Catalog of cometary nebulae and related objects ($-42° < \delta < +60°$)

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Abstract

The catalogue of cometary nebulae and related objects is compiled using the known up to the publication date lists.

Keywords: *Cometary nebulae, coordinats, morphology*

1. Introduction

Among diffuse nebulae, a special group consists of cometary nebulae and related objects (arc or comma-shaped nebulae), a remarkable feature of which is their connection in most cases with T Tauri type variables or peculiar stars of spectral classes Be-Ae.

Strong continuous radiation was detected by Joy (1954) in the T Tauri type stars. Ambartsumian (1954) showed that the radiation is non-thermal in nature and that in T Tauri type stars there is a release of stellar energy into the outer layers of the star's atmosphere. Continuous emission - as this phenomenon was named by him - is non-stationary in nature and, as observations have shown, changes its intensity. Since the cause of the emission of cometary nebulae, apparently, are stars, it is undoubtedly that continuous emission somehow affects the emission of cometary nebulae.

The cometary nebulae were considered reflective, but Ambartsumian (1954) questioned the reflection as the only effective mechanism for the glow in the nebulae. Colorimetric studies of the brightest cometary nebulae NGC 2261, NGC 2245, Anon 6^h04^m, and others (see Johnson, 1960, Khachikyan & Parsamyan, 1964, Parsamian, 1962, 1963) showed that reflection is not the main or only mechanism for their emission. The detailed colorimetry of the nebula 2261 at BWM showed that:

1) In ultraviolet rays, the nebula is much brighter than a star.
2) The color index of the nebula everywhere?
3) Hubble's correlation is broken.
4) Inequality $m_n - m_s \geq -5$ lg $sin\frac{\alpha}{4}$ is broken (Parsamian, 1963), where m_n is the integral brightness of the nebula, m_s - the stellar magnitude of the star, and α is the cometary nebula solution angle.
5) There is no correlation between changes in the star and the nebula.

Subsequently, some of these results were confirmed in papers by Johnson (1960) and Brück (1974). The most detailed spectral study was carried out for the cometary nebula NGC 2261 and the star-like object R Mon associated with the nebula (see, Dibay, 1966, Greenstein, 1948a,b, Greenstein et al., 1976, Herbig, 1960a,b, 1968b, Kazarian & -Vartanian, 1970, Kazarian & Terzan, 1972, Slipher, 1939, Stockton et al., 1975). The spectrum of the nebula has been shown to be unlike the spectra of ordinary diffuse nebulae. Strong continuous spectrum, emission and absorption lines of hydrogen, forbidden

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lines 3727 [OII] were detected (Greenstein, 1948a,b, Kazarian & Terzan, 1972). In the cometary nebula NGC 2579 (Pupis) the lines N1, N2 [OIII] was found as well (Mendez & Parsamyan, 1974).

The detection of forbidden lines N 1, N 2, and 3727 Å once again showed that cometary nebulae are not just reflective, but have their own sources of radiation.

The polarization of cometary nebulae and the stars associated with them has a radial character. This suggests that the reflection factor also plays a certain role, although, without knowing the true nature of the illumination of cometary nebulae, it is somewhat premature to attribute the radiality due only to reflection (Hall, 1964, Johnson, 1960, Khachikyan, 1958, Khachikyan & Kalloglian, 1962, Khachikyan & Parsamyan, 1964, Martel & Rousseau, 1963, Parsamian, 1963, Razmadze, 1960, Zellner, 1970).

It was shown in the paper by Vardanian (1964) that the directions of the axes of cometary nebulae coincide with the mean plane of polarization of the surrounding stars, whence it was concluded that such an orientation is caused by a general galactic or local magnetic field. Cohen (1974) showed that, unlike the usual nebulae, only cometary nebulae have infrared radiation at 10 microns. An infrared study of stars associated with cometary nebulae has been conducted by Cohen (1973a,b). An attempt was made to classify cometary nebulae according to the degree of hydrogen excitation and forbidden lines in Mendez & Parsamyan (1974). It was shown that among the spectra of cometary nebulae, there is some diversity from purely continuous, characteristic of purely reflective nebulae, to emission, resembling spectra of low-excited diffuse nebulae. Interestingly, the spectral types of stars associated with cometary nebulae do not correlate with the spectral type of nebulae.

2. On the classification of cometary nebulae and related objects

Cometary nebulae include nebulae that have at least some of the following characteristics:

1) Comet-shaped appearance.
2) Connection with a T Tauri star or with related objects.
3) Violation of the Hubbles relation.
4) Variability.

The classification of cometary nebulae and related objects was carried out by a number of authors (Badaljan, 1960, Dibay, 1970). The existing classification was not intended to find a connection between the objects included in the classification. This classification had the following form:

I	**II**	**III**	**IV**
The stars with a comma-shaped nebula (Z CMa)	Cometary nebulae (NGC 2261)	The stars with an arc-shaped nebula (T Tau)	Biconical cometary nebulae (Anon $6^h\,04^m$))

However, the discovery of the fuor V 1057 and the possibility of separating stars with P Cyg characteristics into the group of possible post-fuors allows us to approach the classification of cometary nebulae and related objects in a new way. As is well known, flare stars, T Tauri stars associated with comma or arc nebulae, and cometary nebulae are often found in star associations somehow linked to T Tauri stars. As shown by Ambartsumyan et al. (1970), approximately 25 percent of T Tauri type stars in the Orion association are simultaneously flare stars. Thus, it can be schematically represented that, in the course of their evolution, T Tauri stars can pass through the following stages:

T Tauri
- —— 1. flare stars
- —— 2. fuors, stars with comma- or arc-shaped nebulae
- —— 3. cometary nebulae

In this case, stages 2 and 3 are the shortest, and the stars associated with them are not always typical T Tauri stars. Thus, T Tauri stars evolve in different ways, but the common to them all, apparently, is the ejection process, which in some cases comes to light in typical flare stars, in others in the form of fuors, around which nebulae are then formed, third - in the form of cometary nebulae. Although the phenomenon can be described as a sudden rise of the stars luminosity, the causes and mechanisms may be completely different. So, in the case of flare stars, we have an ejection, the release of a certain portion of energy, and the stars after the flare quickly return to their previous state. In the case of fuors (Ambartsumian 1971), the process of increasing the brightness occurs more slowly, the released ultraviolet radiation can cause ionization of the medium, however, the nebulae formed in this case have a certain arc or comma shape. Given the above considerations, we propose the following classification:

I a	**I a**	**II a**	**II b**
Cometary nebulae of conical form (NGC 2261)	Cometary nebulae of the biconical form (Anon $6^h\,04^m$)	Comma-shaped nebulae (Z CMa)	Arc-shaped nebulae (T Tau)

The nebulae in the second group are often associated with stars that have characteristics of R. This group includes the well-known three fuors; It should be expected that among the above list will be unknown to us postfuors. Nebulae in the first group also have common properties; thus, the biconical form, characteristic of subgroup I b, is also found in a less pronounced form in subgroup I a as a "mirror" image of a nebula (NGC 2261, NGC 2245). Among cometary nebulae, 12% are biconical; among related objects, 30% are class II b.

3. Explanation to the catalog

The first attempt to search for "cometary" nebulae on the maps of the Palomar Atlas was carried out by Parsamian (1965). Over the years, this list has been replenished with new data, which included objects found by other authors. It is clear that when selecting objects of this kind only in appearance, the catalog will also include those that are not actually the same according to their physical nature, and also some will fall out of it, due to the orientation, which look somewhat different from the typical representatives. The best criterion should be spectral and colorimetric characteristics. Unfortunately, the latter are known only for a few bright objects. Therefore, this catalog can give the opportunity to select objects for spectral, infrared, polarimetric, colorimetric studies.

The catalog includes mostly objects with $-42° < \delta < +60°$ (see Appendix A). The size of nebulae (height of the cone) is of the order of $0.5' - 3.0'$. About 80% of nebulae have a positive color index. The angle of inclination of the axes of nebulae to the plane of the Galaxy is in the range from 0 to 60°. The cometary nebulae belong to the flat subsystem.

The DSS2 R images of the nebulae are given in Appendix B.The coordinate grid is marked on the images: X axis – RA (2000) and Y axis – Dec (2000).

Comments to the objects from the catalog are given in Appendix C.

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Appendices

Appendix A Catalog of the nebulae

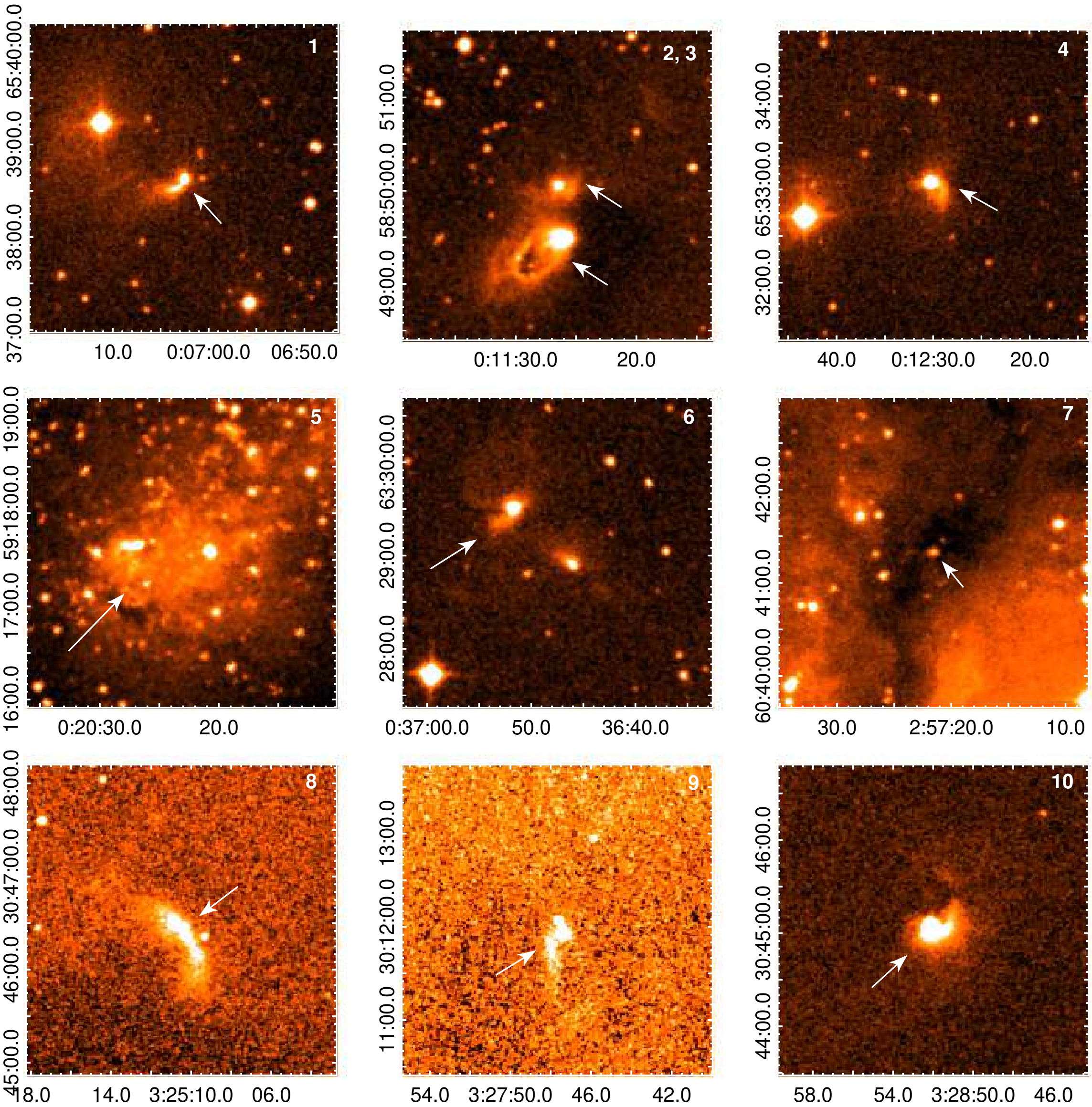
The designations in the catalog are as follows:
(1) – The number of nebula in the catalog.
(2) – Name of the nebula from other sources: *GM* (Gyul'Budagyan & Magakyan, 1977a,b); *Ber* (Bernes, 1977); *B* (Barnard, 1907); *DG* (Dorschner & Gürtler, 1963); *P* (Parsamian, 1965); *Ced* (Cederblad, 1946); *vdB* (Van den Bergh, 1966); *Sh* (Sharpless, 1959); *M* (Minkowski, 1946).
(3) – The cone height d of the nebula in arcmin.
(4) – The class according to the present classification
(5) – The photographic magnitude of the associated star.
(6) – The spectral type of the star.
(7) – The name of the star in the general catalog of variable stars or other sources: *GR* (Romano, 1969); *HRC* (Herbig & Kameswara Rao, 1972); *MacC* (MacConnel, 1968); *Bl* (Blanco, 1962); *H* (Haro, 1953, Haro & Rivera Terrazas, 1954); *Cl* (Claria, 1974); *vdBH* (Van den Bergh & Herbst, 1975); *SR* (Struve & Rudkjøbing, 1949).
(8) – References: 1 – Herbig & Kameswara Rao (1972); 2 – MacConnel (1968); 3 – Herbig (1960a); 4 – Blanco (1962); 5 – Gyul'Budagyan & Magakyan (1977a); 6 – Joy (1949); 7 – Barnard (1907); 8 –Bernes (1977); 9 - – Herbig (1960b); 10 – Kuhi (1964); 11 – Cohen (1973b); 12 – Dorschner & Gürtler (1963); 13 – Herbig (1950); 14 – Osterbrok & Sharpless (1958); 15 – Schwartz (1974); 16 – Schwartz (1975); 17 – Low et al. (1970); 18 – Badaljan (1960); 19 – Haro (1953); 20 – Dibay (1970); 21 - – Cohen (1973c); 22 – Cederblad (1946); 23 – Garrison & Anderson (1978); 24 – Hoffmeister (1949); 25 – Haro (1953); 26 – Parenago (1954); 27 – De Boer (1977); 28 – Morgan & Sharpless (1946); 29 – Merril & Burwel (1950); 30 – Haro & Rivera Terrazas (1954); 31 – Sanduleak (1971); 32 – Ambartsumyan et al. (1970); 33 – Morgenroth (1939); 34 – Herbig (1968b); 35 – Parsamian (1965); 36 – Van den Bergh (1966); 37 – Merril & Burwel (1949); 38 – Gyul'Budagyan & Magakyan (1977b); 39 – Calvet & Cohen (1978); 40 – Calvet & Cohen (1978); 41 – Mendez & Parsamyan (1974); 42 – Penston & Keavey (1977); 43 – Minkowski (1946); 44 – Hall (1964); 45 – Apruzese (1975); 46 – Cohen (1974); 47 – Gyul'Budagyan & Magakyan (1977a); 48 – Claria (1974); 49 – Ahnert (1950); 50 – Swings & Struve (1942); 51 – Pik Sin (1962); 52 – Van den Bergh & Herbst (1975); 53 – Struve & Rudkjøbing (1949); 54 – Joy (1945); 55 – Romano (1969); 56 – Landolt (1977); 57 – Welin (1976); 58 – Herbig (1957); 59 – Kolotilov (1977); 60 – Herbig & Harlan (1971); 61 – Haro (1971); 62 – Glesekingn (1974); 63 – Gahm & Welin (1972); 64 – Glesekingn (1973); 65 – Haro (1972); 66 – Cohen (1973a); 67 – Rosino & Romano (1962); 68 – Aveni & Hunter (1969).

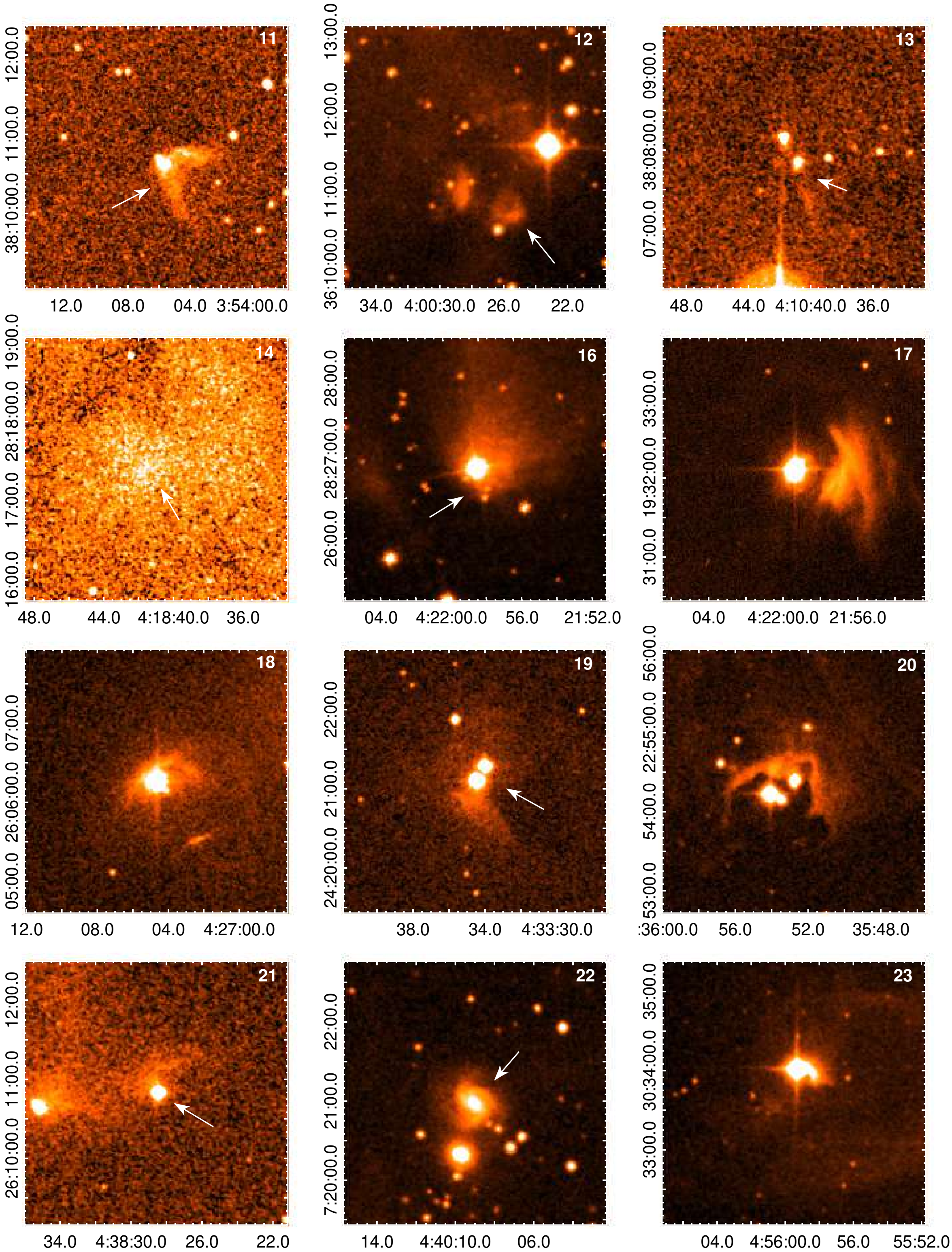
N (1)	Name of nebula (2)	d (3)	Class (4)	m_{ph} (5)	Sp (6)	Name of star (7)	Ref (8)
1		0.4	Iia	17.3		HRC 1n, MacC H12	1, 2
2		0.5	Ia	15.0	A:5eα	L_kH_α 198, 11Rc 3n, V376 Cas	3
3		0.2	Iia	16.0−18.0			3
4		0.4	Iia	16.2	Geβ	HRC 5, B1 10, MacC H9	1, 2, 4
5		0.4	Ia				5
6	GM 33	0.6	Iia				5
7		0.2	Iia	15.4−17.0		LW Cas	
8	GM 55, Ber 53	1.3	Ia				5
9	GM 13	0.6	Ia				5
10		0.5	Iia	14.0	K2eα	L_kH_α 325, HRC 11n	1
11	GM 14	0.7	Ia				5
12	GM 15	0.4	Ia				5
13	GM 68	0.3	IIa				5
14	B 10, IC 359			14.1−15.0	dK6e	DD Tau, HRC 30n	6, 35
15		1.1	IIa				
16	B 96, Ber 73, DG 30	2−3	Ia	9.3−12.3	dF8e−dG2e	RY Tau, HRC 31n	1, 7, 9, 10, 11
17	NGC 1555-4, DG 31		IIa	9.5−13.5v	K1e	T Tau, HRC 35n	5, 10 − 17
18			IIa	11.5−14.0	G:e	DG Tau, HRC 37	1, 6, 18
19	Ber 81, DG 39		IIa	13.0−15.2	K5(e)	GK Tau, HRC 57n, H6−22	1, 8, 12, 19
20	Ber 83, DG 41		IIa	14.0−17.2		HP Tau, L_kH_α 258, HRC 66n	1, 8, 12,18
21		0.6	IIa	12.4−16.5	G:e	DO Tau, HRC 67n	1, 35
22		0.5	IIa				
23		0.5	Ia	9.3−11.5	G2neIII	SU Aur, HRC 79n	1, 3, 11
24	GM 3		IIa				5
25	GM 36	0.4	IIa				5
26	GM 37	0.3	IIa				5
27	GM 38	0.3	IIa				5
28	P 1	1.1	IIa	11.9	B2		20
29	B 122, Ber 89, Ced 51	3−5	Ia	11.1−13.3	A4ep	HK Ort, HRC 94n	6, 7, 8, 19, 21, 22, 23, 24
30	GM 16	0.4	Ia				5
31	GM 17	0.6	IIa				5
32		0.3	Ia	9.6−13.8	A3:eα+shell	T Ori, H4−123, HRC 154n	3, 21, 23, 25, 26
33		0.7	IIa	10.7−17.8	eα	H 4−218,V 582 Ori	
34	NGC 1999	1.5	IIa	9.8−10.5v	A1:e	V 380 Ori, BD +6° 1253, HRC 164n	1, 3, 21, 23, 27, 28
35	GM 39	0.3	IIa				5
36	GM 40	0.4	IIa				5
37	H 13a	0.8	IIa				25
38		0.4	Ia	10.5−14.2	A2eII−III	RR Tau, HD 245906a	3, 21, 23, 29

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
39		0.3	IIa	15.0	eα	HRC 176n, H 4−255	1, 25
40	GM 66		IIa				5
41	P 2	0.6	IIa				5
42	Ber 131		Ia	13.0	G−Ke	HRC 182n, H 7−12, San 6	30, 31
43			IIa	9.7−16.5	F2:peαI-II	FU Ori, HRC 186n	27, 32 − 34
44	Ber 106	0.8	IIa				
45			Iia				
46	P 3, Ber 59, vdB 62	1.6	Ia		K2	BD+1°1156	8, 35, 36
47	GM 18	0.3	Ia				5
48	P 4	1.0	Ia				5
49			Iia	9.7	B9eq	HRC 192n, HD 250550	4, 21, 23, 67
50		1.0	IIa				38
51		2.3	Ia				
52		0.5	Iia				
53	P 5	1.3	IIa				35
54	P 4, Anon $6^h\,04^m$, P 6	2.0	Ia	13.0	FOV	HRC 193n, L_kH_α 208	1, 3, 21, 23, 35, 39
55	P 8, Ced 71, vdB 74	1.0	Ia		B6	BD+6°1414	22, 35, 36
56	P 9	0.6	Ia				35
57	Sh 258	1.1	Ia				40
58	GM 45	0.8	Iia				5
59	P 10, M 3, Sh 259	3.0	Ia		B6e		35, 40, 41, 43
60	P 11, DG 97	0.7	Ia				12, 35
61	P 12, DG 98	1.2	Ia				12, 35
62	P 13, NGC 2245,DG 108	3.5	Ia	10.7	Be+shell	L_kH_α 215	3, 12, 21, 23, 35
63	GM 20	0.4	Ia				5
64	NGC 2261	3.0	Ia	11.3−13.8	A−Fpe	R Mon, HRC 207n	1, 3, 17, 21, 23, 45
65	P 15	1.0	Ia	12.8−14.1	A5V−F8V		35, 39, 46
66	P 16	0.6	Ia				35
67	P 17, NGC 2313	1.1	Ia	15.7			35, 41
68	P 18, NGC 2316	1.6	Ia				34, 45
69		0.4	Ia				
70		0.5	Ia			CI 70	57
71		0.7	IIa	8.8−11.2	eq	Z CMa, HRC 243n	1, 2, 21, 23, 37, 48, 45, 50
72	NGC 2327, DG 135	1.6	Ia		B5V	L_kH_α 231, CI 81	8, 12, 48
73	GM 21	0.4	IIa				5
74	GM 22	0.3	Ia				5
75	P 19	0.8	Ia			BD−16°2003	35
76		0.7	Ia				
77	P 20, M 5, Sh 307	1.1	Ia				35, 40, 43

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
78	NGC 2579	1.5	Ia			vdBH−13a	41, 52
79			Ia			vdBH−47c	52
80			Ia	10.5r		vdBH−65a	52
81		0.7	Ia	15.0	Geα	HRC 248n	1, 51
82		0.2	Ia		eα	SR−24, HRC 232n, H 1−7	1, 5, 14
83	GM 47	0.8	Iia				5
84	GM 48, Ber 1, DG 144	0.8	Ia				5
85	GM 24	0.1	IIa				5
86	GM 56	1.7	Ia	10.0−11.6			5
87	NGC 6729	1.7	IIa	13.5	FO+pe	RCrA, HRC 288n, Ced 165c	1, 22, 54
88	P 21	1.1	Ia		A5eα		35, 46
89	NGC 6829, GM 26	0.9	Ia				5
90	GM 27		Ia				5
91		0.1	IIa	15.4−18.5	eα	L_kH_α 225, GR 168	3, 55
92		0.3	Iia	13.5		V 1515 Cyg	46, 47
93	GM 10		Ia				5
94	GM 11		IIa				5
95	P 22		IIa	17.0			5
96	GM 28	1.1	Ia				5
97	GM 29	0.8	Ia				35, 46, 39
98		0.5	IIa	12.2	GO	V 1057 Cyg, L_kH_α 190	32, 47, 56 − 66
99	Ber 29		IIa	11.8−12.2	eα	L_kH_α 120, HRC 302n, V 1331 Cyg	10, 42
100		0.8	Ia	17.0−17.7		RR−10	67
101	GM 12		Ia				5
102	GM 57	0.8	IIa				5
103		2.3	Ia	14.5	A7eα	L_kH_α 233, HRC 313n	1, 3, 39
104	GM 79	0.7	Ia				5
105		1.0	Ia	12.4−14.6	F8:eα	BM And, HRC 318n	1, 11, 68
106	P 23	1.1	IIa		eα	L_kH_α 259, HRC 321n, MacC H 4	1, 2, 4

Appendix B Images of the nebulae

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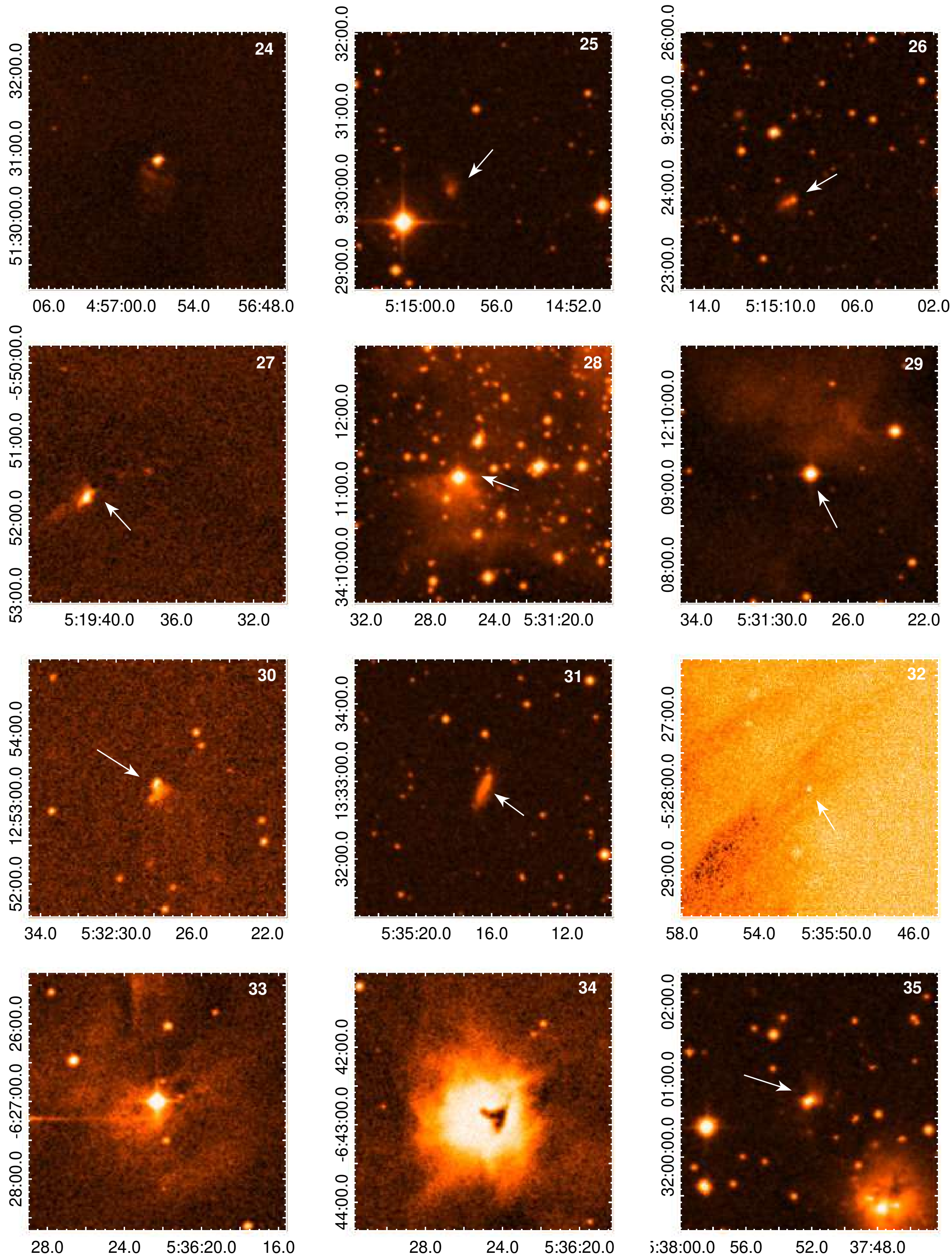
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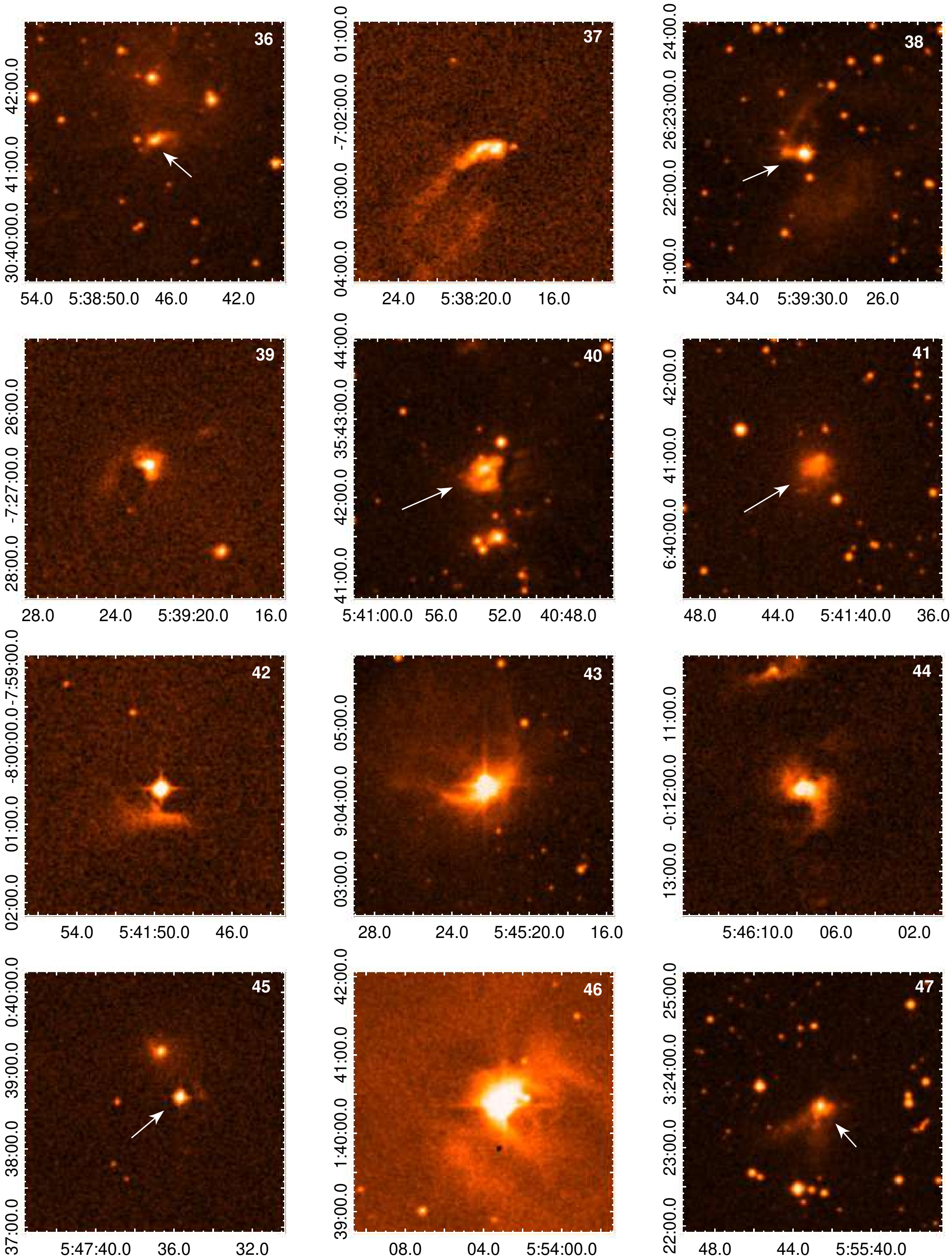
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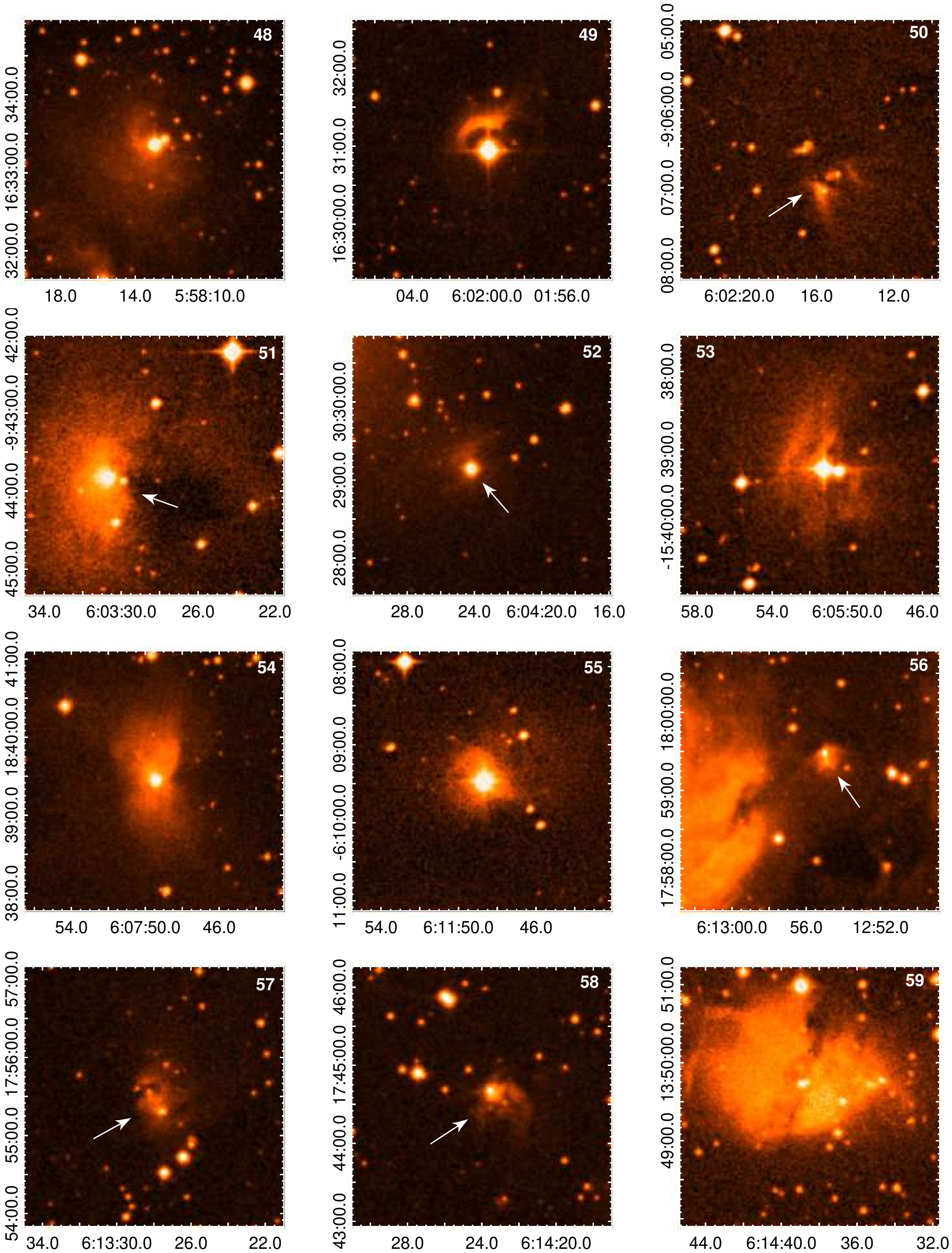
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38:00.0 39:00.0 18:40:00.0 41:00.0
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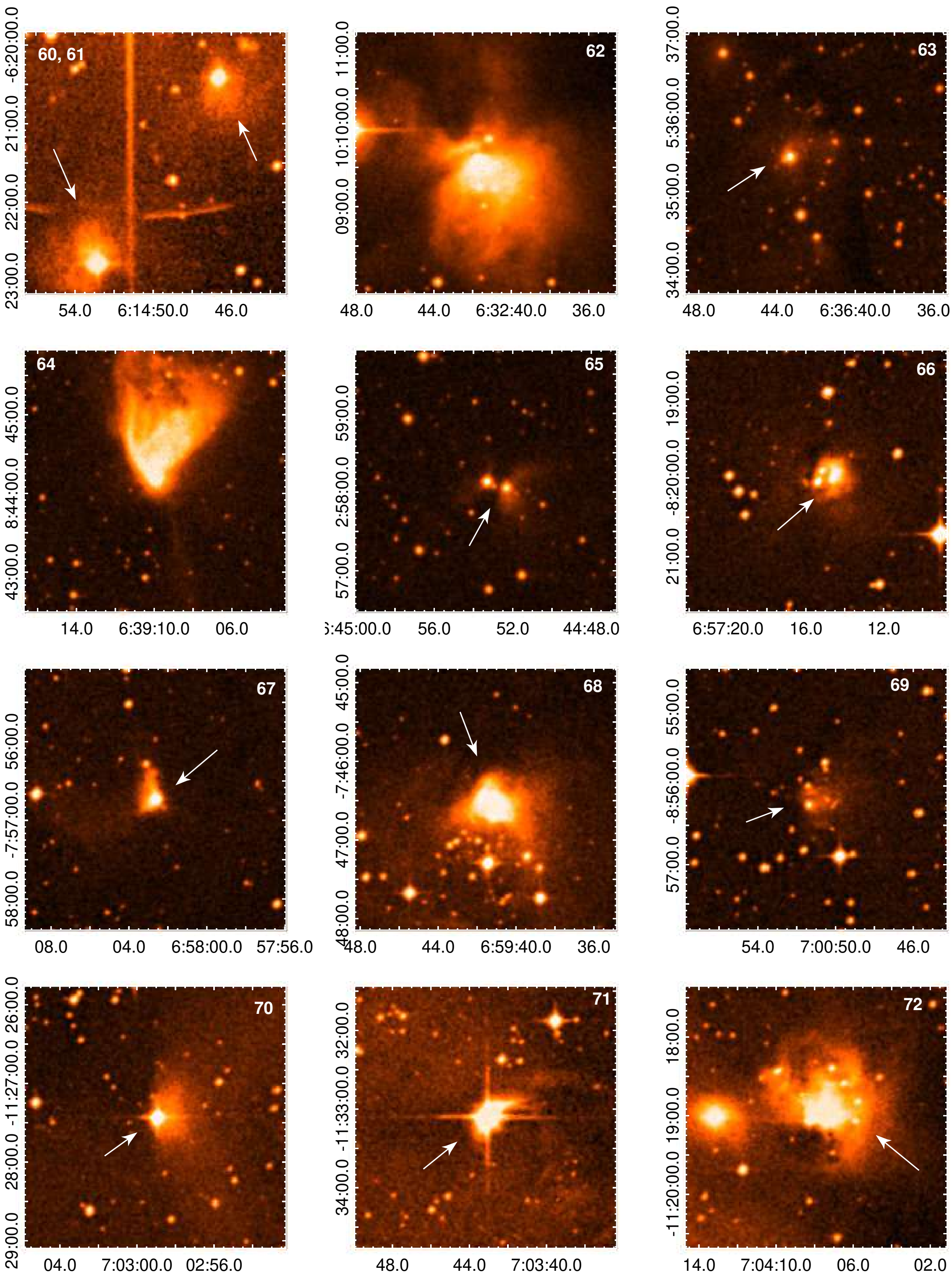
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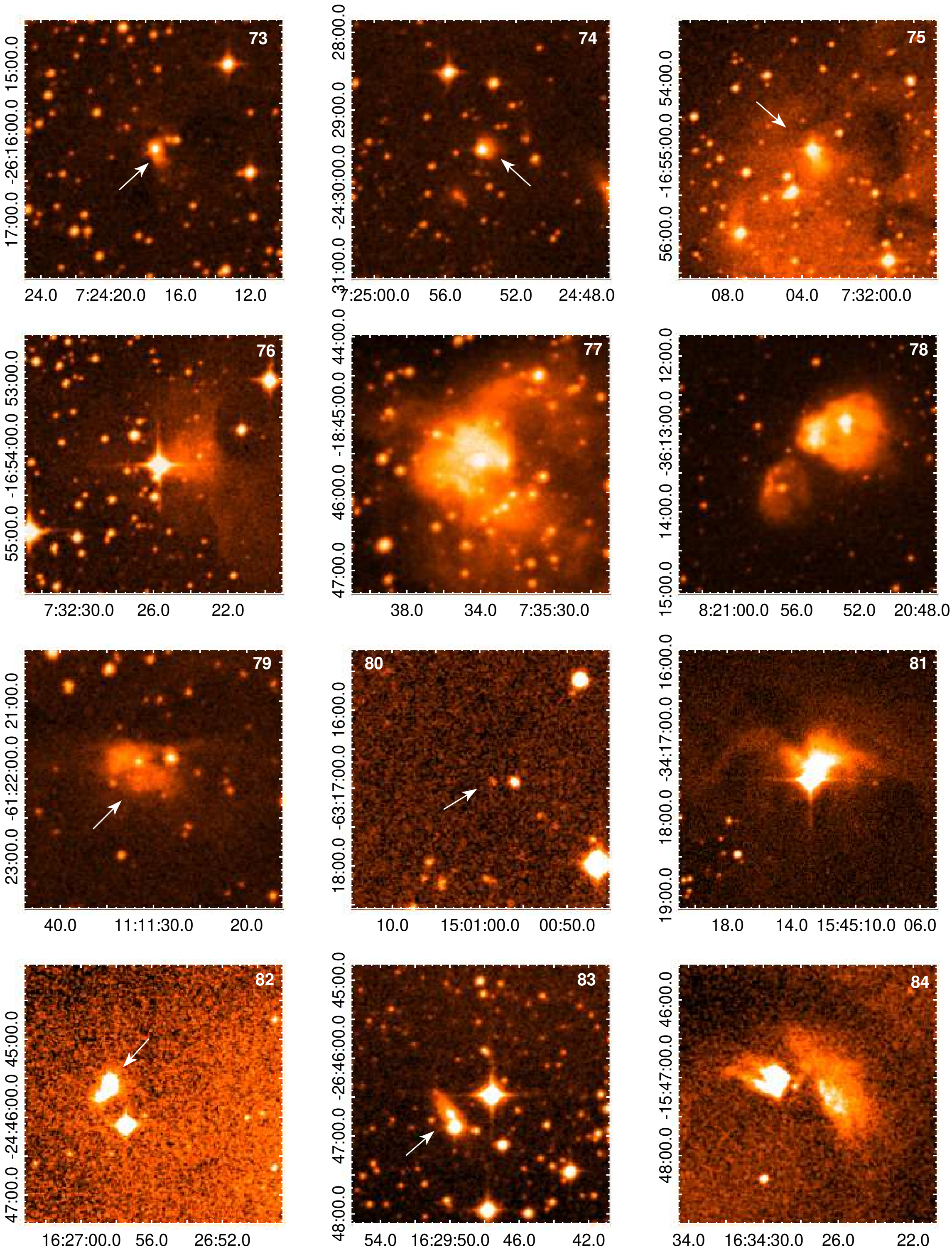
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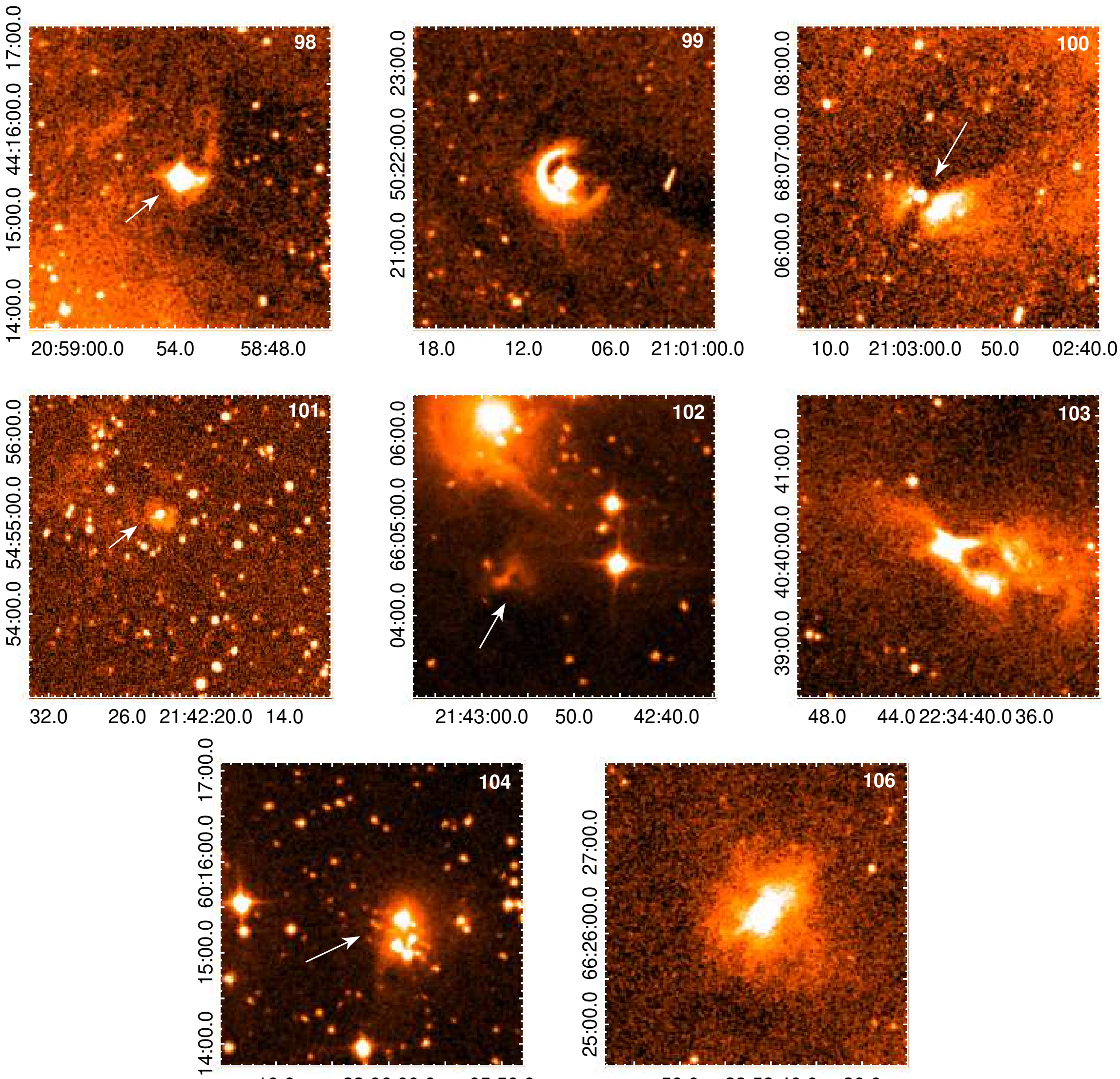
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106
25:00.0 66:26:00.0 27:00.0
50.0 23:58:40.0 30.0

Appendix C Comments to the nebulae

PP 3 – According to Herbig (1960a), the nebula is variable.
PP 5 – Inclusion in a diffuse nebula, stronger in red rays. The picture is given from the blue Palomar maps.
PP 7 – The star is located in the dark channel of the HII region of IC 1848. No emission lines were detected in the spectrum of the star. The picture is given from the blue Palomar maps.
PP 14 – Variable nebula, which was listed to the cometary class by Ambartsumian (1954). According to Struve & Swings (1948), the Hubble ratio in it is violated by more than 7 magnitudes.
PP 15 – The core of the nebula is an asymmetrical starlike object, brighter in blue rays.
PP 17 – Variable nebula associated with a T Tau star. Of particular interest is the oval-shaped nebula surrounding the T Tau star, which has an emission spectrum characteristic for the Hebig-Haro objects.
PP 31 – Following studies have shown that this object is a galaxy.
PP 37 – The star at the top of the nebula is almost invisible in the blue rays and visible in the infrared. According to Haro (1953), the tail of the nebula has an emission spectrum.
PP 38 – Variable nebula associated with the star RR Tau.
PP 54 – The Hubble biconical nebula Anon $6^h 04^m$ is associated with the star $L_k H_\alpha$ 208, which is variable with the amplitude of 0^m,2 in the rays B and has a variable polarization (Garrison & Anderson, 1978).
PP 56 – Nebula P 9 is rediscovered in Gyul'Budagyan & Magakyan (1977a) at number 19.
PP 59 – Nebula has a strong continuous spectrum. In the spectrum of the nebula, the lines of H, Fe, Ti, Ca, as well as the line 3727 [OII] are observed the emission (Mendez & Parsamyan, 1974). P 10 is the only cometary nebula from which radio emission was detected.
PP 64 – The prototype of cometary nebulae.
PP 65 – The nebula P15 is a peculiar object containing two stars of different brightness in the focus of two hyperbolic arcs.
PP 66 – The nebulae P16, P17 and P18 form a cluster of cometary nebulae. They can be connected by one absorbing cloud (Zellner, 1970).
PP 67 – The spectrum of the P17 nebula is continuous, with a maximum intensity at the with no trace of any lines. The Hubble ratio is violated by 3 magnitudes if the illuminating star is a starlike object at the apex (Mendez & Parsamyan, 1974).
PP 68 – The spectrum of the nebula P18 is continuous, without lines. It has two small condensations of variable brightness, the brighter of which is located near the apex (Mendez & Parsamyan, 1974). This condensation in the range between 11.3 μm and 18 μm is the brightest of the objects observed so far and has $CI_{int} = 4^m.6$. It is possible that the nebula represents the shell of a small cluster of faint red stars (Cohen, 1974).
PP 78 – A variable nebula, in the spectrum of which emission lines of hydrogen, N1, N2, 3727 [OII] were observed (Mendez & Parsamyan, 1974). South of the nebula there are two starlike condensations that are very bright in the red and infrared rays.
PP 88 – The starlike core is variable (Parsamian, 1965). In the spectrum of the nucleus obtained at the 6 m telescope of the Special Astrophysical Observatory of the USSR Academy of Sciences, the emission line has an absorption component from the ultraviolet side.
PP 91 – $L_k H_\alpha$ 225 is a variable star. On the plates obtained by the 2.6 m telescope of the Byurakan Observatory, towards the north of the star, a nebula is seen with a condensation in the upper part. It is much brighter in the red rays. From comparisons with the Palomar maps, it turned out that in 1954 there were no nebulae near the star. This means that by then either it has weakened, or has not yet appeared. In the picture given by Herbig (1960a) in 1956, the asymmetry is felt from the northern side, but the author himself writes nothing about it.
PP 92 – A variable nebula near the fuor V 1515 Cyg.
PP 94 – Following studies have shown that this object is a planetary nebula. 97 – A variable nebula, which is located about 1.5' west of the NGC 7023. The star of the nebula is almost exactly at its top and is visible only in the red rays, but the fan has an approximately neutral color.
PP 98 – The nebula appeared after the formation of the fuor V 1057 Cyg.
PP 106 – In the paper by Parsamian (1965) there was an imprint of coordinates.