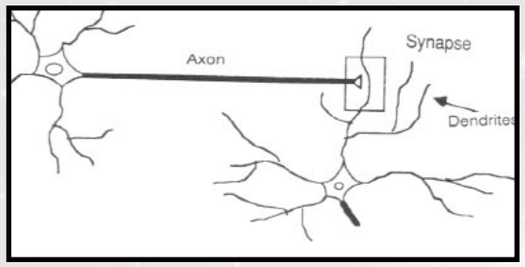
EWASS 2017
EUROPEAN WEEK OF ASTRONOMY AND SPACE SCIENCE
26 - 30 JUNE 2017 PRAGUE, CZECH REPUBLIC

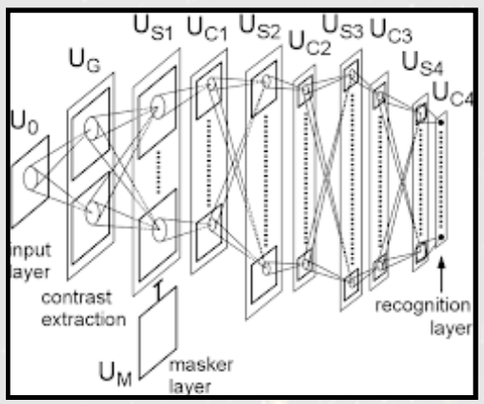
Deep leaning for galaxy surface brightness profile fitting

Diego Tuccillo

(extremely) brief history of deep learning neural networks

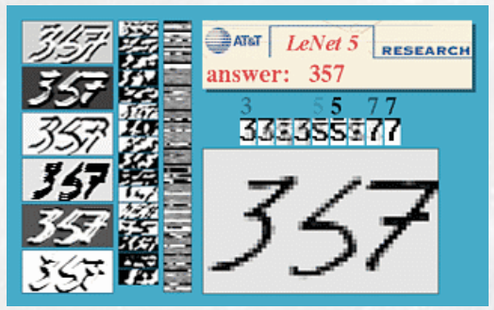


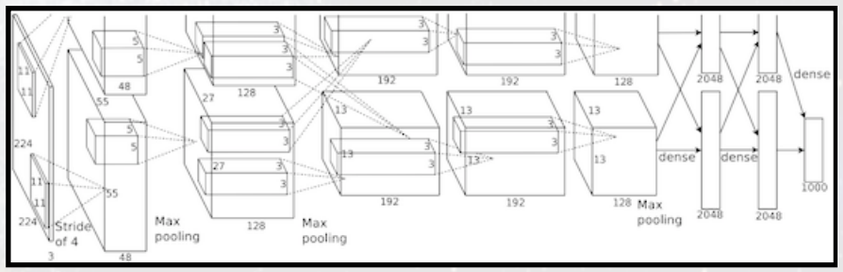
Frank Rosenblatt **1957**
(The **Perceptron)**



Fukushima
Neocognitron

LeCun
LaNet 5





Krizhevsky 2012
AlexNet

cited
> 6,200 times!

1980's

1990's

2000's

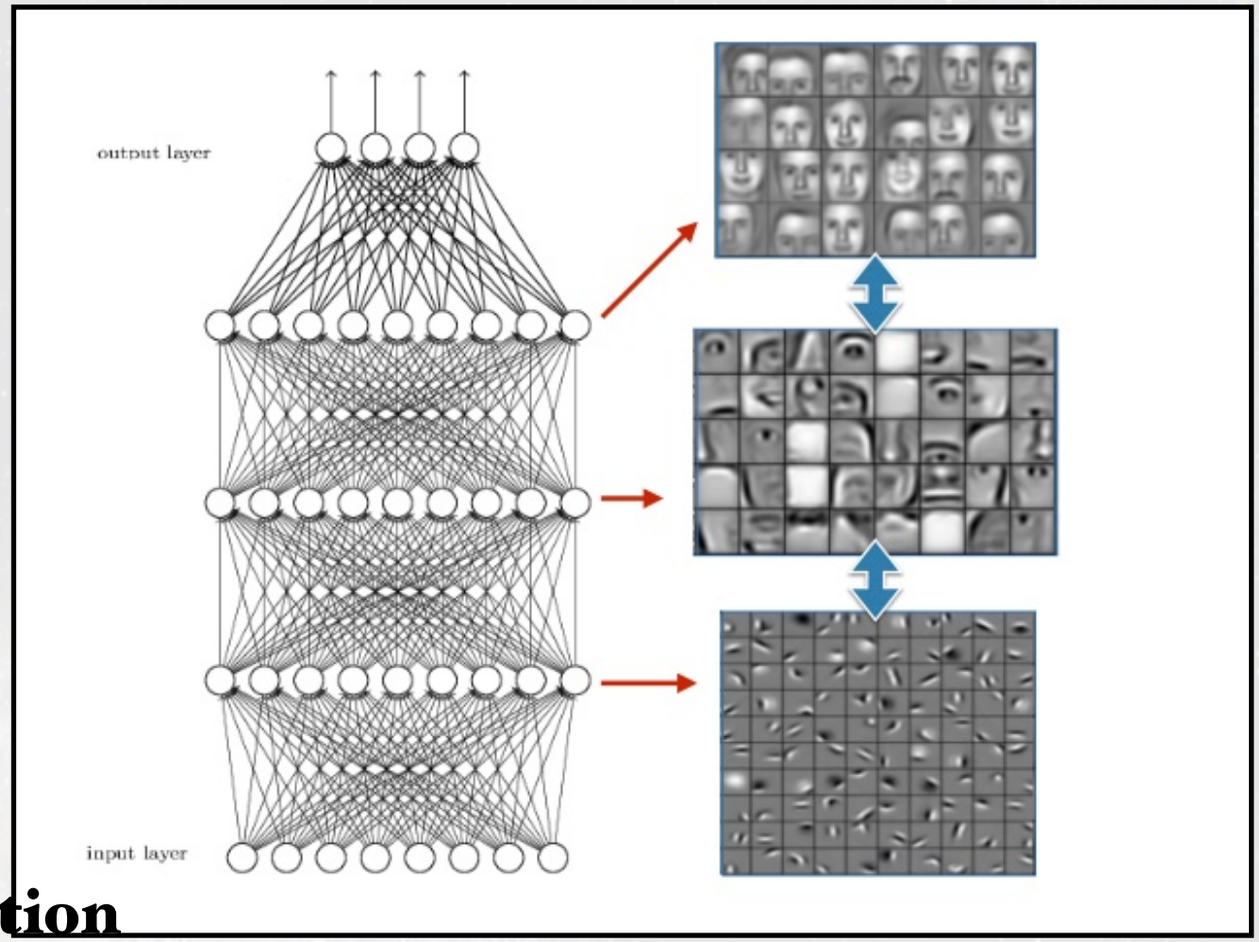
2012

(extremely) brief history of deep learning neural networks

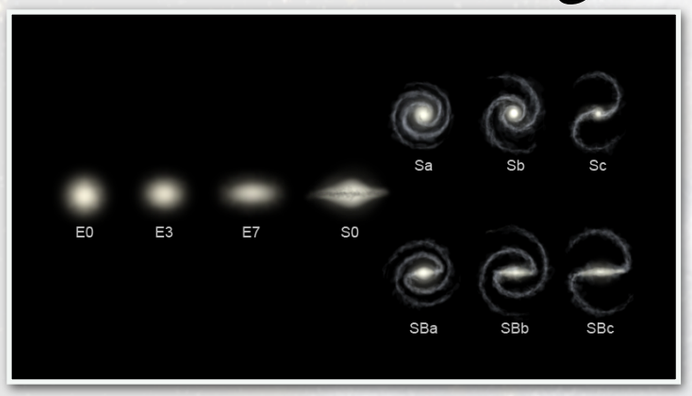
star-galaxy separation
Kim & Brunner (2017)

automated spectral feature extraction

Wang, Guo & Luo (2017)



SDSS - CANDELS galaxy classification



Dieleman, Willett & Dambre (2015)

Huertas-Company et al. (2015)

Strong Lens Finding

Lanusse et al. (2017)

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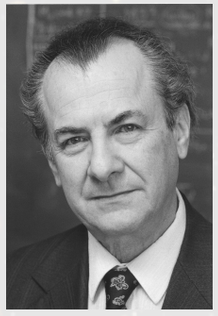
Classification Radio Galaxies

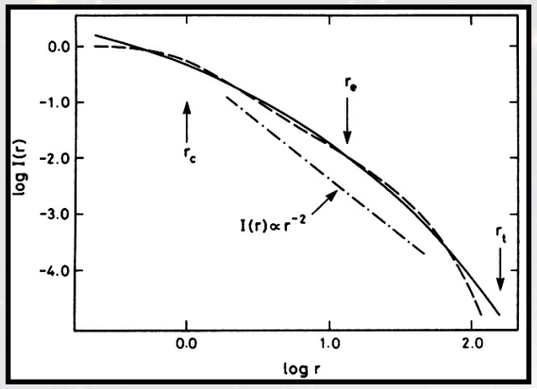
Vesna Lukic here

Galaxy photometrical brightness profiles



de Vaucouleurs profile

(de Vaucouleurs - 1958)



Sersic (1968)

Kormendy (1977) and Kent (1985)

GALFIT

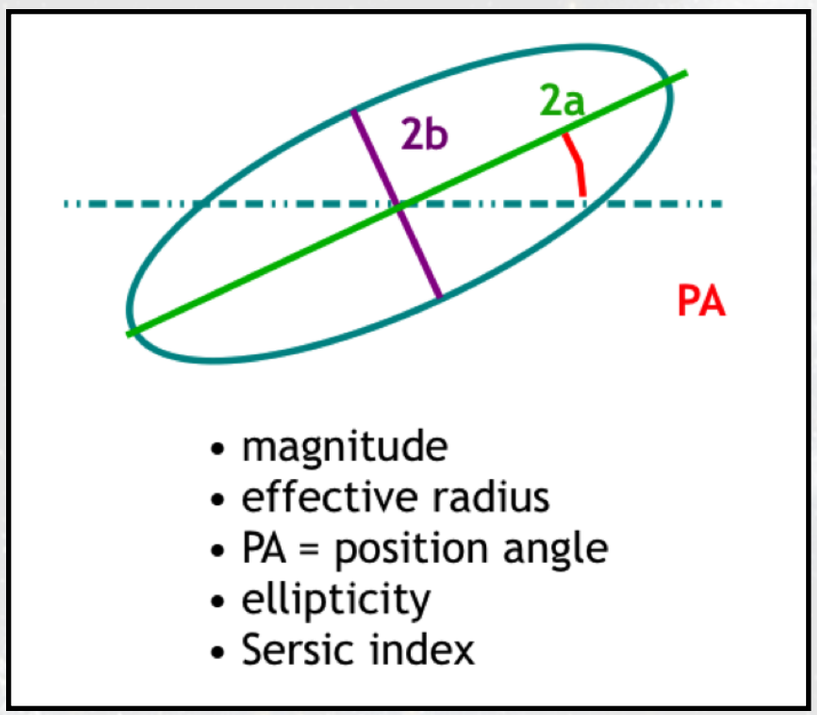
(Peng et al. 2002, 2010),

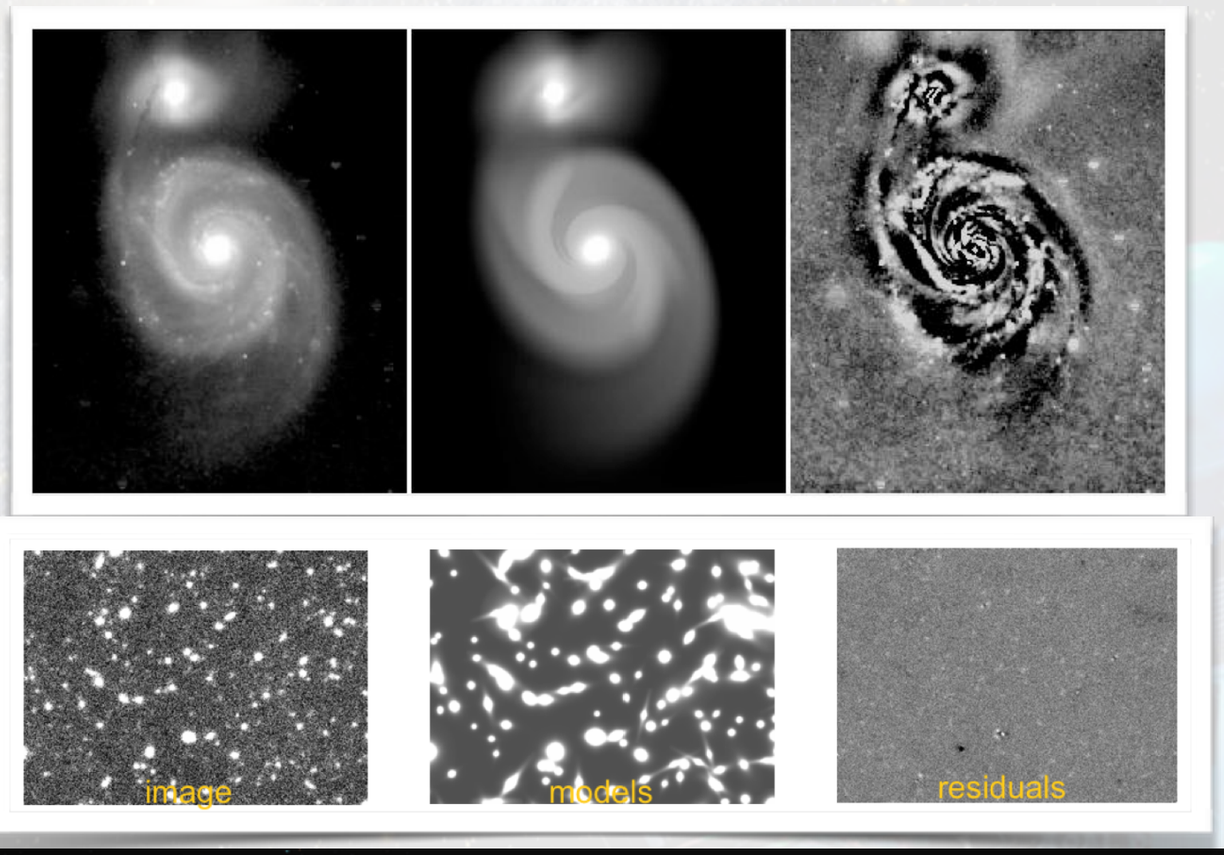
GIM2D

(Simard 1998; 2002)

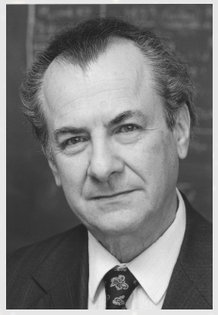
SEXTRACTOR

(Bertin & Arnouts 1996)



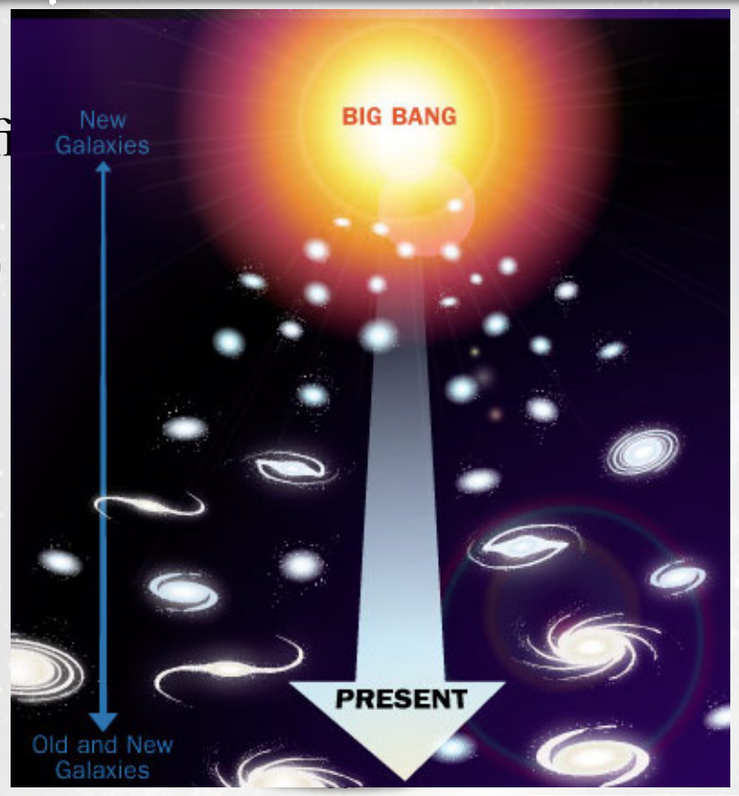


Galaxy photometrical brightness profiles



de Vaucouleurs profi

(de Vaucouleurs - 1958)



Sersic (1968)

Kormendy (1977) and Kent (1985)

GALFIT

(Peng et al. 2002, 2010),

SEXTRACTOR

(Bertin & Arnouts 1996)

- models of evolution and formation over cosmic time

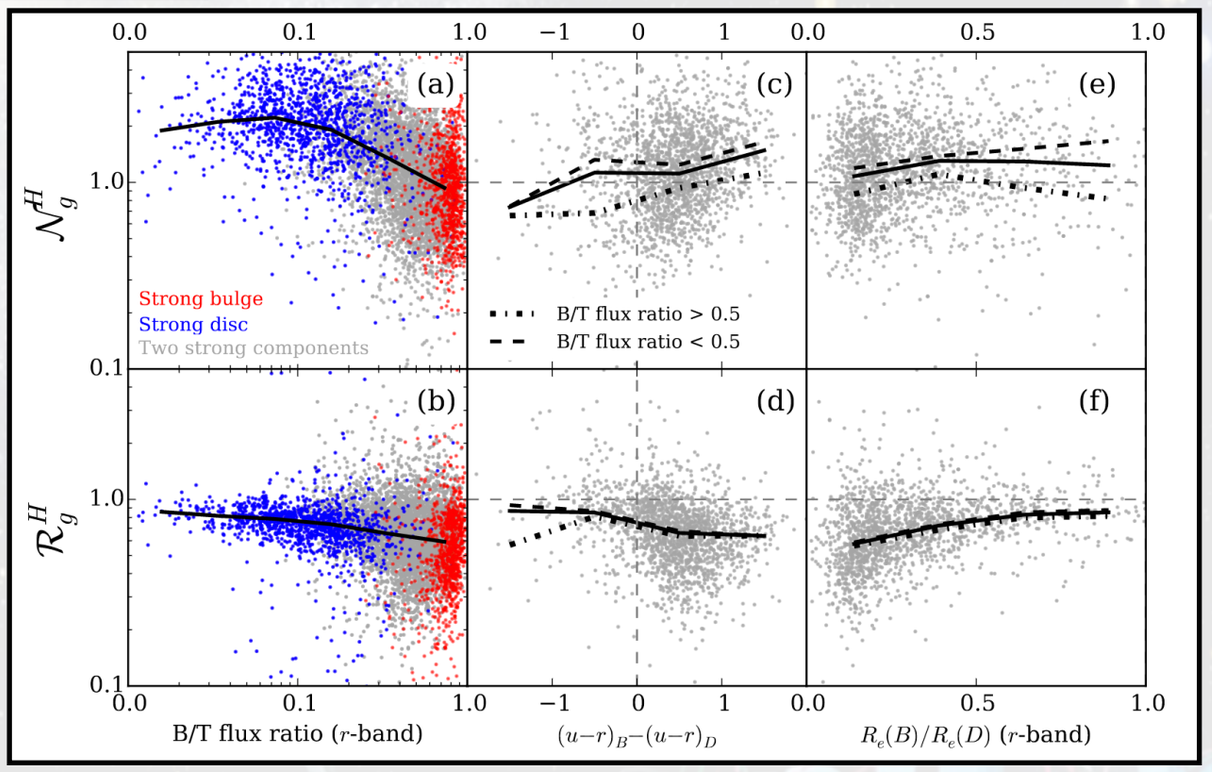
  Kormendy & Kennicutt (2004); (Zavala, Okamoto & Frenk 2008; Lacey et al. 2016)

- distribution of mass and luminosity-surface brightness in relation of different classes of galaxy and types of structure

  Driver et al. 2007; Kelvin et al. (2014); Kennedy et al. 2016).

- size distribution of galaxies and its dependence on their luminosity

  (Shen et al. 2003, Lange et al. 2016).

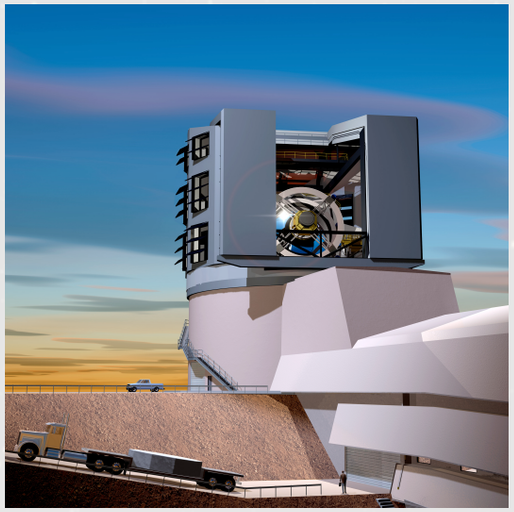


Kennedy et al. 2016

Suited for future large are surveys?

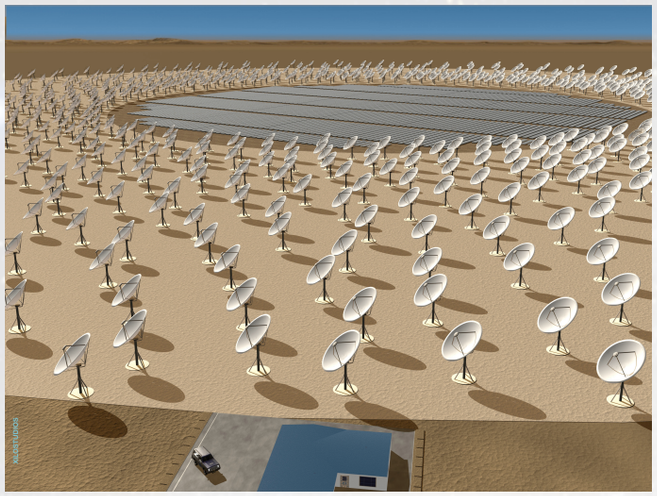
LSST

Large Synoptic Survey Telescope



SKA

(Square Kilometre Array)



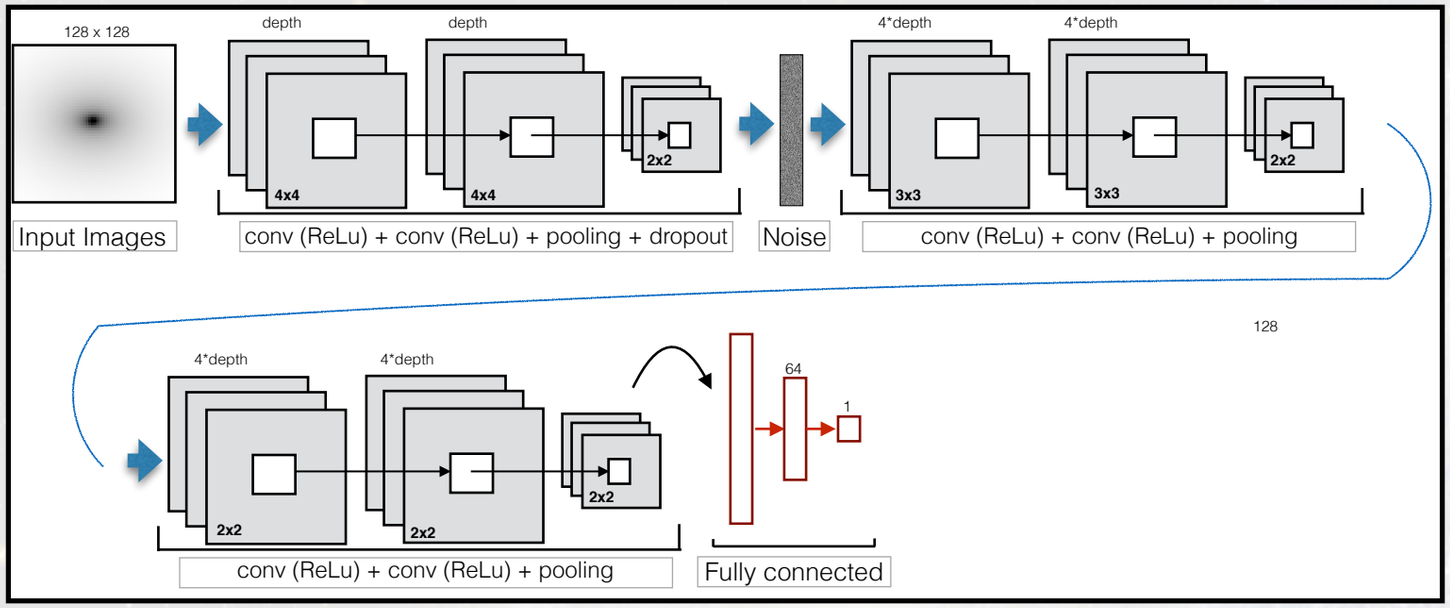
Peng words: “they require some degree of scientific and even artistic sense”

SURVEYS					
	Area (deg2)	Description			
Wide Survey	**15,000 deg²**	Step and stare with 4 dither pointings per step.			
Deep Survey	**40 deg²**	In at least 2 patches of > 10 deg² 2 magnitudes deeper than wide survey			
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	$3\ 10^{-16}$ erg cm-2 s-1 3.5σ unresolved line flux
	Shapes + Photo-z of $n = 1.5 \times 10^9$ galaxies			z of $n=5 \times 10^7$ galaxies	

http://www.euclid-ec.org/?page_id=2581

CNN for Profiling 1-component galaxies

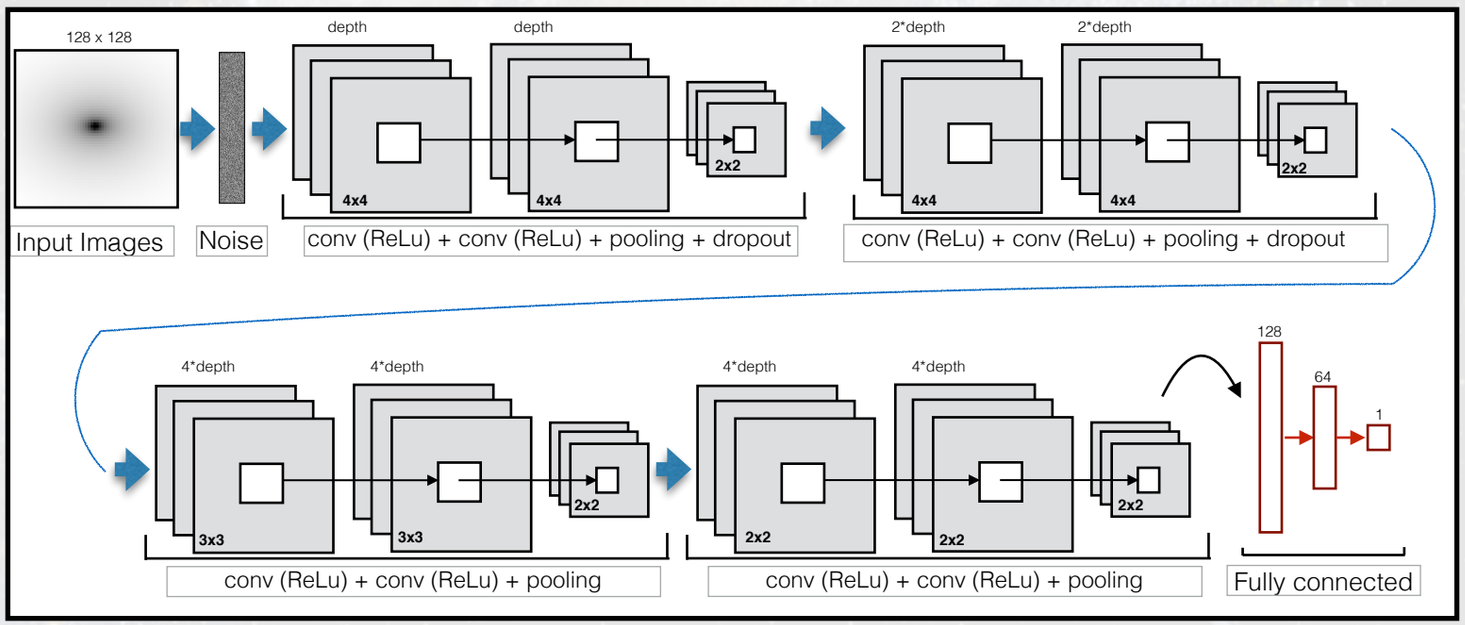
total of 6 convolutional layers, 3 max pooling layers and 2 dropout layers.



Magnitude

Radius

total of 8 convolutional layers, 4 max pooling layers and 2 dropout layers.



Sersic index

Ellipticity

Position Angle

Simulated Data

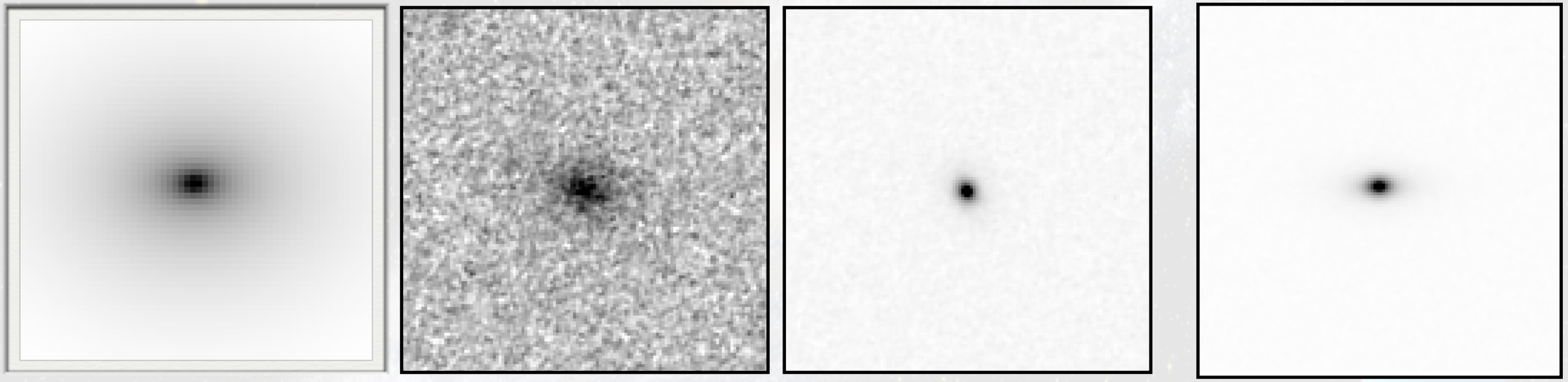
200,000 stamps

Single Sersic HST/CANDELS

REAL NOISE

PIXEL scale 0.06”

REAL PSF CANDELS



0<RADIUS (arcsec)<1.9

18< MAG<23

0.2<ELLIPTICITY<0.8

0.3<SERSIC INDEX<6.3

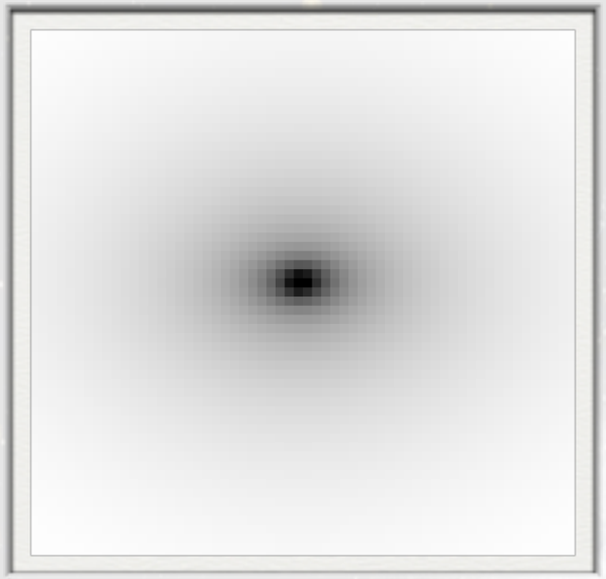
0<Position Angle (degree)<180

Simulated Data

200,000 stamps

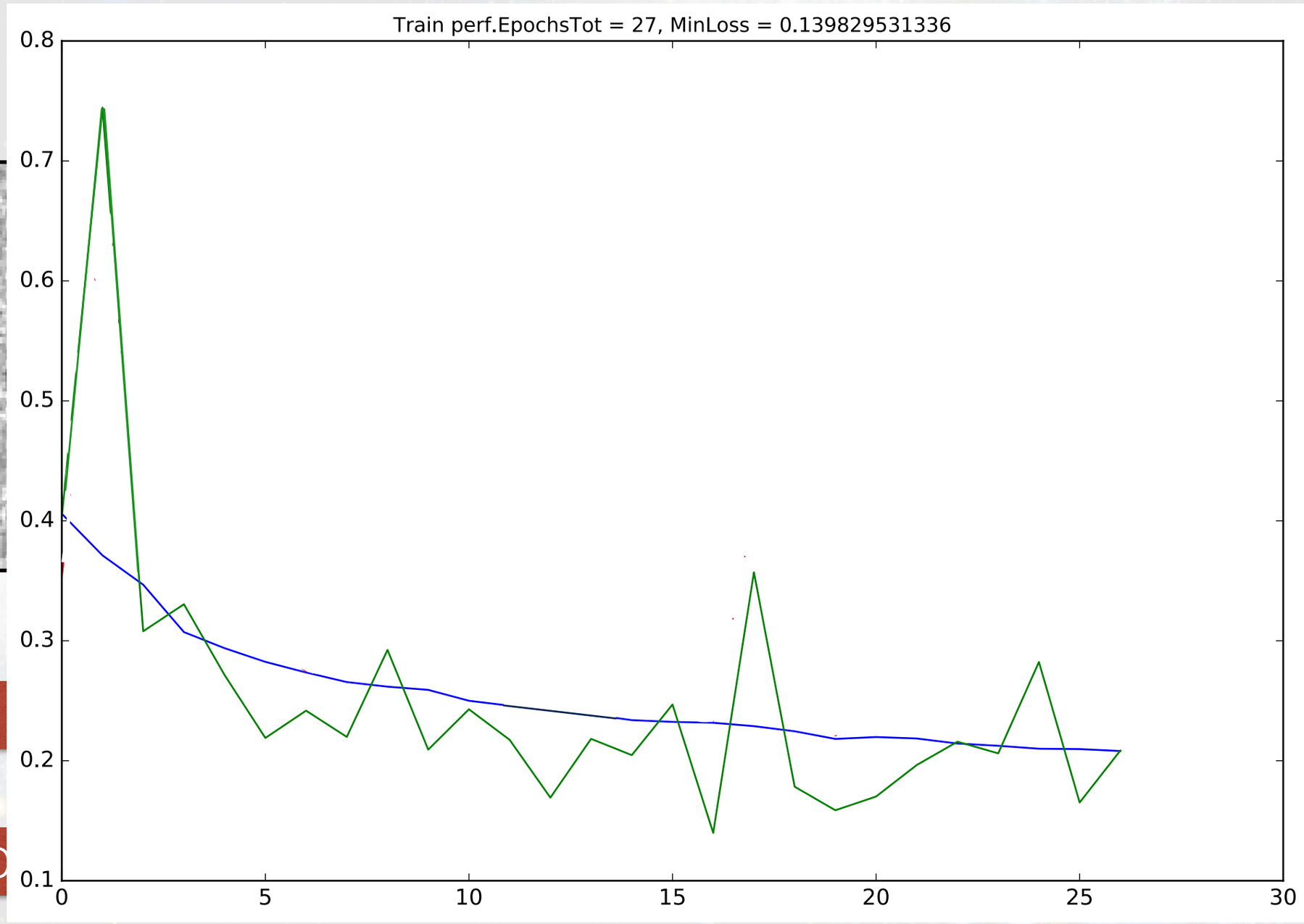
Single Sersic HST/CANDELS

REAL NOISE



0<RADIUS (arcsec)<1

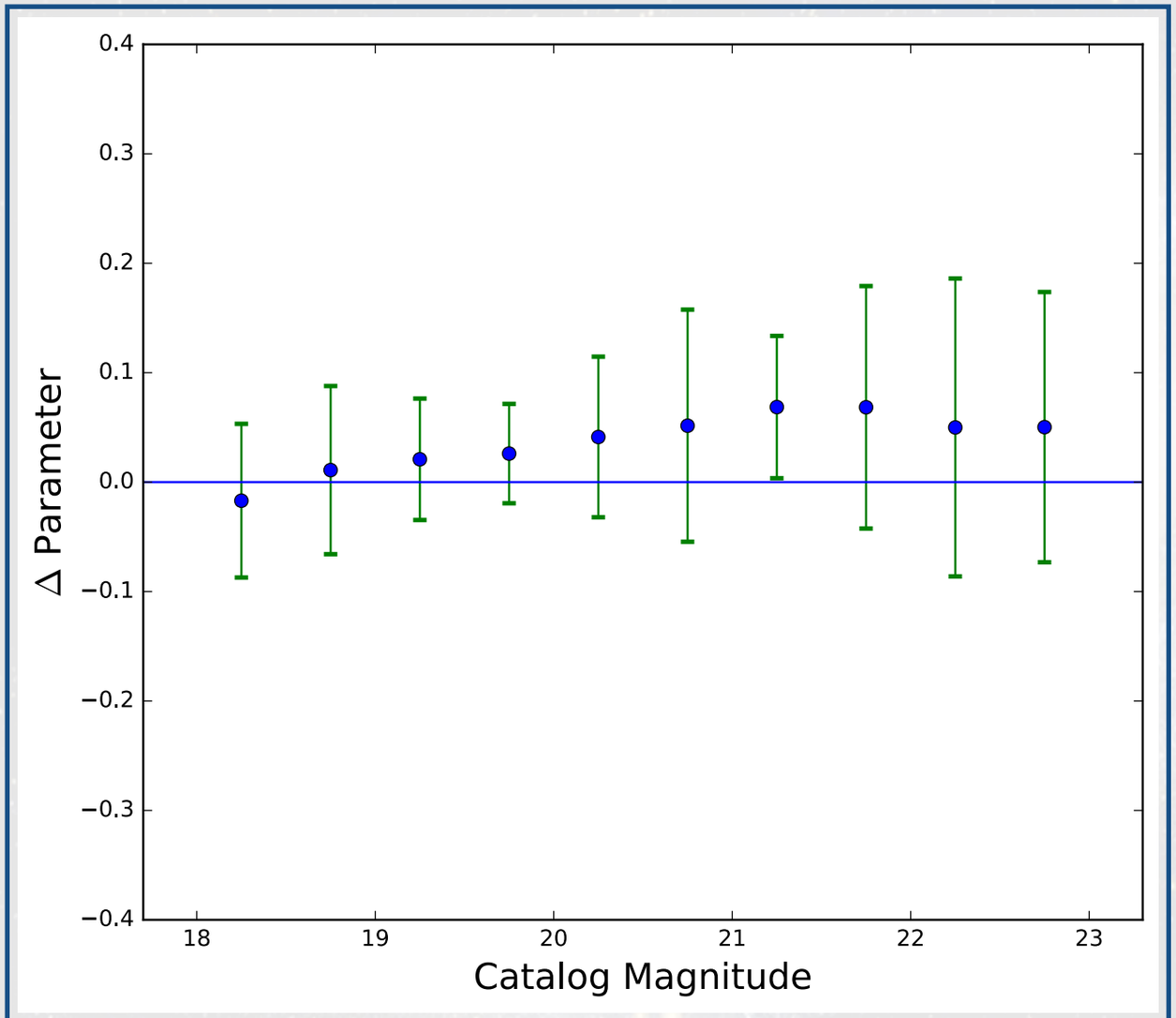
0.3<SERSIC IND



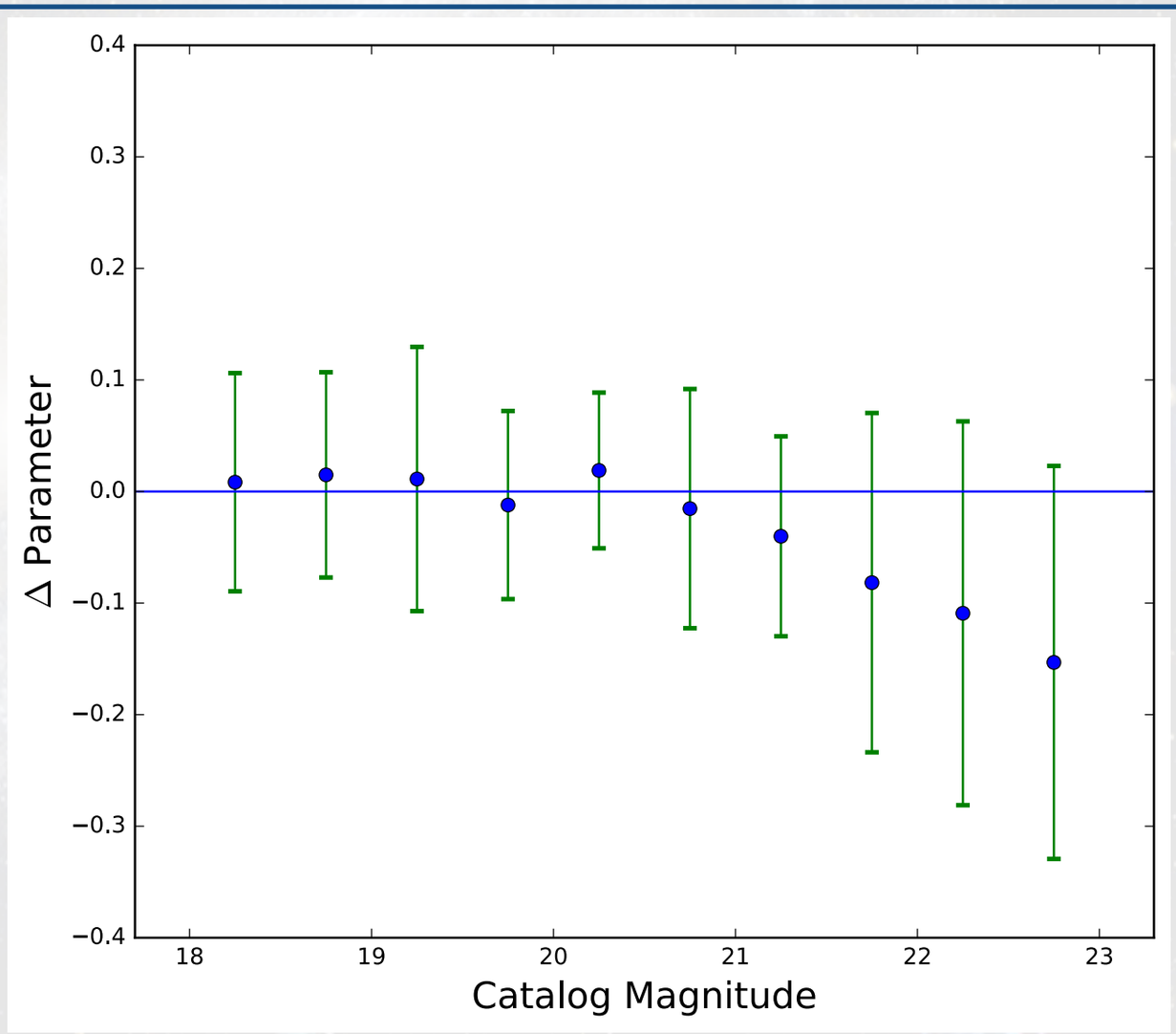
Predictions on Simulated Data

5000 stamps

Magnitude



DNN

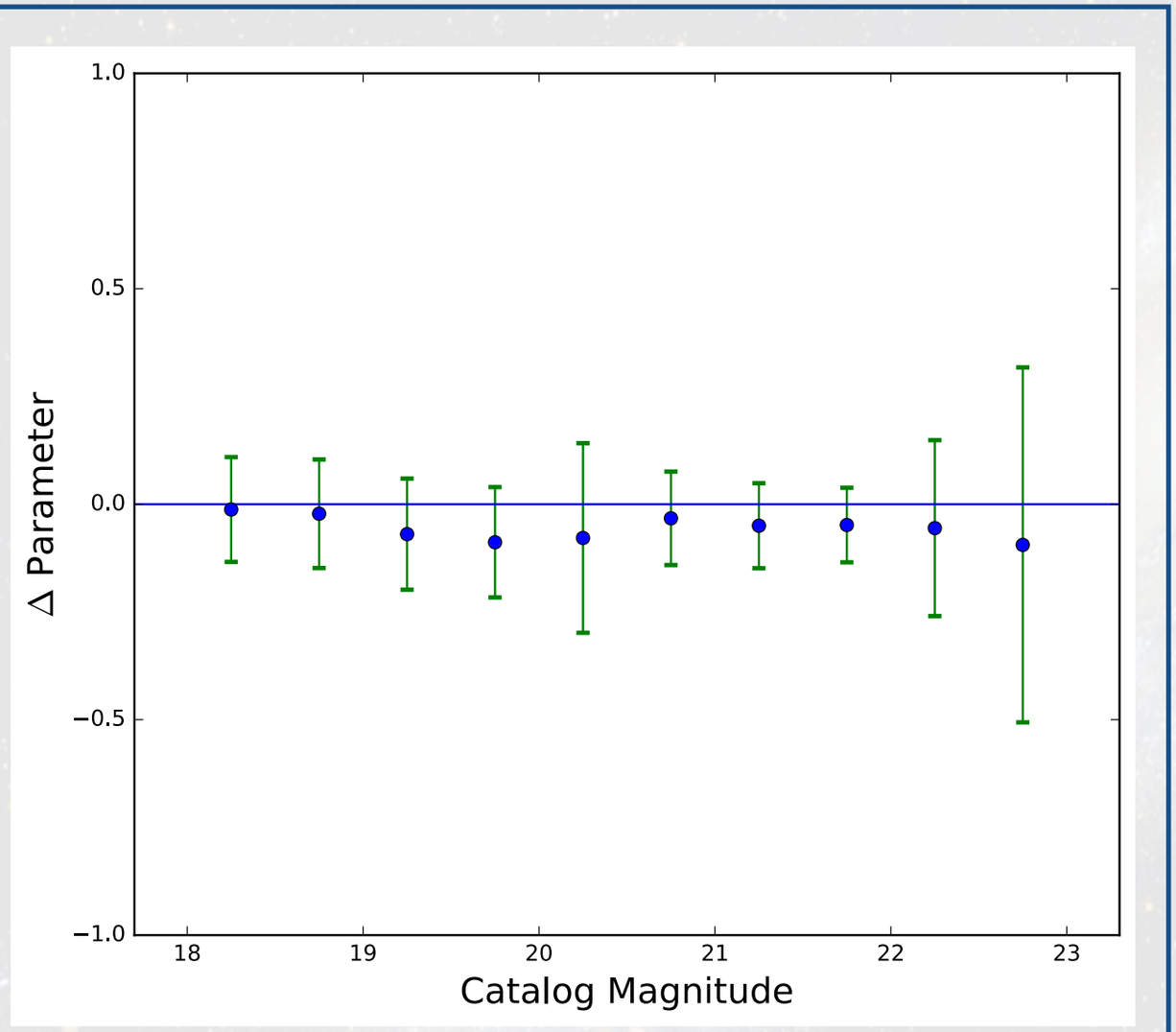


GALFIT-SExtractor

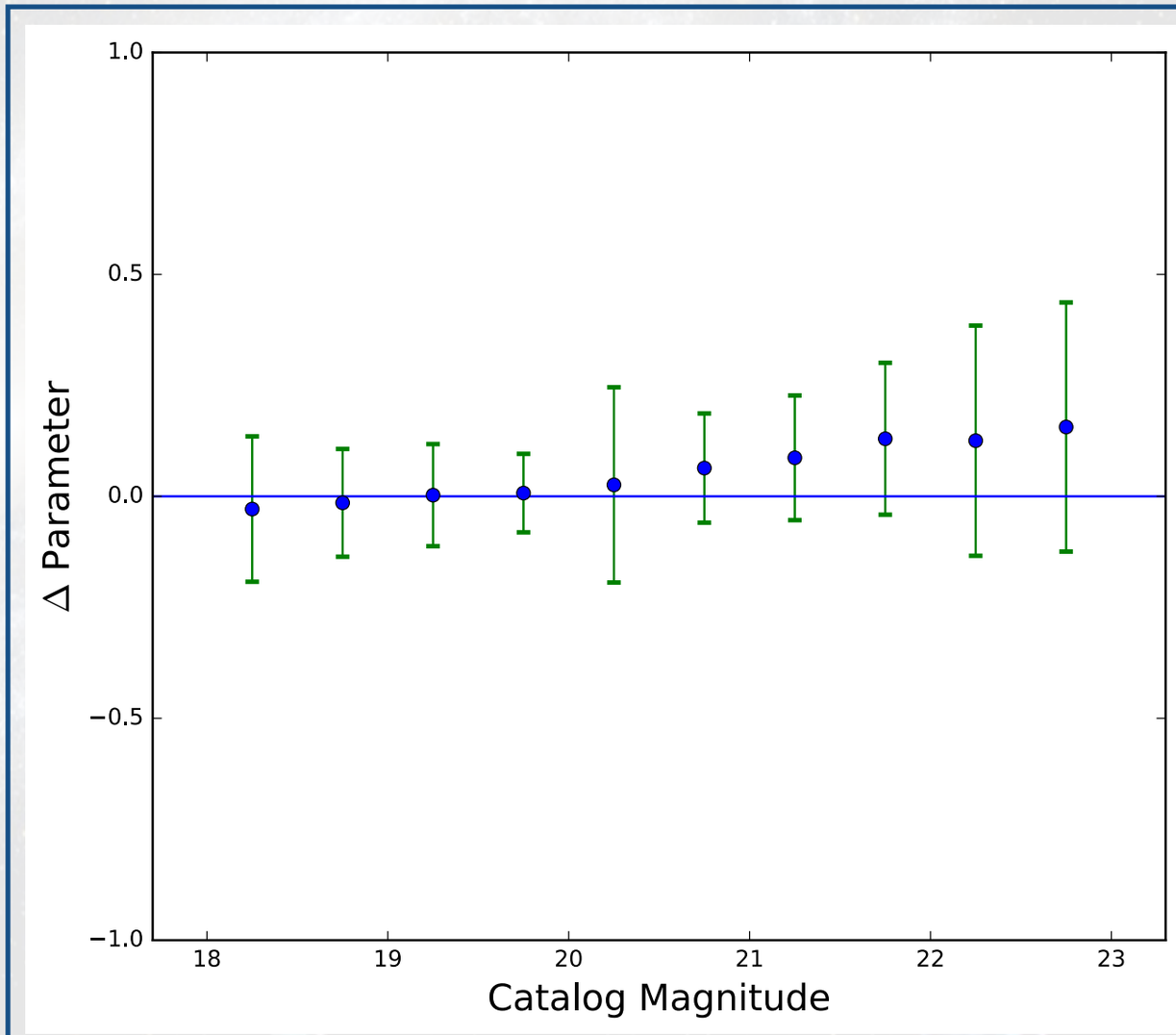
Predictions on Simulated Data

5000 stamps

Radius



DNN

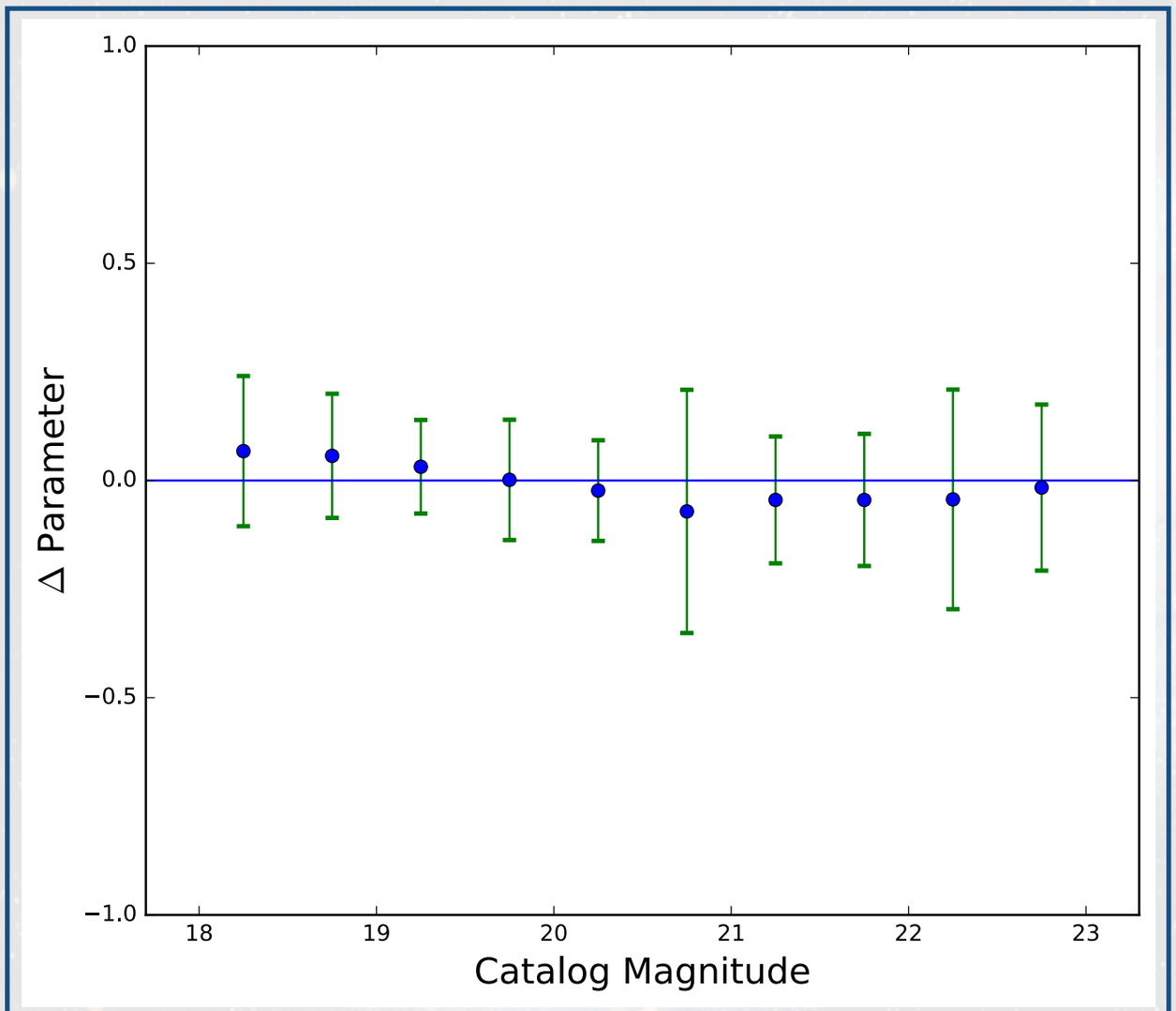


GALFIT-SExtractor

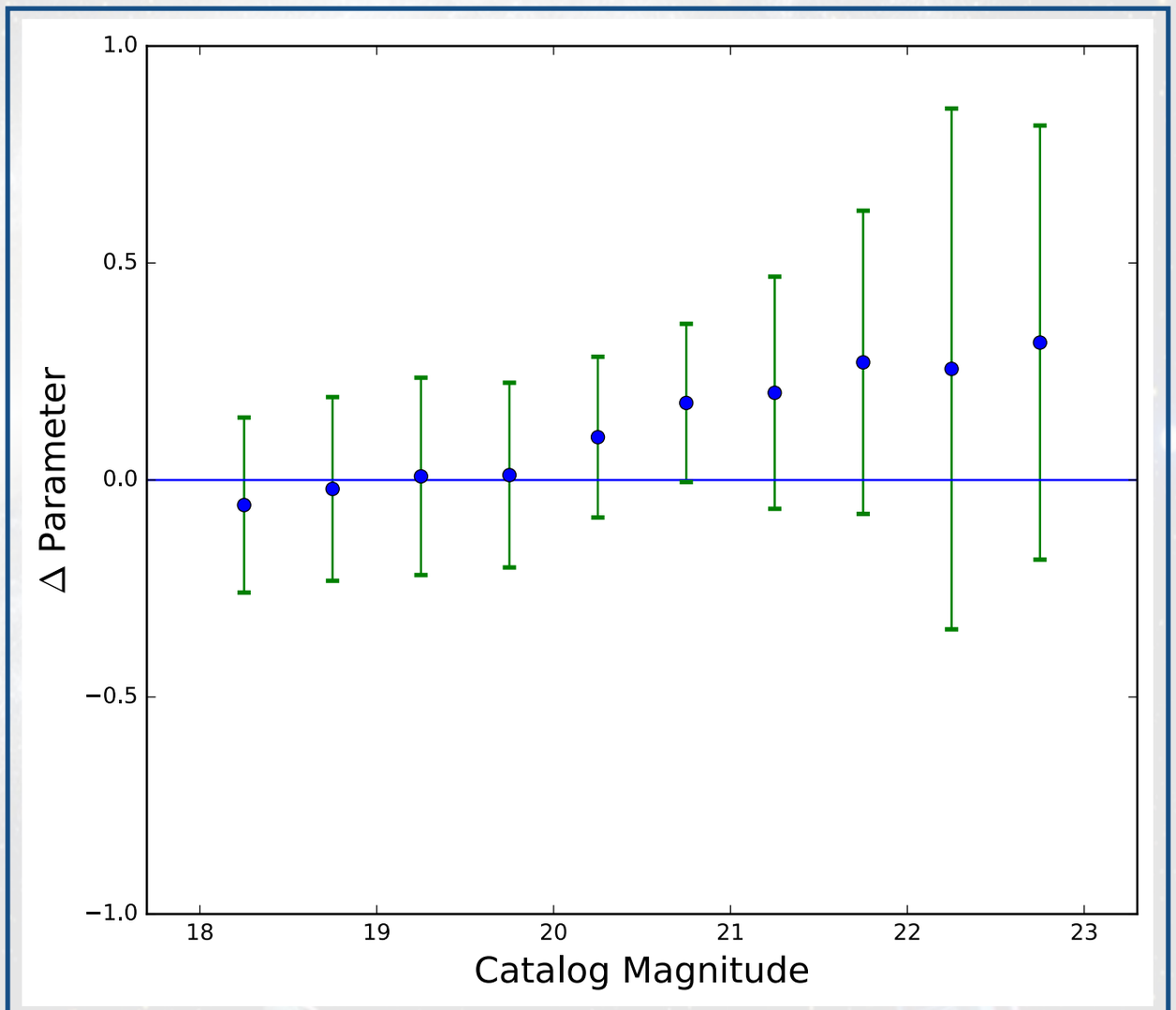
Predictions on Simulated Data

5000 stamps

Sersic index



DNN

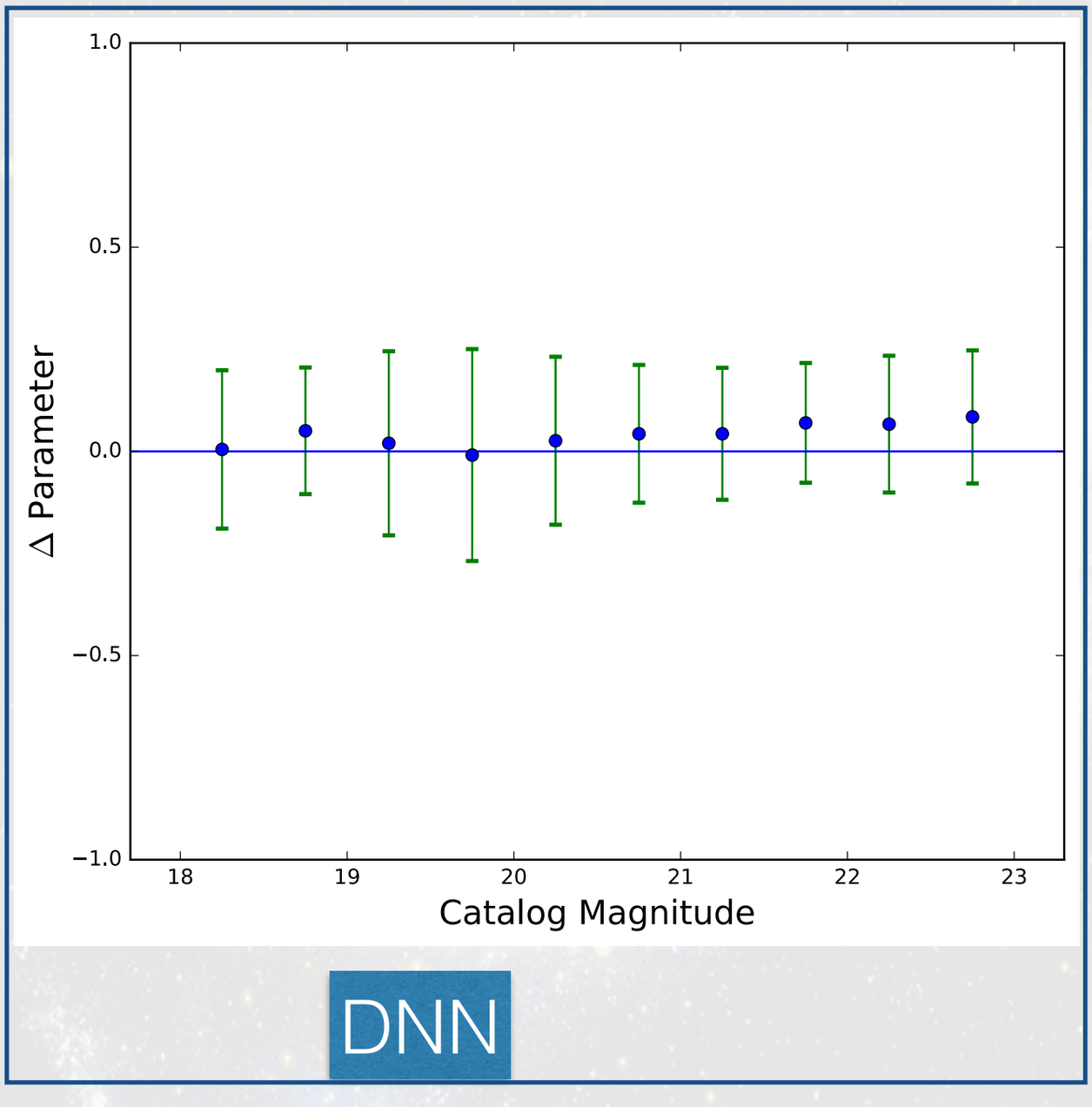


GALFIT-SExtractor

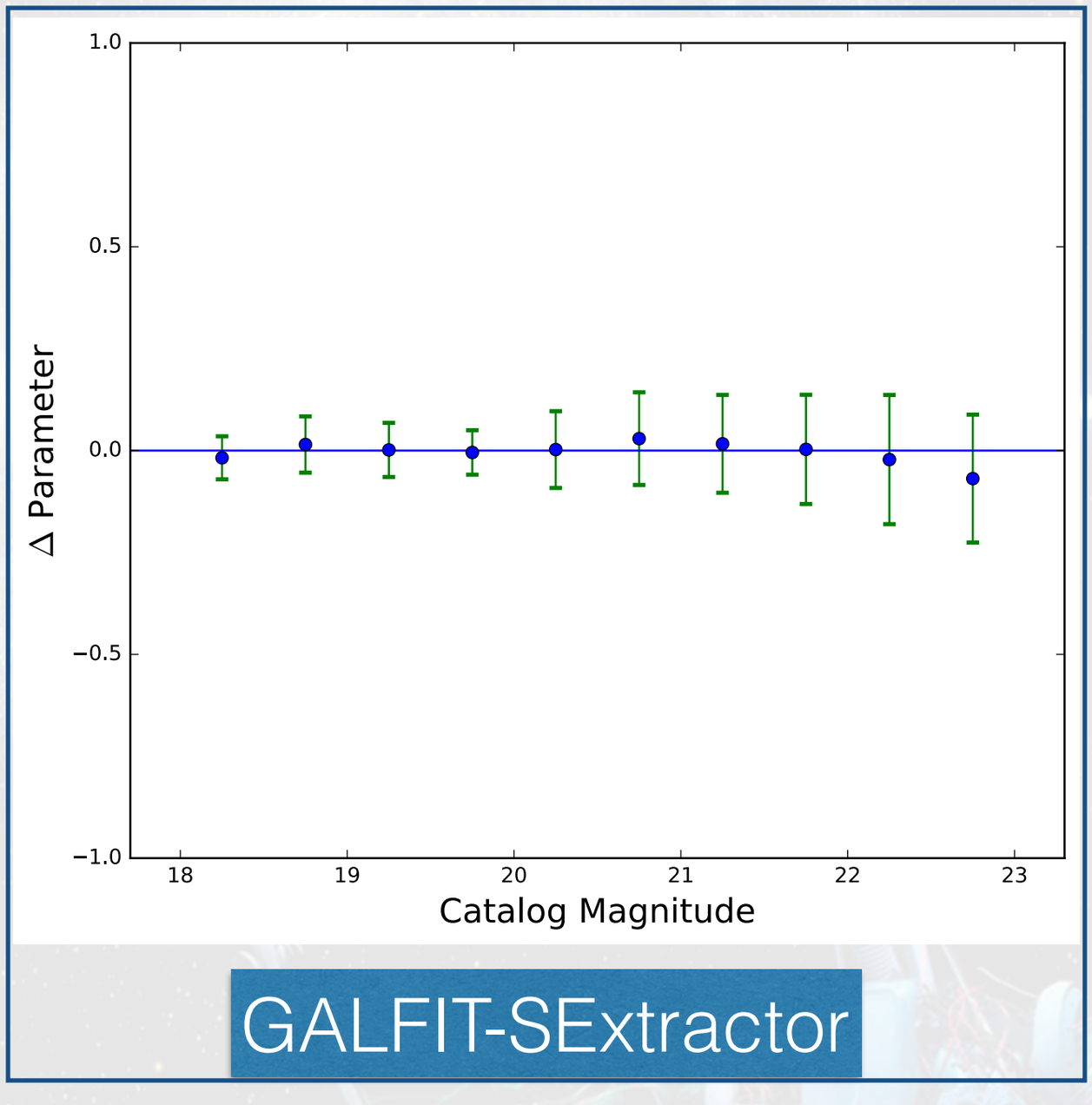
Predictions on Simulated Data

5000 stamps

Ellipticity



DNN



GALFIT-SExtractor

Summary of predictions on simulation

	R^2 simulated data		
Parameter	Architecture 1	Architecture 2	GALFIT
Magnitude	0.947	0.995	0.986
Radius	0.892	0.955	0.738
Sérsic index	0.887	0.348	0.292
Ellipticity	0.755	0.603	0.896
Position Angle	0.941	nc	0.825

coefficient of determination

$$R^2 = 1 - \frac{\sum_i (y_i - f_i)^2}{\sum_i (y_i - \bar{y})^2}$$

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$$R^2 = 1 - \frac{\sum_i (y_i - f_i)^2}{\sum_i (y_i - \bar{y})^2}$$

~5000
sources fitted

GALFIT/GALAPAGOS

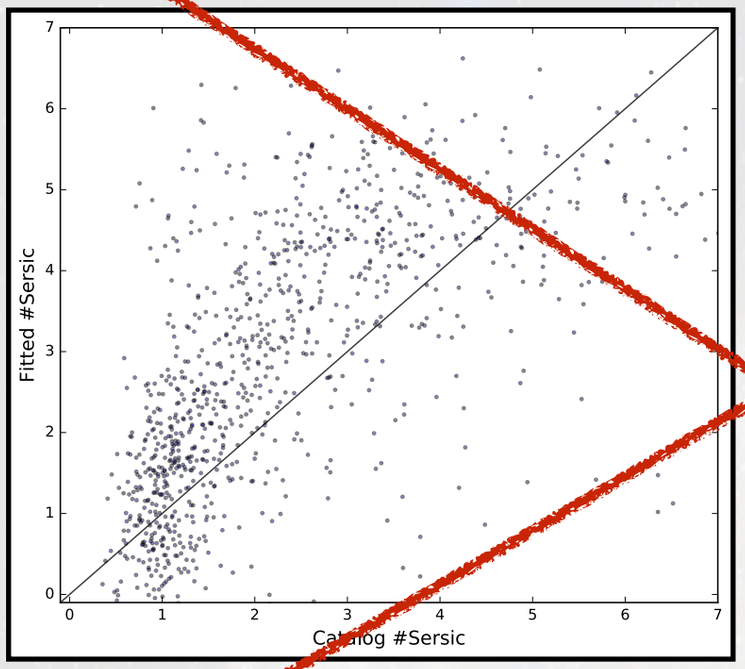
Time: ~ 4 Hours

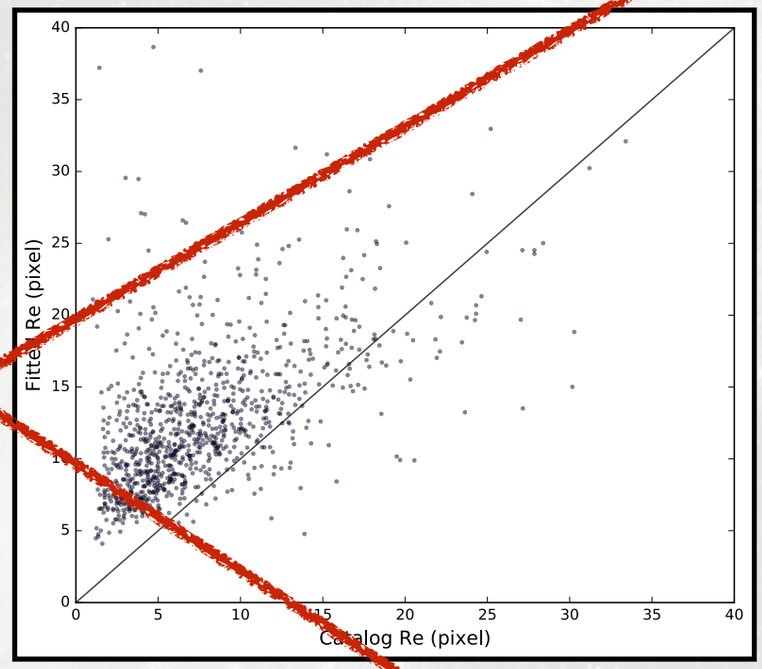
CNN (ONCE TRAINED)

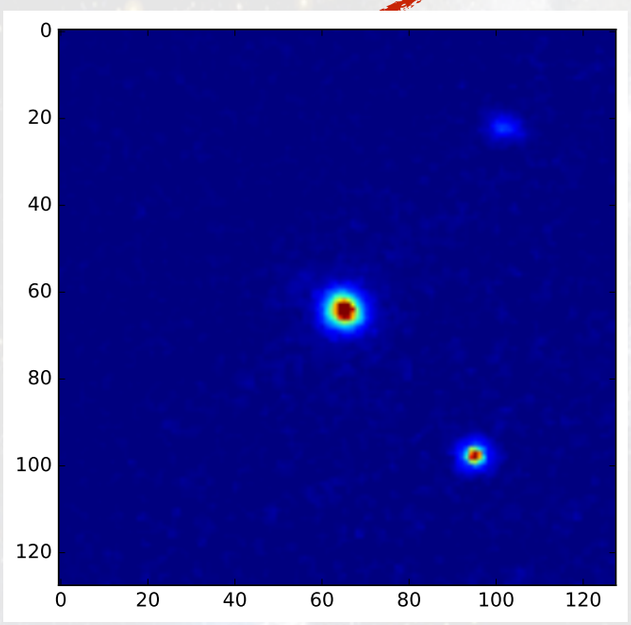
Time: < 3 seconds

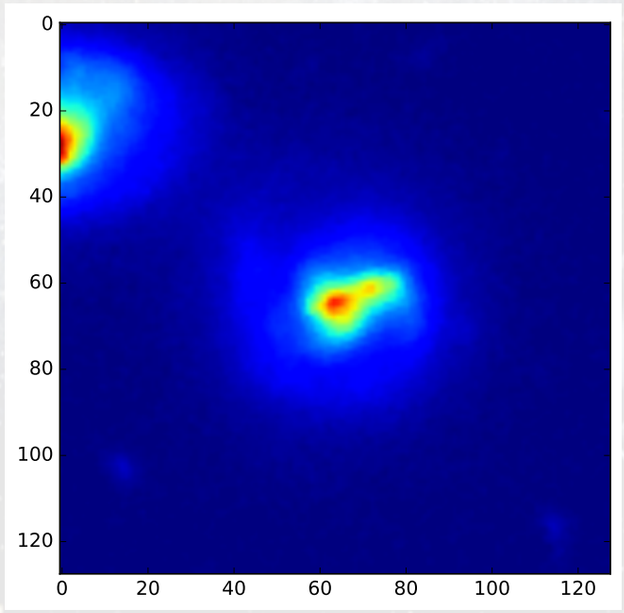
Predictions on Real Data

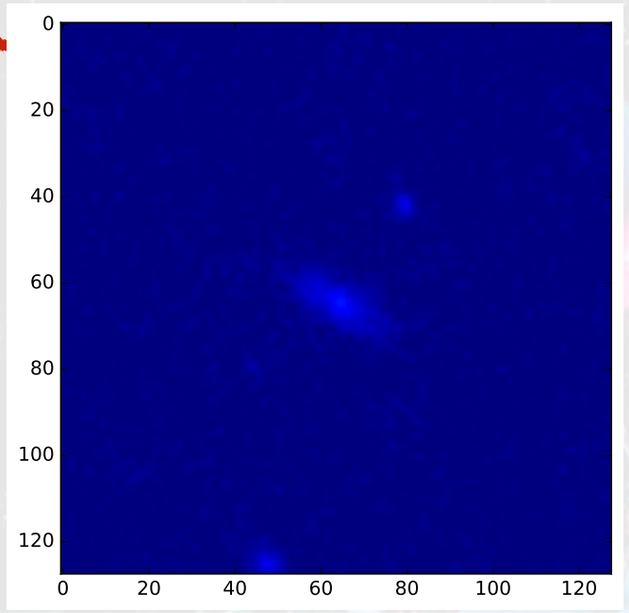
- Direct application



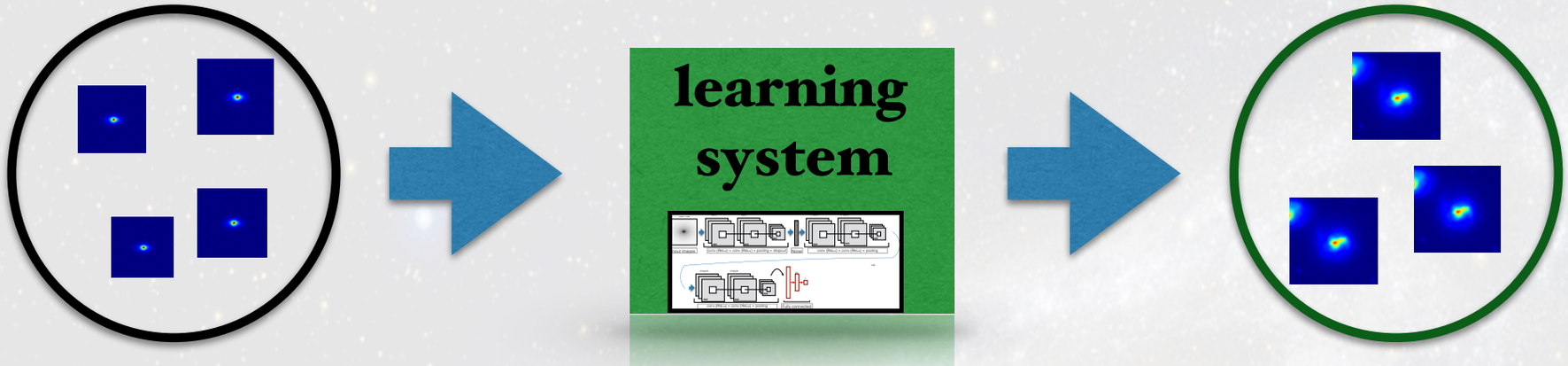








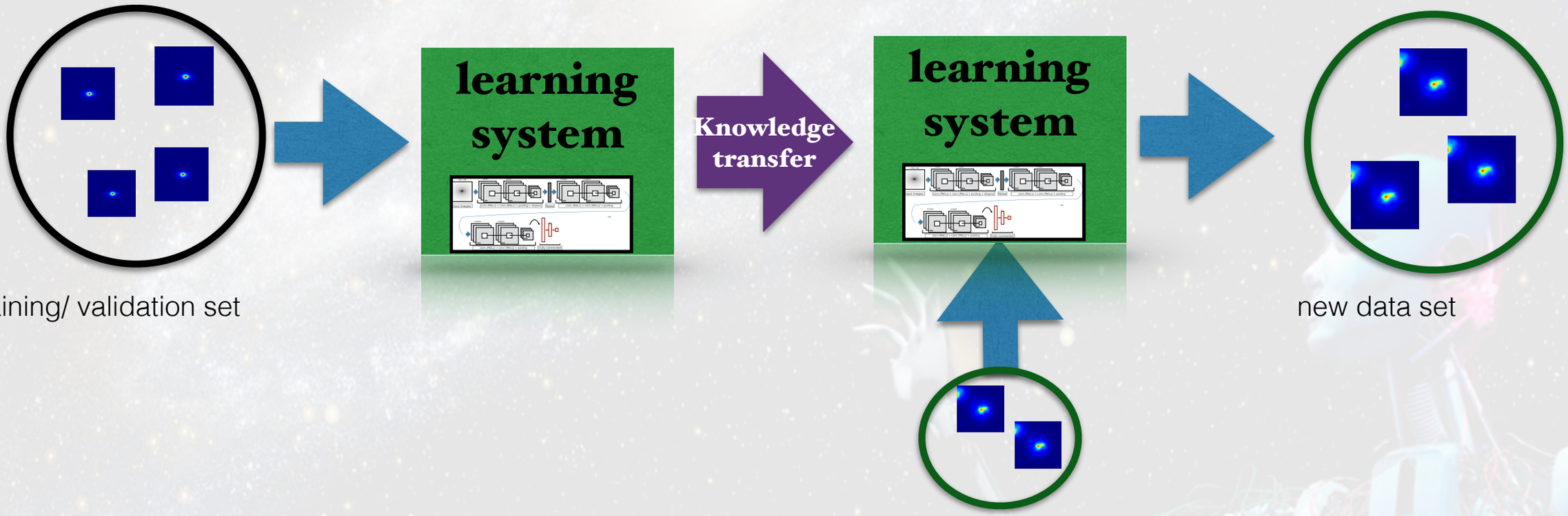
Traditional ML



training/ validation set

new data set

Domain adaptation



training/ validation set

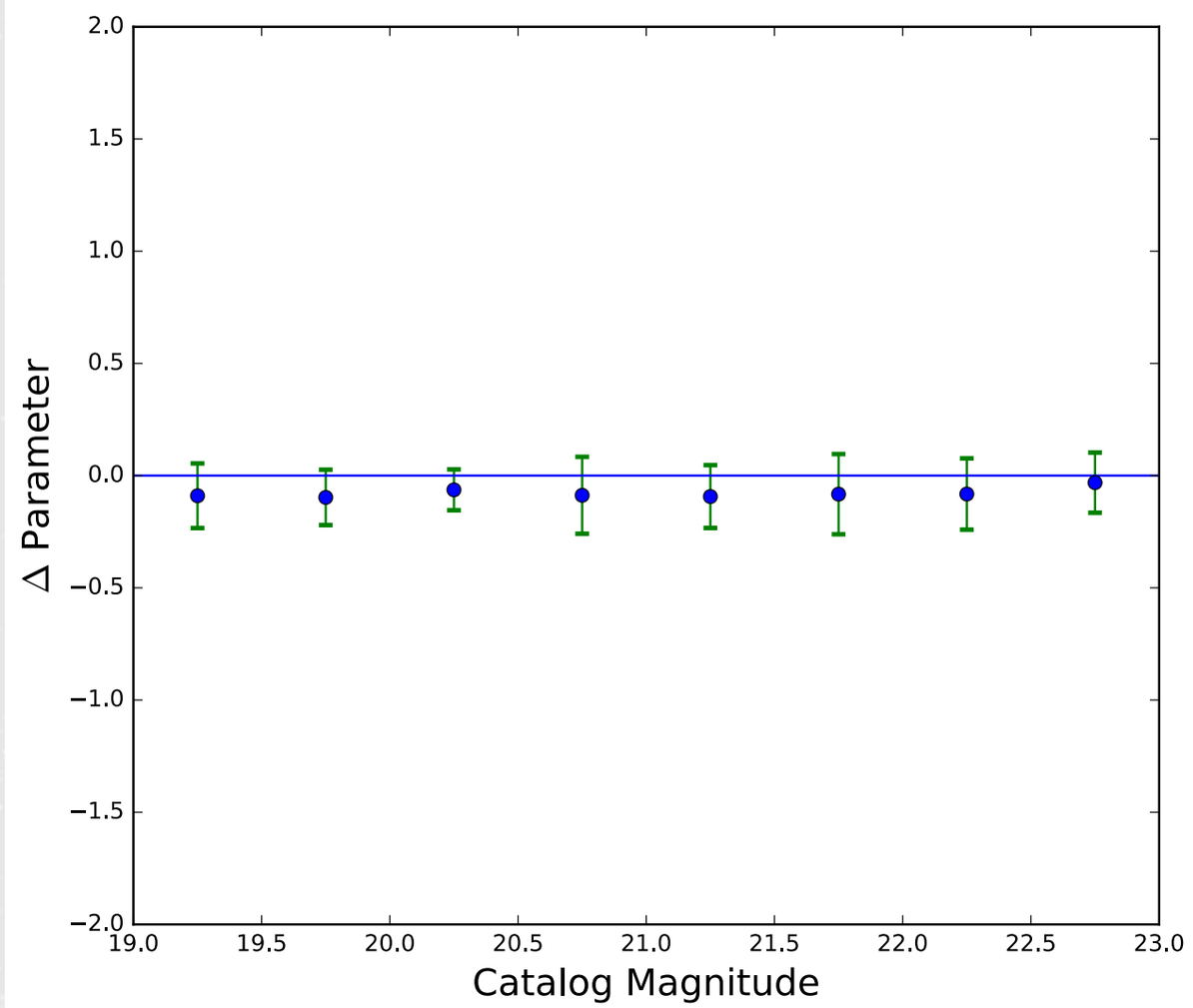
new data set

small new data set type

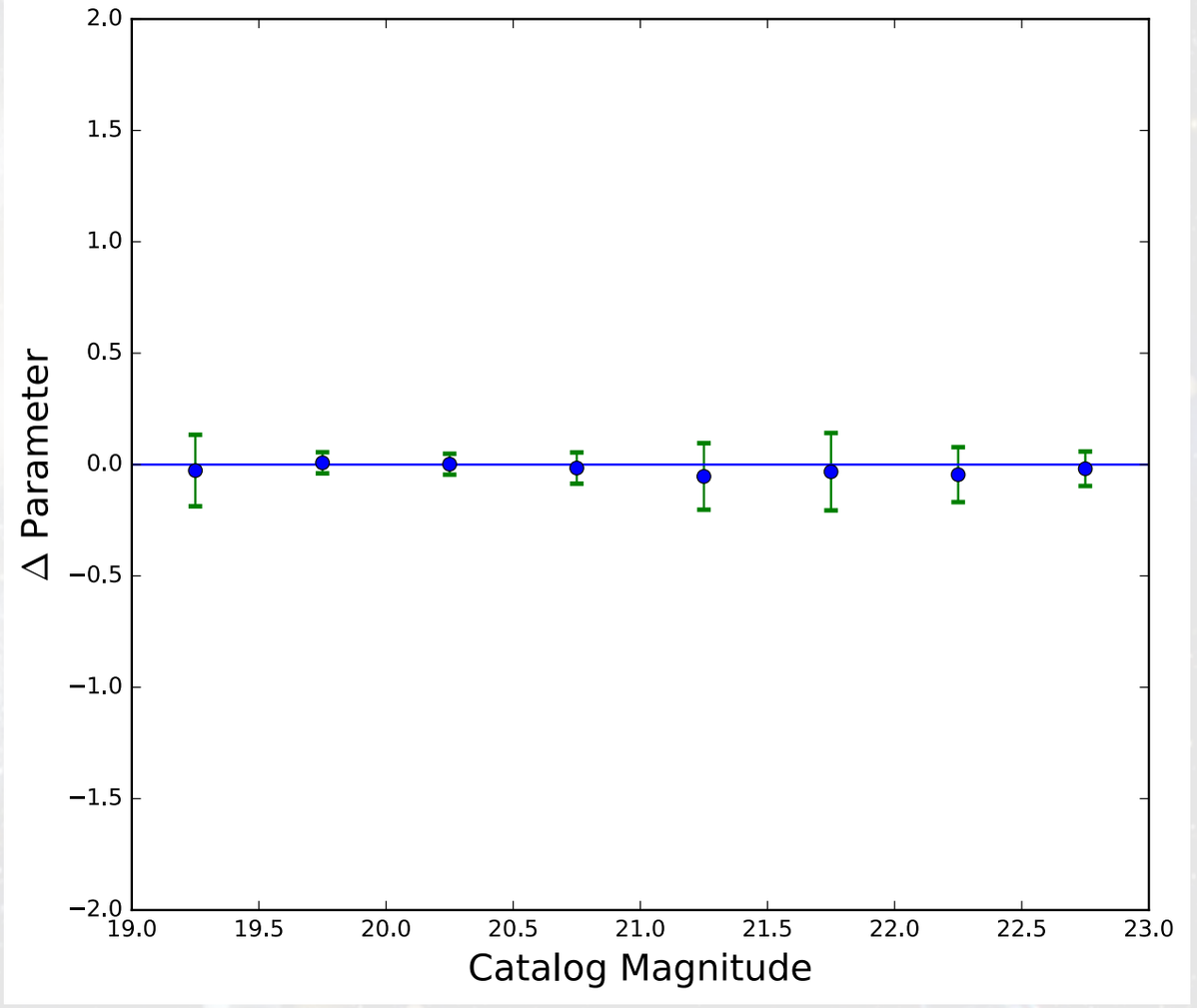
Predictions on Real Data (after domain adaptation)

Magnitude

3000 CANDELS galaxies
ground truth: Van Der Wel +12



DNN



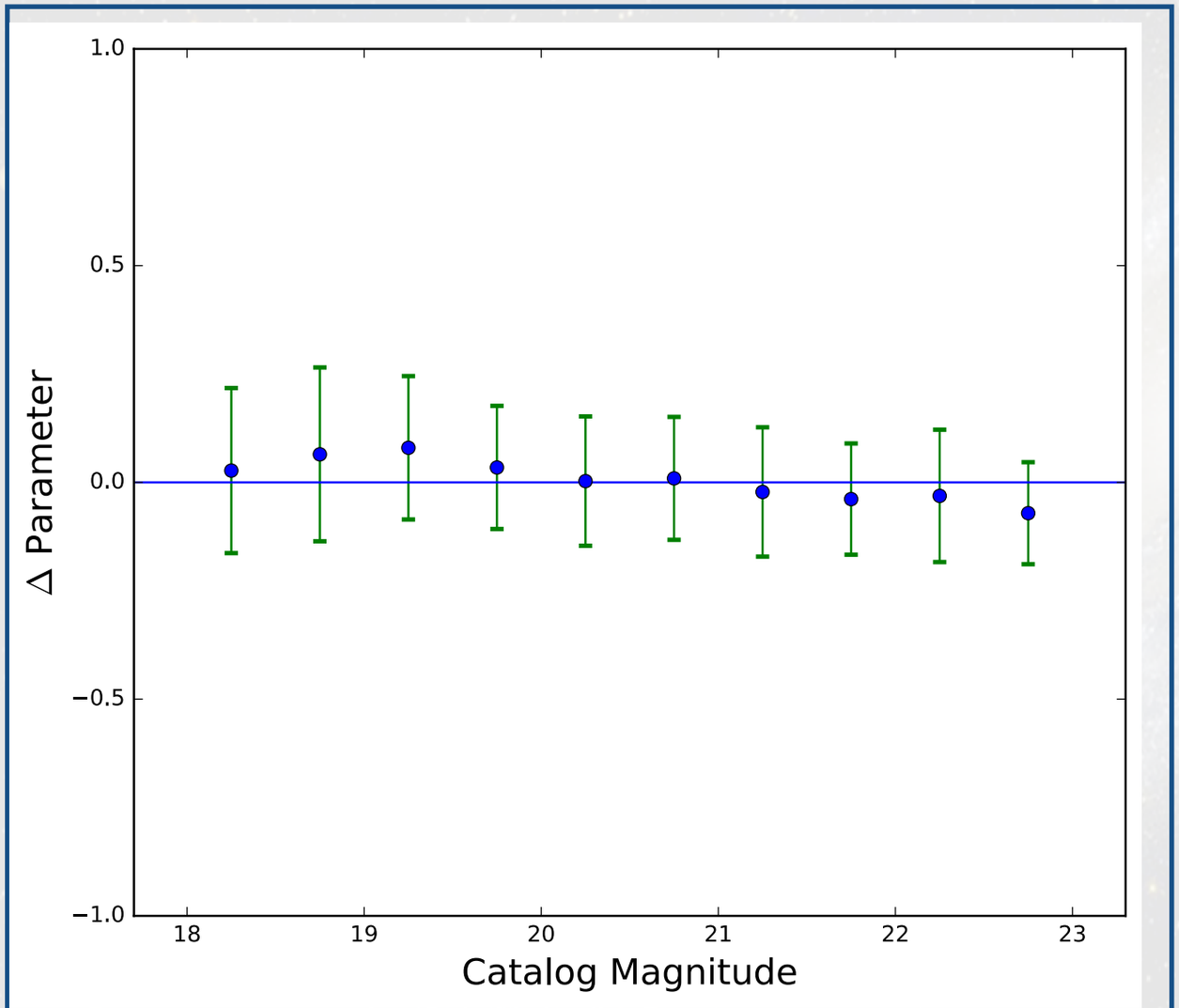
2 GALFIT parametrizations

Van Der Wel +12 Di Mauro +17

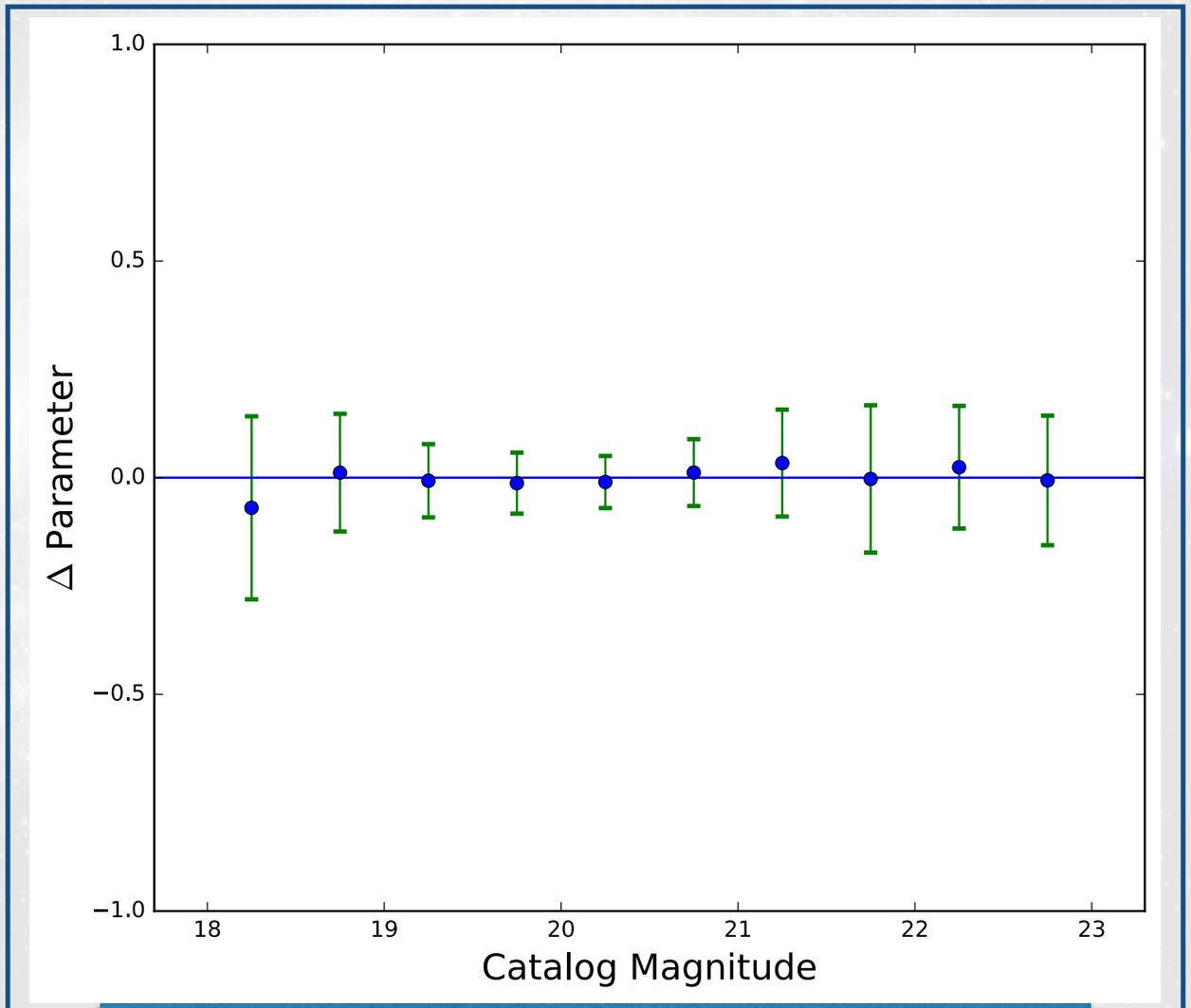
Predictions on Real Data (after domain adaptation)

Radius

3000 CANDELS galaxies
ground truth: Van Der Wel +12



DNN



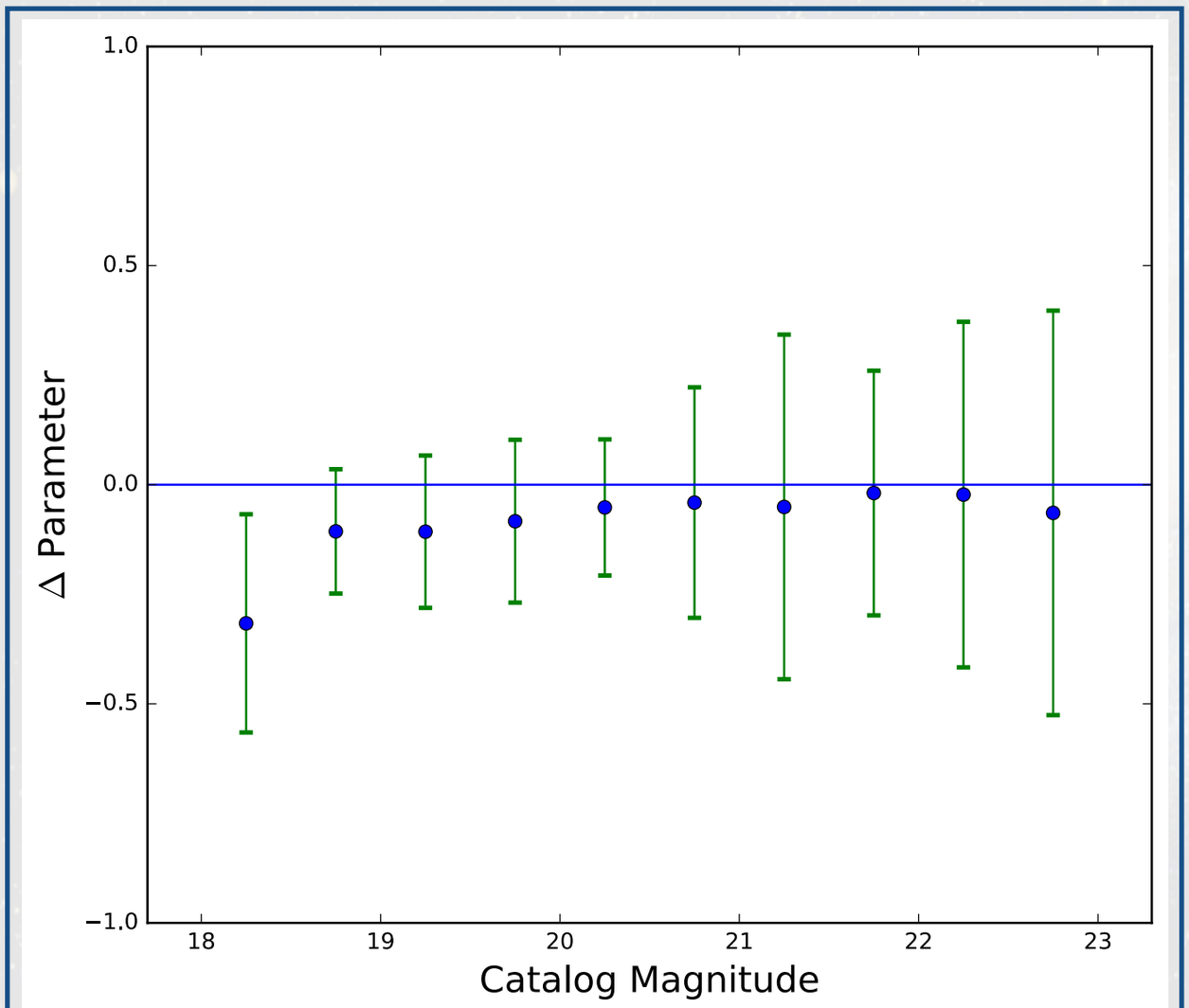
2 GALFIT parametrizations

Van Der Wel +12 Di Mauro +17

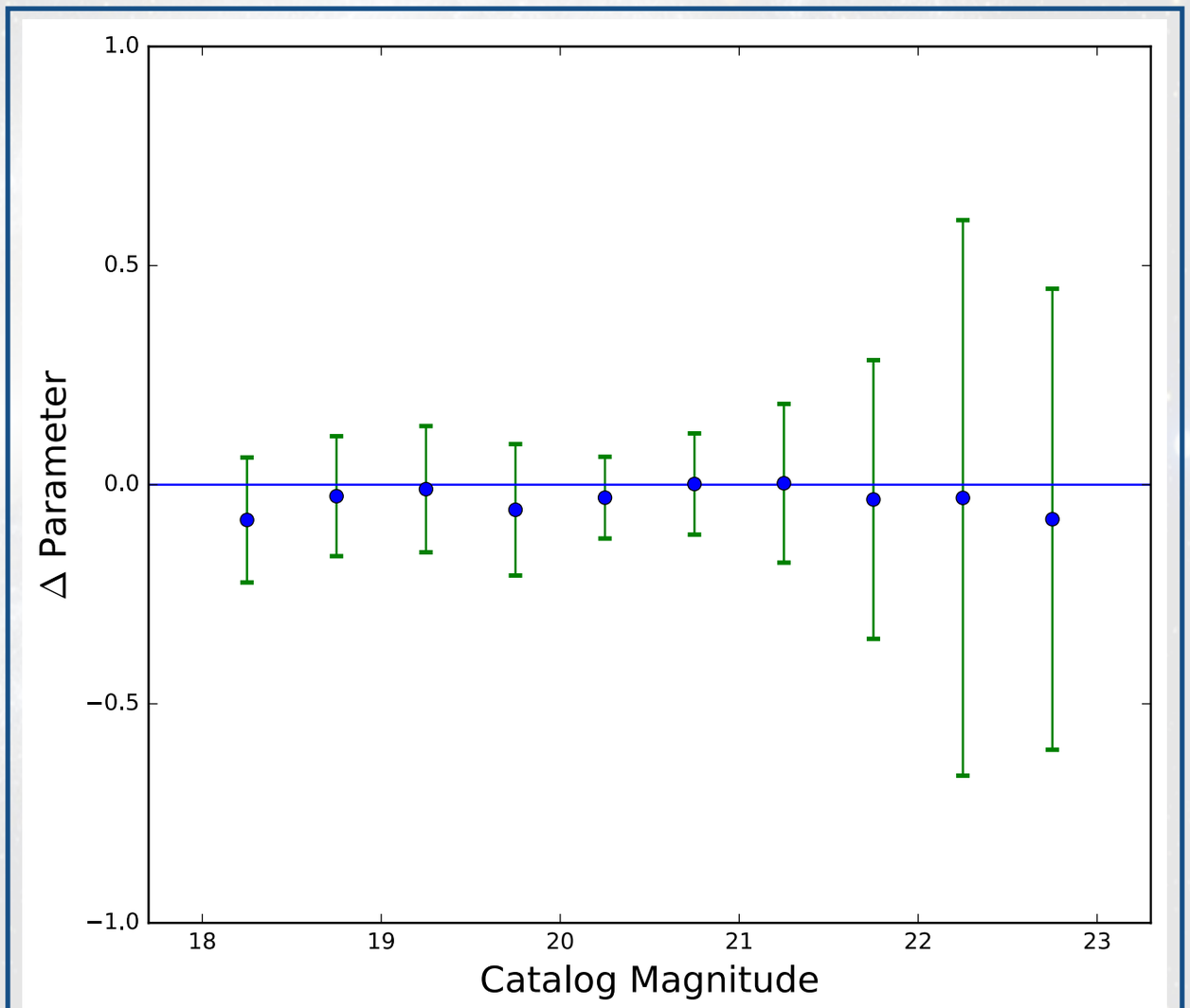
Predictions on Real Data (after domain adaptation)

Sersic index

3000 CANDELS galaxies
ground truth: Van Der Wel +12



DNN



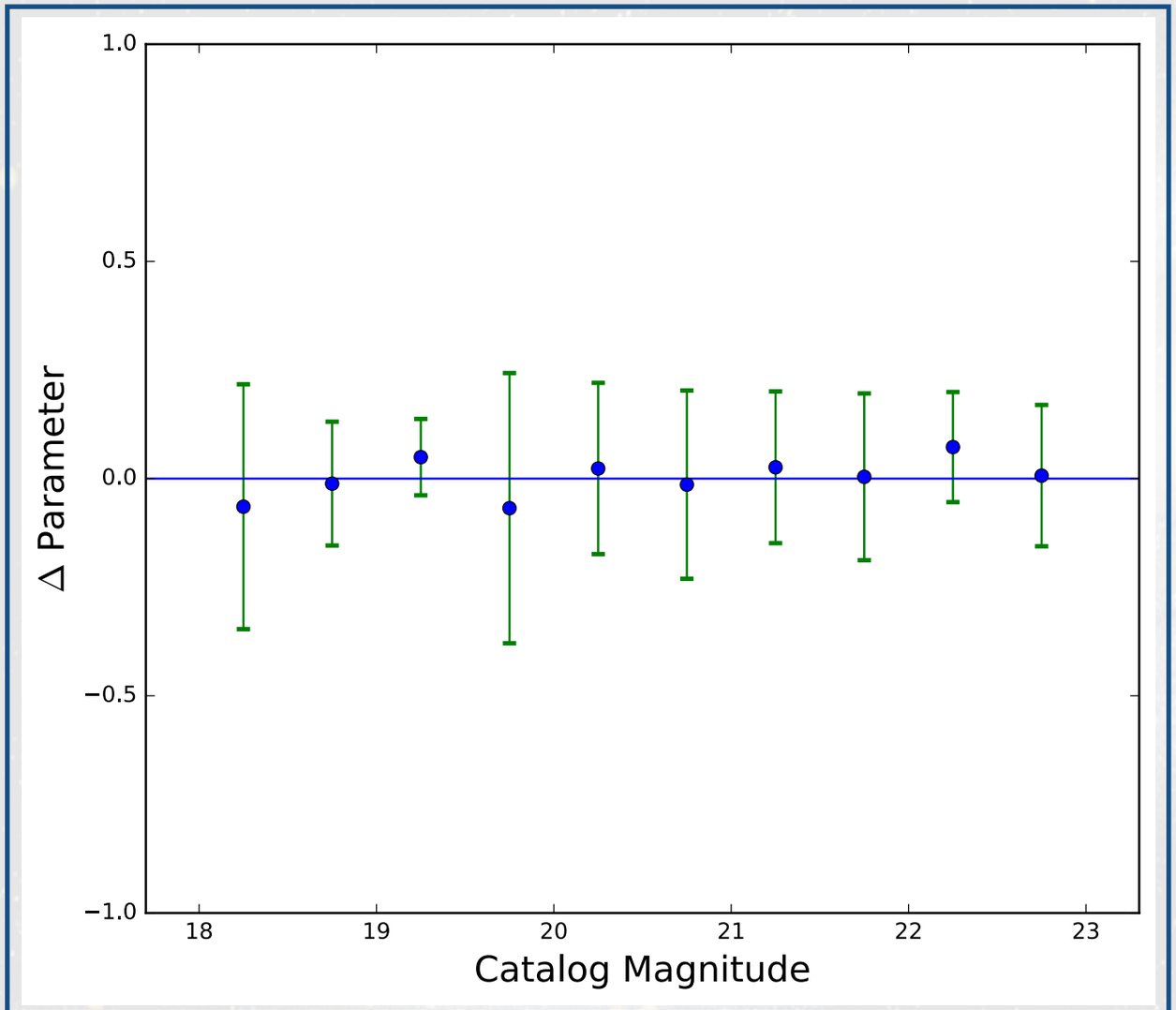
2 GALFIT parametrizations

Van Der Wel +12 Di Mauro +17

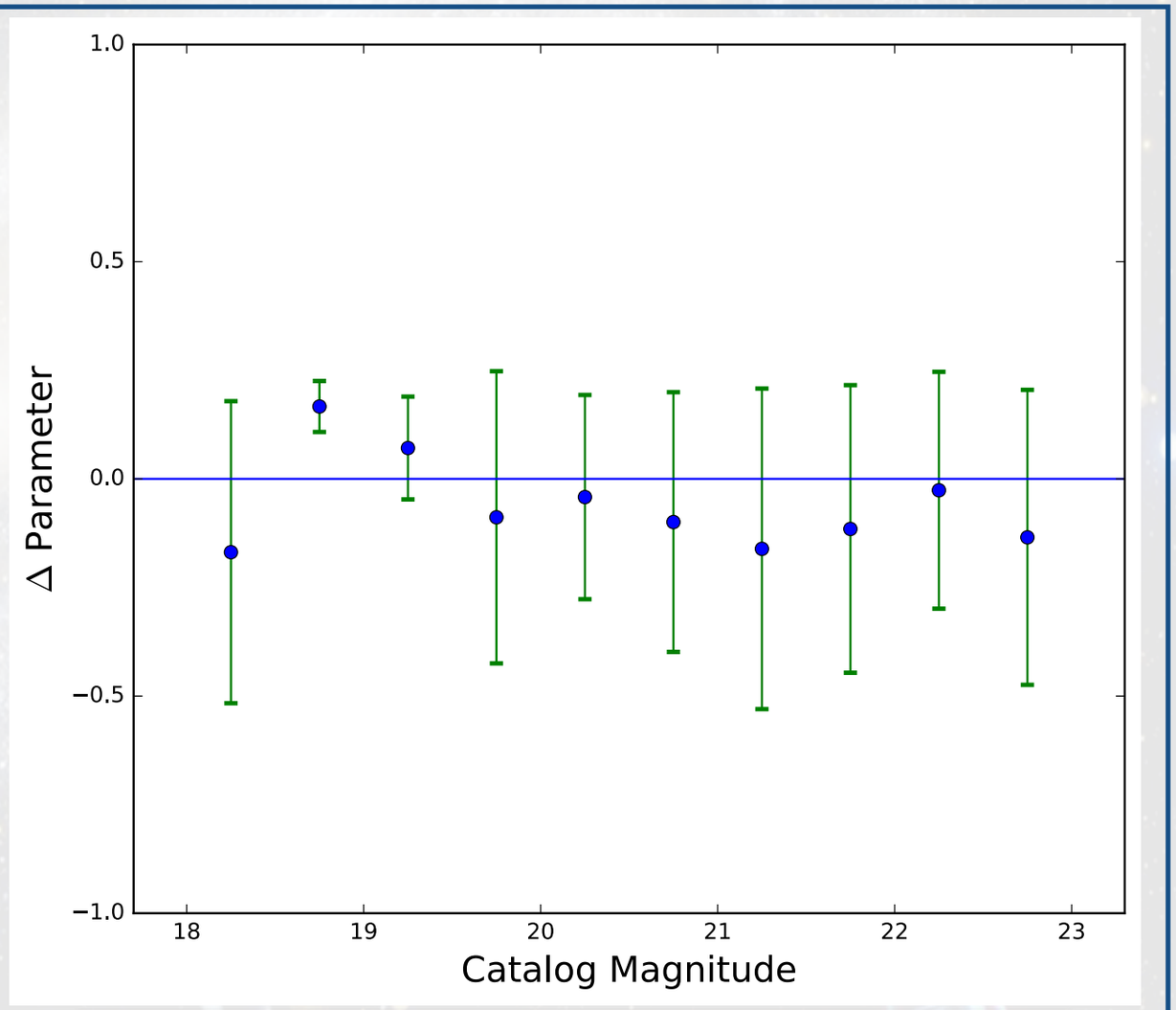
Predictions on Real Data (after domain adaptation)

Ellipticity

3000 CANDELS galaxies
ground truth: Van Der Wel +12



DNN



2 GALFIT parametrizations

Van Der Wel +12 Di Mauro +17

Summary of Predictions on Real Data (after domain adaptation)

	R^2 Real data		
Parameter	Before TL	After TL	2 GALFIT
Magnitude	0.788	0.982	0.985
Radius	-1.639	0.856	0.860
Sérsic index	-0.768	0.718	0.735
Ellipticity	0.256	0.897	0.904
Position Angle	0.132	0.893	0.863

coefficient of determination

$$R^2 = 1 - \frac{\sum_i (y_i - f_i)^2}{\sum_i (y_i - \bar{y})^2}$$

~3000 sources fitted

GALFIT/GALAPAGOS

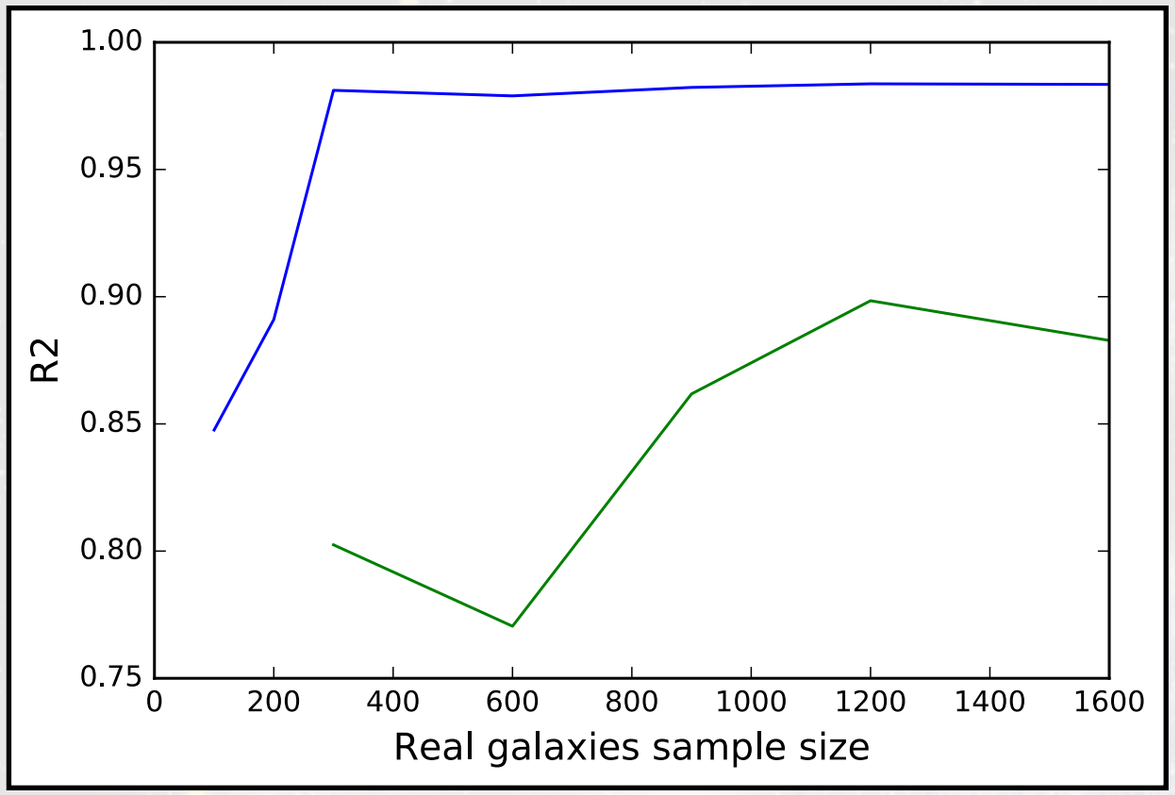
Time: ~ 2h30

CNN

Time: 10 min domain adaptation + 2s

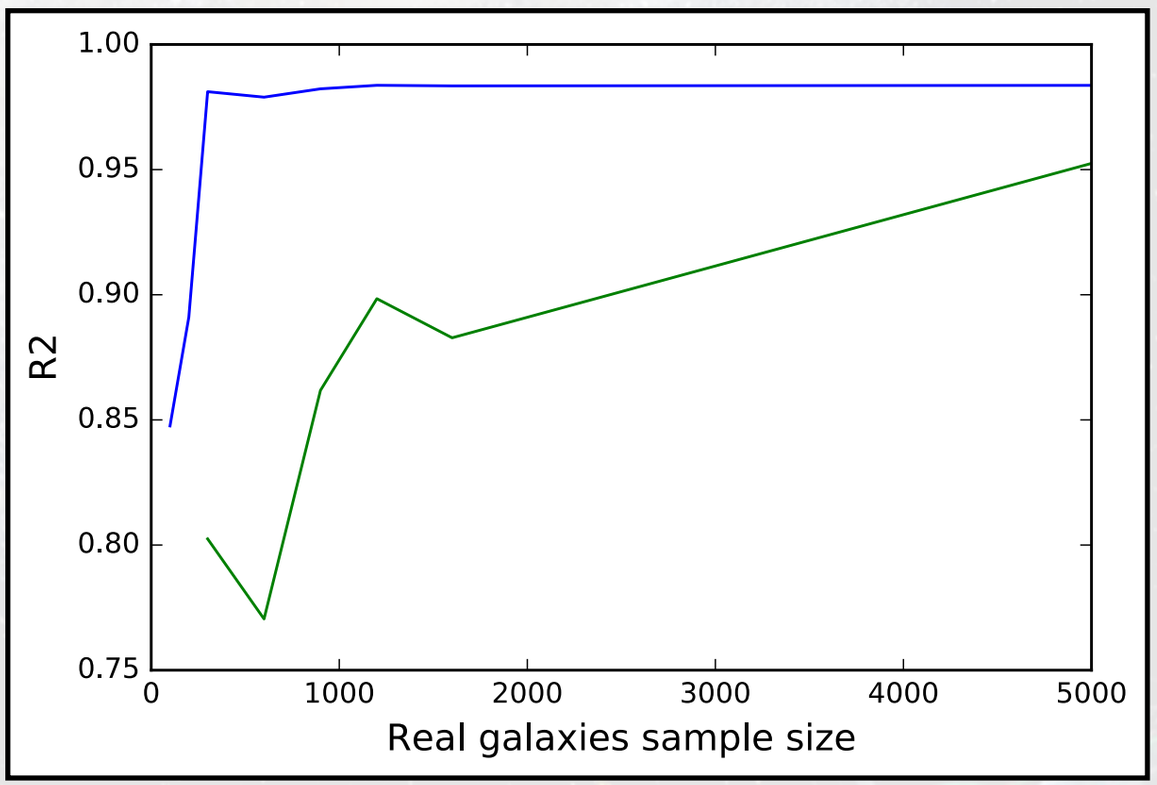
Is it needed domain adaptation?

magnitude



how many real galaxy do we need?

Do we need training on simulations?



Next steps

release of the code

Ideas for the name?

Names 2 words:
DEEP LEGATO = Deep Learning Galaxy Analysis Tool
DELIGHT ProFit = Deep Light Profile Fitting
GAIN Profit = Galaxy Artificial Intelligence Profile Fitting
Brain Profit = Brain Profile Fitting
GAIN FIT = Galaxy Artificial Intelligence Fitting

Names 1 word:
CONGA = convolutional network galaxy analyzer
DeLGaP = deep learning galaxy profiling
DELEGA = Deep Learning Galaxy Analyzer
DELIGHT = Deep Light (Fitting)
DeepFit = Deep (learning) Fit

2-component fit

First results 2 components galaxies

WITH REAL NOISE

REAL PSF CANDELS

PIXEL SCALE 0.06''

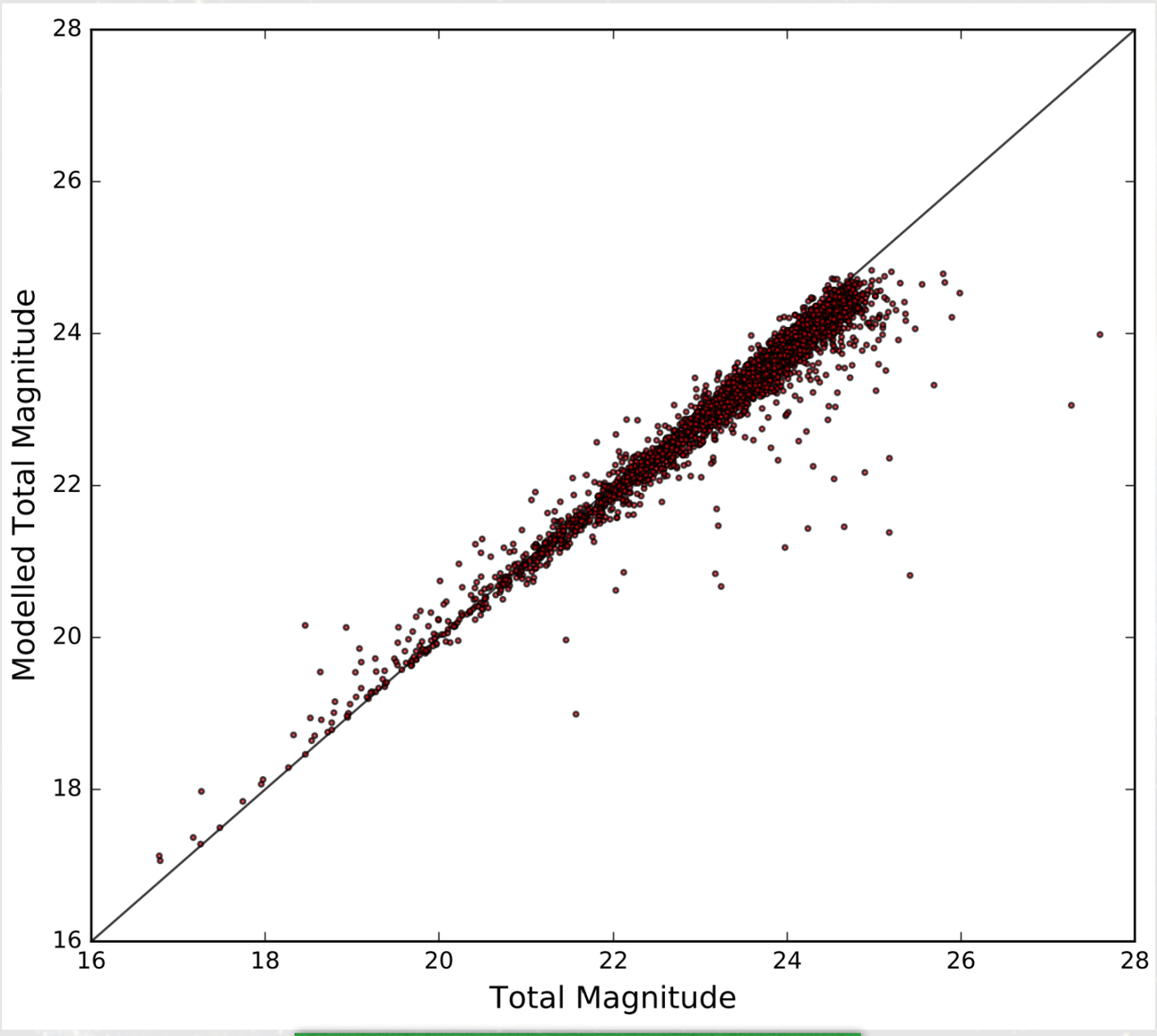
Double Sersic HST galaxies

VARIABLE BULGE/DISK RADIUS

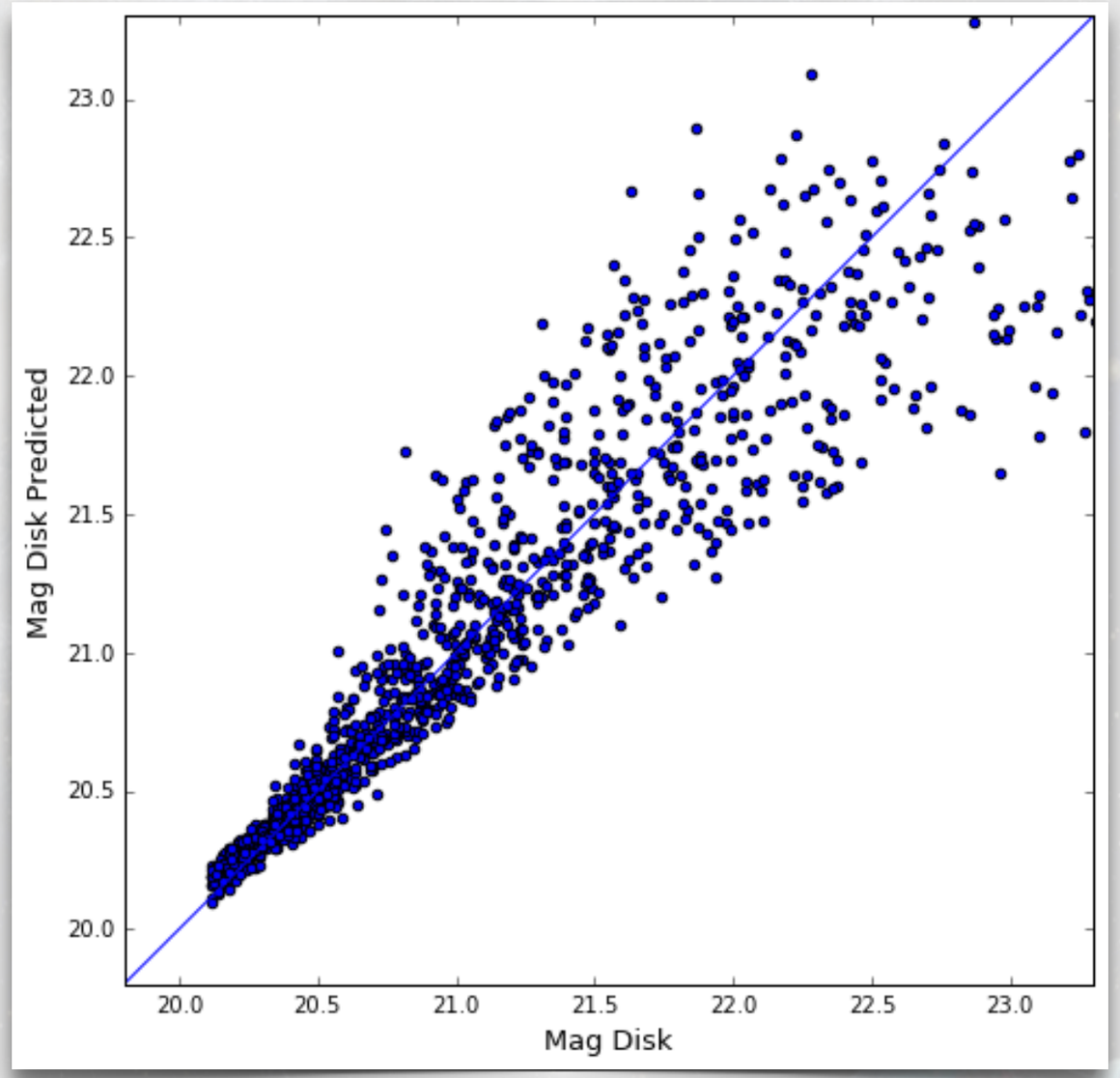
VARIABLE B/T

18< MAG<24

VARIABLE SERCICS

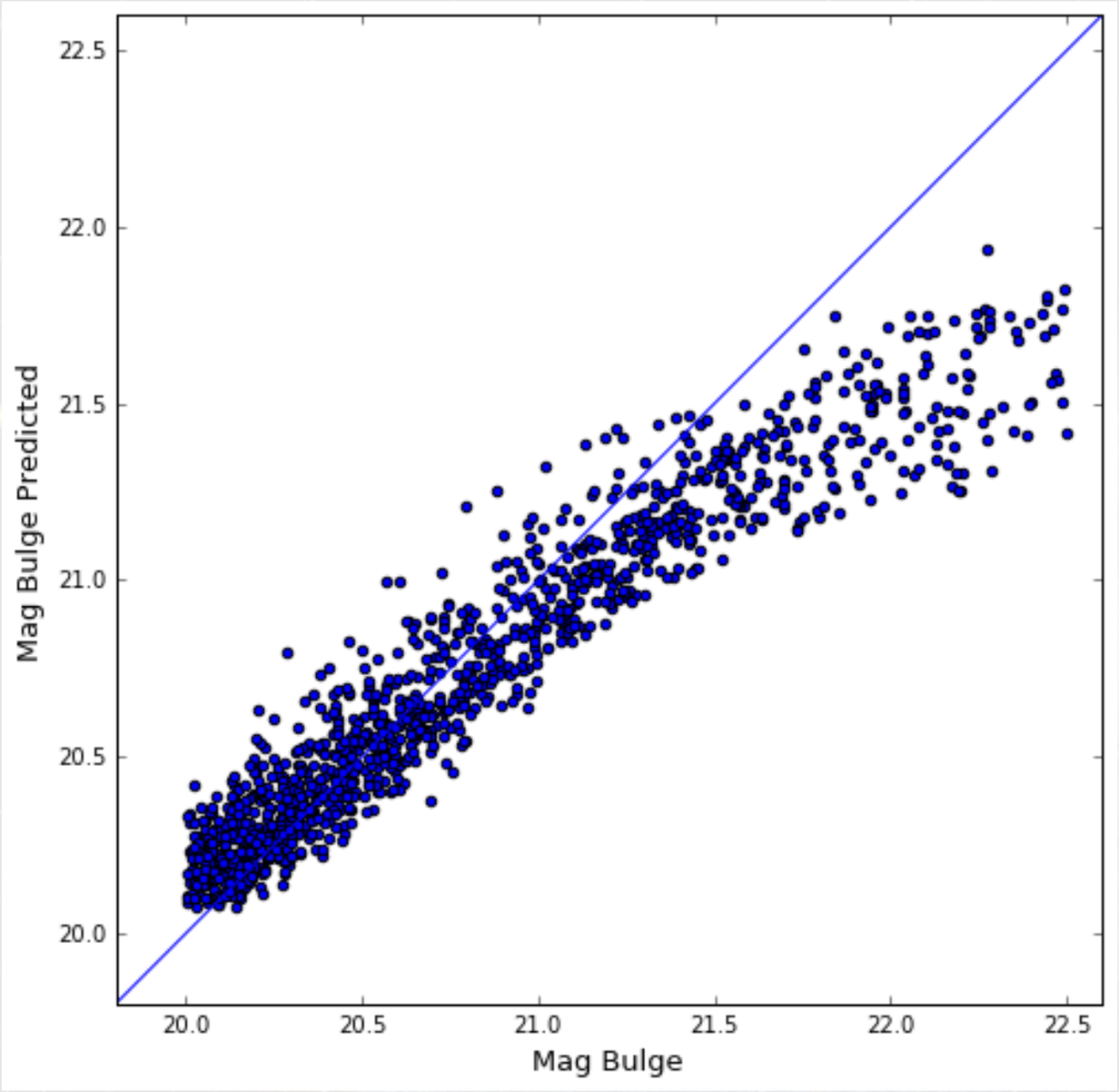


Total Magnitude

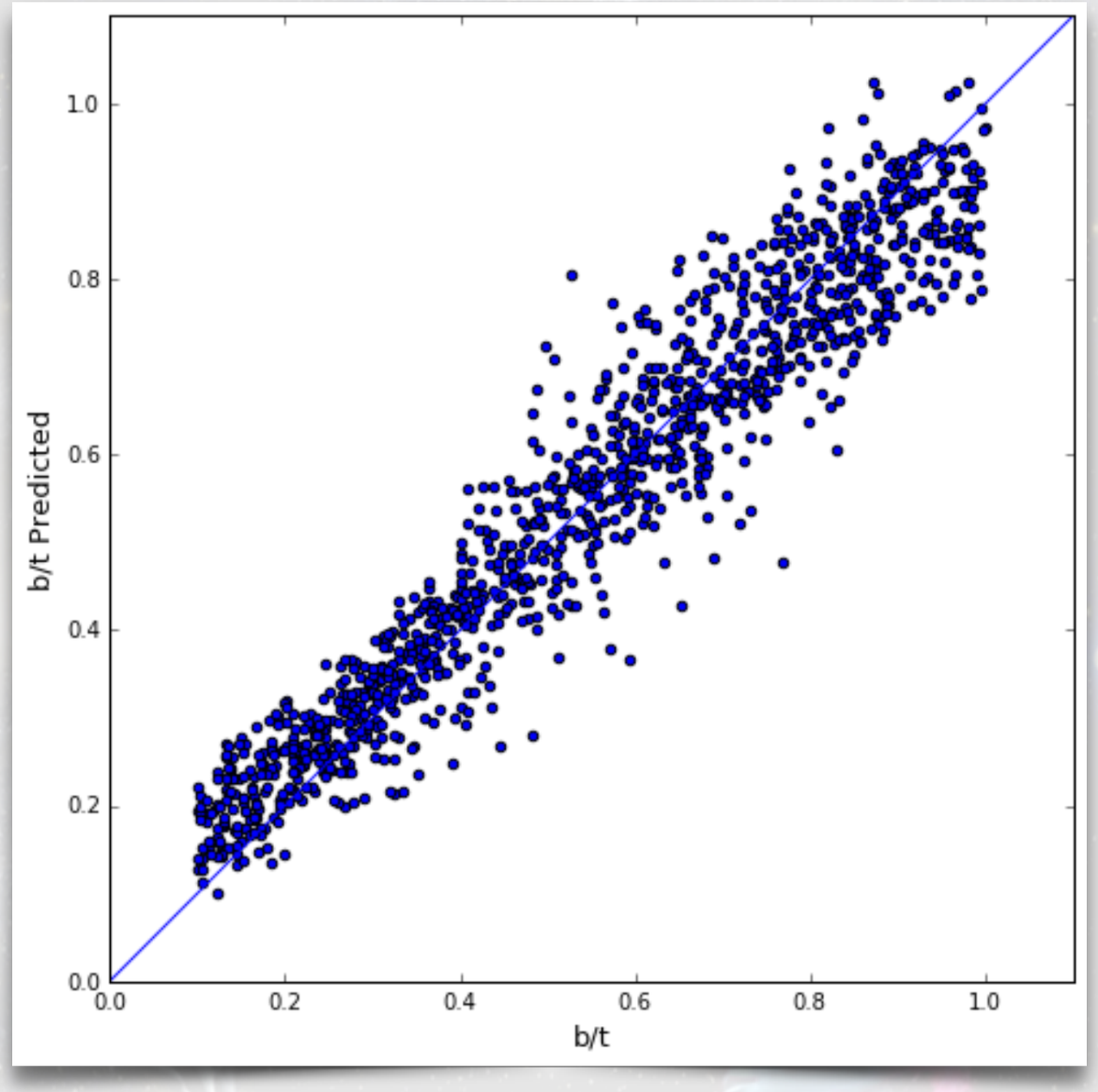


Disk Magnitude

First results 2 components galaxies



Bulge magnitude



B/T

Summary

- Developed a CNN code for galaxy profile fitting
- On simulations perform similarly or better than GALFIT, but about 400 times faster
- On real galaxies, after domain adaptation, perform similar to GALFIT fits
- The code will be public available for domain adaptation on your set of fits

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Thanks for listening!

Team

Marc Huertas-Company

DNN methods for

- ***Galaxy Profiling***
- ***Galaxy Classification***
- ***Strong lensing detection***
- ***Deblending***

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EWASS 2017, 26-30 June, Praga