# Decomposition of Galaxy Images and Galaxy Rotation Curves

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**Abstract.** We present two new Python packages to perform structural and kinematic decomposition of galaxies based on their imaging and rotation curves. The DECA (DEComposition Analysis) code is designed to investigate images of galaxies in an automatic regime (using the simple 'bulge+disc' model) as well as in manual mode for more detailed images and/or for multicomponent structures. DECA can be applied for description of edge-on disc warps, disc truncations, and shape of bulge isophotes. A new developed technique to analyze spiral structure of galaxies if spiral pattern can be well detected on the image has been incorporated into DECA (e.g. estimation of the pitch angle and of the arm width). The GRCF (Galaxy Rotation Curve Fitting) package allows to perform the decomposition of the rotation curve of a disc galaxy onto three components: a bulge, a disc, and a dark halo. The set of possible models includes spherical and oblate Sérsic bulges, infinitely thin and thick exponential discs, isothermal dark halo, and the Navarro-Frenk-White dark halo profile with taking into account the adiabatic contraction. The package contains several fitting techniques including bounded gradient descent routine, maximal and minimal disc approximation. Big advantage of both packages is the presence of the graphical interface which makes the decomposition process more transparent and controllable by user. The packages have been tested on the sample of artificial galaxies. Output galaxy models are in a good agreement with the input ones. The codes are now free available to the astronomical community.

## DEComposition Analysis

### MAIN FEATURES AND ADVANTAGES

- Python wrapper with the implementation of SExtractor and GALFIT.
- Taking into account multiple photometric components: disc, bulge, bar, double disc, lens, spiral arms, AGN.
- Interactive regime with a dialogue interface
- Flexible configuring
- Sophisticated analysis of edge-on galaxies (e.g. disk warp parameters, truncations, shape of bulge isophotes etc.) and galaxies with grand design.

### SPIRAL GALAXIES

The decomposition of spiral galaxies is a complicated problem due to a big number of free parameters in the 'bulge+disc+spirals' model. To solve this problem, we use the so-called genetic algorithm (GA). The main idea of GA is to represent possible solutions as “organisms” with “genes” which are free parameters of a model. During optimization procedure these “organisms” evolve to obtain more and more adequate characteristics (solution).

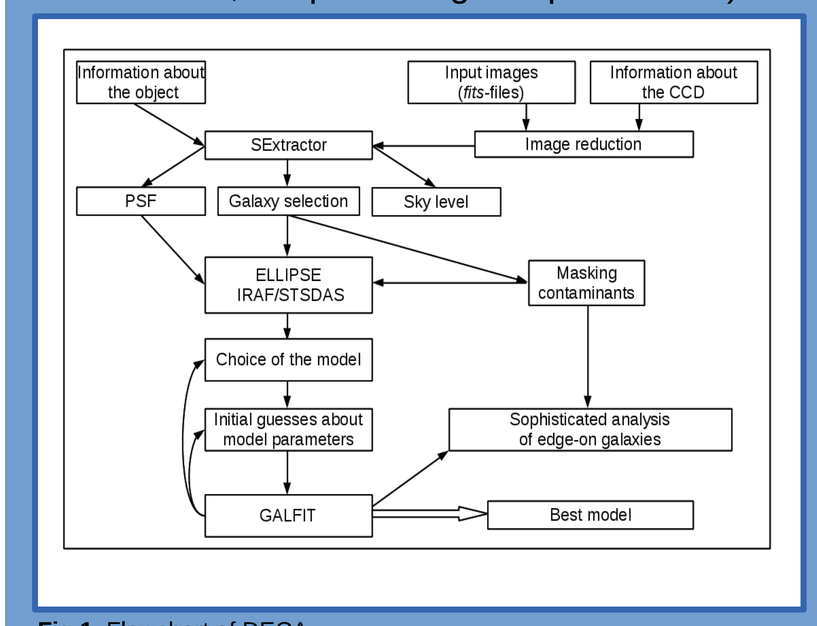


**Fig 1.** Flowchart of DECA

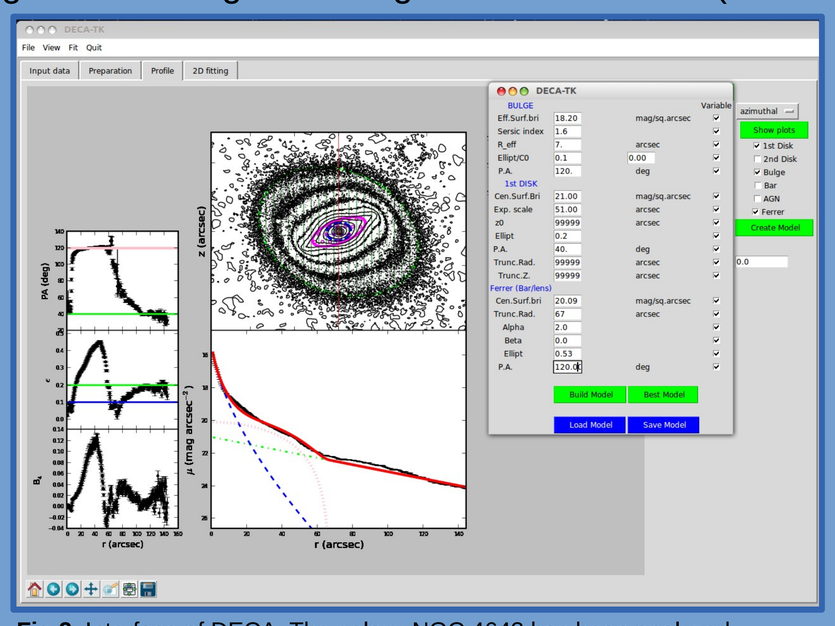


**Fig 2.** Interface of DECA. The galaxy NGC 4643 has been analyzed.

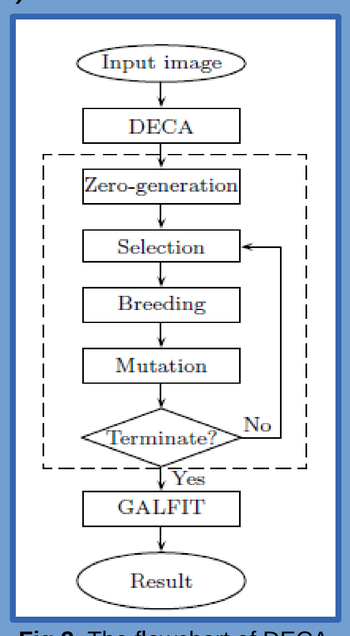


**Fig 3.** The flowchart of DECA with the implementation of the genetic algorithm (inside of the dashed rectangle).

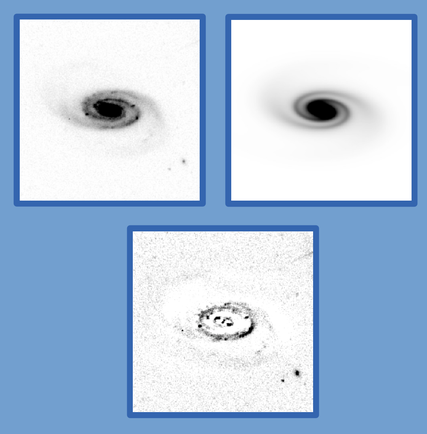

**Fig 4.** The galaxy UGC 5830 with a spiral pattern. The image (top left), the model (top right) and the residual (bottom).

## Galaxy Rotation Curve Fitting

The GRCF package was created for performing the galaxies rotation curve decomposition using the models of the bulge, the disc, and the dark halo. The main purposes of the package are: (1) to combine various models of galactic components (one can choose between them and use the appropriate combination for any particular problem), and (2) to provide a user-friendly interface to operate with these models. As an input, this package takes the observed rotation curve of a galaxy and the values of its structural parameters (which can be obtained via the DECA package). Then user chooses an appropriate model for decomposition and one of possible decomposition techniques. The result of the decomposition is a set of values of the mass-to-light ratios of the disc and the bulge, and tof he structural parameters of the dark halo which can not be observed directly. To test the quality of the decomposition, the package provides the graphic representation of the decomposition onto subcomponents (see image below) and the chi-squared value.

**Programming languages:**
- Python (GUI)
- C++ (math core)

**Requirements:**
- Unix-like OS
- Python >=2.6 (with PWM, matplotlib, numpy)
- g++ (with GSL)

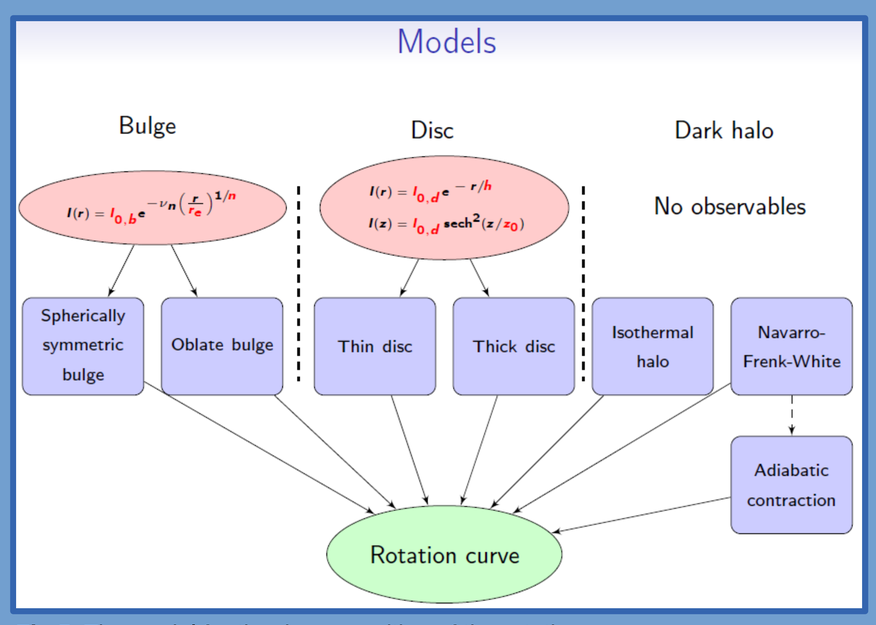


**Fig 5.** The model for the decomposition of the rotation curve.

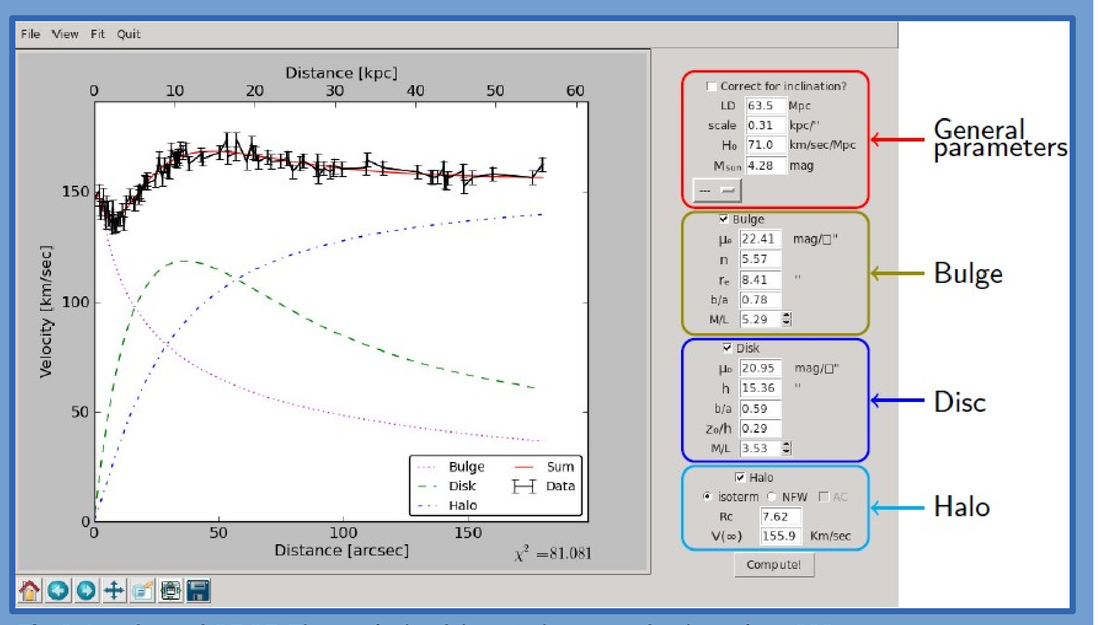


**Fig 6.** Interface of GRCF. The analysis of the rotation curve for the galaxy ???.

## CONCLUSIONS

We presented two codes for retrieving photometric and kinematic parameters of the components of a galaxy model. The results of the decomposition of artificial (simulated) galaxies show that both programs provide robust fitting. The codes can be used for precise investigation of galaxies with available image data (DECA) and rotation curves (GRCF). Together, these packages provide an opportunity to determine model parameters by coherent analysis of galaxy photometry and kinematics.

**You can download the codes at:**
http://lacerta.astro.spbu.ru/?q=node/96 ***(DECA)***
*http://github.com/latrop/GRCF* ***(GRCF)***

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