STARFORMATION IN ORION NEBULAE: PROPLYDS

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We have constructed for the first time the surface-brightness distributions arund 11 bright protostellar objects at three wavelengths. Our results indicate appreciable inhomogeneity in the distribution of the radiating matter around these proplyds. The brightness distributions along the minor and major axes have asymmetrical, bell-like shapes.
The lengths of the tails of proplyds located within 16"of the star $\theta 1$ Ori C depend on the distance to the ionizing star. Proplyds located closer to the star have shorter tails.
The distributions of matter in the protostellar disks differ substantially: The brightness distributions along the minor diameter can be best fitted using a cubic polynomial, while the brightness distributions along the major diameter are better fitted with a power law with index $\alpha < 0$.
No wavelength dependence for the dimensions of the protostellar disks was found. The sizes of different objects in the violet, red, and IR can remain the same, increase, or decrease with wavelength. This is probably related to the physical and evolutionary states of individual objects. The mean absolute luminosities determined from the bright, crescent-shaped regions in the sources studied differ little from the solar luminosity.

Keywords: Pre-Main Sequence stars–circumstellar structure–protostars–proplids.

1. INTRODUCTION

An important task in modern astrophysics is studying the formation of planets and protoplanetary disks. Main key for this task are studies of the characteristics of stars and protostellar formations, as well as the structure of protostellar disks in the region of the Orion Nebula. We used direct images of the vicinity of θ^1 Ori C taken from the Hubble Space Telescope MAST archive as observational

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material for this study. These observations were obtained on January 21, 2004 with the HST using the WFPC1 camera, with an angular resolution of 0.049". Five different narrow-band filters were used. We selected the brightest proplyds located near θ^1 Ori C. We used data from [1]and [2] to find the distance of the proplyds from θ^1 Ori C, which are consistent with the distances to the Orion Nebula with in the uncertainties. At the distance to the Orion Nebula, equal to 420 pc [3], this corresponds to a linear resolution of 21 AU, sufficient to enable studies of the structures of circumstellar disks around young stellar objects in this region. All the objects we chose are located no more than 16" from θ^1 Ori C. The data were reduced using the MIDAS software operating in a Linux Ubuntu environment. Our reduction was guided by standard surface-photometry methods [4]. When constructing the surface-intensity distributions of the proplyds, we chose a direction along which we constructed a photometric cross section. This enables estimation of the intensity from the minimum to the maximum along a photometric cut across the object. After setting reference points along the chosen direction, we obtained a table of data for the intensity distribution in equatorial coordinates (α, δ).The maximum and minimum intensities for a given image were identified in this table, and used to establish the step for the contours used to depict the intensity distribution in the region of the image. Further, we created images with intensity contours in the (α, δ) plane. The subsequent reduction was carried out using these images in the Ds9 package. Fig.1 shows the contours for the three proplyds 163–317, 158–326, and 176–325 and the scheme for measuring distances in the images.

The minimum and maximum intensity and contour step are indicated for each filter. The straight line segments in Fig.1 indicate the directions of the x and y axes, conducted along the major and minor axes of an ellipse. A comparison showed that it was possible to distinguish the intensity distributions obtained mainly in three filters–FR388N, FR656N, and FR914M. Therefore, we used data obtained in these three filters in our subsequent analysis.Fig.1 shows that the structures of the objects are appreciably different in different filters.

Table1 presents our measurements of the cross sectional diameters of each proplyd in the three filters.This is a fundamental parameter of a proplyd. We determined the diameters with in one to two pixels, so that, with a resolution of $0.045''/pixel$, the maximum uncertainty is about 50 AU.Table 6 shows that, for most of the objects, the maximum diameters of the indicated cross sections substantially exceed the instrumental profile. The largest sizes were obtained for 158–327, especially in the red and IR. Table 1 also presents the ratios of the major axes D_y to the minor axes D_x. The bottom row of Table 1 presents the mean val-

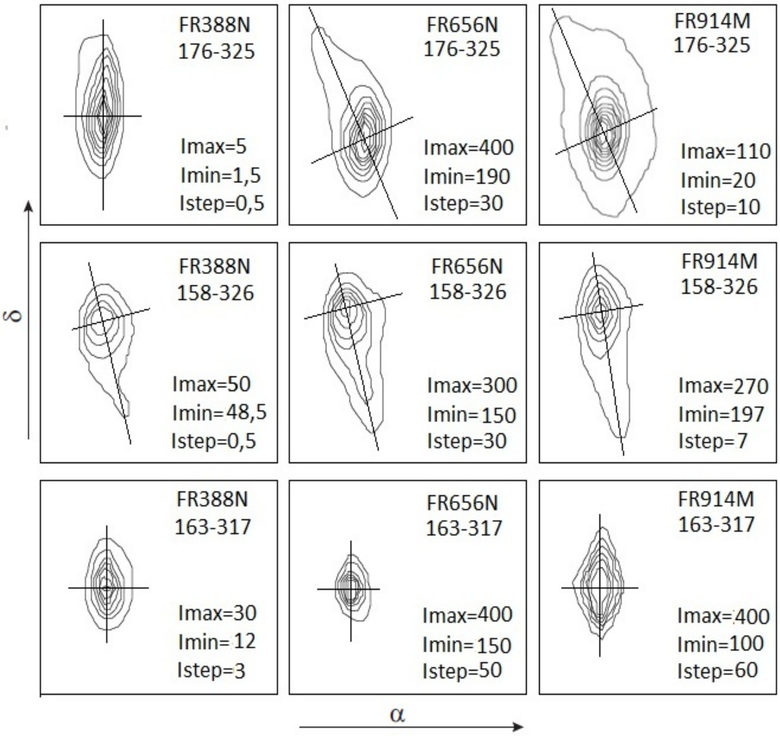

Fig. 1. Examples of contours of the three objects for 3 various bands

ues of the measured sizes and the irratios for all the objects. These values indicate the characteristic sizes of circumstellar disks in early stages of their formation.

We tested for correlations between the ratio D_y/D_x and the angular distance from the irradiating star θ^1 Ori C. The correlation coefficients for the FR388N, FR565N, and FR914M filters are 0.716 ± 0.232, 0.473 ± 0.258, and 0.729 ±0.156, respectively. The confidence levels of the obtained correlation coefficients are no lower than 95%. Proplyds located less than 16" from θ^1 Ori C display significant correlations between D_y/D_x and the angular separation from the star. The dependence of the length of the tail on this distance could be the result of photovaporization, which increases with decreasing distance from the exciting star. This apparently exerts a disruptive influence on the circumstellar disks of the proplyds and enhances the dissipation rate. We also tested for correlations between the individual parameters D_y and D_x. The correlation coefficients between D_y and D_x are 0.564 ± 0.227, 0.742 ± 0.15, and 0.881 ± 0.074, respectively, for the FR388N, FR565N, and FR914M filters. This correlation is weaker in the violet than in the red and IR, suggesting that the disk structures of the proplyds are less clearly expressed in the violet. The existence of linear dependences between the

Table 1. Maximum sizes of the proplyds in the x and y directions

Filters	FR388N			FR656N			FR914M		
Object	Dx(AU)	Dy(AU)	Dy/Dx	Dx(AU)	Dy(AU)	Dy/Dx	Dx(AU)	Dy(AU)	Dy/Dx
157-323	164	217	1.32	107	161	1.50	143	254	1.78
158-323	156	217	1.39	157	258	1.64	181	261	1.44
158-326	140	336	2.40	164	406	2.48	125	234	1.87
158-327	201	476	2.37	251	719	2.86	314	718	2.29
161-324	167	208	1.25	171	459	2.68	80	147	1.84
163-317	168	297	1.77	121	167	1.38	176	215	1.22
166-316	108	144	1.33	94	117	1.24	77	127	1.65
167-317	184	226	1.23	233	343	1.47	132	188	1.42
168-328	75	113	1.51	90	132	1.47	128	173	1.35
168-326	237	230	0.97	252	230	0.91	279	226	0.81
176-325	73	192	2.63	98	253	2.58	150	347	2.31
@@@	151.5	242.1	1.66	156	297.0	1.86	157.5	267.5	1.67

diameters D_y and D_x may testify that the observed disk sizes are proportional to the amount of mass in the central object. No wavelength dependence of the sizes of the protostellar disks was detected.
So, we have received the following results:

1. The lengths of the tails of proplyds located within 16" of the star θ^1 Ori C depend on the distance to the ionizing star. Proplyds located closer to the star have shorter tails.

2. The distributions of matter in the protostellar disks differ substantially: the brightness distributions along the minor diameter can be best fitted using a cubic polynomial, while the brightness distributions along the major diameter are better fitted with a power law with index $\alpha < 0$.

3. No wavelength dependence for the dimensions of the protostellar disks was found. The sizes of different objects in the violet, red, and IR can remain the same, increase, or decrease with wavelength. This is probably related to the physical and evolutionary states of individual objects.

4. The mean absolute luminosities determined from the bright, crescent-shaped regions in the sources studied differ little from the solar luminosity.

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