

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

⇒ 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 → simultaneous decomposition into nuclear & host components by model fitting:

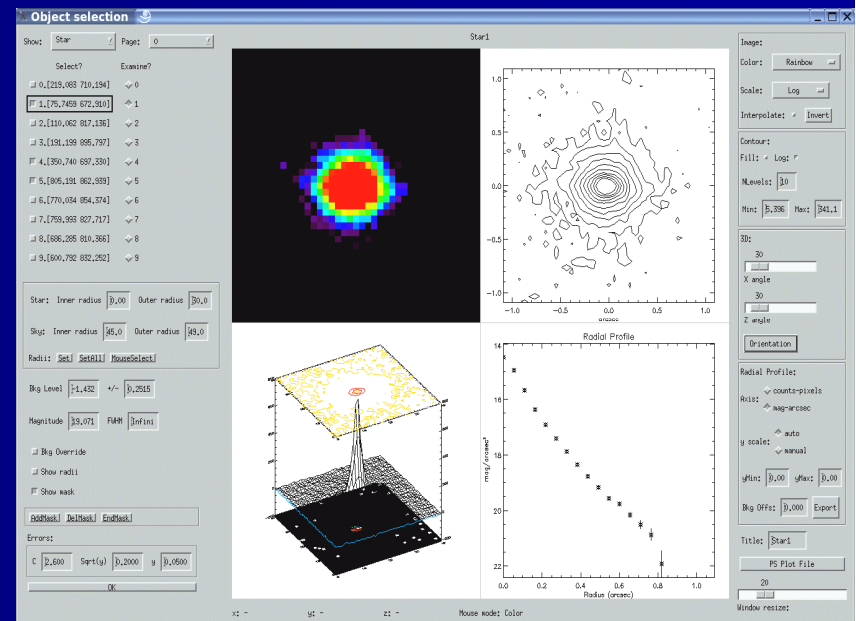
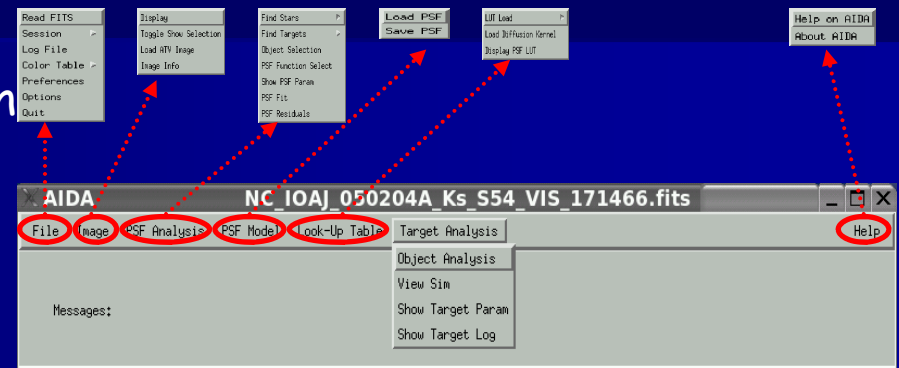
(galaxy+nucleus) \otimes PSF
- Correct decoupling of the shape of the host galaxy and shape of the PSF requires 2d modeling (see e.g. Taylor, Dunlop et al. 1996, Kuhlbrodt et al. 2004, Peng et al. 2002)

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

Montagnana, 23-26/5/2006

AGN7

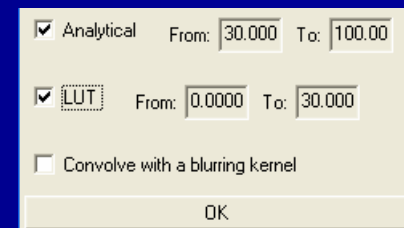
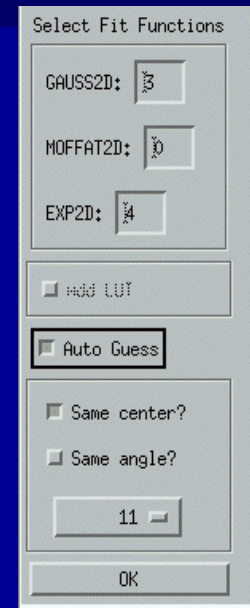
The screenshot displays the AIDA software interface with several windows open:

- AIDA (NC IOA) 050204A Ks S54 VIS_171466.fits**: The main application window with a message box that says: "Move the mouse pointer near the Star; Press <A> to add the Star to the list; Press <D> to delete the Star from the list; Press <E> to exit!".
- qatv**: A window showing a star field image with several stars labeled (Star1, Star2, Star3, Star4, Star5, Star6, Star7, Star8, Star9, Star10, Star11, Star12, Star13, Star14, Star15, Star16, Star17, Star18). It includes controls for Min, Max, and WCS Info.
- Image Info**: A window showing extracted parameters from FITS keywords:
 - Plate Scale [arcsec/pixel]: 0.65460
 - Exposure Time [s]: 78.00
 - Kcal [mag]: 23.20
 - Sky [mag/arcsec²]: 35.00
 - Redshift (z): 0.328
 - Filter: Ks
 - Cosmological Parameters:
 - H0 [km/s/Mpc]: 71.0
 - Omega_m: 0.30
 - Lambda: 0.70
 - k (curvature): 0.00
 - q0: -0.05
- Object selection**: A window with a table of stars and their coordinates:

Star	RA	DEC	Page	Exclusion?
0	0.123,083	70.194	0	
1	1.176,749	67.360	1	
2	2.119,062	67.183	2	
3	3.131,199	69.797	3	
4	4.136,740	69.139	4	
5	5.186,138	66.899	5	
6	6.177,058	69.174	6	
7	7.175,965	67.737	7	
8	8.166,268	65.361	8	
9	9.160,782	62.252	9	
- Star5**: A window showing a zoomed-in view of a star with a radial profile plot and a 3D surface plot. The radial profile plot shows intensity vs. radius (arcsec).

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)



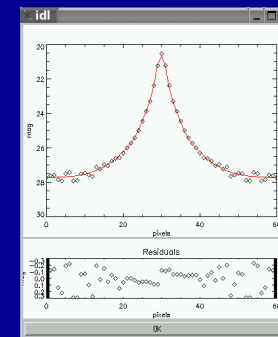
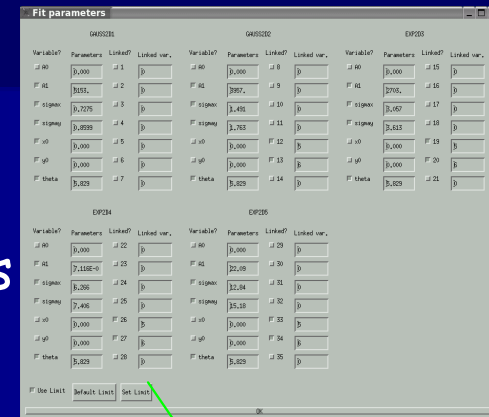
Step 2: PSF model extraction

- 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 ...



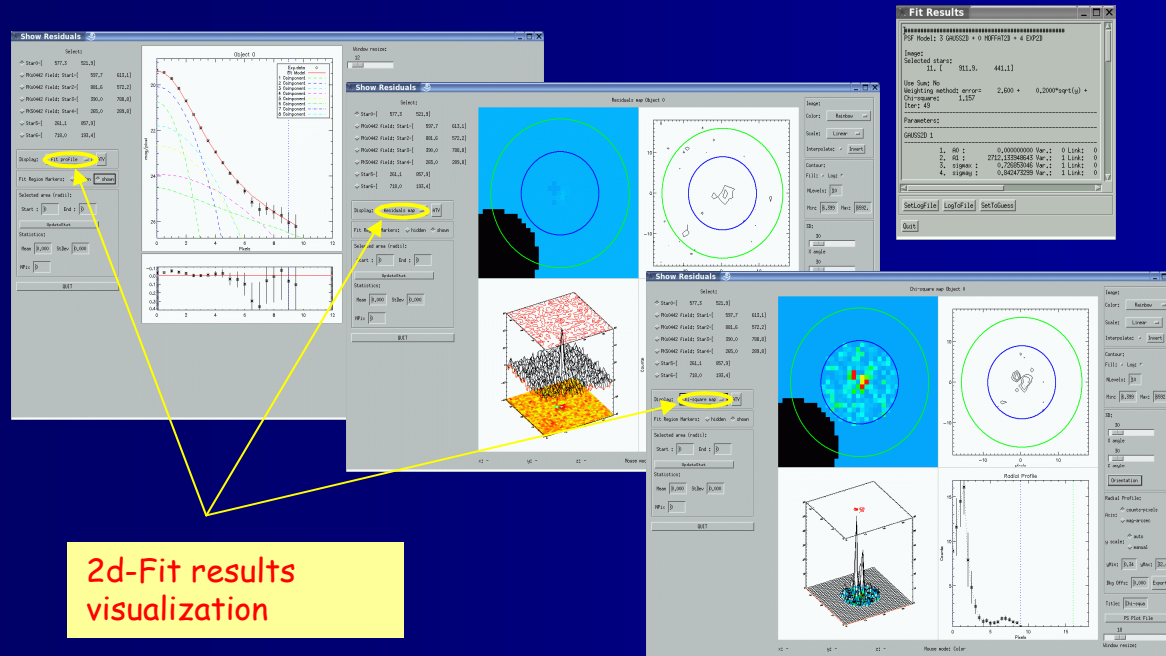
The 'Fit parameters: limit' dialog box shows a table of parameter limits for the fit. The table includes columns for Variable Name, Initial Guess, Limit?, Lin Inf, Lin Sup, and Lin Sup. The parameters are listed with their corresponding initial values and limits.

Variable Name	Init Guess	Limit?	Lin Inf	Lin Sup
GAUSS1:ph	5153	FF	0,000	2,00E+0
GAUSS1:sigma	0,7275	FF	0,1495	2,910
GAUSS1:w	0,8999	FF	0,1720	3,440
GAUSS1:p	0,000	FF	-1,000	1,000
GAUSS1:theta	5,829	FF	0,000	3,142
GAUSS2:ph	3357	FF	0,000	1,500E+0
GAUSS2:sigma	1,491	FF	0,2982	3,964
GAUSS2:w	1,763	FF	0,3026	7,062
GAUSS2:theta	5,829	FF	0,000	3,142
EXP1:ph	2703	FF	0,000	1,00E+0
EXP1:sigma	3,067	FF	0,6114	12,23
EXP1:w	3,613	FF	0,7226	14,45
EXP1:theta	5,829	FF	0,000	3,142
EXP2:ph	7,115E-09	FF	0,000	2,848E+0
EXP2:sigma	6,266	FF	1,203	25,06
EXP2:w	7,466	FF	1,491	29,62
EXP2:theta	5,829	FF	0,000	3,142
EXP3:ph	22,99	FF	0,000	38,36
EXP3:sigma	12,04	FF	0,568	31,36
EXP3:w	15,19	FF	0,636	30,72
EXP3:theta	5,829	FF	0,000	3,142

PSF Model Fitting

Text log
file of the
fit results

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

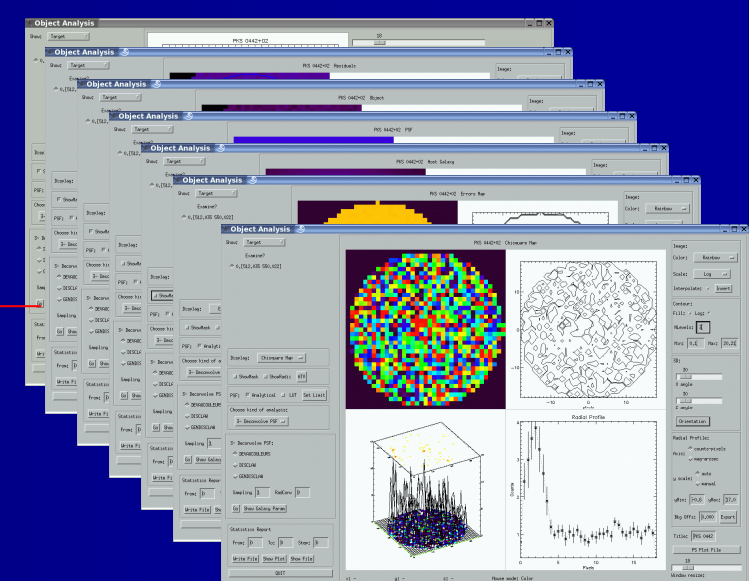
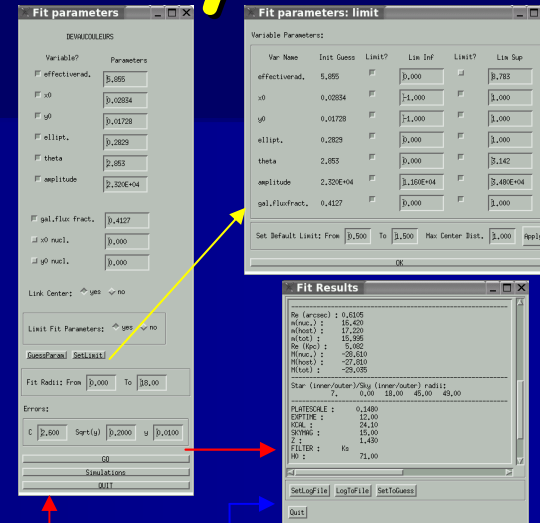


Step 3: Target Analysis

- ✓ Simple PSF subtraction
or
- ✓ Model fitting with PSF convolution

Step 3: Target Analysis

- Convolved model:
(galaxy+nucleus) \otimes 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

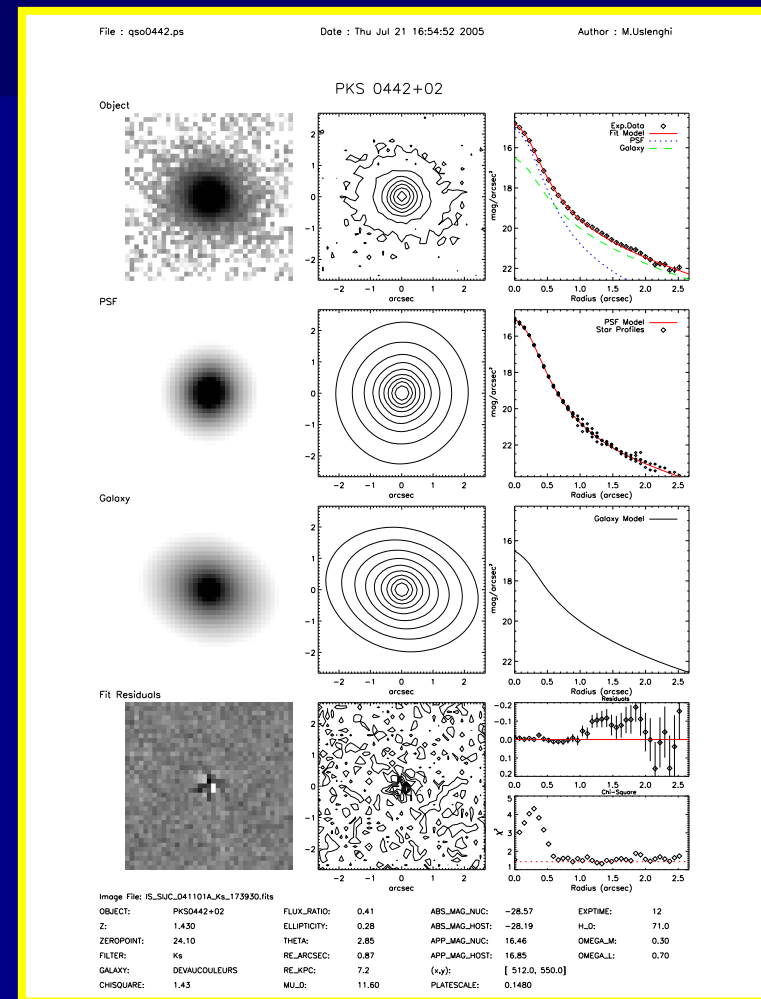
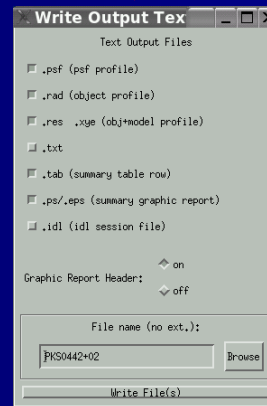


Error Evaluation

- An estimate of the errors associated with the computed parameters values can be obtained by simulating the process with synthetic quasars
- A simulation tool (→ 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



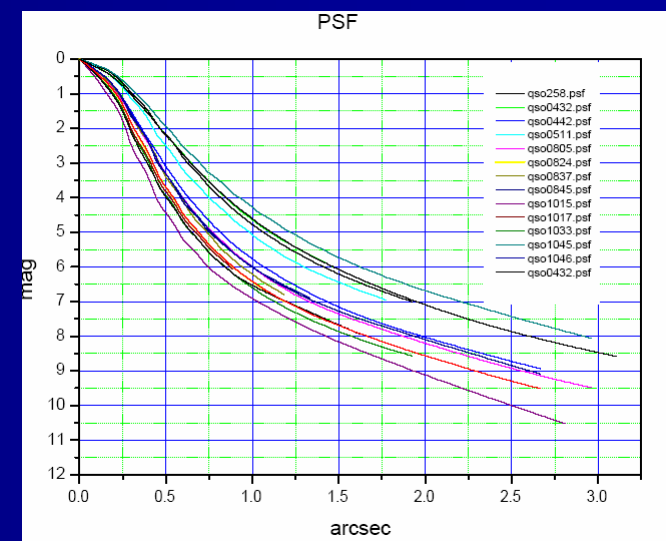
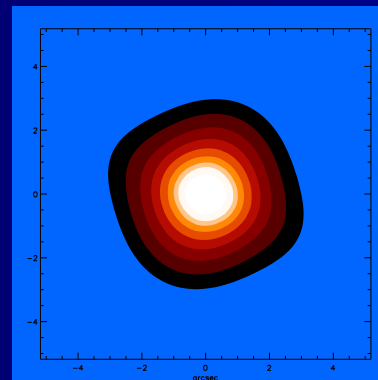
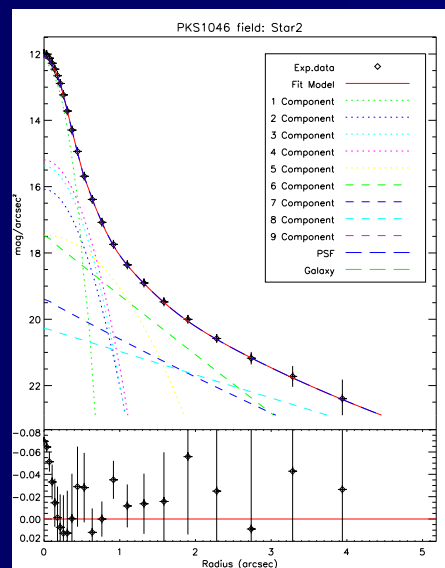
Examples with astronomical data

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 al., 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 \rightarrow all the stars in the FOV are fitted with the same model

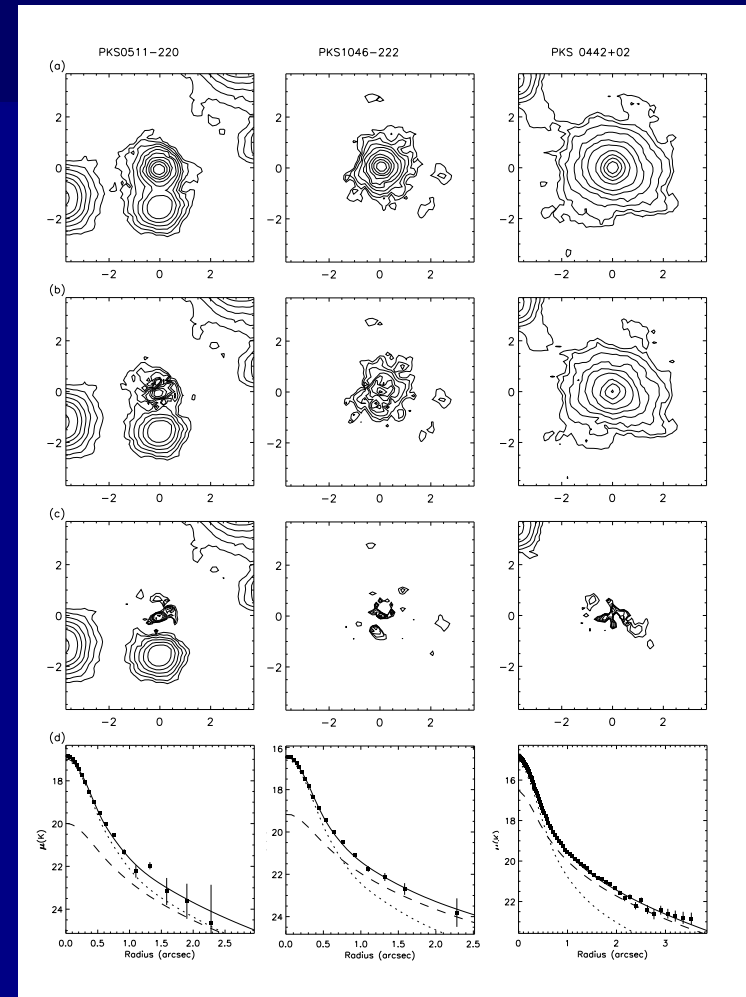


VLT/ISAAC

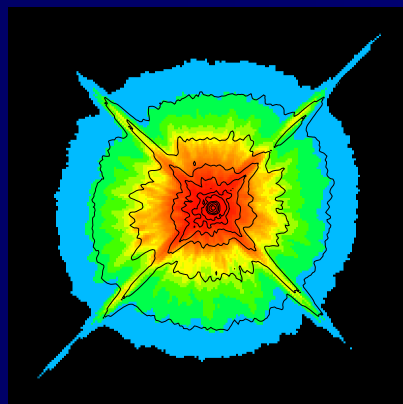
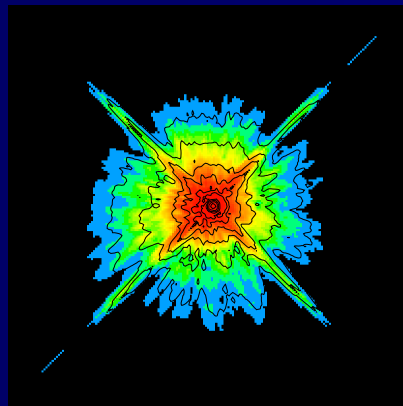
Quasar	z	Filter	m_{nuc}^a	m_{host}^a	r_e (arcsec)	$\chi_{DV}^2{}^b$	$\chi_{DL}^2{}^c$	$\chi_{PSF}^2{}^d$
Radio Quiet Quasars								
Q 0335-3546	1.841	K	17.9	20.1±0.4	1.1±0.5	0.6	0.4	1.4
MS 0824.2+0327	1.431	K	18.4	18.1±0.1	0.5±0.1	1.0	1.1	19.0
2QZ J101733-0049	1.342	H	19.0	20.2±0.3	0.9±0.2	1.3	1.2	4.2
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

$$1.221 \leq z \leq 1.895$$

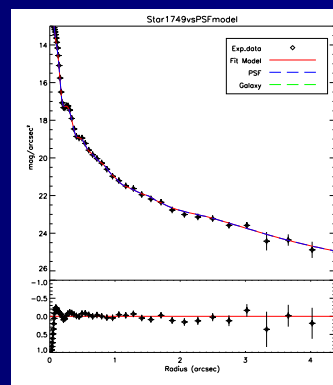
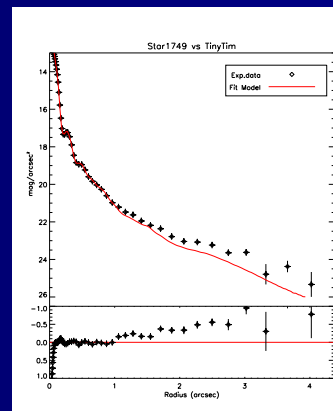
Kotilainen et al., in preparation



HST PSF



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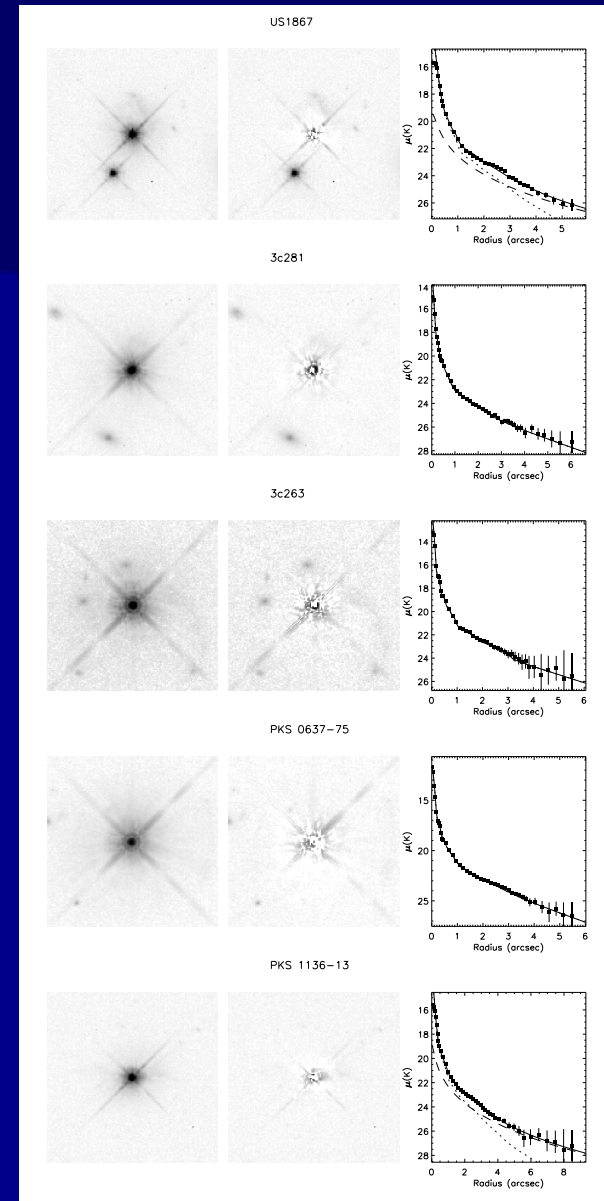
TinyTim PSF

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

HST WFPC2 images

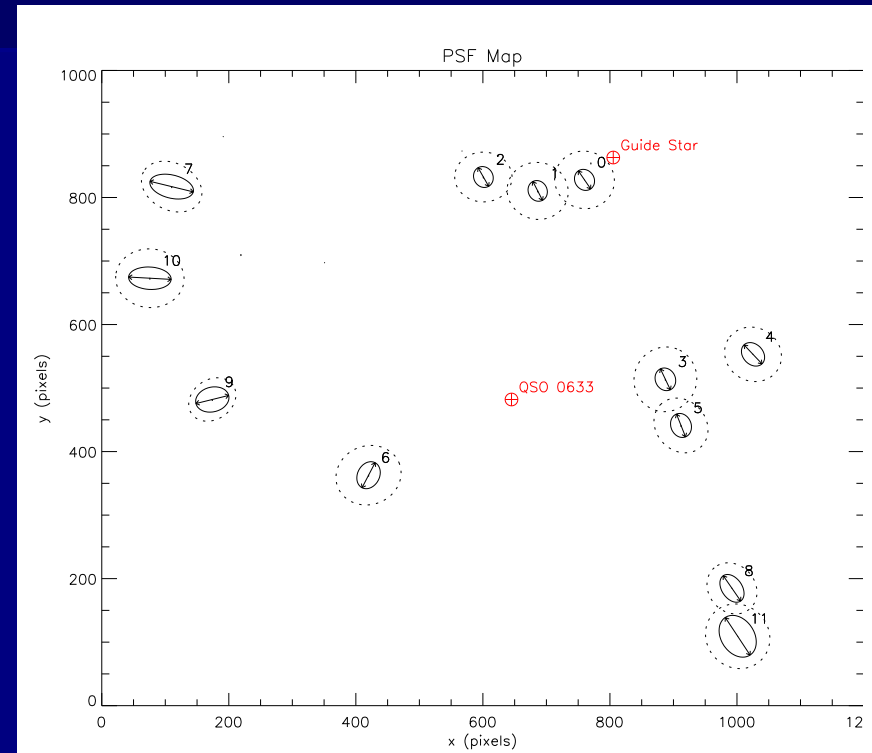
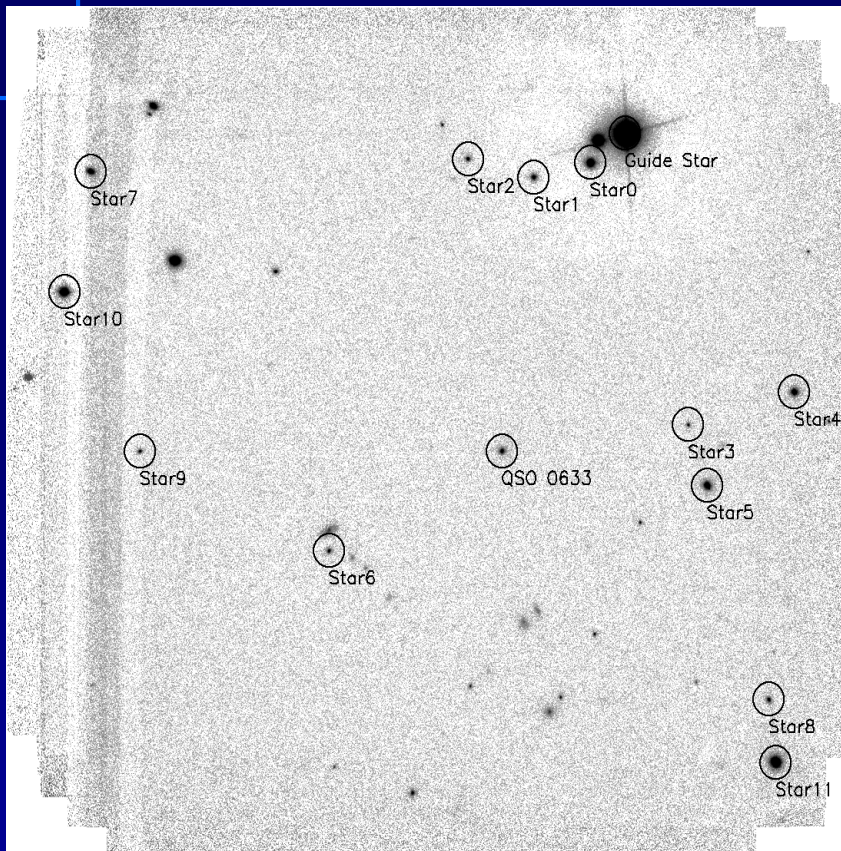
5 objects, 2 resolved

M.Labita et al., submitted to
MNRAS



AO: VLT/NACO

(detecting host galaxies at $z \sim 3$)



Analytical PSF, but strongly variable in the FOV

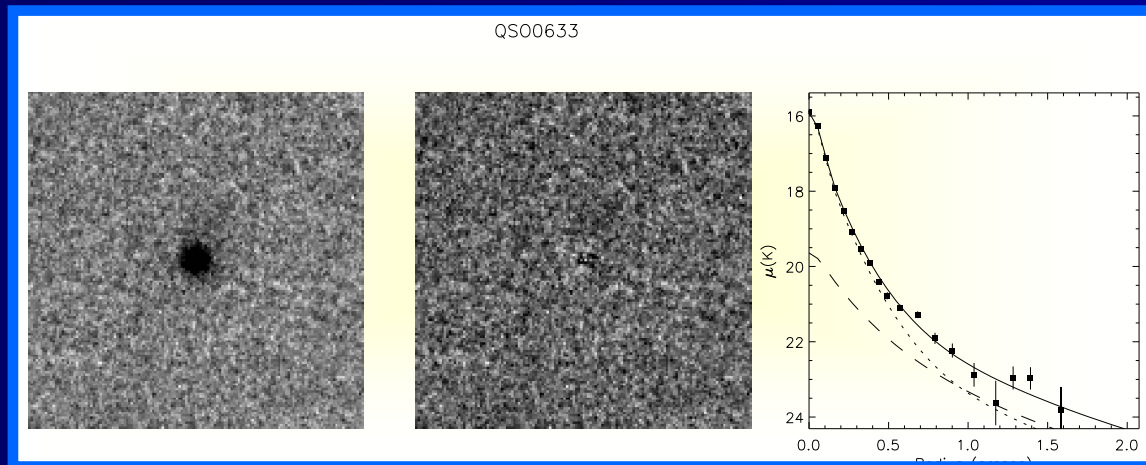
VLT/NACO

WGA J0633.1-2333 ($z=2.928$)

$M_k = -27.1$

$R_e = 6.5$ kpc

($H=70$, $\Omega_m=0.3$, $\Omega_\Lambda=0.7$)



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