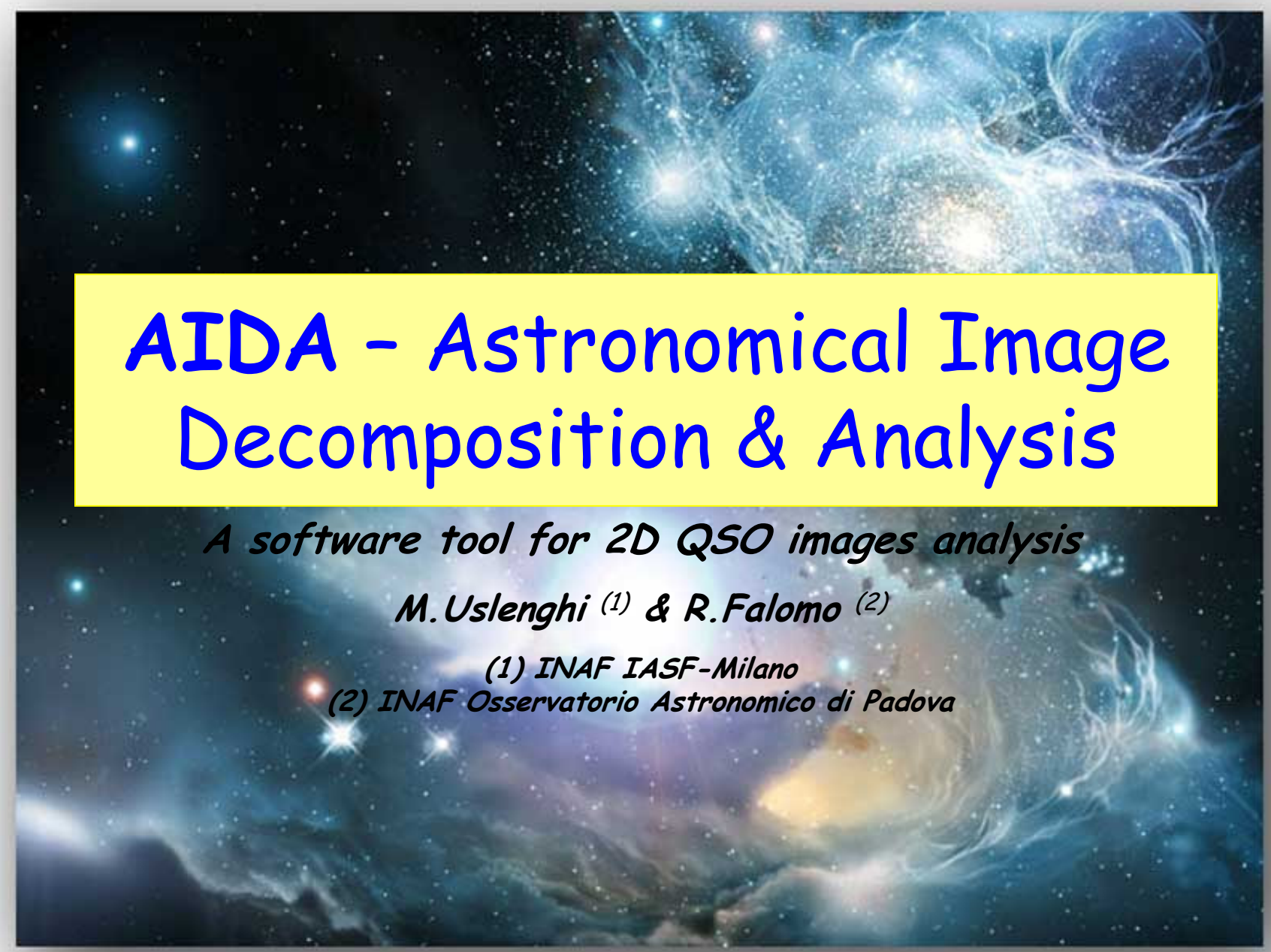

AIDA – Astronomical Image Decomposition & Analysis

A software tool for 2D QSO images analysis

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Detection of Quasar hosts

- To detect & characterize high z quasars hosts is required:
  - High spatial resolution (narrow PSF)
  - Good sensitivity

  $\Rightarrow$ HST, AO

  But … complex PSF shape, variable in the FOV

- Detection of the faint extended emission surrounding a bright point source requires careful characterization of the PSF $\rightarrow$ simultaneous decomposition into nuclear & host components by model fitting:

  (galaxy+nucleus) $\otimes$ PSF

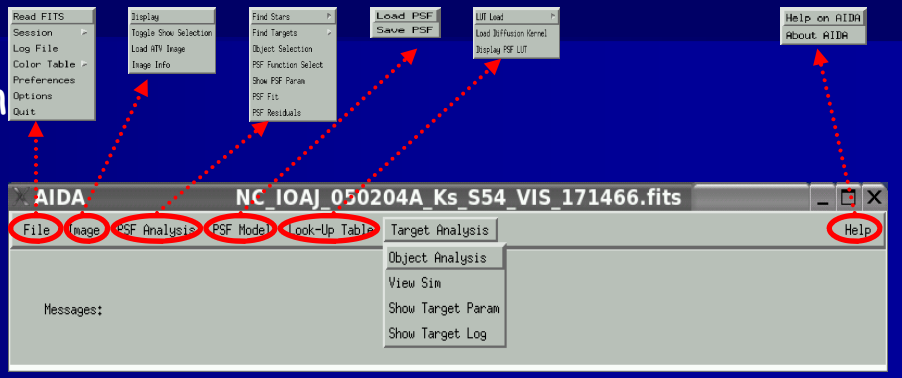
- Correct decoupling of the shape of the host galaxy and shape of the PSF requires 2d modeling (see e.g. Taylor, Dunlop et al. 1996, Kuhlbrodt et al. 2004, Peng et al. 2002)

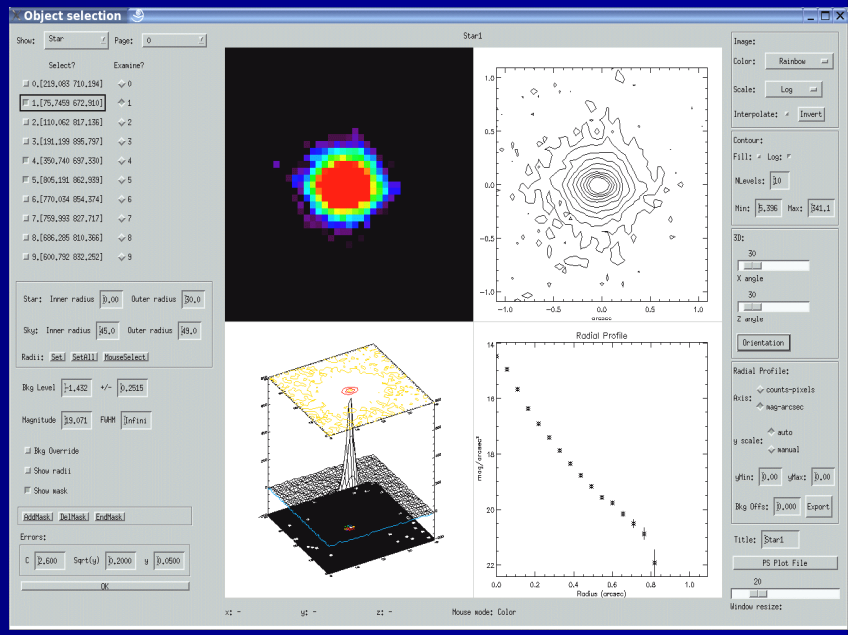
Why a new software ?

- Various "personal" SW (usually not available &/or not documented ….)
- GALFIT usable for galaxy dominated objects; poor results for nucleus dominated objects (QSO, ..)
- No interactive SW available to support analysis of "complex" cases

AIDA: Software Overview

- Developed in IDL 6.0, based on Widgets GUIs (but /NOWIDGET mode is available)
- Tested under Windows XP / Linux SuSE 9.2 / Linux Red Hat
- Simultaneous decomposition into nuclear & host components
  - Step 1: Sources selection/image preparation
  - Step 2: PSF model extraction
  - Step 3: Target model fitting
  - Step 4: Output

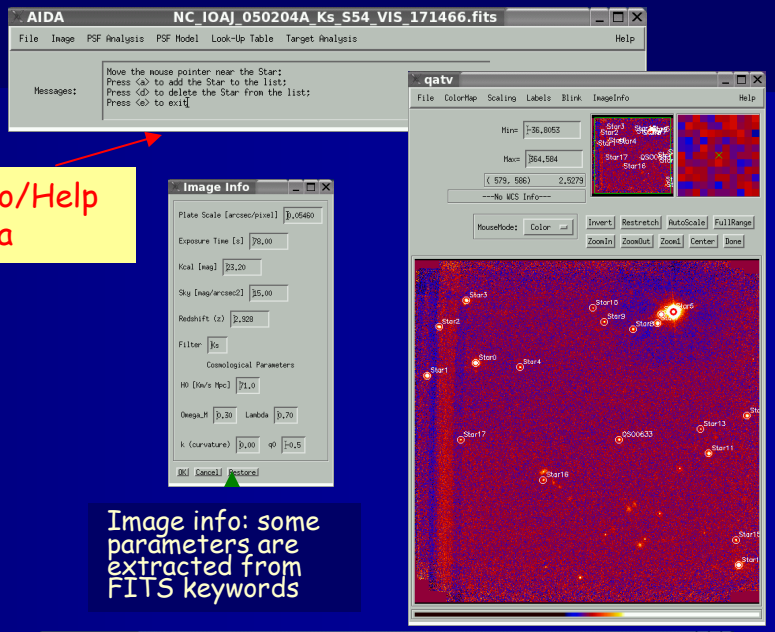


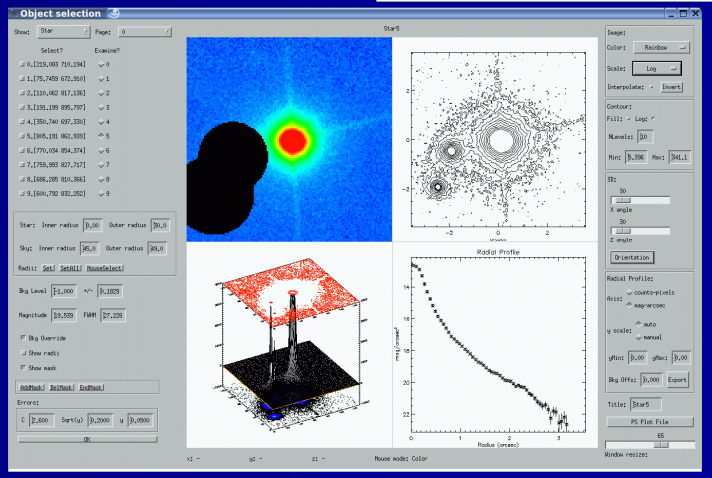


Step 1: - Sources selection/image preparation

Image visualization and preliminary source selection based on a modified version of ATV *(Barth, A. J. 2001, in ASP Conf. Ser. 238,385)*

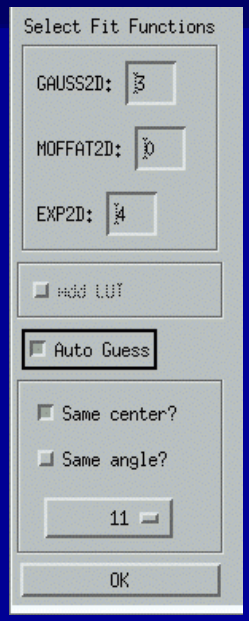
- Select stars to be included in the PSF analysis
- For each selected source:
  - Mask the image
  - Choose fit radii
  - Compute local background
  - Choose fit weighting model

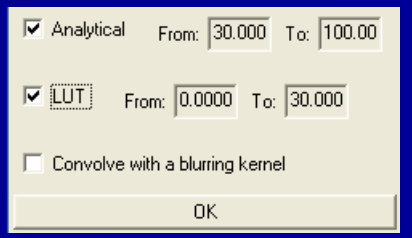




Step 2: PSF model extraction

- PSF model: analytical (any combination of provided 2d-functions) and/or empirical (e.g. TinyTim)
- 2d functions:
  - Gauss
  - Moffat
  - Exponential
- Possibility to define 2 different regions with different PSF models (e.g.: LUT in the core and mixed in the wings → HST)





Step 2: PSF model extraction

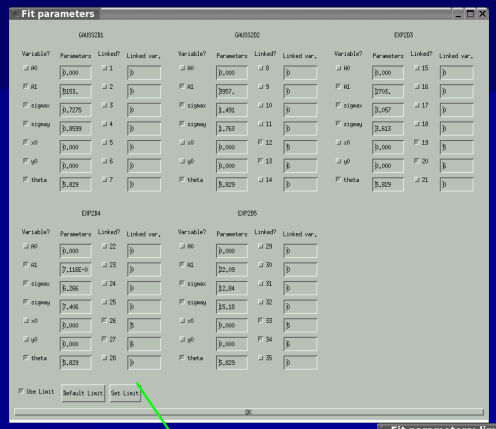
- Multiple stars fitting:
  - simultaneous fitting with the same model parameters

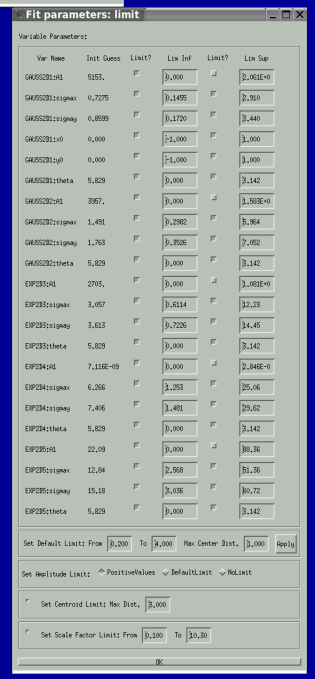
    or
  - individual stars fitting (to model PSF changes in the FOV) → using analytical models with a limited number of parameters, dependence of the PSF parameters on the position can be modeled

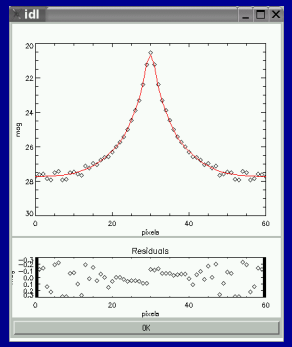
Model fitting: initial guesses

- Initial guess values for the fit parameters can be provided by filling the related form; constraints can also be set on each parameter…

↘ …the software can provide the initial guess & constraints automatically, basing on 1-d fitting of the best star profile, so that the intervention of the user is hardly ever required …



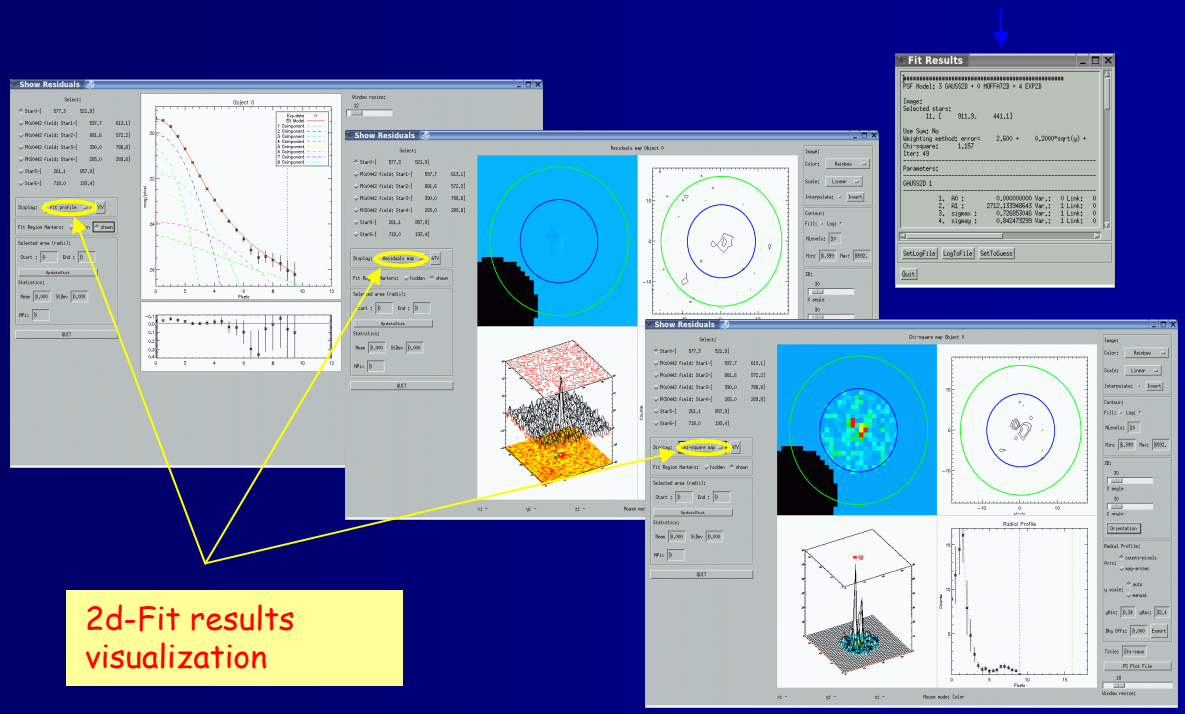




PSF Model Fitting

Text log file of the fit results

2D fit use a modified version of the CURFIT algorithm (*Bevington*)



2d-Fit results visualization

Step 3: Target Analysis

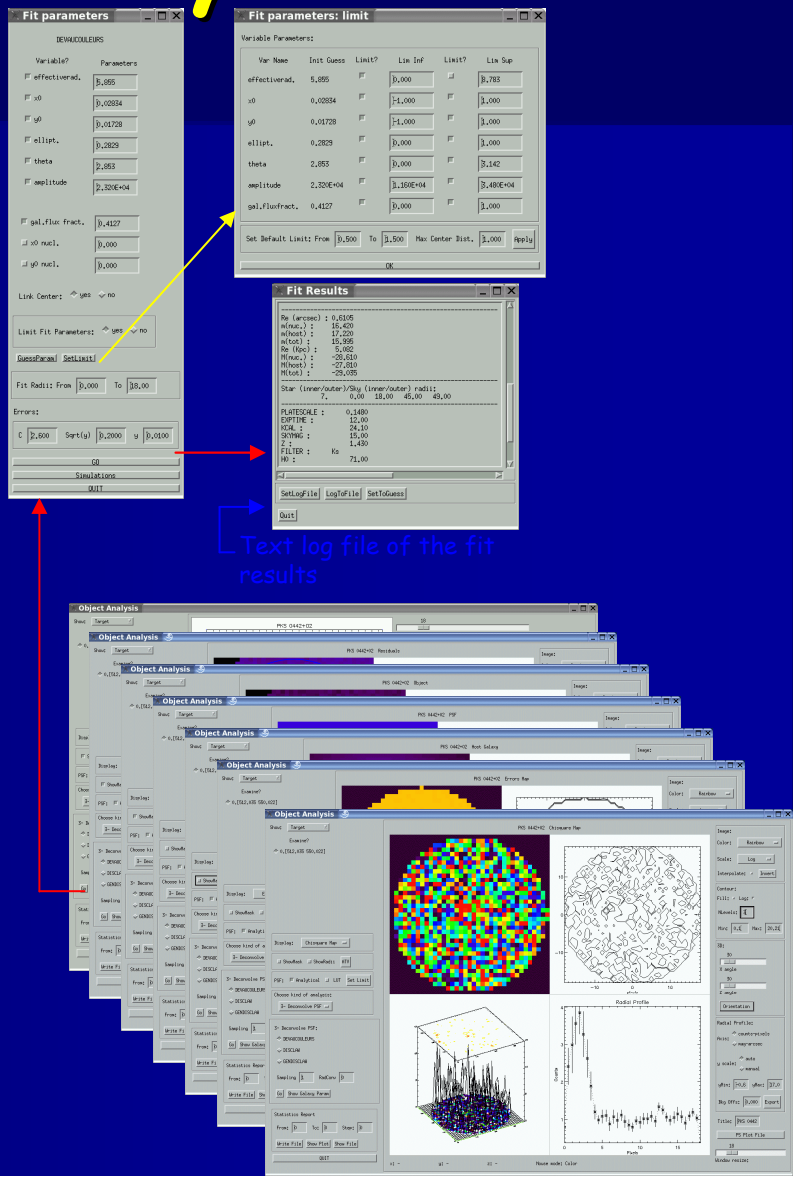
- ✓ Simple PSF subtraction

  or

- ✓ Model fitting with PSF convolution

Step 3: Target Analysis

- Convolved model:
  (galaxy+nucleus) ⊗ PSF
- Galaxy models:
  - De Vaucouleurs
  - Disc Law
  - Generalized Disc Law
  - No galaxy
  - … (other functions can be added by the user)
- To minimize the dependency on the initial guesses, a procedure can compute the fit with different initial guesses, randomly extracted in a suitable range

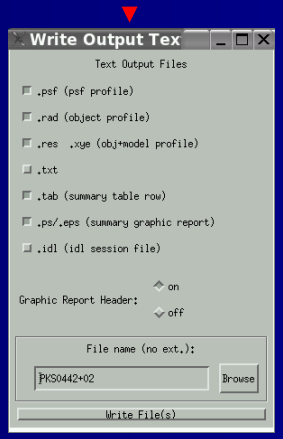


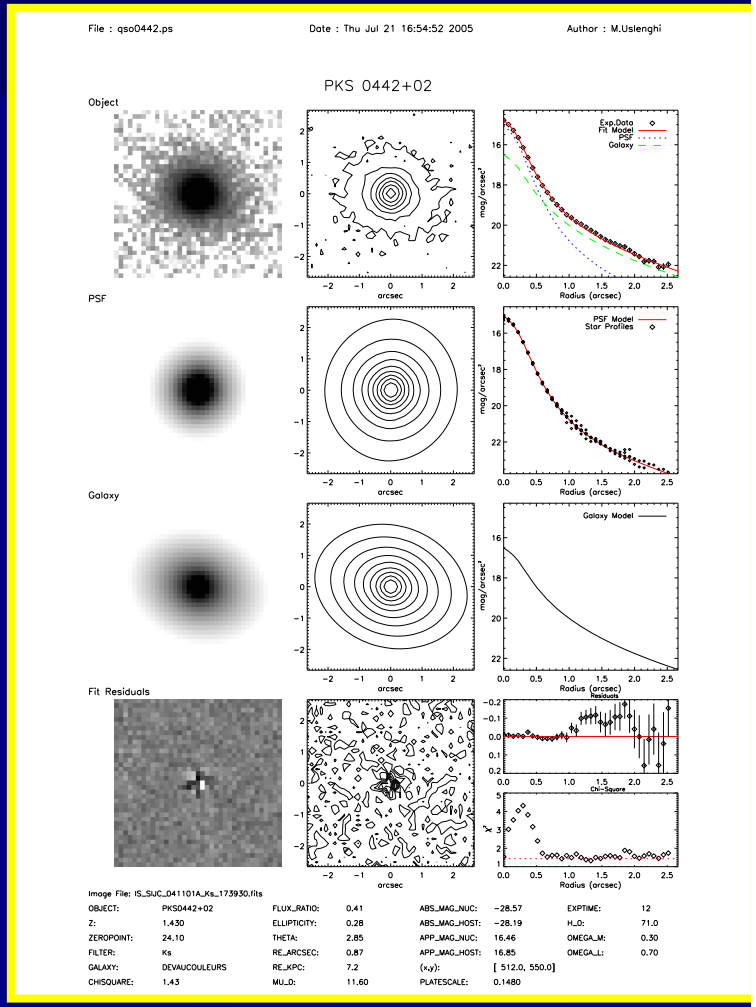
Error Evaluation

- An estimate of the errors associated with the computed parameters values can be obtained by simulating the process with synthetic quasars
- A simulation tool ($\rightarrow$ to build & analyze synthetic images) has been implemented:
  - synthetic quasars images are generated adding noise to the best fit model - then, the fit procedure is applied to the images, producing a "best fit" combination of parameters values for each image
  - for each parameter, the standard deviation of the best-fit values gives an estimate of the uncertainty on the parameters introduced by the noise

Output Products

- Output files can be generated in several formats, e.g:
  - Text files
  - Session IDL file
  - PS graphic report including relevant plots & results of the analysis





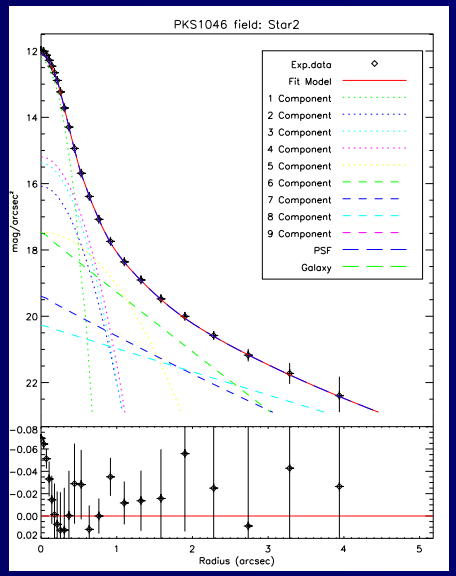
Examples with astronomical data

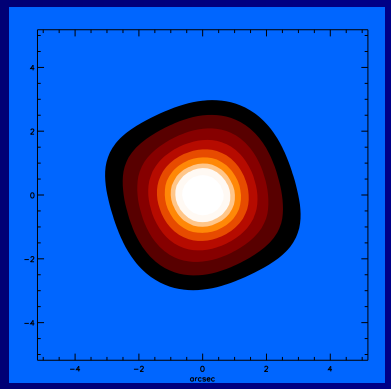
We used AIDA to analyze several astronomical data sets:

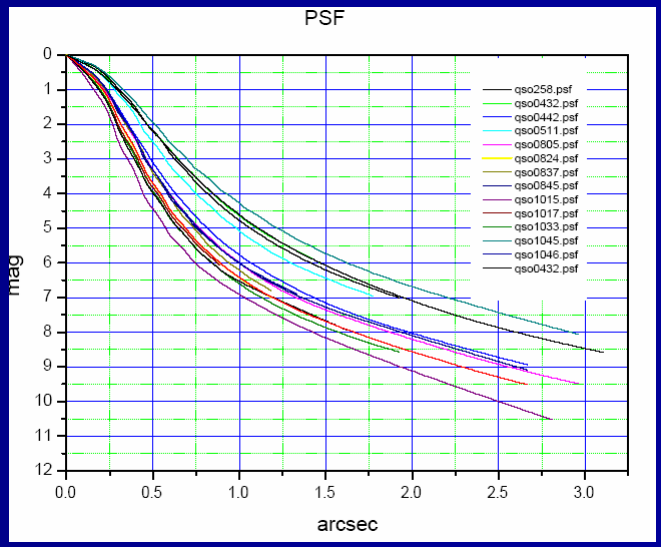
- **VLT/ISAAC**: $1.221 \leq z \leq 1.895$ 15 objects (13 resolved, 1 marginally resolved) *Kotilainen et al., in preparation*
- **NOT/NOTCam** (NIR): $0.515 \leq z \leq 0.994$ 15 objects (12 resolved) *Hyvönen et at., submitted to A&A*
- **HST/WFPC2**: 5 objects (2 resolved) *Labita et al., submitted to MNRAS*
- **VLT/NACO**: $2.030 \leq z \leq 2.928$ 3 objects *Falomo et al., in preparation*

VLT/ISAAC

- Fully analytical PSF (~ 5 gaussians + 3 exponentials)
- PSF invariant in the FOV -> all the stars in the FOV are fitted with the same model





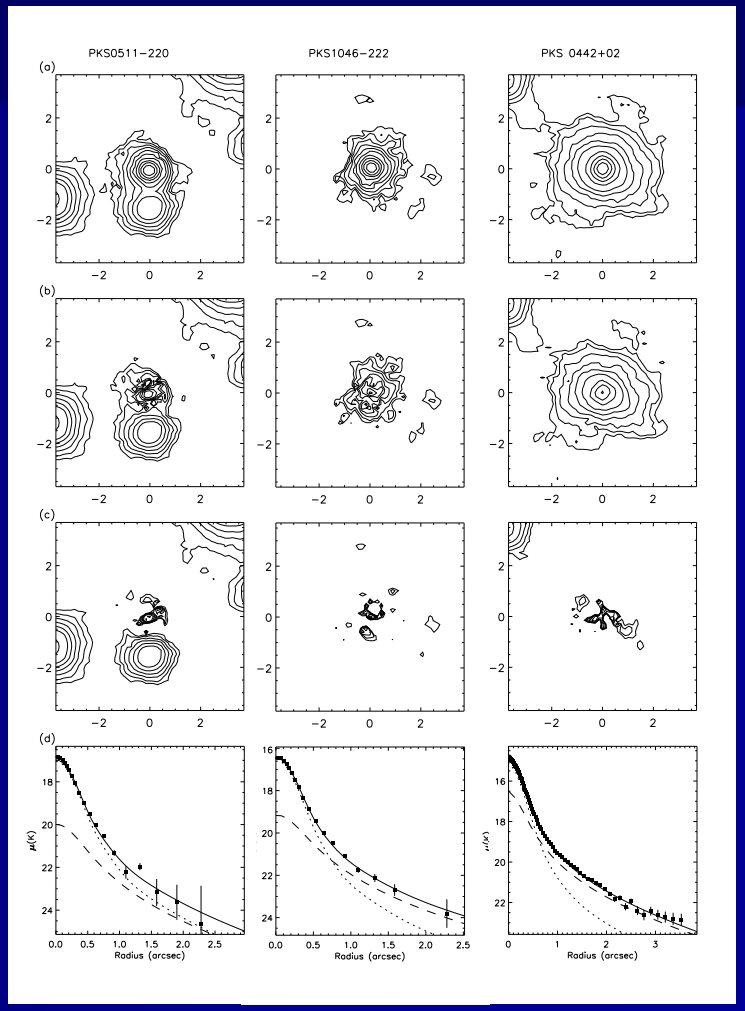


VLT/ISAAC

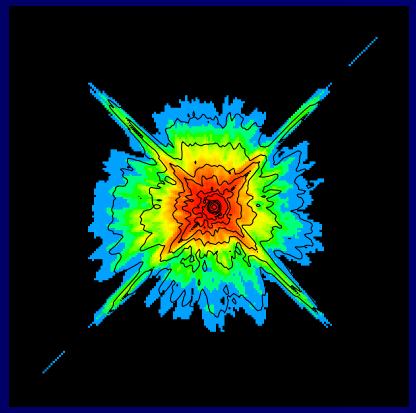
Quasar	z	Filter	m_{nuc}[a]	m_{host}[a]	r_e (arcsec)	χ^2_{DV}[b]	χ^2_{DL}[c]	χ^2_{PSF}[d]
Radio Quiet Quasars								
Q 0335-3546	1.841	K	17.9	20.1±0.4	1.1±0.5	0.6	0.4	1.4
MS 0824.2+0327	1.431	K	18.4	18.1±0.1	0.5±0.1	1.0	1.1	19.0
2QZ J101733-0049	1.342	H	19.0	20.2±0.3	0.9±0.2	1.3	1.2	4.2
2QZ J101733-0203	1.895	K	18.8	19.9±0.2	1.0±0.6	1.6	1.3	4.0
TOL 1033.1-27.3	1.610	K	19.2	17.3±0.1	0.6±0.1	3.6	1.5	67.1
Q 1045+056	1.230	H	17.4	>20.1	...	-	-	0.9
Radio Loud Quasars								
PKS 0258+011	1.221	H	17.5	19.0±0.2	0.7±0.2	0.8	1.0	6.6
PKS 0432-148	1.899	K	17.2	19.6±0.3	1.2±0.2	1.2	1.5	2.0
PKS 0442+02	1.430	K	16.5	16.8±0.1	0.8±0.2	1.1	3.5	33.5
PKS 0511-220	1.296	H	18.1	19.5±0.3	0.7±0.2	1.5	1.6	3.5
PKS 0805-07	1.837	K	16.0	19.2±***	0.6±***	-	-	0.9
PKS 0837+035	1.570	K	17.6	19.3±0.3	0.9±0.3	1.0	2.4	4.1
PKS 0845-051	1.242	H	17.8	18.2±0.1	0.6±0.2	0.5	7.9	38.7
PKS 1015-31	1.346	H	16.1	18.1±0.1	0.9±0.2	1.0	2.3	17.7
PKS 1046-222	1.609	K	17.9	18.7±0.2	0.7±0.2	1.2	1.2	10.3

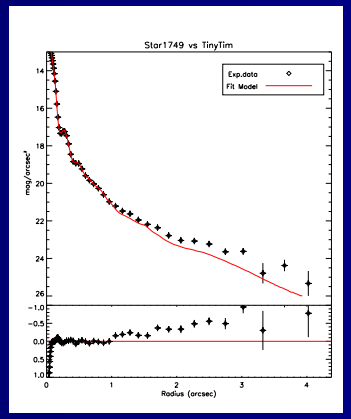
$1.221 \leq z \leq 1.895$

Kotilainen et al., in preparation

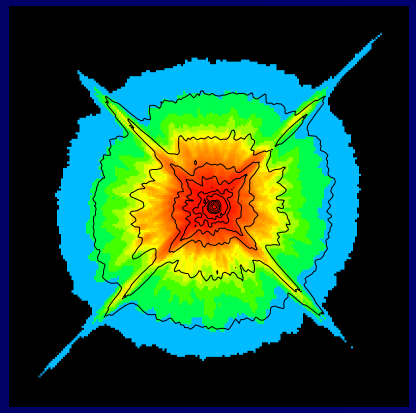


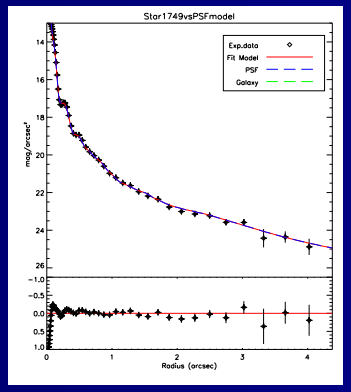
HST PSF





TinyTim PSF



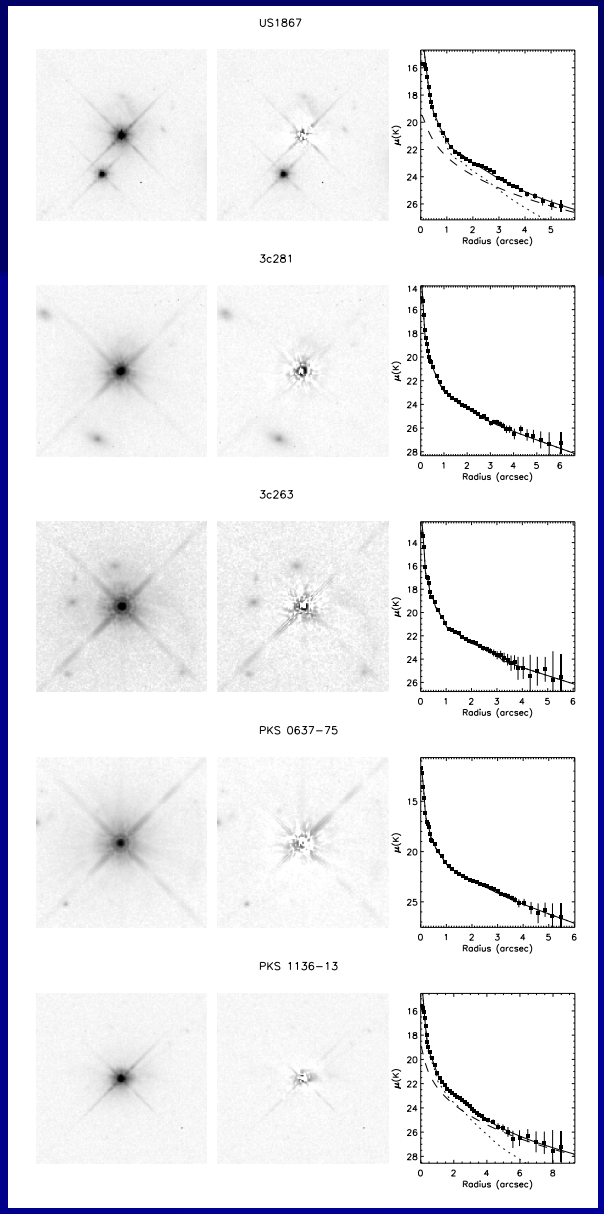


Mixed PSF model: empirical in the inner part (-> TinyTim generated); empirical+analytical (3 exp. Components) in the wings

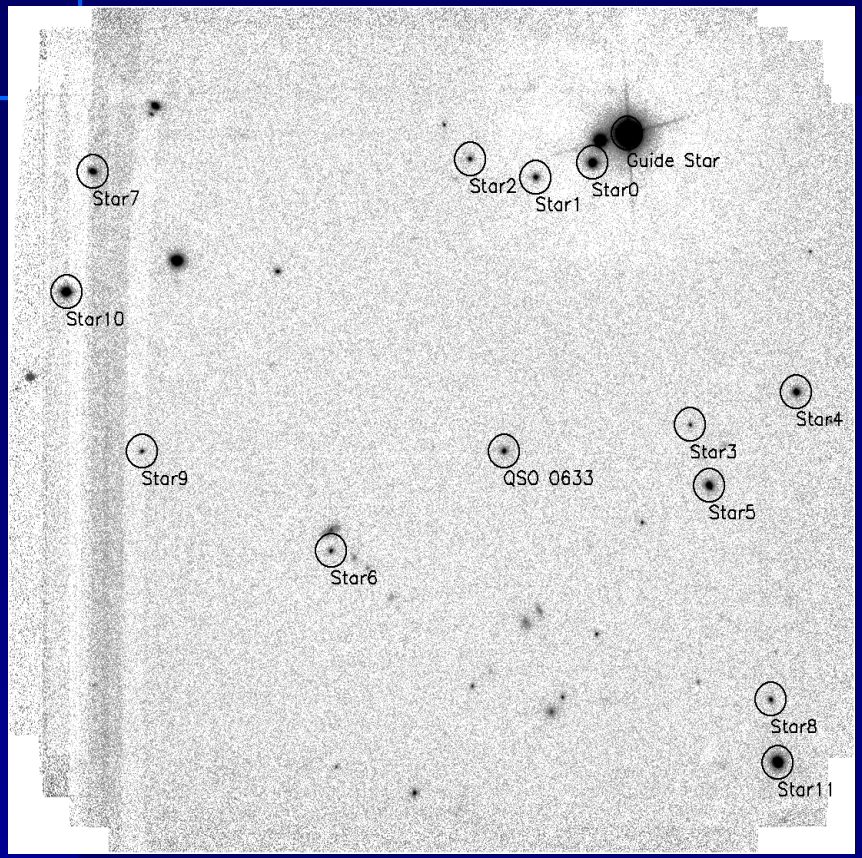
HST WFPC2 images

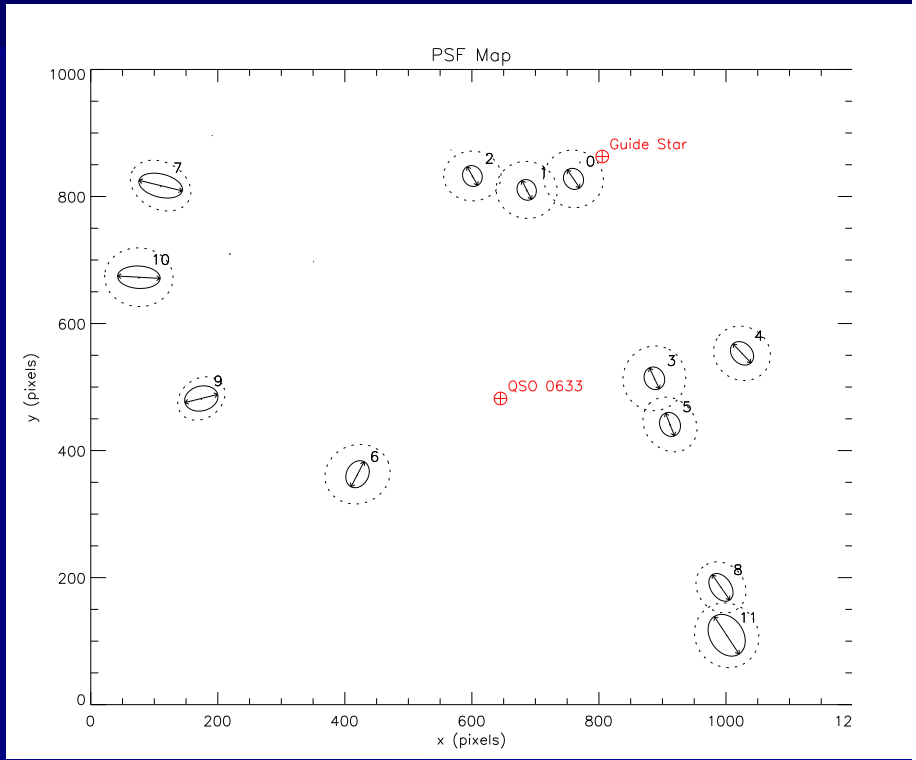
5 objects, 2 resolved

M.Labita et al., submitted to MNRAS



AO: VLT/NACO (detecting host galaxies at z~3)





Analytical PSF, but strongly variable in the FOV

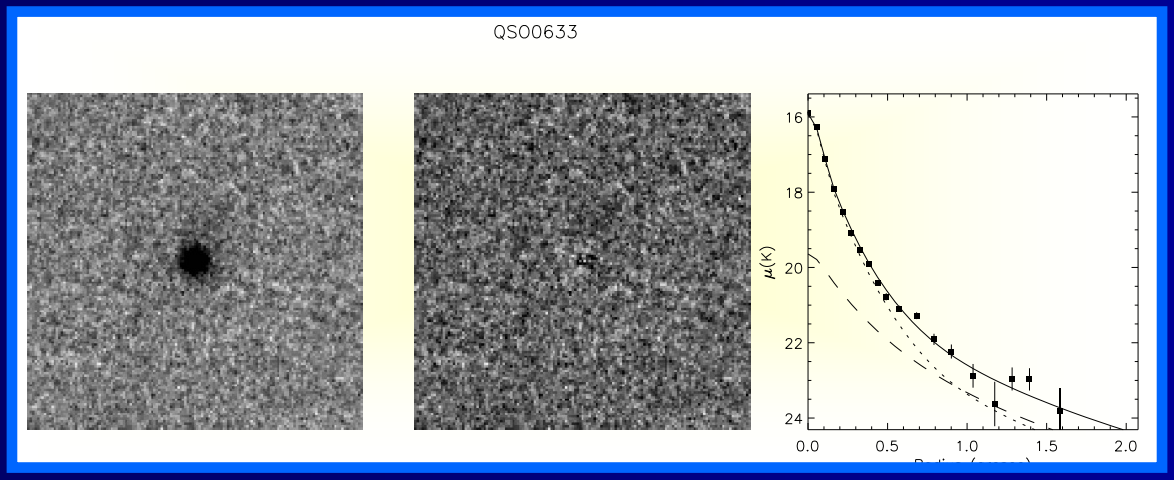
VLT/NACO

WGA J0633.1-2333 (z=2.928)

M_k=-27.1

R_e=6.5 kpc

(H=70, Ω_m=0.3, Ω_Λ=0.7)



Falomo et al., in preparation

Conclusions

- We developed AIDA, a user friendly software for 2D analysis of QSO images (possible applications in other fields…):
  - can manage complex PSF models, including characterization of spatial variability
  - can work in "interactive" mode & in batch mode
  - tested with simulated images and then successfully used to analyze real data from different instruments, including AO with strong dependence of the PSF on the position