# Structural Analysis of Arend-Roland Long-Period Comet Based on Histogram Modeling

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The problem of structural analysis of the long-period comet Arend-Roland is considered based on histogram modeling. As a result of the research, dynamic characteristics associated with the emission of matter from the cometary nucleus were determined, and the parameters of the tail of the celestial body scattered in space were obtained.

**Keywords:** long-period comets, histogram modeling, structural analysis.

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Study of long-period comets passing through the near-solar space provides unique astrophysical information about the external disk of the Solar System where they were formed [1]. Such objects are the remnants of protoplanetary disk planetesimals [2]. When moving inside the Solar System, they get exposed to solar wind turbulence giving rise to coma in a form of plasmoids, which changes their density structure [3]. Cometary dust trails also have banded elements whose configurations also need to be investigated [4] because they include a wide range of structures caused by the solar wind effect [5]. The protoplanetary disk contains water from a star-producing cloud. Accordingly, this water enters large icy comet-like objects unchanged [6]. Thus, together with meteorites and interplanetary dust, comets serve as original organic matter reservoirs [7]. Also, note that the shape of comet nuclei reflects the versatility of structural artefacts such as cracks, boulders and terraces that interact with the nucleus matter dynamics and comet activity in a complicated way [8]. Most of the above-mentioned effects may be studied by means of histogram modeling (HM) of brightness characteristics. Structural description of large galaxies [9–12] may be given as an example.

Digital library of Engelgardt Astronomical Observatory (EAO) contains more than 2150 digitized asteroid and comet images. Study of these celestial bodies using modern approaches provides new dynamic, evolution and structural characteristics of the bodies. For details of astronomic images at EAO, see [13].

Histograms in this study were built from comparison of averaged pixel brightness of a chosen area with the brightness of each individual pixel. Mathematical calculations of brightness and contrast dispersion and mathematical expectation were used as extension of histogram brightness and contrast modeling.

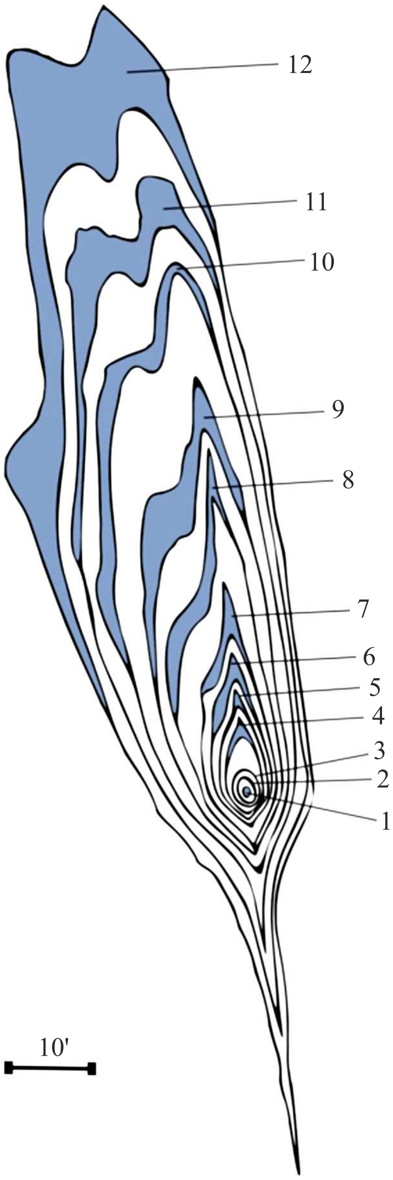
Histograms were built in this work using the Sabattier effect software simulation. For this, image negative and positive were compared to identify areas on the image with the brightness density $D$. By varying the brightness $L$ using a software algorithm, lighter or darker areas were identified on the image. As a result, the histogram system will represent all image areas with different values of $D$. The higher the value of $L$ is, the darker areas are identified. The higher the contrast is, the more accurate photographic density will be identified with this value of $L$. After capture of a combined image, a filter was used to achieve the Solarize effect. Finally, a model with highlighted histograms was formed. Then, Maxlm DL software package [14] was used to find relative star magnitudes for different histograms and a measurement error was estimated by the signal-to-noise ratio.

The histogram modeling method technically included the following comet structuring stages:

1) object image was reviewed and image brightness gradients were obtained in a digital form using computer-aided equipment;

2) a proprietary simulation software package was used to determine histograms with the same brightness density and pre-defined boundaries. For this, software overlapping of negative and positive images is used to determine areas with uniform brightness density distribution. As the analysis involves all light channels, addition and subtraction of negatives and positives allow accurate identification of histogram areas;

3) Maxlm DL was used to determine star magnitudes of histogram areas with respect to effective illumination (without noise) and to account for noise continuum. As a result, a histogram accuracy equal to 0.09 star magnitudes was achieved successfully.




Comet Arend-Roland structure Histograms differ from each other by 0.03 of star magnitude and have a density difference of 0.02. Numbers from 1 to 12 denote the obtained histograms, 10′ corresponds to a scale of ten arc minutes on the celestial sphere.

Thus, a structural model of long-period Comet Arend-Roland (LCAR) was built and qualitative analysis was performed. The figure shows brightness histograms of the comet. It was found that a histogram area with number *1* was a comet nucleus followed by its coma and tail. Ring-shaped structures are observed in zones close to the nucleus and then to the outside elongations towards the tail occur and histogram areas become wider. It is also shown that there is a vast ejection of matter from the comet nucleus, and LCAR has a very space-scattered tail. The model has quite thin and closely-spaced histogram areas depending on the brightness gradients, and the difference is 0.02 of the star magnitude on average. The same value characterizes the model accuracy. Difference between histogram *12* and the brightness of the celestial sphere around the comet is about 0.01 of the star magnitude.

Note that the created histogram model has a more definite structure than other similar structural configurations [15]. As can be seen (see the figure), the hypsometric model of the studied comet has a significant narrow ejection from its nucleus towards the Sun unlike the comet tail. The force of this process is such that even the sun radiation pressure doesn't slow it down at a distance equal to several million kilometers from the comet. As the comet was observed close to the comet orbit perihelion, such anomalous ejection can be explained by the fact that the thermal wave achieved highly volatile components in subsurface dust crust layers and these components evaporate. Gas in the ejection jet is heated causing very high ejection velocity of the comet dust component. Method used in this work may be used for structural activity analysis of cometary and other celestial objects. Particular focus is made on long-period comets because they generally can be studied only during single passage of the perihelion as, for example, in the LCAR case. Further utilization of the obtained results is also possible in the field of lunar explorations [16], examination of the internal structures of celestial bodies [17] and meteor shower analysis [18].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## Conflict of interest

The authors declare no conflict of interest.

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