Database For Studying Edge-on Galaxies

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We present a database created within the project on studying edge-on galaxies. These galaxies provide a unique opportunity to study the three-dimensional distribution of the matter in galaxy disks, which is extremely important for analyzing the influence of internal and external factors on the evolution of galaxies. For the moment, extensive observed material has been accumulated on the kinematics and photometry of such galaxies. The database is designed to organize information, make it easier to visualize, and to improve works on studying this type of objects. The database combines information from previous catalogs on edge-on galaxies and data from current projects; provides access to astrometric and photometric data; carries out interconnection with other databases. The present paper describes the structure and web-access to the database: \url{https://www.sao.ru/edgeon/}.

1. INTRODUCTION

Galaxies seen at an angle close to 90\(^\circ\) provide a unique opportunity to study the vertical structure of galaxy disks and bulges. Thus, they traditionally attract the attention of researchers. P. van der Kruit and K. Freeman with colleagues performed a number of fundamental studies on such galaxies in 1980–1990. They had shown that the vertical distribution of the matter in galaxy disks is well described by the self-gravitating isothermal layer model, in which the vertical disk scale is directly related to the vertical velocity dispersion and surface density of stars in the disk [22]. It was found that the vertical scale of the galaxy disks remains practically constant along the radius of the galaxy.

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The description of the dust influence in edge-on galaxies is a difficult task. It is necessary to take into account the complex structure of a galaxy, differences in the radial and vertical distribution of stars and dust, radiation scattering on dust particles. Dalcanton et al. [6] found that the dust lane only occurs in rapidly rotating systems, \(V_{\text{rot}} > 120 \text{ km s}^{-1}\). Slowly rotating galaxies show a diffuse dust distribution. The thickness of layers of the dust and gas in dwarf, \(V_{\text{rot}} < 100 \text{ km s}^{-1}\), thin galaxies is comparable to the vertical scale of the stellar disk [3]. The occurrence of the dust lane in massive galaxies is most likely associated with gravitational instability in the mixed gaseous-stellar disk and can lead to a significant increase of the star-formation rate in massive galaxies.

Edge-on spirals of late morphological types are flat galaxies with the axis ratio \(a/b > 7\).
As a rule, such galaxies are gas-rich, have a low surface brightness and a low star-formation rate [10, 15, 16]. Kudrya et al. [12], based on the distribution of apparent ellipticity of flat galaxies, showed that the maximum true axial ratio in the blue range for galactic disks is $a/b = 25.8$. In the papers by Zasov et al. [23], Sotnikova and Rodionov [21], and Khoperskov et al. [11], it is emphasized that the existence of very thin, $a/b > 10$, purely disk galaxies is possible only in the presence of a massive dark halo around them. The theoretical ratio between the thickness of the disk and the mass of its spherical component allows one to estimate a lower boundary of the dark halo mass in galaxies. An analysis of the rotation curves of ultra-thin galaxies indicates the existence of the dark matter halo with a compact core, where the characteristic radius of the dark halo core is approximately equal to half the scale of the galaxy disk [13].

The above results urge the importance of studying edge-on galaxies, of understanding the physical processes of formation, evolution, and morphological transformation of galaxies in the Universe.

Databases have proved themselves as an important tool for collecting, organizing, and analyzing various information. To the date, the most famous and largest are: the NASA Extragalactic Database\(^1\) (NED), HyperLeda\(^2\) [14], SIMBAD\(^3\), and Vizier\(^4\). These databases contain data from various sky surveys and observations of individual objects published in the literature; they provide an interface for searching for, identifying, and visualizing a variety of information; they interconnect different databases. However, the versatility and inability to “boil the ocean” lead to certain difficulties and limitations of these resources when studying specific types of objects like a sample of edge-on galaxies. In particular, automatic algorithms for the selection, classification, and photometry of such objects often fail. The distribution of galaxies by size, morphology, and surface brightness is extremely wide. This results in the impossibility of choosing the optimum set of parameters that would equally well describe both extremely distant, practically point objects at cosmological redshifts and nearby extended galaxies showing a complex and rich internal structure. As a result, there are well-known problems of artificial splitting of extended objects into smaller ones and, as a consequence, incorrect estimation of their observation parameters. Edge-on galaxies occupy a specific place in this row, since the effects of integration along the line of sight, the presence of an extremely strong dust lane for giant galaxies, and the considerable ellipticity of objects play an important role in the distribution of their surface brightness. All these facts lead to large systematic errors of the observed parameters of edge-on galaxies.

1. https://ned.ipac.caltech.edu/
2. http://leda.univ-lyon1.fr/
3. http://simbad.u-strasbg.fr/simbad/
4. https://vizier.u-strasbg.fr/viz-bin/VizieR
Recently, edge-on galaxies have been actively studied including by the authors of the paper. The creation of this database was caused by the personal requirements of the authors in structuring and systematization of data, in the convenience of their visualization, and in facilitating the analysis of the results. The need arose to have at hand a universal tool for working with samples of galaxies, which could be easily and quickly adapted to various tasks solved when studying edge-on galaxies. This determined the motivation of creating a database of objects of this type.

2. DESCRIPTION OF THE DATABASE

The database for studying edge-on galaxies operates on the servers of the Special Astrophysical Observatory of the Russian Academy of Sciences: https://www.sao.ru/edgeon/.

The database operates under the control of the PostgreSQL object-relational database management system\textsuperscript{5}. This open source system is characterized by reliability, functionality, and performance. PostgreSQL is based on the structured query language SQL. PostgreSQL provides support for embedded procedural programming languages: PL/pgSQL, PL/Perl, PL/Python, and PL/Tcl. It is possible to load extension modules in C. PostgreSQL provides APIs for a wide variety of programming languages such as Python, Perl, PHP, ODBC, etc. It is characterized by ease of expansion, the ability to create new data types, indices, operators, and functions. PostgreSQL also implements table inheritance.

The database is based on three catalogs of edge-on galaxies. These are: the Revised Flat Galaxy Catalogue (RFGC) \cite{8}, the Catalog of Edge-on Disk Galaxies from SDSS (EGIS), and the 2MASS-selected Flat Galaxy Catalog (2MFGC). The basic structure of the database is shown in Fig. 1 illustrating the relations between various tables.

2.1. Revised Flat Galaxy Catalogue

The RFGC catalog was created in 1999 by Igor D. Karachentsev and his colleagues and contains data on 4236 thin galaxies with diameters $a > 40''$ and the axial ratio $a/b \geq 7$ in “blue” photographic images of POSS and ESO/SERC sky surveys. In addition, with the purpose of continuity, it included 208 objects from previous versions of the FGC \cite{9} catalog, which ceased to meet the selection criterion after the refinement of their parameters.

The catalog contains the data on the positional angle of a galaxy; the “blue” and “red” sizes obtained from the POSS-I prints; the total apparent $B$ magnitude calculated with the dimensions, morphological type, and surface brightness type, as described in the RFGC \cite{8} catalog; the

\textsuperscript{5} https://www.postgresql.org/
morphological type of a galaxy; the asymmetry index; the surface brightness index and the number of significant satellites. The detailed structure of the catalog is given in Appendix A.

2.2. Catalog of Edge-on Disk Galaxies from SDSS

As the name suggests, the EGIS catalog was created based on the SDSS [2] survey and contains the data on 5747 true edge-on galaxies. The catalog consists of three tables:

- \textit{egis}—the list of galaxies with their identification and astrometry;

- \textit{egis\_phot1d}—the photometric parameters of galaxies obtained from the analysis of the one-dimensional profile of a galaxy. The table gives the horizontal exponential scale of the disk; the vertical \text{sech}^2 scale of the disk; the central surface brightness normalized to the face-on position of a galaxy; the total aperture magnitude corrected for extinction in our Galaxy, and the contribution of the bulge to the total luminosity of a galaxy;

- \textit{egis\_phot3d}—the disk parameters (the central surface brightness, the vertical and horizontal scales) obtained from modeling the surface brightness distribution in the galaxy image.

Photometric parameters were derived from the images obtained in three filters, \textit{gri}, from the SDSSdr7 survey [1]. The catalog is provided by an archive of the processed images in the corresponding filters used in the photometry. The structure of the catalog is described in Appendix B.

2.3. 2MASS-Selected Flat Galaxy Catalog

The 2MFGC catalog was created based on the automatic selection of objects from the 2MASS infrared sky survey [17]. It contains 18 020 galaxies distributed over the whole sky with the axial ratio \(a/b \geq 3\). The catalog contains information on photometry in the \(J\), \(H\), and \(K_s\) bands from
the Extended Source Catalog of the 2MASS survey [7]. The structure of the catalog is described in Appendix C.

2.4. Edge-on Galaxy Candidates from the Pan-STARRS Survey

Our database is actively used in the work to create a new catalog of edge-on galaxies based on the Pan-STARRS sky survey. We are preparing this catalog and the search algorithm for galaxies included in it for publication. Here we provide a brief description and data structure of the candidate catalog. All information about the current state of the project is available on the project web-page\(^6\).

Approximately 27,000 candidates were selected using artificial neural networks (ANNs) trained on a sample of galaxies from EGIS and RFGC catalogs. Subsequently, all candidates visually classified to eliminate false objects and various artefacts disguised as edge-on galaxies. At this stage, we are refining the photometry of the selected candidates. The database was used to store and organize the data on candidates; to provide a convenient interface for viewing the data of specific objects; to screen out the image defects disguised as the target galaxies; to visually classify the objects (see Section 3.1); to compile various samples and analyze the data.

Due to the complexity of the project and its multistage structure, the catalog structure is more ramified than the above-described already-present catalogs. The schematic diagram of the catalog in the database is illustrated in Fig. 2. For the sake of compactness, it only lists the panels important for understanding the relationship between tables. The catalog of candidates consists of the following tables:

- \textit{ps1candidate}—the list of candidates;
- \textit{ps1candidate\_annvote}—the classification performed using ANNs;
- \textit{ps1candidate\_class}—the results of visual inspection of candidates;
- \textit{ps1candidate\_phot}—the automatic photometry performed by SExtractor\(^7\);
- \textit{ps1candidate\_crossid}—the cross-identification with the galaxies from the HyperLeda database [14];
- \textit{ps1candidate\_notes}—the various notes made while working with galaxies.

To facilitate the work with the candidate catalog, views were developed that “on-the-fly” combine the data from various tables into a single structure:

- \textit{ps1candidate\_class\_stats} calculates statistics on the visual classification of each galaxy;
- \textit{ps1candidate\_final} is the “cleared” sample of objects to create the final version of the catalog.

\(^6\) https://www.sao.ru/edgeon/catalogs.php?cat=PS1candidate

\(^7\) https://sextractor.readthedocs.io/
The structure of the catalog is described in Appendix D.

The catalog is accompanied by an archive of the images. At the moment, it contains FITS files in five filters taken from the archive of Pan-STARRS\(^8\) and JPEG images with the outlines of the selected objects. JPEG images are used for data visualization using the web interface.

### 2.5. Interaction with HyperLeda

The interrelation between objects in different catalogs within our database is carried out using a unique identifier: the PGC numbers of galaxies in the HyperLeda database\(^9\) [14]. This allows one to link together the galaxy-specific data from various tables and catalogs and visualize the whole dataset. We carry out cross-correlation of objects with galaxies from the HyperLeda database [14]. In the absence of matches, the missing galaxies are added to the HyperLeda database, which allows one, on the one hand, to keep the interrelations up to date and, on the other hand, to replenish HyperLeda with new data.

### 3. WEB INTERFACE

The home page\(^10\) provides information about the project, describes its goals and objectives. The “Projects” and “Catalogs” Sections are dedicated to current projects and data collection. The data-visualization web interface is implemented in the form of two universal options: visualization of the catalog as a whole in the form of a table and visualization of information cards of individual objects with the detailed data. In

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\(^8\) [https://ps1images.stsci.edu/cgi-bin/ps1cutouts](https://ps1images.stsci.edu/cgi-bin/ps1cutouts)

\(^9\) [http://leda.univ-lyon1.fr/](http://leda.univ-lyon1.fr/)

\(^10\) [https://www.sao.ru/edgeon/](https://www.sao.ru/edgeon/)
addition to universal visualization methods, each specific dataset can have its own display system for more flexible adaptation to the specific features of the structure of the catalogs and the data they contain. The search for objects in the database by coordinates is also provided. The web interface of our edge-on galaxy database is implemented in the PHP\textsuperscript{11} scripting language using JavaScript. The system is constantly expanding and supplemented with new data and capabilities.

### 3.1. Service of Visual Classification of Objects

Working with the catalog of edge-on galaxy candidates (see Section 2.4) demanded the large-scale visual inspection of images, object classification, elimination of “waste”, and storing information in the database. Initially, for this purpose, we used the Zooniverse\textsuperscript{12} citizen science service developed from the Galaxy Zoo project. However, this appeared labor intensive in preparing images for viewing, uploading them to the Zooniverse servers, organizing the classification itself, and then analyzing the results. Therefore, we have developed our own visual inspection and classification system for galaxies deployed on our server. This greatly simplified and accelerated the process of creating a questionnaire, conducting a visual inspection, and analyzing the results obtained. Our classification system is ideologically close to the inquiry system in the Zooniverse project. The main difference is associated with the active use of the Aladin Lite\textsuperscript{13} code which allows one to visualize this region of the sky from different views, to scale images for a more detailed examination, and also to freely move around the whole sky to control the surroundings of the object.

The system allows one to quickly and easily create questionnaires, link them to different datasets, and collect responses from the registered users. At the moment, the visual classification service does not imply the public access. Therefore, the responsibility for forming a sample of objects for classification, creating a system of questions, and providing access to project participants rests with the system administrator. For this purpose, the following tables have been created:

- **user**—the list of users to personalize the work performed;
- **quiz** contains a description of a specific project, links it to tables in the database, and sets the limit on the number of classifications per object;
- **quiz_question**—the list of questions that form the basis of the classification;
- **quiz_result**—the collection of classifications made by different users in different projects;
- **quiz_result_info**—the view combining classifi-

\textsuperscript{11} https://www.php.net/
\textsuperscript{12} https://www.zooniverse.org/
\textsuperscript{13} https://aladin.u-strasbg.fr/
Figure 3. Example of the web page with the service of visual classification of galaxies. Each user is informed how many objects from the list he has classified and for how many objects sufficient statistics have been collected (retired). A web link to the page of the object itself is given (1940_054.0). An image of a galaxy with the outline (the left-hand picture) and a corresponding region of the sky map visualized using the Aladin Lite code (the right-hand picture) are given. On the right, is a classification section that allows one to group questions by topic.

The scheme of tables is given in Appendix E. The web interface forms a questionnaire based on information about the current project. Questions can be grouped for easy classification. It is possible to either select one item from a set of questions using the radio buttons, or indicate the presence or absence of a specific feature using flags. Information about the selected options is transferred to the database, where it is written to Table quiz_result with an indication of the specific project, the user who performed the classification, and the time. Objects for classification are selected randomly from the list of those that have not yet been classified by this user and the total number of classifications of which has not exceeded the specified limit. An example of a classification page is shown in Fig. 3. This system was used in the visual inspection of edge-on galaxy candidates in the Pan-STARRS survey.

3.2. Service of Object Identification with the HyperLeda Database

The database implements a simple object identification algorithm, similar to that adopted
in HyperLeda [14]. Two circles with the radii $R_1 < R_2$ are drawn around each identified object. If only one HyperLeda object is found inside these circles and it lies inside the $R_1$ circle, then this object is automatically identified with the corresponding galaxy. If no galaxy is found inside the $R_2$ circle in HyperLeda, then the identified object is marked as a new galaxy. In all other cases, the object is passed for manual verification. For this, the web interface was organized, the work with which is regulated by the administrator. An example of an identification page is shown in Fig. 4. Registered users are given the opportunity to choose the best match between the identified object and the list of known galaxies in HyperLeda presented in a tabular form with the parameters most useful in the identification. For convenience, well-known galaxies are sorted with distance from the identified object. Aladin Lite is used to visualize the surroundings of the object. The image shows both the position of the identified object (marked with a red cross) and known galaxies (blue dots), the characteristic sizes of which are enclosed in white ellipses. The user can identify the object, or mark it as a new galaxy, or postpone for further more detailed consideration. The corresponding selection is entered into the database with information about the user and the time of identification.

4. CONCLUSION

We have created a database for studying edge-on galaxies, https://www.sao.ru/edgeon/. It is based on well-known catalogs: RFGC [8], EGIS [2], and 2MFGC [17]. The system is easy to mod-
ify. This system was the basis for a project to create a new catalog of edge-on galaxies selected in the Pan-STARRS survey using artificial neural networks. The database provides a web interface for accessing catalogs and various data on galaxies such as astrometry, photometric parameters, data on morphology, and visual classification of objects. The interaction with the HyperLeda [14] database and digital data archives through Aladin Lite has been carried out.

This work is the first step in collecting and organizing data on edge-on galaxies. Our nearest plans are to add a catalog of photometric parameters obtained during a large-scale image analysis using the GalFit\footnote{https://users.obs.carnegiescience.edu/peng/work/galfit/galfit.html} [18] code from various sky surveys such as SDSS, Pan-STARRS, and Legacy Survey. At the moment, the vast observed material has been accumulated on the kinematics of gas in flat galaxies, including observations that were carried out at the 6-m SAO RAS telescope. The integration of this information into our database is extremely important. Among the catalogs, with which we intend to replenish our system, we should note a sample of edge-on galaxies found in the deep fields of the Hubble telescope [19]. Comparison of the properties of galaxies in the Local Universe and the galaxies at $z \sim 1$ is extremely important for understanding the evolution and morphological transformation of galaxies. In addition, we plan to add a variety of the data published in the literature.

We are sure that the presented database for the study of edge-on galaxies will contribute to obtaining new astrophysical results.

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We confirm that we used the HyperLeda database\footnote{http://leda.univ-lyon1.fr} [14]. The project used the Aladin Sky Atlas\footnote{https://aladin.u-strasbg.fr/} developed at CDS [4, 5].

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CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this paper.

APPENDIX A: RFGC STRUCTURE

The catalog is presented as a table, following the structure of the RFGC catalog described in the original paper by Karachentsev et al. [8]:

\footnote{14 https://users.obs.carnegiescience.edu/peng/work/galfit/galfit.html} \footnote{15 http://leda.univ-lyon1.fr} \footnote{16 https://aladin.u-strasbg.fr/}
**rfgc**—the galaxy identifier from RFGC catalog in the range from RFGC 0001 to RFGC 4236;

**fgc**—the name of the galaxy from the catalog FGC [9] (FGC 0001–FGC 2573). The southern extension of the catalog contains identifiers from FGCE 0001 to FGCE 1882;

**ra, dec**—the right ascension and declination of the galaxy in degrees for the epoch J2000.0. The coordinates have been refined with the HyperLeda database [14];

**pa**—the positional angle of the major axis of the galaxy in degrees measured from north to east;

**aO, bO**—the “blue” diameters of the major and minor axes of the galaxy in arc minutes in the POSS-I size system;

**aE, bE**—the “red” diameters of the major and minor axes of the galaxy in arc minutes in the POSS-I size system;

**type**—the morphological galaxy type of a galaxy according to the Hubble classification;

**As**—the asymmetry index (0—a symmetrical galaxy, 2—the pronounced asymmetry);

**sb**—the average surface brightness index (1—high, 4—very low);

**Btot**—the total apparent $B$ magnitude calculated based on the sizes, morphological type, and surface brightness type as described in the RFGC catalog;

**nsat**—the number of significant satellites (see description in the original RFGC catalog);

**notes**—the notes on galaxies;

**pgc**—the PGC galaxy number from the HyperLeda database [14].

**APPENDIX B: EGIS STRUCTURE**

The catalog is generated based on the latest versions of Tables 4 and 6 from the paper by Bizyaev et al. [2]. The original tables give photometry of galaxies performed in two different ways. They have been converted into three database tables to eliminate redundancy.

This table contains a list of “true” edge-on galaxies [2]:

**eon**—the unique galaxy identifier from the original paper;

**ra, dec**—the right ascension and declination of a galaxy in degrees for the epoch J2000.0;

**altname**—the name of the galaxy in other catalogs;

**type**—the morphological type of a galaxy: Sa, Sb, Sc, Sd, or Ir;

**rv**—the heliocentric radial velocity in km s$^{-1}$ according to HyperLeda as listed in the original catalog [2].

[17] http://users.apo.nmsu.edu/~dmbiz/EGIS/
The photometry table from the one-dimensional analysis of the brightness profiles of edge-on galaxies:

\[ \text{eon} \]— the unique identifier associated with the \texttt{egis} Table;

\[ \text{band} \]— the SDSS filter (\texttt{gri});

\[ \text{pa} \]— the position angle of the galaxy;

\[ h, e_h \]— the radial exponential scale of the galaxy disk in arc seconds and its error;

\[ z0, e_{z0} \]— the vertical sech\(^2\) scale of the galaxy disk in arc seconds and its error;

\[ sb0, e_{sb0} \]— the central surface brightness of a galaxy modified to the face-on position, in \(\text{mag arcsec}^{-2}\) and its error;

\[ \text{grad}_z z0 \]— the gradient of the vertical scale of the disk \(z0\) normalized to the ratio of the scales: \(\frac{dz0}{dr} \frac{h}{z0}\);

\[ \text{mag} \]— the total aperture magnitude inside the bounding ellipse corrected for extinction in our Galaxy according to [20];

\[ B/T \]— the ratio of the bulge brightness to the total luminosity of a galaxy;

\[ \text{fits} \]— the indicator to the FITS file in the local archive;

\[ \text{ima} \]— the indicator to the galaxy image in the given filter for visualization using the web interface.

The photometry table from the analysis of the brightness distribution of galaxies in the SDSS image in the \(r\) filter (3D-Analysis):

\[ \text{eon} \]— the unique identifier associated with the \texttt{egis} Table;

\[ \text{band} \]— the SDSS filter. Should always be equal to (\(r\));

\[ h \]— the radial exponential scale of the galaxy disk in arc seconds;

\[ z0 \]— the vertical sech\(^2\) scale of the galaxy disk in arc seconds;

\[ sb0 \]— the central surface brightness of the galaxy modified to the face-on position, in \(\text{mag arcsec}^{-2}\).

**APPENDIX C: 2MFGC STRUCTURE**

\[ \text{id} \]— the 2MFGC identifier of a galaxy (2MFGC00001–2MFGC18020);

\[ \text{pgc} \]— the PGC galaxy number from the Hyper-Leda database [14];

\[ ra, dec \]— the right ascension and declination of a galaxy in degrees for the epoch J2000.0;

\[ r \]— the elliptical Kron radius in the 2MASS filter \(K_s\). This aperture was used for photometry in all three 2MASS filters.;

\[ Jmag \]— the Kron magnitude in the \(J\) filter of the 2MASS survey;
$H_{mag}$—the Kron magnitude in the $H$ filter of the 2MASS survey;

$K_{smag}$—the Kron magnitude in the $K_s$ filter of the 2MASS survey;

$b/a$—the axial ratio of a galaxy in the composite $J + H + K_s$ image;

$b/a1$—the axial ratio averaged over individual images in the $J$, $H$, and $K_s$ filters;

$pa$— the positional angle in the composite image measured from north N to east E;

$CI$—the concentration index in the $J$ filter (the ratio of the radii in which $3/4$ and $1/4$ of the galaxy light is concentrated).

**APPENDIX D: STRUCTURE OF TABLES OF CANDIDATES FROM THE PAN-STARRS SURVEY**

*ps1candidate*

The table gives information about edge-on galaxy candidates found in the Pan-STARRS survey. It contains the identifier of the object; its coordinates; photometric parameters obtained during primary selection, and indicators to files in the local archive.

*projcell, subcell, candidate*—this three-digit combination is used as the unique identifier of objects and is determined by the specific character of the image archive organization in the Pan-STARRS survey. The pair of numbers *projcell* and *subcell* indicates the projection number in the sky and the cell number in the given division, respectively. The candidate number—*candidate*—found in this image by our search algorithm for edge-on galaxies;

$ra$, $dec$—the right ascension and declination of the candidate in degrees for the J2000.0 epoch;

$sma_r$—the major semi-axis corresponding to the characteristic width of the Gaussian inscribed in the two-dimensional distribution of light from a galaxy in the $r$-filtered image;

$ell_r$—the ellipticity, $1 - b/a$, of the corresponding Gaussian;

$pa_r$—the corresponding positional angle in the image;

$mag_r$—the estimation of the total apparent magnitude of the object;

$fits_g$, $fits_r$, $fits_i$—the indicators to FITS files in the local image archive for each of the three filters;

$image$, $contour$—the color image and image with the marked outline of the candidate selection, respectively, for the convenience of viewing candidates.

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18 [https://outerspace.stsci.edu/display/PANSTARRS/PS1+Sky+tessellation+patterns](https://outerspace.stsci.edu/display/PANSTARRS/PS1+Sky+tessellation+patterns)
This table gives information on candidate classification obtained in five different artificial neural network models trained to classify edge-on galaxies:

- **projcell, subcell, candidate**—the unique identifier of the object associated with the **psicandidate** Table;
- **n**—the number of a model used to classify a candidate;
- **vote**—the index of conformity to edge-on galaxies obtained within the framework of the corresponding model: 0—does not match, 1—classified as an edge-on galaxy.

This table gives information about the visual classification of candidates by the project participants. The classification process was divided into several stages, thus, the same object could be classified by the same person several times.

- **projcell, subcell, candidate**—the unique identifier of the object associated with the **psicandidate** Table;
- **userid**—the identifier of the user who performed the classification;
- **date**—the classification time;
- **workflow**—the indicator of the stage, during which the identification was carried out;
- **class**—the actual classification performed by this user during the current stage. Possible values are: **good**—a galaxy is almost edge-on; **acceptable**—a galaxy is seen at a high angle to the line of sight; **unsuitable**—an object is not an edge-on galaxy; **wrong**—a candidate is not a galaxy (a defect in the image or a combination of stars);
- **use**—the flag of using this classification in statistics (**true** or **false**).

The table presents the photometry of galaxies performed by the SExtractor\(^\text{19}\) code with the images from the Pan-STARRS survey in five filters:

- **projcell, subcell, candidate**—the unique identifier of the object associated with the **psicandidate** Table;
- **band**—the Pan-STARRS1 filter (\(g, r, i, z,\) and \(y\));
- **ra, dec**—the right ascension and declination of a candidate in degrees for the epoch J2000.0;
- **xima, yima**—the coordinates of the barycenter of an object in the image (the parameters \(X\_IMAGE, Y\_IMAGE\) in SExtractor);
- **aima, bima, paima**—the major and minor semi-axes and the positional angle of the ellipse describing the given object in the

\(^{19}\) [https://sextractor.readthedocs.io/]
image (the parameters A_IMAGE, B_IMAGE, THETA_IMAGE in SExtractor);

a, e_a—the semi-major axis of an object in the sky and its error in arc seconds (the parameters A_IMAGE, ERRA_IMAGE);

b, e_b—the minor semi-axis of an object in the sky and its error in arc seconds (the parameters B_IMAGE, ERRB_IMAGE);

pa—the position angle of an object measured from the north to east (the parameter THETA_J2000);

eell—the ellipticity of the object 1 − b/a (the parameter ELLIPTICITY);

radkron—the Kron pseudo-radius (the parameter KRON_RADIUS);

fluxauto, e_fluxauto—the flux after the background subtraction and its error inside the Kron ellipse (the parameters FLUX_AUTO, FLUXERR_AUTO);

magauto, e_magauto—the magnitude and its error inside the Kron ellipse (the parameters MAG_AUTO, MAGERR_AUTO);

radpetro—the Petrosian pseudo-radius (the parameter PETRO_RADIUS);

fluxpetro, e_fluxpetro—the flux after the background subtraction and its error inside the the Petrosian ellipse (the parameters FLUX_PETRO, FLUXERR_PETRO);

magpetro, e_magpetro—the magnitude and its error inside the Petrosian ellipse (the parameters MAG_PETRO, MAGERR_PETRO);

badpixfraction—the fraction of “bad” pixels inside the Petrosian ellipse describing a galaxy;

quality—the photometry quality obtained on the basis of statistics of deviations of the ellipse parameters from the median values;

fits—the indicator of the file name in the local archive.

The table of cross-identification of candidates with galaxies from the HyperLeda\textsuperscript{20} database [14]:

| projcell, subcell, candidate | projcell, subcell, candidate | projcell, subcell, candidate | projcell, subcell, candidate |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| ra, dec                     | ra, dec                     | ra, dec                     | ra, dec                     |
| pgc                         | pgc                         | pgc                         | pgc                         |
| flag                        | flag                        | flag                        | flag                        |
| userid                      | userid                      | userid                      | userid                      |
| ctime                       | ctime                       | ctime                       | ctime                       |

http://leda.univ-lyon1.fr/
Various notes made during the work with candidates:

projcell, subcell, candidate—the unique identifier of an object associated with the psicandidate Table;

userid—the user who made a note;

ctime—the time of making a note;

note—the note itself.

APPENDIX E: STRUCTURE OF TABLES USED IN THE CLASSIFICATION SYSTEM

user

id—the unique login of a user;

name—the full username.

quiz

id—the unique identifier of the questionnaire;

title—the short description;

tbl—the name of the table with objects to classify;

retired—the maximum number of classifications of an object by different users.

quiz_question

id—the unique number of a question;

quizid—the indicator of the questionnaire in the quiz Table;

value—the assigned value of a characteristic;

description—the short description of a question;

bunch—the number of the question group;

input—determines the way of classification:

radio—selection of one value from the set

checkbox—the presence or absence of this characteristic.

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