

AN ATLAS OF STATIONARY BOW SHOCK ARCS IN THE ORION NEBULA

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Resumen

We present a complete catalog of all the stationary emission line arcs (LL objects and proplyd bowshocks) found in archival HST imaging of the Orion Nebula. The total number of objects detected is 73, of which 20 have not previously been reported in the literature. We classify the shapes of emission line arcs by fitting conic sections to the inner and outer shell boundaries and calculate the background corrected H alpha surface brightness of each object. We find significant differences in the shell shapes between the objects closest to the ionizing stars and those farther away. The closer group, which all represent proplyd interactions with the hypersonic stellar wind, have relatively closed shapes, while the farther group, which are due to interactions with the transonic ionized champagne flow in the nebula, are more open and hyperbolic. Although some of the latter group are also known proplyds, many are not, and the largest and brightest arcs tend to be associated with particularly luminous young stars, suggesting that the intrinsic T Tauri disk wind may play a role. The orientations of the arcs, together with the stagnation pressures estimated from the surface brightness, allow the internal velocity field of the H II region to be probed. We find that approximately radial flows from the core of the nebula dominate over disordered, turbulent flows.

1. INTRODUCTION

2. OBSERVATIONS

3. CATALOG

3.1. *LV knot group*

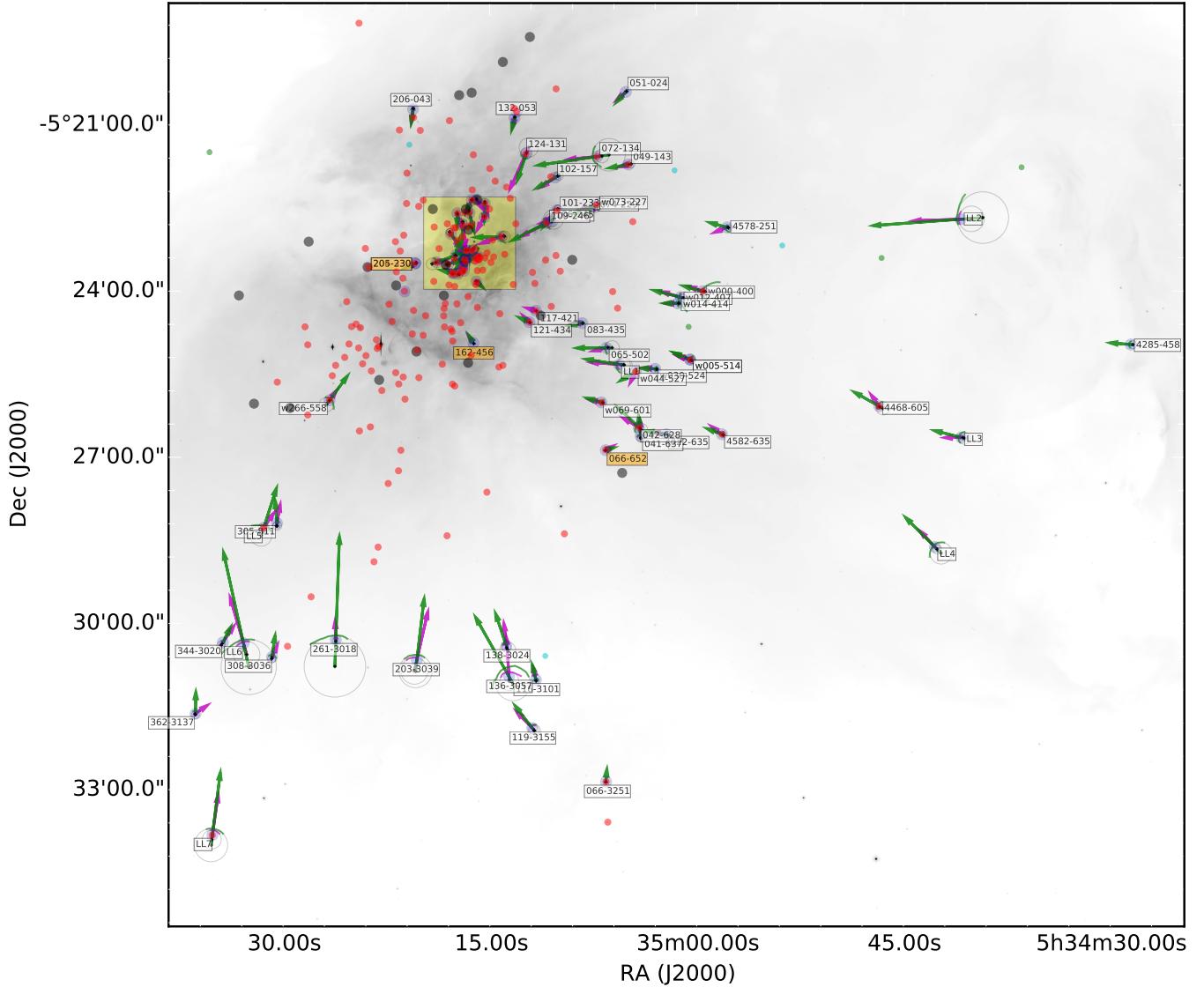


FIG. 1.—Position of bow shock arcs.

TABLE 1
SHELL GEOMETRIC PARAMETERS OF LV KNOTS

Object	RA	Dec	D	PA	R_{out}	R_{in}	$R_{c,\text{out}}$	$R_{c,\text{in}}$	h	PA_{out}	PA_{in}
158-323	05:35:15.83	-05:23:22.5	8.34	90.1	1.85	1.64	2.92	2.35	0.21	114.8	120.0
161-324	05:35:16.06	-05:23:24.3	5.29	70.1	1.16	0.90	3.01	2.03	0.26	70.7	76.6
163-317	05:35:16.28	-05:23:16.6	6.11	164.8	2.32	1.93	4.90	4.44	0.40	148.6	145.5
166-316	05:35:16.61	-05:23:16.2	7.15	207.0	0.69	0.41	1.19	0.85	0.28	181.4	160.5
167-317	05:35:16.74	-05:23:16.5	7.97	220.9	1.96	1.25	3.29	2.05	0.71	178.1	165.4
168-328	05:35:16.76	-05:23:28.1	7.79	315.2	1.06	0.79	1.31	0.80	0.27	345.3	353.0
168-326	05:35:16.84	-05:23:26.3	7.71	299.5	0.95	0.74	3.04	3.01	0.20	314.5	328.1

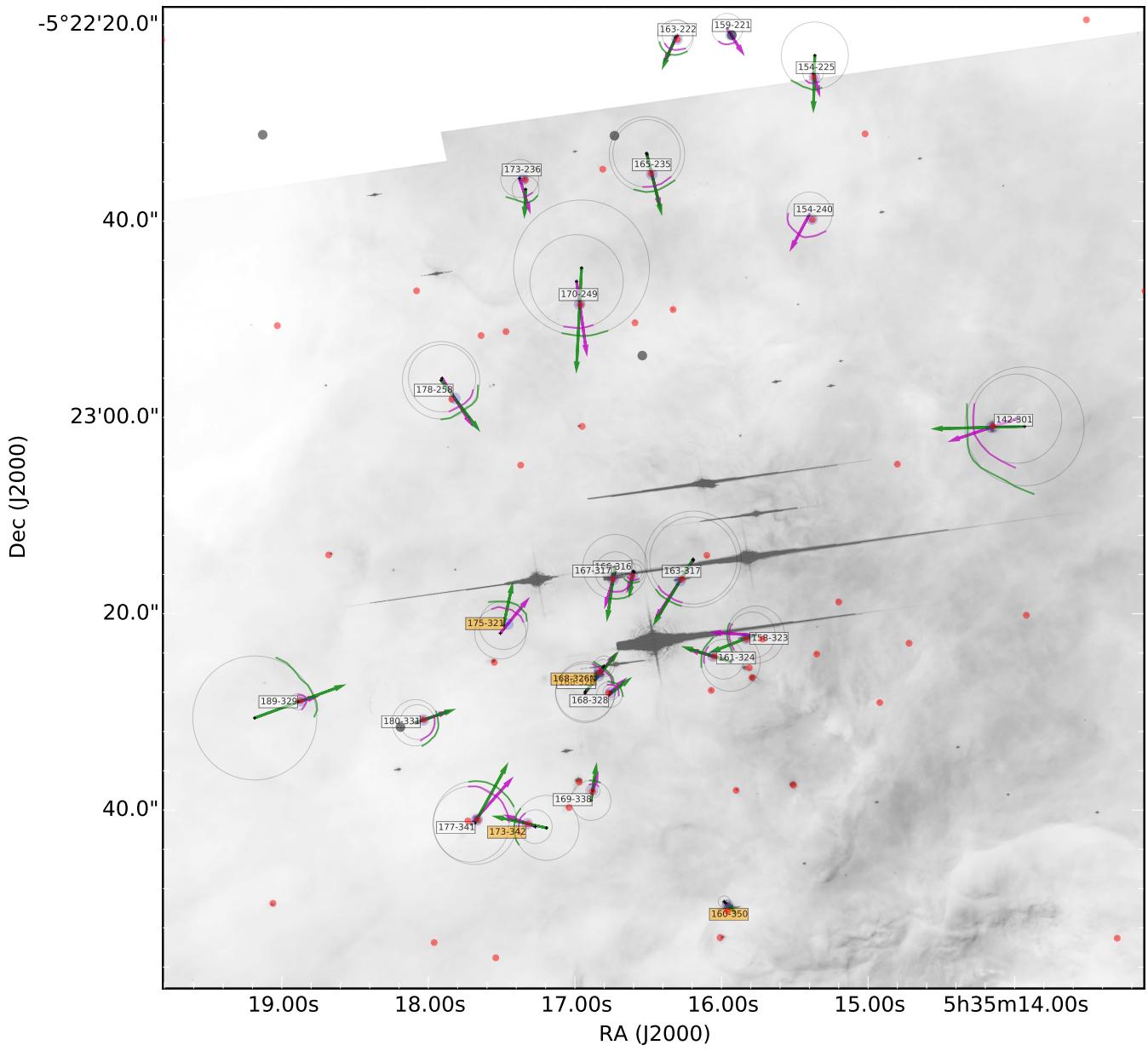


FIG. 2.— Position of bow shock arcs. Zoomed area.

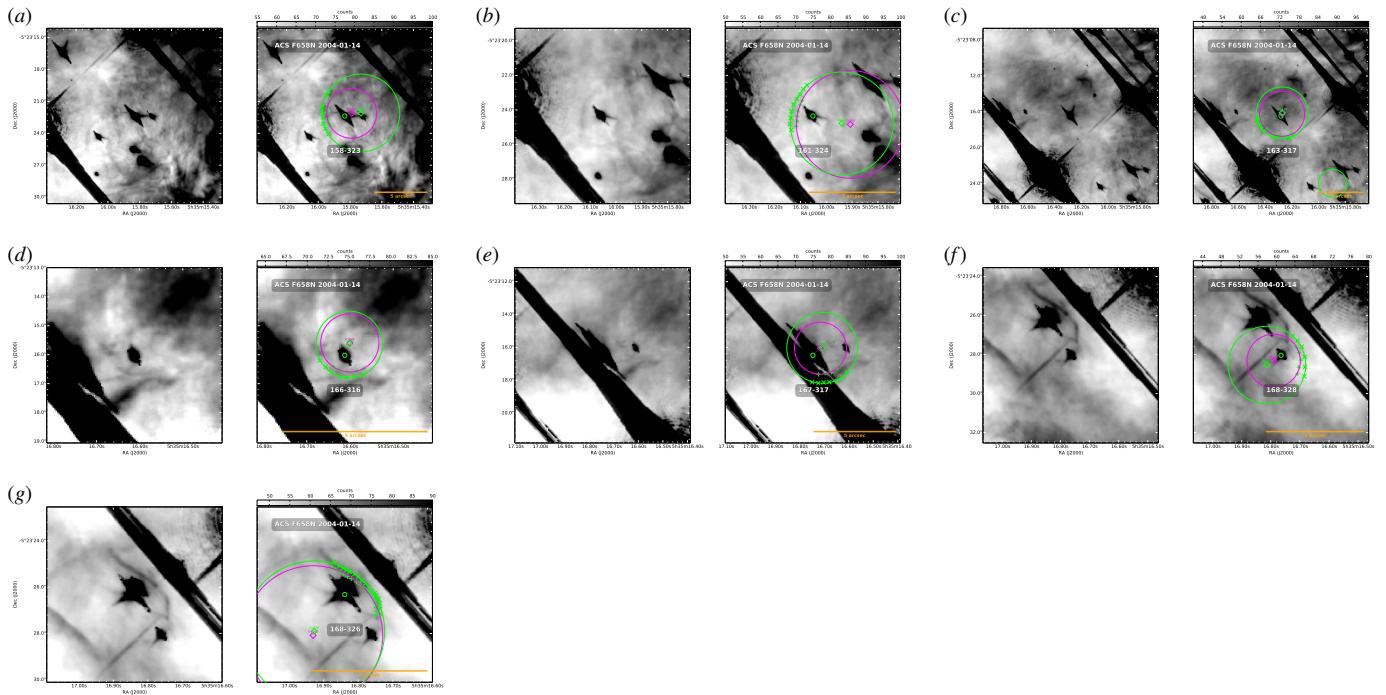


FIG. 3.—Stationary arc sources in the LV knots group.

3.2. *Southeast group*

TABLE 2
SHELL GEOMETRIC PARAMETERS OF SOUTHEAST GROUP

Object	RA	Dec	<i>D</i>	PA	<i>R</i> _{out}	<i>R</i> _{in}	<i>R</i> _{c,out}	<i>R</i> _{c,in}	<i>h</i>	<i>PA</i> _{out}	<i>PA</i> _{in}
169-338	05:35:16.88	-05:23:38.0	17.14	334.7	1.03	0.68	2.04	0.72	0.35	345.9	6.4
177-341	05:35:17.67	-05:23:41.0	26.54	314.0	3.81	3.06	4.25	3.87	0.75	317.0	293.7
180-331	05:35:18.03	-05:23:30.8	25.91	288.7	1.44	1.11	2.36	1.77	0.33	280.8	282.0
189-329	05:35:18.87	-05:23:28.9	37.56	279.7	1.40	0.54	6.32	0.83	0.86	296.4	264.0
204-330	05:35:20.40	-05:23:30.0	60.39	277.1	0.33	0.11	1.34	1.28	0.22	112.4	119.0

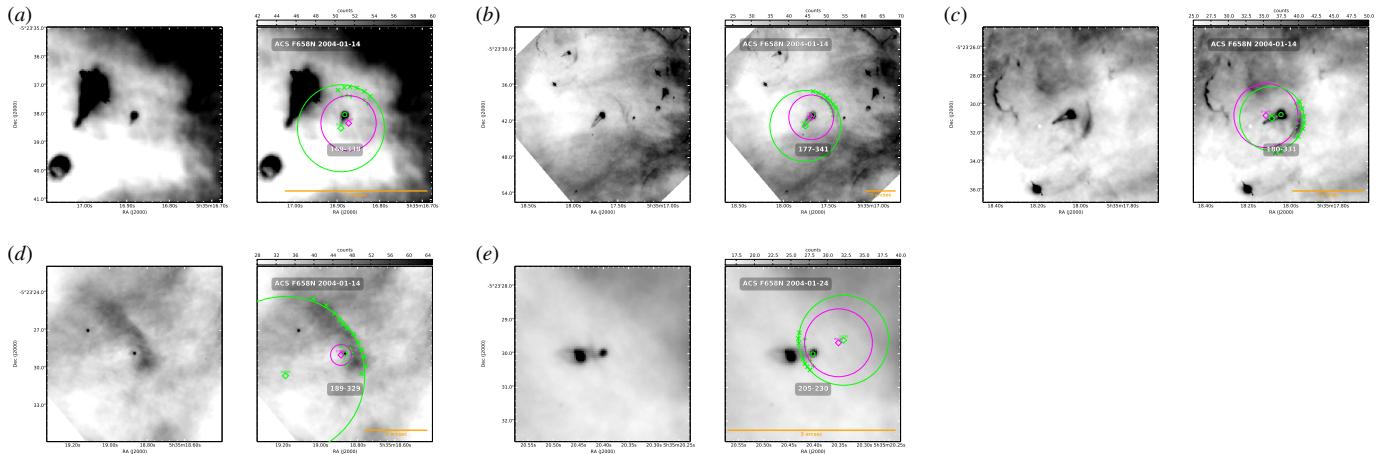


FIG. 4.—Stationary arc sources in the Southeast group.

3.3. *North group*

TABLE 3
SHELL GEOMETRIC PARAMETERS OF NORTH GROUP

Object	RA	Dec	D	PA	R_{out}	R_{in}	$R_{\text{c,out}}$	$R_{\text{c,in}}$	h	PA_{out}	PA_{in}
142-301	05:35:14.16	-05:23:01.0	39.67	122.9	2.42	1.82	6.06	4.55	0.60	91.5	98.6
154-225	05:35:15.37	-05:22:25.3	59.22	165.1	1.29	0.64	3.42	1.05	0.58	158.0	193.1
154-240	05:35:15.38	-05:22:39.8	45.30	160.6	...	1.72	...	2.30	202.3
159-221	05:35:15.93	-05:22:21.0	61.86	173.7	...	0.83	...	1.58	215.4
163-222	05:35:16.30	-05:22:21.5	61.07	178.8	1.54	1.11	1.80	1.55	0.36	198.9	180.1
165-235	05:35:16.48	-05:22:35.2	47.33	181.5	1.78	1.23	3.84	3.44	0.47	197.5	193.2
170-249	05:35:16.97	-05:22:48.4	35.16	194.2	3.23	2.45	6.92	4.75	0.78	173.4	193.3
173-236	05:35:17.35	-05:22:35.7	48.96	197.1	2.28	1.53	1.36	1.94	0.75	255.3	275.5
178-258	05:35:17.82	-05:22:58.1	32.47	221.1	1.48	0.92	3.94	3.43	0.52	218.7	210.3

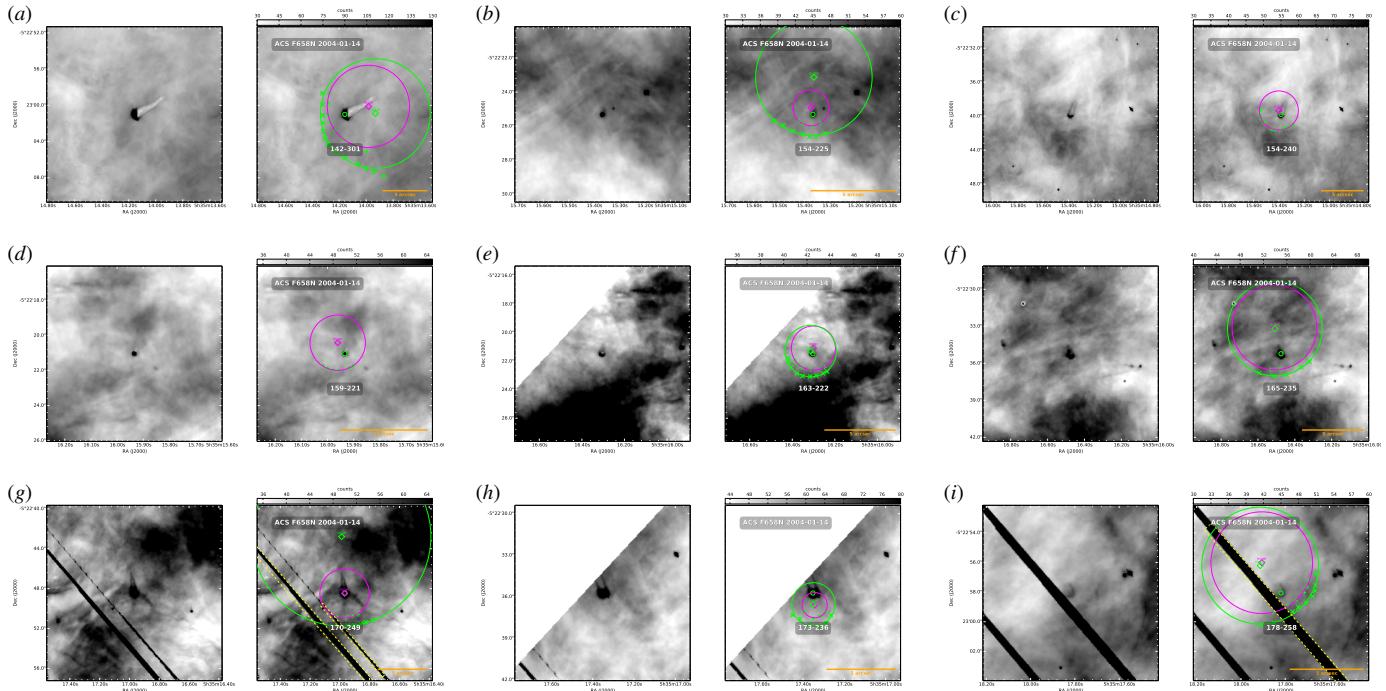


FIG. 5.— Stationary arc sources in the North group group.

3.4. Northwest group

TABLE 4
SHELL GEOMETRIC PARAMETERS OF NORTHWEST GROUP

Object	RA	Dec	<i>D</i>	PA	R_{out}	R_{in}	$R_{\text{c,out}}$	$R_{\text{c,in}}$	h	PA_{out}	PA_{in}
049-143	05:35:04.94	-05:21:42.9	197.82	120.2	1.17	0.62	4.18	0.66	0.56	103.1	139.0
051-024	05:35:05.13	-05:20:24.3	245.01	136.7	1.19	0.90	2.29	1.66	0.27	136.5	123.6
072-134	05:35:07.20	-05:21:34.3	174.74	128.3	4.69	2.26	17.63	7.29	2.42	89.7	94.5
w073-227	05:35:07.27	-05:22:26.5	147.27	112.4	1.63	0.81	6.46	3.98	0.70	117.0	120.5
074-229	05:35:07.38	-05:22:28.9	144.78	111.7	1.36	0.79	1.60	0.75	0.60	120.3	185.7
101-233	05:35:10.13	-05:22:32.6	105.94	118.1	2.46	2.11	4.36	4.21	0.42	131.4	136.6
102-157	05:35:10.25	-05:21:57.1	125.30	133.0	0.80	0.40	5.03	3.54	0.45	118.5	116.6
106-245	05:35:10.58	-05:22:44.7	94.70	113.5	0.63	0.23	2.48	1.12	0.38	122.7	99.0
109-246	05:35:10.90	-05:22:46.3	89.68	113.8	1.95	1.32	10.64	7.33	0.70	112.9	119.5
124-131	05:35:12.38	-05:21:31.4	126.20	151.7	4.48	2.74	5.95	10.41	1.73	134.9	156.0
132-053	05:35:13.20	-05:20:52.6	157.31	162.4	0.72	0.32	1.80	0.68	0.39	153.9	167.0
206-043	05:35:20.56	-05:20:43.1	171.16	201.3	1.61	1.12	2.19	2.08	0.44	176.1	182.7

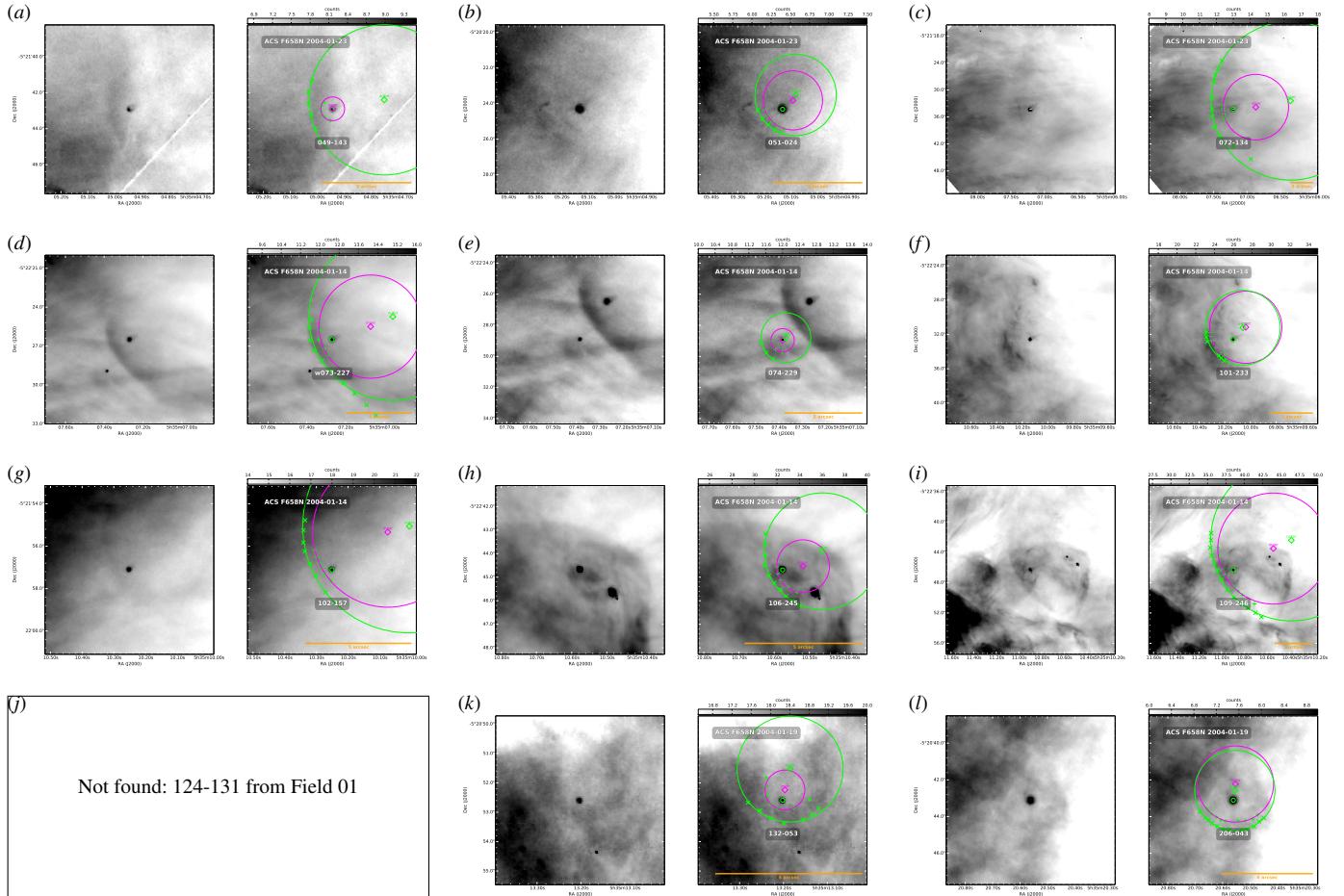


FIG. 6.—Stationary arc sources in the Northwest group.

3.5. Southwest group

TABLE 5
SHELL GEOMETRIC PARAMETERS OF SOUTHWEST GROUP

Object	RA	Dec	<i>D</i>	PA	<i>R</i> _{out}	<i>R</i> _{in}	<i>R</i> _{c,out}	<i>R</i> _{c,in}	<i>h</i>	PA _{out}	PA _{in}
4578-251	05:34:57.79	-05:22:51.1	279.49	96.5	1.85	1.19	3.52	2.07	0.53	81.2	125.0
4582-635	05:34:58.17	-05:26:35.1	333.37	54.7	1.11	0.68	2.93	2.06	0.46	65.7	50.5
w000-400	05:34:59.57	-05:24:00.1	254.03	81.5	1.47	0.80	4.37	2.43	0.68	71.9	73.4
w005-514	05:35:00.47	-05:25:14.3	262.72	64.8	1.65	1.20	3.45	2.03	0.44	64.5	57.9
w005-514	05:35:00.47	-05:25:14.2	262.64	64.8	1.67	1.17	2.24	2.21	0.42	91.0	56.9
w012-407	05:35:01.17	-05:24:06.7	231.47	79.0	2.29	0.95	6.74	4.26	1.23	68.3	69.7
w014-414	05:35:01.37	-05:24:13.4	229.95	77.2	1.21	0.37	2.19	1.61	0.70	98.3	93.2
022-635	05:35:02.20	-05:26:35.3	286.47	47.7	1.10	0.75	4.46	2.29	0.34	83.2	77.5
w030-524	05:35:03.00	-05:25:24.4	234.09	58.6	0.63	0.29	2.56	1.54	0.32	93.8	82.0
041-637	05:35:04.06	-05:26:37.1	267.84	43.4	1.94	1.19	4.39	3.23	0.77	4.2	15.5
042-628	05:35:04.20	-05:26:27.6	259.59	44.5	3.07	1.76	6.90	3.61	1.34	61.6	56.1
w044-527	05:35:04.43	-05:25:27.4	217.94	55.0	2.13	0.78	3.25	1.53	0.85	121.2	267.4
LL1	05:35:05.64	-05:25:19.4	198.63	53.9	3.06	1.90	8.72	7.13	1.13	84.4	78.1
065-502	05:35:06.54	-05:25:01.5	177.29	56.1	1.42	0.49	7.74	2.31	1.21	90.5	104.7
w069-601	05:35:06.91	-05:26:00.6	212.19	41.9	0.85	0.41	2.72	1.77	0.42	86.1	87.1
083-435	05:35:08.29	-05:24:34.9	140.89	59.1	1.25	0.54	2.00	0.66	0.58	84.0	40.5
117-421	05:35:11.65	-05:24:21.4	92.07	50.2	...	0.71	...	0.93	96.7
121-434	05:35:12.12	-05:24:33.8	95.58	41.8	0.76	0.34	1.41	0.69	0.39	65.4	66.2

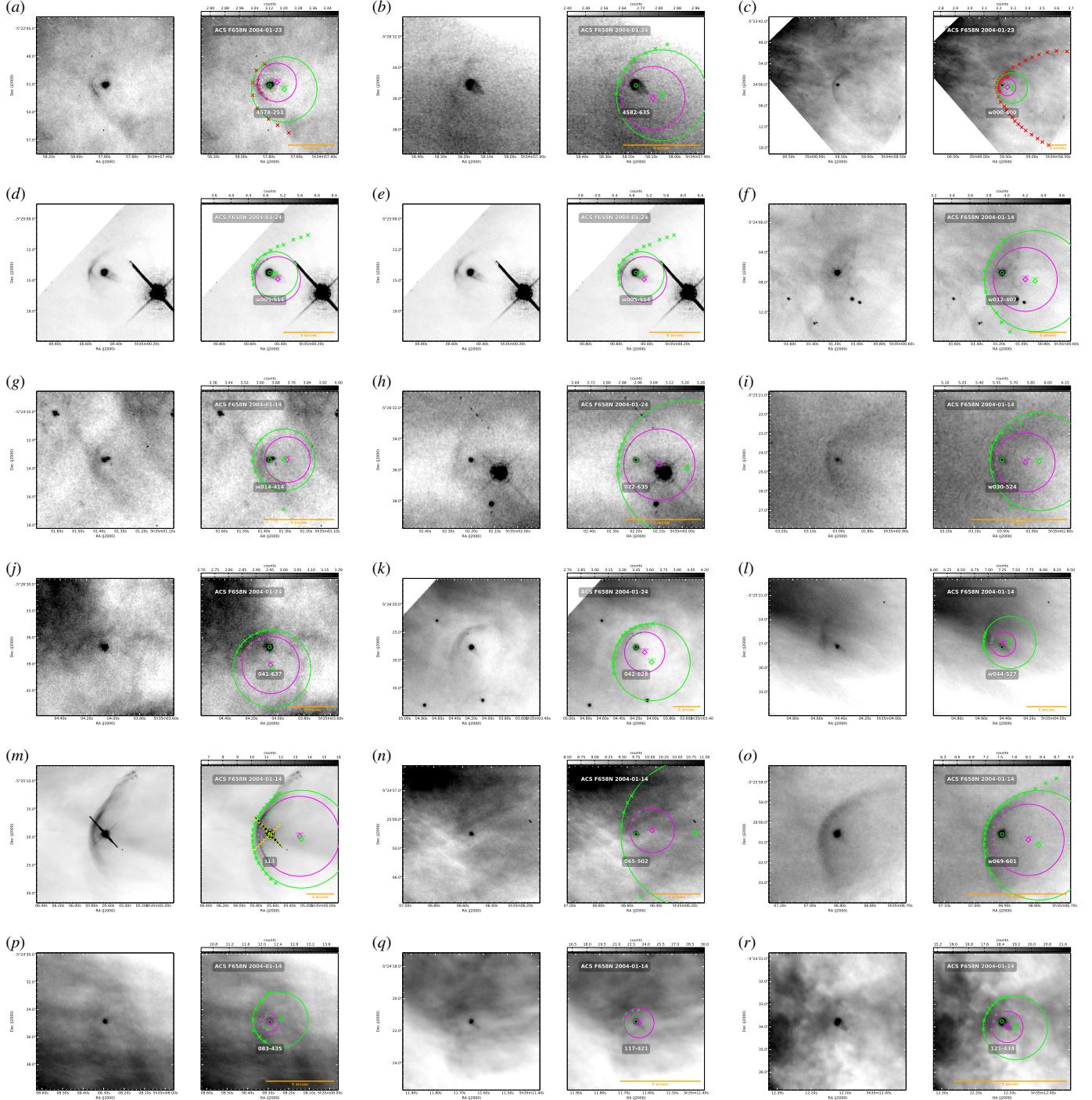


FIG. 7.— Stationary arc sources in the Southwest group group.

3.6. *West group*

TABLE 6
SHELL GEOMETRIC PARAMETERS OF WEST GROUP

Object	RA	Dec	<i>D</i>	PA	<i>R</i> _{out}	<i>R</i> _{in}	<i>R</i> _{c,out}	<i>R</i> _{c,in}	<i>h</i>	<i>PA</i> _{out}	<i>PA</i> _{in}
4285-458	05:34:28.52	-05:24:57.9	721.18	82.4	1.91	...	4.34	87.0	...
LL3	05:34:40.81	-05:26:38.5	566.33	69.8	3.12	1.28	6.54	3.08	1.83	89.2	99.6
LL2	05:34:40.86	-05:22:42.2	532.12	94.3	4.04	2.07	27.93	13.84	1.13	97.6	89.5
LL4	05:34:42.72	-05:28:37.2	593.11	58.0	2.42	1.42	11.79	4.95	0.99	46.7	40.3
4468-605	05:34:46.76	-05:26:04.8	471.30	69.9	2.47	1.33	7.11	2.22	1.20	54.2	59.6

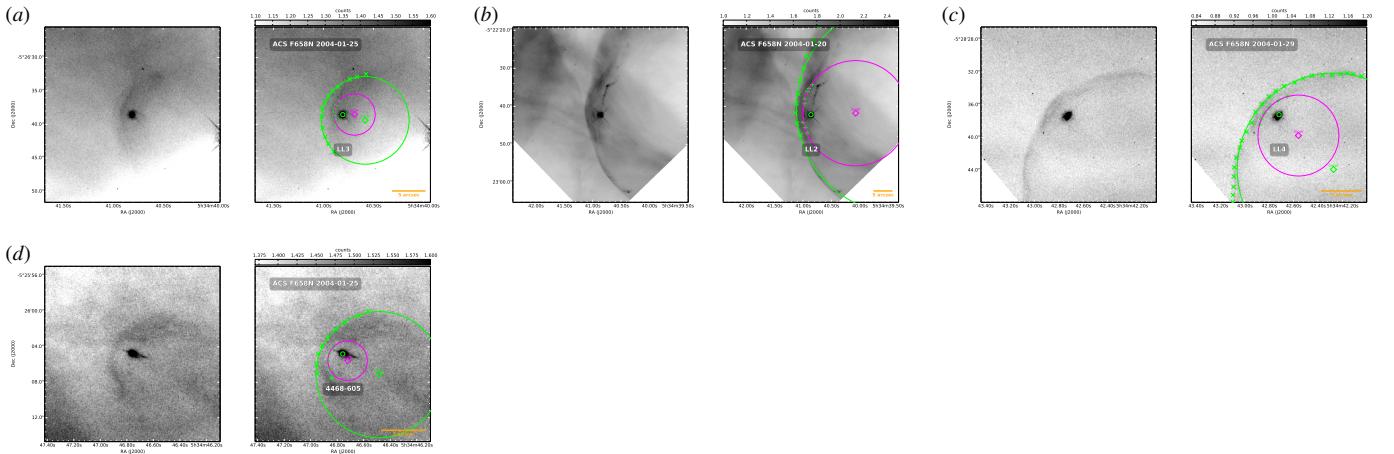


FIG. 8.—Stationary arc sources in the West group group.

3.7. South group

TABLE 7
SHELL GEOMETRIC PARAMETERS OF SOUTH GROUP

Object	RA	Dec	<i>D</i>	PA	<i>R</i> _{out}	<i>R</i> _{in}	<i>R</i> _{c,out}	<i>R</i> _{c,in}	<i>h</i>	<i>PA</i> _{out}	<i>PA</i> _{in}
066-3251	05:35:06.57	-05:32:51.4	587.49	14.5	1.07	...	1.59	300.1	...
116-3101	05:35:11.65	-05:31:01.0	463.92	8.8	1.45	1.00	2.69	1.57	0.44	24.0	7.9
119-3155	05:35:11.93	-05:31:53.3	515.10	7.4	3.02	1.95	6.73	5.11	1.00	33.3	35.3
136-3057	05:35:13.61	-05:30:57.6	456.93	5.2	10.13	4.91	18.71	10.20	4.51	10.9	4.4
138-3024	05:35:13.80	-05:30:24.4	423.64	5.2	3.89	2.74	8.54	4.79	1.11	22.2	17.4
203-3039	05:35:20.29	-05:30:39.4	440.72	352.4	5.38	1.76	17.90	14.50	3.06	359.4	8.2
261-3018	05:35:26.17	-05:30:18.0	440.40	340.6	4.99	2.51	33.29	3.59	2.59	1.7	357.1
w266-558	05:35:26.62	-05:25:58.3	218.16	315.6	1.88	1.13	7.76	1.51	0.78	330.7	298.5
305-811	05:35:30.44	-05:28:11.2	356.86	324.0	1.72	0.89	4.92	3.99	0.80	358.6	349.7
308-3036	05:35:30.79	-05:30:36.3	484.13	333.6	2.56	1.44	4.50	1.78	1.12	359.9	329.8
LL5	05:35:31.40	-05:28:16.4	369.54	322.7	2.96	1.46	11.58	3.52	1.49	339.7	339.7
LL6	05:35:32.87	-05:30:21.5	485.82	329.6	3.63	1.63	29.90	14.20	2.05	7.6	18.0
344-3020	05:35:34.36	-05:30:20.6	496.76	327.3	1.66	0.67	3.15	4.42	0.95	334.9	325.5
LL7	05:35:35.13	-05:33:49.2	686.23	335.9	7.00	5.53	17.96	10.31	1.46	359.2	3.8
362-3137	05:35:36.35	-05:31:37.8	577.96	329.0	3.12	1.57	4.25	2.22	1.47	6.4	267.8

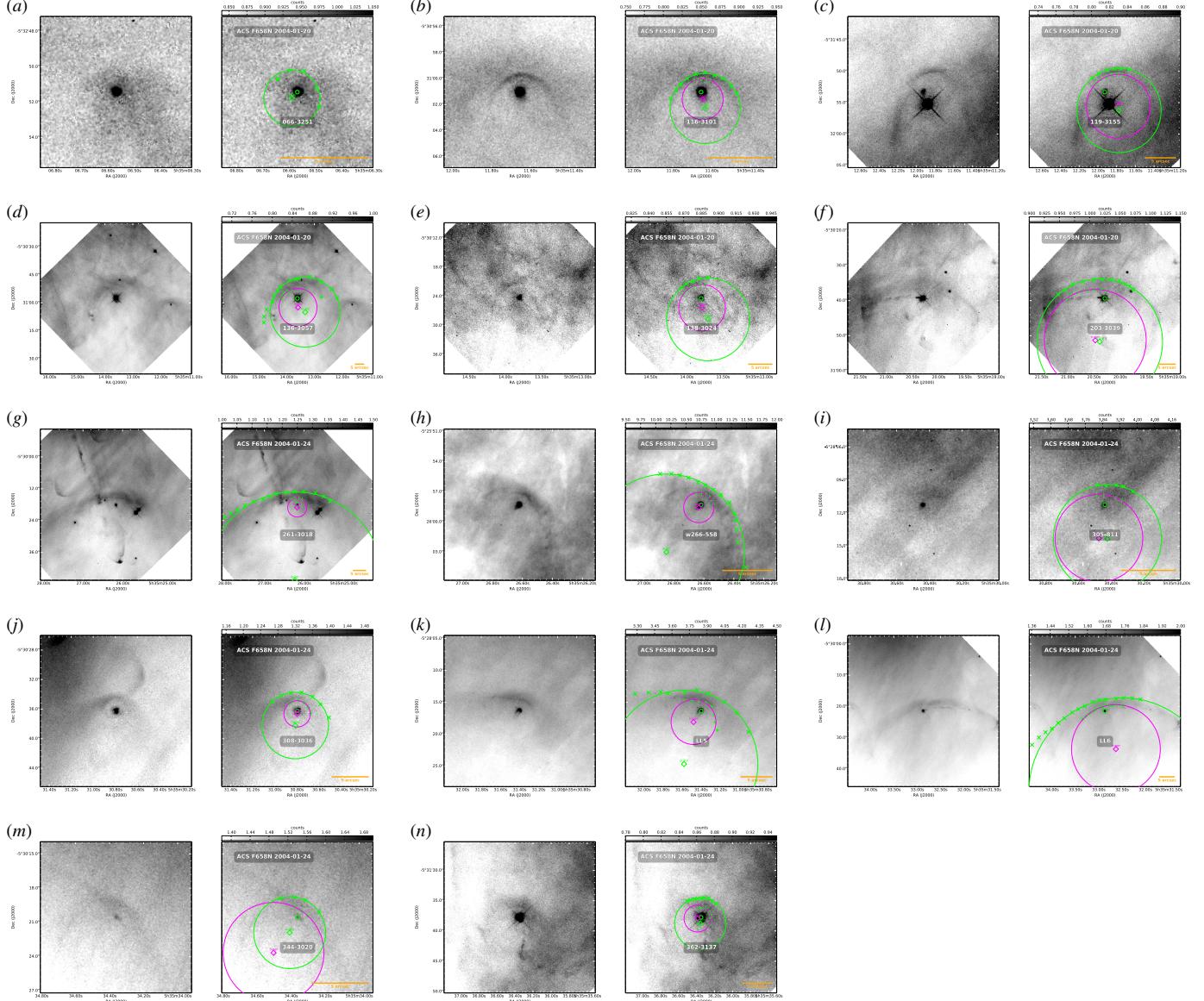


FIG. 9.—Stationary arc sources in the South group.

3.8. *Interpropolyd shells*

TABLE 8
SHELL GEOMETRIC PARAMETERS OF INTERPROPLYD SHELLS

Object	RA	Dec	<i>D</i>	PA	R_{out}	R_{in}	$R_{c,\text{out}}$	$R_{c,\text{in}}$	<i>h</i>	PA_{out}	PA_{in}
066-652	05:35:06.59	-05:26:52.4	255.85	34.9	0.03	-0.07	0.57	0.60	0.10	316.8	341.9
160-350	05:35:15.96	-05:23:49.7	27.91	13.3	0.11	0.04	0.60	0.29	0.07	226.2	224.3
162-456	05:35:16.18	-05:24:56.4	93.91	1.9	0.29	0.21	0.85	0.79	0.09	28.8	49.2
168-326N	05:35:16.83	-05:23:26.0	7.49	297.4	0.23	0.12	1.04	0.79	0.11	137.0	142.2
173-342	05:35:17.32	-05:23:41.4	23.46	323.5	1.29	0.83	3.31	1.72	0.46	82.2	76.1
175-321	05:35:17.46	-05:23:21.1	16.03	264.7	2.03	1.38	2.48	2.63	0.60	298.7	324.5

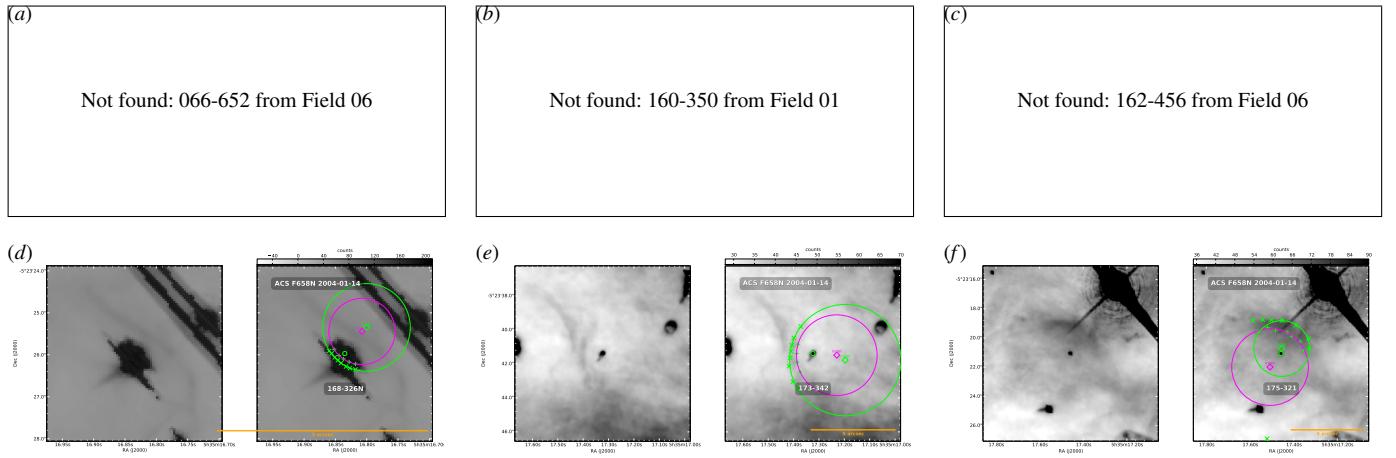


FIG. 10.— Stationary arc sources in the Interproplyd shells group.

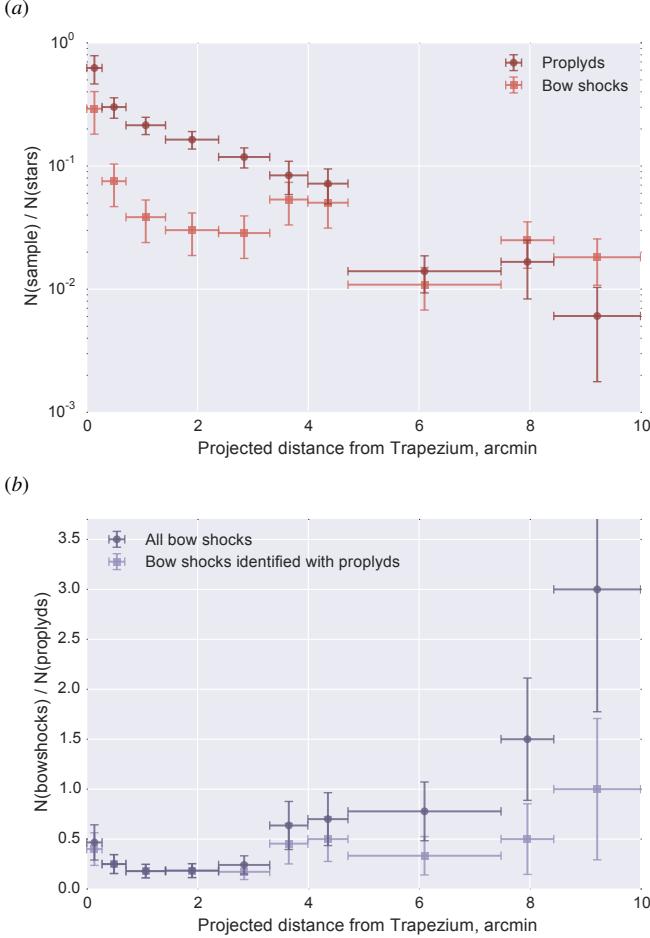


FIG. 11.— (a) Fraction of all optically visible stars that are proplyds (dark circle symbols) or have bowshocks (light square symbols) as a function of projected separation from the Trapezium. (b) Ratio between number of bowshocks and number of proplyds as a function of projected separation from the Trapezium. Dark circle symbols show all bowshocks in our catalog (with the exception of interproplyd shocks) while light square symbols show only those bowshocks associated with known or suspected proplyds.

4. DISCUSSION

Proplyd over star fraction falls off relatively smoothly with projected distance. Albeit with a sudden drop after about 200 arcsec.

Bowshock over proplyd fraction seems to have three separate peaks. Very small distances corresponding to the wind-wind interaction, then there is a dearth of bowshocks until a second peak around four arcmin. Finally at very large radii there may be a third peak of objects that are not proplyds.

But an alternate explanation for the third peak could be that they are all proplyds but that the proplyd fraction is underestimated at large distances.

On the other hand there is also evidence for three distinct populations from the azimuthal distribution around the Trapezium. The group at 4 arcmin separation are mainly to the west whereas the more distant objects are mainly to the south.