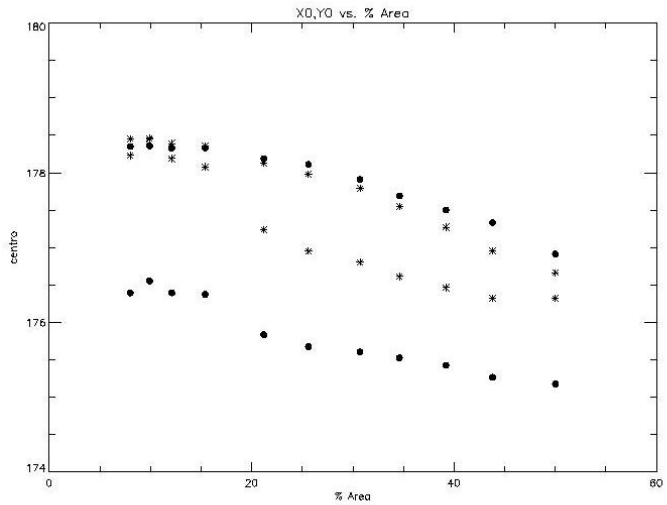
2D Fitting with GALFIT

Stability of parameters



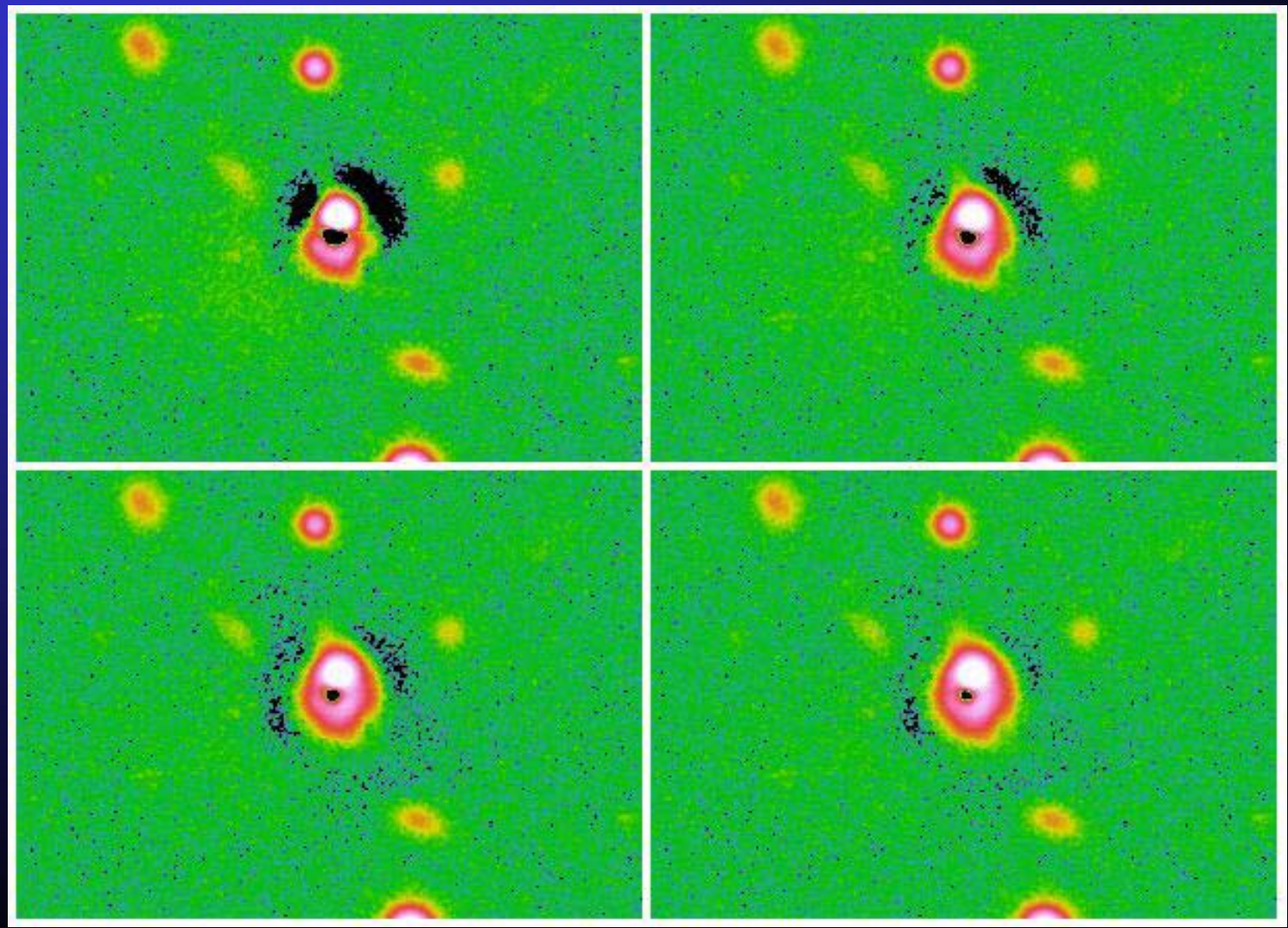






2D Fitting with GALFIT

Iterative process in the estability range



Work in progress

- To work in order to refine the method in order to fit all the sample in the next months

- To obtain deep broad and narrow band images in order to improve the fit

  Aproved proposals (first semester 2005) :

  TNG/NICS

  NOT/ALFOSC

  WHT/LIRIS