

XXI SERBIAN ASTRONOMICAL CONFERENCE

How to decompose thousands of galaxies: a template-based approach

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Pulkovo
observatory

October 5 - 8, 2026, Belgrade, Serbia

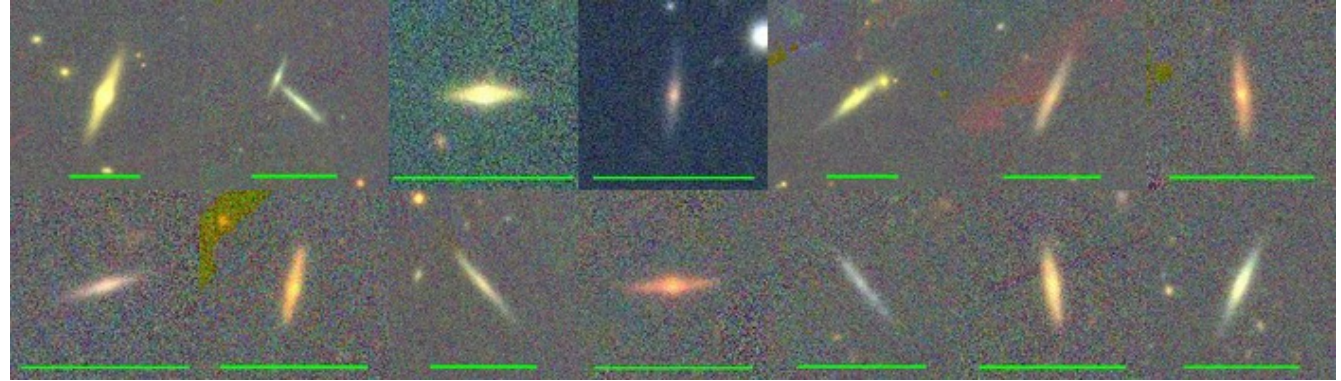


St. Petersburg
State University

Edge-on samples

Pan-STARRS1

EGIPS: 16000 galaxies
(Makarov et al., 2022,
Savchenko et al., 2024)



DESI Legacy

EGIDE: 149215 galaxies
(Marchuk et al., 2026,
also see yesterday's talk
by Alexander Marchuk)

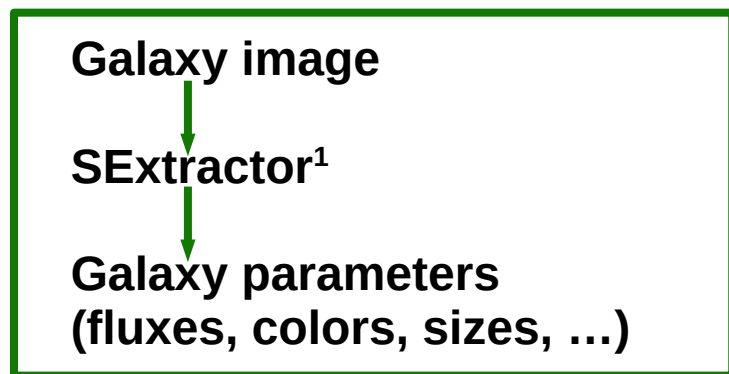


From samples to galactic parameters

Samples are ready, what's next?

Case a)

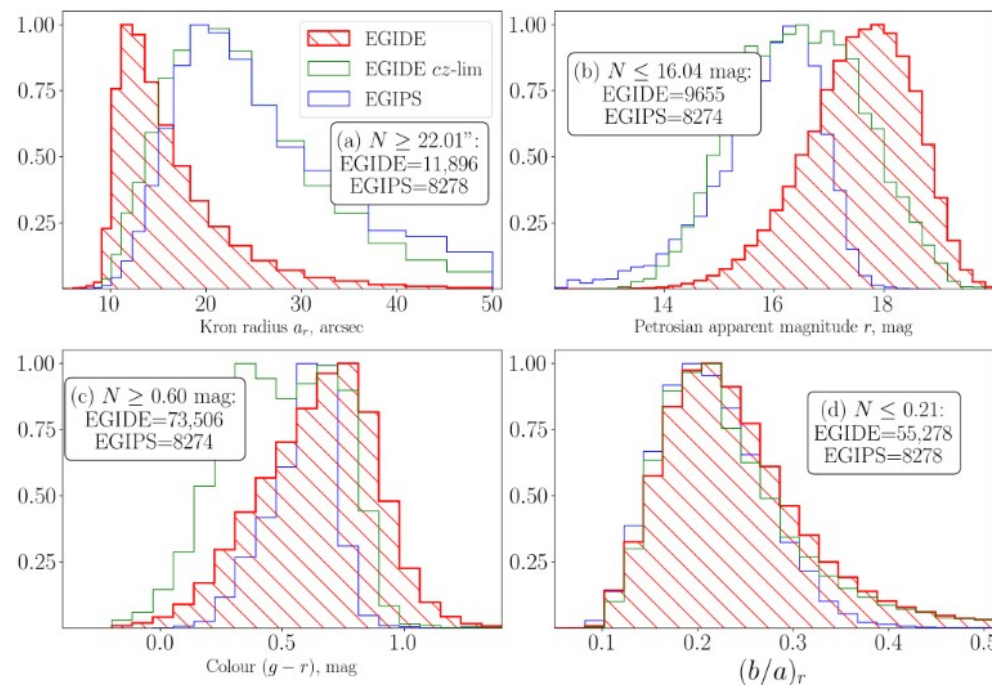
Photometric analysis



Repeat for all galaxies of
the sample



(See talk of A. Marchuk)



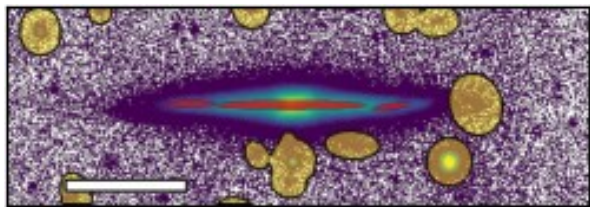
Photometric database

¹(Bertin & Arnouts 1996)

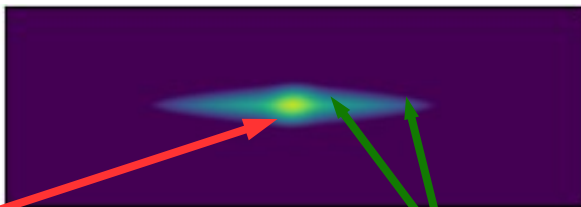
From samples to galactic parameters

Case B: photometric decomposition

Image



Model



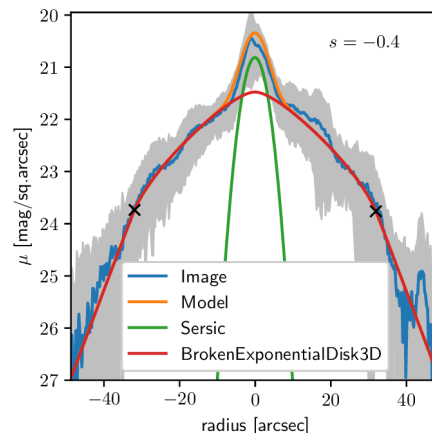
Bulge: $I(R) = I_e \exp \left\{ -b_n \left[\left(\frac{R}{R_e} \right)^{1/n} - 1 \right] \right\}$

Disk: $\rho(R, z) = \begin{cases} \rho_{0,1} \cdot \exp \left(-\frac{R}{h_1} \right) \exp \left(-\frac{|z|}{h_z} \right), & R < R_b \\ \rho_{0,2} \cdot \exp \left(-\frac{R}{h_2} \right) \exp \left(-\frac{|z|}{h_z} \right), & R > R_b \end{cases}$

More detailed view on a galaxy:

- Bulge: $r_e, n, \mu_e, q, \text{color}$
- Disk: $h_1, h_2, z_0, \mu_0, \text{color}$
- Combined parameters: B/D, colors of components, etc.

Photometric cut



From samples to galactic parameters

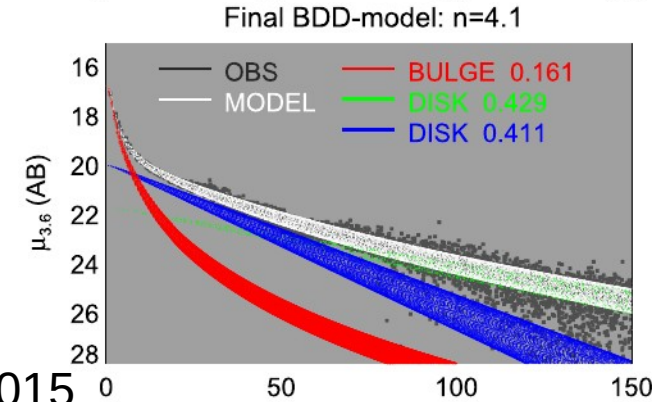
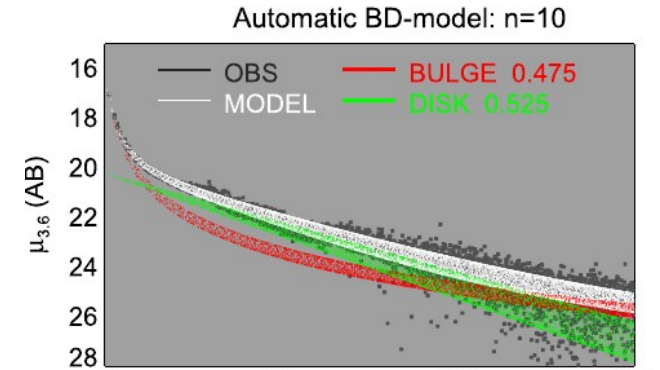
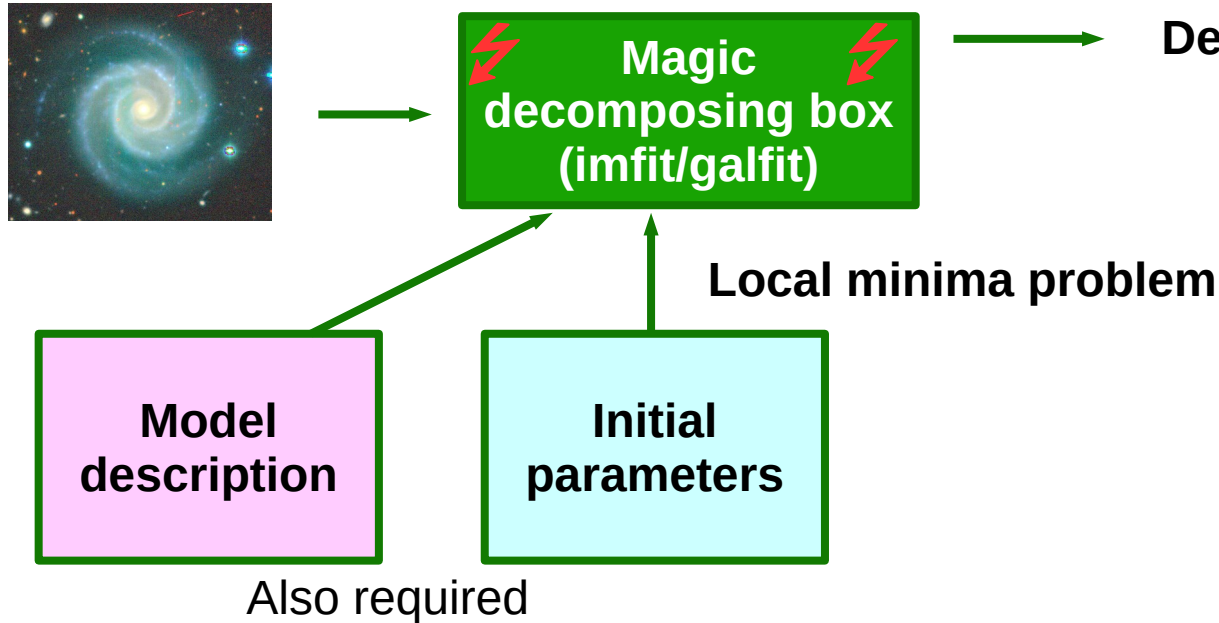
Decomposition process outline



Decomposition parameters

Two problems of decomposition

Decomposition process outline



Two problems of decomposition: how to solve?

Use **simple models** (single Sersic):

- Loses structural information

Brute-force: sort through all possible models, explore the entire parameter space

- not scalable due to limits on CPU time

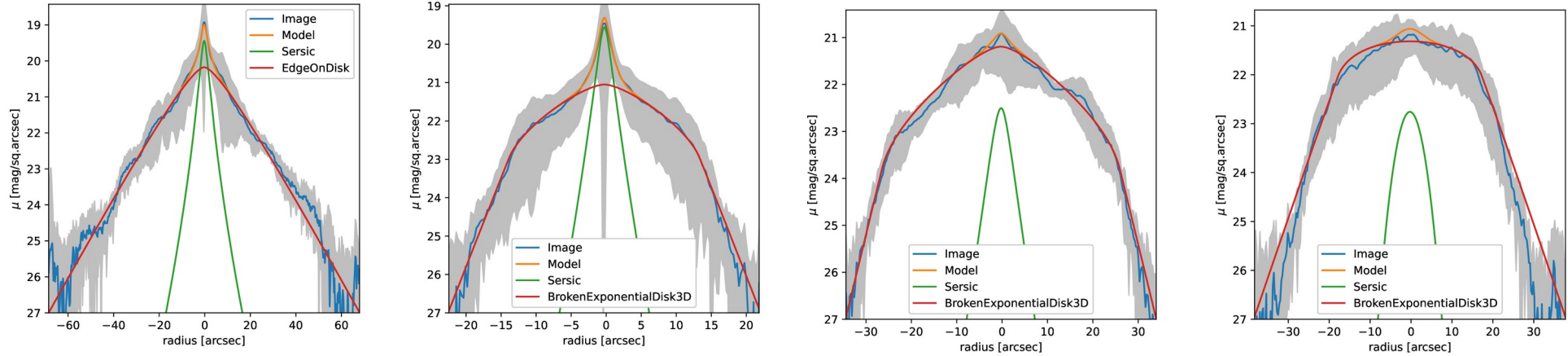
Astronomer-in-the-loop: manually select model, tweak initial conditions + eye-balling result until convergence

- limited by human workload

Computer vision algorithms (including ANN):

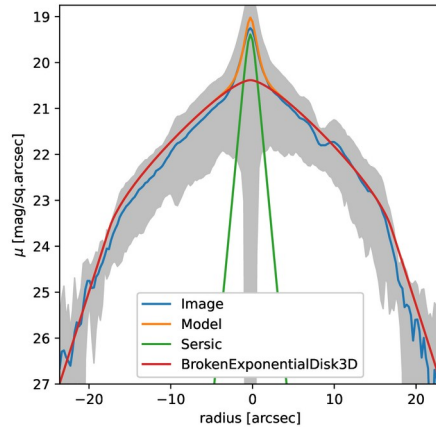
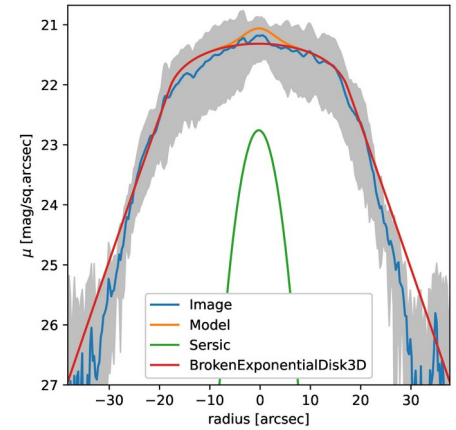
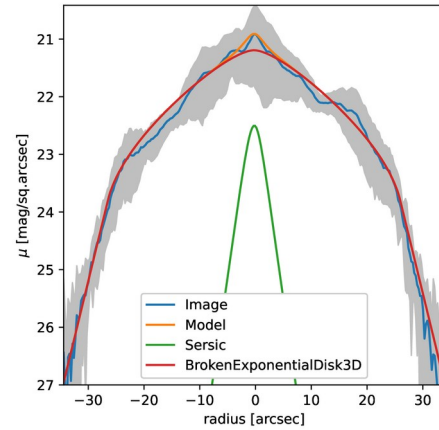
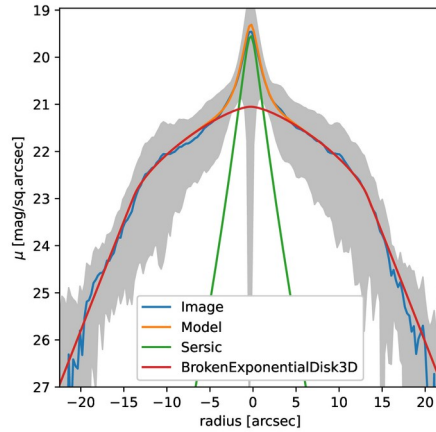
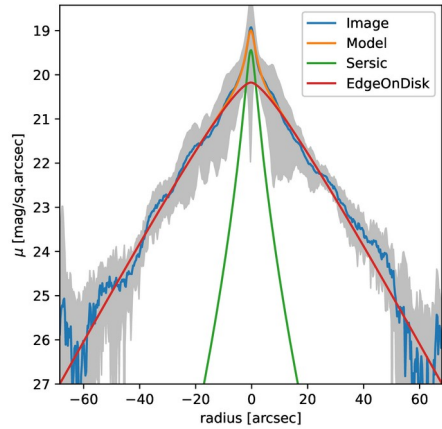
- requires training/setup for the adopted model

Shapes of edge-on galaxies



Shapes of galaxies do vary...

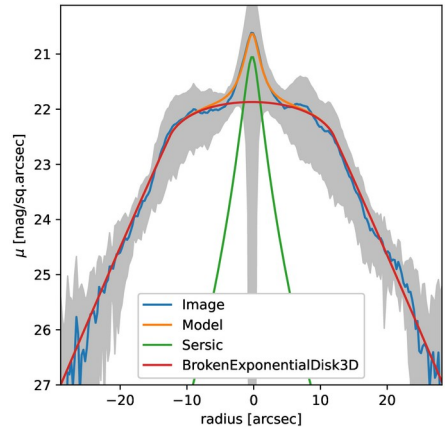
Shapes of edge-on galaxies



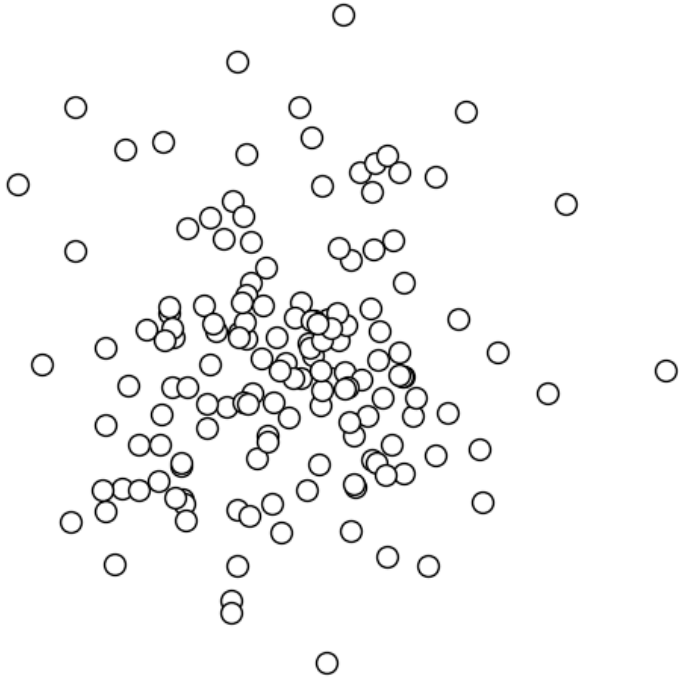
...but not by much

Similar profiles $\rightarrow$ similar decomposition solutions?

Can we reuse decompositions we already trust?

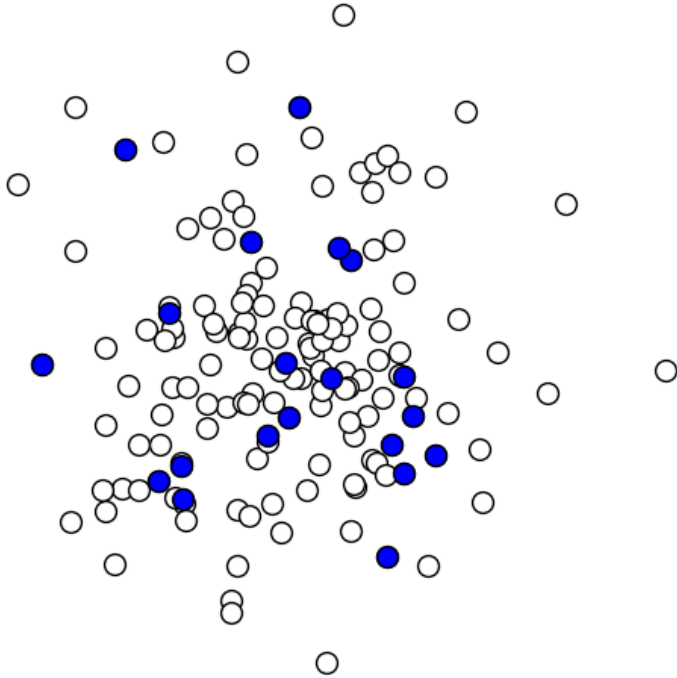


Two problems of decomposition: single solution



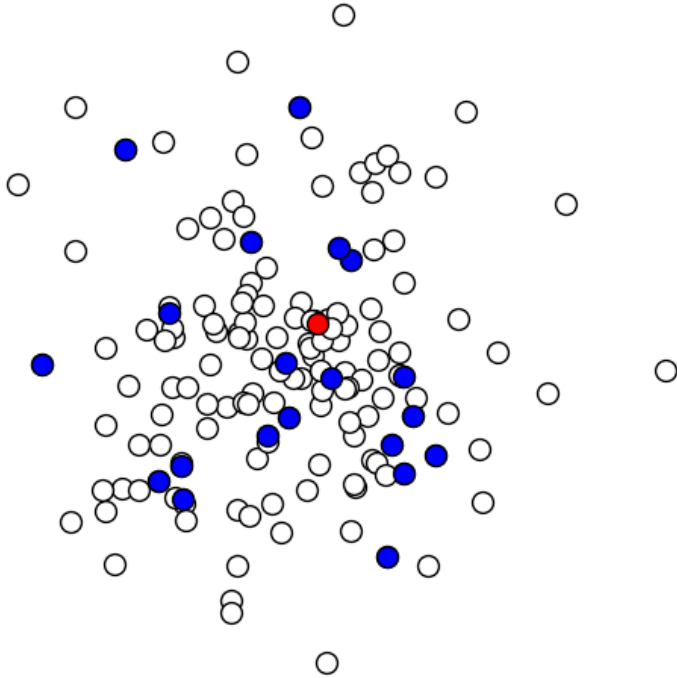
There is a large sample of galaxies to decompose

Two problems of decomposition: single solution



There is a large sample of galaxies to decompose
1) Decompose small subsample to use as templates

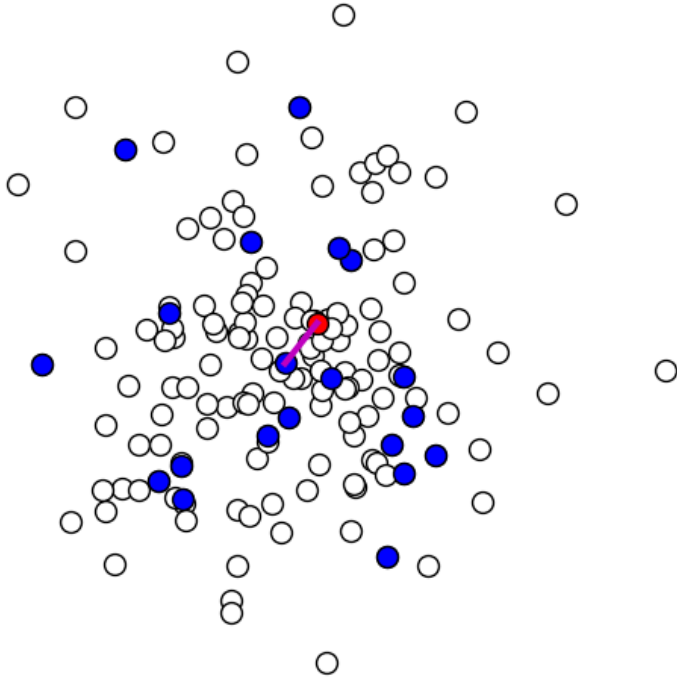
Two problems of decomposition: single solution



There is a large sample of galaxies to decompose

- 1) Decompose small subsample to use as templates
- 2) Take next galaxy

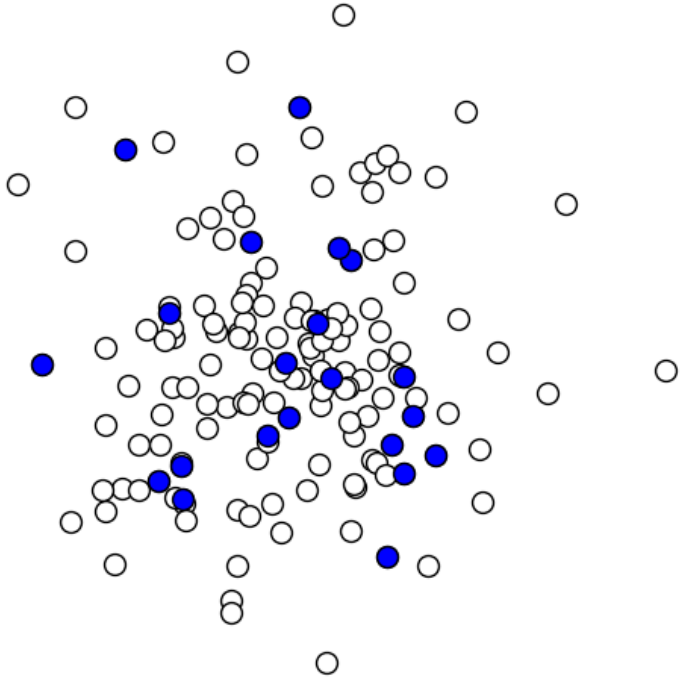
Two problems of decomposition: single solution



There is a large sample of galaxies to decompose

- 1) Decompose small subsample to use as templates**
- 2) Take next galaxy**
- 3) Find the most similar template galaxy,
use its model as the initial guess**

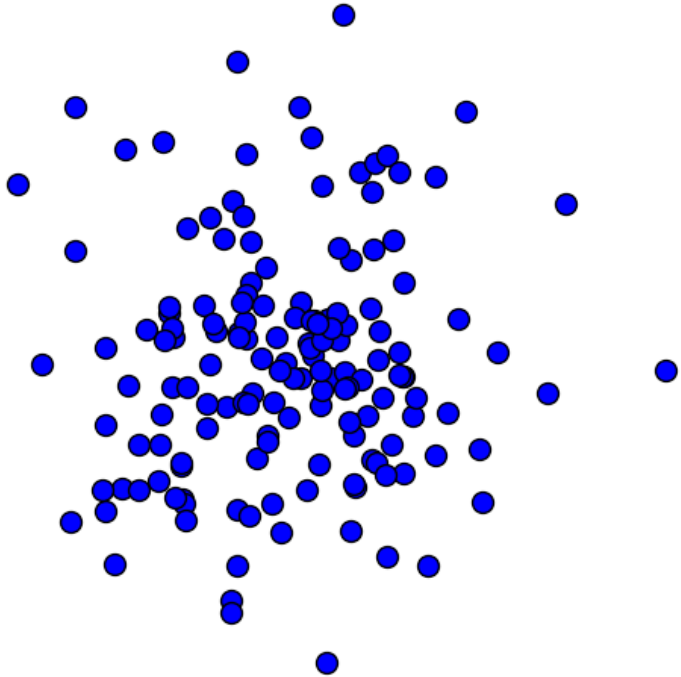
Two problems of decomposition: single solution



There is a large sample of galaxies to decompose

- 1) Decompose small subsample to use as templates**
- 2) Take next galaxy**
- 3) Find the most similar template galaxy,
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- 4) Now we have $N+1$ decompositions**

Two problems of decomposition: single solution

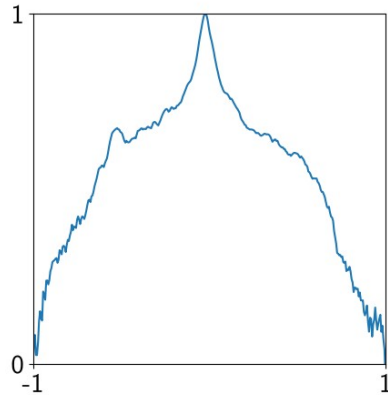


There is a large sample of galaxies to decompose

- 1) Decompose small subsample to use as templates
- 2) Take next galaxy
- 3) Find the most similar template galaxy,
use its model as the initial guess
- 4) Now we have N+1 decompositions
- 5) Repeat until all galaxies are processed

A galaxy is added to the template library only if the fit passes the quality criterion: $\chi^2 < 1.5$

Search for similar galaxies

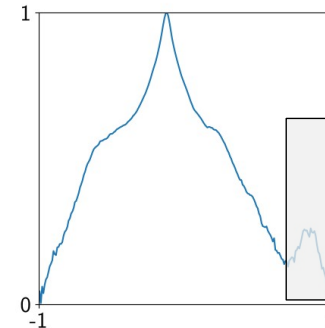
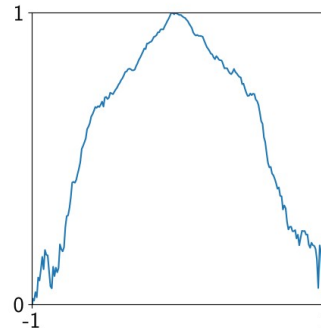
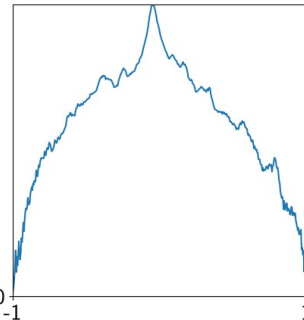
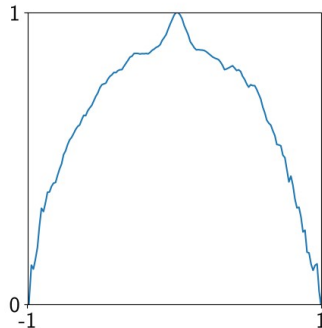


Normalized photometric cut
of a new target galaxy

Distance to the i'th template:

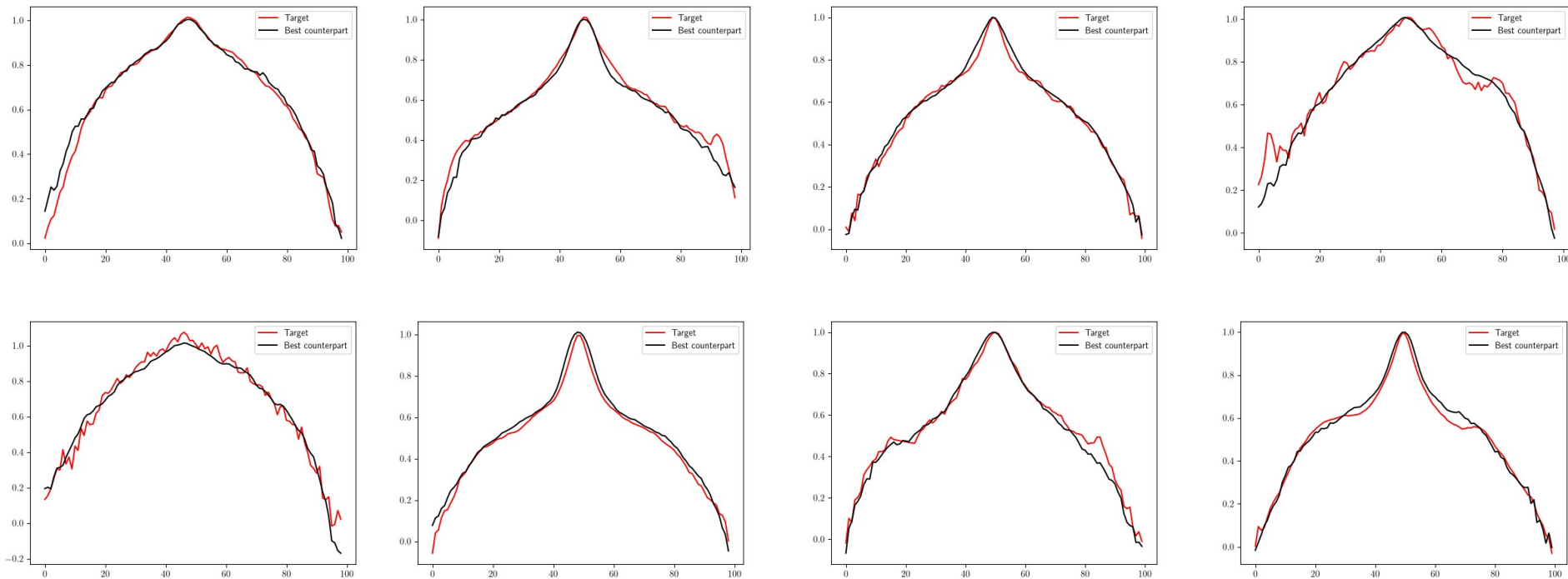
$$d_i = \sum (\text{OBJ} - \text{TEMPLATE}_i)^2$$

Best template is the one with smallest d_i



Normalized photometric cuts of template galaxies

Search for similar galaxies



Initial template sample: 375 galaxies from Savchenko et al., 2026

From template to new input parameters

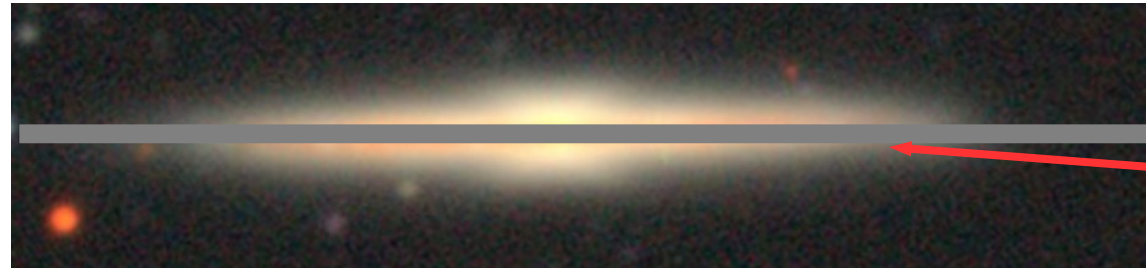
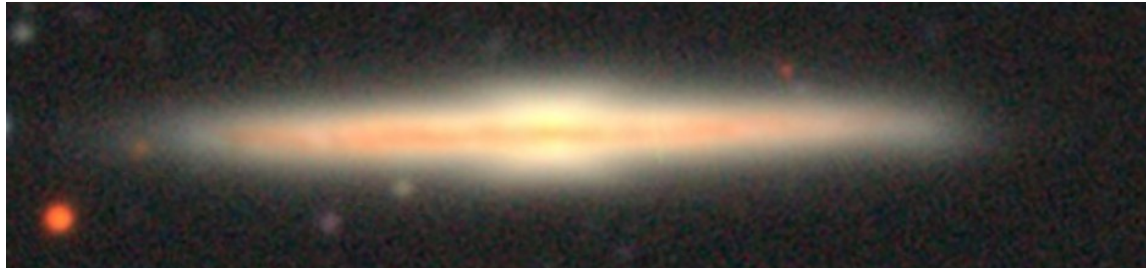
Once the best template is found:

- 1) Its model determines the model applied to the new target (if template has broken disk, so we use a broken disk model for a target galaxy)
- 2) Template's best fitting parameters are used as inputs for target galaxy decomposition after scaling:
 - all sizes (r_e , h_1 , h_2 , r_{break} , etc) are scaled according to the template-to-target apparent-size ratio

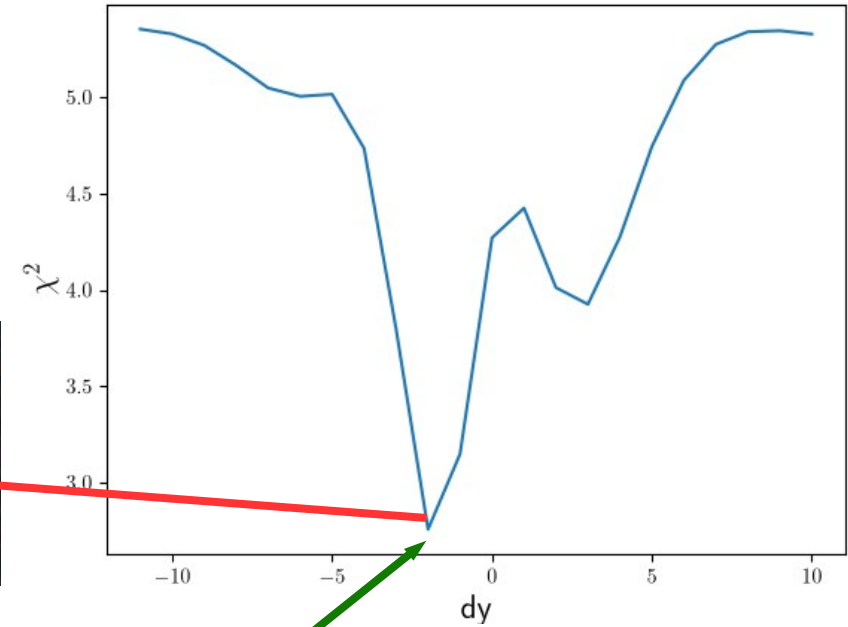
$$p_{\text{target}}^{(0)} = p_{\text{template}} \frac{R_{\text{target}}}{R_{\text{template}}}$$

- all flux parameters (I_e , I_0 , etc) are scaled according to the template-to-target flux ratio

Sweeping the dust (under the carpet)

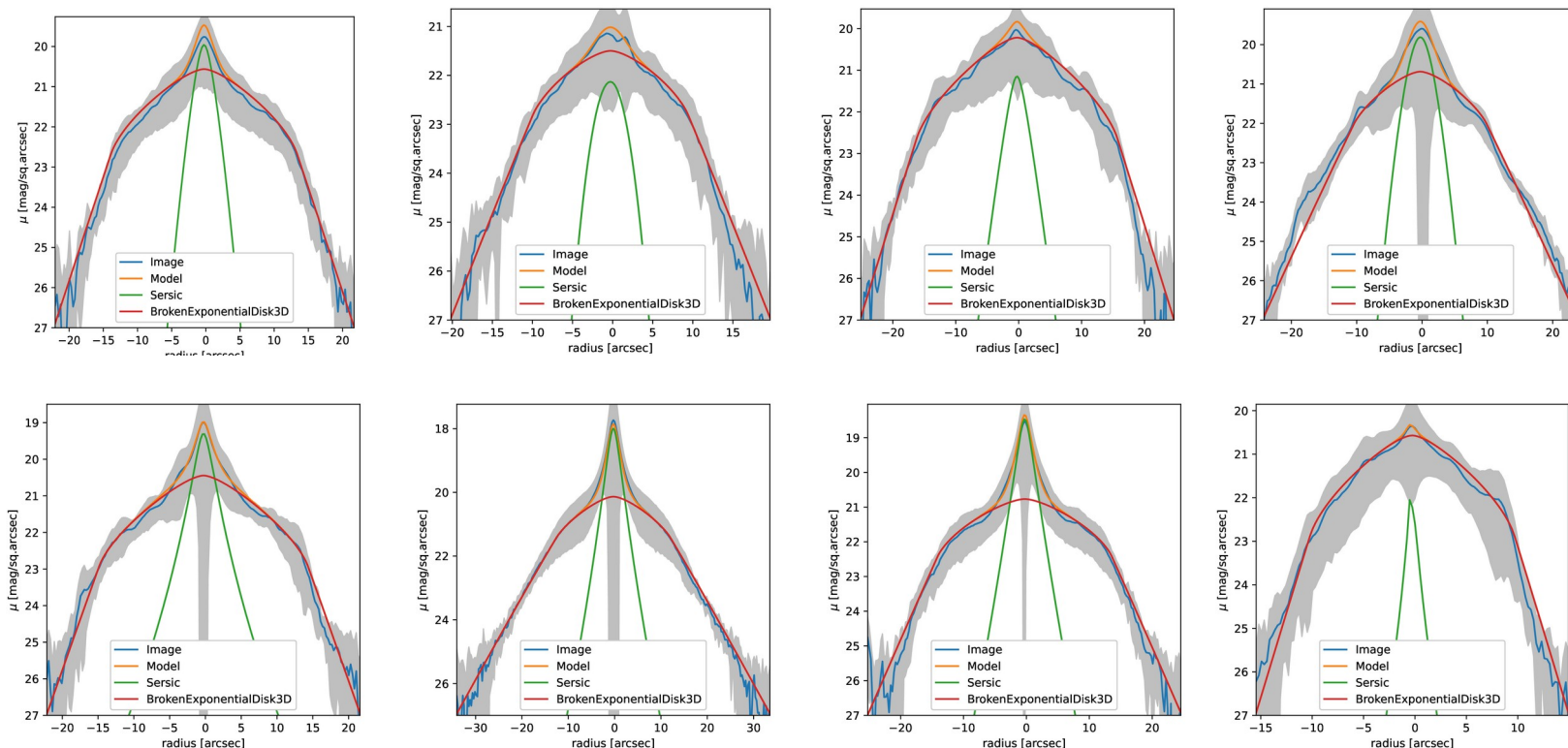


Chi² as a function of mask shift



Optimal mask position

Decomposition results



Currently a sample with 12000 galaxies in four bands is being processed, 4000 completed, success rate $\sim 95\%$.

Conclusions

- A new approach to setup decomposition is proposed:
 - Reuses previously validated decompositions to initialize new galaxies
 - Selects model structure and initial parameters simultaneously
 - Template library grows automatically as the sample is processed
 - Requires no manual intervention after the initial template set
 - Fast, easy to implement
- Currently a large sample of edge-on galaxies is being processed, decomposition results will appear soon