# Morphology on large surveys with SExtractor + PSFEx


Aldée Charbonnier

B. Moraes, M. Elidaiana,
M. Makler, E. Bertin,
and the CS82 collaboration

Valongo Observatory
Rio de Janeiro


ESO, Chile, November 22th, 2013

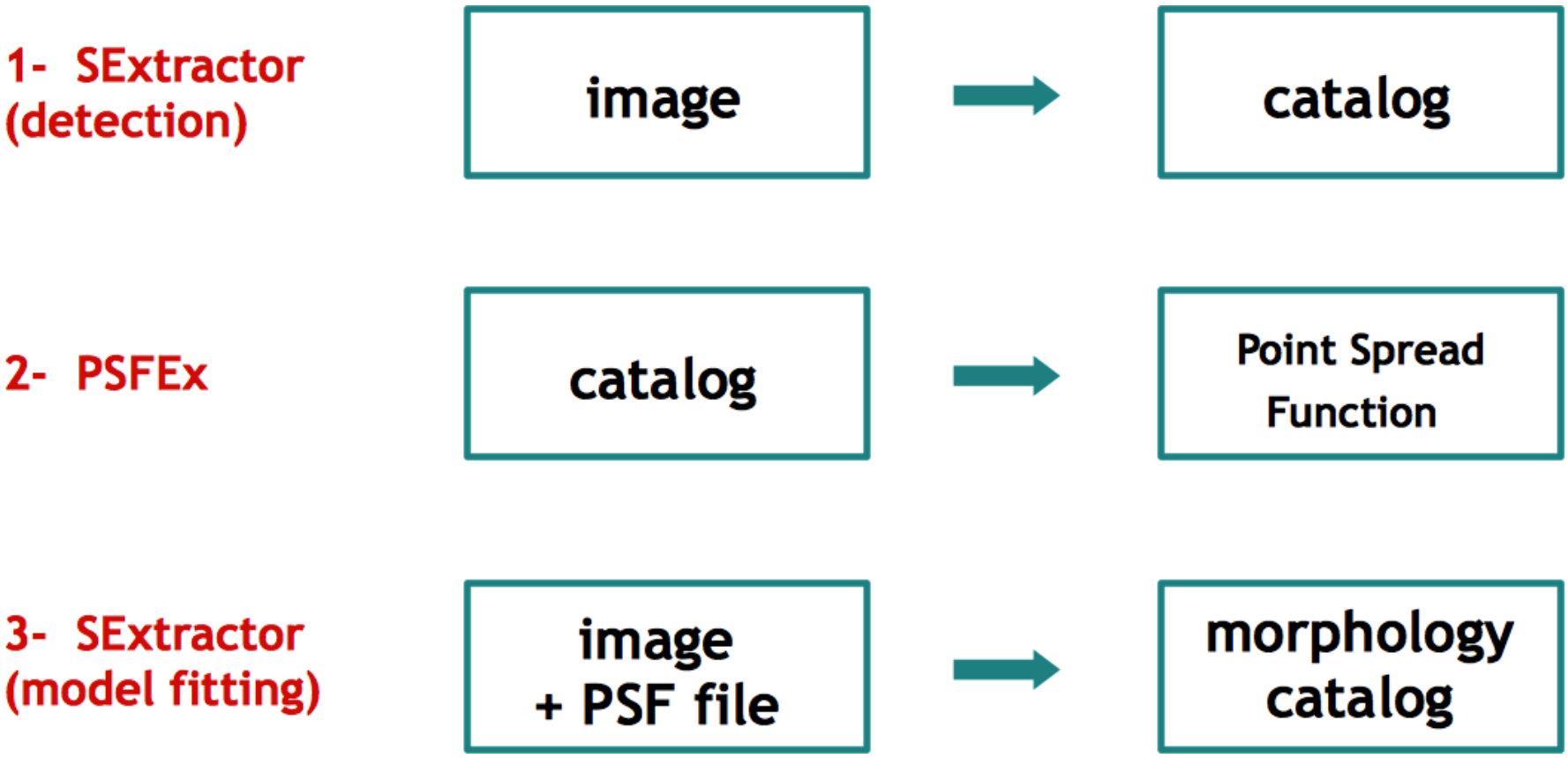
# Outline

SExtractor + PSFEx

CS82 survey

COSMOS field

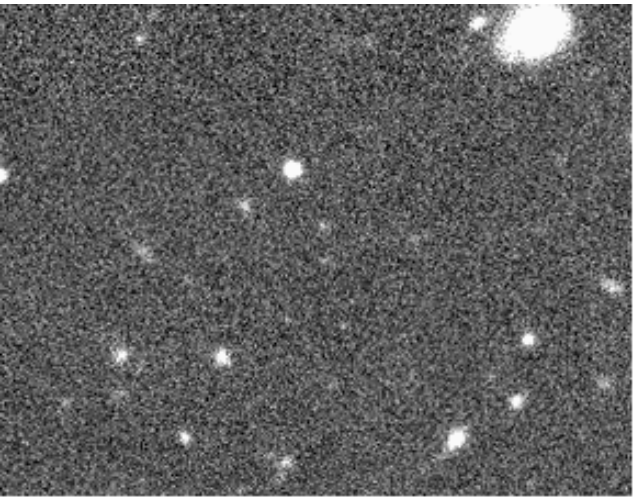
# General procedure




SExtractor: http://www.astromatic.net/software/sextractor
PSFEx: http://www.astromatic.net/software/psfex

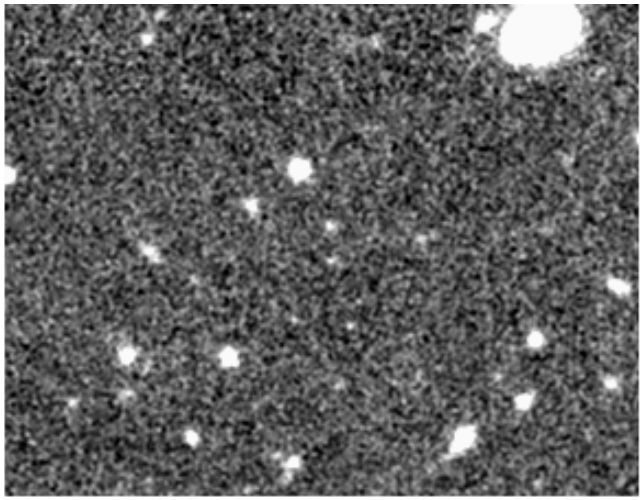
# SExtractor v.1

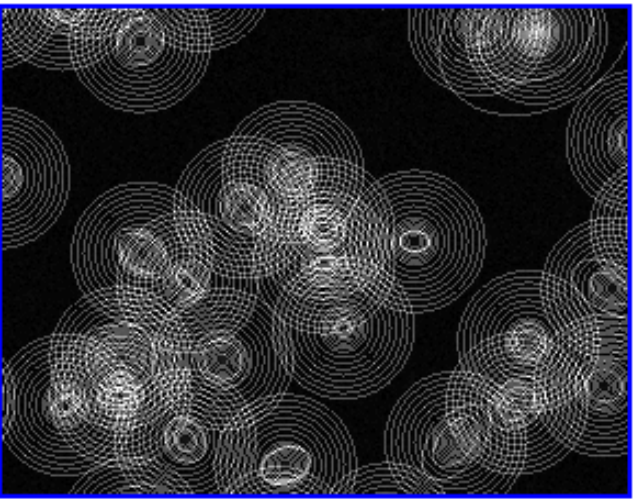
image



background

filtered



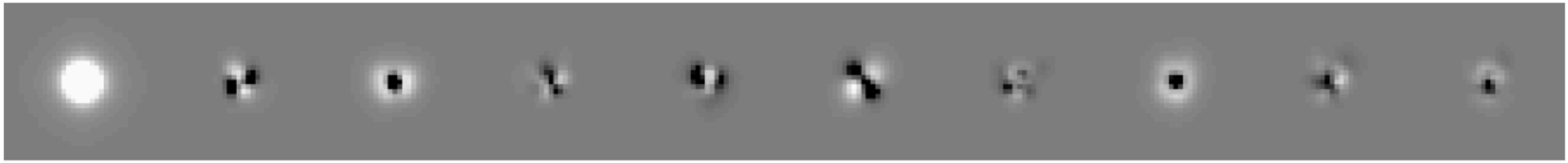


apertures

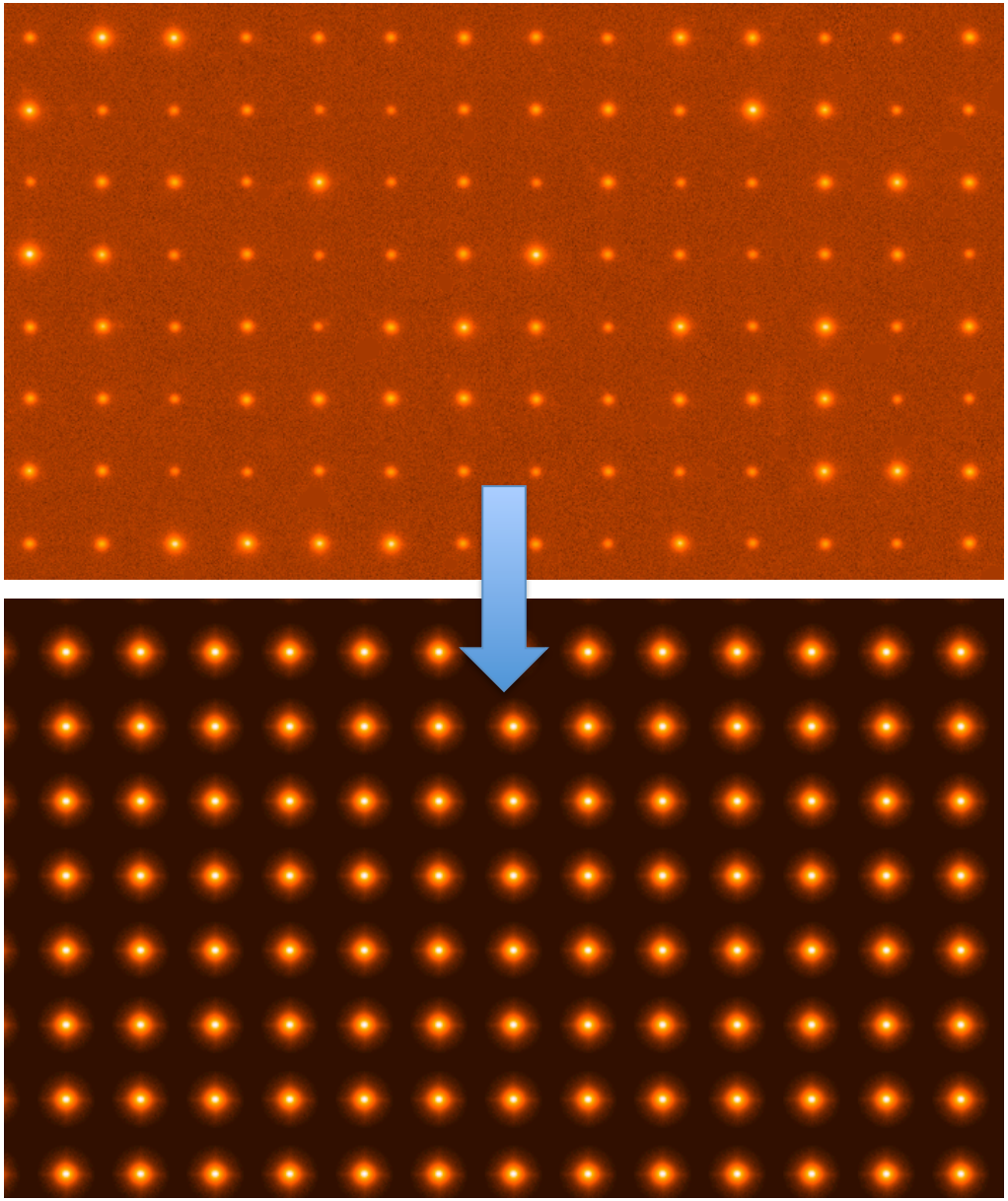
segmentation

# PSFEx ID card

- Solving in direct space (≠ Fourier)
- Automatically selects the point like sources
- PSF modeled as a linear combination of basis functions
- Weighted $\chi^2$ minimization
- **PSF variations may be decomposed on a polynomial basis**
- Homogenization is available



# PSF modelling

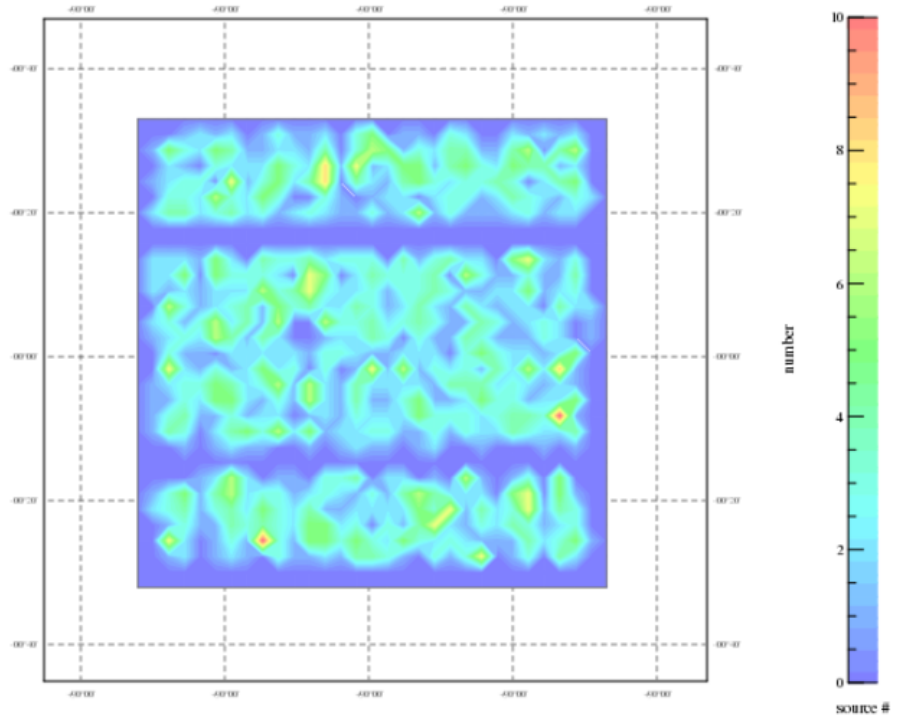


Automatic selection of point like sources

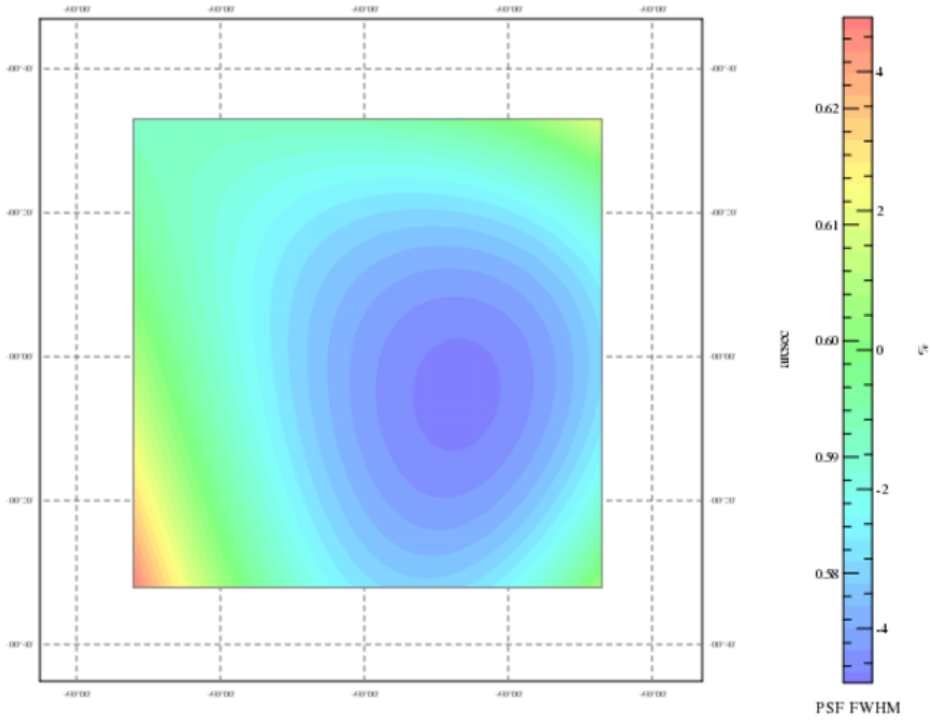
PSF modeled over the field of view

# PSFEx checkplots

**Distribution of point like sources**




**FWHM**




**+ others (chi2, ellipticity..)**

# SExtractor v.i

## SExtractor v.1:

Automated detection of objects — Bertin & Arnouts 1996

## SExtractor v.2:

**2D Model-fitting of stars and galaxies** — Bertin (in prep.)

- **Point sources modeled as local PSF + amplitude**
- **Galaxies: size and orientations convolved with the PSF**
- **Background**

- PSF modeled using PSFEx
- Pixel grid size depends on sampling and on the object
- Models: background, point source, **de Vaucouleurs, Sérsic, exponential**
- Levenberg-Marquardt minimization algorithm
- Initial parameter guesses based on SEx-v.1 measurements
- Residuals are non linear → chi2 modified for improved robustness towards outliers

## SExtractor v.3:

Multi galaxy fit/deblending — Bertin (in prep.)

# SExtractor v.2

**sex -dp**

```
#VECTOR_ASSOC          ASSOCiated parameter vector
#NUMBER_ASSOC          Number of ASSOCiated IDs
#THRESHOLDMAX          Maximum threshold possible for detection                [count]
#FLUX_GROWTH           Cumulated growth-curve                                  [count]
#FLUX_GROWTHSTEP       Step for growth-curves                                  [pixel]
#MAG_GROWTH            Cumulated magnitude growth-curve                        [mag]
#MAG_GROWTHSTEP        Step for growth-curves                                  [pixel]
#FLUX_RADIUS           Fraction-of-light radii                                 [pixel]
#FWHMPSF_IMAGE         FWHM of the local PSF model                             [pixel]
#FWHMPSF_WORLD         FWHM of the local PSF model (world units)               [deg]
#XPSF_IMAGE            X coordinate from PSF-fitting                           [pixel]
#YPSF_IMAGE            Y coordinate from PSF-fitting                           [pixel]
#XPSF_WORLD            PSF position along world x axis                         [deg]
#YPSF_WORLD            PSF position along world y axis                         [deg]
#ALPHAPSF_SKY          Right ascension of the fitted PSF (native)              [deg]
#DELTAPSF_SKY          Declination of the fitted PSF (native)                  [deg]
#ALPHAPSF_J2000        Right ascension of the fitted PSF (J2000)               [deg]
#DELTAPSF_J2000        Declination of the fitted PSF (J2000)                   [deg]
#ALPHAPSF_B1950        Right ascension of the fitted PSF (B1950)               [deg]
#DELTAPSF_B1950        Declination of the fitted PSF (B1950)                   [deg]
#FLUX_PSF              Flux from PSF-fitting                                   [count]
#FLUXERR_PSF           RMS flux error for PSF-fitting                          [count]
#MAG_PSF               Magnitude from PSF-fitting                              [mag]
#MAGERR_PSF            RMS magnitude error from PSF-fitting                    [mag]
#NITER_PSF             Number of iterations for PSF-fitting
#CHI2_PSF              Reduced chi2 from PSF-fitting
#ERRX2PSF_IMAGE        Variance of PSF position along x                        [pixel**2]
#ERRY2PSF_IMAGE        Variance of PSF position along y                        [pixel**2]
#ERRXYPSF_IMAGE        Covariance of PSF position between x and y              [pixel**2]
#ERRX2PSF_WORLD        Variance of PSF position along X-WORLD (alpha)          [deg**2]
#ERRY2PSF_WORLD        Variance of PSF position along Y-WORLD (delta)          [deg**2]
#ERRXYPSF_WORLD        Covariance of PSF position X-WORLD/Y-WORLD              [deg**2]
#ERRCXXPSF_IMAGE       Cxx PSF error ellipse parameter                         [pixel**(-2)]
#ERRCYYPSF_IMAGE       Cyy PSF error ellipse parameter                         [pixel**(-2)]
#ERRCXYPSF_IMAGE       Cxy PSF error ellipse parameter                         [pixel**(-2)]
#ERRCXXPSF_WORLD       Cxx PSF error ellipse parameter (WORLD units)           [deg**(-2)]
```

# SExtractor v.2

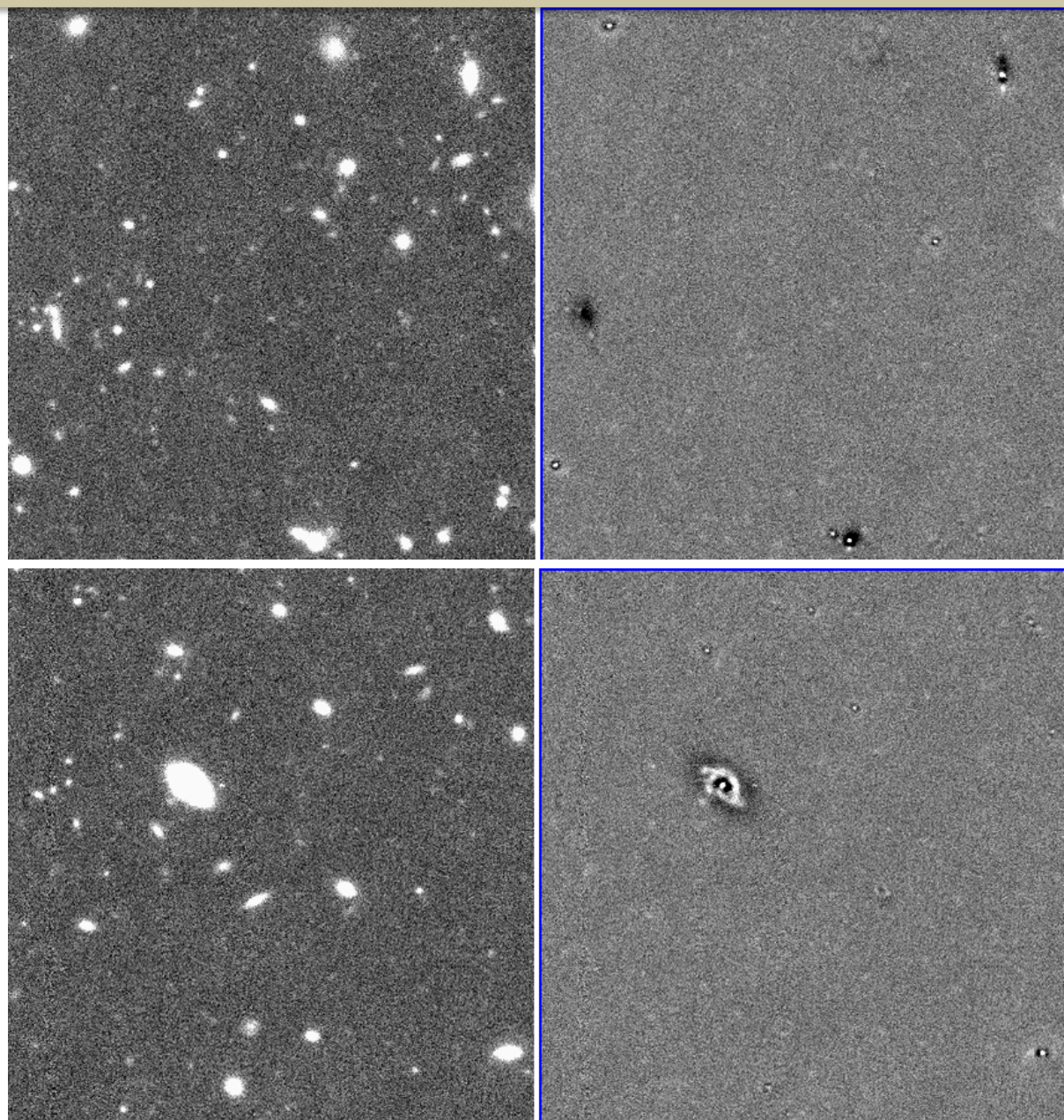
**Residuals**

**Exponential profile**

**CFHT/MegaCam**

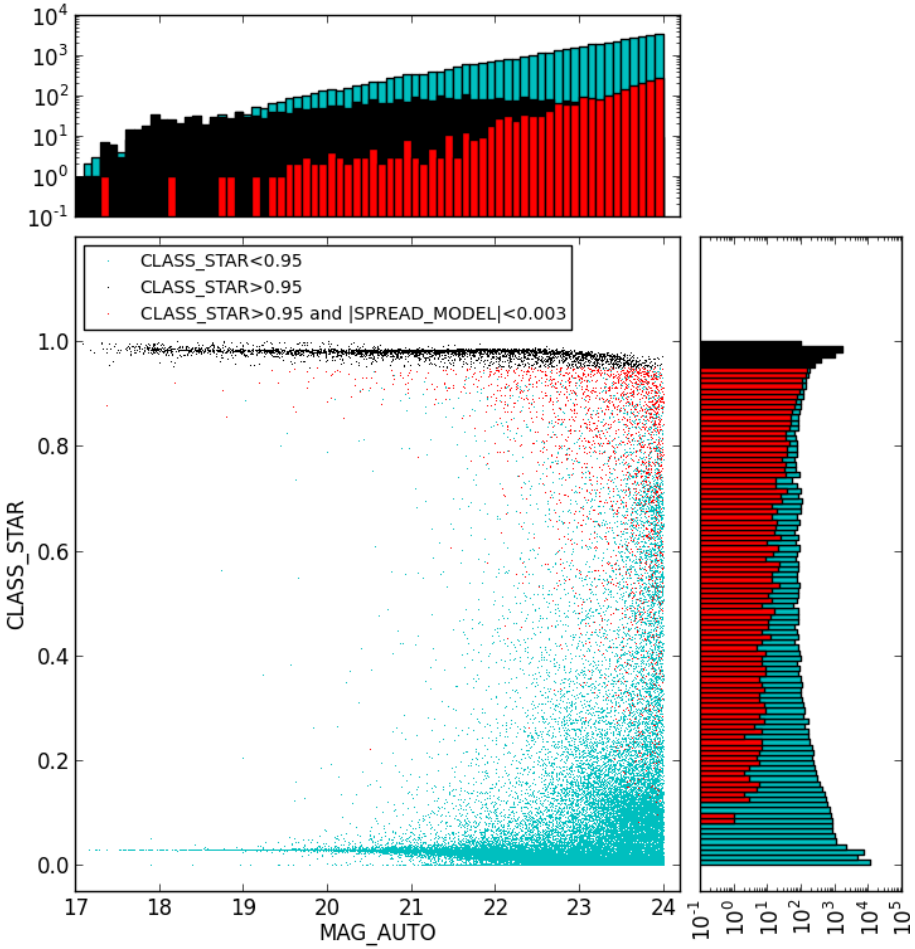
**Output structural parameters:**

- MAG_MODEL
- REFF
- ELLIPTICITY
- errors
- chi2 of fitting
- PSF properties
- star/galaxy discriminators

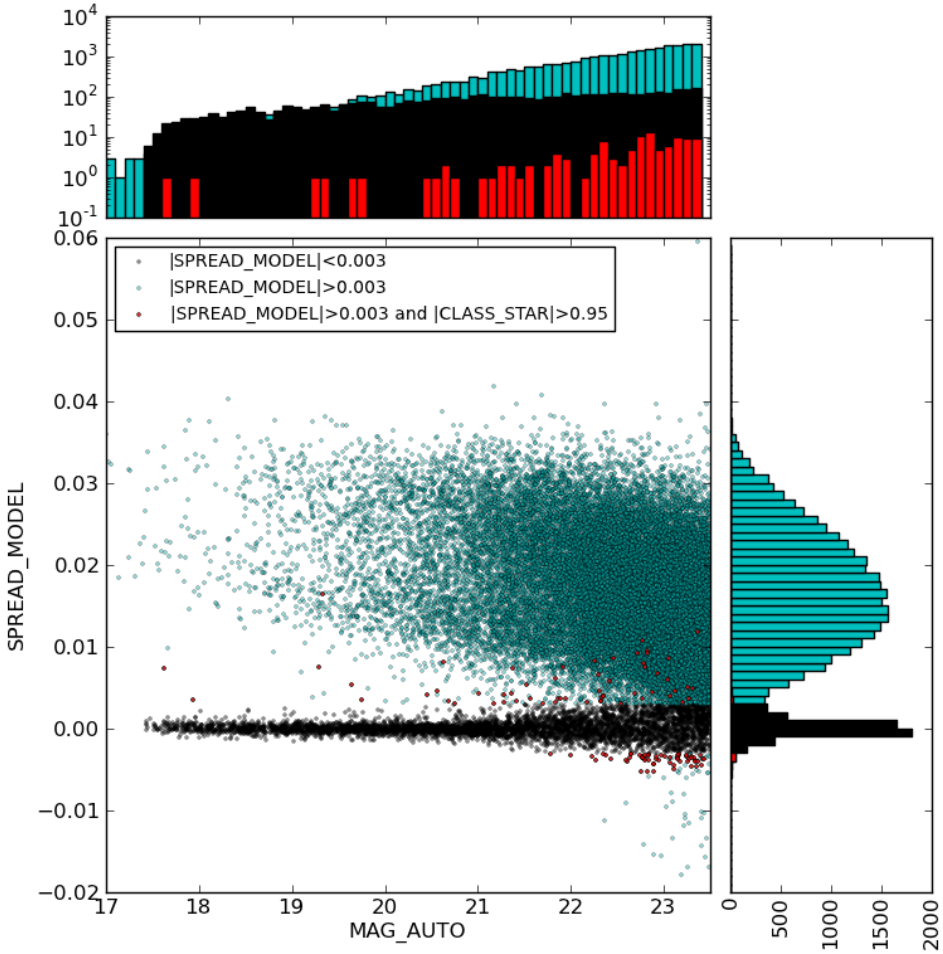


# Star/Galaxy classifier

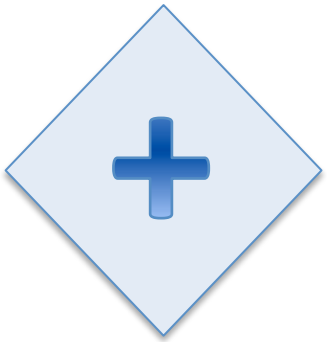
## CLASS_STAR



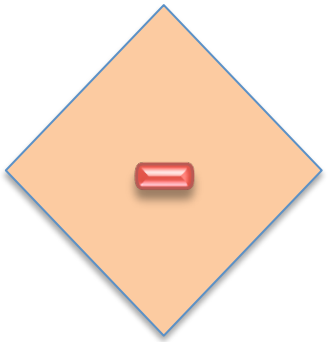

## SPREAD_MODEL



# Pros-cons



- Fast
- SExtractor and PSFEx compatible
- Robust PSF modeling
- developed for large area
- tested on simulations (DES …)
- tested on true data (BCS, CS82 …)



- background treatment
  (e.g. GALAPAGOS
  Barden et al. 2012)
- brightness profiles available

# CFHT – ‘Stripe 82’ data

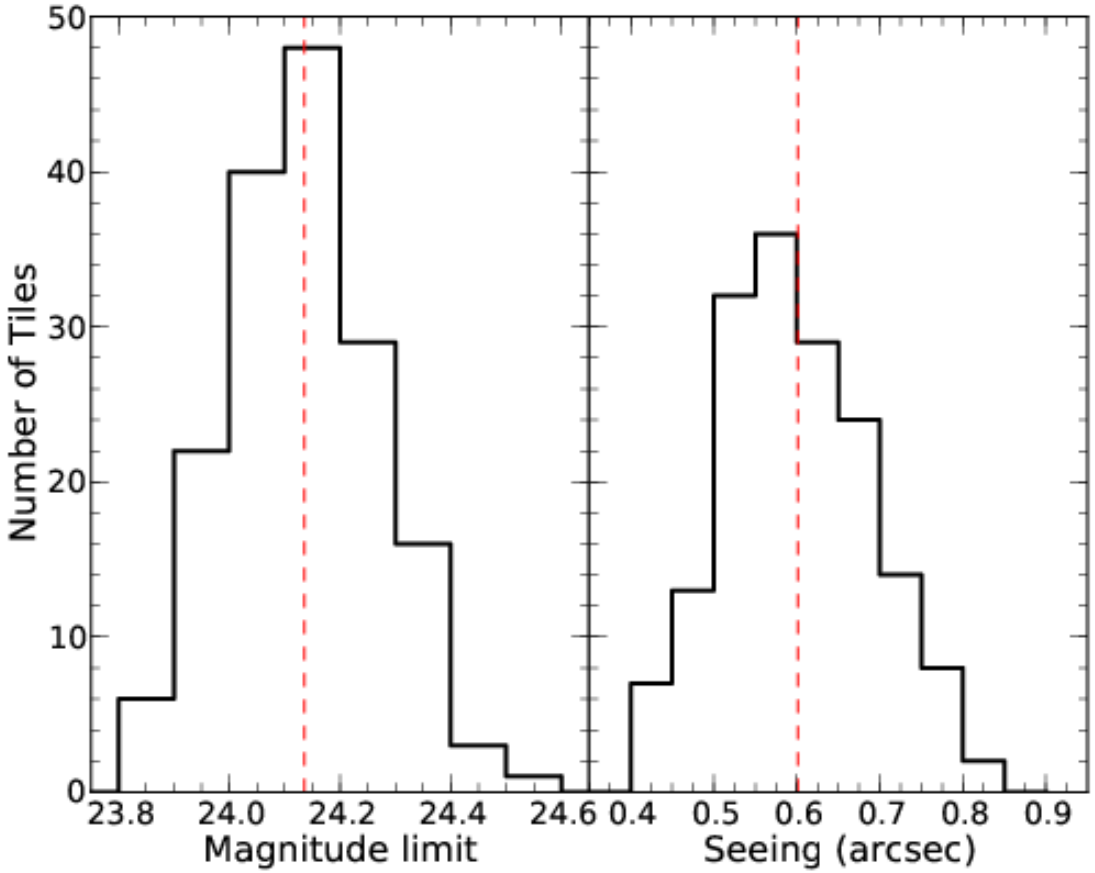
# CS82 survey in a nutshell

- France-Canada-Brazil project
- **CFHT**, **MegaCam**
- 173 science quality pointings with slight overlaps
- ‘Stripe 82’
- goal: weak and strong **lensing** survey
- i-band
- service mode insuring good seeing condition <0.8”

**Proposal accepted spring 2010**
**Observations August 2010 – January 2011**
**Data reduction completed**
**Survey paper: Erben et al. in prep (2013)**

# CS82 observing conditions

- CS82 **mean seeing = 0.6”**
- Depth: **~24.1** in 2-arcsec circular apertures
- Source number density: **~17.25 per arcmin$^2$** (standard cuts)



# CS82 first results

## The CFHT-Stripe 82 survey: Imaging Data and Catalogues

Thomas Erben[1], Jean-Paul Kneib[2,3], Alexie Leauthaud[4,5], Martin Makler[6,7], Ludovic van Waerbeke[8], and the CS82 collaboration.
[1]Argelander Institute for Astronomy, University of Bonn, Auf dem Hügel 71, 53121 Bonn, Germany.
[2]Laboratoire d'Astrophysique de Marseille - LAM, Université d'Aix-Marseille & CNRS, UMR7326, 38 rue F. Joliot-Curie, 13388 Marseille Cedex 13, France.
[3]EPFL
[4] Institute for the Physics and Mathematics of the Universe (IPMU), The University of Tokyo, Chiba 277-8583, Japan.
[5] Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, CA 94720.
[6]Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud 150, Rio de Janeiro, RJ 22290-180, Brazil
[7]Laboratório Interinstitucional de e-Astronomia, Rua Gen. José Cristino 77, Rio de Janeiro, RJ 20921-400, Brazil
[8]Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, V6T 1Z1, BC, Canada.

In preparation

## Weak lensing mass map and peak statistics in CFHT/Stripe82 survey

HuanYuan Shan[1⋆], Jean-Paul Kneib[1,2], Johan Comparat[2], Eric Jullo[2], Alexie Charbonnier[4,5], Thomas Erben[6], Martin Makler[5], Bruno Moraes[5], Ludovic Van Waerbeke[7], Frédéric Courbin[1], Georges Meylan[1], Charling Tao[8,9], James R. Taylor[10]
[1]Laboratoire d'astrophysique (LASTRO), École Polytechnique Fédérale de Lausanne (EPFL), Observatoire de Sauverny, CH-1290 Versoix, Switzerland
[2]Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388, Marseille, France
[3]Centre de Physique des Particules de Marseille, CNRS/IN2P3-Luminy and Université de la Méditerranée, Case 907, F-13288 Marseille Cedex 9, France
[4]Observatório do Valongo, Universidade Federal do Rio de Janeiro, Ladeira do Pedro Antônio 43, Saúde, Rio de Janeiro, RJ 20080-090, Brazil
[5]Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud 150, Rio de Janeiro, RJ 22290-180, Brazil
[6]Argelander Institute for Astronomy, University of Bonn, Auf dem Hügel 71, 53121 Bonn, Germany
[7]Department of Physics and Astronomy, University of British Columbia, 6224 Agricultural Road, Vancouver, V6T 1Z1, BC, Canada
[8]Centre de Physique des Particules de Marseille, CNRS/IN2P3-Luminy and Université de la Méditerranée, Case 907, F-13288 Marseille Cedex 9, France
[9]Department of Physics and Tsinghua Center for Astrophysics, Tsinghua University, Beijing, 100084, China
[10]Department of Physics and Astronomy, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

Submitted to MNRAS

## Stochastic bias of colour-selected BAO tracers by joint clustering-weak lensing analysis

Johan Comparat[1], Eric Jullo[1], Jean-Paul Kneib[1,2], Carlo Schimd,[1] HuanYuan Shan,[2,3] Thomas Erben,[4] Olivier Ilbert[1] Joel Brownstein,[5] Anne Ealet,[6] Stéphanie Escoffier,[6] Bruno Moraes,[7,8] Nick Mostek,[9] Jeffrey A. Newman,[10] M. E. S. Pereira,[7,8] Francisco Prada,[11,12,13] David J. Schlegel,[9] Donald P. Schneider,[14,15] Carlos H. Brandt[7,16]

In preparation

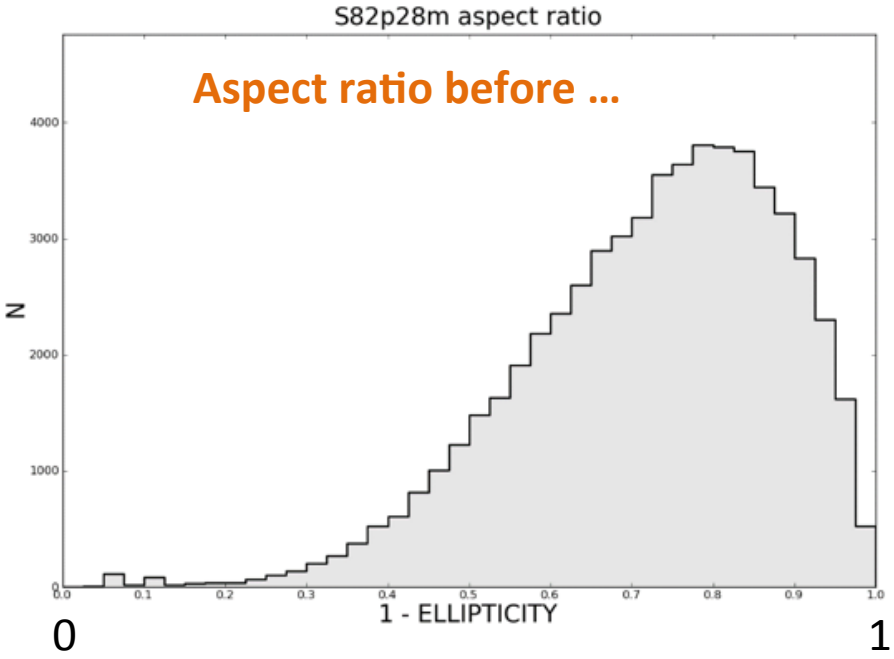
## Cross-correlation of cosmic microwave background lensing and galaxy lensing

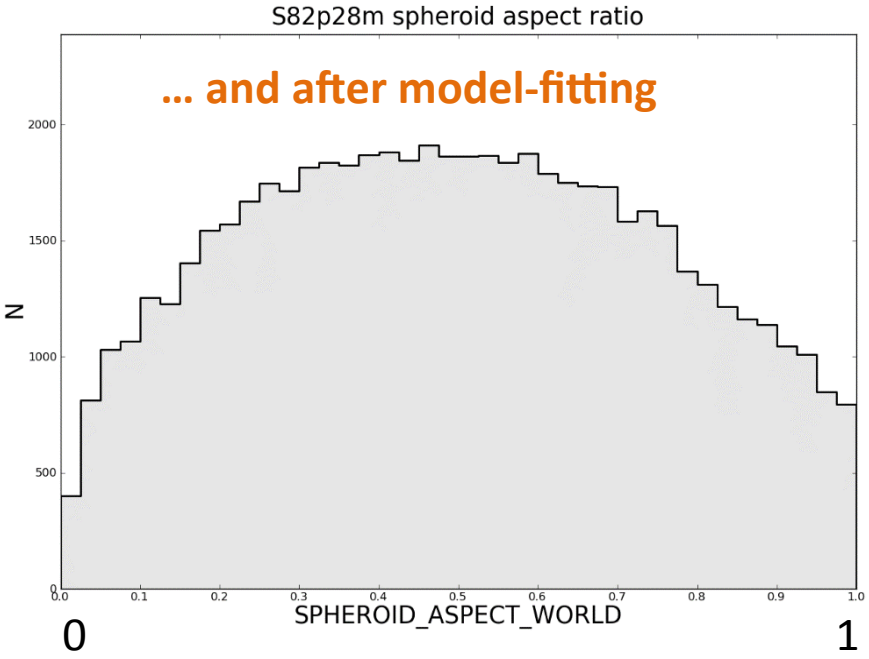
The ACT and CS82 collaborations
(Dated: October 21, 2013)

We measure the cross-correlation of cosmic microwave background lensing convergence maps derived from Atacama Cosmology Telescope data with galaxy lensing convergence maps as measured by the CFHT Stripe 82 Survey. The CMB-galaxy lensing cross power spectrum is detected for the first time with a significance of $3.2\sigma$, which corresponds to a 16% constraint on the amplitude of structure at redshifts $\sim 0.7$. With upcoming improved lensing data, this novel type of measurement will become a powerful cosmological probe, providing a precise measurement of the mass distribution at intermediate redshifts and serving as a calibrator for systematic biases in weak lensing measurements.

# Morphology catalog production

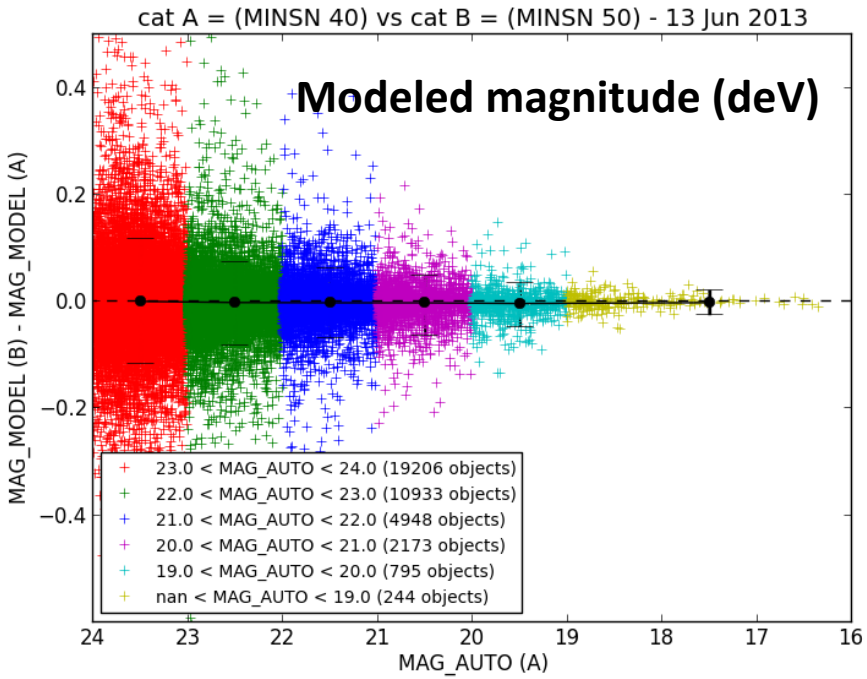
- **~ 16,700,000 objects (~ 150,000/tile)** Moraes et al. in prep
- Deeper than SDSS
- **Choice of configuration**
  - ❖ deblending ❖ deepness ❖ computation time ❖ size of catalogs
- **4 profiles:** de Vaucouleurs, exponential, Sérsic, deV+exp
- 177 tiles x 4 profiles x ~ 12h/profile/tile
- Masking
- **Cuts**: S/N, flagged objects, star/galaxy

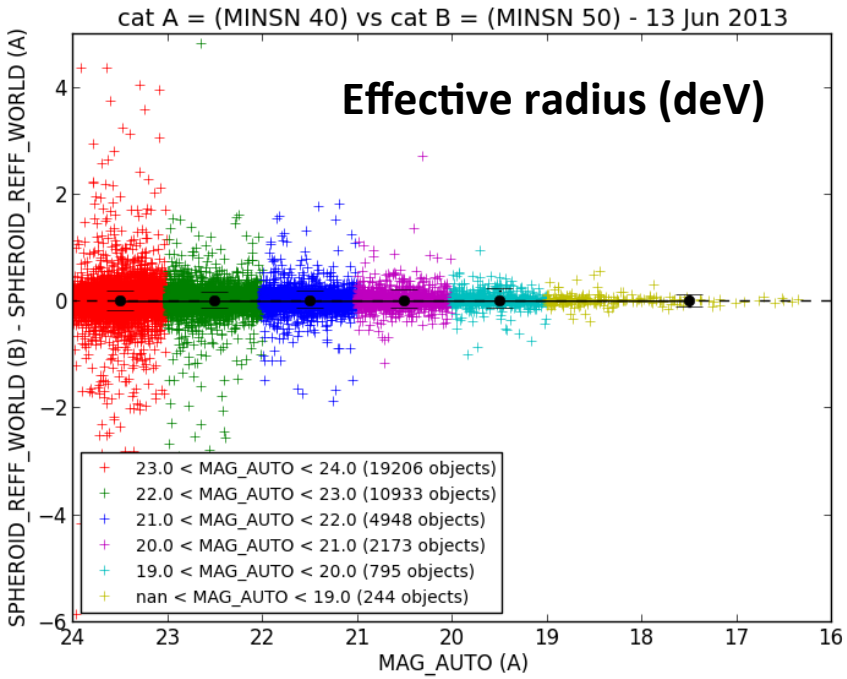


# SEx-PSFEx configurations

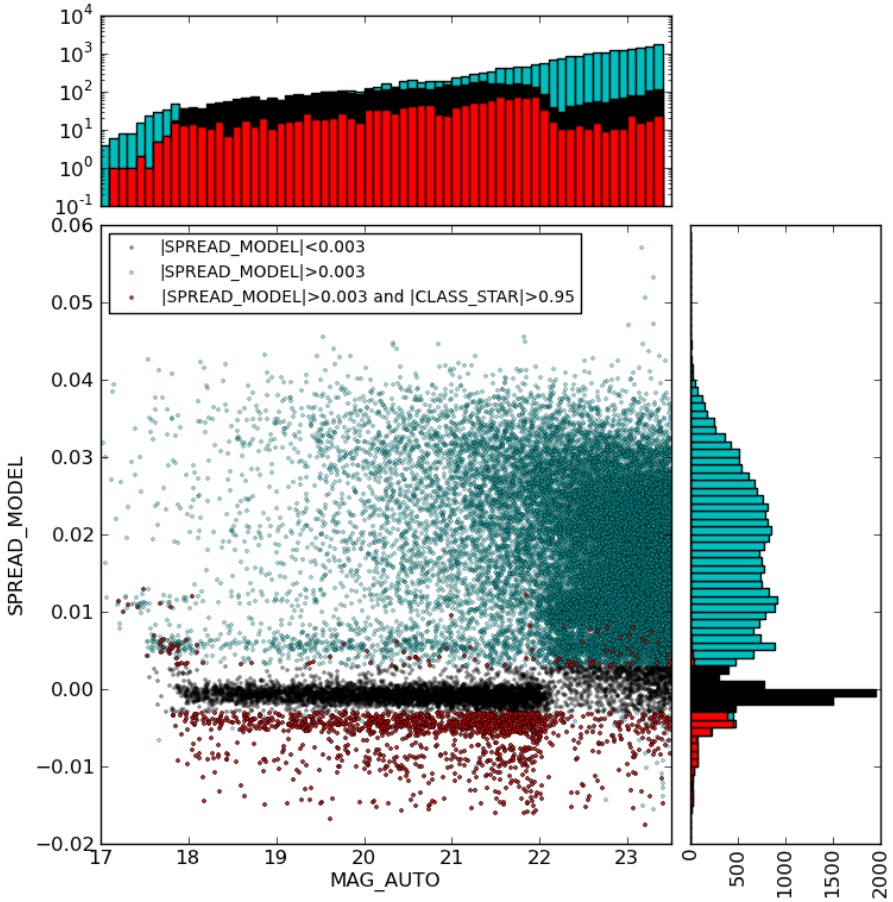
| **VIGNET** | **PSF_SIZE** | **MINSN** | |
|---|---|---|---|
| image cut size | Image size of the PSF | PSF star selection | ... |

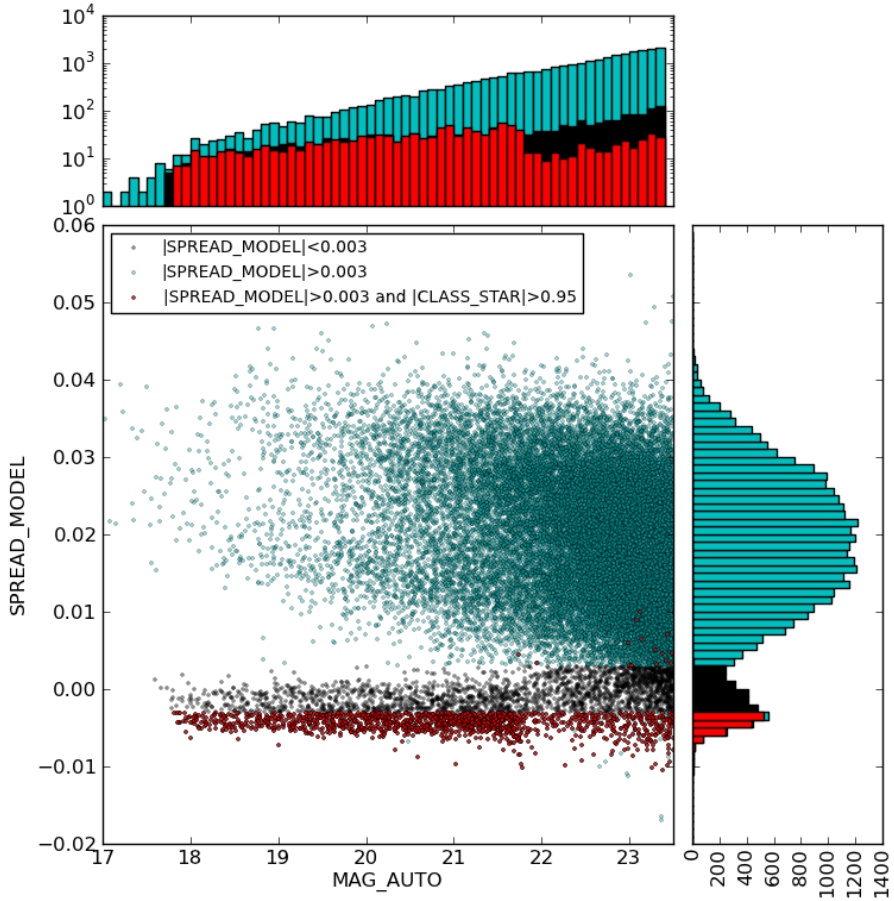



**estimation of the internal statistical errors due to the choice of the configurations**

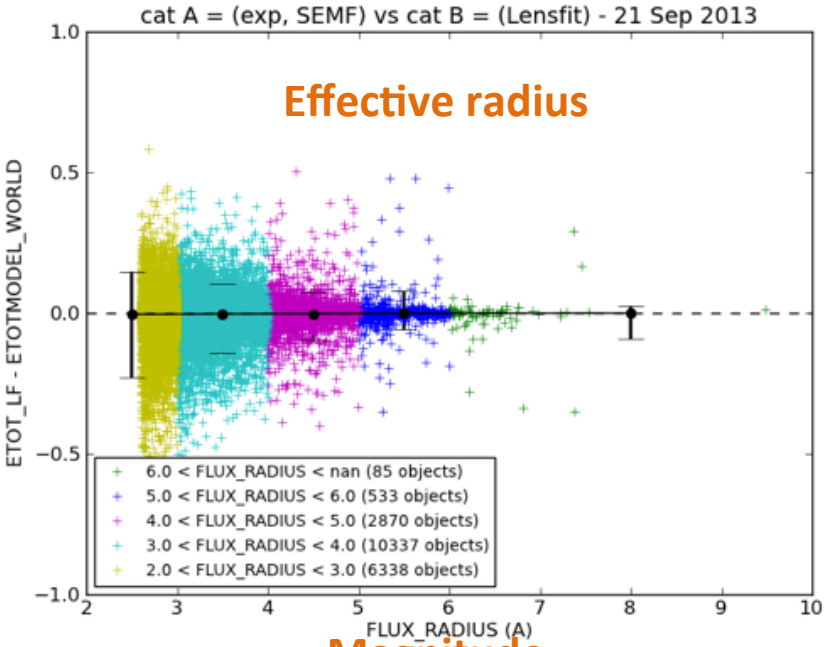
# SPREAD_MODEL as a sanity check

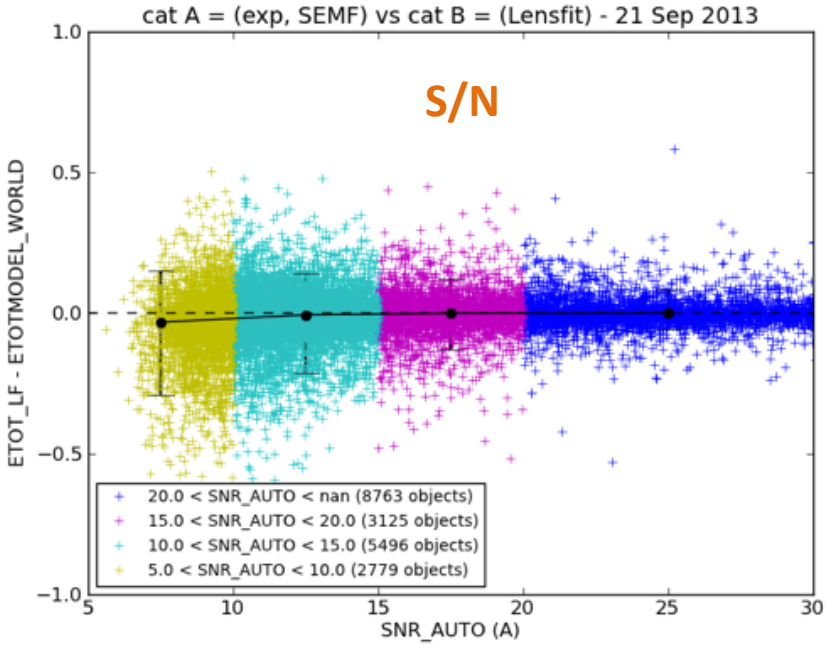


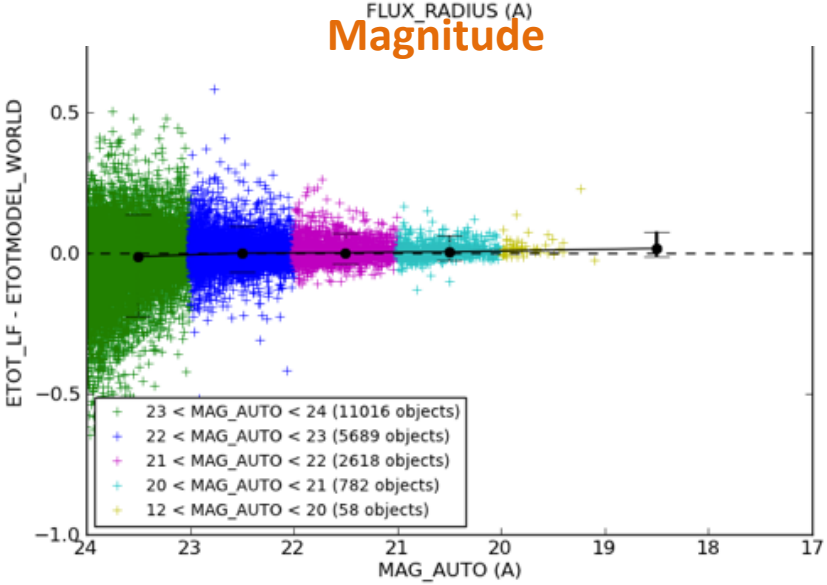




- coadds: different seeings, bad estimation of the PSF
- Point like sources selection crucial

# Lensfit: ellipticity comparison



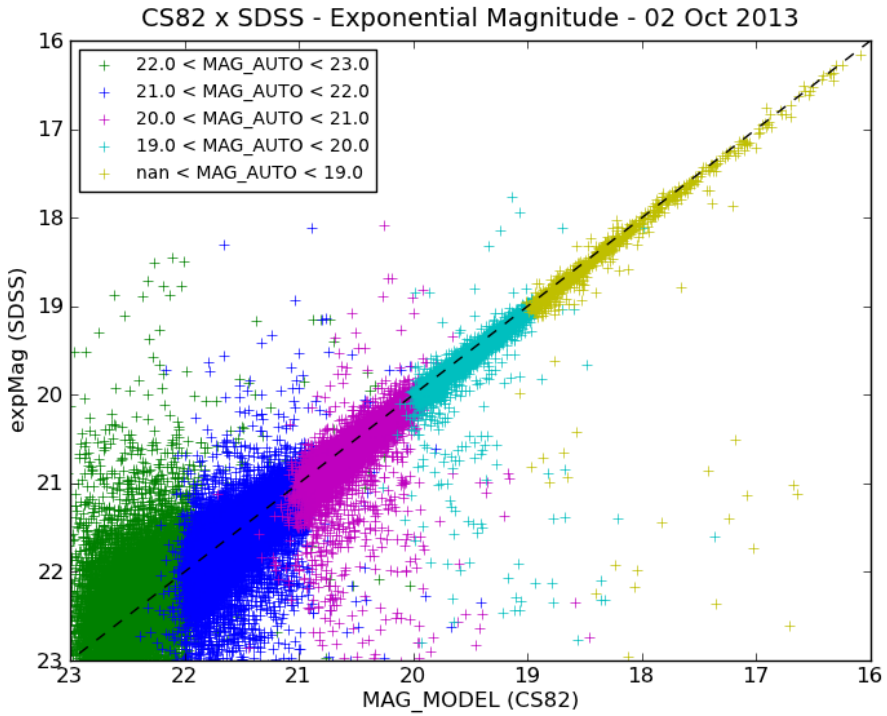



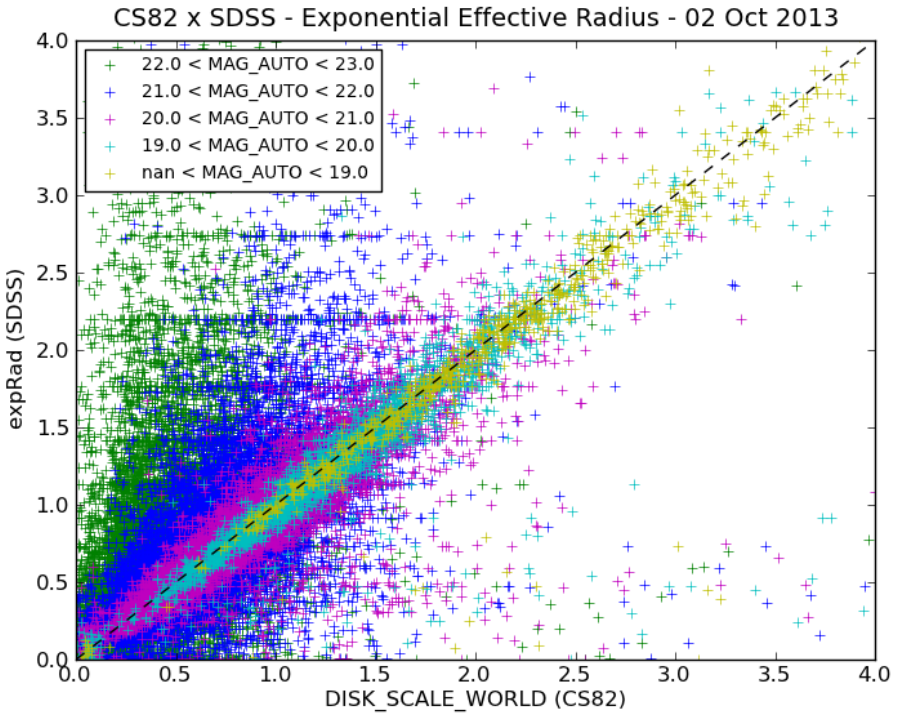

Lensfit:
Miller et al. 2007

**Very good reconstruction (single exposure vs coadds)**

# Comparison with SDSS: exp

**Galaxies – S/N > 5 – SDSS DR9: fracDeV_i < 0.02 (matching)**
**Area of 14 sq. degrees**

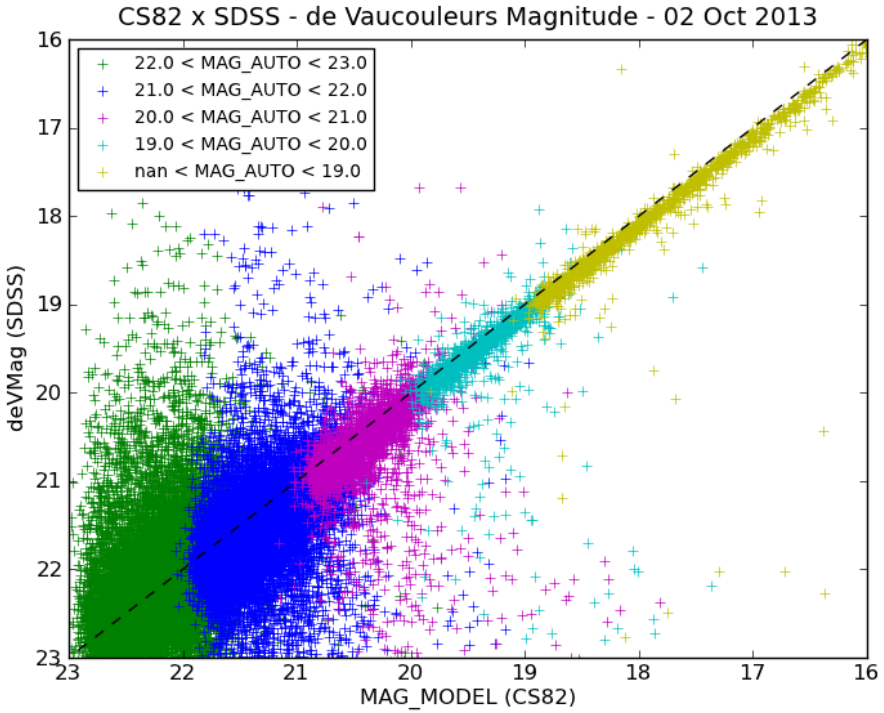


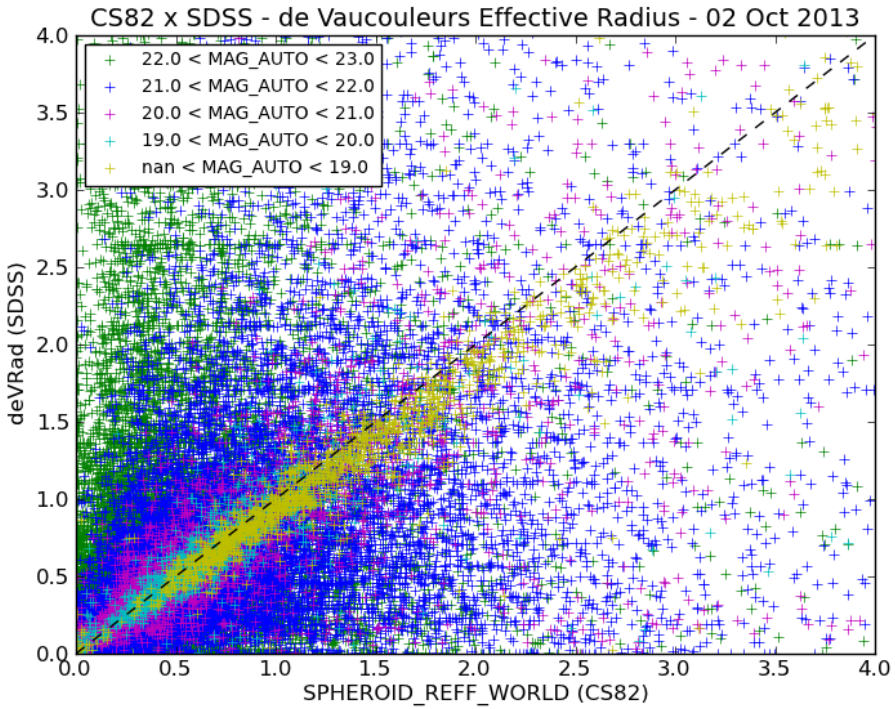




**Good agreement for MAG < 21**

# Comparison with SDSS: deV

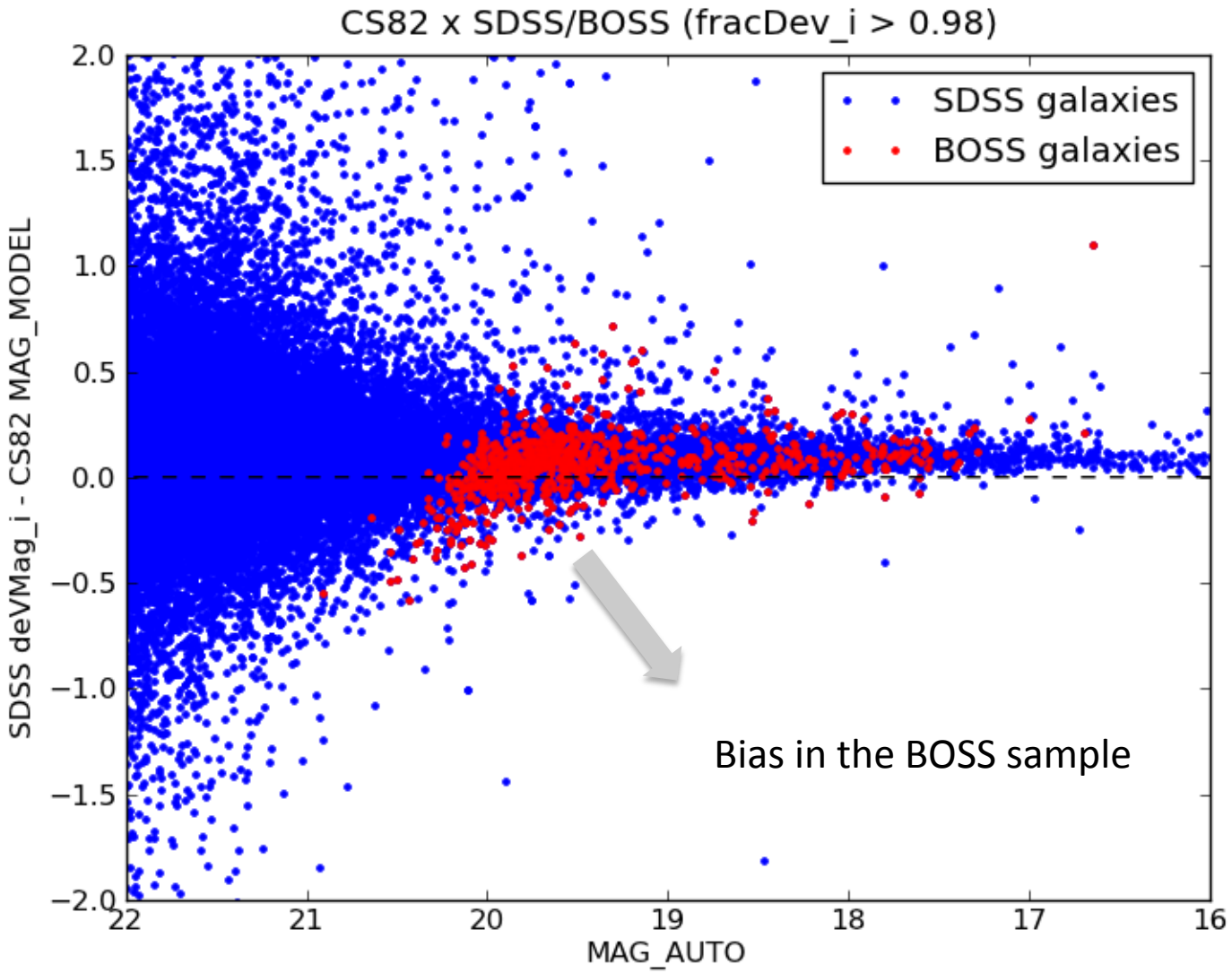
**Galaxies – S/N > 5 – SDSS DR9: fracDeV_i > 0.98 (matching)**
**Area of 14 sq. degrees**




**Good agreement for MAG < 21**

# BOSS/CS82 galaxies



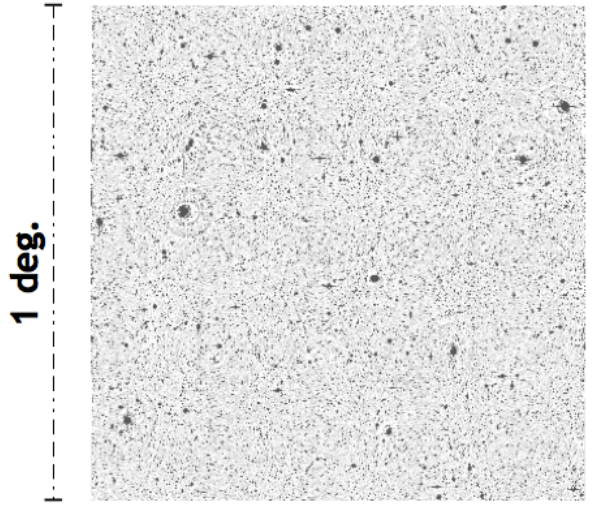

14 sq. degrees

- SDSS
- BOSS sample

# COSMOS field

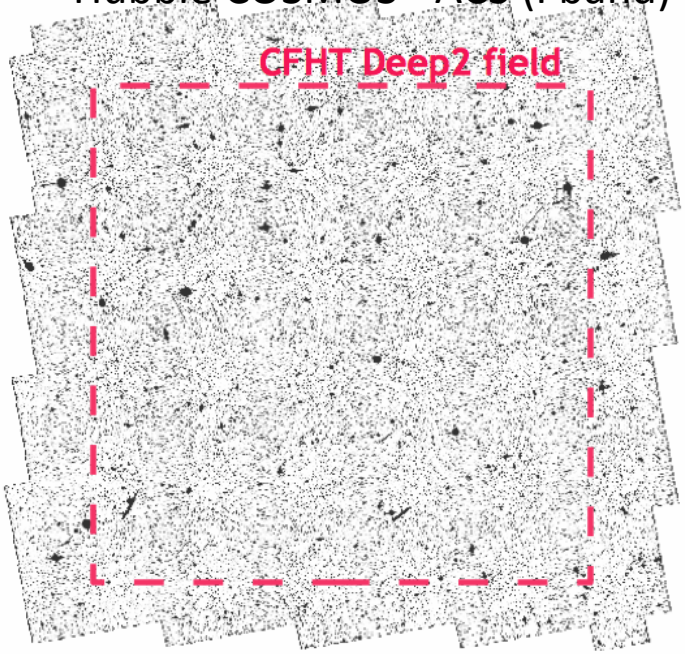
# The COSMOS field

CFHT Deep2 field - MegaCam (y band)




1.4 GB, 19354 x 19354 pixels

Hubble COSMOS - ACS (I band)




225 GB, 168000 x 168000 pixels

seeing ~ 1''

seeing ~ 0.09''

# CFHT-D2: catalog production

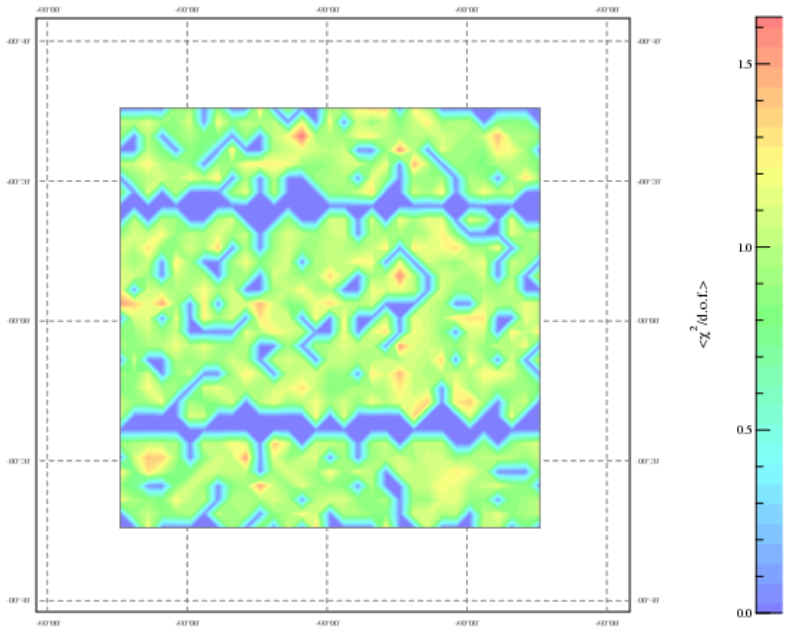
# objects after masking and S/N > 5:

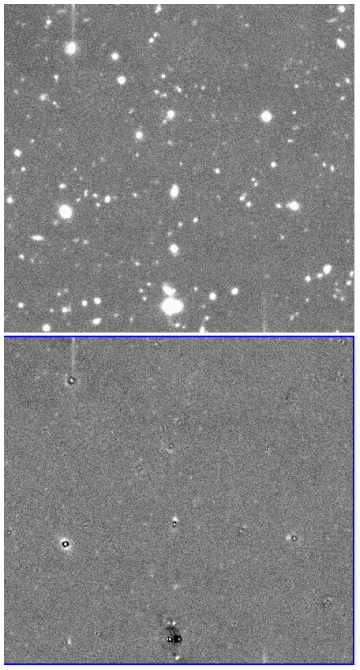
- point-like: ~ **38,700**
- extended: ~ **174,200**

SExtractor run: ~ 30.5 h

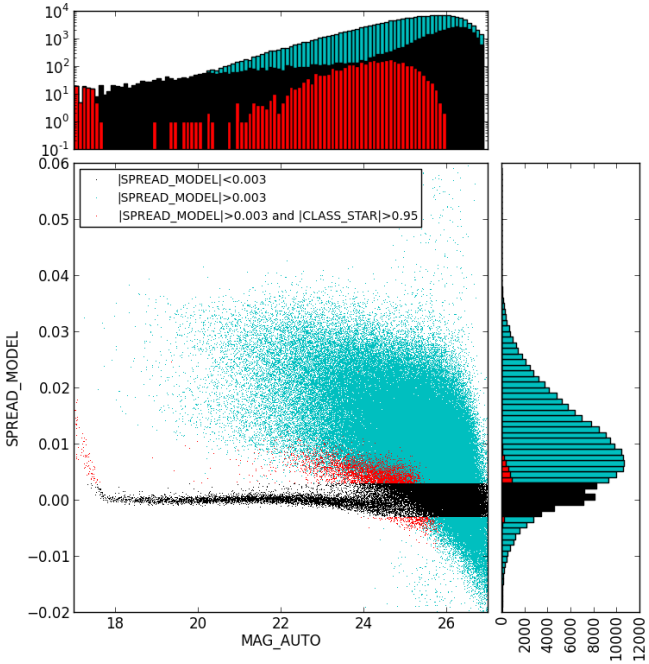
Same diagnostics as CS82

Chi 2 – PSF modelling



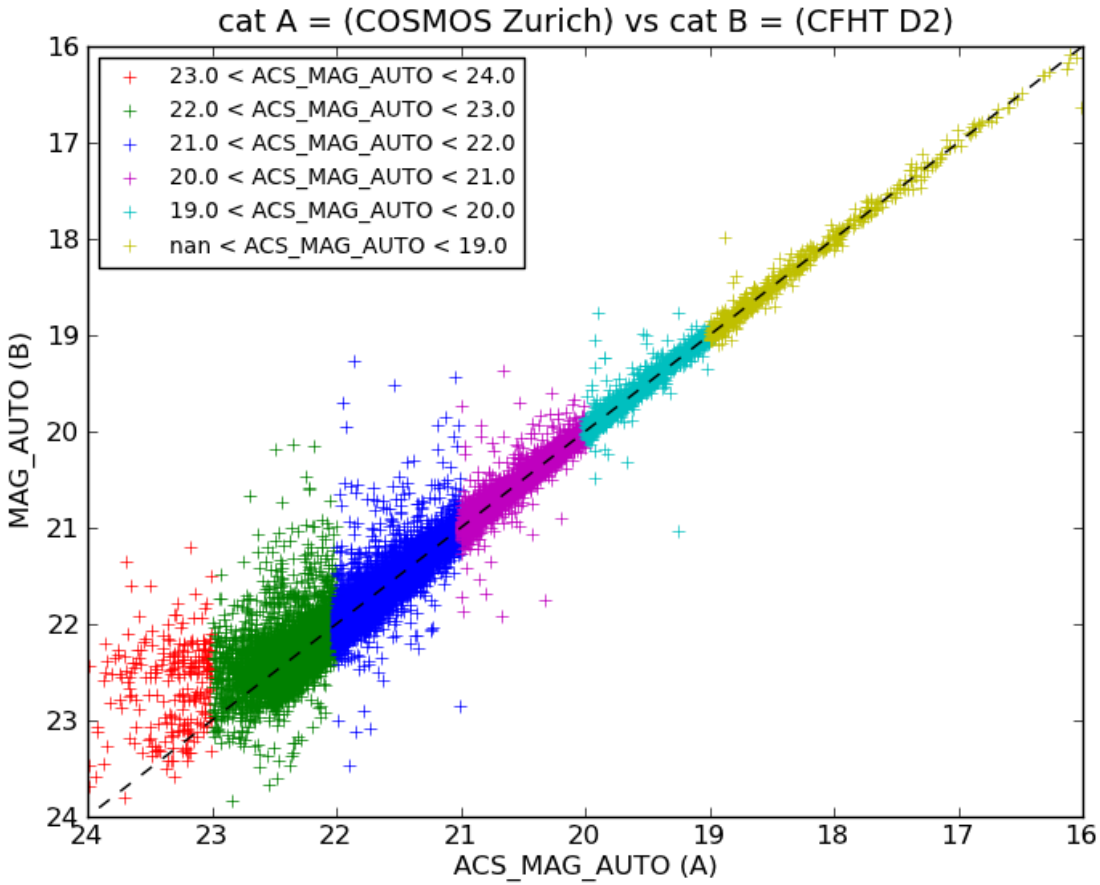



SPREAD_MODEL



# Catalogs comparison

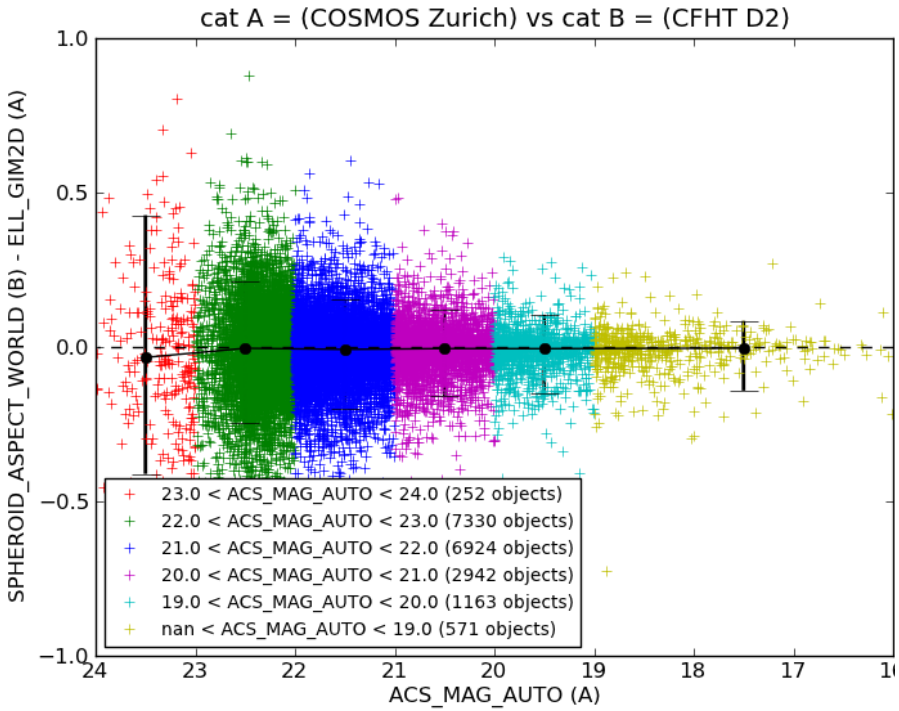
- **COSMOS catalog**: produced with GIM2D
- **CFHT D2 catalog**: our pipeline
- **Objects selection**: elimination of stars, good quality fit



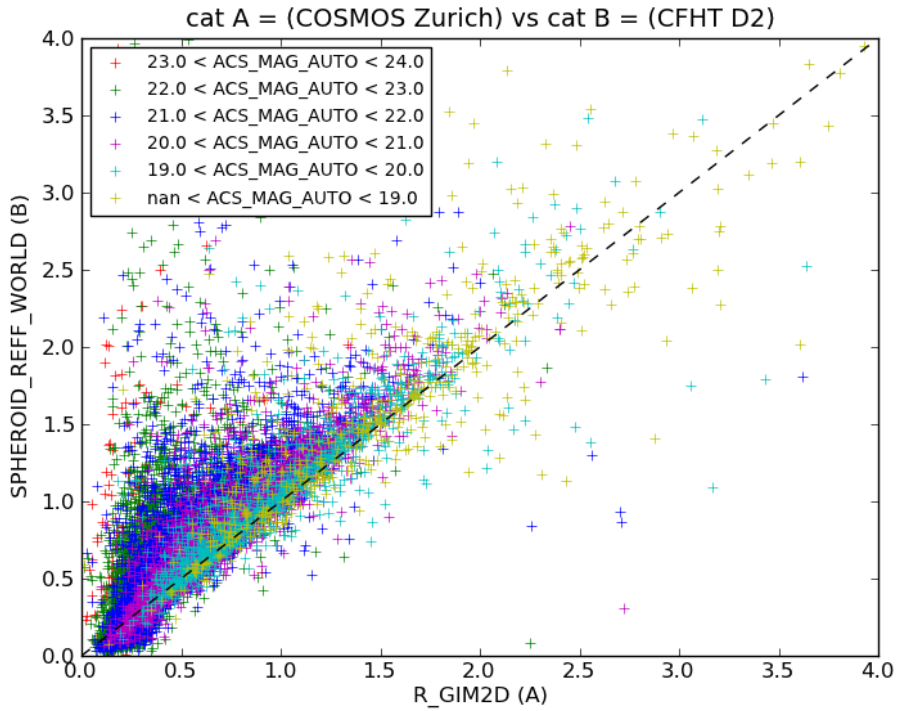

**Good agreement**

# Catalogs comparison

## Ellipticity




## Effective radius




- **Ellipticity and effective radius similar**
- **The PSF is correctly reconstructed**

# Conclusions: 2 points

## SExtractor + PSFEx:

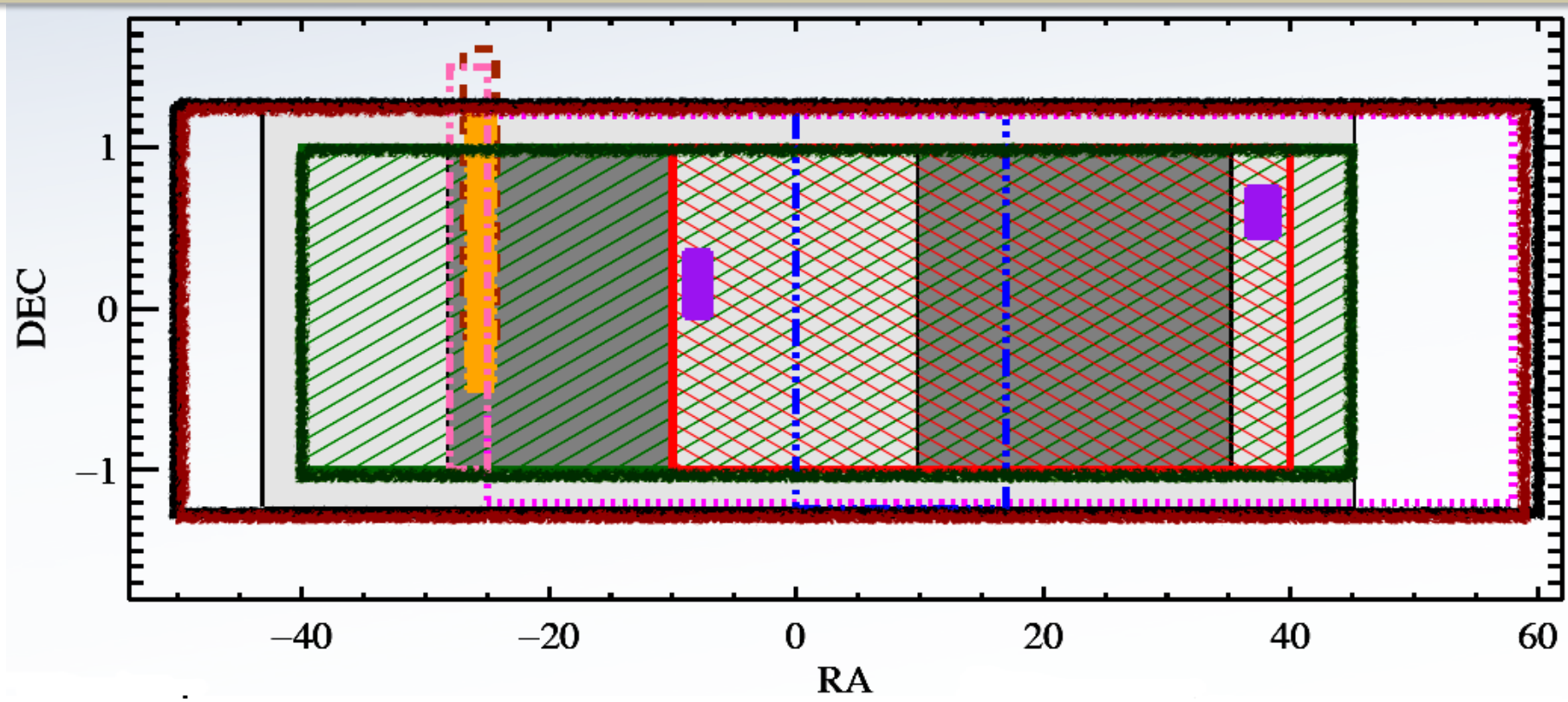
- Estimation of the PSF, variation over the field of view
- The model-fitting is working well
- Very competitive in term of computation time
- Extensive tests to assess its quality

## CFHT – Stripe 82 data:

- Data of very good quality (mean seeing 0.6”) deep (mag limit ~ 24)
- Originally a lensing survey
- Morpholgy catalogs produced (deV, exp, Sersic, deV+exp)
- Redshift z=[0.2;0.7]
- Galaxy evolution/morphology studies to come…

# kecélebackup

# The ‘Stripe 82’




Imaging :

- Stripe 82 SDSS imaging (ugriz, i<22.75, 270 deg$^2$)
- CFHT Stripe−82 survey (170 deg$^2$, i<23.5, seeing<0.8")
- UKIDDS LAS, $K_{vega}$=18.4
- UKIDSS: DXS Field 4
- CFHTLS W4
- WISER (this proposal), $K_{AB}$=22

Spectroscopy :

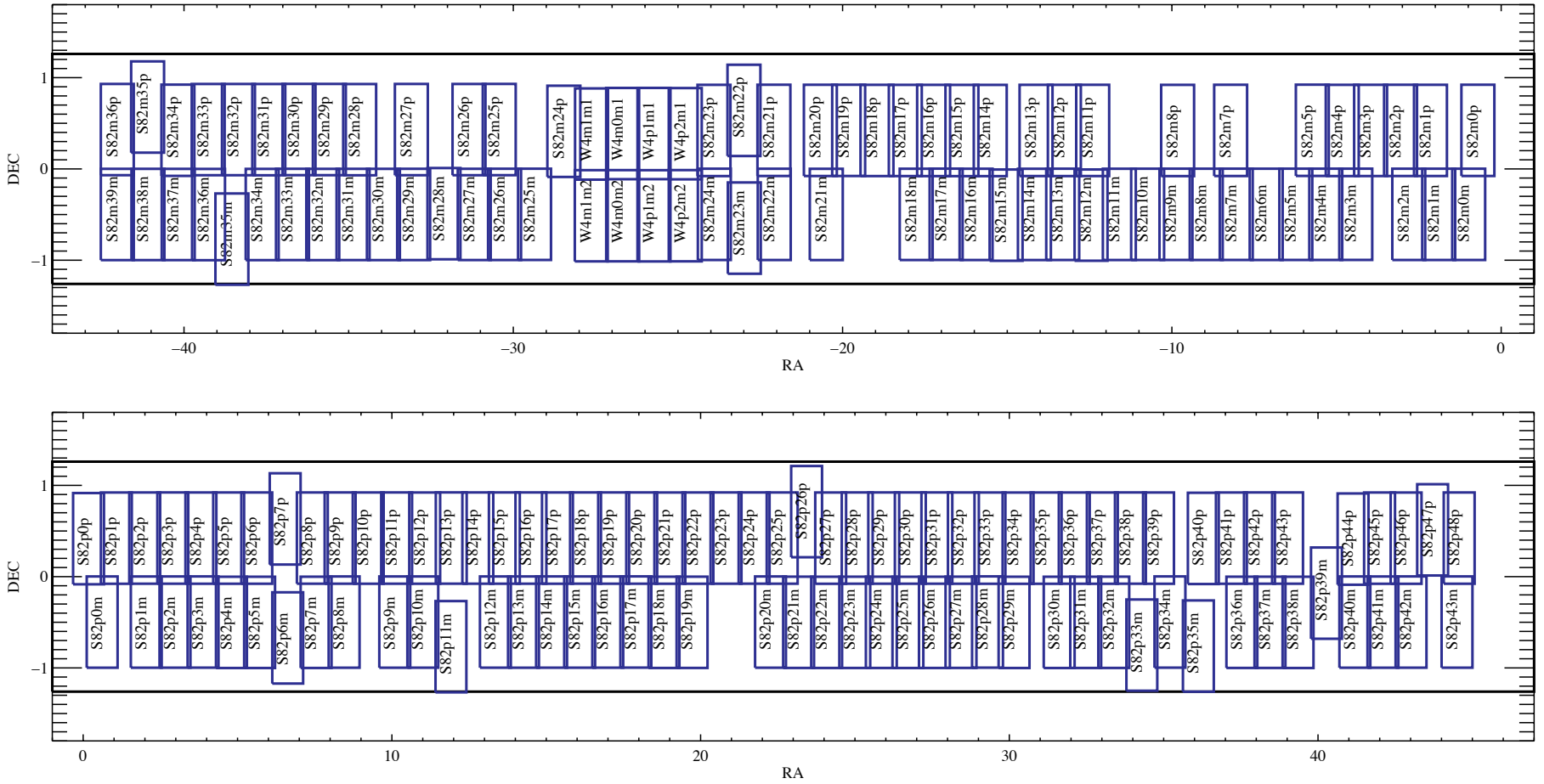
- BOSS (220 deg$^2$, 40,000 redshifts)
- DEEP2 and PRIMUS
- VVDS
- Wiggle−z

Radio :

- VLA

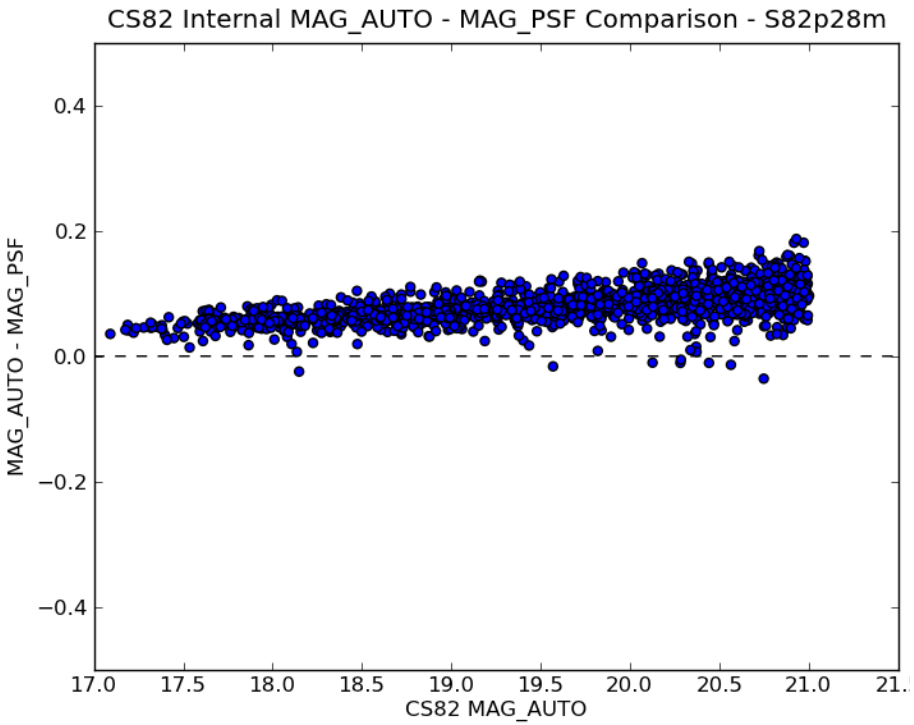
# Strategy of observation

- -40° < RA < +45° and -1° < Dec < +1°
- **avoiding massive stars**

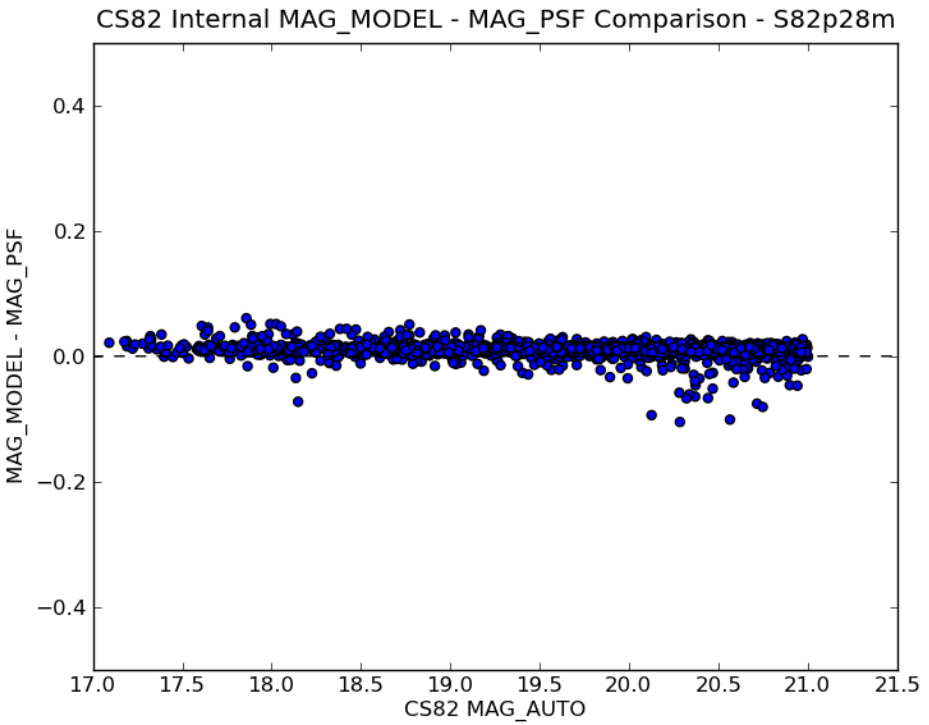


# CS82 magnitudes

**MAG_AUTO – MAG_PSF**




**MAG_MODEL – MAG_PSF**

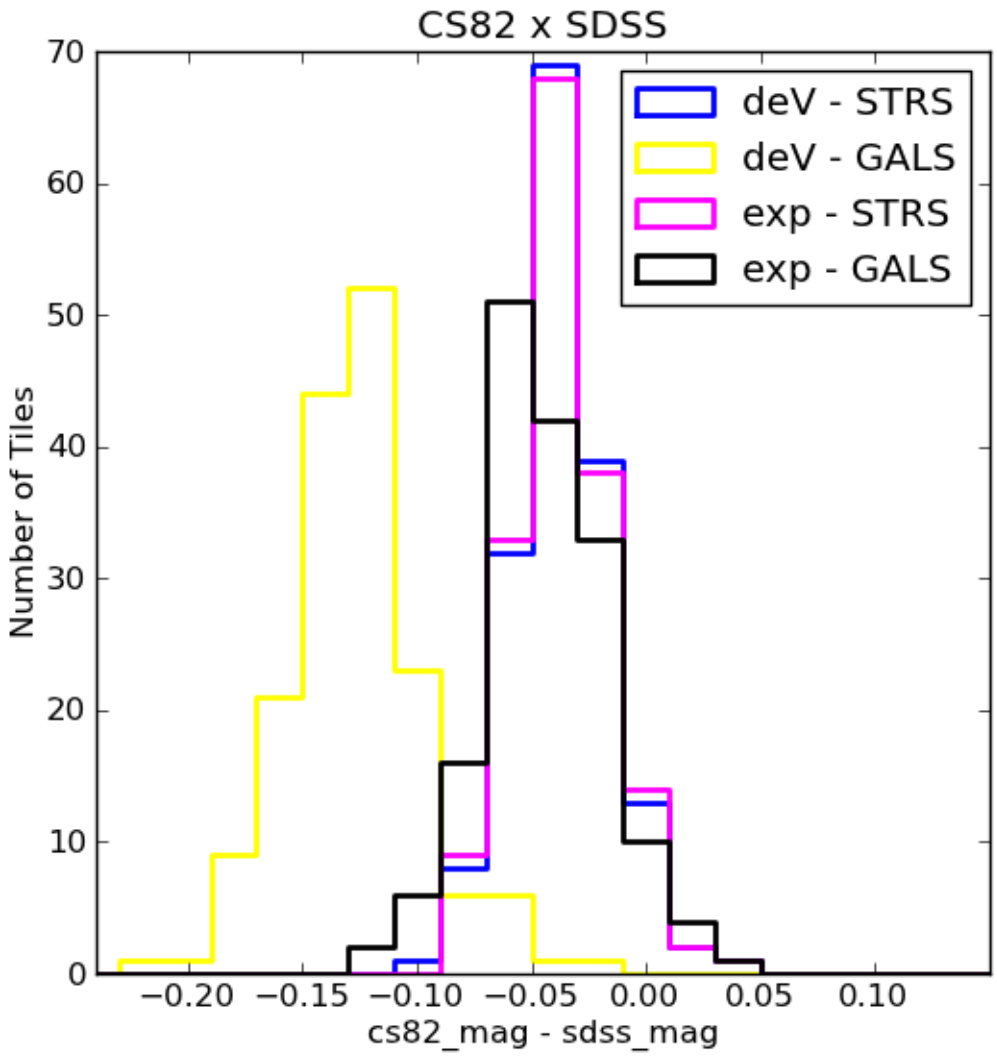



Calibration of the data done with MAG_AUTO

MAG_AUTO is missing flux at the wings (Annunziatella et al. 2012)

→ offset MAG_AUTO – MAG_PSF observed

# CS82/SDSS



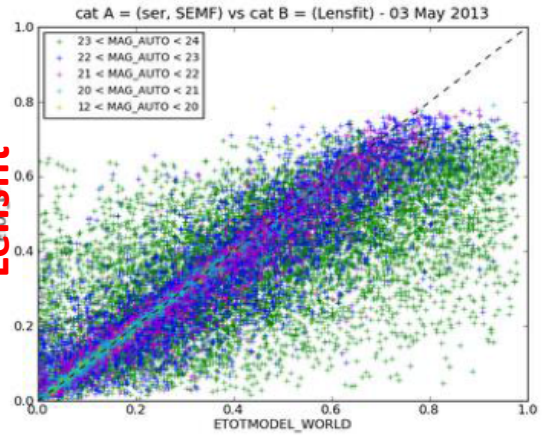

**Point like sources + exp/ deV profiles:** offset due to the calibration with MAG_AUTO

**deV profile:** additional offset due to the truncation of the profile by the SDSS pipeline (info. By Claire Lackner)

# Ellipticity: Lensfit vs Sextractor

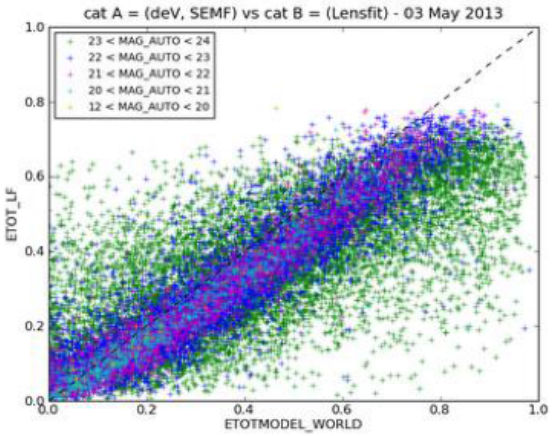
**Comparison on CS82**
**1 tile (p28m)**

## Sersic




Lensfit

## De Vaucouleurs




SExtractor

## exponential