Redshift Simulation outline

1. **Clean contaminations**
   (1) clean background objects
   (2) clean foreground objects (stars in most cases)

2. **Rebin image size in terms of angular size reduction**
   Diminish the pixel number in image according to rebinning factor, calculated through angular distance.

3. **Flux dimming caused by redshift effect**
   Downscale the flux in image by the rescale factor, calculated through luminosity distance.

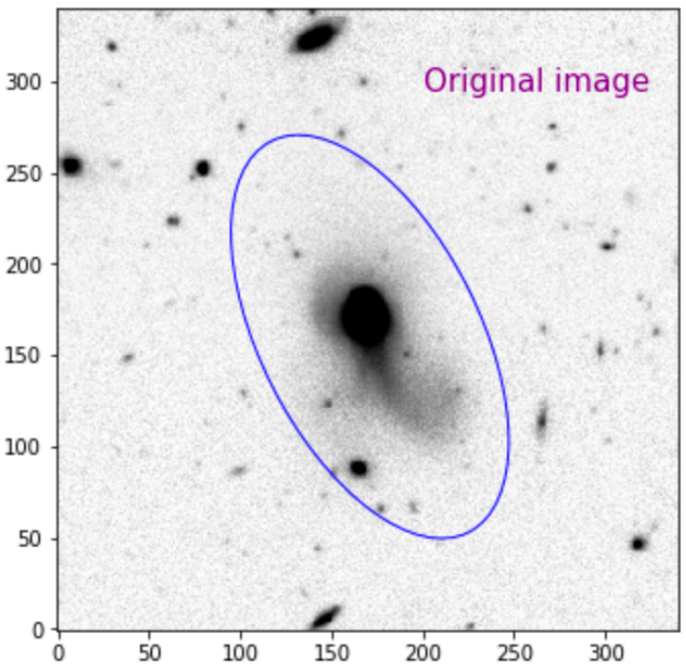
4. **PSF correction**
   Convolve a Gaussian kernel to the rebinned and flux-rescaled image to reach the desired output PSF.

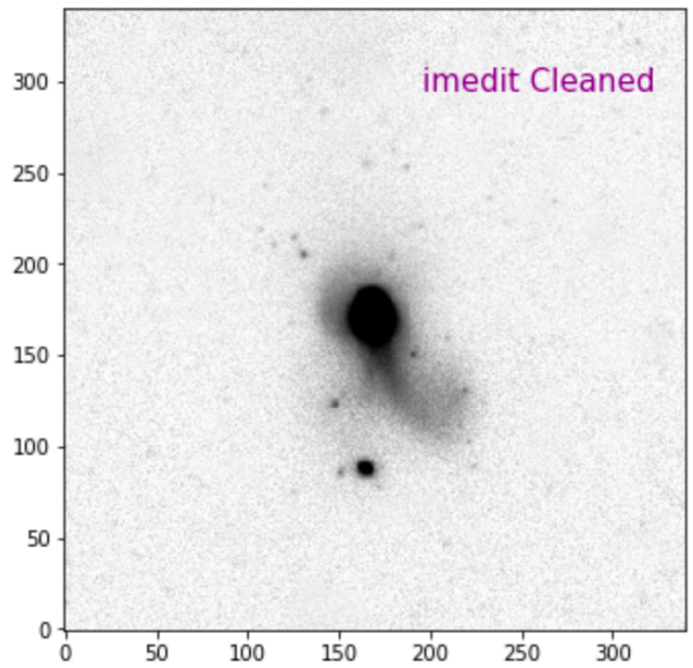
5. **Adding noise**
   (1) add an extra Poisson noise to match the sky noise in the original image
   (2) correct the Poisson noise in the galaxy region

1. Clean contamination

(1). clean background objects

For objects outside aperture sma=2R_petro around target, we use IRAF task ‘imedit’ to remove them. It is operated by replace object by background mean values in the replacement region;





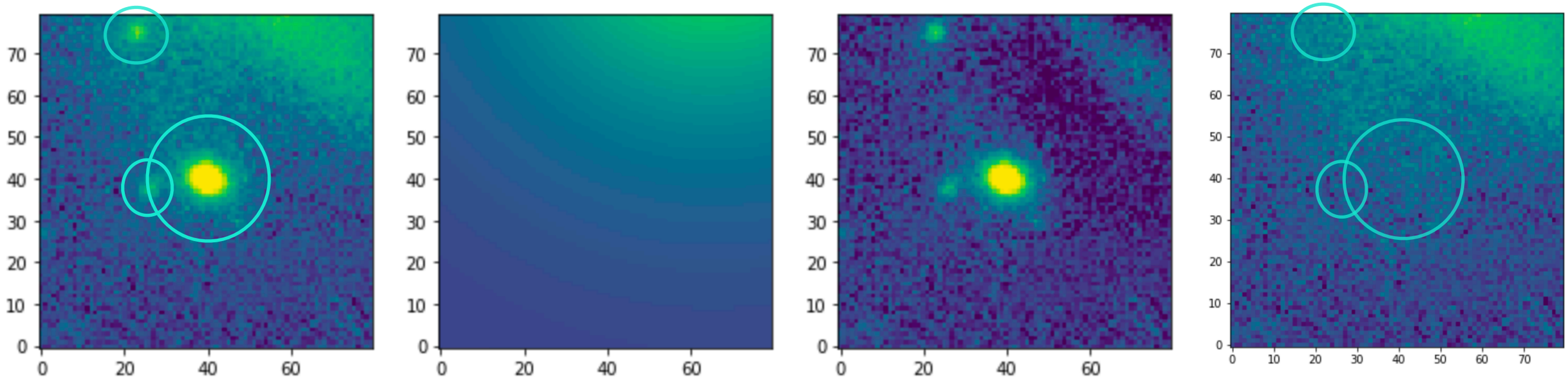
‘imedit’ cleaning:
objects outside the blue elliptical aperture are replaced by background value around the object.
SMA of the blue ellipse is 2 petrosian radius of the target galaxy.

(2). Clean foreground stars (inside ellipse sma=2R_petro):

For each contaminating object located inside the target segment (sma=2Rpetro, derived from SEXtractor), we cut a rectangle around it and remove it. The rectangle has side length 10 times the radius of the object in it. But we’d better avoid to include the bulge of the target galaxy inside the rectangular image cut, because the slope of the background gradient will be too steep and complexed to fit.

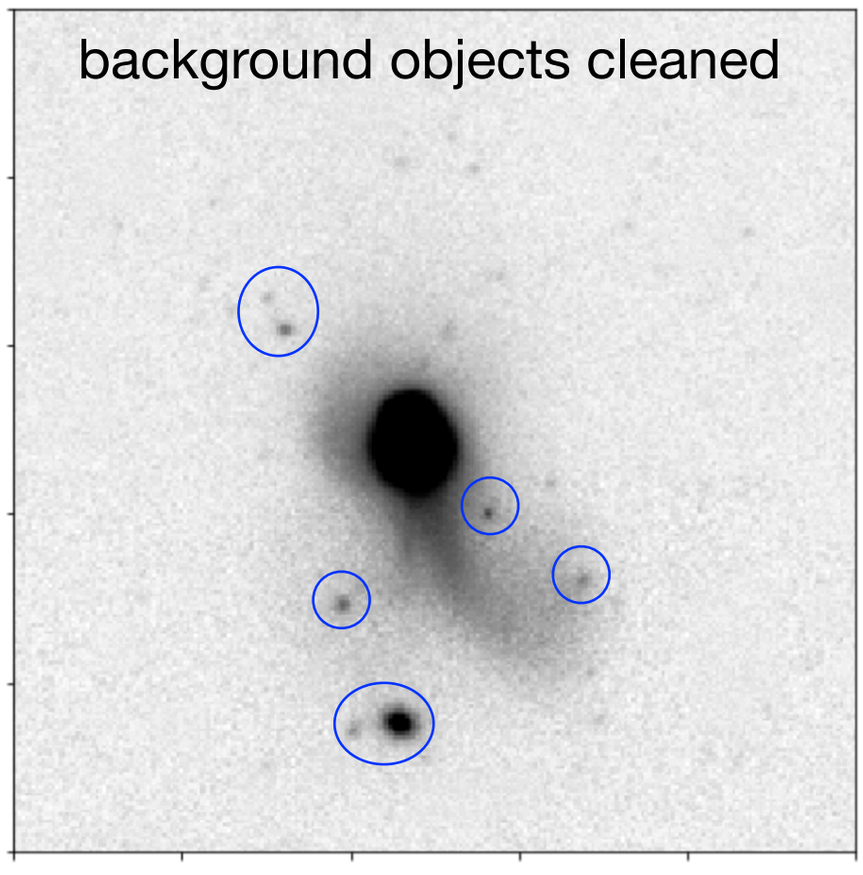
In the rectangle we subtract stars by rescale the extended PSF model (Roman 2019 IAC), and fit the residual ‘background’ by a 2D exponential function (Ho 2011). After fitting, we replace the star contaminated region (with radius = 1.5 R_petro of that star) by the noisy background model in the same region.

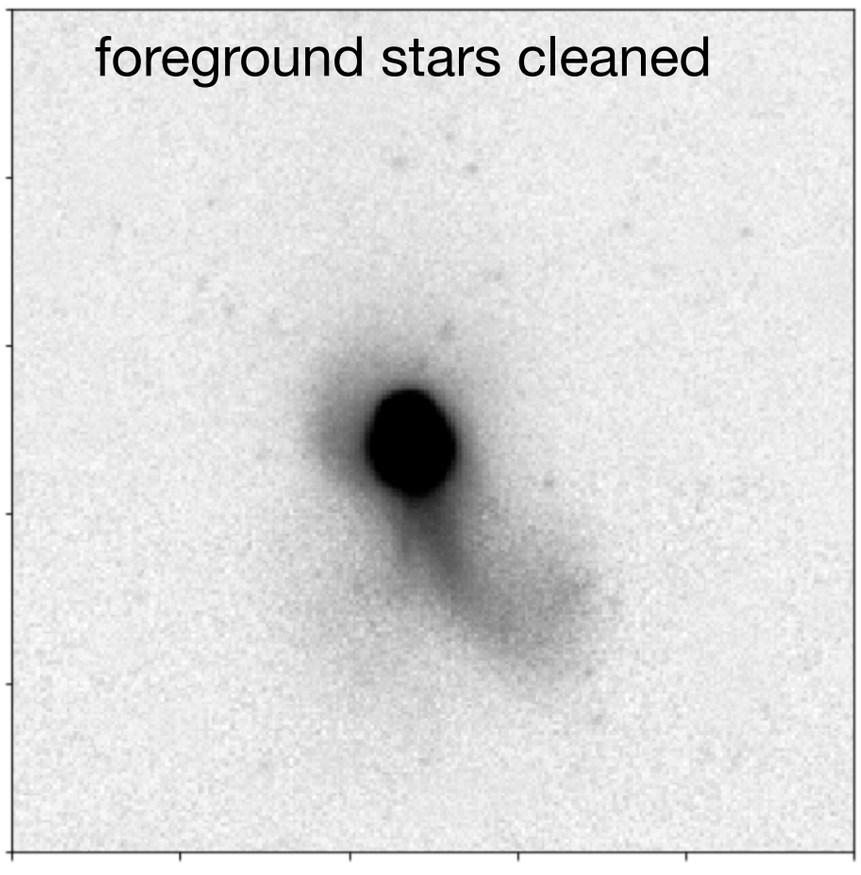
1. (2) Clean foreground stars



left: small cutout zoom-in one star contamination; second: 2D exponential background model; third: residual = left - second; right: noisy background model are patched in the contaminated region (shown as the region in cyan circles).

Result:

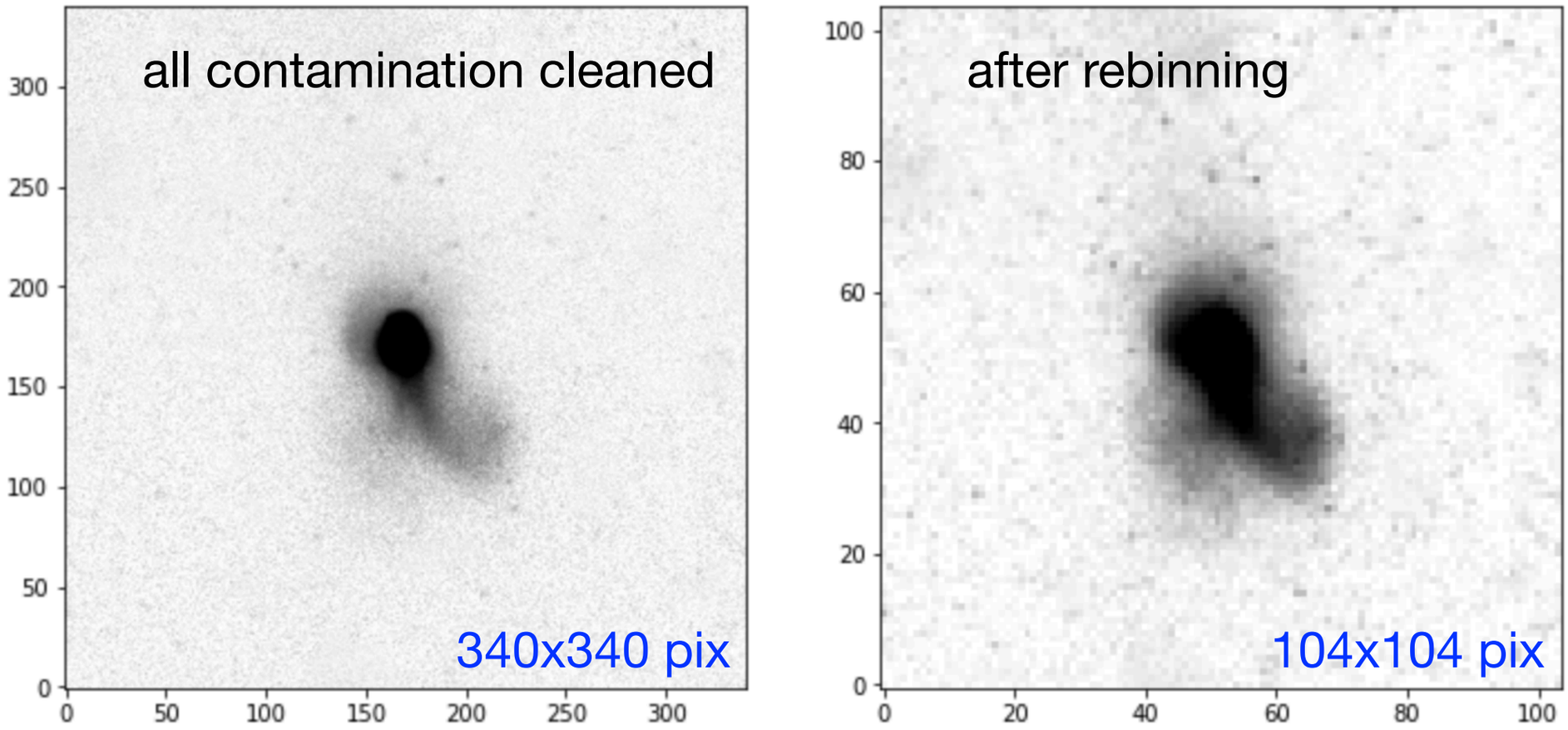




2. Rebin image size

- $fact_{rb} = N_{simu}/N_0 = \theta_{simu}/\theta_0 = DL_0/(1.+z_0)^2 \,/\, (DL_{simu}/(1.+z_{simu})^2)$

where N is pixel number in each axes, DL is luminosity distance, z is redshift.

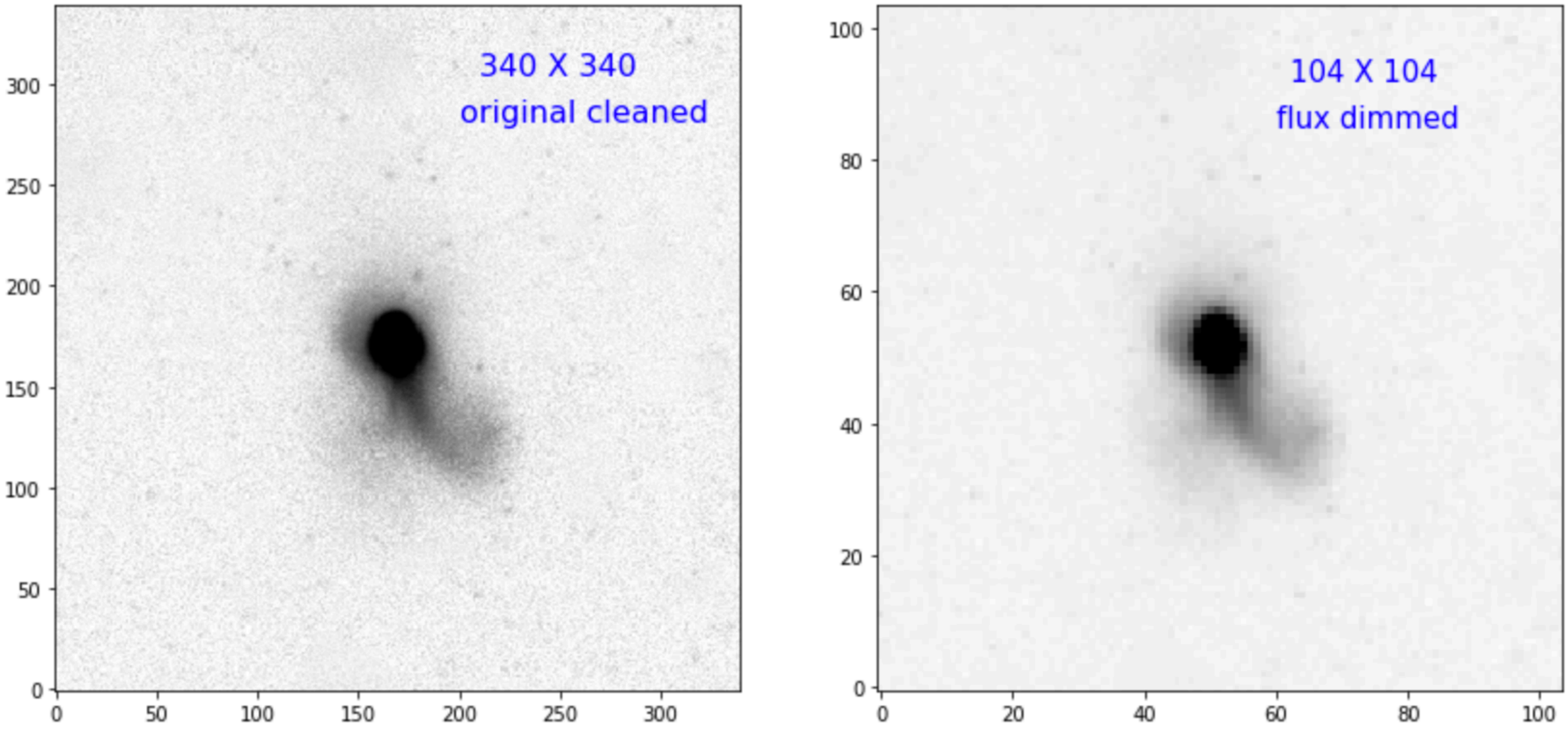


Initial redshift: z0=0.028; simulated redshift: z_simu = 0.1
rebinned pixel value = sum value in box with size 3.27 X 3.27pix
left: image before rebinning; right: zoom in the rebinned target
(vmax=40, vmin=-1)

3. Flux dimming

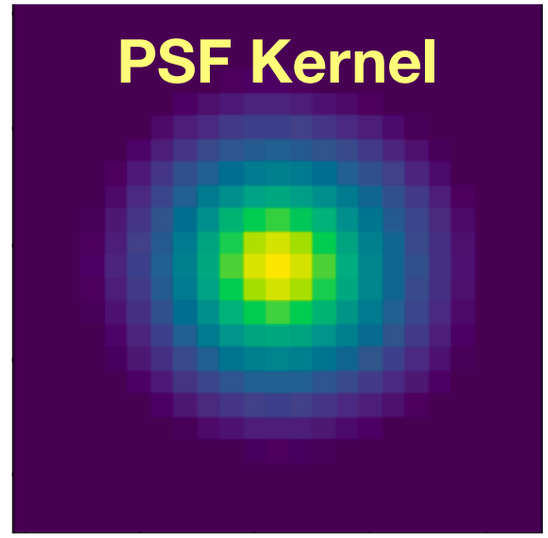
- $fact_{rescl} = F_{simu}/F_0 = (DL_0/DL_{simu})^2$

calculation of flux rescale factor. F is flux in each pixel, DL is luminosity distance



left: original image (vmax=40, vmin=-1);
right: after rescale the flux in each rebinned ‘pixel’ (vmax=40, vmin=-1)

4. PSF convolution



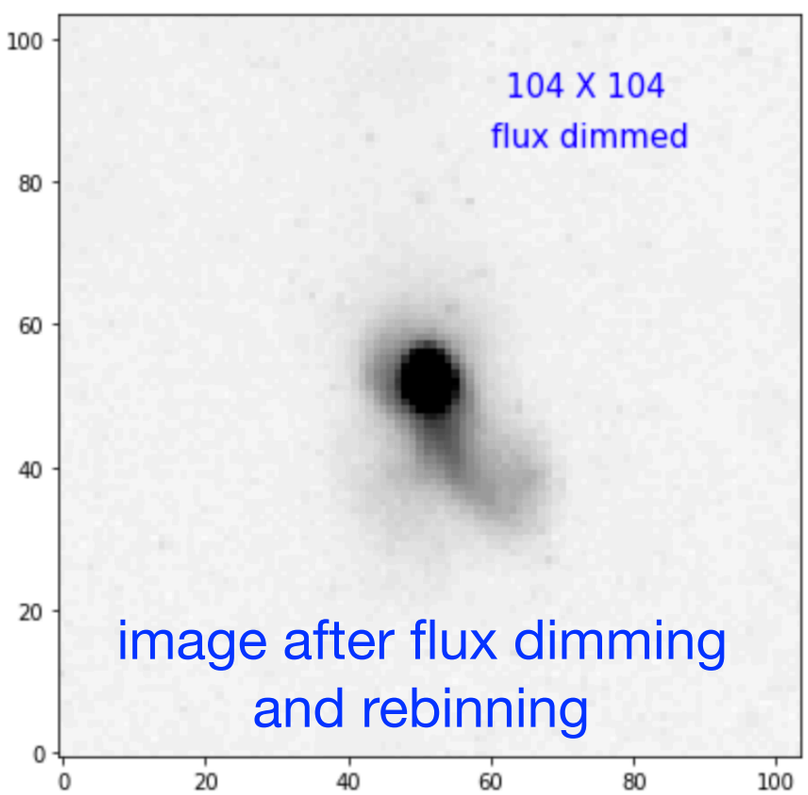
- $PSF_{simu} \otimes Kernel = PSF_0$

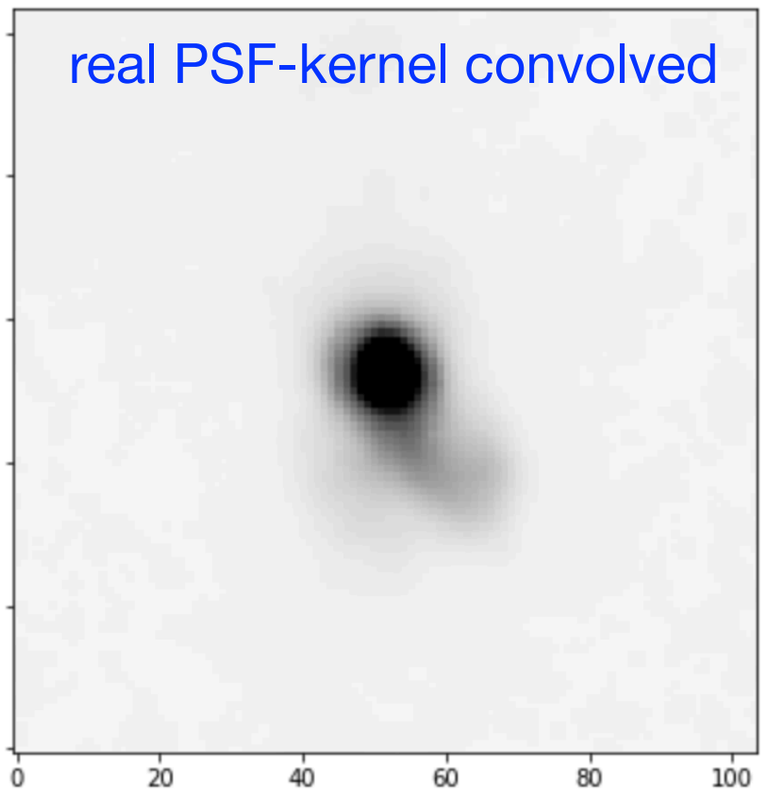
$$Kernel = F^{-1}\left(\frac{F(PSF_0)}{F(PSF_{simu})}\right)$$

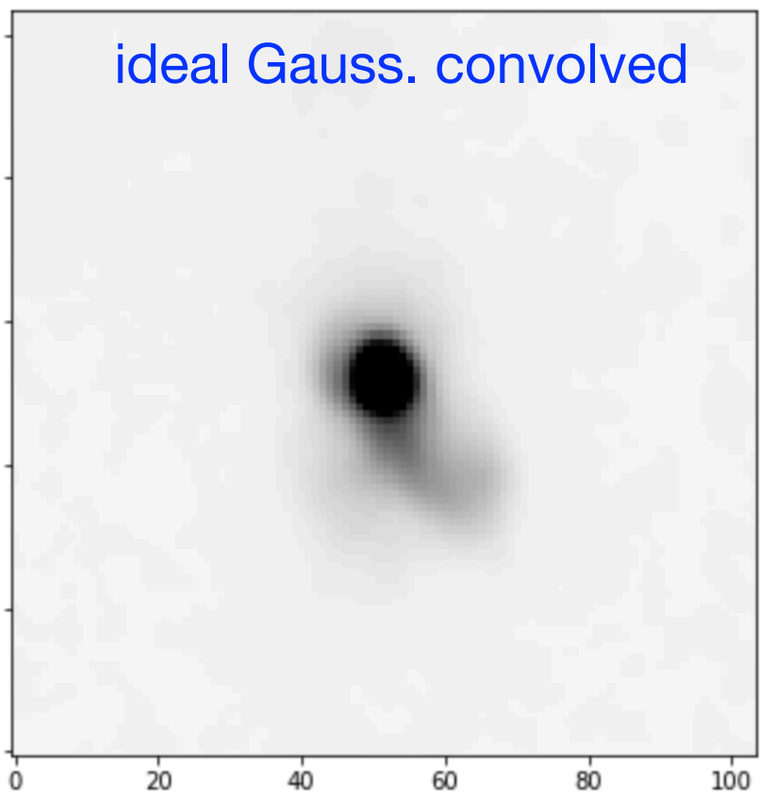
Rebin the extended PSF image by the same rebin-factor, then using the rebinned and original PSF image to calculate the correction kernel (Yu 2018). F^{-1} refers to inverse Fourier transform.
We check the result by created an ideal gaussian kernel with sigma-correction:

$$K = Gauss[\sigma = \sqrt{1 - (fact_{rb} - 1)^2} \cdot \mathrm{FWHM}/2.354]$$

where FWHM is the full width half maximum of the PSF in IAC coadded images.







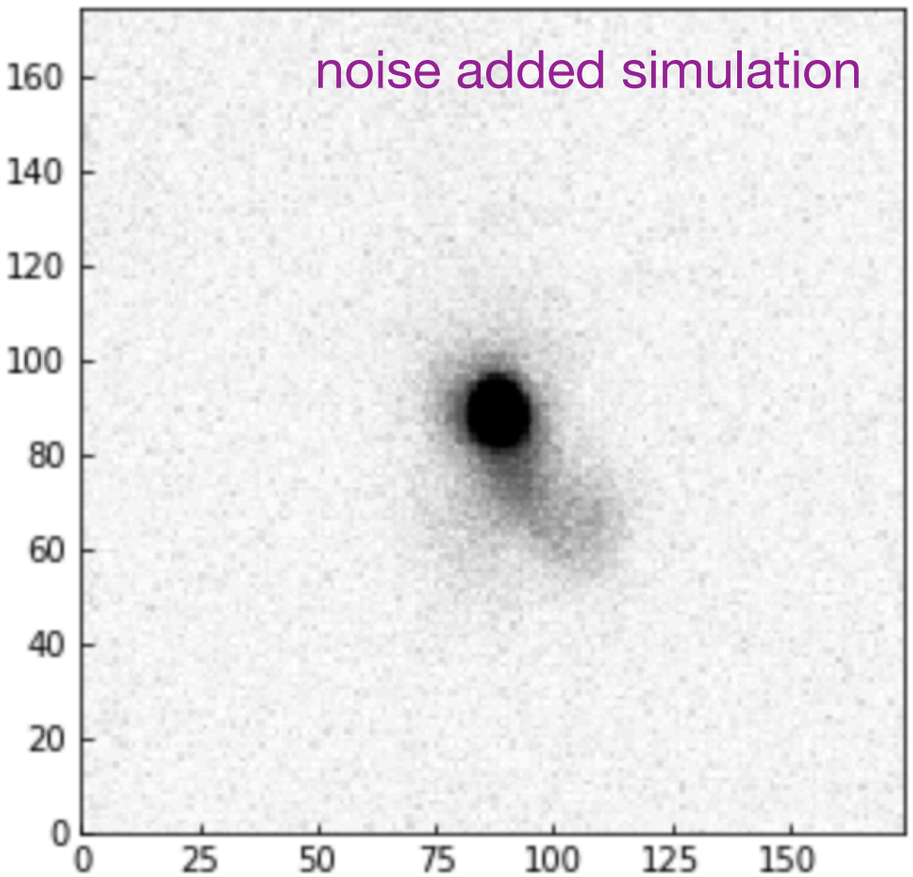
5. Adding noise

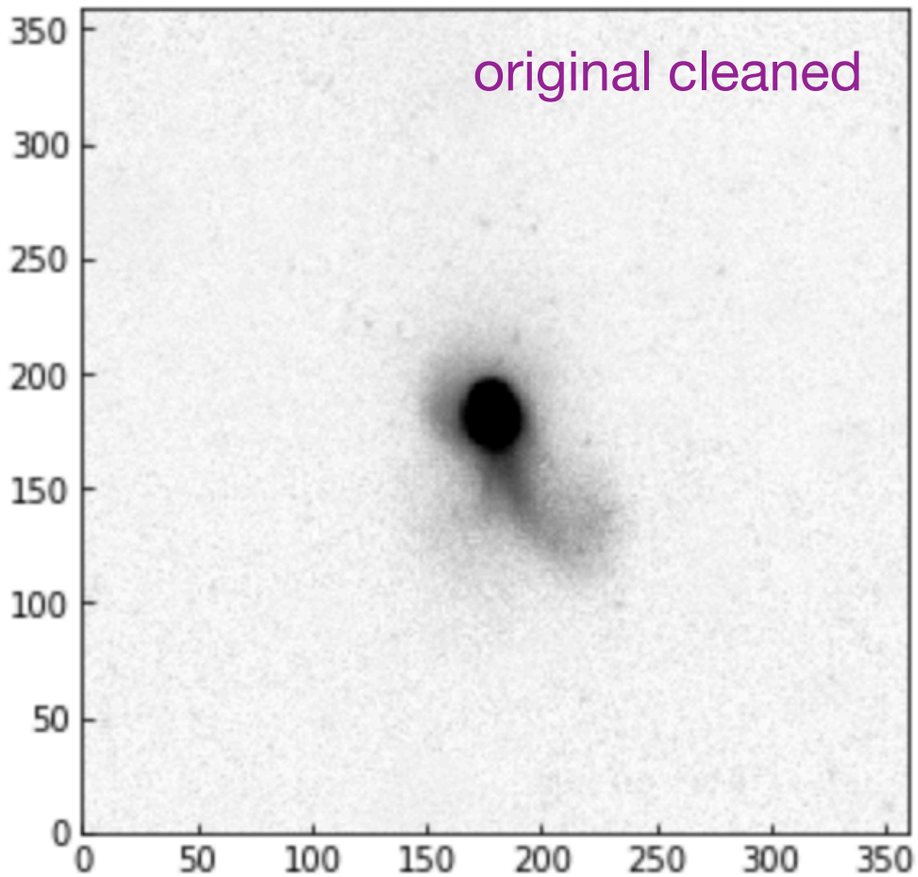
(1) We correct the sky noise after rebinning and flux-rescale, to match the real sky std. We add a Gaussian distribution to the processed image:

$$mean = skymean_{ori} - skymean_{simu} \qquad \sigma_{add} = \sqrt{skystd_{ori}^2 - skystd_{simu}^2}$$

where 'simu' represents the image after rebinning, flux-rescaling and PSF correction; 'ori' is the index for original image after cleaning.

(2) Adding Poisson noise to the galaxy flux: adding an extra poisson distribution to the electron number in pixels dominated by object signal — having value larger than sky 1 std. (IRAF task 'mknoise')





example 1.
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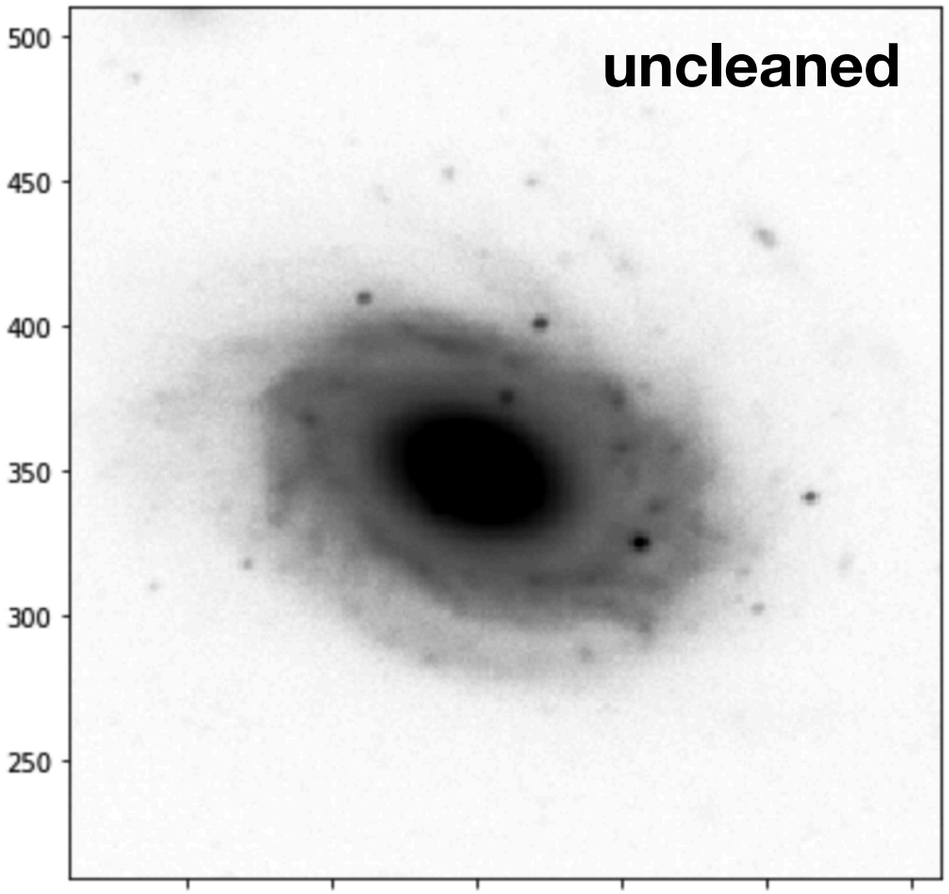

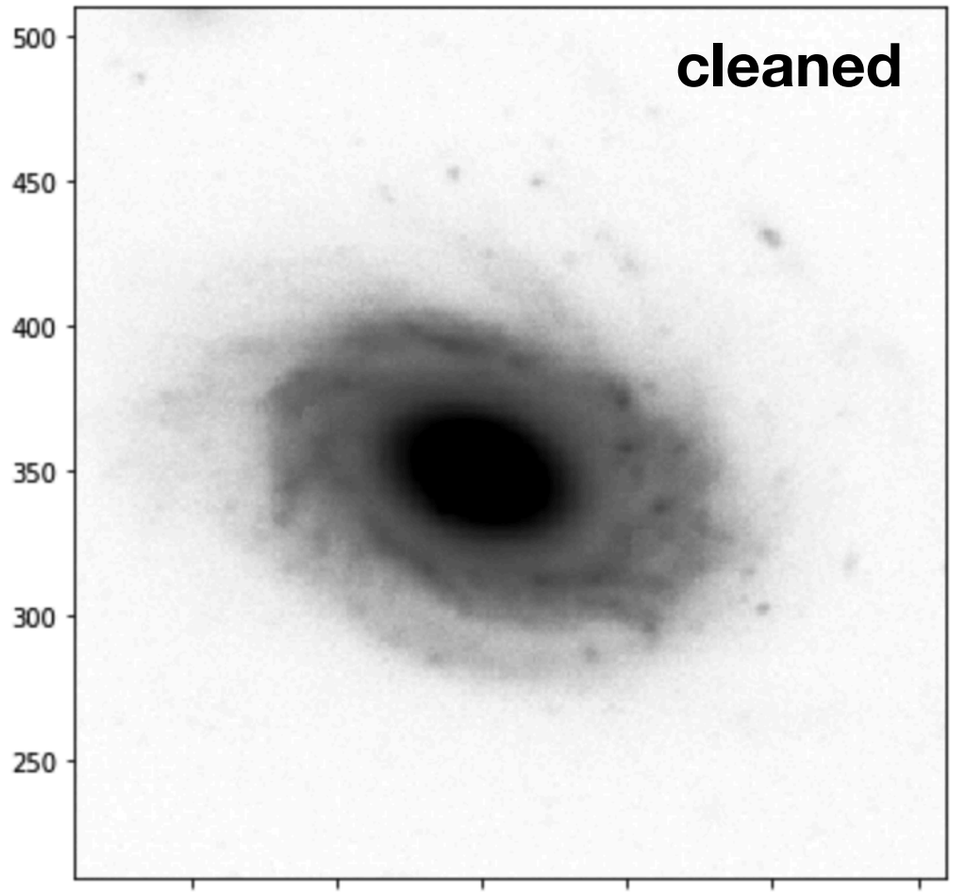

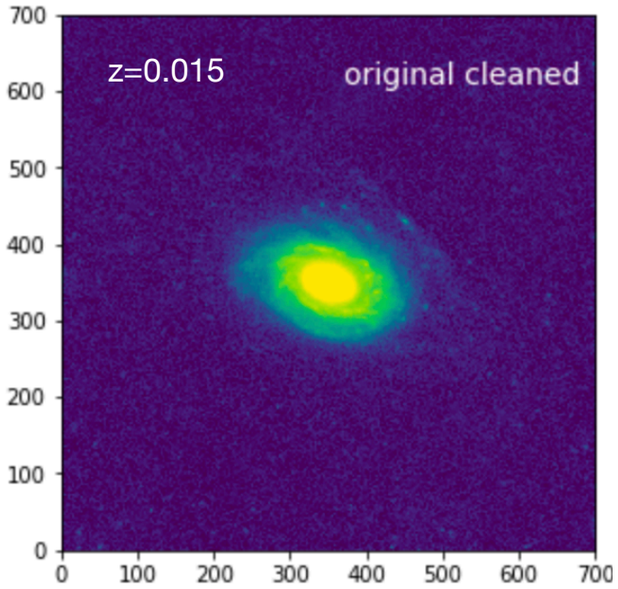

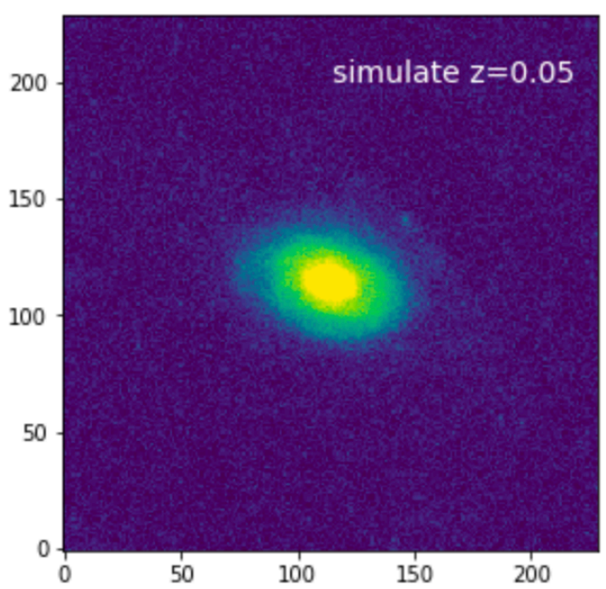

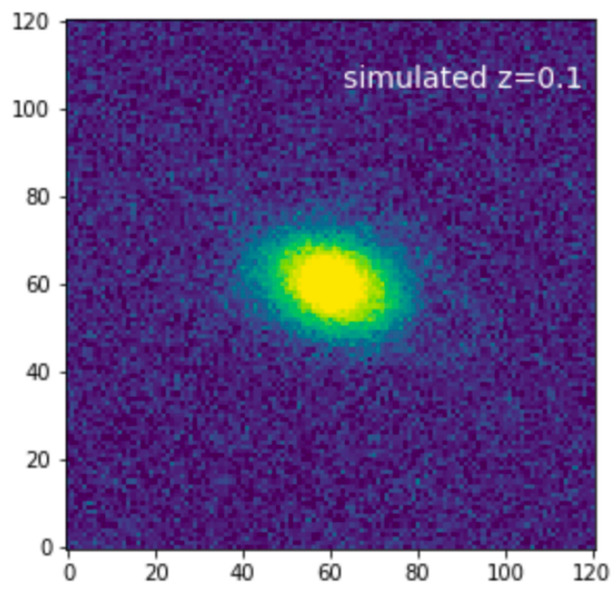

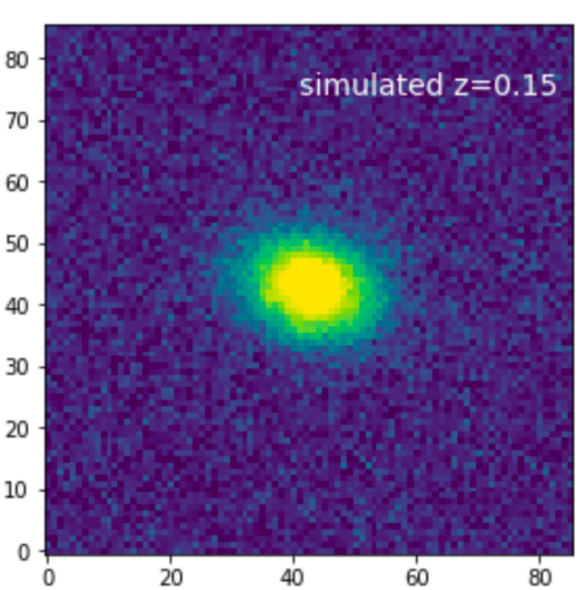

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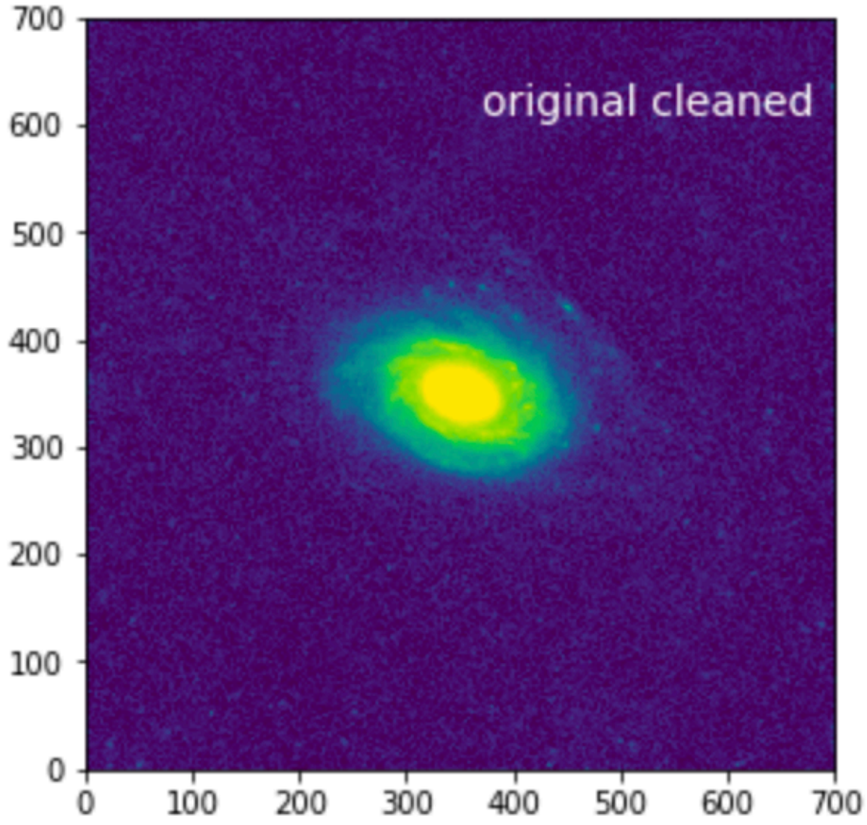
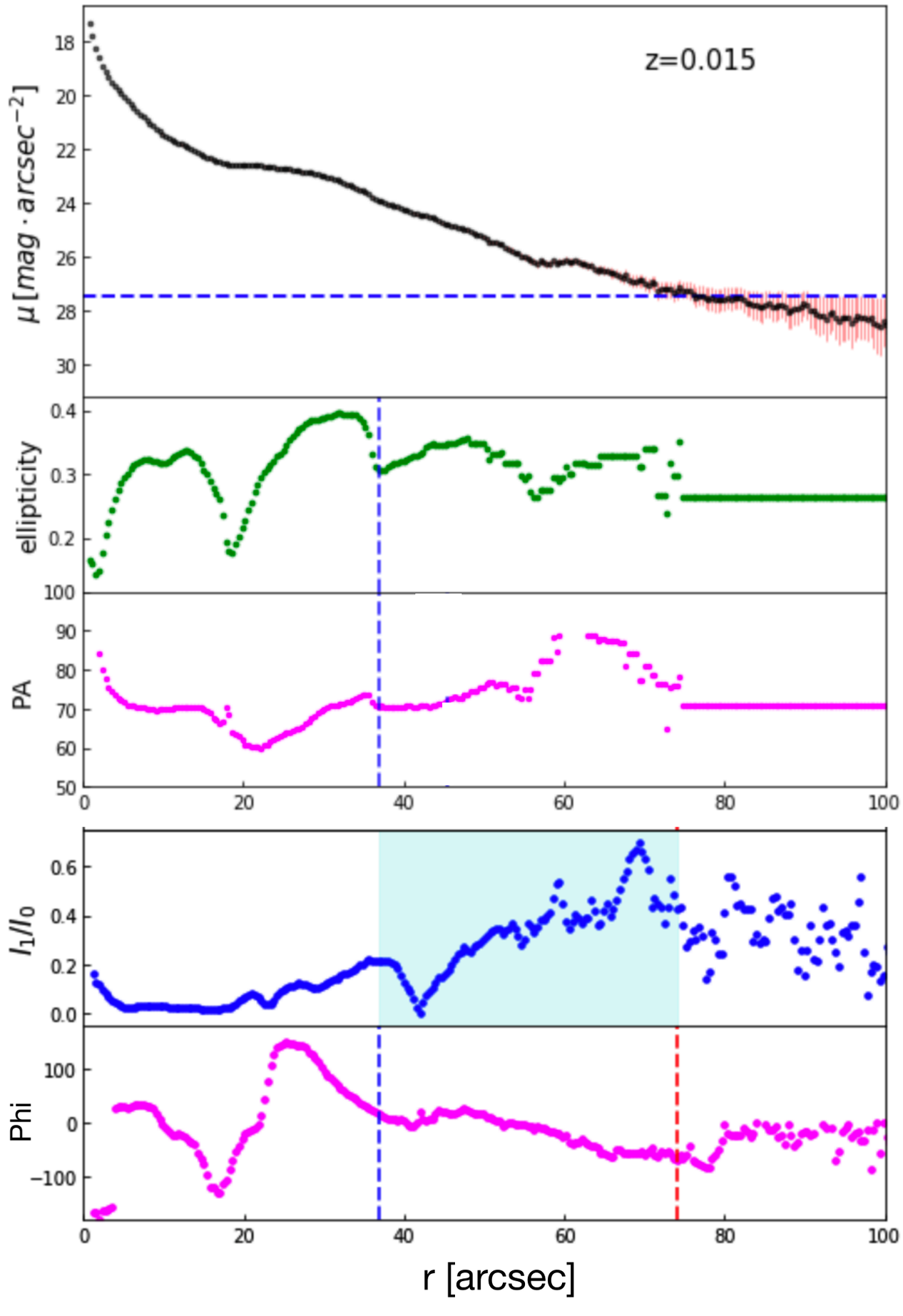
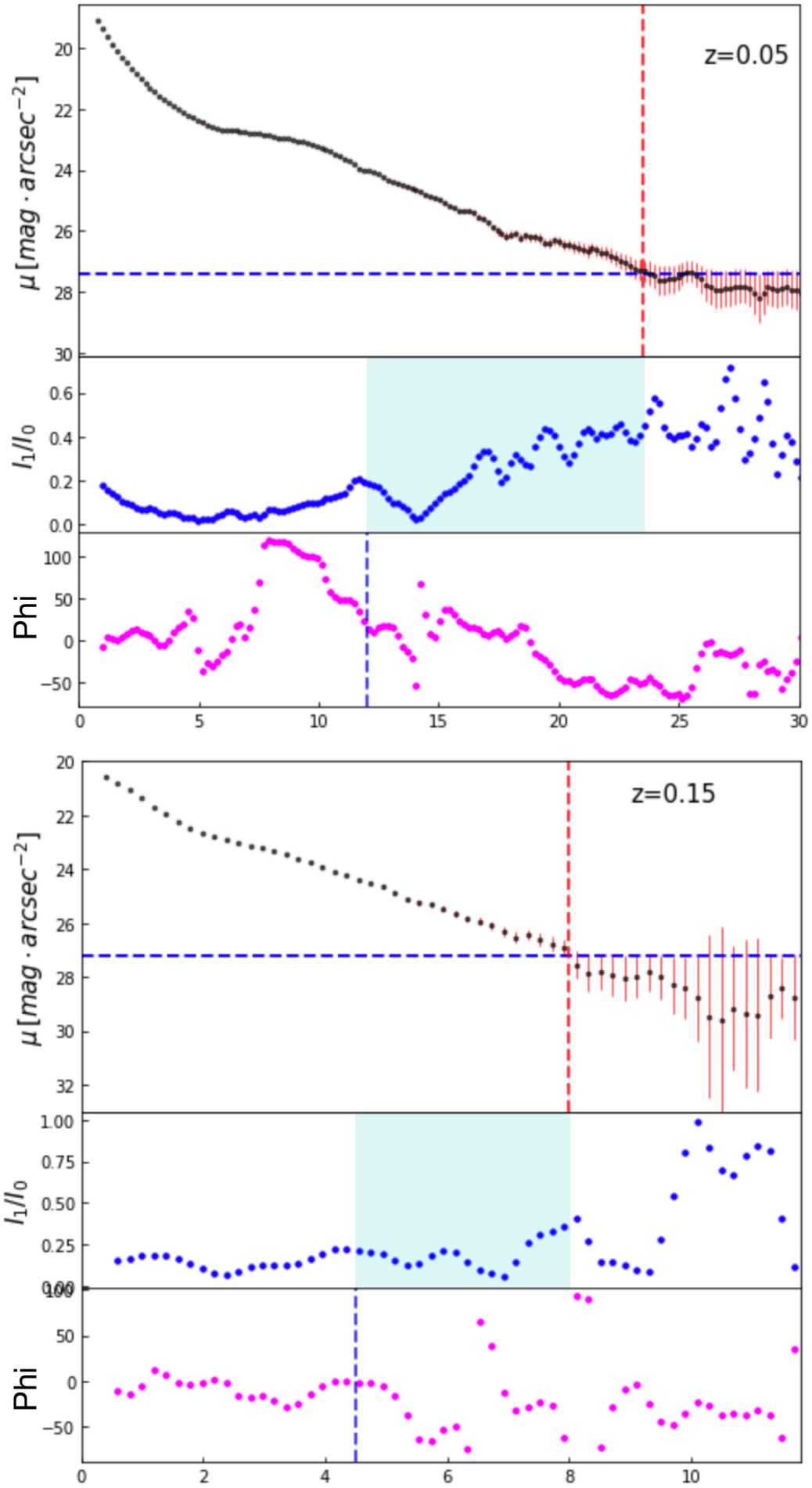
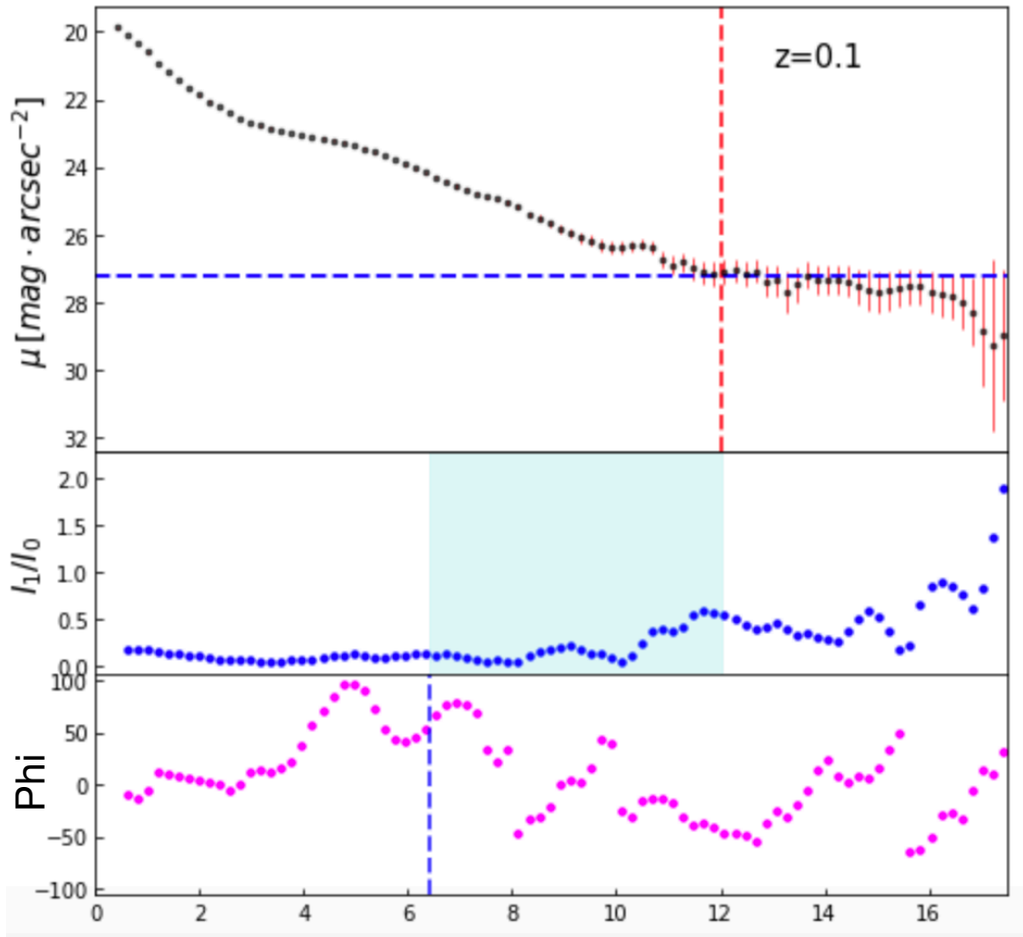


Blue vertical dash line in the *ellipticity-r* diagram: disk scale length with e=0.3 and PA=71, which are the typical e and PA of out disk and was fixed in the last turn isophotal fitting. This radius is also used as the start point to calculate the lopsidedness in original image. The start point in simulations are determined via this radius and rebinning factors corresponding to each simulated redshift.

Red dash line (also the end point for lop.) represents radius at which object flux fades below sky surface brightness limit.







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redshift	Lopsidedness
0.015	0.335
0.05	0.263
0.10	0.203
0.15	0.189

example 2.
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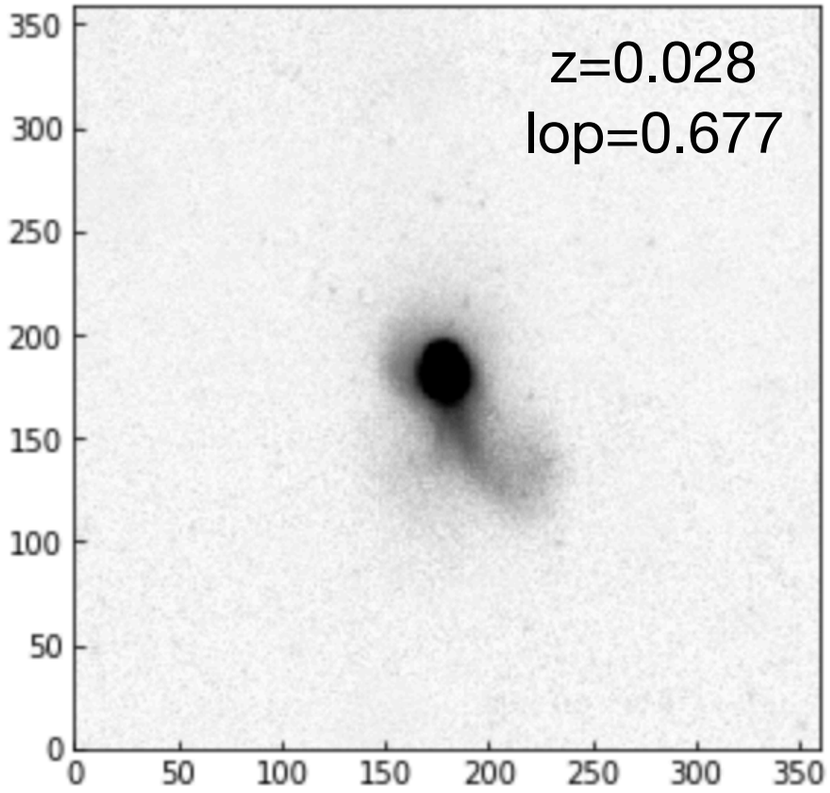
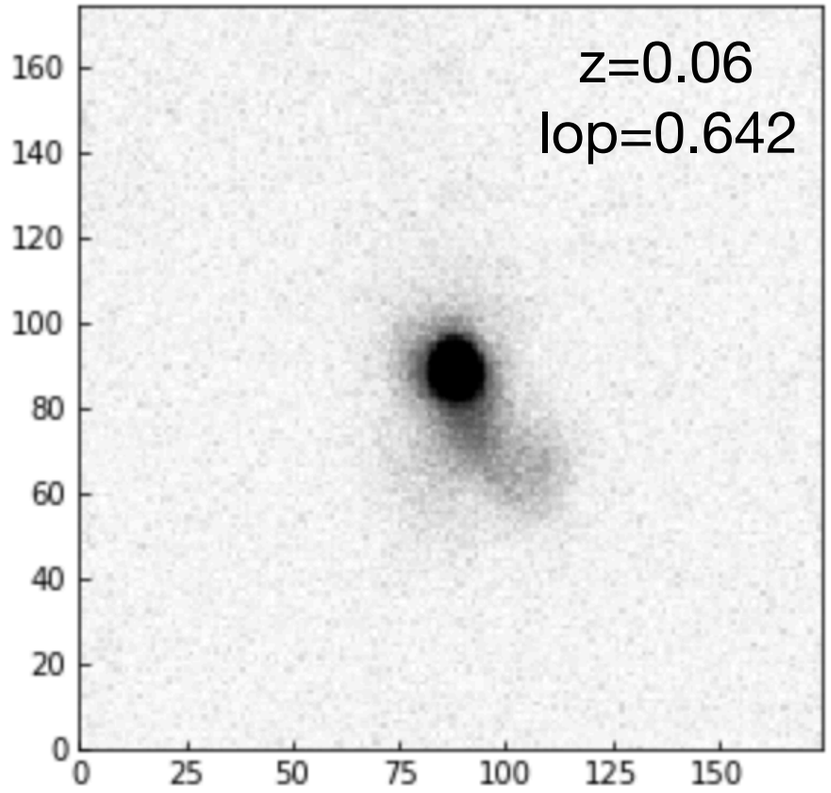
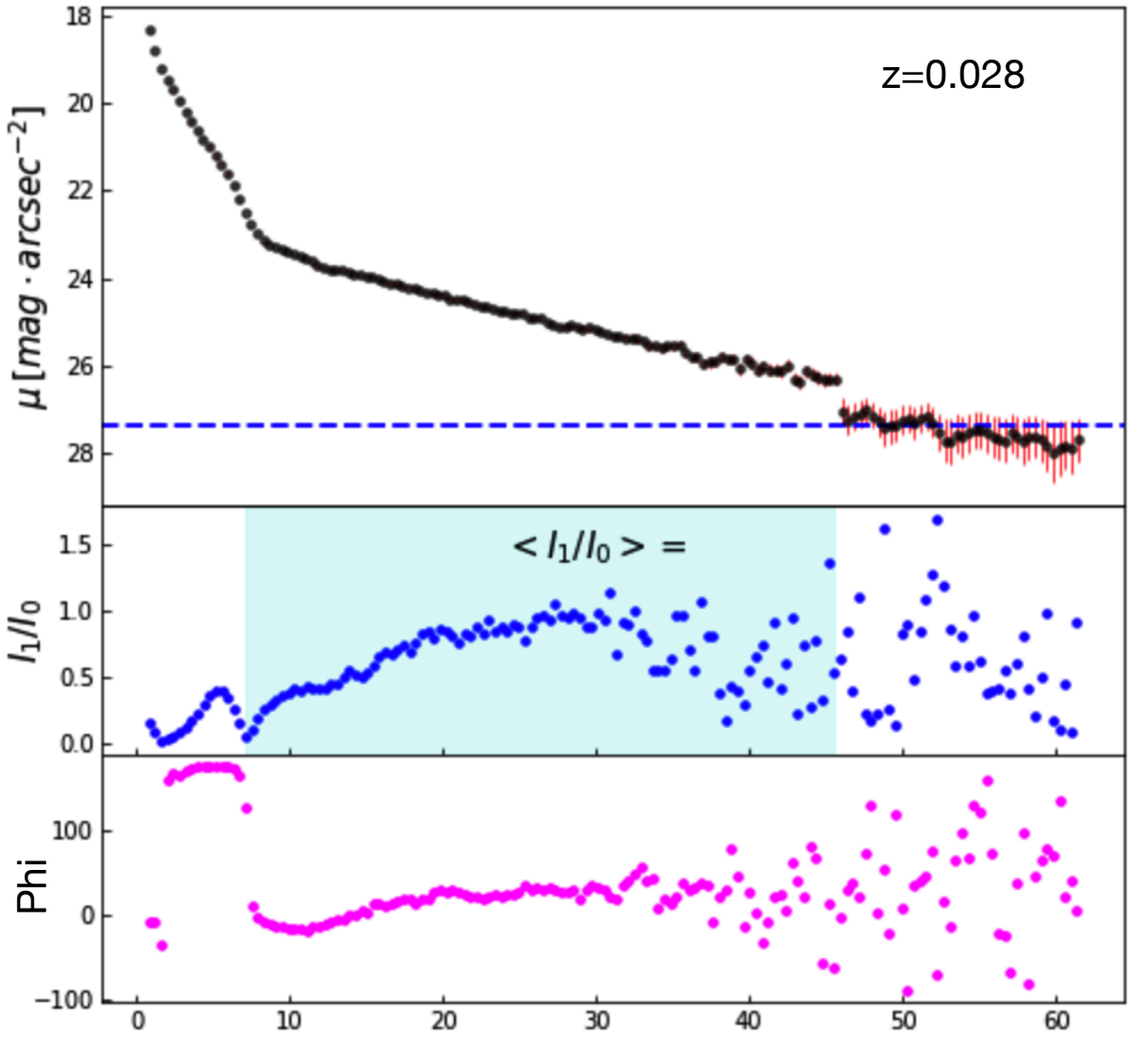
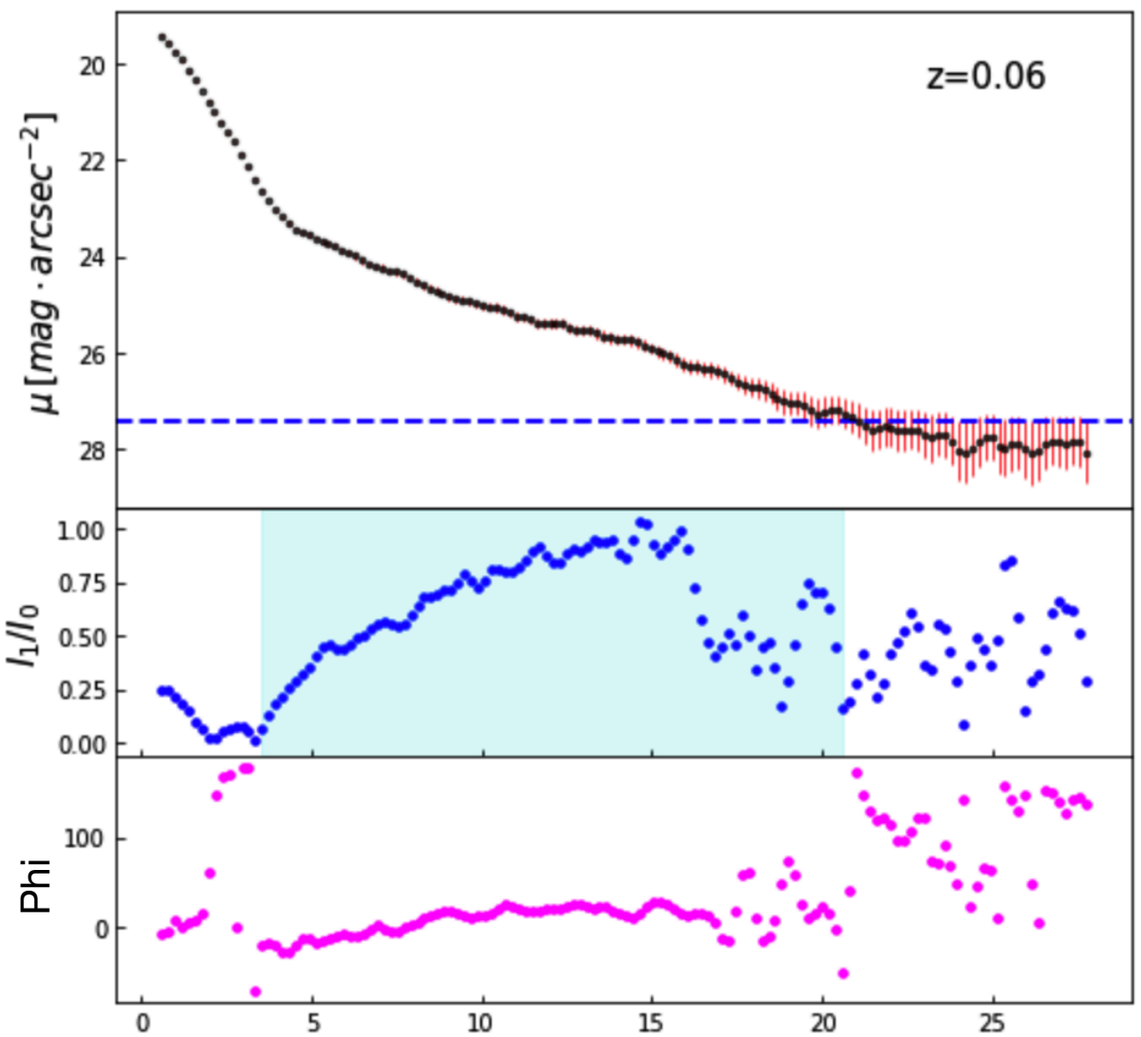
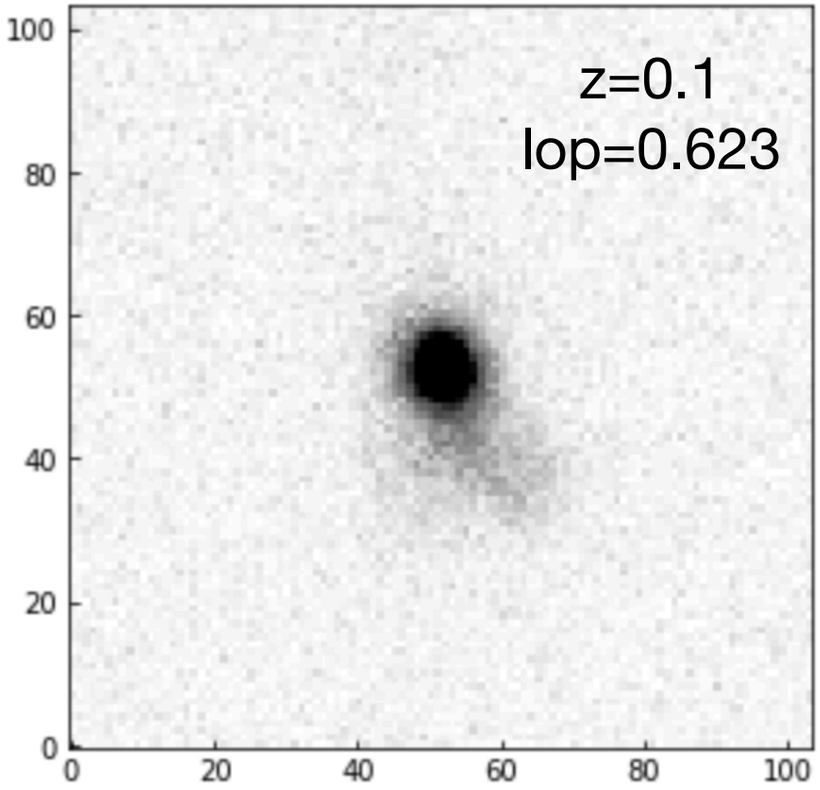


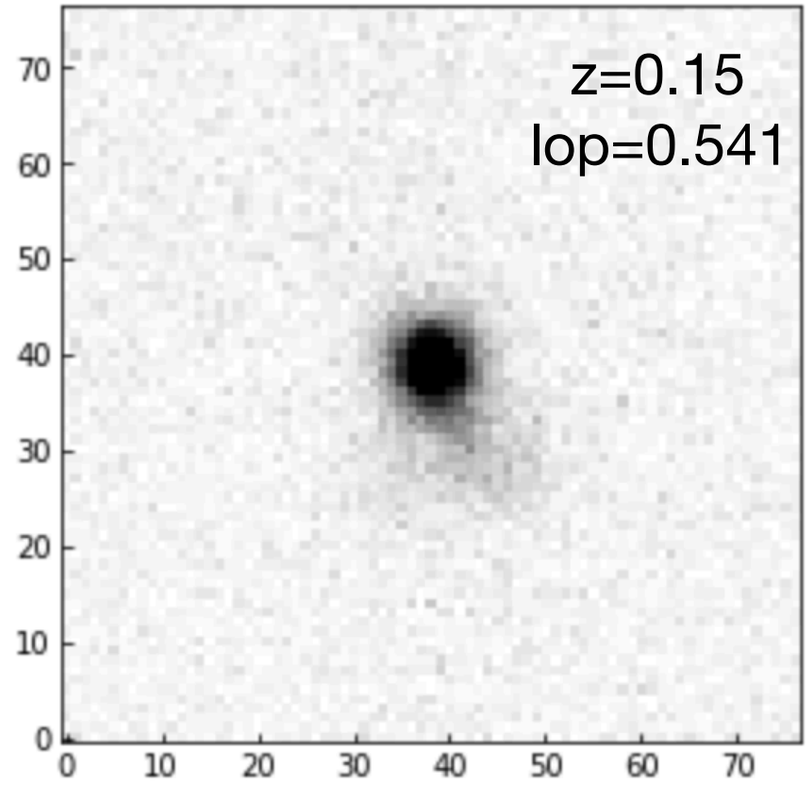


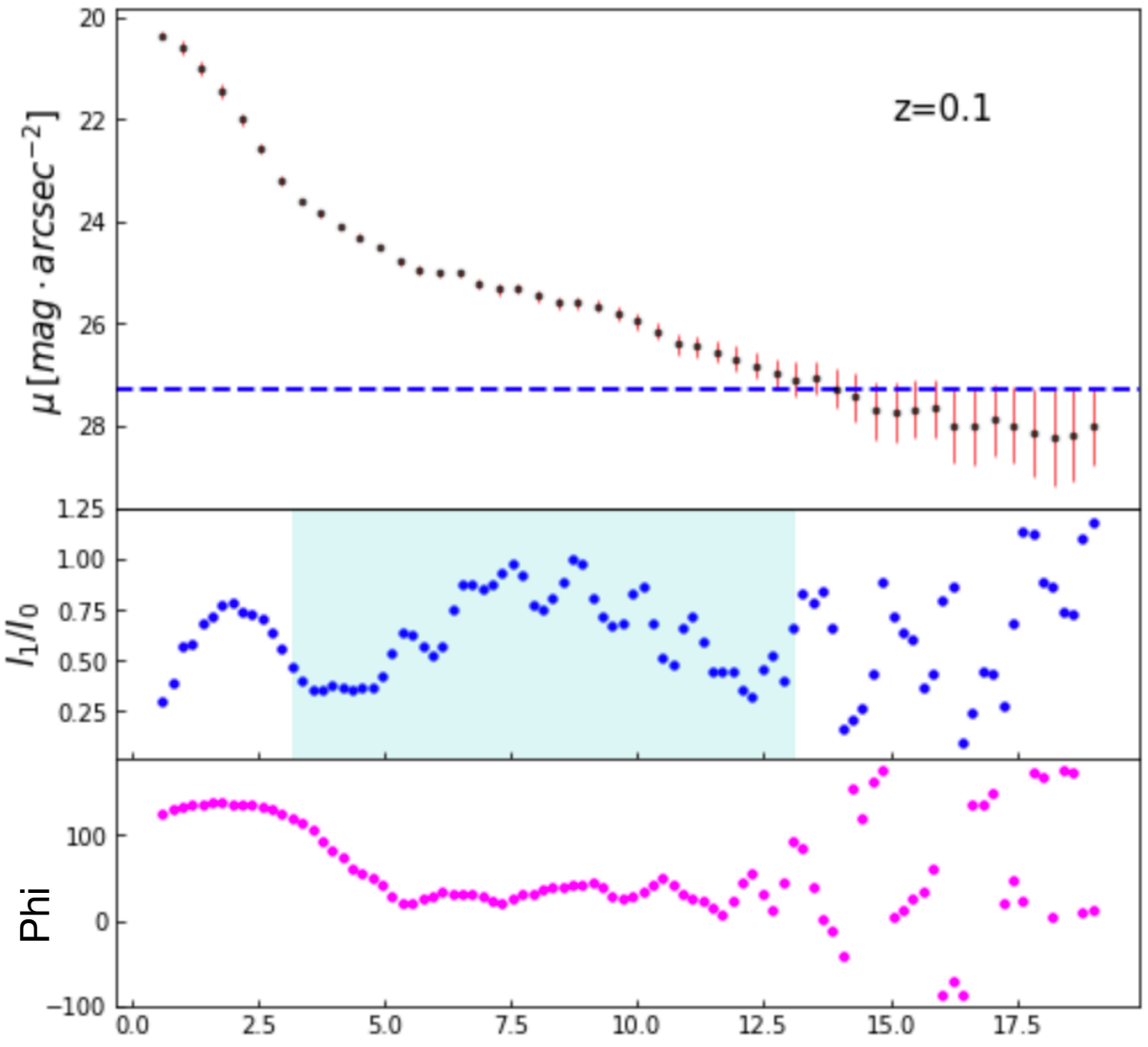


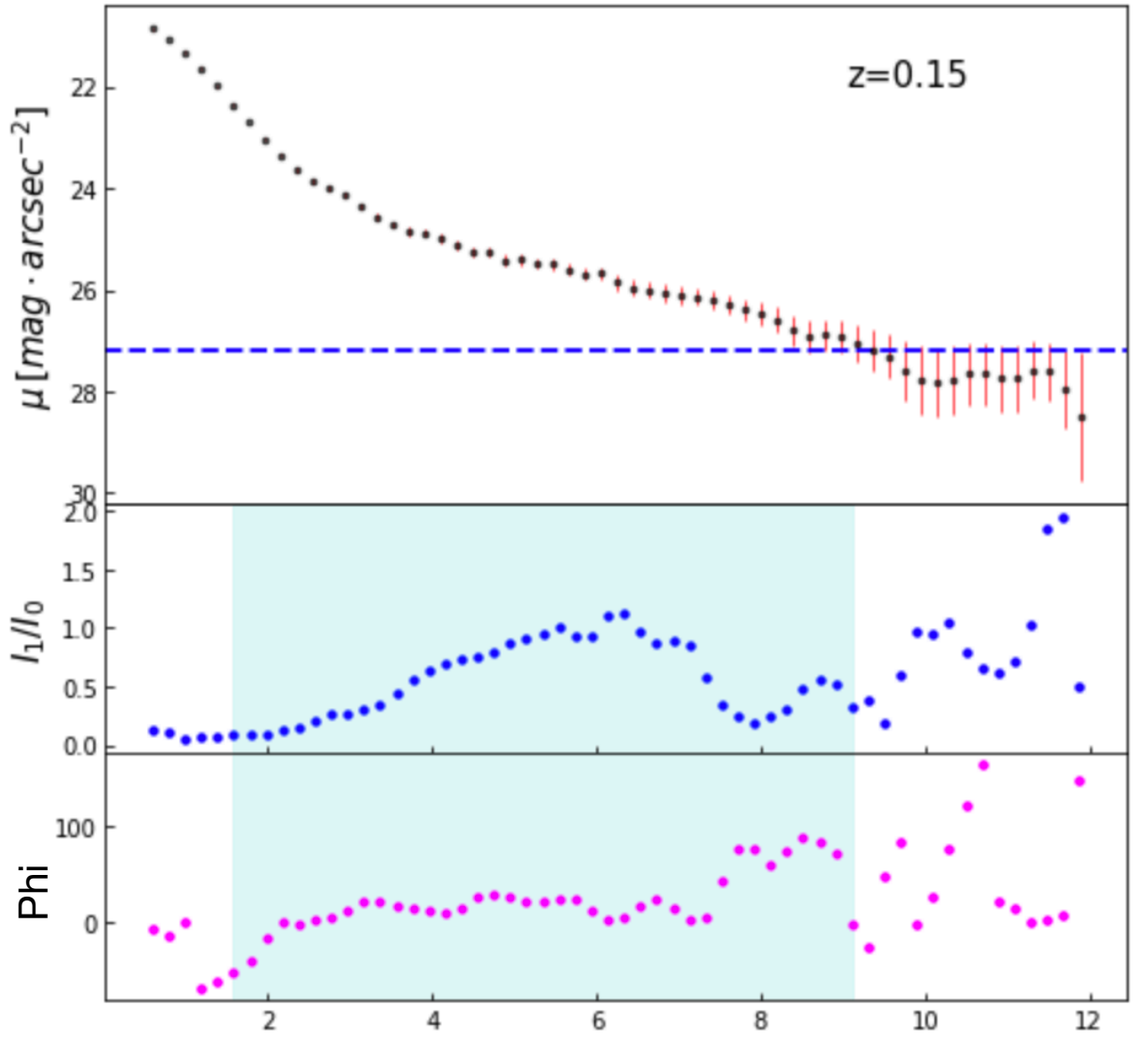


f1941a


z=0.1
lop=0.623


z=0.15
lop=0.541


z=0.1
$\mu\,[mag\cdot arcsec^{-2}]$
I_1/I_0
Phi


z=0.15
$\mu\,[mag\cdot arcsec^{-2}]$
I_1/I_0
Phi

z<0.035 logMs > 10 :
306 objects.
138 of them have Galaxy Zoo 2 indice:
edge-on 10 , disk (not edge-on) 33, elliptical 29, unknown 73